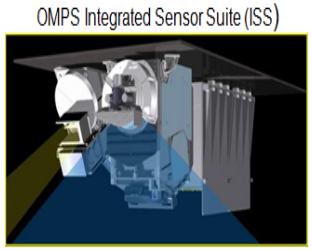
The Ozone Mapping and Profiler Suite (OMPS): From SNPP to JPSS-1

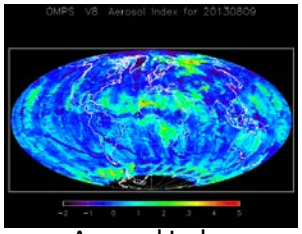
*C. Pan[1] and F. Weng[2]

* 1 ESSIC, University of Maryland, College Park, MD 20740; 2 NOAA NESDIS/STAR, College Park, MD 20740

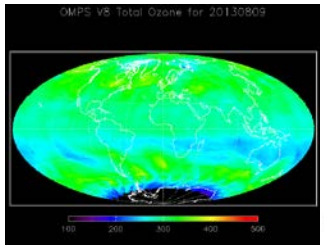
CICS Science Meeting
29 November – 01 December 2016
College Park, MD20740



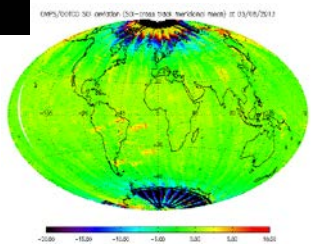
Curtsey of BATC



Aerosol Index



Ozone map



So2 index

This study was supported by NOAA grant NA09NES4400006 (Cooperative Institute for Climate and Satellites -CICS)

Outline

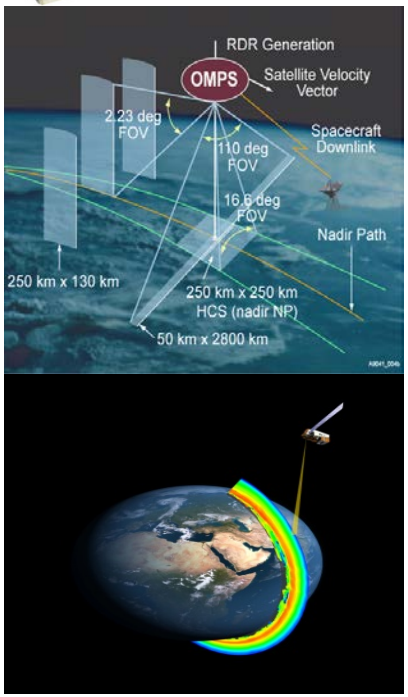
- OMPS and OMPS Sensor data Record (SDR)
- OMPS SNPP Status
  - Calibration/Validation and Data reprocessing
  - Challenges and Users feedback
  - Moving Towards JPSS-1
- OMPS JPSS-1 Status
  - Changes in the sensor design and products
  - SDR Algorithm enhancement
  - Cal/Val Schedules and Milestones
  - Major Risks/Issues/Challenges/ and Mitigation
- Summary and Path Forward

OMPS and OMPS SDR

• OMPS is one of the five instruments on board the SNPP satellite launched in Oct. 2011. J1 OMPS will launch in 2017.
• OMPS has three spectral meters: NP, NM and LP
• Heritage from SBUV/2 and TOMS, OMPS provides ozone total column and vertical profile data that continues ozone daily global data with higher calibration accuracy and higher spatial and spectral resolution.

- **Resolution**
  - Provides Total Column ozone data w/ 50x50 km FOV at nadir
  - Provides ozone profiles in a single ground pixel of 250x250 km at nadir
- **Configuration**
  - Push-broom 110 deg. cross-track FOV telescope
  - Two grating spectrometers
    - » NM covers 300 nm to 380 nm
    - » NP covers 250 nm to 310 nm
  - CCD optical detector for each spectrometer
- **Onboard Calibrators**
  - Light-emitting diode provides linearity calibration
  - Reflective solar diffusers maintain calibration stability
- **Products**
  - Provide globe maps every 24 hours of amount of ozone and volumetric concentration in a vertical column of atmosphere with a 4- days revisit

Spatial resolution can be altered to provide a smaller ground FOV that has a higher spatial resolution.

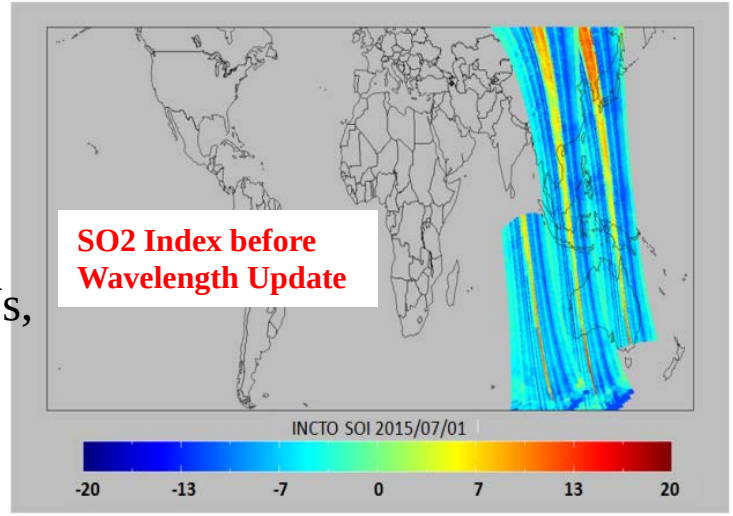


Vertical measurements of the ozone layer from the LP on OMPS. Credit: NASA

SNPP SDR and Cal. Challenge

- **OMPS EV SDR Maturity**
  Beta since 5 March 2012; Provisional since 1 March 2013 and Validated since 09 September 2015

- **Major challenge is optical thermal instability** ➡
  Spectral wavelength varies with telescope temperature change;
  Center wavelength changed across IFOVs, caused stripping in the SO2 products

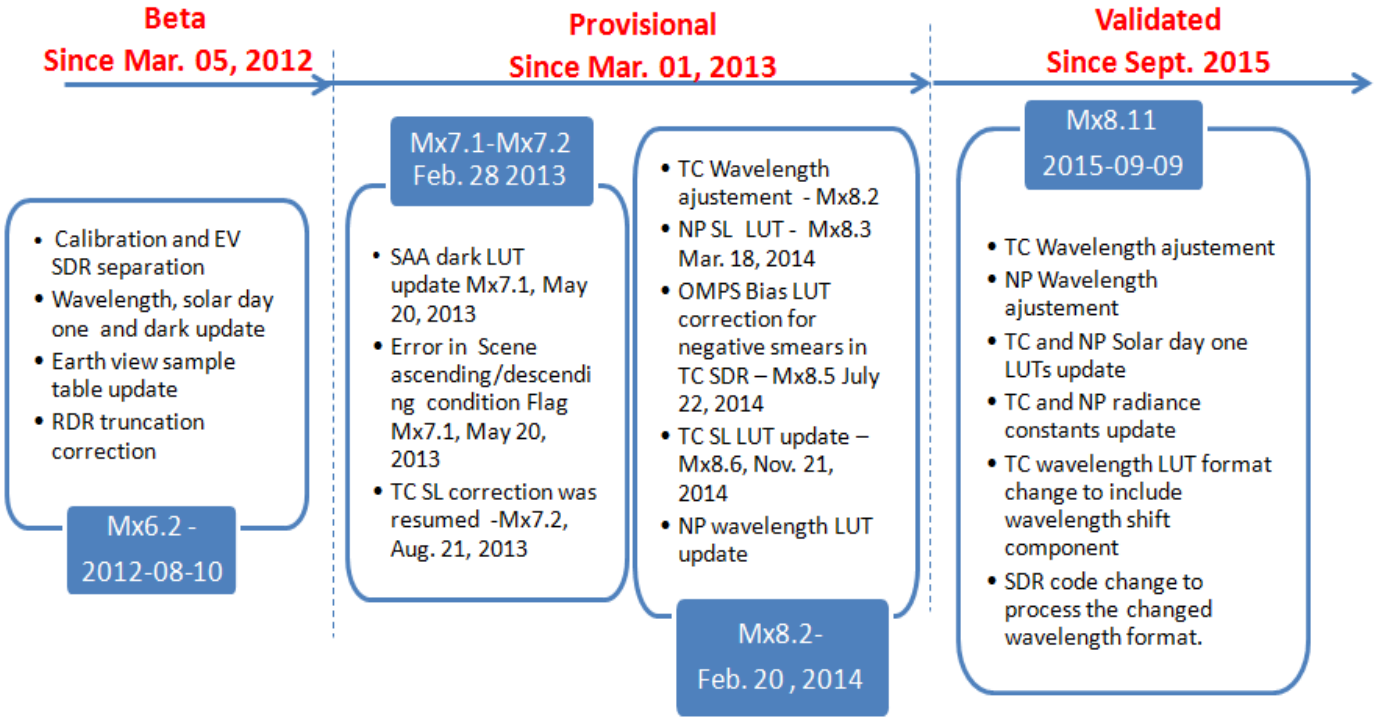


From Trevor Beck

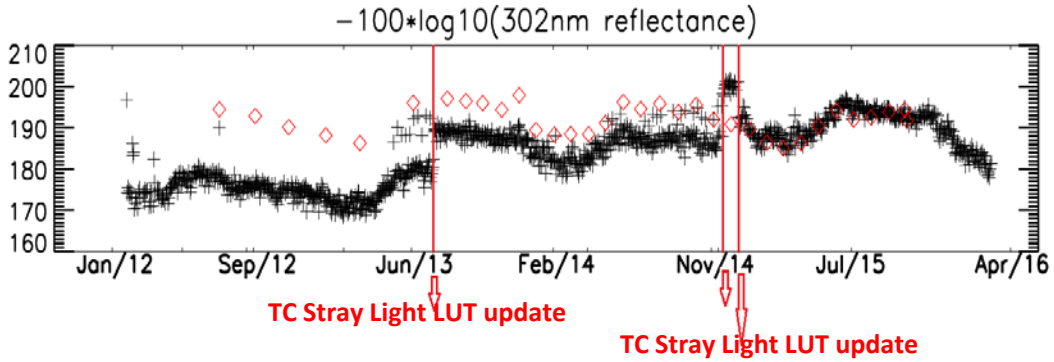
- **OMPS meets SDR performance requirements Since 09/09/2015**
  - ✓ Sensor orbital performance is stable and meet expectation
  - ✓ Geo-location accuracy error < 5.0 km
  - ✓ The cross-track IFOV radiance error is minimized < 2.0
  - ✓ The NM and NP consistency in 300-310 nm has been improved by 2-10%

SDR Improvements and Reprocessing

- SDR quality chronologically improved
- Produce consistent SDRs at the attainable quality level.
- Use up-to-dated calibration LUTs and algorithm in OMPS SDR life-cycle



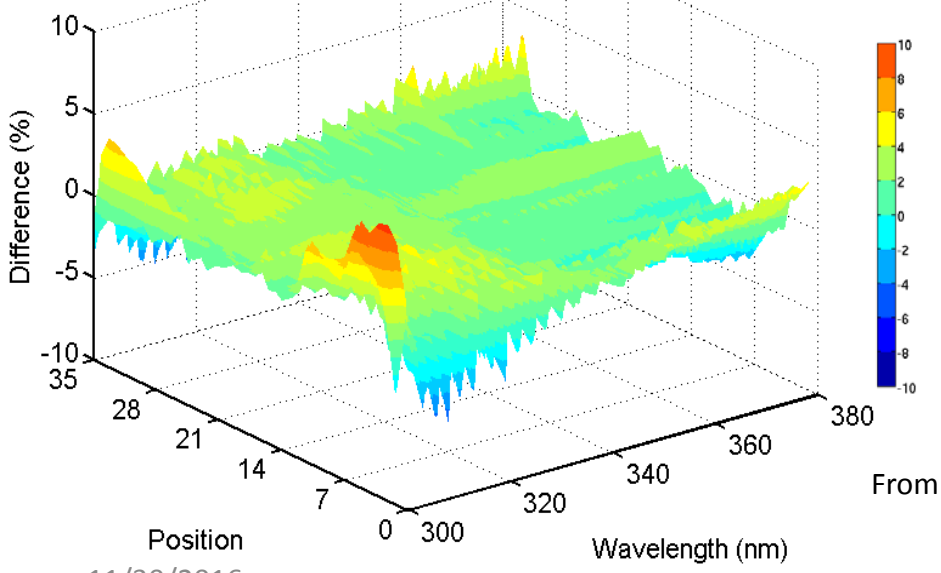
Preliminary reprocessing results of daily average N-value over the Tropical Pacific region from SNPP NP 302 nm channel



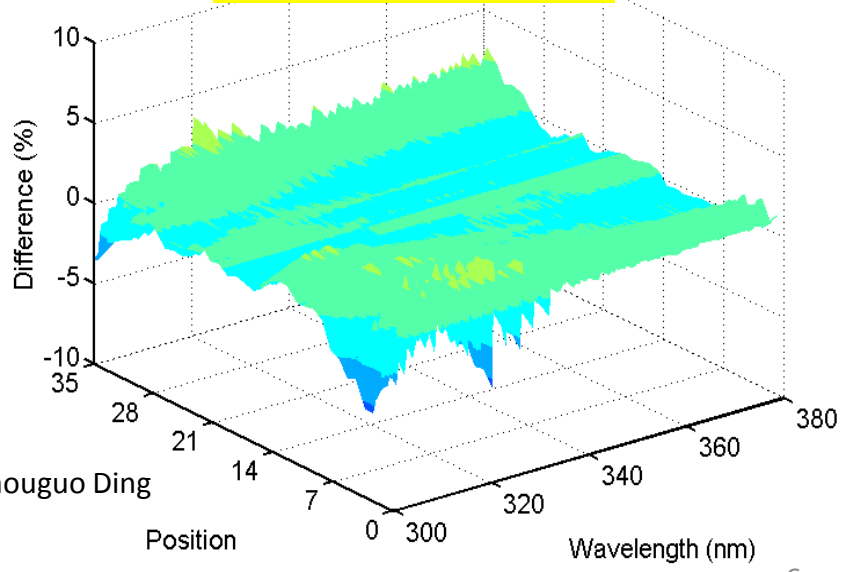
EV SDR Quality Justification

- Instrument: **meeting specifications with adequate margins.**
- SDR: **stable (quality and quantity)** and free of major errors.
- IDPS has been producing satisfactory products.
- Incremental improvements are planned and will continue.
  - Users are satisfied with the current SDR quality while expecting NP wavelength refinement and higher spatial resolution data
  - The requirement of 0.02nm shift was waived at the instrument level. The correction are made on SDR level to meet EDR requirements.

Before 09/09/2015



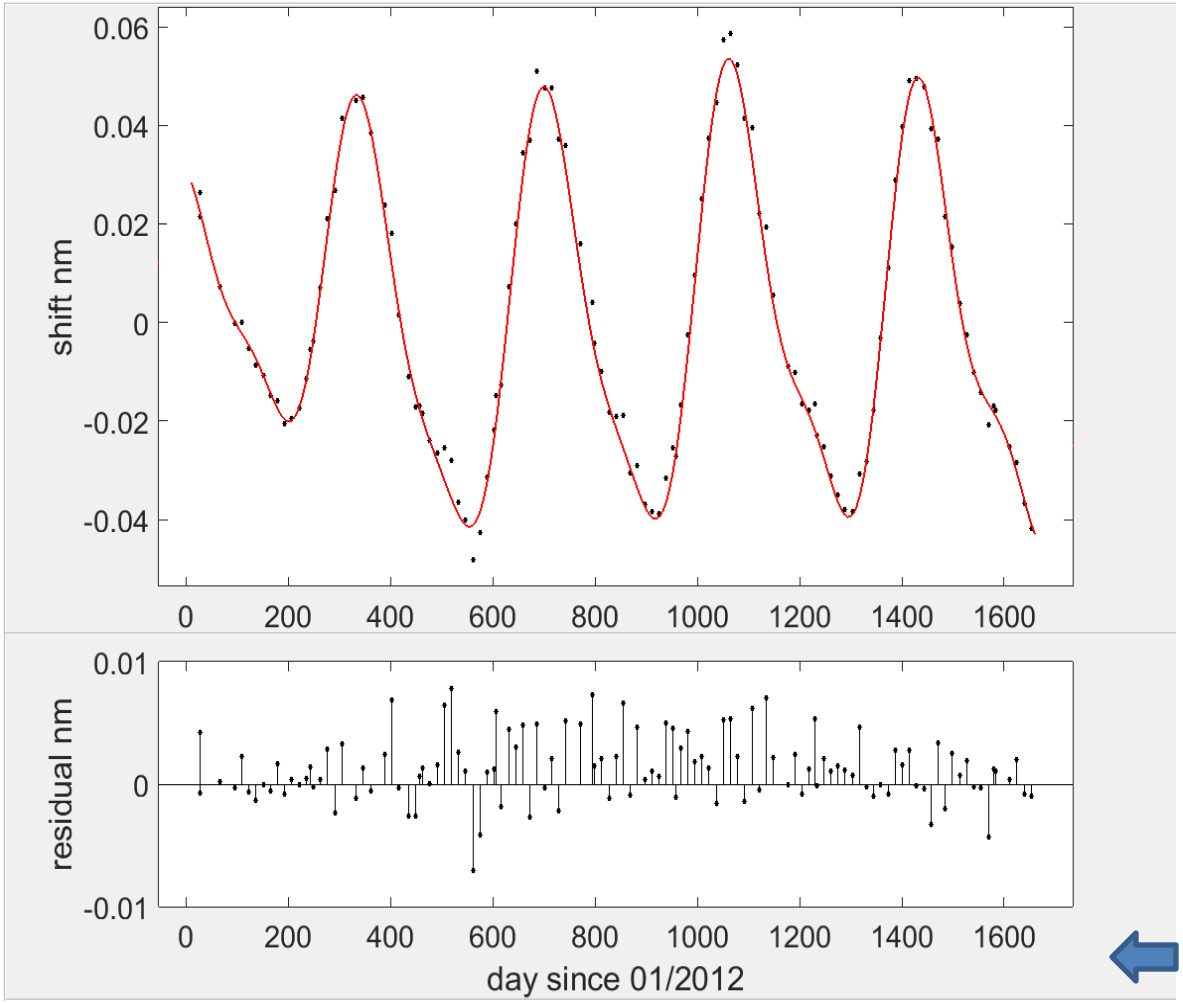
After 09/09/2015



From Shouguo Ding

NP Wavelength Analysis and Modeling

- Computed wavelength shift
- Modeled wavelength shift



➢ Modeling Equation:

f(x) = a1*sin(b1*x+c1) +
a2*sin(b2*x+c2) +
a3*sin(b3*x+c3) +
a4*sin(b4*x+c4)
X: mission time
F(x): wavelength shift

➢ Correlation with thermal gradients (housing temperature change)

Linear model: f(x) = p1*x + p2
Coefficients (@ 95% confidence bounds):
p1 = 32.68 and p2 = 0.006929

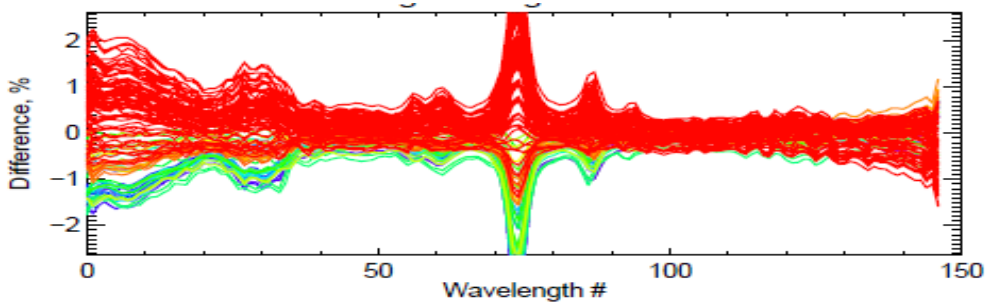
Goodness of fit: SSE: 1.32
R-square: 0.8
RMSE: 0.1549

Modeling error <0.1 nm

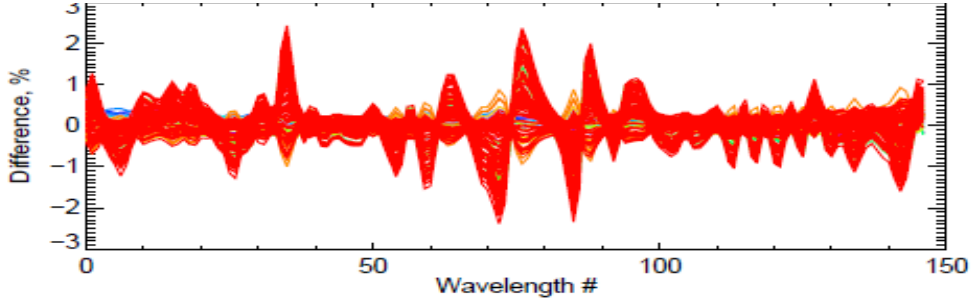
Solar Flux Calibration

Three effects are corrected: degradation, solar activity and wavelength shift

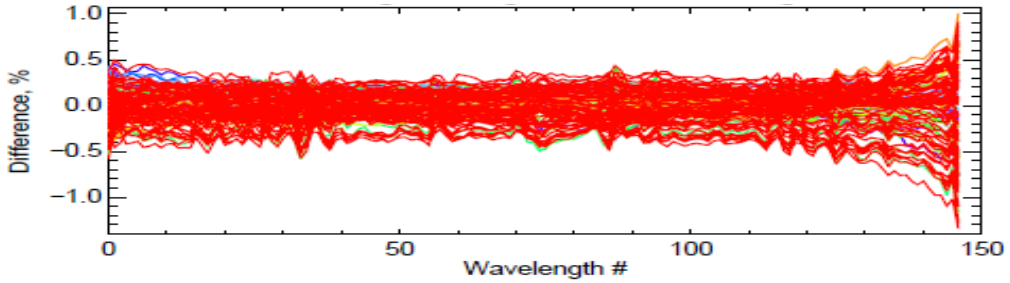
Errors: solar activity + measurement



Error: wavelength shift + measurement

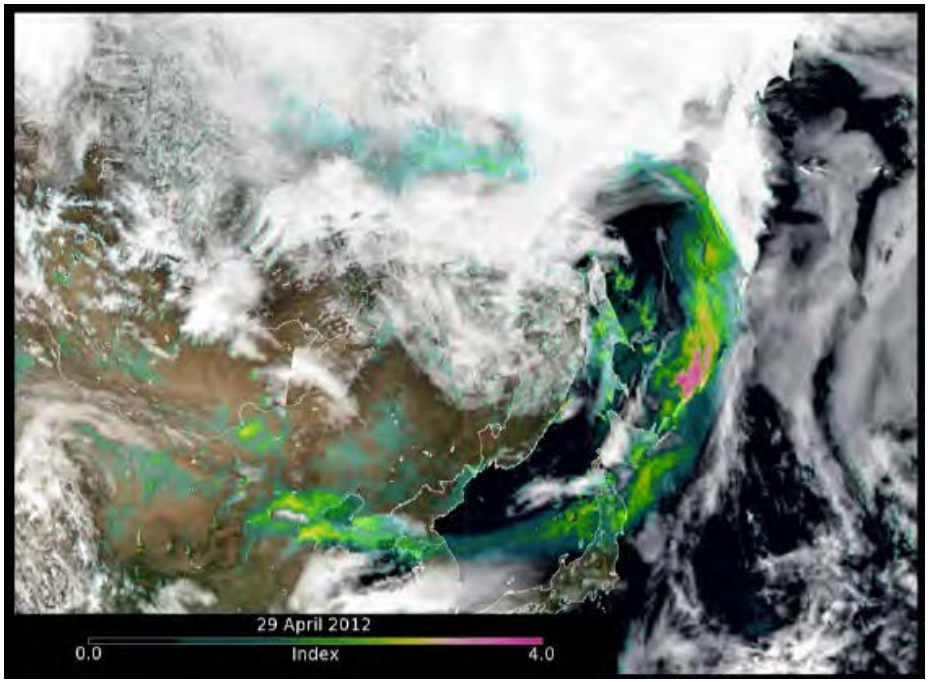


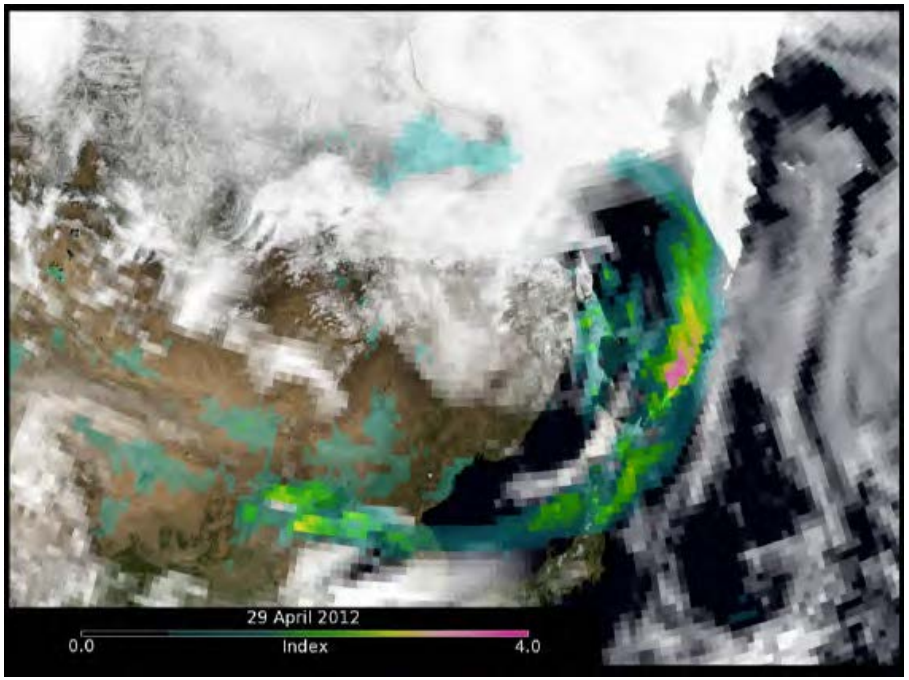
Error: measurement



The calibration algorithm and the calibration tables have been developed and delivered to EDR team on Oct. 18, 2016 for tests. Tables included are daily wavelength LUTs, daily solar flux LUTs and solar irradiance coefficients.

Higher Spatial Resolution Data





Aerosol Studies from Colin Seftor/SSAI: On 29 April 2012, OMPS aerosol index data detected a dust cloud from China's Taklamaken Desert was being transported out over the Pacific Ocean. Blues and greens indicate aerosol index, while yellows and reds indicate higher aerosol index.

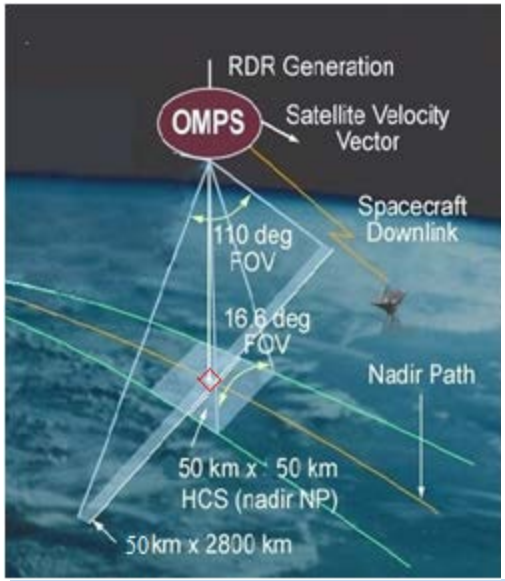
J1 OMPS Design Change

- **Enhanced spatial resolution with new timing patterns**
  - Provides Total Column ozone data w/ 50 km x50 km IFOV at nadir
  - Provides ozone profiles in 5 ground pixels of 50 km x50 km at nadir

- **Configuration**
  - Push-broom 110 deg. cross-track FOV telescope
  - Two grating spectrometers
    - » NM covers 300 – 380, 420 nm
    - » NP covers 250 nm to 310 nm
  - CCD optical detector for each spectrometer

- **Onboard Calibrators**
  - Light-emitting diode provides linearity calibration
  - Reflective quasi-volume diffusers (QVD) maintains calibration stability

- **Products**
  - Provide globe maps every 24 hours of amount of ozone and volumetric concentration in a vertical column of atmosphere with a 4- days revisit



Spatial resolution will be altered to provide low, medium and high spatial resolution data

– The LP will not be present for J1
– NM slit redesigned to reduce "puckering"
– Optical mounts redesigned to improve boresight stability
– Modified optical alignment permits wavelengths up to ~420nm to be measured -- potentially enhances science products and help to correct nadir geolocation and stray light OOB.
– Generation of three SDR products: EV SDRs, Cal. SDRs (offline), and GEOs

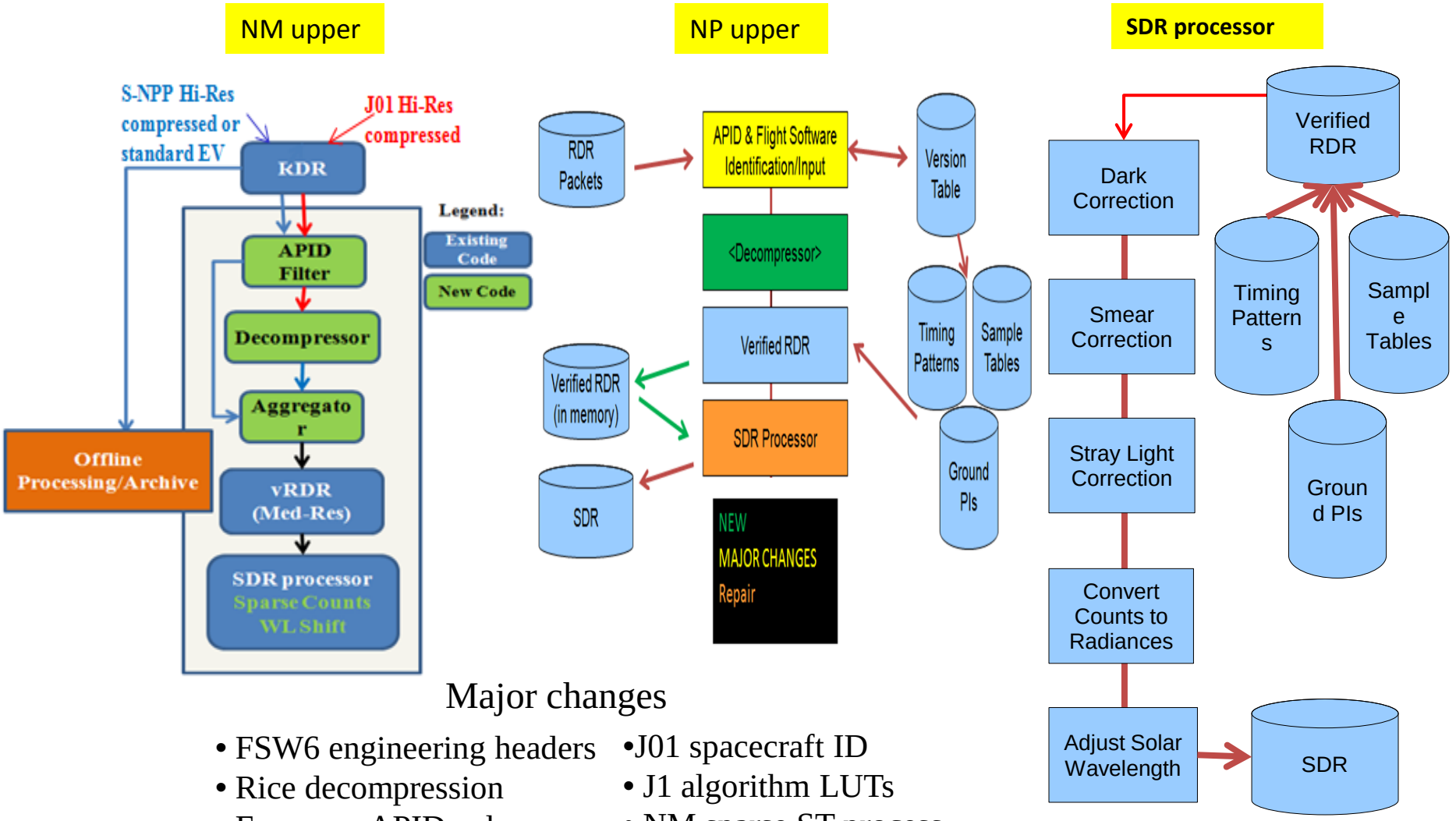
Prelaunch Calibration and Characterization SNPP vs. J1

Prelaunch lab test shows that J1 OMPS calibration stability and accuracy meets science requirements

Source of Uncertainty	Absolute 1σ Fractional Uncertainty (%)				Albedo 1σ Fractional Uncertainty (%)			
	Radiance		Irradiance		λ - independent		λ - dependent	
	NP	TC	NP	TC	NP	TC	NP	TC
SNPP Goniometry	0	0	0.38	0.41	0.38	0.41	0.15	0.36
J1 Goniometry	0	0	0.21	0.21	0.21	0.21	0.1	0.11
OMPS NPP RSS Total	3.383	3.067	3.499	3.194	1.653	1.717	0.426	0.497
OMPS J1 RSS Total	2.637	1.646	2.731	1.8	1.587	1.389	0.405	0.437
Requirement	8.0	8.0	7.0	7.0	2.0	2.0	0.5	0.5

- QVD implementation yields improvements in the albedo uncertainty budget.
- Extended wavelength coverage potentially enhances science return and no significant stray light effects.

Enhanced J1 SDR Algorithm

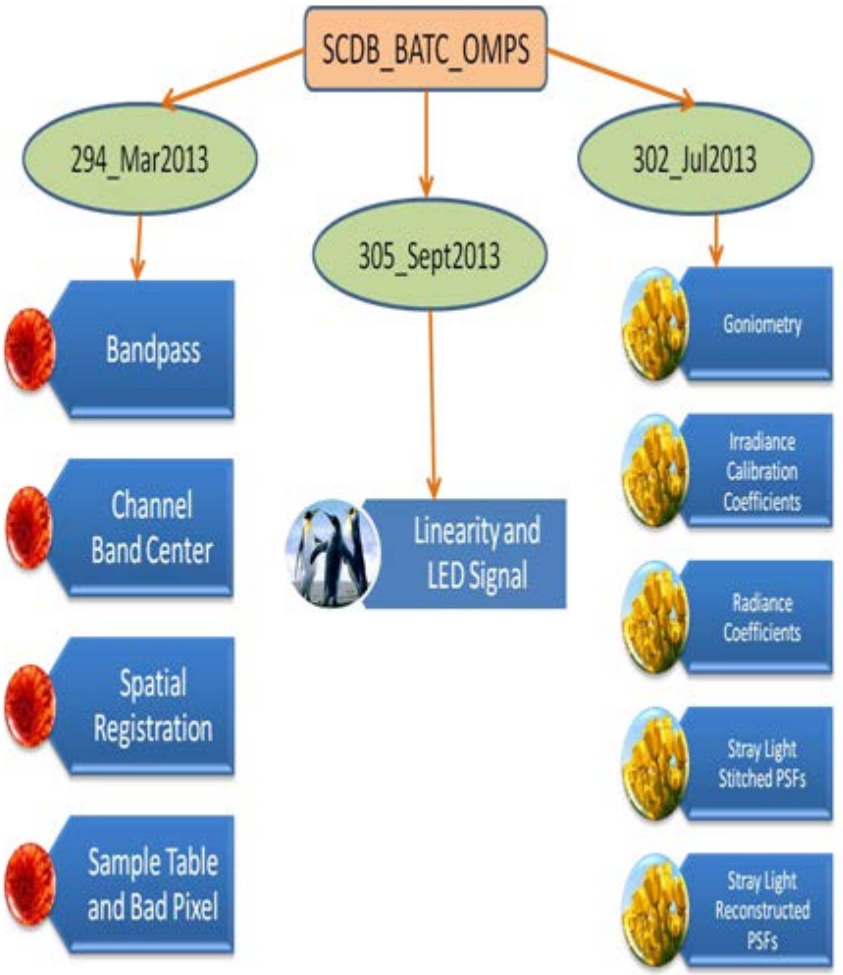


Major changes

- FSW6 engineering headers
- Rice decompression
- Four new APID values
- J01 spacecraft ID
- J1 algorithm LUTs
- NM sparse ST process

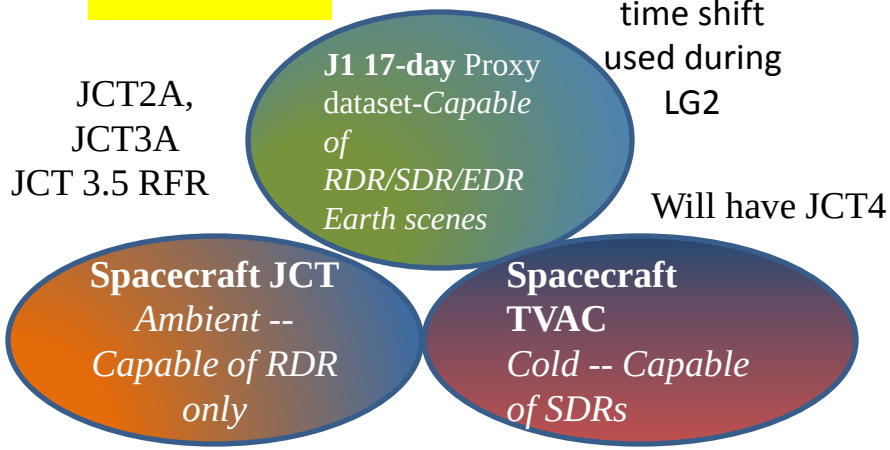
J1 SDR Algorithm Lookup Tables

- OMPS J1 algorithm lookup tables (LUTs) are analyzed and generated from the SCDB which are then processed, as necessary
- LUTs have been delivered in March &July
- SDR algorithm LUTs
  - Measurement: Earth View Sample Table, Macrotable, Timing Pattern
  - Spectrometric LUTs: Spectral Response, Spectral Registration, Wavelengths
  - Radiometric LUTS: Calibration Coefficients, CF-Earth, Darks, Linearity, Stray Light, Solar Irradiance, Observed Solar, Predicted Solar
  - Geolocation LUT: Mounting Matrix and Field Angle Map
  - Table version LUT maps OMPS NM and NP measurement tables to SDR algorithm LUT



OMPS J1 B2.0 Algorithm Evaluation

Data source

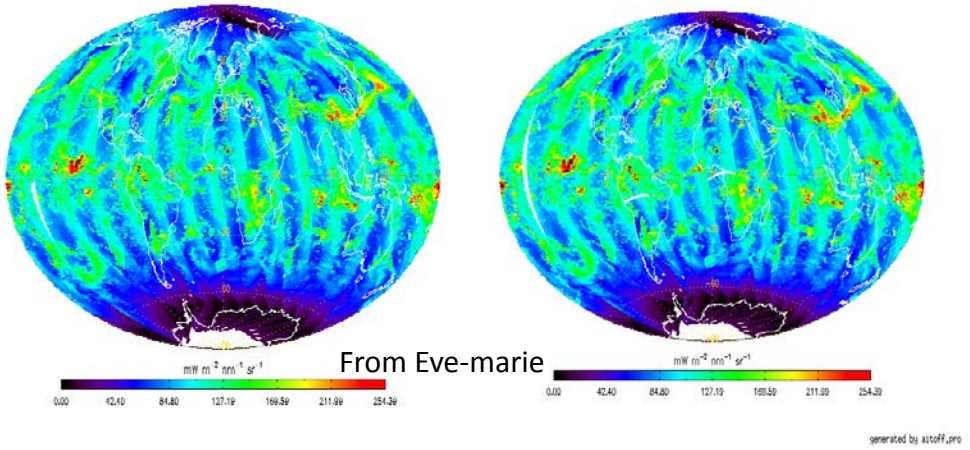


- OMPS43A/B, JCT2.0, JCT3 and will check JCT3.5 and TVAC;
- OMPS closeouts for TVAC – a duration of 50 days
  - All OMPS flight APIDs are expected to be used during TVAC DITL executions
  - OMPS will monitor housekeeping data

Fix anomalies

- IDPS & LG2 Comparison verified ADL5.3 build: resumed stray-light correction in J1 algorithm, added missing pad to process compressed data
- OMPS 43 test data analysis found core dump associated with the compressor.
  - PCR057204: LAY-A-341-R. Closed
- Sample tables, timing pattern and other LUTs were modified to generate

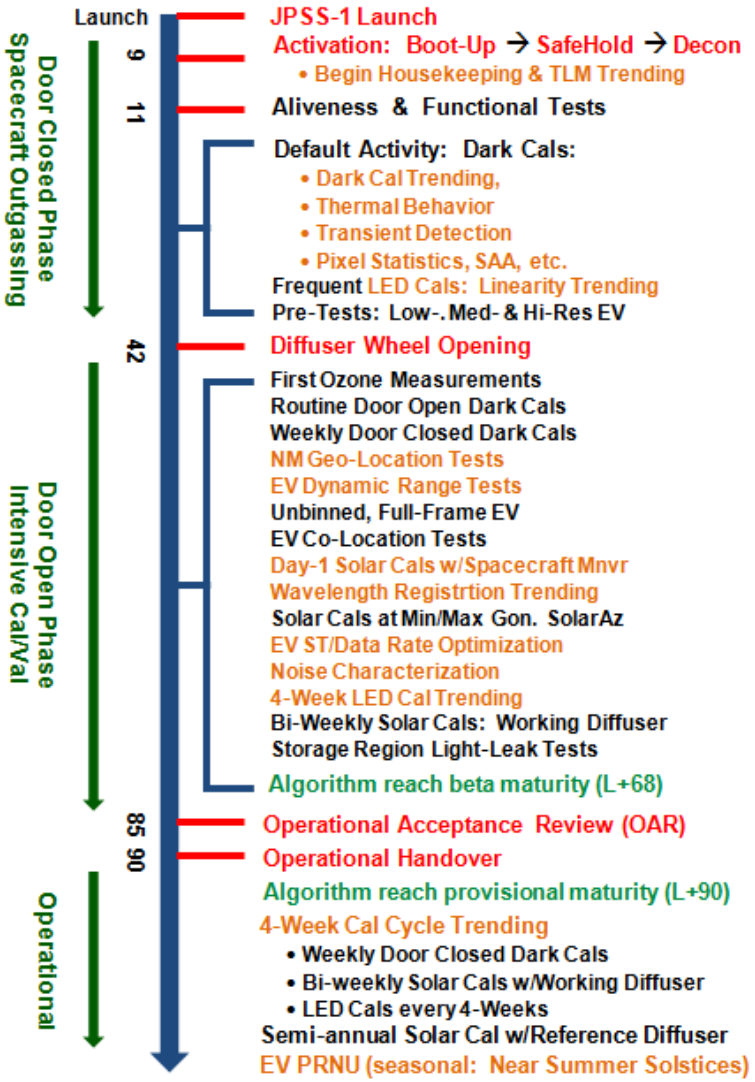
Result Example



From Eve-marie

TC data with B1.2 vs. B2.0 (331.434 nm)

J1 Post-launch Cal/Val Plan



Operational milestones Post-Launch Test (PLT)

Most critical activities SDR maturity

- SDR Maturity Timeline
  - "Beta" L+ 68D
  - "Provisional" around L+ 90D.
  - "Validated/calibrated" around L+9M
- Pre-Launch Calibration/Validation Plans

Year, Phase	Tasks/Activities	Deliverables
2017, PLT to ICV	• Execute the Cal/Val tasks described in the Calval. Plan • Baseline instrument • Adjust instrument settings • Modify measurement sequences when needed • Update appropriate SDR LUTs	Provisional
2018, ICV to LTM	• Improve the calibration; establish LTM • Validate the SDR products • Provide stable and accurate SDR to users.	Validated

Risk, Challenge and Mitigation

- OMPS SNPP Nadir EV SDR products are validated and stable, meet the product requirement.
  - Stabilize and monitor SDR quality conditions at the already established product maturity that represent sensor attainable levels. But there will be late refined version to meet user's needs.
  - Utilize ADL for testing and validation of calibration tables and data anomaly analysis
  - Deploy already established forward model for cross-sensor calibration
- OMPS J1Tasks and schedule are well defined and on schedule. Risk is low for performance.
  - Prelaunch calibration analysis shows OMPS J1 meets system requirement
  - J1 algorithm LUTs and tables were refined and verified through integrated tests from RDR, SDR to EDR.
  - J1 B2.0 algorithm is tested, evaluated and reviewed. Anomalies are fixed.
  - J1 SDRs is of comparable quality as SNPP SDR products, and will be used by the users the same way as they use SNPP data.
- The SDR and EDR team have significant interaction and cooperative planning and development at these algorithms move forward.

Summary and Path Forward

FY17 Milestones

- J1 SDR Beta and provisional status
  - Establish sensor initial settings and parameters
- Alternate Algorithms and Future Improvements for SNPP
  - Correction of NP wavelength thermal sensitivity
  - Generate SNPP high spatial resolution data

J2 and Beyond

- OMPS Limb Profiler SDR algorithm preparation
  - Gridded measurements of atmospheric limb Earth-view measurements for three Nadir orbital track.
  - Spectral coverage from 290 to 1000 nm at 1-km tangent height spacing.