GOES-R and VIIRS
Fire detection and related products

Presented by
William Straka III (CIMSS/JPSS)
With help from Chris Schmidt (CIMSS) and many others
Outline:

• Introduction

• GOES Fire Detection

• Polar Fire Detection

• Other Products - HRRR Smoke model, RGBs and NUCAPS
Introduction
Who we are

- **William Straka (CIMSS)** - [william.straka@ssec.wisc.edu](mailto:william.straka@ssec.wisc.edu)
  - Liaison between JPSS Program and stakeholders
  - Has interacted for the last 3 years with CalFire, NWS and other agencies on Fires and floods

- **Chris Schmidt (CIMSS)** - [chrissch@ssec.wisc.edu](mailto:chrissch@ssec.wisc.edu)
  - GOES-R Fire detection algorithm developer
  - Currently has interactions with PG&E and others to provide GOES-R (16/17) operational fire product

With contributions from

Ravan Ahmadov (CIRES), Emily Berndt (NASA), Rebekah Esmaili (STC) and others. Funding provided by NOAA.
ABI Fire detection

GOES-17

GOES-16
ABI offers high temporal refresh allowing for early detection of fires

- Traditional imagery channels are the 3.9um channel (band 7) as well as the NIR (1.6um and 2.2um) channels at night.
- Current temporal resolution is 10 min FD, 5 min CONUS and two 1 minute Mesoscale (1000x1000km) sectors.
  - Current GOES-17 Meso1 default location is over California
  - NWS WFOs can request Mesoscale images over locations via appropriate channels

In addition, the GOES-R ABI Fire Detection and Characterization Algorithm (FDCA, aka Fire Hot-Spot [FHS]) provides 2 km fire detection and characterization data

- Currently the product is produced operationally ever 5 minutes over CONUS and every 10 minutes over FD
- The one minute mesoscale sectors are not produced operationally at this time, but that could change if sufficient demand arises. *(If you want it, ask for it)*

CONUS and Meso products being run at CIMSS and provided to PG&E. These products are available within CalFire’s GIS system.
The algorithm is contextual, it considers a candidate fire pixel in comparison to its neighbors, but there are some fixed thresholds involved.

- Performs its own opaque cloud screening
- Also accounts for surface emissivity and atmospheric attenuation of the fire signal by water vapor in the atmosphere.
- Future work includes additional persistent hotspot flag (ex. Gas flare, solar farm, etc.)

Due to the subpixel nature of fires:

- The Dozier Method and FRP are describing a hypothetical, uniform fire with those properties that produces the same radiance signature
- The size should not be taken literally
- FRP is the best proxy for intensity
GOES-R ABI Fire Detection Imagery example
Kincade Fire, 24 October 2019, AWIPS view
The Kincade Fire started in Sonoma County on October 23, 2019, at about 9:20 pm PDT (4:20 UTC on 24 October 2019). The ALERTWildfire camera at Barham near Santa Rosa, CA captured the start of the fire. It appears that a light on the horizon went out when a power line fell between 9:19:51 and 9:19:54 pm PDT, the same event that apparently started the fire. The fire intensified rapidly. GOES-17 picked up the first signs at 9:21 pm PDT, and by 9:25 pm PDT the FDCA had detected the fire.

On the next slide, five panels from ABI and the FDCA are synchronized with the ALERTWildfire loop from 9-10 pm PDT. The min and max in the frame are listed on each panel. From left to right:

- 3.9 \( \mu \text{m} \) – midwave infrared window image (sees fires, clouds, and surface)
- 11.2 \( \mu \text{m} \) – longwave infrared window image (sees clouds and surface)
- “3.9 \( \mu \text{m} \)-11.2 \( \mu \text{m} \) radiance” – This is the radiance difference between the two key bands, but the 11.2 \( \mu \text{m} \) data has been converted to 3.9 \( \mu \text{m} \) “space” to make it directly comparable.
- FDCA Mask – algorithm output indicating its decisions about each pixel, including detected fires
- Fire FRP – algorithm output of FRP, for all detected fires (dynamically scaled)
GOES-R ABI Fire Detection and Characterization Algorithm (FDCA)
Kincade Fire, near IR camera and coincident FDCA and ABI data
GOES-R ABI Fire Detection
Key Takeaways

- ABI is very sensitive to heat signatures, but finding fires early requires enhancements and/or band differencing

- Large heat signatures appear in many bands

- The human eye is quicker than the FDCA, but the FDCA isn’t too slow, either

- Fire size and temperature from the FDCA are only available for some fires and do not mean what forecasters and the public might think they mean

- FRP is a good proxy for intensity
Polar Imagery and Fire detection
VIIRS Fire products

- VIIRS is on both Suomi NPP and NOAA-20 (50 minutes apart on the 1330Z orbit)
  - 22 channels, including the Day Night Band
  - 10 are used for fire detection
  - This means you get 4 passes over a given area each day (1 day and 1 night time pass per satellite).

- There are two VIIRS Fires products
  - Current operational algorithm (750m resolution)
  - Experimental operational algorithm (375m resolution) - operational mid-2020
  - Operational latency is 90-180 min, but available within 1hr from CSPP (Direct broadcast)
  - High resolution product can be visualized in RealEarth
    - [http://realearth.ssec.wisc.edu/?products=AFIMG-Points.100](http://realearth.ssec.wisc.edu/?products=AFIMG-Points.100)
  - Produce similar fields as GOES-R algorithm
VIIRS - Example: Australian Wildfires
VIIRS Active Fire in Real Earth - Example
Southern California Wildfires (October 2019)
VIIRS Active Fire in Real Earth - Example
Southern California Wildfires (August 2020)
VIIRS Active Fire in Real Earth - Example
Colorado Wildfires (August 2020)
Other Useful Products
RAP/HRRR-Smoke model

Section prepared by Ravan Ahmadov (CIRES)
RAP/HRRR-Smoke models

- RAP-Smoke enables forecasting smoke from all the fires in North America utilizing a high spatial resolution (3km) and rapidly updating numerical weather model.

- Smoke model initialized based on VIIRS (and GOES) FRP. A rapidly updating data assimilation cycle for meteorology;

- The smoke forecasting capability is a part of the next update of NOAA’s operational RAP, HRRR-CONUS and HRRR-Alaska models beginning summer 2020.

Operational weather forecast models at NCEP:
RAP (white), 13km resolution
HRRR model domains (green), 3km resolution
(https://rapidrefresh.noaa.gov/)
U.S.

WILDFIRE SMOKE: SEA-TAC AIRPORT FLIGHTS DELAYED AS AIR QUALITY IN WASHINGTON STATE CITY BECOMES 'HAZARDOUS'

BY JASON MURDOCK ON 8/20/18 AT 4:17 AM EDT

Newsweek.com

https://www.airnowtech.org/navigator/#
NUCAPS Summary

Section prepared by Emily Berndt and Rebekah Esmaili

NUCAPS vertical soundings are used to assess the presence of moist or dry layers, especially between radiosonde observations.

NUCAPS plan view fields (i.e. Gridded NUCAPS) are used to assess the context of warm, dry conditions favorable for increased wildfire risk.

NUCAPS excels at identifying spatial gradients for the analysis of features such as a Low-Level Thermal Trough.

Derived fields from NUCAPS such as the Haines Index and Total Precipitable Water add value to the verification of model forecasts.

NUCAPS trace gases, especially CO, can be used to monitor thick smoke at 500 mb and above both day/night

NUCAPS soundings provide environmental context for radiosondes.
Fire Weather Example: Taixsalda Hill Fire in Alaska

- The 1200 UTC Fairbanks Radiosonde indicates dry conditions just above the surface and significantly drier air at mid-levels.
- By 0000 UTC, the near-surface layer was much warmer and drier.
- A NUCAPS Sounding near Northway, AK, about 250 miles away from Fairbanks, indicates drier air throughout the atmospheric column. Either 700 mb conditions are drier at Northway or NUCAPS has missed the fine detail of the moisture signature. Analysis of plan view fields can help assess the spatial gradients rather than interrogating individual soundings.
Fire Weather Example: Taixsalda Hill Fire in Alaska

- Gridded NUCAPS 850 mb temperatures compared to GFS, indicate a region of higher temperatures in southern AK and near Northway.
- The AWIPS-derived Haines Index indicates a moderate potential for fire growth.
- The Gridded NUCAP spatial pattern for temperature and Haines Index match the GFS analysis.
VIIRS provides fire-related imagery at higher spatial resolution than GOES-16/17

3000 km-wide swath and two satellites (S-NPP and NOAA-20) provide full global coverage twice per day (~1:30 AM/PM) with ~50 min. separation

- These products available to users throughout CONUS
  - RealEarth
  - Polar SLIDER: http://rammb-slider.cira.colostate.edu/?sat=jpss
Summary

● Both GOES-R and VIIRS provide qualitative and quantitative products for fires, both before (NUCAPS), detection (GOES) and during a fire (VIIRS, HRRR)

● The GOES and VIIRS fire products are meant to complement each other. GOES provides the temporal detection while VIIRS provides high spatial information

● Both of these are key inputs into the HRRR smoke model, which can be used for forecasting visibility and health impacts

● Most of these products are available via WMS/WTMS for integration into GIS platforms
Thank you very much!
Questions
**Key VIIRS Channels used for fire detection**

<table>
<thead>
<tr>
<th>Fire detection Algorithms</th>
<th>VIIRS Band</th>
<th>Central Wavelength (μm)</th>
<th>Band Explanation</th>
<th>Spatial Resolution (m) @ nadir</th>
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<tbody>
<tr>
<td></td>
<td>M1</td>
<td>0.412</td>
<td></td>
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<tr>
<td></td>
<td>M2</td>
<td>0.445</td>
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<td>M3</td>
<td>0.488</td>
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<td>M4</td>
<td>0.555</td>
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<td>M5</td>
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<td>M6</td>
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<td>M7</td>
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<td></td>
<td>M8</td>
<td>1.240</td>
<td>Shortwave IR</td>
<td>750 m</td>
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<td></td>
<td>M9</td>
<td>1.378</td>
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<td>M10</td>
<td>1.61</td>
<td>Shortwave IR</td>
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<td></td>
<td>M11</td>
<td>2.25</td>
<td>Medium-wave IR</td>
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<tr>
<td></td>
<td>M12</td>
<td>3.7</td>
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<td>M13</td>
<td>4.05</td>
<td>Medium-wave IR</td>
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<td>M14</td>
<td>8.55</td>
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<td></td>
<td>M15</td>
<td>10.76</td>
<td>Longwave IR</td>
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<tr>
<td></td>
<td>M16</td>
<td>12.01</td>
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<tr>
<td></td>
<td>DNB</td>
<td>0.7</td>
<td>Visible/Reflective</td>
<td>750 m across full scan</td>
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<tr>
<td></td>
<td>I1</td>
<td>0.64</td>
<td>Visible/Reflective</td>
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<td>I2</td>
<td>0.87</td>
<td>Near IR</td>
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<td>I3</td>
<td>1.61</td>
<td>Shortwave IR</td>
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<td>I4</td>
<td>3.40</td>
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<td></td>
<td>I5</td>
<td>11.45</td>
<td>Longwave IR</td>
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</tbody>
</table>
VIIRS Active Fire

750m “M-band” product
- Current NOAA operational product
- MODIS heritage
- Primary band is VIIRS dedicated fire band (M13)
- Available in CSPP (Community Satellite Processing Package), JPSS direct broadcast processing system (low latency)

375m “I-band” product
- Currently in NOAA experimental production
- Primary band is I4 for detection; M13 is used for characterization due to low I4 saturation
- Much higher sensitivity than the 750m product
- Also available from CSPP
- Displayed in RealEarth
  - (http://realearth.ssec.wisc.edu/?products=AFIMG-Points.100)

Both algorithms
- Work at daytime and nighttime
- Process Suomi NPP and NOAA-20 (50 minutes apart on the 1:30 orbit)
- Provide fire radiative power (FRP) and full fire mask (fire detections, clear land, water, cloud, etc.)
- Contains persistent fire source flag (will be transitioned to CSPP in coming months)
How to interpret NUCAPS relative to other sources

<table>
<thead>
<tr>
<th>RADIOSONDES</th>
<th>NUCAPS</th>
<th>GOES LAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point-source measurement</td>
<td>Averaged columnar measurement that can be interpreted as a stack of many thick layers</td>
<td>Averaged columnar measurement that can be interpreted as a stack of only 1-2 layers</td>
</tr>
<tr>
<td>Launched from specific Lat/Lon</td>
<td>Represents 50km (nadir) to 150km (edge of scan)</td>
<td>10 km resolution</td>
</tr>
<tr>
<td>Detailed vertical structure</td>
<td>High vertical structure with details smoothed out (i.e smoother than radiosondes), but more structured than GOES LAP products</td>
<td>Very smooth vertical structure</td>
</tr>
<tr>
<td>Model independent</td>
<td>Model independent; statistical regression as first guess</td>
<td>Model dependent; GFS as first guess</td>
</tr>
<tr>
<td>Single sounding observations at 1200 and 0000 UTC</td>
<td>Spatially dense swath of sounding observations at overpass times... SNPP – 1:30am/pm, NOAA-20 – 50mins after SNPP</td>
<td>High temporal frequency products (30 mins)</td>
</tr>
</tbody>
</table>

NUCAPS soundings provide environmental context for radiosondes. High vertical resolution NUCAPS observations verify GOES LAP products.
Gridded NUCAPS Example - Australia (CO)

Note that CO and Methane retrievals peak and have the most skill at about 500 mb. Therefore if the smoke is below ~500 mb, there may not be a trace gas signal in the NUCAPS retrieval.

Additional examples and caveats of using NUCAPS trace gas retrievals are discussed in the 2020 AMS presentation: Monitoring Atmospheric Composition and Long-Range Smoke Transport with NUCAPS Satellite Soundings in Field Campaigns and Operations
Different ways and tools to visualize the HRRR-Smoke forecasts

- Web-based tool (zoomable map) by ESRL/GSD: [https://hwp-viz.gsd.esrl.noaa.gov/smoke/index.html](https://hwp-viz.gsd.esrl.noaa.gov/smoke/index.html)

- WAVE - interactive zooming capability, available to all NOAA staff, *the talks by Bill Rasch (NWS) and Jebb Stewart (ESRL/GSD) at the IMET conference*;

- NOAA/ESRL/GSD’s version of WAVE [https://hwp-viz.gsd.esrl.noaa.gov/wave/](https://hwp-viz.gsd.esrl.noaa.gov/wave/)

- AWIPS2 (M.Loeffelbein, NWS)

- RealEarth ([https://realearth.ssec.wisc.edu/](https://realearth.ssec.wisc.edu/)); You can overlay locations and reports for large wildfires over the HRRR-Smoke forecast fields.

- GeoCollaborate ([https://fs.geocollaborate.com/dashboard/](https://fs.geocollaborate.com/dashboard/))

- Several apps provided by the private sector
Surface visibility forecasts by HRRR-Smoke

Visibility is an important forecast product (traffic, aviation...)

Experimental NWP model w/o smoke

Experimental NWP model with smoke

Reduced visibility due to smoke