NPOESS VIIRS: Design, Performance Estimates and Applications

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Overview

• The National Polar-orbiting Operational Environmental Satellite System (NPOESS) Visible Infrared Imaging Radiometer Suite (VIIRS) will offer dramatic spatial, spectral, and radiometric performance improvements over current operational capabilities

• NOAA Advanced Very High Resolution Radiometer (AVHRR) offers 1 km nadir spatial resolution in 5 spectral bands

• The Defense Meteorological Satellite Program (DMSP) Operational Line-scanning System (OLS) offers near constant contrast 1.8km day-night cloud imaging and visible and thermal imagery
VIIRS

• VIIRS offers 22 band spectroradiometry comparable to NASA’s MODerate-resolution Imaging Spectroradiometer (MODIS).

• On NPP and NPOESS
• 3000 Km Swath
• Day-night cloud imagery (constant contrast 750 m resolution)
• 4:1 better edge-of-scan spatial resolution than AVHRR or MODIS
**NOAA AVRRR Contributions to VIIRS Subpoint Spatial Resolution**

<table>
<thead>
<tr>
<th>AVHRR</th>
<th>VIIRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>.63 µm</td>
<td>Imagery, Clouds, Snow, Dust</td>
</tr>
<tr>
<td>.86 µm</td>
<td>Terrain, vegetation, water</td>
</tr>
<tr>
<td>1.6 µm</td>
<td>Snow, Cirrus Properties</td>
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<tr>
<td>3.7 µm</td>
<td>Fires, Low Clouds, SST</td>
</tr>
<tr>
<td>10.8 µm</td>
<td>Images, Cloud height, SST</td>
</tr>
<tr>
<td>11.8 µm</td>
<td>Volcanic Ash, Split Window</td>
</tr>
</tbody>
</table>

| 1.1 km | 0.37 km |

**Wavelength**

- .63 µm
- .86 µm
- 1.6 µm
- 3.7 µm
- 10.8 µm
- 11.8 µm
VIIRS System Provides Excellent Environmental Data Records (EDRs)

- VIIRS System Design based on integrated Sensor and Algorithms
- Engineering Development Unit (EDU) approaching integration
- EDR Science Algorithms developed, documented, and publicly released by Raytheon Technical Services Company (RTSC) Information Technology and Scientific Services (ITSS)
### VIIRS VIS/NIR & IR Bands

**VIIRS, MODIS, FY-1C, AVHRR**

**High resolution atmospheric absorption spectrum and comparative blackbody curves.**

<table>
<thead>
<tr>
<th>Band No.</th>
<th>Wavelength (µm)</th>
<th>Horiz Sample Interval (km Downtrack x Crossoffset)</th>
<th>Driving EDRs</th>
<th>Radiance Range</th>
<th>Ltyp or Ttyp</th>
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<tbody>
<tr>
<td>VIS/NIR FPA</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>M1</td>
<td>0.412</td>
<td>0.742 x 0.259</td>
<td>Ocean Color Aerosols</td>
<td>Low High</td>
<td>44.9 155</td>
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<td>M4</td>
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<td>M6</td>
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<td>Atmospheric Constellation</td>
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<td>CCD DNB</td>
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<tr>
<td>SAMIR</td>
<td></td>
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<td></td>
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<tr>
<td>M10</td>
<td>1.61</td>
<td>0.742 x 0.776</td>
<td>Cloud Particle Size</td>
<td>Single</td>
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<tr>
<td>M9</td>
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<td>0.742 x 0.776</td>
<td>Cirrus/Cloud Cover</td>
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<td>6</td>
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<tr>
<td>M16</td>
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<td>0.742 x 0.776</td>
<td>Clouds</td>
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<tr>
<td>M15</td>
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<td>Snow Fraction</td>
<td>Single</td>
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<tr>
<td>M14</td>
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<td>Imagery Clouds</td>
<td>Single</td>
<td>270 K</td>
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<tr>
<td>M13</td>
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<td>SST</td>
<td>Low High</td>
<td>300 K 380 K</td>
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<tr>
<td>L1R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M14</td>
<td>0.55</td>
<td>0.742 x 0.776</td>
<td>Cloud Top Properties</td>
<td>Single</td>
<td>270 K</td>
</tr>
<tr>
<td>M15</td>
<td>1.075</td>
<td>0.742 x 0.776</td>
<td>SST</td>
<td>Single</td>
<td>300 K</td>
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<tr>
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<td>0.742 x 0.776</td>
<td>Cloud Imagery</td>
<td>Single</td>
<td>210 K</td>
</tr>
<tr>
<td>M16</td>
<td>12.013</td>
<td>0.742 x 0.776</td>
<td>SST</td>
<td>Single</td>
<td>300 K</td>
</tr>
</tbody>
</table>

**Driving EDRs**

- Ocean Color Aerosols
- Atmospheric Contellation
- Imagery
- Cloud Particle Size
- Cirrus/Cloud Cover
- Binary Snow Map
- Snow Fraction
- Imagery Clouds
- SST
- Cloud Top Properties
- Cloud Imagery
- SST
Finer Sampling, Spatial Resolution & Better Sensitivity

SNR predicted and specified at worst-case edge of scan:
~60% better nadir SNR and finer spatial resolution

@ Nadir

@ ~1500 km

@ ~3000 km

Fine-Resolution Imaging ‘I’ Bands

Moderate-Resolution ("Radiometric") ‘M’ Bands
AVHRR VISIBLE SIMULATION

Nadir

Edge of Scan
VIIRS VISIBLE SIMULATION

Nadir

Edge of Scan
San Diego – MODIS Edge
San Diego – MODIS Nadir
GOES versus MODIS
Quality of Subsectors

MODIS

2300 km

VIIRS

3000 km
VIIRS value to forecasters multiplied by efficient data delivery!

- 95% of data delivered within 28 min to central processing stations
- Average delivery time 10.5 min
- Current prototypes using MODIS have latency 2-3 hours
Publicly accessible demonstration of Satellite Products over the continental United States:

1. Simulate future NPOESS capabilities in public forum

2. Near-realtime display of products, some not previously available (e.g., nighttime visible)
NexSat: Web Design
NexSat: 250m City Zooms
NexSat: Dust Storms

True Color

Dust Enhancement

Lake Tahoe
Nevada
California

Dust Plume
NexSat: Aircraft Contrails

“Racetrack” flight pattern
NexSat: Fire Detection
NexSat: Cloud/Snow Discrimination

- Complex snow/cloud scenes during winter in Southwest Asia
- Difficult to distinguish clouds from snow in single visible and window-infrared channels
- The ability to determine the presence of cloud over a snow field is useful to targeting, surveillance, navigation, etc.
DayNight Band (DNB) Constant Resolution

- Purpose: Replicate OLS capability but with updated technology and improvements

- 0.5 -- 0.9 μm broadband visible

- Detectors are aggregated to produce near-constant resolution

- More detectors aggregated near nadir for high SNR; fewer aggregated near edge for lower SNR
**DNB “Constant Contrast”**

<table>
<thead>
<tr>
<th>Three Gains</th>
<th>Relative Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>119,000</td>
</tr>
<tr>
<td>Medium</td>
<td>477</td>
</tr>
<tr>
<td>Low</td>
<td>1</td>
</tr>
</tbody>
</table>

- Improves SNR at low radiances
- All pixels are imaged with all three gains
- Onboard processing selects the most sensitive gain setting without saturation for transmission to the ground
- Goal is “constant contrast” imagery
DMSP (F14) Terminator Image
Full Moon
DMSP OLS

NGDC Poster
No Moon
Full Moon
98% full, 48.1° Elevation
**VIIRS Improvement for DNB**

<table>
<thead>
<tr>
<th>DMSP OLS</th>
<th>NPOESS VIIRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 64 Gray shades</td>
<td>64 X = 4096 Gray shades</td>
</tr>
<tr>
<td>2. 2.2 km Field of View</td>
<td>0.75 km Field of View</td>
</tr>
<tr>
<td>3. Limited Pixel Expansion</td>
<td>No Pixel Expansion</td>
</tr>
<tr>
<td>4. Numerous Image Artifacts</td>
<td>Artifacts Eliminated</td>
</tr>
</tbody>
</table>
Lights over Korea

Image and data processing by NOAA’s National Geophysical Data Center. DMSP data collected by US Air Force Weather Agency.
OLS Lightning Detection

National Lightning Detection Network (Cloud-to-Ground Strikes)
Red = 0-30 min old
Blue = 30-60 min old
Near-Realtime Polar Products from NexSat

Conclusions

- VIIRS adds advanced capability not available from MODIS
- NPOESS will truly be a forecaster’s system
- Constant-Contrast/Constant-Resolution Data will produce vivid, information-rich images for DNB
- Preservation of footprint size will facilitate much more usable images
- VIIRS fine channels replicate the capability of AVHRR
- Many products in addition to EDRs
- True color capability preserved for VIIRS