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

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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
NOAA’s Weather-Ready Nation is about building community resilience in the face of increasing vulnerability to extreme weather and water events. 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 global 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
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.
NOAA/NESDIS/STAR Integrated Cal/Val System (ICVS)

Instrument Performance Monitoring System (IPMS)
- SNPP/JPSS
  - SNPP/JPSS Spacecraft
    - NOAA/MetOp
      - GOES
      - GCOM-W
    - GOES-R
  - SNPP/JPSS
    - ATMS
    - CrIS
    - VIIRS
    - OMPS
    - CERES

SDR Quality Assurance System (SQAS)
- SNPP/JPSS
  - NOAA/MetOp
  - GOES
  - GCOM-W
  - GOES-R
    - ABI
    - AMSR-2
    - Imager
    - Sounder
    - AVHRR
    - HIRS
    - MHS
    - AMSU
    - ATMS
    - CrIS
    - VIIRS
    - OMPS

EDR Quality Assurance System (EQAS)
- SNPP/JPSS
  - NOAA/MetOp
  - GOES
  - GOES-R
    - ABI
    - EDR
    - MIRS
    - NUCAPS
    - MICROS
    - Ozone
    - Imager
    - Sounder

Satellite Data and Application Demonstration System (DADS)
- NWP
  - Global Forecasts
  - Regional Forecasts
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

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

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<th>Cores</th>
<th>GB</th>
<th>TB</th>
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**STAR CICS Cluster**
- Computation intensive jobs
- NWP pre-operational testing
- Mission lifecycle data reprocess

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**UMD/AOSC Servers**
- Data dissemination
- Academia research testing

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<tr>
<td>STAR-UMD2</td>
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</tr>
</tbody>
</table>

**Parts**
- Servers: 12
- CPU Cores: 876
- Memory (GB): 5156
- HDD (TB): 815

**Internet**

- Direct Link
  - GRAVITE: Real-time S-NPP/IPSS data
  - CLASS: Lifetime S-NPP/IPSS data
  - NWP Centers: NWP forecast data
  - Other Data Center: Cosmic, MLS, et. al.
Covered instruments/spacecraft: 29
Generated LTM figures: 4599(All)/2352(S-NPP)
Daily figure update rate: 6 per day
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)
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

Suomi NPP ATMS Scan Drive Main Motor Current (MAIN_MOTOR_CUR)
Updated at Sep 1 23:03:26 2015 UTC

Scan Drive Main Motor Current (12 Orbits)

Scan Drive Main Motor Current (30 Days)

Scan Drive Main Motor Current (1 Year)

Scan Drive Main Motor Current (All Time)

Suomi NPP ATMS Scan Drive Main Motor Loop Integral Error (SD_MAIN_LOOP_INT_ERROR)
Updated at Sep 1 23:03:26 2015 UTC

Scan Drive Main Motor Loop Integral Error (12 Orbits)

Scan Drive Main Motor Loop Integral Error (30 Days)

Scan Drive Main Motor Loop Integral Error (1 Year)

Scan Drive Main Motor Loop Integral Error (All Time)
S-NPP ATMS Scan Drive Monitoring

S-NPP ATMS Scan Drive Main Motor Loop Integral Error
Daily Status on 07/14/2015

Ascending

S-NPP ATMS Dwell - Scan Drive Main Motor Current
(MAIN_MOTOR_CUR)
Daily Status on 07/14/2015

Scan Drive Main Motor Current (15 Orbits)
Scan Mean
Max/Min

06:10 UTC 07/14/2015
08:38 UTC 07/14/2015
17:09 UTC 07/14/2015
01:38 UTC 07/15/2015

S-NPP ATMS Dwell - Scan Drive Main Motor Current
(MAIN_MOTOR_CUR)
Daily Status on 07/16/2015

Scan Drive Main Motor Current (30 Day)
Orbital Mean
Max/Min

06:20 UTC 07/15/2015
08:08 UTC 07/16/2015
15:32 UTC 07/16/2015
00:58 UTC 07/17/2015
06:26 UTC 07/26/2015
07/20/2015
07/25/2015

Descending
Current operational NE\Delta T calculation method,

\[
NE\Delta T_{ch} = \sqrt{\frac{1}{NM} \sum_{i=1}^{N} \sum_{j=1}^{M} \left( \frac{C_{ch}^w(i, j) - \overline{C_{ch}^w(i)}}{G_{ch}(i)} \right)^2}
\]

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, NE\Delta T 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 \( m = 1 \), NE\Delta T can be calculated using neighborhood Allan deviation

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

S-NPP ATMS On-orbit NE\Delta T

- Specification
- Heritage NEdT
- Allan Deviation NEdT

Channels: 1 to 22

NE\Delta T (K)

Values range from 0 to 4

S-NPP ATMS On-orbit NE\Delta T

SI Traceable Noise Evaluation Method - ATMS
Detect CrIS Shortwave (SW) impulse noise events automatically through long term statistic results.

**SNPP CrIS SW Impulse: Earth Scene; 20150811, Number of event: 285**
STAR ICVS Annual Report

- 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

1. **Data collection and storage**
   - Collect data from different sources
   - Store data in DB system
   - Verify datasets

2. **Data import/Pre-processing**
   - Import different DB to centralized cloud storage
   - Data clean, conversion, and pre-processing

3. **Data statistic analysis**
   - Perform simple statistic analysis
   - Extensive computation & I/O requirements

4. **Data mining/prediction**
   - Apply data mining methods for advanced analysis
   - Build prediction model
Big Data Analysis on ICVS

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

03/20/2015

06/07/2015

06/09/2015

07/04/2015

07/14/2015
Mission Lifecycle Reprocessing

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

**NOAA ICVS and operational band averaged F-factors in HAM B**

- **Lines:** NOAA ICVS F-factors, **Symbols:** Operational F-factors
- **H-factor Update**

*1 year window*
Mission Lifecycle Reprocessing

Operational Normalized DNB LGS Detector Averaged Gain

08/18/2015-16:17:42 UTC

- H-factor Error Caused Jump
- Relative Spectral Response Update
- Calibration Algorithm Update
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

Typhoon Bavi – March 14, 2015

**ATMS:** ability to see through clouds

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

VIIRS: 0323-0327 (3 granules)
ATMS: 0322-0330 (1 granule)
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