The role of satellites in biomass burning characterization

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Station Fire in California, near JPL in Aug/Sep 2009 courtesy of http://hometown-pasadena.com/

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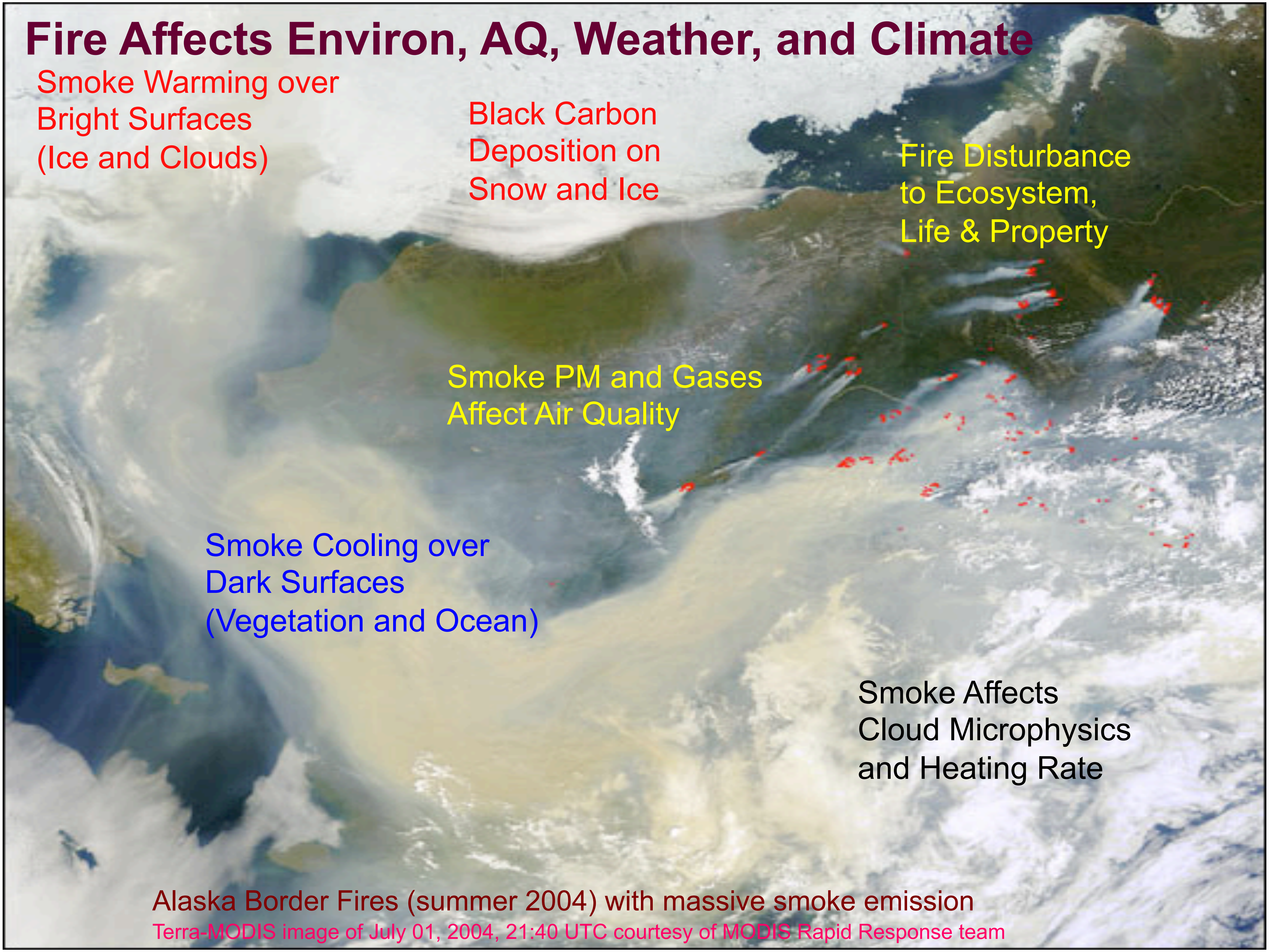
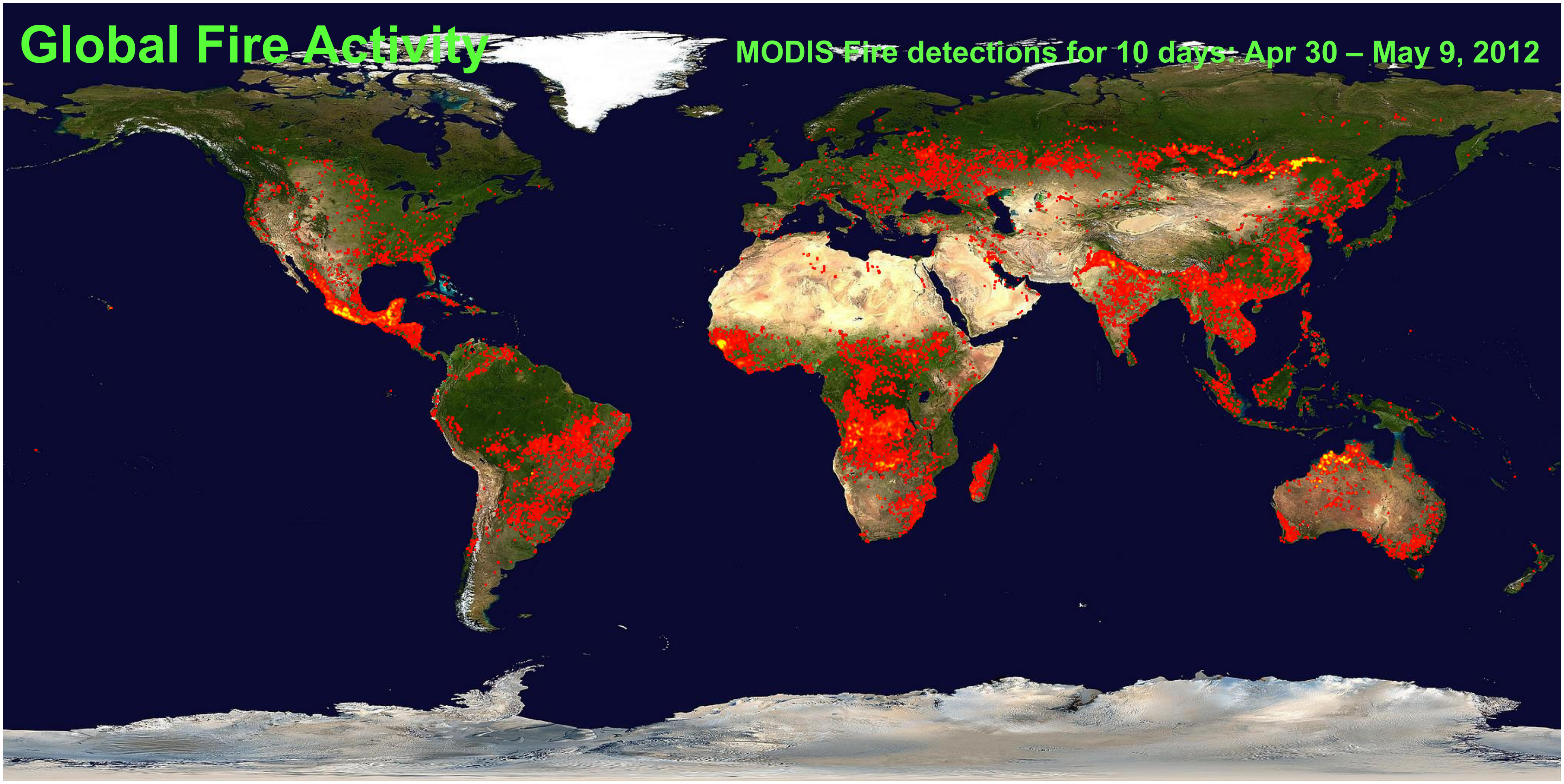
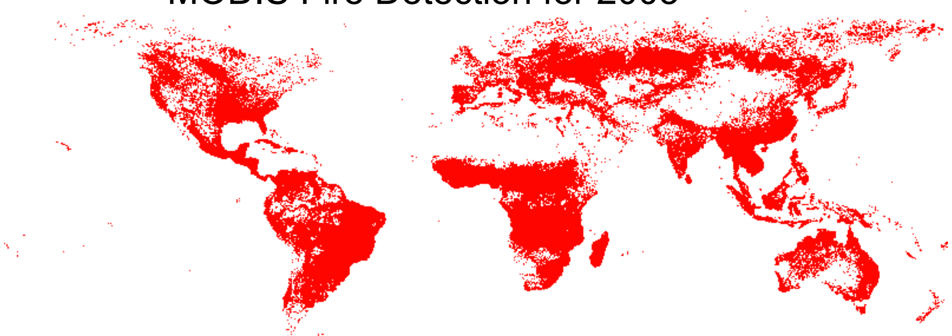
Session: Roundtable on Biomass Burn Observation Project (BBOP)


Fire Affects Environ, AQ, Weather, and Climate
Smoke Warming over
Bright Surfaces
(Ice and Clouds)
Black Carbon
Deposition on
Snow and Ice
Fire Disturbance
to Ecosystem,
Life & Property
Smoke PM and Gases
Affect Air Quality
Smoke Cooling over
Dark Surfaces
(Vegetation and Ocean)
Smoke Affects
Cloud Microphysics
and Heating Rate
Alaska Border Fires (summer 2004) with massive smoke emission
Terra-MODIS image of July 01, 2004, 21:40 UTC courtesy of MODIS Rapid Response team



MODIS Fire Detection for 2003



Annually Persistent Global Issue

3.1×10^9 t of biomass carbon burned

1.1×10^9 t is emitted to the atmosphere

(*Fearnside, 2000, Climatic Change* **46***: 115–158.*)

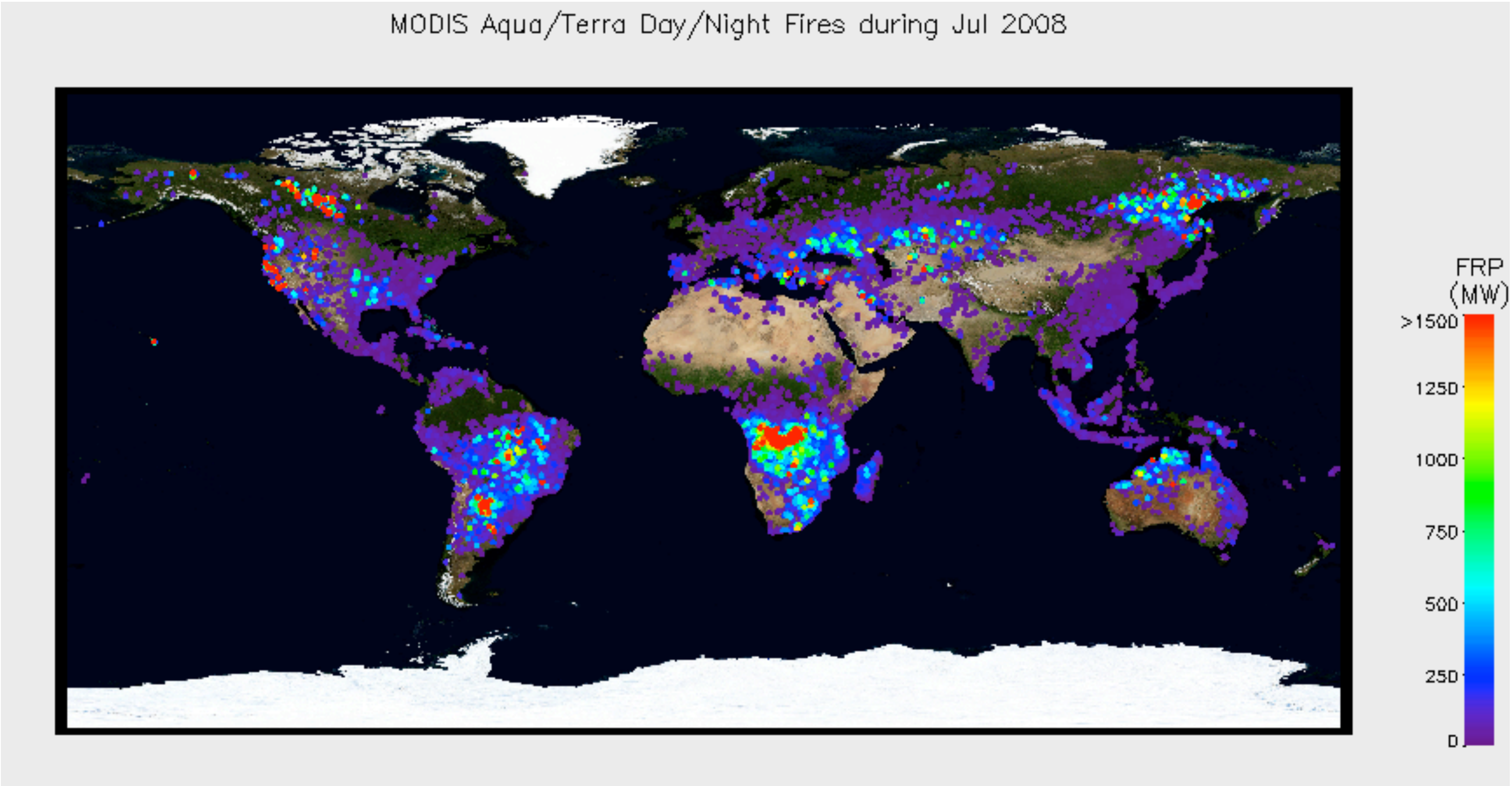
Fires contribute: 40% BC, 25% CO_2 of total annual global emissions

Global Fire Emissions and Impacts

Species	Fire Sources	% of All Sources	Impacts
Carbonaceous Aerosols		34% - 38%	EPA Criteria Pollutant
Black Carbon (BC)		40%	BC Global Mean Radiative forcing 55% of that of CO_2
Carbon Dioxide (CO_2)	~13,400 Tg/yr	25%	
Carbon Monoxide (CO)	~690 Tg/yr		EPA Criteria Pollutant
NMHC	~49 Tg/yr		
Methane (CH_4)	~39 Tg/yr		Over 25 times atmos heating rate of CO_2
N_2	~26 Tg/yr		
NO_x	~21 Tg/yr		EPA Criteria Pollutant

Based on ARCTAS (Summer 2008) it was shown that CO_2, CO, and CH_4 alone comprised 98.6% of the measured carbon released from fires (Simpson et al., 2011).

Active fire radiative power (FRP) observations from satellite



Essential Attributes of FRP

- Contains sub-pixel information.
- Qualitative measure of fire intensity/size.
- Can be used in near real-time for smoke emissions and other applications
- Not sensor dependent: can be used for climate data records.

Traditional Emissions Estimation Approach

Emissions = Emission Factor (EF g/kg) × Biomass (BM kg)

BM = A × B × α × β

Where: **A=Area burned,**
B=Biomass density,
α=Above ground biomass proportion,
β=Combustion Efficiency

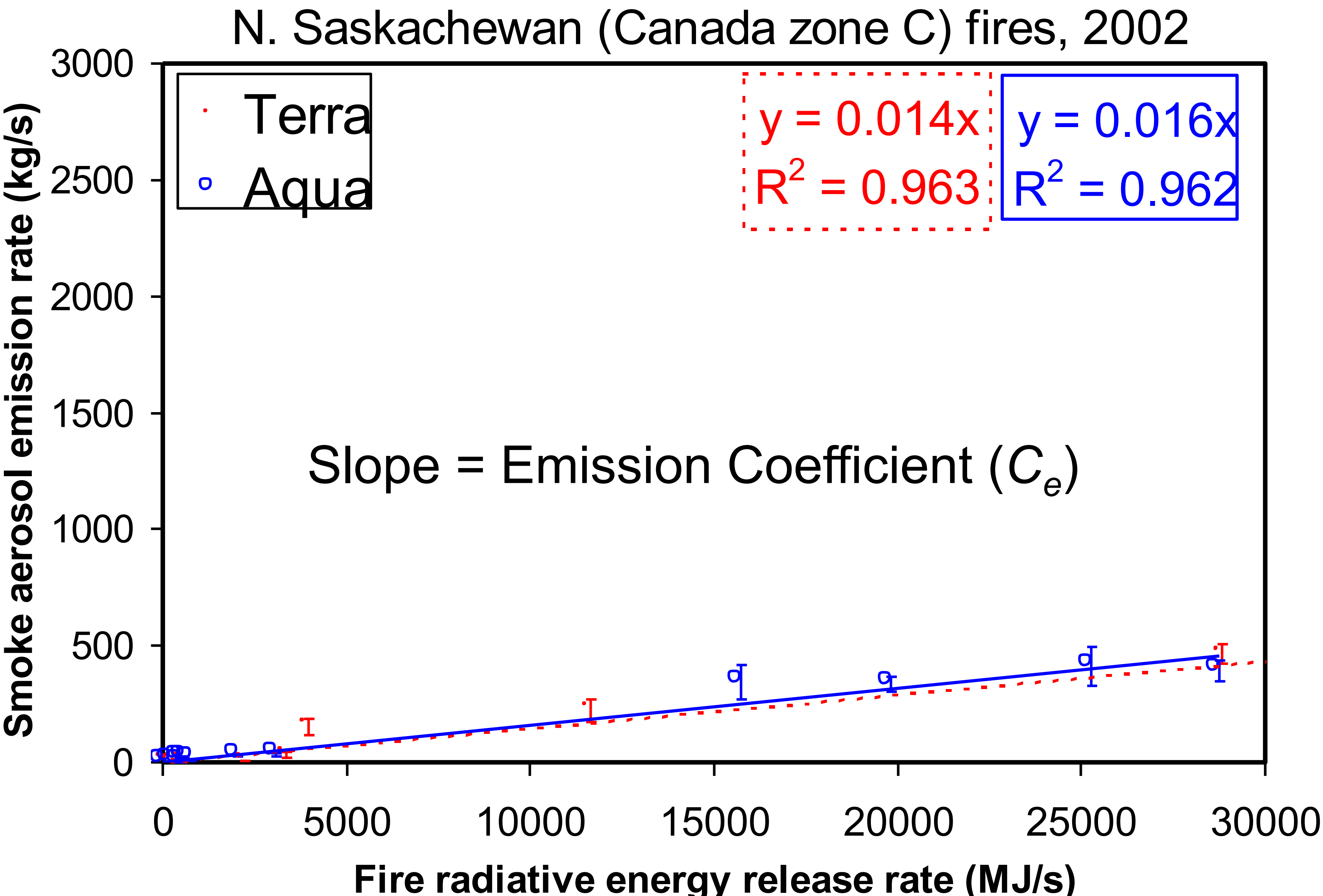
Alternative Approach

Use Satellite Fire Radiative Power/Energy (FRP/FRE)

(1)Emissions = EF × BM (from FRE) *[Wooster]*

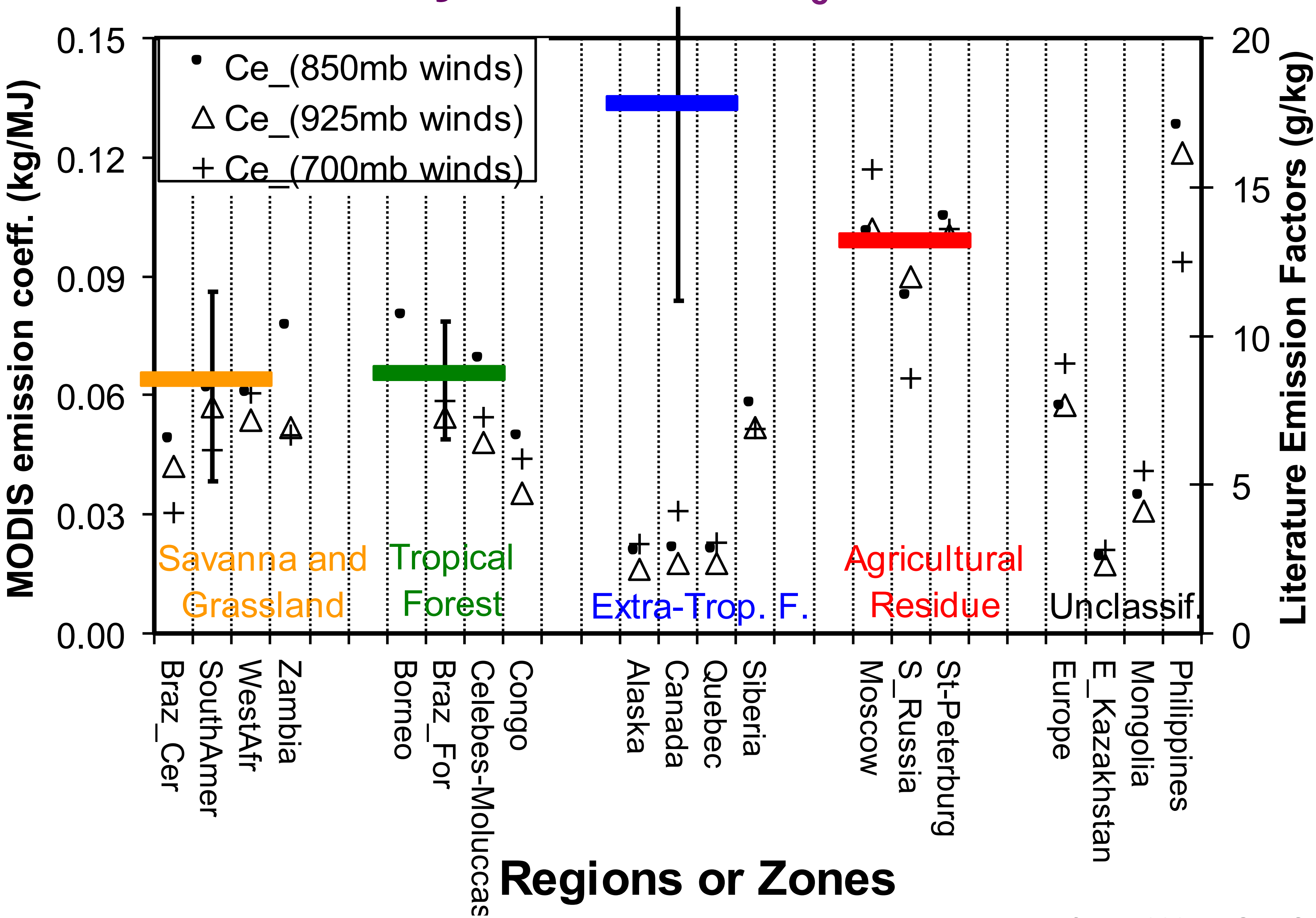
(2)Emissions = Emission Coeff. (C_e) × (FRP or FRE) *[Ichoku]*

Smoke Emission rate Correlates with Fire Radiative Energy release rate



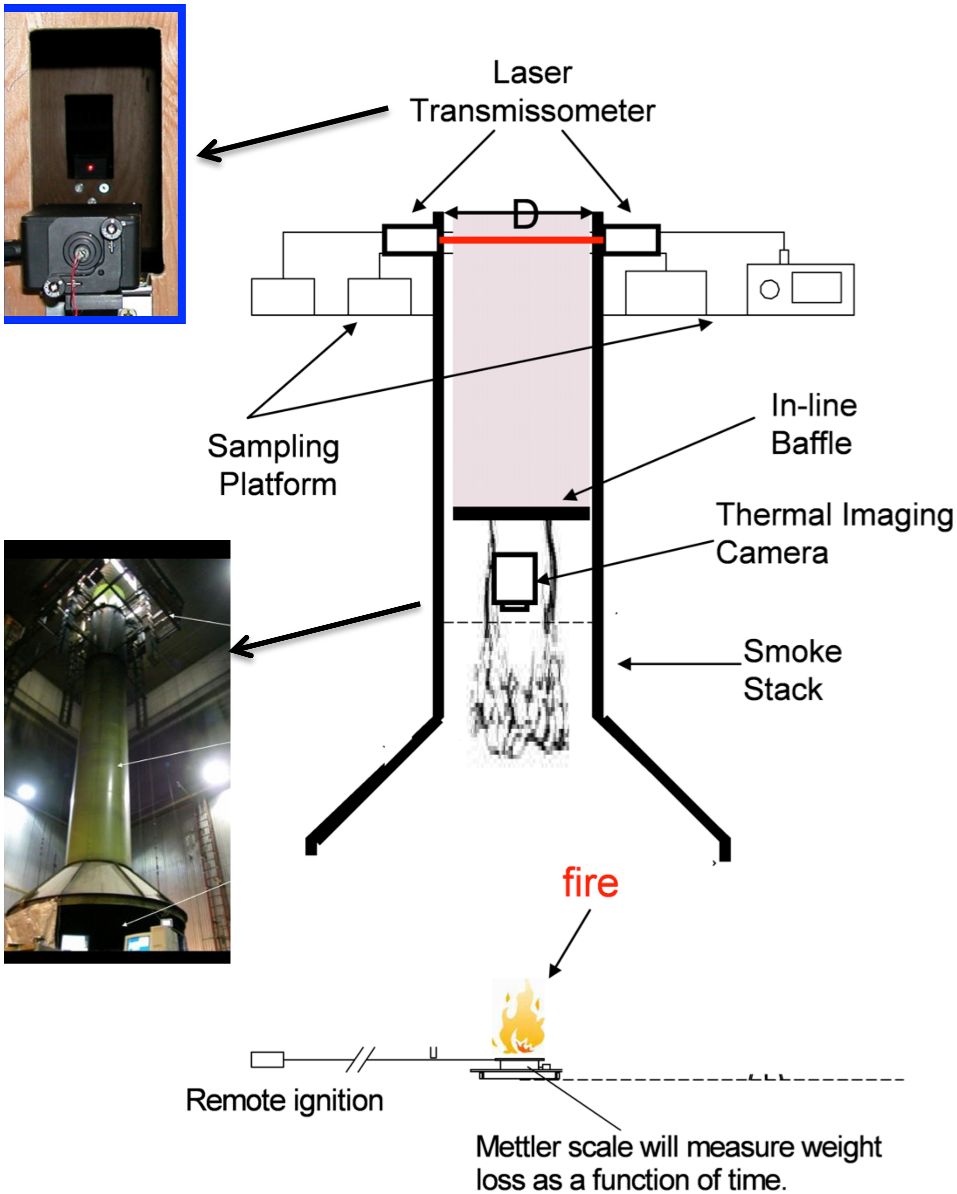
Ichoku and Kaufman, 2005, TGARS

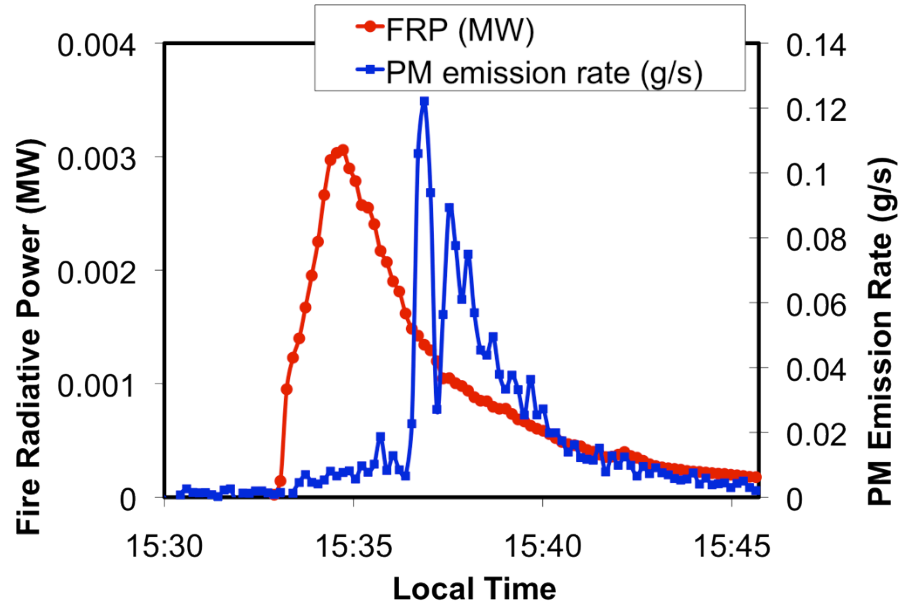
Ecosystem-based C_e vs EF

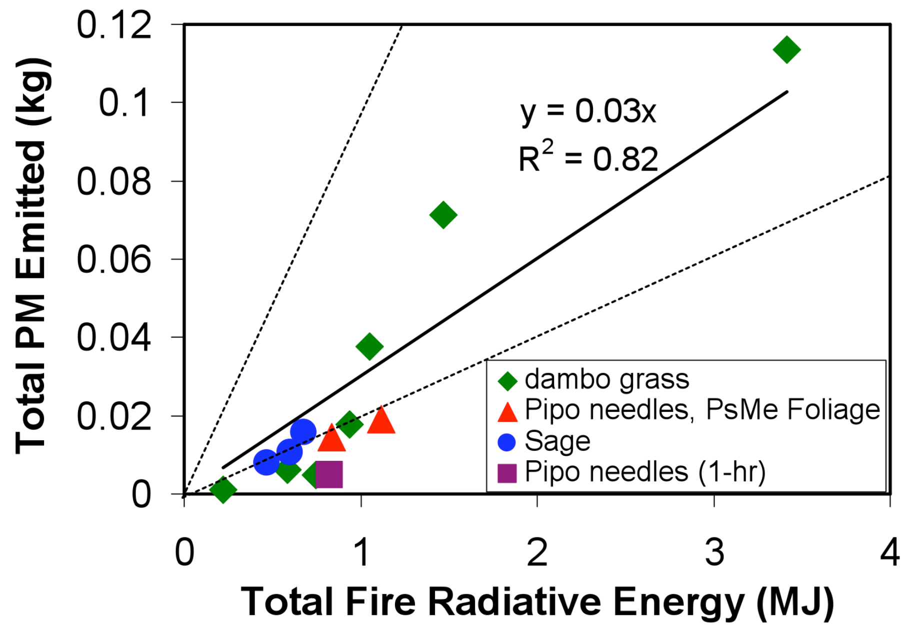


Ichoku and Kaufman, 2005, TGARS

Controlled burns conducted inside the Burn Chamber of the Fire Sciences Lab., USFS, Missoula, MT, Nov. 2003

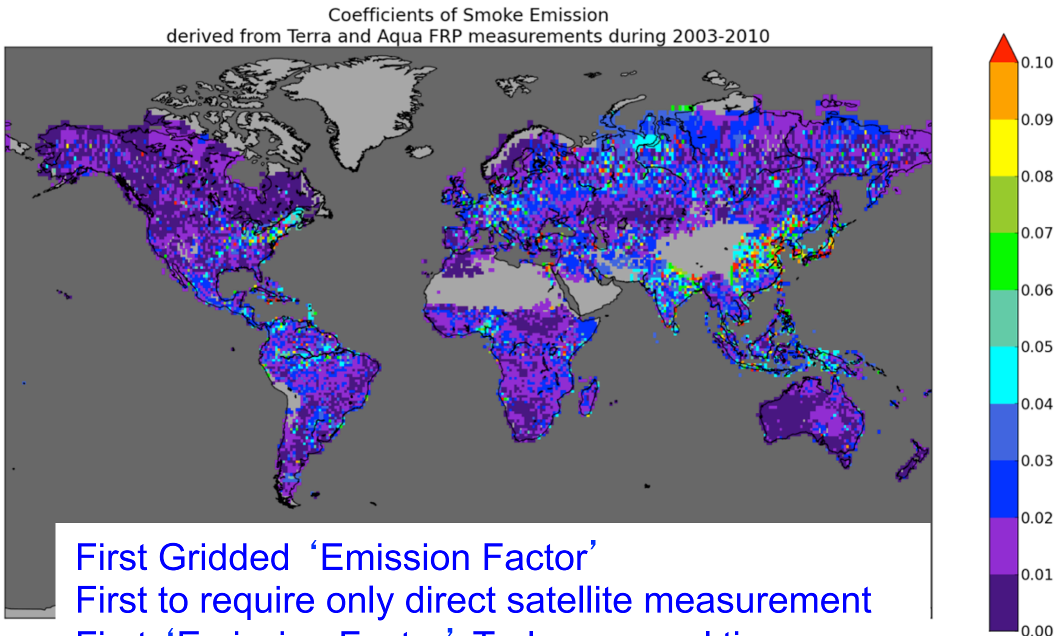




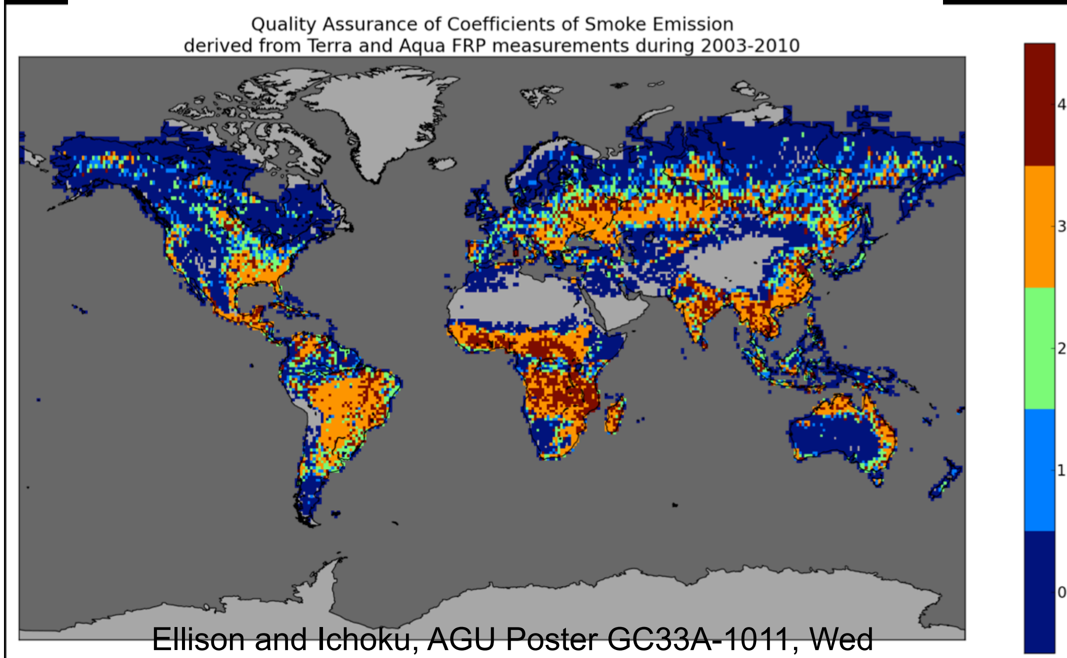


Ichoku et al., 2008, JGR; Freeborn, et al., 2008, JGR

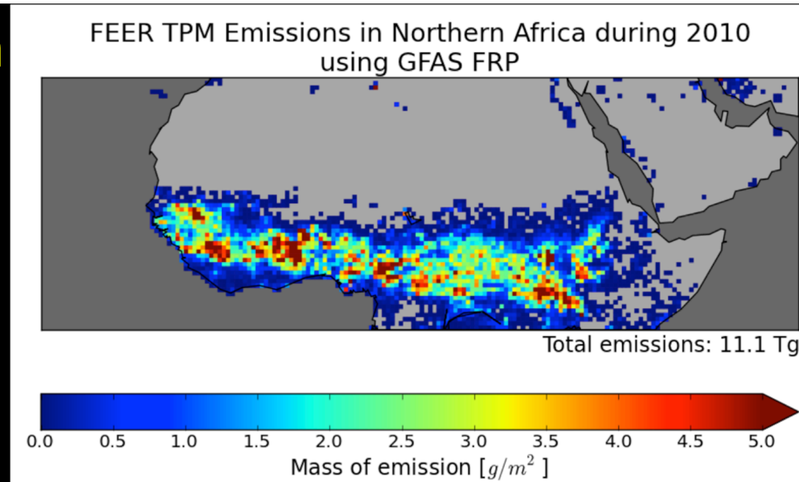
Smoke Emission Estimates and Evaluation

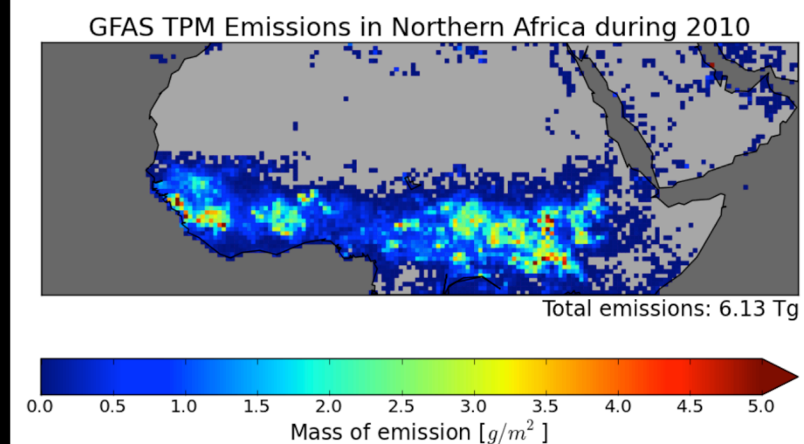


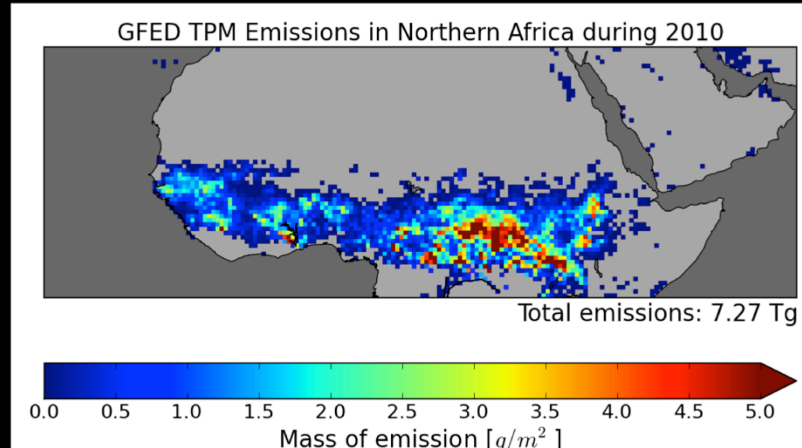
First Gridded 'Emission Factor'
First to require only direct satellite measurement
First 'Emission Factor' Truly near real time



Ellison and Ichoku, AGU Poster GC33A-1011, Wed

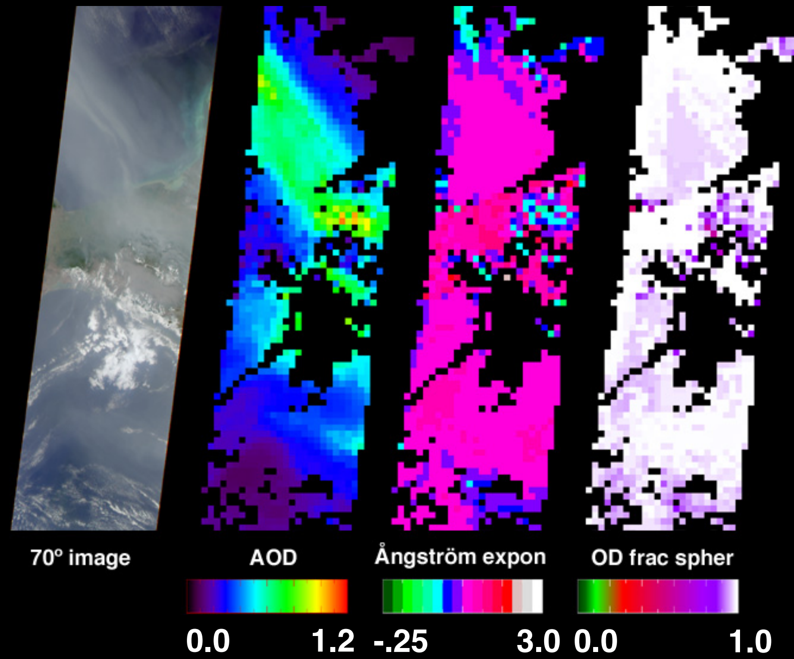






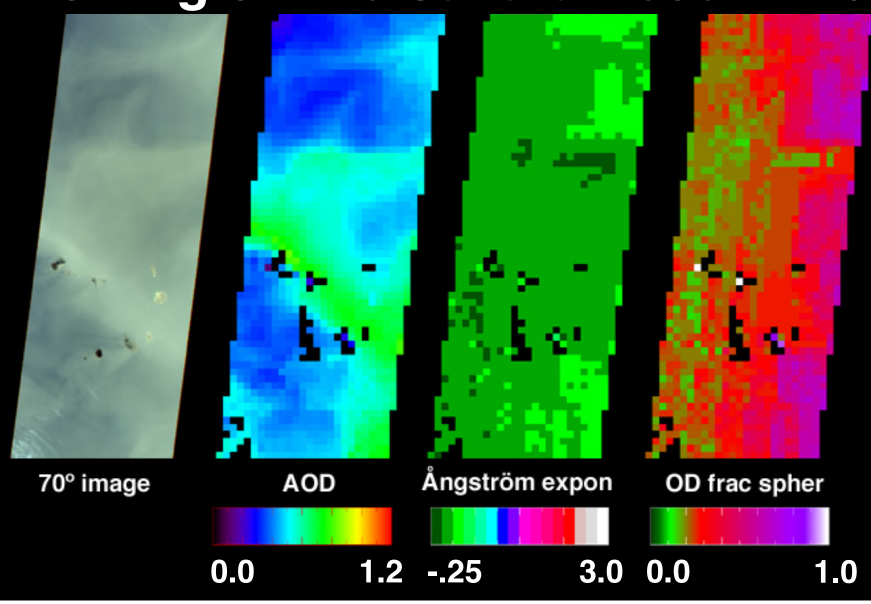
Smoke from Mexico -- 02 May 2002

<u>Aerosol:</u>
Amount
Size
Shape



Medium
Spherical
Smoke
Particles

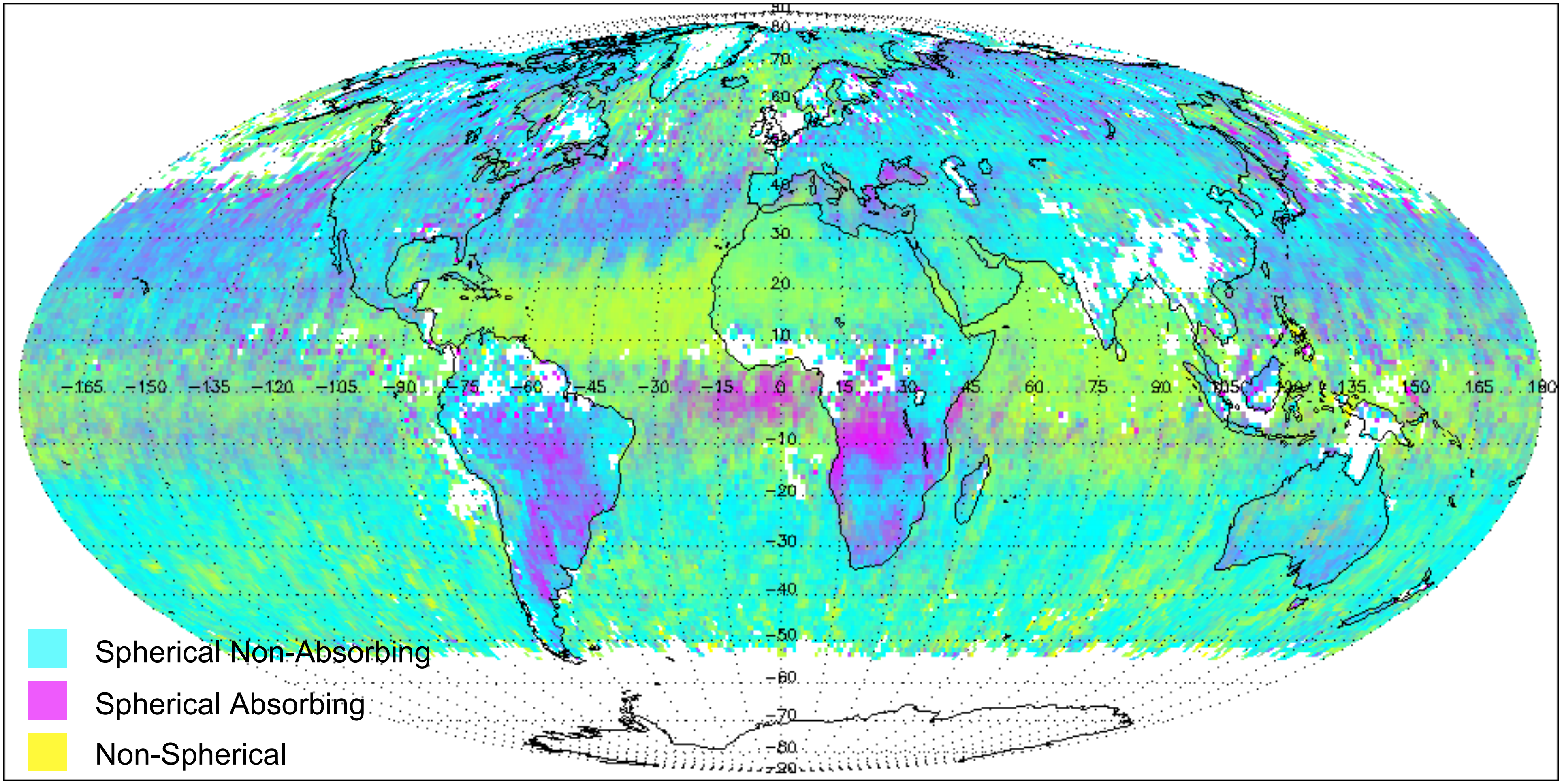
Dust blowing off the Sahara Desert -- 6 February 2004



Large
Non-Spherical
Dust
Particles

MISR *Aerosol Type* Distribution

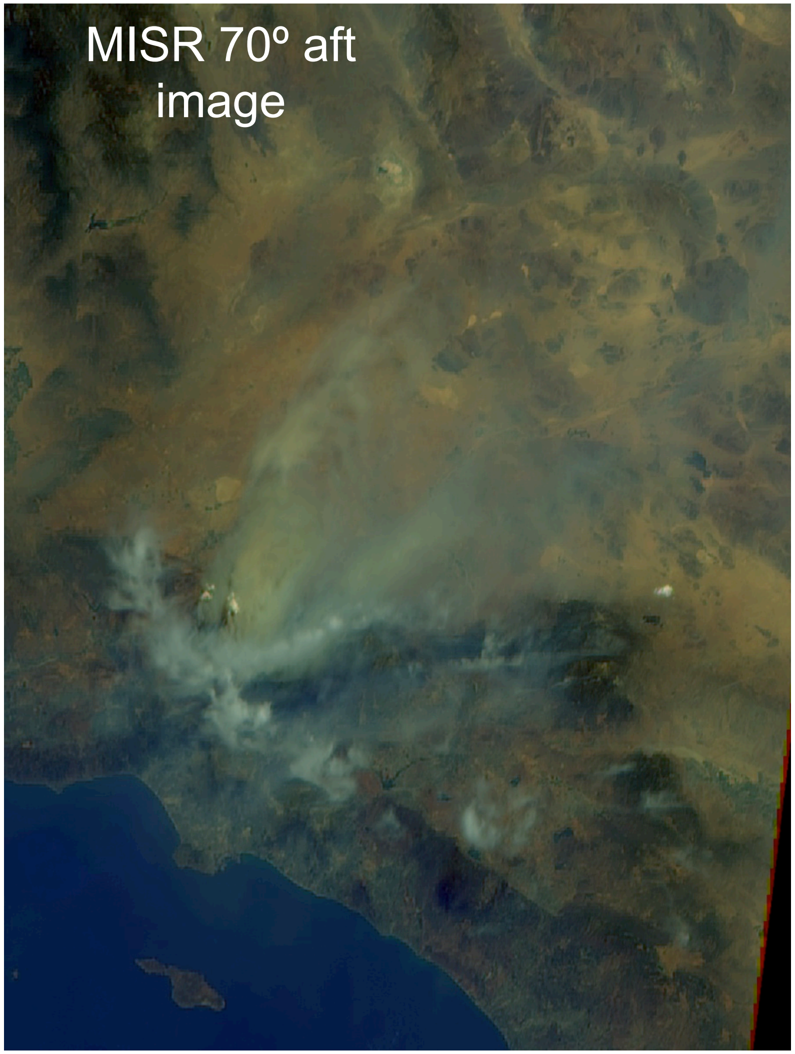
MISR Version 22, July 2007

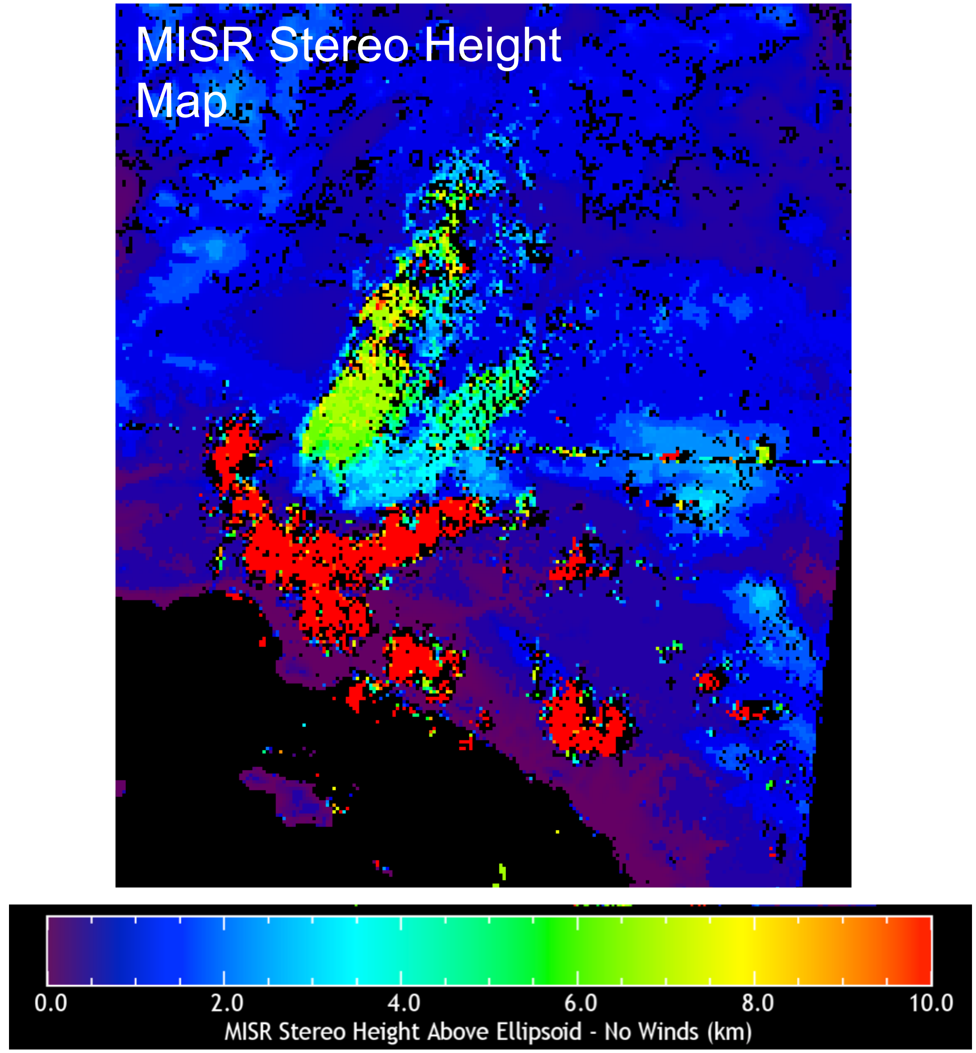


Kahn et al., JGR 2010

MISR *Stereo Heights*

Station Fire, Los Angeles CA August 30 2009, Orbit 50641



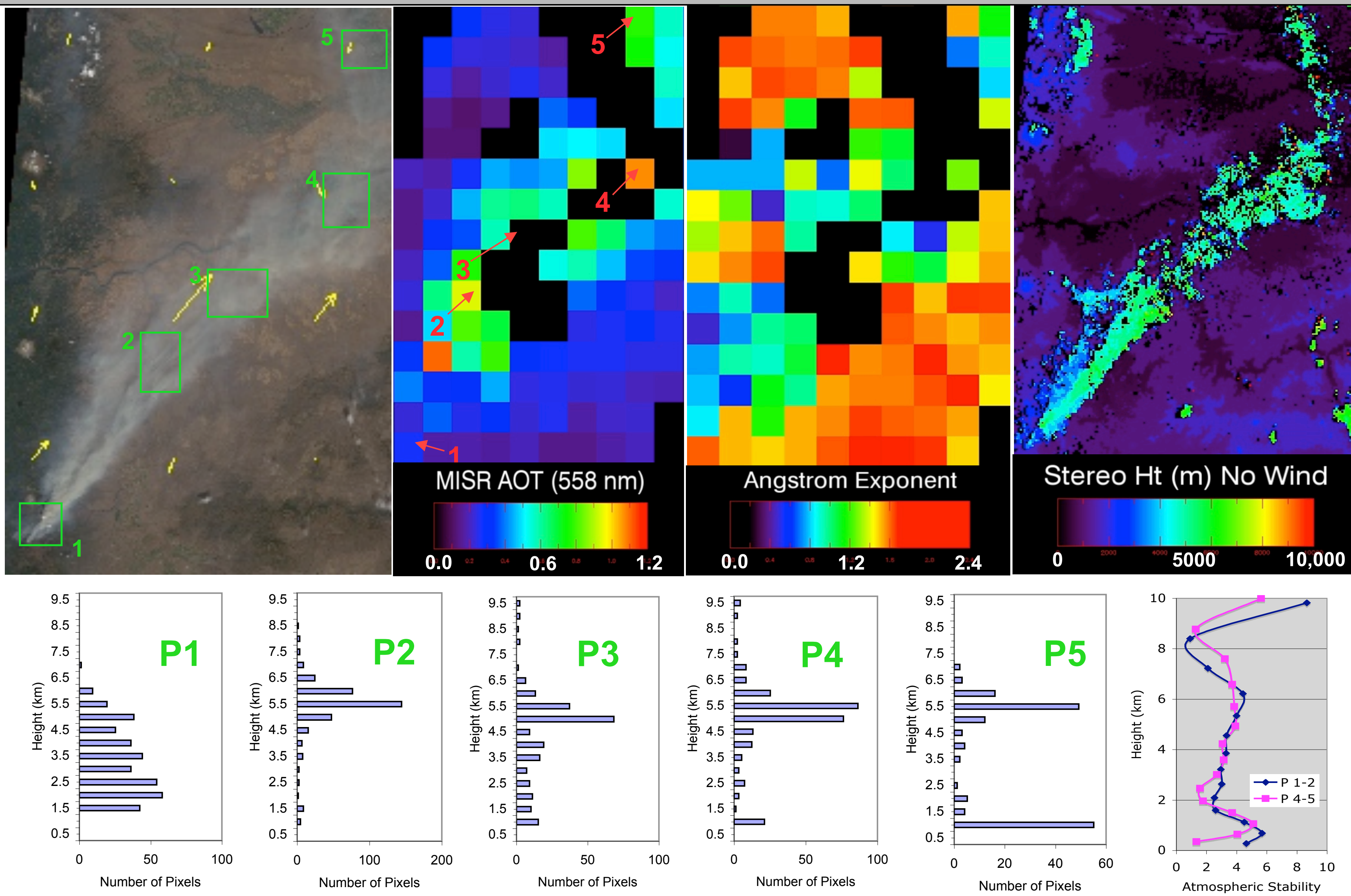


Smoke at more than 7 km ASL (yellow and green in right image), and related clouds at over 10 km (red)

MISR Team, JPL and GSFC

Smoke Plume Characterization from MISR

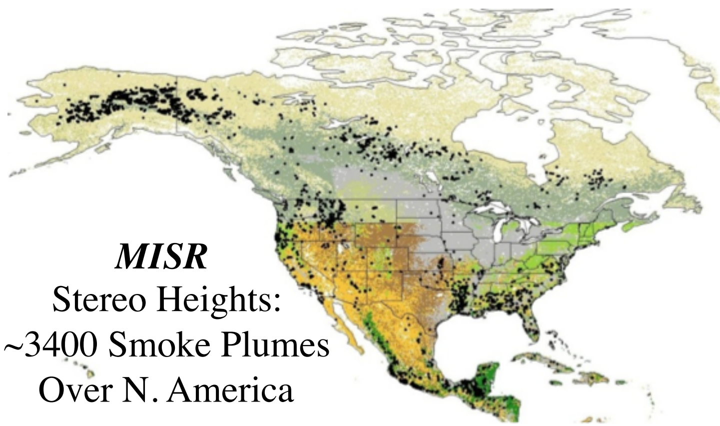
Oregon Fire Sept 04 2003 Orbit 19753 Blks 53-55 MISR Aerosols V17, Heights V13 (no winds)



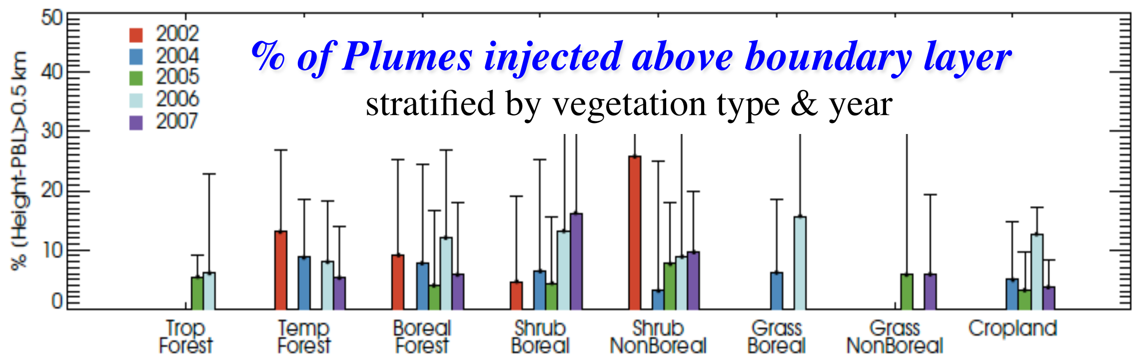
Kahn et al., JGR 2007

Wildfire Smoke *Injection Heights* & *Source Strengths*

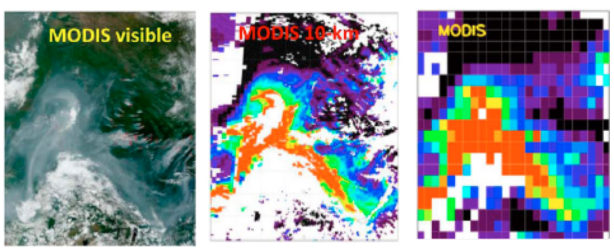
[These are *the two key parameters* representing aerosol sources in climate models]



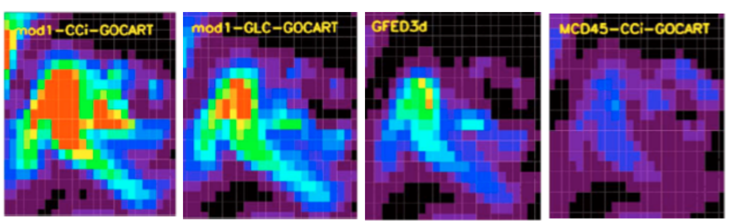
MISR
Stereo Heights:
~3400 Smoke Plumes
Over N. America



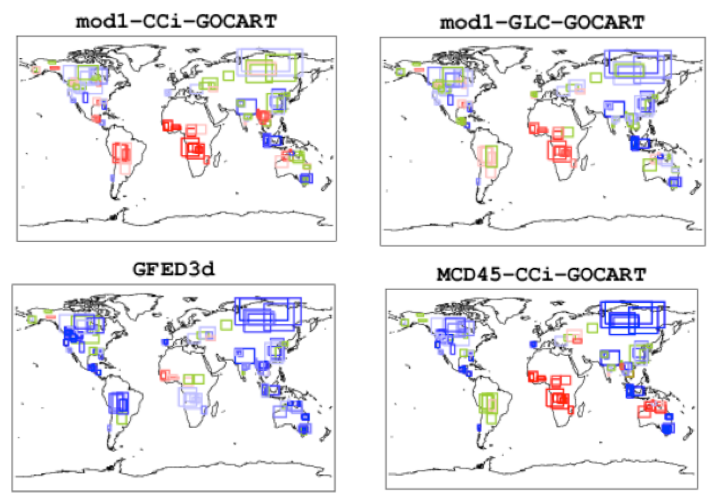
Val Martin et al. ACP 2010



MODIS Smoke Plume Image & Aerosol Amount Snapshots



GoCART Model-Simulated Aerosol Amount Snapshots
for *Different Assumed Source Strengths*



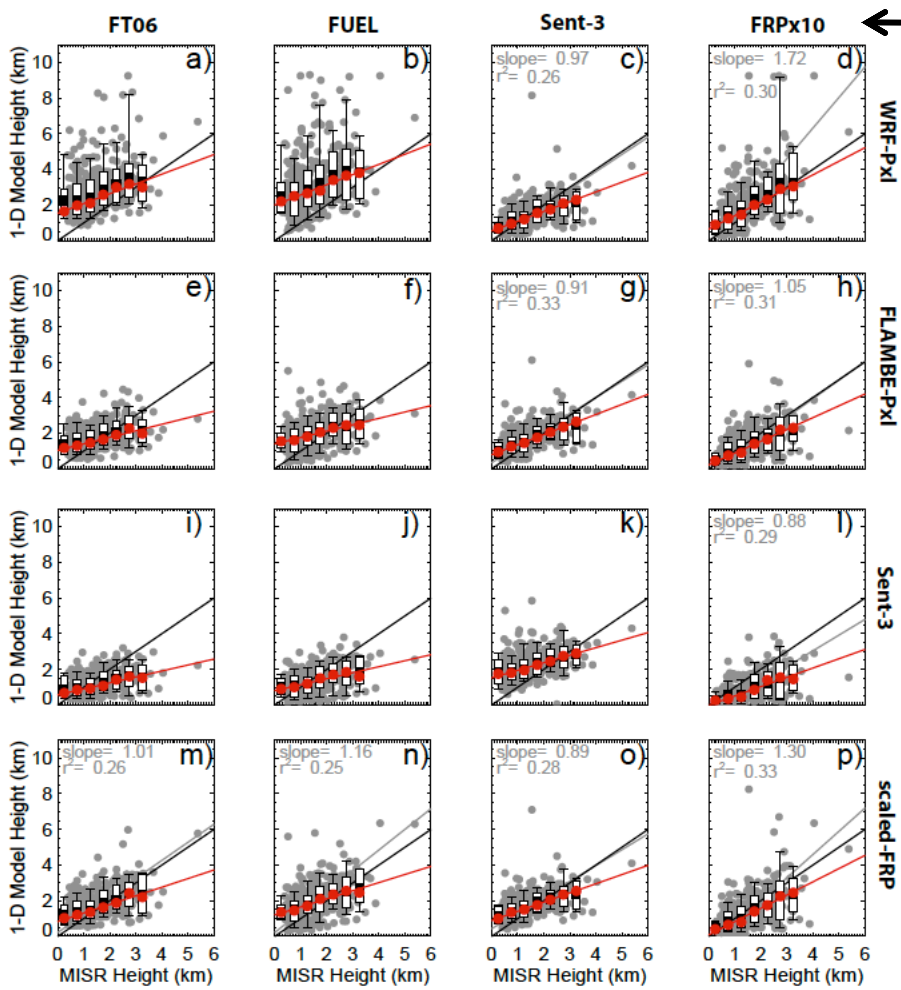
Different Techniques for *Assuming Model Source Strength*
Overestimate or ***Underestimate*** Observation
Systematically in Different Regions

Petrenko et al., JGR 2012

Evaluation of a 1D plume-rise model: Towards a parameterization of smoke *injection heights*

Heat Flux Options

Active Fire Area Options



<u>To Constrain models:</u>

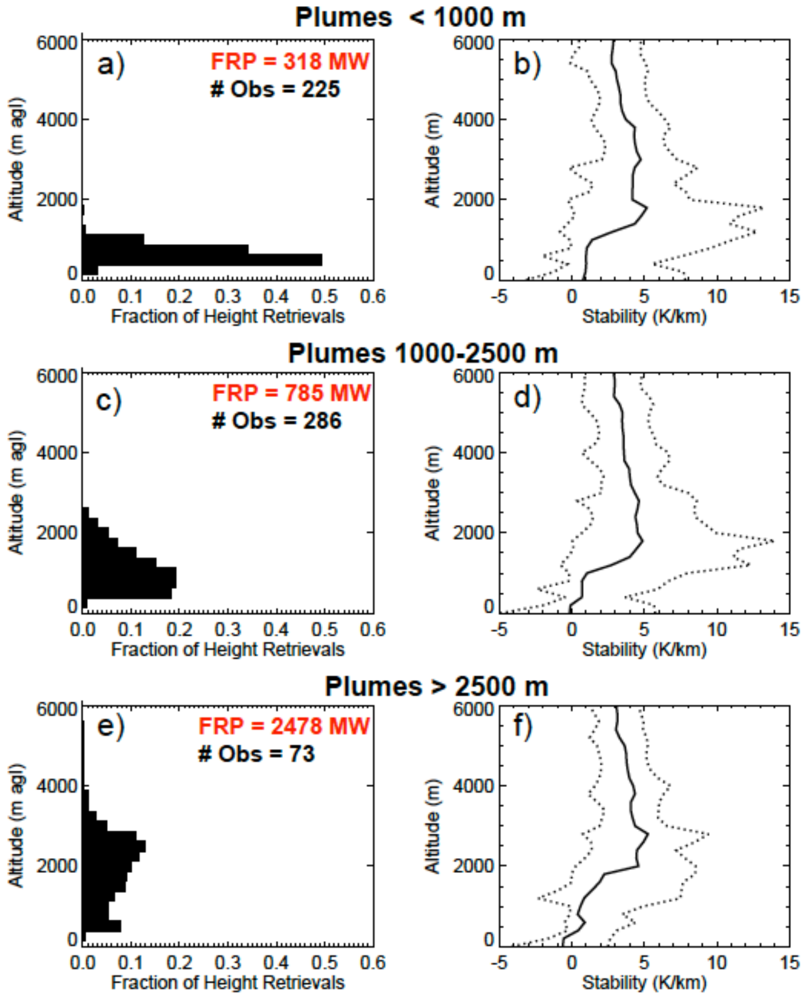
Need to assess the ***Parameterizations*** actually used

1-D Plume-rise model heights vs. MISR-observed max. plume heights

-- Models have ***lower dynamic range than observed***, but very variable

Val Martin et al., JGR 2012

Evaluation of a 1D plume-rise model: Towards a parameterization of smoke *injection heights*

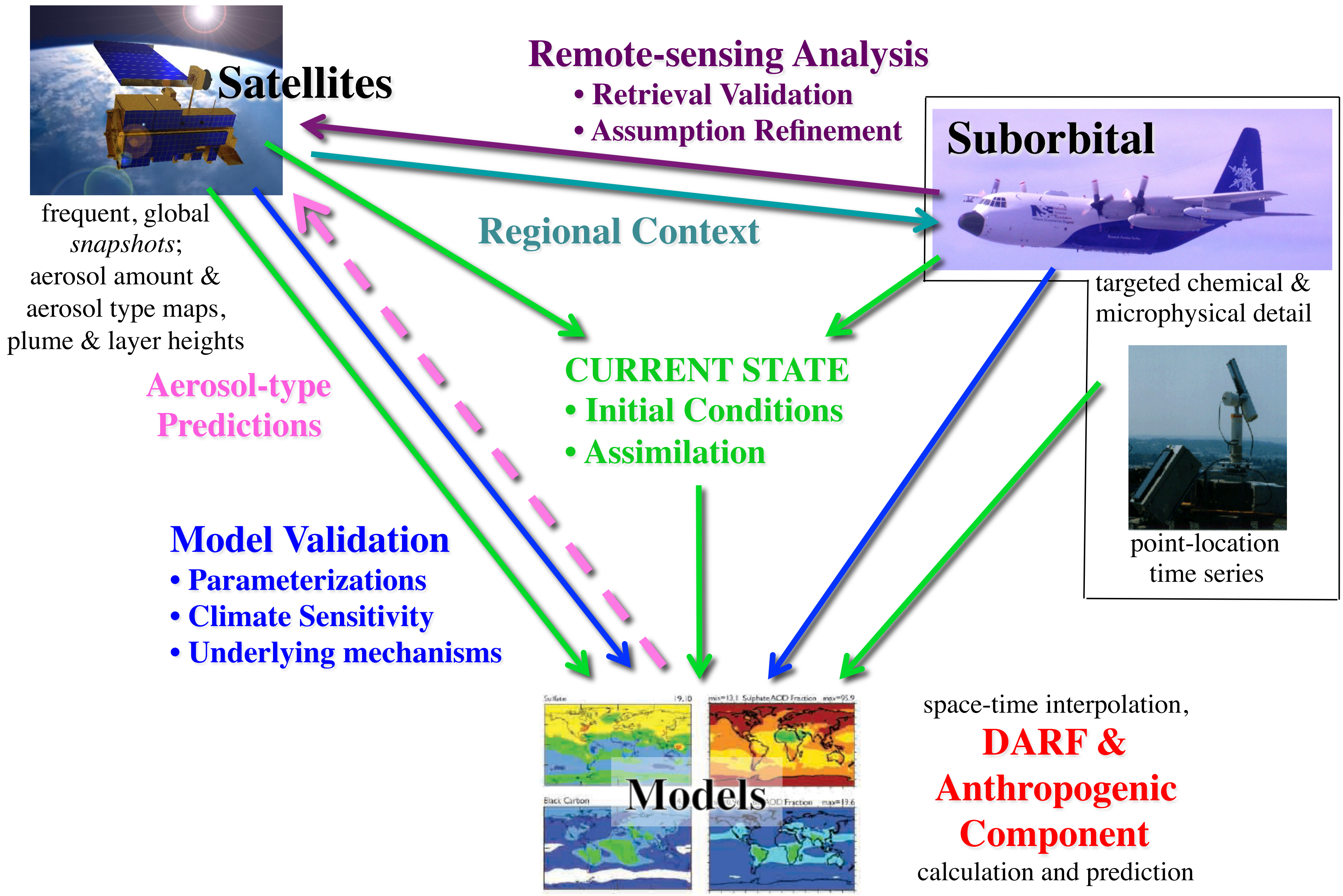


The key factors:

- ***Fire Energy***
  (fire area; heat flux, FRP)
- ***Atmospheric Stability***
- ***Entrainment***

Plume height increases systematically as ***FRP*** increases and ***Atmospheric Stability*** decreases

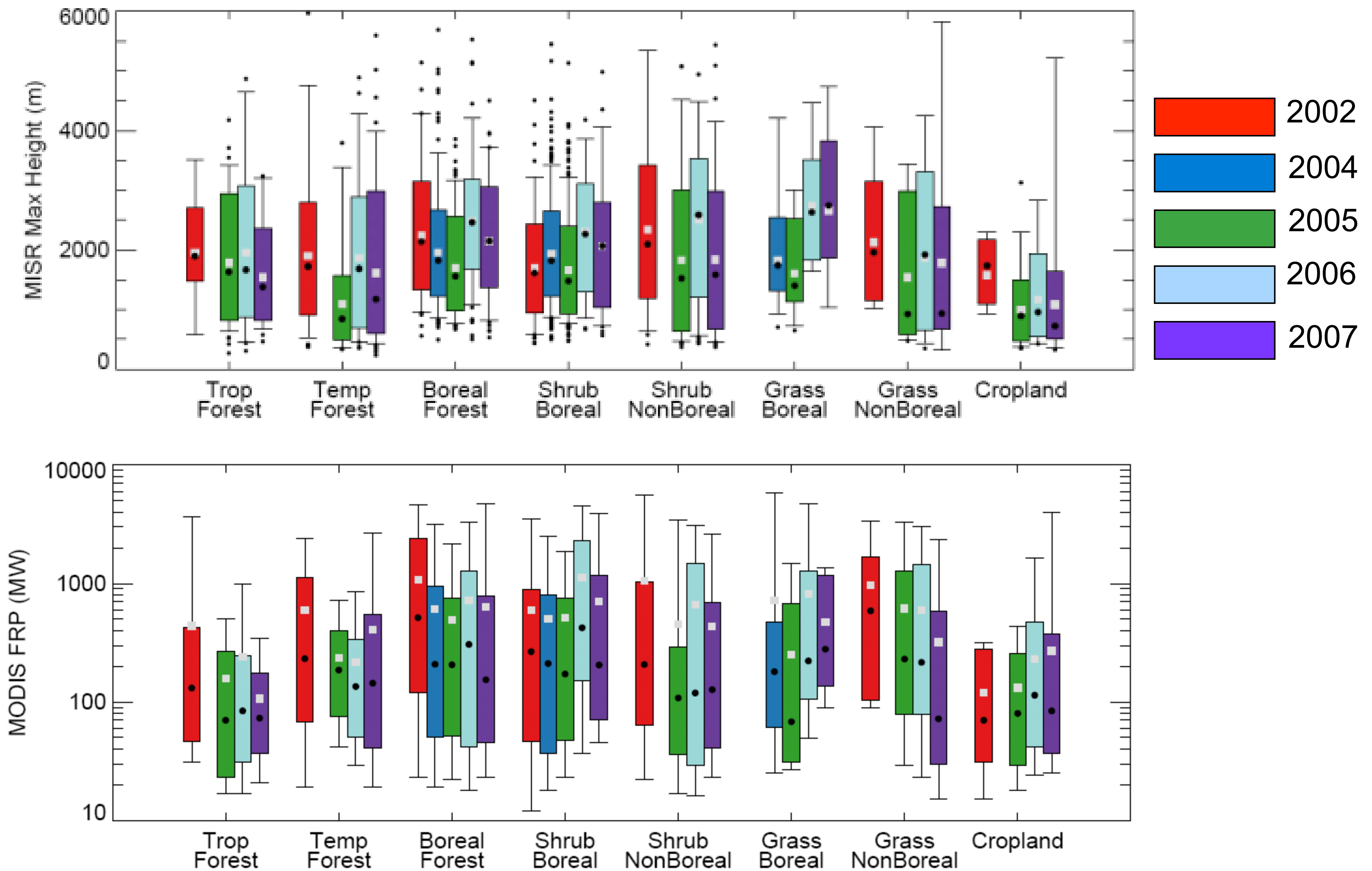
Val Martin et al., JGR 2012



Kahn, Survy. Geophys. 2012

BACKUP SLIDES

Fire Intensity Contributes to Plume Height Variability

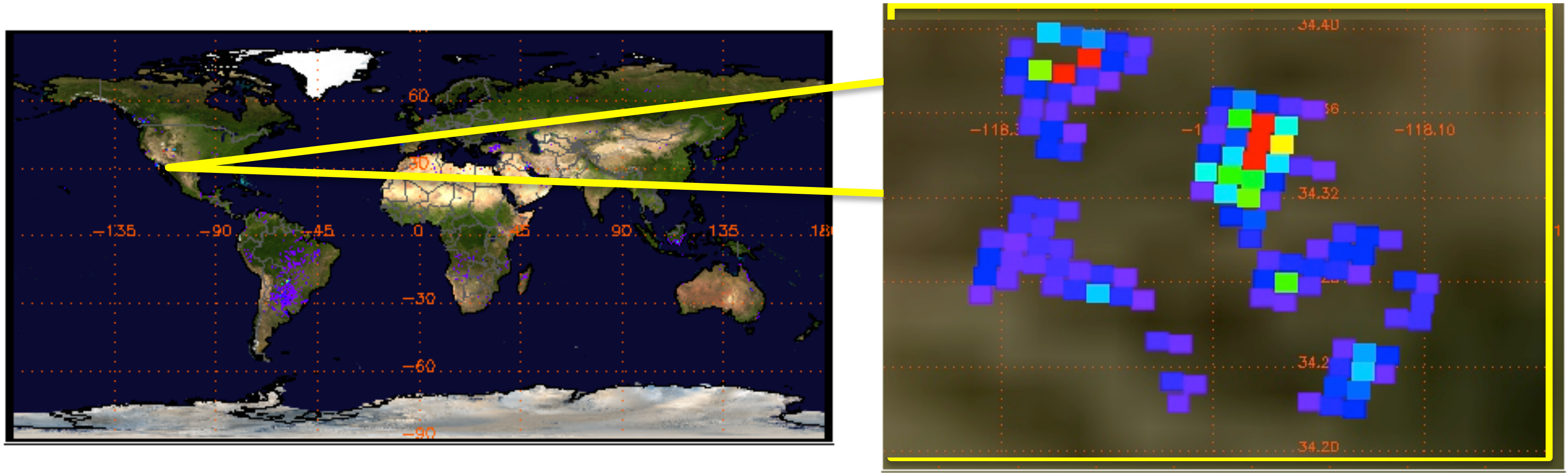


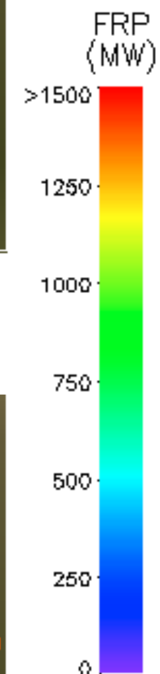
Val Martin et al., ACP 2010

Need to Characterize Fires and their relationship to Heat Energy and Smoke Characteristics and Trajectory

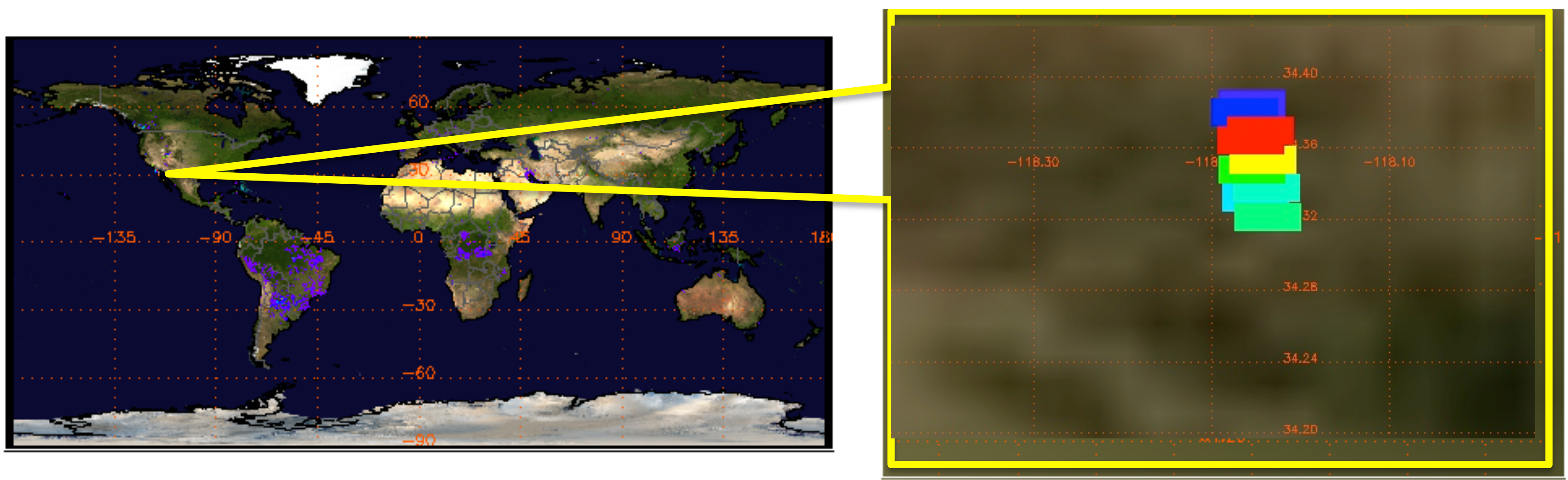
Effects of Scan Angle on MODIS fire observation over JPL Station Fires

Terra-MODIS: LocalTime=11:45 am, Scan Ang=1°, Npix=116, Total FRP=28879 MW



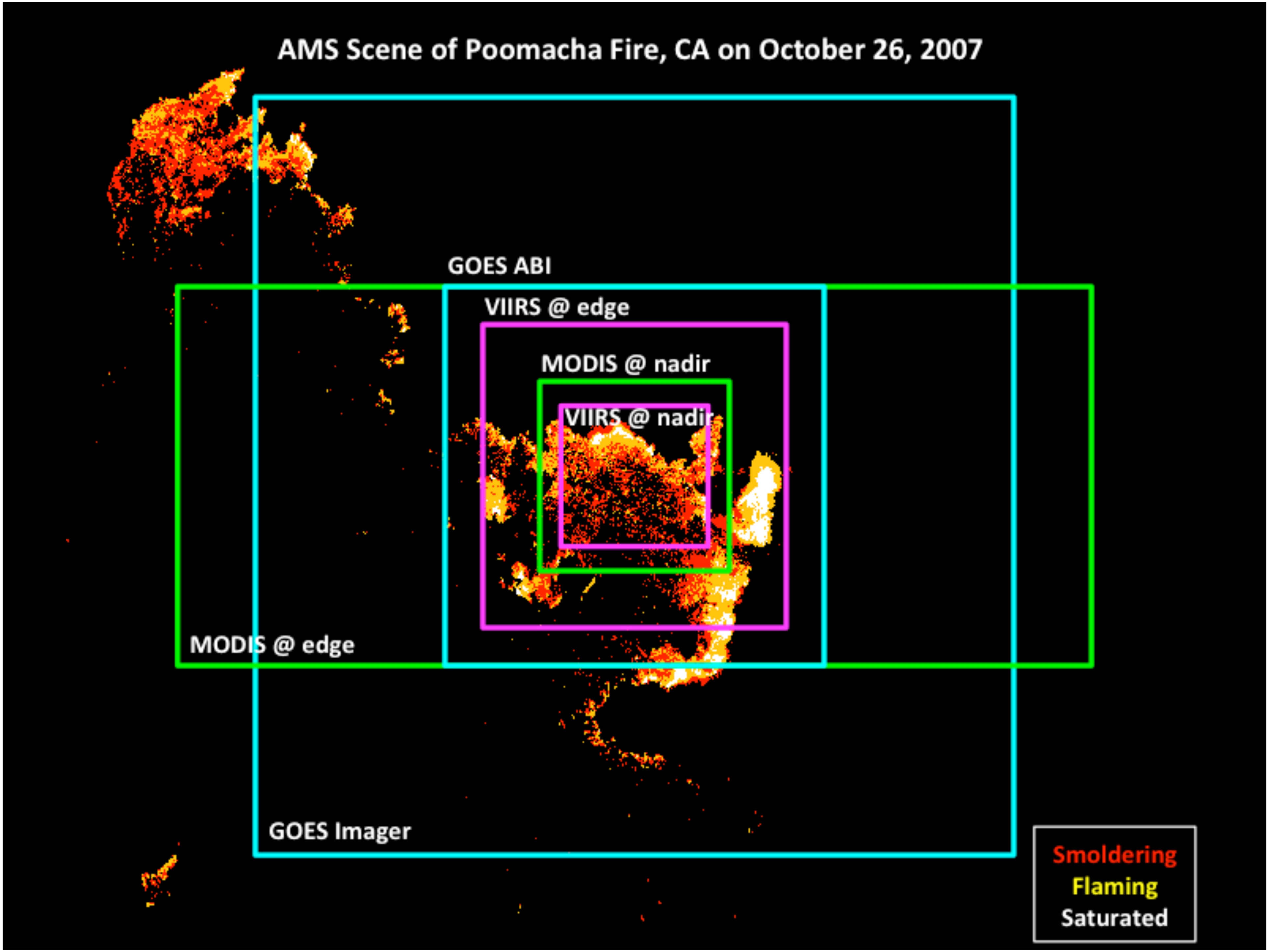


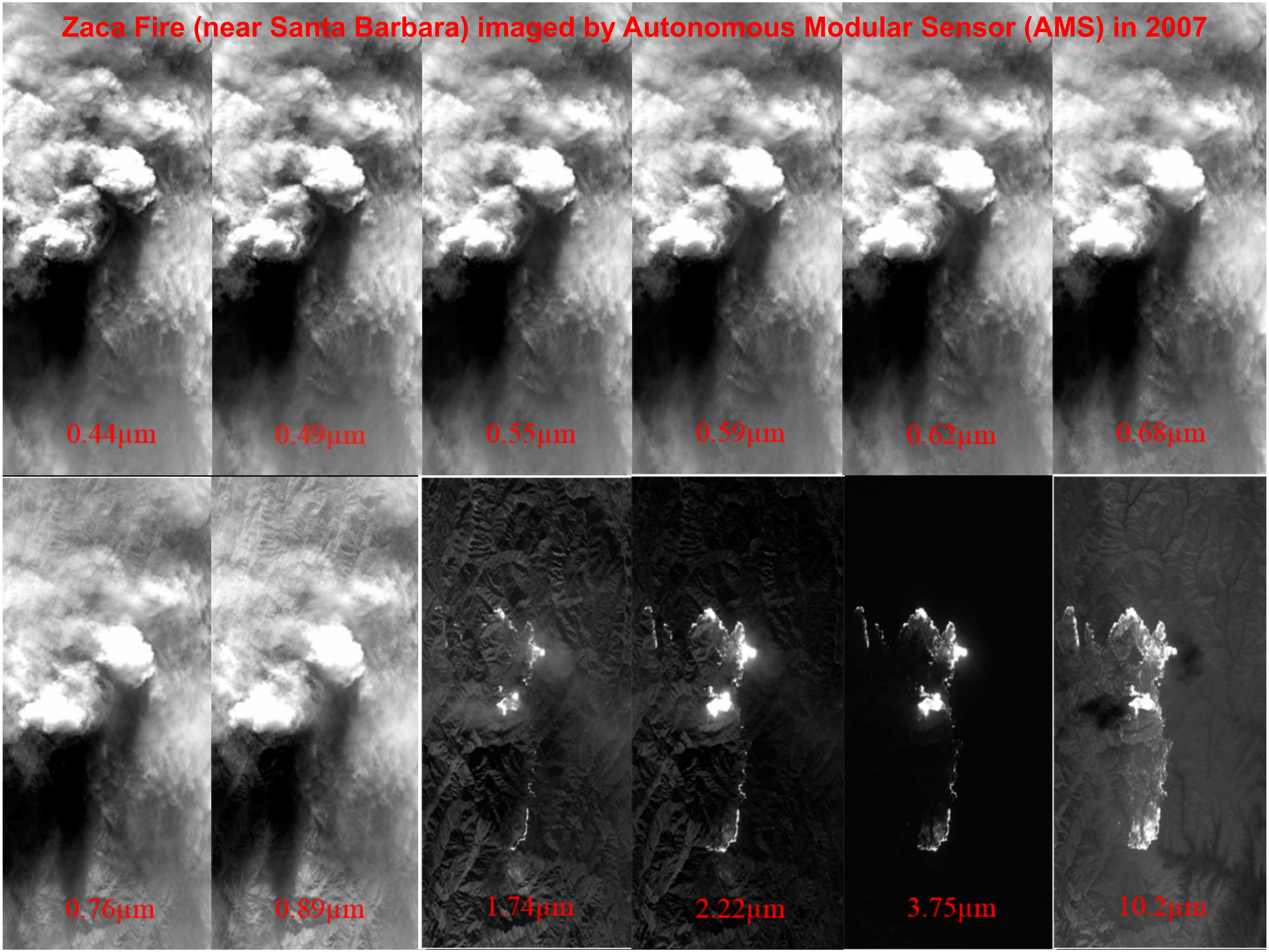
Aqua-MODIS: LocalTime=1:25 pm, Scan Ang=51°, Npix=5, Total FRP=4814* MW



Analysis and Visualization by Luke Ellison

*This value is after removing duplicates


AMS Scene of Poomacha Fire, CA on October 26, 2007
GOES ABI
VIIRS @ edge
MODIS @ nadir
VIIRS @ nadir
MODIS @ edge
GOES Imager
Smoldering
Flaming
Saturated



Zaca Fire (near Santa Barbara) imaged by Autonomous Modular Sensor (AMS) in 2007
0.44µm
0.49µm
0.55µm
0.59µm
0.62µm
0.68µm
0.76µm
0.89µm
1.74µm
2.22µm
3.75µm
10.2µm