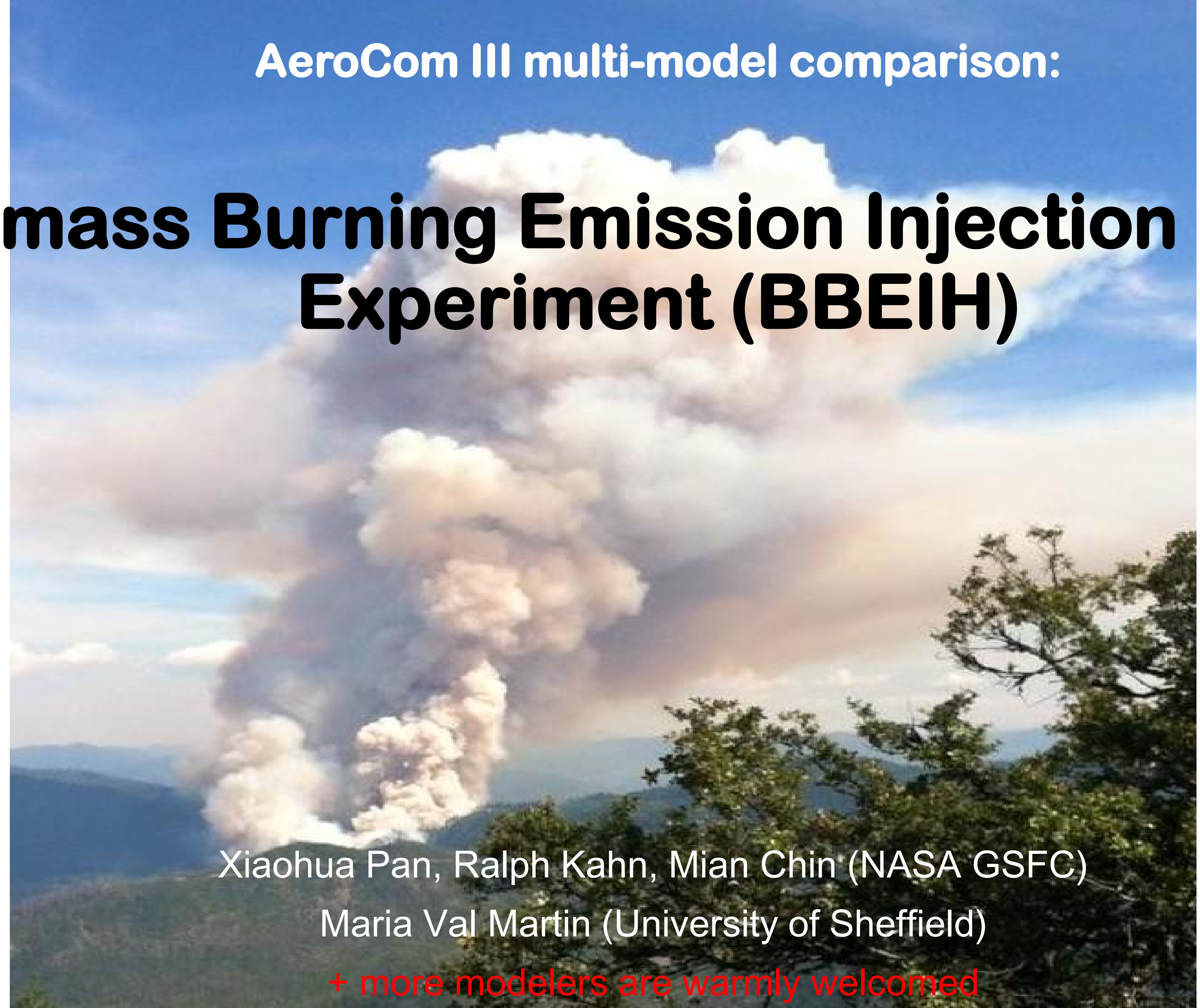
AeroCom III multi-model comparison:

Biomass Burning Emission Injection Height Experiment (BBEIH)



Xiaohua Pan, Ralph Kahn, Mian Chin (NASA GSFC)

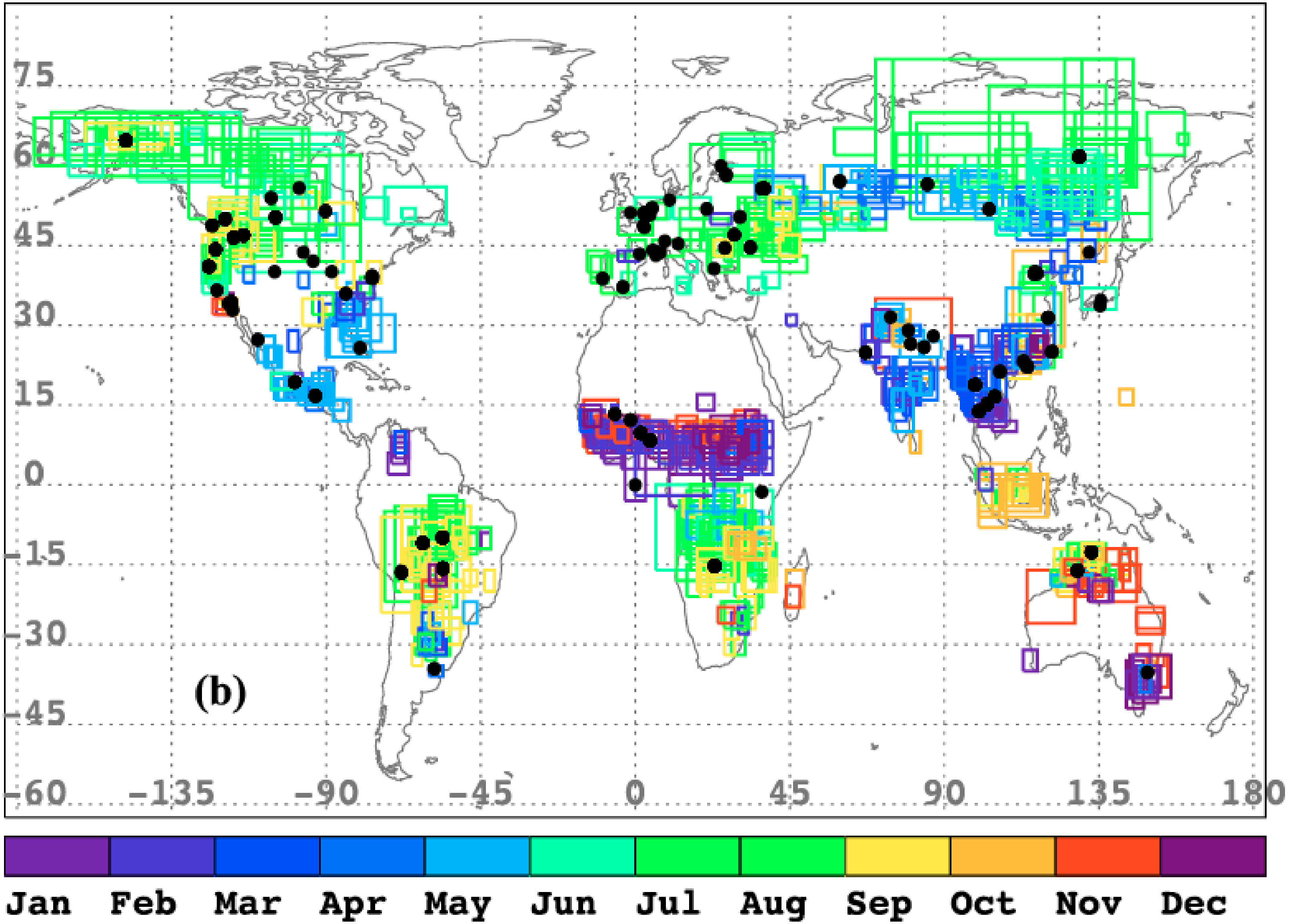
Maria Val Martin (University of Sheffield)

+ more modelers are warmly welcomed

Saddle Fire, CA
June 12, 2015
USFS photo.

Biomass burning cases in 2004, 2006-2008

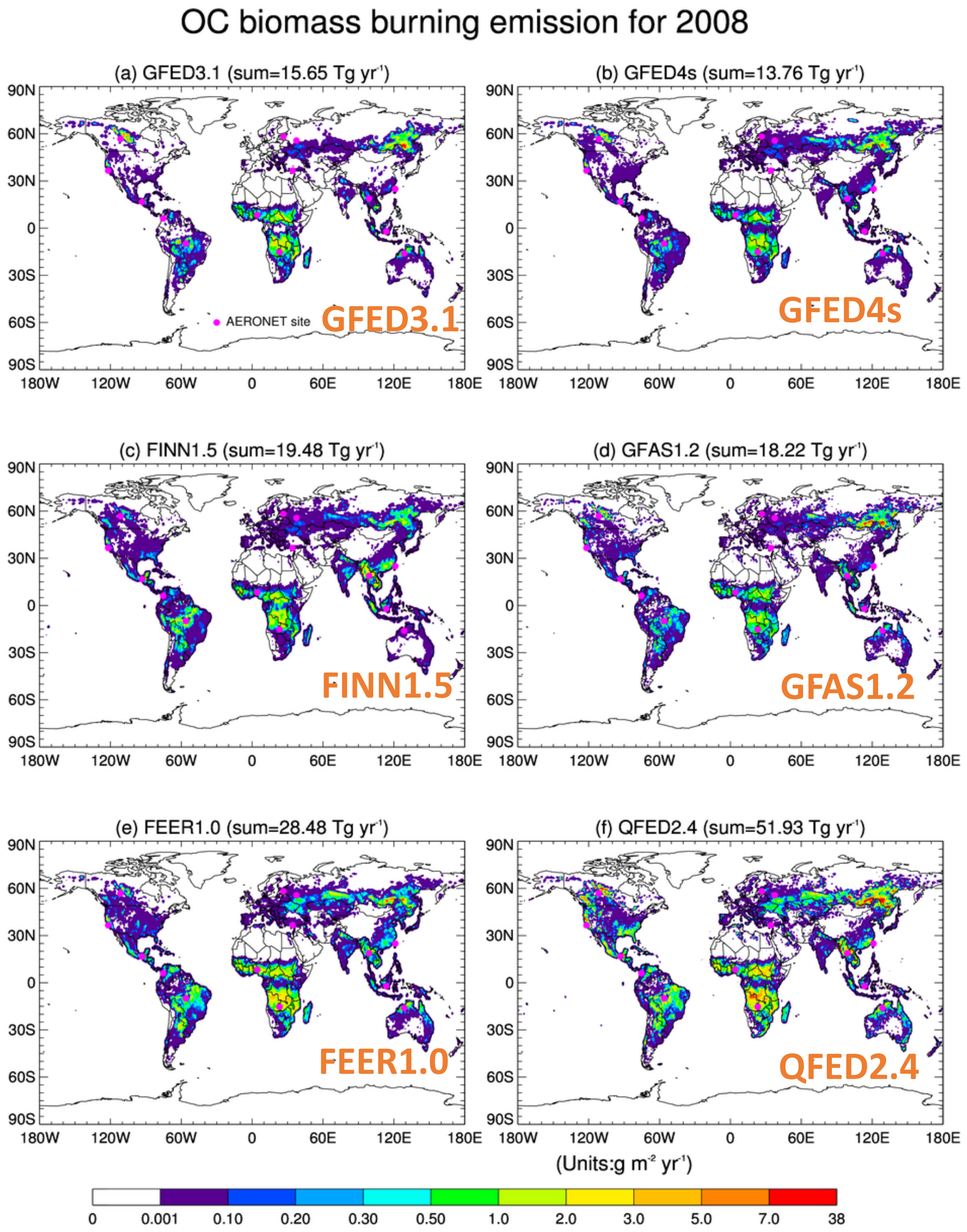
Petrenko et al., 2017



The location and timing of fire occurrences observed by MODIS

Six Global Biomass Burning Emission Datasets

Pan et al., 2019, ACPD

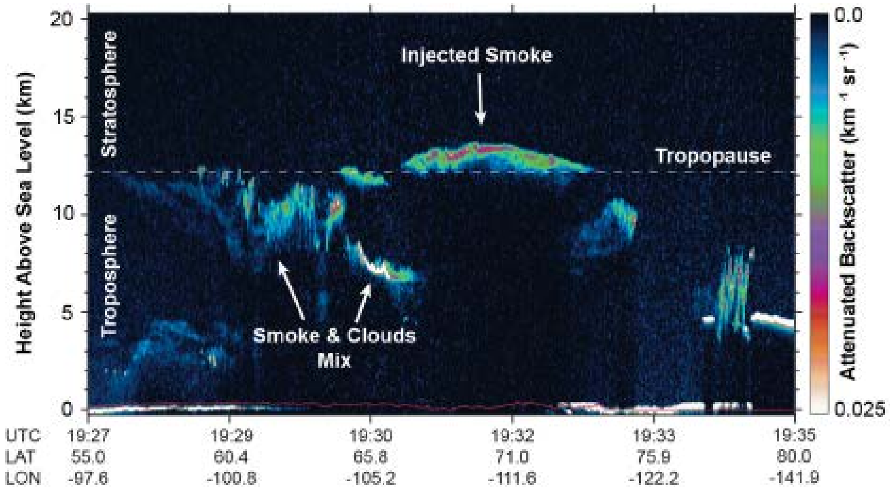


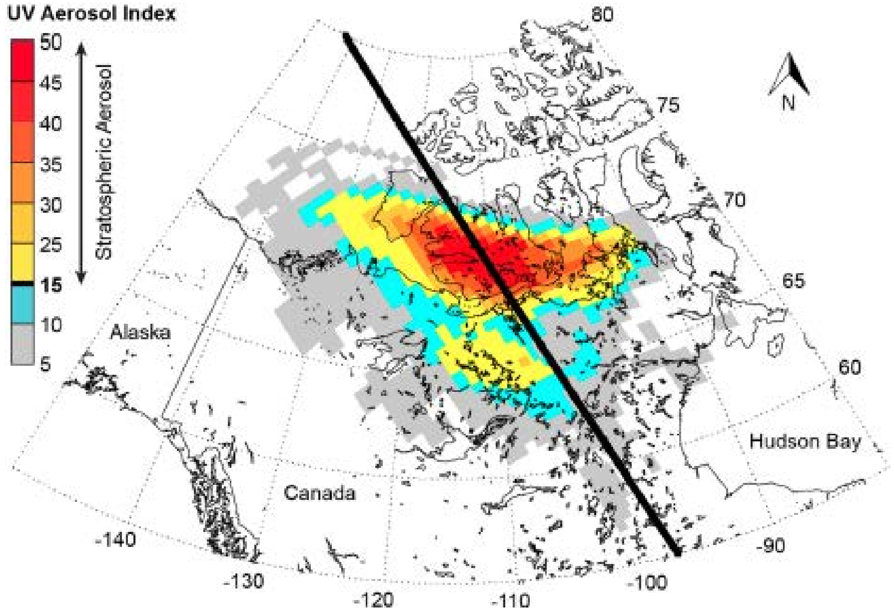
Source strength of
fire occurrences

To assign fire emission correctly is not only about the location, timing, source strength, but also **injection height**!

British Columbia PyroCbs occurred in western Canada on 14 August 2017

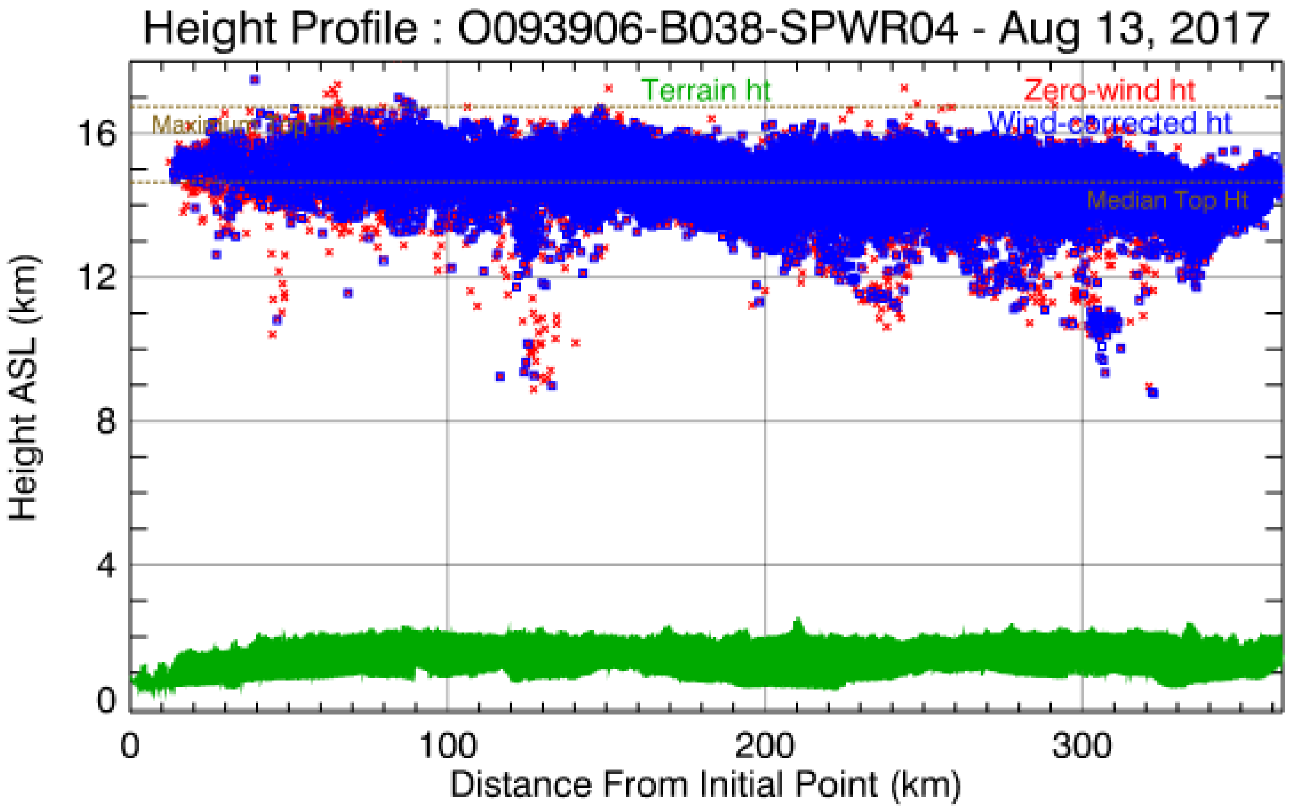
Peterson et al., 2018

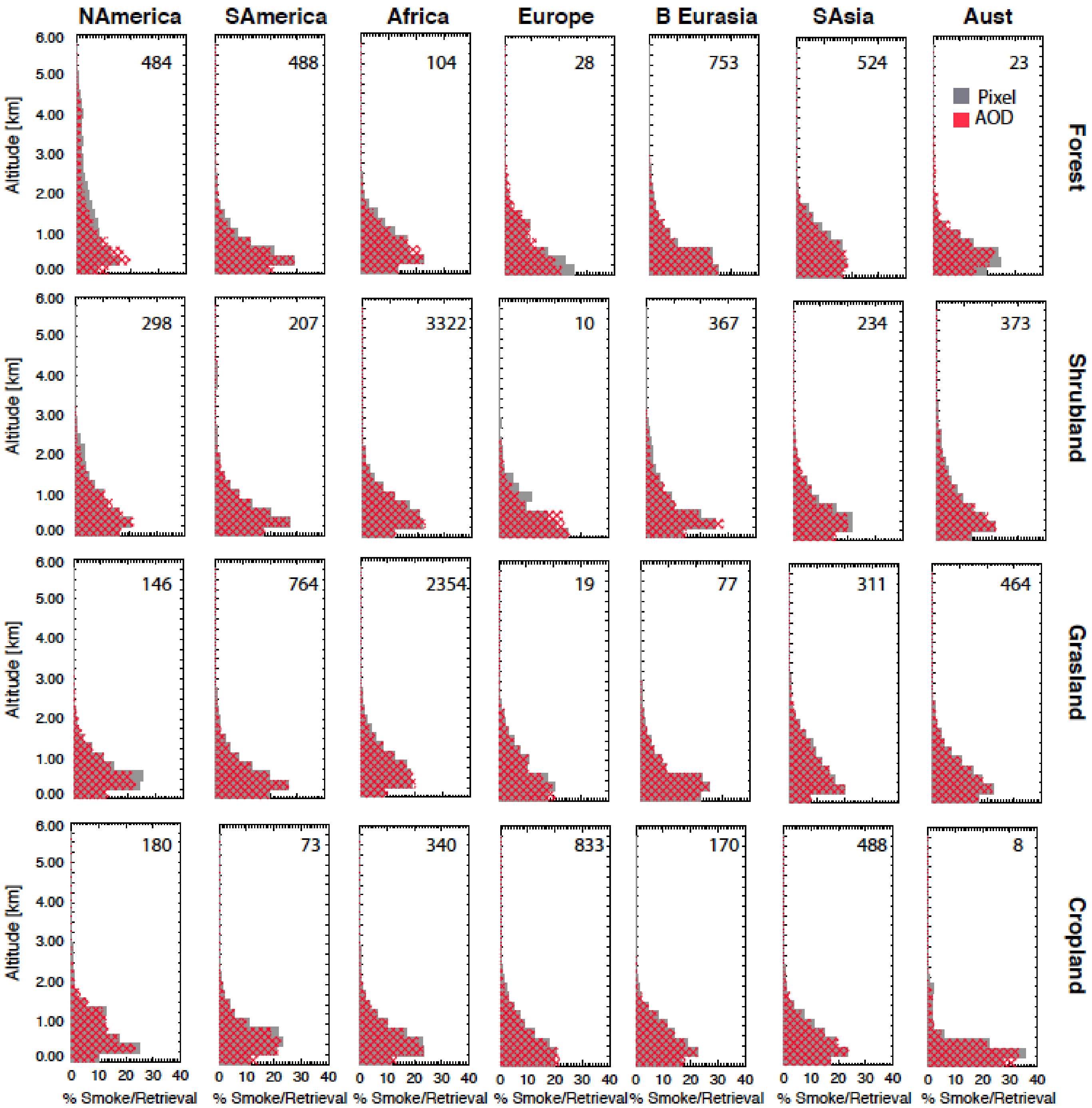




Wildfire-driven thunderstorms cause a volcano-like stratospheric injection of smoke

MISR retrieved fire plume height



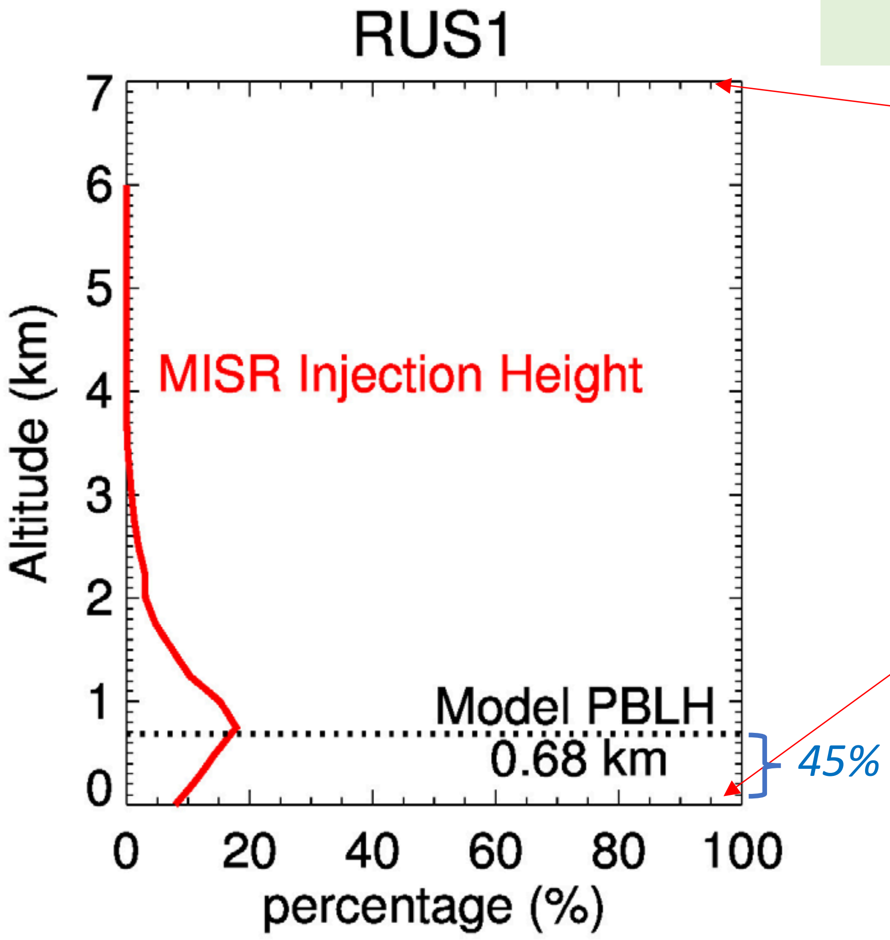


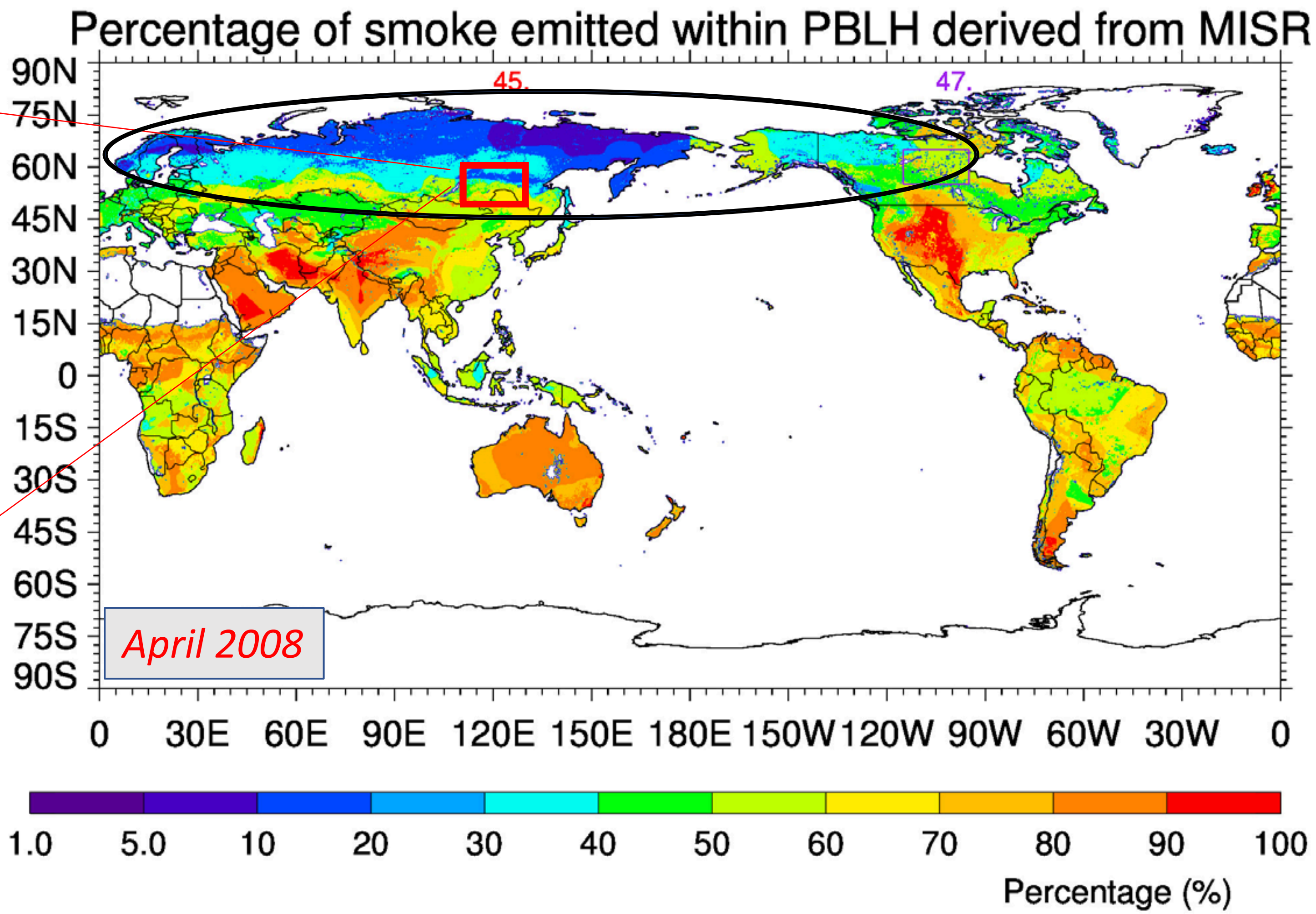
MISR Injection height weighting (i.e., % of emission at each level), stratified by regions, land type (and season) in 2008

Val Martin, Kahn & Tosca; Remt. Sens. 2018

Current limitation of model: NASA GEOS model

Val Martin, Kahn & Tosca; 2018





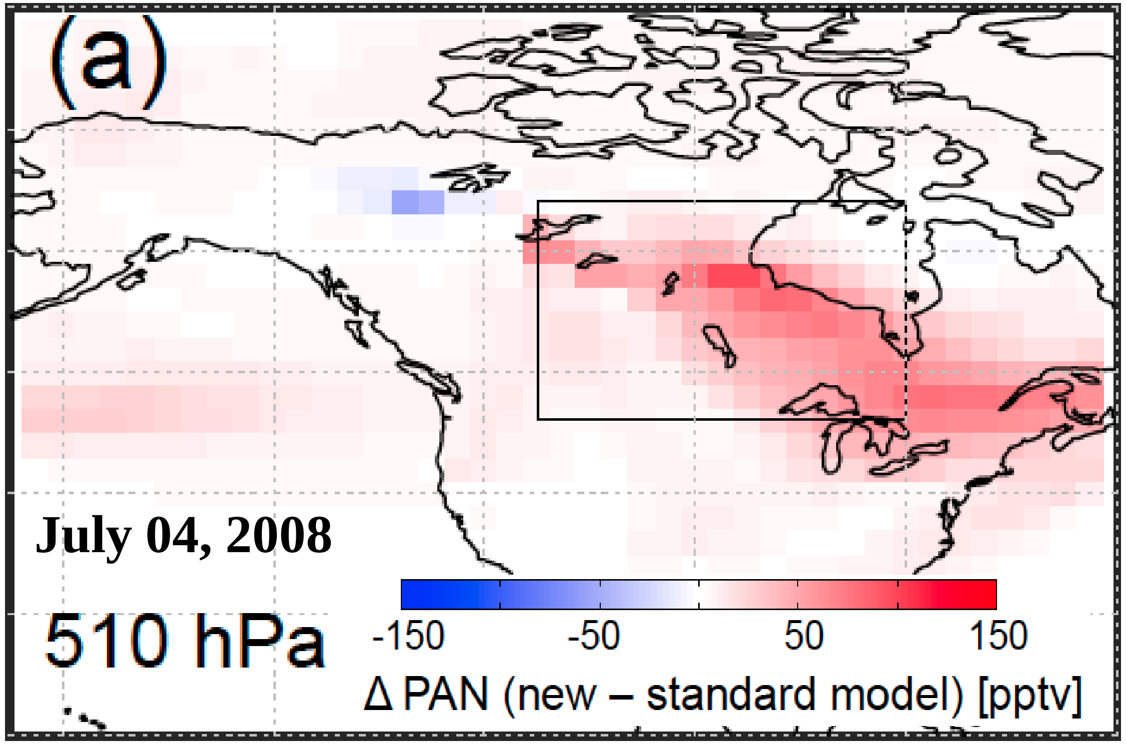
- During April 2008, there are only 45% smoke emitted within PBLH over RUS1
- but by default, the GEOS model emits all smoke within PBLH.

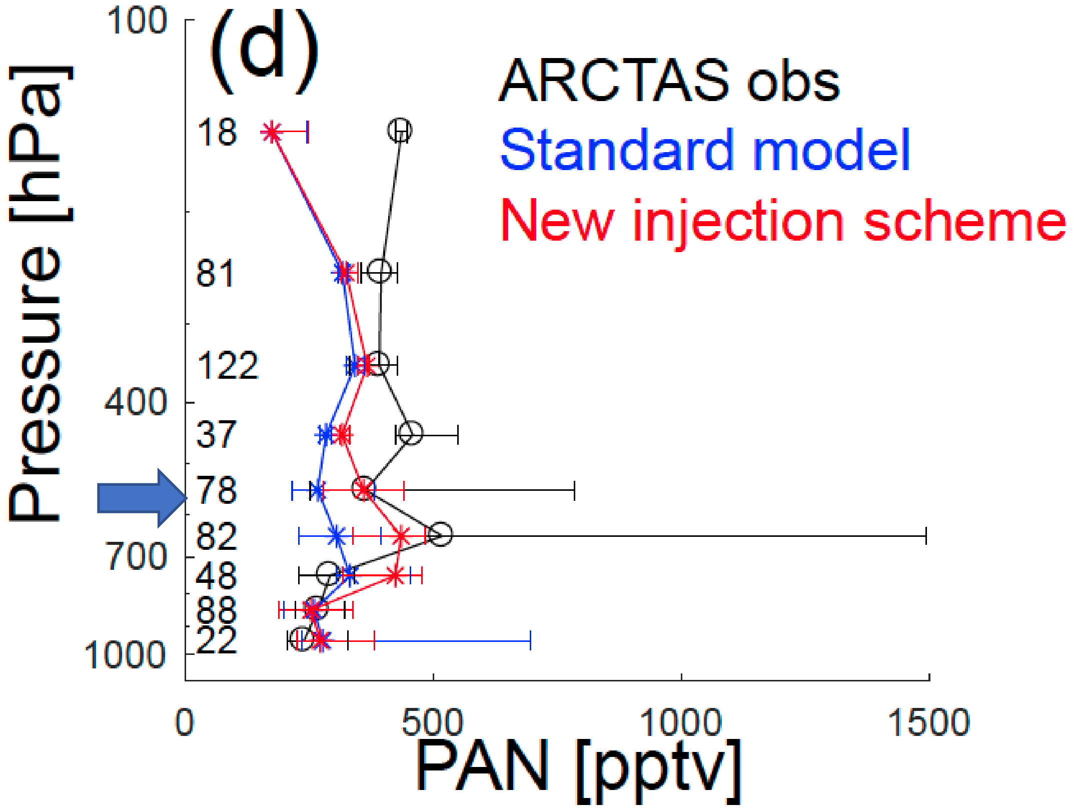
Fire plume injection height matters

Zhu et al., 2018

Implementation of MISR BB emission injection height in *GEOS-Chem* model

Δ PAN = NEW – Standard





Why do we care the heights of smoke emissions?

1. **Chemical processes** within the plume are sensitive to ambient relative humidity, temperature, smoke-cloud interactions, and photolysis rates – all of which depend on smoke injection height (e.g. PAN).
2. Smokes emitted into PBL are **transported** over shorter distances downwind than otherwise into free troposphere;
3. **Surface concentration** of air pollutants near and downwind of fire source are sensitive to the fire plume height;
4. Both **dry and wet removal process** are more efficient in PBL than in the free troposphere;
5. **Aerosol-climate interaction** is sensitive to the vertical distribution of smoke (above, in, or below cloud);

Preliminary results with the NASA GEOS:

Three model experiments:

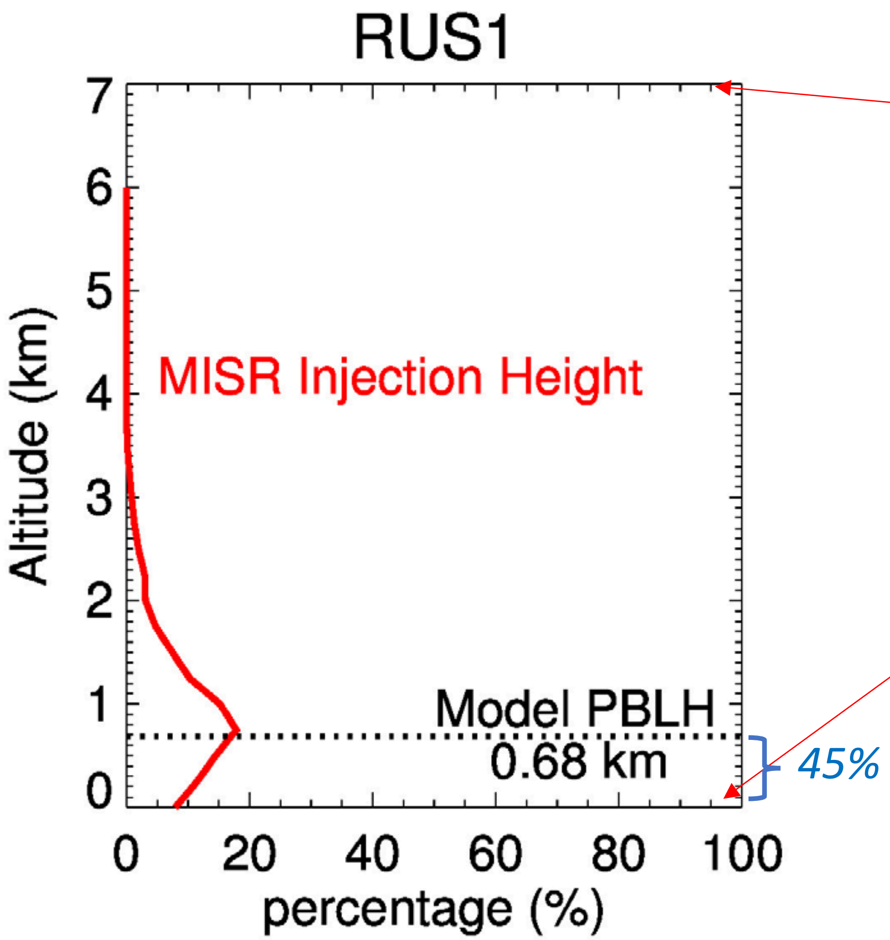
- ❑ **BASE**: all emissions including GFED4.1s, using model-default biomass burning injection height (distributing smoke within PBLH).

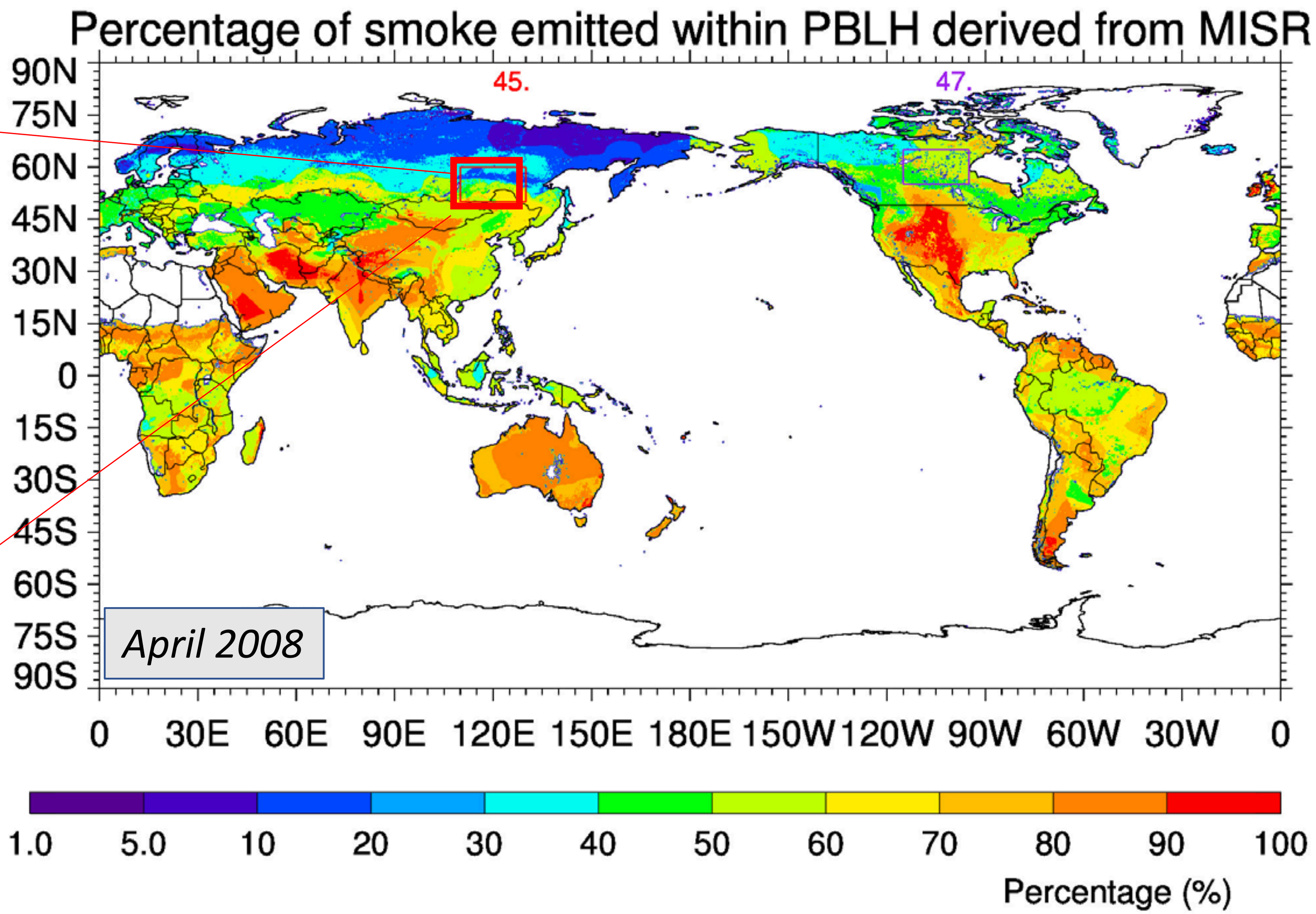
- ❑ **BBIH**: same as BASE but distribute biomass burning emissions vertically constrained by the MISR plume injection height weighting function (Val Martin et al., 2010; 2018).

- ❑ **NOBB**: no biomass burning emissions

April 2008: Smoke emission

**Val Martin et al., 2010; 2018*

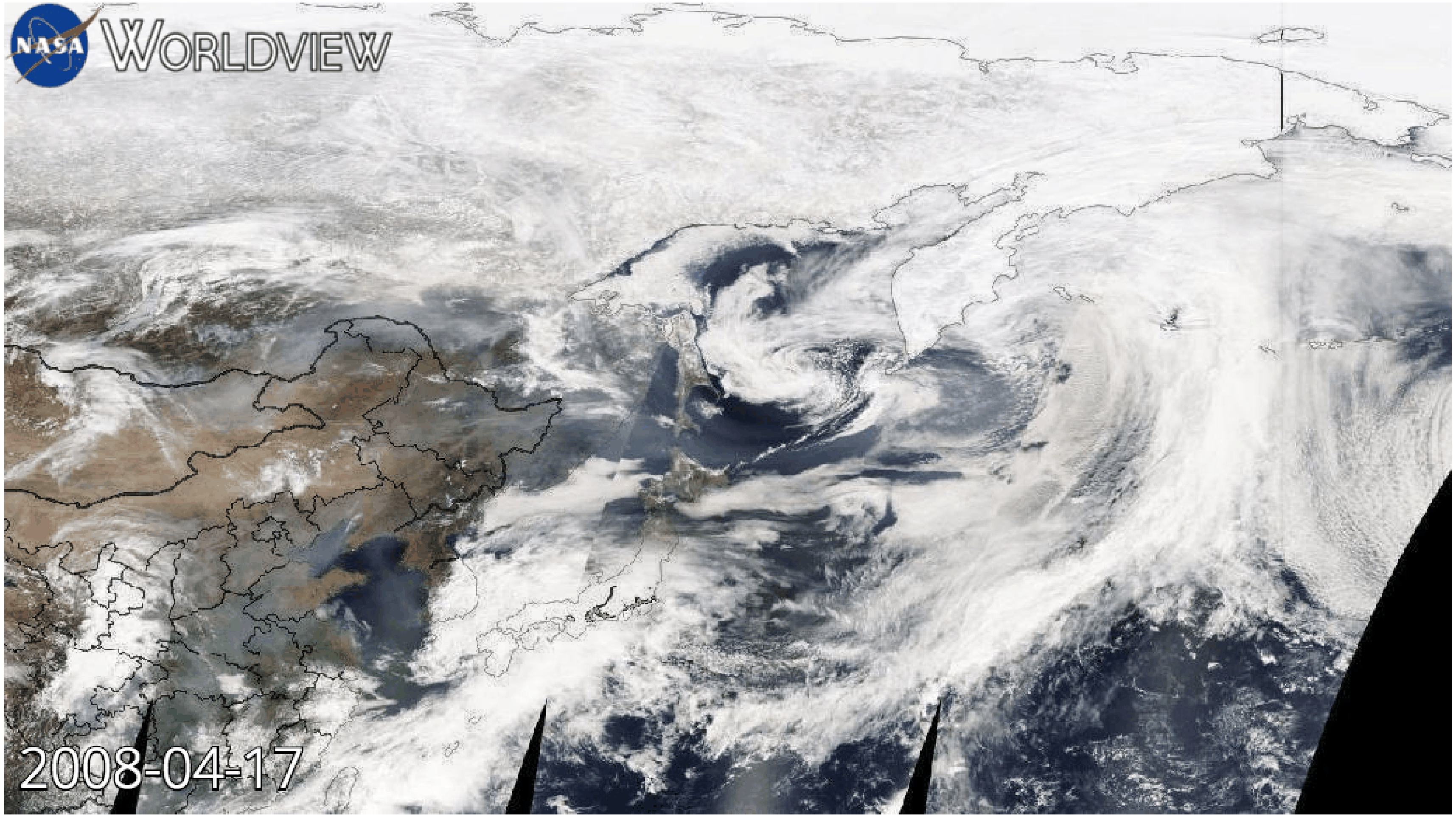




During April 2008, there are only 45% smoke emitted within PBLH over Russia, where the forest fires occur frequently

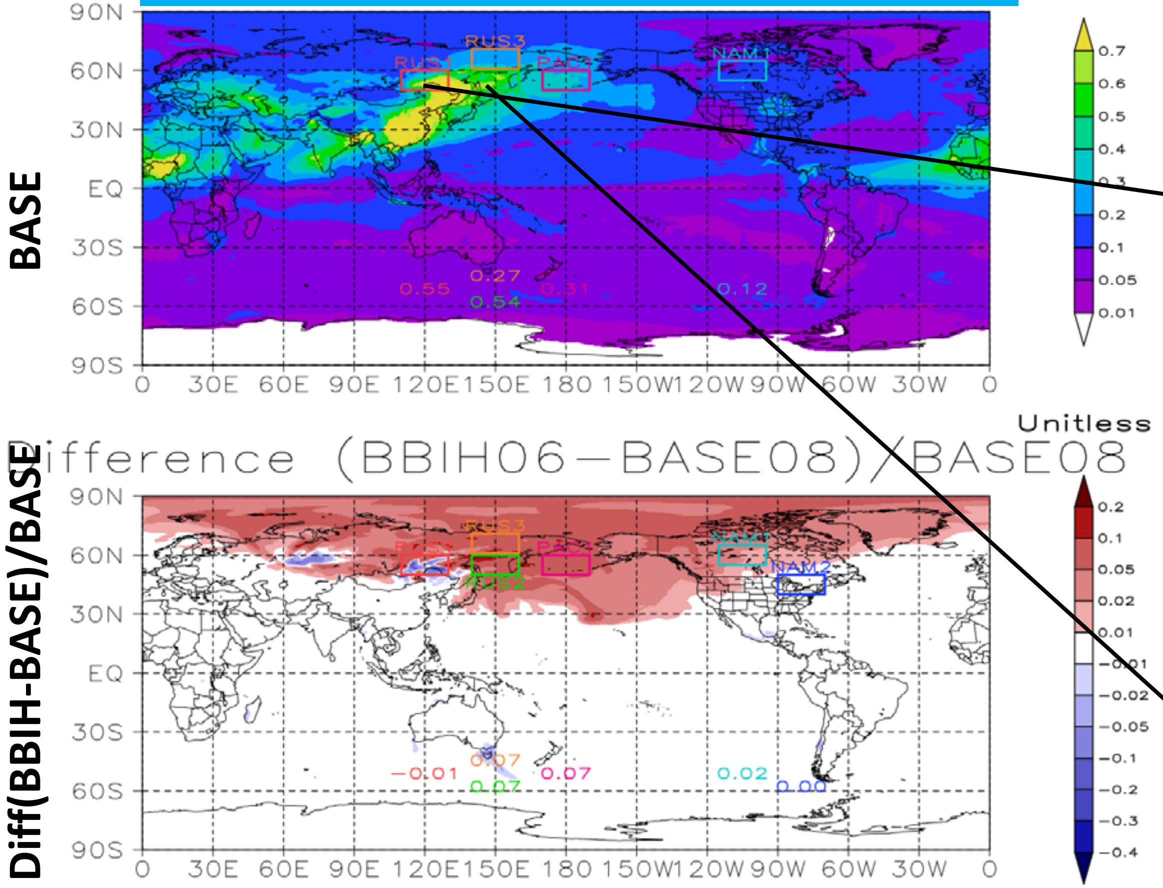
Result: Comparison between BASE and BBIH

Russian wildfires in 17-24 April 2008

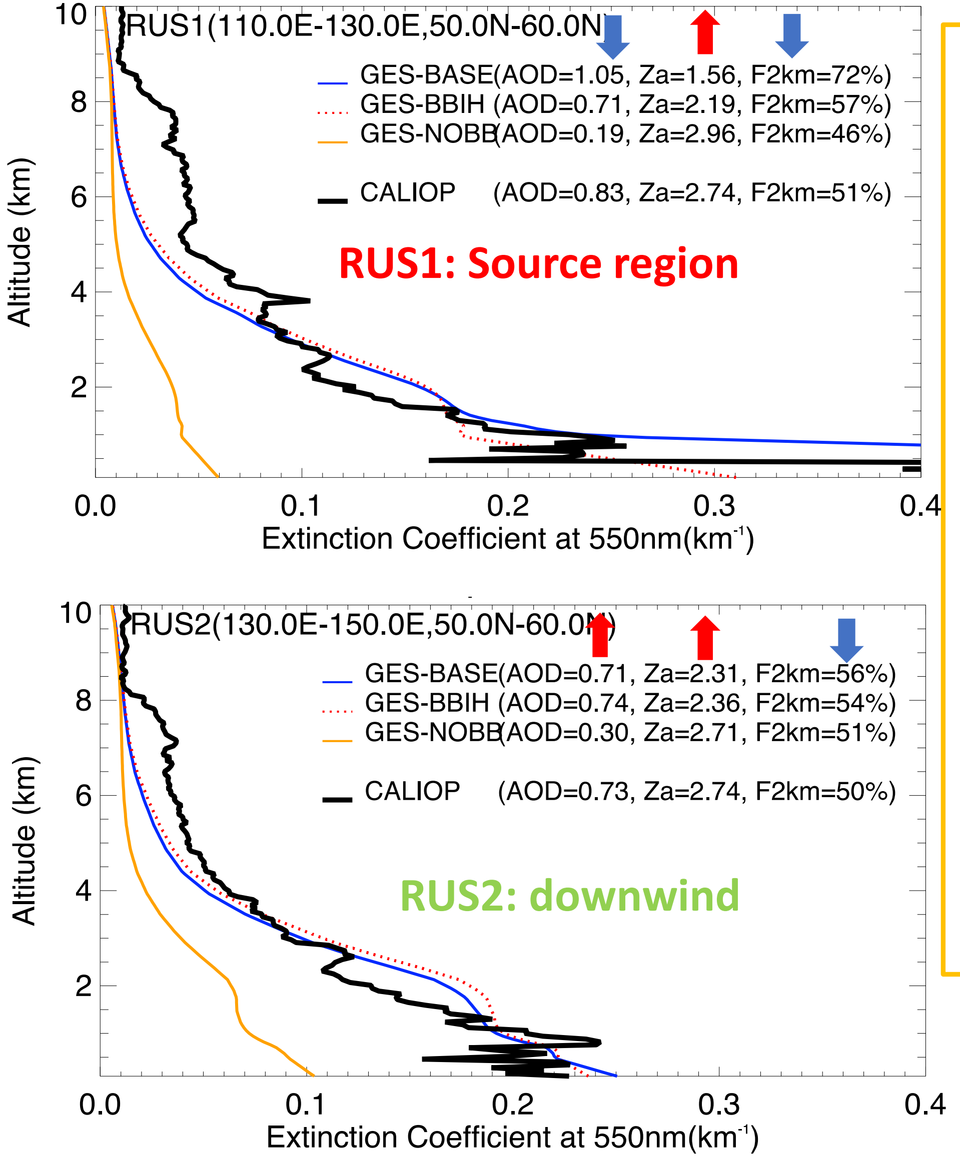


April 2008

Total AOD



Vertical profile of extinction



- There is diff. although it is small
- But, BBIH brings the statistics closer to CALIOP in both RUS1 and RUS2

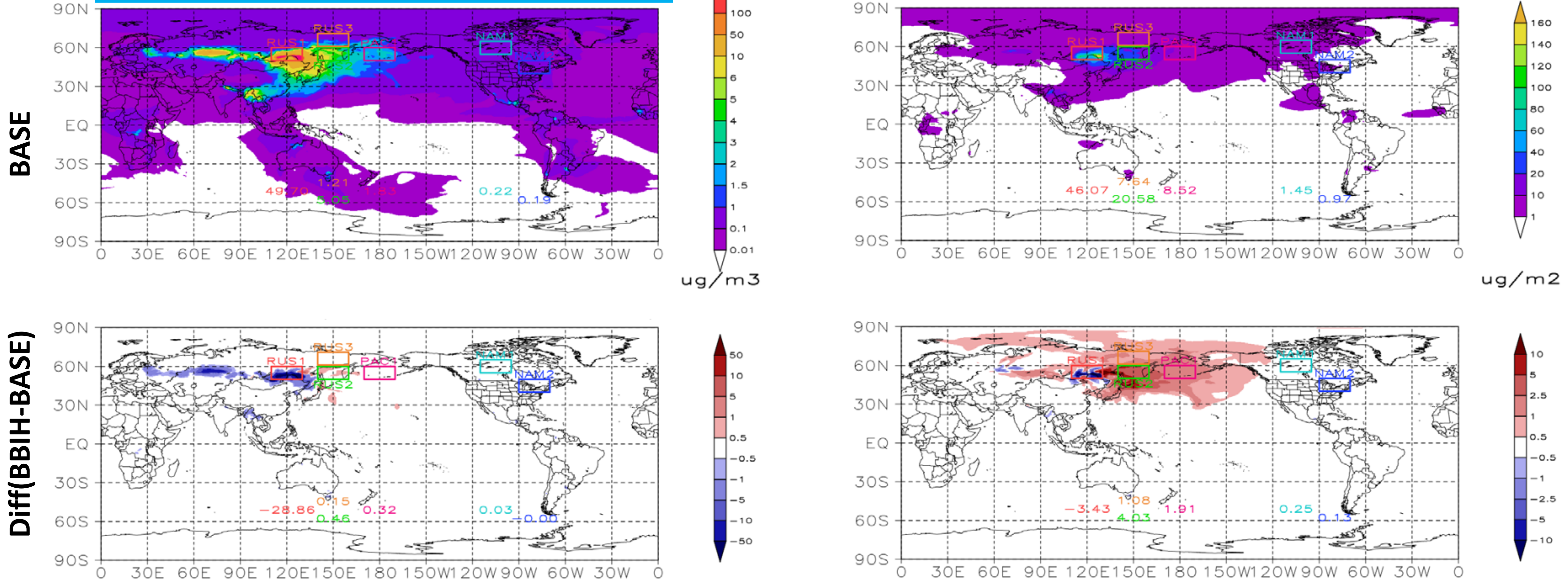
Difference (BBIH-BASE)/BASE

- Reduced near source region (RUS1) by 1%;but enhanced over downwind regions RUS2, RUS3, PAC1 by 7%, and NAM1 by 2%

April 2008

Surf. mass conc. of OC from fire

Column mass load of OC from fire



Difference (BBIH-BASE)

- **SMASS**: Reduced near source region (RUS1) by 28.86 ug m^{-3} ;but enhanced over downwind regions RUS2 by 0.46 ug m^{-3}, and PAC1 by 0.32 ug m^{-3}
- **CMASS**: Reduced close to source region (RUS1) by 3.43 ug m^{-2} but enhanced over downwind region RUS2 by 4.03 ug m^{-2}, PAC1 by 1.91 ug m^{-2}

How is fire plume height configured in YOUR model?

Multi-model comparison: BBEIH in AeroCom III

Four model experiments for 2008

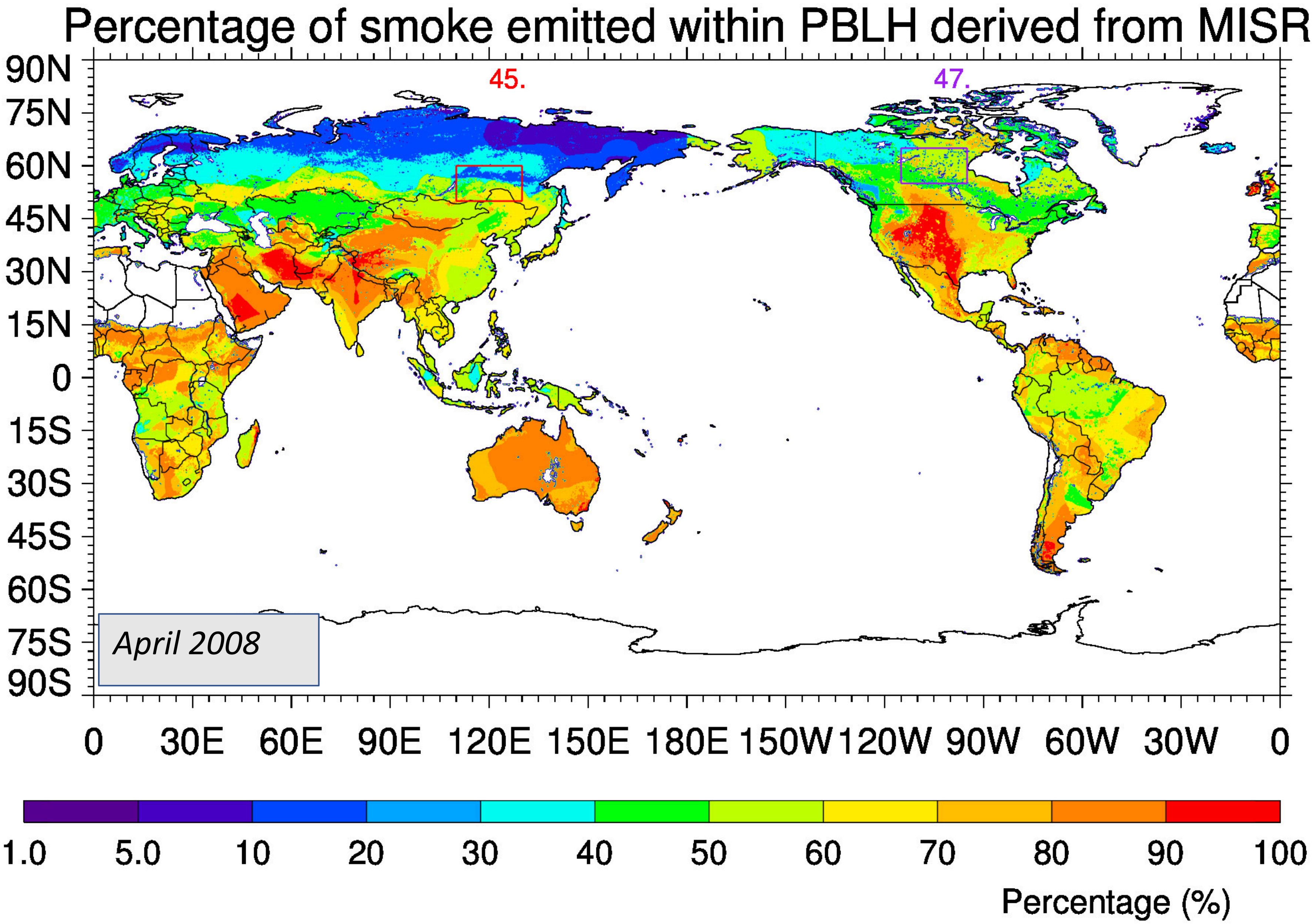
- ❑ **BASE**: all emissions including GFED4.1s, using model-default biomass burning injection height (distributed within PBLH).
- ❑ **BBIH**: same as BASE but distribute biomass burning emissions vertically using MISR plume injection height (Val Martin et al., 2010; 2018).
- ❑ **NOBB**: no biomass burning emissions
- ❑ **BBEM** (optional for you): same as BASE, but using daily FEER biomass burning emission instead of GFED4.1s.

The objectives of BBEIH (Biomass Burning Emission Injection Height Experiments):

We aim to answer the following scientific questions:

- ❑ To what extent are model simulations sensitive to the assumed biomass burning injection height, in terms of near-source characteristics and downwind plume evolution: (a) vertical aerosol distribution, (b) near-surface aerosol concentration, (c) aerosol optical depth, and more generally (d) net radiative forcing of BB-related aerosols, (e) BB-related aerosol transport time in the atmosphere, (f) cloud fraction, and (g) precipitation?
- ❑ In which regions/seasons/surface-types are the aforementioned sensitivities significant?
- ❑ To what extent do the aforementioned sensitivities vary across different models?

MISR smoke injection height

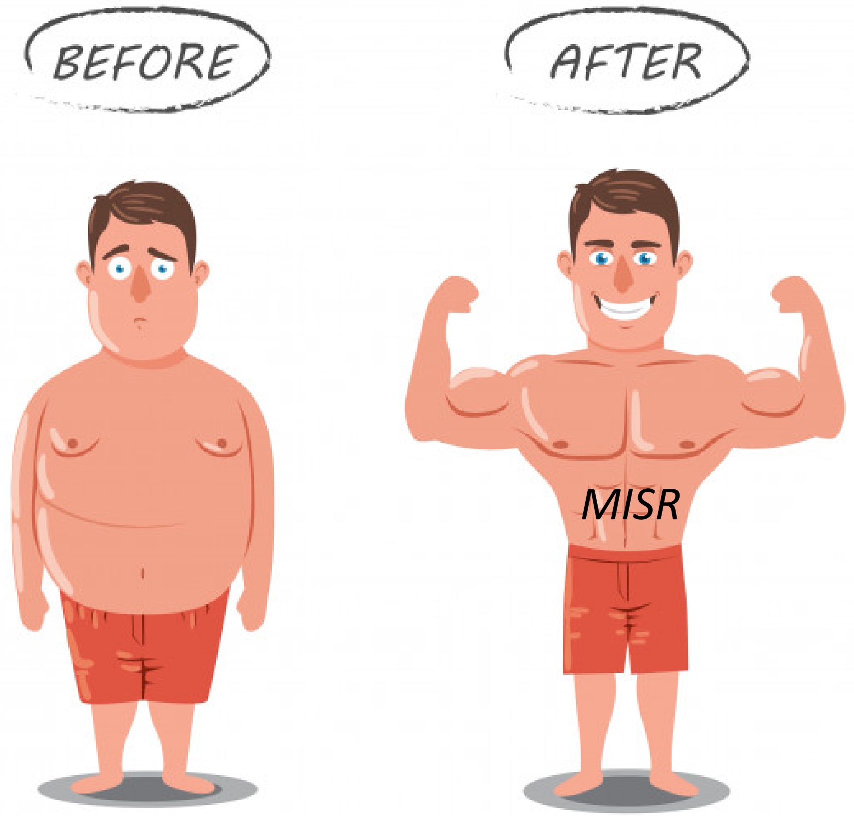


Val Martin, Kahn & Tosca; 2018

Bonus:

We will provide a gridded MISR injection height weight function for you!!!
(lon, lat, lev, mon)

Join us!



Wiki website: https://wiki.met.no/aerocom/phase3-experiments#biomass_burning_emission_injection_height_experiment_bbeih

Phase III Organizers: Xiaohua Pan, Ralph Kahn, Mian Chin, Maria Val Martin

Contacts: Xiaohua xiaohua.pan@nasa.gov, and Ralph Kahn ralph.kahn@nasa.gov

(if you have interest for performing this experiment, please contacts both Xiaohua and Ralph)

Observational datasets used to validate model

- **AOD**

  MODIS, MISR, and AERONET
- **AAOD and AI**

  OMI and OMPS
- **Vertical profile of aerosol extinction profile**

  CALIOP and OMPS
- **Vertical profile of atmospheric composition**
  - USA and Canada: ARCTAS (2008)
  - Russia: ???
- **Surface aerosol concentration network**
  - USA:
    - ✓ EPA: ($PM_{2.5}$, PM_{10})
    - ✓ IMPROVE: 2005-2011, daily, species (BC, OM, aerbext)
  - Canada: ??
  - Russia: ???

Thank you!

Observational data

IMPROVE (and EPA) site map

http://vista.cira.colostate.edu/Improve/monitoring-site-browser/

Reconstructed Fine Mass

http://vista.cira.colostate.edu/Improve/reconstructed-fine-mass/

EPA PM data

Download sites: https://aqs.epa.gov/aqsweb/airdata/download_files.html#Daily

(Including PM and Speciation and other pollutants and meteorological data)

Documentation: https://aqs.epa.gov/aqsweb/airdata/FileFormats.html

Parameter and method Code: https://www.epa.gov/aqs/aqs-memos-technical-note-reporting-pm25-continuous-monitoring-and-speciation-data-air-quality

Table 1, PM2.5 Parameter Codes

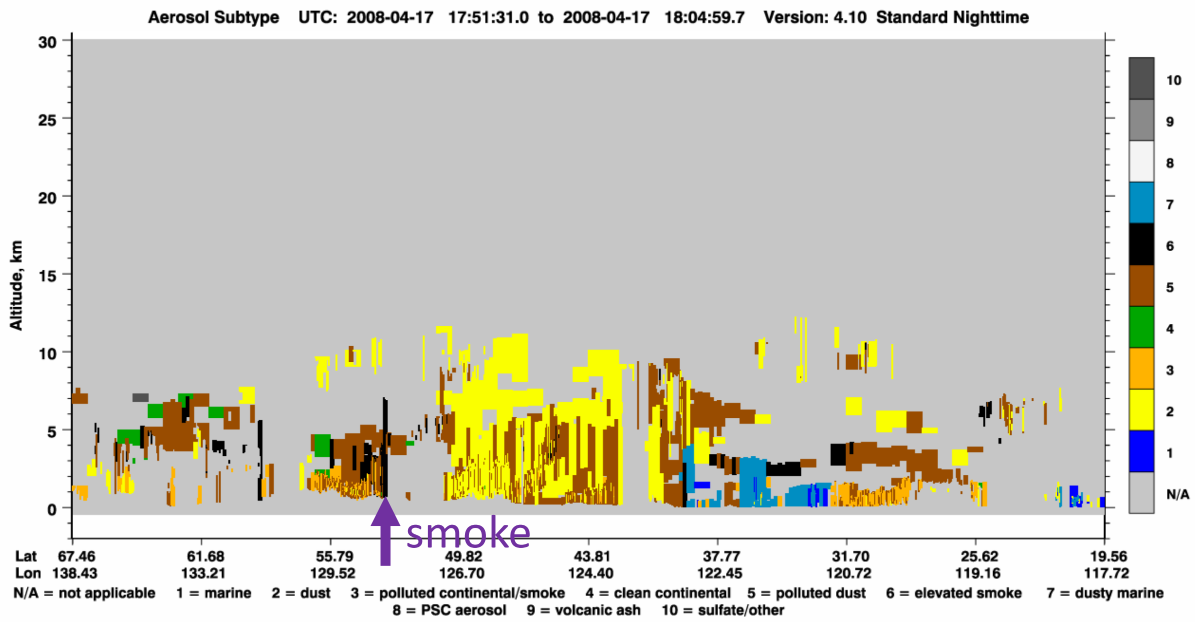
Parameter Name	Parameter Code	Purpose	Notes
PM2.5 LOCAL CONDITIONS	88101	Appropriate code for all FRM/FEM/ARMs	Original code for PM2.5 at local conditions
PM2.5 TOTAL ATMOSPHERIC	88500	Valid data from methods measuring total PM2.5 aerosols in the atmosphere, including those that can be volatilized from the FRM	Introduced in 2005
PM2.5 RAW DATA	88501	Valid uncorrected data that does not reasonably match the FRM	Introduced in 2005
ACCEPTABLE PM2.5 AQI & SPECIATION MASS[1]	88502	Valid data that does reasonably match the FRM with or without correction, but not to be used in NAAQS decisions	Introduced in 2006
PM2.5 VOLATILE CHANNEL[1]	88503	Store important related data such as the FDMS reference channel	Introduced in 2006

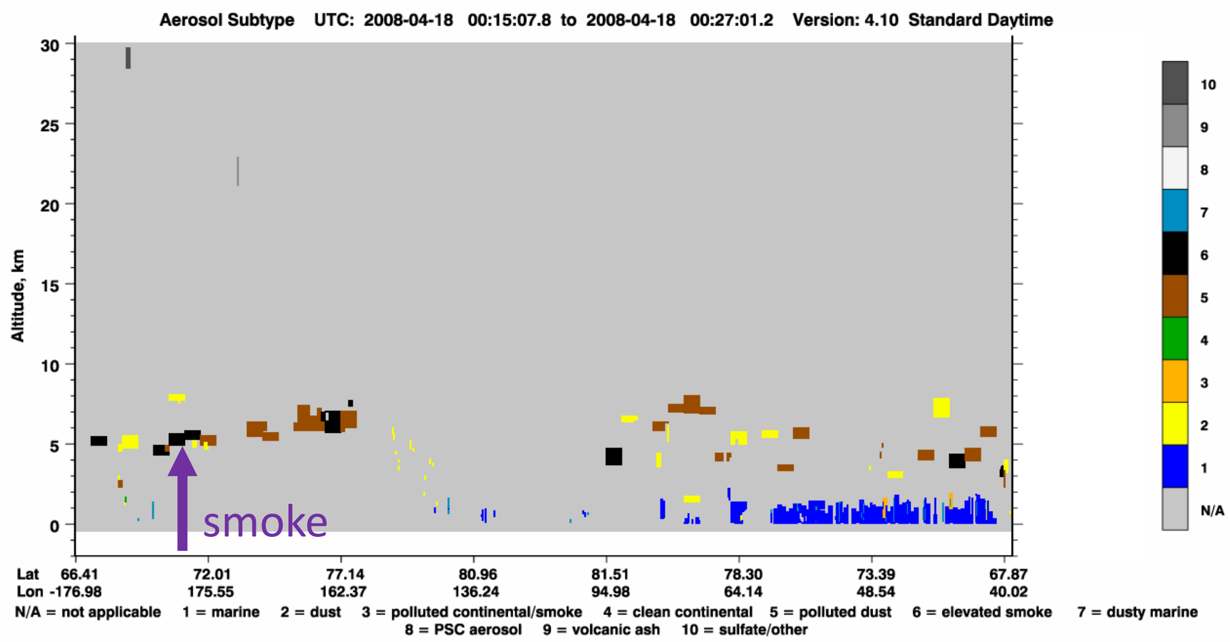
Parameter code 88101: We have decided to make the AQS data even more transparent by allowing parameter code 88101 (PM2.5 at local conditions, only report those data validated from Federal Reference Methods-FRM, Federal Equivalent Methods, or other methods) to only be used for $PM_{2.5}$ data obtained with methods eligible for use in the NAAQS decision making process for the applicable geographical area. Therefore, a new and different parameter code has been created to store all other $PM_{2.5}$ concentration measurement data (from continuous monitors and speciation samplers) that still reasonably match the FRM, but are not to be used for NAAQS decisions.

References:

- **Freitas,** S. R., Longo, K. M., Chatfield, R., Latham, D., Silva Dias, M. A. F., Andreae, M. O., Prins, E., Santos, J. C., Gielow, R., and Carvalho Jr., J. A.: Including the sub-grid scale plume rise of vegetation fires in low resolution atmospheric transport models, Atmos. Chem. Phys., 7, 3385-3398, https://doi.org/10.5194/acp-7-3385-2007, 2007.
- ***Gonzalez-Alonso***, L., M. Val Martin, and R.A. Kahn, 2018. Biomass burning smoke heights over the Amazon observed from the space. *Atmosph. Chem. Phys*. 19, 1685–1702, doi: 10.5194/acp-19-1685-2019.
- ***Val Martin***, M. R.A. Kahn, and M. Tosca, 2018. A Global Climatology of Wildfire Smoke Injection Height Derived from Space-based Multi-angle Imaging. *Remote Sensing 10,* 1609; doi:10.3390/rs10101609.
- ***Vernon***, C. J., Bolt, R., Canty, T., and Kahn, R. A.: The impact of MISR-derived injection height initialization on wildfire and volcanic plume dispersion in the HYSPLIT model, Atmos. Meas. Tech., 11, 6289–6307, https://doi.org/10.5194/amt-11-6289-2018, 2018.
- ***Zhu***, L., M. Val Martin, A. Hecobian, M.N. Deeter, L.V. Gatti, R.A. Kahn, and E.V. Fischer, 2018. Development and implementation of a new biomass burning emissions injection height scheme for the GEOS-Chem model. *Geosci. Model Develop. 11*, 4103–4116, doi:10.5194/gmd-11-4103-2018.

CALIOP 2008-April-17 to 18





Magenta track

Red track