Transitioning from MODIS to VIIRS

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¹IPO: Integrated Program Office, NOAA
²DRL: Direct Readout Laboratory, NASA
The NPP mission collects and distributes remotely-sensed land, ocean, and atmospheric data to the meteorological and oceanographic communities. This data is used for a variety of purposes, including weather forecasting, climate research, and oceanography. NPP is the NPOESS Preparatory Program, which serves as the bridge mission between the EOS satellite missions and NPOESS. NPOESS is the satellite program following NPP.

NPOESS is managed by the Integrated Program Office (IPO), which is jointly organized by the Department of Defense, Department of Commerce (NOAA), and the National Aeronautics and Space Administration (NASA).

Sensors used in the NPP/NPOESS mission include VIIRS (Visible Infrared Imager Radiometer Suite), ATMS (Advanced Technology Microwave Sounder), CrIS (Cross-track Infrared Sounder), and OMPS (Ozone Mapping and Profiler Suite).

What is NPP / NPOESS?

VIIRS: Visible Infrared Imager Radiometer Suite
125 confirmed EOS direct readout ground systems world-wide.
50% owned by government agencies and organization, 35% owned by educational institutions, 15% owned by the commercial sector, 30 countries, 85% support near-realtime applications
NPP/NPOESS Direct Readout Architecture

NPP/NPOESS Satellites

Signal Processing
- Antenna / RF Processing
- GPS and Timing
- Satellite Scheduler
- CCSDS Processing
  - Mission Data
  - Mission Support Data
  - Satellite Pass Storage
  - TLE Extraction
- Decryption (optional)

IPOPP NPP Ancillary Data Server
- Ancillary Data (NCEP-GFS, FNMOC-NOGAPS, NISE)
- Auxiliary Data
- TLE

Responsibility Legend
- HRD/LRD Downlinks NGST
- Operational Algorithms NGST/Raytheon
- User Agency/ Vendor
- IPOPP
- IPO, NASA DRL, UW
- NPOESS Ancillary Data NGST
- NPOESS to FT ICD NGST

NPOESS Mission Support Data Server (C3)
- Mission Status Data

FT-MSDS Interface (Optional)

Direct Readout Ground Station

Data Processing Hardware

IPOPP Operational Algorithms

Mission Applications
- User-defined HDF Product Display

IPOPP NPP Ancillary Data Server
- Ancillary Data (NCEP-GFS, FNMOC-NOGAPS, NISE)
- Auxiliary Data
- TLE

FT Operator or User

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VIIRS at a Glance

• VIIRS: Visible Infrared Imager Radiometer Suite
• VIIRS Heritage
  – OLS: Operational Line Scanner
  – AVHRR: Advanced Very High Resolution Radiometer
  – SeaWiFS: Sea viewing Wide Field-of-view Sensor
  – MODIS: Moderate Resolution Imaging Spectroradiometer
• VIIRS will provide operational and research users with:
  – Spectral coverage from 412 nm to 12 microns in 22 bands
    • Imagery at ~375 m nadir resolution in 5 bands
    • Moderate resolution (~750 m at nadir) radiometric quality data
  – Complete global daily coverage with a single sensor
• Routine data products
  – Cloud cover, cloud layers
  – Cloud and aerosol physical properties
  – Land & ocean biosphere properties, snow & ice
  – Sea Surface Temperature, Land & Ice Temperatures
  – Fire detection
VIIRS Design - Evolutionary from MODIS

- Spatial resolution improved
  - From 500 m & 1000 m to 375 m & 750 m at nadir
  - Reduced pixel growth from nadir to edge of scan
- Spectral coverage slightly smaller
  - From 0.412 – 14.4 microns to 0.412 – 12 microns
  - Longer IR bands for CO₂ covered by sounding instrument, Cross-track Infrared Sounder (CrIS)
- Improved stray light control
  - From Paddle Wheel to Rotating telescope design
- Added “day-night” band for cross-terminator imaging
- Higher orbit yields full global coverage in one day
  - From ~705 km to ~830 km
- Comparable radiometric and spectral quality
  - 12 bit data
  - Similar on-board calibrators
  - Characterization equivalent to Aqua MODIS
  - Bandpasses widened with little loss of specificity
    - Minimal impact to Vegetation Index
- Bandset reduced from 36 to 22
  - Partially offset due to 7 dual gain bands on VIIRS
  - Ocean Color bands reduced by 1

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## Comparison of MODIS & VIIRS Bands

### MODIS

<table>
<thead>
<tr>
<th>Band #</th>
<th>λ (nm)</th>
<th>VIIRS λ (nm)</th>
<th>Band ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>620 - 670</td>
<td>600 - 680</td>
<td>I-1</td>
</tr>
<tr>
<td>2</td>
<td>841 - 876</td>
<td>845 - 885</td>
<td>I-2</td>
</tr>
<tr>
<td>3</td>
<td>459 - 479</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>545 - 565</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1230 - 1250</td>
<td>1230 - 1250</td>
<td>M-8</td>
</tr>
<tr>
<td>6</td>
<td>1628 - 1652</td>
<td>1580 - 1670</td>
<td>M-10</td>
</tr>
<tr>
<td>7</td>
<td>2105 - 2155</td>
<td>2225 - 2275</td>
<td>M-11</td>
</tr>
<tr>
<td>8</td>
<td>405 - 420</td>
<td>402-422</td>
<td>M-1</td>
</tr>
<tr>
<td>9</td>
<td>438 - 448</td>
<td>436-454</td>
<td>M-2</td>
</tr>
<tr>
<td>10</td>
<td>483 - 493</td>
<td>478-498</td>
<td>M-3</td>
</tr>
<tr>
<td>11</td>
<td>526 - 536</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>546 - 556</td>
<td>545-565</td>
<td>M-4</td>
</tr>
<tr>
<td>13</td>
<td>662 - 672</td>
<td>662-682</td>
<td>M-5</td>
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<tr>
<td>14</td>
<td>673 - 683</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>743 - 753</td>
<td>739-754</td>
<td>M-6</td>
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<tr>
<td>16</td>
<td>862 - 877</td>
<td>846-885</td>
<td>M-7</td>
</tr>
<tr>
<td>17</td>
<td>890 - 920</td>
<td></td>
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<tr>
<td>18</td>
<td>931 - 941</td>
<td></td>
<td></td>
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<tr>
<td>19</td>
<td>915 - 965</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MODIS Bands 1-2 are 250 m at Nadir  
MODIS Bands 3-7 are 500 m at Nadir  
MODIS Bands 8-36 are 1,000 m at Nadir

### VIIRS

<table>
<thead>
<tr>
<th>Band #</th>
<th>λ (nm)</th>
<th>λ (nm)</th>
<th>Band ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>3.660 - 3.840</td>
<td>3.610 — 3.790</td>
<td>M-12</td>
</tr>
<tr>
<td>22</td>
<td>3.940 — 4.001</td>
<td>3.973 — 4.128</td>
<td>M-13</td>
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<tr>
<td>23</td>
<td>4.020 - 4.080</td>
<td>4.433 — 4.498</td>
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</tr>
<tr>
<td>25</td>
<td>1.360 - 1.390</td>
<td>1.371 — 1.386</td>
<td>M-9</td>
</tr>
<tr>
<td>26</td>
<td>6.535 - 6.895</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>7.175 - 7.475</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>8.400 - 8.700</td>
<td>8.400 — 8.700</td>
<td>M-14</td>
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<tr>
<td>29</td>
<td>9.580 - 9.880</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>10.780 - 11.280</td>
<td>10.050 - 12.400</td>
<td>I-5</td>
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<tr>
<td>31</td>
<td>11.770 - 12.270</td>
<td>11.538 — 12.488</td>
<td>M-16</td>
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<tr>
<td>32</td>
<td>13.185 - 13.485</td>
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</tr>
<tr>
<td>33</td>
<td>13.485 - 13.785</td>
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<td></td>
</tr>
<tr>
<td>34</td>
<td>13.785 - 14.085</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>14.085 - 14.385</td>
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</tr>
</tbody>
</table>
VIIRS EDRs, IPs, and ARPs

EDR-Environmental Data Record | IP-Intermediate Product | ARP-Application Related Product

**Land**
- Active Fire [ARP]
- Land Surface Albedo
- Land Surface Temperature
- Ice Surface Temperature
- Sea Ice Characterization
- Snow Cover/Depth
- Vegetation Index
- Surface Type

**Imagery & Cloud**
- Imagery
- Cloud Mask [IP]
- Cloud Optical Thickness
- Cloud Effective Particle Size Parameter
- Cloud Top Parameters
- Cloud Base Height
- Cloud Cover/Layers

**Ocean**
- Sea Surface Temperature
- Ocean Color/Chlorophyll

**Aerosol**
- Aerosol Optical Thickness
- Aerosol Particle Size Parameter
- Suspended Matter

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Algorithm Overview

- This deliverable Application Related Product (ARP) provides:
  - Geolocation of the pixels in which active fires are detected,
  - The sub-pixel average temperature of each active fire, and
  - The sub-pixel area of each active fire.

- Execution Conditions:
  - Both day and night
  - Confident Clear pixels

- HCS @ Nadir: 0.75 km

Corresponding MODIS Algorithm

MODIS Thermal Anomalies/Fire products are primarily derived from MODIS 4- and 11-micrometer radiances. The fire detection strategy is based on absolute detection of a fire (when the fire strength is sufficient to detect), and on detection relative to its background (to account for variability of the surface temperature and reflection by sunlight). Numerous tests are employed to reject typical false alarm sources like sun glint or an unmasked coastline. This product includes fire-mask, algorithm quality, radiative power, and numerous layers describing fire pixel attributes.

HCS @ Nadir: 1 km

Inputs Required

- VIIRS Moderate Resolution Reflectances and Brightness Temperatures
  - M5, M7, M11, M13, M15, M16
- VIIRS Quarterly Surface Types IP
- Ancillary Data
  - Land-Water Mask

Active Fires product generated by the VIIRS Test Scene: MOD200025 8.0830; VIIRS Chain Test Report – The VIIRS Land Algorithms

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Algorithm Overview

- Normalized Difference Vegetation Index (Top of the Atmosphere; TOA) uses the traditional NDVI formulation with TOA reflectance inputs. NDVI is most directly related to absorption of photosynthetically active radiation, but is often correlated with biomass or primary productivity. Red spectral measurements are sensitive to the chlorophyll content of vegetation and the near IR to the mesophyll structure of leaves.
- This EDR also contains a Top of the Canopy (TOC) Enhanced Vegetation Index (EVI), based on the MODIS equation.

Execution Conditions
- Land Pixel
- Confident Clear pixels
- During daytime
- HCS @ Nadir: 0.375 km

Inputs Required
- VIIRS Imagery Resolution Reflectances
  - I1 & I2
- Surface Reflectance IP
- No Ancillary Data

Corresponding MODIS Algorithm

The MODIS TOC NDVI complements NOAA’s Advanced Very High Resolution Radiometer (AVHRR) TOA NDVI products and provides continuity for time series historical applications. MODIS also includes a new EVI that minimizes canopy background variations and maintains sensitivity over dense vegetation conditions. The EVI also uses the blue band to remove residual atmosphere contamination caused by smoke and sub-pixel thin cloud clouds. The MODIS NDVI and EVI products are computed from atmospherically corrected bi-directional surface reflectances that have been masked for water, clouds, heavy aerosols, and cloud shadows. The resolution for this product is 500 m.
Algorithm Overview

• Sea surface temperature (SST) is defined as a measurement of the temperature of the surface boundary layer (skin) and upper 1 meter (bulk) of ocean water.
• Retrievals are made using separate relations for skin and bulk SST.
• Execution Conditions
  • Ocean pixels
  • Current and adjacent pixels are Confident Clear
  • No thin cirrus
  • HCS @ Nadir: 0.75 km

Inputs Required

• VIIRS Moderate Resolution Brightness Temperatures
  • M12, M15, M16
• VIIRS Cloud Mask IP
• VIIRS Ice Concentration IP
• VIIRS Aerosol Optical Thickness IP
• Ancillary Data
  • Surface Temperature

Corresponding MODIS Algorithm

MODIS Sea Surface Temperature (MOD28) is generally referred to the non-linear SST (NLSST) algorithm. It is currently being produced and distributed by the Ocean Biology Processing Group at NASA/GSFC. This algorithm uses the same split window algorithm VIIRS has adopted with has heritage back to AVHRR.
International Polar Orbiter Processing Package

IPOPP

- Provide software to generate Environmental Data Records (Level 2) in near real-time from Direct Broadcast of EOS to NPOESS High Rate Data and NPOESS Low Rate Data
  - Open source (GPL)
  - Freely available (no COTS licenses required)
  - Easy to install & run
  - Multi-platform (e.g., Linux, Solaris, OS X)
  - HDF5 data format (NPP and NPOESS)
  - Self-contained, Modular
  - Uses consistent & up to date calibration Look Up Tables
  - Leverage legacy software development lessons learned (IMAPP)
  - Build on NPP In-Situ Ground Station foundation

Smoothly transition from EOS to NPOESS (IMAPP → IPOPP)
International Polar Orbiter Processing Package (IPOPPP) Milestones

Outcomes/Deliverables

- Software/HW Prototyping
- Implementation and Testing of V1.5a
- Conduct training workshop

Timeline CY

2005-6
2007
2008
2009
2010
2011

- Updated Version Release 2.0
- Post launch EDR evaluations
- Algorithm Tuning
- Support User Community
- Conduct training workshop

- Public Release of V 1.5a
- Algorithm Tuning
- Support User Community
- Conduct training workshop

- Updated Version Release 2.0
- Implementation and Testing of V1.5a
- Alpha testing at DB User sites

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IPOPP Alpha Testing

Test Stations participating today in testing IPOPP version 1.5a (MODIS)

- **US Government**
  - NASA Direct Readout Laboratory (SN)
  - USDA Forest Service Remote Sensing Applications Center (RSAC) (SN)
  - USAF MARK IV (coming soon)

- **Universities**
  - Oregon State University (OSU) (SN)
  - University of South Florida (USF)
  - University of Wisconsin (UW – CIMSS) (coming soon) (SN)
  - University of New Mexico

- **International**
  - Instituto Nacional de Pesquisas Espaciais (INPE) (Brazil's National Institute for Space Research) (coming soon)
  - CONABIO, Mexico (SN)
  - Bureau of Meteorology and LANDGATE, Australia (coming soon)
  - India National Remote Sensing Agency (NRSA) (Pending Approval)
  - MAFFIN, Japan (coming soon)

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