Extending the Operational Benefit of the NOAA Integrated Calibration and Validation System

Kenneth Carey[1], Fuzhong Weng[2], Ninghai Sun[1], and the STAR ICVS Team[1]

[1]ERT and NOAA/NESDIS/STAR, [2]NOAA/NESDIS/STAR

NOAA's Mission Supports Collaboration

NOAA is a science-based services agency engaged with the entire Earth system science enterprise.

NOAA's Top Four Priorities:

1. To provide information and services to make communities more resilient
2. To evolve the National Weather Service
3. To invest in observational infrastructure
4. To achieve organizational excellence

Weather-Ready Nation – Saving Lives

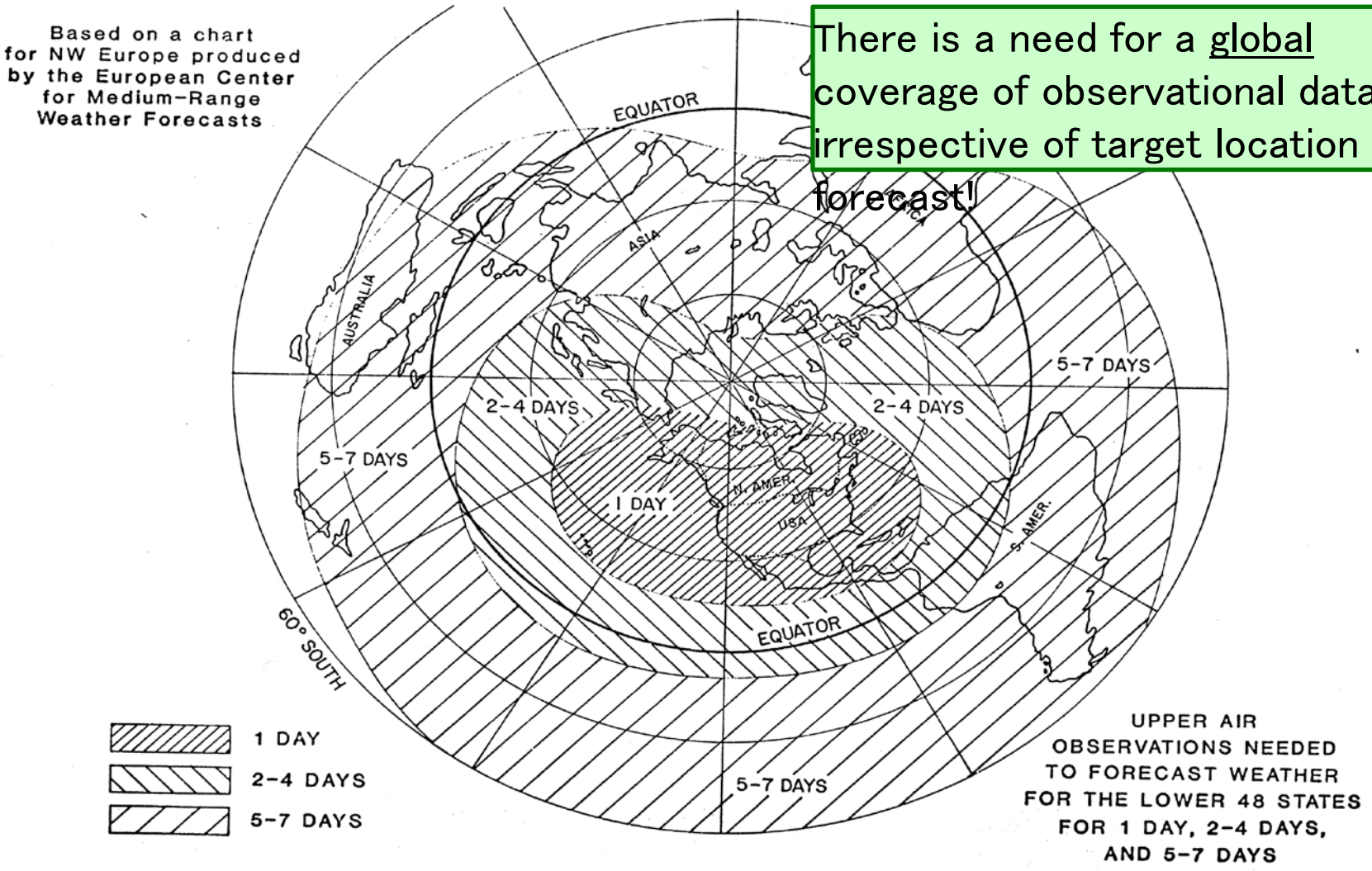
NOAA's Weather-Ready Nation is about building community resilience in the face of increasing vulnerability to extreme weather and water events.


Tornado moving west of Manitou, OK, on November 7, 2011.

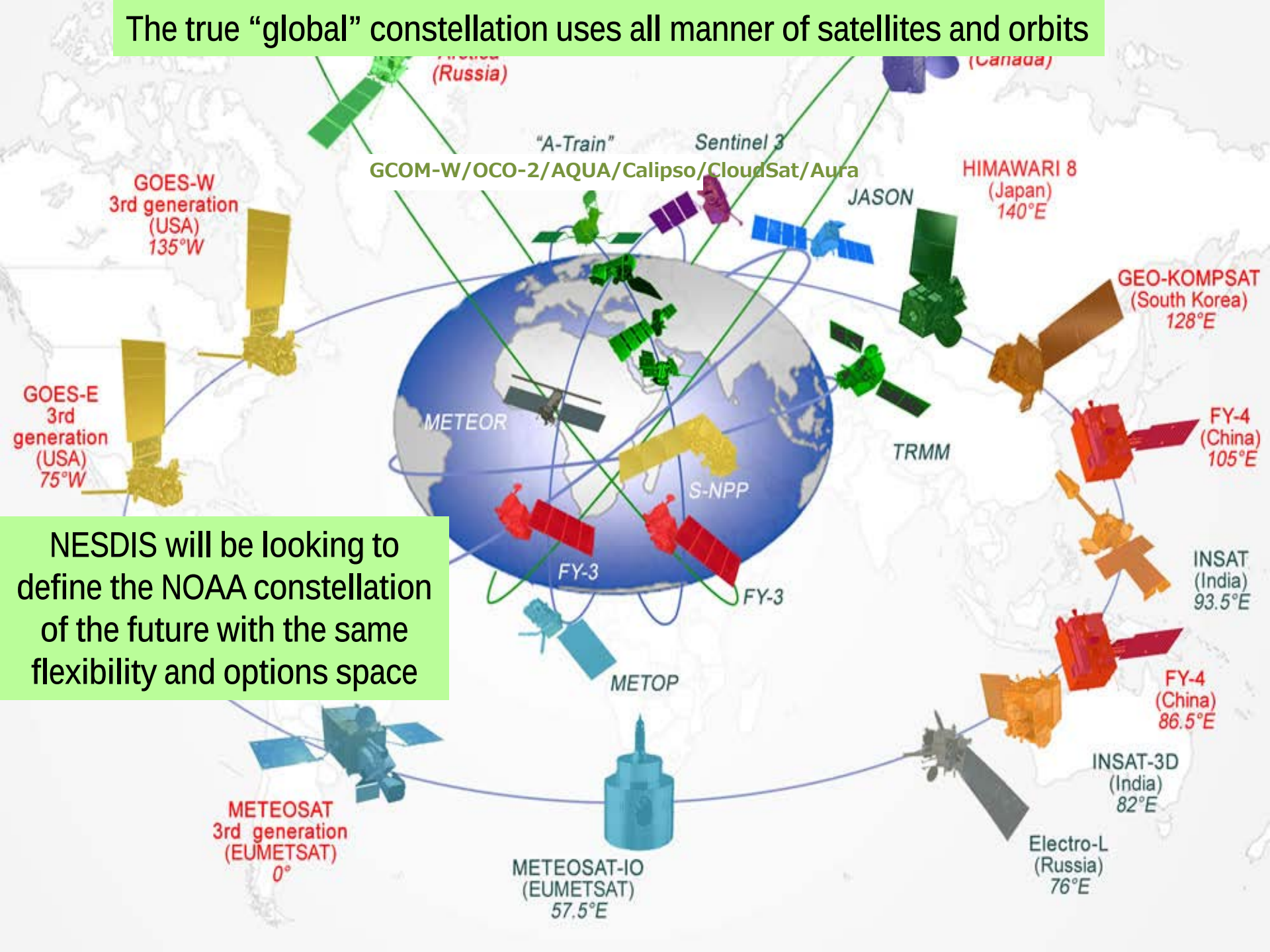
Record-breaking snowfall, cold temperatures, extended drought, high heat, severe flooding, violent tornadoes, and massive hurricanes have all combined to reach the greatest number of multi-billion dollar weather disasters in the nation's history.

Socio-economic Value of Satellite Data

There is a need for a <u>global</u> coverage of observational data, irrespective of target location of forecast!



The true "global" constellation uses all manner of satellites and orbits



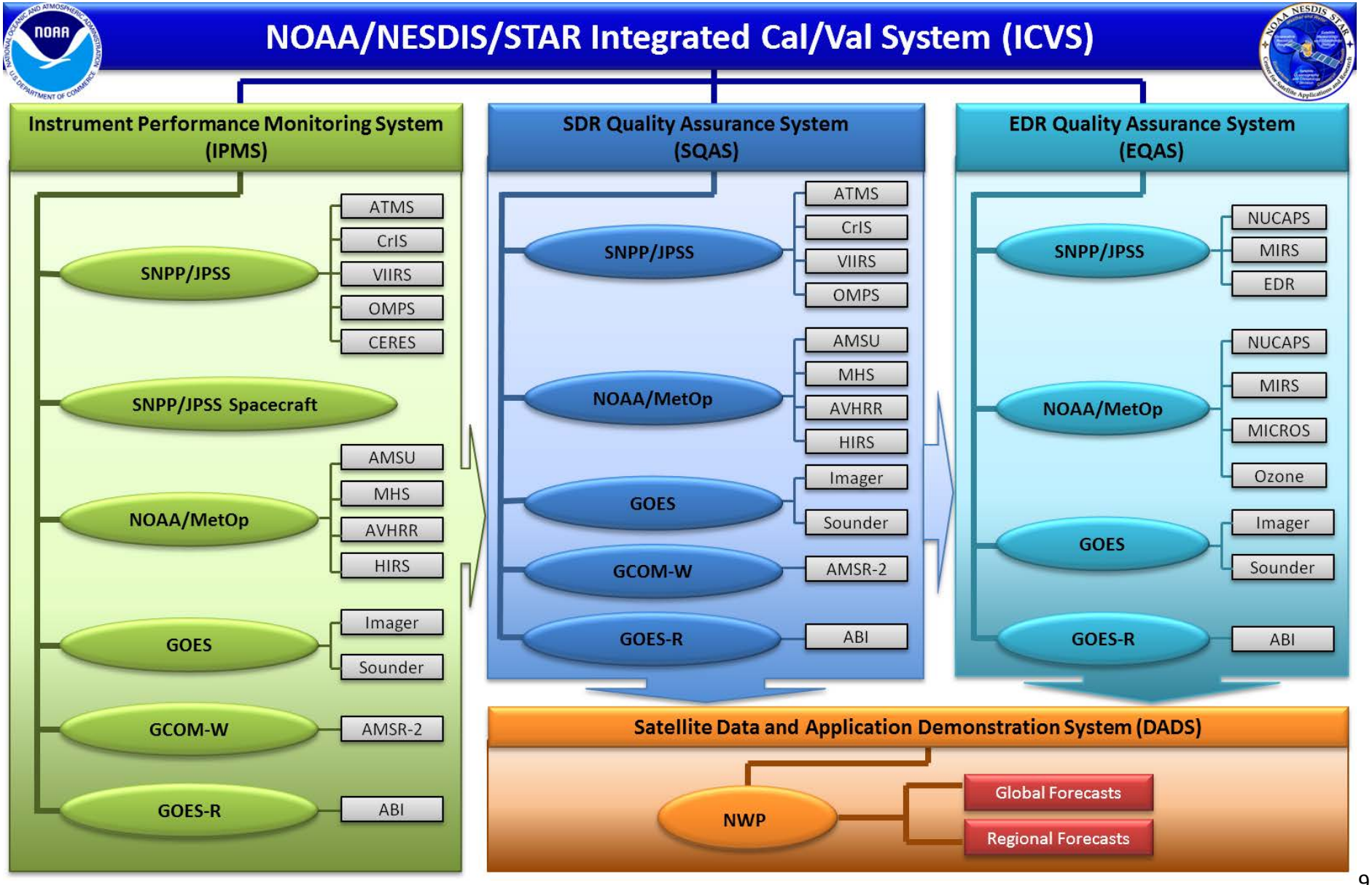
NESDIS will be looking to define the NOAA constellation of the future with the same flexibility and options space

Center for Satellite Applications and Research

- *STAR provides NOAA-relevant applied research, development, and science services to accelerate the transition and transformation of raw satellite observations into operational information products that support environmental assessments and predictions by NOAA land, atmosphere and ocean user communities.*

  - Leads NESDIS research, development, validation and maintenance of satellite derived products and applications from NOAA's operational geostationary and polar-orbiting satellites and from non-NOAA research and international satellites
  - Develops new environmental applications, techniques and algorithms for transforming raw satellite observations into scientifically meaningful, quality assured and calibrated environmental measurements and products, and develops the pre-operational computer codes to implement them;
  - Works with other NESDIS and NOAA offices, universities, NASA and other U.S. agencies, and with international organizations on exchange and evaluation of operational and research satellite data and products;
  - Interfaces with NESDIS and NOAA operational organizations to improve the use of satellite data in operations, accelerating the transfer of new techniques and new satellite data sources (domestic or foreign) into NOAA operations to improve environmental prediction.
  - Supports the calibration and validation of all satellite sensors used in NOAA's satellite operations, develops methods and maintains systems for inter-calibrating NOAA satellite data with other agency and international satellites constellations.

STAR ICVS Structure



Benefits of STAR ICVS System

- Provide near real time and long term spacecraft and instrument health status and performance monitoring
- Provide near real time and long term SDR/EDR data product quality monitoring
- Provide real time support for sensor calibration activities and instrument anomaly troubleshooting
- Provide quick and preliminary estimate of satellite data impact in NWP applications
- Ensure the integrity of the climate data records from broader satellite instruments

STAR ICVS IT Infrastructure

Parts	Total
Servers	12
CPU Cores	876
Memory (GB)	5156
HDD (TB)	815

STAR Internal Servers

- STAR integrated calibration/validation system (ICVS)
- Global Space-based Inter-Calibration System (GSICS)
- Daily JPSS SDR calibration/validation activities

STAR-S1
80 Cores
256 GB
135 TB

STAR-S2
80 Cores
512 GB
230 TB

STAR-S3
80 Cores
512 GB
200 TB

STAR-S4
16 Cores
256 GB
12 TB

STAR-S5
16 Cores
256 GB
12 TB

STAR-S6
8 Cores
16 GB
8 TB

STAR-S7
4 Cores
4 GB
2 TB

STAR-S8
16 Cores
768 GB
20 TB

STAR-S9
16 Cores
768 GB
20 TB

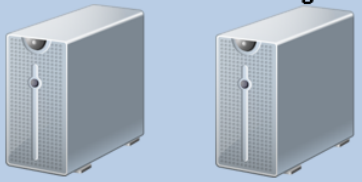
STAR CICS Cluster

- Computation intensive jobs
- NWP pre-operational testing
- Mission lifecycle data reprocess

STAR-CICS1
432 Cores
1296 GB
136 TB

UMD/AOSC Servers

- Data dissemination
- Academia research testing



STAR-UMD1
64 Cores
256 GB
20 TB

STAR-UMD2
64 Cores
256 GB
20 TB

Direct Link

Direct Link

Internet

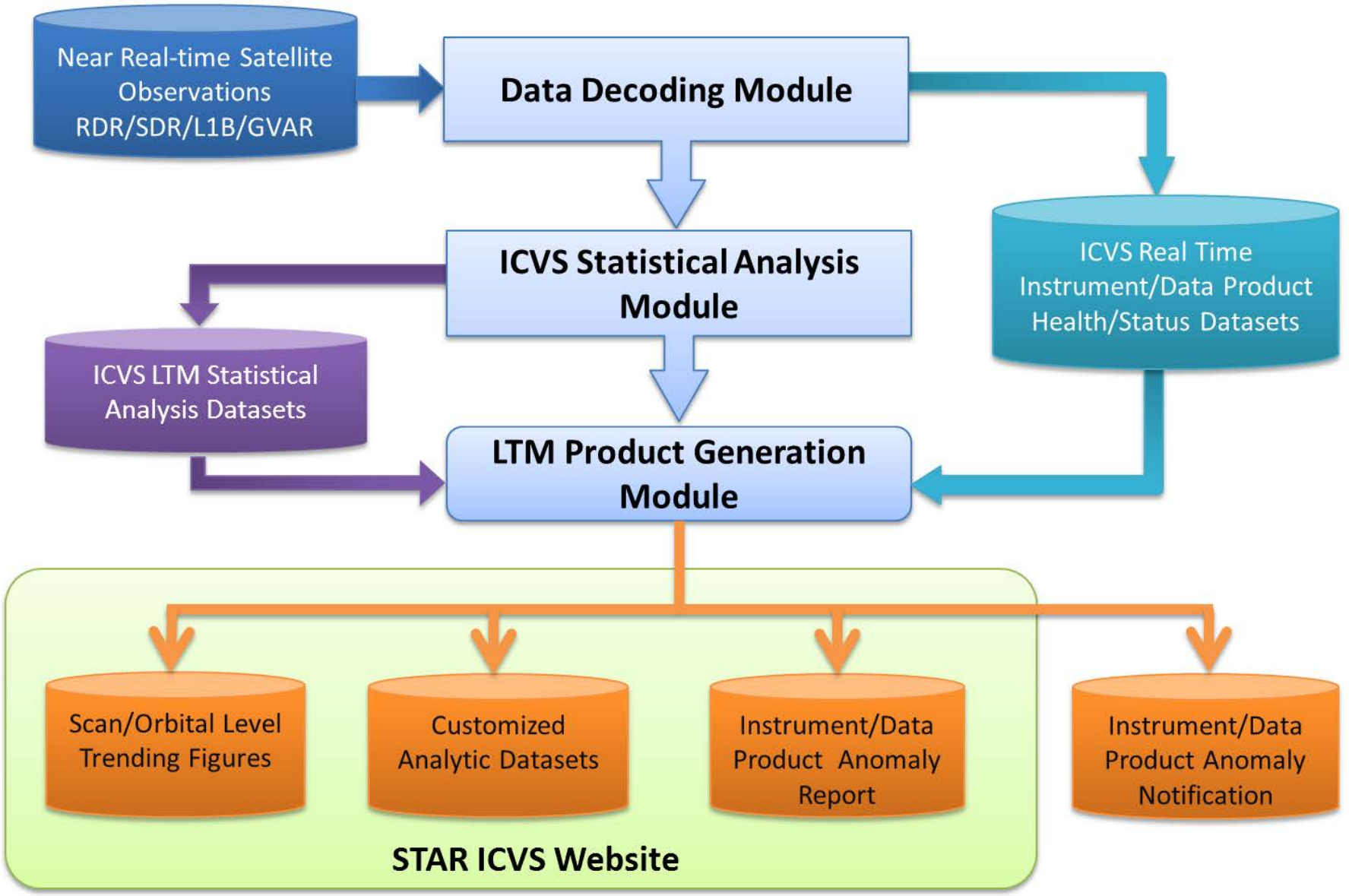
GRAVITE
Real time S-NPP/JPSS data

CLASS
Lifetime S-NPP/JPSS data

NWP Centers
NWP forecast data

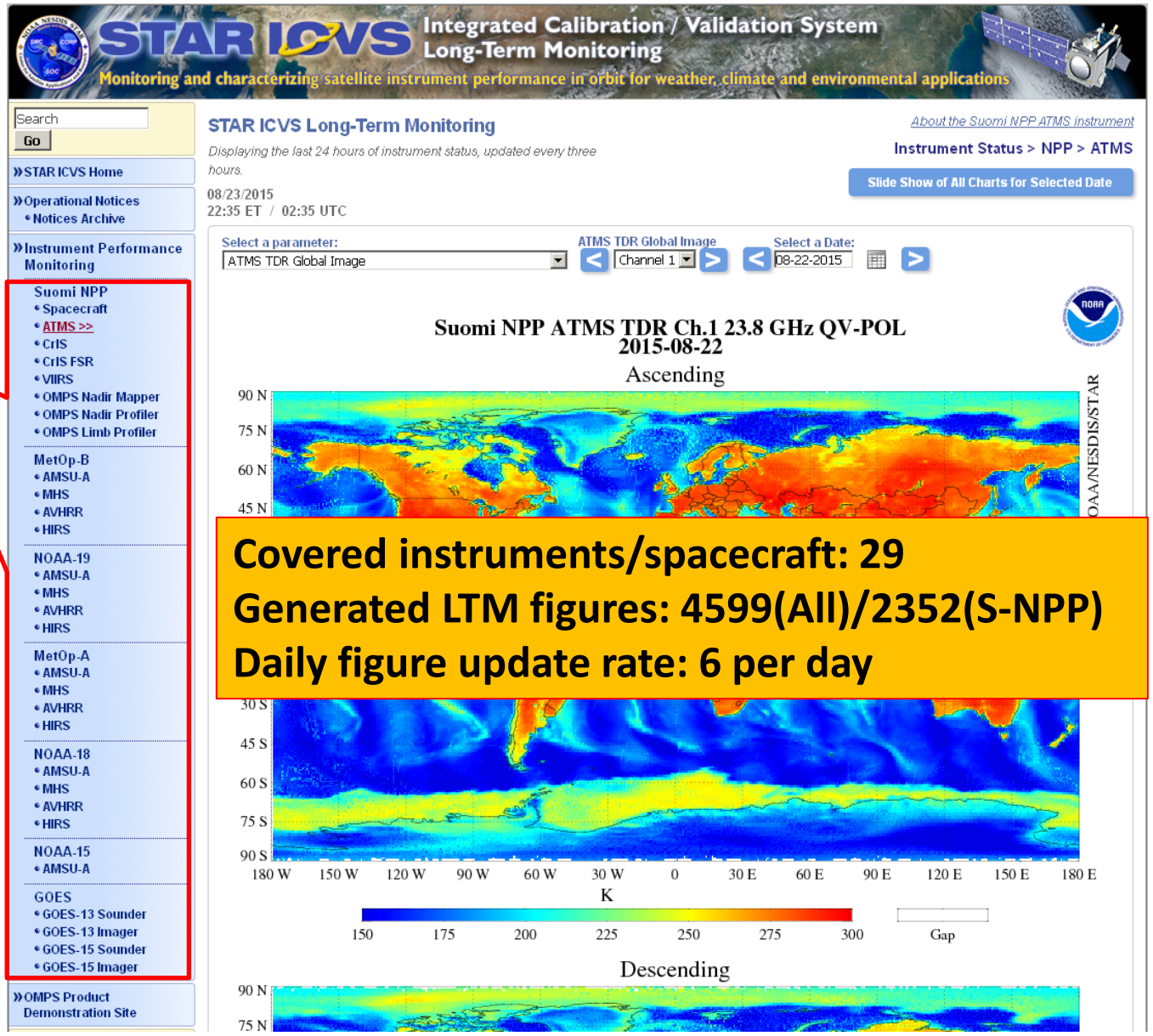
Other Data Center
Cosmic, MLS, et. al.

STAR ICVS Data Processing Flowchart



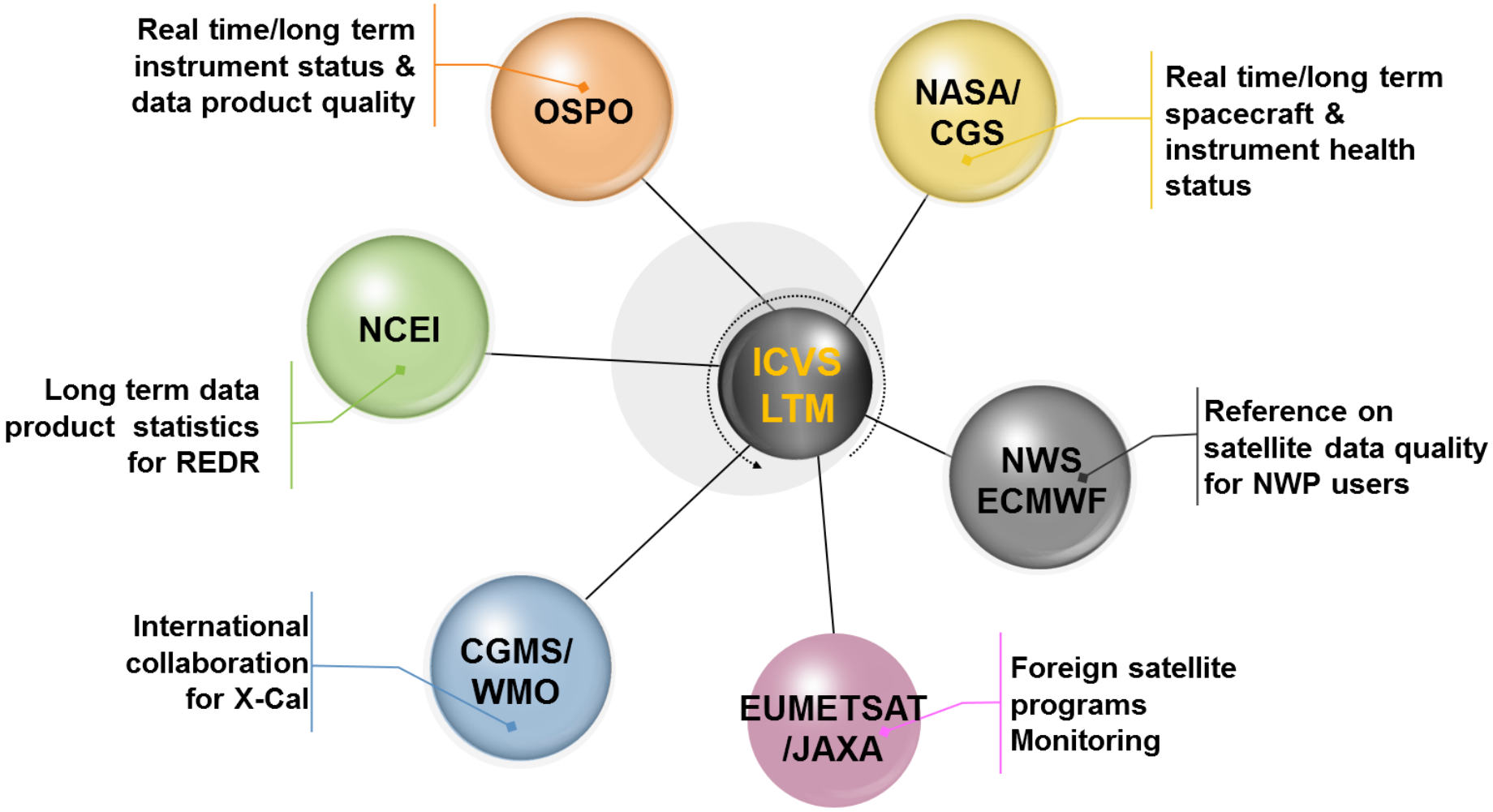
STAR ICVS Website

- Suomi NPP
  - Spacecraft
  - ATMS >>
  - CrIS
  - CrIS FSR
  - VIIRS
  - OMPS Nadir Mapper
  - OMPS Nadir Profiler
  - OMPS Limb Profiler
- MetOp-B
  - AMSU-A
  - MHS
  - AVHRR
  - HIRS
- NOAA-19
  - AMSU-A
  - MHS
  - AVHRR
  - HIRS
- MetOp-A
  - AMSU-A
  - MHS
  - AVHRR
  - HIRS
- NOAA-18
  - AMSU-A
  - MHS
  - AVHRR
  - HIRS
- NOAA-15
  - AMSU-A
- GOES
  - GOES-13 Sounder
  - GOES-13 Imager
  - GOES-15 Sounder
  - GOES-15 Imager



Covered instruments/spacecraft: 29
Generated LTM figures: 4599(All)/2352(S-NPP)
Daily figure update rate: 6 per day

STAR ICVS Users



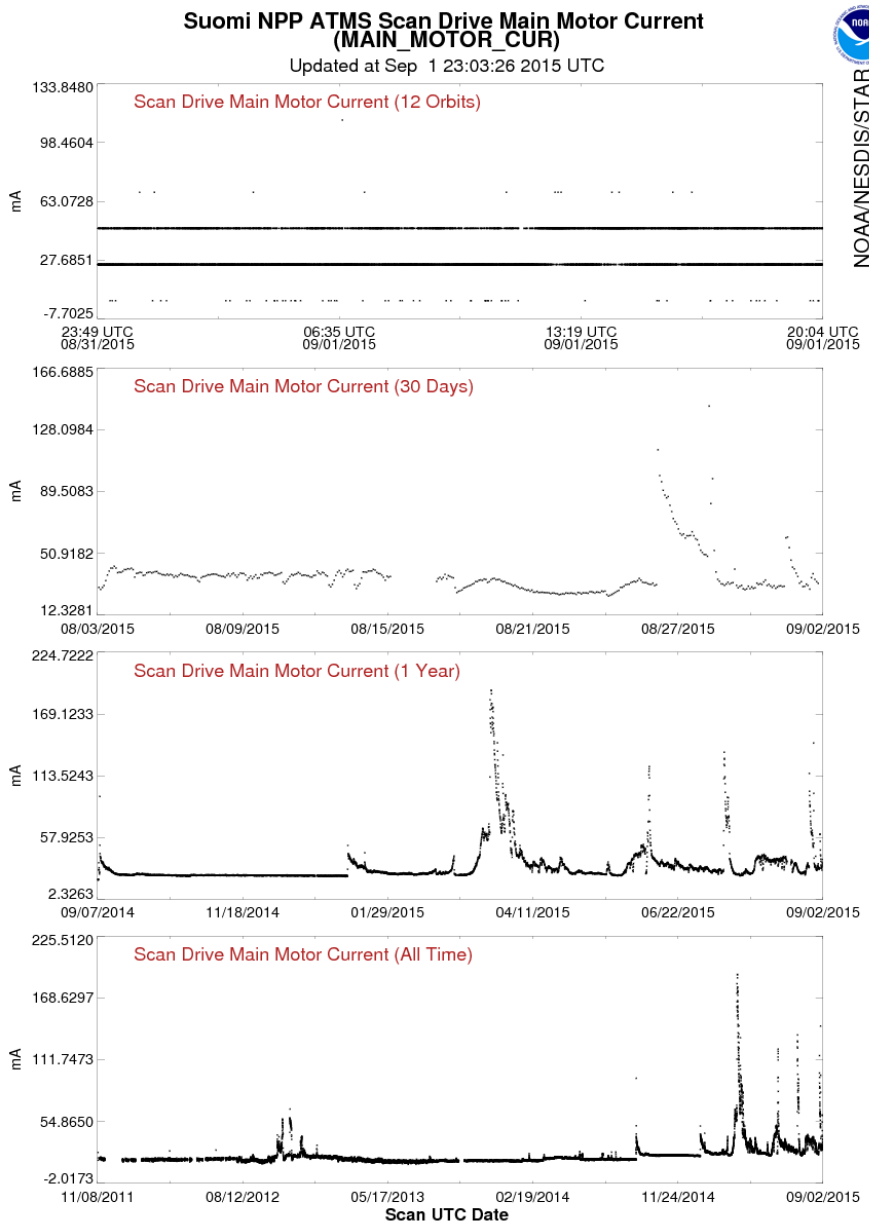
NOAA STAR ICVS are now providing more parameters for applications by broader communities including NWP. It is a very powerful tool and should be set up as a gold standard for all the space agencies to follow in satellite instrument monitoring and trending

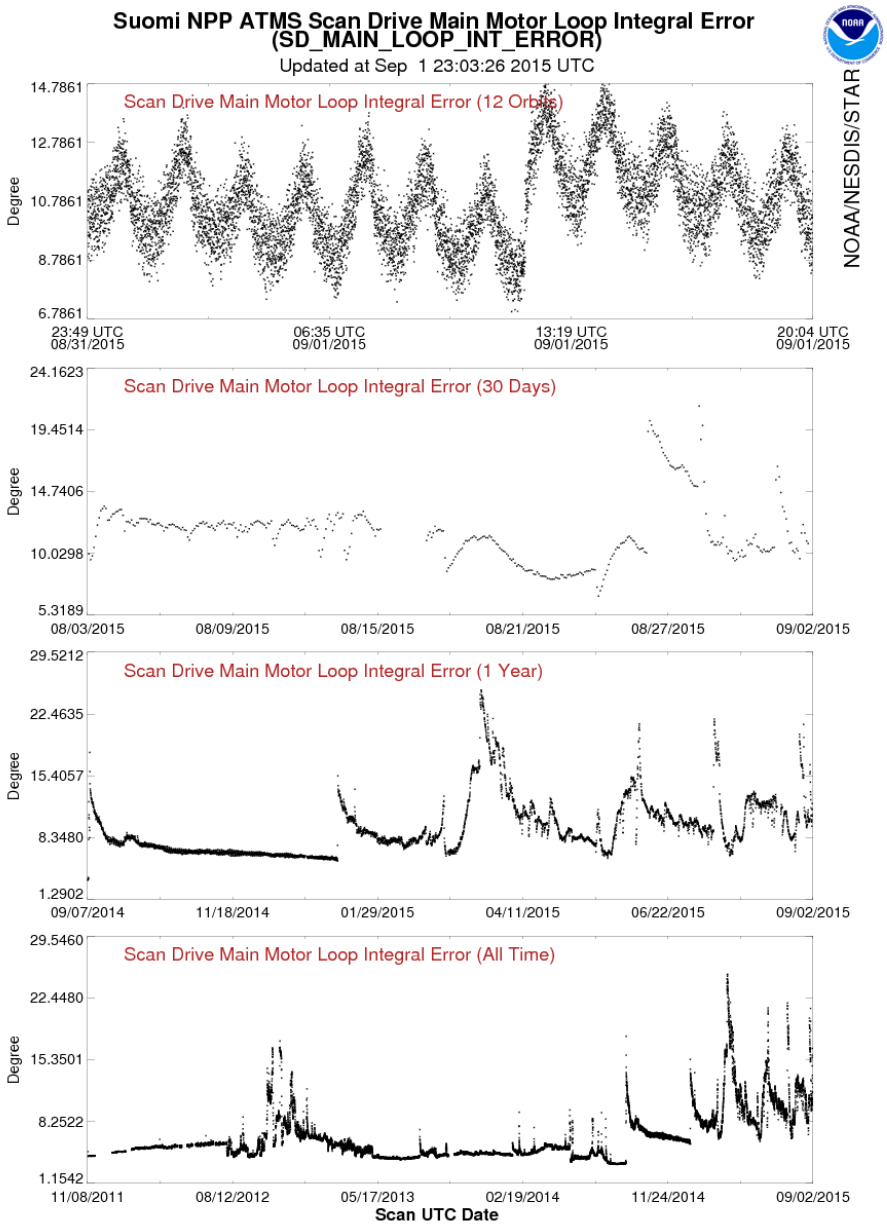
- Stephen English (ECMWF DA Head)

STAR ICVS Accomplishments

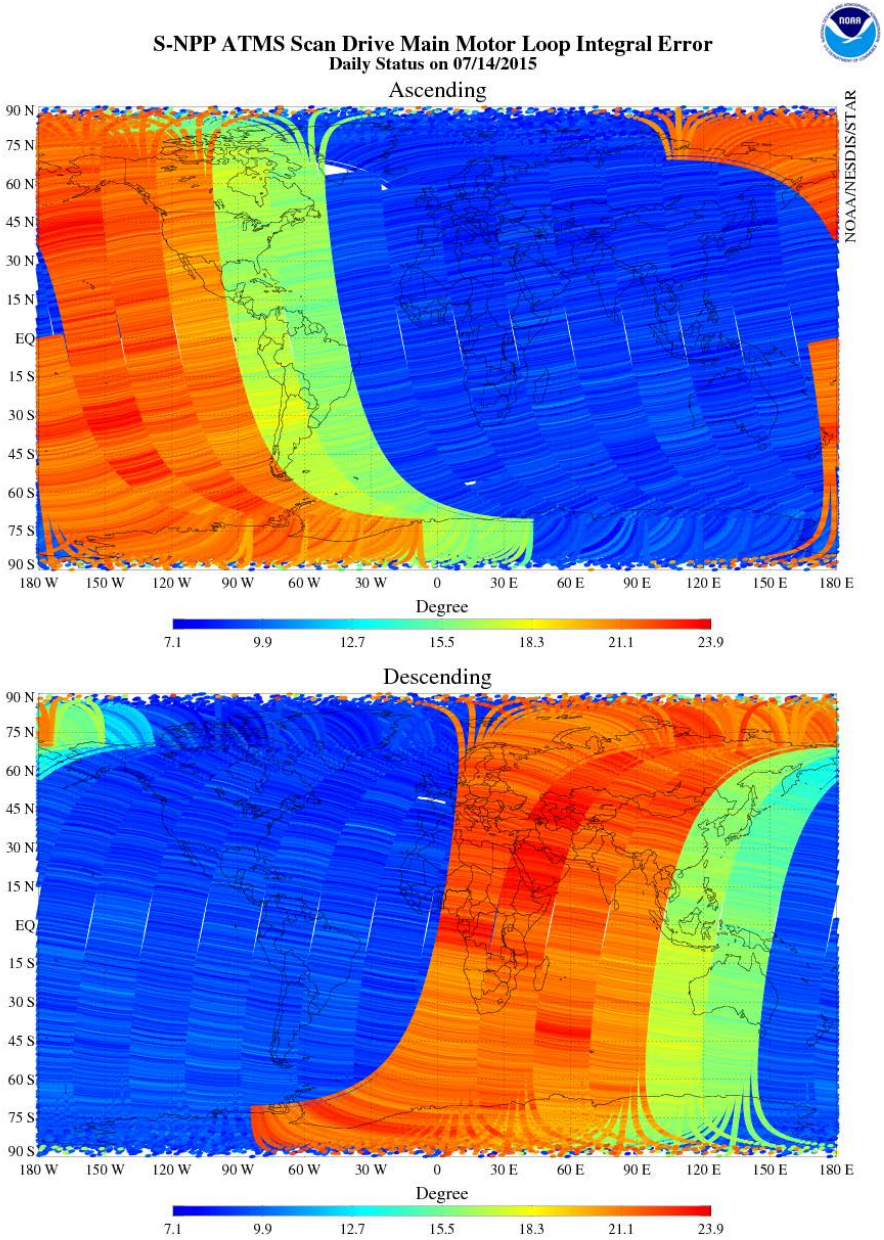
1. Supported S-NPP ATMS scan drive main motor current anomaly analysis and scan reversal activities
2. Defined SI traceable channel noise evaluation algorithm using Allan deviation method for both ATMS and CrIS
3. Transitioned S-NPP instrument health status and data product quality monitoring package (ICVS-Lite) to GRAVITE for OSPO 24/7 operational uses
4. Explored Big Data applications in database construction, statistic analysis, prediction model construction, data mining algorithm development for ICVS
5. Held the first STAR ICVS annual meeting and published STAR ICVS instrument status annual technical report
6. Updated ICVS to improve the instrument status and data quality monitoring capability
   - Added VIIRS band averaged and detector level F/H-factor trending
   - Added ATMS dwell telemetry RDR trending
   - Added CrIS full spectral resolution (FSR) SDR trending
   - Added ATMS/CrIS TDR/SDR bias characterization trending
   - Added VIIRS Imagery over Alaska real time monitoring
   - Rejuvenated OMPS NP/NM/LP SDR trending packages
   - Updated STAR ICVS website to improve user experience

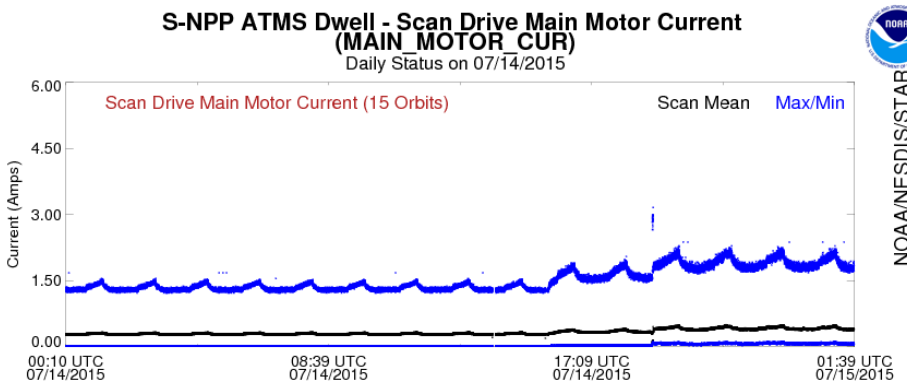
S-NPP ATMS Scan Drive Monitoring

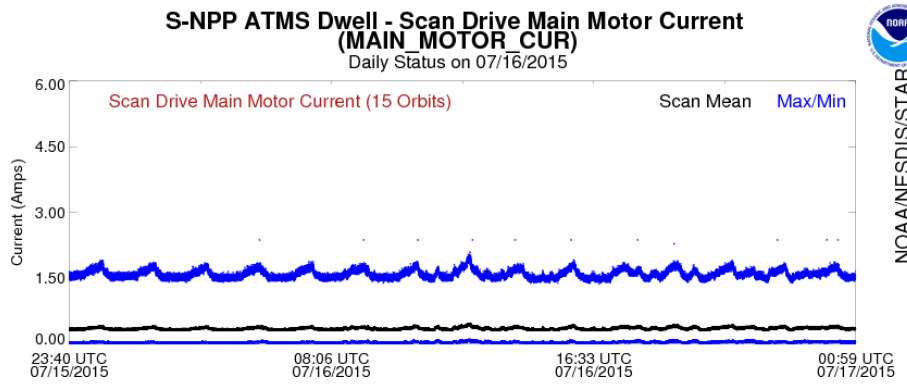


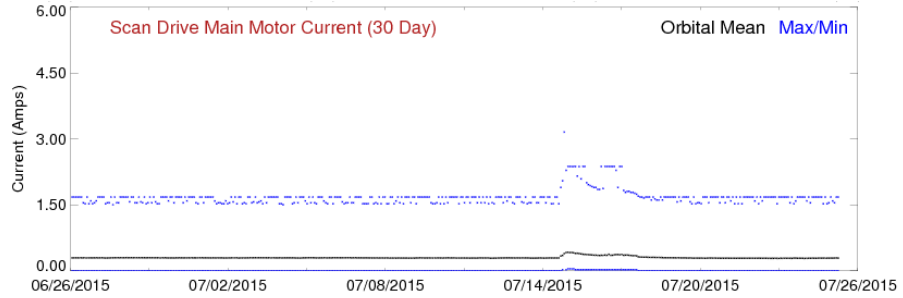


S-NPP ATMS Scan Drive Monitoring









SI Traceable Noise Evaluation Method - ATMS

Current operational NEΔT calculation method,

$$NE\Delta T_{ch} = \sqrt{\frac{1}{NM}\sum_{i=1}^{N}\sum_{j=1}^{M}\left(\frac{C_{ch}^{w}(i,j)-\overline{C_{ch}^{w}}(i)}{\overline{G_{ch}}(i)}\right)}$$

where C_{ch}^{w} represents the warm count readings at each scan, $\overline{G_{ch}}$ is the averaged calibration gain.

By using overlapping Allan deviation, NEΔT can be calculated via

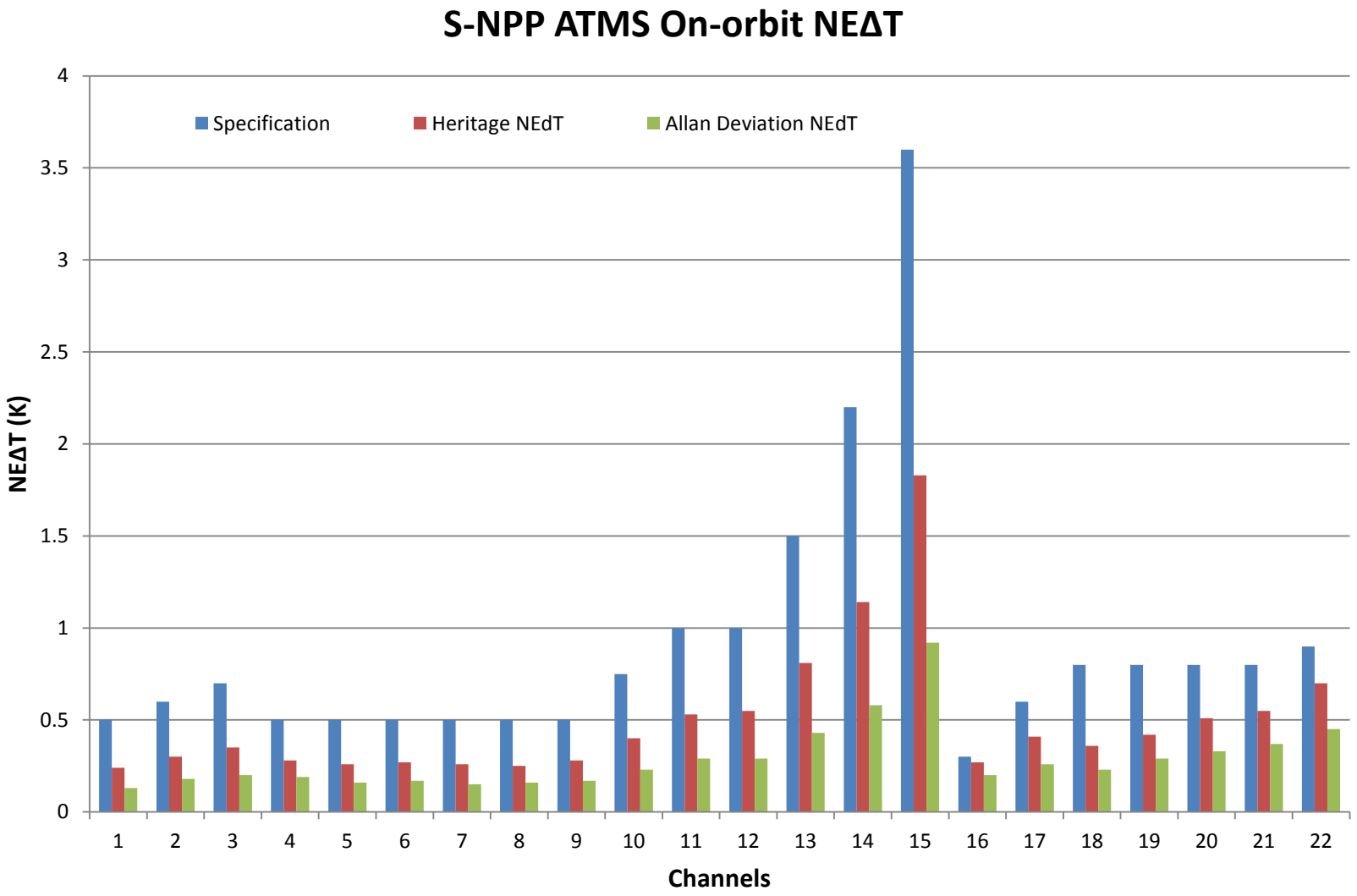
$$NE\Delta T_{ch}^{Allan}(M,m) = \sqrt{\frac{1}{2m^2(M-2m+1)}\sum_{i=1}^{M-2m+1}\sum_{k=i}^{i+m-1}\left[\frac{C_{ch}^{w}(k+m)-C_{ch}^{w}(k)}{\overline{G_{ch}}}\right]^2}$$

when $m = 1$, NEΔT can be calculated using neighborhood Allan deviation

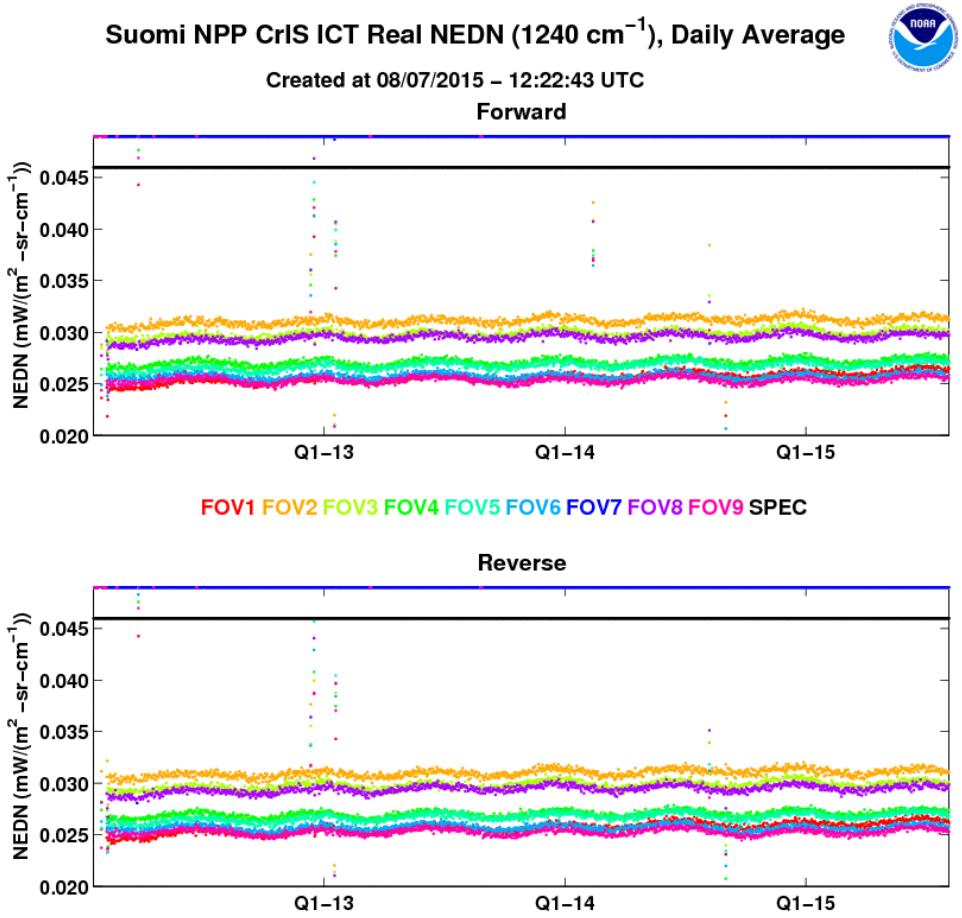
$$NE\Delta T_{ch}^{Allan} = \sqrt{\frac{1}{2(M-1)}\sum_{i=1}^{M-1}\left[\frac{C_{ch}^{w}(i+1)-C_{ch}^{w}(i)}{\overline{G_{ch}}}\right]^2}$$

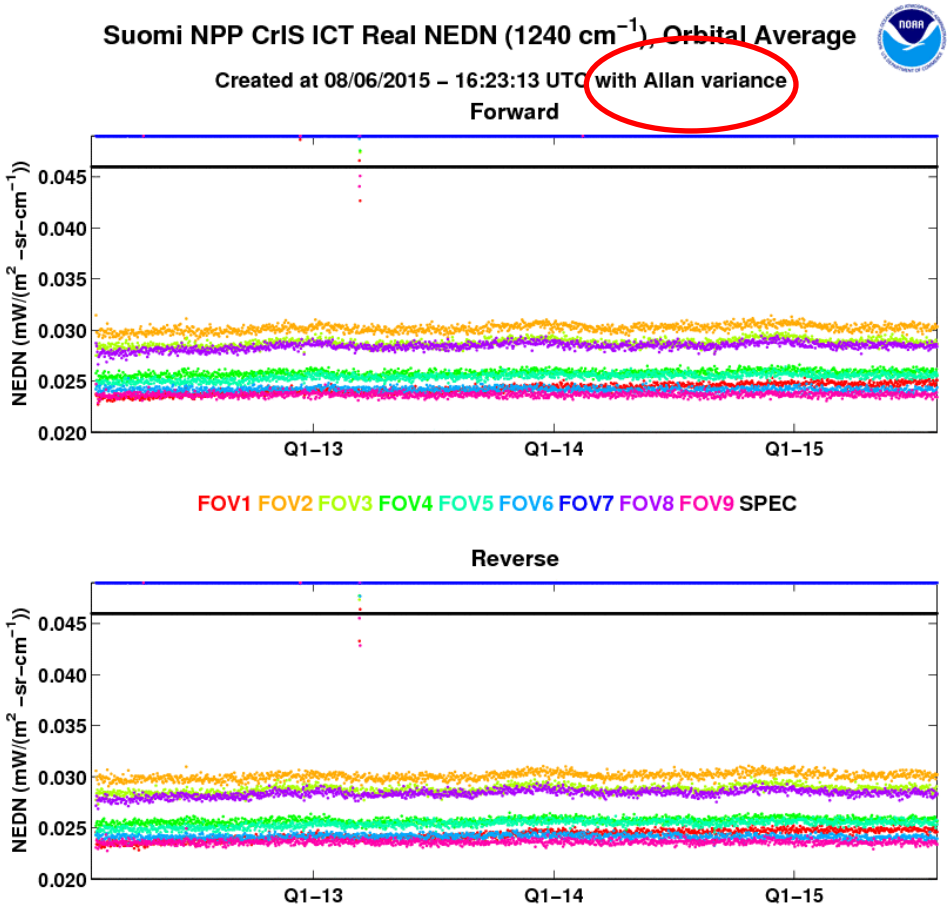
M. Tian, X. Zou and F. Weng, "*Use of Allan Deviation for Characterizing Satellite Microwave Sounders Noise Equivalent Differential Temperature (NEDT)*", IEEE Geosci. Remote Sens. Lett., (Accepted).

SI Traceable Noise Evaluation Method - ATMS



SI Traceable Noise Evaluation Method - CrIS

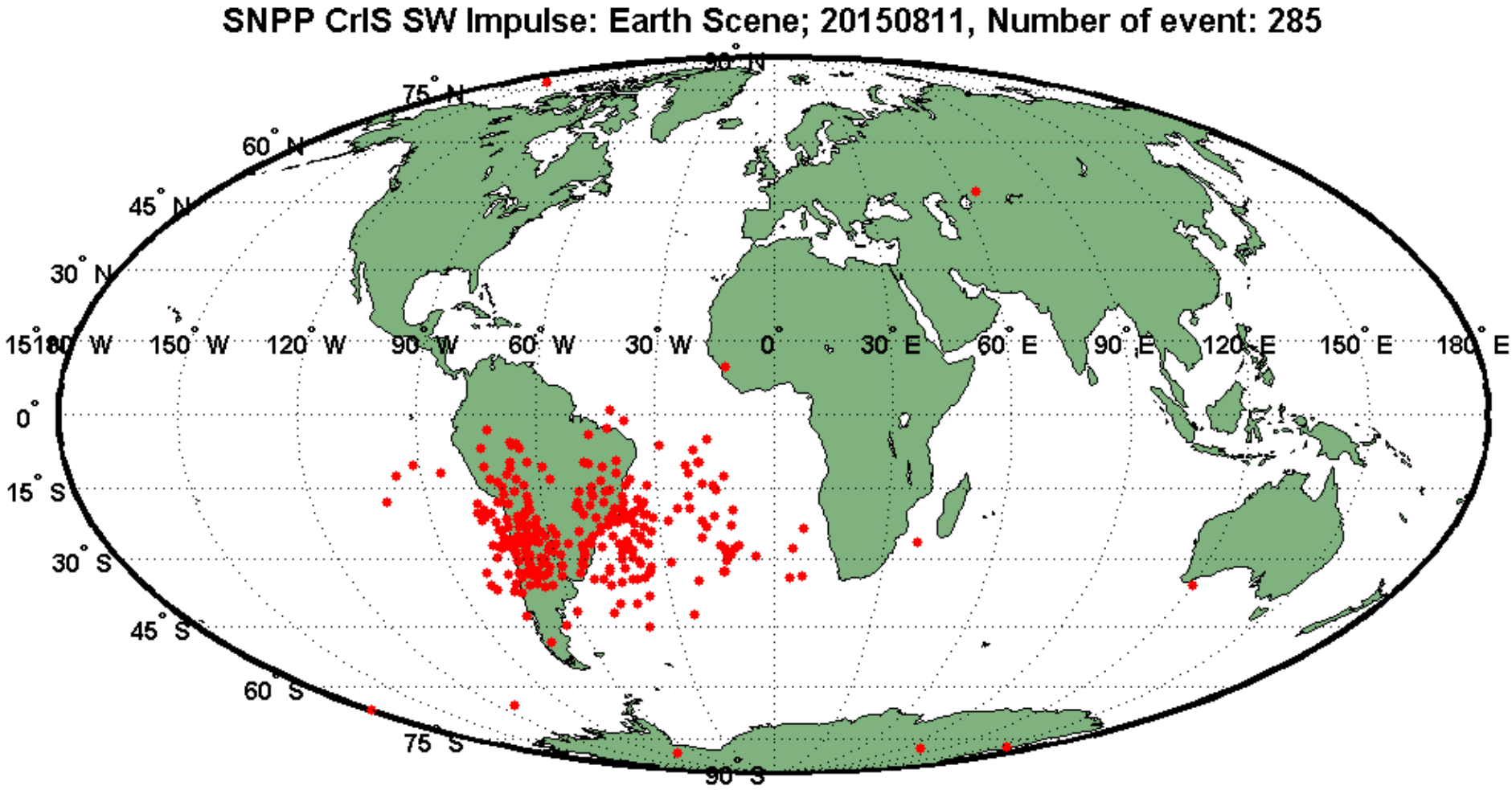




Y. Chen, F. Weng and Y. Han, "*SI Traceable Algorithm for Characterizing Hyperspectral Infrared Sounder CrIS Noise*", Applied Optics, (Accepted).

CrIS Full Spectral Resolution (FSR) Trending

Detect CrIS Shortwave (SW) impulse noise events automatically through long term statistic results



STAR ICVS Annual Report

NOAA Technical Report NESDIS XXX

2014-2015 Annual Instrument Performance Review as Monitored by the NESDIS/STAR Integrated Calibration/Validation System

Ninghai Sun, Xin Jin, Taeyoung Choi, Lawrence E. Flynn, Ding Liang, Chengzhi Zou, Greg Krasowski, and Fuzhong Weng

Washington, DC
August 2015,

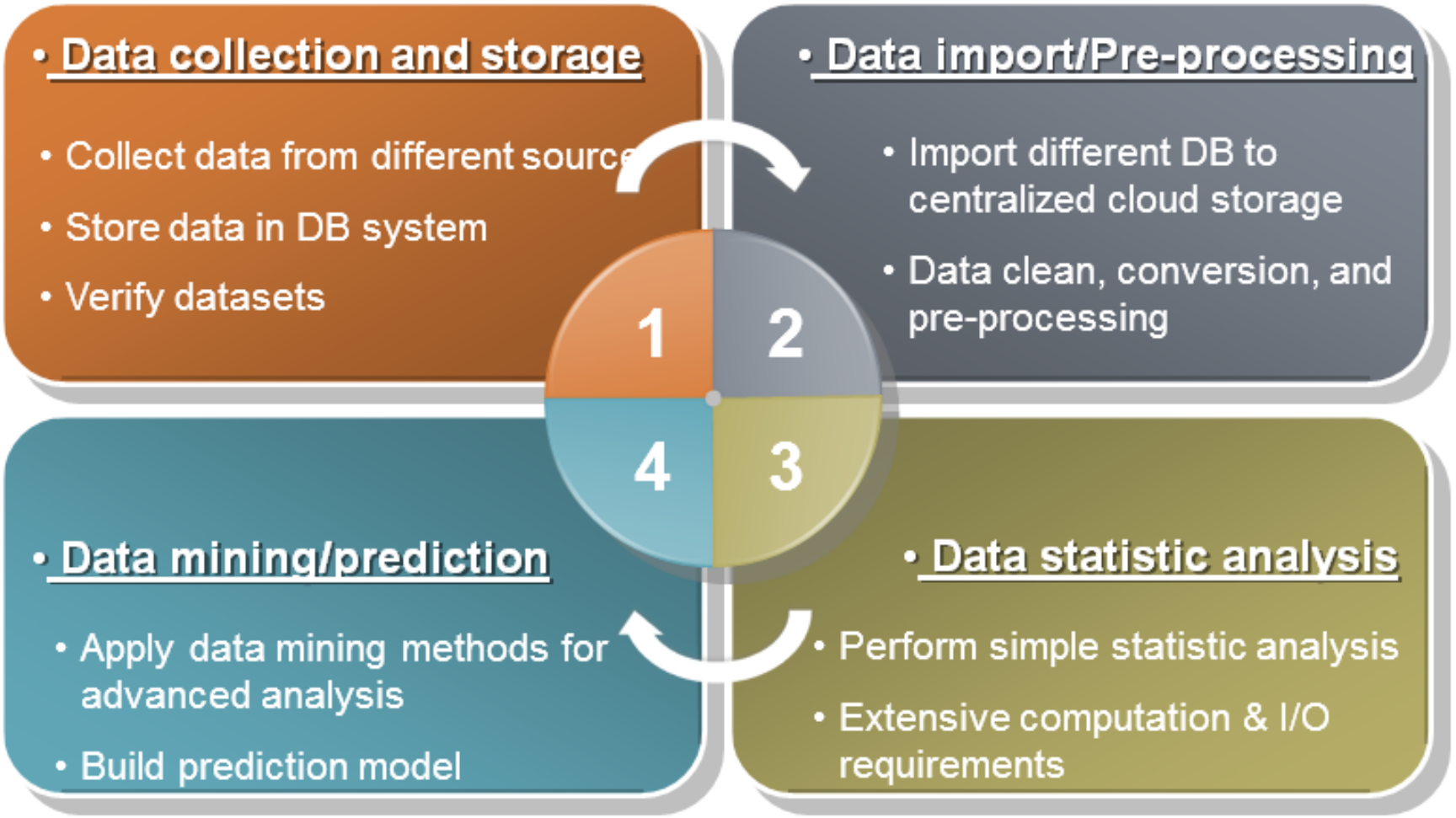
U.S. DEPARTMENT OF COMMERCE
Penny Pritzker, Secretary
National Oceanic and Atmospheric Administration
Dr. Kathryn Sullivan, NOAA Administrator
National Environmental Satellite, Data, and Information Service
Stephen Volz, Assistant Administrator

- Instrument overview including scan geometry
- Instrument health status summary
- Annual instrument anomaly event record
- Include NOAA-19/NOAA-18/Metop-A/Metop-B AMSU-A and MHS, S-NPP ATMS, CrIS, VIIRS, OMPS

Path Forward

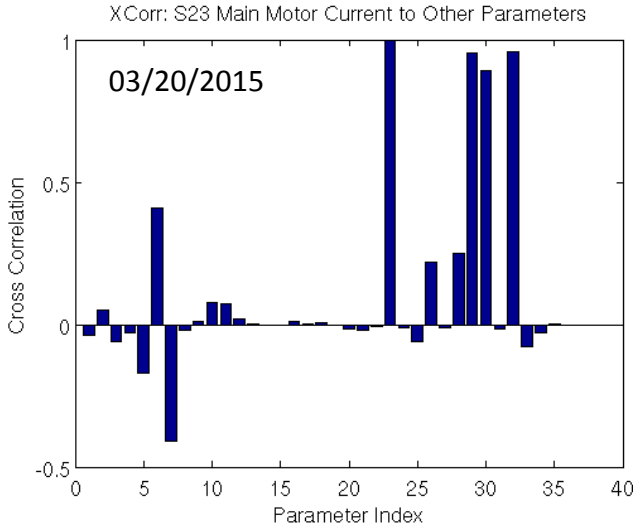
- Explore opportunities to develop STAR ICVS Big Data analysis enterprise system
  - Collect satellite observation and derived environmental data to increase ICVS Big Data analysis database volume
  - Start data importing and pre-processing to improve Big Data analysis efficiency
  - Begin initial statistic analysis on multi-dimensional database
  - Attempt to apply different data mining technical for advanced data analysis for different users
- Plan on S-NPP mission life-cycle reprocessing for reference environmental data record generation
  - Determine the stable version of SDR processing package with latest scientific improvements
  - Finalize the Look-Up-Table (LUT) or Processing-Coefficient-Table (PCT) for SDR reprocessing
  - Collect life-time S-NPP raw data record (RDRs) for reprocessing
- Explore Small Satellite calibration/validation integration
  - Conduct initial study on multiple satellite simulation
  - Attempt to integrate multiple small satellite observations under a consistent calibration standard

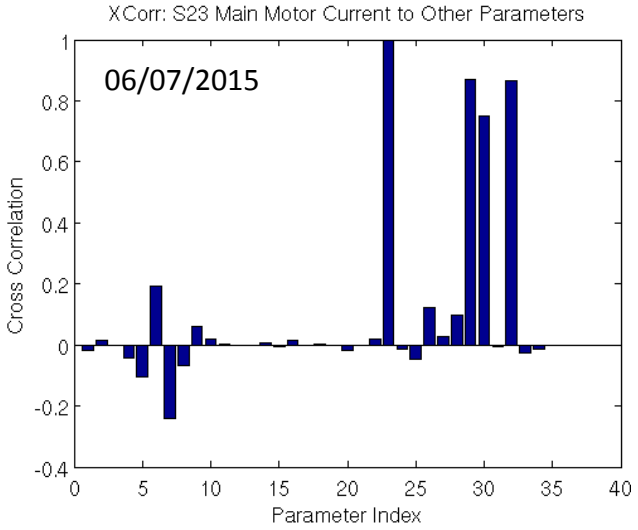
Big Data Analysis on ICVS

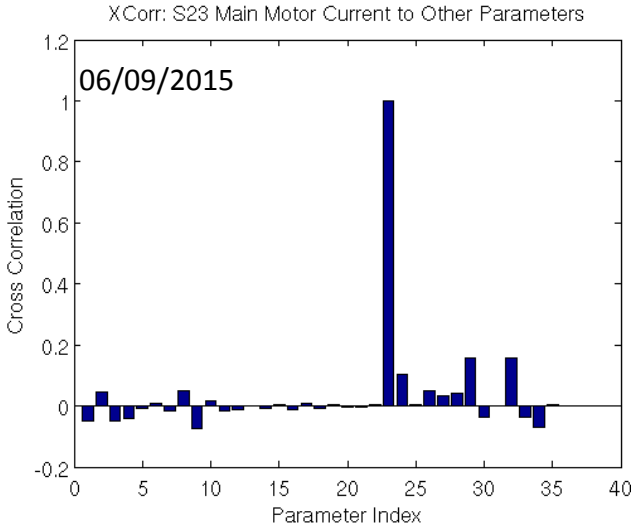


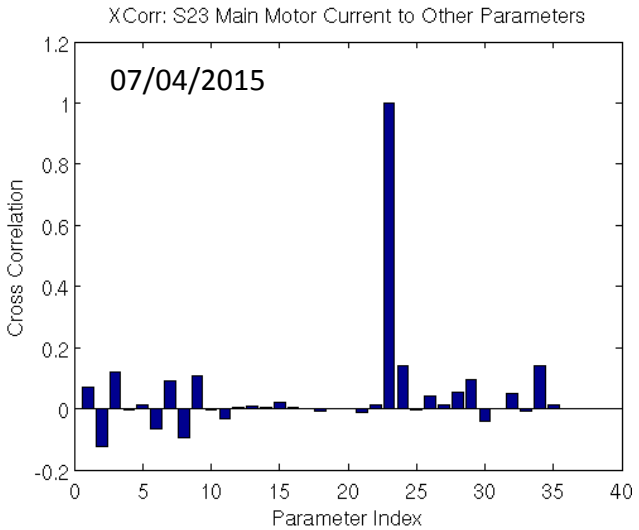
Big Data Analysis on ICVS

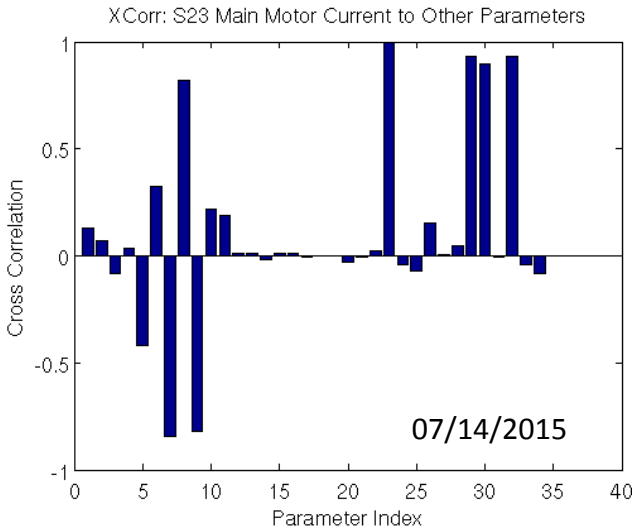
Data Statistic and Analysis for ATMS scan drive main motor current anomaly





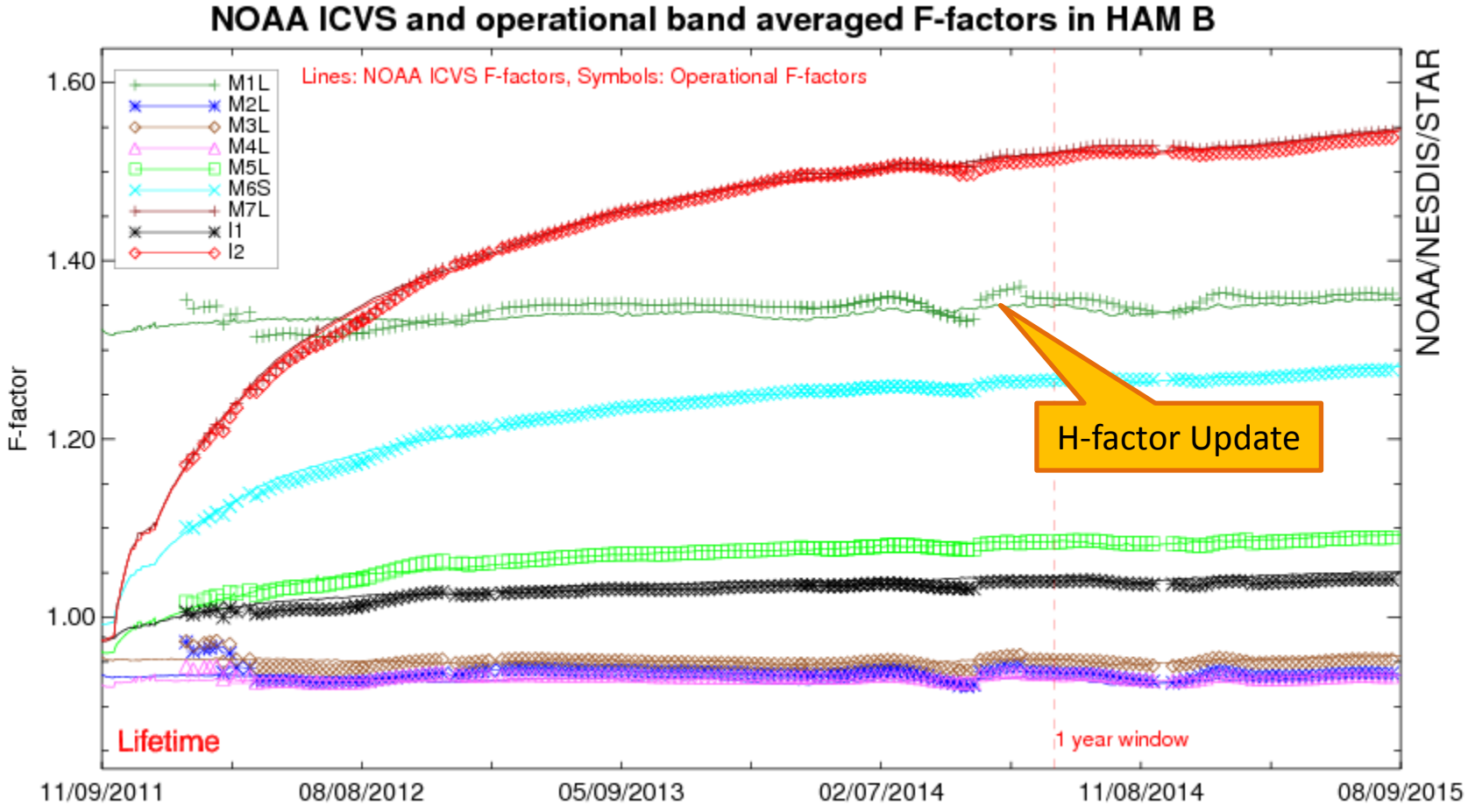




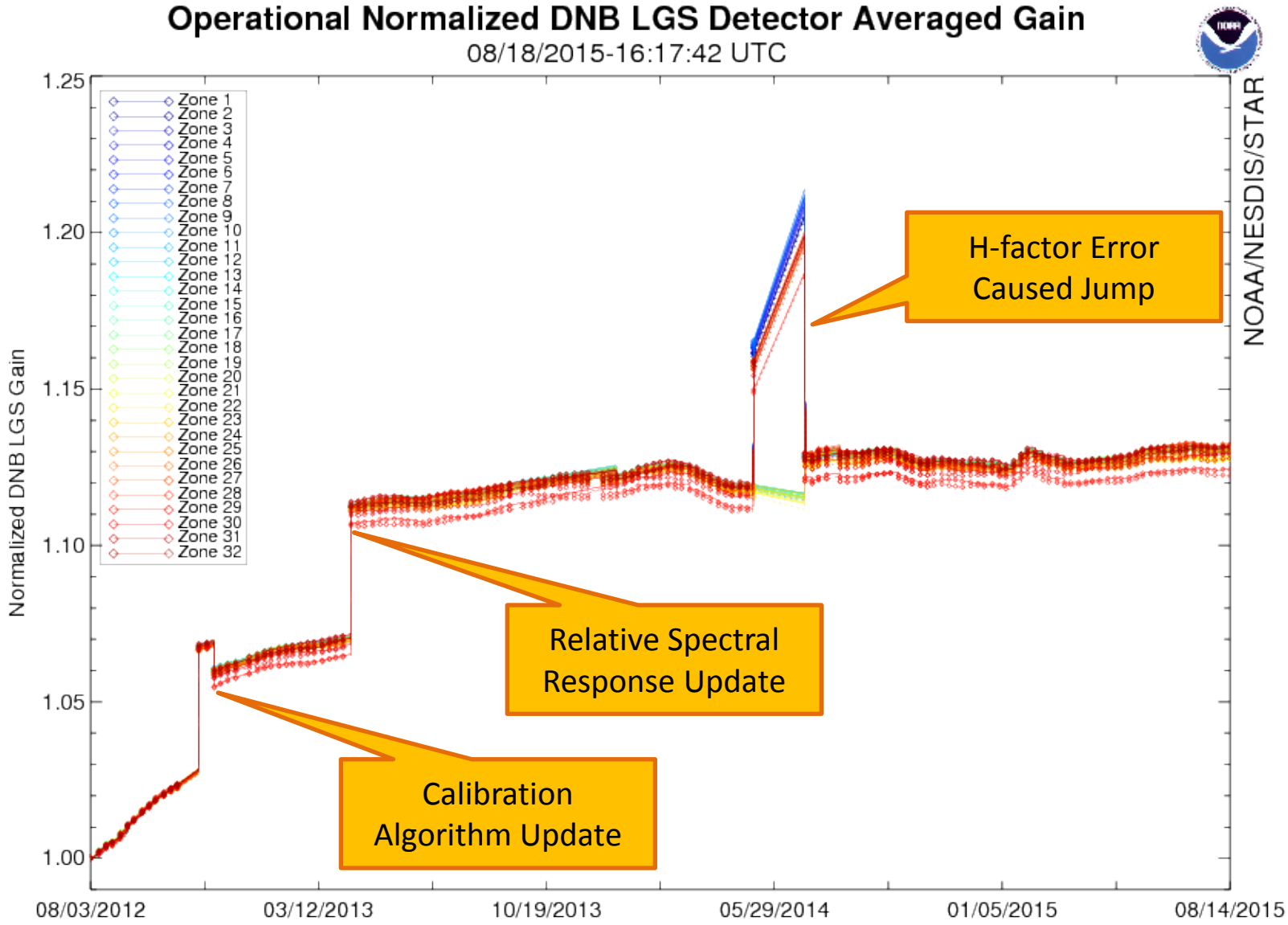


Mission Lifecycle Reprocessing

- Ensure the consistency of data quality with improved calibration algorithm
- Fundamental for reference environmental data record generation



Mission Lifecycle Reprocessing

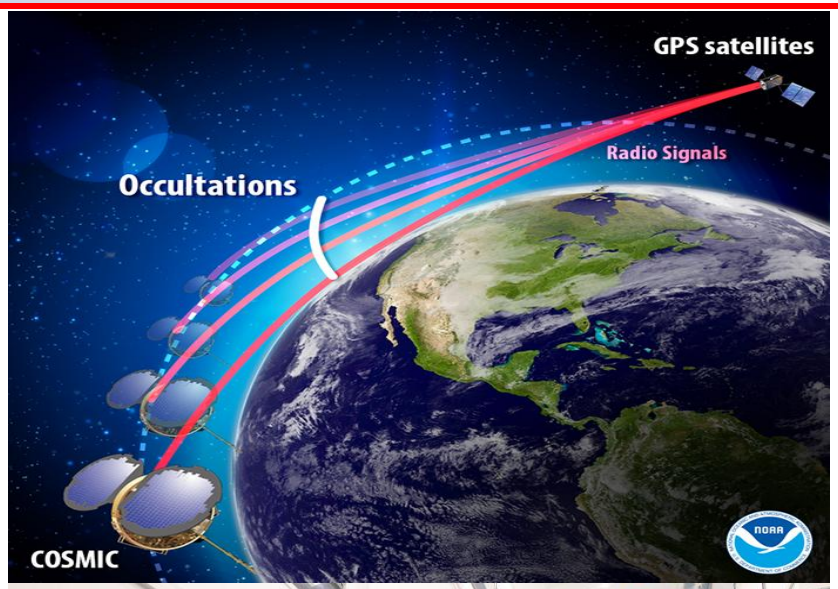


Small Satellites – Hosted Payloads

GPS-RO - Small Satellites Doing Big Work

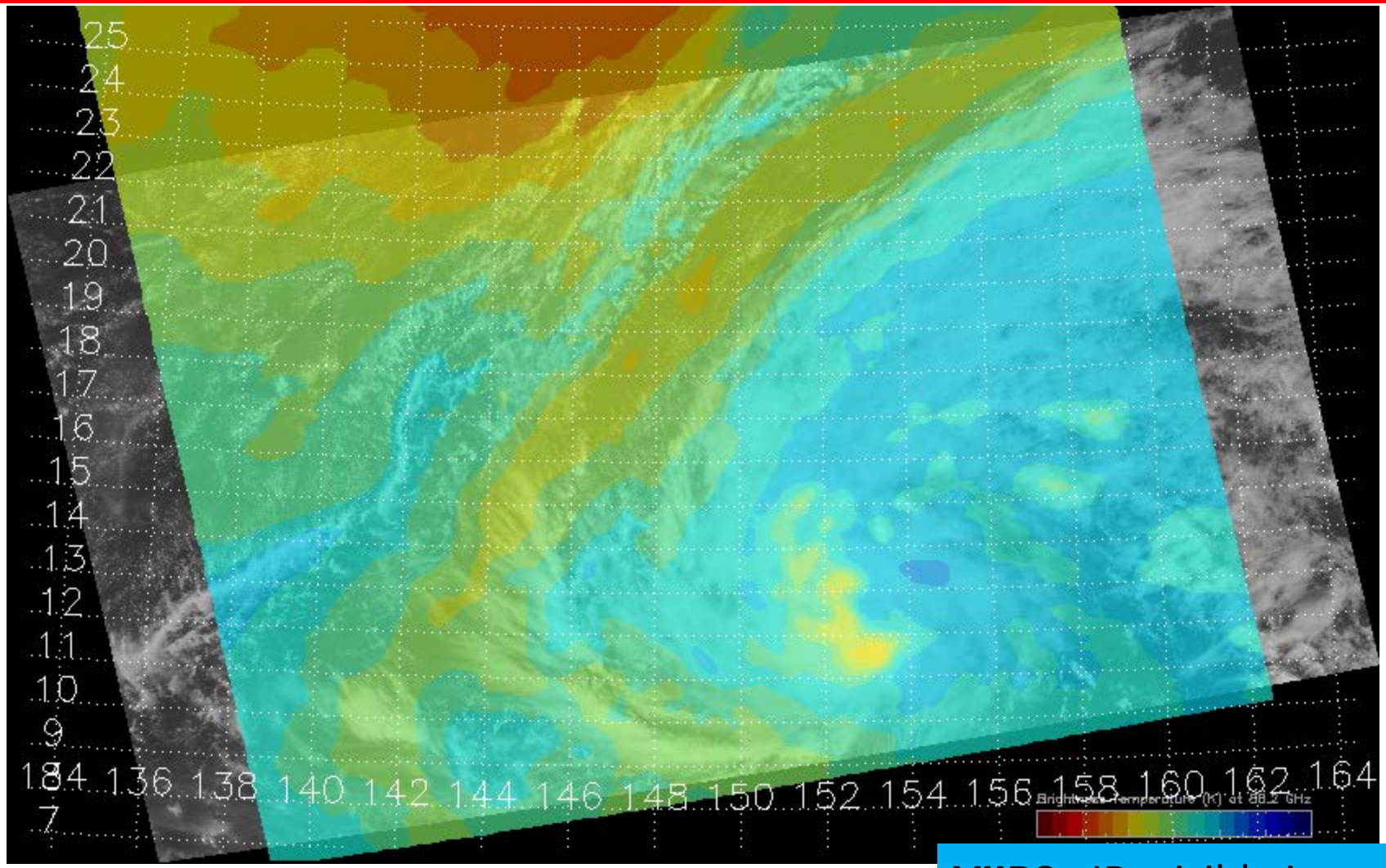
Challenges:

- Determine the optimal number of small satellites
- Calibrate instruments onboard for different satellites to a consistent standard for applications
- Develop risk mitigation plan for individual failure of a small satellite
- Provide real time monitoring and long term trending of small satellites health status and data product quality



Preliminary 3-D Visualization of Hurricane Warm Cores Using ATMS and VIIRS

Integrating ATMS Mapper with VIIRS Imagery



ATMS: ability to see through clouds

Typhoon Bavi – March 14, 2015
VIIRS: 0323-0327 (3 granules)
ATMS: 0322-0330 (1 granule)

VIIRS: IR, visible imagery to identify ice and snow, aerosols, etc.

Summary – STAR ICVS

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- Supported JPSS-1 pre-launch calibration activities and is ready for JPSS-1 post-launch instrument monitoring and calibration activities
- Exploring opportunities to expand ICVS's user impact and benefits using Big Data, Small Satellites, reprocessing and development of operationally-focused products