Biomass Burning Observations for Aerosol Forecasting

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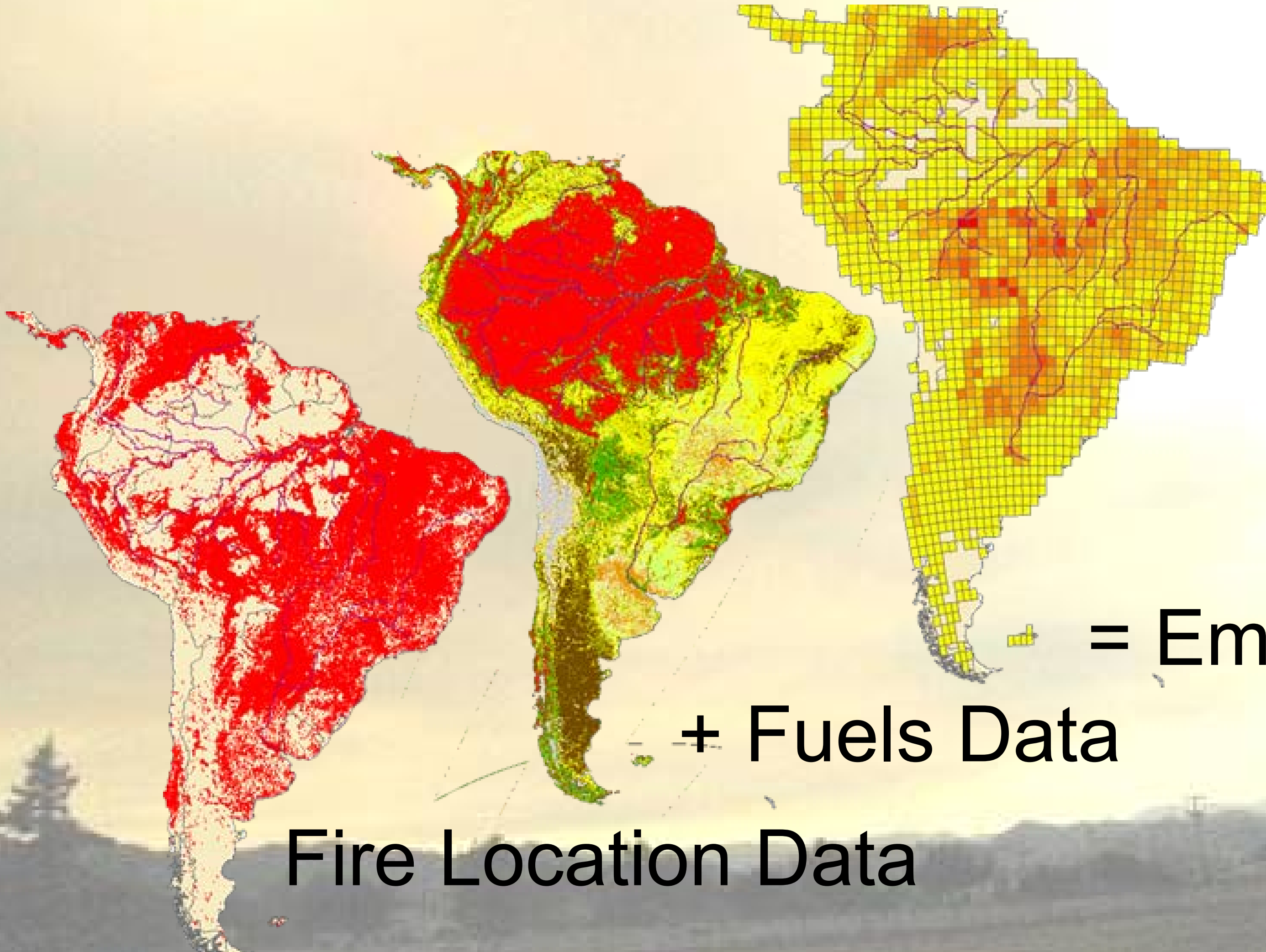
Outline

1. Context: Role of estimated smoke emissions in an aerosol forecast model
2. Data Requirements for Fire Observations
3. Challenges of Multi-Sensor Integration
    1. Fire Sensor Constellation– present + future
    2. Specific challenges with Polar Orbiter Data
    3. Strategy for Sensor Normalization

The Heart of the Process



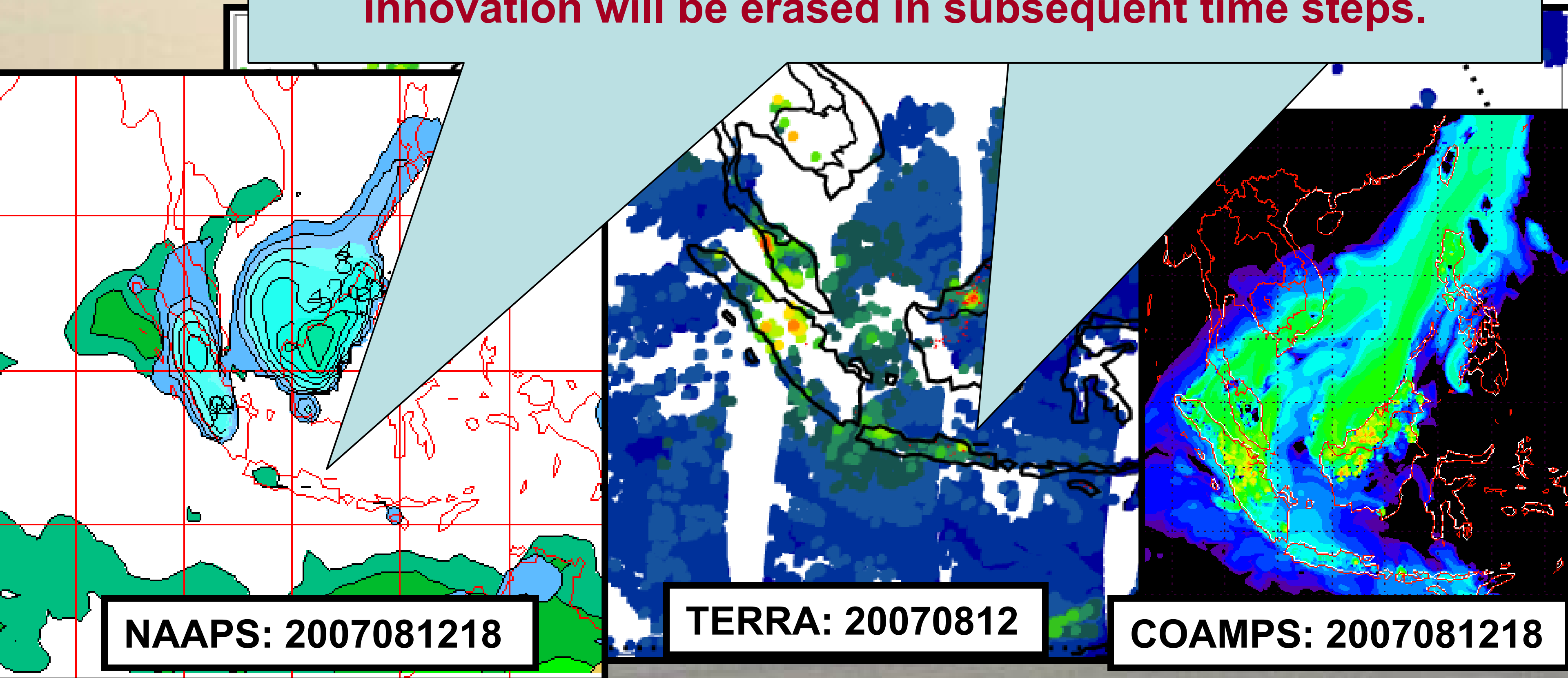
= Emissions

+ Fuels Data

Fire Location Data

Smoke sources in Aerosol Forecasting: If you miss the source, DA helps little.

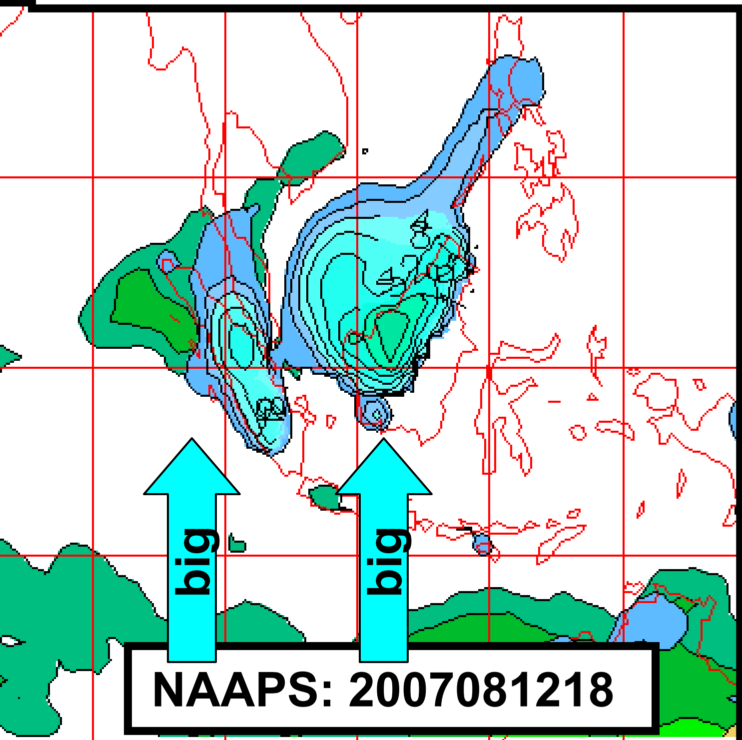
4. When sources are missed by fwd. model, data assimilation will improve instantaneous analysis, but innovation will be erased in subsequent time steps.

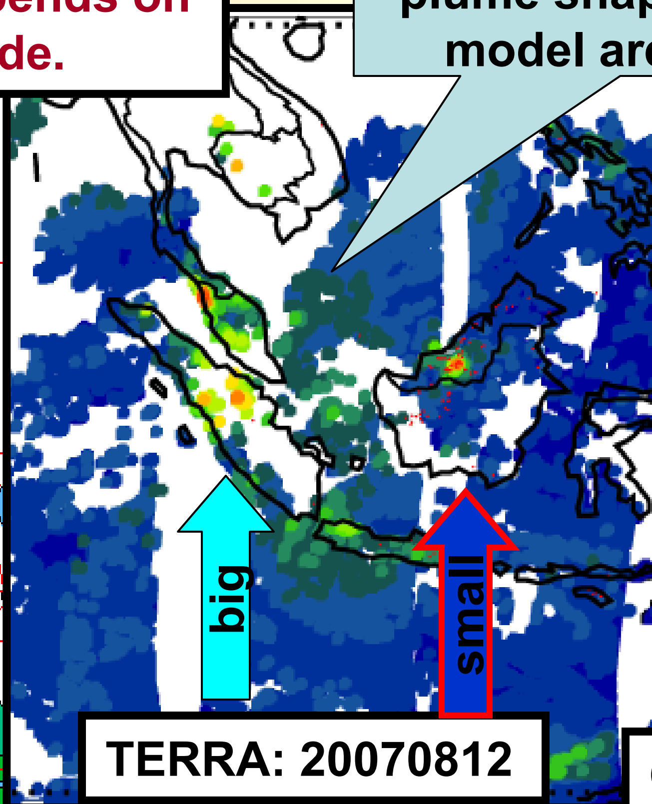


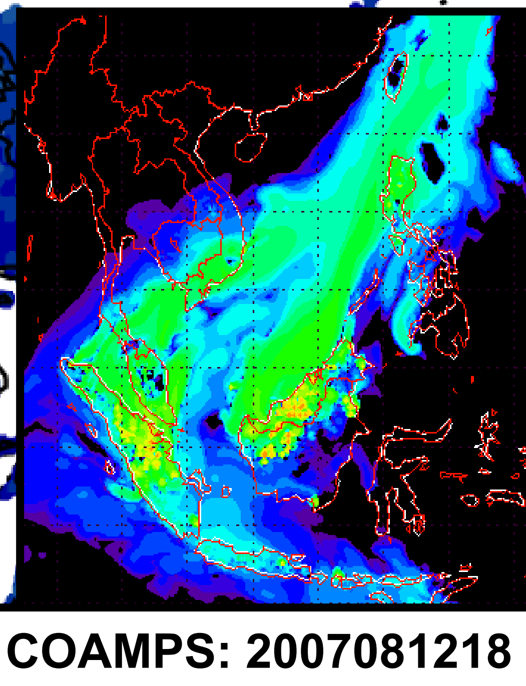
Smoke From Multiple Sources: Demands More from Forward Model

5. Effect of DA in complex transport scenarios (common at mesoscale) depends on plume shape depends on source *relative* magnitude.

DA here will produce mixed results, because plume shapes from fwd. model are incorrect.







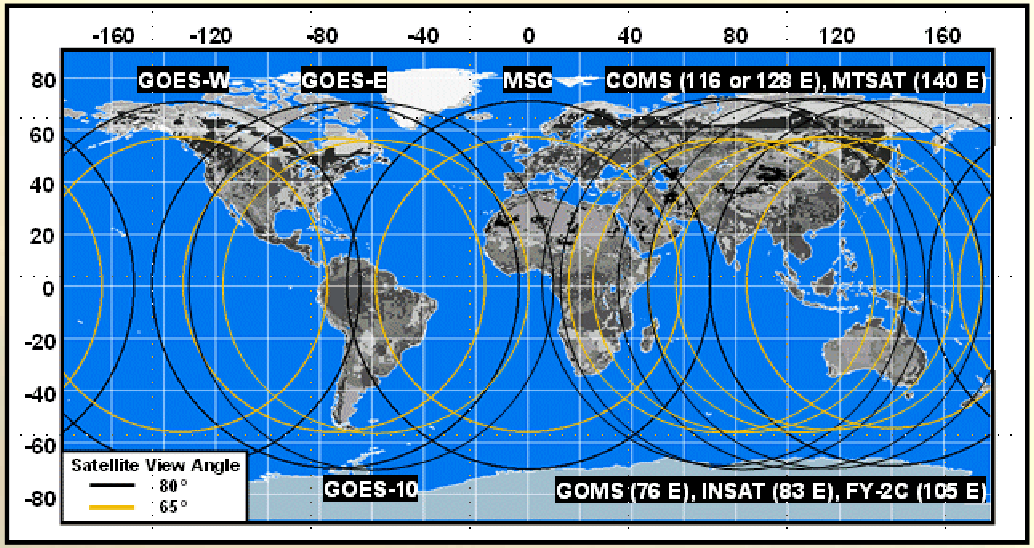
With Data Assimilation, what must the Forward Model Do?

1. Do not miss fire events!
2. Get injection right
3. Get fire timing right
4. Separate "high-emission" and "low-emission" events
5. Use DA systems to provide feedback to emission models
    1. ***Directly*: use innovations to modify source terms at each timestep**
    2. ***Indirectly:* use DA to test emission hypotheses**

Information Requirements

- Latency of Data
  - Faster is better
  - for GEO, should be within one hour
  - for LEO, less strict
    - requires diurnal interpolation
- Data delivered
  - Fire detections
    - location + timing
    - view conditions
  - Satellite Scan pattern
    - scanned
    - not scanned
    - no detection possible
  - Ancillary
- Resolution Requirements
  - Location of Fires (Spatial Resolution)
    - For atmospheric purposes: ~10km
    - For fuels mapping: ~100m
      - Current data sources do not achieve this
      - Ergo, fire location information is incomplete
  - Timing of Fires
    - Hourly
  - Intensity of Fires
    - This is a subpixel property
    - Current products provide information, but application poses challenges

The Global Geostationary Fire Detection Constellation



Global Geostationary Active Fire Monitoring Capabilities *(from Elaine Prins, Wisconsin CIMSS)*

Satellite View Angle
80°
65°

In FLAMBE
At NRL
Not Yet Avail.

Satellite	Active Fire Spectral Bands	Resolution IGFOV (km)	SSR (km)	Full Disk Coverage	3.9 µm Saturation Temperature (K)	Minimum Fire Size at Equator (at 750 K) (hectares)
GOES-E/-W Imager (75ºW / 135ºW)	1 visible 3.9 and 10.7 µm	1.0 4.0	0.57 2.3	3 hours (30 min NHE and SHE)	>335 K (G-11) >335 K (G-12)	0.15
GOES-10 Imager (60ºW) (Cease operation December 2009)	1 visible 3.9 and 10.7 µm	1.0 4.0	0.57 2.3	3 hours (Full Disk) 15 min (SA)	~322 K (G-10)	0.15
Met-8/-9 SEVIRI (9.5 ºE, 0º)	1 HRV 2 visible 1.6, 3.9 and 10.8 µm	1.6 4.8 4.8	1.0 3.0 3.0	15 minutes	~335 K	0.22
FY-2C/2D SVISSR (105 ºE / 86.5ºE)	1 visible, 3.75 and 10.8 µm	1.25 5.0		30 minutes	~330 K	
MTSAT-1R JAMI (140ºE) MTSAT-2 (HRIT) (145ºE) Operational 2010	1 visible 3.7 and 10.8 µm	1.0 4.0		1 hour	~320 K (MTSAT-1R) 330 K (MTSAT-2)	0.15
INSAT-3D (83 ºE ?, TBD) (Launch 4th Qtr 2009)	1 vis, 1.6 µm 3.9 and 10.7 µm	1.0 4.0	0.57 2.3	30 minutes	?	
GOMS Elektro-L N1 (76 ºE) (2009) GOMS Elektro-L N2 (14.5 ºE) (2010)	3 visible 1.6, 3.75 and 10.7 µm	1.0 km 4.0 km		30 minutes	?	
COMS (128 ºE) (Launch 4th Qtr 2009)	1 visible 3.9 and 10.7 µm	1.0 km 4.0 km		30 minutes	~350 K	

Fire Detection from Polar Orbiters

- MODIS (used in Navy Operations / FLAMBE)
  - greatest sensitivity of all current sensors
  - highest spatial resolution
  - global coverage, incl. high latitudes
- NPP VIIRS (info. from Louis Giglio, SSAI)
  - higher spatial resolution
  - slightly improved coverage
  - saturation issue in Band M15 (10.3-11.3μm)
    - expected to saturate for 75% of MODIS-detectable fires
    - on-board aggregation: saturated+unsaturated = ??
    - No pre-launch characterization of sensor above Tsat
  - Best case: equal or better detection, no characterization
    - A big step up from AVHRR, a step back from MODIS
- Others: AATSR, TRMM VIRS (not used for NRT for now)

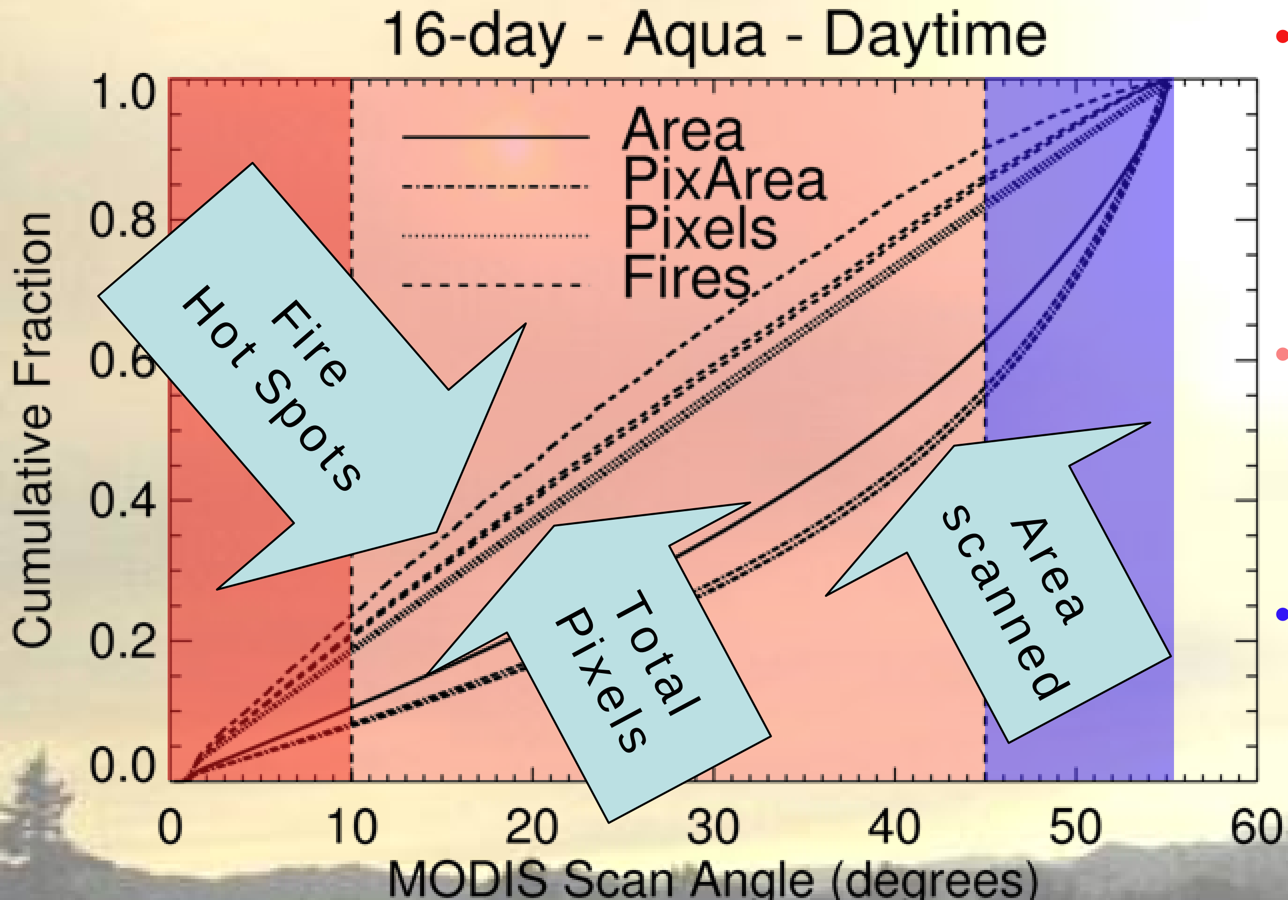
Multi-Sensor Integration

- Relevant sensor characteristics
  - scan pattern
  - sensitivity
  - detection conditions (saturation, etc.)
- These must be modeled to describe differences between sensors
- Sensor outputs can then be normalized
- Ideal Normalization Metric: *Fire Radiative Energy Surplus per area scanned*

Factors Affecting Detection

- Fire Properties
  - Size
  - Temperature
  - Shape
- Sensor Properties
  - resolution
  - radiometric precision
  - saturation level
- Detection Conditions
  - view angle
  - background T
  - surface properties
- Diurnal Cycle

What does MODIS detection look like across the scan?



- **Left zone = nadir**
  - **15% of MODIS pixels**
  - **8% of pixel area**
  - **~20% of fires**
- **Center = mid-scan**
  - **65% of pixels**
  - **48% of pixel area**
  - **~65% of fires**
- **Right = scan edge**
  - **20% of pixels**
  - **45% of pixel area**
  - **~15% of fires**

THESE ARE DIFFERENT SENSORS w/r/t detection

Challenges: LEO sensors

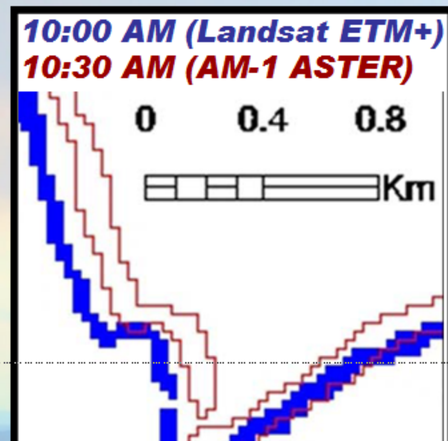
- Wide range of scan angles
- Low Spatial Repeat Frequency
  - Requires external input of diurnal cycle
- Complex scan pattern
  - 16-day orbital repeat cycle
  - Daily coverage with high scan angles
  - Nominal overpass time ≠ actual
- **However, higher resolution == greater sensitivity**

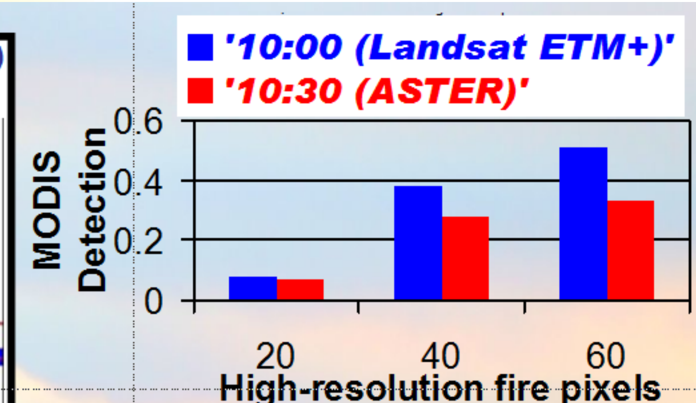
Challenges: Sensor Comparison

- Fire is a highly variable signal
  - 30 minutes is a long time

Nominal overpass time ≠ center of scan

Scan Angle and Overpass Time Interact to Determine Detection Efficiency

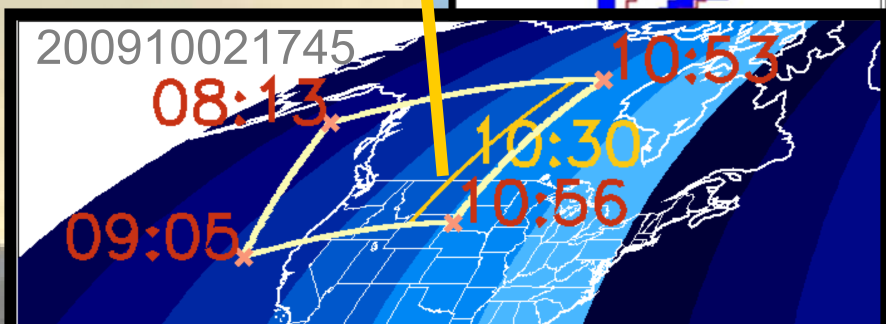




Csiszar and Schroeder, JSTARS 2008

- Fire fronts have significant movement across landscape in 30 minutes
- Fire activity at 1030 local is substantially (~20-40%) greater than at 1000

Scan angle and overpass time interact to determine detection efficiency



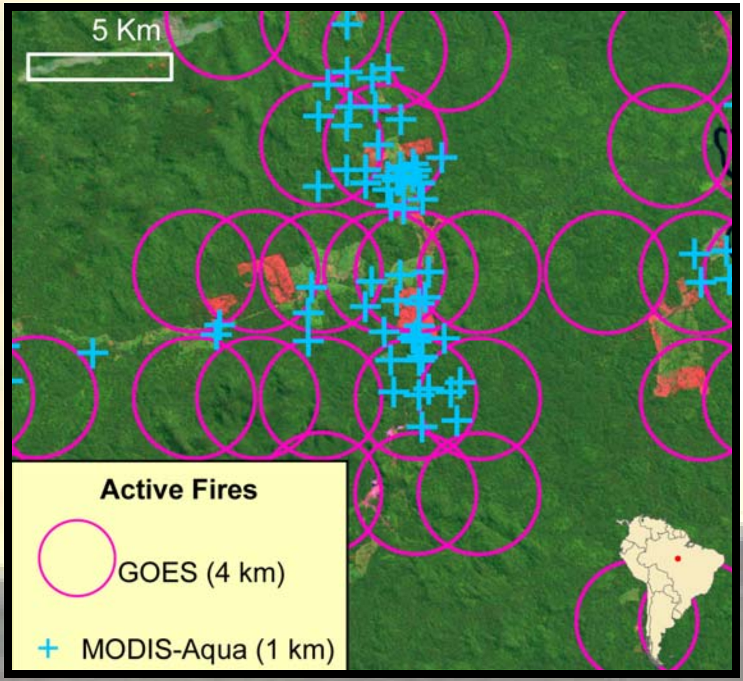
Challenges: Sensor Comparison

- Fire is a highly variable signal
  - 30 minutes is a long time
  - 1500m is a big jump

•Spatial resolution of sensors does not allow 100% attribution of fuels in mixed landscapes

•Systematic bias because fires are not evenly distributed spatially (Hyer and Reid, GRL 2009)

•Random error that disrupts spatial/temporal pattern of emissions



Challenges: Sensor Comparison

- Fire is a highly variable signal
  - 30 minutes is a long time
  - 1500m is a big jump
- Fire is largely a subpixel phenomenon
  - resolution of obs. is critical
  - satellite-to-ground fire attribution will fail in all but the simplest situations
  - In most cases, satellite sees “fire activity,” not “fires”
- Normalization between sensors:
  - is necessarily statistical
  - requires large datasets to compare

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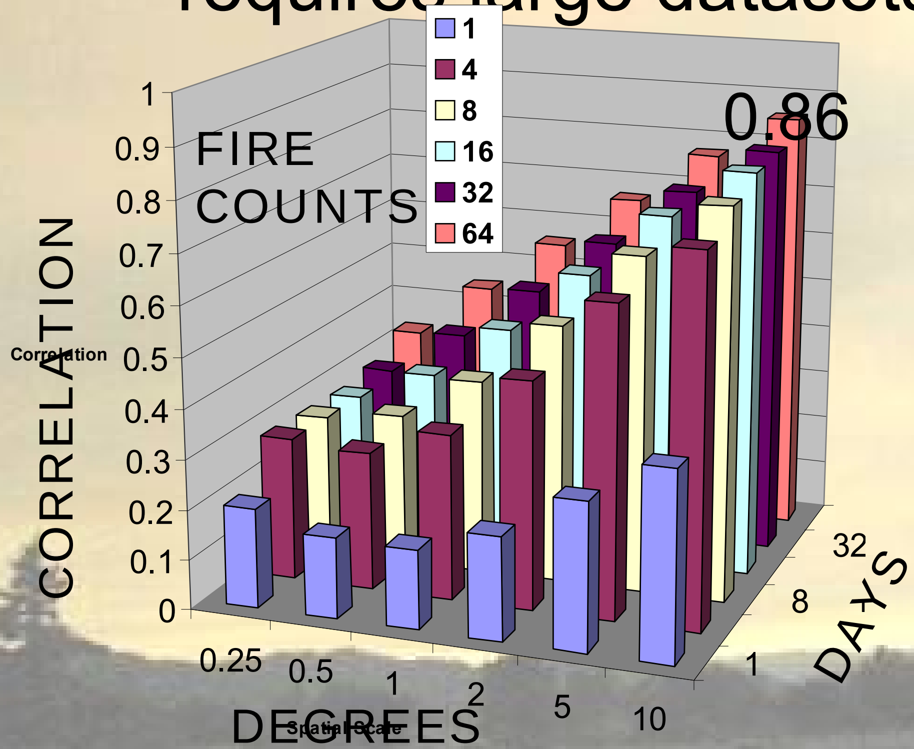

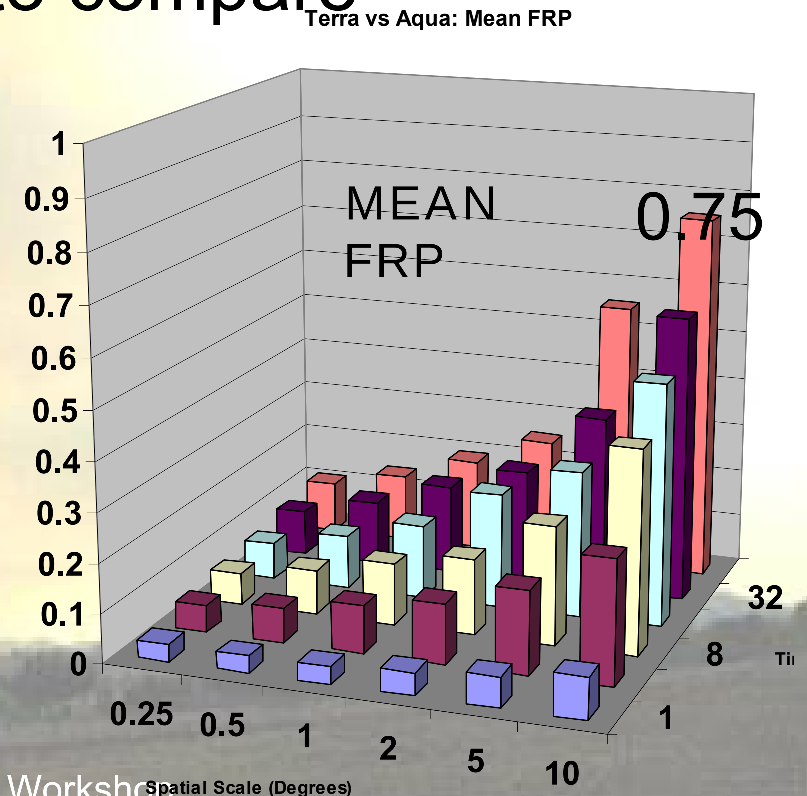

Thanks!

- WF_ABBA team at CIMSS
  - Chris Schmidt & Elaine Prins
- MODIS Fire Team
  - Louis Giglio, SSAI
- FLAMBE team at NRL

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