JPSS Contributions to Climate Applications

Joint Polar Satellite System (JPSS)

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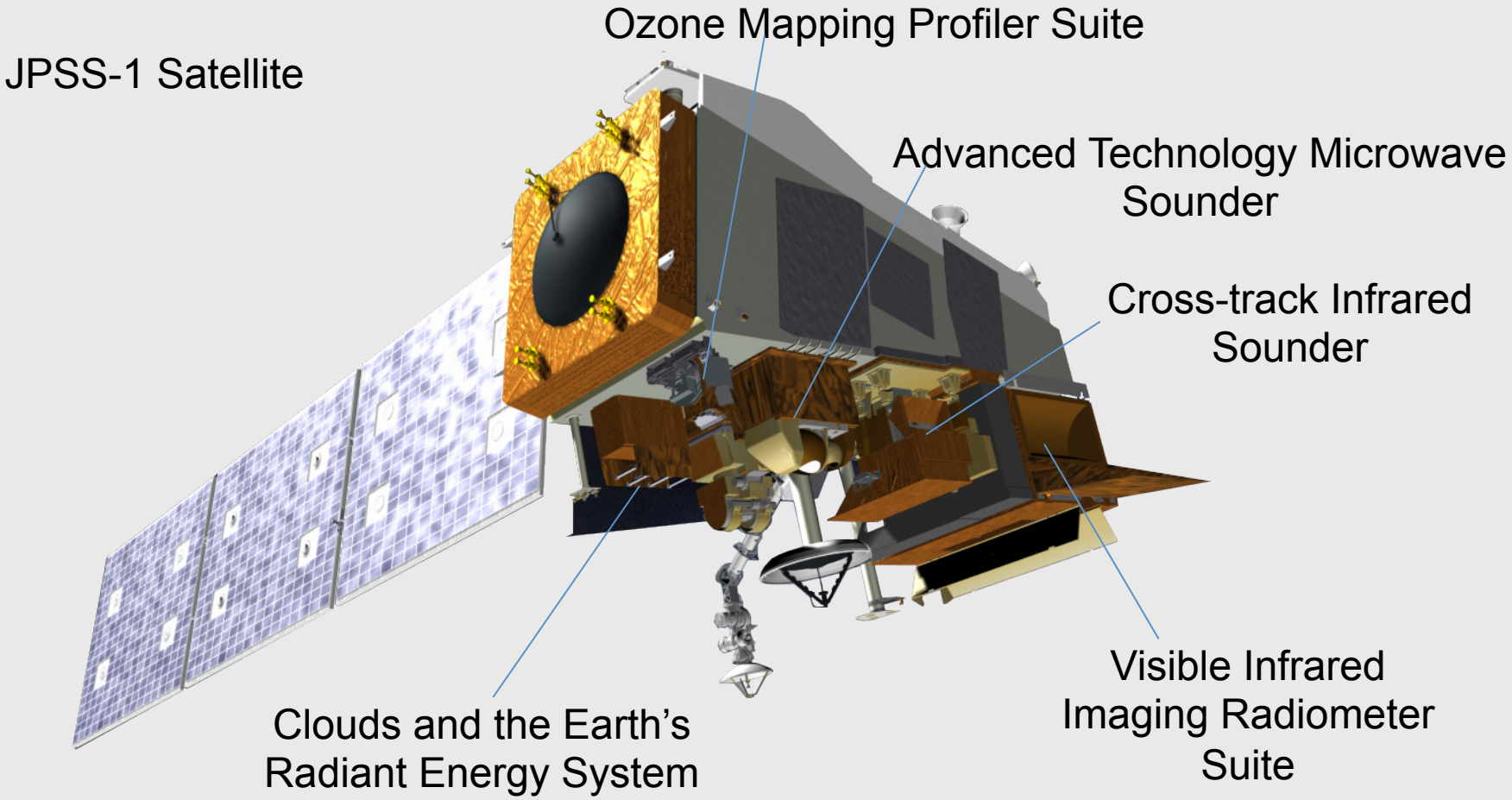
Overview

- JPSS Overview
- Current Status
- Monitoring Climate Variables
  - Principles for Monitoring Climate Variables
  - Actual Performance

JPSS Overview



JPSS Overview

- JPSS is the Nation's next-generation polar-orbiting environmental satellite system
  - Supports space-based observations for weather forecasting, environmental and climate monitoring
  - Provides global measurements of atmospheric, terrestrial and oceanic conditions
  - Key component of NOAA's ability to deliver weather-related products and services:
    - **Quality, quantity, relevance and timeliness of data** (**satellite** and *in situ*)
    - Computing capacity (operational and research)
    - Data assimilation and numerical weather predication
    - Forecaster knowledge, skill and ability

Current Status

- S-NPP is exceeding requirements
  - S-NPP is the primary operational polar-orbiting environmental satellite for NOAA
  - Satellite is healthy – availability exceeds 99.5%
- JPSS-1 executing within budget and on schedule
  - Four of five instruments delivered and integrated – ATMS recovery on track
  - Spacecraft on track
  - Ground system has schedule margin to support JPSS-1 launch
- JPSS-2
  - All satellite elements under contract and instrument build underway
- Polar Follow-On (JPSS-3 / JPSS-4)
  - Procurements underway

Monitoring Climate Variables

Domain		Essential Climate Variables
Atmospheric (over land, sea and ice)	Surface	**Air temperature**, **Wind speed and direction**, **Water vapor**, Pressure, **Precipitation**, Surface radiation budget.
	Upper-air	**Temperature**, **Wind speed and direction, Water vapor, Cloud properties,** Earth radiation budget* (including solar irradiance).
	Composition	**Carbon dioxide, Methane, and other long-lived greenhouse gases; Ozone and Aerosol**, supported by their precursors
Oceanic	Surface	**Sea-surface temperature**, Sea-surface salinity, Sea level, Sea state, **Sea ice**, Surface current, **Ocean color** (for biological activity), Carbon dioxide partial pressure, Ocean acidity
	Sub-surface	Temperature, Salinity, Current, Nutrients, Carbon dioxide partial pressure, Ocean acidity, Oxygen, Tracers, Phytoplankton; Marine biodiversity and habitat properties
Terrestrial		River discharge, Water use, Ground water, Lakes, **Snow cover**, Glaciers and ice caps, **Ice sheets**, Permafrost, **Albedo, Land cover** (including vegetation type), **Fraction of absorbed photosynthetically active radiation (fAPAR), Leaf area index (LAI),** Above-ground biomass, Soil carbon, **Fire disturbance, Soil moisture**

* Instrument carried by JPSS

Monitoring Climate Variables

- Global Climate Observing System (GCOS) published guidelines for producers of climate-relevant datasets (*Guideline for the Generation of Datasets and Products Meeting GCOS Requirements, GCOS-143, EMO/TD No. 1530*)
  - Assists producers such as space agencies judge the quality and fitness for purpose of climate datasets and products

- Satellite systems for climate monitoring should adhere to specific principles
  - **Constant sampling; ensure overlap between satellite systems; continuity of measurements; instrument characterization; on-board calibration;** operational production of climate products; data access; **baseline instruments should be operated as long as possible; complementary *in situ* observations should be maintained;** random errors and time-dependent biases should be identified

Monitoring Climate Variables
(Constant Sampling)

- *Constant sampling within the diurnal cycle (minimizing effects of orbital decay and drift)*

- SNPP enough fuel to provide coverage until JPSS-2 is launched – no life-limiting performance issues
  - Conducting maneuvers to maintain orbit

- Requirements for JPSS-1 and beyond
  - *Operate in a polar sun-synchronous orbit with an altitude of 824 +/- 17 kilometers, ground track repeat accuracy of 20 kilometers at the Equator with a repeat cycle less than 20 days, and ascending Equator crossing time of 13:30 +/- 10 minutes*

Monitoring Climate Variables
(Overlap and Continuity)

- *A suitable period of overlap for new and old satellite systems should be ensured for a period adequate to determine inter-satellite biases and maintain the homogeneity and consistency of time-series observations / Continuity of satellite measurements (i.e., elimination of gaps in the long-term record) through appropriate launch and orbital strategies should be ensured*

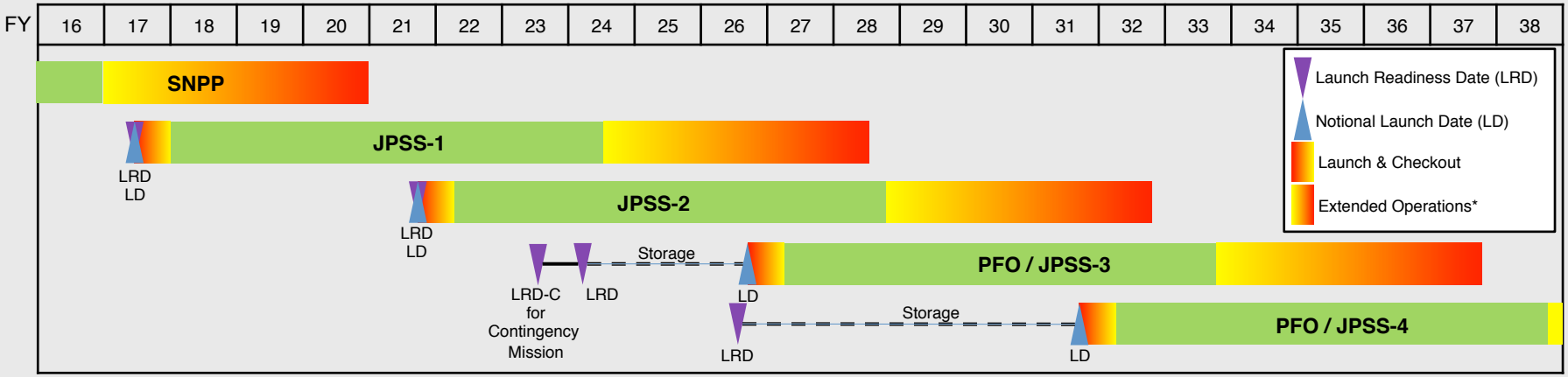
- SNPP enough fuel to provide coverage until JPSS-2 is launched – no life-limiting performance issues

- JPSS satellites designed for extended operations
  - Spacecraft have a seven year design life – fuel for 10.5 years (JPSS-2 to JPSS-4)
  - Instruments have a seven year design life

- Planned overlap of ~ five years and planned coverage to 2038

Monitoring Climate Variables
(Overlap and Continuity)

- Launch and orbital strategy for JPSS avoids gaps
  - Robust constellation which requires two failures to create a gap and an option available to return to a fault-tolerant condition should a failure occur
  - Fly two satellites on orbit (primary and secondary)
  - Allows overlap between satellites



*Notionally Fuel limited life times

Monitoring Climate Variables
(Instrument Characterization)

- *Rigorous prelaunch instrument calibration and characterization including radiance confirmation against an international radiance scale or standards*

- JPSS pre-launch activities include characterizing uncertainties of the sensors and data products (derived from instrument proxy and/or simulated data) and pre-launch calibration

- JPSS uses NIST to assist with instrument characterization
  - Measures relative and absolute spectral responsivity of VIIRS visible and near infrared bands; radiometric characterization; and radiometric trending
  - Verifies the accuracy of the CrIS External Calibration Target (ECT) by deploying a Thermal-infrared Transfer Radiometer (TXR) to the contractor's site

Monitoring Climate Variables
(On-board Calibration)

- *On-board calibration adequate for climate system observations should be ensured and associated instrument characteristics monitored*

- JPSS instruments all have on-board calibration and SNPP/JPSS conduct lunar calibration maneuvers for VIIRS
  - ATMS: Radiation measured from two calibration sources during every scan: cosmic background radiation emanating from space (cold space view) and internal blackbody calibration target (warm body)
  - CrIS: Two on-board calibration sources: internal, high-precision calibration blackbody and deep space view
  - VIIRS: Calibration is performed using a solar diffuser for short wavelengths and a blackbody and deep space view for thermal wavelengths
  - OMPS: On-orbit calibration is maintained using solar measurements

Monitoring Climate Variables
(Operational Production of Climate Products)

- *Operational production of priority climate records should be sustained and peer-reviewed new products should be introduced as appropriate*

- Out of scope for JPSS, but within scope of NASA mission and NOAA CDR program, however:
  - JPSS provides significant investments in the prelaunch and post launch activities to ensure instrument sensor data records and environmental data records are carefully monitored with reactive science maintenance.
  - Fundamental work for enabling climate records within the JPSS mission is being done.

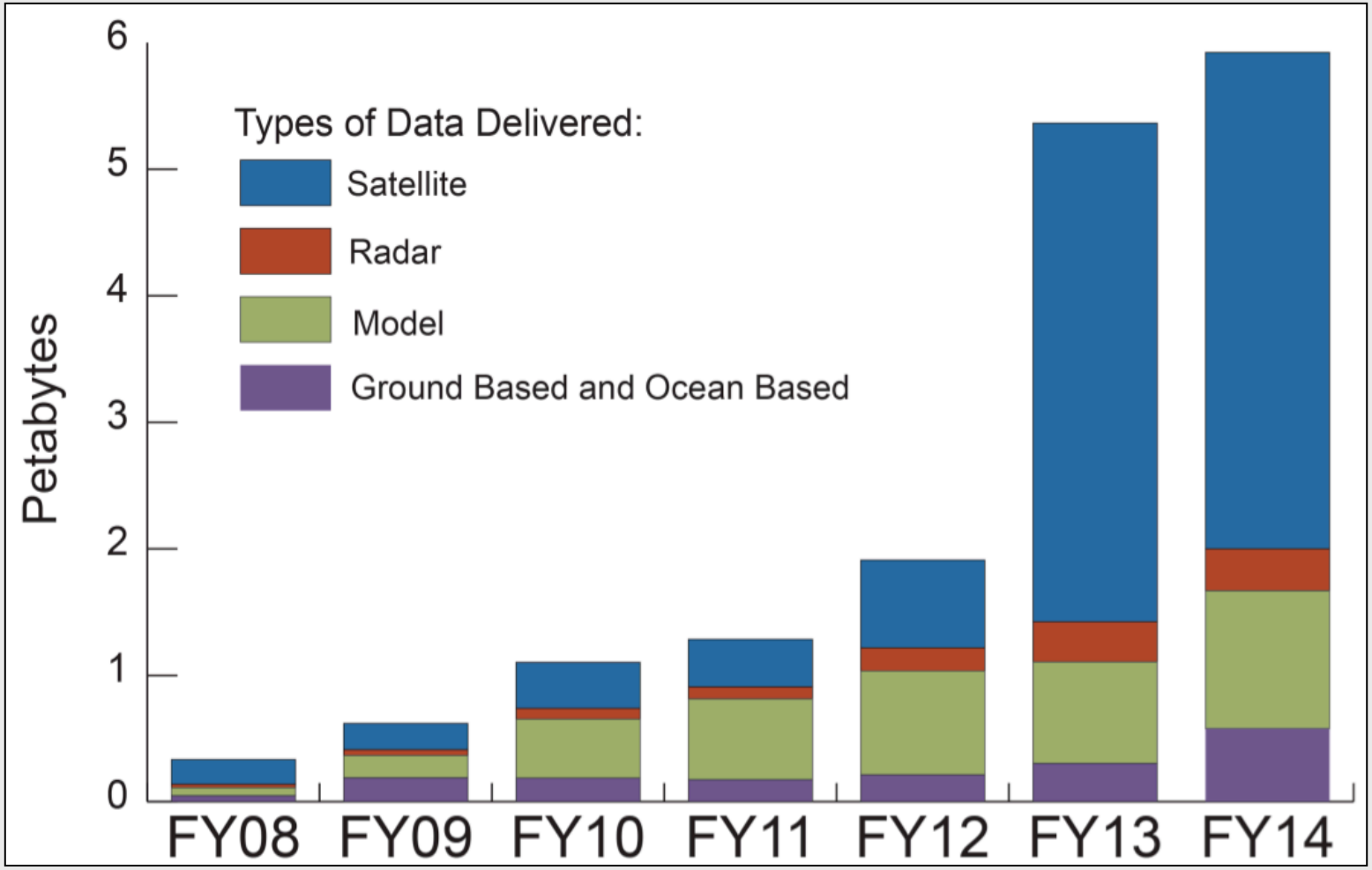
Monitoring Climate Variables
(Operational Production of Climate Products)

- *Data systems needed to facilitate user access to climate products, metadata, and raw data, including key data for delayed-mode analysis, should be established and maintained*

- JPSS raw data accessible
  - Raw Data Records (RDRs) accessible from CLASS; includes metadata
  - STAR's Integrated Calibration/Validation System (ICVS) provides historical information on instrument performance
  - STAR also has a vault of all the artifacts (look up tables, quality assessments, etc.) - Look up tables are also stored in CLASS.

- The ATMS and CrIS team's have demonstrated reprocessing the SDRs from the RDRs because volumes are relatively small.

Monitoring Climate Variables
(Operational Production of Climate Products)



Monitoring Climate Variables
(Complementary *in situ* Observations)

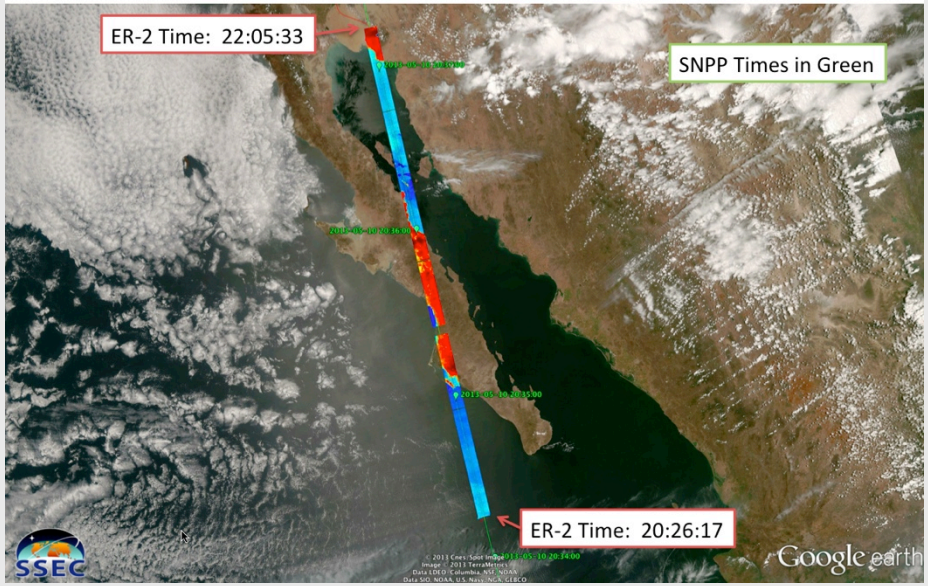
- *Complementary in situ baseline observations for satellite measurements should be maintained through appropriate activities and cooperation*

- JPSS provides support for key *in situ* observations – including dedicated satellite coincident radiosondes (supports GRUAN launches from Beltsville and dedicated DOE satellite coincident radiosondes, some Aerosol Robotic Network (Aeronet) measurements, and significant investment in Marine Optical Buoy (MOBY) program

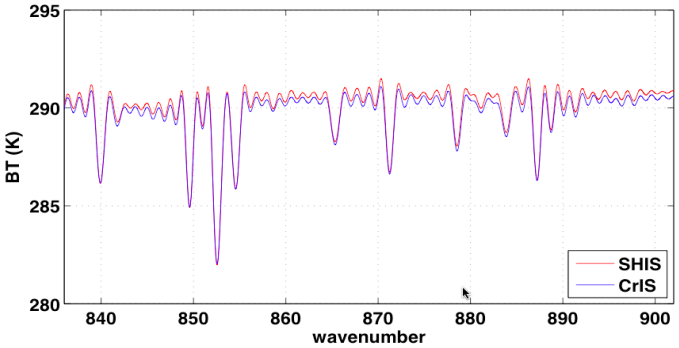
- CrIS compared with airborne interferometer on NASA's ER-2 – airborne instrument tied to SI reference (NIST)
  - Aircraft campaigns show absolute accuracy between 0.1 – 0.2C
  - Larger biases over cold regions require additional analysis

Monitoring Climate Variables
(Complementary *in situ* Observations)

S-HIS 895-900 cm^{-1} (280 – 320K)
over VIIRS Imagery



Zero-th Order S-HIS / CrIS comparison:
Window region comparison. Same spectral resolution.



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- ER-2 with aircraft validation sensors under flies Suomi NPP sensors
  - Validation sensor is Scanning High-resolution Interferometer Sounder (S-HIS)
  - Tied to NIST traceable calibration source

Monitoring Climate Variables
(Random Errors and Time-Dependent Biases)

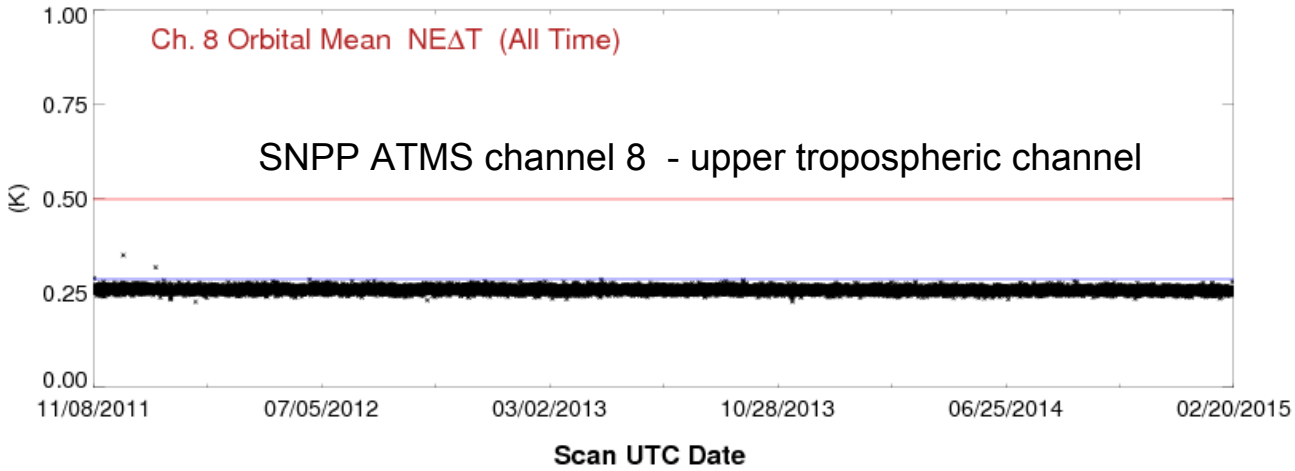
- *Random errors and time-dependent biases in satellite observations and derived products should be identified*

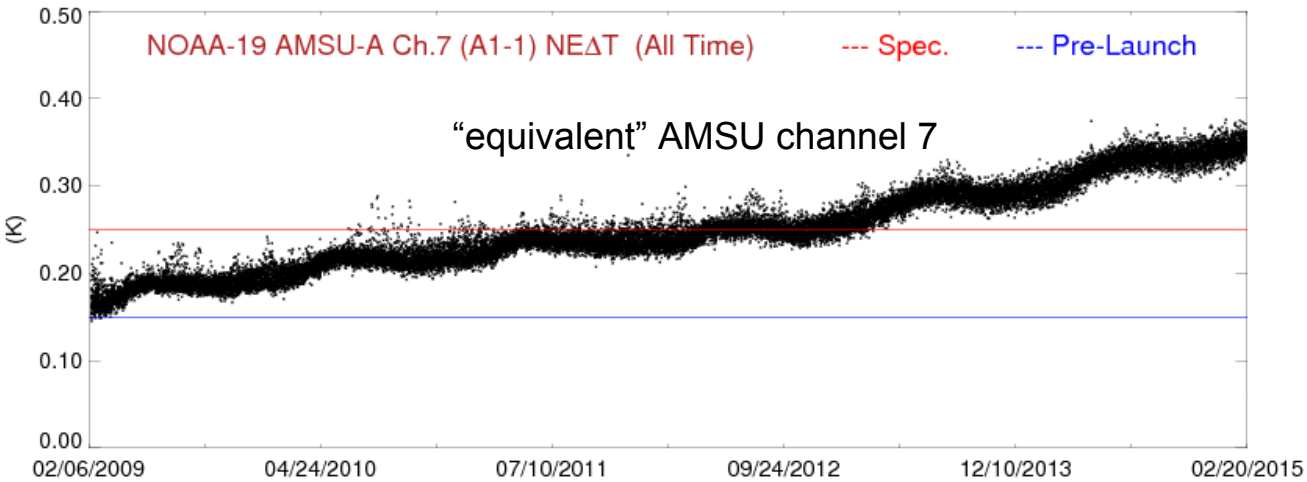
- The STAR ICVS system provides trending of all instrument parameters.

- STAR provides inter-calibration via simultaneous nadir observations via Global Space-based Inter-Calibration System (GSICS) and routinely compares ATMS upper channels with GPS-RO.

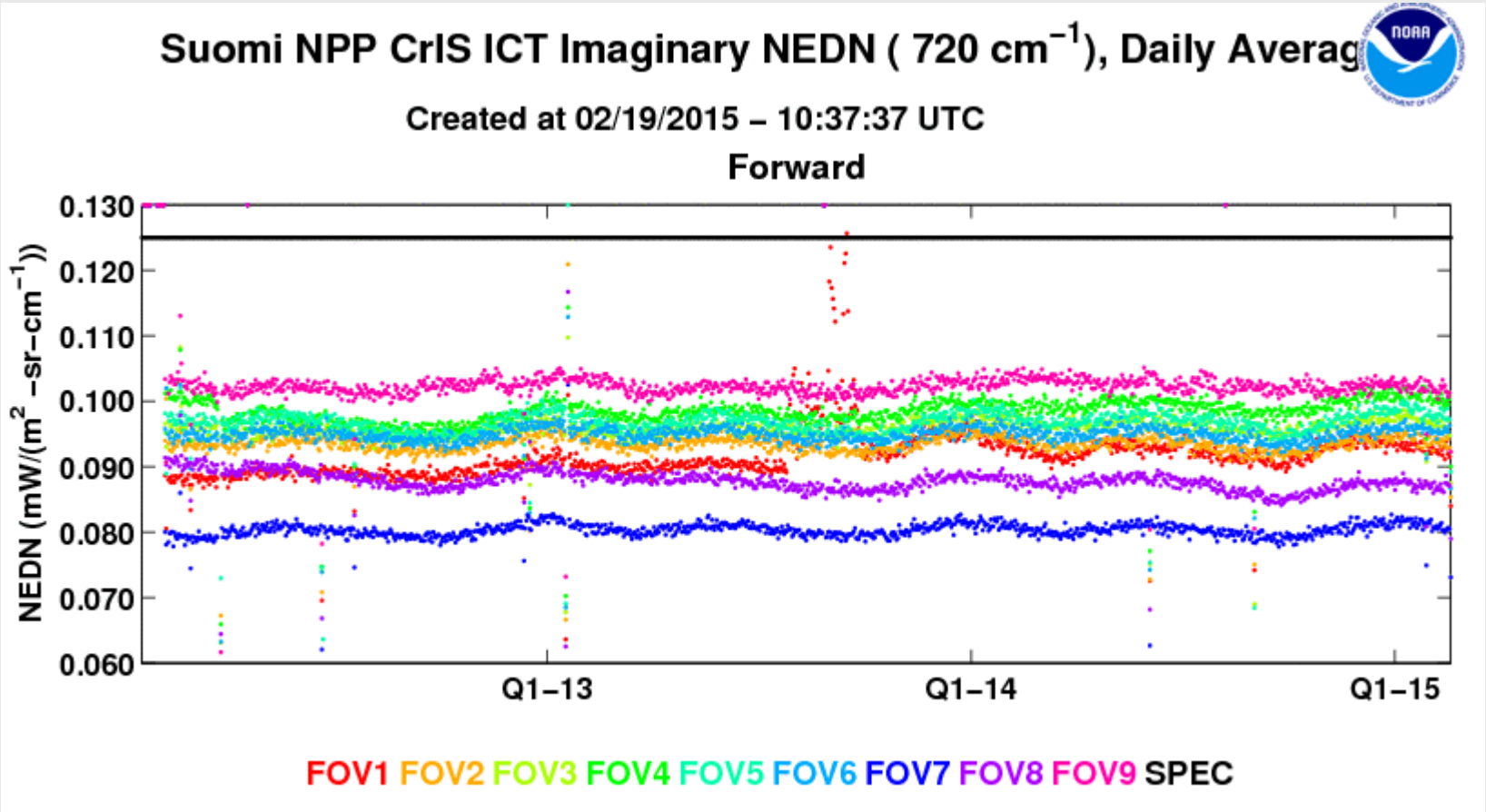
- STAR and NWP centers automatically generate differences with simulated values from forecasts – which gives an indication if there is drifting.

JPSS Overview
(Actual Performance)



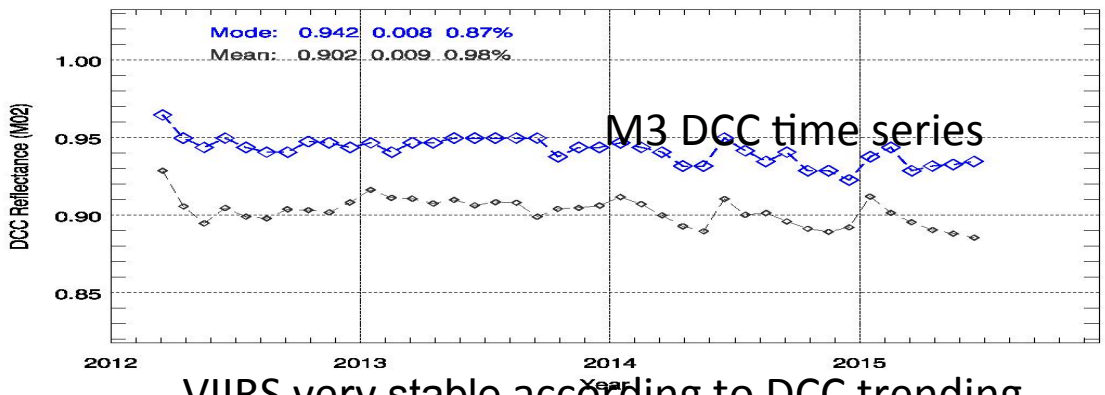


JPSS Overview
(Actual Performance)

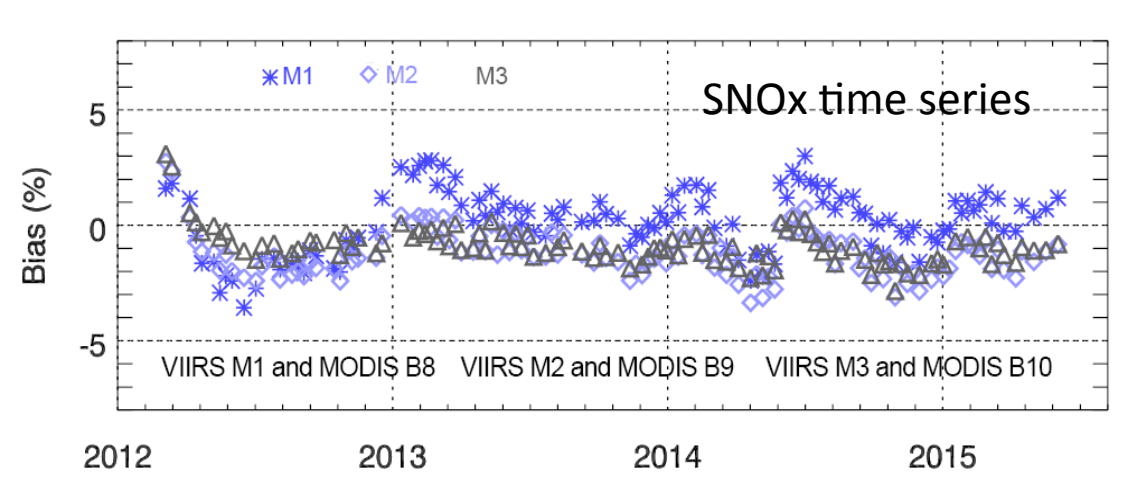


Monitoring Climate Variables
(Actual Performance)

- VIIRS calibration is closely monitored at 30+ cal/val sites worldwide
- Time series shows the calibration is very stable, and accurate (better than the +/-2% spec);
- Comprehensive calibration & monitoring include monthly maneuvers such as lunar cal, as well as DNB offset and gain transfer



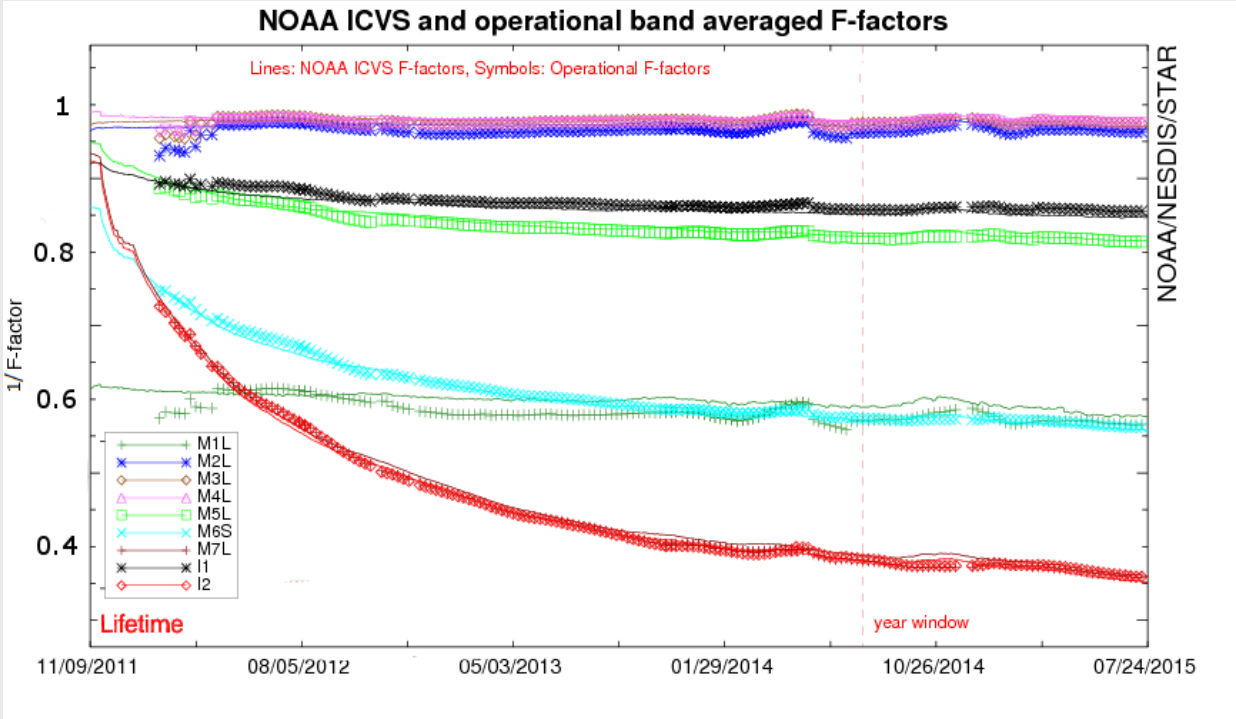
VIIRS very stable according to DCC trending



VIIRS very accurate when compared to MODIS

Monitoring Climate Variables
(Actual Performance)

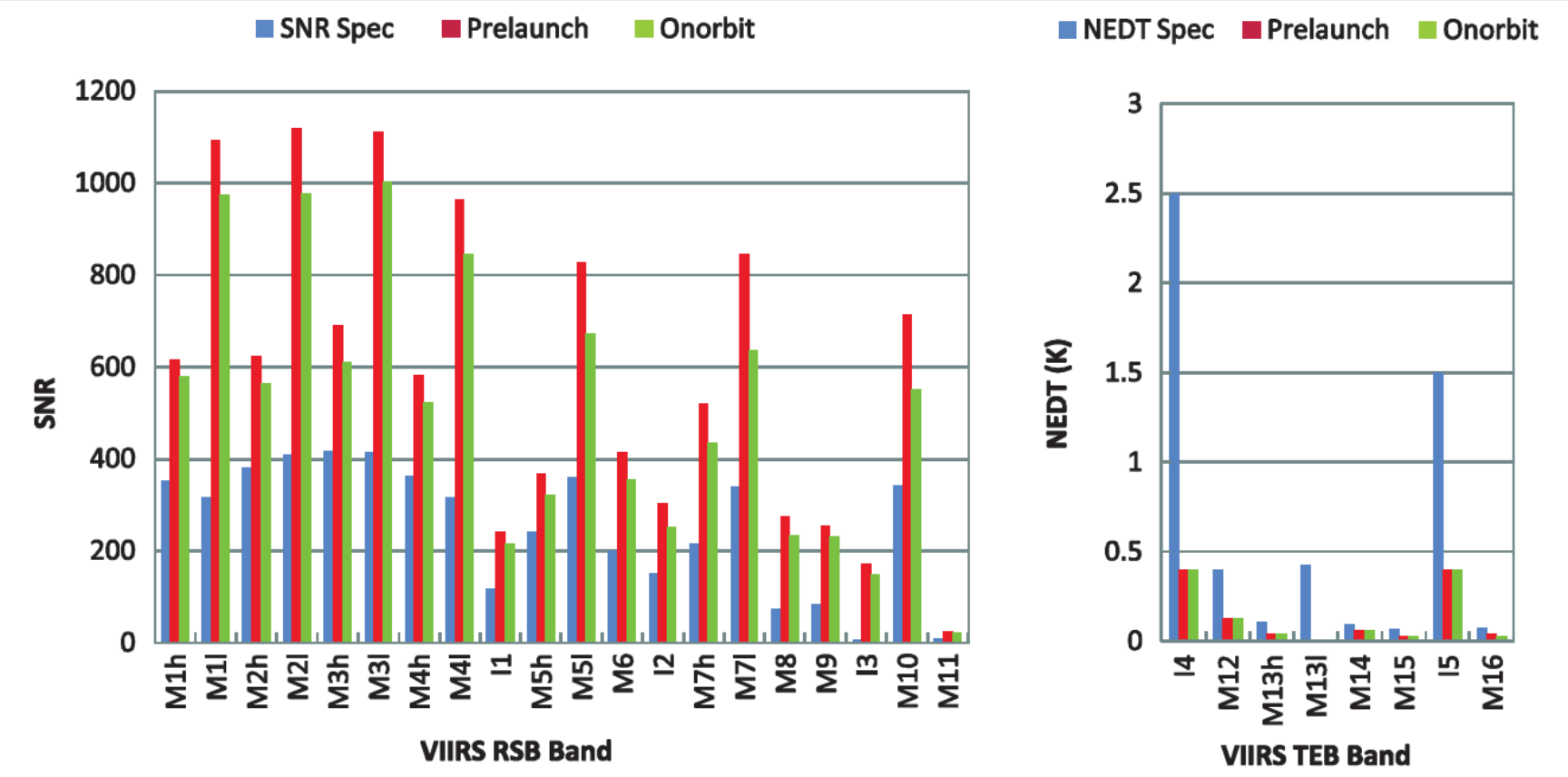
- Rotating Telescope Assembly (RTA) mirror degradation was a major anomaly, due to prelaunch contamination
- Band M7 has the largest degradation (~70%) since launch



- The degradation rate has become negligible since a year ago;
- The VIIRS SDR team actively maintains the calibration to compensate for the degradation;
- Impact on users are only limited to early orbits during beta maturity.

Monitoring Climate Variables
(Actual Performance)

- Initial on-orbit SNR/NEDT by band

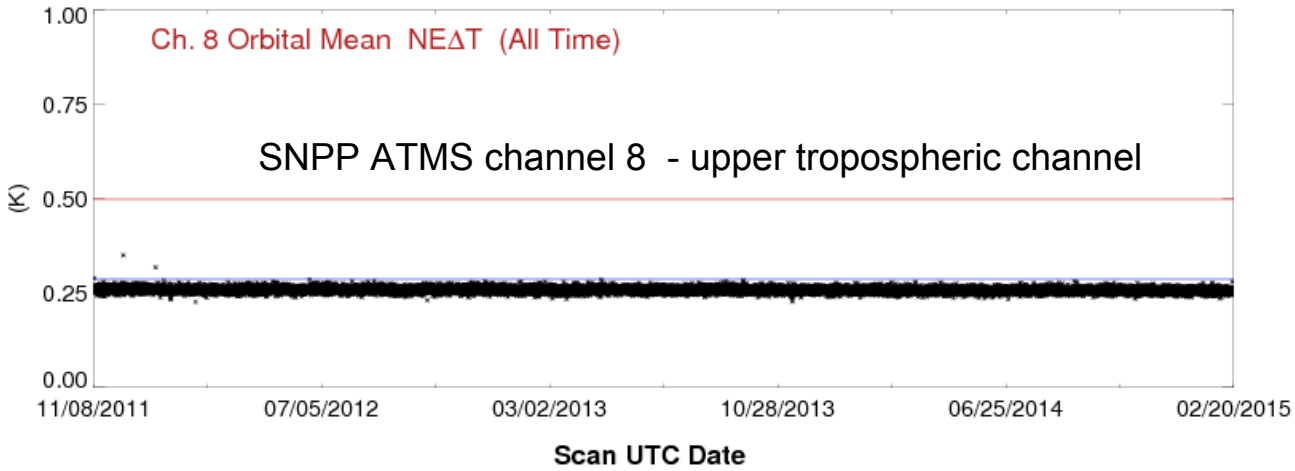


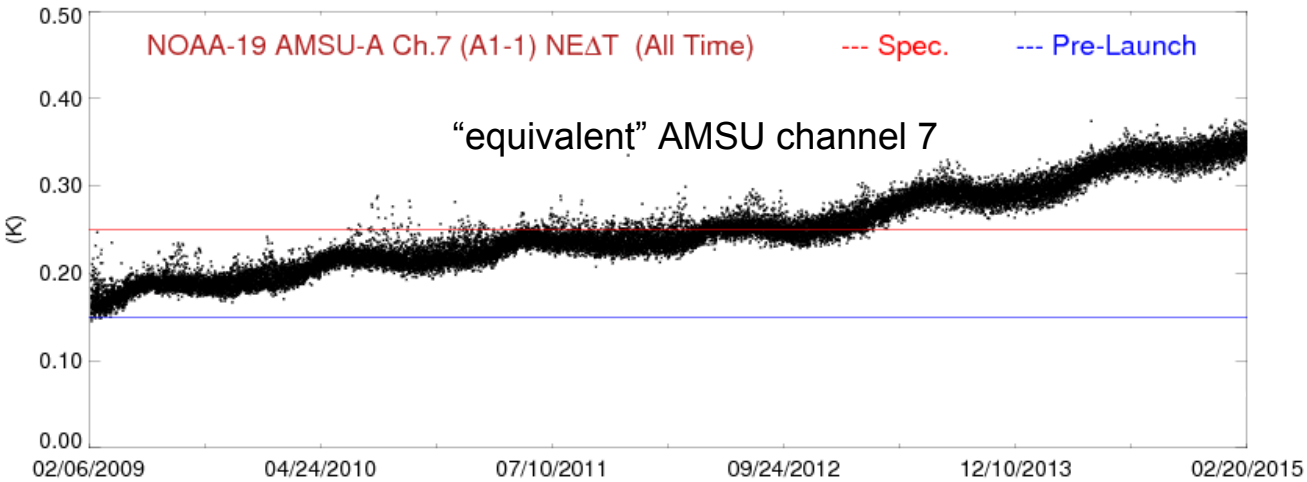
Summary

- S-NPP performing well
- JPSS on track and within budget
- Capabilities and activities designed to support improved weather forecasting also support climate monitoring
  - JPSS supports maximizing utilization and effectiveness of its observations and is committed to maintaining data product quality
  - While JPSS does not have a charter to address climate, it still wants feedback from all users so that use of its data can be maximized

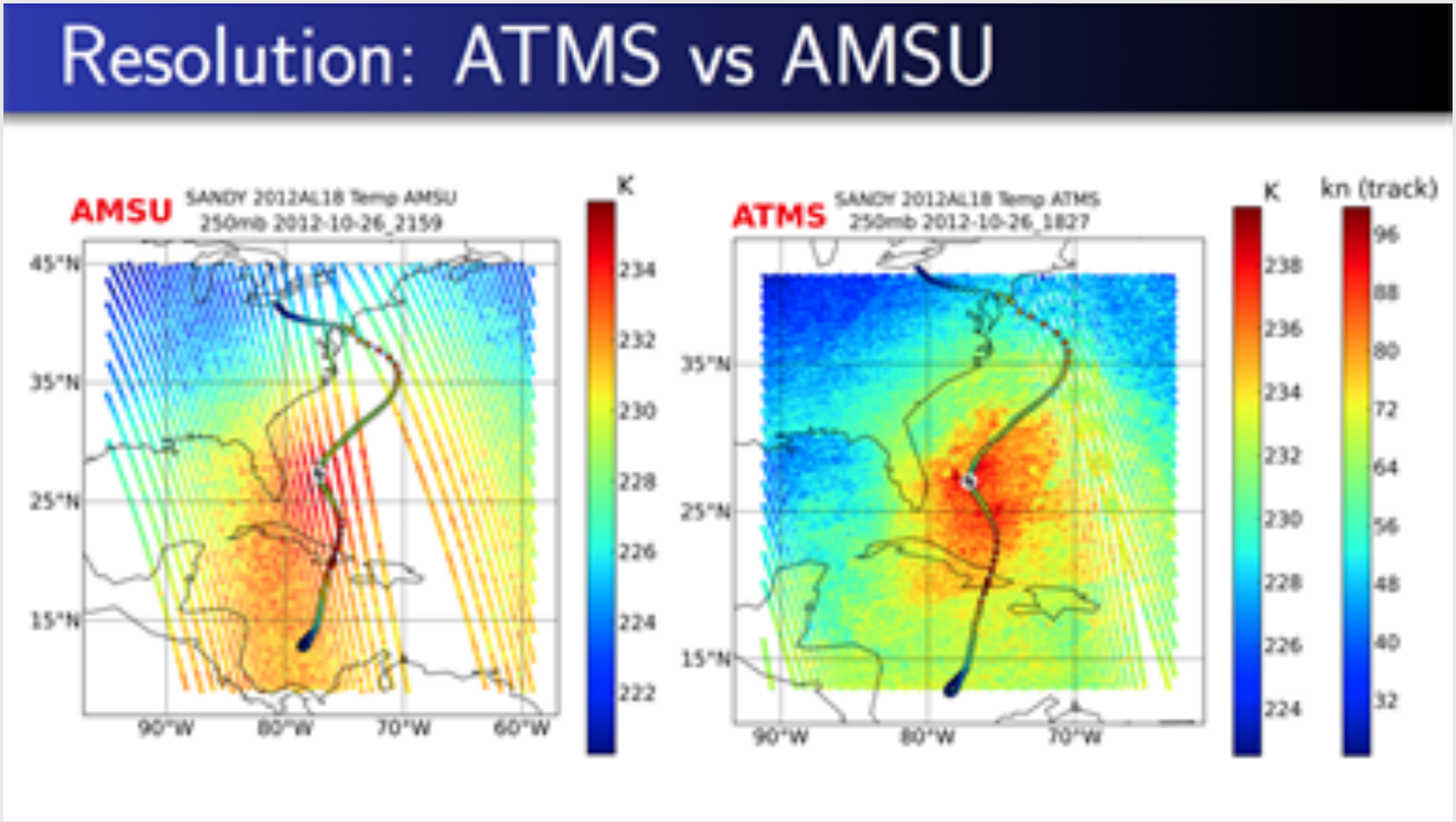
Backup

JPSS Overview
(Quality)





JPSS Overview
(Quality)



JPSS Overview
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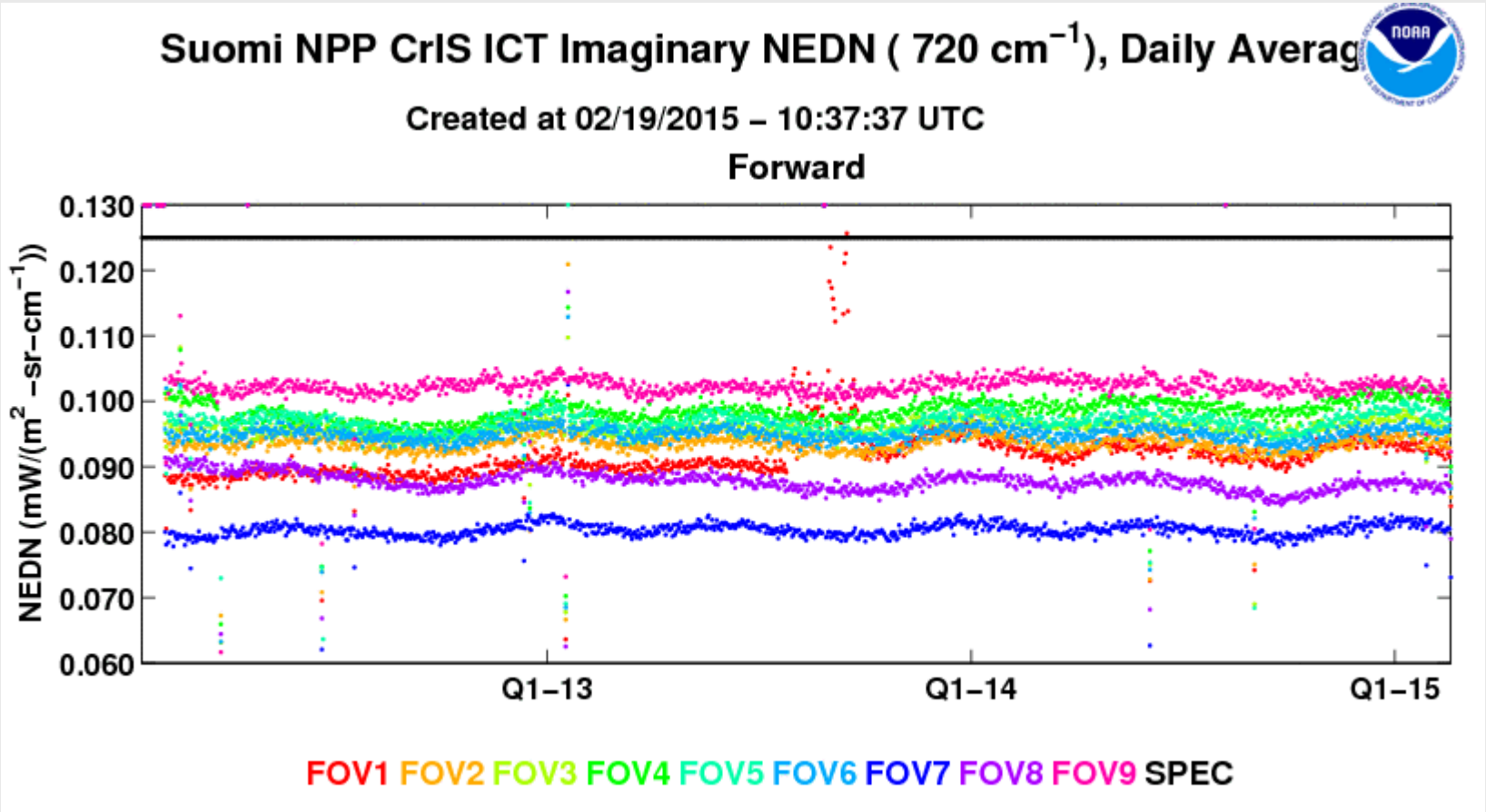
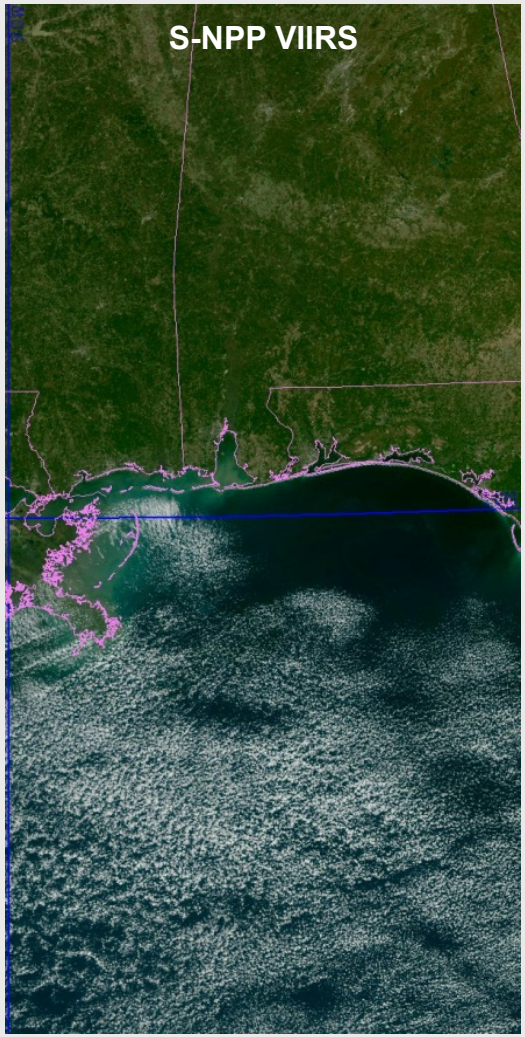
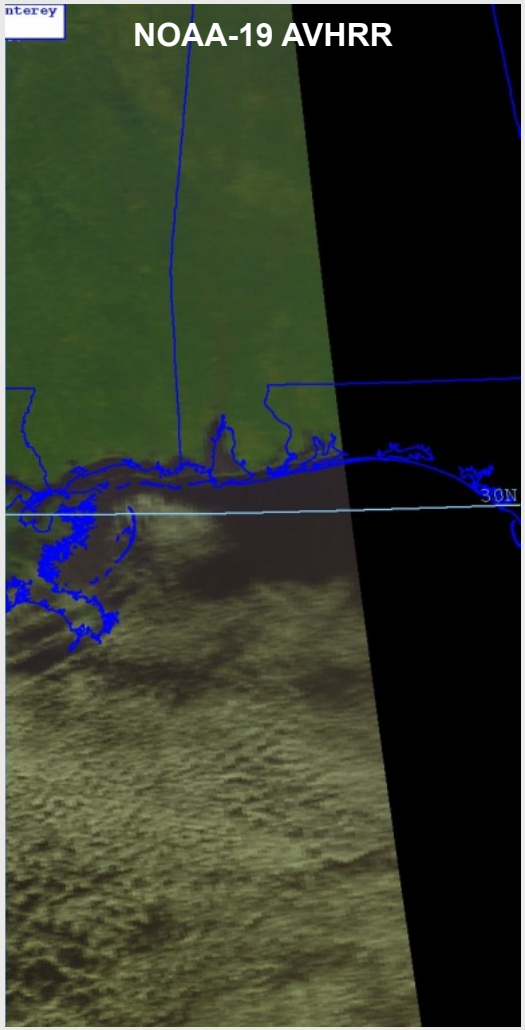


JPSS Overview
(Quality)

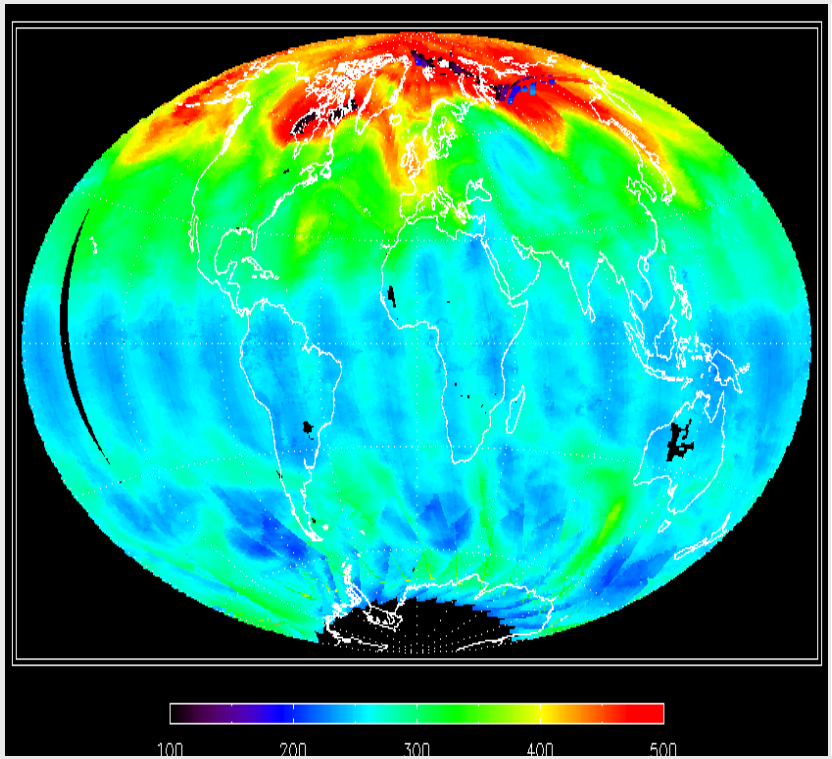
- Spectral and spatial resolution improvement
- Ocean color capabilities
- Night-time visibly imagery capability
- Improvement in discriminating clouds from snow and low clouds from fog; Improved navigation and sensitivity for fire location and intensity
- Improved spatial resolution at edge-of-scan

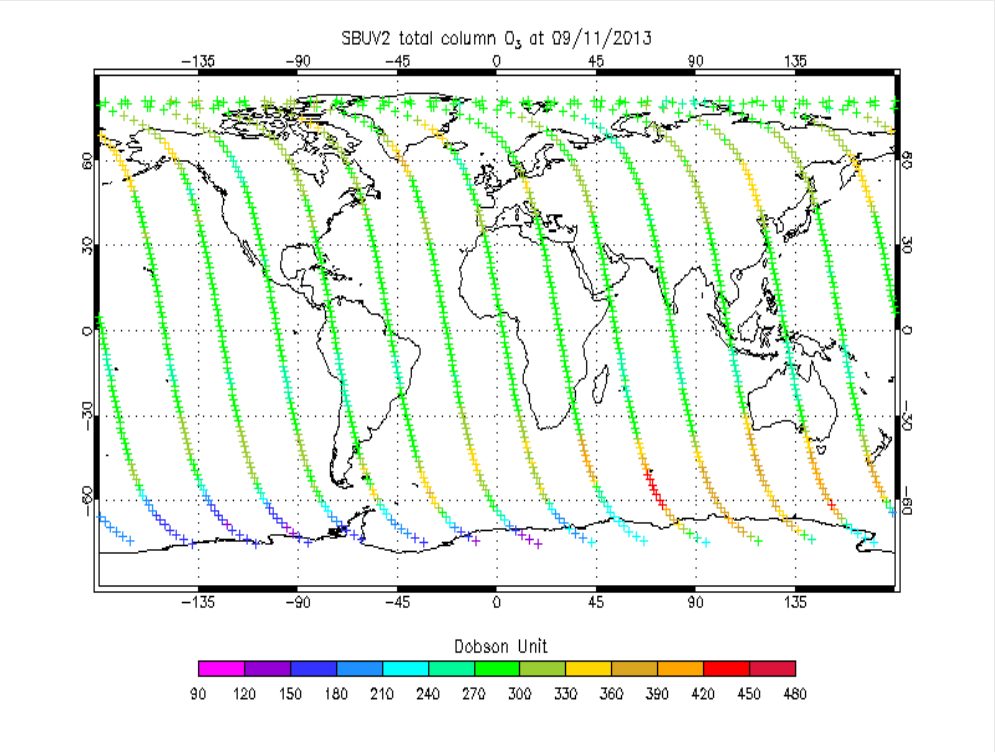




JPSS Overview
(Quality)

- OMPS resolution compared to SBUV/2





JPSS Overview
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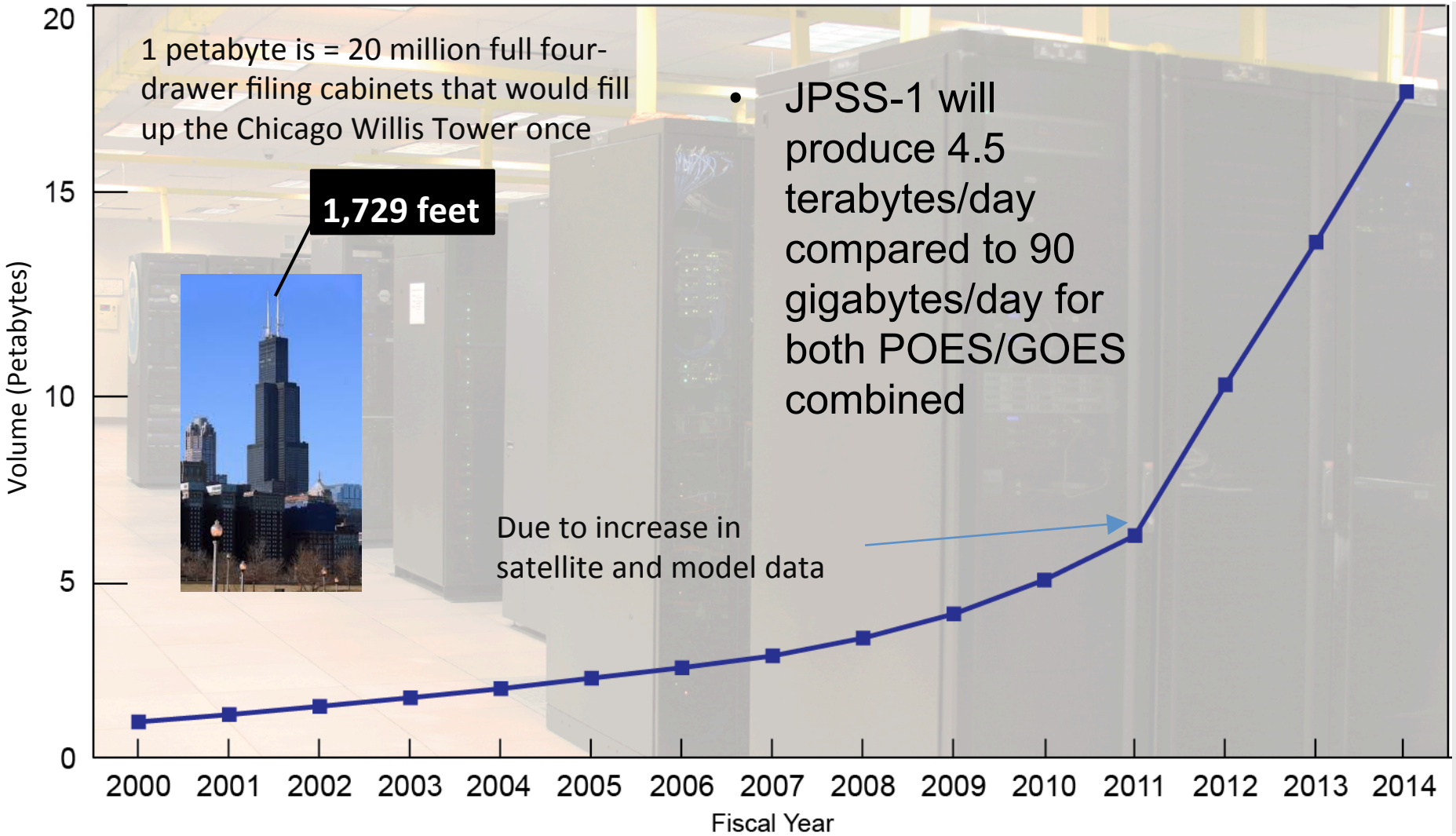
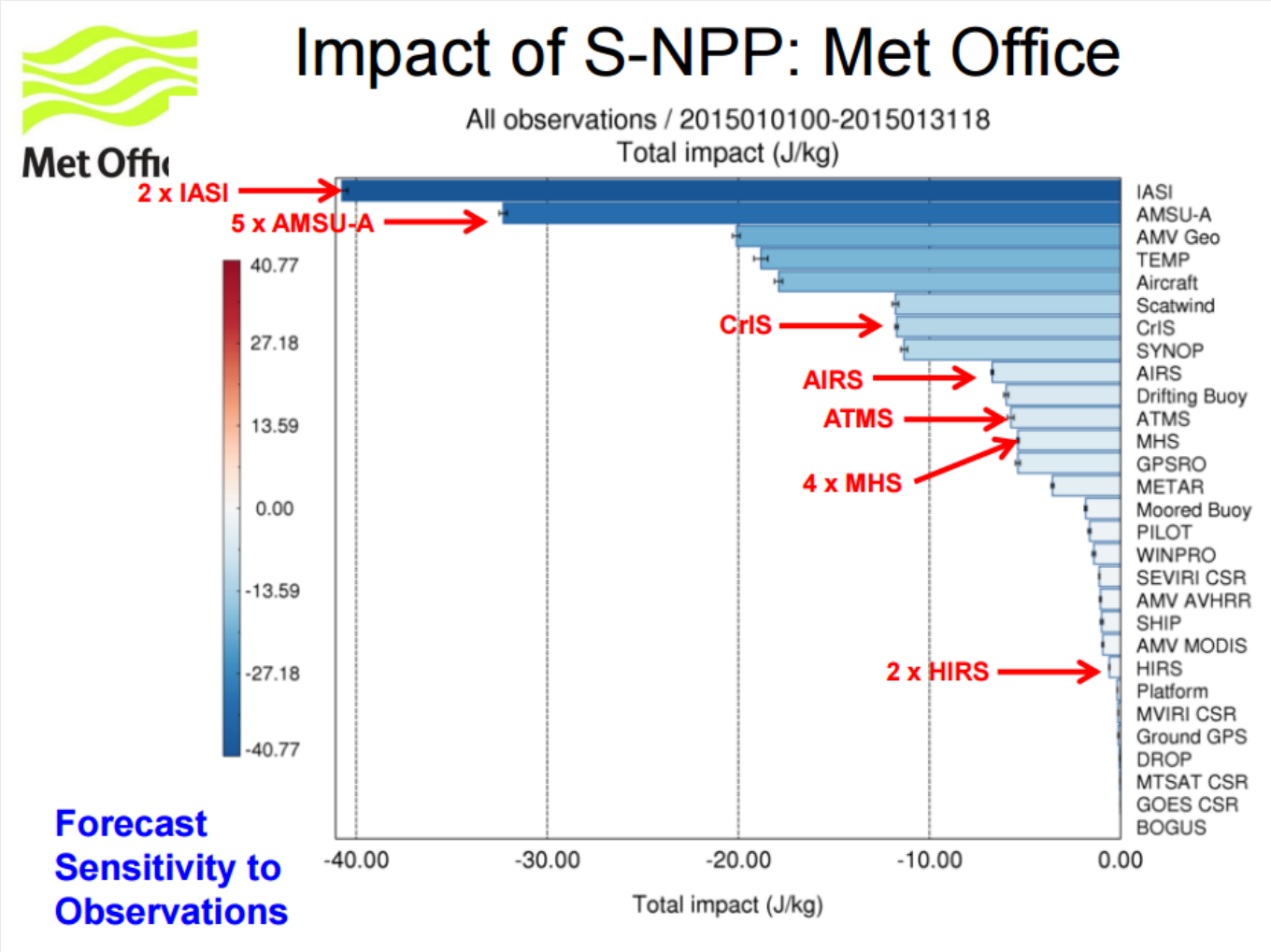


JPSS Overview

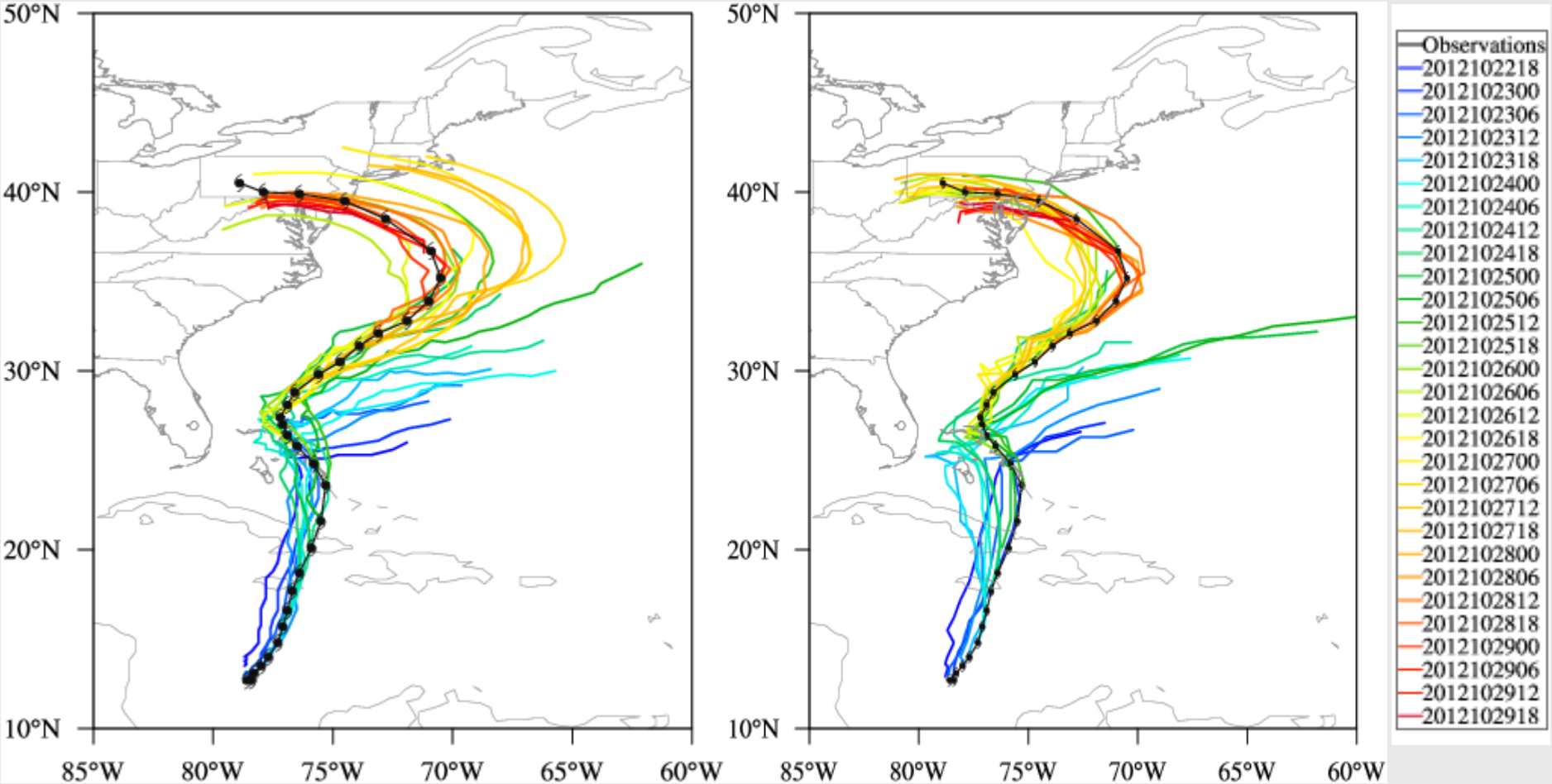
(Relevance)



JPSS Overview

(Relevance)

HWRF-NCEP Operational | **Modified HWRF-NCEP with ATMS**



JPSS Overview
(Timeliness)

- Polar region latency improved from 2 hours to 10 minutes
- 95% of the data is expected within 50 minutes – current performance is 120 minutes
- Actual performance will be 50% better than specification (96 minutes)
- Potential for additional improvements through TDRSS