Joint Polar Satellite System

JPSS overview and air quality applications

Mitch Goldberg, JPSS Chief Scientist
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• JPSS consists of three satellites (Suomi NPP, JPSS-1, JPSS-2), ground system and operations through 2025
  – SNPP is now NOAA’s primary weather polar orbiting satellite providing global data.
## JPSS Instruments

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

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>JPSS Sensor</th>
<th>Measurement</th>
<th>Where Pollutant is Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfur dioxide (SO2)</td>
<td>OMPS, CrIS, VIIRS</td>
<td>Column</td>
<td>Troposphere/stratosphere for volcanic eruptions</td>
</tr>
<tr>
<td>Carbon monoxide (CO)</td>
<td>CrIS</td>
<td>Column</td>
<td>Troposphere</td>
</tr>
<tr>
<td>Nitrogen dioxide (NO2)</td>
<td>OMPS</td>
<td>Column</td>
<td>Troposphere</td>
</tr>
<tr>
<td>Ozone (O3)</td>
<td>OMPS, CrIS</td>
<td>Profile</td>
<td>Troposphere*</td>
</tr>
<tr>
<td>Particulate Matter (PM2.5)</td>
<td>VIIRS, OMPS</td>
<td>Column</td>
<td>Troposphere</td>
</tr>
</tbody>
</table>

*Possible with large uncertainties due to large stratospheric signal.*
Comparing MODIS (250m) to VIIRS (375m) Edge of Scan
The ‘Pyrosphere’ and its Atmospheric Effluents

Complementary information on ash/smoke particles having weak IR signatures.
JPSS Next Generation Instruments

Advanced Technology Microwave Sounder

Cross-track Infrared Sounder

Resolution: OMPS vs SBUV/2

Ozone Mapping Profiler Suite

Higher resolution, wider swath, smaller gaps

6x more vertical resolving power

Provides global coverage ozone monitoring
S-NPP and JPSS Data Products

**VIIRS (24)**
- Albedo (Surface)
- Cloud Base Height
- Cloud Cover/Layers
- Cloud Effective Part Size
- Cloud Optical Thickness
- Cloud Top Height
- Cloud Top Pressure
- Cloud Top Temperature
- Ice Surface Temperature
- Ocean Color/Chlorophyll
- Suspended Matter
- Vegetation Index, Fraction, Health
- Aerosol Optical Thickness
- Aerosol Particle Size
- Active Fires
- Polar Winds
- Imagery
- Sea Ice Characterization
- Snow Cover
- Sea Surface Temperature
- Land Surface Temp
- Surface Type

**CrIS/ATMS (3)**
- ATM Vert Moist Profile
- ATM Vert Temp Profile
- Carbon (CO2, CH4, CO)
- Outgoing Longwave Radiation

**OMPS (2)**
- O3 Total Column
- O3 Nadir Profile
- SO2 and Aerosol Index

**ATMS (11)**
- Cloud Liquid Water
- Precipitation Rate
- Precipitable Water
- Land Surface Emissivity
- Ice Water Path
- Land Surface Temperature
- Sea Ice Concentration
- Snow Cover
- Snow Water Equivalent
- ATM Temperature Profile
- ATM Moisture Profile

**GCOM AMSR-2 (11)**
- Cloud Liquid Water
- Precipitation Type/Rate
- Precipitable Water
- Sea Surface Winds Speed
- Soil Moisture
- Snow Water Equivalent
- Imagery
- Sea Ice Characterization
- Snow Cover/Depth
- Sea Surface Temperature
- Surface Type

**CERES (1)**
- RDRs

Data available through PDA, CLASS, and Direct Readout
Currently antennas at Hawaii, Alaska, and Wisconsin, are being used routinely by weather forecast offices using AWIPS’s Local Data Acquisition and Dissemination (LDAD).
Products:

- Water vapor (soundings, fluxes, winds)
- Temperature (sounding, stability)
- Carbon monoxide concentration (2 layers) and total CO₂ concentration
- Methane concentration (total column)
- Ozone concentration (4 layers)
- Surface temperature, Emissivity, Land characterization
- Clouds (altitude, optical depth, microphysical properties, winds)
- Aerosol concentration and depth
List of operational retrieval products

### Retrieval Products

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Frequency Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud Cleared Radiances</td>
<td>660-750 cm⁻¹, 2200-2400 cm⁻¹</td>
</tr>
<tr>
<td>Cloud fraction and Top Pressure</td>
<td>660-750 cm⁻¹</td>
</tr>
<tr>
<td>Surface temperature</td>
<td>window</td>
</tr>
<tr>
<td>Temperature</td>
<td>660-750 cm⁻¹, 2200-2400 cm⁻¹</td>
</tr>
<tr>
<td>Water Vapor</td>
<td>780 – 1090 cm⁻¹, 1200-1750 cm⁻¹</td>
</tr>
<tr>
<td>O3</td>
<td>990 – 1070 cm⁻¹</td>
</tr>
<tr>
<td>CO</td>
<td>2155 – 2220 cm⁻¹</td>
</tr>
<tr>
<td>CH4</td>
<td>1220-1350 cm⁻¹</td>
</tr>
<tr>
<td>CO2</td>
<td>660-760 cm⁻¹</td>
</tr>
<tr>
<td>N2O</td>
<td>1290-1300 cm⁻¹, 2190-2240 cm⁻¹</td>
</tr>
<tr>
<td>HNO3</td>
<td>760-1320 cm⁻¹</td>
</tr>
<tr>
<td>SO2</td>
<td>1343-1383 cm⁻¹</td>
</tr>
</tbody>
</table>

### NUCAPS Temperature retrieval @ 500mb

![Temperature Map](image)

### NUCAPS Ozone retrieval @ 500mb

![Ozone Map](image)
Instrument and Spectral Characteristics

Spectral Coverage and Resolution of AIRS, IASI, and CrIS

- **IASI-A**: 2006-
- **IASI-B**: 2012-
- **AIRS**: 2002-
- **CrIS**: 2011-
  - CrIS: 2014.10-
  - 2378 channels, 9 FOVs/50 km FOR
  - 8461 channels, 4 FOVs/50 km FOR
  - 1305 channels, 9 FOVs/50 km FOR
  - 2211 channels, 9 FOVs/50 km FOR
In this animation made with data from the Atmospheric Infrared Sounder on NASA's Aqua satellite, the plume of carbon monoxide released by sixteen wildfires in Washington state can be seen to bloom and transport east, from August 9 through 24, 2015. The AIRS instrument is sensitive to carbon monoxide at roughly 18,000 feet altitude and at this height we can see how the gas is transported eastward along the U.S.–Canadian border, pushed along by the lower reaches of the polar jet stream. The leading edge of the plume reaches the U.S. east coast over the Saint Lawrence Seaway on August 25, five days after it initially became visible by AIRS in the imagery shown here. Also visible in this animation is carbon monoxide released from Siberian boreal forest wildfires and slash-and-burn agriculture in Africa and South America.
**Advancing Atmospheric Chemistry Through the Use of Satellite Observations from the Cross-track Infrared Sounder (CrIS)**

CrIS Atmospheric Chemistry Data User’s Workshop Report

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**Recommendation 3b:**
More frequent NOAA Earth System Research Laboratory (ESRL) aircraft flights are needed for validation of trace gas retrievals from CrIS (as well as from other satellite observations) for both climate-relevant and air quality-relevant species, including flights designed to investigate apparent anomalies in the CrIS trace gas retrievals. Since CrIS is sensitive to different altitude ranges for different gases, flights of a variety of aircraft with different instrumentation and altitude ranges will be required to validate all of the trace gases retrieved by CrIS.

**Recommendation 3c:**
In addition to the above activities, additional field campaigns and validation activities should be performed to fully validate the CrIS trace gas products, including products from future JPSS missions. These campaigns should involve both the retrieval development and the product user community.

**Recommendation 3d:**
All validation data should be added to the NESDIS Validation Archive (VALAR) so that future CrIS retrieval algorithms can be more easily evaluated against these data sets.

**Conclusion 4:**
We find that CrIS can continue most of the NASA EOS TIR trace gas data records (e.g., CO, O$_3$, CH$_4$, CO$_2$, NH$_3$, N$_2$O, SO$_2$, HNO$_3$, CH$_3$OH; see Sections 4 and 7.1), with the key exceptions of formic acid (HCOOH) and peroxyacetyl nitrate (PAN), which fall in the CrIS spectral gaps. In addition, the remarkably low noise of CrIS opens the possibility for several new trace gas retrieval products (see Section 7.2), including important species such as ethane (C$_2$H$_6$), acetylene (C$_2$H$_2$), ethylene (C$_2$H$_4$), hydrogen cyanide (HCN), and acetic acid (CH$_3$COOH).

**Recommendation 4a:**
We recommend that the CrIS retrieval community explore the development and validation of retrievals for the potential new species in close coordination with atmospheric chemistry research users who desire these products.

**Recommendation 4b:**
We recommend that the current spectral gap between the long-wave and mid-wave bands of CrIS be closed for JPSS-2, allowing the continuation of the EOS trace gas data records for HCOOH and PAN. We note that closing these spectral gaps was also a recommendation of the "JPSS 2 and Beyond: Instrument Improvements for Science Benefits" Workshop held on October 23, 2014.

**Recommendation 4c:**
We recommend that for post-JPSS planning, NOAA continue the polar-orbiting IR sounder program, and that NOAA consider approaches to both reduce the noise and increase the resolution of future versions of CrIS, as is being done in the New Generation of Infrared Atmospheric Sounding Interferometer (IASI-NG) program.
The JPSS Proving Ground and Risk Reduction program’s primary objective is to maximize the benefits and performance of NPP/JPSS data, algorithms, and products for downstream operational and research users (gateways to the public) through:

- Engaging users to enhance/improve their applications through the optimal utilization of JPSS data.
- Education, Training and Outreach
- Facilitating transition of improved algorithms to operations.
- Detailed characterization of data attributes such as uncertainty (accuracy and precision) and long-term stability
- Provides user feedback to the cal/val program

Significant amount of NOAA operational use of SNPP data has been made possible through JPSS PGRR and Direct Readout
Visualization and interacting with data is important.
FY15 & 16 Call for Proposals

• New JPSS PGRR Call for Proposals was released on December 2, 2014.
  – Call focuses on 13 initiatives

• Over 130 Letters of Intent were received.

• New projects will be selected by the JPSS PGRR Executive Board (with feedback from relevant users and stakeholders) in March/April
PGRR Initiatives

About 40 proposals selected so far out of 87 full proposals out of 136 LOIs

- Aerosol Data Assimilation
- Fire and Smoke
- River Ice and Flooding
- Atmospheric Sounding Applications
- NWP impact studies (via HRRR and GFS) and other critical weather applications
- OCONUS and NCEP Service Centers AWIPS Initiative
- Cryosphere Initiative
- Land Data Assimilation
- Ocean and Coastal
- Atmospheric Chemistry
- Hydrology
- Innovation
- Training
Aerosol Data Assimilation (1)

- Improve the use of VIIRS and OMPS aerosol products in operational models at NWP centers or developmental models at partner agencies that have defined pathways to transition to NWP centers.
- Make use and demonstrate the value of VIIRS aerosol optical depth, aerosol (smoke, dust, volcanic ash) detection, and OMPS UV Aerosol Index products in improving forecasts.
Current Air Quality Applications

Pixel level AOT clearly shows smoke plumes from different fires including the small ones.

High spatial resolution valuable for operational forecasters

EDR AOT looks pixelated with smoke plumes not very obviously visible

IP High quality (750 m)

EDR High quality (6 km)
Latency for daily global gridded product availability is 1-2 days.
• Makes use of the VIIRS active fire location, fire radiative power and aerosol optical depth, and potentially OMPS derived aerosols to predict fire movement and dispersion of smoke using high spatial resolution and timely forecast models.

• Products focus on determining the current location of a fire and gathering as much information as possible on its history.
Integrating various satellite data is well recognized and emphasized.
But Landsat has a 16 day repeat cycle – it will not observe this location for another 16 days

VIIRSS 375 meter resolution is adequate for fire behavior modeling – predicting fire movement and smoke direction and speed. GOES-R will tell you where the smoke came from, but difficult to predict because of spatial resolution (need < 500 meter resolution)
Transport of Russian Smoke Across Pacific
(OMPS AI over VIIRS RGB)

Credit: Colin Seftor (NASA)
Combine VIIRS and OMPS radiances to generate aerosol indices that can clearly separate smoke, dust, urban/industrial aerosol.

**VIIRS:** Aerosol Index separates dust and smoke but urban haze (sulfate aerosol) can be mis-identified as smoke.

**OMPS:** Aerosol Index separates absorbing aerosol (dust and smoke) from scattering aerosol (sulfate aerosol).
OMPS: NO$_2$ Trop Vertical Columns

Credit: Kai Yang, UMD
Unprecedented SO$_2$ Sensitivity: Pollution over US

SNPP/OMPS
October 2013
Monthly Mean
DVCF Algorithm

Credit: Kai Yang, UMD
SO$_2$ products from processing by K. Yang, NASA OMPS Science Team Member. The data for the low-resolution orbit has 35 cross-track FOVs 50x50 KM$^2$ at nadir. The high-resolution orbit has 175 cross track FOVs 10x10 KM$^2$ at nadir. Lower resolution data will be obtained starting with OMPS on JPSS01. The data shows the volcanic SO$_2$ plume from Kliuchchevskoi (located at the red triangle) as observed by S-NPP OMPS for October 19-20 2013.
A multi-sensor SO$_2$ analysis is badly needed.
(left) CrIS NH₃ retrieval results over California plotted using the NH₃ representative volume mixing ratio (RVMR), which is approximately the retrieved value at the height of peak sensitivity of CrIS to NH₃. Most missing data is due to the presence of clouds. (right) The same but for the Southeast US during the NOAA SENEX campaign.
Global Distribution of Marine Isoprene
Path Forward

• The JPSS Proving Ground program is working with NOAA users to further promote the use of SNPP and JPSS data for operational use.
  – Use of fire location and radiative power in regional fire and smoke models
  – Assimilation of VIIRS aerosols and land products in NCEP global models
  – Working with OAR to validate the NUCAPS CO and CH4 products

• But what we need from you is a clear plan of your operational product and services, and JPSS will support demonstration of your highest priority utilization of JPSS data.
Want to learn more?

- 2013 and 2014 Annual Science Digests are available
- Check out the JPSS Website [http://www.jpss.noaa.gov/science.html](http://www.jpss.noaa.gov/science.html)
Thank you!

For more information visit

www.jpss.noaa.gov

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