Transport Modeling Issues

Lori Bruhwiler

Continental Observations Influence Flux Estimates Less than Marine Boundary Observations

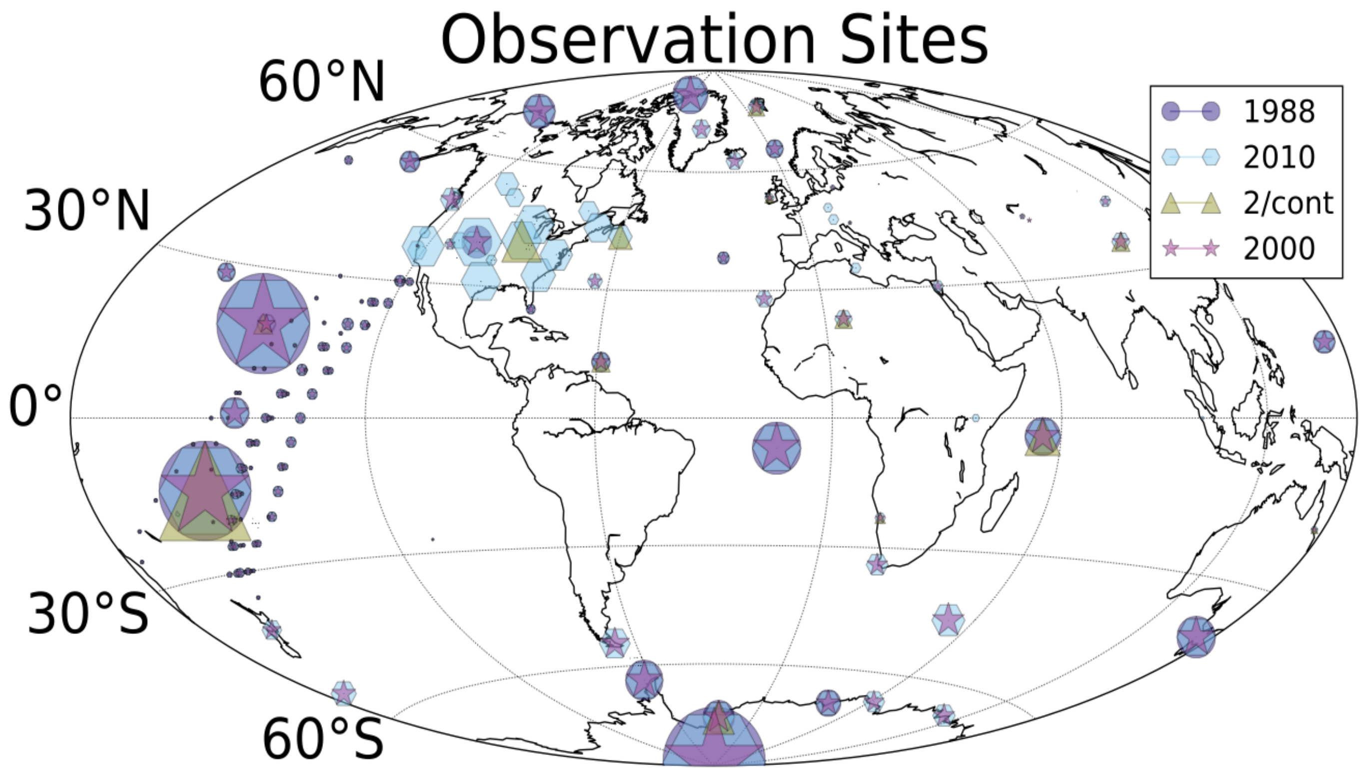
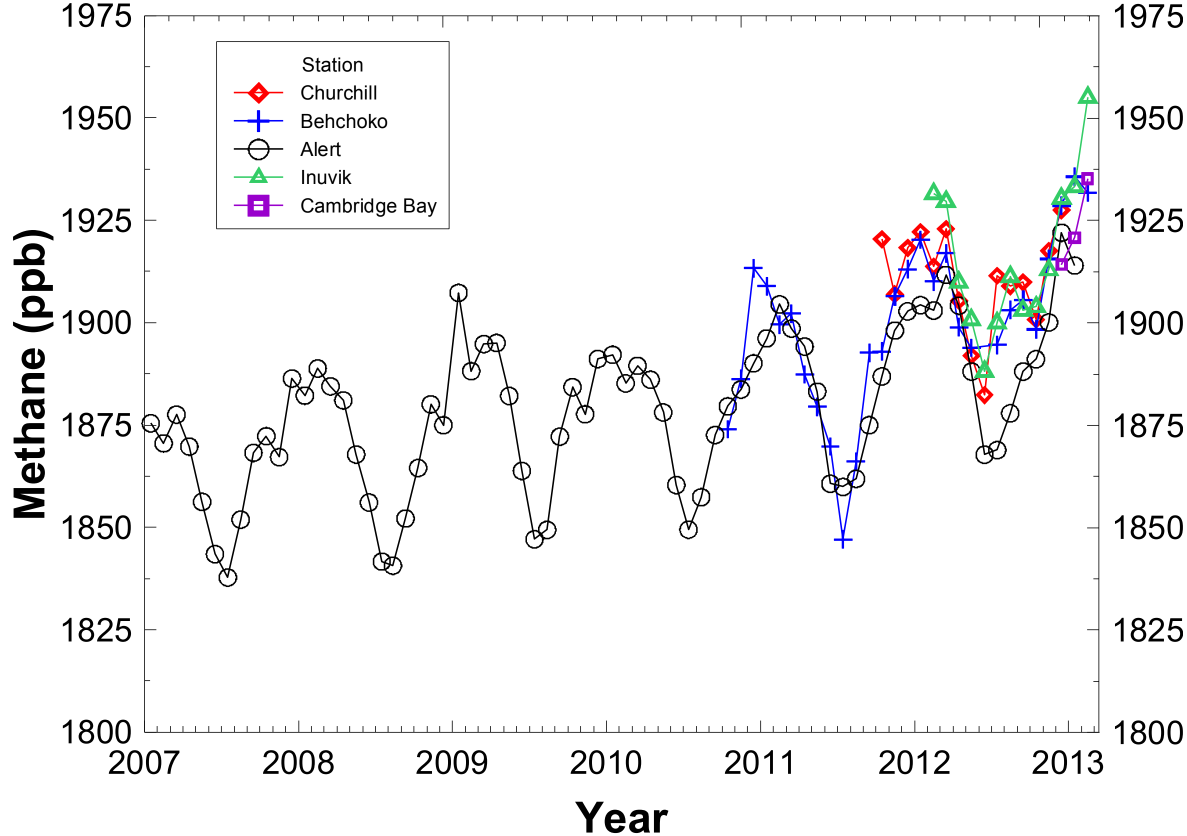


Figure 2: Observation sites assimilated by the '2/cont', '1988', '2000' and '2010' historical runs. The size of the symbol is proportional to $\frac{\sqrt{N}}{\sigma}$ with N the number of available measurements and σ their uncertainty estimate. The larger the symbol, the larger the weight of the site in the model.

Babenhauserheide, A., Basu, S., Houweling, S., Peters, W., and Butz, A.: Comparing the CarbonTracker and TM5-4DVar data assimilation systems for CO2 surface flux inversions, Atmos. Chem. Phys. Discuss., 15, 8883-8932, doi:10.5194/acpd-15-8883-2015, 2015.

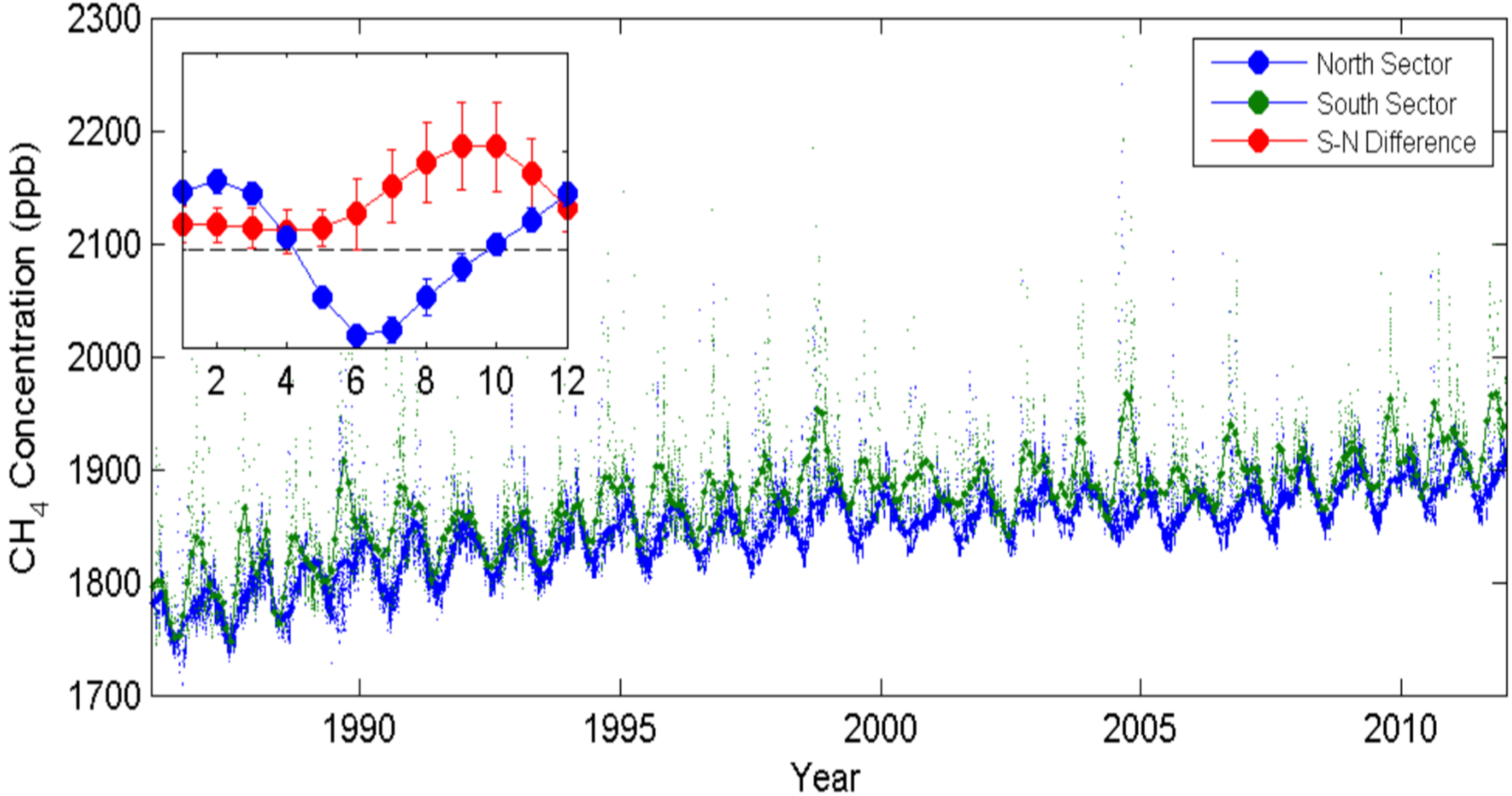
CH_4 in the Canadian Arctic: Continental Data Could Constrain Terrestrial Emissions



Alert is a "background site", the others are continental and likely near strong local sources.

(Data courtesy of D. Worthy, Environment Canada)

What Can Be Learned From High-Frequency Data?



Heterogenous Emissions

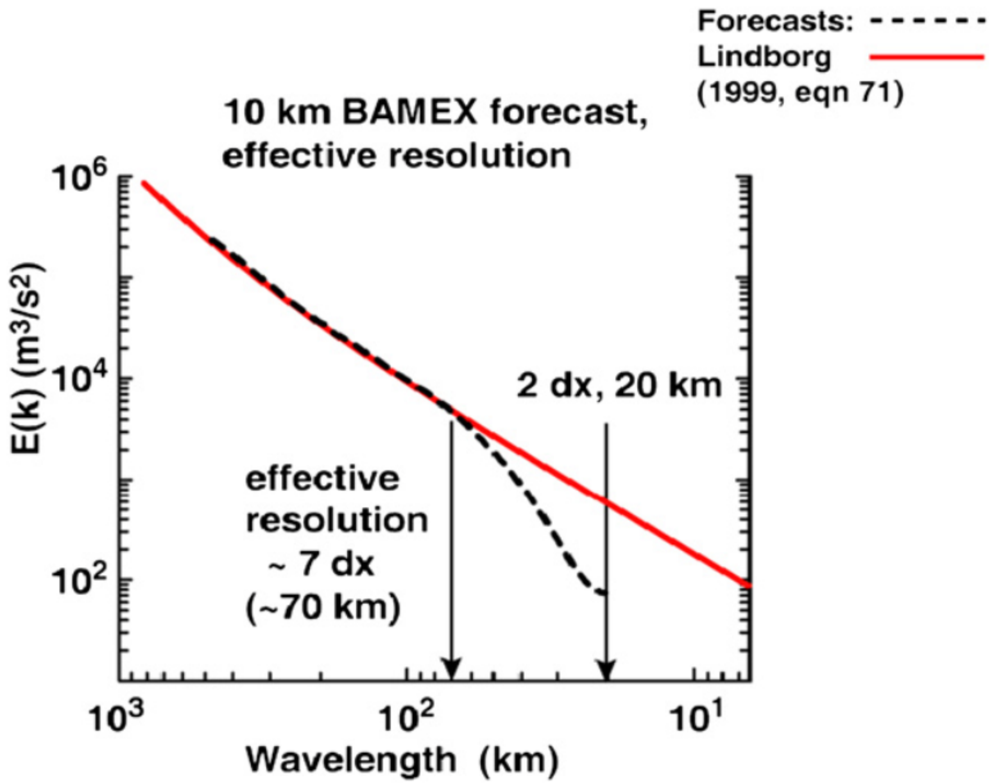


Fig. 1. Energy power spectrum from a WRF forecast with 10-km horizontal resolution (dashed black line) and analytic results from Lindborg (1999).

"Using Fig.1, for transport processes a corresponding time resolution (eff_T) may be on the order of $O(U/L)^{-1}$. Using an advective speed of about 10 m s^{-1} we may get eff_T ~ $(eff_r/4)/10$ ~ 30 min. A coupling interval of 60 min would in this case correspond to an effective horizontal resolution of 14dx."

Grell and Baklanov, 2010

The Flux Inversion Cost Function

$$L_s = (z - \mathbf{H}s)^T \mathbf{R}^{-1} (z - \mathbf{H}s) + (s - s_p)^T \mathbf{Q}^{-1} (s - s_p)$$

z = observations

$\mathbf{H}s$ = simulated observations

s_p, s = prior and posterior sources/sinks

$\mathbf{Q}$ = prior source/sink uncertainty

$\mathbf{R}$ = "measurement" uncertainty

What Does the Measurement Uncertainty Represent?

$\mathbf{R_{obs}}$ = the actual measurement uncertainty (usually really small)

$\mathbf{R_{rep}}$ = the representation error resulting from sub-grid scale variability

$\mathbf{R_{trns}}$ = transport model errors

$$\mathbf{R = (R_{obs}^2 + R_{rep}^2 + R_{trns}^2)^{1/2}}$$

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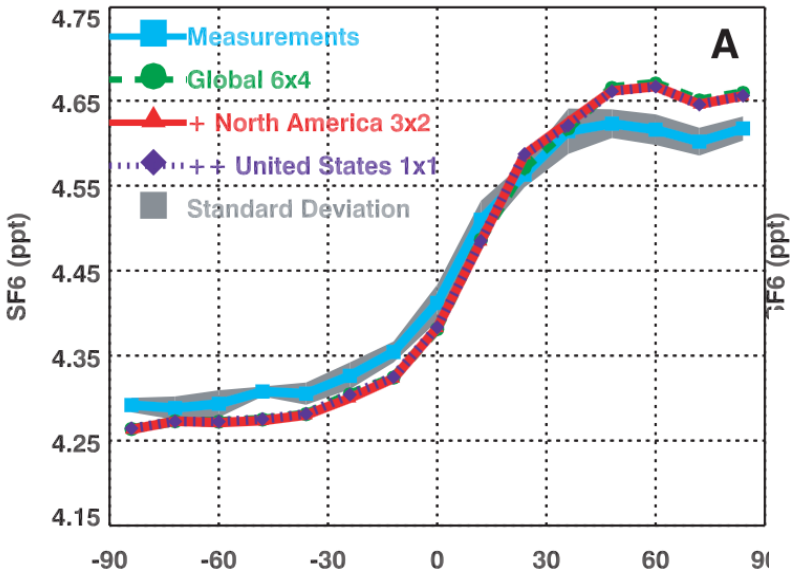
But…

1) Errors are probably correlated.
2) There are also biases.
3) It's difficult to quantify transport **R**'s

So…

1) Understand model performance.
2) Use the best model.

Meridional Tracer Gradients



The TM5 gradient is too steep!
(Peters et al., 2004)

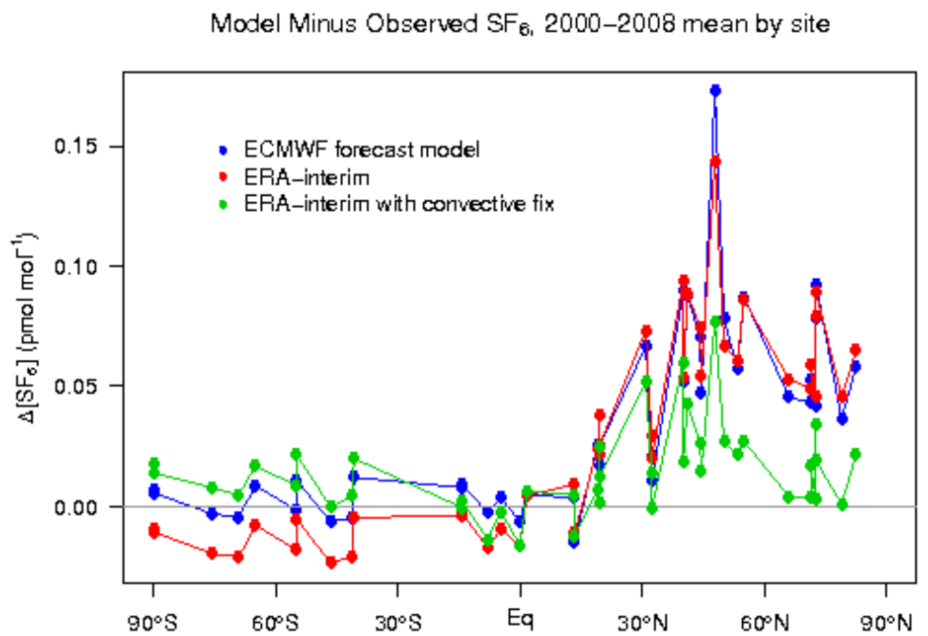
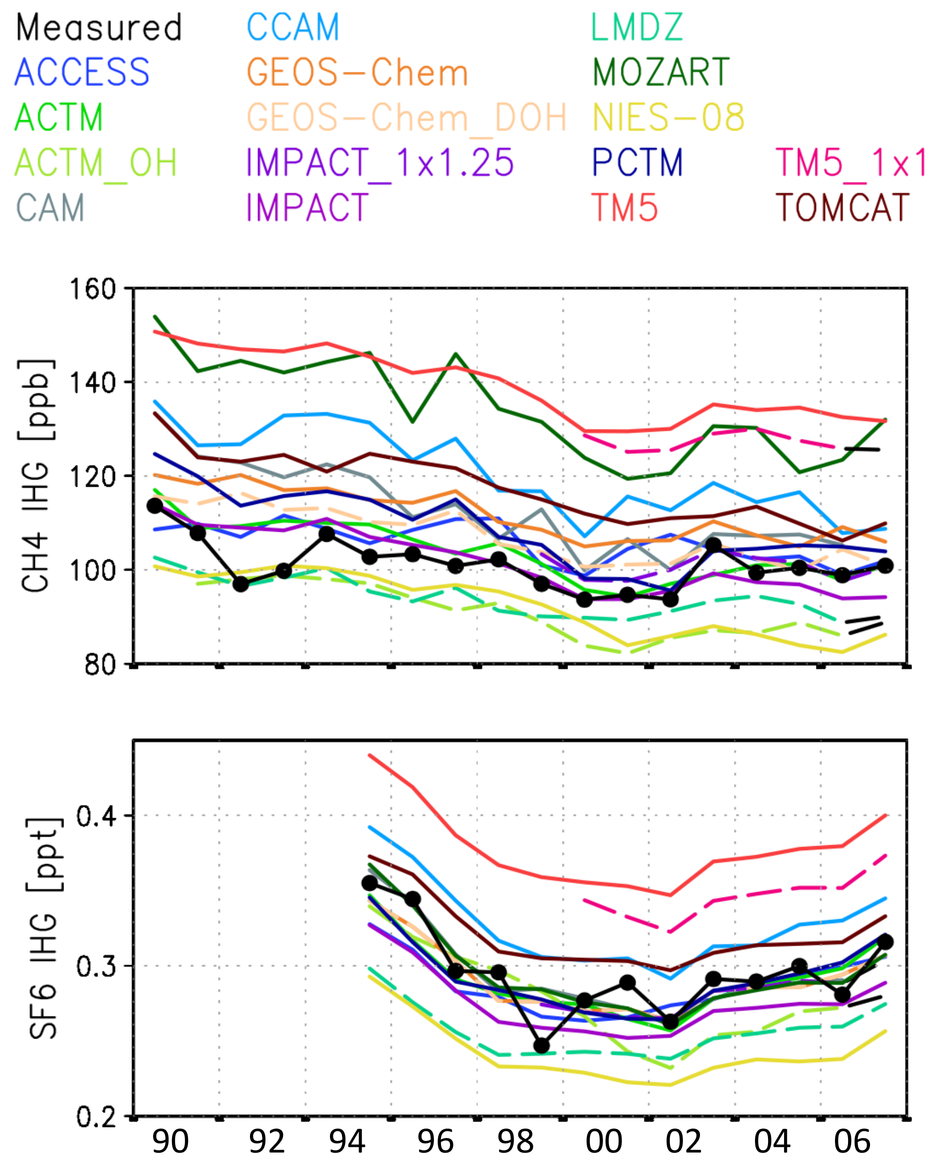


Figure 13: Long-term mean model residuals of SF_6 concentrations as a function of latitude. Residuals are defined as model-minus-observation, so a positive residual indicates the model has too much SF_6. Three different transport model simulations

The Meridional Gradient helps us to evaluate a model change.
(http://www.esrl.noaa.gov/gmd/ccgg/carbontracker/CT2013B_doc)

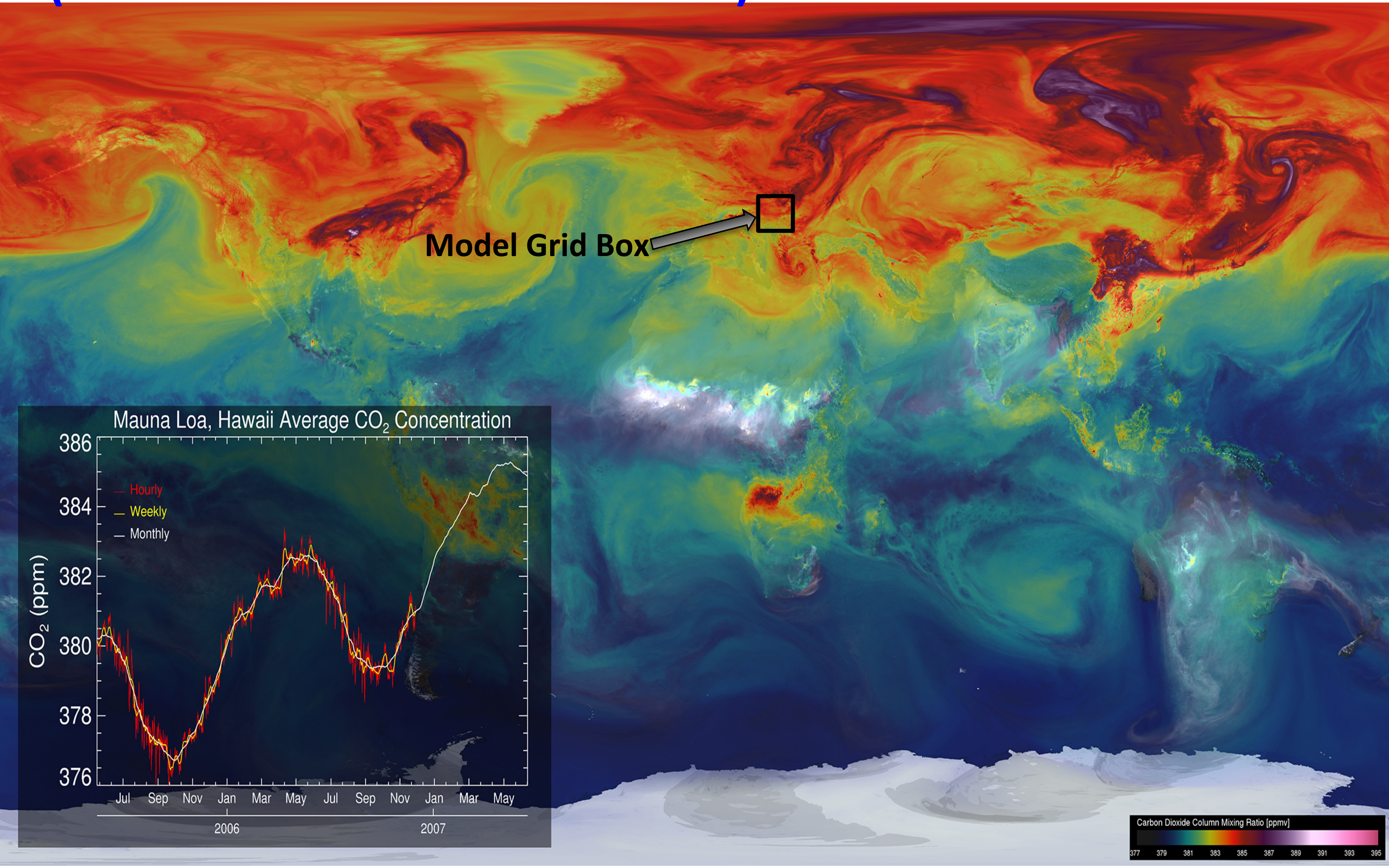
The Inter-Hemispheric Gradient

Patra et al., 2011

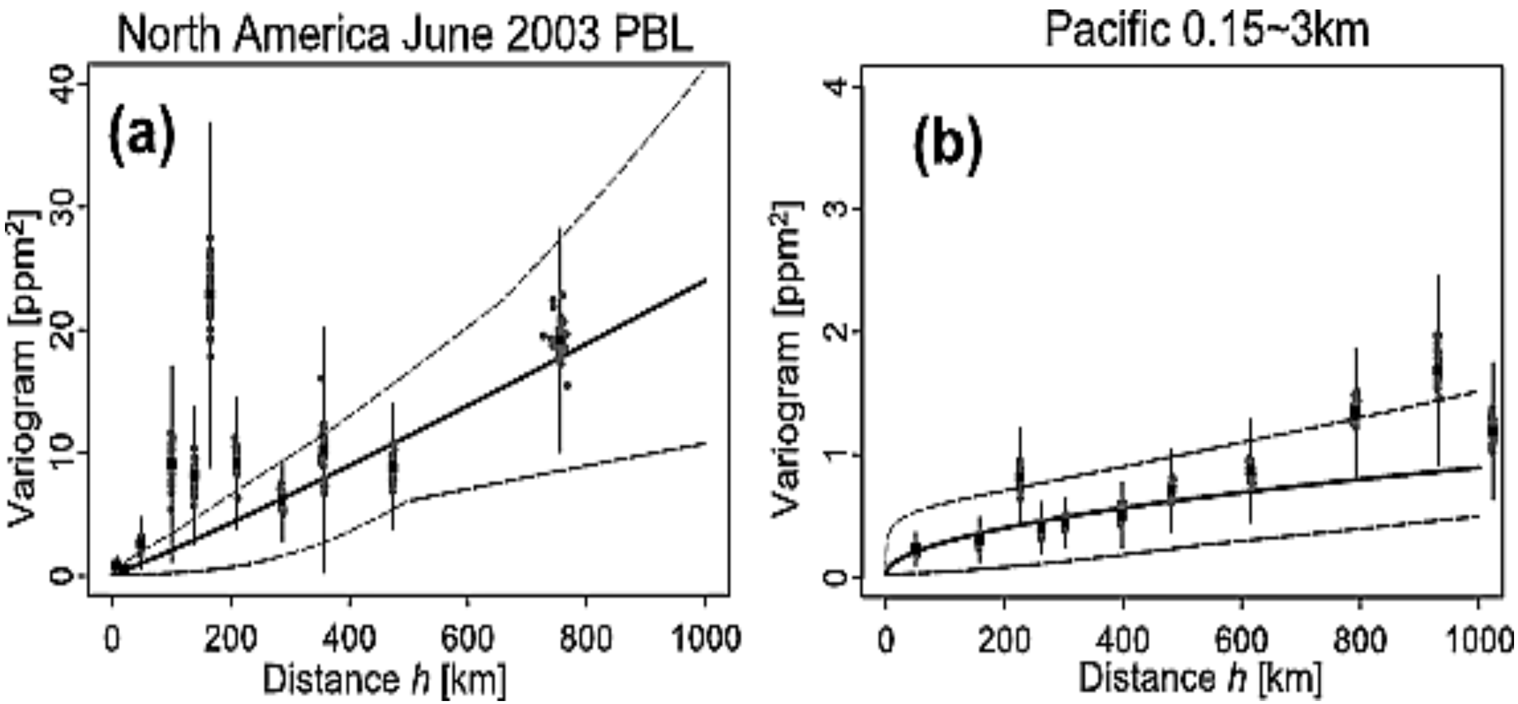


Models used the same emissions so differences are due to transport

Representation Error
(7 km NASA Nature Simulation)



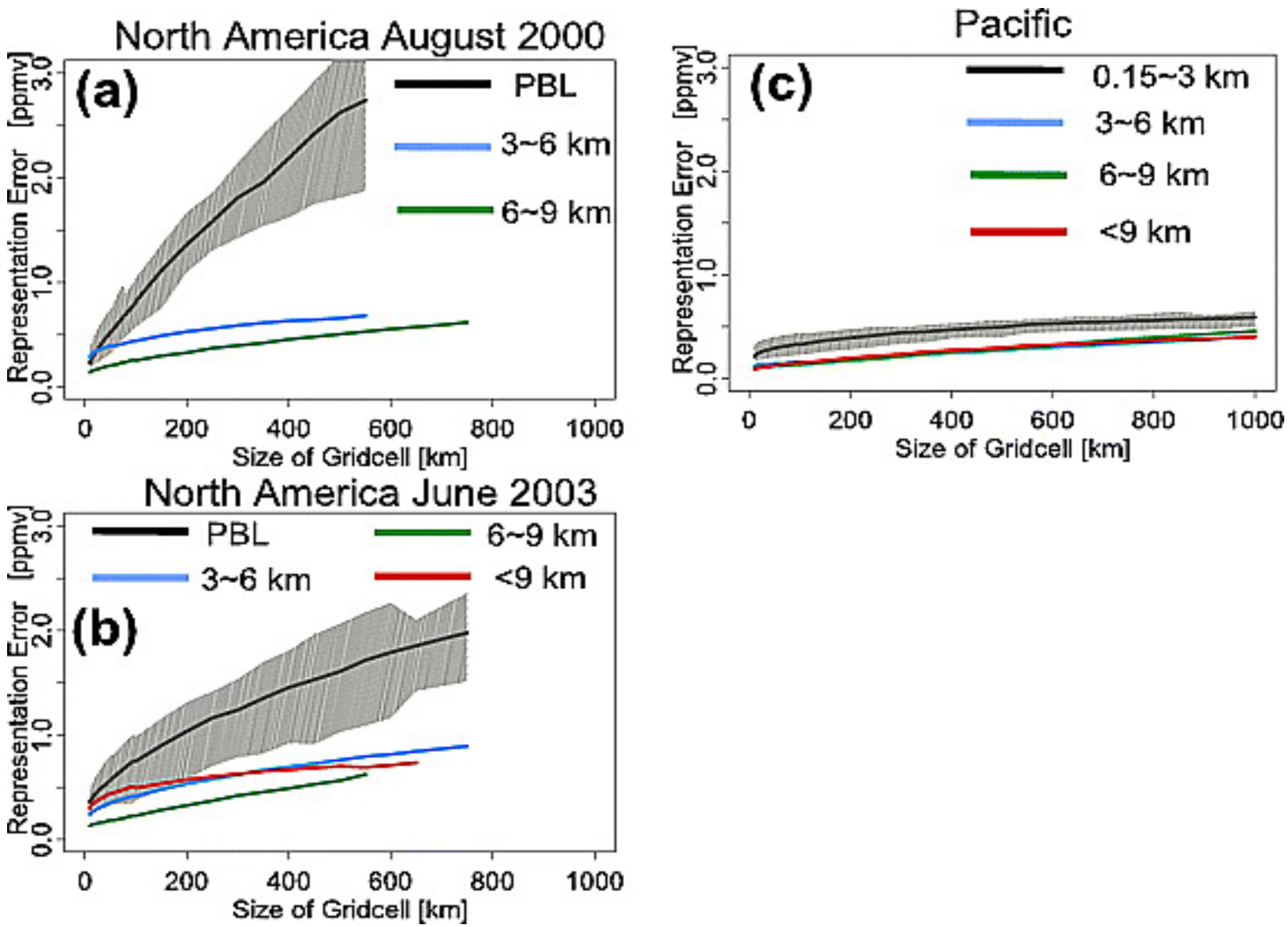
Representation Error



The variance of differences (variogram) in column-averaged CO_2 as a function of separation distance *h*. Points in grey are variogram estimates with one observation deleted (Jackknife method). Vertical bars represent 1-σ errors derived from Jackknife statistics. The solid line represents a power variogram model, and the dashed lines correspond to the 95% confidence interval for the variogram fit.

Lin et al., GRL 2004; An empirical analysis of the spatial variability of atmospheric CO2: Implications for inverse analyses and space-borne sensors

Representation Error



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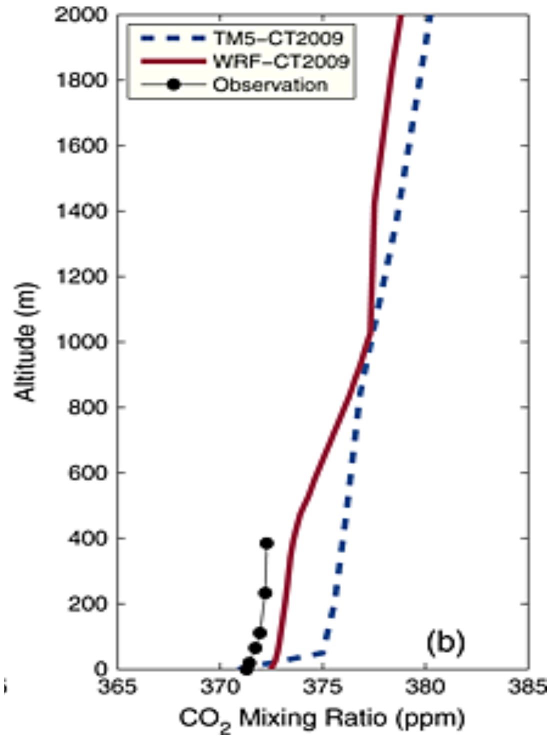
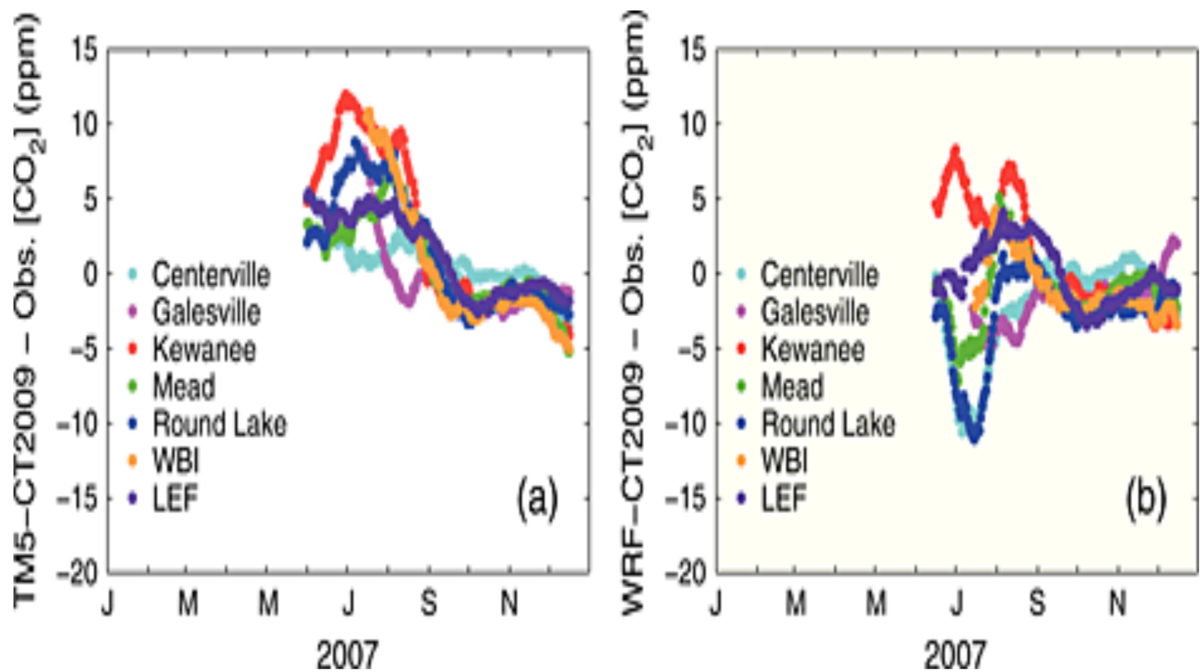
TM5 (100km) vs. WRF (10km) driven with same CO_2 fluxes



WRF may have better vertical mixing near surface. (LEF-WI)

Large differences in model-data residuals in summer driven entirely by transport differences.



Diaz Isaac et al., Journal of Geophysical Research: Atmospheres
Volume 119, Issue 17, pages 10536-10551, 2 SEP 2014 DOI: 10.1002/2014JD021593
http://onlinelibrary.wiley.com/doi/10.1002/2014JD021593/full#jgrd51666-fig-0003

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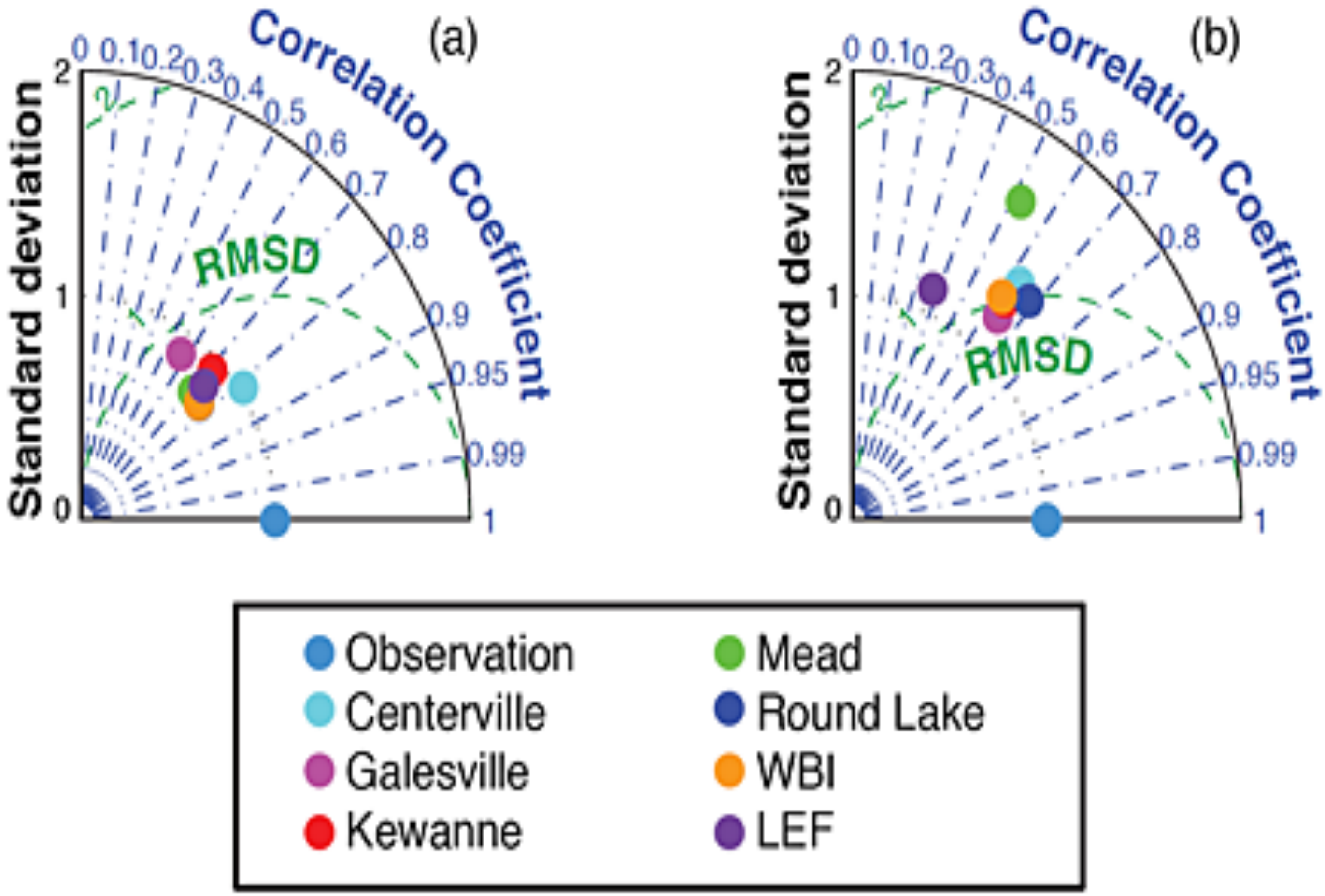

Taylor diagram summarizes statistical info. on model-obs agreement. It's not obvious that WRF is better!

Diaz Isaac et al., Journal of Geophysical Research: Atmospheres
Volume 119, Issue 17, pages 10536-10551, 2 SEP 2014 DOI: 10.1002/2014JD021593
http://onlinelibrary.wiley.com/doi/10.1002/2014JD021593/full#jgrd51666-fig-0003

Assessing Transport Error using an Ensemble Approach

Angevine et al., 2014

6 member WRF Ensemble

Ensemble spread (0-100m a.g.l.) suggests that transport errors for CO may be significant.

Normalized to mean CO (1 means that the spread equals the mean area).