CO pollution episodes observed at Rishiri Island explored by global CTM simulations and AIRS satellite measurements: Long-range transport of burning plumes and implications for emissions inventories

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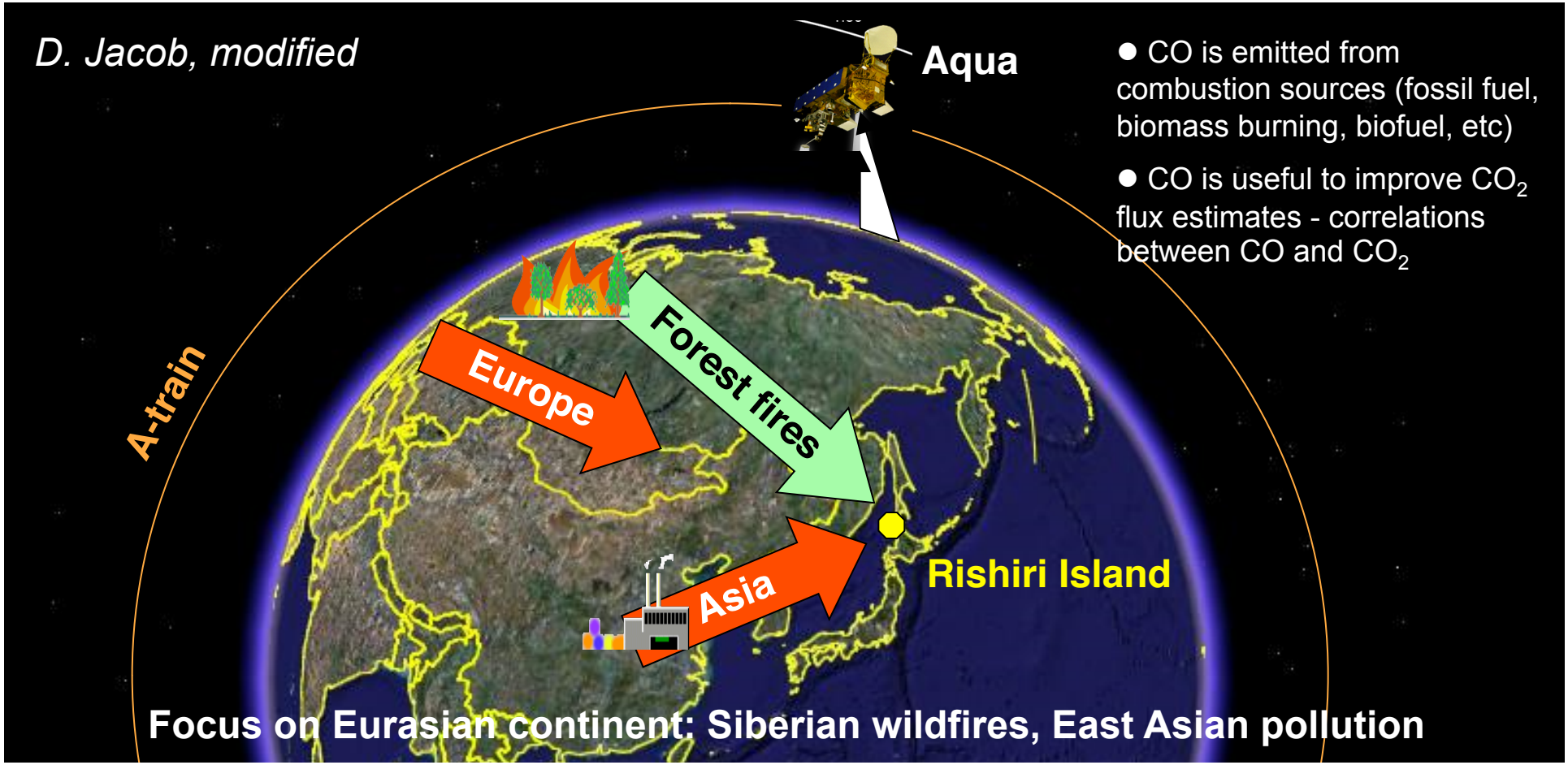
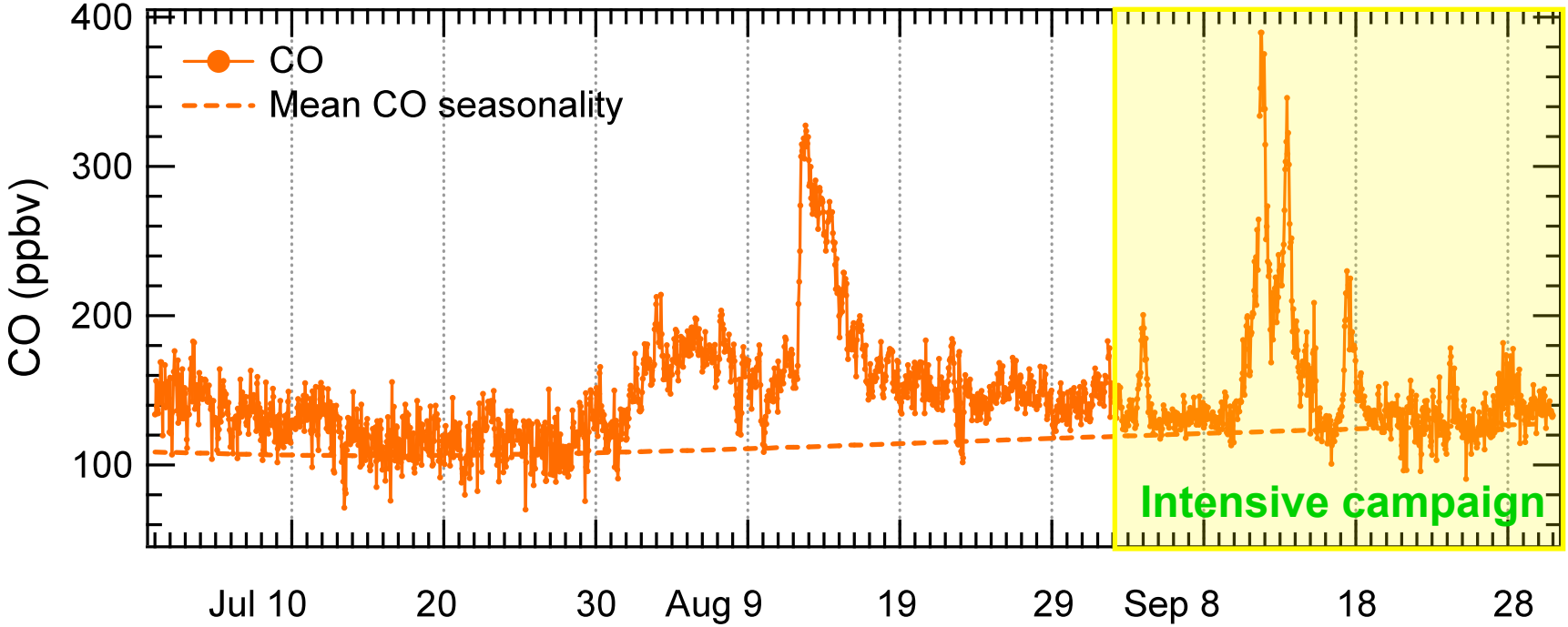
Tanimoto et al., Tellus-B, 2009

Views of CO from surface and satellite observations, connected with global CTM simulations



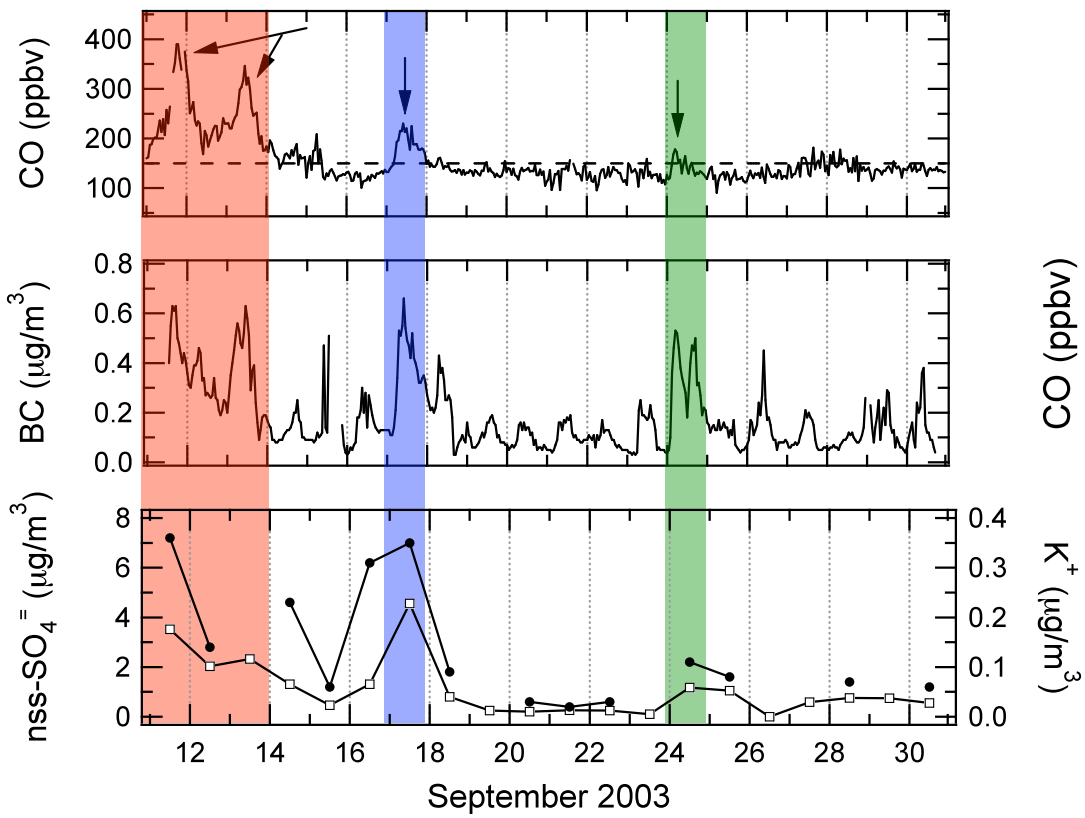
- **Challenges**
  - **use of satellite obs. to capture CO plumes over Eurasian continent**
  - **attribution of sources (and transport paths) of CO to N. Japan**
  - **improvement of current emissions inventories of CO**

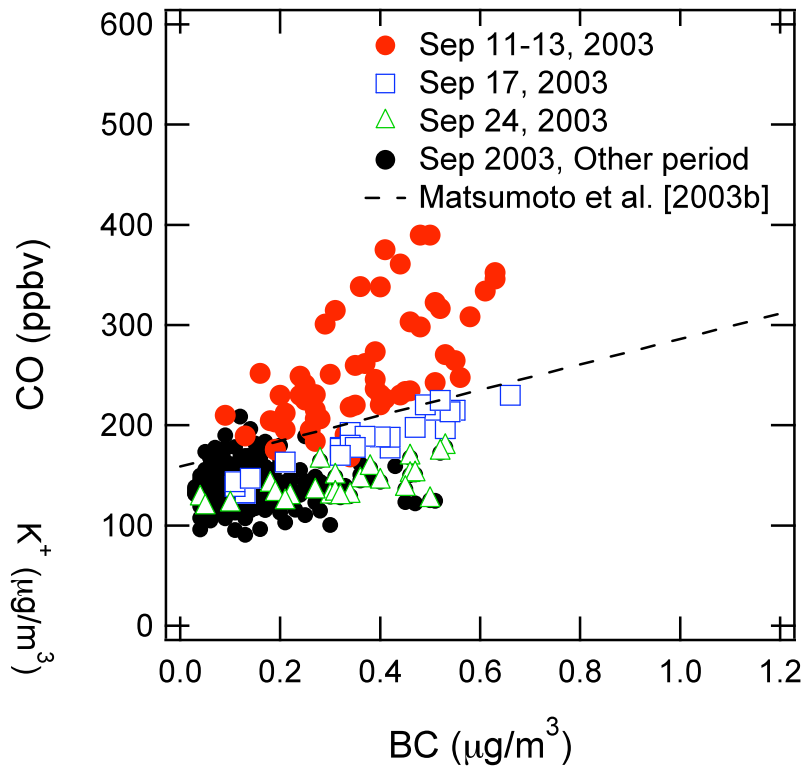
CO Episodes in Summer-Fall 2003



- Several high-CO events were observed in summer-fall 2003
- The summer of 2003 was an active forest fire season in Siberia
- Rishiri Is. receives air masses from <u>both</u> Siberia and East Asia

Tracer-correlations are not always good enough

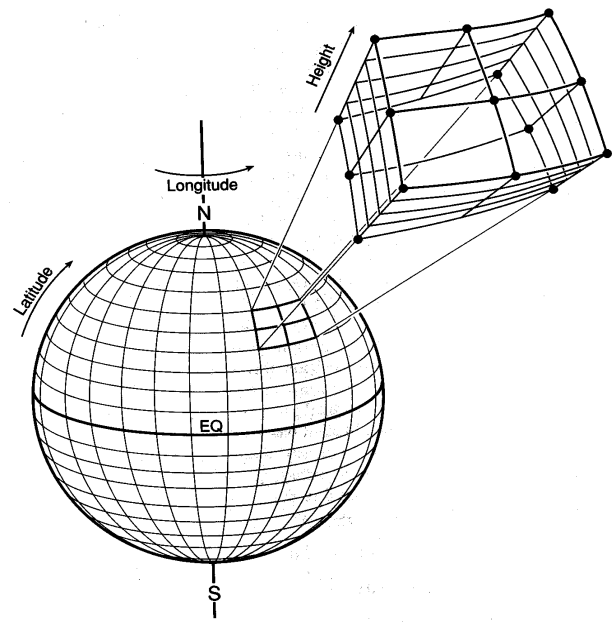




- Analysis of tracer-correlations could result in controversial interpretation. (larger uncertainties due to longer distance from sources)

Global CTM Simulations

MATCH-MPIC CTM

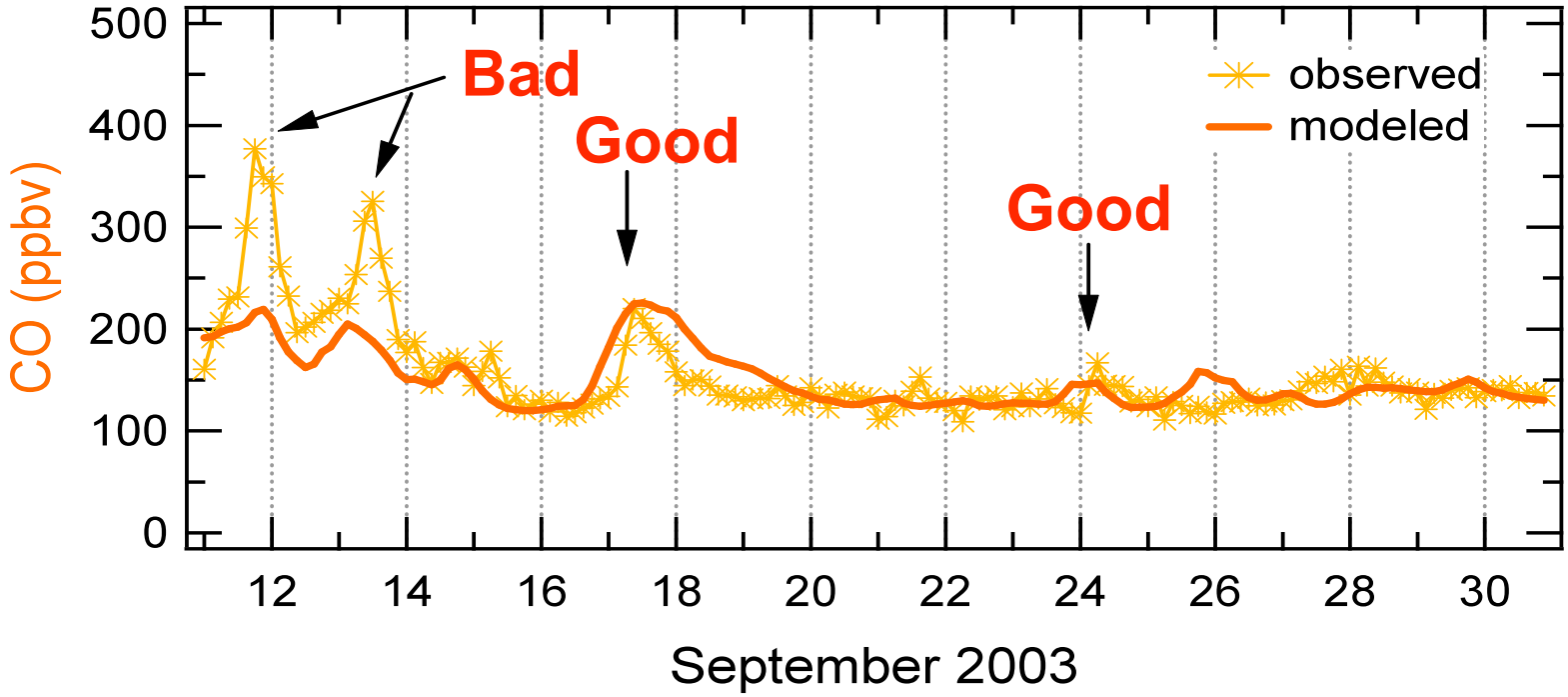


- is an Eulerian model
- is developed at Max Planck Institute
- uses NCEP/NCAR reanalysis meteorology
- uses detailed chemical mechanism
- has T42 horizontal resolution (2.8 x 2.8), 42 vertical levels (surface~2 hPa)
- For CO, it implements EDGAR v3.2 (1995) + Galanter et al. (2000) emissions inventories for 'standard' run

MAX-PLANCK-GESELLSCHAFT

Lawrence et al. (2003), von Kuhlmann et al. (2003)

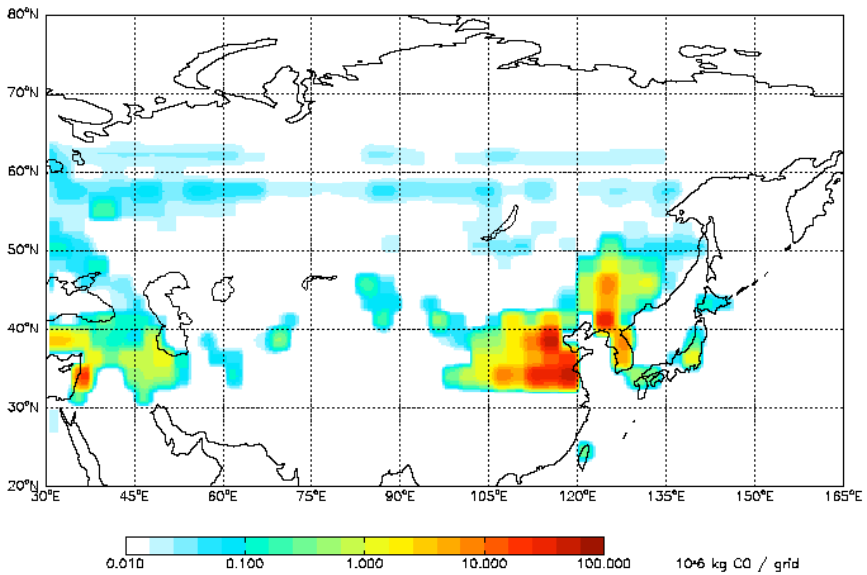
Does Model Reproduce Observed CO?



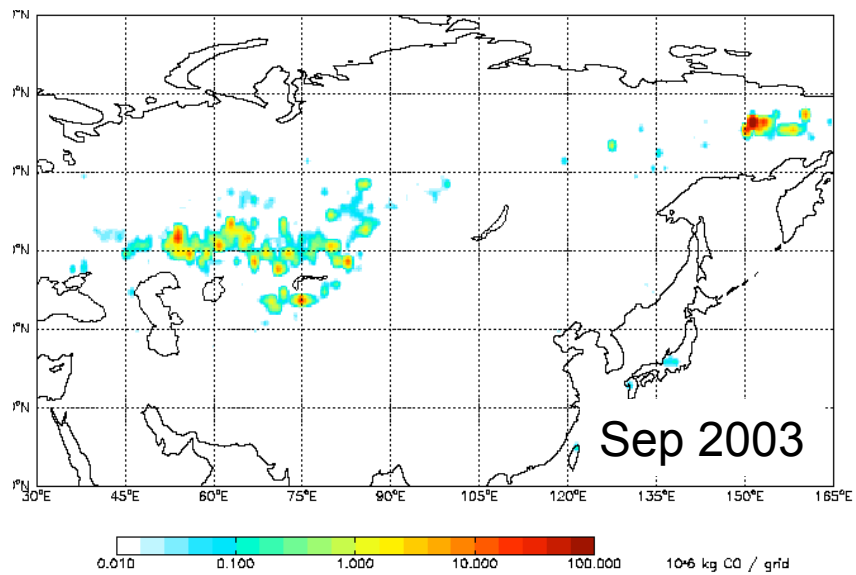
- Model well reproduced baseline & high-CO episodes for Sep. 17 & 24 events
- Model underestimated the amplitude for Sep 11-13, indicating missing sources?
- Why? – biomass burning in Siberia?

BB Emissions Inventories: Standard vs. GFEDv2

Standard (Galanter et al. 2000)

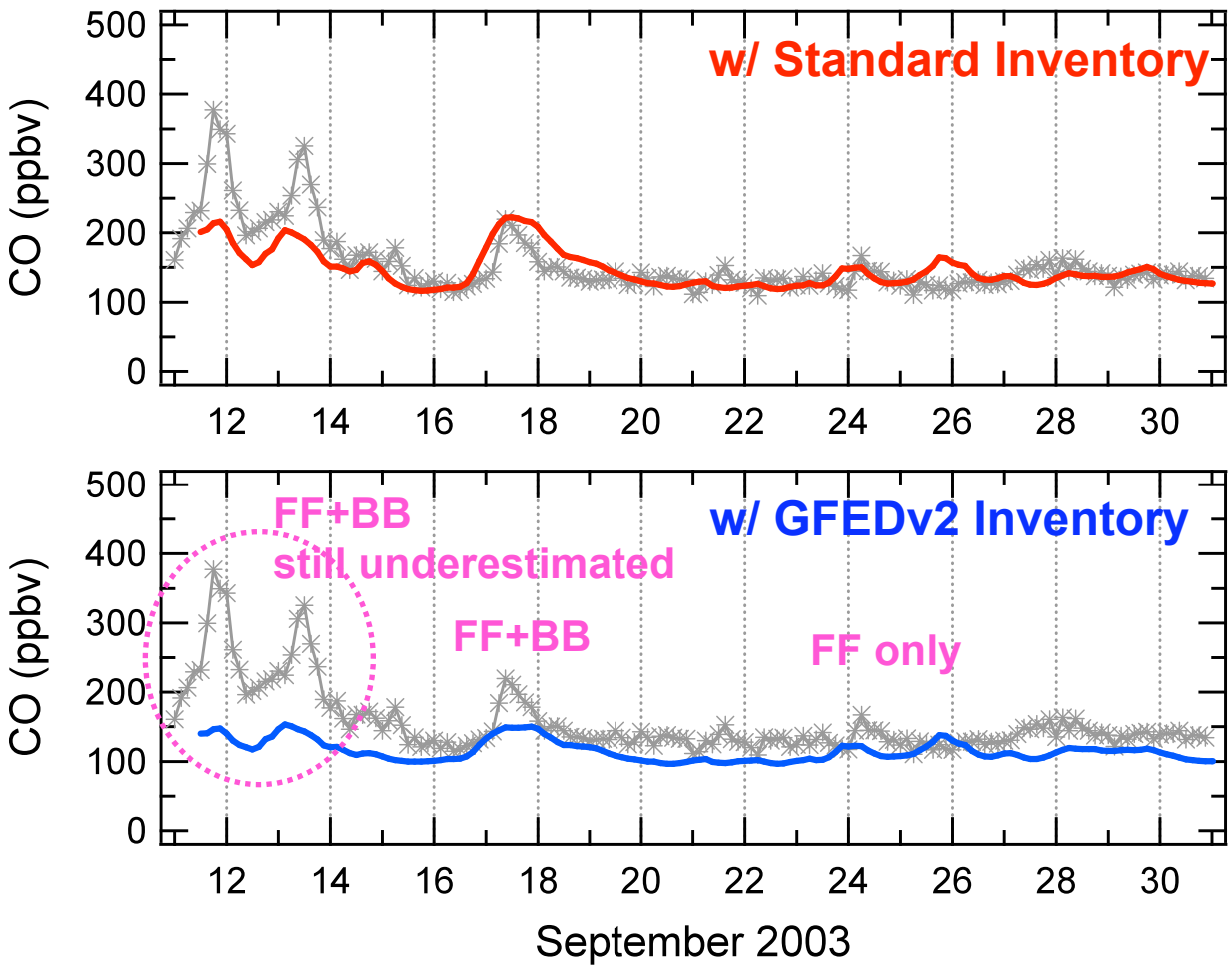


GFEDv2 (van der Werf et al. 2006)



- Sensitivity simulations w/ 2 emissions inventories for BB
  - ‘standard’ – Galanter et al. (2000), climatological emissions
  - GFEDv2 – van der Werf et al. (2006), MODIS-based distribution, time-varying
- GFEDv2 has more appropriate source regions for the specified year
- Both inventories use same emission factor from Andreae & Merlet (2001)

Sensitivity of Modeled CO to Emissions Inventories



- GFEDv2 doesn't improve model vs. obs. agreement
- Sep 11-13 event is not reproduced well by none of these inventories

AIRS Can Capture Long-range Transport of CO

AIRS: Atmospheric Infrared Sounder

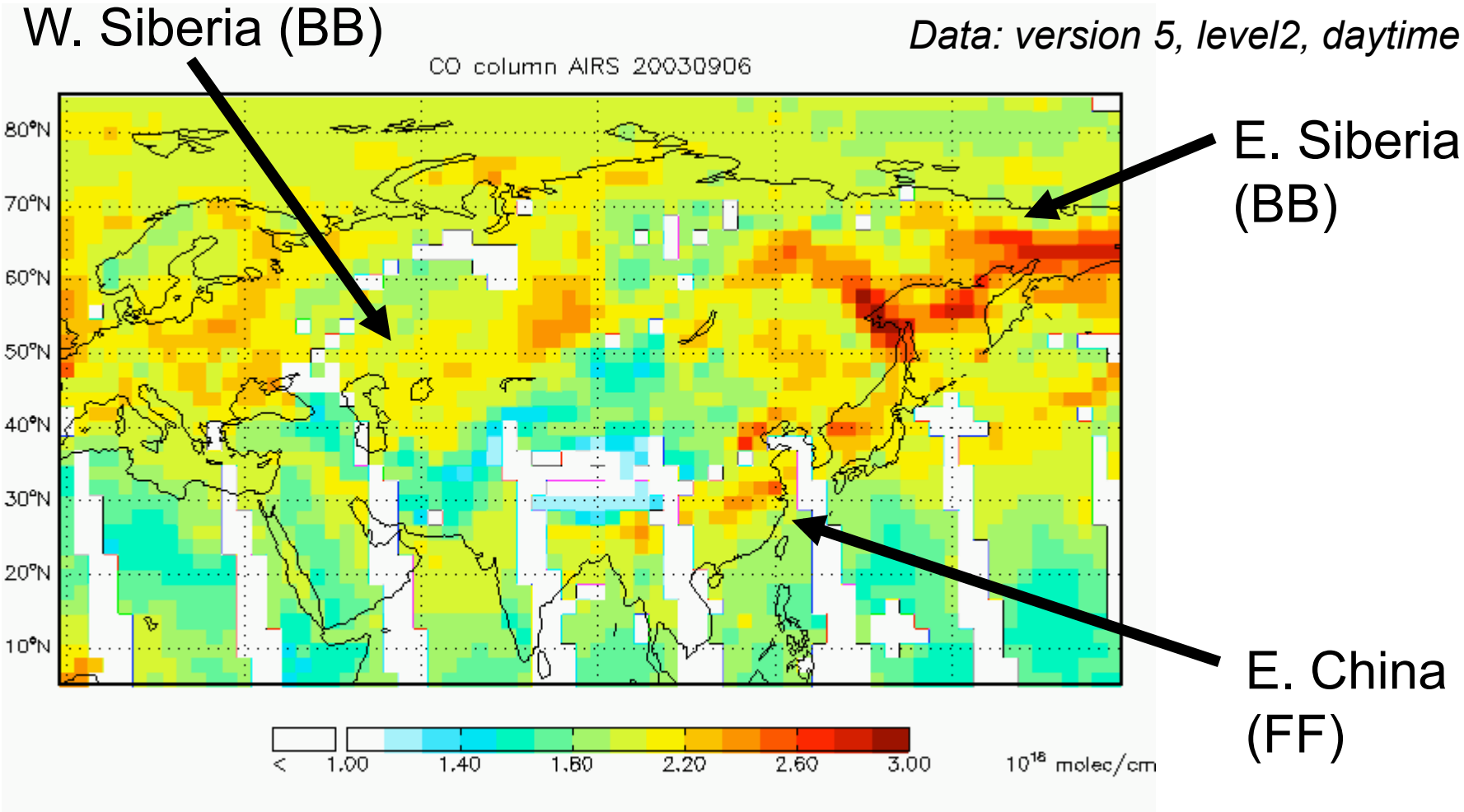
- Onboard NASA's Aqua satellite
- Launched in May 2002
- Retrieval at 4.7 μm
- Spatial resolution of 45 x 1650 km
- Sensitive to CO in the mid-trop.

- Bias of +15-20 ppbv over oceans relative to MOPITT on EOS/Terra satellite (Warner et al. 2007)
- Events can be seen (Yurganov et al. 2008; Zhang et al. 2008)

Greater advantage of AIRS is its increased horizontal spatial coverage (70% of the globe each day, versus 3 days by MOPITT)

Greater spatial coverage allows us to track CO plumes transported from the emission sources to distances of several thousands km on each day

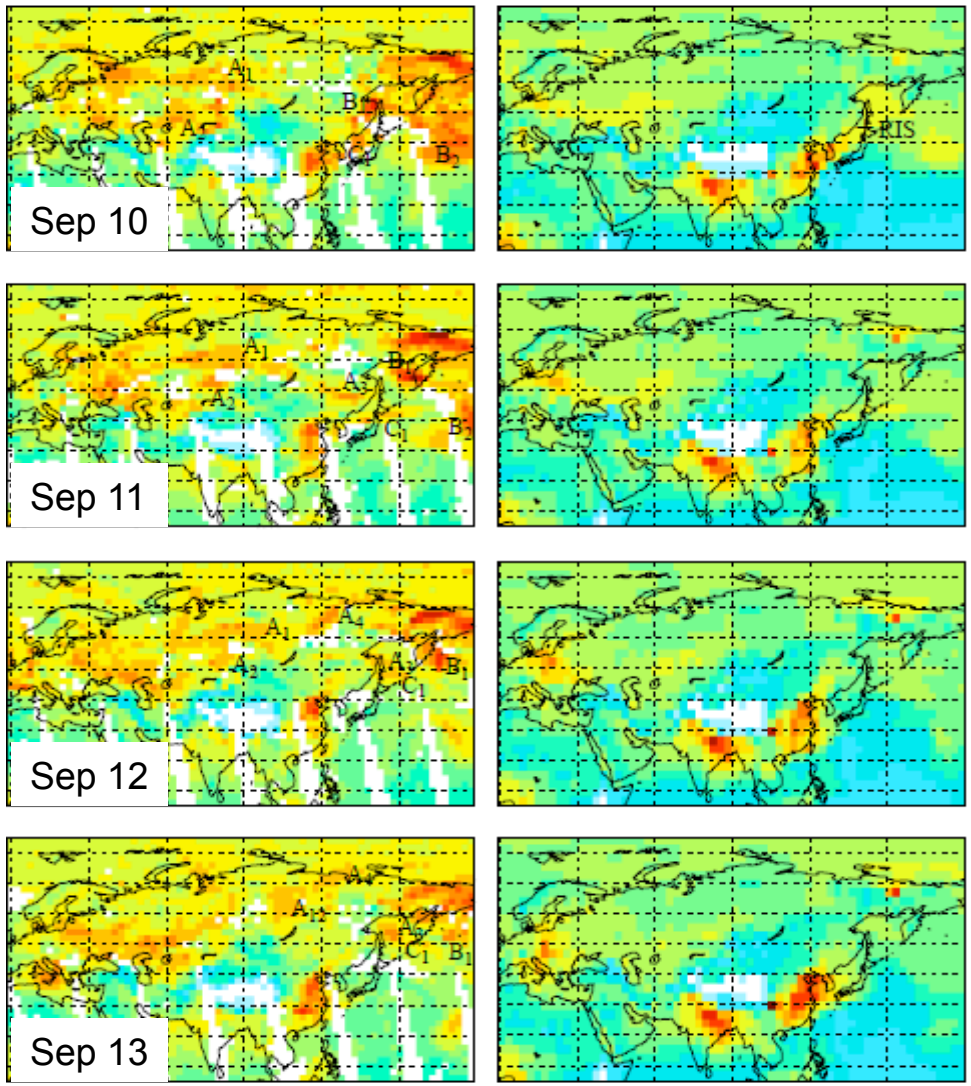
How AIRS sees CO over the Eurasian Continent?



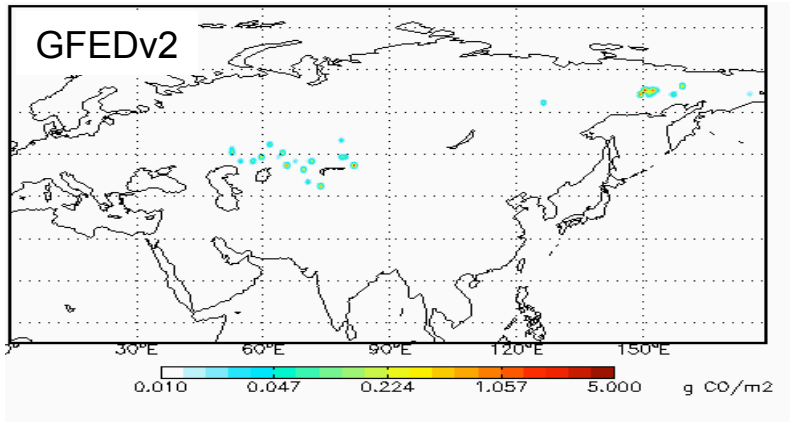
- AIRS detected CO enhancement over source regions
- AIRS tracked CO pollution plumes over Eurasia on a daily basis

AIRS vs. CTM : Sep 10-13 (BB > FF)

AIRS CTM (hybrid-GFEDv2)

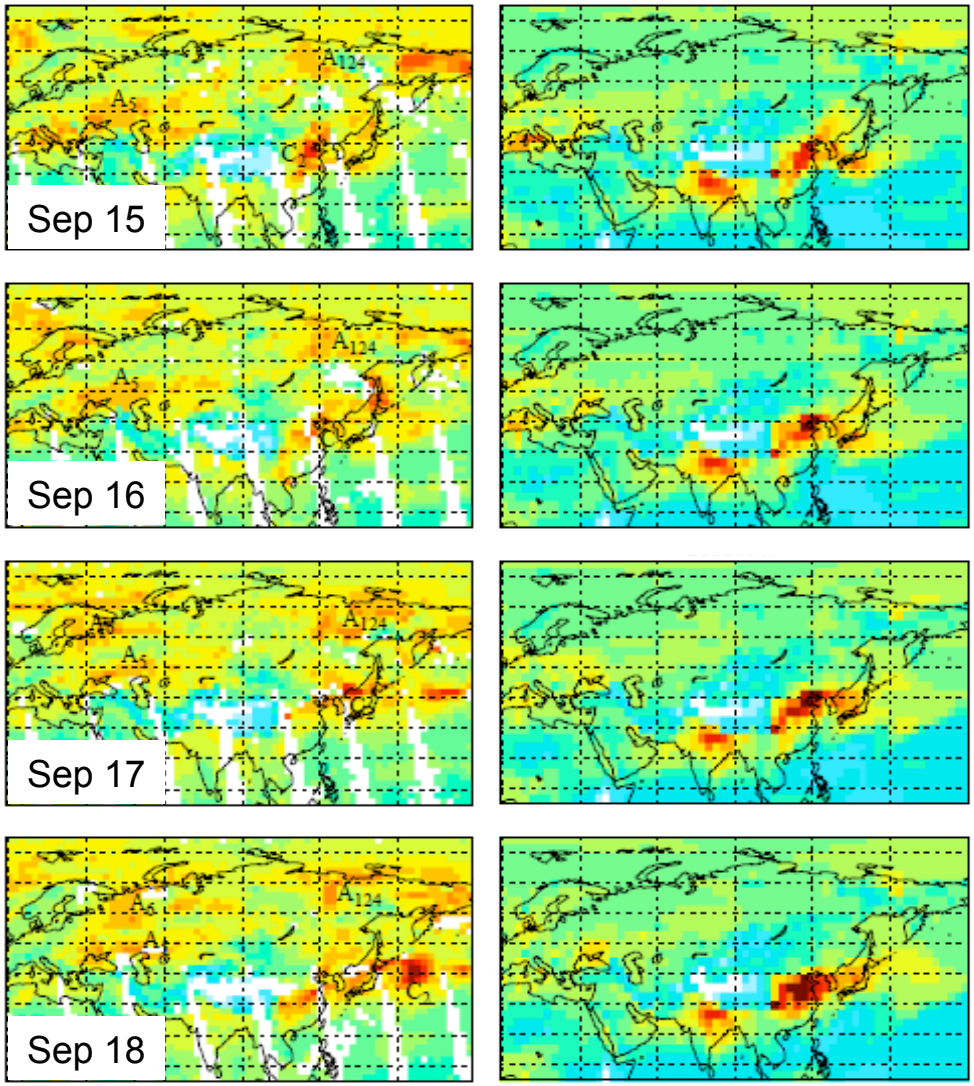


- AIRS
  - sees enhanced CO over E. & W. Siberia
  - detects LRT from W. Siberia to N. Japan
- CTM
  - w/ GFEDv2 reproduces elevated CO over same regions but look lower
  - discrepancy w/ surface measurements is due to LRT from W. Siberia

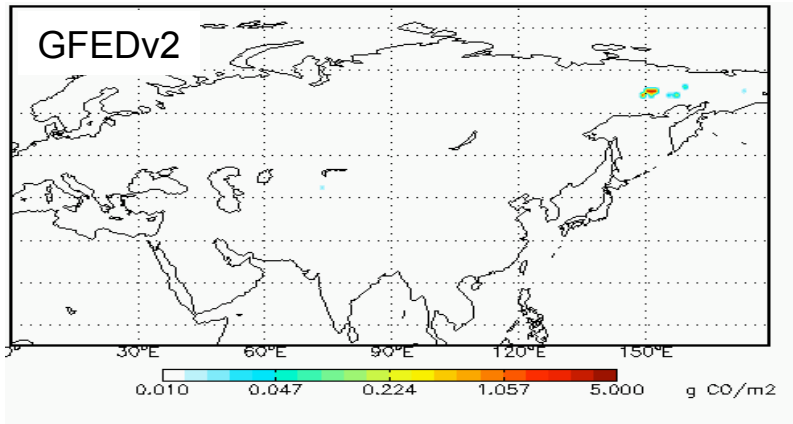


AIRS vs. CTM : Sep 15-18 (BB = FF)

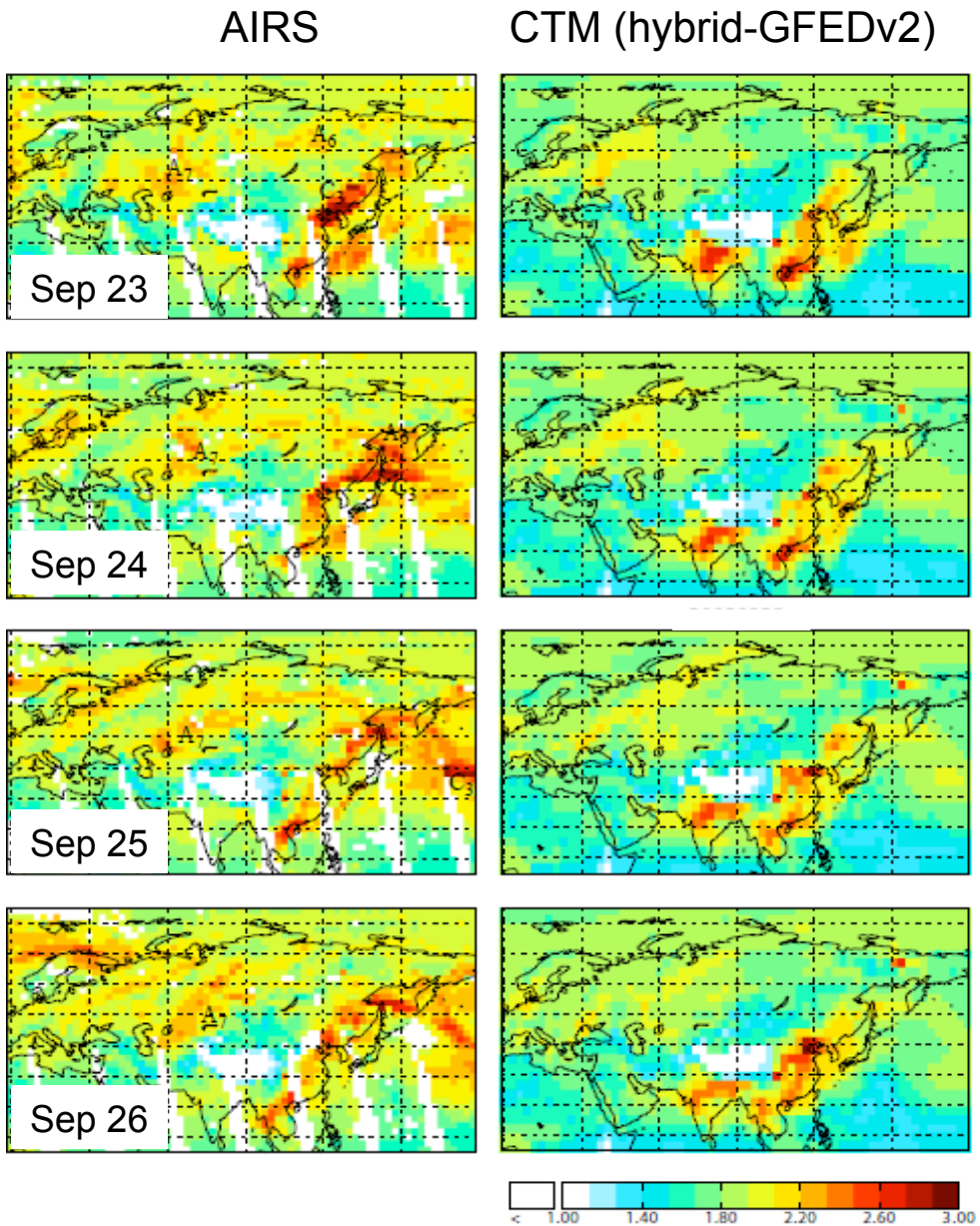
AIRS CTM (hybrid-GFEDv2)



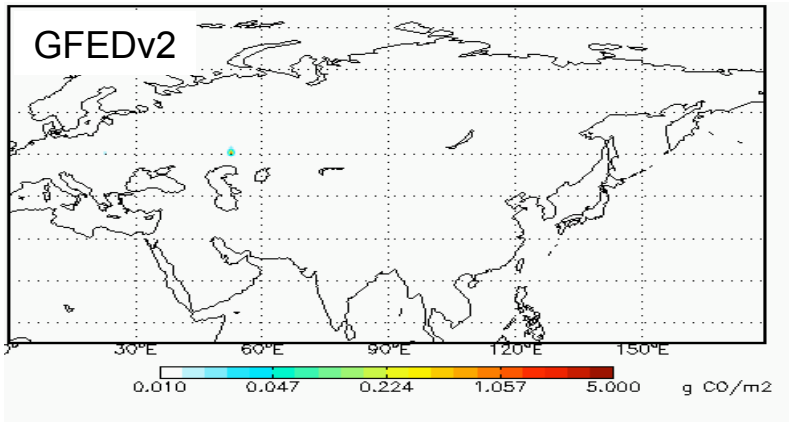
- AIRS
  - sees enhanced CO over W. & E. Siberia
  - detects LRT from E. Siberia to W. Pacific
- CTM
  - w/ GFEDv2 reproduces elevated CO over same locations but looks lower and less spreading



AIRS vs. CTM : Sep 23-26 (BB < FF)



- AIRS
  - sees less CO over E. Siberia than in previous 2 weeks
  - sees transport from E. China to the W. Pacific via N. Japan
- CTM
  - well predicts this transport of anthropogenic pollution from continental Asia



Summary & Conclusions

- GFEDv2-based simulations predict CO enhancement over W. & E. Siberia, same locations with AIRS observations. However, CO enhancement modeled with GFEDv2 is smaller and less widespread than AIRS

- GFEDv2 may underestimate CO emissions per area by failing to implement small fires from MODIS

- 2003 burning area in W. Siberia contains large amounts of peat and buried carbon; main burning in W. Siberia could be peat burning (smoldering) – by Leonid Yurganov
  - Emissions estimates from peat burning seem very difficult to assess, due to large uncertainties such as the amount of organic matter, depth of organic layers, soil moisture under ground
  - Emission factors from peat burning may be greatly different from Andreae & Merlet (2001) values

- GFEDv2 is one of the state-of-science inventories for BB. AIRS revealed that it may still need improvements for boreal fires in Siberia

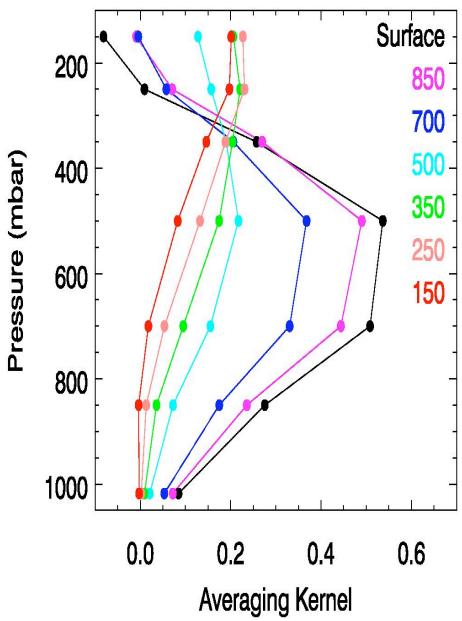
Acknowledgments

- Suggestions, Support, Help
  - Leonid N. Yurganov (UMBC)
  - Daniel J. Jacob (Harvard)
  - Mitsuo Uematsu (Univ. Tokyo)
  - Miori Ohno (NIES)
- Funding
  - NIES Asian Environment Research Program
- AIRS data
  - NASA's Atmospheric Composition Data and Information Services Center (ACDISC)

Monika Kopacz (Harvard)

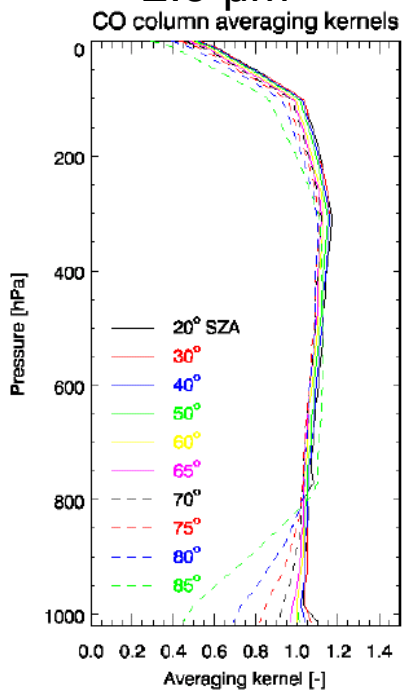
Satellite instruments providing CO column

4.7 μm



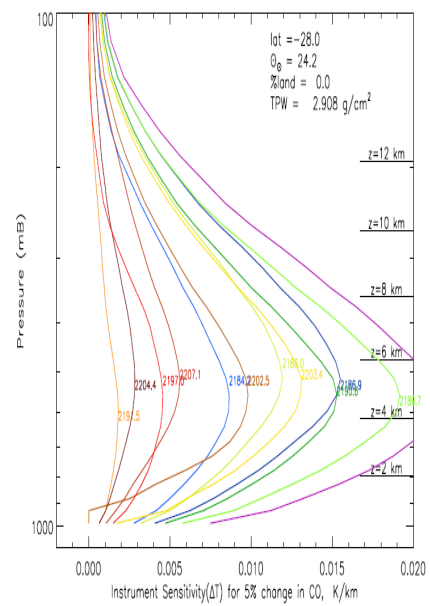
validated data product, global coverage every 3 days, used in inversions and comparisons previously

2.3 μm



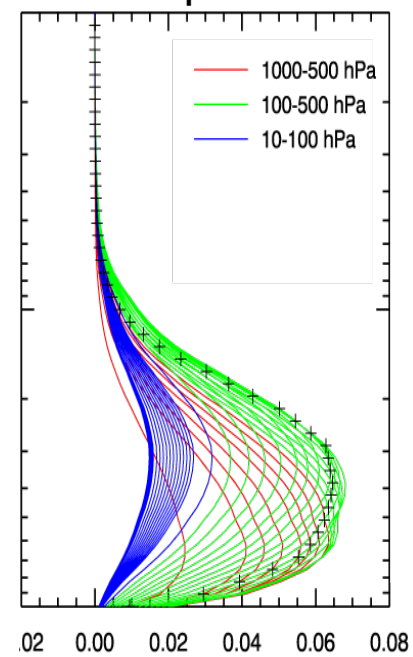
sensitive throughout the column, large errors, relatively unexplored

4.7 μm



extremely dense coverage (daily global), v5 retrieval not used so far

4.7 μm

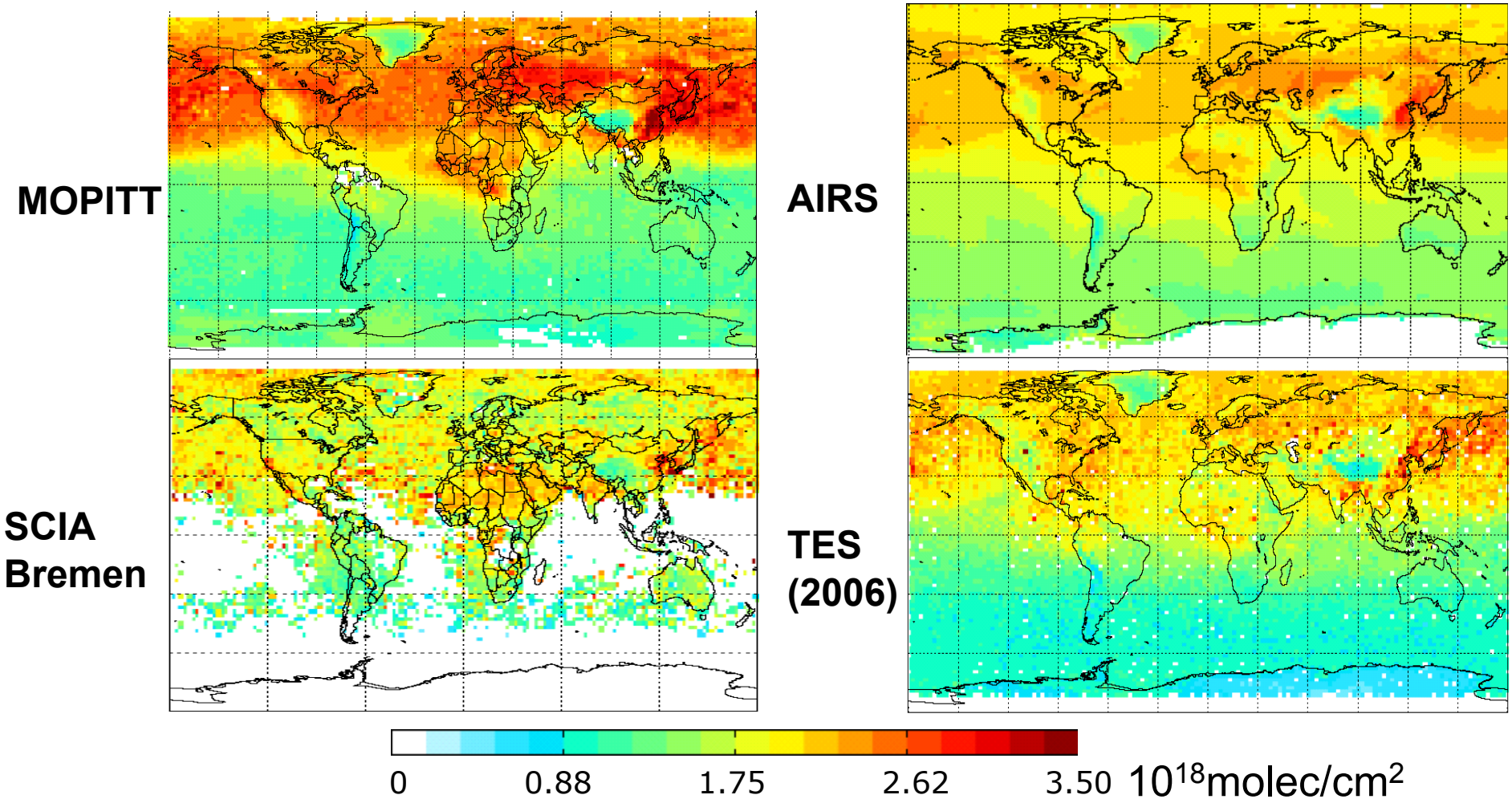


relatively unexplored, provides collocated information on tropospheric O_3

Monika Kopacz (Harvard)

Available satellite CO (column) data

May 2004

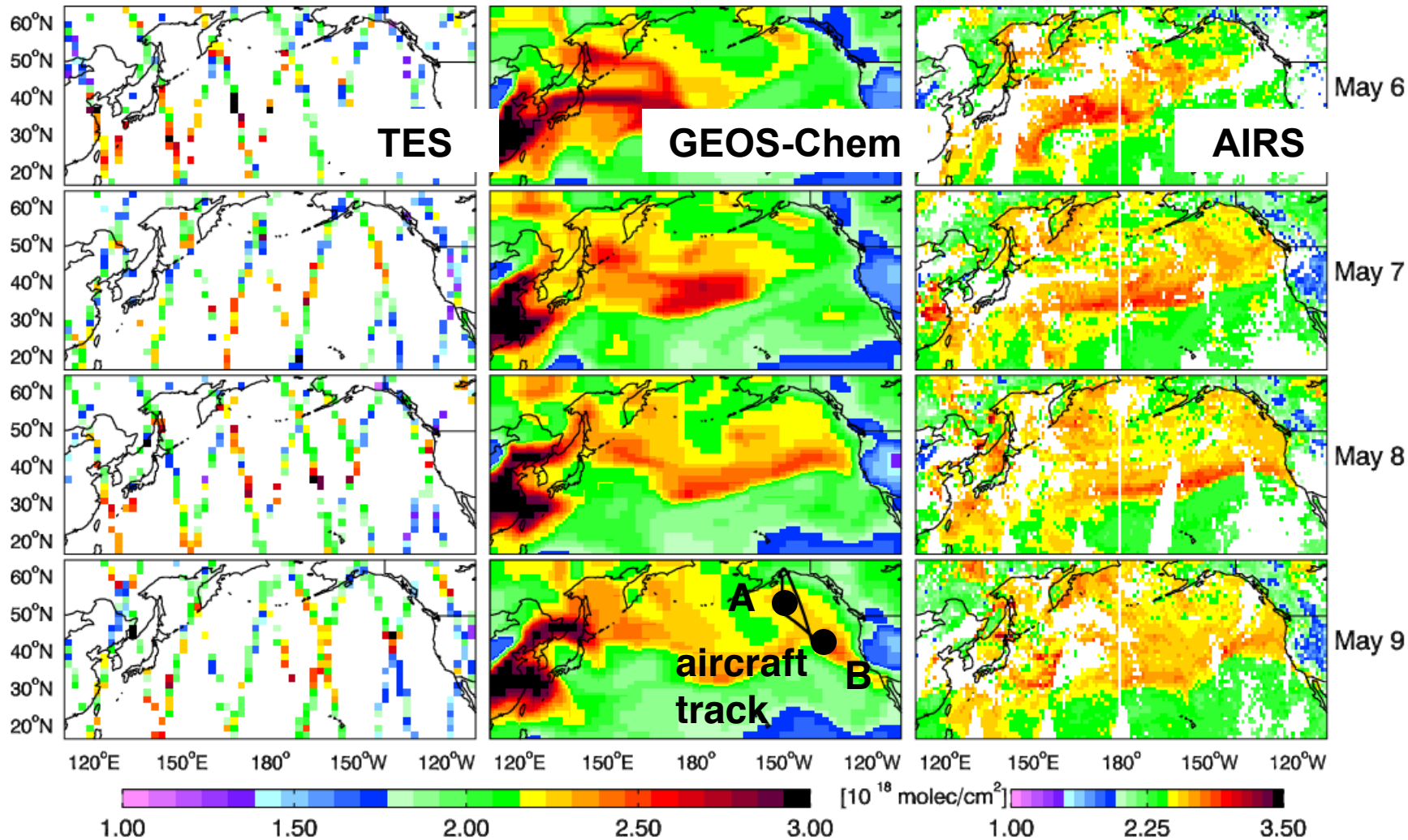


CO columns expected to be different due to different vertical sensitivity

INTEX-B AIRCRAFT CAMPAIGN OVER NORTHEAST PACIFIC (2006)

AIRS and TES satellite observations of transpacific plume

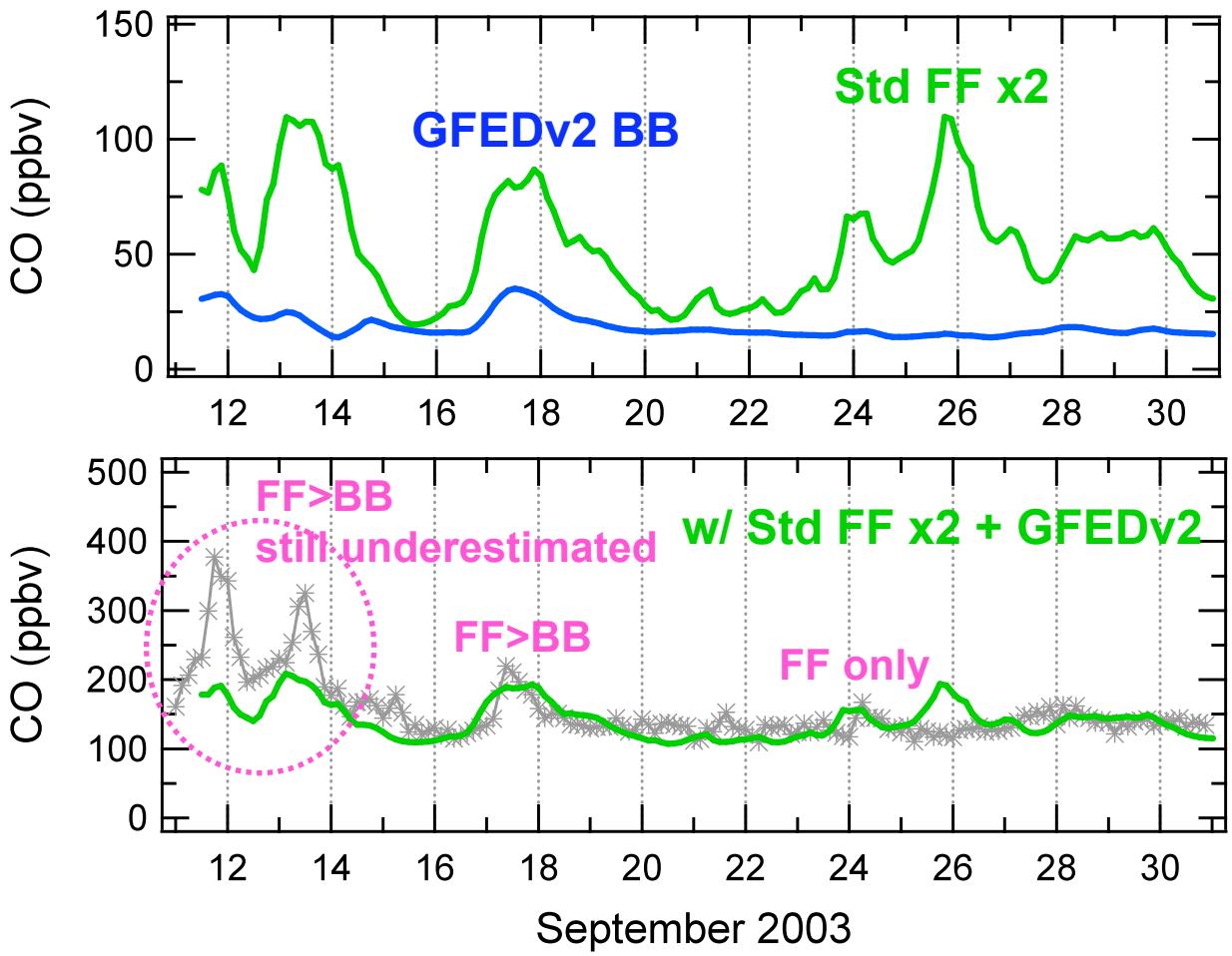
CO columns



TES observes ozone as well as CO; observed ozone-correlation indicates ozone production over Pacific but signal is noisy (observations are sparse)

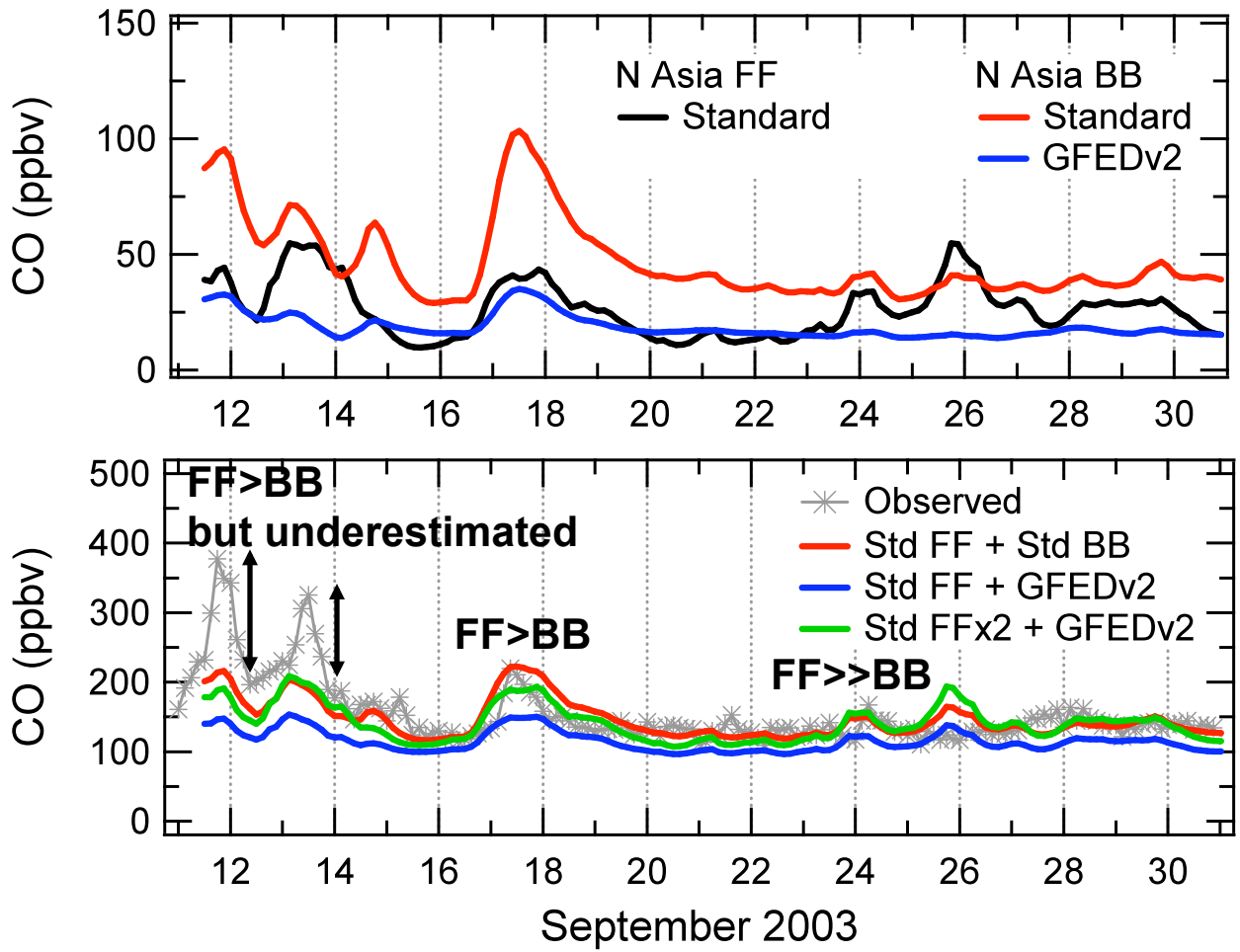
Zhang et al., ACP

Sensitivity of Modeled CO to Emissions Inventories



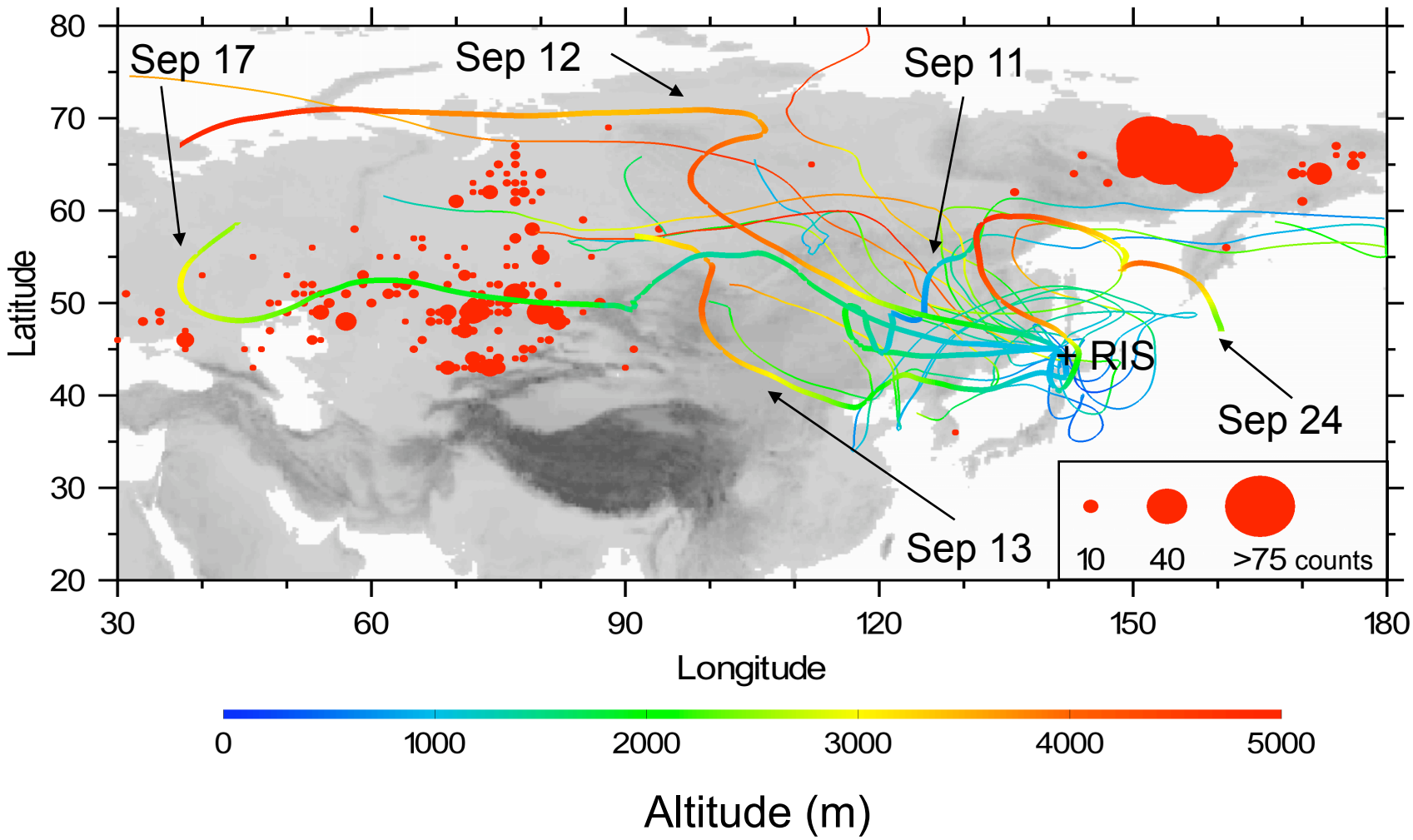
- GFEDv2 doesn't improve model vs. obs. agreement
- Std. Asian FF emissions are underestimated, Std. Asian BB compensated FF
- Even [Std. FF x2 + GFEDv2] emissions cannot fill the gap for Sep 11-13 event

Sensitivity of Modeled CO episodes to Inventories



- Std. Asian BB is larger than Std. Asian FF, and co-located with FF
- Std. Asian FF emissions are underestimated (Std. FF x2 agrees with Streets et al. 2006)
- GFEDv2 is smaller than Std. Asian BB, doesn't improve model-obs. agreement
- Even [Std. FF x2 + GFEDv2] emissions-driven model cannot reproduce Sep 11-13 episode

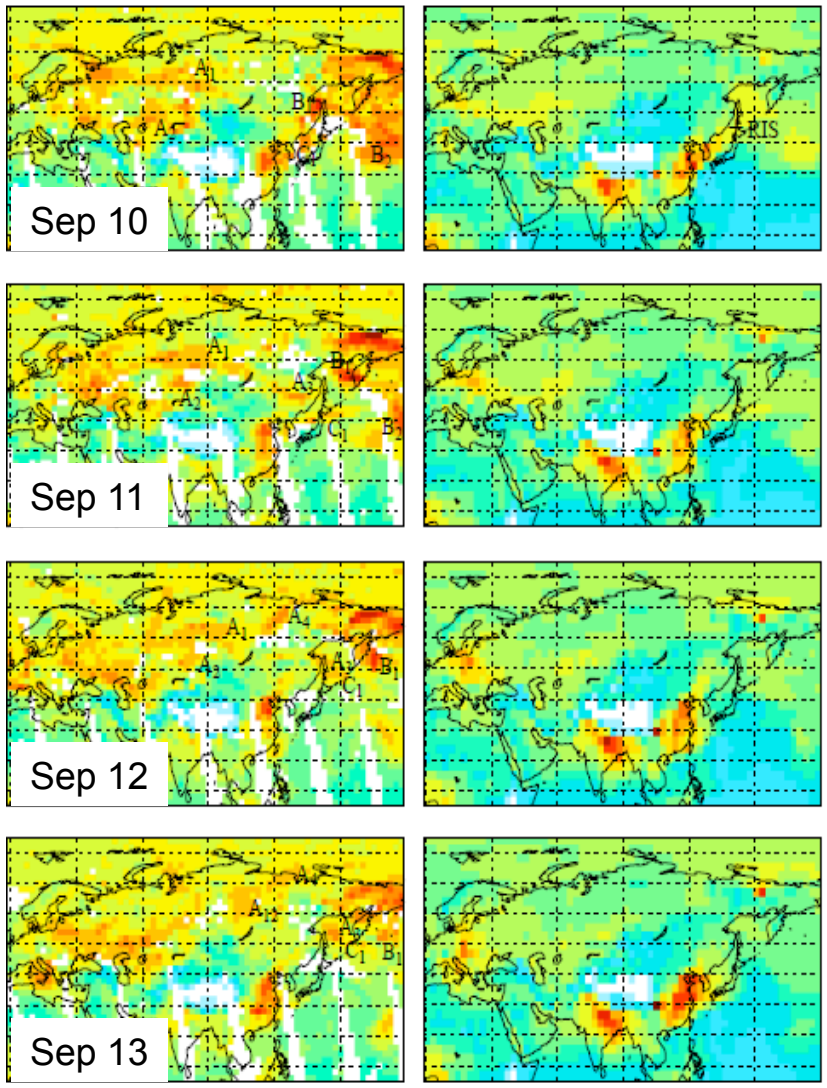
Back-Trajectories and Hot Spots



- Trajectories have uncertainties, as time goes back

Which Inventory is Better? – Sep 11-13

AIRS Model (hybrid-GFEDv2)



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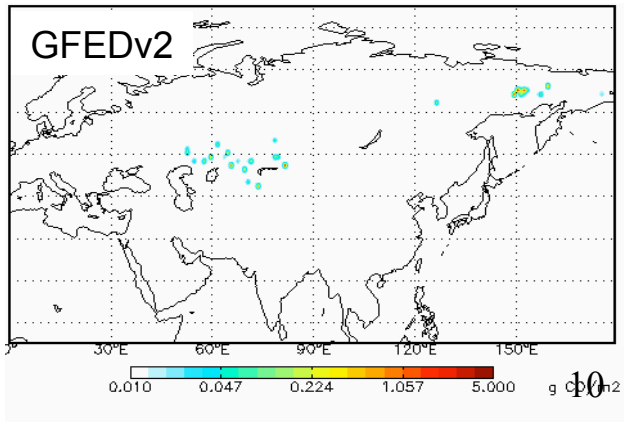
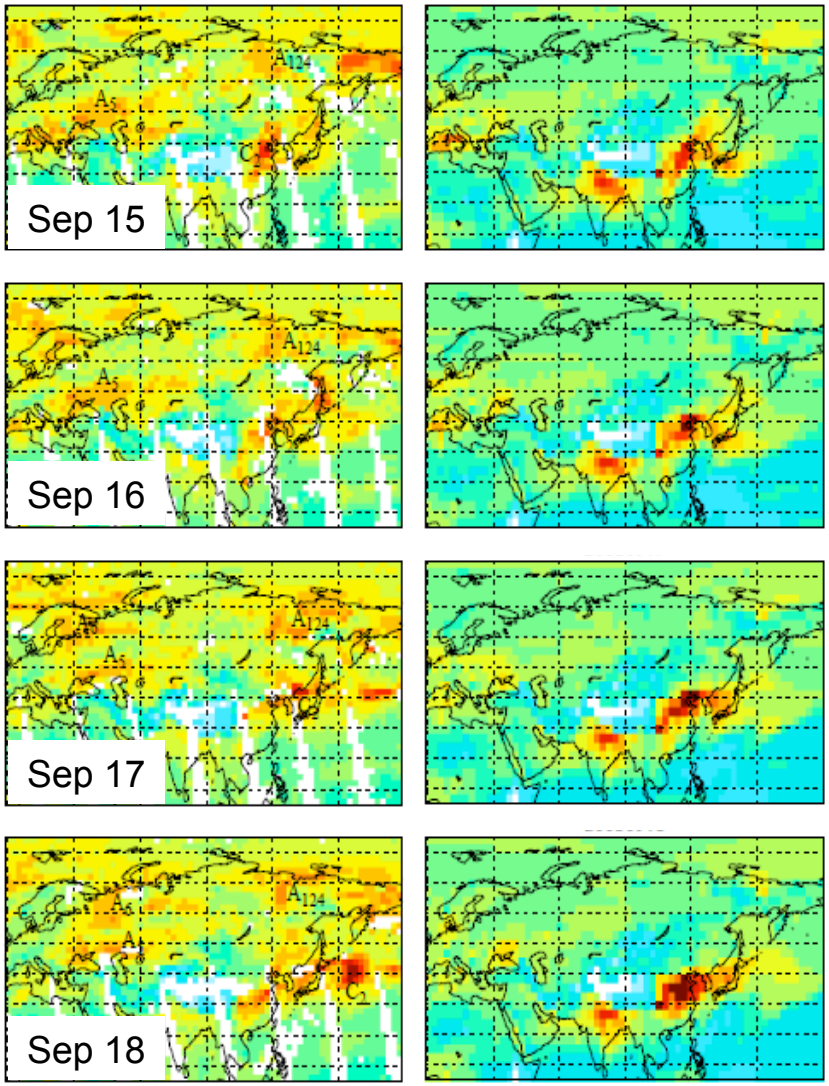


Which Inventory is Better? – Sep 17

AIRS Model (hybrid-GFEDv2)



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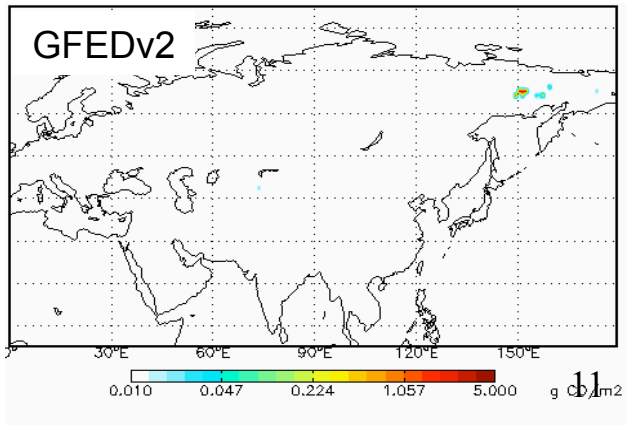
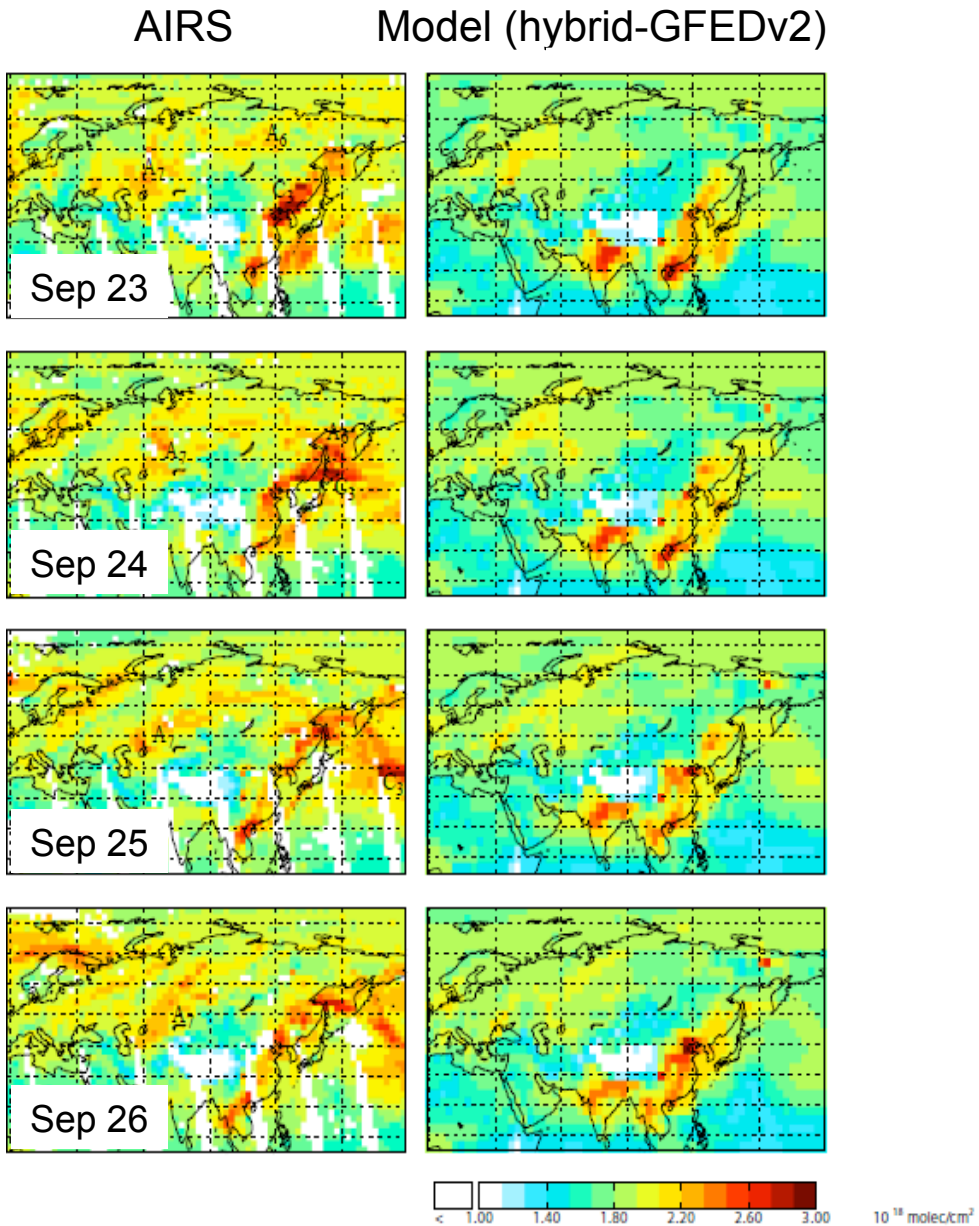
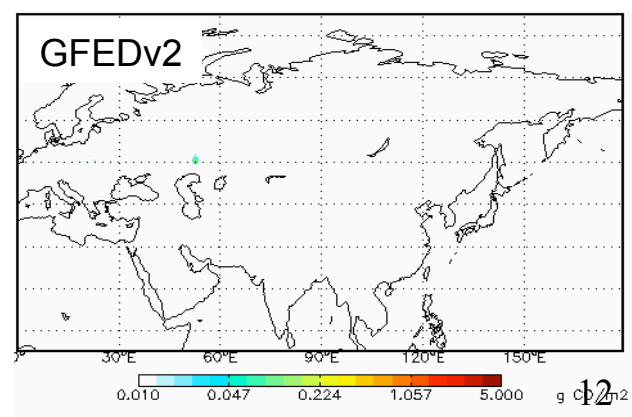


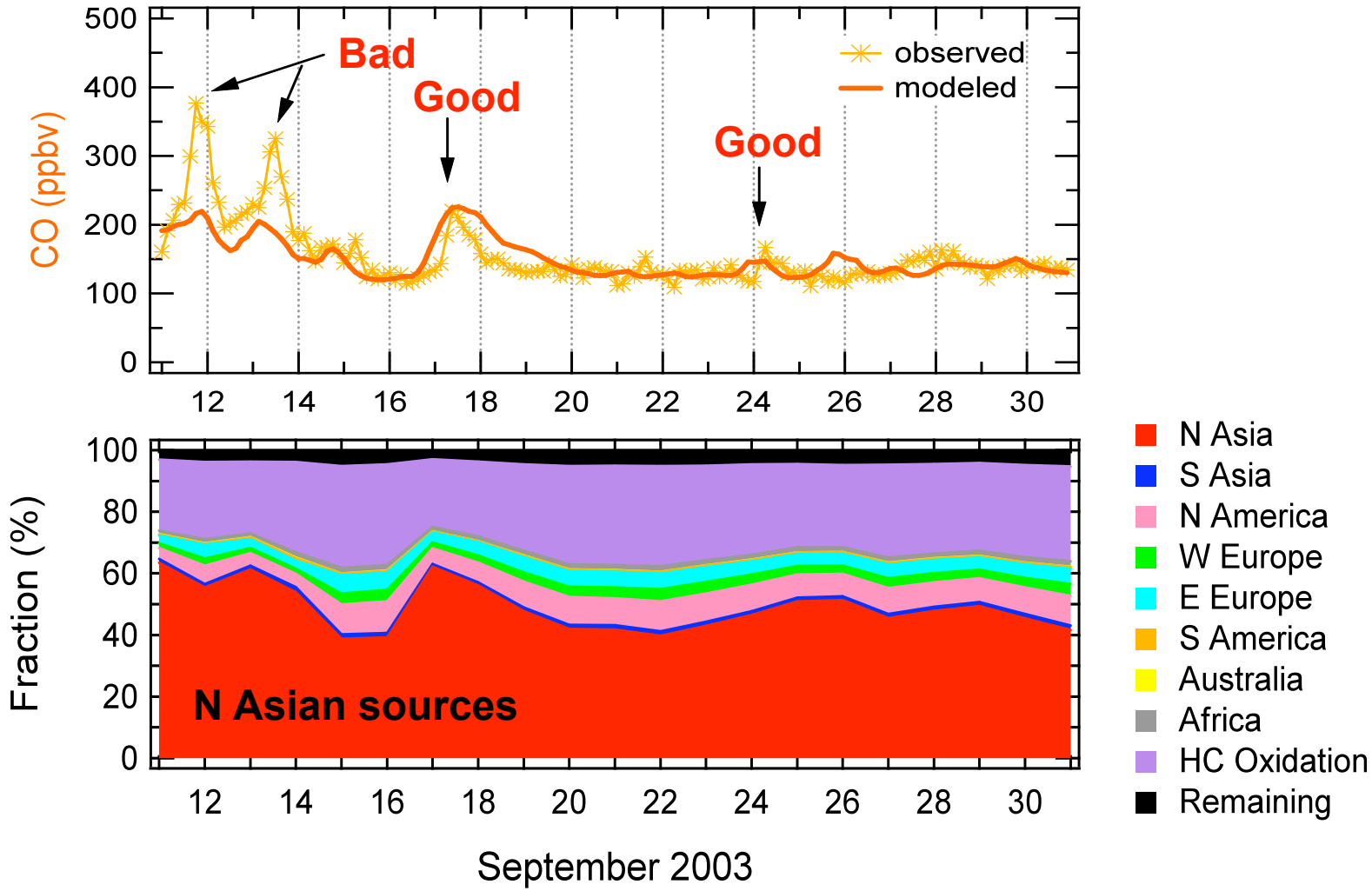
Which Inventory is Better? – Sep 24



- AIRS
  - sees smaller CO over Siberia
  - sees transport from China to the W. Pacific via N. Japan
- Model
  - w/ both inventories predict this transport
  - w/ standard inventory looks better (due to co-located BB emissions)



Observed vs. Modeled CO, Source Contributions



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