SNOW, ICE, AND POLAR WINDS

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The Cryosphere and JPSS

River and lake ice ✓

✗ Ice sheets, ice caps, ice shelves

Sea ice ✓

Snow ✓

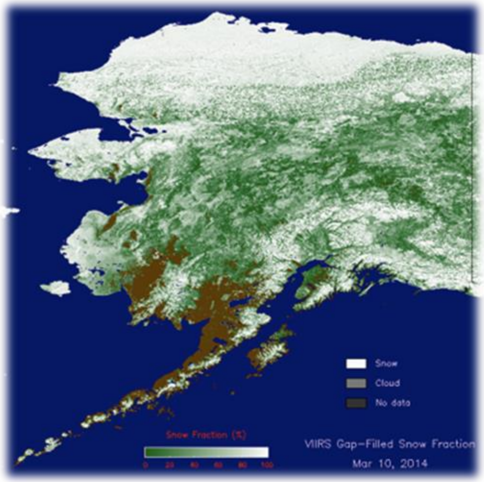
✗ Permafrost and seasonally-frozen ground

✗ Glaciers

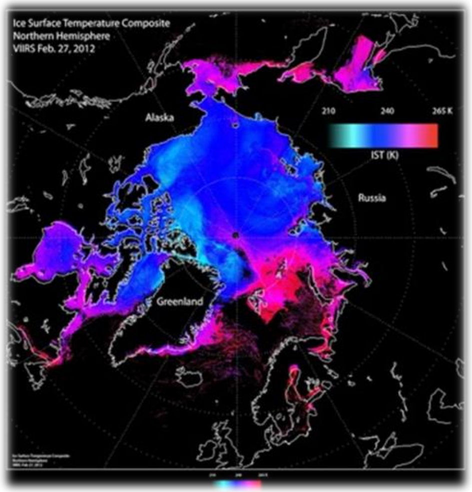
Global Cryosphere Watch

VIIRS Operational Products

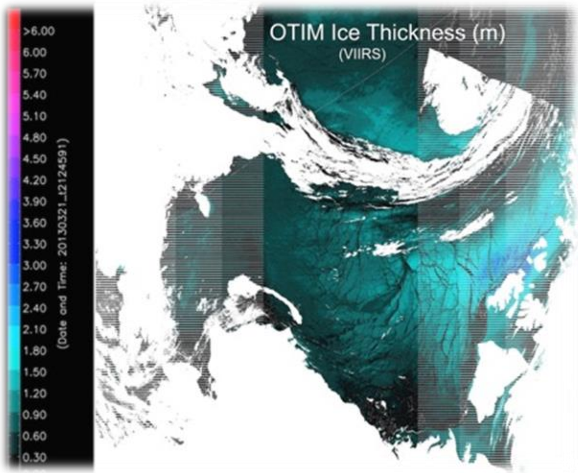
Snow Fraction



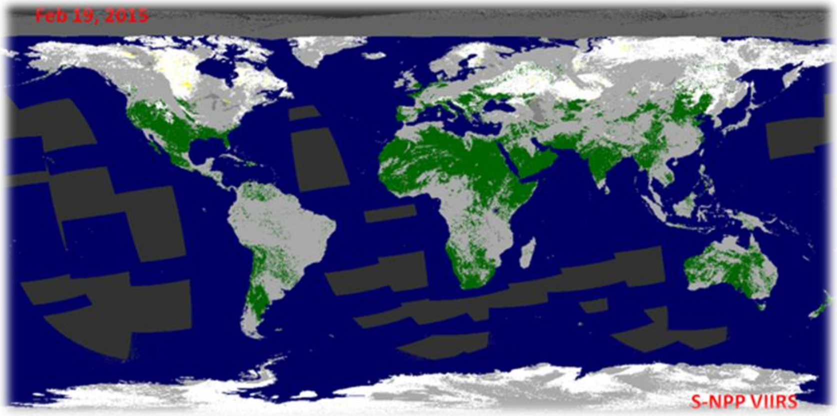
Ice Surface Temperature



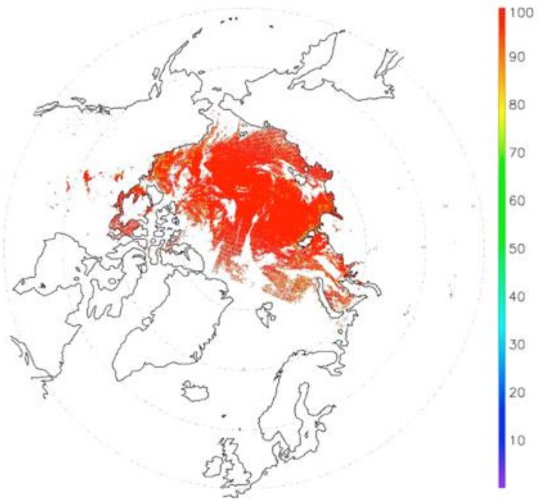
Ice Thickness/Age



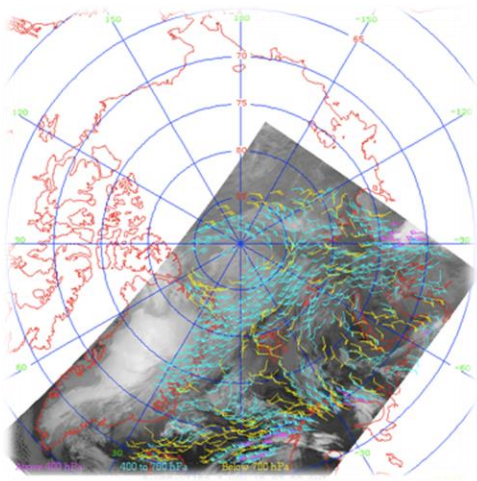
Snow Cover (binary)



Ice Concentration

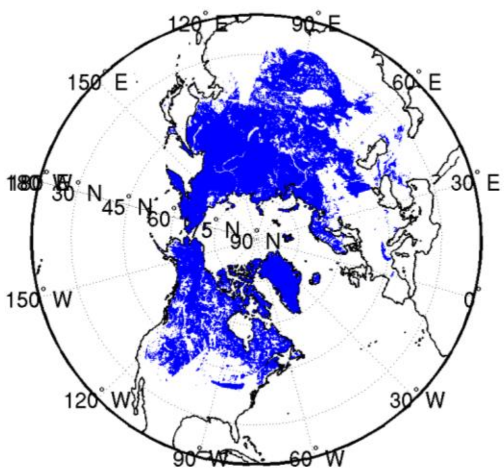


Polar Winds

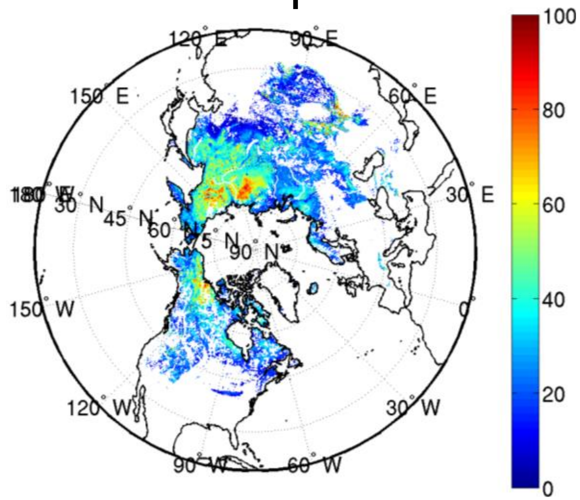


AMSR2 Operational Products

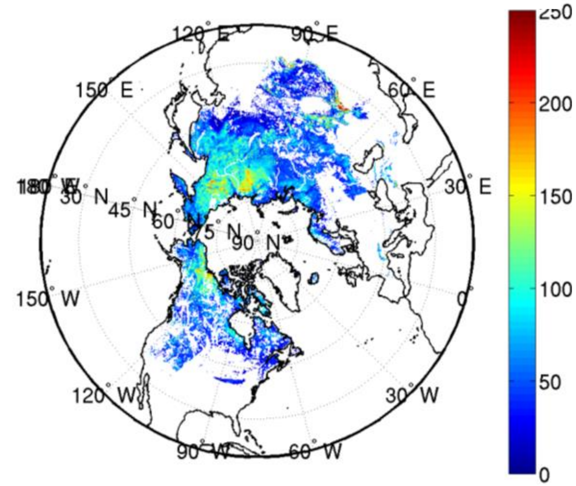
Snow Cover

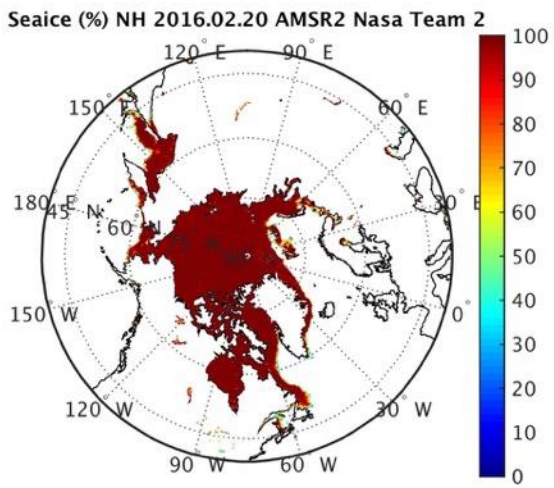


Snow Depth



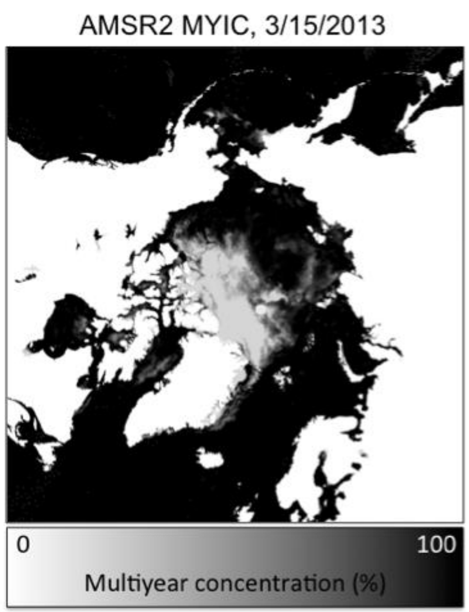
Snow Water Equivalent



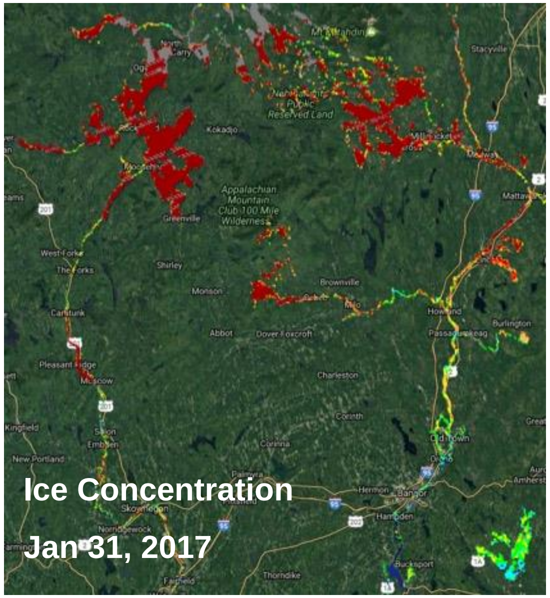


Sea Ice Concentration

Sea Ice Type

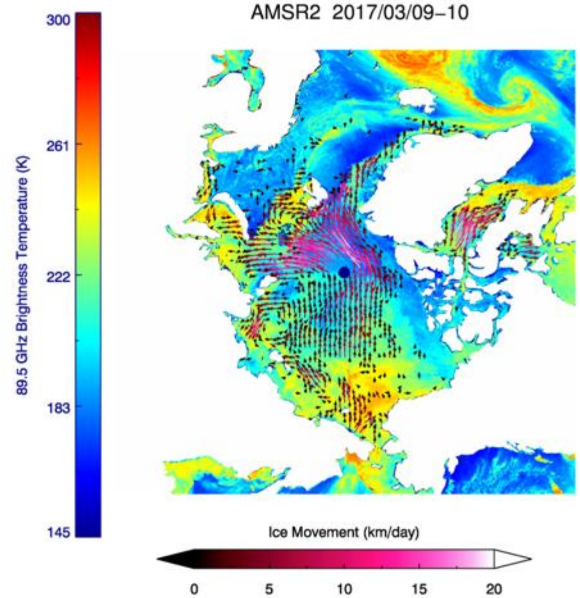


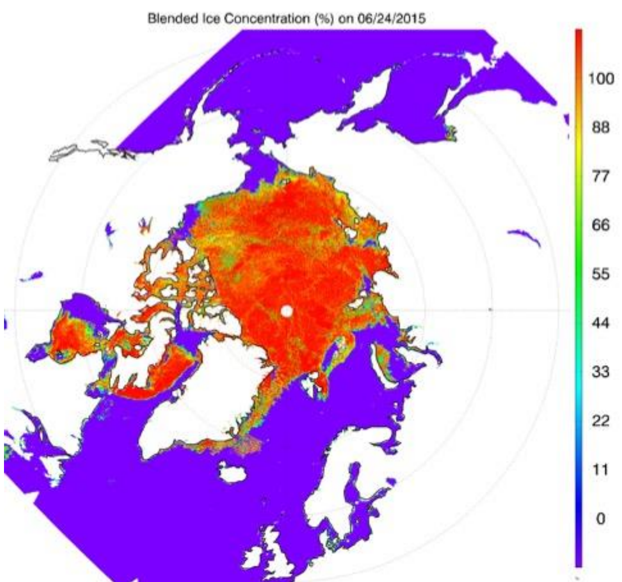
Experimental Products



River Ice

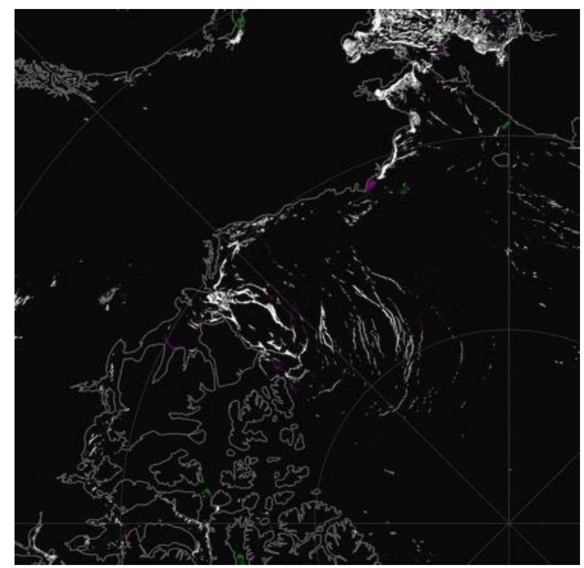
Ice Motion





Blended Ice Concentration

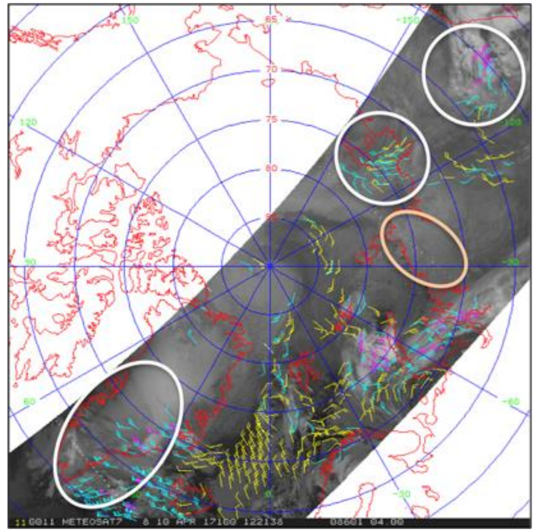
Sea Ice Leads

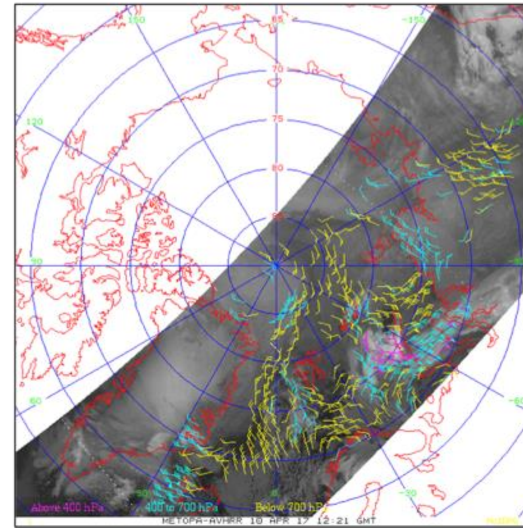


Experimental Products, cont.

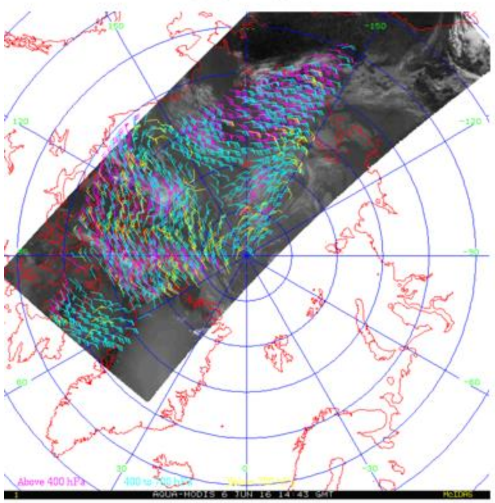
Winds from combined S-NPP and JPSS-1

Far right: Single-satellite AVHRR winds. Right: Winds from Metop-A and –B.

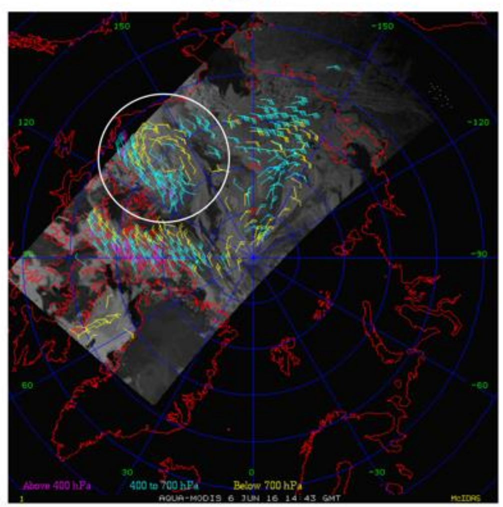




WV + IR



SWIR



Polar winds with the SWIR band

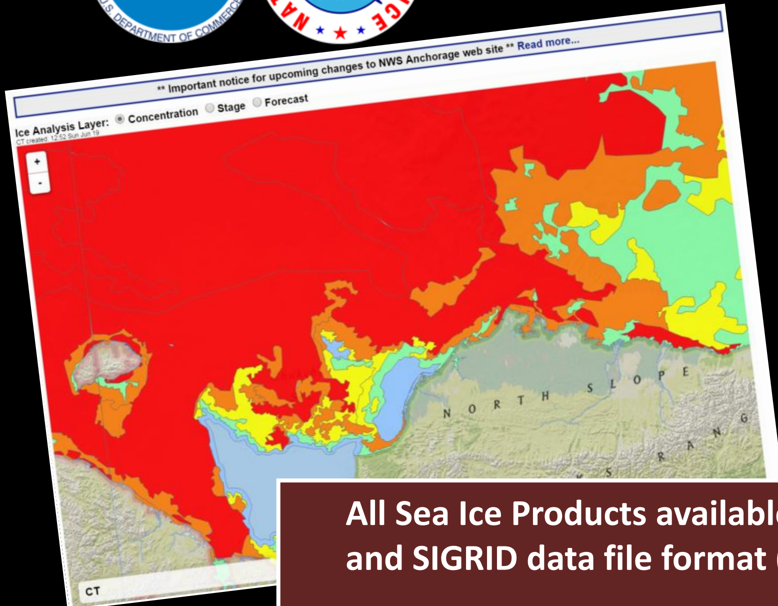
Summary

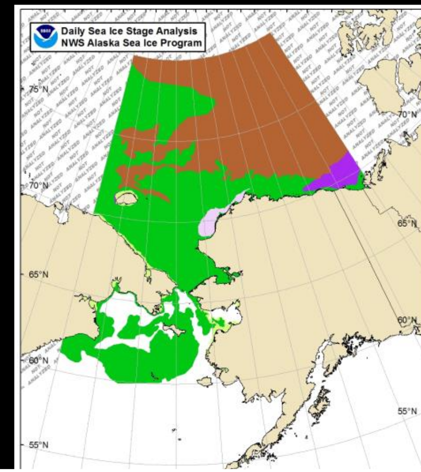
- VIIRS Products:
  - Snow: Binary snow cover, snow fraction
  - Ice: Ice surface temperature, ice concentration, ice thickness/age
  - Polar winds
- AMSR2 Products:
  - Snow: Snow cover, snow depth, snow water equivalent
  - Ice: Ice concentration, ice type
- VIIRS ice products are being added to PolarWatch.
- All products meet requirements.
- All products are operational.
- Planned improvements for J1 are minor and all are ready.
- Experimental products include river ice, ice motion, blended ice concentration, sea ice leads, polar winds with new bands, winds from tandem satellites.

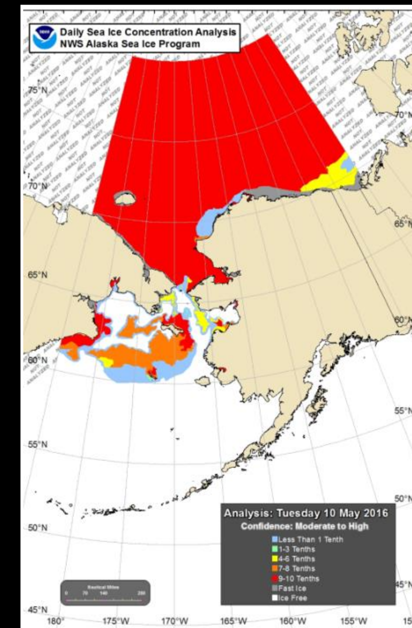
NWS Alaska
Sea Ice Program (ASIP)

Evaluation of JPSS VIIRS and AMSR-2 Ice Products

Products – Issued Daily







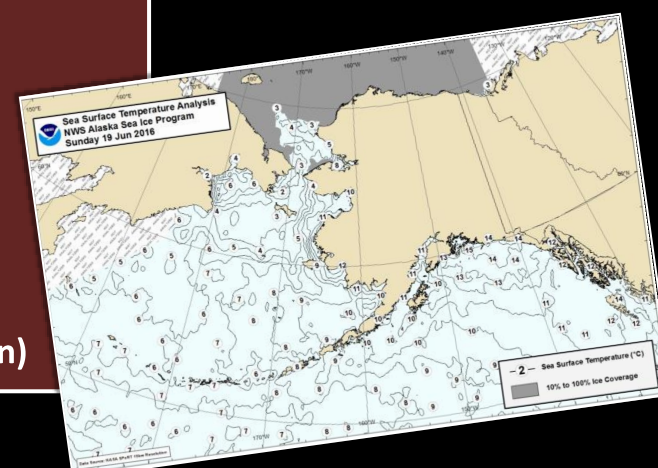
All Sea Ice Products available in WMO Standard color mapping and SIGRID data file format (as of Oct 2015)

Daily Sea Ice Products

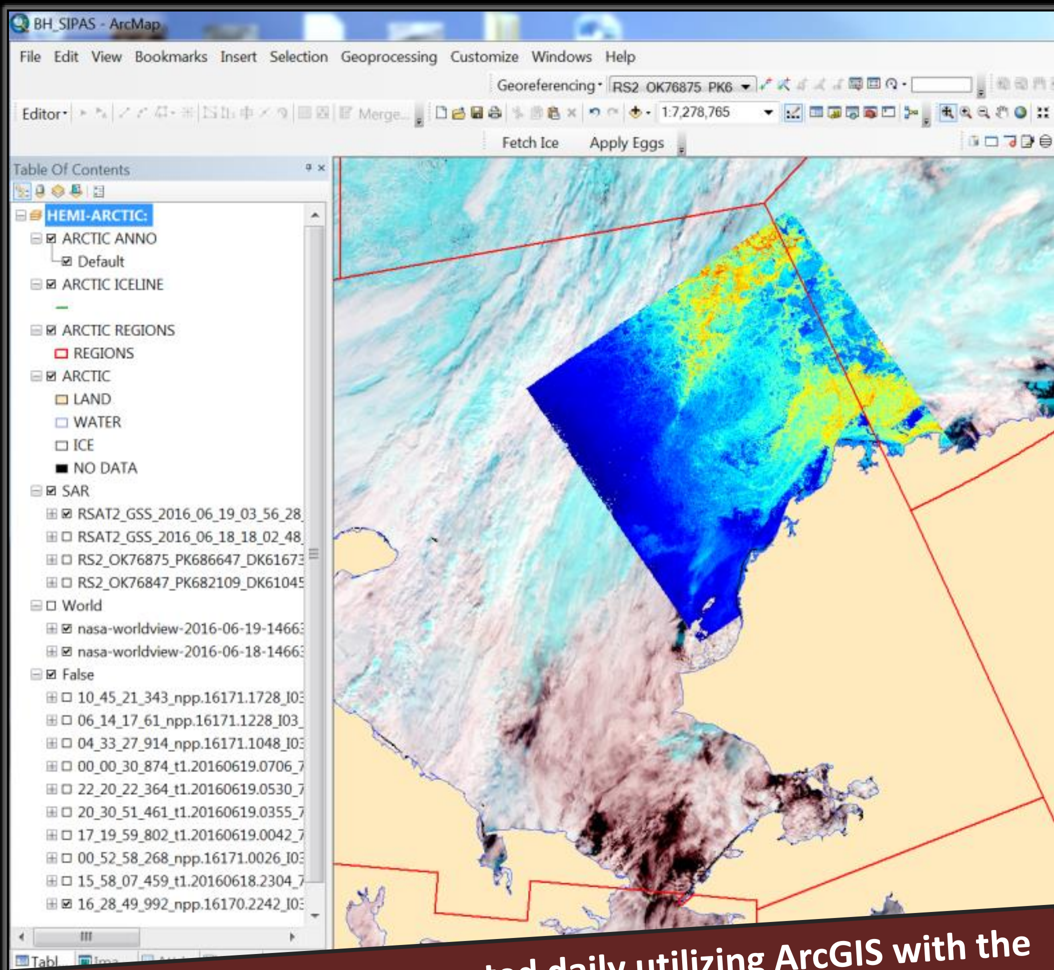
- Sea Ice Concentration Analysis Map
- Sea Ice Stage Analysis Map
- SIGRID shapefiles
- KMZ data files
- ESRI interactive map display (Concentration/Stage/Forecast)

Daily Sea Surface Temperature Maps

- Utilizing NASA SPoRT dataset (15km resolution)



Operations – Resources



Sea Ice Analysis are generated daily utilizing ArcGIS with the SIPAS application – Generously shared with us by the NIC

Primary Satellite Resources:

- RadarSAT2
- Sentinel-1a & Sentinel-1b
- Suomi NPP
  - Day-Night-Band
  - IR/Visible (True and False Color)
  - Obtained via GINA Puffin Feeder
- NASA Aqua & Terra
  - IR/Visible (True and False Color)
  - Obtained via NASA Worldview webpage & GINA Puffin Feeder

Sea Ice Forecasting Resources:

- Ice Analyst Experience & Knowledge
- ACNFS (soon to be GOFS 3.1)
  - Obtained via ftp with the NIC
- Weather Models in AWIPS
- Understanding of Local Currents and Bathymetry
- Buoy data and local observations
- MMAB Drift Model
- Seasonal Experimental Models:
  - ESRL-RASM
  - COAMPS
- Future: NGGPS

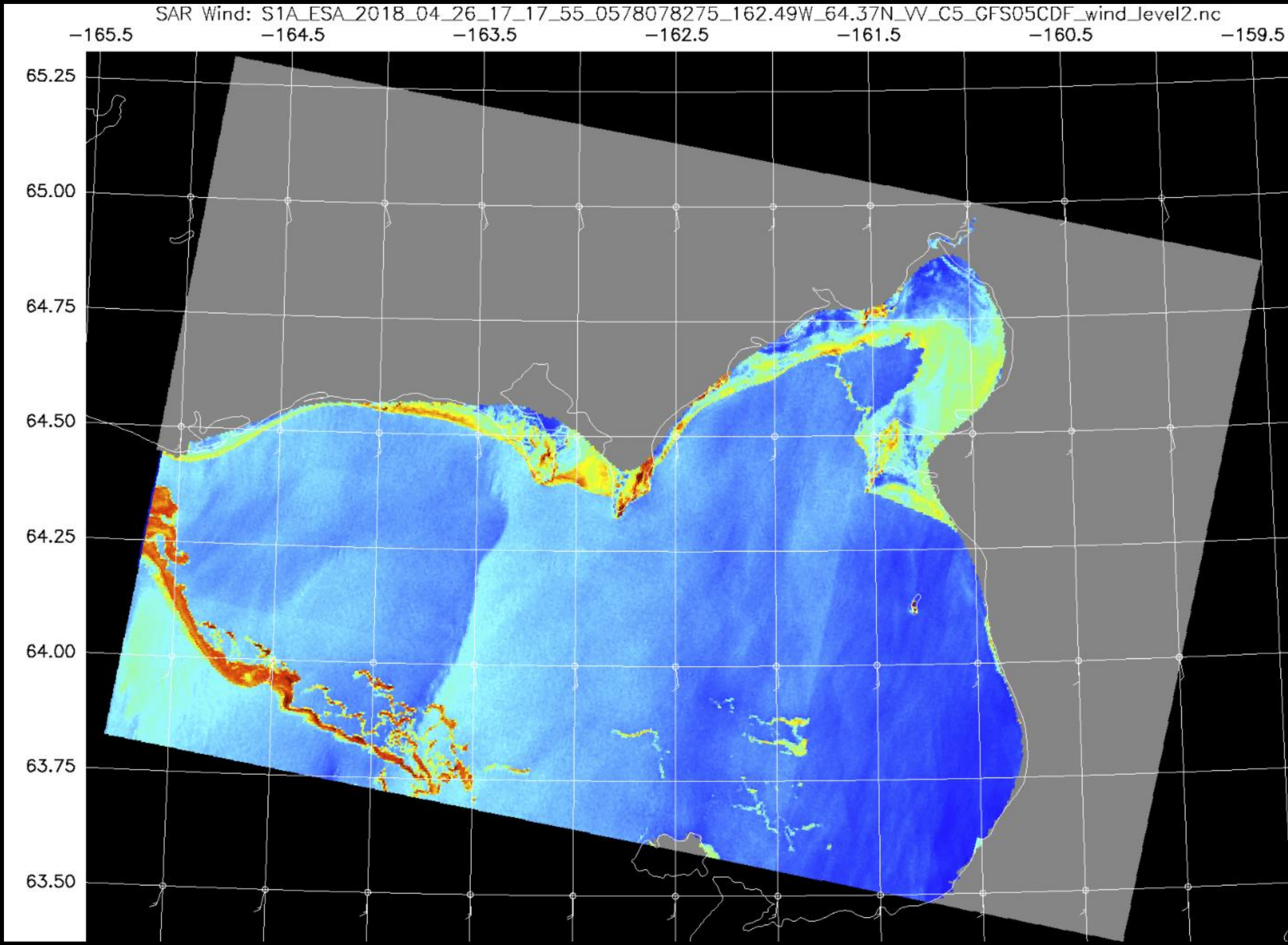
Synthetic Aperture Radar

Strengths:

- Highest resolution imagery
- Can see through clouds
- Best at sensing new ice
- Both color/B&W images

Limitations:

- Poor spatial/temporal coverage
- Individual floes within the pack become masked
- Wind/cloud “contamination”
- Degradation near swath edge



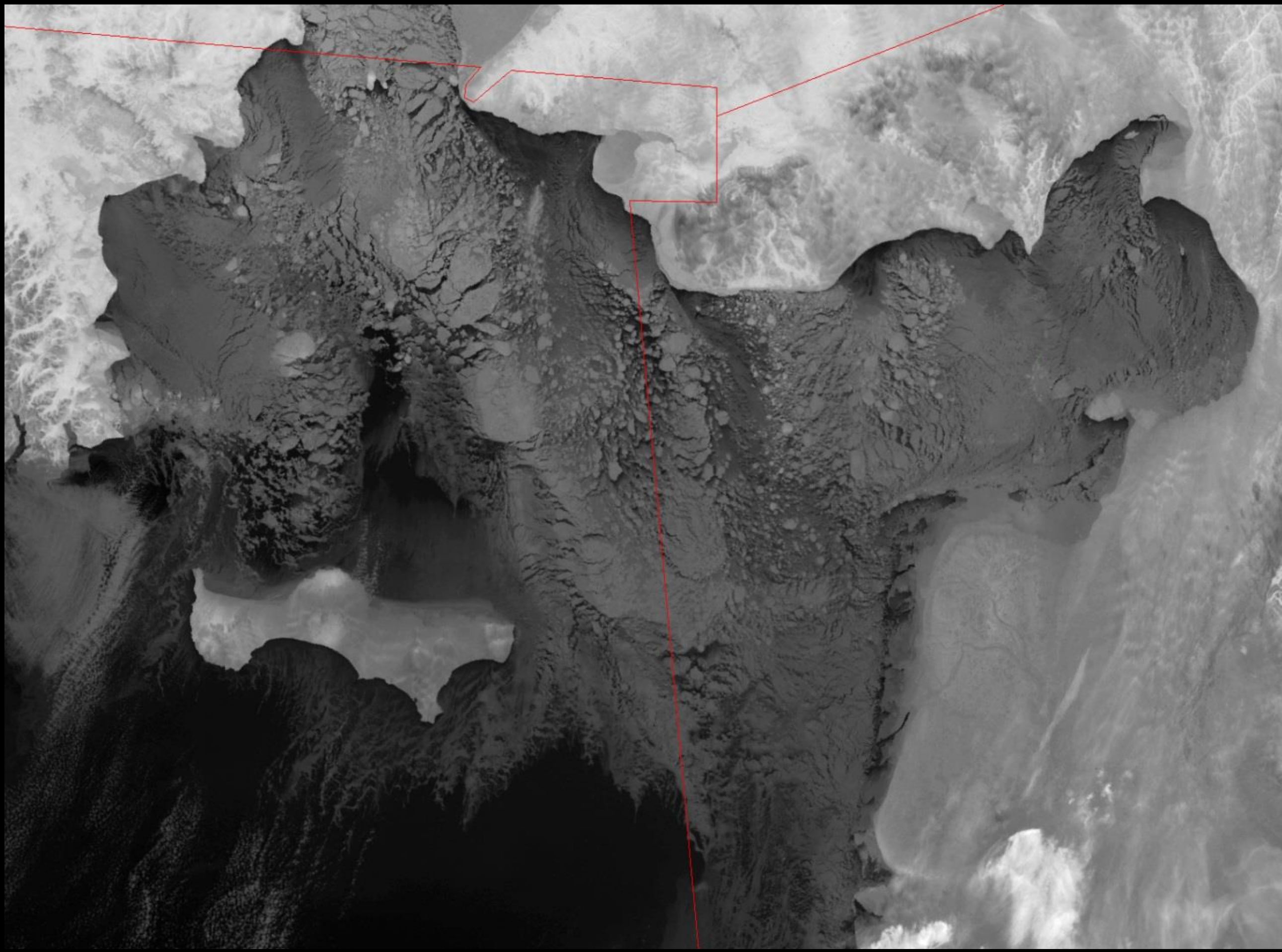
Longwave Infrared

Strengths:

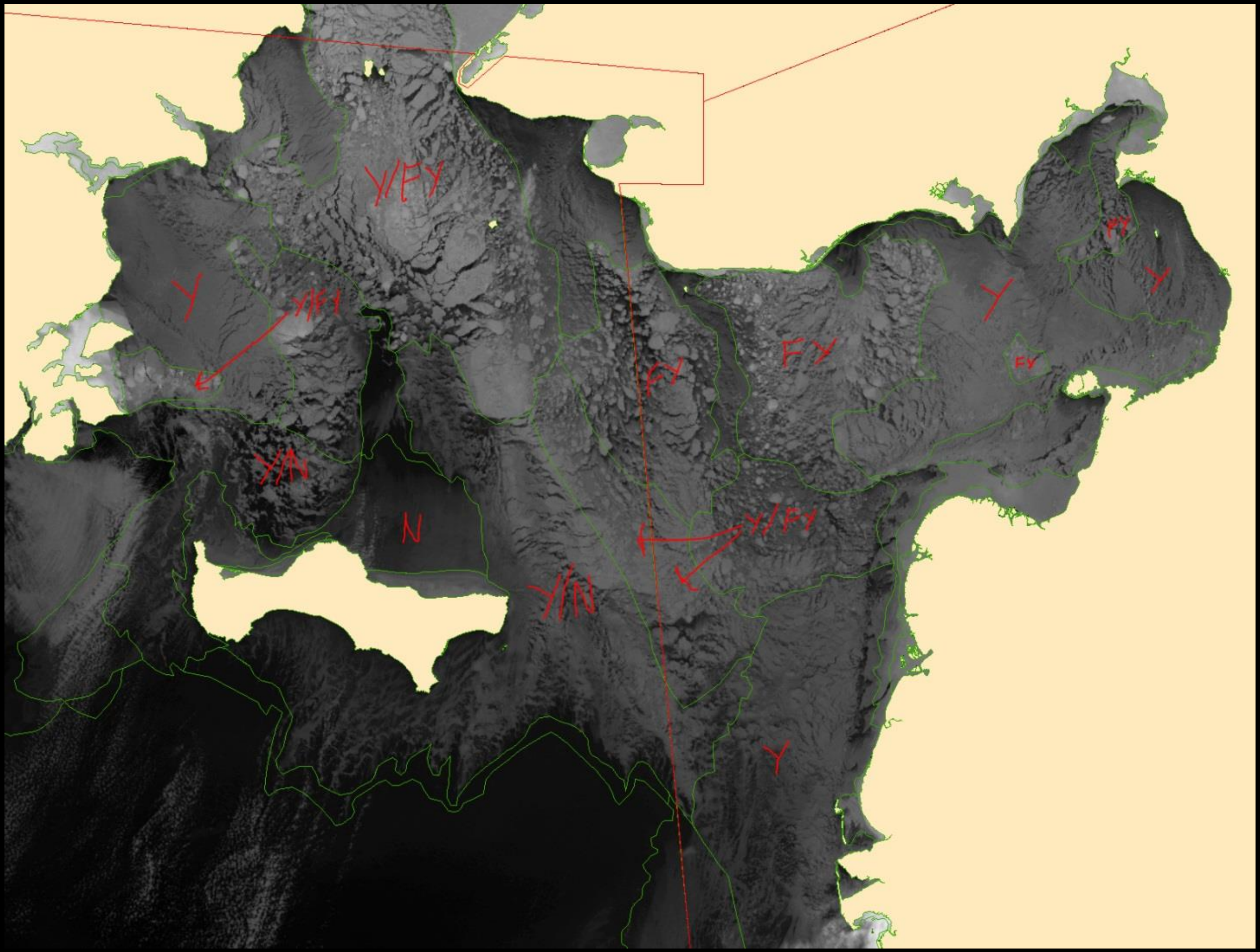
- Older/colder ice easily identifiable
- Nighttime use
- Resolution
- Increasing usefulness in winter

Limitations:

- Cloud cover
- Unable to detect new ice



Longwave Infrared



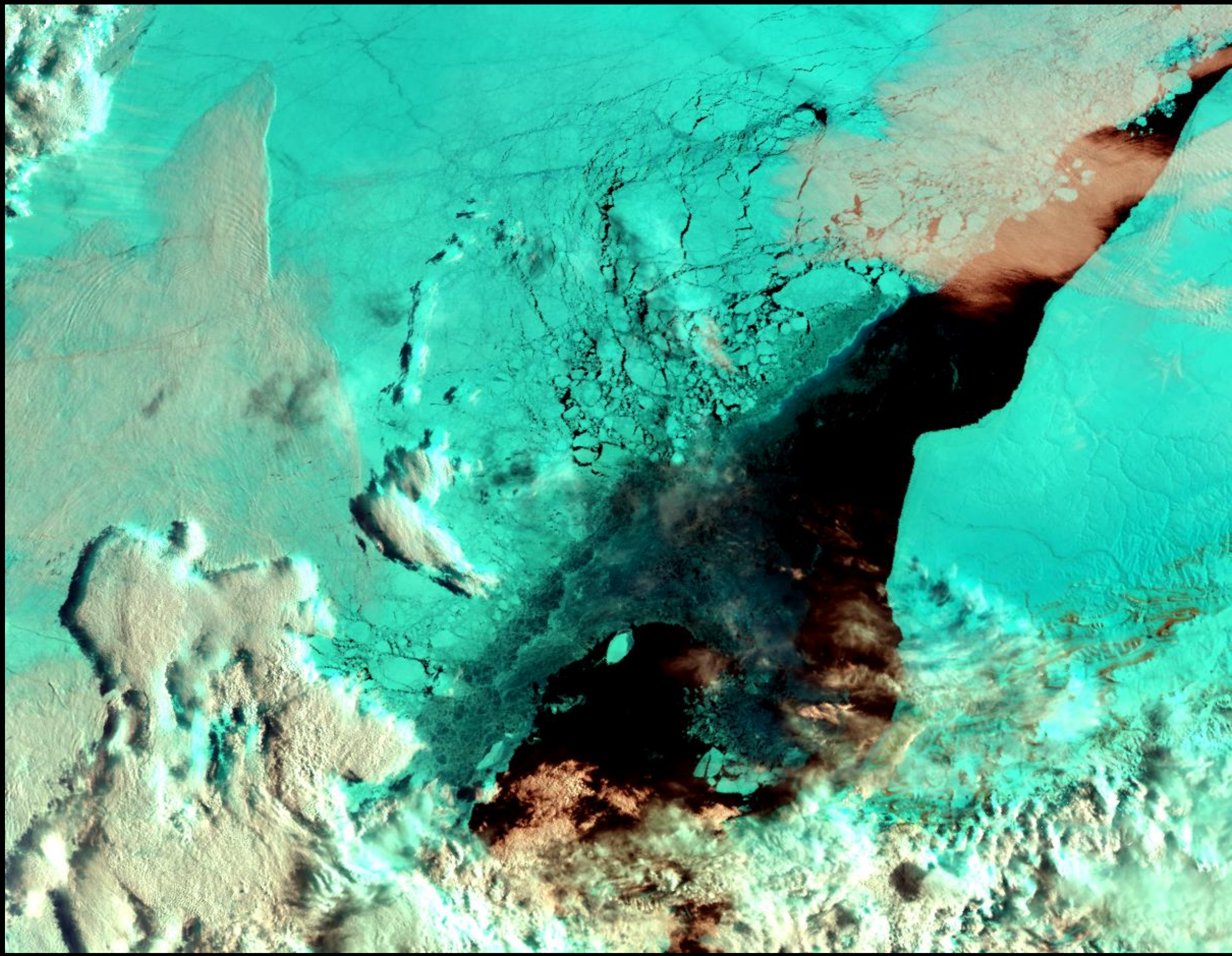
False color

Strengths:

- Ice contrasts vs. clouds in partly cloudy scenes
- Can make ice visible through thin clouds

Weaknesses:

- Daytime only
- New ice
- Contrast only shows vs. water clouds
- Ice clouds will look similar to ice below
- Can't distinguish between ice/mudflats



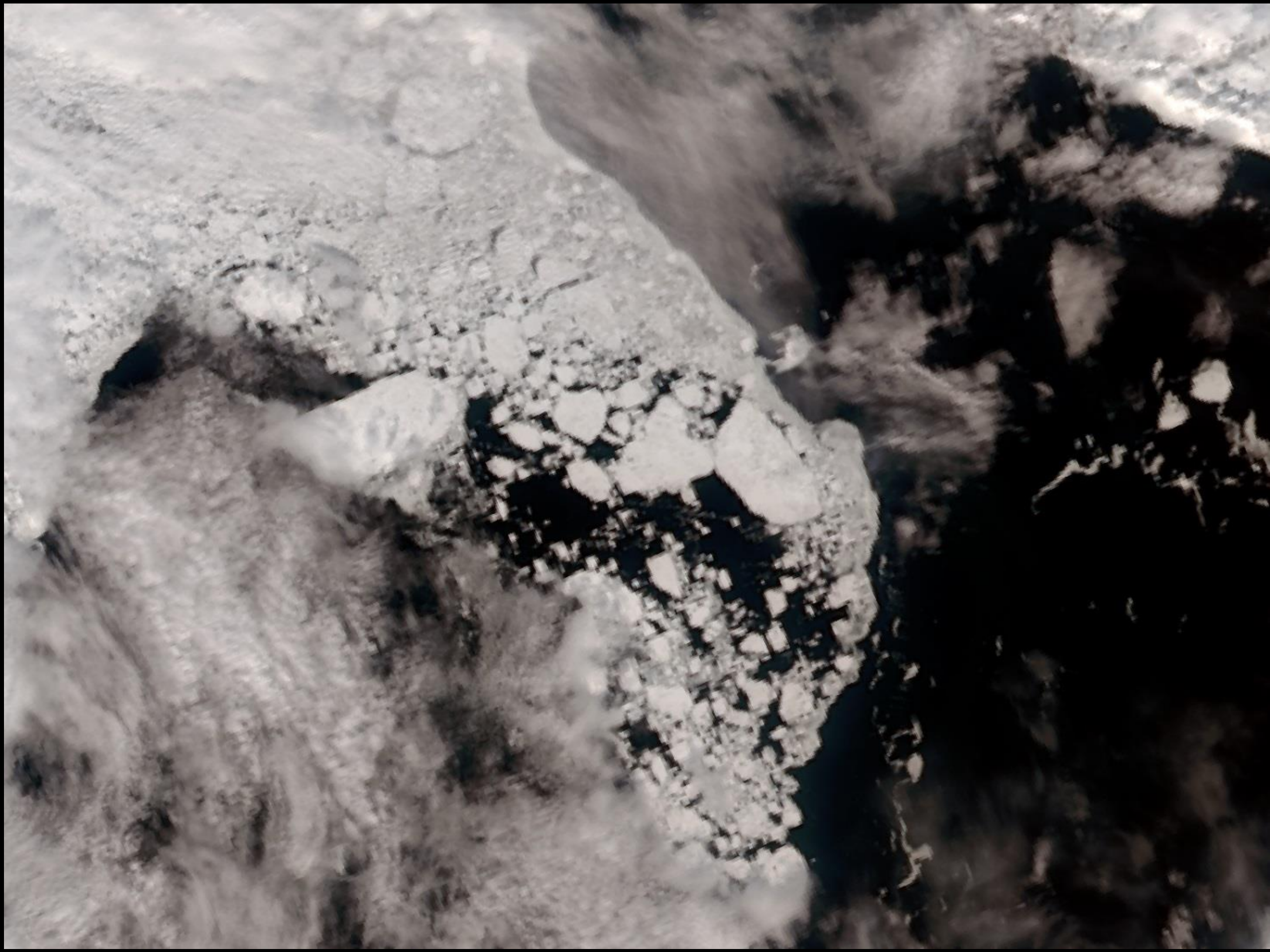
True color/visible

Strengths:

- Concentration and floe size easily identifiable
- Resolution
- Can ID mudflats vs ice if not ice/snow covered

Limitations:

- Daytime only
- Cloud cover
- Hard to distinguish ice from cloud in partly cloudy scenes
- New ice



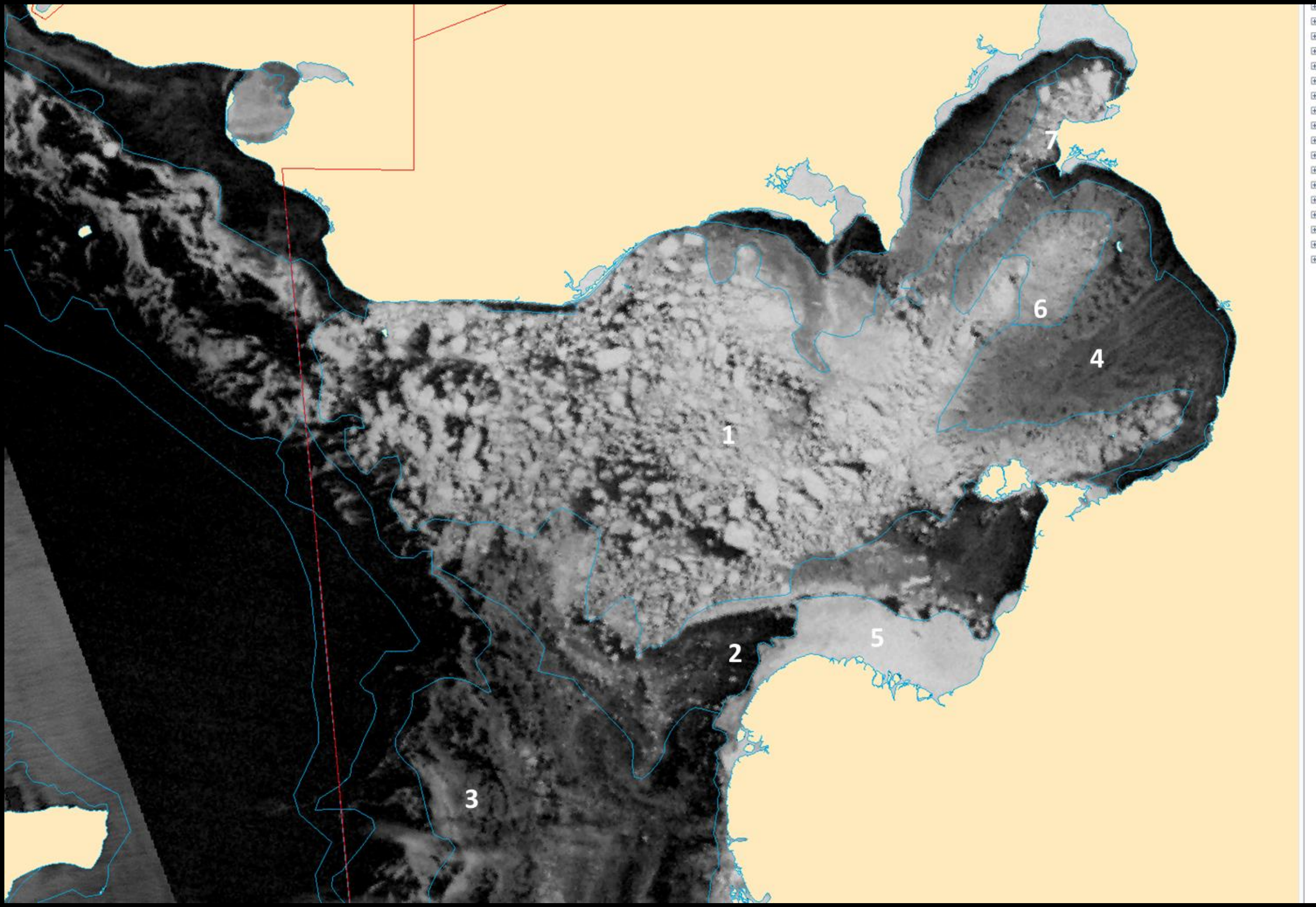
Day Night Band

Strengths:

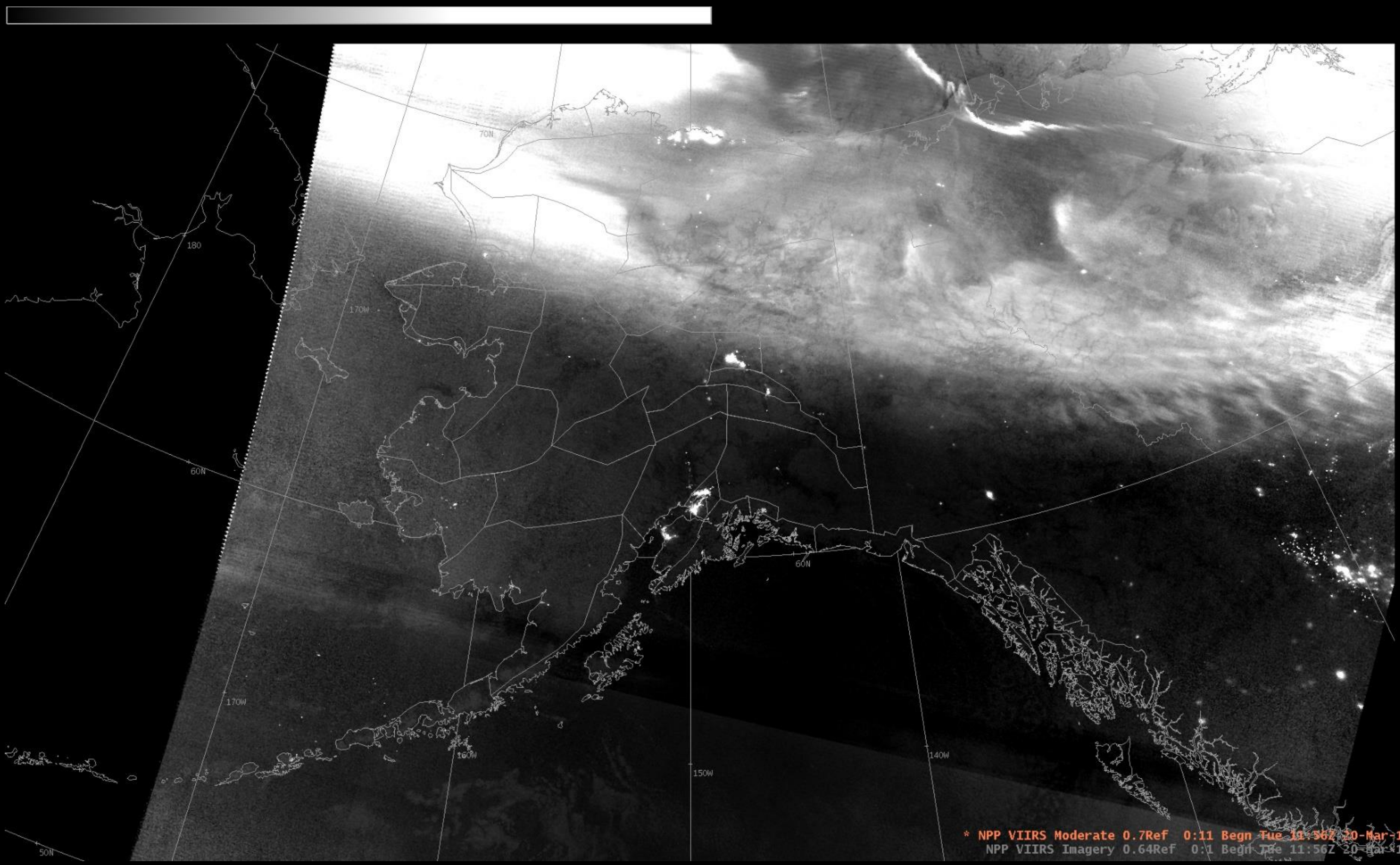
- Continuity with visible imagery
- Older ice very identifiable
- Nighttime use

Limitations:

- Cloud cover
- Lower resolution vs. visible or IR
- Artifacts in image (horizontal lines in swath)
- Less useful in summer
- Obscuration by aurora



Day Night Band



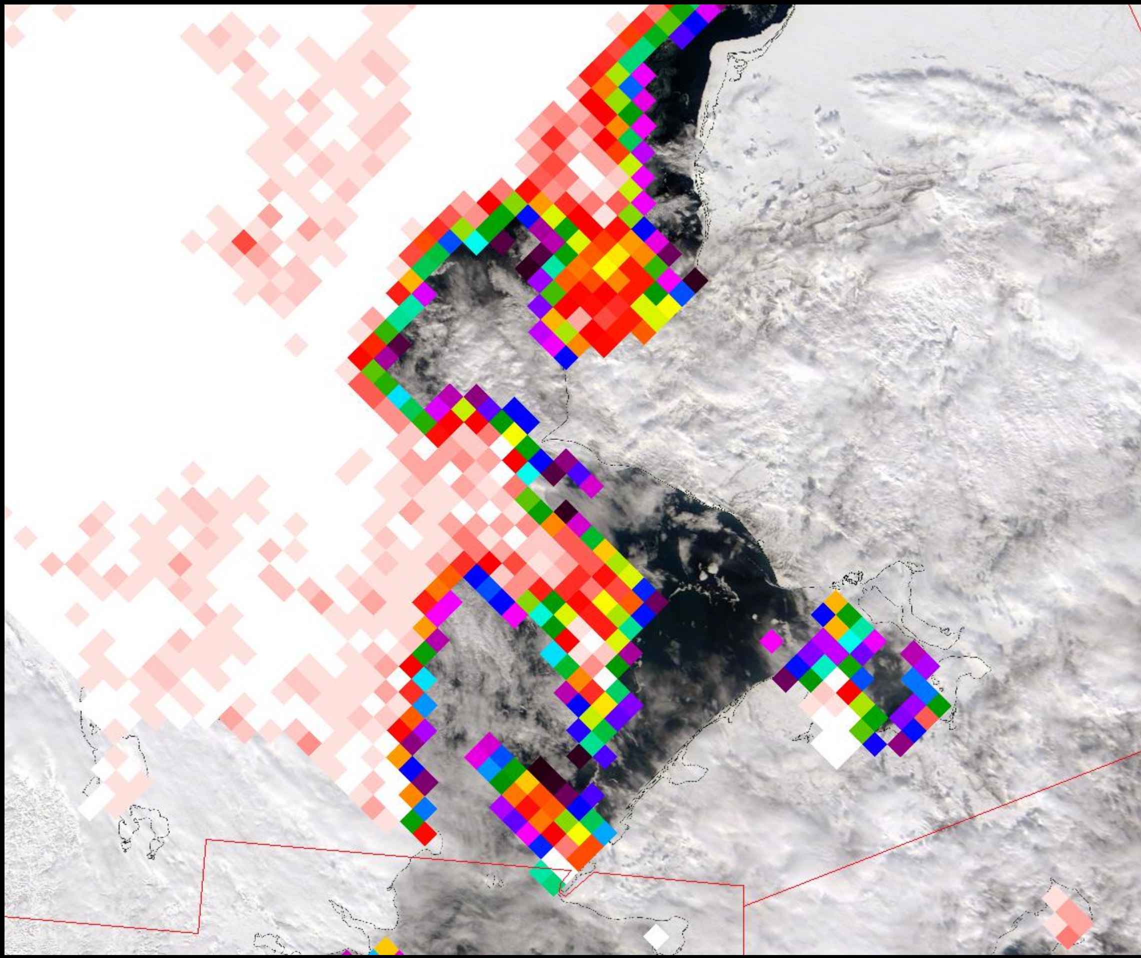
AMSR2 Sea Ice Concentration

Strengths:

- High concentration/pack ice
- Sees through clouds
- Useful for interpolation between SAR images
- Good for low-image days

Limitations:

- Resolution relative to other imagery
- Low concentration ice
- Analysis is more detailed than product resolution



Observations

Strengths:

- “Ground” truth
- Can provide thickness observations

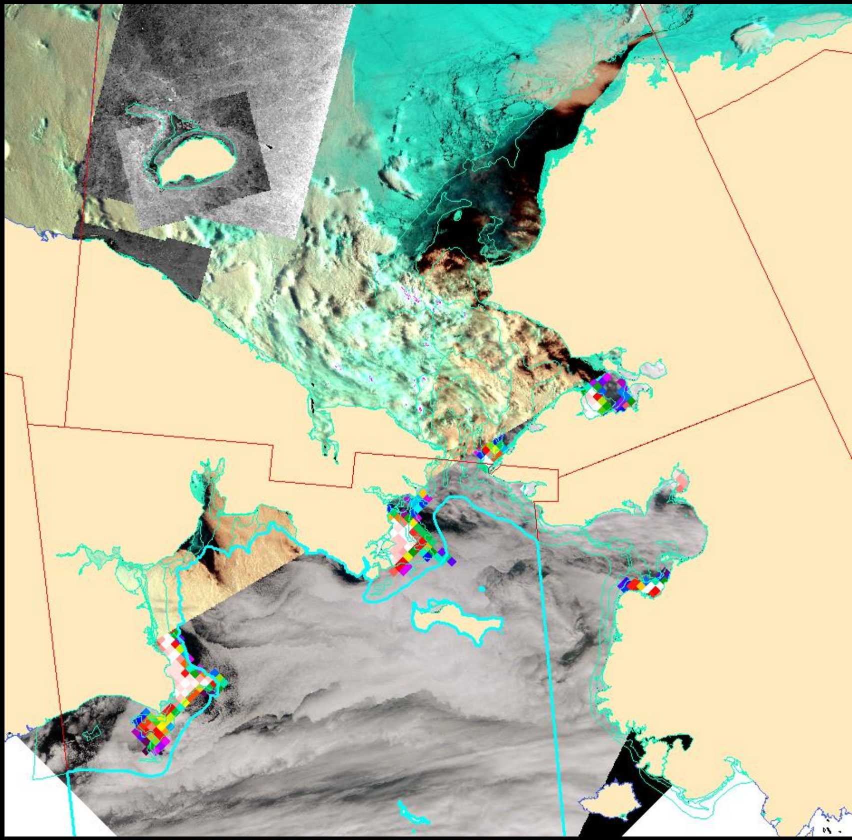
Limitations:

- Point observation (limited representation)

Imagery/analysis in general

Strengths:

- 24 hours worth of images from a variety of sources make up a mosaic.



Limitations:

- **CLOUDS**
- Temporal continuity

ASIP analysts

Strengths:

- Analyzing sea ice concentration in cloud free scenes
- Interpolating data from image sources of varying spatial coverage, and temporal resolution

Limitations:

- Judging ice stage/thickness
  - Our gauge of thickness is a proxy based on shape/ empirical knowledge of stage residence time

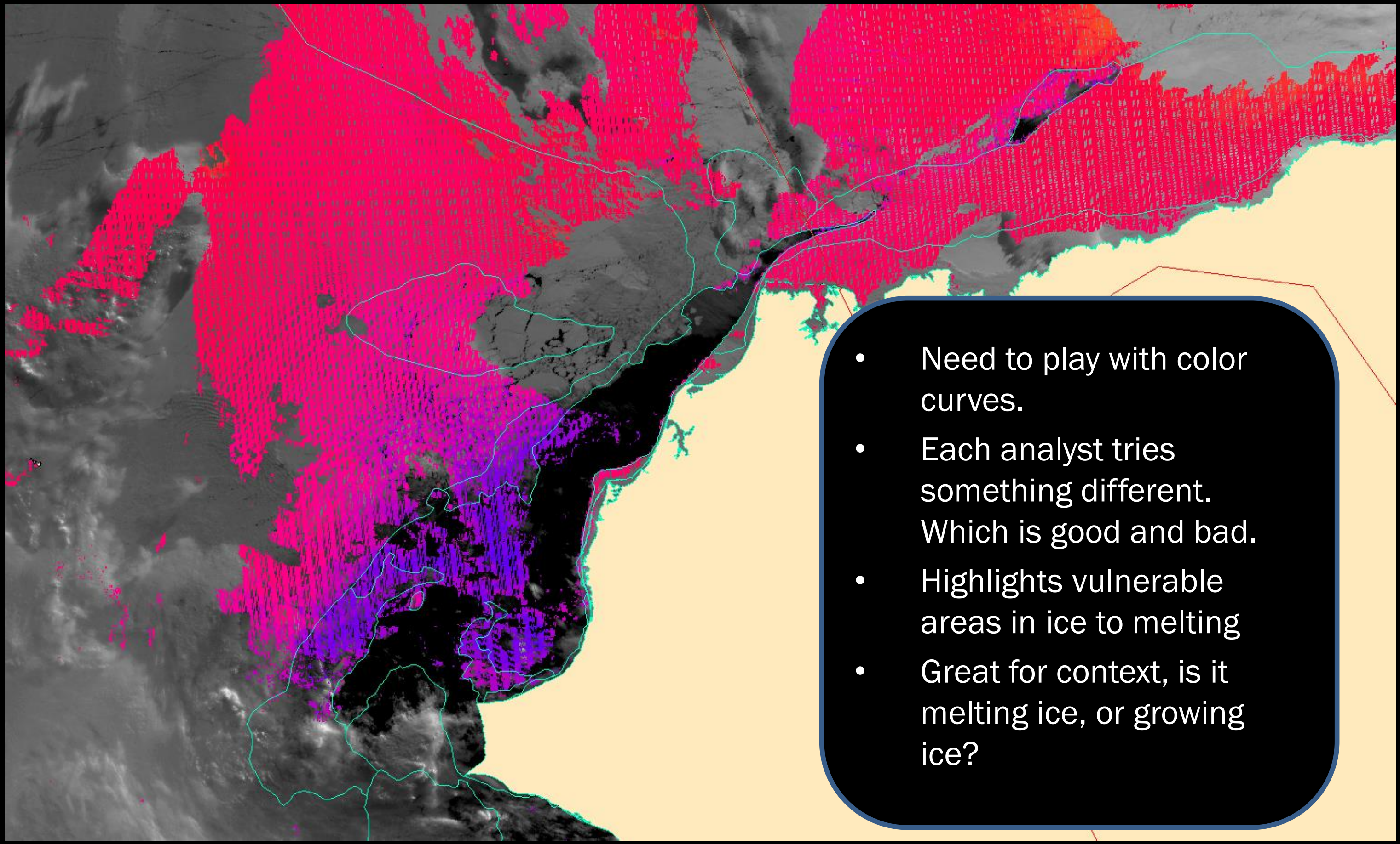
What do we need?

- Our biggest need as a program is ice thickness/stage data
- Short term drift/growth data
- Modelling

Ice Surface Temperature - Feedback

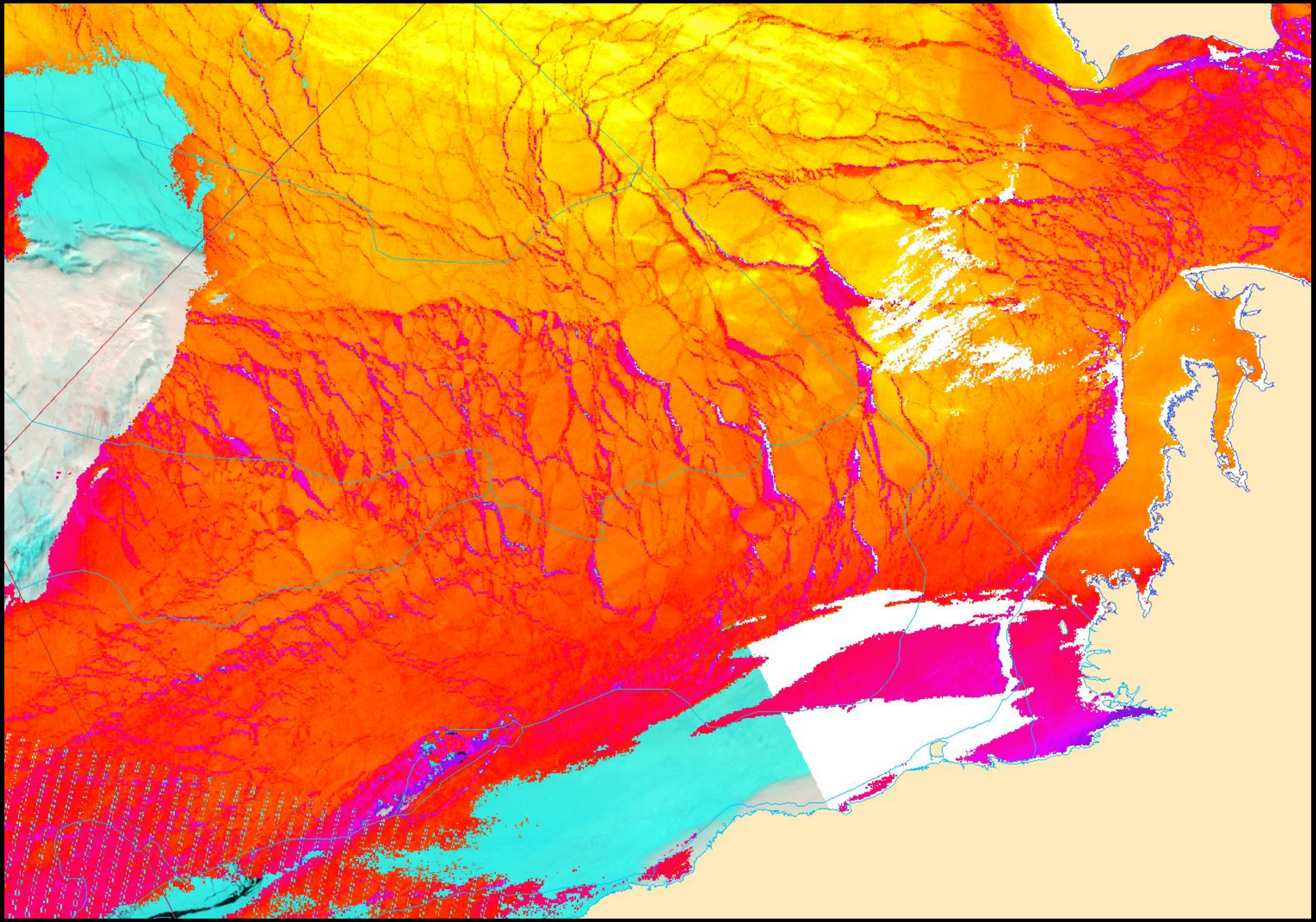
- IST looks to be of great resolution to see details
- Data plotting where clouds are
- Generally shows what I would expect
- Continued issues due to cloud contamination
- Fairly uniform, but great detail shown in leads
- Helps ID areas vulnerable to melting ice
- Great context for the new analyst
- Needs to be sampled to be useful
- Data artifacts make interpretation difficult

Ice Surface Temperature

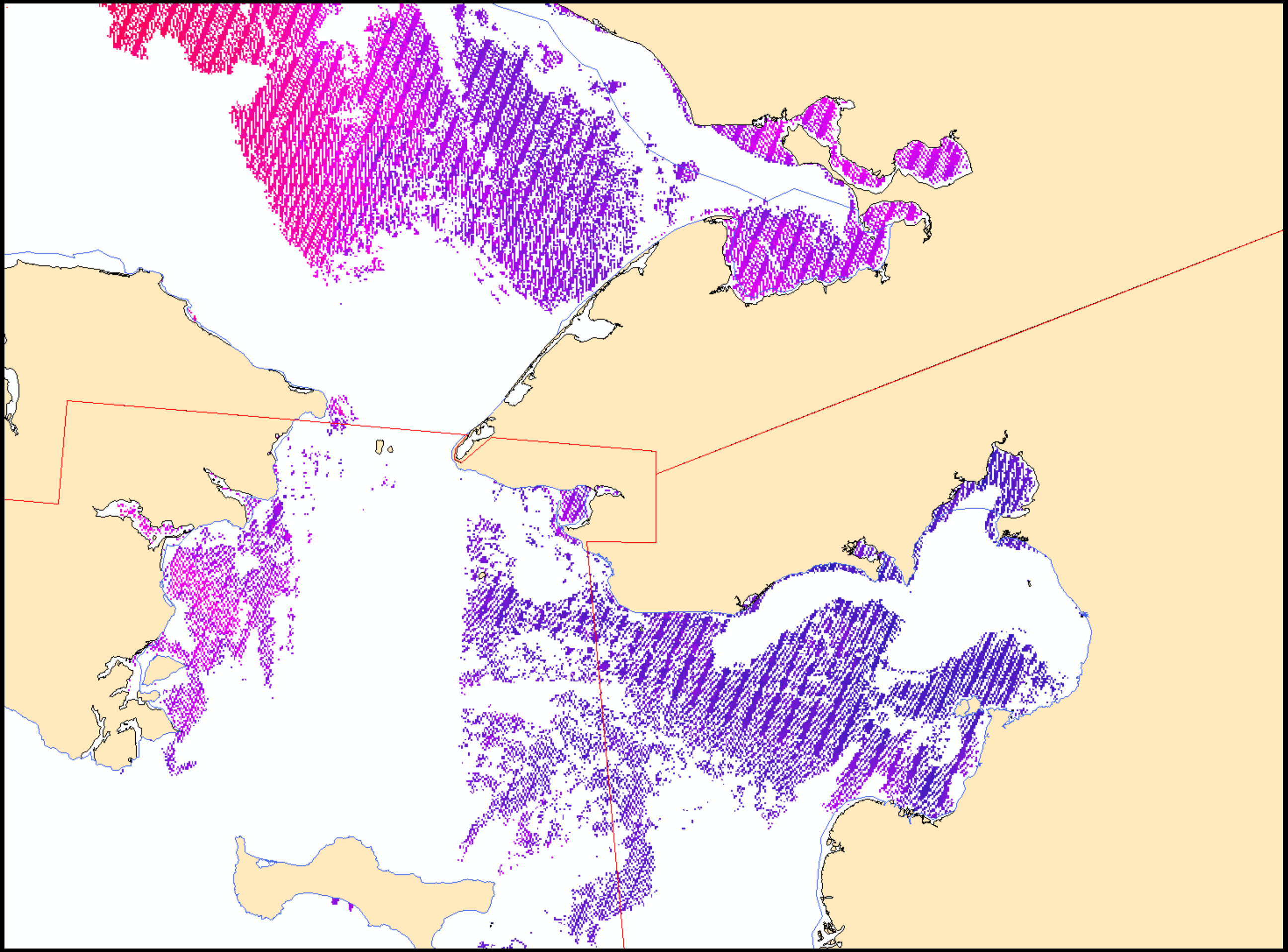


- Need to play with color curves.
- Each analyst tries something different. Which is good and bad.
- Highlights vulnerable areas in ice to melting
- Great for context, is it melting ice, or growing ice?

Ice Surface Temperature



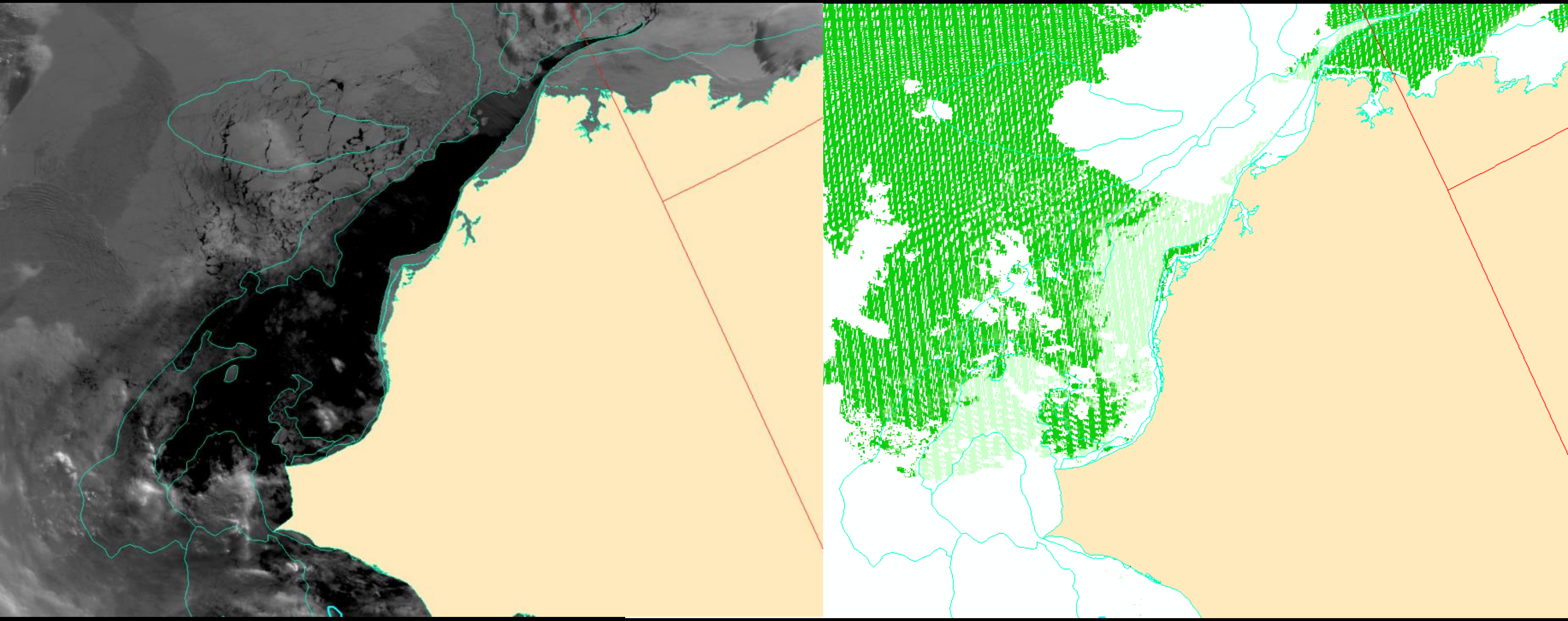
Ice Surface Temperature



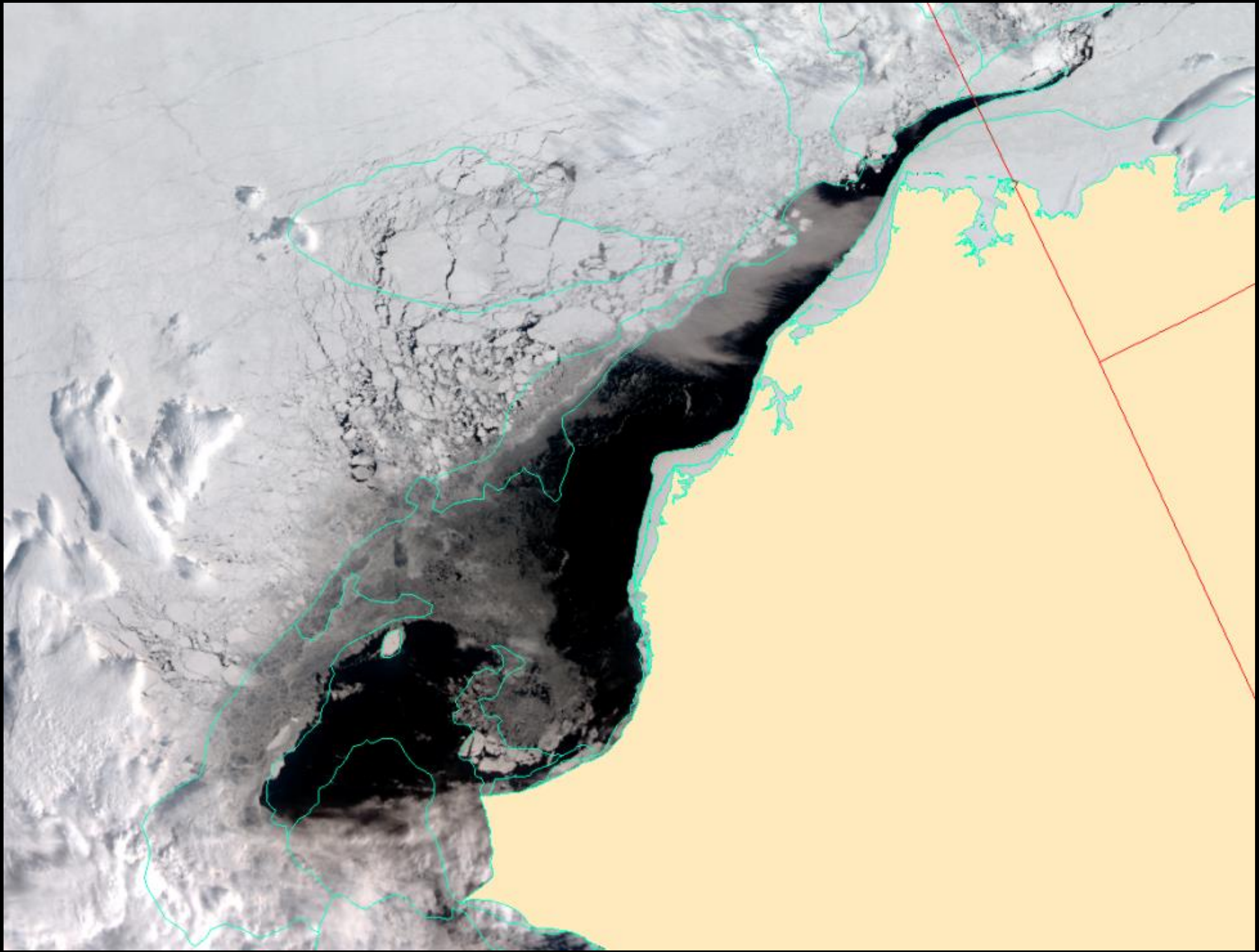
Ice Concentration - Feedback

- Need to be careful in areas of thin clouds where the product tries to discern ice concentration
- Not helpful for our purposes since we have more detail in visible/IR for cloud-free areas
- Data seems to be backwards, most of the detailed data is where there is minimal to no sea ice or very thin ice, over the main pack it is not very useful
- Seems to do a decent job delineating between the main pack and areas of brash along the ice edge on a broad scale. Hard to discern details when focusing on smaller areas where larger changes have taken place.
- Most useful as a supplement to other types of imagery.
- Seems to be great for 100% concentration. While it nails the low concentration/high concentration boundaries it seems to be too “binary” as the low concentration areas looked uniform. No detail other than “low concentration.” (Example on next slide)

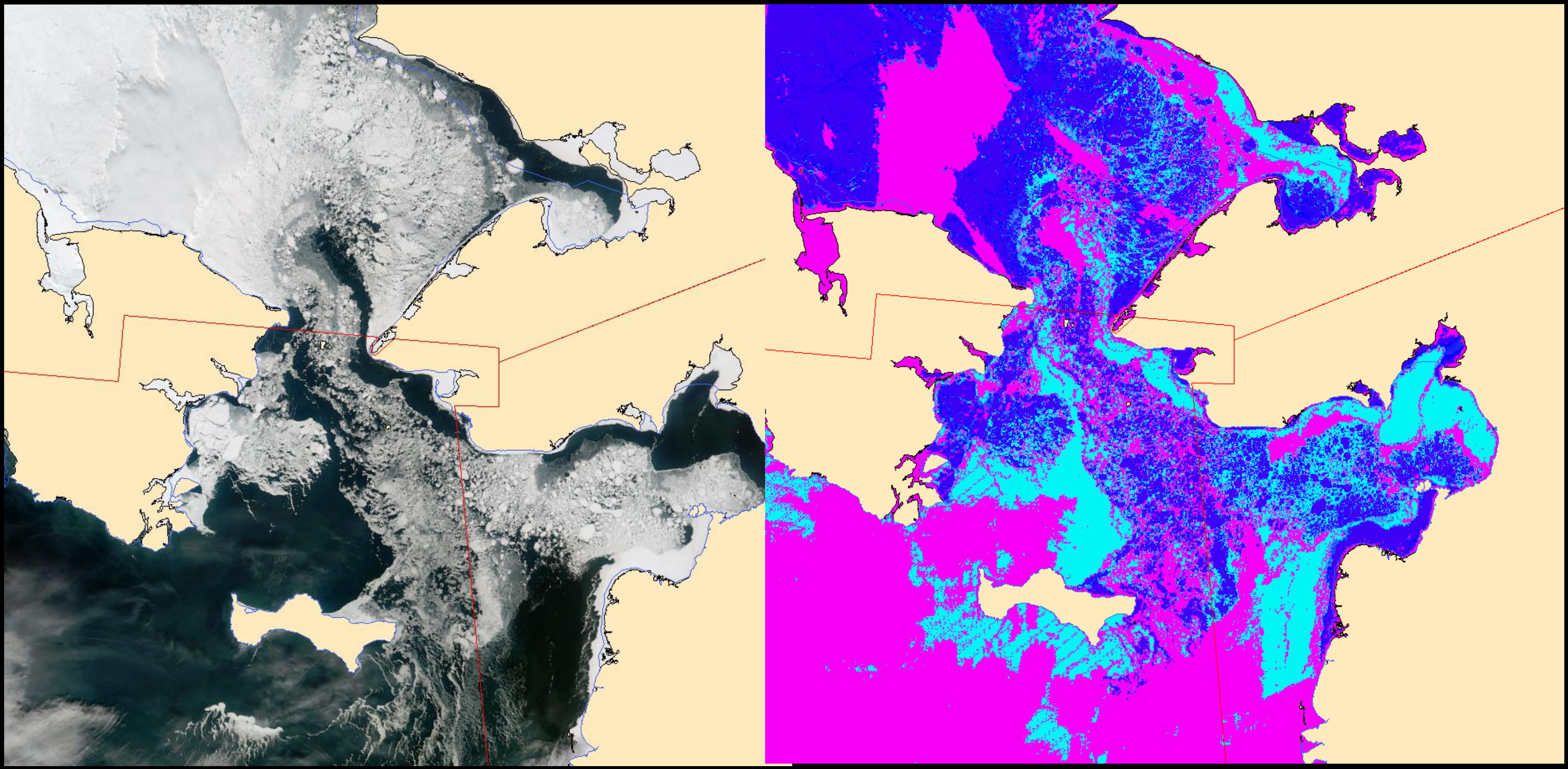
Ice Concentration



Ice Concentration



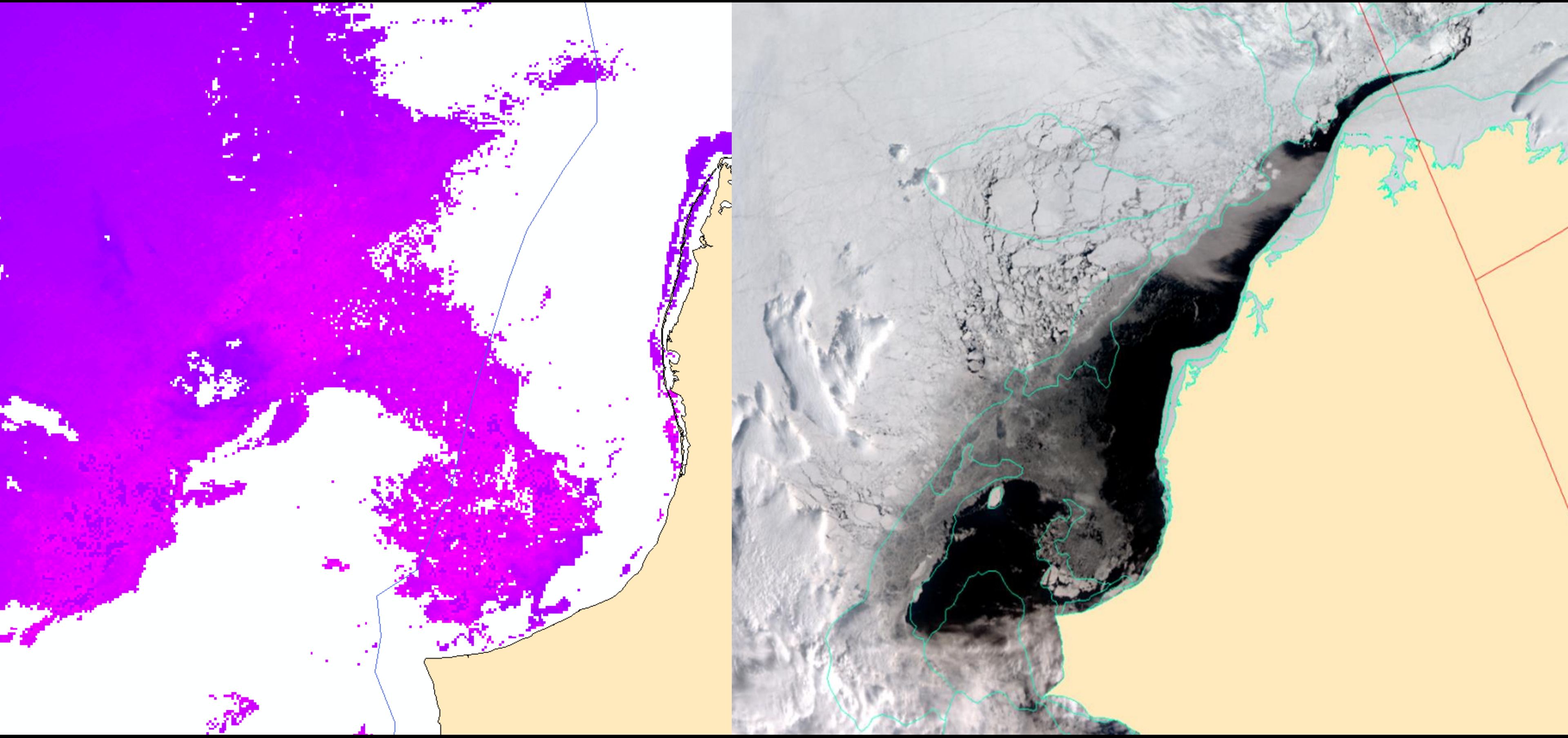
Sea Ice Concentration



Ice Age/Thickness - Feedback

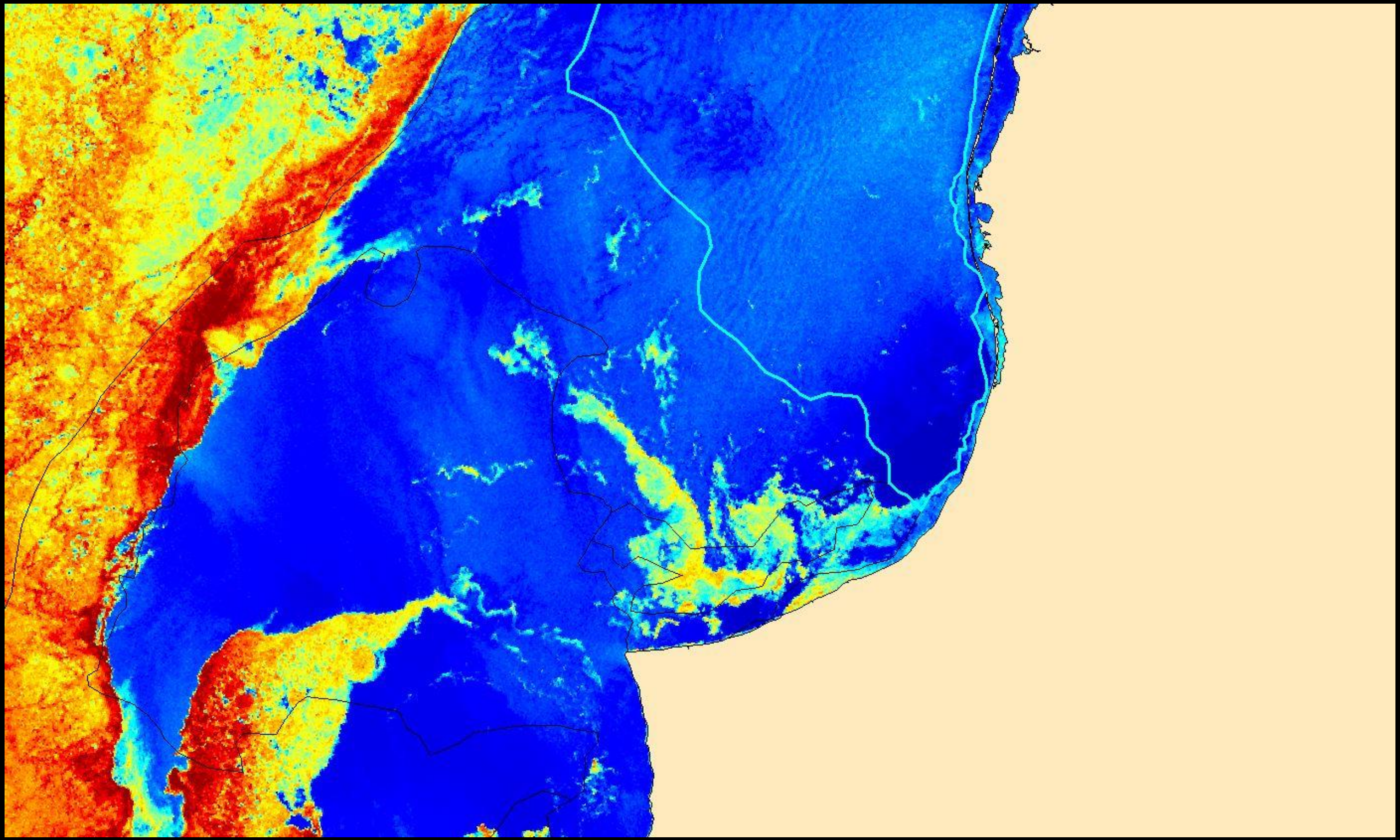
- Useful in areas of varying thickness, but no way to actually confirm the data (actual ice thickness). Enough of a gradient in the product to make some general assumptions about the analysis in the area of data
- Doesn't seem to pick up thicknesses less than 1.2 m, we need to know thickness data much less than that.

Ice Age/Thickness



Ice Age/Thickness

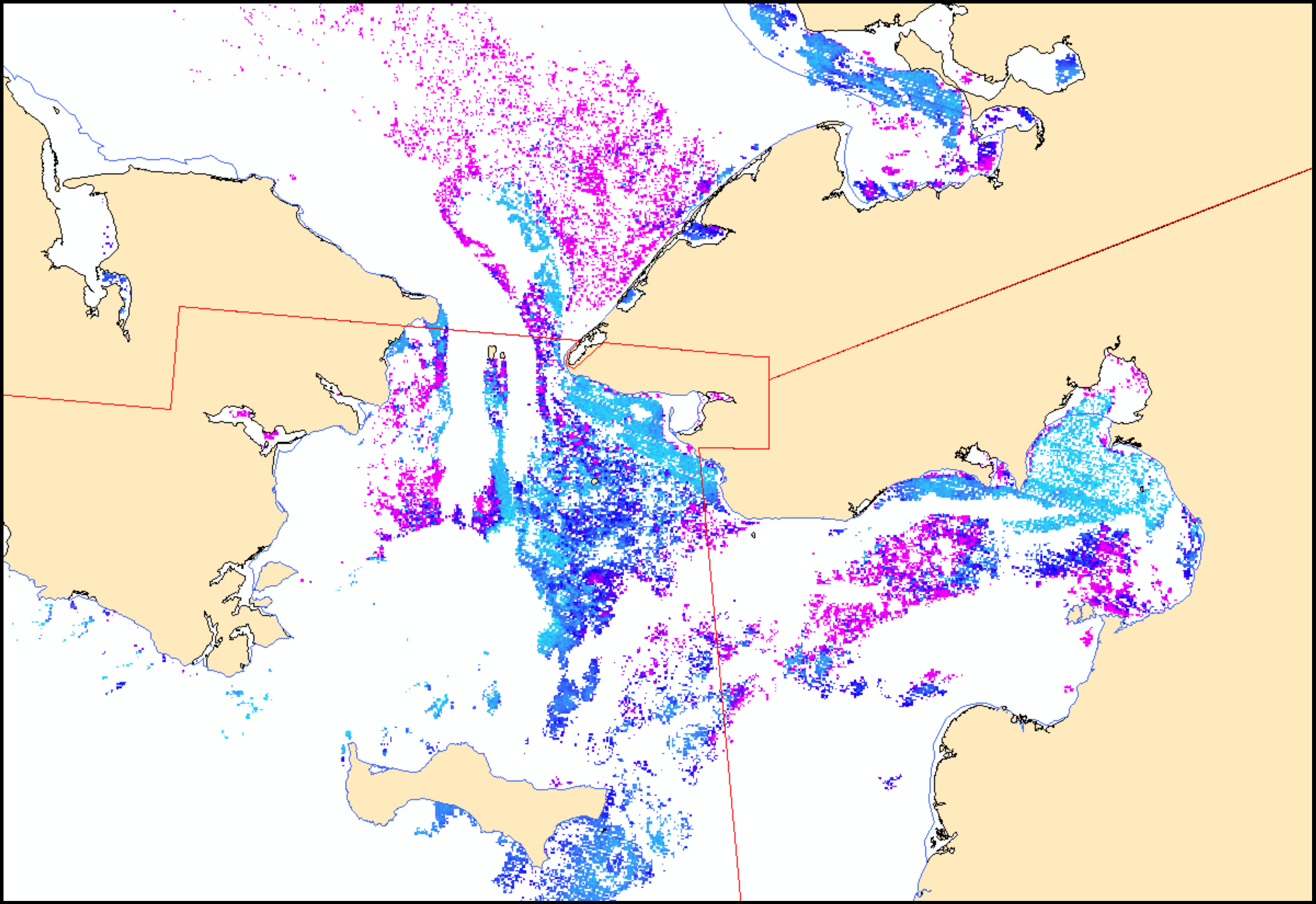
A few days later…



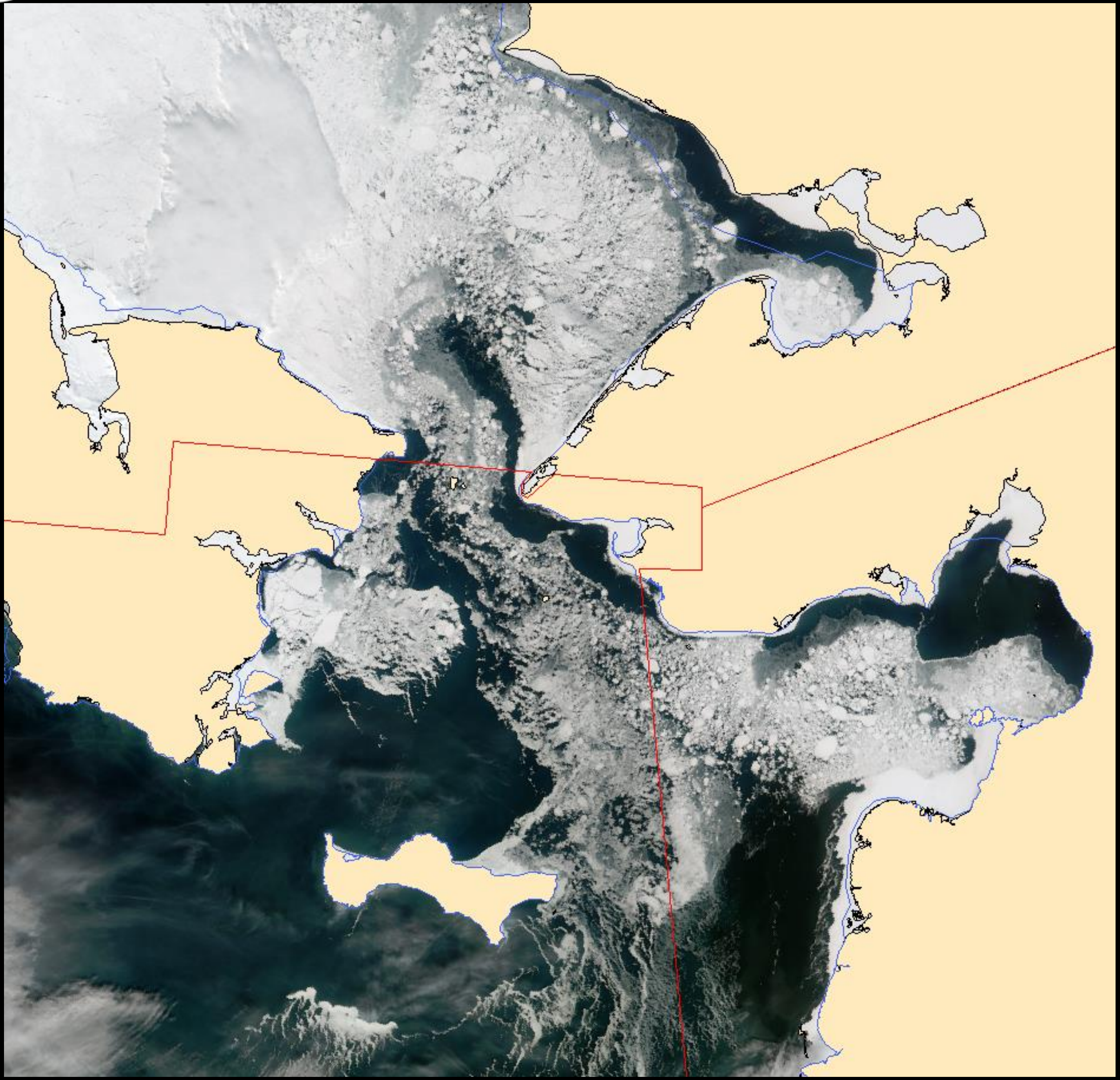
Radarsat image courtesy OSPO

Ice Age/Thickness

Same as Sea Ice Concentration example



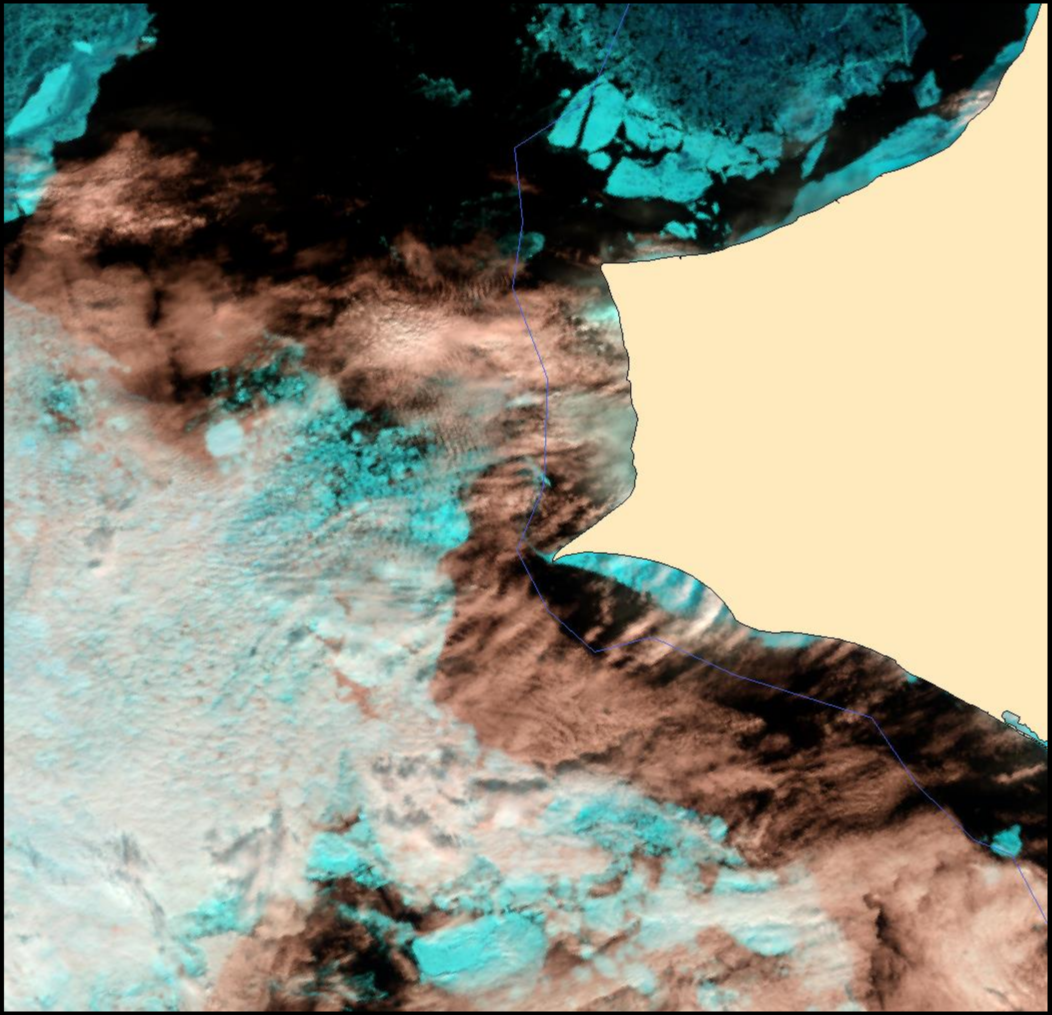
Ice Age/Thickness



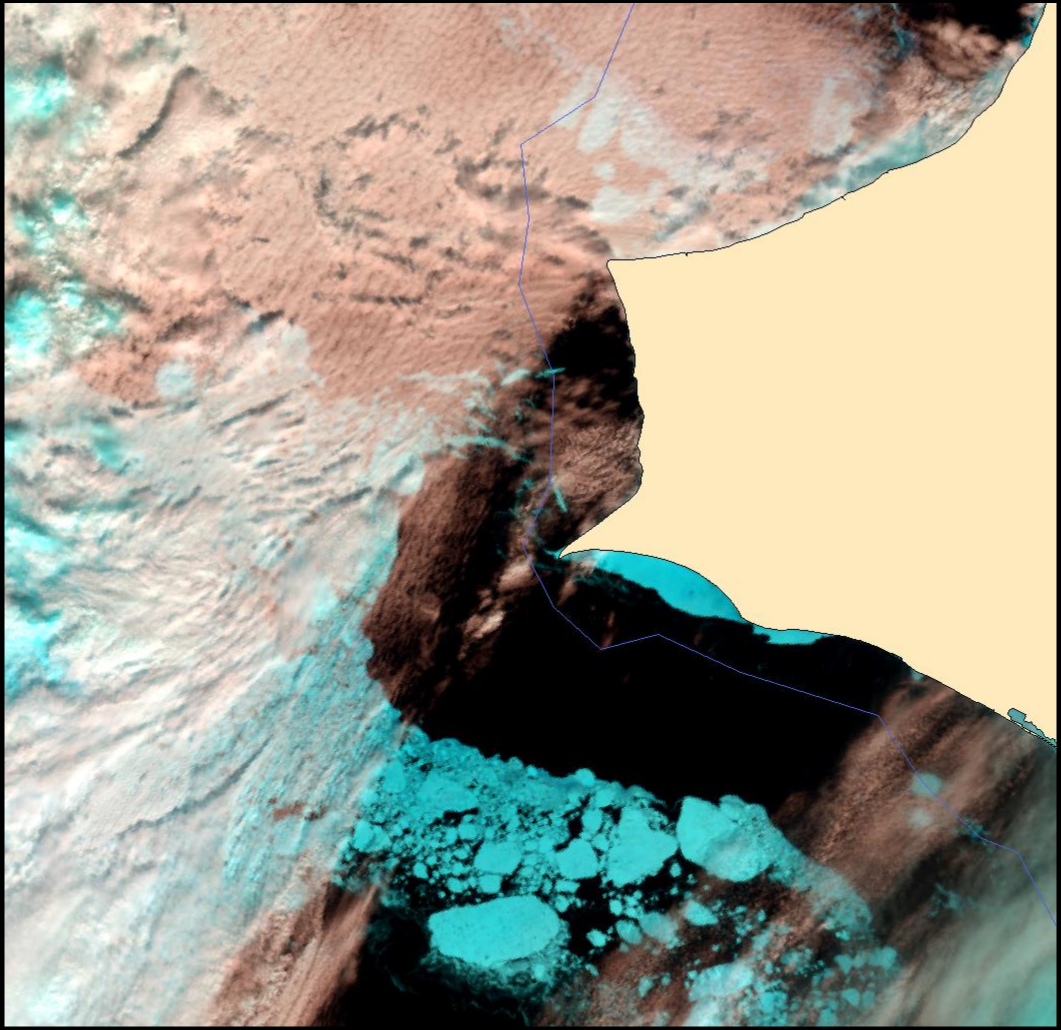
Blended Ice Motion - Feedback

- Data looks good, I can see this data being very helpful especially for our forecasts and special projects
- Useful for forecast purposes and for conceptualizing changes noted in a given area when a day or two passes between good images
- Great context for the new analyst coming on duty.

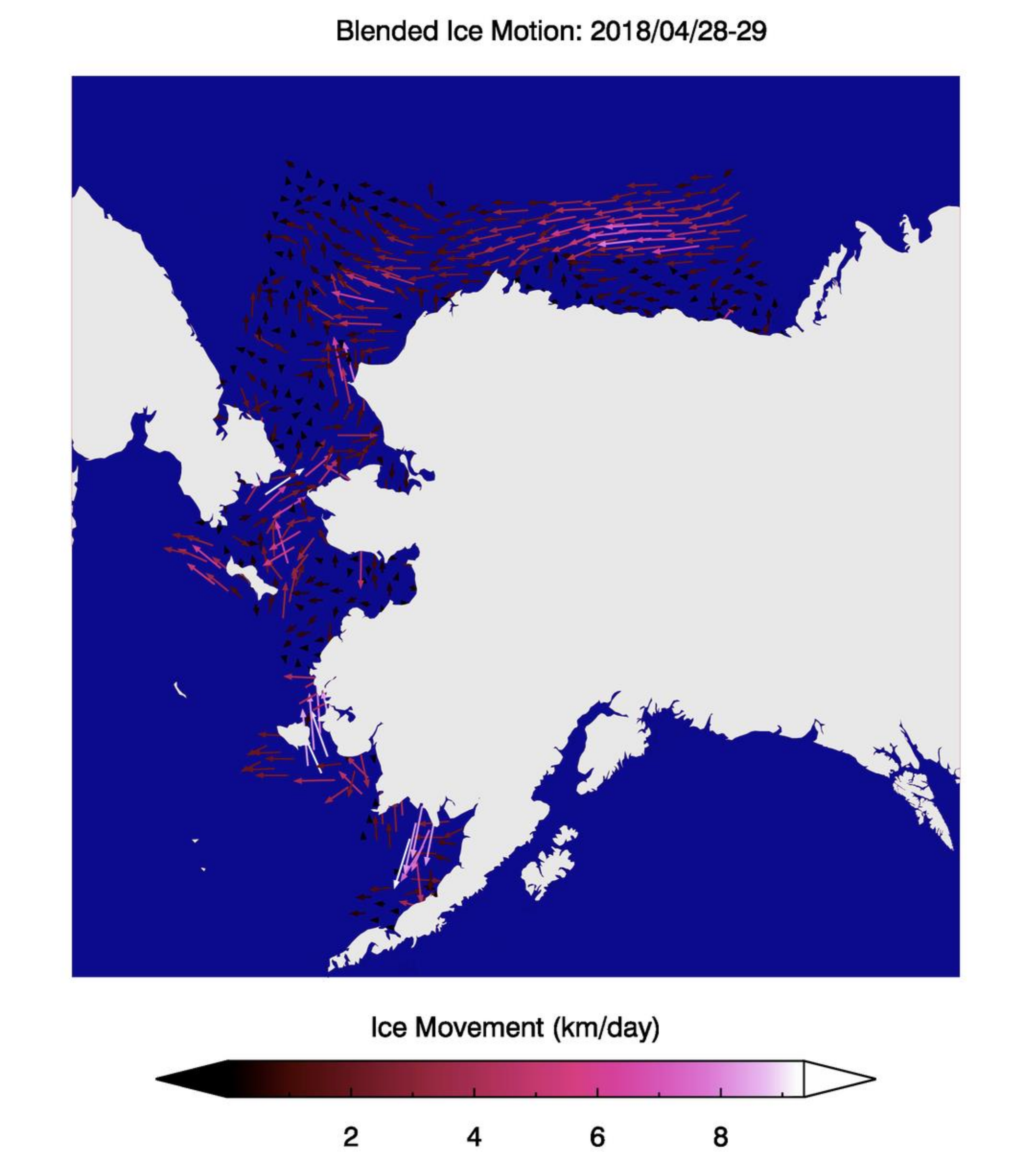
24 hours between images



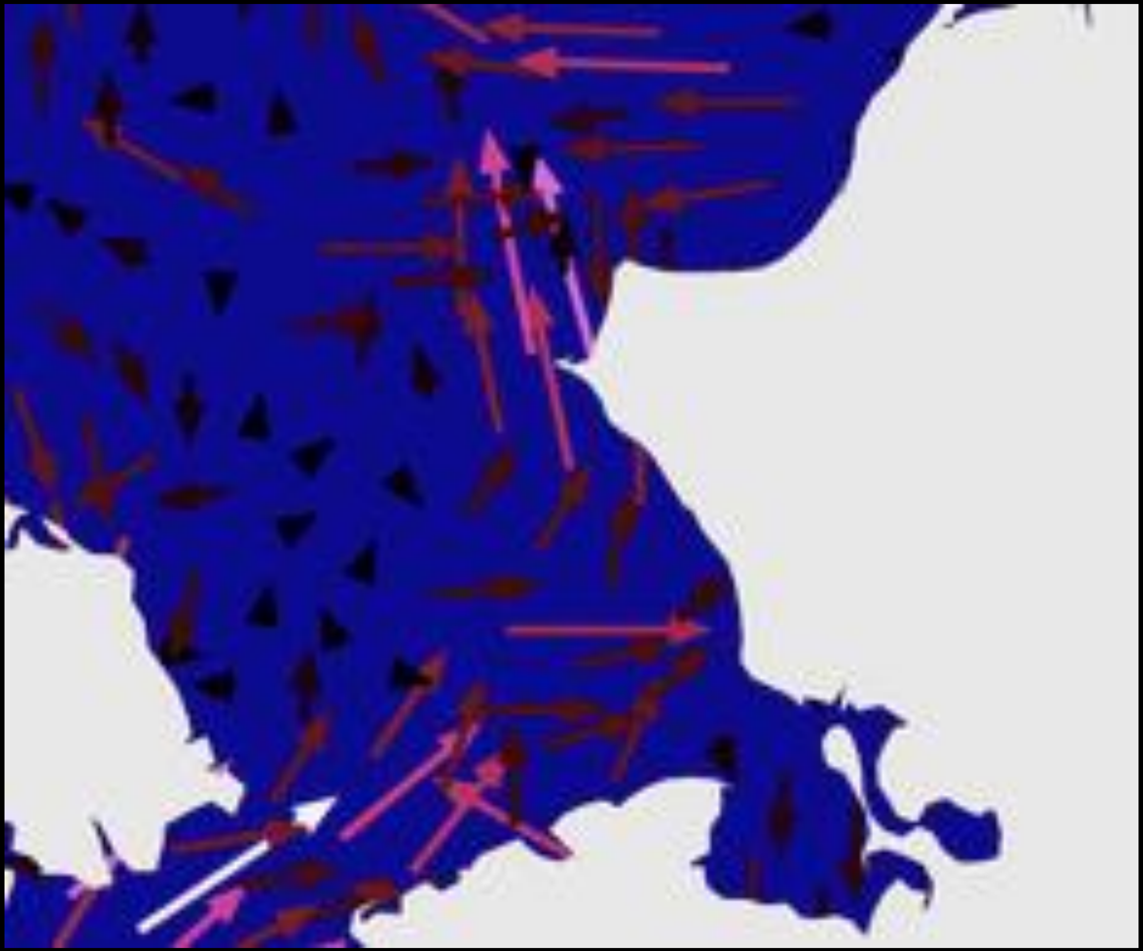
Blended Ice Motion



24 hours between images

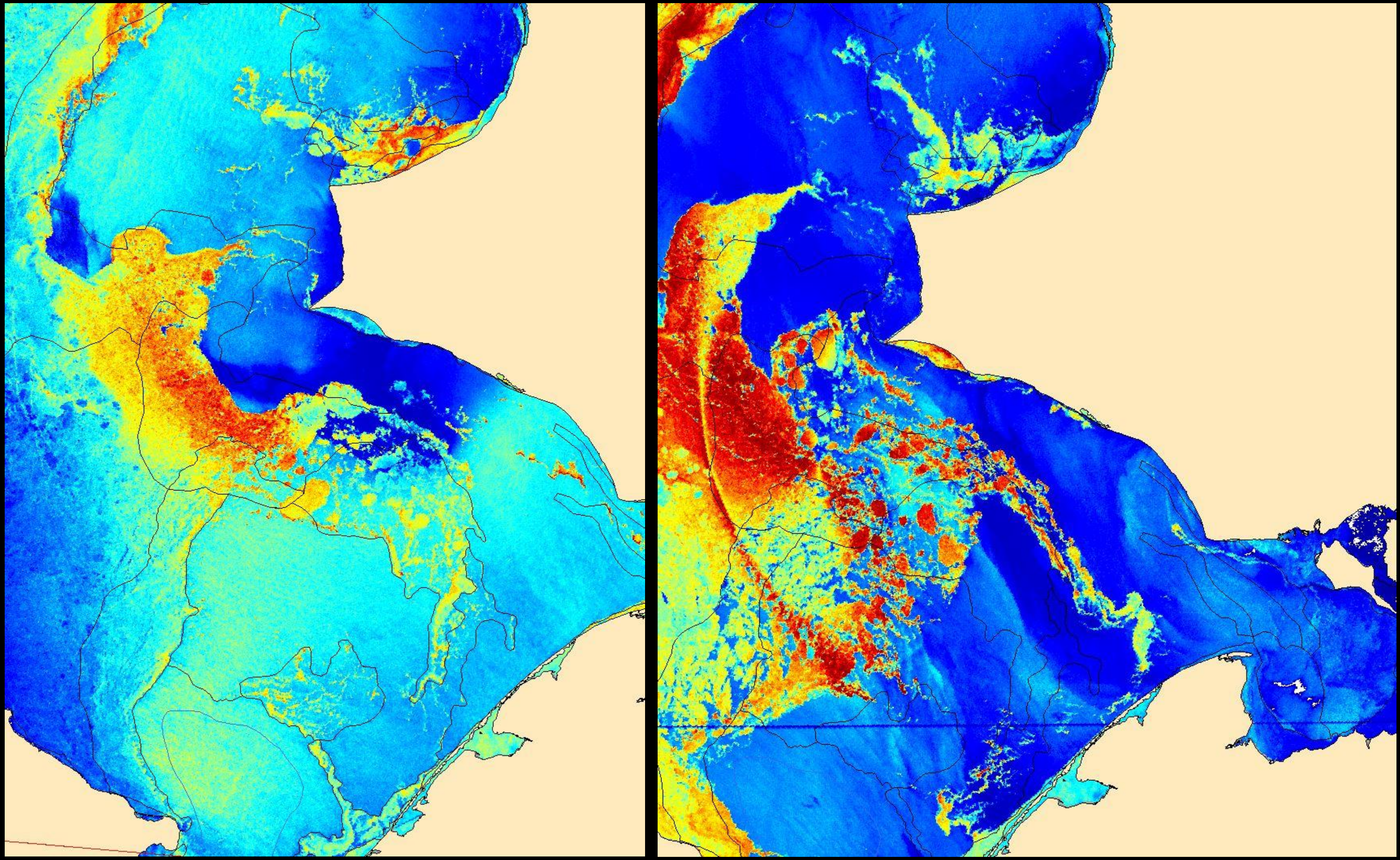


Blended Ice Motion



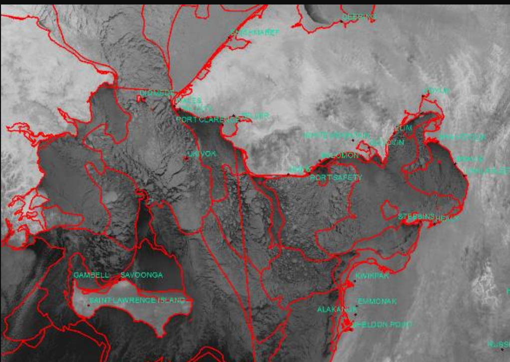
Blended Ice Motion

36 hours between images

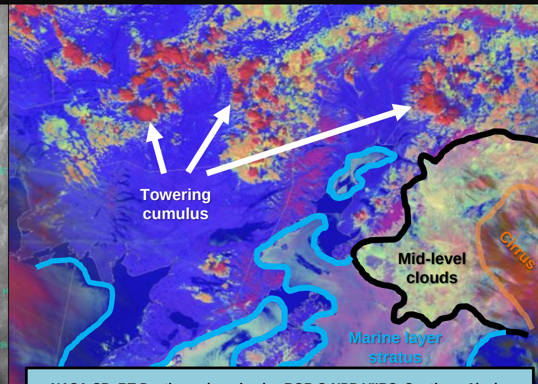


Integration of Polar-Orbiting and Geostationary Satellite Information in Forecast and Sea Ice Operations

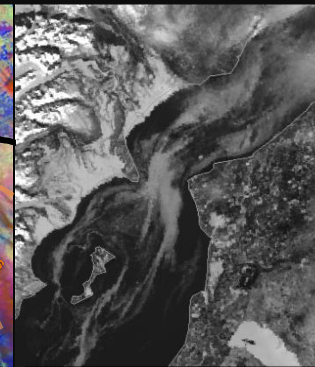
Michael Lawson, General Forecaster/Satellite focal point, NWS Anchorage Forecast Office



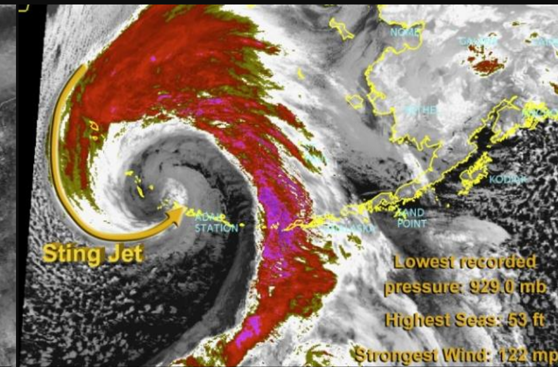
S-NPP VIIRS 11.45 µm in ArcGIS. Bering Strait / Norton Sound ice 1/19/18. Each shape represents different concentrations/stage.



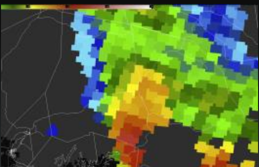
NASA SPoRT Daytime microphysics RGB S-NPP VIIRS. Southern Alaska



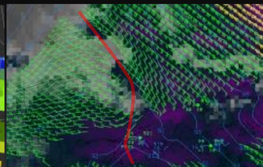
NOAA-20 .64 µm visible. Sea ice/Cook Inlet



S-NPP VIIRS 11.45 µm/longwave IR. Western Bering Sea 12/13/15: Social media

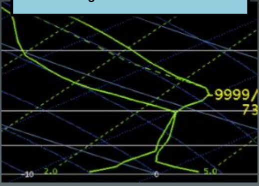


Snowfall Rate Product. Atmospheric river snow event. Thompson Pass 12/06/17

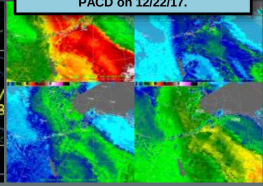


ASCAT Scatterometer winds. Stationary boundary. PACD warning level snow event 12/22/17

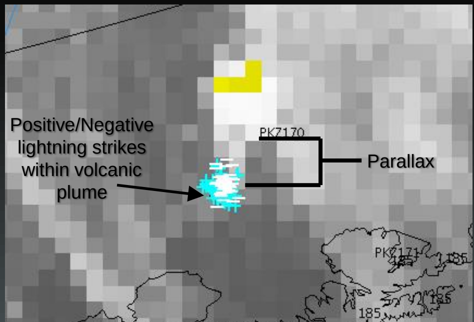
NUCAPS sounding. Cold side of stationary boundary. PACD warning level snow 12/22/17



Layered Precipitable Water product showing robust low-level moisture in upper left at PACD on 12/22/17.



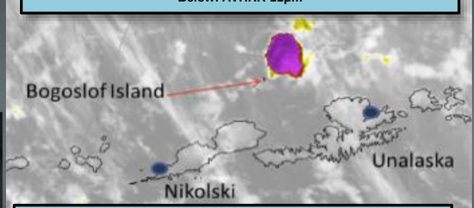
Polar-orbiting satellite products are increasingly useful at high latitudes, where the amount of imagery is significantly greater than lower latitudes. Data sparse locations, such as Alaska, benefit from the pole-to-pole coverage these satellites provide. Imagery from Himiwari-8 also gives Alaska forecasters a look into the future of high spatial/temporal resolution geostationary satellite products. NWS Anchorage uses a diverse selection of products to monitor a variety of meteorological conditions including cyclogenesis, low stratus/fog, blowing dust, volcanic as, winds, and sea ice. Forecasters at NWS Anchorage continually collaborate with agency partners on evaluation of new satellite products. In addition, the combination of geostationary and polar-orbiting imagery, including the newly launched NOAA-20, gives forecasters a glimpse of single and multi-channel products that are expected with the operational capability of GOES-17. An evaluation of these proxy data conducted by NWS Anchorage has given forecasters advanced knowledge of product interpretation, so they can be prepared for GOES-17 on day one.



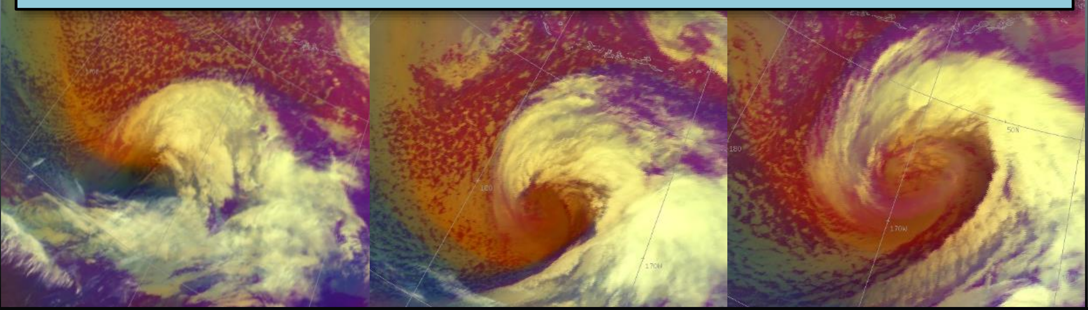
Bogoslof Volcano eruption 12/22/16

Above: GOES-15 IR w/ground based lightning detection, highlighting parallax at high latitude

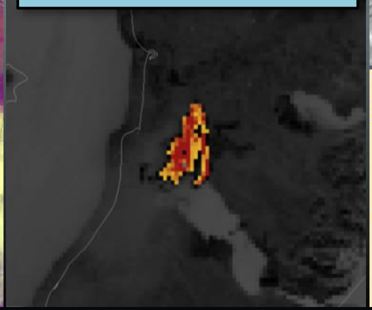
Below: AVHRR 11µm



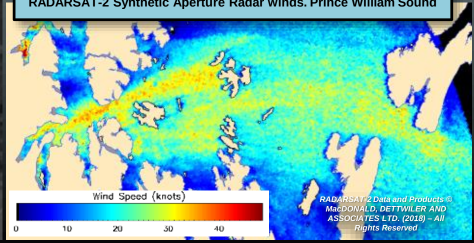
Progression of rapid cyclogenesis from Himiwari-8 Air Mass RGB 1/18/18. North Pacific Ocean/Aleutians. Yellows in the image depict high potential vorticity stratospheric air aiding in rapid deepening of the system.



Funny River fire, 5/20/14
S-NPP VIIRS 3.74 µm



RADARSAT-2 Synthetic Aperture Radar winds. Prince William Sound



AMS Poster Collaboration?

Use of High Resolution Polar-Orbiter Imagery and Evaluation of JPSS Ice Products in Sea Ice Analysis and Forecasting

The amount of detail required to track and analyze the concentrations and stage of sea ice is best provided by high-resolution polar-orbiting satellite imagery. The diminished temporal frequency of imagery, as compared to geostationary satellites, is balanced by the superior spatial resolution they provide. High-resolution imagery is capable of providing a plethora of information on sea ice. Concentration of ice is the most apparent data from the two dimensional top-down view, however, the appearance of ice over time can be used as a proxy for stage (thickness/age). The National Weather Service Alaska Sea Ice Program (ASIP) makes use of a multitude of satellite platforms and imagery to construct the daily analysis of ice concentration and stage from the Bering Sea through the Beaufort and Chukchi Seas as well as Cook Inlet. Visible and true color imagery from MODIS and VIIRS continue to serve well, sensing ice in cloud-free scenes. Infrared imagery becomes increasingly useful during the long winter as daylight is scarce while the Near Constant Contrast product (formerly known as the day/night band) allows for a consistent and comparable view with respect to visible imagery. Multi-channel RGB imagery combinations help discern ice from clouds and other land features. Synthetic aperture radar (SAR) and the Advanced Microwave Scanning Radiometer (AMSR-2) provide much needed microwave data coverage during prolonged cloudy periods as the signal is unaffected by clouds and precipitation. Despite the many and varying types of imagery available, there are still many days in which the imagery is insufficient for current meteorological conditions. The lack of data facilitates a need to collaborate with other agency partners for new analysis and forecasting techniques. In April of 2018 the Alaska Sea Ice Program participated in an evaluation of ice products from the Joint Polar Satellite System (JPSS). Products provided to the ASIP included analysis of Sea Ice Concentration, Ice Surface Temperature, Ice Thickness, and Blended Ice Motion. Examples intended for display will include the JPSS evaluation products, S-NPP Truecolor imagery, S-NPP Landcover, synthetic aperture radar, AMSR-2 Sea Ice Concentration, infrared and Near Constant Contrast.

Comments/Questions?

Contact information

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michael.lawson@noaa.gov
nws.ar.ice@noaa.gov

VIIRS ICE PRODUCTS: SURFACE TEMPERATURE, CONCENTRATION, AND THICKNESS

Mark Tschudi, CCAR, University of Colorado, Boulder

Y. Liu, R. Dvorak, X. Wang, SSEC, University of Wisconsin, Madison

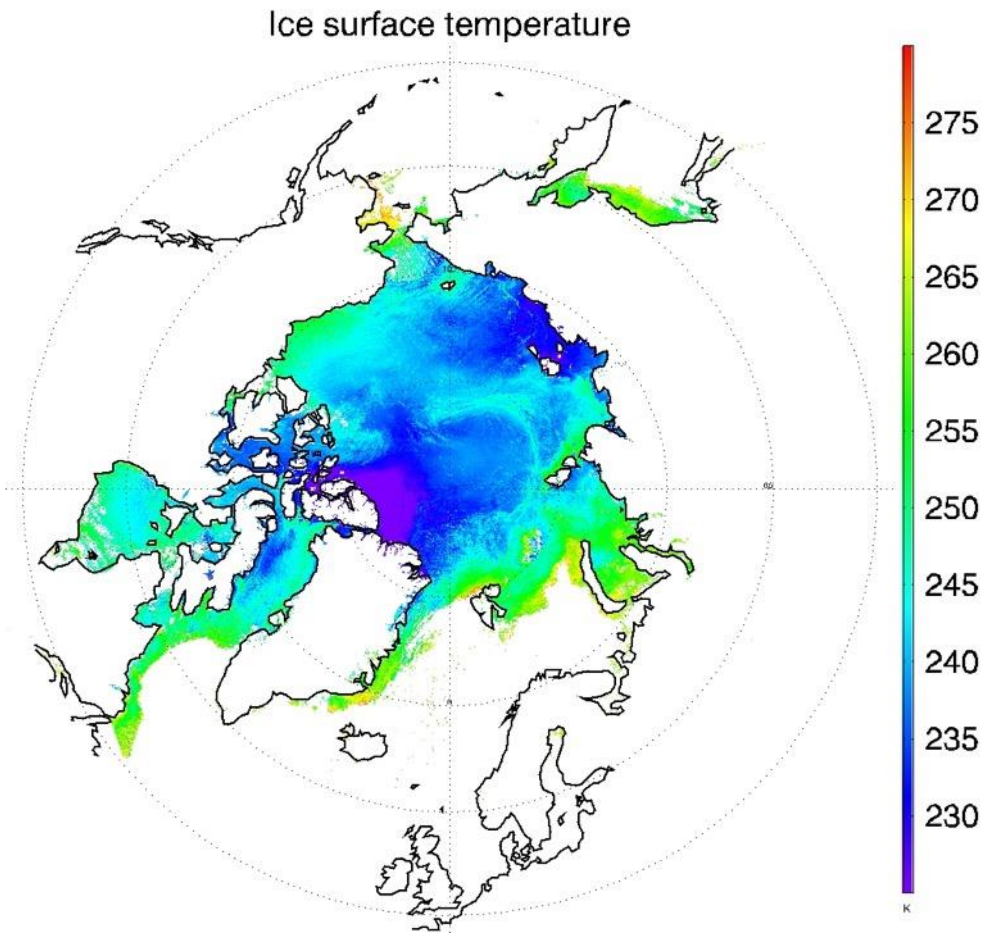
J. Key, NOAA/NESDIS

Sea Ice Cal/Val Team Members

PI	Organization	Team Members	Roles and Responsibilities
J. Key	NOAA NESDIS	M. Tschudi Y. Liu R. Dworak X. Wang A. Letterly	Ice conc & thickness cal/val IST development, cal/val IST cal/val Ice thickness development, cal/val NDE cryo products assessment

VIIRS Ice Surface Temperature

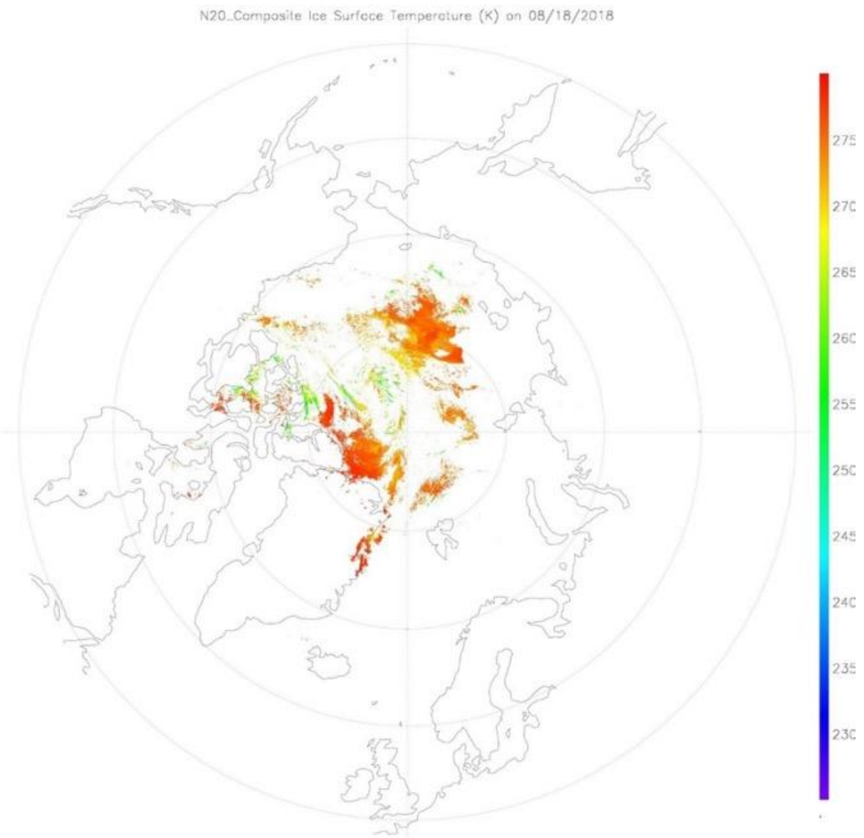
IST is the radiating, or "skin", temperature at the ice surface. It includes the aggregate temperature of objects comprising the ice surface, including snow and melt water on the ice.

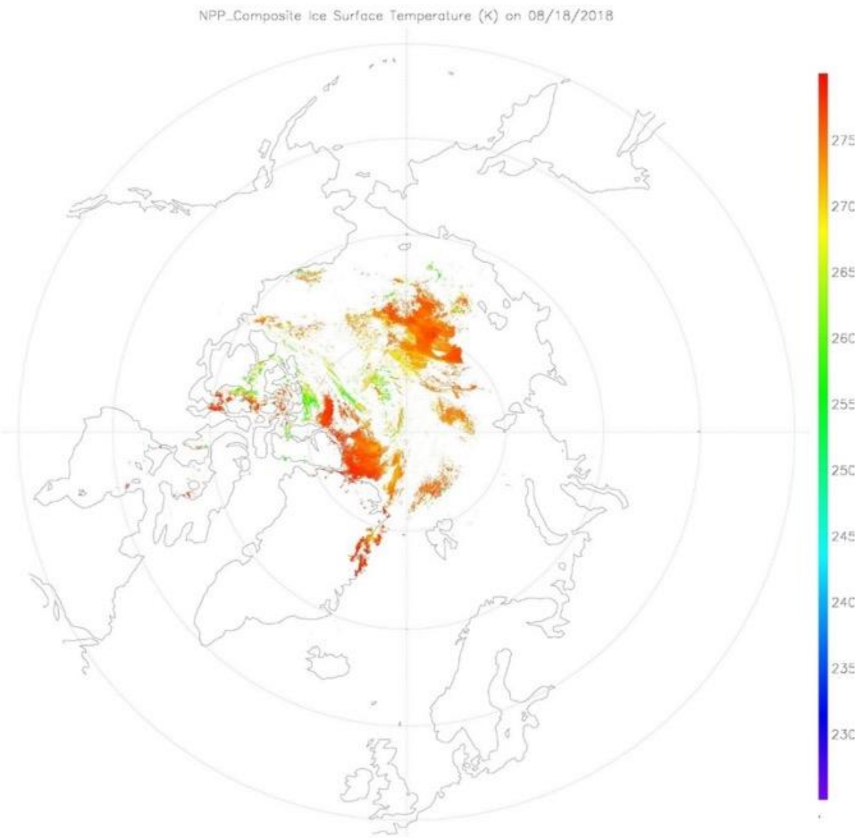


Ice surface temperature (IST) composite from all overpasses over the Arctic on March 1, 2015. From *Liu et al*., 2015.

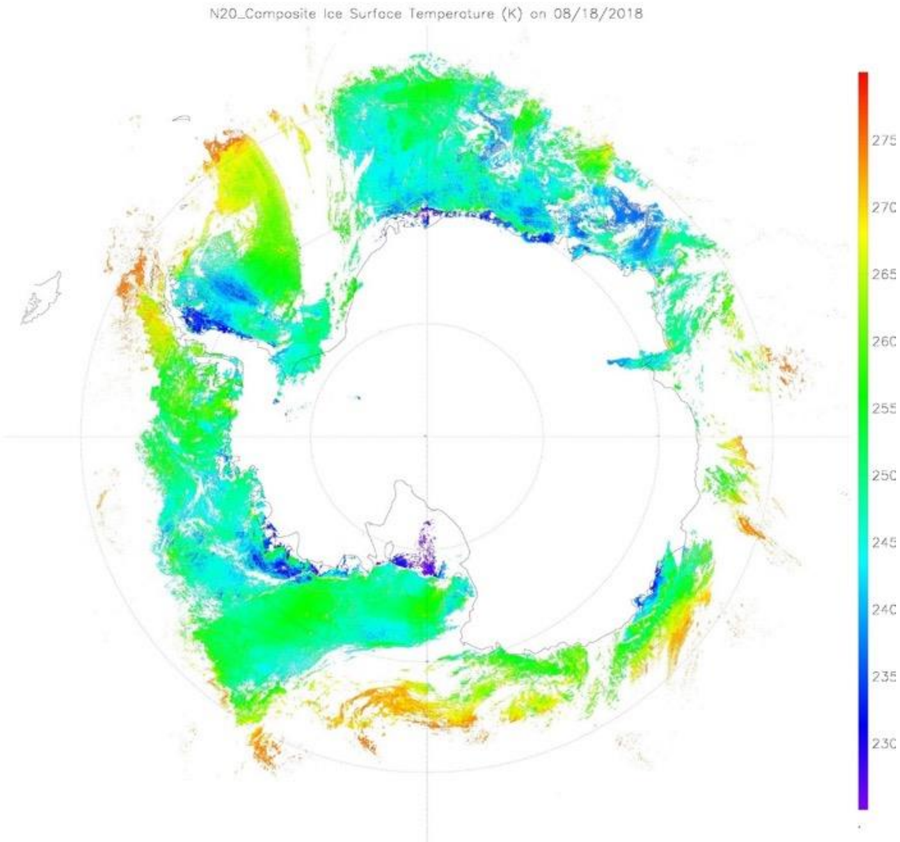
NOAA-20 and S-NPP IST, Arctic, Aug 18, 2018

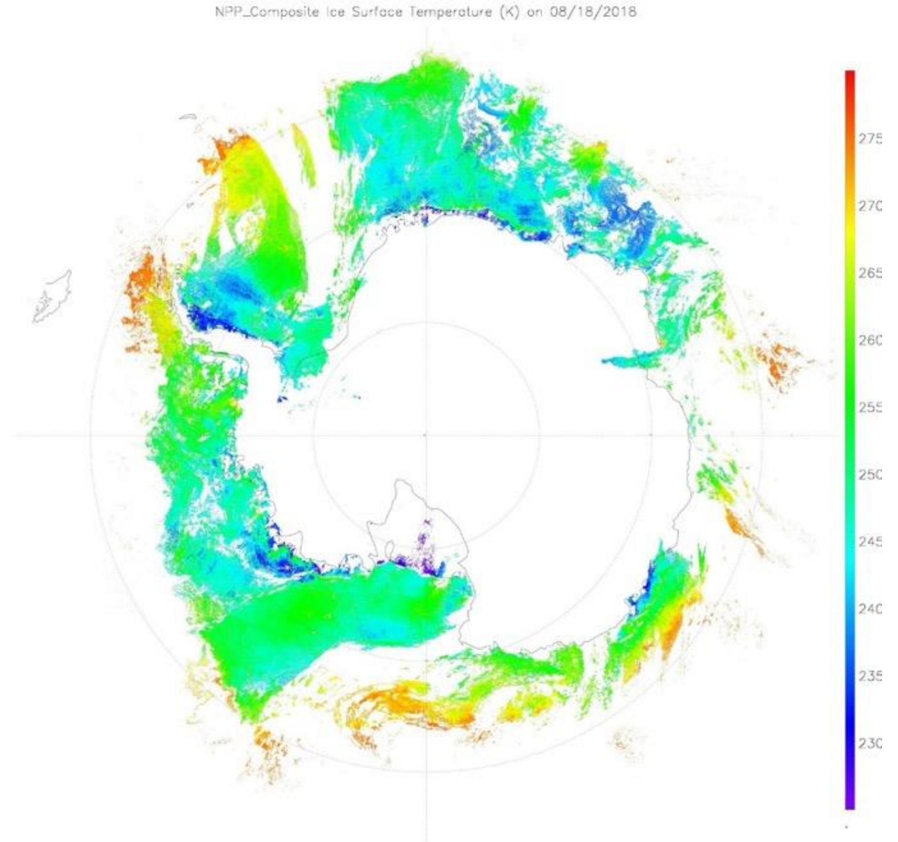
(all NOAA-20 images in this presentation are generated by CIMSS)



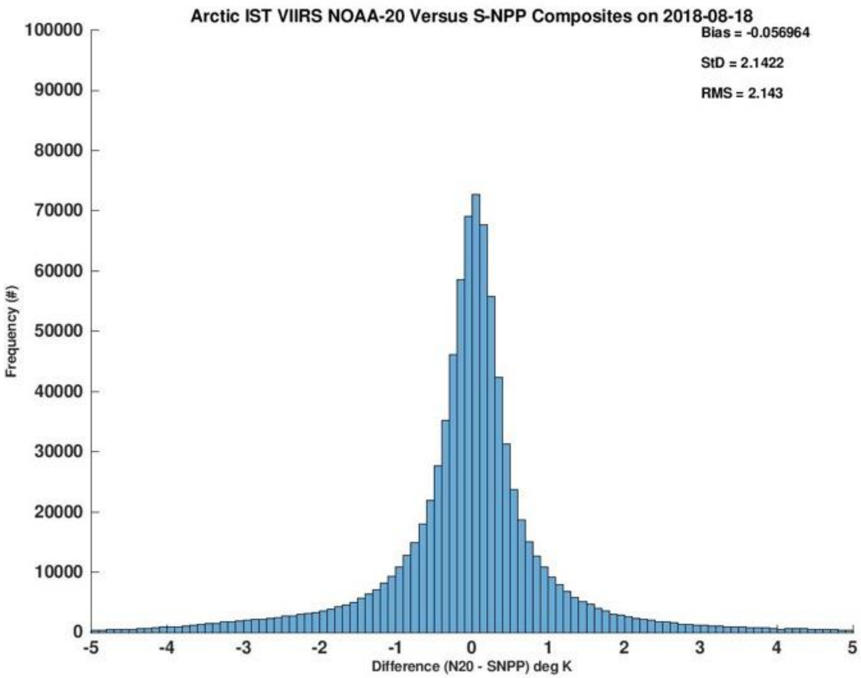


NOAA-20 and S-NPP IST, Antarctic, Aug 18, 2018

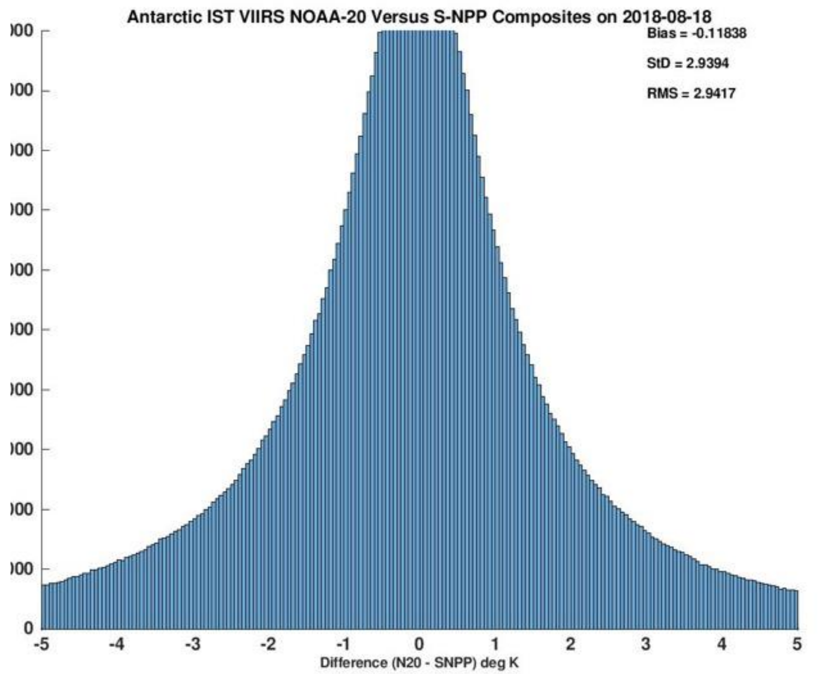




NOAA-20 vs S-NPP IST

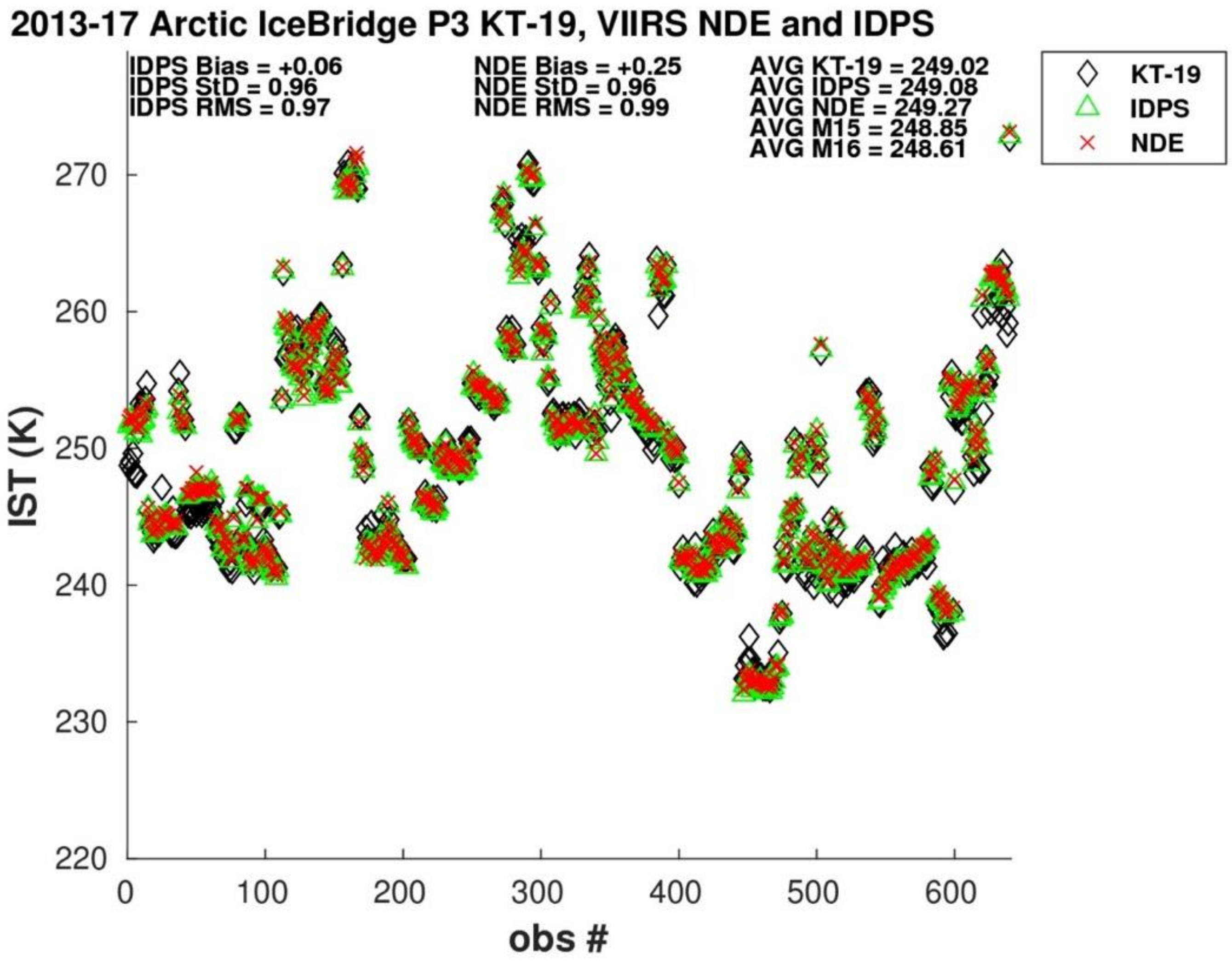


Bias: -0.057
RMS: 2.143



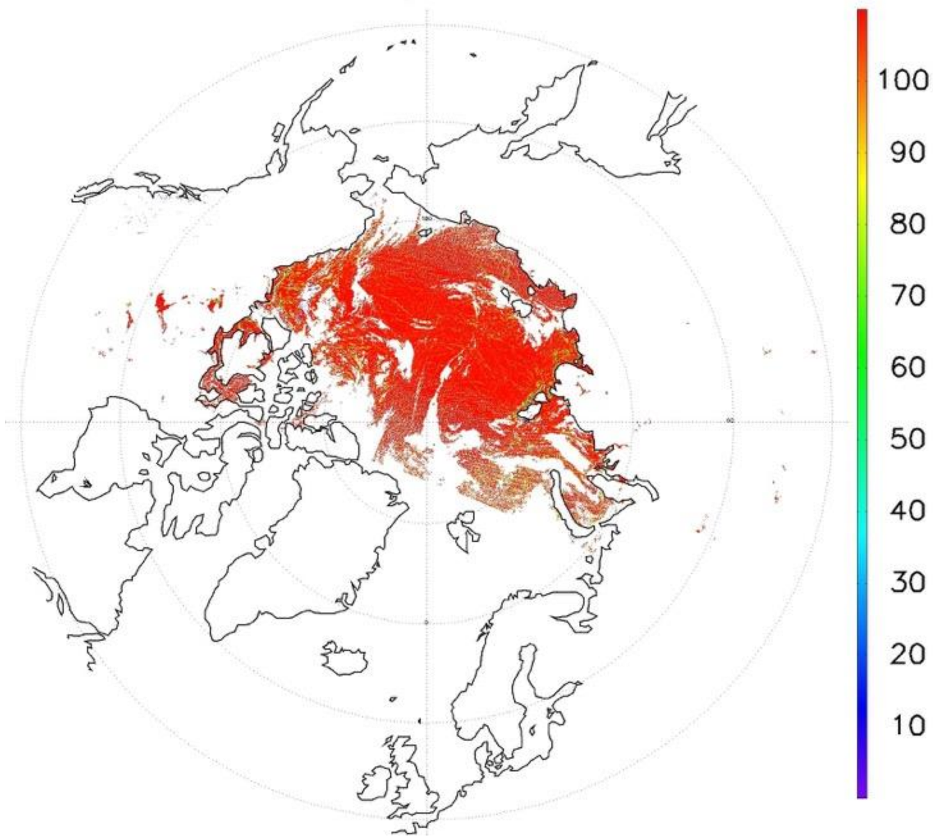
Bias: -0.118
RMS: 2.942

VIIRS IST IceBridge Validation



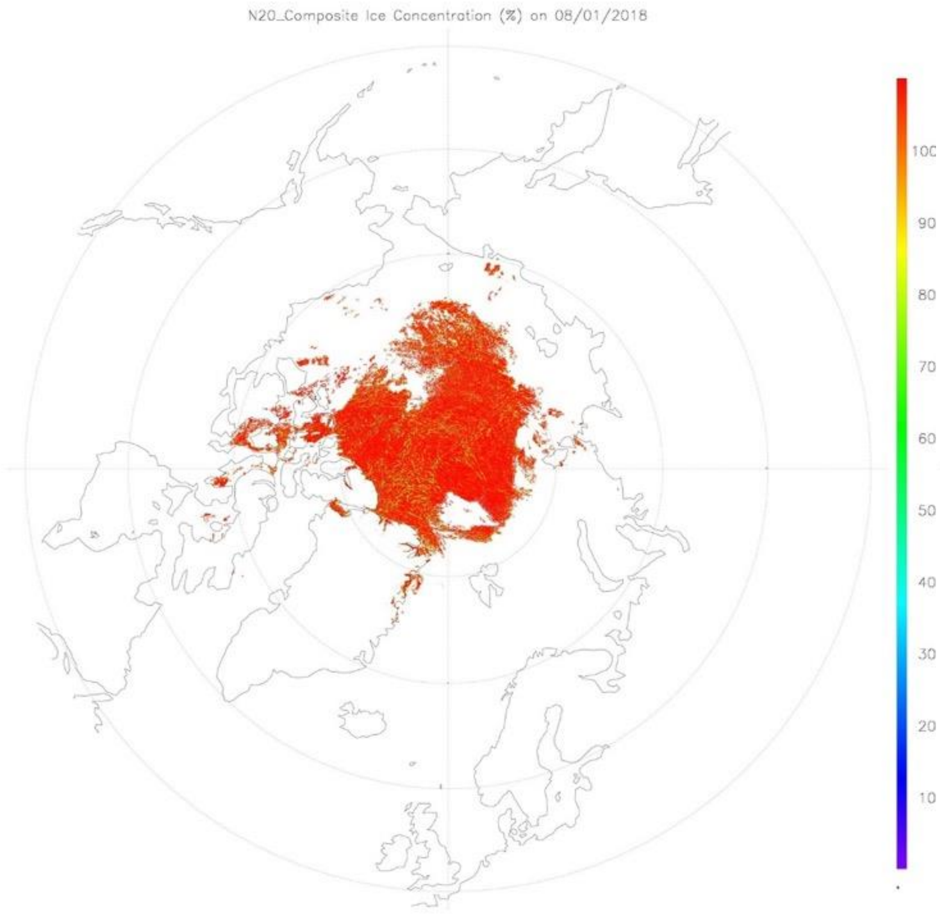
Ice Concentration

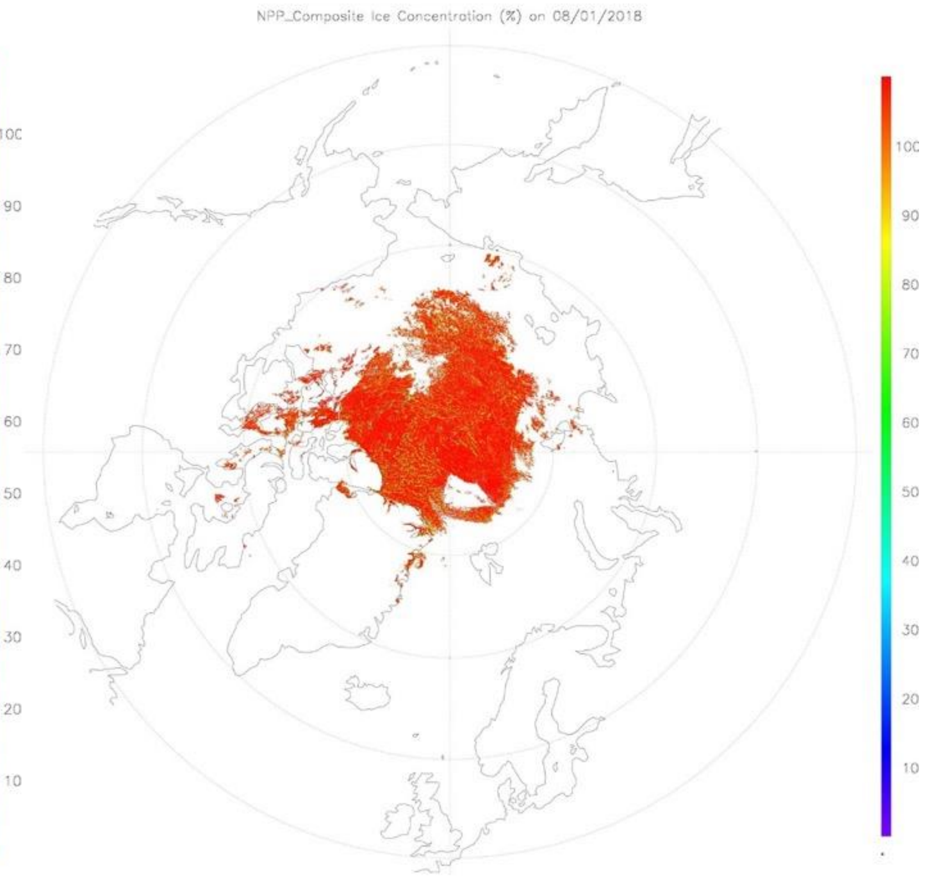
Sea ice concentration is the areal extent of ice, calculated as the fraction of each pixel covered in ice. The concentration of sea ice varies within the ice pack due to deformation, new ice development, melting, and motion.



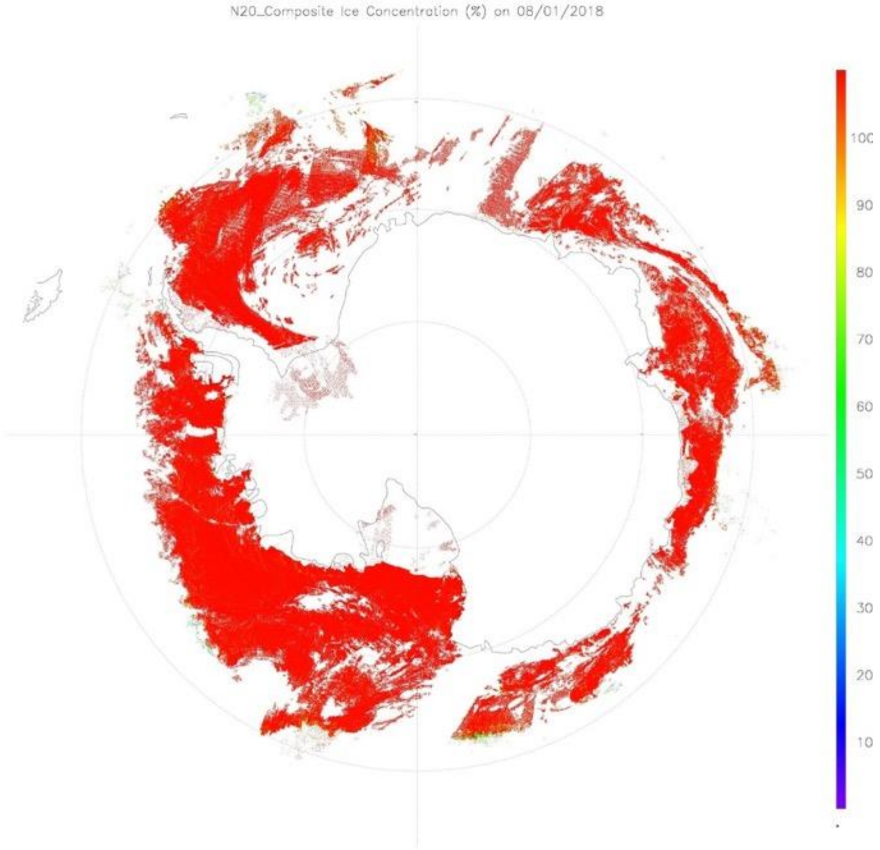
Ice concentration over the Arctic Ocean from VIIRS on February 20, 2015.

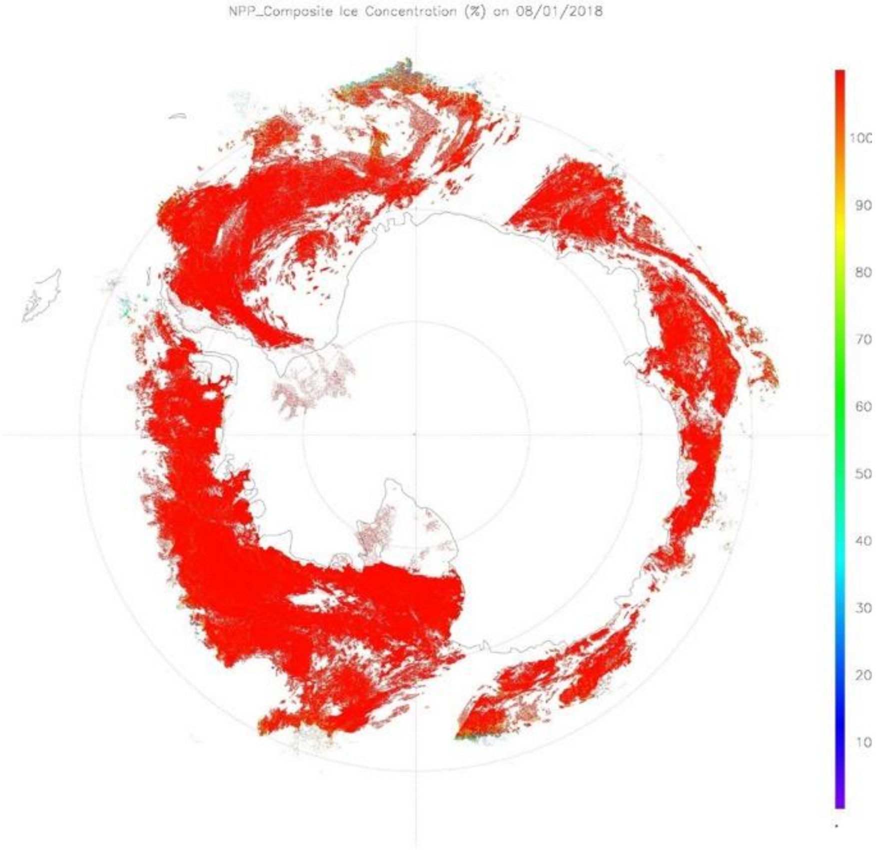
NOAA-20 and S-NPP Ice Concentration, Arctic, Aug 1, 2018



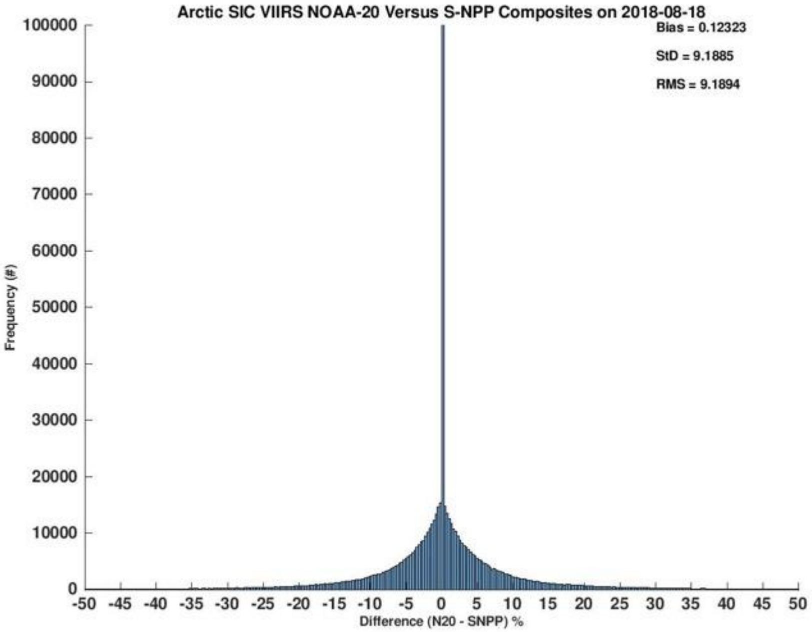


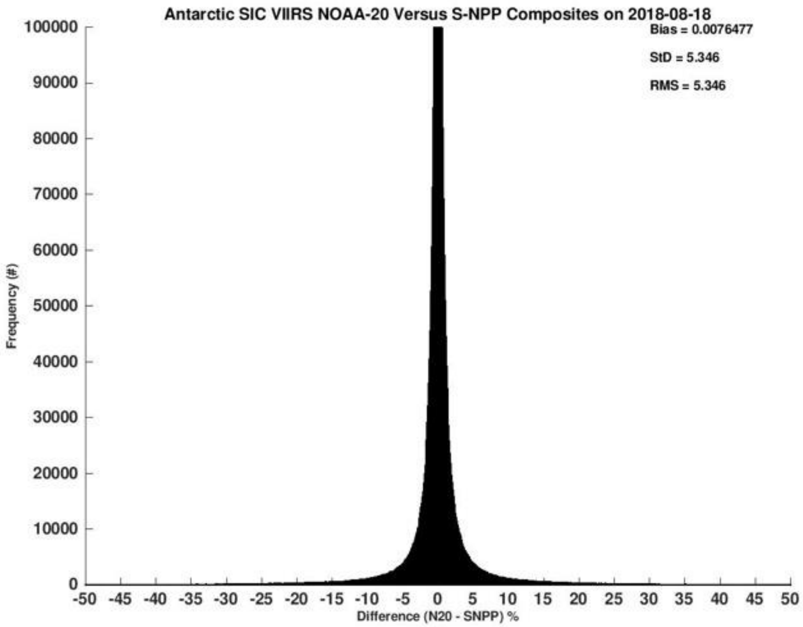
NOAA-20 and NPP Ice Concentration, Antarctic, Aug 1, 2018





NOAA-20 vs S-NPP Ice Concentration



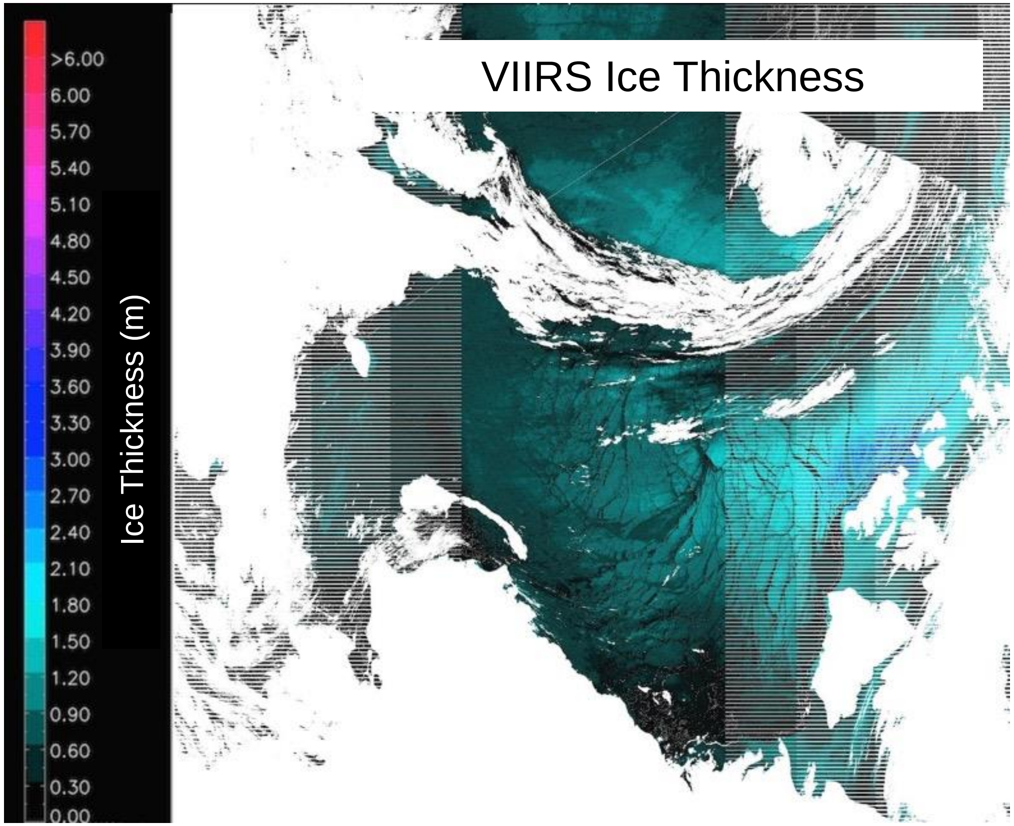


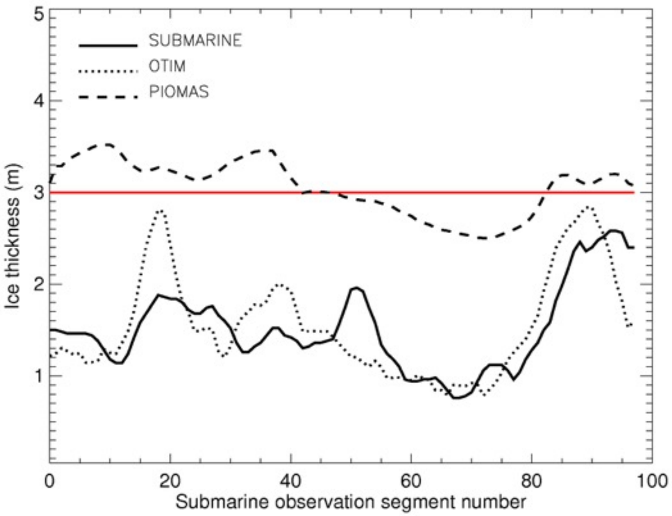
Bias: 0.123
RMS: 9.189

Bias: 0.0076
RMS: 5.346

Sea Ice Thickness

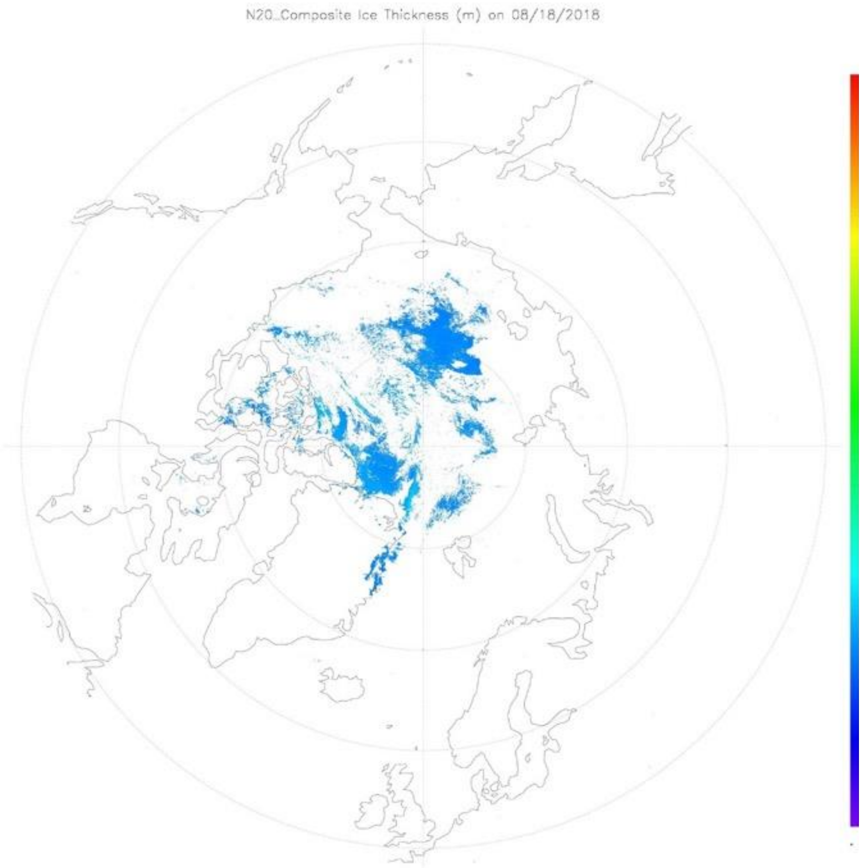
The Sea Ice Characterization EDR is a 3-category product: new/young ice (< 30 cm thick), “other ice”, and ice-free. The Enterprise product provides a continuous ice thickness range from 0 ~ 2.5 m.

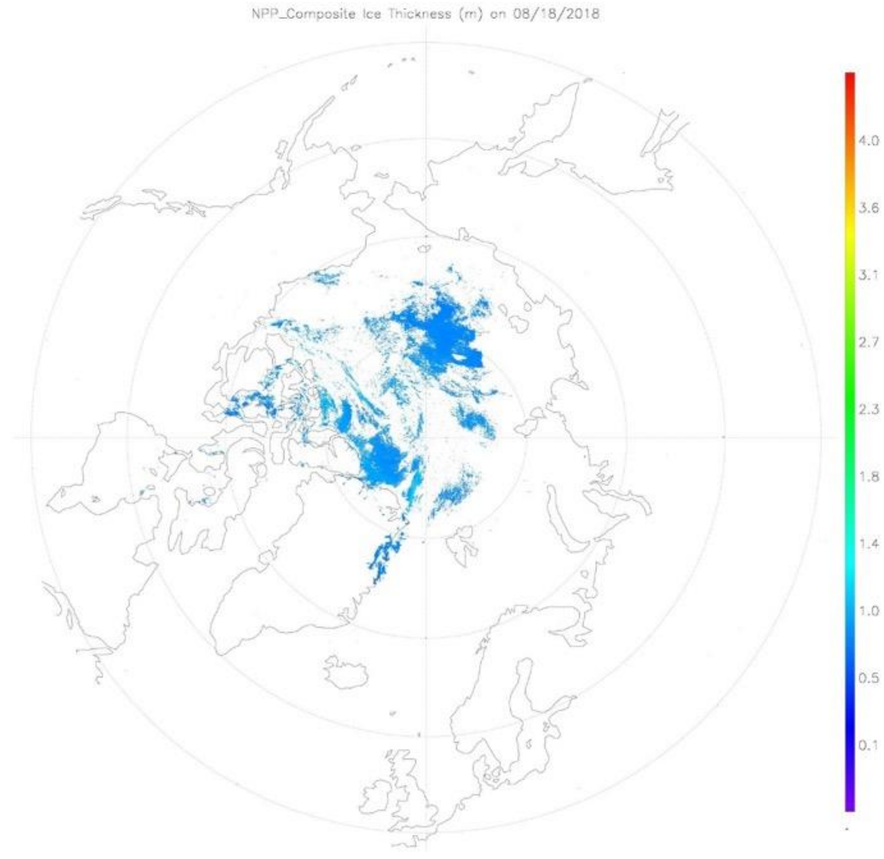




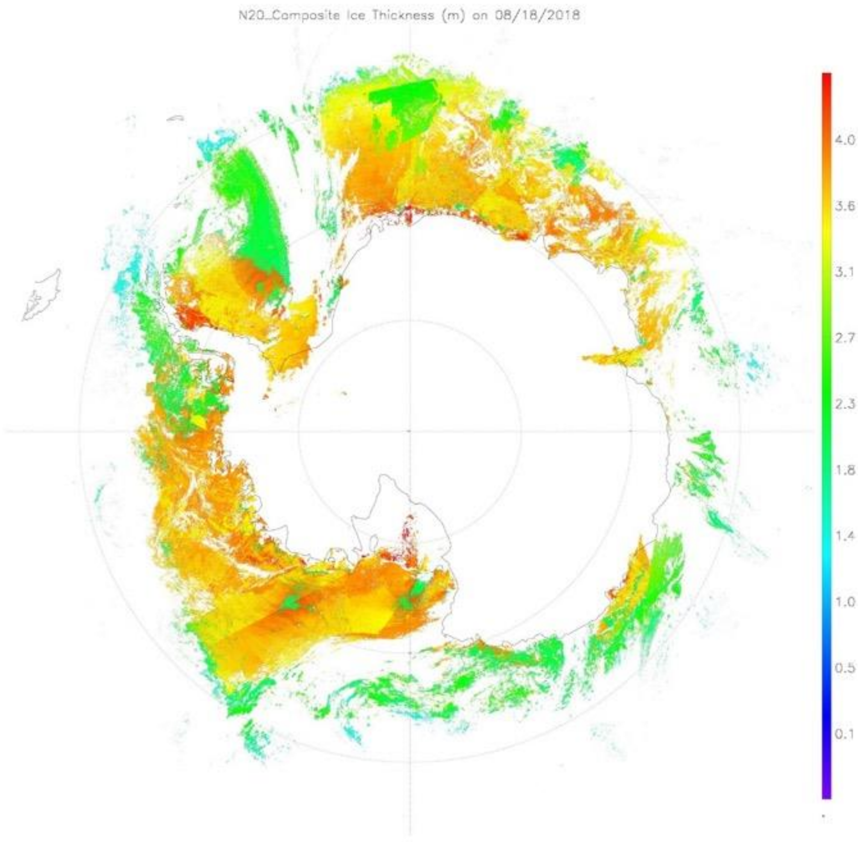
Validation with submarine sonar and modeled ice thicknesses.

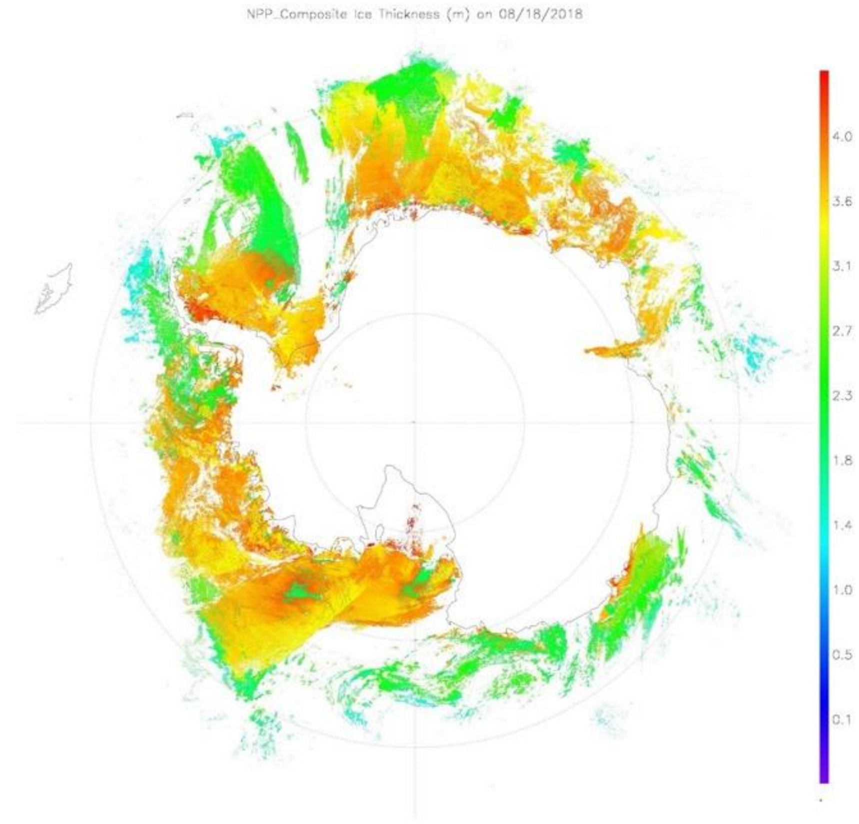
NOAA-20 and S-NPP Ice Thickness, Arctic, Aug 18, 2018



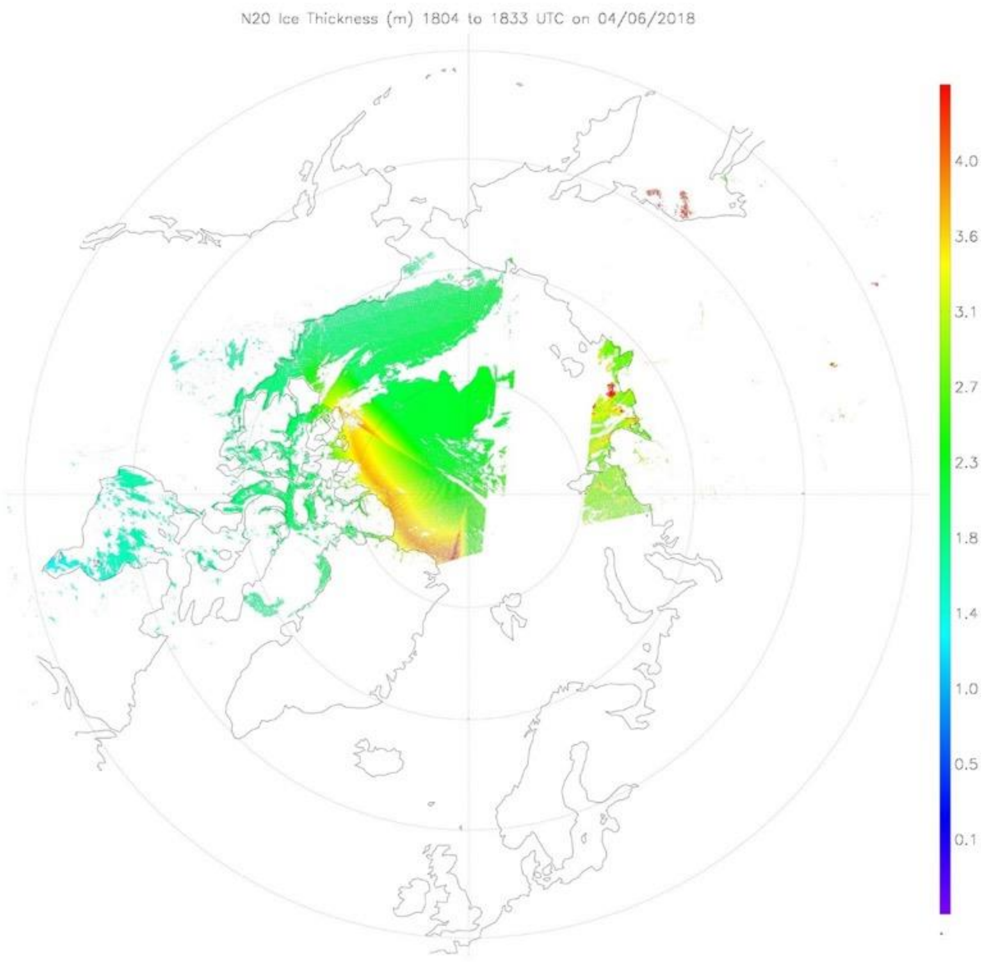


NOAA-20 and S-NPP Ice Thickness, Antarctic, Aug 18, 2018





NOAA-20 Ice Thickness vs. IceBridge

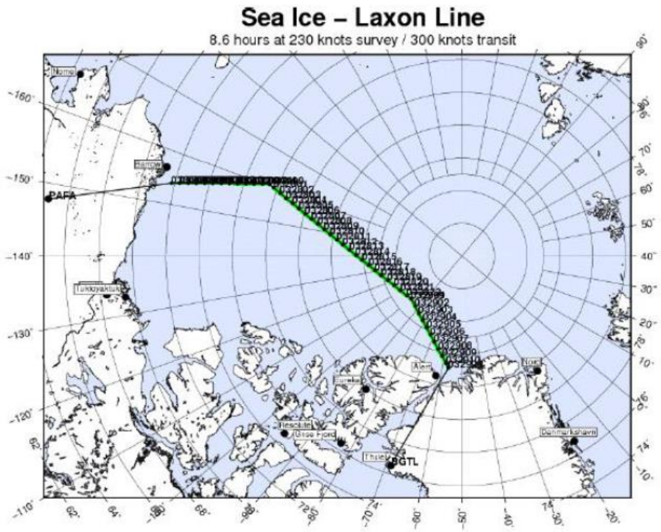


<u>April 6, 2018</u>

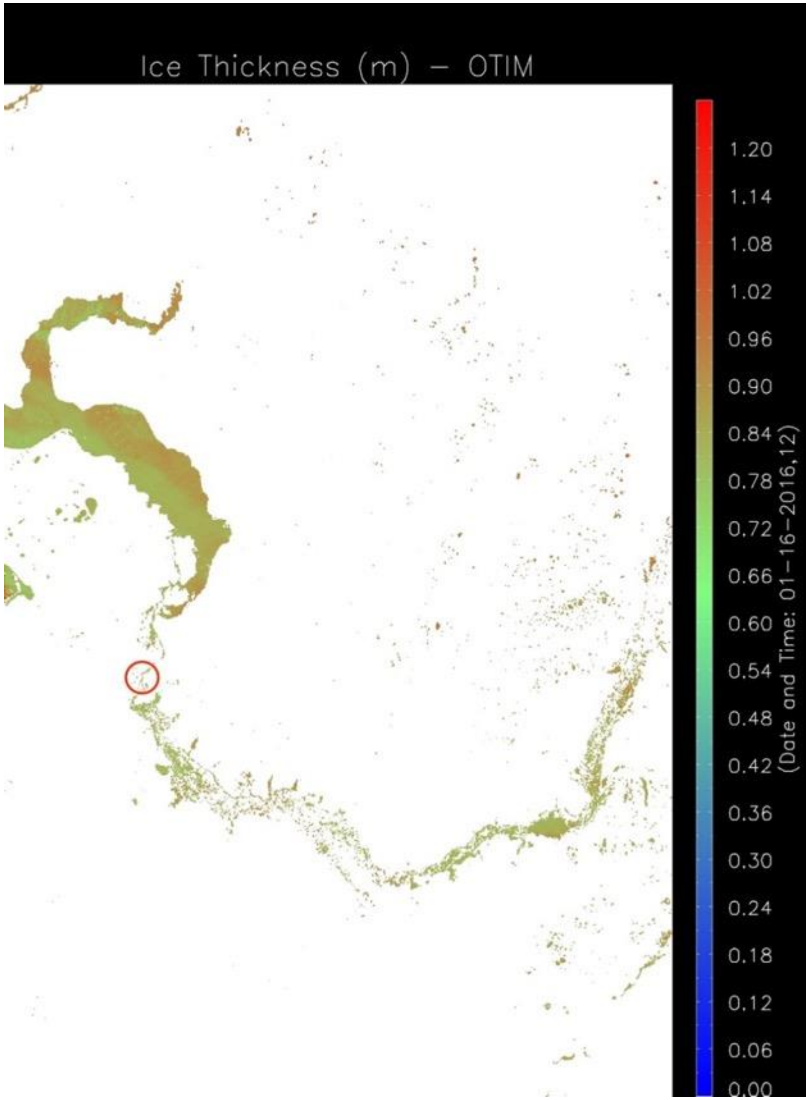
Mean OIB thickness: 3.014m
Mean N-20 thickness: 3.114m

OIB Std Dev: 1.313m
N-20 Std Dev: 0.270m

Correlation: 0.124



VIIRS Sea Ice Thickness on the OB River, Western Siberia



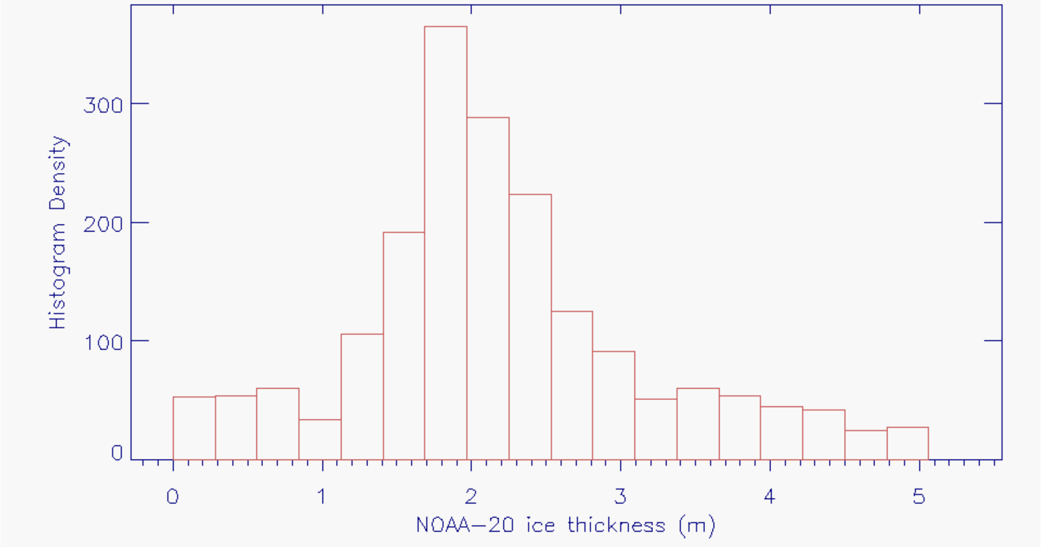
On-ice thickness: 55-60 cm
S-NPP VIIRS thickness: 70 cm

Sea Ice Thickness: NOAA-20 vs CryoSat-2

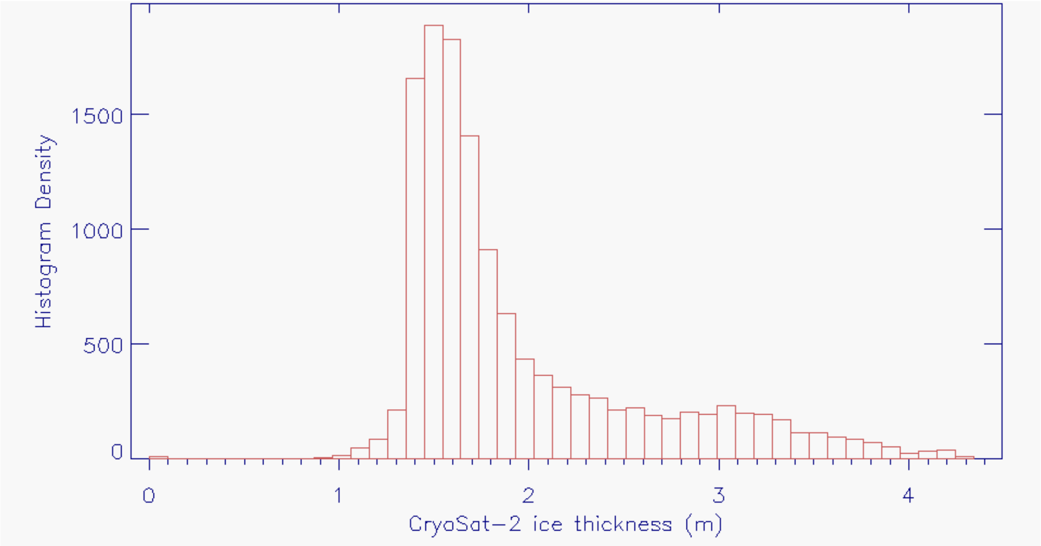
Arctic

April 22-29, 2018

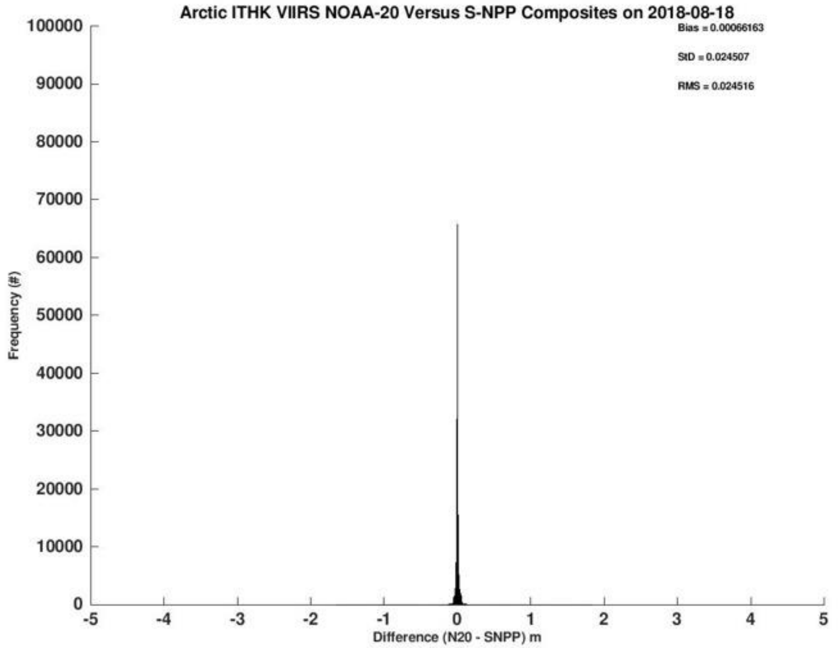
NOAA-20

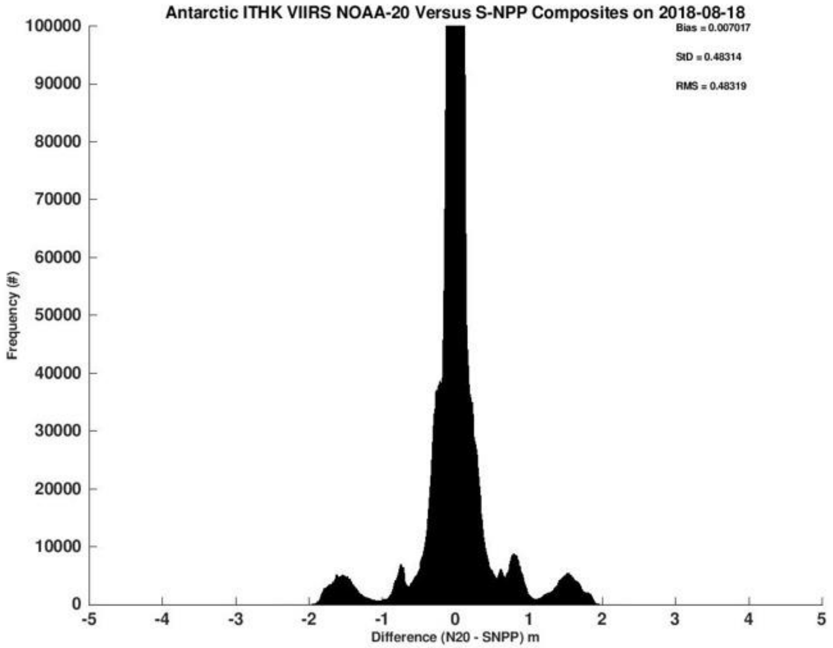


CryoSat-2



NOAA-20 vs S-NPP Ice Thickness





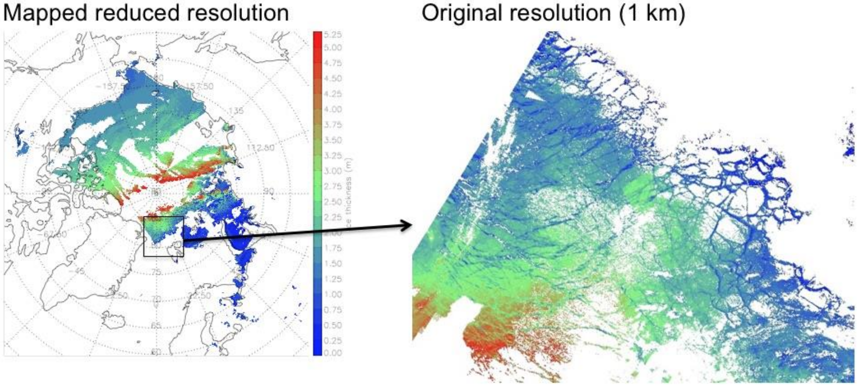
Bias = 0.00066
RMS = 0.0245

Bias = 0.0070
RMS = 0.4832

NOAA-20 Beta Maturity Review

- The Cryosphere Team participated in the May/June 2018 N20 Calibration/Validation Beta Maturity Review on June 15, 2018.
- The cryosphere products reviewed were binary and fractional snow cover, ice surface temperature, ice concentration, and ice thickness/age.
- The products were accepted as achieving the Beta Maturity level.

NOAA-20 Sea Ice Thickness



Daily composite on April 23, 2018, ice thickness (m).

Example of the sea ice thickness product that was evaluated in the maturity review.

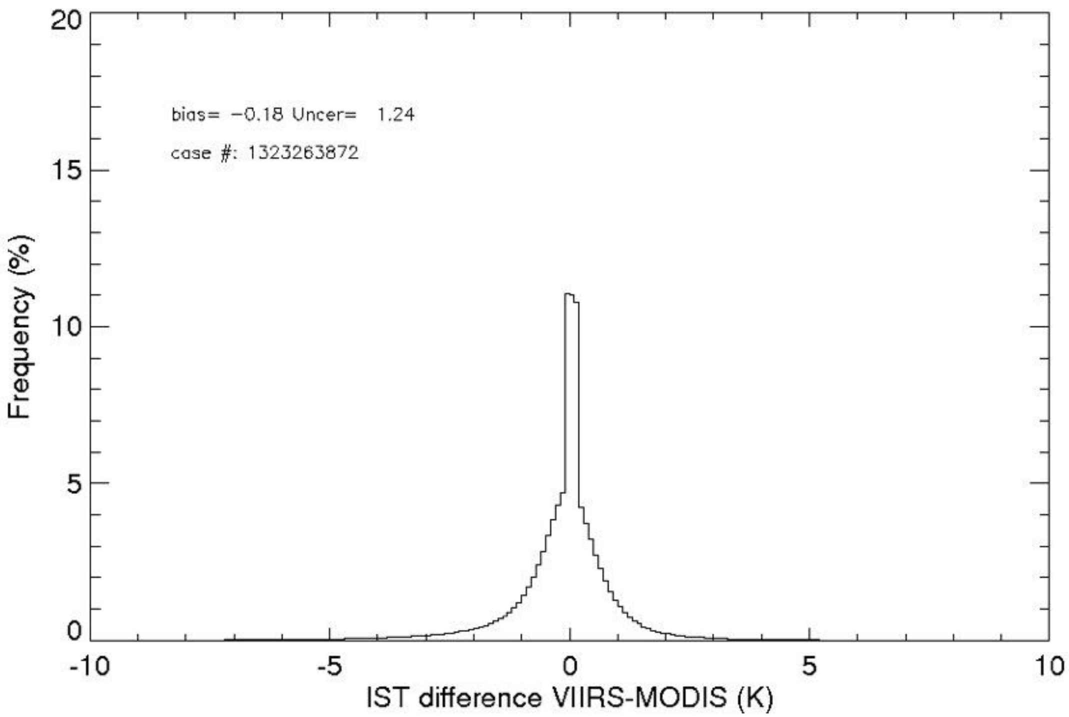
VIIRS Sea Ice Product Performance Summary

Product	L1RDS APU Thresholds	Performance	Meets Spec?
Ice surface temperature	1 K uncertainty	0.9 K	Y
Ice concentration	10% uncertainty	8.9%	Y
Ice thickness/age	70% correct typing (new/young, other ice); no thickness requirement	90% (first-year/other); 0.5 m precision for thickness	Y

Thank you

OVERFLOW SLIDES

VIIRS / MODIS IST Inter-comparison



Differences between NPP VIIRS and MODIS (Aqua and Terra) IST in the Arctic from August 2012 to July 2015.

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

VIIRS IST Validation Approach

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

NRT Demo for NWS ASIP; Status; Milestones

Accomplishments / Events:

- In April, 2018, the VIIRS Cryosphere Team performed a near-real-time demonstration of ice products for the Alaska Sea Ice Program (ASIP, NWS).
- Level 1b data and the Enterprise Cloud Mask were obtained from the University of Alaska-Fairbanks direct broadcast system. Ice products were then generated by CIMSS and sent to GINA for display and use by ASIP.
- The ice products include ice concentration, ice thickness, ice surface temperature, and ice motion.
- While some issues were encountered, they were quickly resolved and testing by ASIP was largely successful.

Overall Status:

	Green[1] (Completed)	Blue[2] (On-Schedule)	Yellow[3] (Caution)	Red[4] (Critical)	Reason for Deviation
Cost / Budget		x			
Technical / Programmatic		x			
Schedule		x			

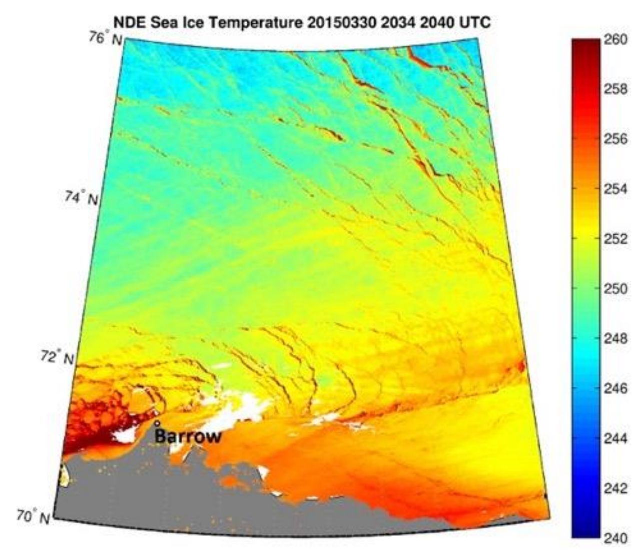
1. *Project has completed.*
2. *Project is within budget, scope and on schedule.*
3. *Project has deviated slightly from the plan but should recover.*
4. *Project has fallen significantly behind schedule, and/or significantly over budget.*

Issues/Risks:

None

FY18 TTA Milestones	Original Date	Forecast Date	Actual Completion Date	Variance Explanation
J1 post-launch calibration/validation				
Beta Maturity: IST	May-18	May-18		
Beta Maturity: Snow	Jun-18	Jun-18		
Beta Maturity: SeaIce	Jul-18	Jul-18		
Provisional Maturity (IST, Snow, and SeaIce)	Sep-18	Sep-18		
J1 algorithm adjustments:				
Preliminary DAP to ASSISTT (science team to ASSISTT)	Apr-18	Apr-18		
Preliminary DAP to NDE (ASSISTT to NDE)	Jun-18	Jun-18		
SNPP/J1 algorithm Refinement (Maintenance DAP)				
Improvements to snow and ice algorithms	Sep-18	Sep-18		
Add J1 products to EDR monitoring web	Sep-18	Sep-18		
JPSS EPS algorithm updated DAPs	11/21/17; 02/02/18 (J1 capability)			

Highlights:



Ice surface temperature (IST) north of Alaska from VIIRS.

NOAA-20 Maturity Review

June, 2018

Accomplishments / Events:

- NOAA-20 Maturity Review:
  - The Cryosphere Team participated in the May/June 2018 N20 Calibration/Validation Maturity Review on June 15, 2018.
  - The cryosphere products reviewed were binary and fractional snow cover, ice surface temperature, ice concentration, and ice thickness/age.
  - They were accepted as achieving the Beta Maturity level.
- The Provisional Maturity review will be held in a few months, possibly September.

Overall Status:

	Green[1] (Completed)	Blue[2] (On-Schedule)	Yellow[3] (Caution)	Red[4] (Critical)	Reason for Deviation
Cost / Budget		x			
Technical / Programmatic		x			
Schedule		x			

1. *Project has completed.*
2. *Project is within budget, scope and on schedule.*
3. *Project has deviated slightly from the plan but should recover.*
4. *Project has fallen significantly behind schedule, and/or significantly over budget.*

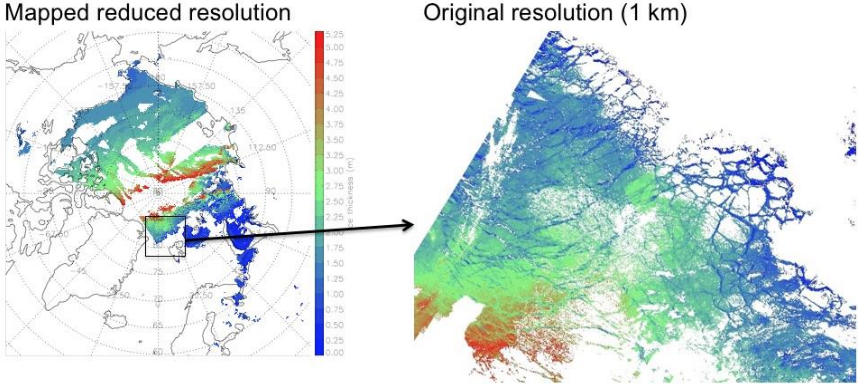
Issues/Risks:

None

FY18 TTA Milestones	Original Date	Forecast Date	Actual Completion Date	Variance Explanation
J1 post-launch calibration/validation				
Beta Maturity: IST	May-18	May-18	06/15/18	Scheduled 6/15
Beta Maturity: Snow	Jun-18	Jun-18	06/15/18	
Beta Maturity: SeaIce	Jul-18	Jul-18	06/15/18	
Provisional Maturity (IST, Snow, and SeaIce)	Sep-18	Sep-18		
J1 algorithm adjustments:				
Preliminary DAP to ASSISTT (science team to ASSISTT)	Apr-18	Apr-18	Apr-18	
Preliminary DAP to NDE (ASSISTT to NDE)	Jun-18	Jun-18		
SNPP/J1 algorithm Refinement (Maintenance DAP)				
Improvements to snow and ice algorithms	Sep-18	Sep-18		
Add J1 products to EDR monitoring web	Sep-18	Sep-18		
JPSS EPS algorithm updated DAPs	11/21/17;	02/02/18 (J1 capability)		

Highlights:

NOAA-20 Sea Ice Thickness



Daily composite on April 23, 2018, ice thickness (m).

Example of the sea ice thickness product that was evaluated in the maturity review.

VIIRS SNOW COVER PRODUCTS: CURRENT STATUS AND PLANS

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

Outline

- VIIRS Binary Snow Cover and Fractional Snow Cover
  - Definition, requirements
  - NDE product performance
  - NOAA-20 Snow Product Status
  - Further algorithm enhancements

Cal/Val Team Members

Name	Organization	Roles and Responsibilities
Jeff Key	NOAA/NESDIS	Cryosphere Team Lead
Peter Romanov	CUNY/CREST	Snow Products Lead
John Woods	NOAA/NIC	User/Applications
William Lapenta, Jiarui Dong	NOAA/NWS	User/Applications

JPSS ESPC (JERD) Requirements

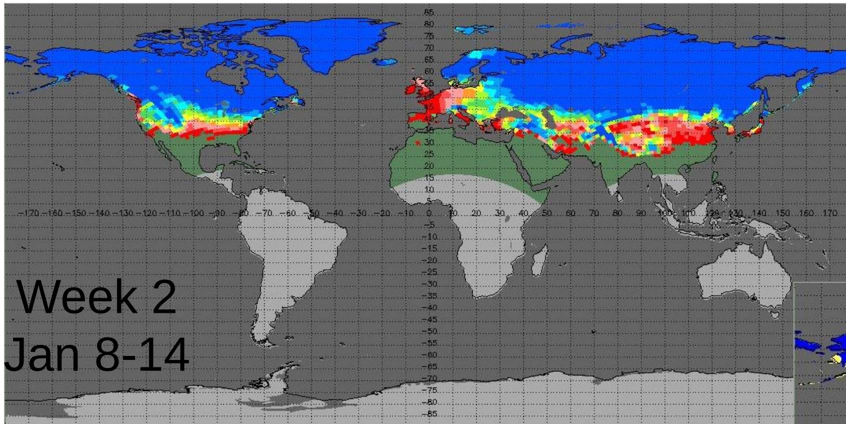
- Binary snow map:
  - Snow/no snow discrimination
  - 90% probability of correct typing
    - Over climatologically snow-affected areas

- Snow fraction:
  - “Viewable” snow fraction
  - 20% accuracy

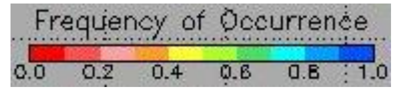
- Both products are
  - Clear-sky daytime-only land products
  - Derived at 375 m resolution

- Both products depend on the accuracy of VIIRS cloud mask.

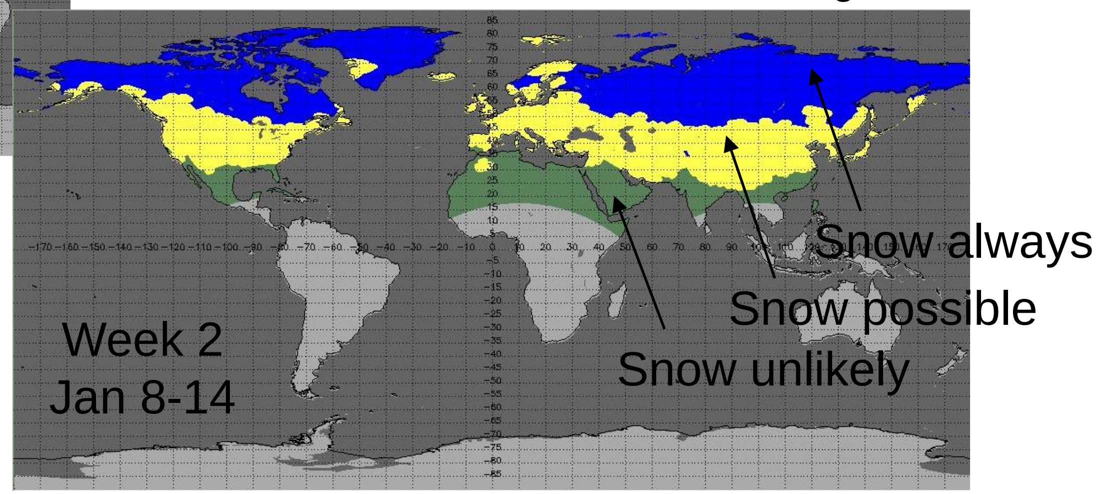
Climatologically snow-affected areas



Weekly climatic snow cover occurrence



Snow cover occurrence categories



- Accuracy estimates are provided for the “snow possible” region (shown in yellow)
- Boundaries of the “snow possible” region change with time during the year

Binary Snow Cover

NDE Binary Snow Algorithm

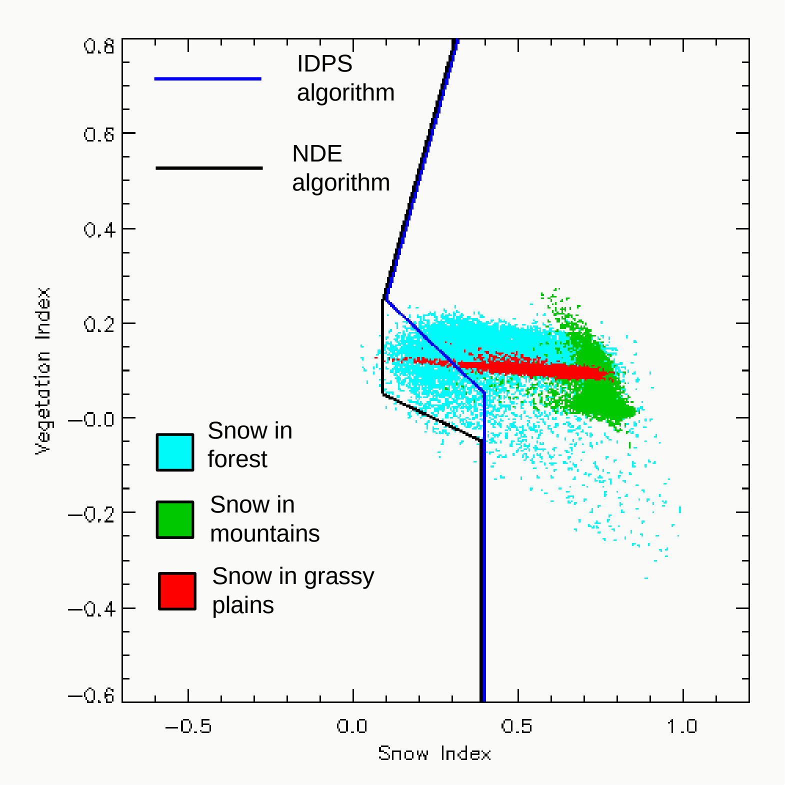
Two-stage algorithm:

1. Spectral threshold tests

- VIIRS Bands I1, I2, I3, I5
- NDVI, NDSI
- Improved snow identification in forest

2. Consistency tests

- Eliminate spurious snow



Consistency tests (applied to "snow" pixels) :

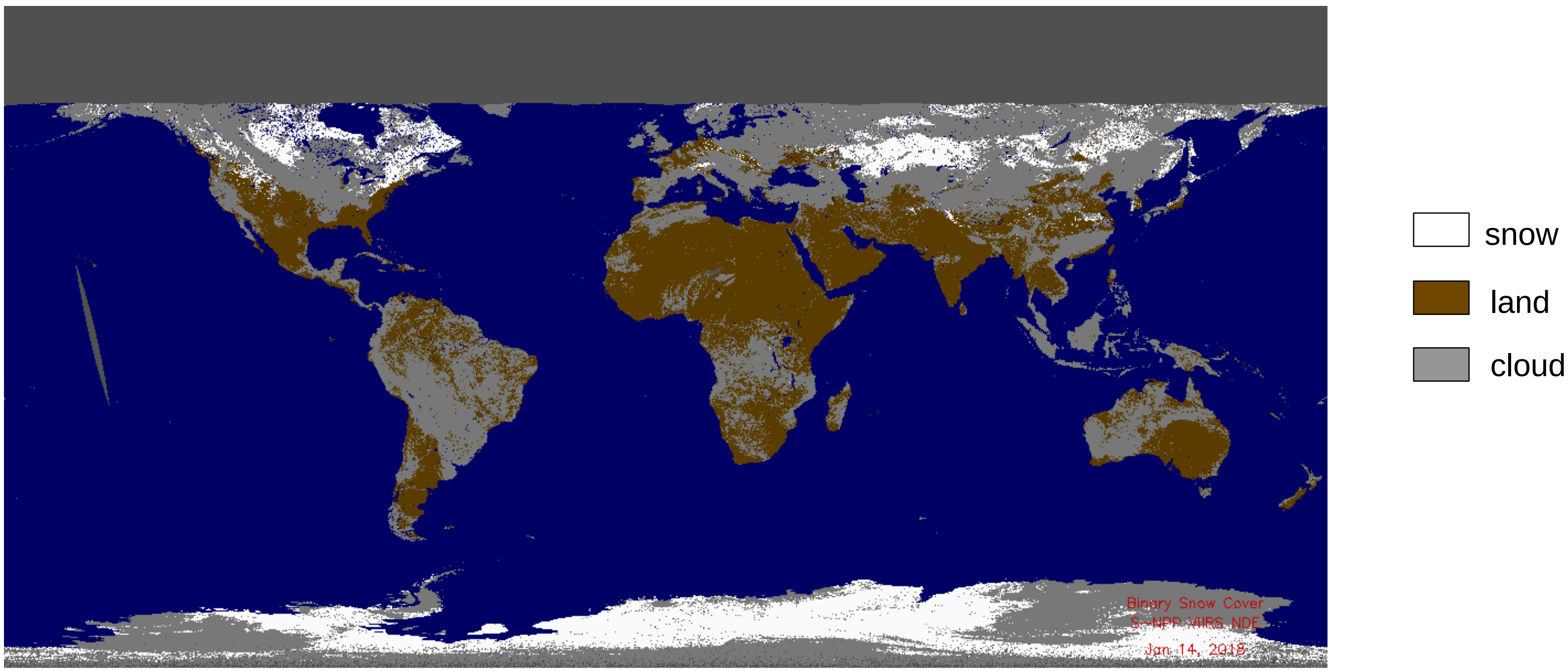
- Snow climatology
- Surface temperature climatology
- Spatial consistency
- Temperature spatial uniformity

Algorithm applied only:

- Over land surface (as per land/water mask)
- Over clear sky scenes (as per external cloud mask, confidently clear only)
- During daytime

NDE Daily Product Monitoring

- Granules are aggregated and gridded to 0.01^0 geographical projection
- Product quality and performance is evaluated by:
  - Visual examination (includes comparison with true color imagery)
  - Comparison with IMS and in situ data



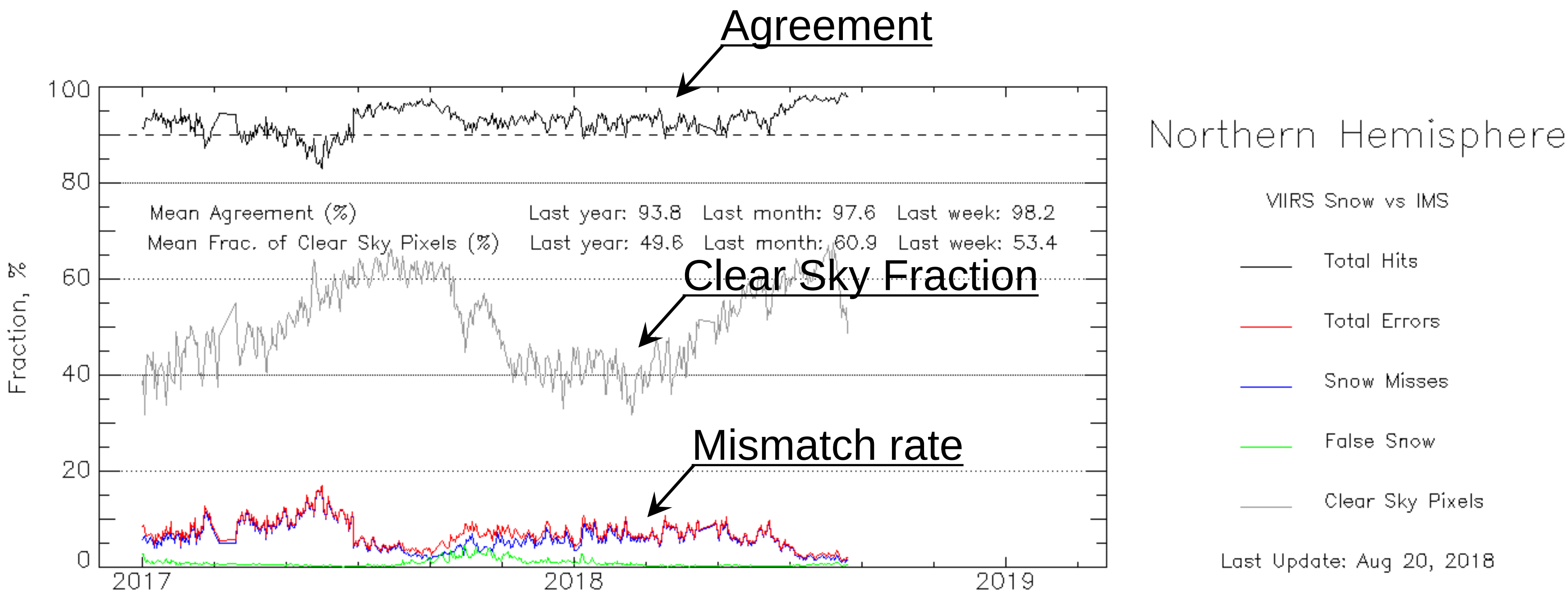
- On the Web (map updated daily)

  http://www.star.nesdis.noaa.gov/smcd/emb/snow/viirs/viirs-snow-fraction.html
  http://www.star.nesdis.noaa.gov/jpss/EDRs/products_snow.php

SNPP VIIRS NDE Snow vs IMS

SNPP VIIRS Binary Snow Map : Daily agreement to IMS

Climatologically snow-affected areas only



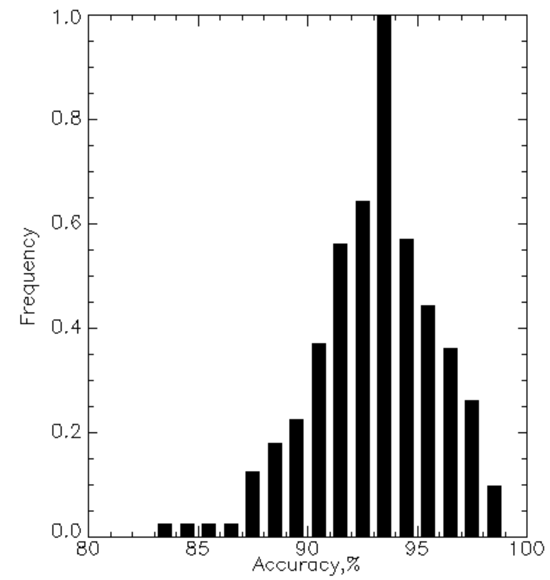
- Agreement rate mostly exceeds 90%
- IMS maps more snow than VIIRS
- VIIRS clear sky fraction over land: ~ 40- 60%, varies with season

SNPP NDE Binary Snow: Accuracy

Daily rate of agreement of VIIRS NDE snow maps*

- To IMS (NH, over "snow possible" area)
  - Mean: 93.8%,
  - Range: 85-97%
- To in situ reports (CONUS & Southern Canada)
  - Mean: 93.3%
  - Range: 82-98%

* Assessment based on 2017-2018 winter season data of SNPP VIIRS



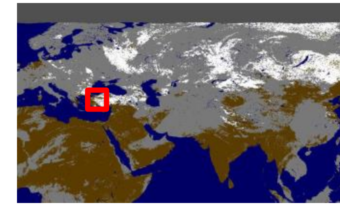
Statistics of VIIRS NDE vs IMS daily agreement rate over NH

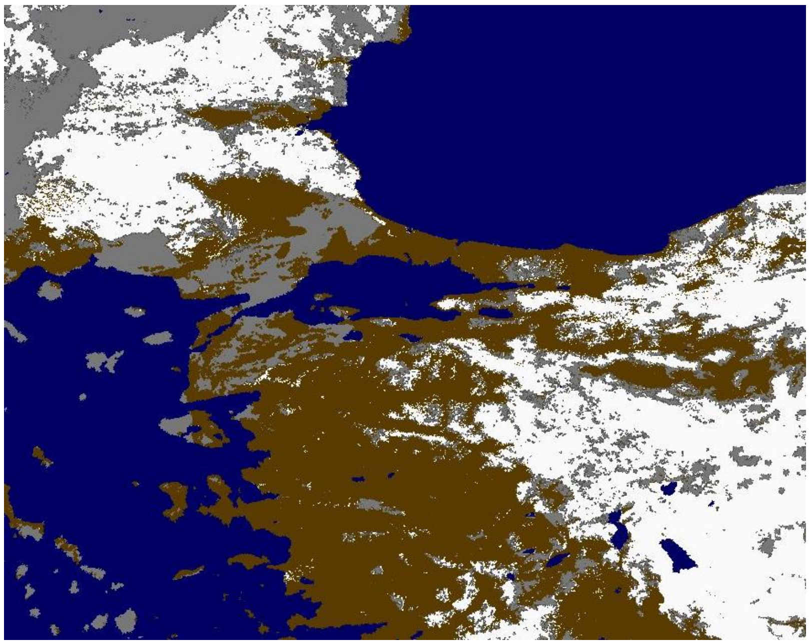
Product	Requirement	Performance
Binary Snow	90% Correct Typing	Mean: 93-94% Range: 82-98%

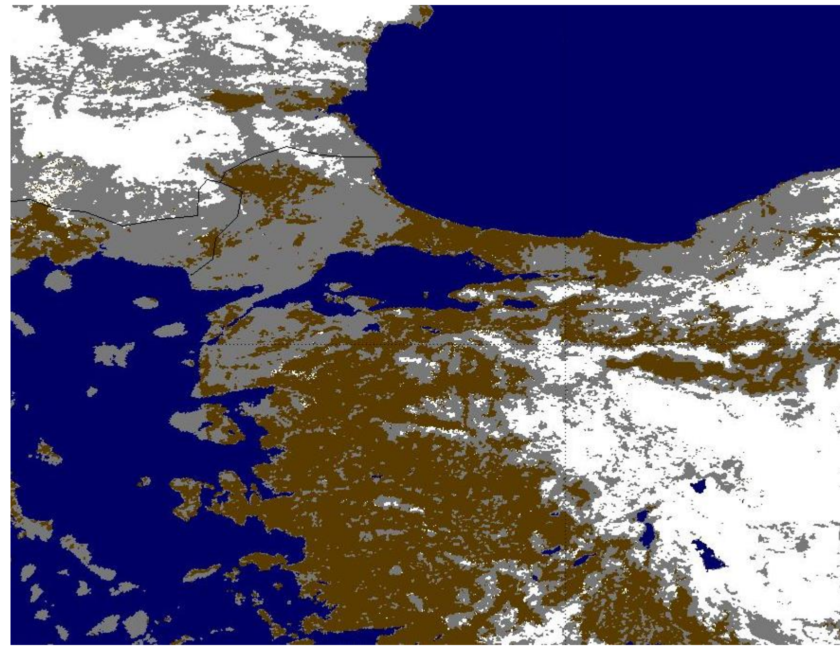
Product generally satisfies current requirements

NDE vs IDPS Binary Snow Product

NDE: Better delineation of the snow cover boundary due to less conservative cloud masking in the snow/no-snow transition zone







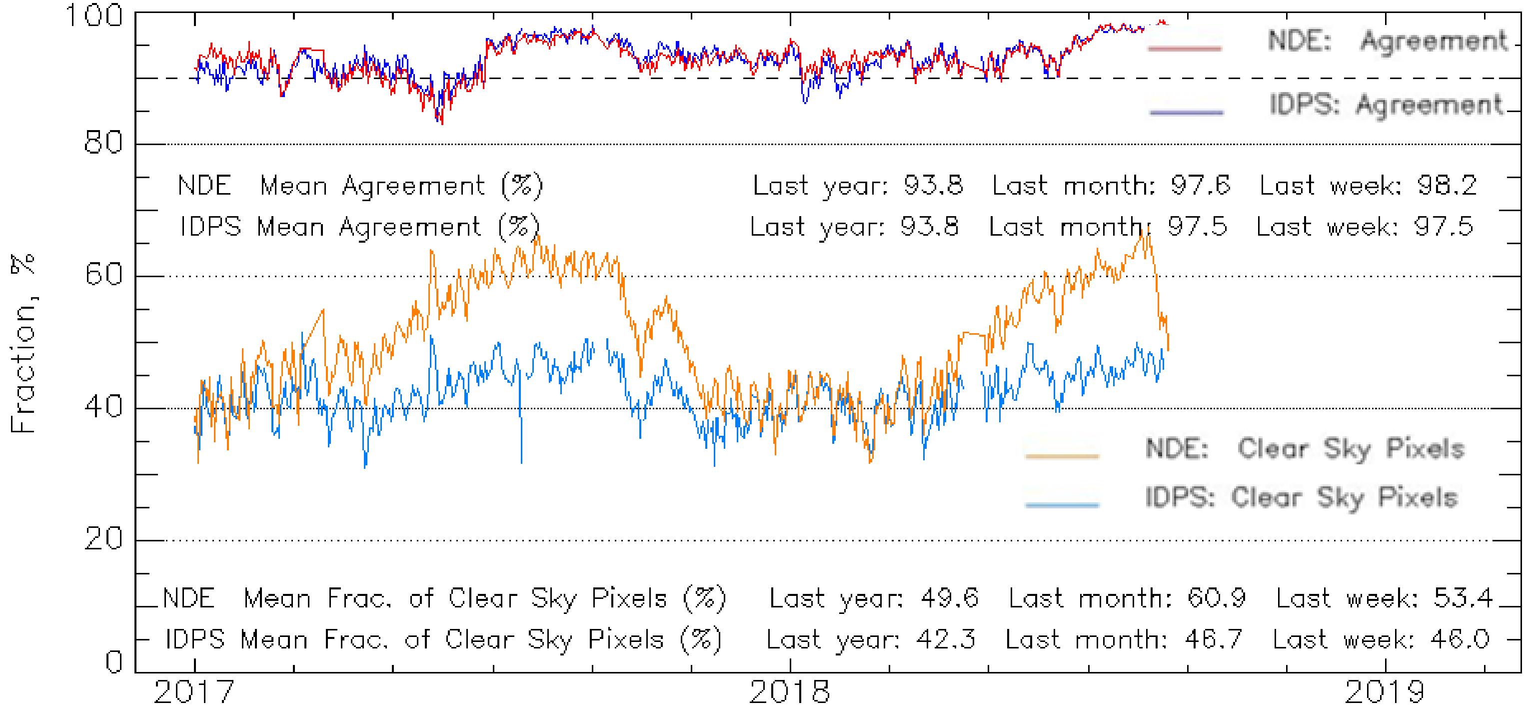
NDE, Feb 2 2017

IDPS, Feb 2 2017

snow land cloud No data

NDE & IDPS: Binary Snow Accuracy

IDPS and NDE products vs IMS over N.Hemisphere



NDE vs IDPS

- Similar accuracy as compared to IMS
- NDE: More clear sky views (less clouds), hence, better area coverage

Snow Fraction

Enterprise (NDE) Snow Fraction

Viewable Snow Fraction: Two algorithms

1. Visible reflectance-based

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

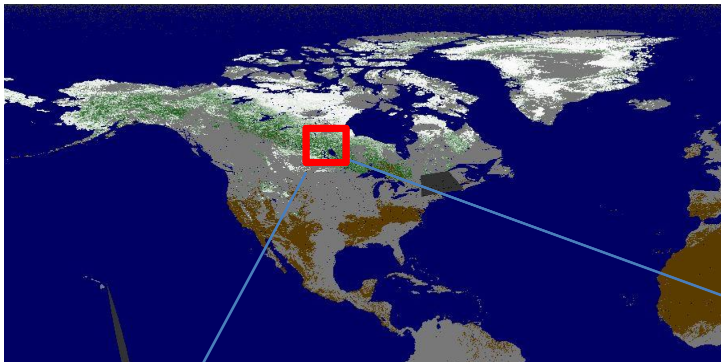
- Uses VIIRS band I1 (0.6 µm) reflectance (**R**)
- End-members (**R_{land}, R_{snow}**) account for surface reflectance anisotropy
- Algorithm used with GOES Imager and AVHRR; Approach similar to GOES-R

2. NDSI-based

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

- **NDSI = $(R_{0.6} - R_{1.6}) / (R_{0.6} + R_{1.6})$**
- MODIS heritage algorithm
- Algorithm needs to be locally tuned,
- NDSI strongly depends on the viewing-illumination geometry
- NASA stopped generating NDSI-based snow fraction since Collection 6

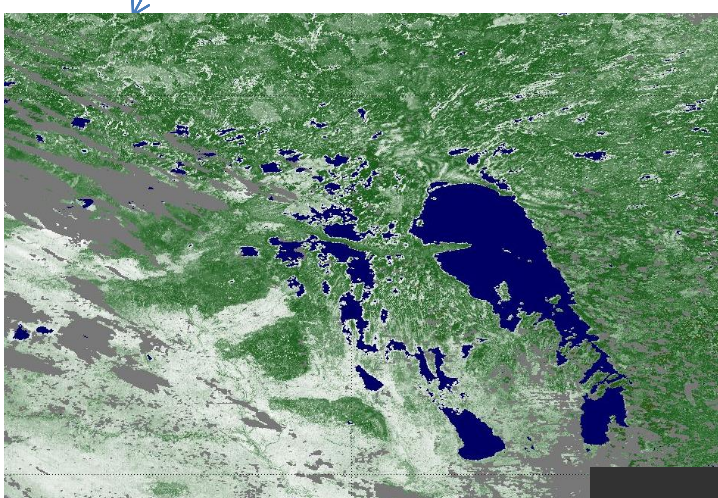
Snow Fraction: Two Algorithms



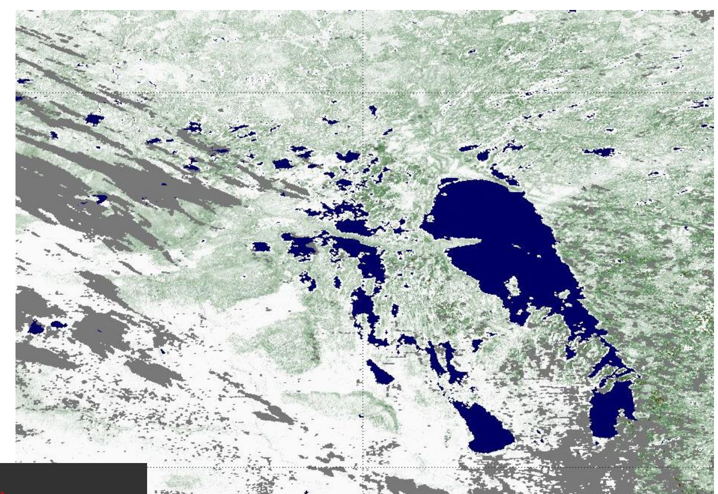
Reflectance-based Snow Fraction vs NDSI-based snow fraction

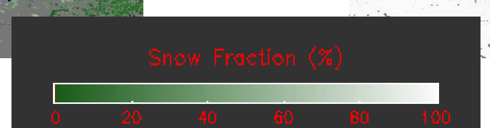
- Generally similar snow fraction patterns
- NDSI snow fraction is unrealistically large in the forest

Reflectance-based snow fraction



NDSI-based snow fraction





Clouds are shown in gray

Snow Fraction Evaluation

Direct accuracy assessment is impossible: no in-situ measurements

Reflectance-based snow fraction:

Theoretically estimated accuracy: 10-20%

SNPP VIIRS derived snow fraction demonstrates

- Consistency with the forest cover distribution (negative correlation)
- Consistency with in situ snow depth (positive correlation)
- Robust reproducibility of spatial patterns of snow fraction

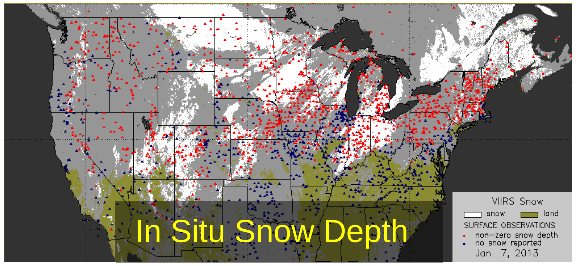
Comparison with Landsat: mean agreement ~ 17%, range: 5-25%

- Estimates are not independent, limited validity

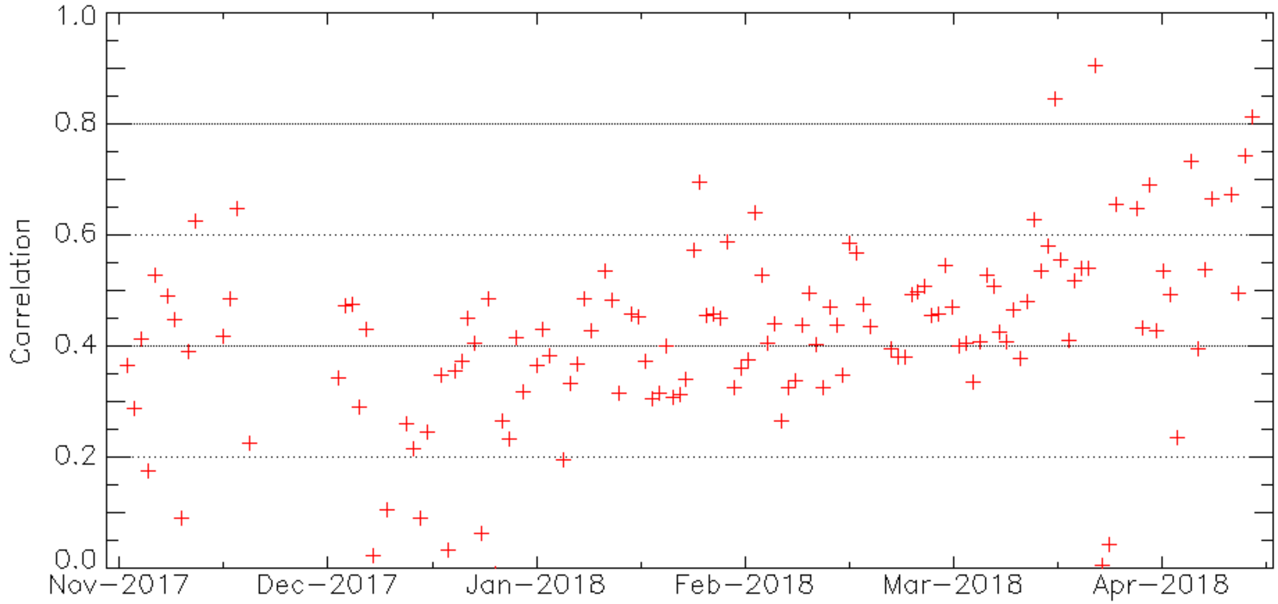
Product is expected to meet the requirements

Consistency with Snow Depth

- VIIRS Snow Fraction vs matched In situ Snow Depth
- Correlation calculated over Great Plains
- 10 to 300 match-ups daily
- 5-30 cm mean snow depth
- <u>Correlation is positive</u> meaning that estimated <u>snow fraction is consistent with the snow depth data</u>

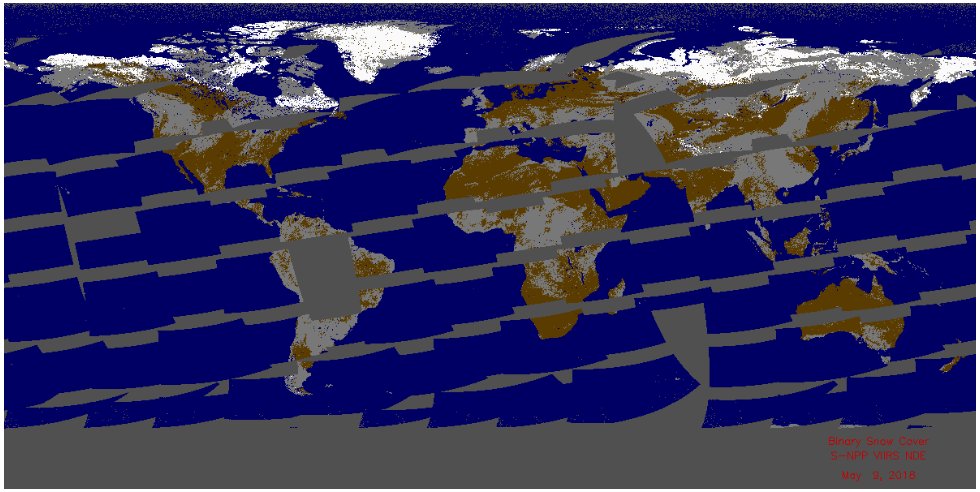


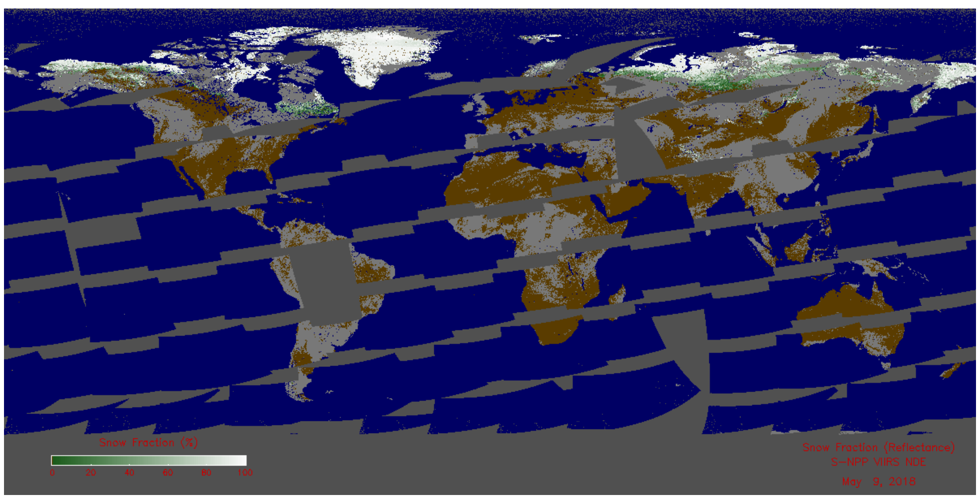
Snow Fraction vs Snow Depth Daily Correlation



Status of NOAA-20 NDE Snow Product

NOAA-20 NDE Gridded Snow





Produced since May 2018

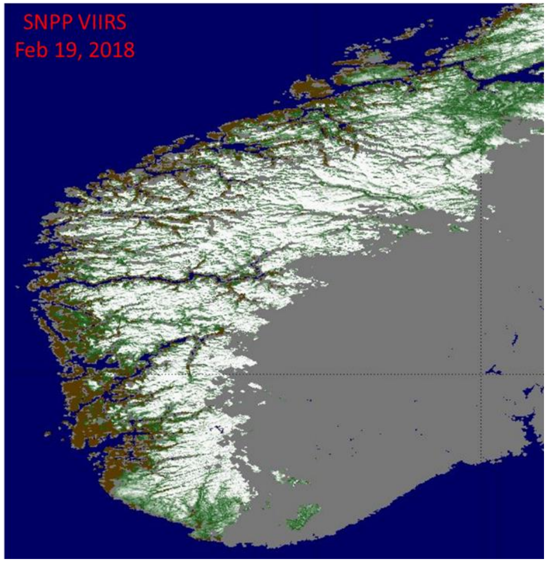
Algorithms implemented correctly

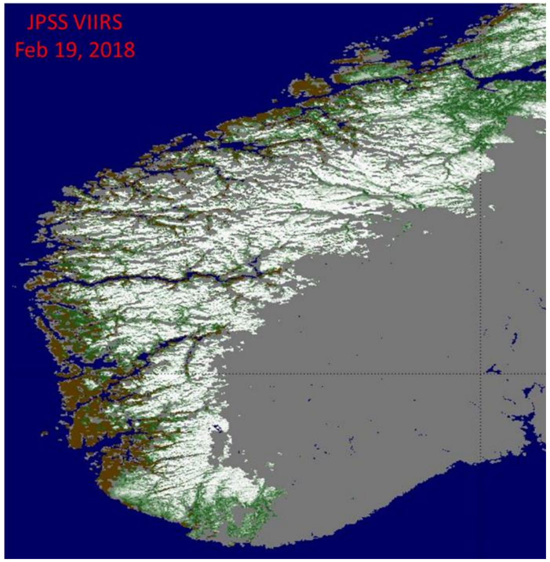
Missing granules, hence incomplete daily area coverage

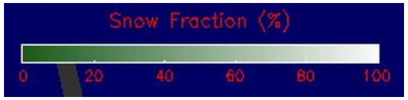
Beta maturity in June 2018

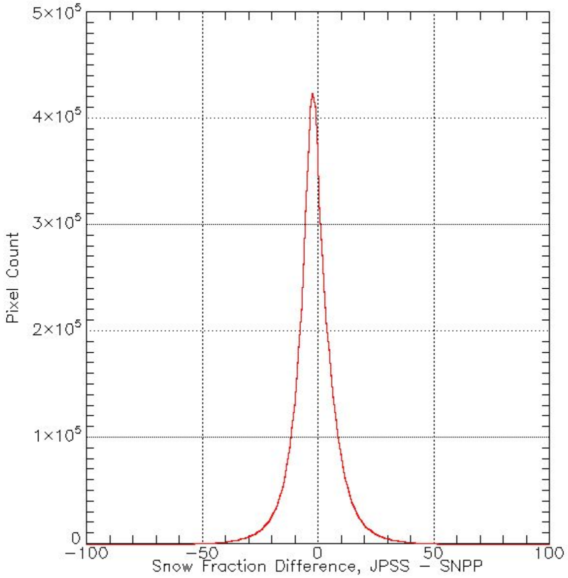
Products are expected to satisfy requirements once the missing granule problem is fixed

NOAA-20 vs SNPP Snow









Matched N20 and SNPP snow fraction difference statisics

NOAA-20 and SNPP Snow Products

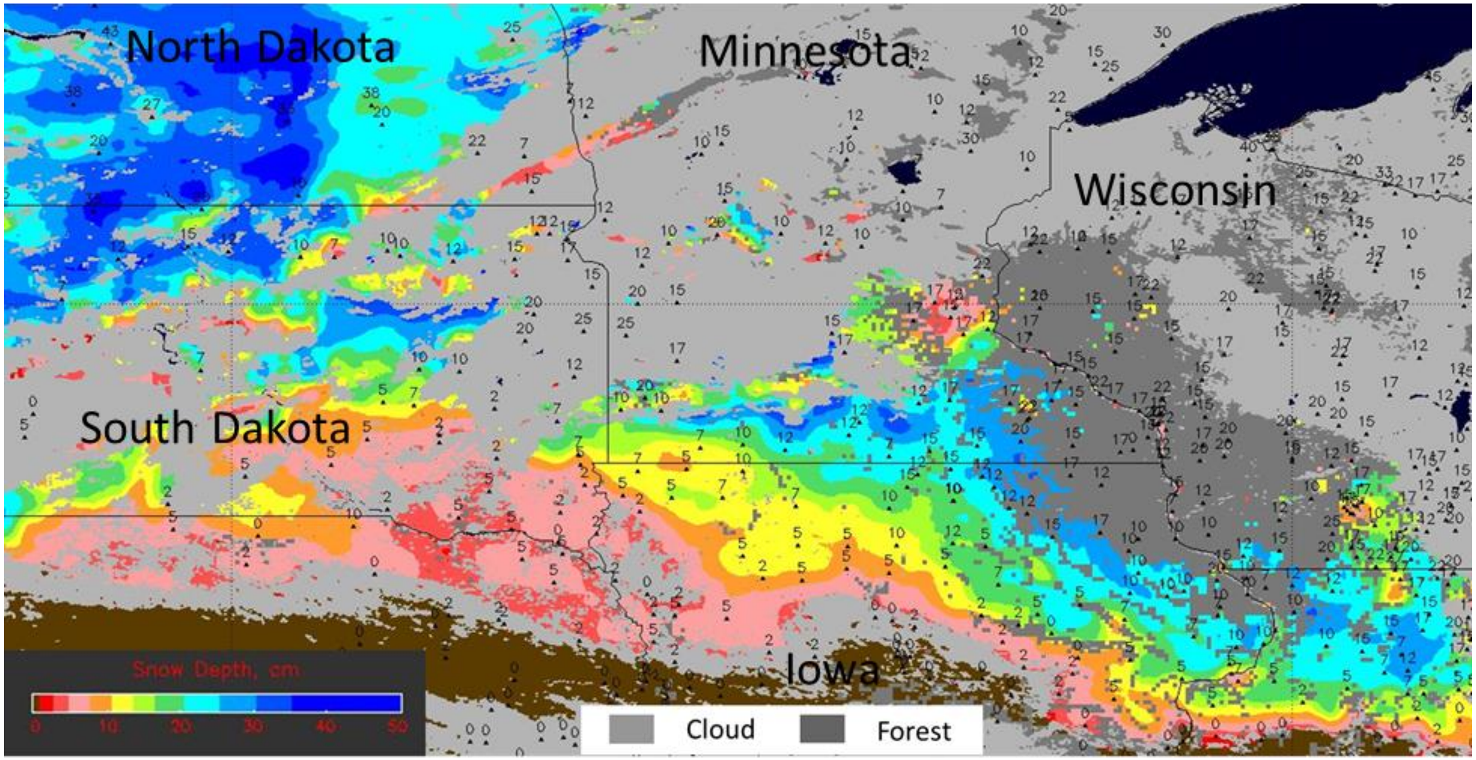
- ~ 99% agreement on the snow cover (yes/no)
- ~ 6% mean difference in estimated snow fraction
- Estimates are based on IDPS,
  NDE N20 and SNPP differences should be similar

Further Enhancements

Further Enhancements

Snow depth estimates

- Employs correlation between snow fraction and snow depth
- Retrievals limited to plain non-forested areas
- “Saturation” occurs at 30-40 cm snow depth



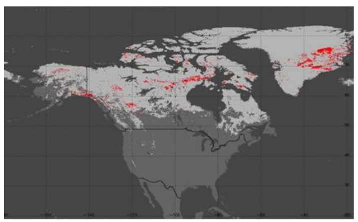
Snow Depth
Dec 18, 2016

Numbers present the snow depth observed in situ

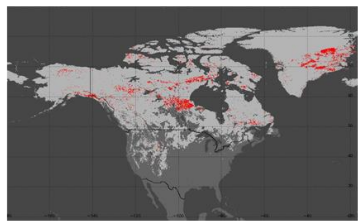
Further Enhancements, Cont'd

Ice/crust layers in the snow pack

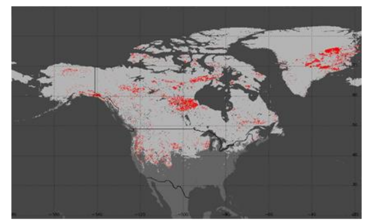
- Needed in microwave retrievals, snowmelt runoff modelling
- Uses surface temperature to identify snow melt/freeze
- Calculates the number of melt-freeze events



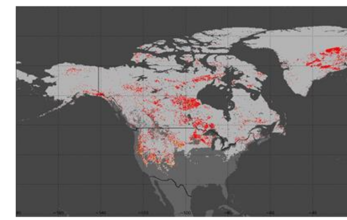
Nov 2, 2016



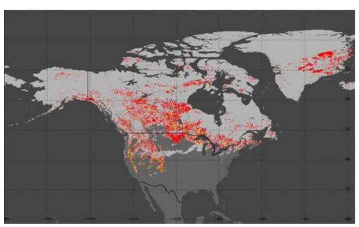
Dec 3, 2016



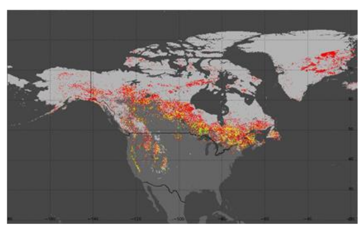
Jan 4, 2017



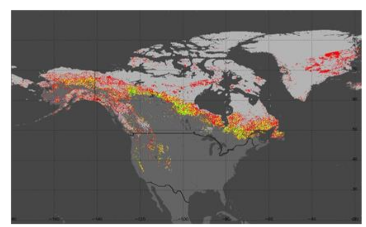
Feb 3, 2017



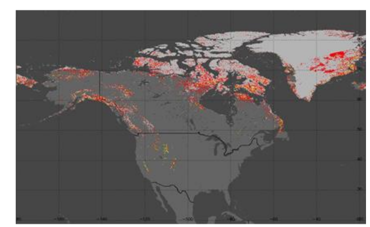
Mar 5, 2017



Apr 4, 2017



May 4, 2017



Jun 4, 2017

Number of ice/crust layers in the snow pack

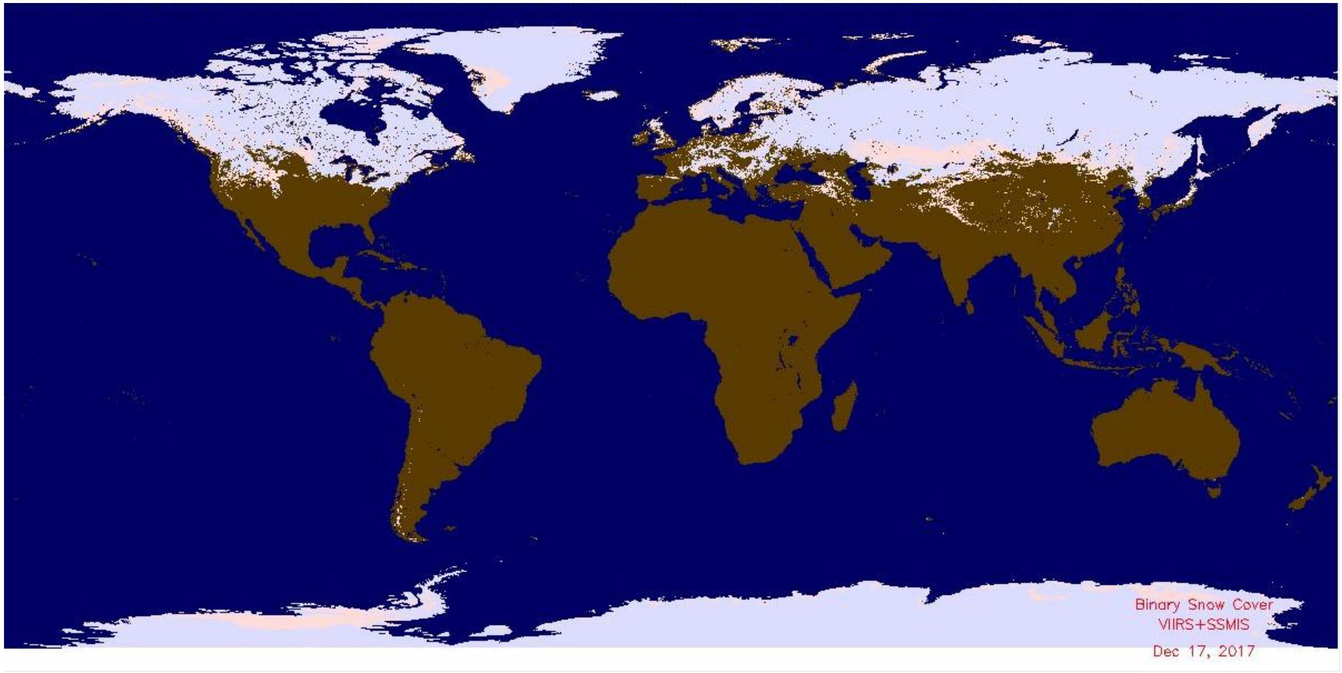
1   2   3   4 and over

Ice/crust layers in the snow pack during the 2016-2017 winter season

Further Enhancements, Cont'd

Gap-free blended snow cover map (VIIRS + microwave)

- Involves GCOM AMSR2 or DMSP/SSMIS snow retrievals
- Uses GMASI approach to merging vis/IR and MW data
- Effective spatial resolution: 1 km clear sky, 8 km cloudy
- May add ice cover to the gridded product



Summary

SNPP snow algorithms and products

- Operational within NDE
- Demonstrate robust performance
- Satisfy requirements

NOAA-20 snow products

- Snow algorithms appear to perform correctly
- Granules are missing, incomplete coverage
- Beta maturity in June 2018, Provisional: later this year

Further improvements of algorithms are planned

New products are being developed

Ralph Ferraro, NESDIS/STAR
Ralph.R.Ferraro@noaa.gov

With contributions from many others –
Peter Romanov, Patrick Meyers, Veljko Petkovic

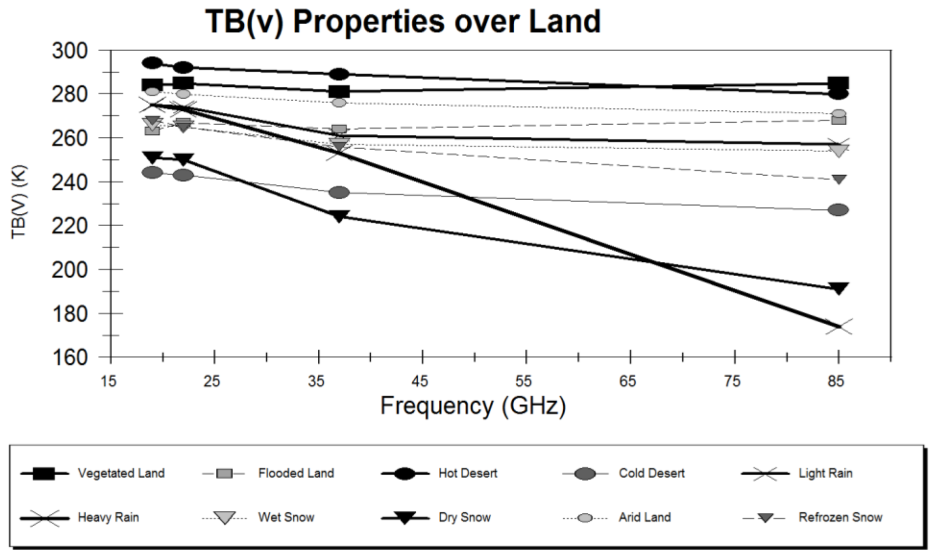
THE IMPORTANCE OF AND USE OF SNOW PRODUCTS IN PRECIPITATION RETRIEVALS

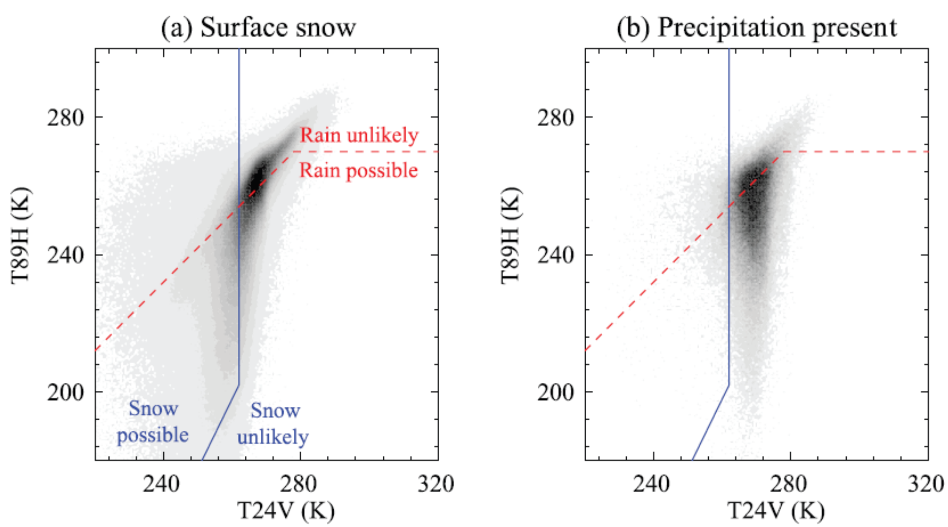
OUTLINE

- Scientific Issue
- Historical perspective
- Current status
- What was requested and done for NASA
- Impacts
- What are future plans for GCOM precipitation EDR at NOAA

Scientific Issue

- Precipitation has a similar signal to surface snow and arid surfaces in the microwave spectrum
  - Also impacted by diurnal variations
- Many measurements are correlated, so not enough unique information to separate **all signals all of the time**
  - Impact of misclassification can be quite dramatic (next slide)

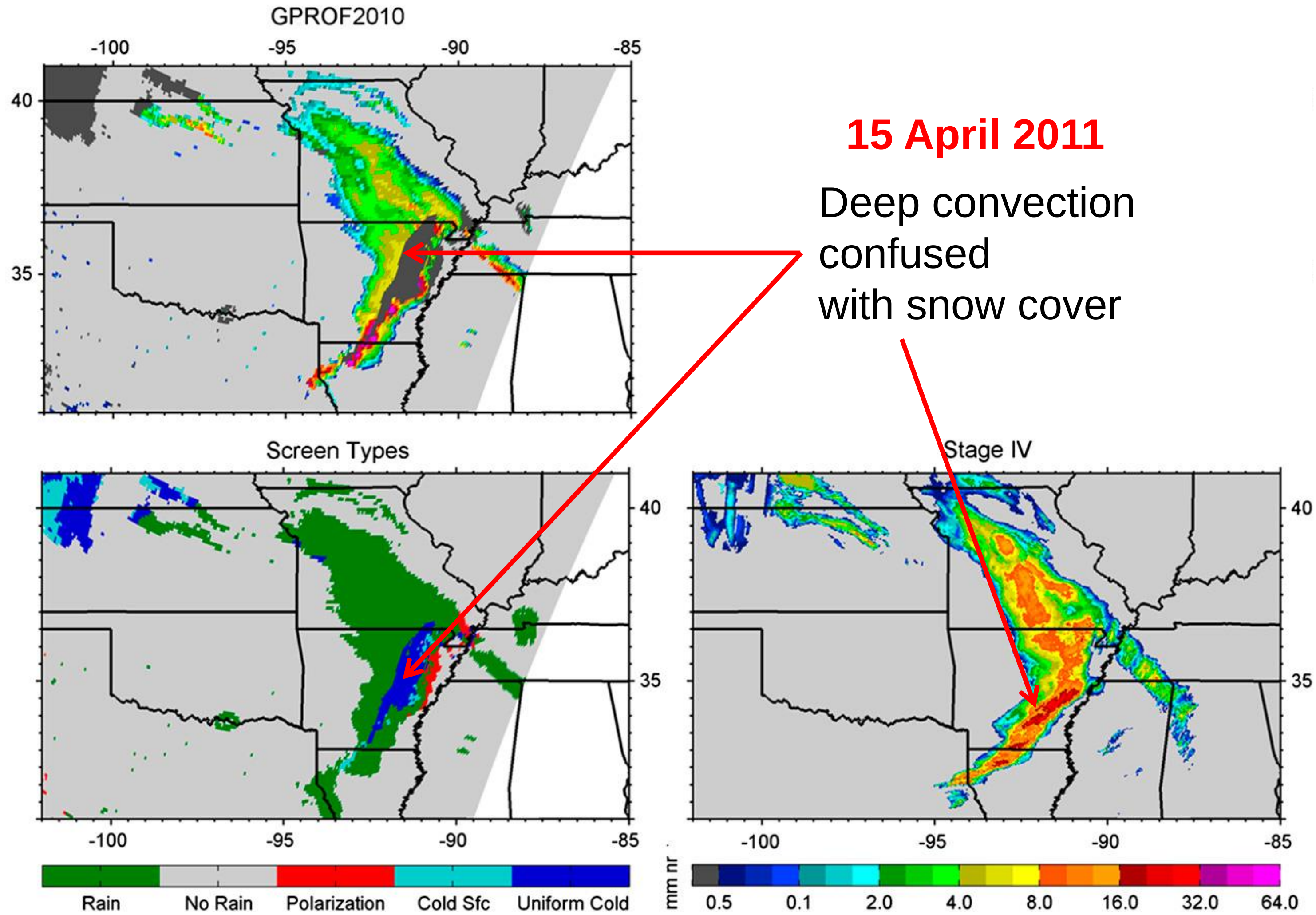




Meyers and Ferraro, 2015 – AMSR-2

Example of Misclassification using radiometric screening

Meyers et al 2015 – AMSR-2



Historical Perspective

Grody 1991 - SSMI

- Restricted to just MW satellite data and static data bases – stove pipes, lack of data interoperability, etc.
- Need for simple approaches for operational use – shared computer resources, etc.

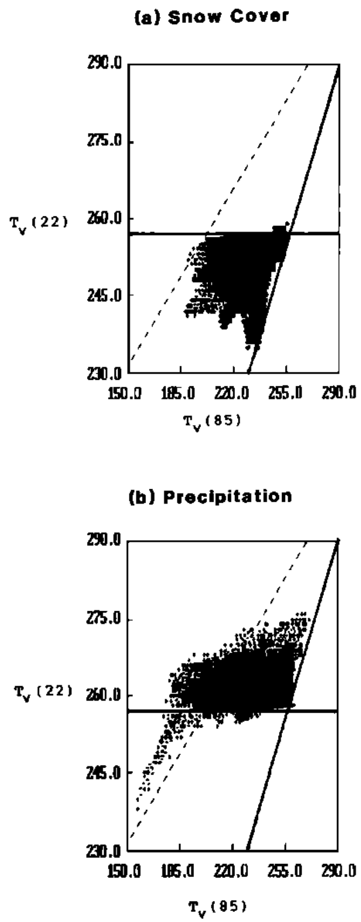
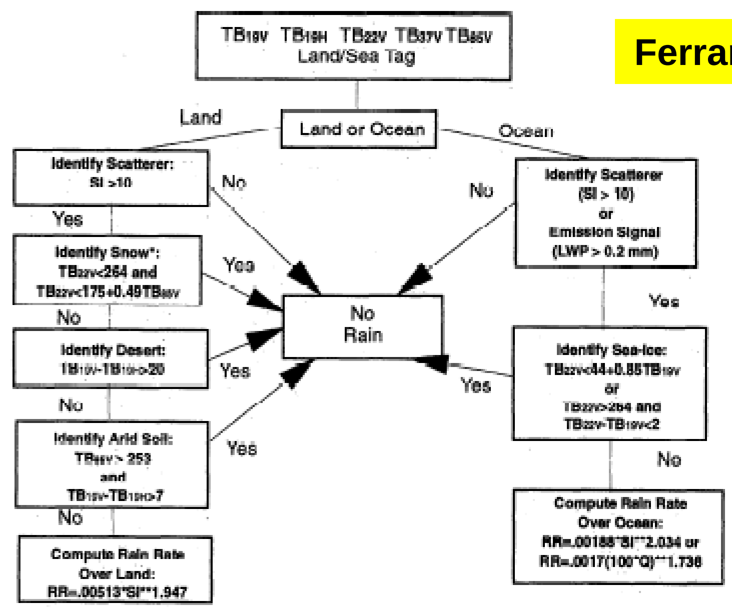


Fig. 5. SSMI measurements at 22 GHz plotted against the 85-GHz vertically polarized measurements for (*a*) snow cover and (*b*) precipitation over land. The dashed sloping line is given by equation (3*b*), and the horizontal line is given by equation (3*a*) of the text. Also shown is the line of perfect agreement.

Ferraro 1997 - SSMI



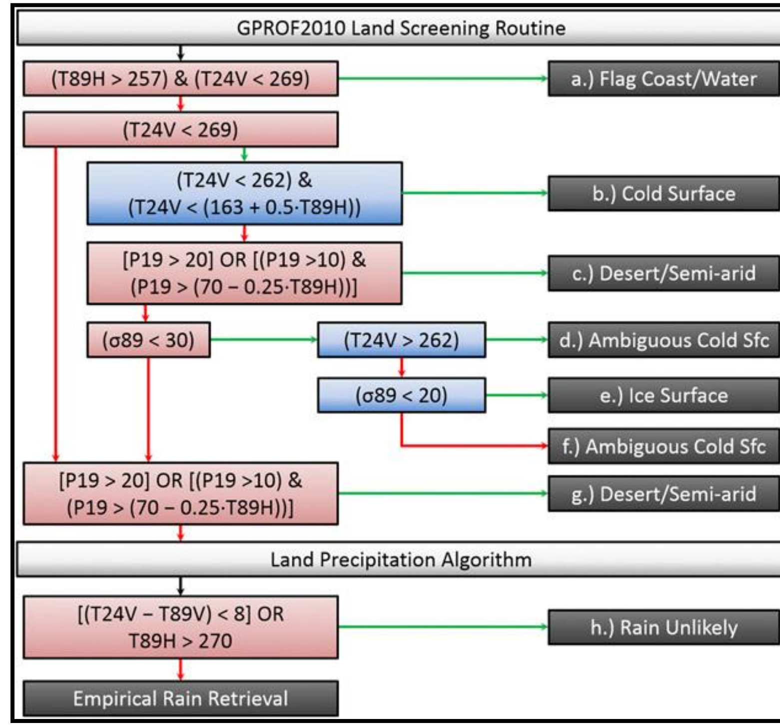
* An additional check is made for refrozen snow when for the following regions: January-March [Latitudes 25-90], April-May [Latitudes 40-90], June [Latitudes 60-90]

Refrozen snow is flagged if SI<60 and 264≤TB(22V)≤268

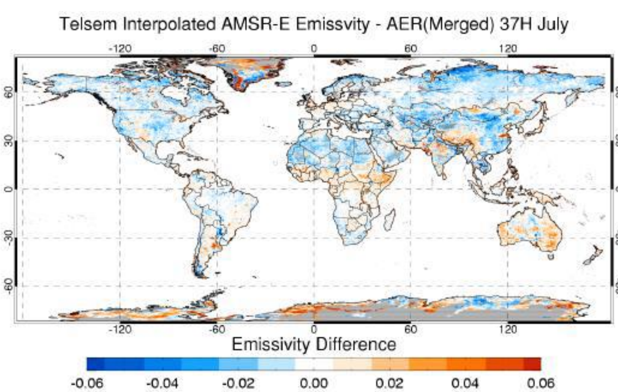
Incremental Progress & Paradigm Shift

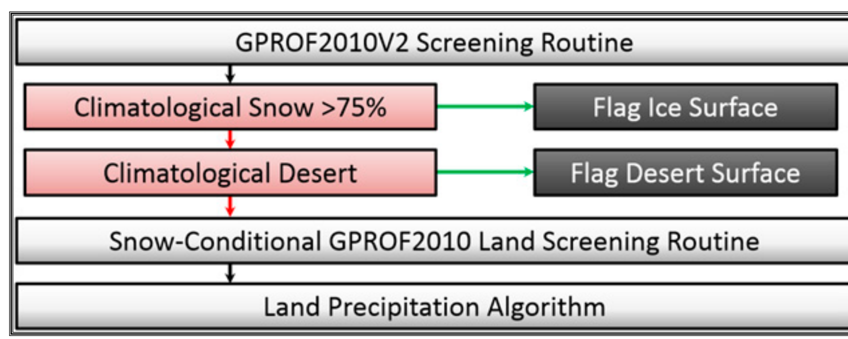
- Additional MW sensors followed SSM/I
  - Better spatial resolution
  - MW sounders/additional channels
  - Better ability to separate surfaces
- Access to other real-time, dynamic data sources become a reality
  - NWP model fields
  - Other satellite and in-situ data
  - Climatological data sets
- Physical retrievals developed and now feasible for operational use
  - Leverage off of other disciplines
    - Land sfc. Emissivty (TELSEM)
    - RTM community (RTTOVS, CRTM)
  - Examples – GPROF, MiRS

Meyers et al 2015 – AMSR-2

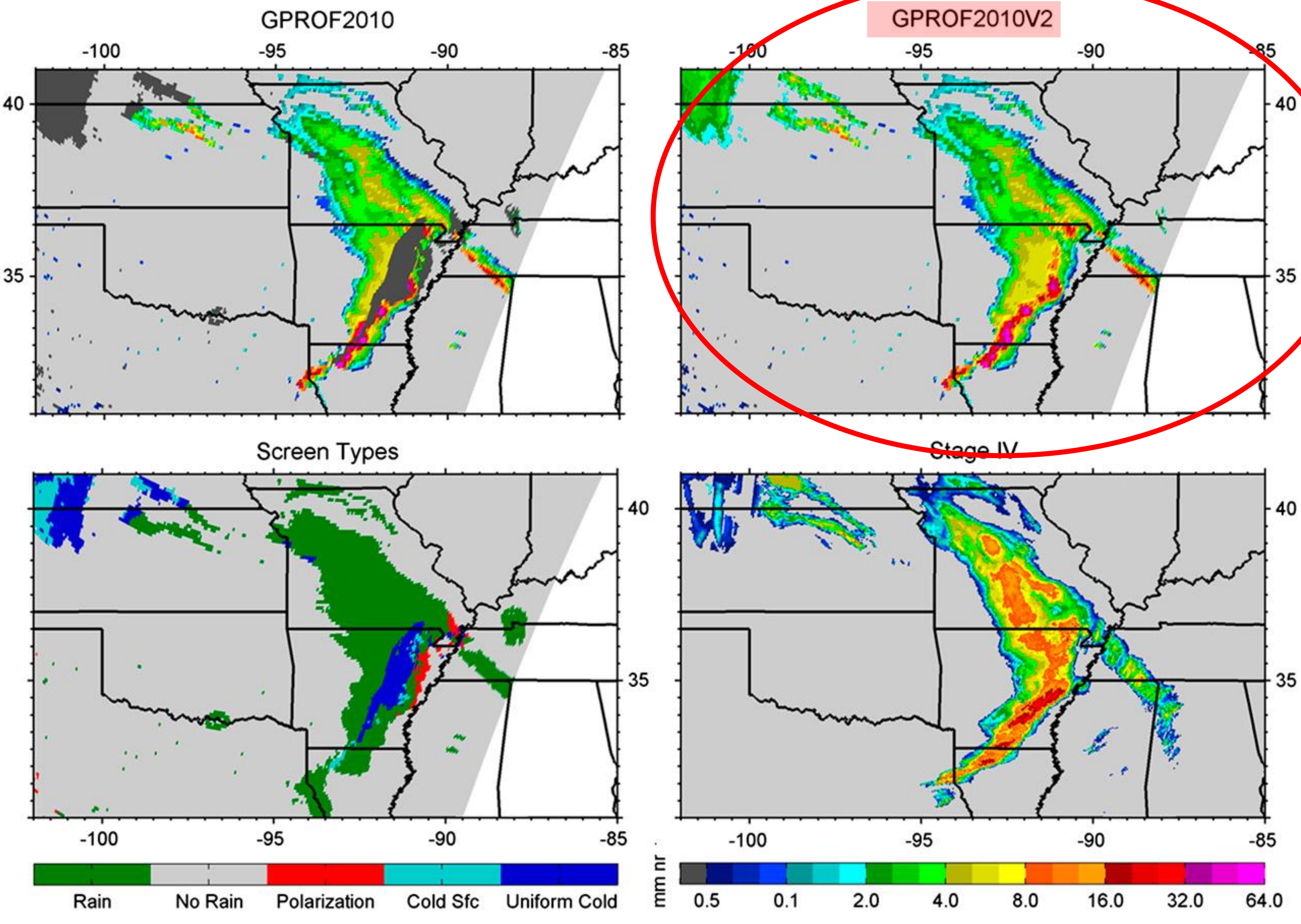


Aires et al 2011 – AMSR-E





Impact of using climatology

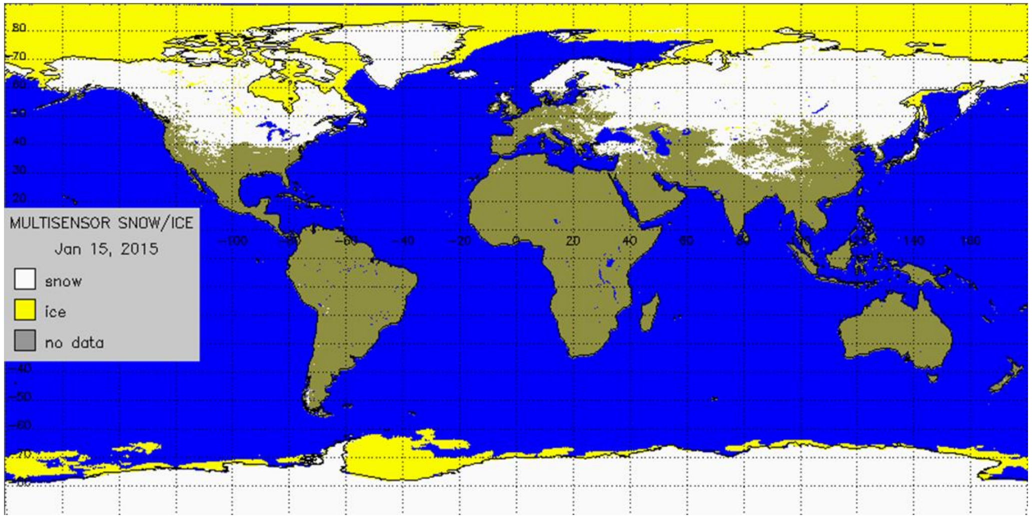


Current Status/Needs by NASA and Community

Via Peter Romanov

- A global, high resolution daily snow cover field for as long as a time period as possible – back to 1998/TRMM era

- The best NOAA candidate – The Global Multisensor Automated Snow/Ice (GMASI-Autosnow) Mapping System
  - Produces daily spatially-continuous (gap-free) global snow/ice cover maps ~4 km for use in operational applications
  - Synergy of satellite snow/ice retrievals from observations in the Vis/IR and passive microwave
  - Operational since 2006….



Autosnow Reprocessing: Sensors used

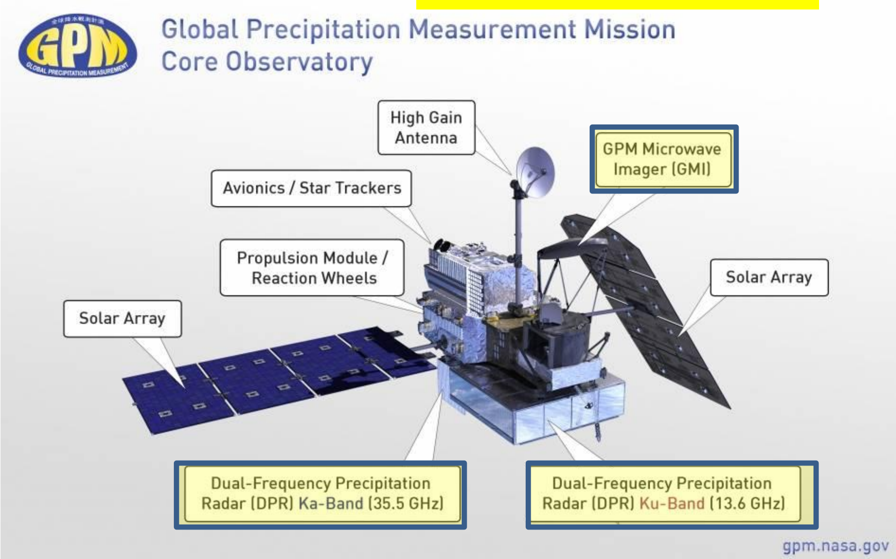
Year	Primary AVHRR carrier	Number of SSMI(S)	F-11	F-13	F-14	F-15	F-16	F-17	F-18	F-19
1998	NOAA-14	3								
1999		3								
2000		3								
2001	NOAA-16	3								
2002	NOAA-17	3								
2003		3								
2004		3								
2005		3								
2006		4								
2007	METOP-A	4								
2008		4								
2009		4								
2010		3								
2011		4								
2012		4								
2013		4								
2014		4								
2015		5								
2016		5								
2017		4								

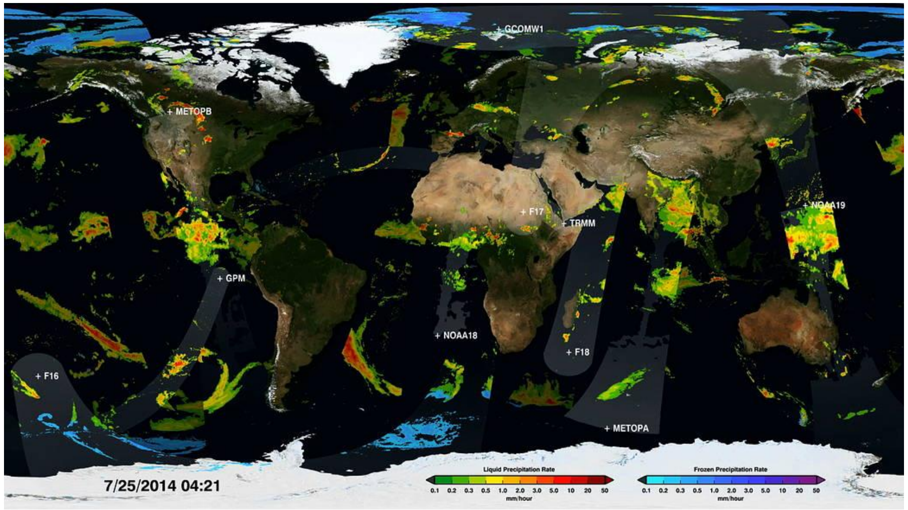
Many thanks to CREST for supporting this activity!

Which NASA Products use the Autosnow?

Via Erich Stocker/GSFC

- All **GPM** GPROF (GMI, AMSR2, SSMIS, MHS, ATMS) use the autosnow product to produce the retrievals
- **GPM** Radar L2 Ku/Ka/DPR uses the autosnow data for retrieval and stored in ENV file.
- Combined **GPM** GMI/DPR L2 uses the autosnow information that the radar L2 put into the ENV file
- **GPM** IMERG half-hourly uses the autosnow file for its retrievals.
- **TRMM** PR/Ku does not use autosnow files but the **TRMM** TMI GPROF retrievals do use the autosnow.

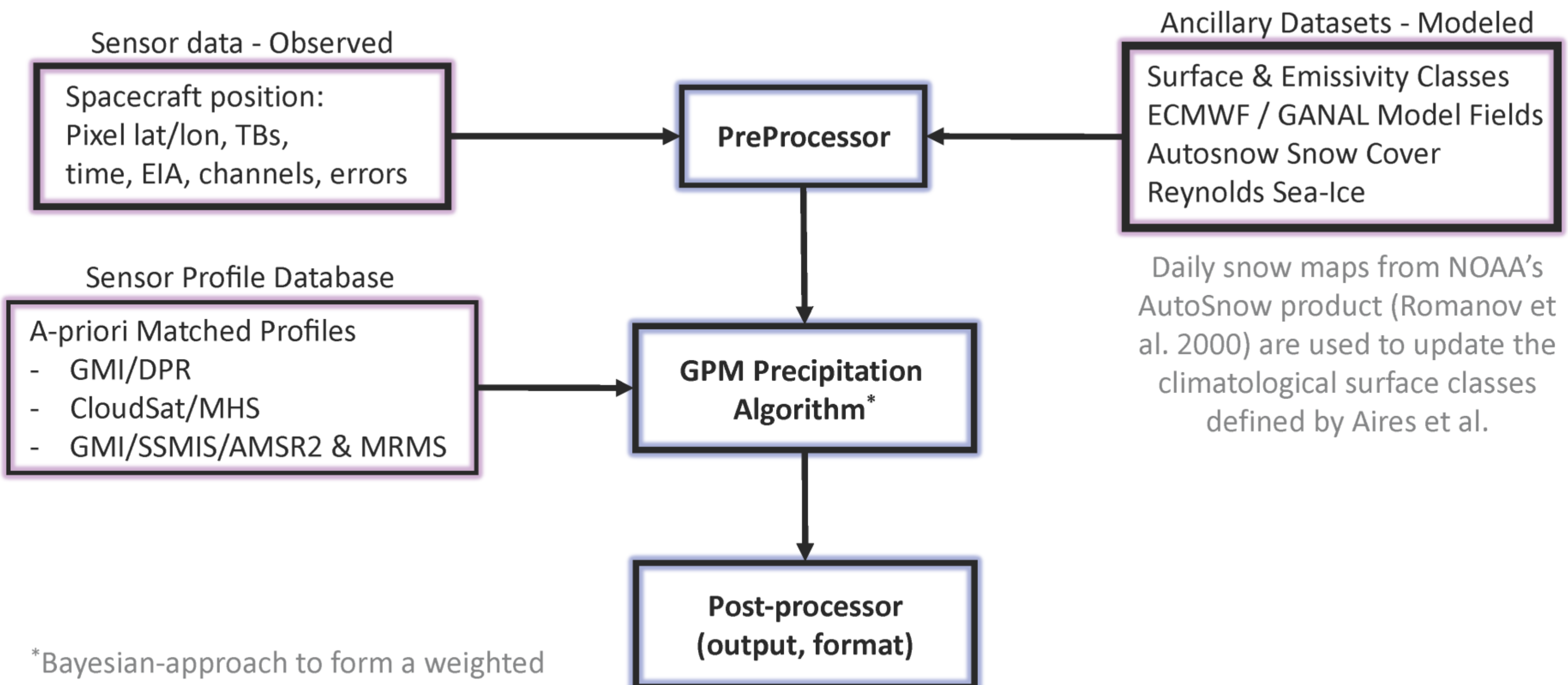




GPROF Algorithm Structure

Via Veljko Petkovic

GPROF Algorithm Structure



Daily snow maps from NOAA's AutoSnow product (Romanov et al. 2000) are used to update the climatological surface classes defined by Aires et al.

*Bayesian-approach to form a weighted mean of a priori profiles based on their distances from the observed TB vector.

Snow surface type in GPROF Algorithm

Snow surface type in GPROF Algorithm

PreProcessor ← Ancillary Datasets - Modeled

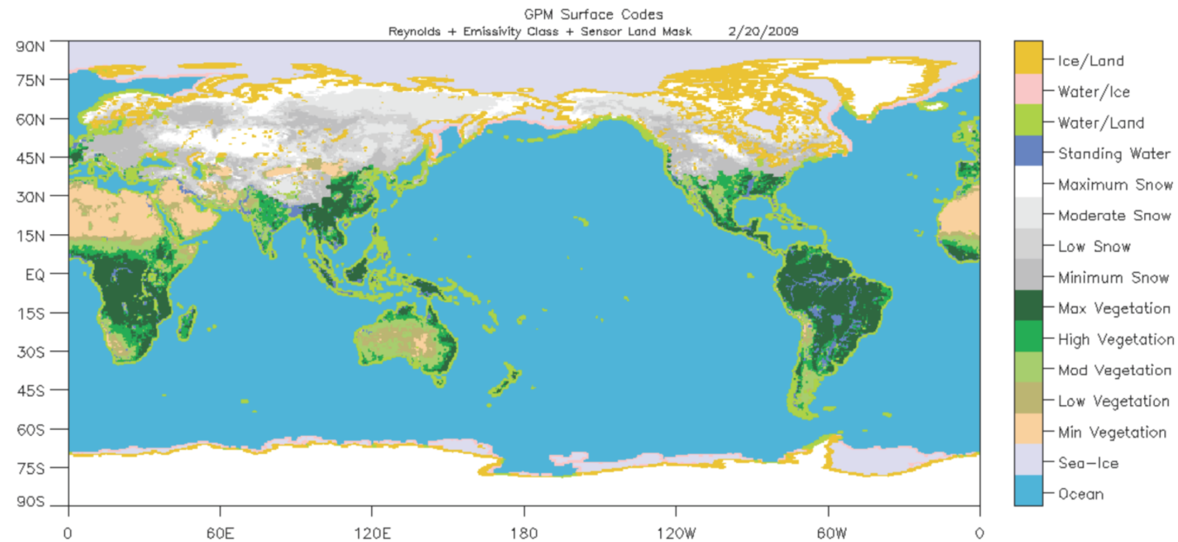
- Surface & Emissivity Classes
- ECMWF / GANAL Model Fields
- Autosnow Snow Cover
- Reynolds Sea-Ice

Step 1 in preprocessor:

- Emissivity Class from TELSEM – monthly climatology
- Four snow categories (min, low, moderate, max)

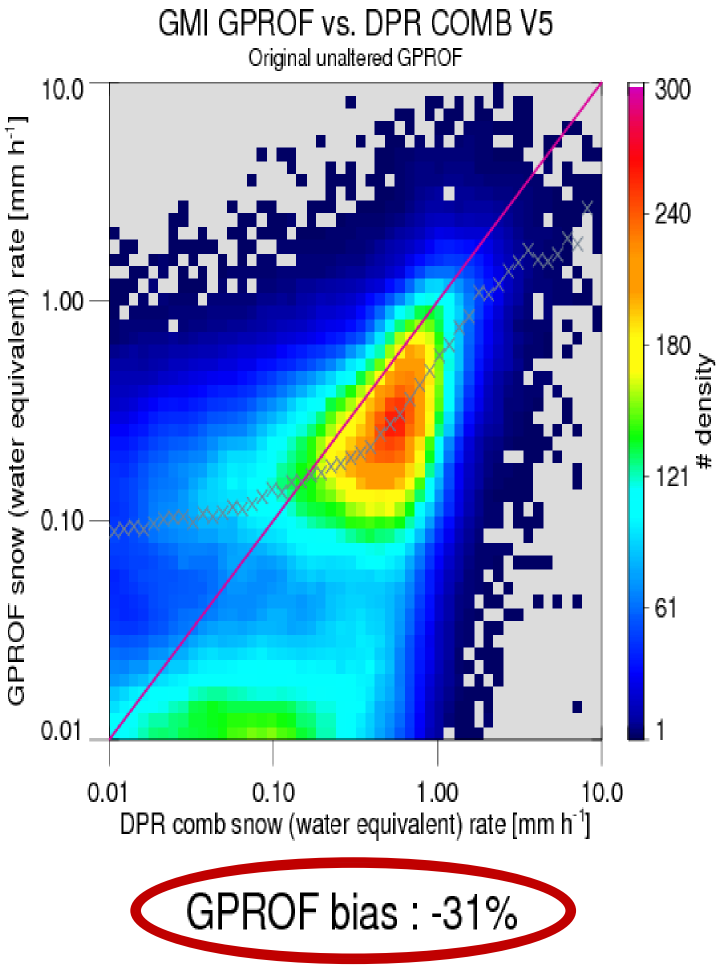
Step 2 in preprocessor:

- Autosnow Snow Cover
- TELSEM category is adjusted to match Autosnow product
- If TELSEM snow is to be removed, the closest (in time) non-snow surface type for a given pixel is assigned



Effect of adding Autosnow surface type information to the Bayesian averaging

- Operational PPS GPROF V5 precipitation retrieval using both monthly TELSEM climatology and daily Autosnow surface type information.
- In the plot: snowing pixels only; globally; over land; October – April 2017.
- Overall bias: -31 %
- When Autosnow is **EXCLUDED**, bias increases by 15% (to -35%)

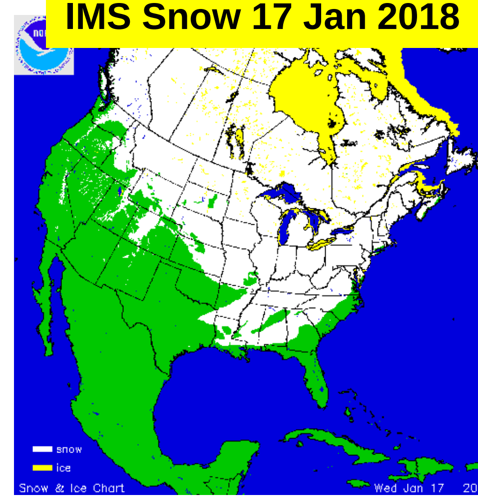


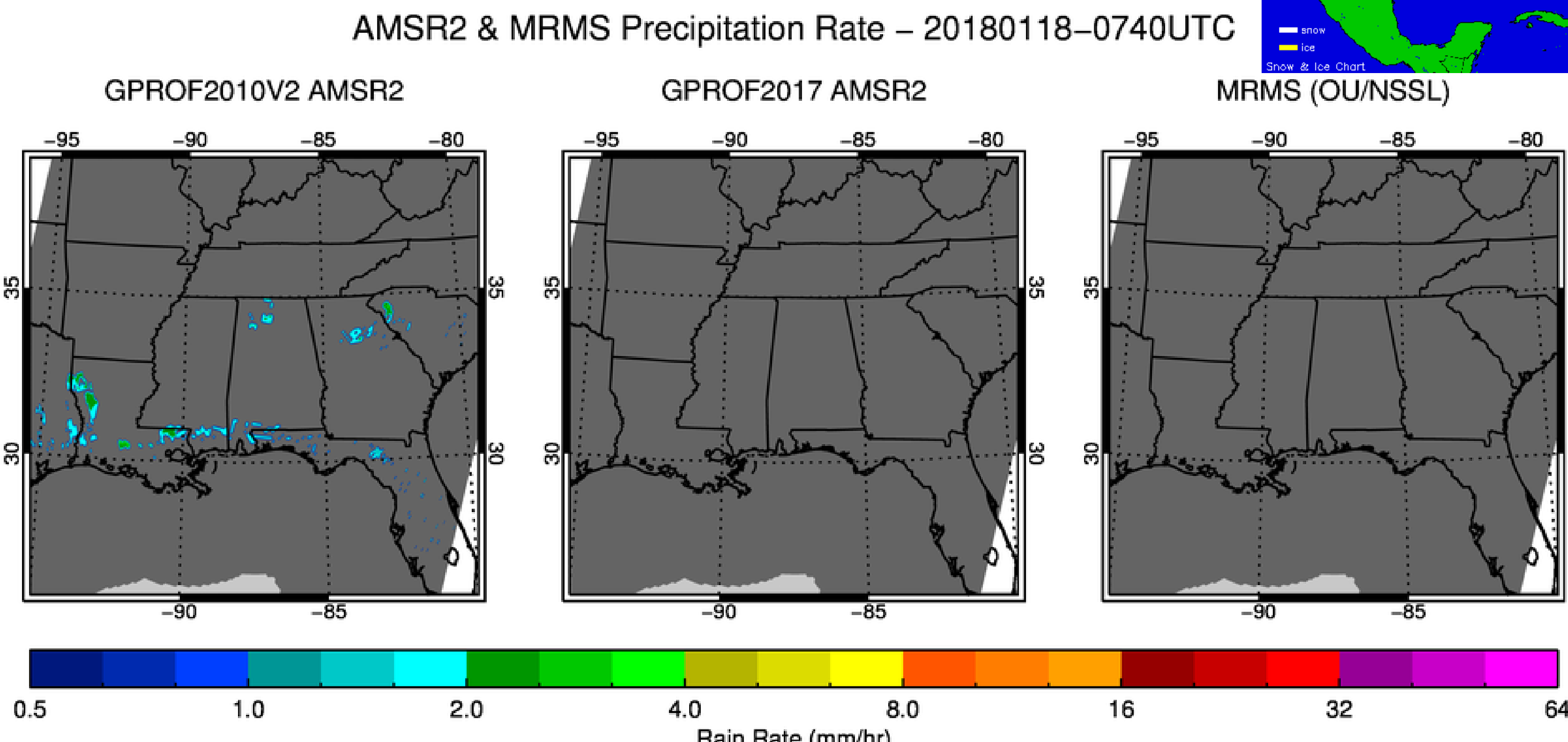
Example of current NOAA GCOM vs. GPM GCOM

False rain retrievals due to confusion with snow on ground and outside of climatology

Accurate “no rain” retrieval via dynamic use of Autosnow in GPROF retrieval

IMS Snow 17 Jan 2018





Summary and looking ahead

- Accurate snow cover information is critical for passive microwave precipitation retrievals
  - Lack of unique radiometric information to delineate "scattering" surfaces
  - Even using ancillary data and full physical retrievals does not work 100% of time
- Autosnow provides global, high spatial resolution information that is compatible with passive MW sensors and provides complimentary information
- NOAA GCOM project is evaluating latest NASA GPM passive MW retrieval (GPROF2017) for future implementation
  - Anticipated for sometime in 2019

VIIRS POLAR WINDS

Jeff Key, Jaime Daniels, Rico Allegrino, Wayne Bresky
608-263-2605, Jeff.Key@noaa.gov

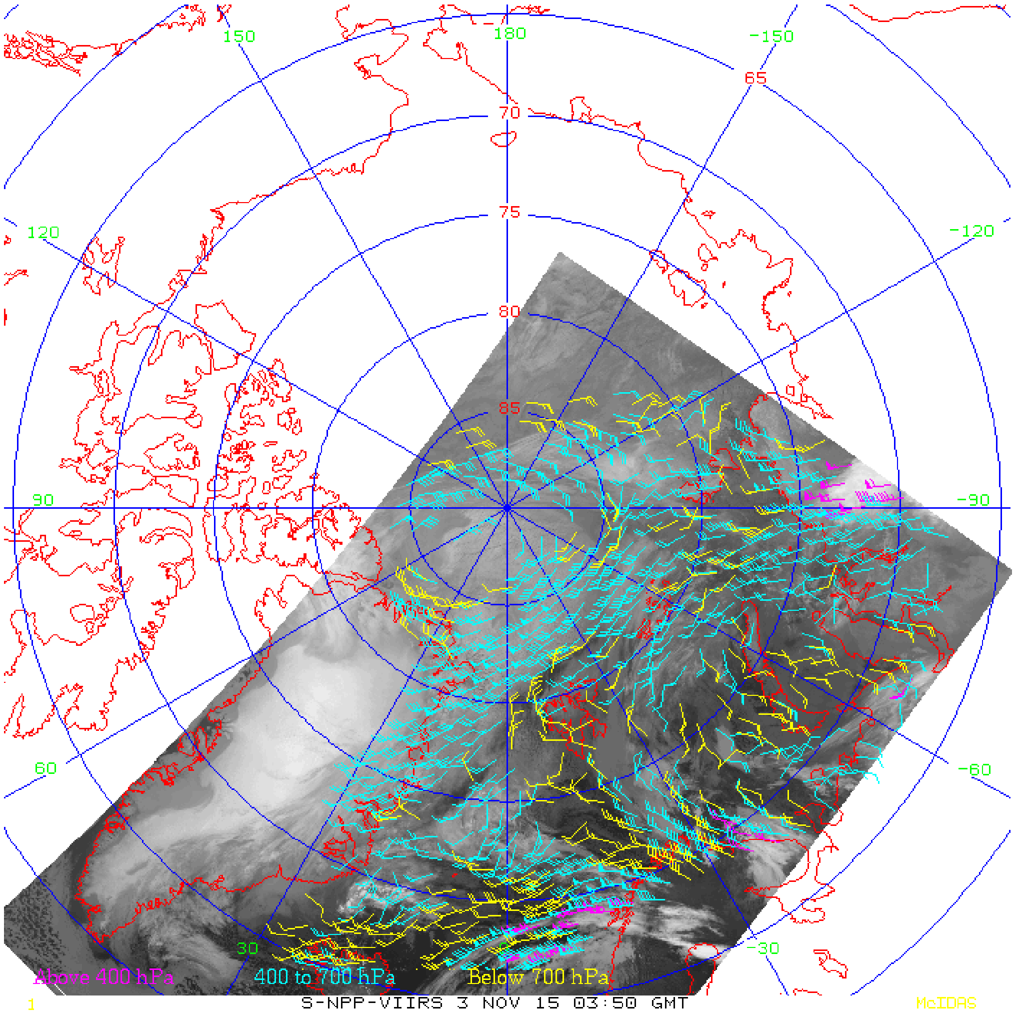
VIIRS Polar Winds Team

Name	Organization	Major Task
Jeff Key	STAR	Project management, DB winds
Jaime Daniels	STAR	Project management, algorithm development and testing
Wayne Bresky	IMSG	Algorithm development and testing
Andrew Bailey	IMSG	Algorithm development and testing
Rico Allegrino		Validation
Dave Santek	CIMSS	Algorithm and product testing
Rich Dworak	CIMSS	Algorithm and analysis
Steve Wanzong	CIMSS	Algorithm and product testing
Hongming Qi	OSPO	Operations
Walter Wolf and others	STAR, AIT	Implementation

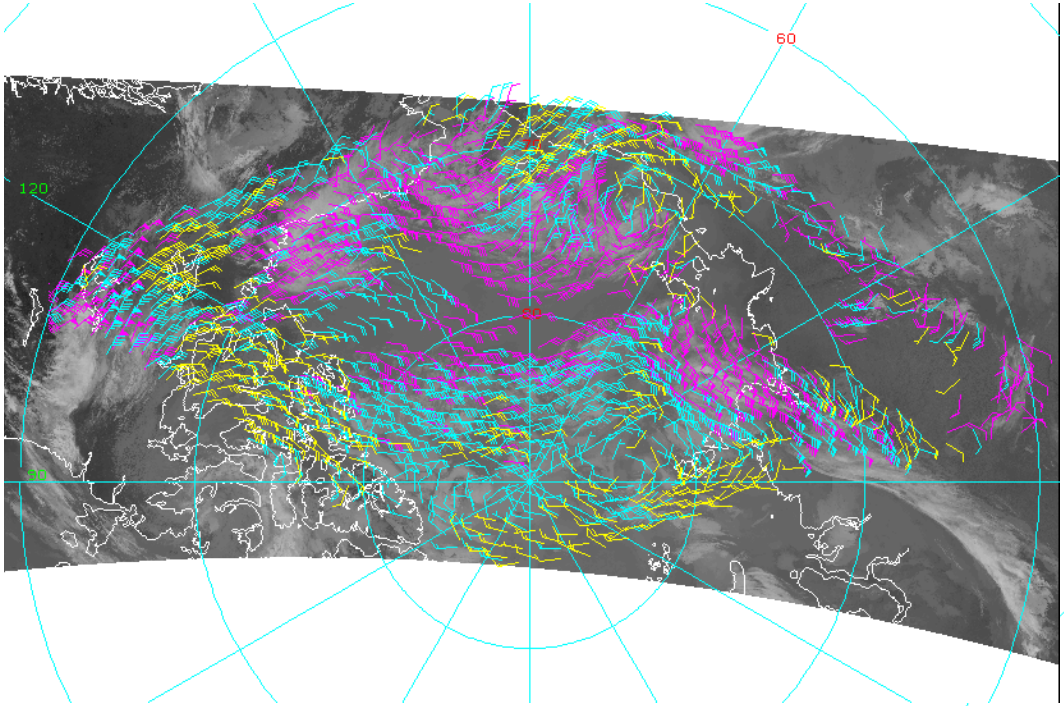
VIIRS Polar Winds (VPW) in Brief

VIIRS Polar Winds are derived by tracking clouds features in the VIIRS longwave infrared channel

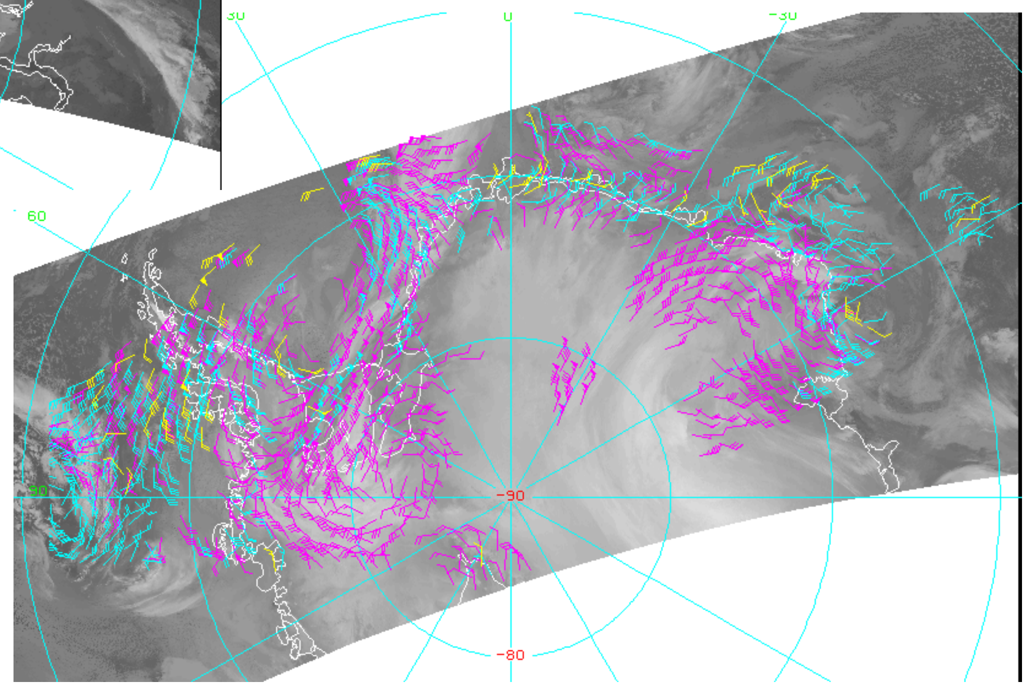
- Wind speed, direction, and height are determined throughout the troposphere, poleward of approximately 65 degrees latitude, in cloudy areas only
- Wind information is generated in both the Arctic and Antarctic regions
- The algorithm utilizes the Enterprise cloud height, phase, and (soon) mask



NOAA-20 VIIRS Winds Examples



Left: Arctic, 28 Jul 2018, 1942Z



Right: Antarctic, 28 Jul 2018, 2033Z

Validation Statistics

NPP VIIRS Winds vs. Radiosondes July 5-29, 2018

100_1000mb	90S – 90N	25N – 90N	25S – 25N	25S – 90S
Accuracy	5.79	5.79	0.00	0.00
Precision	3.58	3.58	0.00	0.00
Speed Bias	1.03	1.03	0.00	0.00
Speed	20.44	20.44	0.00	0.00
Sample	4668	4668	0	0

101_400mb	90S – 90N	25N – 90N	25S – 25N	25S – 90S
Accuracy	6.39	6.39	0.00	0.00
Precision	3.76	[illegible]	[illegible]	[illegible]
Speed Bias	1.33	[illegible]	[illegible]	[illegible]
Speed	23.85	2[illegible]	[illegible]	[illegible]
Sample	2085	[illegible]	[illegible]	[illegible]

401_700mb	90S – 90N	25N[illegible]	[illegible]	[illegible]
Accuracy	5.42	[illegible]	[illegible]	[illegible]
Precision	3.40	[illegible]	[illegible]	[illegible]
Speed Bias	0.81	[illegible]	[illegible]	[illegible]
Speed	18.95	1[illegible]	[illegible]	[illegible]
Sample	2071	[illegible]	[illegible]	[illegible]

701_1000mb	90S – 90N	25N[illegible]	[illegible]	[illegible]
Accuracy	4.81	[illegible]	[illegible]	[illegible]
Precision	3.13	[illegible]	[illegible]	[illegible]
Speed Bias	0.66	[illegible]	[illegible]	[illegible]
Speed	12.56	12.56	0.00	0.00
Sample	512	512	0	0

NOAA-20 VIIRS Winds vs. Radiosondes July 5-29, 2018

100_1000mb	90S – 90N	25N – 90N	25S – 25N	25S – 90S
Accuracy	5.99	5.99	0.00	0.00
Precision	3.64	3.64	0.00	0.00
Speed Bias	1.02	1.02	0.00	0.00
Speed	20.19	20.19	0.00	0.00
Sample	3860	3860	0	0

101_400mb	90S – 90N	25N – 90N	25S – 25N	25S – 90S
Accuracy	6.36	6.36	0.00	0.00
sion	3.82	3.82	0.00	0.00
Bias	1.23	1.23	0.00	0.00
	23.71	23.71	0.00	0.00
e	2073	2073	0	0

700mb	90S – 90N	25N – 90N	25S – 25N	25S – 90S
acy	5.79	5.79	0.00	0.00
sion	3.47	3.47	0.00	0.00
Bias	0.53	0.53	0.00	0.00
	17.93	17.93	0.00	0.00
e	1190	1190	0	0

1000mb	90S – 90N	25N – 90N	25S – 25N	25S – 90S
acy	5.10	5.10	0.00	0.00
sion	3.16	3.16	0.00	0.00
Speed Bias	1.28	1.28	0.00	0.00
Speed	12.47	12.47	0.00	0.00
Sample	597	597	0	0

Observed
Accuracy: 5.79-5.99 m/s
Precision: 3.58-3.64 m/s

Requirements:
Accuracy: 7.5 m/s
Precision: 4.2 m/s

NPP VIIRS winds generated at OSPO

NOAA-20 VIIRS winds generated at STAR. Statistics include only VIIRS winds at 12Z. NOAA-20 VIIRS Winds/Raob co-location files being reprocessed for the month of July to include 00Z matchups

Users

- **13 NWP centers in 9 countries use polar winds** (MODIS, AVHRR, VIIRS); some using VIIRS winds operationally.
- U.S. Users:
  - NCEP (Dennis Keyser)
  - NRL/FNMOC (Randy Pauley)
  - GMAO/JCSDA
- Foreign Users:
  - UK Met Office (Mary Forsythe)
  - JMA (Masahiro Kazumori)
  - ECMWF (Jean-Noel Thepaut)
  - DWD (Alexandar Cress)
  - Meteo-France (Bruno Lacroix)
  - CMC (Real Sarrazin)
  - BOM (John LeMarshall)
  - EUMETSAT (Simon Elliott)
  - Russian Hydrometcenter (Mikhail Tsyrulnikov)
  - CMA (China)

User Feedback

- Over the last decade, model impact studies at >10 major NWP centers have demonstrated that model *forecasts for the NH and SH extratropics are improved when the MODIS polar winds are assimilated. Forecasts can be extended 2-6 hrs, depending on the location.*
- *NWP users have reported similar results for the VIIRS Polar Winds*, as reported at the most recent International Winds Workshop (2016, Monterey) and at other venues.

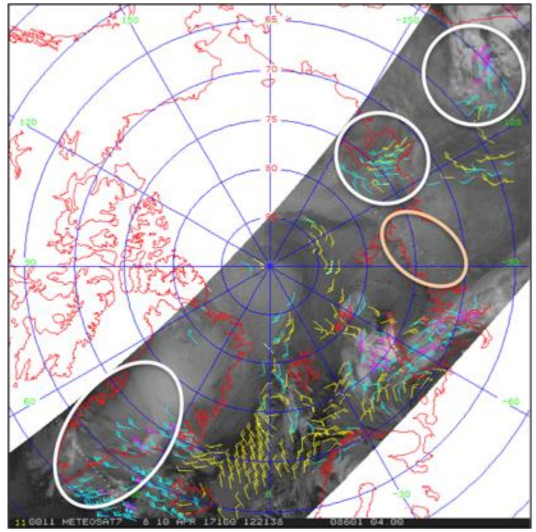
Organization	Use VPW operationally	Currently monitoring	Plan to use?
NCEP	Yes (SNPP)		Yes (early 2019 for N20)
DWD	Yes		
Navy	Yes		
ECMWF	Yes		
Met Office		Yes	Yes
CMC	Yes		
MeteoFrance		Yes	Yes

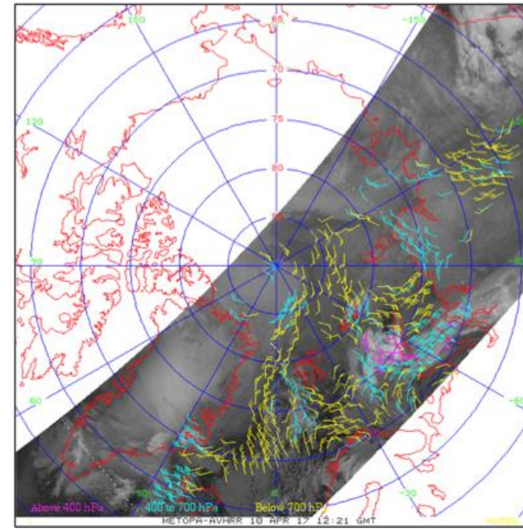
Awaiting information from the other NWP centers.

Experimental Products

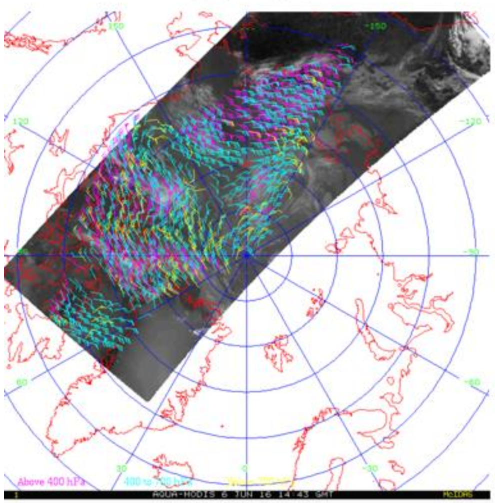
Winds from combined S-NPP and JPSS-1

Far right: Single-satellite AVHRR winds. Right: Winds from Metop-A and –B.

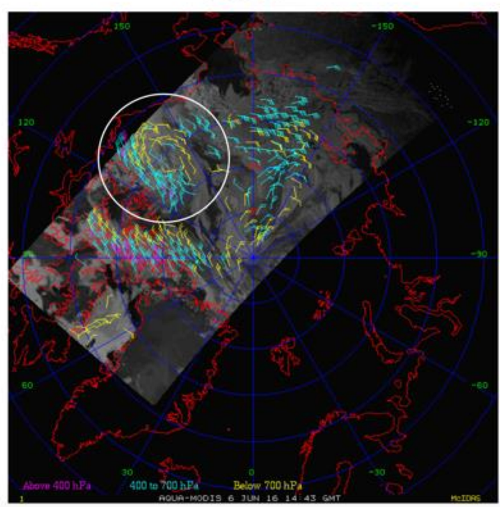




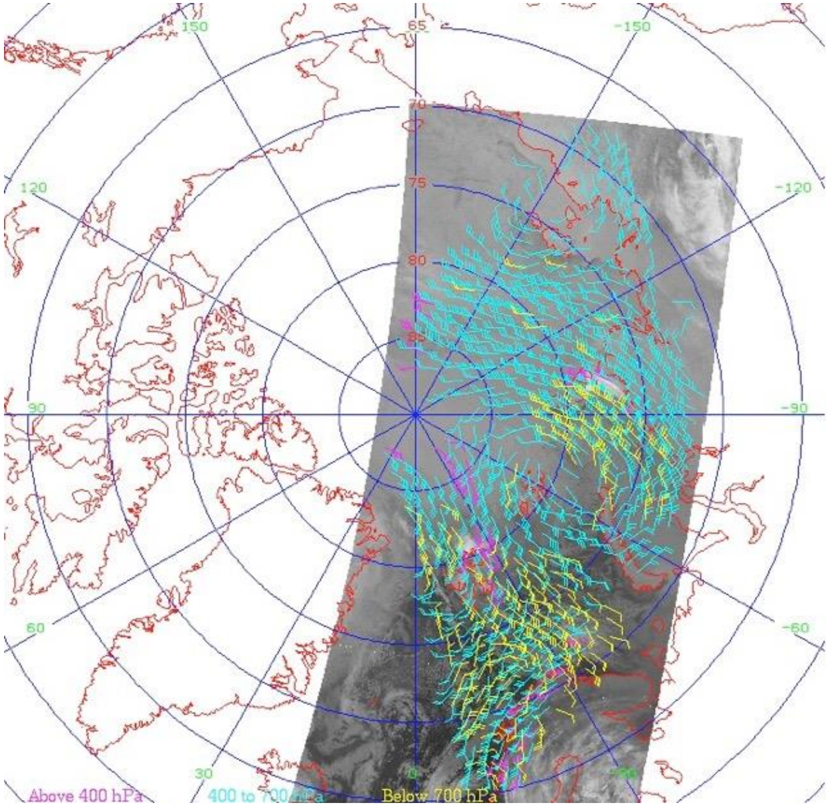
WV + IR



SWIR



Polar winds with the SWIR band



Thank you!

AMV Performance Metrics

AMVs (QI>60) are matched and compared against RAOBS or GFS model analysis winds. Metrics:

$$Accuracy = \frac{1}{N}\sum_{i=1}^{N}(VD_i)$$

$$\Pr ecision = \sqrt{\frac{1}{N}\sum_{i=1}^{N}((VD_i) - (MVD))^2}$$

where:

$$(VD)_i = \sqrt{(U_i - U_r)^2 + (V_i - V_r)^2}$$

U_i and V_i ---> AMV
U_r and V_r ---> "Truth"

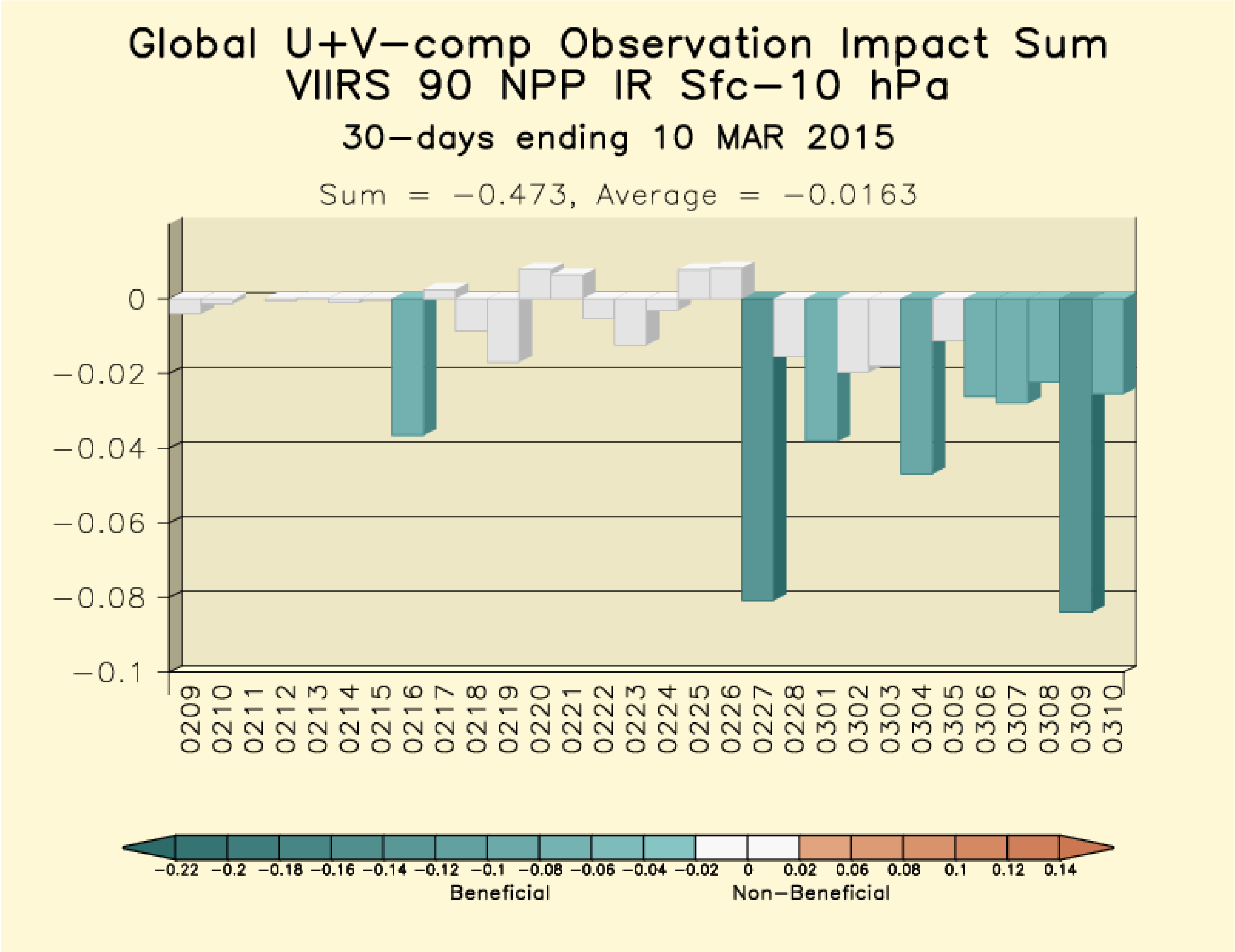
Status

Error Budget, S-NPP and NOAA-20:

Attribute Analyzed	L1RD Threshold	Analysis/Validation Result	Meets spec?
Accuracy	7.5 m/s	5.7-7.0 m/s	Y
Precision	4.2 m/s	2.7-3.8 m/s	Y
Horizontal cell size	10 km	19 km (inherent to the algorithm)	N; Change the requirement as it is an error
Mapping uncertainty	0.4 km nadir; 1.5 km EOS	0.57 km	Y

- **The S-NPP VIIRS Polar Winds product has been operational since May 2014.**
- **NOAA-20 VIIRS Winds Validated Maturity review scheduled for October 2018**
- VPW is also generated at direct broadcast sites and delivered to NWP centers.

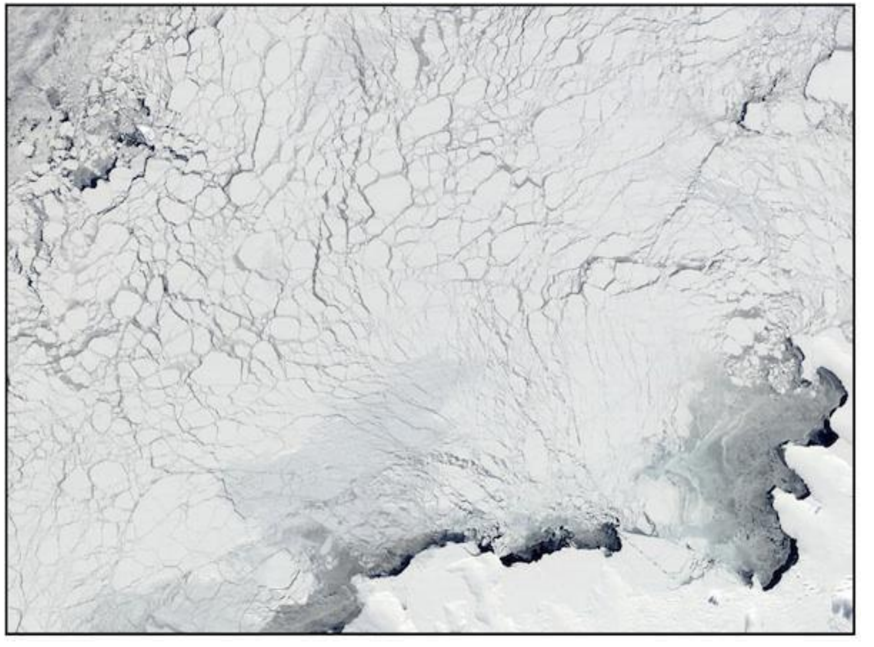
Users, cont.



Courtesy of Naval Research Lab

NOAA AMSR2 SNOW AND ICE PRODUCTS

(abridged version)



Jeff Key

NOAA/NESDIS

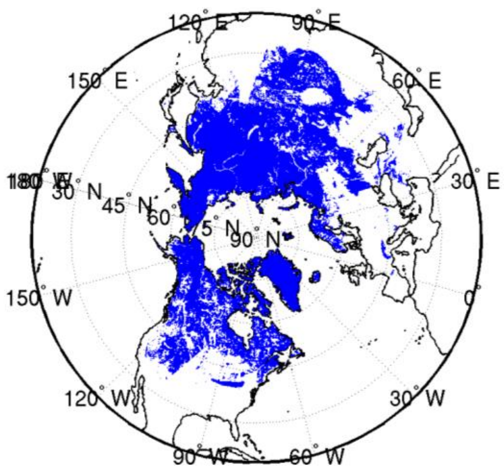
Madison, Wisconsin USA

Team Members

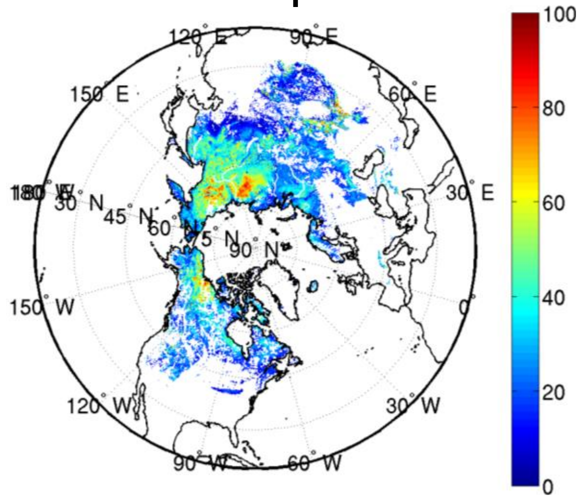
EDR	Name	Organization
Lead; Snow, ice	Jeff Key	NESDIS/STAR
Wisconsin:		
Snow products	~~Yong-Keun Lee~~	CIMSS (now CICS)
Maryland:		
Snow	Cezar Kongoli	CICS
Colorado:		
Sea ice	Walt Meier	NSIDC (formerly NASA GSFC)
Sea ice	Scott Stewart	CU Contractor
Sea ice	Florence Fetterer	NSIDC

AMSR2 Snow and Ice Products

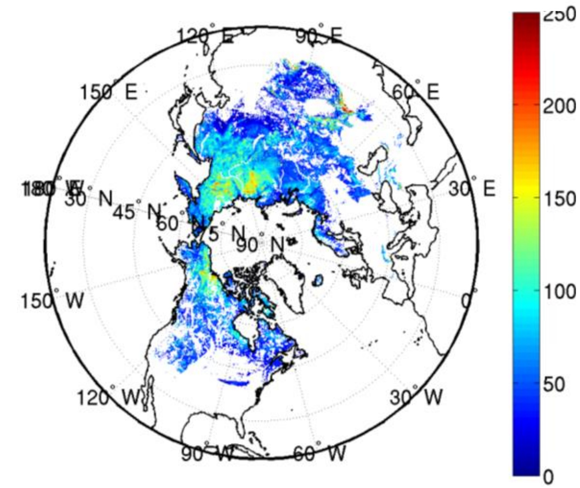
Snow Cover



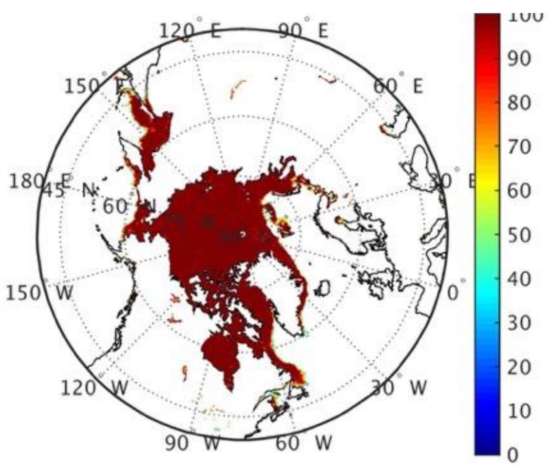
Snow Depth



Snow Water Equivalent

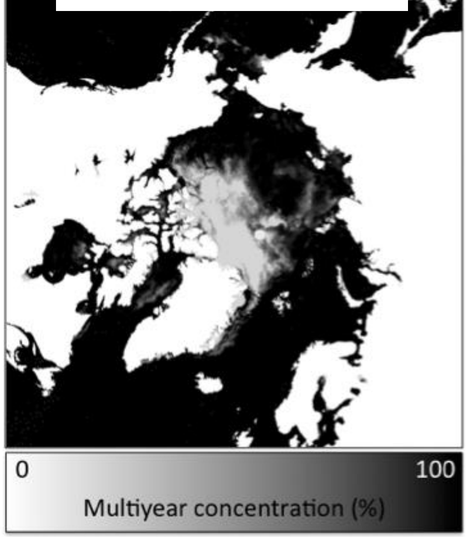


Sea Ice Concentration



Status: Operational, nominal, products meet requirements

Sea Ice Type



Product Performance – AMSR2

Product	L1RDS APU Thresholds	Performance	Meets Spec?
Snow cover (binary)	80% correct typing	72-97%	Y
Snow depth	20 cm uncertainty	15-22 cm	Y (marginal)
SWE	50-70% uncertainty (shallow to thick snowpacks)	~20-22%	Y
Ice concentration	10% uncertainty	3.9% NH; 4.4% SH	Y
Ice type	70% correct typing	80-90%, Arctic winter	Y

Future Plans

Snow:

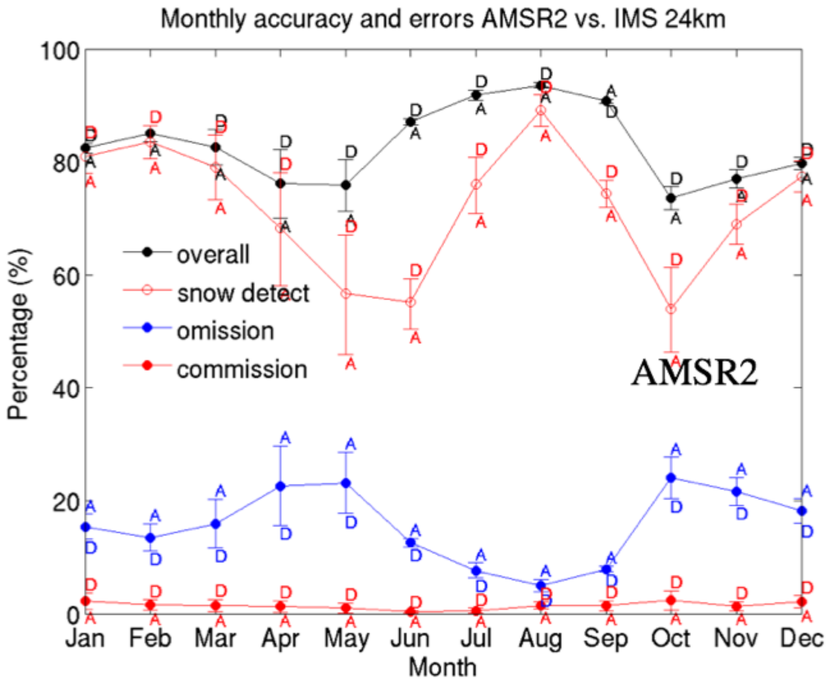
- Regional assessment of biases in AMSR2 snow products and adjustment of algorithm parameters to improve retrievals;
- Explore and develop a data assimilation-based AMSR2 SWE product similar to ESA's GlobSnow.

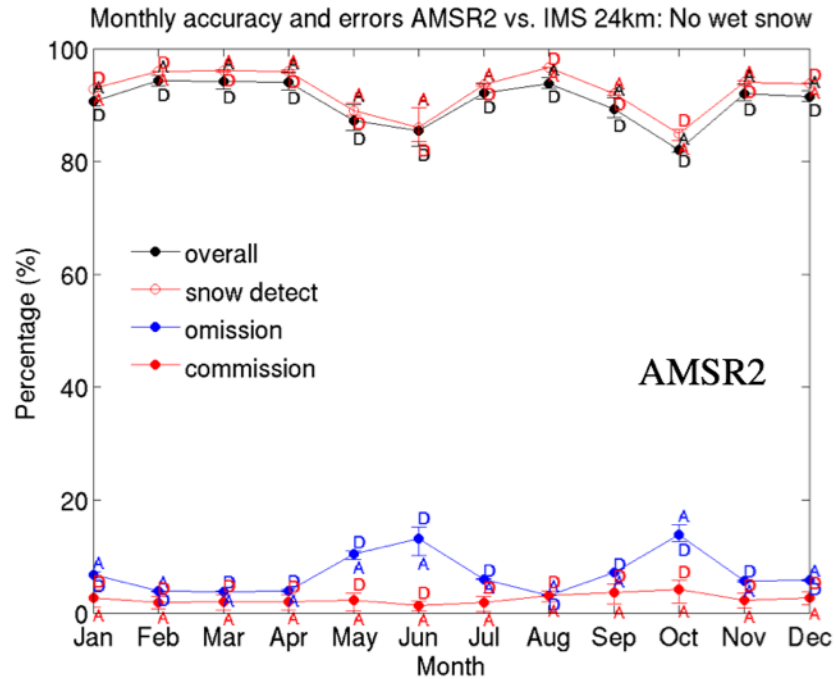
Sea ice:

- Further development and validation of ice type and publication of ice type methodology.

Extra Slides

Snow Cover Validation

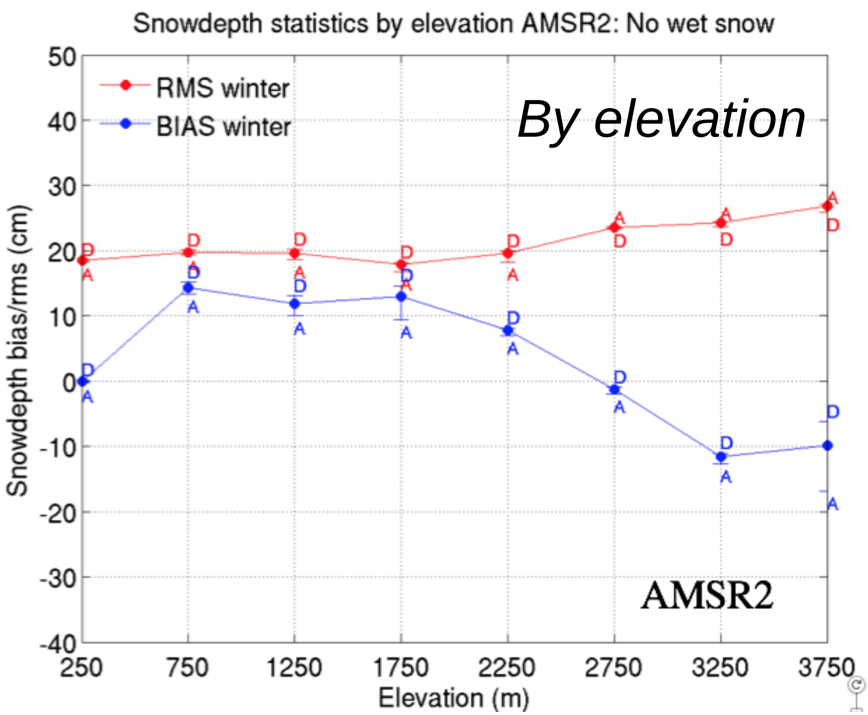


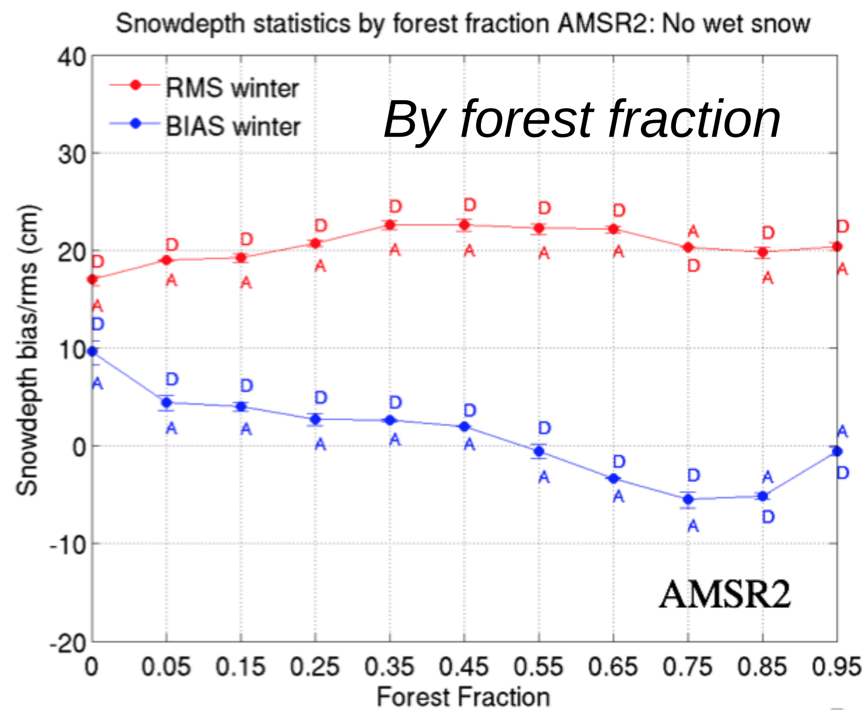


If wet snow is not included, detection accuracy is higher.

	Tundra	Taiga	Maritime	Ephemeral	Prairie	Alpine
Overall Accuracy	94.6%	97.4%	80.9%	71.7%	74.0%	86.9%

Snow Depth Validation





	Tundra	Taiga	Maritime	Ephemeral	Prairie	Alpine
RMSE (cm)	18.77	20.96	19.37	14.95	18.93	21.97
Bias (cm)	4.51	3.77	-5.34	6.05	2.75	-4.45
Mean (cm) of in-situ obs	25.10	19.18	20.20	8.40	18.49	25.14

Snow Water Equivalent Validation

SWE comparison between AMSR2 retrievals and **GHCN**

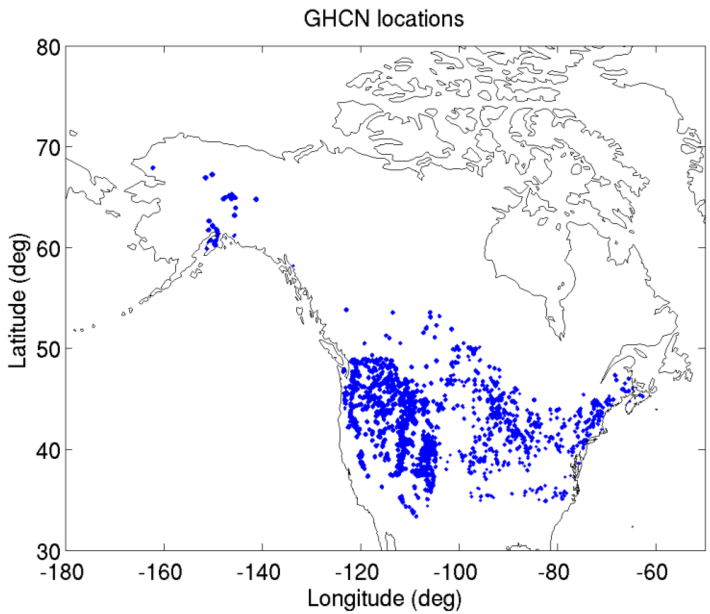
When 10 < AMSR2 SWE < 100 and 10 < GHCN SWE < 100 and the location altitude < 3000m:

bias	std	rmse	mean1	mean2	number of pixels
-7.97	30.77	31.79	46.54	54.52	45033

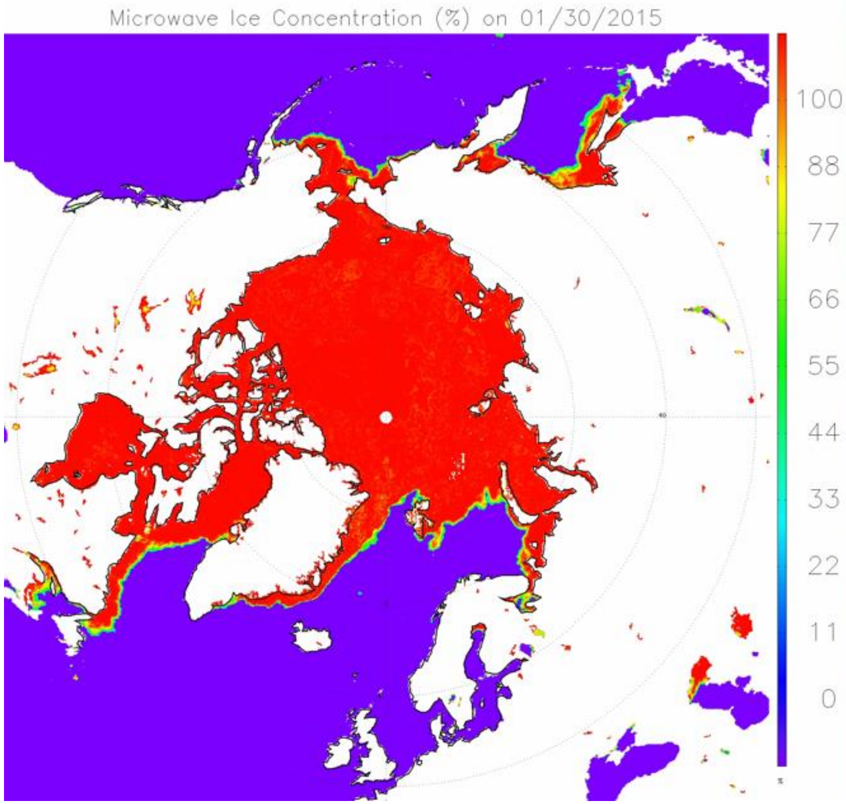
When 100 < AMSR2 SWE and 100 < GHCN SWE and the location altitude < 3000m:

bias	std	rmse	mean1	mean2	number of pixels
-29.91	50.91	59.05	115.56	145.47	657

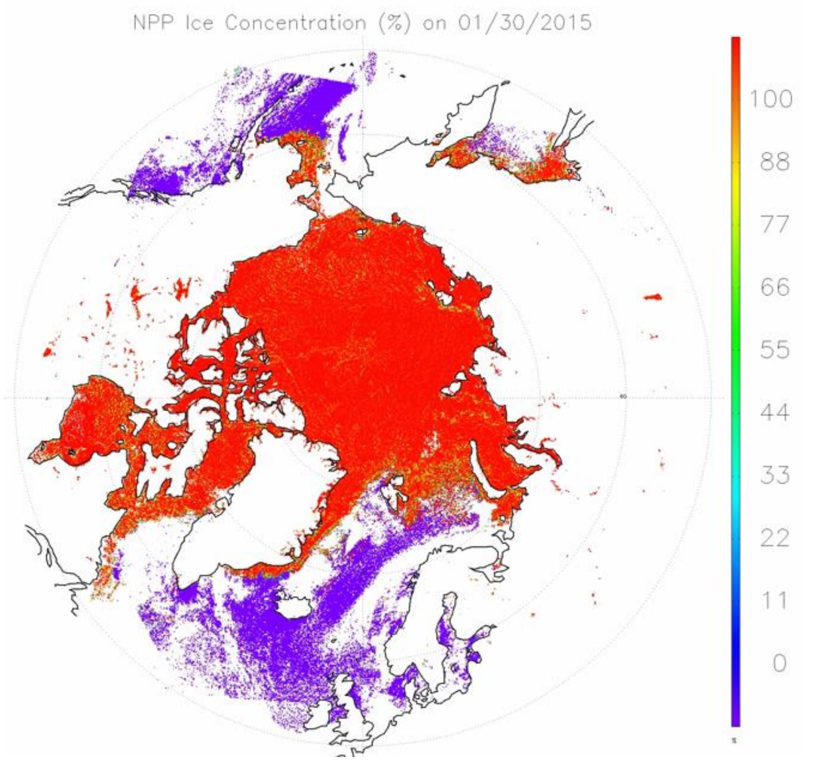
mean1: average of AMSR2 SWE
mean2: average of GHCN SWE
bias: mean of AMSR2 SWE - GHCN SWE
GHCN: Global Historical Climatology Network



Validation



Comparison of AMSR2 (left) and VIIRS (below) sea ice concentration over the Arctic on 31 January 2015.

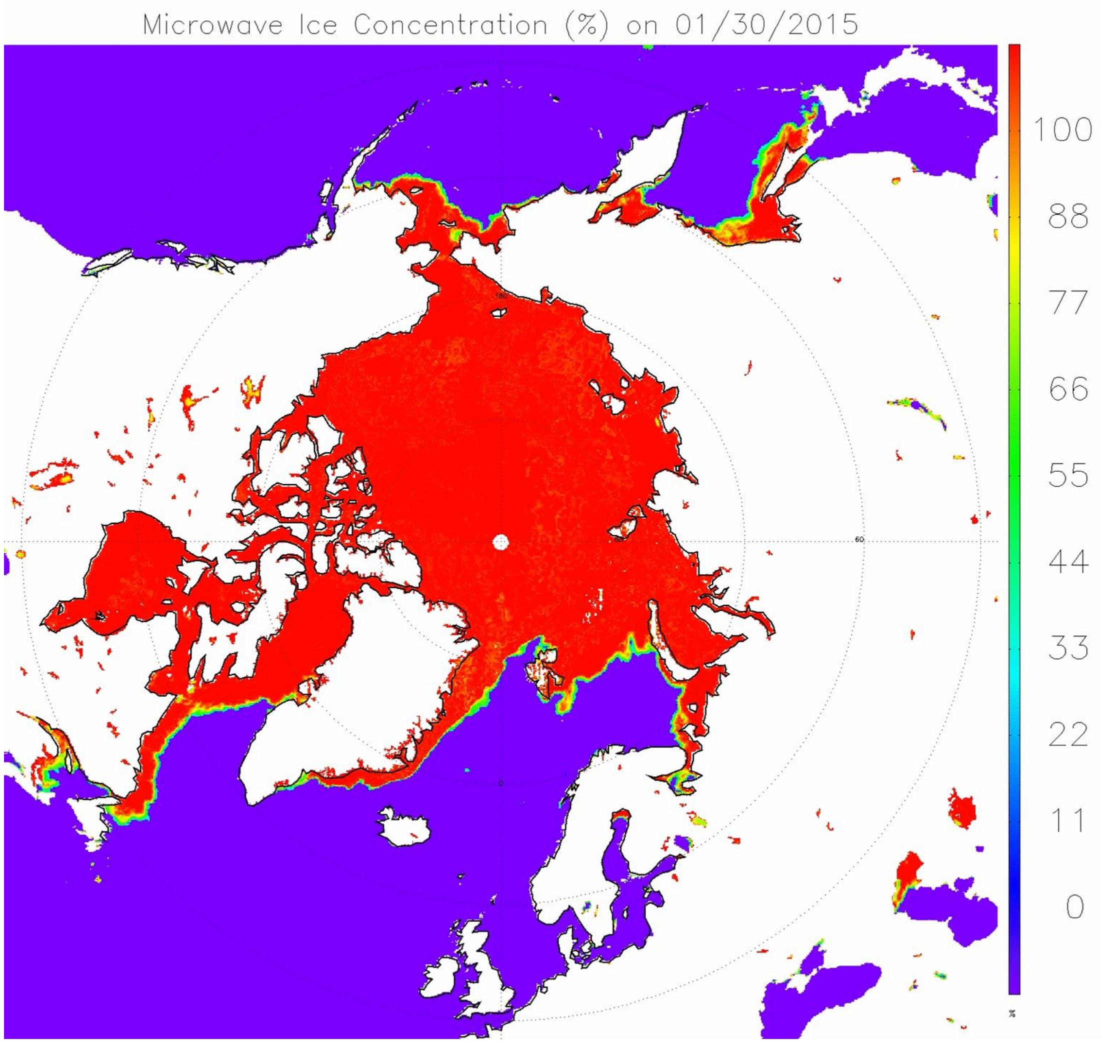


Additional information on validation is in the notes section of this slide

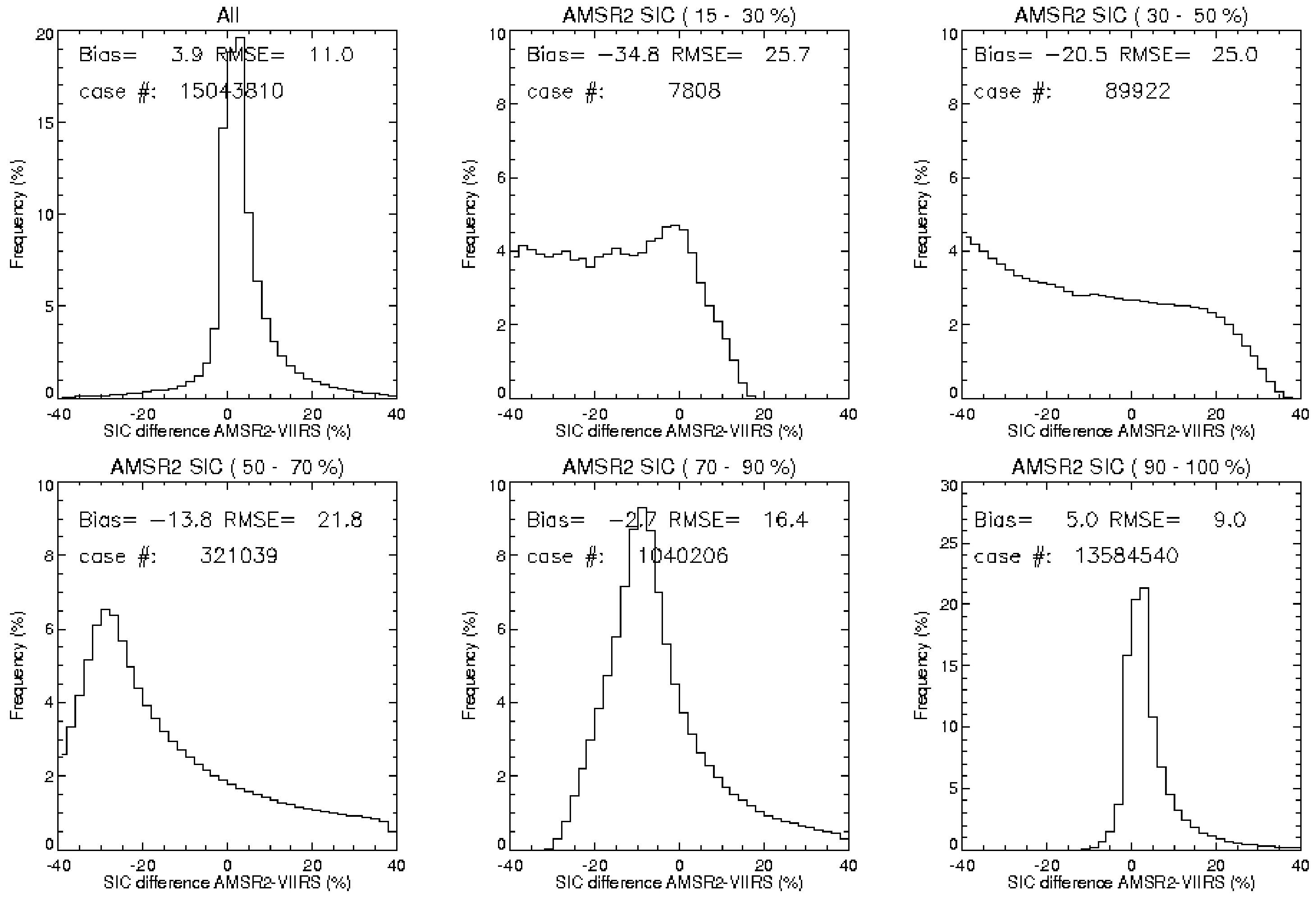
Sea Ice Concentration Validation

Comparison of AMSR2 and VIIRS sea ice concentration over the Arctic on 31 January 2015.

(animation)

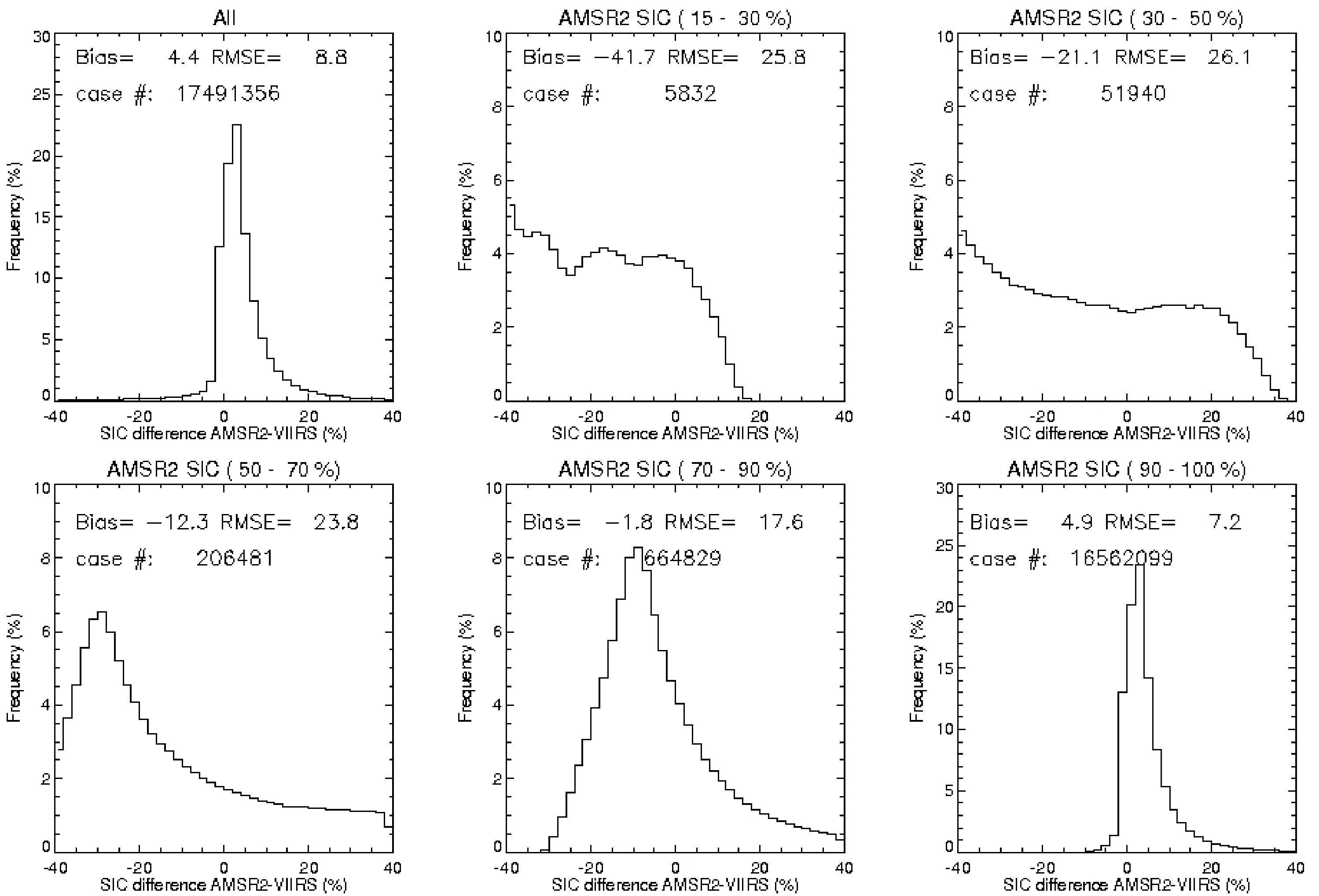


Sea Ice Concentration Validation



Comparison of AMSR2 minus VIIRS ice concentrations for different AMSR2 ice concentration ranges/bins in the Arctic. Note that the y-axis range is different for "All", "90-100%", and the other plots. Data are from January to October 2016.

Sea Ice Concentration Validation



Same as previous slide except for the Antarctic.

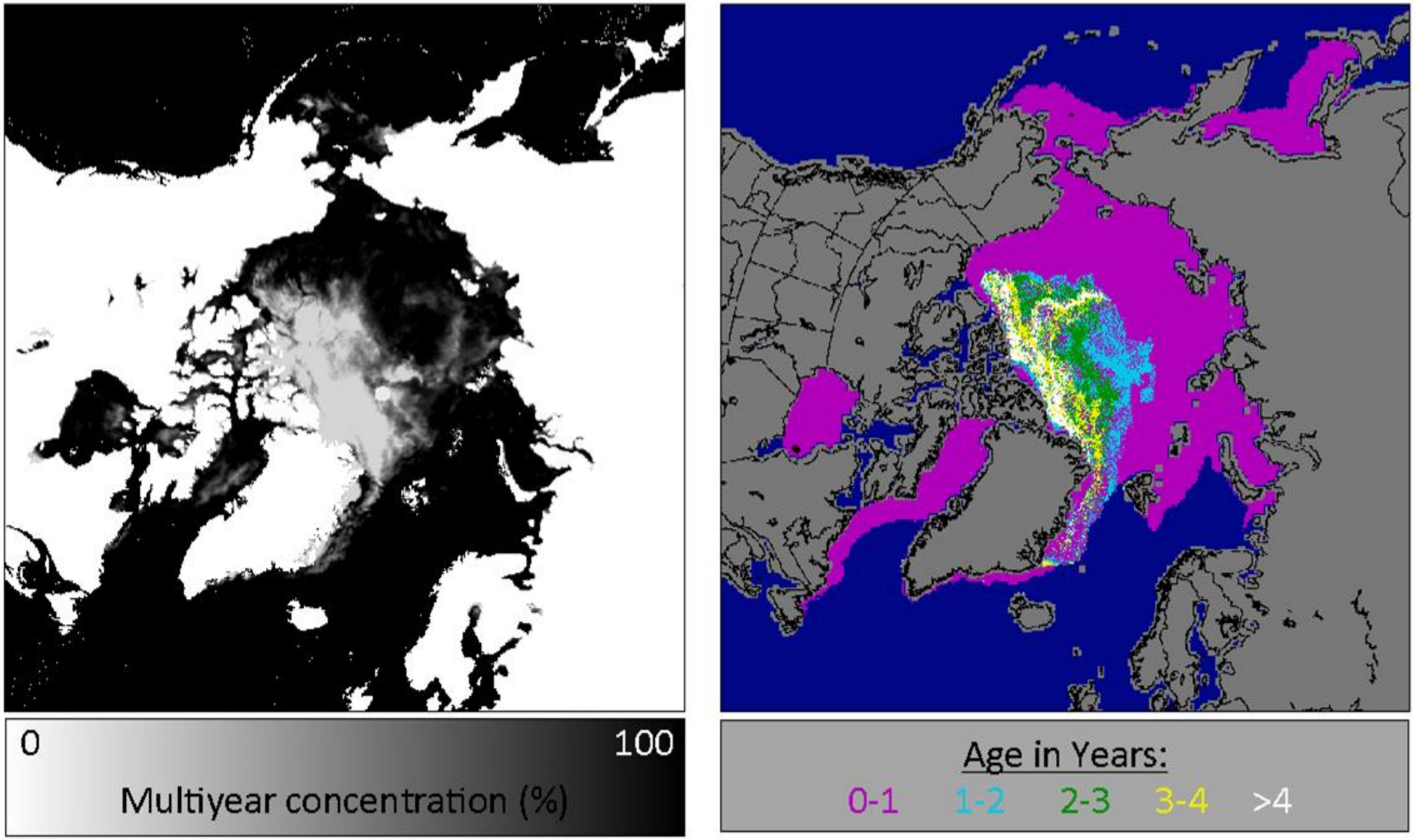
Sea Ice Concentration Validation

Statistical results of the comparison in sea ice concentration between AMSR2 and VIIRS.

Maximum (red) and minimum (blue) values in each column are highlighted.

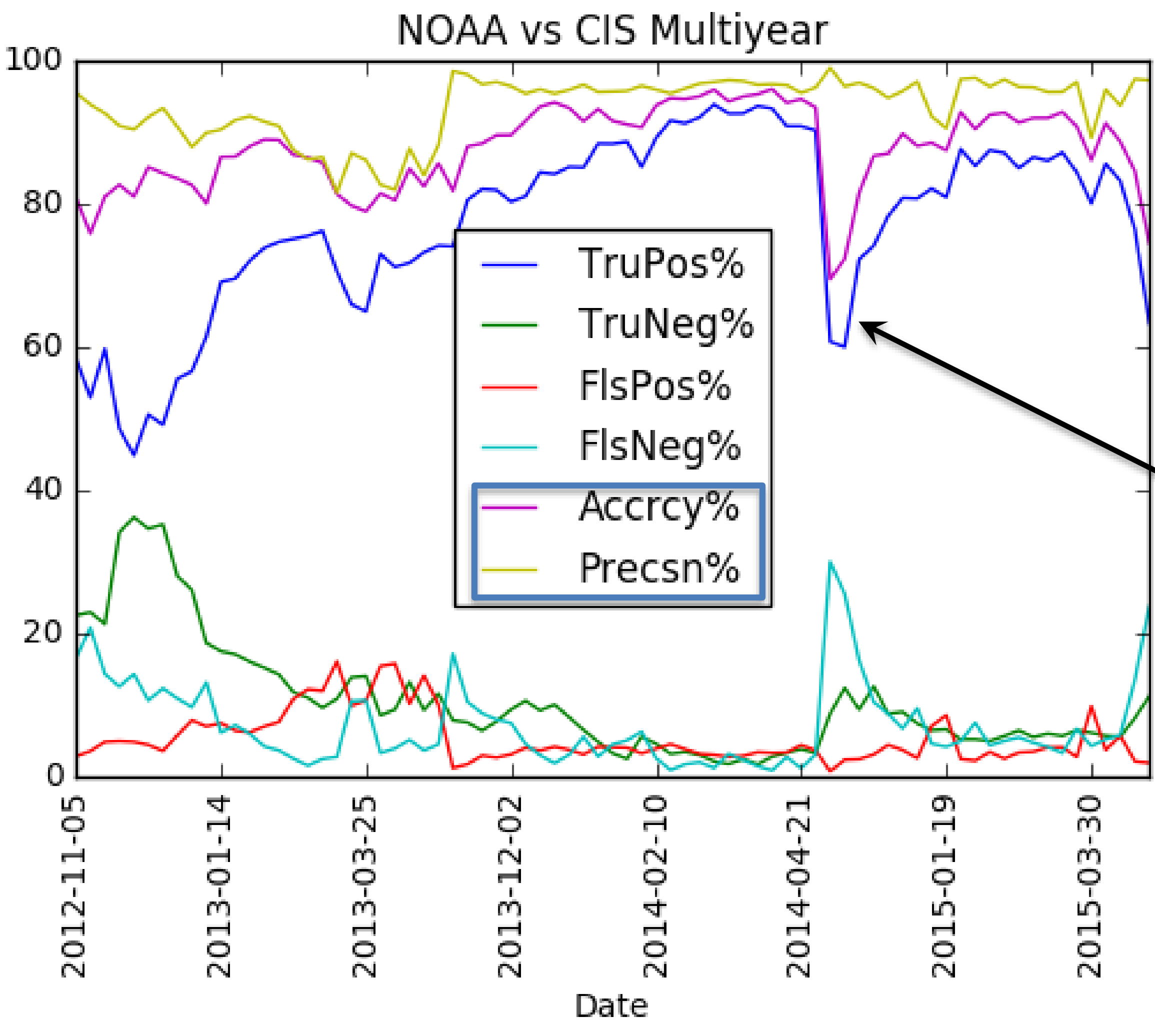
	Arctic			Antarctic		
	Accu	Prec	Cases	Accu	Prec	Cases
01/30	1.61	***8.76***	123747	0.50	21.45	22776
01/31	1.62	9.10	***124514***	1.53	***22.03***	***19556***
02/27	2.05	9.91	122376	1.04	20.19	20101
02/28	2.03	9.35	120343	***0.21***	20.88	22256
03/30	2.45	10.01	122108	1.52	14.90	48343
03/31	2.12	9.39	118841	2.48	15.24	43737
04/30	3.02	11.98	88959	1.85	12.64	79228
04/31	3.01	11.87	79756	2.24	12.62	82094
05/30	3.20	11.46	65418	2.19	13.03	99093
05/31	***3.22***	11.92	70990	1.80	12.97	104142
06/30	2.19	14.05	56864	1.55	***11.08***	121964
06/31	1.89	14.41	55580	1.56	11.78	123805
07/30	1.89	18.33	35577	2.43	12.62	***142350***
07/31	2.53	18.20	38069	2.58	12.34	138524
08/30	***0.25***	***18.48***	28727	2.79	11.87	133027
08/31	0.61	17.19	***27315***	***2.95***	12.71	142208

Multiyear Ice Validation



Initial comparison with independent ice age fields (Lagrangian tracking of ice parcels) indicates good agreement in terms of spatial distribution of multi-year ice cover.

Ice Type Validation: Ice Charts

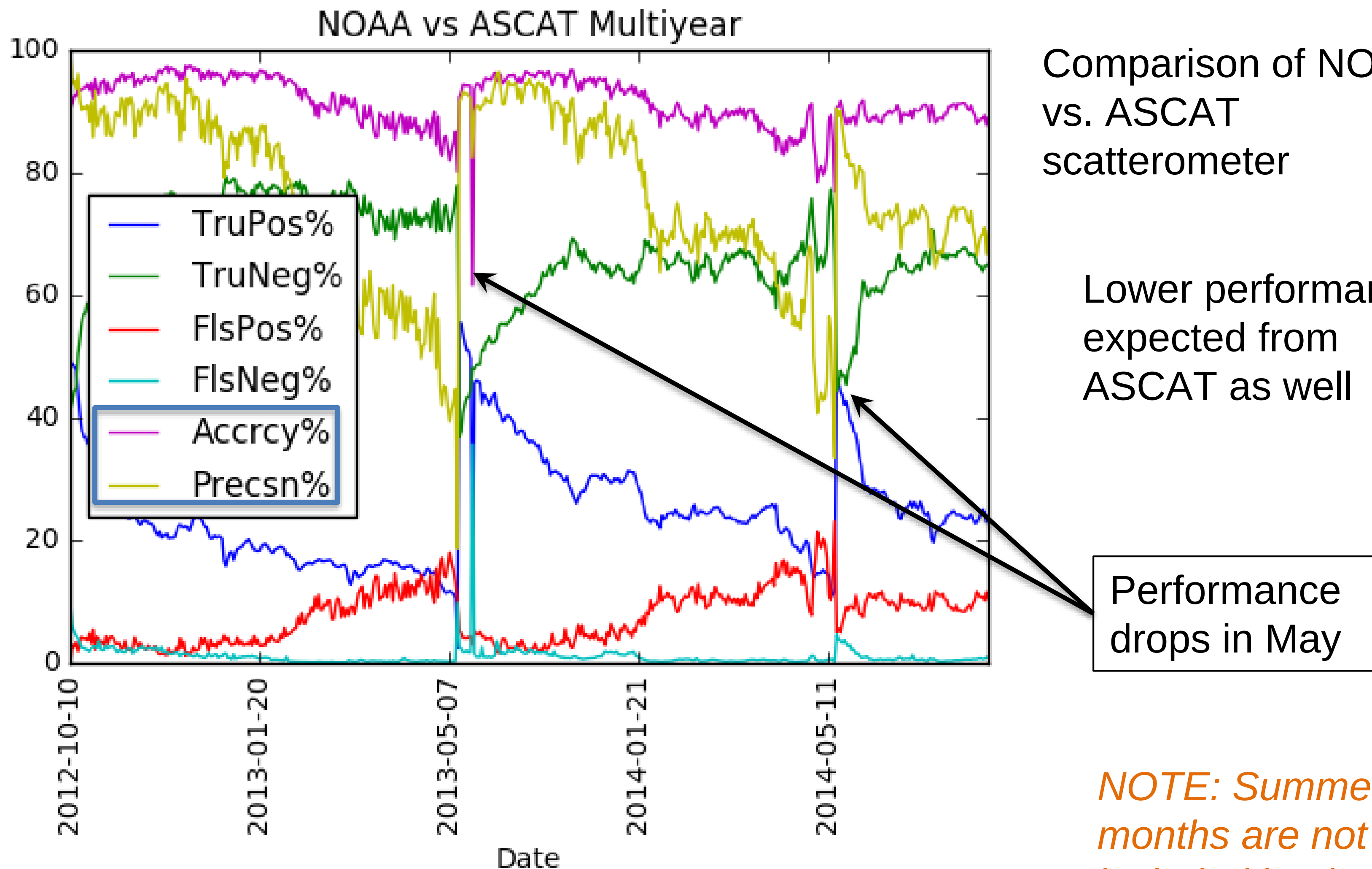


Comparison of NOAA vs. Canadian Ice Service (CIS) charts in high Arctic

Performance drops in May (melt onset)

NOTE: Summer months are not included in plot.

Ice Type Validation: ASCAT



Comparison of NOAA vs. ASCAT scatterometer

Lower performance expected from ASCAT as well

NOTE: Summer months are not included in plot.

Ice Type Validation: OSI-SAF

Confusion Matrix results, 2012-2015

- Average over all 3.5 years (Oct. 2012 – Dec. 2015)
- Mid-October through mid-April each year

	OSISAF MYI	OSISAF no-MYI
NOAA MYI	28.1%	2.1%
NOAA no-MYI	4.8%	65.1%

Accuracy: 93.2 ± 2.3%
Precision: 84.5 ± 8.5%

NOAA agrees with OSISAF (i.e., "correct" retrieval)

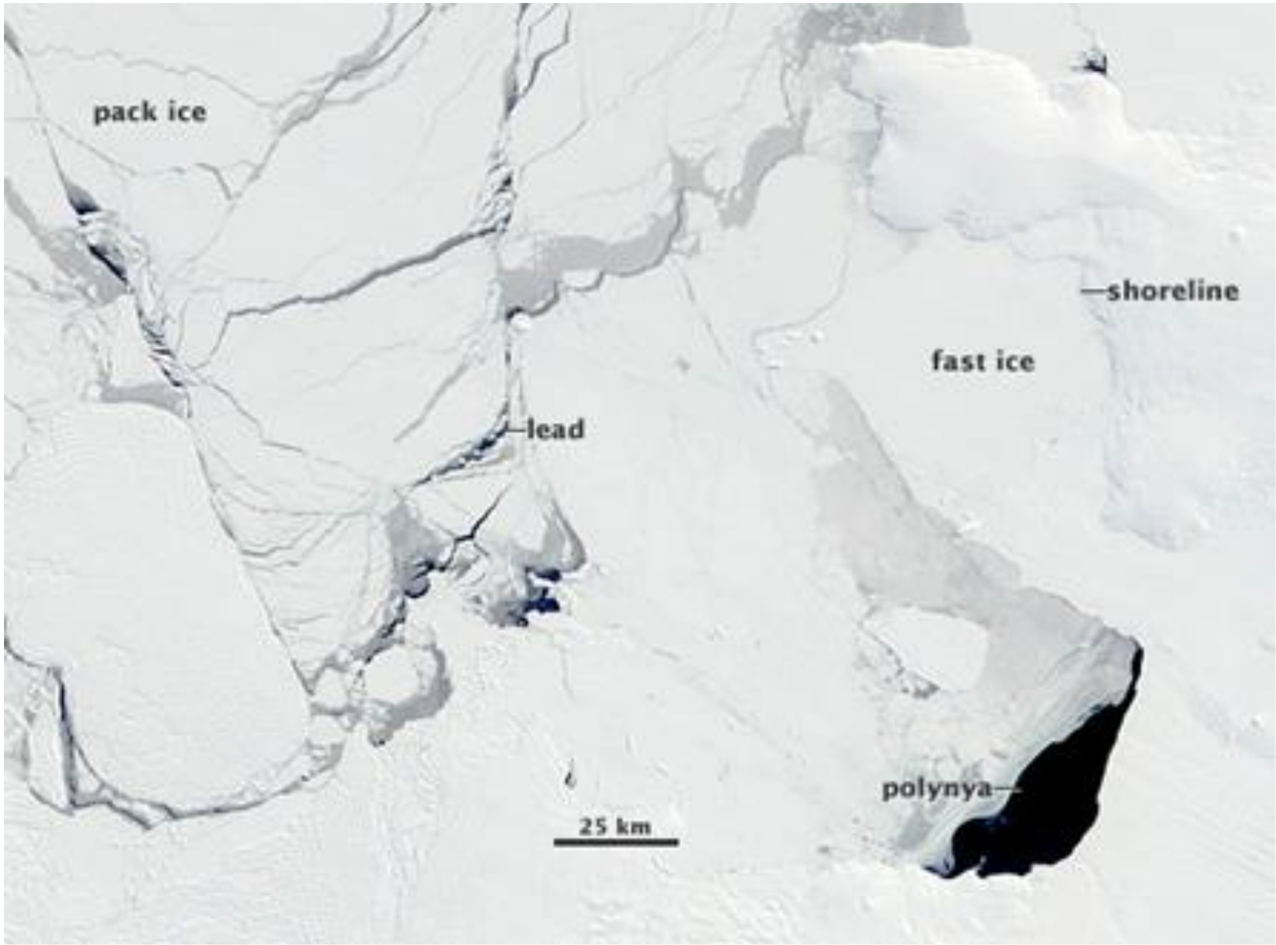
SEA ICE LEADS

Jay P. Hoffman[1], S. Ackerman[1], Y Liu[1] and, J. Key[2]

[1]Cooperative Institute for Meteorological Satellite Studies
[2]NOAA/NESDIS Madison, WI

Background

- Leads are elongated fractures in the sea ice cover. They form under atmospheric and oceanic stresses (Smith et al., 1990).
- Leads provide a source of heat and moisture to the Arctic atmosphere (Alam and Curry 1995, Maykut, 1987).



(From earthobservatory.nasa.gov)

Objective

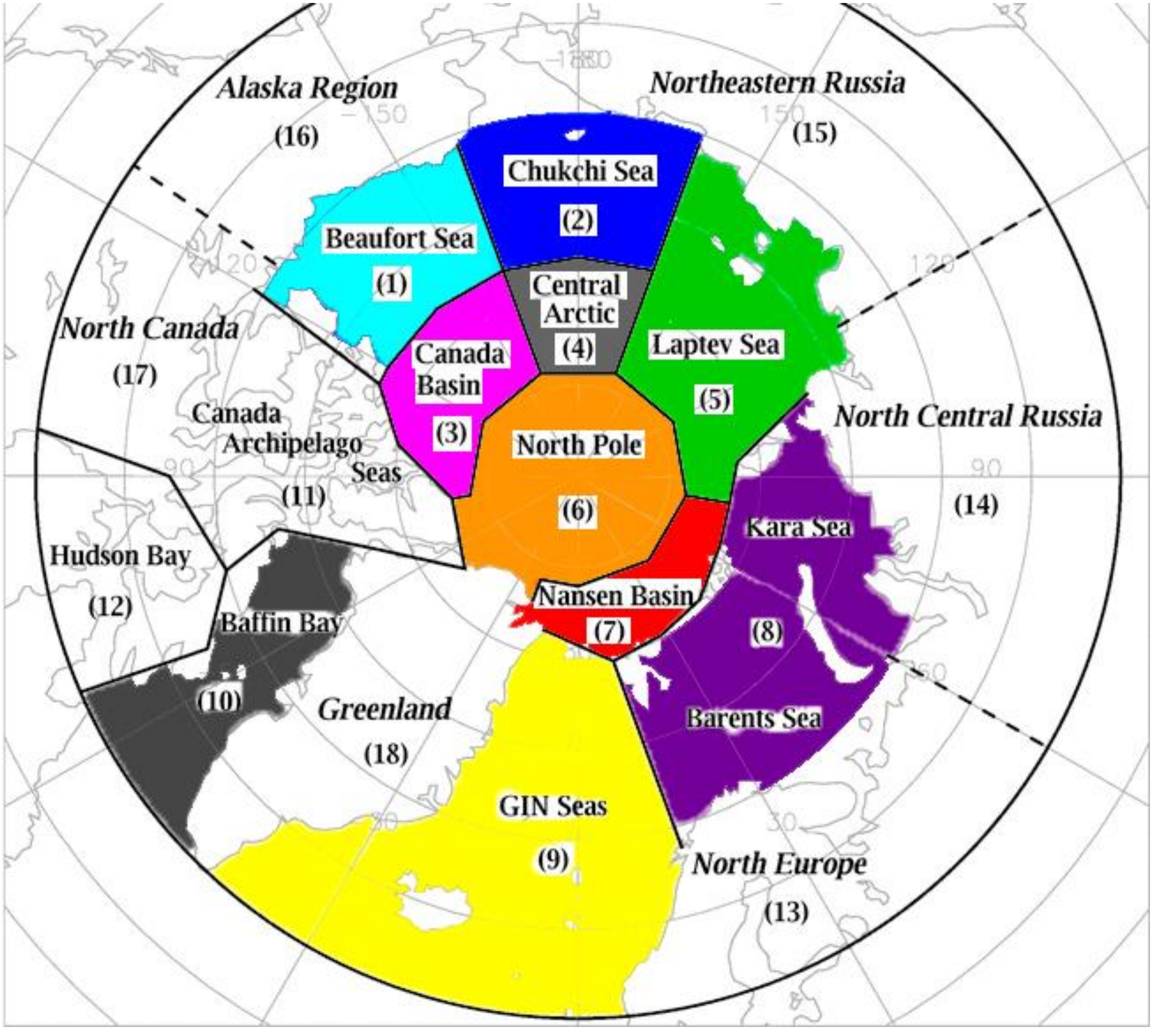
- Identify the spatial and temporal distributions of sea ice leads (fractures) in the Arctic
- Generate near-real-time sea ice leads product in the Arctic using VIIRS

Image credit: National Ice Center

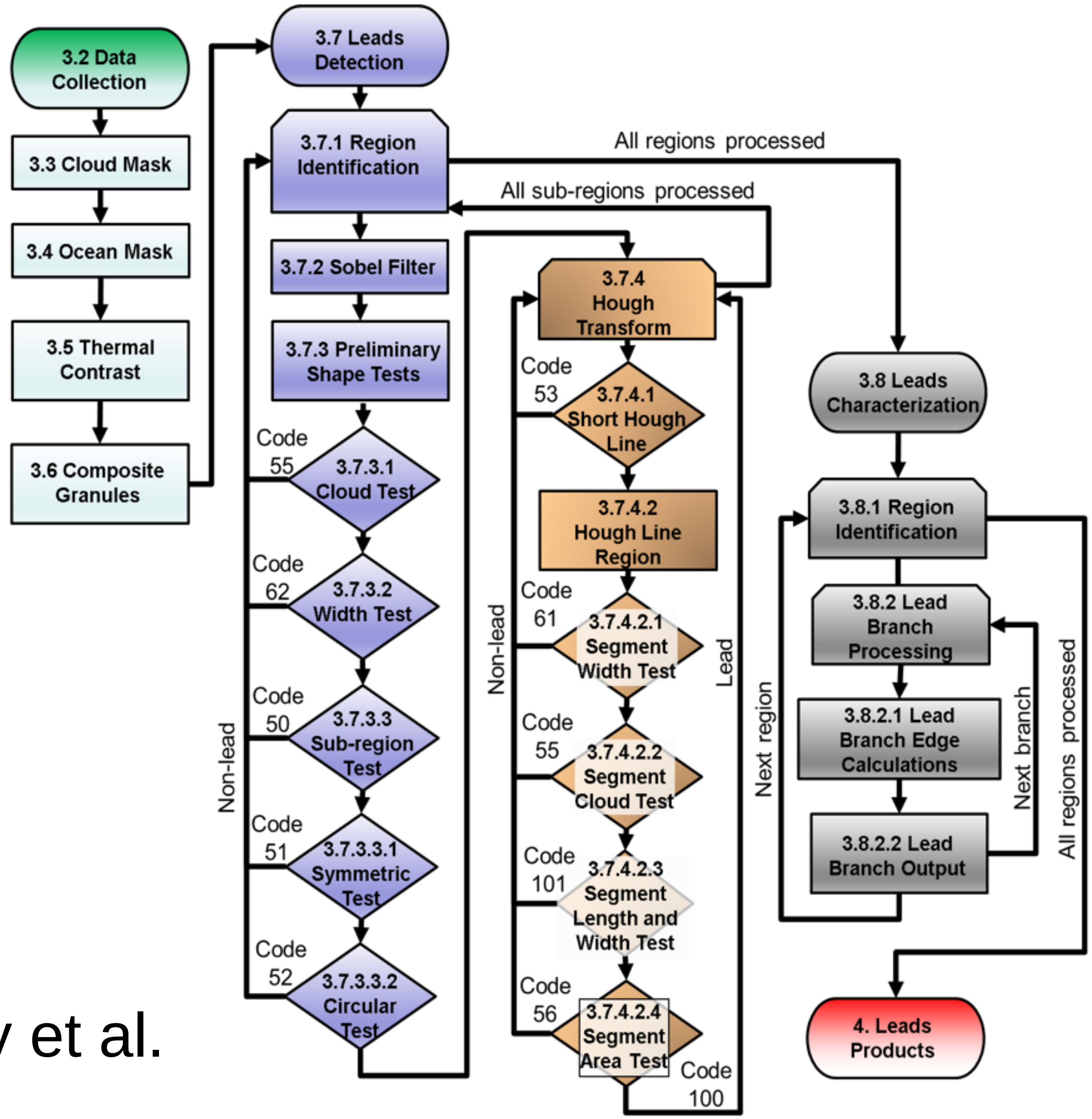
Study Area

Arctic:

- 10 polar regions
  - Beaufort Sea
  - Chukchi Sea
  - Canada Basin
  - Central Arctic
  - Laptev Sea
  - North Pole
  - Nansen Basin
  - Kara & Barents Sea
  - GIN Seas
  - Baffin Bay



Algorithm Description



Adapted from Key et al. (1993 and 1994)

Thermal Contrast

- Leads are identifiable by thermal contrast; warmer than the surrounding ice
- With more consistent along-swath resolution, leads detection is possible for a larger swath from VIIRS than MODIS

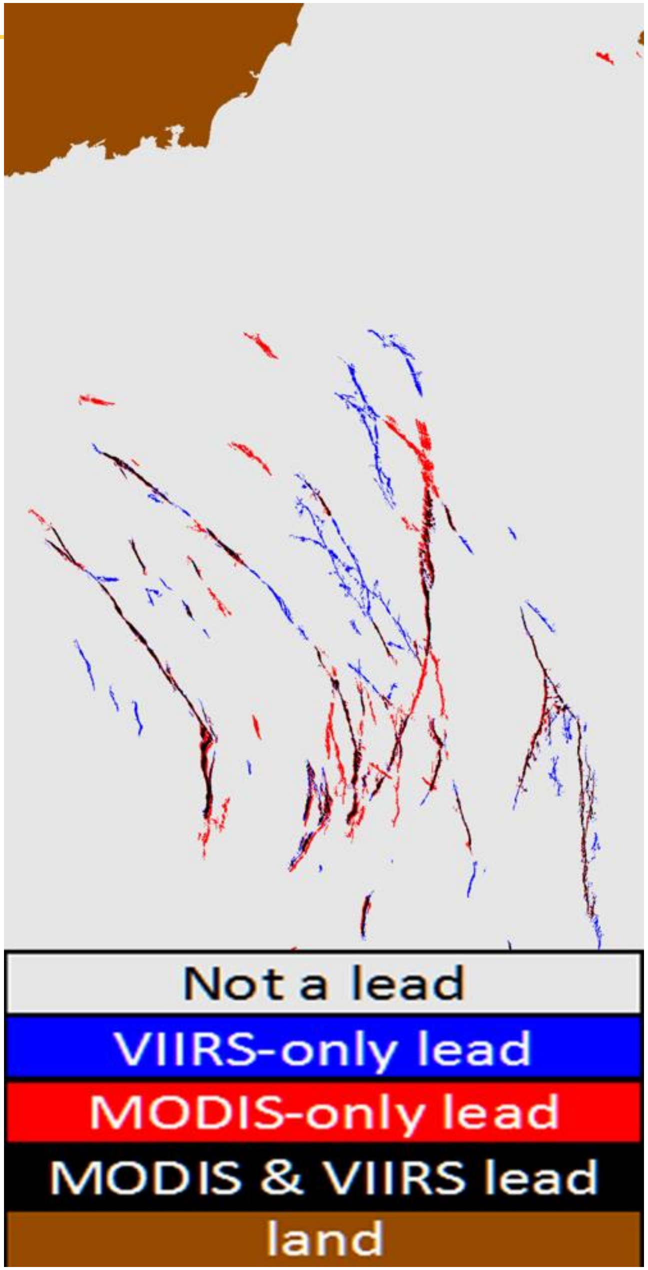
MODIS-TERRA BT31 image on 15 February 2018 at 0545UTC. Leads are readily apparent as bright (warm) features relative to the darker (colder) ice and clouds.

Cloud Filter

- MODIS-TERRA cloud mask image from 15 February 2016, at 0545UTC.
- The original cloud mask defines clouds as all non-black areas
- A spatial filter is applied to remove thin features from the mask and orange in the figure reprints clouds removed

Leads Detection

- VIIRS and MODIS leads detections have some similarities and differences
- VIIRS has better constrained pixel size and a wider swath.
- With JPSS-1 more increase the chances for cloud-free overpasses; similar to MODIS (AQUA & TERRA)

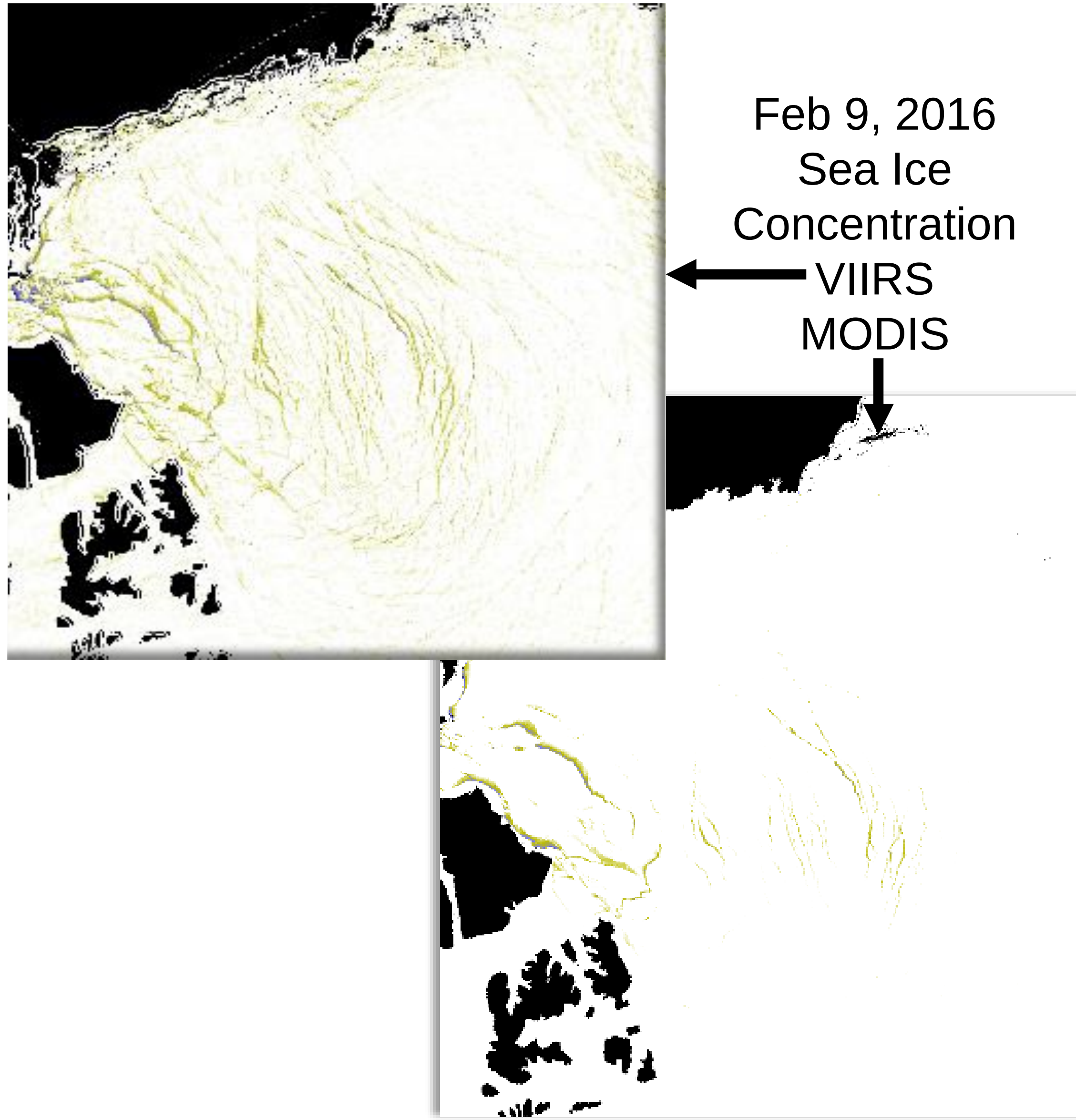


Leads detected in MODIS and VIIRS on 15 February 2018.

Why VIIRS ?

VIIRS's wider swath and consistent along-swath resolution results in better ice leads retrievals

- More detail in thermal contrast in more leads detected
- VIIRS detects more leads in regions where MODIS scan angles are greater than 30°

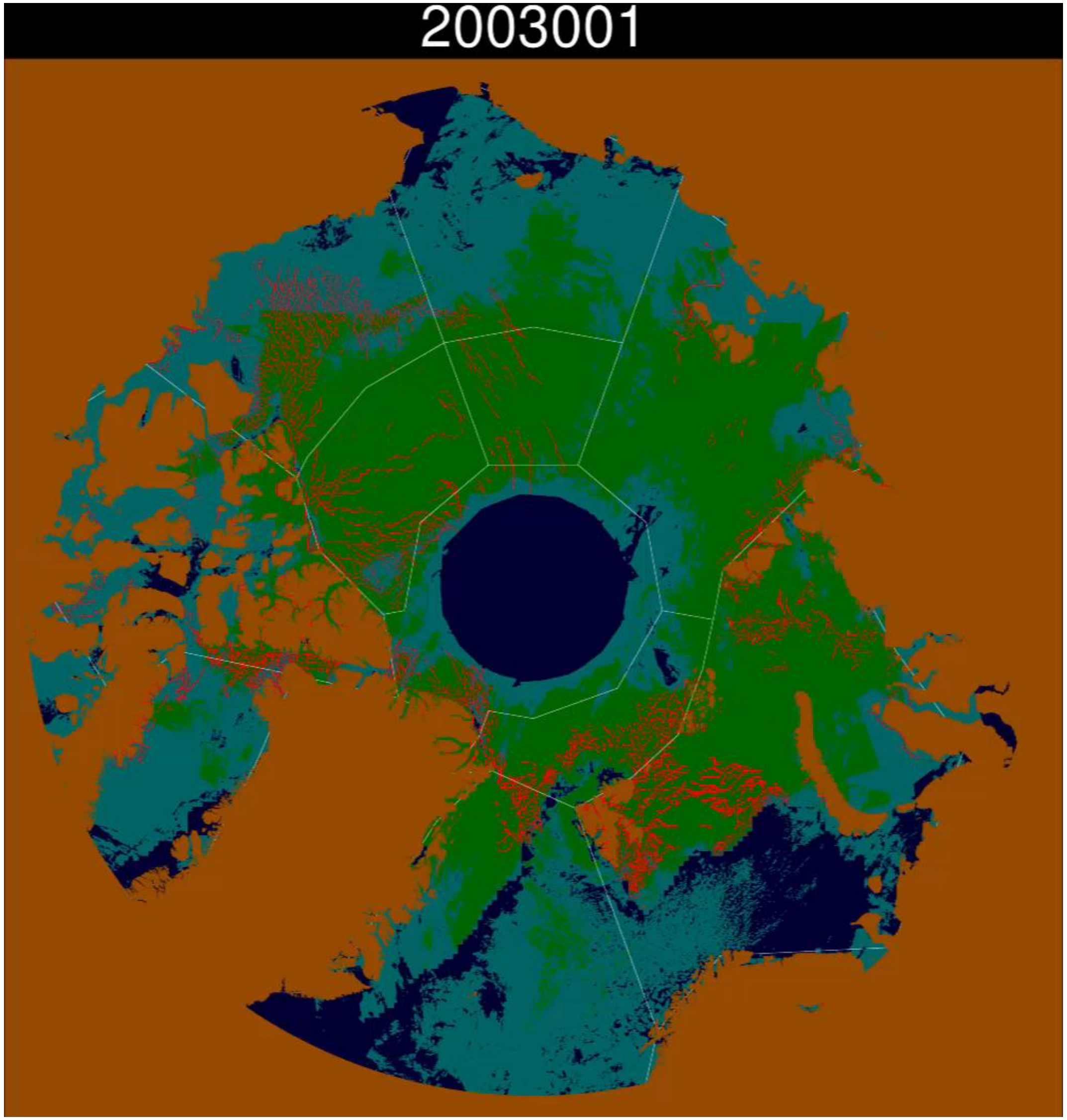


Summary

Daily leads
Jan-Apr 2003-2017

- Sea ice leads algorithm has been developed for MODIS

- Future steps
  - Extend algorithm to VIIRS
  - Real-time product using VIIRS



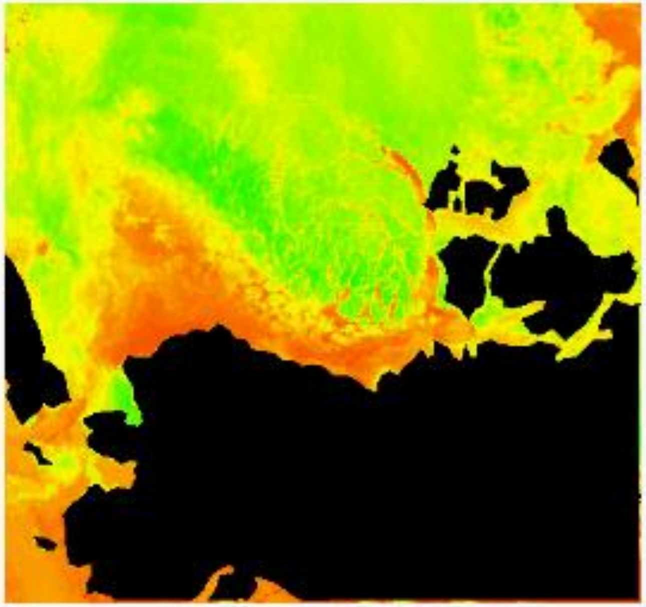
- New lead
- Lead from previous day(s)
- 5+ clear overpasses
- 1-4 clear overpasses
- No clear overpasses
- Land/latitude block-out

Sea Ice Motion

- Ice motion computes displacement between features in two separate satellite images

- Currently generated from :

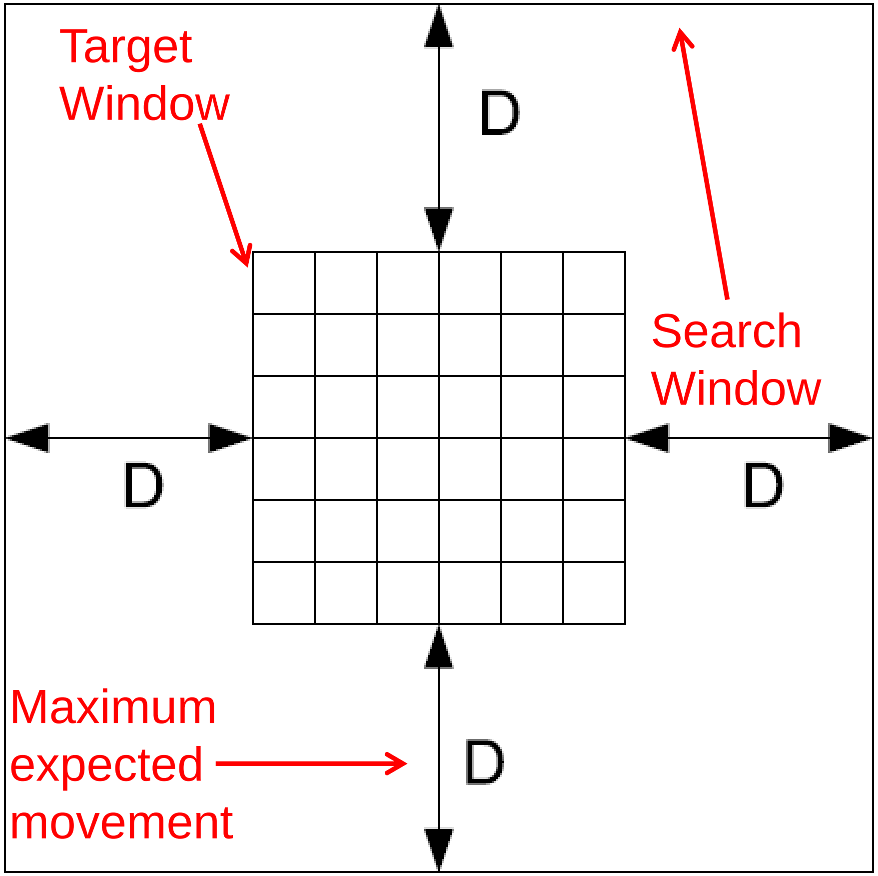
AMSR2 (89 GHz)
VIIRS infrared window (M15)
Blended AMSR2+VIIRS(IR)
VIIRS day-night band (DNB)



AMSR2 89GHz Brightness Temperatures, April 24-May 26, 2016

Sea Ice Motion, Algorithm

- Automated, maximum cross-correlation (MCC) procedure is used to features within the target window
- Target window size, search range, and time between images can be edited
- Imagery must be placed on similar grid for consistency

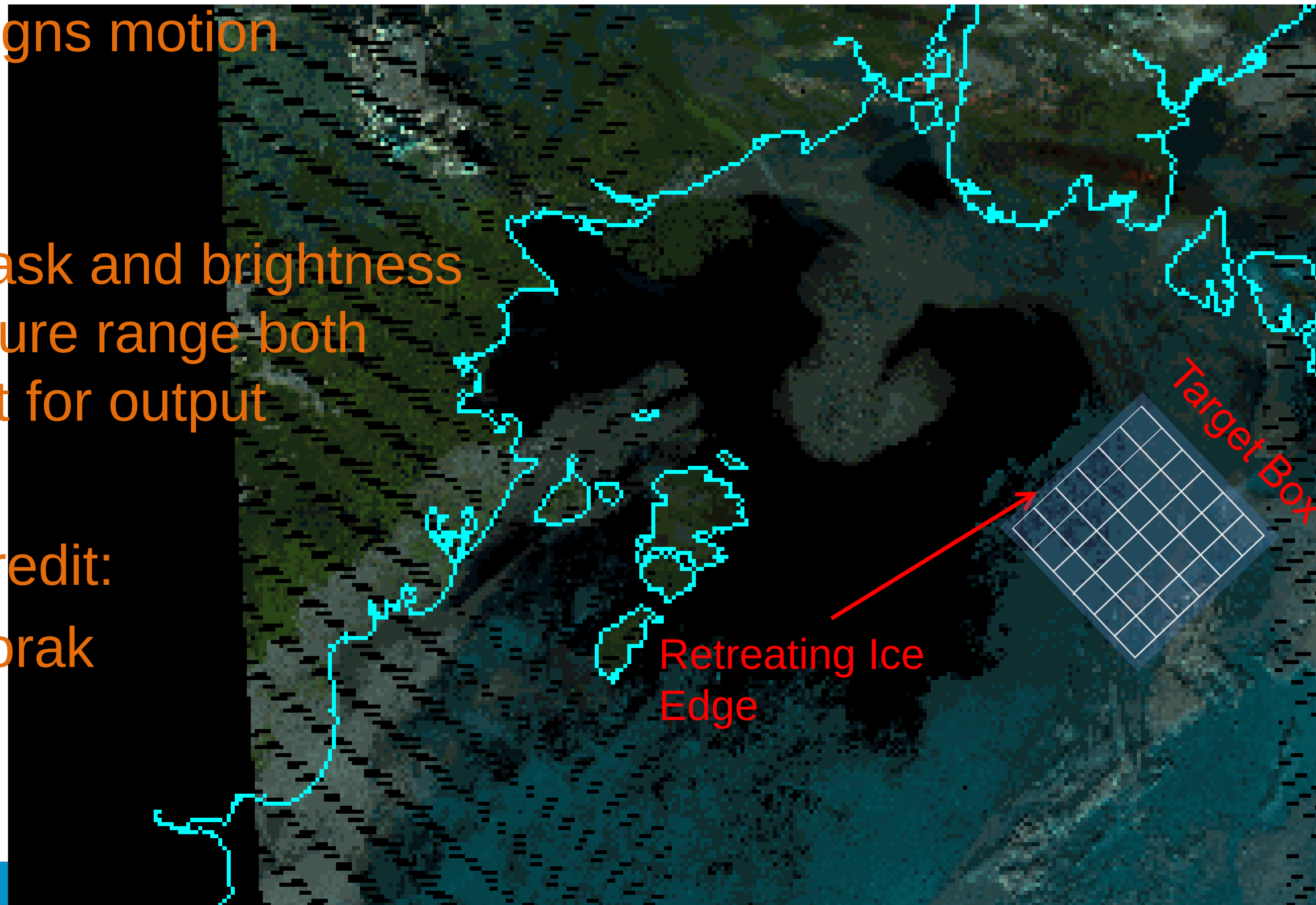


Sea Ice Motion, Algorithm

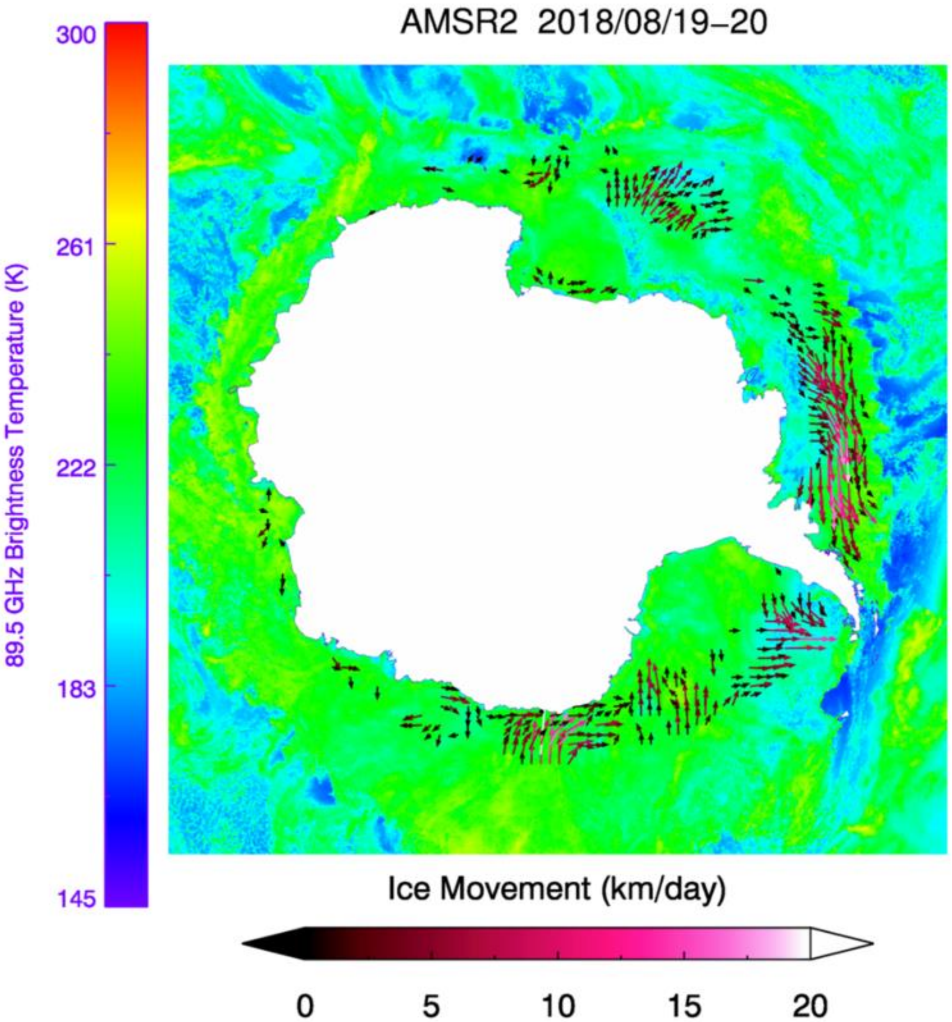
- Algorithm searches for changes in the target box then assigns motion vectors
- Cloud mask and brightness temperature range both important for output
- Image Credit:

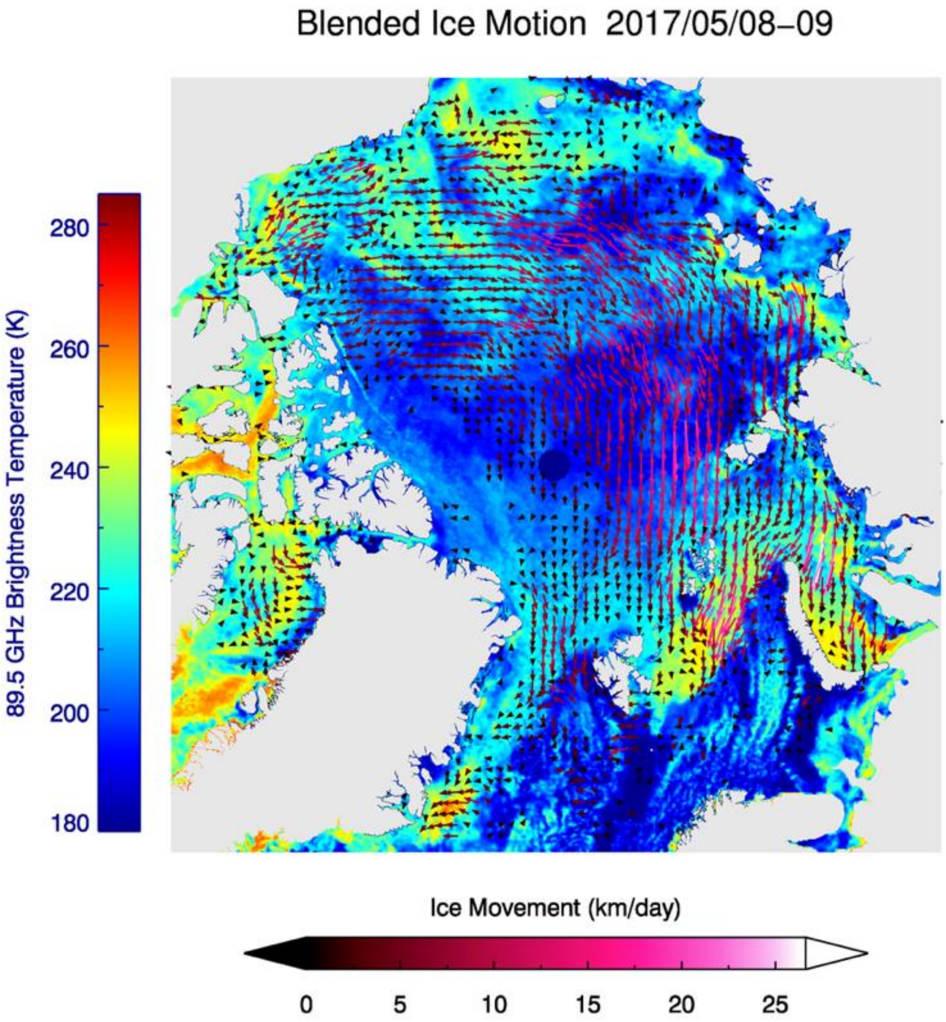
  Rich Dworak

Image Credit: Rich Dworak, CIMSS



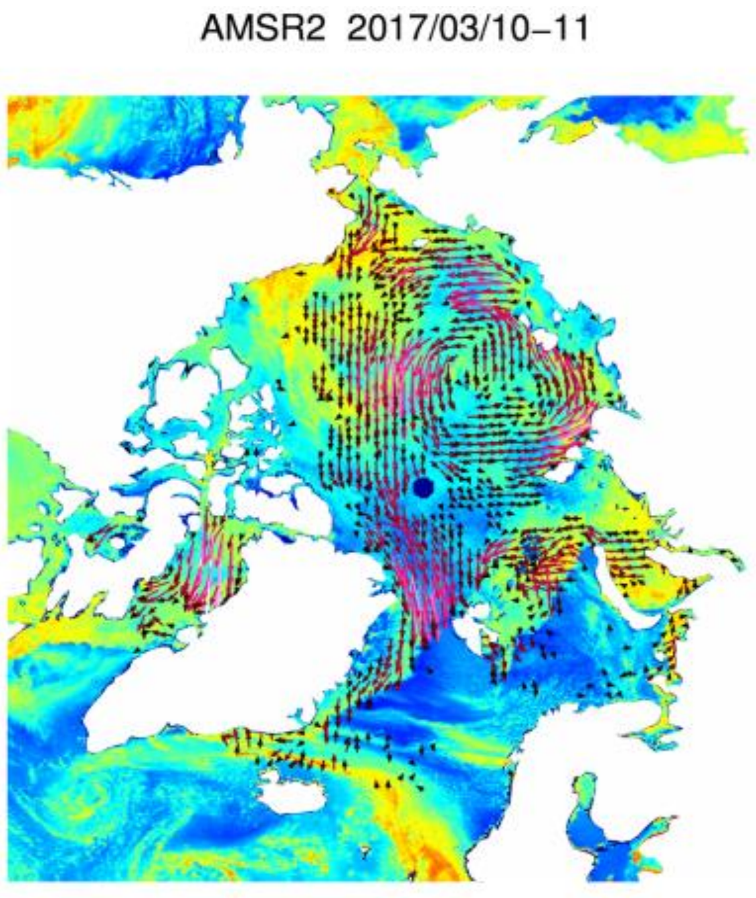
Sea Ice Motion

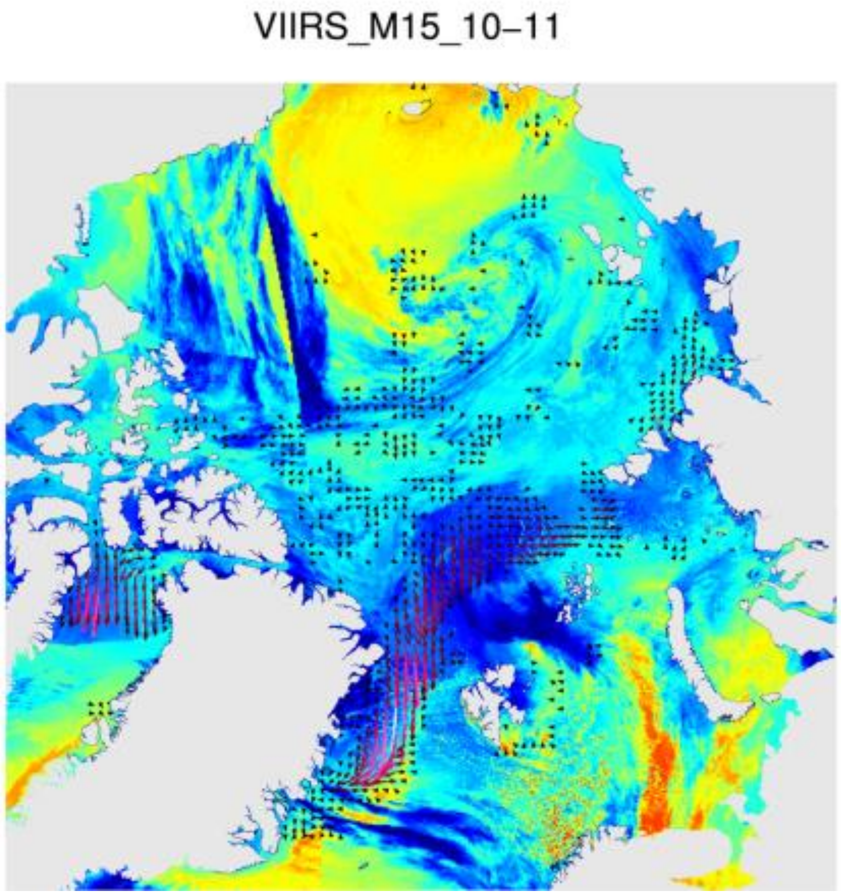




Daily generation over Arctic and Antarctic with more precise motion available for areas of interest

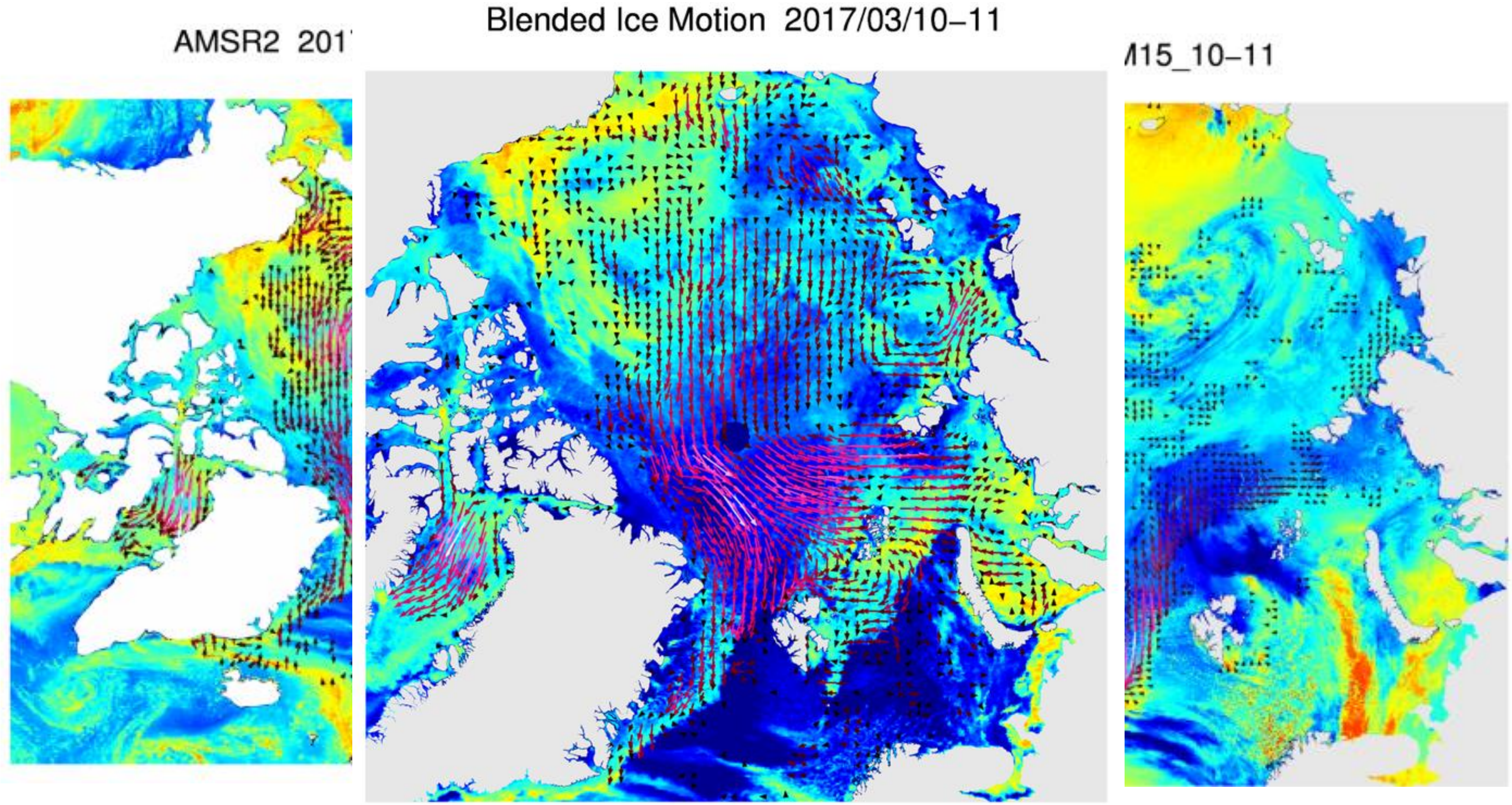
Blended Sea Ice Motion





Motion from all-weather AMSR2 may be combined with high-resolution (but cloud-sensitive) VIIRS

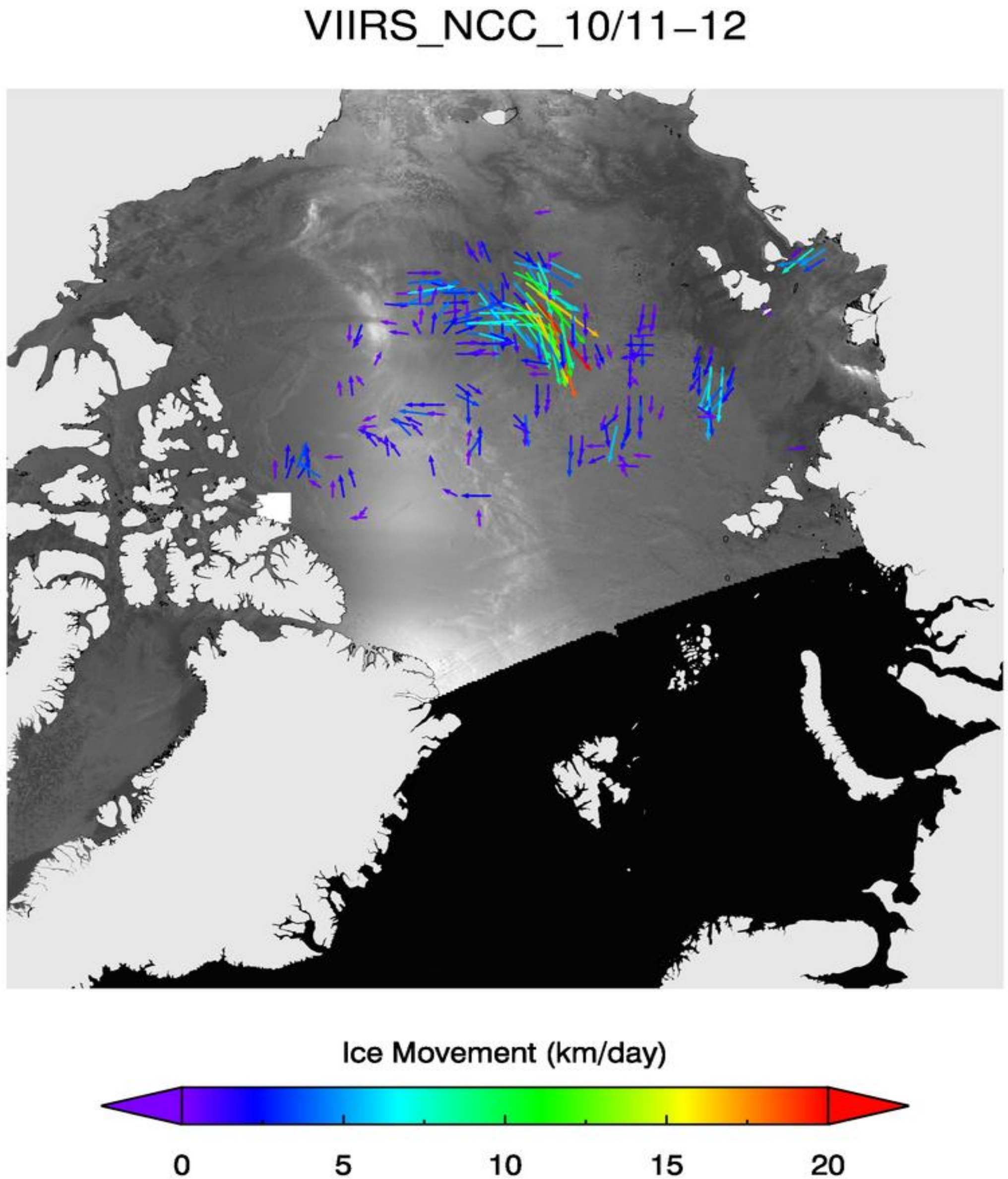
Blended Sea Ice Motion



Blended product provides high spatial resolution under all-weather conditions

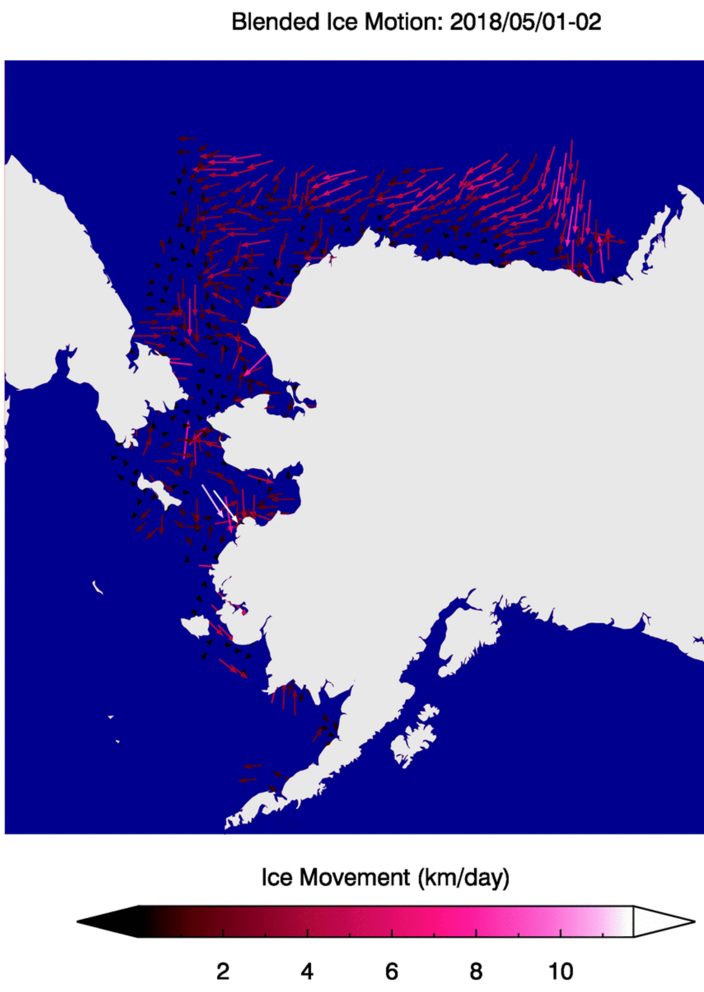
Sea Ice Motion- Day/Night Band

- High spatial resolution (750m) compared to AMSR2
- Not limited to daytime overpasses
- No additional processing for blending with other VIIRS M bands



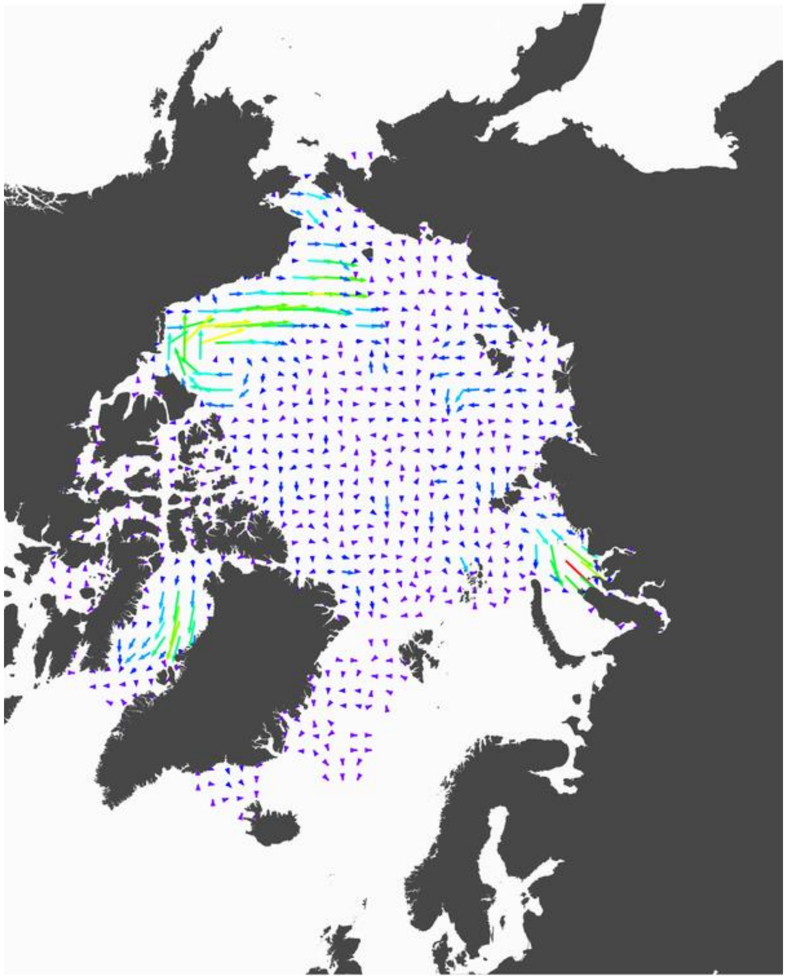
Sea Ice Motion- Arctic Initiative

- Provided blended AMSR2+VIIRS sea ice motion over the Alaskan Region
- Daily updates provided 24-hour motion vectors to Alaskan Sea Ice Program analysts
- Experimented with "near real-time" ice motion that updates every 3 hours



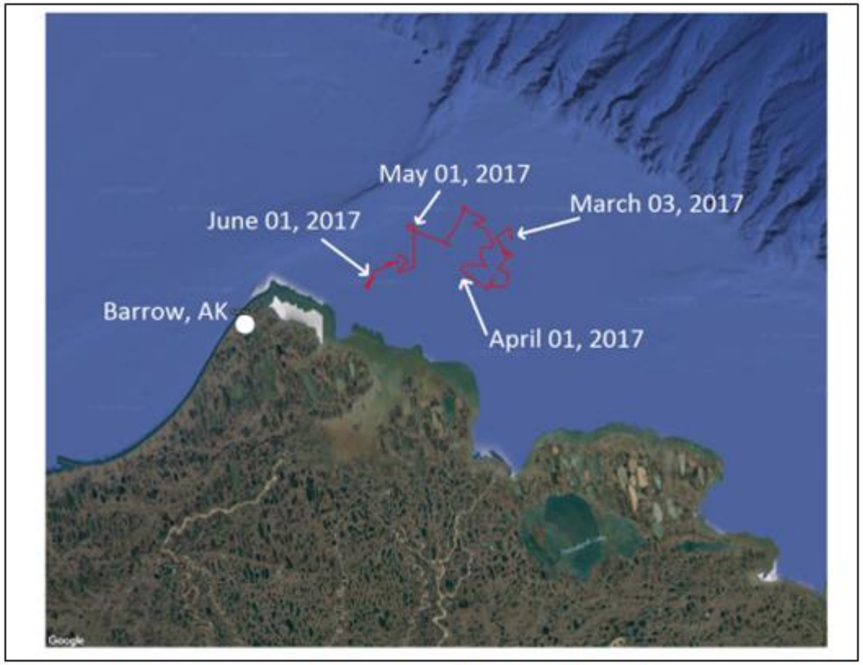
Sea Ice Motion- Other Applications

VIIRS M15 Ice Motion: 20180107 - 20180113



Monthly/Seasonal Ice Motion

Lagrangian Tracking



Daily changes in ice position off of Barrow, Alaska, derived from the blended sea ice motion product.