Land / cryosphere breakout
Welcome and introduction

Ivan Csiszar, Jeff Key

NOAA/NESDIS/STAR

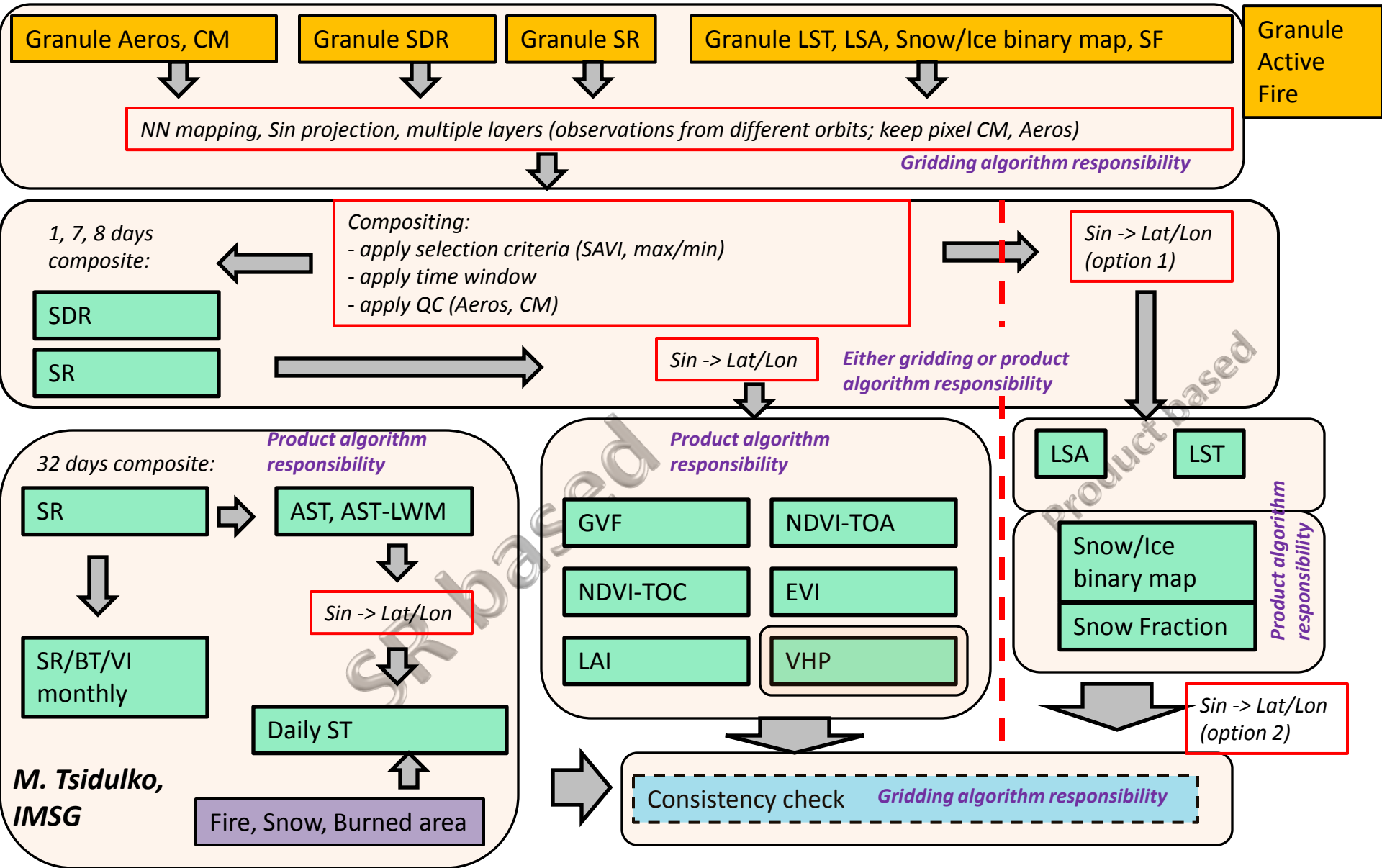
Dial-in info:

http://www.star.nesdis.noaa.gov/star/meeting_2016JPSSAnnual_DialIn.php

Land / cryosphere algorithm status

- Algorithms are currently transitioning to Enterprise solutions
  - changes in retrieval algorithm, product content, format
  - see presentations from the NOAA JPSS Enterprise Workshop for details
  - http://www.star.nesdis.noaa.gov/star/meeting_SJEAW2016.php
- Preparations for reprocessing are ongoing
  - http://www.star.nesdis.noaa.gov/star/meeting_JPSS2016_LDRW.php
- Long-term product monitoring and maintenance continues
  - http://www.star.nesdis.noaa.gov/jpss/EDRs/index.php
- Product development is generally in sync with operational applications
  - NCEP/EMC land: consistent, gridded, global, 1-km composites
  - biophysical variables for terrestrial ecological studies
  - fire radiative power for smoke/air quality applications
  - National Ice Center (NIC), Navy, NWS Alaska
  - etc.
- NASA ST production / reprocessing ongoing
  - continuing coordination and synchronization for select algorithms
  - implementation challenges
    - NASA-unique SDR, formats, NDE vs. SIPS production systems

Schematic view of proposed Land Enterprise System



Enterprise implementation schedule

- Algorithm readiness
  - Surface reflectance: February 2017
  - VI, LST, LSA: August 2017
  - Active Fire – already operational
  - Surface Type – annual updates
  - Snow Cover / fraction – in transition
  - Ice Surface Temperature – in transition
  - Sea Ice Thickness/Age – in transition
  - Sea Ice Concentration – in transition
  - VIIRS polar winds – operational since May 2014
- Two-phased approach
  - granule-based products
  - global gridded composites
- JPSS-1 readiness in general is confirmed
  - Evaluated test datasets provided to STAR
  - Ran select algorithms in STAR environment
    - Further interaction with NDE needed for pre-launch testing

Land /cryosphere algorithm readiness for reprocessing: general comments

- Test datasets of upstream products are needed for algorithm validation and verification
  - SDR, SR, AOT, VCM
  - Opportunity for accelerated product maturity
  - Training / validation datasets are needed
  - JPSS-1 cal/val plan and CEOS validation protocol, as applicable
- Reprocessing schedule is contingent on
  - Reprocessing of upstream products
    - Reprocessing should be done after evaluation by downstream product teams
  - Readiness of Enterprise algorithm and processing code
    - At least validated maturity Stage 2 level is required
      - Full global and seasonal sampling

Agenda (am)

0830 – 0850	***Introduction and welcome***	Ivan Csiszar
0850 – 0910	***Surface reflectance***	Eric Vermote
0910 – 0930	***Terrestrial biophysical product suite***	Marco Vargas
0930 – 0950	***Land surface albedo***	Yunyue (Bob) Yu
0950 – 1010	***Land surface temperature***	Yunyue (Bob) Yu
1010 – 1030	***Break***	
1030 – 1050	***Active fire***	Ivan Csiszar
1050 – 1110	***Surface type***	Xiwu (Jerry) Zhan
1110 – 1130	***Binary snow cover and snow fraction***	Peter Romanov
1130 – 1150	***Sea ice surface temperature***	Mark Tschudi
1150 – 1210	***Sea ice concentration***	Jeff Key
1210 – 1230	***Sea ice characterization and thickness***	Jeff Key

Agenda (pm)

1330 - 1350	***Enterprise system status***	Ivan Csiszar
1350 – 1410	***Suomi NPP reprocessing status***	Jason Choi
1410 – 1430	***NASA Science Team***	Miguel Román
1430 – 1450	***CEOS Land Product Validation***	Miguel Román
1450 – 1510	***Land product characterization system***	Gregory Stensaas
1510 – 1530	***Break / poster session***	
1530 – 1550	***Vegetation Health Applications***	Wei Guo
1550 – 1610	***NCEP Land Applications***	Mike Ek
1610 – 1130	***National Ice Center Applications***	Pablo C. Colón
1630 – 1650	***Open discussion and wrap-up***	

Principal questions

- Is transition to enterprise processing on track?
  - science, format, dependencies
  - transition to “true” enterprise products
    - GOES-R, non-NOAA / foreign satellites
- Are we ready for reprocessing?
  - product-specific requirements
- Are the products ready to use? Are they used?
  - true operational applications
    - process for implementing operational use
    - demonstrated potential and impacts

Surface Reflectance

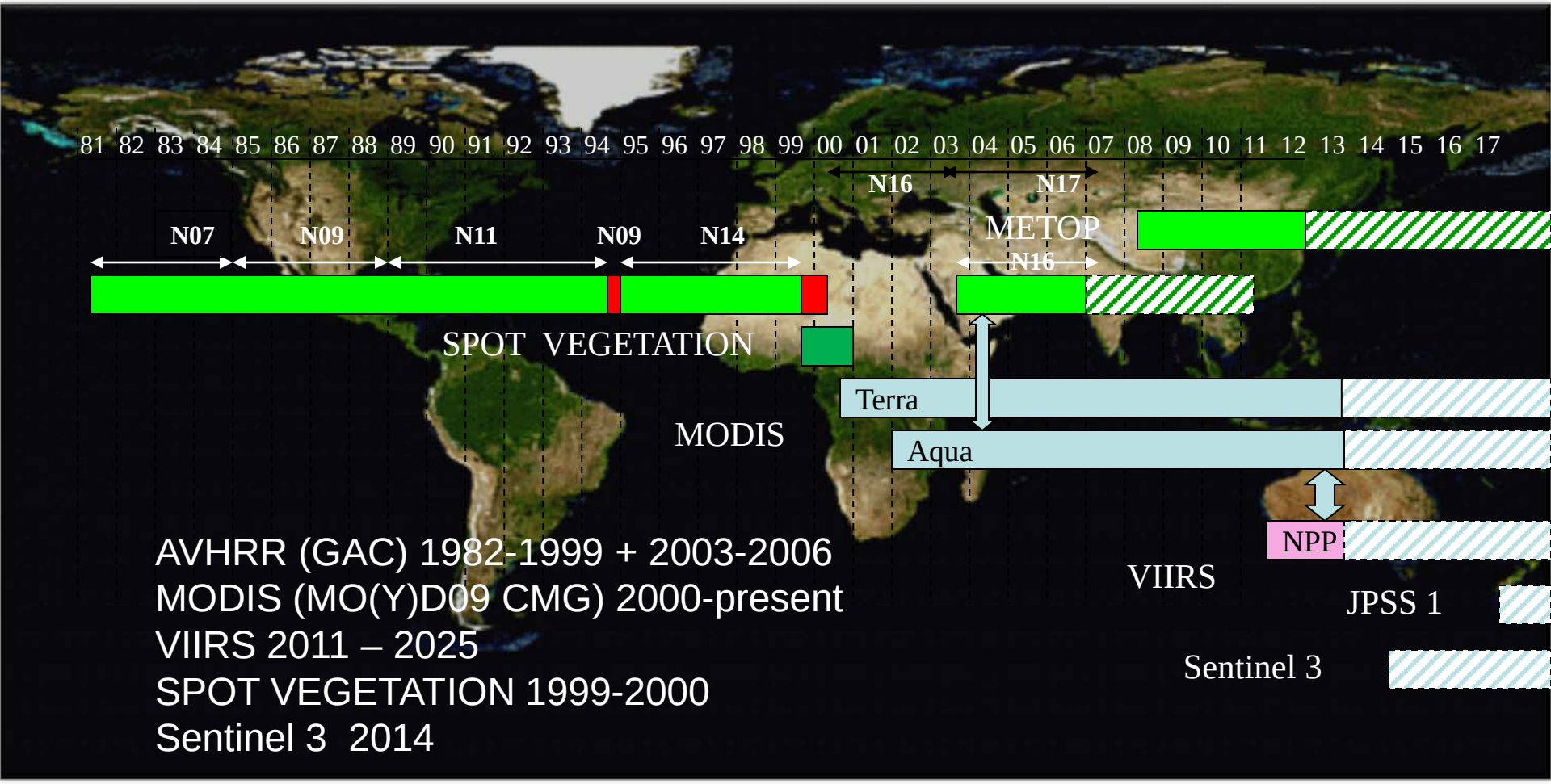
Eric Vermote
NASA GSFC Code 619
eric.f.vermote@nasa.gov

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STAR JPSS Science Team Meeting, August 8 – 12, 2016, NCWCP, College Park, MD

A Land Climate Data Record

Multi instrument/Multi sensor Science Quality Data Records used to quantify trends and changes



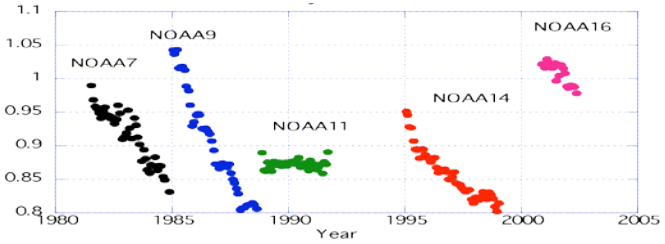
Emphasis on data consistency – characterization rather than degrading/smoothing the data

Land Climate Data Record (Approach)

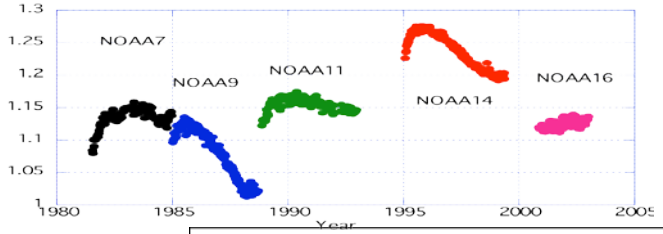
Needs to address geolocation,calibration, atmospheric/BRDF correction issues

CALIBRATION

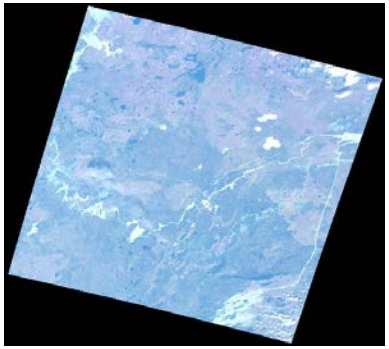
Degradation in channel 1
(from Ocean observations)

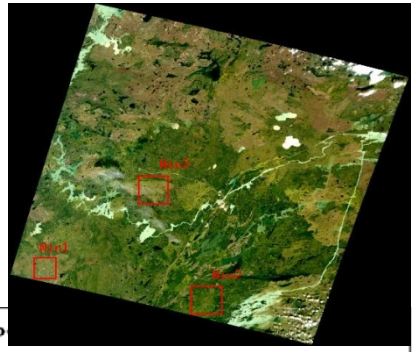


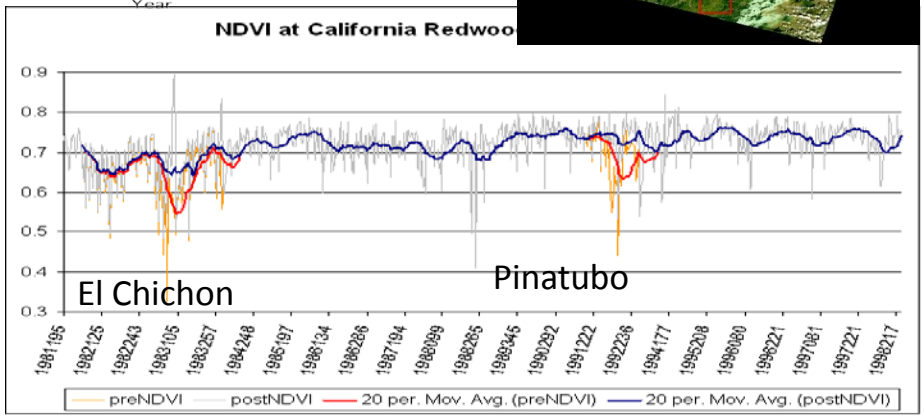
Channel1/Channel2 ratio
(from Clouds observations)



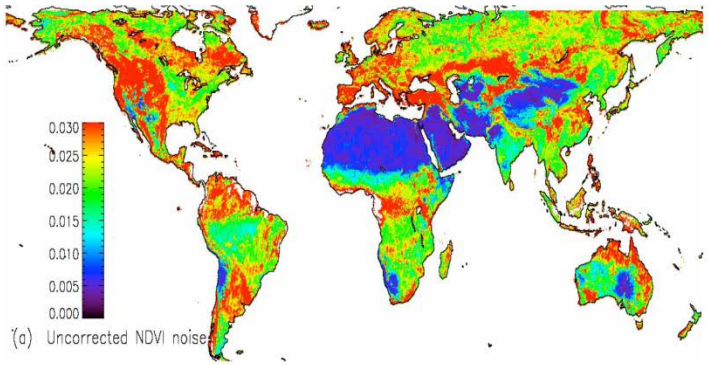
ATMOSPHERIC CORRECTION

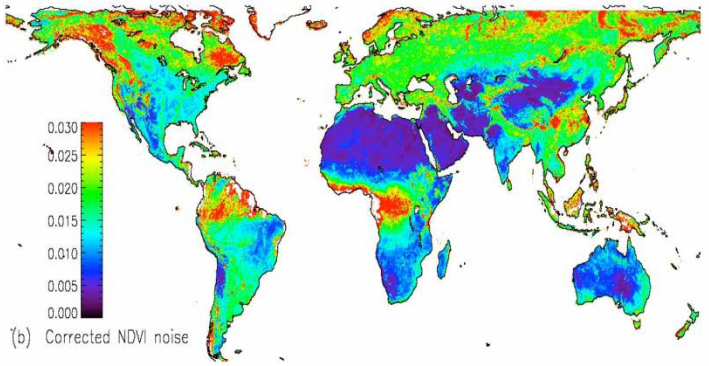


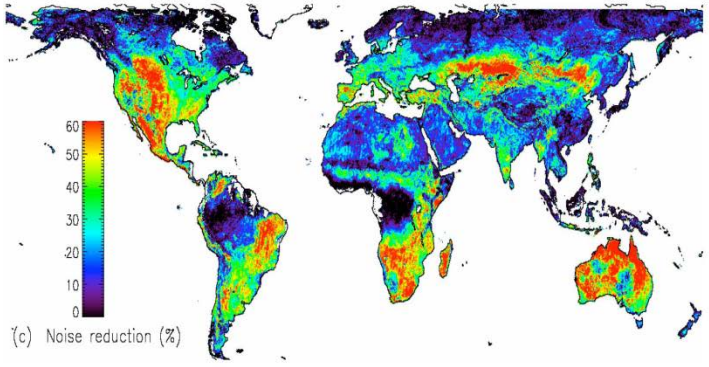




BRDF CORRECTION







Generic Surface Reflectance Algorithm for VIIRS, MODIS Landsat 8…

The surface reflectance algorithm relies on:

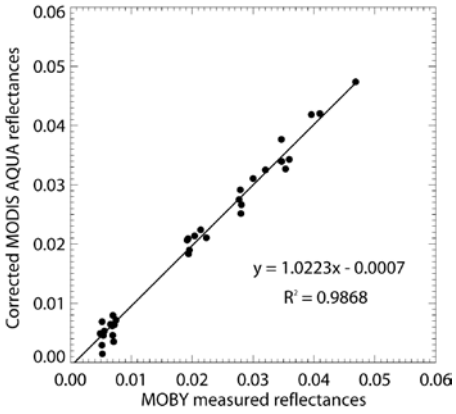
- the use of very accurate (better than 1%) vector radiative transfer modeling of the coupled atmosphere-surface system
- the inversion of key atmospheric parameters (aerosol, water vapor)

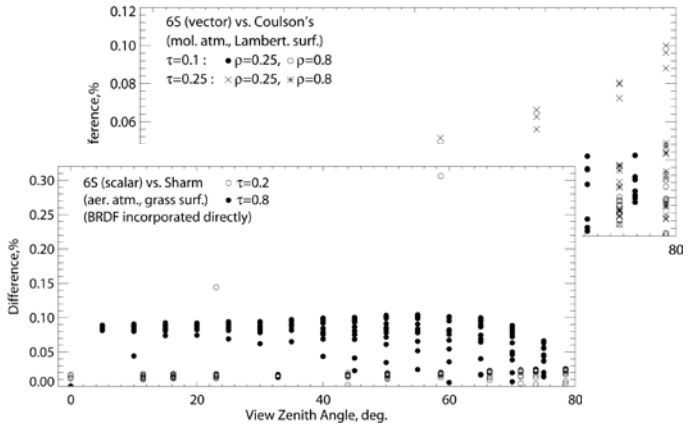
Home page: http://modis-sr.ltdri.org

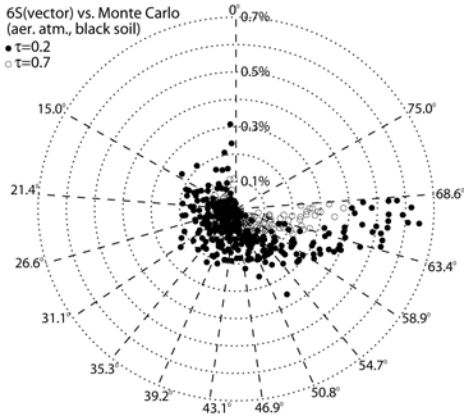
6SV Validation Effort

The complete 6SV validation effort is summarized in three manuscripts:

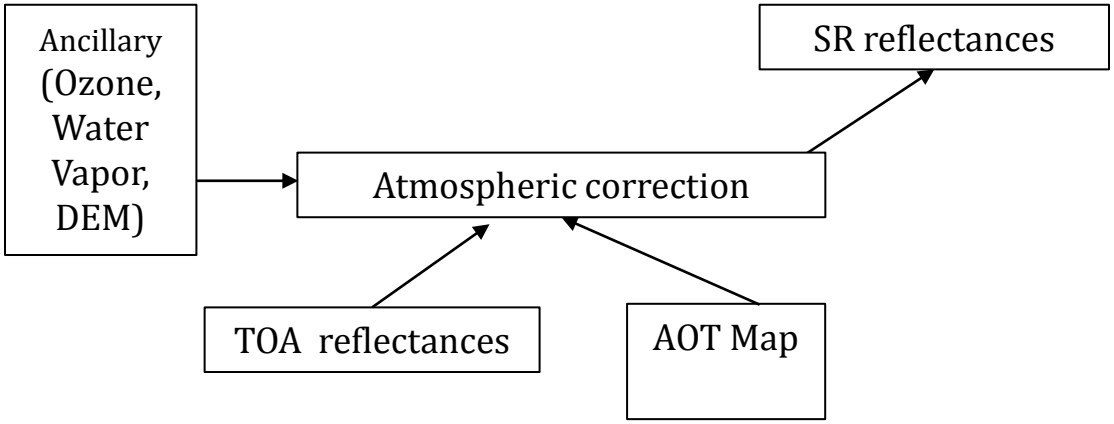
- Kotchenova, S. Y., Vermote, E. F., Matarrese, R., & Klemm Jr, F. J. (2006). Validation of a vector version of the 6S radiative transfer code for atmospheric correction of satellite data. Part I: Path radiance. *Applied Optics*, *45*(26), 6762-6774.
- Kotchenova, S. Y., & Vermote, E. F. (2007). Validation of a vector version of the 6S radiative transfer code for atmospheric correction of satellite data. Part II. Homogeneous Lambertian and anisotropic surfaces. *Applied Optics*, *46*(20), 4455-4464.
- Kotchenova, S. Y., Vermote, E. F., Levy, R., & Lyapustin, A. (2008). Radiative transfer codes for atmospheric correction and aerosol retrieval: intercomparison study. *Applied Optics*, *47*(13), 2215-2226.







Generic flowchart for atmospheric correction



Aerosol inversion

Reading **Inputs, LUT** and **Ancillary data**

ρ_{surf} determined (*) using ρ_{atm}, T_{atm} and S_{atm} **from LUT** assuming AOT, Aerosol model and knowing pressure, altitude, water vapor, ozone…

Aerosol Opt. Thick. and **Aerosol model** for each pixel

Using the relationship between the blue surface reflectance (490 nm) and the red surface reflectance (665 nm) known from MODIS, we are able to retrieve the **AOT.**

We loop the AOT until $(\rho_{surf}$ blue / ρ_{surf} red$)_{MSI} = (\rho_{surf}$ blue / ρ_{surf} red$)_{MODIS}$

The retrieved AOT is used to compute the surface reflectance at 443 and 2190 nm. The **aerosol model** is then derived by minimizing the residual.

$$residual = \frac{\sum_{i=1}^{2}\left(\rho_{surf}^{i} - Ratio_{665}^{i} * \rho_{surf}^{665}\right)}{2}$$

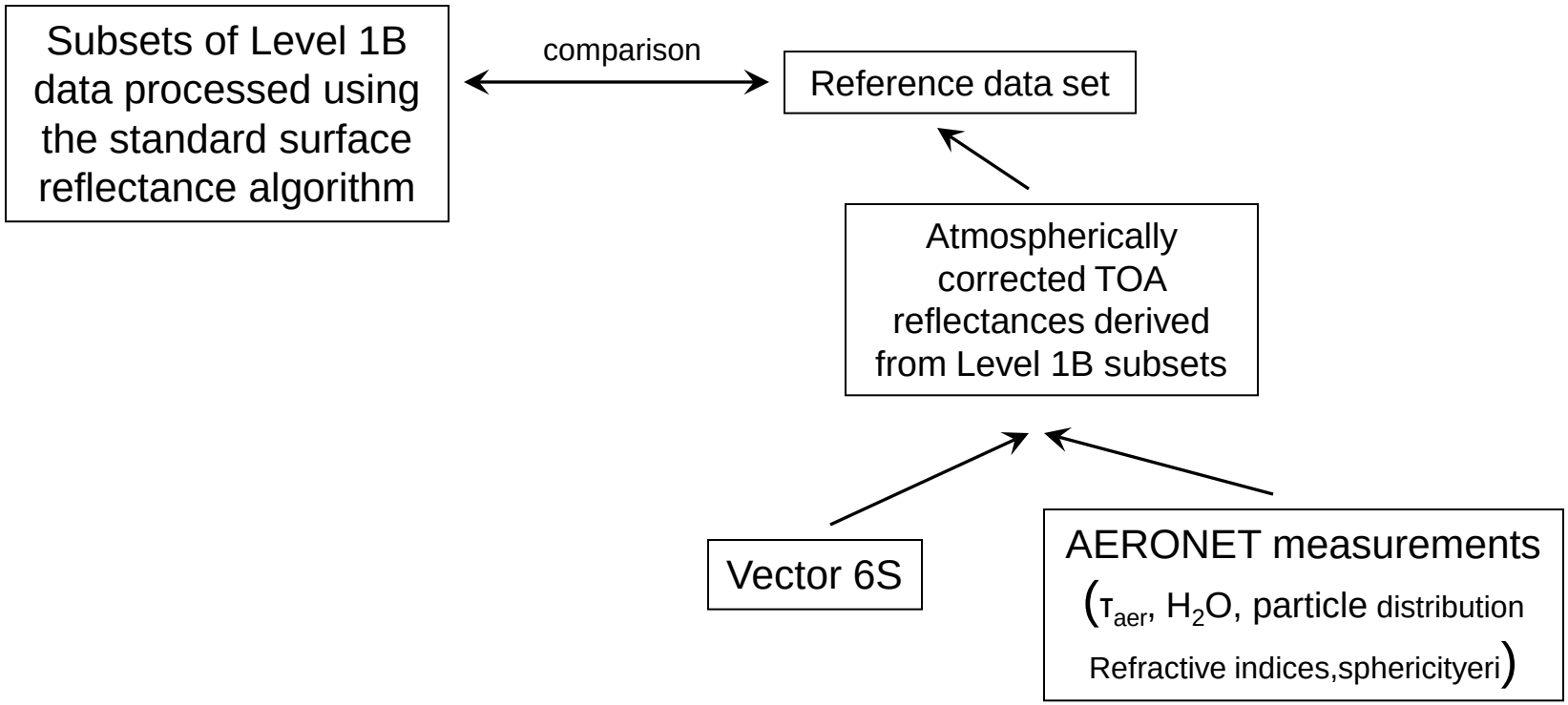
Surface reflectance for each pixel and each band

Computation of **surface reflectances** for all channels

ρ_{surf} determined (*) using ρ_{atm}, T_{atm} and S_{atm} **from LUT** knowing AOT, Aerosol model, pressure, altitude, water vapor, ozone…

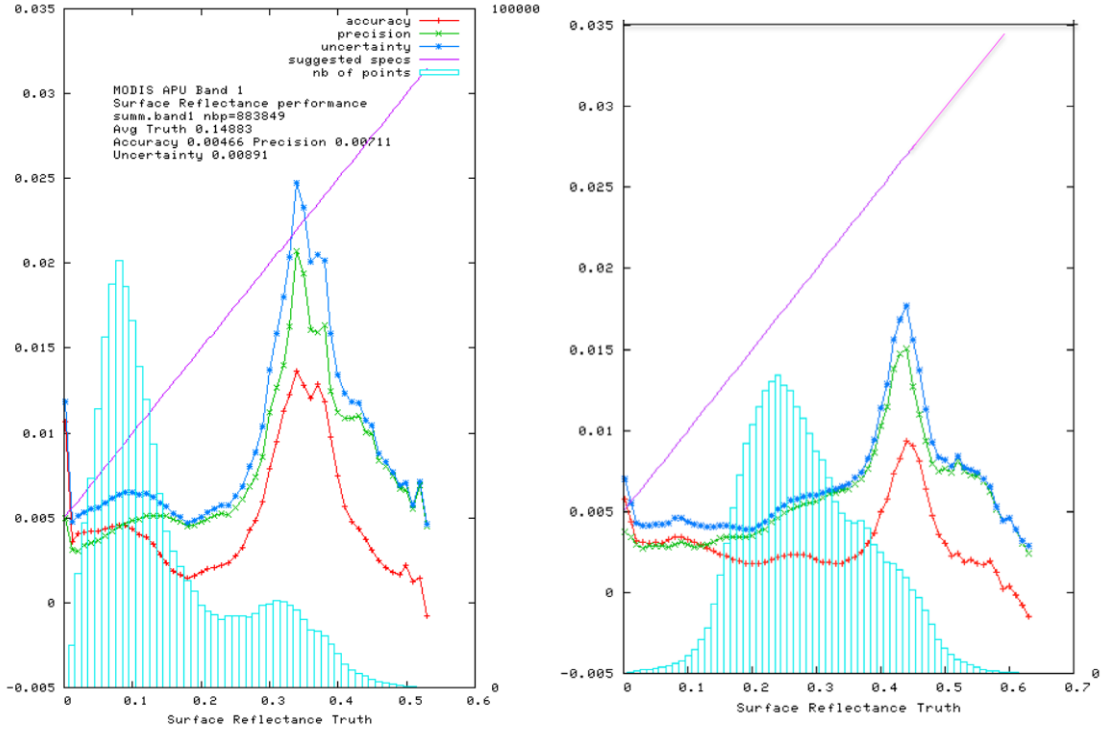
$$(*)\quad \rho_{surf} = \frac{Y}{1 + S_{atm}.Y} \quad \text{with} \quad Y = \frac{1}{T_{atm}.tg^{wv}}\left[\left(\frac{\rho_{TOA}}{tg^{O3}.tg^{others}} - \right) - \left(\rho_{atm} - \rho_{ray}\right).tg^{wv/2} - \rho_{ray}\right]$$

Methodology for evaluating the performance of surface reflectance



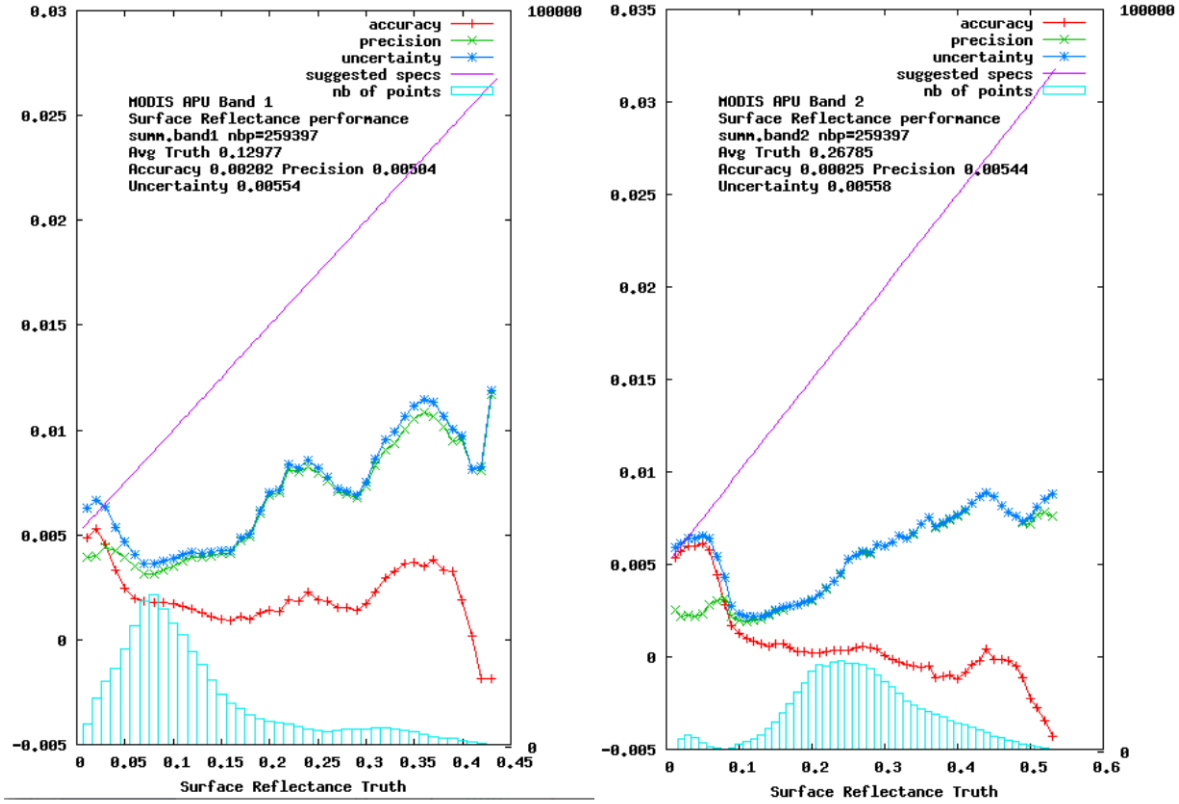
http://mod09val.ltdri.org/cgi-bin/mod09_c005_public_allsites_onecollection.cgi

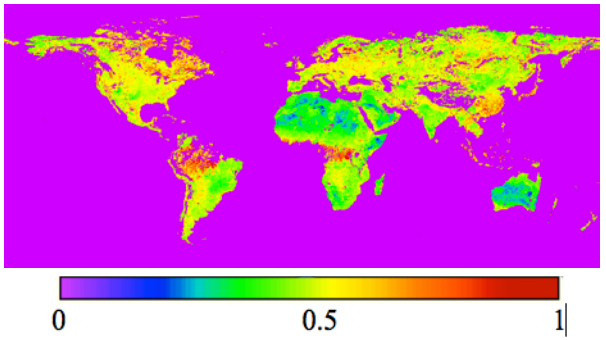
quantitative assessment of performances (APU)



COLLECTION 5: accuracy or mean bias (red line), Precision or repeatability (green line) and Uncertainty or quadratic sum of Accuracy and Precision (blue line) of the surface reflectance in band 1 in the Red (top left), band 2 in the Near Infrared (top right also shown is the uncertainty specification (the line in magenta), that was derived from the theoretical error budget. Data collected from Terra over 200 AERONET sites from 2000 to 2009.

Improving the aerosol retrieval in collection 6 reflected in APU metrics

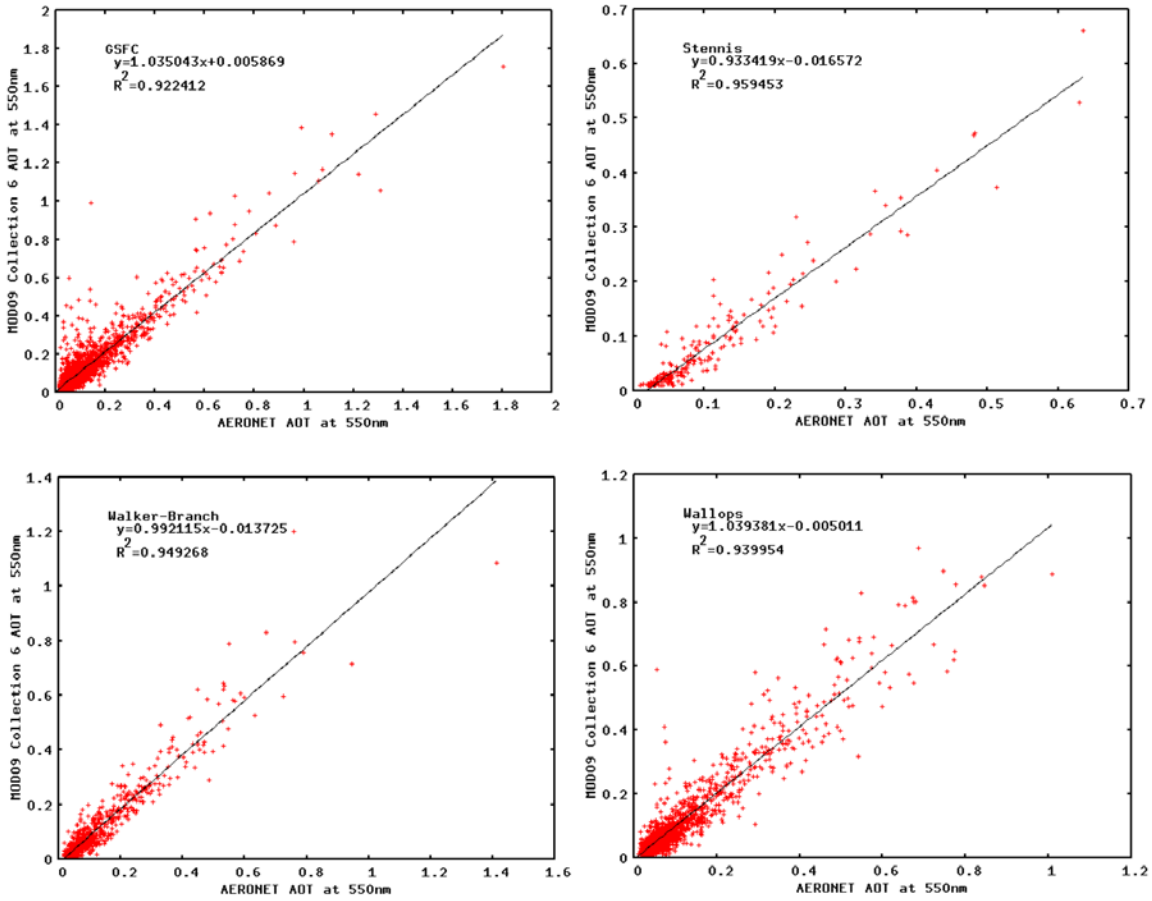




ratio band3/band1 derived using MODIS top of the atmosphere corrected with MISR aerosol optical depth

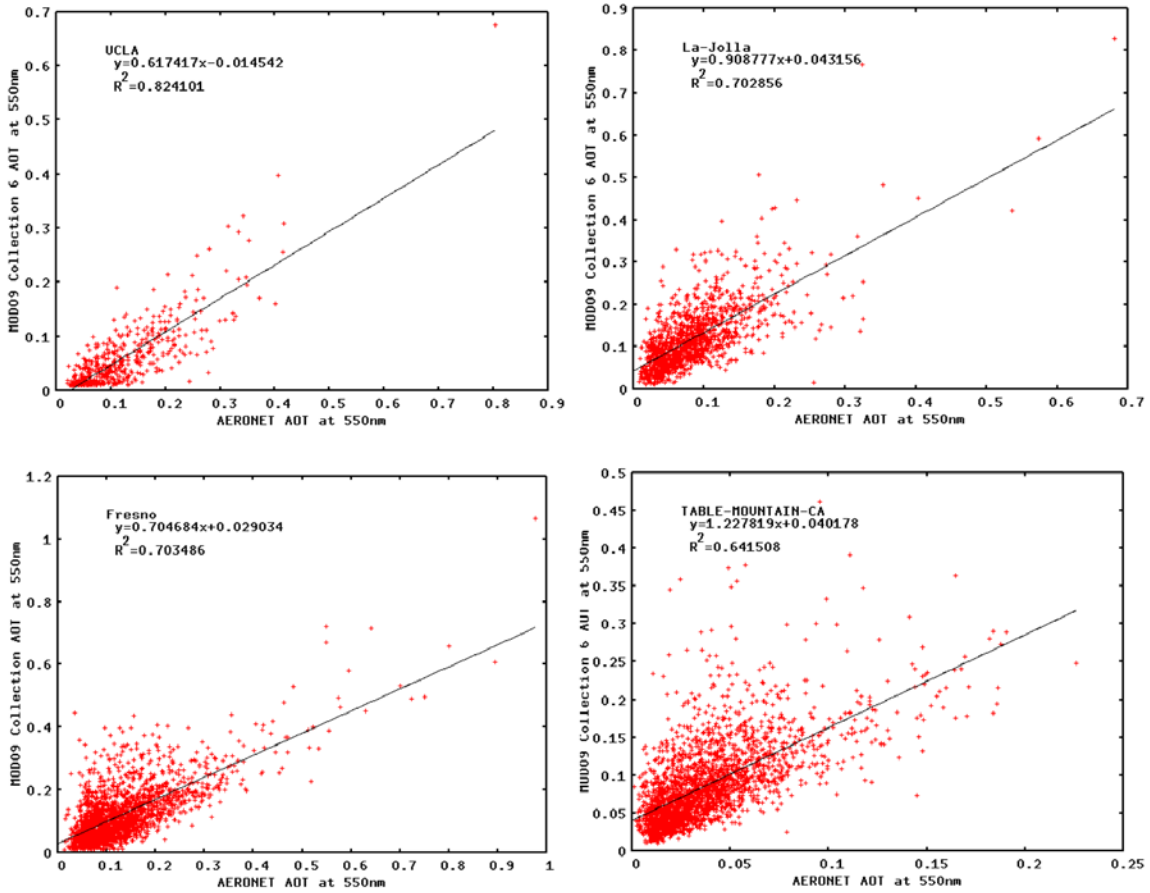
COLLECTION 6: accuracy or mean bias (red line), Precision or repeatability (green line) and Uncertainty or quadratic sum of Accuracy and Precision (blue line) of the surface reflectance in band 1 in the Red (top left), band 2 in the Near Infrared (top right also shown is the uncertainty specification (the line in magenta), that was derived from the theoretical error budget. Data collected from Terra over 200 AERONET sites from 2003.

Aerosol retrieval also shows improvement



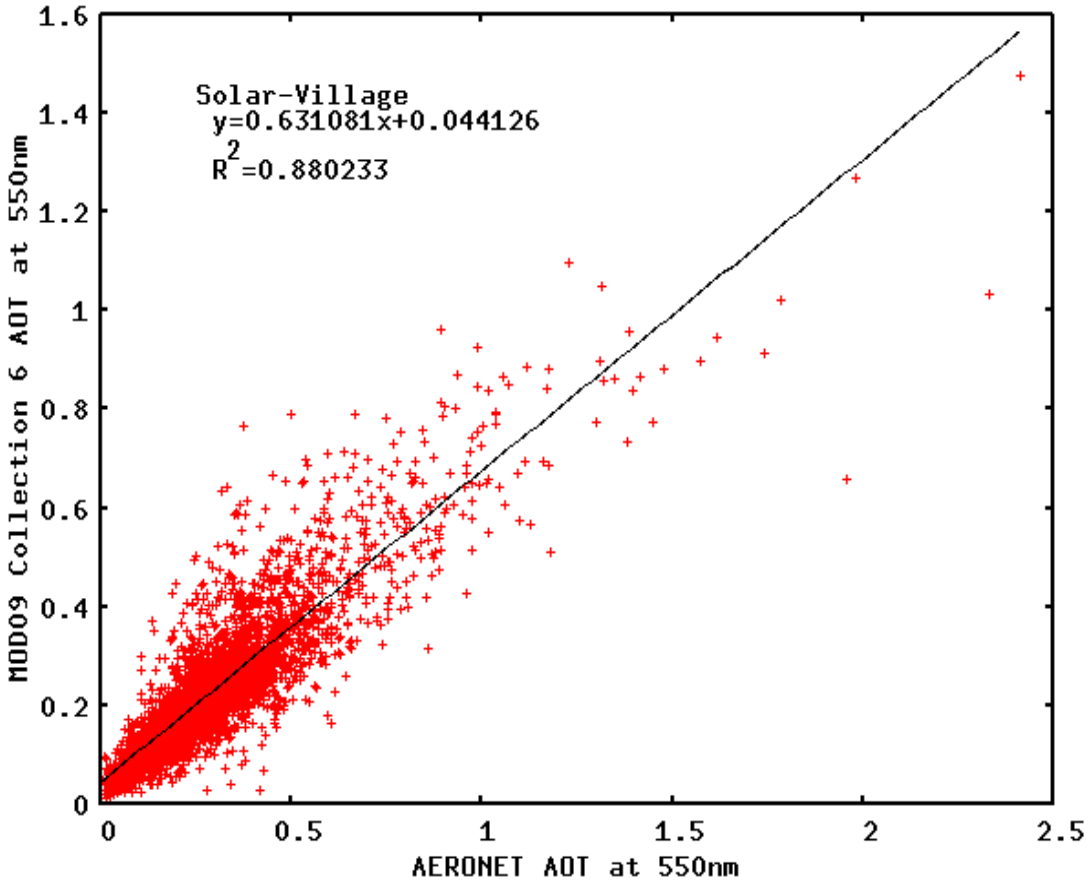
Scatterplot of the MOD09 AOT at 550nm versus the AERONET measured AOT at 550nm for East Coast sites selection: GSFC (top left), Stennis (top right), Walker Branch (bottom left) and Wallops (bottom right).

Aerosol retrieval also shows improvement



Scatterplot of the MOD09 AOT at 550nm versus the AERONET measured AOT at 550nm for the West Coast sites selection: UCLA (top left), La Jolla (top right), and Fresno (bottom left) and Table Mountain (bottom right).

Aerosol retrieval also shows improvement



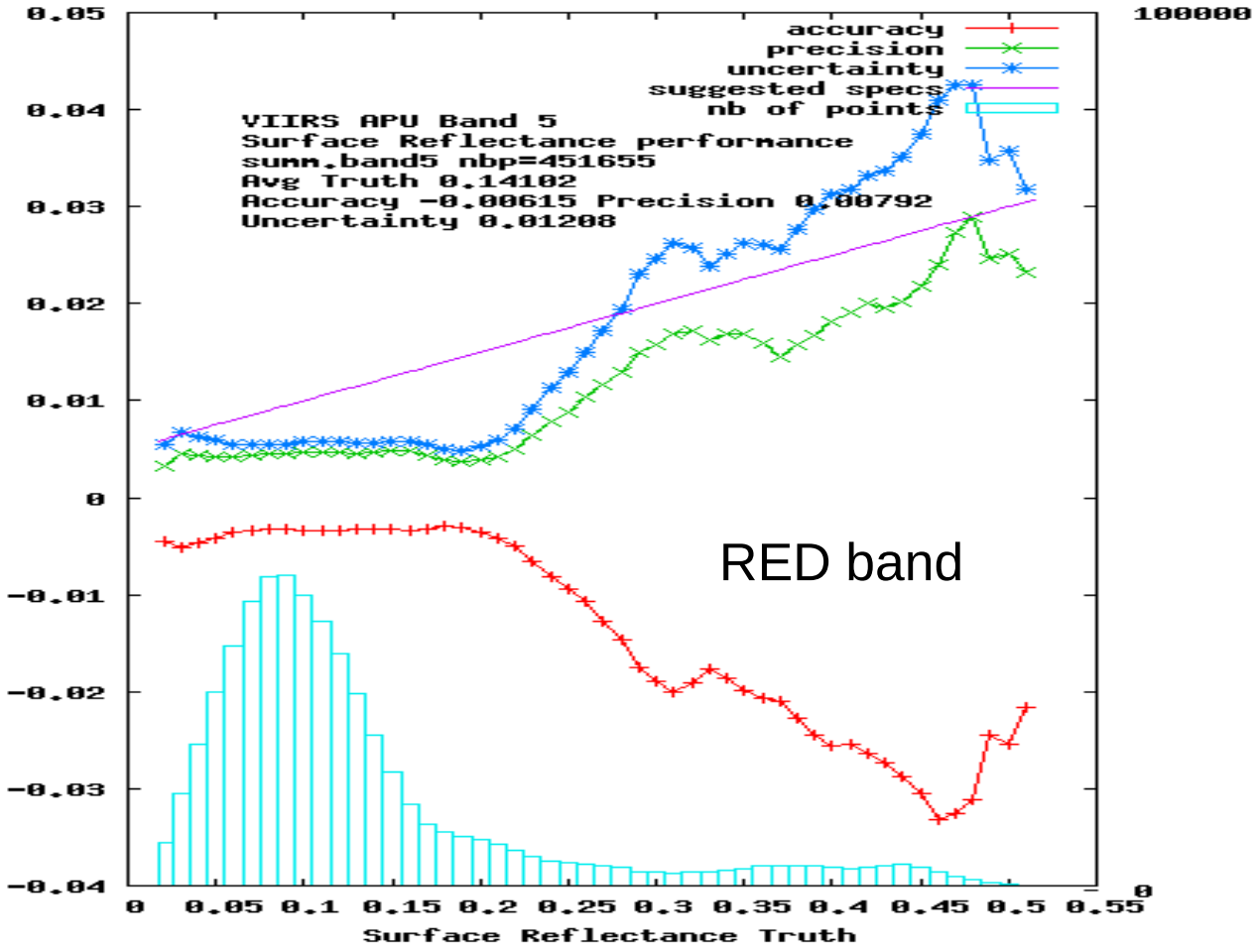
Scatterplot of the MOD09 AOT at 550nm versus the AERONET measured AOT at 550nm for for a very bright site in Saudi Arabia (Solar Village)

VIIRS Surface reflectance

- the VIIRS SR product is directly heritage from collection 5 MODIS and that it has been validated to stage 1 (Land PEATE adjusted version)
- MODIS algorithm refinements from Collection 6 are being integrated into the VIIRS algorithm and shared with the NOAA JPSS project for possible inclusion in future versions of the operational product (NDE) .

Evaluation of Algorithm Performance

VIIRS C11 reprocessing (2013-2015)

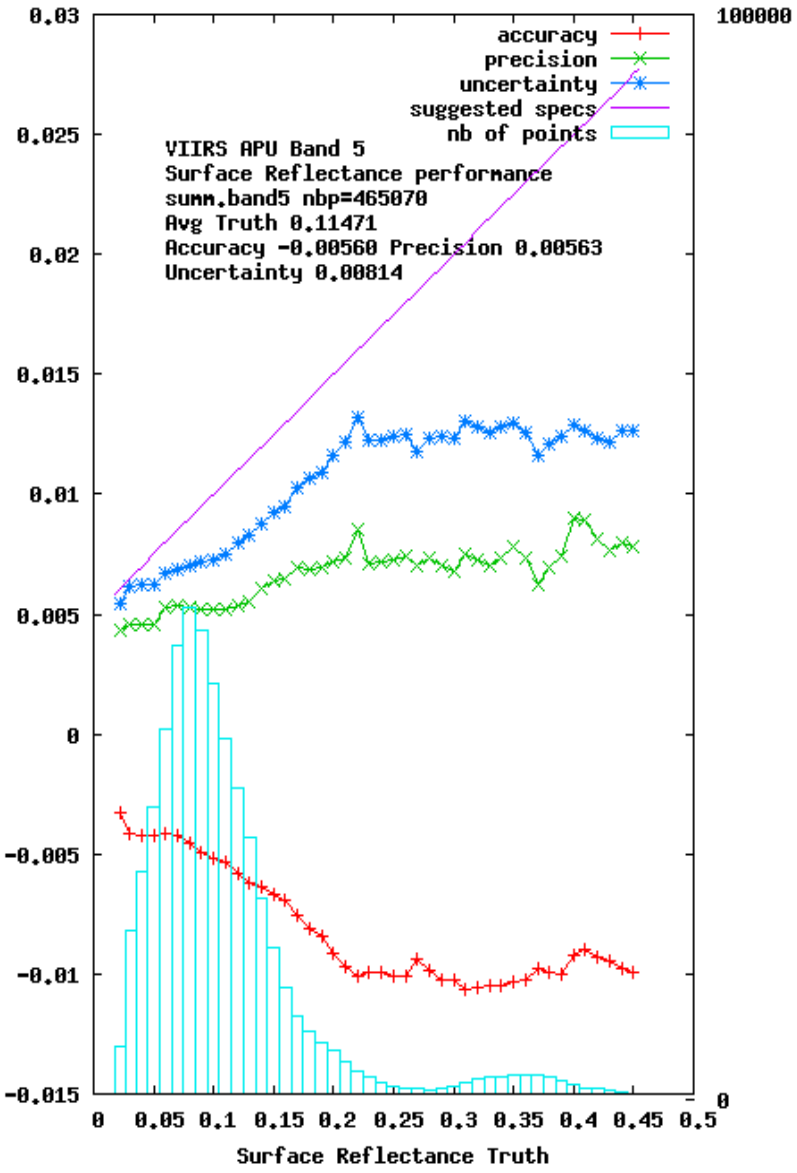


450000 pixels were analyzed for each band.

Red = Accuracy (mean bias)
Green = Precision (repeatability)
Blue = Uncertainty (quadatric sum of A and P)

On average well below magenta theoretical error bar

VIIRS AS5000 reprocessing (NDE version)



The need for a protocol to use of AERONET data

To correctly take into account the aerosols, we need the **aerosol microphysical properties** provided by the AERONET network including size-distribution (%C_f, %C_c, C_f, C_c, r_f, r_c, σ_r, σ_c), complex refractive indices and sphericity.

Over the 670 available AERONET sites, we selected **230 sites** with sufficient data.

To be useful for validation, the aerosol model should be readily available anytime, which is not usually the case.

Following *Dubovik et al.*, 2002, JAS,*[2] one can used regressions for each microphysical parameters using as parameter either τ_{550} (aot) or τ_{440} and α (*Angström* coeff.).

The protocol needs to be further agreed on and its uncertainties assessed (work in progress)

ACIX: CEOS-WGCV Atmospheric Correction Inter-comparison Exercise (ESA/NASA/UMD)

The exercise aims to bring together available AC processors (**actually 14 processors including SEN2COR, MACCS, L8-S2-6SAC, …**) to generate the corresponding SR products.

The input data will be **Landsat-8 and Sentinel-2 imagery** of various test sites, i.e. coastal, agricultural, forest, snow/artic areas and deserts.

Objectives
- To better understand uncertainties and issues on L8 and S2 AC products
- To propose further improvements of the future AC schemes

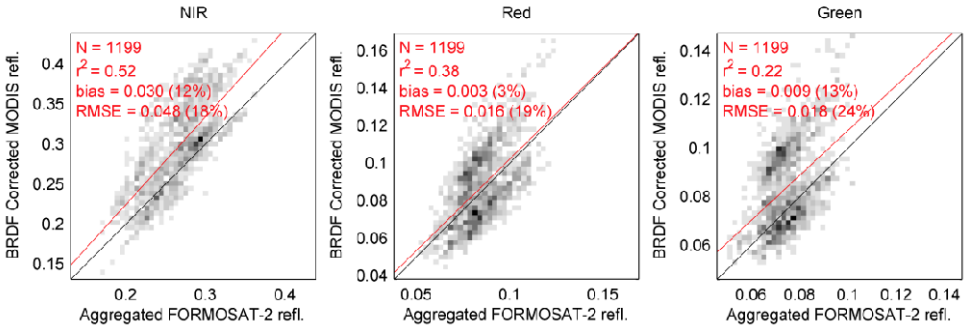
* 1st Workshop in June 21st-22nd @ University of Maryland (by invitation): to elaborate concepts, protocols and guidelines for the inter-comparison and validation of SR products

  Program (with first suggestions) will be provide April 30th (available on the web site for eventual end users feedbacks)

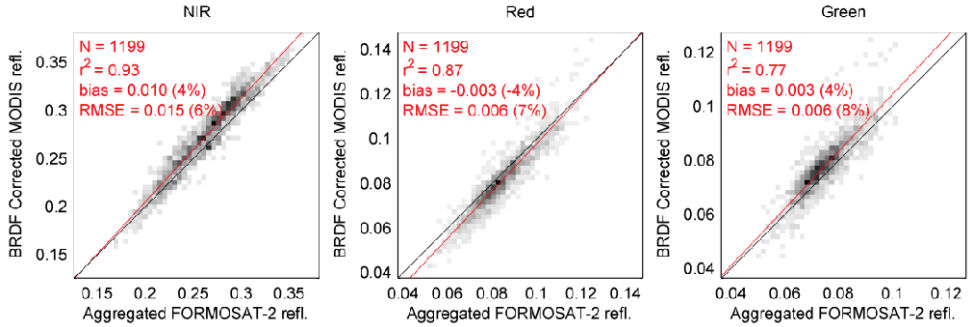
* 2nd workshop in January 2017 (open)

https://earth.esa.int/web/sppa/meetings-workshops/acix

Use of BRDF correction for product cross-comparison



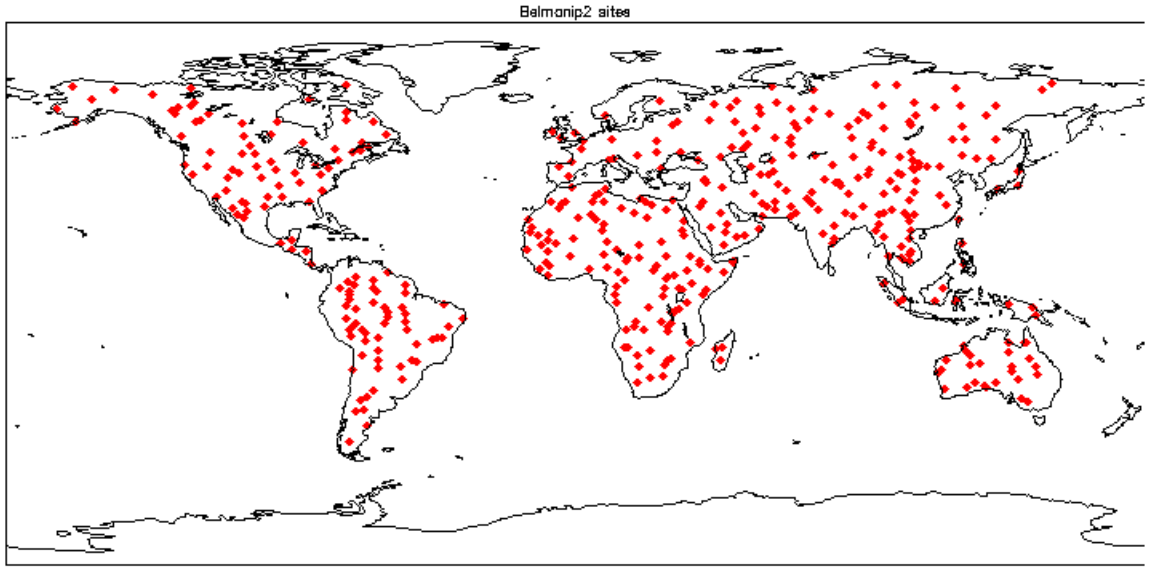
Comparison of aggregated FORMOSAT-2 reflectance and MODIS reflectance. No BRDF correction. Density function from light grey (minimum) to black (maximum); white = no data.

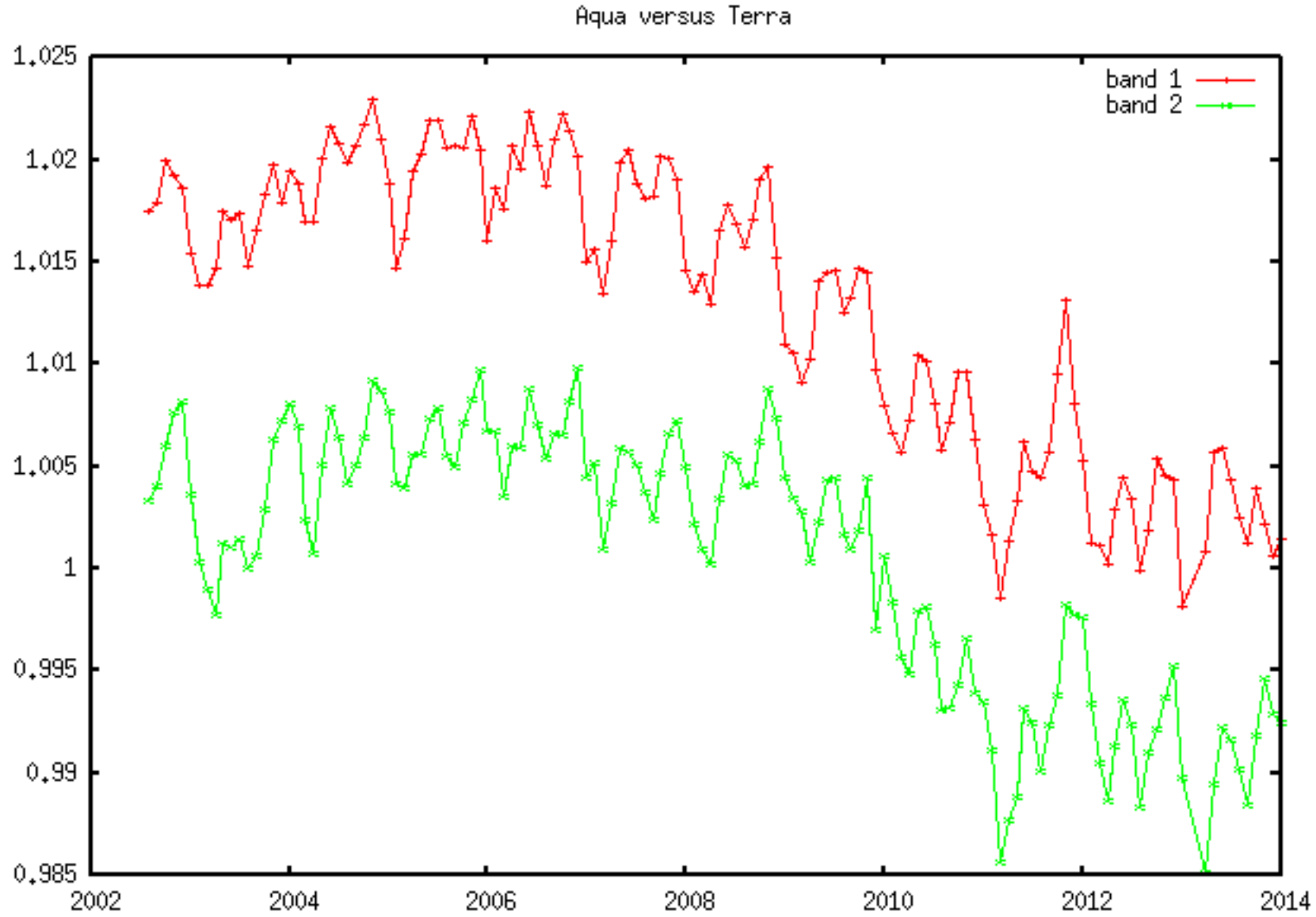


Comparison of aggregated FORMOSAT-2 reflectance and BRDF corrected MODIS reflectance. Corrections were performed with Vermote al. (2009) method using for each day of acquisition, the angular configuration of FORMOSAT-2 data.

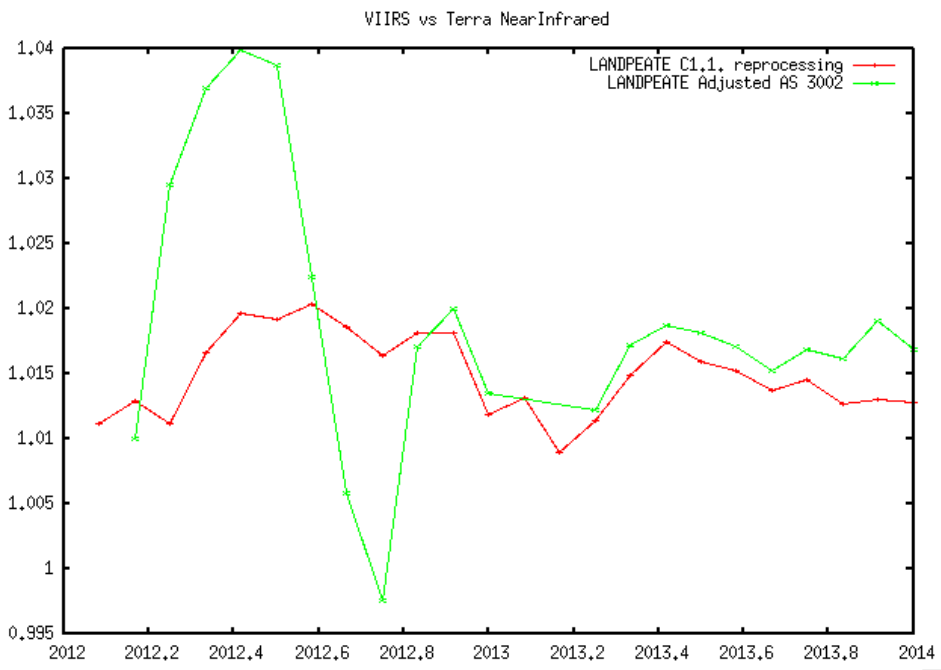
Cross comparison with MODIS over BELMANIP2

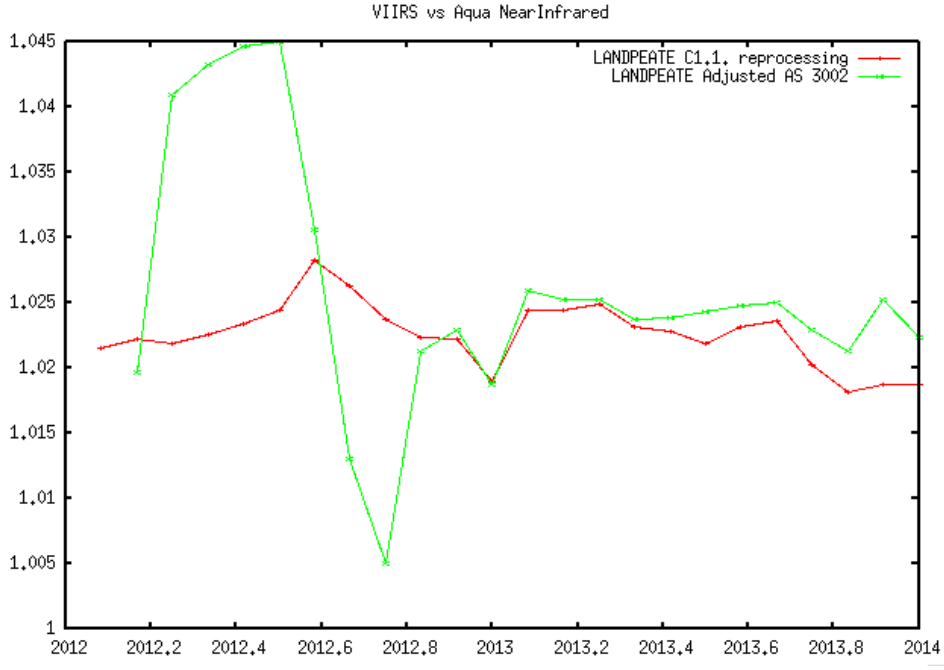
The VIIRS SR is now monitored at more than 400 sites (red losanges) through cross-comparison with MODIS.

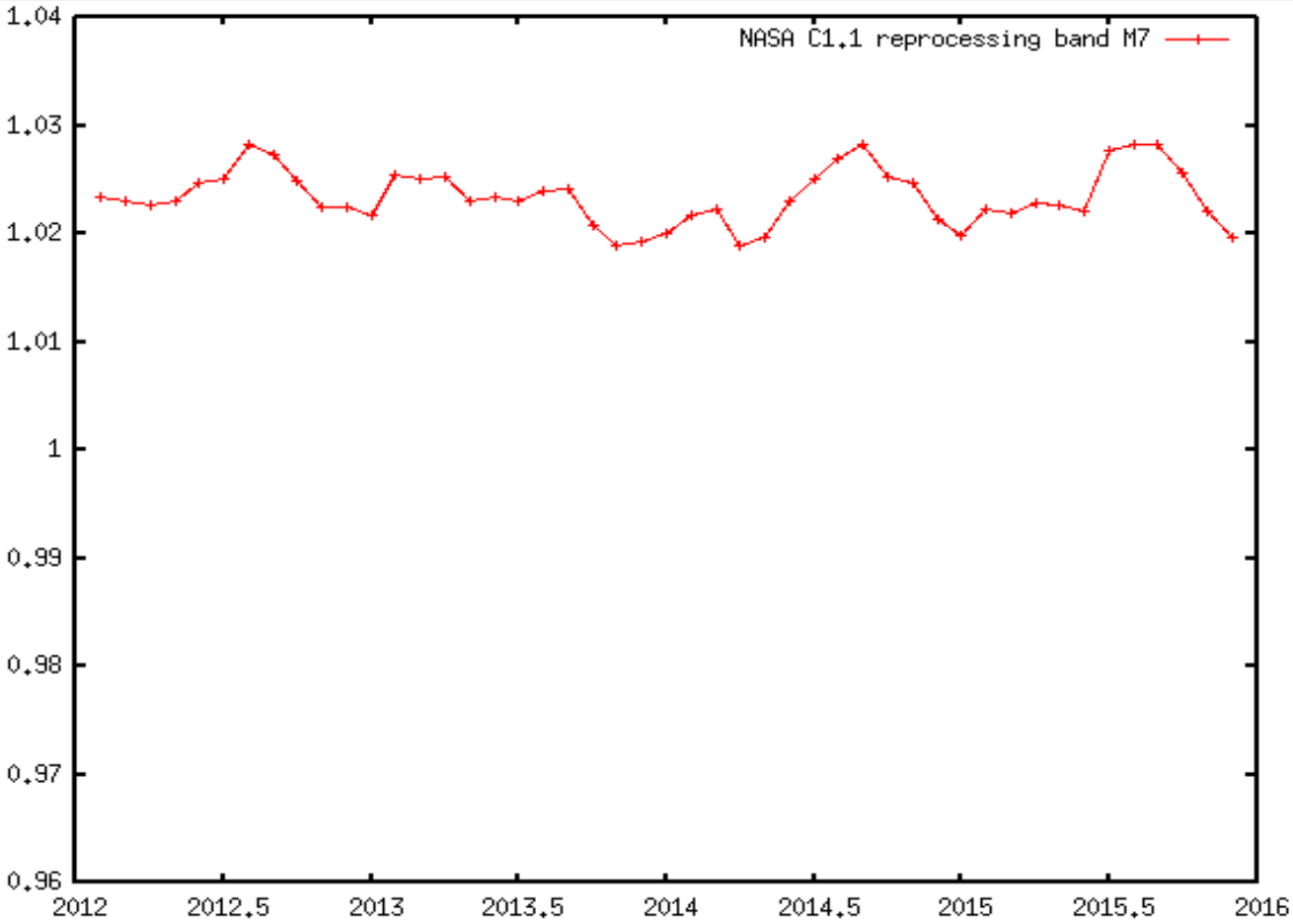



Aqua versus Terra
band 1
band 2
1.025
1.02
1.015
1.01
1.005
1
0.995
0.99
0.985
2002
2004
2006
2008
2010
2012
2014

Results over BELMANIP2

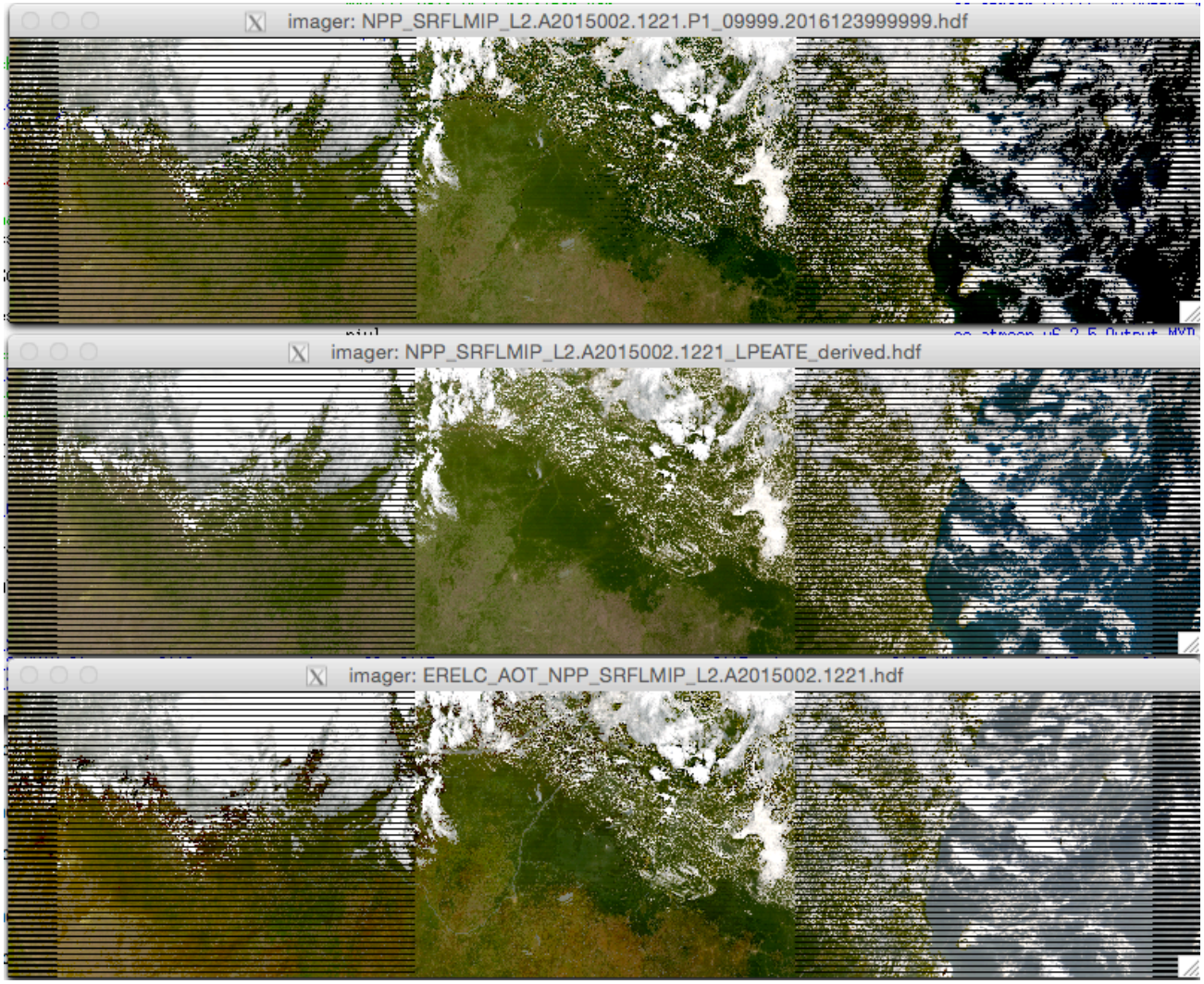




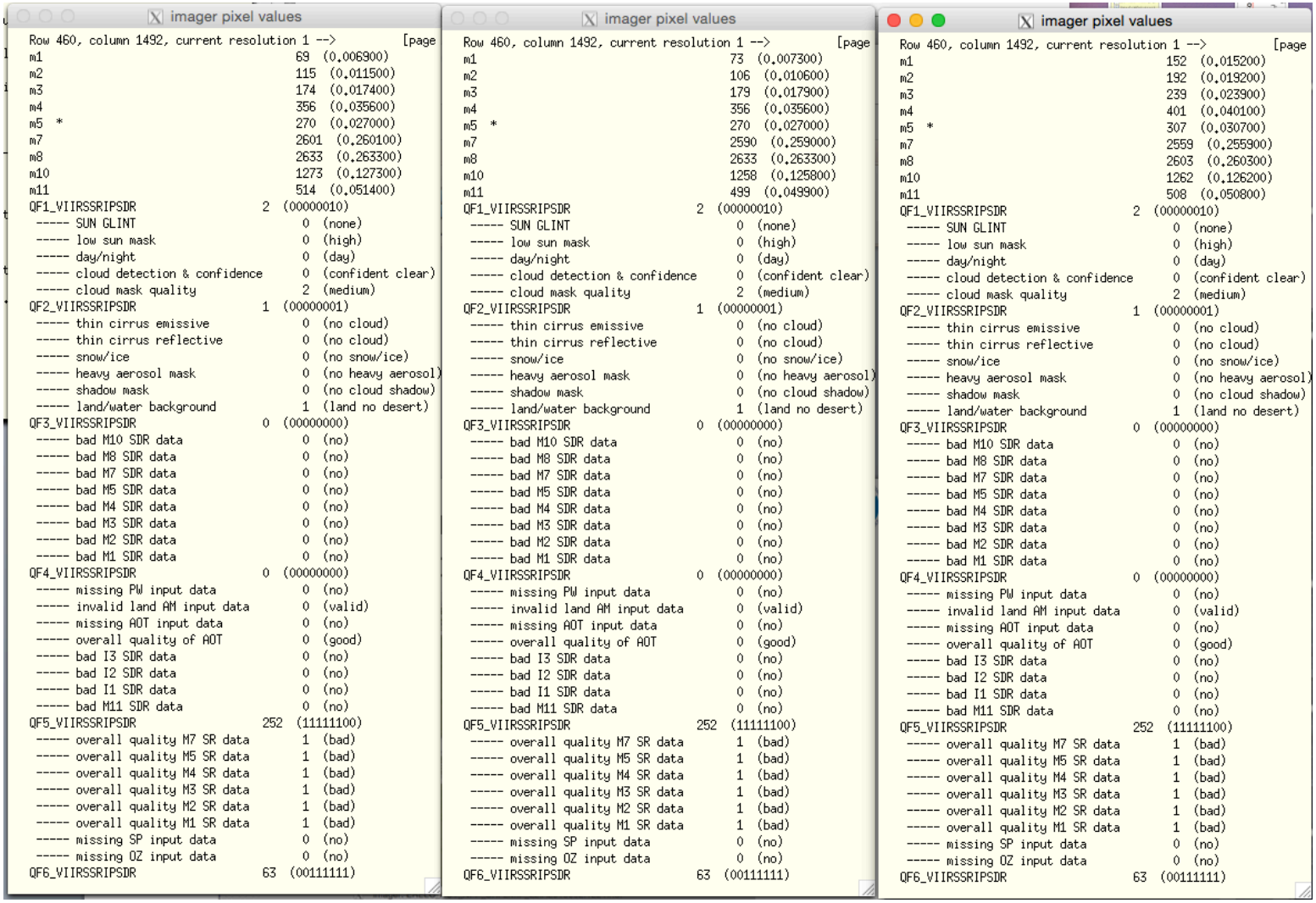


Cross comparison results of the VIIRS and MODIS-Aqua SR product on a monthly basis for the BELMANIP sites reprocessed version (C1.1) for the near infrared band (M7).

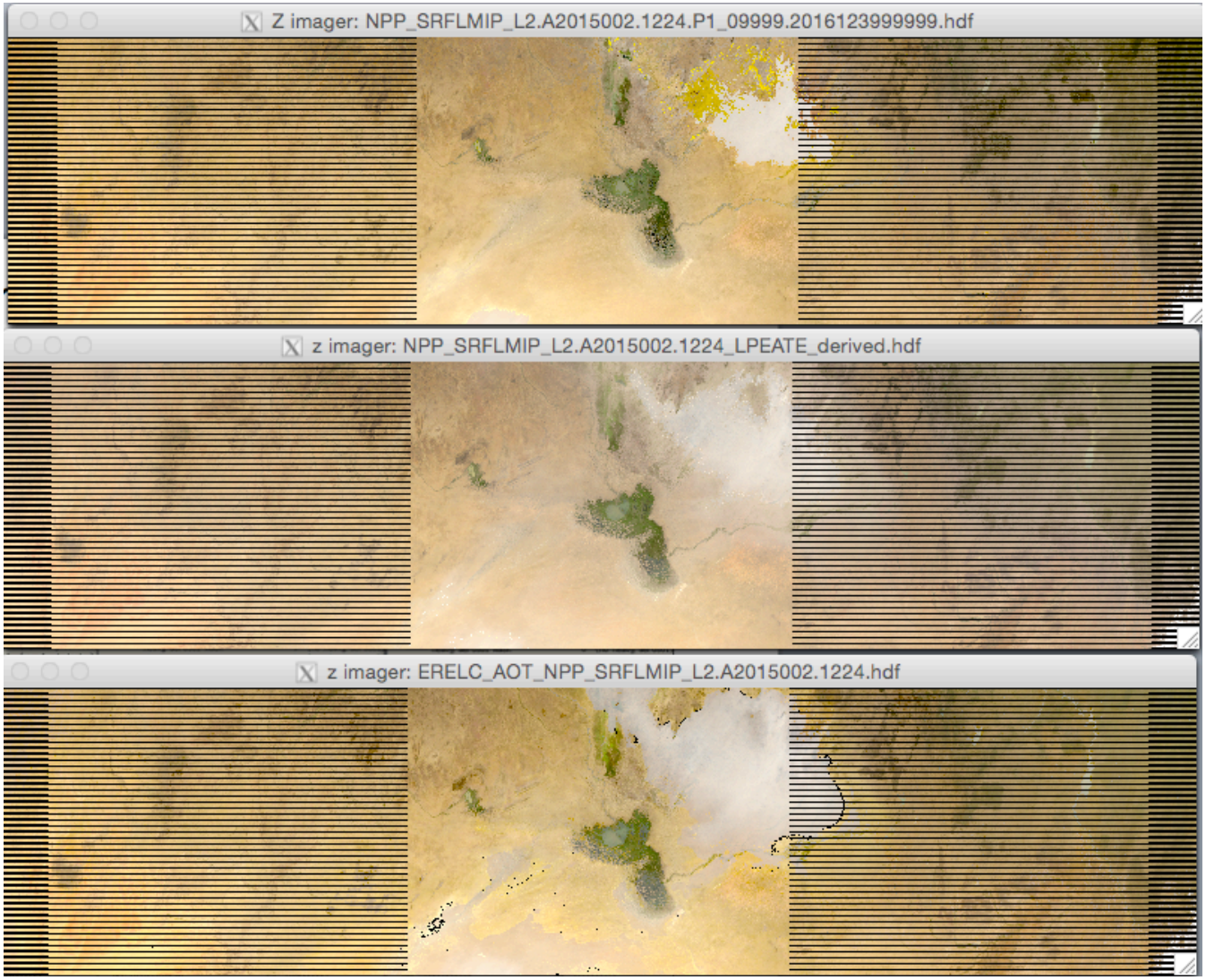
Preliminary version of Enterprise VIIRS SR has been tested



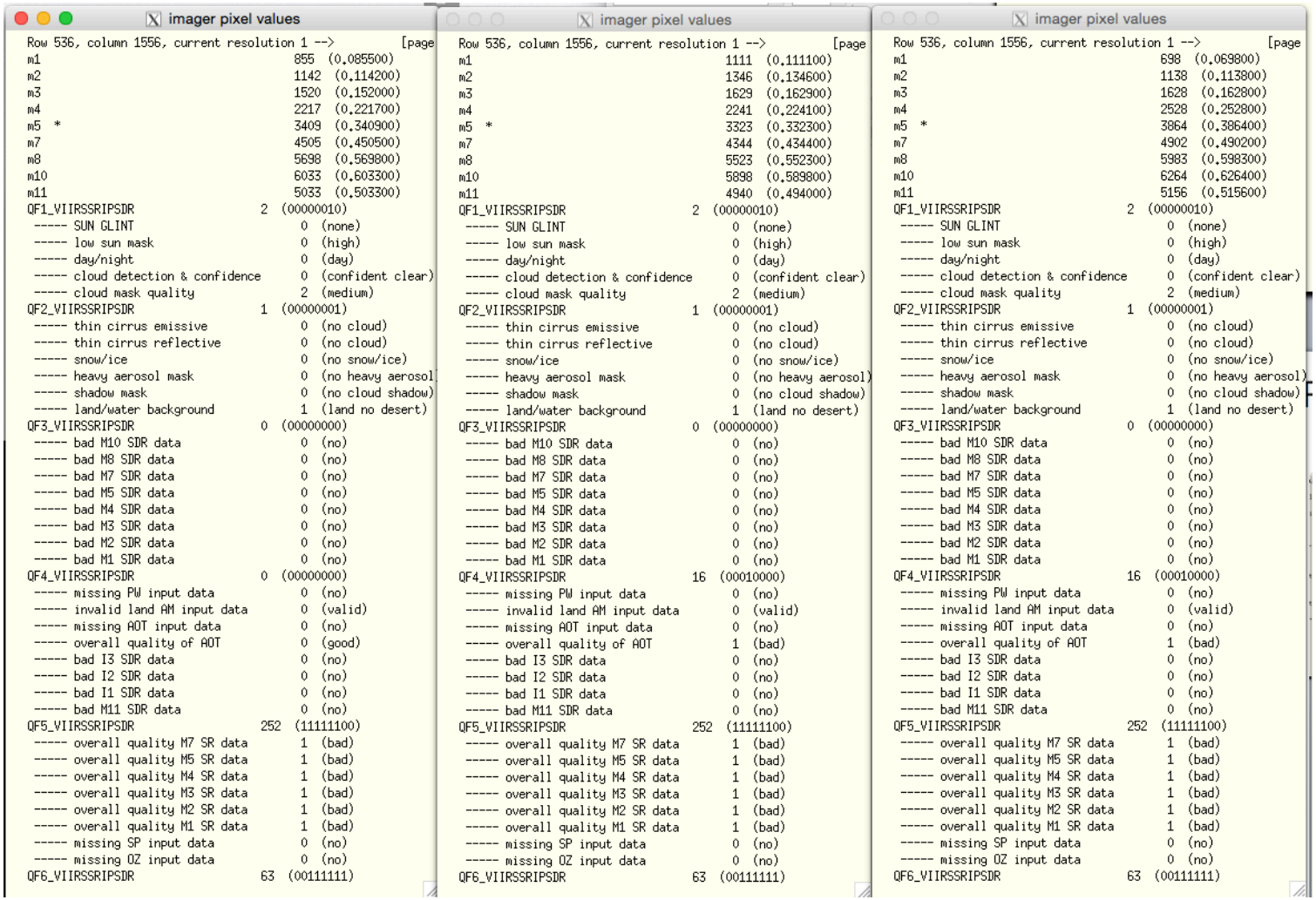
Preliminary version of Enterprise VIIRS SR has been tested



Preliminary version of Enterprise VIIRS SR has been tested



Preliminary version of Enterprise VIIRS SR has been tested



imager pixel values

```
Row 536, column 1556, current resolution 1 -->          [page
m1                                      855  (0.085500)
m2                                      1142  (0.114200)
m3                                      1520  (0.152000)
m4                                      2217  (0.221700)
m5  *                                   3409  (0.340900)
m7                                      4505  (0.450500)
m8                                      5698  (0.569800)
m10                                     6033  (0.603300)
m11                                     5033  (0.503300)
QF1_VIIRSSRIPSDR                    2  (00000010)
 ----- SUN GLINT                        0  (none)
 ----- low sun mask                     0  (high)
 ----- day/night                        0  (day)
 ----- cloud detection & confidence     0  (confident clear)
 ----- cloud mask quality               2  (medium)
QF2_VIIRSSRIPSDR                    1  (00000001)
 ----- thin cirrus emissive             0  (no cloud)
 ----- thin cirrus reflective           0  (no cloud)
 ----- snow/ice                         0  (no snow/ice)
 ----- heavy aerosol mask               0  (no heavy aerosol
 ----- shadow mask                      0  (no cloud shadow)
 ----- land/water background            1  (land no desert)
QF3_VIIRSSRIPSDR                    0  (00000000)
 ----- bad M10 SDR data                 0  (no)
 ----- bad M8 SDR data                  0  (no)
 ----- bad M7 SDR data                  0  (no)
 ----- bad M5 SDR data                  0  (no)
 ----- bad M4 SDR data                  0  (no)
 ----- bad M3 SDR data                  0  (no)
 ----- bad M2 SDR data                  0  (no)
 ----- bad M1 SDR data                  0  (no)
QF4_VIIRSSRIPSDR                    0  (00000000)
 ----- missing PW input data            0  (no)
 ----- invalid land AM input data       0  (valid)
 ----- missing AOT input data           0  (no)
 ----- overall quality of AOT           0  (good)
 ----- bad I3 SDR data                  0  (no)
 ----- bad I2 SDR data                  0  (no)
 ----- bad I1 SDR data                  0  (no)
 ----- bad M11 SDR data                 0  (no)
QF5_VIIRSSRIPSDR                    252  (11111100)
 ----- overall quality M7 SR data       1  (bad)
 ----- overall quality M5 SR data       1  (bad)
 ----- overall quality M4 SR data       1  (bad)
 ----- overall quality M3 SR data       1  (bad)
 ----- overall quality M2 SR data       1  (bad)
 ----- overall quality M1 SR data       1  (bad)
 ----- missing SP input data            0  (no)
 ----- missing OZ input data            0  (no)
QF6_VIIRSSRIPSDR                    63  (00111111)
```

imager pixel values

```
Row 536, column 1556, current resolution 1 -->          [page
m1                                      1111  (0.111100)
m2                                      1346  (0.134600)
m3                                      1629  (0.162900)
m4                                      2241  (0.224100)
m5  *                                   3323  (0.332300)
m7                                      4344  (0.434400)
m8                                      5523  (0.552300)
m10                                     5898  (0.589800)
m11                                     4940  (0.494000)
QF1_VIIRSSRIPSDR                    2  (00000010)
 ----- SUN GLINT                        0  (none)
 ----- low sun mask                     0  (high)
 ----- day/night                        0  (day)
 ----- cloud detection & confidence     0  (confident clear)
 ----- cloud mask quality               2  (medium)
QF2_VIIRSSRIPSDR                    1  (00000001)
 ----- thin cirrus emissive             0  (no cloud)
 ----- thin cirrus reflective           0  (no cloud)
 ----- snow/ice                         0  (no snow/ice)
 ----- heavy aerosol mask               0  (no heavy aerosol)
 ----- shadow mask                      0  (no cloud shadow)
 ----- land/water background            1  (land no desert)
QF3_VIIRSSRIPSDR                    0  (00000000)
 ----- bad M10 SDR data                 0  (no)
 ----- bad M8 SDR data                  0  (no)
 ----- bad M7 SDR data                  0  (no)
 ----- bad M5 SDR data                  0  (no)
 ----- bad M4 SDR data                  0  (no)
 ----- bad M3 SDR data                  0  (no)
 ----- bad M2 SDR data                  0  (no)
 ----- bad M1 SDR data                  0  (no)
QF4_VIIRSSRIPSDR                    16  (00010000)
 ----- missing PW input data            0  (no)
 ----- invalid land AM input data       0  (valid)
 ----- missing AOT input data           0  (no)
 ----- overall quality of AOT           1  (bad)
 ----- bad I3 SDR data                  0  (no)
 ----- bad I2 SDR data                  0  (no)
 ----- bad I1 SDR data                  0  (no)
 ----- bad M11 SDR data                 0  (no)
QF5_VIIRSSRIPSDR                    252  (11111100)
 ----- overall quality M7 SR data       1  (bad)
 ----- overall quality M5 SR data       1  (bad)
 ----- overall quality M4 SR data       1  (bad)
 ----- overall quality M3 SR data       1  (bad)
 ----- overall quality M2 SR data       1  (bad)
 ----- overall quality M1 SR data       1  (bad)
 ----- missing SP input data            0  (no)
 ----- missing OZ input data            0  (no)
QF6_VIIRSSRIPSDR                    63  (00111111)
```

imager pixel values

```
Row 536, column 1556, current resolution 1 -->          [page
m1                                      698  (0.069800)
m2                                      1138  (0.113800)
m3                                      1628  (0.162800)
m4                                      2528  (0.252800)
m5  *                                   3864  (0.386400)
m7                                      4902  (0.490200)
m8                                      5983  (0.598300)
m10                                     6264  (0.626400)
m11                                     5156  (0.515600)
QF1_VIIRSSRIPSDR                    2  (00000010)
 ----- SUN GLINT                        0  (none)
 ----- low sun mask                     0  (high)
 ----- day/night                        0  (day)
 ----- cloud detection & confidence     0  (confident clear)
 ----- cloud mask quality               2  (medium)
QF2_VIIRSSRIPSDR                    1  (00000001)
 ----- thin cirrus emissive             0  (no cloud)
 ----- thin cirrus reflective           0  (no cloud)
 ----- snow/ice                         0  (no snow/ice)
 ----- heavy aerosol mask               0  (no heavy aerosol)
 ----- shadow mask                      0  (no cloud shadow)
 ----- land/water background            1  (land no desert)
QF3_VIIRSSRIPSDR                    0  (00000000)
 ----- bad M10 SDR data                 0  (no)
 ----- bad M8 SDR data                  0  (no)
 ----- bad M7 SDR data                  0  (no)
 ----- bad M5 SDR data                  0  (no)
 ----- bad M4 SDR data                  0  (no)
 ----- bad M3 SDR data                  0  (no)
 ----- bad M2 SDR data                  0  (no)
 ----- bad M1 SDR data                  0  (no)
QF4_VIIRSSRIPSDR                    16  (00010000)
 ----- missing PW input data            0  (no)
 ----- invalid land AM input data       0  (valid)
 ----- missing AOT input data           0  (no)
 ----- overall quality of AOT           1  (bad)
 ----- bad I3 SDR data                  0  (no)
 ----- bad I2 SDR data                  0  (no)
 ----- bad I1 SDR data                  0  (no)
 ----- bad M11 SDR data                 0  (no)
QF5_VIIRSSRIPSDR                    252  (11111100)
 ----- overall quality M7 SR data       1  (bad)
 ----- overall quality M5 SR data       1  (bad)
 ----- overall quality M4 SR data       1  (bad)
 ----- overall quality M3 SR data       1  (bad)
 ----- overall quality M2 SR data       1  (bad)
 ----- overall quality M1 SR data       1  (bad)
 ----- missing SP input data            0  (no)
 ----- missing OZ input data            0  (no)
QF6_VIIRSSRIPSDR                    63  (00111111)
```

Conclusions

- Surface reflectance (SR) algorithm is mature and pathway toward validation and automated QA is clearly identified.
- Algorithm is generic and tied to documented validated radiative transfer code so the accuracy is traceable enabling error budget.
- The use of BRDF correction enables easy cross-comparison of different sensors (MODIS,VIIRS,AVHRR, LDCM, Landsat, Sentinel 2 ,Sentinel 3…)
- AERONET is central to SR validation and a “standard” protocol for its use to be defined (CEOS CVWG initiative)

JPSS1 AND SNPP VIIRS VEGETATION INDEX PRODUCTS

Presenter: Marco Vargas[1]

Collaborators: Tomoaki Miura[2], Zhangyan Jiang[3] ,Mingshi Chen[4]

[1]NOAA Center for Satellite Applications and Research, College Park, MD,
[2]Department of Natural Resources & Environmental Management University of Hawaii at Manoa
[3]NOAA/STAR/RTI/AER, College Park, MD
[4]NOAA/STAR/IMSG, College Park, MD

Outline

- Team Members
- S-NPP VIIRS VI Algorithm & Products
- JPSS-1 Readiness
- Enterprise Algorithm for Vegetation Products
- S-NPP VIIRS VI Reprocessing
- VI Operational Use
- Summary

Team Members

Name	Organization	Roles and Responsibilities
Marco Vargas	NOAA STAR	VI Algorithm Lead
Tomoaki Miura	University of Hawaii	VI Cal/Val lead
Zhangyan Jiang	NOAA STAR/AER	Algorithm and Cal/Val Support
Mingshi Chen	NOAA STAR/IMSG	Algorithm and Cal/Val Support
Anna Kato	University of Hawaii (PhD student)	Cal/Val Support
Ashley Griffin	ASRC Management Services Inc	Land JAM
Walter Wolf	NOAA STAR	STAR AIT Team Lead
Valerie Mikles	NOAA STAR/IMSG	STAR AIT
Michael Ek	NOAA NCEP/EMC	User readiness
Yihua Wu	NOAA NCEP/EMC	User readiness
Weizhong Zheng	NOAA NCEP/EMC	User readiness

IDPS SNPP Operational Algorithm Overview (1/2)

The current IDPS SNPP VIIRS Vegetation Index (VI) EDR consists of two vegetation indices:

1. Normalized Difference Vegetation Index ($NDVI^{TOA}$) from top-of-atmosphere (TOA) reflectances
2. Enhanced Vegetation Index (EVI^{TOC}) from top of canopy (TOC) reflectances.

IDPS SNPP VIIRS VI EDR Algorithm

$$NDVI^{TOA} = (\rho_{I2}^{TOA} - \rho_{I1}^{TOA}) / (\rho_{I2}^{TOA} + \rho_{I1}^{TOA})$$

$$EVI^{TOC} = (1+L) \cdot \frac{\rho_{I2}^{TOC} - \rho_{I1}^{TOC}}{\rho_{I2}^{TOC} + C_1 \cdot \rho_{I1}^{TOC} - C_2 \cdot \rho_{M3}^{TOC} + L}$$

ρ_{M3}^{TOC} Surface reflectance band M3 (488 nm)

ρ_{I1}^{TOC} Surface reflectance band I1 (640 nm)

ρ_{I2}^{TOC} Surface reflectance band I2 (865 nm)

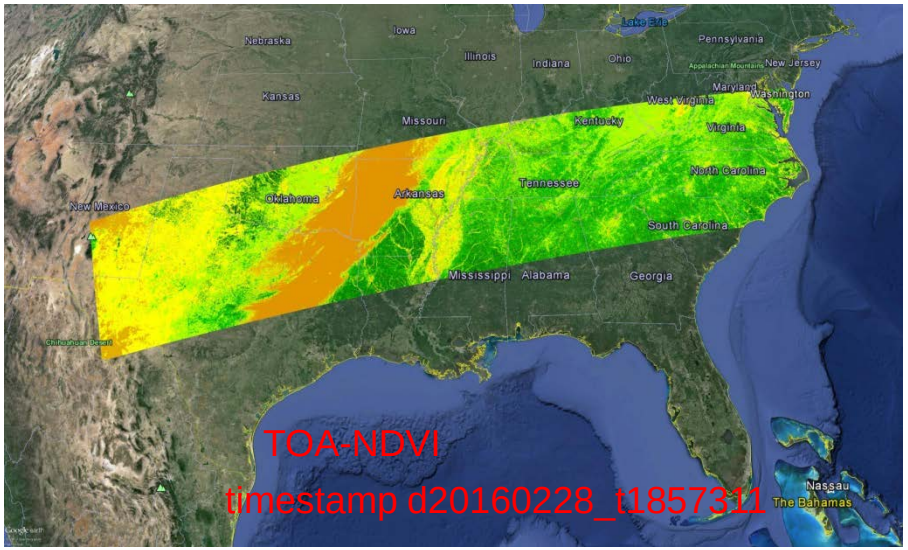
ρ_{I1}^{TOA} Top of the atmosphere reflectance band I1 (640 nm)

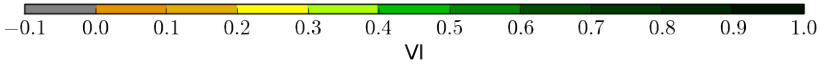
ρ_{I2}^{TOA} Top of the atmosphere reflectance band I2 (865 nm)

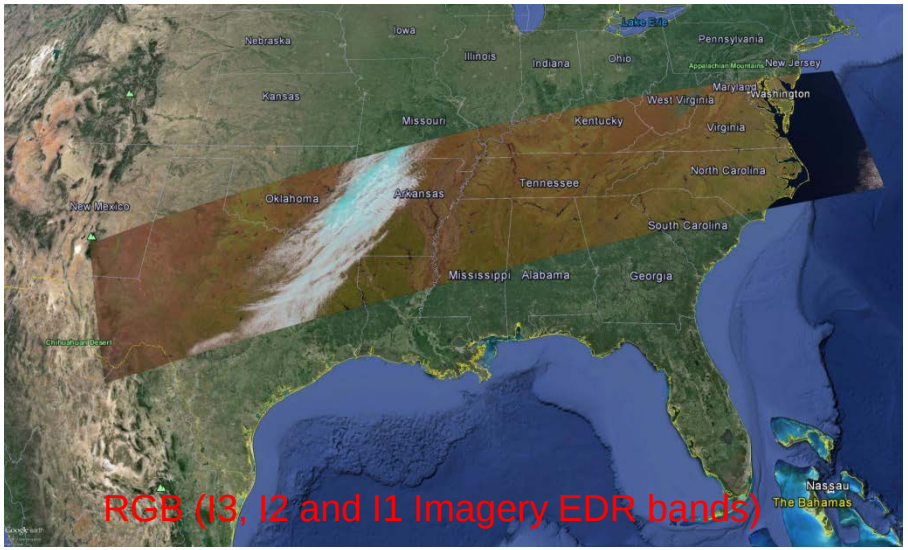
C_1, C_2 and L are constants

IDPS SNPP Operational Algorithm Overview (2/2)

- The VIIRS VI EDR operational product is generated as ~86 seconds granules at Imagery resolution (375m)
- VI EDR is produced over land only and during day time
- Format HDF5
- The granule file contains:
  - TOA NDVI
  - TOC EVI
- Also included in the product are four quality flag (QF) layers on land/water mask, cloud confidence, aerosol loadings, and exclusion conditions
- Product available at NOAA CLASS http://www.class.ncdc.noaa.gov/







NDE SNPP VIIRS Green Vegetation Fraction Product

SNPP VIIRS Green Vegetation Fraction (GVF) Algorithm

- The VIIRS GVF algorithm is a modified version of the Gutman and Ignatov's (1998) GVF algorithm
- The VIIRS GVF algorithm uses the VIIRS I1, I2 and M3 TOC reflectances as input
- The VIIRS GVF is derived form EVI

The Enhanced Vegetation Index (TOC)

$$EVI = G\frac{\rho_{\text{NIR}} - \rho_{\text{red}}}{\rho_{\text{NIR}} + C_1 \cdot \rho_{\text{red}} - C_2 \cdot \rho_{\text{blue}} + 1}$$

The Green Vegetation Fraction

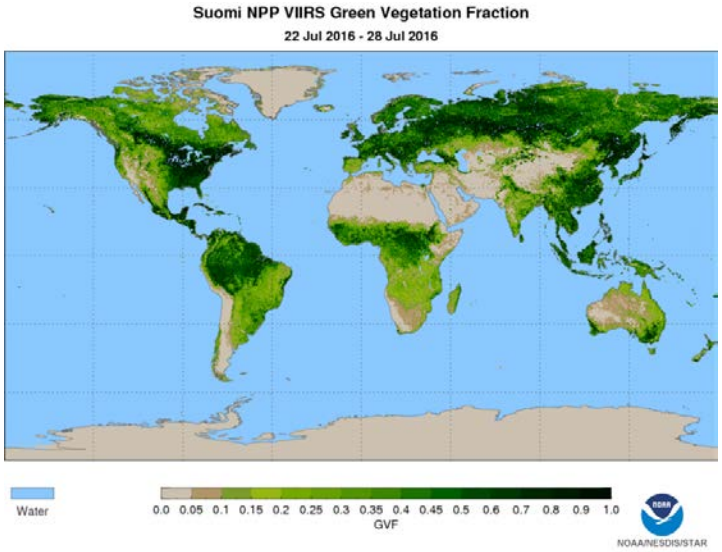
$$GVF = \frac{EVI - EVI_0}{EVI_\infty - EVI_0}$$

The SNPP VIIRS GVF system generates two products

1. *Weekly Global GVF at 4 km res*
2. *Weekly Regional GVF at 1 km res*

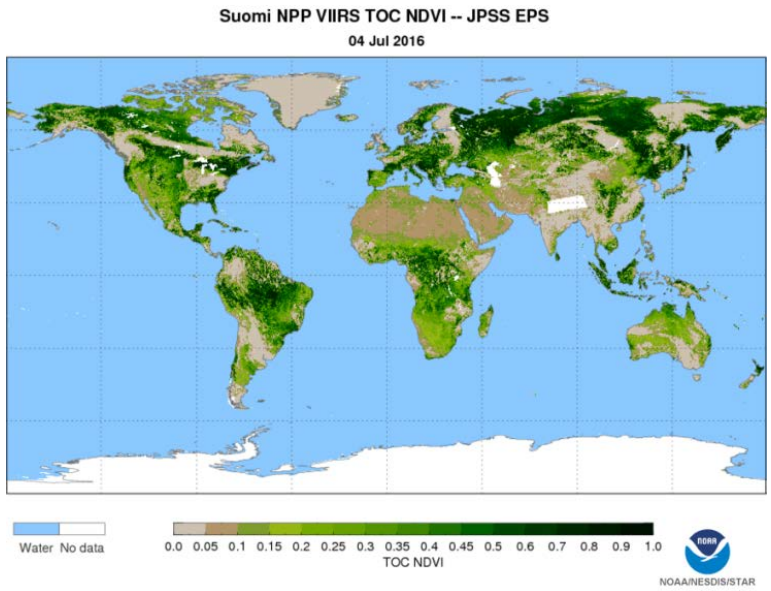
(Lat 7.5°S to 90°N, Lon 130°E to 30°E)

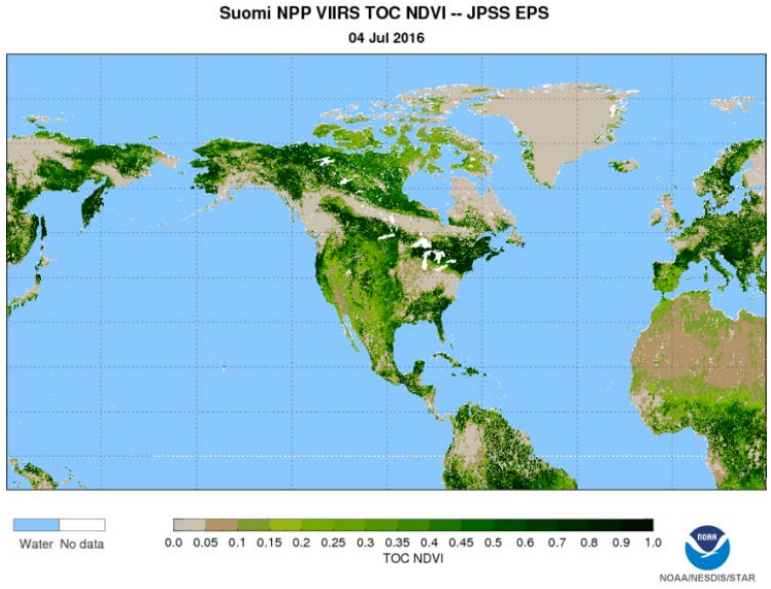
- Weekly (updated daily) GVF products are generated in Lat/Lon projection
- Output File Format: NetCDF4
- The GVF product is available at NOAA/CLASS



NDE 2.0 Vegetation Index Products (under development)

- The NDE Vegetation Products System (VPS) is currently under development
- The NDE VPS will generate:
  - Global Gridded (4km res) TOA NDVI, TOC NDVI, TOC EVI and GVF
  - Regional Gridded (1km res) TOA NDVI, TOC NDVI, TOC EVI and GVF
- Temporal resolution: Daily, Weekly (updated daily), and Bi-weekly (updated daily)
- Format NetCDF4
- Project CDR scheduled in Sep 2016
- Estimated TTO August 2017





S-NPP VIIRS VI EDR and GVF STATUS

IDPS VIIRS VI EDR

- The VI EDR always has met the JPSS performance specifications since the beginning of the SNPP mission
- Product Maturity
  - Beta Maturity: February 2012
  - Provisional Maturity: August 2013
  - Validated Maturity: September 2014
  - IDPS VI EDR LTM in progress

VI EDR Global APU Estimates

Attribute	L1RDS Threshold (VI units)	Validation Results
TOA NDVI Accuracy	0.05	0.019
TOA NDVI Precision	0.04	0.009
TOA NDVI Uncertainty	0.06	0.021
TOC EVI Accuracy	0.05	0.012
TOC EVI Precision	0.04	0.019
TOC EVI Uncertainty	0.06	0.023
TOC NDVI Accuracy	0.05	0.017
TOC NDVI Precision	0.04	0.014
TOC NDVI Uncertainty	0.06	0.022

NDE VIIRS GVF

- Declared operational by on 02/12/2015
- Product maturity: Provisional
- Validated maturity review in Sep 2016

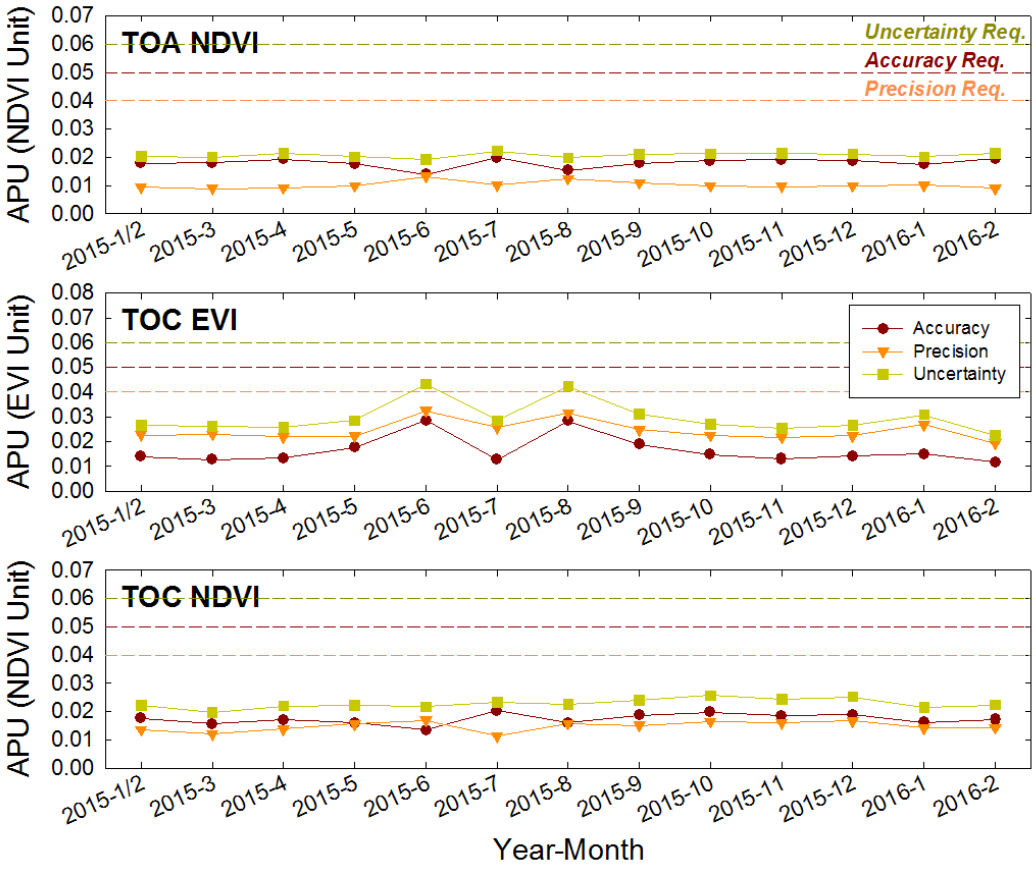
GVF APU Estimates

Attribute	L 1RD Threshold (GVF units)	Validation Results
Measurement Accuracy		
1. Global	0.12	0.076
2. Regional	0.12	0.062
Measurement Precision		
1. Global	0.15	0.096
2. Regional	0.15	0.113
Measurement Uncertainty		
1. Global	0.17	0.126
2. Regional	0.17	0.134

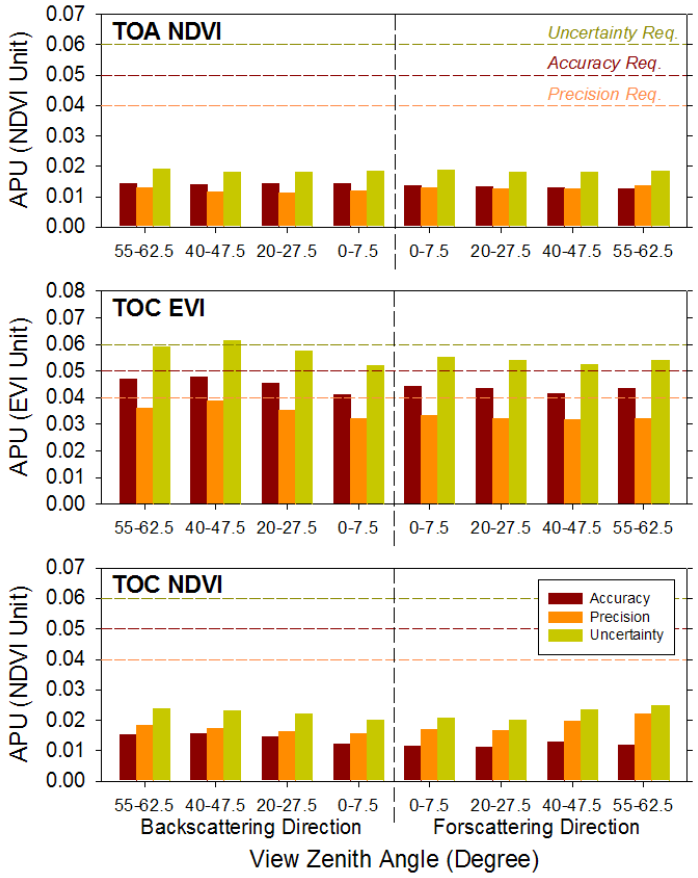
IDPS S-NPP VIIRS VI EDR STATUS: Global APU (LTM)

- VIIRS VI APU meet the L1RDS requirements over time, across seasons and view angles
  - APU derived from global data using Aqua MODIS as a reference
  - VIIRS-MODIS observation pairs from matched orbital tracks used

Global APU Time Series Plot (2015-2016)



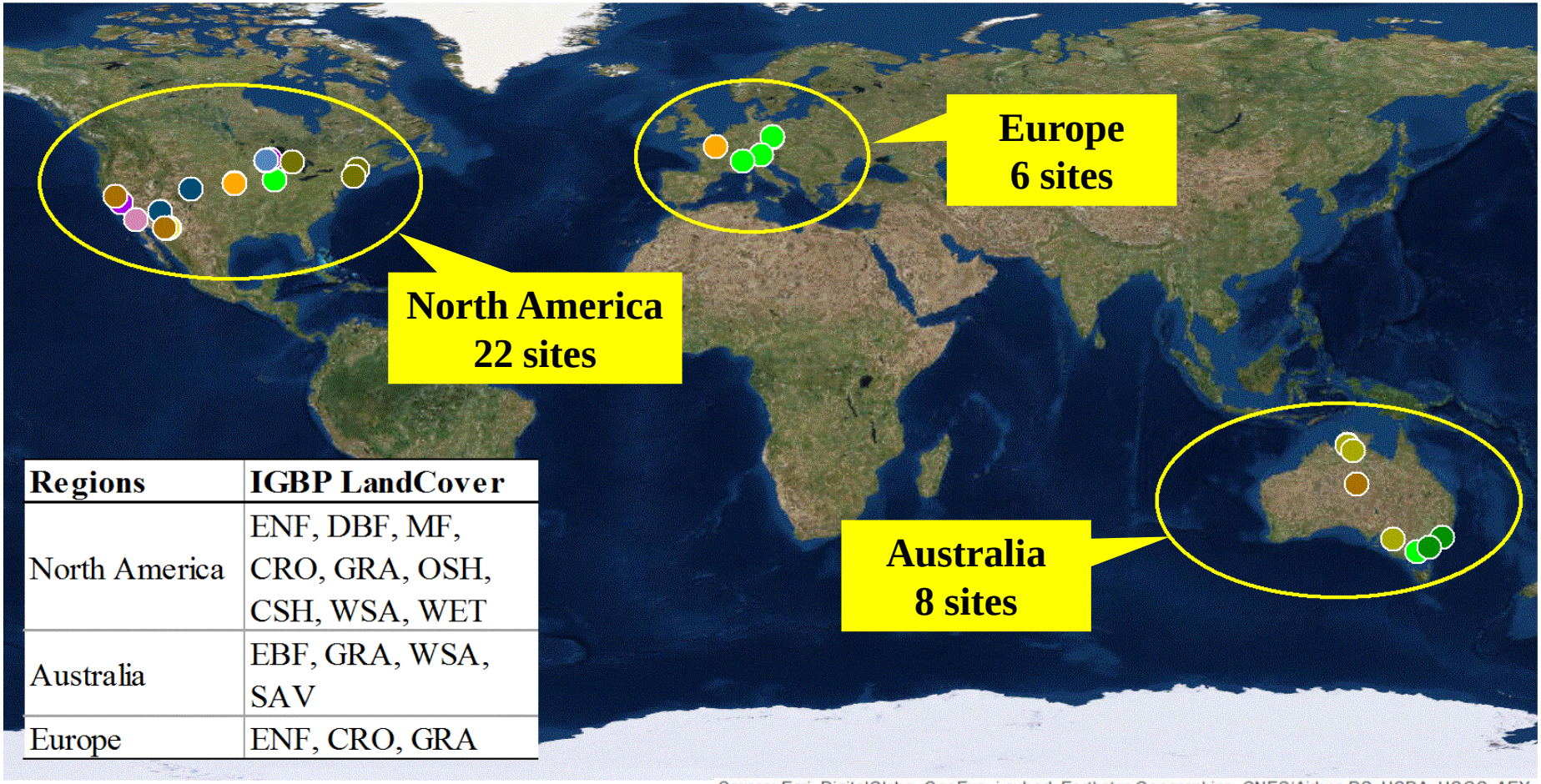
Global APU Across View Angles (Jan – Dec 2015)



IDPS S-NPP VIIRS VI EDR: Temporal Profile Evaluation (LTM)

- Quality of VIIRS VI EDR temporal profiles have been evaluated via visual inspection & comparison with Aqua MODIS

VIIRS Subset Sites for Temporal Profile Evaluation



Regions	IGBP LandCover
North America	ENF, DBF, MF, CRO, GRA, OSH, CSH, WSA, WET
Australia	EBF, GRA, WSA, SAV
Europe	ENF, CRO, GRA

IGBP landcover class (number of site)

Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

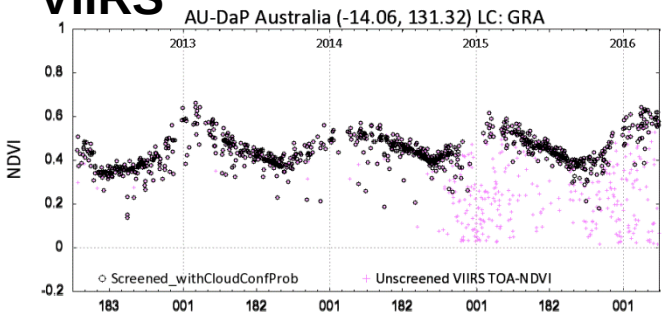
ENF (2) EBF (2) DBF (5) MF (2) CSH (1) OSH (1) GRA (10) CRO (5) WSA (3) SAV (3) WET (1)

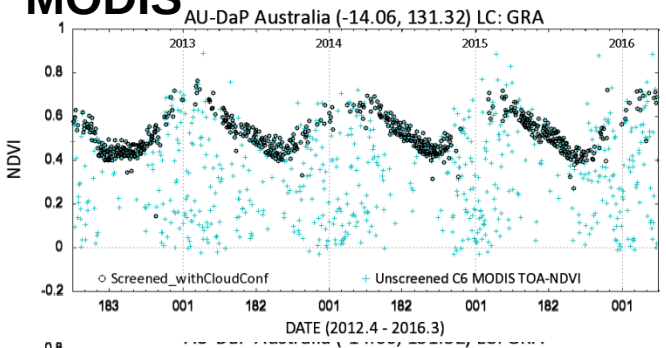
IDPS S-NPP VIIRS VI EDR: Temporal Profile Evaluation (LTM)

- Quality of VIIRS VI EDR temporal profiles evaluated via visual inspection & comparison with Aqua MODIS
  - VIIRS VI temporal profiles matching very well with the MODIS counterparts
  - VCM cloud confidence flag performing well for screening suspicious observations overall
  - VCM and MODIS snow masks somewhat incompatible

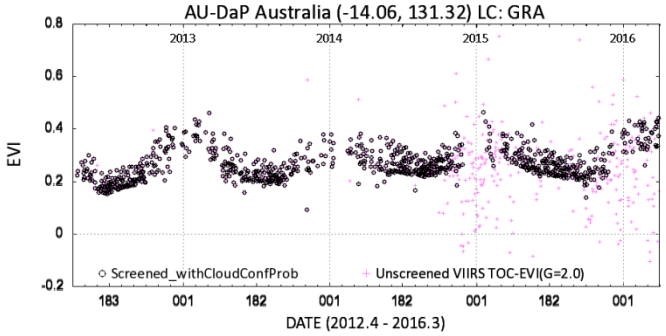
VIIRS **MODIS**

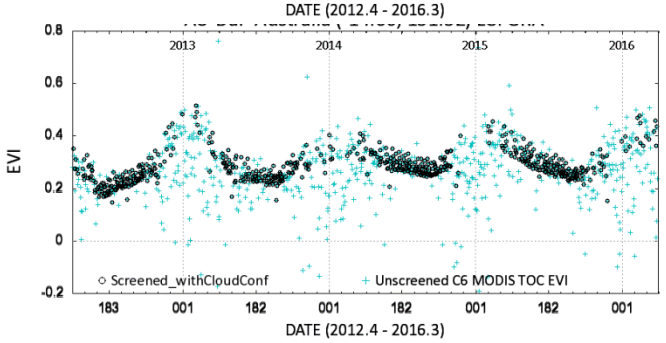
TOA-NDVI



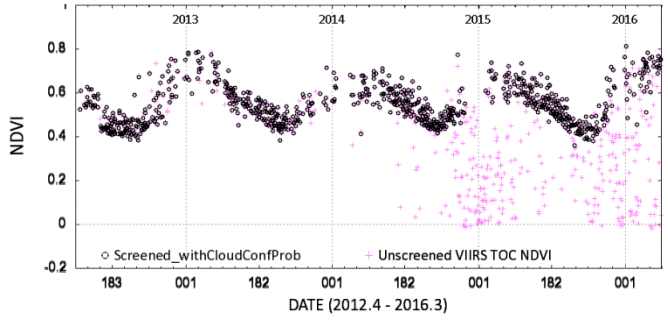


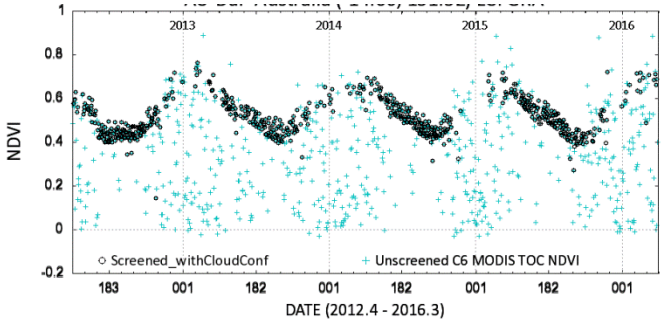
TOC-EVI





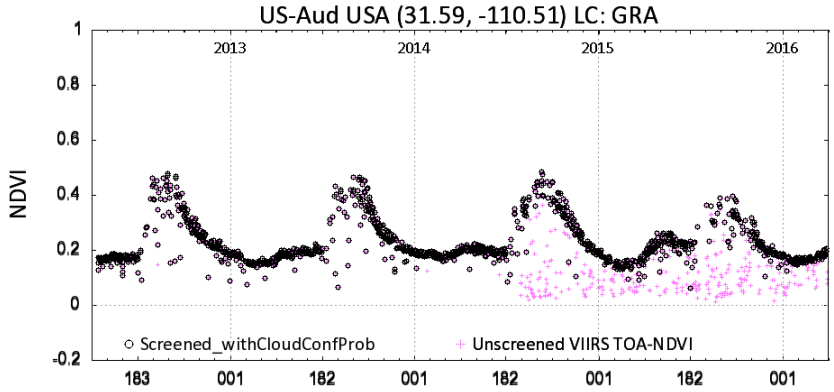
TOC-NDVI



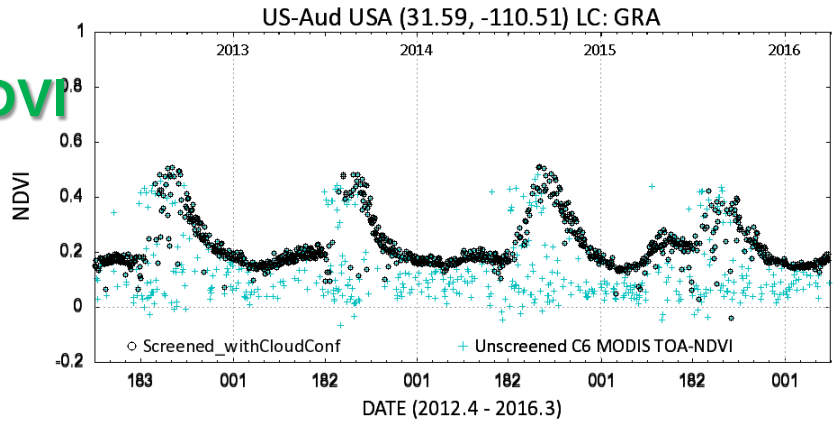


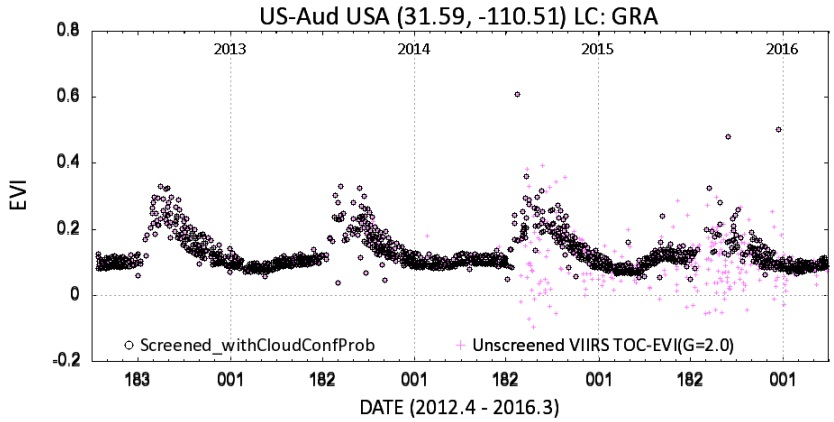
VIIRS VIs vs. MODIS C6 VIs (Cloud screening)

- Observations remained after cloud screening

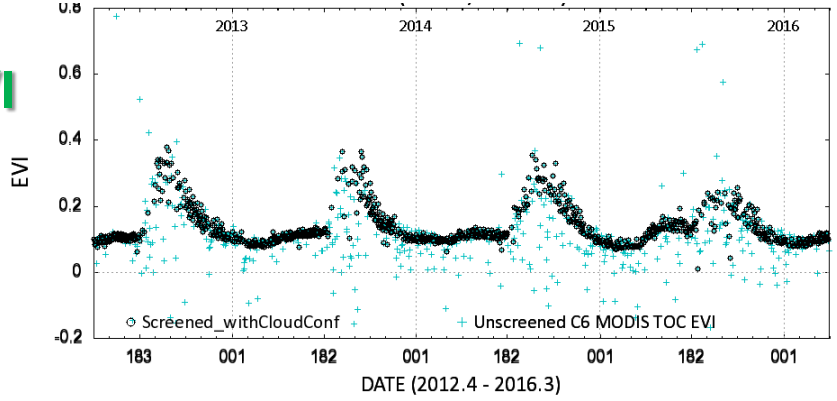


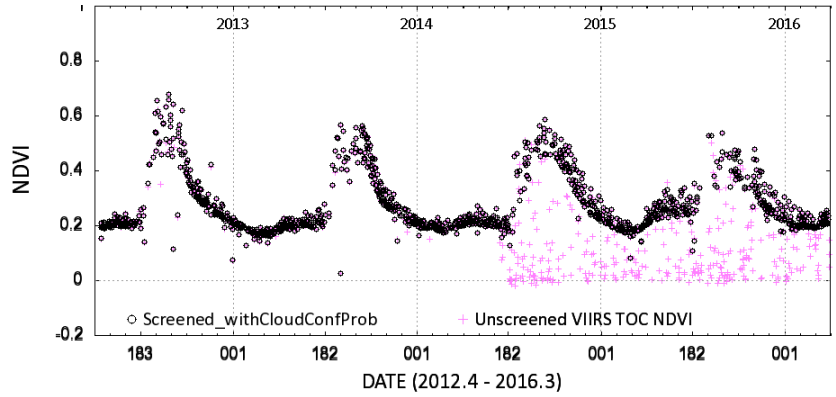
TOA-NDVI



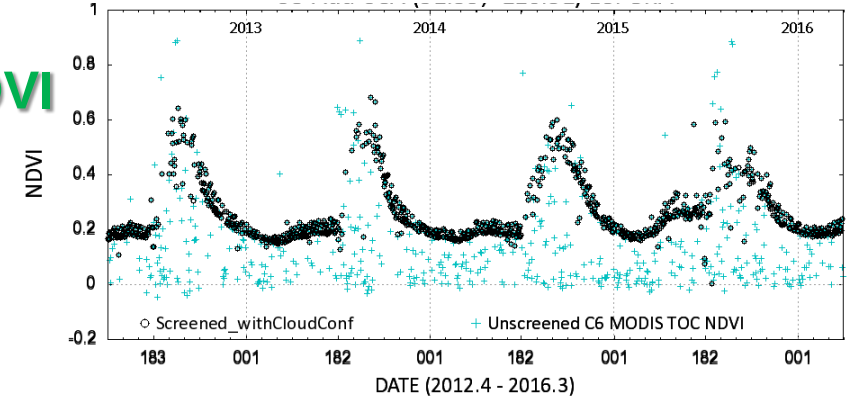


TOC-EVI





TOC-NDVI



IDPS S-NPP VIIRS VI EDR: Inter-Comparison Exercise

11 flux tower sites across the conterminous U.S.

Temperate grassland (2), Semi-arid grassland (2), Woody savanna (1), Cropland (2), Deciduous forest (4)



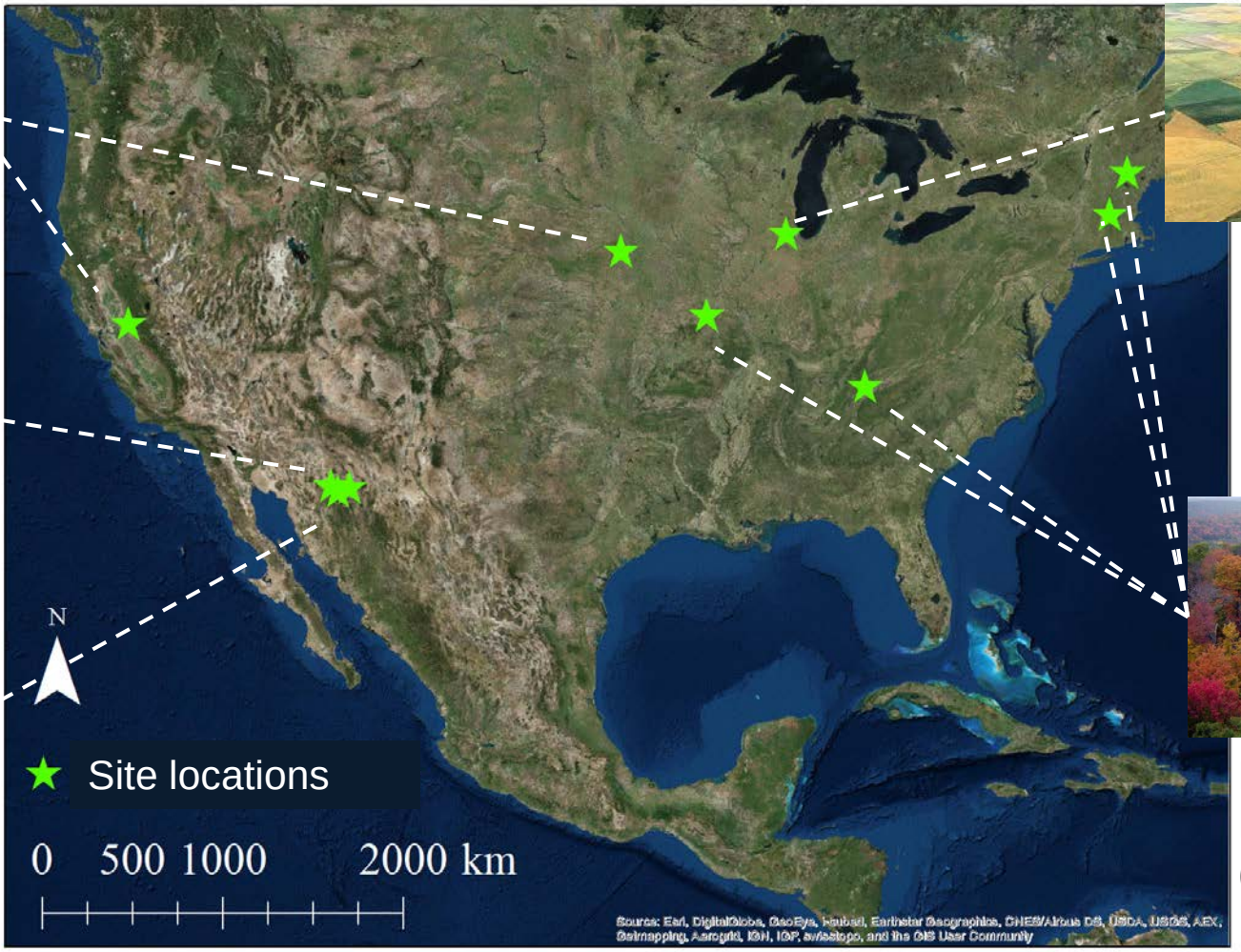
Temperate grass (GRA_t)



Semi-arid grass (GRA_{arid})



Woody savanna (WSA)



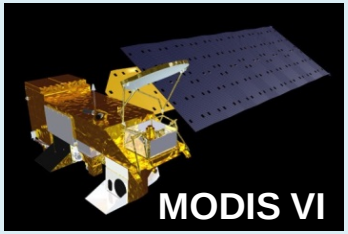


Cropland (CRO)



Deciduous Forest (DBF)

Methods

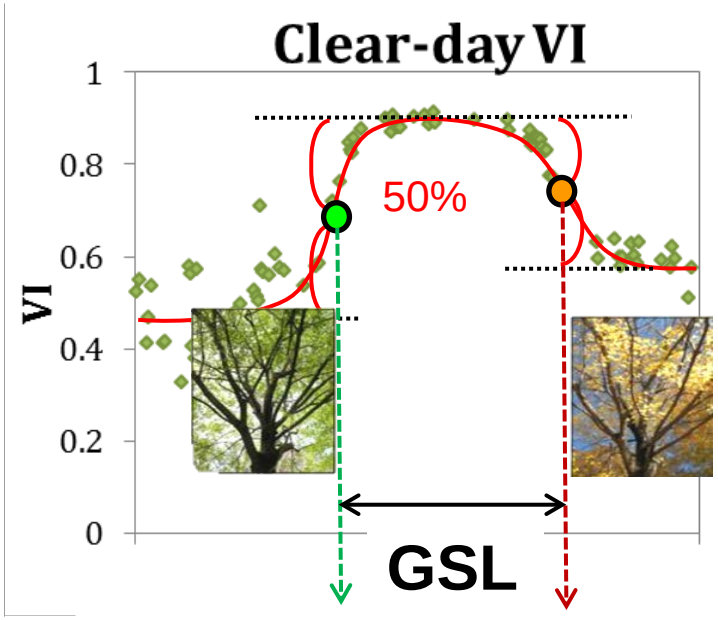






data

Processing



Start-of-Season (**SOS**)

End-of-Season (**EOS**)

Data screening
Satellite: Quality flags
In-situ data: radiation & precipitation

VI time series with data gap

Model Daily VI (Fisher et al., 2006)

Modeled multi-years VI curve

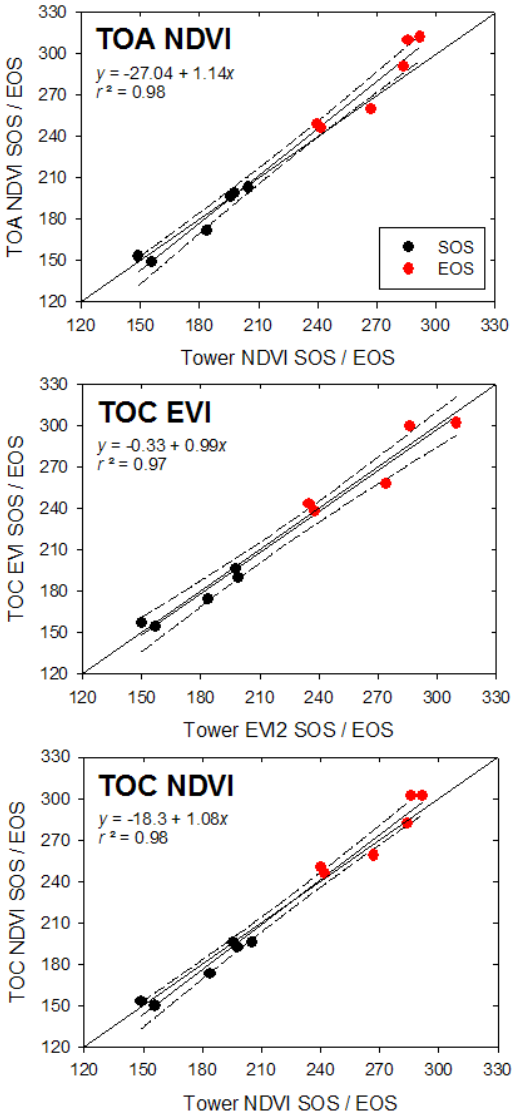
Calculate SOS, EOS, GSL
(Fisher et al., 2007; Zhang et al., 2014)

Multi-years **SOS**, **EOS**, **GSL**

Correlation analysis between SOS & GSL, EOS & GSL
(Spearman's rank correlation, *r*)

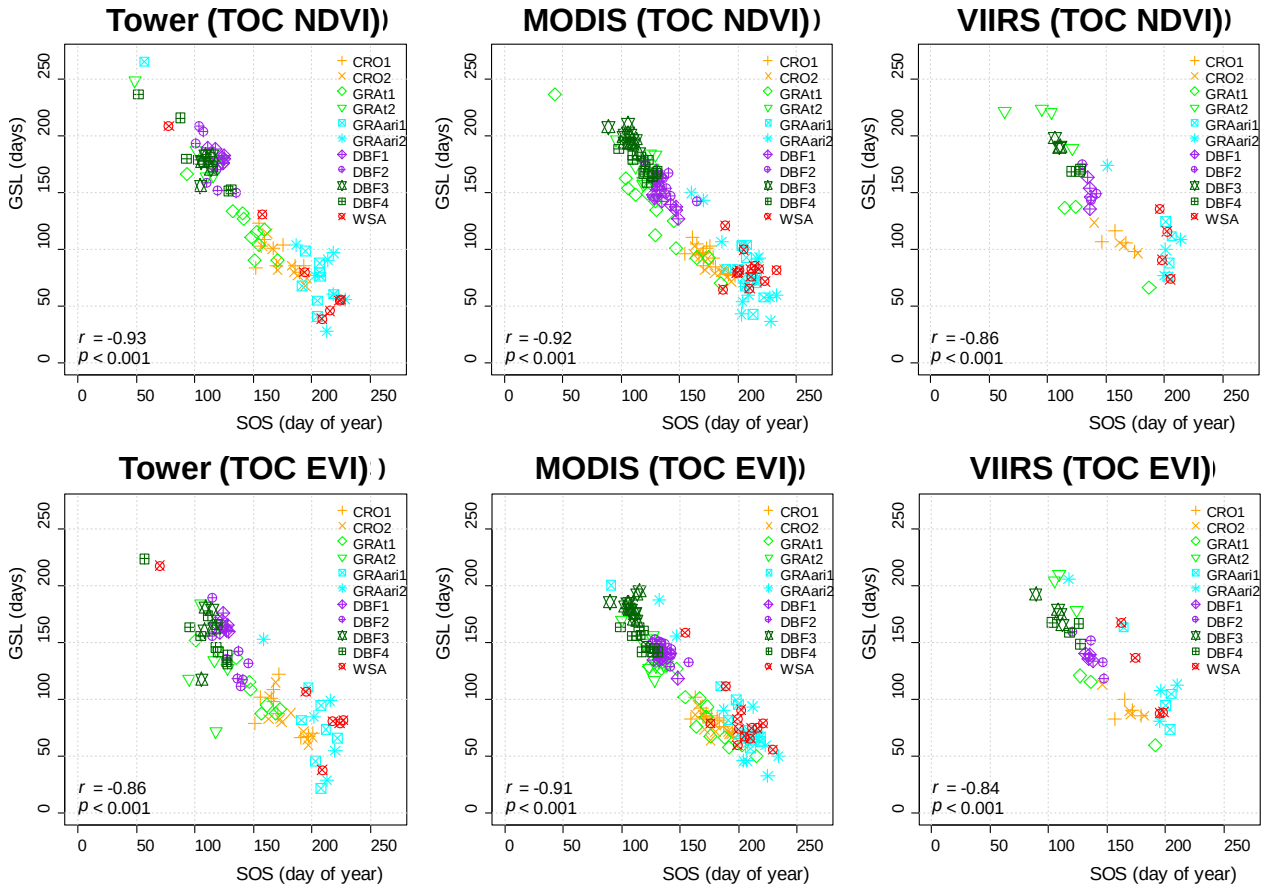
IDPS S-NPP VIIRS VI EDR: Inter-Comparison Exercise

VIIRS vs. *In Situ* Phenological Metrics Cross-Comparison



- VIIRS- & *In Situ*-derived phenological metrics corresponded well (e.g., SOS MD < 5 days; SOS RMSE < 7 days)
- Temporal & spatial treads obtained from VIIRS VI EDR compared well with those from MODIS and *In Situ* VIs.

In Situ vs. MODIS vs. VIIRS Inter-Comparison of Temporal Phenological Trends



NDE S-NPP VIIRS GVF Validation (1/3)

Home | GVF

JPSS VIIRS Green Vegetation Fraction

Data Sources:
- VIIRS
- AVHRR
- VIIRS-AVHRR

Data Sets:
- GVF
- Surface Type
- Climatology

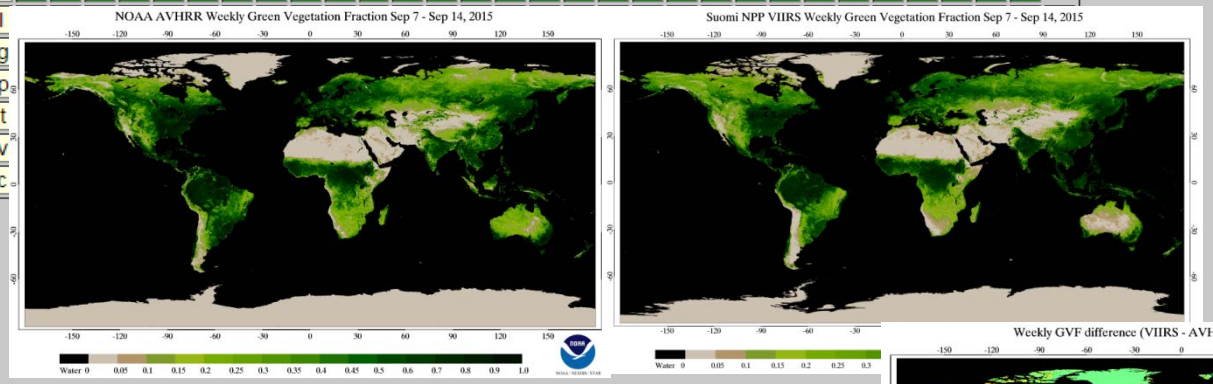
Compositing:
- Daily Rolling Weekly

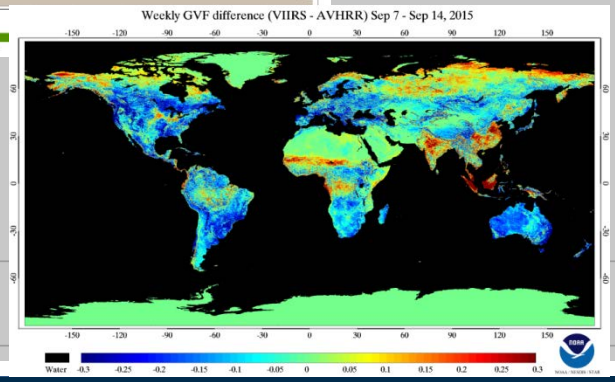
Analysis:
- Availability Tables
- Maps

Date: dd 08 mm 08 yyyy 2016

VIIRS | Year 2016

M\D	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Jan	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Feb	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
Mar	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Apr	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
May	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Jun	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
Jul																															
Aug																															
Sep																															
Oct																															
Nov																															
Dec																															



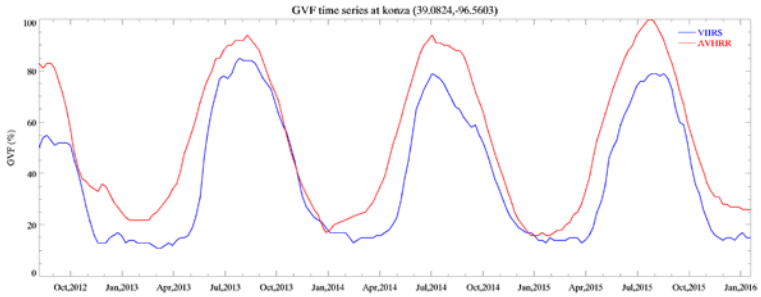


http://www.star.nesdis.noaa.gov/smcd/viirs_vi/gvf/gvf.htm

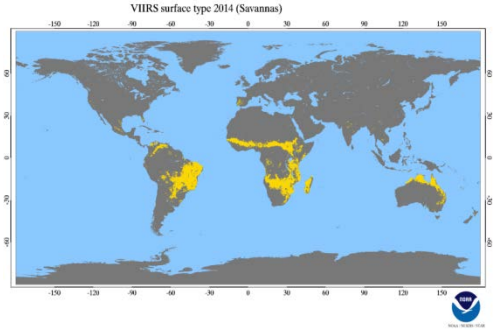
NDE S-NPP VIIRS GVF Validation (2/3)

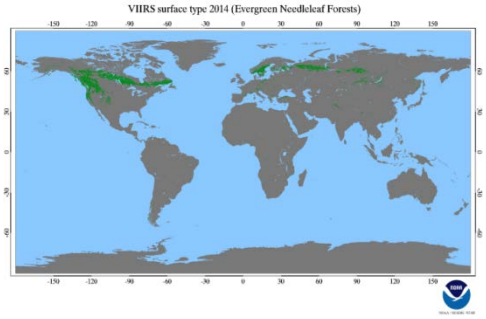
GVF Time Series and Correlative Analysis Between VIIRS and AVHR

GVF Temporal Trajectories VIIRS vs. AVHRR Konza Validation Site

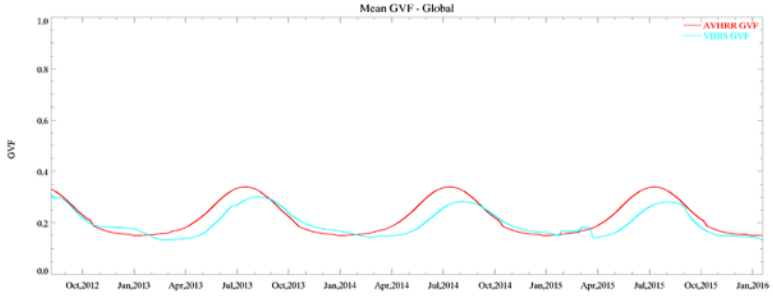


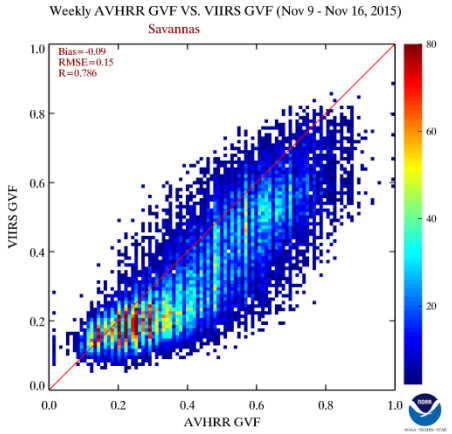
GVF Comparison by Surface Type VIIRS vs. AVHRR

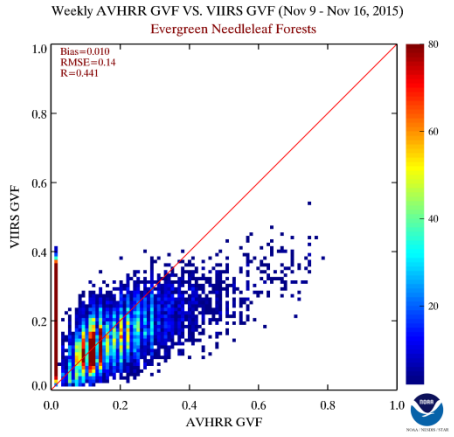




Global GVF Temporal Trajectories VIIRS vs. AVHRR

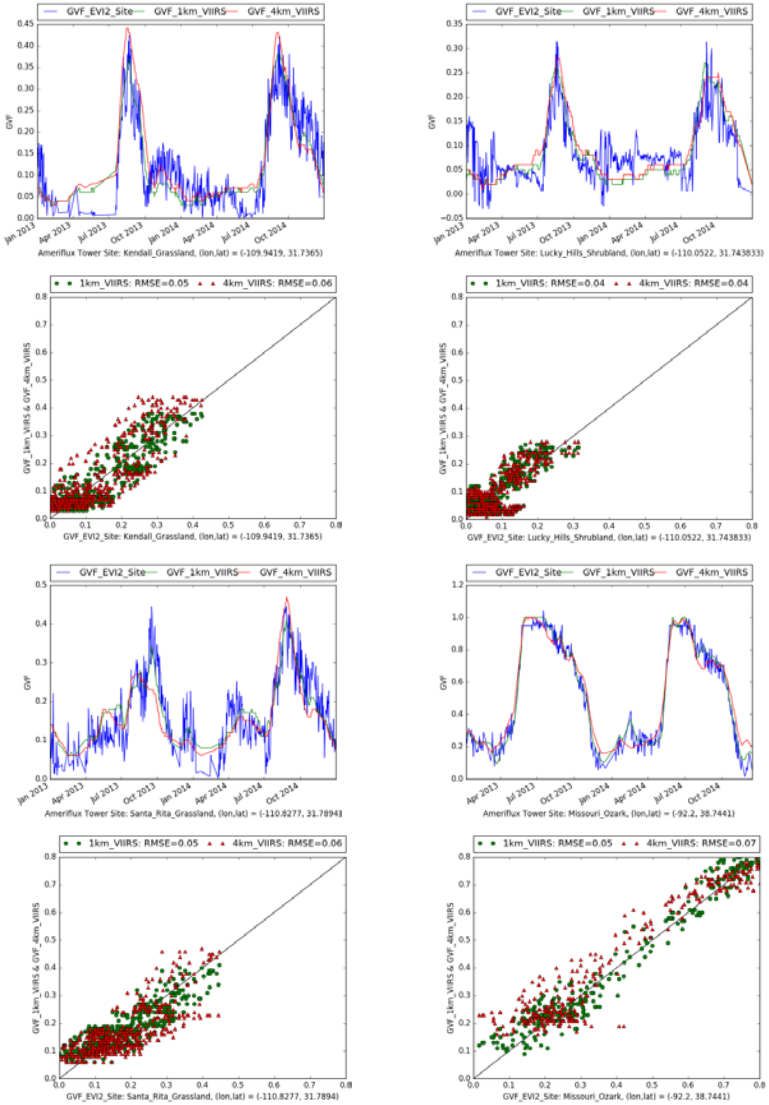






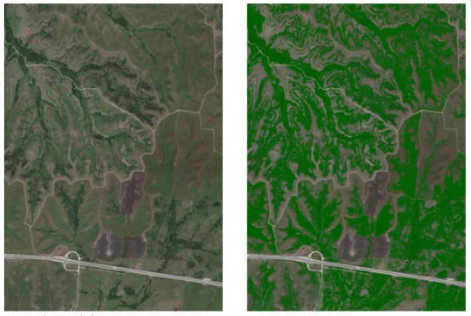
NDE S-NPP VIIRS GVF Validation (3/3)

GVF Time Series Inter-Comparison Using In Situ Networks



Comparison Between VIIRS GVF and Google Earth GVF

Konza

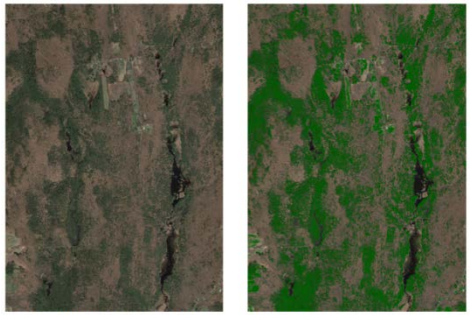


Google Earth image over a 0.036-degree VIIRS GVF pixel (8/13/2014)

Classified image (green vegetation: green)

Google Earth GVF= 0.44
VIIRS GVF= 0.55

Harvard Forest

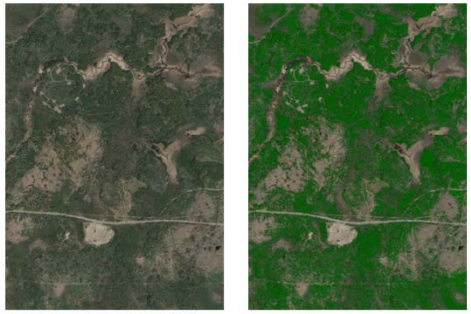


Google Earth image over a 0.036-degree VIIRS GVF pixel (4/27/2016)

Classified image (green vegetation: green)

Google Earth GVF= 0.26
VIIRS GVF= 0.34

Park Falls

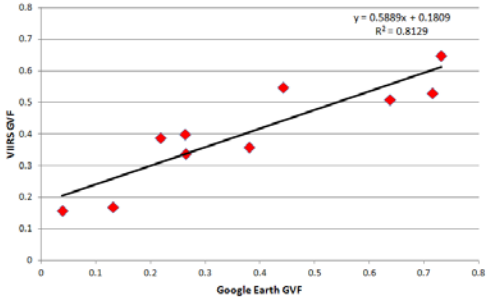


Google Earth image over a 0.036-degree VIIRS GVF pixel (5/10/2013)

Classified image (green vegetation: green)

Google Earth GVF= 0.38
VIIRS GVF= 0.36

Scatter Plot
VIIRS GVF vs. Google Earth GVF

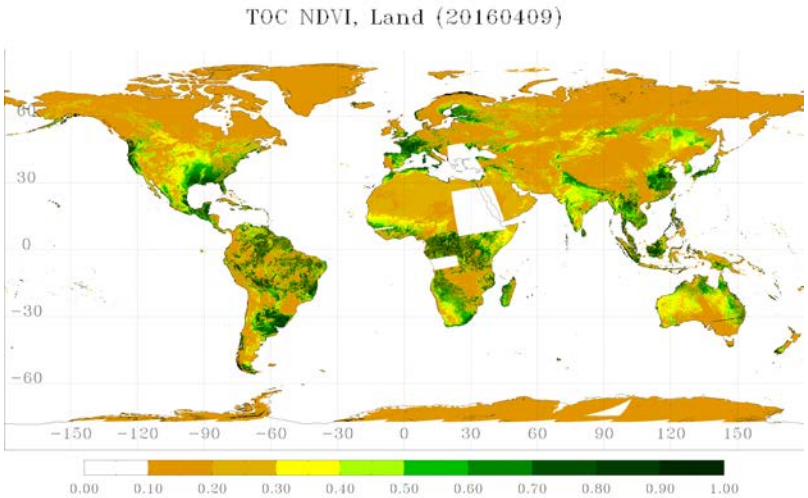


JPSS-1 Readiness (1/3)

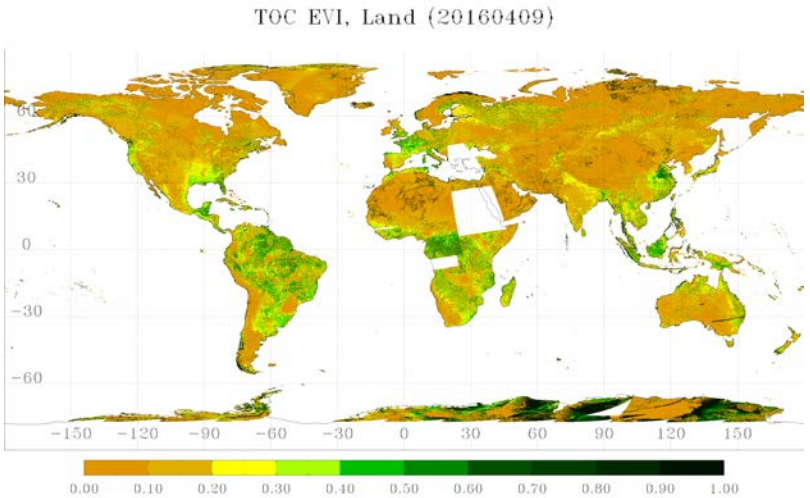
- A new vegetation index, the TOC NDVI, has been added to the JPSS-1 VIIRS VI EDR
- An improved EVI algorithm has been incorporated which stabilizes the EVI performance over snow/ice/cloud-contaminated pixels
- The Block 2.0 VIIRS VI EDR algorithm has been tested (LG2 and OBSAT tests) and it is performing well
- JPSS VI EDR Cal/Val plan was delivered last year
- Cal/Val datasets: J1 Test Data, SNPP VI, MODIS VI, AERONET, FLUXNET
- SNPP Cal/Val tools are being adapted to work with JPSS-1 VI products
- J1 GVF continuity and upgrades project funded
- Schedules and Milestones
  - Beta: October 2017 (VIIRS SDR Beta + 7 months)
  - Provisional: April 2018 (Beta + 6 months)
  - Validated: April 2019 (Provisional + 12 months)

JPSS-1 Readiness (2/3)

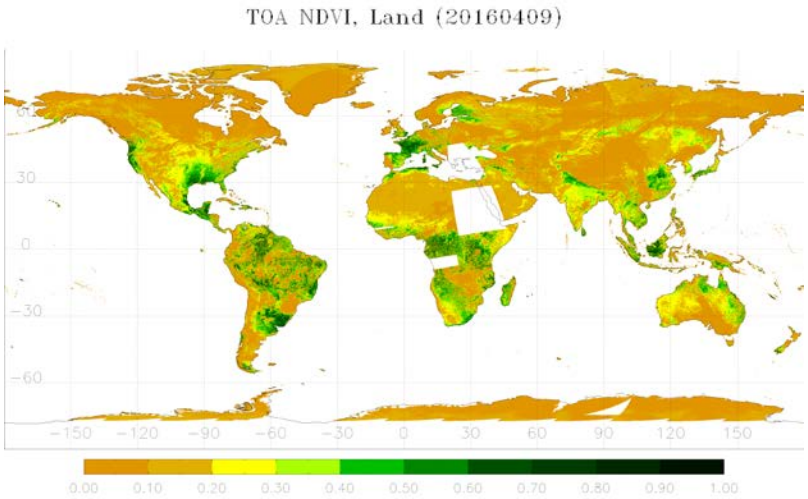
TOC NDVI



TOC EVI



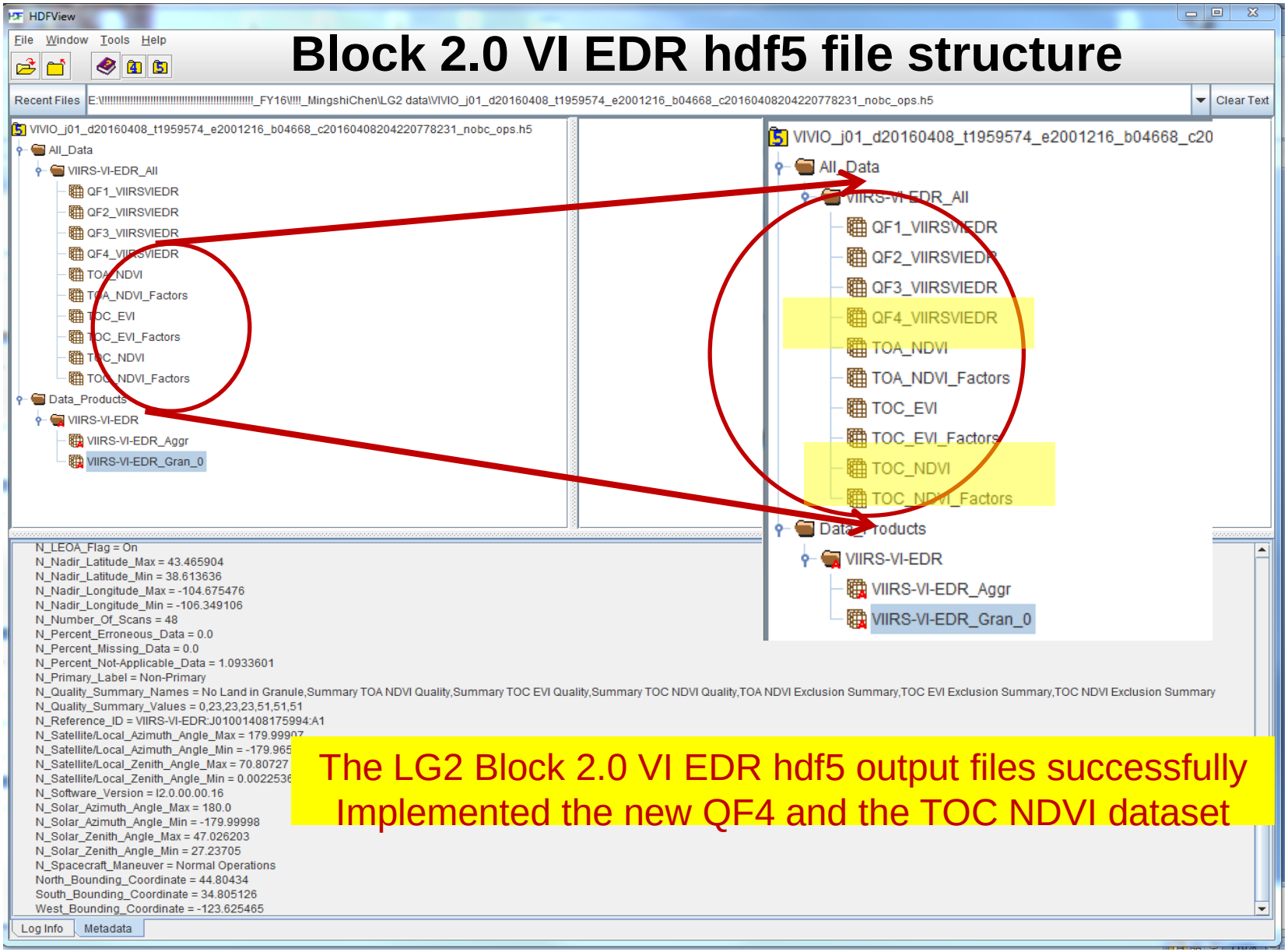
TOA NDVI



LG2 Test (Block 2.0)
20160409

JPSS-1 Readiness (3/3)

Block 2.0 VI EDR hdf5 file structure


HDFView
File Window Tools Help
Recent Files
E:\!!!

Enterprise Algorithm for Vegetation Products

- Land algorithms are currently transitioning to Enterprise solutions

- The Enterprise Algorithm for Vegetation products is in the planning stage
- Enterprise Vegetation Products: TOA-NDVI, TOC-NDVI, GVF, EVI, EVI2*, LAI*, fPAR*, PSN* and NPP*
- Global gridded products in Lat/Lon projection
- Spatial resolution: 1 km (0.009 degree)
- Temporal resolution: daily, weekly updated daily, and bi-weekly updated daily
- Output File Format: NetCDF4

*No L1 requirement to create these new products

2-phased Development Strategy

- Implement a 2-phased approach for the development of the Enterprise Algorithm for Vegetation Products

➢ Phase 1

Products to be implemented in this phase:

TOC EVI, TOC EVI2, TOC NDVI, TOA NDVI, GVF

➢ Phase 2

Products to be implemented in this phase:

LAI, fPAR, NPP, PSN

S-NPP VIIRS VI EDR Reprocessing

- The VI Team will reprocess all the VIIRS Vegetation products since the beginning of the SNPP mission, using the Enterprise Algorithm for Vegetation Products (EAVP) that will run operationally at NDE in the near future
- During reprocessing the EAVP will ingest the reprocessed versions (enterprise versions) of the VIIRS SDR, CM, SR, and AOT datasets
- The reprocessed VI products will incorporate all the refinements in sensor calibration (VIIRS SDR), improvements to the input datasets (CM, SR, and AOT), as well as changes/improvements to the VI-EDR algorithm (additional quality flags, new TOC NDVI dataset, improved quality definition)

Operational Use

- VIIRS EVI used to derive VIIRS Green Vegetation Fraction (GVF)
- STAR Land Team members (Csiszar/Vargas/Yu) are working with NCEP/EMC to incorporate the near-real-time Suomi NPP Green Vegetation Fraction into NCEP Land modeling suite
- This effort will lead to the operational use of the existing Suomi NPP GVF product in EMC modeling

Summary

- All the SNPP VIIRS Vegetation Index products are performing well
- The VI Team is ready for the EOC of the JPSS1 VI EDR
- The NDE implementation of the SNPP VI products is under development
- The Enterprise Algorithm for Vegetation Products is being prototyped. STAR Land Team has identified the deficiencies in the requirements and is working on the CCRs
- Reprocessing of the SNPP VIIRS VI products is necessary to incorporate all the refinements in sensor calibration (VIIRS SDR), improvements to the input datasets (CM, SR, and AOT), as well as changes/improvements to the VI-EDR algorithm
- VIIRS VI product validation will be coordinated with CEOS/WGCV LPV which has established a new “Vegetation Index” focus area

For more information on VIIRS Vegetation Products

- http://www.star.nesdis.noaa.gov/jpss/EDRs/products_VegIndex.php
- http://www.star.nesdis.noaa.gov/smcd/viirs_vi/Monitor.htm
- http://www.star.nesdis.noaa.gov/smcd/viirs_vi/gvf/gvf.htm
- http://www.nsof.class.noaa.gov/
- http://www.ospo.noaa.gov/Products
- http://www.star.nesdis.noaa.gov/jpss/
- http://viirsland.gsfc.nasa.gov/Products/GVF.html

Back up slides

Enterprise Algorithm for Vegetation Products

Acronym	Description	Purpose
TOA NDVI	Normalized Difference Vegetation Index, at the top of the atmosphere	Continuity with AVHRR heritage
TOC NDVI	Normalized Difference Vegetation Index, at the top of the canopy	Continuity with MODIS/AVHRR heritage, focused on surface values
EVI / *EVI2	Enhanced Vegetation Index	Continuity with MODIS heritage. Useful parameter for biogeophysical models and scientific interpretation. Complement the NDVI
GVF	Green Vegetation Fraction	Useful parameter for biogeophysical models and scientific interpretation
***LAI**	Leaf Area Index	Useful parameter for biogeophysical models and scientific interpretation
***fPAR**	Fraction of absorbed Photosynthetically Active Radiation	Useful parameter for biogeophysical models and scientific interpretation
***PSN**	Net Photosynthesis	Useful parameter for assessing the magnitude of CO2 transport in the carbon cycle
***NPP**	Net Primary Production	Useful parameter for monitoring of crops and forests

*No L1 requirement to create these new products. The JPSS ATBD for Vegetation Index products describes that those products will be produced

Enterprise Algorithm for Vegetation Products

Product	VIIRS	ABI	AVHRR	MODIS	Users of NOAA Product
TOA NDVI	O	F	O	—	NWS, USDA, USGS
TOC NDVI	R	—	—	O*	
EVI	O	—	—	O*	
EVI2	—	—	—	P*	
GVF	O	F	O	—	NWS/NCEP
LAI	—	—	—	O*	
fPAR	—	—	—	O*	
PSN	—	—	—	O*	
NPP	—	—	—	O*	

O – operational, F – future capability
R – Ready for operational implementation
*P – planned for production at NASA
*MODIS production at NASA

JPSS LAND SURFACE ALBEDO

Yunyue Yu
NOAA/NESDIS/STAR
Yunyue.Yu@noaa.gov

Shunlin Liang, Dongdong Wang, Yuan Zhou
UMD/CICS

Outline

- ❑ Cal/Val Team Members
- ❑ VIIRS LSA Production Overview
  - Current IDPS LSA Algorithm
  - Performance Overview
  - New Development
    - Enterprise LSA Algorithm
  - Reprocessing plans
  - Long term monitoring
  - Issues
- ❑ JPSS-1 Readiness
- ❑ Summary and Path Forward

Cal/Val Team Members

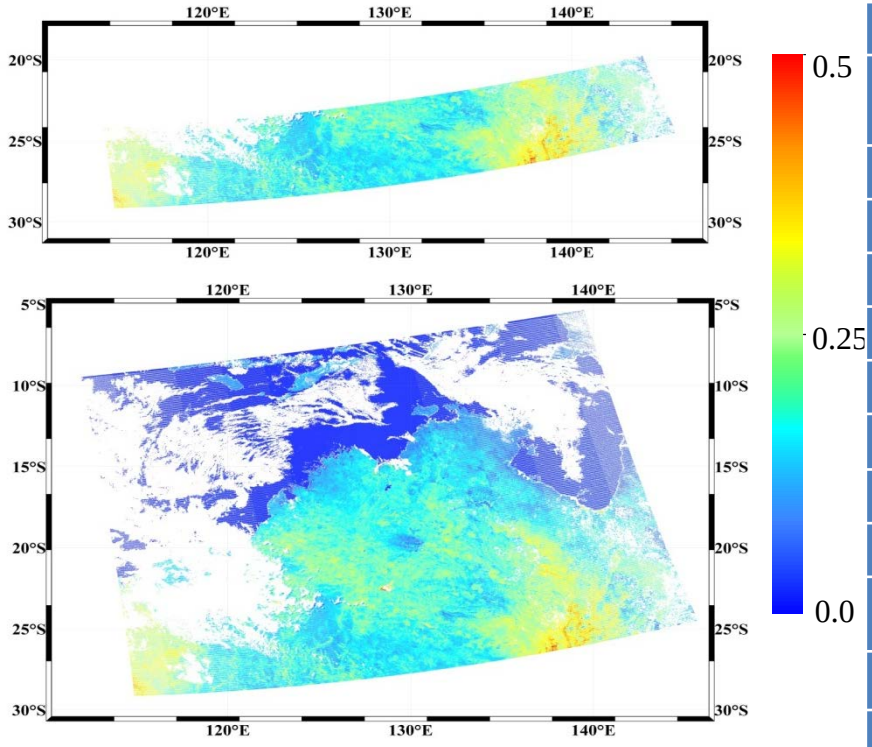
PI	Organization	Team Members	Roles and Responsibilities
Ivan Csiszar	NOAA/NESDIS/SATR		Land Lead, Project Management
Yunyue Yu	NOAA/NESDIS/SATR		EDR Lead, algorithm development, validation, team management
Shunlin Liang	UMD/CICS		Algorithm development, validation
		Dongdong Wang	Algorithm development, validation, monitoring
		Yuan Zhou	Algorithm development, validation, monitoring
Walter Wolf	NOAA/NESDIS/SATR		System Integration, Transition
		Valerie Mikles	System Integration, Transition
		Marina Tsidulko	STAR IT support
Michael EK	NOAA/EMC/NCEP		User readiness
		Weizhong Zheng	User readiness : Model albedo application, verification
		Yihua Wu	User readiness : Model albedo application, verification
Miguel Roman	NSAS/GSFC		NASA Land Science Investigator-led Processing System Lead
		Sadashiva Devadiga	System support, product monitoring

Current VIIRS LSA Algorithm Overview

$$LSA = a_0 + \sum_i a_i r_i$$

a_i is regression coefficient for Band i.

i is VIIRS band number, including the channels 1,4,5,7,8,10 and11.



- Operational Products
  - Single 1.5 min granule data
  - Combined 4 x 1.5 min granule data
- Production team
  - STAR Science Team : Scientific development and validation
  - JPSS DPE (Data Product Engineering) : Production

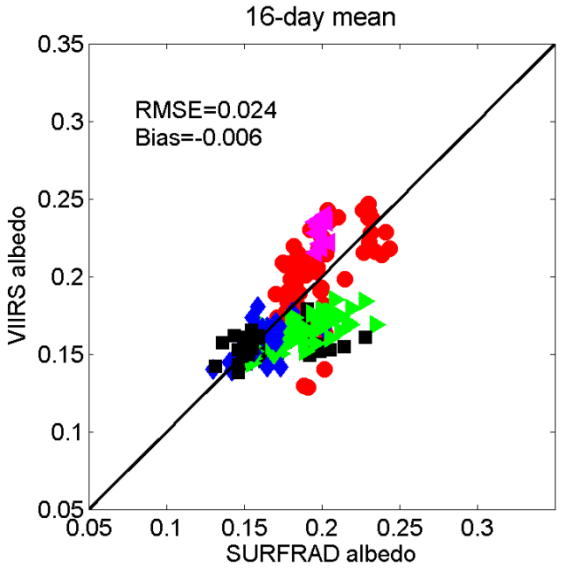
Name	Type	Description	Dimension	Unit
Primary Sensor Data(SDR)				
Spectral reflectance	input	TOA spectral reflectance at M1, 4,5,7,8,10,11	grid (xsize, ysize)	unitless
Solar zenith	input	Solar zenith angles	grid (xsize, ysize)	Degree
View zenith	input	Satellite view zenith angle	grid (xsize, ysize)	Degree
Solar azimuth	input	Solar azimuth angles	grid (xsize, ysize)	Degree
View azimuth	input	Satellite view azimuth angle	grid (xsize, ysize)	Degree
SDR QC flags	Input	Level 1b data quality	grid (xsize, ysize)	unitless
Derived Sensor Data				
Cloud mask	Input	Cloud mask data	grid (xsize, ysize)	unitless
Snow mask	Input	Level 2 snow/ice mask data	grid (xsize, ysize)	unitless
Surface type	Input		grid (xsize, ysize)	unitless
LUT and Configuration File				
Coefficients LUT	Input	Regression coefficients for BPSA	2(two surface types)*18(sza) *18(vza)*23(raa)* 8(coef items)	Unitless
Output				
LSA	Output	LSA values	grid (xsize, ysize)	Unitless
QF	Output	Associated pixel quality flags	grid (xsize, ysize)	Unitless

Product Performance Overview

Current VIIRS Surface albedo EDR is a full resolution granule instantaneous product. LSA is only generated for clear-sky land pixels.

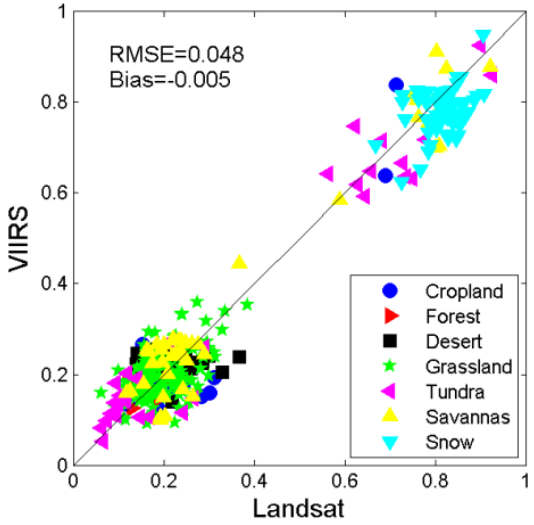
Product	L1RDS APU Thresholds	Performance
VIIRS LSA	Precision: 0.05	RMSE: 0.05
VIIRS LSA	Accuracy: 0.08	Bias: 0.01

- Comprehensive evaluation was conducted using field measurements and high-resolution LSA reference maps
- The current LSA data can meet the requirements for snow-free cases.



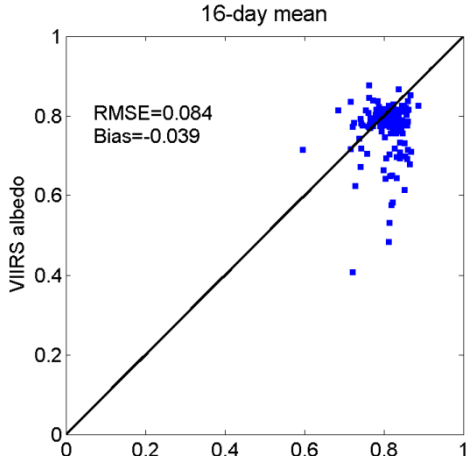
Left: Comparison of snow free albedo with SURFRAD measurements.

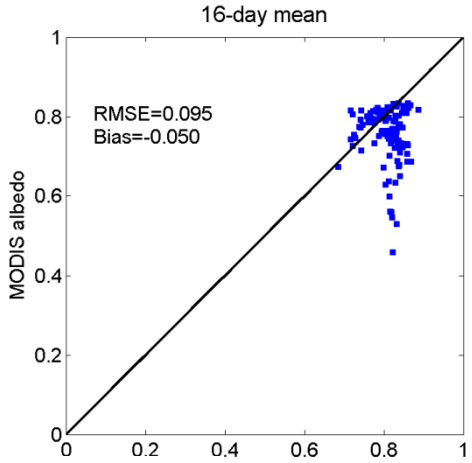
Right: Validating snow-free and snow albedo using Landsat albedo maps

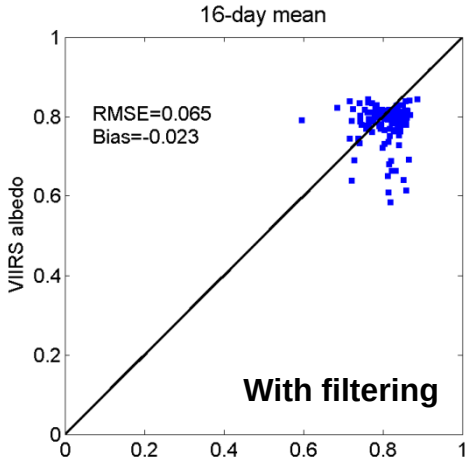


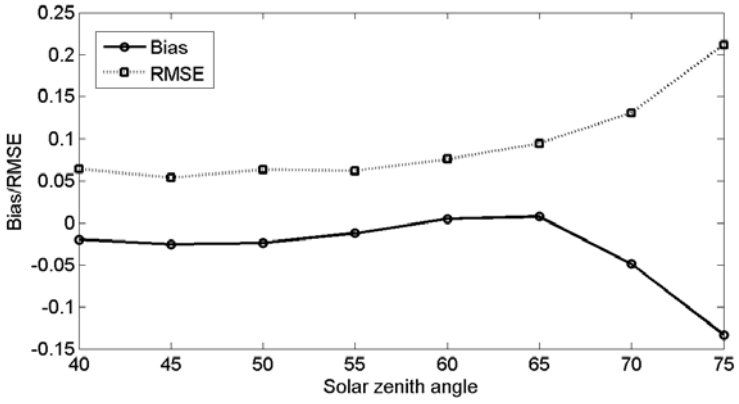
Product Performance: snow albedo

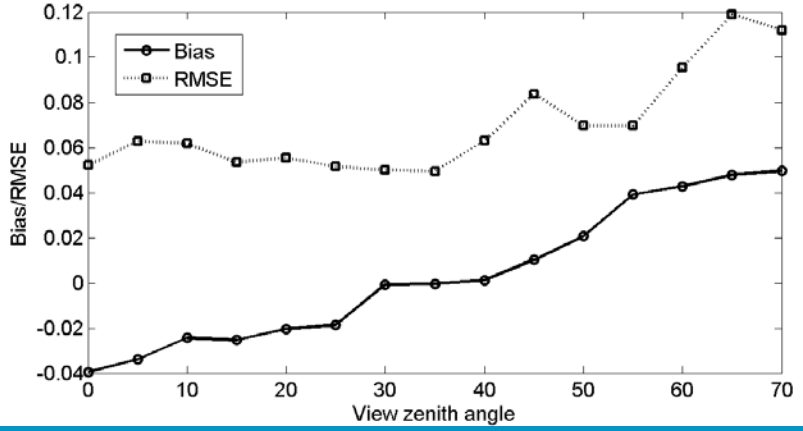
- Accuracy of estimating snow albedo was evaluated at GC-Net stations.
- VIIRS generally has improved results.
- Retrieval accuracy is strongly dependent on quality of cloud detection.
- RMSE varies with solar and view zenith angles.
- Temporal filtering can improve retrieval quality and data continuity.







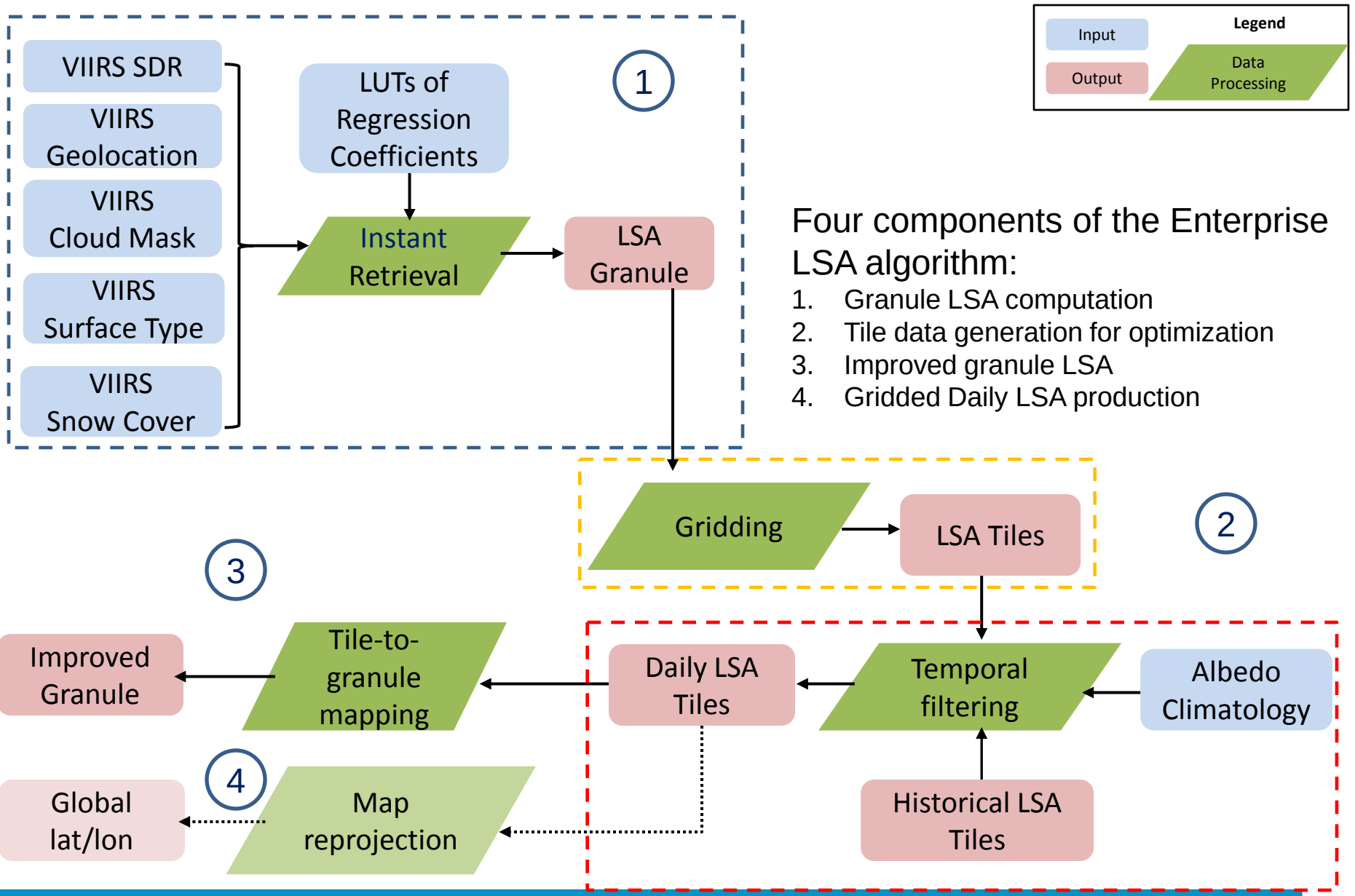




Enterprise Algorithm Development

- Substantial improvement needs on the basis of the current IDPS LSA algorithm.
  - Missing values
    - Current product: granule instantaneous, for clear-sky pixels only
  - Intraday residual variations
    - A direct estimation method is used for VIIRS to capture LSA variations of rapidly-changing surfaces.
    - Meanwhile, the albedo retrieved from a single observation may contain some levels of random noises.
  - Possible gridded product
    - End users need gridded product with common map projection.
- We propose to develop a new high-level LSA product on the basis of VIIRS SA EDR, which has the following features:
  - Gap-filled
  - Noise-reduced
  - Having potential of generating gridded product, which is desired by user community.
- The prototype system in IDL language is ready.
  - We are developing the operational system in C language to improve efficiency.
- Critical Design Review is planned for August 2016.

Enterprise Algorithm Development



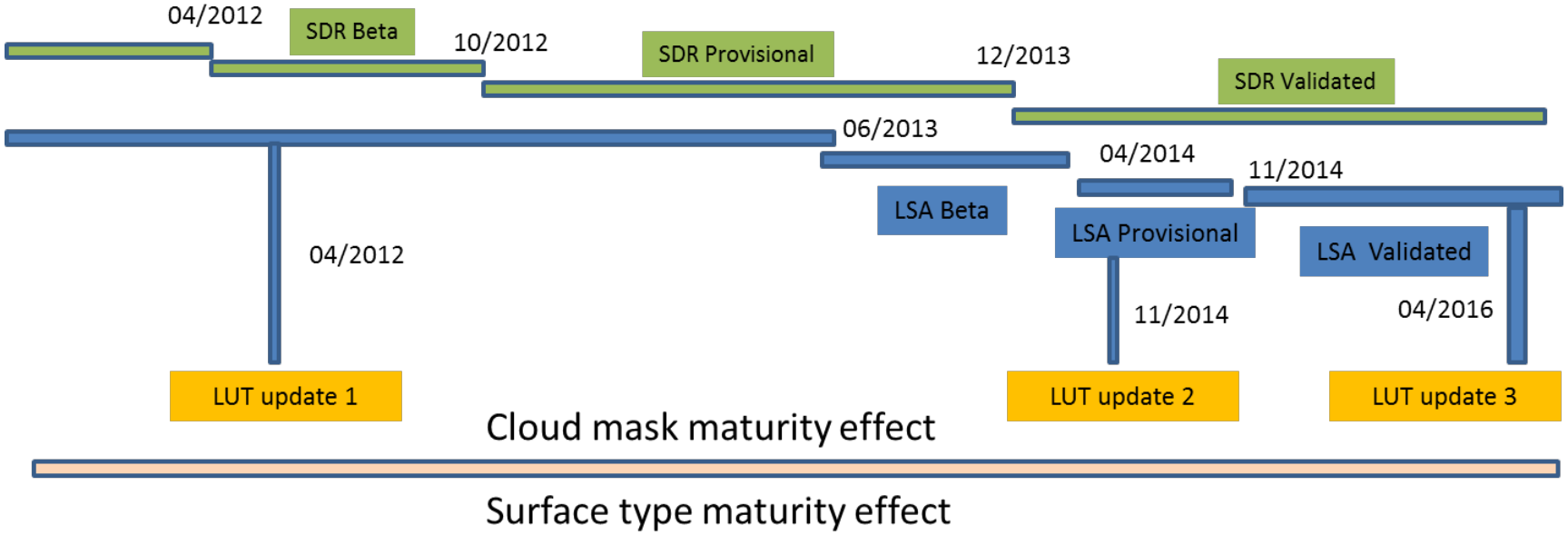
Input Data of Enterprise Albedo Algorithm

Name	Type	Description	Dimension	Unit
Primary Sensor Data(SDR)				
Spectral reflectance	input	TOA spectral reflectance at M1,2,3,4,5,7,8,10,11	grid (xsize, ysize)	unitless
Latitude	input	Pixel latitude	grid (xsize, ysize)	Degree
Longitude	input	Pixel longitude	grid (xsize, ysize)	Degree
Solar zenith	input	Solar zenith angles	grid (xsize, ysize)	Degree
View zenith	input	Satellite view zenith angle	grid (xsize, ysize)	Degree
Solar azimuth	input	Solar azimuth angles	grid (xsize, ysize)	Degree
View azimuth	input	Satellite view azimuth angle	grid (xsize, ysize)	Degree
SDR QC flags	Input	Level 1b data quality	grid (xsize, ysize)	unitless
Derived Sensor Data				
Cloud mask	Input	Cloud mask data	grid (xsize, ysize)	unitless
Snow/ice mask	Input	Level 2 snow/ice mask data	grid (xsize, ysize)	unitless
Surface type	Input		grid (xsize, ysize)	unitless
Climatology data for temporal filter				
Climatology	input	Correlation and variance of historical climatology	grid (xsize, ysize)	unitless
LUT and Configuration File				
Coefficients LUT	Input	Regression coefficients for BPSA	2(two surface types)*18(sza) *18(vza)*23(raa)*8 (coef items)	Unitless

VIIRS LSA Reprocessing Plan

- LSA algorithms have been updated several times.
- Reprocessing is in urgent need to provide users with consistent and high-quality albedo data.
- Based on the reprocessing of upstream data: SDR, cloud mask, surface type.
- The reprocessing is intended for VIIRS data using the IDPS algorithm (granule product) with the latest LUT.
- A new gridded daily LSA product will be generated separately.
- The reprocessing is expected to cover the time period from 11/19/2012 to present.

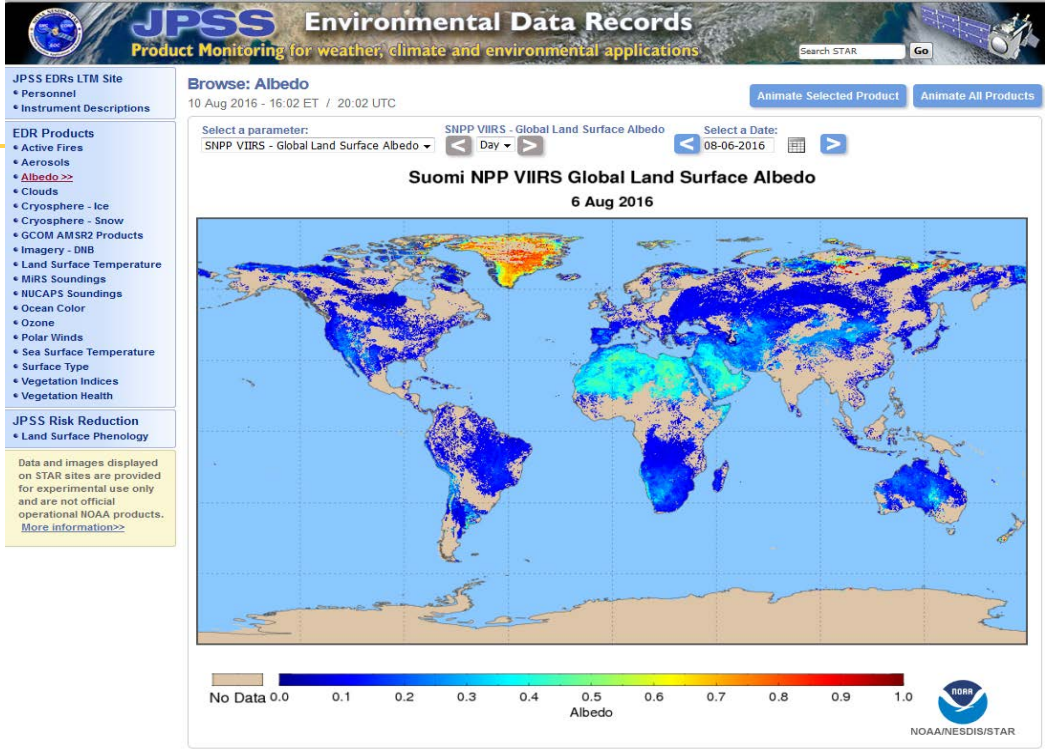
Impact of upstream data changes

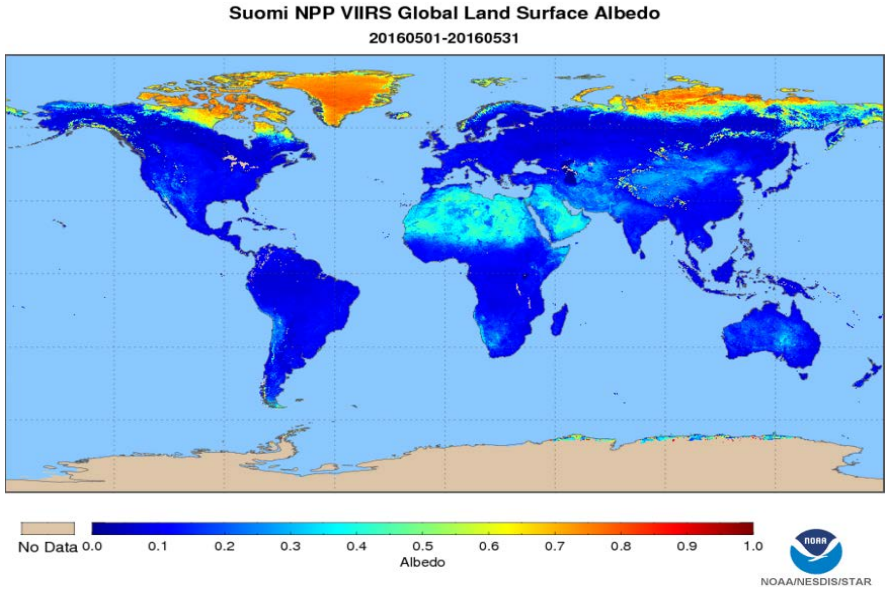


VIIRS LSA Long-term Monitoring

Developed a long-term monitoring tool

- Automatically validate against field measurements;
- Generate global composite maps on a regular basis ;
- Send alerts when abnormal results occurs;
- Update maps through WWW
- http://www.star.nesdis.noaa.gov/jpss/EDRs/products_Albedo.php





A global map of land surface albedo composite with VIIRS products of May, 2016

Issues of current LSA algorithm

Major issues of existing VIIRS albedo product:

1. Missing values
2. Intraday residual variations
3. Possible gridded product

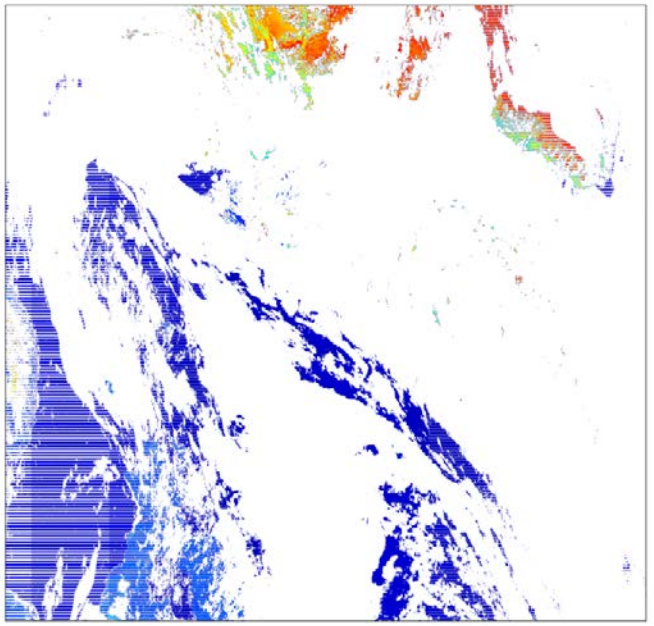
Features of current algorithm

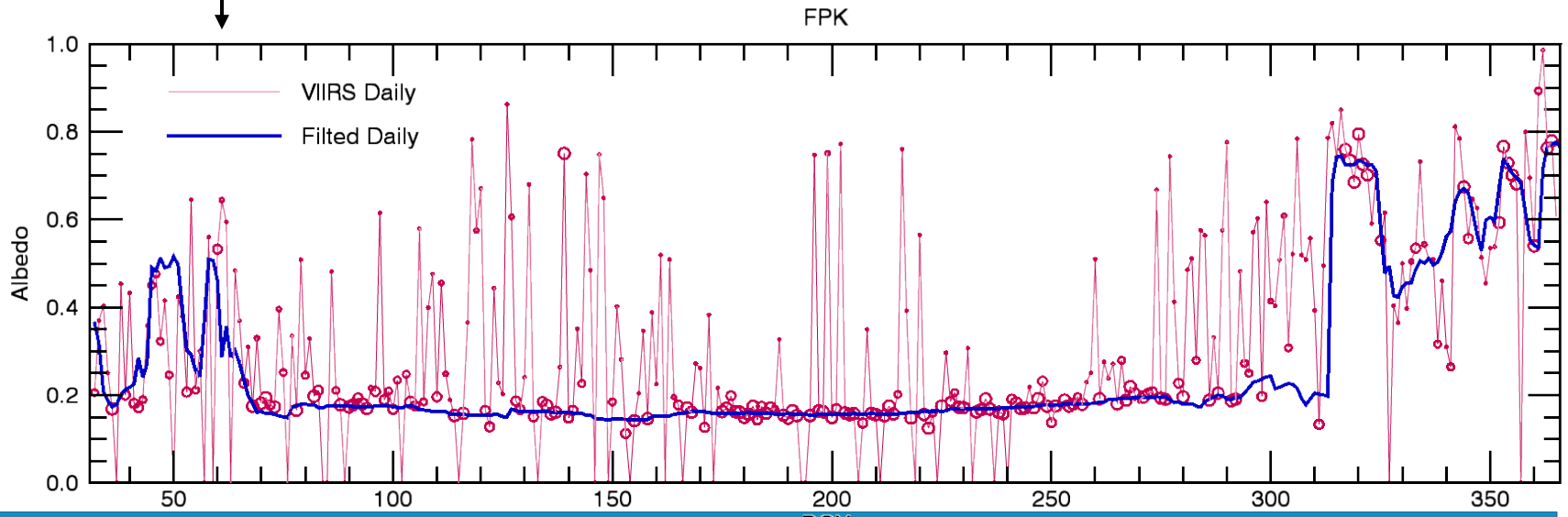
- Using single overpass
- Needing clear-sky pixels

Data gaps

Residual noise

Possible multiple values for a day



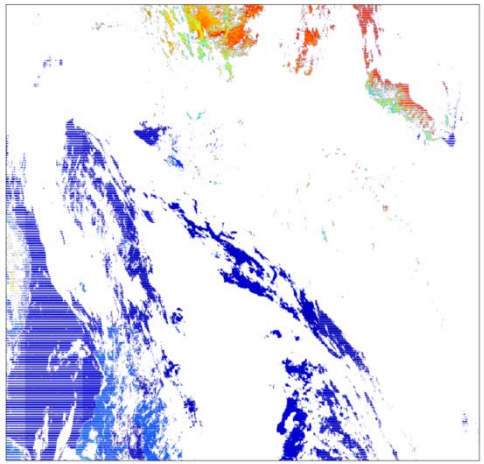


External Users of Albedo product

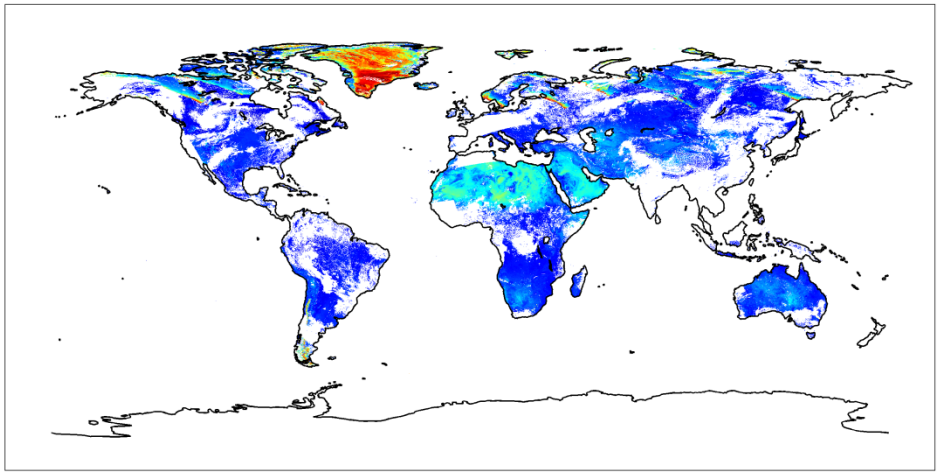
- **U. S. Users:**
  - NOAA National Weather Service Environmental Modeling Center (Michael EK, Jesse Meng, Weizhong Zheng)
  - USDA Agricultural Research Services(Martha Anderson)
  - USDA Forest Service (Brad Quayle)
  - NOAA/NESDIS Center for Satellite Applications and Research (Jerry Zhan)
  - NOAA/NESDIS National Climate Data Center (Peter Thorne)
  - Academy -- University of Maryland (Konstantin Vinnikov, Shunlin Liang, Cezar Kongoli)
  - Army Research Lab (Kurt Preston)
- **Foreign Users**
  - EUMETSAT (Yves Govaerts)
  - Météo France (Jean-Louis Roujean)
  - Academy: Italy IASMA Research and Innovation Centre (Barbara Marcolla), Beijing Normal University (Qiang Liu)

Users Feedback

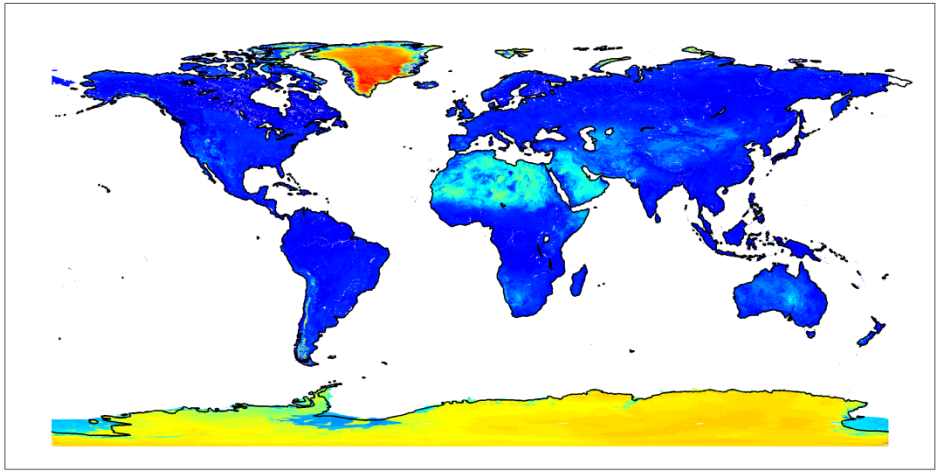
- Granule-based files are not ready-to-eat
  - First convert map-projection
  - Conduct “temporal composite” before they can actually use the granule data in their modeling or analysis.
- Current data are not continuous
  - The issue of missing values limits the application of albedo in modelling and analysis
- Residual noise
  - Retrievals from individual observation are not stable over “pseudo-invariant” surfaces



Example of a single granule



Original map of July 17 2015



Map of July 17 2015 after temporal filtering

JPSS-1 Readiness

- No significant algorithm changes for LSA from S-NPP to JPSS-1.
- The transition of LSA product from SNPP to J1 is expected to be smooth and the data will be consistent.
- Pre-launch Characterization
  - Conducted simulations of atmospheric radiative transfer to generate new LUTs of regression coefficients for J1.
  - Calibration/validation/monitoring tools developed for SNPP are applicable for J1 mission
  - SNPP data serves as proxy of JPSS-1
- Post-Launch Cal/Val Plans
  - GOES-R Field Campaign data will used for J1 mission as well
  - In-situ validation: existing + new site data; domestic + international
  - Cross comparisons: S-NPP, MODIS, GOES-R
  - Schedules and Milestones: based on the mission requirement

J1 Cal/Val plan

- Comprehensive evaluation of the J1 LSA product
  - Spatial scaling problem
  - Dependency of LSA retrievals on solar and view angles
  - Global accuracy of both snow-free and snow-covered data
  - Capability of capturing rapidly-changing surfaces
- Correlative Data Sources
  - Ground stations
  - Airborne multi-angular measurements
  - High resolution reference maps
  - Other albedo products
- Development of cal/val tool
  - Generating quality metrics commonly used by the international land community
  - Participating in the international cooperation on validation of satellite land products

Summary

- Quality of LSA retrievals have been significantly improved, after three updates of LUTs of regression coefficients since launch. However, gridded daily albedo rather needed for users.
- Accuracy of the current non-snow LSA retrievals are smaller than the L1RD threshold. The performance of snow LSA is also comparable (slightly better) than the existing albedo product, although RMSE of current snow retrievals are greater than the precision requirement.
- An improved enterprise albedo algorithm is currently under development.
- The enterprise algorithm will be also applied to J1 and future J2 missions.

Future Plans/Improvements

- LUTs update for sea ice albedo production
- Land-cover-specific LUT will further improve quality of albedo retrieval.
- Enterprise LSA development and framework test
- Reprocessing LST data when the upstream data are ready.
- JPSS-1 LSA product evaluation and monitoring
- Level-3 gridded data production
- Further interactive with EMC/NCEP model team: intensive LSA model assimilation

JPSS LAND SURFACE TEMPERATURE

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Yuling Liu, Peng Yu, Heshun Wang
UMD/ESSIC

Outline

- ❑ Cal/Val Team Members
- ❑ JPSS LST Production Overview
  - Current IDPS LST algorithm
  - Performance Overview
  - New Development
    - ✓Enterprise LST Algorithm
    - ✓Emissivity Development
  - Reprocessing Status
  - Long Term Monitoring
  - Issues
- ❑ JPSS-1 Readiness
- ❑ Summary and Path Forward

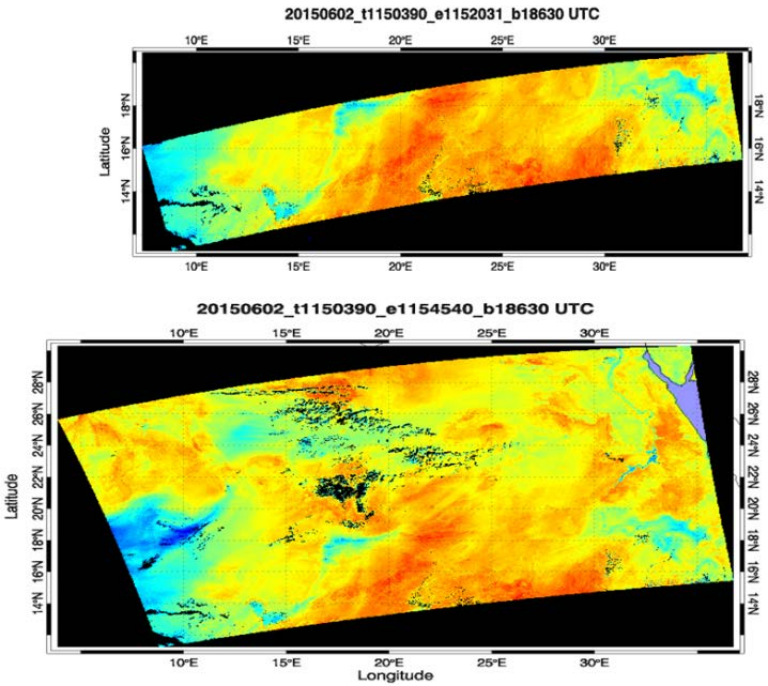
Cal/Val Team Members

PI	Organization	Team Members	Roles and Responsibilities
Ivan Csiszar	NOAA/NESDIS/SATR		Land Lead, Project Management
Yunyue Yu	NOAA/NESDIS/SATR		EDR Lead, algorithm development, validation, team management
		Yuling Liu	product monitoring and validation ; algorithm development
		Heshun Wang	algorithm improvement, emissivity development
		Peng Yu	product validation tool, monitoring, applications
Walter Wolf	NOAA/NESDIS/SATR		System Integration, Transition
		Valerie Mikles	System Integration, Transition
		Marina Tsidulko	STAR IT support
Michael EK	NOAA/EMC/NCEP		User readiness
		Weizhong Zheng	User readiness : Model LST verification
		Yihua Wu	User readiness : Model LST verification
Miguel Roman	NSAS/GSFC		NASA Land Science Investigator-led Processing System Lead
		Sadashiva Devadiga	System support, product monitoring

Current VIIRS LST Algorithm Overview

$$LST_{i,j} = a_0(i,j) + a_1(i,j)T_{15} + a_2(i,j)(T_{15} - T_{16}) + a_3(i,j)(\sec\theta - 1) + a_4(i,j)(T_{15} - T_{16})^2$$

Where a_k (with k=0 to 4) are coefficients depending on surface type (with i =0 to 16 for 17 IGBP surface types) and day/night condition (with j=0 to 1), and θ is satellite viewing zenith angle.



- Operational Products
  - Single 1.5 min granule data
  - Combined 4 x 1.5 min granule data
- Production team
  - STAR Science Team : Scientific development and validation
  - JPSS DPE (Data Product Engineering) : Production

Name	Type	Description	Dimension	Unit
Input				
Primary Sensor Data(SDR)				
Brightness temperature at 11μm	input	brightness temperature at 11μm	grid (xsize, ysize)	K
Brightness temperature at 12μm	input	brightness temperature at 12μm	grid (xsize, ysize)	K
Geolocation file	input	It includes solar zenith angles and Satellite view zenith angle	grid (xsize, ysize)	Degree
Derived Sensor Data				
Cloud mask	Input	Cloud mask data	grid (xsize, ysize)	unitless
Surface Type EDR	Input	Level 2 surface type data which includes Snow/ice, and IGBP types	grid (xsize, ysize)	unitless
AOT	Input	Level2 AOT data	grid (xsize, ysize)	unitless
LUT and Configuration File				
Coefficients LUT	Input	Algorithm coefficient file	2(day/night)*17(IGBP)*9(coef items)	Unitless
Parameter control	Input	Configuration value file		Unitless
Output				
LST	Output	LST value	grid (xsize, ysize)	K
QF	Output	Associated pixel quality flags	grid (xsize, ysize)	Unitless

Product Performance Overview

Attribute Analyzed	Performance	Description
L1RD APU Threshold	1.4K (2.5K)	
In-situ Validation	**-0.41(2.35)**	Results are based on the VIIRS data over six **SURFRAD** sites for over 3 years . The error budget estimation is limited by ground data quality control, cloud filtering procedure and upstream data error.
	-0.68(1.79) **-0.41(2.09)**	Results are based on the VIIRS data over two sites from **BSRN**. One site is in Gobabeb, Namibia and the other one is located in Cabauw, Netherland. The error budget estimation is limited by ground data quality control, cloud filtering procedure and upstream data error.
	0.19(2.13) **-001(2.24)**	Results are based on the VIIRS data over the **ARM** site in South Great Plain in Oklahoma; over **GMD** site in Summit, Greenland The error budget estimation is limited by ground data quality control, cloud filtering procedure and upstream data error.
R-based Validation	**0.47(1.12)**	A forward radiative transfer model is used, over 9 regions in globe, representing all 17-IGBP types over the seasons. The error budget estimation is limited by profile quality, cloud screening procedure and sampling procedure.
Cross satellite Comparison	**0.59(1.93): day** **0.99(2.02): night**	The results are based on comparisons to **MODIS** LST, over 100 scenes, over low latitude, polar area and CONUS. The error budget estimation is limited by the spatial and temporal difference, sensor difference, angle difference etc.
	Winter: -0.15(2.16):night **-2.02(2.81):day** **Summer:** **0.2(1.55):night** **-2.95(4.76):day**	The results are based on comparisons to **SEVIRI** LST in summer and winter seasons over Iberian Peninsula. The error budget estimation is limited by the spatial and temporal difference, sensor difference, angle difference etc.

Enterprise Algorithm Development

A unified LST retrieval algorithm is necessary for consistent LST production with different satellite missions

- Better Cross-satellite evaluation
- Better global validation effort
- Engineering and maintenance easiness

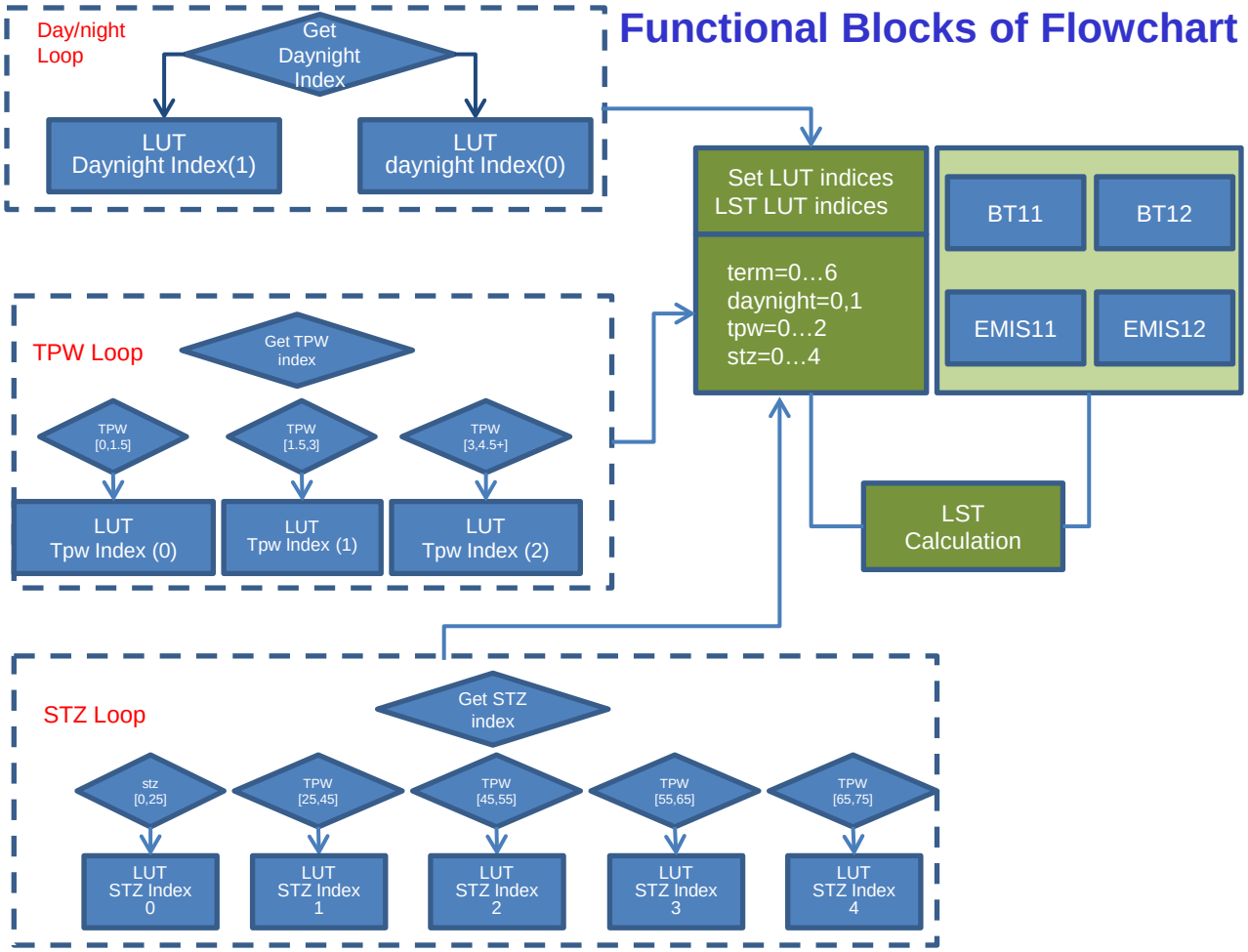
Consideration of enterprise algorithm development

- Simplify
- Robustness
- Applicable to both LEO and GEO satellite missions
- Consistent quality flags for users and for evaluation analysis
- Rely on thermal split window for best accuracy

Practical algorithm determination

- Over 20 algorithms being tested
- Simulation study for Coeffs dimension
- ATBD is in writing

$$T_S = C + A_1 T_{11} + A_2(T_{11}-T_{12}) + A_3\varepsilon + A_4\varepsilon(T_{11}-T_{12}) + A_5(T_{11} + T_{12})\,\Delta\varepsilon$$

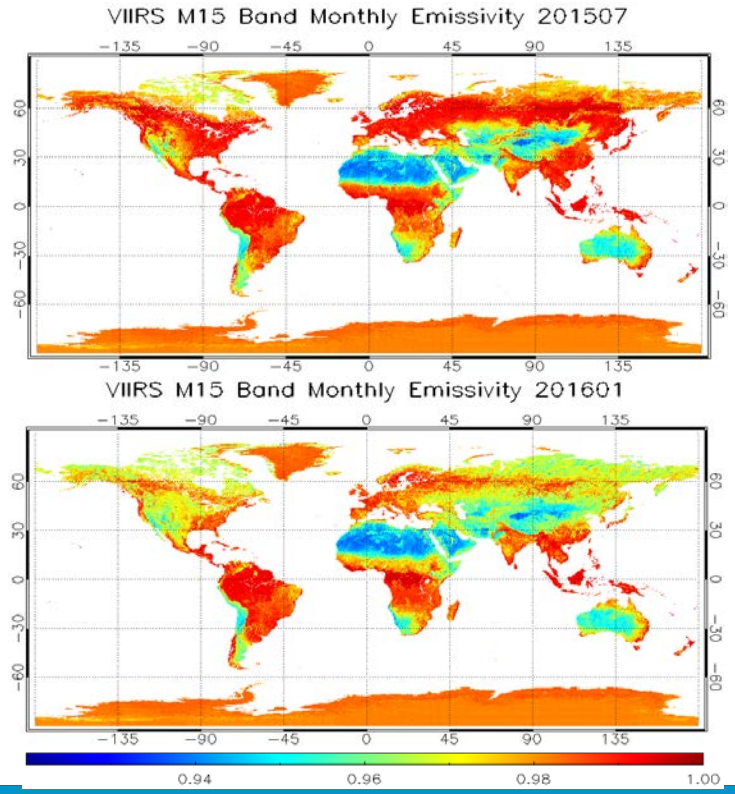


Enterprise Algorithm Status

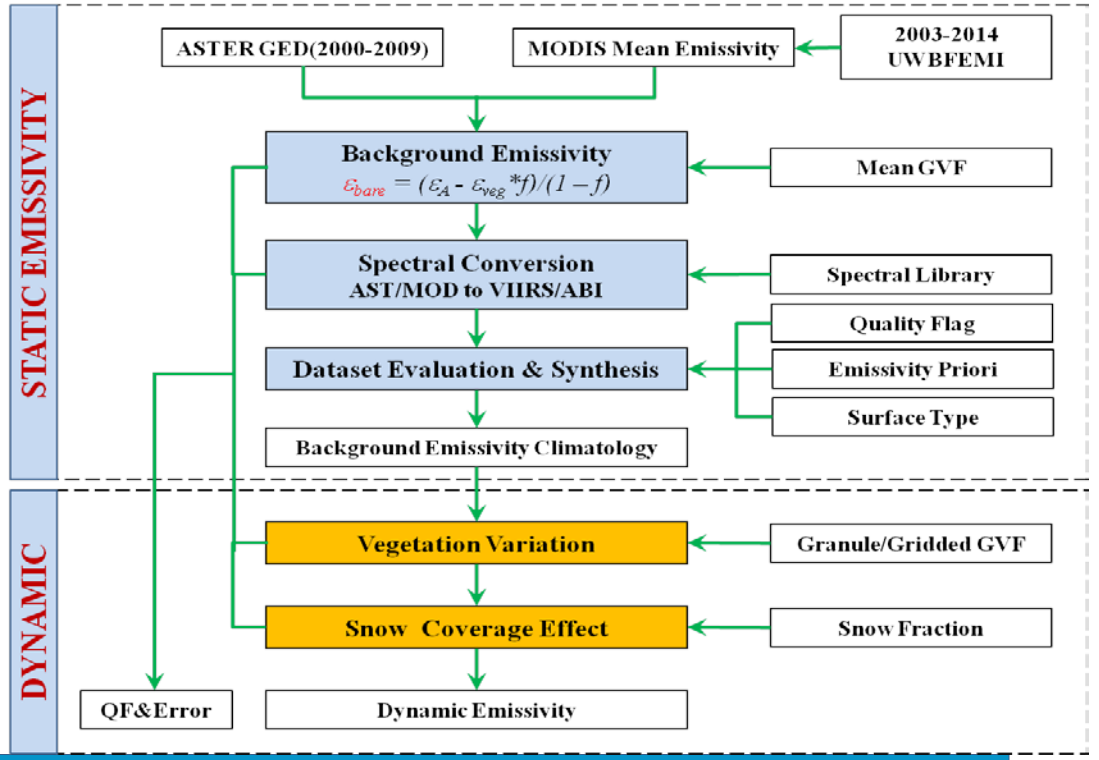
- Simulation study of algorithm test, uncertainty and sensitivity analysis have been performed.
- Real satellite data tests using VIIRS, MODIS, AHI and SEVIRI have been conducted.
- Evaluation of the algorithm is performed using 1) in-situ observations from SURFRAD, BSRN, ARM and GMD, and 2) cross satellite comparisons.
- A consistent pixel level quality flag set are determined for different satellite platform.
- Concurrently, land surface emissivity (LSE) algorithm has been developed; a daily global LSE data will be available for the LST production.
- The core part of the science code has been finished.
- The detailed design of the software architecture is on-going, with the AIT team.
- Draft version of enterprise LST ATBD and ppt slides for the coming critical design review is on-going.

Emissivity Data Development

- **Developed a new emissivity algorithm**
  - Using historical emissivity products to generate background emissivity climatology.
  - Employing a relationship between emissivity and GVF & Snow fraction to account for dynamic change.
  - Produce high resolution (0.009 degree) daily emissivity product for JPSS and GOES-R missions.
- **Advantages**
  - The dynamic emissivity provides more accurate surface emission property than static emissivity
  - High resolution GVF & Snow data gives the dynamic emissivity change information.
- **Limitations**
  - The new emissivity product only include thermal infrared channels



Flowchart of Emissivity Production Process



Reprocessing Plans/Status

- Reprocess Necessity has been proposed
  - SDR data corrections (Cal/Val, Strips, etc.)
  - LUT corrections (three times)
  - Surface Type Update
  - Cloud Mask update
- Reprocessing is planned: *after the Enterprise Algorithm development; covering the entire SNPP period (i.e. from 11/19/2012 to present)*
- Upstream data check for the reprocessing: *SDR, cloud mask and AOT and the availability of the ancillary data such as total precipitable water and snow/ice information*
- The input/output data structure and QC flags are generally determined for the enterprise LST algorithm
- Concern: data storage need

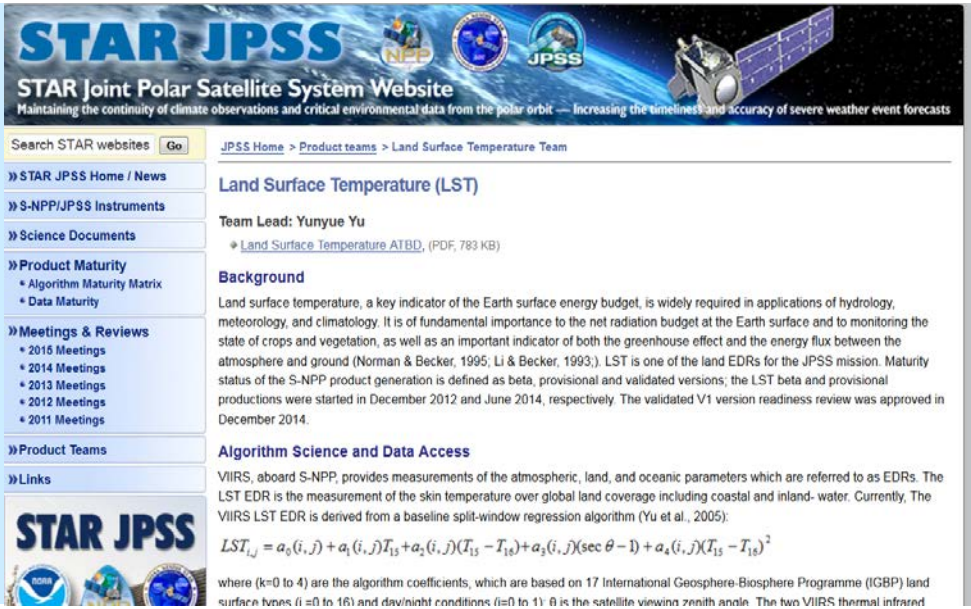
Long-term monitoring

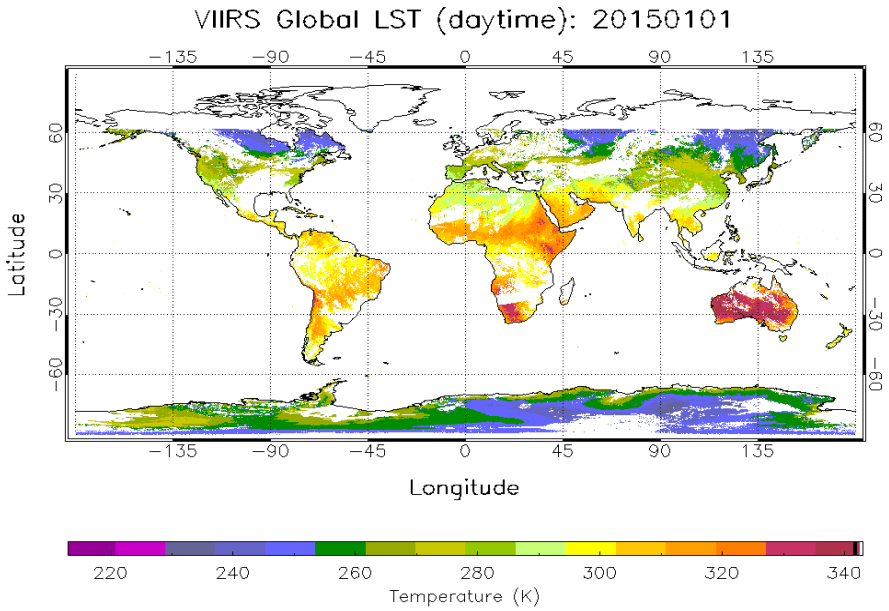
- **Monitoring/Validation tool drafted**
- **Webpage development**

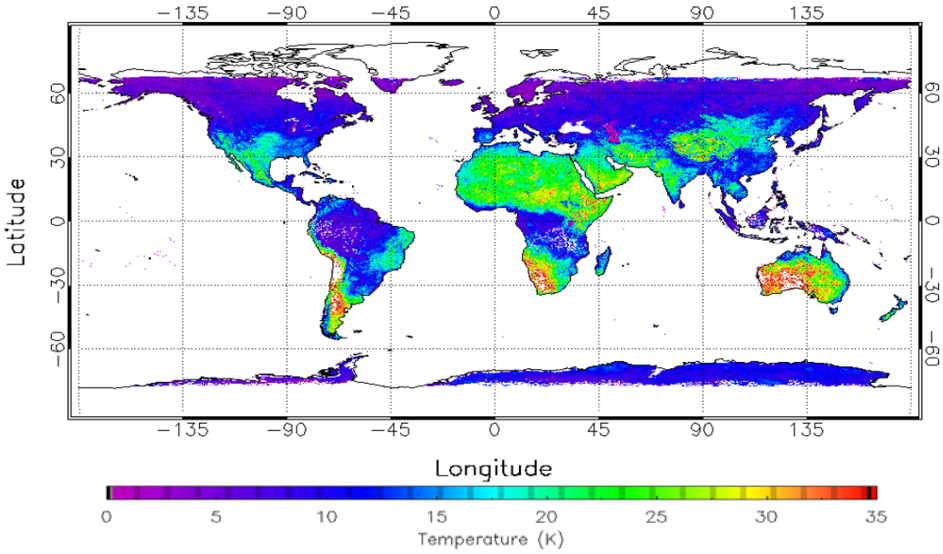
✓ A monitoring tool has been developed, which generates daily global VIIRS LST maps, and the diurnal temperature range (DTR) from the operational VIIRS LST EDR data and routinely validate with SURFRAD data.

✓ An ftp site and notification system has been setup for the monitoring, which runs the daily global LST, the monthly DTR, and the routine validation automatically. ftp://ftp.star.nesdis.noaa.gov/pub/smcd/emb/pyu/VIIRS_monitoring/.

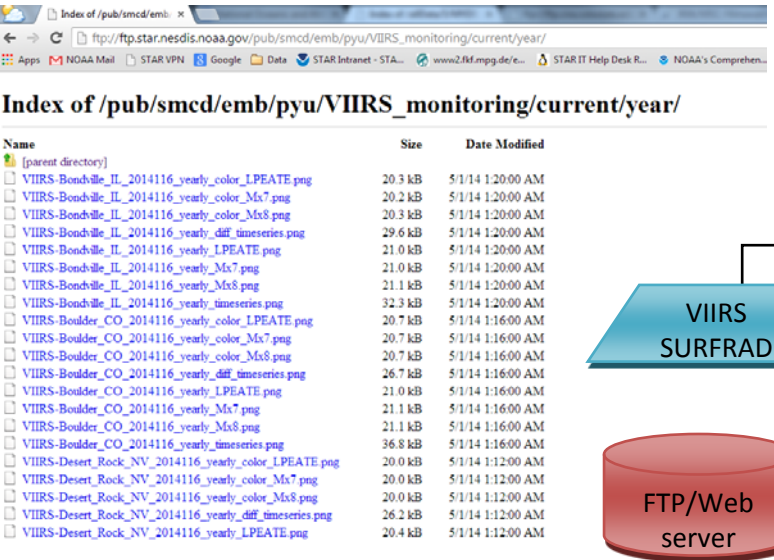
✓ A webpage development is on-going for public to review and download the global daily LST and the monthly DTR maps.

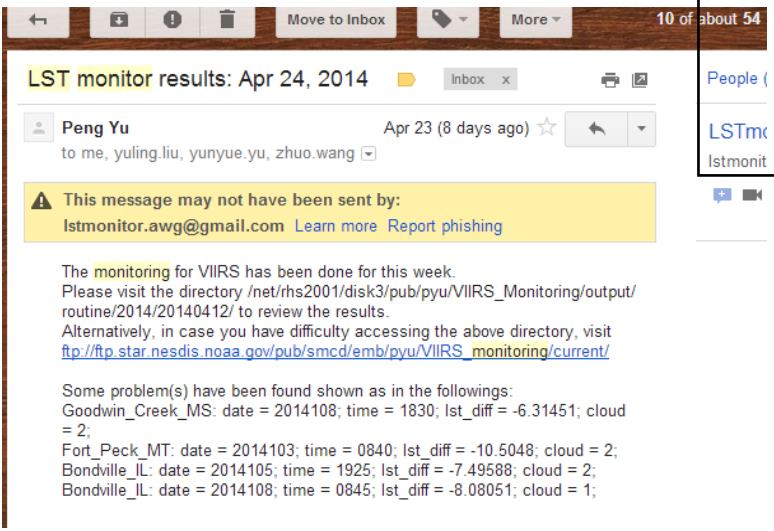


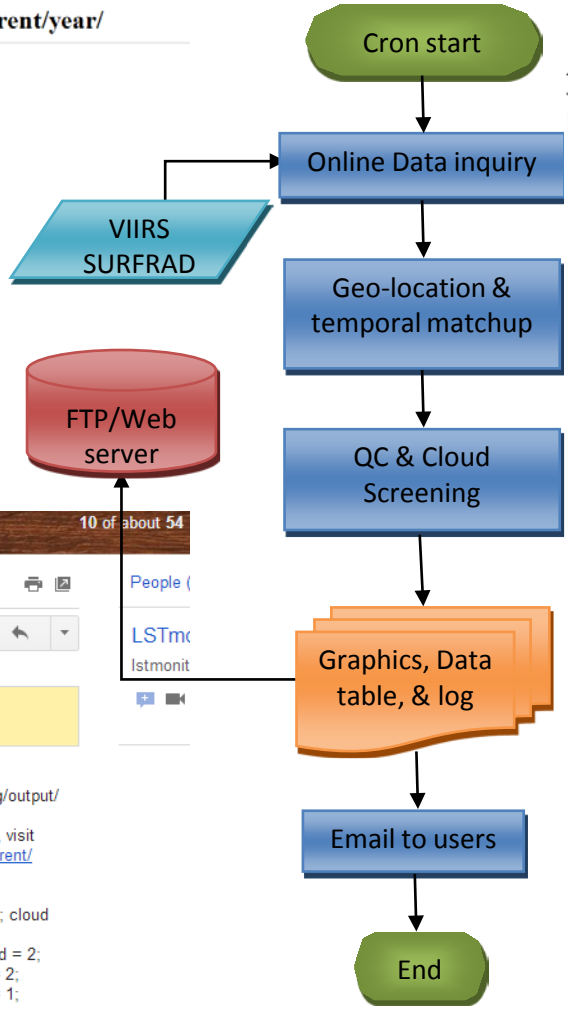


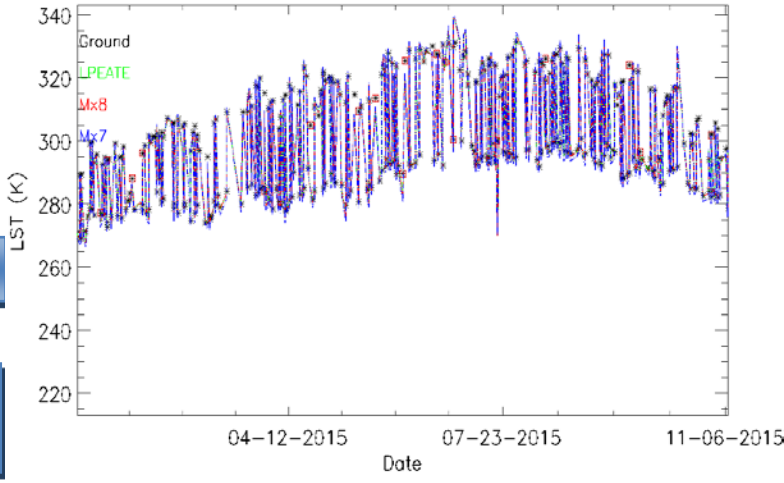


Long-term monitoring - 2

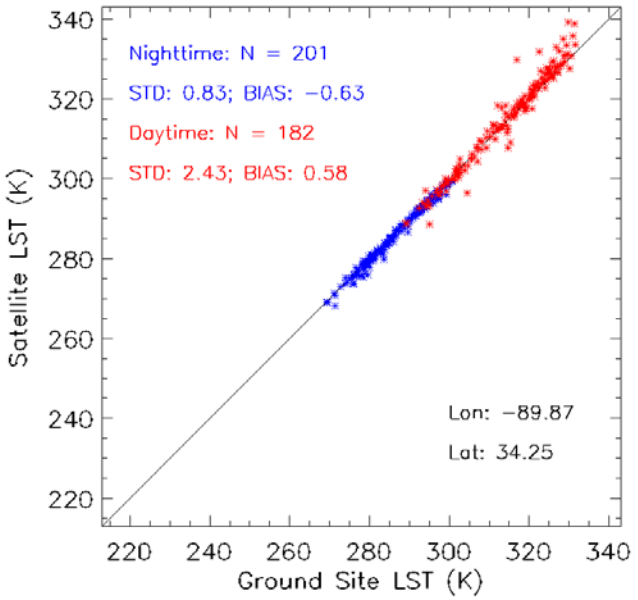








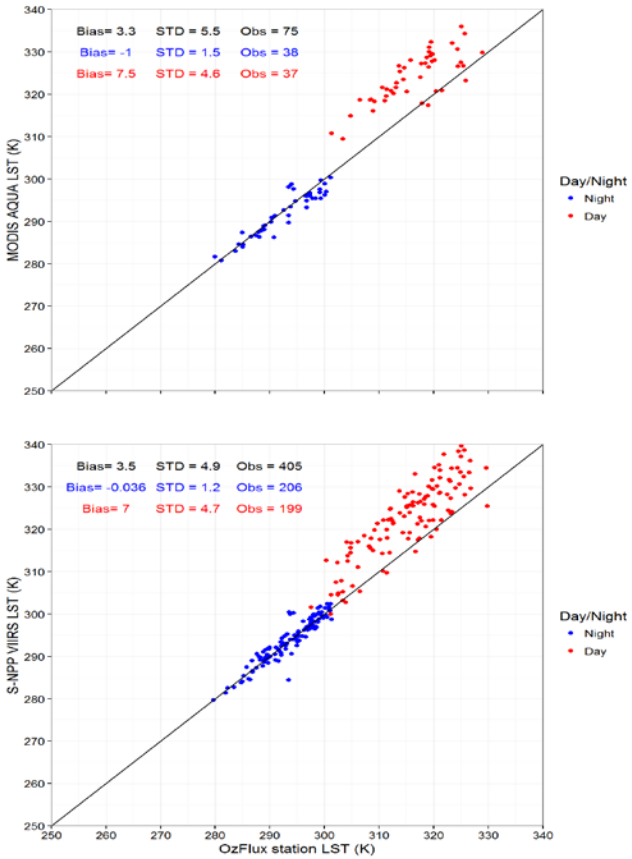
Desert Rock: 2015001-2015311

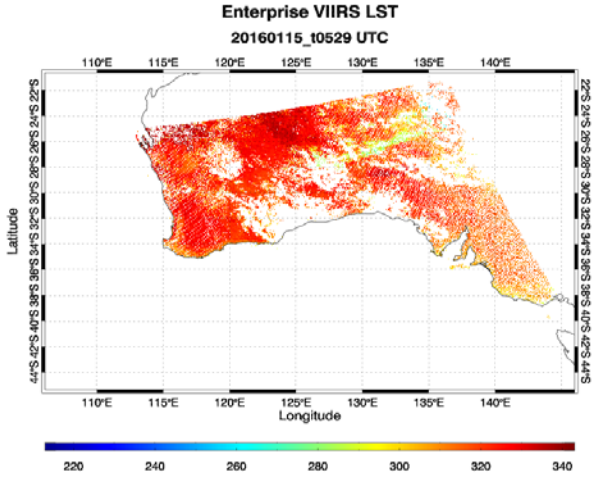


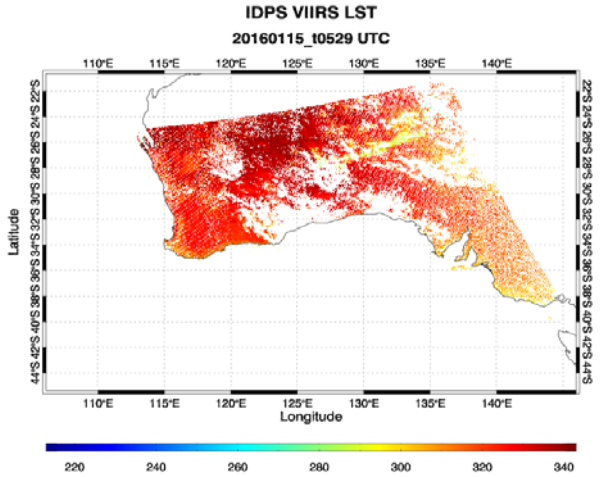
ftp://ftp.star.nesdis.noaa.gov/pub/smcd/emb/pyu/VIIRS_monitoring/current/year/

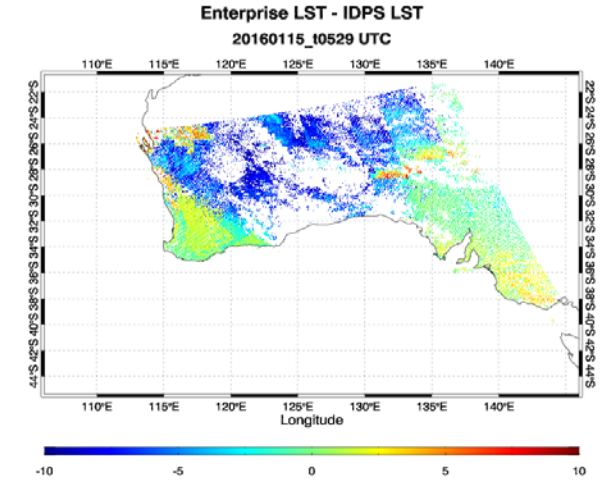
Issues In Australia region

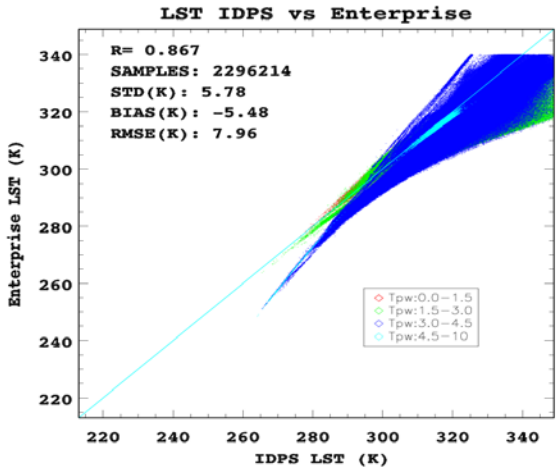
Suspicious High IDPS LST values observed in Australia Region in Summer.











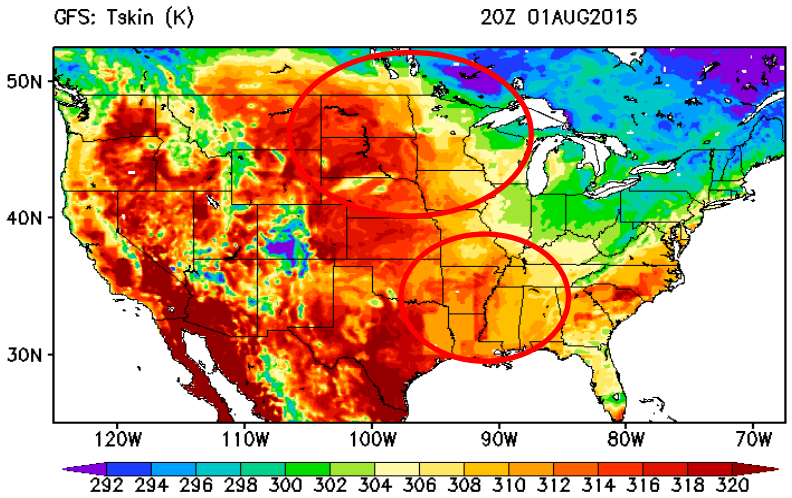
Left: The MODIS LSTs (top) and VIIRS IDPS LSTs (bottom) against ground station LST estimates
Right: VIIRS Enterprise LSTs and the IDPS LSTs

External Users of LST product

- USDA Agricultural Research Services(Martha Anderson)
- USDA Forest Service (Brad Quayle)
- Academy – Univ. of Maryland (Konstantin Vinnikov, Shunlin Liang, Cezar Kongoli)
- Army Research Lab (Kurt Preston)
- EUMETSAT LSA SAF LST group (Isabel Trigo, Project Manager)
- ESA/ESRIN, Italy (Simon Pinnock & Olivier Arino)
- Univ. Of Edinburgh, UK (Chris Merchant)
- OBSPM, and LSCE, France (Catherine Prigent & Carlos Jimenez, and Catherine Ottlé)
- Universitat de les Illes Balears, Spain (Maria Antonia Jimenez Cortes)
- eLEAF, The Netherlands (Henk Pelgrum & Wim Bastiaanssen)
- Centre for Ecology and Hydrology, UK (Rich Ellis)
- Institute of Geodesy and Cartography, Poland (Katarzyna Dabrowska-Zielinska)

Users feedback

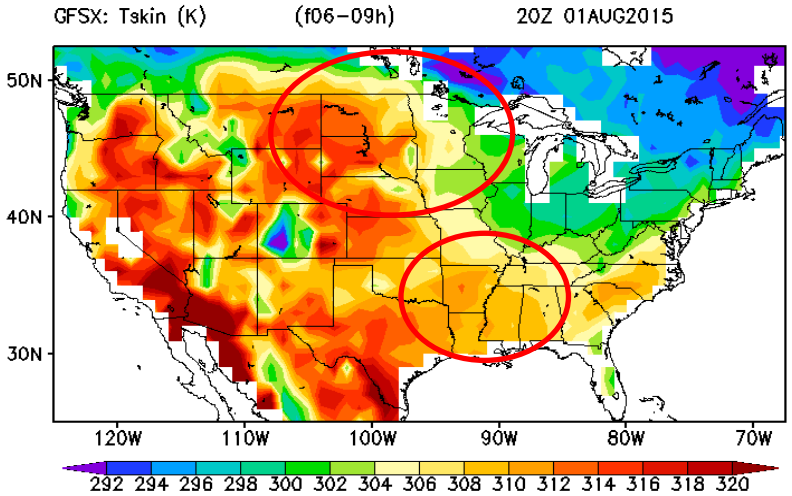
Operational GFS LST



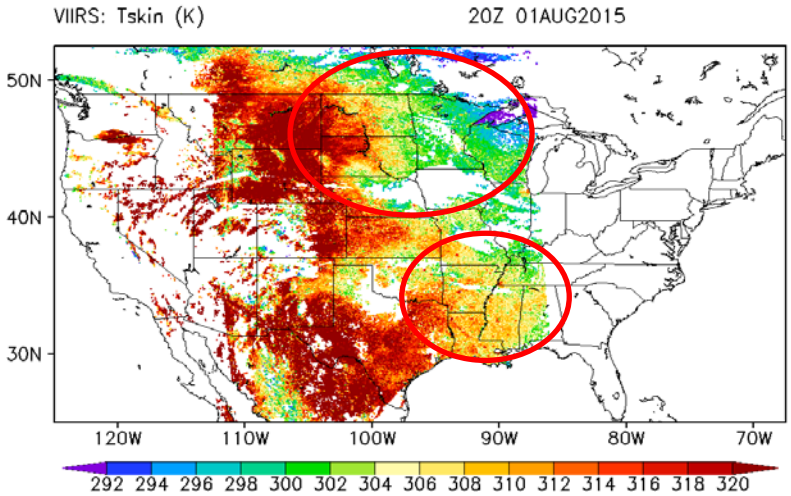
Gridded VIIRS LST data has been sampled over CONUS for verification of NCEP GFS model LST output.

EMC/NCEP requested daily gridded VIIRS LST product. The VIIRS LST team is developing a spatial and temporal gridding model for the production

Adjusted GFS model LST



VIIRS LST



VIIRS LST used to verify GFS with updated land model physics.

JPSS-1 Readiness

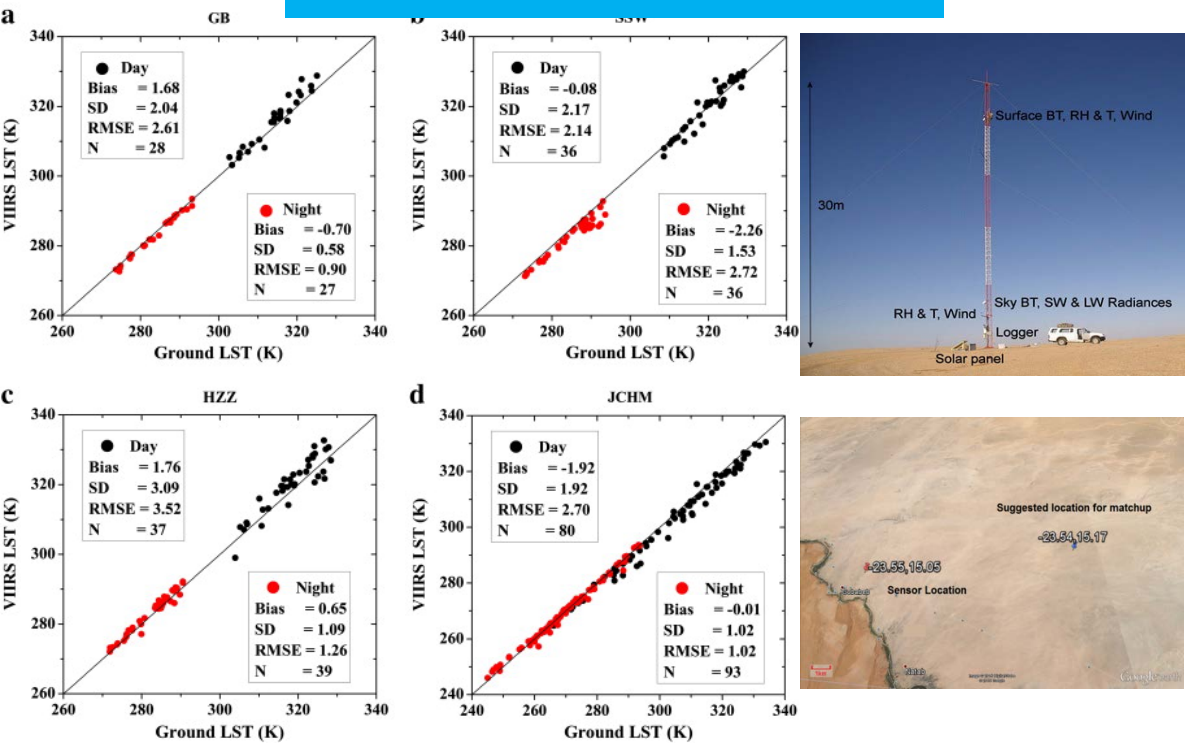
- Enterprise LST algorithm will be run at NOAA NDE system to replace the IDPS LST algorithm
  - Emissivity explicit algorithm
  - Consistent QC flags
  - Detail LUT dimension
    - Better clarification of atmospheric conditions
    - Better clarification of view geometry
  - Comprehensive evaluation and calibration
- Pre-launch Characterization
  - SNPP data serves as proxy for JPSS-1.
  - Simulation software package and database are updated for J-1 LST LUT generation
  - Calibration/validation/monitoring tools developed for SNPP are applicable for J1 mission
- Post-Launch Cal/Val Plans
  - GOES-R Field Campaign data will used for J1 mission as well
  - In-situ validation: existing + new site data; domestic + international
  - Cross comparisons: S-NPP, MODIS, +Sentinel-3
  - Schedules and Milestones: based on the mission requirement

JPSS-1 Readiness -2

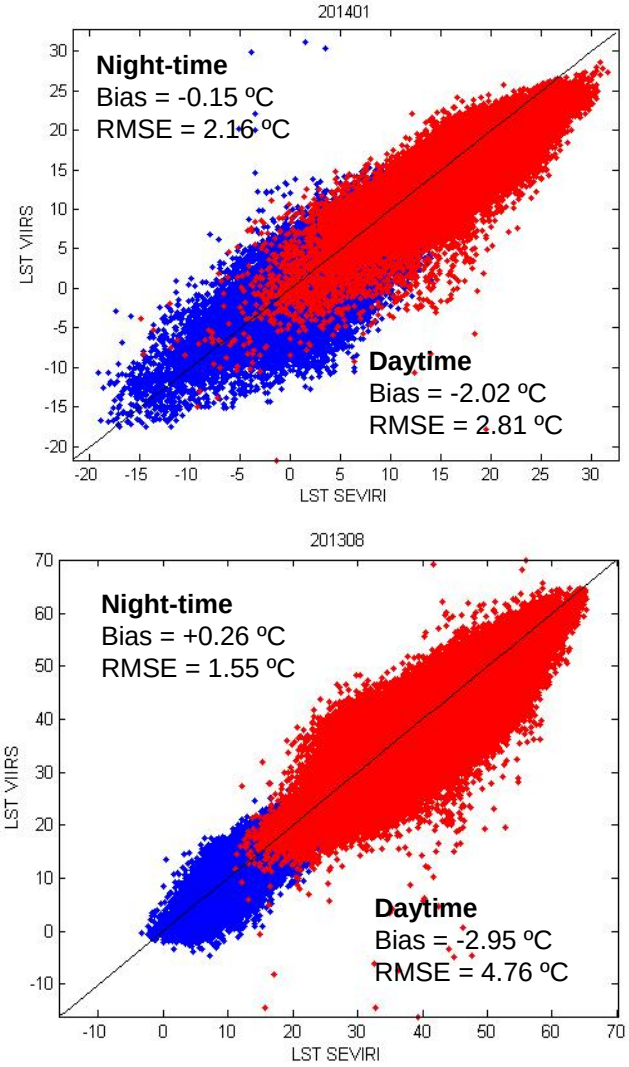
- Major Risks/Challenges/ and Mitigation
  - The enterprise algorithm run is scheduled by August 2017.
    - Mitigation: Current IDPS LST algorithm will be kept running before then
  - Availability of full resolution GVF data for the emissivity data generation
    - Mitigation: full resolution GVF product is in development
  - Emissivity data evaluation and monitoring
    - Mitigation: limited in-situ validation; LST application ; LST monitoring tool for LSE
  - Lack of high quality validation data set.
    - Mitigation: continue data collection through international cooperation; additional SURFRAD stations
  - High quality spot measurements
    - Mitigation: conduct further upscaling model study
  - Cloud contamination impact
    - Mitigation: additional cloud filtering in deep-dive validation
- Collaboration with international LST community and Stake Holders/User Agencies
  - Keep a close contact with ground data measurements providers for data quality issues and data stream anomalies
  - Provided technical support for user's questions and difficulties in the use of the LST data
  - Actively working with EMC/NCEP users and External Users

International cooperation

LST Validation in China

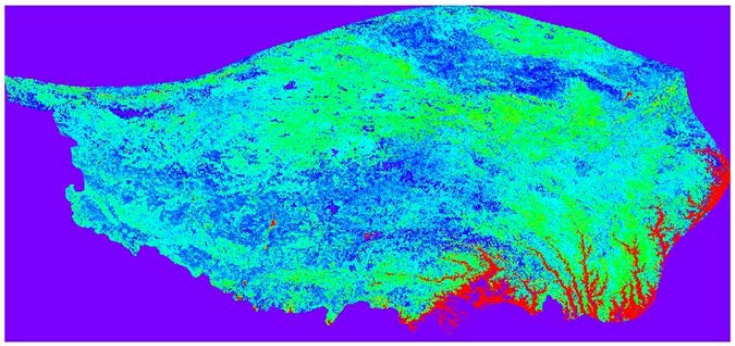


VIIRS/LST vs SEVIRI/LST comparison In Europe



LST Applications in Tibet

Difference of Frozen days (LST-L05)



VIIRS LST is used for the analysis of seasonal and diurnal cycle of freeze/thaw over Tibet Plateau area

Summary

- SNPP LST performance
  - The SNPP LST marginally meets the mission requirements based on the validation result s obtained from
    - Ground based validations(CONUS, Europe, Greenland, Australia, China)
    - Radiance based validations over global and four seasons
    - Cross satellite comparisons with MODIS, AATSR, SEVIRI etc.
  - Validation tools are run regularly for routing monitoring and web info update
  - Working with EMC/NCEP for the model verification
  - Suspicious High LSTs observed in Australia in Summer time; lack of in-situ data available for deep-dive validation
  - Cloud contamination is still the issue for accurate validation .
- Enterprise LST algorithm progress
  - Emissivity explicit algorithm developed and tested
  - Emissivity estimation algorithm is developed and tested
  - NDE LST production system is in development
- Reprocessing status
  - A reprocessing plan is proposed
  - Enterprise algorithm will be used for the reprocessing for LST consistency
- JPSS-1 readiness
  - All the validation tools and simulation tools/database are ready for the J-1 mission
  - J-1 LST production in NDE will be based on the Enterprise Algorithm
  - The J-1 Cal/Val plan has been submitted, with the schedule and milestones consistent to the mission's plan

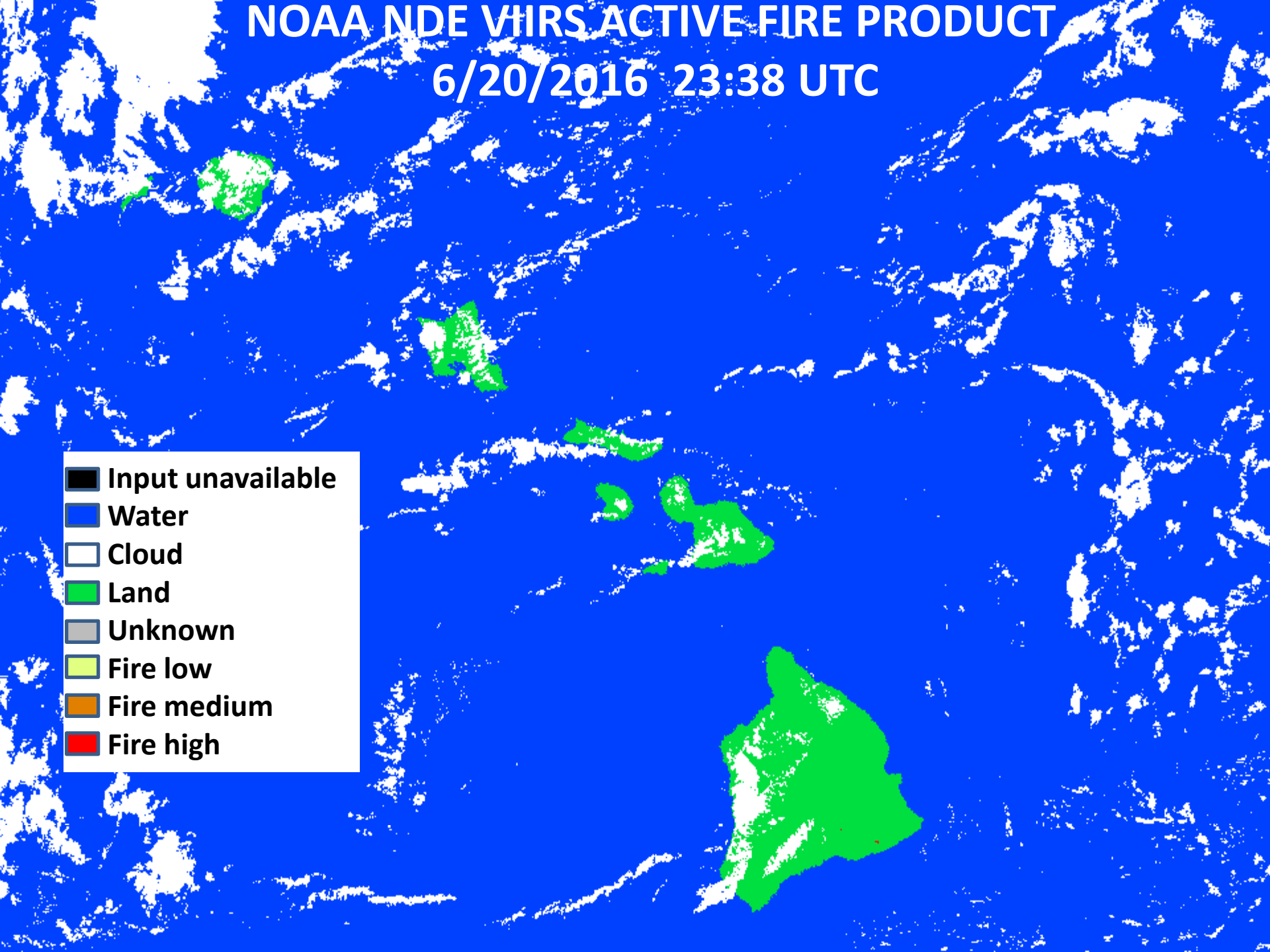
Future Plans/Improvements

- Enterprise LST development and framework test
- Reprocessing LST data when the enterprise algorithm is ready.
- JPSS-1 LST product evaluation and monitoring
- Emissivity Data evaluation
- Level-3 gridded data production
- In-situ site upscaling model study
- LUT improvement : detail clarification of the LUT dimension
- Further interactive with EMC/NCEP model team: intensive LST model verification

Active fire

Ivan Csiszar, Shobha Kondragunta (STAR),
Marina Tsidulko (IMSG), Wilfrid Schroeder,
Louis Giglio, Evan Ellicott (UMD)

additional credits are given on select slides


NOAA NDE VIIRS ACTIVE FIRE PRODUCT
6/20/2016 23:38 UTC
Input unavailable
Water
Cloud
Land
Unknown
Fire low
Fire medium
Fire high

NOAA Operational VIIRS Fire Product Status (2/1)

- Tailored version of the M-band UMD / NASA ST algorithm operational within the Suomi NPP Data Exploitation (NDE) system since March 15, 2016
  - includes fire mask and fire radiative power (FRP)
- Data available from OSPO in simplified text and other formats
  - ftp://satepsanone.nesdis.noaa.gov/FIRE/VIIRS/
- Data available from CLASS
  - currently ftp interface at ftp://ftp-npp.class.ngdc.noaa.gov/
  - pick the date, then to the folder NDE-L2/VIIRS-Active-Fire-EDR-NOAA-Enterprise-Algorithm/
  - ordering capability through the Web interface will be available in August
  - all operational data will be backfilled by late summer from the STAR archive
- Long-term quality monitoring ongoing (including both NDE and IDPS products)
    - https://www.star.nesdis.noaa.gov/jpss/EDRs/products_activeFires.php

NOAA Operational VIIRS Fire Product Status (2/2)

- Ongoing integration into NOAA operational and experimental systems e.g.
  - Hazard Mapping System
  - eIDEA – extended Infusing Satellite Data into Environmental Applications
    - http://www.star.nesdis.noaa.gov/smcd/spb/aq/eidea/
  - NWS Advanced Weather Interactive Processing System (AWIPS-II)
  - High Resolution Rapid Refresh (HRRR) http://rapidrefresh.noaa.gov/HRRRsmoke/
- IDPS production, long-term monitoring and maintenance until all downstream products in NDE / NOAA ESPC Enterprise system
- Other ongoing activities:
  - JPSS-1 testing / preparations
  - preparations for VIIRS SDR reprocessing
  - code integration into CSPP (Community Satellite Processing Package)
  - work towards UMD / NASA I-band / hybrid product transition to operations
  - end user interaction / support - NOAA JPSS Fire and Smoke Initiative
    - RealEarth™ – Google Maps etc.

NDE output file content

Name	Description	Type
fire mask	Fire mask 2D array (unit-less)	8 bit int
algorithm QA	Fire algorithm QA mask 2D array (unit-less)	32 bit Int
FP_line	Fire pixel line Sparse data array	16 bit Int
FP_sample	Fire pixel sample Sparse data array	16 bit Int
FP_latitude	Fire pixel latitude Sparse data array (deg)	32 bit Float
FP_longitude	Fire pixel longitude Sparse data array (deg)	32 bit Float
FP_power	Fire radiative power Sparse data array (MW)	32 bit Float
FP_confidence	Fire detection confidence Sparse data array (%)	8 bit Int
FP_land	Land pixel flag Sparse data array	8 bit Int

Total output for one granule: 11.7 Mb
+ number of fires * 79 bytes

Missing – 0	Brightness temperatures for M13 or M15 unavailable
Scan – 1	Not processed (trim)
Other – 2	Not processed (other reason)
Water – 3	Pixel classified as non fire water
Cloud – 4	Pixel classified as cloudy
No Fire – 5	Pixel classified as non fire land
Unknown – 6	Pixel with no valid background pixels
Fire Low – 7	Fire pixel with confidence strictly less than 20% fire
Fire Medium – 8	Fire pixel with confidence between 20% and 80%
Fire High – 9	Fire pixel with confidence greater than or equal to 80%

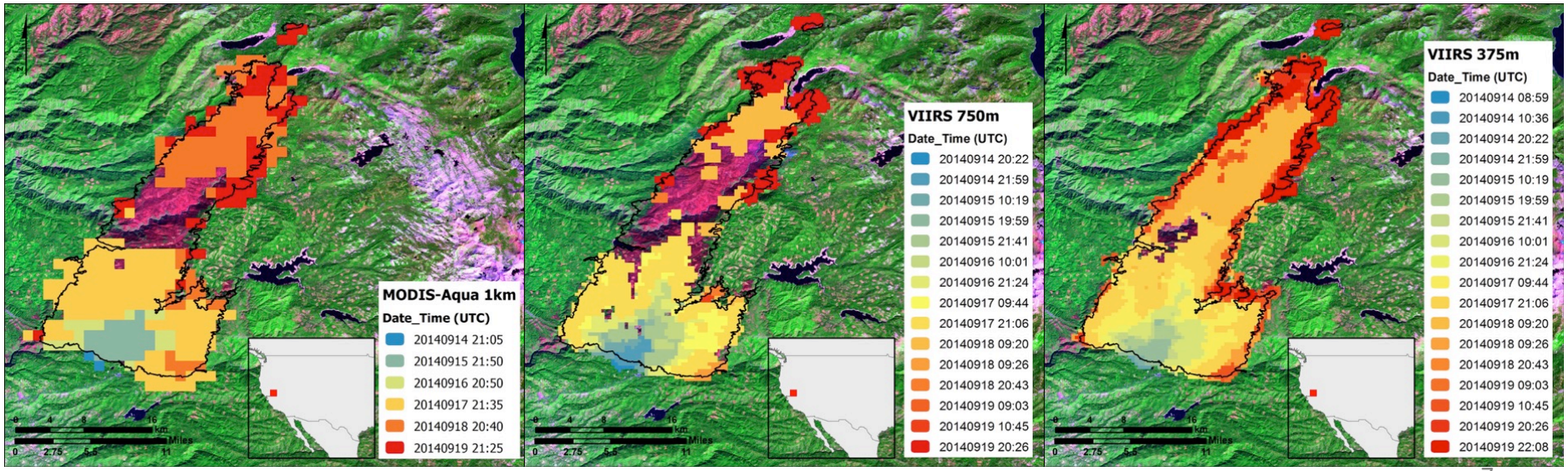
0-1	Surface Type (water=0, coastal=1, land=2)
2-3	Atmospheric correction (reserved for future use)
4	Day/Night (daytime = 1, nighttime = 0)
5	Potential fire (0/1)
6-10	Background window size parameter
11	Fire Test 1 valid (0 - No, 1 - Yes)
12	Fire Test 2 valid (0 - No, 1 - Yes)
13	Fire Test 3 valid (0 - No, 1 - Yes)
14	Fire Test 4 valid (0 - No, 1 - Yes)
15	Fire Test 5 valid (0 - No, 1 - Yes)
16	Fire Test 6 valid (0 - No, 1 - Yes)
17-19	N/A
20	Adjacent clouds (0/1)
21	Adjacent water (0/1)
22-23	Sun Glint Level (0-3)
24	Sun glint rejection
25	False Alarm 1 (excessive rejection of legitimate background pixels)
26	False Alarm 2 (water pixel contamination)
27	Amazon forest-clearing rejection test
28-31	N/A

NDE VIIRS Fire Text Output Example

year,month,day,hh,mm,lon,lat,mask,confidence,bright_t13,frp,line,sample
2016, 06, 30, 13, 31, 14.393053, -16.983391, 8, 57, 316.378326, 28.955824, 75, 114
2016, 06, 30, 13, 31, 14.396797, -16.972019, 8, 53, 339.941559, 77.328888, 84, 113
2016, 06, 30, 13, 31, 14.384778, -16.974693, 8, 69, 344.900421, 97.380959, 84, 114
2016, 06, 30, 13, 31, 14.405772, -16.956085, 8, 44, 313.854004, 19.589737, 85, 112
2016, 06, 30, 13, 31, 14.393543, -16.958811, 8, 37, 321.766541, 32.511524, 85, 113
2016, 06, 30, 13, 31, 15.573229, -15.742855, 8, 49, 306.925323, 23.677296, 228, 4
2016, 06, 30, 13, 31, 14.185258, -15.916477, 8, 69, 310.967590, 21.830891, 246, 103
2016, 06, 30, 13, 31, 14.688642, -15.625280, 8, 64, 327.718658, 63.247353, 267, 60
2016, 06, 30, 13, 31, 14.691998, -15.618657, 8, 55, 321.560547, 41.713535, 276, 59
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2016, 06, 30, 13, 31, 14.675403, -15.607850, 9, 88, 332.556183, 75.214859, 277, 60
2016, 06, 30, 13, 31, 14.976258, -14.989869, 8, 72, 312.135651, 30.420597, 358, 26
2016, 06, 30, 13, 31, 14.554691, -12.548762, 8, 56, 314.716003, 35.709991, 731, 5
2016, 06, 30, 13, 31, 14.559263, -12.547178, 8, 57, 314.763763, 35.436863, 740, 4
2016, 06, 30, 13, 31, 14.450356, -12.540216, 8, 74, 313.761322, 33.999859, 742, 11
2016, 06, 30, 13, 31, 14.410105, -12.396758, 8, 47, 311.148468, 25.756071, 761, 11

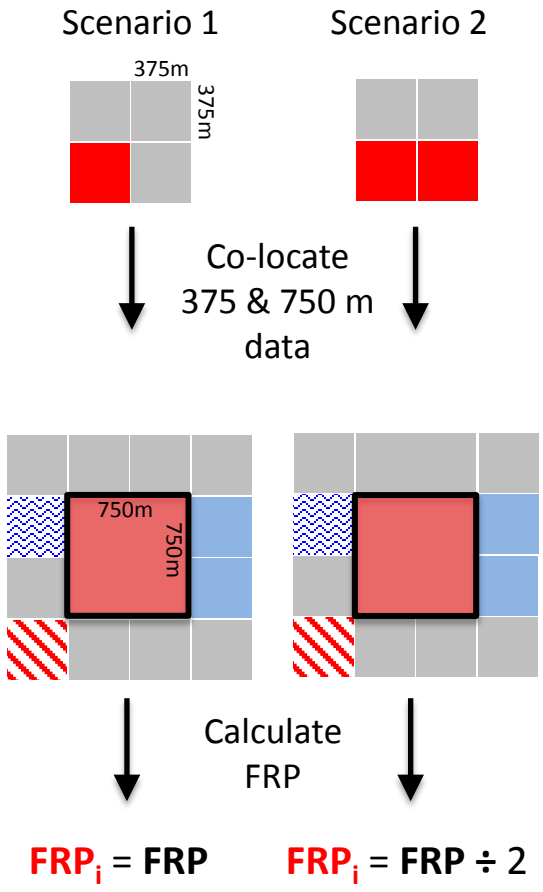
UMD/NASA VIIRS Active Fire Product Update

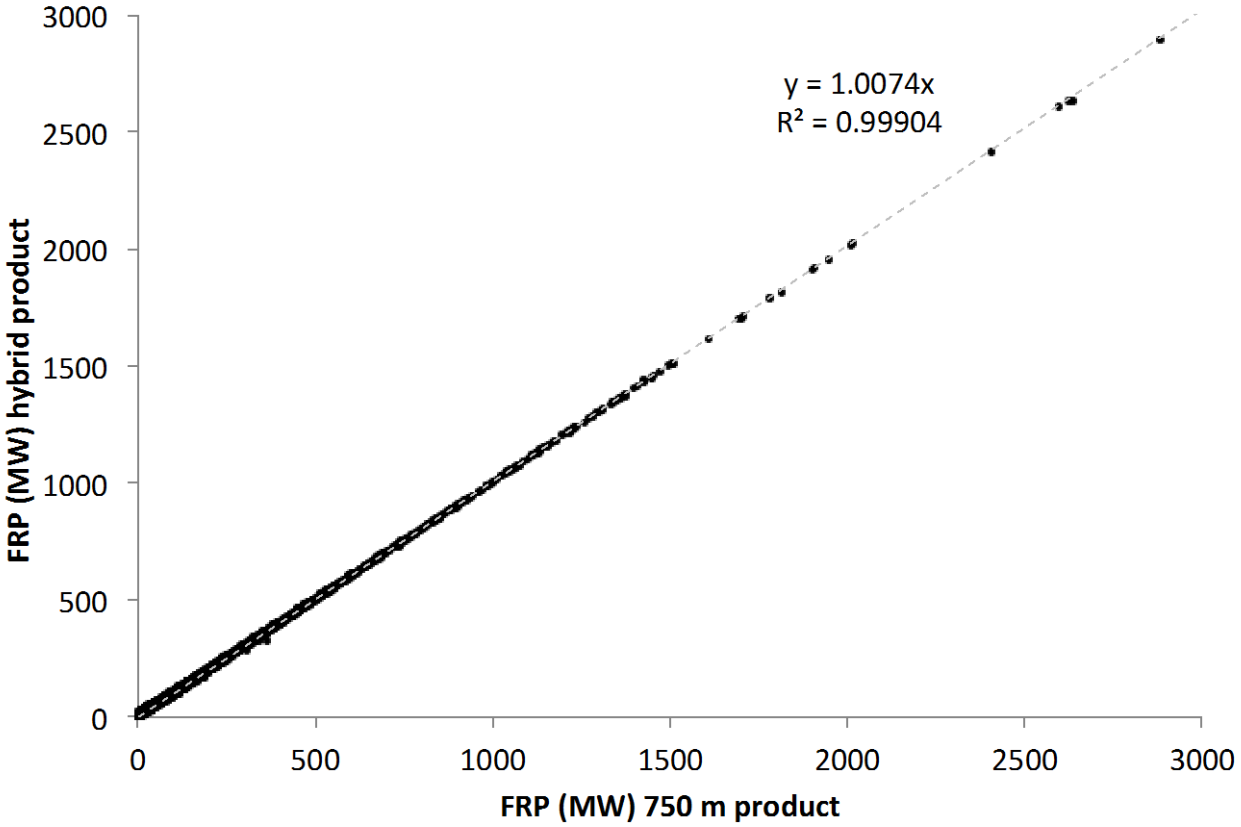
- Baseline **750 m active fire product** built on MODIS Collection 6 algorithm
  - L2 product basis for NOAA NDE
  - Small customization performed in order to account for unique L1B data
  - Fire detection and characterization (fire radiative power)
  - Output format supporting MODIS-VIIRS data continuity
- Alternative **375 m active fire product** developed
  - Unique algorithm optimizing use of channel I4 (MIR) data (frequent saturation, folding)
  - First version produced fire detections only
  - Latest version providing fire detection and FRP
    - Hybrid approach using 375 and 750 m data
  - Output format supporting MODIS-VIIRS data continuity



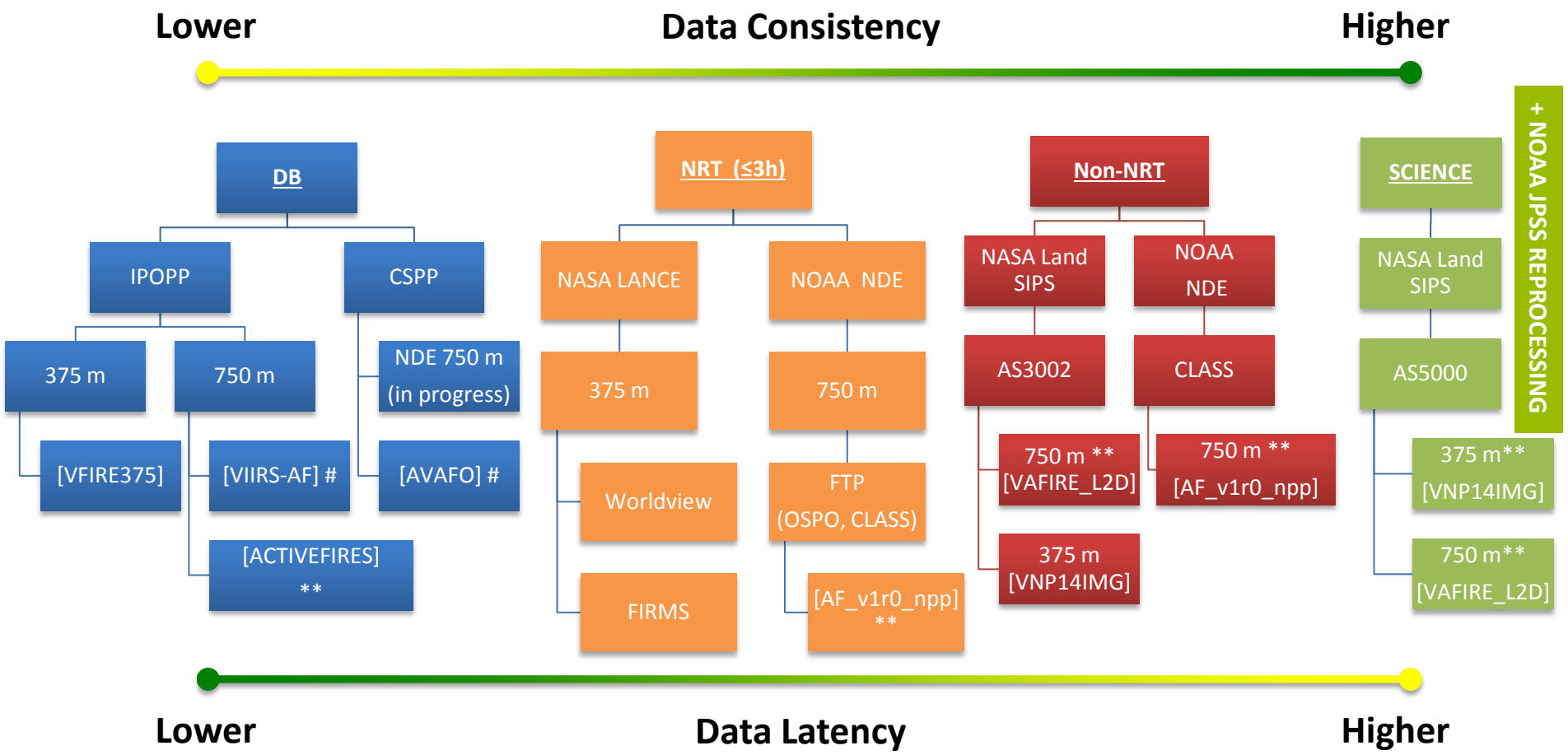
King Fire/CA, September 2014

Hybrid (375+750m) FRP Retrieval





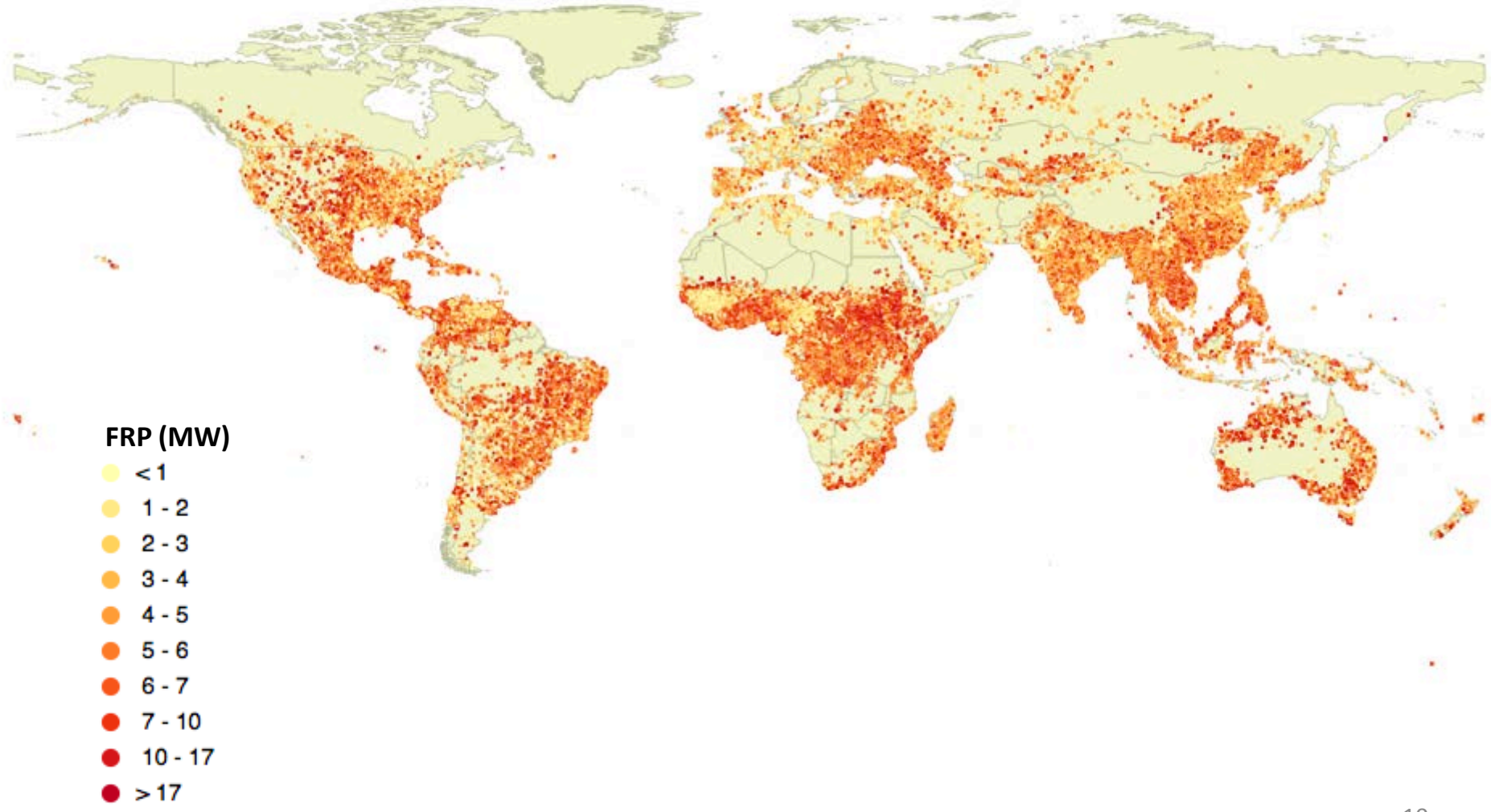
VIIRS Active Fire Product Lineage



** marked products include FRP retrieval
# marked products describe discontinued algorithm
[ ] indicate official product name

Details soon to be available at:
http://viirsfire.geog.umd.edu/

VIIRS 375m (hybrid) Fire Pixels (March 2016)
'Collection 2'

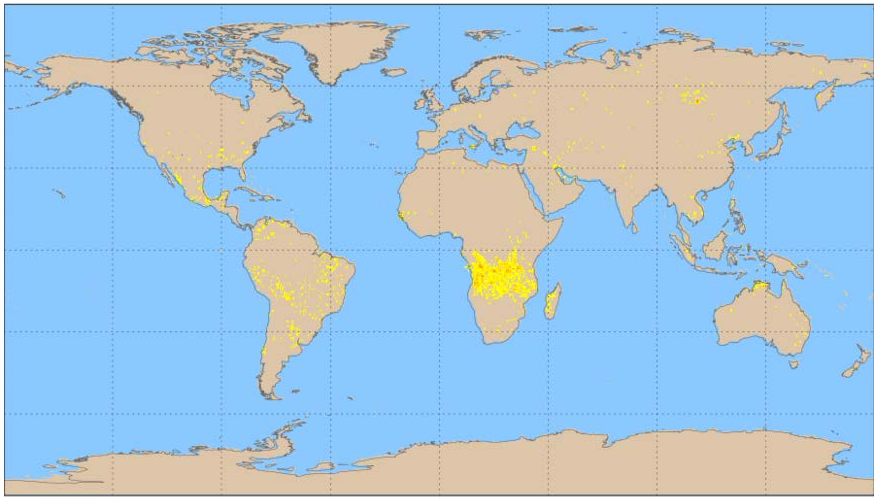


VIIRS Active Fire Long-term Monitoring

http://www.star.nesdis.noaa.gov/jpss/EDRs/products_activeFires.php

Suomi NPP - VIIRS - NDE - Active Fires

16 Jun 2016



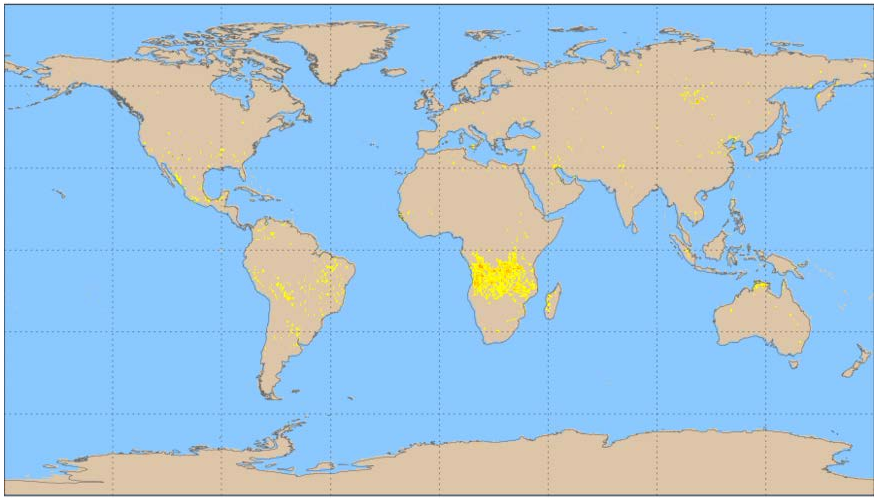
0 10 20 30 40 50 60 70 80 90 100

Fire Frequency

NOAA/NESDIS/STAR

Suomi NPP - VIIRS - IDPS - Active Fires

16 Jun 2016



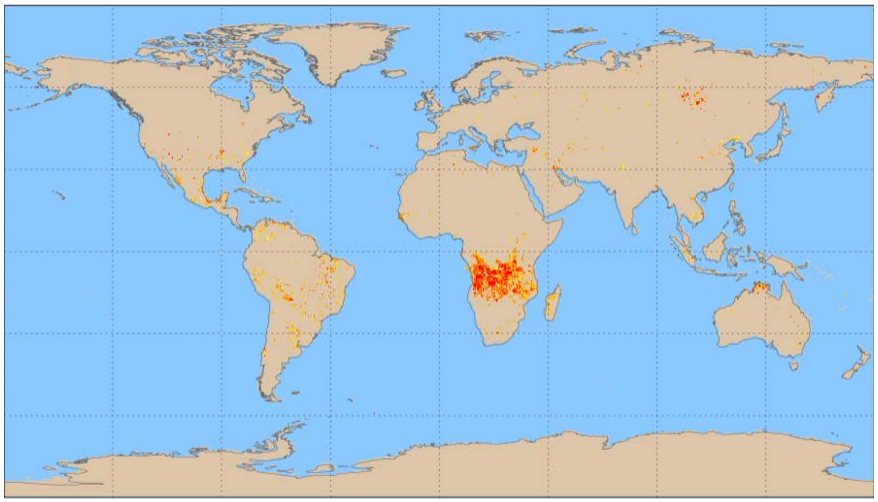
0 10 20 30 40 50 60 70 80 90 100

Fire Frequency

NOAA/NESDIS/STAR

Suomi NPP - VIIRS - NDE - Fire Radiative Power - Total

16 Jun 2016



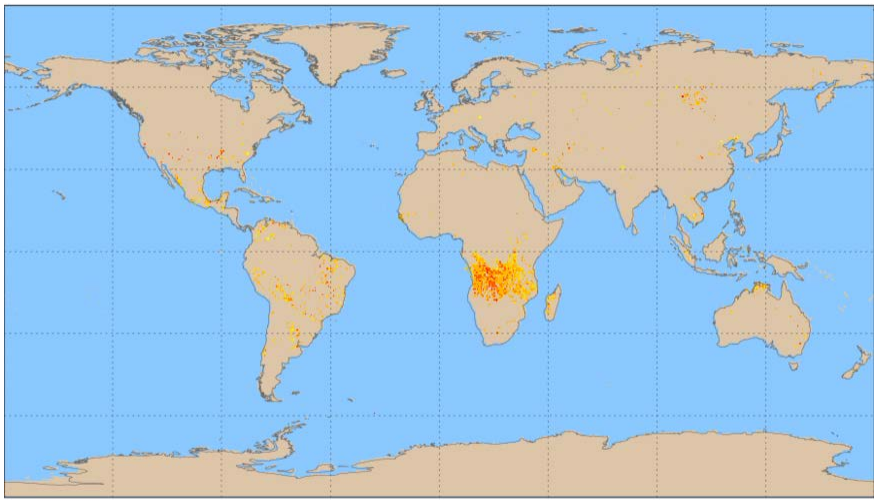
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5

$\log_{10}$ (Megawatts)

NOAA/NESDIS/STAR

Suomi NPP - VIIRS - NDE - Fire Radiative Power - Mean

16 Jun 2016

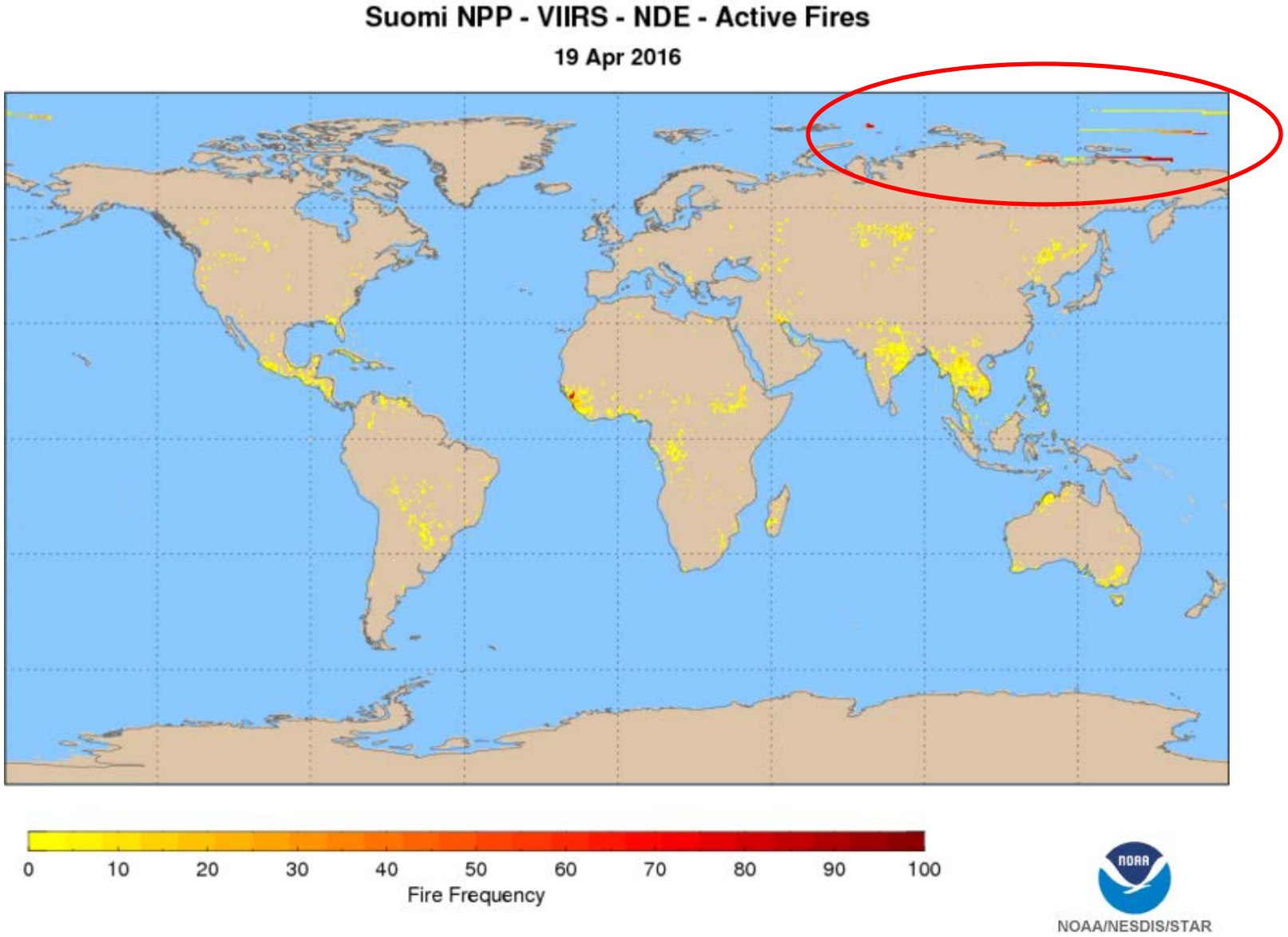


0.0 0.50 1.0 1.5 2.0 2.5

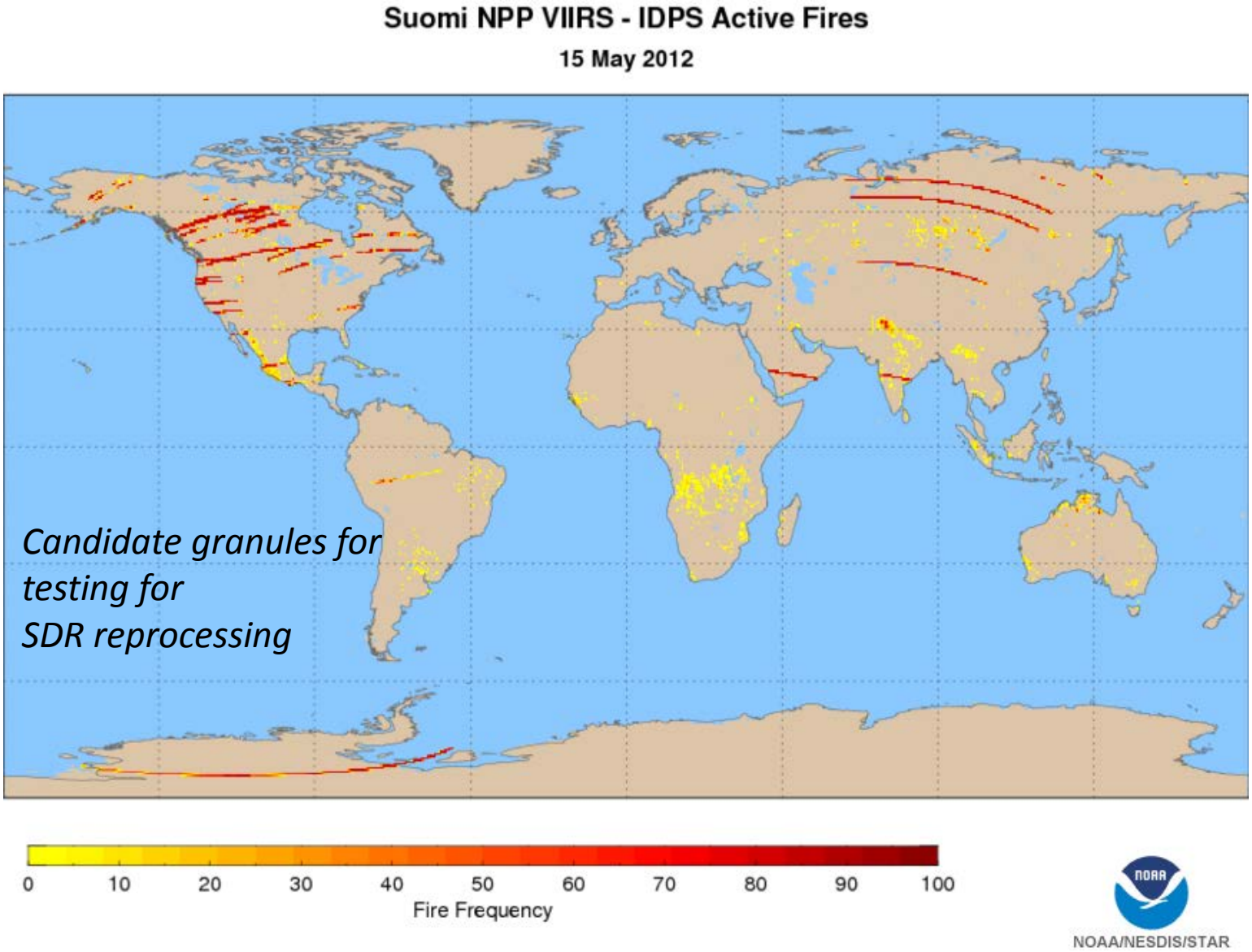
$\log_{10}$ (Megawatts)

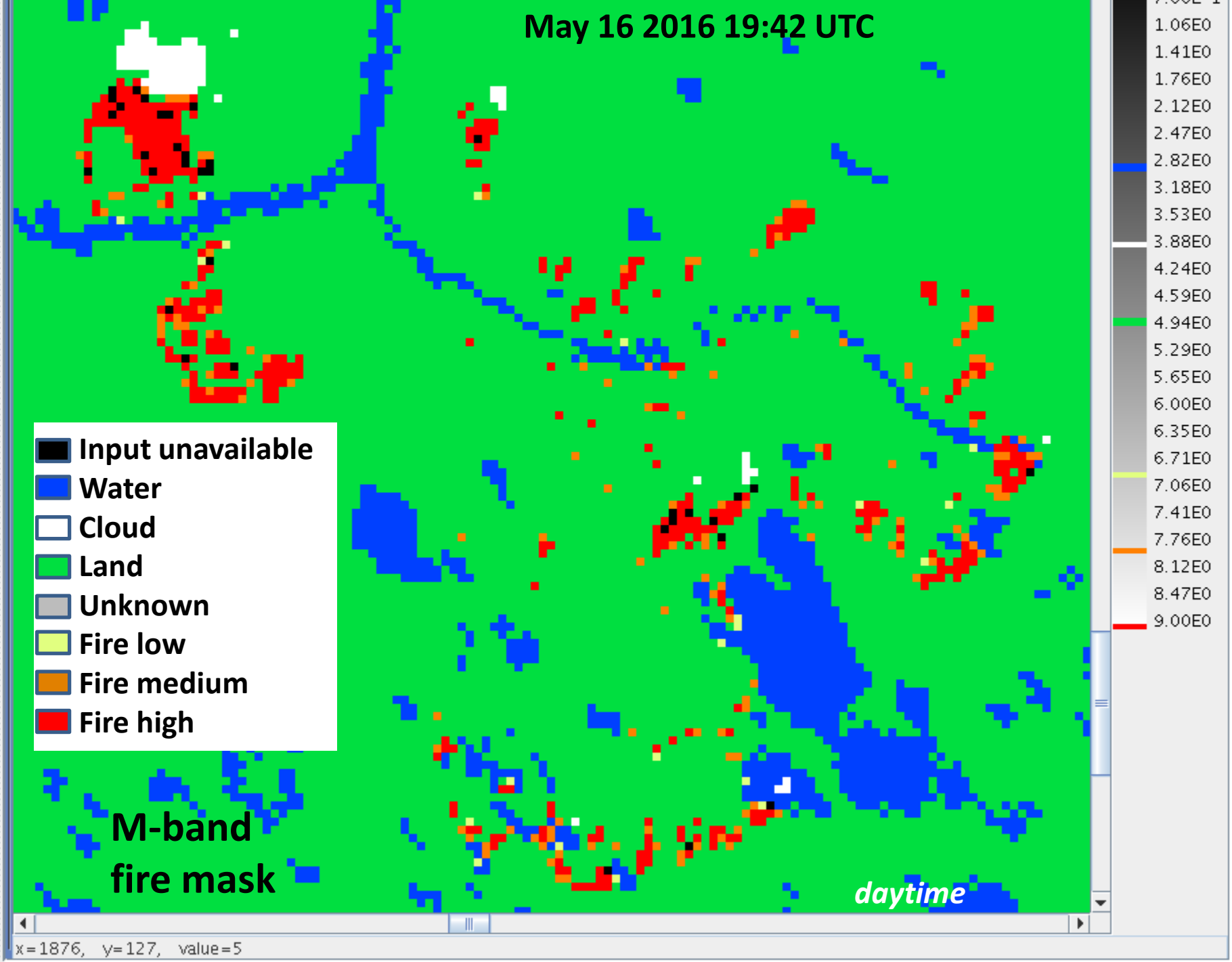
NOAA/NESDIS/STAR

Active fire data anomaly during VIIRS flight software update

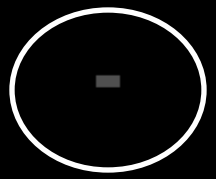


Active fire data anomalies during the early period of the Suomi NPP data record




May 16 2016 19:42 UTC
Input unavailable
Water
Cloud
Land
Unknown
Fire low
Fire medium
Fire high
M-band
fire mask
daytime
1.06E0
1.41E0
1.76E0
2.12E0
2.47E0
2.82E0
3.18E0
3.53E0
3.88E0
4.24E0
4.59E0
4.94E0
5.29E0
5.65E0
6.00E0
6.35E0
6.71E0
7.06E0
7.41E0
7.76E0
8.12E0
8.47E0
9.00E0
x=1876, y=127, value=5

May 16 2016 19:42 UTC



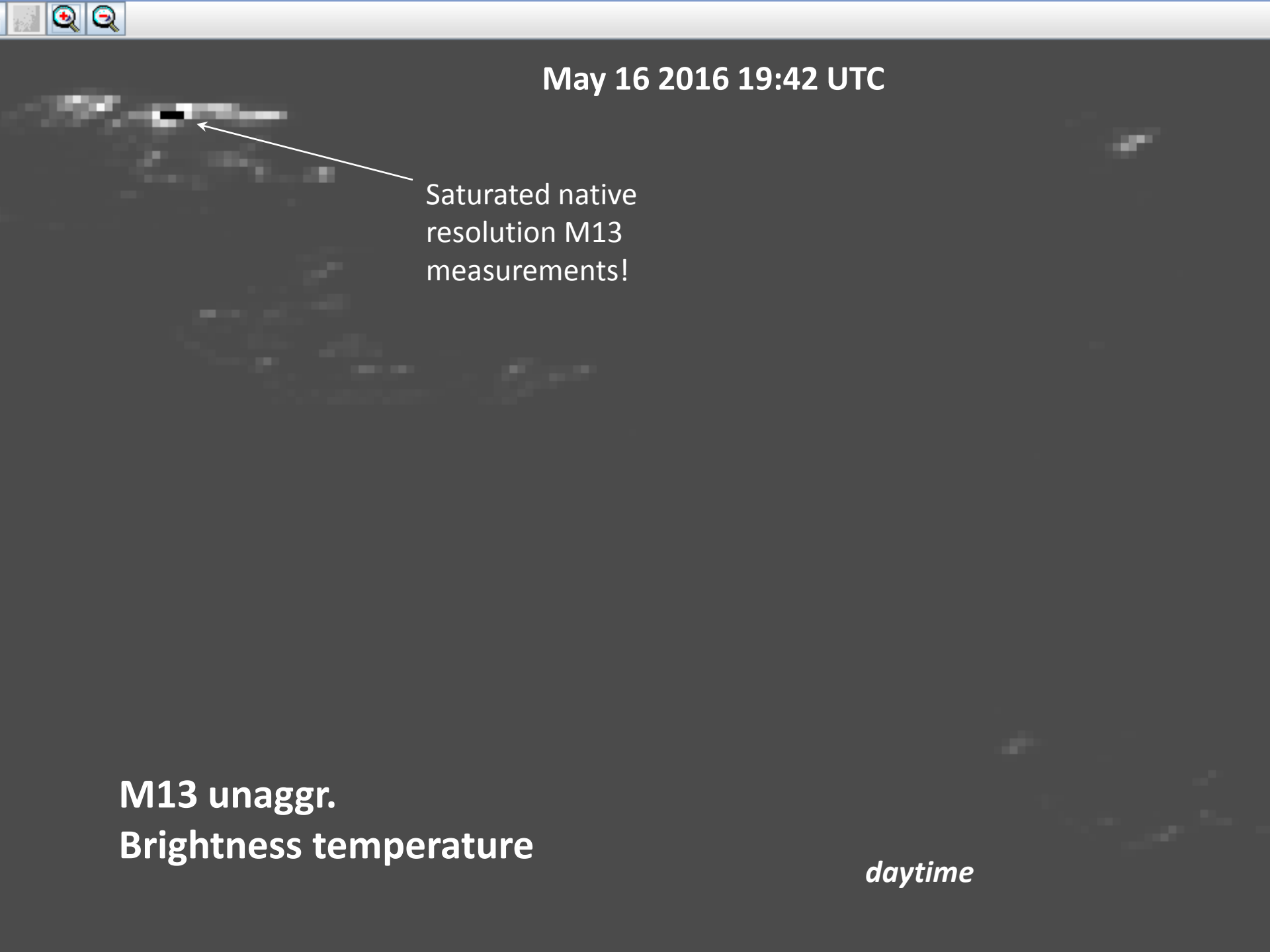
“some saturated”

1.25E
1.88E
2.51E
3.14E
3.76E
4.39E
5.02E
5.65E
6.27E
6.90E
7.53E
8.16E
8.78E
9.41E
1.00E
1.07E
1.13E
1.19E
1.25E
1.32E
1.38E
1.44E
1.51E
1.60E

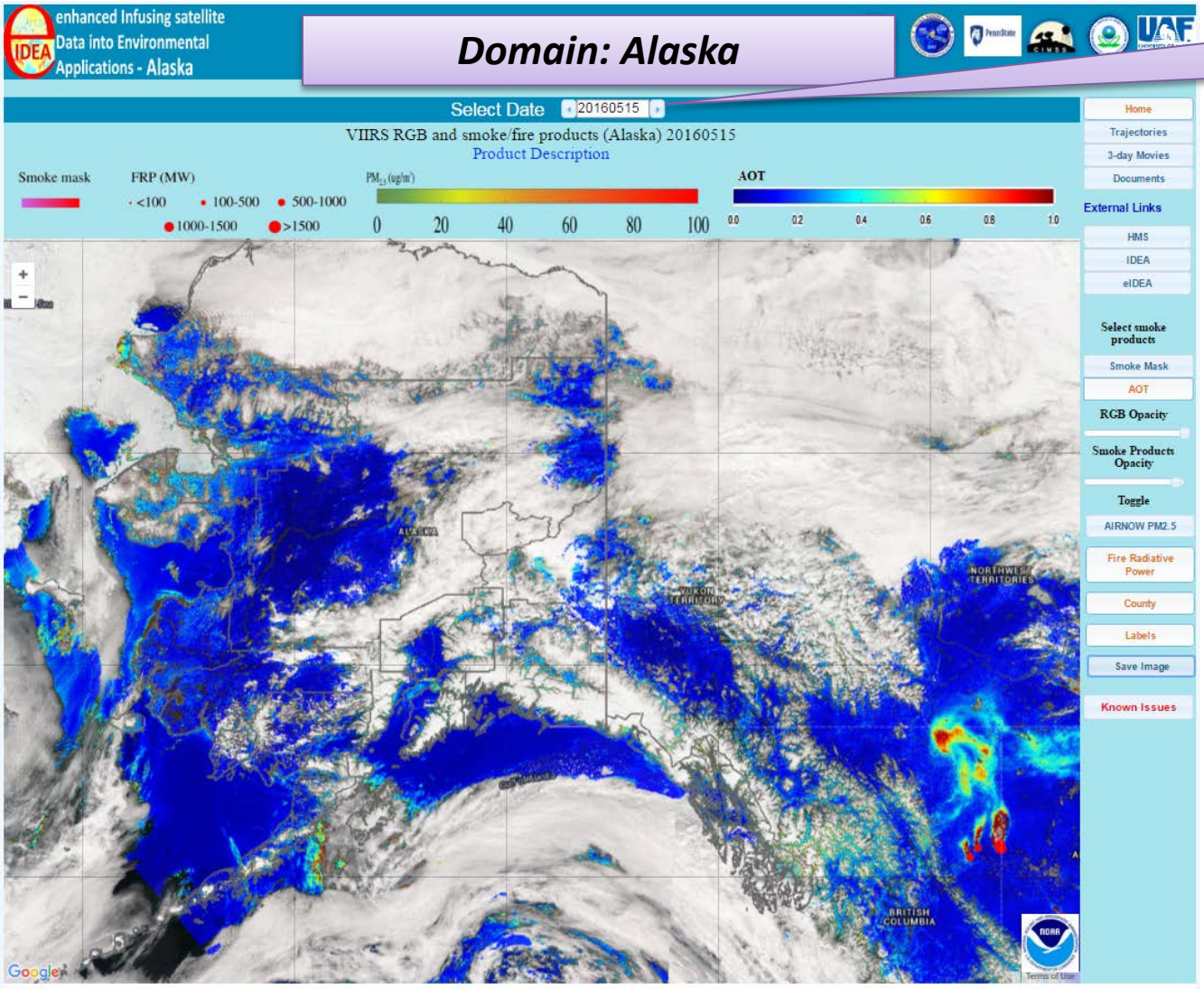
M13 quality flag
Byte 1

daytime

794, y=126, value=0


May 16 2016 19:42 UTC
Saturated native resolution M13 measurements!
M13 unaggr.
Brightness temperature
daytime

Web-Based Blended Fire and Smoke Product: eIDEA-Alaska



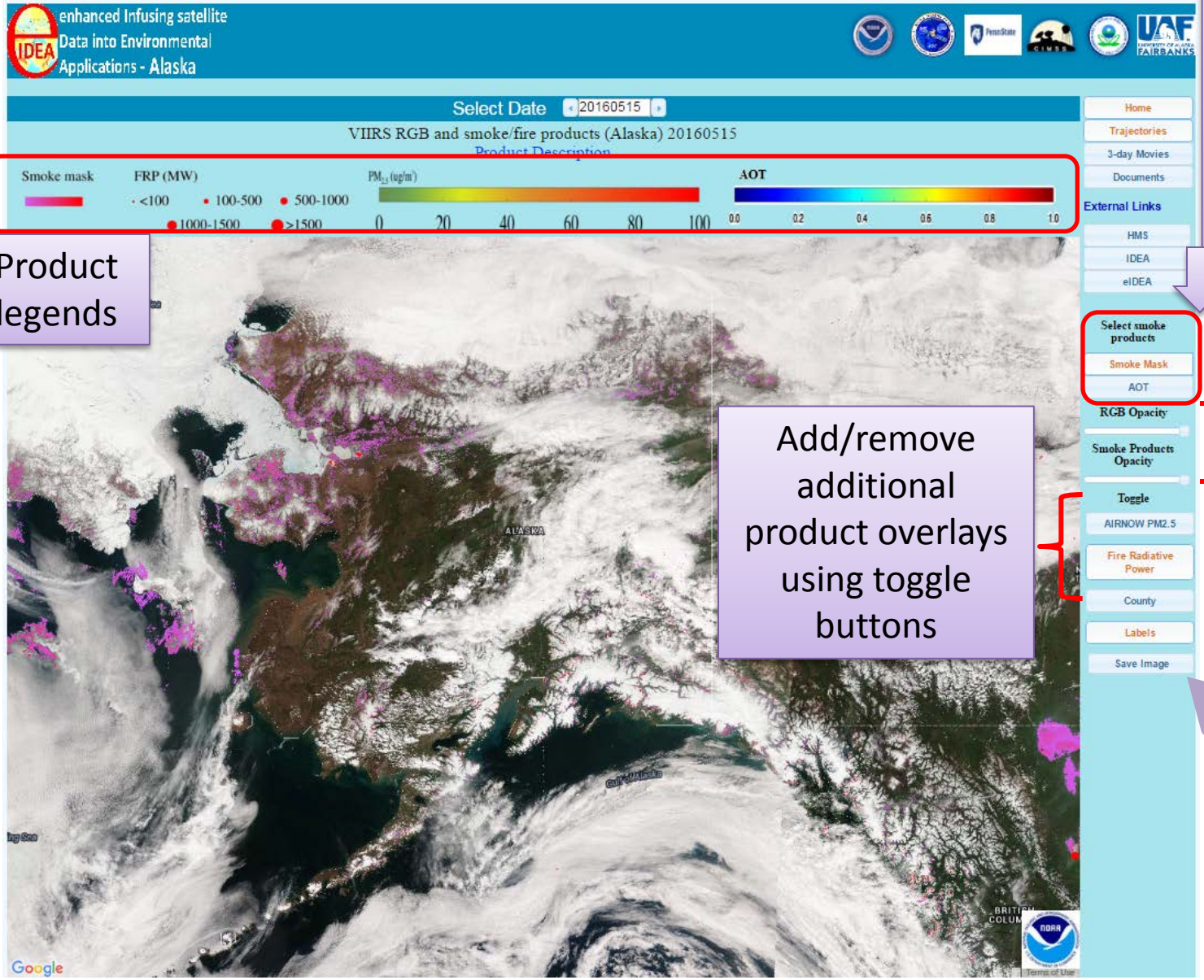
Calendar to select date of interest

Main product overlay buttons

VIIRS SDR data from GINA DB.
Aerosol and fire products generated at STAR.

http://www.star.nesdis.noaa.gov/smcd/spb/aq/eidea-ak/

eIDEA-Alaska: Overlays



Product legends

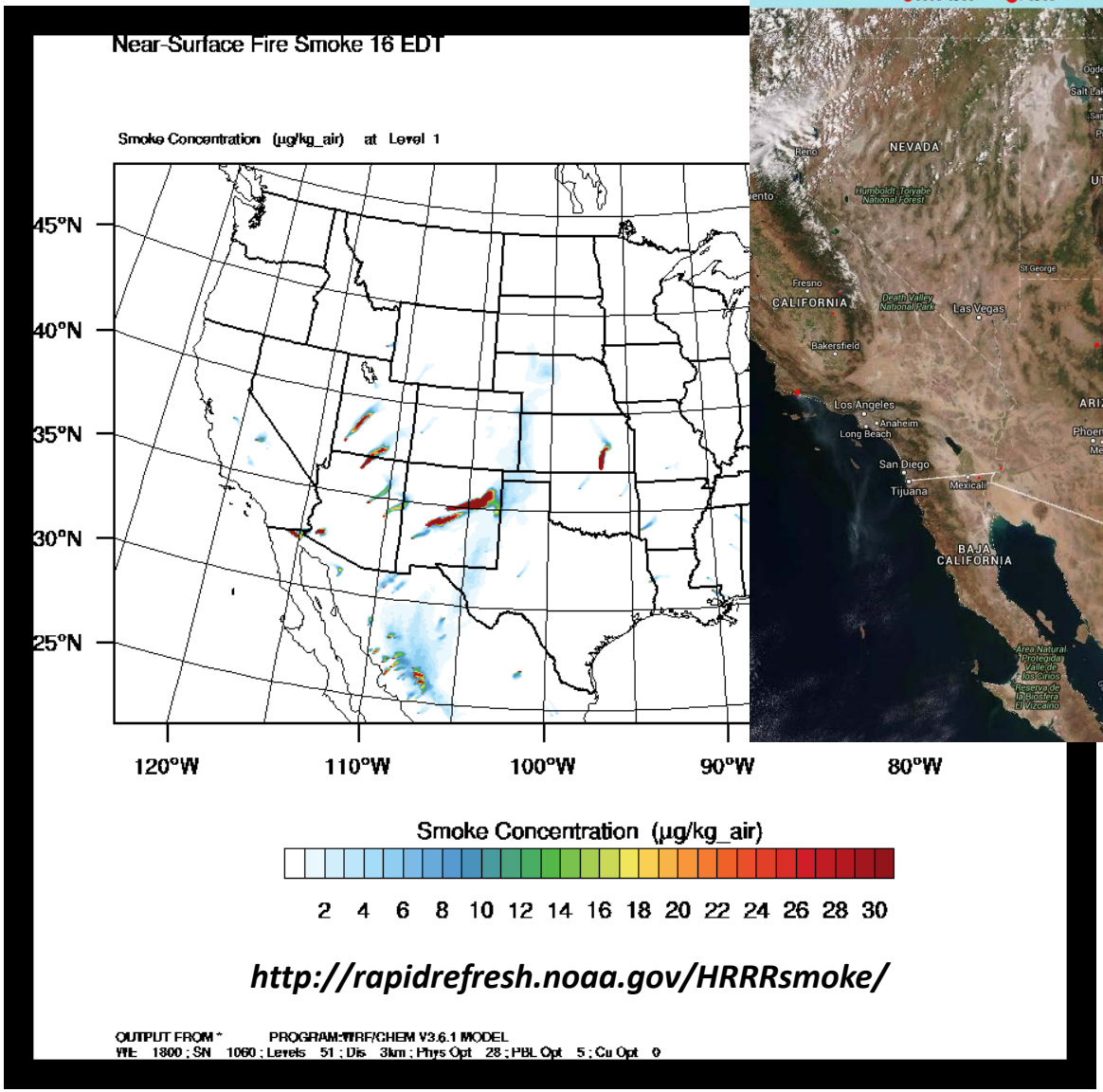
Add/remove additional product overlays using toggle buttons

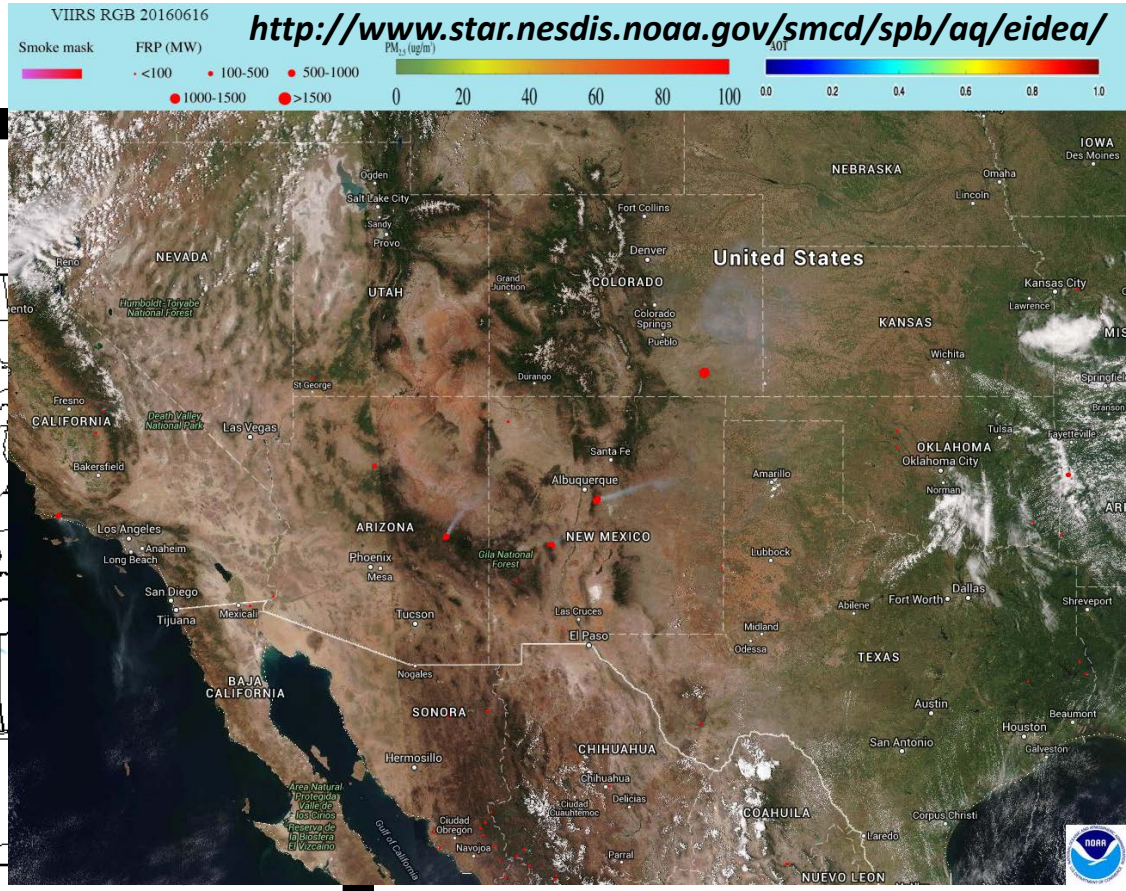
"Smoke Mask" is default smoke product; click on "AOT" or "Satellite Derived $PM_{2.5}$" to switch b/w smoke products

Slider bars adjust opacity of RGB and smoke products

Click "Save Image" to save configuration as a graphics file

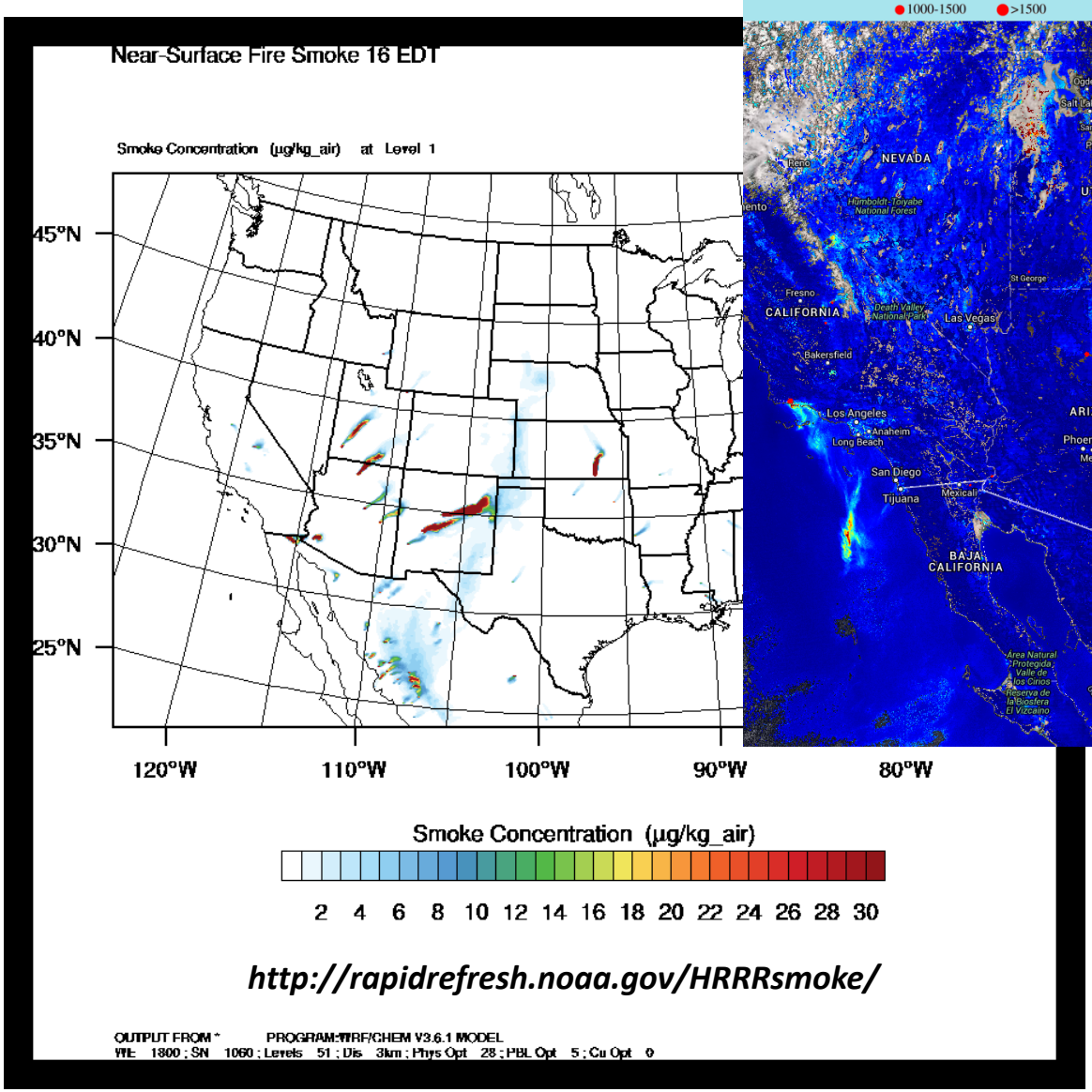
HRRR smoke forecast vs. eIDEA observations

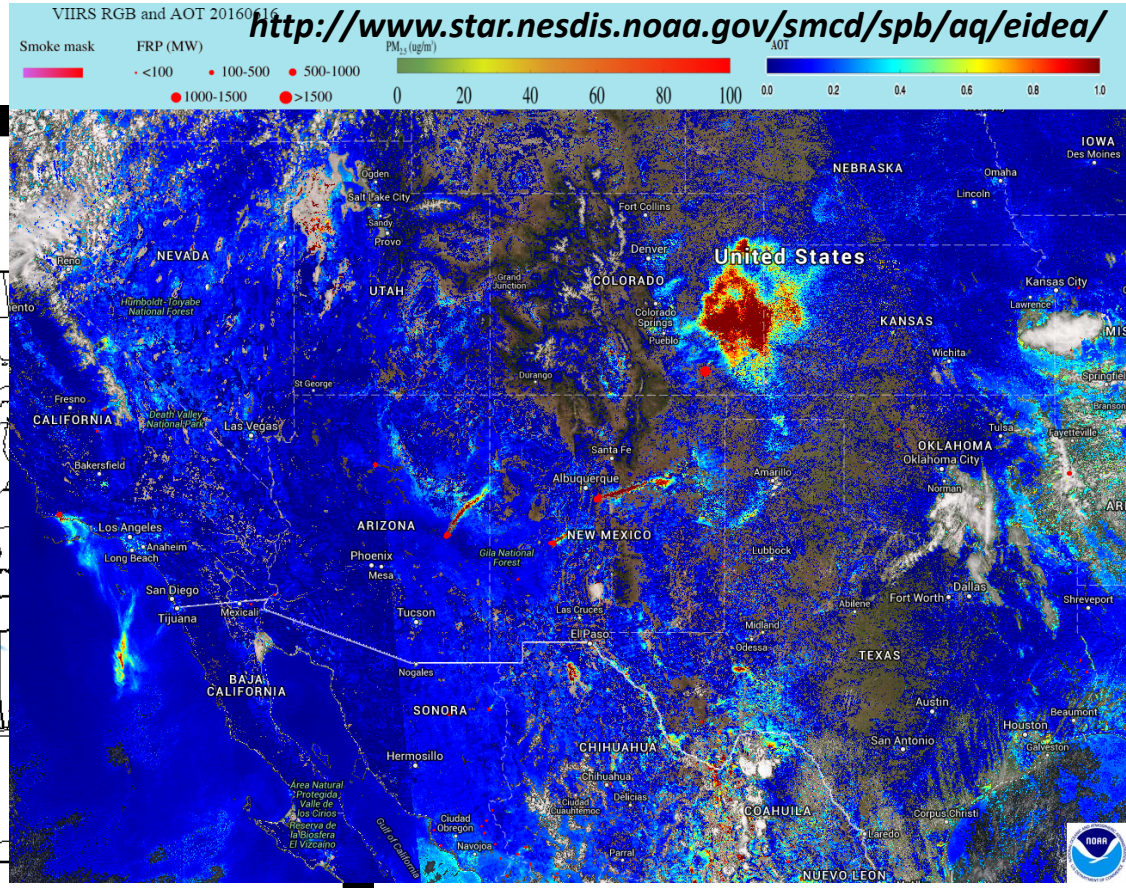




June 16, 2016

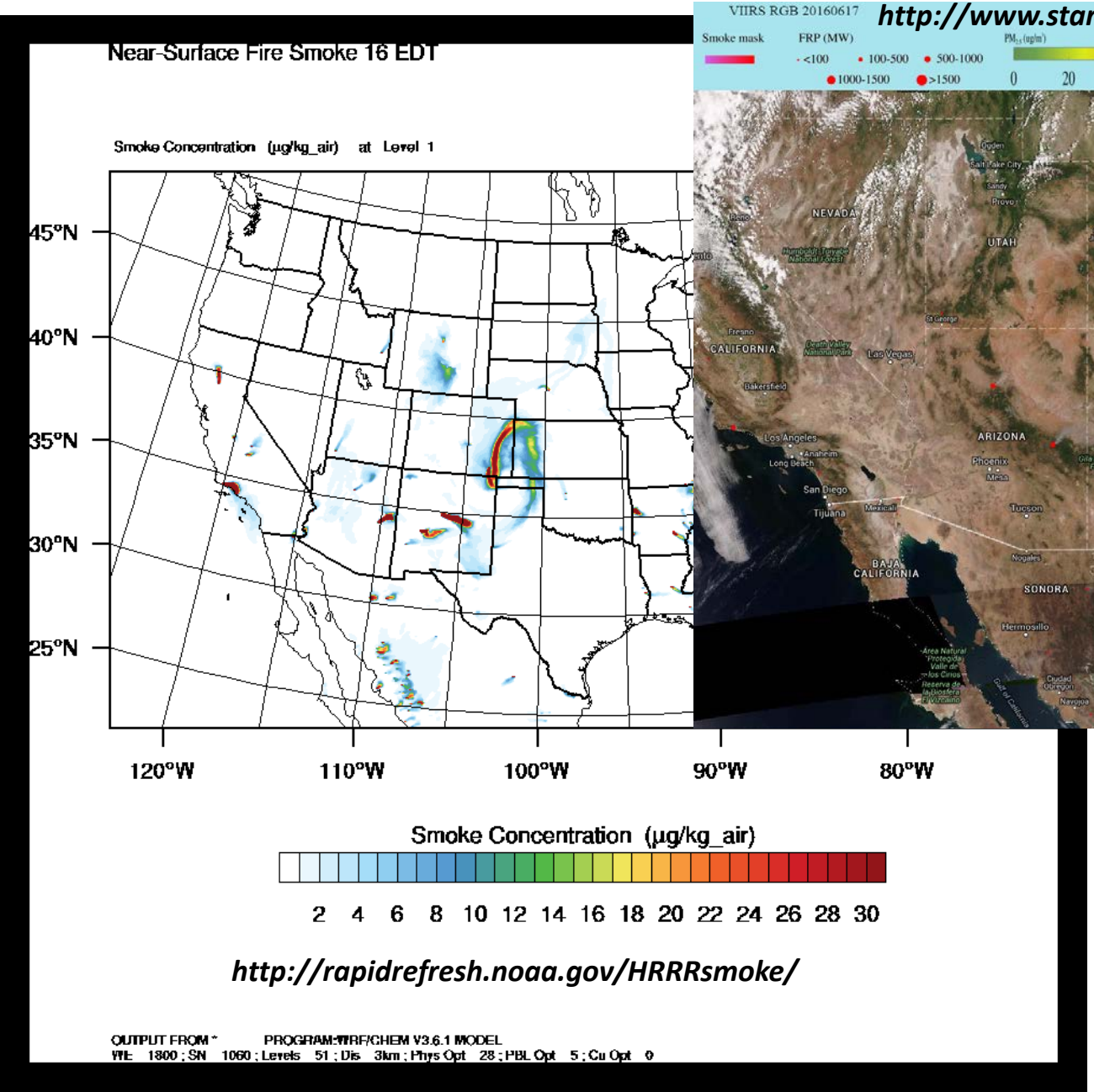
HRRR smoke forecast vs. eIDEA observations

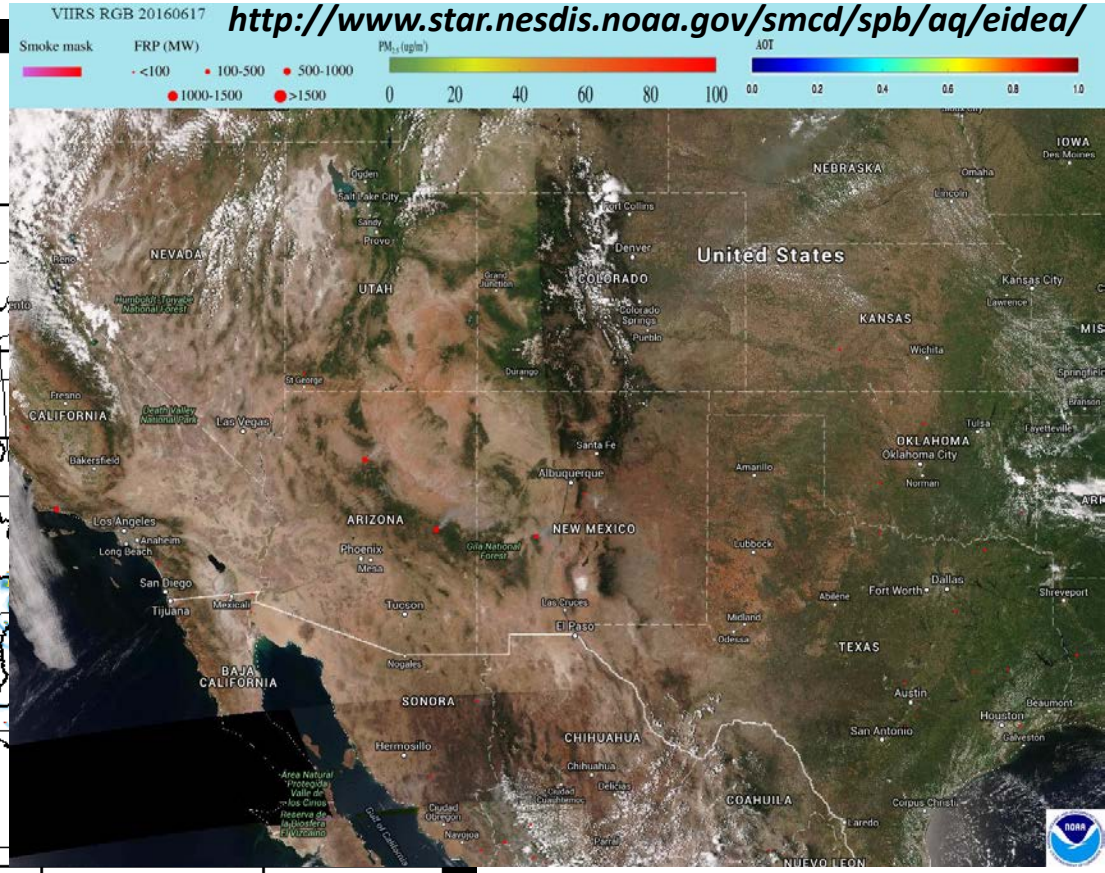




June 16, 2016

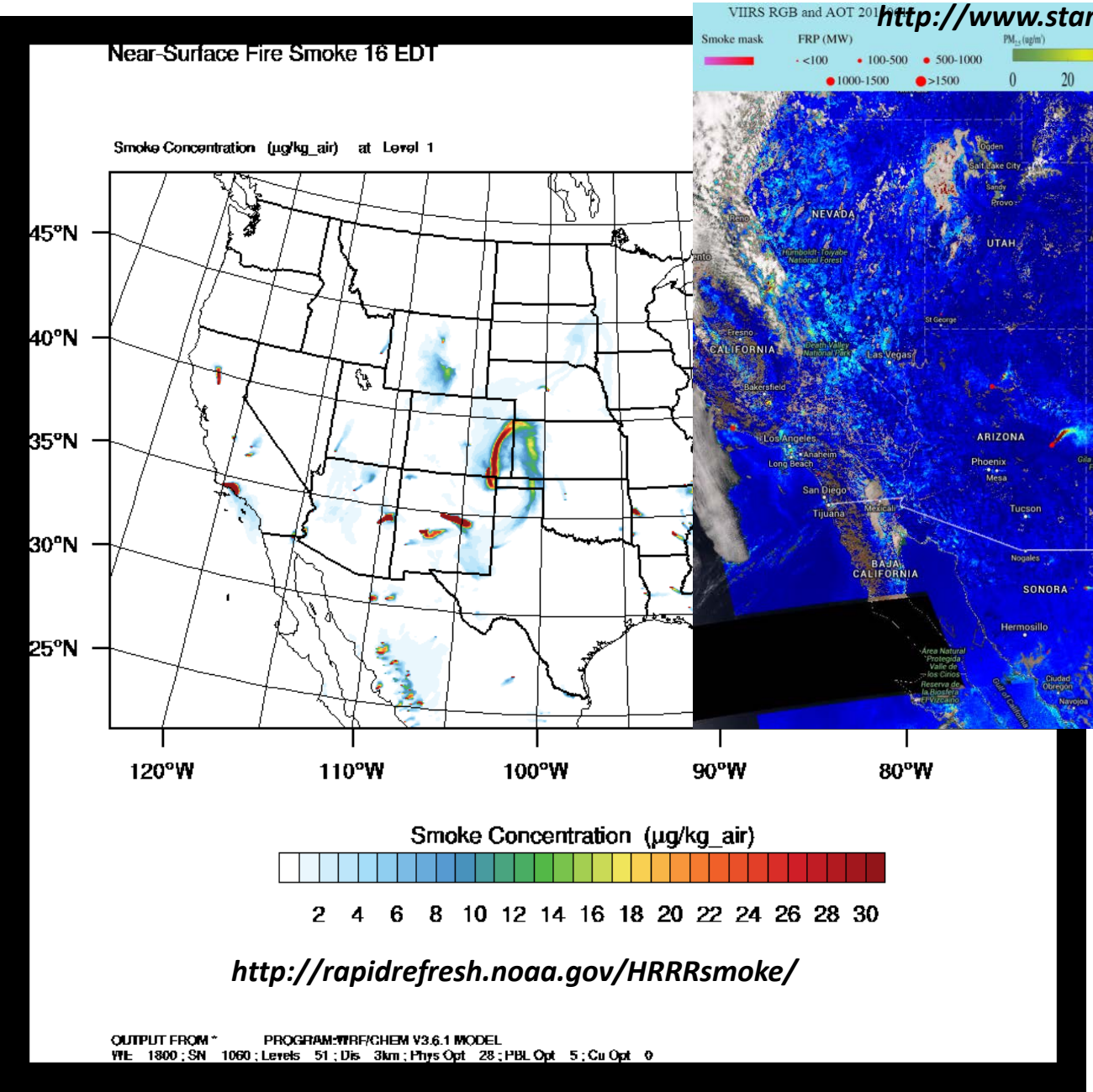
HRRR smoke forecast vs. eIDEA observations

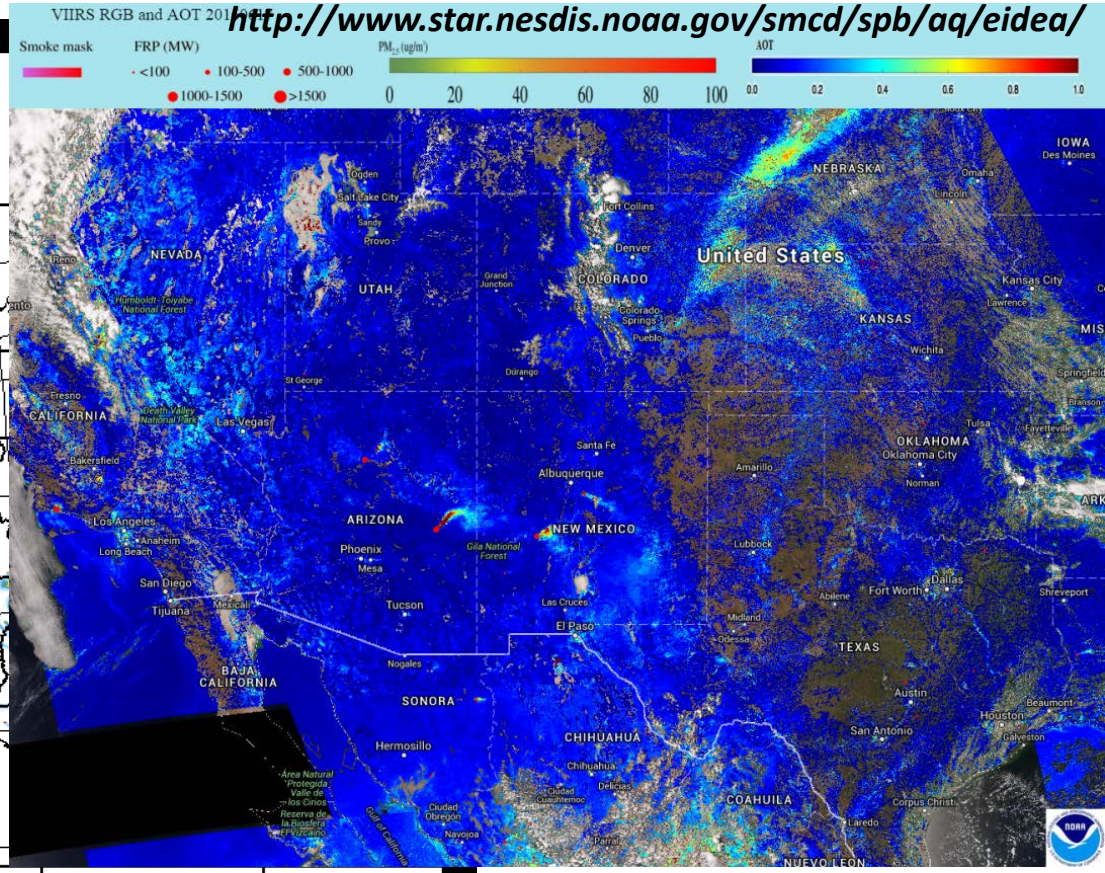




June 17, 2016

HRRR smoke forecast vs. eIDEA observations





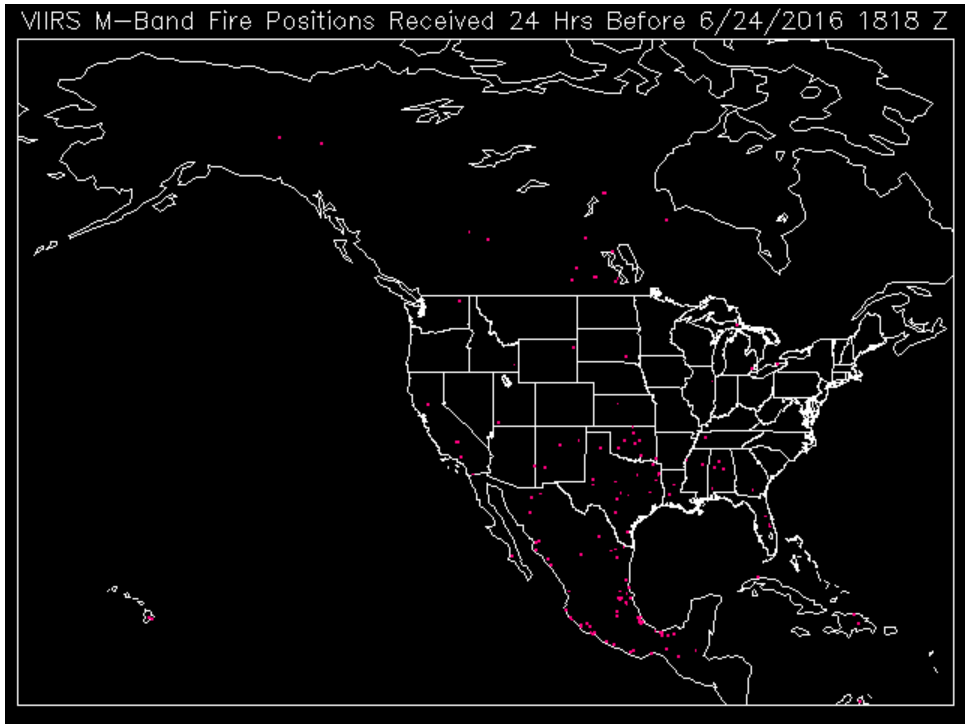
June 17, 2016

CSPP and AWIPS-II status

- CSPP
  - Currently IDPS product included
  - NDE product implementation ongoing
    - Current version – land /water mask from ADL
      - NDE code runs on DB for eIDEA
    - New version – land / water mask from Enterprise
- AWIPS-II
  - Software development, integration and testing ongoing
  - plans to submit for the next AWIPS release (16.4.1) in October 2016

Hazard Mapping System / OSPO status

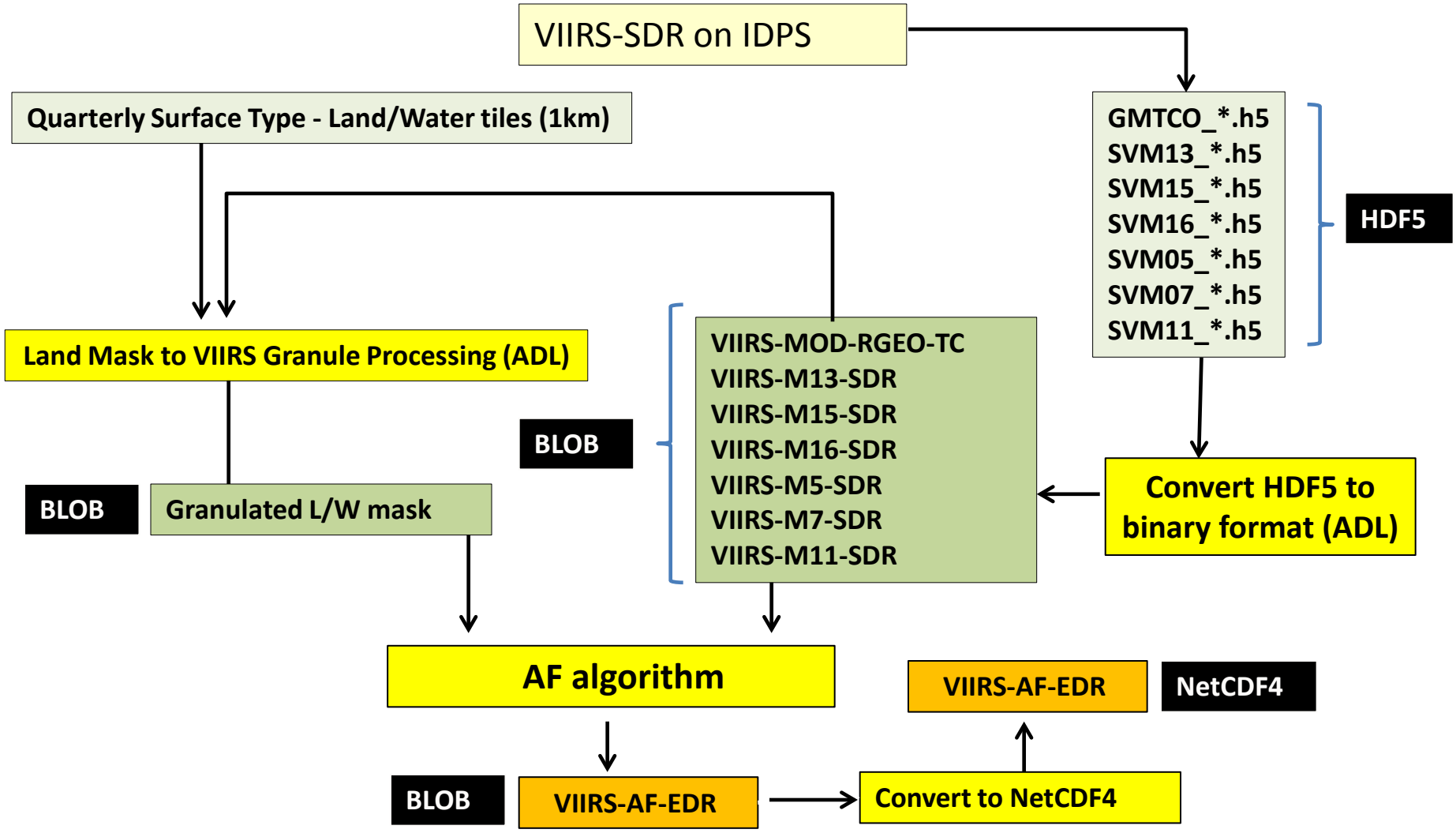
- Global NDE data are available in text format
  - granule-based (.txt) : real-time
  - daily summary (.dat)
- Graphics / web GIS under development
- VIIRS data to appear in HMS in the next release (October 2016)



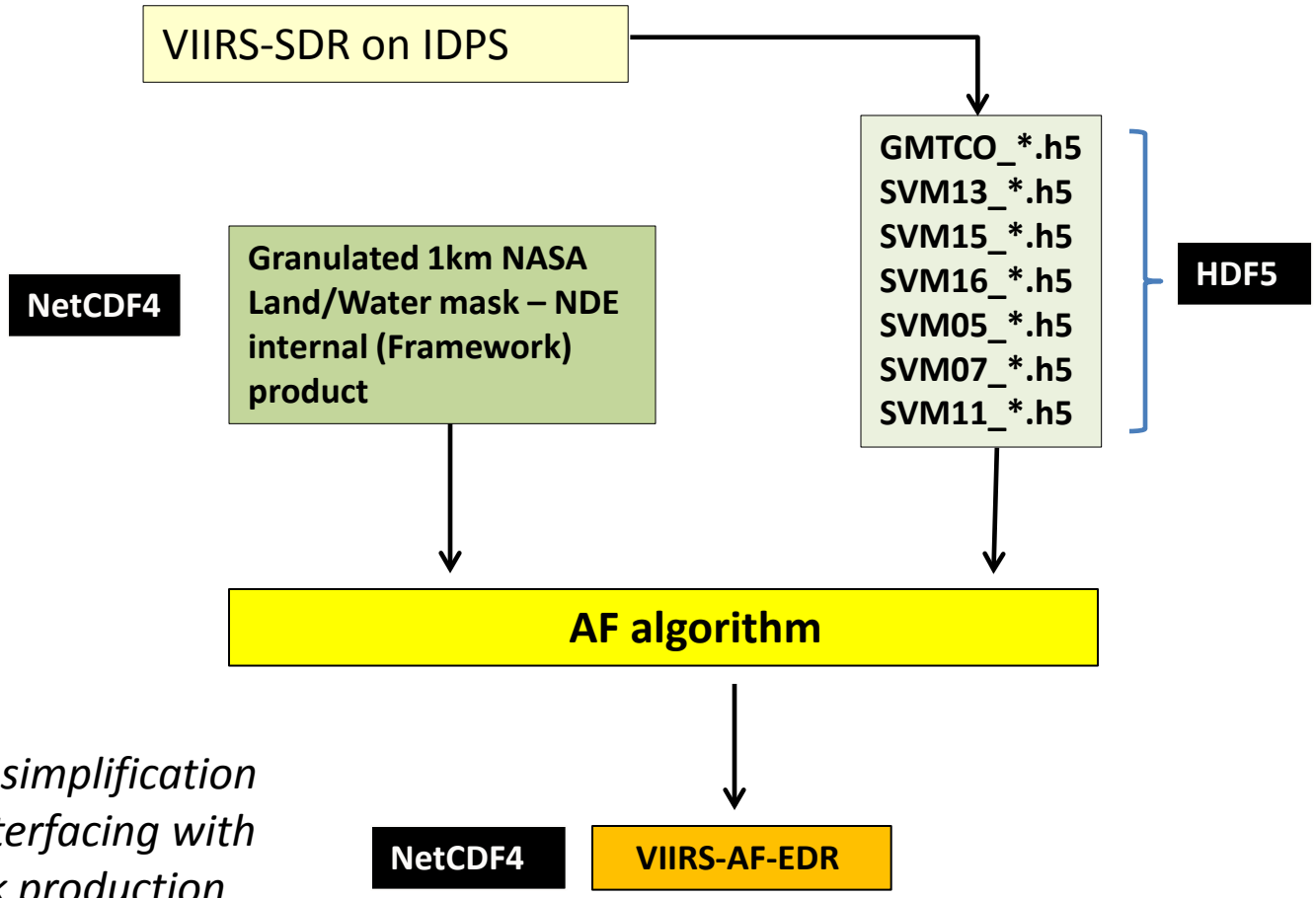
NOAA NESDIS Office of Satellite and Product Operations (OSPO)

http://satepsanone.nesdis.noaa.gov/pub/FIRE/VIIRS/

Current NDE AF Algorithm Processing



Future NDE AF Algorithm Processing



Significant simplification through interfacing with Framework production instead of ADL

Summary

- NDE implementation was a major step forward in 2016
- New, advanced products are emerging
  - VIIRS fire product development and distribution is done by various key stakeholders
    - concerted effort ongoing to assist users to find the most appropriate product
    - NOAA, NASA, USDA Forest Service products and activities
  - work is starting towards I-band and hybrid product evaluation and integration
- New NOAA operational product is coupled with air quality / smoke modeling and user feedback has been very positive
  - eIDEA, HRRR etc.
- CSPP implementation and version control is critical for operational users

VIIRS SURFACE TYPE

NOAA NESDIS STAR
301-683-3599; Xiwu.Zhan@noaa.gov
X. Zhan, C. Huang, R. Zhang, H. Jin, I. Csiszar

Outline

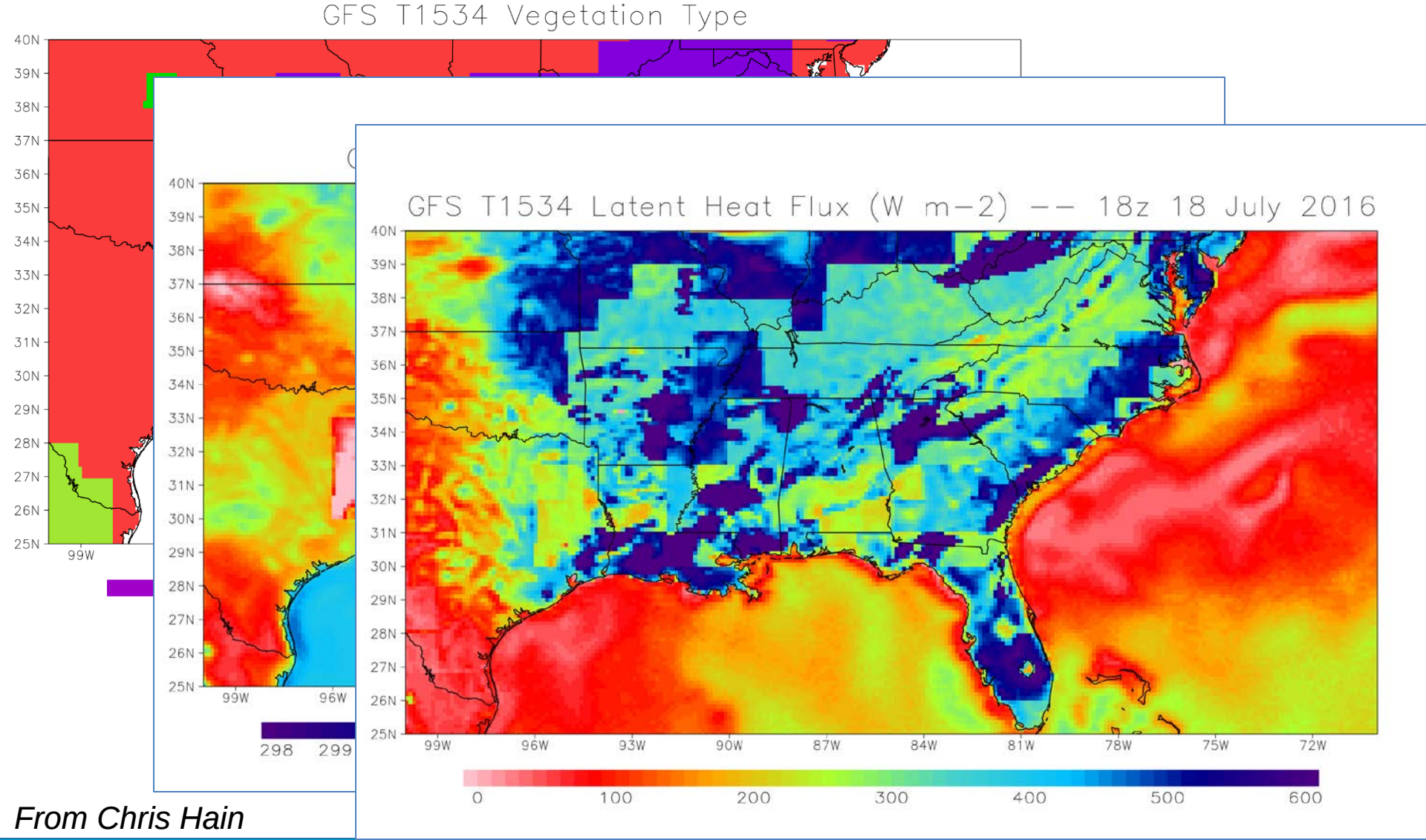
- VIIRS Surface Type Product Team Members
- Surface type algorithm overview
- S-NPP Surface Type Product Overview
- JPSS-1 Readiness for Surface Type products
- Summary and Path Forward

VIIRS Surface Type Team Members

Team Member	Organization	Roles and Responsibilities
Xiwu Zhan	NESDIS-STAR	PI of VIIRS Surface Type Team
Chengquan Huang	UMD Geography	Lead of UMD team members
Rui Zhang	UMD Geography	Algorithm, validation and production lead
Huiran Jin	UMD Geography	Validation
Ivan Csiszar	NESDIS-STAR	VIIRS Land Team Lead

Surface Type Products Overview

- Impact of Surface Type to NWP model performance:



From Chris Hain

Surface Type Products Overview

ST-EDR/AST Requirements from JPSS L1RD

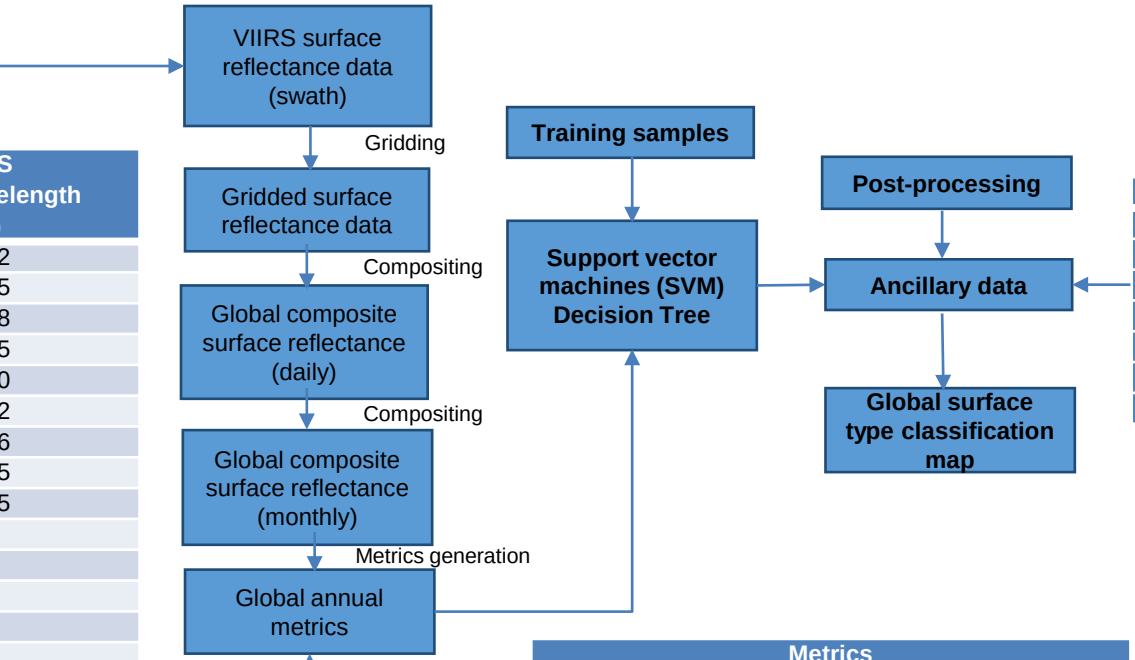
Attribute	Threshold	Performance
Geographic coverage	Global	Global
Vertical Coverage		
Vertical Cell Size	N/A	N/A
Horizontal Cell Size	1 km at nadir	1 km at edge of scan
Mapping Uncertainty	5 km	1 km
Measurement Range	17 IGBP classes	17 IGBP classes
Measurement Accuracy	70% correct for 17 types	~78% for 17 types
Measurement Precision		
Measurement Uncertainty		

Surface Type Products Overview

- Surface Type products include Surface Type EDR (ST EDR) and Global Annual Surface Type Maps (AST)
- Global Annual Surface Type Maps provide static labels for each 1km land grid for NWP models and other users
- Surface Type EDR is to provide current day surface type status for LST EDR and other users
- AST offline generation is the main task of the VIIRS ST team
- AST is generated using Decision Tree or Support Vector Machine algorithm based on global training polygons database and dozens of classification metrics that are computed from daily surface reflectance and brightness temperature observations from VIIRS

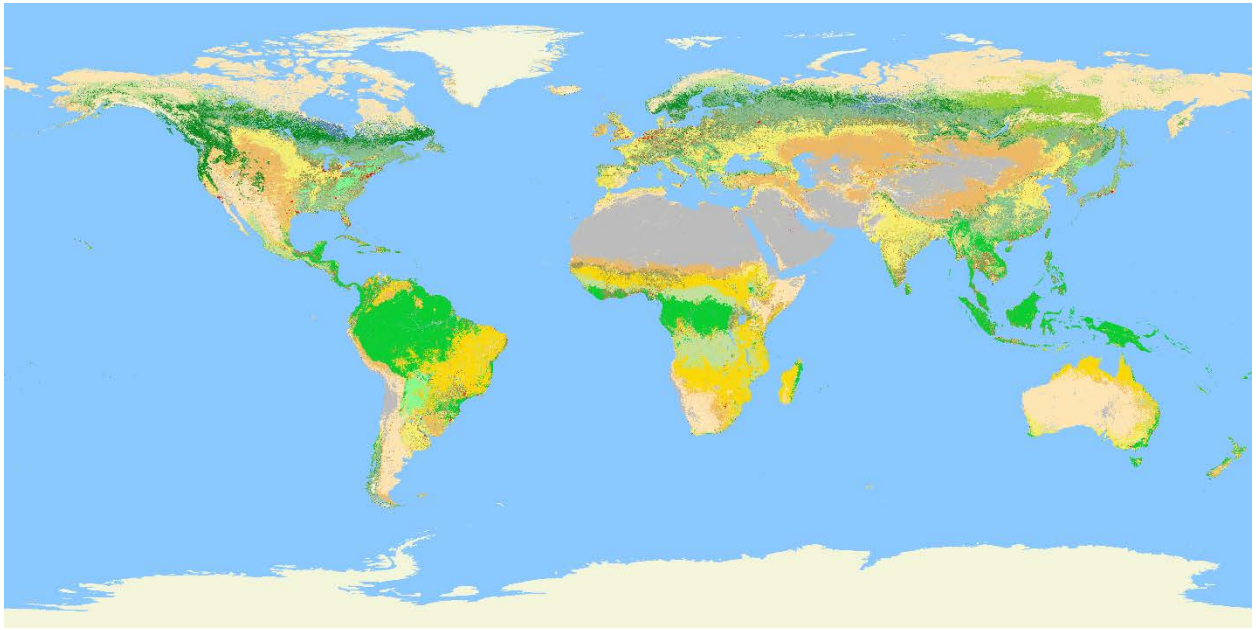
Surface Type Algorithm Overview

Band number (comparable in MODIS)	VIIRS wavelength (μm)
M1 (8)	0.412
M2 (9)	0.445
M3 (3 or 10)	0.488
M4 (4 or 12)	0.555
I1 (1)	0.640
M5 (13 or 14)	0.672
M6 (15)	0.746
I2 (2)	0.865
M7 (16 or 2)	0.865
DNB	0.7
M8 (5)	1.24
M9 (26)	1.38
M10 (6)	1.61
I3 (6)	1.61
M11 (7)	2.25
M12 (20)	3.70
I4 (20)	3.74
M13 (21 or 22)	4.05
M14 (29)	8.55
M15 (31)	10.76
I5 (31 or 32)	11.45
M16 (32)	12.01



Surface Type Products Overview

- New global surface type map using 2014 VIIRS data was generated.







Eastern Africa

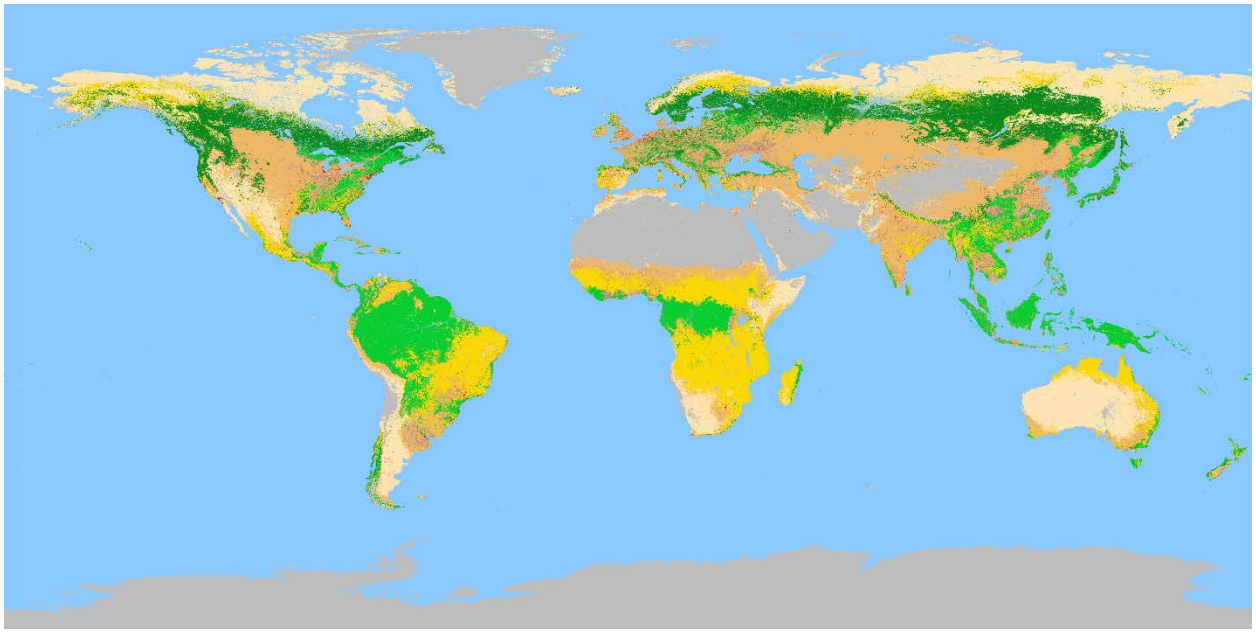


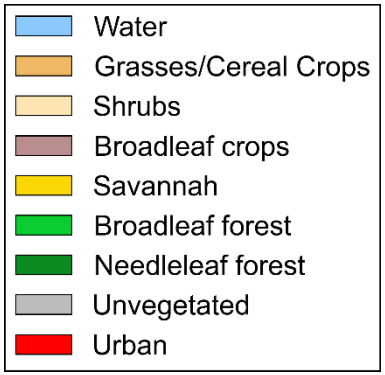
Canada

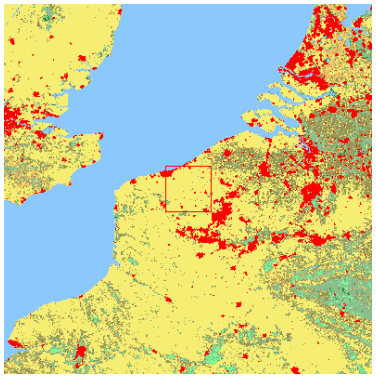
While the overall classification accuracy (~78%) of the new map is similar to 2012 delivery, some accuracy improvements are observed, such as croplands. The images shown left demonstrate two examples of the improved cropland mapping results, where the old version presented wrong type labels. Google images verified the mapping results.

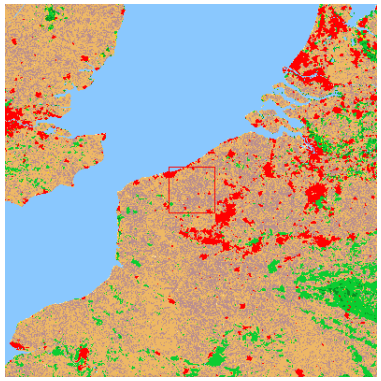
Surface Type Products Overview

New global surface type map in biome classification types to support LAI/FPAR and other studies









Europe

The biome scheme surface type map was generated using a IGBP-biome LUT plus a second SVM classification to further separate cereal crops and broadleaf crops. Validation in progress. The two images shown left is an example of crop mapping result in IGBP and biome legends. Cereal and broadleaf croplands are further separated in biome ST map.

Surface Type Products Overview

		Reference																		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total (%)	User's accuracy (%)	Producer's accuracy (%)
Map	1	2.04	0.01	0.06	0.05	0.29	0.01	0.01	0.23	0.04	0.07	0.02	0.01	0	0.01	0	0	0.01	2.86	**71.3±2.9**	**72.6±3.4**
	2	0	8.46	0	0.09	0.05	0	0	0.4	0.08	0.02	0	0.06	0	0.12	0	0	0	9.28	**91.2±1.2**	**92.6±1.1**
	3	0.05	0	1.08	0	0.13	0	0.01	0.09	0	0.02	0.02	0	0	0	0	0	0	1.41	**76.7±3.9**	**68.7±4.7**
	4	0	0.01	0.01	0.95	0.05	0	0	0.09	0.03	0	0	0	0	0.02	0	0	0	1.14	**82.8±2.8**	**42.8±3.4**
	5	0.2	0.17	0.21	0.64	3.52	0.03	0.02	0.59	0.15	0.02	0.03	0	0.02	0.33	0	0	0.02	5.95	**59.2±2.6**	**76.2±2.6**
	6	0	0	0	0	0	0.05	0	0	0	0.01	0	0	0	0	0	0	0	0.07	**70.0±6.0**	**3.6±0.8**
	7	0.22	0.02	0.07	0.05	0.19	0.48	11.64	0.51	0.36	1.24	0.17	0.36	0.02	0.15	0	0.48	0.02	16.00	**72.7±1.7**	**83.9±1.8**
	8	0.26	0.17	0.06	0.28	0.17	0.09	0.3	4.84	0.58	0.11	0.07	0.09	0.01	0.44	0	0	0.02	7.50	**64.6±1.9**	**57.5±2.2**
	9	0	0.16	0.03	0.05	0.05	0.46	0.24	1.02	5.25	0.13	0.03	0.22	0.05	0.38	0	0	0	8.08	**65.0±2.8**	**71.9±2.4**
	10	0.02	0	0.04	0.02	0.06	0.23	0.79	0.19	0.21	6.37	0	0.48	0.02	0.21	0	0.23	0.01	8.90	**71.5±1.7**	**72.1±2.1**
	11	0.01	0.02	0	0	0.01	0.01	0.06	0.05	0.06	0.01	0.48	0.01	0	0	0	0	0	0.73	**65.0±6.2**	**57.3±7.5**
	12	0.01	0.01	0	0	0.04	0.02	0.07	0.05	0.16	0.46	0.01	6.97	0.08	0.55	0	0	0.02	8.44	**82.6±1.2**	**79.7±1.7**
	13	0	0	0	0	0	0	0.01	0.01	0	0	0	0.04	0.35	0.01	0	0	0	0.42	**81.7±3.6**	**58.9±6.7**
	14	0	0.1	0.02	0.06	0.05	0.01	0.06	0.34	0.39	0.18	0	0.41	0.03	2.7	0	0.01	0	4.35	**62.0±2.1**	**53.9±2.7**
	15	0	0	0	0	0	0	0.17	0	0	0	0	0	0	0	10.19	0	0	10.36	**98.3±1.7**	**100.0±0.0**
	16	0	0	0	0	0	0	0.49	0	0	0.18	0	0.09	0	0.09	0	12.53	0	13.37	**93.7±1.4**	**94.5±0.9**
	17	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	1.11	1.13	**98.3±1.7**	**91.3±3.2**
	Total	2.81	9.13	1.57	2.21	4.62	1.4	13.87	8.42	7.31	8.83	0.83	8.75	0.59	5.01	10.19	13.26	1.21	100		

Error matrix of estimated area proportions (in percentage). Overall accuracy is **78.5 ± 0.6**%.



Note: the error matrix was created using area proportion of each class in the classification map, which could avoid estimation bias observed in simple pixel count based error matrices, in which the estimated overall classification accuracy is 74.7%

Reprocessing Plan

- The generation of surface type map depends on data availability of surface reflectance data. If surface reflectance reprocessing data is produced, the surface type products could benefit from improved data quality of the surface reflectance data.

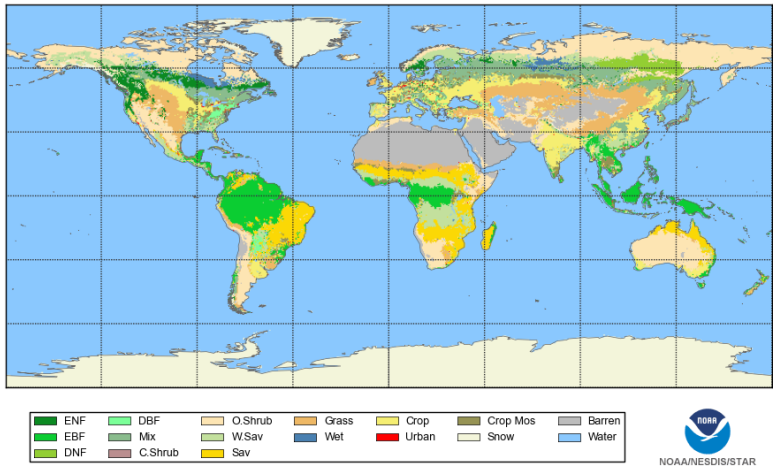
- The generation of surface type requires at least one whole year multiple bands surface reflectance data inputs, and the sophisticated classification algorithm usually takes significant amount of time to classify composited metrics, so extra computing resources are needed if reprocessing is planned.

Long Term Monitoring

- http://www.star.nesdis.noaa.gov/jpss/EDRs/products_surfacetype.php

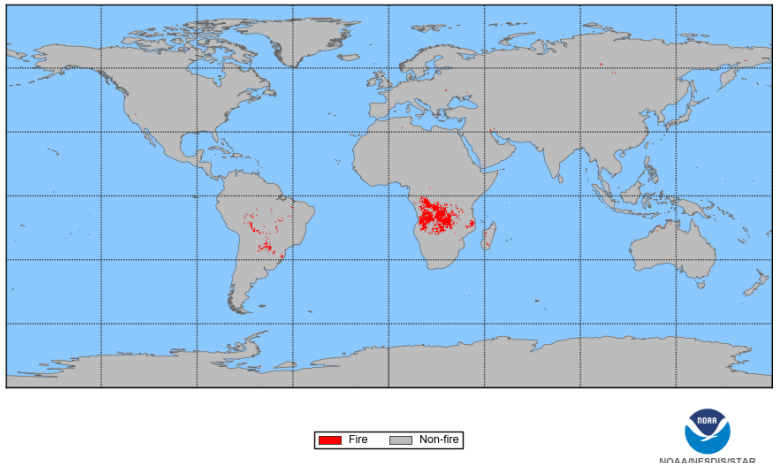
Suomi NPP VIIRS Global Surface Type Composite (ST-EDR)

5 Aug 2016



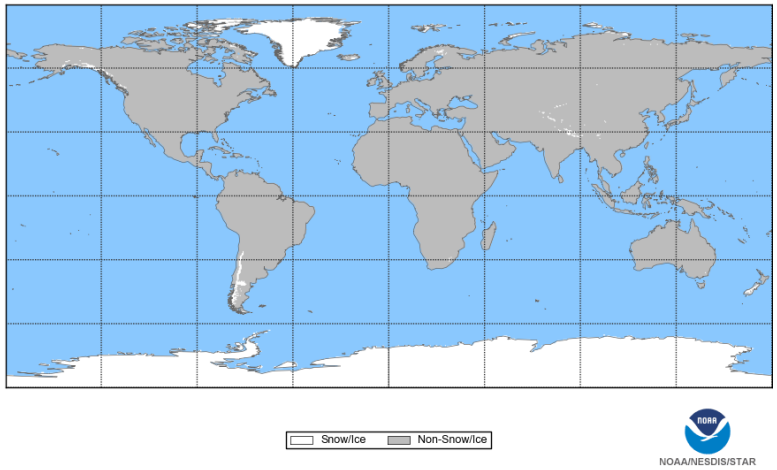
Suomi NPP VIIRS Global Active Fire Composite (ST-EDR)

5 Aug 2016



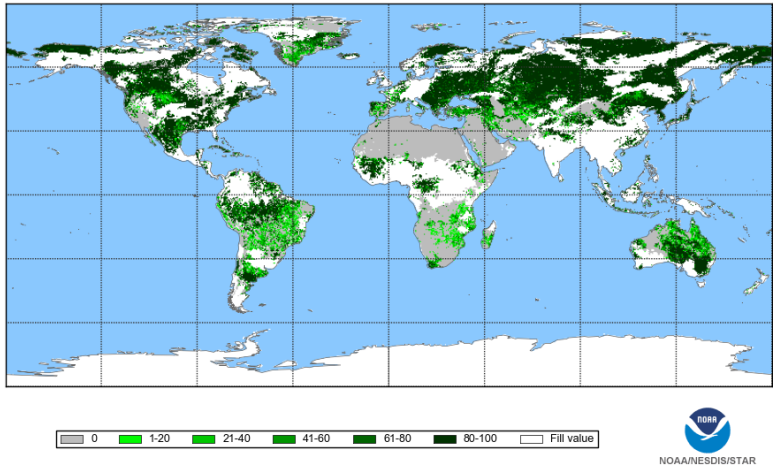
Suomi NPP VIIRS Global Snow/Ice Composite (ST-EDR)

5 Aug 2016



Suomi NPP VIIRS Global Vegetation Fraction (ST-EDR)

5 Aug 2016



Enterprise Algorithm Status

- Annual surface type map is produced offline, but it required VIIRS surface reflectance data input, which could be produced by the enterprise environment.

- Because surface type team needs a whole year observation to start processes, the production schedule for ST is at least one year delayed. For example, 2015 annual ST map will be delivered at the end of 2016.

- The surface type team has coordinated with other enterprise algorithm teams about all aspects of technical details of the enterprise data products, such as data format, and output projections.

User Feedback

- User list
  - Modeling studies
    - Land surface parameterization for GCMs
    - Biogeochemical cycles
    - Hydrological processes
  - Carbon and ecosystem studies
    - Carbon stock, fluxes
    - Biodiversity
- Feedback from users (*Primary user: NCEP land team led by M. Ek*)
  - 2014 annual surface type map with three tundra types was delivered to NCEP earlier this year.
- Downstream product list
  - Land surface temperature (direct, could change)
  - Cloud mask, aerosol products, other products require global land/water location information (indirect)

Daily Surface Type Product

- Rapid surface changes can be caused by many events:
  - Flooding, severe drought, snow storm, fire, large scale deforestation
- These changes cannot be captured by the annual GST product
- A suite of daily products or change indicator products are needed to capture such rapid changes
  - Can build on the original ST-EDR concept
  - Where available, use existing VIIRS products (e.g., Snow, Fire, vegetation cover)
    - Better temporal consistency needed to allow change detection
    - For fire, post fire surface type information needs to be derived
  - Some changes require new products, e.g.:
    - Daily surface inundation needed to capture surface changes due to flooding and flood receding
    - Sub-annual tree cover data needed to capture deforestation

JPSS-1 Readiness

- Significant Algorithm changes from S-NPP to JPSS-1
  - Metrics and post-processing could be improved. No significant algorithm changes planed for J-1.
- Pre-launch Characterization: None.
- Post-Launch Cal/Val Plans
  - Dataset: Validation sites database. Collecting new sites. No field campaigns planned.
  - Schedule and Milestones: First J-1 based surface type map with validation should be generated in 18 months after JPSS-1 launch (Need one year to collect J-1 data, and 6 months for processes). **2017 J-1 surface type map will be delivered in year 2018**.
- Risks/issues/challenges: None.
- Collaboration with stake holders/users : In progress.

Summary

- 2014 VIIRS annual surface type (AST) classification map was generated, validated and distributed through STAR-JPSS and other websites. 2015 VIIRS AST product is to be delivered and distributed from Sept/Oct.
- Validation results on 2014 surface type map suggest the new product meets the JPSS L1RD.
- Global surface type map with tundra types has been delivered to NCEP for evaluation.
- First global biome type map based on VIIRS observations is generated and being validated for scientific users such as NASA VIIRS LAI team.

Path Forward

- 2017 Milestones:
  - Delivery 2016 Global Annual Surface Type (AST) classification map
  - Develop and validate biome legend surface type map for science and other users (e.g. NASA VIIRS LAI team)
- Alternate algorithms and future improvements:
  - Keep using SVM, improve metrics and post-processing steps
  - Keep collecting new training and validation datasets
- J2 and Beyond:
  - Refine the algorithm details while keeping the overall data processing framework and continue the offline production of the AST product

Thanks!

VIIRS SNOW COVER PRODUCTS: CURRENT STATUS AND PLANS

Peter Romanov
CREST/CUNY at NOAA/STAR
peter.romanov@noaa.gov

Outline

- VIIRS Binary Snow Cover and Fractional Snow Cover
  - Definition, requirements
  - IDPS product performance
  - Improvements in the Enterprise system (NDE)
  - JPSS-1 readiness, post-launch plans
  - NOAA vs NASA approach
  - Further algorithm enhancements

Cal/Val Team Members

Name	Organization	Roles and Responsibilities
Jeff Key	NOAA/NESDIS	Cryosphere Team Lead
Peter Romanov	CUNY/CREST	Snow Products Lead
Sean Helfrich	NOAA/NIC	User/Applications
Michael Ek	NOAA/NWS	User/Applications

VIIRS Snow Cover Products

- Binary snow map:
  - Snow/no snow discrimination
  - 375m resolution
  - 90% probability of correct typing
    - Over climatologically snow-affected areas
    - Excludes forested areas

- Snow fraction:
  - “Viewable” snow fraction
  - 750m resolution (IDPS), 375m for JPSS-1
  - 10% accuracy

- Both products are clear-sky daytime-only land products
- Both products depend on the accuracy of VIIRS cloud mask.

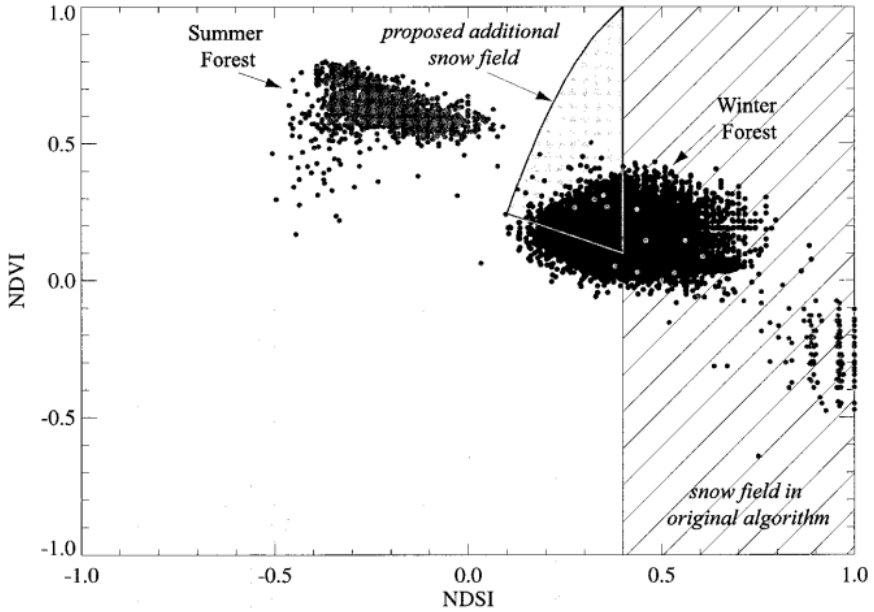
Binary Snow Cover

IDPS Binary Snow Cover Algorithm

- Analogous to MODIS SnowMap algorithm (Hall et.al 2002)
- Decision-tree threshold-based classification approach
- Uses NDSI, NDVI, reflectance, temperature (VIIRS bands I1,I2,I3, I5)

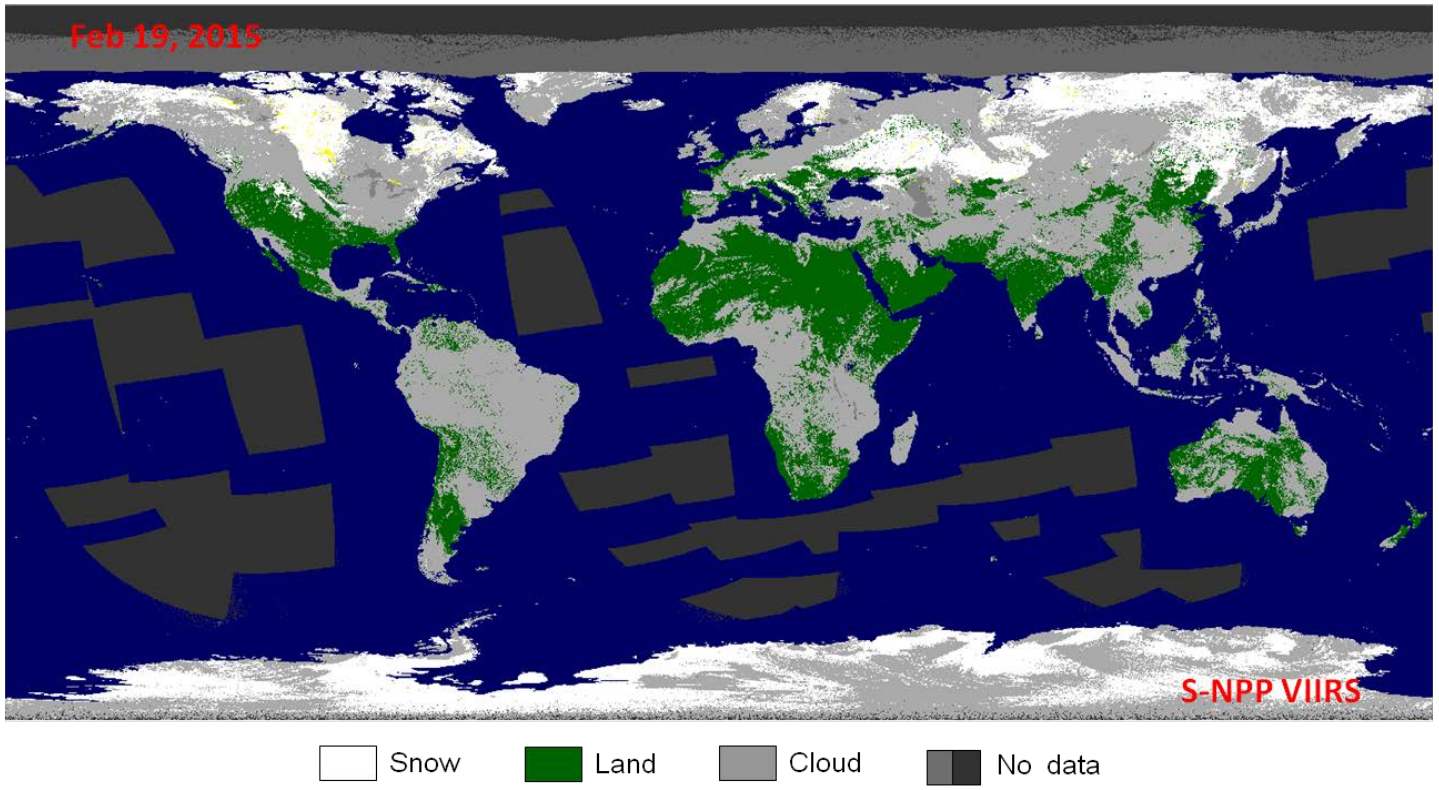
$$NDSI = (R_{0.6\mu m} - R_{1.6\mu m}) / (R_{0.6\mu m} + R_{1.6\mu m})$$

- Output: Binary snow/no-snow map at 375 m resolution



MODIS SnowMap
snow acceptance region

VIIRS IDPS Daily Snow Map



- Daily global gridded snow maps at 1 km resolution produced since 2013
- Granules with no land pixels are not processed (shown in dark gray)
- On the Web:
  http://www.star.nesdis.noaa.gov/smcd/emb/snow/viirs/viirs-snow-fraction.html
  http://www.star.nesdis.noaa.gov/jpss/EDRs/products_snow.php

IDPS Binary Snow: Accuracy

Daily rate of agreement of VIIRS IDPS binary snow maps

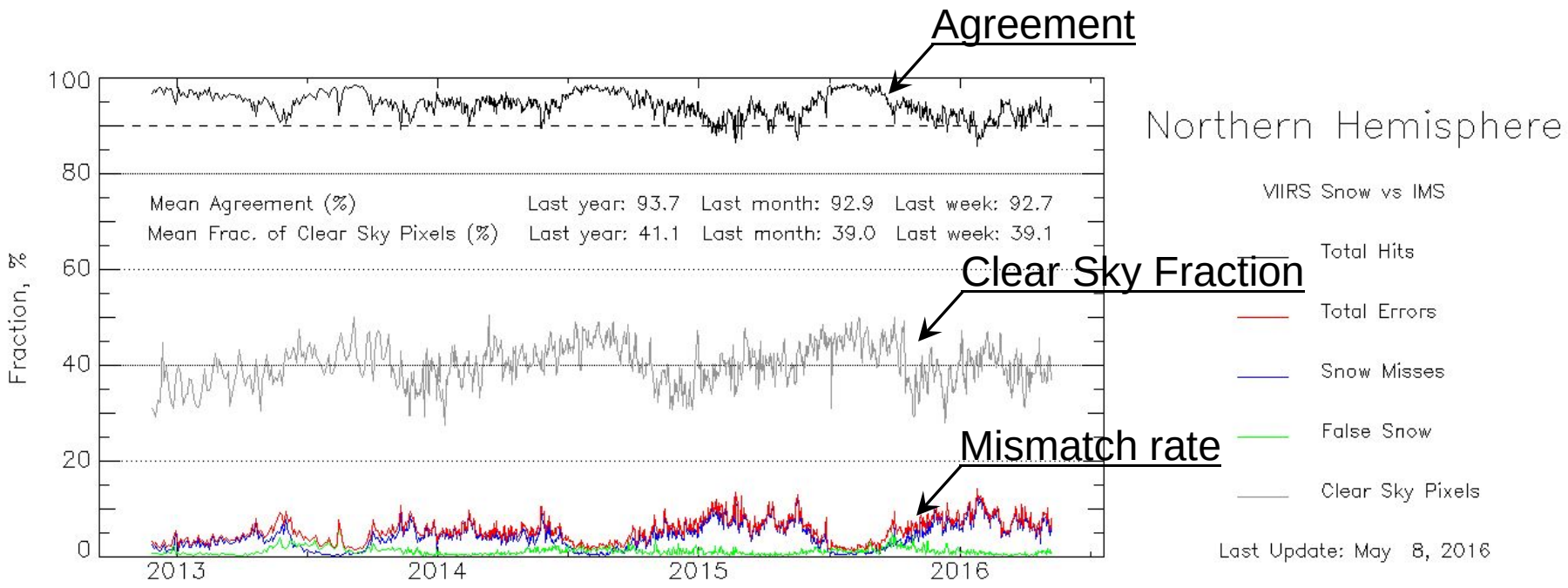
- To Interactive Snow Product (IMS)
  - Yearly mean: 94%, range: 88-98% (NH, over “snow possible” areas)
- To in situ reports
  - Mean: 92%, range: 85-96% (CONUS, November-April)

Product	L1RDS APU Thresholds	Performance
Binary Snow	90% Correct Typing	Mean Daily: 92-94% Range: 85-98%

Product generally satisfies current requirements

VIIRS Snow vs IMS

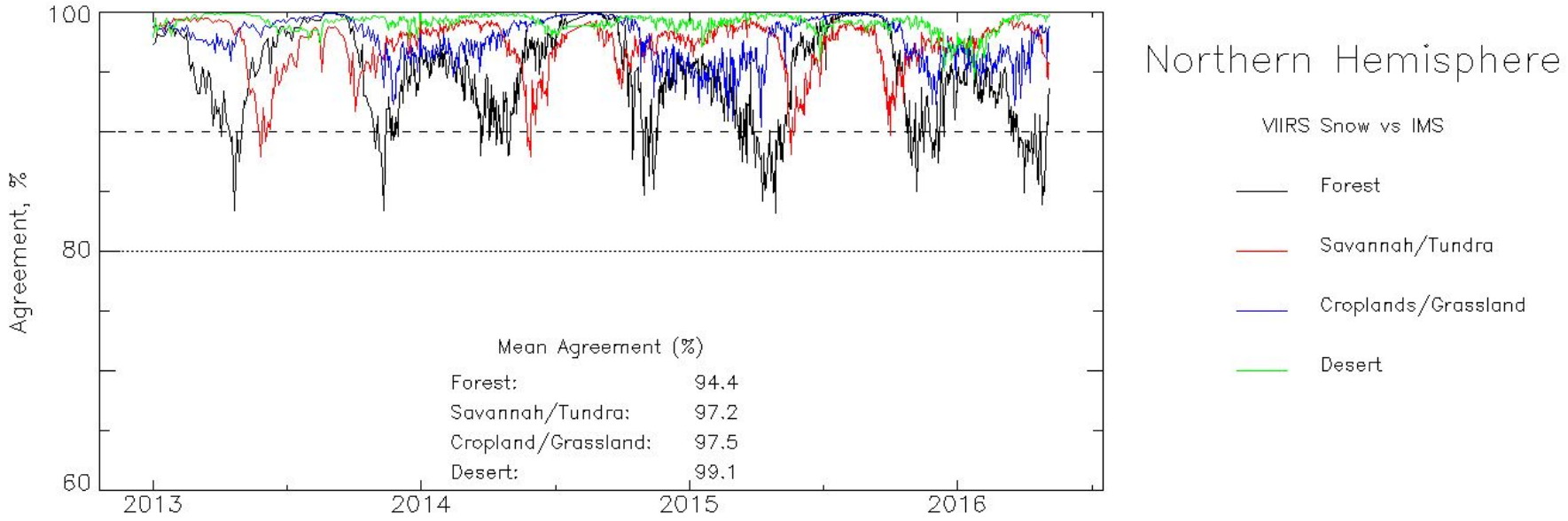
VIIRS binary snow map : Daily agreement to IMS



- Cloud fraction over land in the VIIRS IDPS snow product is about 60%
- This is more than in similar MODIS and AVHRR products

VIIRS Snow vs IMS

VIIRS binary snow map : Agreement to IMS by surface type



Agreement decreases

- In forests
- During transition seasons (Fall/Spring)

Enterprise Snow Algorithm

Modifications focus at

- More efficient snow detection in forests
- Elimination of spurious snow retrievals (e.g. due to missed clouds)

Two-stage algorithm:

1. Spectral tests

- Improved snow identification in the forest

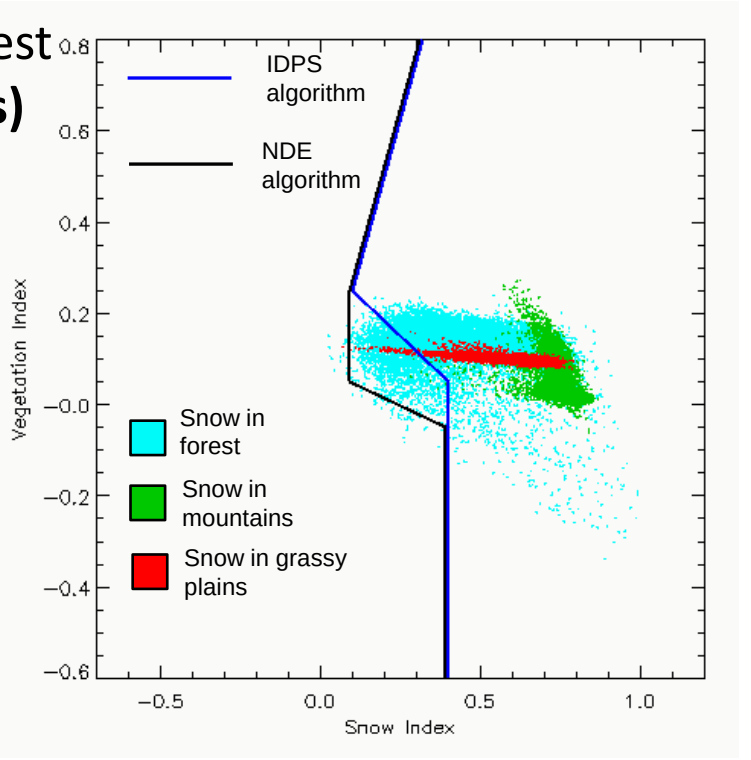
2. Consistency tests (applied to "snow" pixels)

- Eliminate spurious snow

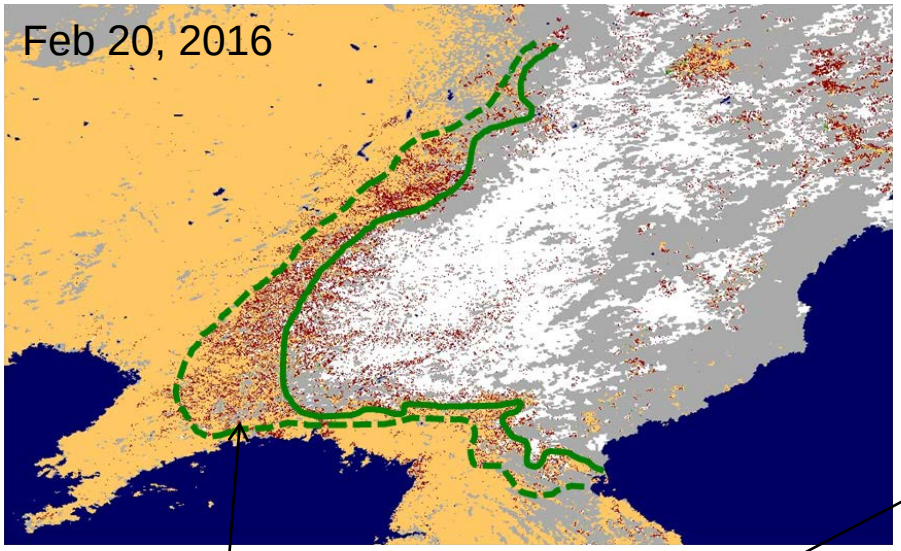
Consistency tests:

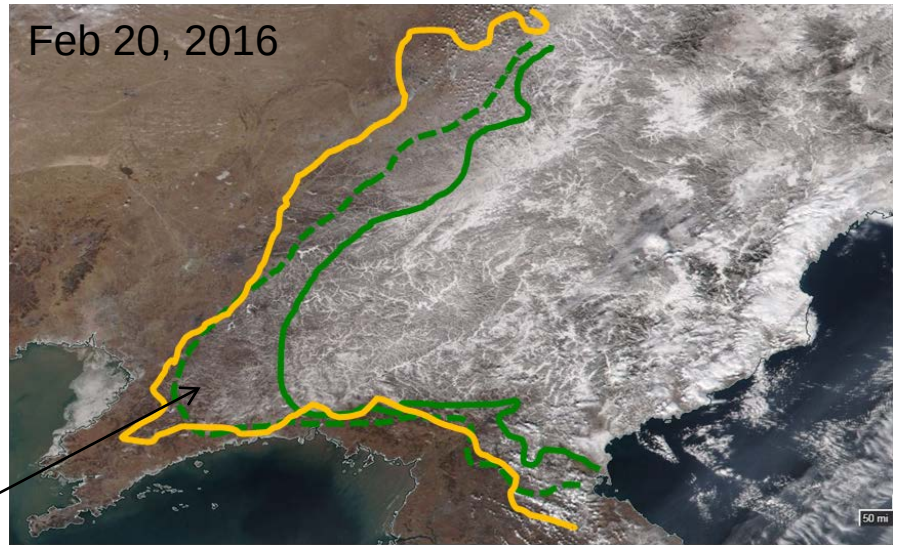
- Snow climatology
- Surface temperature climatology
- Spatial consistency
- Temperature spatial uniformity

Algorithm implemented as part of NDE system



NDE vs IDPS Binary Snow Product





IMS snow

IDPS snow

NDE snow

Snow mapped by NDE <u>but not IDPS</u>

Snow mapped by both NDE and IDPS

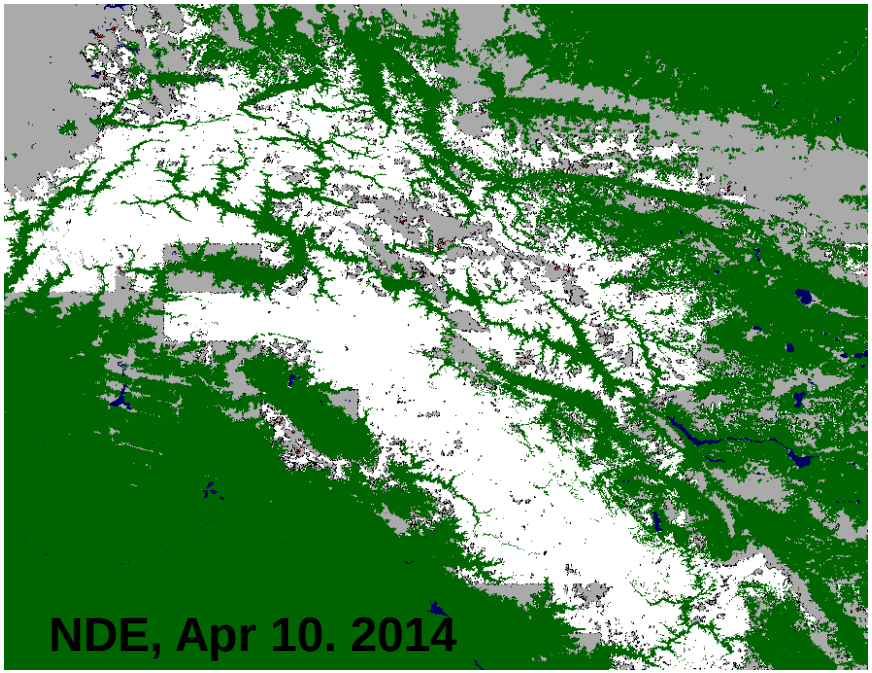
Clouds

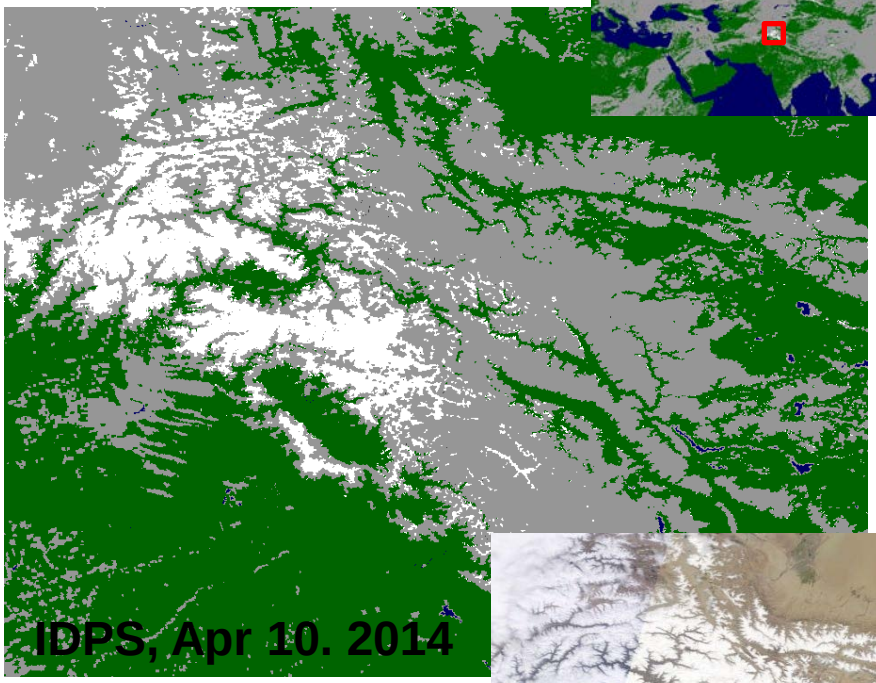
IMS snow

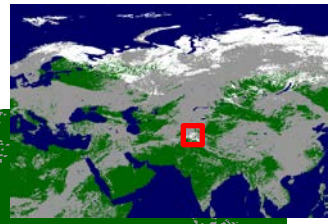


NDE vs IDPS Binary Snow Product

NDE: Better delineation of the snow cover boundary due to less conservative cloud masking









snow land cloud No data

NDE vs IDPS Accuracy

Mean daily agreement to IMS and mean cloud cover extent over Northern Hemisphere

Date	Agreement to IMS, %			Cloud Fraction, %	
	IDPS	NDE		IDPS	NDE
Jan 01, 2015	96.9	96.5		58	52
Apr 10, 2014	97.5	96.9		52	47
Jul 10, 2014	98.4	99.0		55	44
Oct 10, 2014	97.4	96.6		65	55

IDPS vs NDE:
- Similar accuracy as compared to IMS
- More clear sky retrievals (less clouds) in the NDE product

NOAA vs NASA Approach

NASA:

- IDPS algorithm with minor modifications
- Will remove IR temperature screen allowing pixels at all temperatures be classified as snow (same as MODIS Collection 6)

NOAA:

- New 2-stage algorithm
- Spectral thresholds + consistency testing

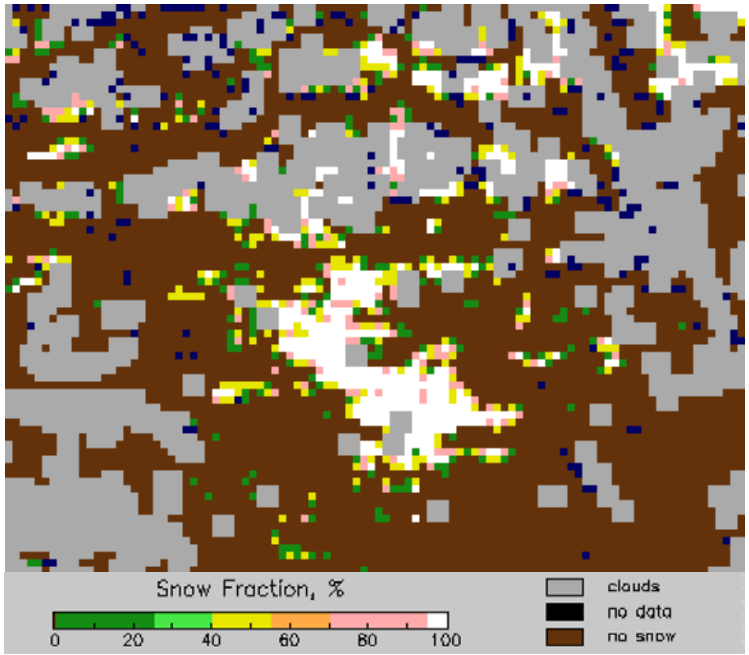
Snow Fraction

IDPS Snow Fraction

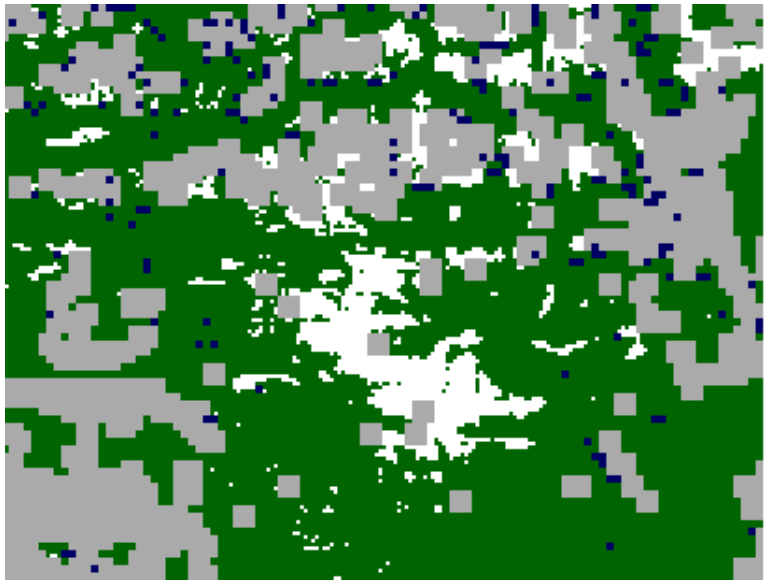
IDPS: Based on aggregated 2x2 binary snow retrievals

- No added value as compared to Binary Snow
- Can be easily generated by users
- Accuracy is defined by the binary snow product accuracy

Granule date: 20130915 time: 0355267



Snow fraction map (granule fragment)
750 m spatial resolution



Binary snow map (granule fragment)
375 m spatial resolution, white: snow, gray: clouds, green: land

Enterprise (NDE) Snow Fraction

NDE: Two algorithms implemented

1. NDSI-based

$$\textbf{SnowFraction} = -0.01 + 1.45 * \textbf{NDSI}$$

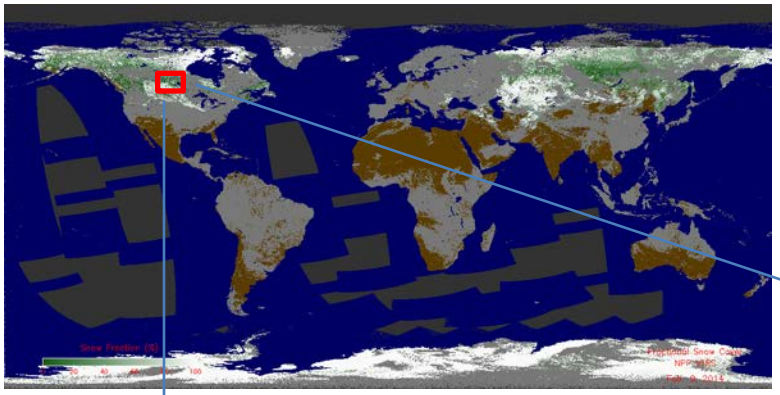
- **NDSI** = $(R_{0.6} - R_{1.6}) / (R_{0.6} + R_{1.6})$
- MODIS heritage algorithm, used up to Collection 5 (not in Collection 6)

2. Visible reflectance-based

$$\textbf{SnowFraction} = (R - R_{land}) / (R_{snow} - R_{land})$$

- Uses VIIRS band I1 (0.6 µm) reflectance (**R**)
- Algorithm used with GOES Imager and AVHRR; Approach similar to GOES-R

Snow Fraction: Two Algorithms

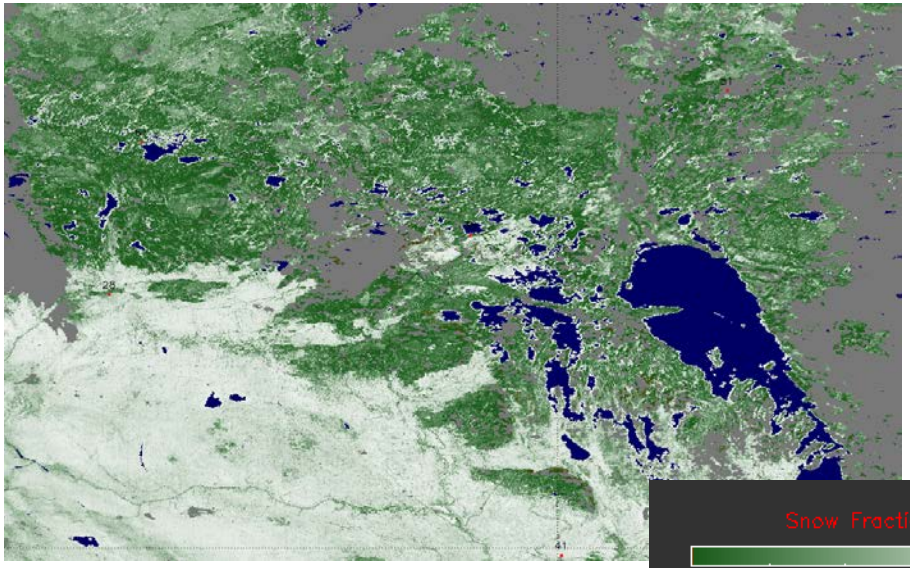


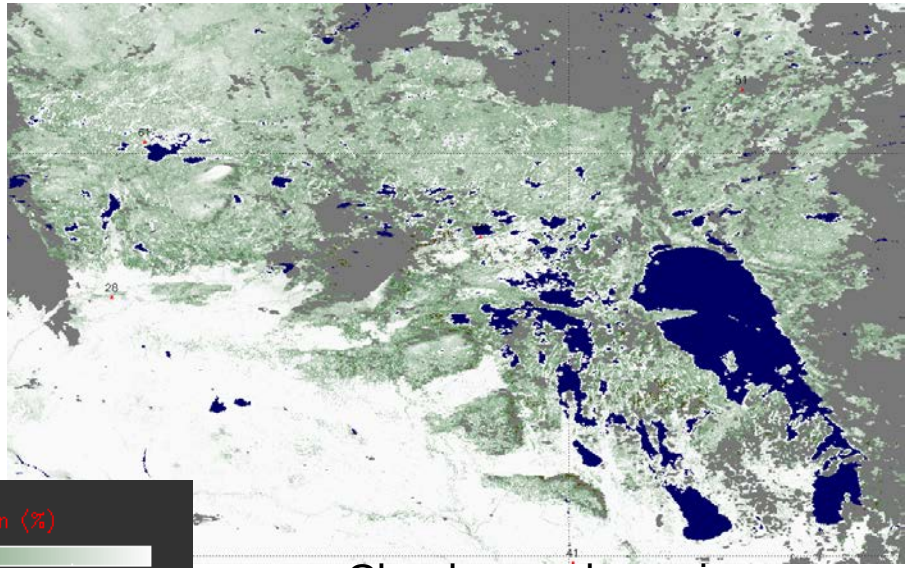
Reflectance-based Snow Fraction vs NDSI-based snow fraction

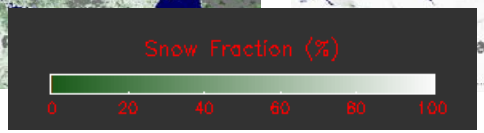
There is some similarity in the snow fraction patterns in the two products on the regional scale. NDSI-based snow fraction is much larger in the forest

Reflectance-based snow fraction

NDSI-based snow fraction







Clouds are shown in gray

Snow Fraction Evaluation Approach

Snow fraction: No in situ data. Quantitative validation is not feasible

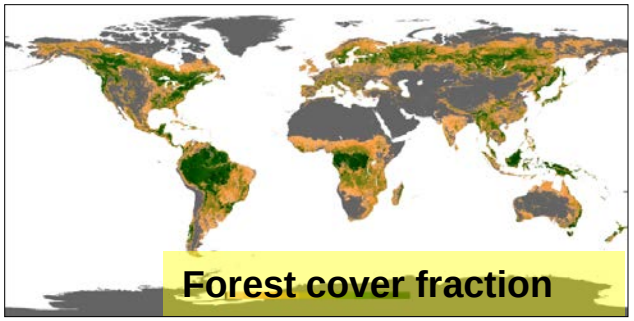
Higher spatial resolution retrievals are not independent. Limited applicability

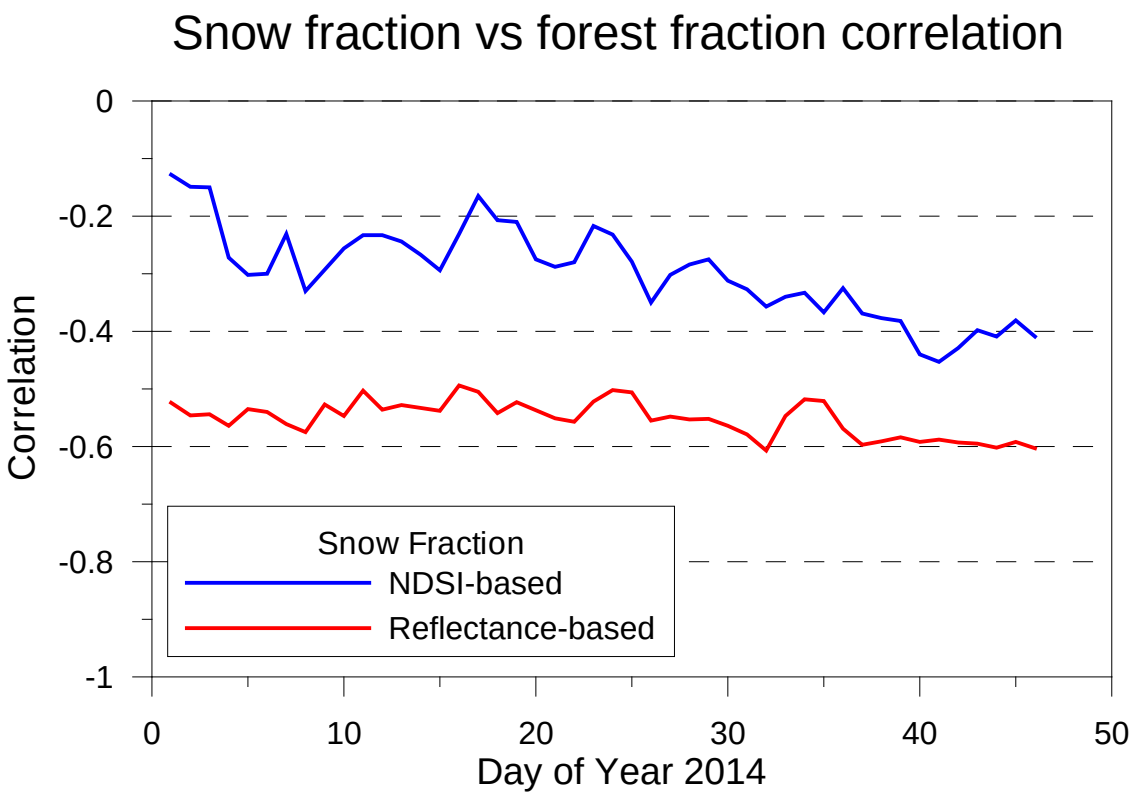
Theoretically estimated accuracy is within 10-20%

Verification of retrievals is possible through consistency testing

- Self-consistency
  - Lack of abnormal spatial patterns
  - Day-to-day repeatability of spatial patterns
- Consistency with the forest cover distribution
- Consistency with in situ snow depth data over open flat areas.

Consistency with Forest Fraction



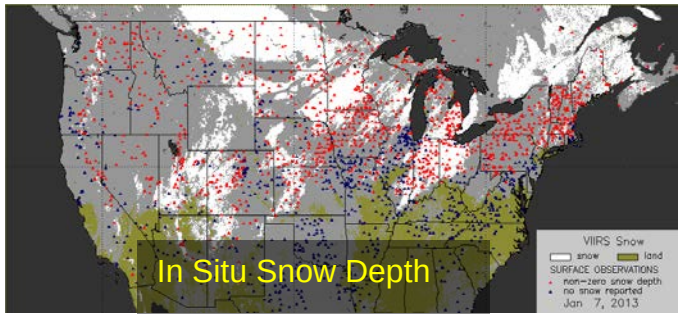


- Stronger correlation (-0.5 ÷-0.6), indicates better consistency of Reflectance-based snow fraction with forest cover properties

Consistency with Snow Depth

- VIIRS Snow Fraction vs matched In situ Snow Depth
- Correlation calculated over Great Plains
- Correlation is positive meaning that estimated snow fraction is consistent with the snow depth data





Snow Fraction vs Snow Depth Statistics

Date	Snow Depth Range, cm	Number of match-ups	Reflectance-based		NDSI-based	
			Mean SnFrac	Correlation	Mean SnFrac	Correlation
01/14/15	2 - 27	66	0.57	0.31	0.83	0.29
01/16/15	2 - 25	90	0.41	0.11	0.71	0.07
01/17/15	2 - 25	47	0.43	0.52	0.79	0.49
01/18/15	2 - 15	42	0.25	0.40	0.57	0.47
01/19/15	2 - 12	15	0.27	0.34	0.64	0.61
Mean			0.39	**0.34**	0.71	**0.38**

Comparison with Landsat Data

Approach

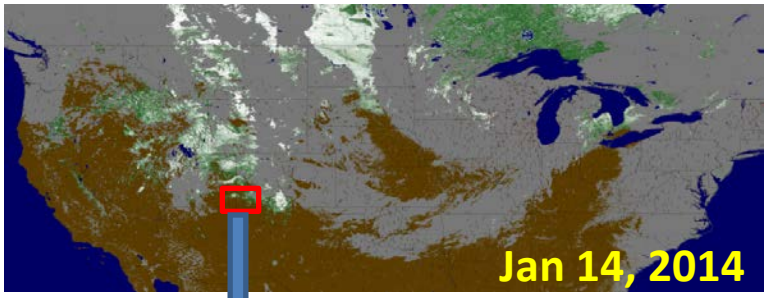
(1) Generate binary snow mask for a Landsat scene at 30 m resolution

(2) Aggregate Landsat binary snow identifications to estimate snow fraction at VIIRS spatial resolution

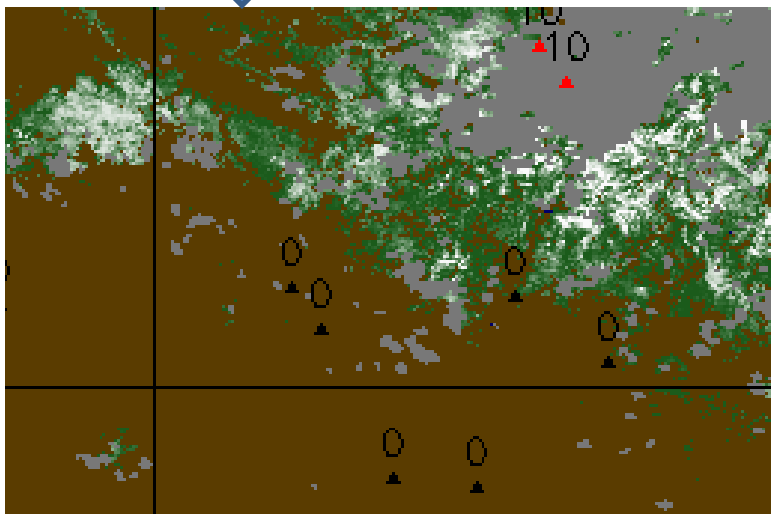
(3) Compare with VIIRS sub-pixel snow fraction estimate

Comparison with Landsat Data

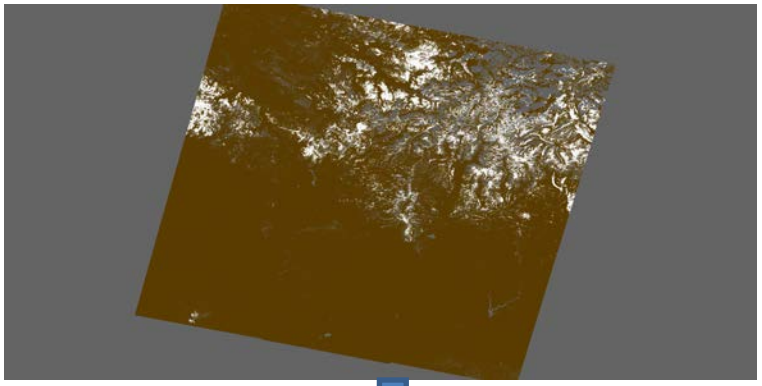
VIIRS Snow Fraction



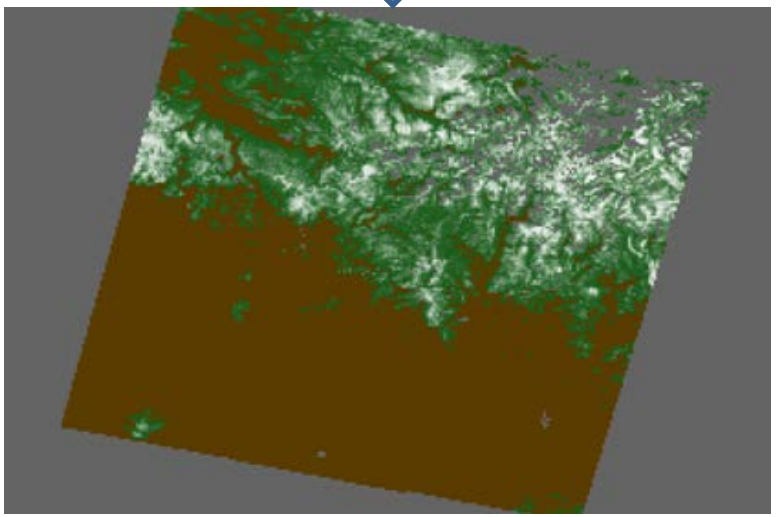
VIIRS Snow Fraction, 0.01 deg

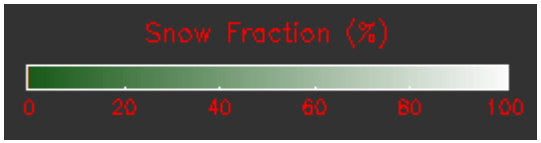


Landsat Binary Snow



Landsat Snow Fraction, 0.01 deg





Comparison with Landsat Data



VIIRS reflectance-based snow fraction vs Landsat

Date	Place	Path	Row	Aggregation: 1 km			Aggregation: 5 km		
				Corr	Bias	RMSE	Corr	Bias	RMSE
01/01/15	Mongolia	140	28	0.78	-0.054	0.247	0.85	-0.076	0.162
01/13/15	Germany	192	26	0.78	-0.004	0.04	0.93	-0.006	0.021
01/13/15	Austria	192	27	0.67	0.064	0.208	0.87	0.077	0.144
01/14/15	Iran	167	35	0.88	-0.031	0.122	0.94	-0.039	0.096
01/14/15	Iran	167	36	0.82	-0.018	0.085	0.91	-0.027	0.072
01/15/15	Caucasus	174	28	0.95	-0.035	0.150	0.98	-0.037	0.082
01/15/15	Caucasus	174	29	0.93	-0.025	0.174	0.98	-0.026	0.079
01/15/15	Turkey	174	32	0.76	-0.025	0.263	0.94	-0.037	0.089
01/16/15	Kazakhstan	165	27	0.92	-0.025	0.197	0.95	-0.019	0.163
01/22/15	Rocky Mnts	38	30	0.80	-0.095	0.210	0.89	-0.105	0.134
04/10/14	Himalaya	150	36	0.95	0.001	0.099	0.93	0.002	0.106
04/10/14	Himalaya	150	35	0.89	-0.013	0.193	0.87	0.001	0.112
07/14/14	Greenland	6	13	0.93	-0.040	0.181	0.84	-0.046	0.156
07/14/14	Greenland	6	14	0.86	-0.070	0.154	0.95	-0.07	0.128
07/14/14	Greenland	6	15	0.93	-0.045	0.150	0.95	-0.051	0.114
Mean				**0.84**	**-0.036**	**0.174**	**0.89**	**-0.054**	**0.127**

Each Landsat-VIIRS matched scene includes from about 400 to several thousand matched snow fraction estimates.

The RMSE between VIIRS and Landsat snow fraction estimates is **17.4%** for 1 km grid cells and **12.7%** for 5 km aggregation

NOAA vs NASA Approach

NASA:

- Dropped snow fraction retrieval
- Will provide NDSI values only (same as MODIS Collection 6)

NOAA:

- Two snow fraction products
  - May follow NASA and drop NDSI snow fraction, provide NDSI value only

JPSS-1 Readiness

- Enterprise algorithms will be used
    - Minor modifications are expected (coefficients, thresholds)

- Algorithms have been implemented within NDE

- Accuracy, Binary Snow: Requirements will be met

-Accuracy, Fractional Snow: Direct validation is not feasible

Indirect estimates: 10-20% (below requirements)

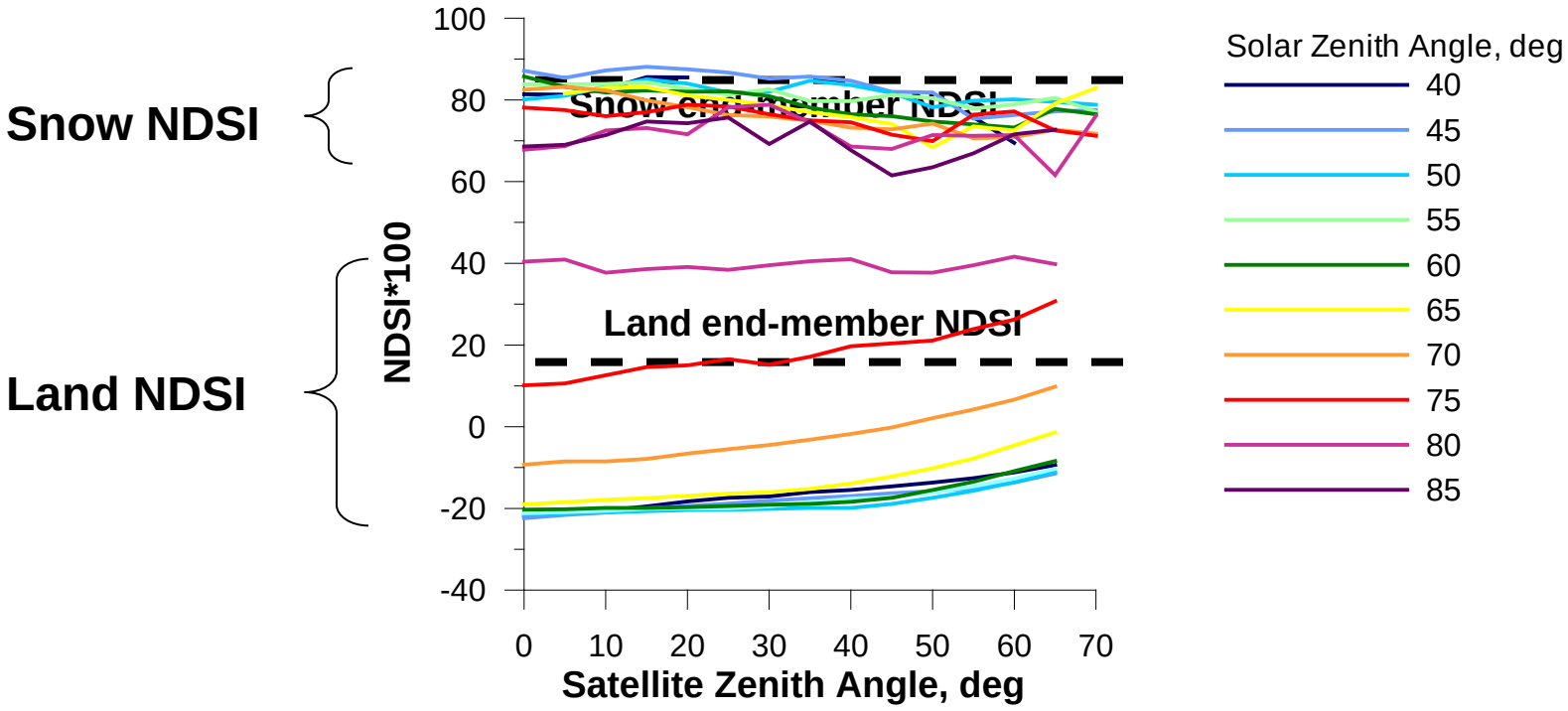
Requirements (10%) may be too strict

GOES-R: 15% accuracy, 30% precision

Further Enhancements: Binary Snow

- Develop and implement an improved snow cover climatology
- Account for angular anisotropy of NDSI, NDVI, Reflectance

Important: NDSI of snow-free land surface exhibits a substantial angular anisotropy. This should be accounted for to improve snow detection.



Further Enhancements: Fraction

- Incorporate shadows as class, multi-endmember retrievals
- True (not “viewable ”) snow fraction
  - Need to account for snow masking by forests

JPSS-1: Post-Launch Plans

- Testing (FY17) and implementation (FY18) of improved algorithms
- Routine next-day accuracy assessments (FY17)
- Involve additional validation datasets (FY17)
  - CoCoRAHS (ground-based network) added to SYNOP and COOP data
  - Sentinel-2 added to Landsat
- Upgrade VIIRS snow validation web page (FY17-18)

Summary

IDPS algorithm performance:

- Binary Snow: adequate, within requirements, robust performance
- Fractional snow: Product has little value, not needed

Enterprise Algorithms are ready for use with JPSS-1

- Binary snow:
  - Better performance over forest, better area coverage
  - Meets requirements
- Fractional snow:
  -“Viewable” snow fraction
  - Two products to satisfy most potential users
  - No direct validation
  - Further work needed to meet accuracy requirements

Further improvements of both algorithms are planned

SUOMI-NPP VIIRS ICE SURFACE TEMPERATURE STATUS

Mark Tschudi
CCAR, University of Colorado, Boulder
303-492-8274; mark.tschudi@colorado.edu

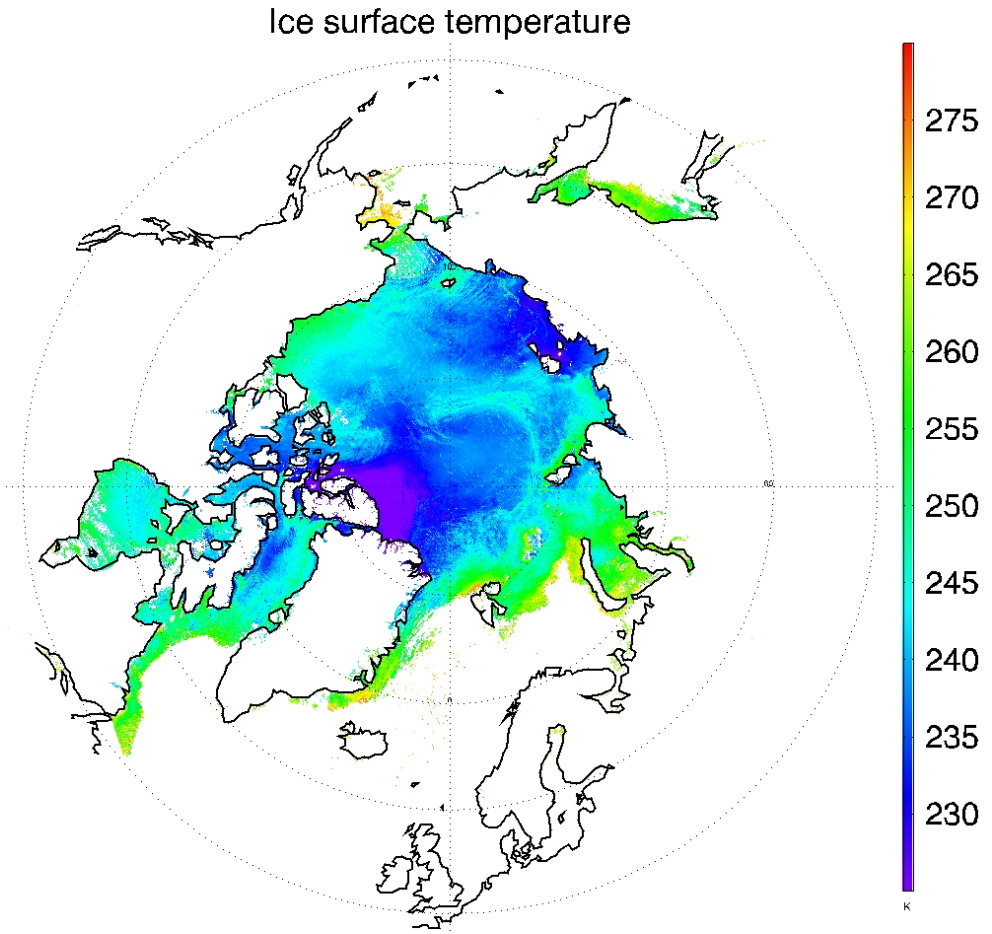
Collaborators: Y. Liu, R. Dvorak, J. Key, D. Baldwin

IST Cal/Val Team

PI	Organization	Team Members	Roles and Responsibilities
J. Key	NESDIS	M. Tschudi (CU/CCAR)	IST cal/val
		Y. Liu (UW/CIMSS)	IST development and cal/val
		R. Dworak (CIMSS)	IST cal/val
		D. Baldwin (CCAR)	IST cal/val
		X. Wang (CIMSS)	IST application

IDPS VIIRS Ice Surface Temperature

IST is the radiating, or "skin", temperature at the ice surface. It includes the aggregate temperature of objects comprising the ice surface, including snow and melt water on the ice.

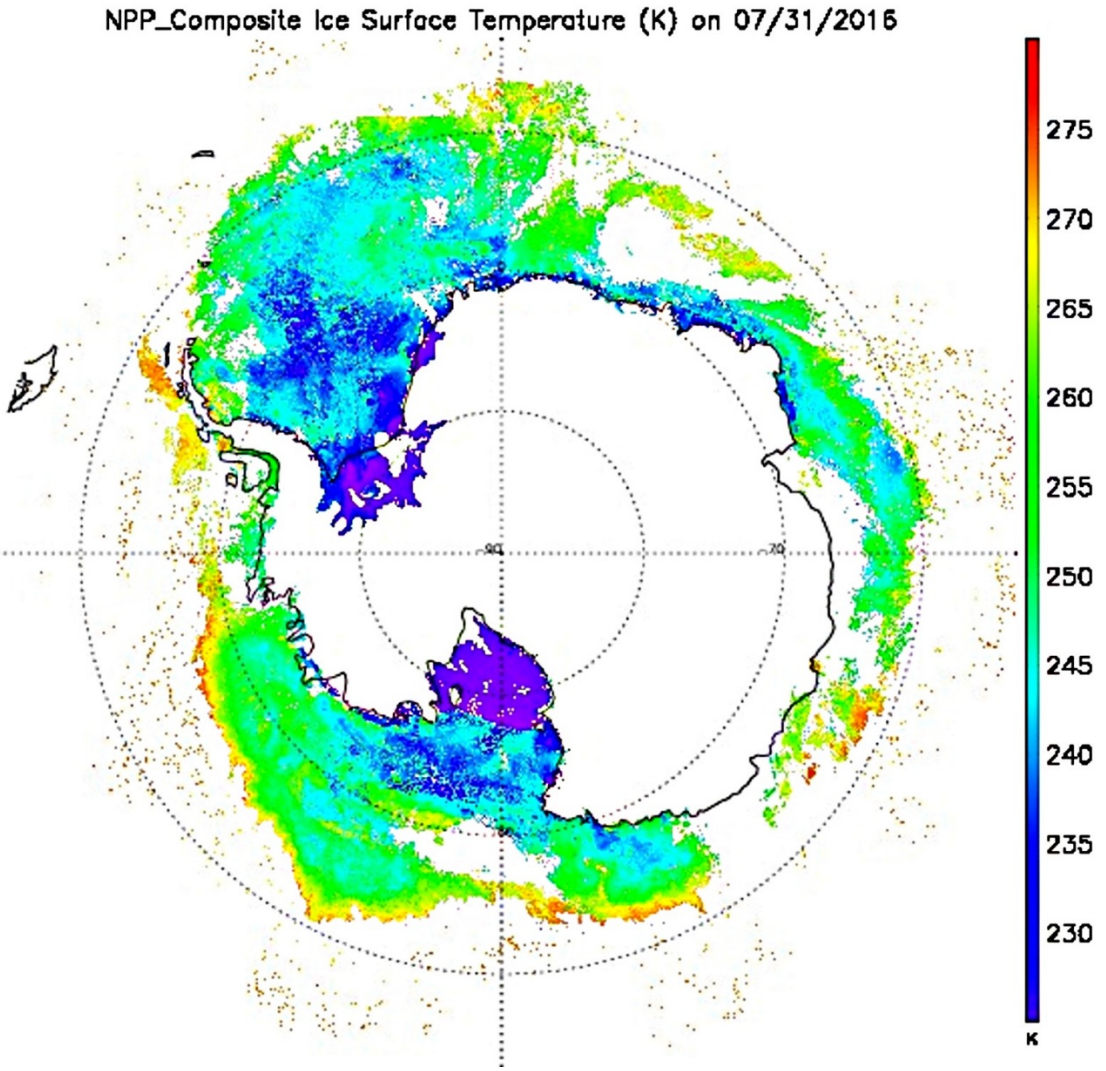


Ice surface temperature (IST) composite from all overpasses over the Arctic on March 1, 2015. From *Liu et al.*, 2015.

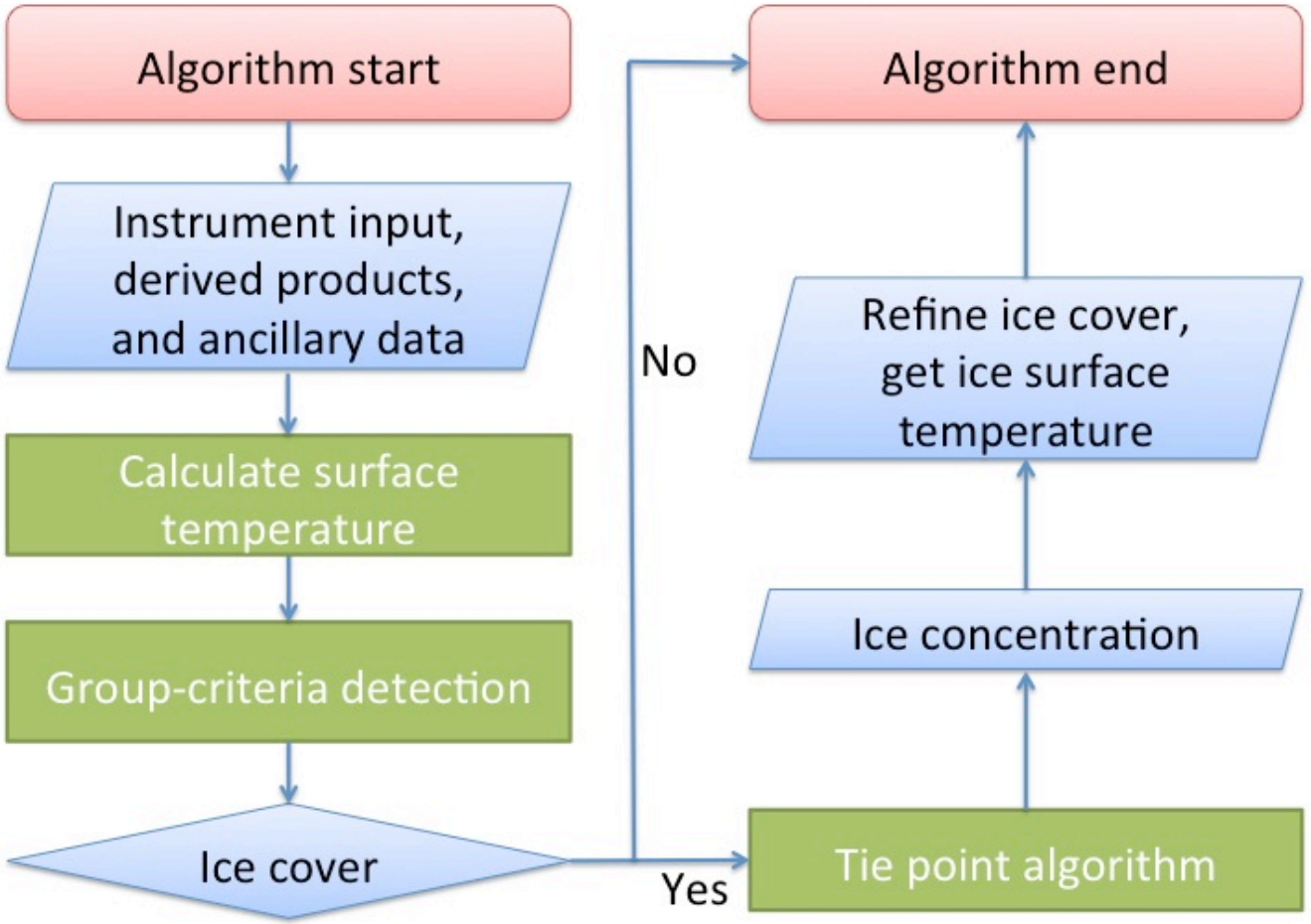
Enterprise VIIRS IST on Aug 5, 2016

From U. Wisc/CIMSS near real-time VIIRS ice products, based on JPSS Enterprise algorithms

https://stratus.ssec.wisc.edu/ice-products/anibrowser/



JPSS VIIRS Enterprise IST flow chart



Summary of the VIIRS IST EDR

- The VIIRS Ice Surface Temperature (IST) EDR provides surface temperatures retrieved at VIIRS moderate resolution (750m), for Arctic and Antarctic sea ice for both day and night.
- The baseline split window algorithm statistical regression method is based on the IST algorithm of *Key and Haefliger (1992) and Key et al. (1997)*:

$$IST = a + bT_{11} + c(T_{11}-T_{12}) + d(T_{11}-T_{12})(\sec(z)-1)$$

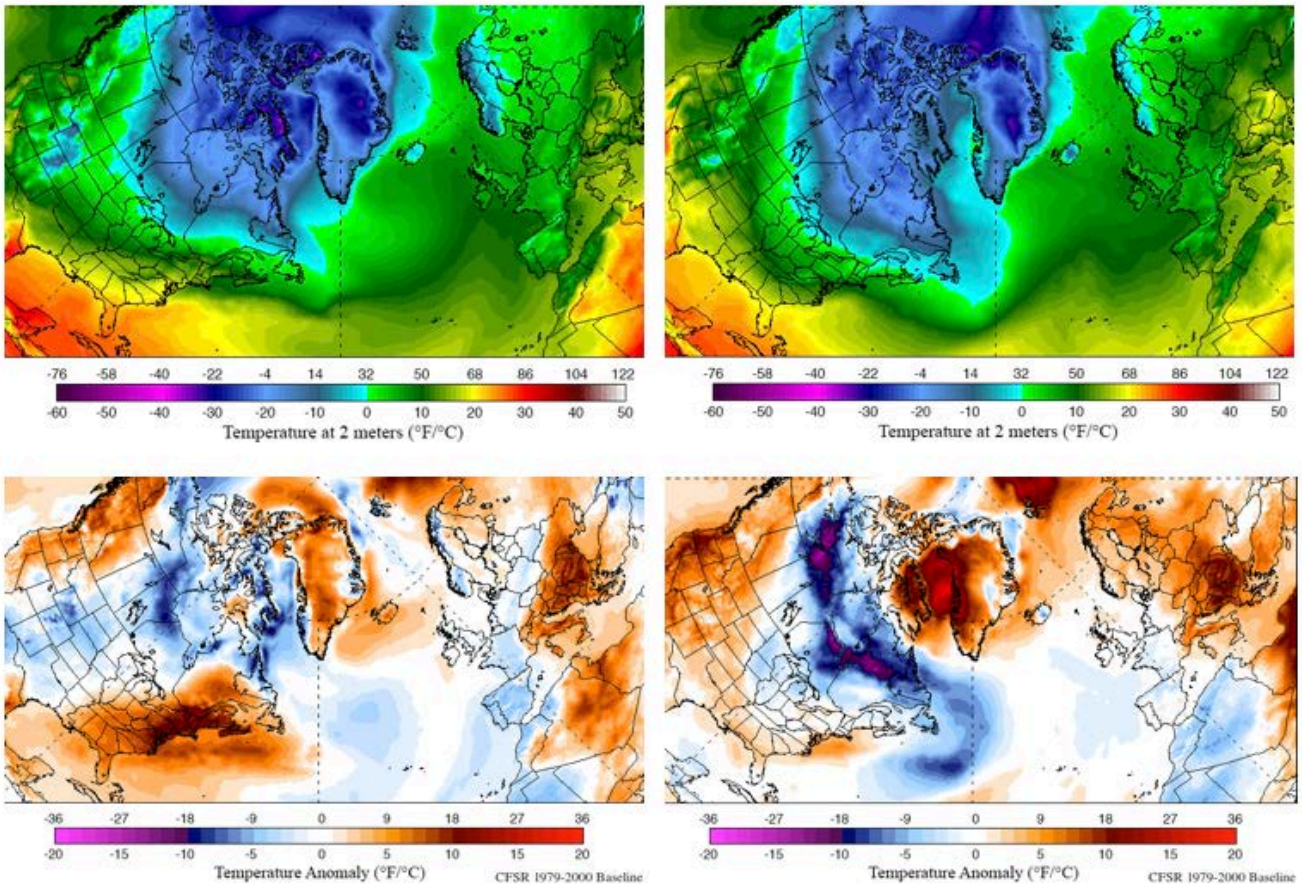
T_{11} and T_{12} : TOA TB's for ~11 and 12 μm bands
z: satellite zenith angle
a, b, c, d: regression coefficients.

- Threshold Measurement Uncertainty = **1K** over a measurement range of 213–275 K.

Key, J., and M. Haefliger (1992), Arctic ice surface temperature retrieval from AVHRR thermal channels, J. Geophys. Res., 97(D5), 5885–5893.

Key, J., J. Collins, C. Fowler, and R. Stone, 1997. High-latitude surface temperature estimates from thermal satellite data. Remote Sensing Environ., 61, 302-309.

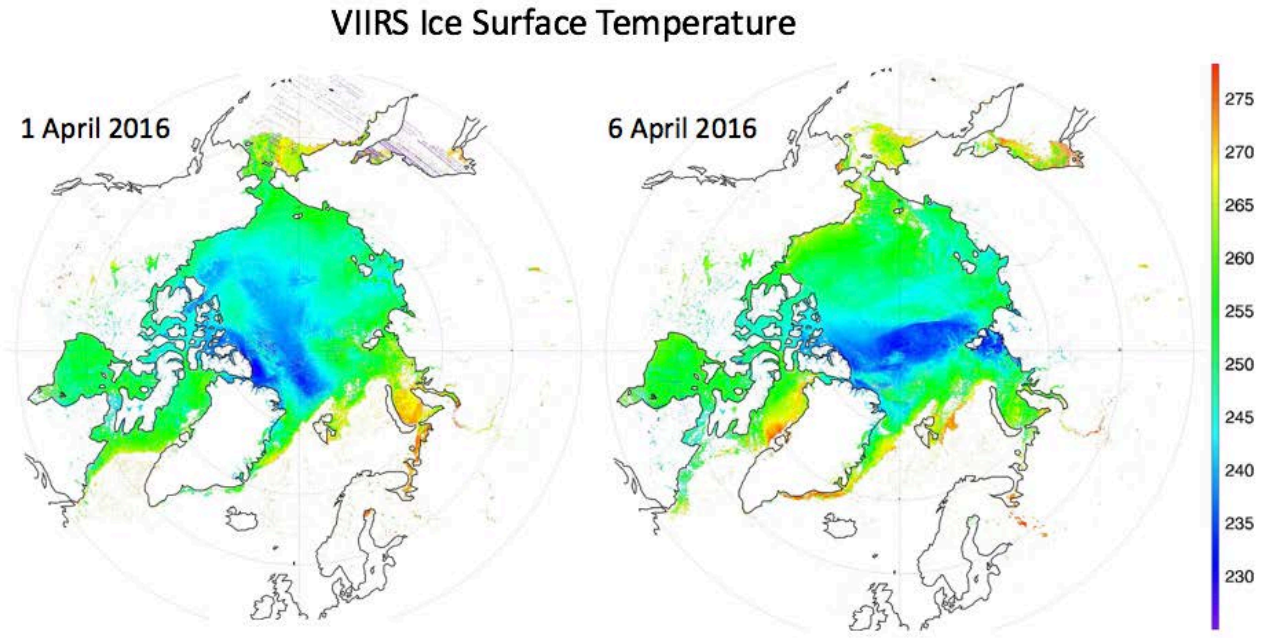
April surface warming event over Baffin Bay



During the first week of April 2016 a significant surface warming event was observed over Baffin Bay (left). Mean surface temperatures over the area from The NCEP Climate Forecast System Version 2 (CFSv2) Reanalysis ranged from -30 to -10º C on 1 April 2016 with anomalies of -10º C in the south to +5º C in the north. By 7 April 2016 the mean surface temperatures rose by 10 to 20º C with surface temperature anomalies of up to 20º C off the west central coast of Greenland.

Top row is daily mean 2-meter temperatures for 1 April 2016 left and 7 April 2016 right. Bottom row is daily mean temperature anomaly. Data from CFSv2 provided by the University of Maine Climate Change Institute Climate Reanalyzer (http://cci-reanalyzer.org/)

April surface warming event over Baffin Bay



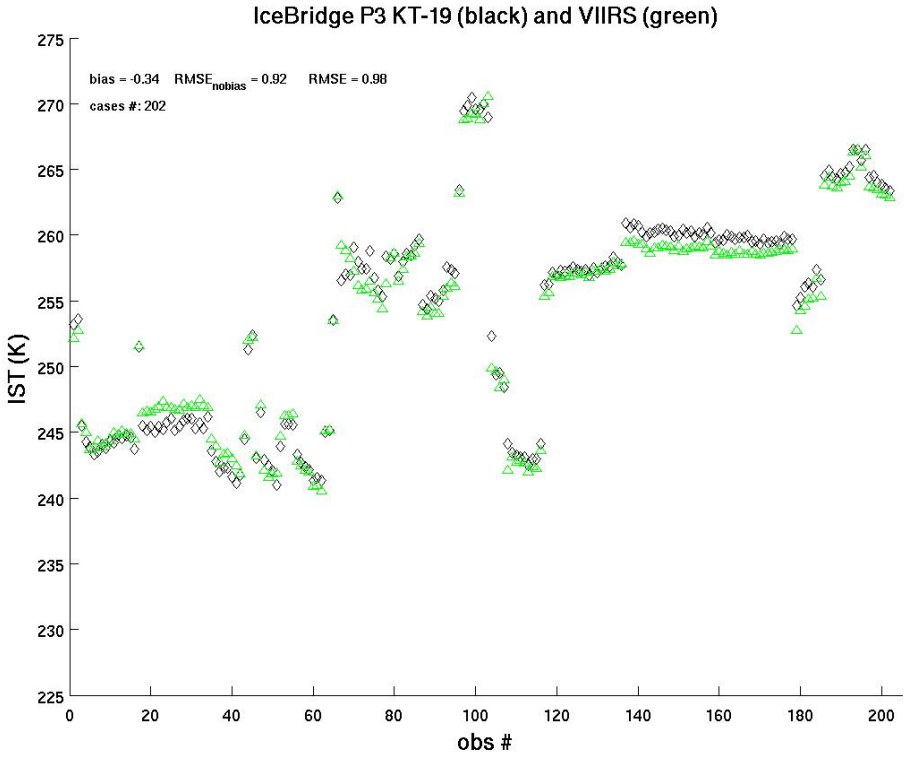
Daily composites of S-NPP VIIRS Ice Surface Temperature using the Enterprise algorithm. Left: 1 April 2016; right: 6 April 2016.

The NPP VIIRS Ice Surface Temperature (IST) Enterprise algorithm observed the same warming event over the 1 to 6 April period (left). IST was in the range of 245-265 K on 1 April, warming to 255-275 K by 6 April. A strong ridge of high pressure developed over Greenland, allowing warm air from the south to be advected over the Baffin Bay region. On a related but broader scale, a record-breaking level of surface melt on the Greenland ice sheet has been observed for this early in the year. *By R. Dvorak*

VIIRS IST Validation Approach

Validation Dataset	Parameter	Spatial Resolution	Spatial Coverage	Temporal Coverage
NASA IceBridge KT-19 IR Surface Temperature	Snow/ice temperature	15 x 15 m	Arctic and Antarctic	Arctic: 2012-2014 Antarctic: 2012-2013
MODIS Ice Surface Temperature	Snow/ice temperature	1 km	Arctic and Antarctic	August 2012-July 2015
MODIS simultaneous nadir overpass	Snow/ice temperature	0.05 degree longitude by 0.05 degree latitude	Arctic	March 2013 – April 2014
Arctic drifting buoy	2 m air temperature	Point observations	Arctic	August 2012 - June 2014
NCEP/NCAR reanalysis	Air temperature at 0.995 sigma level	2.5 x 2.5 degree latitude/longitude	Arctic and Antarctic	August 2012-July 2015

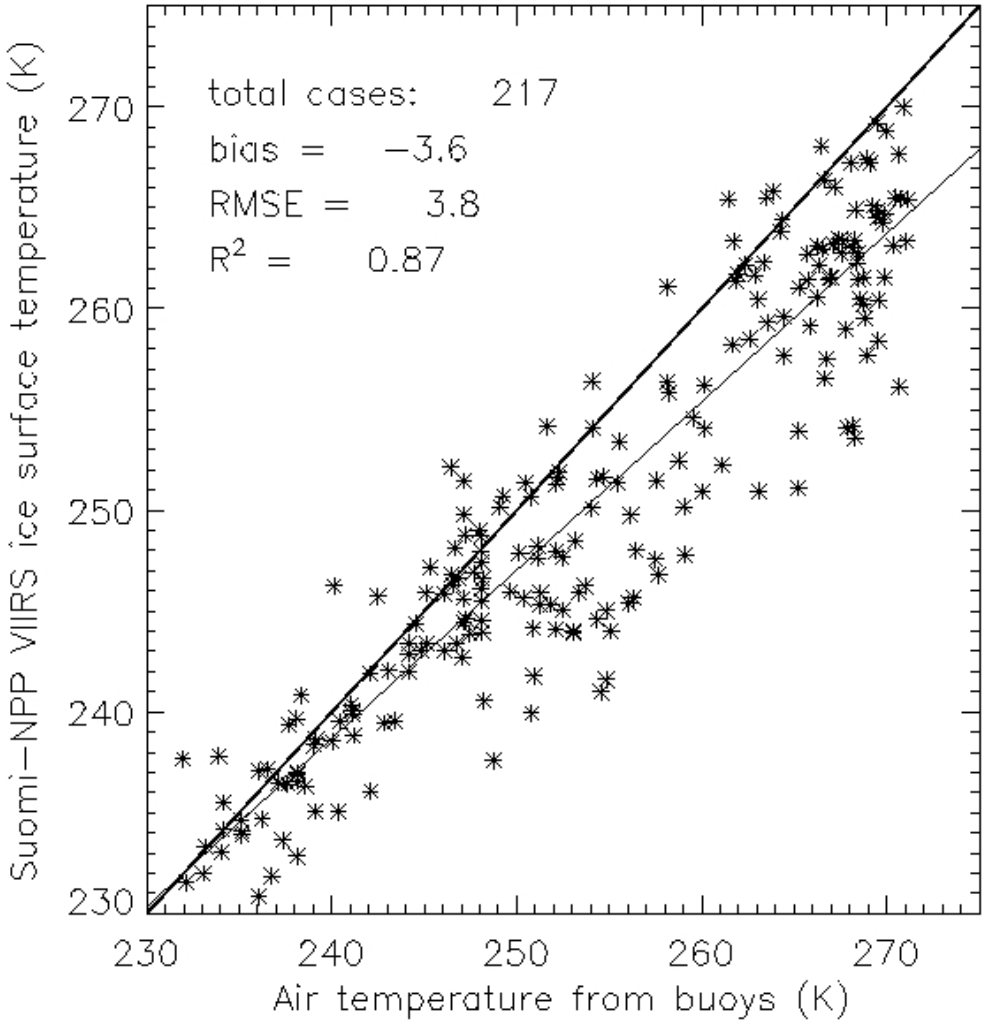
VIIRS IST IceBridge Validation



VIIRS IST (green) and KT-19 IST (black) for all coincident IceBridge flights with cloud-free observations over the Arctic (March-May 2014) and Antarctic (October-November 2012-13).

From: *Yinghui Liu, Jeffrey Key, Mark Tschudi, Richard Dworak, Robert Mahoney, and Daniel Baldwin*, 2015: Validation of the Suomi NPP VIIRS Ice Surface Temperature Environmental Data Record, *Remote Sens.* **2015**, *7*, 13507-13527; doi:10.3390/rs71013507

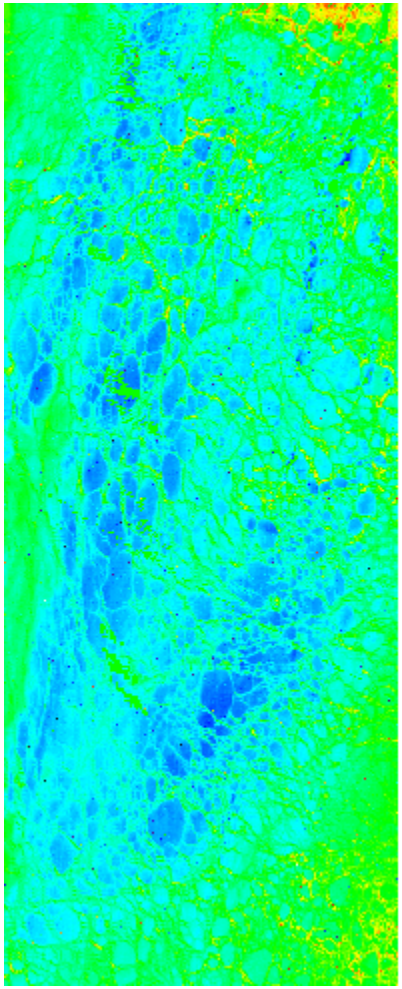
VIIRS IST vs. buoys

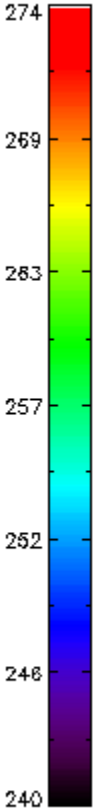


Scatter plot of surface air temperature from Arctic buoys and NPP VIIRS IST from August 2012 to June 2014, with the thick line as the 1 to 1 ratio line, and thin line as the linear regression.

From *Liu et al.*, 2015.

Suomi-NPP VIIRS IST – NASA product





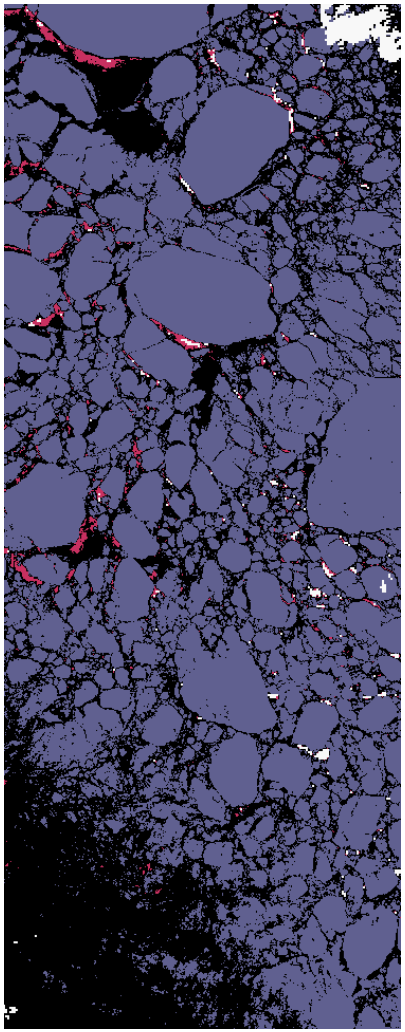
- Utilizes split window:

$$IST = a_o + a_1 T_{M15} + a_2(T_{M15} - T_{M16}) + a_3(T_{M15} - T_{M16})(\sec(z) - 1)$$

- Initial code generated from MODIS code by NASA's Science Investigator-led Processing System (SIPS)
- Code being updated for VIIRS (calibration coefficients, etc.)
- New Quality Flags to be added
- Inter-comparison: MODIS, NCEP
- Validation: IceBridge, buoys

Left: VIIRS IST (K) from the NASA VIIRS IST product
Sept 12, 2014, 21:10 UTC
Beaufort Sea, AK

NASA VIIRS Sea Ice Cover Product

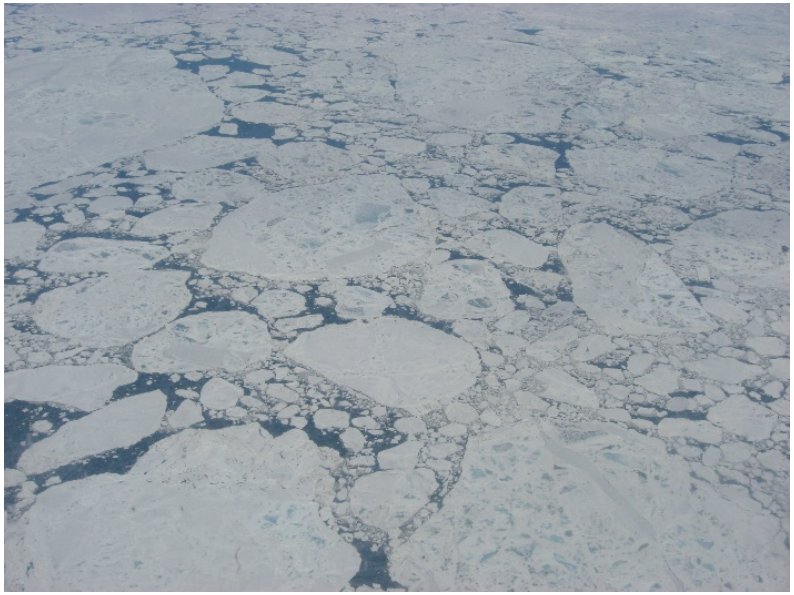


NASA VIIRS Sea Ice Cover
April 7, 2015, Beaufort Sea

- NASA VIIRS Sea Ice Cover by Reflectance
- Follow-on from MODIS (D. Hall & G. Riggs)
- Code generated by NASA SIPS
- In development by M. Tschudi (CU), George Riggs (SSAI)
- Reflectance-based during daytime, nighttime uses the IST product
- Sea ice by reflectance utilizes the NDSI:
  - NDSI = [R(I1) – R(I3)] / [R(I1) + R(I3)]
  - R=reflectance, VIIRS I1 (0.64um), VIIRS I3 (1.61um)
- Ice cover is mapped:
  - Snow-covered ice:
    - NDSI > thold and R(I1) > thold2
  - Thin ice (<10 cm, no snow cover)
    - IST – SST > thold
- Validation: IceBridge, Digital Globe, …
- Intercomparison: AMSR-2, IDPS Sea Ice Age, VIIRS Sea Ice Concentration, NDE Sea Ice Thickness

Conclusions

- VIIRS IST algorithm in most cases meets the requirement of 1K measurement uncertainty
- The VIIRS IST has detected early warming in Baffin Bay which parallels other observations.
- Improvements in the VIIRS IST performance have been realized as the VIIRS Cloud Mask matures
- NASA's Sea Ice Extent and IST products will provide continuity with the MODIS product



S-NPP ICE CONCENTRATION STATUS

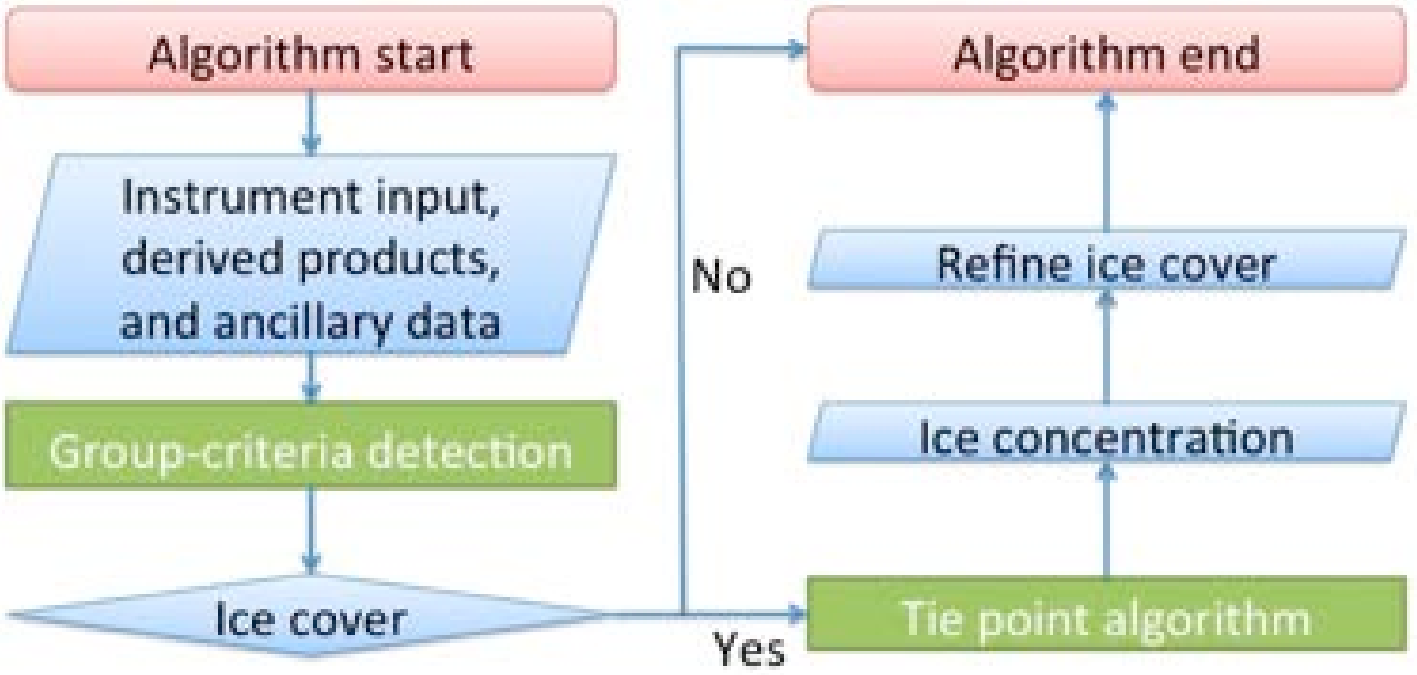
Yinghui Liu, CIMSS, University of Wisconsin at Madison
608-890-1893; yinghuiliu@wisc.edu

Collaborators: Jeff Key, Rich Dworak, Mark Tschudi, Dan Baldwin, Robert Mahoney

Ice Concentration Team

PI	Organization	Team Members	Roles and Responsibilities
J. Key	NESDIS	Y. Liu (UW/CIMSS) M. Tschudi (CU/CCAR) D. Baldwin (CCAR) R. Dworak (CIMSS) X. Wang (CIMSS)	Ice conc. cal/val and development Ice concentration cal/val Ice concentration cal/val Ice concentration data analysis Ice concentration application

Enterprise Algorithm Overview



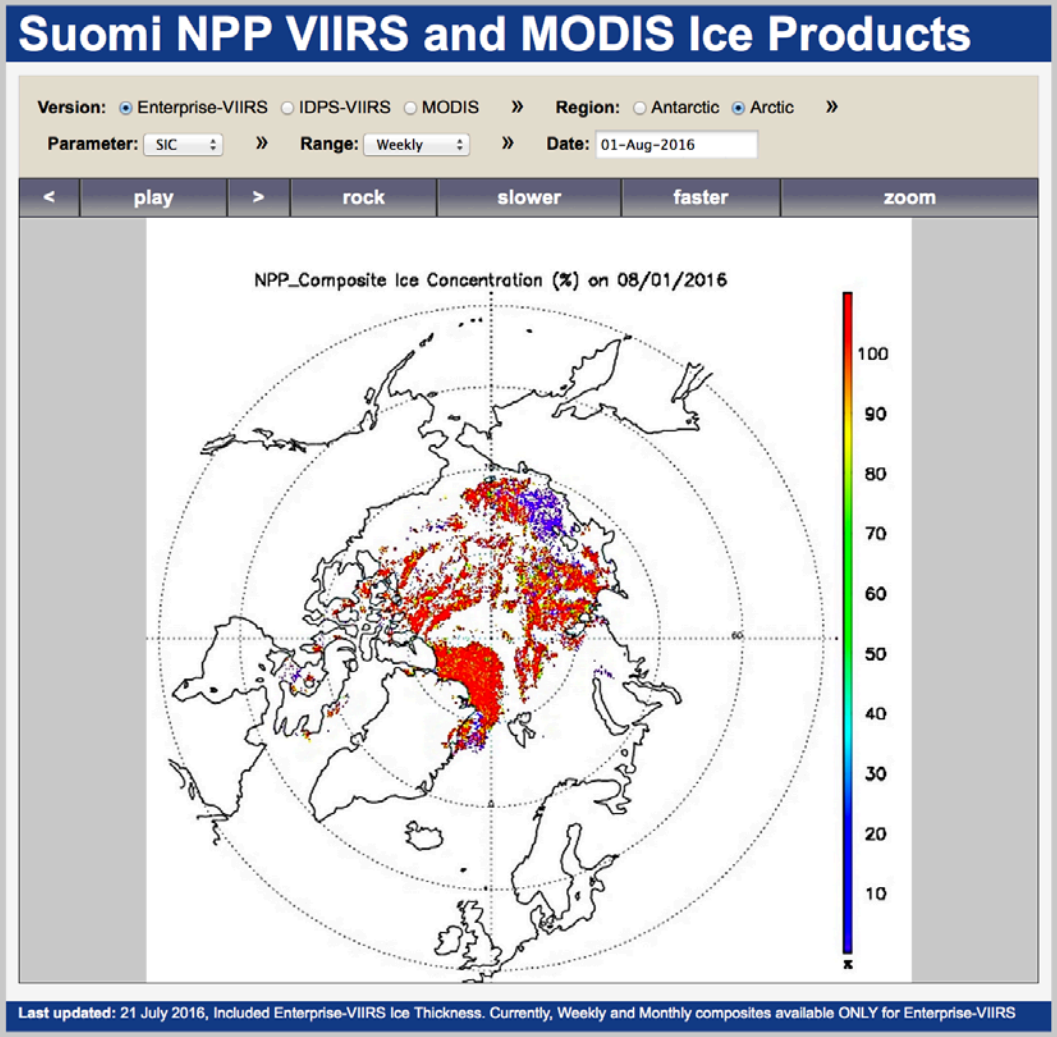
Difference with IDPS algorithm:

- Enterprise algorithm applies threshold method to identify ice covered pixels first with Normalized Difference Snow Index (NDSI) explicitly used;
- Retrieves Ice Concentration (IC) using tie-point algorithm on single band information of 0.64 μm reflectance at daytime and surface temperature at nighttime,
- Final ice identification is refined by the retrieved SIC;
- IDPS SIC algorithm applies band weighted ICs from tie point algorithm on multiple bands, with identification of ice covered pixels implicitly included.
- Enterprise IC is in M-band resolution, and IDPS product is in I-band resolution

Requirements

Attribute	Threshold	Performance
a. Vertical Coverage	Ice Surface	Ice Surface
b. Horizontal Cell Size		
1. Clear	1.0 km	1.0 km
2. All Weather	No capability	No capability
c. Mapping Uncertainty, 3 Sigma		
1. Clear	1 km at Nadir	1.0 km
2. Cloudy	No capability	No capability
d. Measurement Range		
2. Ice Concentration	0.0 – 1.0	0.0 – 1.0
e. Measurement Uncertainty		
2. Ice Concentration	10%	10%
f. Refresh	At least 90% coverage of the globe every 24 hours (monthly average)	At least 90% coverage of the globe every 24 hours (monthly average)
g. Geographic coverage	All ice-covered regions of the global ocean	All ice-covered regions of the global ocean

Long term Monitoring and Website Links

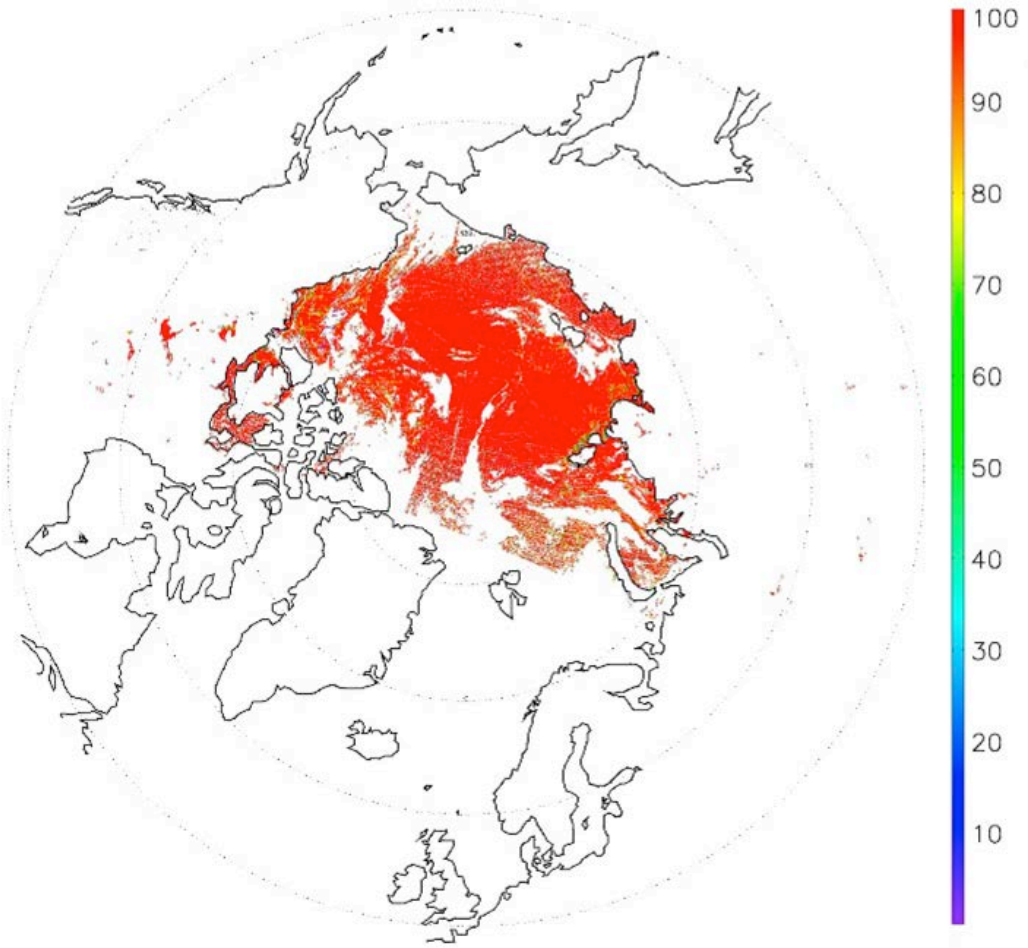


Ice concentration near real-time Enterprise product has been generated and monitored routinely, and figures have been archived and shown on CIMSS website at http://stratus.ssec.wisc.edu/ice-products/anibrowser/index.php, and at JPSS EDRs LTM site, http://www.star.nesdis.noaa.gov/jpss/EDRs/products_cryosphere.php

User Interaction

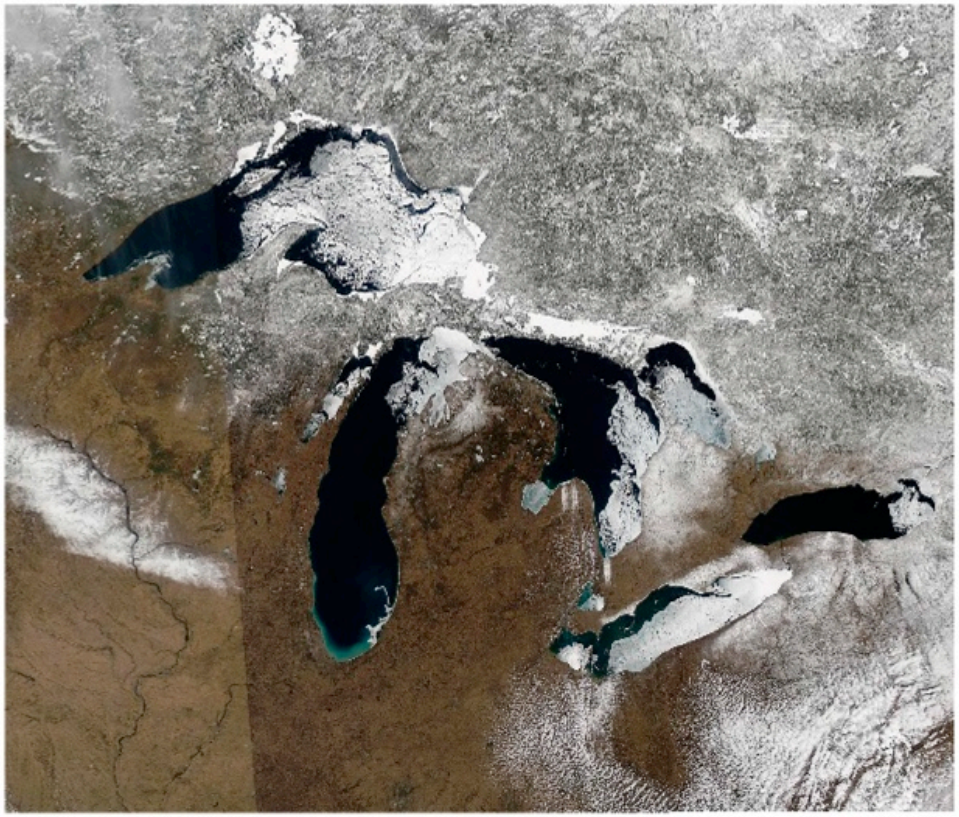
- Ice concentration is being archived by Naval Research Laboratory for applications in model simulation
- Ice concentration will be used by National Ice Center
- Ice concentration has been archived for Walt Meier of GSFC for comparison with microwave products
- Have been in contact with researchers on the possibility in using JPSS ice concentration product in the operational weather forecasting model

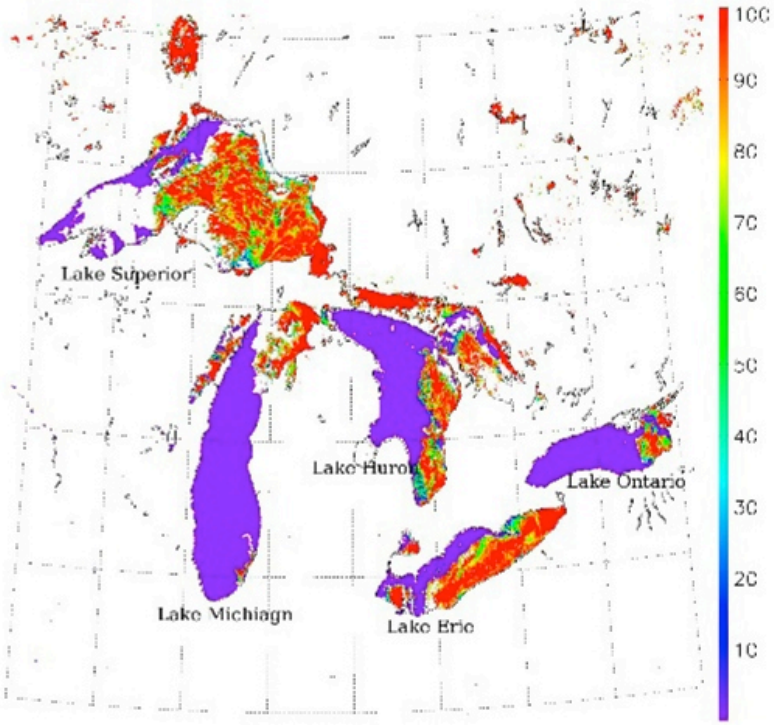
Product Example



Ice concentration over the Arctic Ocean from the VIIRS overpass 8:43 p.m. to 9:03 p.m. UTC on 20 February 2015. The cloud-covered areas are white.

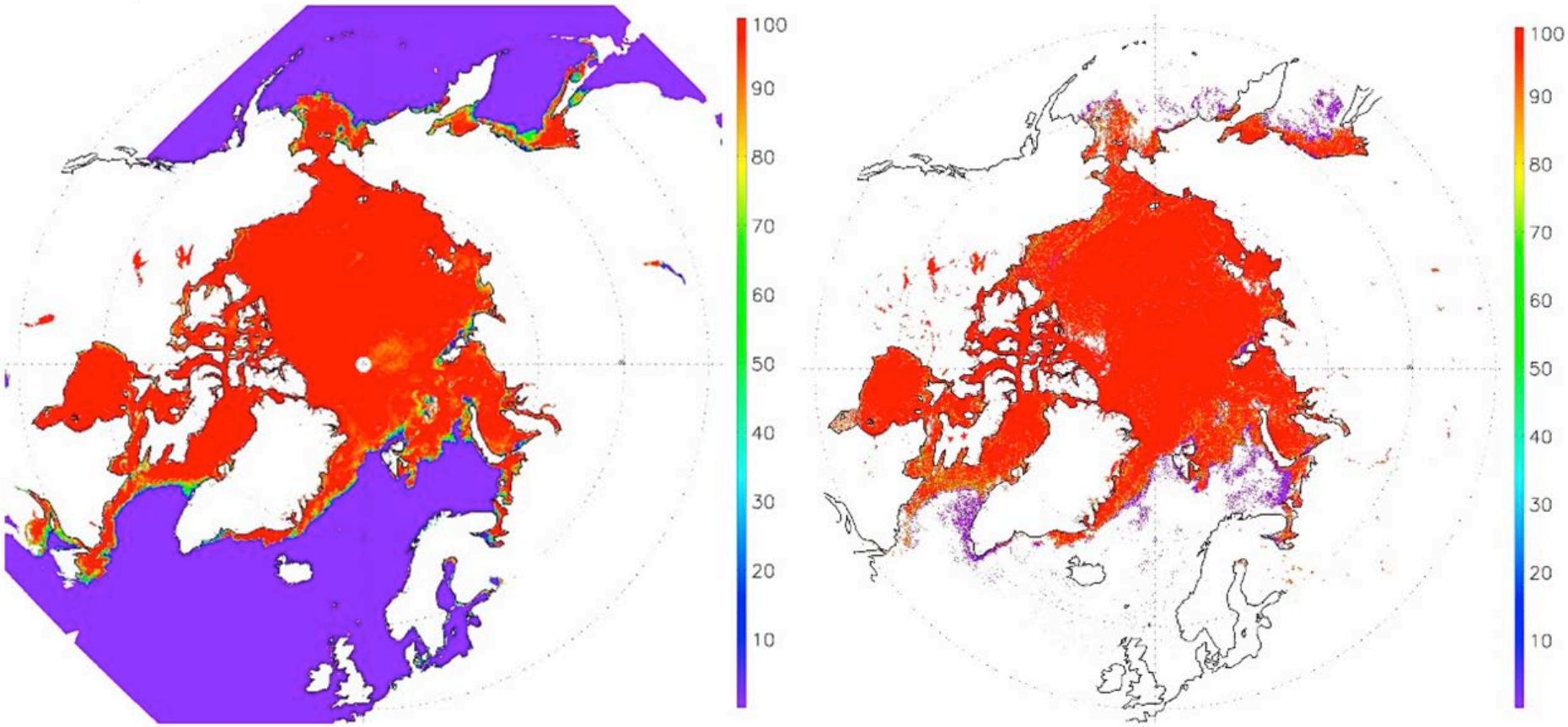
Product Example





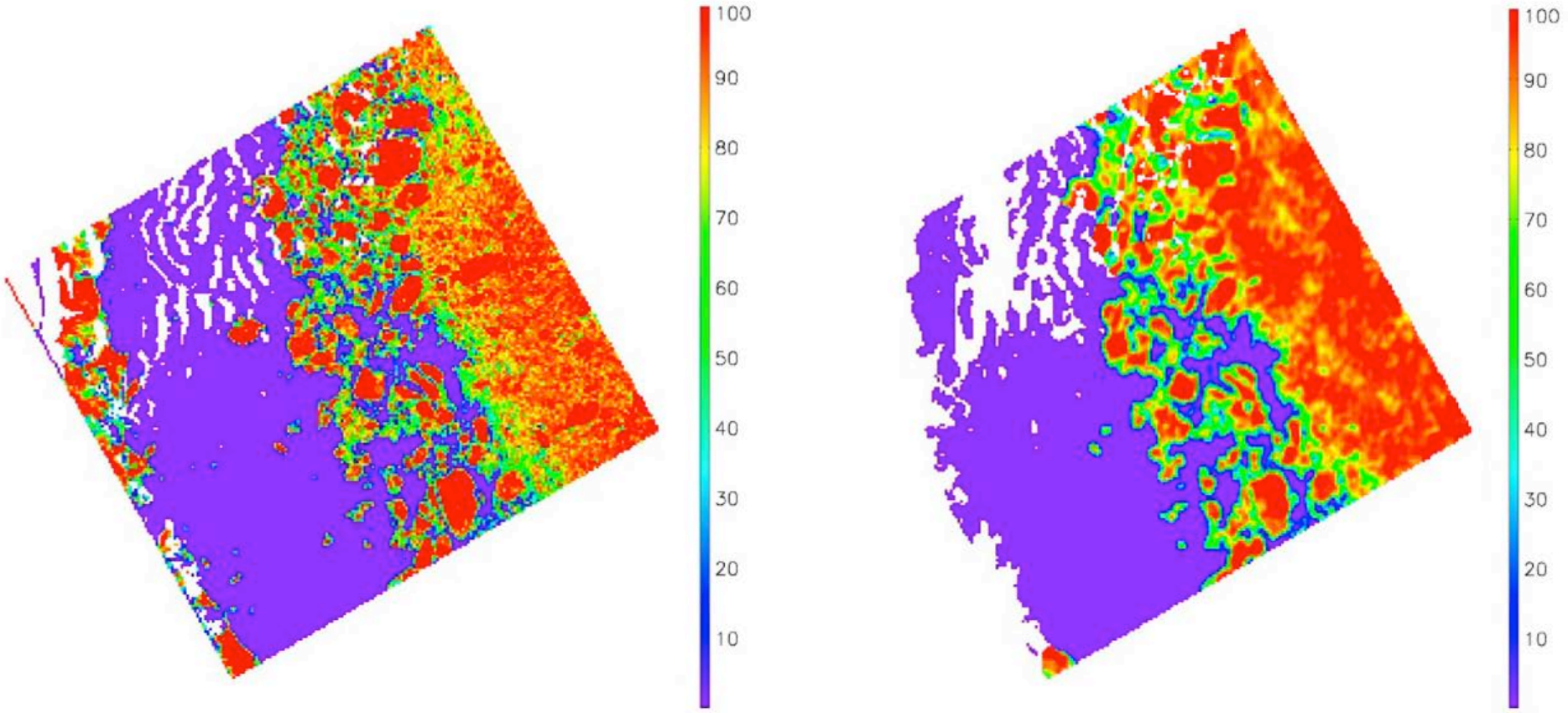
Aqua MODIS true-color image at 6:20 p.m. UTC on 28 March 2015 (**left**); and the corresponding ice concentration (**right**).

Validation



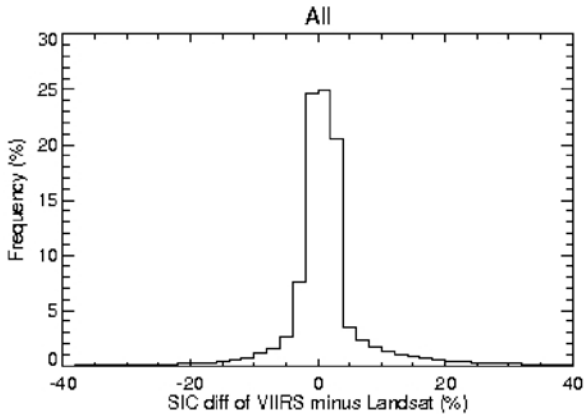
Ice concentration (IC) from SSMIS (**left**); and a daily IC composite from VIIRS (**right**) over the Arctic on 20 February 2015. White areas in the SSMIS image denote pixels flagged as either land or the area around the pole that is not covered by the instrument. White areas in the VIIRS data denote pixels flagged as land, ice-free ocean, or cloud.

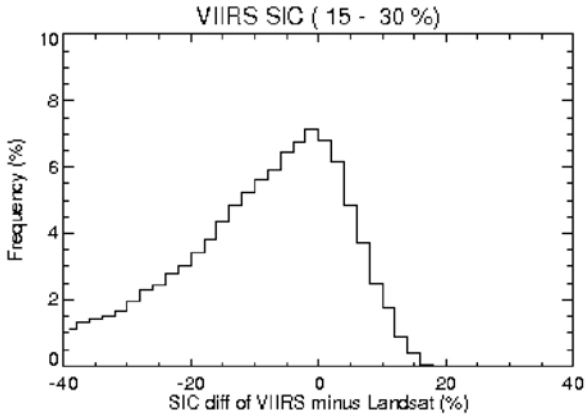
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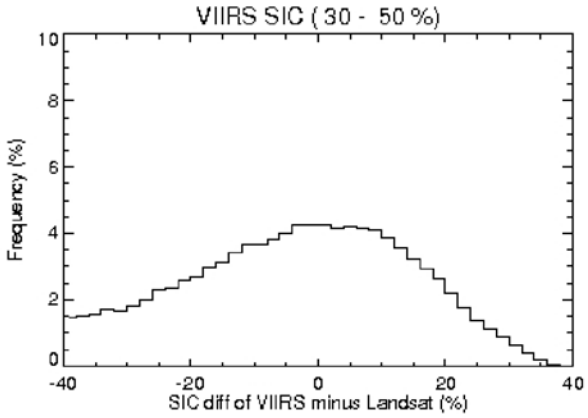


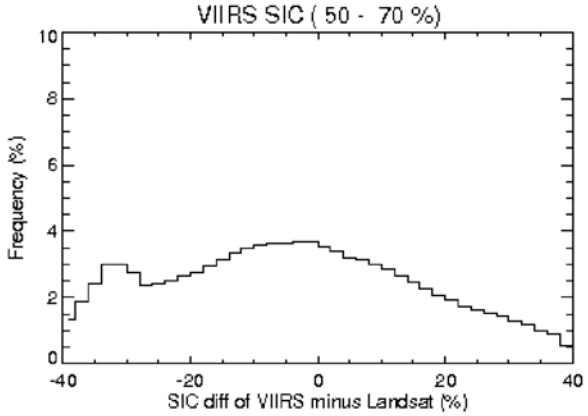
(**left**) Ice concentration (IC) derived from the Landsat image (30 m resolution); and (**right**) the calculated IC using the Suomi NPP VIIRS. White areas denote pixels flagged out as either land or cloud.

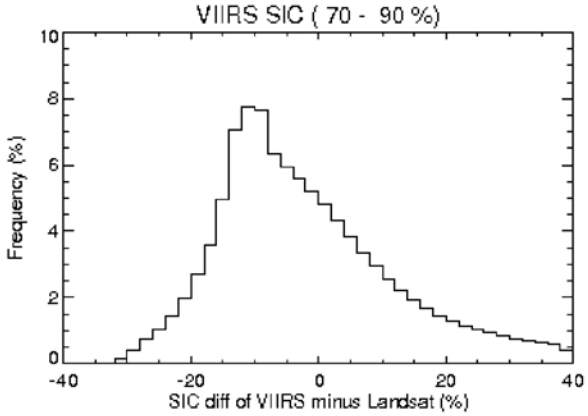
Validation

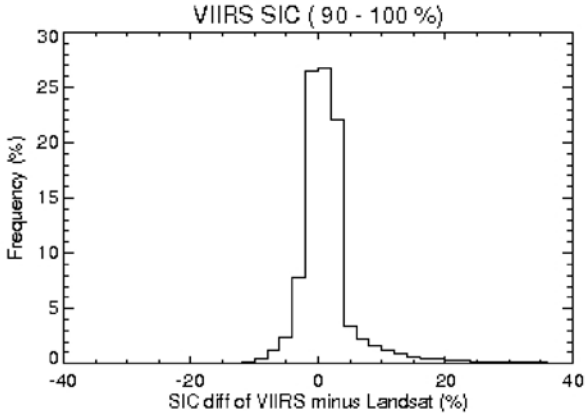












Comparison of VIIRS and Landsat ice concentrations for different concentration ranges/bins when a tie point adjustment scheme is employed.

Validation

Table 8. Bias and RMSE with bias removed (precision) for comparisons of VIIRS minus Landsat ice concentrations for different concentration ranges/bins after tie point adjustment.

	Overall	VIIRS SIC 15%–30%	VIIRS SIC 30%–50%	VIIRS SIC 50%–70%	VIIRS SIC 70%–90%	VIIRS SIC 90%–100%
Case number	2,480,093	6055	16,559	34,428	168,009	2,255,042
Bias (%)	1.4	−12.6	−9.1	−4.5	0.3	1.6
RMSE (%)	8.9	17.4	22.4	21.7	17.2	7.2

JPSS-1 Readiness

Future plan:

- Algorithm can be improved with further evaluation to include the tie point adjustment approach.
- Algorithm can be improved to produce higher spatial resolution products of I-band spatial resolution, with ice surface temperature with I-band spatial resolution available.
- Blended VIIRS ice concentration with microwave ice concentration will be valuable.
- Validation will be expanded with more Landsat data, historical SAR data, C-band SAR onboard Sentinel-1, and high optical imagery onboard Sentinel-2.

Summary and Path Forward

- The Suomi NPP and JPSS VIIRS Enterprise Ice Concentration product has high potential to become an extremely useful JPSS product.
- Performance evaluation based on comparisons with microwave and Landsat indicate that the VIIRS Ice Concentration meets the performance requirements, and is an useful product for identifying ice extent for both day and night for clear sky conditions.
- Further evaluation isneeded with new ice concentration products from sensors with very high spatial resolution onboard the newly launched European satellites.

VIIRS SEA ICE THICKNESS

Xuanji Wang[1] and Jeff Key[2]

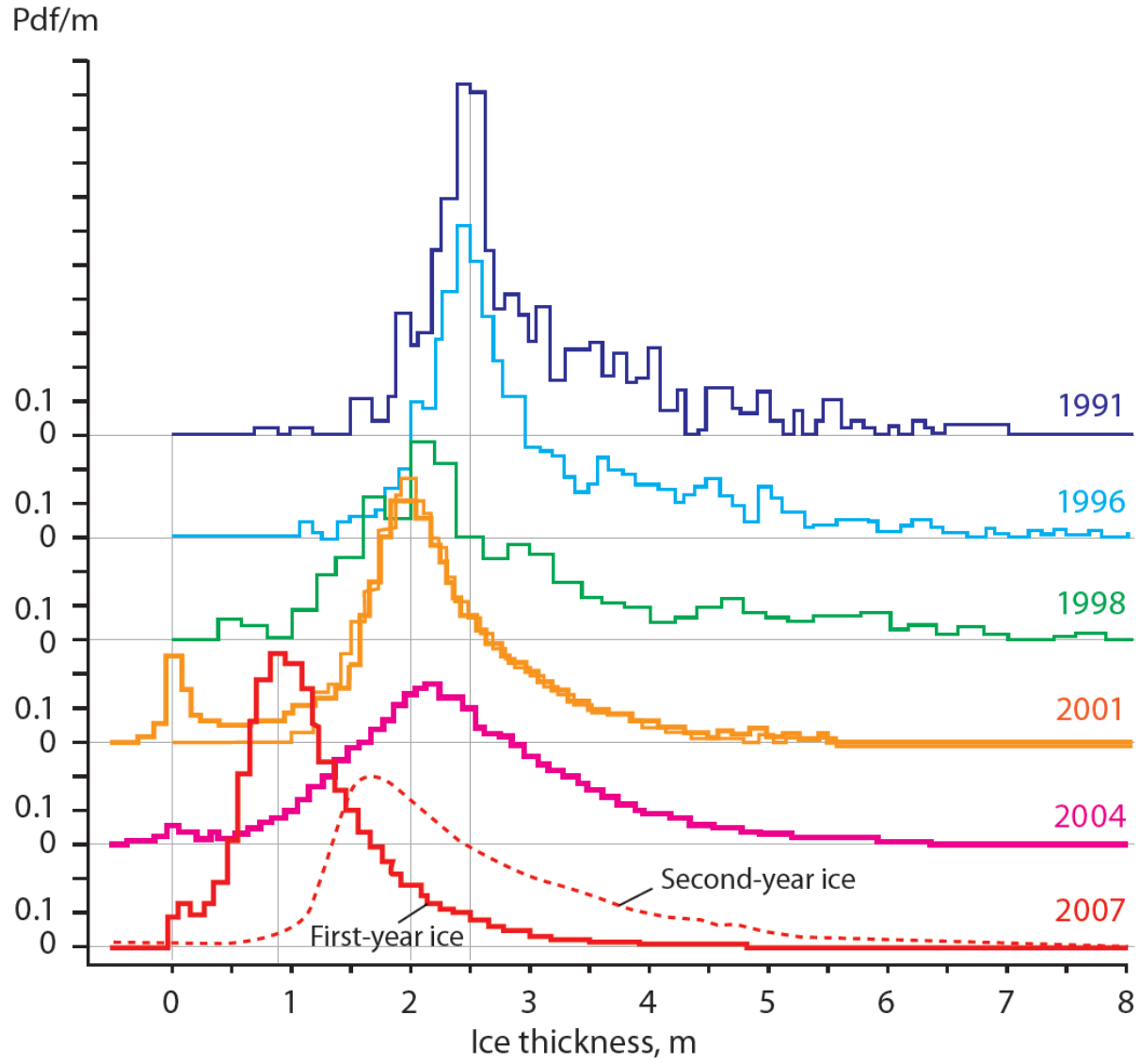
[1]Cooperative Institute for Meteorological Satellite Studies, U. Wisconsin-Madison, xuanji.wang@ssec.wisc.edu

[2]NOAA Satellite and Information Services, Madison, Wisconsin

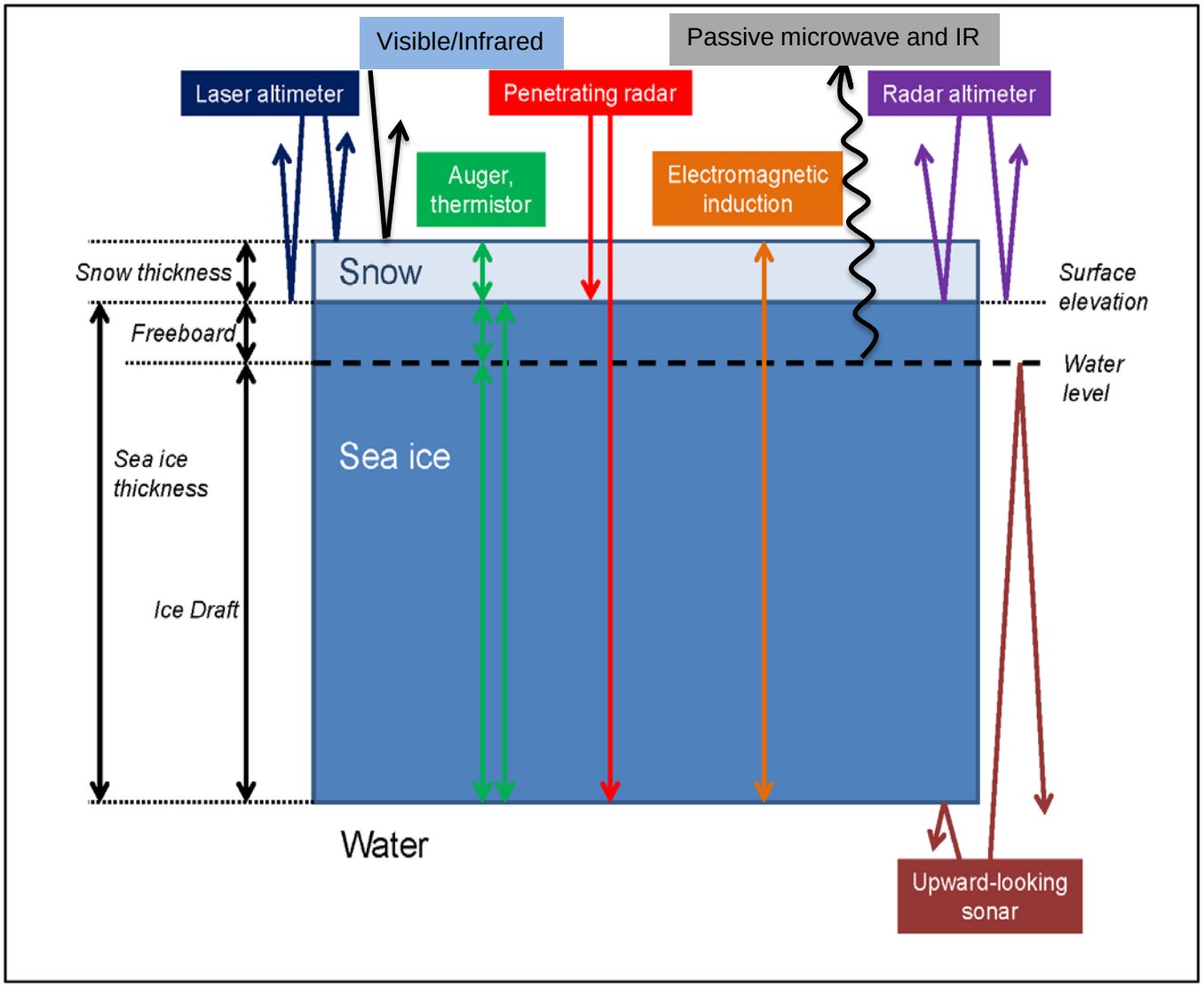
Ice Concentration Team

PI	Organization	Team Members	Roles and Responsibilities
J. Key	NESDIS	X. Wang (CIMSS)	Ice thickness development and cal/val
		M. Tschudi (CU/CCAR)	Ice thickness cal/val
		D. Baldwin (CCAR)	Ice thicknesscal/val

Arctic Sea Ice Thickness Distributions



Measuring Ice Thickness



(adapted from Meier et al., 2014)

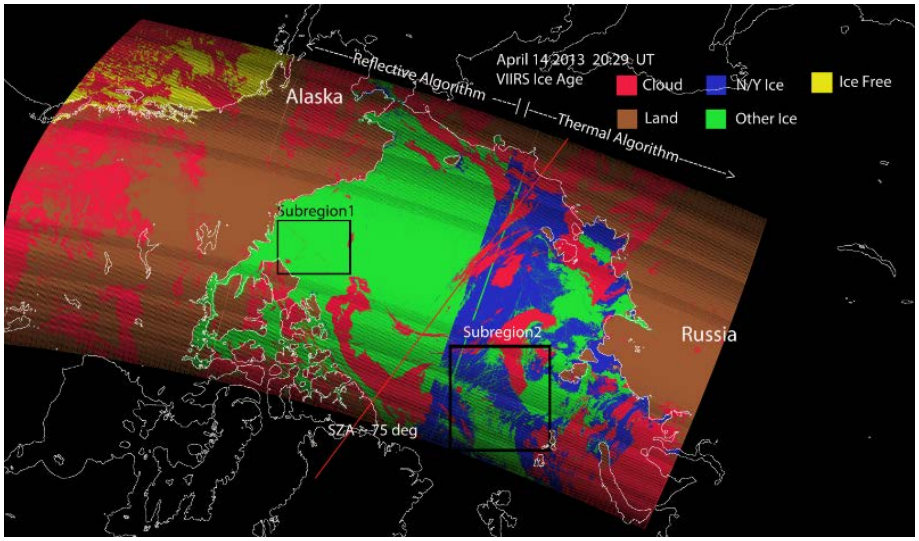
Requirements

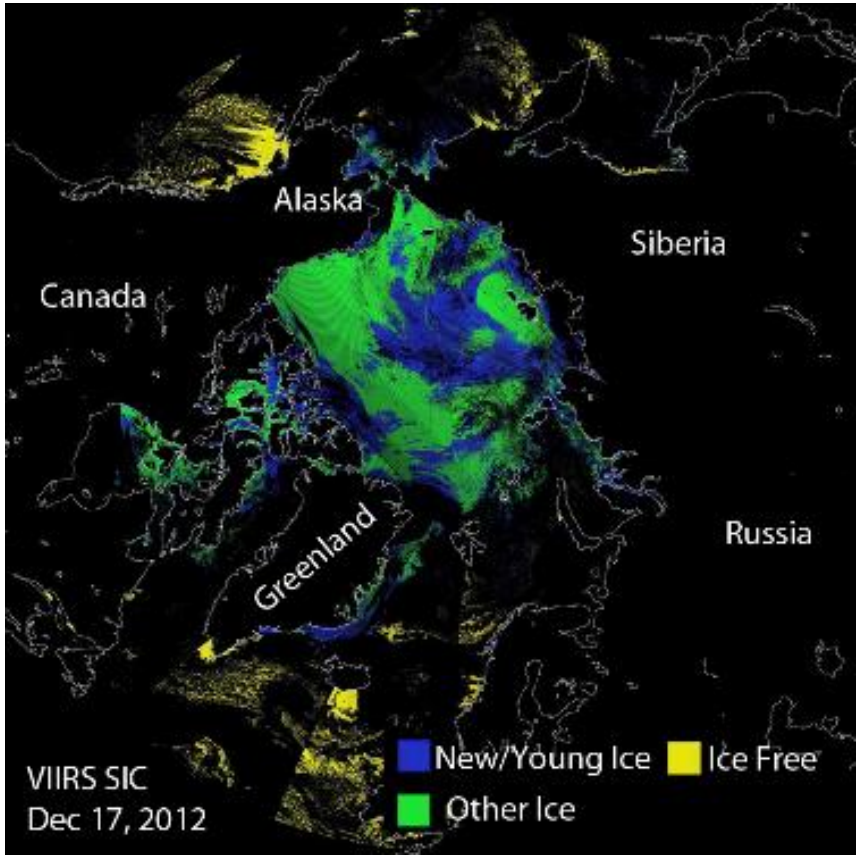
EDR Attribute	Threshold	Objective
a. Vertical Coverage	Ice Surface	Ice Surface
b. Horizontal Cell Size **1. Clear** **2. All weather**	 1.0 km No capability	 0.5 km 1 km
c. Mapping Uncertainty, 3 sigma **1. Clear** **2. Cloudy**	 5 km No capability	 0.5 km 1 km
d. Measure Range **1. Ice Age** **2. Ice Concentration**	 Ice Free, New Young, all other ice 0/10 to 10/10	 Ice free, Nilas, Grey, Grey-white, First Year Medium, First Year Thick, Second Year, Multiyear, Smooth and Deformed Ice 0/10 to 10/10
e. Measurement Uncertainty **1. Probability of Correct Typing (Ice Age)** **2. Ice Concentration**	 70% Note 1	 90% 5%
f. Refresh	At least 90% coverage of the global every 24 hours (monthly average)	6 hrs
g. Geographic coverage	All Ice-covered regions of the global ocean	All Ice-covered regions of the global ocean

Notes:
1. VIIRS produces a sea ice concentration IP in clear sky conditions, which is provided as an input to the ice surface temperature calculation

IDPS VIIRS Sea Ice Characterization EDR

- The operational (IDPS) VIIRS Sea Characterization EDR classifies the ocean surface as *Ice Free*, *New/Young* and *Other Ice*.
- Discrimination of New/Young ice from thicker ice is achieved by two algorithms: (1) Energy balance at night and (2) reflectance during the day.
- Many problems were found, including day-night inconsistency (see below).





Enterprise Ice Thickness Algorithm: The One-dimensional Thermodynamic Ice Model (OTIM)

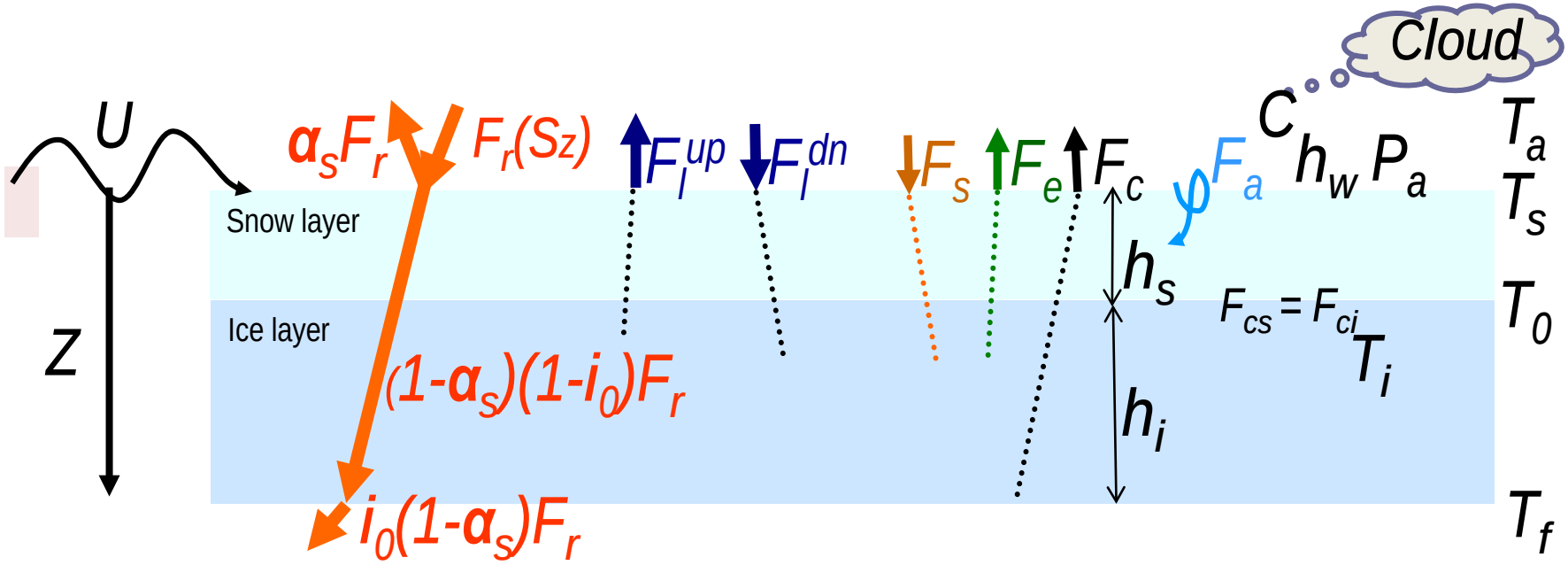
Based on the surface energy budget at thermo-equilibrium state, the fundamental equation is

$$(1-\alpha_s)(1-i_0)F_r - F_l^{up} + F_l^{dn} + F_s + F_e + F_c = F_a(\alpha_s, T_s, U, h_i, C, h_s, \ldots)$$

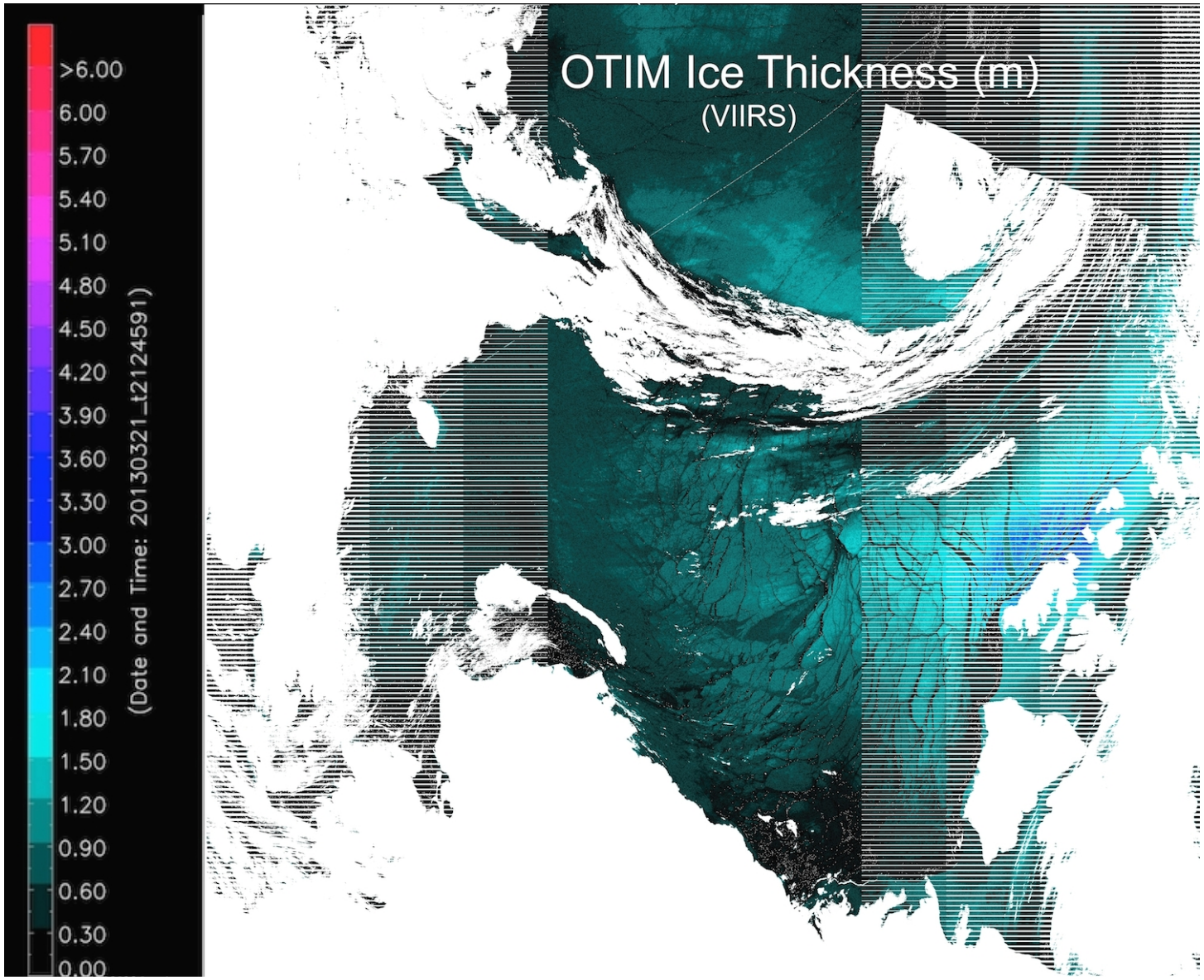
After parameterizations of thermal radiation (F_r, F_l^{up}, F_l^{dn}) and turbulent (sensible & latent) heat (F_s, F_e), ice thickness h_i becomes a function of 11 model controlling variables plus two factors:

$$h_i = f(\alpha_s, i_0, Sz, T_s, T_i, T_a, P_a, h_w, U, C, h_s, F_a, R_g, R_d),$$

where R_g, R_d are ice growth/melting and ice dynamic process adjustment factors.

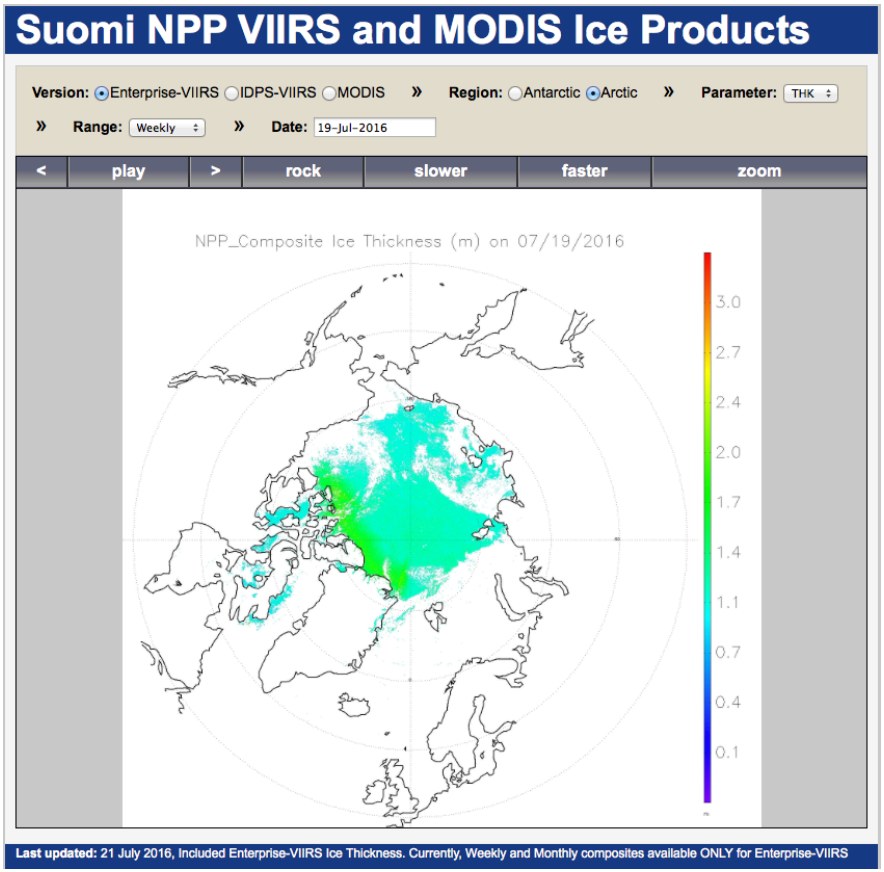


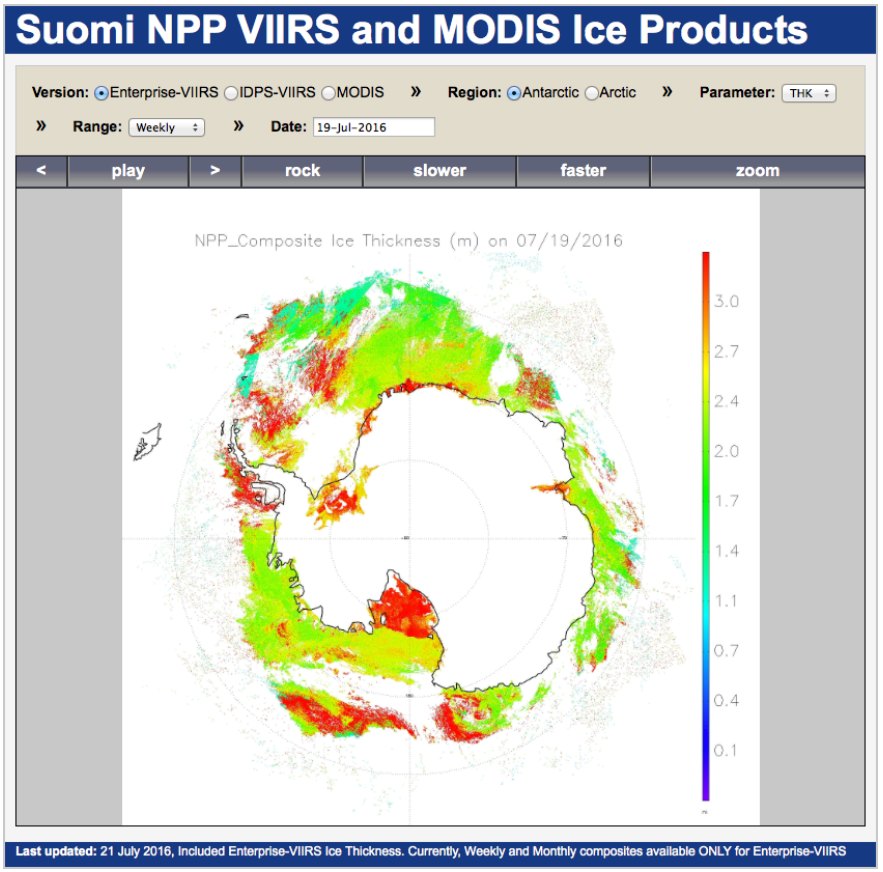
Example of OTIM Ice Thickness from VIIRS



Near real-time VIIRS Sea Ice Thickness

The OTIM retrieved near real-time Arctic and Antarctic sea ice thickness with Suomi NPP VIIRS data is now available at CIMSS. They will be added to the STAR LTM website in the near future.

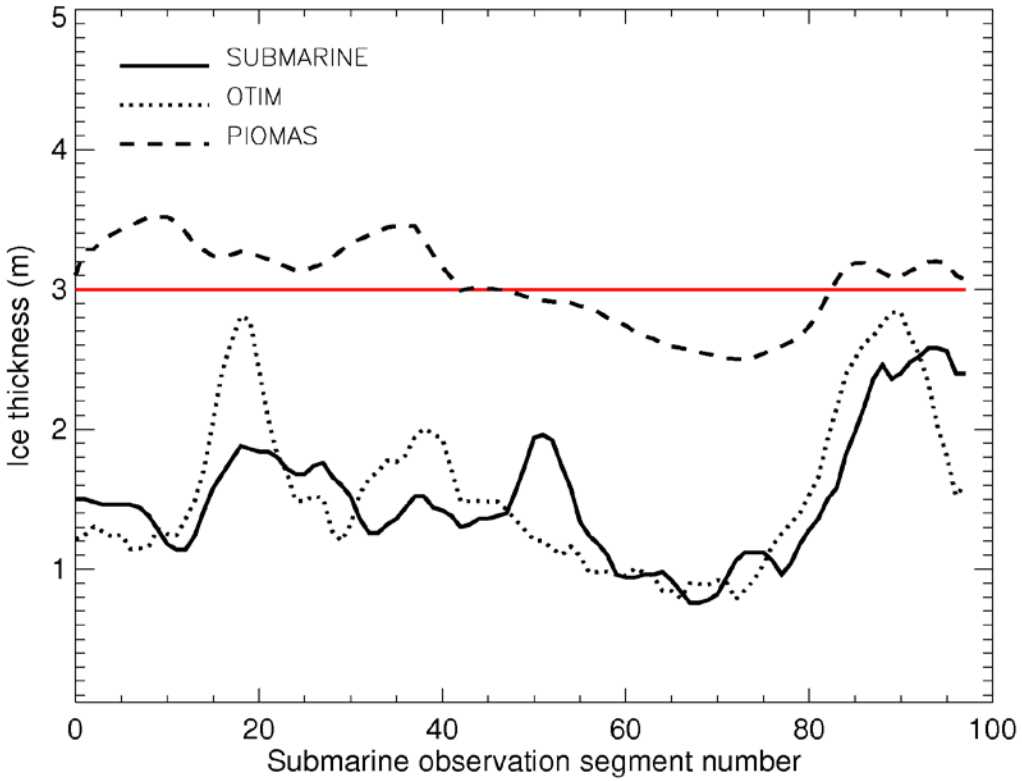




https://stratus.ssec.wisc.edu/ice-products/anibrowser/

Validation

Validation has been done with upward-looking sonar from submarines and moored buoys in situ thickness measurements ICESat, CryoSat-2, IceBridge, and an ice-ocean model.



Right: Validation with submarine sonar and modeled ice thicknesses.

	OTIM	Submarine
Thickness Mean (m)	1.55	1.51
Bias (m)	0.04	
RMS difference (m)	0.52	

Validation

Statistical results of the comparison in sea ice thickness between S-NPP and NASA IceBridge (aircraft lidar + snow radar) for matched locations (S-NPP pixels).

Case no	Date	S-NPP		IceBridge		S-NPP minus IceBridge			
		mean	STD	mean	STD	mean	STD	percent (%)	matched pixels
1	2014.03.12	1.18	0.52	1.45	0.69	-0.27	0.55	-5.34	495
2	2014.03.13	2.48	0.55	2.24	0.52	0.24	0.55	16.49	438
3	2014.03.24	1.88	0.78	2.33	0.48	-0.45	0.78	-6.31	803
4	2014.03.31	2.28	0.21	2.56	0.35	-0.28	0.43	-8.97	37
5	2015.03.24	2.06	0.59	2.45	0.43	-0.39	0.75	-11.63	1050
6	2015.03.29	1.72	0.43	1.88	0.54	-0.16	0.74	-1.69	5153
Average		1.93	0.50	2.15	0.50	-0.22	0.63	-2.91	7976 (total)

From 24 cases of S-NPP granule data when IceBridge has measurements, 6 cases out of the total 24 cases from S-NPP have good overlapped locations with IceBridge where they both have ice thickness values for comparison.

JPSS-1 Readiness

- Significant algorithm changes from S-NPP to JPSS-1:
  - Daytime-nighttime consistency has been significantly improved
- Post-Launch Cal/Val Plans
  - Most important new dataset will be ICESat-2 (delayed until early 2018)
  - IceBridge flights will continue to be important
  - Near real-time validation will be set up using SMOS and Cryosat-2
- Accomplishments and Highlights Moving Towards J1
  - Minor improvements to the model, e.g., residual heat flux that for better daytime (sunlit) retrievals
  - Near real-time generation
  - Application to 30+ years of AVHRR
- Major Risks/Issues/Challenges/ and Mitigation
  - Limitations need to be made clear to users, e.g., upper limit of ice thickness retrieval (~3 m) and larger uncertainty in melt conditions
  - Ultimately, either a VIIRS product adjusted by Cryosat/ICESat thicknesses, or a blended product may provide the best estimate.

Summary & Path Forward

- Summary
  - The **VIIRS Ice Thickness/Age product is ready for J1**
- Path Forward
  - FY17 Milestones: Add ICESat-2 to validation plans (CY 2018); begin to test regional bias corrections with altimeter-based ice thickness
  - Alternate Algorithms and Future Improvements: no alternate algorithms; add VIIRS surface radiation

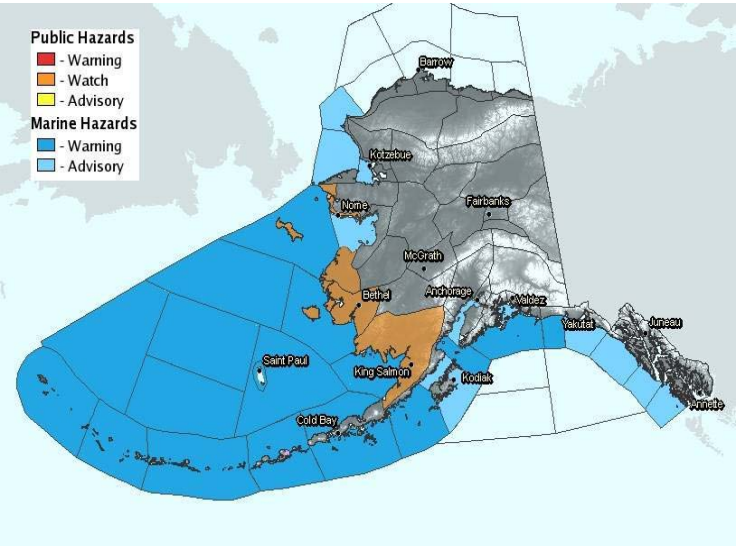
Snow and Ice Product Users (planned)

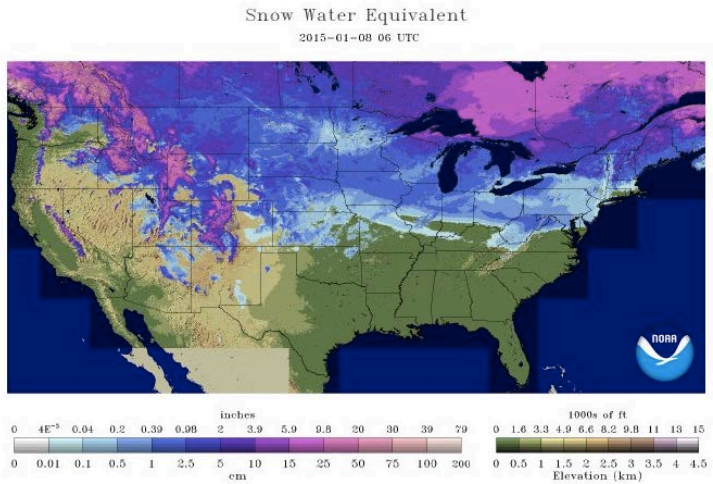
Operational Ice Services

- U.S. National Ice Service
- North American Ice Service
- NWS Alaska Sea Ice Program

Modeling

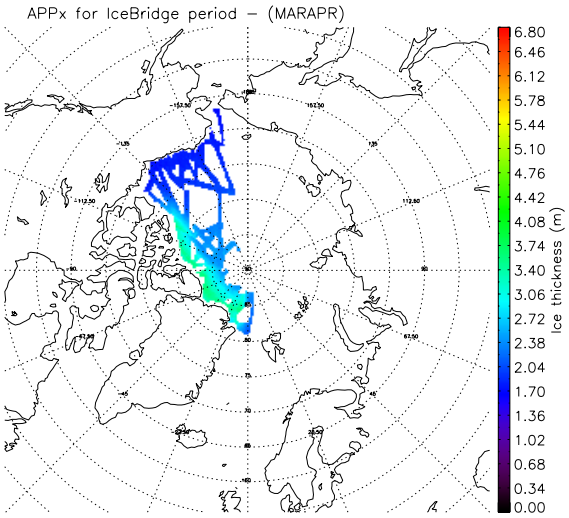
- (Need to set up collaborations and funding) Naval Research Lab, Arctic Cap Nowcast/Forecast System (ACNFS), NCEP
- Universities (Washington, Hamburg)



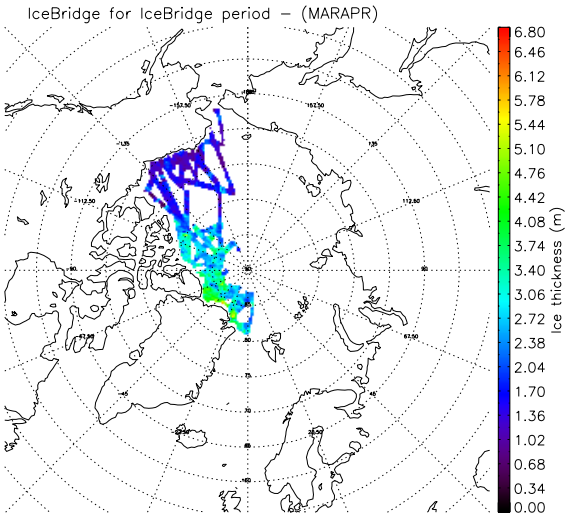


Intercomparison for IceBridge Period, 03/2011 - 04/2013

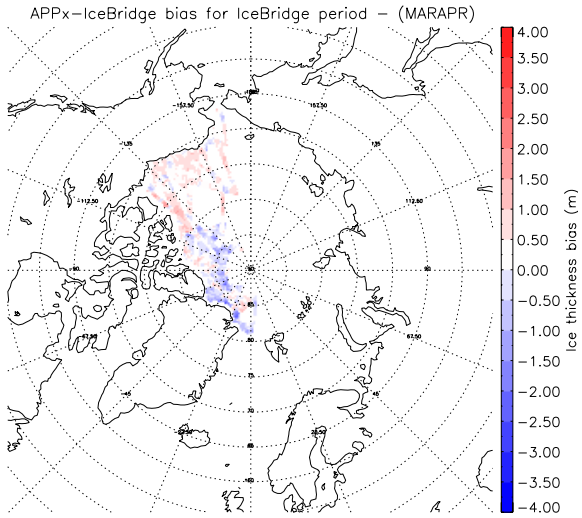
APP-x

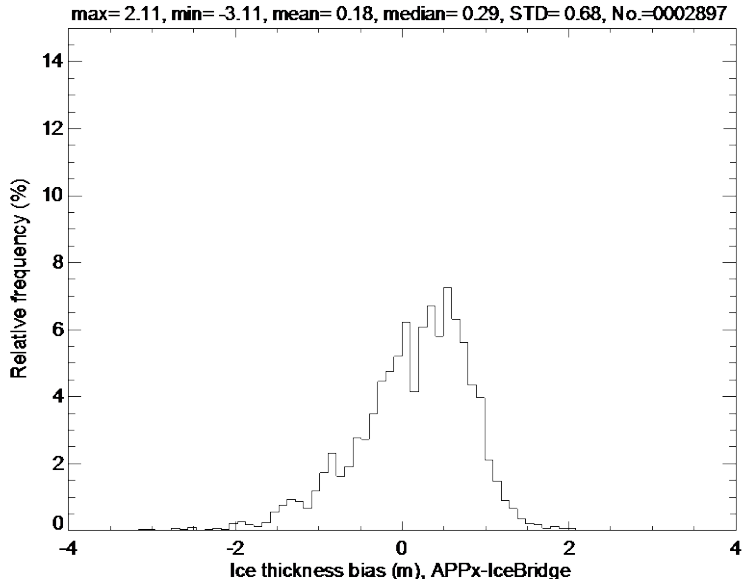


IceBridge



Bias (APP-x minus IceBridge)





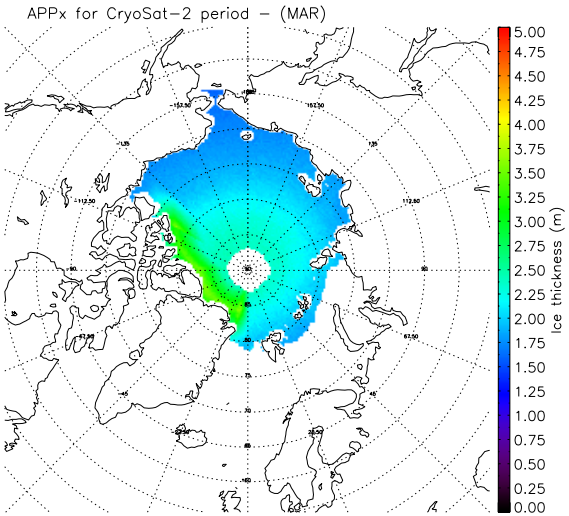
Bias statistics:

mean = 0.18 m
STD = 0.68 m
Median = 0.29 m
Mode = 0.00 m
Skewness = -0.88

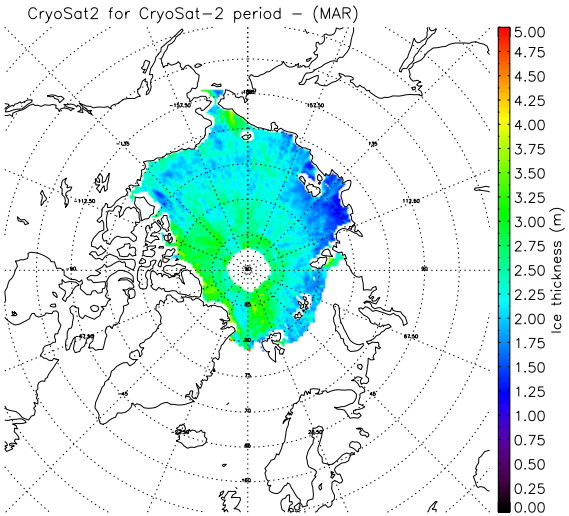
Correlation = 0.70

Intercomparison for CryoSat-2 Period, 01/2011 - 03/2013

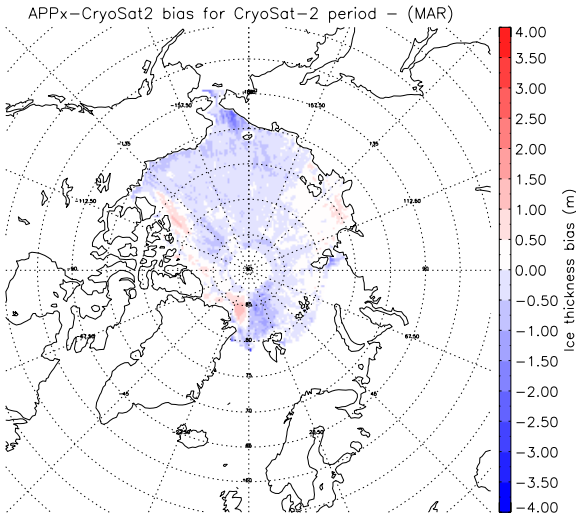
APP-x

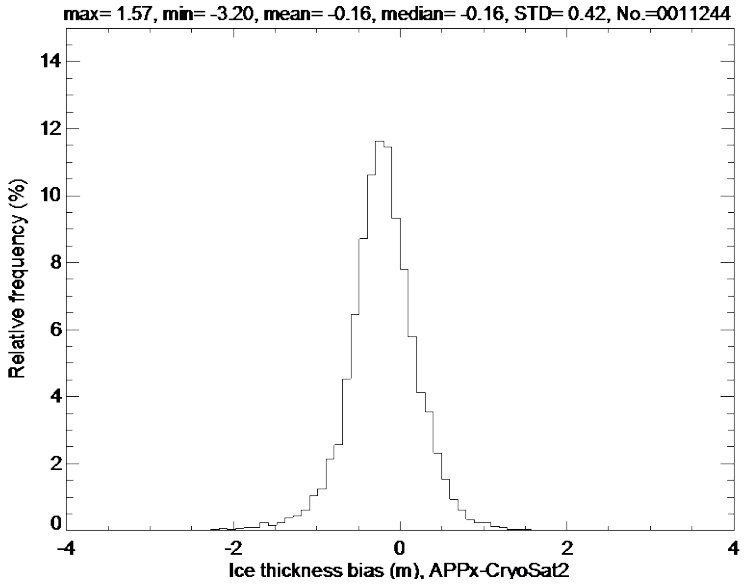


CryoSat-2



Bias (APP-x minus CryoSat-2)





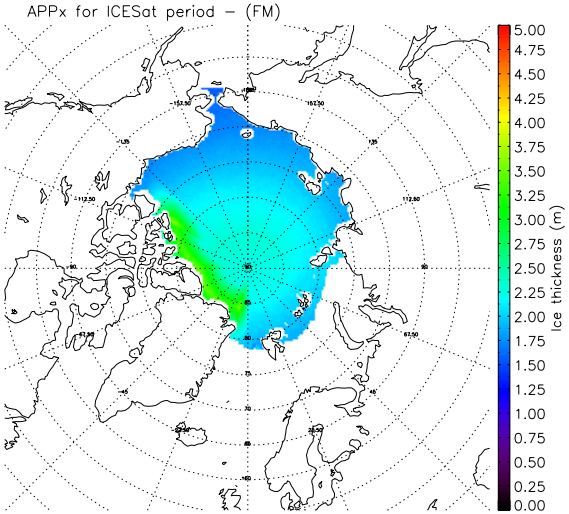
Bias statistics:

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STD = 0.57 m
Median = -0.16 m
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Skewness = -0.90

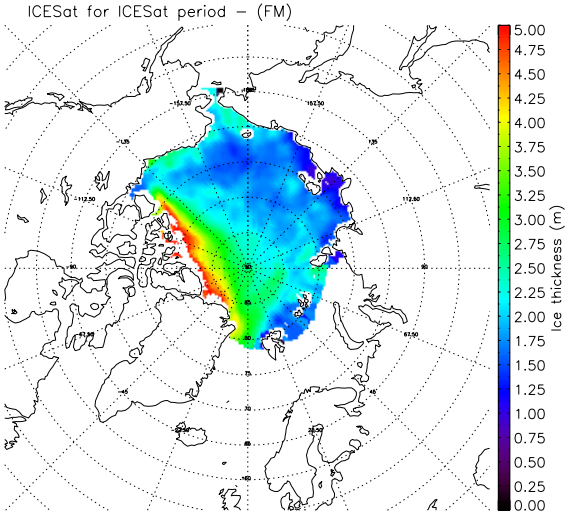
Correlation = 0.66

Intercomparison for ICESat Period, 09/2003 - 03/2008

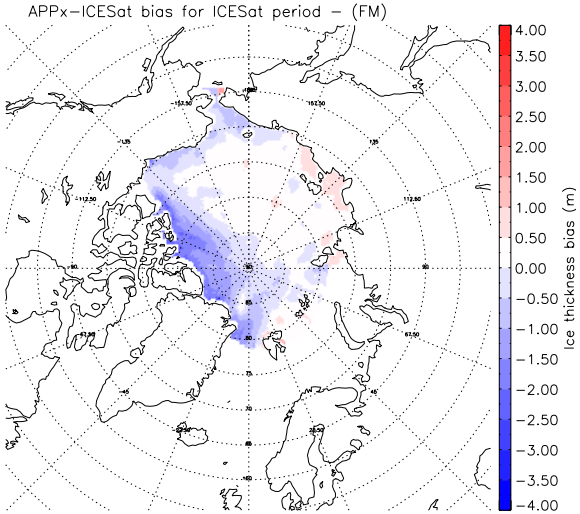
APP-x

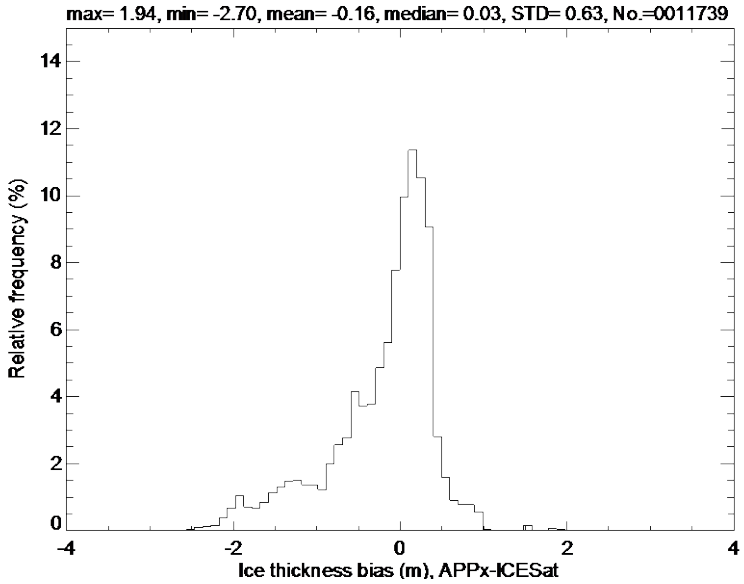


ICESat



Bias (APP-x minus ICESat)





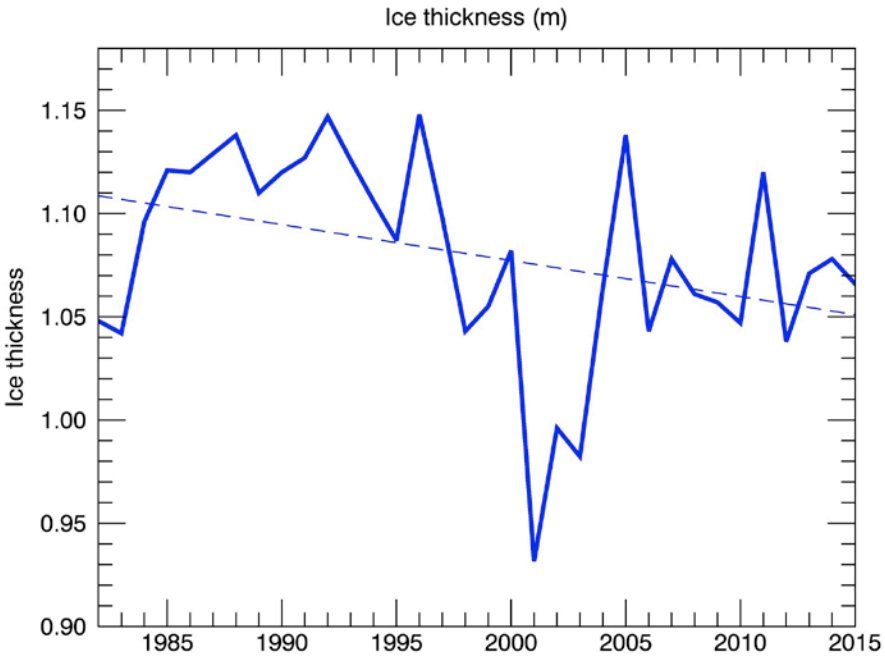
Bias statistics:

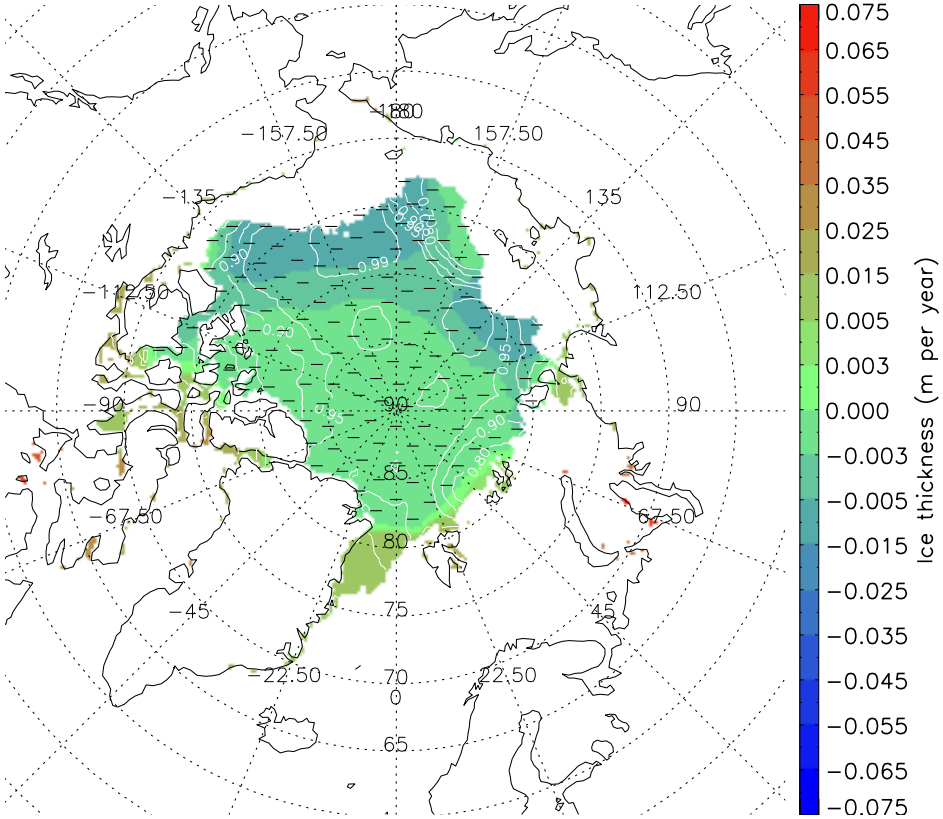
mean = -0.16 m
STD = 0.63 m
Median = 0.06 m
Mode = 0.00 m
Skewness = -1.13

Correlation = 0.71

Arctic Sea Ice Thickness Trend in September, 1982-2015

OTIM retrieved Arctic sea ice thickness trend in September with the APP-x data, 1982-2015.

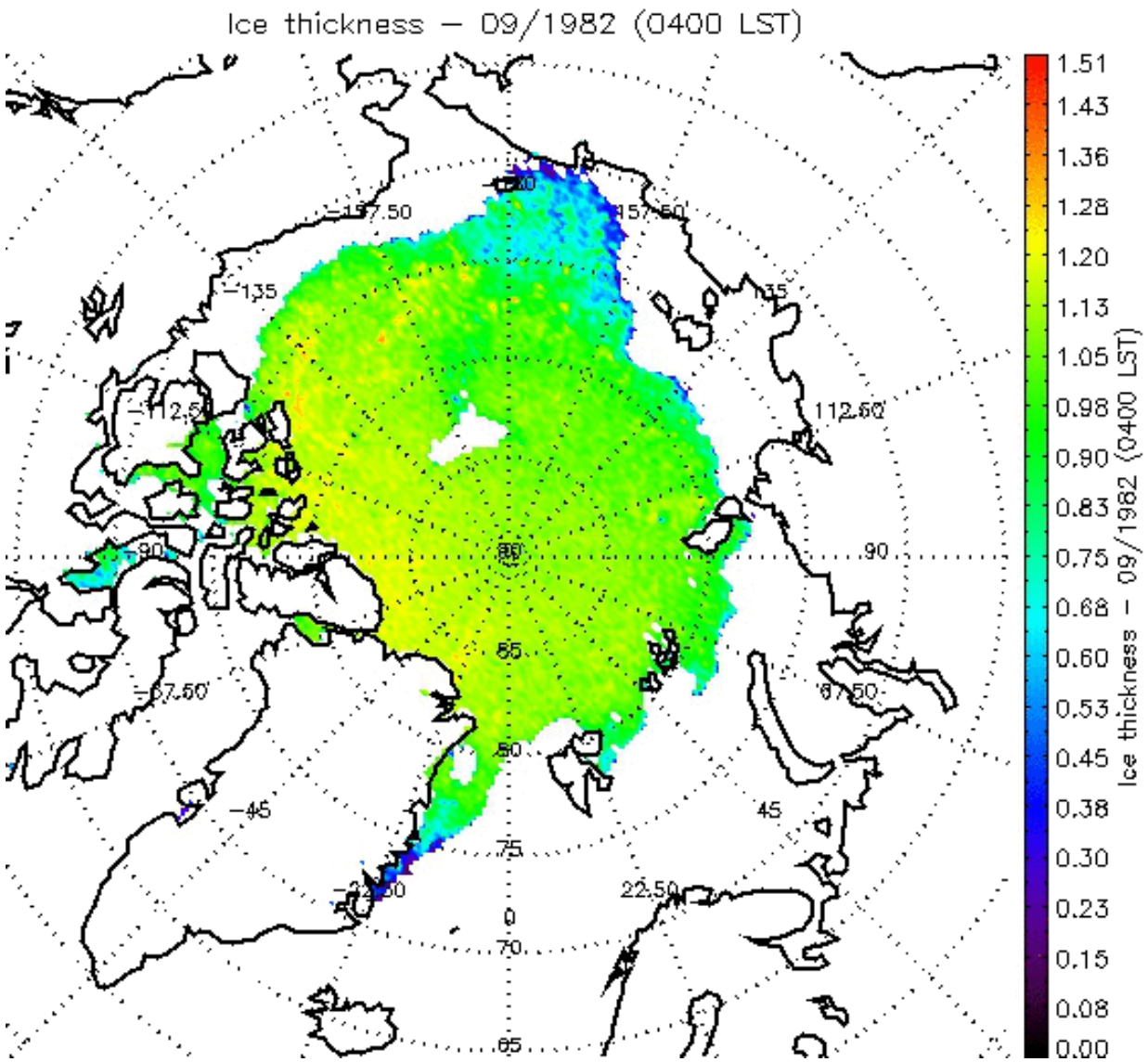




Trend : -1.74 ± 0.81 cm per decade for the Arctic ocean north of 60ºN.

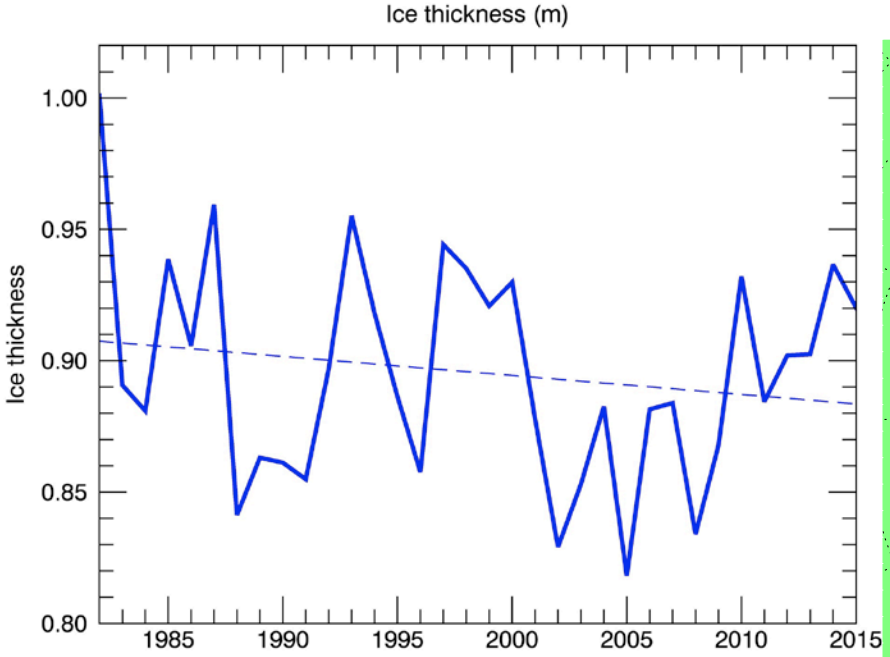
(Statistical Significance level = 0.96)

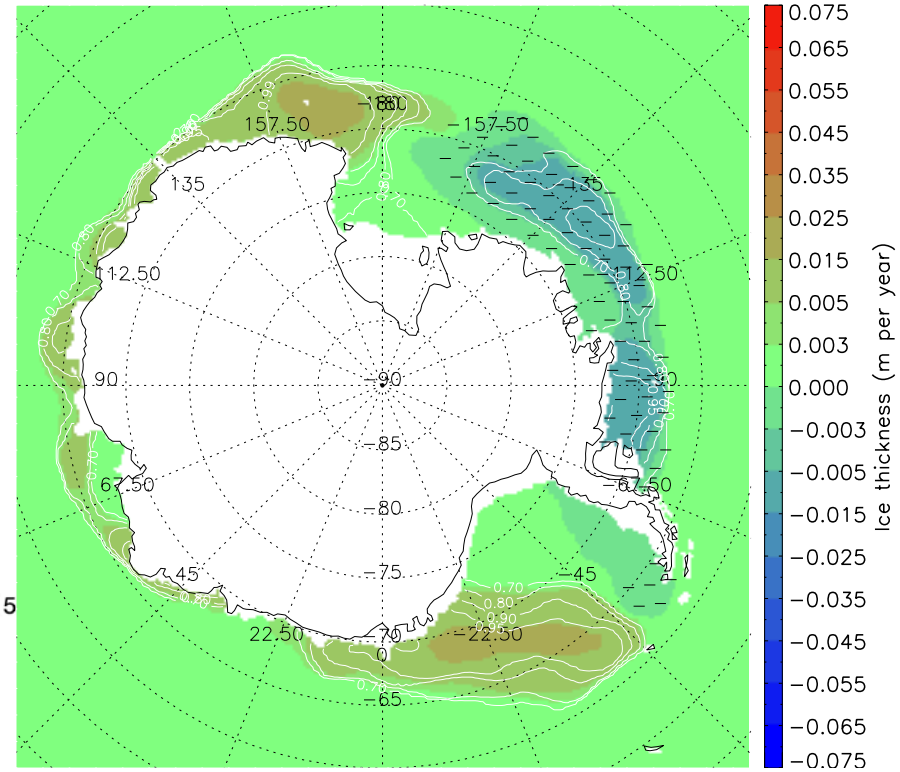
Arctic Sea Ice Thickness Trend in September, 1982-2015
(Movie Clip)



Antarctic Sea Ice Thickness Trend in April, 1982-2015

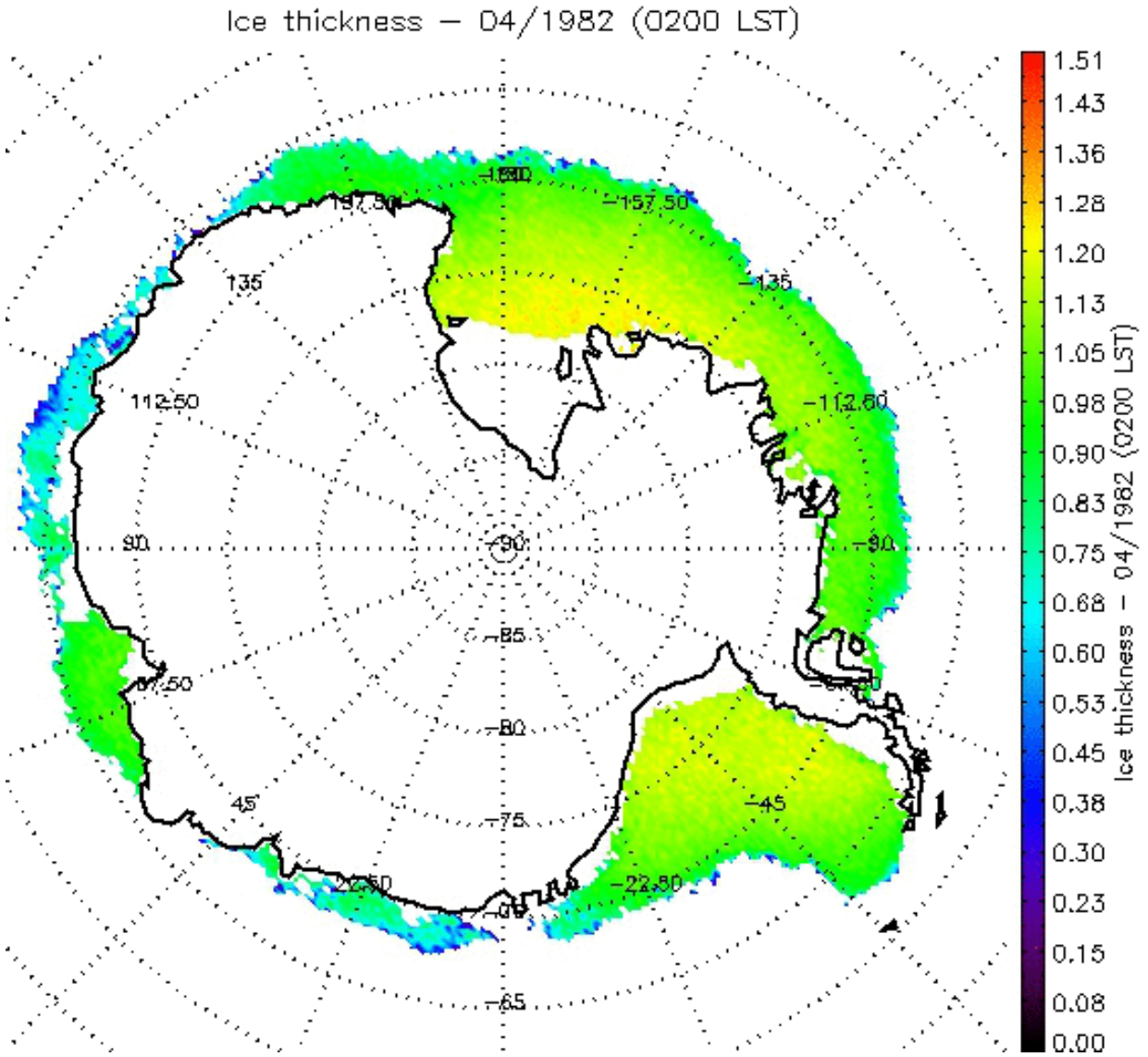
OTIM retrieved Antarctic sea ice thickness trend in April with the APP-x data, 1982-2015.





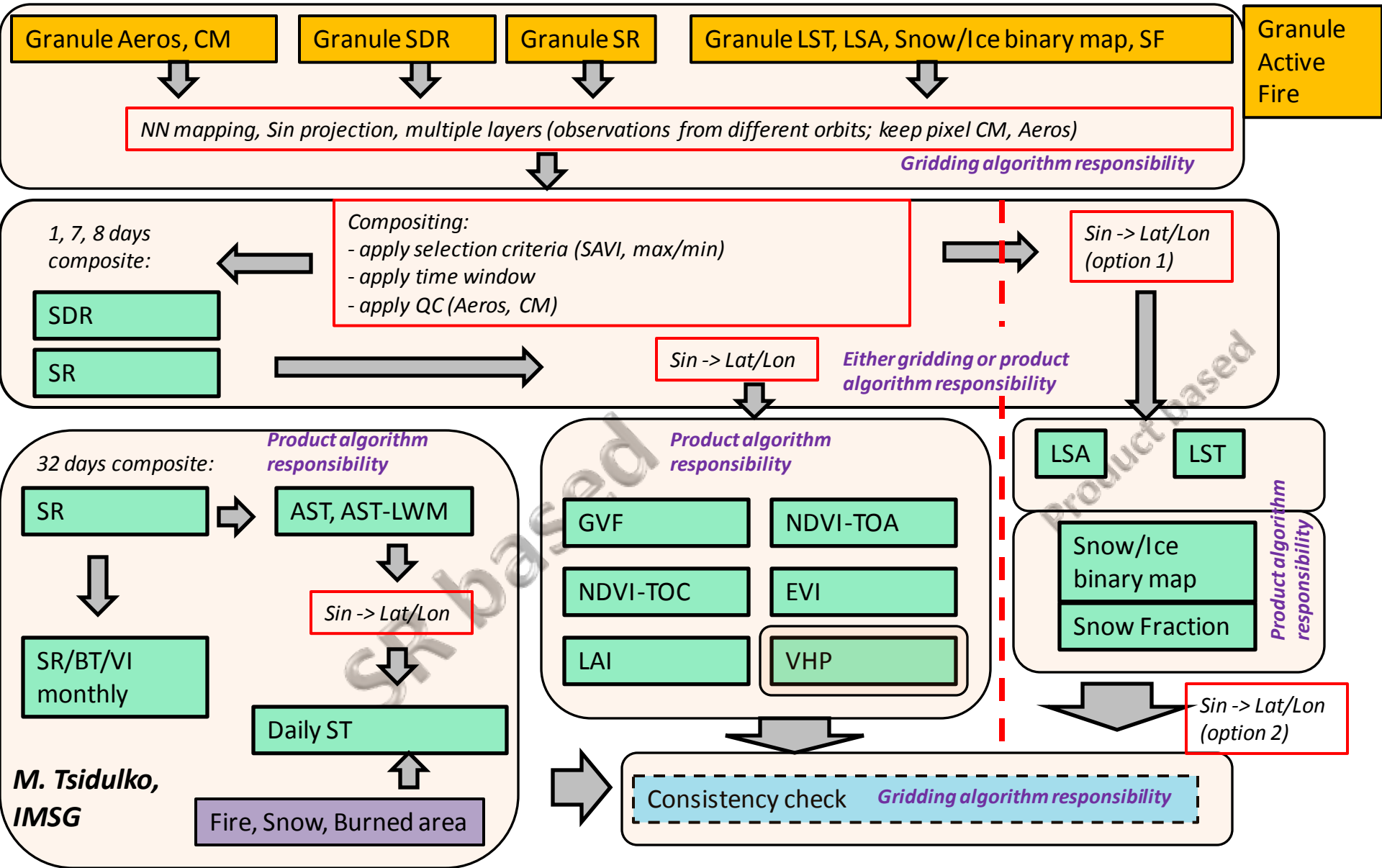
Trend : -0.72 ± 0.73 cm per decade for the Antarctic ocean south of 60°S.
(Statistical Significance level = 0.67)

Antarctic Sea Ice Thickness Trend in April, 1982-2015
(Movie Clip)



Enterprise land / cryosphere production system status (discussion)

Schematic view of proposed Land Enterprise System



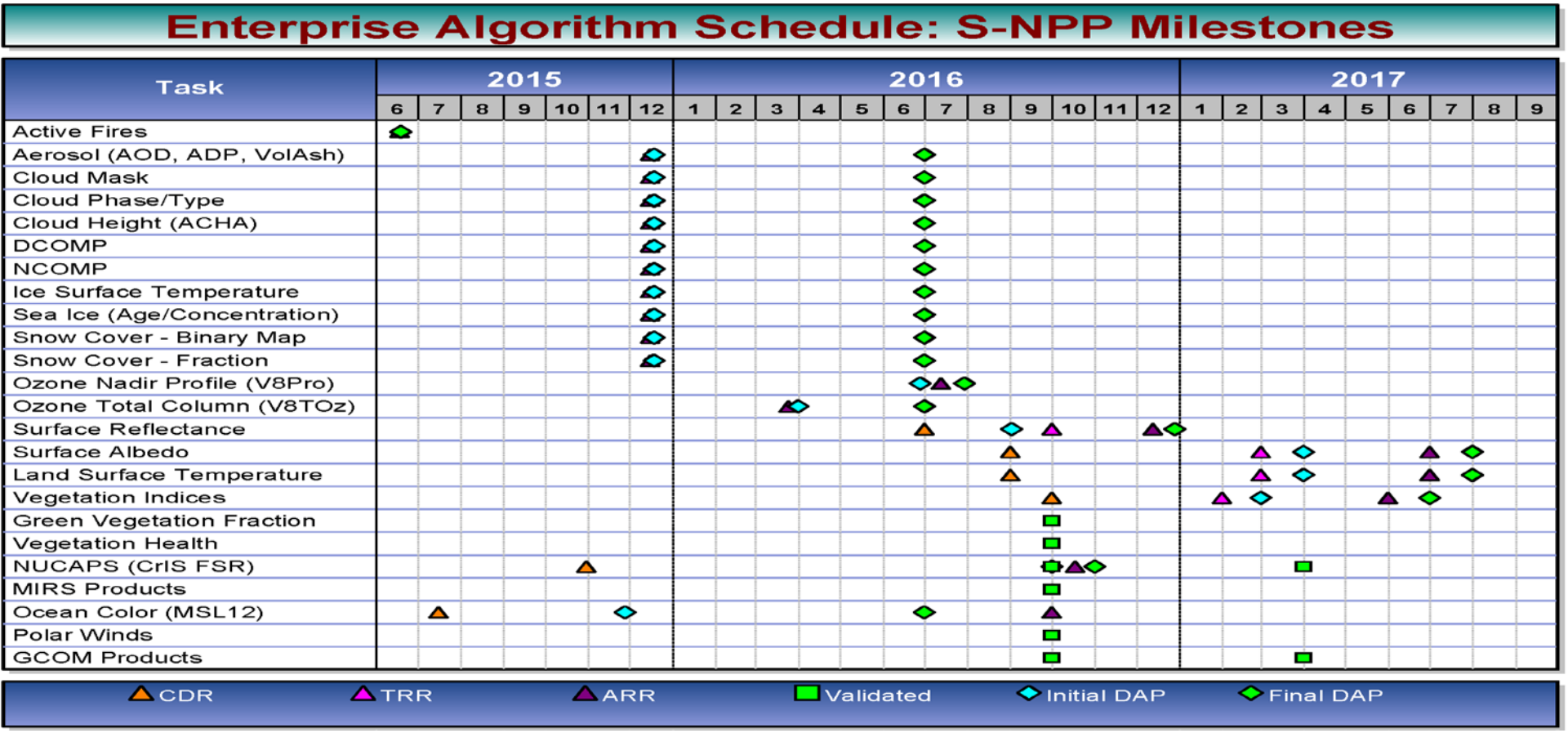
Enterprise algorithm status

Enterprise		
Aerosol Detection (VIIRS)	Global Surface Type (VIIRS)*	Rainfall Rate (ATMS)
Active Fires (VIIRS)	Green Vegetation Fraction (VIIRS)	Sea Ice Characterization (AMSR-2)
Aerosol Optical Depth(VIIRS)	Ice Age/Thickness (VIIRS)	Sea Surface Temperature (AMSR-2)
Aerosol Particle Size (VIIRS)	Ice Concentration (VIIRS)	Sea Surface Temperature (VIIRS)
Albedo (Surface) (VIIRS)	Ice Concentration (ATMS)	Sea Surface Wind Speed (AMSR-2)
AMSR Calibrated Sensor Data (AMSR-2)	Ice Surface Temperature (VIIRS)	Snow Cover/Depth (AMSR-2)
Atmospheric Vertical Moisture Profile (CrIS/ATMS)	Imagery (AMSR-2)	Snow Cover (ATMS)
Atmospheric Vertical Temperature Profile (CrIS/ATMS)	Imagery (ATMS)	Snow Cover (VIIRS)
Carbon Dioxide (CO) (CrIS)**	Infrared Ozone Profile (CrIS)	Snow Water Equivalent (ATMS)
Carbon Monoxide (CO2) (CrIS)**	Land Surface Emissivity (ATMS)	Snow Water Equivalent (AMSR-2)
Cloud Cover/Layers (VIIRS)	Land Surface Temperature (VIIRS)	Soil Moisture (AMSR-2)
Cloud Height (Top and Base) (VIIRS)	Land Surface Temperature (ATMS)	Surface Reflectance (VIIRS)
Cloud Liquid Water (AMSR-2)	Methane (CH4) (CrIS)**	Surface Type (AMSR-2)
Cloud Liquid Water (ATMS)	Moisture Profile (ATMS)	Temperature Profile (ATMS)
Cloud Mask (VIIRS)	Ocean Color/Chlorophyll (VIIRS)	Total Precipitable Water (AMSR-2)
Cloud Optical Depth (VIIRS)	Outgoing Longwave Radiation (CrIS)	Total Precipitable Water (ATMS)
Cloud Particle Size Distribution (VIIRS)	Ozone Nadir Profile (OMPS-N)	Vegetation Indices (VIIRS)
Cloud Phase (VIIRS)	Ozone Total Column (OMPS-N)	Vegetation Health Index Suite (VIIRS)
Cloud Top Pressure (VIIRS)	Polar Winds (VIIRS)	Volcanic Ash Detection And Height (VIIRS)
Cloud Top Temperature (VIIRS)	Precipitation (Type/Rate)(AMSR-2)	

Already available in ESPC	Expected to be operational in NDE 1.0 soon	Will be available when NDE 2.0 is operational	Will be available soon after NDE 2.0 is operational	Implementation in NDE planned in 2017

A. Layns JPSS; L. Zhou, STAR

Enterprise implementation schedule



L. Zhou, STAR

Land / cryosphere enterprise implementation schedule

- Algorithm readiness
  - Surface reflectance: February 2017
  - VI, LST, LSA: August 2017
  - Active Fire – already operational
  - Surface Type – annual updates
  - Snow Cover / fraction – in transition
  - Ice Surface Temperature – in transition
  - Sea Ice (Age/Concentration) – in tranition
- Two-phased approach
  - granule-based products
  - global gridded composites
- JPSS-1 readiness in general is confirmed
  - Evaluated test datasets provided to STAR
  - Ran select algorithms in STAR environment
    - Further interaction with NDE needed for pre-launch testing

ECM Format Basics

- The primary output of the ECM is the cloud probability for each VIIRS M-band pixels (CloudProbability in the netCDF file)
- A 4-tier cloud mask with the same categories as with the VCM may be found as well (CloudMask)
- The binary cloud mask, generally not used but required as an output, is found in CloudMaskBinary
- We encourage users to employ cloud probability, as in that form the users may set whatever value they close to determine clear or cloudy conditions
- The breakdown of the individual elements is found in CloudMaskPacked
  - It is not in CloudMaskFlags, there is no use of this for VIIRS based output

Individual ECM Outputs

- The description of the individual bits in the 8 byte CloudMaskPacked output is found in Table 4 of the ECM ATBD
  - For those who have the current version, be aware the Surface Type values given are off by one (Deep Water is 001, Shallow Water 010, etc.)
- Note the original ECM was developed for GOES-R, and hence there are embedded tests that are not applicable to VIIRS
  - BTM11
  - RTCT
  - BTD11_6.7 thermal contrast
  - BTD11_6.7 thermal covariance
  - EMISS4
  - Ref0.63STD
- Each of the other tests are used as described in the ATBD

T. Kopp, Aerospace; A. Heidinger, STAR

Individual ECM Outputs

- The individual cloud detection tests, contained in bytes 3 through 7, may be 00 (clear), 01 (probably clear), 10 (probably cloudy), or 11 (cloudy)
- The 6 unused cloud detection tests will always contain values of 00
- The remaining tests will contain a climatological value for conditions where they are not executed (e.g. reflective tests at night)
  - Be aware this default value is often one of the probable conditions, and it can vary with surface type
  - The internal logic of the ECM knows when a value is from climatology and when it has been determined by internal logic
  - The thin cirrus bit is a special case and will be described in an update to the ECM ATBD

T. Kopp, Aerospace; A. Heidinger, STAR

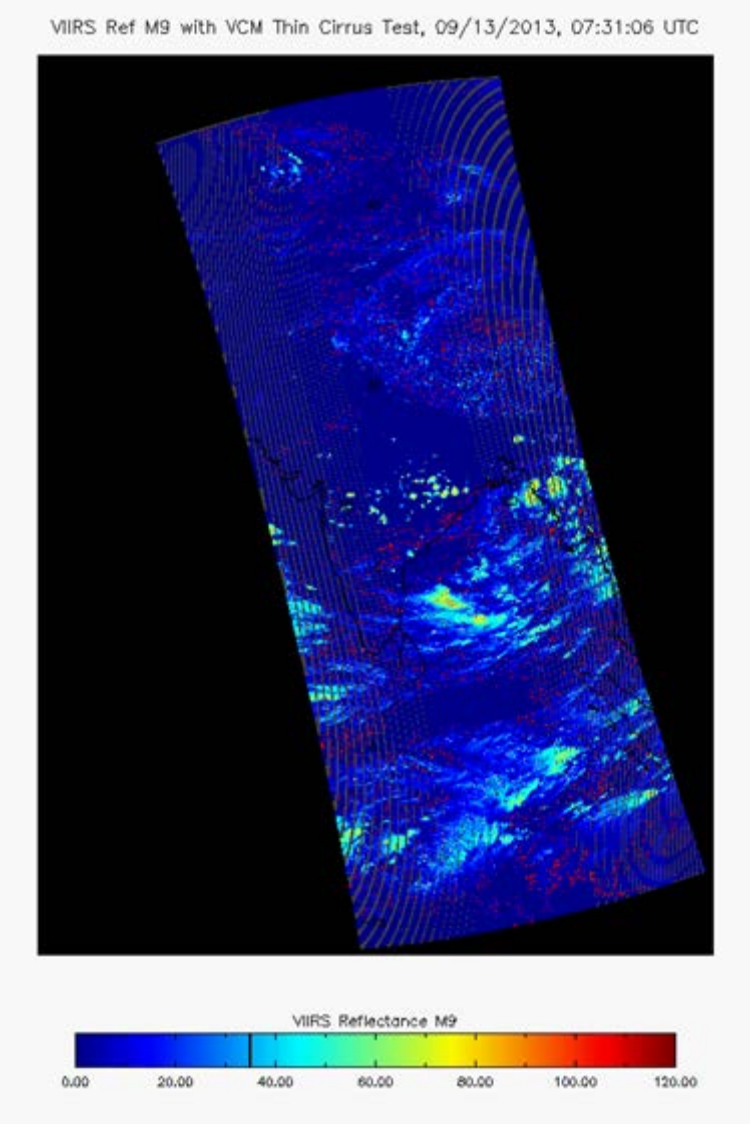
Thin Cirrus Addition

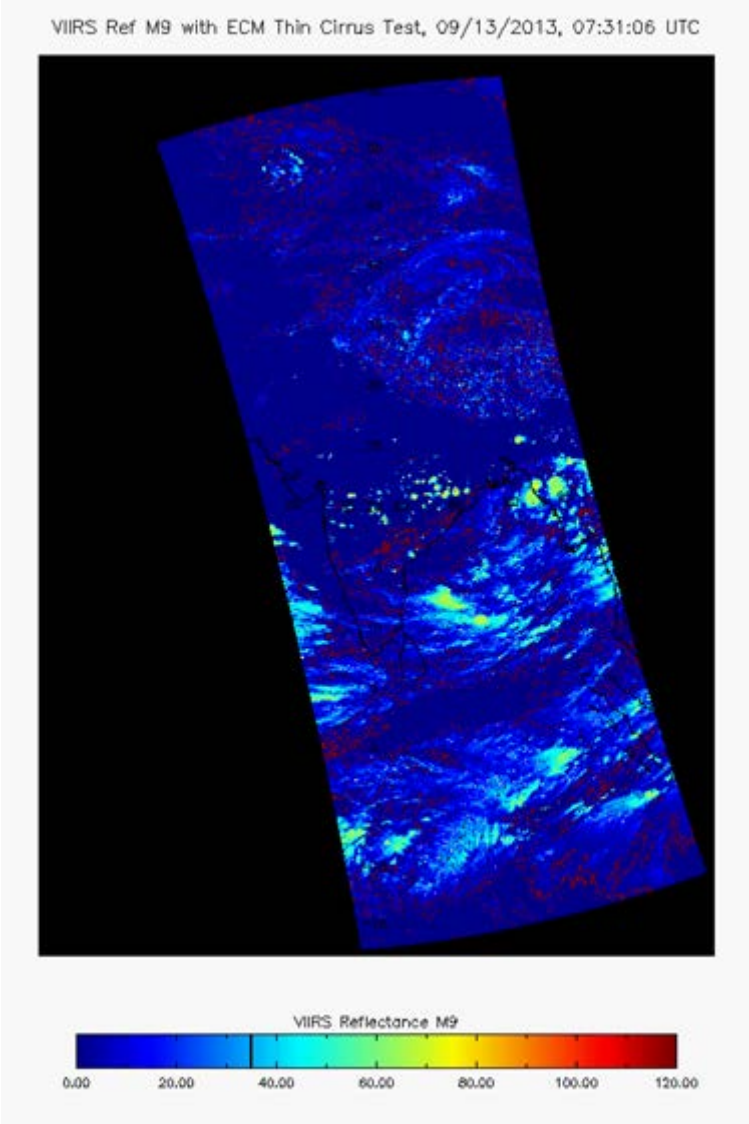
- Users asked to provide a Thin Cirrus bit in the Packed Bits Structure.
- Logic for Thin Cirrus in the ECM will be similar to that used in the VIIRS Cloud Mask (VCM)
- Thin Cirrus test development is nearly complete and will be part of the August 2016 delivery
- As will be shown, thin cirrus will be yes/no and not the same as the other cloud detection tests

T. Kopp, Aerospace; A. Heidinger, STAR

Thin Cirrus Test

VCM





ECM

T. Kopp, Aerospace; A. Heidinger, STAR

ECM Bit Structure

- Proposed Place to Ingest Thin Cirrus Test bit to ECM

Byte	Bit	Flag Description Key	Result
2	0-2	Surface Type Used for Thresholds	001 = Deep Ocean 010 = Shallow Water 011 = Land 100 = Snow 101 = Arctic 110 = Antarctic + Greenland 111 = Desert
	3	Thin Cirrus Test	0 = Clear 1 = Cloudy
	4-5	BT11 – 11 μm Thermal Test	00 = Clear 01 = Probably Clear 10 = Probably Cloudy 11 = Cloudy
	6-7	RTCT – Relative Thermal Contrast Test	00 = Clear 01 = Probably Clear 10 = Probably Cloudy 11 = Cloudy

Table 4. Cloud mask tests and flags and their descriptions.
A Naïve Bayesian Cloud Mask Delivered to NOAA Enterprise ATBD.
Version 1.1, June 3rd, 2016.

T. Kopp, Aerospace; A. Heidinger, STAR

Suomi NPP Reprocessing Status

8/11/2016

Fuzhong Weng, Changyong Cao,
Lihang Zhou, Taeyoung (Jason) Choi,
NOAA VIIRS SDR/ICVS,
NOAA Ocean Color,
NASA VCST,
& Aerospace Corp.

Outline

- Introduction
- Algorithm Updates and Issues
  - Reflective Solar Bands (RSB)
  - Thermal Emissive Bands (TEB)
  - Day Night Band (DNB)
- Provisional Schedule
  - Processing capability
- Summary

Introduction

- S-NPP VIIRS SDR product needs to be reprocessed
  - To improve early lifetime SDR data in all RSB, TEB and DNB.
- Anomalies in RSB
  - Sudden H-factor updates in 2014
  - Long-term differences between SD and lunar F-factors
  - Possible degradation in SWIR bands
  - Applying lunar F-factor into SD F-factors
- TEB Warm-Up-Cool-Down (WUCD) issues with SST
  - Option 1 : Aerospace solutions
  - Option 2: NOAA VIIRS SDR team's current progress
- DNB improvements
  - Initial calibration changes
  - DNB Relative Spectral Response (RSR) changes
  - Updated VROP for DN0 (bias)
  - Stray light LUT update

Algorithm Updates & Issues in RSB

- Significant F-factor discontinues were found in bands M1~M4 (up to 1.5% differences in band M1) cause by sudden H-factor (Solar Diffuser degradation).
- Initial VIIRS SDR products in early 2012 need to be updated with new RSB F-factors.

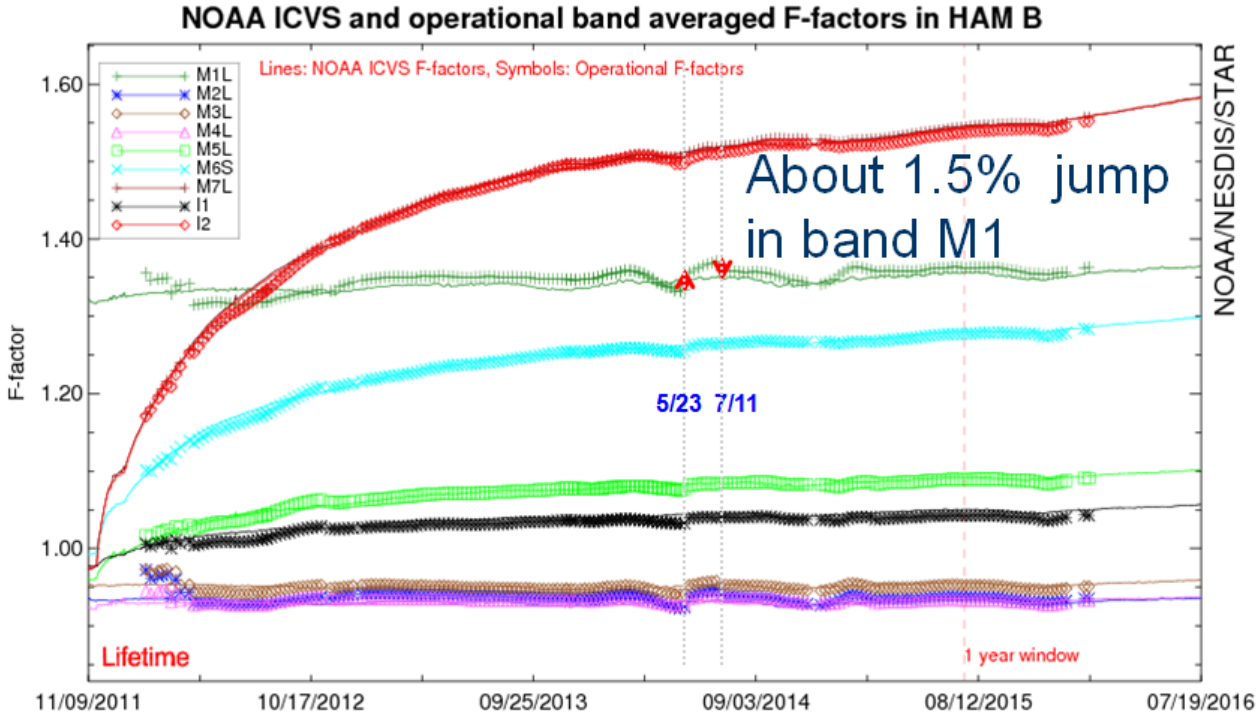
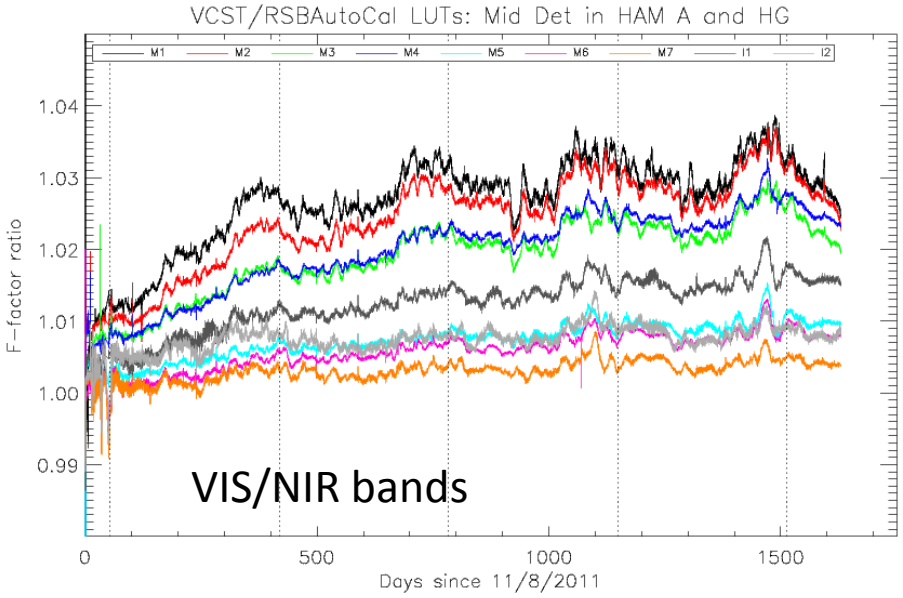
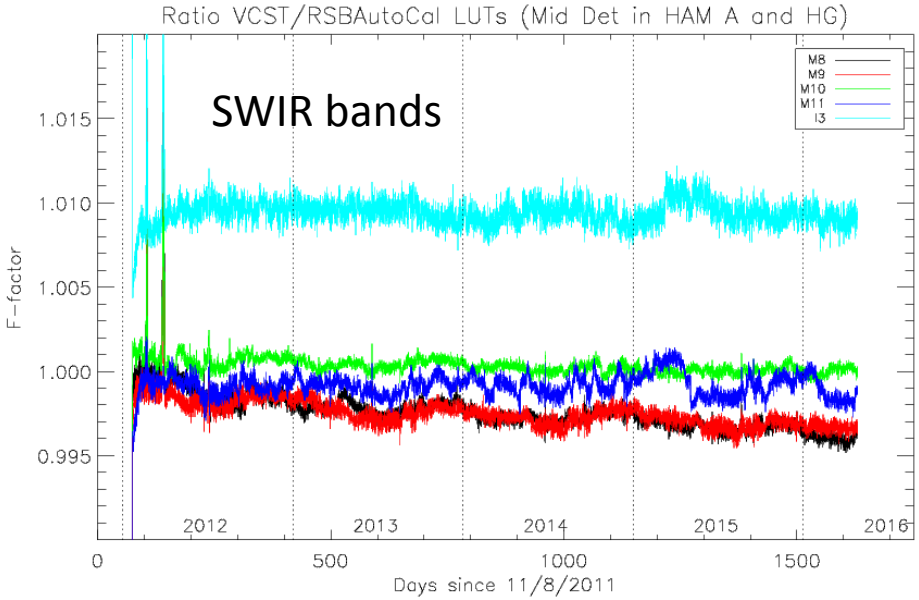


Figure 1. S-NPP VIIRS RSB Operational (Symbols) and ICVS F-factors (lines)

Algorithm Updates & Issues in RSB

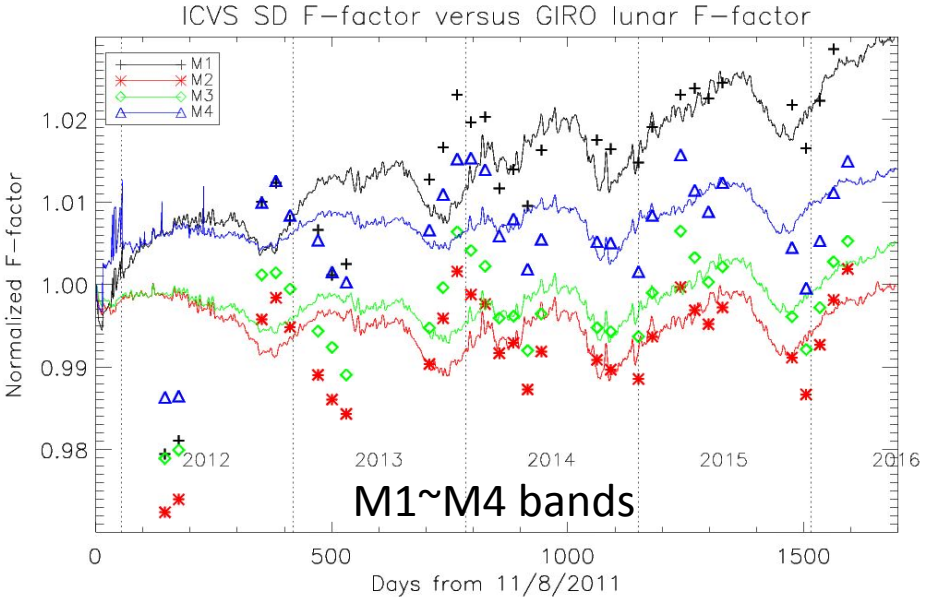
- F-factor ratio (NASA VCST/ NOAA RSBAutoCal)
  - VIS/NIR bands
    - There are initial offsets and long-term drifts.
    - The differences are larger in short wavelength bands and getting smaller in longer wavelengths.
    - Because of NASA's lunar corrections into the SD F-factors.
  - SWIR bands
    - H-factor (SD degradation) free bands show long-term drifts.
    - Because of NASA's update SD degradation into the SD H-factors.

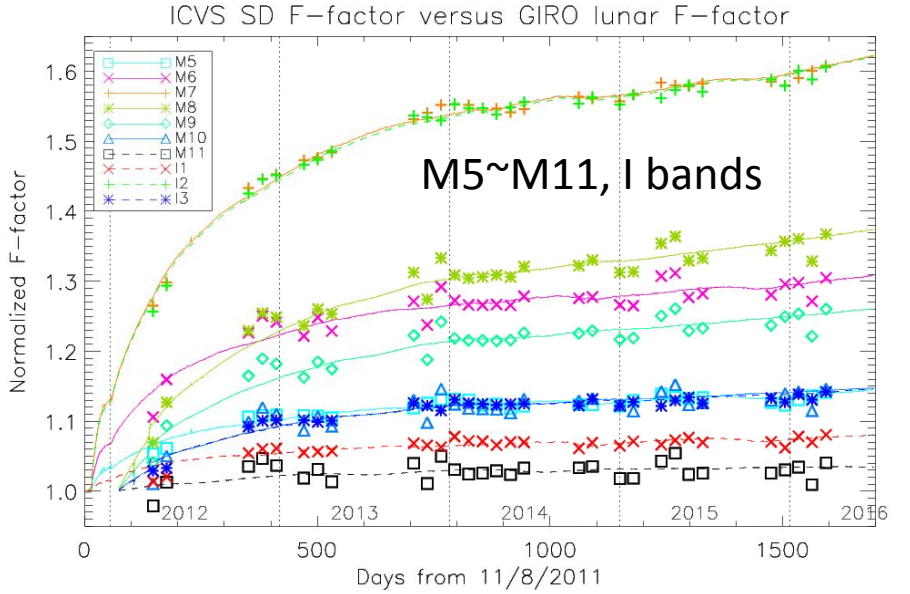




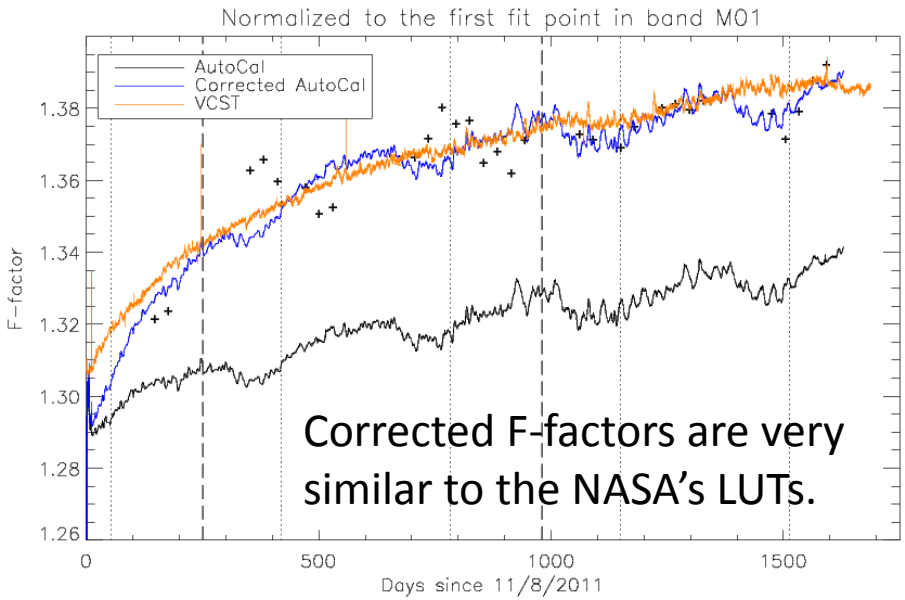
Algorithm Updates & Issues in RSB

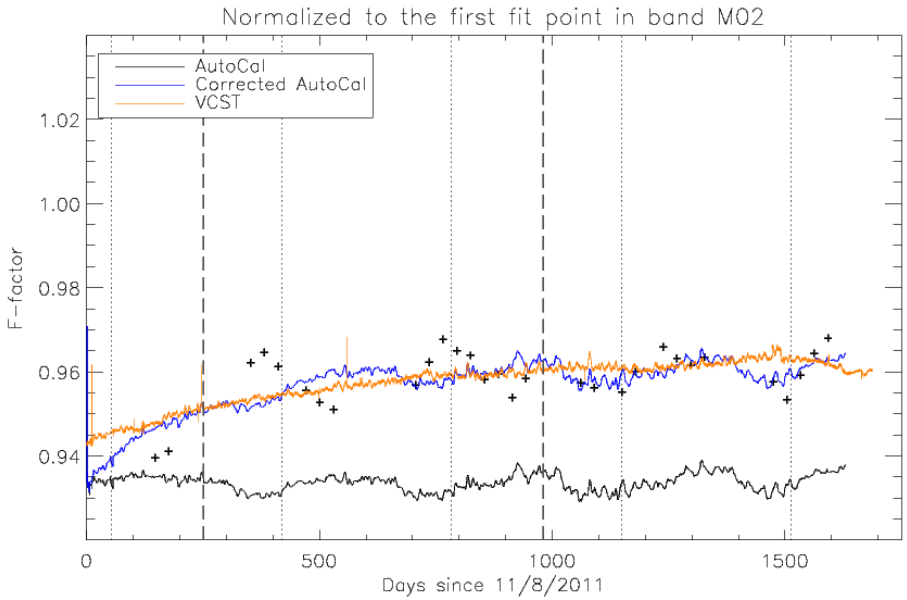
- The two F-factors need to be normalized (or scaled) properly because of the different solar irradiance models.
- The SD F-factors (solid lines) are normalized for better comparison and visualization in the figures.
- The best fitting scaling factors are calculated and applied for lunar F-factors (symbols).
- Lunar and SD F-factors are showing similar annual trends in starting from end of 2014 to current time.
- The first two lunar points are below the SD F-factors.
  - Potential errors in SD F-factors.

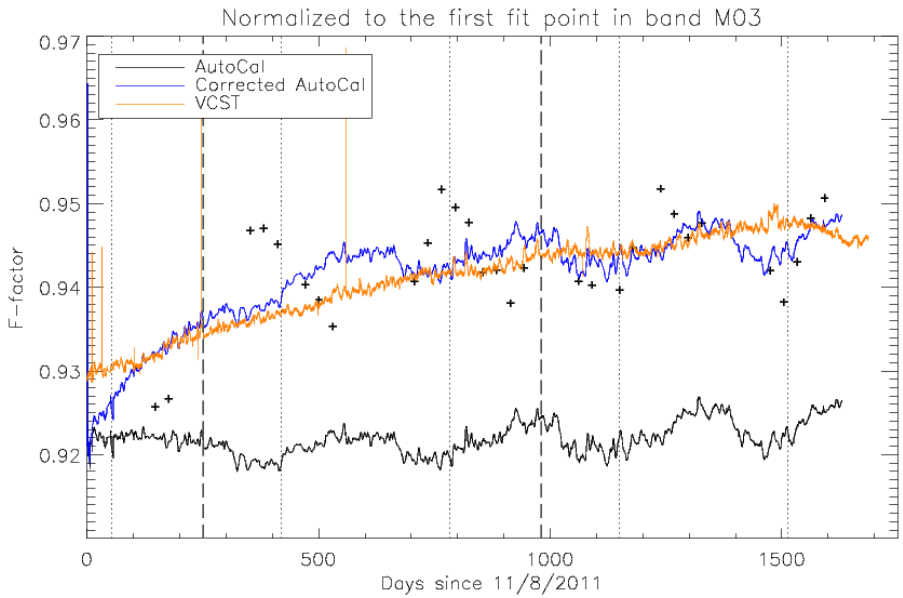


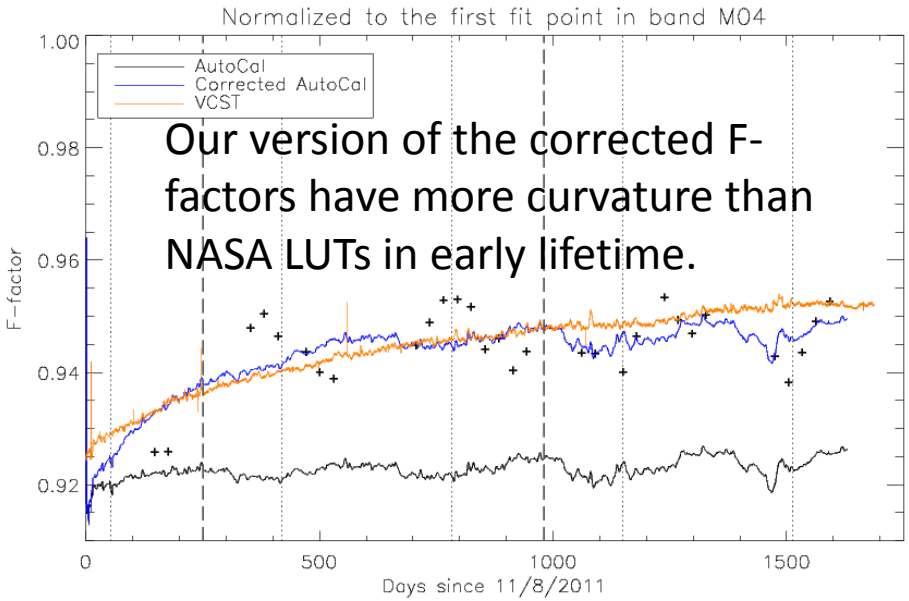


Algorithm Updates & Issues in RSB









Algorithm Updates & Issues in RSB

Ocean Color Group **Hybrid Approach**

- SD Calibration
  - SD degrades non-uniformly, resulting long-term drifts
  - Results are stable and smooth
  - Observation in every orbit
- Lunar Calibration
  - No degradation issue
  - Infrequent and no observation in three months every year
- **Hybrid Approach**

$$\mathcal{F}(B,D,M,G) = R(B,t)\cdot F(B,D,M,G)$$

$$R(B,t) = \left\langle f(B,M,t)\right\rangle_{M} / \left\langle F(B,D,M,0,t)\right\rangle_{D,t-15<t_i<t+15,M}$$

F-Factors Ratios are fitted to quadratic polynomials of time

  - **Lunar calibration provides long-term baseline**
  - **SD calibration provides smoothness and frequency**

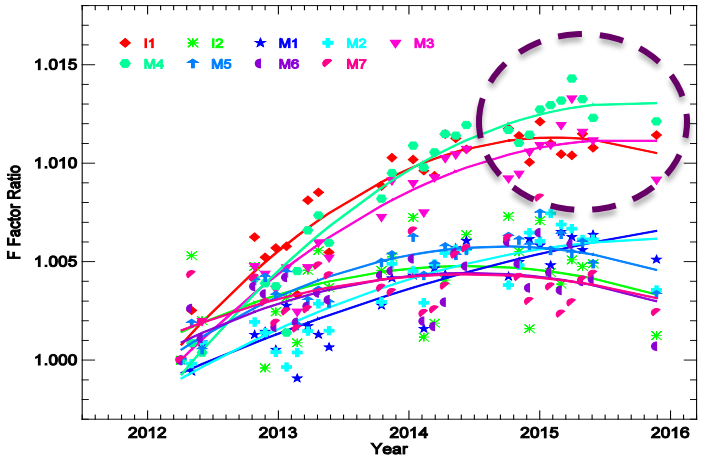
- *J. Sun and M. Wang, "Radiometric Calibration of the VIIRS Reflective Solar Bands with Robust Characterizations and Hybrid Calibration Coefficients," Appl. Opt., 54, 9331-9342 (2015).*
- *J. Sun and M. Wang, "VIIRS Reflective Solar Bands Calibration Progress and Its Impact on Ocean Color Products," Remote Sensing, 8, 194 (2016).*

Slide is taken from *VIIRS RSB Calibration for Ocean Color applications by* Junqiang Sun and Menghua Wang

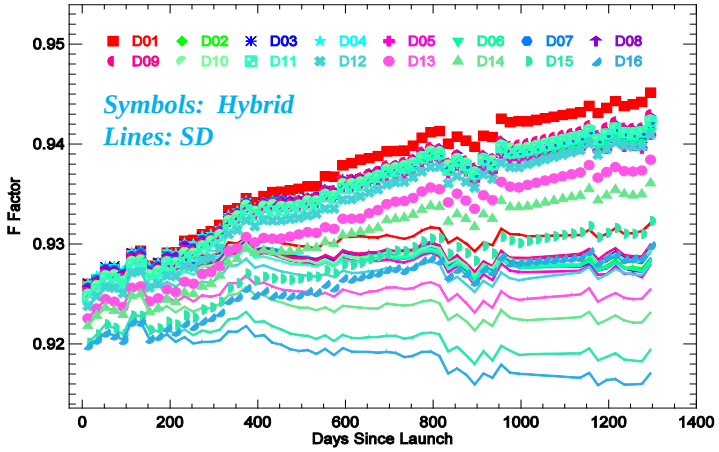
Algorithm Updates & Issues in RSB

Ocean Color Group **Hybrid Calibration**

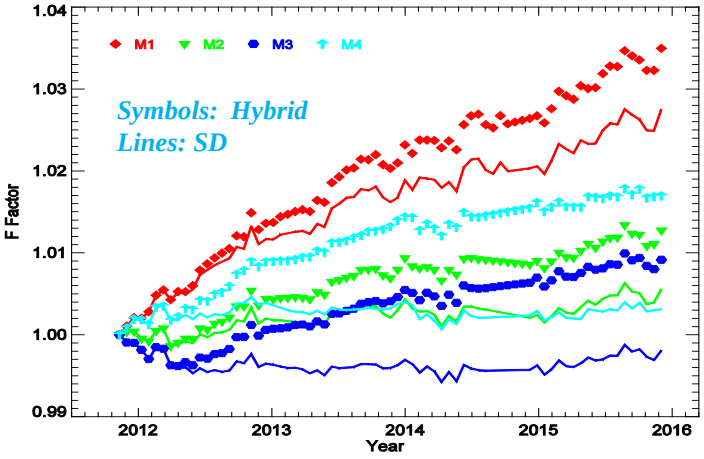
Calibration coefficients Ratios



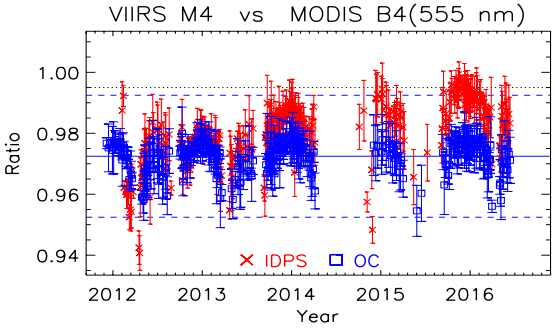
Calibration Coefficients (M4)



Calibration Coefficients



Earth-based SDR studies show that Hybrid-mitigated SDRs give correct time series



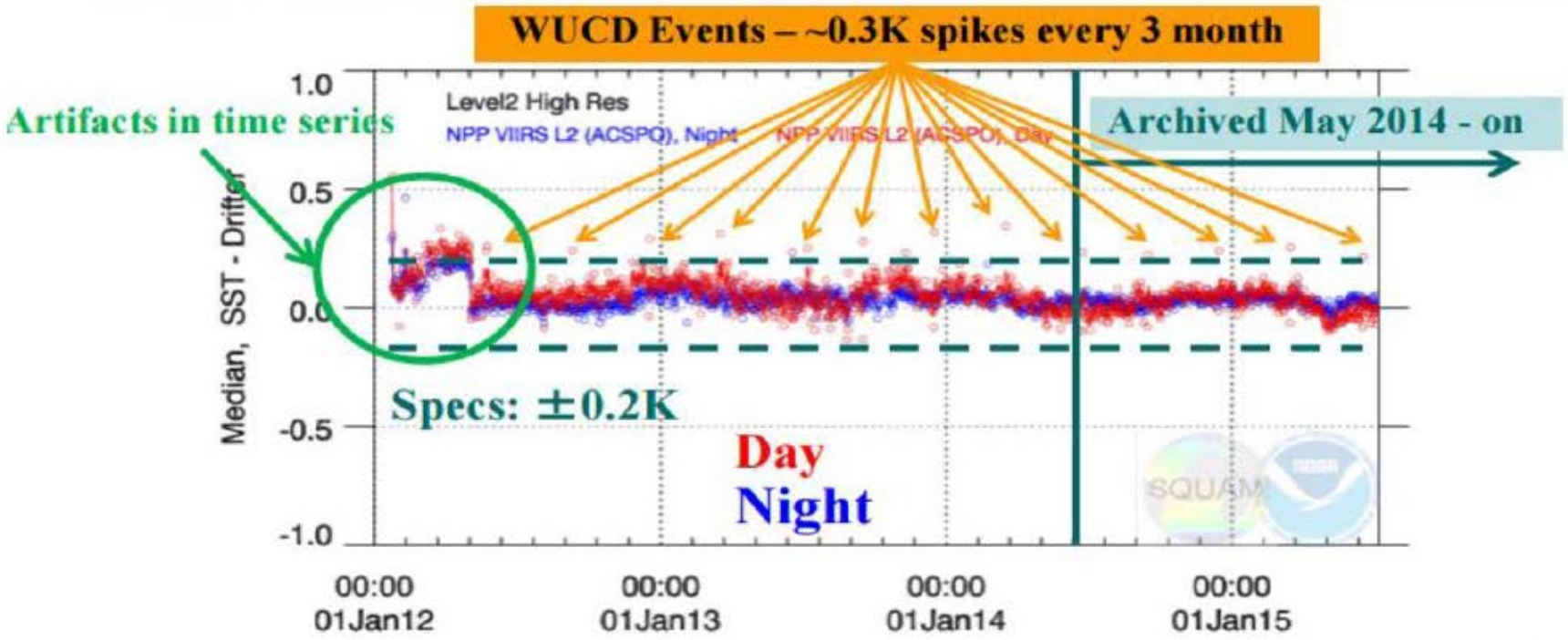
Poster: "Radiometric Comparison of the RSBs of the SNPP VIIRS and Aqua MODIS through SNO analysis" by M. Chu, J. Sun and M. Wang.

Slide is taken from *VIIRS RSB Calibration for Ocean Color applications by* Junqiang Sun and Menghua Wang

Algorithm Updates & Issues in RSB

- A tentative decision was made recently for VIIRS RSB calibration.
- NOAA Ocean Color group will provide
  - Ocean Color RSB calibration coefficients to STAR VIIRS SDR team for testing.
- The OC group's RSB F-factors will be scrutinized before making the further decision.
  - From inputs from other working groups such as Land/Fire and Atmosphere.

Algorithm Updates & Issues in TEB



Courtesy of Dr. Ignatov, 2015 JPSS Annual Science Team Meeting

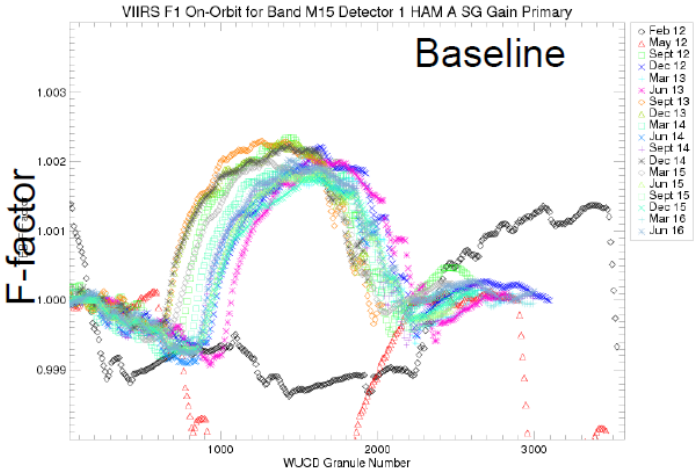
- VIIRS SST product is generally consistent with drifter measurements, except
- Issue 3: "Global warming of ~0.3K" occurs in VIIRS SST every 3 months, due to warm up cool down (WUCD) calibration anomaly.

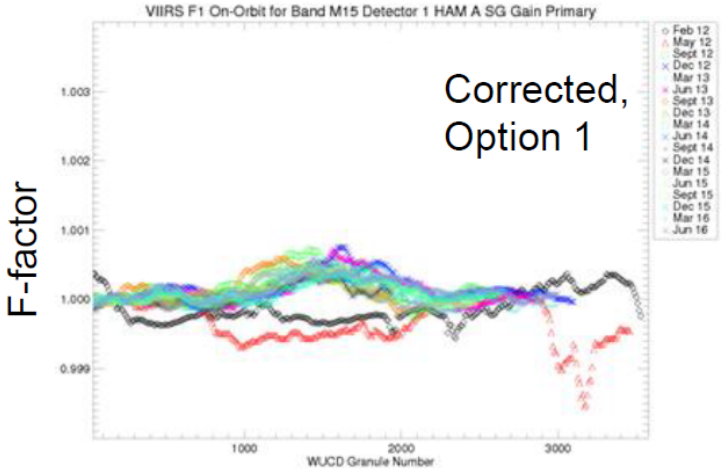
This slide is taken from VIIRS TEB calibration potential improvements by Wenhui Wang et. al.

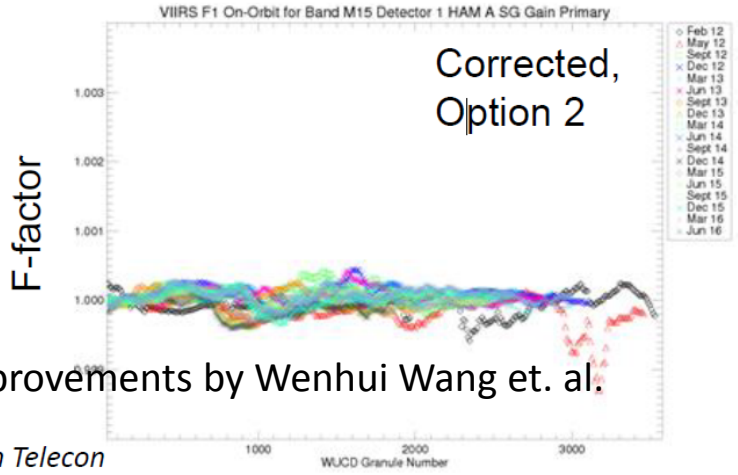
Algorithm Updates & Issues in TEB

- Aerospace proposed a method to reduce F-factor anomalies and scene temperature biases during WUCD (October 7, 2015, Option 1):
- The initial proposed method was further updated to flatten F-factors during WUCD by implementing (August 3, 2016, Option 2) :

M15, HAM-A, D1







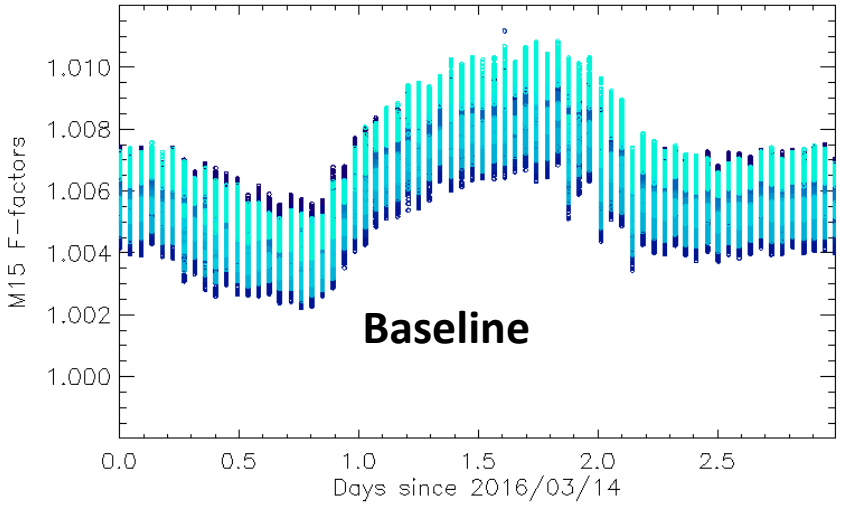
Other detectors/bands show similar patterns
F Factors Smoothed Over Orbits

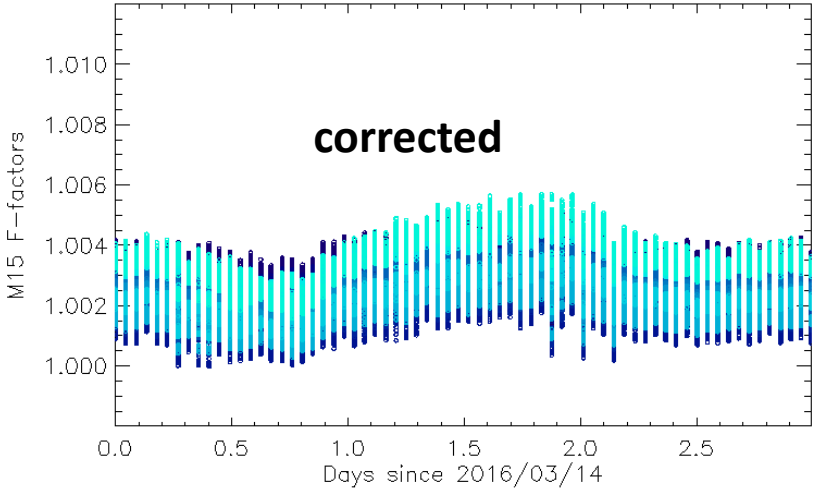
This slide is taken from VIIRS TEB calibration potential improvements by Wenhui Wang et. al.

Courtesy of David Moyer, Aerospace, Aug 3, 2016 VIIRS SDR Team Telecon

Algorithm Updates & Issues in TEB

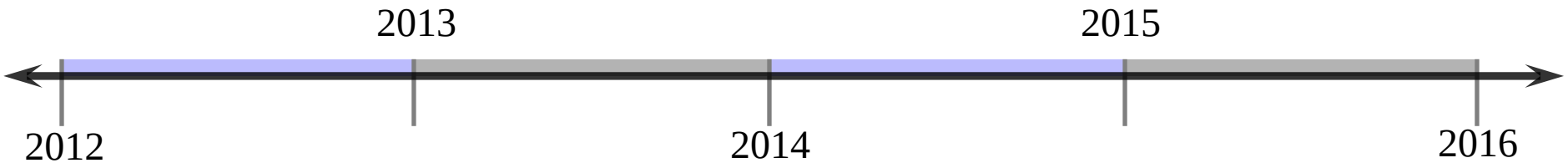
- NOAA SDR Team's Recent Progress
- As a part of reconciling the pre/post calibration differences activities, a new C0 coefficient update method was tested.
  - Only change one LUT, no other change is needed;
  - Effectively reducing 3 types of M15 scene BT biases:
  - 1)Cold scene bias; 2)Constant bias; 3) WUCD bias.
- Further analyzing the sensitivity of different terms, including C coefficients, on WUCD F-factor anomaly and scene temperature biases;
- Currently we have 2 options.
  - Continue to investigate for a better solution.





This slide is taken from VIIRS TEB calibration potential improvements by Wenhui Wang et. al.

Algorithm Updates & Issues in DNB



March 2012
1st calibration update using VROP

- *Updated both onboard and ground offset tables and gain ratio*
- *Improved the radiometric accuracy of esp. for HGS data.*

April 2013
DNB RSR LUT updated with modulated RSRs

- *Accounts for the RTA degradation impact on RSRs*
- *Improved the radiometric accuracy of all gain stages*

August 2013
Straylight correction implemented

- *Characterize and correct the straylight*
- *improves the data quality*

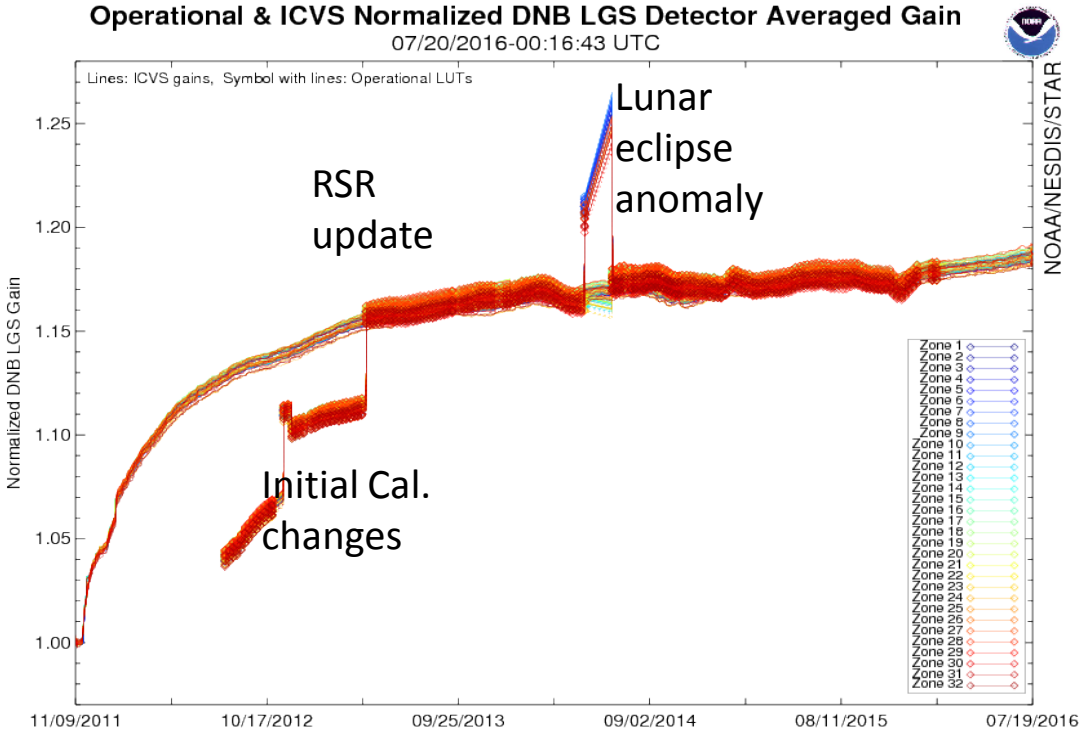
May 2015
DNB terrain correction implemented

- *Improves the geolocation accuracy (accuracy from few pixels (over high altitudes such as Tibet) to sub-pixel level)*

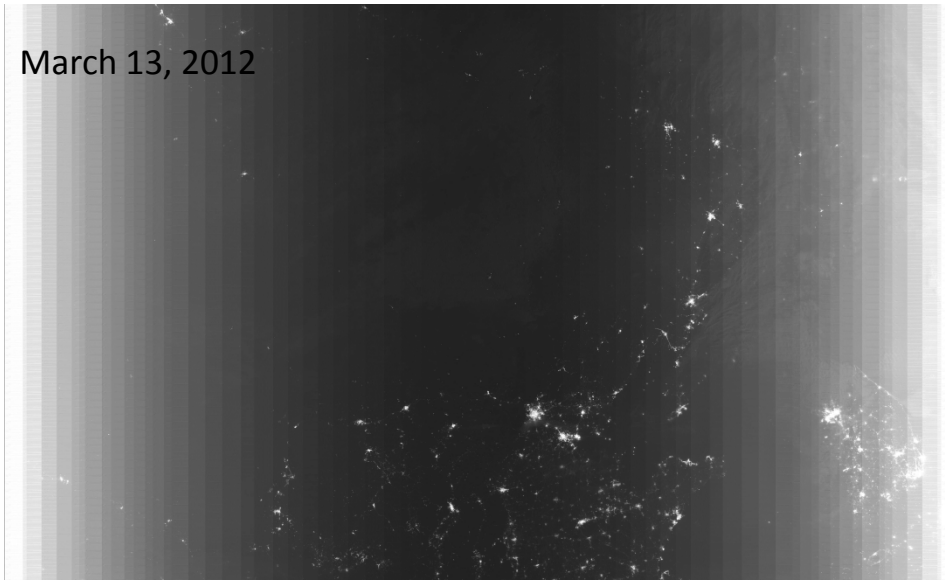
This slide is taken from Preparation for DNB recalibration by Sirish Uprety and Yalong Gu

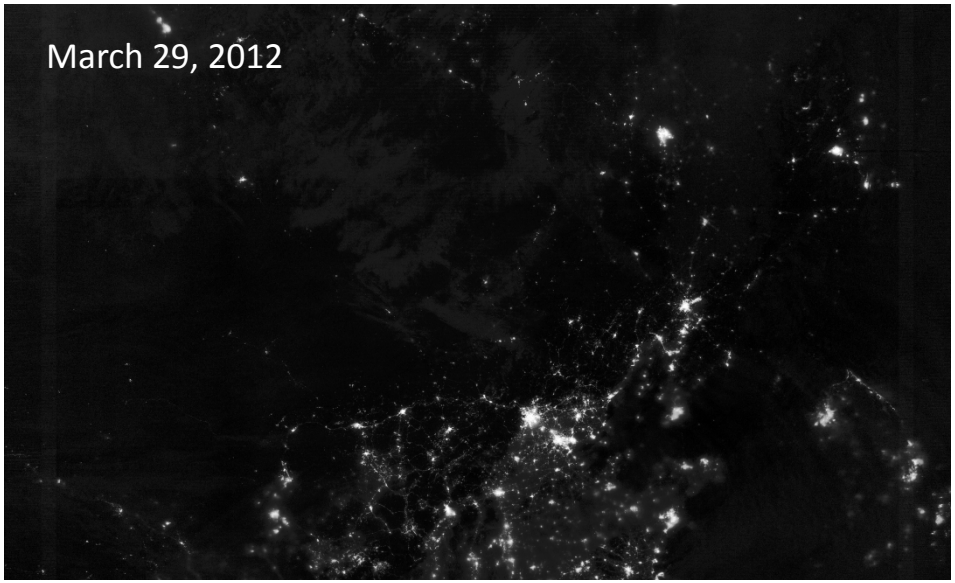
Algorithm Updates & Issues in DNB

- The DNB gain LUTs only applied one time Relative Spectral Response (RSR) update in 2013
  - causing approximately 5% jump in DNB calibration.
- ICVS DNG gain uses a continuous RTA Degradation Model.
  - Correcting the initial calibration changes, RSR update in 2013 , and lunar eclipse anomaly in 2014.



Algorithm Updates & Issues in DNB

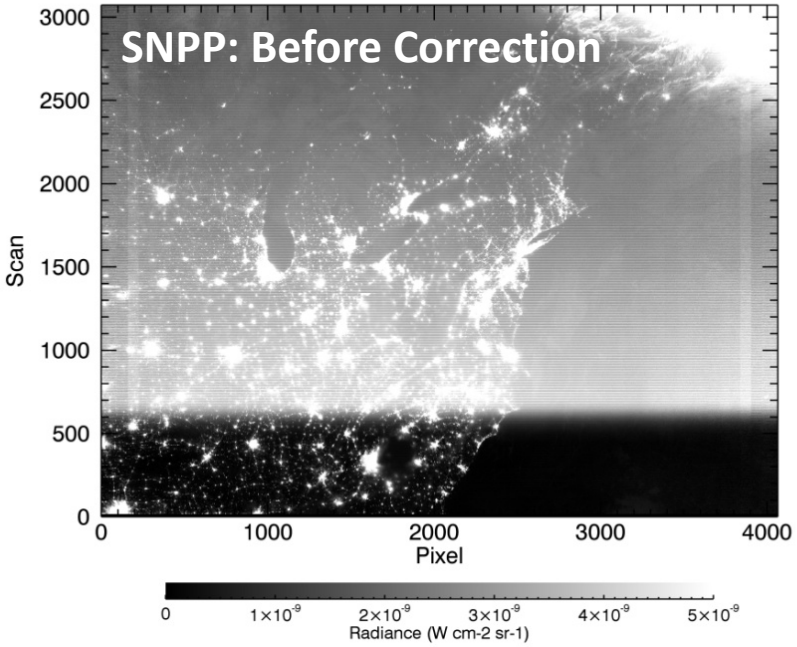


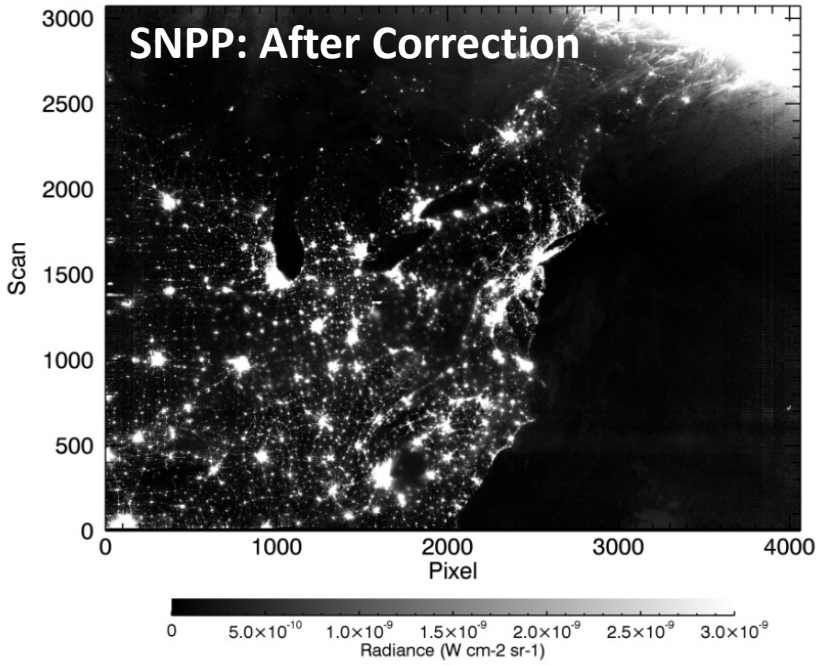


- Show DNB image over same location in earth after 16-day repeat cycle.
- Figure on right shows improvement in DNB calibration after updating offset table (onboard and ground offset) and gain ratio tables for the first time on March 22, 2012 based on VROP.

This slide is taken from Preparation for DNB recalibration by Sirish Uprety and Yalong Gu

Algorithm Updates & Issues in DNB





- SNPP DNB Stray Light correction transitioned from NG to STAR in 2014
- STAR supported the updates of operational stray light LUT for solar vector error correction.
- All 12 LUTs were updated by the end of 2015

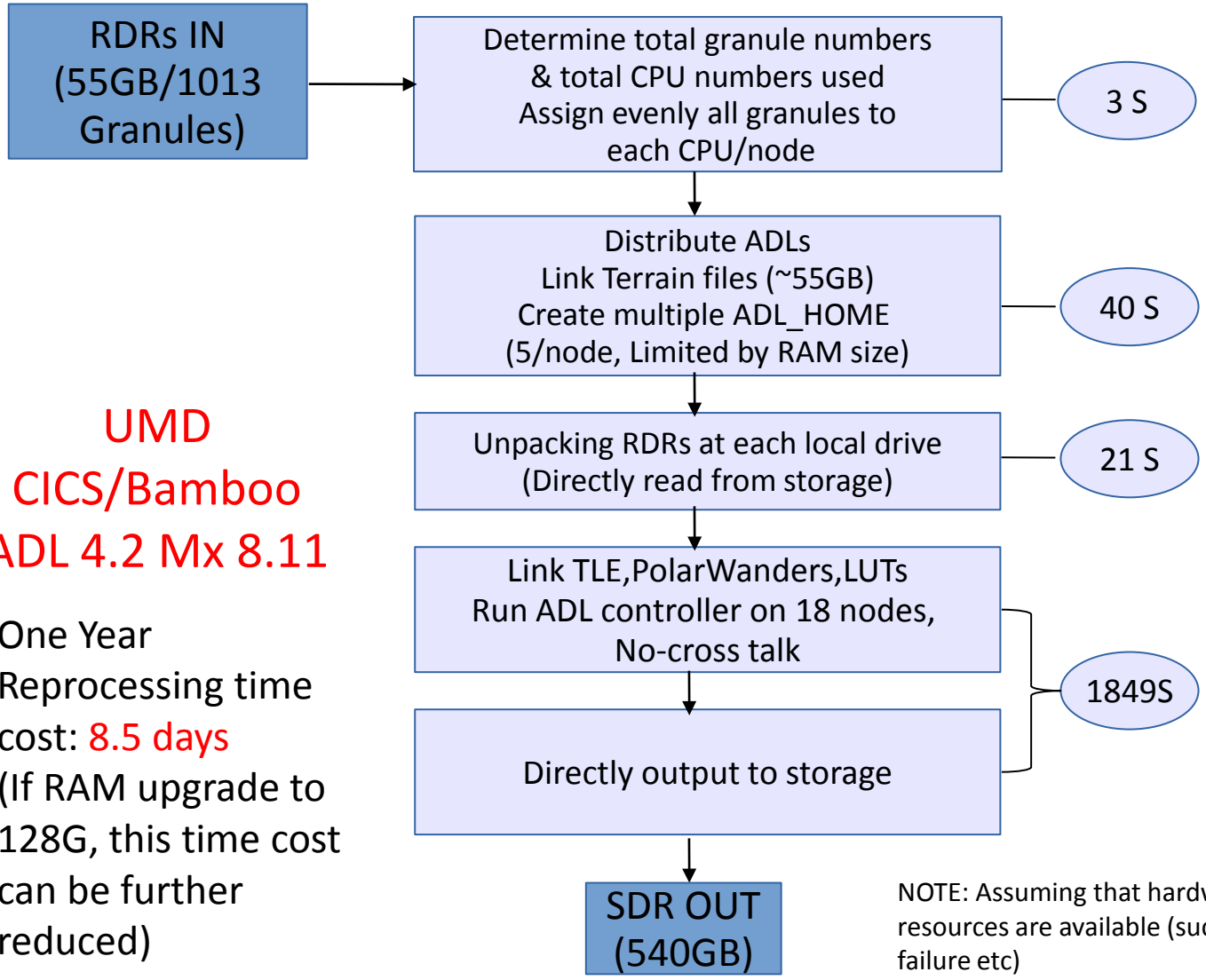
This slide is taken from Preparation for DNB recalibration by Sirish Uprety and Yalong Gu (Courtesy, Wenhui Wang)

Provisional Reprocessing Schedule

- RSB (Not ready yet)
  - NOAA Ocean Color group will provide RSB LUTs by September 15th, 2016.
  - One year of VIIRS data will be ready by the end of November, 2016.
  - RSB LUTs for reprocessing will be ready by December 15th, 2016.
- TEB (Conditionally ready)
  - The option 1 solution from Aerospace is ready as a baseline.
  - Currently working on better solution.
- DNB (Ready)
  - LGS gain LUTs are ready.
  - DN0 LUTs are ready.
  - Stray light correction LUTs are ready.
  - Currently working on better gain ratio LUTs.
    - With baseline operational gain ratio LUTs.

Provisional Reprocessing Schedule

One day processing scenario



UMD
CICS/Bamboo
ADL 4.2 Mx 8.11

One Year Reprocessing time cost: 8.5 days
(If RAM upgrade to 128G, this time cost can be further reduced)

Total: 33.4 Min

Total CPU hours: 229 (19/24 idle)

NOTE: Assuming that hardware works normally and resources are available (such as no power outage, no disk failure etc)
Assuming all input data (RDR, TLE, Polar Wander and LUTs) are ready.

Summary

- RSB band improvements
  - The reprocessing LUTs will correct up to 1.5% sudden changes caused by sudden H-factor updates, C0=0 update, and F-fast track to RSBAutoCal LUT transition.
  - The unstable initial calibration LUTs will be updated.
  - A new OC group's RSB F-factor LUTs with Lunar correction will be tested for their 0.1~0.3% radiometric uncertainty requirements.
- TEB band improvements.
  - TEB F-factor changes during the blackbody Warm-Up Cool-Down (WUCD) needs to be resolved before reprocessing (currently under study).
- DNB band improvements
  - The reprocessing LUTs will correct radiometric calibration up to 5%.
    - Caused by the initial calibration changes, RSR update, and lunar eclipse anomaly.
  - The new bias (DN0) LUTs will improve bias errors.
    - Using the VIIRS Recommended Operation Procedure (VROP) 702.
  - The new stray light correction LUTs will correct the contaminated scenes before August 2013.

VIIRS (Land SIPS)
Processing, Code Delivery and Integration Status

Miguel Román, Chris Justice, Sadashiva Devadiga, Carol Davidson, and Ed Masuoka

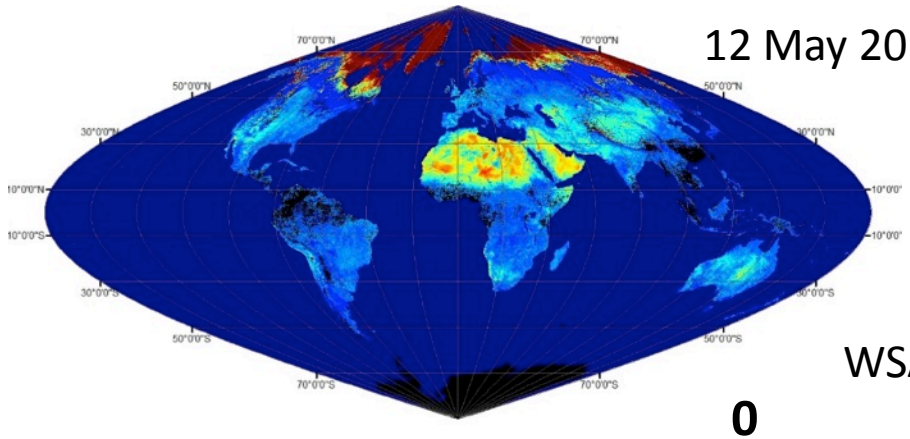
(NASA/GSFC)

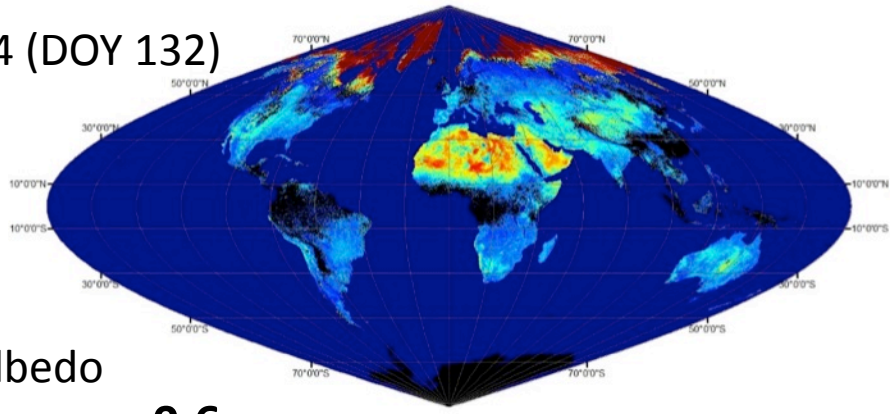
BRDF, ALBEDO, NBAR Continuity

MODIS

VIIRS

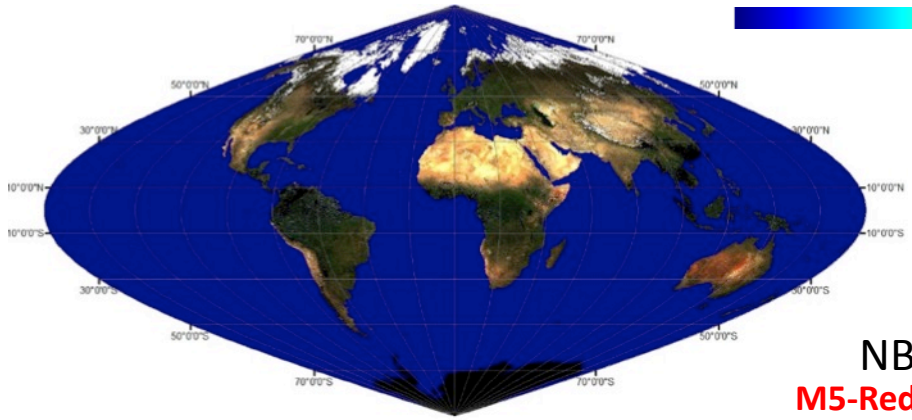
12 May 2014 (DOY 132)

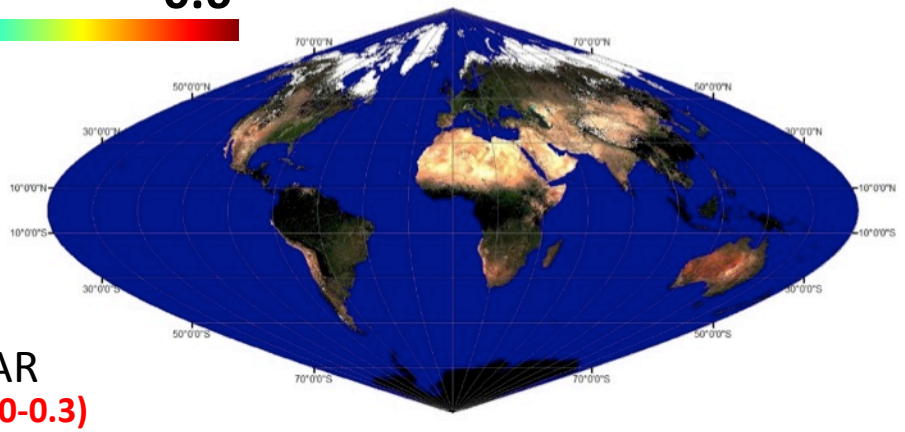




WSAlbedo

0 0.6



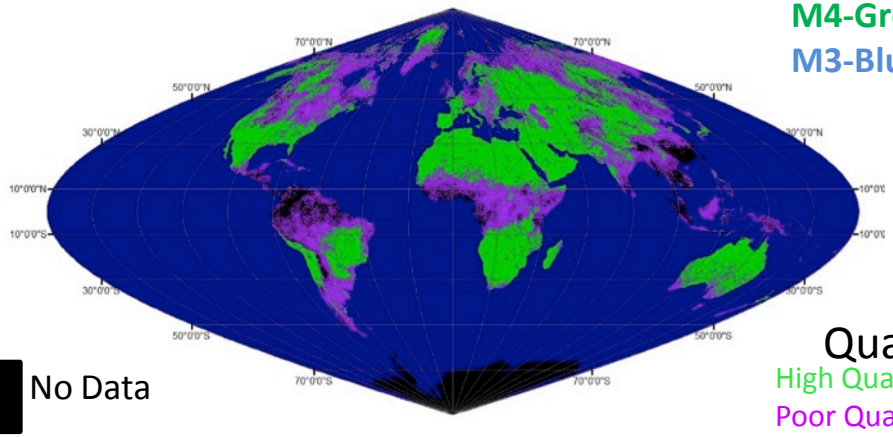


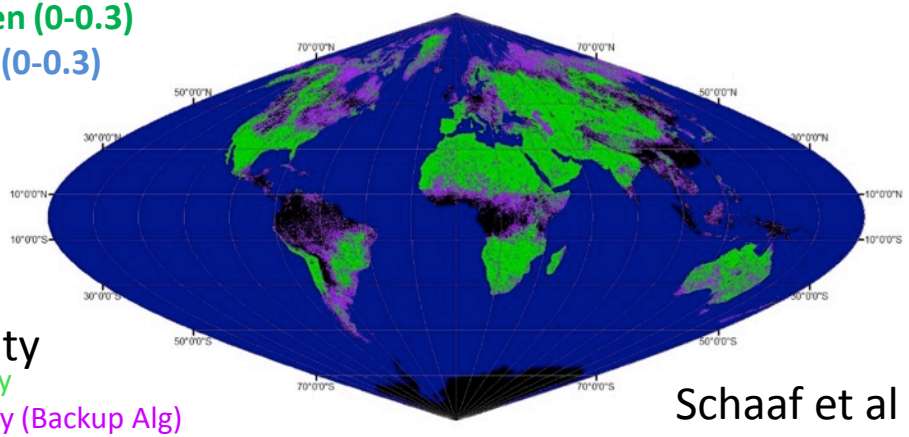
NBAR

M5-Red(0-0.3)

M4-Green (0-0.3)

M3-Blue(0-0.3)





Quality

High Quality

Poor Quality (Backup Alg)

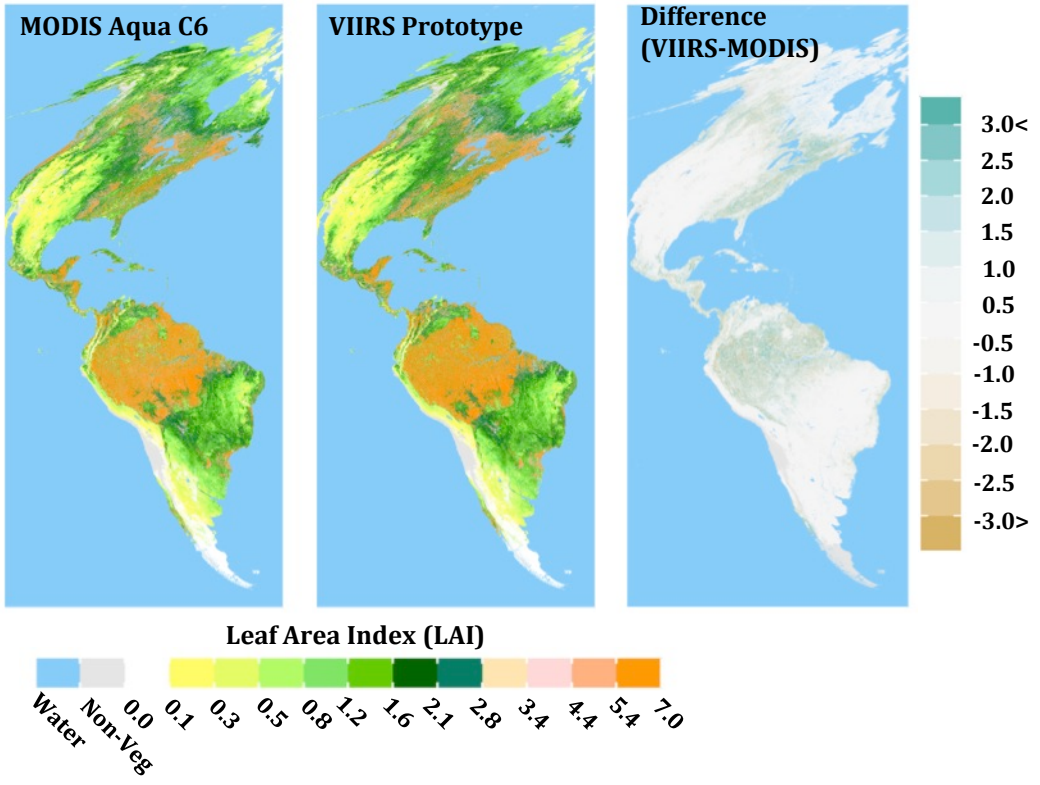
No Data

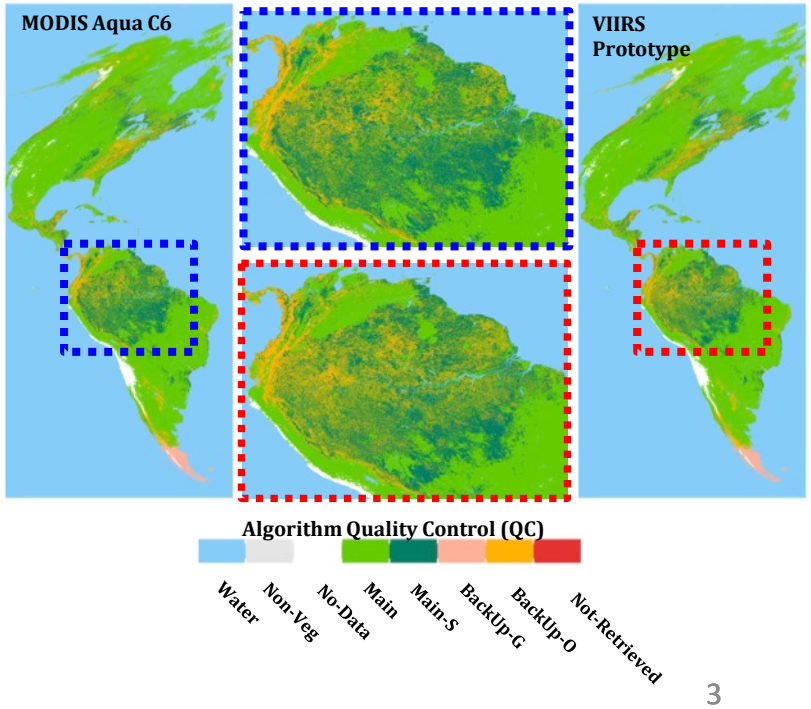
Schaaf et al



✓ Global scale LAI/FPAR comparison between optimized VIIRS & MODIS C6

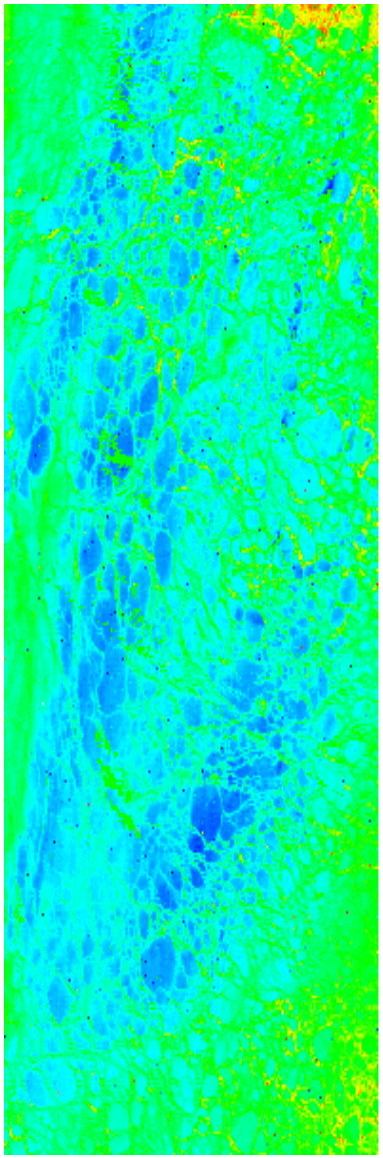
- Overall, comparable spatial distribution of LAI/FPAR & spatial coverage
- Larger discrepancies are mostly induced by algorithm path mismatch (i.e., Main vs. Backup)
- Relatively higher uncertainty in dense forest can be another causal factor (i.e., saturation)

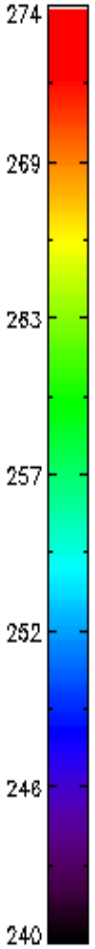




Myneni et al

Ice Surface Temp



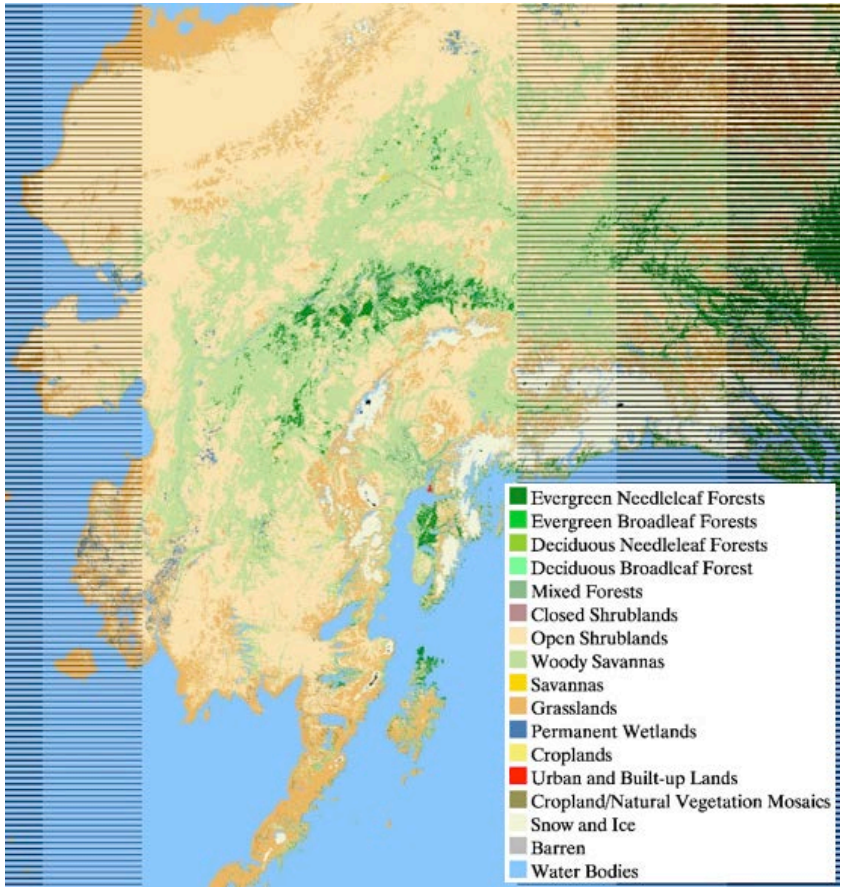


- Initial code generated from MODIS code by NASA's Land Science Investigator-led Processing System (LSIPS)
- Code being updated for VIIRS (calibration coefficients, etc.)
- New Quality Flags to be added
- Inter-comparison: MODIS, NCEP
- Validation: IceBridge, buoys
- First draft of ATBD delivered Jan. 2016

Left: VIIRS IST (K) from the NASA VIIRS IST product
uses new calibration coefficients from J. Key
Sept 12, 2014, 21:10 UTC
Beaufort Sea, AK

VIIRS Land Cover Issue

- NASA LC Product missing from the current VIIRS product suite
- Some higher level land products are dependent on land cover
- Current Approach:
  - Use MODIS Land Cover Product
  - Work with NOAA Annual Surface Type team to evaluate whether the product is sufficient



Land SIPS: Code Delivery and Integration Status

Land SIPS Products	Algorithms Delivered to Land SIPS	Product Integration and Testing	Draft ATBD Delivery	Delivery of User's Guide	Products Delivered to assigned DAAC
Surface Reflectance	✓	✓	✓	✓	Summer, 2016
LAI/FPAR	Underway	Underway	Summer, 2016	Summer, 2016	Fall, 2016
Snow Products	Underway	Underway	✓	Fall, 2016	Fall, 2016
MAIAC	Summer, 2016	Pending	Fall, 2016	Fall, 2016	Fall, 2016
BRDF/Albedo	Underway	Underway	✓	Summer, 2016	Fall, 2016
Burned Area	Fall, 2016	Pending	Spring, 2017	Spring, 2017	Spring, 2017
Active Fires	Underway	Underway	Spring, 2016	Fall, 2016	Fall, 2016
Vegetation Index	✓	Pending	Summer, 2016	Summer, 2016	Fall, 2016
LST&E	Underway	Pending	✓	Fall, 2016	Fall, 2016
Ice Products	Fall, 2016	Pending	✓	Fall, 2016	Fall, 2016
Phenology	Fall, 2016	Pending	Fall, 2016	Fall, 2016	Spring, 2017
Day/Night Band	✓	Underway	Fall, 2016	Fall, 2016	Spring, 2017

Land SIPS: Code Delivery and Integration Status

Land SIPS Products	Algorithms Delivered to Land SIPS	Product Integration and Testing	Draft ATBD Delivery	Delivery of User's Guide	Products Delivered to assigned DAAC
Surface Reflectance					ummer, 2016
LAI/FPAR					Fall, 2016
Snow Products					Fall, 2016
MAIAC					Fall, 2016
BRDF/Albedo					Fall, 2016
Burned Area					pring, 2017
Active Fires					Fall, 2016
Vegetation Index					Fall, 2016
LST&E					Fall, 2016
Ice Products	Fall, 2016	Pending	✓	Fall, 2016	Fall, 2016
Phenology	Fall, 2016	Pending	Fall, 2016	Fall, 2016	Spring, 2017
Day/Night Band	✓	Underway	Fall, 2016	Fall, 2016	Spring, 2017

Takeaway: Most products still in HDF 4
Need to transition to HDF 5 - Conversion may cause c. 6 week delay in BRDF Suite and LAI /FPAR – land team working together through the conversion issues

Land DAAC provided guide to convert to HDF 5 compatible tools to minimize user impact

Land SIPS: Production Status

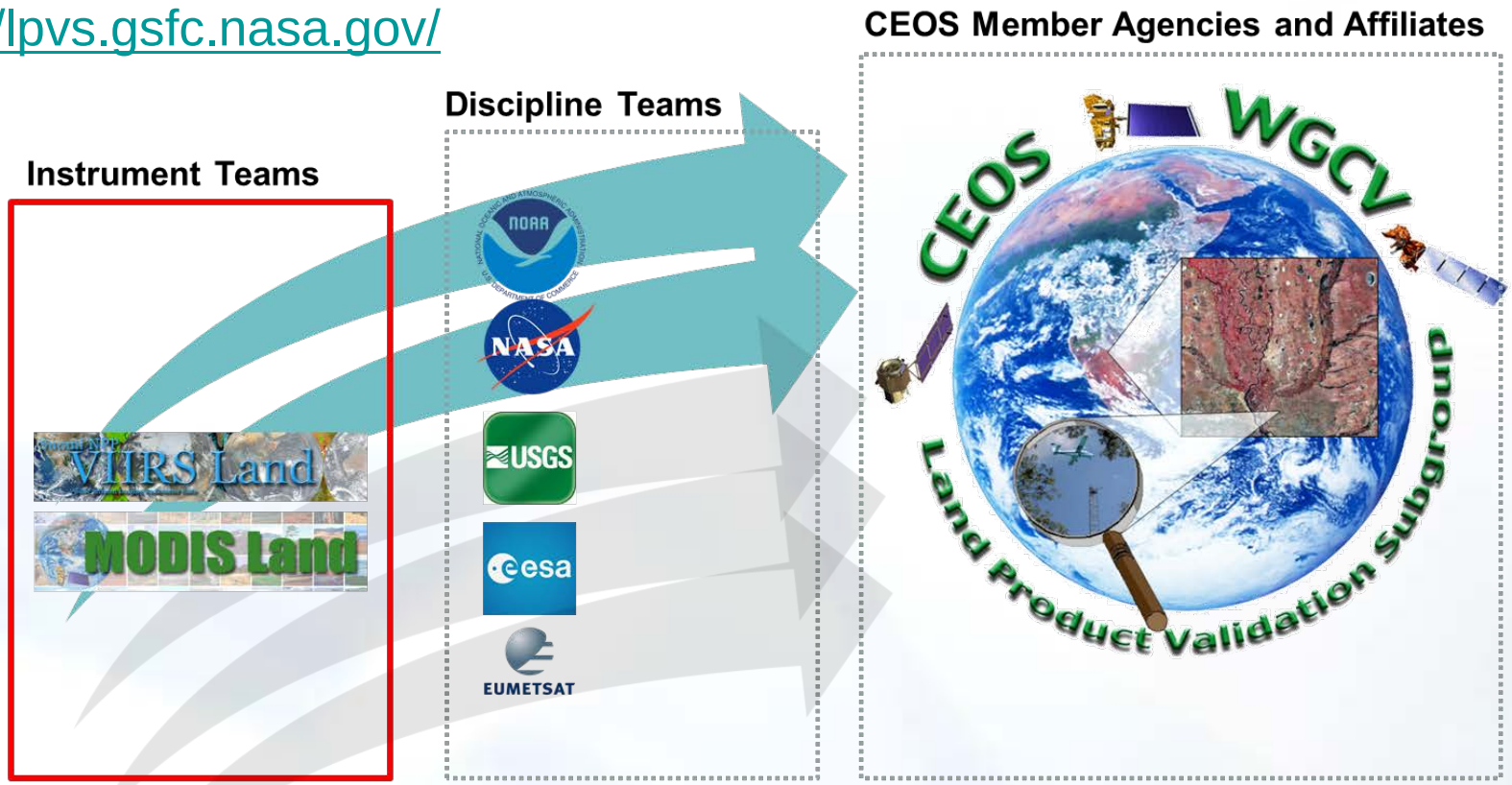
Processing stream and LAADS AS	C11 Reprocessing AS 3110	Forward Processing AS 3002	V1 Forward processing and Reprocessing AS 5000
Data day being processed?	Not operational. Last data day processed Jan 31, 2016.	Not operational. Last data day processed Jul 13, 2016 (day 195)	Forward processing started on day 188, now at leading edge a day behind current data day. Reprocessing year 2015.
Mission period the data available?	Jan 19, 2012 – Jan 31, 2016	L2: last 30 days L3: most available for the mission period.	Expected to be available for the mission period
Are products available from DAACs	No	No	Yes
L1B Calibration Algorithm version?	IDPS L1B SDR Mx7.2 + L1B LUT from NASA VCST	IDPS L1B SDR Mx8.11 + IDPS SDR Melded LUT (IDPS uses RSB Auto Cal)	NASA L1B V2.0 + L1B LUT from NASA VCST
L1B/L2 Granule size?	Aggregated ~5min from IDPS verified RDR	5 min from NASA L1A/L0	6 min from NASA L1A/L0
L2/L3 Algorithm versions?	IDPS Mx7.2 + LPA	IDPS Mx8.11 + LPA	NASA V1 / V2 algorithms
File format	HDF4/HDF4-EOS	HDF4/HDF4-EOS	HDF5/HDF5-EOS (if distributed from DAACs)

VIIRS Land PGEs: Code Delivery and Integration

- VIIRS Land SIPS proposed same approach as MODIS Land and Atmosphere SIPS (MODAPS) for science software delivery and integration of the VIIRS Land software by the NASA VIIRS Land Science Team.
- Land SIPS expects same level (MODIS pre-C6) of commitment as MODIS science team from the VIIRS science teams for science code development and delivery.
- Factors impacting the delivery schedule and resource at Land SIPS.
  - Delay in delivery of NASA L1B/Geo until NASA version available from NASA VCST/Geo team
  - Update all upstream processes, and libraries to HDF5, the new format adopted for VIIRS product from Land SIPS. MODIS C6 product are still being generated in HDF4.
  - Many of the deliveries from the science team are in HDF4 format or science team expected the Land SIPS to transition the DDR process (MODIS C6 PGE remapped to VIIRS) from Land PEATE
  - Transitioning even the MODIS C6 algorithm to HDF5 is significant effort and Land SIPS is not resourced for this effort.

CEOS Land Product Validation Update

http://lpvs.gsfc.nasa.gov/



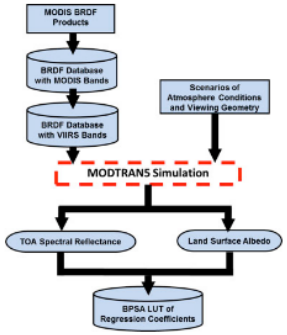
Miguel Román, Fernando Camacho, Jaime Nickeson, Pierre Guillevic, Zhuosen Wang, and Chris Justice
with contributions from the CEOS-LPV agency POCs and focus area leads

Suomi NPP VIIRS Land

Visible Infrared Imaging Radiometer Suite

NOAA Albedo and Bidirectional Reflectance EDR

Yunyue (Bob) Yu, Product Lead
Shunlin Liang, Dongdong Wang, and Yuan Zhou (UMD), Development and Validation

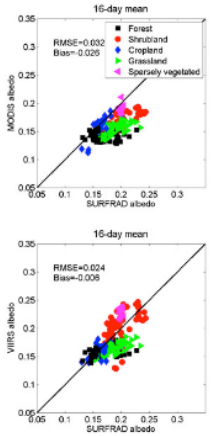


A brief flowchart showing how the BPSA LUT of regression coefficients is generated (Wang et al. 2013).

Surface albedo, defined as the ratio between shortwave radiation reflected by Earth's surface and shortwave radiation incident at the surface, is a function of both solar illumination and the reflective properties of the Earth's surface. The VIIRS Surface Albedo EDR consists of land surface albedo (LSA), ocean surface albedo and snow or sea ice surface albedo. Among them, LSA is an essential variable linking the land surface and the climate system. It is a unique property for studying how land surface changes affect the energy balance and the overall climate system.

The current VIIRS LSA algorithm is a direct estimation method, which directly links surface broadband albedo with VIIRS top-of-atmosphere (TOA) reflectance through radiative transfer and statistical modeling (left). Since the launching of Suomi NPP, the LSA algorithm has gone through two major improvements. The validated Version 1.0 readiness review was approved in December 2015.

Validation against field measurements at 25 stations shows that VIIRS can estimate surface albedo over non-snow pixels with a root mean square error (RMSE) of 0.024 a small negative bias of 0.006, comparable with the existing MODIS data (right).

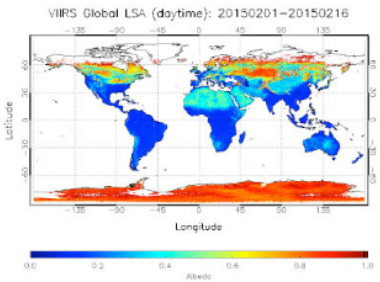


Validation results of 16-day mean snow-free albedo from VIIRS (top) & MODIS (bottom).

With the direct-estimation algorithm, LSA is estimated for all VIIRS land pixels (~ 750 m) with clear-sky conditions.

Two granule products are currently available: a single swath granule dataset with the dimension of 768 x 3200, and a 4-swath aggregated granule dataset with the dimension of 3072 x 3200. The official JPSS Surface Albedo EDR product can be accessed from NOAA's Comprehensive Large Array-data Stewardship System (CLASS).

A composite global map of VIIRS LSA is shown below as an example.



A global map of land surface albedo composite with VIIRS products from Feb 1-16, 2015

Reference

Wang, D. D., S. L. Liang, et al. (2013). Direct estimation of land surface albedo from VIIRS data: Algorithm improvement and preliminary validation. *Journal of Geophysical Research-Atmospheres* 118(22): 12577-12586.

NOAA Surface Type EDR

Xiwu Zhan, Product Lead
Chengquan Huang (UMD), Rui Zhang (UMD), Development and Validation

The VIIRS Surface Type EDR is a swath product built by re-projecting the Gridded Quarterly Surface Type Intermediate Product (ST-IP) and overlaying it with the Active Fire ARP, Snow Cover EDR, and Green Vegetation Fraction for each 750m pixel. The VIIRS Global Surface Type Map represents the continuity of NASA EOS MODIS and NOAA POES AVHRR land cover products.



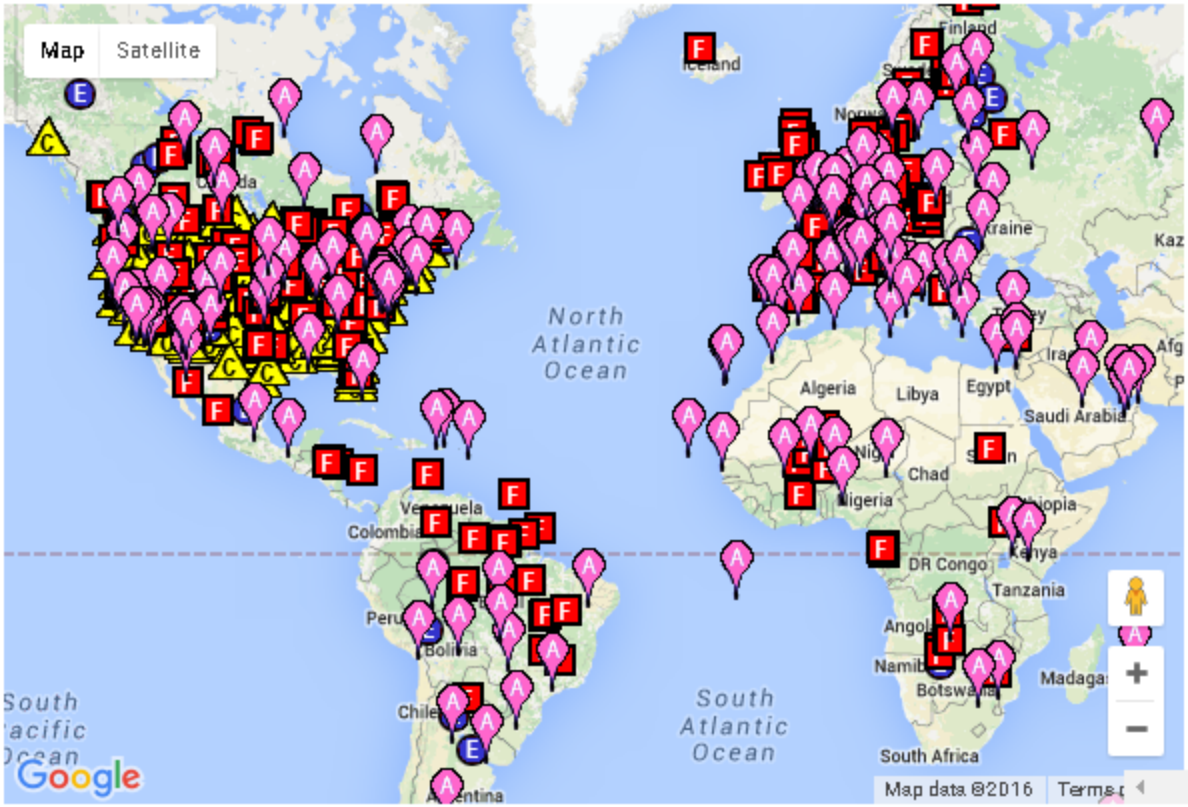
Example of Surface Type EDR product (ST-EDR)

While the VIIRS Surface Type EDR is an input to the VIIRS Land Surface Temperature (LST) EDR and other downstream products in the JPSS IDPS system, the VIIRS Global Surface Type Map is a required input by many land surface models for numerical weather, climate and hydrological models, studies on natural resources and disaster management, and for ecosystem monitoring.

The global surface type map is produced at 1 km spatial resolution based on the previous one or more years of VIIRS surface reflectance, brightness temperature and vegetation index data. Both VIIRS Surface Type EDR and the Global Surface Type Map provide 17 surface type classes following the IGBP classification scheme. Accuracy requirements for the EDR and the global map is a 70 percent metric of correct classification.

The 1st gridded VIIRS global surface type map providing the basis for the Surface Type EDR was generated offline with the MODIS heritage C5.0 decision tree classification algorithm by the University of Maryland's VIIRS Surface Type EDR team and validated by the Boston University validation team. Future annual updates of VIIRS Global Surface Type Map will be developed and validated by the UMD team. The most recent version of the VIIRS Global Surface Type Map is available for download at this ftp link. and information about the product is provided in this Readme document also available by ftp.

MODIS/VIIRS Subsets FTP Access Page



- Peatland
- AB-Western Peatland Poor Fen
- AB-Western Peatland Rich Fen
- Abisko
- Adelaide River
- Agoufou G
- Agoufou S
- Aguamarga
- Aiken
- Ailaoshan
- Akanuma- Kushiro Mire
- Alkkia Scots pine forest
- Alp Weissenstein
- Amoladeras
- Amplero
- Anaktuvuk River Moderate Burn
- Anaktuvuk River

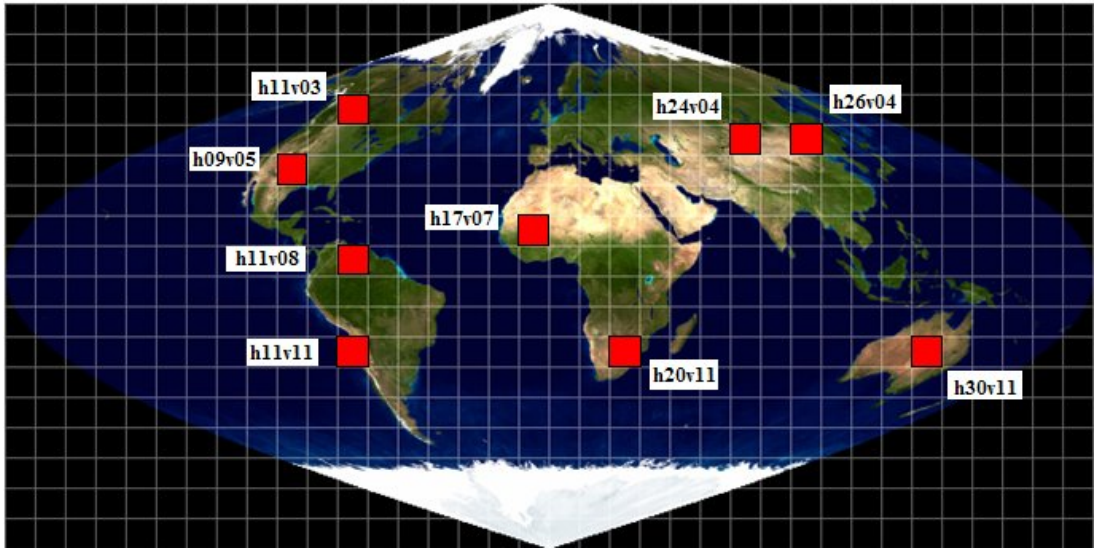
Product Short Name	Product Description
NPS_CMIP_L2	VIIRS/NPP Cloud Mask 5-Min L2 Swath IP 750m - Subset
NPS_IMFT_L1	VIIRS/NPP Imagery Resolution 5-Min Swath SDR 375m - Subset
NPS_QMMVIIP_L2	VIIRS/NPP Gridded Annual Min/Max Vegetation Index Quarterly 5 Min Swath IP 750m Granulation - Subset
NPS_QSIP_L2	VIIRS/NPP Gridded Surface Types Quarterly 5-Min L2 Swath IP 750m Granulation - Subset
NPS_QSLWMIP_L2	VIIRS/NPP Gridded Surface Types Land Water Mask Quaterly 5-Min L2 Swath IP 750m Granulation - Subset

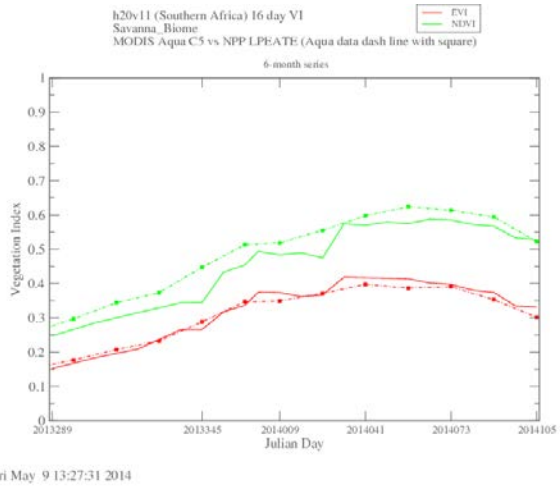
Used by multiple teams (VIIRS ST, VCST, LPDAAC, ORNL, NOAA/STAR)

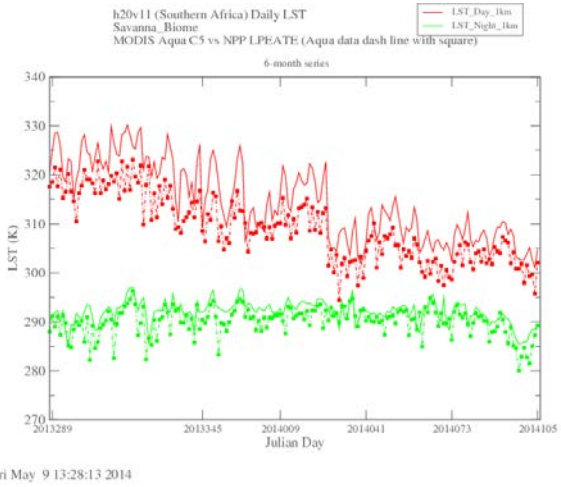
Land Product Quality Assessment Golden Tile Time Series

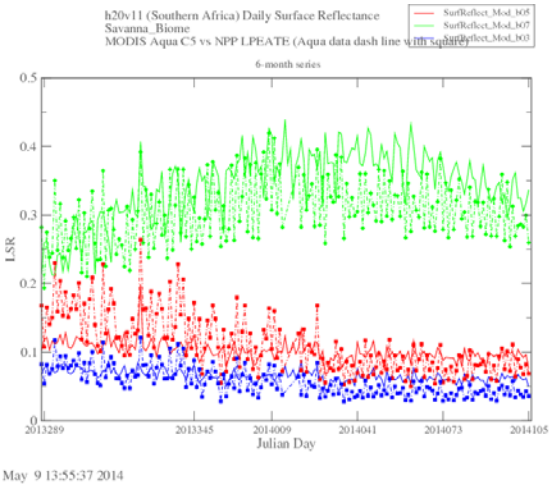
Approach:

Summary statistics for (10° X 10°) SIN golden tiles.









Early VIIRS (solid lines) vs. Aqua MODIS C6 (dashed-dot lines) **Vegetation Index** (left), **LST** (center), and **Surface Reflectance** (right). 6-month trending shown for observations from savanna class (tile h20v11).

CEOS-LPV's Core Mission

http://lpvs.gsfc.nasa.gov/

Instrument Teams

VIIRS Land

MODIS Land

Discipline Teams

Agency POCs:

NOAA — I. Csiszar, M. Vargas

NASA — H. Margolis, M. Román

USGS — G. Stensaas, J. Dwyer

esa — S. Plummer, F. Gascon

EUMETSAT — A. Lattanzio

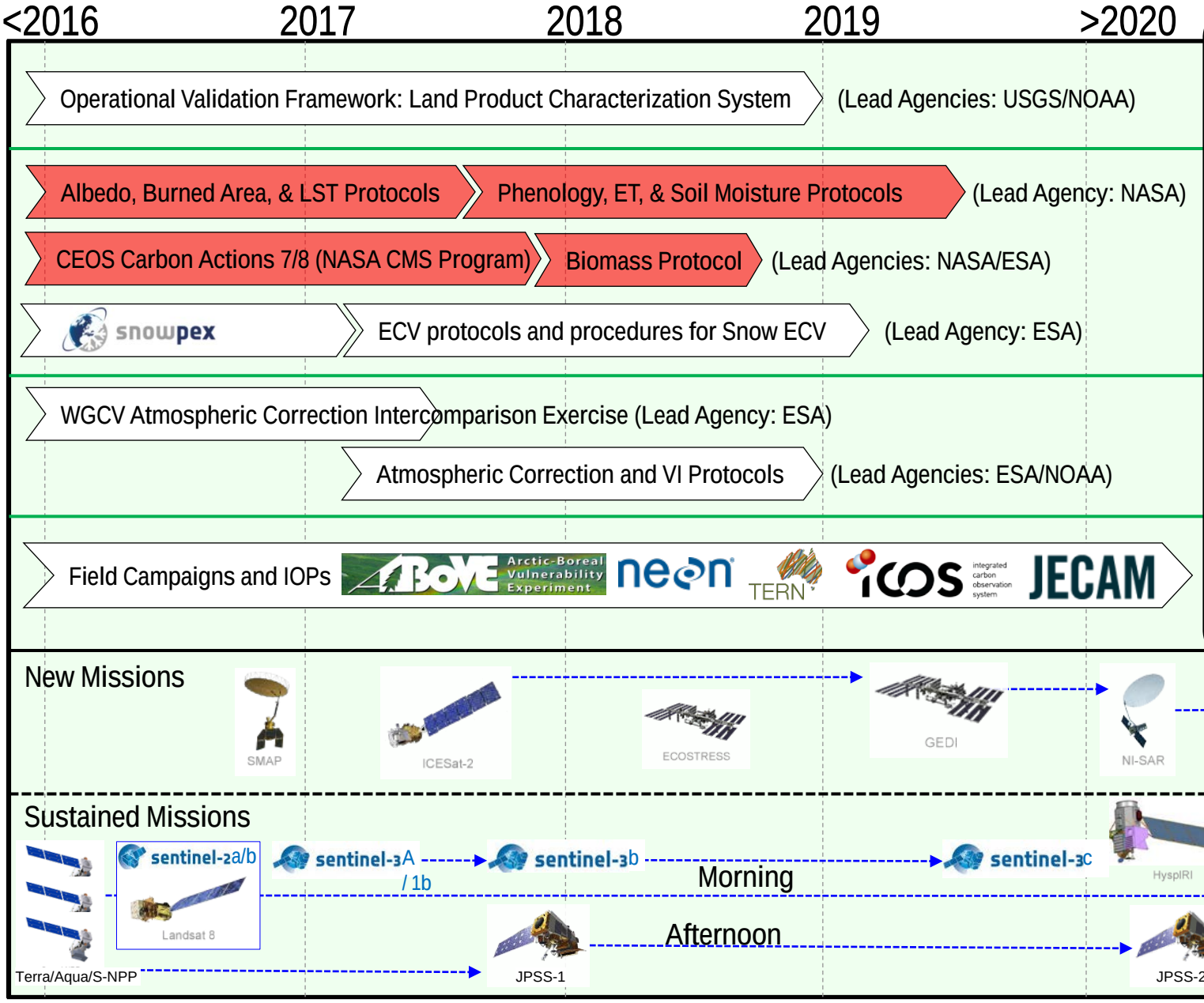
CEOS Member Agencies and Affiliates



http://ceos.org/about-ceos/agencies/

To integrate across LPV Focus Areas, CEOS Space Agencies, and the Land Discipline & Instrument Teams.

CEOS-LPV 5-Year Roadmap



Vision

All missions support validation & validation is on-going

Uncertainty information determined through standard practices & protocols

Algorithms are iteratively improved based on validation results

Lead Coordinating Agency: NASA

The LPV Validation Framework

Validation Good Practice Document



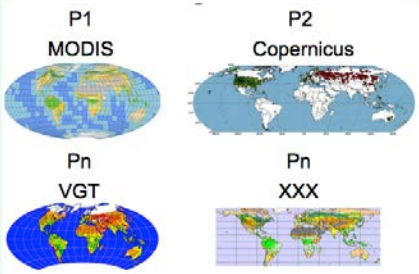
Fernandes et al., (2014). Global LAI Product Validation Good Practices. doi:10.5067/doc/ceoswgcv/lpv/lai.002

Fiducial Reference Data Sets



Example of fiducial reference data for soil moisture.

Global Satellite Product Subsets



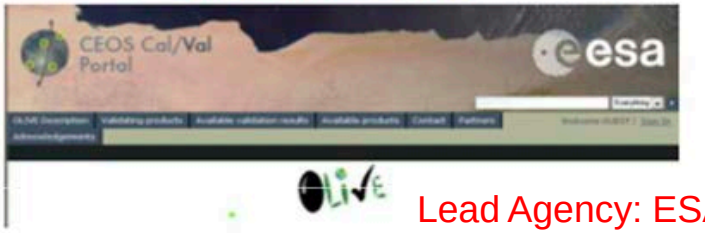
Subsets over fiducial reference data sites for each product automatically delivered.

Lead Agencies: Various

Lead Agency: NASA

Lead Agencies: USGS/NOAA

Online Validation Tool

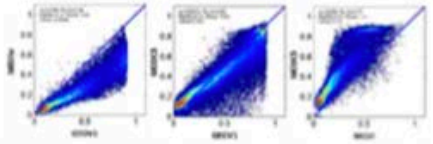


Lead Agency: ESA

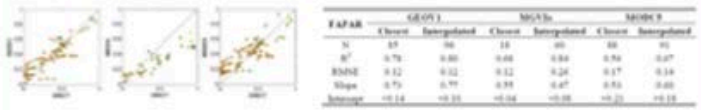
Example of OLIVE validation tool for LAI and FAPAR [3].

Lead Agency: ESA

Standardized Intercomparison Report



Standardized Validation Report



CEOS WORKING GROUP ON CALIBRATION & VALIDATION

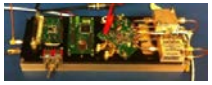
NASA small-UAS Partnerships:

GSFC, ARC and *BlackSwift Technologies LLC*

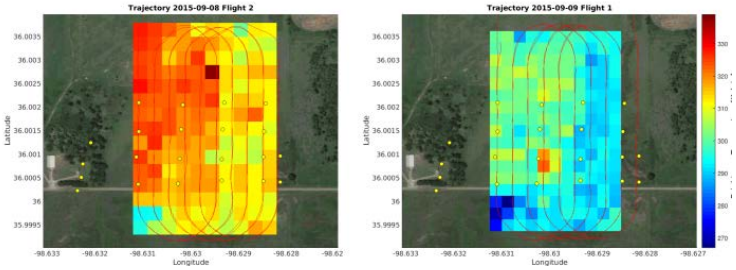
Two Instrument Systems

Soil Moisture (w/ L-Band Radiometer - SBIR)









Multiangle, Multispectral imaging sensors (Román, et al - IRAD)
Surface Reflectance/Albedo, VI, LAI&FPAR, and Burned Area.

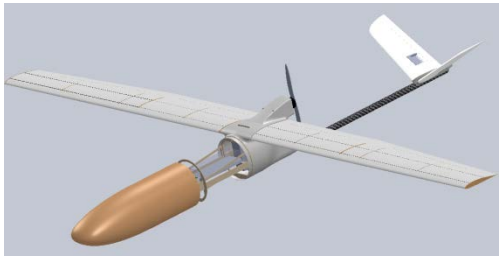


Two Types of s-UAS

Tempest (Established Platform)



SuperSwift (New, GeoScience Tailored Platform)



Electric s-UAS (both):
Max Wt. ~15 lbs
P/L Wt. ~5 lbs
Endurance~1 Hr

SBIR·STTR
America's Seed Fund™
POWERED BY NASA

http://sbir.nasa.gov/content/black-swift-technologies-llc

NASA Flight Readiness Review Approval
COA-Gov't

National Aeronautics and
Space Administration

Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, Virginia 23337-5099

Reply to Attn. of: Code 830 / AFSRB Chairman April 20, 2016

TO: 840/PM, Tempest UAS

FROM: 830/Chairman, Airworthiness and Flight Safety Review Board (AFSRB)

SUBJECT: Flight Release for the Tempest UAS

REF:
(a) FRR Meeting Minutes. March 25, 2016.
(b) UAS FOM, March 2016
(c) Tempest UAS Pilot Operating Handbook (Flight Manual)
(d) NPR 7900.3, "Aircraft Operations Management Manual", July 15, 2011

1. In accordance with the recommendations of the AFSRB in Reference (a), the Tempest UAS is certified for flight under the sUAS Provisions of the UAS FOM, Reference (b). All flights shall be flown in accordance with the Tempest UAS pilot operating handbook, Reference (c), UAS FOM and NPR7900.3, Reference (d). In the event of conflicting guidance, the more restrictive policy shall be used.

FAA Section 333 and Transport Canada Full Blanket Exemptions

U.S Department
of Transportation
**Federal Aviation
Administration**

800 Independence Ave., S.W.
Washington, D.C. 20591

December 11, 2015

Exemption No. 13967
Regulatory Docket No. FAA–2015–1684

Mr. Jack Elston
Black Swift Technologies
2100 Central Avenue
Boulder, CO 80301

Dear Mr. Elston:

This letter is to inform you that we have granted your request for exemption. It transmits our decision, explains its basis, and gives you the conditions and limitations of the exemption, including the date it ends.

BlackSwift TECHNOLOGIES
2100 CENTRAL AVE STE 102
BOULDER, CO 80301
(720)638-9656

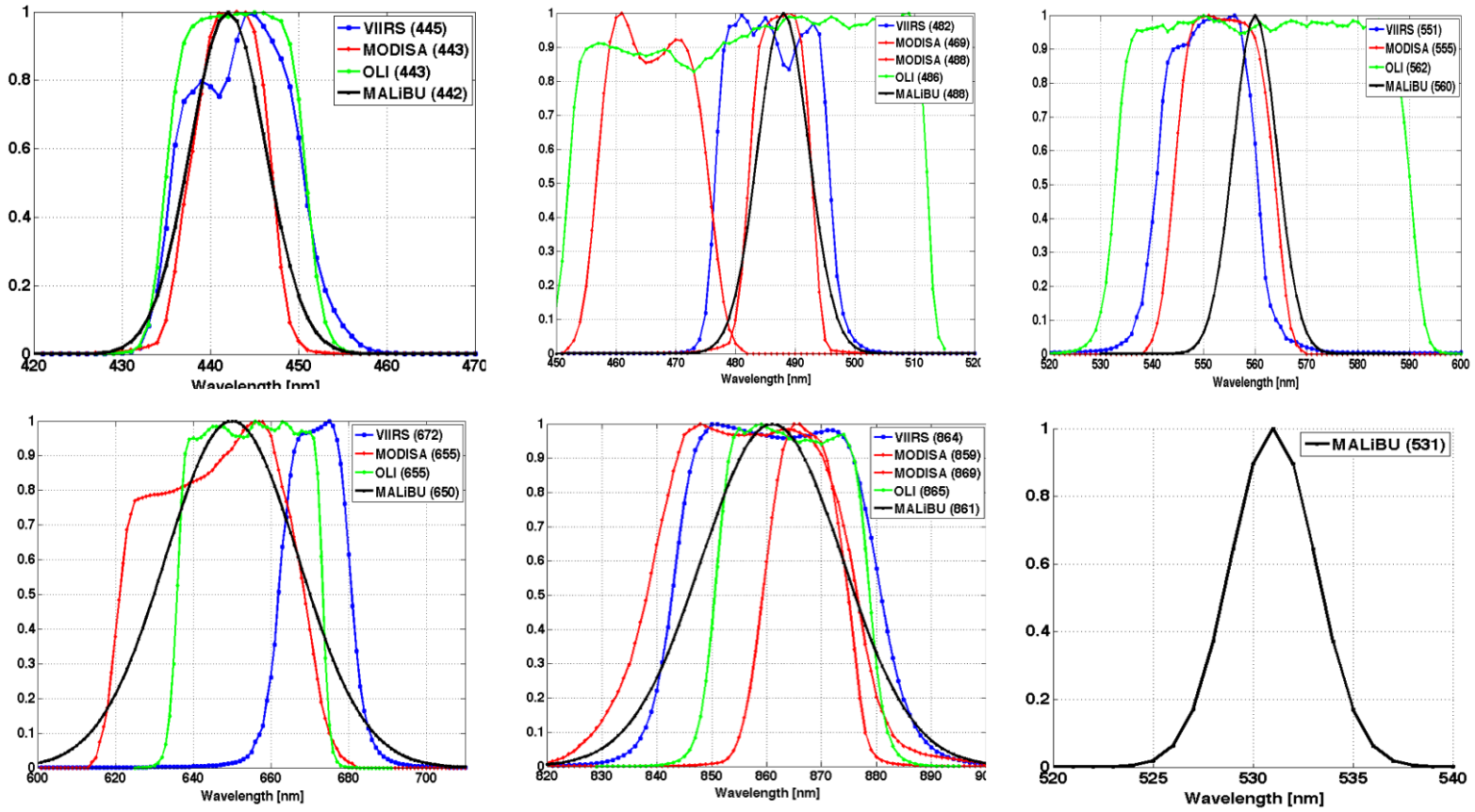
This document is concerned with operations of UAS in Canada for commercial use weighing less than 25 kg (55 lbs). More specifically, this document is concerned with operations of UAS that do NOT require a Special Flight Operations Certificate (SFOC). To operate a UAS that is exempt from an SFOC, this falls into 2 categories, sub 2 kg and 2 kg to 25 kg. The requirements and operational limitations for each class are listed below in the following two sections. The infographic outlining these rules is attached in the Appendix. However, the detailed requirements listed in the following two sections are taken from the more detailed Advisory Circular (AC) No. 600-004 [1]. Note that Transport Canada can issue a fine of up to $25,000 to a company not following these rules.

The operator must have the following 4 things in their possession, ready to show to any Transport Canada representative:

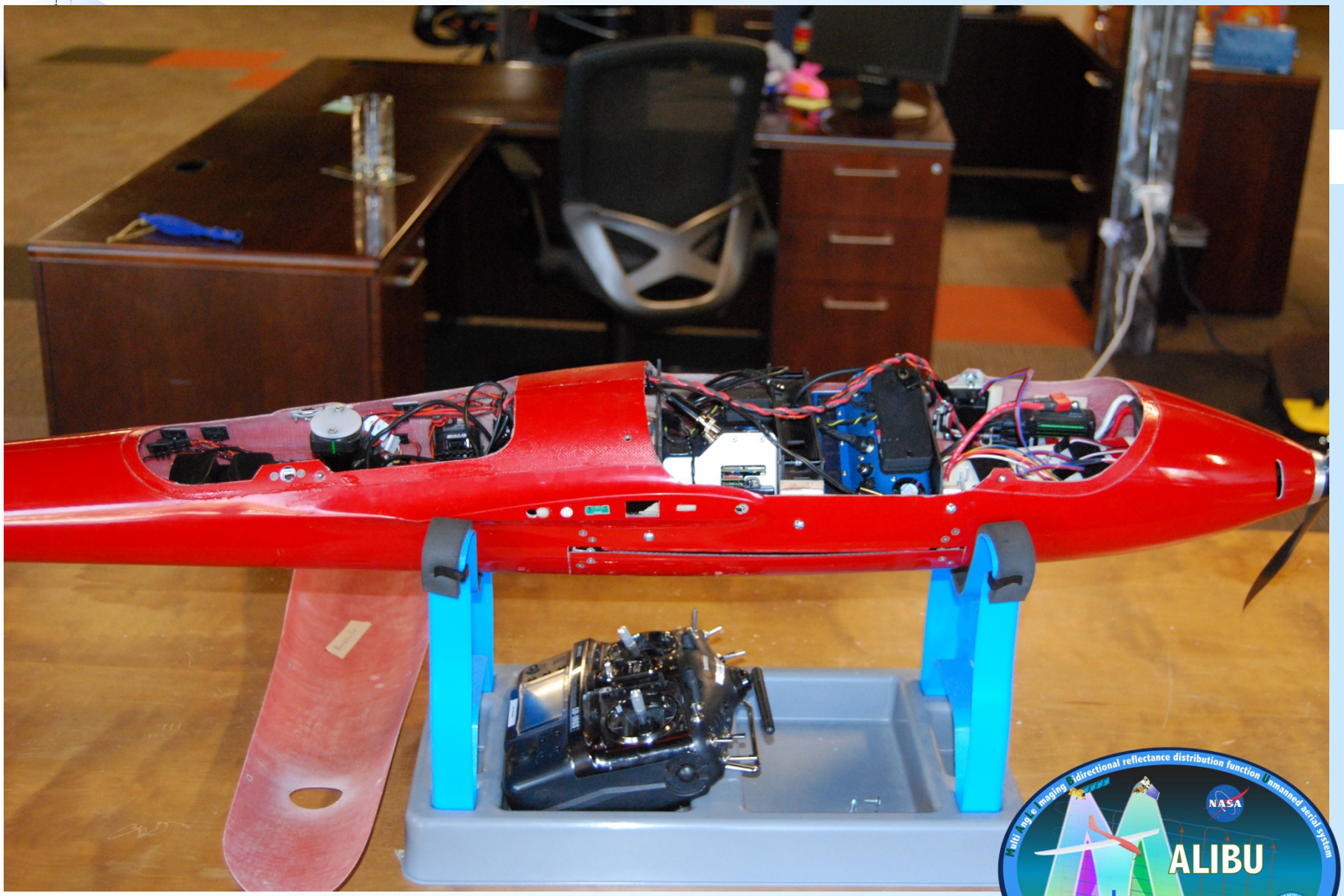
	Copy of UAS Exemption (i.e., this document with all provisions in the previous section followed)
	Proof of liability insurance
	Contact Information
	Aircraft System Limitations (i.e. manuals)

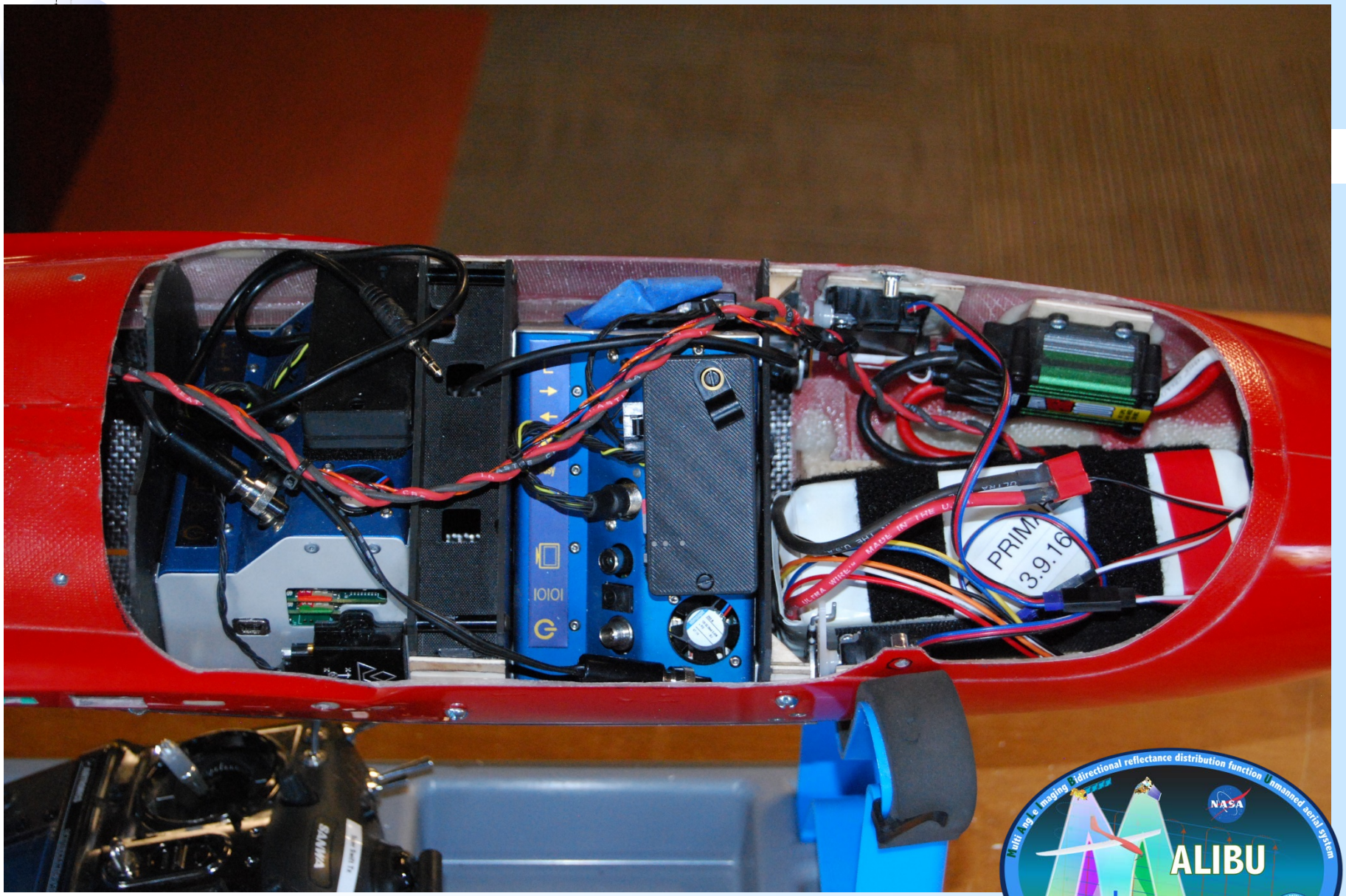


MALIBU Spectral Response

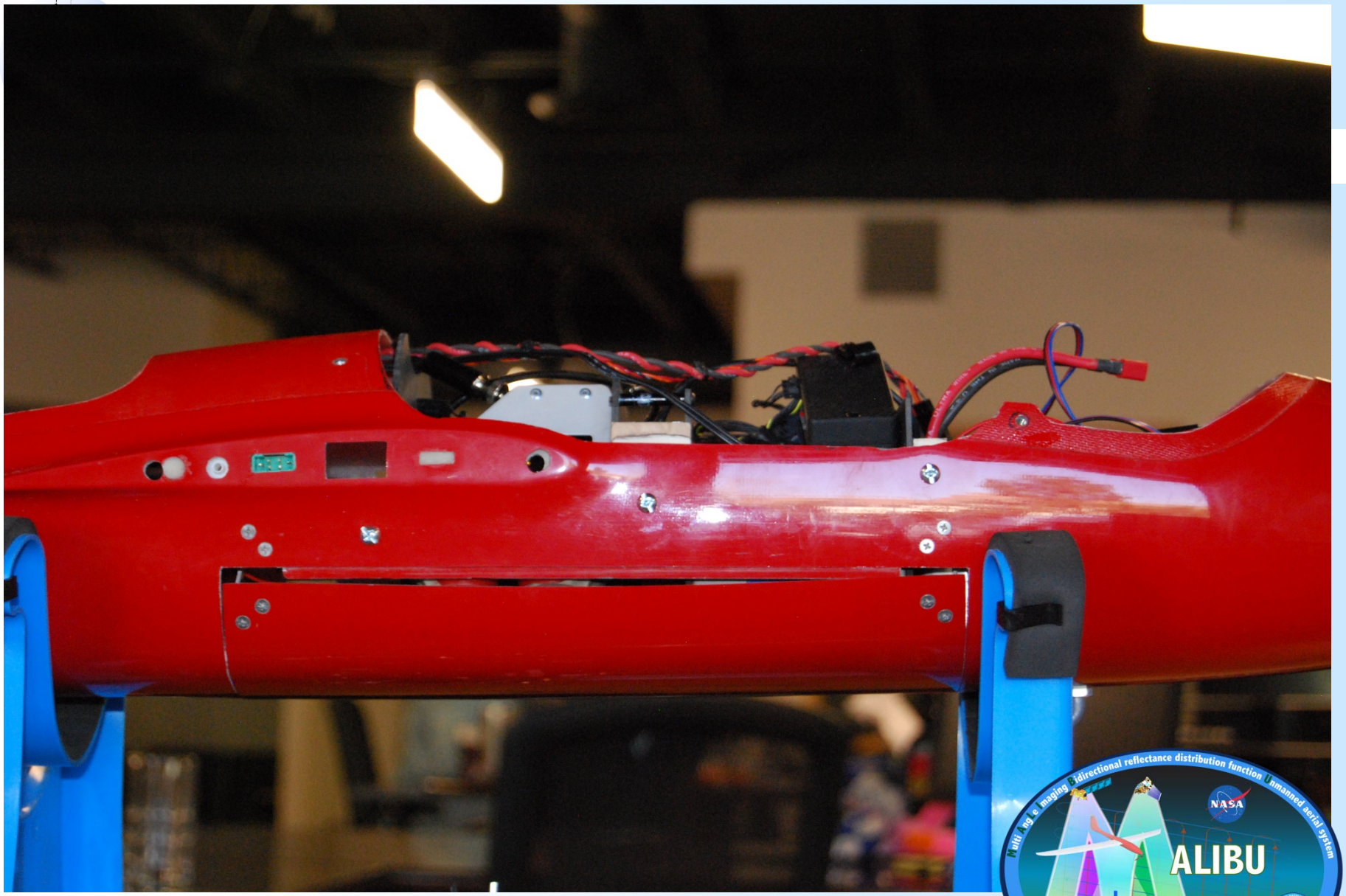


The MALIBU instrument design includes two Tetracam optical units matching the optical Land channels of key Land sensors such as Landsat-8 OLI, Sentinel-2 MSI, Sentinel 3-OLCI, Terra/Aqua MODIS, Terra MISR, and Suomi-NPP/JPSS VIIRS.

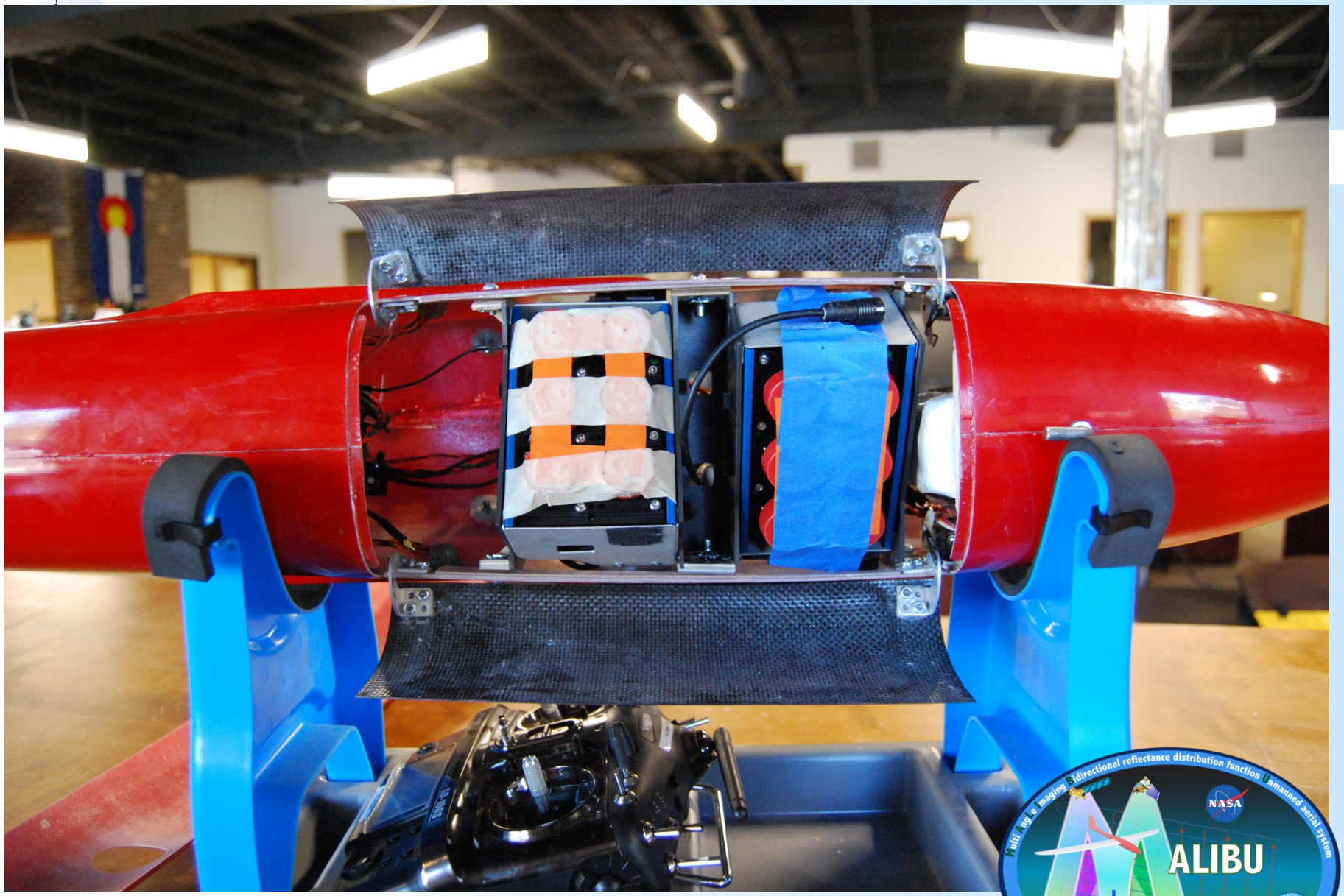

ALIBU
NASA
JPSS
NASA - Goddard Space Flight Center


PRIM
3.9.16


Multi-Angle Imaging Bidirectional reflectance distribution function Unmanned aerial system
NASA
ALIBU
JPSS
NASA - Goddard Space Flight Center

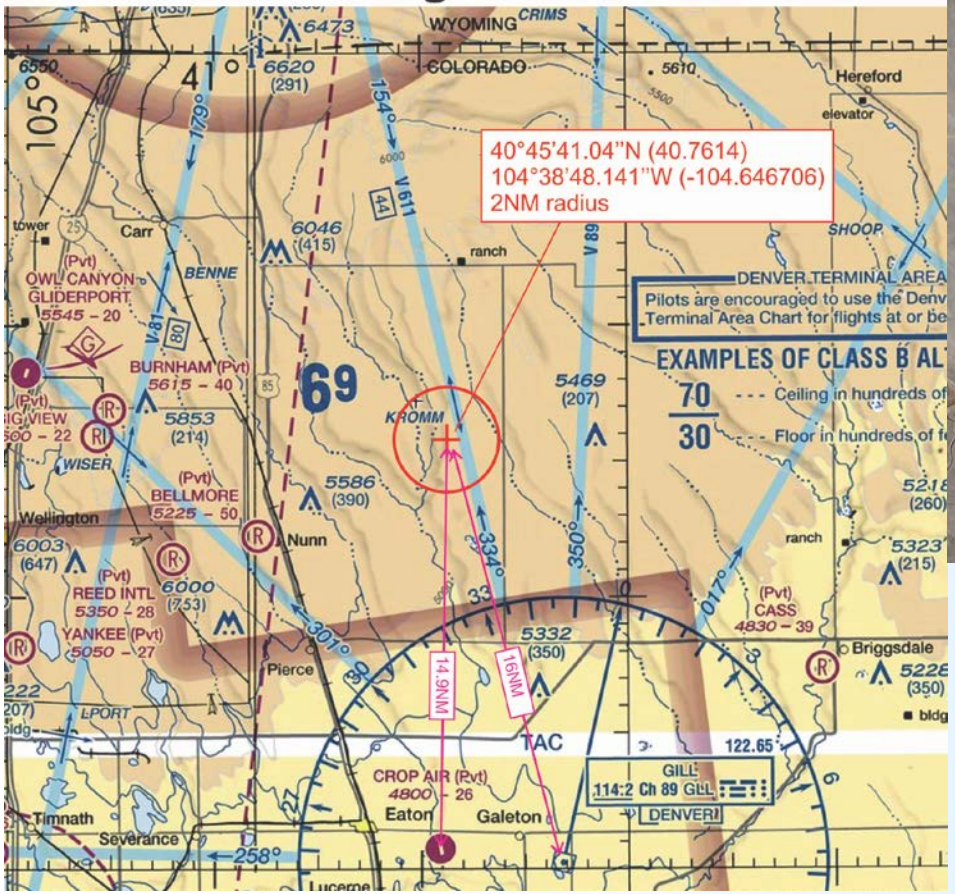


GODDARD SPACE FLIGHT CENTER


Multi Angle Imaging Bidirectional reflectance distribution function Unmanned aerial system
NASA
ALIBU
JPSS
NASA - Goddard Space Flight Center

MALIBU Test Flights – (6/29/16 – 7/1/16) (Pawnee National Grasslands, CO)

Pawnee NGL flight area

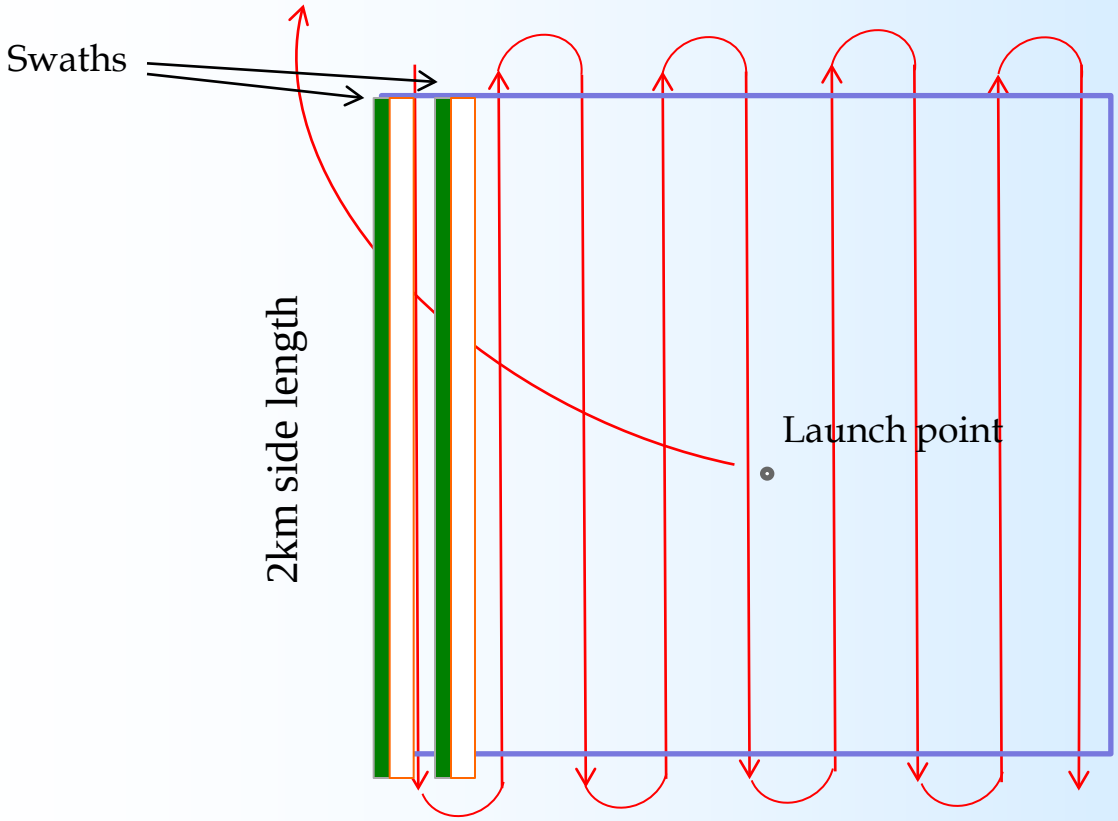






Operations Plan Flight Plan

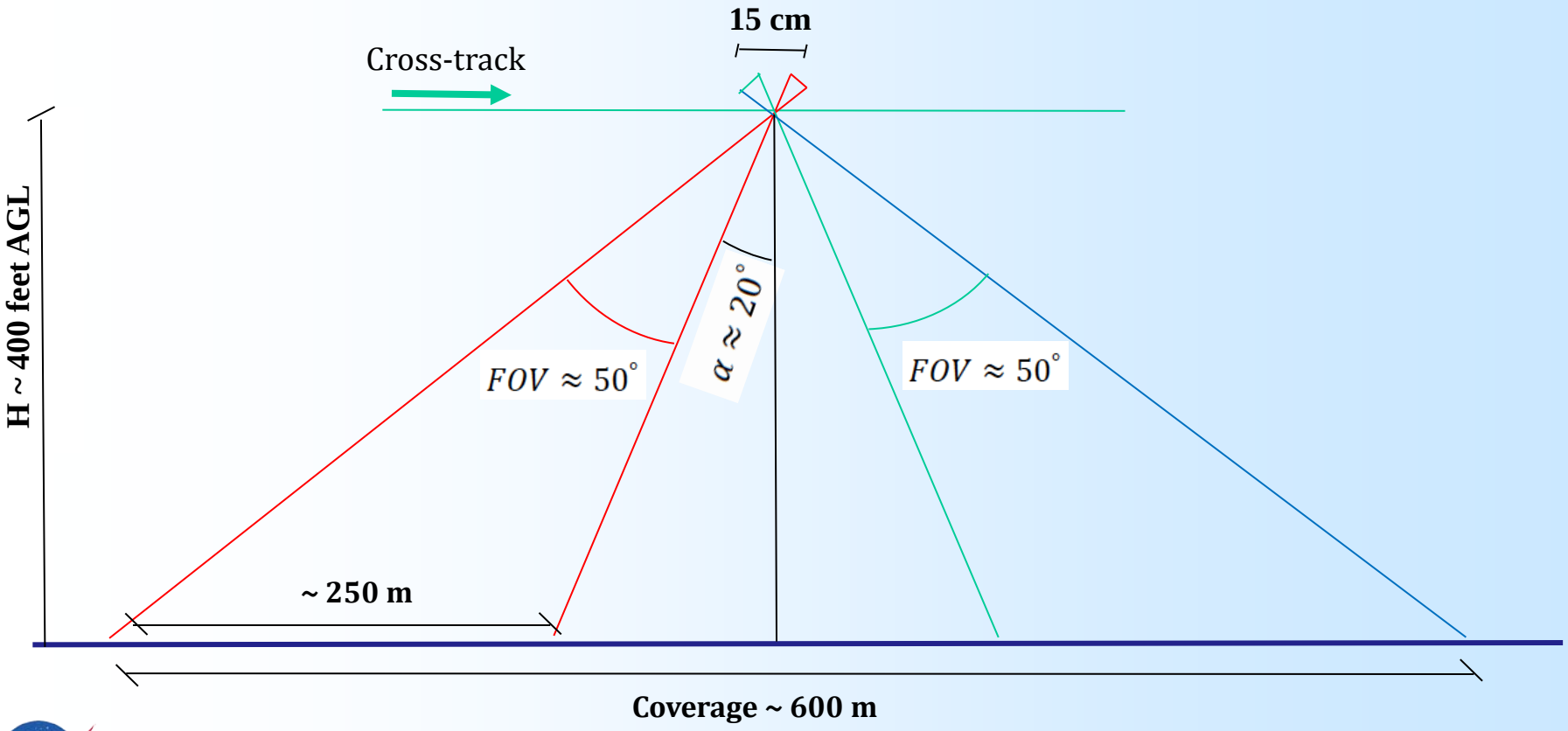
- 2×2 km^2 is covered during two-day deployment
- Requires visible line-of-sight less than 2 km





Viewing Geometry: Cross-track

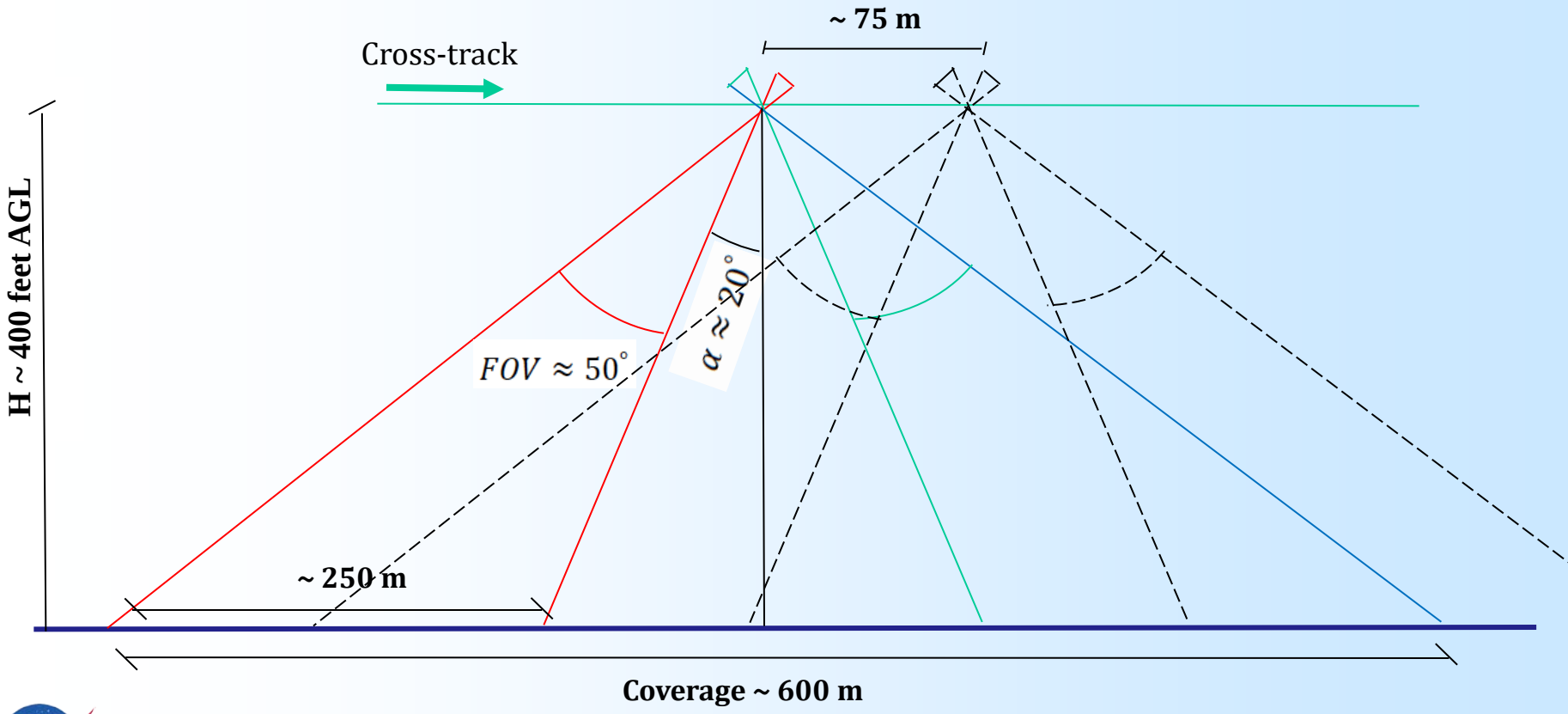
- **Dual Tetracam cameras (with non-overlapping swaths) mounted on the platform across-track**





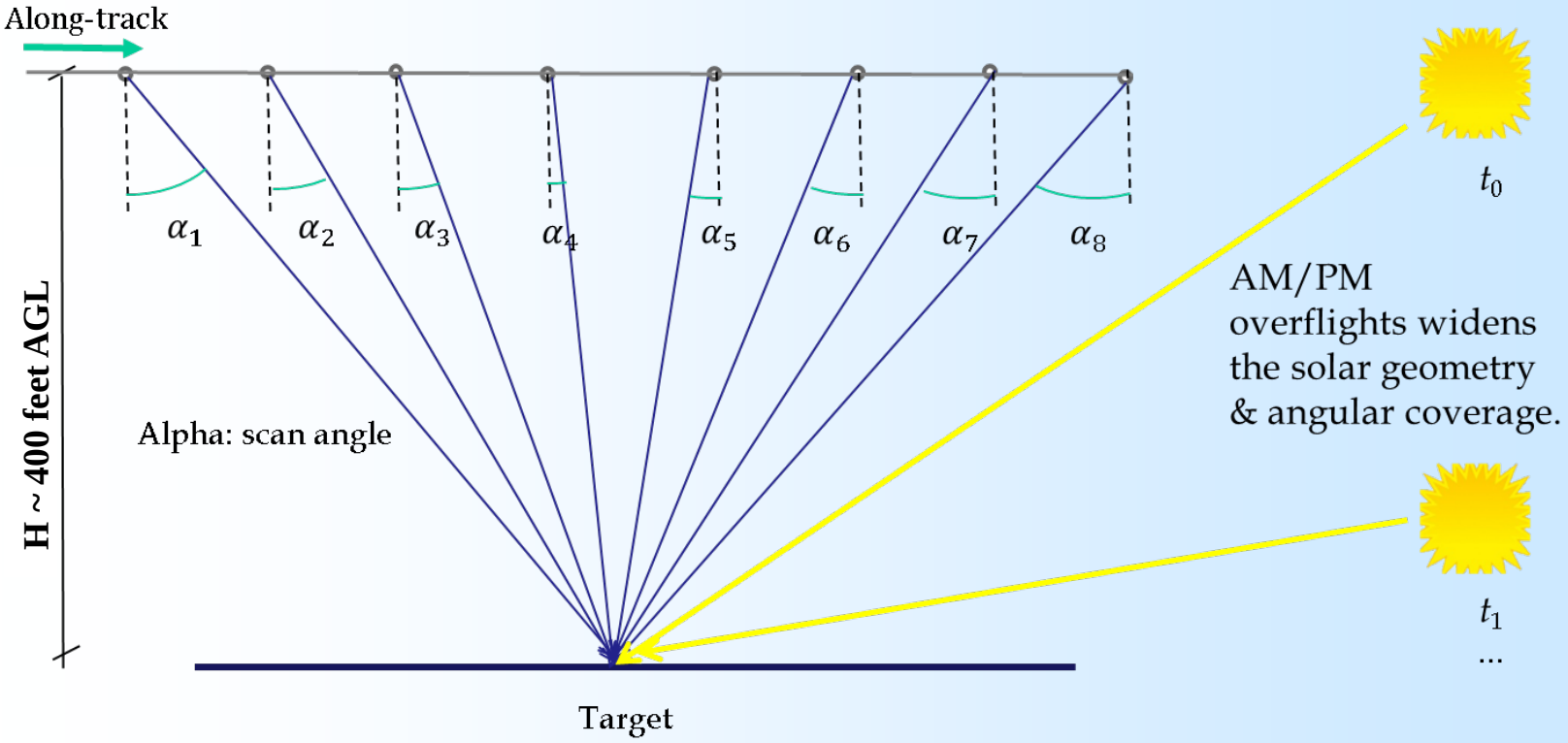
Viewing Geometry: Cross-track

- **Dual Tetracam cameras (with non-overlapping swaths) mounted on the platform across-track**

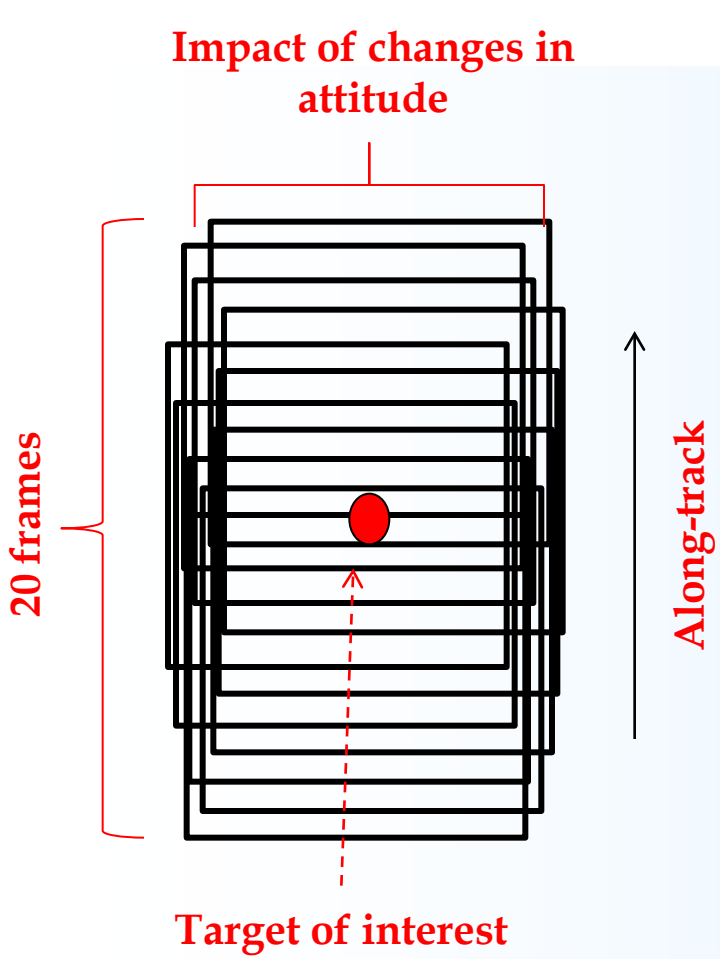


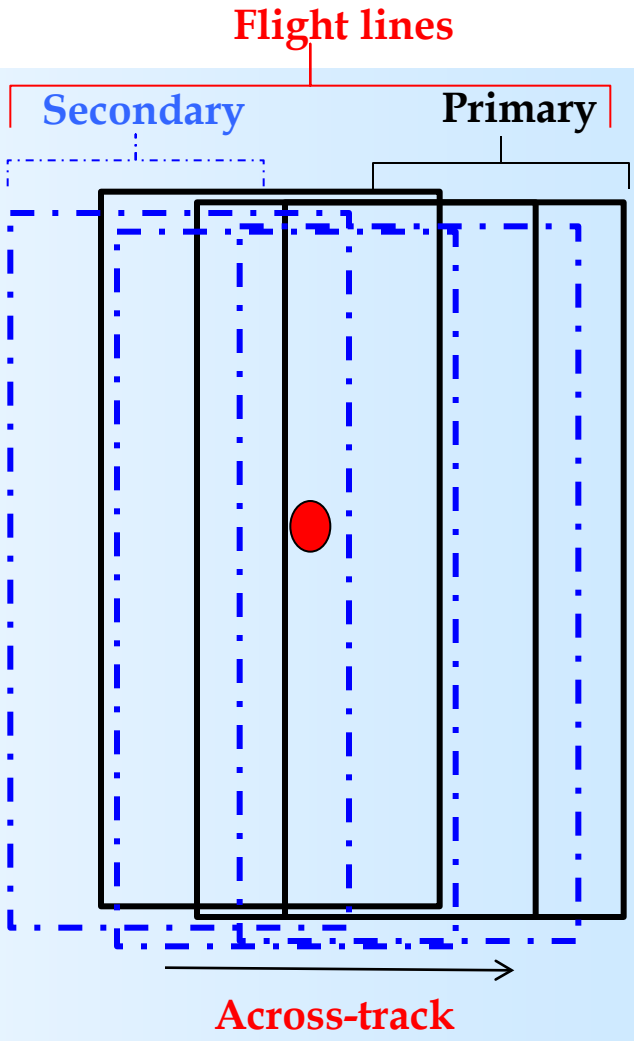
MALIBU Flight Path(cont.)

Overlapping scenes along-track provide multi-angular retrievals.



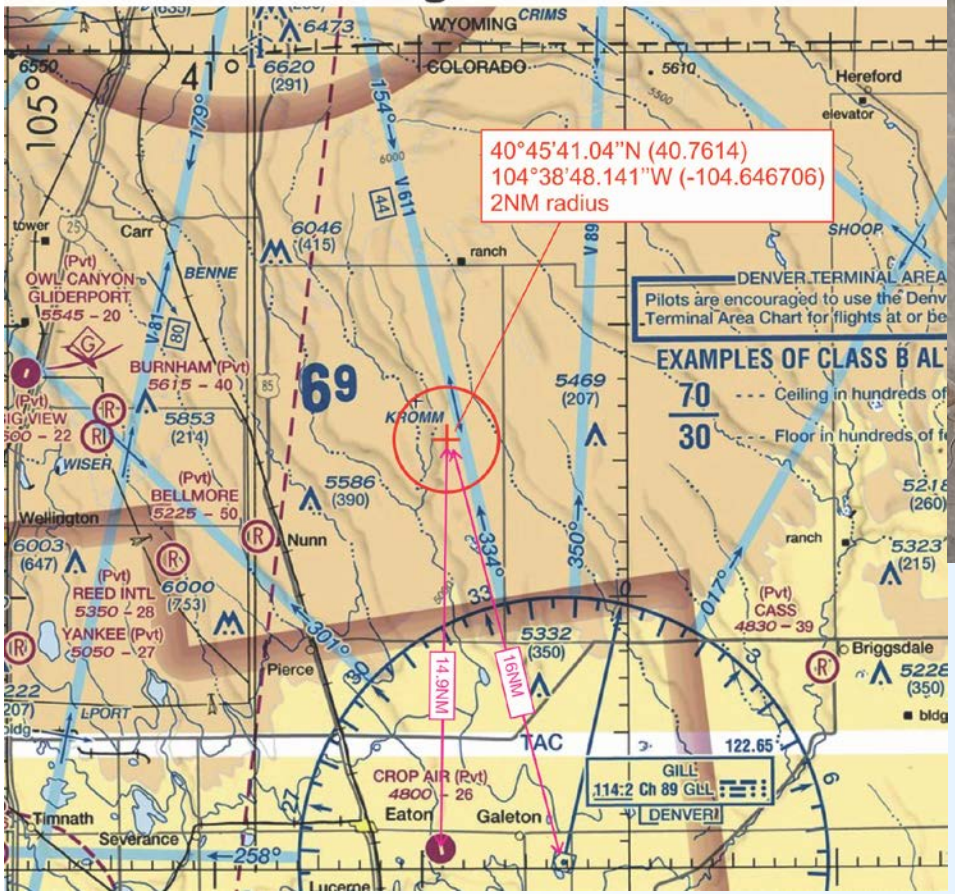
Overlapping Regions





MALIBU Test Flights – (6/28/16 – 7/1/16) (Pawnee National Grasslands, CO)

Pawnee NGL flight area







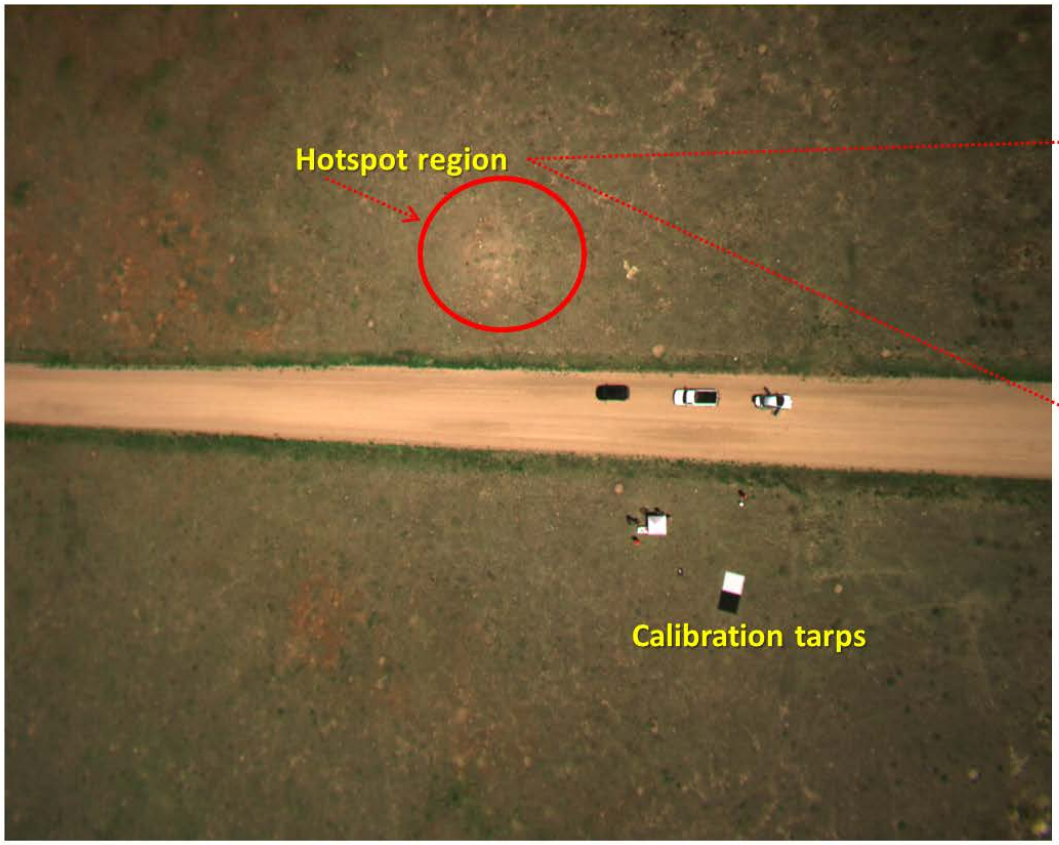
MALIBU Field Campaign at Pawnee

Play Video and hope that it works…

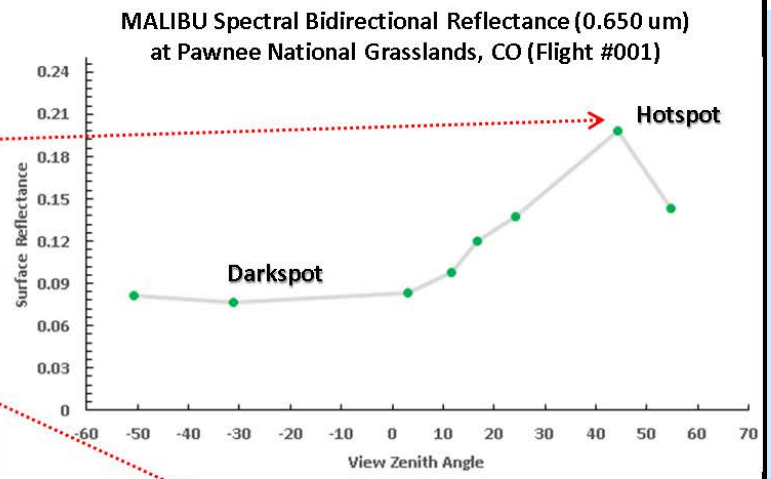
https://youtu.be/Vd8c-4rXQOo

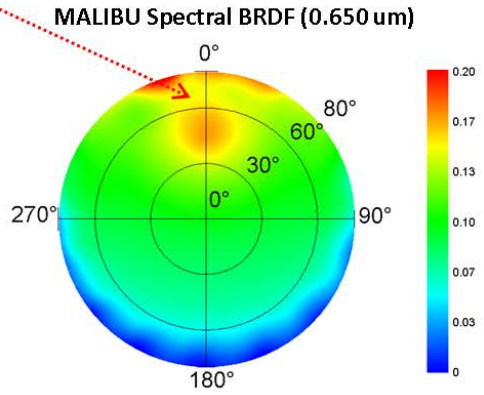
[Back Up File: MALIBU_Test_Flights_Pawnee_National_Grasslands_001-003.mp4]

First Light BRDF Products

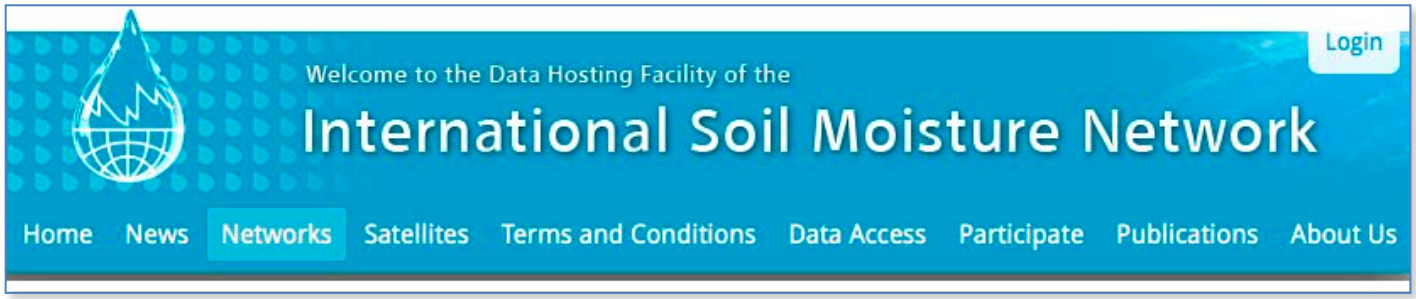


MALIBU True Color Surface Reflectance Composite (Red: 0-0.3; Green 0-0.3; Blue 0-0.3)





Fiducial Reference Data Sets



LTER

FLUXNET
A Global Network

AERONET
AEROSOL ROBOTIC NETWORK

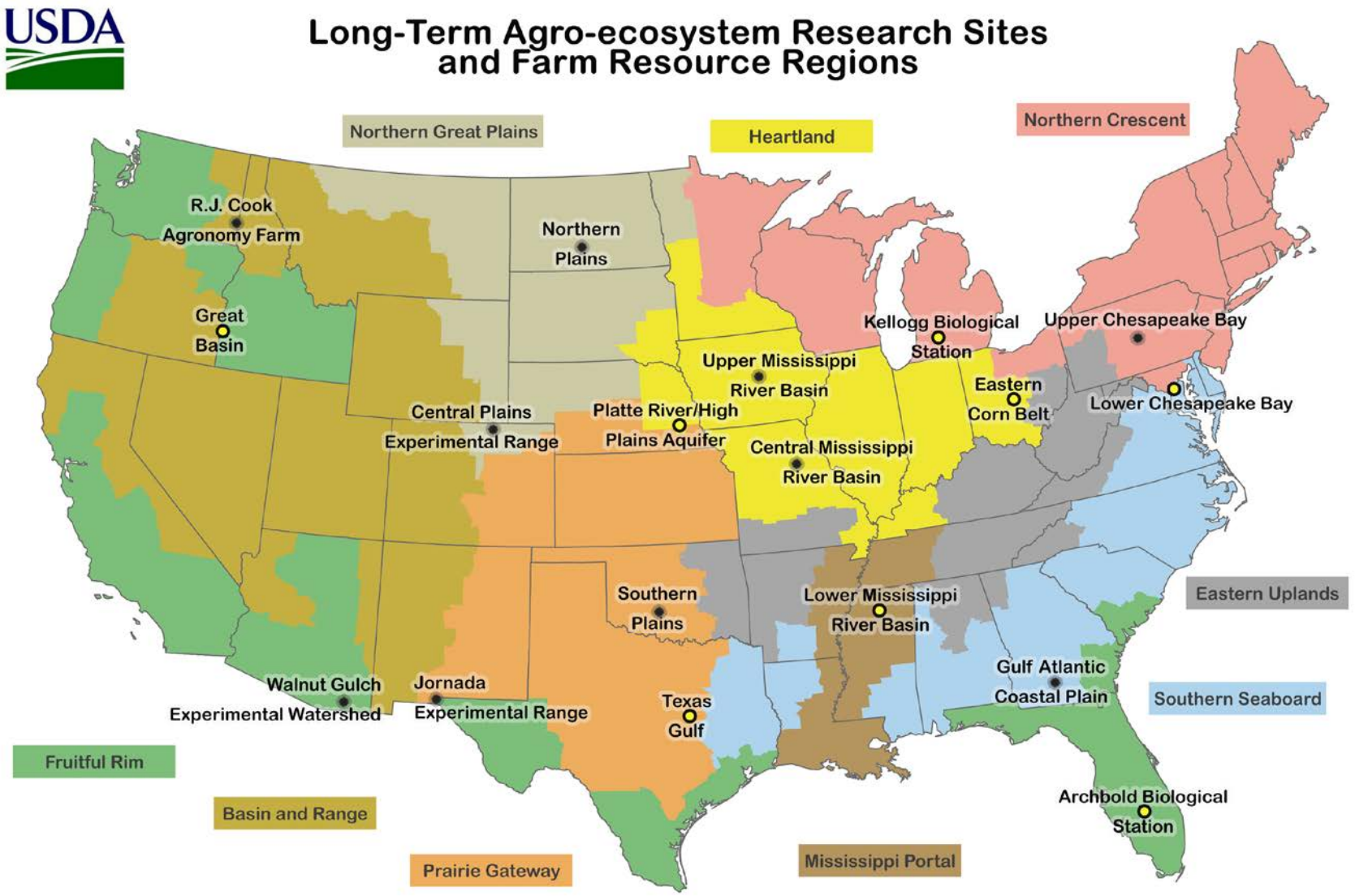
neon® Data
The National Ecological Observatory Network Data Portal

ABoVE
ARCTIC BOREAL VULNERABILITY EXPERIMENT

US Climate Reference Network

CEOS WORKING GROUP ON CALIBRATION & VALIDATION

Fiducial Reference Data Sets: Key Players



NASA POCs (Pierre Guillevic, Brad Doorn, Chris Justice)
Full List of Organizations:
http://www.ars.usda.gov/SP2UserFiles/Program/211/LTAR%20Collaborators%20alphbetical%20FINAL.pdf

CEOS WORKING GROUP ON CALIBRATION & VALIDATION

CEOS LPV Focus Areas and Co-leaders *ECV

Snow Cover*, Sea Ice	Thomas Nagler (ENVEO, Austria)	Tao Che (Chinese Academy of Sciences)
Surface Radiation (Reflectance, BRDF, Albedo*)	Crystal Schaaf (U Mass Boston)	Alessio Lattanzio (EUMETSAT)
Land Cover* and Land Use Change	Pontus Olofsson (Boston University)	Martin Herold (Wageningen University, NL)
Above Ground Biomass*	**Vacant**	**Vacant**
FAPAR*	Arturo Sanchez (University of Alberta)	Nadine Gobron (JRC, IT)
Leaf Area Index*	Oliver Sonnentag (University of Montreal)	Stephen Plummer (ESA)
Fire* (Active Fire, Burned Area)	Luigi Boschetti (University of Idaho)	Kevin Tansey (University of Leicester, UK)
Land Surface Temperature* (LST and Emissivity)	Simon Hook (NASA JPL)	Jose Sobrino (University of Valencia, SP)
Soil Moisture*	Tom Jackson (USDA ARS)	Wolfgang Wagner (Vienna Univ of Technology, AT)
Land Surface Phenology	Matt Jones (Oregon State University)	Jadu Dash (U Southhampton)
Vegetation Index	Tomoaki Miura (University of Hawaii)	Marco Vargas (NOAA/NESDIS/STAR)

CEOS-LPV's Core Mission

http://lpvs.gsfc.nasa.gov/

Instrument Teams

VIIRS Land

MODIS Land

Discipline Teams

NOAA

NASA

USGS

esa

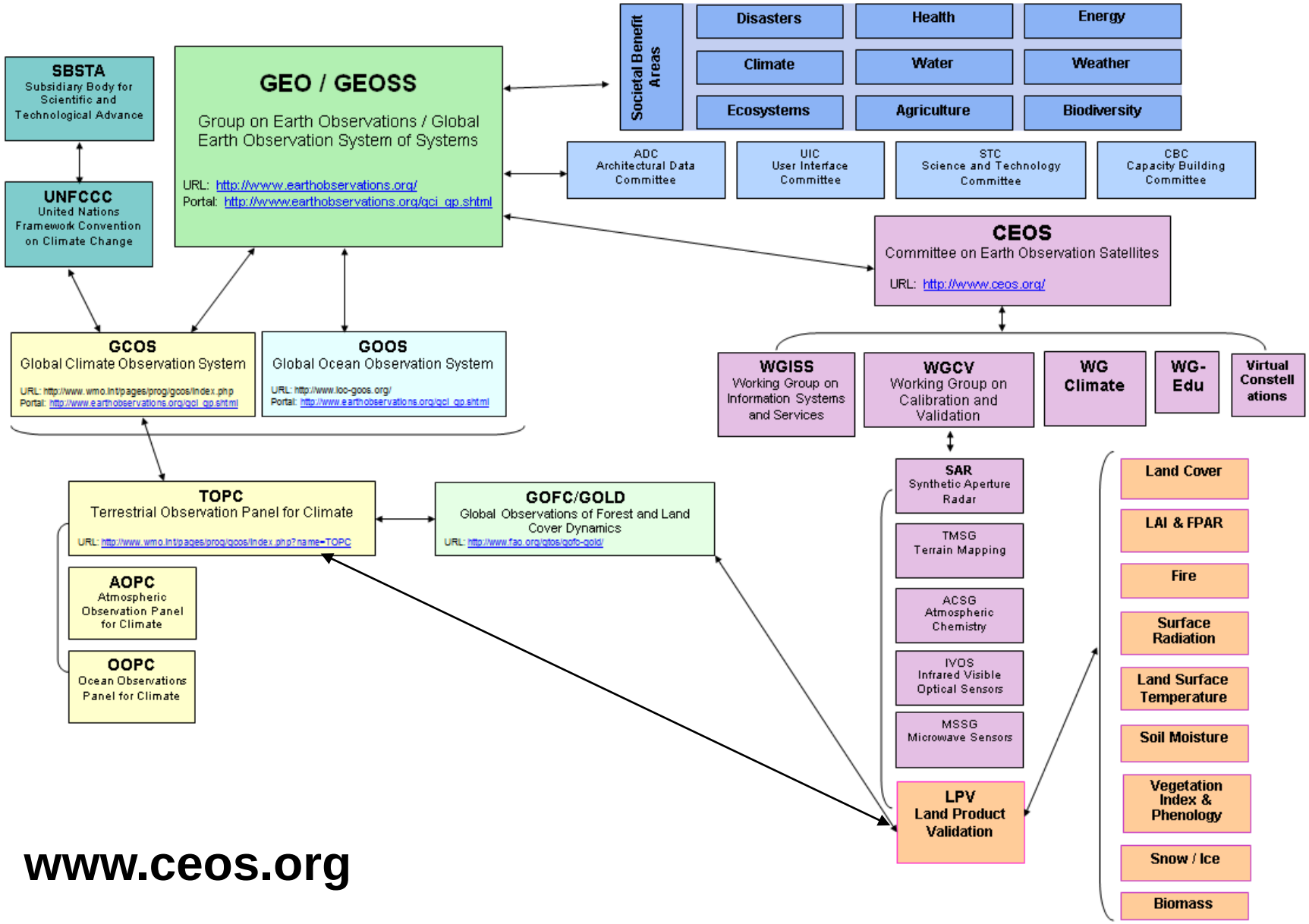
EUMETSAT

CEOS Working Groups and Associates



To integrate across LPV Focus Areas, CEOS Space Agencies, and the Land Discipline & Instrument Teams.

International Programs concerned with Terrestrial Earth Observations

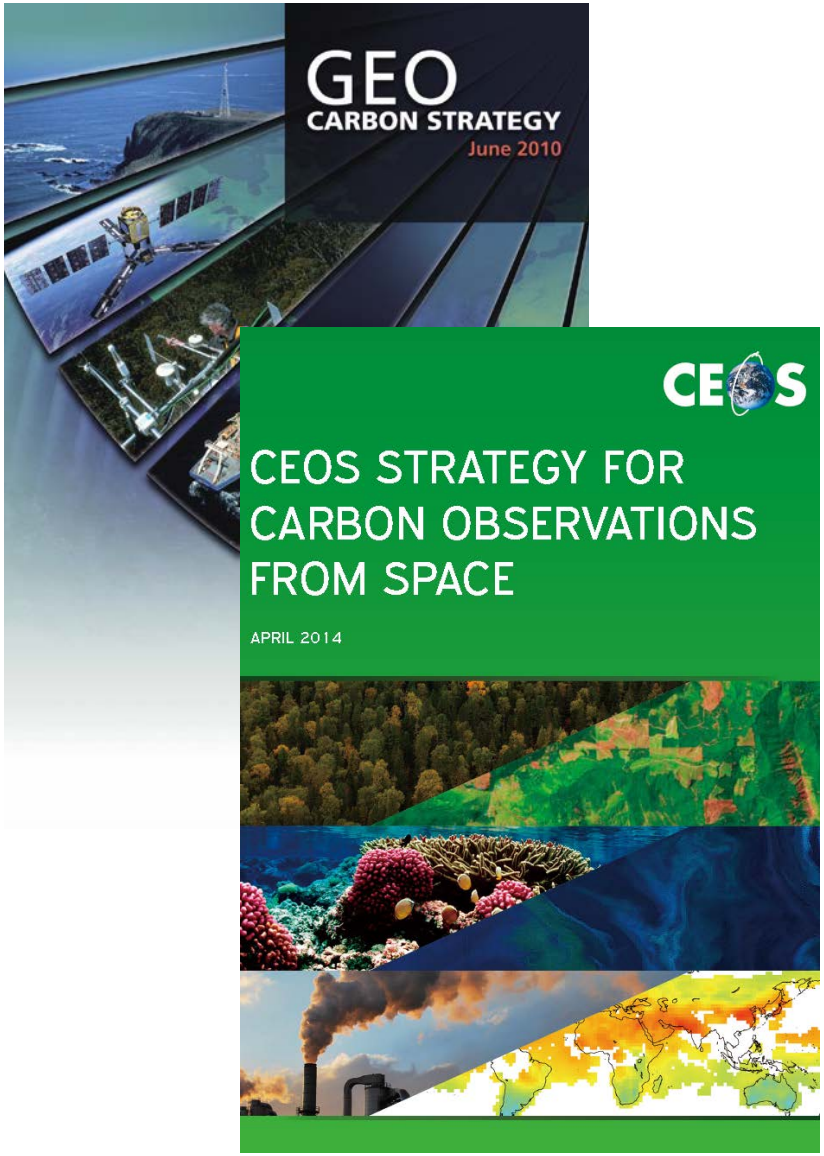


www.ceos.org

Key CEOS Carbon Actions

- **Carbon Action 7:** "Improve and ***expand upon the availability of the in-situ observations needed for the calibration and validation of satellite land data products used for carbon science***".

- **Carbon Action 8:** "The ***CEOS WGCV's Land Product Validation (LPV) Subgroup*** will continue its work to validate satellite land data products and ***expand the number of land variables addressed*** as priorities are identified and available resources permit.).



CEOS WORKING GROUP ON CALIBRATION & VALIDATION

LPV Biomass Focus Area Goals:



Practicality Optimizations:
- 3.4 kg
- 33 second scan
- IP68 waterproof
- Wireless operation

UMB CBL (RIT SICK)	Instrument	RIEGL VZ400
Time-of-flight	Ranging Technique	Time-of-flight
1st and 2nd discrete return	Recorded Data	Multiple discrete return Waveform
0-135 zenith 0-360 azimuth	Scan Configuration	30-130 zenith 0-360 azimuth
905 nm	Wavelengths	1550 nm
0.25 deg 0.50 deg	Angular Resolution	0.04-5.03 mrad zenith 0.04-8.73 mrad azimuth
15 mrad	Beam Divergence	0.35 mrad
1	Laser Class	1
50 Hz	Pulse Rate	100 kHz 300 kHz
3.4 kg	Weight	9.6 kg
40 m	Max. Range	200 m 120 m



Capability Optimizations:
- 0.04 mrad max resolution
- 200 m max range
- Multiple return / waveform

Fusing GLiHT airborne LiDAR (yellow) with the underlying UMB Canopy Biomass Lidar (CBL) (red) provides additional information on the undercanopy structure.



Validation protocols focusing on: (1) core site selection, (2) field sampling (< 4 ha), (3) scaling techniques, and (4) uncertainty quantification of reference measurements.

CEOS WORKING GROUP ON CALIBRATION & VALIDATION

TOPC-18 Panel & Experts



Land Surface Temperature ECV



Focus Area on Land Surface Temperature and Emmissvity Product Validation

Simon Hook, NASA Jet Propulsion Laboratory, USA
Jose Sobrino, University of Valencia, Spain

Meetings

The Earthtemp initiative 35th EARSeL Symposium Stockholm, Sweden, June 15 to 19. Abstract Deadline is February 2015.

ISRSE36, Berlin, Germany, 11-15 May.

Land Surface Temperature Definition

Land surface temperature (LST) is defined as the temperature derived from a radiative energy balance of a surface and provides the best approximation to the surface skin thermodynamic temperature based on a measure of radiance (Norman and Becker, 1995). LST is also called (directional) radiometric temperature or skin temperature.

Units: The unit of LST is Kelvin [K]. Degree Celsius [°C] is also commonly used.

Land Surface Emissivity Definition

The emissivity of an isothermal, homogeneous emitter is defined as the ratio of the actual emitted radiance to the radiance emitted from a black body at the same thermodynamic temperature (Norman and Becker 1995).

Units: Dimensionless.

Norman, G., and Becker, F. (1995). Terminology in thermal infrared remote sensing of natural surfaces. Agricultural and Forest Meteorology, Volume: 77, Issue: 3-4, Pages: 153-166, DOI: 10.1016/0168-1923(95)02259-Z

Highest Validation Stage Currently Reached for Satellite-Derived Land Surface Temperature and Emissivity Products

Validation stage 1 (LPV validation stage hierarchy) - The highest LPV validation stage reached for satellite-derived land surface temperature and emissivity products. For reaching validation stage 3 and higher, an increased number of global validation sites, covering all surface types, with extended temporal coverage, as well as intercomparison of different LST products are needed.

Land Surface Temperature Validation Methods

Four different methods have been widely used to validate and determine the uncertainties in LST products derived from satellite measurements (Schneider et al., 2012; Guillevic et al., 2014):

CEOS WORKING GROUP ON CALIBRATION & VALIDATION

Driving the Global Climate Observation Agenda

Identify/Review Essential Climate Variables (ECVs) through science panels

Regular review of how these ECV are observed

Develop plans to ensure continuity and improvement of observations

- GCOS follows a 3 phase approach driven by users
- 2015 Status Report started the 3rd assessment cycle with a new Implementation Plan due in Oct 2016 for the UNFCCC Subsidiary Body for Scientific and Technological Advice (SBSTA).

(1st cycle: 1995-1998)



(2nd cycle: 2003-2004-2010)



(3rd cycle: 2015-2016)



WMO IOC UNEP ICSU International Council for Science

19 Essential Climate Variables

Current focus of TOPC is to identify measurable terrestrial key variables that control the physical, biological and chemical processes affecting climate and are indicators of climate change.

Biological/Ecological (6)

Land cover and Land Use Change
FAPAR
Leaf area index
Above ground biomass
Soil carbon
Fire disturbance

Hydrological (5)

River discharge
Water use
Ground water
Lakes
Soil moisture

Cryospheric (4)

Snow cover
Glaciers ~~and ice caps~~
Ice sheets and ice shelves
Permafrost

Surface Properties (4)

Albedo
Land surface temperature
Energy fluxes
Anthropogenic greenhouse gases

New, **Revised**, and **Proposed**

11 ECVs are directly linked to MODIS/VIIRS Land Products

Summary of Activities for PY-1 and Challenges Ahead

Agency-Level:

- [*Nickeson*] Maintenance and upkeep of the MODIS/VIIRS-Land websites and validation portal

LPV Subgroup Level:

- [*Guillevic & Wang*] Surface Albedo and LST ECV Protocols (Draft to be completed by end of PY-1)
- [*Guillevic & Camacho*] LPV Status Report (RSE Special Issue) [*in preparation*]
- [*Román, Wang, Pahlevan, and McCorkel*] Field Campaigns (MALIBU-sUAS): Reference data supporting NASA/NOAA/USGS/ESA missions. Deployments at NEON, LTER/LTAR, BSRN, and/or ABoVE sites.
- [*Wang and Gallo*] Land Product Characterization System (LPCS): Integration of MODIS/VIIRS Land Quality Assessment and Validation tools.
- [*Román & Camacho*] Term limits for 9 LPV focus area leads (Dec, 2016)
- [*Nickeson & Román*] AGU'16 Special Session on Land Product Validation Efforts [*submitted*]

CEOS-WG, Plenary, and Higher Level:

- [*Thome*] Upcoming WGCV-41 Plenary:
  - [*Dubayah and Plummer*] CEOS Carbon Actions 7/8: *Formation of LPV AG Biomass Focus area*
    - *Initial Protocols will Focus on Terrestrial Lidar Systems (TLS)*
    - *Identify 3 Priority Core Sites (US, EU, AUSTRALIA) and Support a TLS Intercomparison Study*
- [*Camacho*] 2016 GCOS/TOPC Implementation Plan for UNFCCC COP22 SBSTA-45 *Addressing Orphaned Terrestrial ECVs:*
    - *Fundamental Data Records (Reflectance, BRDF)*
    - *Land Cover & Land Use Change (not just Land Cover)*
    - *Emissivity and Evapotranspiration (not just Land Surface Temperature)*
    - *Higher-level biophysical parameters: LUE, NPP/GPP, Water Content, Pigments*

CEOS WORKING GROUP ON CALIBRATION & VALIDATION

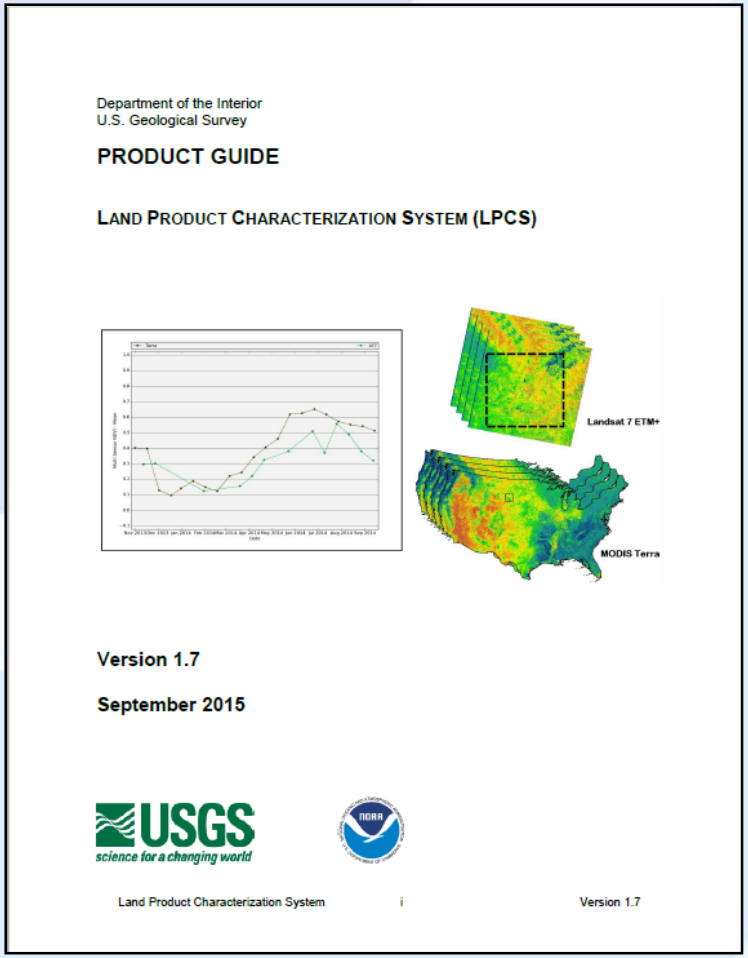


http://lpvs.gsfc.nasa.gov

Land Product Characterization System

STAR JPSS Science Team Meeting
11 August 2016

Kevin Gallo: NOAA/NESDIS
Greg Stensaas: USGS/EROS
John Dwyer: USGS/EROS
Calli Jenkerson: SGT/EROS
Steve Foga: SGT/EROS
Linda Owen: SGT/EROS
Ryan Longhenry: USGS/EROS


Department of the Interior
U.S. Geological Survey

PRODUCT GUIDE

LAND PRODUCT CHARACTERIZATION SYSTEM (LPCS)

Version 1.7

September 2015

USGS science for a changing world

Land Product Characterization System i Version 1.7

LPCS Land Product Characterization System
USGS science for a changing world
USGS Home
Contact USGS
Search USGS
Land Product Characterization System (LPCS)
Page Expires In 1:59:22

Land Product Characterization System (LPCS)

What is LPCS

Highlights of LPCS

1. Inventory & Ordering
2. Analysis Tools

Path Forward

1. Status and Readiness
2. CEOS LPV collaboration

Summary

Land Product Characterization System (LPCS)

What is LPCS

Highlights of LPCS

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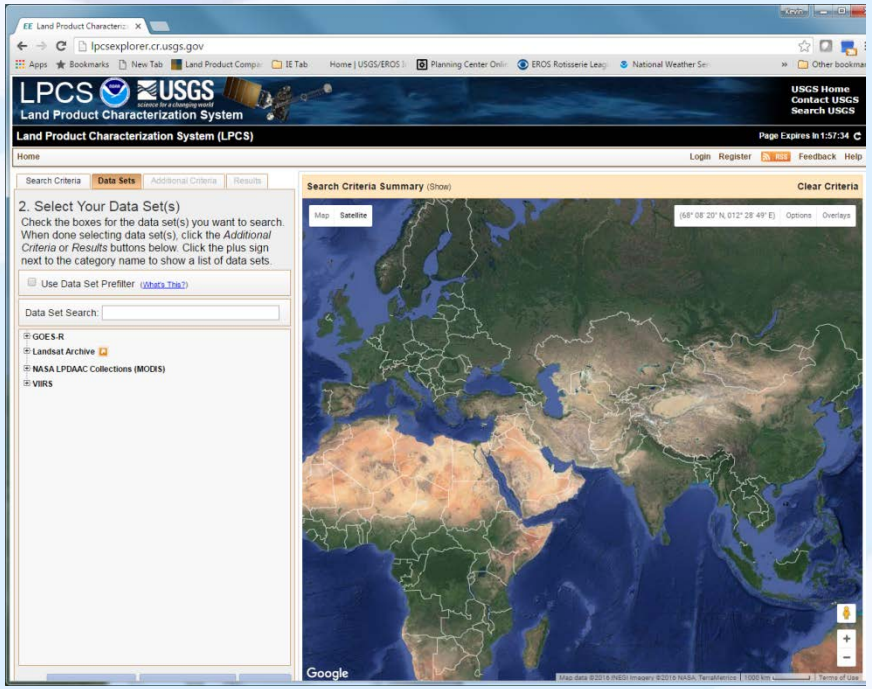
1. Status and Readiness
2. CEOS LPV collaboration

Summary

What is LPCS

A web-based system designed for comparative analysis of **global** satellite higher-level land products.

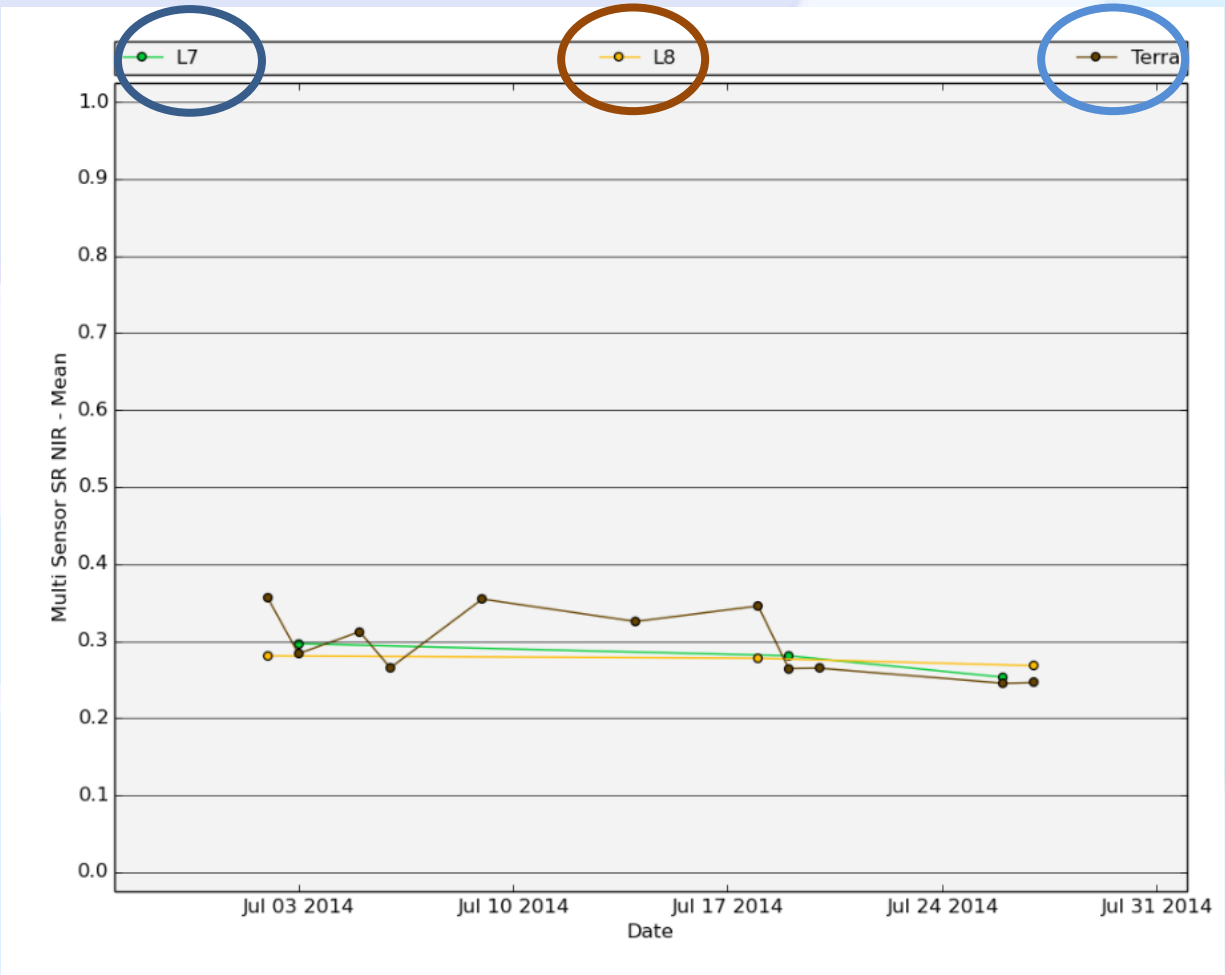




What is LPCS:
Output example

Trending of similar bands of data from multiple sensors.

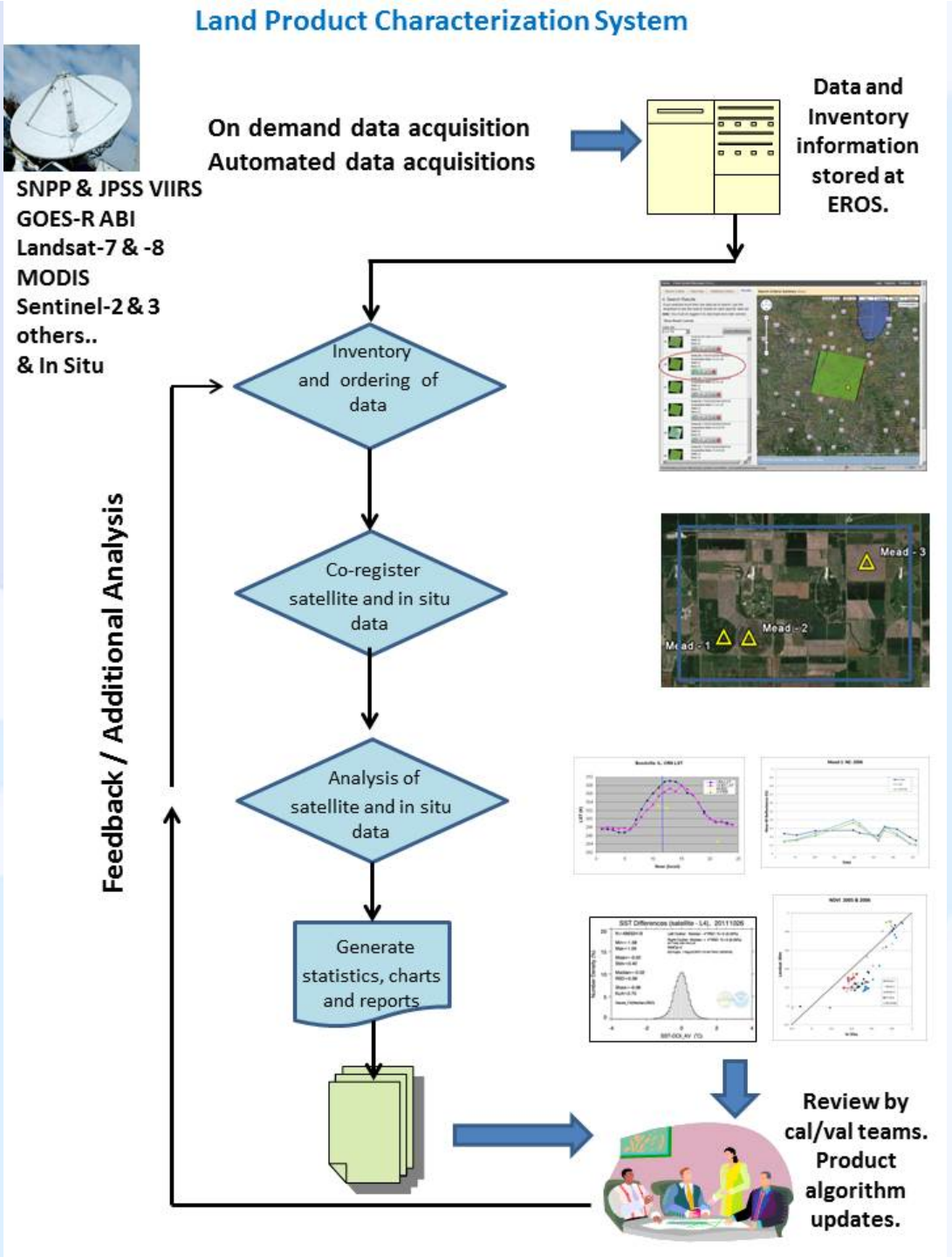
Near-IR Surface Reflectance



What is LPCS

A web-based system designed for comparative analysis of global satellite higher-level land products.

- Inventory & order data
- Advanced processing
- Basic analysis
- Output charts , images, & tables



Land Product Characterization System (LPCS)

What is LPCS

Highlights of LPCS

1. Inventory & Ordering
2. Analysis Tools

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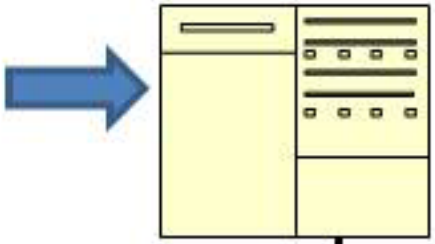
Inventory and Ordering

Land Product Characterization System



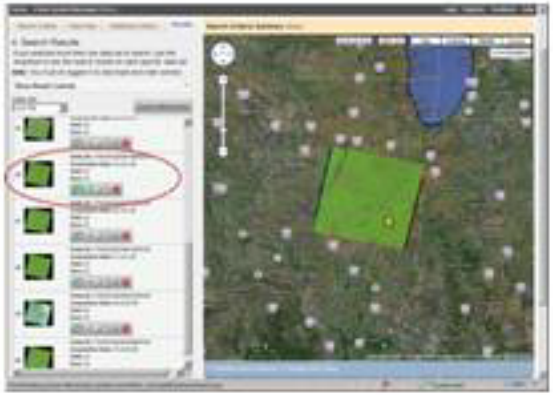
SNPP & JPSS VIIRS
GOES-R ABI
Landsat-7 & -8
MODIS
Sentinel-2 & 3
others..
& In Situ

On demand data acquisition
Automated data acquisitions



Data and Inventory information stored at EROS.

Inventory and ordering of data



Inventory and Ordering

Begin at Search Criteria and Data Select tabs of LPCS.

Included data sets not arbitrary.



Inventory and Ordering

Included data sets not arbitrary, will permit comparison of land products from multiple sensor systems.

Current

- 3 Landsat SR products
- 16 MODIS SR and NDVI
- Sample VIIRS
- Simulated GOES-R ABI

Future

- VIIRS
- GOES-R ABI
- Sentinel 2
- Sentinel 3
- in situ

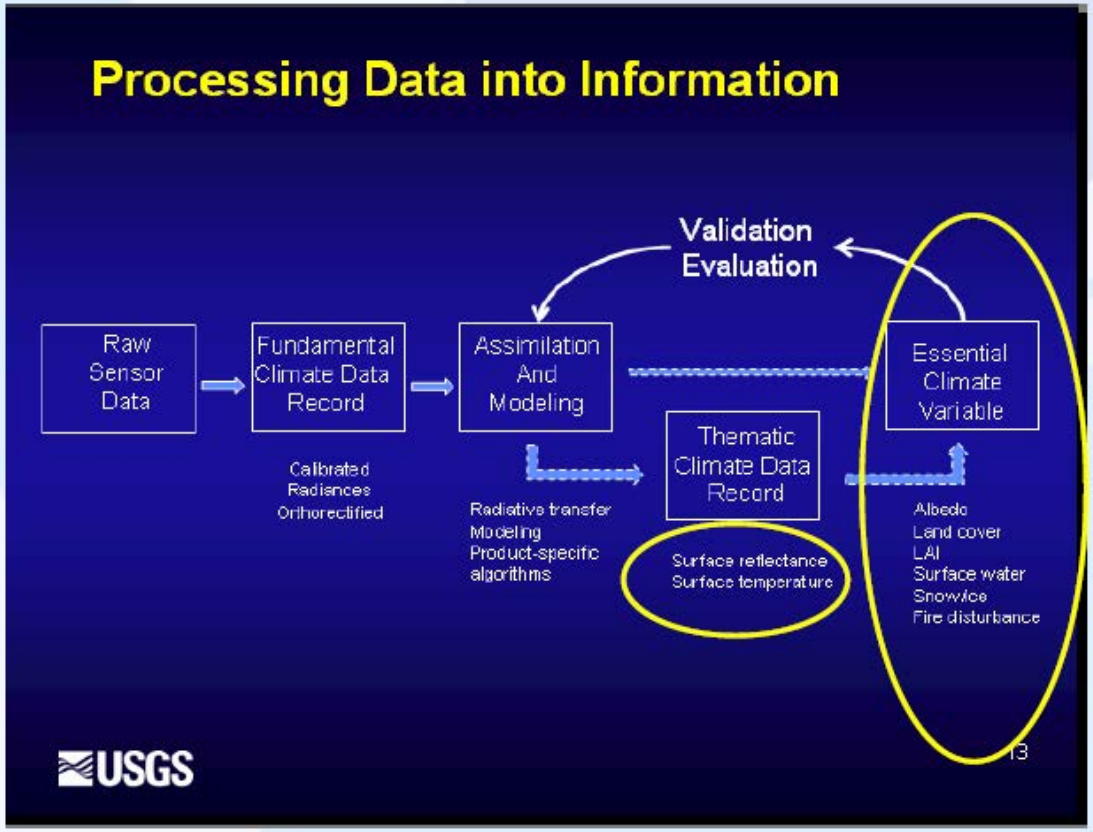
LPCS User Requirements Database

Organization	Mission	Instrument	Variable	Product Name	Spatial Coverage	Spatial Scale	Temporal Coverage	Temporal Scale	Validation Sites List
USGS/NASA	Landsat	Landsat 4-5	SR	Landsat Surface Reflectance L4-5 TM	Global	30 m		Daily (AM local time)	
USGS/NASA	Landsat	Landsat 7	SR	Landsat Surface Reflectance L7 ETM+	Global	30 m		Daily (AM local time)	
USGS/NASA	Landsat	Landsat 8	SR	Landsat Surface Reflectance L8 OLI/TIRS	Global	30 m		Daily (AM local time)	
NASA	EOS	MODIS	NDVI/EVI	MOD13A1 Vegetation Indices 16-Day L3 Global 500m	Global	500 m		Daily (AM local time)	
NASA	EOS	MODIS	NDVI/EVI	MOD13A2 Vegetation Indices 16-Day L3 Global 1km	Global	1000 m		Daily (AM local time)	
NASA	EOS	MODIS	NDVI/EVI	MOD13A3 Vegetation Indices Monthly L3 Global 1km	Global	1000 m		Daily (AM local time)	
NASA	EOS	MODIS	NDVI/EVI	MOD13Q1 Vegetation Indices 16-Day L3 Global 250m	Global	250 m		Daily (AM local time)	
NASA	EOS	MODIS	NDVI/EVI	MYD13A1 Vegetation Indices 16-Day L3 Global 500m	Global	500 m		Daily (PM local time)	
NASA	EOS	MODIS	NDVI/EVI	MYD13A2 Vegetation Indices 16-Day L3 Global 1km	Global	1000 m		Daily (PM local time)	
NASA	EOS	MODIS	NDVI/EVI	MYD13A3 Vegetation Indices Monthly L3 Global 1km	Global	1000 m		Daily (PM local time)	
NASA	EOS	MODIS	NDVI/EVI	MYD13Q1 Vegetation Indices 16-Day L3 Global 250m	Global	250 m		Daily (PM local time)	
NASA	EOS	MODIS	SR	MOD09A1 Surface Reflectance 8-Day L3 Global 500m	Global	500 m		Daily (AM local time)	
NASA	EOS	MODIS	SR	MOD09GA Surface Reflectance Daily L2G Global 1km and 500m	Global	500 m		Daily (AM local time)	
NASA	EOS	MODIS	SR	MOD09GQ Surface Reflectance Daily L2G Global 250m	Global	250 m		Daily (AM local time)	
NASA	EOS	MODIS	SR	MOD09Q1 Surface Reflectance 8-Day L3 Global 250m	Global	250 m		Daily (AM local time)	
NASA	EOS	MODIS	SR	MYD09A1 Surface Reflectance 8-Day L3 Global 500m	Global	500 m		Daily (PM local time)	
NASA	EOS	MODIS	SR	MYD09GA Surface Reflectance Daily L2G Global 1km and 500m	Global	500 m		Daily (PM local time)	
NASA	EOS	MODIS	SR	MYD09GQ Surface Reflectance Daily L2G Global 250m	Global	250 m		Daily (PM local time)	
NASA	EOS	MODIS	SR	MYD09Q1 Surface Reflectance 8-Day L3 Global 250m	Global	250 m		Daily (PM local time)	
NOAA	GOES-R	ABI	NDVI	Simulated TOA NDVI	CONUS	2222 m	31 May, 3 June, 26 Jun	1800, 1900, 2000 UTC	
NOAA	S-NPP	VIIRS	NDVI	Sample VIIRS Vegetation Index	SW CONUS	500 m	30 May - 29 June 2013	Daily (PM local time)	
NASA	S-NPP	VIIRS	NDVI	Sample VIIRS Vegetation Index	SW CONUS	488 m	31 May, 3 June, 26 Jun	Daily (PM local time)	
NASA	EOS	MODIS	land cover	MCD12Q1 Land Cover Type Yearly L3 Global 500 m SIN Grid	Global	500 m		Annual	
NASA	EOS	MODIS	LST	MOD11A1 LST and Emissivity Daily L3 Global 1 km Grid SIN	Global	1000 m		Daily (AM local time)	
NASA	EOS	MODIS	LST	MYD11A1 LST and Emissivity Daily L3 Global 1 km Grid SIN	Global	1000 m		Daily (PM local time)	
USGS/NASA	Landsat	Landsat 8	Albedo	TBD					
USGS/NASA	Landsat	Landsat 8	LST	TBD					
NOAA	GOES-R	ABI	TBD	TBD					
NOAA	GOES-R	ABI	TBD	TBD					
NOAA	GOES-R	ABI	TBD	TBD					
NOAA	GOES-R	ABI	TBD	TBD					
NOAA	S-NPP	VIIRS	TBD	TBD					
NOAA	S-NPP	VIIRS	TBD	TBD					
NOAA	S-NPP	VIIRS	TBD	TBD					
NOAA	S-NPP	VIIRS	TBD	TBD					
NASA	S-NPP	VIIRS	TBD	TBD					
NASA	S-NPP	VIIRS	TBD	TBD					
NASA	S-NPP	VIIRS	TBD	TBD					
NASA	S-NPP	VIIRS	TBD	TBD					
ESA	Sentinel-2	MSI	TBD	TBD					
	CRN	in situ	TBD	TBD					
	SURFRAD	in situ	TBD	TBD					
	AERONET	in situ	TBD	TBD					
	EOS Land Core	in situ	TBD	TBD					
				Currently available in LPCS					
				Soon to be avialble					
				Planned to be available					

USGS-NOAA validation synergy

USGS Requirements

- Landsat ECVs



USGS ECVs

- Albedo
- Land Cover
- LAI
- Surface Water
- Snow/Ice
- Fire disturbance
- LST

USGS-NOAA validation synergy

Several products of mutual interest (**e.g. GOES-R ABI**)

BASELINE PRODUCTS
Aerosol Detection (Including Smoke and Dust)
Aerosol Optical Depth (AOD)
Volcanic Ash: Detection and Height
Cloud and Moisture Imagery
Cloud Optical Depth
Cloud Particle Size Distribution
Cloud Top Phase
Cloud Top Height
Cloud Top Pressure
Cloud Top Temperature
Hurricane Intensity
Lightning Detection: Events, Groups & Flashes
Rainfall Rate / QPE
Legacy Vertical Moisture Profile
Legacy Vertical Temperature Profile
Derived Stability Indices
Total Precipitable Water
Clear Sky Masks
Radiances
Downward Shortwave Radiation: Surface
Reflected Shortwave Radiation: TOA
Derived Motion Winds
Fire/Hot Spot Characterization
Land Surface Temperature (Skin)
Snow Cover
Sea Surface Temperature (Skin)
Energetic Heavy Ions
Mag. Electrons & Protons: Low Energy
Mag. Electrons & Protons: Med & High Energy
Solar & Galactic Protons
Geomagnetic Field
Solar Flux: EUV
Solar Flux: X-Ray
Solar Imagery: X-Ray

OPTION 2 PRODUCTS
Aerosol Partical Size
Aircraft Icing Threat
Cloud Ice Water Path
Cloud Layers/Heights
Cloud Liquid Water
Cloud Type
Convective Initiation
Enhanced "V" / Overshooting Top Detection
Low Cloud and Fog
Tropopause Folding Turbulence Prediction
Visibility
Probability of Rainfall
Rainfall Potential
Absorbed Shortwave Radiation: Surface
Downward Longwave Radiation: Surface
Upward Longwave Radiation: Surface
Upward Longwave Radiation: TOA
Ozone Total
SO2 Detection
Flood/Standing Water
Ice Cover
Snow Depth (Over Plains)
Surface Albedo
Surface Emissivity
Vegetation Fraction: Green
Vegetation Index
Currents
Currents: Offshore
Sea and Lake Ice: Age
Sea and Lake Ice: Concentration
Sea and Lake Ice: Motion

KEY

ABI	SUVI	EXIS
GLM	SEISS	MAG

ABI: Advanced Baseline Imager

SUVI: Solar Ultraviolet Imager

EXIS: Extreme Ultraviolet and X-ray Irradiance Suite

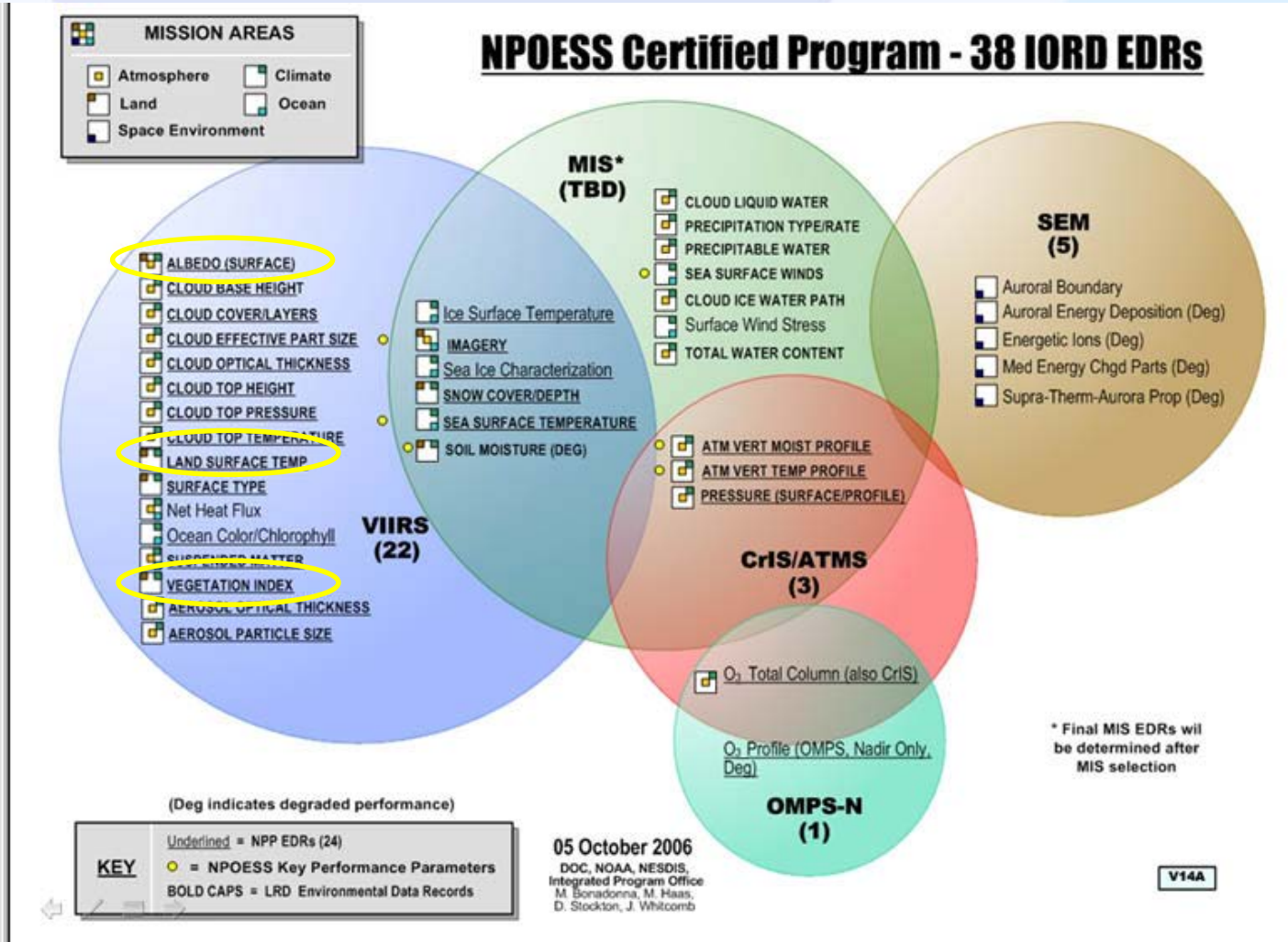
GLM: Geostationary Lightning Mapper

SEISS: Space Environment In-Situ Suite

MAG: Magnetometer

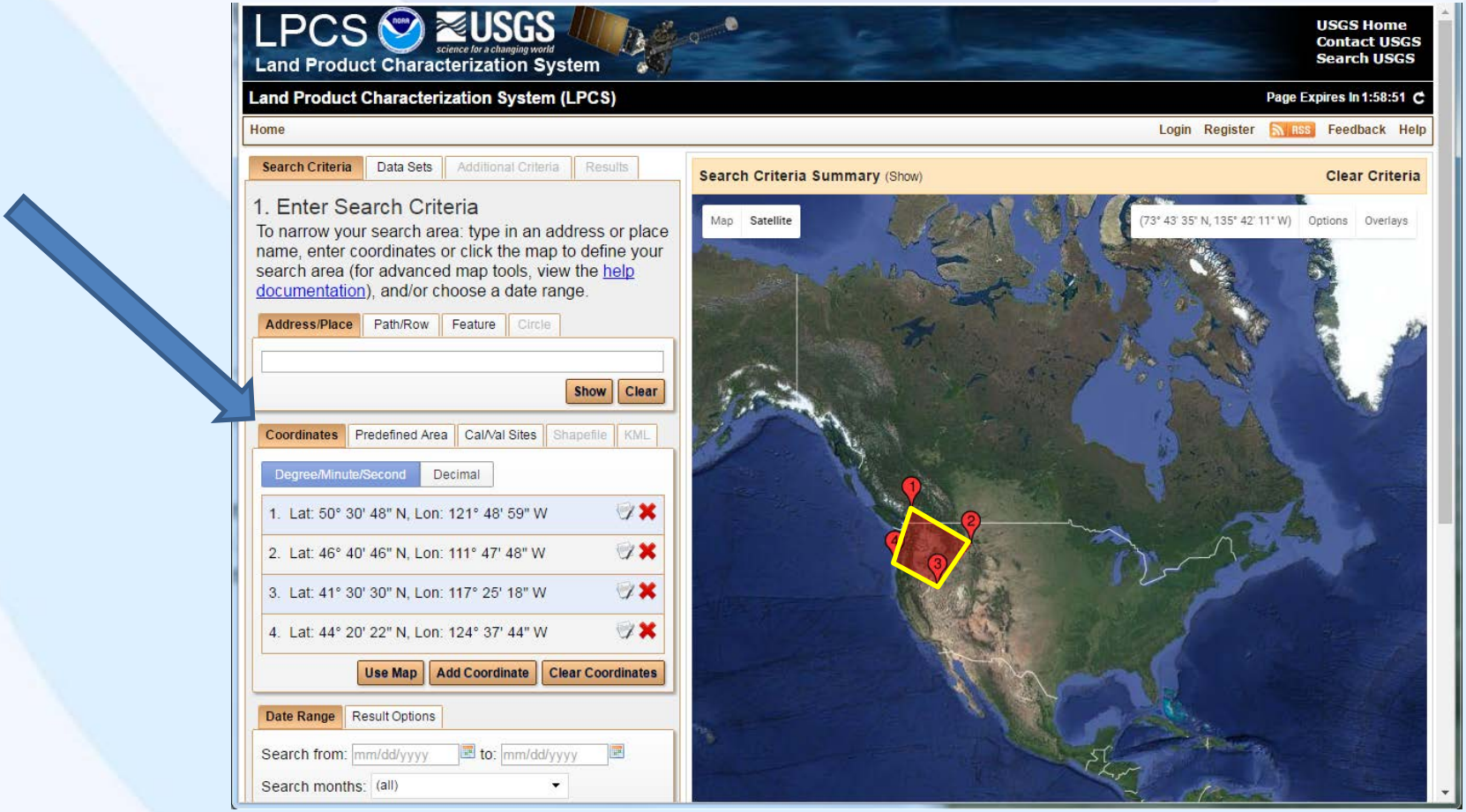
USGS-NOAA validation synergy

Several products of mutual interest (**e.g. VIIRS**)



Inventory and Ordering

Several options to search and order data. Can search by entering latitude and longitude information or interactively drawing area of interest .



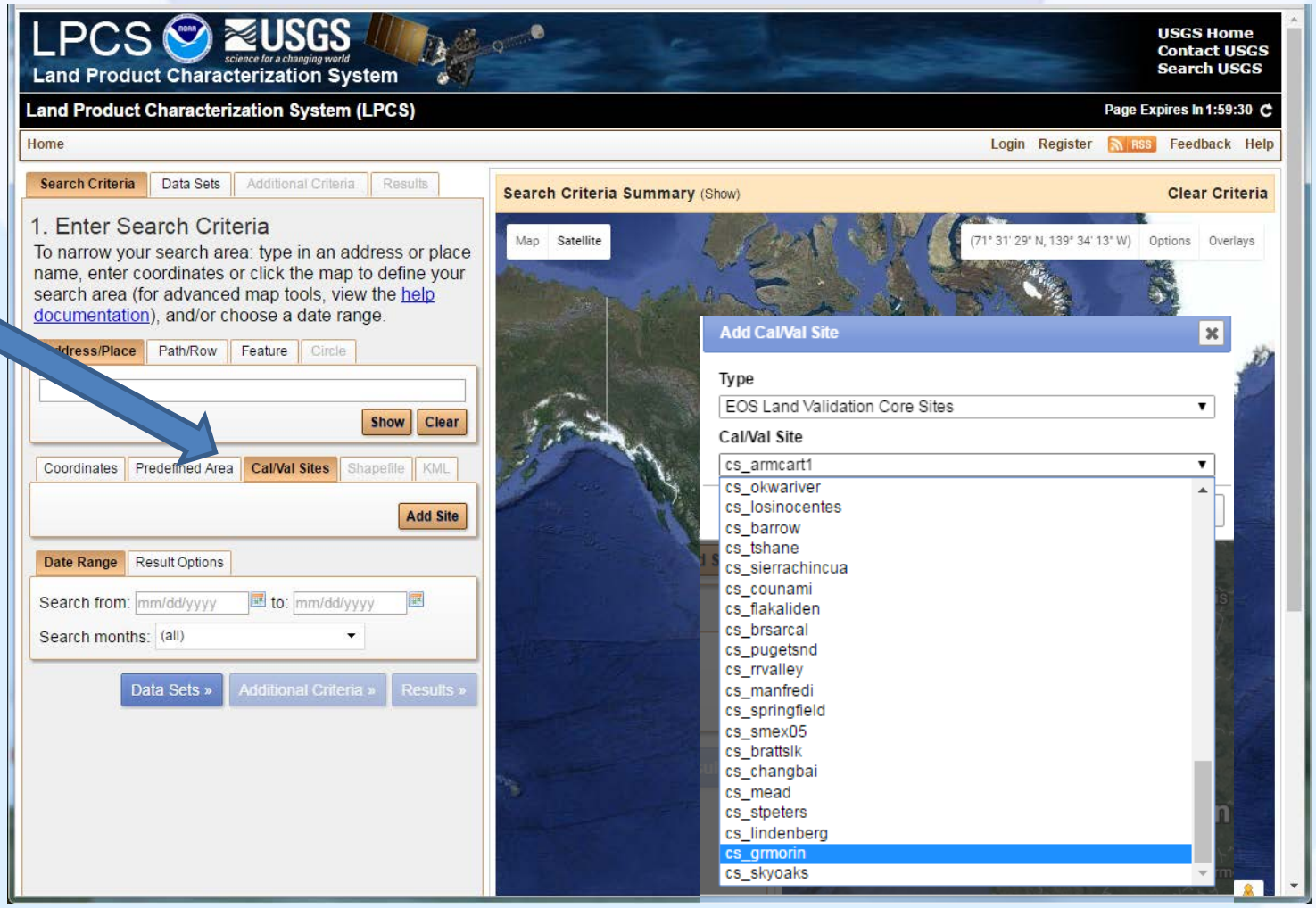
Inventory and Ordering

NEW: Can search by location of several in situ networks.



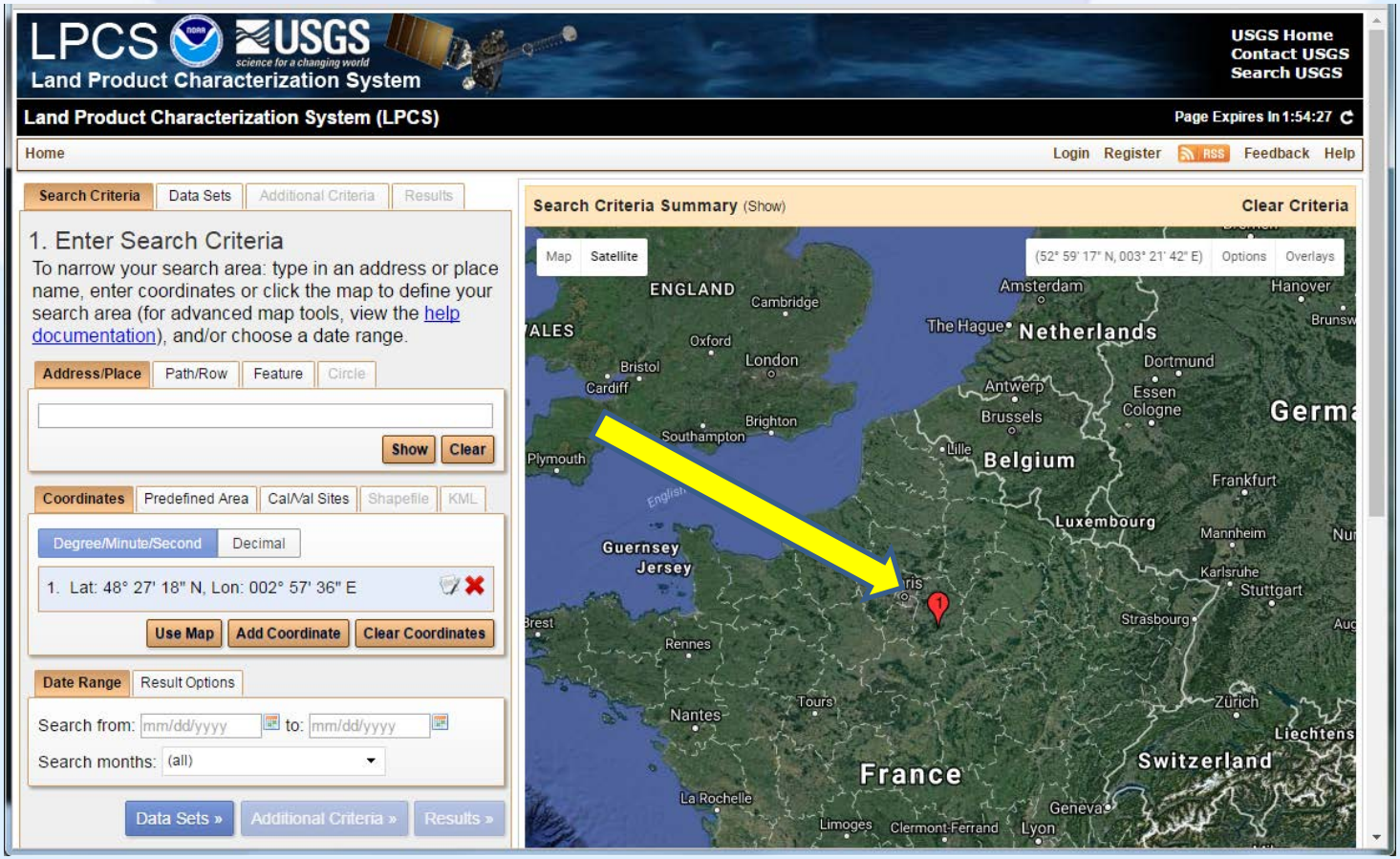
Inventory and Ordering

NEW: Can search by location of several in situ networks – example: Grand Morin, France.



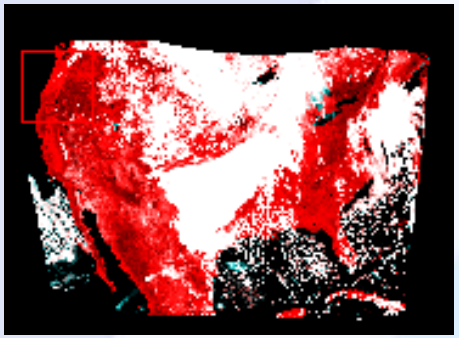
Inventory and Ordering

NEW: Can search by location of several in situ networks.



Inventory and Ordering

Search for Landsat 8 data on date of simulated GOES-R ABI data (23 April 2013) (provided by Univ. Wisc./CIMSS).

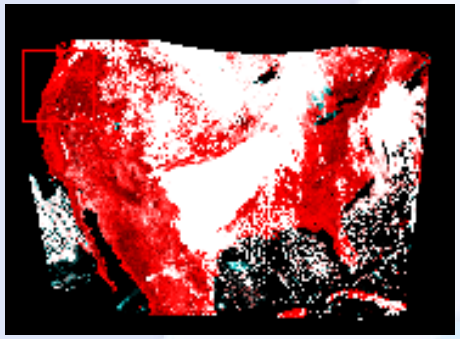


Users can search for multiple sensors over selected range of dates.

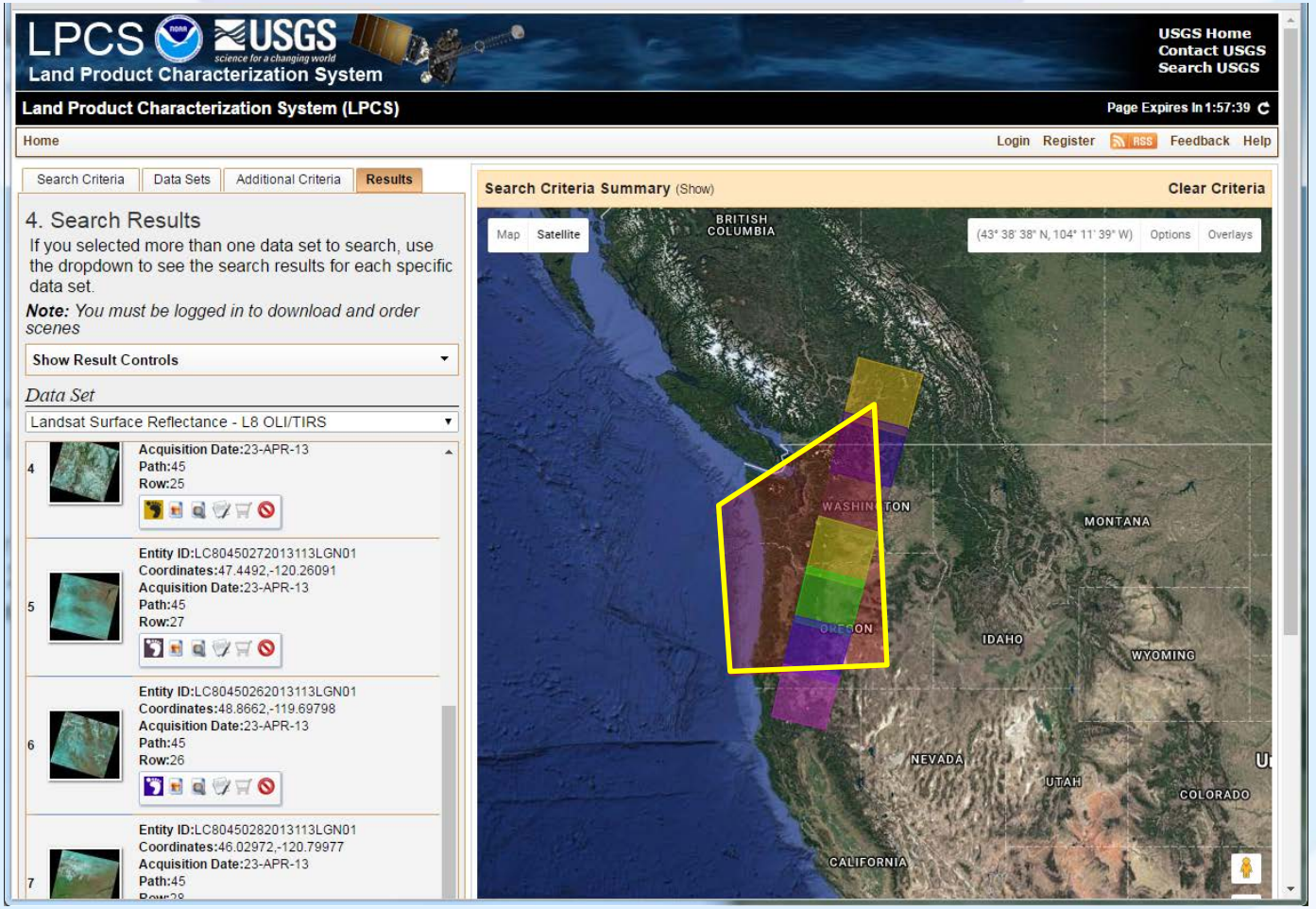


Inventory and Ordering

Search for Landsat 8 data on date of simulated GOES-R ABI data (23 April 2013).



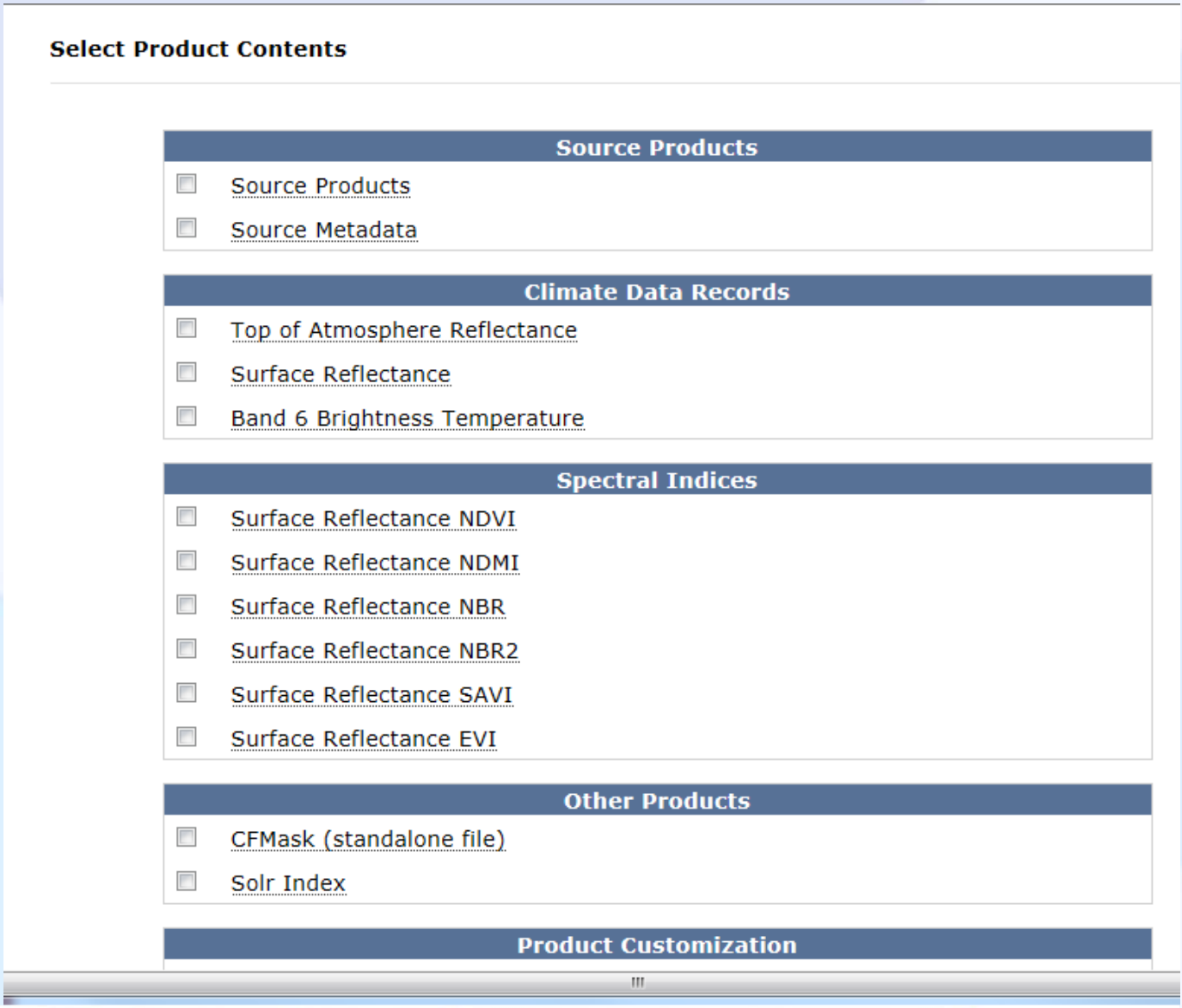
Users can view browse images to select clear scenes for further processing.



Inventory and Ordering

Higher Level Products

Choose higher level products from selected data. *Additional ECVs and CDRs will be added to menu as available.*

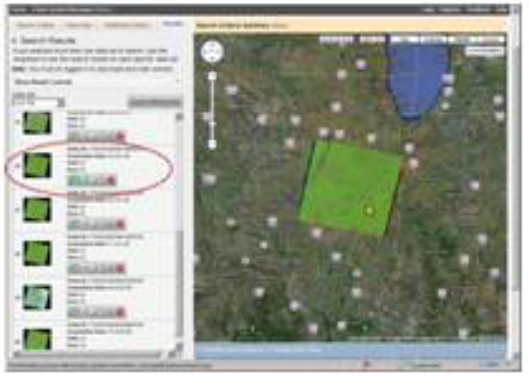


Advanced Processing

SNPP & JPSS VIIRS
GOES-R ABI
Landsat-7 & -8
MODIS
Sentinel-2 & 3
others..
& In Situ

stored at EROS.

Inventory and ordering of data



Co-register satellite and in situ data



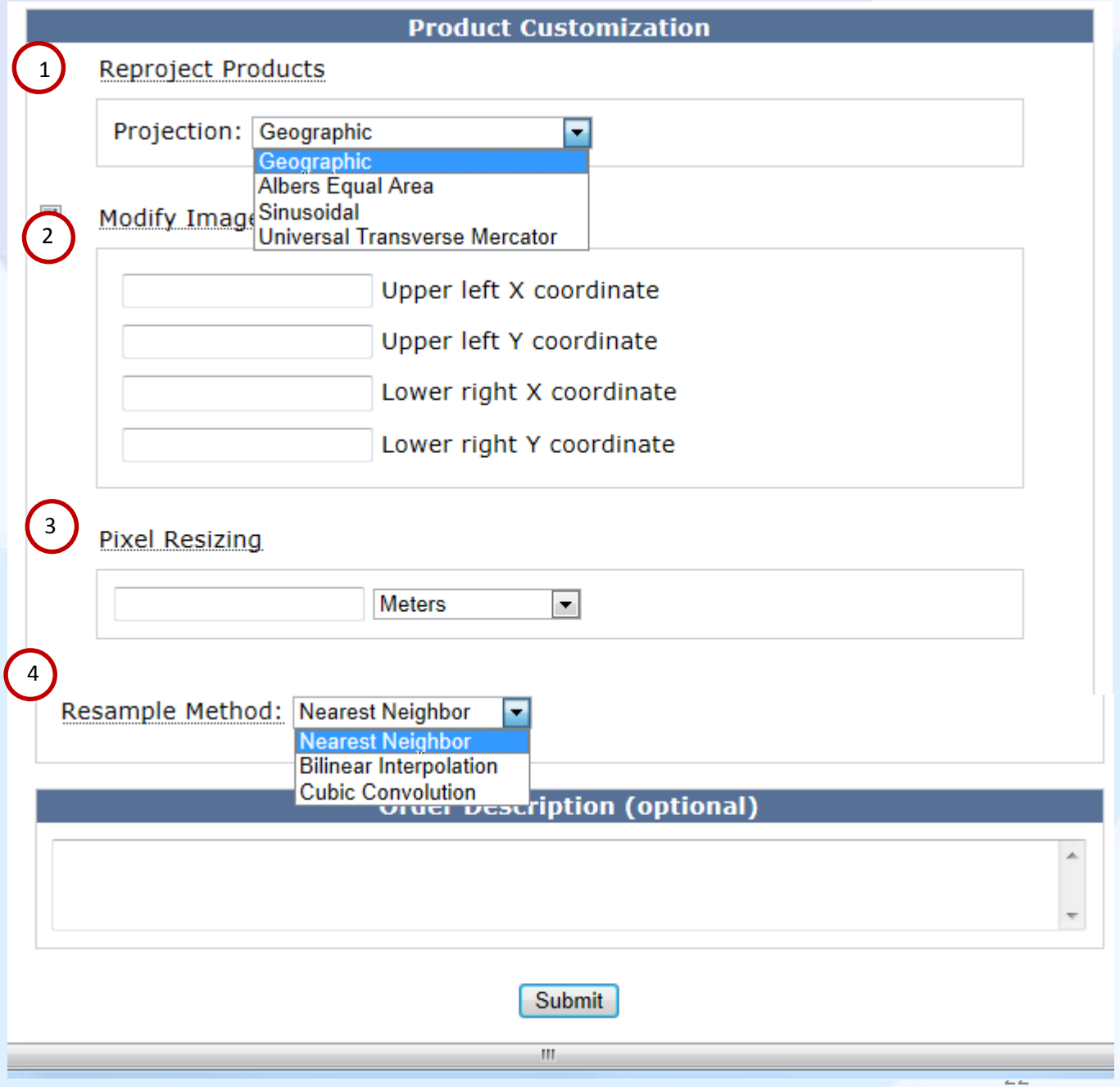
Additional Analysis

Advanced Processing

Define Output Products
Product Customization

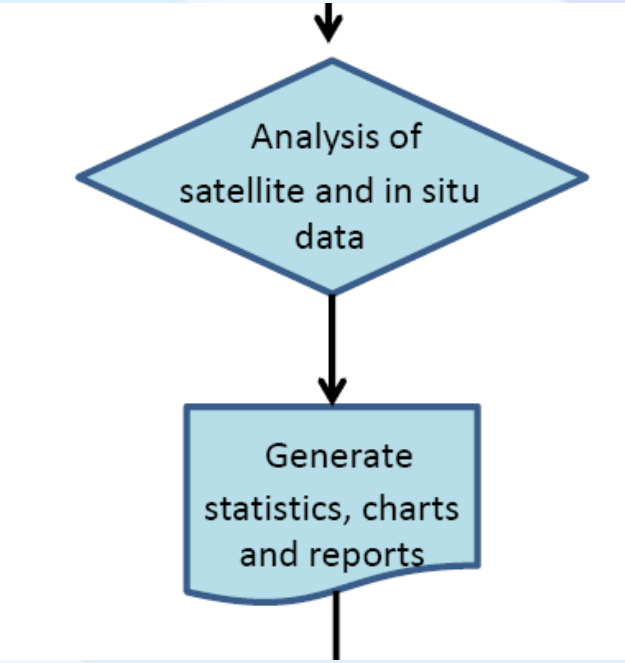
1. Auto-registration of data to common map projections for analysis.
2. User defines area of interest for analysis
3. Match pixel size for all images *(30 – 5000 m)*
4. Several resampling options

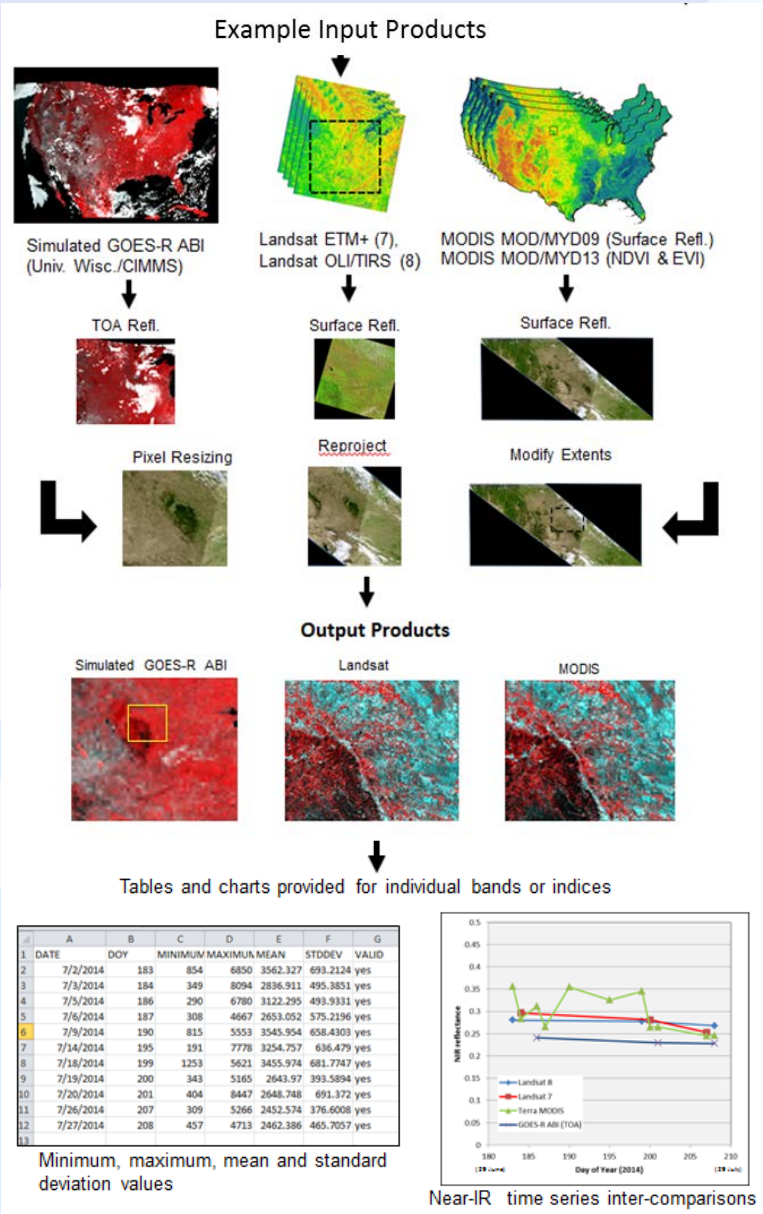
Output formats include



Analysis Tools

Input products resized, remapped and output products generated.

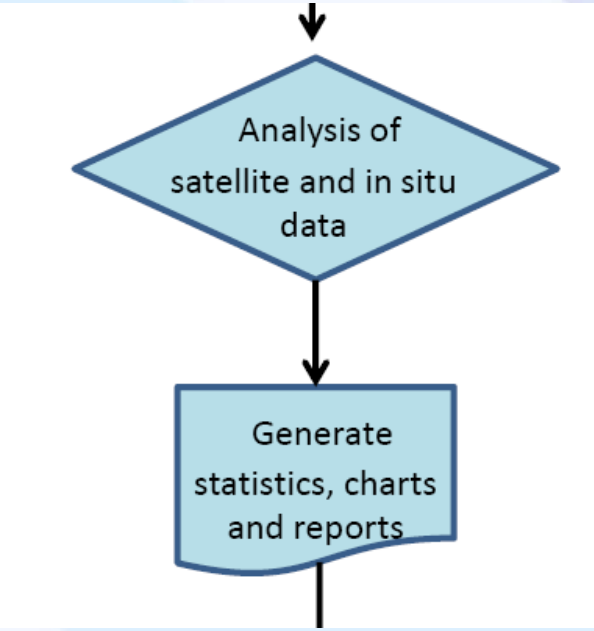


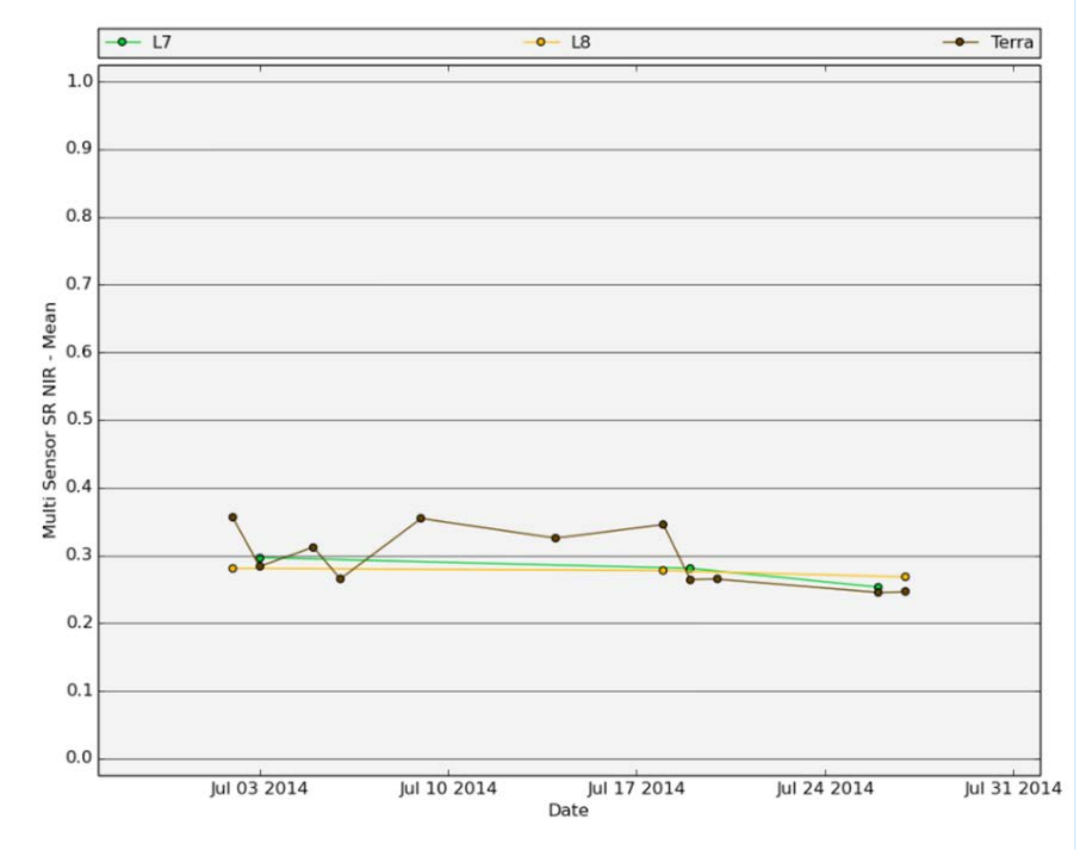


	A	B	C	D	E	F	G
1	DATE	DOY	MINIMUM	MAXIMUM	MEAN	STDDEV	VALID
2	7/2/2014	183	854	6850	3562.327	693.2124	yes
3	7/3/2014	184	349	8094	2836.911	495.3851	yes
4	7/5/2014	186	290	6780	3122.295	493.9331	yes
5	7/6/2014	187	308	4667	2653.052	575.2196	yes
6	7/9/2014	190	815	5553	3545.954	658.4303	yes
7	7/14/2014	195	191	7778	3254.757	636.479	yes
8	7/18/2014	199	1253	5621	3455.974	681.7747	yes
9	7/19/2014	200	343	5165	2643.97	393.5894	yes
10	7/20/2014	201	404	8447	2648.748	691.372	yes
11	7/26/2014	207	309	5266	2452.574	376.6008	yes
12	7/27/2014	208	457	4713	2462.386	465.7057	yes

Analysis Tools

Output products include several charts, e.g., sensor values vs. time.

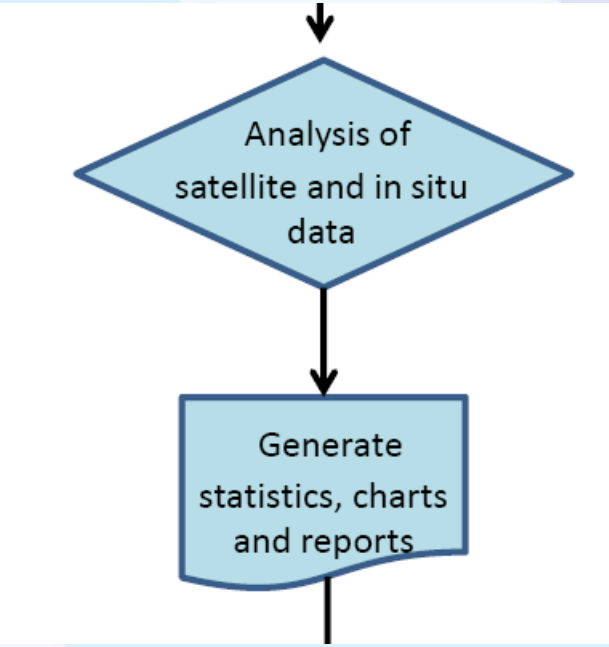


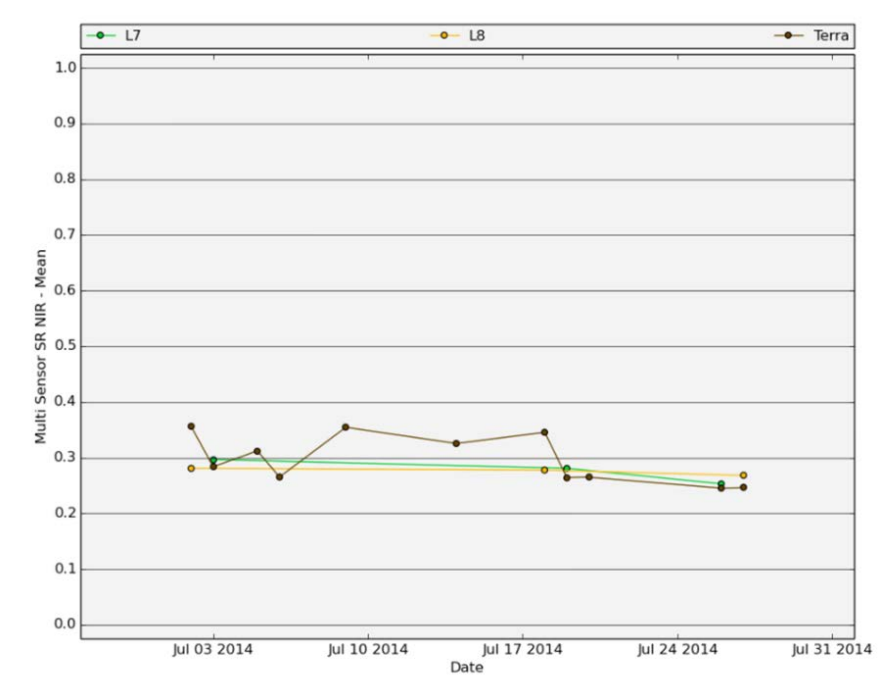


Near-IR Surface Reflectance (L7, L8, and Terra/MODIS.

Analysis Tools

Tables provided with additional data for more intensive analyses.



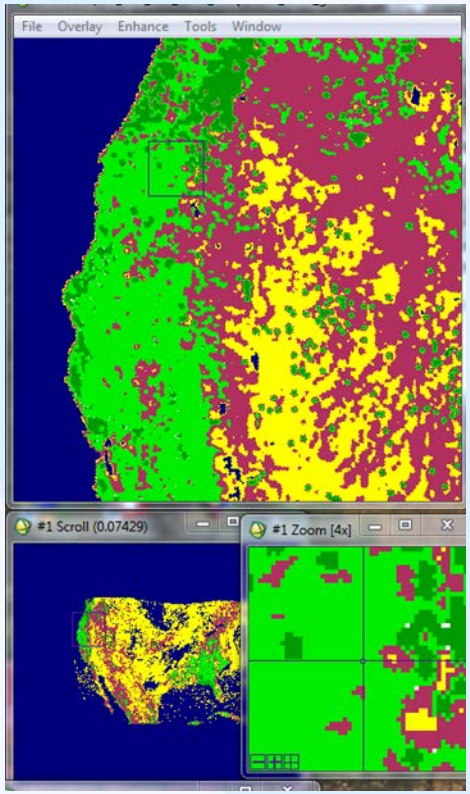


	A	B	C	D	E	F	G
1	DATE	DOY	MINIMUM	MAXIMUM	MEAN	STDDEV	VALID
2	7/2/2014	183	854	6850	3562.327	693.2124	yes
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12	7/27/2014	208	457	4713	2462.386	465.7057	yes
13							

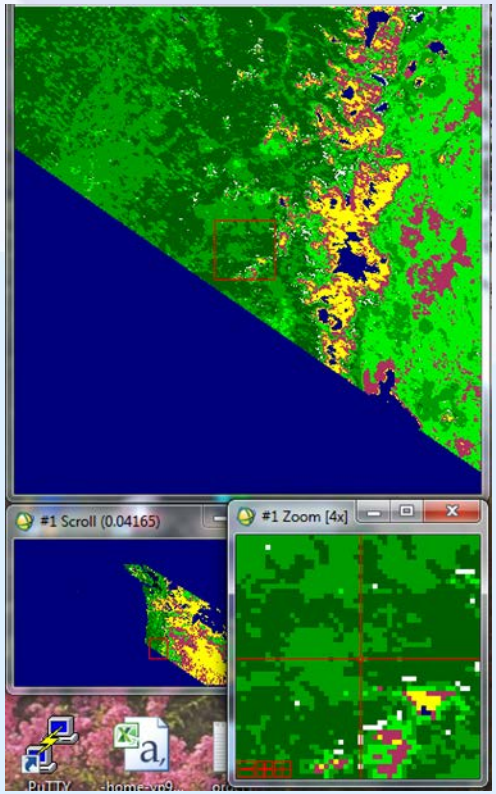
Analysis Tools

*LPCS also provides as output products **georegistered images** of input images for additional analysis (same map projection, cell size, etc., as defined within product customization).*

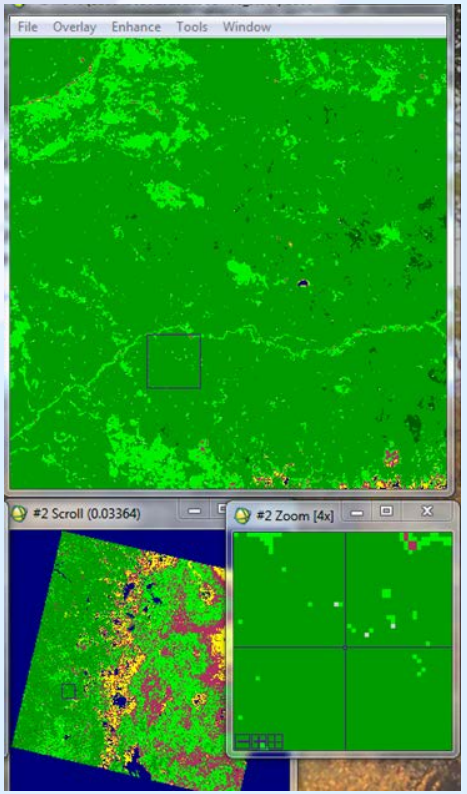
Simulated GOES-R ABI



VIIRS



Landsat 8

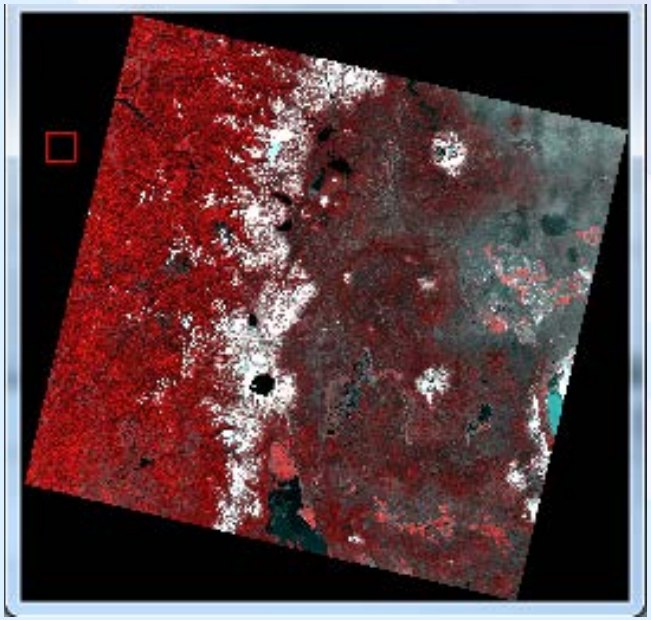


Analysis Tools

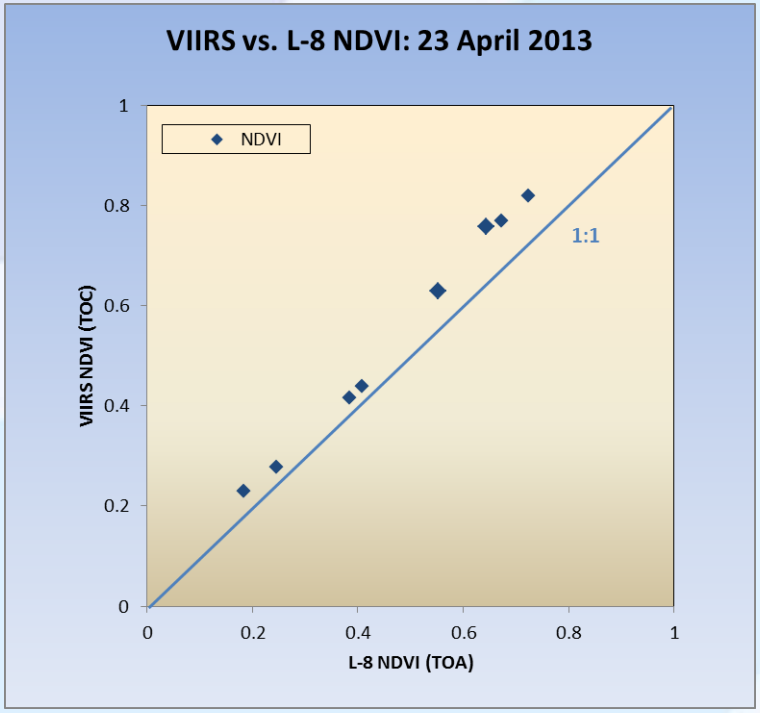
Example of Potential Analysis

VIIRS (TOC) NDVI compared to *Landsat-8 (TOA) NDVI*

Each point within figures represents 100 km^2 sample area.



Landsat 8: 23 April 2013, NW USA.



Land Product Characterization System (LPCS)

What is LPCS

Why LPCS developed/hosted at EROS

Highlights of LPCS

1. Inventory & Ordering
2. Analysis Tools

Path Forward

1. Status and Readiness
2. CEOS LPV collaboration

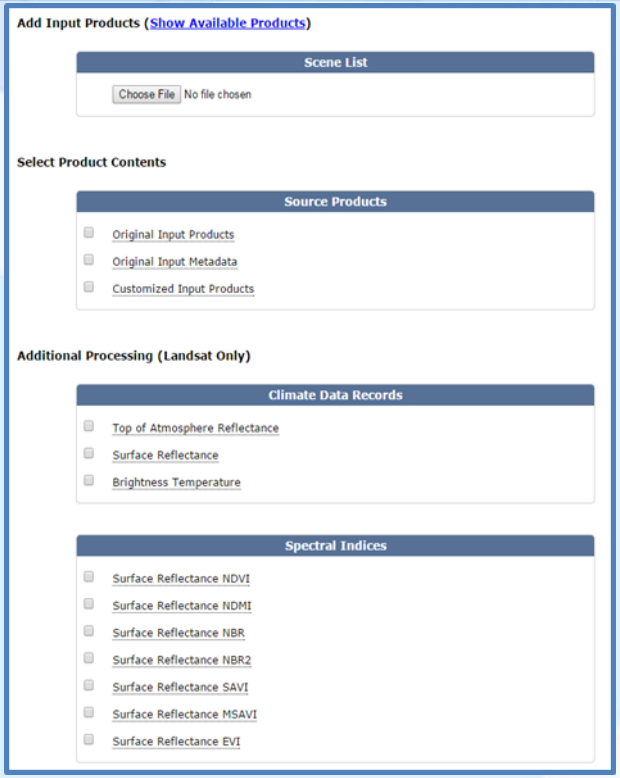
Summary

LPCS Status and Readiness

Current: two – step process

1) Users order and download data, and
2) Retrieve downloaded data into product customization system for processing and product generation.

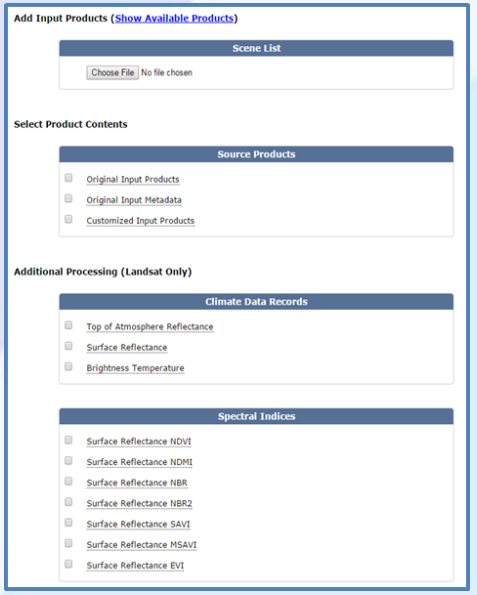




LPCS Status and Readiness

Future: one – step seamless ordering and processing of data (Jan 2017).





Release timelines:

Task	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17
Internal (USGS/EROS) system testing						
External (NESDIS and NASA Science teams) testing						
Public Release						

LPCS Status and Readiness

Introduction of future *data sets* and *analysis tools* within LPCS are planned, however, dependent on additional resources.

Current

MODIS

GSFC SBRC

Landsat 8

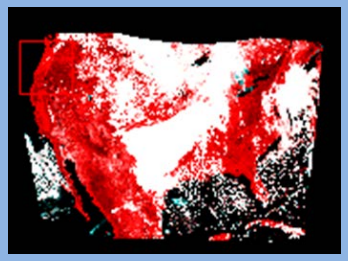


Future

Joint Polar Satellite System (JPSS) Visible Infrared Imaging Radiometer Suite (VIIRS)



NOAA-NASA Geostationary Operational Environmental Satellites - R Series (GOES-R)



European Space Agency (ESA) Sentinel-2



sentinel-3

GMES MEDIUM RESOLUTION LAND AND OCEAN MISSION



Land Product Characterization System (LPCS)

What is LPCS

Why LPCS developed/hosted at EROS

Highlights of LPCS

1. Inventory & Ordering
2. Analysis Tools

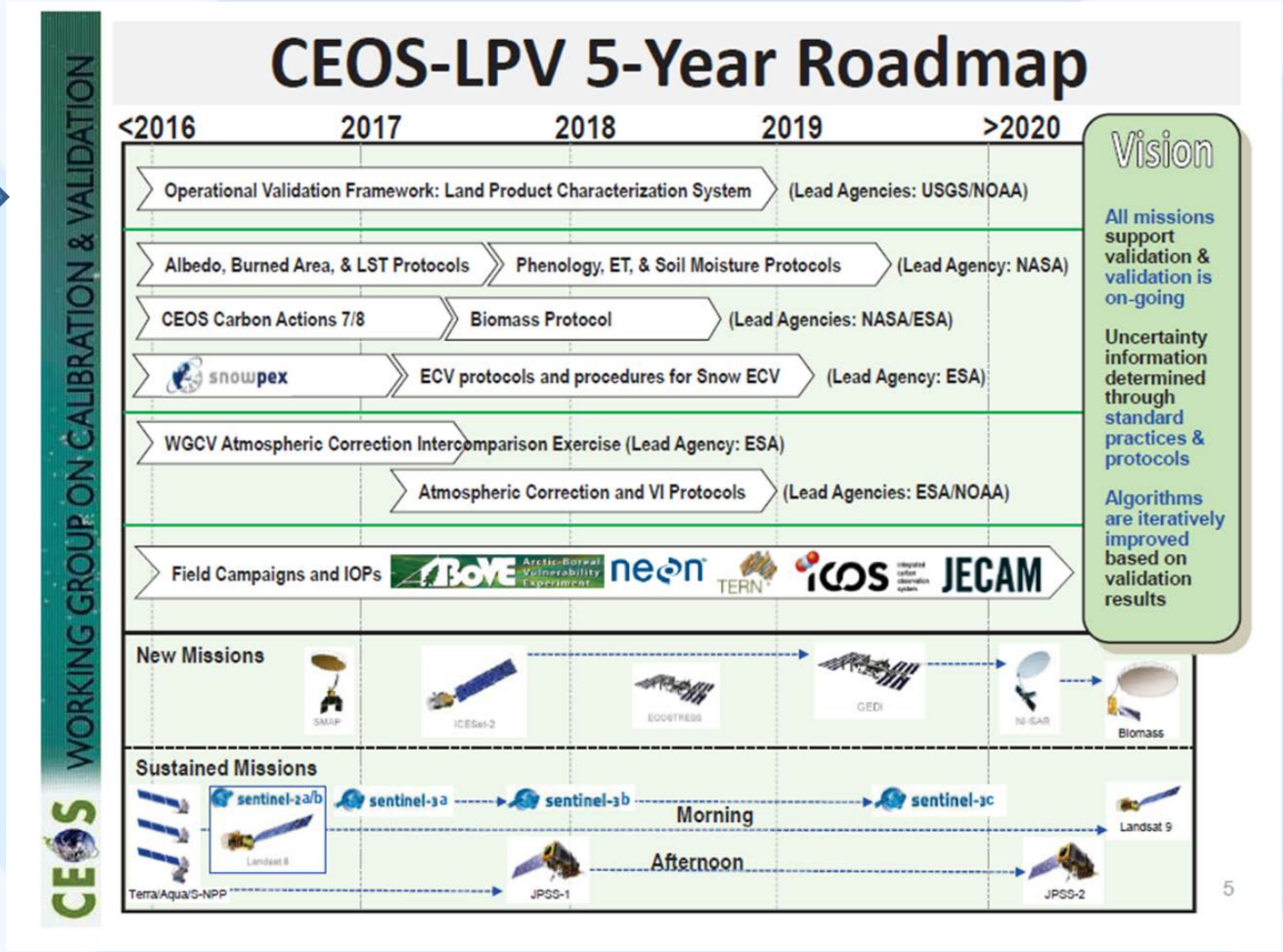
Path Forward

1. Status and Readiness
2. CEOS LPV collaboration

Summary

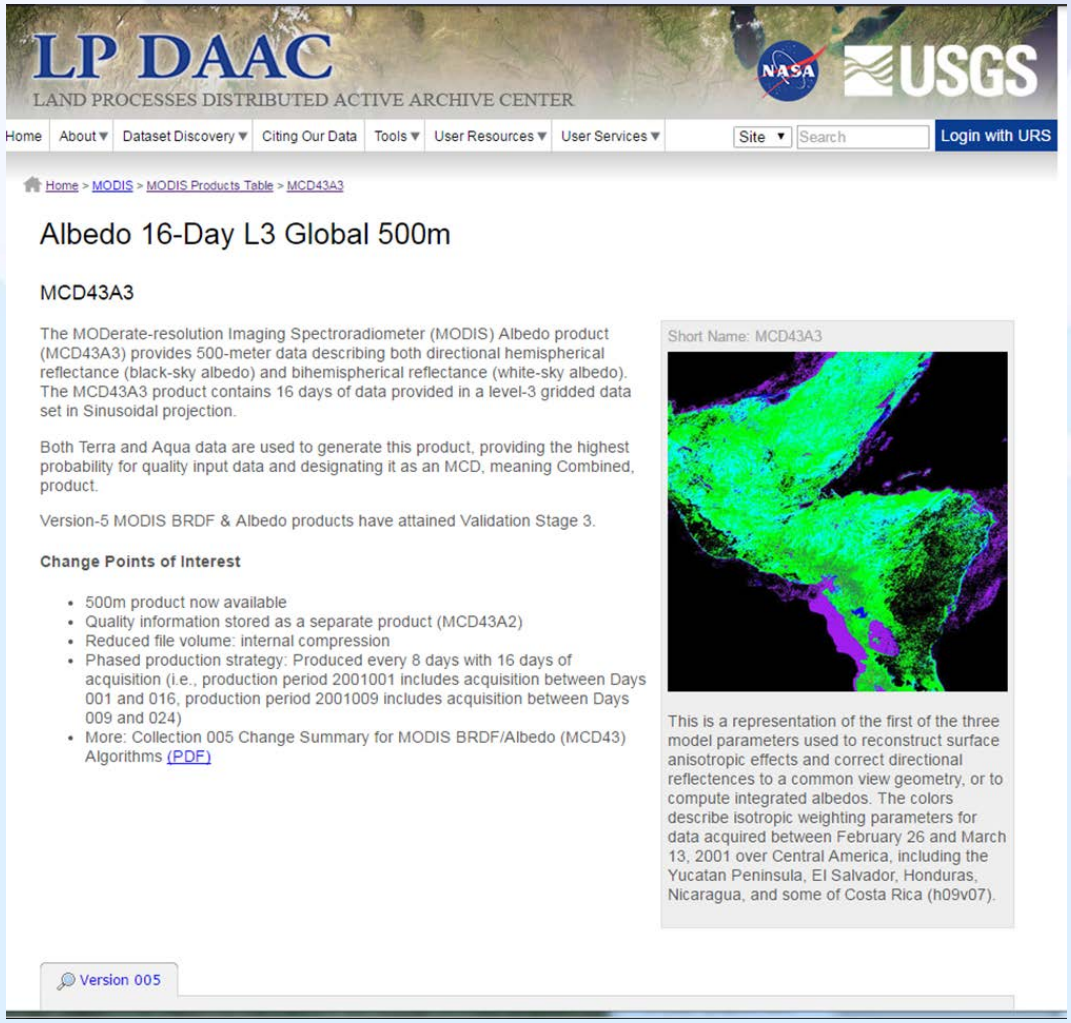
CEOS LPV collaboration

LPCS proposed/accepted as CEOS-LPV Online Validation Tool.



CEOS LPV collaboration

Albedo (MODIS MCD43A3) planned for addition to LPCS as requested by CEOS-LPV.



CEOS LPV collaboration

Additional analysis tools recommended by CEOS-LPV are under review for addition to LPCS.



Land Product Characterization System (LPCS)

What is LPCS

Why LPCS developed/hosted at EROS

Highlights of LPCS

1. Inventory & Ordering
2. Analysis Tools

Path Forward

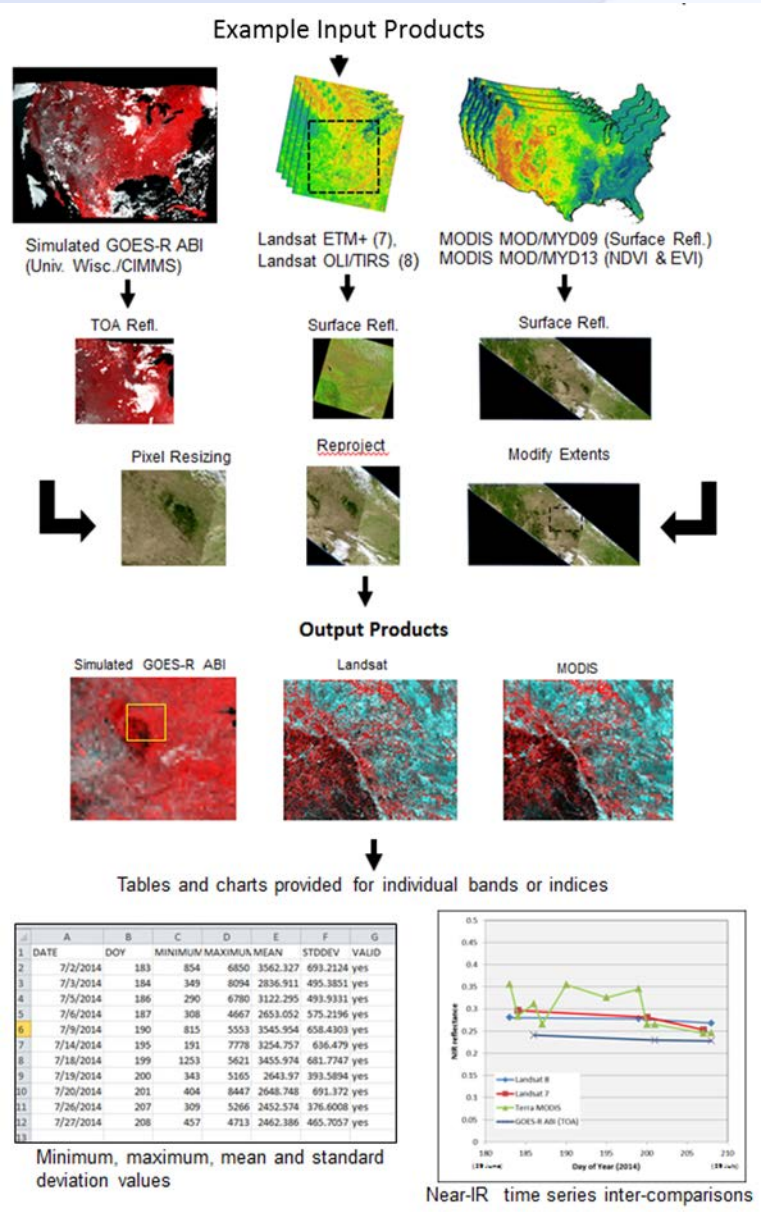
1. Status and Readiness
2. Expectations for User Interactions

Summary

Summary

A web-based system designed for comparative analysis of global satellite higher-level land products.

- Inventory & order data
- Advanced processing
- Basic analysis
- Output charts , images, & tables



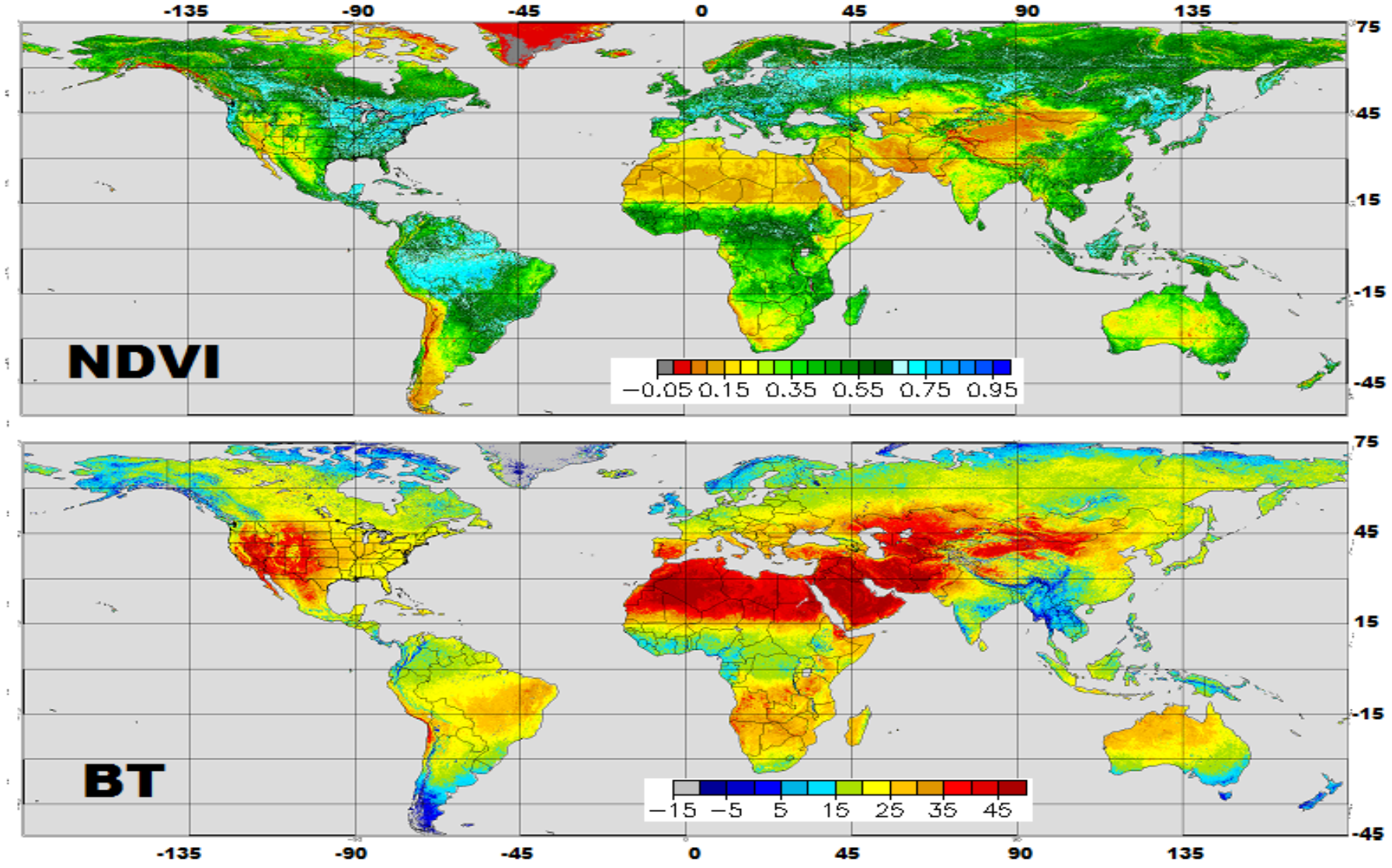
Questions?

Vegetation Health from SNPP/VIIRS

Wei Guo & Felix Kogan

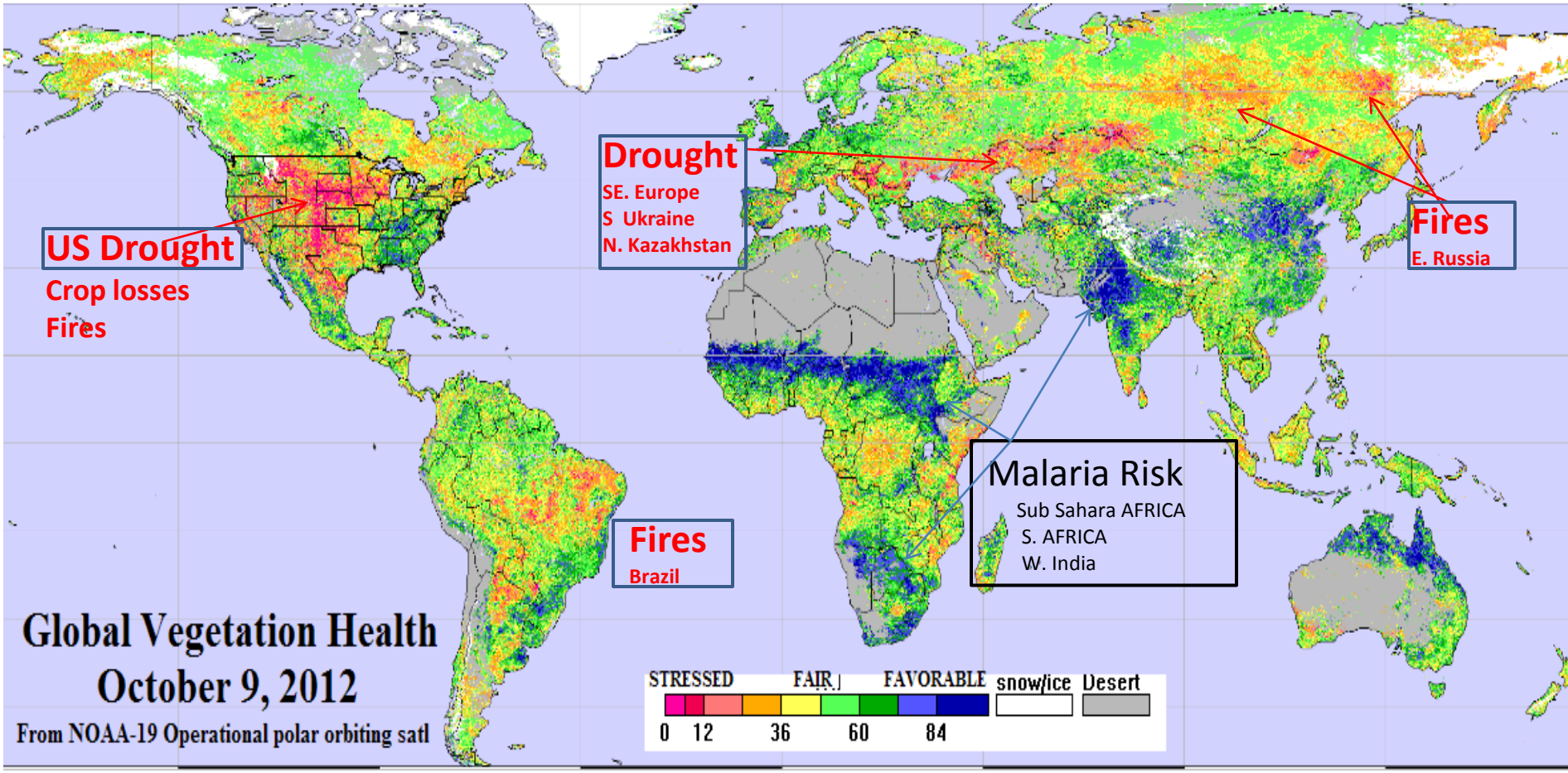
JPSS-16
2016

WE START FROM: Normalized Difference Vegetation Index (NDVI) & Brightness Temperature (BT)



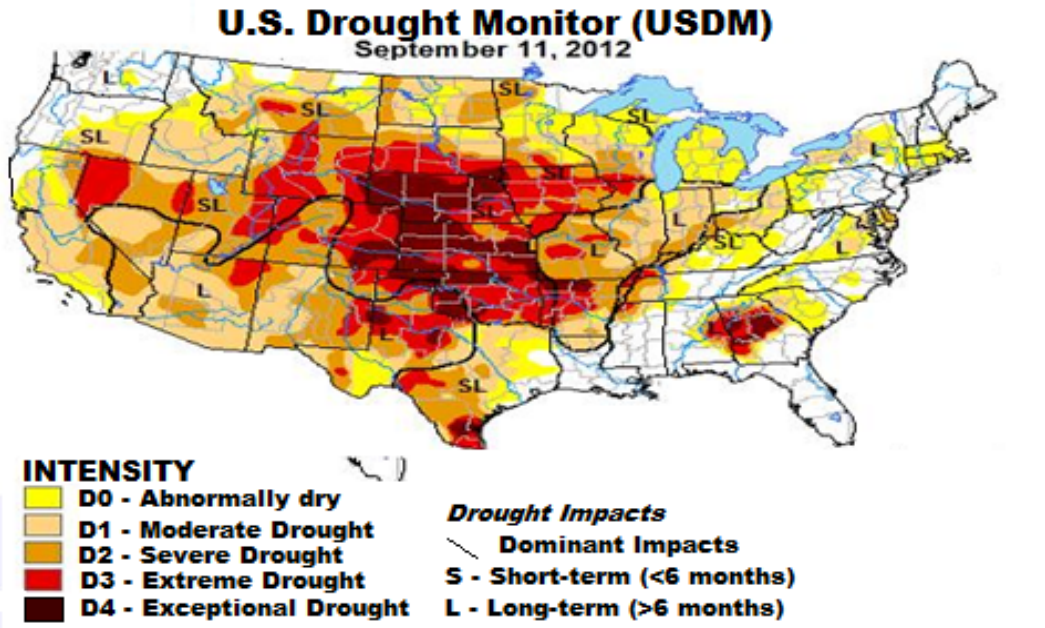
WE PRODUCE: Global Vegetation Health (VH)

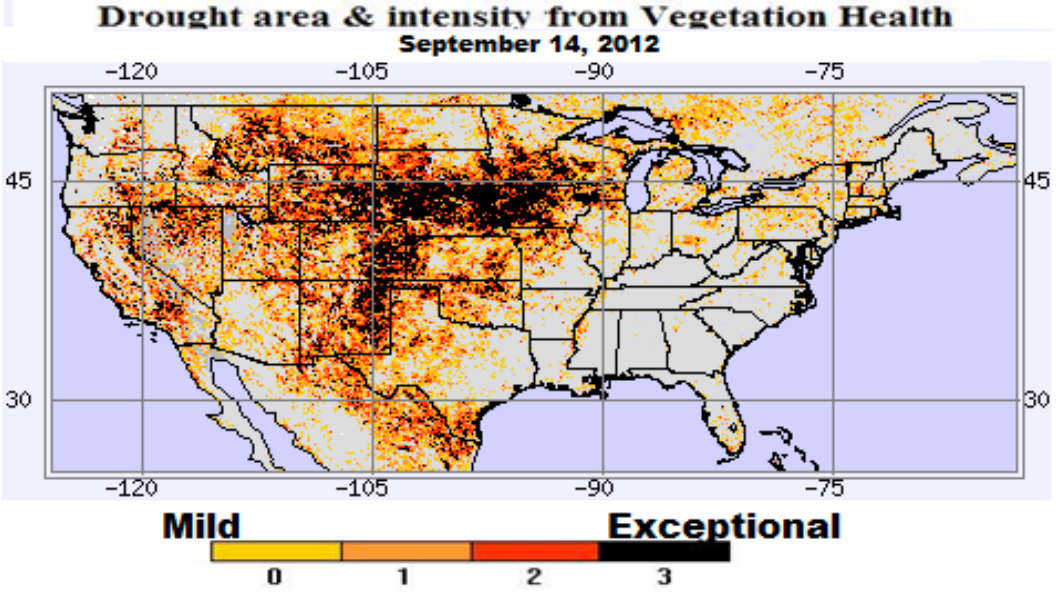
From AVHRR/NOAA-19 Operational Polar Orbiting Satellite



http://www.star.nesdis.noaa.gov/smcd/emb/vci/VH/index.php

Drought from USDM & SNPP/VIIRS

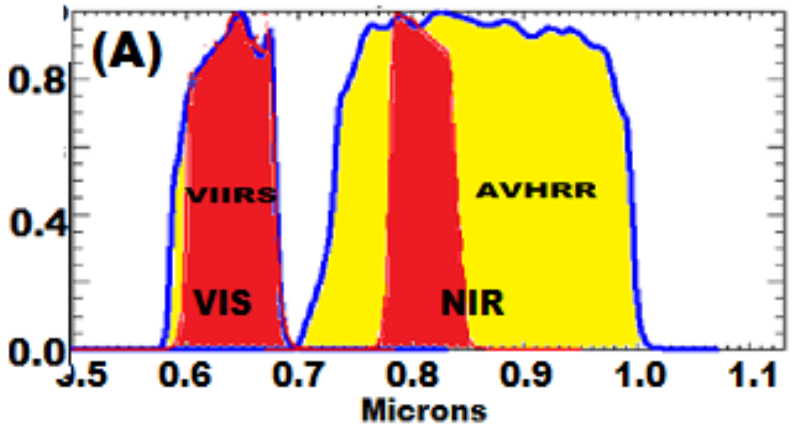




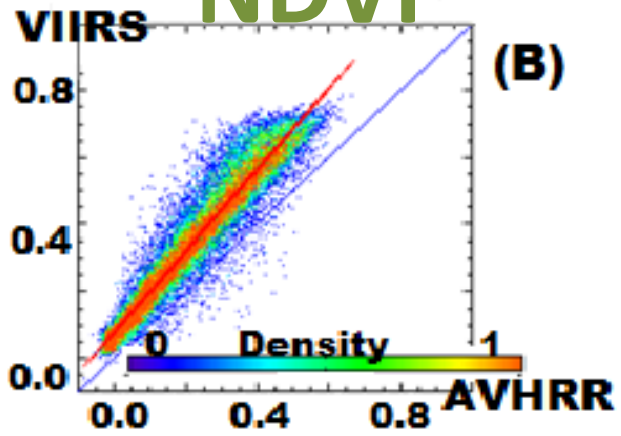
NEW vs OLD: VIIRS versus AVHRR

Climate data records problems

Channels

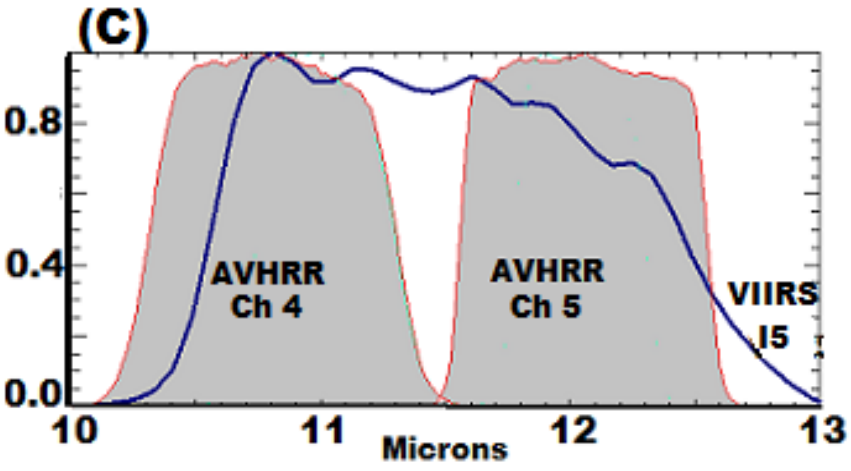


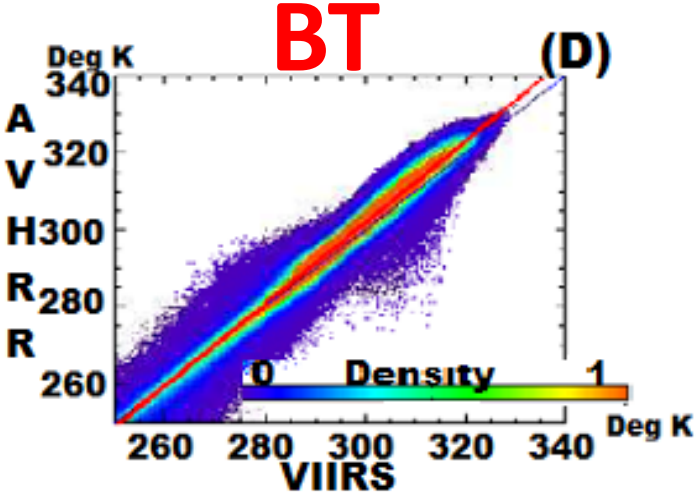
NDVI



Normalized Difference Vegetation Index (NDVI)

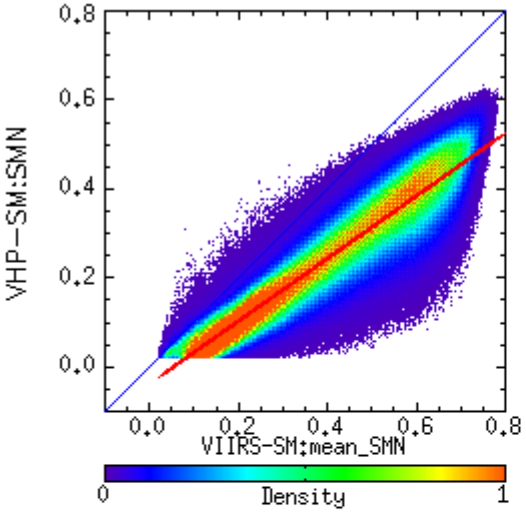
BT





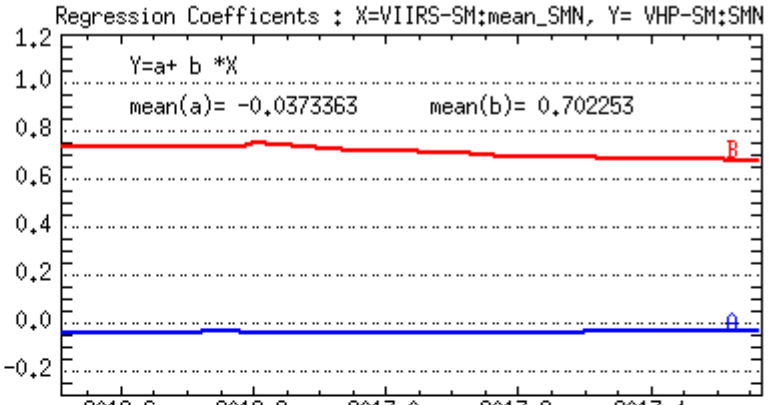
Brightness Teperature (BT)

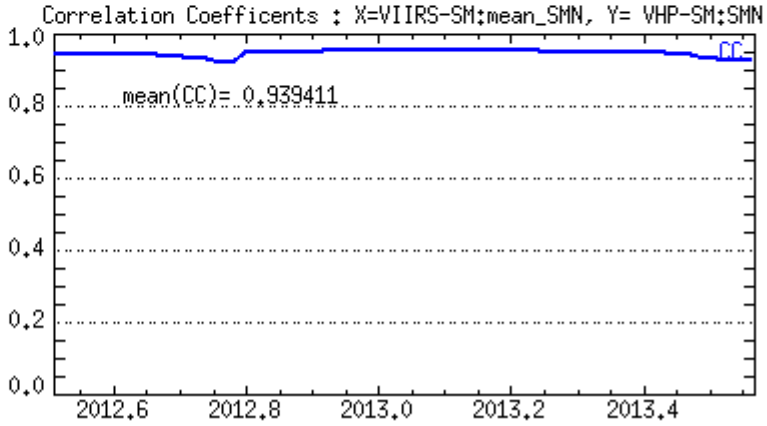
ADJUSTMENT: NDVI (SMN): AVHRR-VIIRS time series



Y= a +b * X
a= -0.0374925
b= 0.703031

Nsamples=4963003
CC = 0.9374
RMSE =0.0486750

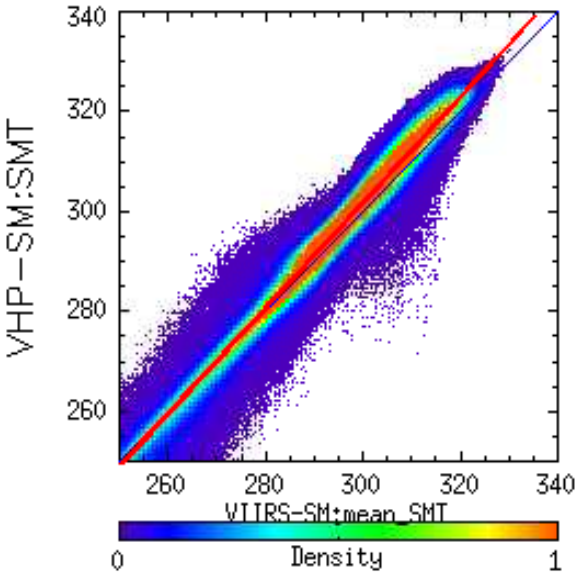




lon=[-180.00, 180.00] lat=[-40.00, 40.00]

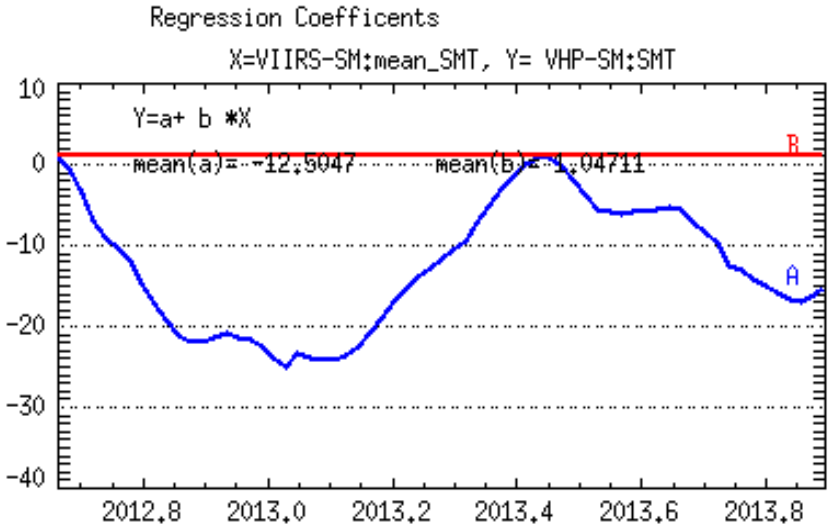
Data used: 2012 week 27 to 2013 week 30

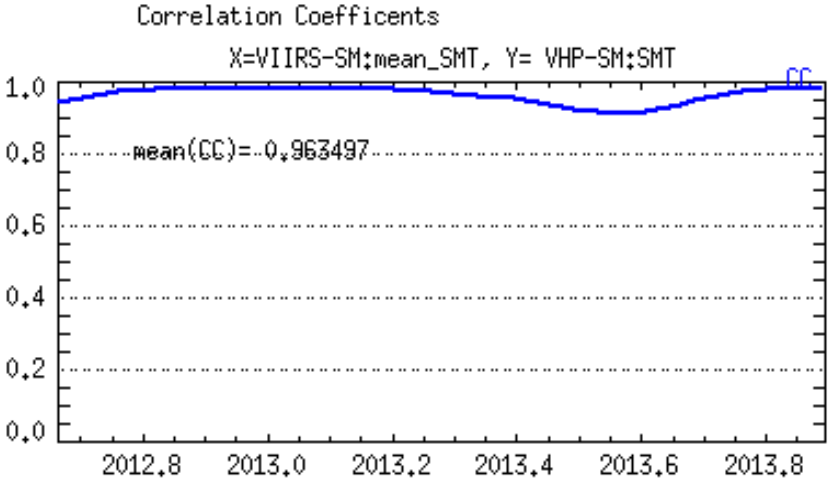
ADJUSTMENT: BT (SMT): AVHRR-VIIRS COR and Time Series



Y= a +b * X
a= -15.3288
b= 1.05696

Nsamples=8638092
CC = 0.9610
RMSE =3.51405





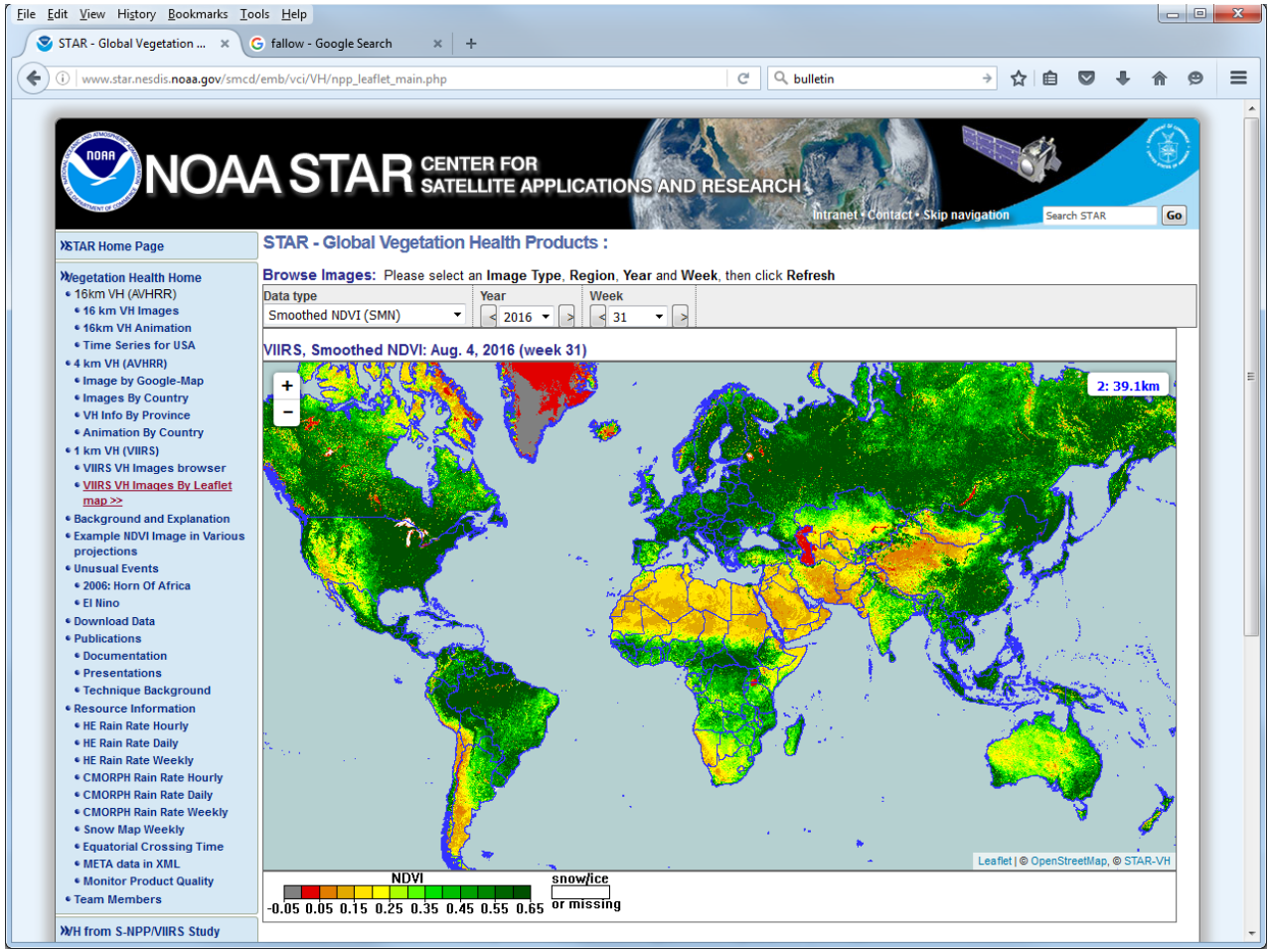
lon=[-180.00, 180.00] lat=[-40.00, 60.00]

Data used: 2012 week 35 to 2013 week 47

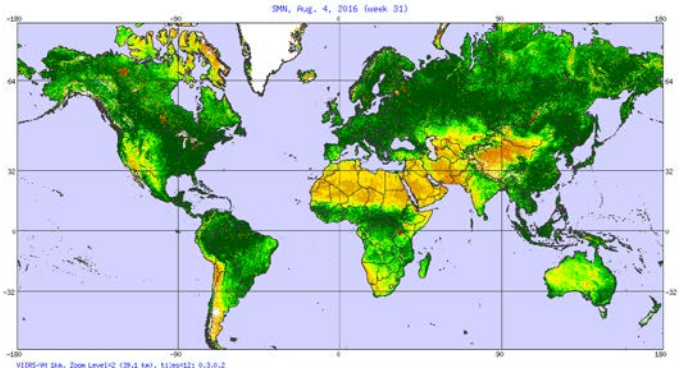
Using High resolution VH products

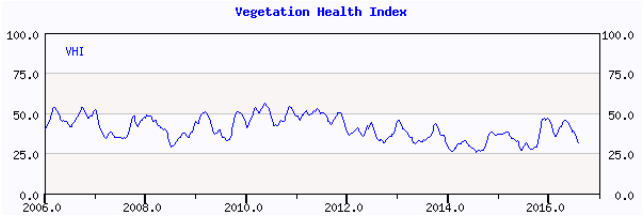
- Present high resolution data by
  - Map tiles
  - Detail map of province or sub-divisions
- Using with GIS data

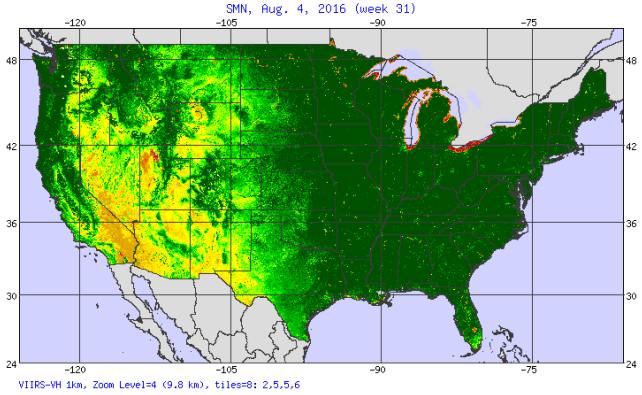
Viewed the 1km VH products by Leaflet (like Google map)

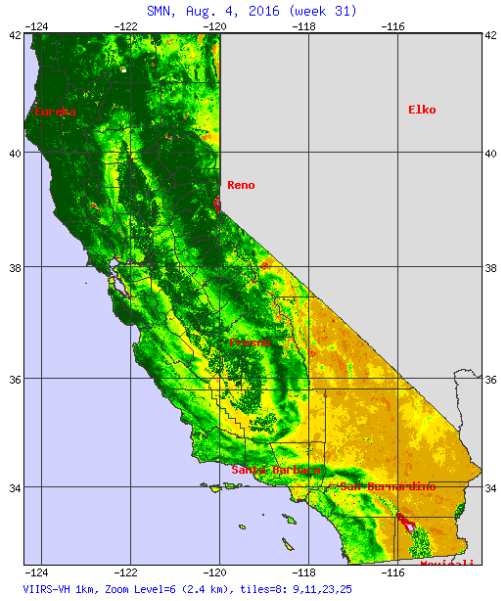


Using map tiles technology to present 1km VH data through web pages





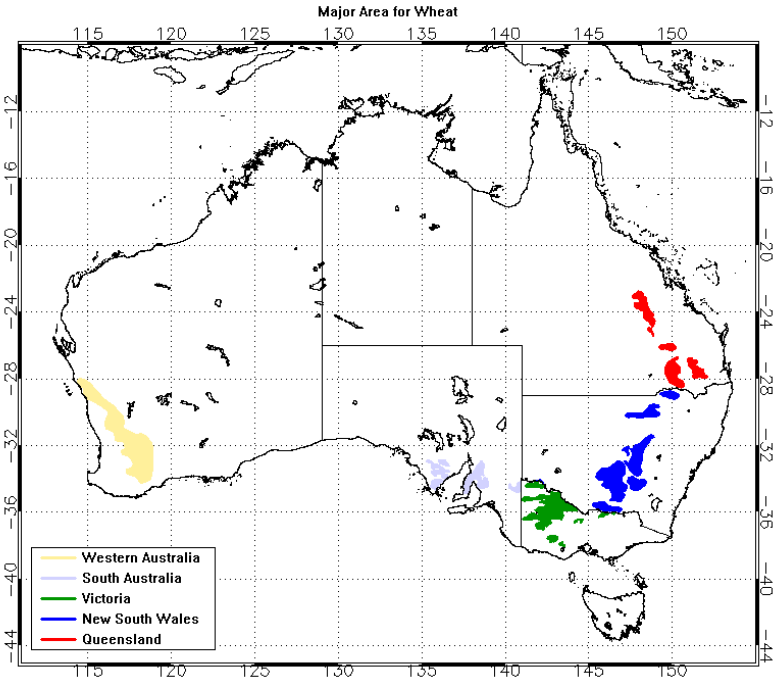




Users access the country and province maps by clicking the web page.

Major Wheat Area of Australia







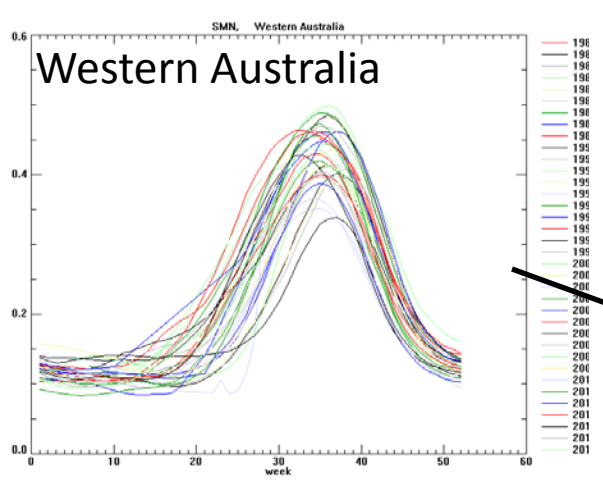


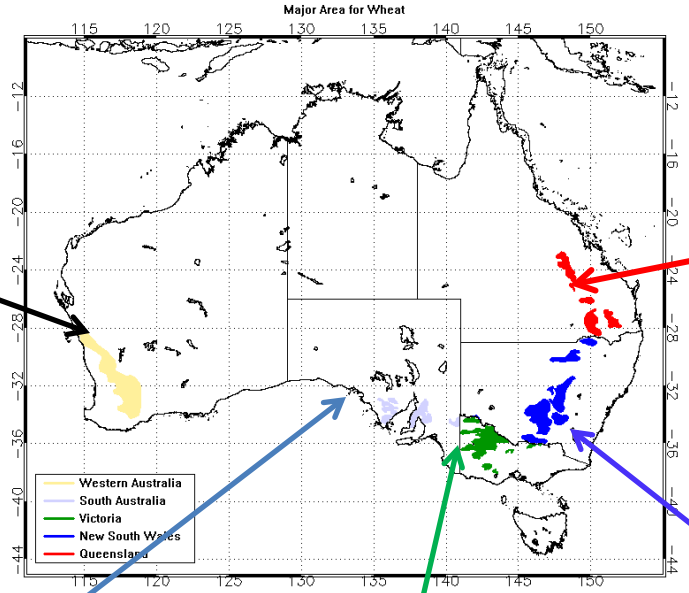


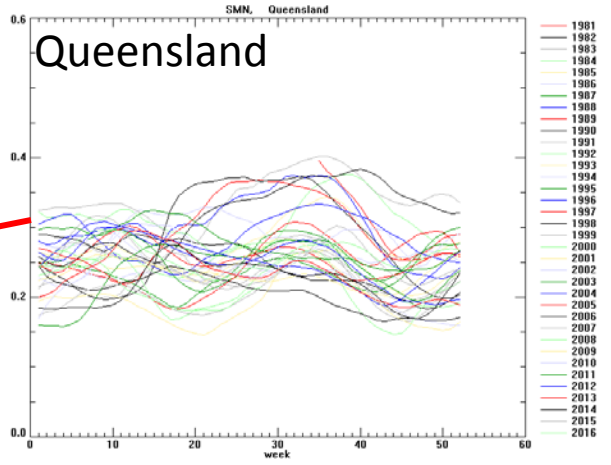


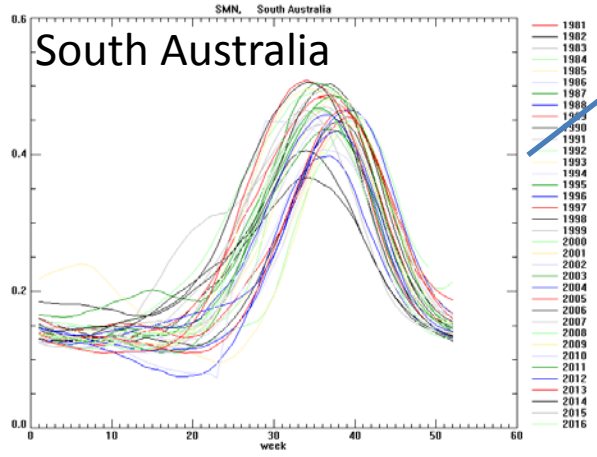
The small images with blue background are mask files generated from the polygons provided by USDA.

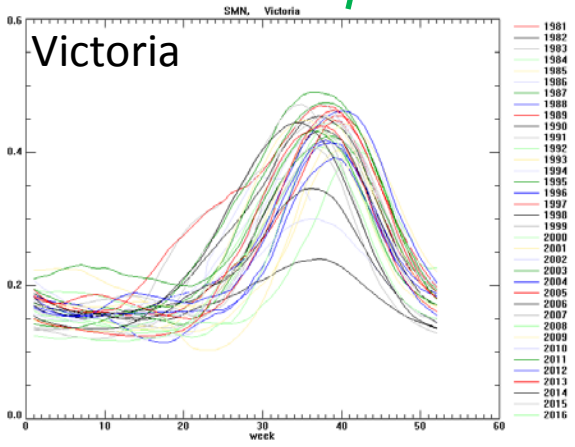
SMN time series, averaged for the selected regions

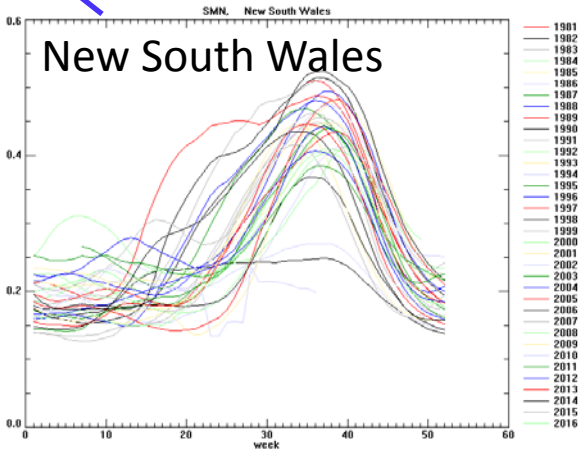




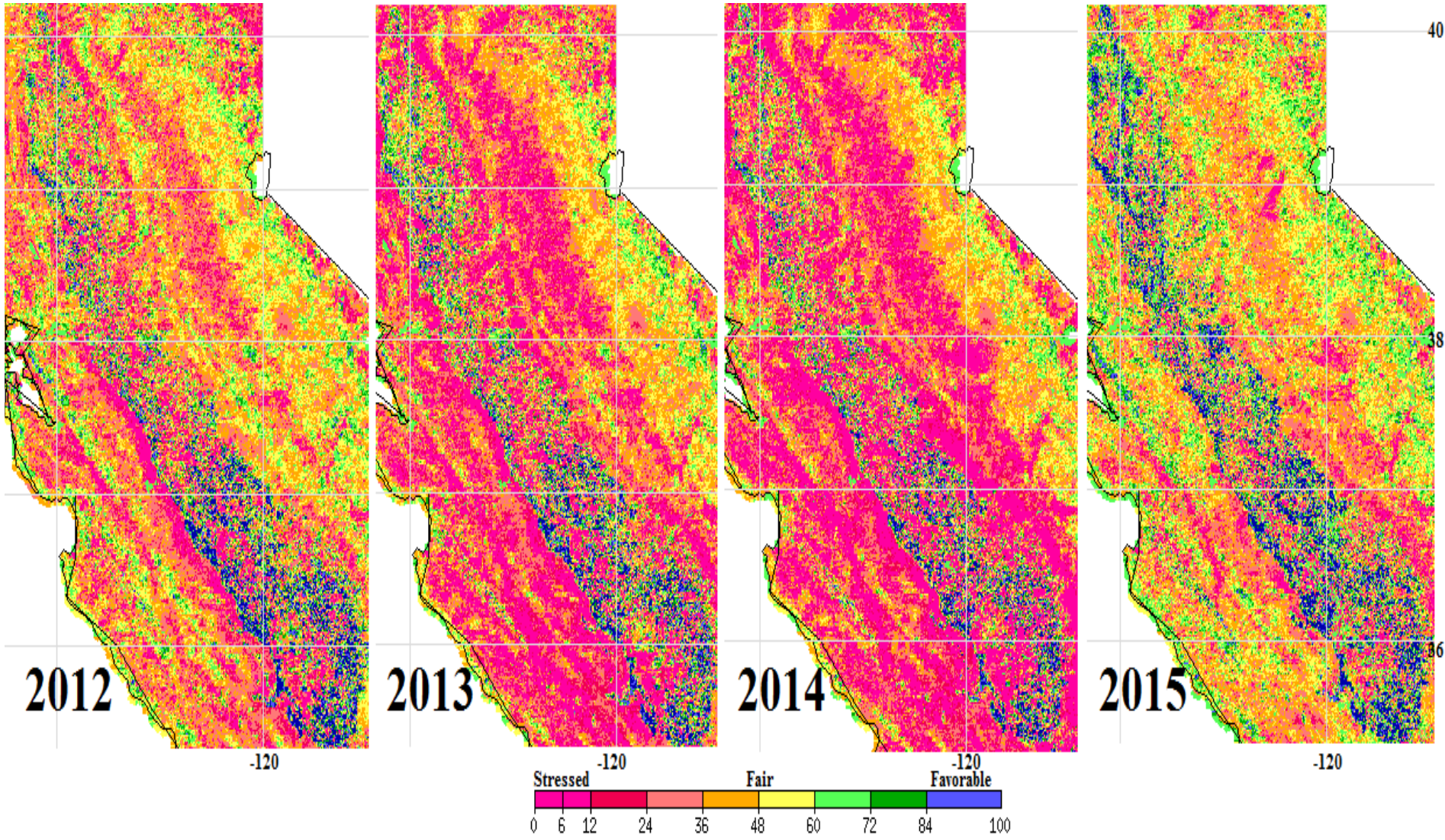






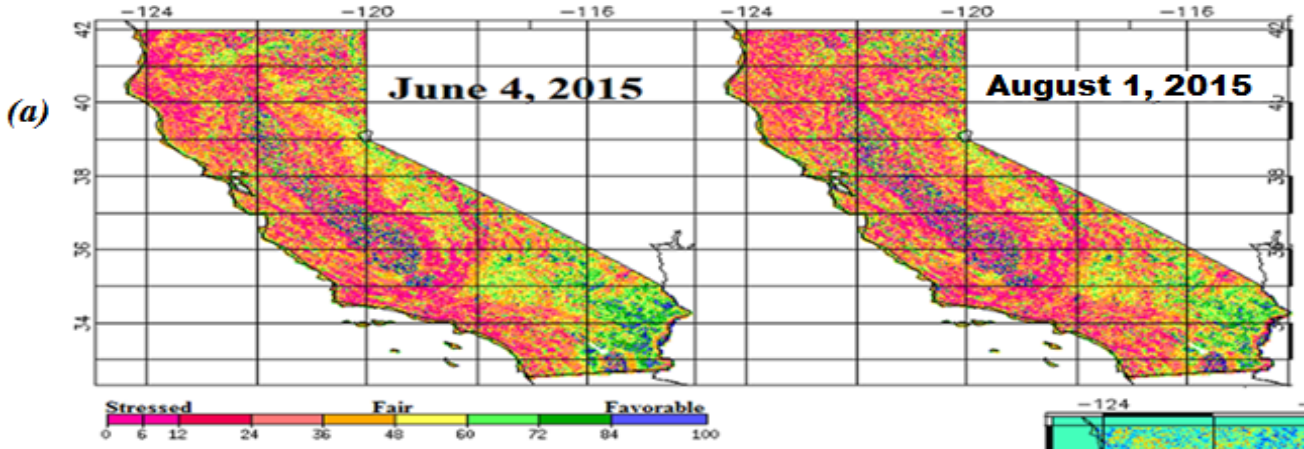


EXPERIMENTS: 500 m S-NPP/VIIRS Vegetation Health: California

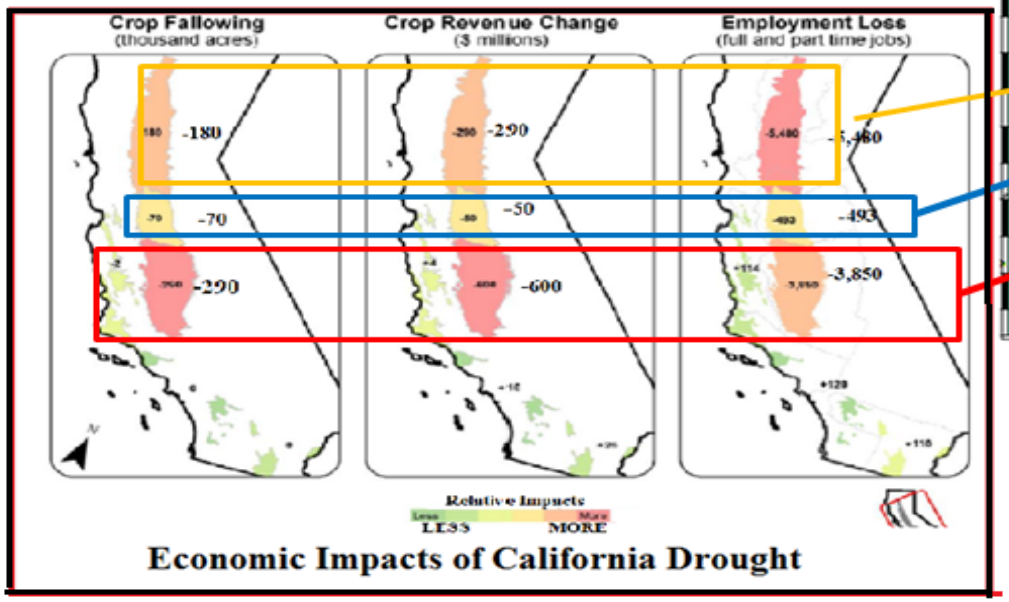


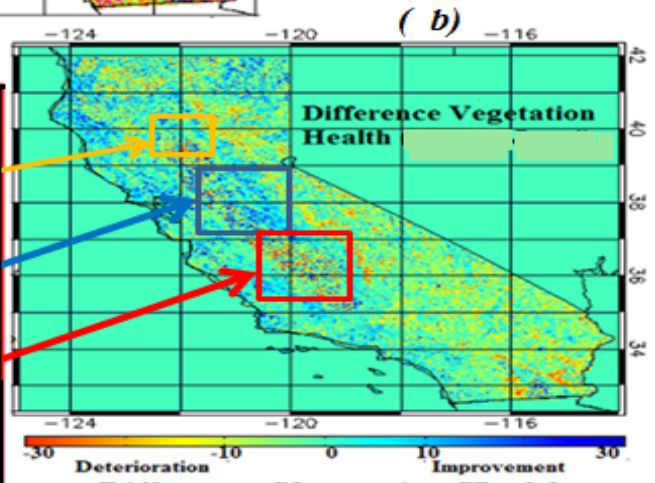
S-NPP/VIIRS-500m Vegetation health, June 12, USA, California, Central Valley

Vegetation Health from SNPP/VIIRS & Economic Indicators



Vegetation Health from 500 m S-NPP/VIIRS





Difference Vegetation Health
August 1 - June 4, 2015

(c)

Intensity of Economic and VH-assessed Impacts
Stronger Moderate Weaker

NCEP LAND APPLICATIONS

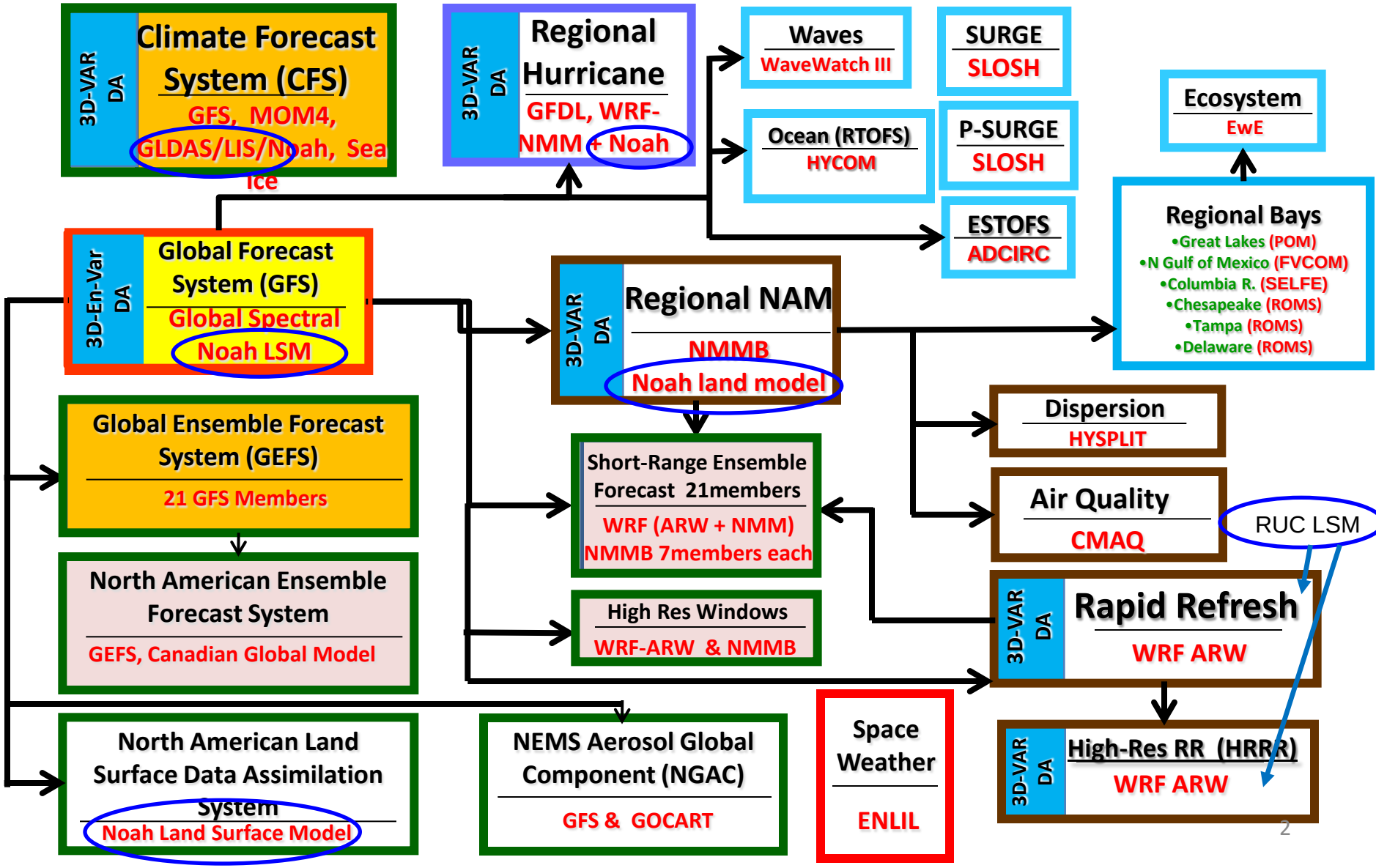
Mike Ek

NCEP/EMC

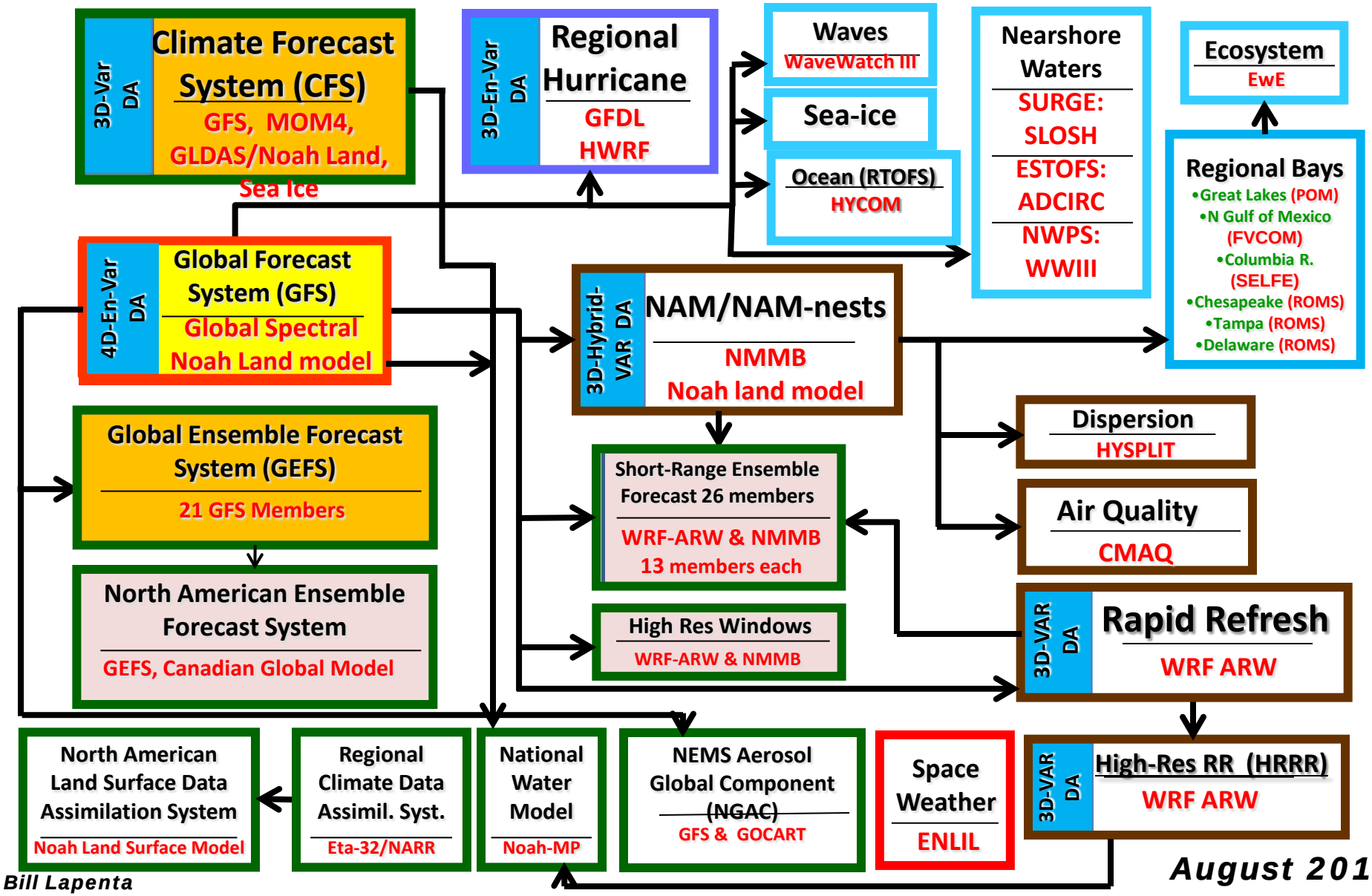
Yihua Wu, Weizhong Zheng, Helin Wei

IMSG

Land Prediction in Weather & Climate Models: NOAA's Operational Numerical Guidance Suite



NOAA's Operational Numerical Guidance Suite

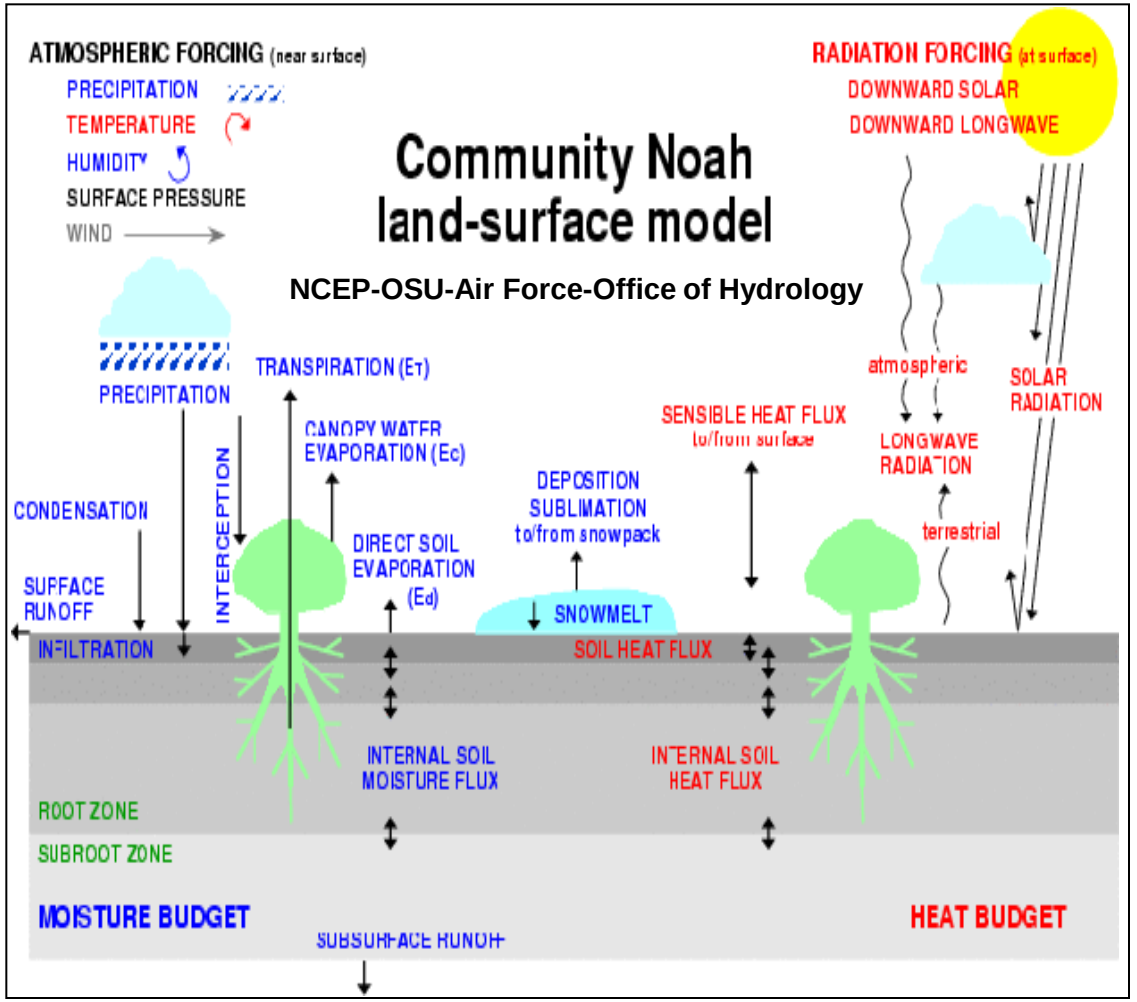


Bill Lapenta

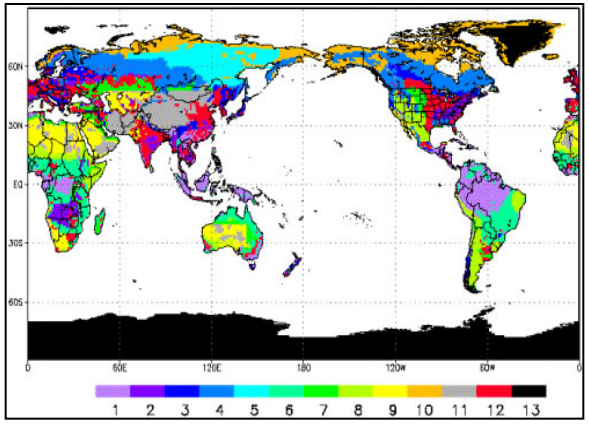
August 2016

NCEP-NCAR unified Noah land model

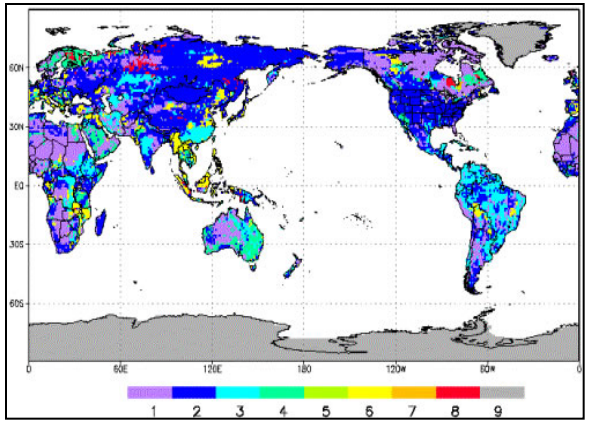
- Surface **energy** (linearized) & **water** budgets; 4 soil layers.
- **Forcing**: downward radiation, precip., temp., humidity, pressure, wind.
- **Land states**: T_{sfc}, T_{soil}*, soil water* and soil ice, canopy water*, snow depth and snow density.
  **prognostic*
- **Land data sets**: veg. type, green vegetation fraction, soil type, snow-free albedo & maximum snow albedo.



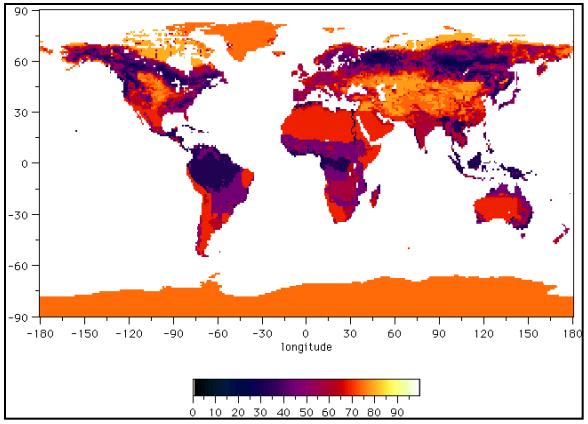
Land Data Sets *(GFS and CFS, GLDAS)*



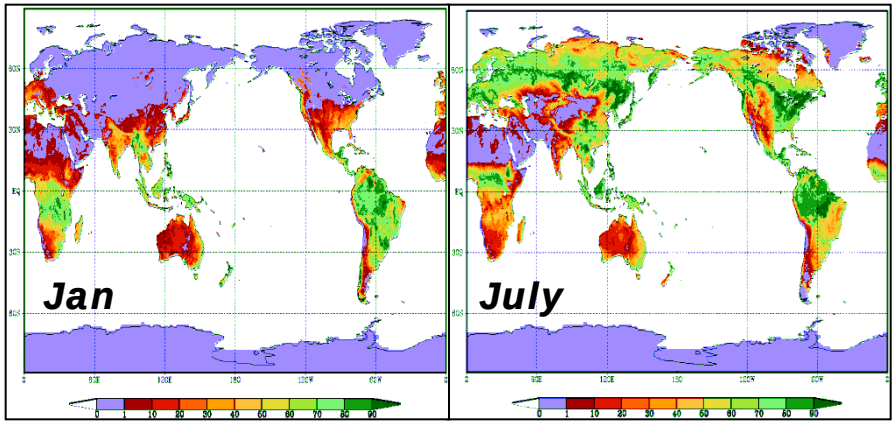
Vegetation Type
(1-deg, UMD)



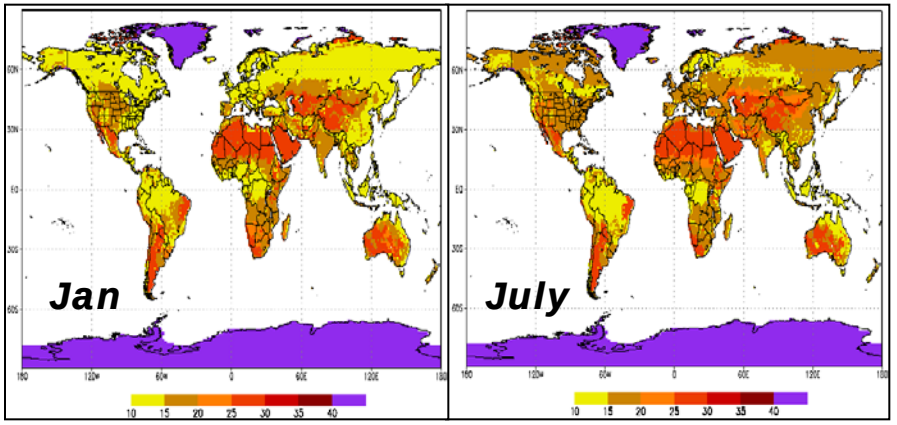
Soil Type
(1-deg, Zobler)



Max.-Snow Albedo
(1-deg, Robinson)

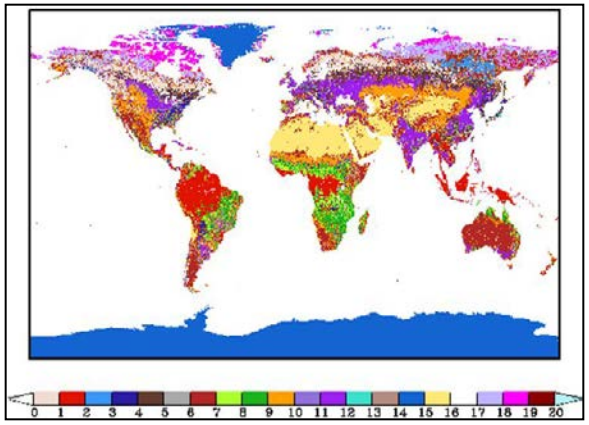


Green Vegetation Fraction
(monthly, 1/8-deg,
NESDIS/AVHRR)

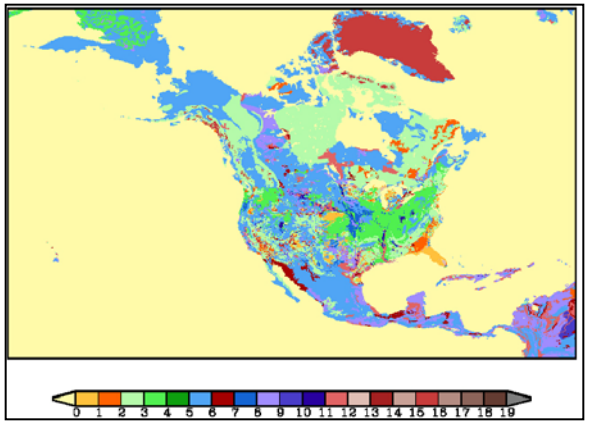


Snow-Free Albedo
(seasonal, 1-deg,
Matthews)

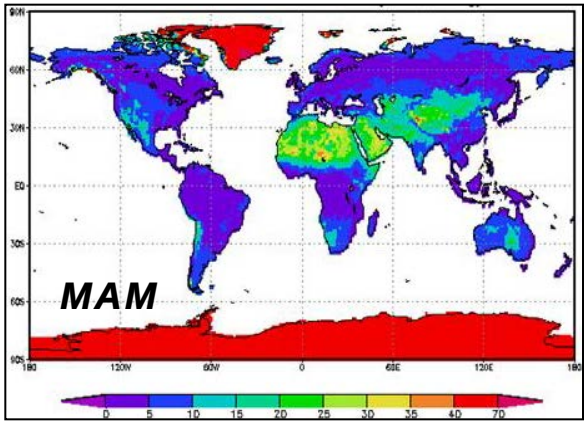
Land Data Sets *(NAM, NLDAS)*



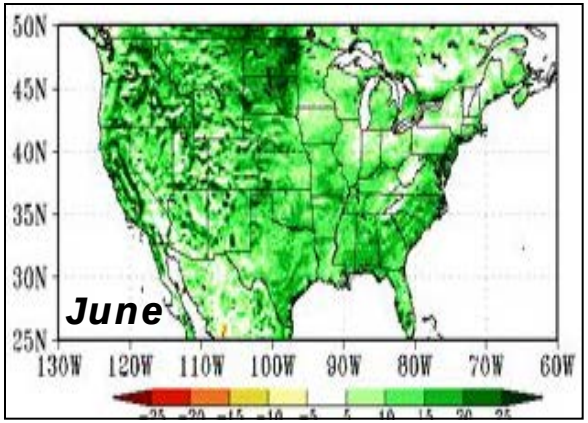
Vegetation Type
(1-km, MODIS)



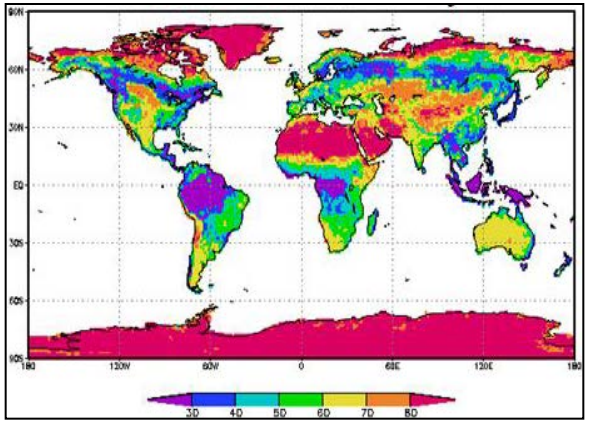
Soil Type
(1-km, STATSGO/FAO)



Snow-Free Albedo
(1-km, MODIS)



Green Vegetation Fraction
(1/8-deg, new NESDIS/AVHRR)



Max.-Snow Albedo
(5-km, MODIS)

LAND PRODUCTS USED IN MODELS

OBS TYPE	DATA SOURCE				APPLICATION IN MODELS	
	CURRENT		FUTURE			
	SOURCE	REQUIREMENTS	SOURCE	REQUIREMENTS	INITIAL	VERIFICATION
GVF	AVHRR	5 year Climate	VIIRS	Weekly value updated daily, 1 KM	X	
ALB	Table	Seasonal		Hourly, 1KM	X	
LST			VIIRS	Hourly, 1KM		X
LAND TYPE	MODIS	Annual, 1KM	VIRRS	ANNUALLY Updated, 1KM	X	
SNOW COVER	AVHRR	12/24 Hour 1KM/4KM/24KM	VIRRS	HOURLY, 1KM	X	X
SWE/SNOW DEPTH	AVHRR	12/24 HOUR	VIRRS	HOURLY, 1KM	X	X
EMISSIVITY	Table	Seasonal	VIRRS	HOURLY, 1KM	X	
BURNED AREA	AVHRR/MODIS	6/12/Hour, 1KM/4KM	VIRRS	HOURLY, 1KM	X	
LW RADIATION			VIRRS	HOURLY, 1KM		X
SW RADIATION			VIRRS	HOURLY, 1KM		X

Consistency among all of the products is very important in developing future products

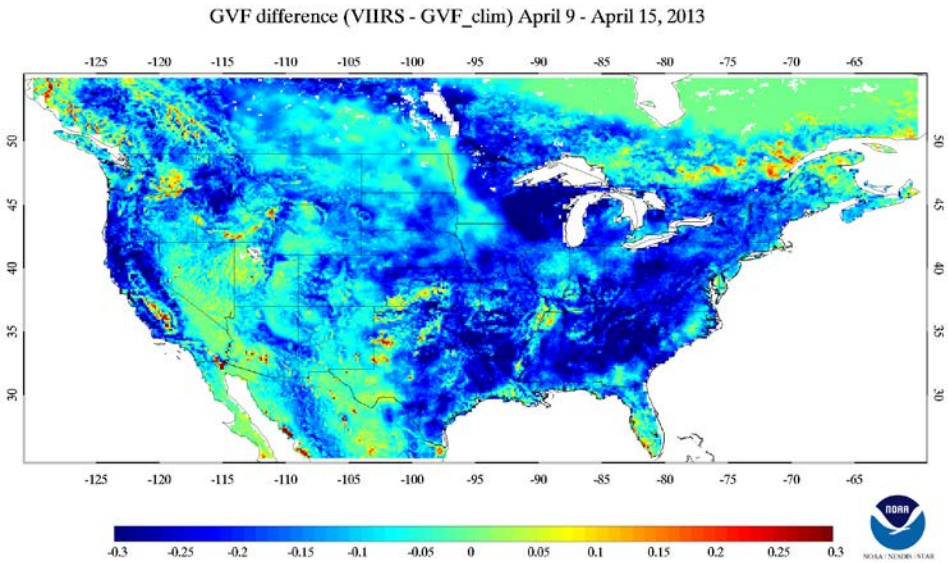
Testing in Coupled Models

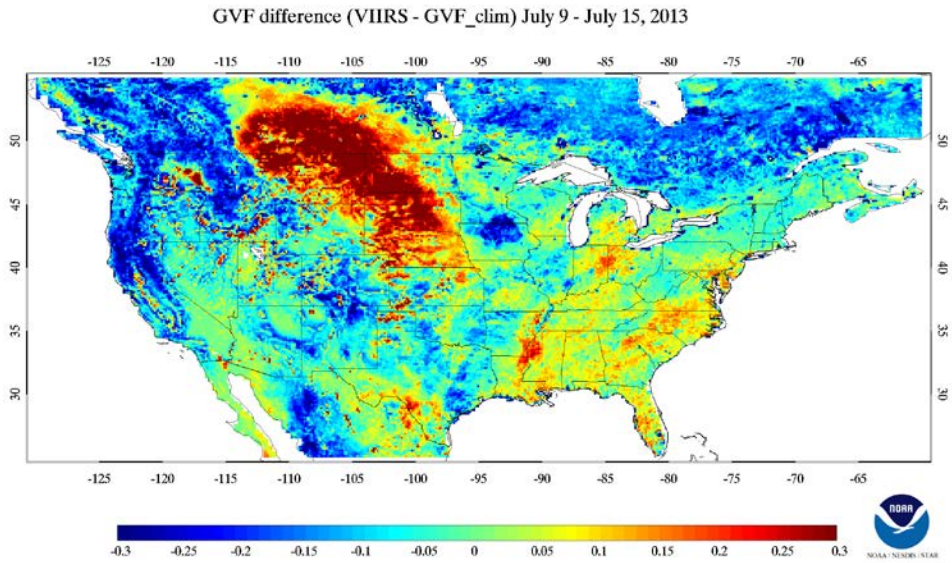
- Near real time GVF compared with the climatology
- Near real time GVF tested in NAM and GFS
- Burned Area used in NAM
- LST Validated over CONUS

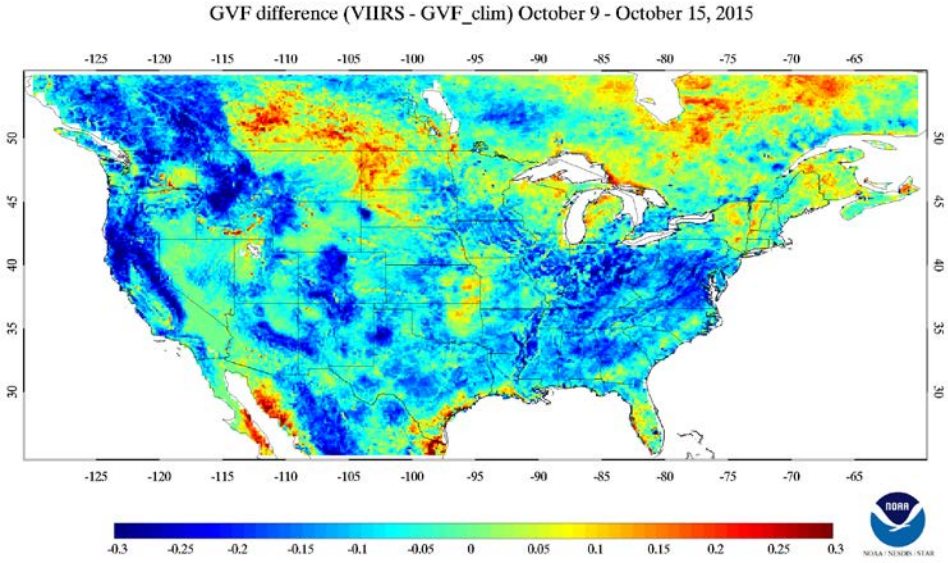
Tests IN NAM

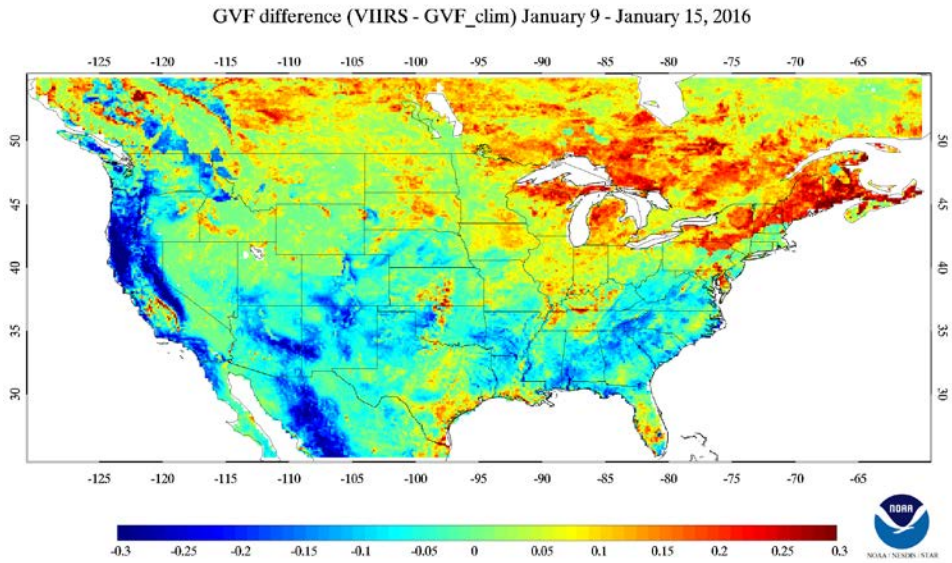
- 24 days (2 days each month, the beginning and the middle of each month) in 2014 were chosen for runs with NAM
- 3 GVFs were used
  - CLIMO—Control run
  - RGVF1—Xiaoyang Zhang
  - RGVF2—NESDIS
  - Surface update program developed by George Gayno was used to interpolate the real time GVF to NAM domain
- 84 hours simulation was conducted for each run
- Analysis was conducted over 218 GRID domain

GVF difference (VIIRS-AVHRR clim.)





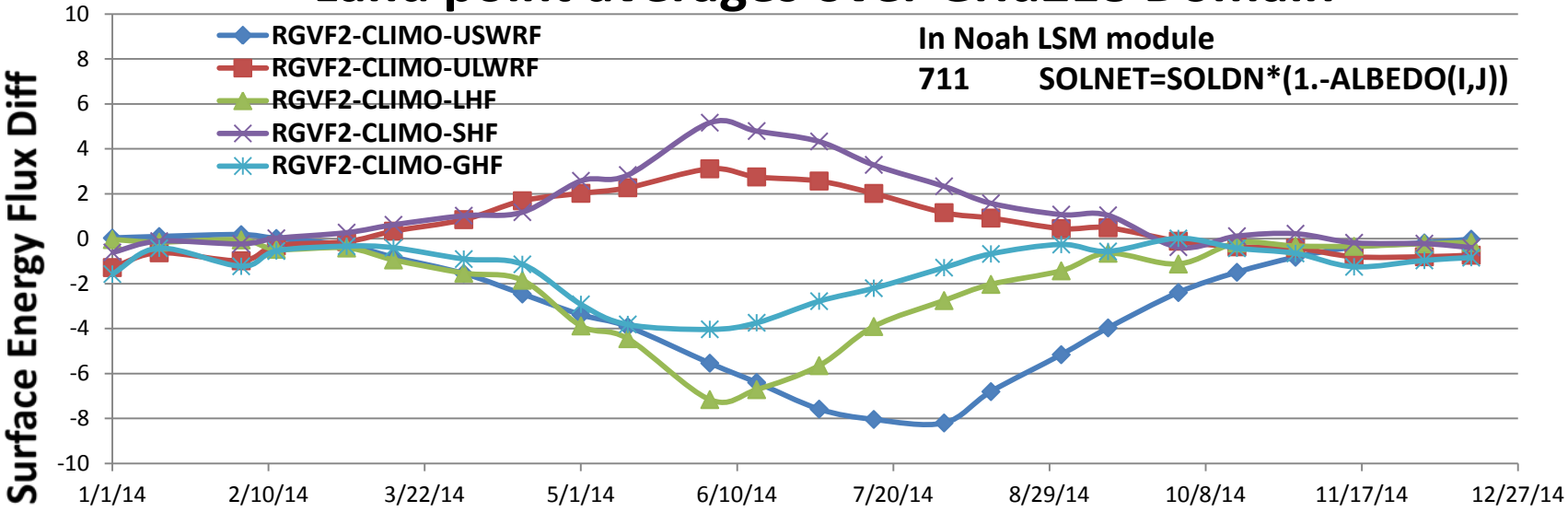


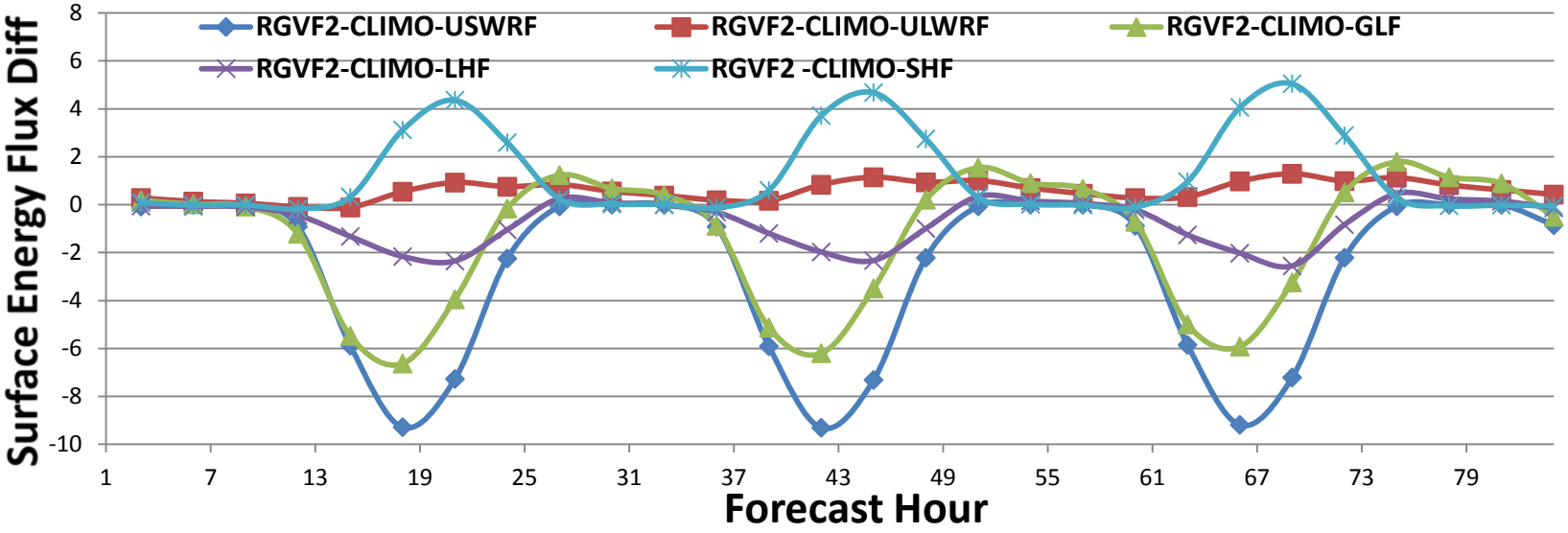


GVF climatology is higher than VIIRS GVF over vegetated area in spring

NAM GVF TESTING

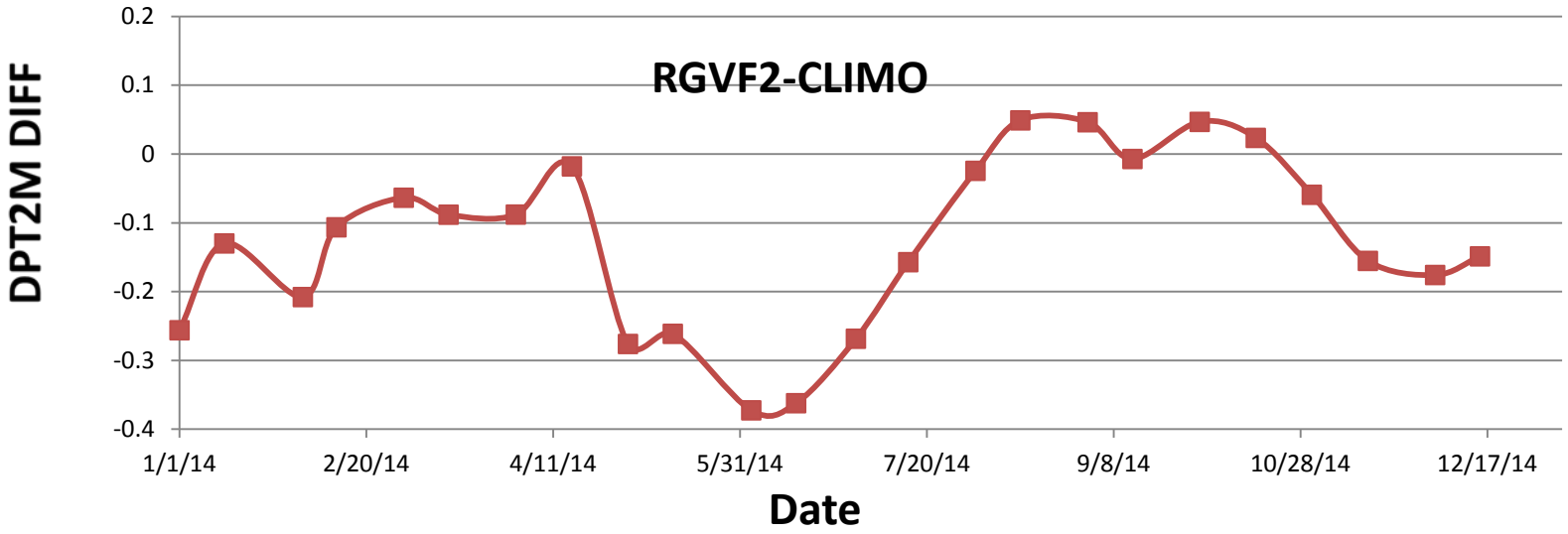
Land point averages over Grid218 Domain

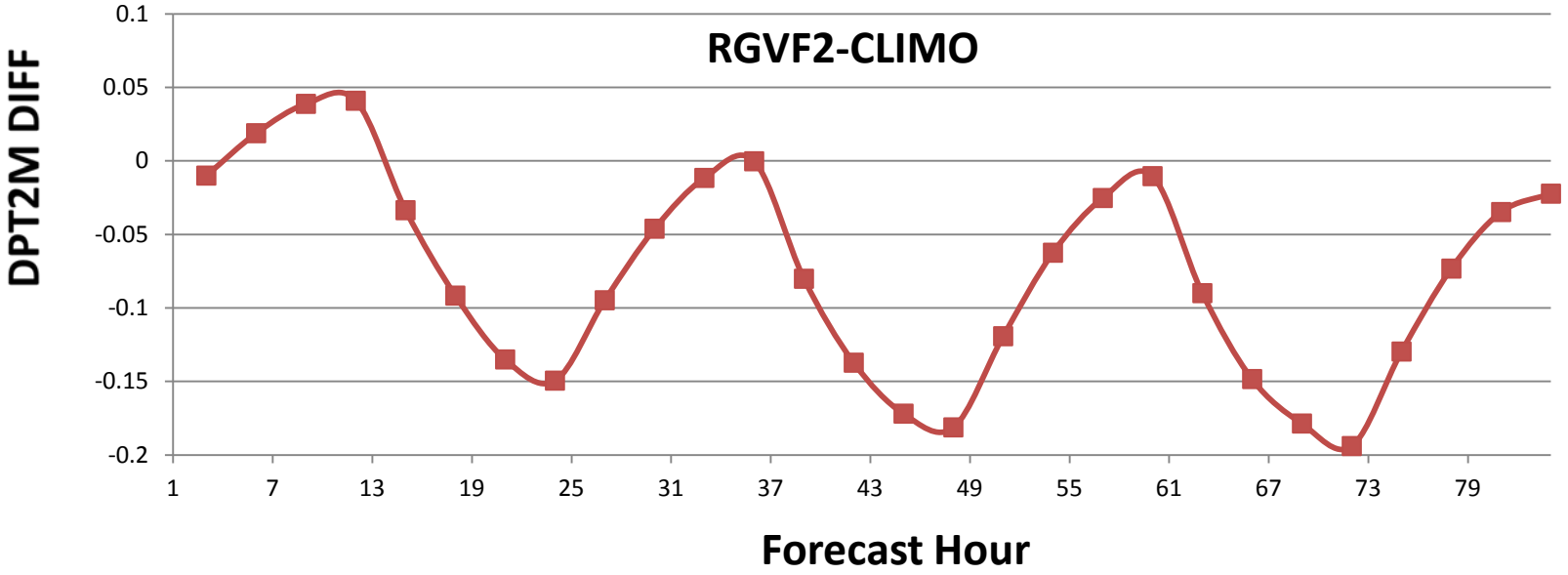




NAM GVF TESTING

Land point averages over Grid218 Domain





TESTS in GFS

- **NCEP Operations: Monthly 0.14-deg (16-km) global climatology of GVF from AVHRR. (Gutman & Ignatov, 1998).**

- **Weekly GVF: VIIRS near real-time weekly global 0.036-deg (4-km) GVF (Marco Vargas team). It starts from Sep. 2012 to current.**

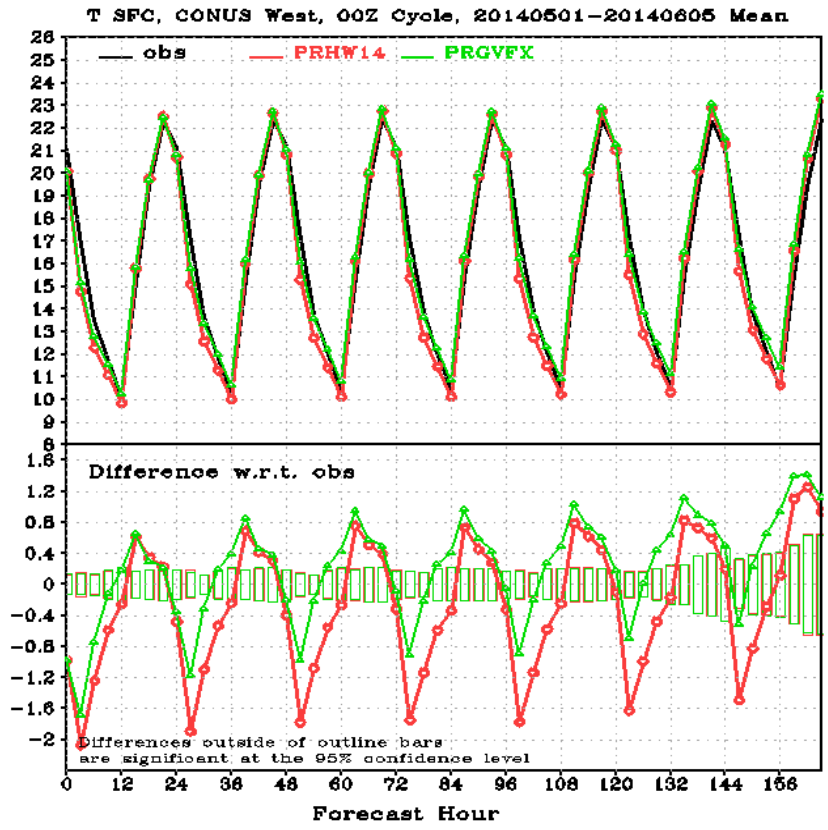
- **Three data sets: (a)Weekly climatology GVF;**
  (b) Monthly climatology GVF;
  (c) Near real-time weekly GVF

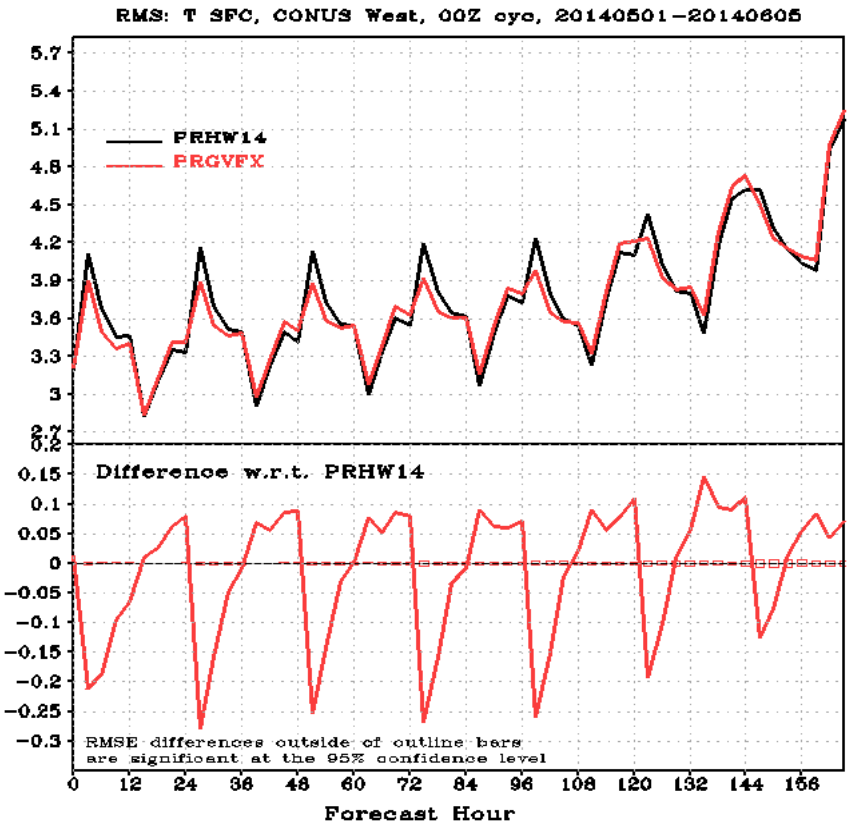
- **The new GVF data sets can potentially improve the NWP skills, especially during the spring growing season when vegetation has large variations.**

GFS GVF testing

GFS: Surface temp. and its RMSE

CONUS West

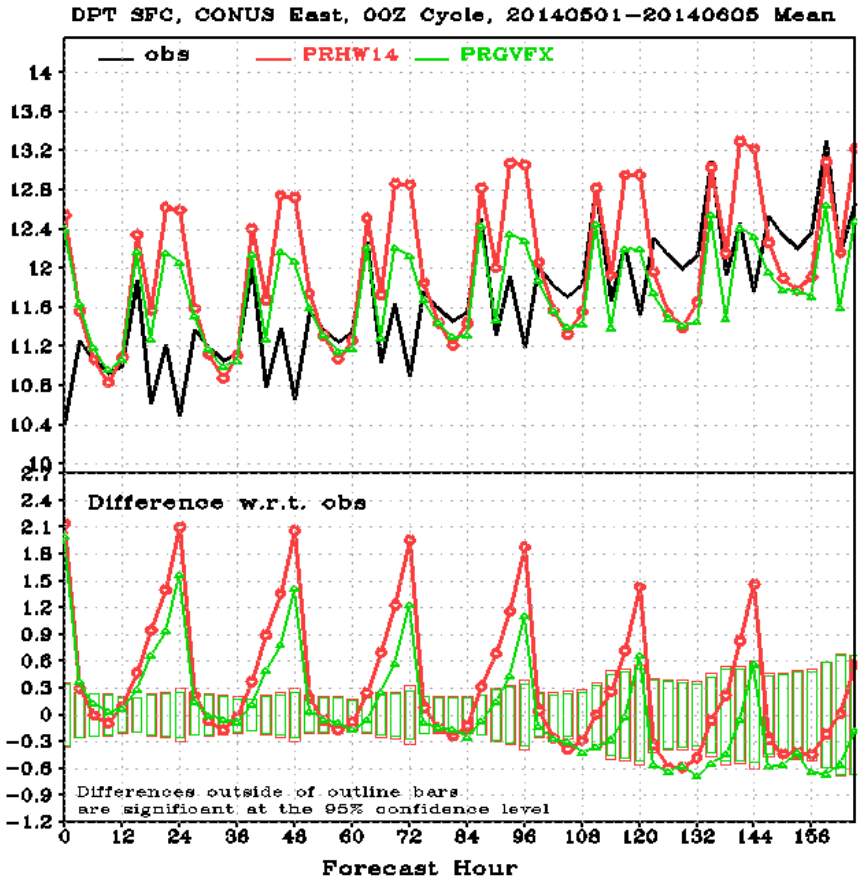


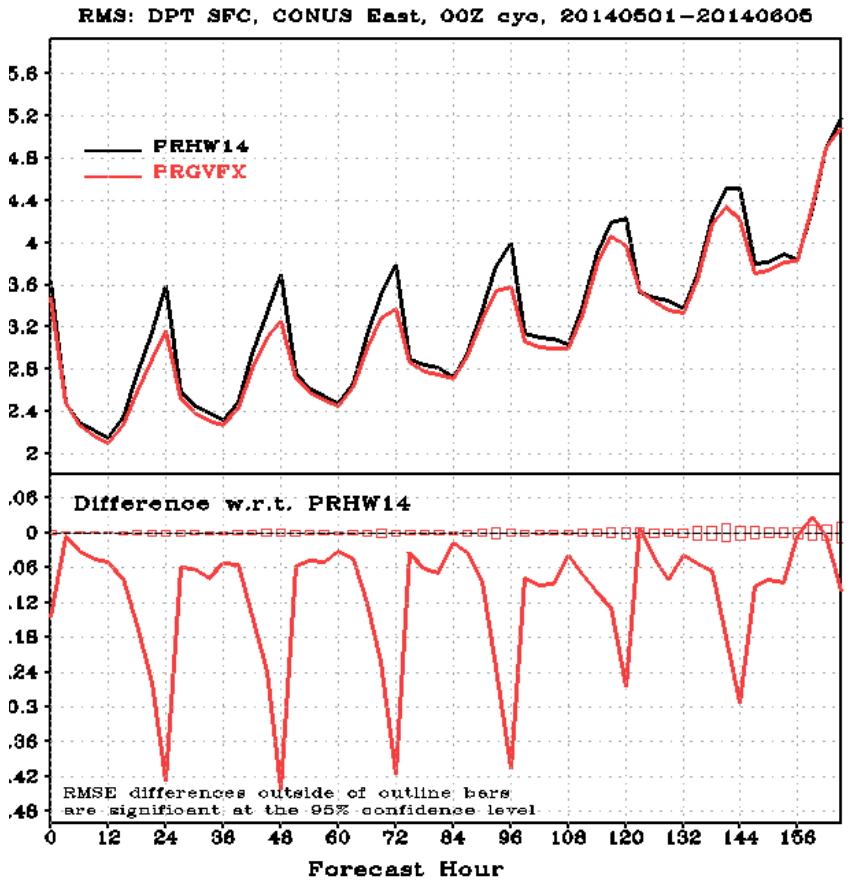


Reduced cold bias(~1 °C) and RMSE (~0.25 °C) afternoon and nighttime.

GFS GVF testing

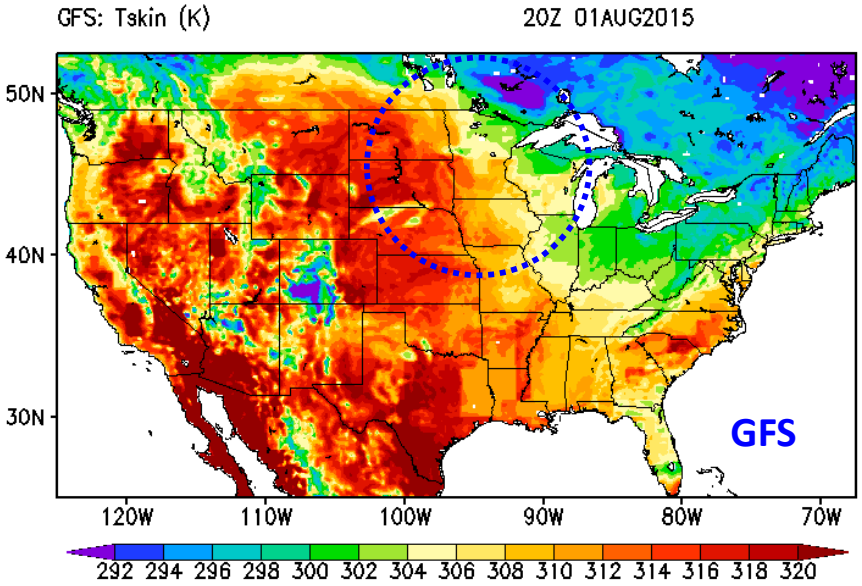
Surface dew point temp and its RMSE CONUS West

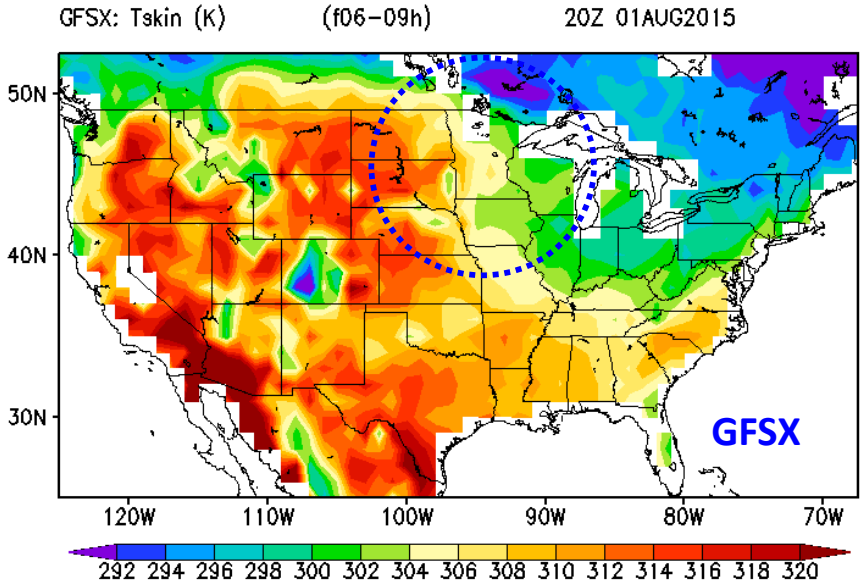




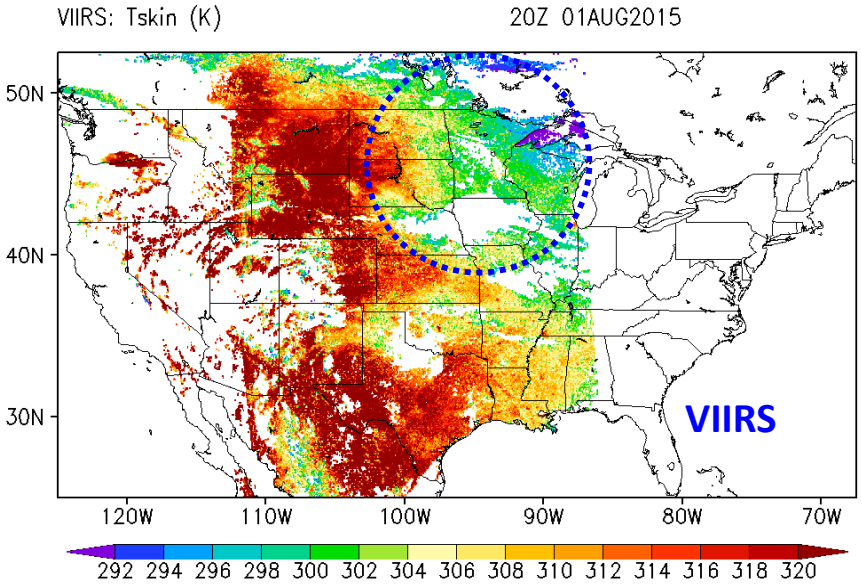
Reduced wet bias and RMSE afternoon and nighttime (~0.4 °C)

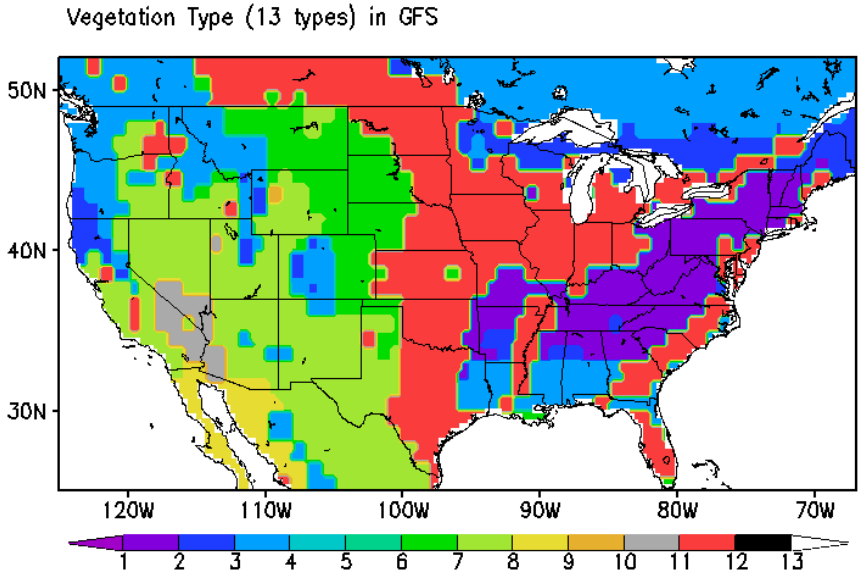
Comparison of LST: GFS, GFSX and VIIRS 20Z Aug 1, 2015





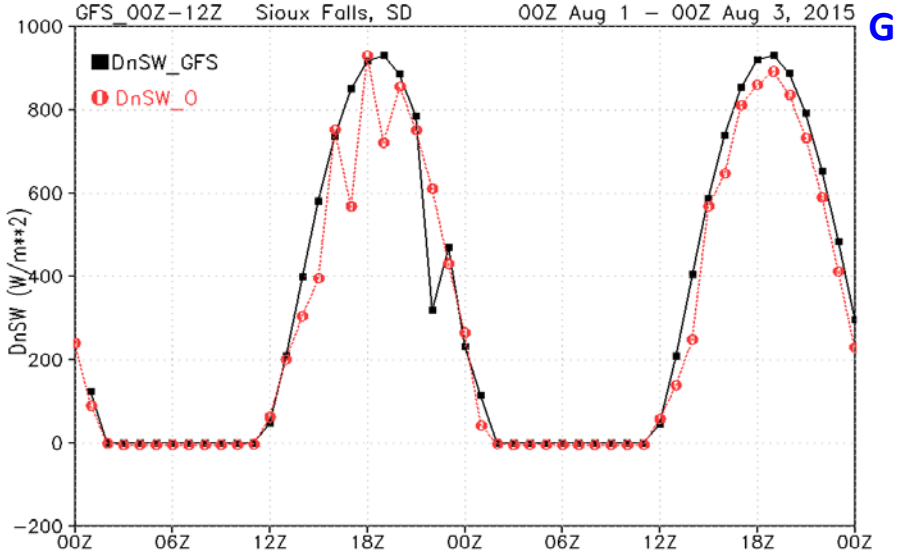
Zhen Song & Bob Yu



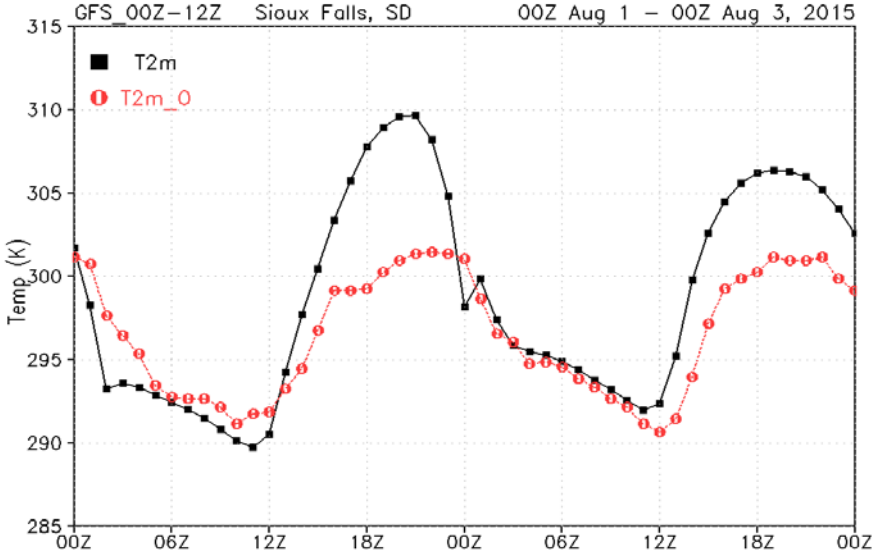


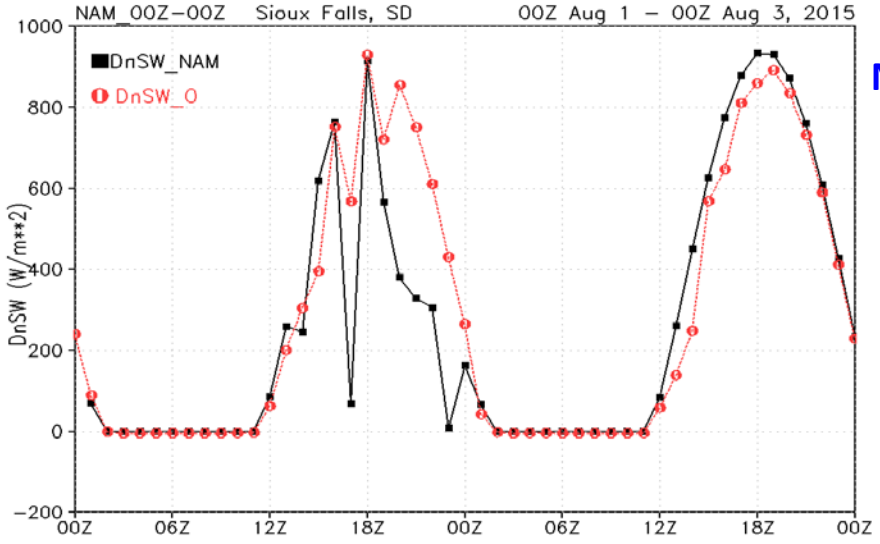
VIIRS LST VS Model LST

Verification of Swdn and T2m for GFS & NAM: 00Z Aug1-3, 2015

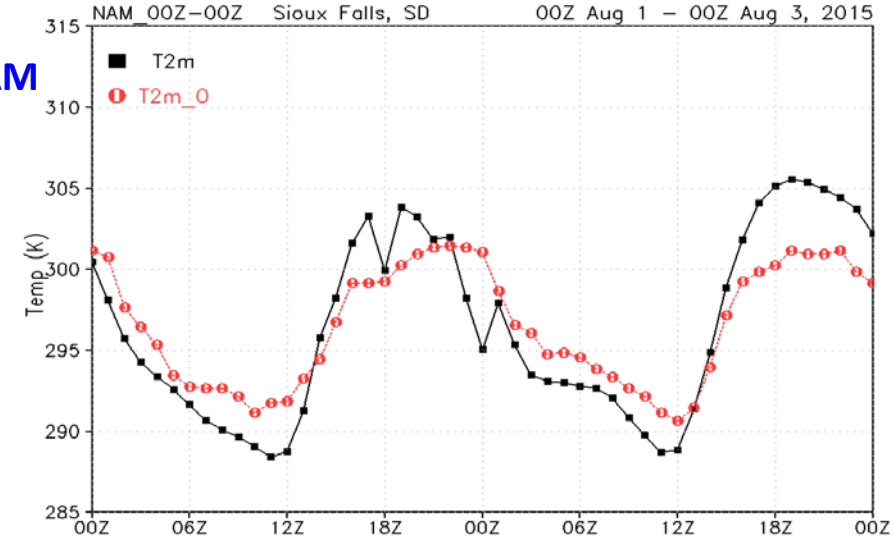


GFS





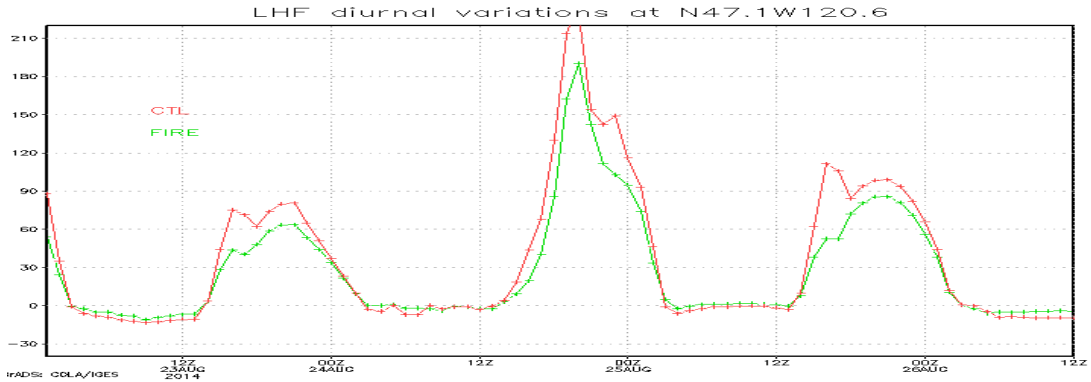
NAM

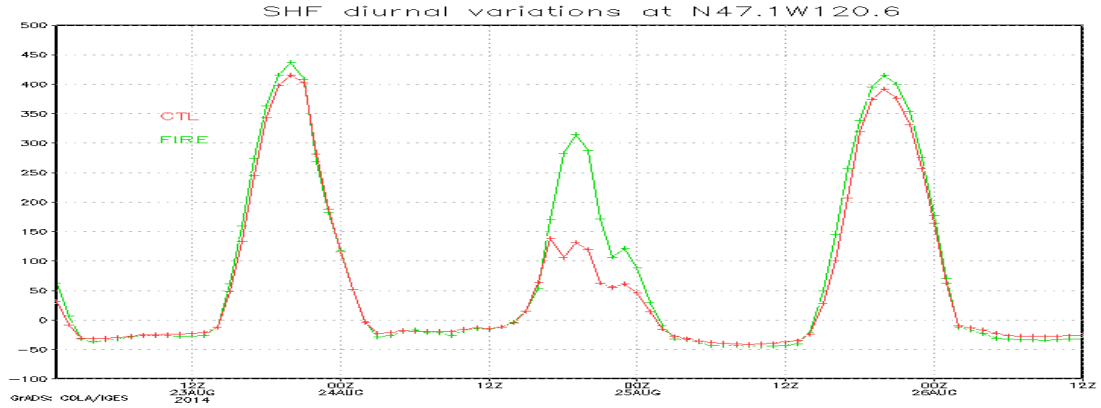


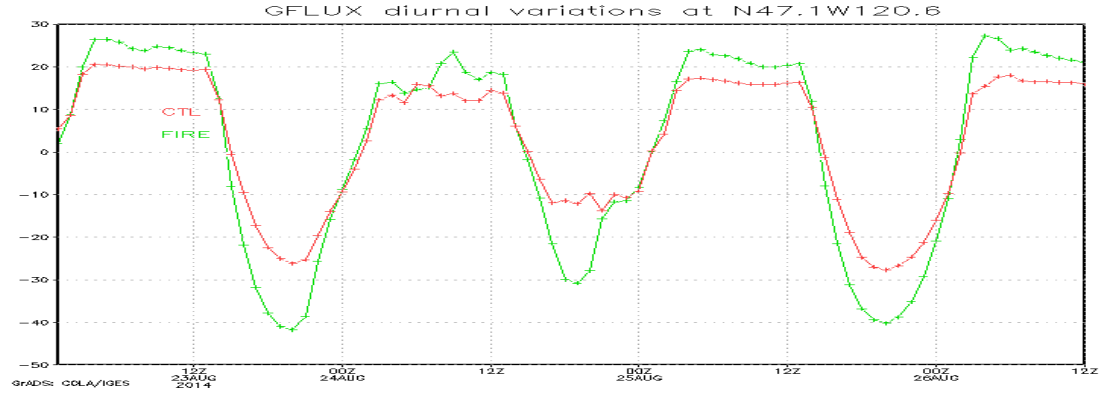
To Incorporate Fire Effect in NAM

- Surface physical characteristics in NAM are updated based burning products derived from satellite
- Two burned files are read in by the surface update program of NAM:
  - 30 day accumulation of burned area
  - 2 day accumulation of burned area which is included in the 30 day accumulation
- Vegetation cover, Roughness and Albedo are updated based on the 30 day accumulation while the surface temperature, soil temperature and moisture for top soil layer are updated based on the 2 day accumulation

Fire Effect in NAM







SUMMARY

- Several satellite data sets developed recently (e.g., GVF, LST and albedo) have been tested in the NCEP models.
- The results show good improvements, compared with the current data sets
- However, some data sets need further verification with ground measurements.
- Consistency among all of the products is very important in developing future products

U.S. National Ice Center







National Ice Center Applications

STAR JPSS 2016 Annual Science Team Meeting
NCWCP, College Park, MD
8-12 August, 2016

Presenter: Dr. Pablo Clemente-Colón, NIC Chief Scientist

CDR Ruth Lane
Director / Commanding Officer

Mr. Kevin Berberich
Deputy Director

LCDR Robert Atkinson
Naval Ice Center Executive Officer

The U.S. National Ice Center (NIC)

Mission

The U.S. National Ice Center (NIC) is a tri-agency partnership of the United States Navy (USN), the National Oceanic and Atmospheric Administration (NOAA), and the United States Coast Guard (USCG) providing global ice and snow analysis and short term forecasting services for the maximum benefit of the United States government.

Vision

To be the U.S. government's authority on global sea ice and snow analysis and forecasting.

Goals

Goal 1. Develop Capabilities

Goal 2. Transition Science and Technology

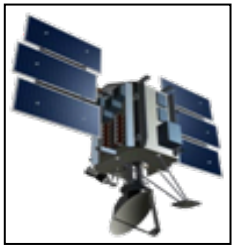


Goal 3. Strengthen Partnerships

Goal 4. Professional Excellence

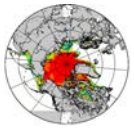
NIC Product Generation

Arctic Maritime Domain Awareness


Satellites

+


Buoys


Models

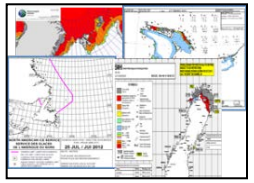

Aircraft


Webcam


Radar


Ship Obs

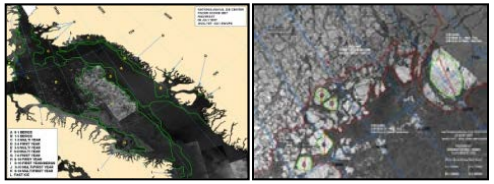

Surface Obs


International Partners

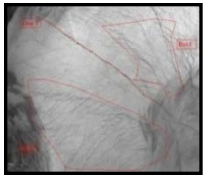
Interpretive Snow and Sea Ice Analysis and Sea Ice Forecasting

- Geographic Information System
- Meteorology
- Semi-automation
- Subject Matter Expertise

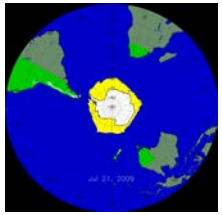
Annotated Images

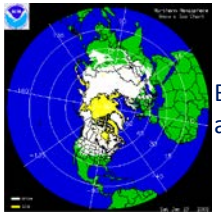


Fractures, Leads and Polynyas (FLAP)



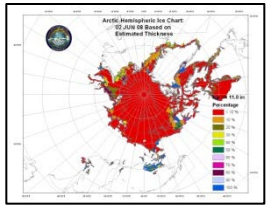
Automated Snow and Ice products



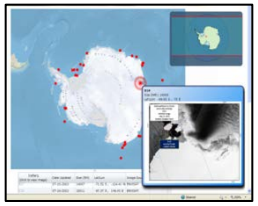


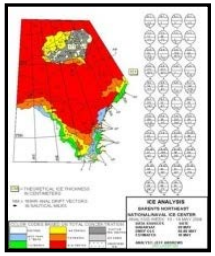
Blended Snow and ice cover

Ice Thickness Estimations



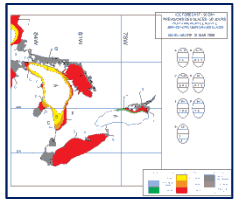
Antarctic Icebergs

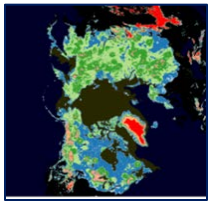




Hemispheric and Regional Ice Charts

Ice Outlooks



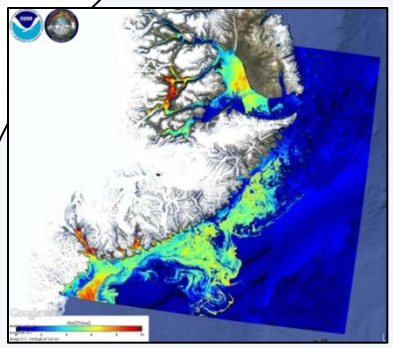


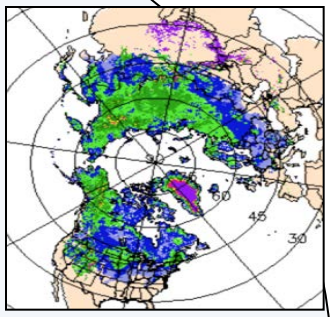
Blended Snow Depth

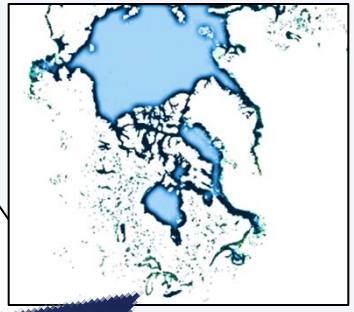
Sea Ice and Snow Analysis Integration with Models

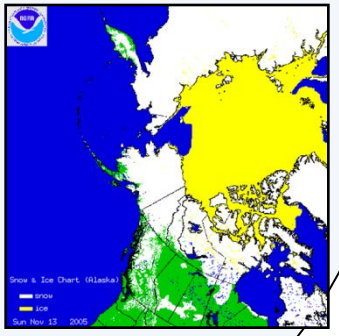
CUSTOMERS & PUBLIC

NIC Analysis

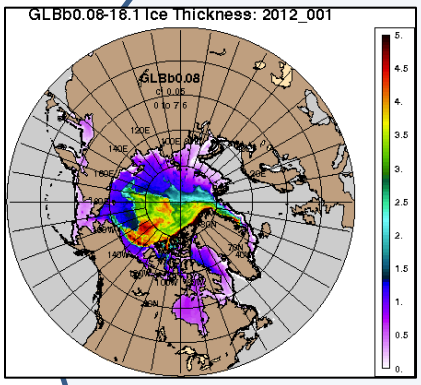


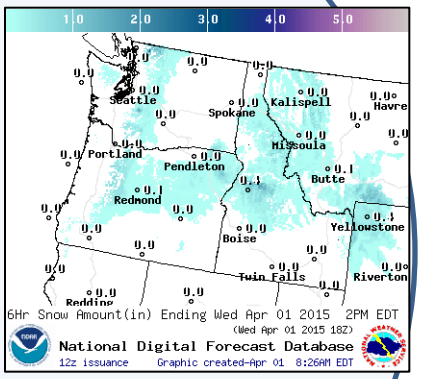


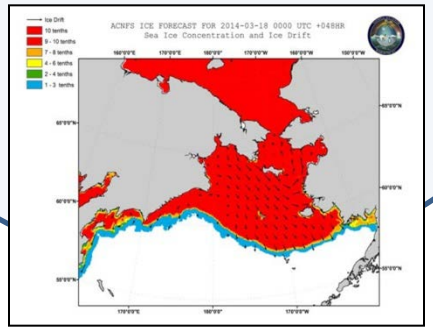




Navy and NOAA Models







Models provide forecast guidance and NIC analysts incorporate real time data to produce interpretive analysis.

Continued SNPP Utility in NIC Products

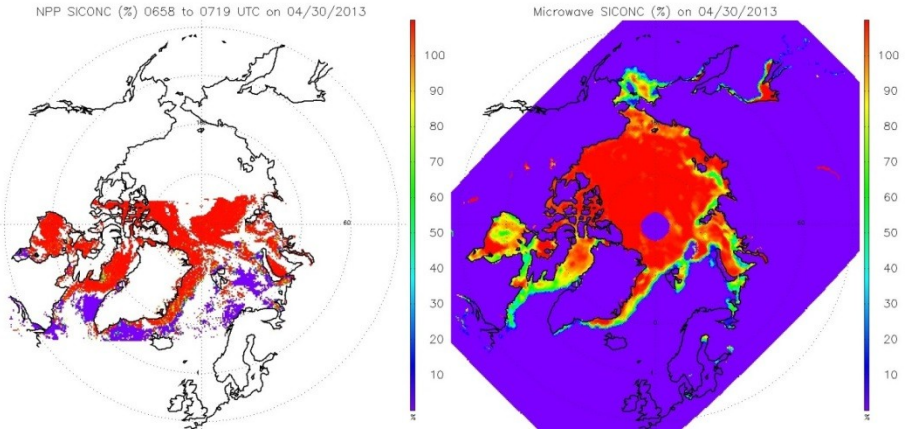
1. Imagery (I1, I2, I3, I5, DNB) (All)
2. VIIRS Sea ice characterization (IMS)

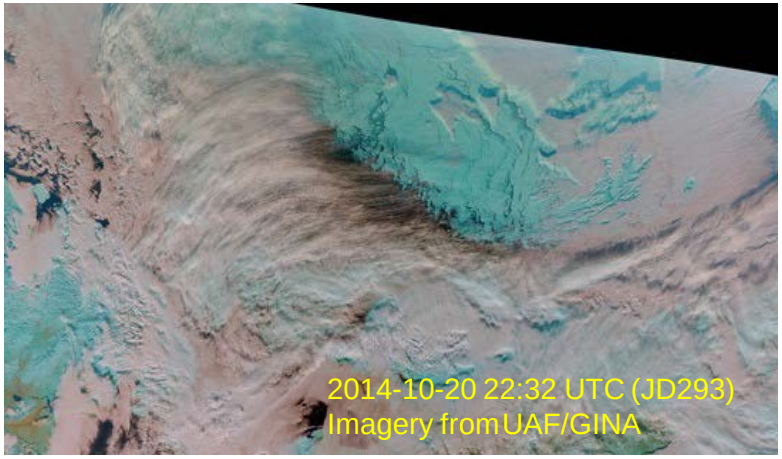
   Only used for Ice/No Ice (inaccurate ice typing), Cloud Mask issues
3. VIIRS Sea Ice concentration IP (Working on IMS, Hemi Ice Charts, & MIZ)

   Data format (HDF5 to Geotiff conversion being built)

   Will be helpful in IMS Blended Ice Con.
4. VIIRS Snow cover (IMS)

   OK, but conservative cloud mask





Continued SNPP Utility in NIC Products

5. AMSR2 Ice Concentration (MIZ, Hemispheric Ice Charts)

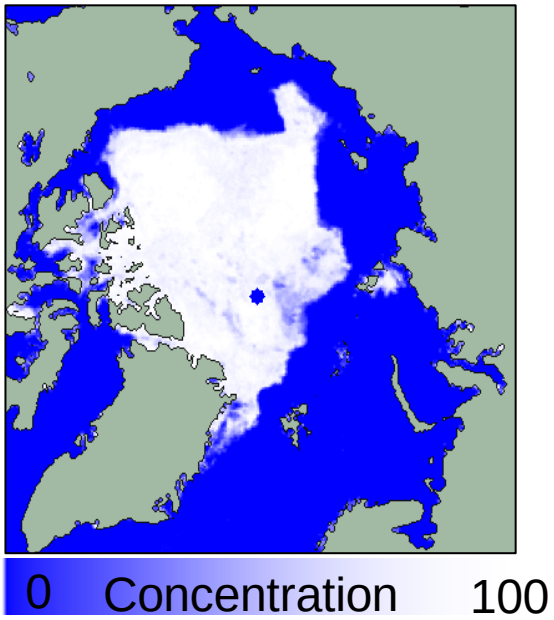
   Applied in IMS Blended Ice Concentration

   Using ASI (Univ Bremen), last resort data source,

6. ATMS Snow Water Equivalent (IMS)

   Used to make IMS Snow Depth

   Release of Version 11.1 – better agreement with AMSR 2 except in boreal forest areas



Continued Potential JPSS Utility in NIC Products

7. ATMS Snow Grain Size (IMS)

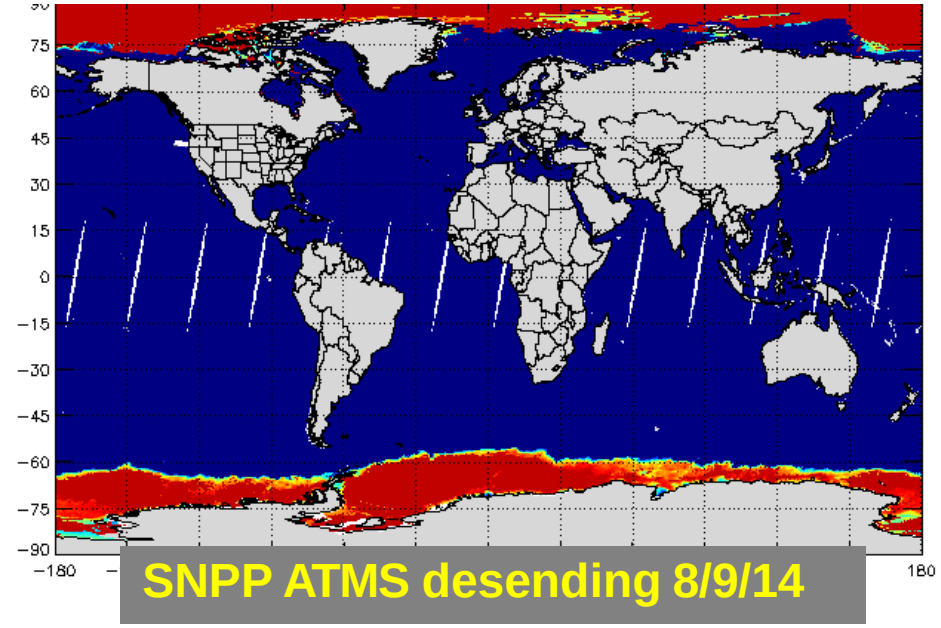
   Desired to adjust IMS Snow Depth

8. ATMS First Year Ice Concentration (IMS, Hemispheric Ice Charts)

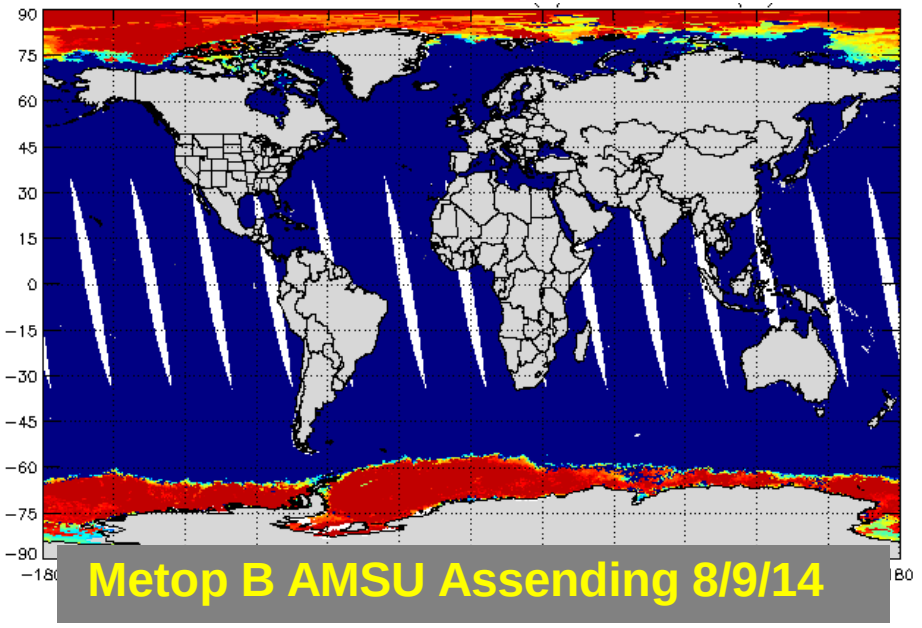
   Could be used in IMS Blended Ice Con

9. ATMS Multi-Year Ice Concentration (IMS, Hemi Ice Charts)

   Will be helpful in IMS Blended Ice Con



SNPP ATMS desending 8/9/14



Metop B AMSU Assending 8/9/14

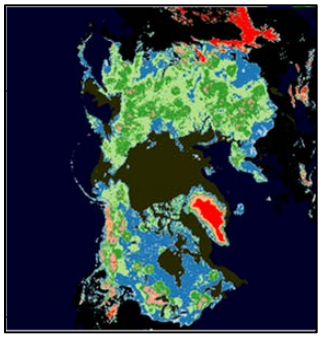
NIC Interactive Multisensor Snow and Ice Mapping System (IMS) Products

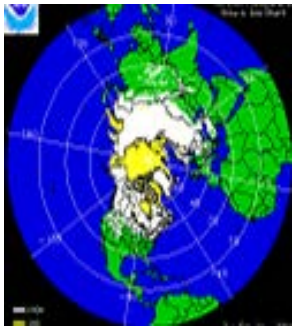
Primary Customers

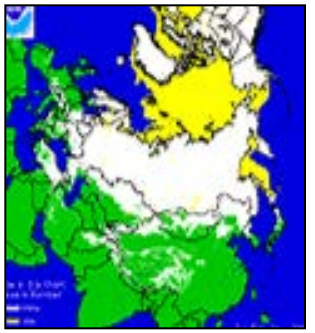
- NOAA NWS NCEP Environmental Modeling Center (EMC)
- Climate Prediction Center (CPC)

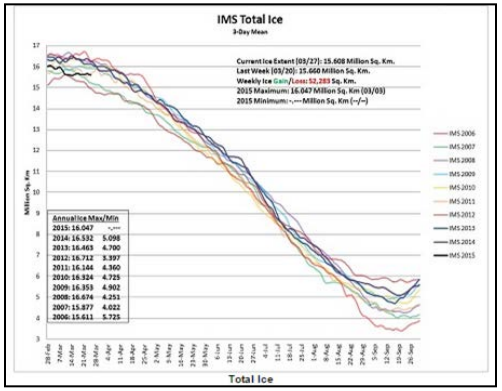
Secondary Customers

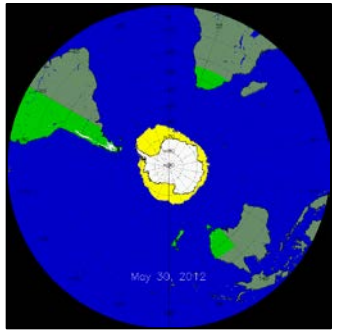
- US Army
- US Air Force
- US Department of Agriculture
- Great Lakes Engineering Research Lab
- NOAA SSD
- US Department of Transportation
- Environment Canada
- ECMWF
- UK Met
- Fleet Numerical Meteorology and Oceanography Center
- Naval Oceanographic Office
- Numerous Universities
- Media Outlets such as: Weather Channel, AccuWeather
- Private Companies
- General Public

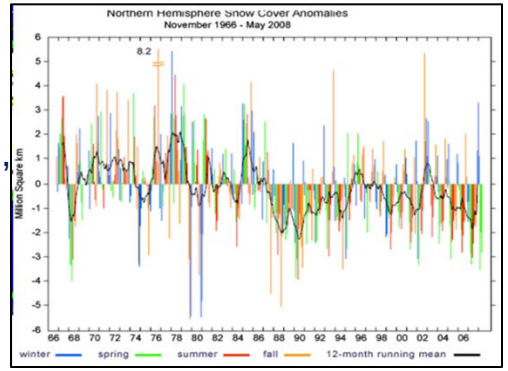




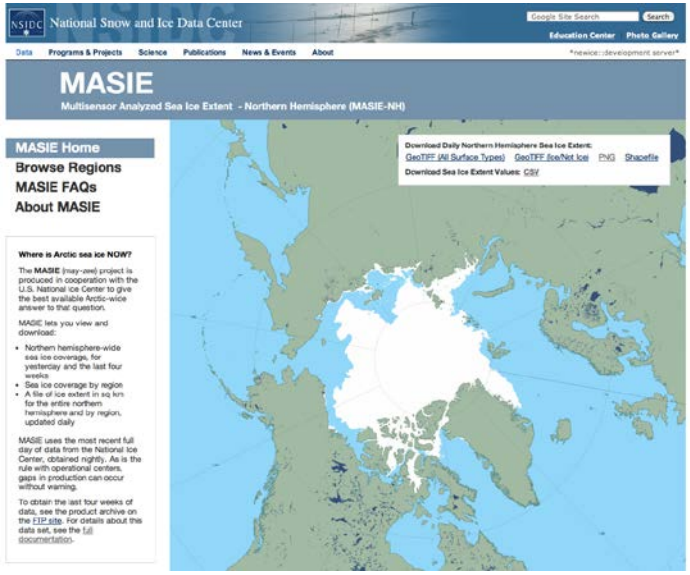


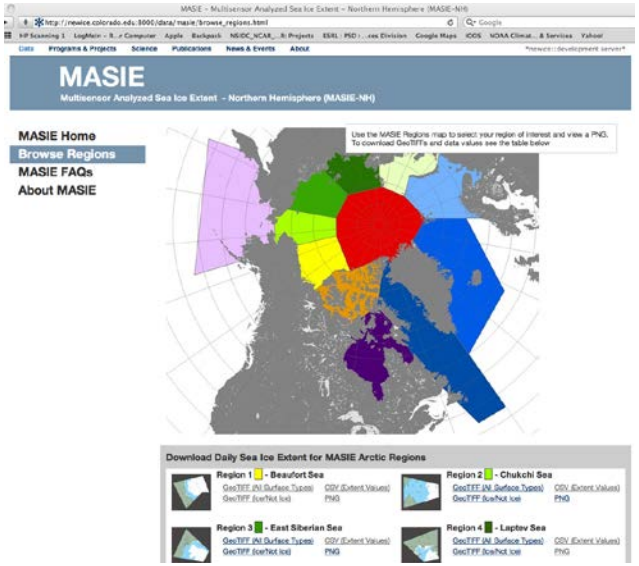


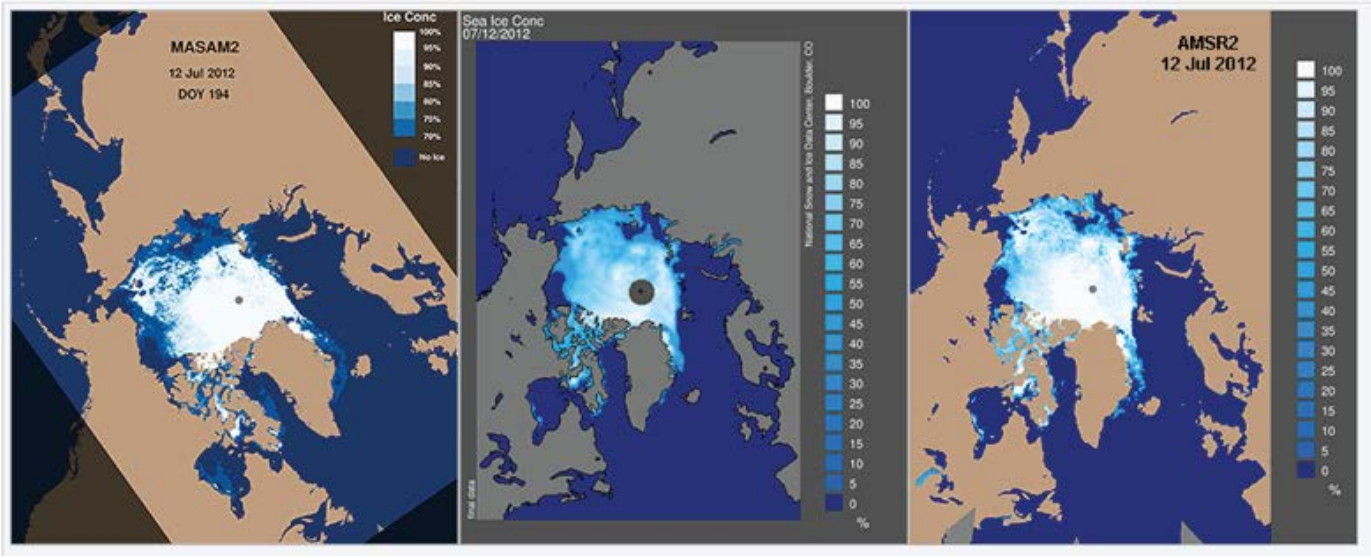




MASIE and MASAM2: NSIDC Exploitation of the NIC Ice Edge Analysis

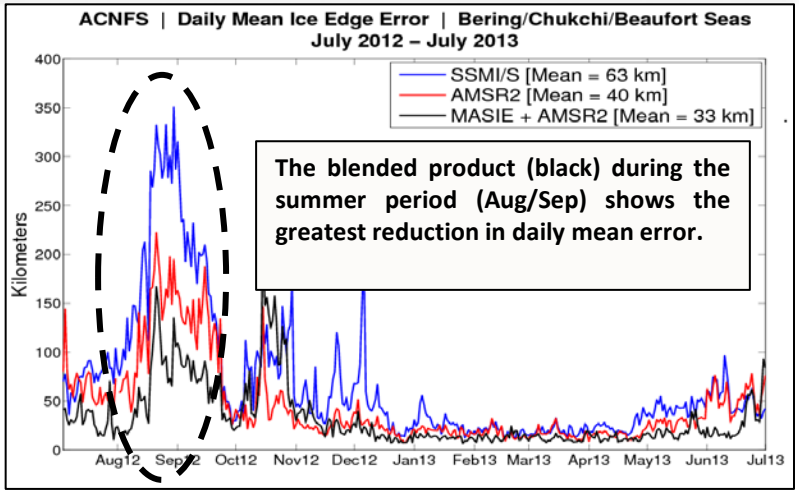


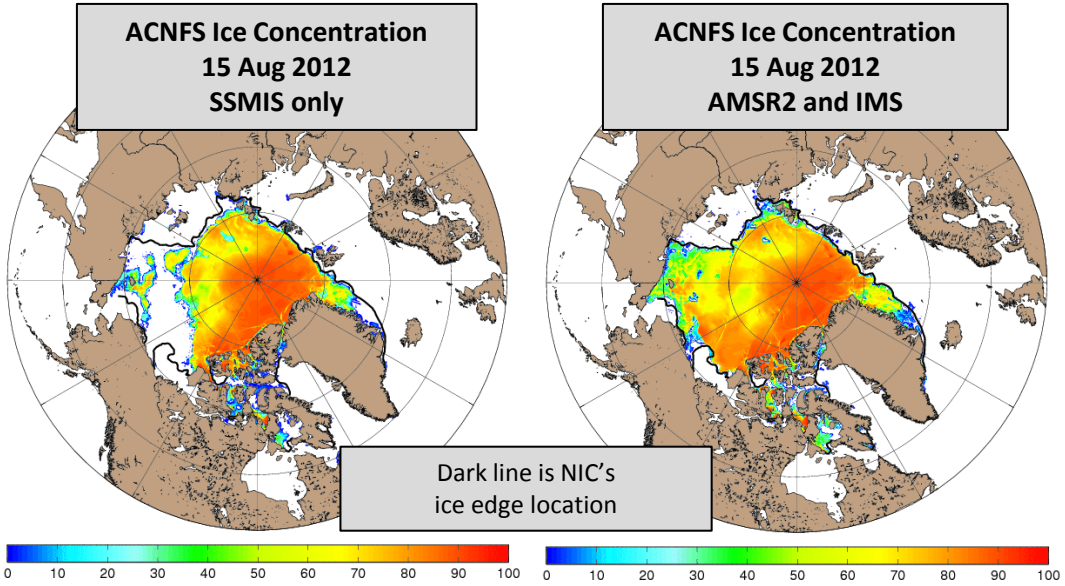




Improved Sea Ice Edge Forecasting Through Assimilation of NIC IMS Analysis

Since the late 1990's, DMSP SSMI and then SSMIS ice concentration (25km) has been assimilated in the Navy's ice forecast systems.
Passive microwave sensors have a known problem identifying melt ponds as open water which leads to underestimating sea ice especially during the summer.
Developed technique with National Snow and Ice Data Center (NSIDC) to assimilate: AMSR2 (10km) and NIC's Interactive Multisensor Snow and Ice Mapping System (IMS) ice mask (4km).



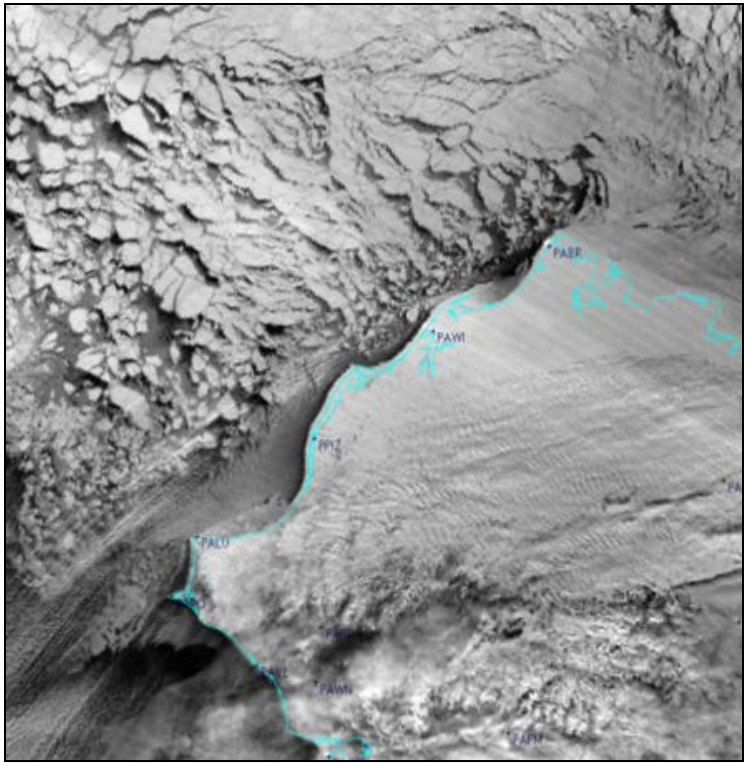


- Sensitivity studies assimilating SSMIS, AMSR2 and IMS data sources were completed.
- Adding in new data sources (AMSR2 and IMS), overall ice edge errors in the Arctic were reduced by ***36%*** and ***56%*** (year and summer, respectively).
- Submitted paper to "The Cryosphere" – Posey et al., 2015

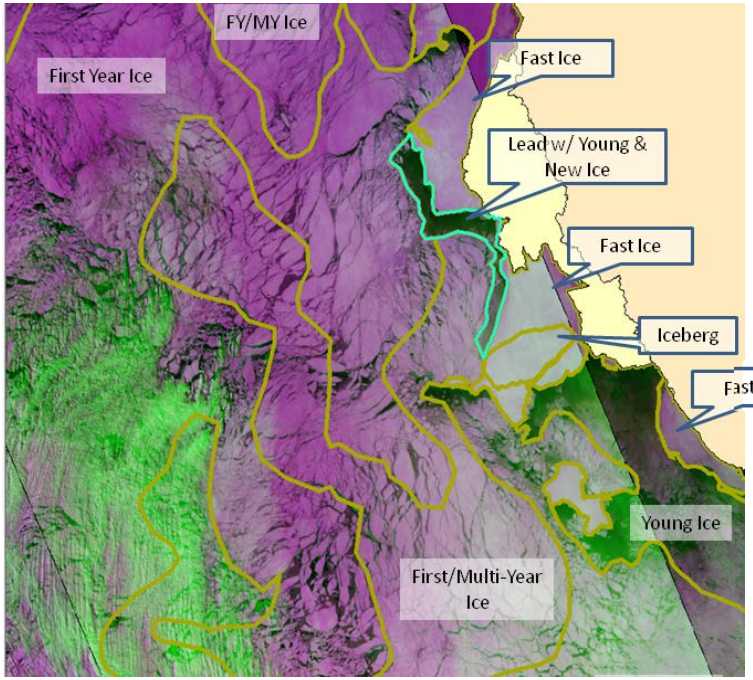
New data sources implemented into ACNFS and GOFS 3.1 on 2 Feb 2015.

SNPP Imagery Operational Use at NIC

- **NIC applies imagery and derived data from NASA/NOAA Suomi NPP**
  - High resolution visible channels
  - High resolution infrared channels
  - Visible imagery at night, needed for the polar winters
  - Sea ice concentrations
  - Snow cover detection
  - Microwave snow depth and sea ice concentrations



SNPP Visible imagery at night
over Alaska

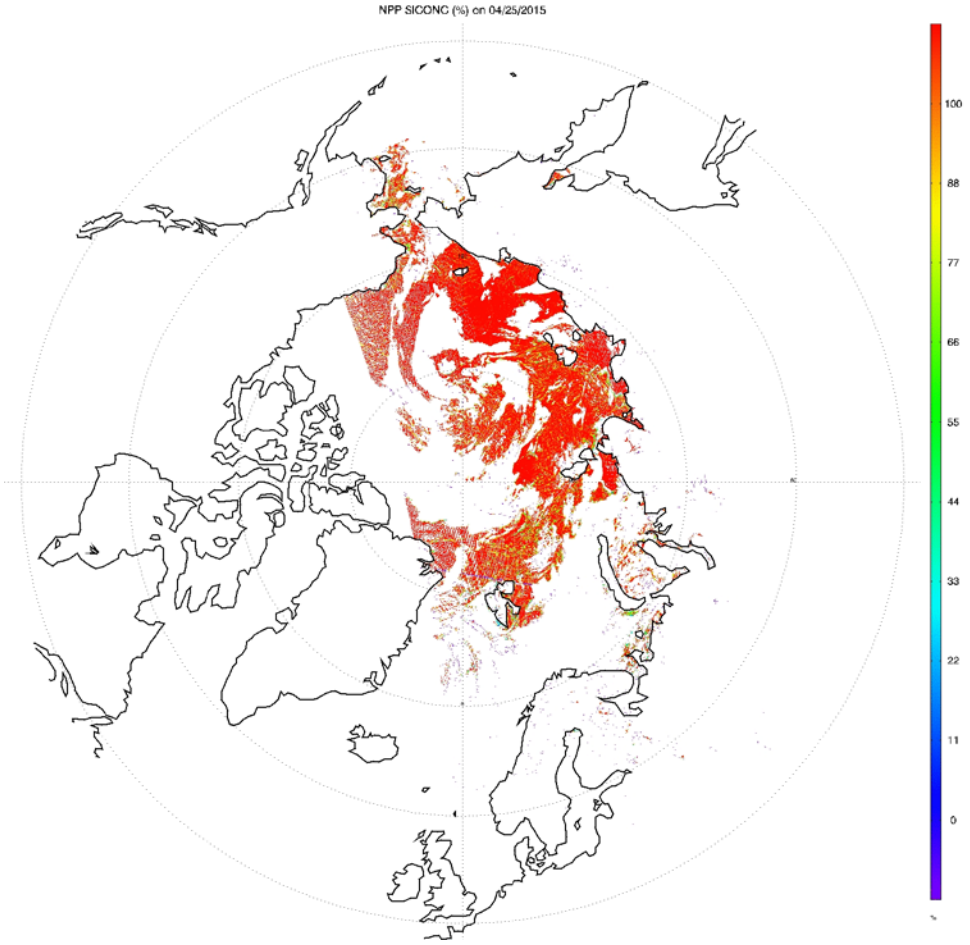


Antarctica – Amery East

Imagery: VIIRS 1/3/2 Composite
10 Aug 2016 0845Z

Analyst: M. Welshans (NIC/NAVICE)

SNPP VIIRS Ice Concentration

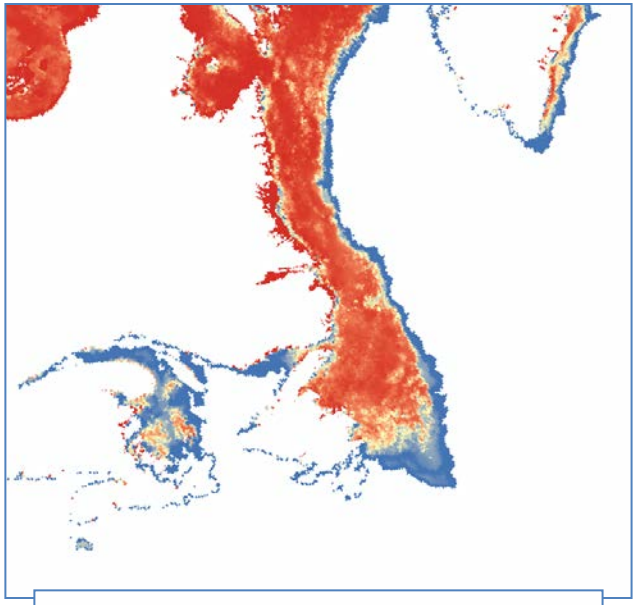


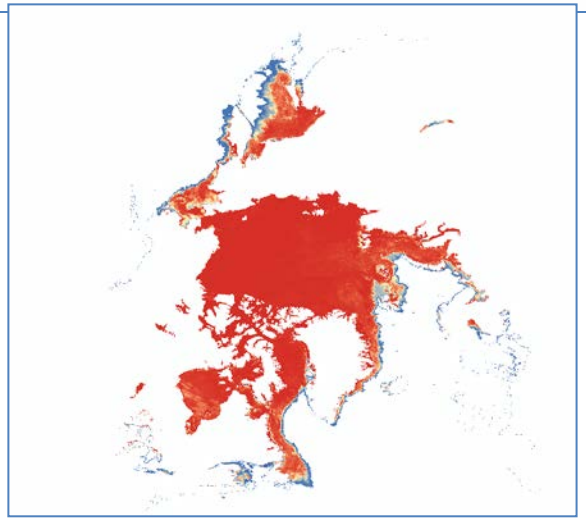
(animation)

Preliminary Blended Sea Ice Concentrations

<u>BLENDED ICE CONCENTRATIONS</u>: STAR and NIC are developing a Blended Ice Concentration primarily for modeling

- **Using Differential Weighting and Interpolation to blend ice concentrations**
- **Ice Concentrations determined from:**
  - *IMS Ice Cover*
  - ***AMSR 2***
  - ***ATMS MIRS***
  - ***VIIRS Ice Con***
  - *Ice Charts (NIC, CIS, DMI, MetNo, NWS Alaska, etc)*
  - *NWP model SST*
- **Jan 2017 Release**

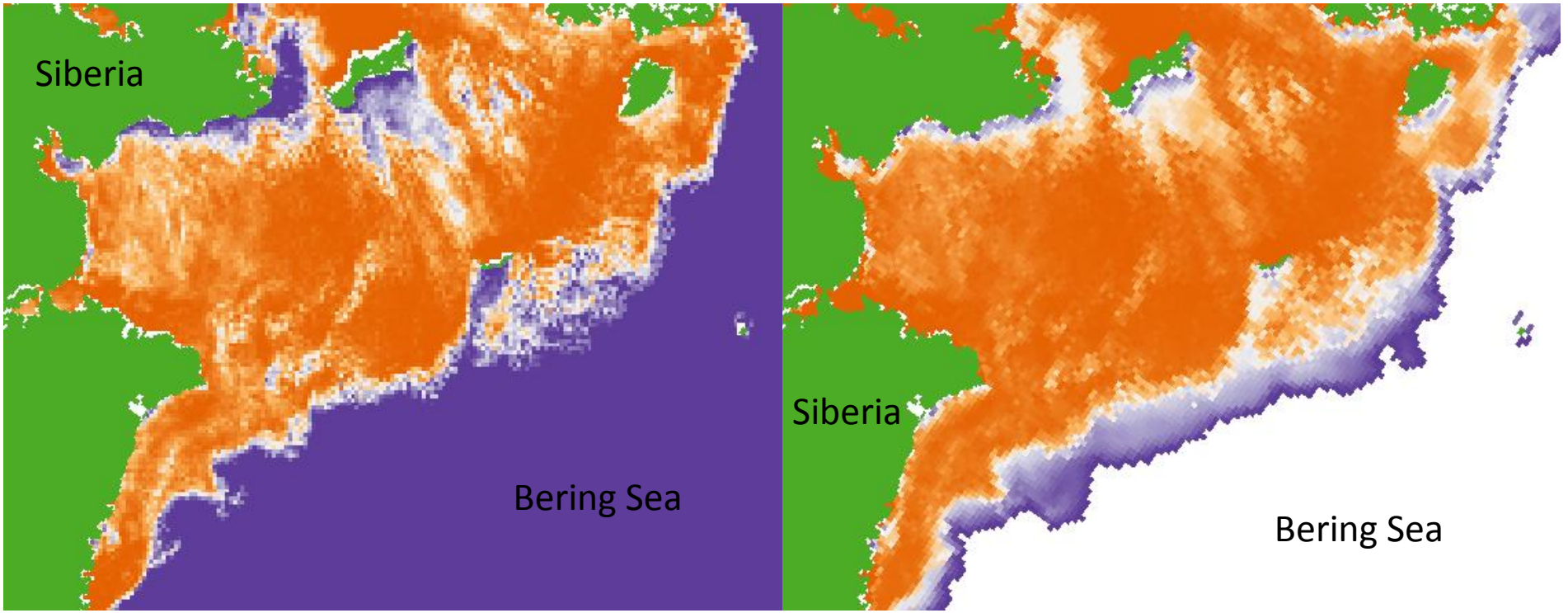




Blended Ice Conc. Enhancements

AMSR 2 Only

Blended Ice Con



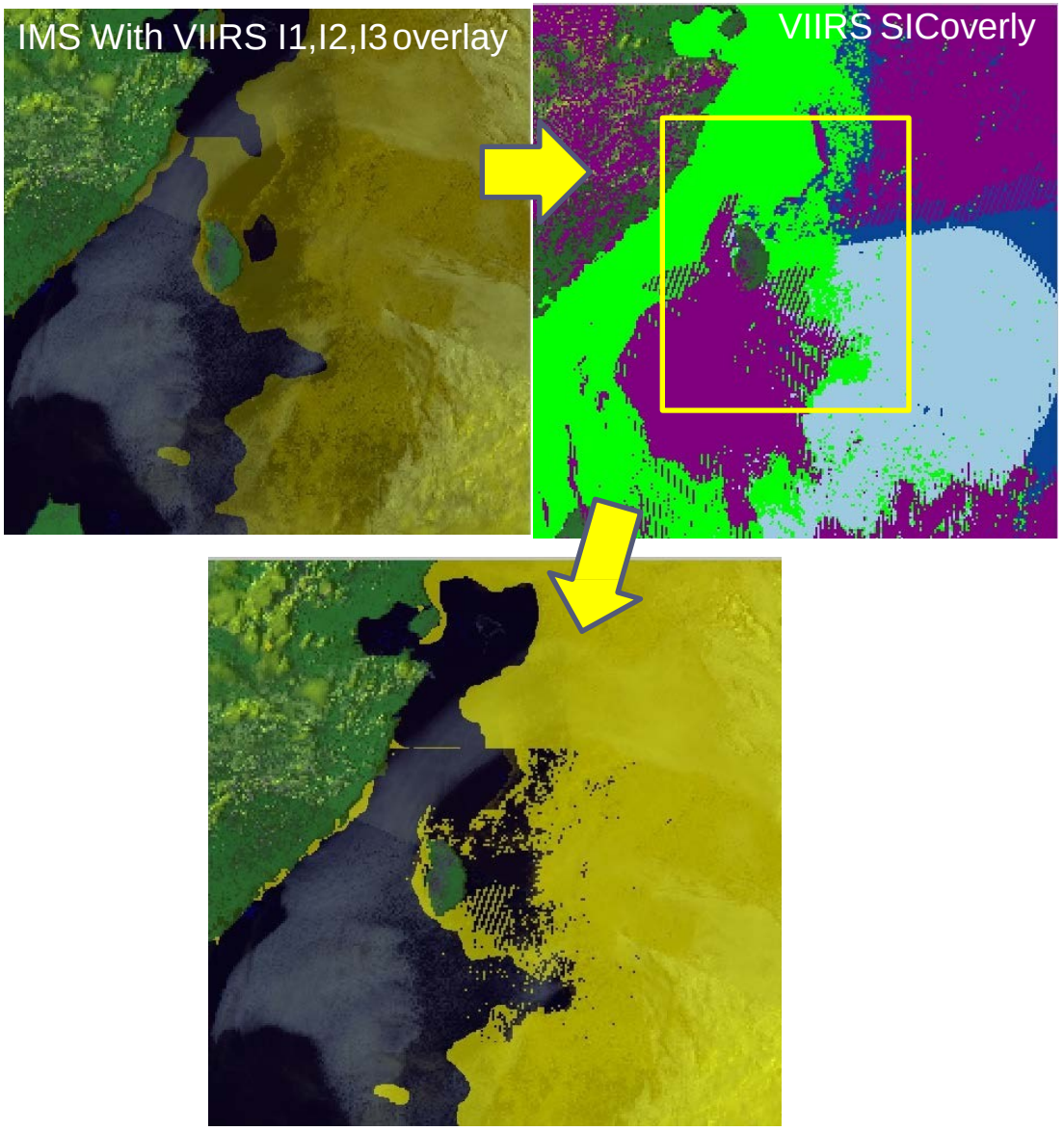
Adding Elements to IMS Direct Import of Automated Snow & Ice Cover

Analysts will be able to selectively import the data from satellite derived products directly into the Blended Analysis

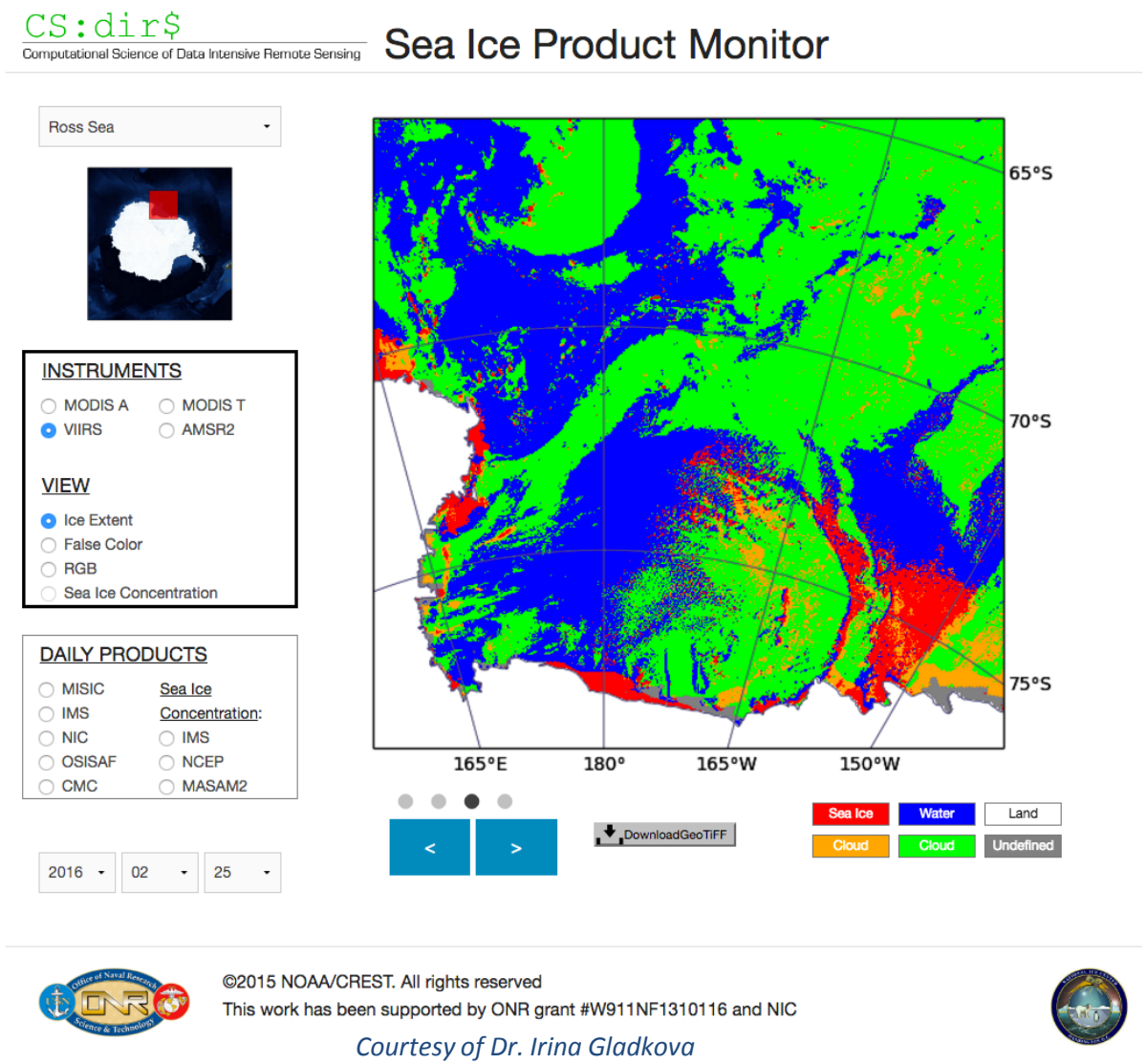
Analysis will have selection box to select snow cover and ice cover from the VIIRS, NOHRSC, Blended Ice Concentrations, SAR Ice Mask and NH AutoSnowIce.

Human data selection to optimize product use based on expert knowledge and imagery interpretation

Combines the speed and reliability of automated products with the QC and flexibility of Human Analysts



NOAA CREST Sea Ice Product Monitor for the Ross Sea



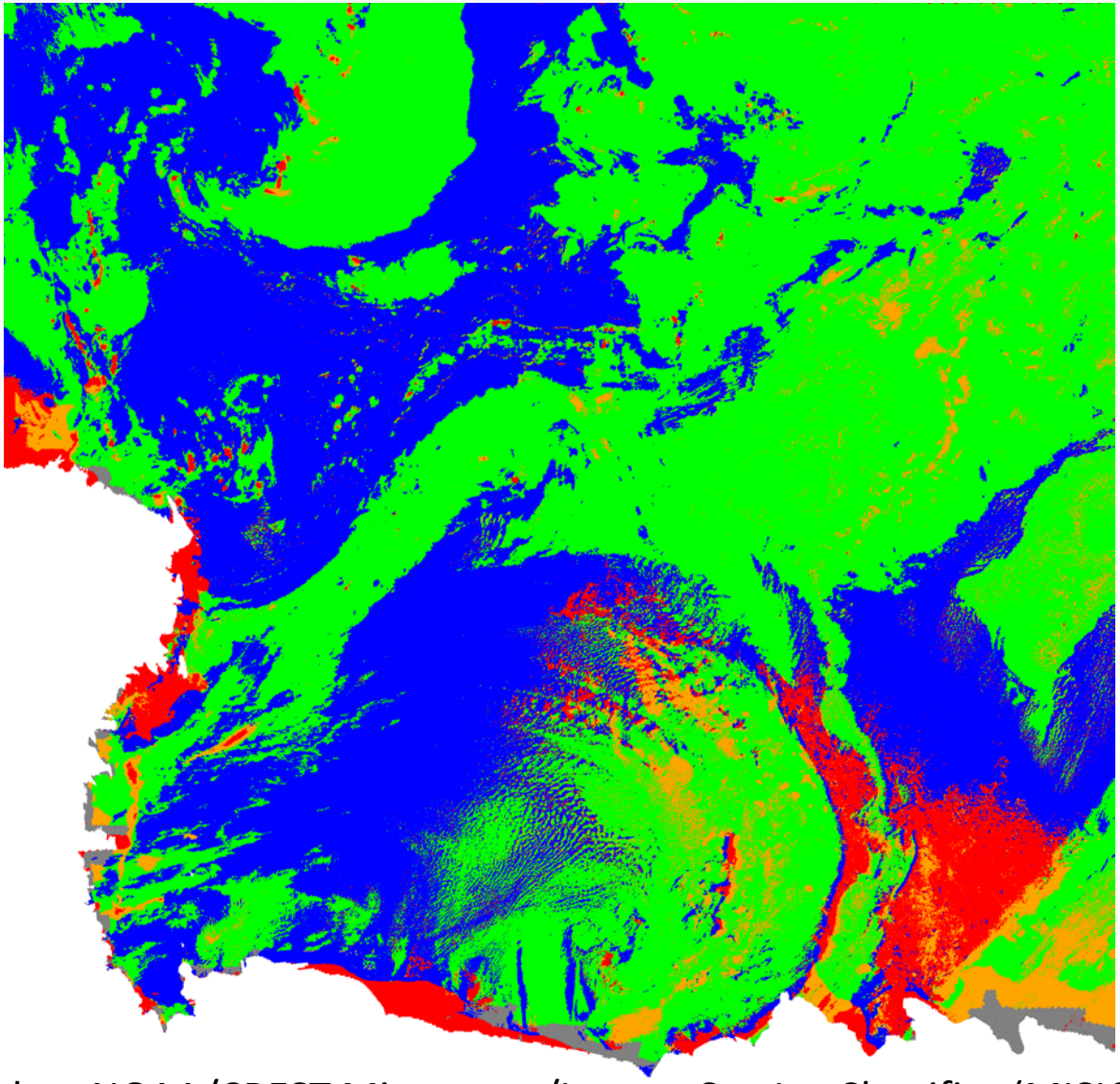
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This work has been supported by ONR grant #W911NF1310116 and NIC

Courtesy of Dr. Irina Gladkova

Sea ice classification based on NOAA/CREST Microwave/Imager Sea Ice Classifier (MISIC)

NOAA CREST Sea Ice Classification

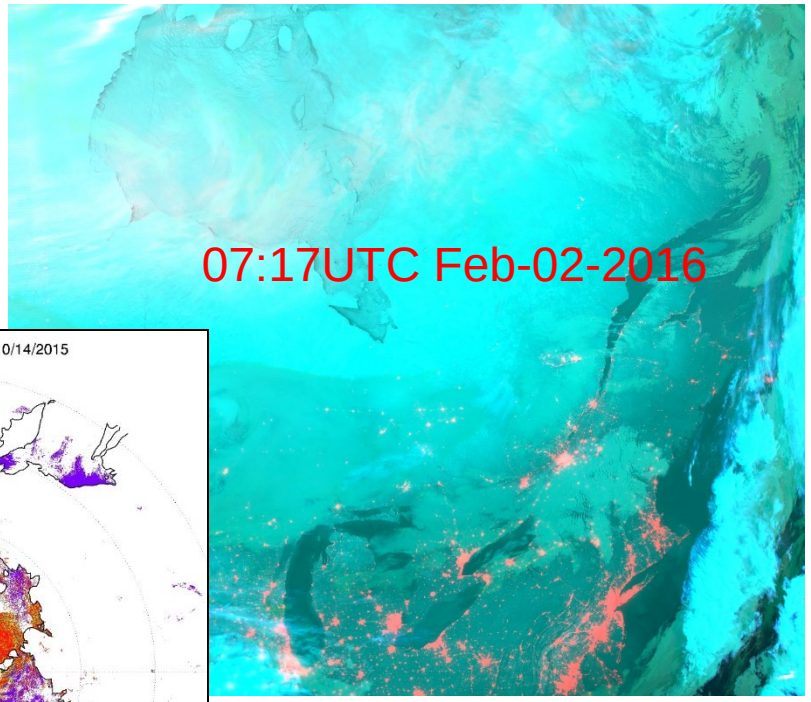




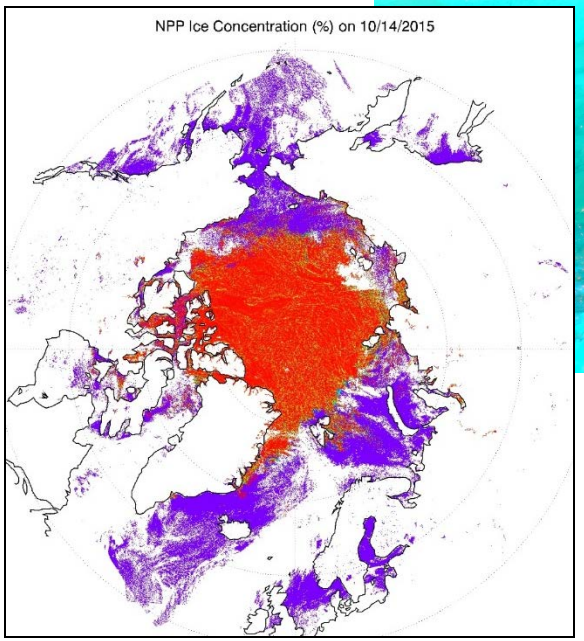
Sea ice classification based on NOAA/CREST Microwave/Imager Sea Ice Classifier (MISIC)

NAIS Remote Sensing - VIIRS

CIS and NIC is processing day and night imagery in near real time images from VIIRS

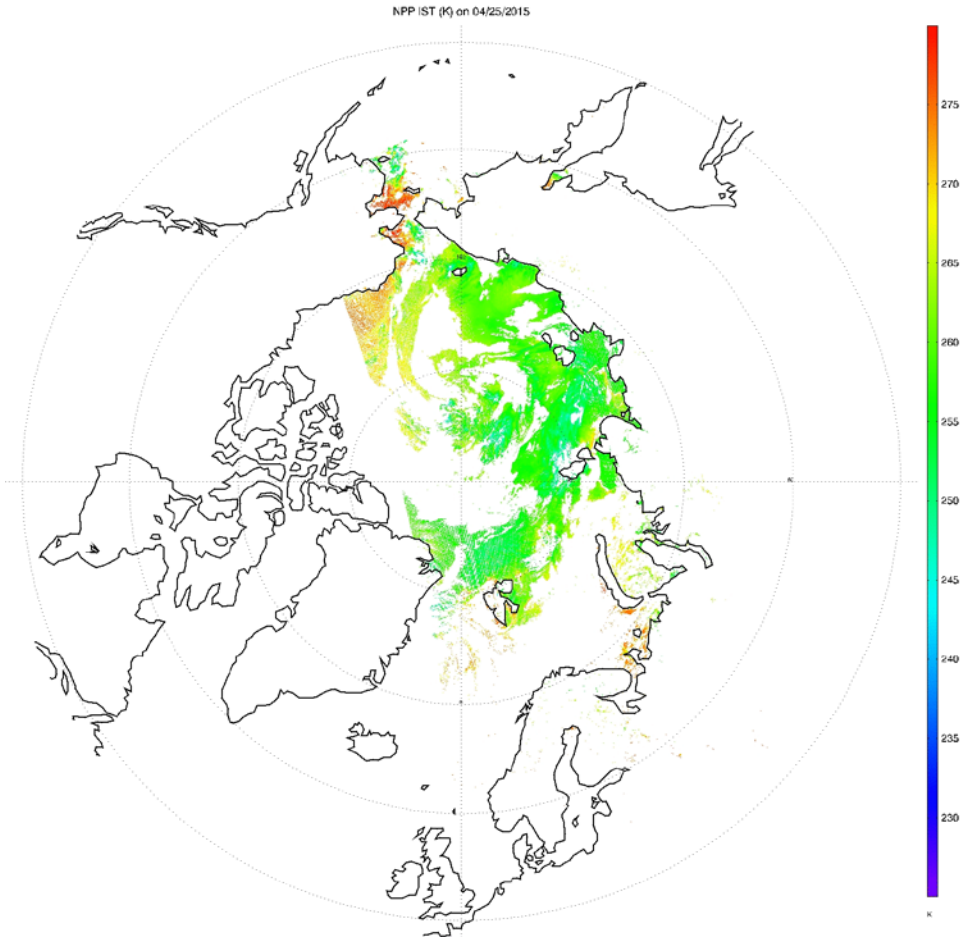


CIS worked on improved visualization of VIIRS data



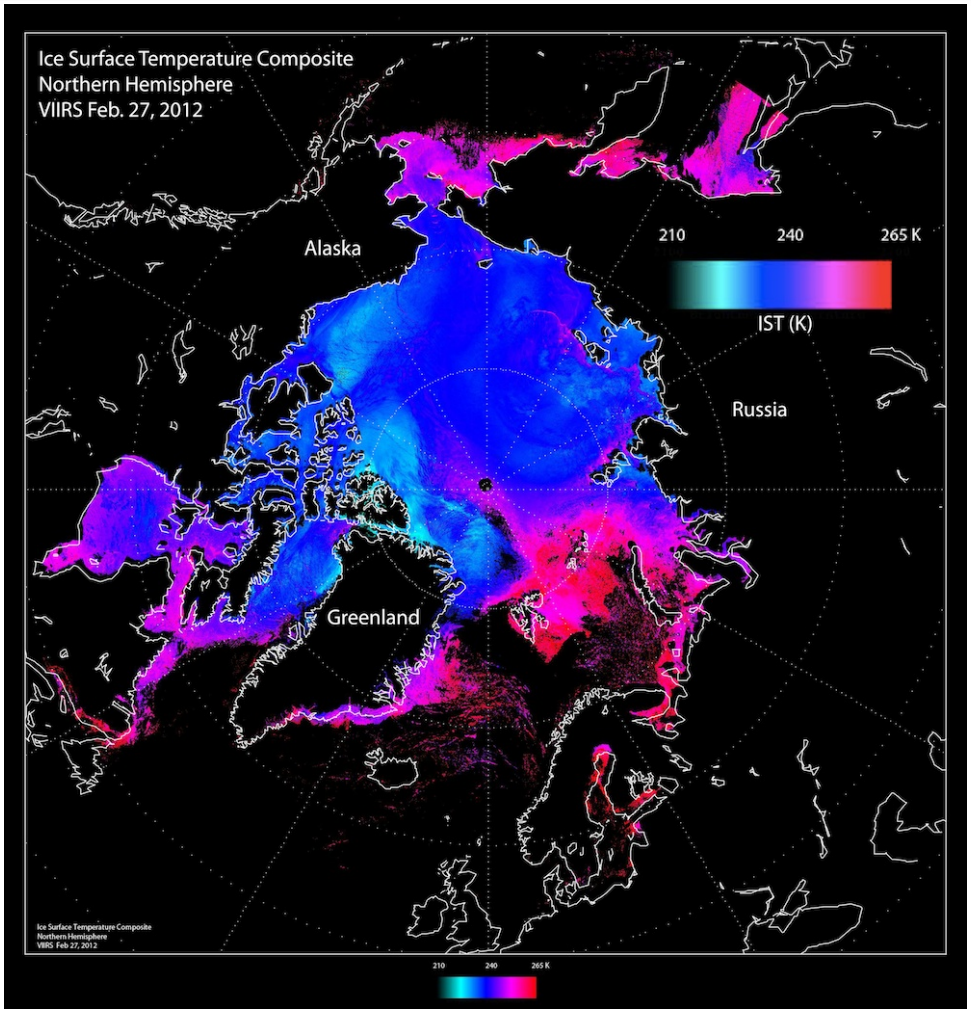
NIC is working with CIMSS and NRL on the integration of VIIRS ice concentrations into ArcGIS, GOFS and potentially other models such as GIOPS.

SNPP VIIRS Ice Surface Temperature (IST)



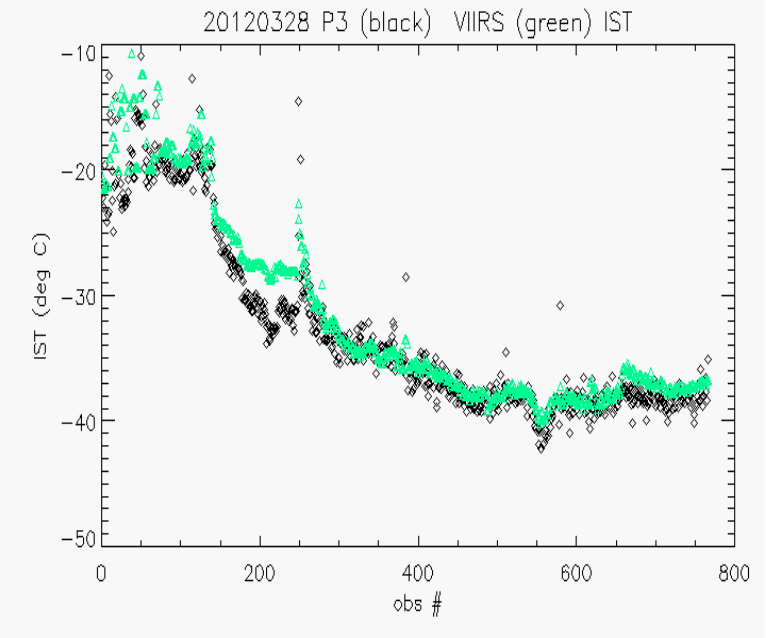
(animation)

SNPP VIIRS Ice Surface Temperature (IST)

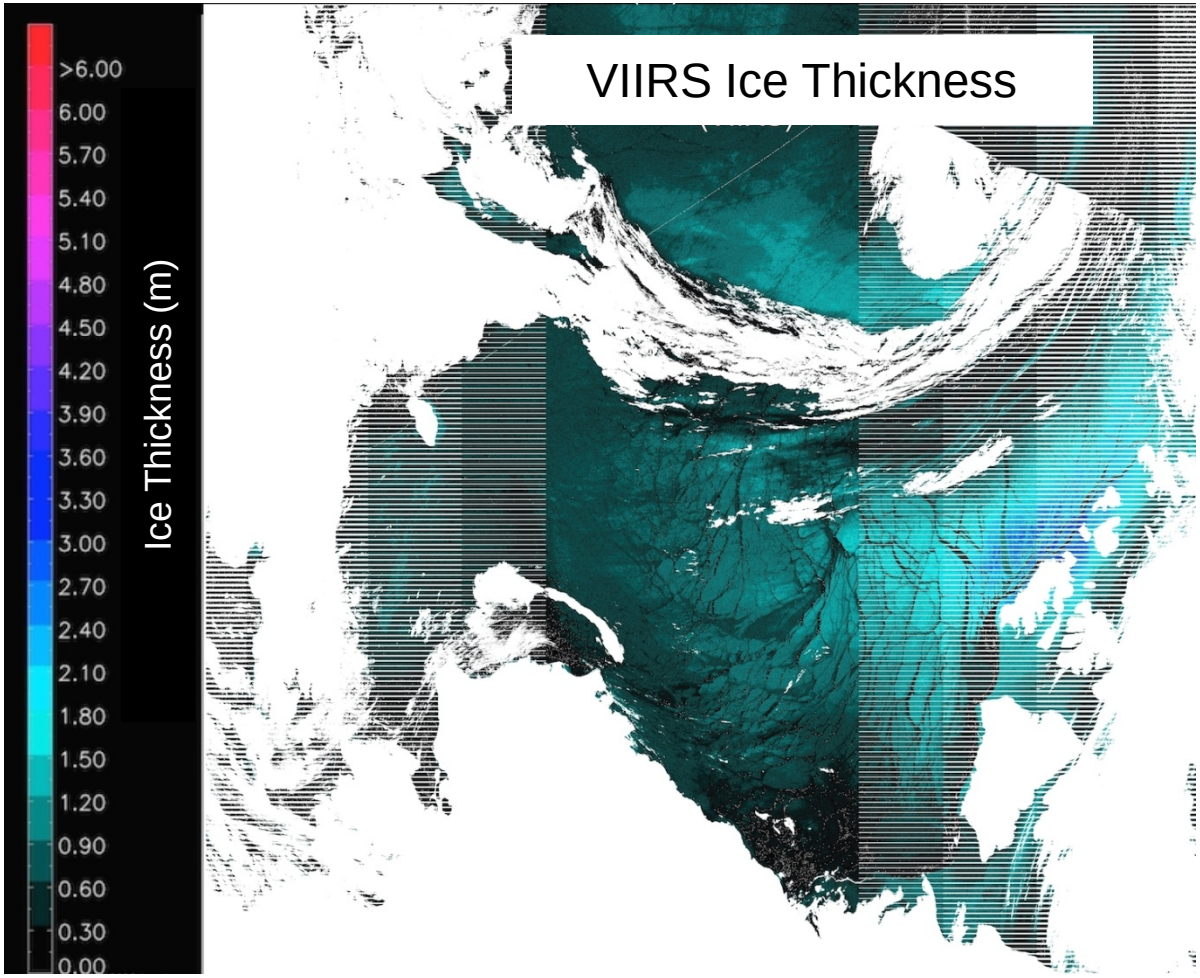


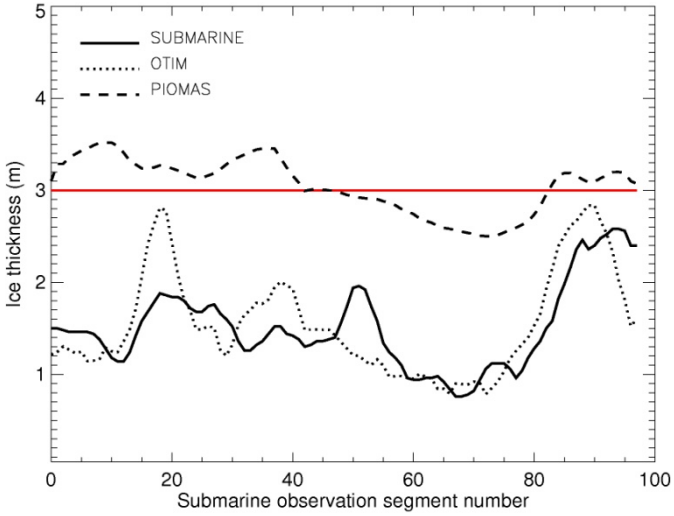
Composite of VIIRS Ice Surface Temperature on 27 Feb 2012.

IceBridge KT19 vs VIIRS IST, 2012



The Holy Grail: Sea Ice Thickness





Validation with submarine sonar and modeled ice thicknesses.

NIC SNPP/JPSS Wish list for Future Work Still Holds

(1) Geotiff formats (All)

NIC spends much of its infrastructure, bandwidth and processing on file conversion from HDF formats from VIIRS and MODIS

(2) Include Lake ice in the Ice products (IMS, Great Lakes Analysis)

(3) Product Composites at 1km (IMS, Hemispheric Ice Charts)

Difficulty stitching multiple swath and resampling to lower resolution

(4) Ice Edge (Marginal Ice Zone)

(5) Ice Drift (Ice Forecasting, IMS, annotated imagery)

(6) Ice Lead Detection (FLAP, Annotated Imagery)

(7) Snow Fraction (IMS, ASI)

(8) Blended products (All)

(9) Optional Cloud masks (All)

Present and Upcoming Operational VIS/IR Missions

JPSS/VIIRS
- JPSS-2 – launch scheduled for 2021
- JPSS-1 Launch delayed to March 2017
- Design life 7 years

Sentinel-3/OLCI & SLSTR
- Sentinel-3c launch before 2020
- Sentinel-3b launch scheduled for 2017
- Sentinel-3a launched 16 February 2016
- Design life 7 years (consumables 12 years)

NPP/VIIRS
- Launched on 28 October 2011
- Design life 6 years (consumables 7 years)

Aqua and Terra/MODIS
- Aqua launched 4 May 2002 (over 14 years in operation)
- Terra launched 18 December 1999 (over 16 years in operation)
- Design life 6 years
- Life expectancy into 2020's

DMSP/OLS
- DMSP F-20 (S-20) launch date projected for 2020
- DMSP F18- launched 18 October 2009 (over 6 years in operation)
- DMSP F-17 launched 4 November 2006 – Primary (over 9 years in operation)
- Design life 5 years

Thank You!

