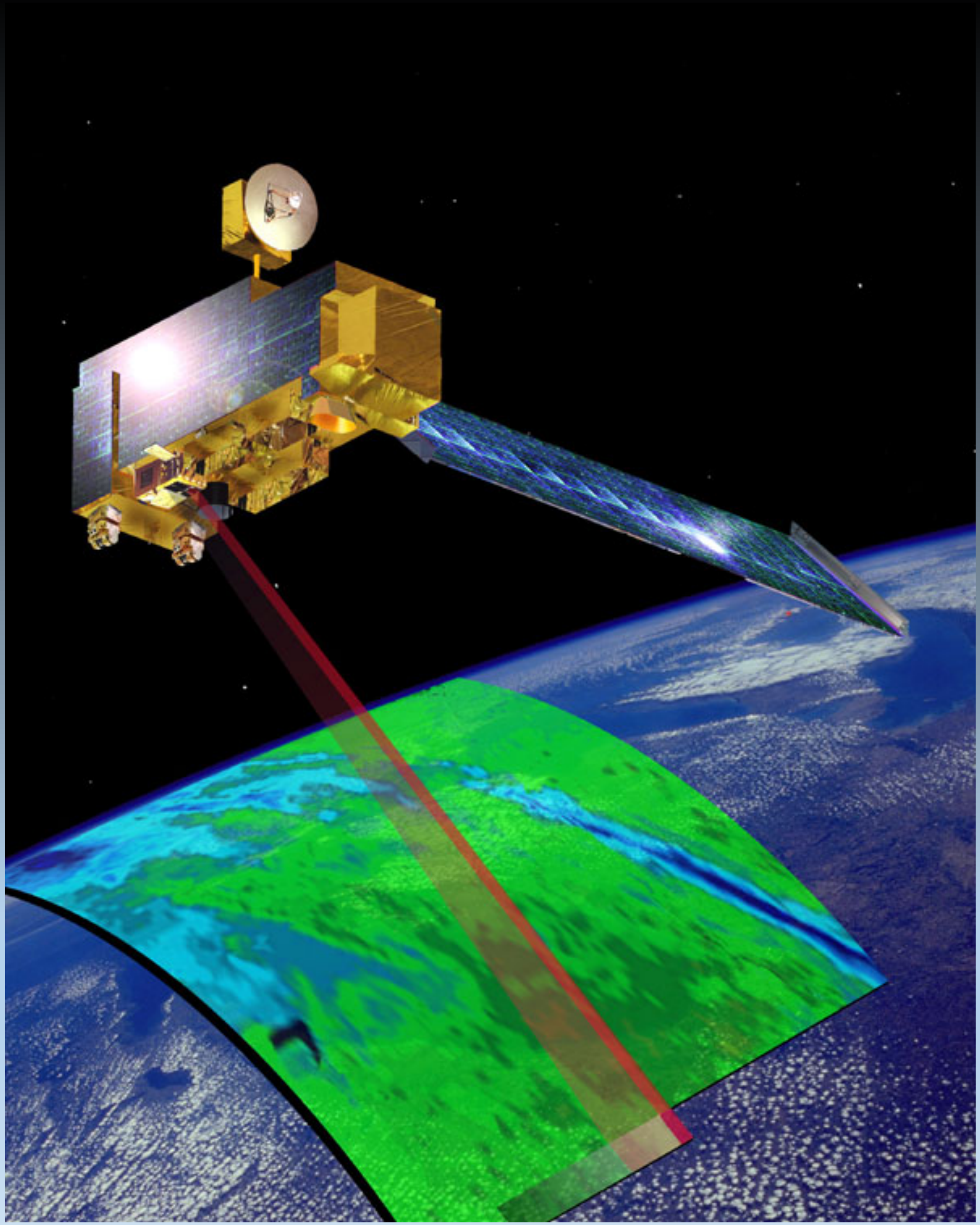
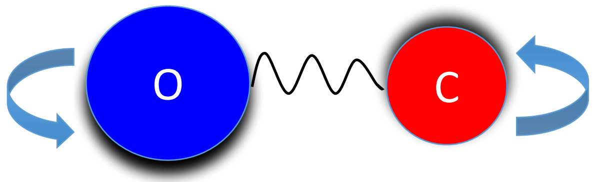


17 years of MOPITT carbon monoxide data: results and prospects for future satellite CO observations

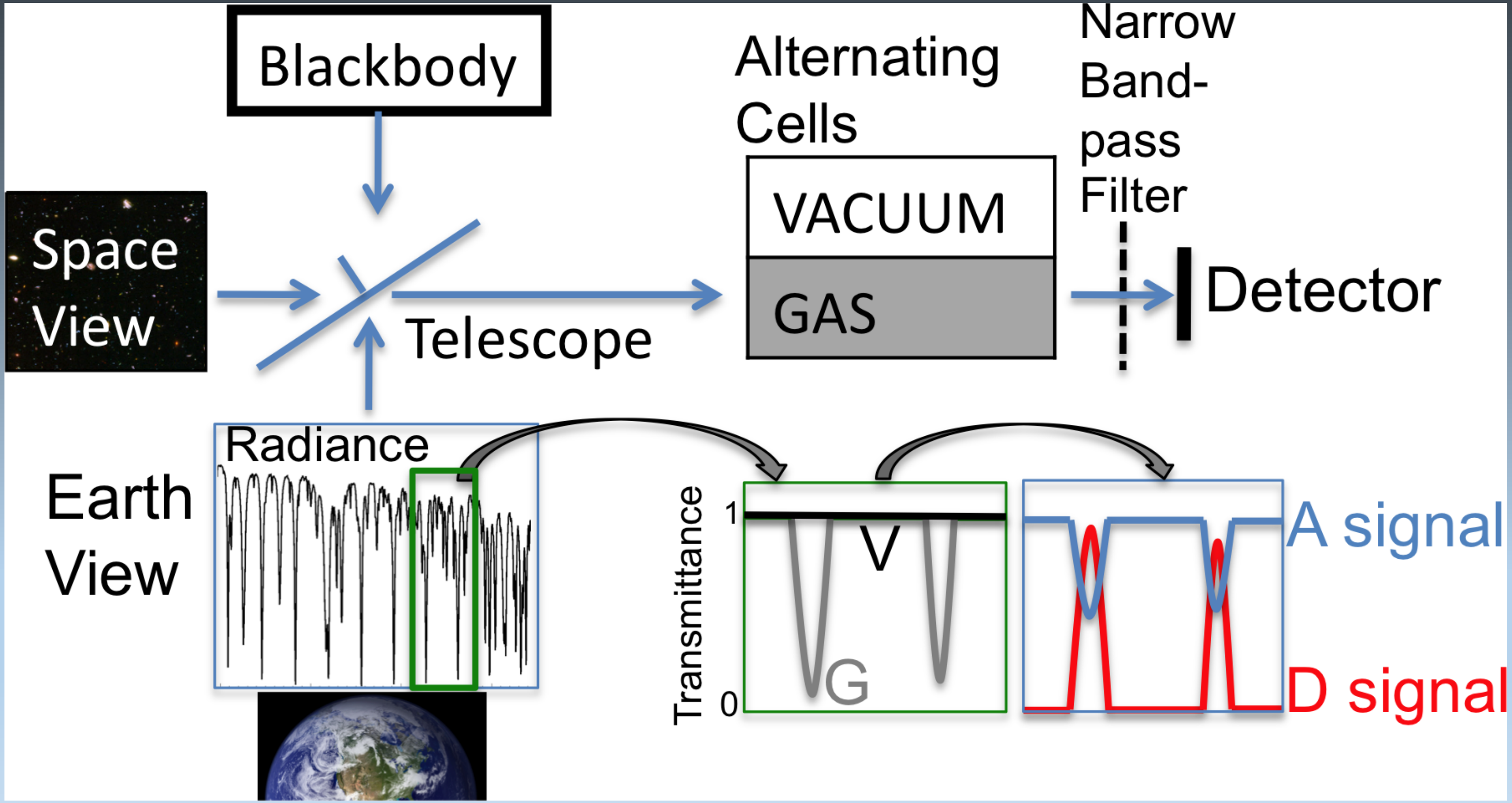
Helen Worden (MOPITT U.S. P.I.) and the NCAR/ACOM MOPITT team

Why CO?

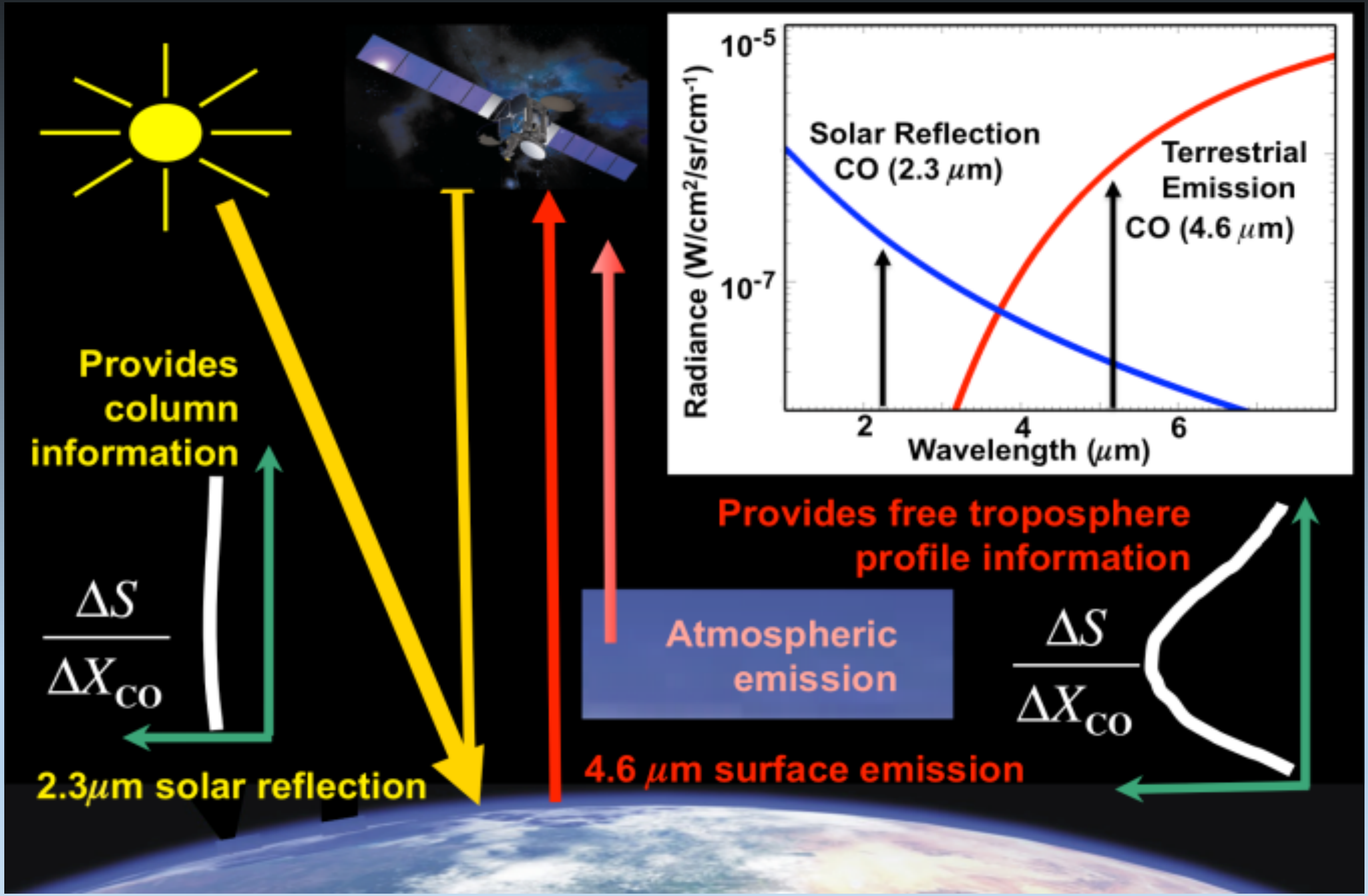


- Important role in atmospheric chemistry & climate
  - Main sources are incomplete combustion (both fires & fossil fuel), biogenic emissions & hydrocarbon oxidation
  - Primary sink is oxidation by OH – more CO => longer CH_4 lifetime
  - Precursor to CO_2 and tropospheric O_3
  - Indirect radiative forcing (RF) of 0.22 W/m^2 for CO emissions (IPCC AR5)
- Ideal tracer for pollution transport
  - Lifetime is weeks to months, so CO is transported globally, but not evenly mixed (like longer lived species)
  - Easy to measure elevated CO above background levels with infrared spectra
- Global direct emissions of CO (~half of atmospheric CO)
  - ~500-600 Tg/yr anthropogenic (relatively stable)
  - ~300-600 Tg/yr biomass burning (large interannual variability)

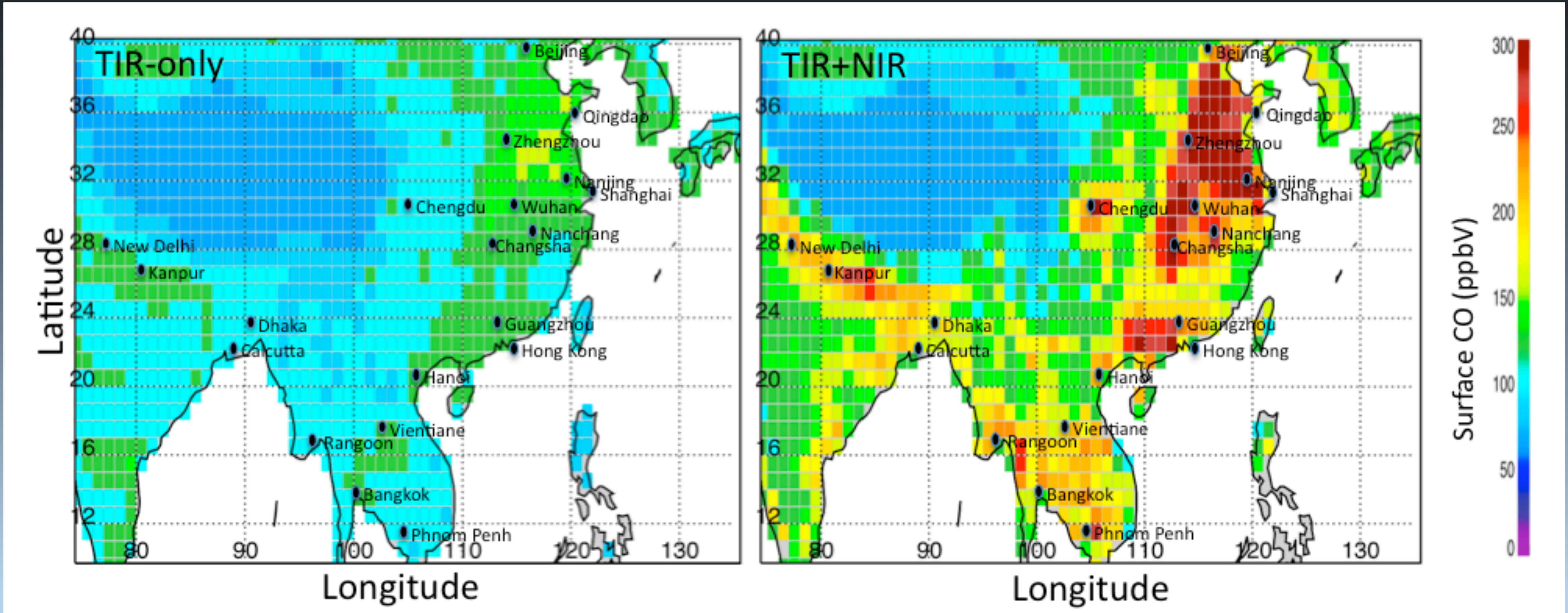
MOPITT Instrument Concepts:
Simple Gas Filter Correlation Radiometer (GFCR)



MOPITT Instrument Concepts:
Thermal and Shortwave Infrared Measurements

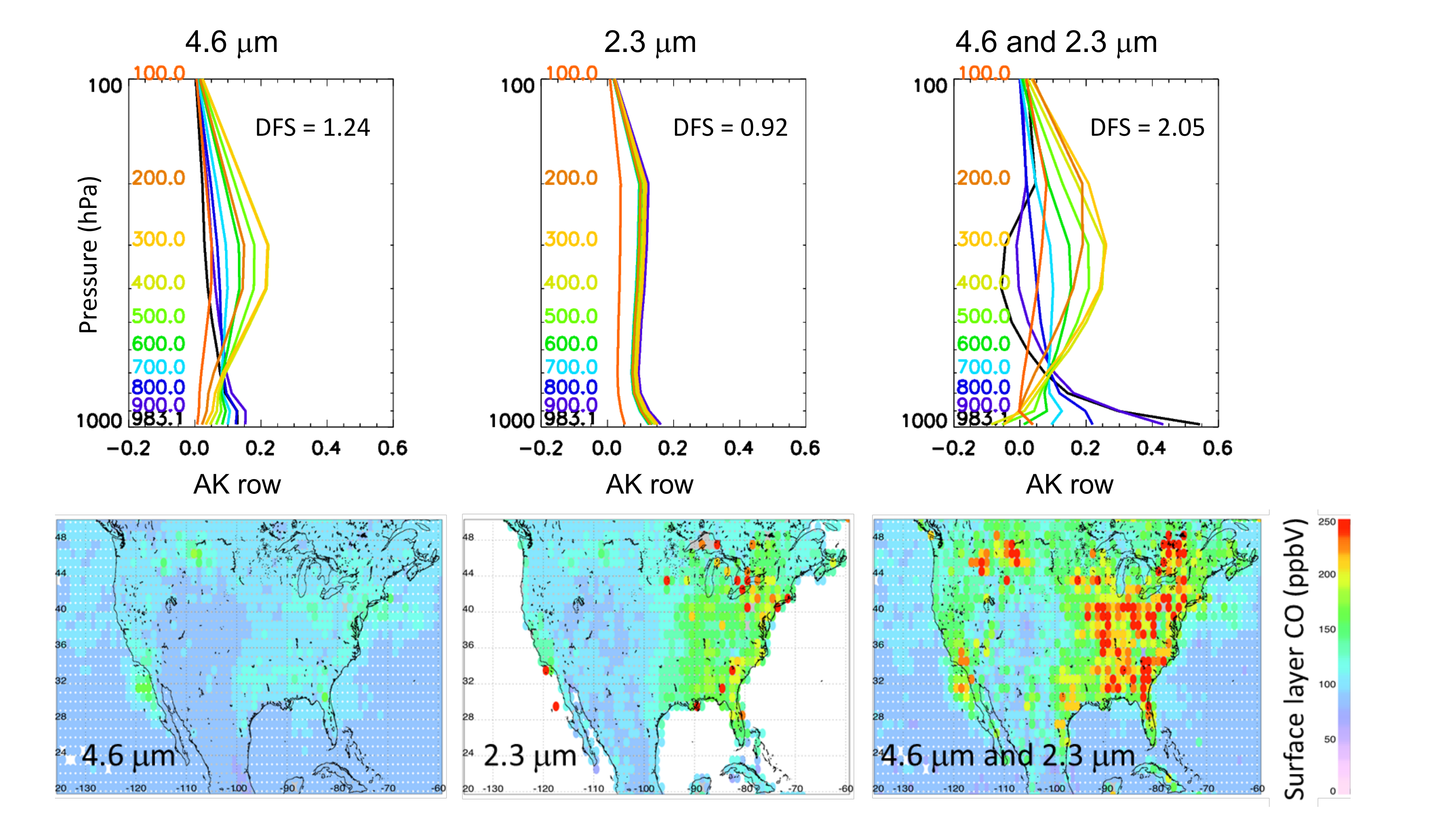


MOPITT Multispectral Measurements: China

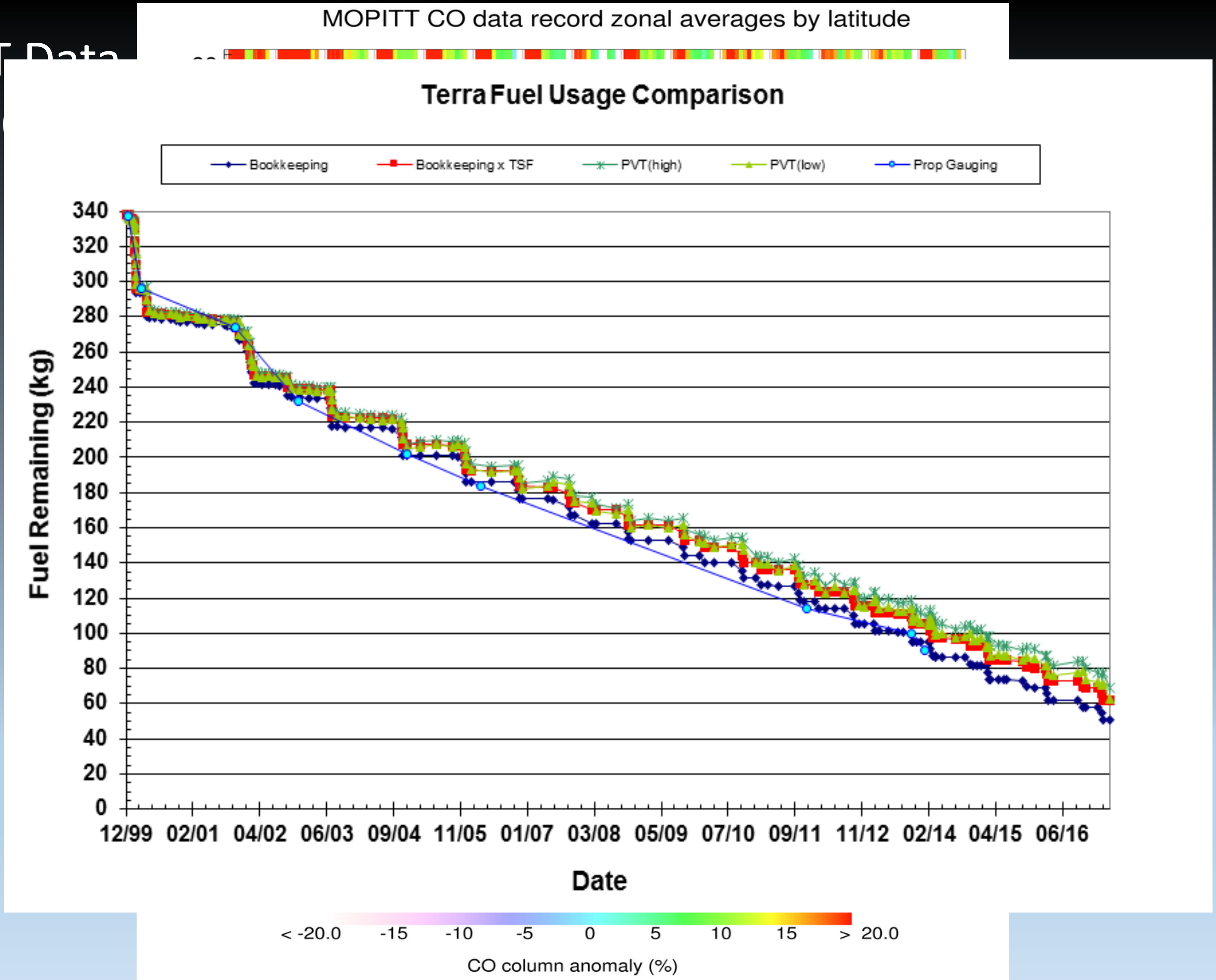


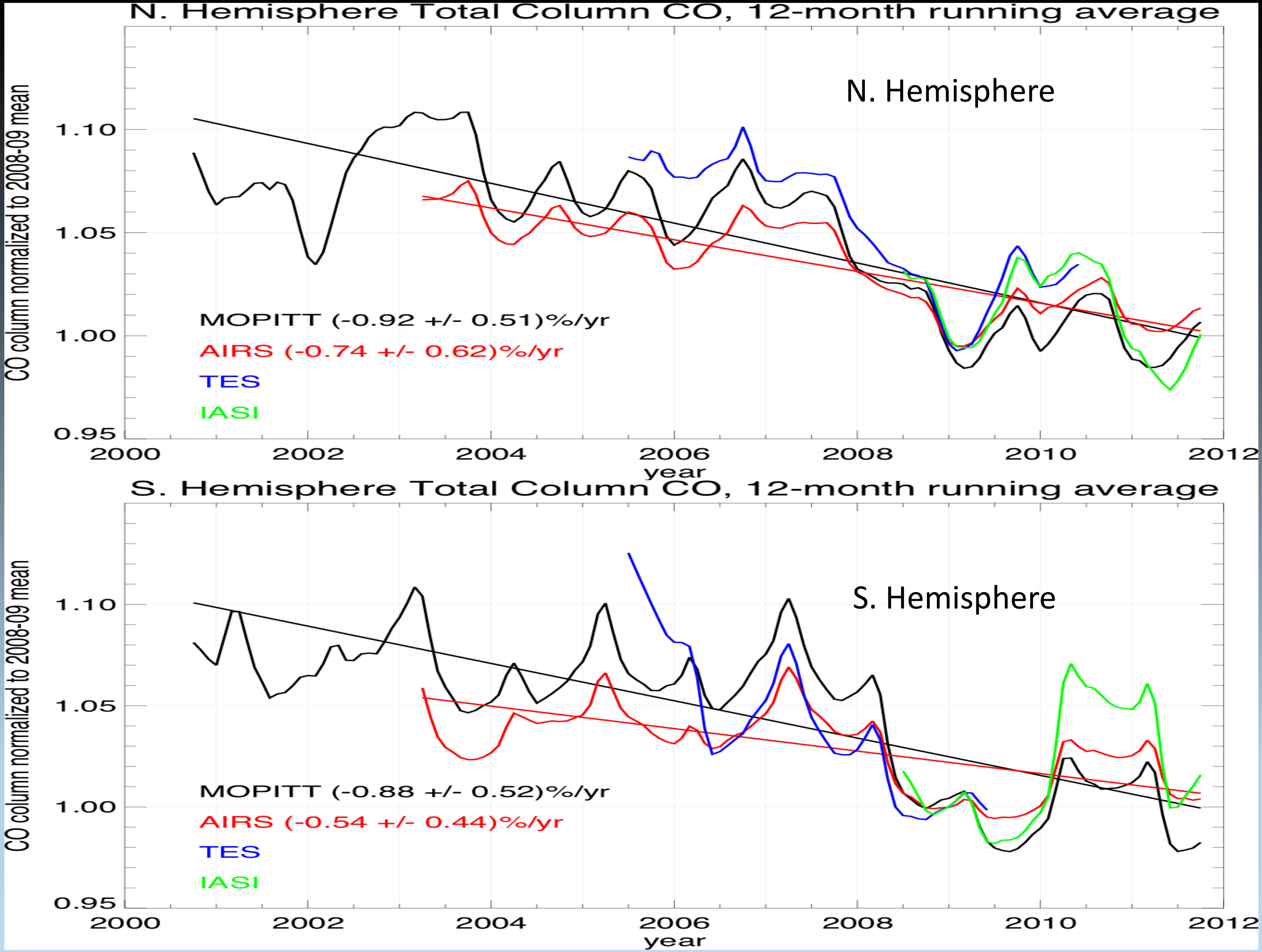
Worden et al., JGR, 2010

MOPITT Multispectral Measurements: CONUS



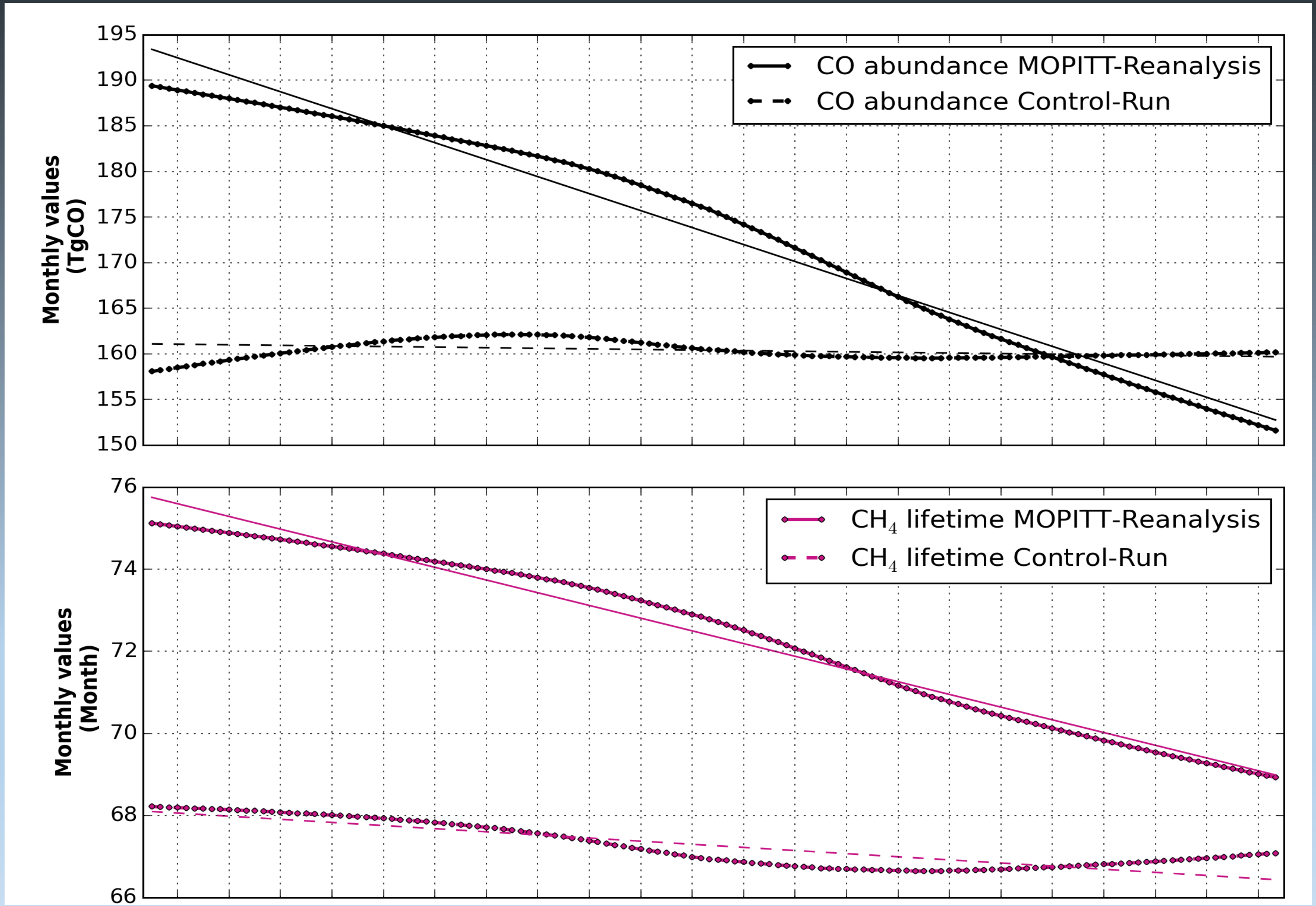
MOPITT Data Record





Worden et al., ACP, 2013

Impact of decreasing CO on methane lifetime



Tropics (30°S to 30°N)

$$\frac{d[CH_4]}{dt} = S_{CH_4} - R1; R1 = k_1[CH_4][OH]$$

$$\frac{d[CO]}{dt} = S_{CO} - R2; R2 = k_2[CO][OH]$$

$$\frac{d[OH]}{dt} = S_{OH} - R1 - R2 - R3\,; R3 = k_3[X][OH]$$

Gaubert et al., in prep.

2001-2015 trends in CO: Attribution of changes

Assimilating MOPITT in GEOS-Chem to constrain emissions

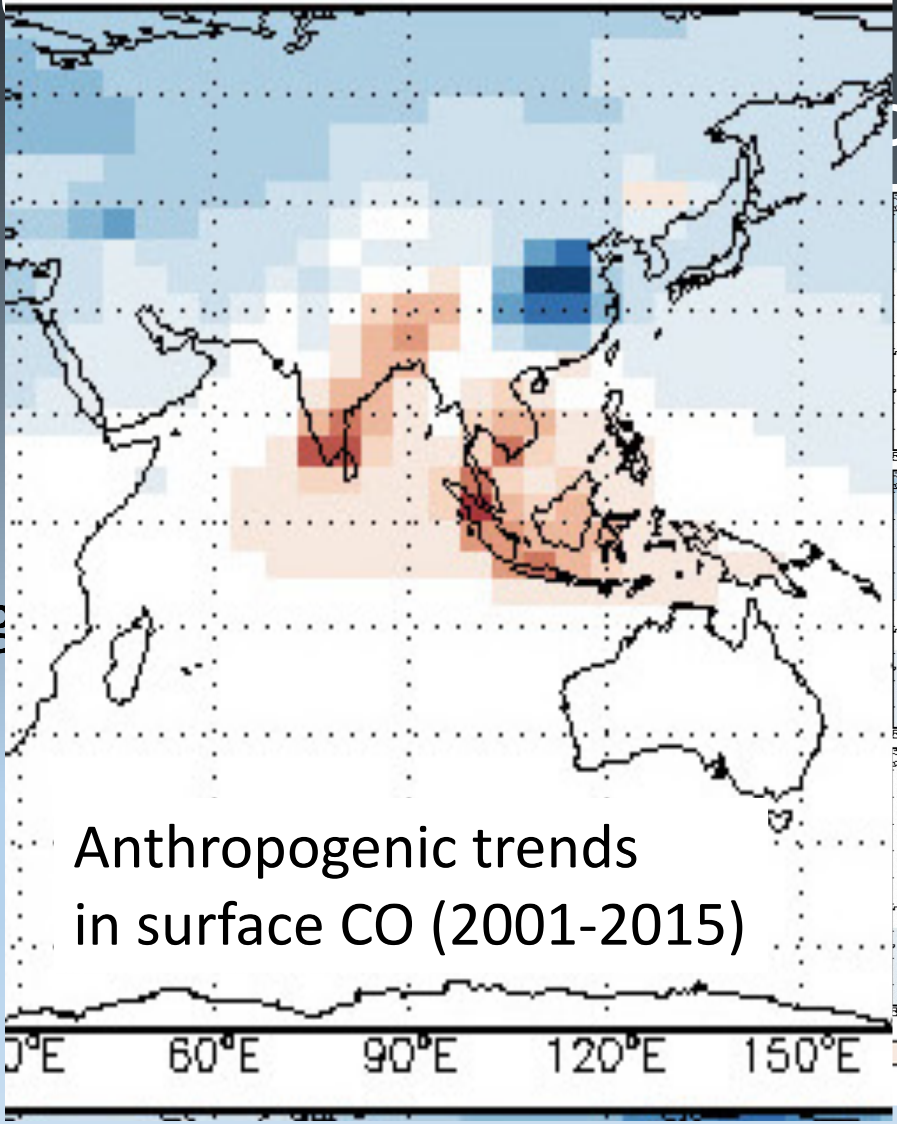
(Jiang et al., ACP 2017)

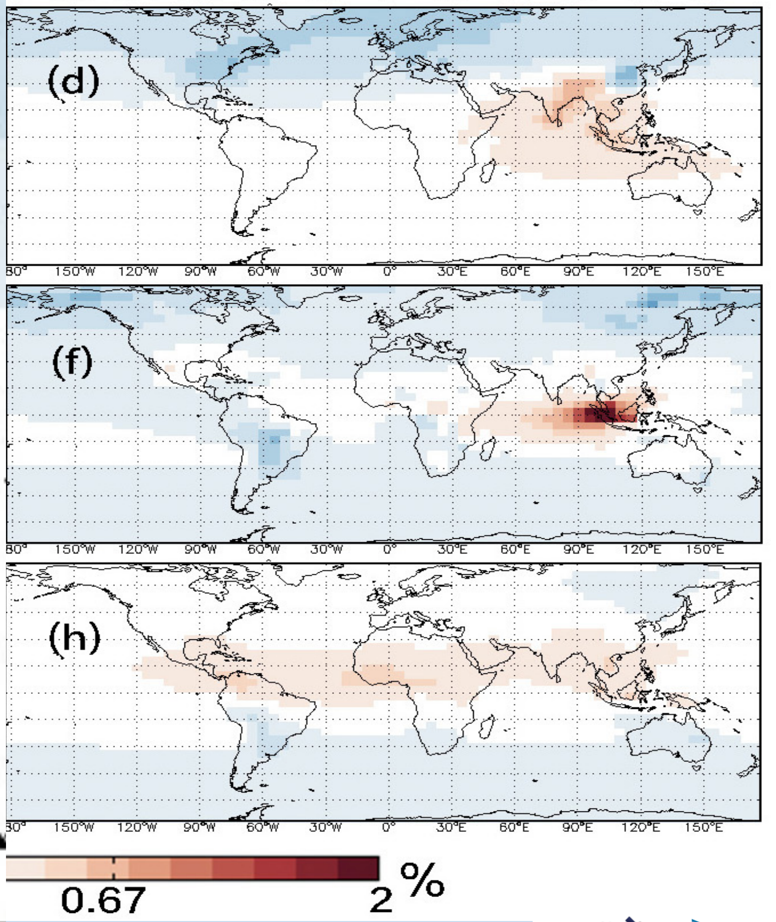
Total Column CO trends

Anthropogenic

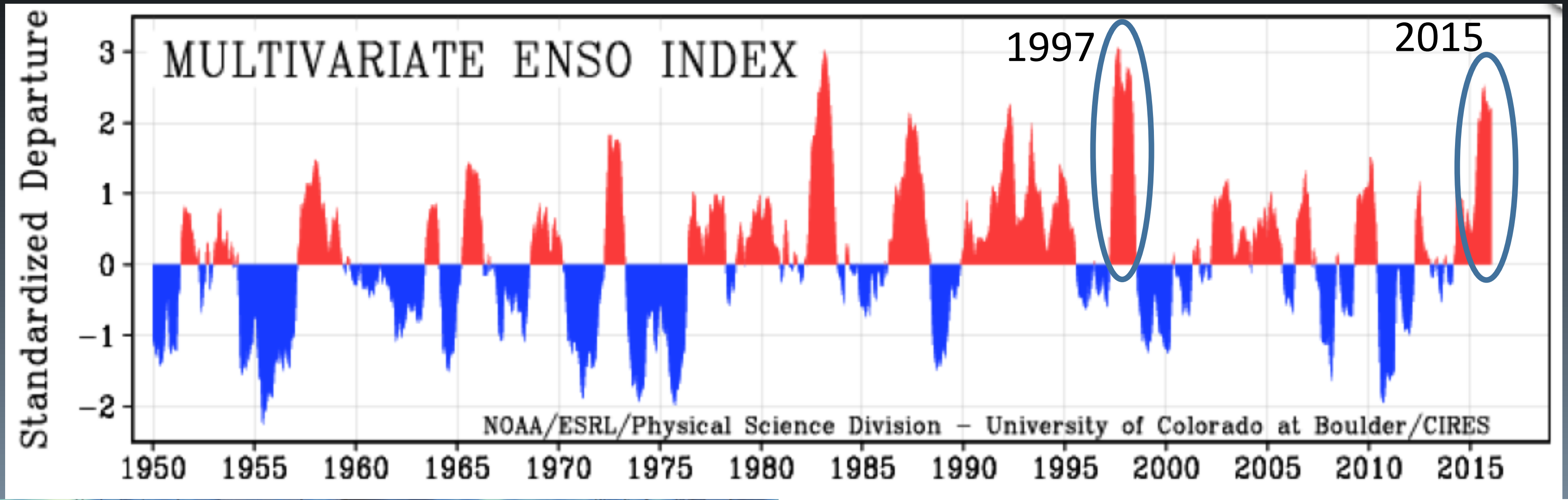
Biomass Burning

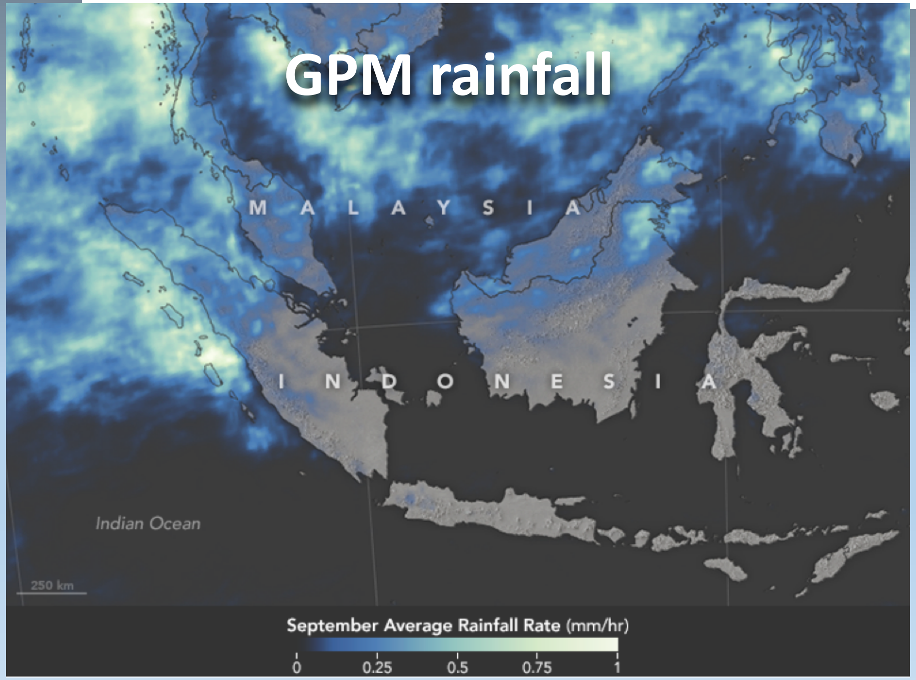
Biogenic VOCs

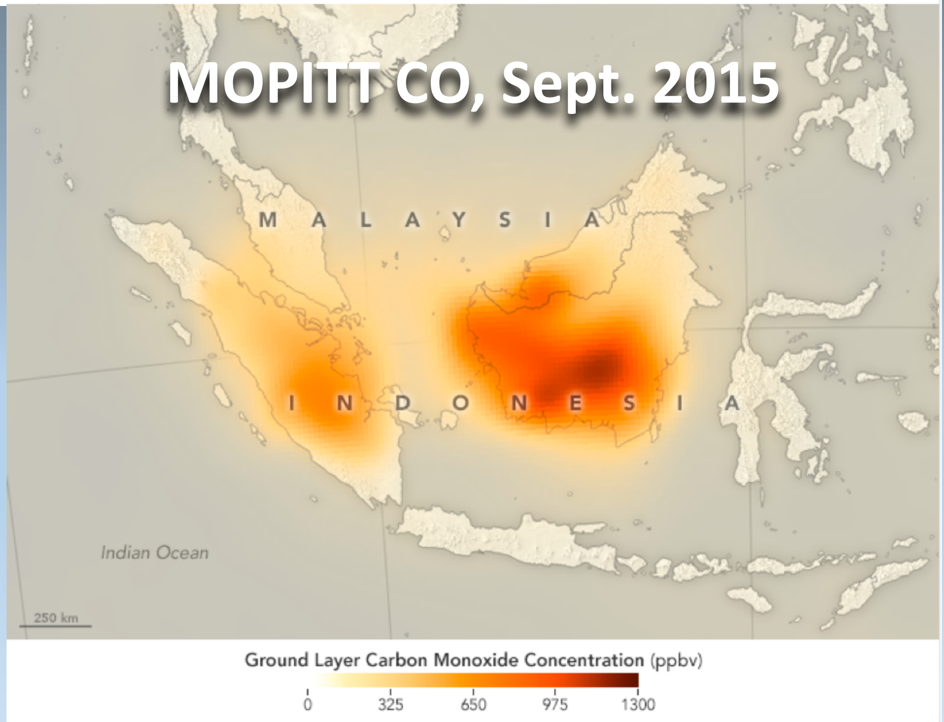




Question: Did ENSO-driven fires in Indonesia, 2105, influence Asian pollution?

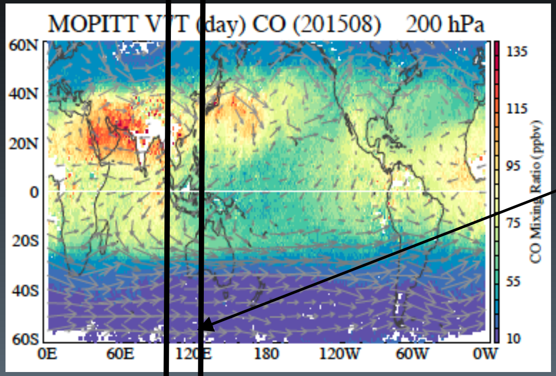




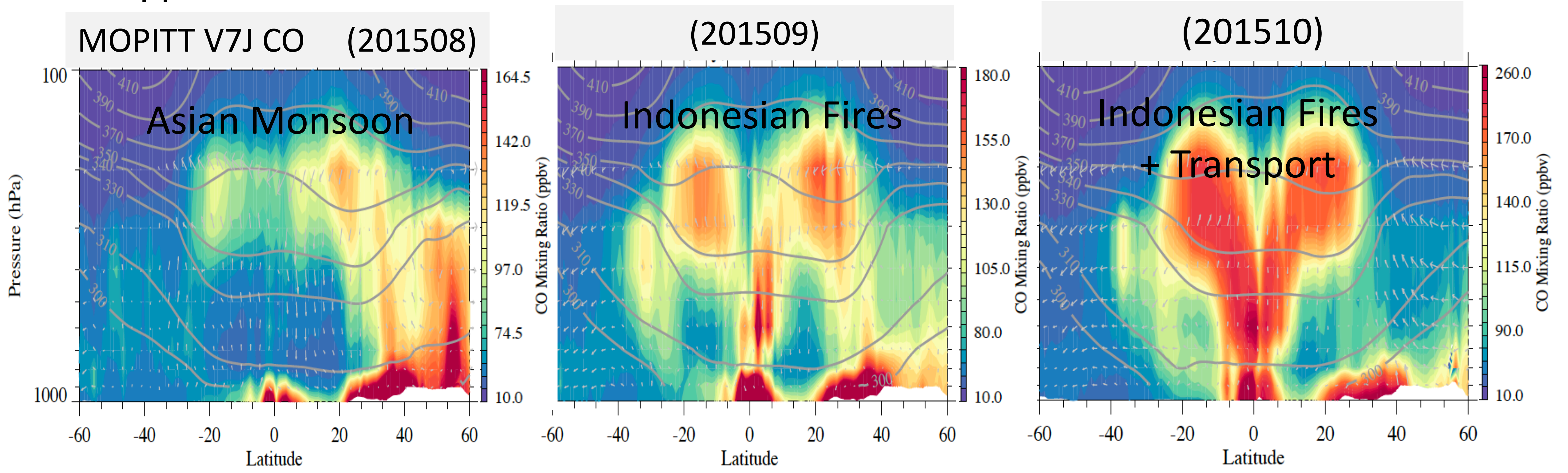


Rainfall and CO images from NASA Earth Observatory

MOPITT CO vertical structures (Aug,Sep,Oct 2015)

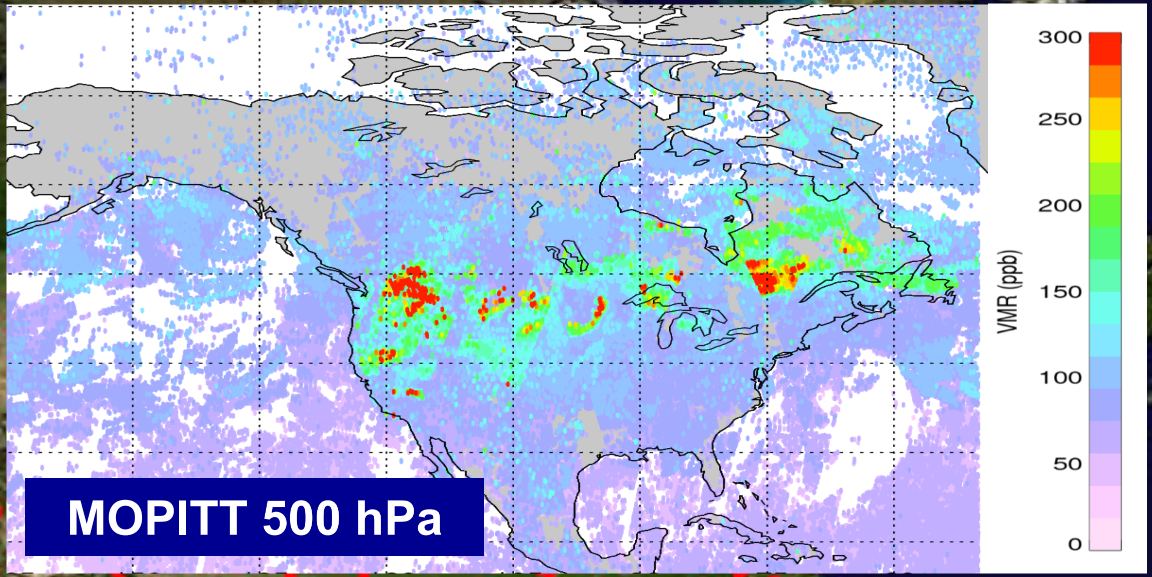


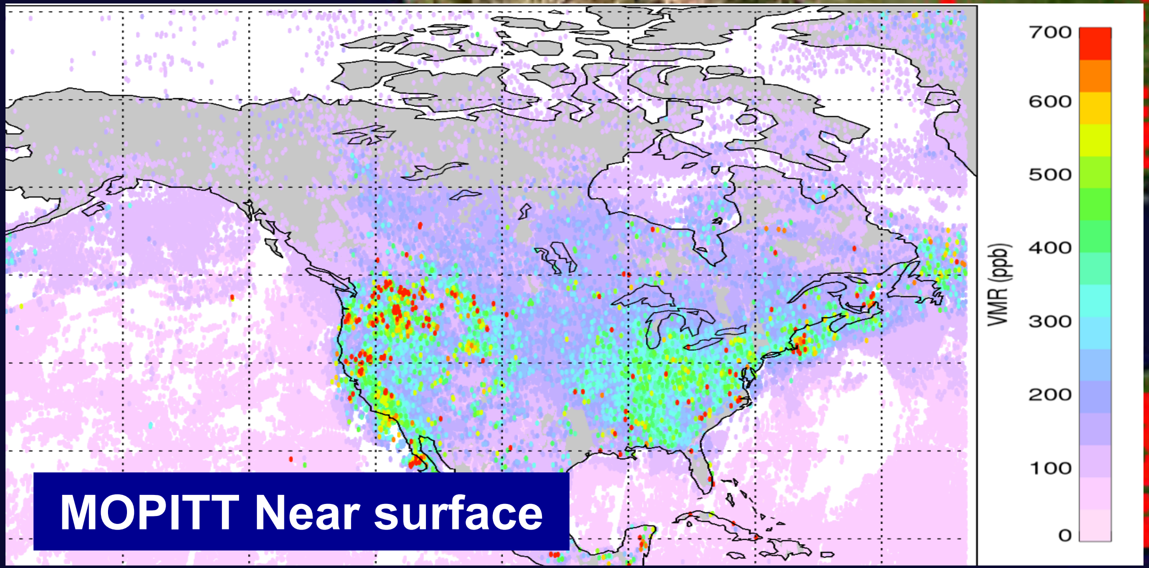
Lon: 110-120E Averages



Multispectral retrievals distinguish signatures of pollution sources and transport

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



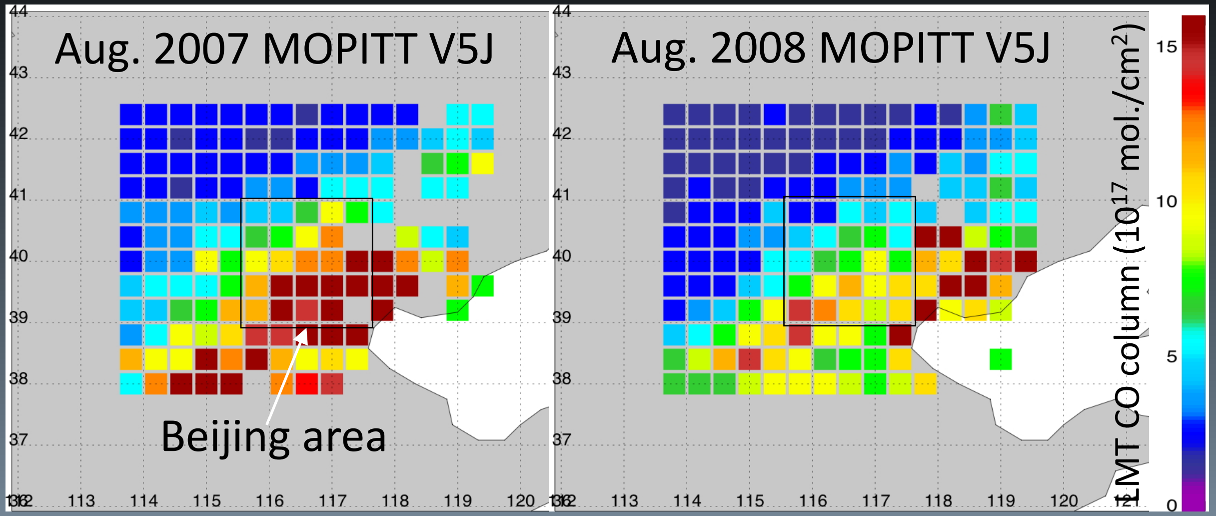


Note different scales

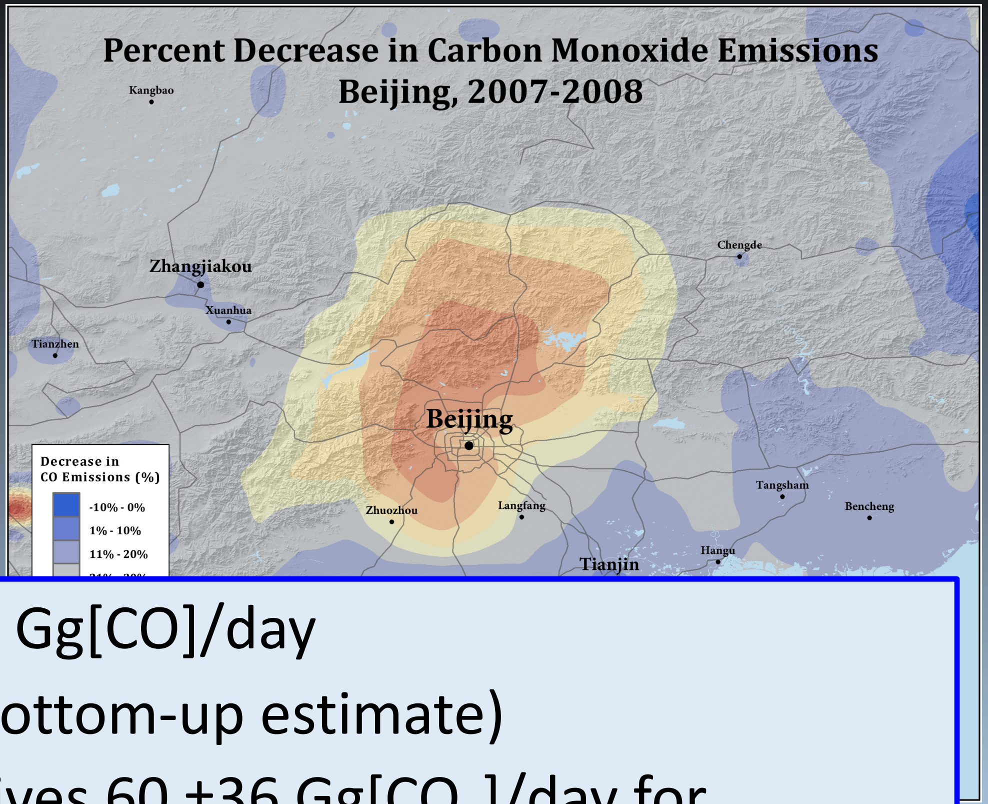
MODIS Fire Counts 19-28 August 2015 showing the WA north-central Okanogan Complex

NCAR

Satellite-based estimates of reduced CO and CO_2 emissions due to traffic restrictions during the Beijing 2008 Olympics (MOPITT & WRF-Chem)



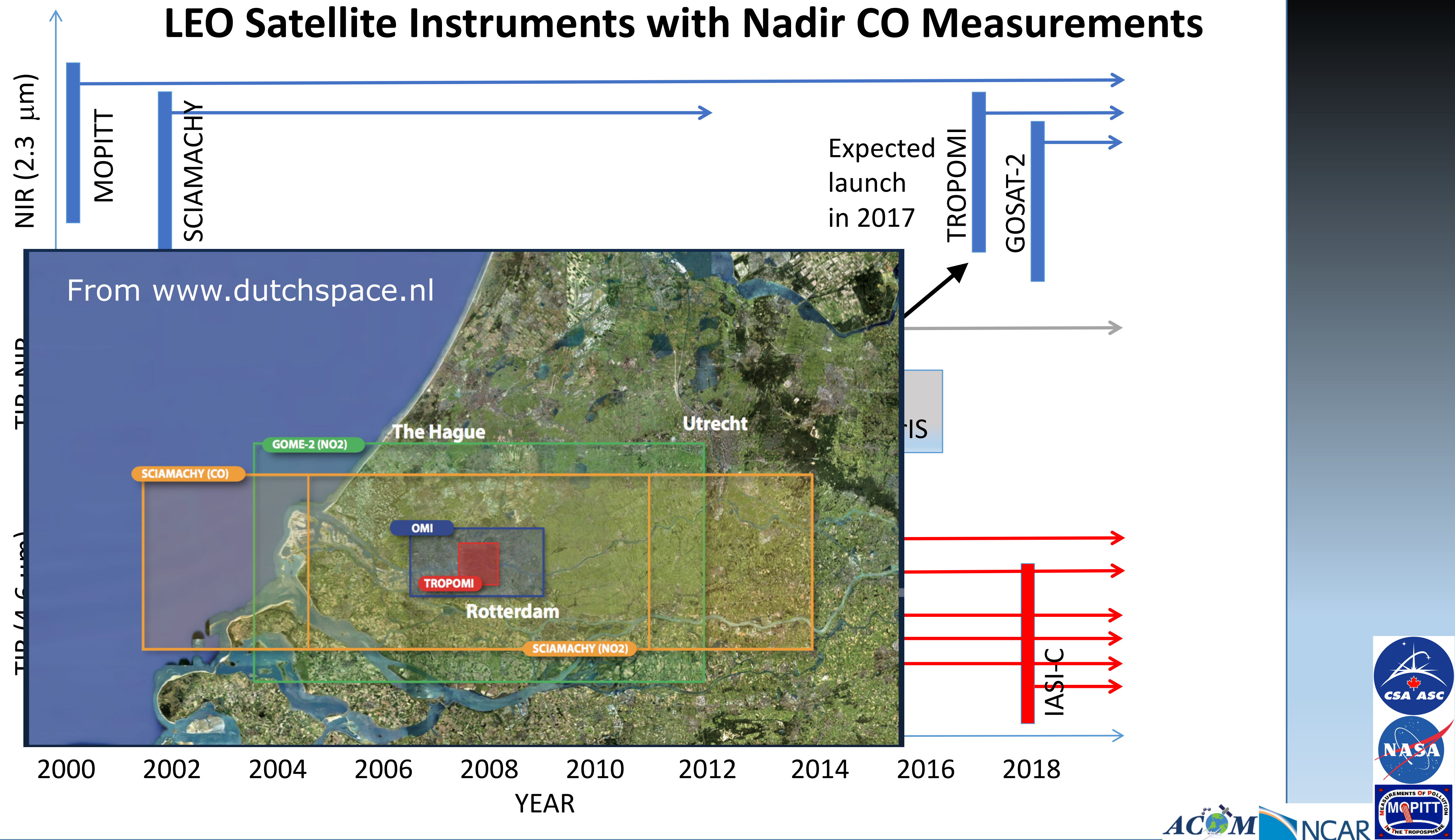
Near-surface CO from MOPITT observations



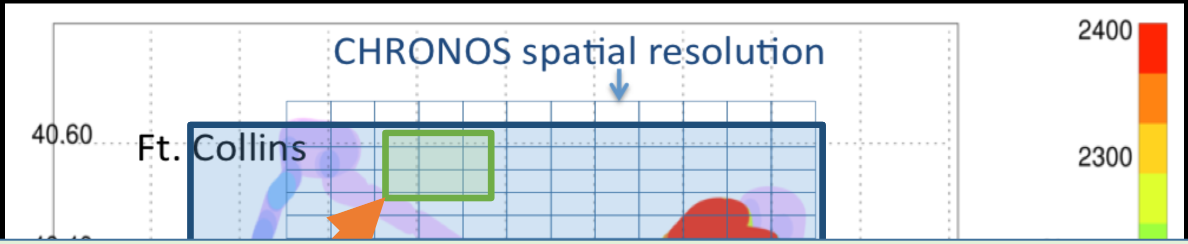
- Total CO reduction from Olympics = 2.95 ±1.8 Gg[CO]/day
- 60% reduction in the transportation sector (bottom-up estimate)
- Using FF CO/CO_2 emission factor for Beijing gives 60 ±36 Gg[CO_2]/day for reduction in CO_2 emissions
- This is ~1/360 of the reduction in CO_2 emissions needed to keep warming under 2°C by 2100 (IPCC-RCP2.6), which suggests urban traffic controls could have a significant impact on CO_2 emissions given there are now 490 cities with more than 1 million people

[Worden et al., *GRL*, 2012]

LEO Satellite Instruments with Nadir CO Measurements



CHRONOS Proposal to NASA EVI-4

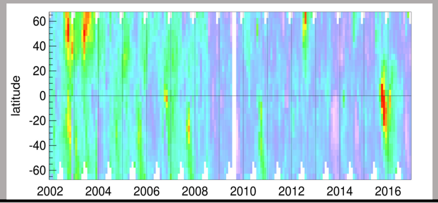


Future CO observations from Geostationary Earth Orbit (GEO) in the next decade:

- **MTG-S (IRS) on Sentinel 4: Sub-hourly, 4x4 km^2 spatial res., TIR CO.**
- **geoCARB: Sub-daily, 4.4 x 5.7 km^2 spatial res., W. Hemis. domain for NIR column CO - selected for NASA EVM-2**
- **CHRONOS: Sub-hourly, 4x4 km^2 resolution at center of N. American domain for TIR + NIR CO – if selected**

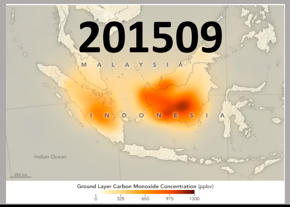
Conclusions

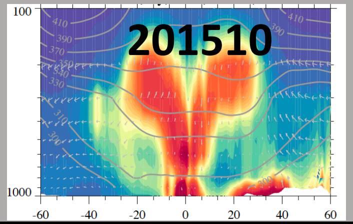
MOPITT has the longest satellite record of global CO and CO concentrations have been decreasing.



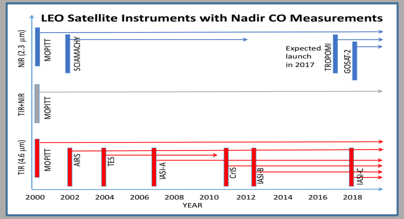
2002-2016

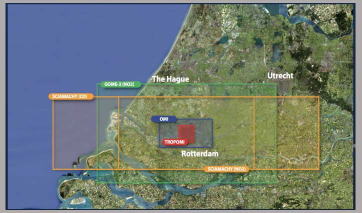
Multispectral observations allow a full picture of sources and transport



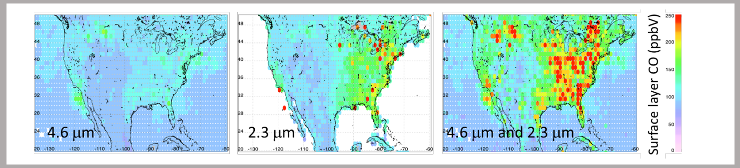


Future satellite CO observations will have finer spatial/temporal resolution but no planned multispectral measurements





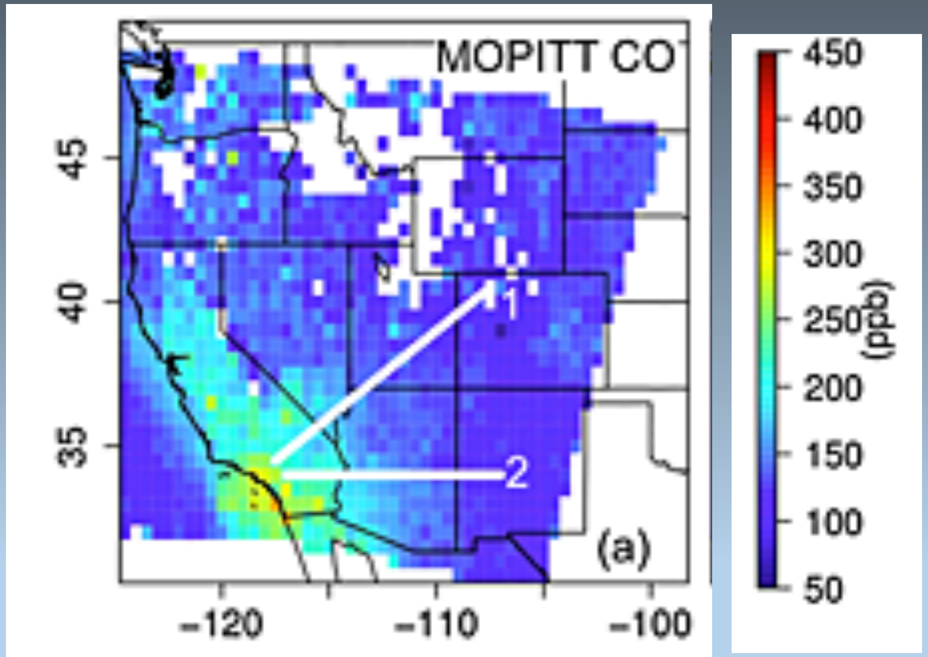
Need more OSSEs to understand combined assimilation of separate TIR an NIR observations. Do we see the same increase in information as a joint retrieval?

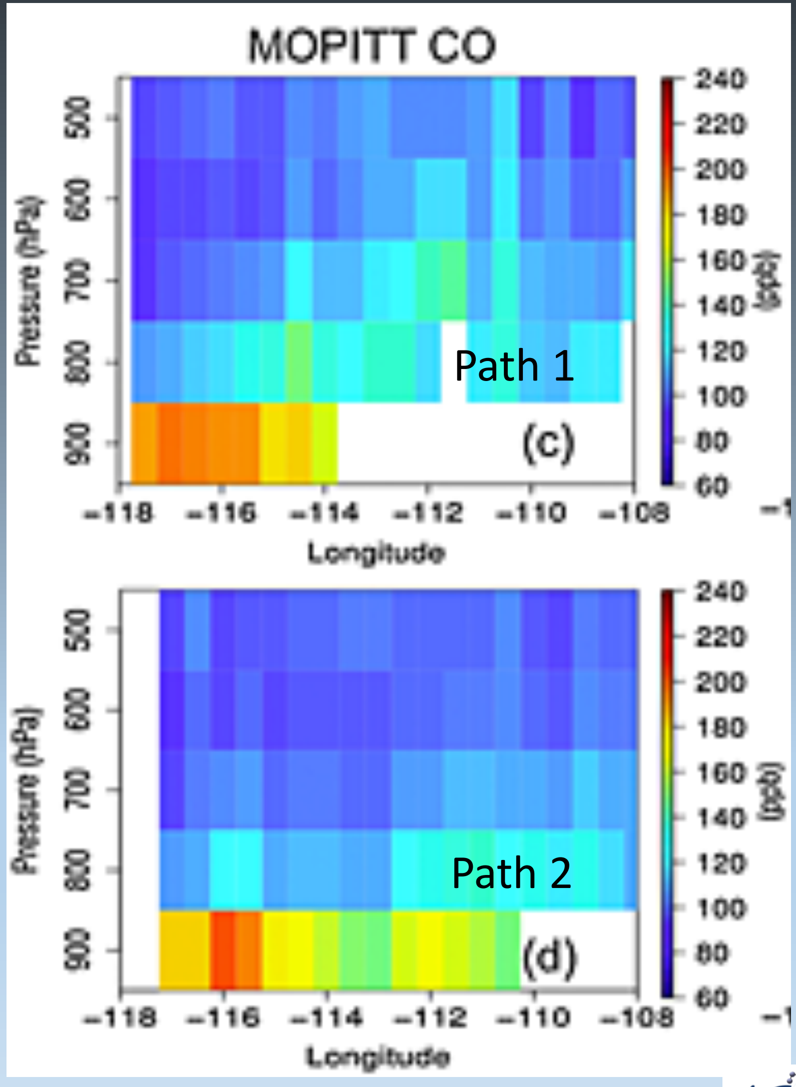


Thanks!

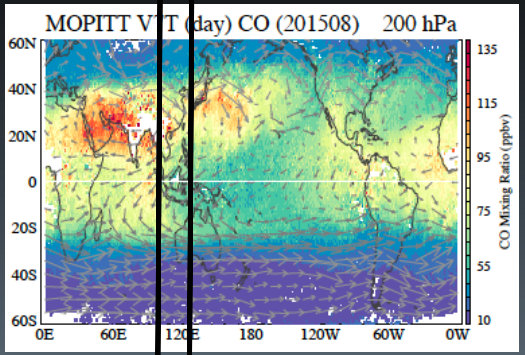
MOPITT V5J CO shows transport over California mountains

Huang et al., JGR, (2013)

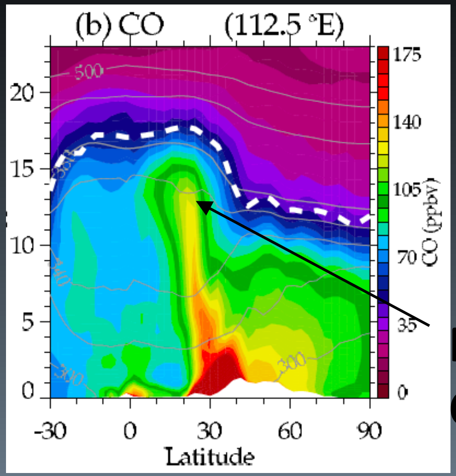




MOPITT CO vertical structures (August) – Asian Monsoon

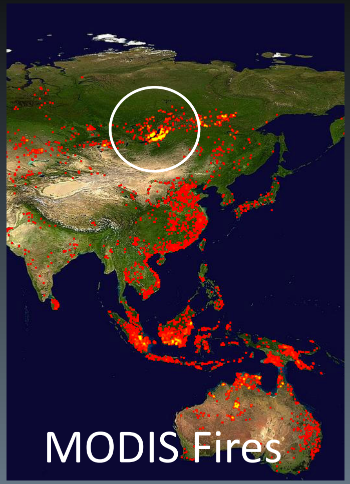


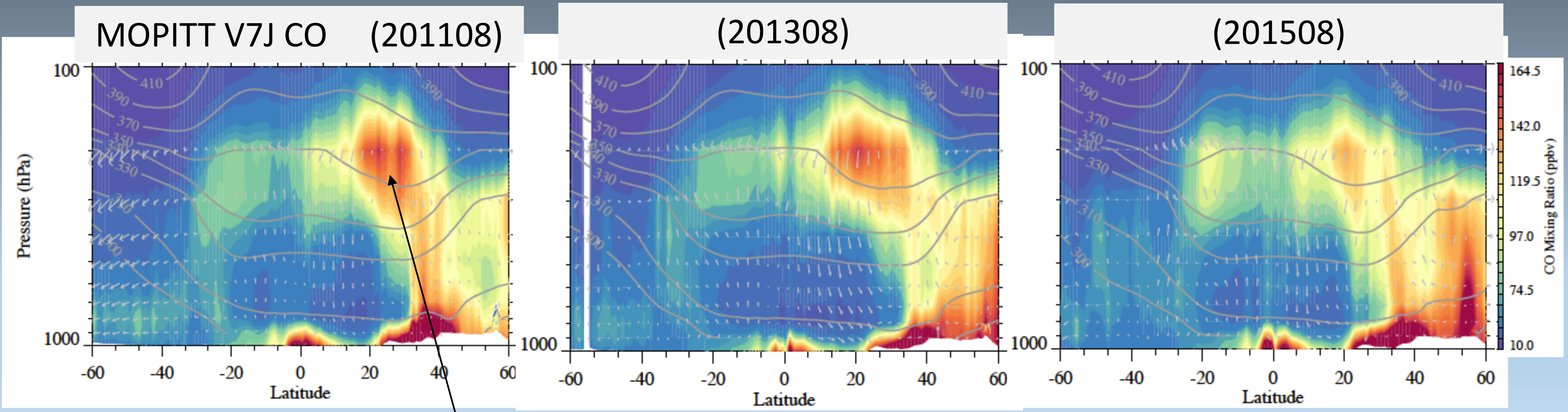
Lon: 110-120E Averages



Park et al. (2009)
CO from MOZART-4

Siberian Fires, 201508



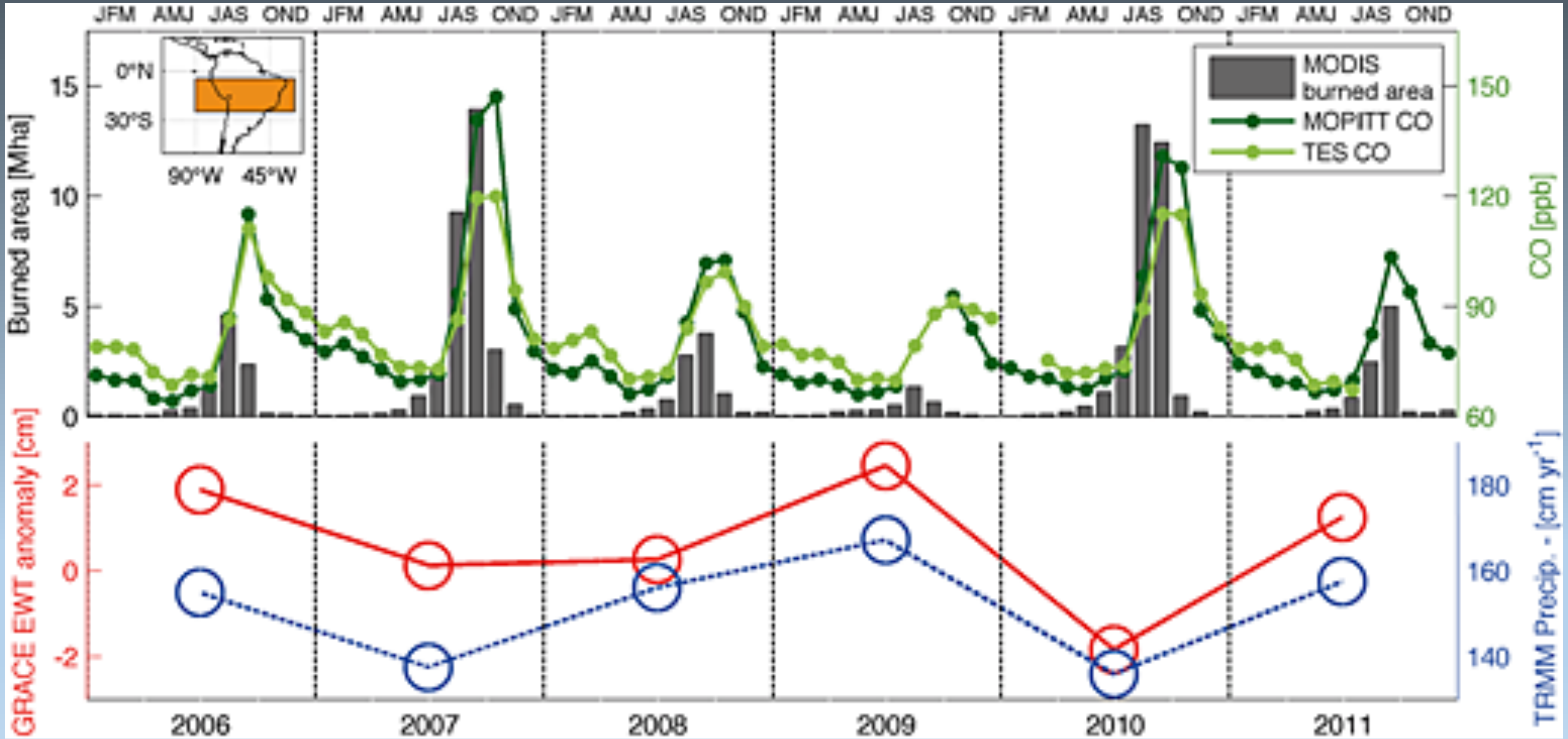


High CO in the UTLS – due to Asian monsoon circulation

ERA_Interim potential temperature and winds

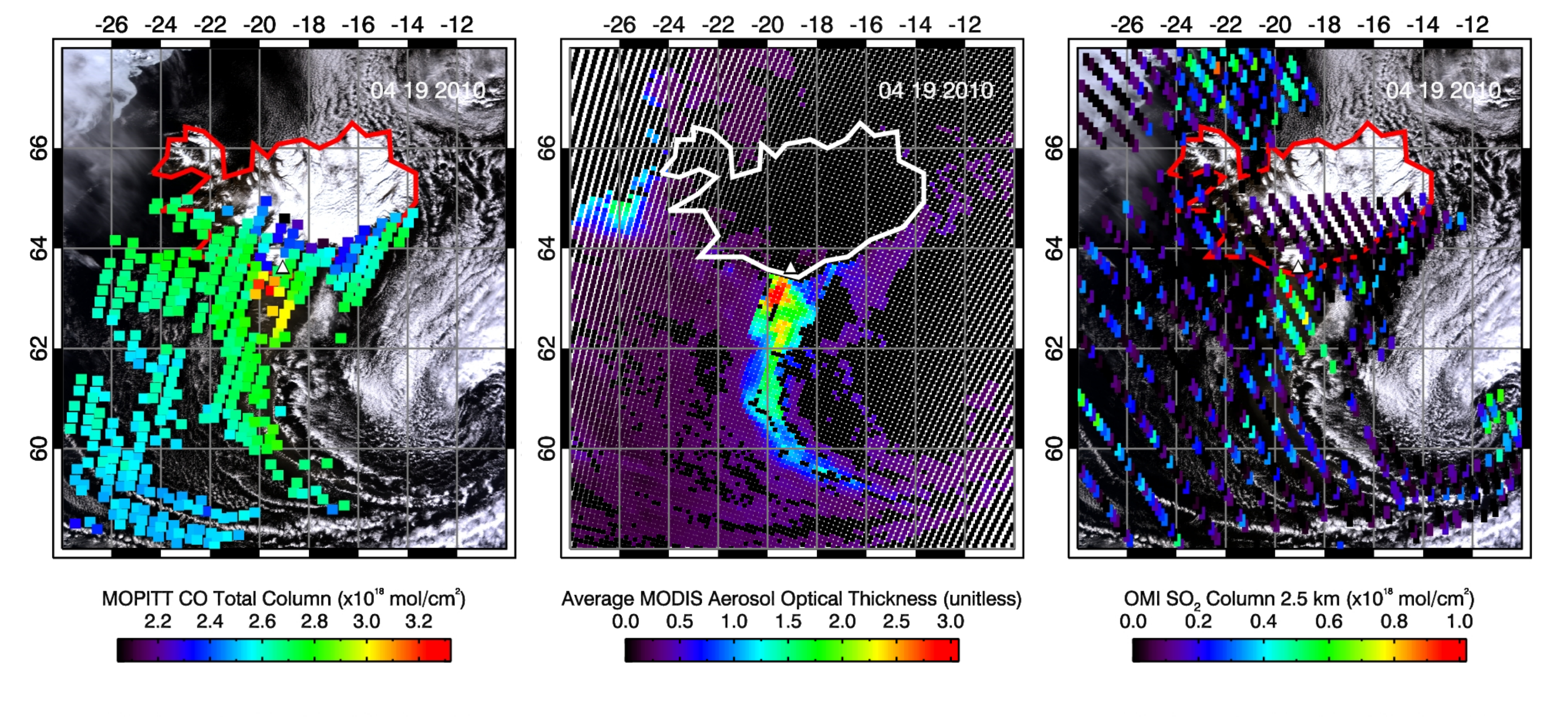
MOPITT V6J used in multi-satellite analysis of Amazon fires

- Bloom, et al., *GRL, 2015*



First detection of volcanic CO from space

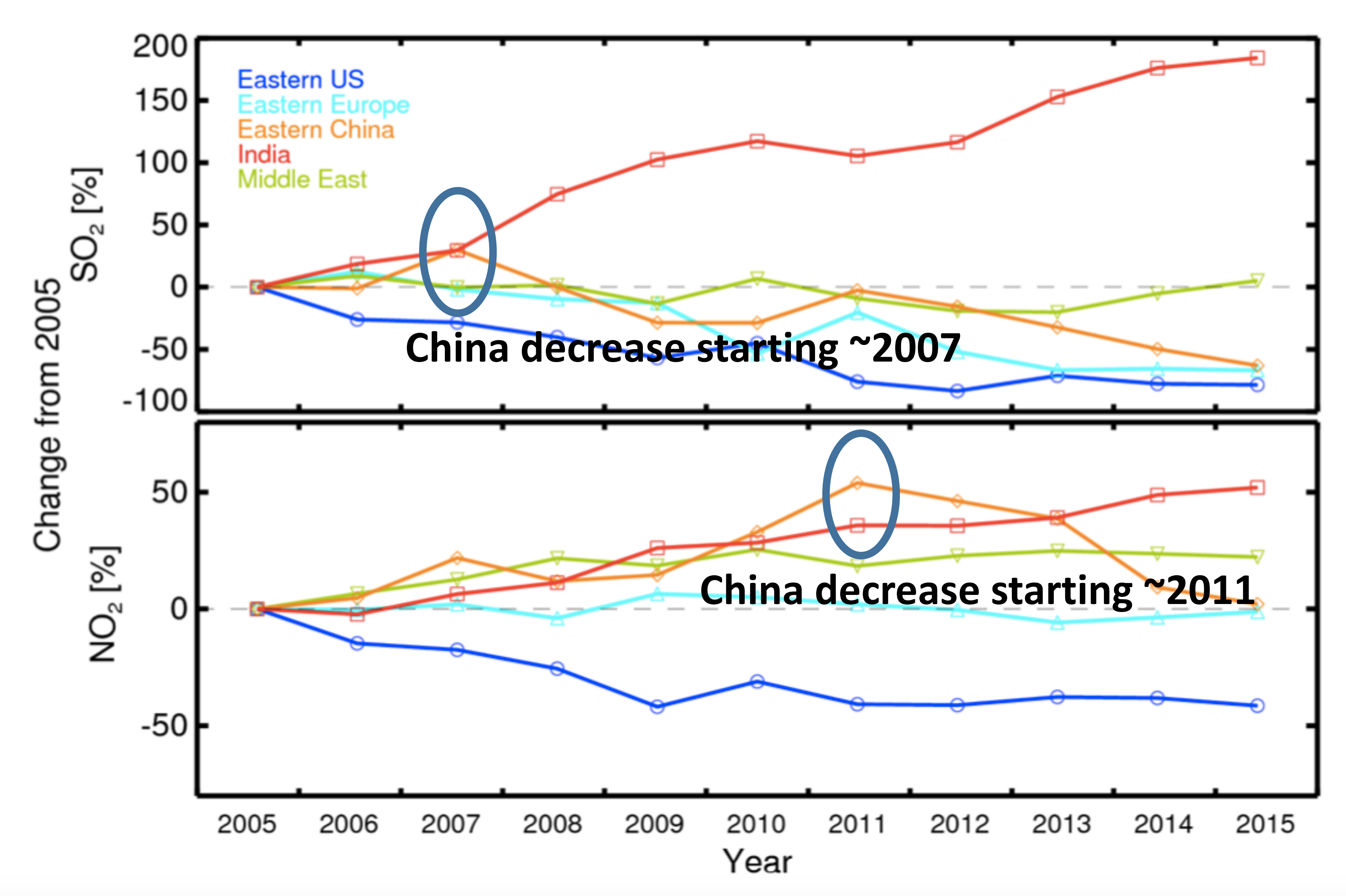
MOPITT CO | MODIS AOD | OMI SO_2



Iceland Eyjafjallajökull eruption, April 19, 2010

Martínez-Alonso, GRL, 2012

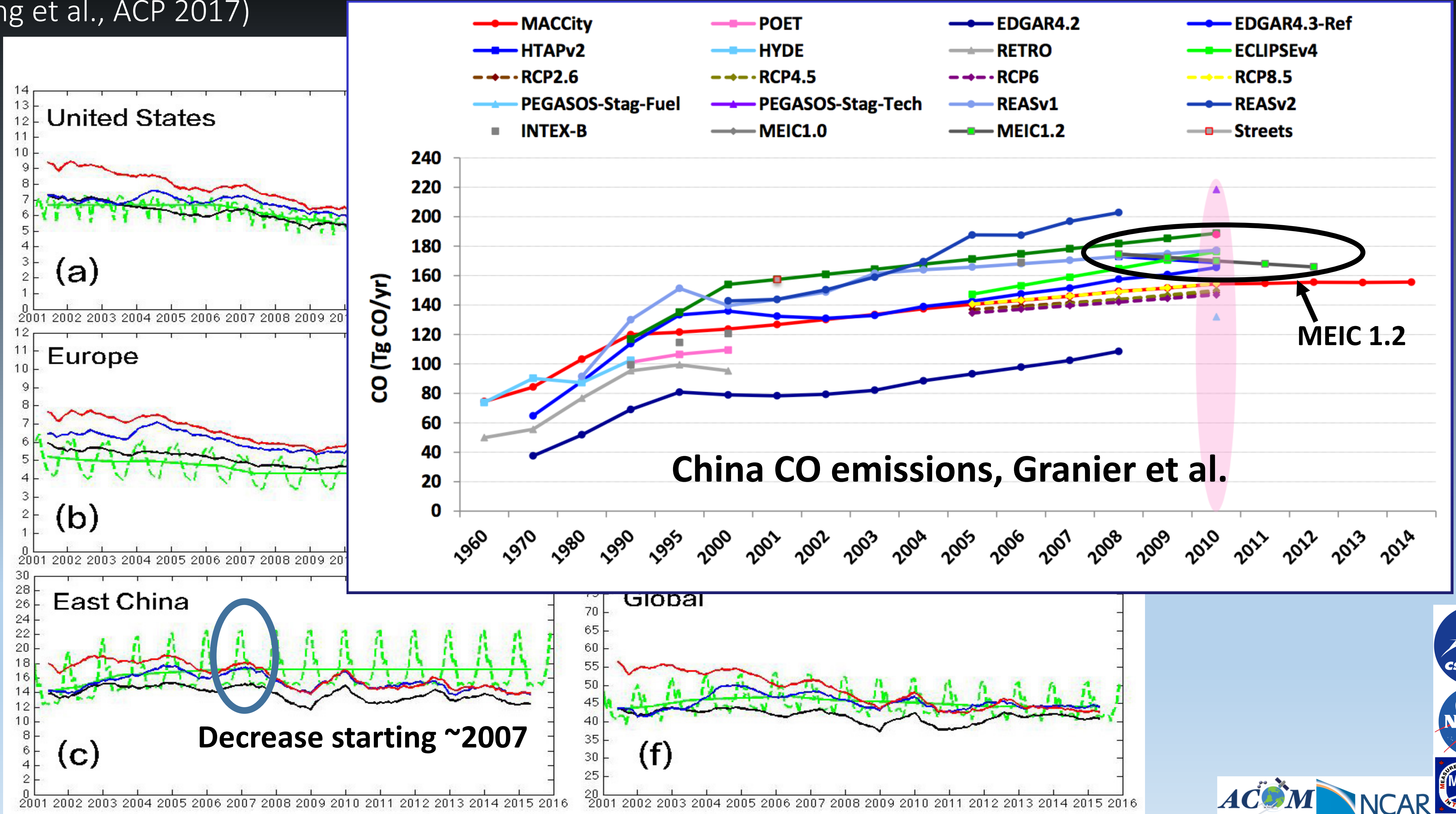
Changes in SO_2 and NO_2 since 2005 from OMI



(Krotkov et al., 2015)

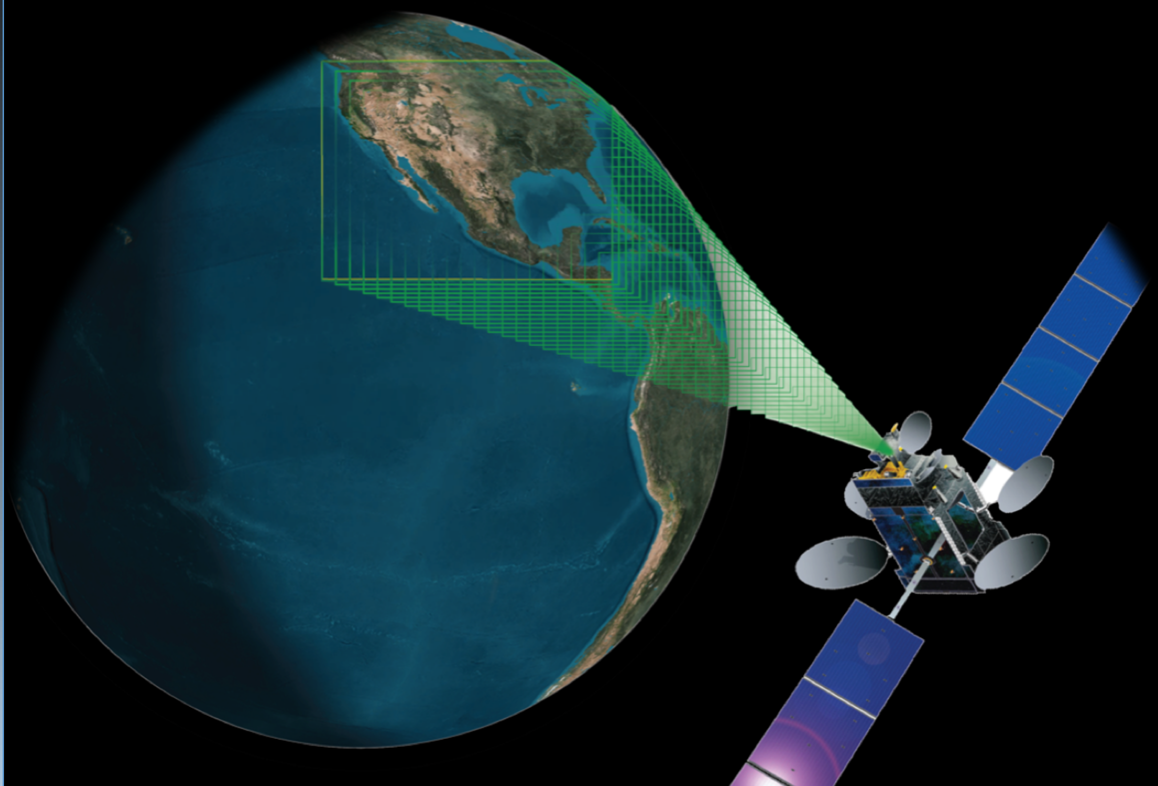
CO emissions trends: Assimilating MOPITT in GEOS-Chem Model

(Jiang et al., ACP 2017)



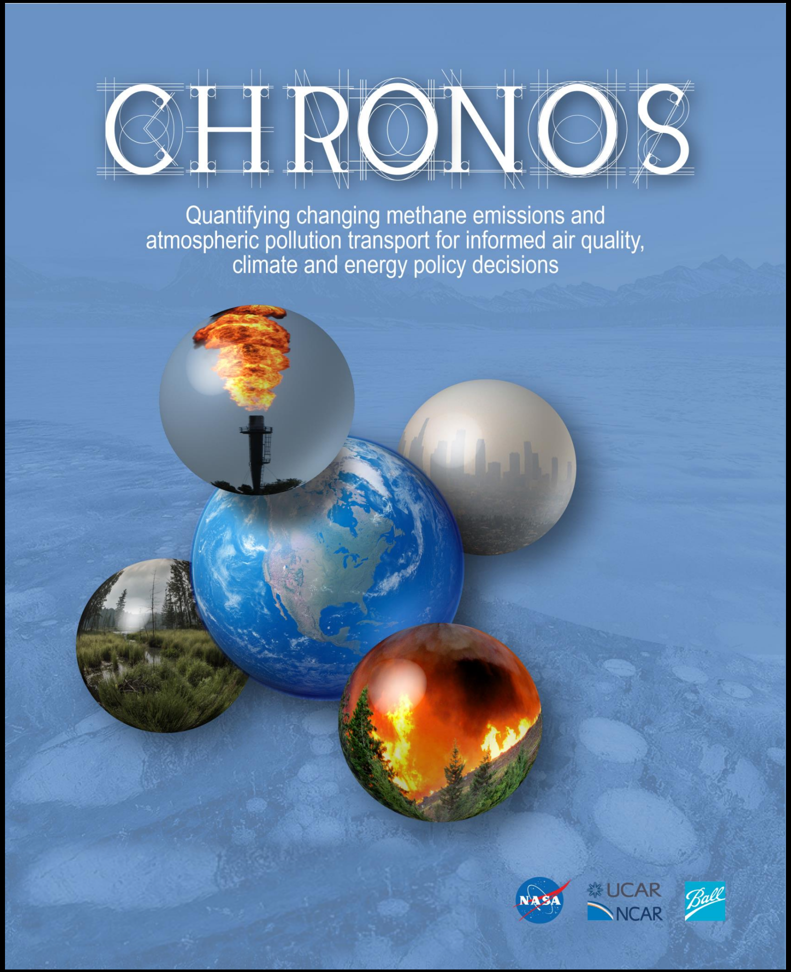
CHRONOS Proposal to NASA EVI-4

Submitted 18 November 2016



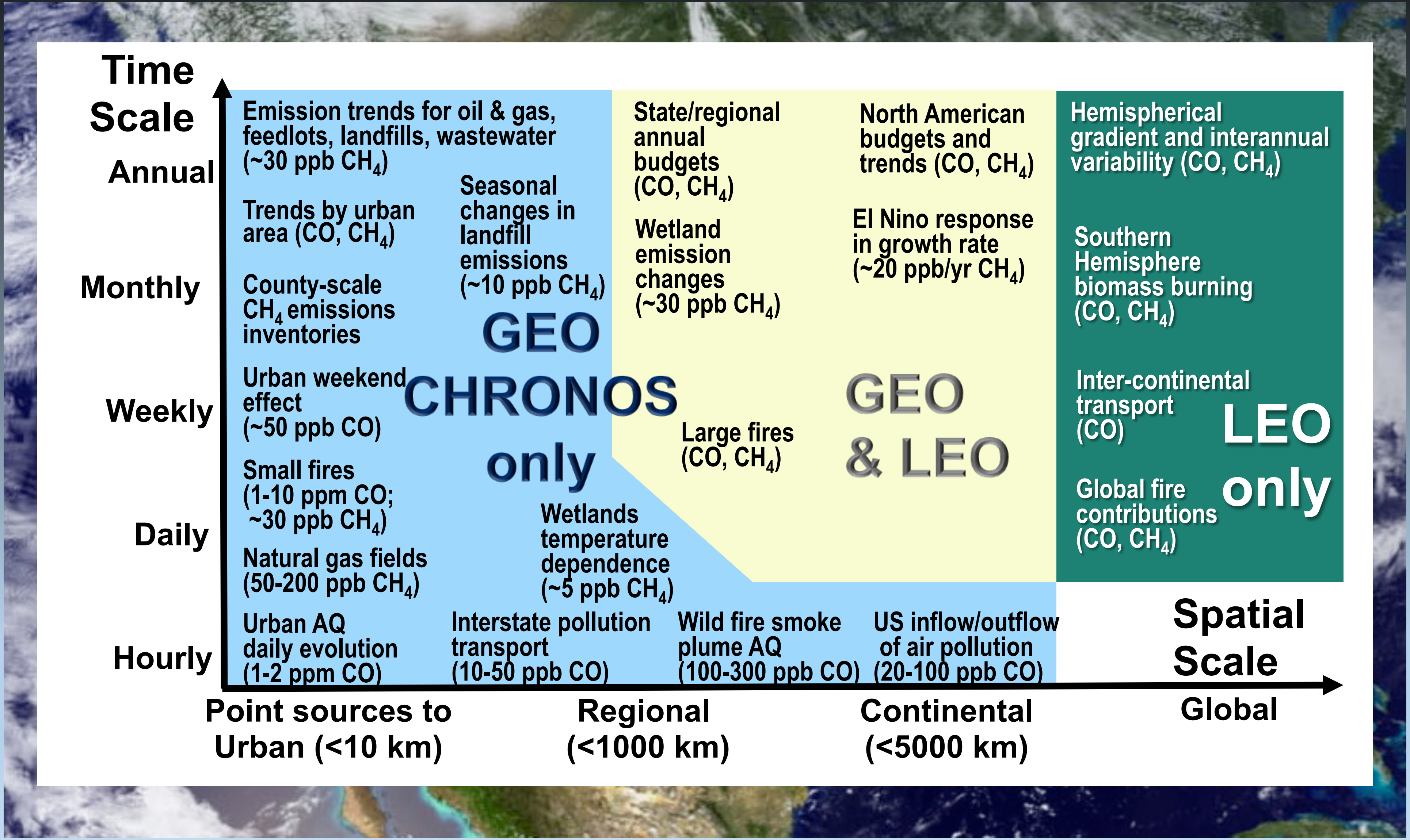
David Edwards, *Principal Investigator*
Helen Worden, *Deputy P.I.*
and the CHRONOS Science Team

NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH · NASA · Ball Aerospace & Technologies Corp.



CSA ASC · NASA · MOPITT · ACOM · NCAR

Why go to GEO?



Time Scale
Annual
Monthly
Weekly
Daily
Hourly
Emission trends for oil & gas, feedlots, landfills, wastewater (~30 ppb CH4)
Trends by urban area (CO, CH4)
Seasonal changes in landfill emissions (~10 ppb CH4)
County-scale CH4 emissions inventories
GEO CHRONOS only
Urban weekend effect (~50 ppb CO)
Small fires (1-10 ppm CO; ~30 ppb CH4)
Natural gas fields (50-200 ppb CH4)
Wetlands temperature dependence (~5 ppb CH4)
State/regional annual budgets (CO, CH4)
Wetland emission changes (~30 ppb CH4)
Large fires (CO, CH4)
North American budgets and trends (CO, CH4)
El Nino response in growth rate (~20 ppb/yr CH4)
GEO & LEO
Hemispherical gradient and interannual variability (CO, CH4)
Southern Hemisphere biomass burning (CO, CH4)
Inter-continental transport (CO)
Global fire contributions (CO, CH4)
LEO only
Urban AQ daily evolution (1-2 ppm CO)
Interstate pollution transport (10-50 ppb CO)
Wild fire smoke plume AQ (100-300 ppb CO)
US inflow/outflow of air pollution (20-100 ppb CO)
Spatial Scale
Point sources to Urban (<10 km)
Regional (<1000 km)
Continental (<5000 km)
Global

Outline

- MOPITT CO measurements and data record
- Trends in CO abundance & emissions
- Applications of MOPITT multispectral observations
- Future CO observations from space
- Conclusions