# Joint Polar Satellite System (JPSS)

## United States Plans for Continuity of Operational Polar Weather and Environmental Observations

Harry Cikanek, Director
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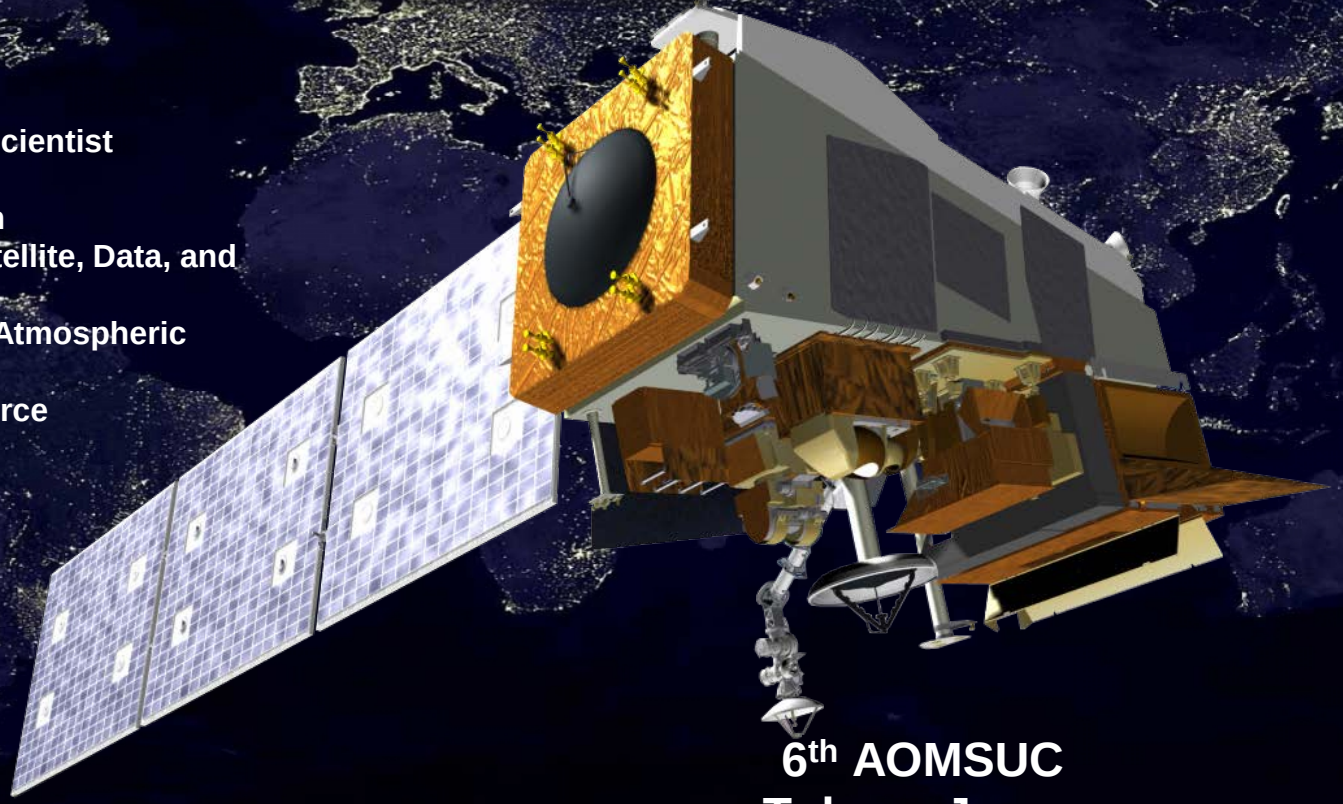
Joint Polar Satellite System
National Environmental Satellite, Data, and Information Service
U.S. National Oceanic and Atmospheric Administration
U.S. Department of Commerce



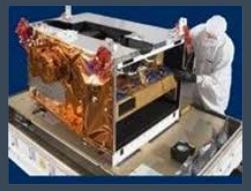
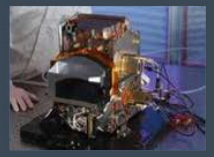
6th AOMSUC
Tokyo , Japan

www.jpss.noaa.gov

# JPSS Overview

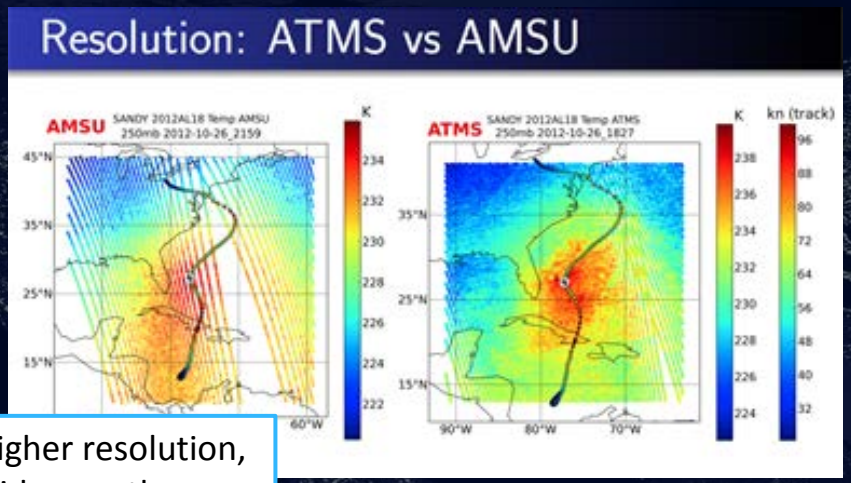
- JPSS is the next generation of U.S. civil operational polar-orbiting satellites, and includes Suomi NPP
- The JPSS program is a partnership between NOAA and NASA, including agreements with EUMETSAT, JAXA and DoD.
- NOAA plans and directs the program, while NASA acts as the acquisition agent for flight and elements of the ground system.
- JPSS provides operational continuity of satellite-based observations and products beyond the current NOAA Polar-orbiting satellites series.
- The JPSS program is on budget and on schedule to launch the next satellite, JPSS-1, in 2017 and after successful launch becomes NOAA-20

# JPSS Instruments

| JPSS Instruments | | Measurements & Products | Contractor |
|---|---|---|---|
|  | **ATMS** - Advanced Technology Microwave Sounder | High vertical resolution temperature and water vapor information critical for forecasting extreme weather events, 5 to 7 days in advance | Northrup Grumman Electronic Systems |
|  | **CrIS** - Cross-track Infrared Sounder | | Exelis |
|  | **VIIRS** – Visible Infrared Imaging Radiometer Suite | Critical imagery products, including snow/ice cover, clouds, fog, aerosols, fire, smoke plumes, vegetation health, phytoplankton abundance/chlorophyll | Raytheon Space and Airborne Systems |
|  | **OMPS** - Ozone Mapping and Profiler Suite | Ozone spectrometers for monitoring ozone hole and recovery of stratospheric ozone and for UV index forecasts | Ball Aerospace and Technologies Corp. |
|  | **CERES** – Clouds and the Earth's Radiant Energy System (S-NPP and JPSS-1)<br>**RBI** – Radiation Budget Instrument (JPSS-2, 3, 4; provided by NASA) | Scanning radiometer which supports studies of Earth Radiation Budget (ERB) | CERES - Northrup Grumman Aerospace Systems<br>RBI - Exelis |

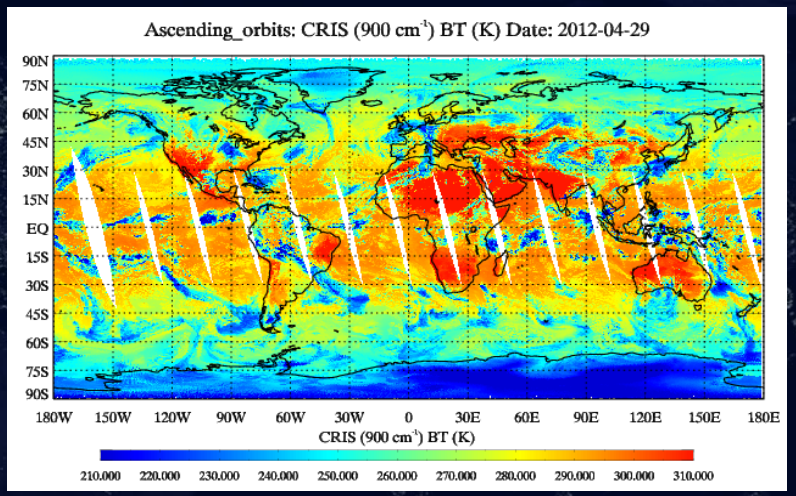
# JPSS Next Generation Instruments

## Advanced Technology Microwave Sounder




Higher resolution, wider swath, smaller gaps

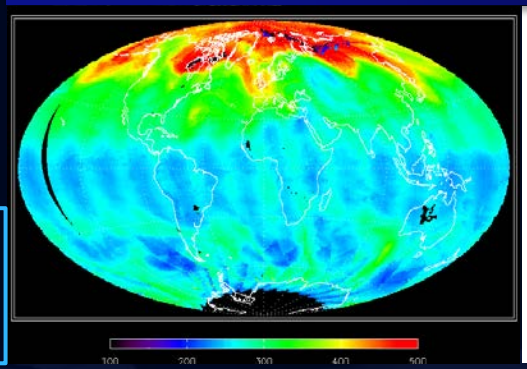
## Cross-track Infrared Sounder

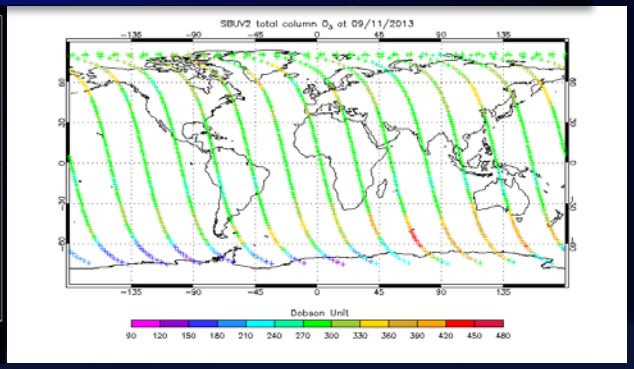



6x more vertical resolving power

## Ozone Mapping Profiler Suite

### Resolution: OMPS vs SBUV/2

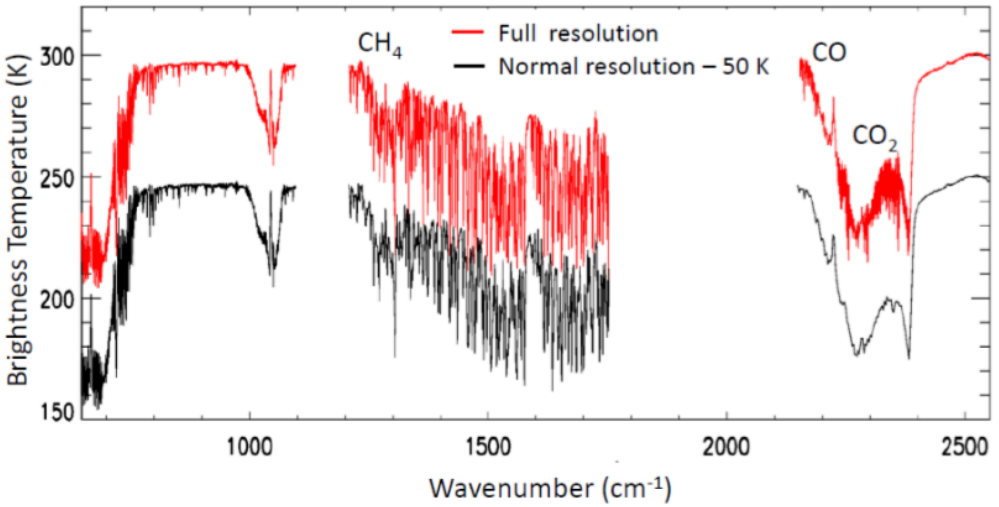





Provides global coverage ozone monitoring

# S-NPP CrIS Normal & Full Resolution SDRs

- **Spectral resolution modes:**
  - Full spectral resolution (FSR):
    - 0.625 $cm^{-1}$ all three bands
    - 2211 channels
  - Normal spectral resolution (NSR):
    - 0.625 $cm^{-1}$(LW), 1.25 $cm^{-1}$(MW), 2.5 $cm^{-1}$(SW)
    - 1305 channels




- **NOAA CrIS SDR processing:**

Beginning S-NPP measurements (NSR mode) March, 2012

transition to FSR mode Dec. 4, 2014

**NOAA IDPS Processing Data on CLASS**

Normal mode SDRs

**NOAA STAR offline processing**

FSR mode SDRs

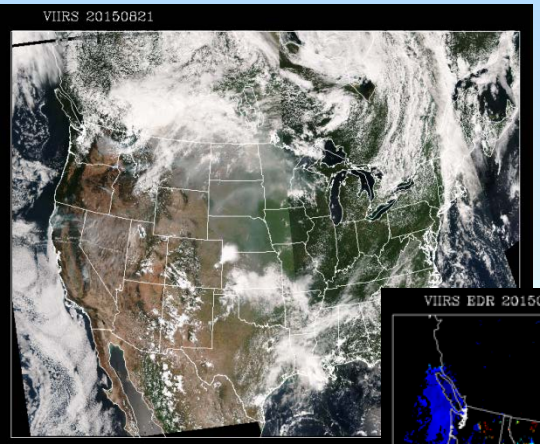
**Data:** ftp://ftp2.star.nesdis.noaa.gov/smcd/xxiong

- **Planned reprocessing:**

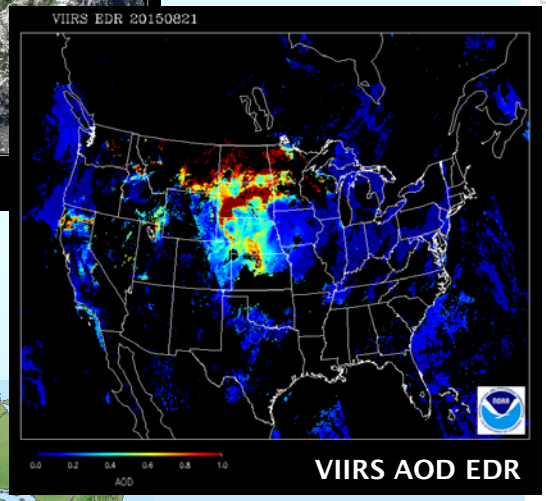
NOAA will reprocess CrIS data with latest ADL Block-2.0 5.x code in early 2016

NOAA • NESDIS JPSS Joint Polar Satellite System

# August 21, 2015 NUCAPS CO Trajectory Forecasts

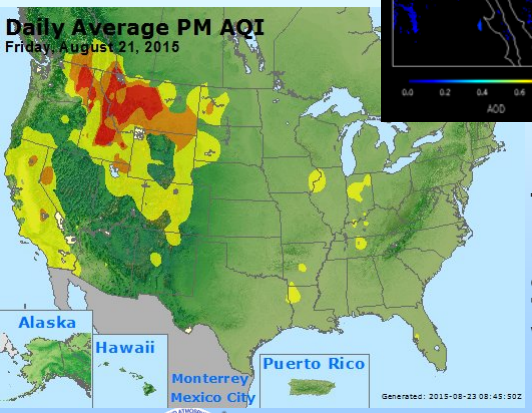



VIIRS True Color Imagery



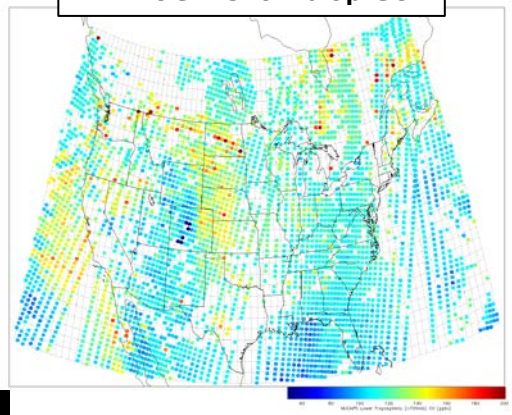

VIIRS AOD EDR

EPA Air Quality Index (AQI)

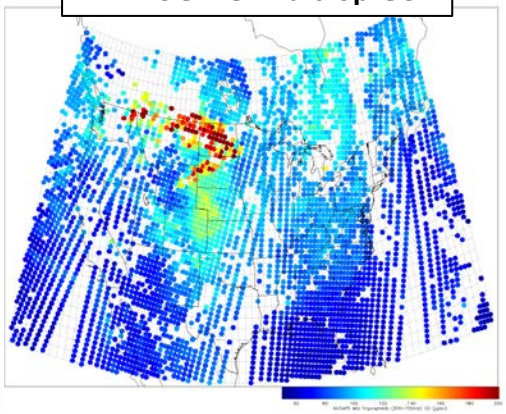


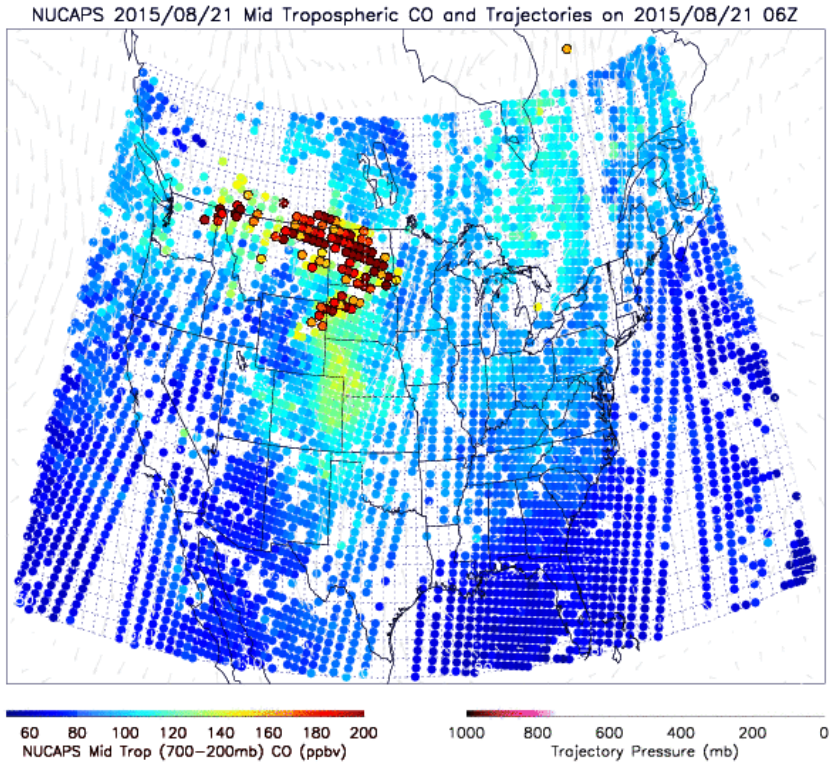

NUCAPS CO shows that most of the smoke over ND/ SD/MN is aloft and will not impact the surface

AM NUCAPS low-trop CO



AM NUCAPS mid-trop CO






Credit: Brad Pierce

# Spectral Differences: ATMS vs. AMSU/MHS

| | AMSU/MHS | | | ATMS | | |
|---|---|---|---|---|---|---|
| | Ch | GHz | Pol | Ch | GHz | Pol |
| AMSU-A | 1 | 23.8 | QV | 1 | 23.8 | QV |
| | 2 | 31.399 | QV | 2 | 31.4 | QV |
| | 3 | 50.299 | QV | 3 | 50.3 | QH |
| | | | | 4 | 51.76 | QH |
| | 4 | 52.8 | QV | 5 | 52.8 | QH |
| | 5 | 53.595 ± 0.115 | QH | 6 | 53.596 ± 0.115 | QH |
| | 6 | 54.4 | QH | 7 | 54.4 | QH |
| | 7 | 54.94 | QV | 8 | 54.94 | QH |
| | 8 | 55.5 | QH | 9 | 55.5 | QH |
| | 9 | fo = 57.29 | QH | 10 | fo = 57.29 | QH |
| | 10 | fo ± 0.217 | QH | 11 | fo±0.3222±0.217 | QH |
| | 11 | fo±0.3222±0.048 | QH | 12 | fo± 0.3222±0.048 | QH |
| | 12 | fo ±0.3222±0.022 | QH | 13 | fo±0.3222±0.022 | QH |
| | 13 | fo± 0.3222±0.010 | QH | 14 | fo±0.3222 ±0.010 | QH |
| | 14 | fo±0.3222±0.0045 | QH | 15 | fo± 0.3222±0.0045 | QH |
| MHS | 15 | 89.0 | QV | | | |
| | 16 | 89.0 | QV | 16 | 88.2 | QV |
| | 17 | 157.0 | QV | 17 | 165.5 | QH |
| | 18 | 183.31 ± 1 | QH | 18 | 183.31 ± 7 | QH |
| | 19 | 183.31 ± 3 | QH | 19 | 183.31 ± 4.5 | QH |
| | 20 | 191.31 | QV | 20 | 183.31 ± 3 | QH |
| | | | | 21 | 183.31 ± 1.8 | QH |
| | | | | 22 | 183.31 ± 1 | QH |

- **ATMS has 22 channels and AMSU/MHS have 20, with polarization differences between some channels**
  - **QV = Quasi-vertical; polarization vector is parallel to the scan plane at nadir**
  - **QH = Quasi-horizontal; polarization vector is perpendicular to the scan plane at nadir**

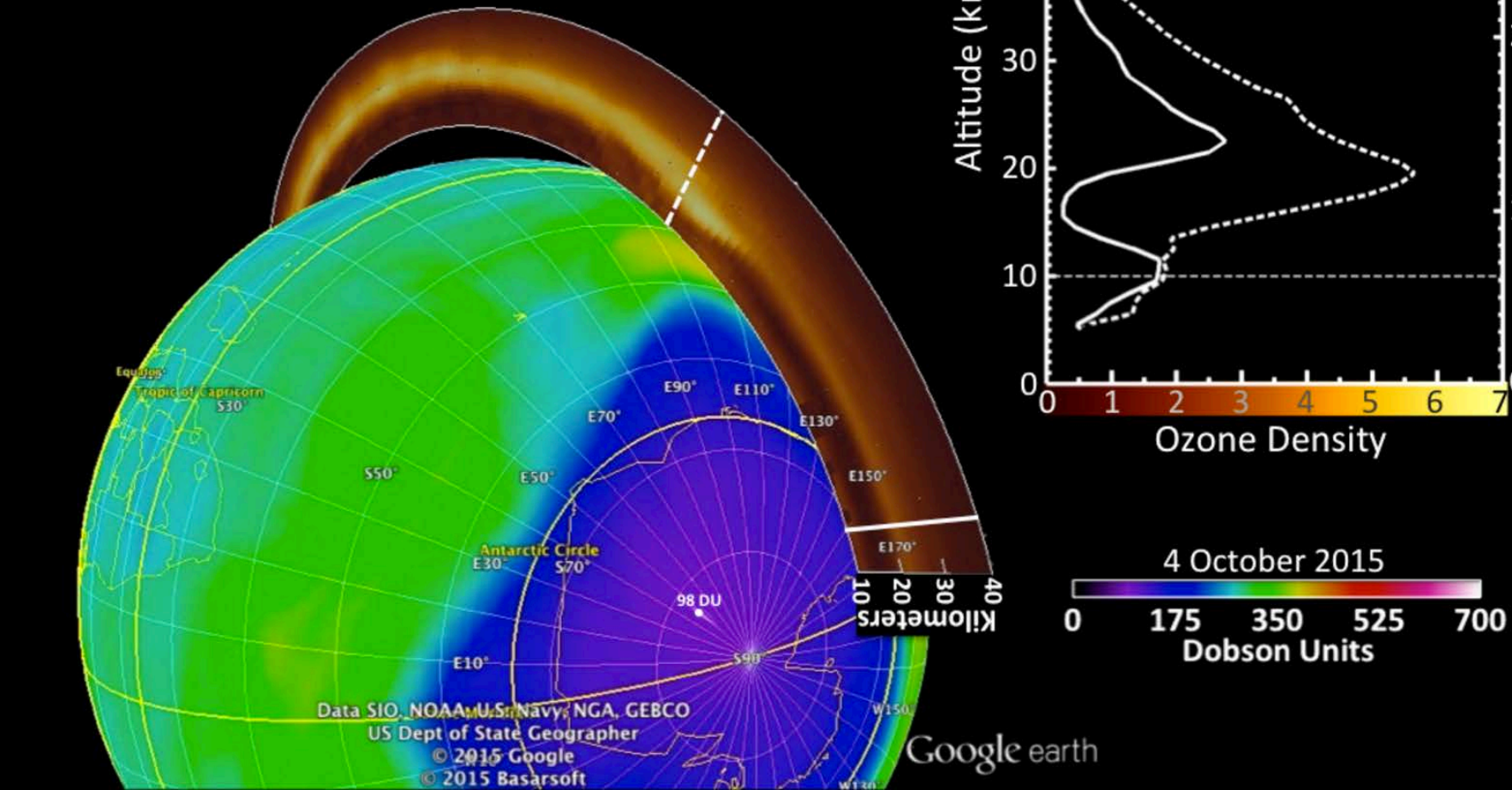
Exact match to AMSU/MHS
Only Polarization different
Unique Passband
Unique Passband, and Pol. different from closest AMSU/MHS channels

The 2015 Antarctic ozone hole area was larger and formed later than in recent years, according to scientists from NOAA and NASA.

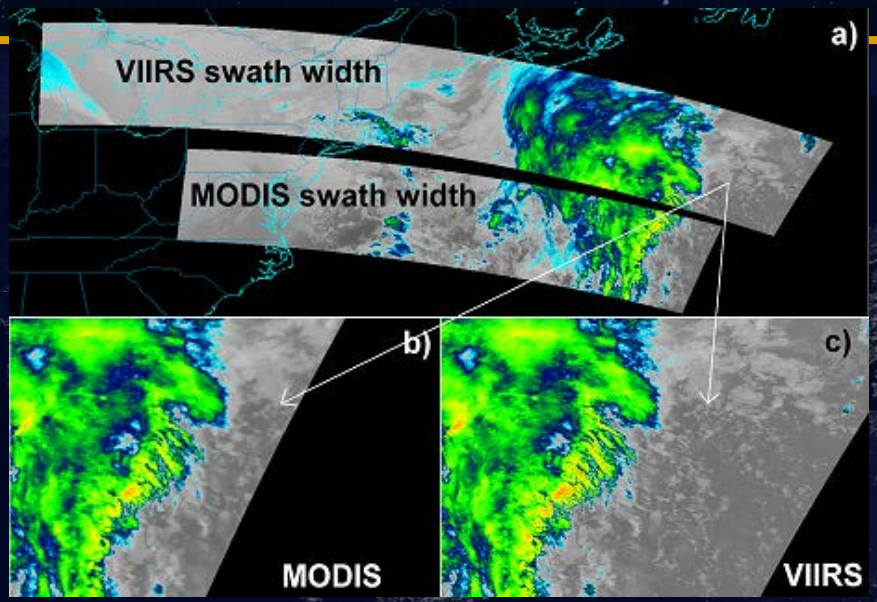
On Oct. 2, 2015, the ozone hole expanded to its peak of 28.2 million square kilometers (10.9 million square miles), an area larger than the continent of North America. Throughout October, the hole remained large and set many area daily records.

**Cold temperatures fuel ozone loss**

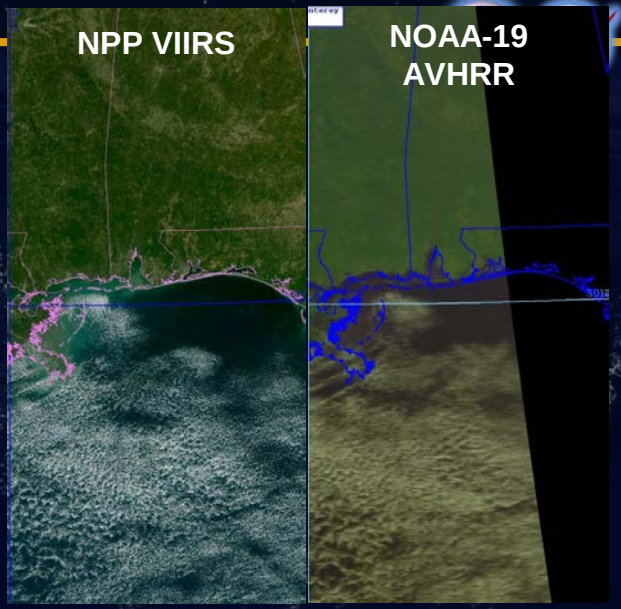
Unusually cold temperature and weak dynamics in the Antarctic stratosphere this year resulted in this larger ozone hole. In comparison, last year the ozone hole peaked at 24.1 million square kilometers (9.3 million square miles) on Sept. 11, 2014. Compared to the 1991-2014 period, the 2015 ozone hole average area was the fourth largest.

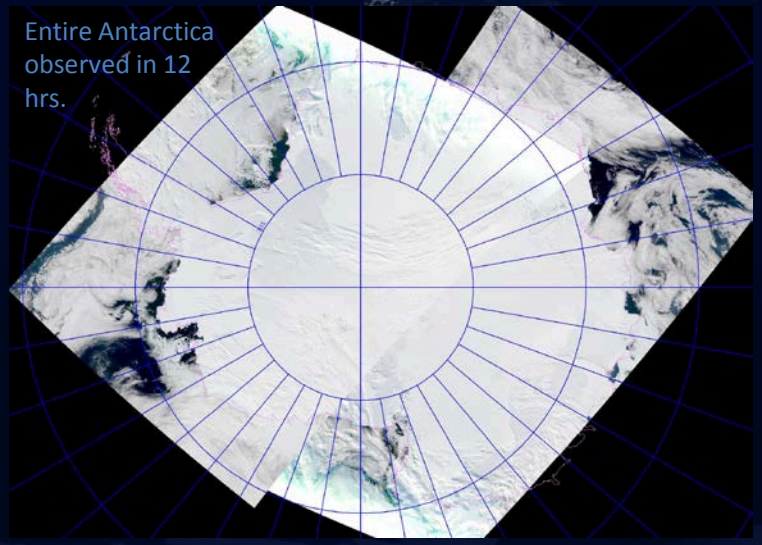


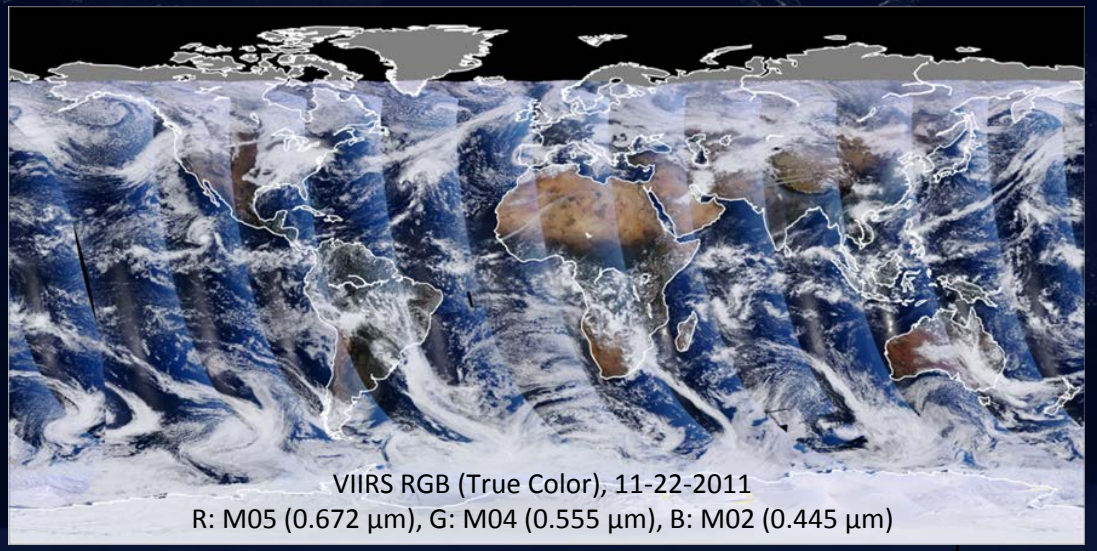
# JPSS Next Generation Instruments




The Visible Infrared Imaging Radiometer Suite offers more spectral bands, higher resolution, wider swath and greater accuracy, resulting in a large number of products



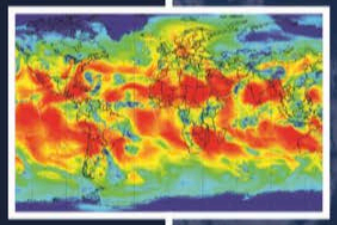



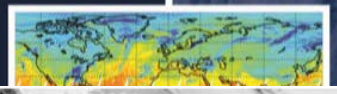
VIIRS RGB (True Color), 11-22-2011
R: M05 (0.672 µm), G: M04 (0.555 µm), B: M02 (0.445 µm)

Bands at Nadir

JOURNAL OF GEOPHYSICAL RESEARCH SPECIAL ISSUE OF THE

# Suomi National Polar-Orbiting Partnership Satellite Calibration





## ADVANCES IN SPACE-BASED NIGHTTIME VISIBLE OBSERVATION

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UAF-GINA

- Introduction
- Nightime Visible Imaging With the DNB
- Lunar Phases and Modeling
- Applications of Nightime Visible Imaging
  - Introduction
  - City Lights
  - Tropical Cyclones
  - Fog/Stratus
  - Airglow
  - Polar Nights and Auroras
  - Wildland Fires
  - Volcanoes
  - Dust Storms
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  - Population/Economic Geography
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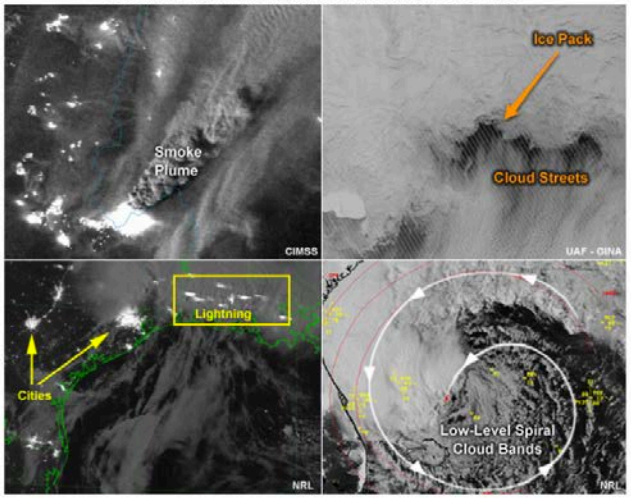
This section explores the use of nighttime visible images and derived products to detect and monitor a variety of meteorological and other features at night. The derived products are made from VIIRS DNB visible images and infrared channels. As of 2013, some are currently available while others are still experimental.

**Suomi NPP VIIRS DNB Nighttime Visible Images & Products**




If you are not familiar with RGB products, we recommend that you take COMET's Multispectral Satellite Applications: RGB Products Explained module at https://www.meted.ucar.edu/training_module.php?id=568.

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# FIRST-LIGHT IMAGERY FROM SUOMI NPP VIIRS

BY DONALD HILLGER, THOMAS KOPP, THOMAS LEE, DANIEL LINDSEY, CURTIS SEAMAN, STEVEN MILLER, JEREMY SOLBRIG, STANLEY KIDDER, SCOTT BACHMEIER, TOMMY JASMIN, AND TOM RINK

Dramatic examples from first-light imagery, both single and multi-band, as well as the day-night-band, show that the 22-band sensor aboard the Suomi NPP satellite exceeds both requirements and expectations.

The launch of the Suomi National Polar-Orbiting Partnership (NPP) on 28 October 2011 marked a new generation of operational polar-orbiting spacecraft. Suomi NPP, which was renamed in January 2012 to honor "the father of satellite meteorology" Verner Suomi (Lewis et al. 2010), was originally called the National Polar-orbiting Environmental Satellite System (NPOESS) Preparatory Project (Lee et al. 2010), utilizing the same NPP initialism. NPP was originally considered a risk-reduction mission, but after the breakup of NPOESS, the Joint Polar Satellite System (JPSS) inherited NPP to become the prototype operational satellite anticipating the renamed JPSS-1 and -2 (Fig. 1) yet to be launched.

**AFFILIATIONS:** HILLGER AND LINDSEY—NOAA/NESDIS/STAR, Fort Collins, Colorado; KOPP—The Aerospace Corporation, El Segundo, California; LEE AND SOLBRIG—Naval Research Laboratory, Monterey, California; SEAMAN, MILLER, AND KIDDER—Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, Colorado; BACHMEIER, JASMIN, AND RINK—Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin—Madison, Madison, Wisconsin
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*The abstract for this article can be found in this issue, following the table of contents.*
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In final form 6 December 2012



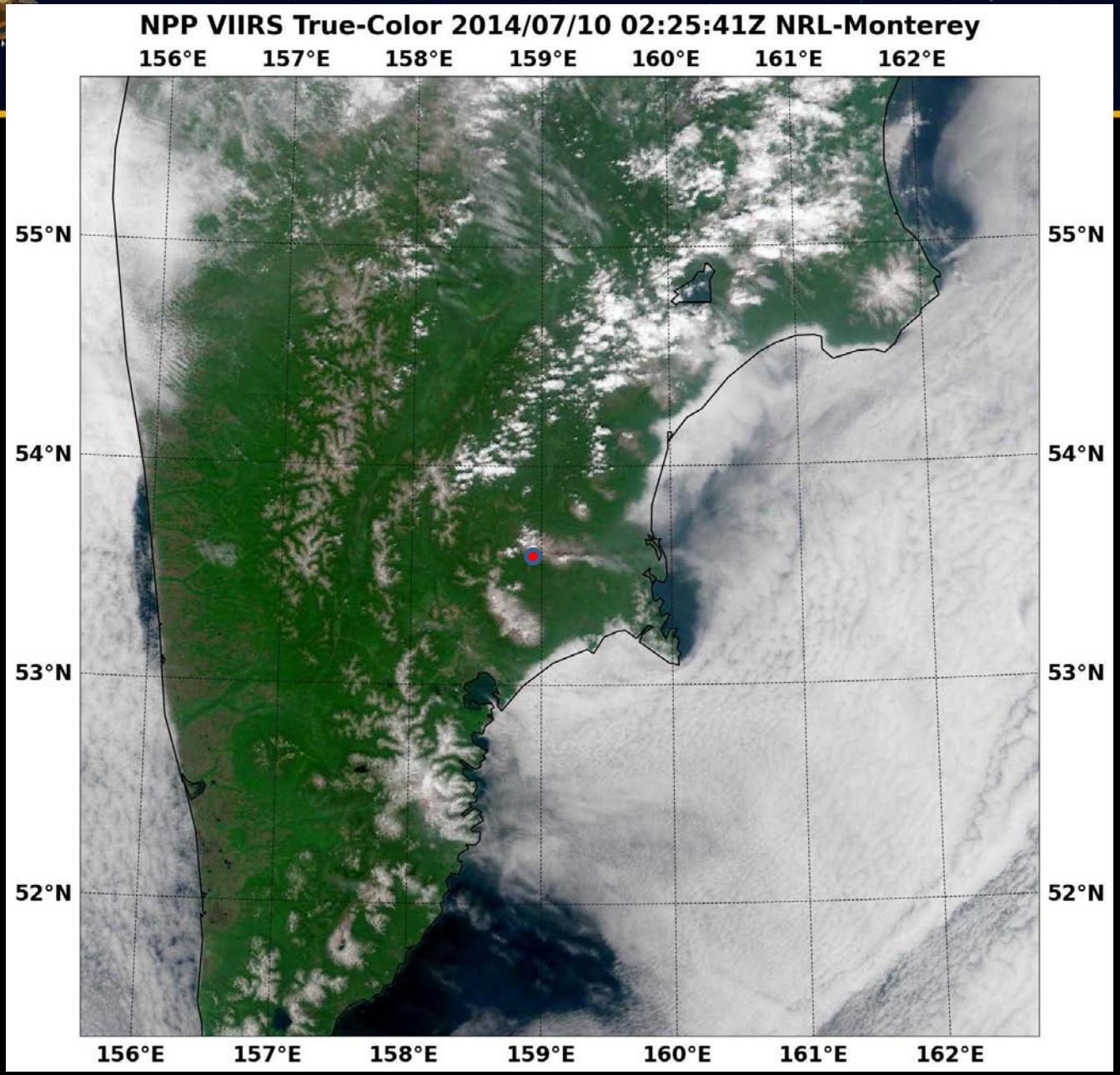
**FIG. 1. Logo for the JPSS constellation, which includes the Suomi NPP satellite.**

The Visible–Infrared Imaging Radiometer Suite (VIIRS; please see sidebar for additional information), the primary imaging instrument on JPSS spacecraft, includes an expanded set of visible and infrared spectral bands (Table 1) to greatly improve upon its operational predecessor Advanced Very High Resolution Radiometer (AVHRR), as well as an enhanced-capability day/night band (DNB) (Lee et al. 2006) to improve upon the day/night imagery available from the Operational Linescan System (OLS) on the Defense Meteorological Satellite System (DMSP) series.

After a brief explanation of what is new with Suomi NPP, the following sections will provide dramatic examples of the improved capabilities of VIIRS imagery.

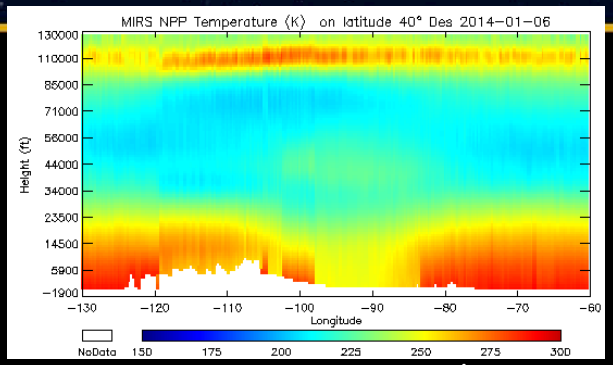
**WHAT IS NEW AND IMPROVED WITH VIIRS ON SUOMI NPP?** This article highlights VIIRS imagery, one of many environmental data records (EDRs) from VIIRS. Many additional EDRs are being developed and tested (sea surface temperature, cloud properties, ocean color, aerosol characteristics, etc.), but the imagery EDR has recently achieved the "beta" stage of maturity and is on its way to further levels of quality control. The examples presented here

# Comparing MODIS (250m) to VIIRS (375m) Edge of Scan

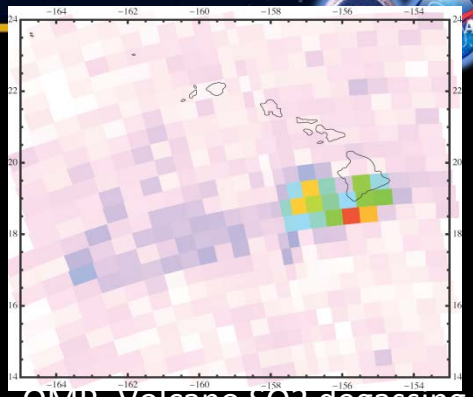


# JPSS provides a wide range of capabilities

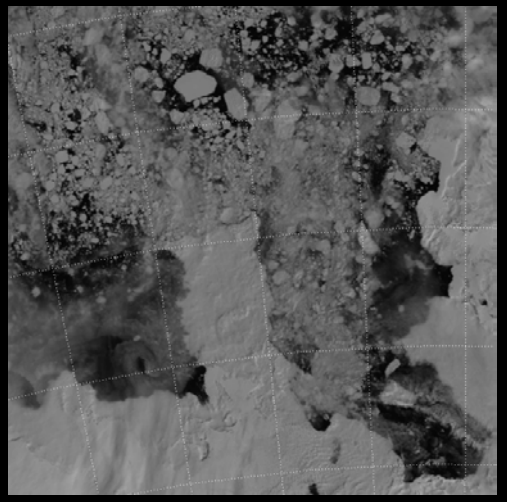
- Microwave – provides temperature and moisture soundings in cloudy conditions and rainfall rates, sea ice, snow, surface temperature
- Infrared – provides high vertical resolution temperature and moisture soundings in clear and cloud corrected regions; atmospheric chemistry - CO, CH4, SO2, … and cloud products
- Visible (day & night) and Infrared Imagery (including deep blue channels) – chlorophyll, cloud imagery, cloud products, SST, Active Fires, Smoke, Aerosols, land products, Snow, Ice, oil spills… at exceptional resolution/global coverage
- UV - ozone - Aerosols over bright surfaces, SO2 plumes, NOx (air quality)…

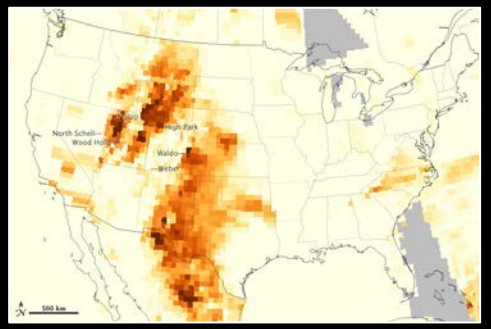


Temperature X-Section Polar Vortex

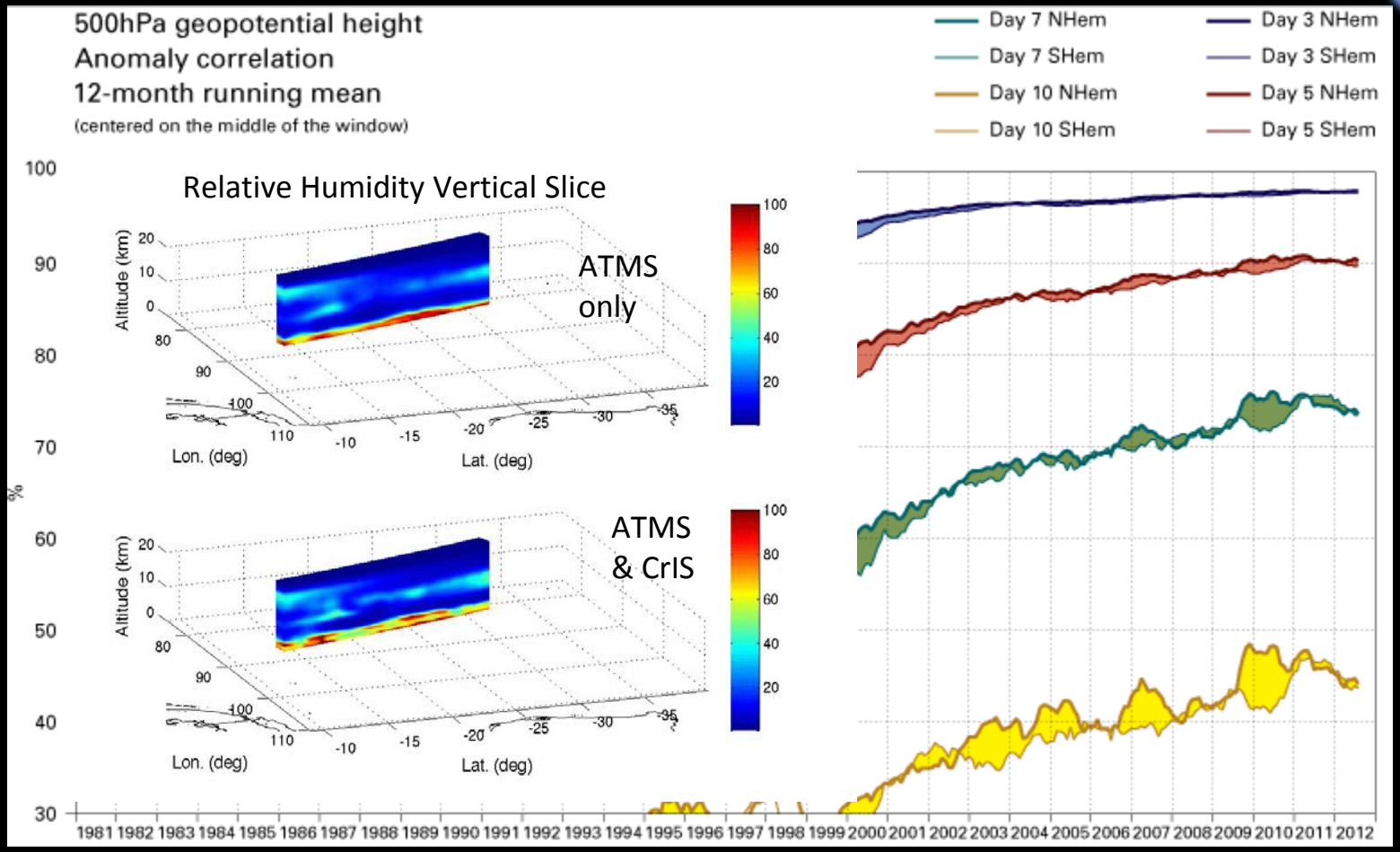

OMP- Volcano SO2 degassing


Algae in Lake Erie

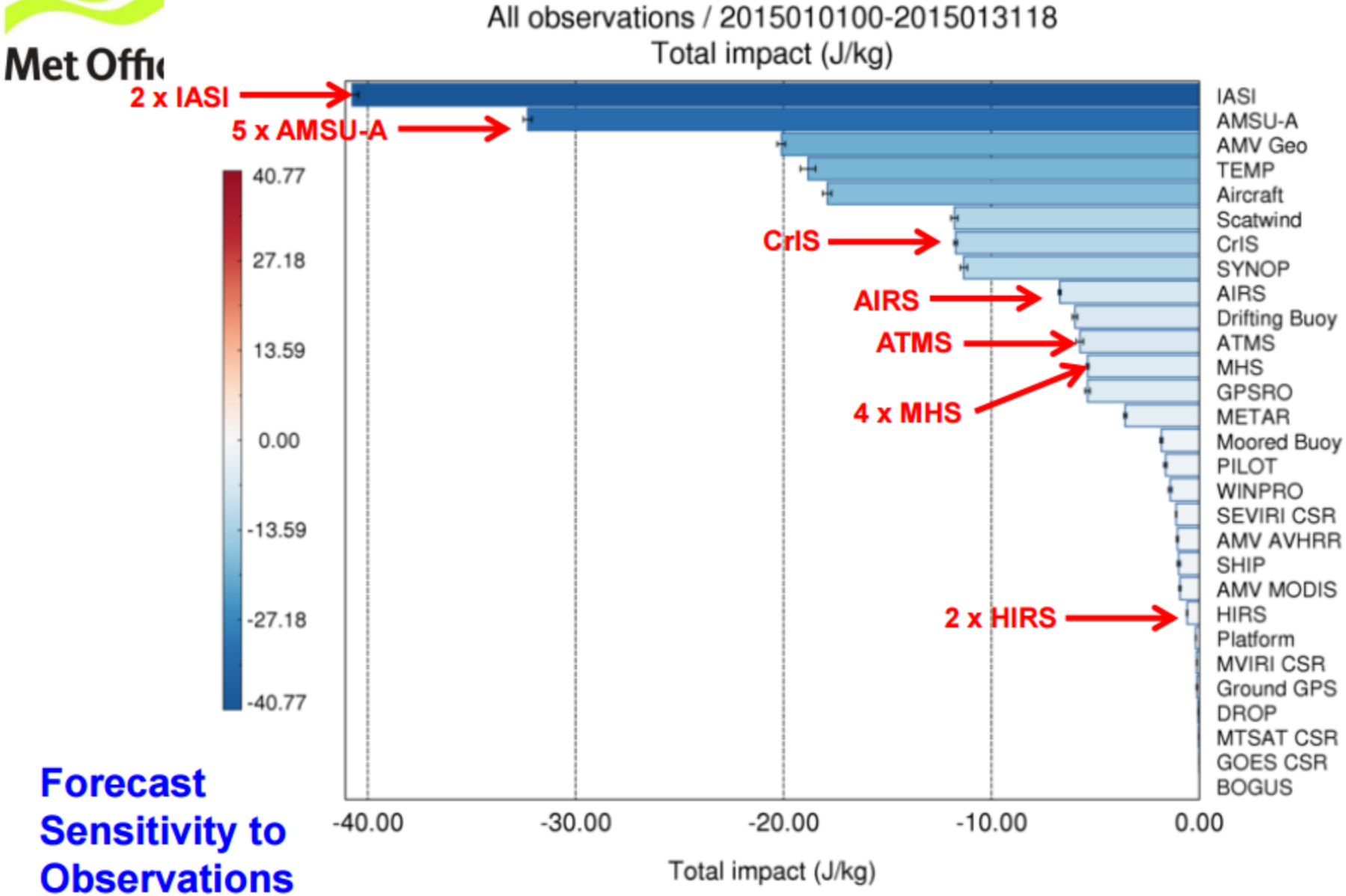

DNB Ice detection


OMPS Aerosols from Fires

# Improvements in forecasting



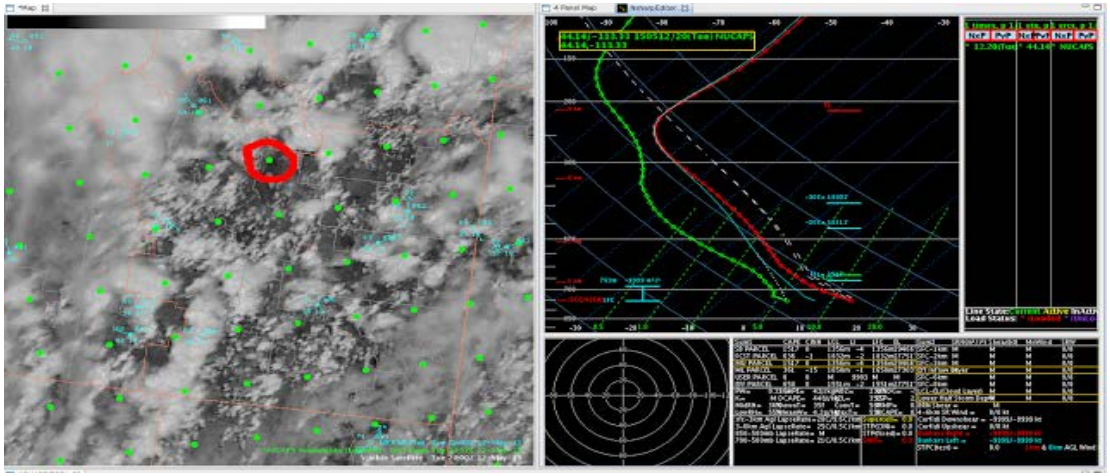
# Impact of S-NPP: Met Office

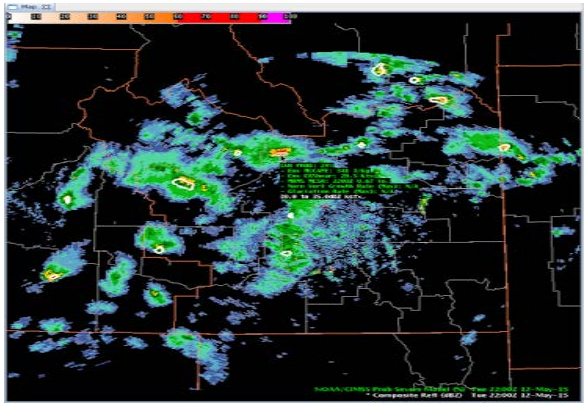



**Forecast Sensitivity to Observations**

# NUCAPS Evaluated in NWS Hazardous Weather Testbed (HWT)

- Background
  - What is the HWT: a joint testbed in Norman OK managed by the NWS Storm Prediction Center, the NWS Weather Forecast Office and the National Severe Storms Laboratory
  - Purpose: plan and execute operational tests focused on national hazardous weather needs
  - Spring Experiment: annual, 5-week test periods. Researchers, forecasters, and broadcast meteorologists evaluate emerging research concepts and tools through experimental forecast and warning generation exercises. NUCAPS was a key focus area in the Spring Experiment 2015





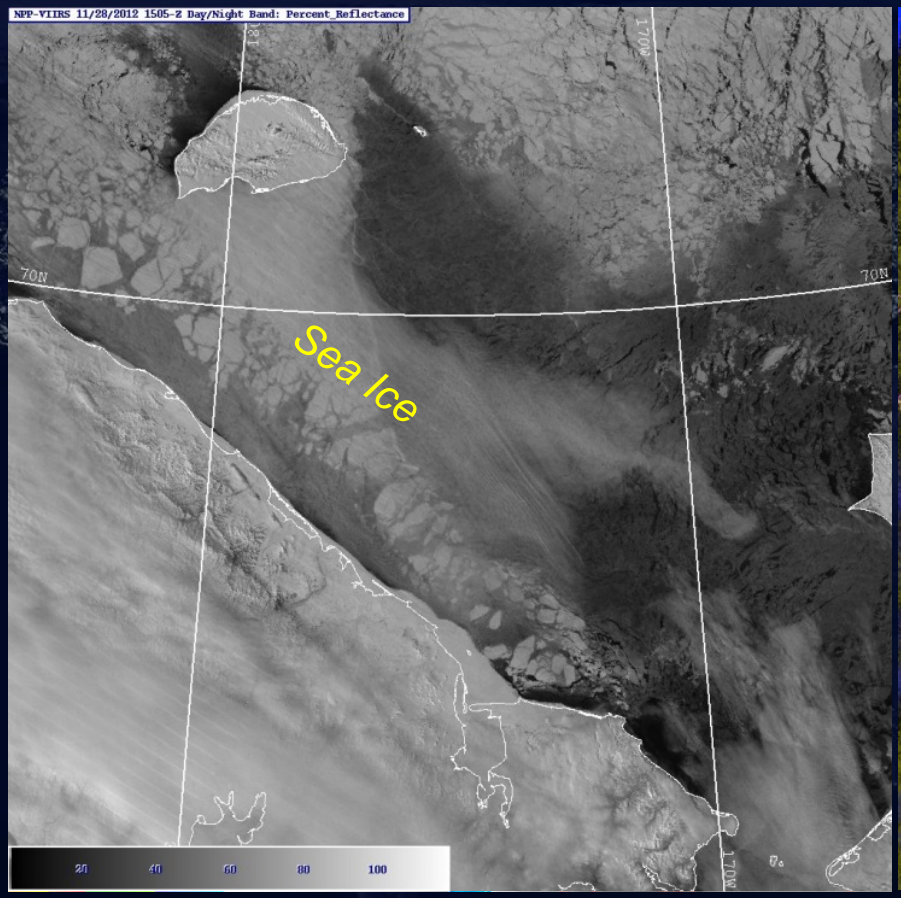
Examples of Forecaster feedback

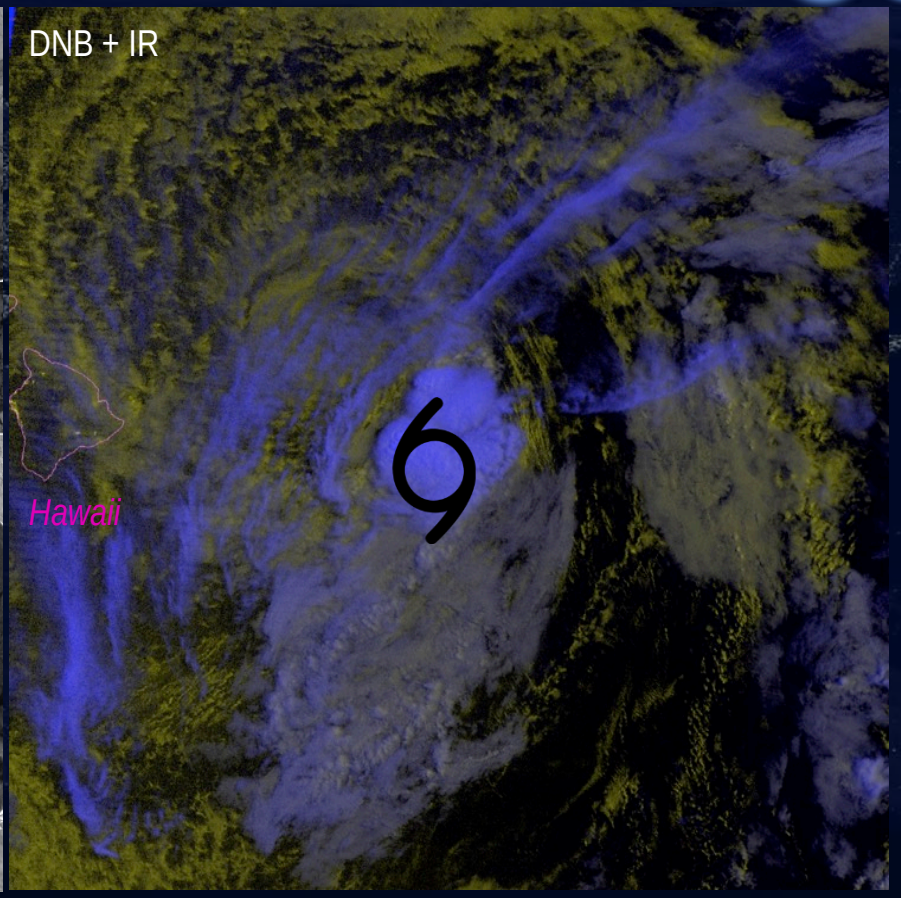
Waiting for deep convection to start. Denver's 18z special sounding showed a strong inversion around 700mb. The 20Z NUCAPS showed the lower levels not quite fully mixed. NUCAPS increased confidence that deep convection would occur but not quite yet. (comment edited)

NUCAPS sounding shows the presence of a cold pocket aloft and relatively low precipitable water values around a half an inch confirm elevated convection along with the scattered reports of severe hail in eastern Idaho.

A VIIRS Satellite Pass at 1944Z provided a NUCAPS Profile near some developing storms in Texas. It provided a nice snapshot of the atmosphere in between [radiosonde] soundings.

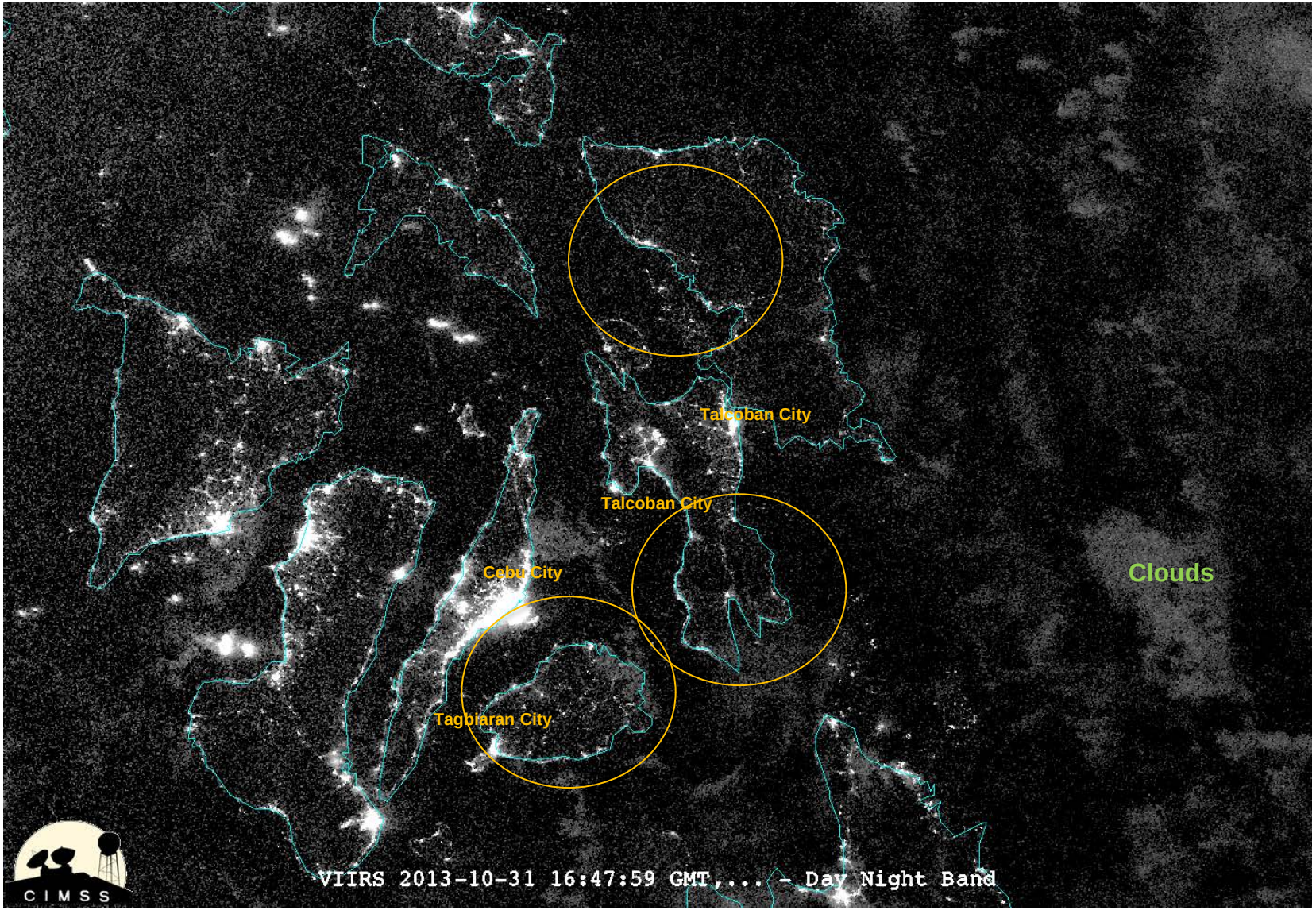
# JPSS Night Imaging



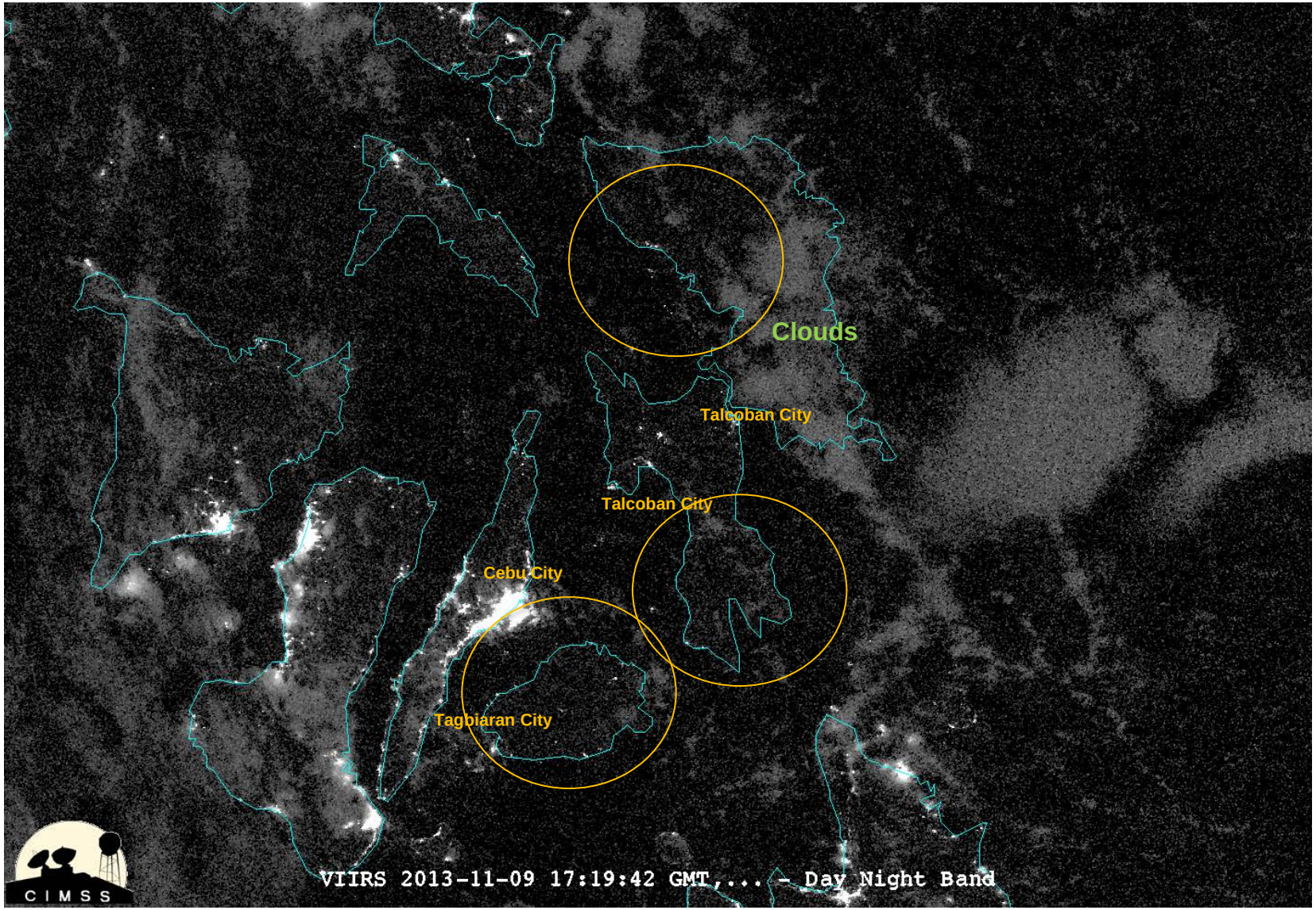




Visible light to scatter through optically thin clouds (opaque at thermal infrared bands) enables the VIIRS DNB to image lower atmosphere and surface features not possible by any other instrument (Courtesy Steve Miller – CIRA)

# VIIRS Day Night Band
# 1647Z on October 31, 2013



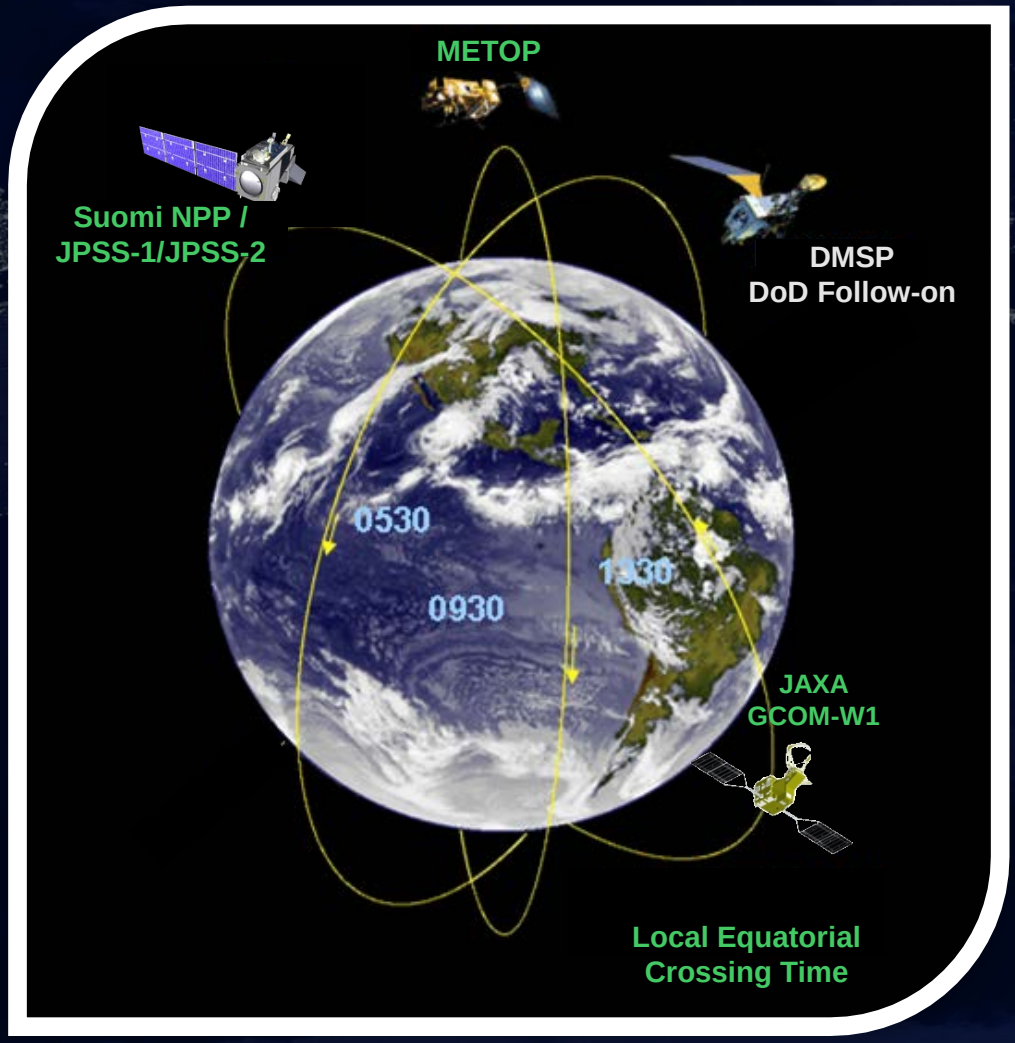
# VIIRS Day Night Band
# 1719Z on November 9, 2013



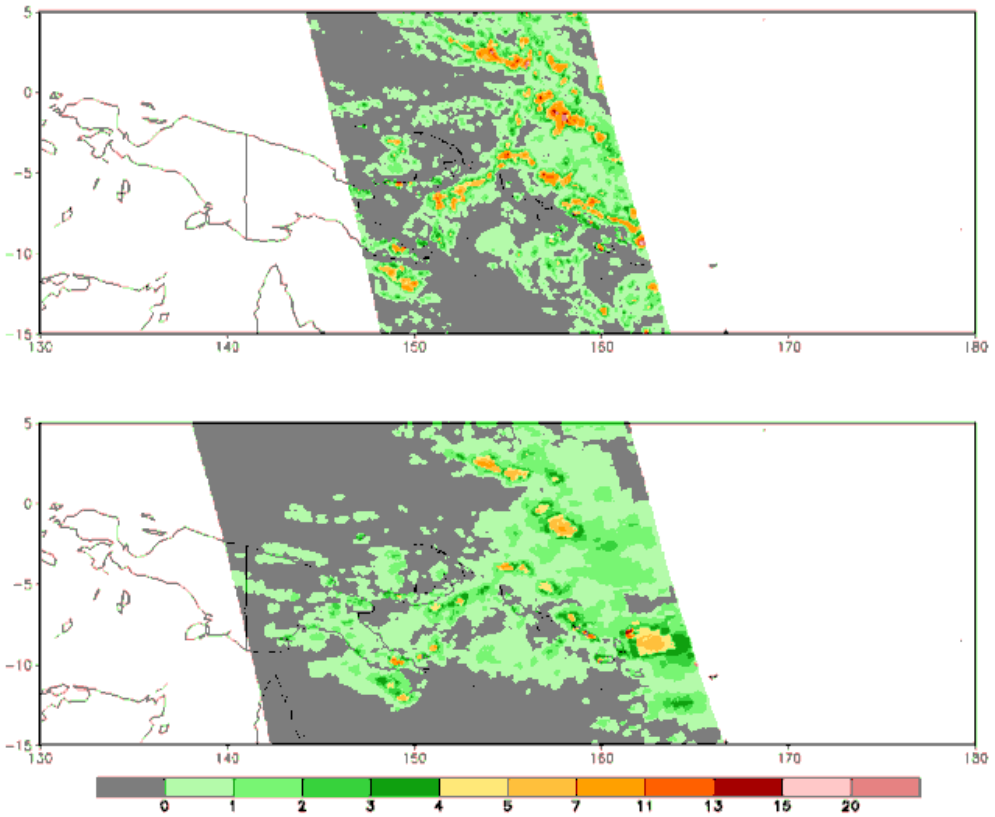
# JPSS: Integral to 3-Orbit Global Polar Coverage

- JPSS implements U.S. Space Policy and international agreements to ensure global coverage.
- NOAA's polar satellite covers the afternoon orbit, EUMETSAT's satellite covers the mid-morning orbit and DoD covers the early morning orbit.
- The data from these three orbits are fundamental to the 3-7 day forecast to provide advanced warning of severe weather, as well as environmental monitoring .
- JAXA provides microwave imagery used for a variety of applications; most importantly of precipitation in areas not covered by radar.

*JPSS provides observational continuity for the afternoon orbit*



# Comparisons between AMSR2 and ATMS precipitation




Rain rates from AMSR2 and ATMS within minutes after satellites fly over

**GCOM-W1 AMSR-2 (top), S-NPP ATMS (bottom)**
**06:30-07:00 UTC 7 April 2014**

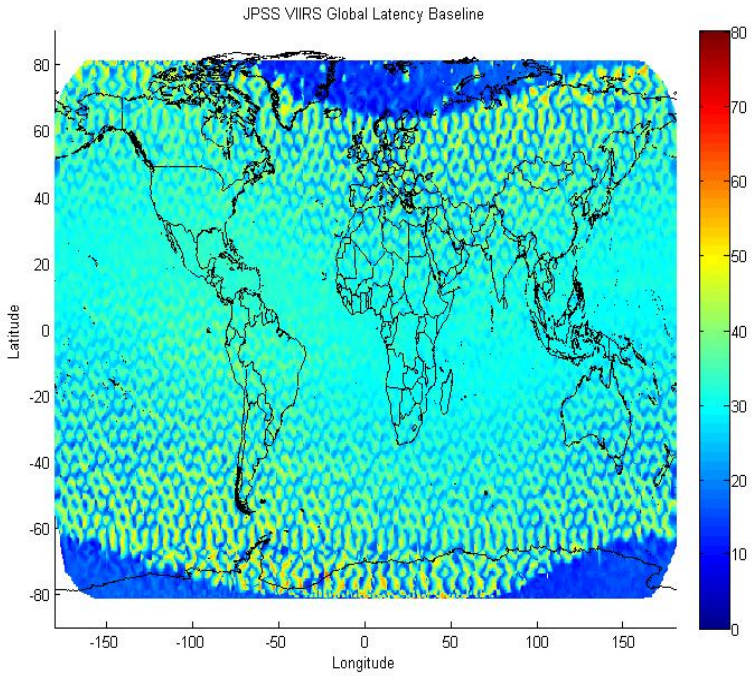
Notice the higher spatial resolution of AMSR2 compared to ATMS



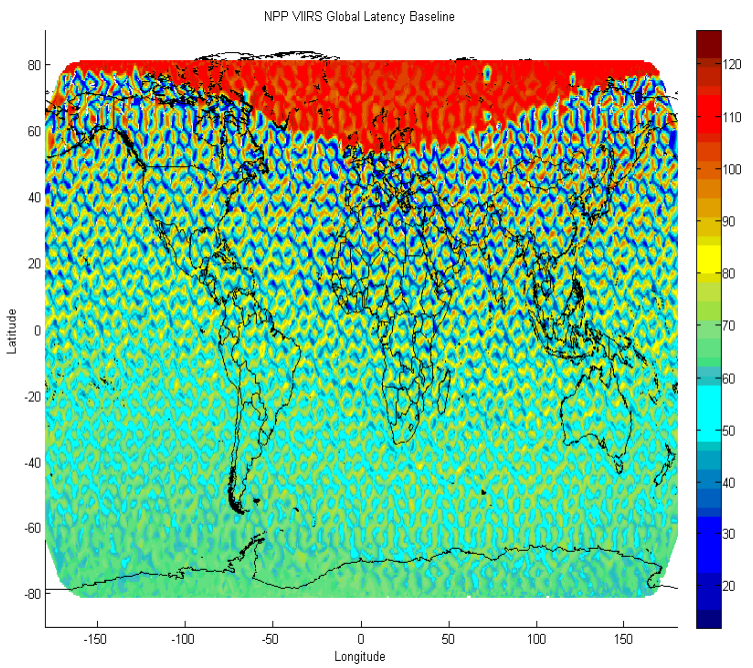
20

# Driving requirements are global coverage of a wide range of environmental parameters with improved latency and high accuracy and reliability

## JPSS

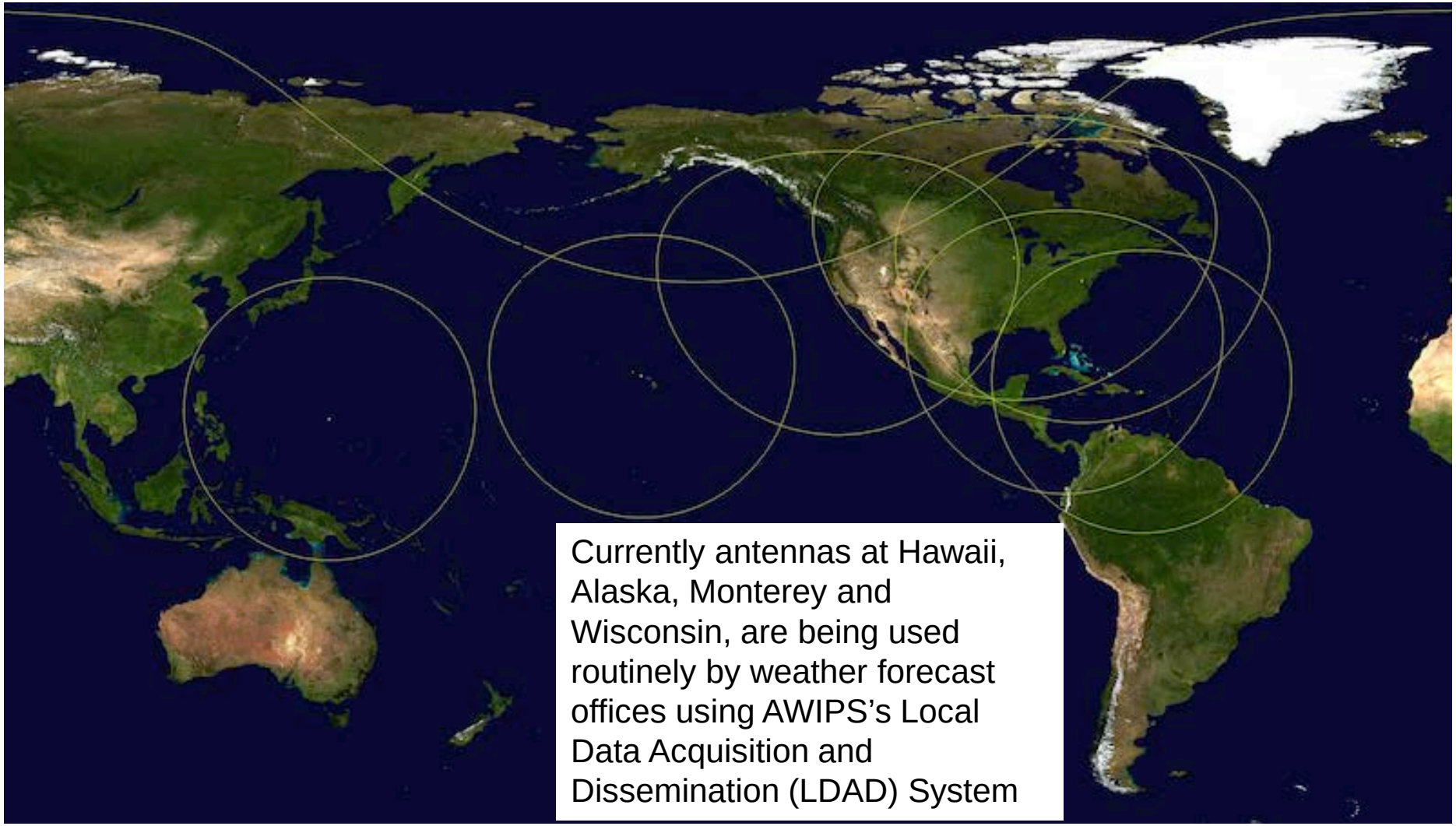



## SNPP



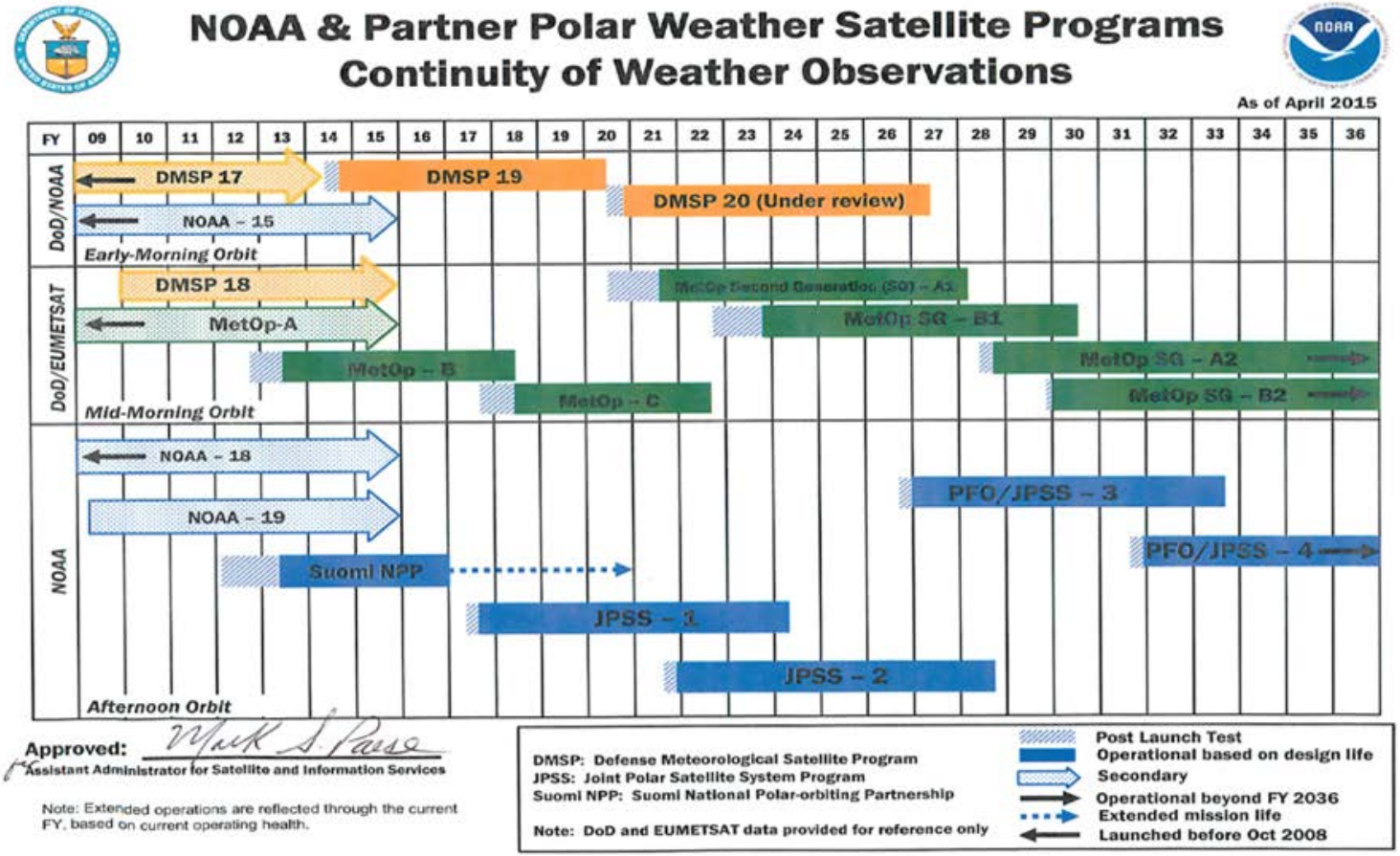

***Polar region latency improved from 2 hours to 10 minutes***
***95% of the data is within 50 minutes (taking into account BUFR conversion, etc.)***
***Between +- 50 degrees latitude ~ 30 minutes***
***Actual performance will be 50% better than specification***

# NOAA supported direct readout sites

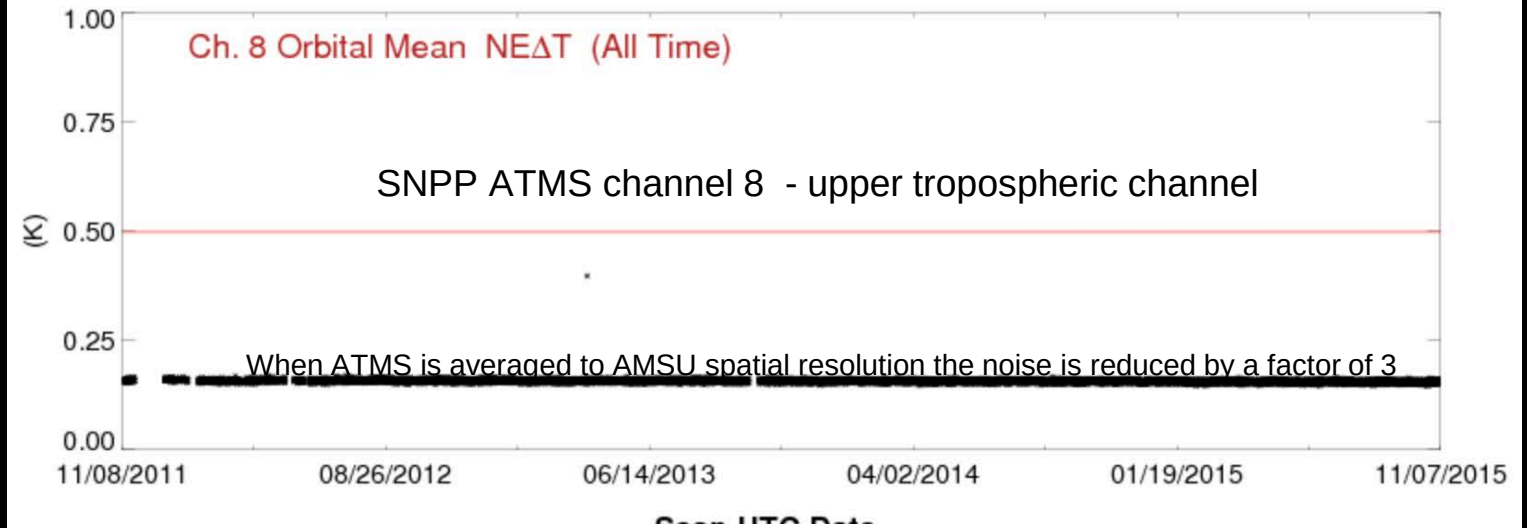


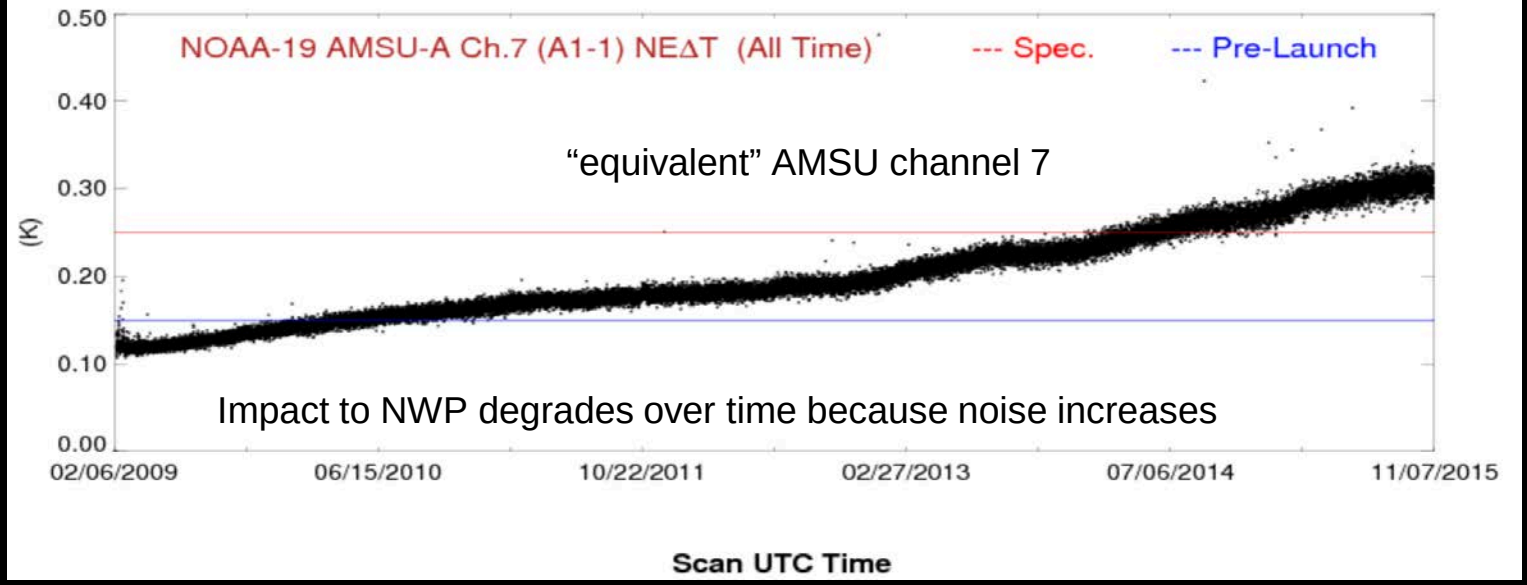

Guam, Honolulu, Fairbanks, Monterey, Madison, NYC, Miami, Mayaguez (PR)

# Polar Satellite Launch Schedule

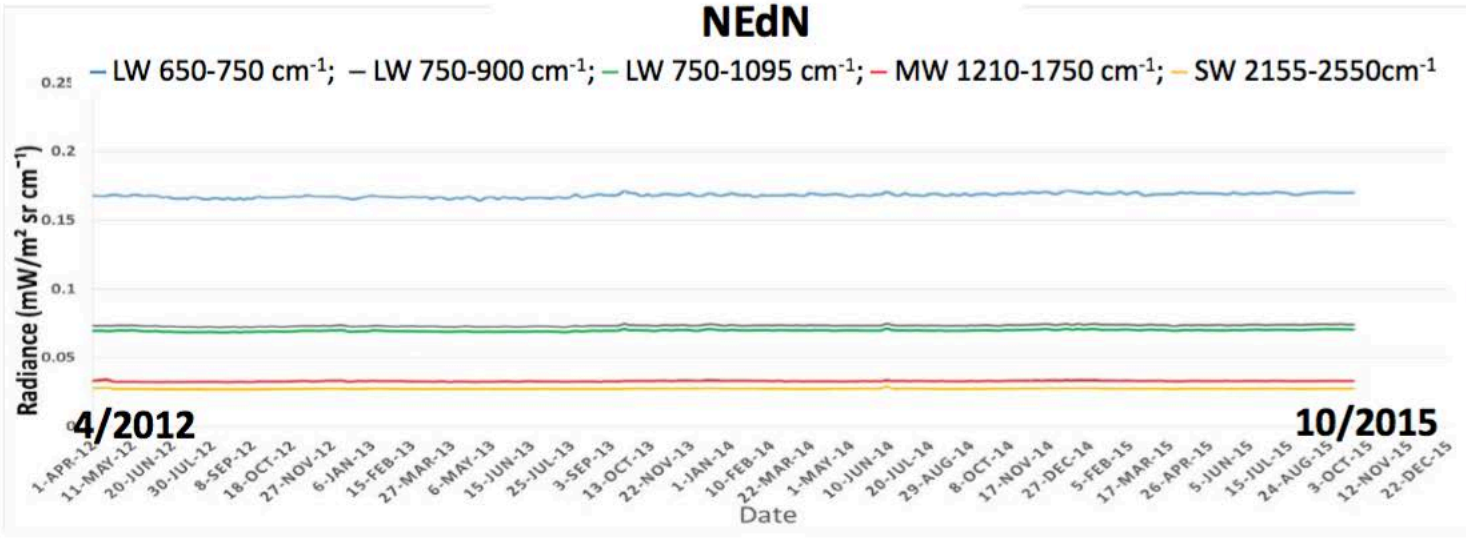


# ATMS is outperforming AMSU in noise and long-term stability

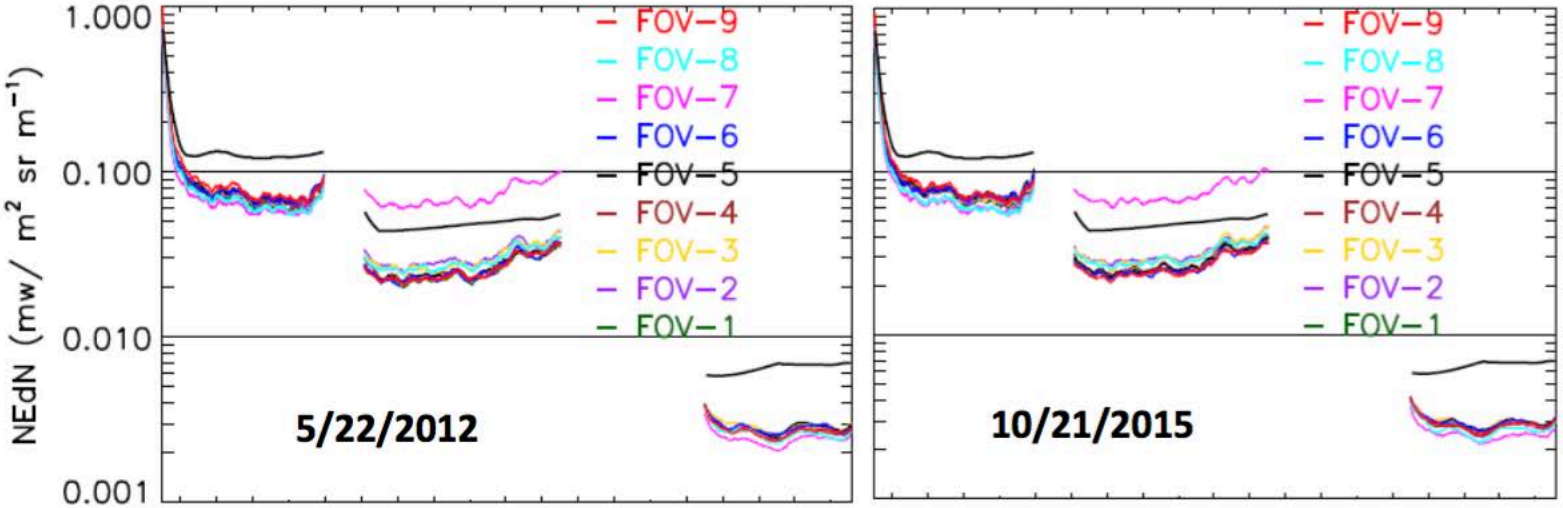


# S-NPP CrIS NEdN



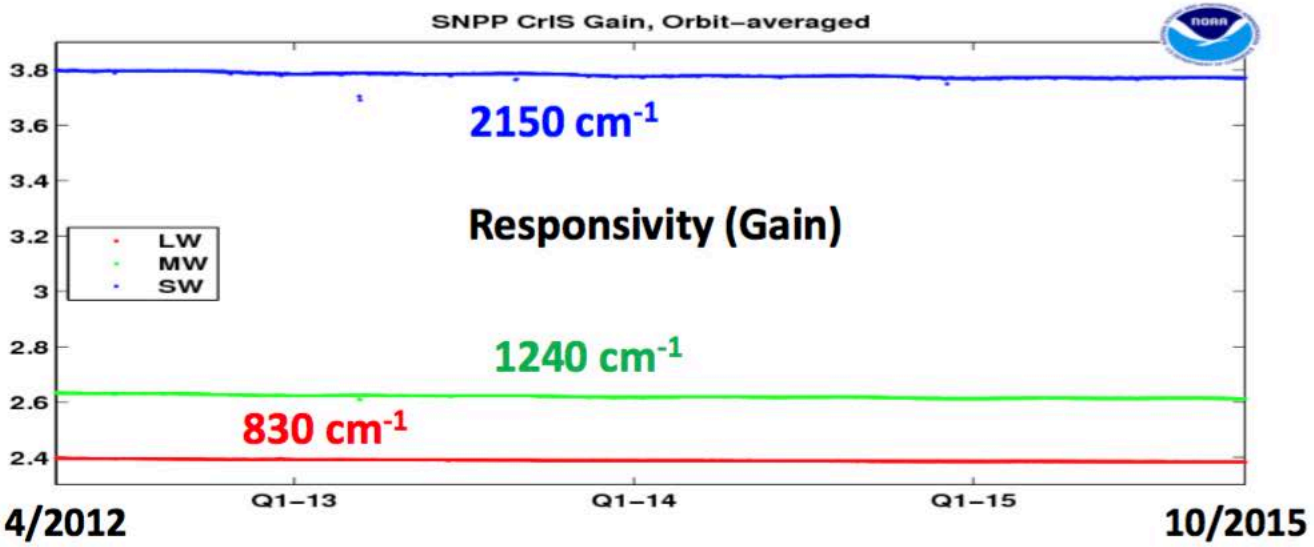

From SDL



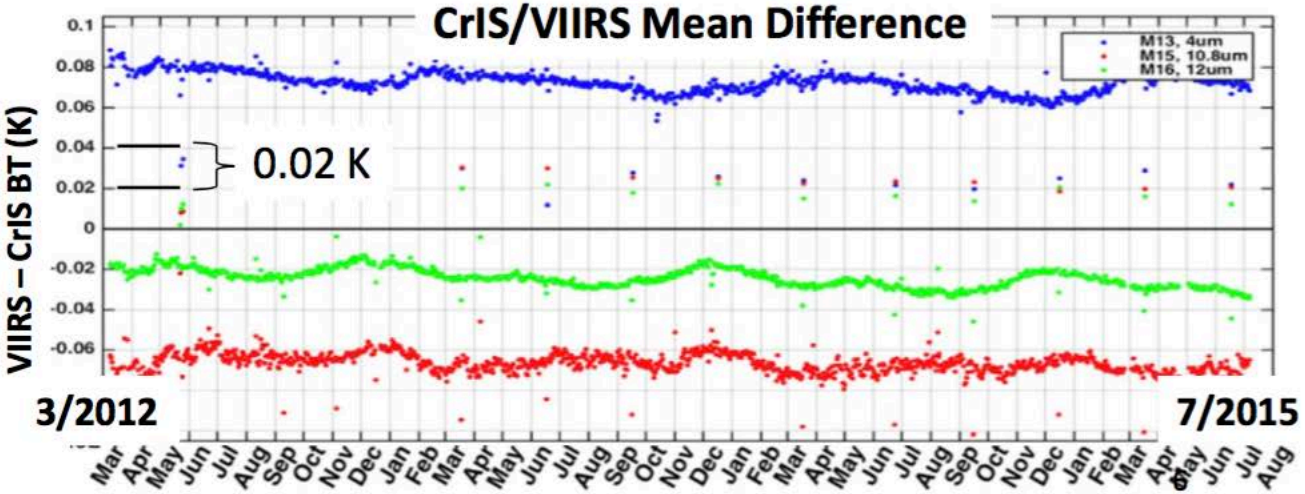

**Stable NEdN performance**

# S-NPP CrIS Gain & Performance Stability

**Less than 1% change of instrument responsivity over 3.5 years**



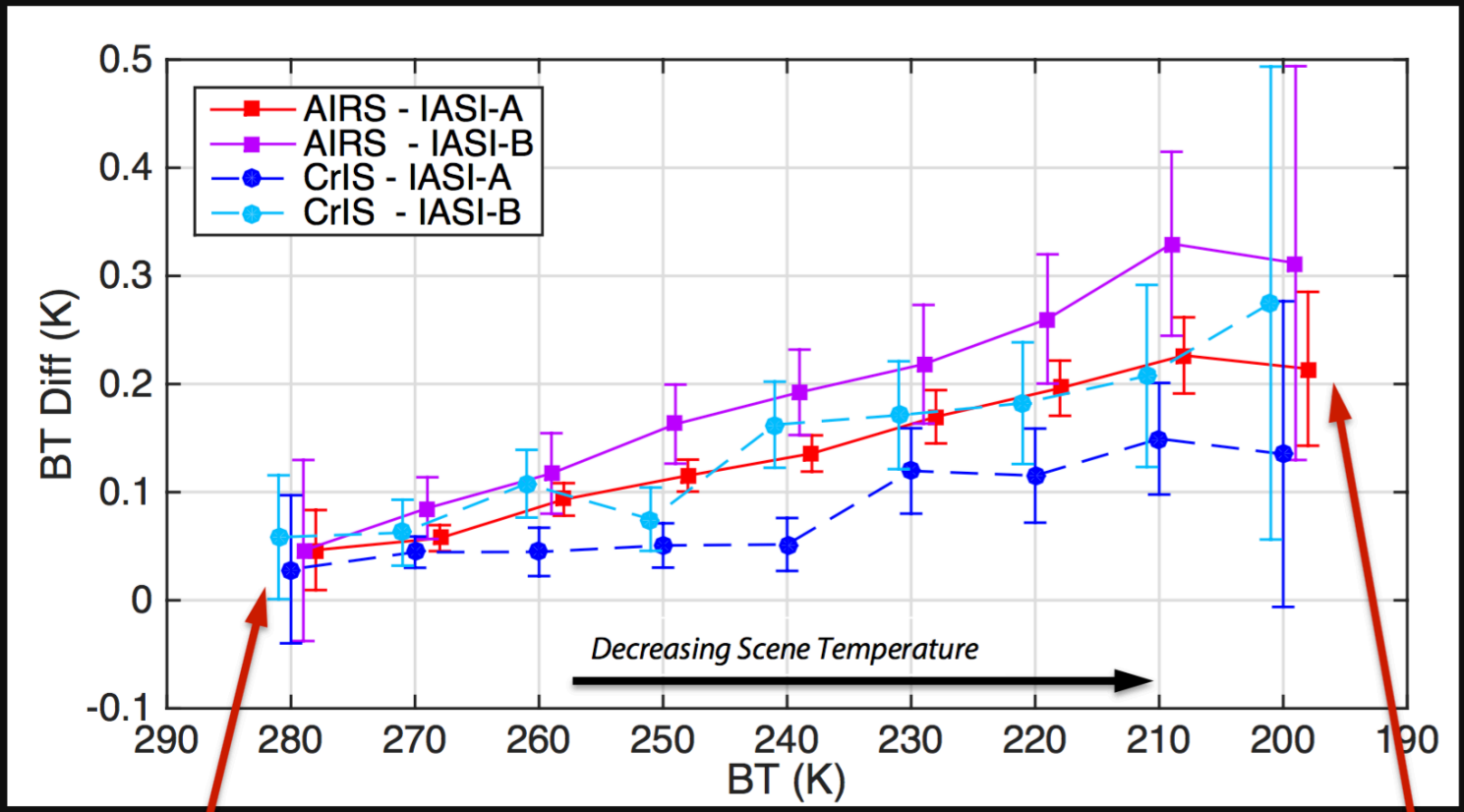

- **Variation of the difference is less than ±0.01**
- Large outliers are due to VIIRS quarterly nonlinearity tests




From UW

# Assessment of the calibration accuracy for cold Earth scenes

Mean SNO differences for 910-930 $cm^{-1}$



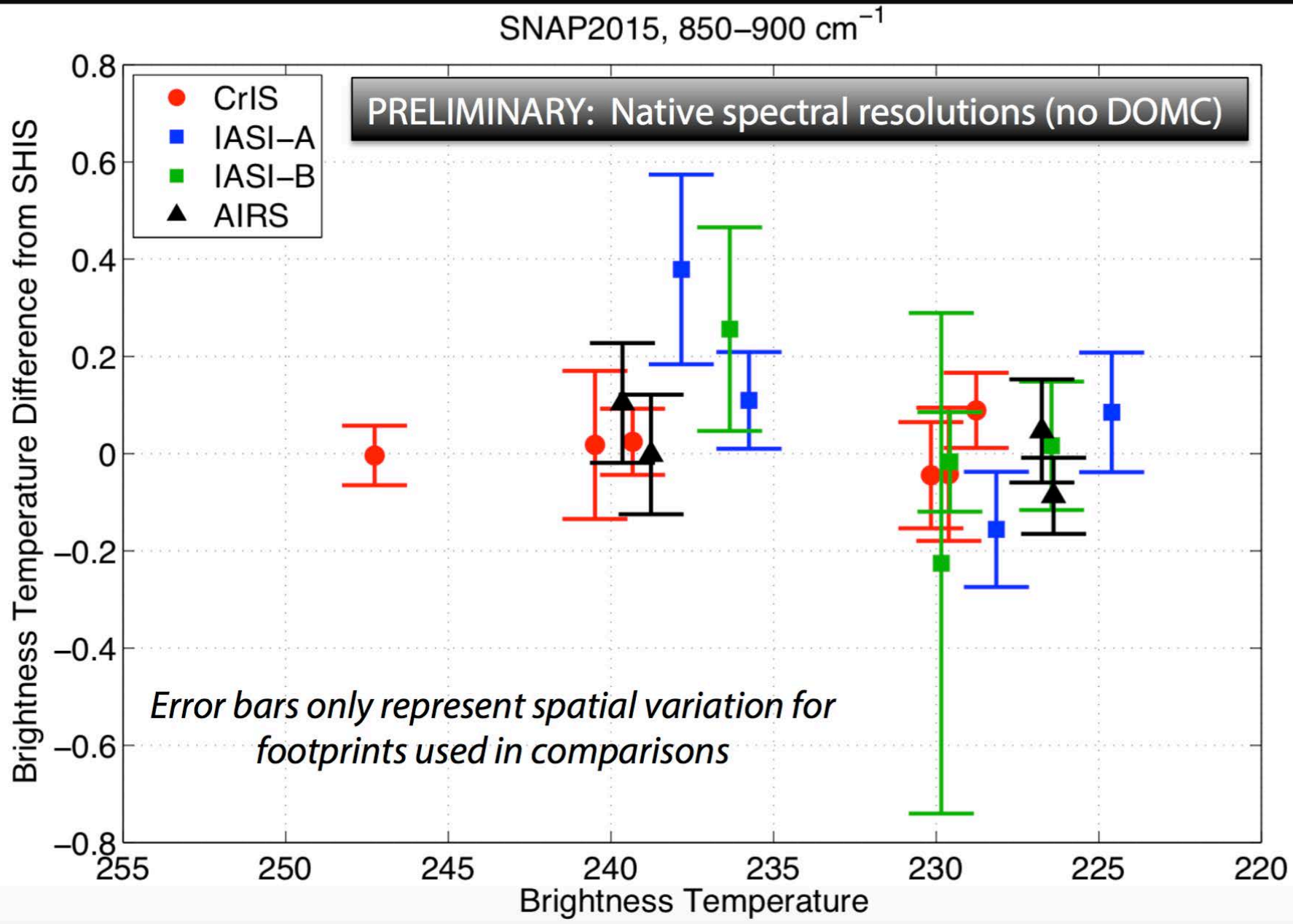

Error-bars represent statistical matchup uncertainty, not sensor uncertainty

0.050 K Agreement

> 0.3 K relative differences

Credit: Tobin

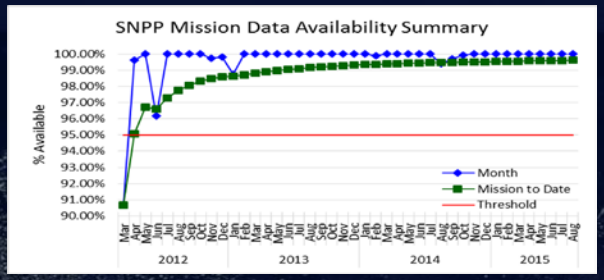
# Preliminary Analysis and Results: SNPP Calibration Validation Campaign 2015

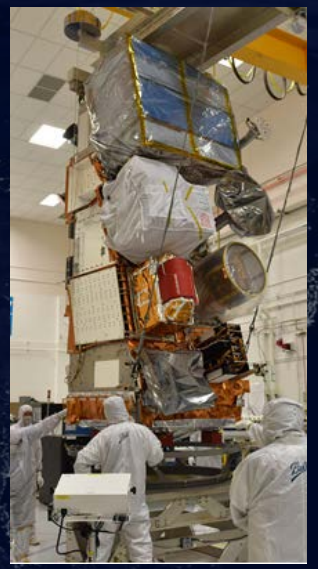


# Mission Status

## S-NPP

- 4 years on orbit - October 28
- Rapid data product transition to operational use
- Primary for weather since 1 MAY 2014
- Excellent health and data availability



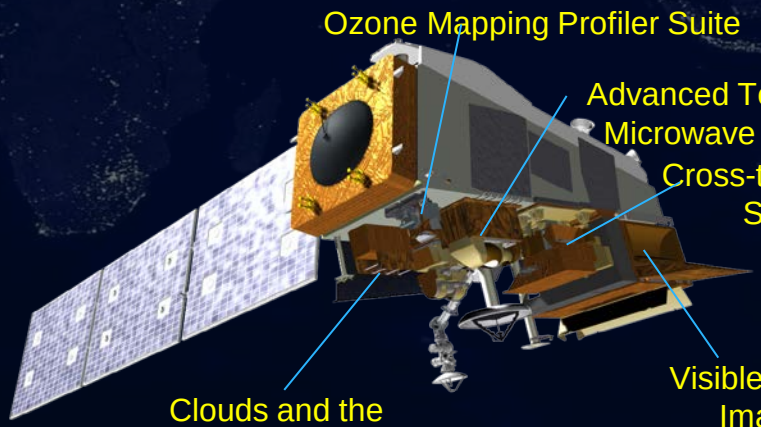
## JPSS-1

- Integrated satellite test phase
- On track for early 2017 launch

## JPSS-2

- Instrument parts/assembly phase
- Spacecraft kick-off phase

**JPSS-1 Spacecraft**



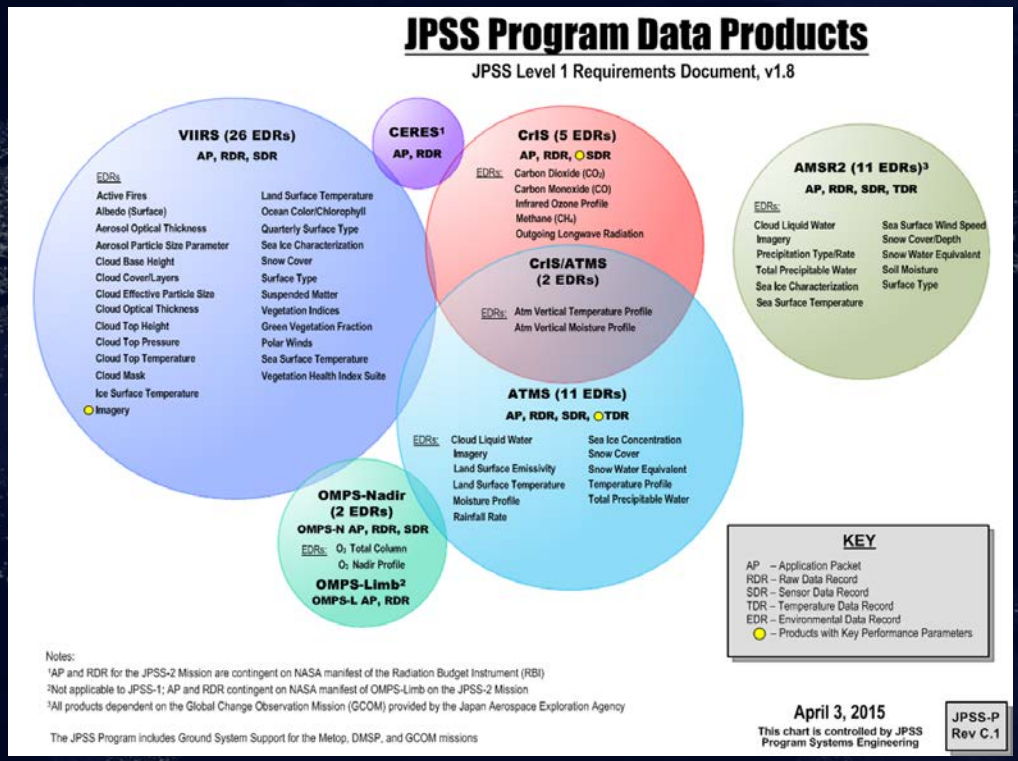
# JPSS Performance for Users

## Data Products Cal/Val and quality

- Three maturity levels
- Traceability to NIST standards
- Constant quality monitoring

## Transition to enterprise algorithms

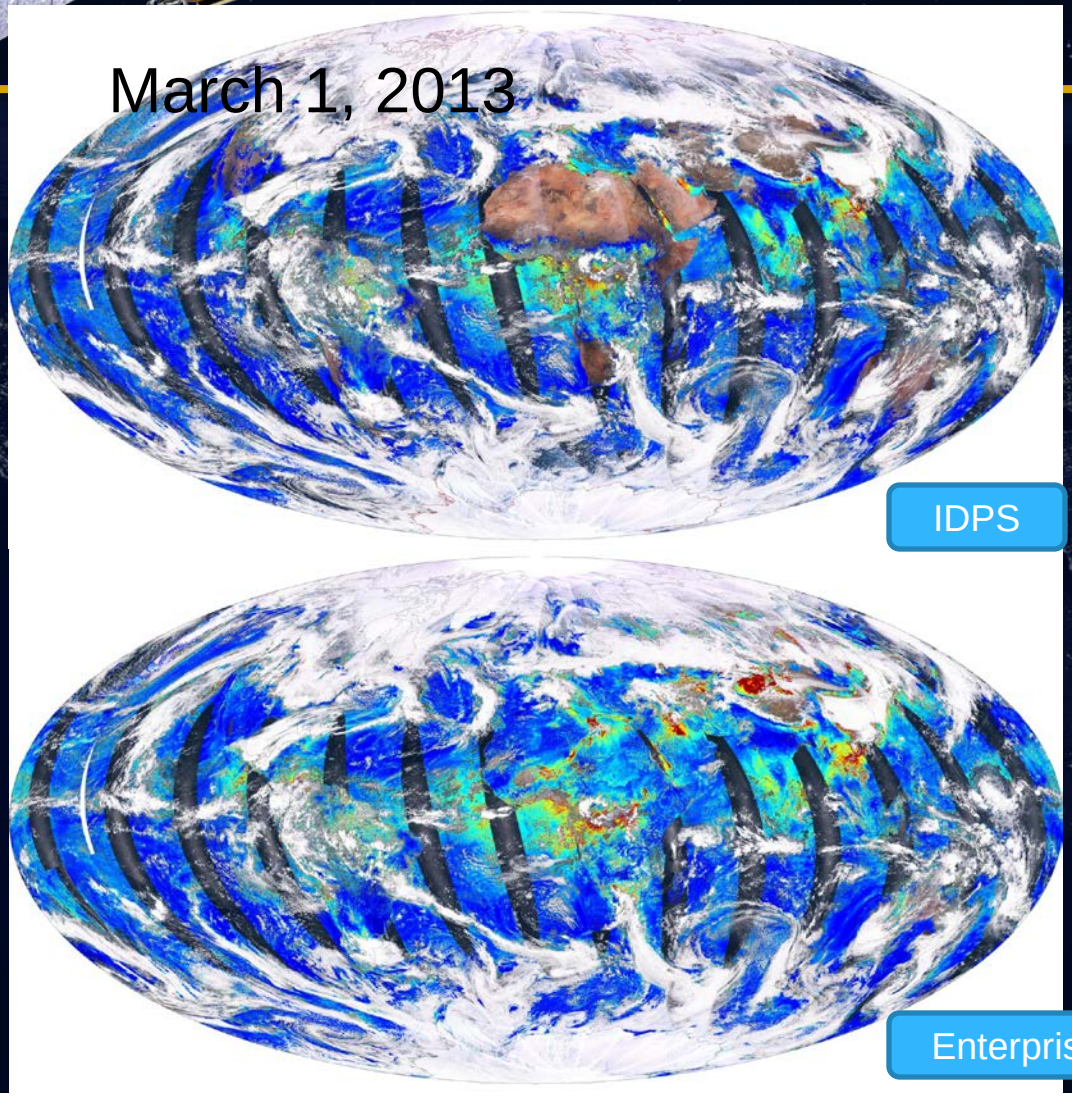
- JPSS inherited NOAA legacy and NPOESS heritage
- Developed sustainable / maintainable/compatible suite




## User Focused Improvements

- Full spectrum CrIS, direct readout improvements
- Program Science -user readiness/risk reduction to enable quicker/broader utilization
- Half orbit latency, 17km resolution OMPS introduced with JPSS-1

# SNPP VIIRS Aerosol Optical Thickness (AOT) Retrieval




- Operational IDPS AOT product has data gaps over bright surfaces and other regions where incorrect spectral surface reflectance ratios used in the algorithm lead to negative retrievals.
- Enterprise algorithm combines GOES-R ABI dark target algorithm for vegetated surfaces with atmospheric correction approach using spatially varying spectral surface reflectance ratio database for bright surfaces to improve spatial coverage.

Look for improved coverage in the Enterprise algorithm retrievals over desert regions in Africa, middle East, and other regions in Asia

*Courtesy of H. Liu (IMSG), H. Zhang (IMSG), I. Laszlo (STAR), and S. Kondragunta (STAR)*

# Summary

Substantial Progress in 5 years since program started

- Program Base-lined to Focus on Weather mission
- 5 instrument suite; S-NPP, JPSS-1, JPSS-2 Missions, Block 2 Ground development
- Four years of S-NPP operations, observatory working well, excellent user feedback

Focus on Users

- Rapid user readiness, extensive calibration/ validation, risk reduction
- Increased performance

Plan for Continuity

- Impact Mitigations
- Robust  plan
- Two new missions requested: PFO/ JPSS-3, JPSS-4

## News Highlights

**October 28, 2015 marked the fourth anniversary of the launch of the Suomi NPP satellite.**

Suomi NPP is critical for weather forecasts beyond 48 hours and increase the consistency and accuracy of forecasts three to seven days in advance of a severe weather event, generating dozens of environmental data products, and predicting weather in locations that are not visible to conventional observing systems.

Read full story here >>

**JPSS Data Aid Forecasting of Tuna Habitats**

**JPSS-1 Solar Array Completes Deployment Testing**



Forecasters use data from JPSS satellites to help the Alaska Fire Service monitor weather conditions that trigger fires and track the resulting smoke drifting across the state.

## Why JPSS?

The Joint Polar Satellite System (JPSS) is our Nation's next generation polar-orbiting operational environmental satellite system. JPSS is a collaborative program between NOAA and its acquisition agent NASA.