A spatially and temporally consistent smoke emissions from polar and geostationary satellite observations

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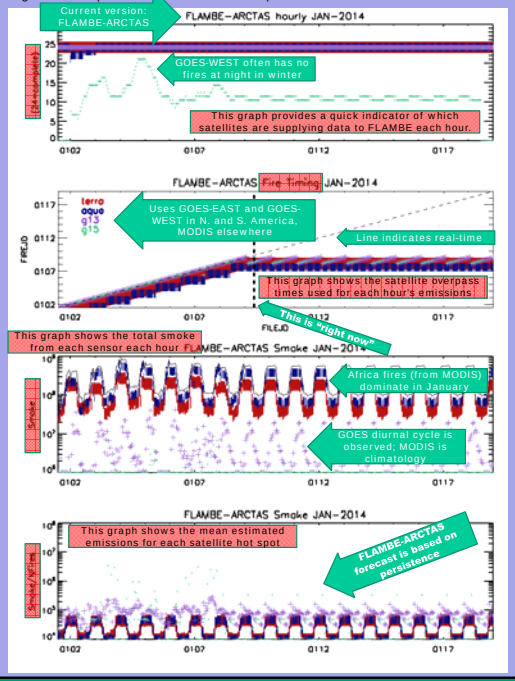
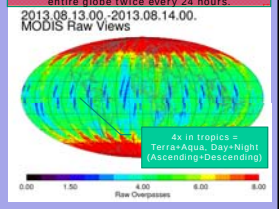
1. FLAMBE: Globally consistent smoke emissions for aerosol modeling

The Fire Locating and Monitoring of Burning Emissions (FLAMBE) system ingests satellite fire detections in near real time and produces global hourly estimates of smoke emissions from open biomass burning. The FLAMBE hourly emissions are publicly available from NRL. This is an example of the diagnostic output used to monitor the operational FLAMBE model.

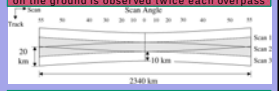


2. MODIS Coverage Correction

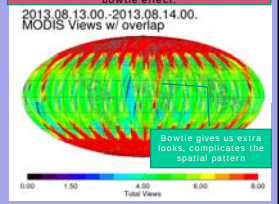
1) Each MODIS instrument views nearly the entire globe twice every 24 hours.



A) At the edge of the MODIS swath, every point on the ground is observed twice each overpass



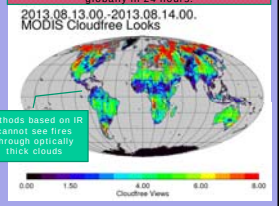
2) MODIS views in 24 hours accounting for bowtie effect.



B1) Not everywhere is suitable for MODIS fire detection: oceans, coastlines, inland water, ice, and urban areas are excluded.

B2) Opaque clouds also obstruct the infrared signal used by MODIS for fire detection.

3) MODIS opportunities for fire detection globally in 24 hours.



All plots based on MODIS MOD14 and MOD03 data

3. Correction for MODIS Detection Efficiency

C1) At the edge of the MODIS swath, the integrating area of each 1km pixel is roughly 8x larger than at the scan center.

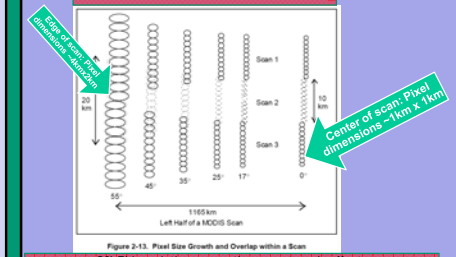
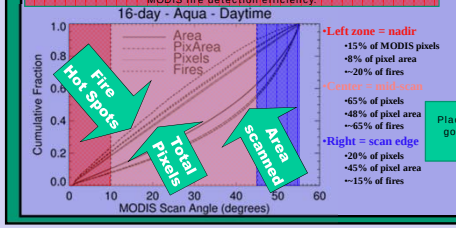
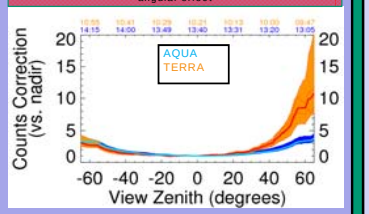


Figure 2-13. Pixel Size Growth and Overlap within a Scan

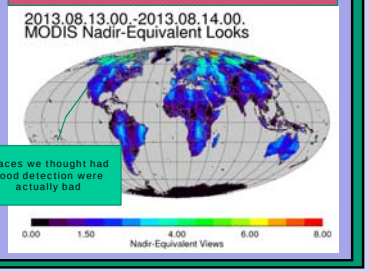
C2) This variation across the scan strongly affects MODIS fire detection efficiency.



C3) We can construct a robust empirical correction for this angular effect

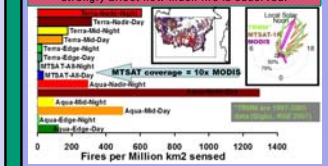


4) We apply this correction to calculate 'nadir-equivalent looks' we can use to normalize MODIS



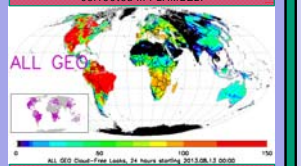
4. Calculation of Diurnal Cycle

D1) MODIS detections occur at different times. Open biomass burning has a sharp diurnal gradient, meaning that the timing of an observation will strongly affect how much fire is observed.

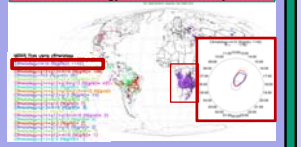


D2) *Giglio* (RSE 2007) used TRMM observations from 1997-2005 to calculate diurnal cycles for a set of fire-prone ecosystems. FLAMBE2 uses these diurnal cycles as a basis for normalizing MODIS fire detections over 24 hours.

D3) Observations from geostationary sensors require the same corrections for overpasses and cloud cover that MODIS does. Geostationary observations also have varying sensitivity by view angle, but that is not yet corrected in FLAMBE2.

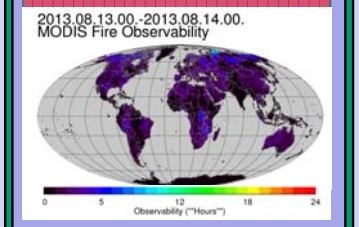


D4) Geostationary observations are combined with climatology to obtain diurnal cycles.



5. MODIS observability

5) By applying all of the corrections in Sections 2-4 to the MODIS data, we can calculate the relationship between the fire observations from MODIS in a given 24 hours with a 'nominal' fire detection system based on hourly looks at 1km resolution. This gives us a metric of fire observability from MODIS.



- Even with two MODIS sensors, observability is far less than the 'nominal' system
- Spatial variability in observability is very high, and explains much of the variation in spatial patterns of daily observed fires
- Observability in many locations is near zero, because of clouds, and because of very limited expected fire activity at night. Simple scaling of observed fires is unlikely to work when observability is this low.

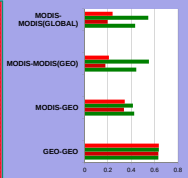
6. FLAMBE2 Development: Next Steps

RIGHT) Angular and coverage correction of MODIS data can dramatically increase spatial and temporal correlations of satellite-derived fire observations.

These results are based on 1-day lag correlations at a resolution of 2 degrees. Correlations with GEO data are calculated only in the Meteosat coverage area.

This suggests that spatial and temporal patterns of emissions are being more accurately captured by using these corrections.

This hypothesis will be tested using the NAAPS and WRF models in the upcoming year.



- Calculation of seasonal time series of fully corrected MODIS
- Cross-calibration of coverage-corrected geostationary data with fully corrected MODIS
- Experimental determination of MODIS/GEO weightings for calculation of a merged product
- Experiments to determine thresholds when persistence of older, better observations is likely to be more accurate than scaling of current observations
- Preparation and testing of near-real-time FLAMBE2.0 polar+geostationary emissions products
- Preparation of archival FLAMBE2 products for retrospective studies
- Development of short-term predictor of fire activity for near-real-time

7. Relevant Papers and Resources

NRL Aerosol webpage: http://www.nrlmry.navy.mil/aerosol_web

Papers about the FLAMBE emissions model:

Reid JS, Hyer EJ, et al. (2009) Global Monitoring and Forecasting of Biomass-Burning Smoke: Description of and Lessons from the Fire Locating and Modeling of Burning Emissions (FLAMBE) Program. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing 2(3), 144-162.

Papers about satellite fire detections:

Hyer EJ, Reid JS, Prins EM, Hoffman JP, Schmidt CC, Miettinen JI, Giglio L (2013) Patterns of fire activity over Indonesia and Malaysia from polar and geostationary satellite observations. Atmospheric Research 122, 504-519.

Miettinen J, Hyer E, Chia AS, Kwoh LK, Liew SC (2013) Detection of vegetation fires and burnt areas by remote sensing in insular Southeast Asian conditions: current status of knowledge and future challenges. International Journal Of Remote Sensing 34(12), 4344-4366.

Peterson D, Wang J (2013) A sub-pixel-based calculation of fire radiative power from MODIS observations: 2. Sensitivity analysis and potential fire weather application. Remote Sensing Of Environment 129, 231-249.

Peterson D, Wang J, Ichoku C, Hyer E, Ambrosia V (2013) A sub-pixel-based calculation of fire radiative power from MODIS observations: 1 Algorithm development and initial assessment. Remote Sensing Of Environment 129, 262-279.

Papers about fire prediction:

Peterson D, Hyer E, Wang J (2013) A short-term predictor of satellite-observed fire activity in the North American boreal forest: Toward improving the prediction of smoke emissions. Atmospheric Environment 71, 304-310.