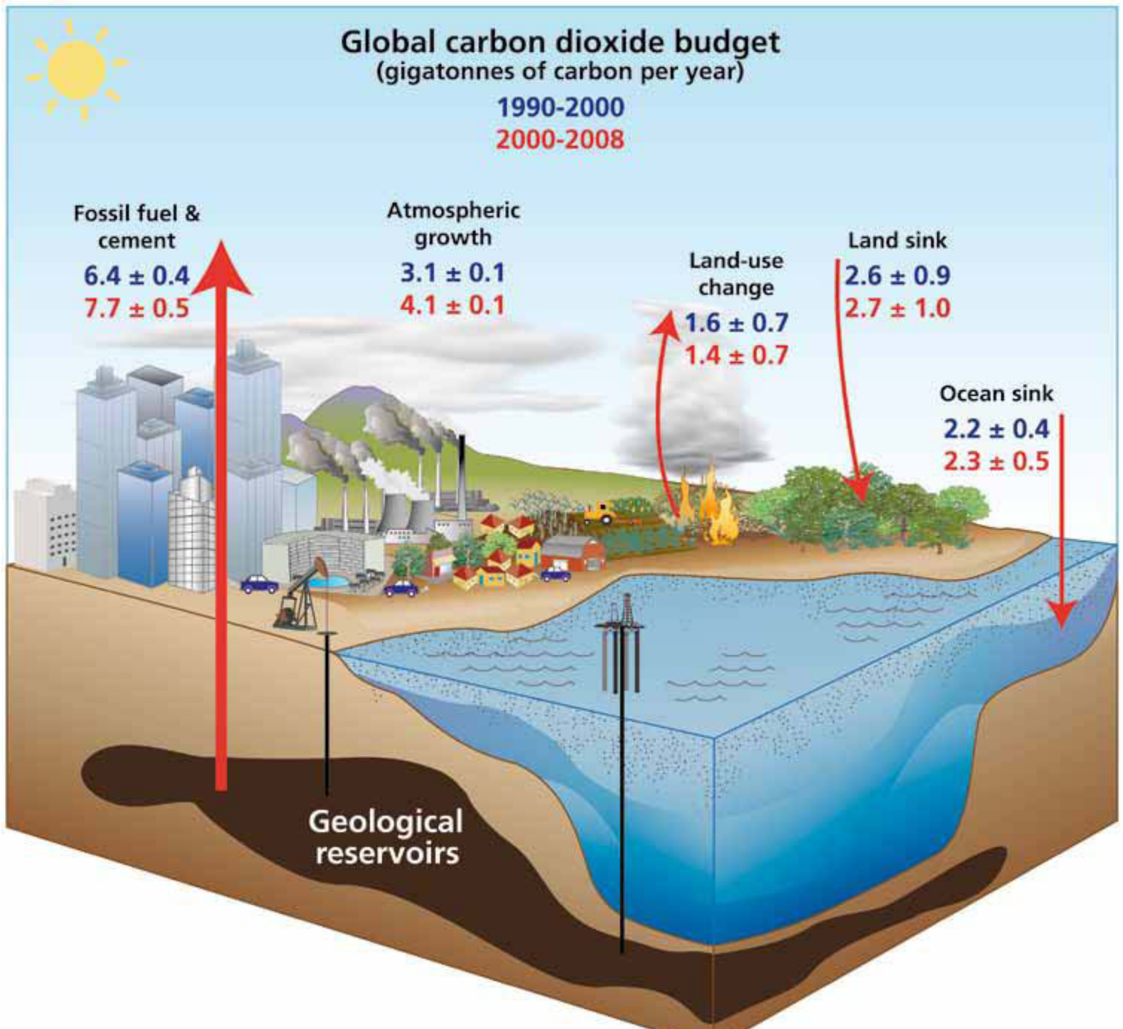
Practical considerations regarding the use of HyspIRI for fire monitoring

Evan Ellicott (University of Maryland)
Louis Giglio (University of Maryland)
Ivan Csiszar (NOAA/NESDIS)
Wilfrid Schroeder (NOAA)
August 24th, 2011

Biomass Burning



Decadal Survey – Thematic Questions

TQ2. Wildfires

- How are global fire regimes changing in response to, and driven by, changing climate, vegetation, and land use practices?
- Is regional and local scale fire frequency changing?
- What is the role of fire in global biogeochemical cycling, particularly trace gas emissions?
- Are there regional feedbacks between fire and climate change?

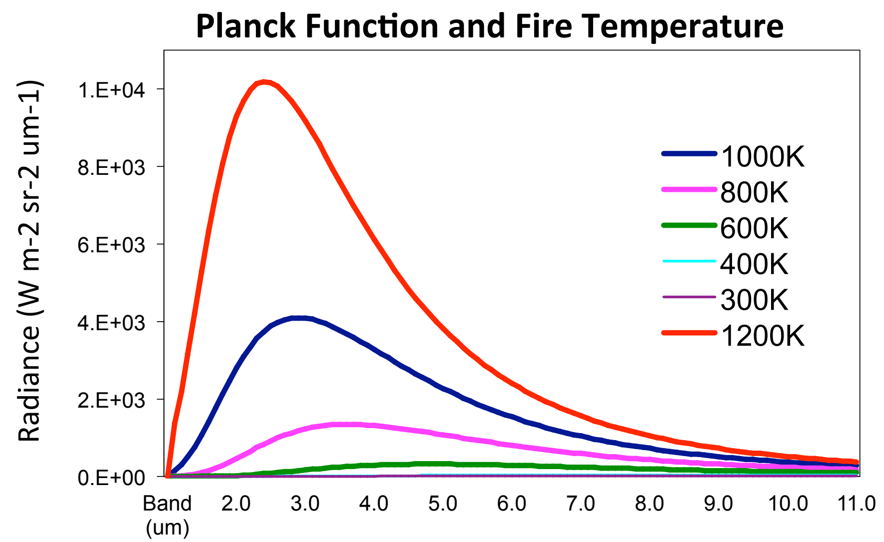
Decadal Survey – Thematic Questions

CQ2. Wildfires

- How does the timing, temperature and frequency of fires affect long-term ecosystem health?
- How does vegetation composition and fire temperature impact trace gas emissions?
- What are the feedbacks between fire temperature and frequency and vegetation composition and recovery?
- How does vegetation composition influence wildfire severity?
- How does invasive vegetation cope with fire in comparison to native species?

Active Fires

- Current detection scheme for coarse resolution polar-orbiting platforms exploits the strong emission response in the MIR (4µm) channel (ideally placed to limited atmospheric perturbation)

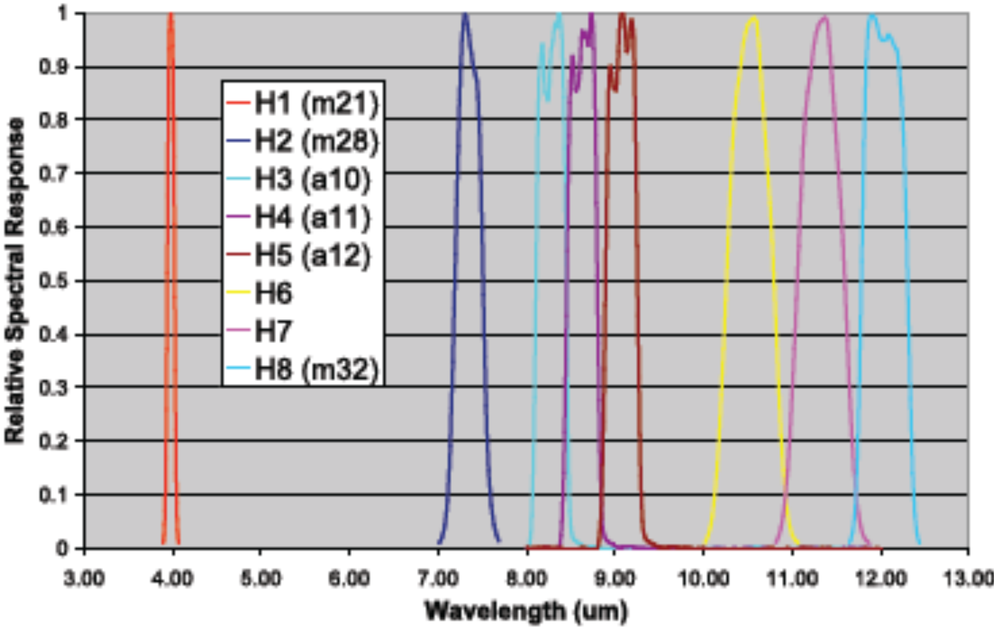


Channel number	Central wavelength (µm)	Purpose
1	0.65	Sun glint and coastal false alarm rejection; cloud masking.
2	0.86	Bright surface, sun glint, and coastal false alarm rejection; cloud masking.
7	2.1	Sun glint and coastal false alarm rejection.
21	4.0	High-range channel for active fire detection.
22	4.0	Low-range channel for active fire detection.
31	11.0	Active fire detection, cloud masking.
32	12.0	Cloud masking.

Benefits

HyspIRI Active Fires

- Measure the land surface temperature and emissivity
- 5 day equatorial revisit to generate monthly, seasonal and annual products.
- 60 m spatial resolution
- 4µm band saturates at 1400K
- 7.5-12 µm bands saturate at 400K



Hyperspectral Fire Detection

- Dennison, P.E., and D.S. Matheson, 2011.
  - Comparison of fire temperature and fractional area modeled from SWIR, MIR, and TIR multispectral and SWIR hyperspectral airborne data. Remote Sensing of Environment, 115, 876-886.
- Dennison, P.E. and D.A. Roberts, 2009.
  - Daytime fire detection using airborne hyperspectral data. Remote Sensing of Environment, 113, 1646-1657.

$$\mathrm{HFDI} = \frac{\left(L_{2.43\,\mu m} - L_{2.06\,\mu m}\right)}{\left(L_{2.43\,\mu m} + L_{2.06\,\mu m}\right)}$$

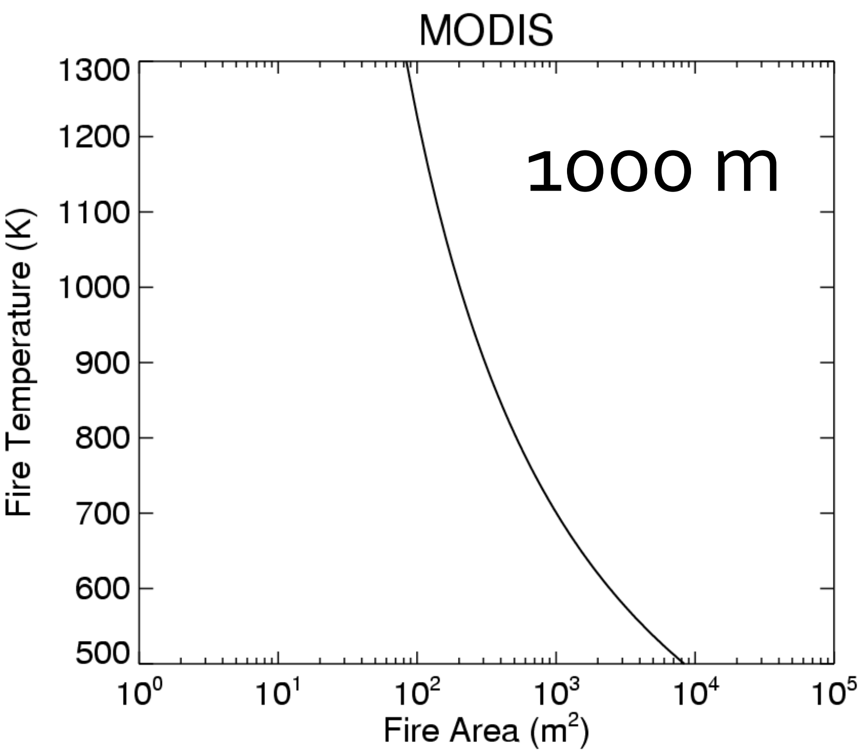
- Dennison, P.E., 2006
  - Fire detection in imaging spectrometer data using atmospheric carbon dioxide absorption. International Journal of Remote Sensing, 27, 3049-3055.

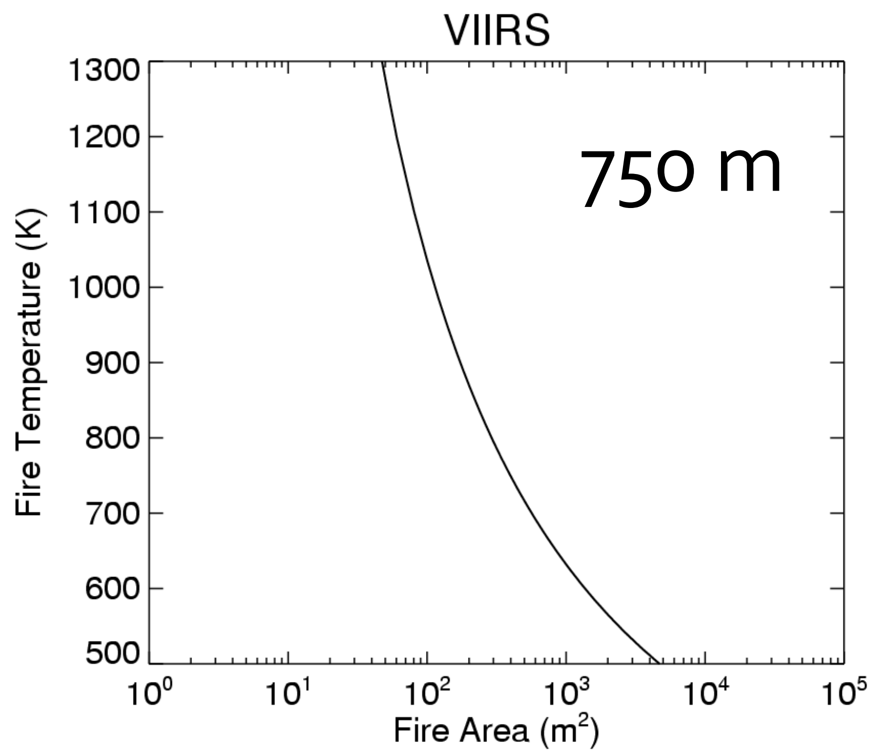
$$CO_2\ \text{Absorp. Index} = \frac{L_{2010}}{0.666 \cdot L_{1990} + 0.334 \cdot L_{2040}}.$$

- Vodacek, A., et al., 2002.
  - Remote optical detection of biomass burning using a potassium emission signature. International Journal of Remote Sensing, 13, 2721–2726.

$$\text{potassium emission index} = \frac{L_{770}}{L_{780}}$$

Detection Envelopes

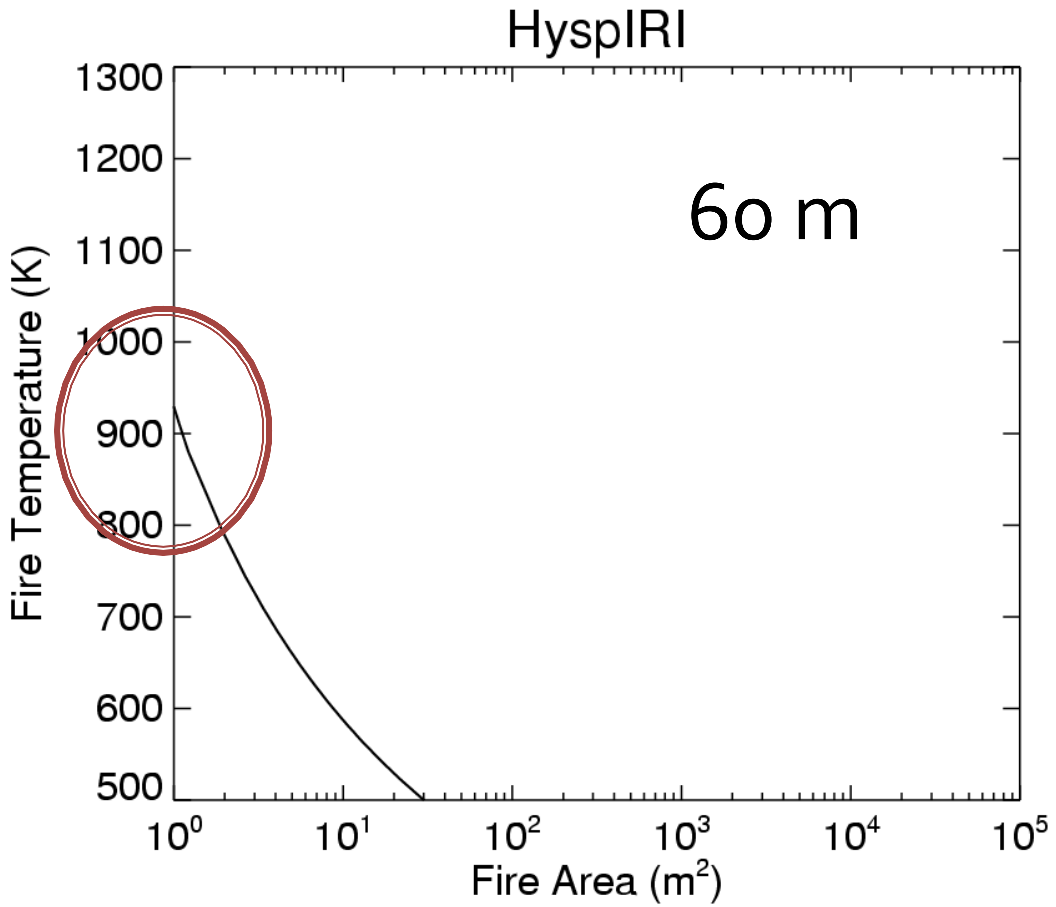




90% probability of detection; boreal forest; nadir view

L. Giglio

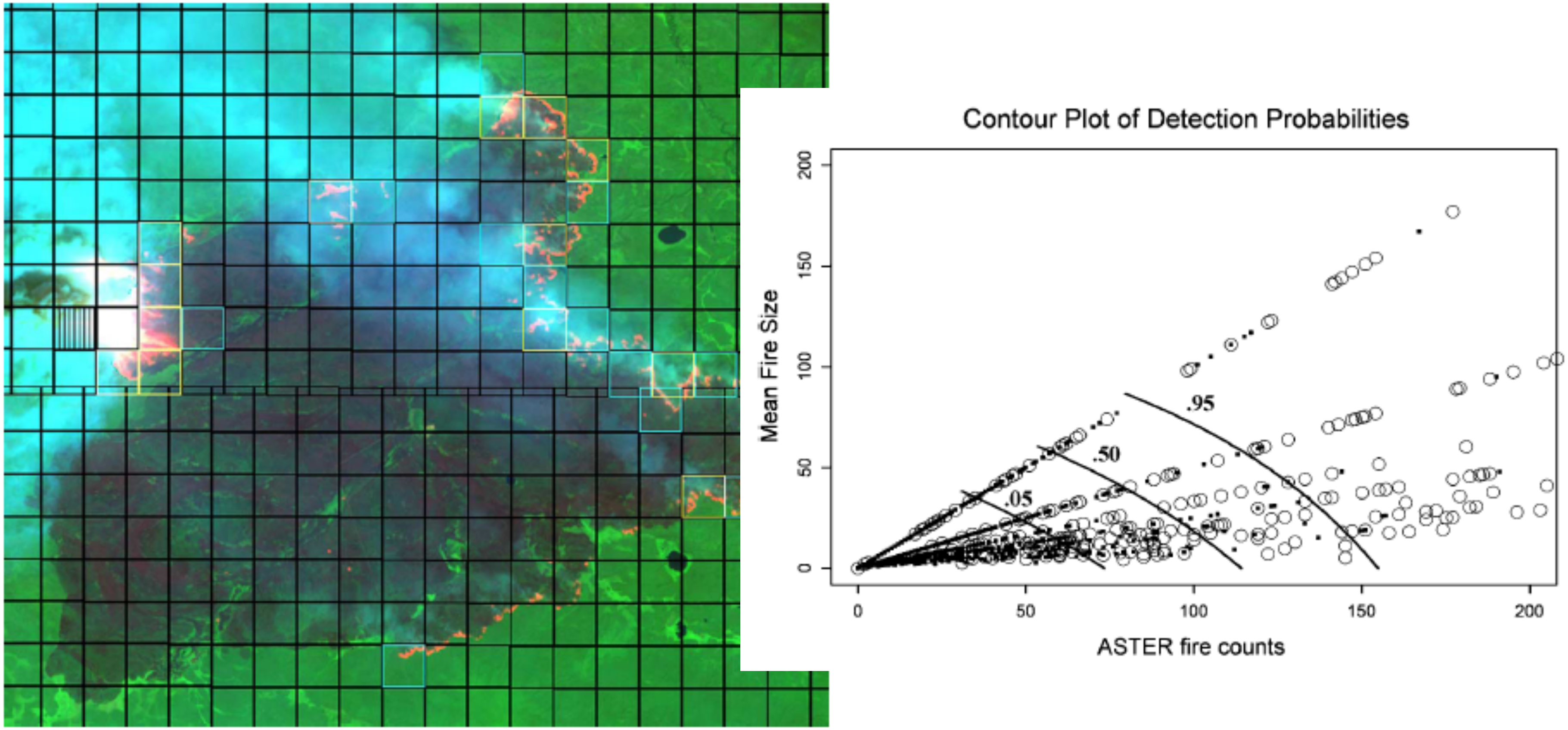
Detection Envelopes



90% probability of detection; boreal forest; nadir view

L. Giglio

Cal/Val



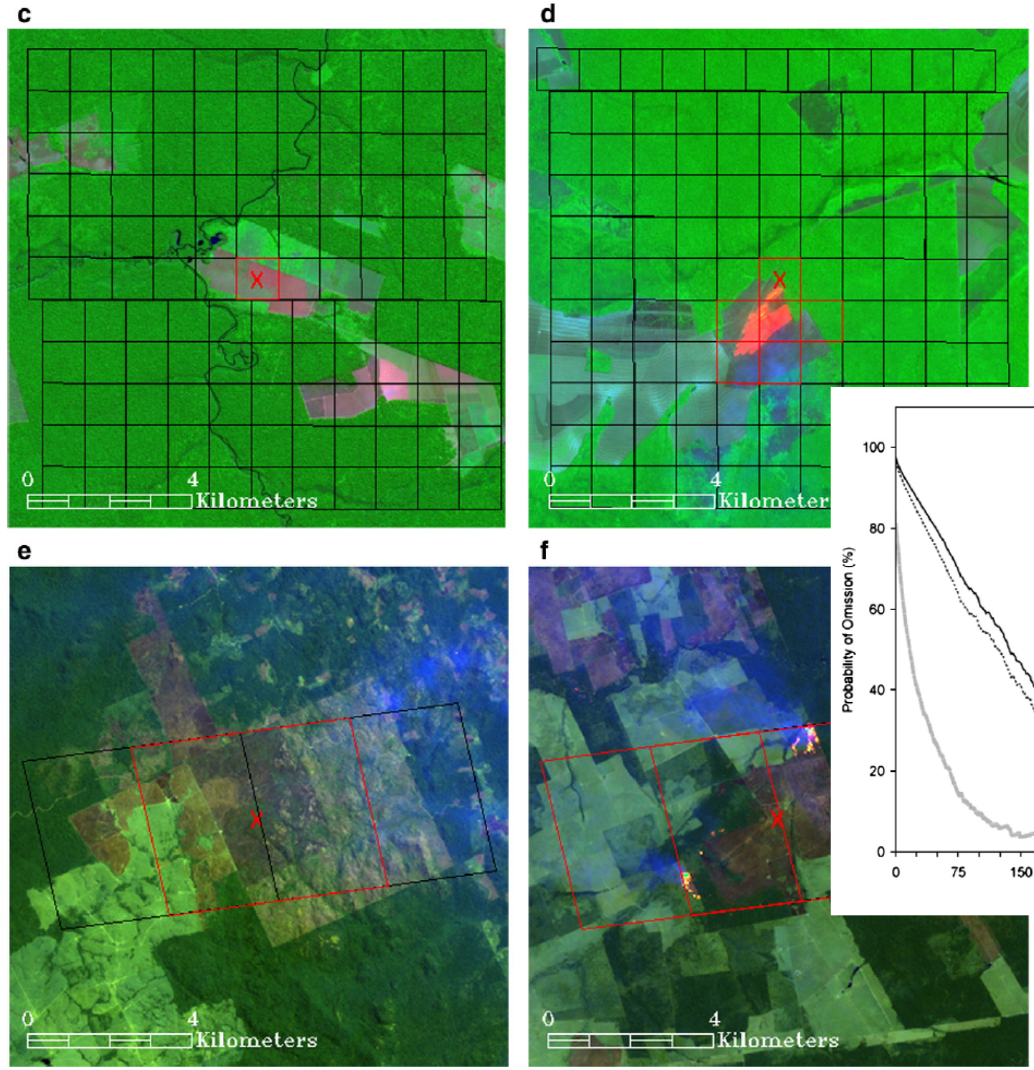
Csiszar et al., 2006

Cal/Val

False Color Composites:
30m ASTER
MOD14:
False (c) and True (d) Detections

30m ETM+
WFABBA
False (e) and True (f) Detections

Schroeder et al., 2008



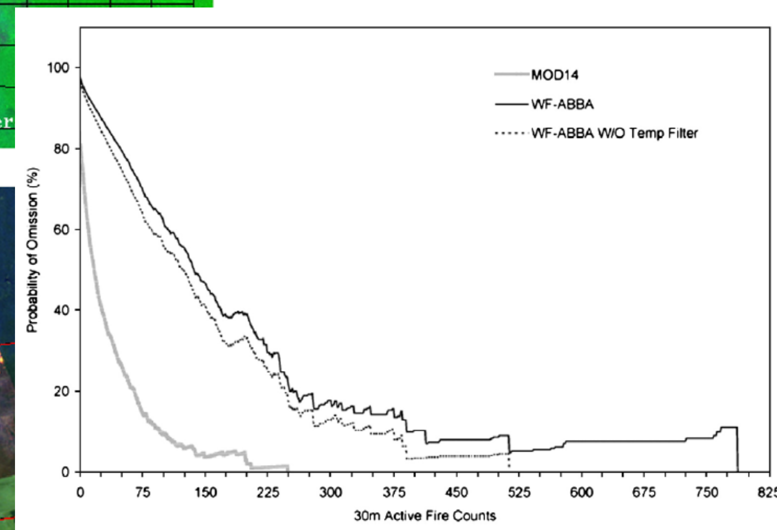


Fig. 11 (*continued*).

Emissions

CO_2 emissions from forest loss

G. R. van der Werf, D. C. Morton, R. S. DeFries, J. G. J. Olivier, P. S. Kasibhatla, R. B. Jackson, G. J. Collatz and J. T. Randerson

Deforestation is the second largest anthropogenic source of carbon dioxide to the atmosphere, after fossil fuel combustion. Following a budget reanalysis, the contribution from deforestation is revised downwards, but tropical peatlands emerge as a notable carbon dioxide source.

"The combined contribution of deforestation, forest degradation and peatland emissions to total anthropogenic CO2 emissions is about 15% (range 8–20%)"

Emissions

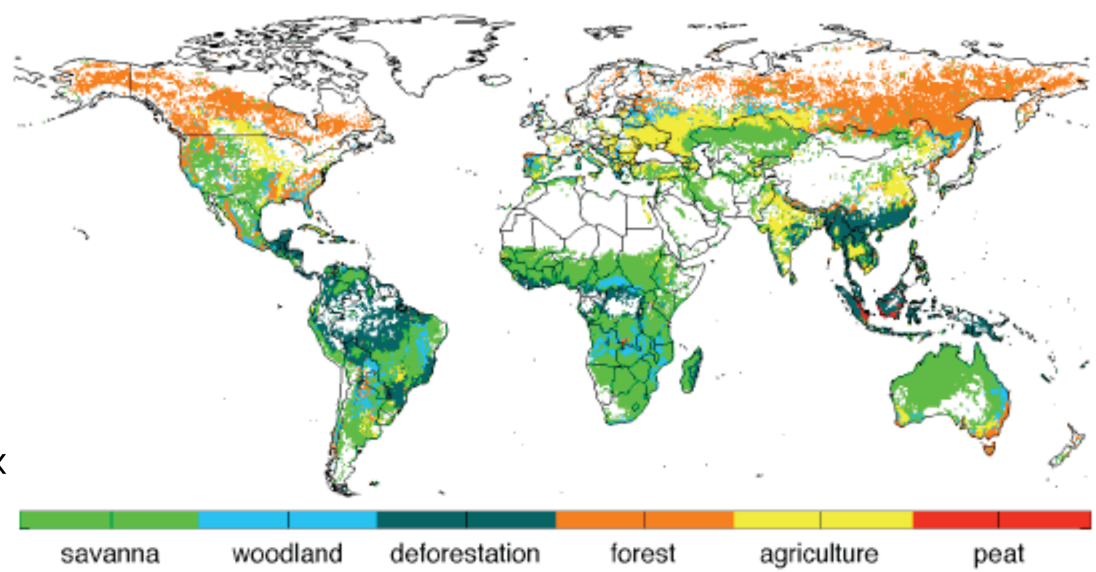
Atmos. Chem. Phys., 10, 11707–11735, 2010
www.atmos-chem-phys.net/10/11707/2010/
doi:10.5194/acp-10-11707-2010

Atmospheric Chemistry and Physics

Global fire emissions and the contribution of deforestation, savanna, forest, agricultural, and peat fires (1997–2009)

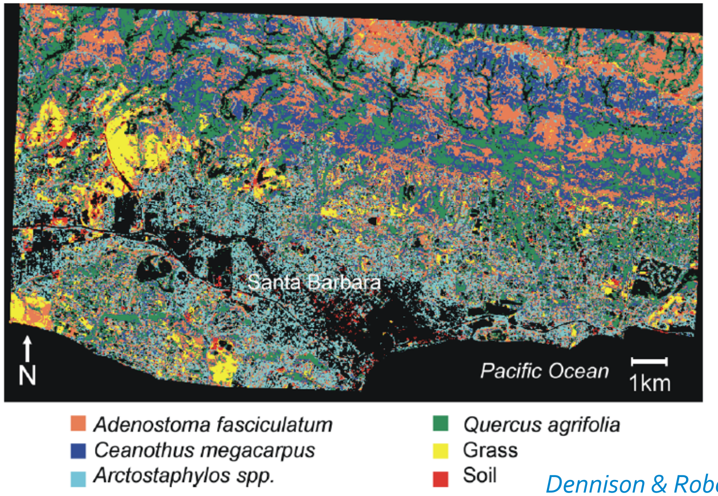
G. R. van der Werf[1], J. T. Randerson[2], L. Giglio[3,4], G. J. Collatz[4], M. Mu[2], P. S. Kasibhatla[5], D. C. Morton[4], R. S. DeFries[6], Y. Jin[2], and T. T. van Leeuwen[1]

"While the sum of deforestation, degradation, and peat fire emissions accounted for about a quarter of total C emissions, for CH_4 these sources were key **contributing to 44% of total CH_4 emissions** of 20 Tg CH_4 $year^{-1}$. This was mostly due to the large EF for CH_4 in **peat areas**, which was 3x as high as the EF for tropical deforestation fires, and almost 10x that of the EF for grassland and savanna fires"

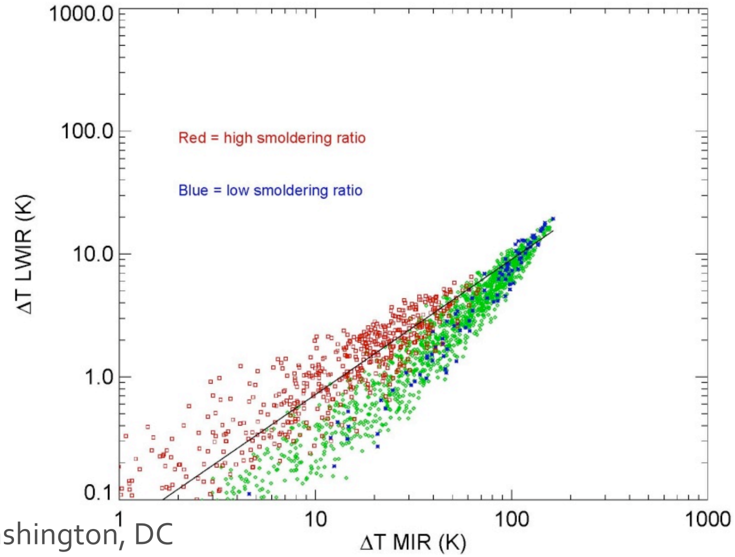


Emissions

- Fuels (type, moisture)
- Inventory (bottom-up) vs. Fire Energy
- Emission factors (related to fuel type) and relationship with temperature
- Combustion completeness
- Flaming : Smoldering ratio

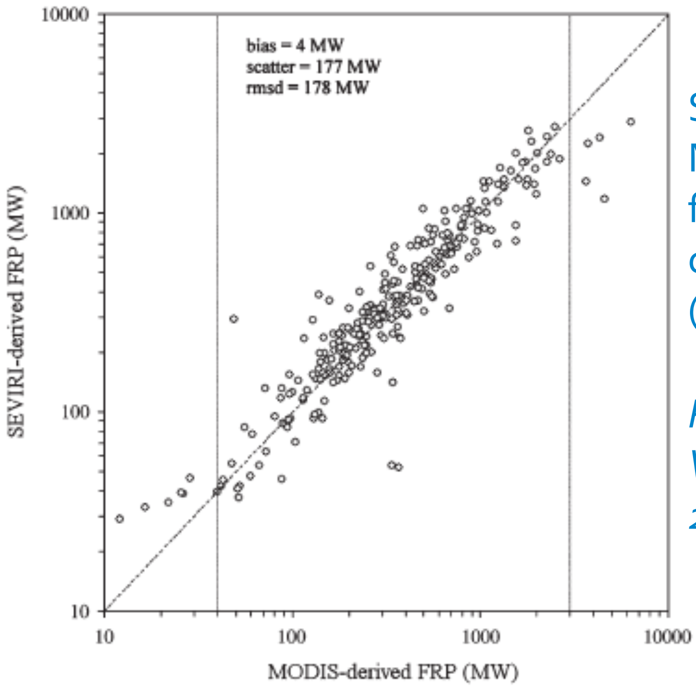


Dennison & Roberts, 2003



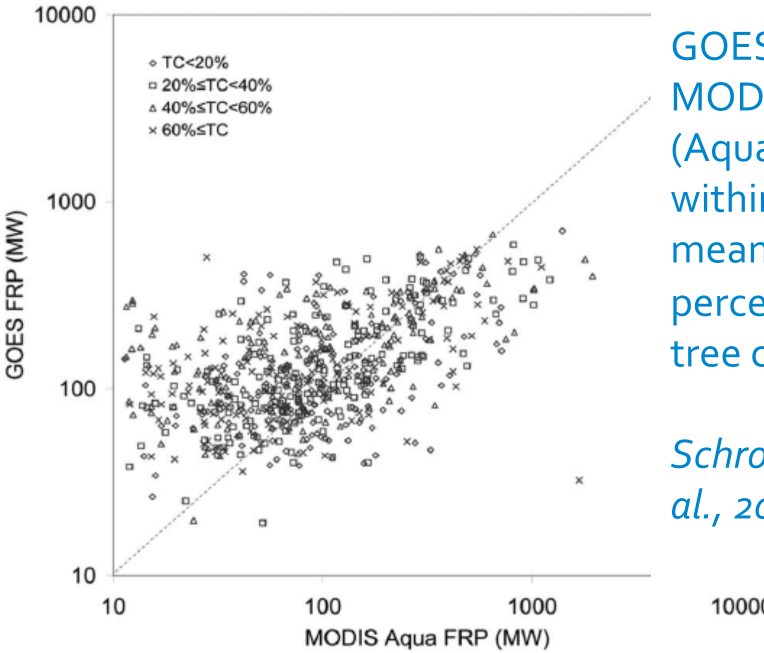
FRP

- Reconcile discrepancies between sensors
  - Errors due to spatial distribution of fires, sensor characteristics (PSF), spatial/temporal resolution



SEVIRI vs. MODIS per-fire FRP comparison (289 "fires").

Roberts & Wooster, 2008



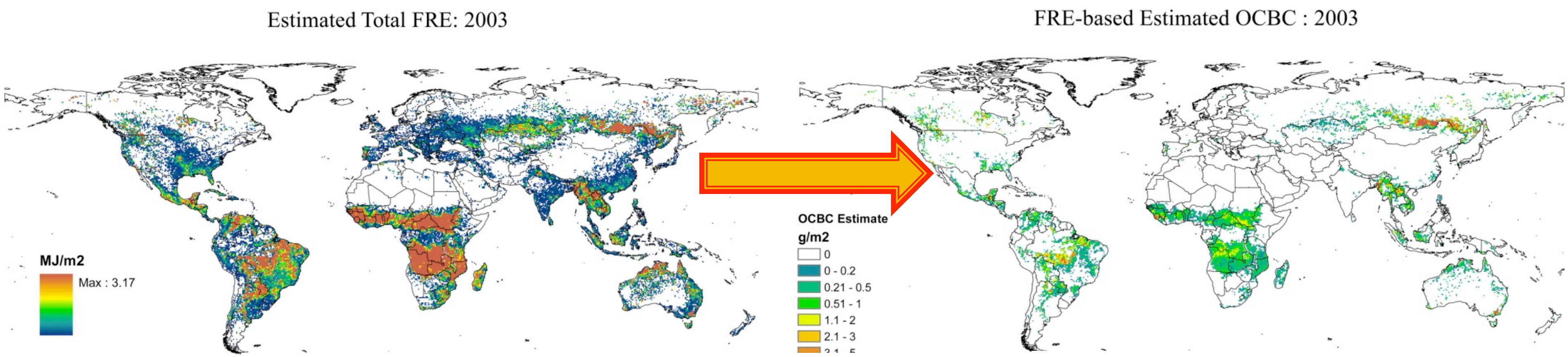
GOES vs. MODIS (Aqua) FRP within varying mean percentage of tree cover

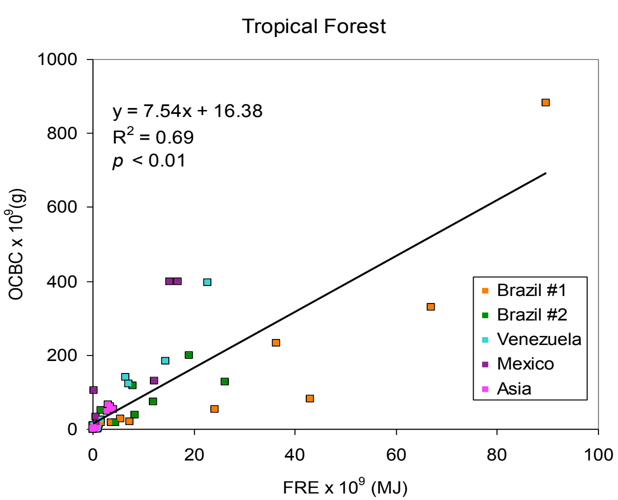
Schroeder et al., 2010

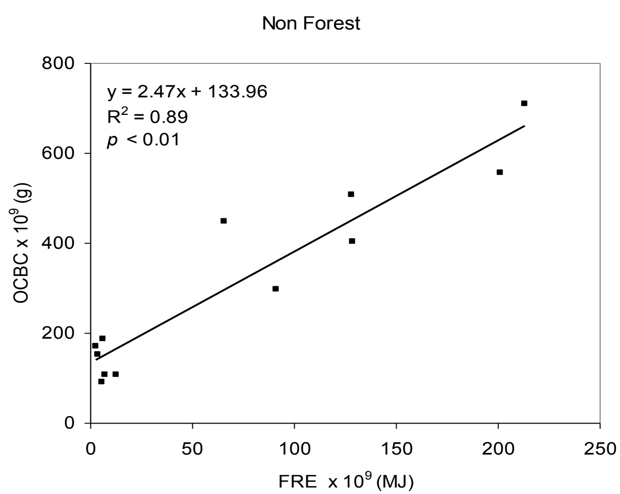
FRP > FRE > Emissions

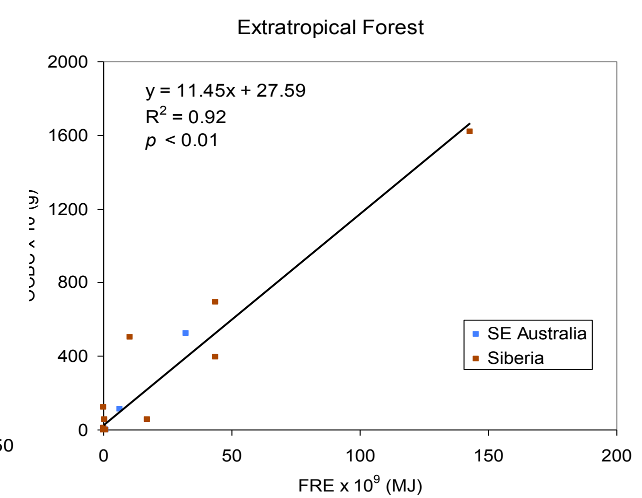
- Fire Radiative Energy

Ellicott et al., 2009; Vermote et al., 2009









Burned Area

- Agriculture fires
  - Till vs. No-Till
  - Till vs. Harvested
  - Harvested vs. Burnt
  - Burnt vs. Till

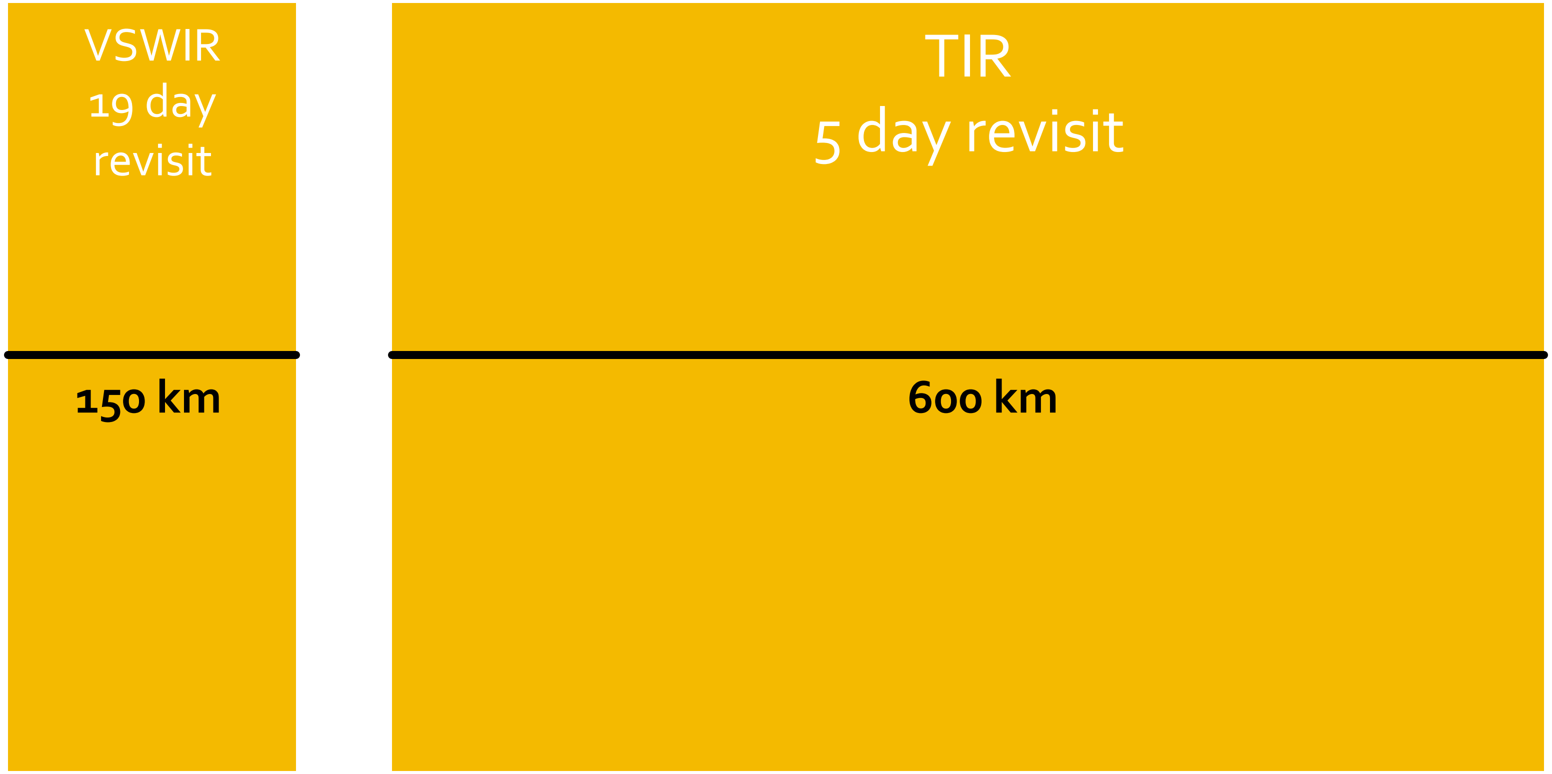
Example of the mosaic of recently burned fields, newly harvested, plowed fields where the spectral resolution of Landsat ETM+ is insufficient for producing an accurate thematic map

Subset of scene 176/26, acquired on 07/25/2001

Courtesy of Luigi Boschetti

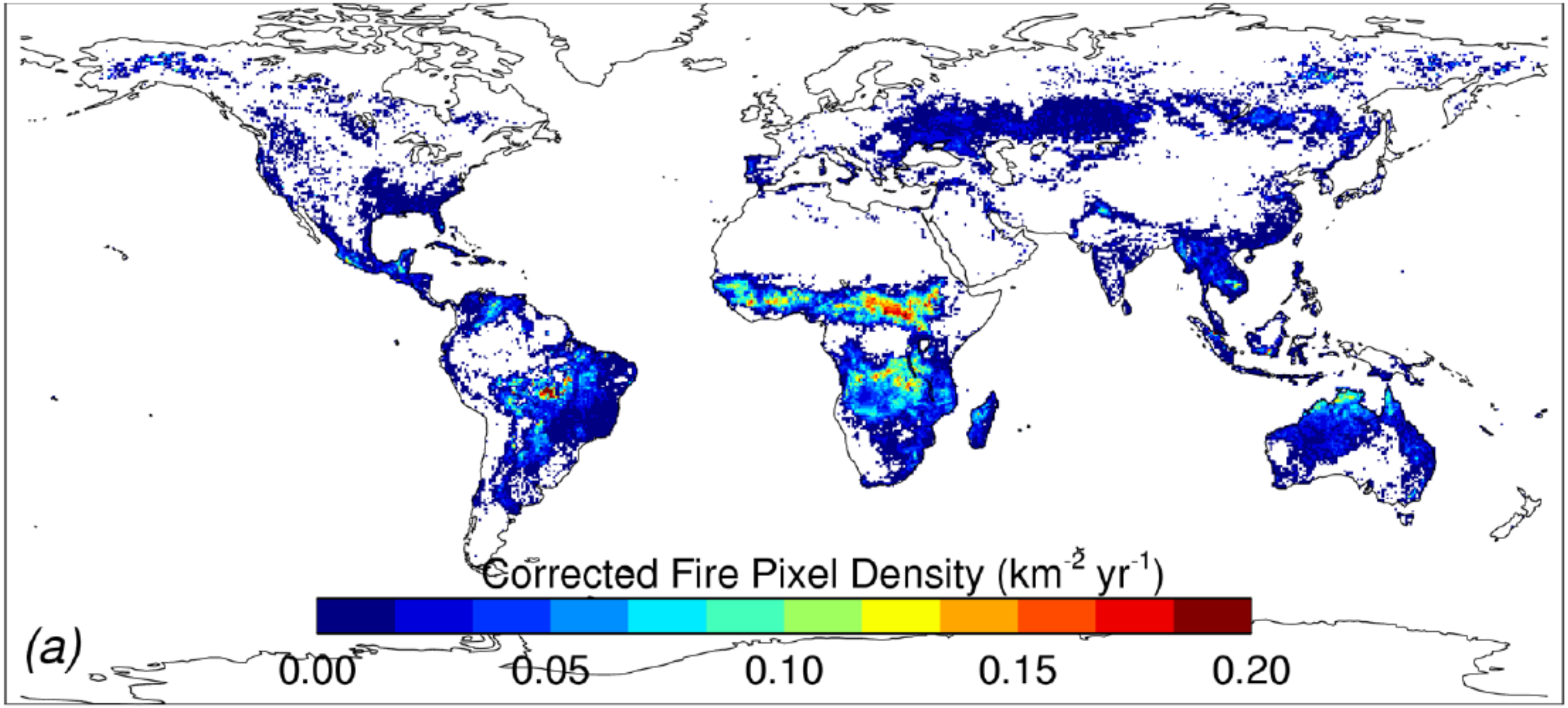
Limitations

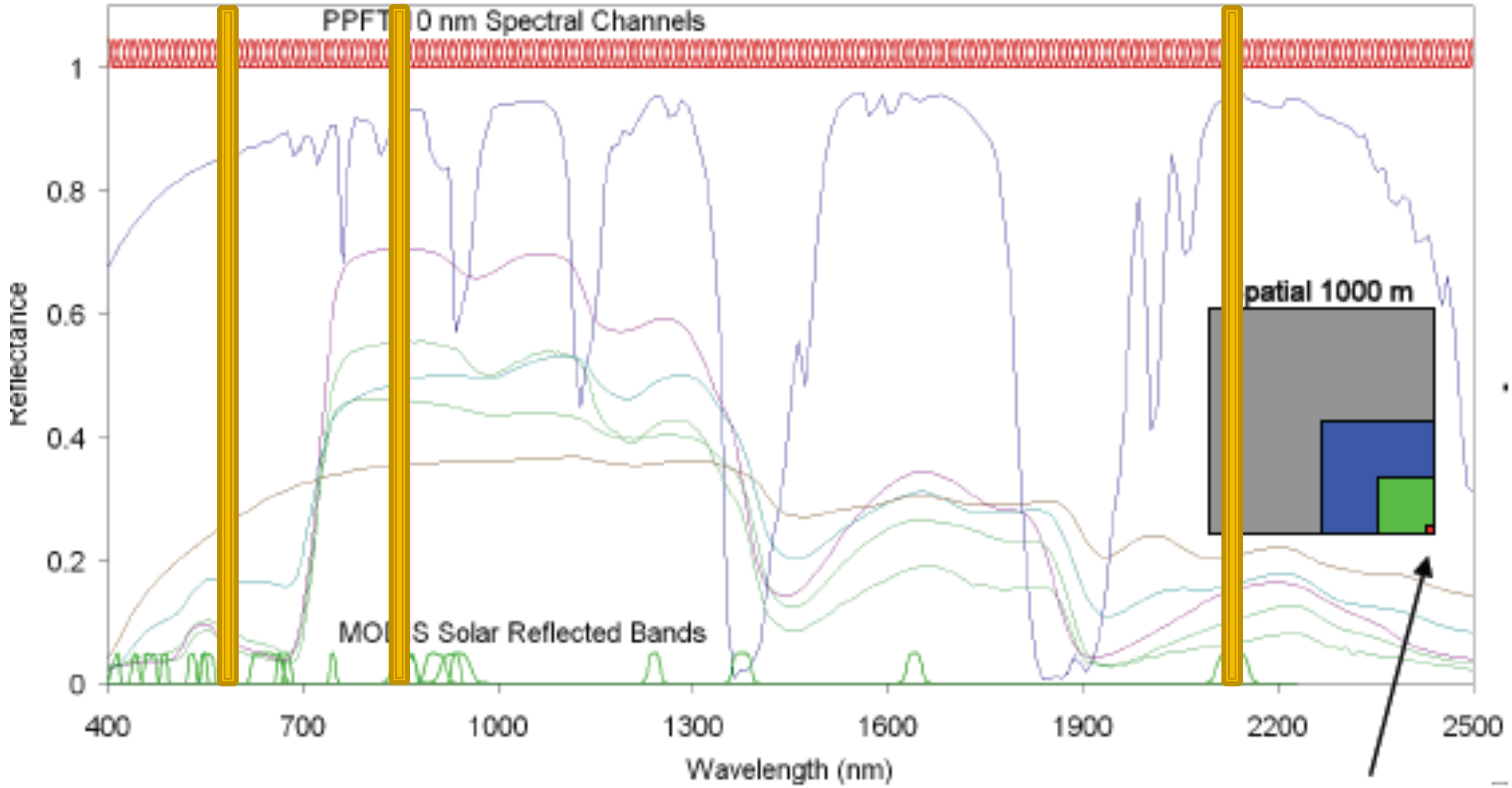
VSWIR – TIR swath mismatch



Cloud Cover

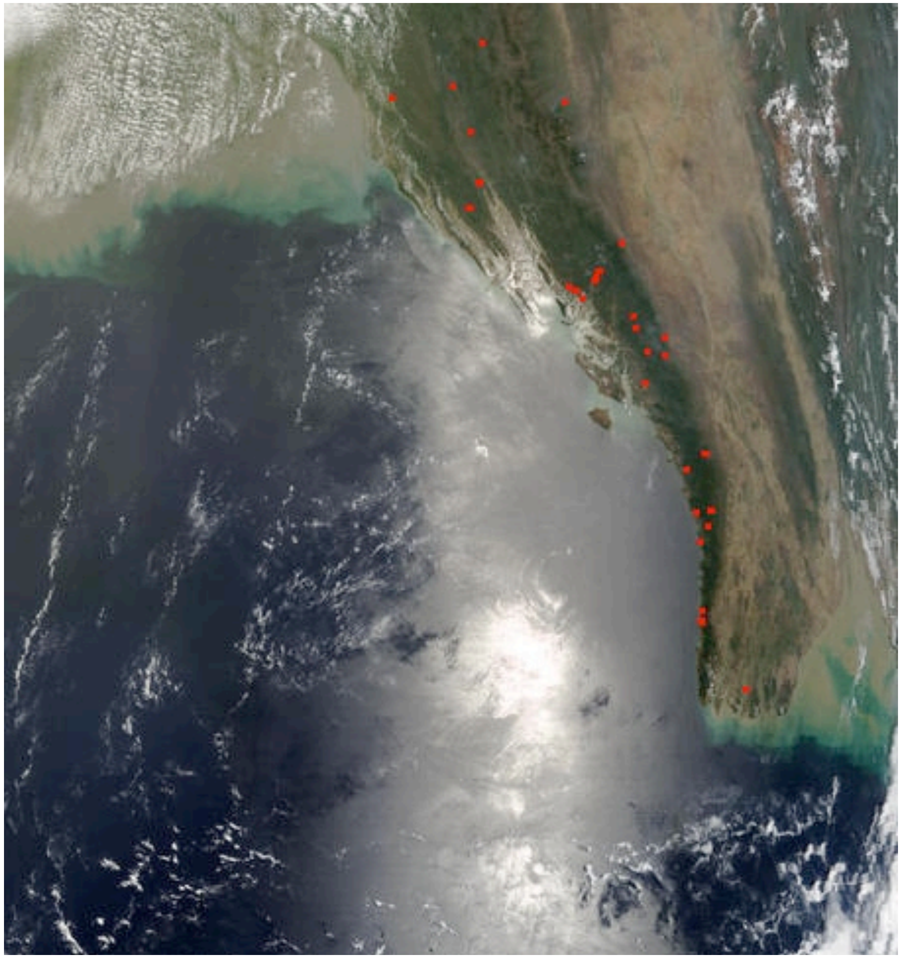
5 – 19 day repeat at the equator, the region most responsible for biomass burning and LCLUC





0.65 - Sun glint and coastal false alarm rejection, cloud masking
0.86 - Bright surface, sun glint, coastal alarm rejection, cloud masking
2.1 - Sun glint and coastal alarm rejection

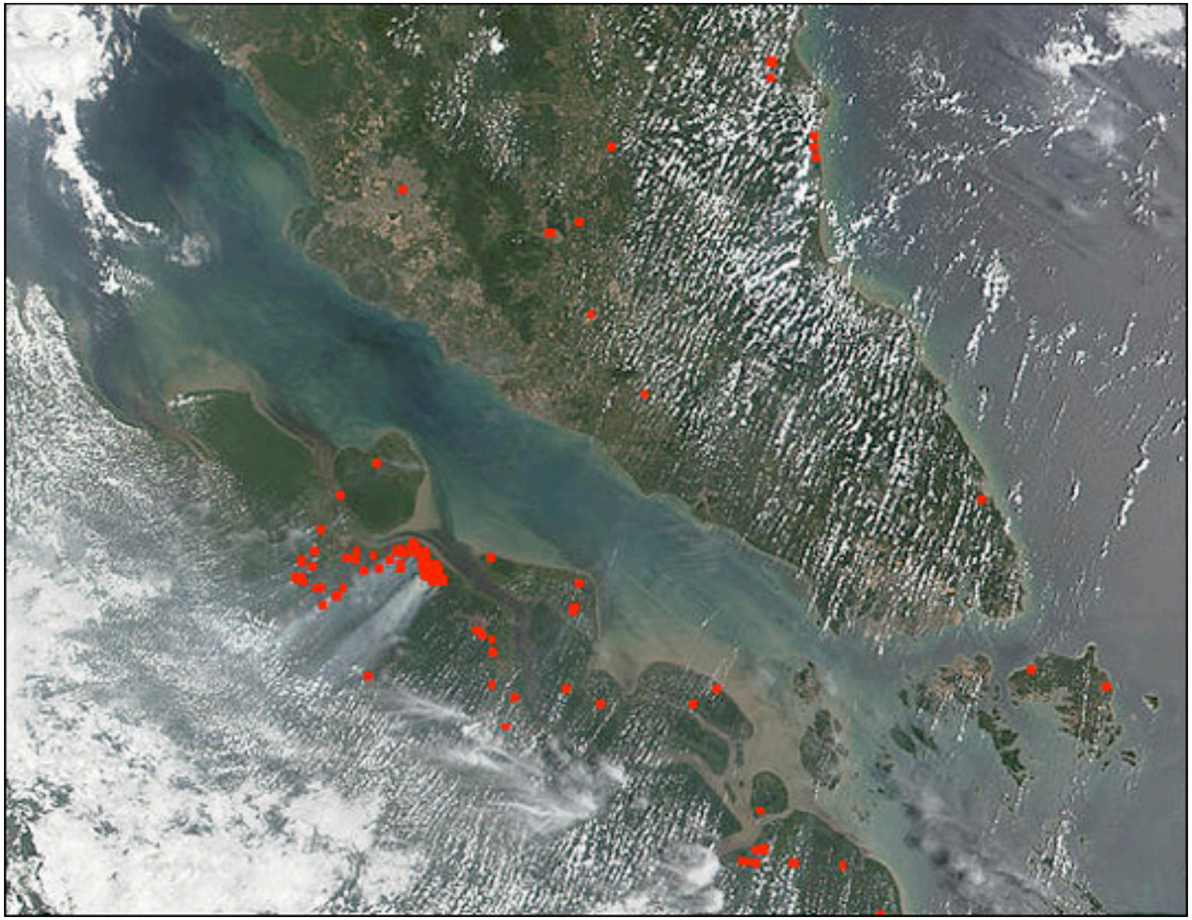
Sun Glint



Need reflective bands to identify glint, otherwise detection algorithm can be fooled into thinking that glint-contaminated pixels contain fires.

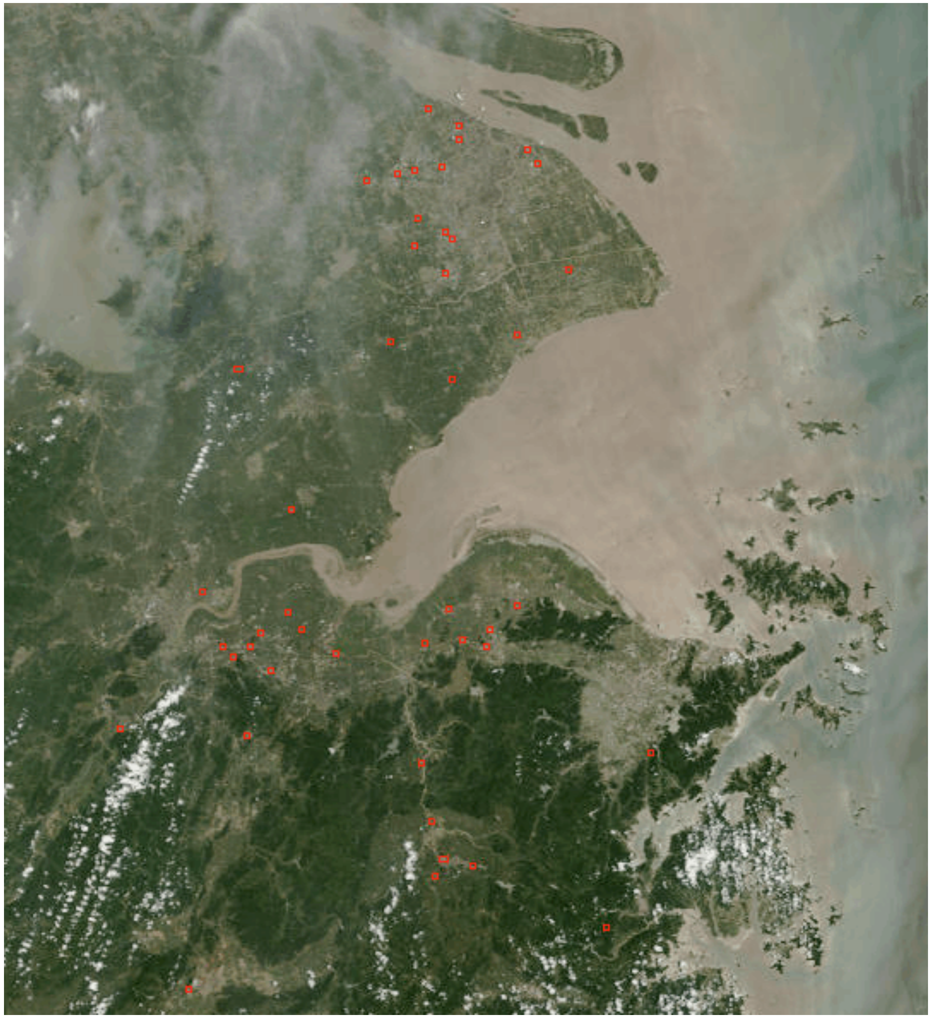
Most, if not all, of the fire pixels in this scene are true fires. Note how MODIS algorithm continues to function (albeit in a degraded mode) in areas affected by sun glint.

Cloud Mask



Detection algorithm must function in the presence of small, convective clouds, which in some ways resemble small fires during the daytime.

Coastal Alarm Rejection



This rejection test helps to eliminate false alarms caused by cooler water pixels contaminating the contextual background. Note: We will need a 60 m land/sea mask for HyspIRI active fire detection and burned area mapping.

Terra MODIS
Shanghai - 18 July 2004, 02:45 UTC

Conclusions

- HyspIRI will provide unique capabilities for fine spectral and spatial characterization of wildfires (fuels, energy, emissions)
- While offering cal/val opportunities for coarser resolution sensors
- Improve our understanding of fire behavior as a function vegetative condition, microclimate conditions, land cover / land use, etc.

Conclusions

- Science, not operational
- Regular monitoring of wildfires not possible with such a large gap in repeat visits
  - Rather, the opportunities will exist to generate a robust snapshot of data understanding fires in a given time and place.
- 3 year mission (hopefully to see add-on missions) is too short for long term records needed.
- Persistent cloud cover and 19-day repeat time means the tropics will have limited “looks”.