NRL-Monterey Aerosol Prediction Update

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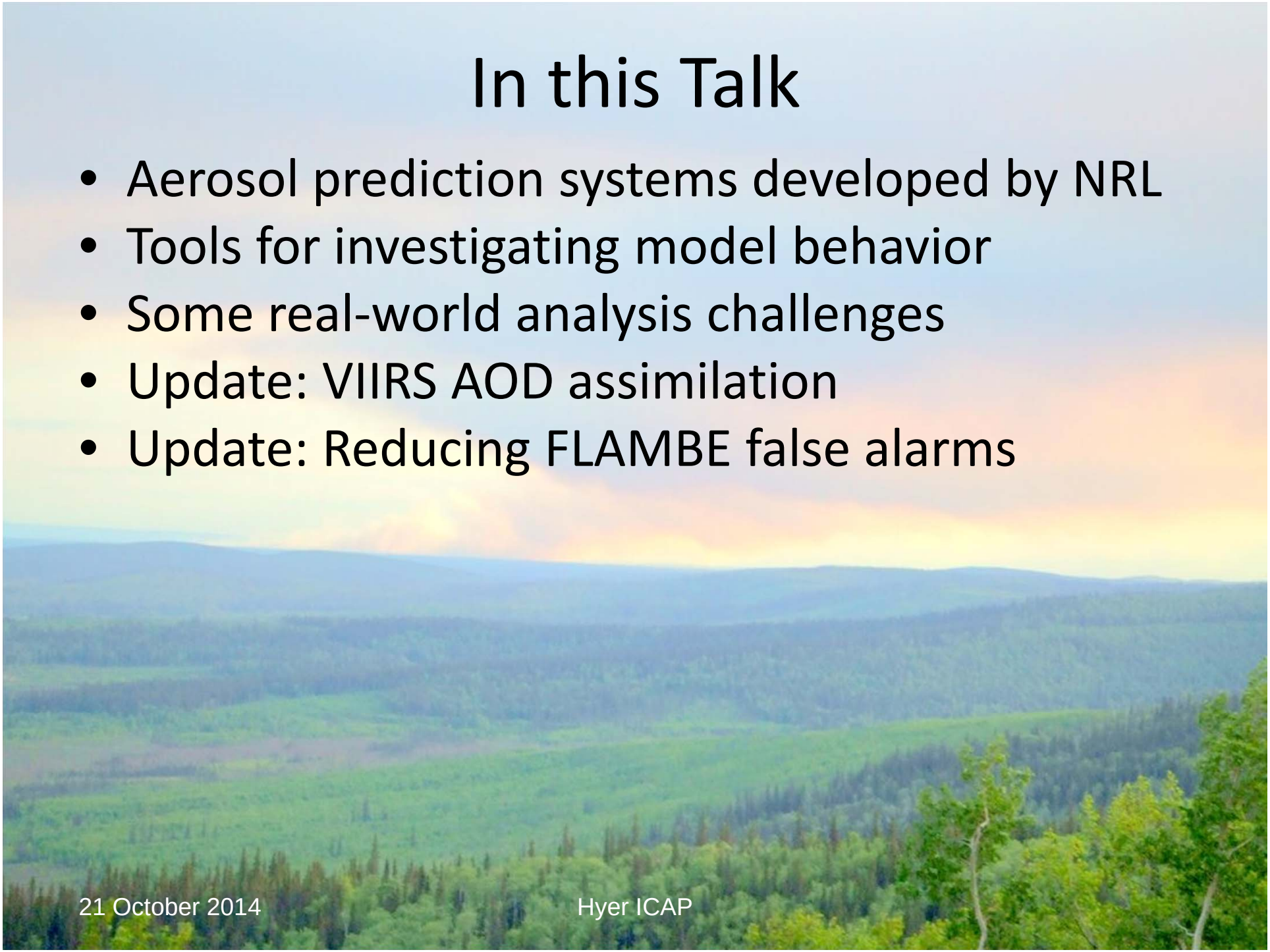
In this Talk

- Aerosol prediction systems developed by NRL
- Tools for investigating model behavior
- Some real-world analysis challenges
- Update: VIIRS AOD assimilation
- Update: Reducing FLAMBE false alarms

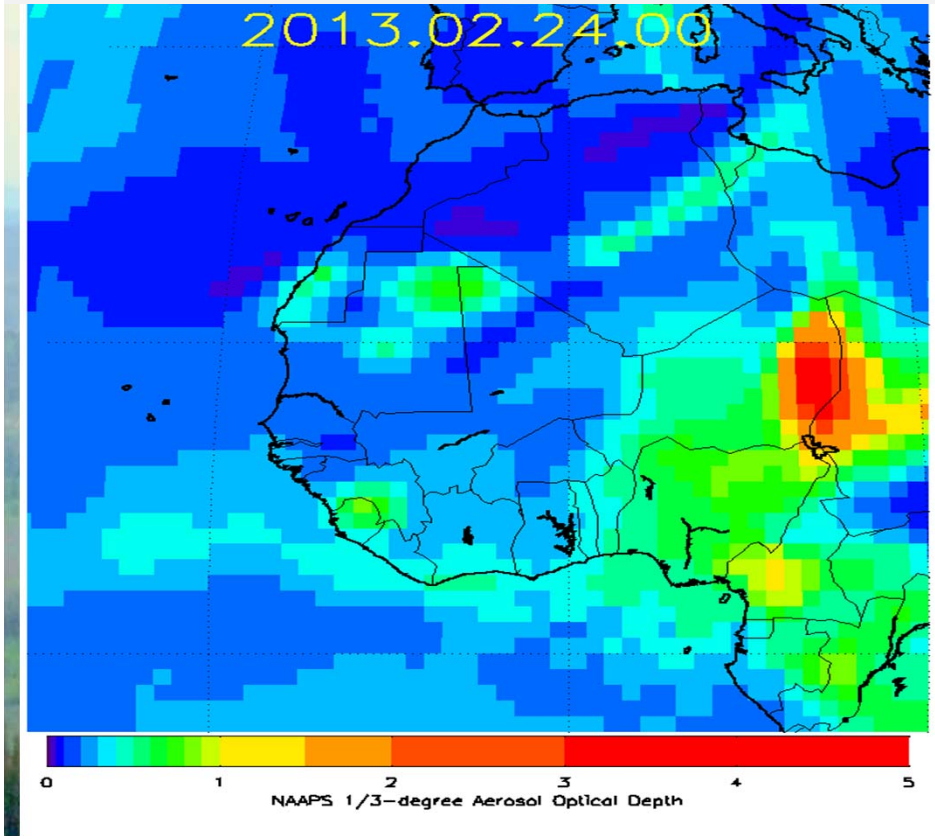


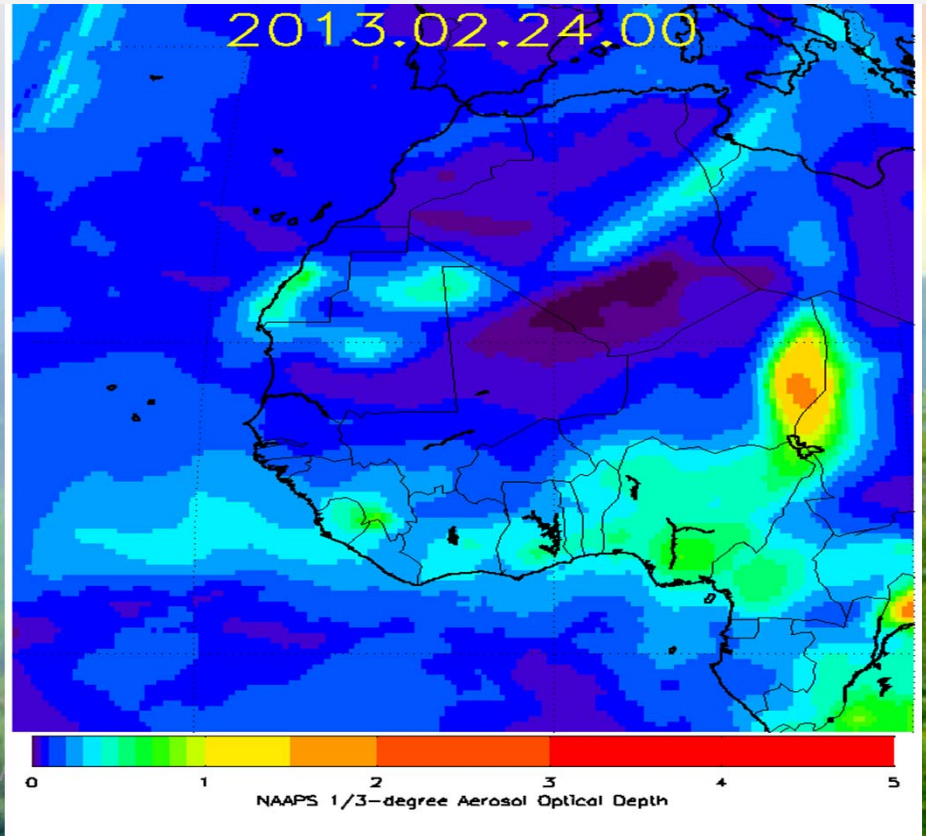
Navy Aerosol Applications

- Navy Aerosol Analysis and Prediction System (NAAPS)
  - Global
  - Offline driven by NAVGEM meteorology
  - AOD assimilation with NAVDAS-AOD
- Coupled Ocean-Atmosphere Model Prediction System (COAMPS®)
  - Regional (3-15 km resolution)
  - Coupled dynamics with boundary conditions from NAVGEM
  - Aerosol capability used operationally for dust

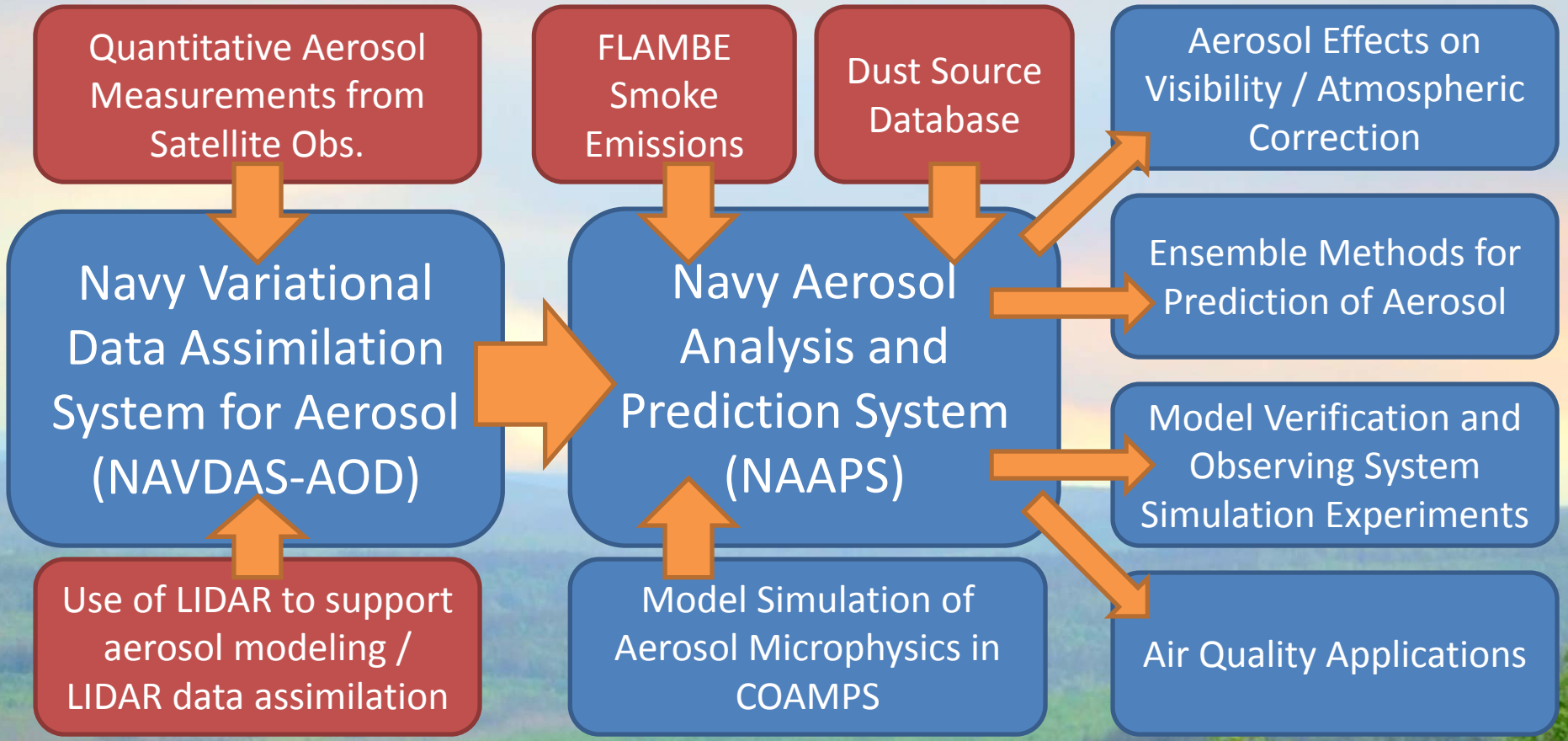
Navy Aerosol Analysis and Prediction System (NAAPS)

- Operational at FNMOC since 2005 (first global operational forecast in the world)
- Assimilation of satellite AOD operational since 2009
- In 2013, operational NAAPS was upgraded from 1-degree to 1/3-degree resolution
  - Also upgraded from NOGAPS to NAVGEM meteorology





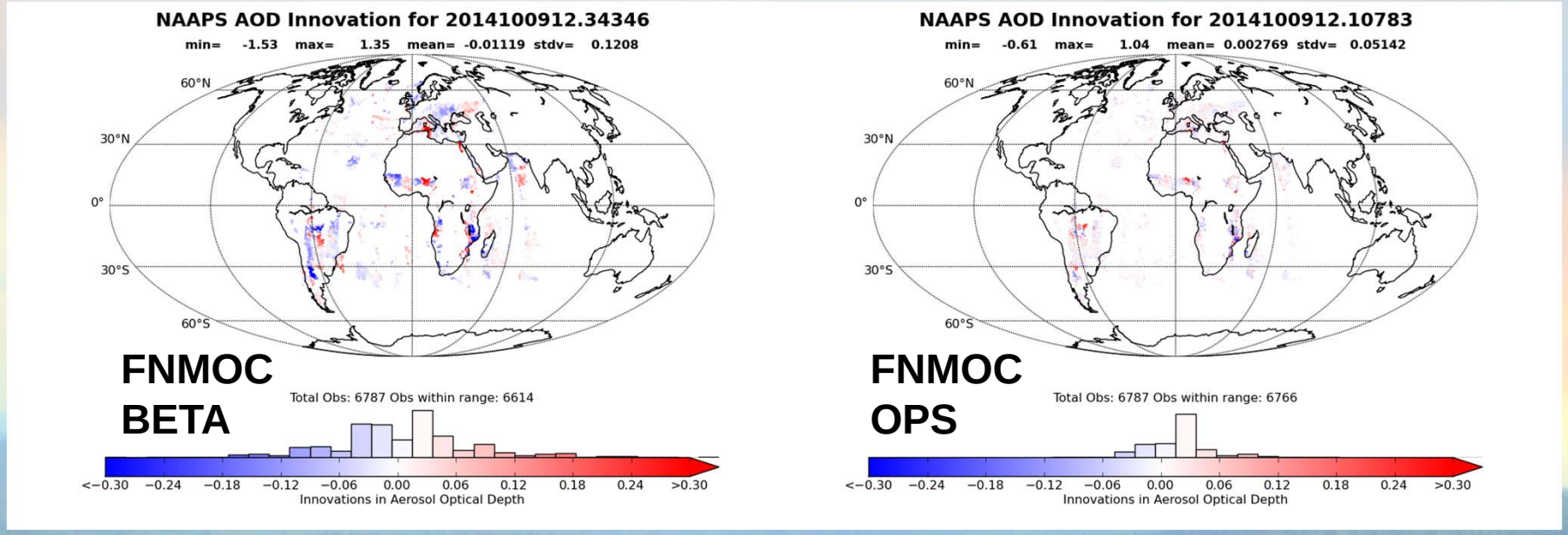
NRL Aerosol and Radiation Activities



Overview of Satellite Data Usage in NAVDAS-AOD and NAAPS:

Component	Assimilated Data
FLAMBE – Hourly, global, biomass emission fluxes in real-time and archived since 2000	**MODIS and GOES data used to produce gridded smoke emissions (FLAMBE, WF-ABBA)**
DSD – Global dust source database	**MODIS Dust Enhancement Product and TOMS AI used to identify dust sources**
NAVDAS-AOD – data assimilation, produces 6-hourly, global 3-d distributions of aerosol species (sulfate, smoke, dust, salt), in real-time and back to 2000	**NRL Level 3 version of MODIS AOD** **AERONET and CALIPSO climatology used for speciation** **R&D: CALIPSO used for 3-d var data assimilation and validation** **Unused: MODIS Deep Blue, MISR, AVHHR AOD**
NAAPS Validation	**AERONET – AOD, absorption, size** **CALIPSO and MISR - Altitude**

Better tools for examining model behavior in real time: Innovation and Increment



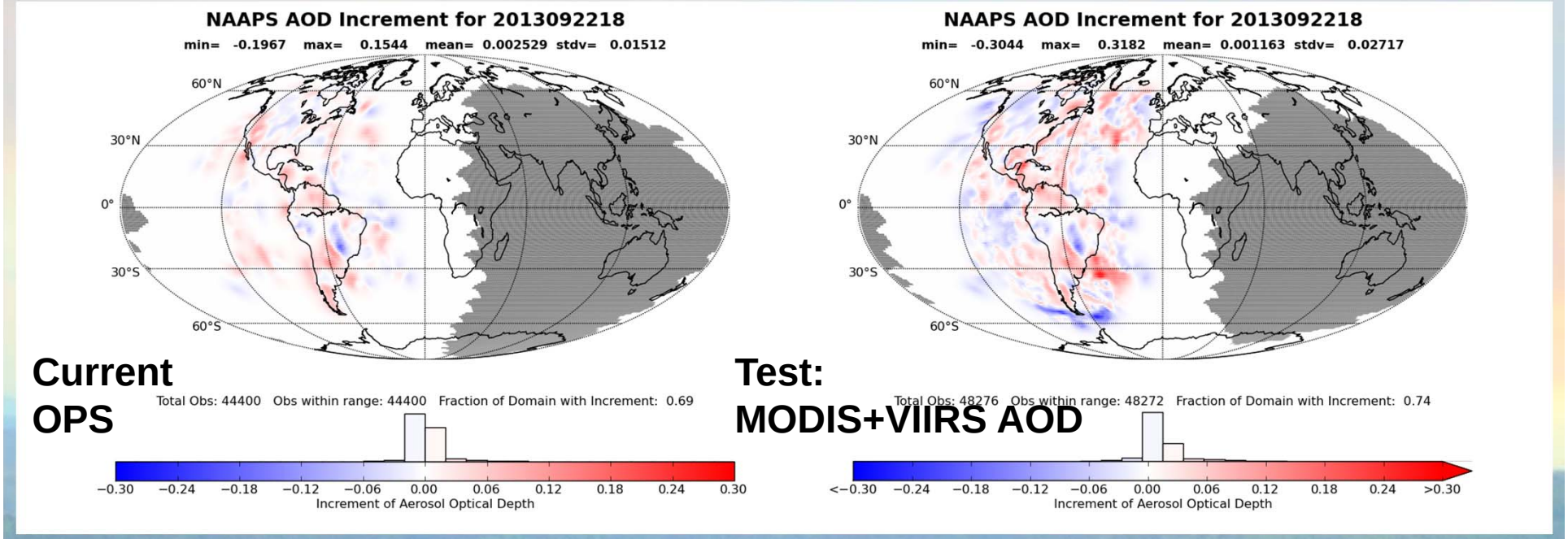
With an innovation plot, we can instantly verify:

- Location and quantity of obs. assimilated
- Range of innovations (OBS – 6hour forecast)
- Global bias of model forecast AOD vs OBS

This example shows plots comparing a FNMOC BETA run to the OPS run.

- This BETA run had been recently restarted from old data: large innovations result
- 12 hours (2 cycles of NAVDAS-AOD) later, BETA and OPS appear identical

Better tools for examining model behavior in real time: Innovation and Increment



Current OPS

Test: MODIS+VIIRS AOD

With an increment plot, we can instantly verify:

- Location of all obs (nothing out of place)
- Range and spread of increments (ANALYSIS - 6hour forecast)
- Global correction of model forecast AOD in analysis

This example shows plots comparing a test with MODIS+VIIRS to the operational configuration (details below)

Real World Validation Issues

- How to have confidence in results based on short time series?
  - Update cycle of different model components
  - Not possible to do long runs for all changes
  - Scorecards for rapid evaluation
- We need clever ways to diagnose cloud
  - Comparisons between paired mmts always reflect the best filtering of both instruments

Update: VIIRS aerosol assimilation

- Bottom Line Up Front:
  - VIIRS AOD over land not ready (MODIS-like algorithm would be better)
  - VIIRS AOD over-ocean looks generally OK
  - Last round of testing showed improved correlation, worsened RMSE
  - Diagnostics indicate additional cloud filtering of VIIRS over-ocean is necessary

VIIRS Aerosol Products (1)

- **Aerosol Optical Thickness (AOT)**
  - for 11 wavelengths (10 M bands + 550 nm)
- **APSP (Aerosol Particle Size Parameter)**
  - Ångström Exponent derived from AOTs at M2 (445 nm) and M5 (672 nm) over land, and M7 (865 nm) and M10 (1610 nm) over ocean
  - qualitative measure of particle size
  - over-land product is not recommended!
- **Suspended Matter (SM)**
  - classification of aerosol type (dust, smoke, sea salt, volcanic ash) and smoke concentration
  - currently, derived from VIIRS Cloud Mask (volcanic ash) and aerosol model identified by the aerosol algorithm
- **Only day time data**
- **Only over dark land and non-sunglint ocean**

VIIRS Aerosol Products (2)

At NOAA Comprehensive Large Array-data Stewardship System (CLASS):

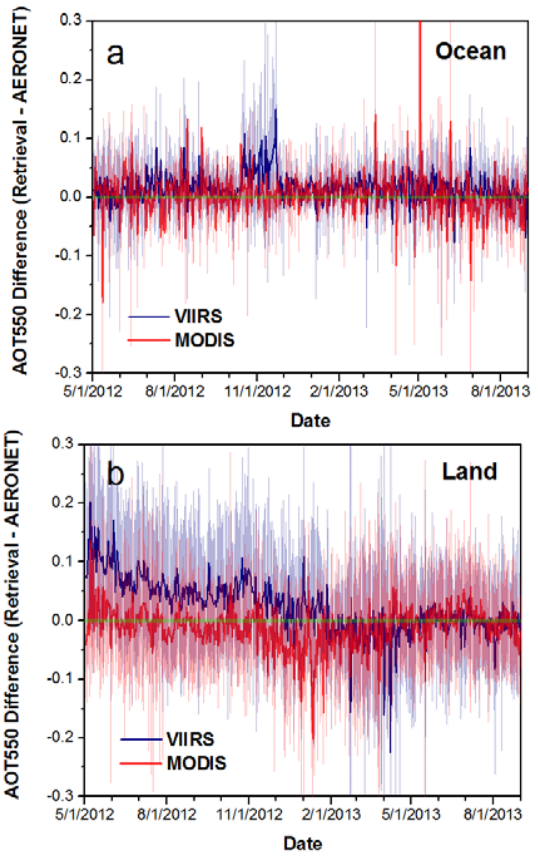
- **Intermediate Product (IP)**
  - 0.75-km pixel
    - AOT, APSP, AMI (Aerosol Model Information)
      - land: single aerosol model
      - ocean: indexes of fine and coarse modes and fine mode fraction
    - quality flags
- **Environmental Data Record (EDR)**
  - 6 km aggregated from 8x8 IPs filtered by quality flags
    - granule with 96 x 400 EDR cells
    - AOT, APSP, quality flags
  - 0.75 km
    - SM

At NOAA/NESDIS/STAR:

- **Gridded 550-nm AOT EDR**
  - regular equal angle grid: 0.25°x0.25° (~28x28 km)
  - only high quality AOT EDR is used

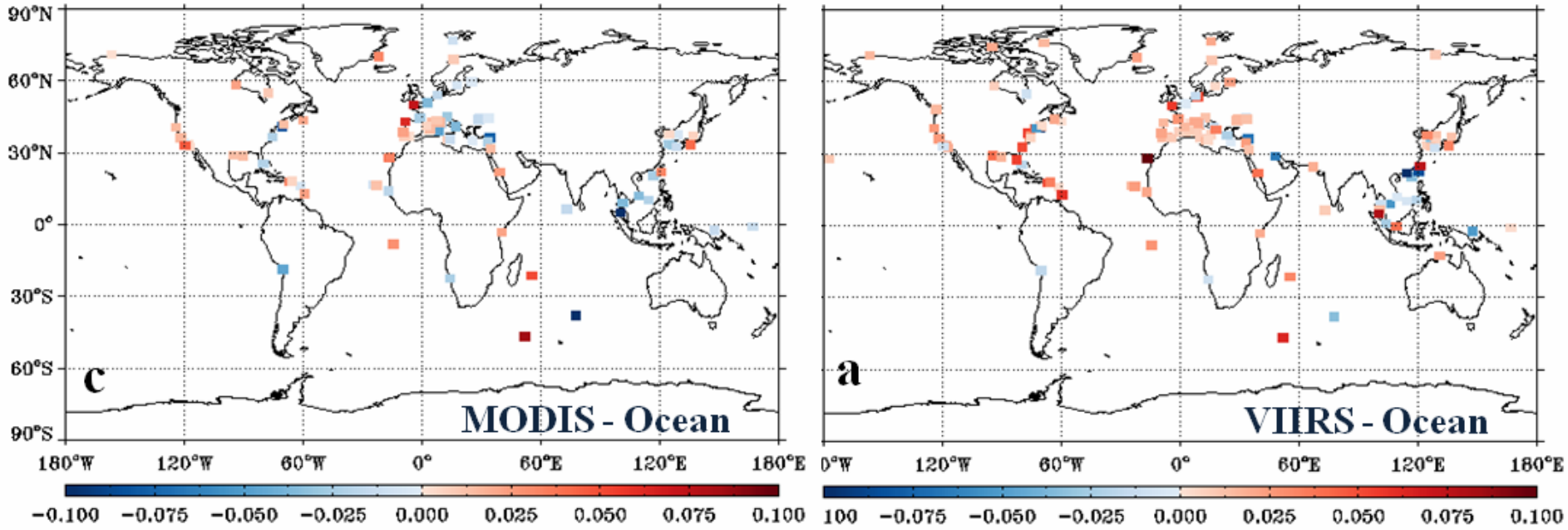
VIIRS Aerosol Cal/Val

- AERONET sun photometers are the gold standard
  - Accuracy and precision exceed what is expected even from the best satellite products
  - Data should not be used uncritically in regions with thin cirrus (Chew et al. *Atm. Env* 2011; Huang et al. *JGR* 2011*)*
- Right: time series of AERONET vs VIIRS AOD (blue) and MODIS-Aqua C5 AOD (red) over ocean (top) and land (bottom).
  - Evolution of VIIRS algorithm (blue) can be seen
  - MODIS Collection 5 (red) and VIIRS have similar accuracy after 1/24/2013



Hongqing Liu et al., *JGR 2014*

VIIRS Aerosol Cal/Val



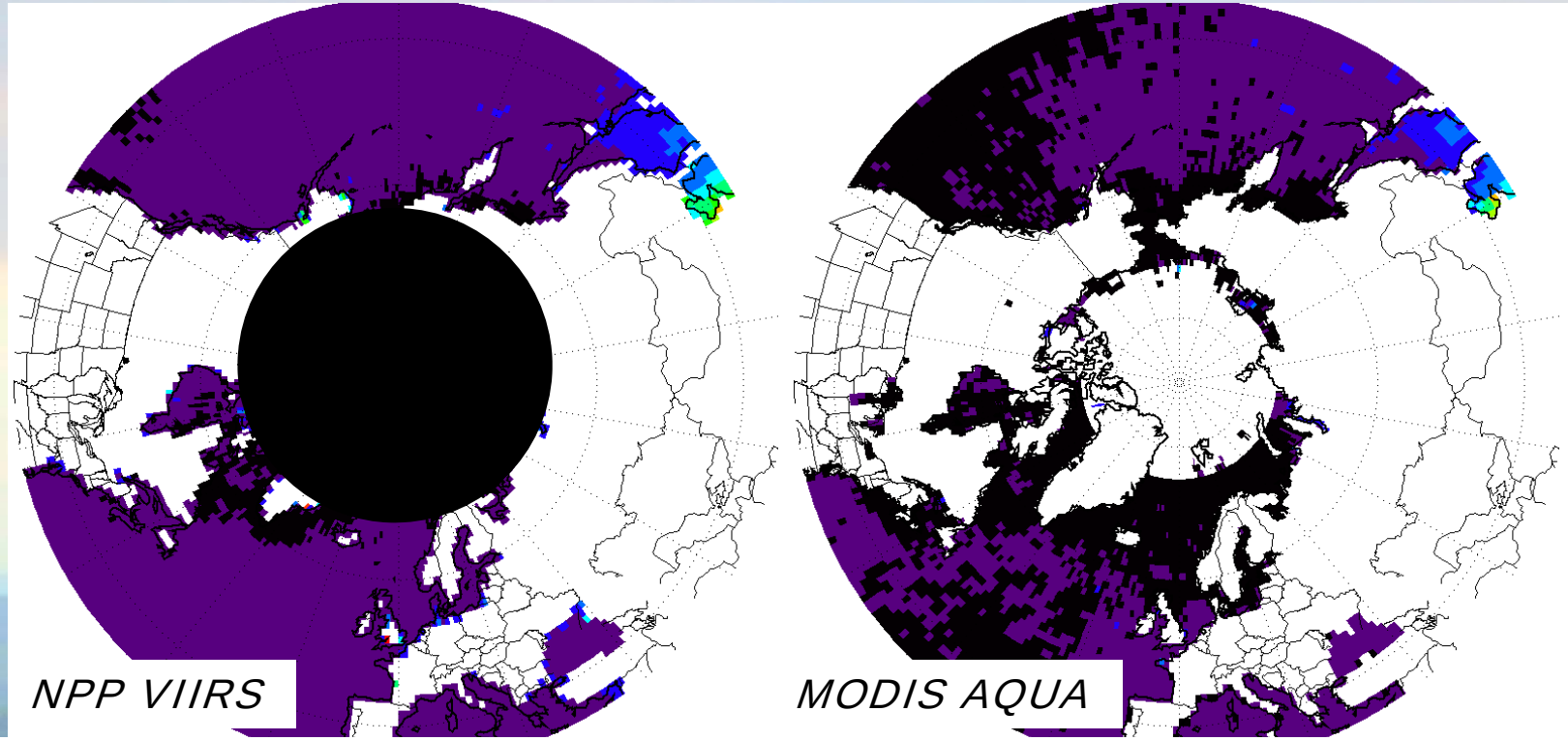
Hongqing Liu et al. *JGR 2014*

- geographically, VIIRS and MODIS ocean retrievals have similar errors vs AERONET
- Note that all SAT-AERONET results use the intersection of all cloud-cleared pixels

NPP VIIRS pre-processor

- 1-degree, 6-hour
  - **Operational NAAPS now 1/3°**, 1° used for testing
- "fullQA" uses information packaged with EDR granules
  - Over ocean only
  - QA = 'Good' (highest EDR QA value)
  - Cloud mask, cloud proximity, snow flags, glint flags
  - No textural filtering
  - Polar regions excluded (>75N)

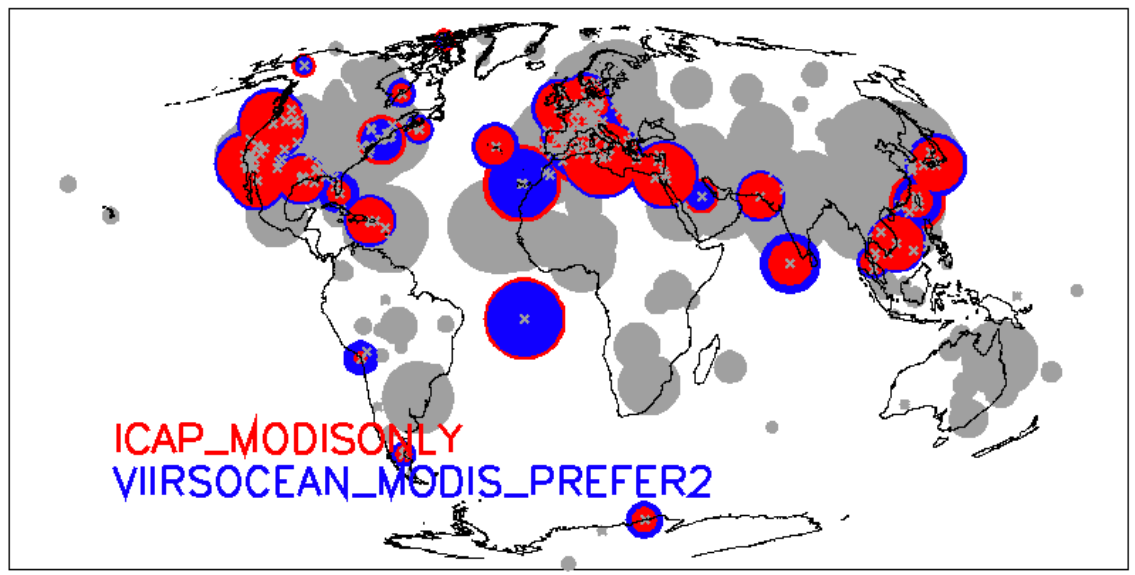
VIIRS ‘fullQA’ AOD vs NRL-UND Level 3 MODIS-- Ocean



- VIIRS background AOD is noticeably higher (+0.05)
- Asian outflow feature is similar

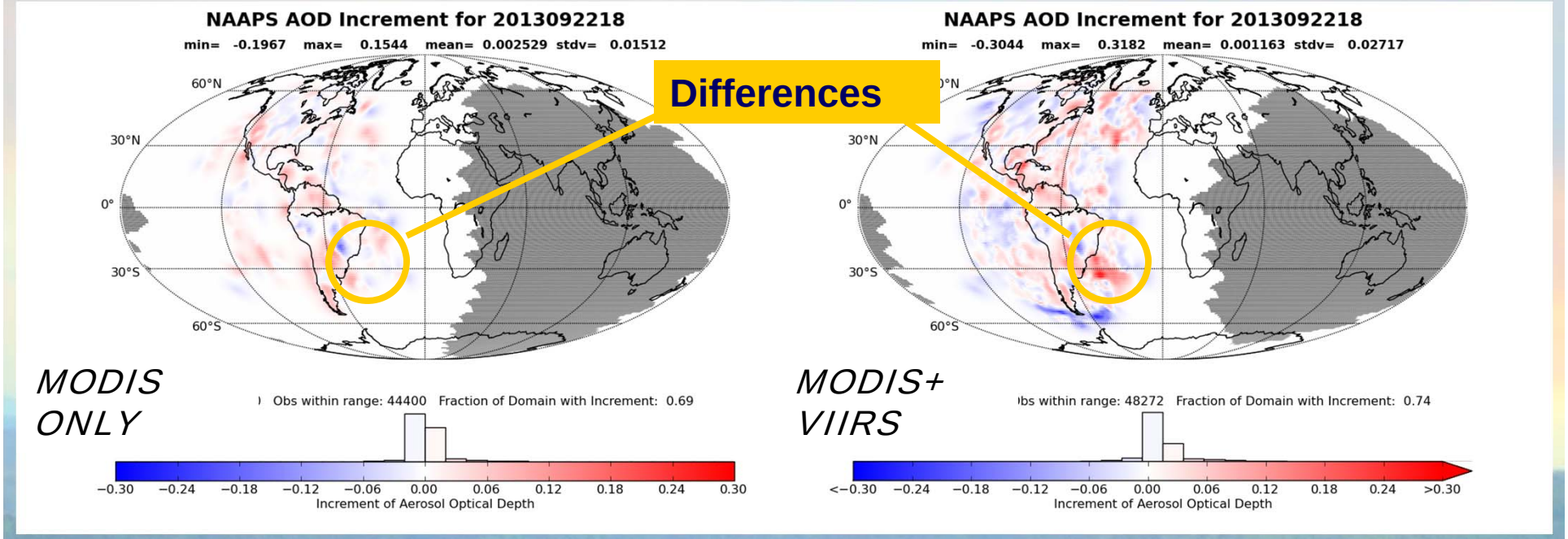
VIIRS+MODIS vs MODIS-only

- Correlation improved at numerous AERONET stations
  - Gray = no difference
  - Larger circle = higher correlation
  - Blue circles are larger (VIIRS+MODIS has higher correlation) for most coastal areas
- However, RMSE is not improved (not shown)



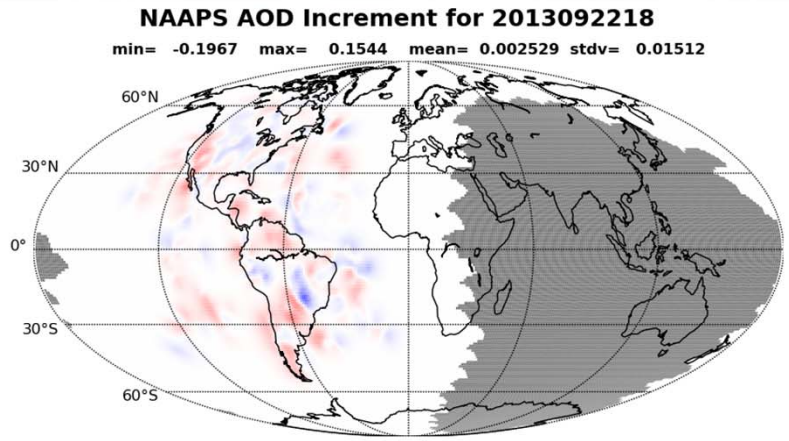
Bottom line: VIIRS+MODIS assimilation is better than MODIS-only in some regions, but effects are regionally variable and not significant globally

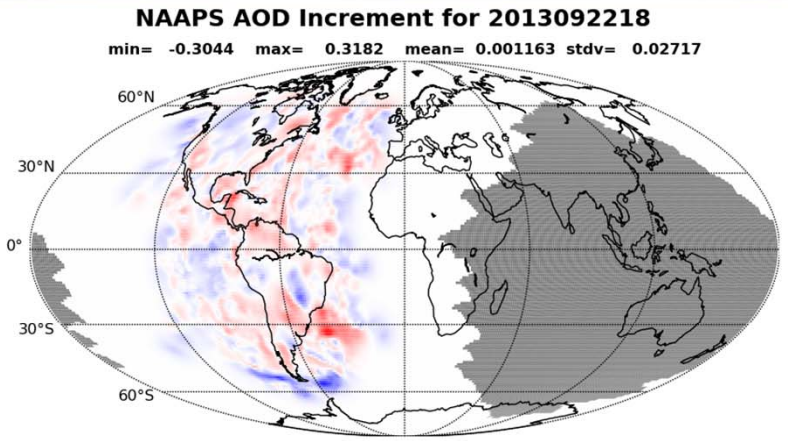
Using Increments to Diagnose AOD Assimilation Results

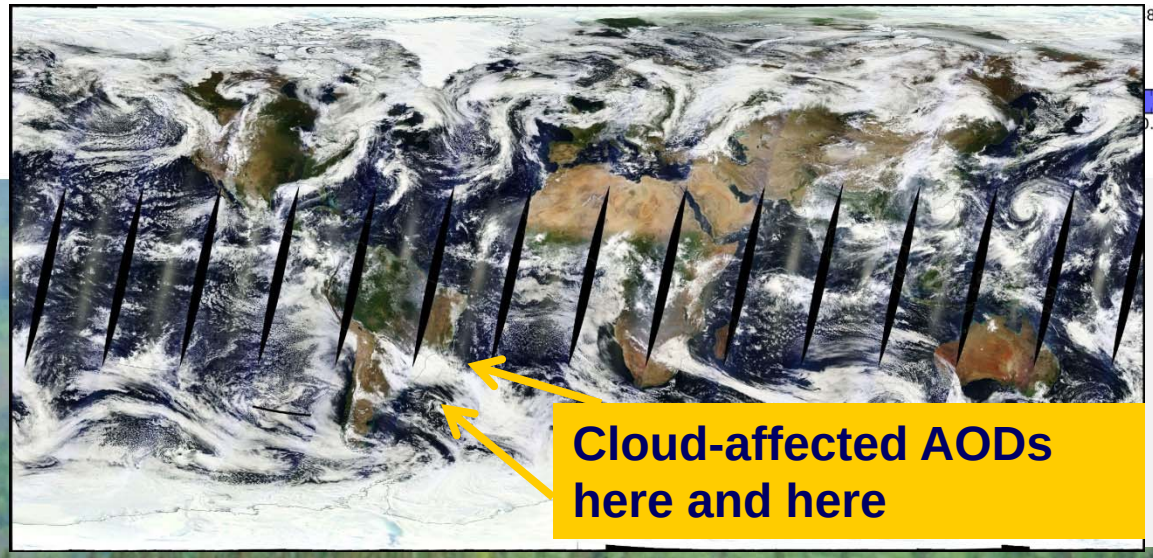


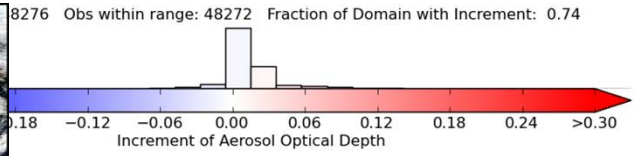
- Left: MODIS-only Right: MODIS+VIIRS
- Note St. Dev. of Increment: 0.015 vs 0.027
- VIIRS offers significant coverage benefit
  - Or seems to

Using Increments to Diagnose AOD Assimilation Results



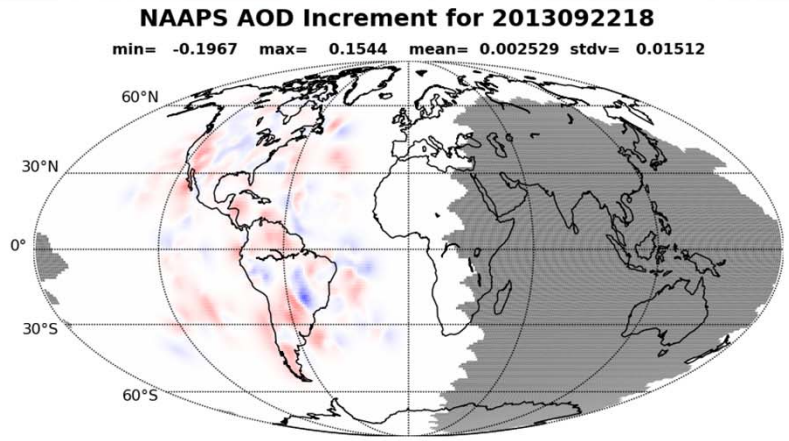


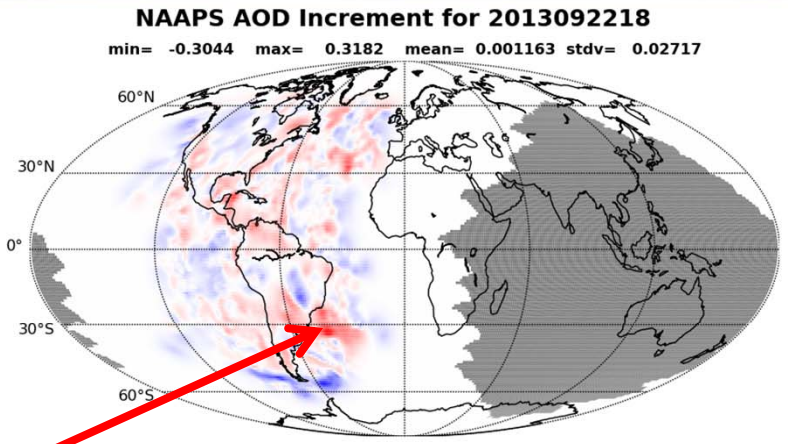


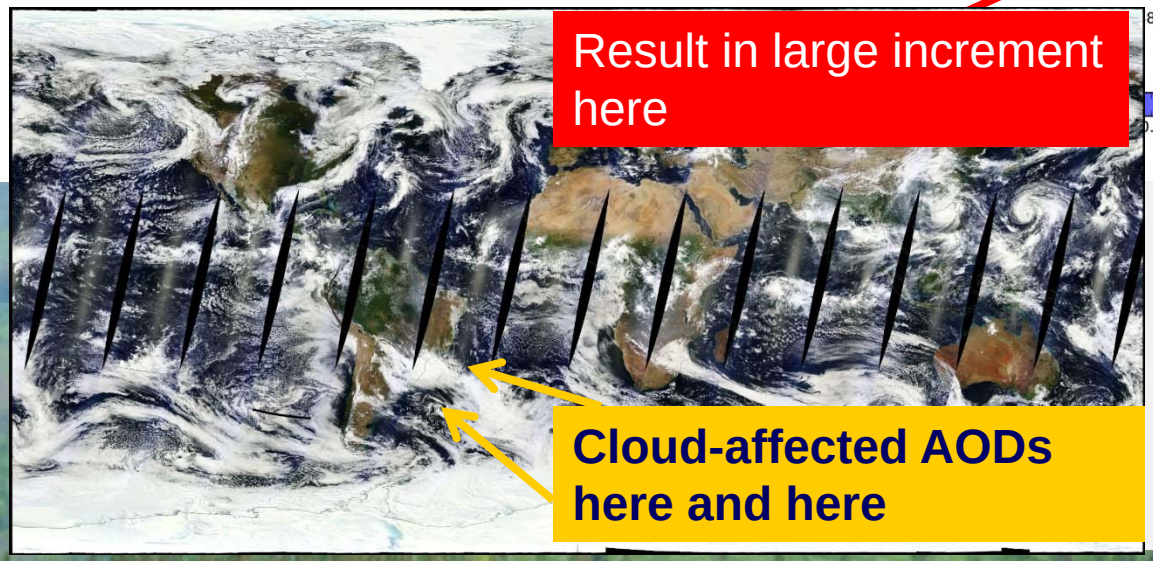


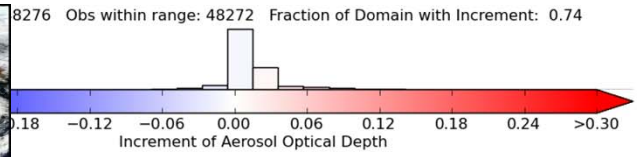
- Better results can probably be achieve with more cloud filtering
  - This will reduce the coverage benefit of VIIRS

Using Increments to Diagnose AOD Assimilation Results









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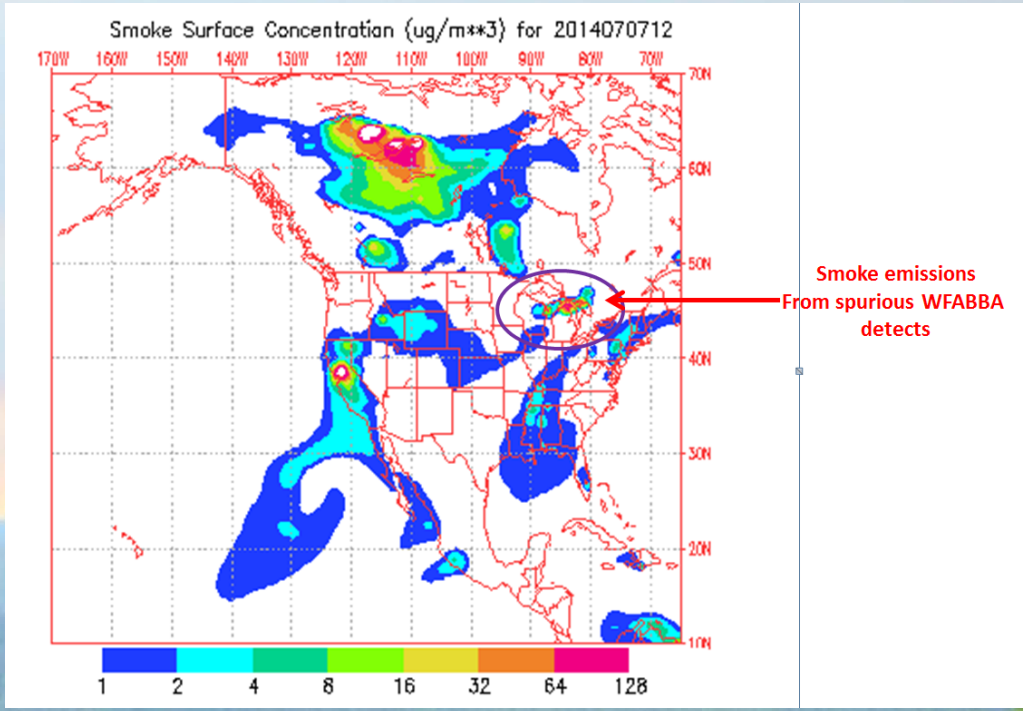
Update: False Alarm Removal for Operational FLAMBE

- Bottom Line Up Front:
  - GOES WF_ABBA showed significant false detections in summer 2014
  - Glint problems at high angles appear to be the culprit
    - The real problem is certainly more complex
  - Additional Glint filter was implemented in FLAMBE
  - Artifactual fires removed

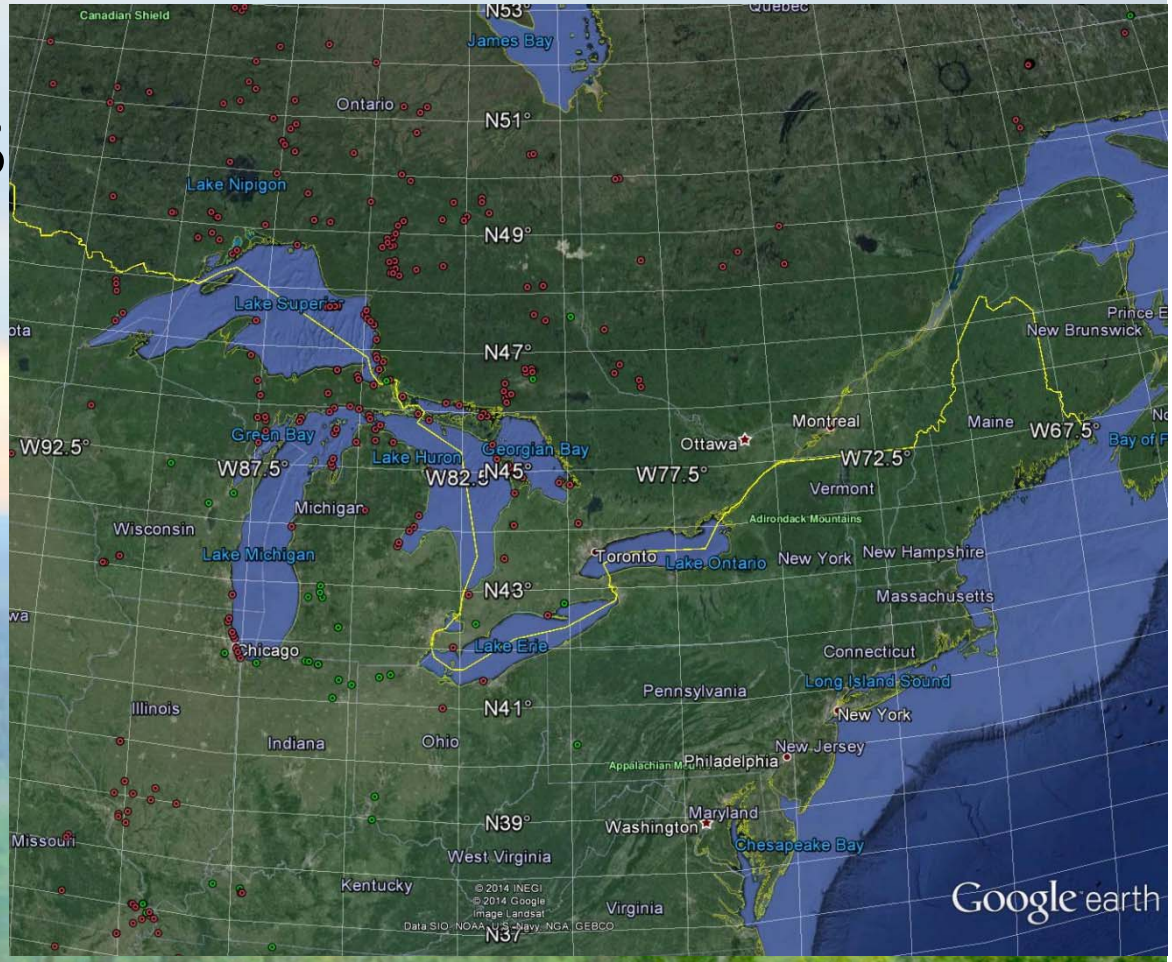
Update: False Alarm Problem in operational FLAMBE

- Early in July 2014, we noticed spurious smoke emissions near the US Great Lakes



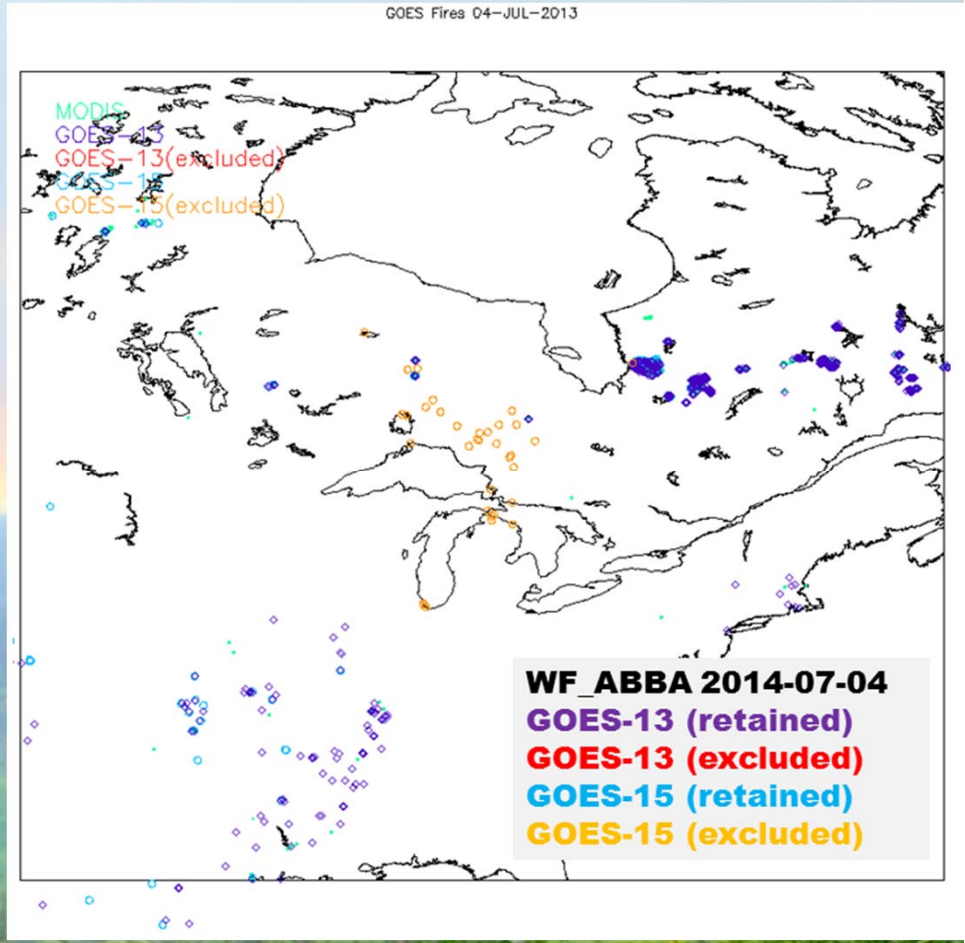
Diagnosis of fire detect false alarms

- Operational FLAMBE uses GOES WF_ABBA fire fires in N. America (and S. America)
- Clustering of fires along lakeshore indicates a problem



Filtering to exclude potential false alarms

- WF_ABBA already has a glint exclusion
- Applies only to pixels mapped near water
- Broader application of glint mask at high scan angles resolves false alarms
- Empirically determined we should filter pixels with scan angle >67 and glint angle <32 degrees



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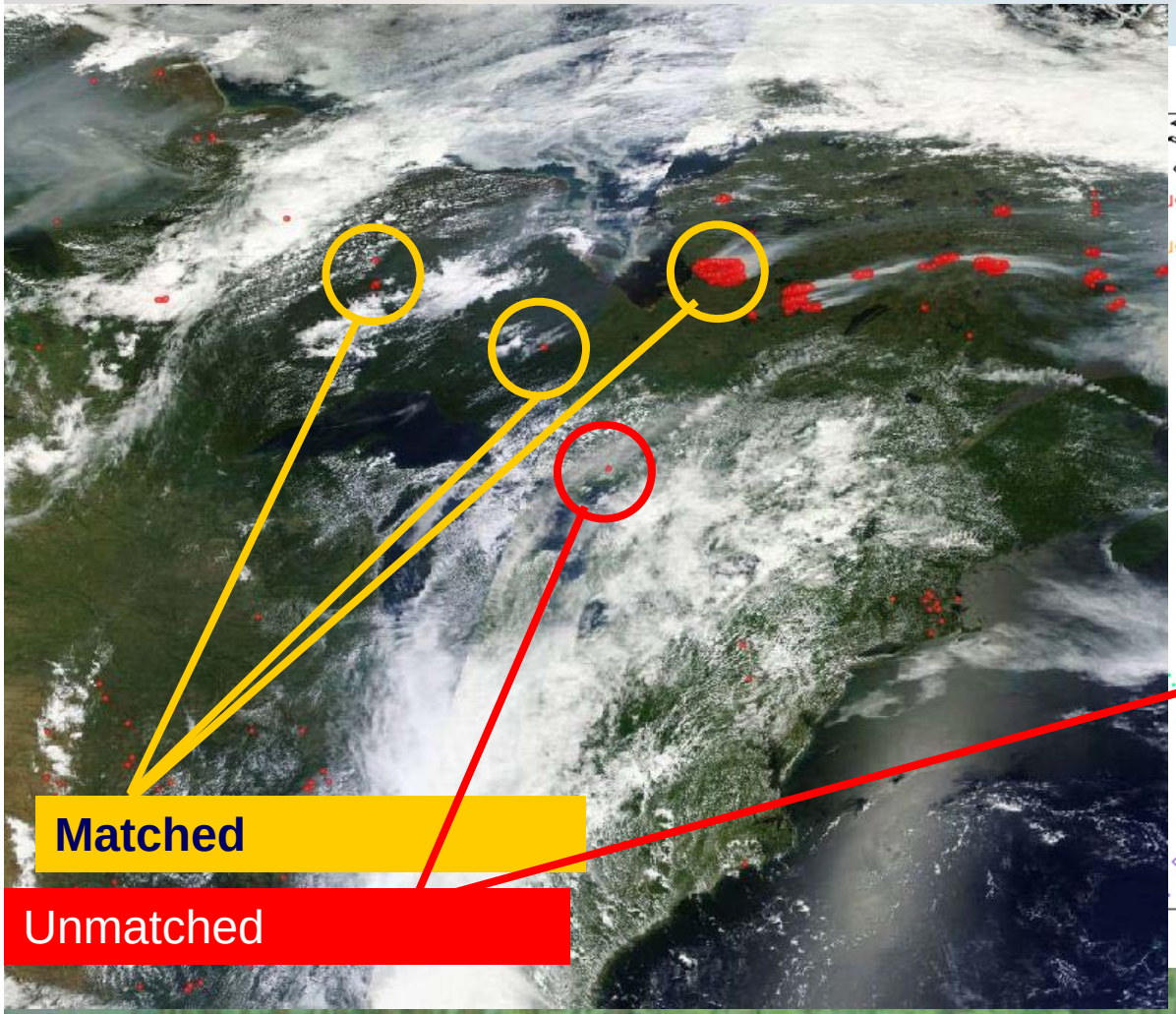
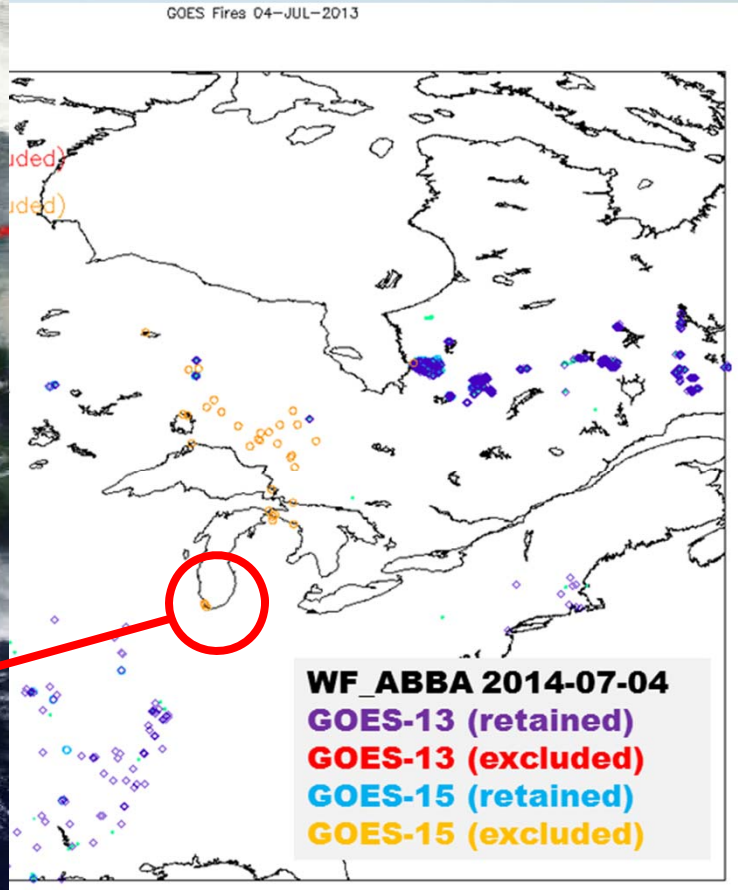
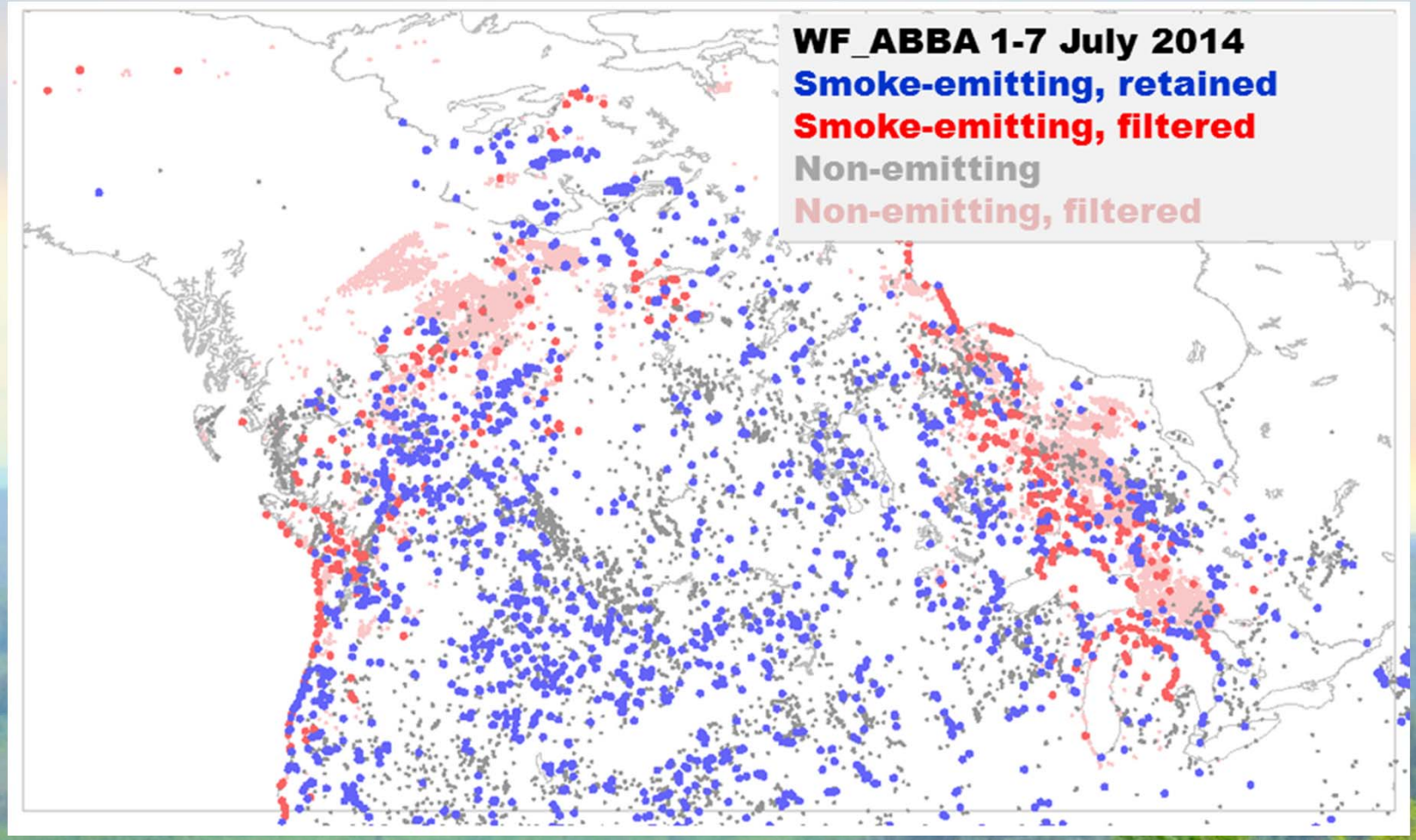




Results of filtering



Filtering applied in operational FLAMBE

- Routines added to FLAMBE perform these functions:
  - Look up the sub-satellite point based on sensor and date;
  - Calculate the solar zenith and azimuth for each WF_ABBA fire detection;
  - Calculate the sensor zenith and azimuth for each WF_ABBA fire detection;
  - Calculate the glint angle from the sun and sensor angles;
  - Filter the WF_ABBA detections based on the glint thresholds described above.
- Patched FLAMBE code handed off to FNMOC in early August– now operational

Thanks!