ACTIVE FIRE

Presented by Ivan Csiszar

NOAA/NESDIS/STAR

Outline

- Introduction
  - Team Members/Users
  - Requirements Summary
- Background
  - Algorithms Products
- Enterprise Algorithm Development
  - Current Operational Product
  - Design/ High level process flow
  - Testing and Validation
- Lessons Learned
- Risks
  - Impact of transition on users
- Summary and Recommendations

Team Members / Users

- STAR: Ivan Csiszar (Federal), Marina Tsidulko (IMSG)
  - LTM: Frank Tilley, Lori Brown, Tom Atkins
- UMD/Geography: Wilfrid Schroeder, Louis Giglio
- UW/CIMSS: Chris Schmidt

- NOAA Hazard Mapping System
- High Resolution Rapid Refresh (HRRR)
- Enhanced Infusing satellite Data into Environmental air quality Applications (eIDEA)
- Total Operational Weather Readiness – Satellites (TOWR-S)

Requirement Summary
Based on JPSS L1RD Supplement v2.10

Attribute	Requirement	Proposed	Observed/Verified
AF Applicable Conditions: 1. Delivered in daytime and night-time regimes under clear-sky conditions and within the clear areas between scattered and broken clouds.			
a. Horizontal Cell Size (2)			
1. Nadir	0.80 km	0.25km	0.75km
2. Worst Case	1.6 km	NS	1.6km
b. Horizontal Reporting Interval (2)	HCS	NS	HCS
c. Horizontal Coverage (2)	Global	Global	Global
d. Mapping Uncertainty, 3 sigma (2)	1.5 km	0.75km	1.5km
e. Measurement Range			
1. Fire Radiative Power (FRP) (3)	1 MW to 5,000 Megawatts	1 MW to 5,000 Megawatts	1 MW to 5,000 Megawatts
f. Measurement Uncertainty			
1. Fire Radiative Power (FRP)	50%	20%	50%(estimated)
g. Refresh	At least 90% coverage of the globe every 12 hours (monthly average)	NS	At least 90% coverage of the globe every 12 hours (monthly average)

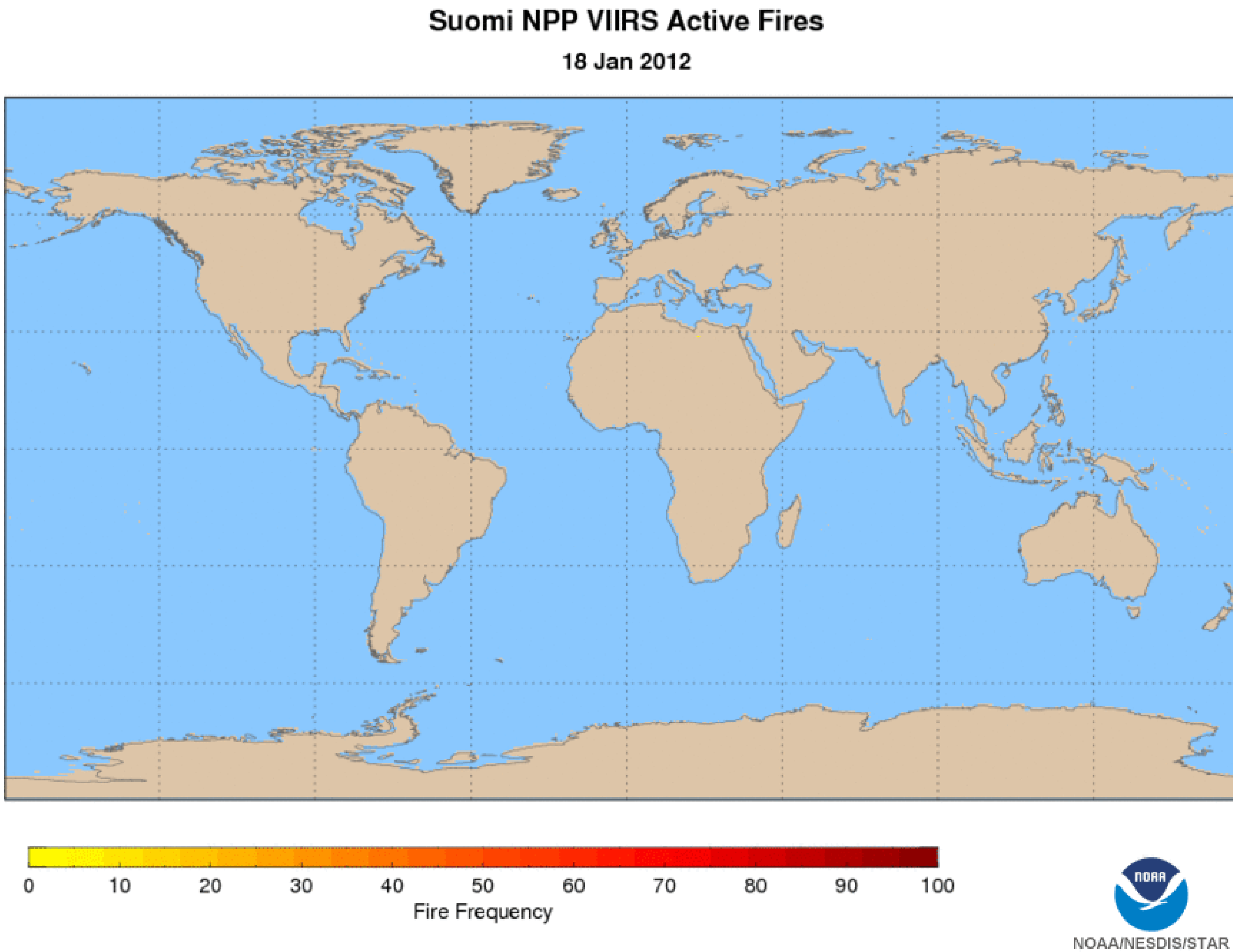
Notes:

1. NOAA has endorsed the inclusion of an Active Fire EDR based on strong community interest in providing continuity of validated MODIS-based fire products (geolocation of fire detections, FRP, and a full fire mask) consistent with the recommendations of the NOAA-NASA Land Science Team. This change proposes the institution of Active Fire as an EDR with threshold requirements based on the demonstrated capabilities of the VIIRS F1 sensor and S-NPP spacecraft.
2. The requirement of global coverage is based on user community stated intentions to extend Active Fire product capabilities to non-land based targets (e.g.,offshore gas flares).
3. The high end of the FRP Measurement Range threshold requirement (5000 MW) is based on current design capabilities (i.e., the present 634 K saturation specification for the M13 Band on VIIRS) and the recommendation of the NOAA-NASA Land Science Team.

Four years of the IDPS VIIRS fire product

from the NOAA NESDIS STAR long-term monitoring system

https://www.star.nesdis.noaa.gov/jpss/EDRs/products_activeFires.php



No spurious scanlines were found in 2015 in the IDPS VIIRS Active Fire product. This is the result of improvements in the input SDR processing in IDPS.

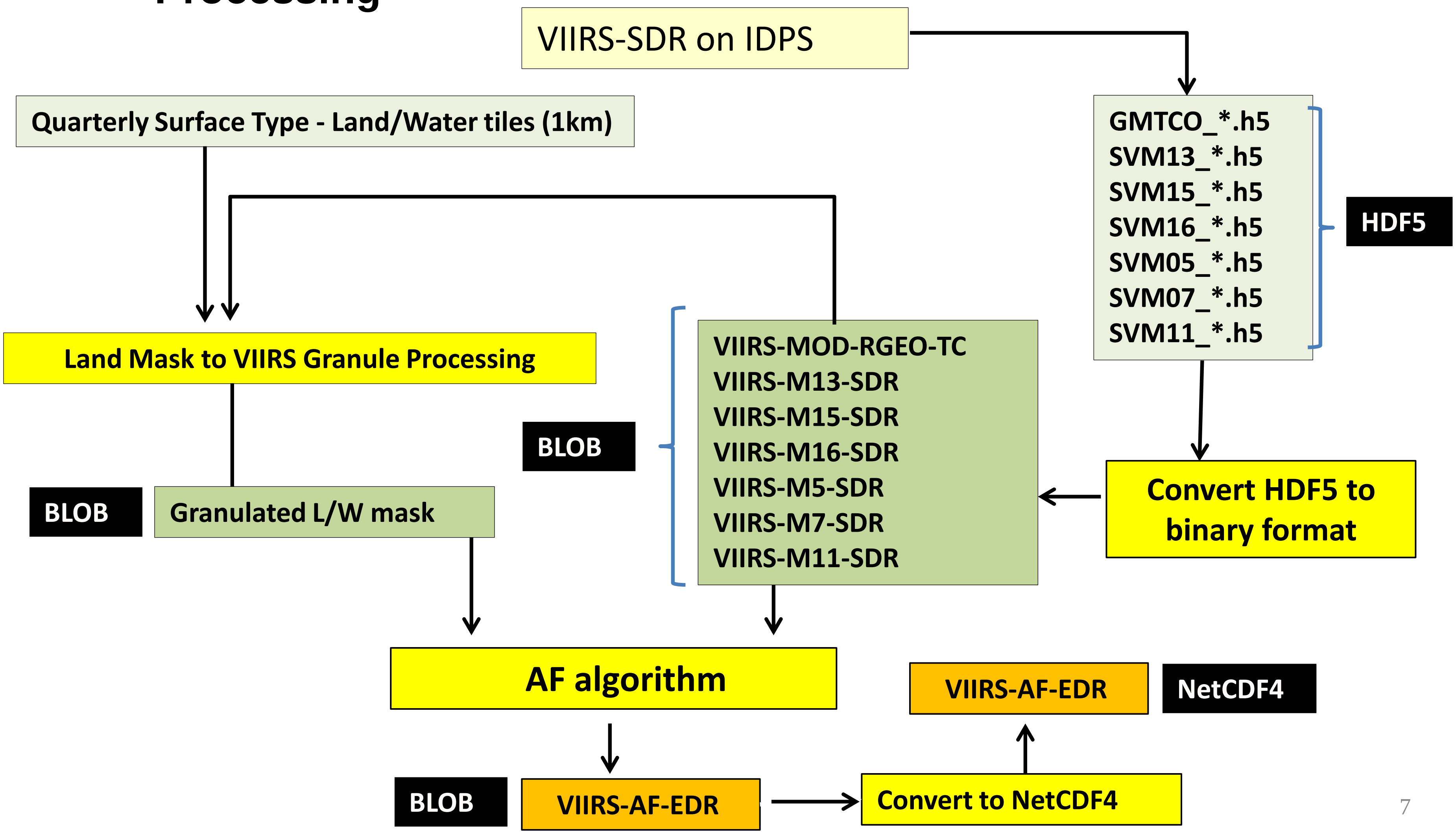
Examples of the operational real-time IDPS product as archived in NOAA CLASS.
Not reprocessed; not to be used for science analysis. Product history demonstration only.
Preparations for reprocessing are ongoing.

Operational NDE Product

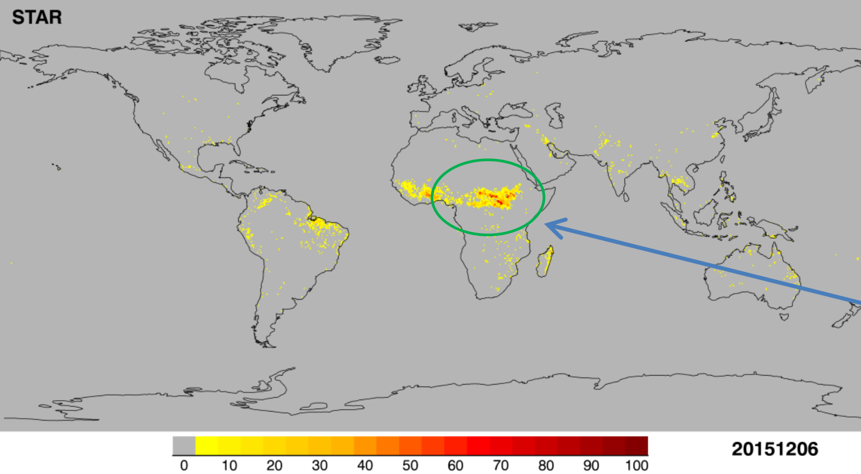
- NDE VIIRS M-band Active Fire EDR
  - Tailored Version of UMD/NASA
  - Includes additional output: Fire Radiative Power
  - Provides a 2D array of values representing the fire and other relevant thematic classes of each pixel. This is a new attribute to describe land/water/cloud etc for each pixel.
  - Provides global coverage (include water)
  - **VIIRS Active Fire is no longer a “land” product!**
- Users
  - NESDIS Hazard Mapping System
  - NOAA aerosol / air quality product suite
  - NWS Fire Weather Program
  - USDA Forest Service and other US agencies through the National Interagency Fire Center
  - NOAA High Resolution Rapid Refresh (HRRR)
  - A broad community of international users

High Level Process Flow

AF Algorithm Processing

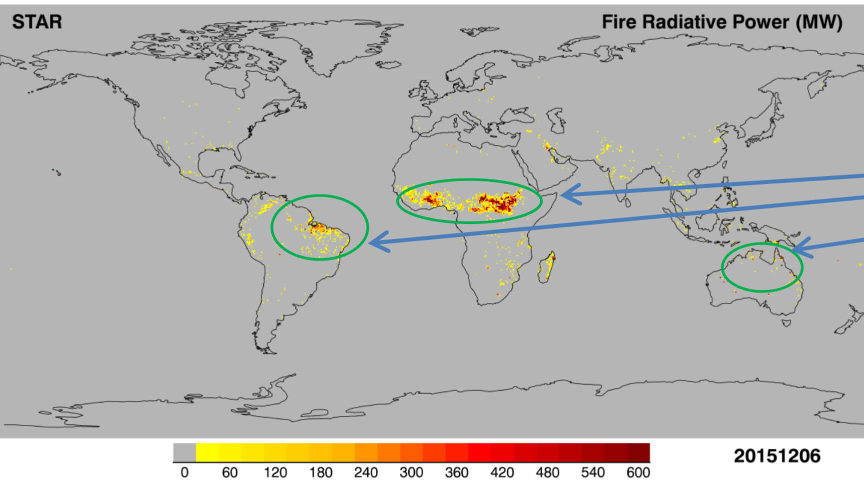


NDE VIIRS Active Fire Product



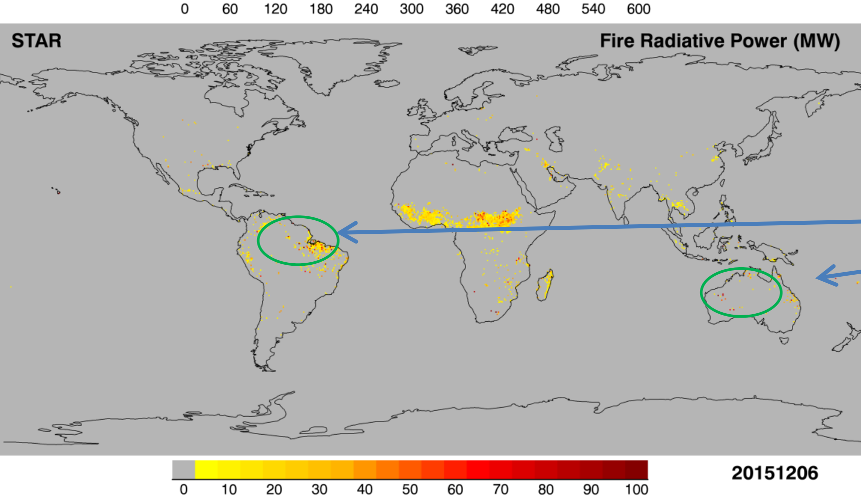
Number of fires per 0.5 deg:

Highest number of fires per 0.5 deg area



0.5 deg integrated radiative power:

Most integrated radiative output



0.5 deg mean radiative power:

Most intense average radiative output from individual fire pixels

NDE output file content

Name	Description	Type
fire mask	Fire mask 2D array (unit-less)	8 bit int
algorithm QA	Fire algorithm QA mask 2D array (unit-less)	32 bit Int
FP_line	Fire pixel line Sparse data array	16 bit Int
FP_sample	Fire pixel sample Sparse data array	16 bit Int
FP_latitude	Fire pixel latitude Sparse data array (deg)	32 bit Float
FP_longitude	Fire pixel longitude Sparse data array (deg)	32 bit Float
FP_power	Fire radiative power Sparse data array (MW)	32 bit Float
FP_confidence	Fire detection confidence Sparse data array (%)	8 bit Int
FP_land	Land pixel flag Sparse data array	8 bit Int

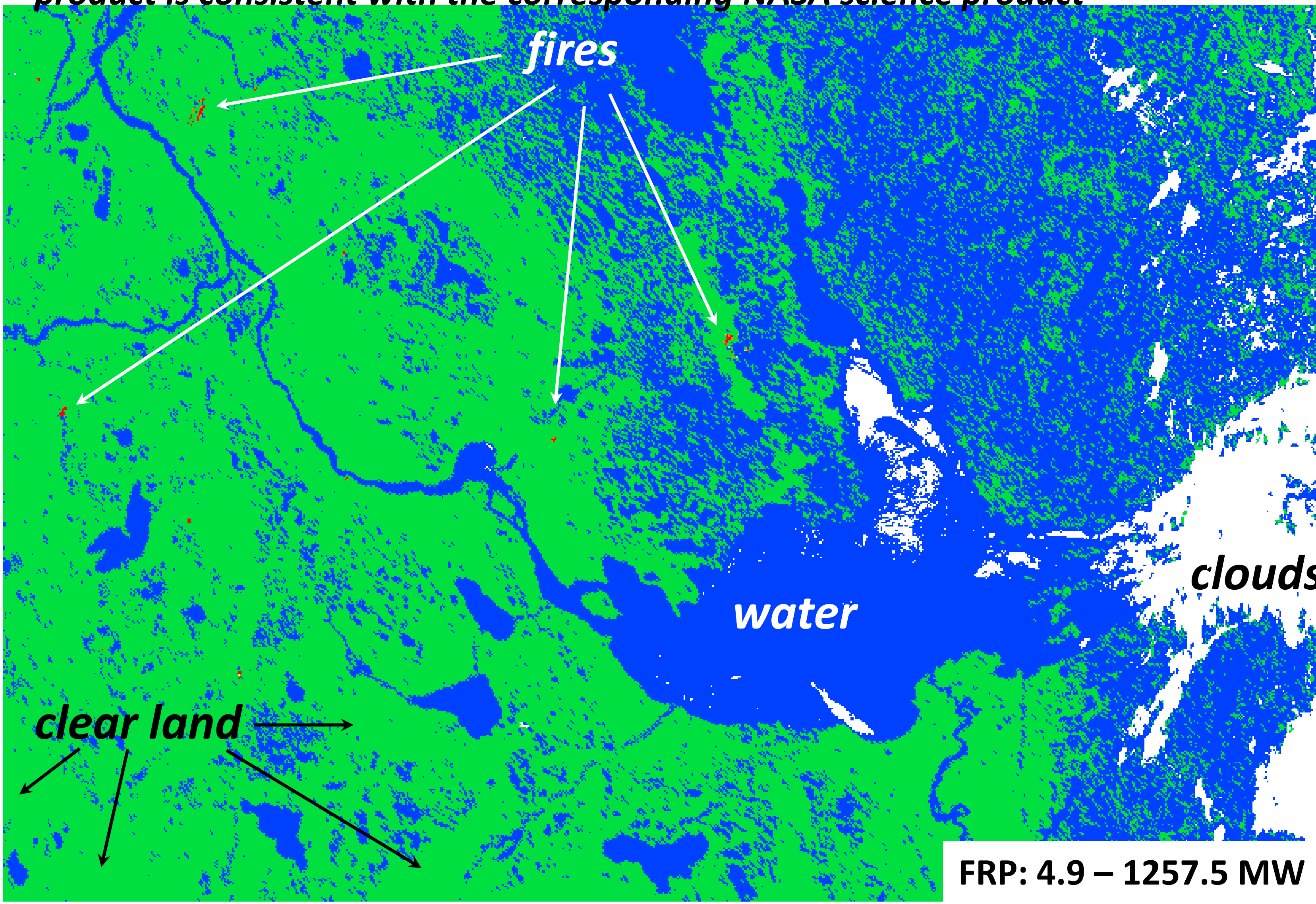
Total output for one granule: 11.7 Mb + number of fires * 79 bytes

Missing – 0	Brightness temperatures for M13 or M15 unavailable
Scan – 1	Not processed (trim)
Other – 2	Not processed (other reason)
Water – 3	Pixel classified as non fire water
Cloud – 4	Pixel classified as cloudy
No Fire – 5	Pixel classified as non fire land
Unknown – 6	Pixel with no valid background pixels
Fire Low – 7	Fire pixel with confidence strictly less than 20% fire
Fire Medium – 8	Fire pixel with confidence between 20% and 80%
Fire High – 9	Fire pixel with confidence greater than or equal to 80%

0-1	Surface Type (water=0, coastal=1, land=2)
2-3	Atmospheric correction (reserved for future use)
4	Day/Night (daytime = 1, nighttime = 0)
5	Potential fire (0/1)
6-10	Background window size parameter
11	Fire Test 1 valid (0 - No, 1 - Yes)
12	Fire Test 2 valid (0 - No, 1 - Yes)
13	Fire Test 3 valid (0 - No, 1 - Yes)
14	Fire Test 4 valid (0 - No, 1 - Yes)
15	Fire Test 5 valid (0 - No, 1 - Yes)
16	Fire Test 6 valid (0 - No, 1 - Yes)
17-19	N/A
20	Adjacent clouds (0/1)
21	Adjacent water (0/1)
22-23	Sun Glint Level (0-3)
24	Sun glint rejection
25	False Alarm 1 (excessive rejection of legitimate background pixels)
26	False Alarm 2 (water pixel contamination)
27	Amazon forest-clearing rejection test
28-31	N/A

NDE VIIRS Active Fire Product: Fire Mask

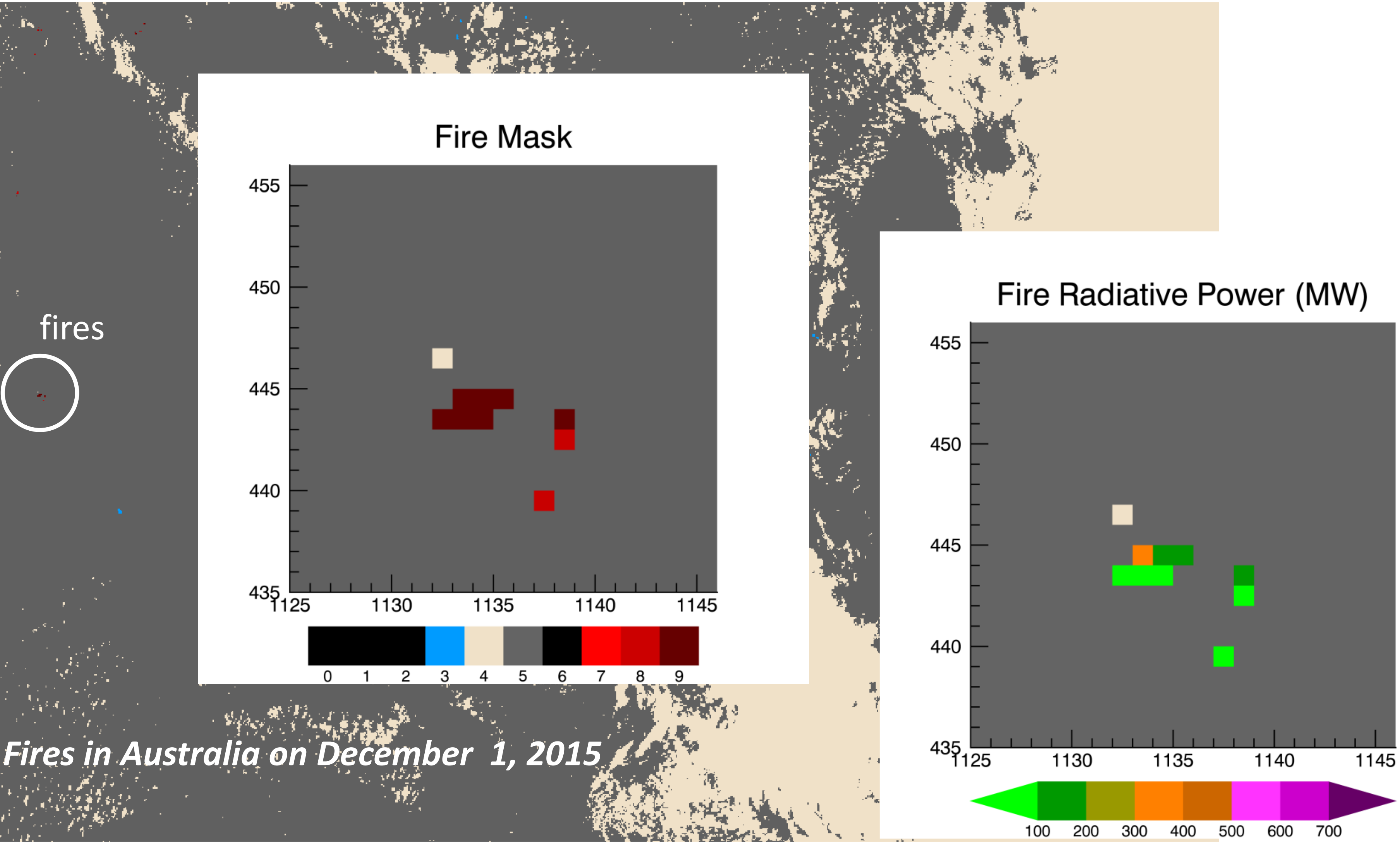
VIIRS fire mask generated at NOAA/NESDIS/STAR from IDPS input data. The NOAA Level-2 product is consistent with the corresponding NASA science product



VIIRS fire mask over NW Canada 5/29/2015 20:06 UTC

(daytime)

Characterizing Fires: confidence and radiative power

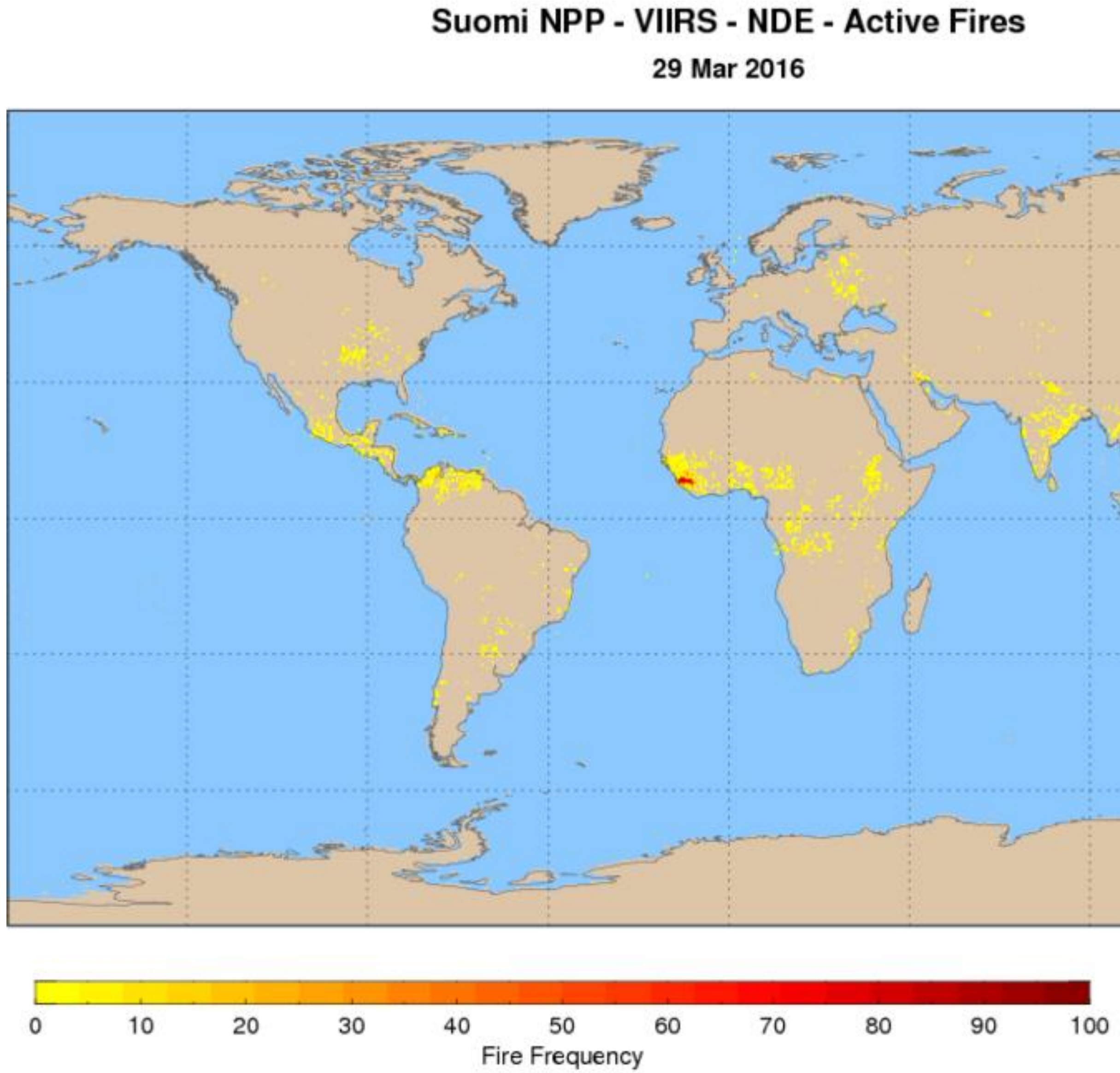


Testing and Validation

- Continuing long-term science monitoring
  - Product was incorporated into the STAR LTM system within two weeks of operational transition
    - Offline monitoring started immediately
- Implementation of J1 cal/val plan
  - Independent reference data
  - Correlative analysis with compatible products
- Detection performance
  - Probability of detection as a function of fire characteristics
  - Omission / commission rates
    - Need definition of “fire”!
- FRP
  - retrieval accuracy against reference measurements

VIIRS Fire in the STAR LTM system

https://www.star.nesdis.noaa.gov/jpss/EDRs/products_activeFires.php



NOAA/NESDIS/STAR

VIIRS Fire in the STAR LTM system

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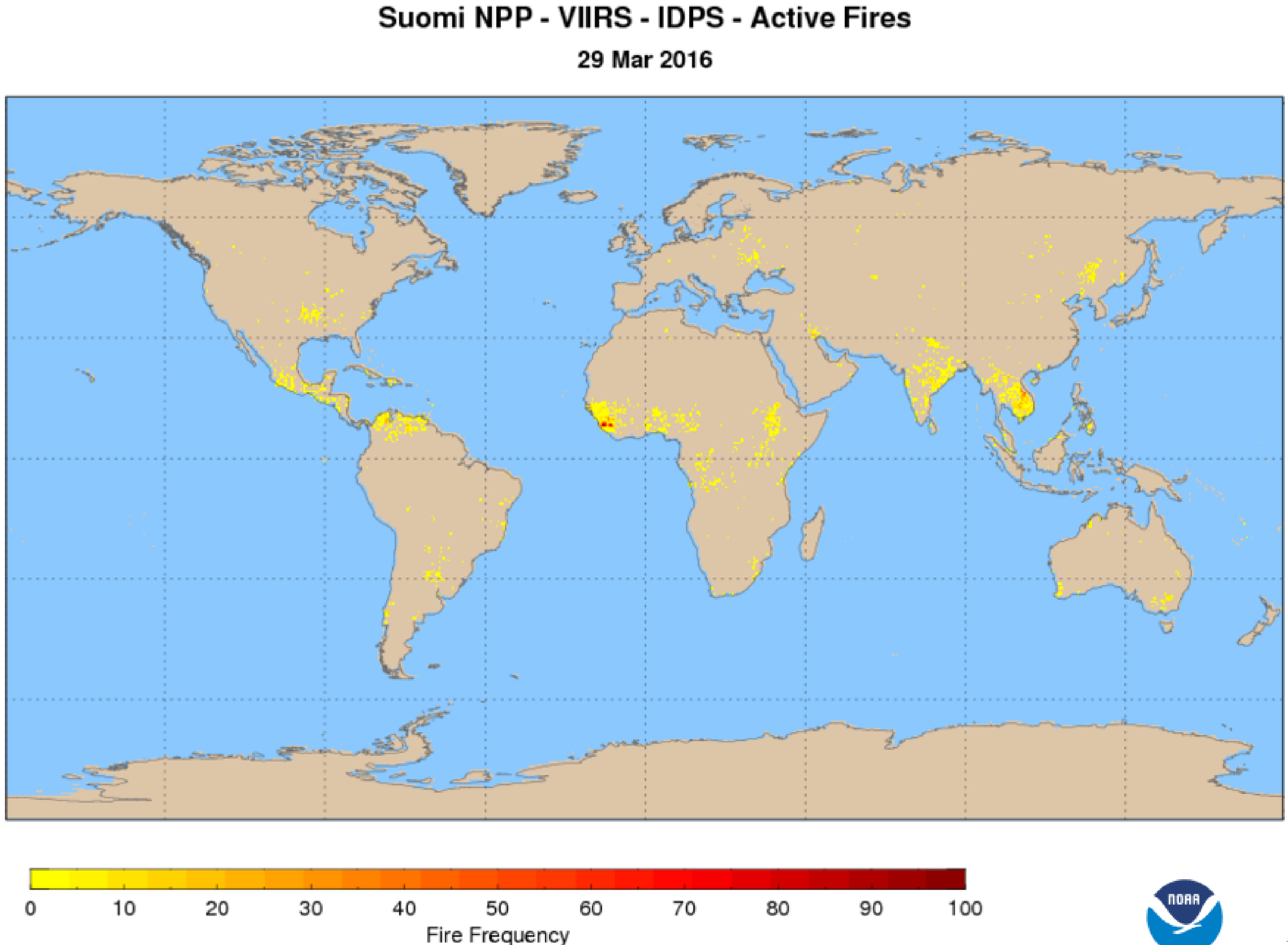

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Lessons Learned

- NDE implementation was nearly seamless
- Easy access to global near-real-time data from NDE to SCDR
- NDE does not process repaired granules, which impacts the data record
- CLASS archival did not start immediately
  - Discussions on metadata details etc.
- Very strong interest from key NOAA operational users

Risks and Review Items

- Strong dependency on SDR performance and product content
  - fire detection / characterization is a very unique problem due to at least two reasons:
    - 1. the target variable is sub-pixel and
    - 2. the radiometric signal is at the high end of the dynamic range for many channels used which results in sensor-specific artifacts and necessary corrections.
- Implementation of a generalized enterprise solution is deemed to be (nearly) impossible for all practical purposes

The Alternative 375m Fire Algorithm

- Takes advantage of the higher resolution VIIRS bands
  - Simple adaptation of MODIS C6 algorithm produced poor results
    - Widespread <u>commission errors</u>
    - Data artifacts affecting channel I4 (MIR driving the fire detection)
      - Frequent data saturation and folding causing <u>omission errors</u>
      - South Atlantic Magnetic Anomaly (SAMA) causing large number of <u>spurious detections</u>
  - Custom algorithm developed
    - Tuning of all tests used in the algorithm
    - Development of several additional tests in order to deal with data artifacts
      - Two-stage analysis of daytime fire pixels
      - Special module to deal with SAMA affecting nighttime pixels

Fire Detection Metrics (3-month sample)

VIIRS 375 m Fire Detection Data

Daytime Total	Unique Daytime	% Unique Daytime	Nighttime Total	Unique Nighttime	% Unique Nighttime
3763104	1656443	**44.0**	1233974	972878	**78.8**

VIIRS 750 m Fire Detection Data

Daytime Total	Unique Daytime	% Unique Daytime	Nighttime Total	Unique Nighttime	% Unique Nighttime
1093666	40194	**3.7**	53715	87	**0.2**

Unique 375 m (750 m) fire pixels describe those cases without coincident 750 m (375 m) detection (including adjacent pixels)

Larger percentage of unique 375 m nighttime fire pixels caused by diurnal cycle (smaller/lower intensity night fires) and – to a less extent – pending 750 m algorithm tuning

VIIRS Fire Algorithm Optimization

- Latest version of 375 m algorithm incorporates several modifications
  - Hybrid algorithm using both I and M-band data
    - Using I4&I5 brightness temp and quality flag data to identify pixel saturation and folding
    - Using I4&M13 (un-aggregated) channel test to identify spurious detections due to South Atlantic Magnetic anomaly
    - Using M13 (aggregated) channel to derive FRP
      - ➢ Downscaling of M13 pixel to I-band resolution
    - Using combination of internal/external land-water pixel classification scheme to avoid false alarms along coastlines

Hybrid Algorithm Processing Flow

Daytime

- Screen for saturation/folding pixels (two unique BT/QF combinations), clouds and water [I1-I5]
- First-stage detection tests [I4&I5]
- Test for glint contamination (exclusion of potential false alarms) [I1&I2]
- Second-stage detection tests (identification of outstanding saturation/folding/low confidence pixels) [I4&I5]
- FRP retrieval using aggregated M13

  [background sampling guided by I4&I5]

Nighttime

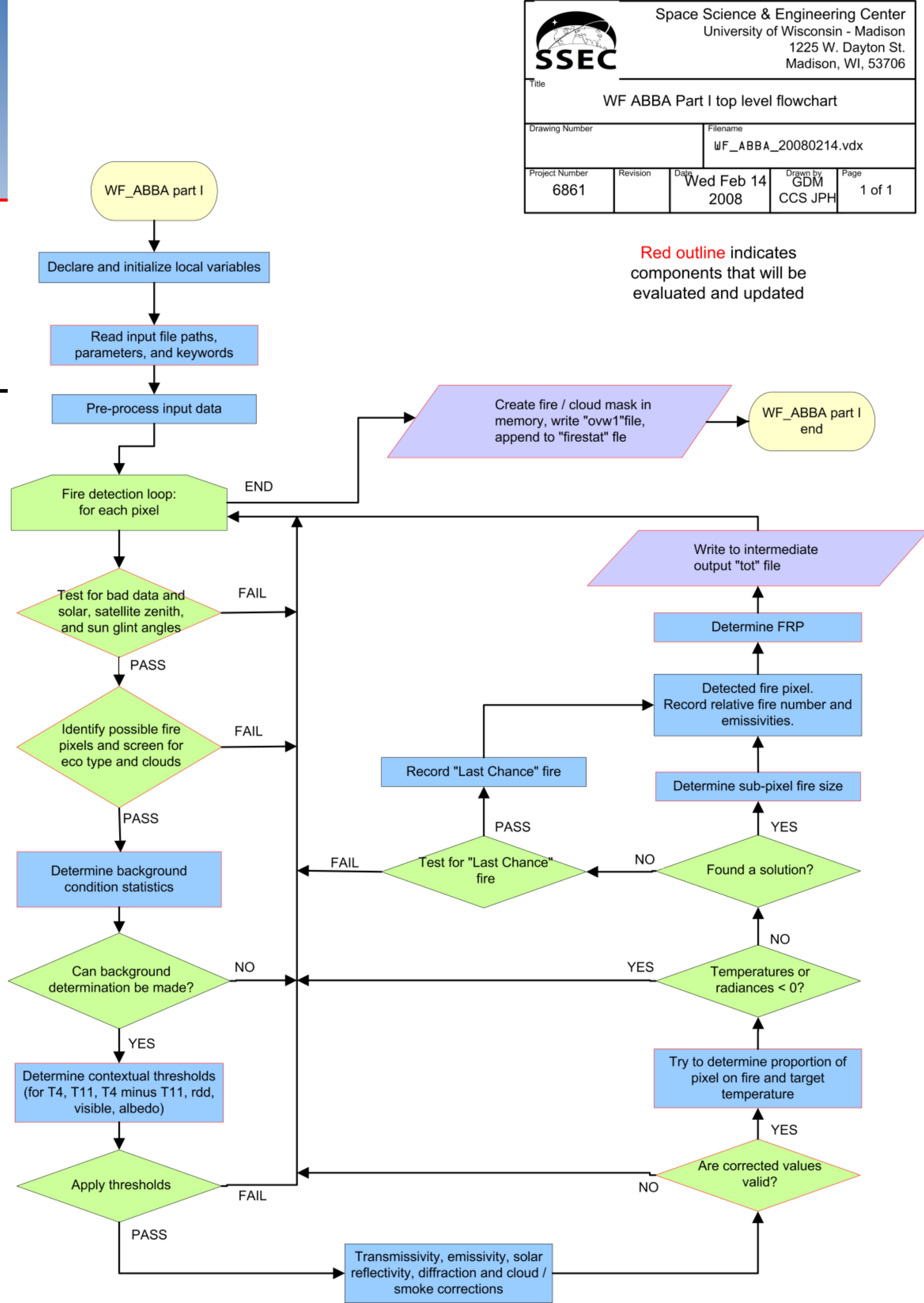
- Screen for saturation/folding pixels (three unique BT/QF combinations), and clouds [I4&I5]
- Single stage detection tests [I4&I5]
- SAMA region test [aggregated+ unaggregated M13]
- FRP retrieval [aggregated M13]

  [background sampling guided by I4&I5]

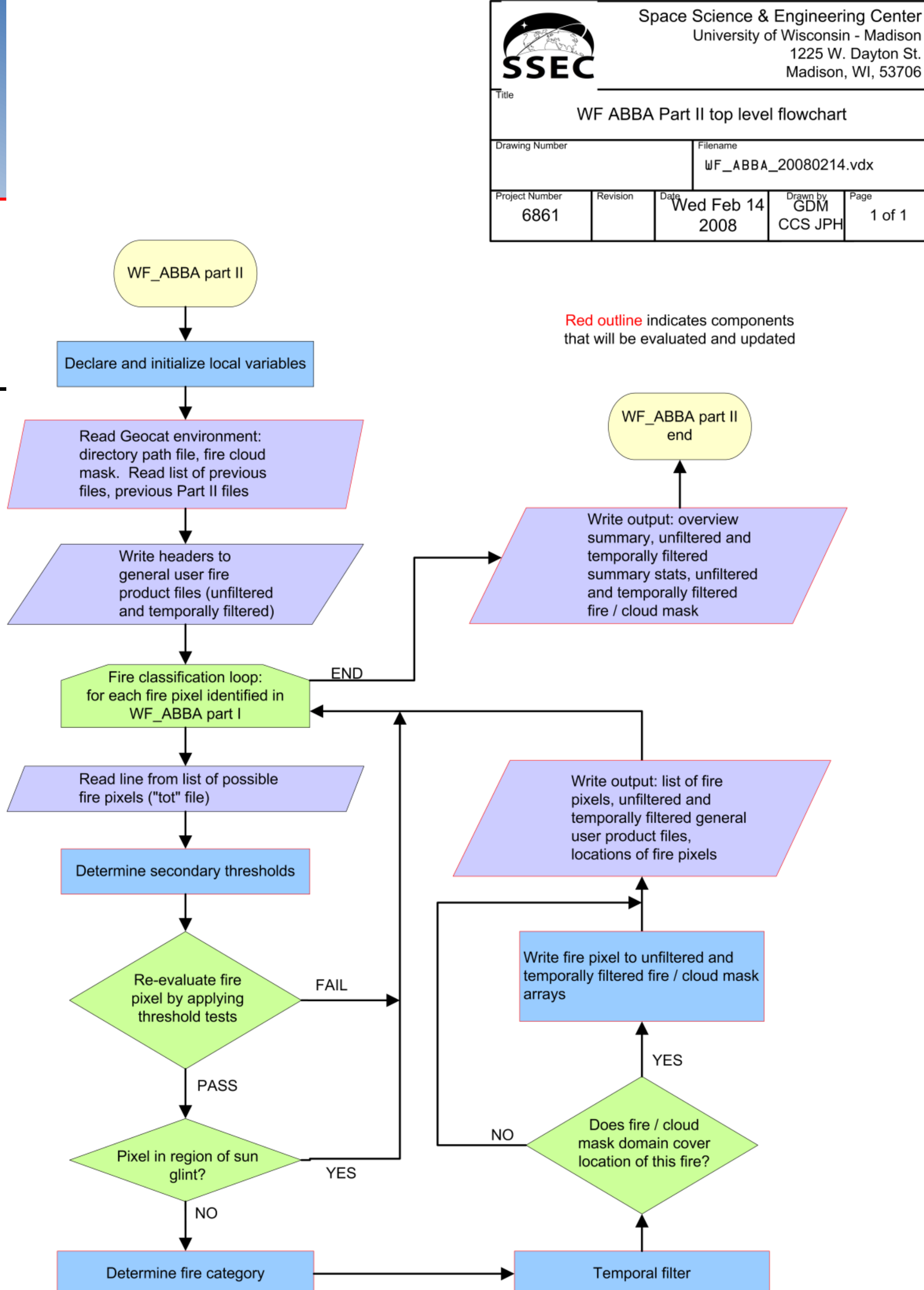
Brackets define channels used in each data processing module

I1:	**0.600 – 0.680**
I2:	**0.846 – 0.885**
I3:	**1.580 – 1.640**
I4:	**3.550 – 3.930**
I5:	**10.500 – 12.40**
M13:	**3.973 – 4.128**

GOES-R FDCA Flowchart, Part 1



GOES-R FDCA Flowchart, Part 2



Notes on merging Geostationary (GOES) and Polar (VIIRS) fire algorithms

- **Similarities:**
  - Both use 4 and 11 μm bands
  - Contextual calculations for background temperatures have similar algorithm flow and outputs (not identical)
  - Fire algorithm-specific cloud masks used for both
- **Differences:**
  - Minimum threshold for detection uses T4-T11 of 4 K for GOES, 10 K for VIIRS, due to differing footprint size
  - Size of area used for background context (temperature, etc) can be much larger for GOES than VIIRS
  - Tests to further determine if a pixel is a fire after initial screen are markedly different
  - Thresholds for rejecting pixels with sunglint are handled differently due to differing viewing geometry
  - Final rejection tests are markedly different, apparently due to brightness temperatures (BT) differences due to differing wavelengths and viewing geometry
  - GOES utilizes more surface type metadata
  - VIIRS handles coastlines differently due to higher resolution
  - GOES corrects BTs for water vapor attenuation before calculating fire properties, VIIRS does not appear to
  - GOES calculates fire size, temperature, and FRP; VIIRS calculates FRP

Notes on merging Geostationary (GOES) and Polar (VIIRS) fire algorithms

- Conclusions based on preliminary investigation:
  - Assessment was made by comparing VIIRS ATBD of April 22, 2011 to GOES-R ABI FDCA ATBD and code
  - There are significant differences in the details of fire detection, classification, and characterization between the two algorithms. **The number of possible shared functions is relatively low** without completely reworking one or both algorithms. The background statistic calculations could potentially be a shared routine but it would likely need to branch for different satellite types.
  - Both algorithms operate on assumptions regarding the nature of the satellite footprints, **tests used for one may not translate to another, requiring two different execution paths** or development work to determine how well one approach works for both satellite platforms.
  - **Fire detection is very sensitive to the properties of the sensor providing the data**, and there are large differences between ABI-class and VIIRS-class sensors. Details like differing point-spread function, oversampling, and remapping influence what types of tests are employed and what thresholds are used. Some tests are relevant for ABI but not VIIRS, and vice-versa.
  - **Combining the two algorithms is not trivial** and, if it is to be attempted, should be viewed as a long-term research project while the two mature algorithms continue to run in Operations.

Conclusion

- M-band algorithm is in operations
- I-band / hybrid product
  - The occurrence of frequent I-band data artifacts (saturation/folding/SAMA) require the adoption of unique pre-/post-screening of data
  - Use of both I and M-band data create additional VIIRS-specific data handling/processing compared to MODIS, GOES/-R fire algorithms
  - Hybrid I-M band algorithm could replace current baseline (750m) algorithm
    - Improved detection of small fires, mapping of large fires
    - Improved FRP retrievals due to enhanced background sampling used in calculations
    - Reduced VIIRS fire data redundancy/confusion
- VIIRS / ABI common algorithm is a significant challenge

Summary

- Recommendations
  - Ensure immediate data archival and long-term monitoring
    - Any generic archival / metadata issues?
  - Implement I-band / hybrid I-M band product(s) in NOAA operations
  - Backfill repaired granules in operational stream
  - Reprocess once all SDR / AF interface / QF issues are resolved
  - Continue detailed comparative assessment of polar and geostationary algorithms
    - a long-term research activity, not ready for implementation
- Outstanding issues
  - Fire detection / characterization is a very unique problem due to at least two reasons:
    - 1. the target variable is sub-pixel and
    - 2. the radiometric signal is at the high end of the dynamic range for many channels used which results in sensor-specific artifacts and necessary corrections.