

# **Snow Cover and Sea Ice: Extending MODIS to VIIRS**

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**MODIS – VIIRS Team Meeting  
Silver Spring, Md.  
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# Outline

- MODIS Collection-6 (C6) snow products\*
- VIIRS snow and sea ice products
  - SIPS test runs
- Some preliminary validation results
- Conclusions and future work

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\*There were no substantial changes to the MODIS sea ice IST algorithm for C6



# MODIS Snow Cover

A satellite image showing snow cover over North America. The snow is concentrated in the northern regions, including Canada and the northern United States, as well as in mountainous areas. The southern United States and Mexico are mostly green, indicating vegetation. The surrounding oceans are dark blue.

# Primary MODIS Snow-Cover Collection-6 (C6) Revisions

- Drop binary snow-cover product; detect snow using the Normalized Difference Snow Index (NDSI); drop fractional snow cover (FSC) terminology
- Develop screens to alleviate snow commission errors. (A non-snow feature with  $NDSI > 0.0$  will cause a snow commission error.)
- Output will be:
  - An NDSI snow cover extent map
    - It will be thematic, including cloud mask, ocean mask, etc.
  - A general QA value for each pixel
  - QA bit flags for screens applied in the algorithm



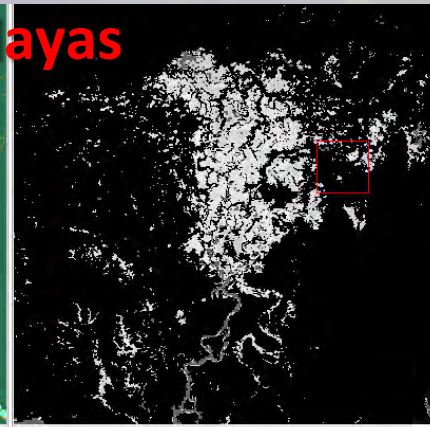
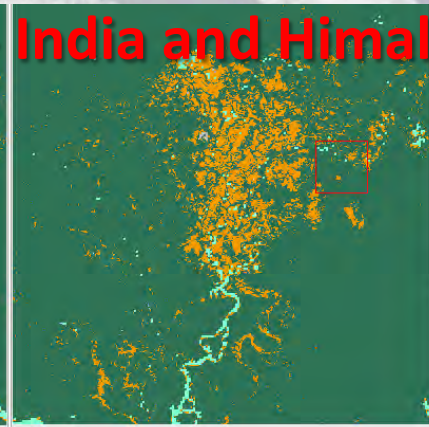
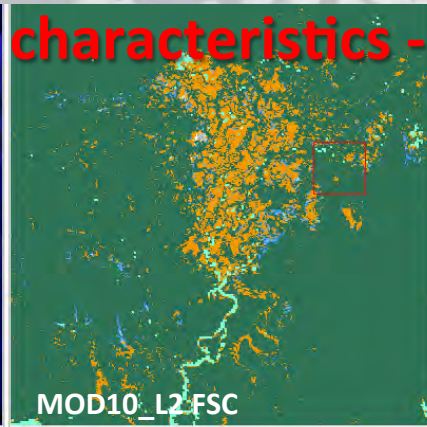
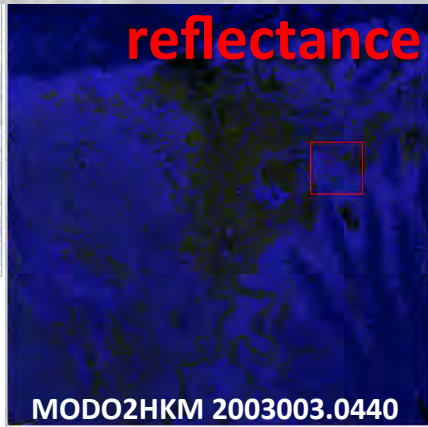
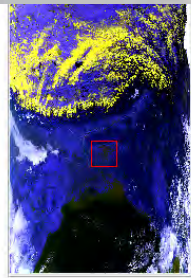
# MODIS Snow-Cover Screens to Reduce Snow Commission Errors in C6

- Develop screens based on reflectance characteristics to prevent false snow detections on non-snow features
- Re-evaluate use of the surface temperature screen which is very effective at alleviating snow commission errors on warm features, but has the drawback that it can reverse snow detection of mountain snow cover in spring and summer
  - Probably apply surface temperature screen at elevations lower than 1300 m
- Screens are needed for:
  - Low illumination and/or reflectance situations, e.g. cloud-shadowed landscape
  - Some bright surface mineral features
  - Cloud/snow discrimination; will use the MOD35\_L2 cloud mask



# Screens developed to prevent snow commission errors based

## reflectance characteristics - India and Himalayas



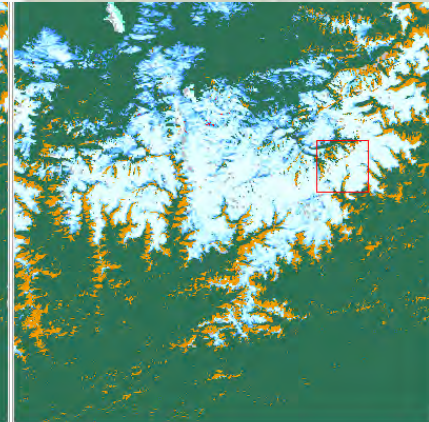
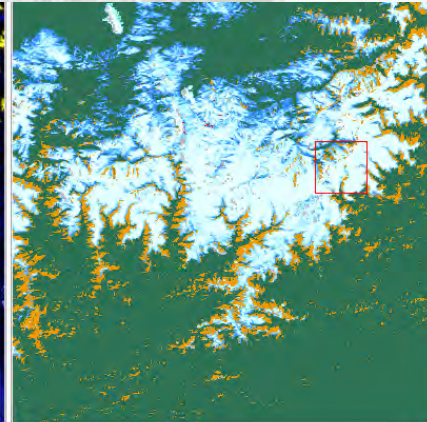
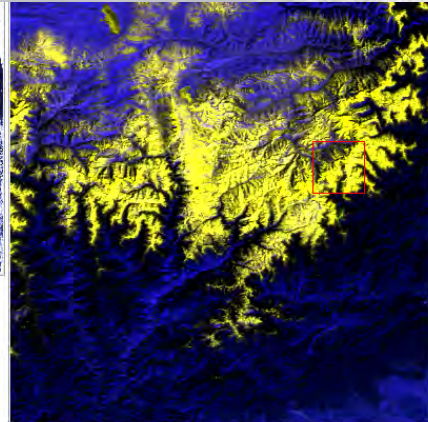
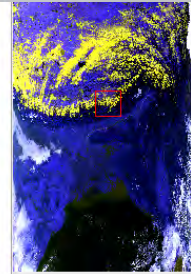
Top - regions of low reflectance;

Bottom - snow covered Himalayas

Top - image has snow commission errors (blue) in snow free region. Only the low visible reflectance screen is applied and results in no decision, the orange pixels.

Spectral screens applied prevent snow commission errors in above situations and have minimal effect on snow cover detection in the Himalayas (below).

Screens are set as bit flags in the QA to track which screen(s) were applied. Shades of gray indicate which flag(s) were set to on.





## **MODIS Snow-Cover C6 Revisions, cont'd.**

- **Use more information from the MOD35\_L2 cloud mask:**
  - Reduce cloud mask detection of snow as 'certain cloud' in some situations by examining MOD35 processing path and cloud spectral tests results, to reduce snow/cloud confusion

# MODIS Snow Products used in SnowPEX

- Satellite Snow Products intercomparison and evaluation Exercise (SnowPEX) consists of an international team that will evaluate and compare current global / hemispheric snow-cover products to quantify uncertainty of long-term trends in snow-cover extent (SCE) and snow-water equivalent (SWE)
- ESA initiated SnowPEX, a high priority for the Global Cryosphere Watch (GCW)
- The MODIS snow project has so far contributed five years of MOD10A1 SCE products in the format required by SnowPEX
- Snow map validation for SnowPEX will be accomplished using Landsat and other high-resolution imagery
- The standard MODIS snow-cover product, MOD10A1, is one of the key products of interest to SnowPEX



# MODIS Collection-6 (C6) status

- Implemented the Quantitative Image Retrieval (QIR) algorithm\* for Aqua MODIS band 6 (1.6  $\mu\text{m}$ ). Terra and Aqua will use same snow algorithm in C6. MODAPS has implemented the QIR algorithm for testing and production. This should greatly improve the MODIS Aqua snow-cover product.
- Increased accuracy of the UMD land/water mask has improved the accuracy of the snow products
- When evaluation of the C6 algorithm has been completed, MODAPS will make the product in Tier 2 processing

\*Developed by Irina Gladkova et al. - QIR url: [csdirs.cuny.cuny.edu/csdirs/projects/multi-band-statistical-restoration-aqua](http://csdirs.cuny.cuny.edu/csdirs/projects/multi-band-statistical-restoration-aqua)


# New C6 snow products

The following new products will be requested for Tier 2 C6 processing:

- Daily cloud-gap-filled (CGF) snow maps at 500-m and 5-km resolution, and
- Daily snow-cover map (MOD10A1S), using surface reflectance input (MOD09GA)

These products have no downstream product dependencies.



A satellite-style map of North America and the surrounding oceans. The landmasses are shown in shades of green and brown, indicating vegetation and terrain. Large areas of white and light blue are overlaid on the map, representing snow cover on land and sea ice extent in the Arctic and sub-Arctic regions. The text is centered over the northern part of the continent.

**VIIRS Snow Cover, Sea Ice  
Ice-Surface Temperature  
(IST) and Sea Ice Extent**

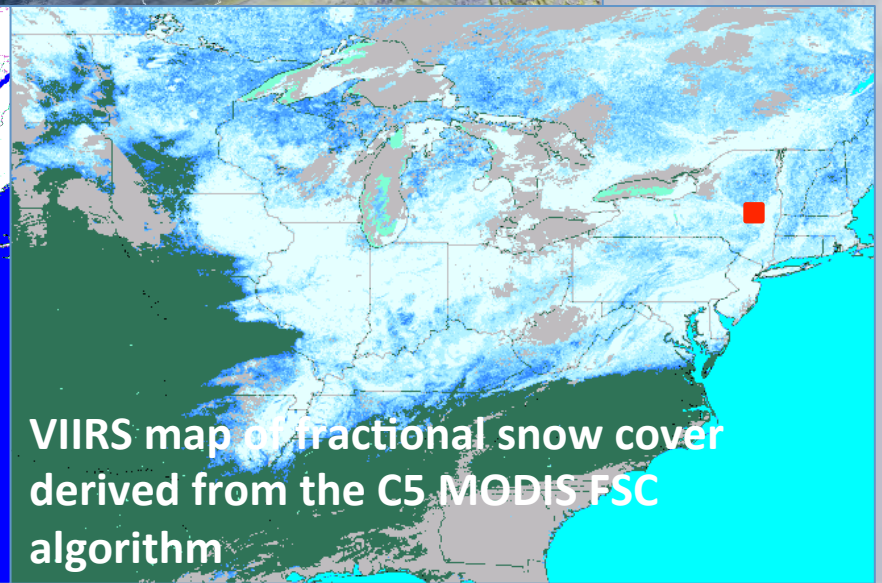
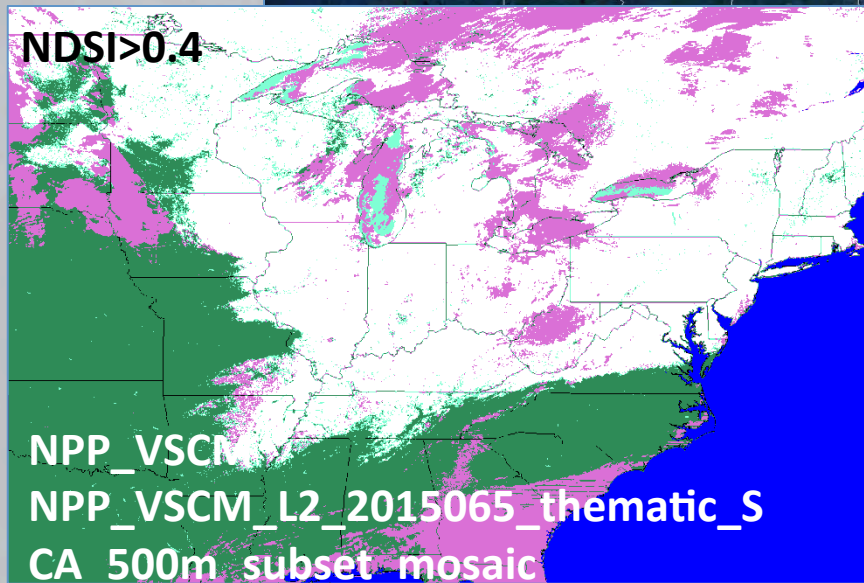
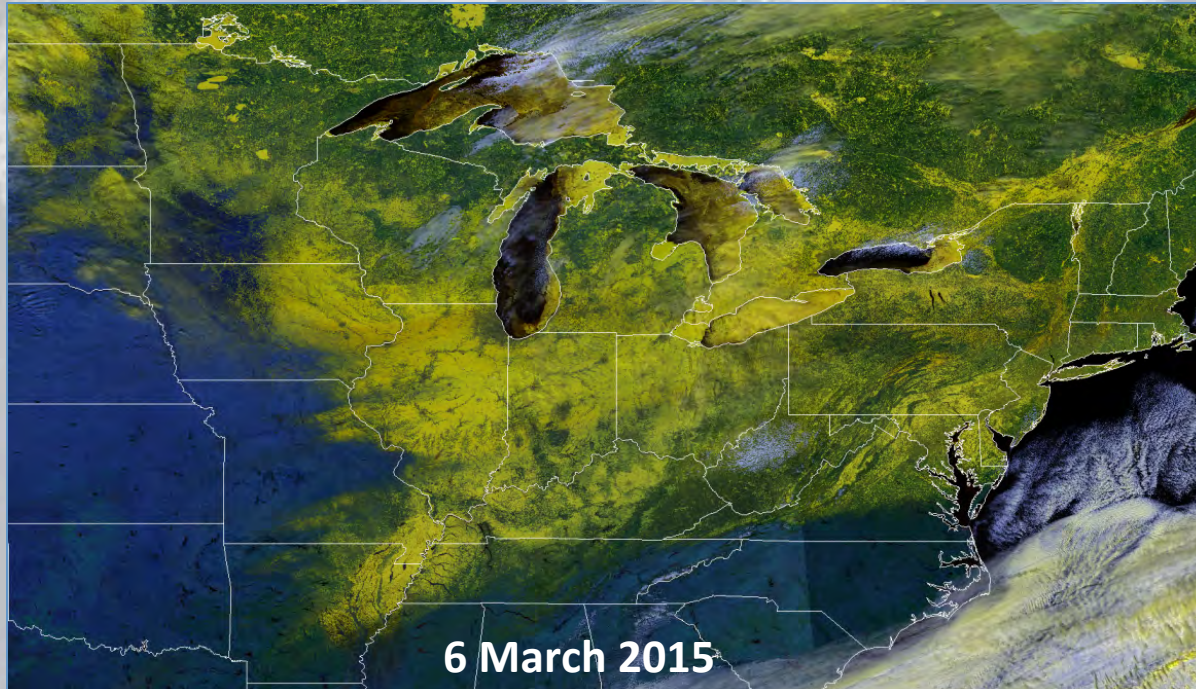
# Snow Cover – NASA VIIRSNP10\_L2

- The NASA VIIRS NP10\_L2 snow map has been made for a one day global test run
- SIPS\* has collaborated with the VIIRS Snow Team to adapt the MODIS snow cover MOD10\_L2 algorithm (C5) to create the NASA VIIRS snow cover algorithm and data product VIIRSNP10\_L2, and evaluate test runs
- Draft of ATBD has been completed

\* Science Investigator-led Processing System



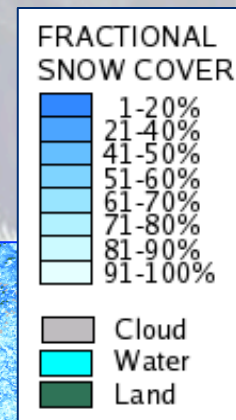
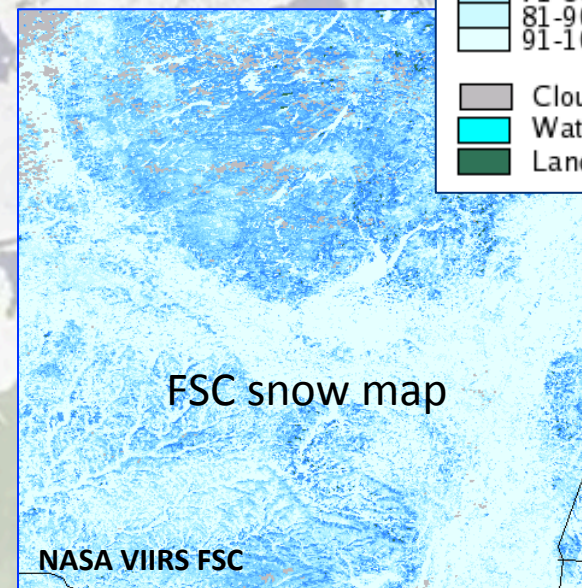
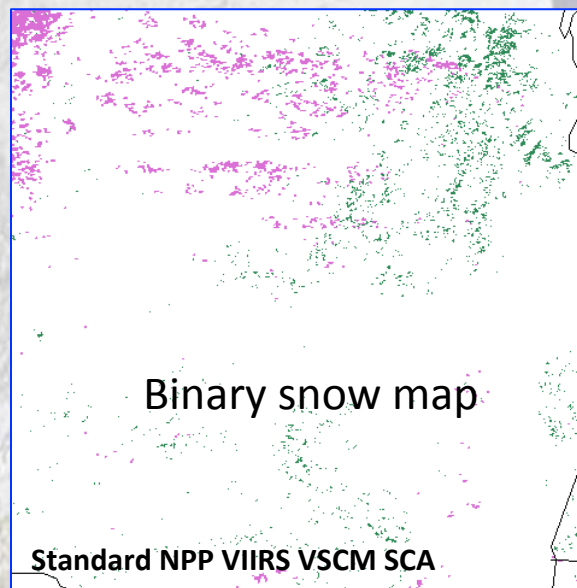
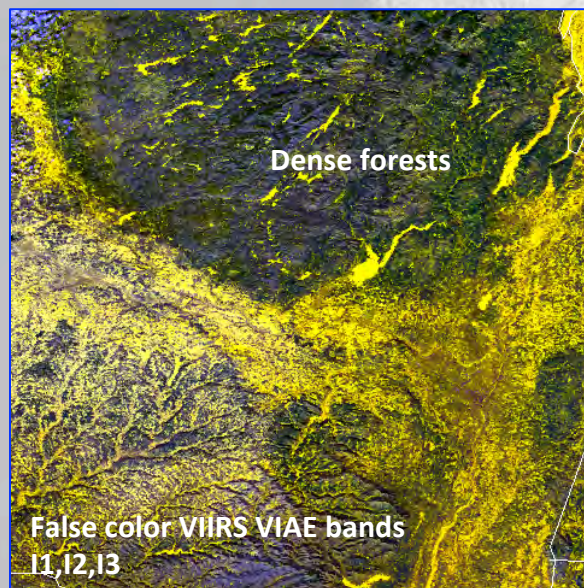
# VIIRS false color image and snow-cover maps of the Eastern United States





# Snow cover extent is mapped more accurately with the NDSI-based FSC vs the binary snow covered area (SCA)

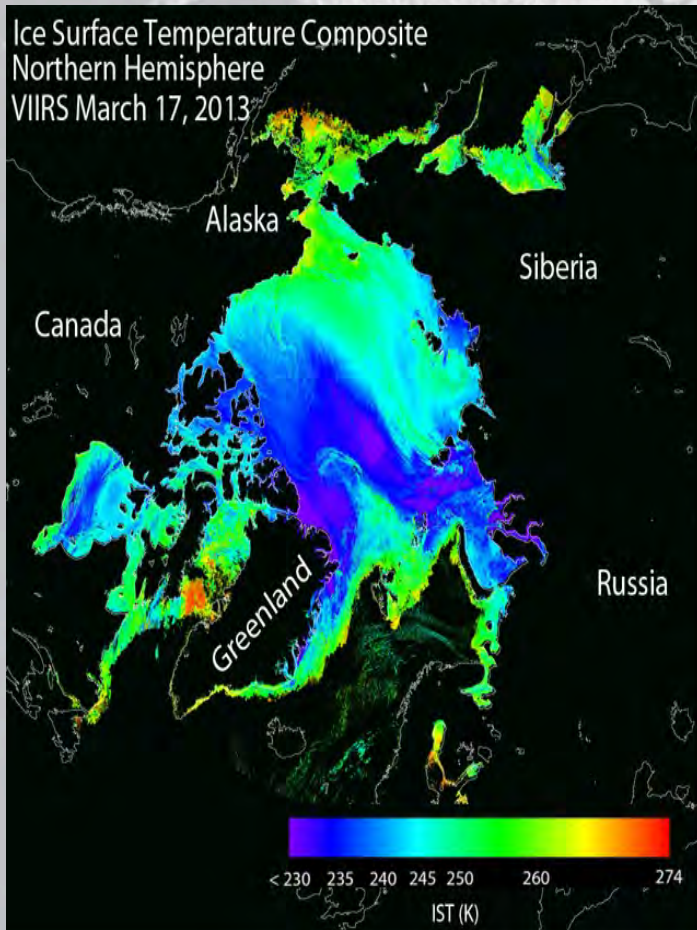
## Snow cover in the Hudson River Valley (near Albany) 6 March 2015



For MODIS C6 and VIIRS Snow-cover extent, snow will be reported based on the NDSI, not FSC because we cannot see the actual amount of snow on the ground from above.



# VIIRS Sea Ice - Ice Surface Temperature (IST) Product



- The operational Suomi-NPP VIIRS IST product for the Arctic Ocean on March 17, 2013 is shown at left, before application of the VIIRS cloud mask.
- The VIIRS IST provides surface temperatures:
  - For Arctic and Antarctic
  - For ice-covered oceans both day and night
  - Retrieved at VIIRS moderate resolution (750 m at nadir)
- The desired measurement uncertainty is 1 K over a measurement range of 213–275 K.

# VIIRS IST

The NASA VIIRS IST is computed using a split window algorithm that employs two VIIRS Infrared bands, 10.76  $\mu\text{m}$  (M15) and 12.01  $\mu\text{m}$  (M16). This technique is based on the AVHRR heritage IST algorithm (*Key and Haefliger, 1992*):

$$\text{IST} = a_0 + a_1 * T_{M15} + a_2 * (T_{M15} - T_{M16}) + a_3 * (T_{M15} - T_{M16}) (\sec(z)-1),$$

where  $T_{M15}$  and  $T_{M16}$  are the brightness temperatures for VIIRS bands M15 and M16, respectively, and  $a_0$ ,  $a_1$ ,  $a_2$ , and  $a_3$  are regression coefficients determined empirically.

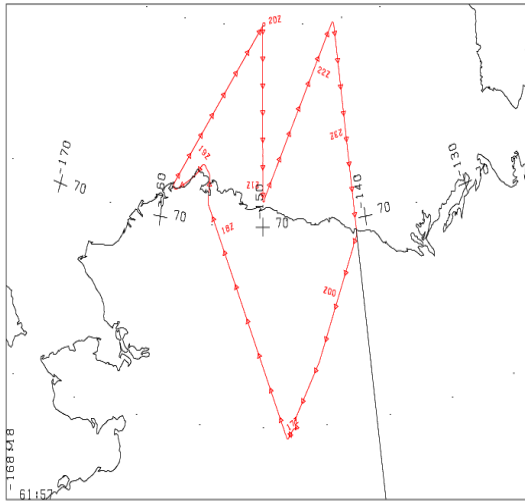


# VIIRS IST Validation Approach - IceBridge

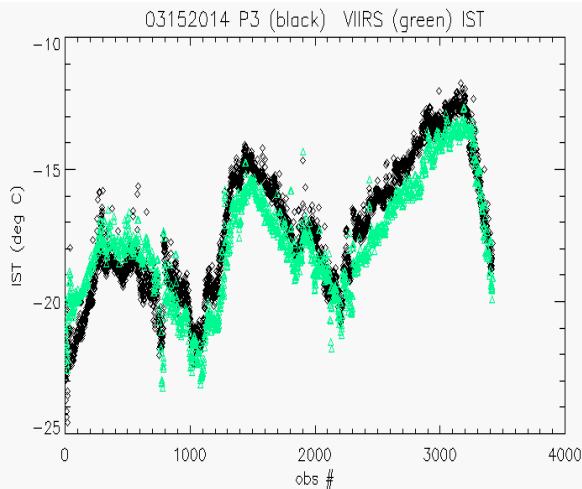


- The IceBridge aircraft campaign commenced in 2009 and is ongoing, typically deploying a P-3 aircraft (left) over the Arctic during the spring and the NASA DC-8 over the Antarctic in the fall.
- The aircraft deploys a Heitronics, Inc. KT-19 (left), which measures surface temperature with a resolution of  $0.1^{\circ}\text{C}$ .
- To obtain IST measurements, the aircraft flies about 460m above the surface, resulting in a KT-19 spot size of 15m. This pyrometer records at 10Hz.

# VIIRS IST validation - IceBridge



FLIGHT 14-426-15 15 MARCH 2014 A/C 426 (NASA P-3) ICEBRIDGE OMS  
LAMBERT CONFORMAL PROJECTION: SP1 = 63.0 SP2 = 73.4 CM = -150.0 ROTATED BY 0.0  
16:55:00 TO 0:55:00 UT SCALE 1:6.00E+06 TIME TICK EVERY 10.00 MINUTES

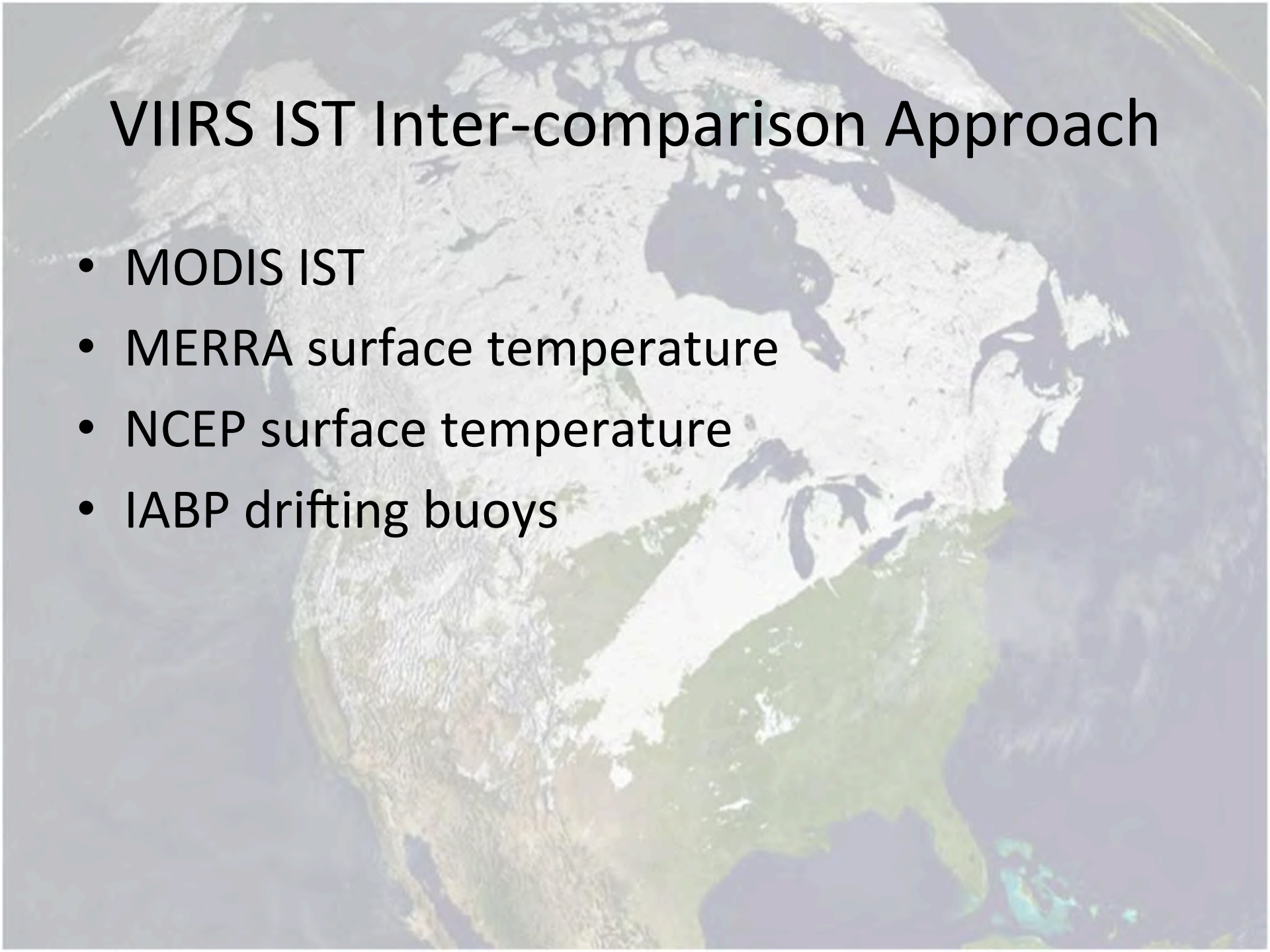


- Example of validation efforts between IceBridge and the current operational VIIRS IST product
- The map at left shows a flight track by the P-3 on March 15, 2014
- Comparison of the IceBridge KT-19 IST data and the VIIRS operational IST (left) is favorable for this flight



# VIIRS IST Inter-comparison Approach

- MODIS IST
- MERRA surface temperature
- NCEP surface temperature
- IABP drifting buoys

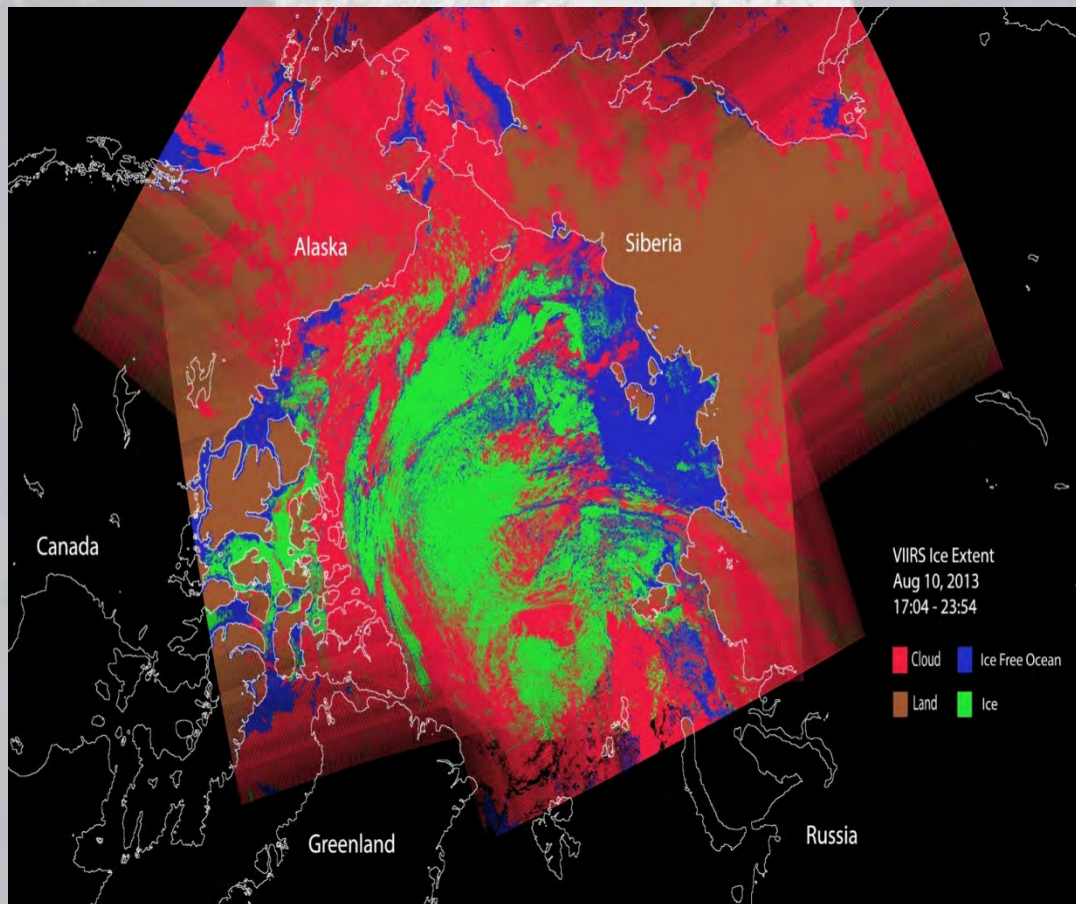


# VIIRS Ice Extent

- There is no current VIIRS Ice Extent product
- The new NASA VIIRS Ice Extent product will follow the approach to the MODIS product:
  - Reflectance-based (daytime): identification of sea ice uses the NDSI, which for VIIRS is:
$$\text{NDSI} = (M4 - M10) / (M4 + M10),$$
where M4 is VIIRS band 4 (0.555  $\mu\text{m}$ ), M10 band 10 (1.61  $\mu\text{m}$ )
  - IST-based: Utilize the IST product to identify sea ice (polar night)



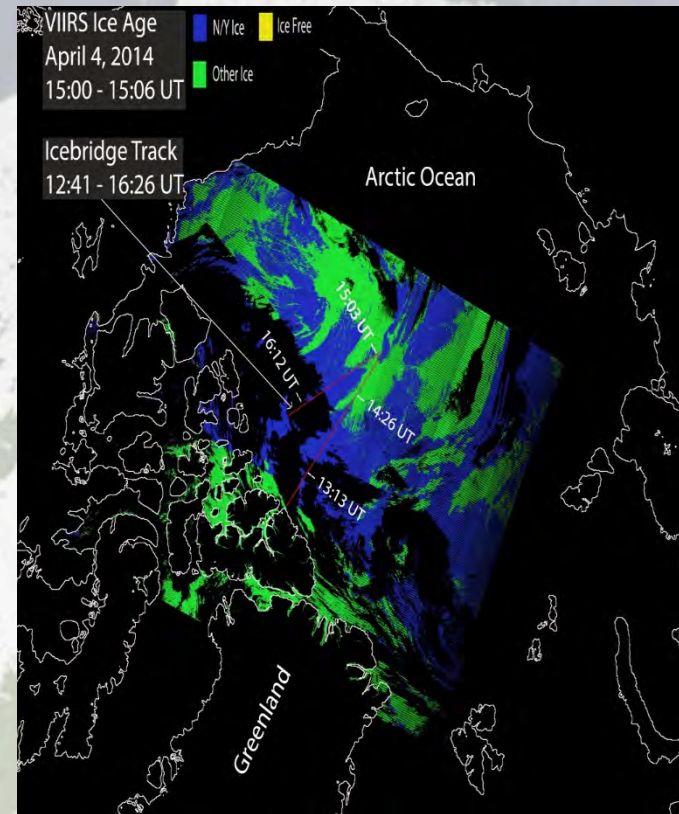
# VIIRS Ice Extent



- Simulated VIIRS Ice Extent using VIIRS Ice Age Product
- Aug 10, 2013


# VIIRS Ice Extent

- Validation Approach:
  - IceBridge
  - Digital Globe imagery
- Inter-comparison Approach:
  - MODIS Ice Extent
  - VIIRS Ice Age
  - VIIRS IST (flag to identify sea ice)
  - NIC Ice charts



IceBridge flight tracks over VIIRS ice cover (ice age product), April 4, 2014

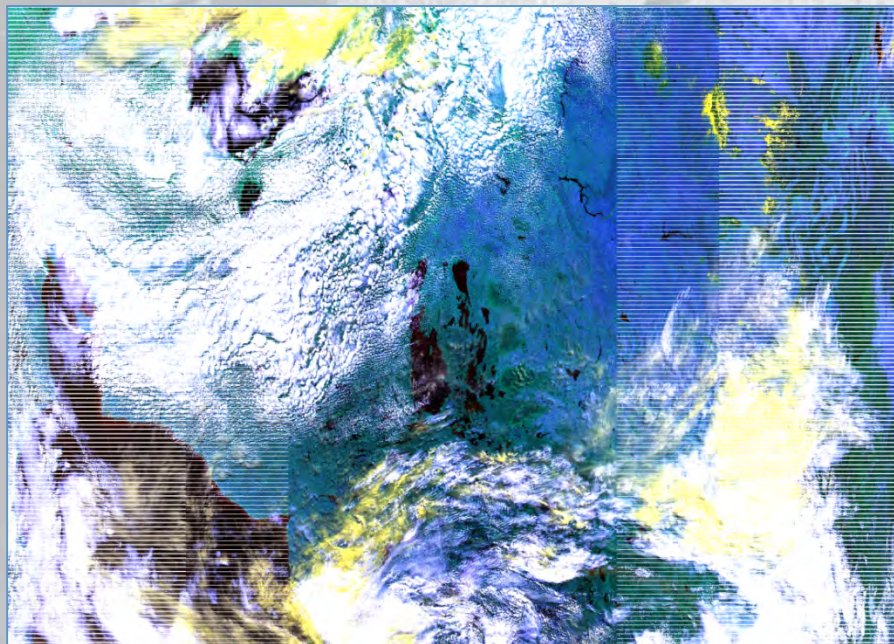


A satellite-style map of North America, showing the continent in shades of green and brown, with significant areas of white snow cover, particularly in the northern and mountainous regions. The map is overlaid with a semi-transparent blue filter.

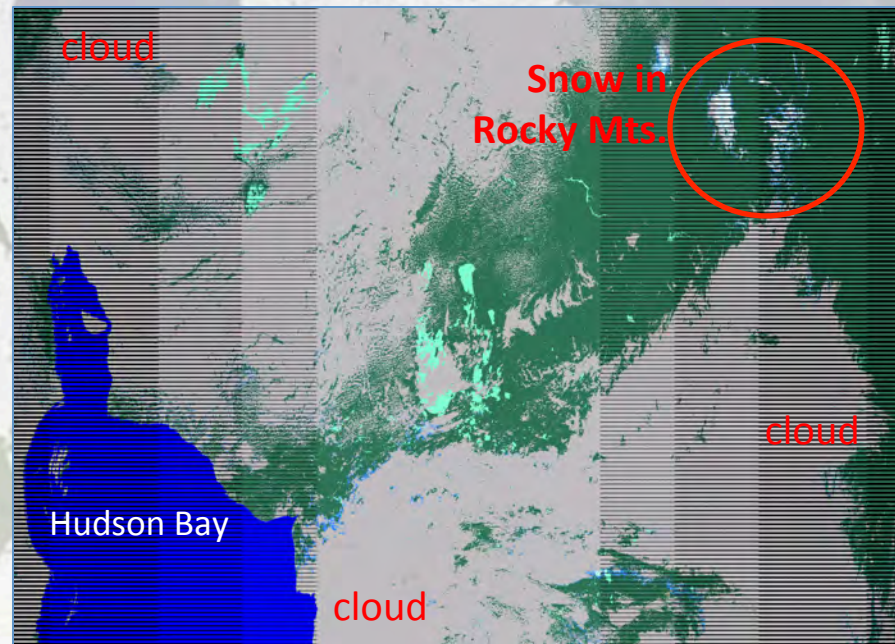
**Science Investigator-led  
Processing System (SIPS)  
Test Runs for Snow  
Cover and Sea Ice IST**



# SIPS\* snow cover global day test run of VIIRSNP10\_L2 FSC (swath) Snow Cover for 12 September 2014




VIAE image of bands I1,I2,I3



Snow cover from SIPS global day test run

Accurate detection of snow cover in Rocky Mountains. There are snow commission errors associated with cloud edges or broken/scattered cloud cover.

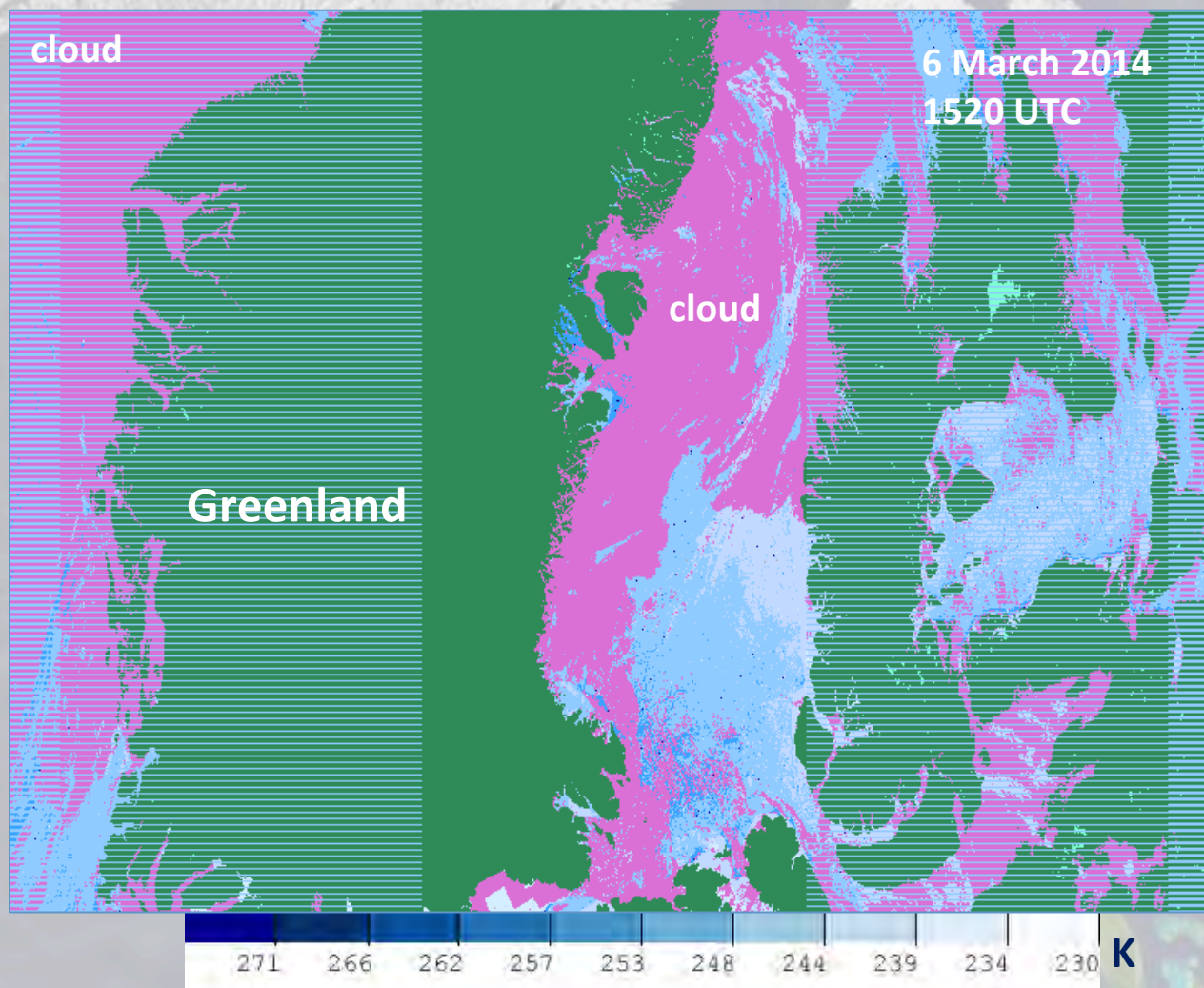


A satellite-style map of the Arctic region, showing the North Pole and surrounding landmasses. The sea ice is depicted in white and light blue, contrasting with the darker blue of the open ocean and the green and brown of the land. The map is centered on the North Pole and covers the entire Arctic basin.

# NASA VIIRS Ice Surface Temperature - VIIRSNP29\_L2

- SIPS has begun adapting the MODIS sea ice surface temperature (IST) MOD29\_L2 algorithm (C6) to create the NASA VIIRS IST algorithm and data product, VIIRSNP29\_L2
- SIPS and VIIRS Cryosphere Team collaborate to convert the algorithm code and evaluate test runs

# SIPS\* test run of NASA VIIRSNP29\_L2 (swath) Ice Surface Temperature (IST)



\* Science Investigator-led Processing System



A satellite-style map of North America, showing the continent in shades of green and brown, with the surrounding oceans in blue. The map is centered on the continent and serves as a background for the text.

**Preliminary Validation of  
MODIS, VIIRS and Landsat-7  
surface-temperature  
products**

# MODIS, VIIRS & Landsat-7 LST Validation – Preliminary Results

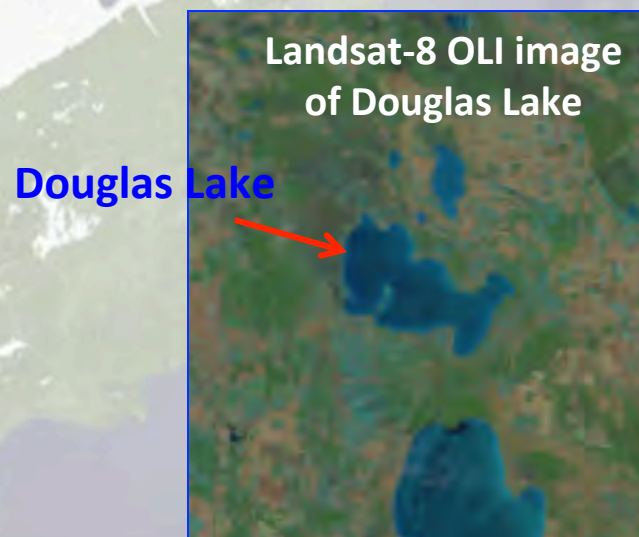
## Satellite and in-situ temperatures on Douglas Lake, Michigan, 28 March 2015

Satellite	Time (local)	Satellite-derived temperature (°C) at time of overpass	Thermochron temperature (°C) at time of overpass (avg of both)*	Difference between satellite-derived temperature and thermochron temperature (°C)
Terra MODIS	12:35	-2.25	-2.93	0.68
Aqua MODIS	14:20	-1.07	-0.77	0.30
VIIRS	13:40	-0.29	-1.42	1.13
VIIRS	15:20	+0.84	-1.22	2.06
Landsat-7	12:20	-2.78***	-3.02**	0.24

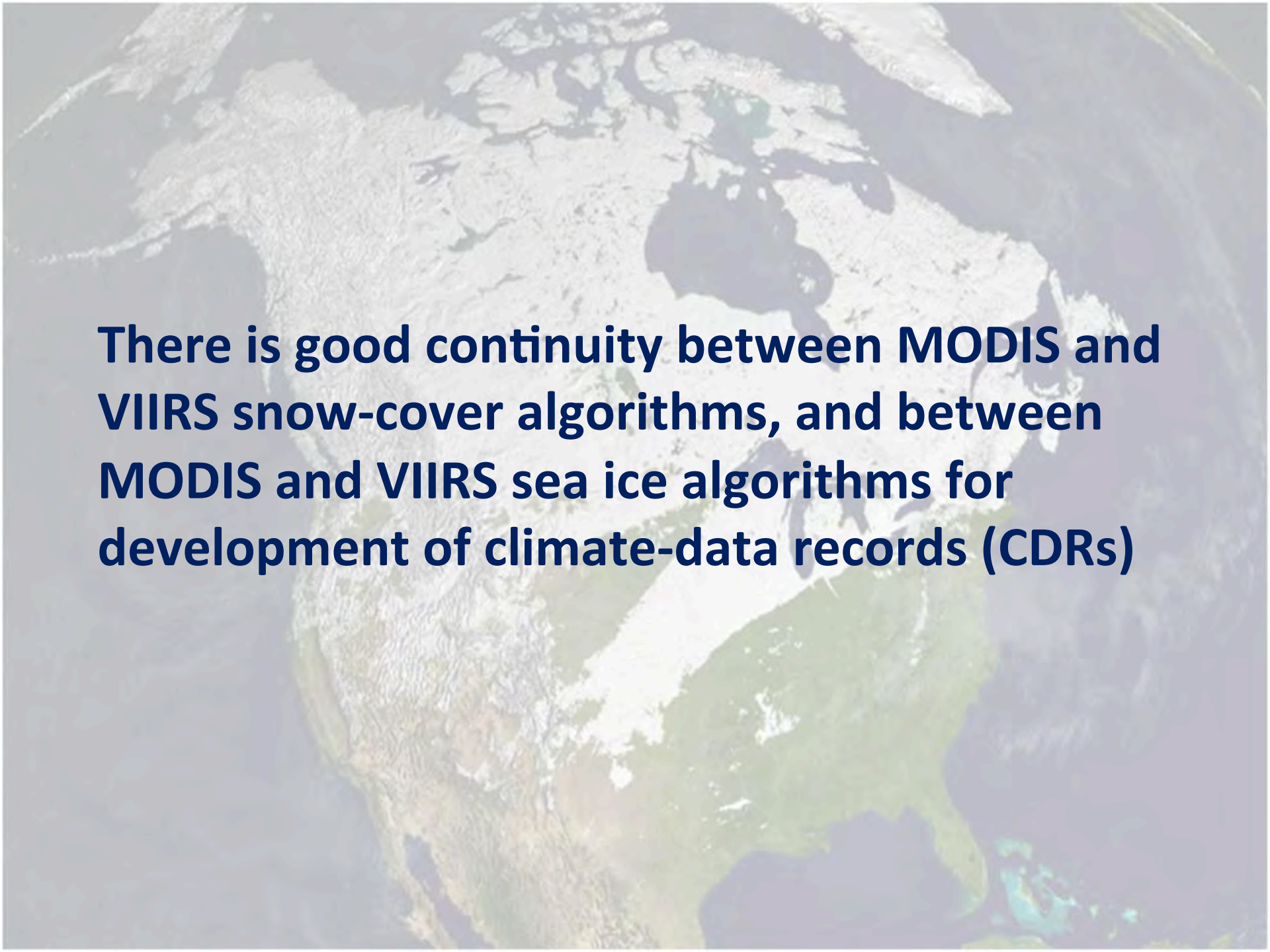
\*average of temperatures from two thermochrons

\*\*average of 10 minutes (12:15:01 to 12:25:01) and average of both thermochrons

\*\*\*using Yale Center for Earth Observation, 2010 document



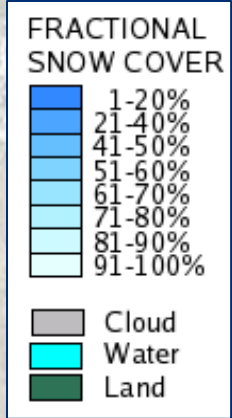
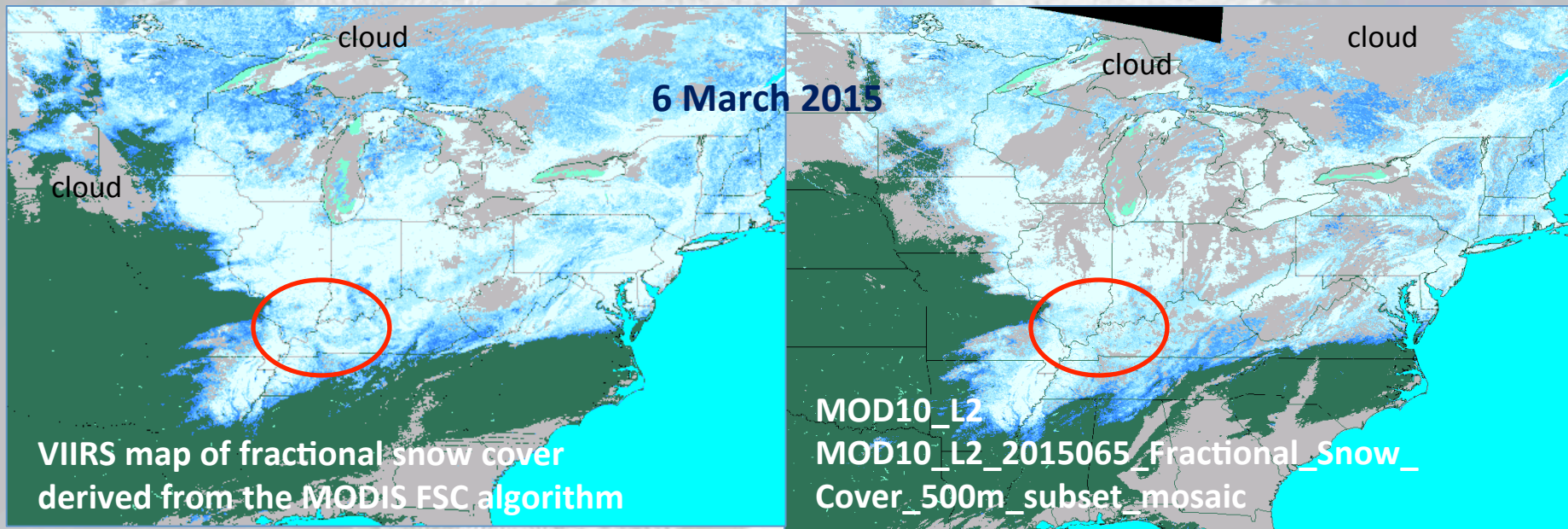


A satellite-style map of the Arctic region, showing the Arctic Ocean and surrounding landmasses. The map is semi-transparent, allowing the text to be overlaid. The colors represent different surface types: white for snow and ice, green and brown for land, and blue for water.

**There is good continuity between MODIS and VIIRS snow-cover algorithms, and between MODIS and VIIRS sea ice algorithms for development of climate-data records (CDRs)**

# NASA VIIRS FSC (left) and MODIS FSC (right) of the Eastern United States at 500-m resolution

Excellent progress toward development of a CDR





# Conclusions - Snow

- Drop binary snow-cover product for MODIS C6; detect snow using the NDSI; drop fractional snow cover (FSC) terminology
- Develop screens to alleviate snow commission errors
- Re-evaluate use of the surface temperature screen for C6
- For SnowPEX, the MODIS snow project has so far contributed five years of MOD10A1 SCE products in the required format
- No substantial changes in MODIS sea ice IST algorithm for C6
- There is good continuity between MODIS and VIIRS snow-cover algorithms and products
- A SIPS test run of snow cover has been conducted successfully

# Conclusions – Sea Ice

- The NASA VIIRS IST is computed using a split window algorithm that is based on the AVHRR heritage IST algorithm and the MODIS IST algorithm (*Key and Haefliger, 1992*)
- Comparison of the IceBridge KT-19 IST and the VIIRS operational IST has been favorable
- The new NASA VIIRS Ice Extent product will follow the algorithm approach of the MODIS product
- Both intercomparison and validation are being conducted to evaluate the VIIRS sea ice products
- A SIPS test run of sea ice IST has been successfully conducted



# Future Work

## MODIS snow and sea ice

- MODIS C6 snow cover will be provided as NDSI, not FSC
  - the binary snow cover and regression calculated FSC will no longer be output
- MODIS snow-cover changes for C6 focus on creating additional screens to prevent snow commission errors, and reducing cloud/snow confusion
- Deliver algorithms for the new snow cover products for Tier 2 processing

# Future Work

## VIIRS snow and sea ice

- Next version of VIIRS snow cover algorithm will include revisions from MODIS C6 algorithm
- Will develop daily gridded NASA VIIRSNP10\* (snow) and NASA VIIRSNP29\* (sea ice) tiled and CMG products
- Will evaluate and adjust coefficients for NASA VIIRS IST algorithm
- Develop, along with SIPS, initial VIIRS sea ice extent algorithm based on the MODIS sea ice extent algorithm
- Validate and intercompare NASA VIIRS snow sea ice extent products
- Continue validation and intercomparison of surface temperature using IceBridge aircraft and in-situ measurements
- Write ATBDs and user guides for the NASA VIIRS cryospheric products