A fire emission plume injection height parameterization

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Thanks to Yang Chen and James Randerson (University of California, Irvine)

The University Of Sheffield.

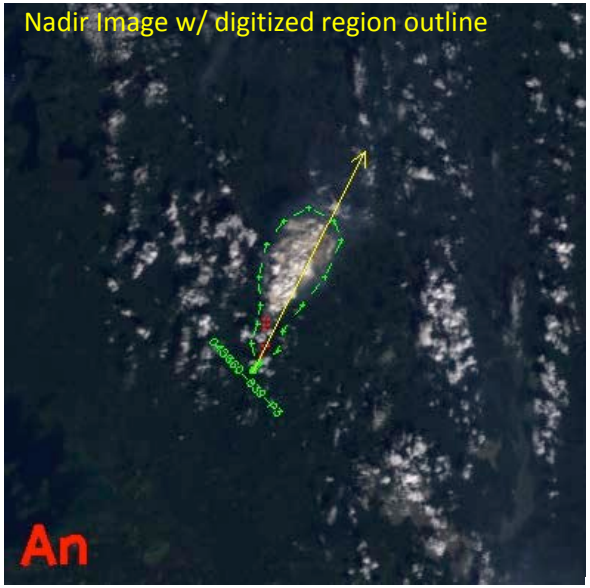
Modeling Wildfire Smoke Injection Heights

Many fire emission injection height parameterizations are currently being used in CTMs:

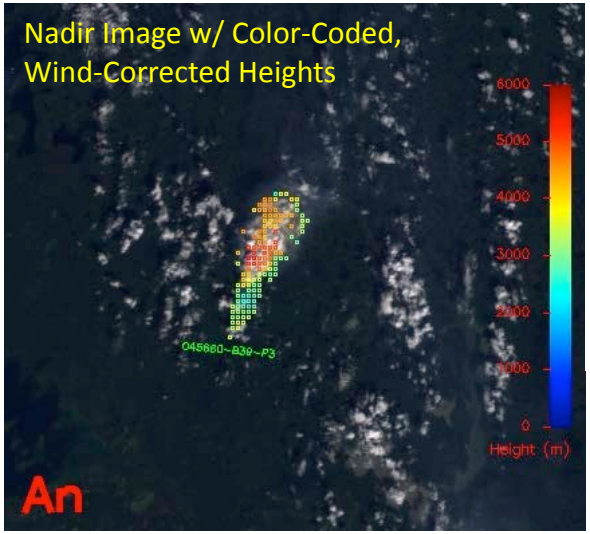
- Emissions released initially within the BL mixed throughout the troposphere, or pre-selected fraction above/below BL
- Emissions released at specified altitudes based on an empirical height-fire intensity and atmospheric stability relationship (e.g., Sofiev et al., 2012)
- Embed sub-grid plumerise model schemes (e.g., Freitas et al., 2007)

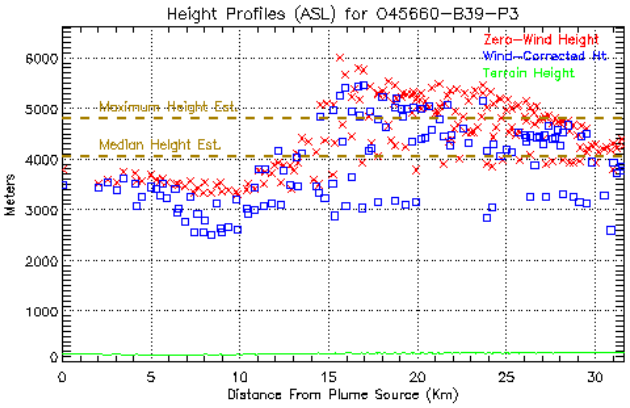
But, many models use fire smoke injection heights based on almost no data, and modeling fire emission injection heights is still a topic of debate (e.g., Paugam et al., 2015, Veira et al., 2015)

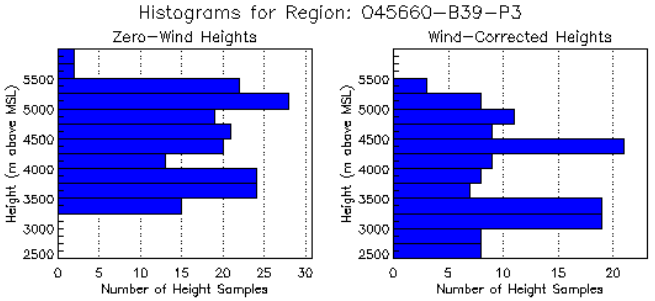
Plume digitized with the MISR INteractive eXplorer (MINX)



July 18, 2008 Canada

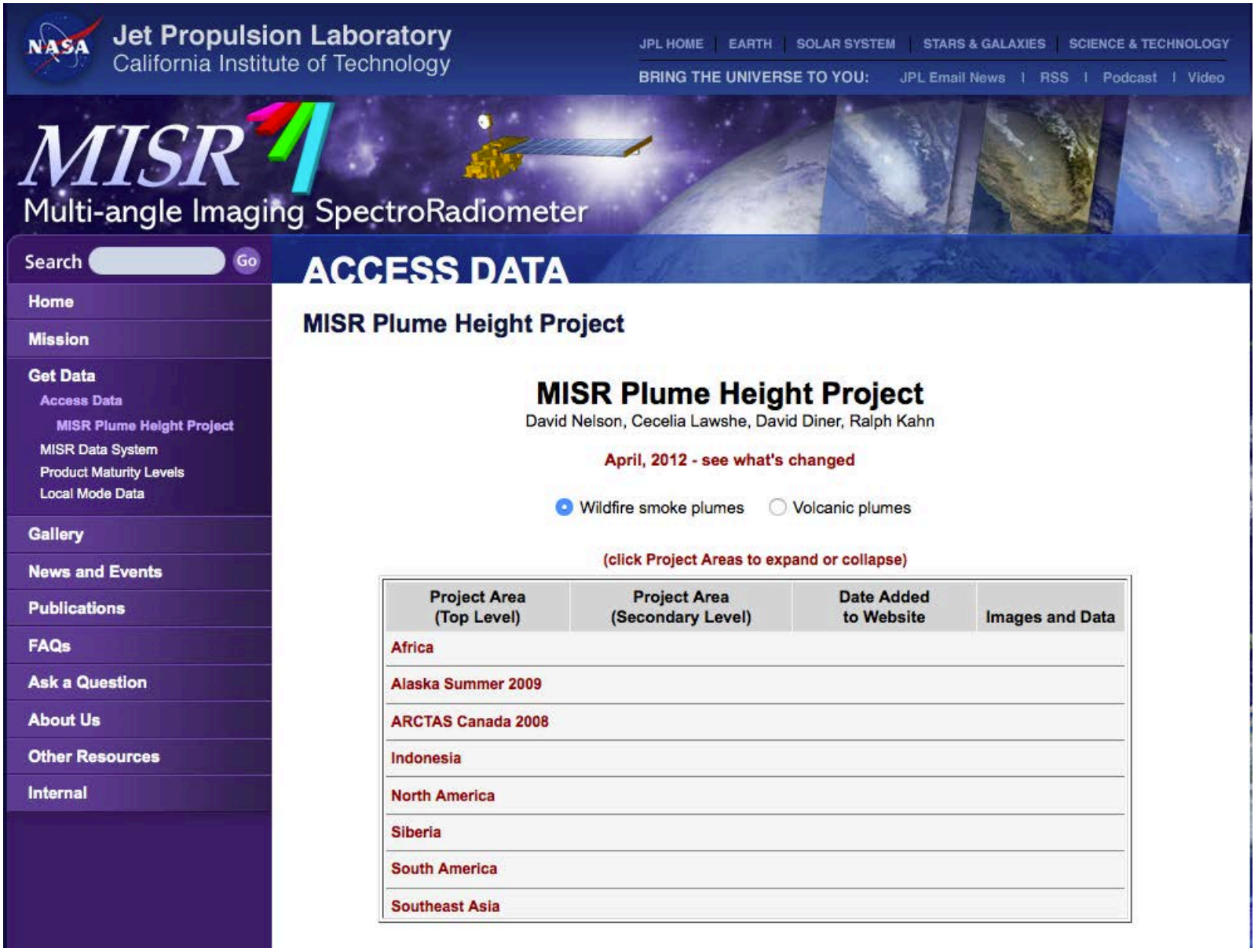






[Slide from Mariya Petrenko]

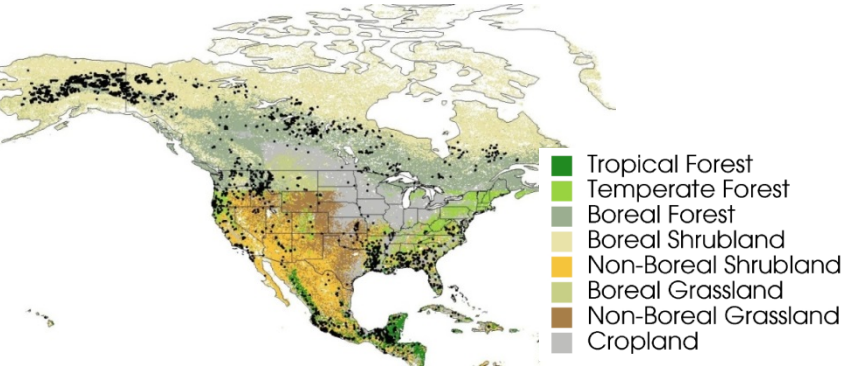
MISR Plume Heights Climatology



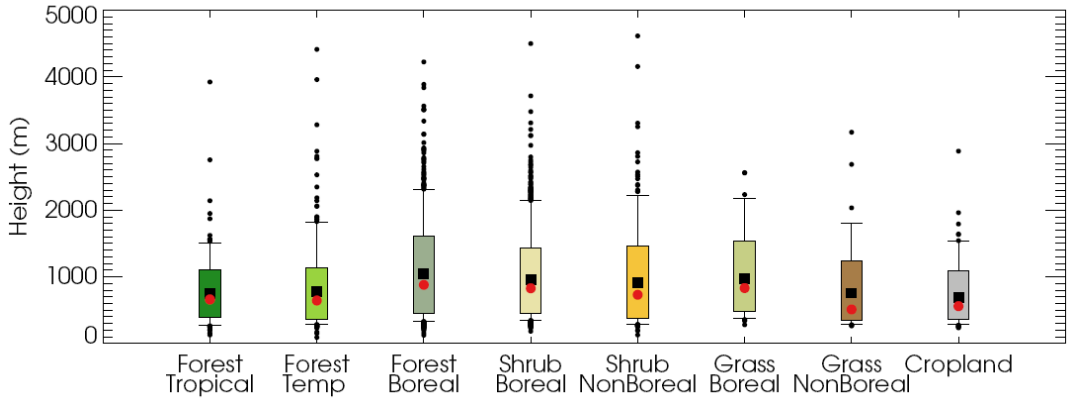
https://www-misr.jpl.nasa.gov/getData/accessData/MisrMinxPlumes/#

Some results of MISR plume height analysis

5-yr record of plume heights over North America



MISR Plume Median Heights by Vegetation



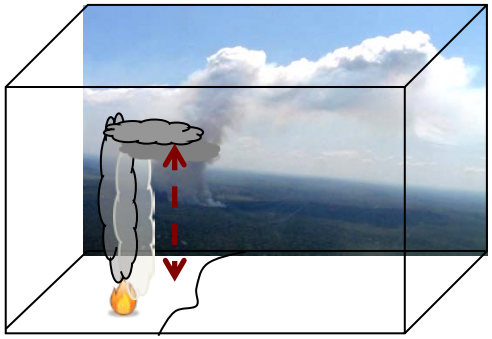
- **Large variability of smoke injection heights**
- **Important fraction (5-40%) of plumes inject smoke into the free troposphere**
- **Smoke plume rise is associated with fire intensity and atmospheric stability**

[Val Martin et al., 2010]

See also,

- Tosca et al., (2011) for Borneo and Sumatra
- Jian et al., (2013) for southeast China
- Mims et al., (2010) for grasslands in Australia

EVALUATION OF A 1D PLUME-RISE MODEL: TOWARDS A PARAMETERIZATION OF SMOKE INJECTION HEIGHTS



Freitas et al., [2007, 2010]

Buoyancy Flux:

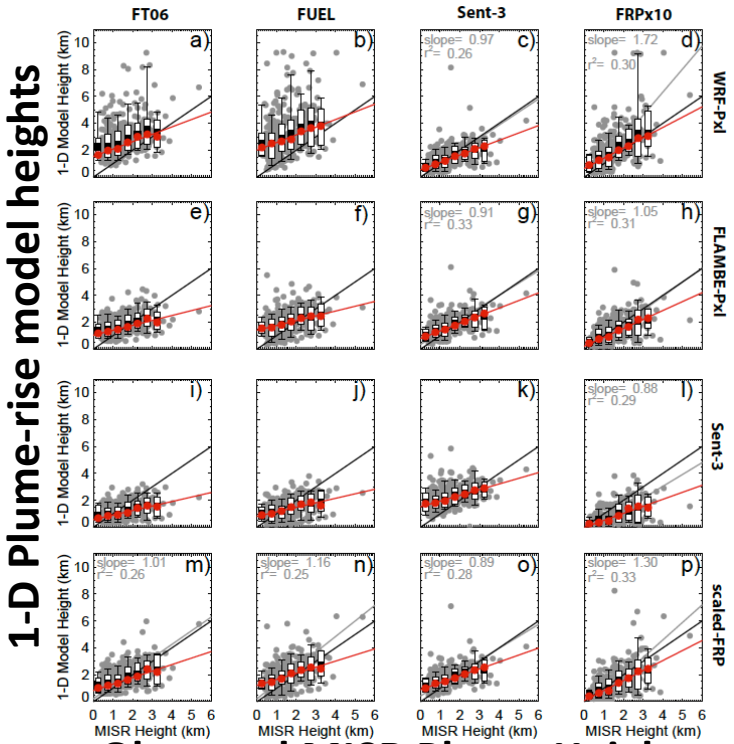
$$F = \frac{g\Re}{c_p p_e} E R^2$$

Radius of Fire

Fire Energy

Heat Flux Options →

Active Fire Area Options ↓



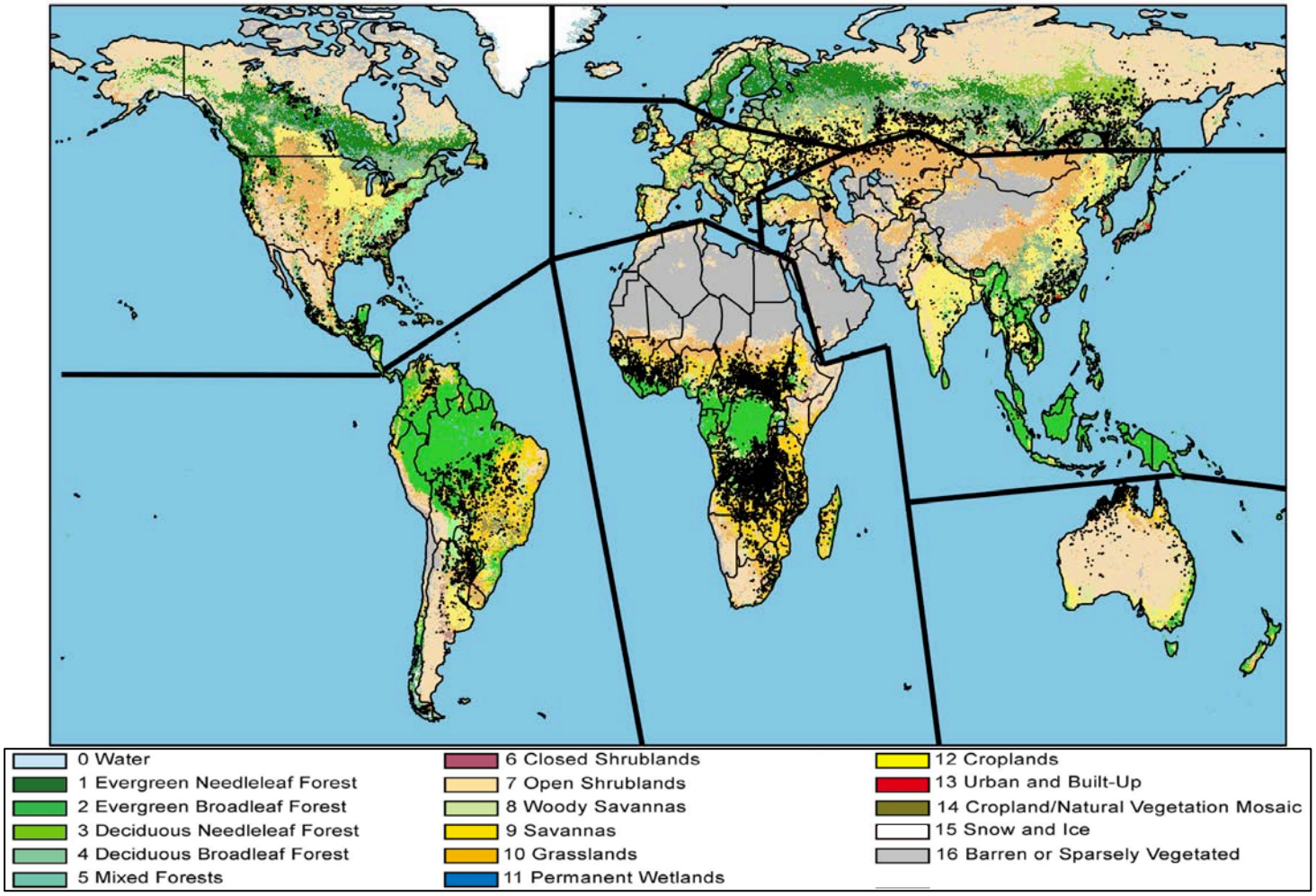
The model has a lower dynamic range than observed, but very variable depending on the fire inputs used

Key factors for plume rise:

- **Fire Energy ↔ FRP**
- **Atmospheric Stability**
- ***[Entrainment]***

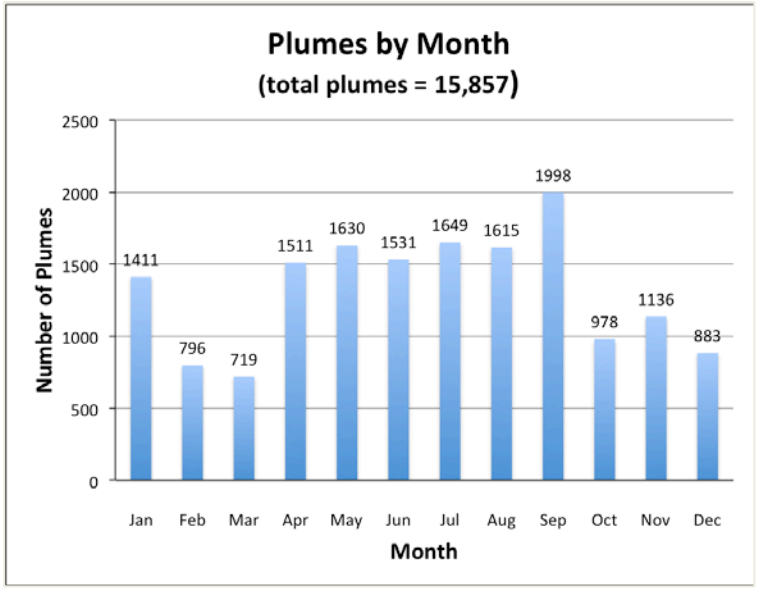
[Val Martin et al., 2012]

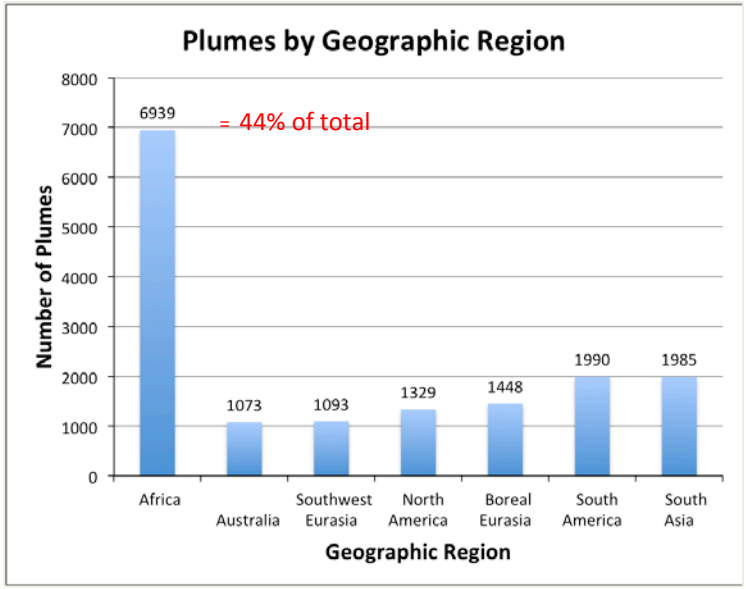
AeroCom BB Phase II: Emission Injection Height
New MISR stereo-derived plume heights dataset 2008

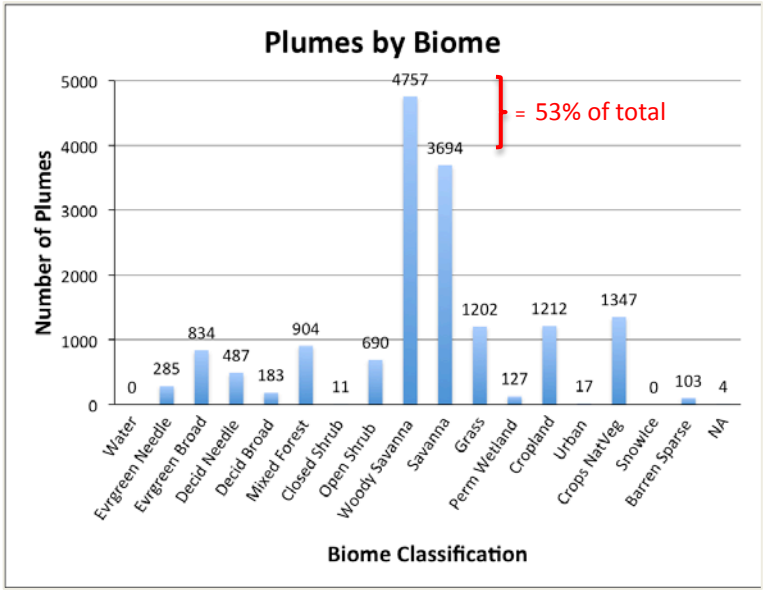


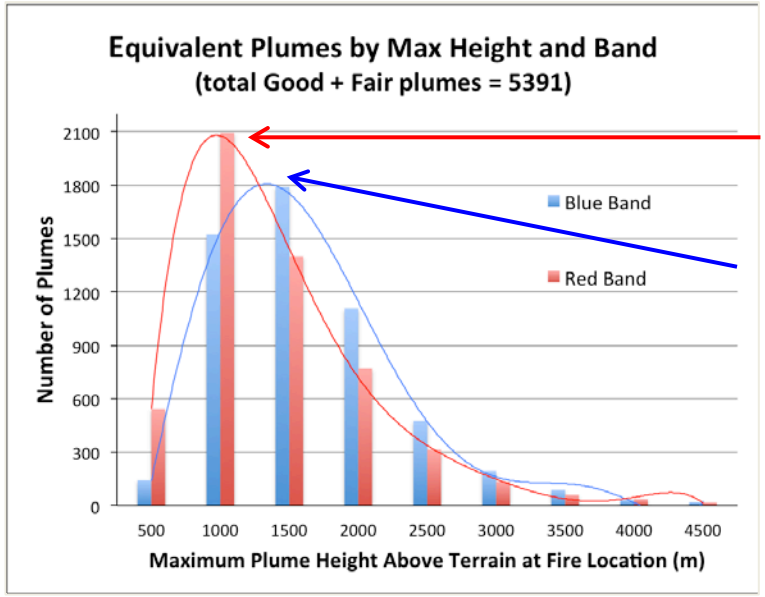
- 15,857 smoke plumes digitized for full 2008
- Each plume is operator-processed using MINXv4.0, and QC'd
- Raw, graphics and summary files, and documentation will be available on-line

Global 2008 Statistics







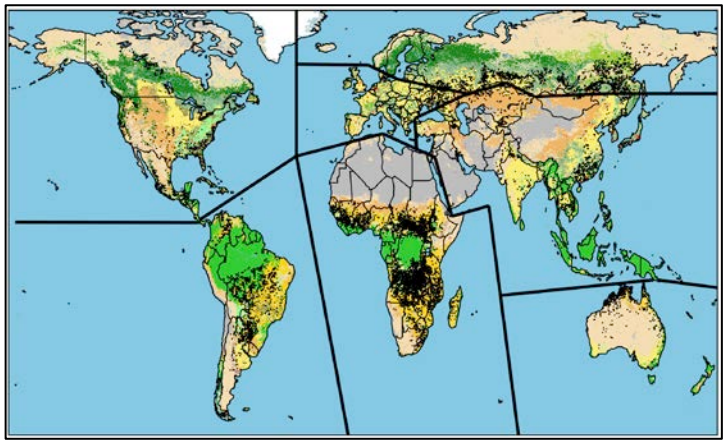


Mode of red band max ht ~= 700 m

Mode of blue band max ht ~= 1050 m

[Slide from David Nelson]

Developing a fire smoke injection height parameterization with new MISR stereo-derived plume heights and GFEDv4



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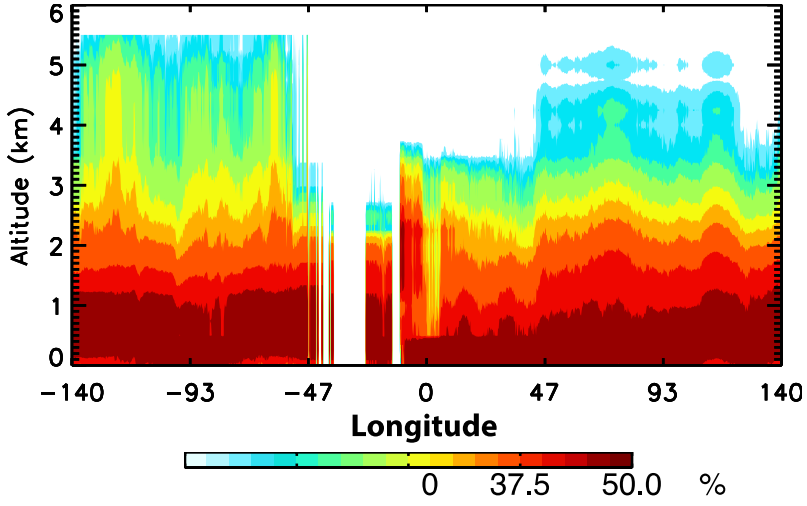
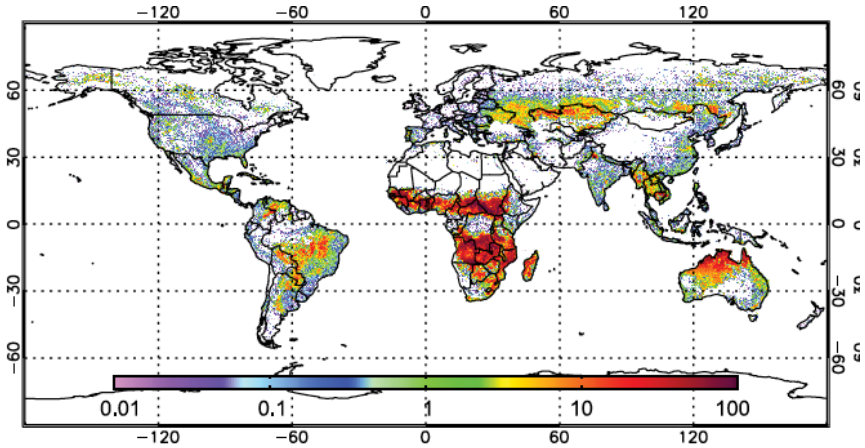
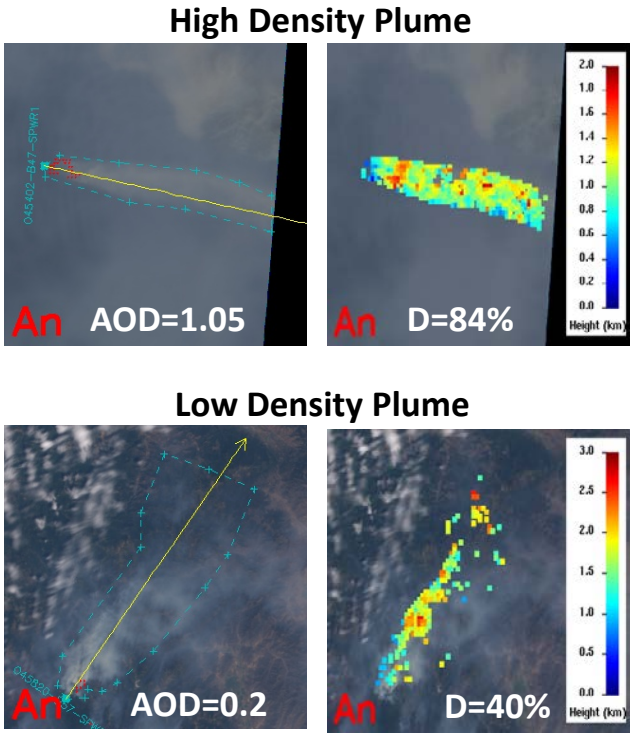


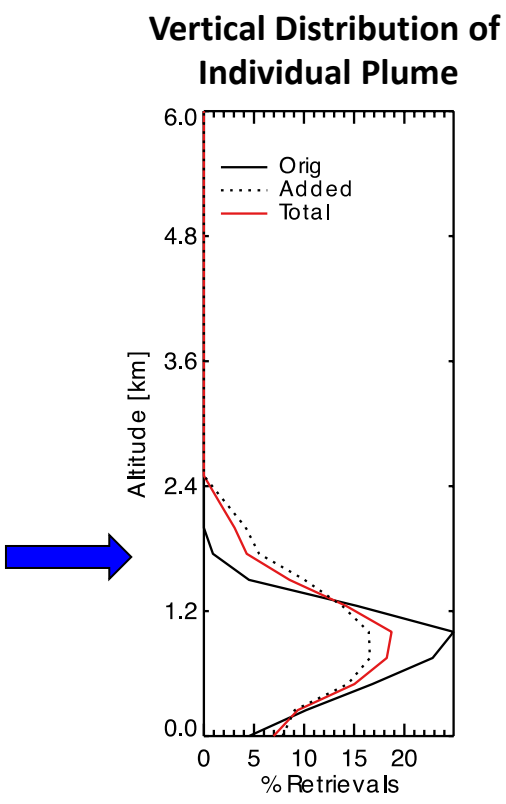
GFED average annual burned (fraction/yr)
(small and large fires)

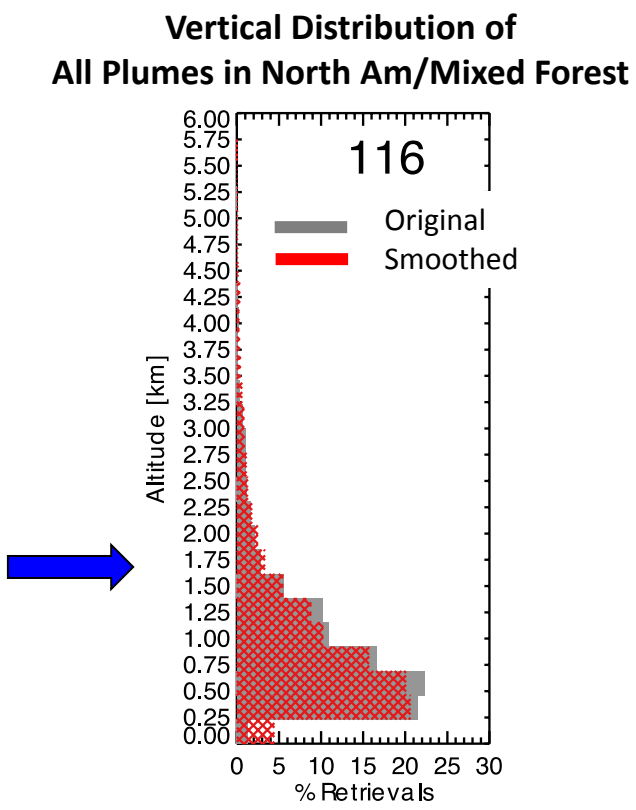


Randerson et al., (2012)

Considered only good/fair quality plumes and smoothed out plumes with low stereo-height retrieval densities

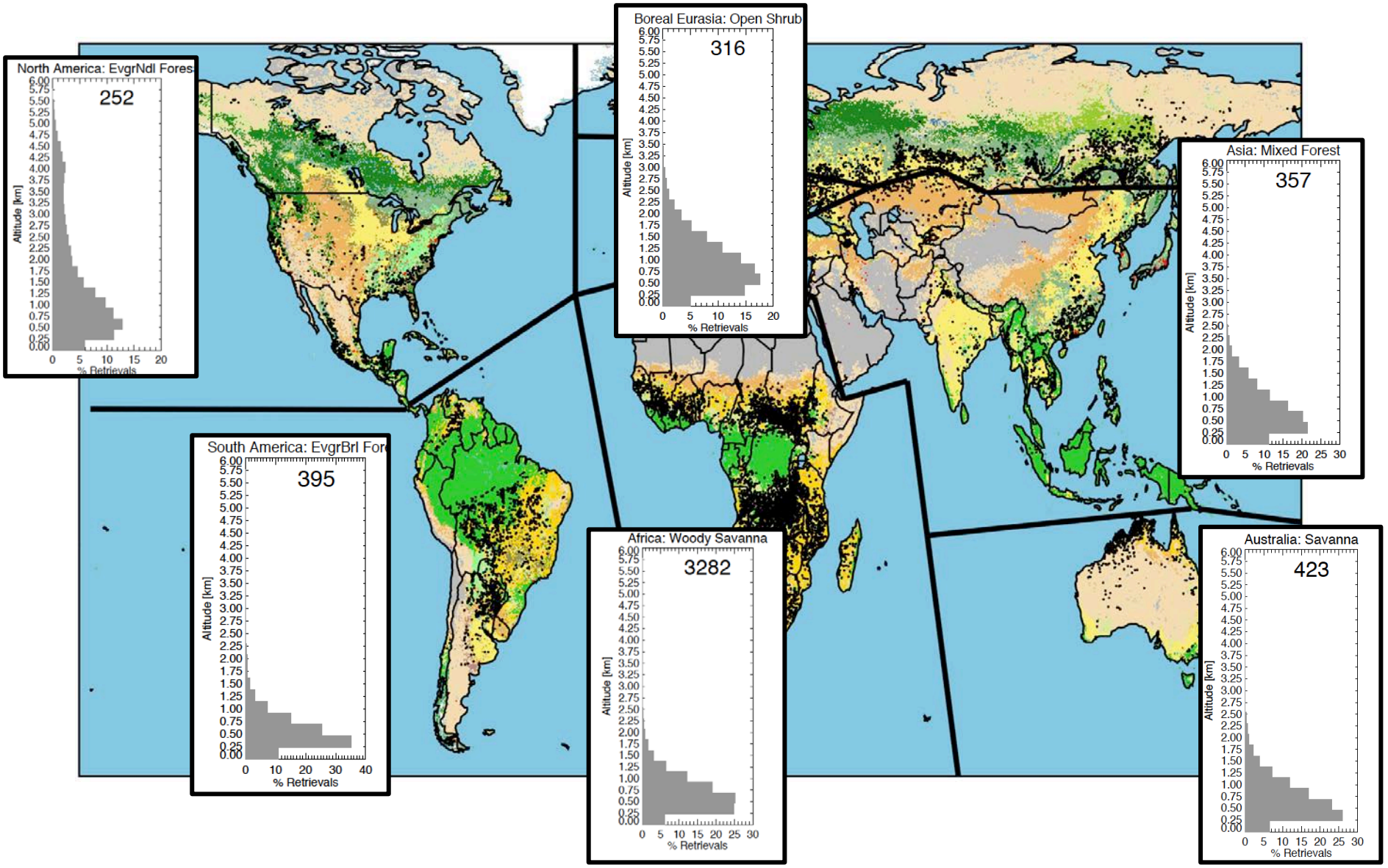




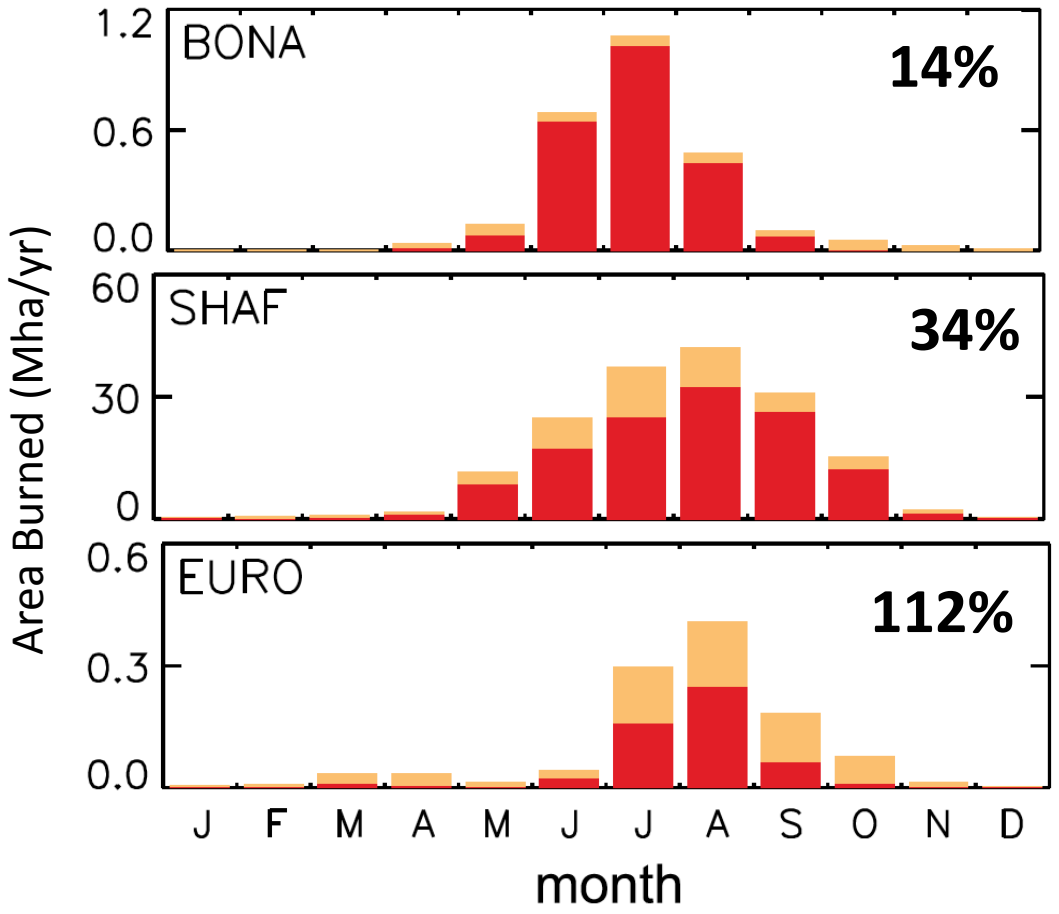


- Removed plumes digitized with a bad quality flag. Used a total of 13,800 plumes
- Low number of stereo heights retrieved in plumes with low density is associated with poor optical quality, rather than the non-presence of smoke
- Filled the non-retrieved height points within the plume adding points randomly sampled from a distribution that best fits the retrieved height points

Examples of vertical distribution of injection heights across regions and biomes



Small fires are typically not considered in global area burned inventories, but they can be significant

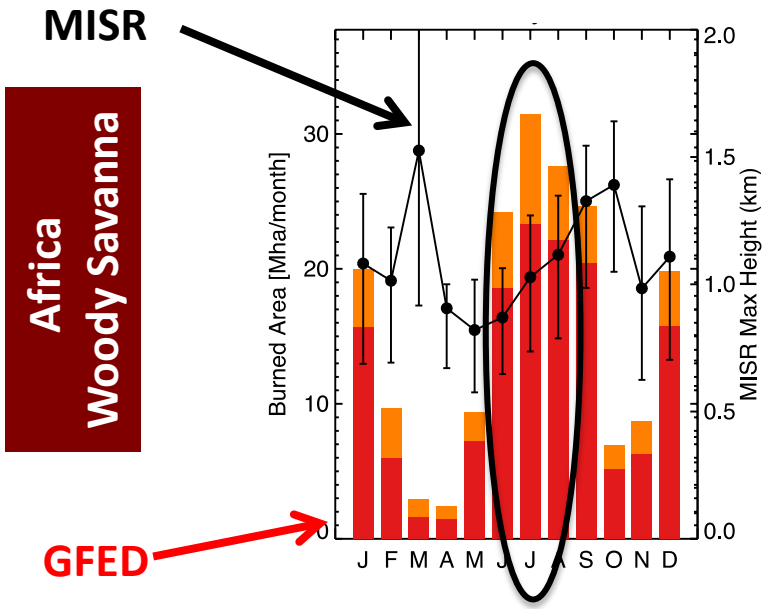


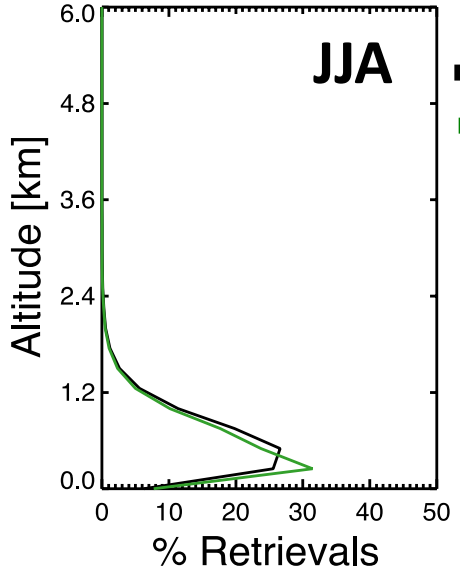
Randerson et al., (2012)

MINX cannot digitize many small fires because the plume-related features at about kilometer scale are not visible at multiple angles

Adjusted the MISR vertical distribution smoke heights to take into account small fires and seasonality

Africa Woody Savanna

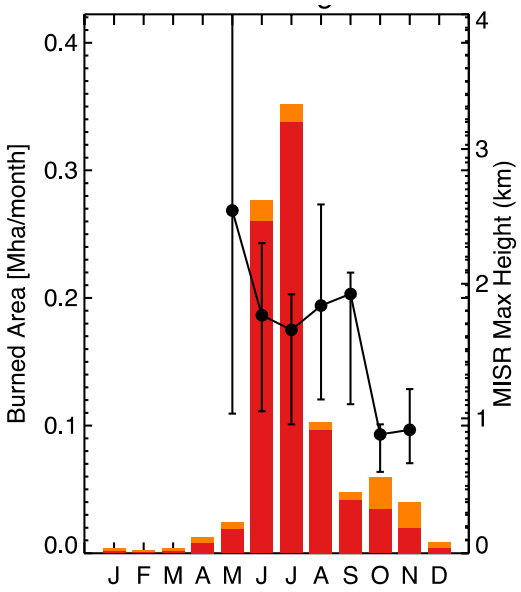


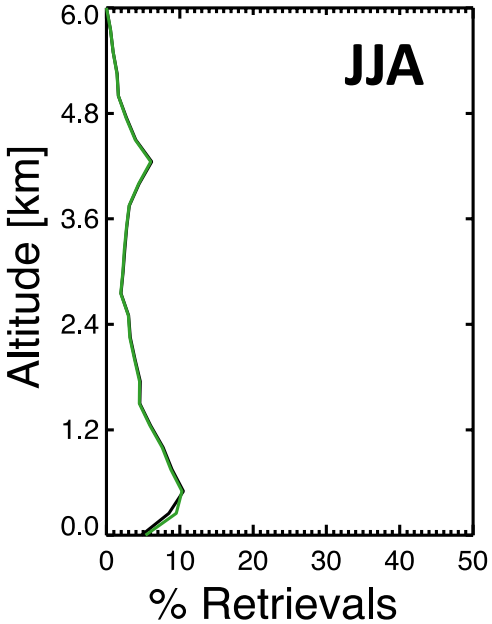


MISR Original

MISR Adjusted for small fires

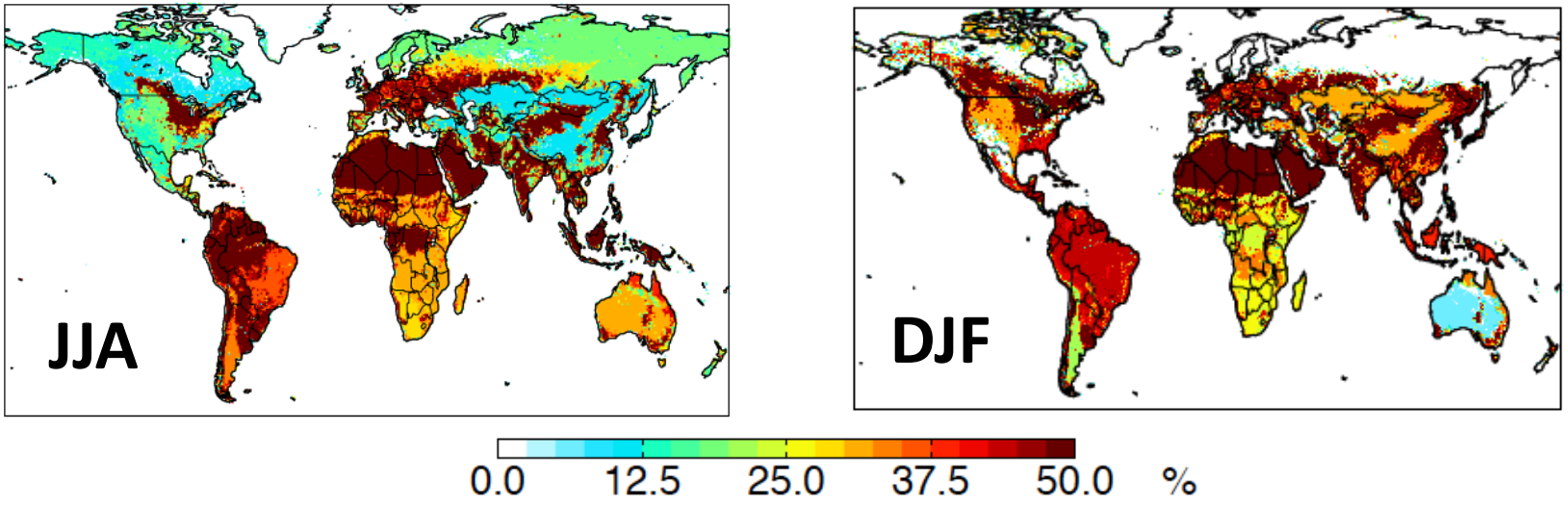
North America Evergreen Needleleaf Forest



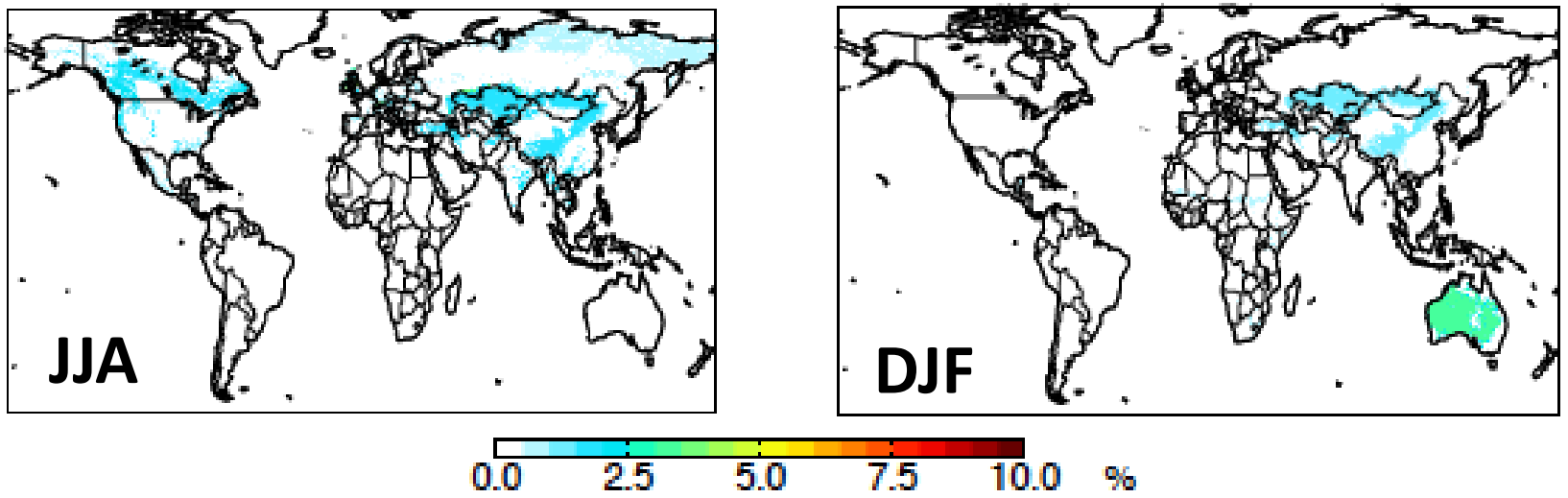


Percentage smoke injected into each layer, stratified by region and season

Near Surface (0-250 m)



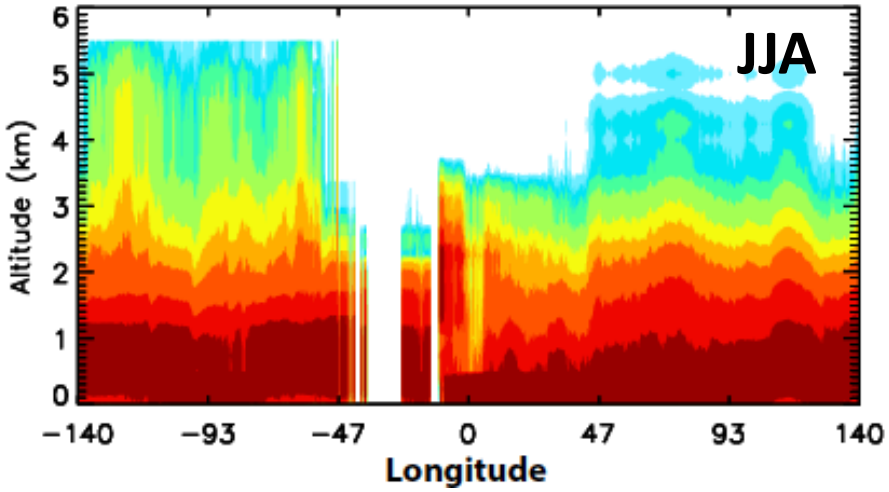
Elevated Injection (2750-3000 m)

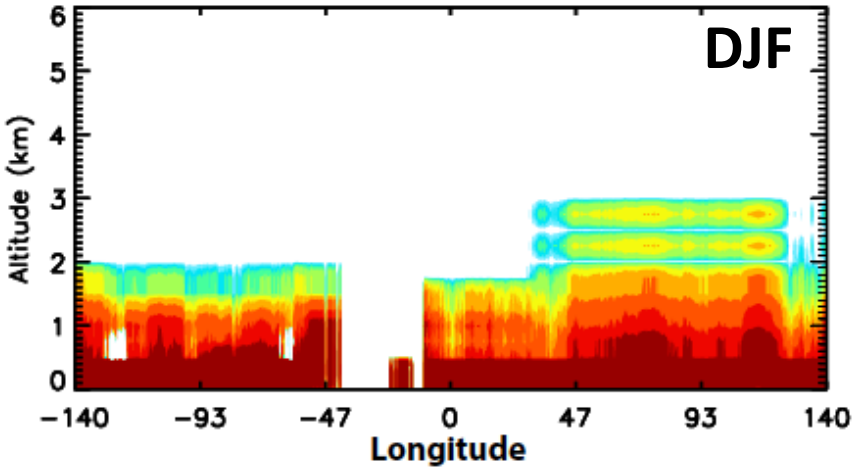


NOTE: For crop, desert and urban fires considered injection heights from 0 to 500 m

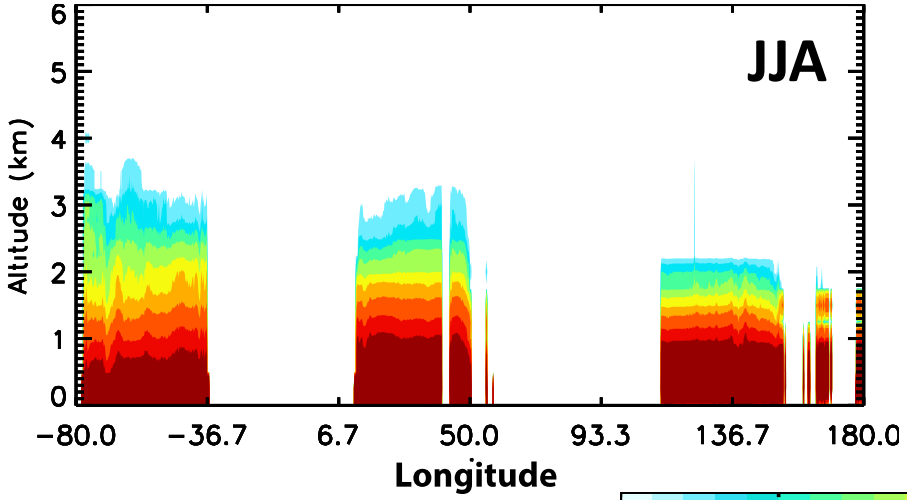
Percentage zonal mean smoke injected into each layer, stratified by region and season

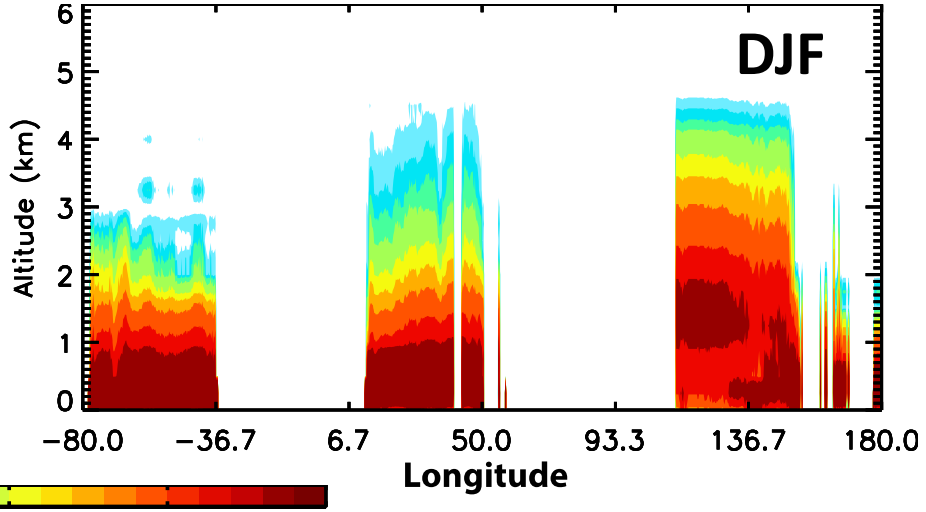
Northern Hemisphere (40-60 N)





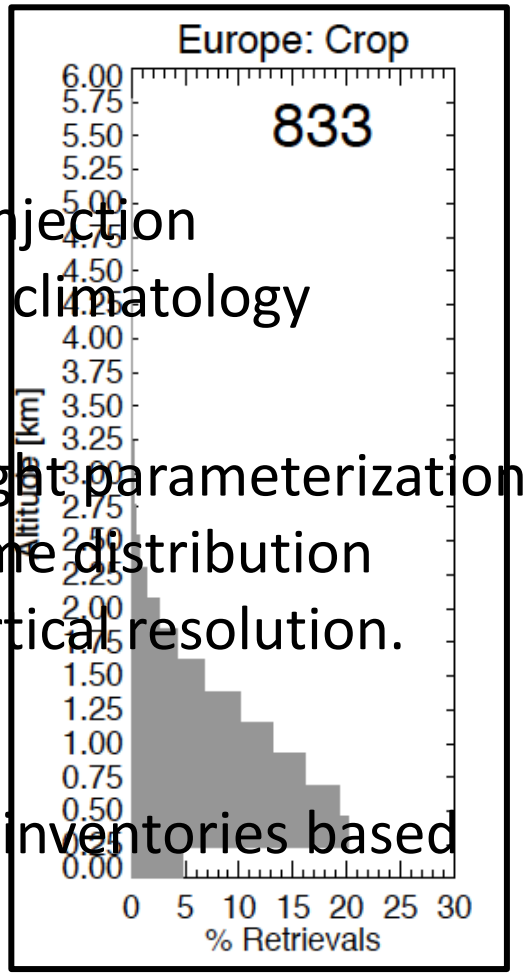
Southern Hemisphere (10-30 S)





Final remarks

- Revise parameterization to include more accurate vertical distribution of crop fire emissions.
- Adjustment for the presence of pyrocumulus
- Evaluate interannual variability of smoke fire injection heights using the available MISR plume height climatology



- Propose to deliver the fire smoke injection height parameterization by lat/lon/nlev/month following the GFED biome distribution (MODIS) at 0.25x0.25 horizontal and 250 m vertical resolution.
- Feasibility of this approach for other emission inventories based on FRP (e.g., GFAS, QFES)

SUGGESTIONS/COMMENTS?

Seasonality is important for fire smoke injection Heights, in some biomes