Land breakout
Welcome and introduction

Ivan Csiszar
NOAA/NESDIS/STAR
Land algorithm status

• Algorithms are currently transitioning to Enterprise solutions
  – changes in retrieval algorithm, product content, format
• Preparations for reprocessing are ongoing
• Long-term product monitoring and maintenance continues
• 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

- **Granule Aeros, CM**
- **Granule SDR**
- **Granule SR**
- **Granule LST, LSA, Snow/Ice binary map, SF**

**Gridding algorithm responsibility**

**NN mapping, Sin projection, multiple layers (observations from different orbits; keep pixel CM, Aeros)**

**1, 7, 8 days composite:**
- **SDR**
- **SR**

**Compositing:**
- apply selection criteria (SAVI, max/min)
- apply time window
- apply QC (Aeros, CM)

**Sin -> Lat/Lon**

**Either gridding or product algorithm responsibility**

**32 days composite:**
- **SR**
- **SR/BT/VI monthly**

**Product algorithm responsibility**

- **AST, AST-LWM**
- **Sin -> Lat/Lon**

- **M. Tsidulko, IMSG**
- **Fire, Snow, Burned area**

**Product algorithm responsibility**

- **GVF**
- **NDVI-TOA**
- **NDVI-TOC**
- **EVI**
- **LAI**
- **VHP**

**Product algorithm responsibility**

- **LSA**
- **LST**
- **Snow/Ice binary map**
- **Snow Fraction**

**Consistency check**

**Gridding algorithm responsibility**
Enterprise implementation schedule

• Algorithm readiness
  – Surface reflectance: September 2017
  – VI, LST, LSA: August/September 2017
  – Active Fire – already operational – updates coming
  – Surface Type – annual updates – updates coming

• JPSS-1 readiness
  – Recent 8-day dataset provided to STAR needs to be evaluated
  – Validation schedule updates?
  – Expect some changes in SDR, ECM etc.
Principal issues

• Operational NDE implementation needs more coordination
  – Need to know status of upstream products
  – Need to access to correct versions of upstream products
  – Operational implementation appears to be slower than expected
  – Need to properly plan for update bundles

• Readiness for reprocessing lagging
  – Need SDR evaluation and upstream EDR readiness

• Operational (i.e. OSPO quality monitoring)
  – Need better coordination and notification of issues

• Requirement changes and data access (PDA etc.)
  – User-driven processes

• Operational use of products lagging
  – re-think approaches to the problem
  – How do the products fit into the new NCEP modeling framework?
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<th>Presenter</th>
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| 0915 - 1710 | Land  
Chair: Ivan Csiszar  
ESSIC Room 4102 |          |              |
<p>| 0915 - 0935 | Introduction and Welcome | Ivan Csiszar | STAR         |
| 0935 - 0955 | Surface Reflectance | Eric Vermote | NASA        |
| 0955 - 1015 | Vegetation Product Suite | Ivan Csiszar | STAR        |
| 1015 - 1030 | Break |          |              |
| 1030 - 1050 | Land Surface Albedo | Yunyue (Bob) Yu | STAR        |
| 1050 - 1110 | Land Surface Temperature | Yunyue (Bob) Yu | STAR        |
| 1110 - 1130 | Active Fire | Ivan Csiszar | STAR        |
| 1130 - 1150 | Vegetation Health | Felix Kogan | STAR        |
| 1150 - 1200 | Discussion |          |              |
| 1200 - 1315 | Lunch |          |              |</p>
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<th>Agenda Item</th>
<th>Presenter(s)</th>
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<td>1315 - 1335</td>
<td><strong>Surface Type and Surface Type Change</strong></td>
<td>Xiwu (Jerry) Zhan</td>
<td>STAR</td>
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<td>1335 - 1355</td>
<td><strong>Land Product Characterization System</strong></td>
<td>Kevin Gallo</td>
<td>STAR</td>
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<td>1355 - 1415</td>
<td><strong>NASA Land Science Team Status</strong></td>
<td>Miguel Román</td>
<td>NASA</td>
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<td>1415 - 1435</td>
<td><strong>CEOS Land Product Validation</strong></td>
<td>Miguel Román, Tomoaki Miura</td>
<td>NASA</td>
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<td>1435 - 1445</td>
<td><strong>Discussion</strong></td>
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<td>1530 - 1550</td>
<td><strong>Product Interdependencies, Consistency, Common Gridding and Compositing, Upstream Product Issues</strong></td>
<td>Open discussion</td>
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<td><strong>Reprocessing</strong></td>
<td>Open discussion</td>
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<td>1610 - 1630</td>
<td><strong>New Operational Land Products</strong></td>
<td>Open discussion</td>
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<td>1630 - 1650</td>
<td><strong>JPSS - GOES-R Algorithm Integration and Enterprise Products</strong></td>
<td>Open discussion</td>
<td></td>
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<tr>
<td>1650 - 1710</td>
<td><strong>Non-NOAA Satellite Assets</strong></td>
<td>Open discussion</td>
<td></td>
</tr>
</tbody>
</table>
Surface Reflectance

Eric Vermote
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Ivan Csiszar
STAR

Mike Wilson
STAR ASSIST

STAR JPSS Science Team Meeting, August 14 – 18, 2017, 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

STAR JPSS Science Team Meeting, August 14 – 18, 2017, NCWCP, College Park, MD
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**
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](http://modis-sr.ltdri.org)
The complete 6SV validation effort is summarized in three manuscripts:

Generic flowchart for atmospheric correction

- **Ancillary** (Ozone, Water Vapor, DEM)
- **TOA reflectances**
- **AOT Map**
- **SR reflectances**

Flowchart: Atmospheric correction
Aerosol inversion

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.

\[
(\rho_{\text{surf blue}} / \rho_{\text{surf red}})_{\text{MSI}} = (\rho_{\text{surf blue}} / \rho_{\text{surf red}})_{\text{MODIS}}
\]

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.

\[
\text{residual} = \frac{\sum \left( \rho_{\text{surf}}^l - \text{Ratio}_{665} \times \rho_{\text{surf}}^{665} \right)}{2}
\]

Computation of surface reflectances for all channels

\[
\rho_{\text{surf}} \text{ determined (*) using } \rho_{\text{atm}}, T_{\text{atm}} \text{ and } S_{\text{atm}} \text{ from LUT knowing AOT, Aerosol model, pressure, altitude, water vapor, ozone...}
\]

\[
\rho_{\text{surf}} \text{ determined (*) using } \rho_{\text{atm}}, T_{\text{atm}} \text{ and } S_{\text{atm}} \text{ from LUT assuming AOT, Aerosol model and knowing pressure, altitude, water vapor, ozone...}
\]
Methodology for evaluating the performance of surface reflectance

Subsets of Level 1B data processed using the standard surface reflectance algorithm

Reference data set

Atmospherically corrected TOA reflectances derived from Level 1B subsets

AERONET measurements ($\tau_{\text{aer}}, H_2O, \text{particle distribution}$, refractive indices, sphericity)

Vector 6S

comparison

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

STAR JPSS Science Team Meeting, August 14 – 18, 2017, NCWCP, College Park, MD
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 a very bright site in Saudi Arabia (Solar Village)

\[ y = 0.631081x + 0.044126 \]

\[ R^2 = 0.880233 \]
Aerosol retrieval also shows improvement

Scatterplot of the Landsat 8 AOT at 550nm versus the AERONET measured AOT at 550nm for all AERONET matchups since Landsat 8 activation
the VIIRS SR product is directly heritage from collection 6 MODIS and that it has been validated to stage 1-2

MODIS algorithm refinements from Collection 6 have been integrated into the VIIRS algorithm and are included in the operational product (NDE) equivalent of NASA VIIRS Version 1.
Evaluation of VIIRS SR Algorithm Performance (example Red band)

IDPS version

NASA C1.1

NDE, NASA Version 1

Improvement is clearly visible from IDPS to current NDE version
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 et 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.
Results over BELMANIP2 (IDPS and C1.1)
Cross comparison results of the VIIRS and MODIS-Aqua SR product on a monthly basis for the BELMANIP sites reprocessed version NDE/NASA SIPS Version 1 for the near infrared band (M7).
Transitioning from MODIS to VIIRS

- **VIIRS** was launched, in part to provide **continuity** with **MODIS**

- The **VIIRS** will eventually **replace MODIS** for both land science and applications, and add to the coarse-resolution, **long term data record**

- It is, therefore, important to provide the user community with an **assessment of the consistency** of equivalent products from the two sensors

Spectral adjustment:

\[ \rho_{\text{red}}^M = a_{\text{red}} \rho_{\text{red}}^V + b_{\text{red}} \rho_{\text{NIR}}^V \]

\[ \rho_{\text{NIR}}^M = a_{\text{NIR}} \rho_{\text{red}}^V + b_{\text{NIR}} \rho_{\text{NIR}}^V \]

where \( \rho_{\text{red}}^M, \rho_{\text{NIR}}^M, \rho_{\text{red}}^V, \rho_{\text{NIR}}^V \) are surface reflectance values in red and NIR for MODIS (superscript \( M \)) and VIIRS (superscript \( V \)), and \( a_{\text{red}}, b_{\text{red}}, a_{\text{NIR}}, b_{\text{NIR}} \) are conversion coefficients

Relative spectral response functions for MODIS/Aqua and VIIRS sensors in the red and NIR spectral domain.
Comparing (in terms of APU) of NDVI’s derived from MYD09CMG and VNP09CMG surface reflectance products at global scale (approximately $2 \times 10^9$ pixels) for 2012–2016 \textbf{without (a) and with (b) spectral adjustment of red and NIR bands}. The light blues bars show the number of points used in each bin of NDVI values from MODIS (used as a reference). The APU values are computed for points in each bin and being shown in red (accuracy), green (precision) and blue (uncertainty). The pink line represents the specified uncertainty based on theoretical error budget.
Corn growth dynamics derived from MODIS/Aqua and VIIRS in 2012 in Iowa (US) compared to the median NDVI values for 2002–2016 derived from MODIS/Aqua. Due to a drought, corn growth started to decrease significantly from June which resulted in a 25% yield reduction.
Transitioning from MODIS to VIIRS

• Spatial consistency

NDVI anomalies at 0.05° spatial resolution for the state of Iowa (US) derived from MODIS/Aqua (a), and adjusted VIIRS (b) data on August 21, 2012. Anomalies were computed by subtracting NDVI values from the median NDVI values for 2002–2016 derived from MODIS/Aqua.
Surface Reflectance Conversion from IDPS to NDE

• The main issues in the conversion of the surface reflectance code from the IDPS system to NDE were as follows:

  1) The code was designed to read and write in HDF-EOS format. NDE does not support HDF-EOS, so NASA developers added HDF-5 capability.

  2) The code requires the VIIRS Cloud Mask, Aerosol Optical Depth product, total precipitable water, total column ozone, and surface pressure in order to run. The algorithms that produce these are different in the NDE system. NOAA-STAR developers wrote codes to convert the NDE products into a format that mimics the IDPS version for compatibility.

  3) The naming convention of the files is different between NDE and IDPS, so NOAA-STAR developers wrote scripts to design unique file names.

  4) Global attributes are different between NDE and IDPS, so NOAA-STAR developers wrote scripts to create both static and dynamic global attributes.
NOAA-STAR Contribution

• NASA provided the main algorithm, while NOAA-STAR provided ancillary codes and scripts to allow the system to run at NDE. These codes/scripts include:
  • Preprocessor: converts the NDE versions of cloud mask, cloud height (which includes the cloud shadow mask), aerosol optical depth, and GFS (which contains surface pressure, total precipitable water, and total column ozone) into HDF-5 files that resemble the IDPS versions of these masks.
  • PERL Global Attribute Conversion: creates both static and dynamic global attributes to append to the final NDE output file.
  • Postprocessor: names the final output file, writes the output, appends the global attributes and designs variable attributes.

• A flow chart of these algorithms follows on the next slide.
Surface Reflectance Algorithm Overview

- **Preprocessor**
  - Populated Templates (HDF5)

- **Main Algorithm**
  - VNP09.*.h5 (HDF5)

- **PERL Global Attribute Conversion**
  - VNP09.*.h5 (HDF5)
  - plus list of NDE global attributes

- **Postprocessor**
  - SR_v1-0-8_npp.*.nc (NetCDF4)
  - Contains Surface Reflectance for: I1, I2, I3, M1, M2, M3, M4, M5, M7, M8, M10, M11
  - Contains QC values.

Legend:
- From IDPS
- From NDE Framework
- Static Files / LUTs
- Executable PERL/C++
- Output from Executable

- **IDPS: (HDF5)**
  - GMTCO geolocation file

- **NDE Framework: (NetCDF4)**
  - NDE Aerosol Model
  - Enterprise Cloud Mask
  - NDE Cloud Height
  - GFS Data

- **Templates to mimic IDPS: (HDF5)**
  - Aerosol Model
  - VIIRS Cloud Mask / Height
  - GFS Data

- **Static LUTs: (binary)**
  - Optical depth, reflectivity, transmittance, viewing zenith, solar zenith, spherical albedo, scattering angle, transmittance coefficients

- **IDPS: (HDF5)**
  - VIIRS SDR/Geolocation:
    - SVI*.h5 and GITCO*.h5
    - SVM*.h5 and GMTCO*.h5

- **IDPS: (HDF5)**
  - VIIRS Geolocation:
    - GITCO*.h5 and GMTCO*.h5

- **IDPS: (HDF5)**
  - GMTCO geolocation file

- **IDPS: (HDF5)**
  - GMTCO geolocation file
Known Differences in Surface Reflectance

• Slight variations occur for surface pressure, total column ozone, and total precipitable water, due to upstream algorithm differences.
• Slight variations occur for aerosol optical depth due to upstream algorithm differences.
• Larger variations occur in the cloud mask because of large algorithm differences. Impacts are:
  • The NDE cloud mask does not provide a quality (high, medium, poor, etc.), which impacts the surface reflectance retrieval itself.
  • Quality Flags are impacted by differences in sun glint, snow categorization, and the lack of a thin cirrus flag or a cloud adjacency flag. This affects downstream products.
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 is being defined (CEOS CVWG initiative)
NDE Vegetation Product System (NVPS): Vegetation Indices (VI) and Green Vegetation Fraction (GVF)

Ivan Csiszar, Mingshi Chen, Min Li, Zhangyan Zhang, Marco Vargas
The GVF system is currently running in NDE and the product suite includes:
- The Green Vegetation Fraction Global Product
- The Green Vegetation Fraction Regional Product

Top of Atmosphere Normalized Difference Vegetation Index (TOA NDVI), Top of Canopy Normalized Difference Vegetation Index (TOC NDVI), and Top of Canopy Enhanced Vegetation Index (TOC EVI) are currently running in IDPS.

- The VIIRS Vegetation Index Validated Stage 1 Science Maturity Review took place on September 4, 2014. Documentation is available on the STAR/JPSS website: https://www.star.nesdis.noaa.gov/jpss/documents/AMM_All/Land_VI/Validated/VIIRSVIStage1MaturityPresentationtoSTAR.pdf
- The NDE Vegetation Product Suite Critical Design Review took place on September 29, 2016. Documentation is available on google drive: https://drive.google.com/open?id=0B-kRoSoyMpuAb3JyXzZFUjJUTmc
The VIIRS Vegetation Index products will be incorporated into the GVF system. These include:

- NDVI at TOA for continuity with AVHRR
- NDVI at TOC for continuity with MODIS
- EVI at TOC for continuity with MODIS
NDE Vegetation Products Stakeholders

- Customers/Users
  - NCEP/EMC
  - STAR
  - CLASS
  - USDA
  - USGS
  - NWS/WFO/Spokane WA
  - University of Hawaii at Manoa
  - NASA SPoRT
  - NOAA ESRL
# Vegetation Index (VI) External Inputs

<table>
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<tr>
<th>Item</th>
<th>Type</th>
<th>Source</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geolocation (GITCO)</td>
<td>Input</td>
<td>IDPS</td>
<td>VIIRS Terrain Corrected Geolocation and geometry (imagery resolution)</td>
</tr>
<tr>
<td>TOA Reflectance</td>
<td>Input</td>
<td>IDPS</td>
<td>IDPS VIIRS I1 and I2 SDR bands at imagery solution</td>
</tr>
<tr>
<td>TOA Reflectance</td>
<td>Input</td>
<td>NDE EAOT</td>
<td>NDE VIIRS Enterprise aerosol optical depth product (EAOT) at moderate resolution</td>
</tr>
<tr>
<td>Aerosol Optical</td>
<td>Input</td>
<td>NDE ECM</td>
<td>NDE VIIRS Enterprise Cloud Mask (ECM) at moderate resolution</td>
</tr>
<tr>
<td>Depth</td>
<td></td>
<td>NDE ESR</td>
<td>NDE VIIRS Enterprise Surface reflectance (ESR) I1, I2 and M3 bands (granule files)</td>
</tr>
<tr>
<td>Cloud Mask</td>
<td>Input</td>
<td>Ancillary</td>
<td>Derived from MODIS global water mask (MOD44W) by projecting to the VIIRS GVF grid (used by the operational NDE VIIRS GVF)</td>
</tr>
<tr>
<td>Surface Reflectance</td>
<td>Input</td>
<td>Ancillary</td>
<td>The origin and spatial resolution and partition of the VI coordinate system (used by the operational NDE VIIRS GVF)</td>
</tr>
</tbody>
</table>
# Outputs

<table>
<thead>
<tr>
<th>Sample Filename</th>
<th>Data from Filename</th>
</tr>
</thead>
<tbody>
<tr>
<td>VI–GLB*.nc (Global)</td>
<td>- TOA NDVI</td>
</tr>
<tr>
<td>VI–REG*.nc (Regional)</td>
<td>- TOC NDVI</td>
</tr>
<tr>
<td></td>
<td>- TOC EVI</td>
</tr>
<tr>
<td></td>
<td>- Reflectance I1</td>
</tr>
<tr>
<td></td>
<td>- Reflectance I2</td>
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<tr>
<td></td>
<td>- Surface Reflectance I1</td>
</tr>
<tr>
<td></td>
<td>- Surface Reflectance I2</td>
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<tr>
<td></td>
<td>- Surface Reflectance M3</td>
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<tr>
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<td>- Solar Zenith Angle</td>
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<td>- Viewing Zenith Angle</td>
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<tr>
<td></td>
<td>- Relative Azimuth Angle</td>
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<tr>
<td></td>
<td>- Quality Flags: QF1, QF2, QF3, QF4</td>
</tr>
<tr>
<td>• Daily</td>
<td></td>
</tr>
<tr>
<td>• 7–Day (Weekly)</td>
<td></td>
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<tr>
<td>• 16–Day (Bi–Weekly)</td>
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</tr>
</tbody>
</table>
The Context Layer is the highest level of the software architecture. It describes the flows between the system and its external interfaces.
IDPS Surface Reflectance is replaced by the NDE Enterprise Surface Reflectance

INPUT

- Geolocation (GITCO)
- IDPS Surface Reflectance (crossed out)
- NDE Enterprise Surface Reflectance (new)
- Land Water Mask
- Grid & Tile Scheme

PROCESSING

GVF Processing

OUTPUT

- Weekly Global GVF 4-km resolution
- Weekly Regional GVF 1-km resolution
NVPS Context–Layer

INPUT

Geolocation (GITCO)
TOA Reflectance (SVI01, SVI02)
Enterprise Surface Reflectance
Enterprise Cloud Mask
Enterprise Aerosol Optical Depth
Land Water Mask
Grid & Tile Scheme

PROCESSING

GVF Processing

OUTPUT

GVF Products

VI Processing

VI Products
The VI grid system is divided into square tiles to facilitate parallel computing spatially and therefore faster processing.

The VI grid is a set of tiles that are 18 degrees square.

200 tiles (20 tiles horizontally and 10 tiles vertically) are needed to cover the entire globe.

Each 18° x 18° tile has 6000 x 6000 grid cells (0.003° pixels).

The grid provides global coverage in Geographic Lat/Lon projection at a resolution of 0.003°.
The upper-left corner of the tile map is 180° W, 90°N. Each tile is 18° x 18°, with 6000 x 6000 grid cells (0.003° pixels). Only those tiles that contain land but are not in the Antarctic Region are processed (There are 122 non-fill tiles)
Units of VI Algorithm:

- TGM: Tile Granule Mapper
- GRD: Reflectance Griddler
- RCP: Reflectance Compositor
- RAG: Reflectance Aggregator
- VIC: Vegetation Index Calculator
- QAA: Quality Assurance Assigner
Vegetation Index System–Layer Data Flows

- Geolocation GITCO
- VI Grid & Tile Scheme
- TGM
  - Tile-Granule Relationship
  - TOC Reflectance ESR
  - TOA Reflectance SVI01,02
  - Geolocation GITCO
  - EAOT, ECM
- GRD
- RAG
  - Weekly or 16-Day Reflectance Composite
- RCP
  - Daily Gridded and Tiled TOA and TOC Reflectance
  - Daily Gridded and Tiled TOA and TOC Reflectance from the previous 6 or 15 days
- VIC
  - Weekly Global VI (4-km)
  - Weekly Regional VI (1-km)
  - 16-Day Global VI (4-km)
  - 16-Day Regional VI (1-km)
- QAA
- RAG
  - Daily TOA and TOC Reflectance (global and regional)
- VIC
  - Daily Global VI (4-km)
  - Daily Regional VI (1-km)
Tile–Granule Mapper (TGM) Unit

Geolocation GITCO:

$GRANULE_DIR/20150819/GITCO/

GITCO_npp_d20150819_t000*.h5

......

GITCO_npp_d20150819_t235*.h5

$VIIRS_VI_WORKDIR:
temp.GITCO.uniq.list
temp.SVI01.uniq.list
temp.SVI02.uniq.list
temp.IVISR.uniq.list
temp.IICMO.uniq.list
temp.IVAOT.uniq.list

$VIIRS_VI_WORKDIR/
temp.GranuleOnTileOutDir.20150819
h00v01_granulelist.txt
......
h19v07_granulelist.txt

Each file lists all the needed granules for each tile

Same matched up granules of ESR, ECM, EAOT, SVI01, SVI02 in:

$GRANULE_DIR/20150819/
Reflectance Gridder (GRD) Unit

All Input Granules:

$GRANULE_DIR/20150819/
GITCO/
ESR
EAOT
ECM
SVI01
SVI02

Granulelist:

$VIIRS_VI_WORKDIR/
temp.GranuleOnTileOutDir.
20150819
h00v01_granulelist.txt
......
h19v07_granulelist.txt

$VIIRS_VI_WORKDIR/daily_sr/20150819/
VI-SR_s20150819_e20150819_h00v01_c201704211757510.h5
......
VI-SR_s20150819_e20150819_h19v07_c201704212302540.h5

Granule space (one VIIRS granule)

Grid space (one tile)
All the tile files in the past 7 days:
$VIIRS_VI_WORKDIR/daily_sr/20160812/
$VIIRS_VI_WORKDIR/daily_sr/20160813/
......
$VIIRS_VI_WORKDIR/daily_sr/20160818/

RCP (weekly)

$VIIRS_VI_WORKDIR/weekly_sr/20160812-
20160818/
VI-
SR_s20160812_e20160818_h00v01_c20170425145
0370.h5
......
VI-
SR_s20160812_e20160818_h19v07_c20170425165
7040.h5

All the tile files in the past 16 days:
$VIIRS_VI_WORKDIR/daily_sr/20160812/
$VIIRS_VI_WORKDIR/daily_sr/20160813/
......
$VIIRS_VI_WORKDIR/daily_sr/20160827/

RCP (biweekly)

$VIIRS_VI_WORKDIR/biweekly_sr/20160812-
20160827/
VI-
SR_s20160812_e20160827_h00v01_c20170425145
2200.h5
......
VI-
SR_s20160812_e20160827_h19v07_c20170425181
2150.h5

Daily reflectance
(7 or 16 tiles)

Composited reflectance
(weekly or bi-weekly)
Quality Assurance Assigner (QAA) Unit Daily

RAG, VIC, QAA

$\text{VIIRS\_VI\_WORKDIR/daily\_sr/20150819/}$

$\text{VI-SR\_s20150819\_e20150819\_h00v01\_c201704211757510.h5}$

$\text{.......}$

$\text{VI-SR\_s20150819\_e20150819\_h19v07\_c201704212302540.h5}$

$\text{RAG, VIC, QAA (daily)}$

$\text{\$\text{VIIRS\_VI\_WORKDIR/daily\_aasr/20150819/}}$

$\text{VI-GLB\_v1r0\_npp\_s20150819\_e20150819\_c201704241434170.nc}$

$\text{VI-GLB\_v1r0\_npp\_s20150819\_e20150819\_c201704241434170\_stat.txt}$

$\text{VI-REG\_v1r0\_npp\_s20150819\_e20150819\_c201704241534310.nc}$

$\text{VI-REG\_v1r0\_npp\_s20150819\_e20150819\_c201704241534310\_stat.txt}$

$\text{VI-EVI-GLB\_v1r0\_npp\_s20150819\_e20150819\_c201704241434170.tif}$

$\text{VI-EVI-REG\_v1r0\_npp\_s20150819\_e20150819\_c201704241534310.tif}$

$\text{VI-TOA-NDVI-GLB\_v1r0\_npp\_s20150819\_e20150819\_c201704241434170.tif}$

$\text{VI-TOA-NDVI-REG\_v1r0\_npp\_s20150819\_e20150819\_c201704241534310.tif}$

$\text{VI-TOC-NDVI-GLB\_v1r0\_npp\_s20150819\_e20150819\_c201704241434170.tif}$

$\text{VI-TOC-NDVI-REG\_v1r0\_npp\_s20150819\_e20150819\_c201704241534310.tif}$

Daily TOC EVI 2015–08–19
Prototype Global Daily VI Output File NetCDF4

HDFView screen capture
Vegetation Index Daily Global Products (4 km res)

Daily products generated with the Enterprise Surface Reflectance granule data in NetCDF format
Vegetation Index Daily Regional Products

REGIONAL TOA NDVI 2015/08/19

REGIONAL TOC NDVI 2015/08/19

REGIONAL TOC EVI 2015/08/19
Vegetation Index Weekly Global Products

Global weekly products generated from Surface Reflectance granule Data in HDF5 format (from the IDPS)
Vegetation Index Bi-Weekly Global Products

Global Bi-weekly products generated from Surface Reflectance granule Data in HDF5 format (from the IDPS)

**Daily VIIRS I1 ESR (Aug 19, 2015)**

**Daily VIIRS I2 ESR (Aug 19, 2015)**

**Daily VIIRS M3 ESR (Aug 19, 2015)**

**Daily EVI (Aug 19, 2015)**

Intermediate files within the VIIRS GVF processing system
Validation Strategy

- NDE Vegetation Index (VI) products will be validated and evaluated by:
  - Product inter-comparison with other satellites (e.g., MODIS, Sentinel, Landsat) over overlapping orbital tracks and over a globally-distributed set of sites
  - Time series comparison with in situ VI data and vegetation productivity (e.g., gross primary productivity) data over FLUXNET sites
  - Cross-comparison with AERONET-processed data
VIIRS VI EDR Global APU

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

### Global APU Over Dynamic Range

<table>
<thead>
<tr>
<th></th>
<th>TOA NDVI</th>
<th>TOC NDVI</th>
<th>TOC EVI</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.013</td>
<td>0.012</td>
<td>0.020</td>
</tr>
<tr>
<td>P</td>
<td>0.012</td>
<td>0.018</td>
<td>0.011</td>
</tr>
<tr>
<td>U</td>
<td>0.018</td>
<td>0.021</td>
<td>0.023</td>
</tr>
</tbody>
</table>

### Global APU Time Series Plot

- TOA NDVI
- TOC NDVI
- TOC EVI
Product Inter-comparison Over a Distributed Set of Sites

- Quality of VIIRS VI EDR temporal profiles evaluated via visual inspection & comparison with Aqua MODIS and in situ data when available
Product Inter-comparison Over a Distributed Set of Sites

- Quality of VIIRS VI EDR temporal profiles evaluated via visual inspection & comparison with Aqua MODIS and *in situ* data when available
High-quality time series measurements obtained through *in situ* tower networks will be used in time series validation of Phases 1 & 2 products (e.g., variables from FLUXNET: tower VIs, NPP, GPP, NEE)

**VIIRS vs. In Situ: SOS & EOS**

**VIIRS vs. MODIS vs. In Situ Cross-Comparison of Phenological Metrics (SOS, EOS, & GSL)**

- VIIRS– & *In Situ*–derived phenological metrics corresponded well (e.g., SOS MD < 5 days; SOS RMSE < 7 days)

**VIIRS vs. In Situ: GSL**

**VIIRS vs. MODIS: GSL**
Globally-distributed match-up sites, covering different surface types and including urban areas, can be used to evaluate accuracy of atmospherically-corrected, TOC VIs. The protocol is applicable to Phase 1 products.

Global APUs
(Jan 1, 2013 – Mar 31, 2014)

<table>
<thead>
<tr>
<th></th>
<th>TOC EVI</th>
<th>TOC NDVI</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.004</td>
<td>0.009</td>
</tr>
<tr>
<td>P</td>
<td>0.015</td>
<td>0.035</td>
</tr>
<tr>
<td>U</td>
<td>0.016</td>
<td>0.038</td>
</tr>
</tbody>
</table>

(Shabanov et al., 2015, RSE)
Land water mask:
The new LWM has snow in it, but Arctic and Antarctic+Greenlands are treated as separate categories.

Problem:
VI is degraded over snow/ice pixels. Over Antarctic and Greenland, we don't know whether there are snow/ice or not. We don't know how to treat Antarctic and Greenland overall (degrade them all?)
Snow/Ice: There are no snow/ice information over Antarctic and Greenland. This is linked to the Land Water Mask issue.

Problem: VI is degraded over snow/ice pixels. Over Antarctic and Greenland, we don't know whether there are snow/ice or not. We don't know how to treat Antarctic and Greenland overall (degrade them all?)
IDPS has two sunglint flags, one is geometry based (over land) and one based on wind speed (over water). NDE ECM only has the oceanic version, meaning there is no sun glint over land.

**Problem:**
VI has known biases over pixels with sunglint over land. Without information of sun glint over land, we will have 'contaminated' VI product for the areas with sunglint over land. We hope we can get the 'Geometry based sunglint QF' back to ECM and ESR.

**Issue #3: Attributable to ECM, as ESR only passes it on**

**Sunglint over land is planned to be added to ECM revision 4**
Evaluation using ECM v1r1 (i.e. current operational ECM product)

Issue #4: Attributable to ECM, as ESR only passes it on

Cloud Mask Quality:
NDE cloud mask ECM has ‘cloudmaskqualflag’ but appears to be empty with fill value ‘-128’. So, ESR calls cloud mask high quality as long as there is a cloud mask. This is why ESR has high quality cloud mask almost everywhere.

Problem:
VI does not have quality assurance criteria based on cloud mask quality yet. However, we do hope we can get a meaningful ‘cloudmaskqualflag’ in ECM.
Evaluation using ECM v1r1 (i.e. current operational ECM product)

Issue #5: Attributable to ECM, as ESR only passes it on

**Cloud Adjacency:**
IDPS VCM has this QF, but NDE ECM does not.

**Problem:**
‘Cloud Adjacency’ is an important parameter to avoid cloud contamination to ECM’s downstream products. VI is degraded over pixels with ‘cloud adjacency’. Without ‘cloud adjacency’ information, VI retrievals are likely ‘contaminated’ over pixels with cloud in adjacency.

*Cloud Adjacency has been added to ECM*
**Issue #6: Need help from both ECM and ESR**

**Thin Cirrus Reflective:**
VCM reports either no-cloud or cloud, but ECM reports a 4-category mask here: confident clear, probably clear, probably cloudy, and confident cloudy. ESR processes this as confident clear (no-cloud) versus everything else (cloud), so the thin cirrus reflective QF will potentially look very cloudy in ESR. ESR can change the sensitivity of this flag if needed, since surface reflectance only passes it on.

**Problem:**
VI is degraded over pixels with ‘thin cirrus reflective’. We will appreciate ESR can change the sensitivity of this flag. Right now we have overwhelming thin cirrus reflective, which is one of the main reasons that we have ‘too many’ low quality VI.

**Thin Cirrus has been added to ECM**
*Sun Glint
11 = Geometry & Wind
10 = Wind Speed Based
01 = Geometry Based
00 = None
20160819
H03V02
Cloud Shadow (QF4, Bit 0)

20160812–20160827
H03V02
Cloud Shadow (QF4, Bit 0)

*Cloud Shadows
0 = False (no)
1 = True (yes)
20160819
H03V02
Cloud Adjacency (QF3, Bit 5)

20160812–20160827
H03V02
Cloud Adjacency (QF3, Bit 5)

*Cloud Adjacency
0 = False (no)
1 = True (yes)
The current Max–SAVI compositing method picks up too much sunglint, cloud adjacency and cloud shadows in the weekly and biweekly composites, which degrades the quality of weekly and biweekly VI products.
Summary and Conclusion

- Enterprise daily GVF and VI product were tested successfully with full day (20150819) run of Enterprise inputs.

- Enterprise weekly and bi-weekly product tested with IDPS inputs (20160812–20160827). Enterprise products started flowing on 8/15/17 for testing in preparation for the ARR in September.

- Two DAPs were delivered for code testing at NDE.

- Prepare for Algorithm Readiness Review in September 2017

- Improve the current Max–SAVI compositing method

- Improve the integration of VI and GVF systems within NVPS
JPSS LAND SURFACE ALBEDO EDR

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Yunyue.Yu@noaa.gov

Shunlin Liang, Dongdong Wang,  
Yuan Zhou, Jingjing Peng  
UMD/CICS
Outline

- Cal/Val Team Members
- JPSS LSA Product Overview
- Validation and Monitoring
- Algorithm Improvement
  - Issues
  - New NDE Gridded LSA Product
  - Updates to Sea Ice Surface Albedo Algorithm
  - Validation
- User feedbacks
- Summary and Path Forward
# Cal/Val Team Members

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<td>Land Lead, Project Management</td>
</tr>
<tr>
<td>Yunyue Yu</td>
<td>NOAA/NESDIS/SATR</td>
<td></td>
<td>EDR Lead, algorithm development, validation, team management</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jingjing Peng</td>
<td>Algorithm development, validation, monitoring</td>
</tr>
<tr>
<td>Shunlin Liang</td>
<td>UMD/CICS</td>
<td></td>
<td>Algorithm development, validation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dongdong Wang</td>
<td>Algorithm development, validation, monitoring</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yuan Zhou</td>
<td>Algorithm development, validation, monitoring</td>
</tr>
<tr>
<td>Walter Wolf</td>
<td>NOAA/NESDIS/SATR</td>
<td></td>
<td>System Integration, Transition</td>
</tr>
<tr>
<td></td>
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<td>Valerie Mikles</td>
<td>System Integration, Transition</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Marina Tsidulko</td>
<td>STAR IT support</td>
</tr>
<tr>
<td>Michael EK</td>
<td>NOAA/EMC/NCEP</td>
<td></td>
<td>User readiness</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weizhong Zheng</td>
<td>User readiness : Model albedo application, verification</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yihua Wu</td>
<td>User readiness : Model albedo application, verification</td>
</tr>
<tr>
<td>Miguel Roman</td>
<td>NSAS/GSFC</td>
<td></td>
<td>NASA Land Science Investigator-led Processing System Lead</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sadaswiva Devadiga</td>
<td>System support, product monitoring</td>
</tr>
</tbody>
</table>
Overview: Current VIIRS IDPS LSA Product

\[ LSA = a_0 + \sum a_i r_i \]

\( a_i \) is regression coefficient for Band \( i \).

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

\( i \) is VIIRS band number, including the channels 1,4,5,7,8,10 and 11.
Overview: Performance of VIIRS IDPS LSA Product

- Several algorithm improvements have been made since S-NPP was launched.
- A set of surface-specific LUTs with consideration of surface reflectance anisotropy are used.
- Validation results suggest the VIIRS direct estimation approach can generate albedo retrievals with accuracy similar (or superior) to existing products.

Comprehensive Assessment of VIIRS LSA

- Two years data over 23 sites
- Field measurements together with Landsat 7 ETM+ and Landsat 8 OLI maps (~3Tb)
- Intercomparison with MODIS product

Independent Validation Study

- Investigators from CAS used sophisticatedly-designed spatial sampling technique to address issues of spatial scaling in validating coarse spatial resolution LSA products.

- Validation results suggested superior quality of VIIRS data.

- Graphs showing correlation between 16-day mean VIIRS albedo and 16-day mean in situ truth at VIIRS pixel scale.

- Graphs showing magnitude inversion and full inversion results with RMSE, R^2, and Bias values.
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 occur;
- Update maps through WWW
- [http://www.star.nesdis.noaa.gov/jpss/EDRs/products_Albedo.php](http://www.star.nesdis.noaa.gov/jpss/EDRs/products_Albedo.php)
Issues of IDPS LSA Granule Product

• Issues of the current IDPS granule 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.
  – Un-gridded product
    • End users need gridded product with common map projection.
Issues of IDPS LSA Granule Product: Illustration

Features of current algorithm
- Using single overpass
- Needing clear-sky pixels

Data gaps
Residual noise
Possible multiple values for a day
New Method for Daily Mean Albedo

- Use of instantaneous albedo to calculate daily surface radiation budget may result in ~10% bias.
- We developed a method to estimate daily mean albedo directly from VIIRS data.
- The new method uses similar LUTs of regression coefficients, but considers variations of albedo and diffuse radiation ratio with solar angles.

Wang et al. 2015, JGR; Wang et al. 2017, TGRS
Advanced Statistics-based Temporal Filtering

- Temporal filtering is a key step of the NDE LSA algorithm:
  - Improve accuracy
    - Reduce temporal variations
    - Exclude undetected cloud and shadow
  - Fill data gaps
- A sophisticated statistical based filtering approach was developed
- Capable of integrating multisource of information
  - VIIRS retrieval and its QF
  - Climatology (mean and variance)
  - Temporal correlation (historical observation)
Developing Gridded NDE LSA Product

• We developed 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 software package in C programming language has been delivered.
  – C source codes
  – LUTs
  – Climatology data
  – Documents

• Improved Granule LSA product in NDE
  – Critical Design Review was passed in Sept. 2016.
  – Test Readiness Review is scheduled for August 2017.
Major steps of generating NDE LSA

Retrieving daily albedo

Gridding

Preparing time series

Cutting into tiles

Temporal filtering
Four components of the Enterprise LSA algorithm:
1. Granule LSA computation
2. Tile data generation for optimization
3. Improved granule LSA
4. Gridded Daily LSA production
Example of NDE Gridded LSA

- Two global products of VIIRS LSA on April 1 2015 were shown here.
- Compared to the current granule product, the newly-developed NDE product represents several substantial major improvements:
  - Gap-filled: continuous map
  - Noise-reduced: higher accuracy
  - Gridded: ready to user
Update to Sea Ice Surface Albedo Algorithm

- We applied a new sea-ice albedo LUT in NPP VIIRS albedo calculation. The sea-ice albedo become available in the NDE LSA product. The coverage is consistent with the sea ice concentration product.

- We generated a 5-km daily sea-ice albedo climatology and used it as background information for temporal filtering of sea-ice albedo.

![](image)

2017078 from NDE algorithm

global albedo map (sea-ice included)

![Comparison between VIIRS sea-ice albedo and GC-net albedo](image)

RMSE = 0.049

at Tunu-N of GCnet

The sea-ice albedo climatology from AVHRR APP-x albedo product
For further improvement the VIIRS sea-ice albedo LUT, we are working on enhancing the representativeness of the training data by building a spatio-temporal representative sea-ice BRDF database. The Ice concentration, Snow fraction and Snow parameters would be deployed as knowledge database for BRDF simulation and compositing.
Validation of NDE LSA data

• The new NDE albedo was validated using field measurements and inter-compared with other albedo products.
  • Preliminary assessment results suggested substantial improvement over existing datasets:
    – Gap-free continuous data
    – Higher accuracy:
      • Snow-covered and snow-free
      • Better prediction over ethereal snow cases

Example of time series of one year VIIRS NDE albedo at Fort Peck

Comparison of snow-free and snow-covered VIIRS albedo with gap-filled MODIS C5 and C6 data, and GLASS albedo data
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)
Collaboration with EMC/NCEP Team

• The new gridded, gap-filled, noise-reduced product is developed to meet the requirements of modeling team and data analysis.
  – Working with the modeling team to test the application of new product
  – Customized the codes to generate tailored data sets.

Examples of albedo data customized for modeling team
• 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 NDE albedo product was developed.

• Initial evaluation suggested this new gridded, gap-filled, noise-reduced NDE product represent substantial improvements over previous granule product and other existing products.

• LUT of retrieving sea ice surface albedo was updated.

• Additional maintenance and further algorithm refinement is critical to assure the production of high-quality gridded LSA product.
Future Plans/Improvements

• Land-cover-specific LUT will further improve quality of albedo retrieval.

• Enterprise LSA development: TRR and ARR preparation

• 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
Outline

• Cal/Val Team Members
• JPSS LST Production
  ➢ Algorithm/Product Overview
  ➢ Algorithm Improvement
• Validation and Monitoring
• S-NPP LST reprocessing
• JPSS-1 Readiness
• Gridding LST product development
• External Cooperation
• Summary and Path Forward
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<td>NOAA/NESDIS/SATR</td>
<td>Yuling Liu</td>
<td>LST Lead, algorithm development, validation, user promotion, team management</td>
</tr>
<tr>
<td></td>
<td>NOAA Affiliate, UMD/CICS</td>
<td>Heshun Wang</td>
<td>algorithm improvement, emissivity development</td>
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<tr>
<td></td>
<td>NOAA Affiliate, UMD/CICS</td>
<td>Peng Yu</td>
<td>product validation, monitoring tool</td>
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<tr>
<td>Walter Wolf</td>
<td>NOAA/NESDIS/SATR</td>
<td>Valerie Mikles</td>
<td>System Integration, Transition</td>
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<tr>
<td>Michael Ek</td>
<td>NOAA/NCEP/EMC</td>
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<td>Model application Lead</td>
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<td></td>
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<td>Weizhong Zheng</td>
<td>User readiness: Model albedo application, verification</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yihua Wu</td>
<td>User readiness: Model albedo application, verification</td>
</tr>
<tr>
<td>Miguel Roman</td>
<td>NSAS/GSFC</td>
<td>Sadashiva Devadiga</td>
<td>NASA Land Science Investigator-led Processing System Lead</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>System support, product monitoring</td>
</tr>
</tbody>
</table>
VIIRS LST Algorithm Overview

**IDPS LST Algorithm**

\[
LST_{i,j} = a_0(i, j) + a_1(i, j)T_{11} + a_2(i, j)(T_{11} - T_{12}) + a_3(i, j)(\sec \theta - 1) + a_4(i, j)(T_{11} - T_{12})^2
\]

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 \(\theta\) is satellite viewing zenith angle.

**Enterprise LST Algorithm**

\[
T_s = A_0 + A_1T_{11} + A_2(T_{11} - T_{12}) + A_3\epsilon + A_4\epsilon(T_{11} - T_{12}) + A_5\Delta\epsilon
\]

Where \(A_k\) (with \(k=0\) to \(5\)) are coefficients stratified by day/night, viewing angle and precipitable water vapor. \(\epsilon\) and \(\Delta\epsilon\) are the mean and difference of the spectral emissivity of the two split windows. \(T_{11}\) and \(T_{12}\) are brightness temperature at 11\(\mu\)m and 12\(\mu\)m.
• Enterprise LST algorithm is ready for implementation
  – Algorithm test, uncertainty and sensitivity analysis has been performed
  – Consistent quality flags
  – Preliminary tests using real satellite data from multiple sensors including VIIRS, MODIS, AHI and SEVIRI have been conducted.
  – Preliminary validation with in-situ observations from SURFRAD, BSRN, ARM and GMD, and cross satellite comparisons using the above satellite data.
• The enterprise LST algorithm has gone through the critical design review; test readiness review will be conducted by Aug 24th.
• The DAP files are ready to deliver, which includes the science code, test data, LUT, configuration file, input and output I-O structure etc. The system integration is undergoing.
• The first version of the enterprise LST ATBD has been completed.
Improvement: Simulation Database

Improvements on the global representativeness of the simulation database with regard to the regional climate, water vapor range, elevation and seasonality etc.

- TIGR collection: v3.0, 2311 profiles in total
- SEEBOR collection: v5.0, 15704 profiles in total.
Emissivity algorithm is developed and implemented

- 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 mission, and GOES-R mission as well.
Long Term Monitoring: ftp links

Long Term Monitoring: Global VIIRS LST

VIIRS Global LST (daytime): 20160101

Temperature (K)

STAR JPSS Science Team Meeting, 14-18 August 2017
Long Term Monitoring: Monthly Diurnal LST Range

Global Monthly mean diurnal LST range from VIIRS: 201601
Validation and Evaluation

Enterprise VIIRS LST against ground data from SURFRAD, BSRN and GMD

Enterprise SEVIRI LST vs Heimat

Enterprise SEVIRI and VIIRS LST against ground data from KIT(left) and OZFlux(Middle and Right)
Reprocessing Status

- Investigated three weeks of reprocessed SDR data and its impact on LST product.
  - Investigation results have been presented in the reprocessing workshop
  - The brightness temperature of the band 15 and band 16 and geometry data are investigated and the statistics of the difference between the reprocessed SDR and the operational SDR are summarized.
  - It is found that the reprocessed sdr data in 2012 will cause a significant LST change at local scale under specific time span.
- Reprocessing is planned for LST derived from the enterprise algorithm for the time period from 11/19/2012 to present.
- Based on the reprocessing of the upstream data: SDR, enterprise cloud mask and AOD and the availability of the ancillary data such as total precipitable water and snow/ice information.
Organizational Structure: 8-12 August 2016

**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
- 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**

- In-situ validation: existing + new site data; domestic + international
- Cross comparisons: S-NPP, MODIS, +Sentinel-3
- Schedules and Milestones: based on the mission requirement
• Major Risks/Challenges/ and Mitigation
  – The enterprise algorithm may not be able to run by Sept. 2017, as scheduled
    **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
  – Available water vapor data is in coarse resolution and forecast accuracy is unknown
    **Mitigation:** theoretical analysis of the water vapor uncertainty on LST quality
  – Limitation on emissivity data evaluation and monitoring
    **Mitigation:** limited in-situ validation; LST application ; LST monitoring tool for LSE
  – Lack of high quality, global validation data set.
    **Mitigation:** continue data collection through international cooperation;
  – Cloud contamination impact
    **Mitigation:** additional cloud filtering in deep-dive validation
• Collaboration with 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 in their applications.
  – Actively working with EMC/NCEP users and External Users
Gridded LST Development

- From Users: a global continuous gridded LST product is required, in addition to the current granule LST data.
- An investigation was performed on developing a Level-3 VIIRS Gridded LST product, with intensive user interactions; major product features were determined:
  - Global coverage with two spatial resolutions: 0.009 degree and 0.036 degree
  - Gridded with tile system management
  - Gap-filled at invalid pixel (TBD)
  - Daytime and nighttime daily products.
4km Gridded VIIRS Land Surface Temperature for daytime

1km Gridded VIIRS Land Surface Temperature for daytime
(4×2 tiles for globe)
4km Gridded VIIRS Land Surface Temperature for nighttime

1km Gridded VIIRS Land Surface Temperature for nighttime (4×2 tiles for globe)
External Cooperation

Comprehensive VIIRS/LST vs SEVIRI/LST comparison

One year VIIRS subset data over 6 areas in Europe and Africa is used for the comprehensive cross comparison between VIIRS and SEVIRI LST. The result has been presented in EGU 2017.

Above: Satellite LST is compared to the model LST output in time series

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

Difference of Frozen days (LST-L05)
SNPP LST performance
- The SNPP LST marginally meets the mission requirements based on the validation results
- Validation tools are run regularly for routing monitoring and web info update
- Working with EMC/NCEP for the model verification
- International cooperation with ESA/EUMETSAT LST groups for the cross comparison to Sentinel-3 LSTs and SEVIRI LSTs

Enterprise LST algorithm progress
- The DAP files are ready to deliver.
- Land surface emissivity has been developed to support the enterprise LST.
- The first version ATBD for the enterprise LST and LSE are ready.

Reprocessing status
- Sample reprocessed SDR data has been investigated and its impact on LST has been evaluated.
- 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
- J-1 Cal/Val plan has been reviewed

Gridded LST development
- Major features of the gridded LST product has been determined with major users
- Software architecture and technical solutions have been investigated
- A very preliminary code has been developed and tested; a simple version of the gridded LST production is running in a local server for current LST product monitoring purpose.
- LST diurnal model and temporal interpolation has been studied.
Future Plans/Improvements

• Operational implementation of gridded LST data production
• Pre/post operational review and support
• Final version of the enterprise LST ATBD and related documentations
• Final DAP delivery
• Reprocessing LST data when the enterprise algorithm and upstream data is ready.
• JPSS-1 LST product evaluation, monitoring and maturity support
• Emissivity Data evaluation
• 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
• Resume international cooperation
VIIRS product status

Ivan Csiszar
NOAA NESDIS Center for Satellite Applications and Research

Marina Tsidulko
I.M. Systems Group, Inc.

Wilfrid Schroeder, Louis Giglio, Evan Ellicott
University of Maryland, Department of Geographical Sciences
Outline

• VIIRS active fire product status and data access
  – VIIRS baseline (MODIS heritage) fire product
  – Improved hybrid VIIRS fire product

• Ongoing science issues and product improvements

• Examples of key operational applications

• Reprocessing the Suomi NPP VIIRS data record

• Summary
### NDE output file content

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<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Type</th>
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<tbody>
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<tr>
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<td>Fire algorithm QA mask</td>
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Total output for one granule: 11.7 Mb + number of fires * 79 bytes

**Fire pixel information is also available in text files**
## NDE output file content

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

*Fire pixel information is also available in text files*
NOAA NDE VIIRS ACTIVE FIRE PRODUCT: FIRE MASK
Central Africa, 5/1/2017  11:33 UTC

Fire locations, confidence and FRP are available in sparse array and text files
Hybrid I/M-band product

**Scenario 1**

$$\text{FRP}_i = \text{FRP}$$

**Scenario 2**

$$\text{FRP}_i = \frac{\text{FRP}}{2}$$

**King Fire/CA, September 2014**

**Map:**
- MODIS-Aqua 1km
- VIIRS 750m
- VIIRS 375m

**Legend:** FRP (MW)
- < 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 10
- 10 - 17
- > 17

**Colocation:**
- 375 & 750 m

**Dates:**
- 20140914 08:59
- 20140914 10:36
- 20140914 20:22
- 20140914 21:59
- 20140915 10:19
- 20140915 19:59
- 20140915 21:41
- 20140916 10:01
- 20140916 21:24
- 20140917 09:44
- 20140917 21:06
- 20140918 09:26
- 20140918 20:43
- 20140919 09:03
- 20140919 10:45
- 20140919 22:08
The JPSS VIIRS active fire products provide high quality information:

- 750m M-band product in operations since March 15, 2016
- 375m I-band algorithm evaluated for operational implementation
- both products deliver fire mask and fire radiative power (FRP)
- FRP used in air quality, and smoke analysis and prediction systems
- FRP is incorporated into AWIPS-II

Updated M-band algorithm in delivery to NDE.

Fire masks from the M-band (top and left) and I-band (bottom and right) algorithms on 6/18/2017 02:04 UTC.

I. Csiszar, STAR; M. Tsidulko, IMSG@STAR, W. Schroeder, UMD
VIIRS 375 m Fire Radiative Power
Jan-Dec 2015 (Julian days 1,10,20,…,360)

Sum of top-of-atmosphere (TOA) FRP over sampling period using 0.5° grid

Frequent saturation prevents FRP retrieval using 375 m mid-IR data
Alternative calculation implemented using co-located 750 m mid-IR unsaturated data
MYD14 1km Collection 6 Fire Radiative Power
Jan-Dec 2015 (Julian days 1, 10, 20, ..., 360)

Sum of top-of-atmosphere (TOA) FRP over sampling period using 0.5° grid

Global TOA FRP totals:
- Terra/MODIS: $6.1 \times 10^6$ MW
- Aqua/MODIS: $13.4 \times 10^6$ MW
- S-NPP/VIIRS: $19.6 \times 10^6$ MW

Higher VIIRS spatial resolution means:
- 3-4 more daytime fire pixels
- 20-25 more nighttime fire pixels

Compared to Aqua/MODIS
VIIRS 375 m x MODIS 1km
TOA Fire Radiative Power (FRP)

45% of daytime and 80% of nighttime VIIRS 375m fire pixels have no match in Aqua/MODIS fire data

VIIRS 375m systematically detecting more fires than same-day MODIS (Terra & Aqua) in areas dominated by small/low-intensity fires
Fires from MODIS and VIIRS matched in individual fire events. Each fire event is considered as a cluster (total 301 fire events were selected)
Comparison of current Operational / systematically generated products
MODIS vs. VIIRS FRP considerations

• Differences in
  – Scanning geometry
    • Pixel size distribution
  – Handling of bow-tie effects
    • Duplicate detections
  – Pixel aggregation
    • Relative signal within pixel
  – Atmospheric transmittance
    • More CO₂ absorption in VIIRS M13

FRP is critical input for emission estimates!
Cross-comparison of atmospherically corrected MODIS x VIIRS FRP Data

FRP retrievals corrected for atmospheric attenuation using MODTRAN + MERRA-2 (0.625° x 0.5°)

Before atmospheric correction

After atmospheric correction
VIIRS vs. MODIS pixel area and swath width

VIIRS M band

MODIS

June 3, 2016

No VIIRS gaps at low latitudes!

1 km to 4 km

750 m to 1.2 km (M-band)
**VIIRS vs. MODIS pixel area and swath width**

Granules of two neighboring orbit tracks

(blue: 11:48-11:53am, orange: 10:09-10:12am)

Significantly more VIIRS 750m detections at low latitudes

April 2016 – March 2017

Good quality VIIRS observations at low latitudes from consecutive orbits!
Examples of real-time fire and smoke monitoring systems using VIIRS active fire data

HRRR: High Resolution Rapid Refresh

https://www.star.nesdis.noaa.gov/smcd/spb/ag/eidea/

https://www.star.nesdis.noaa.gov/smcd/spb/ag/eidea-ak/

https://rapidrefresh.noaa.gov/HRRRsmoke

eIDEA: enhanced Infusing satellite Data into Environmental Applications

https://rapidrefresh.noaa.gov/HRRRsmoke
VIIRS Active Fire Long-term Monitoring

http://www.star.nesdis.noaa.gov/jpss/EDRs/products_activeFires.php
Active fire data anomalies during the early period of the Suomi NPP data record

Examples of the first operational real-time IDPS product as archived in NOAA CLASS (http://www.class.ncdc.noaa.gov/).

Not reprocessed; not to be used for science analysis. Reprocessing is ongoing.
Missing data packets / calibration mismatch

npp_d20120520_t1533555_e1535197

Earth scene data with calibration mismatch

Earth scene data with correct calibration

Bow-tie deletion

Missing data

Fire

Clear land

Water

Original real-time

IDPS M13 SDR

NDE fire mask*

Reprocessed

M13 SDR

NDE fire mask*

*including on ground bow-tie deletion
Summary

• Operational NDE production with a mature 750m algorithms is now ongoing
  – Some changes forthcoming

• Near-real-time product and distribution enables regional applications

• Algorithms incorporated into major direct broadcast packages
  – IPOPP and CSPP

• Extensive outreach, resulting in critical operational applications
  – e.g. coupled with air quality / smoke monitoring and modeling
  – Weather / fire

• Reprocessing of the data record with highest quality input and most mature algorithms is ongoing
  – Not only eliminates spurious detections, but also enables the detection of previously missed fires
Vegetation Health Development and Applications
Transition from AVHRR to JPSS

Presenters:
Felix Kogan, Wei Guo & Wenze Yang
Vegetation Health (VH) is an indicator of satellite-based vegetation response to weather (mostly P and T).

GTS (WMO-based) weather station network

One weather station covers
GLOBAL - 10,000 sq. km
Africa - 31,000 sq. km

NOAA satellites cover
AVHRR: 4 & 16 km²
VIIRS: 0.5, 1 & 4 km²
Vegetation Health

(1) Normalized Difference Vegetation Index (NDVI)
   VIS (Ch1) and NIR (CH2)
   Brightness Temperature (BT)
   IR (CH4)

(2) NDVI & BT Climatology
Vegetation Health (VH) Indices

Vegetation condition index (VCI), values 0 - 100

\[ VCI = \frac{(NDVI - NDVI_{\text{min}})}{(NDVI_{\text{max}} - NDVI_{\text{min}})} \]

NDVI_{\text{max}}, and NDVI_{\text{min}} – climatology (1981-2000 maximum and minimum NDVI for a pixel;)

Temperature condition index (TCI), values 0 - 100

\[ TCI = \frac{(BT_{\text{max}} - BT_{\text{min}})}{(BT_{\text{max}} - BT_{\text{min}})} \]

NDVI_{\text{max}}, and NDVI_{\text{min}} – climatology (1981-2000 maximum and minimum NDVI for a pixel)

Vegetation Health Index (VHI), values 0 – 100

\[ VHI = a \times VCI + (1 - a) \times TCI \]

0 – indicates extreme stress; 100 – indicates favorable conditions
VCI, TCI & VHI Aug 11, 2017

VCI
Vegetation Condition Index

TCI
Thermal Condition Index

VHI
Vegetation Health Index

World Vegetation Health August 11, 2017
2015 PORTUGAL

Vegetation health

April  May  June  July  August  September  October

Vegetation Health  VHI
Moisture Condition  VCI
Thermal Condition  TCI

STRESSED  fair  FAVORABLE

Vegetation Health 2015, PORTUGAL
Vegetation Health (VH) Data

• NOAA/AVHRR (37y) 16 sq. km
  4 sq. km

• SNPP/VIIRS (6 y) 4 sq. km
  1 sq. km
  0.5 sq. km
Drought USDM & VH

U.S. Drought Monitor (USDM)
September 11, 2012

INTENSITY
- D0 - Abnormally dry
- D1 - Moderate Drought
- D2 - Severe Drought
- D3 - Extreme Drought
- D4 - Exceptional Drought

Drought Impacts
Dominant Impacts
S - Short-term (<6 months)
L - Long-term (>6 months)

Drought area & intensity from Vegetation Health
September 14, 2012

Mild
Exceptional
Corn Yield vs AVHRR-based Vegetation health indicator (VCI) Midwest, USA

NOAA/AVHRR

R=0.75

Correlation of Corn Yield Anomaly with VCI and Drought Classification
Pasture biomass vs VCI, MONGOLIA

MONGOLIA
Biomass

Corn yield vs VCI, ZIMBABWE

ZIMBABWE
Corn
VH Predicted vs Observed Wheat Yield

**Russia**

Russia, Saratov Spring Wheat

$R = 0.81$

**Argentina**

Argentina, Dep. 9 Wheat

$R = 0.84$

**India, Rajasthan**

RsQ = 0.78

MSE = 0.0291

SE = 3%

UE = 97%

**Kazakhstan**

Independent Test

Mean Yield (bars) and VCI, Kazakhstan, Spring Wheat

$R = 0.76$
VH-Crop Losses Prediction: USA, Kansas

Winter Wheat

Sorghum

Corn

Observed & Predicted Yield, USA, Kansas
Channels: VIIRS versus AVHRR

Climate data records problems

Normalized Difference Vegetation Index (NDVI)

Brightness Temperature (BT)
Transition to SNPP/VIIRS & J-1

• TWO methods:

1. Adjust SNPP/VIIRS weekly NDVI & BT to weekly NOAA/AVHRR

2. Adjust SNPP/VIIRS 5-year weekly NDVI & BT climatology to NOAA/AVHRR 36-year climatology
Time series of SMN from VIIRS and AVHRR

The SMN from VIIRS and AVHRR are not on the same level. Adjustment is required to make the long term time series aligned.
Drought & Impacts from VIIRS 0.5 km California

(a) Vegetation Health from 500 m S-NPP/VIIRS

(b) Difference Vegetation Health

Economic Impacts of California Drought

(c) Intensity of Economic and VH-assessed Impacts

- Stronger
- Moderate
- Weaker
Vegetation Health 0.5 sq.km: New & old Climatology

Vegetation Health Index (VHI)

2012 2013 2014 2015 2016 2017

New Climatology

Old Climatology

2012 2013 2014 2015 2016 2017
Users attending Vegetation Health WEB

https://www.star.nesdis.noaa.gov/smcd/emb/vci/VH/vh_browse.php
• Camara N.E. and F.N. Kogan 2017. Monitoring landslides conditions in Madeira Island from NOAA operational satellites.

• Kogan F, W. Guo & W. Ysang 2017. SNPP/VIIRS vegetation health to assess 500 California drought, Geomatics, Natural Hazards and Risk, DOI:10.1080/19475705.2017.1337654 (http://dx.doi.org/10.1080/19475705.2017.1337654)


Publication since the early 1980s


• BACK UP
ACCOMPLISHMENTS

- Data collection from SNPP/VIIRS, AVHRR/NOAA-18 & 19, MODIS/AQUA
- Algorithm Development (data sampling, gap filling, reflectance calculation, noise removal)
- Data processing (NDVI, BT, no noise NDVI & BT)
- Data Stability tests
Algorithm Background

- The SNPP & J1/VIIRS Vegetation Health (VH) Indices from EDR
- VIIRS/VH-1 is global weekly composite products with 1 km² resolution
- The VH-EDR consists of three indices, Vegetation Condition Index (VCI), Thermal Condition Index (TCI) and Vegetation Health Index (VHI)
- The algorithm is based on three bio-physical laws: Liebig’s Law-of-Minimum, Shelford’s Law-of-Tolerance & Carrying Capacity
- Daily SNPP/VIIRS-1 is derived from the TOA radiances: VIS, NIR - image bands: & Thermal bands
- The radiances are pre-launch & post-launch calibrated, checked for accuracy
- Weekly composite raw Normalized Difference Vegetation Index (NDVI) and raw Brightness temperature (BT) are calculated after adjustment for sun angle, observation time & atmospheric effects
- Noise removal from weekly raw NDVI & BT and converting them to no noise NDVI (SMN) and BT (SMT)
- Climatology derivation from multi-year SMN and SMT weekly data, using three Bio-physical Laws
- Two SNPP/VIIRS & J1/VIIRS climatology conversions to longer data sets & tests:
  - NDVI & BT real-time weekly from 5-year SNPP/VIIRS to 36-year NOAA/AVHRR
  - NDVI & BT climatology weekly from 5-year SNPP/VIIRS to 36-year NOAA/AVHRR
- Modeling SNPP/VIIRS-1 Vegetation condition index (VCI), Temperature condition index (TCI) & Vegetation health index (VHI)
- Derivation of VH-EDR’s per-pixel quality flags (e.g., land/water snow, desert, cloud mask and random noise)
- Test SNPP VIIRS/VH-1 performance with in situ data
36-year Climatology: Max, Min, Mean
The SMN from VIIRS and AVHRR are not on the same level. Adjustment is required to make the long term time series aligned.
Vegetation Health Milestones Update
June 10, 2017

• Calculate 5 year climatology (max and min) from S-NPP VIIRS (Apr, 2017)
• Calculate same 5 year climatology from AVHRR (Apr 2017)
• Similar/dissimilar for the two climatology (May, 2017)
• Similar/dissimilar for 5-year & 36-year climatology
• Calculate VIIRS/VH (VCI, TCI, VHI) (Jun, 2017)
• Compare VIIRS/VH to AVHRR/VH for 2012-2017 (Jan, 2018)
  – If there are issues with the VIIRS climatology re-calculate it each year with J1 data.
Algorithm Improvements

- 4 km Climatology from AVHRR
- 4 and 1 km Climatology from VIIRS
- Cal/Val Climatology for evaluating algorithm performance
  a. Comparison with AVHRR algorithms
  b. Comparison with *in situ* data
SNPP/VIIRS-1 Climatology

• Directly generate 5-year VIIRS 1km climatology (V5);

• Generate pseudo 36-year VIIRS 1km climatology (V36) based on VIIRS 4km V36 climatology and 1km V5 climatology:

  • Get mean value over 4km grid cell for climatology mean:
    
    From V5 1km MEAN at specific week (MEAN_{viirs1km}), calculate mean values over 4km grid (MEAN_{viirs4km}).

  • Calculate adjustment:
    
    Adjustment = MEAN_{viirs1km} - MEAN_{viirs4km}

  • Interpolate 4km VIIRS climatology to 1km resolution (MXN_{VIIIRS1km})
    
    MXN_{viirs4km} \rightarrow MXN_{viirs1km}

  • MXN_{new} = MXN_{viirs1km} + Adjustment
Back Up
Weather Stations & Satellite Data Coverage

LAND COVERAGE

Satellite:
Every 4, 1 and 0.25 sq.km

Weather: One Station
Every 7,140 sq.km
(1,760,000 acres)
Vegetation Health Jul 8, 2017 and % Pasture/Range Land in POOR & Very POOR Conditions, Jul 2, 2017 (USDA)
Number of VH Users per Year

- 2010: 2,459
- 2011: 25,866
- 2012: 38,243
- 2013: 56,176
- 2014: 58,855
- 2015: 64,655
## Vegetation Health data sources

<table>
<thead>
<tr>
<th>Sensors</th>
<th>Advanced Very High Resolution Radiometer (AVHRR)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Visible Infrared Imaging Radiometer Suite (VIIRS)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Satellites</th>
<th>NOAA/AVHRR: NOAA-7, 9, 11, 14, 16, 18, 19</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S-NPP/VIIRS, J-1 (JPSS)/VIIRS</td>
</tr>
</tbody>
</table>

| Data Resolution | Spatial | 0.5, 1, 4 (GAC), 8 & 16 (GVI) km; |
|                | Temporal | 7-day composite |

<table>
<thead>
<tr>
<th>Period</th>
<th>37-year (1981-2017), future?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5-year (2012-2016) currently</td>
</tr>
<tr>
<td></td>
<td>(2017 – 2030) future</td>
</tr>
</tbody>
</table>

| Coverage | World (75 N to 55 S) |

Channels: VIS, NIR, IR; Indices: NDVI & BT
AVHRR Algorithm Architecture (SA)

1. NDVI & BT
2. N-B Climatology
Transition to SNPP/VIIRS & J1/VIIRS

1. NDVI & BT
2. N-B Climatology

CURRENT

PLUS 3-5 years from Year 3-5 of J1
Transition to SNPP/VIIRS & J-1

• From the TWO methods the **first** one is used:

1. Adjust SNPP/VIIRS weekly NDVI & BT to weekly NOAA/AVHRR
Expl: NDVI (SMN): AVHRR-VIIRS time series

Regression Coefficients: \( Y = a + b \times X \)
- \( a = -0.0374925 \)
- \( b = 0.703031 \)

Mean of \( a = -0.0373363 \)
Mean of \( b = 0.702253 \)

Correlation Coefficients: \( Y = a + b \times X \)
- Mean of \( CC = 0.934111 \)

Data used: 2012 week 27 to 2013 week 30

\( X = \text{VIIRS-SM:mean_SMN} \)
\( Y = \text{VHP-SM:SMN} \)

\( Y = a + b \times X \)

\( a = -0.0374925 \)
\( b = 0.703031 \)

Mean of \( a = -0.0373363 \)
Mean of \( b = 0.702253 \)

Correlation Coefficients: \( Y = a + b \times X \)
- Mean of \( CC = 0.934111 \)

Data used: 2012 week 27 to 2013 week 30
Expl: BT (SMT) AVHRR-VIIRS COR

Regression Coefficients

\[ Y = a + b \times X \]

- mean(a) = -12.9047
- mean(b) = 1.04711

Correlation Coefficients

- mean(CC) = 0.963497

- 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
USA Drought from USDM & VHI

Drought from US Drought Monitor (USDM)

Drought from NOAA-19/AVHRR Vegetation health index (VHI)
VIIRS VHP IT Architectures: Apply #1
Adjust SNPP/VIIRS weekly NDVI & BT to weekly NOAA/AVHRR

VIIRS VHP IT Architectures

NDE IT Environment

- **VH**
  - "Operation"
  - PE-1

- **VH**
  - "Test"
  - PE-2

**STAR Development**

- STAR VIIRS data Ingest
- STAR Ancillary Data Ingest
- STAR Climatology Ingest

**Dissemination Users**

- VIIRS VHP(VCI, TCI, VHI) to NDE Distribution System
- Online QC Monitoring
  - Internet STAR/OSPO
  - CLASS/NCDC

**Archive**

44
VHI: VIIRS-1km vs AVHRR-4 km
May 20, 2017

- SNPP/VIIRS-1
- NOAA/AVHRR-4

VHI for May 20 2017
Expl: Error reduction is required

1. Raw data collection
2. VIS, NIR & IR
3. Climatology

SMN

$R = 0.85$

VCI

$R = 0.67$

TRUE        ????
Transition to SNPP/VIIRS & J-1

• From the TWO methods the second one is used:

Adjust SNPP/VIIRS 5-year weekly NDVI & BT climatology to NOAA/AVHRR 36-year climatology
Climatology A-36 vs V-5

ILLINOIS, USA (89W, 39N) Grassland

Saratov, RUSSIA (43E, 50N) Steppe

Directly generate 5-year VIIRS 4km climatology (V5);

Directly generate 5-year AVHRR 4km climatology (A5) at the same period with V5;

Directly generate 36-year AVHRR 4km climatology (A36);

Generate pseudo 36-year VIIRS 4km climatology (V36) based on the calculation from V5, A5 and A36 climatology:

\[ V_{36} = V_{5} \times \frac{A_{36}}{A_{5}} \]
Test: VHI 4 km Product (Wz)

A36 vs. V5

Data #1: /data/home002/wyang/idl_GVI/prog/data_yang/AVHRR_VHP/4km/VH_AVHRR_3
VHP,G04,C07,NP,P2O30,VH,nc : VHI
Data #2: /data/home002/wyang/idl_GVI/prog/data_yang/VIIRS/4km/VH_VIIRS,5/
VGI21Bands,G04,C07,npp,P2O30,VH,nc : VHI

lon=[-179.98, 179.23] lat=[-55.10, 74.29]

Normalized Histogram

<table>
<thead>
<tr>
<th></th>
<th>Data #1 (1)</th>
<th>Data #2 (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>samples</td>
<td>17750</td>
<td>50,4126</td>
</tr>
<tr>
<td>mean1</td>
<td>54,3909</td>
<td>17,3904</td>
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<tr>
<td>mean2</td>
<td>54,3909</td>
<td>17,3904</td>
</tr>
<tr>
<td>std1</td>
<td>28,2921</td>
<td>26,6163</td>
</tr>
<tr>
<td>std2</td>
<td>28,2921</td>
<td>26,6163</td>
</tr>
<tr>
<td>DiffMax</td>
<td>33,6000</td>
<td>-97,1300</td>
</tr>
<tr>
<td>DiffMin</td>
<td>33,6000</td>
<td>-97,1300</td>
</tr>
<tr>
<td>mean(diff)</td>
<td>3,97823</td>
<td>26,6163</td>
</tr>
<tr>
<td>stddev(diff)</td>
<td>25,351818</td>
<td>25,351818</td>
</tr>
</tbody>
</table>

Scatter Plot

Y = a + b * X
a = 21.070226
b = 0.66095743

Samples: 17750
CC: 0.4063
RMSE = 25.351818

A36 vs. V36

Data #1: /data/home002/wyang/idl_GVI/prog/data_yang/AVHRR_VHP/4km/VH_AVHRR_3
VHP,G04,C07,NP,P2O30,VH,nc : VHI
Data #2: /data/home002/wyang/idl_GVI/prog/data_yang/VIIRS/4km/VH_VIIRS_36_v2/
VGI21Bands,G04,C07,npp,P2O30,VH,nc : VHI

lon=[-179.98, 179.23] lat=[-55.10, 74.29]

Normalized Histogram

<table>
<thead>
<tr>
<th></th>
<th>Data #1 (1)</th>
<th>Data #2 (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>samples</td>
<td>13300</td>
<td>50,4600</td>
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<tr>
<td>mean1</td>
<td>50,7305</td>
<td>17,2314</td>
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<tr>
<td>mean2</td>
<td>50,7305</td>
<td>17,2314</td>
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<tr>
<td>std1</td>
<td>18,4042</td>
<td>11,2981</td>
</tr>
<tr>
<td>std2</td>
<td>18,4042</td>
<td>11,2981</td>
</tr>
<tr>
<td>DiffMax</td>
<td>62,4500</td>
<td>-66,0800</td>
</tr>
<tr>
<td>DiffMin</td>
<td>62,4500</td>
<td>-66,0800</td>
</tr>
<tr>
<td>mean(diff)</td>
<td>0.270321</td>
<td>11,2981</td>
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<tr>
<td>stddev(diff)</td>
<td>11,011643</td>
<td>11,011643</td>
</tr>
</tbody>
</table>

Scatter Plot

Y = a + b * X
a = 7.5482257
b = 0.85777037

Samples: 13300
CC: 0.8012
RMSE = 11,011643
Test: VHI 1km Product

A36 vs. Former Scheme

| Data #1: | /data/home002/uyang/idl_GVI/prog/data_yang/AVHRR_VHP/4km/AVHRR_3
| Data #2: | /data/home002/uyang/idl_GVI/prog/data_yang/AVHRR_VHP/4km/AVHRR_3

Sample: 17370
Mean1: 50,3594
Mean2: 42,8548
Std1: 17,4276
Std2: 20,9877
Diffmax: 63,3600
Diffmin: -78,7500
Mean(diff): -7,9653
Stddiff: 18,4370

Normalized Histogram

Data #1 (1)
Data #2 (2)

Scatter Plot

A36 vs. V36

| Data #1: | /data/home002/uyang/idl_GVI/prog/data_yang/VIIRS/1km/VIIRS_3
| Data #2: | /data/home002/uyang/idl_GVI/prog/data_yang/VIIRS/1km/VIIRS_3

Sample: 17280
Mean1: 50,3519
Mean2: 51,7603
Std1: 17,4240
Std2: 18,7134
Diffmax: 86,1600
Diffmin: -73,5900
Mean(diff): -7,9653
Stddiff: 18,4370

Normalized Histogram

Data #1 (1)
Data #2 (2)

Scatter Plot

Y = a + b * X
a = 10,62270
b = 0,63815816

Samples: 17370
CC: 0,5402
RMSE: 17,324607

Data #1

Density

0 1

Data #2

Density

0 1

0.54

0.70
New VIIRS-VH system: Data Flow (Wz)

Input VIIRS data:

- 357m image bands: SVI01, SVI02, SVI05, GTCGO
- 1014 granules/day
- 700 GB/day

Use similar procedure as AVHRR-VH

Climatology From VIIRS, Incorporated with AVHRR Information

VH calculator

VIIRS VCI/TCI/VHI (VH file)
VHI from V-36, V-5 & A-36 climatology

VHI calculated with the V-36 climatology
### VH-WEB Users in 2016

#### Page Views

<table>
<thead>
<tr>
<th>Month</th>
<th>Page Views</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>356</td>
</tr>
<tr>
<td>February</td>
<td>361</td>
</tr>
<tr>
<td>March</td>
<td>422</td>
</tr>
<tr>
<td>April</td>
<td>431</td>
</tr>
<tr>
<td>May</td>
<td>296</td>
</tr>
<tr>
<td>June</td>
<td>129</td>
</tr>
<tr>
<td>July</td>
<td>806</td>
</tr>
<tr>
<td>August</td>
<td>1.1K</td>
</tr>
<tr>
<td>September</td>
<td>961</td>
</tr>
<tr>
<td>October</td>
<td>709</td>
</tr>
<tr>
<td>November</td>
<td>860</td>
</tr>
<tr>
<td>December</td>
<td>197</td>
</tr>
</tbody>
</table>

#### Unique Visits

<table>
<thead>
<tr>
<th>Month</th>
<th>Unique Visits</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>431</td>
</tr>
<tr>
<td>February</td>
<td>568</td>
</tr>
<tr>
<td>March</td>
<td>635</td>
</tr>
<tr>
<td>April</td>
<td>443</td>
</tr>
<tr>
<td>May</td>
<td>129</td>
</tr>
<tr>
<td>June</td>
<td>806</td>
</tr>
<tr>
<td>July</td>
<td>961</td>
</tr>
<tr>
<td>August</td>
<td>709</td>
</tr>
<tr>
<td>September</td>
<td>860</td>
</tr>
<tr>
<td>October</td>
<td>197</td>
</tr>
<tr>
<td>November</td>
<td>647</td>
</tr>
</tbody>
</table>

#### First Time Visits

<table>
<thead>
<tr>
<th>Month</th>
<th>First Time Visits</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>36</td>
</tr>
<tr>
<td>February</td>
<td>44</td>
</tr>
<tr>
<td>March</td>
<td>54</td>
</tr>
<tr>
<td>April</td>
<td>56</td>
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<tr>
<td>May</td>
<td>129</td>
</tr>
<tr>
<td>June</td>
<td>806</td>
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<tr>
<td>July</td>
<td>961</td>
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<tr>
<td>August</td>
<td>709</td>
</tr>
<tr>
<td>September</td>
<td>860</td>
</tr>
<tr>
<td>October</td>
<td>197</td>
</tr>
<tr>
<td>November</td>
<td>647</td>
</tr>
</tbody>
</table>

#### Returning Visits

<table>
<thead>
<tr>
<th>Month</th>
<th>Returning Visits</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>129</td>
</tr>
<tr>
<td>February</td>
<td>44</td>
</tr>
<tr>
<td>March</td>
<td>54</td>
</tr>
<tr>
<td>April</td>
<td>383</td>
</tr>
<tr>
<td>May</td>
<td>44</td>
</tr>
<tr>
<td>June</td>
<td>806</td>
</tr>
<tr>
<td>July</td>
<td>961</td>
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<tr>
<td>August</td>
<td>709</td>
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<tr>
<td>September</td>
<td>860</td>
</tr>
<tr>
<td>October</td>
<td>197</td>
</tr>
<tr>
<td>November</td>
<td>647</td>
</tr>
</tbody>
</table>

#### Vegetation Health (VH) Total Users in 2016 and Daily

<table>
<thead>
<tr>
<th>Category</th>
<th>Total</th>
<th>Daily Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Page Views</td>
<td>140,163</td>
<td>383</td>
</tr>
<tr>
<td>Unique Visits</td>
<td>30,868</td>
<td>85</td>
</tr>
<tr>
<td>First Time Visits</td>
<td>17,849</td>
<td>49</td>
</tr>
<tr>
<td>Returning Visits</td>
<td>13,019</td>
<td>36</td>
</tr>
</tbody>
</table>
NOAA NESDIS STAR
301-683-3599; Xiwu.Zhan@noaa.gov
X. Zhan, C. Huang, R. Zhang, P. Wang, I. Csizsar
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

<table>
<thead>
<tr>
<th>Team Member</th>
<th>Organization</th>
<th>Roles and Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xiwu Zhan</td>
<td>NESDIS-STAR</td>
<td>PI of VIIRS Surface Type Team</td>
</tr>
<tr>
<td>Chengquan Huang</td>
<td>UMD Geography</td>
<td>Lead of UMD team members</td>
</tr>
<tr>
<td>Rui Zhang</td>
<td>UMD Geography</td>
<td>Algorithm, validation and production lead</td>
</tr>
<tr>
<td>Panshi Wang</td>
<td>UMD Geography</td>
<td>Algorithm, validation</td>
</tr>
<tr>
<td>Ivan Csiszar</td>
<td>NESDIS-STAR</td>
<td>VIIRS Land Team Lead</td>
</tr>
</tbody>
</table>
Surface Type Products Overview

- Impact of Surface Type to NWP model performance:

  **GFS T1534 Vegetation Type**

  **GFS T1534 Latent Heat Flux (W m$^{-2}$) -- 18z 18 July 2016**

*From Chris Hain*
## Surface Type Products Overview

### ST-EDR/AST Requirements from JPSS L1RD

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Threshold</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geographic coverage</td>
<td>Global</td>
<td>Global</td>
</tr>
<tr>
<td>Vertical Coverage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical Cell Size</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Horizontal Cell Size</td>
<td>1 km at nadir</td>
<td>1 km at edge of scan</td>
</tr>
<tr>
<td>Mapping Uncertainty</td>
<td>5 km</td>
<td>1 km</td>
</tr>
<tr>
<td>Measurement Range</td>
<td>17 IGBP classes</td>
<td>17 IGBP classes</td>
</tr>
<tr>
<td>Measurement Accuracy</td>
<td>70% correct for 17 types</td>
<td>~78% for 17 types</td>
</tr>
<tr>
<td>Measurement Precision</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measurement Uncertainty</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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 Support Vector Machine algorithm based on global training polygons database and dozens of classification metrics that are computed from daily surface reflectance observations from VIIRS
- A series of ancillary data are used in the post-classification processes to improve the initial classification result.
Surface Type Algorithm Overview

**Band number**
- **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

**VIIRS surface reflectance data (swath)**

**Gridding**

**Gridded surface reflectance data**

**Compositing**

**Support vector machines (SVM) Decision Tree**

**Post-processing**

**Ancillary data**

**Ancillary data source**
- Land cover agreement map
- Urban mask
- Land/water mask
- Ecoregion map
- Crop probability map
- Google Map/Earth data
- Local Landsat data
- NSDI 30m land cover map

**Metrics**
- Maximum NDVI value
- Minimum NDVI value of 8 greenest months
- Mean NDVI value of 8 greenest months
- Amplitude of NDVI over 8 greenest months
- Mean NDVI value of 4 warmest months
- NDVI value of warmest month
- Maximum band x value of 8 greenest months.
- Minimum band x value of 8 greenest months.
- Mean band x value of 8 greenest months.
- Amplitude of band x value over 8 greenest months.
- Band x value from month of maximum NDVI.
- Mean band x value of 4 warmest months.
- Band x value of warmest month.
In the new 2016 AST production, a new urban percentage mask is created from the 30m NSDI land cover map, which has been used in the post-classification processes to improve the quality of the urban type. By integrating high-resolution based urban mask, more detailed residential regions could be identified. Additionally, other artificial surfaces, such as industrial lands, could also be separated.
Surface Type Products Overview

- New global surface type map using 2016 VIIRS data was generated.

While the overall classification accuracy (~78%) of the new map is similar to 2015 delivery, some accuracy improvements are observed, such as urban/built-up lands. The images shown left demonstrate an example of the newly labeled oil drilling land in Texas, US, which is considered built-up lands, where the old version presented wrong type labels. Google images verified the mapping results.
### Surface Type Products Overview

#### Error matrix of estimated area proportions (in percentage). Overall accuracy is $77.9 \pm 0.6\%$.

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 74.5%

By incorporating new urban mask, the producer’s accuracy (omission) for urban/built-up increased approximately 23.5%.

#### Validation sites

#### Reference

<table>
<thead>
<tr>
<th>Map</th>
<th>Total (%)</th>
<th>User’s accuracy (%)</th>
<th>Producer’s accuracy (%)</th>
</tr>
</thead>
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Total: 0.0261 0.0216 0.0468 0.0148 0.1413 0.0868 0.0684 0.0919 0.0081 0.088 0.0663 0.0508 0.1006 0.1293 0.0121

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 74.5%.
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

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, 2017 annual ST map will be delivered at the Sep. of 2018.

• 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)
• 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
• 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

• 2016 VIIRS annual surface type (AST) classification map was generated, validated and in preparation of delivery through STAR-JPSS and other websites.

• High resolution land cover map (30 m NSDI) has been used to generate urban/built-up lands percentage for improving the quality of urban type. This data could also be used to improve other types, such as cropland, and current land/water mask.

• Validation results on 2016 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.
Path Forward

• 2018 Milestones:
  – Delivery 2017 Global Annual Surface Type (AST) classification map
  – Develop new land/water mask for science and other users from collection of high resolution land cover map.

• 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!
Land Product Characterization System

STAR JPSS Science Team Meeting
17 August 2017

Kevin Gallo: NOAA/NESDIS/STAR

collaborators

Greg Stensaas: USGS/EROS
John Dwyer: USGS/EROS
Ryan Longhenry: USGS/EROS
Land Product Characterization System (LPCS)

What is LPCS
Highlights of LPCS
  1. Search, Inventory & Ordering
  2. Analysis Tools
Path Forward
  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

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Tables and images provided for more intensive analyses.
What is LPCS

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

- Search, inventory & order data
- Advanced processing
- Basic analysis options
- Output charts, images, & tables
Search, Inventory and Ordering

Several options to search and order data. Can search by entering latitude and longitude information or interactively drawing area of interest.
NEW: Can search by location of several in situ networks.
Search, Inventory and Ordering

NEW: Can search by location of several in situ networks.
Search, Inventory and Ordering

**NEW:** Can search by location of several in situ networks (e.g., Konza Prairie, KS).
Search, Inventory and Ordering

Search for Landsat 8 data for comparison with GOES-16 ABI data for severe hail event in S. Dakota (June 2017).

Users can search for data from multiple sensors over selected range of dates.
Search, Inventory and Ordering

Search for Landsat 8 data for comparison with GOES-16 ABI data for severe hail event in S. Dakota (June 2017).

Selected Landsat 8 data (other data options available and planned)
Search, Inventory and Ordering

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<th>LPCS User Requirements Database</th>
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<td>EOS Land Core Sites</td>
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**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

*Included data sets not arbitrary.*
Search, Inventory and Ordering

USGS-NOAA validation synergy

USGS Requirements
- Landsat ECVs

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

Processing Data into Information
USGS-NOAA validation synergy

Several products of mutual interest (e.g. GOES-R ABI)
USGS-NOAA validation synergy

Several products of mutual interest (e.g. VIIRS)
Search, Inventory and Ordering

Search for Landsat 8 data for comparison with GOES-16 ABI data for severe hail event in S. Dakota (June 2017).

Once inventory of images provided, users can view browse images and...
Search, Inventory and Ordering

Search for Landsat 8 data for comparison with GOES-16 ABI data for severe hail event in S. Dakota (June 2017).

.... select scenes for further processing.
Search, Inventory and Ordering

2017 Highlight.... seamless handoff of data from inventory/ordering to processing system.
**Custom Processing**

### Higher Level Products

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

#### Climate Data Records
- Surface Reflectance

#### Other Landsat Level-2 Products
- Top of Atmosphere Reflectance
- Brightness Temperature
- Pixel QA
- Spectral Indices

#### Customize Outputs

#### Customization Options
- **Output Format**: GeoTIFF, ENVI, HDF-EOS2, NetCDF
- Reproject Products
- Modify Image Extents
- Pixel Resizing

#### Intercomparison & Statistics
- Plot Output Product Statistics
Custom Processing

Define Output Products

*Product Customization*

1. Several Output formats

2. Auto-registration of data to map projections

3. User defined area of interest

4. Defined pixel size for all images (30 – 5000 m)

5. Several resampling options
Custom Processing

Basic Analysis Tools

1. Product charts and tables
Custom Processing (summary)

Input products: resized, remapped.

Output products: images, charts, and tables.
Analysis Tools

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

EOS Land Validation Core Site: Konza Prarie, KS USA

Near-IR Surface Reflectance (Aqua/MODIS, L8, and Terra/MODIS.)
Analysis Tools

Tables provided with additional data for more intensive analyses.
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).

**Analysis Tools**

Simulated GOES-R ABI  
VIIRS  
Landsat 8
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

https://landsat.usgs.gov/lpcs

Public Release: February 2017

Includes a Landing Page and Tutorial

The National Oceanic and Atmospheric Administration (NOAA) and the U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center are collaborating on the development of a Land Product Characterization System (LPCS) that will facilitate the application of multi-satellite and in-situ data for characterization and validation of satellite-derived land-related products (e.g., Surface Reflectance, Normalized Difference Vegetation Index, and Land Surface Temperature). The system is designed to utilize data and products available and anticipated from the Landsat 8, ESA Sentinel-2 and -3 series of satellites, and other relatively high and medium resolution sensors, to assist in validation of GOES-16 Advanced Baseline Imager (ABI) and Suomi National Polar-orbiting Partnership (S-NPP)/Joint Polar Satellite System (JPSS) Visible Infrared Imaging Radiometer Suite (VIIRS) land products. Although initially designed to assess ABI and VIIRS land products, any of the sensor data or products included in the LPCS can be included in the products requested for comparative analysis with any of the other products available within LPCS.

The LPCS includes data inventory, access, and analysis functions that will permit the currently included land products to be easily identified, retrieved, co-registered, and compared statistically through a single interface. Output products from LPCS include graphics (charts) and tabular data, and georeferenced images of all sensors selected for analysis within LPCS. The LPCS functionality, and data sets available for analysis, are continually evolving. Full functionality within LPCS is currently limited to several Landsat and MODIS data products; however, placeholders are included for GOES-16 ABI and VIIRS products.

The land science community is encouraged to utilize the current LPCS capabilities, and is invited to provide feedback for future enhancements in the development of the LPCS. First-time users are recommended to review the below LPCS Tutorial that provides step-by-step guidance through the data searching criteria, advanced processing options, and output products. The LPCS User Guide provides detailed information related to the system features and functionality.

Access LPCS - direct access to LPCS.
LPCS Tutorial - provides step-by-step example of ordering data products through LPCS.
LPCS User Guide - provides important information about LPCS products and services.
User Feedback Form - provide input and feedback about searching portals, data products, and services.
Contact User Services - contact us with questions about LPCS.
LPCS Status and Readiness

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

**Current**

- Landsat 8

**Under Development**

- Joint Polar Satellite System (JPSS) Visible Infrared Imaging Radiometer Suite (VIIRS)
- NOAA-NASA Geostationary Operational Environmental Satellites - R Series (GOES-R)

**Future**

- European Space Agency (ESA) Sentinel-2
- Sentinel-3

**Surface Radiation Budget (SURFRAD) Network**

**The EOS Land Validation Core Sites**
LPCS proposed/accepted as CEOS-LPV Online Validation Tool.
CEOS LPV collaboration

Albedo (MODIS MCD43A3) added to LPCS (limited capabilities) as requested by CEOS-LPV.
CEOS LPV collaboration

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

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

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

https://landsat.usgs.gov/lpcs
NASA Land Science Team Status

Miguel Román (NASA GSFC)
Chris Justice (UMCP)
with contributions from:
The Terra/Aqua/Suomi-NPP Land Discipline Team
NASA’s Disasters Response Program

STAR JPSS NCWCP
8/17/2017 (13:55-14:15)
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✓ Completed Task;

S-NPP VIIRS Land Discipline Website ([http://viirsland.gsfc.nasa.gov](http://viirsland.gsfc.nasa.gov)) and current schedule including key milestones.
Significant greening of 25 to 50% of the Earth's vegetated lands was detected using data from the MODIS/VIIRS and NOAA-AVHRR satellite sensors of the past 34 years. This represents an increase in leaves on plants and trees equivalent in twice the area of the Continental USA.

The increase was linked to the fertilization effect from increasing concentration of carbon dioxide in the atmosphere.

Zhu et al., Greening of the Earth and its Drivers. Nature Climate Change, doi:10.1038/nclimate3004.
Global fire radiative power totals for 2015 showed that VIIRS can pick up as much fire activity as two heritage MODIS instruments: (Terra/MODIS: $6.1 \times 10^6$ MW; Aqua/MODIS: $13.4 \times 10^6$ MW; S-NPP/VIIRS: $19.6 \times 10^6$ MW).

VIIRS can detect significantly more fire activity compared to heritage MODIS fire products.

As a result, regions dominated by small and low intensity fires (e.g., Southeast Asia) are now becoming ever more apparent – enhancing awareness of global hotspots and improving carbon emissions accounting.

Credit: W. Schroeder & L. Giglio / UMD
New MODIS surface temperature data can pinpoint current and future communities that are most vulnerable to the detrimental effects of heat waves. These satellite products are helping guide efforts to advise local governments on effective climate adaption and mitigation strategies.
Objective: Develop a new land surface temperature and emissivity product using MODIS/VIIRS thermal infrared data that improves our ability to detect changes in land cover/use.

Finding: The new MOD21 emissivity product increased sensitivity to land cover changes from desertification (left image) in a more consistent manner to complement existing long-term time series of vegetation data.

Significance: Desertification in drylands at the fringes of the world's major deserts has been a prime environmental concern affecting the livelihoods of millions of people on Earth. The new MOD21 product will monitor desertification in these regions with much greater sensitivity than previously possible.

Tracking Nature’s Calendar using Suomi-NPP VIIRS

Daily Global VIIRS observations enables scientists to track the timing and magnitude of plant growth.

VIIRS also provides accurate information related to the timing of ecosystem properties, which is important for monitoring forests, croplands, grazing lands, and as input for modeling weather and biospheric processes.

Who uses MODIS phenology products? (1) Farmers, ranchers, and meteorologists that want to monitor drought extent and severity; (2) foresters that want to detect disturbances related to wind damage, pests and disease outbreaks, and invasion of exotic species; (3) public health officials looking for short-term forecasts of allergenic pollen; (4) scientists looking to improve weather and environmental models; and (5) tourists and the travel industry with information on the timing and location of spring wildflowers blooms or peak fall foliage.
MODIS/VIIRS, Landsat, and GOES Enable Daily Monitoring of Crop Condition and Water Use

Frequent observations at the field level are necessary for effective precision agriculture, which benefit local farmers. Daily monitoring of crop condition and water use at fine scales has become possible by fusing MODIS/VIIRS, Landsat and Geostationary data. These measurements are critical for decision making in estimating crop yield, mitigating risks and ensuring food security.

Daily monitoring of vineyard water use and conditions for optimal grape management.
Disaster Risk Reduction and Response from a NASA Perspective

- Engagement with Stakeholders and Partners
- Monitoring and Observation
- Data Acquisition, Processing, and Distribution
- Interpretive and Decision Support

https://disasters.nasa.gov/
https://disasters.nasa.gov/argentina-summit-2017
Disaster Response Capacities

- **Airborne Instruments**
  - UAVSAR – Radar
  - LVIS – Lidar
  - AMS, MASTER – Thermal Infrared
  - HIWRAP, APR2, HAMSR, HIRAD, PALS
  - MAPIR – Active and passive microwave

- **Data processing, analysis systems, Data Centers**
  - EOSDIS-ESDIS
  - LANCE/NRT/DB

- **Modeling and Analysis**
  - Flood and Earthquake Models,
    Damage and infrastructure Maps,
    Day/Night and plum extent maps
  - Capacity Building
  - Response Exercises & Simulations
2016 Midwest Floods

Sensor: ALOS-2 SAR (JAXA)
Coverage: 70km x (240km + 420km)
Resolution: ~12m
Blue pixels: Open Land Floods
Red pixels: Vegetation Floods
Available online at http://aria-share.jpl.nasa.gov/events/

FEMA stated that SAR provides inspection priority for optical imagery and ground response. The ALOS-2 data and the products have been a very important source of information during this response as the flood crest has moved downstream. The SAR data continue to be an important resource during times when optical observations are often not useful.
Massive fires extent over 100’s of kilometers (km) in Chile, and the smoke pollution extends 1000s of km over the Pacific Ocean.
Puerto Rico Goes Dark

Puerto Rico
San Juan
Aguirre Power Station

BEFORE (Sept 21, 2016; 02:00EDT)

Puerto Rico
San Juan
Aguirre Power Station

AFTER (Sept 22, 2016; 02:10EDT)

https://earthobservatory.nasa.gov/NaturalHazards/view.php?id=88796
syria from space
At Year 5, the S-NPP Land Discipline team has met its mission success criteria – (1) Provide continuation of the EOS measurements for at least 3 years; (2) Provide risk reduction for JPSS 1/2 and beyond.

The focus now is on transition of EOS continuity products into designated DAACs by Mid-to-Late 2017.

Continued exploitation of unique S-NPP capabilities (e.g., 375m Fire, NASA Black Marble) into LANCE NRT and other decision support systems.

Increased emphasis on multimission and multisensor innovative research that can be used to quantify change, characterize human-natural processes, and examine function within the Earth System over time.
CEOS/WGCV/LPV Update

Miguel Román (NASA)
Miguel.O.Roman@nasa.gov

Tomoaki Miura (University of Hawaii at Manoa)
TomoakiM@hawaii.edu
# CEOS-LPV Structure and Agency Programs

<table>
<thead>
<tr>
<th>Group</th>
<th>First Name</th>
<th>Surname</th>
<th>Country</th>
<th>Supporting Agency / Program</th>
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NOAA Contributions to LPV

- LPV focus area leads funded by NOAA – Vegetation Indices, Land Surface Temperature
- Creates operational NDVI, Fire, Snow products
- NOAA PIs on the VIIRS Land Science team are developing and validating VIIRS Environmental Data Records (EDRs)

EUMETSAT Contributions to LPV

- CEOS leadership – vice-chair of WG Climate
- Albedo focus area lead supported by EUMETSAT
- Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring – SCOPE-CM – retrieval of satellite albedo from geostationary satellites from various agencies
Area and accuracy estimation of land change
Pontus Olofsson (Boston University)

- Image classification errors can greatly bias mapped areas of land change – also, “pixel-counting” in maps is inconsistent with IPCC criteria reporting of land change.
- CEOS-LPV is providing guidance to implement protocols for unbiased estimation of area and accuracy.
- NASA and other agencies support development and implementation of estimation protocols.
Rigorous design-based validation of global burned area products, in which reference data are selected via a probability sampling design, is effective in reducing the standard errors of accuracy and area estimators compared to simple random sampling.
Multi Angle Imaging BRDF Unmanned aerial system

SuperSwift Platform with:
(1) Soil moisture radiometer,
(2) Volcano payload,
(3) MALIBU
MALIBU Campaign Status

- Ortho-rectified imagery @ BSRN Table Mountain (Nov 30, 16.)
- FAA approvals went through without a hitch – from flight request, to approval, to deployment in < 2 weeks!

Time Series plot from: https://www.esrl.noaa.gov/gmd/grad/meetings/BSRN_talks/P2_3_Crystal_Schaaf_BSRN_validation_2016_v0.8.pdf
### 3.2 Progress on the implementation of the CEOS Strategy for Carbon Observations from Space

<table>
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<th>CARB-19: Land product validation listing and framework</th>
<th>Q4 2017</th>
<th><strong>Summarize current list of validated land data products relevant to Carbon Strategy.</strong></th>
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<td>Document validation framework and protocols</td>
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<td>Provide guidance for online platform for intercomparison of terrestrial carbon products.</td>
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<td>WGCV</td>
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CEOS/WGCV/LPV has completed listing of 11 carbon-focused variables, totaling 138 land products from 11 CEOS Agencies.

https://lpvs.gsfc.nasa.gov/

- 9 product categories are listed as GCOS Essential Climate Variables (ECVs*).
- 2 product categories are listed as GEOBON Essential Biodiversity Variables (EBVs*).
CARB-19: Land product validation listing (Example #3)

CEOS-LPV Validation Reports – Land Surface Temperature & Emissivity Focus Area

Provides List of Products with
• Meta-data
• Contacts
• Links to Validation Reports
• Links to Data Centers
| CARB-19: Land product validation listing and framework | Q4 2017 | **Summarize current list of validated land data products relevant to Carbon Strategy.** Document validation framework and protocols Provide guidance for online platform for intercomparison of terrestrial carbon products. | WGCV |
CARB-19: CEOS Land Validation Framework

- CEOS LPV has established a framework with the aim of independent validation and consistent uncertainty reporting across products as main output.
- Multiple agencies are coordinating five actionable tasks:
  1. [NASA] Developing best practice validation protocols, where validation methods are sent through rigorous peer-review (Q4-2018).
  2. [NOAA/ESA/EUMETSAT] Ensuring access to processed fiducial reference data (ongoing).
  3. [USGS/NOAA] Supporting automated subsets of global satellite products (LPCS; Q2-2017.)
  4. [NASA] Implementing data analysis tools (Q2-2018).
  5. [NASA/ESA] Delivering standardized intercomparison and validation reports (Q4-2018)

Schaepman-Strub et al., (2017) submitted
Protocol Status: LST validation protocol document is complete and undergoing peer-review. The protocol will present recommendations on internationally accepted validation good practices.

Overarching Goal: To ensure thematic compatibility across products, reference datasets, and methods. CEOS agency deliverables include:

- Support product development, validation, and interconsistency efforts (ROSES, MEaSUREs), maintain the On Line Interactive Validation Exercise (OLIVE) platform to assess global satellite products (LAI, Albedo, LST).

- Maintain observational networks in the US (BSRN/SURFRAD, USCRN) used for routine validation of LST.

- Develop and maintain the online Land Product Characterization System (https://landsat.usgs.gov/lpcs) to facilitate the characterization and validation of multi-satellite products using in-situ data.

- Provide users with multi-mission LST data (GlobTemperature). Engage with the user community through the International LST and Emissivity Working Group (http://ilste-wg.org).

CV-12 WGCV action: Evaluation of validation supersites and new validation approaches

Evaluation of well-characterized supersites with data continuity prospects for validation purposes that allow for testing of products, algorithms, and validation strategies through radiative transfer modeling.

LPV Supersite Definition

- A Supersite should be fully characterized (3D canopy structure, plus key land variables) to allow a RT model parameterization, whereas a core site refers typically to the same variable.

- A Supersite should be useful for the validation of several land products (> 3).

Candidates Networks:

- TERN Australian Super Sites
- ICOS Ecosystem network
- NEON
- Sites proposed by LPV members
National Ecological Observatory Network (NEON)

- Continental-scale ecological observation facility sponsored by the National Science Foundation to gather and synthesize data on the impacts of climate change, land use change and invasive species on natural resources and biodiversity.
- Strategically locates sites across the U.S. to capture variability in ecological and climatological conditions (terrestrial and aquatic stations).
- Coordinates local measurements in the field with high-resolution airborne remote sensing.
- Provide resources for the ecological community to integrate observations and datasets independently, such as collection and processing protocols.
- NEON network includes core and relocatable terrestrial sites across the U.S. (including Alaska, Hawaii and Puerto Rico). Core sites (20) are fixed, collect data for a minimum of 30 years and are designed to represent and capture wildland conditions. Relocatable sites (27) move through time to capture environmental gradients not captured at core sites.
- Open access to sites data is provided through the NEON data portal (http://data.neonscience.org/home).

Contact:
- Shelley Petroy

source: http://www.neonscience.org/science-design/field-sites
http://www.neonscience.org/science-design/spatiotemporal-design
The networks referred previously have been investigated to select the candidate sites. Two major criteria were first applied:

- **Availability of data**: the station is active.
- **Spatial representativeness**: to guarantee the highest level of homogeneity and to minimize issues associated with spatial representativeness in the point-to-pixel comparison.

- Using high resolution satellite images (available via Google Earth™), to identify those matching the requirement of homogeneity in the area surrounding the measurement tower
- Only visually homogeneous sites at 3x3 km and 1x1 km are considered.

### Overall, 61 Supersites selected out of:

- TERN: 18 nodes in 10 Supersites
- ICOS: 71 sites
- NEON: 47 sites
- LPV: 13 sites
Vegetation Index Focus Area

- May 2016: Proposed at CEOS WGCV LPV meeting
- Sep 2016: Officially established
- Nov 2016: Held a VI & LSP workshop (Fort Collins, CO)

1) Initiate the development of validation protocols for Vegetation Indices and Land Surface Phenology products.

2) Develop a strategy to advance the validation stage of one or more operational Land Surface Phenology Products and one or more Vegetation Index Products
   - To learn the current validation status of VI products
   - To exchange validation methodologies used for VI products
   - To discuss and develop a list of action items and a strategic plan
Participants touring NEON site caught on the PhenoCam!
Three components of VI validation needed to define and characterize VI uncertainties and to satisfy the user needs:
1) Uncertainty of VIs in their units (e.g., $\Delta$NDVI)
2) VI sensitivity to vegetation biophysical/physiological conditions
3) Long-term stability of VI time series data

Potential data sources for VI validation were identified:
- NEON airborne hyperspectral data
- AERONET-based surface reflectance data
- Ground-/drone-observational reflectance data
- FLUXNET data

*Each participant volunteered to look into one or more of these datasets and to begin evaluating their VI products of interest
Vegetation Index Focus Area

- **Mar 2017:**
  - Else Swinnen (VITO) appointed as co-lead
  - Invitation to participate in the VI focus area was sent (127 potential participants)

- **July 2017:**
  - The VI focus area website launched and completed ([https://lpvs.gsfc.nasa.gov/NDVI/VI_home.html](https://lpvs.gsfc.nasa.gov/NDVI/VI_home.html))
  - Updated VI product list
  - Updated VI validation references
Vegetation Index Focus Area

Action Items:
- Preliminary validation exercises using the identified validation data sources
- Selection of a globally representative set of sites for inter-comparison
- Inter-comparison exercise
- Reconvening in a year or 1.5 years
Visit our web site, subscribe to the listserv!
lpvs.gsfc.nasa.gov
Incorporate Satellite GVF & LAI Products into NOAA NEMS System

Yihua Wu$^{1,2}$, Weizhong Zheng$^{1,2}$, Mike Ek$^{2}$, Yunyue Yu$^{3}$, Marco Vargas$^{3}$

$^{1}$IMSG at NOAA/NCEP/EMC, $^{2}$NOAA/NCEP/EMC, $^{3}$NOAA/NESDIS/STAR
Outline

• Motivation
• Products of GVF & LAI
• Numerical Experiments
• Results
• Summary
Motivation

• Both GVF and LAI are very important parameters for representing the interactions between the land surface and the atmosphere in LSM. GVF is used to characterize land surface while LAI is used to characterize plant canopies in LSM.

• Both GVF and LAI have seasonal, spatial changes and annual variations; both can be affected by natural hazards, such as droughts, frosts and wild fires.

• The GVF currently used in NOAA Environmental Modeling System (NEMS) are monthly mean values from AVHRR data (from April 1985 to March 1991 with year 1988 excluded)

• The LAI used in the current model systems is an unrealistic constant value for all plant types.
The Easter Freeze of April 2007

- In March 2007, unseasonably warm weather over the eastern half of the United States prompted early growth of many agricultural and horticultural crops.
- In early April (4-10), an arctic cold hit the same region. Air temperatures in many locations were well below 25°F and lasted almost a week in some areas.
- The widespread freeze extensively damaged agriculture in 18 states in the region, resulting in losses over $2 billion. Many farmers lost about 90% or nearly all of their crops.
- It also caused problems in NOAA weather forecast.
Canopy Damage from The Easter Freeze of April 2007

LAI Reduced by The Easter Freeze of April 2007

2006

2007

Chestnut Ridge, TN

Model ET
NAM

Observed ET

Latent Heat Flux (W m⁻²)

LST

OBS_LH
OBS_LH-sw
OBS_LH-res
NLDAS_LH
NDAS_LH
NAM_LH
NARR_LH
GLDAS_LH
GDAS_LH
GFS_LH

Courtesy: Tilden Meyers
Products of GVF & LAI

- Near real time satellite products for GVF starting from 2012 have been developed.
- Near real time LAI products will be developed from VIIRS?
- These new products have weekly values and are updated daily.
- These new products have 4-km resolution at global scale and 1-km resolution at regional scale.
- The products will be in lat/lon project and in GRIB2 data format.

http://www.ospo.noaa.gov/Products/land/gvf/
Comparison between VIIRS and Climatology GVF

- Climatology GVF green up earlier
- Climatology GVF is higher most of a year

VIIRS GVF is higher at high latitude in January
- VIIRS GVF is much lower over the entire USCONUS in April
- VIIRS GVF is higher in southeast US in July
- VIIRS GVF is higher over the eastern US
2014 Cold Spring & Drought Effects on GVF in US

GVF Difference (VIIRS-CLIMO) 20140416

February 2014 Mean Temperature Departure from 1981-2010 Normal

March 2014 Mean Temperature Departure from 1981-2010 Normal

Numerical Experiments

• NAM was run with 2 GVF products for 2014: AVHRR climatology, the real time VIIRS GVF
• The BUDGET method was used to interpolate the products to the NAM domain (at least 25 points are chosen in one model grid box, then are weighted with area to get one value for the model grid box)
• Data on 24 days (two from each month, the beginning and middle day of each month) were used for tests. Total 48 runs were conducted with the 2 GVF products.
• 84 hour simulation was conducted for each run. Analysis was done for all land points over 218 grid domain.
Land Surface Albedo in the Two Runs

- **CLIMO**
- **RGVF1**

Date: 1/1/14 to 12/17/14

Albedo values and forecast hours are shown for each run.
Flux Difference Between the Two Runs

- NRTGVF-CLIMA-USWRF
- NRTGVF-CLIMA-ULWRF
- NRTGVF-CLIMA-GHF
- NRTGVF-CLIMA-LHF
- NRTGVF-CLIMO-SHF
DPT2m & TMP2m Difference Between the Two Runs
Bias & RMSE of DPT2m & TMP2m in the Two Runs
Summary

- Near real time VIIRS GVF products has been developed and tested with the North American Model system.
- Numerical sensitive tests were conducted with NAM for 2014
- Replacing Climatology GVF changes not only GVF, but also surface albedo in NAM.
- The near real time GVF has smaller values which reduced latent heat fluxes, increased sensible heat fluxes, and reduced the NAM wet bias of DPT2m and cold bias of T2m in 2014
- VIIRS GVF dataset have been produced to enable ingest into the NCEP NEMS system
- Near real time LAI will be developed soon, and be used in NCEP NEMS system?
Application of Satellite Land Surface Observations in NCEP Models: VIIRS GVF Data

Weizhong Zheng¹,² and Mike Ek¹

¹NOAA/NCEP/Environmental Modeling Center, College Park, MD
²IMSG@NOAA/NCEP/EMC, College Park, MD

Contributions: Jiarui Dong, Yihua Wu, Helin Wei, Jesse Meng and Youlong Xia (NCEP/EMC); Marco Vargas, Zhagyan Jian, Xiwu Zhan, Jicheng Liu, Li Fang, Jifu Yin, Yunyue Yu and Ivan Csiszar (NESDIS/STAR); Zhen Song (UMD)
Motivation

**Objective:**
To improve satellite data utilization over land in NCEP forecast models and data assimilation system and then improve the numerical weather prediction (NWP).

**Land satellite data assimilation:**
- Utilization of satellite data sets in the models (e.g., GVF, snow, burning area, albedo, emissivity, LST, radiation, vegetation and soil type, etc.)
- Assimilation of satellite products (e.g., Soil moisture (SMAP, SMOPS); snow);
- Direct radiance assimilation (Tb)

  Requiring a forward radiative transfer model (RTM) to calculate Tb with input of model atm profiles and sfc parameters. (sfc emissivity, sfc parameters).

  (Understand the interaction and feedback between land and atmosphere, and then improve NWP and DA)
- **NCEP Operations**: Monthly 0.14-deg (16-km) global climatology of GVF

- **Weekly GVF**: VIIRS near real-time weekly global 0.036-deg (4-km) GVF

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

- **The other GVF data sets are also examined**:  
  (a) Near real-time weekly AVHRR (Le Jiang et al., NESDIS);  
  (b) Near real-time weekly MODIS (Xiaoyang Zhang, SD State U.).
Multi-year mean VIIRS GVF over CONUS
Average VIIRS GVF over CONUS: Near Real-Time
Average AVHRR GVF over CONUS: Near Real-Time
Average MODIS GVF over CONUS: Near Real-Time

GVF (%) vs. Ave (CONUS)

- Clim
- VIIRS: multi-year weekly mean
- MODIS: Real-Time 2012
- MODIS: Real-Time 2013
- MODIS: Real-Time 2014

Courtesy Xiaoyang Zhang for MODIS data
VIIRS GVF (4-y monthly mean) test:

5/02 – 6/02, 2016
Near real-time VIIRS GVF is similar to the 4-year VIIRS monthly mean;

Both are lower than the old AVHRR monthly climatology.
- Near real-time VIIRS GVF is similar to the 4-year VIIRS monthly mean;

- Both are lower than the old AVHRR monthly climatology.
(mean) test:  5/02 – 6/02, 2016

AC:  HGT 500 hPa G2/NHX

Precipitation Skill Scores over CONUS:  f12-f36

VIIRS test:  Improve AC score @500 hPa.

VIIRS test:  positive impact for light precipitation
VIIRS:
Increase warm bias and RMSE!
VIIRS: Increase warm bias and RMSE!
VIIRS:

**East CONUS:**
Reduce wet bias and RMSE.

**West CONUS:**
Increase dry bias and RMSE.
VIIRS GVF (4-y monthly mean) test:

5/13 – 6/15, 2014
VIIRS test: Improve AC score @500 hPa.
East CONUS

VIIRS:
East CONUS:
Reduce RMSE.

West CONUS:
Increase warm bias.

West CONUS
VIIRS:

**East CONUS:** Reduce wet bias and RMSE.

**West CONUS:** Increase dry bias.

---

**W. CONUS  5/13-6/15, 2014**

- **East CONUS**
- **West CONUS**
Temp Bias

VIIRS: Increase warm bias and RMSE!
Summary

- Several satellite data sets developed recently (e.g., GVF, snow, burning area, albedo, radiation, soil and vegetation type) have been tested in the NCEP models. The results show good improvements, compared with the current data sets; However, some data sets need further validation with ground measurements, and consistence of all these data sets is required.

- VIIRS GVF data has lower values than other data sets, especially in growing seasons, which needs further investigation with ground measurements.

- We will continue our efforts and working together with several research teams including NESDIS to improve satellite data utilization and data assimilation and then improve NCEP NWP.
Thank You!

Any questions/comments?
VIIRS VI Product Validation Methods

1. Global Inter-comparison with Aqua MODIS (or other sensors)

2. Validation using subsets
   a) Inter-comparison with Aqua MODIS
   b) Comparison with Aeronet-based surface reflectance
   c) Comparison with in situ reflectance (tower, UAV, airborne)
   d) Validation using FLUXNET productivity data
Global Comparison with Aqua MODIS

APU for the Month of July (DOY 192, 194, & 197) 2017

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<tr>
<th></th>
<th>TOA NDVI</th>
<th>TOC EVI</th>
<th>TOC NDVI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Global APU</td>
<td>L1R</td>
<td>Global APU</td>
</tr>
<tr>
<td>Accuracy</td>
<td>0.016</td>
<td>0.05</td>
<td>0.020</td>
</tr>
<tr>
<td>Precision</td>
<td>0.011</td>
<td>0.04</td>
<td>0.009</td>
</tr>
<tr>
<td>Uncertainty</td>
<td>0.019</td>
<td>0.06</td>
<td>0.022</td>
</tr>
</tbody>
</table>

Global APU Time Series Plots for 2017
Inter-Comparison of VI Profiles

**Missouri Ozark (DBF)**

**Grignon, France (CRO)**

**Daly River Pasture (GRA)**
Quality of VIIRS VI time series data were quantitatively evaluated by inter-comparing phenological metrics extracted from VIIRS VIs to those from MODIS and Tower VI time series data at 11 AmeriFlux sites located in the conterminous US.
Comparison with *in situ* VIs

Quality of VIIRS VI time series data were quantitatively evaluated by inter-comparing phenological metrics extracted from VIIRS VIs to those from MODIS and Tower VI time series data at 11 AmeriFlux sites located in the conterminous US.
Quality of VIIRS VI time series data were quantitatively evaluated by inter-comparing phenological metrics extracted from VIIRS VIs to those from MODIS and Tower VI time series data at 11 AmeriFlux sites located in the conterminous US.
Inter-Comparison of Start and End of Growing Seasons (SOS & EOS) Derived from VIIRS, MODIS, and Tower NDVI

- **MODIS SOS (NDVI)** vs. **Tower SOS (NDVI)**: $y = 0.98x + 4.33$, $R^2 = 0.90$
- **MODIS SOS (NDVI)** vs. **VIIRS TOC SOS (NDVI)**: $y = 1.06x + 7.27$, $R^2 = 0.94$
- **MODIS SOS (NDVI)** vs. **VIIRS TOA SOS (NDVI)**: $y = 1.14x + 22.31$, $R^2 = 0.91$
- **MODIS EOS (NDVI)** vs. **Tower EOS (NDVI)**: $y = 0.79x + 50.94$, $R^2 = 0.36$
- **MODIS EOS (NDVI)** vs. **VIIRS TOC EOS (NDVI)**: $y = 1.30x + 92.74$, $R^2 = 0.82$
- **MODIS EOS (NDVI)** vs. **VIIRS TOA EOS (NDVI)**: $y = 1.27x + 85.85$, $R^2 = 0.84$
Inter-Comparison of Length of Growing Season Derived from VIIRS, MODIS, and Tower VIs

Tower vs. MODIS (C6)  
\[ y = 0.99x + 0.81 \]  
\[ R^2 = 0.87 \]

Tower vs. VIIRS  
\[ y = 0.93x + 4.79 \]  
\[ R^2 = 0.89 \]

MODIS (C6) vs. VIIRS  
\[ y = 0.89x + 7.93 \]  
\[ R^2 = 0.83 \]