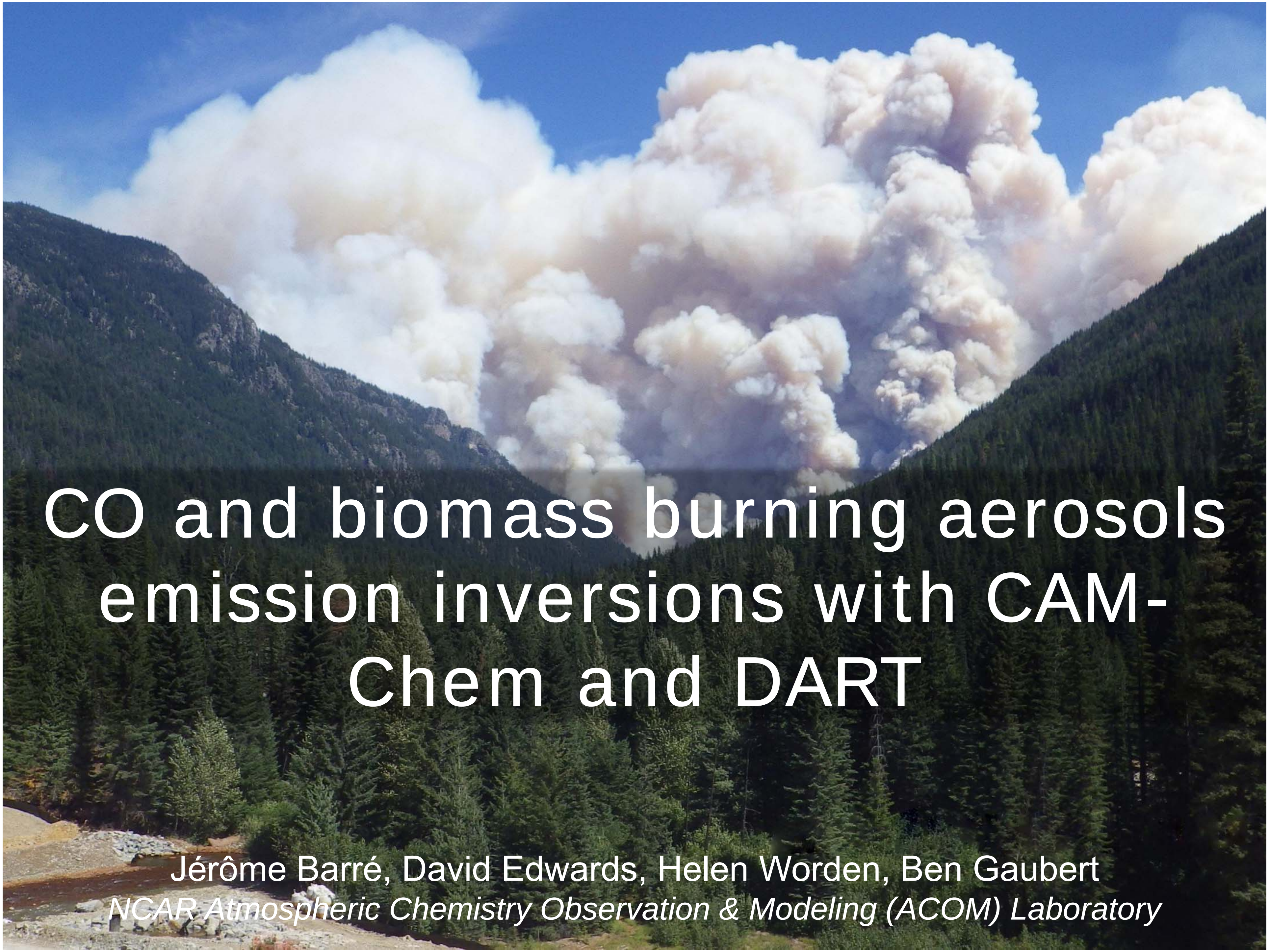


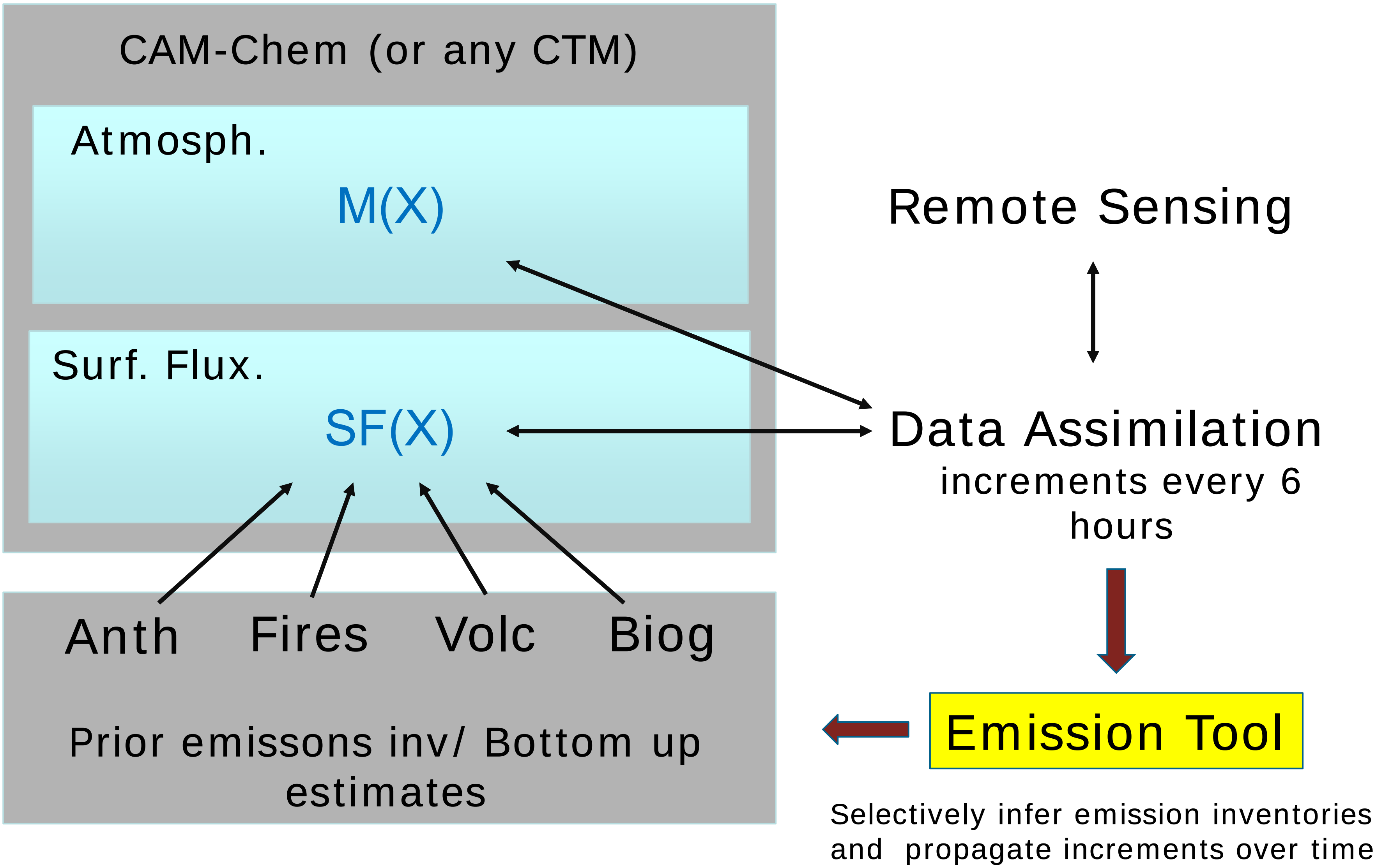
CO and biomass burning aerosols emission inversions with CAM-Chem and DART

Jérôme Barré, David Edwards, Helen Worden, Ben Gaubert
NCAR Atmospheric Chemistry Observation & Modeling (ACOM) Laboratory

Setup

- Model: CAM-Chem (CESM122, CAM4 MOZART4 and BAM)
- Emissions: HTAP for anthropogenic; FINN for BB; MEGAN for biogenic
- Data assimilation: DART EnKF with an ensemble of 30 members and a 6 hourly assimilation window
- "State augmentations/localizations": Choice of which state variables are constrained from the satellite data
- For example: Departures between CO MOPITT and CAM-Chem can be used to constrain CO 3D fields but also CO emissions and additionally related aerosols e.g. OC and BC.

Motivations - Methodology



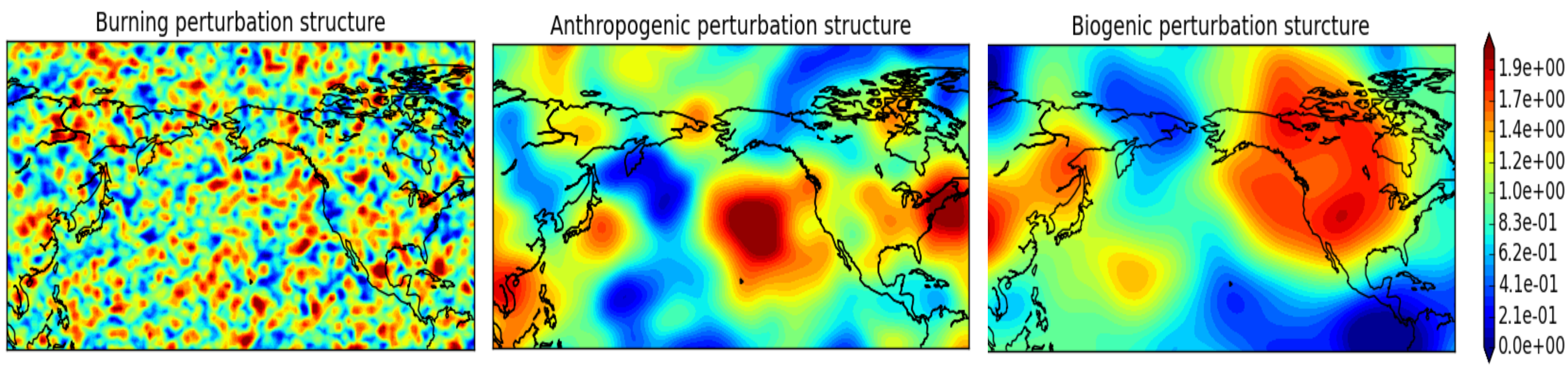
Perturbations - Methodology

$$\overline{q(x_1,y_1)q(x_2,y_2)} = \Delta \mathbf{k} c^2 \sum_{l,p} e^{-2(\kappa_l^2+\gamma_p^2)/\sigma^2} e^{i\left[\kappa_l(x_1-x_2)+\gamma_p(y_1-y_2)\right]}.$$

Ls

- Ensemble covariance for Emissions, using Evensen 2003 equations.
- Perturbation code can be used to set different length scales and correlate/de-correlate emissions variables and types: the user can build his own background covariance matrix making “good” apriori assumptions

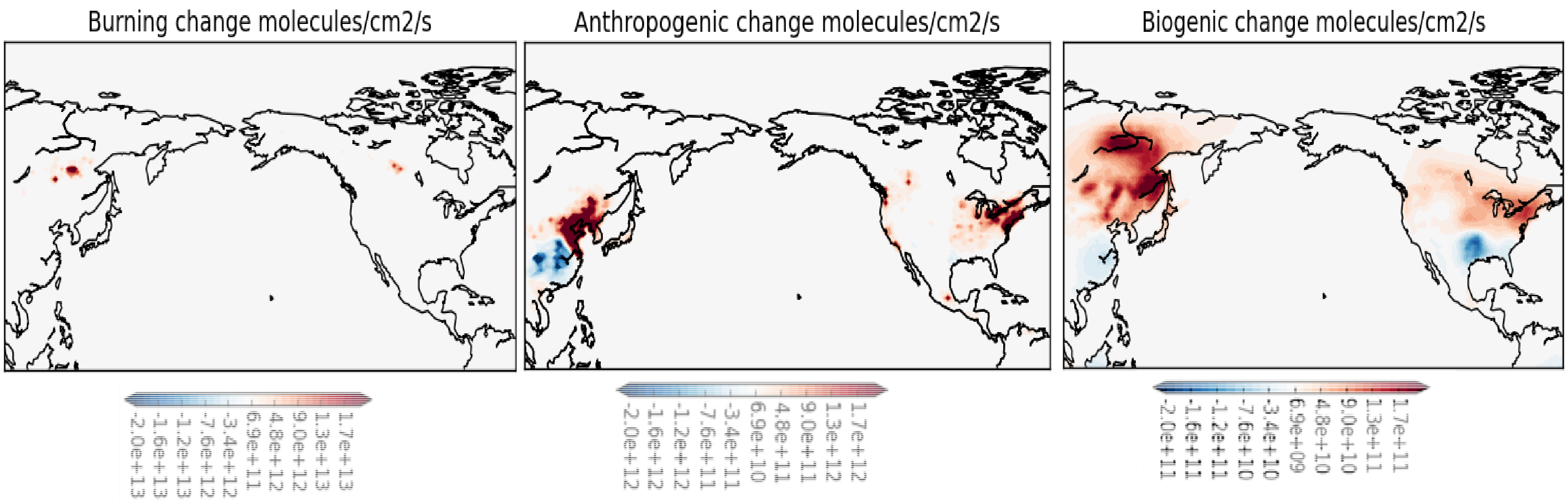
Perturbations coefs on one member



Ls=200km, Lt=3days | Ls=1000km, Lt=1month | Ls=2000km, Lt=1month

CO increments- Methodology

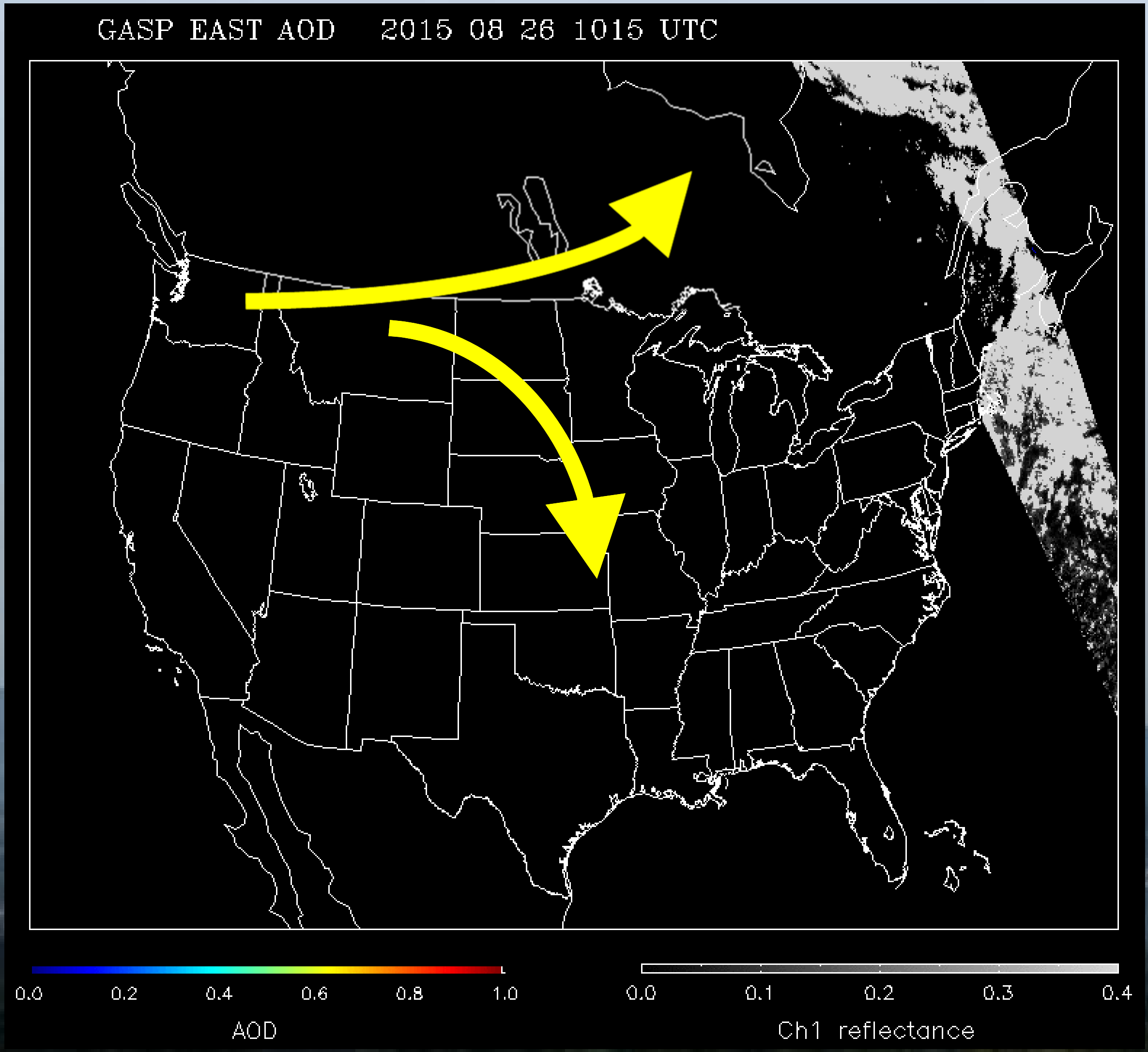
- First tests: After a month of MOPITT CO inversion
- Impacts on different types of emissions are clearly different



WA fires case study

The Washington State fires of summer 2015:
Total fires: 1,541
Total area: 1,005,423 acres
Cost: $253 million


Haze over Denver 08/27/15



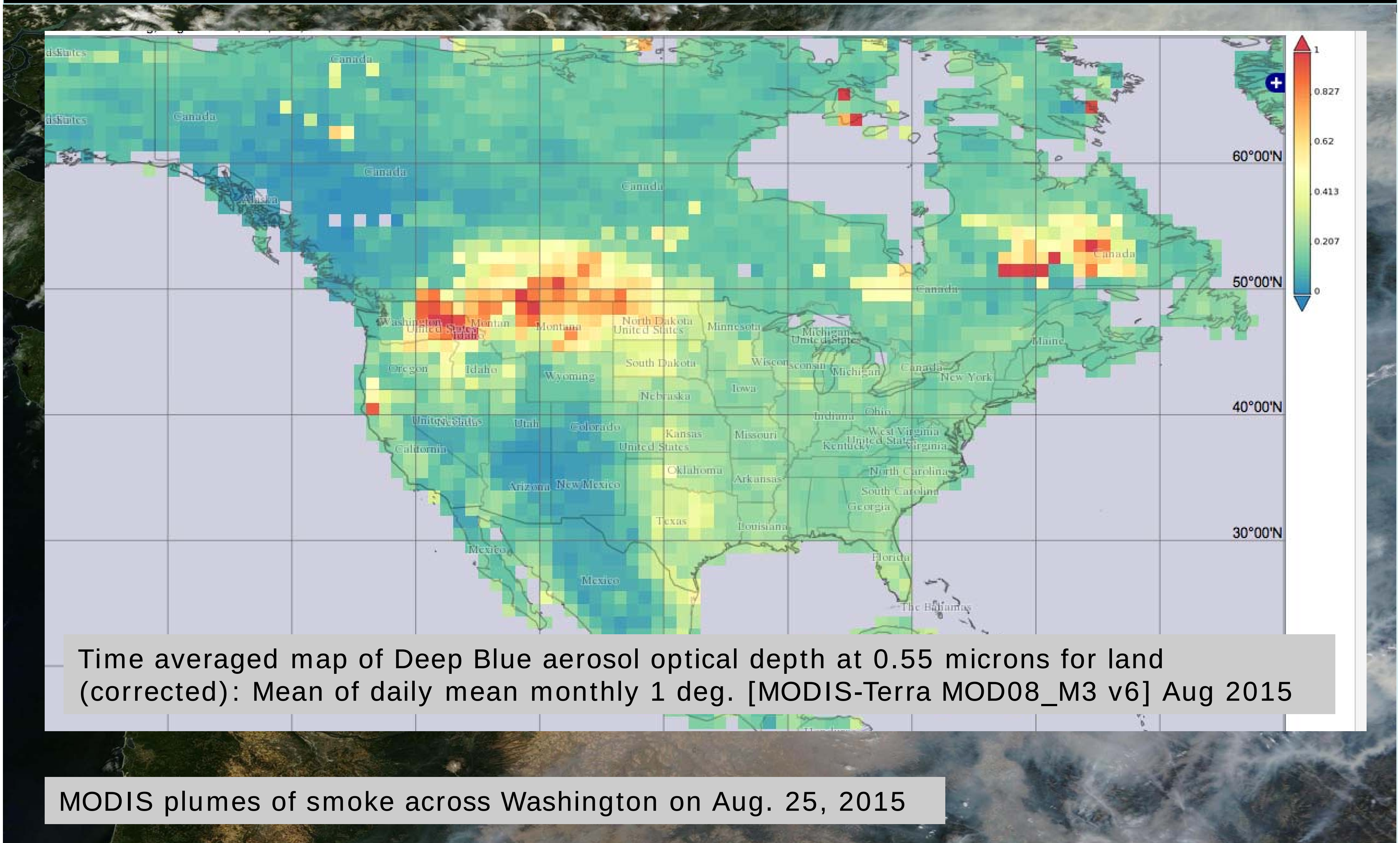
Model and data assimilation setup

- Model: CAM-Chem (CESM122, CAM4 with MOZART4 and BAM) at 1 degree horizontal resolution with 56 vertical levels from the surface to 1 hPa; driven by GEOS-5 analyses
- Experiments run for August 2015: from 1^{st} - 20^{th} as spin-up, and from 20^{th} - 31^{st} as the period of interest
- Emissions: HTAP for anthropogenic; FINN for BB; MEGAN for biogenic
- Data assimilation: DART EnKF with an ensemble of 30 members and a 6 hourly assimilation window
- Choice of whether 3D fields or emissions are constrained from the satellite data
- The emission types (anthropogenic, BB, biogenic) are perturbed independently allowing the EnKF to invert separately for the different emission types

➢ Emissions experiment:

- Invert the MODIS AOD data to update the FINN BB emission sources for black and organic carbon (BC+OC) in the model
- Assumption that these species dominate the wildfire plume

Smoke and aerosol

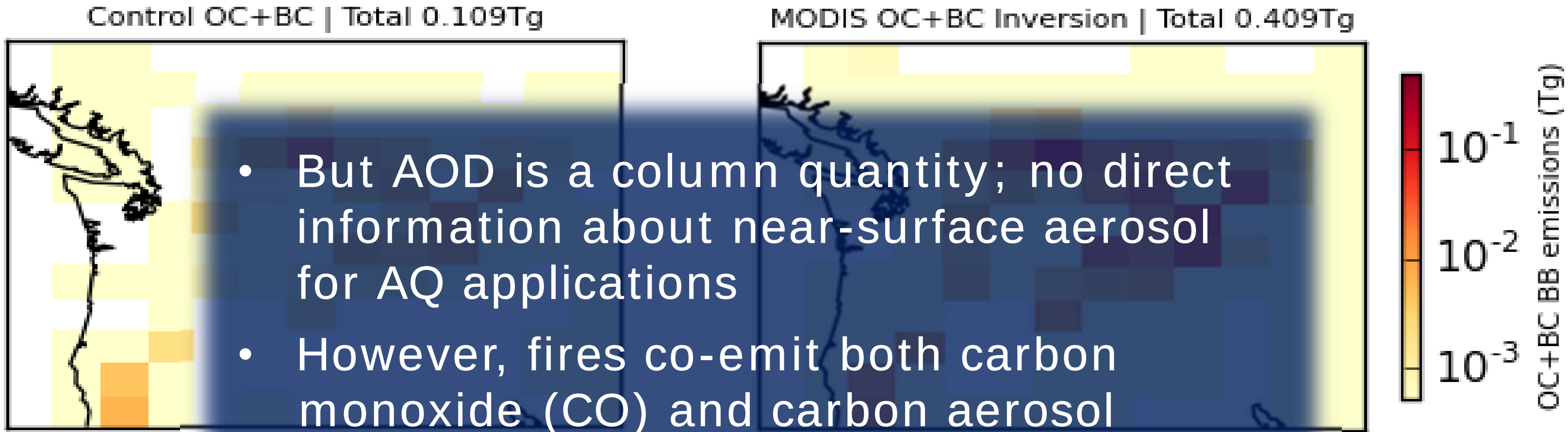


Time averaged map of Deep Blue aerosol optical depth at 0.55 microns for land (corrected): Mean of daily mean monthly 1 deg. [MODIS-Terra MOD08_M3 v6] Aug 2015

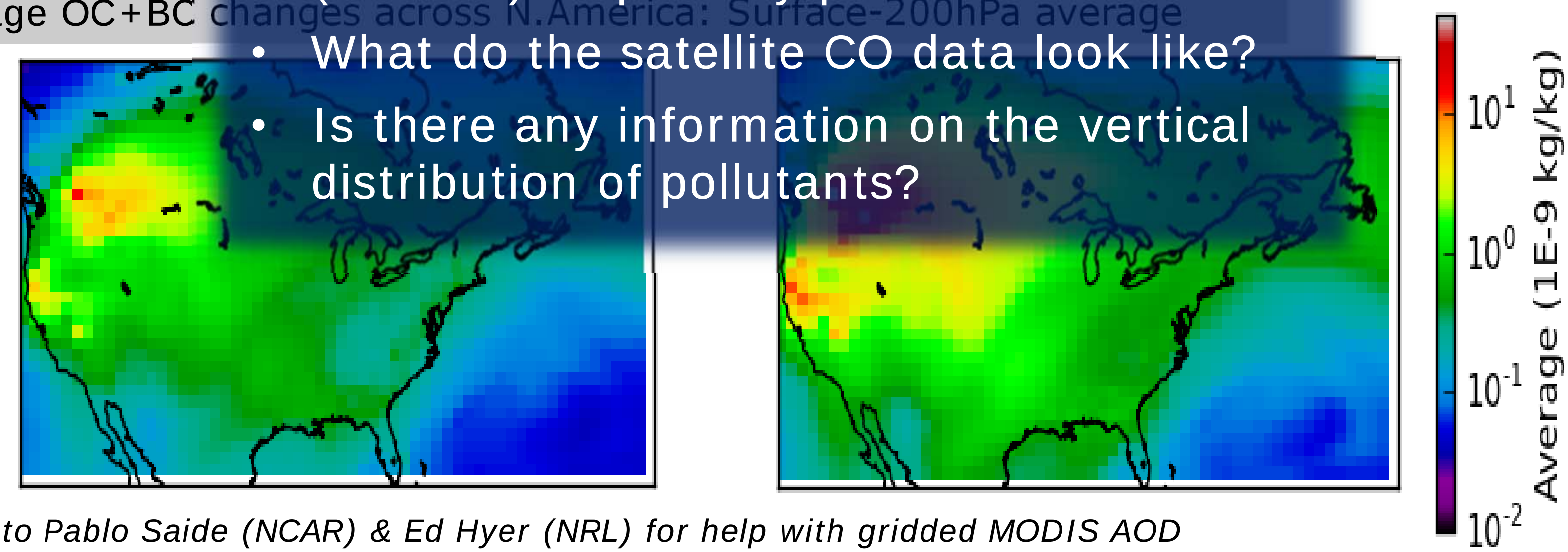
MODIS plumes of smoke across Washington on Aug. 25, 2015

Updated OC+BC emissions estimates

Emission totals from 20-31 Aug. 2015: ***Factor 3.7 increase***



Average OC+BC changes across N.America: Surface-200hPa average

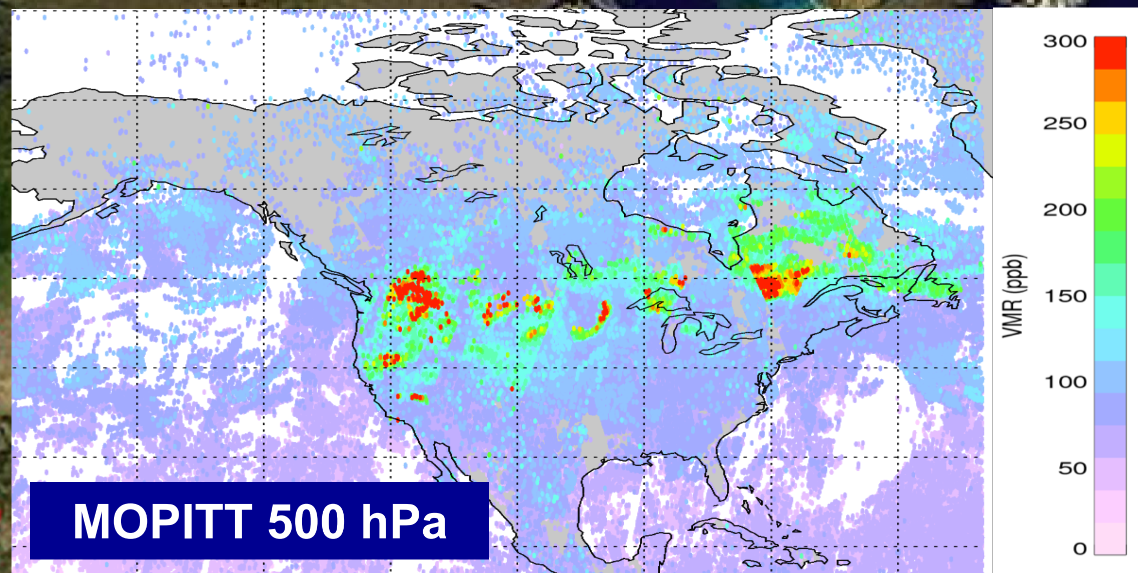


- But AOD is a column quantity; no direct information about near-surface aerosol for AQ applications
- However, fires co-emit both carbon monoxide (CO) and carbon aerosol (OC+BC) as primary pollutants
- What do the satellite CO data look like?
- Is there any information on the vertical distribution of pollutants?

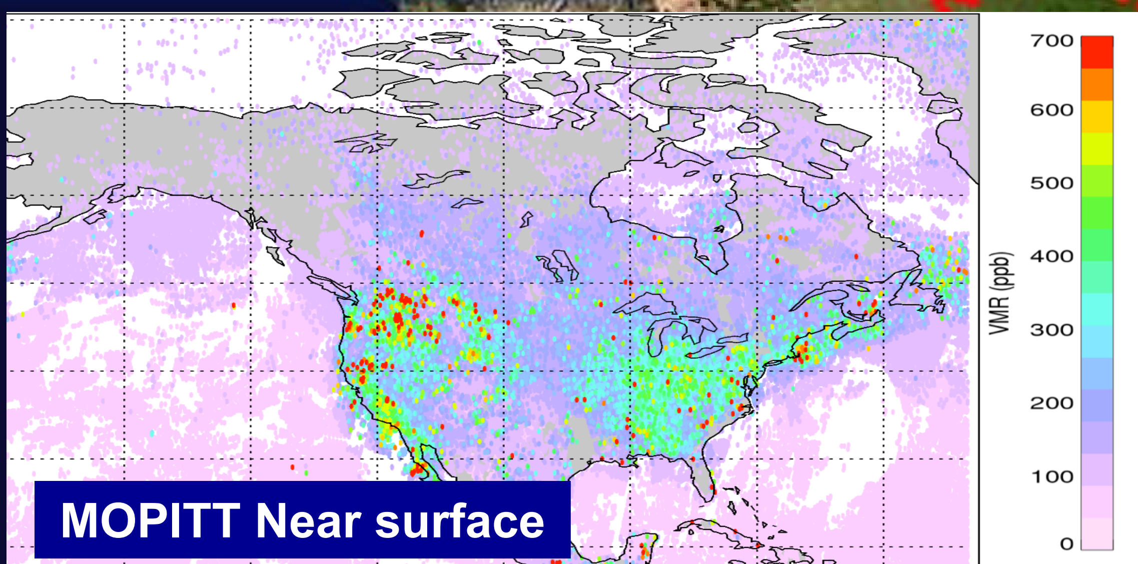
Thanks to Pablo Saide (NCAR) & Ed Hyer (NRL) for help with gridded MODIS AOD

MOPITT multispectral CO retrievals provide some profile information

MOPITT V5J multispectral retrievals of CO from MOPITT provide profile information that distinguishes fire source regions from free troposphere long range transport of pollution. 20-27 August 2015



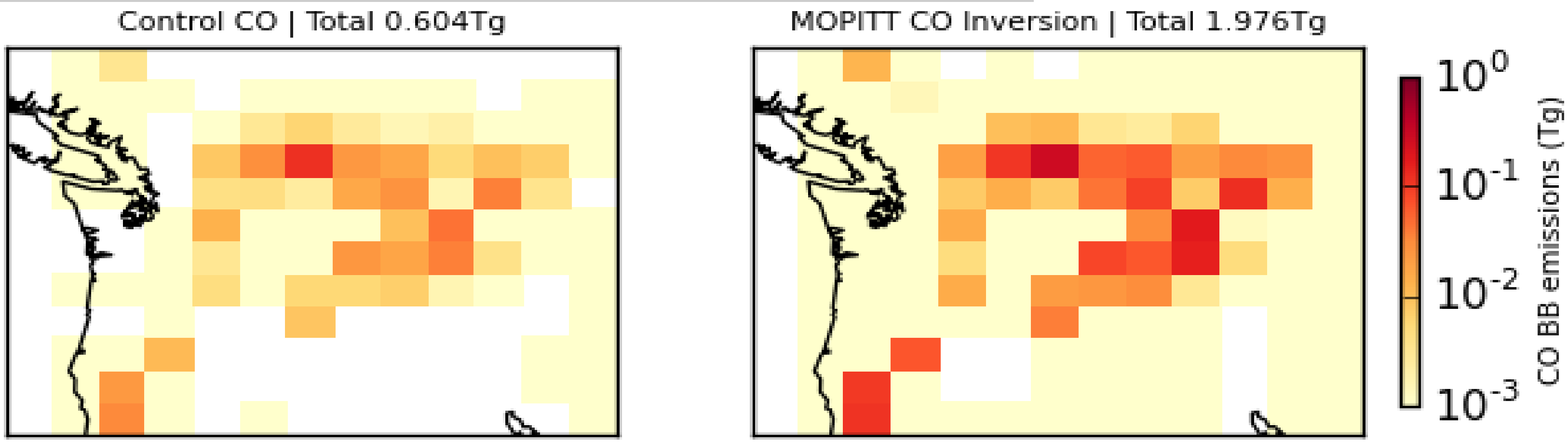
Note different scales



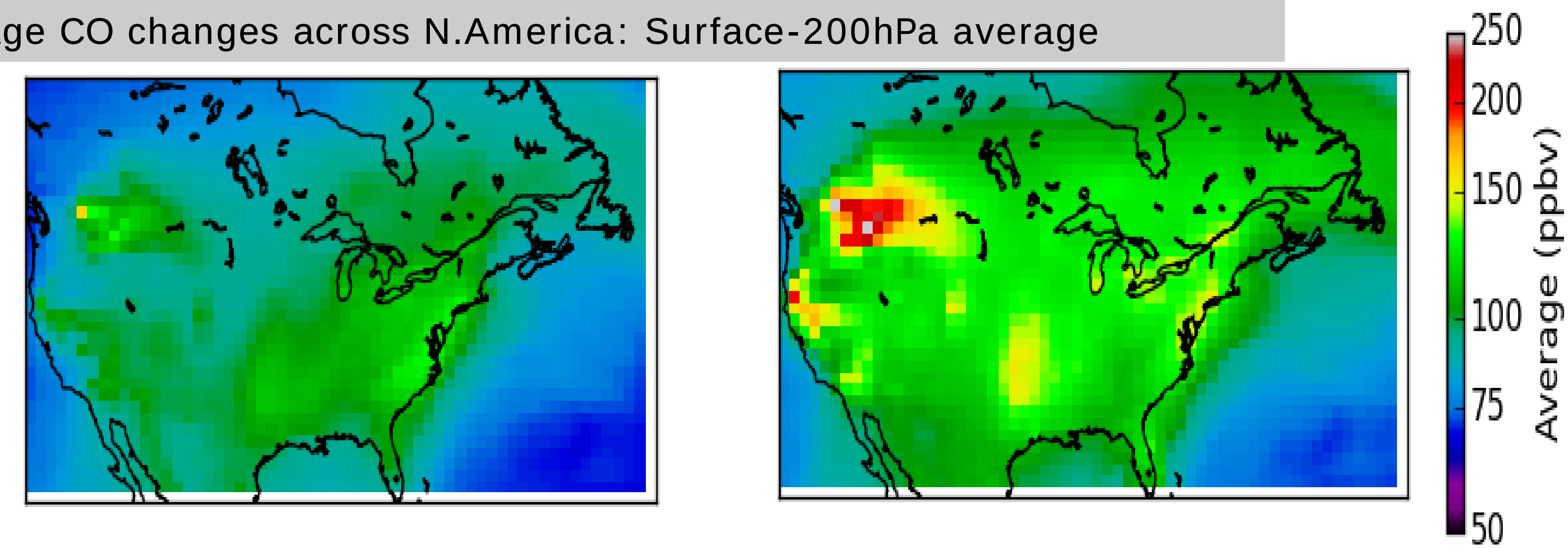
MODIS Fire Counts 19-28 August 2015 showing the WA north-central Okanogan Complex

Updated CO emissions estimates

Emission totals from 20-31 Aug. 2015: ***Factor 3.3 increase***

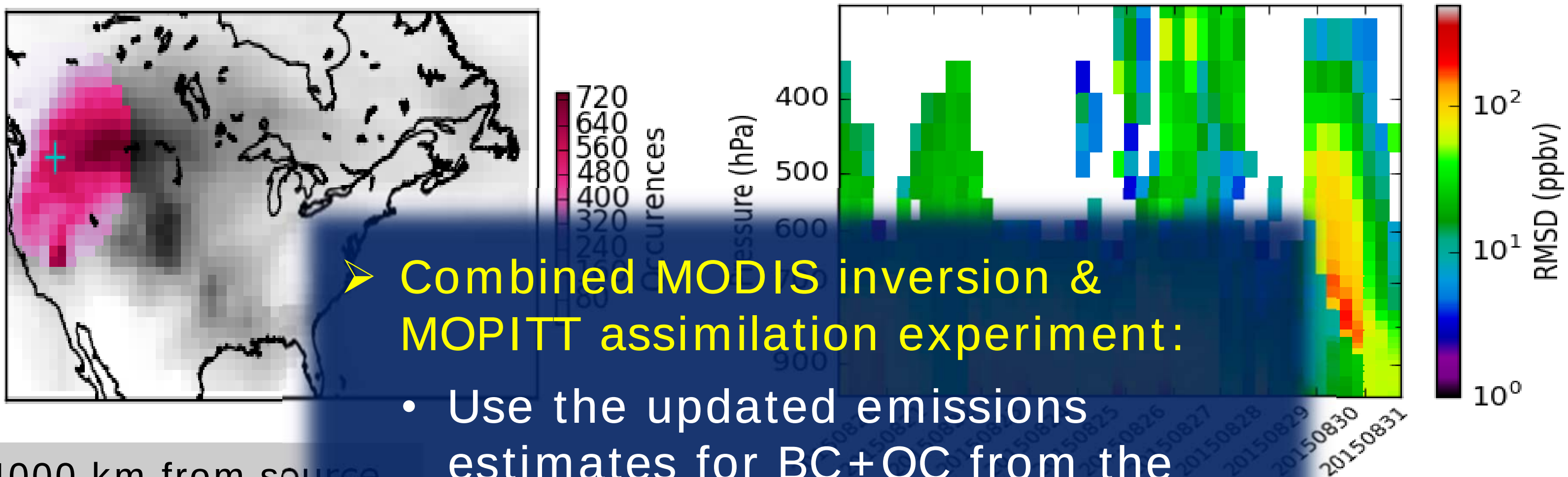


Average CO changes across N.America: Surface-200hPa average

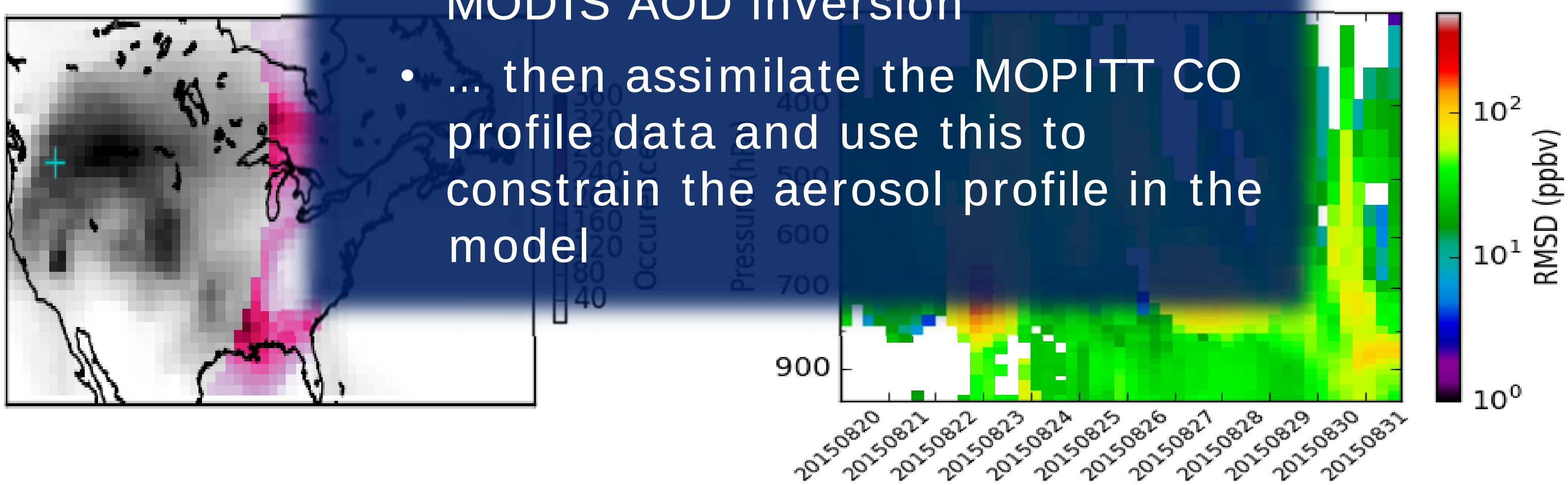


CO assimilation

CO profile changes from Control Run where BB tracer >10ppb, 1000 km from source



3000-4000 km from source

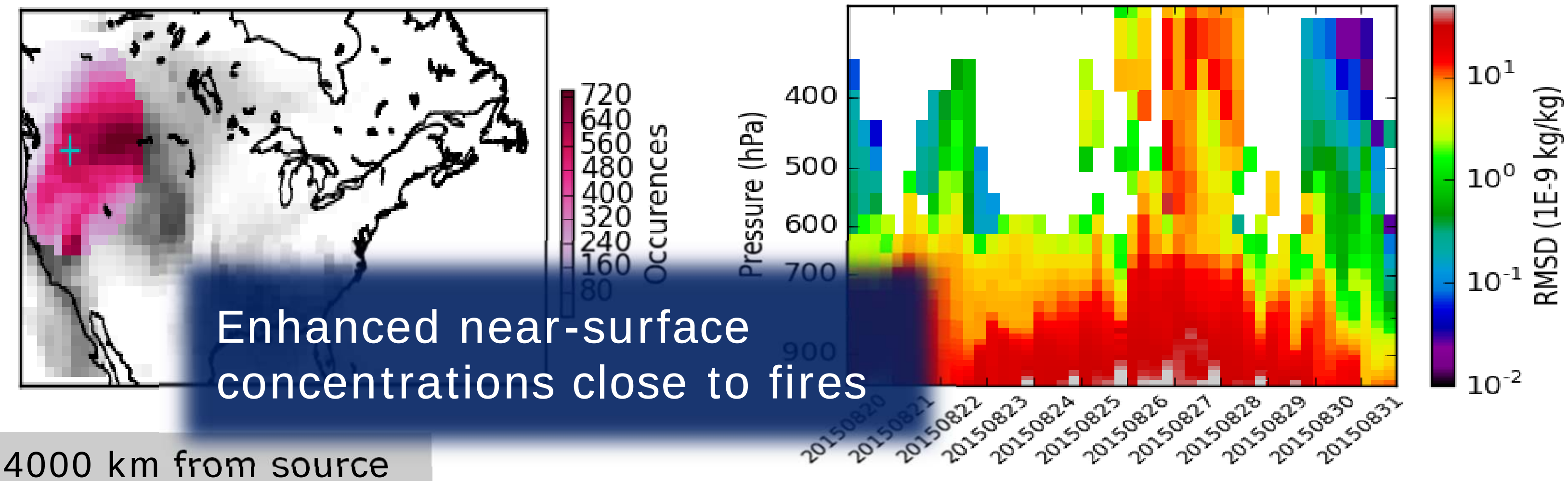


➢ Combined MODIS inversion & MOPITT assimilation experiment:

- Use the updated emissions estimates for BC+OC from the MODIS AOD inversion
- … then assimilate the MOPITT CO profile data and use this to constrain the aerosol profile in the model

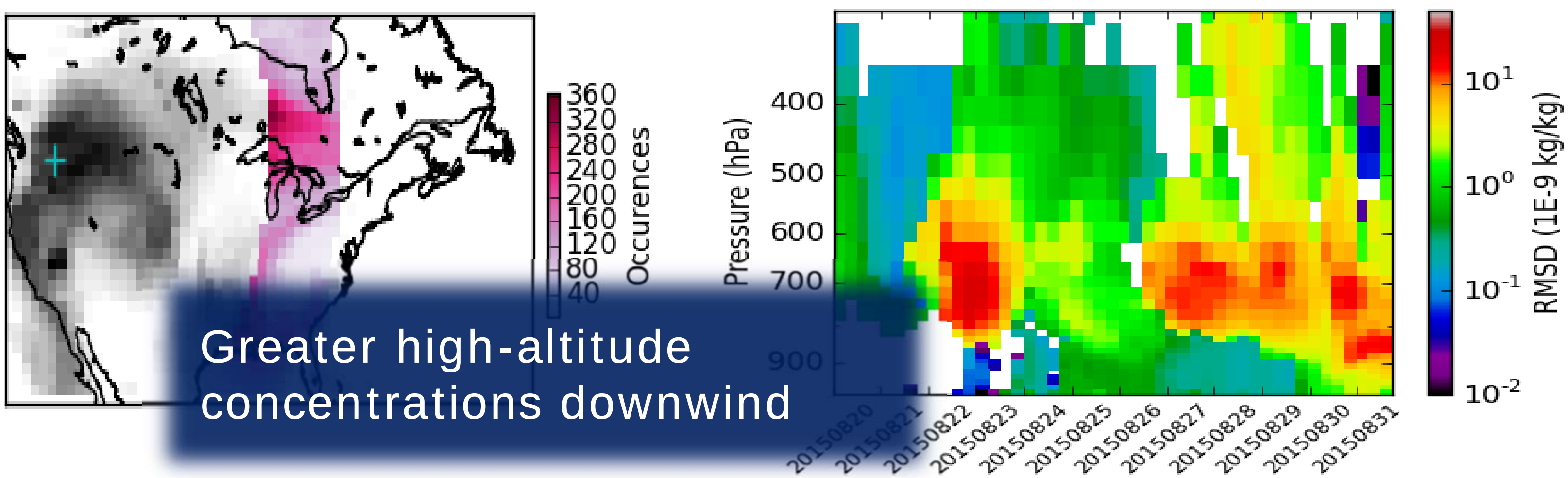
Combined AOD inversion/CO assimilation

OC+BC profile changes from Control Run where BB tracer >10ppb, 1000 km from source



Enhanced near-surface concentrations close to fires

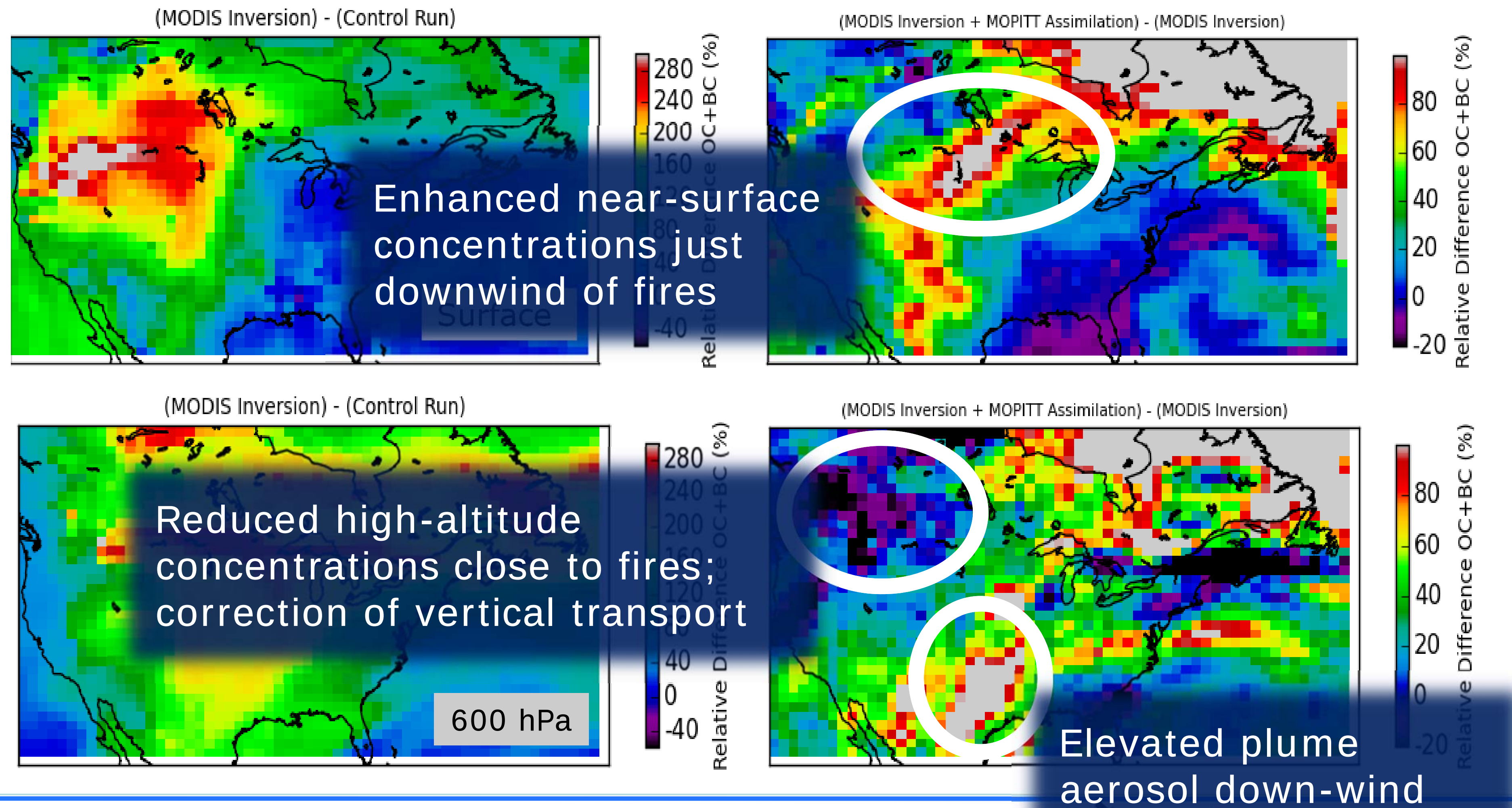
3000-4000 km from source



Greater high-altitude concentrations downwind

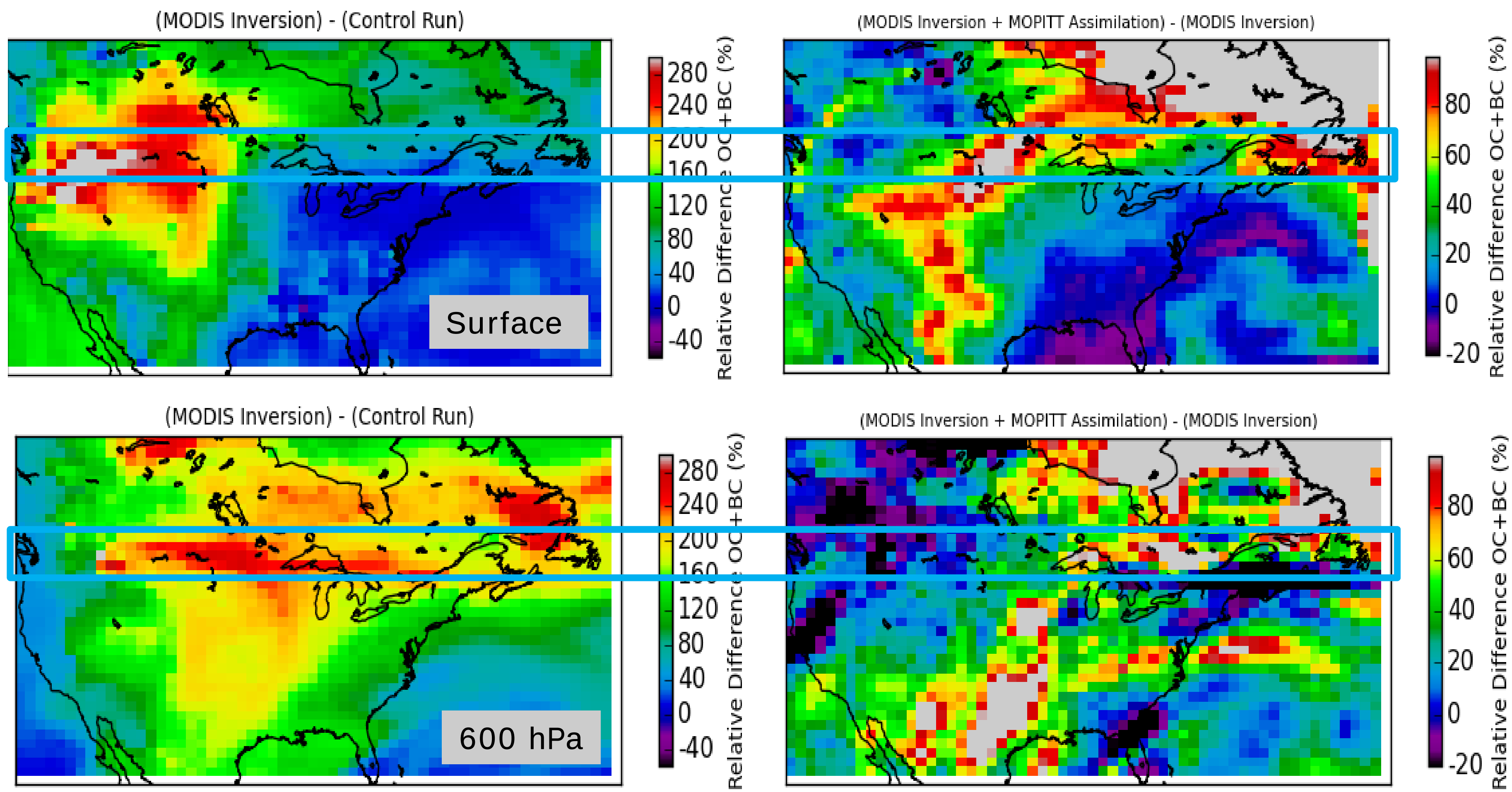
Combined AOD inversion/CO assimilation

Average OC+BC changes across N.America from 20-31 Aug. 2015
relative average difference compared to Control Run



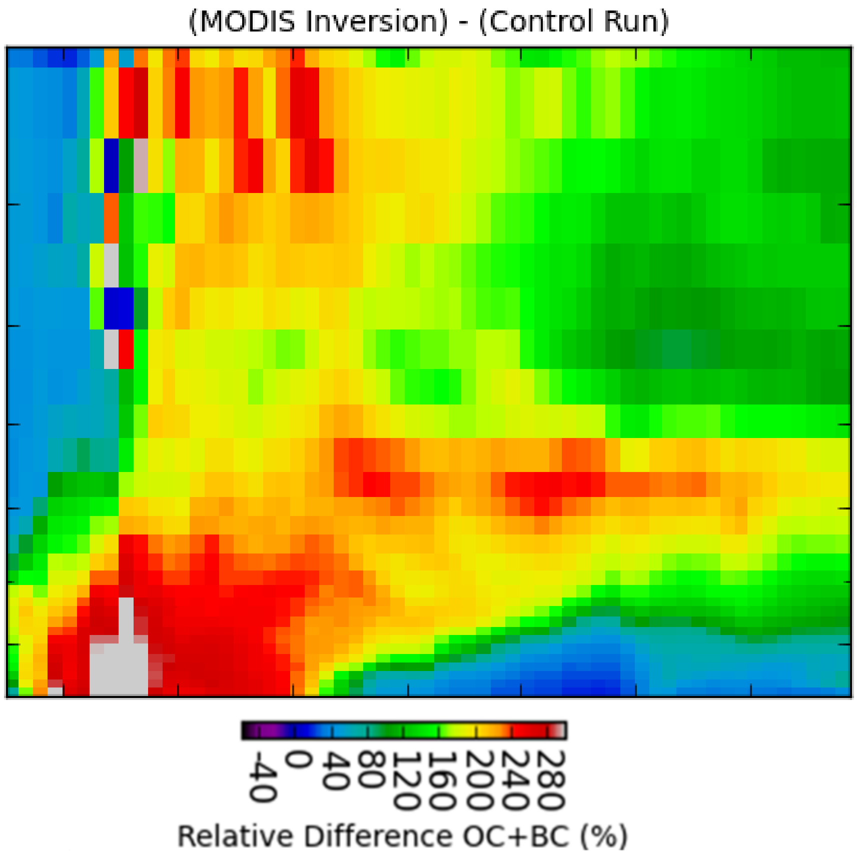
Combined AOD inversion/CO assimilation

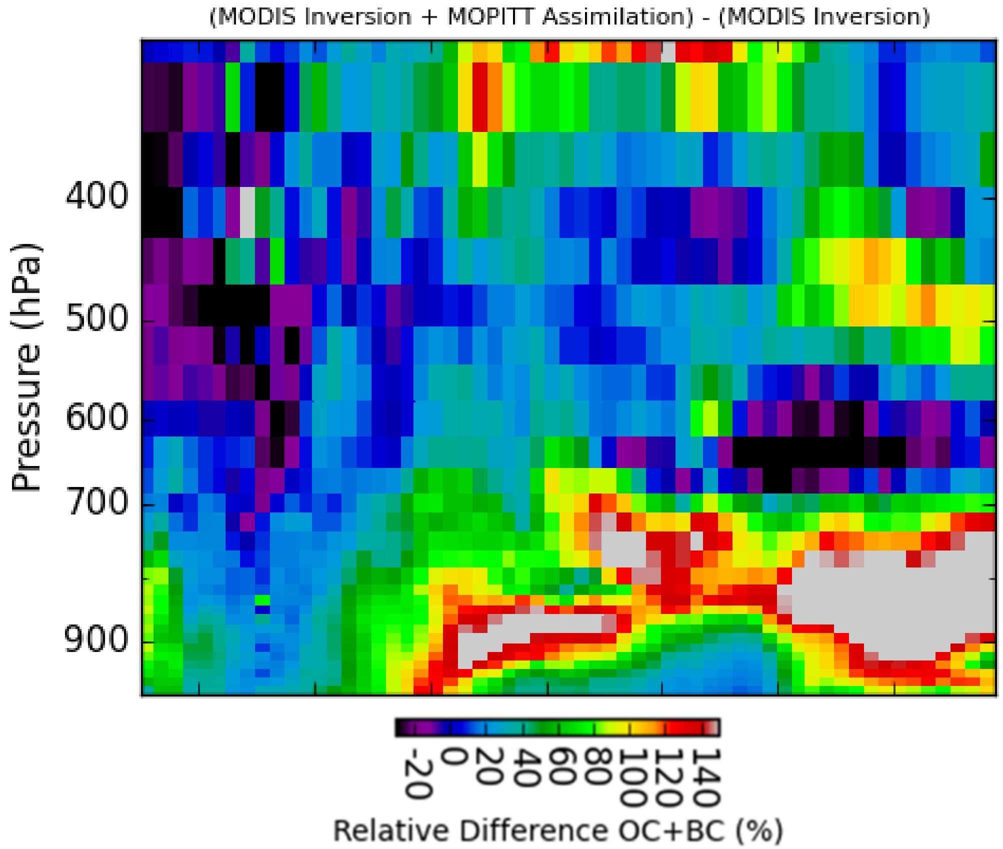
Average OC+BC changes across N.America from 20-31 Aug. 2015
relative average difference compared to Control Run



Combined AOD inversion/CO assimilation

Average OC+BC changes across N.America from 20-31 Aug. 2015
relative average difference compared to Control Run

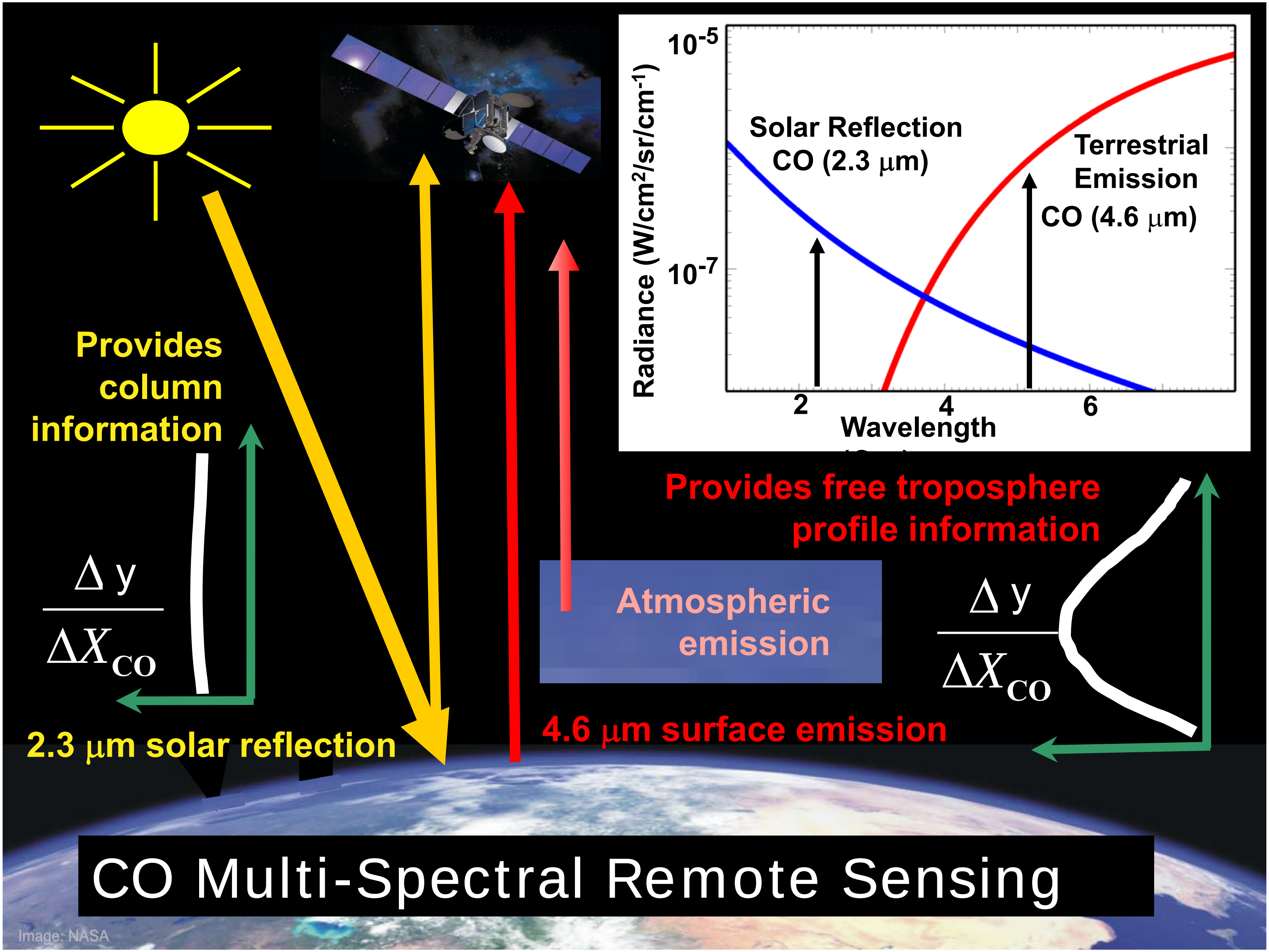




Summary and Next steps

- Developed an online emission tool for ensemble methods
- Inversion of MODIS AOD and MOPITT CO data change FINN model a priori emissions estimates for the WA fires by a factor of about 3.5
- Presents an opportunity to explore and explain the differences between the bottom-up and top-down emissions estimate approaches
- Subsequent assimilation of the MOPITT CO profile can be used to constrain the aerosol profile
- This elevates near-surface aerosol down-wind of the plume and decreases higher altitude aerosol concentrations closer to the fires; essentially correcting plume vertical transport
- Currently evaluating near-surface aerosol analysis results with ground-based PM2.5 measurements
- Release the emission tool for the community (GMD in prep.)

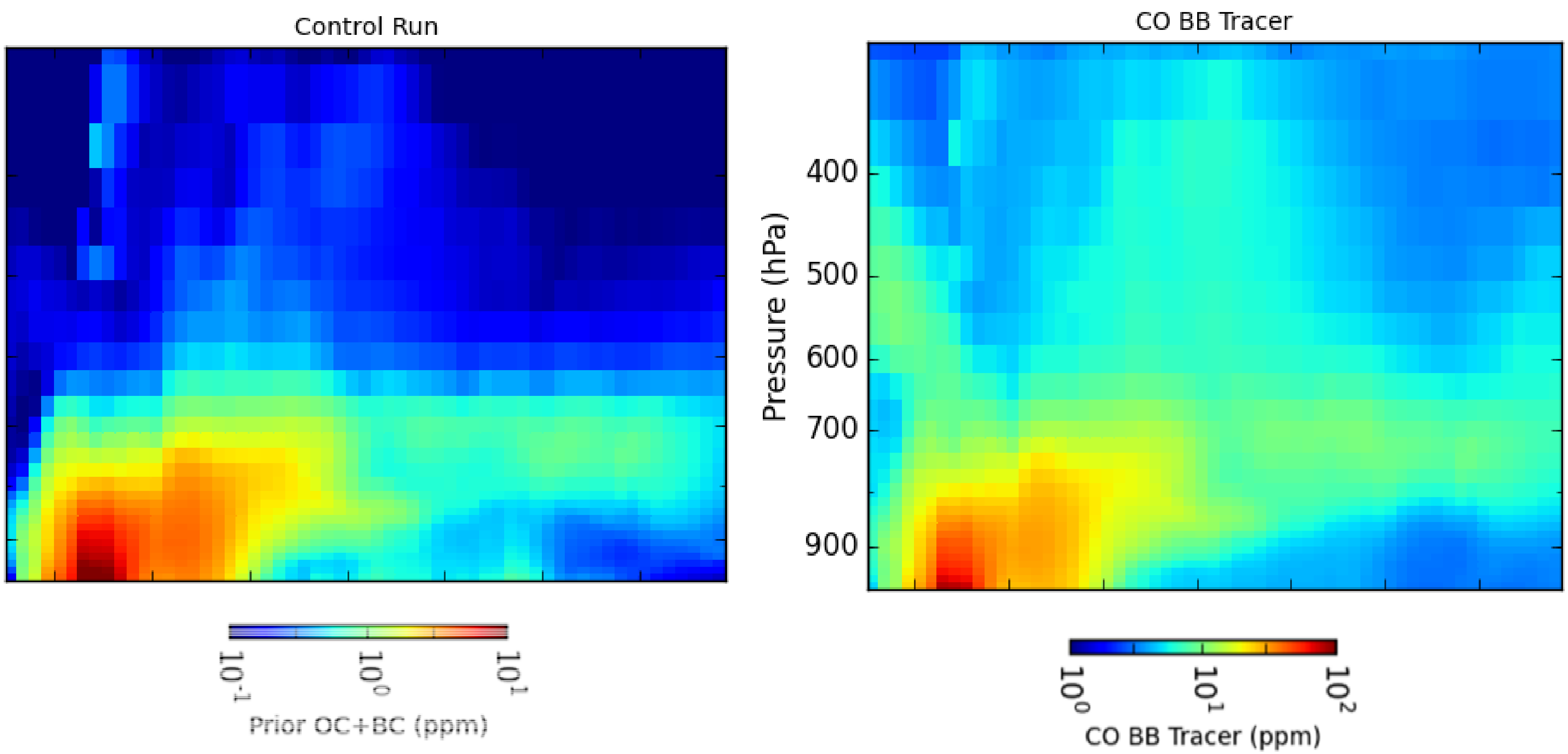
Thank you!



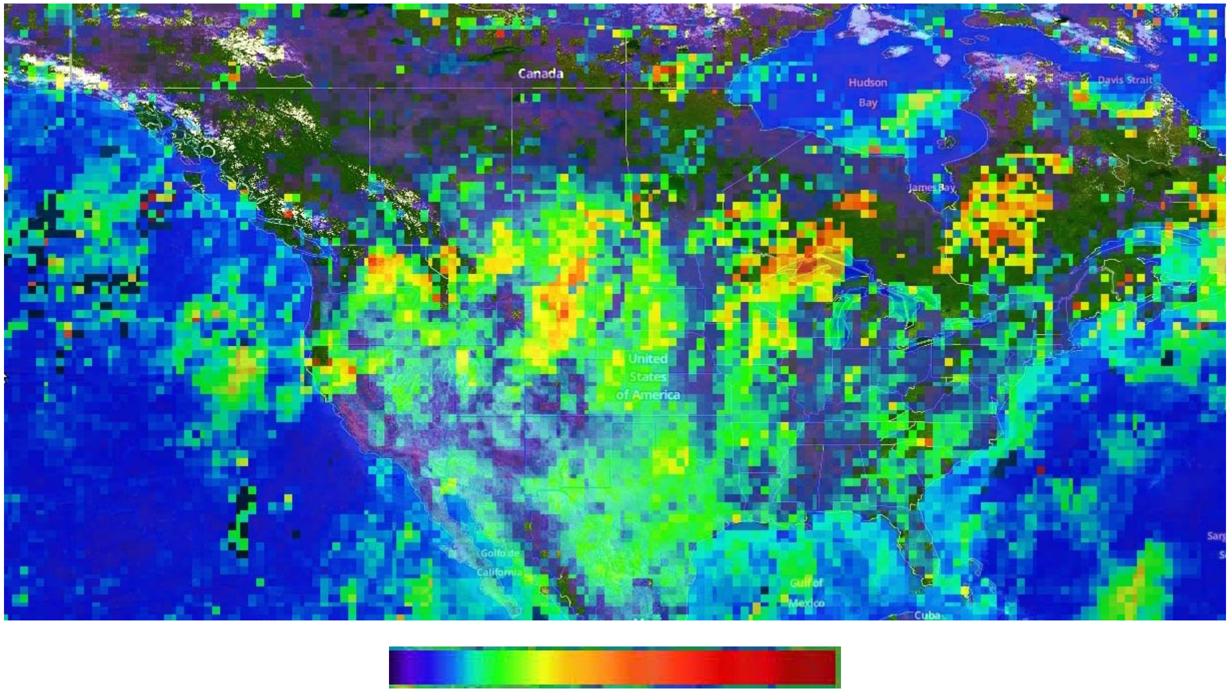
10-5
10-7
Radiance (W/cm2/sr/cm-1)
Solar Reflection
CO (2.3 μm)
Terrestrial
Emission
CO (4.6 μm)
2
4
6
Wavelength
Provides
column
information
Δ y
ΔX CO
2.3 μm solar reflection
Provides free troposphere
profile information
Atmospheric
emission
Δ y
ΔX CO
4.6 μm surface emission
CO Multi-Spectral Remote Sensing
Image: NASA

Combined AOD inversion/CO assimilation

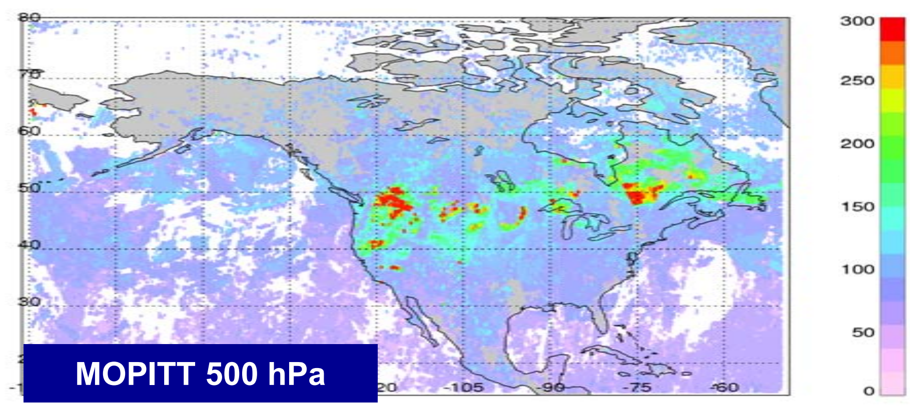
Average OC+BC and CO BB tracer across N.America from 20-31 Aug. 2015 relative average difference compared to Control Run



MISR AOT August 2015 average

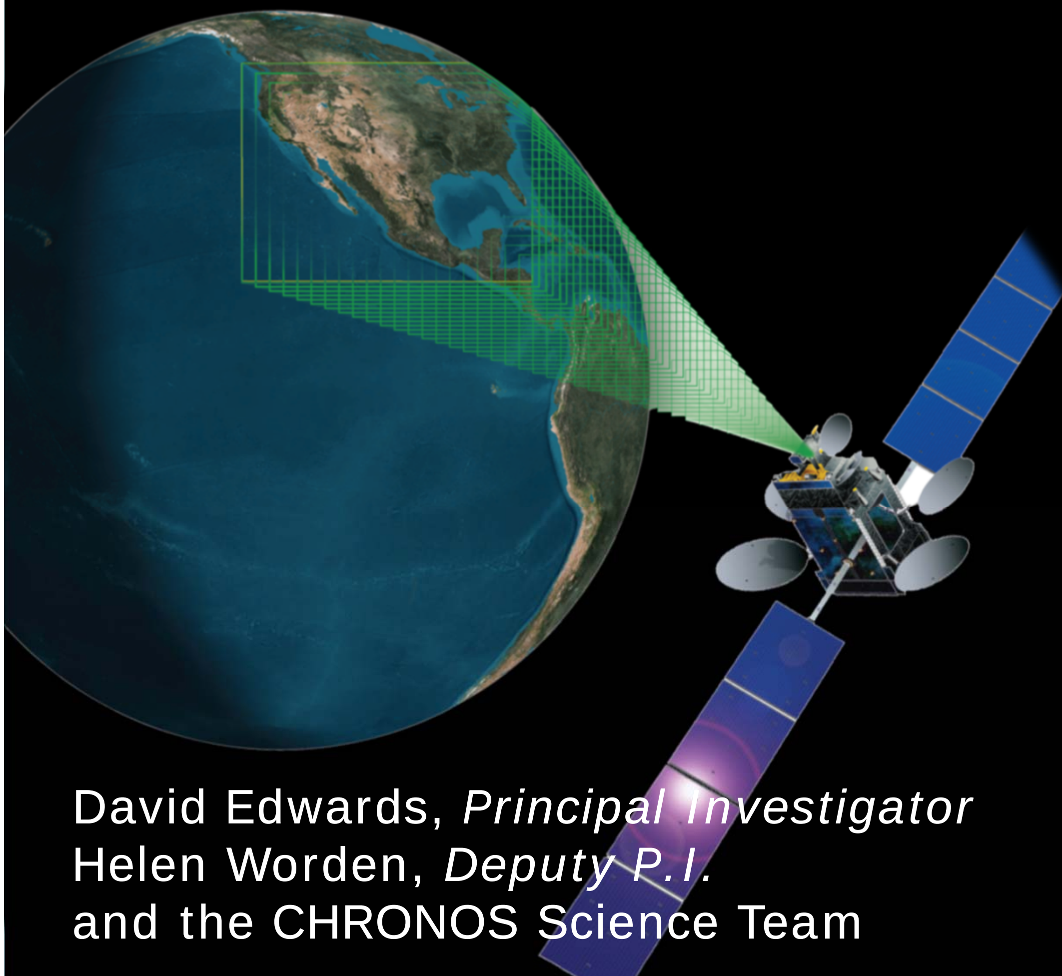


0.0 1.0
MISR AOT



MOPITT 500 hPa

CHRONOS Proposal to NASA EVI-4



David Edwards, *Principal Investigator*
Helen Worden, *Deputy P.I.*
and the CHRONOS Science Team

Ball Aerospace & Technologies Corp.