VIIRS EDR IMAGERY

OVERVIEW

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VIIRS EDR Imagery Team
16 August 2017
Outline

VIIRS Imagery Overview

• Cal/Val Team Members
• Sensor/Algorithm (GTM EDRs)
• S-NPP Product(s) / Examples
• JPSS-1 Readiness (12 October 2017 launch)
• Summary and Path Forward
# Cal/Val Team Members

<table>
<thead>
<tr>
<th>PI</th>
<th>Organization</th>
<th>Team Members</th>
<th>Roles and Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>D. Hillger</td>
<td>StAR/RAMMB</td>
<td>D. Lindsey, D. Molenar</td>
<td>Imagery Product Lead, weekly reports, <strong>social media interactions</strong>, data infrastructure</td>
</tr>
<tr>
<td>T. Kopp</td>
<td>Aerospace</td>
<td></td>
<td>Cal/Val Lead, VIIRS heritage</td>
</tr>
<tr>
<td>S. Miller</td>
<td>CIRA/RAMMB</td>
<td>C. Seaman, S. Finley, G. Chirokova, J. Torres, L. Grasso, G. Chirokova</td>
<td>Imagery cal/val, VIIRS online, end user support (including tropical cyclones), VIIRS training</td>
</tr>
<tr>
<td>K. Richardson</td>
<td>NRL – Monterey</td>
<td>A. Kuciauskas</td>
<td>NexSat, VIIRS web</td>
</tr>
<tr>
<td>C. Elvidge</td>
<td>NCEI – Boulder</td>
<td>K. Baugh</td>
<td>DNB</td>
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<tr>
<td>JAM</td>
<td>NASA DPE</td>
<td>R. Marley</td>
<td>Algorithm testing</td>
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<tr>
<td></td>
<td>Noblis</td>
<td>G. Mineart</td>
<td>Requirements</td>
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<tr>
<td></td>
<td>Raytheon</td>
<td>W. Ibrahim, K. Ahmad</td>
<td>Operations</td>
</tr>
<tr>
<td>AIT</td>
<td>StAR</td>
<td>M. Tsidulko</td>
<td>Integration</td>
</tr>
<tr>
<td>Alaska users</td>
<td>GINA, NWS</td>
<td>E. Stevens, M. Kreller, others</td>
<td>End users, analysis and forecasting</td>
</tr>
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VIIRS EDR Imagery

- **VIIRS Imagery** remapped to the **Ground Track Mercator (GTM)** grid, eliminating overlapping pixels and bowtie deletions.
  - **NCC Imagery** is a *pseudo-albedo* derived from the DNB by normalizing the large *radiance* contrast in **DNB** from day to night (7 orders of magnitude)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>SDR</th>
<th>EDR</th>
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<tbody>
<tr>
<td>Visible and IR bands</td>
<td>Radiances and/or reflectances</td>
<td>Radiances and/or reflectances (<em>same</em> as SDR)</td>
</tr>
<tr>
<td>Geo-spatial mapping</td>
<td><strong>Satellite projection</strong></td>
<td><strong>Ground Track Mercator (GTM) projection:</strong></td>
</tr>
<tr>
<td></td>
<td>• Cross-track scans</td>
<td>• Rectangular grid</td>
</tr>
<tr>
<td></td>
<td>• Bowtie (on spacecraft) deletions</td>
<td>• No imagery gaps</td>
</tr>
<tr>
<td></td>
<td>• Overlapping pixels</td>
<td>• No pixel overlap</td>
</tr>
<tr>
<td>Day/night imagery</td>
<td><strong>DNB (radiances)</strong></td>
<td><strong>NCC (pseudo-albedos)</strong></td>
</tr>
</tbody>
</table>
VIIRS SDR vs. EDR

Bowtie deletions ➔
Near Constant Contrast (NCC) vs. Day-Night Band (DNB)

Example of NCC vs. DNB for a day/night terminator (non-lunar) case. **NCC extends constant contrast into the twilight portion of the granule swath.**

*Curtis Seaman, CIRA*
Better spatial resolution at swath edge

VIIRS swath width

MODIS swath width

MODIS

VIIRS
VIIRS EDR Imagery

- **EDR Imagery is a **Priority 1** **VIIRS product**
  - Certain EDR Imagery bands are **Key Performance Parameters (KPPs)**
    - I1, I4, I5, M14, M15, M16 (6 original L1RD KPPs)
    - DNB/NCC and I3 are now also KPP bands (new in 2015)
  - The **KPP definition** reads as follows:
    - For latitudes greater than 60 deg N in the Alaska Region, VIIRS Imagery EDRs at 0.64 µm (I1), 1.61 µm (I3), 3.74 µm (I4), 11.45 µm (I5), 8.55 µm (M14), 10.763 µm (M15), 12.03 µm (M16), and the 0.7 µm Near-Constant Contrast (NCC) EDR

- **S-NPP Cal/Val Status**
  - Imagery has been **Validated since early 2014** (about 2 years after first light VIIRS imagery)
  - Remaining Imagery issues are minor, except for **long data latency for some (non-Direct Broadcast) granules** (to be minimized with 2 readout sites, resulting in **maximum of ½ orbit latency**)
  - Several **websites** for the Imagery (including LTM (Long Term Monitoring))
  - **Engaging users** for validation and feedback (utilizing JPSS liaisons)
  - NESDIS **Social Media** highly receptive of VIIRS Imagery
### Table 1: Required Imagery EDR Products

#### Key Performance Parameters (KPPs) – 8 bands

<table>
<thead>
<tr>
<th>Imagery EDR Product</th>
<th>VIIRS Band</th>
<th>Wavelength (µm)</th>
<th>Spatial Resolution Nadir/Edge-of-Scan (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daytime Visible</td>
<td>I1</td>
<td>0.60 – 0.68</td>
<td>0.4/0.8</td>
</tr>
<tr>
<td>Short Wave IR (SWIR)</td>
<td>I3</td>
<td>1.58 – 1.64</td>
<td>0.4/0.8</td>
</tr>
<tr>
<td>Mid-Wave IR (MWIR)</td>
<td>I4</td>
<td>3.55 – 3.93</td>
<td>0.4/0.8</td>
</tr>
<tr>
<td>Long-Wave IR (LWIR)</td>
<td>I5</td>
<td>10.5 – 12.4</td>
<td>0.4/0.8</td>
</tr>
<tr>
<td>LWIR</td>
<td>M14</td>
<td>8.4 – 8.7</td>
<td>0.8/1.6</td>
</tr>
<tr>
<td>LWIR</td>
<td>M15</td>
<td>10.263 – 11.263</td>
<td>0.8/1.6</td>
</tr>
<tr>
<td>LWIR</td>
<td>M16</td>
<td>11.538 – 12.488</td>
<td>0.8/1.6</td>
</tr>
<tr>
<td>NCC</td>
<td>DNB</td>
<td>0.5 – 0.9</td>
<td>0.8</td>
</tr>
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# Table 2: Other IDPS-generated Imagery EDRs

**Other Priority 1 (non-KPP) EDRs – 4 more bands**

<table>
<thead>
<tr>
<th>Imagery EDR Product</th>
<th>VIIRS Band</th>
<th>Wavelength (µm)</th>
<th>Spatial Resolution Nadir/Edge-of-Scan (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Near Infrared (NIR)</td>
<td>I2</td>
<td>0.846 – 0.885</td>
<td>0.4/0.8</td>
</tr>
<tr>
<td>Visible</td>
<td>M1</td>
<td>0.402 – 0.422</td>
<td>0.8/1.6</td>
</tr>
<tr>
<td>Visible</td>
<td>M4</td>
<td>0.545 – 0.565</td>
<td>0.8/1.6</td>
</tr>
<tr>
<td>SWIR</td>
<td>M9</td>
<td>1.371 – 1.386</td>
<td>0.8/1.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>KPPs</th>
<th>EDRs</th>
<th>Total VIIRS bands</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>12</td>
<td>22</td>
</tr>
</tbody>
</table>
Multi-spectral Applications (with DNB)

- Through the use of a City Lights Mask (Chris Elvidge/Kim Baugh, NCEI) we can better quantify where fires were detected by the Day/Night Band in the Ft. McMurray Fire

- A hot spot mask applied to M-13 shows where the Day/Night Band detected light emissions from fires that were difficult to detect in M-13

- The eruption of the Pavlof volcano in Alaska was seen by M-13

- An RGB composite using the Day/Night Band better highlights the ash plume

Courtesy: Curtis Seaman
Suomi NPP passed over Super Typhoon Noru at 0310 UTC on 31 July 2017 as it churned in the west Pacific Ocean. The image on the left is a VIIRS I-band-5 IR image and the one on the right is I-band-1 Visible. At the time of these images, the storm was estimated to have maximum sustained winds of 130 knots, a category 4 storm on the Saffir-Simpson scale. (D. Lindsey, StAR)
Hurricane Lester 2016

Hurricane Lester - VIIRS IR - 29 Aug. 2016 - 2144 UTC

Closeup view of Lester’s eye from the corresponding visible band

NOAA/NASA RAMMB/CIRA
Spreading the Word

- CIRA VIIRS images have been delivered to a variety of **standard media and social media outlets**
  - The Weather Channel
  - CNN
  - BBC
  - WagTV (producer of shows for *Discovery* and *Science Channel*)
  - *Washington Post* / Capital Weather Gang
  - @NOAASatellites on Twitter
  - And many more…

Courtesy: Curtis Seaman
For the User Community

- Imagery **EDR User’s Guide** for all users
  - Guide to using VIIRS EDRs and differences with SDRs

- **Quick Guides** for forecasters
  - NCC in AWIPS
  - Contributed to several GINA Quick Guides
  - More to come!

Courtesy: Curtis Seaman
References

VIIRS Imagery at other sites

• **NRL-Monterey** uses of VIIRS:

• **NEIC-Boulder** Earth Observation Group (EOG):

• **StAR JPSS** VIIRS “Image of the Month”

• **StAR ICVS** Long Term Monitoring:
**JPSS-1 Cal/Val Plan**

- **JPSS-1 Image Cal/Val Plan**
  - *Quantitative calibration* (radiances/reflectances) at SDR level
  - *Qualitative validation* of Imagery by end users

- **Preparations for JPSS-1 VIIRS Imagery**
  - **DNB changes** due to increased pixel aggregation at edge of scan and extended swath width
    - This was tested using simulated data for JPSS-1
    - No changes to **NCC software/product** needed
From EDR Imagery (KPP)

• NCC Imagery is dependent on the stray light and other DNB fixes from the VIIRS SDR Team.

• The NCC LUT that may require adjustment, but it is a long-term need and it would NOT require an update in the first 90 days

• Need to visualize Imagery as soon as possible, given we have to reach validation by L+90 days
  – Imagery to users
  – Feedback from users
  – Particularly NWS/AWIPS and Alaska

• Extended granule for DNB due to increased aggregation of J-1 data at end of swath (see next slide)
Simulation of increased aggregation at edge of swath and extended granule and offset of nadir for JPSS-1 DNB

A) DNB from S-NPP used to display how DNB will look from JPSS-1, with the blue area on the right filled with extended scene imagery (currently missing in this simulation)

B) The DNB remapped into the GTM mapping used for NCC, showing that the NCC shifts the DNB imagery to the right, placing nadir at the center and ignoring the extended scene data on the right. In each image, the dashed line shows the approximate location of nadir.
NCC in AWIPS - Fires

Do the fires move? Or does the ground move?
Terrain Correction needed (and required in Block 3.0) for NCC and other Imagery EDRs! (an ongoing effort)
FY17 Accomplishments and FY18 Plans

• VIIRS Imagery is Excellent:
  • Visible/IR are especially high quality (and best spatial resolution among operational satellites, at 375 m)
  • DNB/NCC is the innovative product from VIIRS that is not available from any geostationary satellite/orbit (or will be for many years!)
  • Interactions with users vital for Validation (particularly Alaska and other NWS users)
  • Social Media outlets highly receptive of VIIRS Imagery. Good publicity for NOAA/NESDIS and JPSS/VIIRS

• Path Forward with JPSS-1
  • NCC Terrain-Corrected Geo-locations needed (shifts of several kilometers at higher elevations with ellipsoid geo-locations)
  • New DNB aggregation modes for end of swath pixels, resulting in extended swath and offset of nadir
  • Imagery from 2 satellites with 50 minute separation, to be able to do temporal analysis of imagery features (clouds, fires, smoke, ash, etc.)
US postage stamp (2016) showing the “Blue Marble” composite image created from VIIRS true-color imagery from 2012.
Netherlands postage stamps (2016) showing the DNB imagery in the background of this souvenir sheet.
VIIRS Imagery: Transitioning Novel Ideas into Operations

Curtis Seaman¹, Steven Miller¹ and Jorel Torres¹

Carl Dierking², Jay Cable² and Eric Stevens²

Kathy Strabala³ and the CSPP Development Team³

Don Hillger⁴

Anita Leroy⁵, Emily Berndt⁵ and Kevin Fuell⁵

4th Annual STAR JPSS Science Team Meeting, College Park, MD
14-18 August 2017
Outline

• Making the most out of the Day/Night Band
• VIIRS imagery for fire weather monitoring
• The Snow/Cloud Discriminator
• Summary
Making the Most of the Day/Night Band
The Day/Night Band is sensitive to radiation over a range of intensity spanning 8-orders of magnitude from sunlight to new moon (airglow).

This presents a particular challenge for Imagery.

Global Nighttime Lights of the World (Chris Elvidge; NOAA/NGDC), Baugh et al. (2013)
DNB radiance values vary between $\sim 10^{-2}$ and $\sim 10^{-10}$ W cm$^{-2}$ sr$^{-1}$

Simple scaling methods fail to capture the full range of the data

What is the best way to capture the full range in 256 colors?
Forecasters in the Alaska Region have been using imagery in AWIPS that have been provided to them with a variety of scaling algorithms. These algorithms have artifacts near the terminator.

Remember: the terminator is always present in Alaska for “daytime” overpasses in Winter, “nighttime” overpasses in Summer.
Enables Calculation of Lunar Reflectance:

\[ R_m = \frac{\pi I_m}{\left(\mu_m F_m\right)} \]

→ Reduces 8 orders of magnitude range in radiance to <1 order of magnitude range in reflectance
→ Opens the door to possible quantitative applications involving the calibrated DNB observations of moonlight
From Irradiance to Reflectance

Typhoon Jelawat: 9/25/2012 ~1700Z
Lunar Reflectance in Operations

- Used by NRL and distributed to users via FNMOC
- NASA SPoRT provides Lunar Reflectance to NWS WFOs that request it through AWIPS LDM


https://weather.msfc.nasa.gov/sport/

\[ D(z) = -L_1 - L_2 \left[ 1 + erf \left( \frac{z - \mu}{\sigma \sqrt{2}} \right) \right] \]

**ERF-Dynamic Scaling**

Strength: produces imagery with nearly constant contrast across the day/night terminator. (ERF-Dynamic Scaling is as good as, or better, than NCC in these cases.)
CSPP Polar2Grid

CSPP/CIRA ERF-Dynamic Scaling

5 August 2015

CSPP: Community Satellite Processing Package

http://cimss.ssec.wisc.edu/cspp/
Forecasters in the Alaska Region have been using imagery in AWIPS that have been provided to them with a variety of scaling algorithms. Remember: the terminator is always present in Alaska for "daytime" overpasses in Winter, "nighttime" overpasses in Summer. These algorithms have artifacts near the terminator.

Just talking informally with a couple of the forecasters there earlier this week, I get the impression they are very happy with this scaling approach.

Eric Stevens (GINA)
ERF-Dynamic Scaling now on Puffin Feeder

Old Logarithmic

12 August 2015

ERF-Dynamic Scaling

11 July 2017

GeoTIFFs available!

http://feeder.gina.alaska.edu/
The Near Constant Contrast (NCC) EDR has been delivered to AWIPS through the SBN since December 2015.

We have developed training on NCC (Thanks, Joreel!) and look forward to implementing our Auto Contrast algorithm to optimize the display of the NCC.
Stay tuned for Galina Chirokova’s talk...
VIIRS Imagery for Fire Weather Monitoring
Introduction to RGB Composites

• Every color on a computer monitor may be expressed as 1-byte (8-bit) values of red, green and blue (0-255).

• RGB composites take three different values (raw channels, channel differences, Rayleigh corrected values, etc.), scale them from 0-255 and assign them to red, green or blue.

• In this way, three different images are combined to produce one color image.
Fire Temperature RGB

CIRA’s “Fire Temperature” RGB uses M-10/1.61 µm, M-11/2.25 µm and M-12/3.7 µm.

- Smaller/cooler fires only show up at 3.7 µm and appear red.
- Moderate fires show up at 3.7 µm and 2.25 µm and appear orange/yellow.
- Intense fires show up in all three bands and appear white (or cyan if saturation/fold-over occur in M-12).

- Sees through smoke and makes fires look like fires!
An “active” fire season

Animation (15-25 June 2015)
Northwest Territories (2014)

Animation (June/July 2014)
CIRA’s “Natural Fire Color” RGB uses I-1/0.64 µm, I-2/0.86 µm and I-4/3.7 µm (375 m resolution!)

Looks similar to the “Natural Color” RGB, except fires show up as bright red pixels (unless saturation/fold-over occurs in I-4)

More sensitive to smoke than Fire Temperature RGB; smoke appears blue/cyan

Not good for people who are red-green colorblind!
Fort McMurray Fire (2016)

True Color  
Fire Temperature

Natural Color  
Natural Fire Color

20:25 UTC 3 May 2016
Fort McMurray Fire (2016)

True Color

Fire Temperature

Natural Color

Natural Fire Color

20:05 UTC 4 May 2016
Fort McMurray Fire (2016)

19:47 UTC 5 May 2016
Fort McMurray Fire (2016)

True Color

Fire Temperature

Natural Color

Natural Fire Color

21:06 UTC 6 May 2016
Fort McMurray Fire (2016)

20:48 UTC 7 May 2016
Fire RGBs for Alaska Fire Service (AFS)

We have been using it and we are HUGE fans!!! Seriously, it is just about the closest thing we have to real-time information on fire growth and behavior. Over the past few days we (AFS GIS) have been checking the page multiple times a day and grabbing new images. I am partial to the I-Band combo due to the better resolution.

Jenn Jenkins (BLM/AFS)

M-band combo = Fire Temperature RGB
I-band combo = Natural Fire Color RGB

URL above is temporary. Check for updates at: http://feeder.gina.alaska.edu/
Comparing Landsat with VIIRS for the Ammerman Creek Fire (2017/07/08)

AFS has traditionally been a bit resistant to using remote sensing data to monitor and map fires, and it seems like your products have made pretty big in roads in a very short time.

Jay Cable (GINA)
Fire RGBs in AWIPS

VIIRS Fire Temperature RGB

VIIRS Natural Fire Color RGB

VIIRS Fire RGBs now sent from GINA to Alaska Region WFOs through the AWIPS LDM

ABI Fire Temperature RGB

Now a standard RGB for ABI in AWIPS:
This Fire Temperature RGB needs to be added to the list. It's a simple RGB, has been researched for a while, and is far superior to the other fire detection/monitoring RGBs. On top of that, Louis (Uccellini) is going to be showing it in a few of his upcoming high-profile presentations that he will be giving. Including one to the Senate Appropriations Committee.

Chad Gravelle (OPG)

NASA SPoRT has agreed to send the Fire Temperature RGB to non-AWIPS users!
The Snow/Cloud Discriminator
The Great Blizzard of ‘16

• Can you tell what is cloud and what is snow in the True Color RGB (M-3, M-4, M-5)?

• EUMETSAT Natural Color RGB (M-5, M-7, M-10) discriminates low clouds from snow and ice

• Variation of EUMETSAT Snow RGB (M-11, M-10, M-7) highlights snow in pink/red

• Snow RGB from Météo France produced upon request from UK Met Office (M-7 through M-11)

• CIRA’s Snow/Cloud Discriminator (uses up to 11 bands) keeps snow white and highlights low, mid and high clouds

18:12 UTC 24 January 2016
Multilayer Blending: A Novel RGB Concept

- Each layer of information is assigned a 2D transparency field (defined at every pixel location).
- A separate blend can be done for each color gun (R/G/B), achieving realistic ‘color bleed-through’ effects.
- Allows for the simultaneous display of multiple semi-transparent layers and blending in both the horizontal and vertical dimensions.
As many layers as you wish...

Layers of Information

Blending is done in both the vertical and horizontal dimensions of the image

\[ C = (N_1 + (1.0 - N_1)(N_2 + (1.0 - N_2)[... (N_{M-1} + (1.0 - N_{M-1})N_M ))]) \]

“N-Dimensional Blending” allows for the **dynamic blending of multiple information layers**
**The Snow/Cloud Discriminator**

- Blends information from 11 different VIIRS bands, plus NCEI Nighttime Lights dataset (C. Elvidge) to discriminate snow from clouds
- First snow detection RGB that works at night!
On the Path to Operations

→ Now produced in real time at GINA using CIRA code

→ GeoTIFFs available

→ Soon to be added to GINA's Puffin Feeder

→ AWIPS to follow through GINA LDM feed

→ To be completed before Arctic Initiative extensive evaluation period (Spring 2018)
Summary

- Partnerships between CIRA, GINA, CIMSS, NRL and NASA SPoRT have brought improved VIIRS imagery products to forecasters

- AWIPS/NAWIPS, GeoTIFF, Puffin Feeder, Nexsat

- Improved Day/Night Band imagery

- Fire RGBs

- Snow/Cloud Discriminator (almost in ops!)

- We continue to collaborate on training materials with the Satellite Liaisons and SPoRT
Other Products
DEBRA Dust

→ Dynamic Enhanced Background Reduction Algorithm (DEBRA) uses the multi-layer blended RGB concept to highlight dust in yellow according to confidence

→ Used operationally by the US Navy
Geocolor

- Blends True Color imagery during the day with a low cloud detection algorithm at night
- Applied to GOES, GOES-R, Himawari
- Used heavily by NWS Aviation Weather Center (AWC), Weather Prediction Center (WPC), Ocean Prediction Center (OPC)

→ VIIRS version in the works (request from GINA for Alaska WFOs)
Motion of Diffraction Pattern on VIIRS Detectors

Louie Grasso (CIRA) and Don Hillger (NESDIS)
JPSS Annual Science Meeting
14-18 August 2017
\[ E_P = \left( \frac{E_A}{r_o} \right) \iint \exp(ik\Delta) \, dA = \left( \frac{E_A}{r_o} \right) \iint \exp(ik(s\sin \theta)) \, dA \]
\[ dA = x \, ds = 2 \sqrt{R^2 - s^2} \, ds \]
Let \( \nu = s/R, \gamma = kR\sin \theta \), then
\[ E_P = 2E_A R^2 / r_o \left( \int_{-1}^{1} \exp(i\gamma \nu) \ast \sqrt{1 - \nu^2} \, d\nu \right) \]
\[ = 2E_A R^2 / r_o \left( \pi J_1 (\gamma) / \gamma \right), \text{ thus} \]
\[ I(\theta) = I(0) \ast \left( 2J_1 (\gamma) / \gamma \right)^{**2.0} \]
Cross section of intensity pattern on the focal plane. First zero is the edge of the central Airy disk.

Plan view of intensity pattern. Inner most dark circle bounds the interior bright Airy disk.
dx = 50.0 ! Meters
distance = dx*sqrt( dfloat((i-1)-(center-1))**2.0 + dfloat((j-1)-(center-1))**2.0 )

*** From slide 2 we have the following:

theta = atan(distance/h) (On Earth). theta=atan(y/f) (On focal plane)
sin_theta = sin(theta)

\[ \gamma = kR \sin \theta = \frac{2\pi}{\lambda} \cdot R \sin \theta = \frac{\pi d}{\lambda} \cdot \sin \theta \]

Aside: \( \theta_R \sim \sin \theta_R = \gamma_1 \frac{\lambda}{\pi d} \sim \frac{3.83 \lambda}{\pi d} \sim 1.22 \frac{\lambda}{d} \)

Where \( \theta_R \) is radius of Airy disk; \( \gamma_1 \) first zero of \( J_1 \)

*** We'll replace \( \gamma \) with “phase” below.

phase = ( (pi*d)/(wavelength) ) * abs(sin_theta)
call Int_Bessel(m,phase,Y)
J1(i,j) = Y(1)
Intensity(i,j) = ( 2.0*Y(1)/phase )**2.0

For calculations: \( \lambda = 3.9e-6 \) (m) (wavelength of incident radiation—on detector in satellite)
h = 35786e3 (m) (distance from satellite to the surface of the Earth)
d = 0.3048 (m) (12 inch aperture of telescope)
dx = 50.0 (m) (length—on the surface of the Earth)
Diffraction patterns for GOES-16 ABI
Figure 1: Plots of the Bessel function of the first kind, order 1, $J_1$ in (A) two dimensions and (B) one dimension. Both the $x$-axis and $y$-axis are in km.
Figure 2: Plots of $I(\theta) = I(0) \times (\frac{2J_1(\gamma)}{\gamma})^{2.0}$, where $\gamma=kR\sin\theta$ and $I(0)=1.0$ projected on the surface of the Earth, in (A) two dimensions and (B) one dimension. Both the x-axis and y-axis are in km. These plots would show the diffraction pattern on detectors in a satellite by replacing $h$ with $f$. I think the x-axis would be on the order of the wavelength of the incident radiation: $\sim 1.0\times10^{-6}$ m. See slide 4.
Figure 3: Plots of $\log_{10}(I(\theta))$ (A) two dimensions and (B) one dimension. Both the x-axis and y-axis are in km. Downward “spikes” in (B) represent undefined values of $\log_{10}(I(x,y)=0)$. 
Figure 4: Plots of PSF (A) two dimensions and (B) one dimension. Both the x-axis and y-axis are in km. Red box in (A) is one GOES-16 footprint. These plots show PSF(x,y) on the surface of the Earth. Note: PSF(x,y) here (Zhang et al. 2006) excludes the Δt measurement of energy during satellite scanning. Zhang et al. Impact of PSF on Infrared Radiances from Geostationary Satellites, IEEE Trans. Geosci. Remote Sens., vol. 44, no. 8, August 2006
Figure 5: A comparison of PSFs at 3.9 µm and 12.3 µm. From slide 4: \( \sin \theta = \frac{\lambda y}{\pi d} \). Thus, the width of the Airy disk is proportional to wavelength. This is why the Airy disk at 12.3 µm is larger than that at 3.9 µm. Note the Airy disk is larger than the ABI 2 km footprint. Alternately, the intensity at 3.9 µm/12.3 µm is concentrated/spread out on a focal plane of a satellite.
Diffraction patterns for VIIRS M12 (3.7μm)
Figure 6: Plots of the Bessel function of the first kind, order 1, $J_1$ in (A) two dimensions and (B) one dimension. Both the x-axis and y-axis are in meters for VIIRS M-Bands: Footprint~750 m.
Figure 7: Plots of $I(\theta) = I(0) \times \left( \frac{2J_1(\gamma)}{\gamma}\right)^{2.0}$, where $\gamma = kR \sin \theta$ and $I(0) = 1.0$ projected on the surface of the Earth, in (A) two dimensions and (B) one dimension. Both the x-axis and y-axis are in meters for VIIRS M-Bands: *Footprint~750 m.*
Figure 8: Plots of $\log_{10}(I(\theta))$ (A) two dimensions and (B) one dimension. Both the x-axis and y-axis are in meters for VIIRS M-Bands: Footprint~750 m. Downward “spikes” in (B) represent undefined values of $\log_{10}(I(x,y)=0)$. 
Figure 9: Plots of PSF (A) two dimensions and (B) one dimension. Both the x-axis and y-axis are in meters for VIIRS M-Bands: Footprint~750 m. These plots show PSF(x,y) on the surface of the Earth. Note: PSF(x,y) here (Zhang et al. 2006) excludes the Δt measurement of energy during satellite scanning. Zhang et al. Impact of PSF on Infrared Radiances from Geostationary Satellites, IEEE Trans. Geosci. Remote Sens., vol. 44, no. 8, August 2006
From slide 7, Fig.2 caption, we have $\gamma=kR\sin\theta=(\pi D/\lambda)*\sin\theta$. Solve for $\sin\theta$ yields, $\sin\theta = \gamma\lambda/\pi D$. Using the small angle approximation, $\sin\theta \sim \theta$. We now have $\theta = \gamma\lambda/\pi D$.

From the figure on slide 2, $\theta = d/h$. Since $\theta = \theta$, we have $d/h = \gamma\lambda/\pi D$. Solving for $d$ we get $d = \gamma\lambda h/\pi D$.

$\gamma=3.832$ gives the first zero of $J_1(\gamma)$.

$\lambda=3.9\times10^{-6}$ m (ABI), $=3.7\times10^{-6}$ m (VIIRS M-Band) is the wavelength of incident radiation.

$h=3.5786\times10^7$ m (ABI), $=8.24\times10^5$ m (VIIRS) is the height of sensor above the surface of the Earth.

$\pi$ is very irrational.

$D=3.048\times10^{-1}$ m (ABI), $=1.91\times10^{-1}$ m (VIIRS) is the aperture diameter.

$d=558$ m (ABI), $=19.47$ m (VIIRS M-Band) is the radius of the Airy disk.

***NOTE***

The diameter of an Airy disk to an ABI footprint is $(2*558/2000)*100.0 = 55.8 \%$.

The diameter of an Airy disk to an M-Band footprint is $(2*19.47/750)*100.0 = 5.18 \%$.

VIIRS has a focal length of $f=1.14$ m. We can use similar triangles (Slide 2) to get, $d(\text{detector})=(1.14*19.47)/824000 = 0.27 \mu m$. Thus the angular measure of the detector would be $\theta = d(\text{detector})/f = 0.27 \mu m/1.14m \sim 0.24 \mu rad$. We can also compute $\theta = d/h = 19.47m/82400m \sim 0.24 \mu rad$.

Thus, detector radius=$0.27 \mu m$ or $\theta(\text{half width})=0.24 \mu rad$ for VIIRS: Can anyone confirm this result?
**My Thoughts**

- A diffraction pattern of the intensity is what the sensors, in the optics of a satellite, measure. When the measurement occurs for a time $\Delta t$, a $\text{PSF}(x,y,t)$ results for scanning (pick your broom type) sensors.
- Some refer to the PSF as being “on the surface” of the Earth and neglect $\Delta t$ sampling. For example,


- Fires outside an ABI central footprint may influence the radiance of the central footprint via the $\text{PSF}(x,y,t)$. Since the **diameter** of the Airy for a VIIRS M-band is so small (5.18%) relative to an M-band footprint, can fires outside a central VIIRS footprint influence the radiance of a central footprint?
Applications

1) Build PSF(x,y,t) for any satellite and any wavelength. Need height of satellite from the surface of the Earth, wavelength of incident light, telescope aperture, satellite image footprint size and dx of PSF. You pick dx.

2) Apply PSF(x,y,t) at ~3.9 µm to fires of, which have a size that is a multiple of dx meters. This application will be used to examine the sensitivity of fire hotspots, “under” the PSF(x,y,t), to build one JPSS footprint. Since the size of the Airy disk is so small relative to one VIIRS M-band footprint (5.18 %, slide 16), can we actually use the “surface of the Earth” PSF(x,y,t) concept? Do we need to know more about how the sensor (detector) works?

3) Ed Hyer (NRL, Monterey) just visited and delivered a presentation in which the above application has already been done by


Thank You
That's all Folks!
JPSS Training and Products in AWIPS-II for NWS forecasters

Jorel Torres, Bernie Connell & Steve Miller
CIRA/CSU
16 August 2017
STAR JPSS 2017 Annual Science Team Meeting
The Need for JPSS Training

- Suomi-NPP (VIIRS) was launched in October 2011 and JPSS-1 that will be launched in Fall 2017.

- Beneficial for NWS forecasters to utilize satellite data in their forecasts and daily operations. Key for forecasters to understand how JPSS satellite products add observational value to the forecast process.

- Awareness of Existing Training
Key aspects of Polar-orbiting Satellites

- Also known as Low Earth Orbiting (LEO) satellites
- Sun-synchronous
- Improved weather forecasting via assimilation of observations twice a day into Numerical Weather Prediction (NWP) models
- Provide global coverage over the oceans/remote areas where radar coverage and ground observations are poor and or limited
- Higher spatial and spectral resolution
- Provides observational value in complement to GOES-R

Source: Introduction to VIIRS Imaging and Applications Module (COMET)
Who are the primary/targeted users?
- NOAA and non-NOAA users
- How mature are the user relationships?
  - More established for OCONUS
  - CONUS less established
Training Examples
Day/Night Band (DNB)

’Hurricane Franklin, 7-10 August 2017. See reflected and emitted light sources, and their appearance in satellite imagery. Night-time images in animation are ~ 6-8Z local time.’
Hurricane Matthew

‘Near-Constant Contrast (NCC): Faint Eye Wall detected with No Moon Present.’
West Mims Fires, Georgia

‘Fires detected by DNB in southeastern Georgia, 5-12 May 2017’.

Okefenokee National Wildlife Refuge
‘Wildfire Area’

Emitted City Lights

Gainesville

Day/Night Band (DNB) (0.7um) at 0735Z, 5 May 2017

Elevation: 2.8°
Emitted city lights reduced in Puerto Rico, 21-22 September 2017
NUCAPS: MICROWAVE/IR Soundings

- NOAA – Unique Combined Processing System (NUCAPS)
- Operational CrIS and ATMS Physical Retrieval Algorithm
- Vertical temperature and moisture soundings ~50 km (30 miles) apart

Source: Bill Line, Hazardous Weather Testbed Presentation (2016)
Quality Control Flags
- **Green** = Good (microwave, IR regression, retrieval)
- **Yellow** = Caution (microwave OK, IR regression or retrieval failed)
- **Red** = Data likely unusable (microwave and other sensors failed)

Source: Bill Line, Hazardous Weather Testbed Presentation (2016)
NUCAPS

‘Pop-up Skew-T Soundings over New York City.’ (29 June 2017)
NUCAPS: COLOR VISION DEFICIENCY

Configuration of the NUCAPS soundings (colors) will be implemented in AWIPS 18.1.1 to adapt for users that have color-vision deficiencies.
Blended Total Precipitable Water (bTPW)

Derived from several data sources: SSM/I (DMSP), AMSU (POES), GPS, GOES-East and GOES-West sounders. Currently operational and can be accessed in AWIPS-II for NWS forecasters. Animation of bTPW shown throughout the morning hours on 1 August 2017.
A TPW anomaly that displays the percentage departure from climatology. High percentages indicate strong flooding potential, conversely, low percentages indicate potential fire hazards. Animation shown throughout the morning hours on 1 August 2017.
How to Access Polar Data

Animation shows how to access polar data (i.e. bTPW, NCC and NUCAPS) in AWIPS-II interface.
Satellite Foundational Course – JPSS (SatFC-J)

- Current Status: underway
- Collaborative development effort between: OCLO/STAT, CIRA, CIMSS, NASA-SPoRT, and COMET
- Length: 3-4 hours of content
- Available: Fall/Winter 2017

<table>
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Past JPSS Training Workshops
Chilean Wildfires: Imagery Band (I-4) (3.74um), January 2017

Viirs Active Fire (Viirs-AF) Data
- Viirs-AF Download
- Viirs-AF Text File (26 January 2017 @ 0531Z)
- Viirs-AF PNG File (26 January 2017 @ 0531Z)
- Viirs-AF NetCDF File (26 January 2017 @ 0531Z)

Viirs Active Fire Global Map
- Global Map

Chilean Wildfires Handout
- Handout

Photos of the Event via various Media Outlets
- Photos from CNN,
- Photos from The Guardian,
- Photos from National Geographic.

JPSS Training

0430-0455PM: JPSS Online Training Resources (Jorel Torres)
- JPSS Online Training Resources Presentation

0455-0500PM: Wrap-Up, Questions from audience
- JPSS Training Evaluation Form

0500PM: End of Workshop

Training Resources
- JPSS Satellites (COMET)
- VIIRS Products (NASA SPoRT)
- The Wide World of SPoRT Blog (NASA SPoRT)
- VISIT Satellite Chat (CIRA)
- VISIT: Meteorological Interpretation Blog (CIRA)
- CIMSS Satellite Blog (CIMSS)
- Direct Broadcast Applications Workshop (CIMSS)
- JPSS Training Questionnaire
More Existing JPSS Training Links....

- Suomi NPP: A New Generation of Environmental Satellites (COMET, 2012)
  https://www.meted.ucar.edu/training_module.php?id=948
- Introduction to VIIRS Imaging and Applications (COMET, 2013)
  https://www.meted.ucar.edu/training_module.php?id=1075
  https://www.meted.ucar.edu/training_module.php?id=1327
- NUCAPS Soundings in AWIPS (VISIT/CIMSS, 2015)
  http://rammb.cira.colostate.edu/training/visit/training_sessions/nucaps_soundings_in_awips/
- The use of JPSS Soundings in the Forecast Process (VISIT, 2014)
  https://www.youtube.com/watch?v=JpQ0KUJXOhQ
  https://www.meted.ucar.edu/training_module.php?id=979
  https://www.meted.ucar.edu/training_module.php?id=226
  https://www.meted.ucar.edu/training_module.php?id=1100
List of Available Satellite Blogs and Additional Training Resources

- JPSS Satellites (COMET)
- VIIRS Products (NASA-SPoRT)
- The World Wide of SPoRT Blog (NASA-SPoRT)
- VISIT Satellite Chat (CIRA)
- VISIT Meteorological Interpretation Blog (CIRA)
- CIMSS Satellite Blog (CIMSS)
- Direct Broadcast Applications Workshop (CIMSS)
- GEONETCast Blog
- More Links to Blogs
It's #WorldOceansDay! Join us in celebrating the beauty, wonder, and ecological importance of the Earth's oceans! goo.gl/QYXnC1

Look forward to future JPSS Workshops

Questions ????

Contact Information
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Jorel.Torres@noaa.gov
Supplemental slides
VIIRS FLOOD Detection MAP

- 375 m spatial resolution
- Map of Northern California
  - Flooding evident north-east of San Francisco Bay Area
  - After atmospheric river event last weekend, 13 January 2017 at 2036 UTC
User Engagement - Interactions/Feedback

- How do we engage users?
  - Blogs, input to satellite chats, quick guides.
  - [http://rammb.cira.colostate.edu/training/visit/blog/](http://rammb.cira.colostate.edu/training/visit/blog/)
  - JPSS Workshops: Case Scenarios
- Welcome feedback to address product issues and improve training.
Surface-850mb

LPW

- 850-700mb

- 700-500mb

- 500-300mb
Advected LPW
CIMSS support of Imagery EDR team

William Straka III\textsuperscript{1}

Tommy Jasmin\textsuperscript{1}, Bob Carp\textsuperscript{1}, Dan Lindsey\textsuperscript{2}, Steve Miller\textsuperscript{3}, Don Hillger\textsuperscript{2}

\textsuperscript{1}Cooperative Institute for Meteorological Satellite Studies, Space Science and Engineering Center, University of Wisconsin-Madison
\textsuperscript{2}NOAA, RAMMB
\textsuperscript{3}Cooperative Institute for Research in the Atmosphere, Colorado State University
Outline

• Overview of McIDAS-V
• Examples
• McIDAS-V summary
• Other work
What is McIDAS-V

McIDAS-X ➔ VisAD + IDV + HYDRA = McIDAS

- Integration of Geophysical Data
- Remote and Local Data Access
- Powerful Analysis Tools
- 3D Visualization
- Ease of Re-projection
Key Aspects of McIDAS-V

- Built on top an extensible framework for adapting new sources of data (format and type, local or remote), user interface components and for creating novel displays and analysis techniques

- Developed in the Java programming language – object oriented, write once run anywhere, very portable

- Persistence mechanism (bundles) for saving and sharing interesting displays/analysis with other McIDAS-V users

- Python based user defined computation

- Open source, freely available, community driven software

- Is able to easily load and manipulate Suomi NPP (Block 1 and 2) and JPSS-1 simulated Block 2 data without any special readers
It has 5 instruments which retrieve data regarding the atmosphere, land and ocean. 3 of these instruments can be display in McIDAS-V

- VIIRS
- CERES
- CrIS
- ATMS
- OMPS
• 22 microwave channels, combining all the channels of the preceding AMSU-A1, AMSU-A2, and AMSU-B sensors into a single package

• Provides sounding observations needed to retrieve profiles of atmospheric temperature and moisture for forecasting models and continuity for climate monitoring purposes.
Cross-track Infrared Sounder (CrIS)

- 1,305 infrared spectral channels
- Designed to provide high vertical resolution information on the atmosphere's structure of temperature and water vapor.
• Has 22 channels at three different resolutions
  – 16 Moderate Band (M-Band) channels (~750 m at nadir)
  – 5 high resolution (I-Band) channels (~375 m at nadir)
  – Day Night Band (~750 m at nadir)
• M and I band data encompass data from 412 nm to 12 μm
• Used to produce Level 2 products
VIIRS Channel Differencing
DNB Stray light example
VIIRS SDR
Ancillary data

VIIRS-DNB-GEO_All/Height
VIIRS-DNB-GEO_All/Latitude
VIIRS-DNB-GEO_All/Longitude
VIIRS-DNB-GEO_All/LunarAzimuthAngle
VIIRS-DNB-GEO_All/LunarZenithAngle
VIIRS-DNB-GEO_All/QF2_VIIRSSDRGEO
VIIRS-DNB-GEO_All/SatelliteAzimuthAngle
VIIRS-DNB-GEO_All/SatelliteRange
VIIRS-DNB-GEO_All/SatelliteZenithAngle
VIIRS-DNB-GEO_All/SolarAzimuthAngle
VIIRS-DNB-GEO_All/SolarZenithAngle
VIIRS-DNB-SDR_All/Missing_Data
VIIRS-DNB-SDR_All/Out_of_Range
VIIRS-DNB-SDR_All/QF1_VIIRSDNBSDR
VIIRS-DNB-SDR_All/Radiance
VIIRS-DNB-SDR_All/SDR_Quality
VIIRS-DNB-SDR_All/Saturated_Pixel
• There are a series of 20 Environmental Data Records (EDRs) produced from VIIRS
• McIDAS-V has been able to successfully ingest all EDRs including NDE Enterprise output
• McIDAS-V can unpack and display bit level data.
  – Ex. Displaying VCM test results
VIIRS DNB and Surface temperature EDR
2236Z, 09/29/2012

Lake Victoria
Imagery EDR example
Scatter analysis
Product EDR Variable selection

McIDAS-V - Data Explorer

Fields

Displays

Image Display
Image Display Over Topography
Image Sequence Display
3 Color (RGB) Image
3 Color (RGB) Image over topography
MultiSpectral Display
ProfileAlongTrack Display

Region

Create Display
Support for the VICMO cloud mask EDR (released March 2017) as well as backwards compatibility with IICMO data.

Added a new "show variables" button to the Field Selector tab of the Data Explorer which can show the variable shortname or (if present) long name.

VIIRS Formulas plugin that gives formulas to remove the bowtie deletion and create RGB displays without the bowtie.

Added several VIIRS specific Scripting functions to load and grab information from SNPP/J1 files.
S-NPP specific McIDAS-V 1.7 Updates
OTHER CIMSS SDR/EDR SUPPORT
Mesospheric Gravity Wave monitoring
Comparisons of DNB observations with ground based observations

- Palomar Observatory
- Amateur airglow photography (US and China)
- Ground based low-light cameras (US and China)
Texas Thunderstorm

Eastward View from Lamy, NM over Texas Panhandle

Courtesy: T. Ashcraft and W. Lyons
Other activities

• Observations of other interesting phenomena
  – Unexplained streaking in DNB
  – Aurora
  – search for marine bioluminescent sources in Southwest Asia and Indonesia

• Participation in ongoing Cal/Val Team discussions, TIMs, and support studies concerning DNB data quality on J1 and beyond.
Fires, flares, boats and lights: product lines from nighttime VIIRS data

Christopher D. Elvidge, Ph.D.
NOAA-NESDIS-NCEI Earth Observation Group
Boulder, Colorado USA
chris.elvidge@noaa.gov
Kimberly Baugh, Mikhail Zhizhin, Feng-Chi Hsu, Tilottama Ghosh
University of Colorado
August 16, 2017
Lights At Night!

Cities and human settlements
Industrial Sites
Gas Flares
Boats
Fires
VIIRS Collects Two Styles of Low Light Imaging Data

1. Signal intensification to detect faint radiant emissions in the visible and near infrared – the Day Night Band (DNB).

2. Daytime channels at night – enabling the detection of radiant emissions that are obscured by reflected sunlight. VIIRS collects the following at night:
   - M7 at 0.865 um
   - M8 at 1.24 um
   - M10 at 1.61 um
   - M11 at 2.25 to be added soon!
VIIRS low light imaging at night: DNB detects electric lighting, fires and flares. M7,8 & 10 detect combustion sources.
Three global product lines
https://ngdc.noaa.gov/eog/viirs/index.html


- **VIIRS nighttime lights (VNL):** Global annual average radiances filtered to remove sunlit, moonlit, and cloudy observations. Additional filtering to remove lightning, fires, aurora, and background noise. NASA VIIRS Science Team (FY15-17). Widely used in the sciences, social sciences, and development tracking communities. https://ngdc.noaa.gov/eog/viirs/download_dnb_composites.html
VIIRS boat detection (VBD)

Boats in Java Sea

Jakarta
Algorithms run on images, output points, vast data volume reduction

VIIRS
day/night band (DNB)
nighttime

Boat detection data (points)
Single Night of Detections (June 9, 2017)

Standard is four hour temporal latency, with files available at 06:00 local time.
Placemarks sized based on radiance and have information panels.
VIIRS Boat Detection (VBD)

- Expanded from Asia-Pacific to global May, 2017.
- Temporal latency is ~4 hours, with last night’s data files available at 06:00 local time.
- Files are available at: https://ngdc.noaa.gov/eog/viirs/download_boat.html
- Services running for 44 countries (in addition to global).
- Alerts running for MPAs, restricted coastal waters, and seasonal fishery closures in Indonesia and Philippines. BFAR region 5 (Philippines) reported 14 apprehensions in 2016 based on VBD alerts.
- Methods developed for identification of “dark” vessels that lack VMS (vessel monitoring system).
Detection of illegal fishing boats in restricted coastal waters

June 1, 2017 alert for municipal waters in the Philippines. Commercial fishing is banned in these coastal waters.
VMS Tracks in Natuna Sea
October 1, 2016
October 1, 2016 boats detected by VIIRS but lacking VMS are suspect
VIIRS Nightfire (VNF)

• A multispectral global fire product
• Makes use of near-infrared and shortwave infrared data.
• What is different from other global fire products?
  – Two independent hot source detection algorithms:
    • M10 in the shortwave infrared
    • M12-M13 in the midwave infrared
  – Dual Planck curve fitting (background and hot source) followed by calculations using physical laws
  – Temperature calculation based on Wien’s Displacement Law
  – Source area estimation based on Planck’s Law
  – Radiant heat (W/m2) calculated using the Stefan-Boltzmann Law
• Nightly global data are available at: https://ngdc.noaa.gov/eog/viirs/download_viirs_fire.html
• Global gas flaring data are available at: https://www.ngdc.noaa.gov/eog/viirs/download_global_flare.html
VIIRS Nightfire (VNF): A global multispectral fire product
Nine channels of data collected at night

Nighttime collection of channel 11 is expected to start in 2017
Why Multispectral?

To get at the Planck curves!

Daily files are in csv and kmz formats.
Typical Biomass Burning Detection

Lower temperature than gas flaring. Often these have larger source size than gas flares.
Daily VNF data are available at:
http://ngdc.noaa.gov/eog/viirs/download_viirs_fire.html

Current processing typically runs with a four hour delay
Temperatures are bimodal

![Histogram showing bimodal distribution of temperatures with peaks labeled Fires and Flares.](image-url)
Gas Flaring

• A widely used practice to dispose of natural gas that cannot be utilized or brought to market due to lack of infrastructure.
• VNF is ideally suited for detecting and estimating flare volumes because the M10 band covers the peak radiant emissions for flares.
• Using VNF data we have identified 18,129 flares from 2012-2015.
• Russia has the largest flare volume.
• USA has the largest number of flares.
• VIIRS data can be used for Monitoring, Reporting, and Verification (MRV) of gas flaring reductions:
  – Greenhouse gas emission reduction commitments under the Paris Climate Agreement
  – UN & Worldbank “Zero routine flaring by 2030” initiative.
UN Initiative to end routine flaring by 2030

How will progress be tracked? VIIRS!

Zero Routine Flaring by 2030

The Zero Routine Flaring Initiative
May 22, 2015 — The initiative was launched by UNSG Ban Ki-moon and WBG President Jim Yong Kim with governments, oil
Read More »

During oil production, associated gas is produced from the reservoir together with the oil.
Annual summaries of gas flare locations and gas flare volume estimates are available at:
https://ngdc.noaa.gov/eog/viirs/download_global_flare.html
VIIRS Nighttime Lights (VNL)

- Raw cloud-free composite: Average DNB radiance filtered to remove sunlit, moonlit, cloudy, and lightning.
- Outlier removal to filter out the biomass burning and most of the aurora contamination.
- VIIRS nighttime lights: Filtered to remove background noise and manual editing to removed remaining aurora features.
VIIRS Nighttime Lights (VNL)

Raw cloud-free composite

Outlier removed

Nighttime lights
Summary: Three global products

- **VBD: Nightly VIIRS boat detection (VBD) data** produced with 4 hour latency. Alerts for closures and protected areas. ID of boats lacking tracking records from VMS or AIS. Monthly and annual summary grids. Data access:
  - [https://ngdc.noaa.gov/eog/viirs/download_boat.html](https://ngdc.noaa.gov/eog/viirs/download_boat.html)

- **VIIRS nightfire.**
  - Nightly data: [https://ngdc.noaa.gov/eog/viirs/download_viirs_fire.html](https://ngdc.noaa.gov/eog/viirs/download_viirs_fire.html)
  - Annual gas flaring data: [https://ngdc.noaa.gov/eog/viirs/download_global_flare.html](https://ngdc.noaa.gov/eog/viirs/download_global_flare.html)

- **VIIRS nighttime lights** – monthly and annual cloud-free composites.
  - [https://ngdc.noaa.gov/eog/viirs/download_dnb_composites.html](https://ngdc.noaa.gov/eog/viirs/download_dnb_composites.html)
Publications

• 2013: What is so great about nighttime VIIRS data for the detection and characterization of combustion sources? doi: 10.7125/APAN.35.5
• 2013: Using the short-wave infrared used for nocturnal detection of combustion sources in VIIRS data. doi: 0.7125/APAN.35.6
• 2013: Why VIIRS data are superior to DMSP for mapping nighttime lights. doi:10.7125/APAN.35.7
• 2013: Nighttime lights compositing using the VIIRS day-night band: Preliminary results. doi: 0.7125/APAN.35.8
• 2013: Steve Miller’s Illuminating the capabilities of the Suomi NPP VIIRS Day/Night Band. doi: 0.3390/rs5126717
Supporting the NWS in San Juan, Puerto Rico with VIIRS-derived Products

Arunas P. Kuciauskas, Peng Xian, Edward J. Hyer, James R. Campbell, and Mayra I. Oyola*

Naval Research Laboratory, Marine Meteorology Division, Monterey, CA
* American Society for Engineering Education, Washington, DC
Outline of Saharan Air Layer (SAL) project

Improvements in Predicting Saharan Air Layer (SAL) Events over the Greater Caribbean using Modeling and Satellite Resources

1. Project description & recent activities
   • What is SAL?
   • Milestones during 2017

2. Customer interaction
   • NWS San Juan, Puerto Rico site visit
   • SAL event: a) operational perspective b) NRL resources

3. Current and planned activities
   • Modeling
   • Satellite products
   • JPSS instruments
Defining SAL

3D cutout

Isentropic diagram

Karyampudi and Carlson, J. Atmos. Sci., 1988

Kuciauskas et al., BAMS, 2017 (accepted for publication)
Product suite

Satellite Imagery:
- Visible
- IR
- True & Natural and GEO Color
- Nocturnal Low Clouds
- Dust (Bluelight, DEBRA, AOD, RGB)
- TPW (NRL, NESDIS/CIRA, MIMIC)
- Water Vapor

Lidar Instruments: * currently unavailable
- CALIPSO/CALIOP *
- MPLNET *

Ground-based instruments:
- AQ (PM$_{2.5}$, PM$_{10}$, pollution level measurements)
- AERONET

Modeling (dust):
- NAAPS MODIS + VIIRS AOD
- Navy NWP Model wind overlays
- CIMH (WRF-Chem), ICAP, NGAC
Project Recent Activities

- **R&D: SAL chemistry, thermodynamics, predictability, public impacts**
  - Satellite-based product development (focus: VIIRS)
  - Model-based forecast products (focus: VIIRS AOD as Data Assimilation)
  - In-situ measurements that are not readily available
  - Hosted (near real time) and maintained on NRL website (SAL-WEB)
  - BAMS Publication: project summary

- **Conducted NWS site visit (31 July – 03 August)**
  - Overview of forecast operations: weather impacts, social interaction
  - Product feedback
  - SAL impacts
  - Forecaster needs outside of AWIPS-II
  - Future collaboration, including other Caribbean agencies

- **Blend environment with health aspects**
  - Puerto Rico/West Indies: among the world’s worst asthma conditions
  - Participated with various environment/health agencies throughout Greater Caribbean
    - Caribbean Institute for Meteorology and Hydrology, Barbados (CIMH)
    - Caribbean Aerosol and Health Network (CAHN)
    - University of Puerto Rico
Customer Interaction: NWS Site Visit
San Juan, Puerto Rico

Ernesto Rodriguez
SOO

Roberto Garcia
MIC

Ernesto Morales
WCM
Highlights of Site Visit

**Overall, very positive feedback**
- SAL-WEB applied as resource of daily analysis
- Growing interest/concern during SAL events, mainly during summertime

**AQ/Dust Aerosol Modeling**
- No aerosol model in AWIPS-2
- NWS, San Juan unaware of NGAC dust model
- NWS has been reliant on NAAPS and GEOS-5
- NAAPS will be 1st to incorporate Enterprise VIIRS AOD into data assimilation (DA)

**Surface observations**
- Greater access to site containing AQ measurements in NRT
- Lidar (MPLNET): *currently unavailable*
  - Backup in Key Biscayne

**Public Awareness/Social media**
- SAL has gained notoriety, but concepts are distorted
  - Need better definition
  - NWS is evolving toward Facebook, Twitter, media interaction

**Environment & Health impacts of SAL**
- Dr. Olga Mayol-Bracero, Professor at U of P.R.
  - Widely known as expert in Caribbean environment
  - Lidar installation in Capo San Juan (northeast P.R.)
  - Wealth of instruments throughout P.R.
- Dr. Bolaños, Professor at U of P.R. 13 year study
  - Little correlation between African dust events and respiratory ailments
  - Spore production within rain forests major asthma contributor during fall/winter & nighttime conditions
  - African dust can act as an irritant for the respiratory system

**Future support**
- Satellite needs: Atmospheric profiling
  - GOES-16 products
  - JPSS-1 launch
  - Ozone (pollution) research: OMPS
  - CrIS sensing
- Training: “Just-in-time” as SAL events occur
SAL Case Study:
An Operational Perspective

29 July – 04 August
Showcase NRL resources
Case Study: 29 July – 04 August 2017

VIIRS true color

MODIS AOD
SAL impacts: AERONET

Puerto Rico

Key Biscayne, FL

AERONET courtesy: Brent Holben
Model Perspective
Evolving SAL Over Miami

20170802

20170803

20170804

Developing SAL

Developing SAL

Mature SAL

University of Wyoming
TPW Perspective
03 – 04 August 2017

TPW: NESDIS/CIRA

TPW: NRL w/NAVGEM winds
Split Window SAL Views

Better spectral/spatial resolution
NAAPS Vertical Profile Forecasts during SAL

Florida EPA AirNow Sites (PM$_{2.5}$)

NAAPS (red) vs sfc TEOM sites (black)

NAAPS profile: total PM mass concentration from dust, smoke, sea salt, and anthropogenic aerosol tracers

retrospective  fcst

retrospective  fcst
1. Coordination with NWS:
   a) Evolve SAL into higher impact status -> forecast discussions, social media
      i. Better understanding of SAL
      ii. Training => forecasters/public/gov. agencies: weather & health impacts
      iii. Beyond VIIRS: acquire additional resources from NEXGEN sensors
          • GOES-16 fusing with polar orbiters, models, in-situ measurements

2. Improve Navy dust model:
   a) Incorporate Enterprise VIIRS AOD into NAAPS
   b) Integrate international dust models (ICAP)

3. Leverage Navy funding: R&D toward Caribbean dust/pollution/health:
   a) SAL dust vs localized pollutants characterization
      i. Ozone studies related to detecting/discriminating pollution from dust
      ii. Apply OMPS retrievals
   b) Visibility aspects related toward trafficability
“We must advance our technological expertise to predict how electromagnetic waves will move through the physical battlespace.”

~ RDML Tim Gallaudet, USN
NRL Monterey VIIRS imagery comparisons with other sensors

Kim A. Richardson, Melinda L. Surratt, Arunas P. Kuciauskas, Richard L. Bankert

U.S. Naval Research Laboratory
Marine Meteorology Division
Monterey, CA
NRL-MMD Satellite Constellation

Total Sensors: 36

Low Earth Orbiting (LEO): 30

IR/Vis Imagers:
- NOAA - AVHRR (4)
- METOP - AVHRR (2)
- DMSP - OLS (4)
- NASA - MODIS (2)
- NOAA - VIIRS

Microwave Imagers:
- DMSP - SSM/I, SSMIS (3)
- NASA - AMSR-2, GMI, SMOS
- NRL - WindSat

Micro Sounders:
- NOAA - AMSU (2), MHS (2), ATMS
- METOP - AMSU (2)
- MeghaTropiques - SAPHIR

Microwave Radar:
- NASA - GPM
- Foreign - ASCAT (2), OceanSat-2

Collaborations: FNMOC, AFWA, NASA, NOAA, CIRA

GEO Sensors: 6
- GOES-W
- GOES-E
- MET-10
- MET-8
- Himawari-8
- GOES-16
# NexSat Products

## Standard Products
- **Visible (daytime)**
- **Visible (night time)**
- **Infrared**
- **Water Vapor**
- **True Color**
- **Pseudo/GEO True Color**
- **Rain Rates**
  - 3, 6, 12, 24 hours
  - 2, 3, 4, 5, 6, 7, 10, 12, 14 days
- **Rain Totals**
- **Winds**
  - Scatterometer (sfc)
  - GEO
    - low level
    - middle level
    - upper level

## Cloud Products
- **Cloud layers (snow, low-middle, high)**
- **Cirrus cloud detection**
- **Contrail detection**
- **Low cloud detection (night)**
- **Convective cloud top height**
- **Cloud properties**
  - effective radius
  - optical depth
  - cloud top temperature
  - cloud top height
  - cloud type

## Environmental Products
- **Aerosol amounts (optical depth)**
- **Biomass (vegetation type)**
- **Dust detection**
  - MODIS
  - VIIRS
  - MSG (DEBRA)
- **Fire detection (hot spots)**
- **Lightning detection**

## Models
<table>
<thead>
<tr>
<th>Navy global (NAVGEM)</th>
<th>NAAPS dust model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea Level Pressure</td>
<td>Total AOD</td>
</tr>
<tr>
<td>500 mb Heights</td>
<td>Coarse AOD</td>
</tr>
<tr>
<td>sfc, 700 500 300 mb Winds</td>
<td>Fine AOD</td>
</tr>
<tr>
<td>1000-500 mb Thickness</td>
<td>Concentration [dust]</td>
</tr>
<tr>
<td>Surface Temperature</td>
<td></td>
</tr>
<tr>
<td>Jet Stream</td>
<td></td>
</tr>
</tbody>
</table>
NexSat Home Page
How to find VIIRS imagery on NexSAT

Use the Products Pull down menu
Dust case study over land
True Color

VIIRS/MODIS

NPP VIIRS True-Color 2017/05/04 05:36:13Z NRL-Monterey

AQUA MODIS True-Color 2017/05/04 06:45:00Z NRL-Monterey
Visible Imagery

VIIRS/Himawari-8/DMSP
Infrared
VIIRS/AHI
Low Cloud
VIIRS/AHI
Greenland offshore ice movement
VIIRS/MODIS
Dust case study over water
Bluelight Dust VIIRS/MODIS

MSG-1 DEBRA

Scatterometer ASCAT
Tropical cyclone
09S. ENAWO