NCAR CESM Working Group Meeting

Nudging Timescales and Vertical Transport in CAMChem-SD and WACCM-SD

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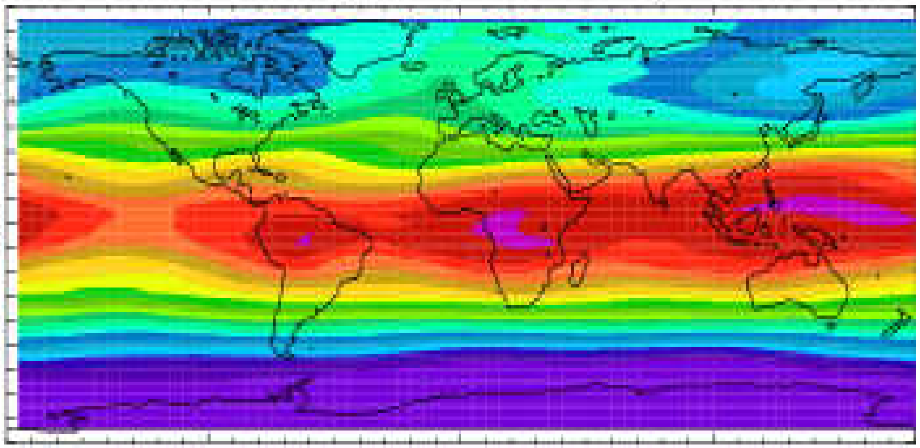
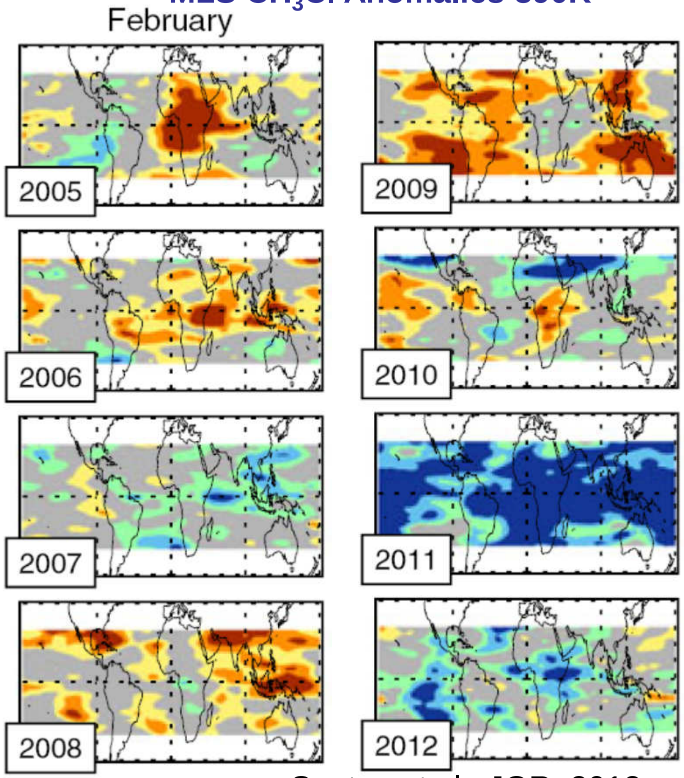


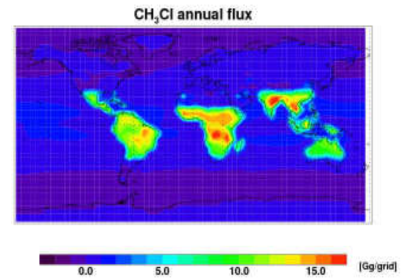
Model Setup and Emissions

MLS CH_3Cl Anomalies 390K



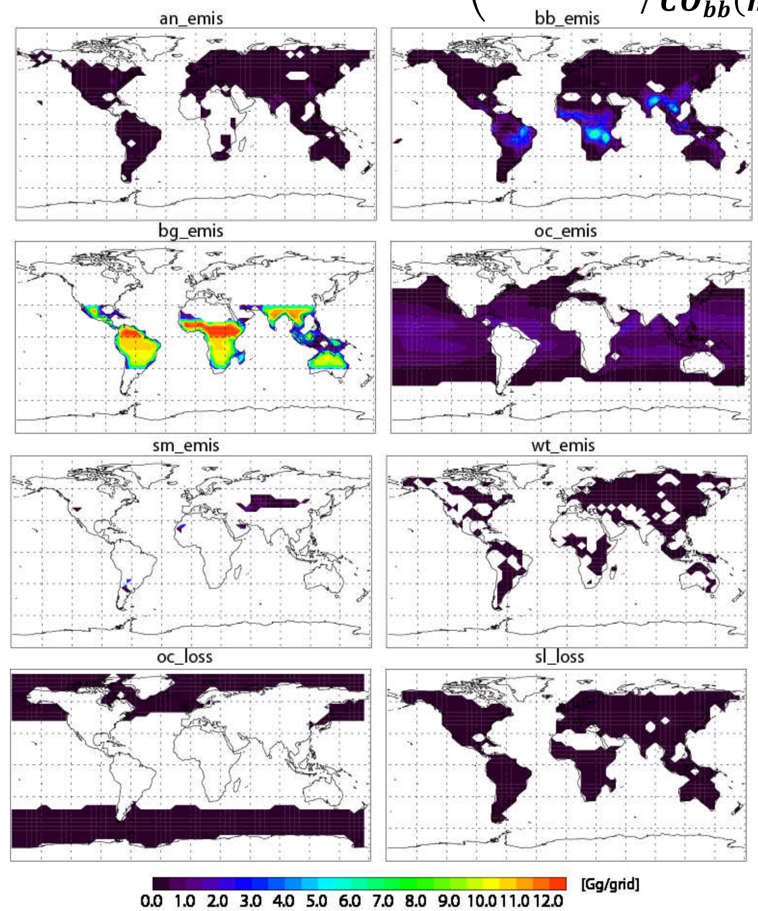
Santee et al., JGR, 2013

CH_3Cl Emissions from Yoshida et al. (JGR 2006)



Time-Varying Biomass Burning Emissions

$$CH_3Cl_{bb}(m,y) = CH_3Cl_{bbYOS} * \left(CO_{bb}(m,y) \Big/ \overline{CO_{bb}(m)} \right)$$



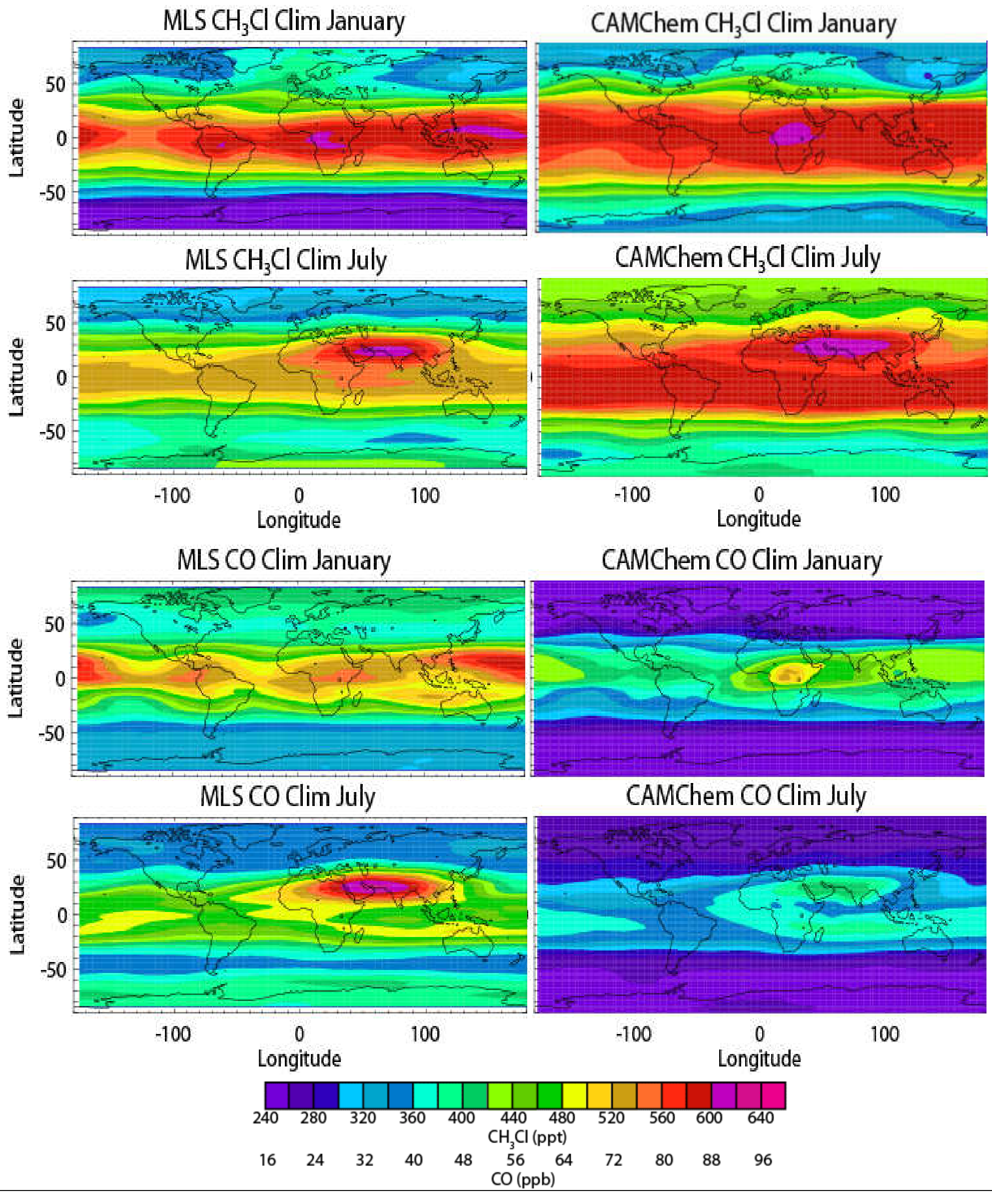
For everything else, we use the CCMi RefC1-SD model setup and emissions. The model is nudged to MERRA meteorology

The original goal of this work was to use CAMChem-SD to understand the observed variability of CH_3Cl in the upper troposphere.

We found significant differences in convective transport with 50-hour and 5-hour nudging

Observed and Modeled CH_3Cl and CO Climatologies

100 hPa CH_3Cl and CO, 50 hour nudging

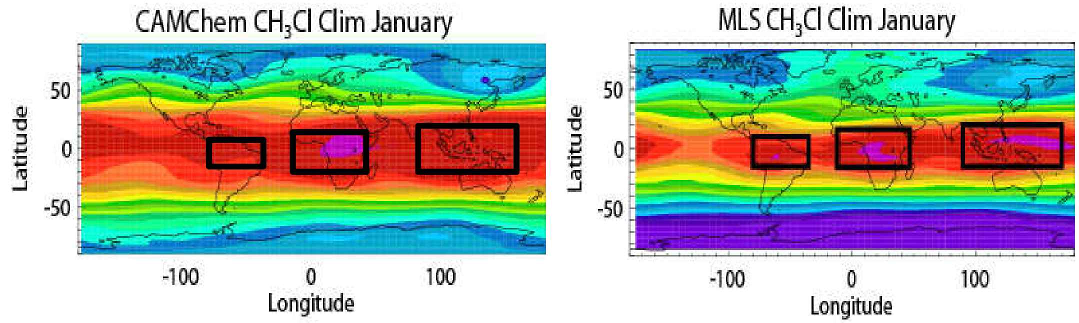


October to May: maxima in UT trace gases with surface sources are seen over South America, Africa, and Indonesia

June to September: maximum abundances are found in the Asian monsoon anticyclone.

The model captures the spatial distribution of CH_3Cl and CO fairly well, but underestimates CO at 100 hPa by ~40%

Relationship Between Observed and Modeled CH_3Cl and CO over Tropical Regions



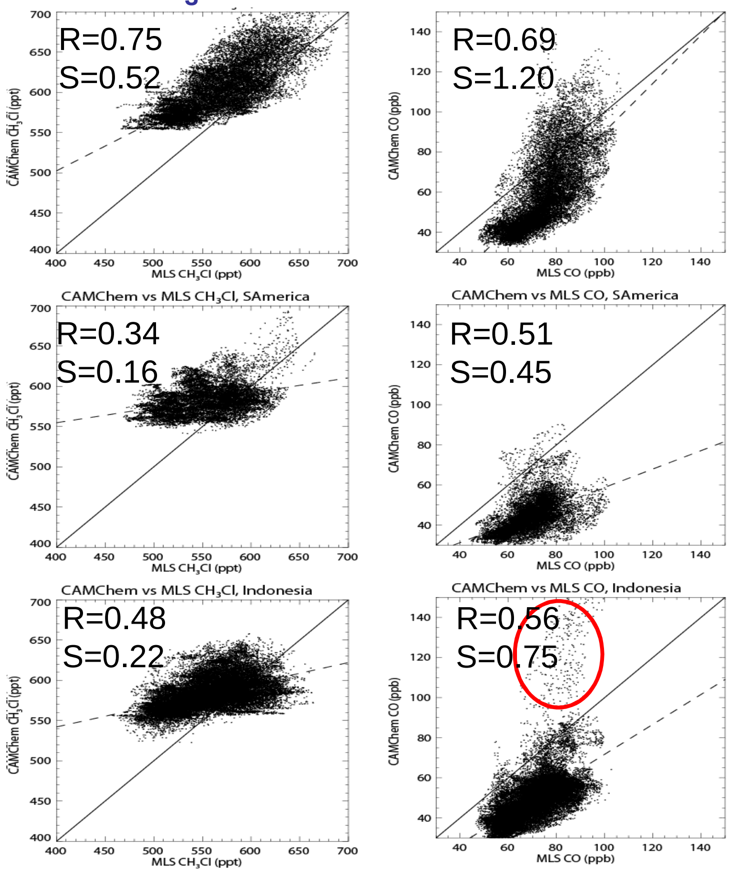
CH_3Cl **100 hPa** **CO**

Results with 50 hour nudging

Africa

S. America

Indonesia

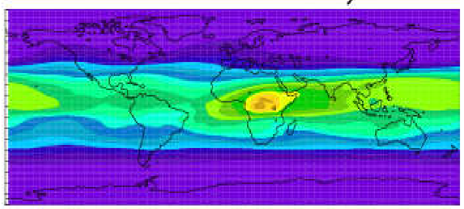


Over South America and Indonesia, the slopes of the CH_3Cl and CO correlations are significantly <1 and also much smaller than the slopes over Africa

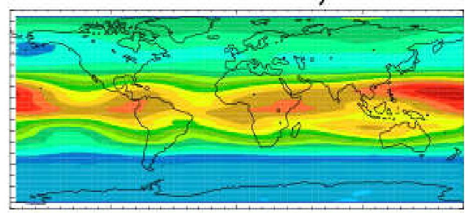
This suggests that the model convection may be too weak over these regions *relative to the convection over Africa*

Relationship Between Observed and Modeled CH_3Cl and CO over Tropical Regions - Dependence on Nudging Timescale

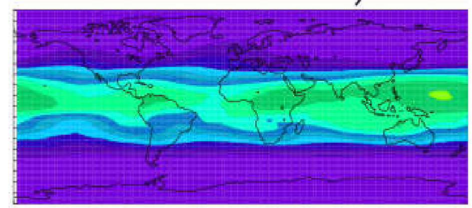
50 hour nudging

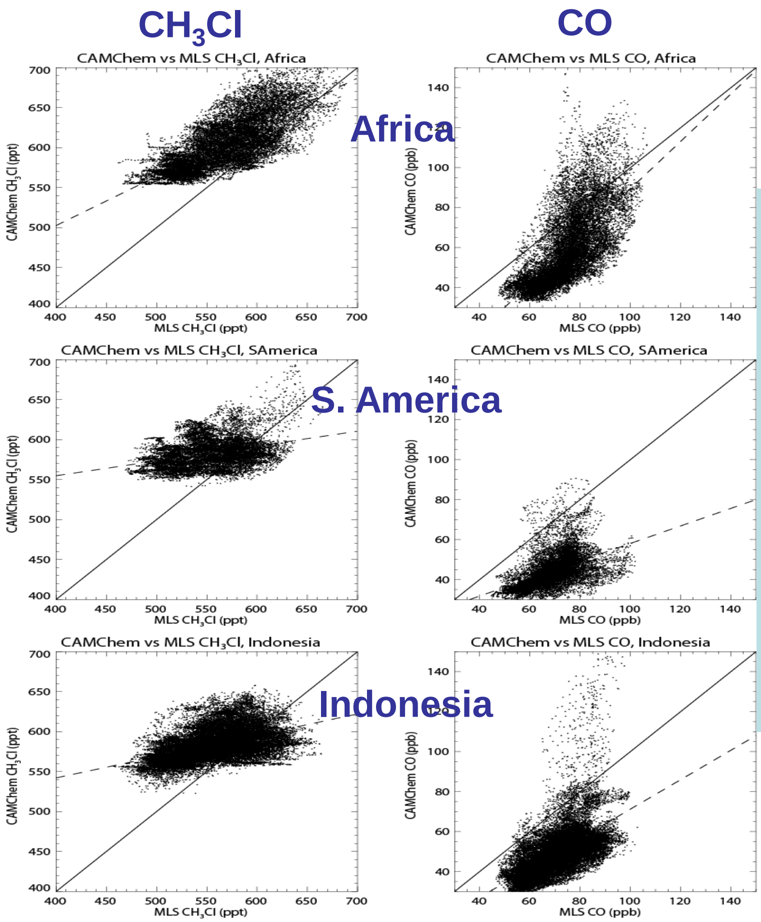


Observations

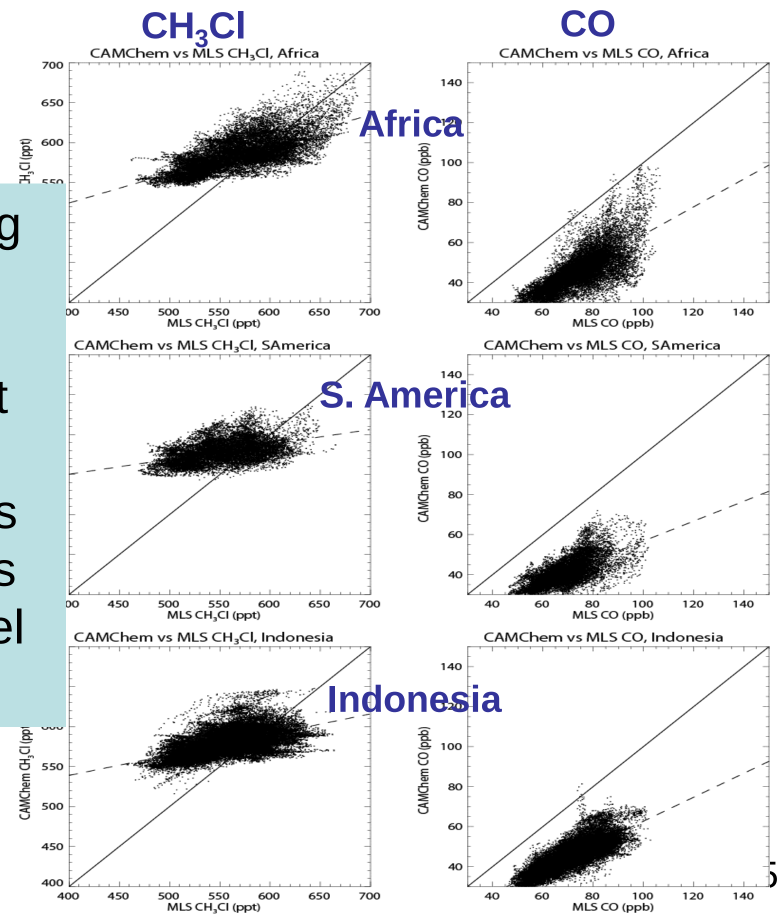


5 hour nudging

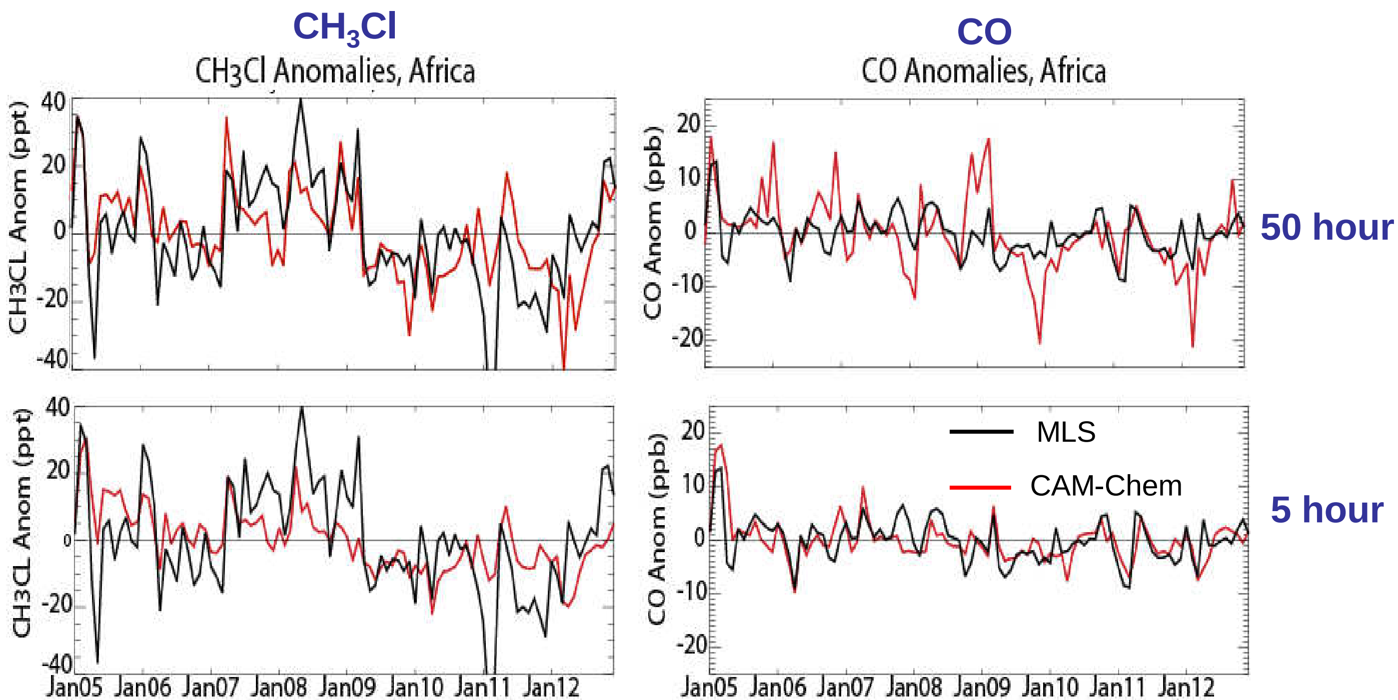




5 hour nudging improves the model-measurement consistency across regions and eliminates spurious model abundances



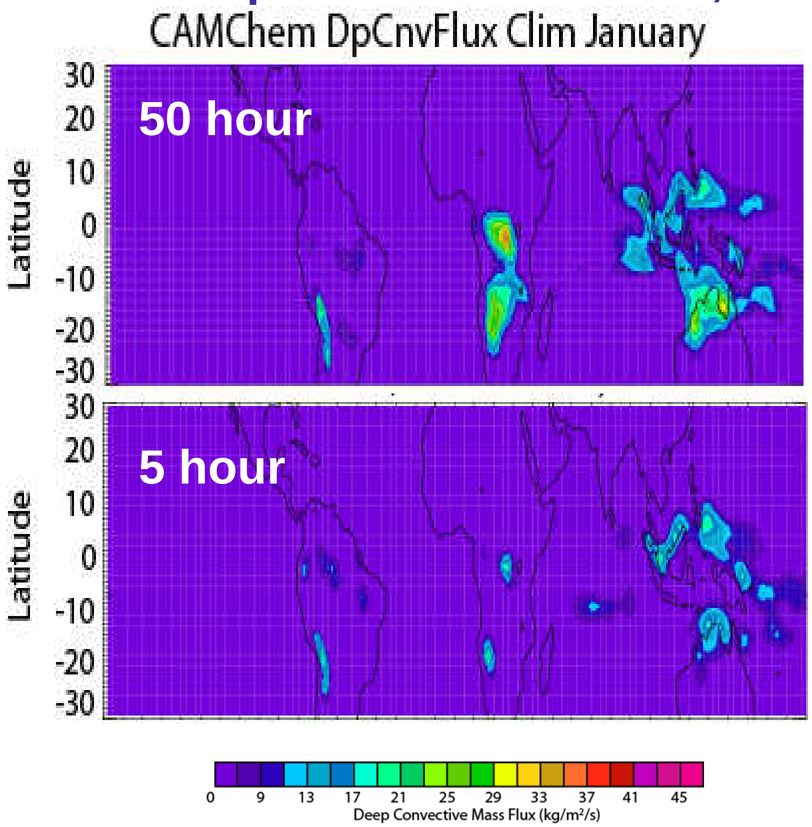
Relationship Between Observed and Modeled CH_3Cl and CO over Tropical Regions - Dependence on Nudging Timescale



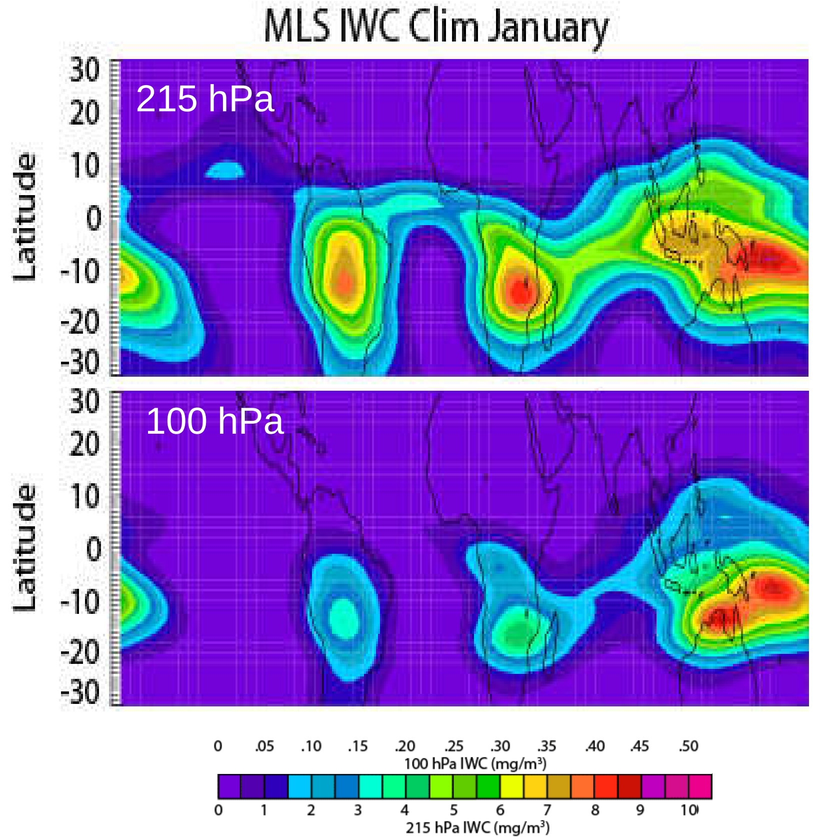
The simulation of CO anomalies is greatly improved, particularly over Africa; there is less change to CH_3Cl anomalies, but the model-measurement differences are reduced.

Convection is Strongly Dependent on the Nudging Timescale

Model Deep Convective Fluxes, 225 hPa



IWC Observations

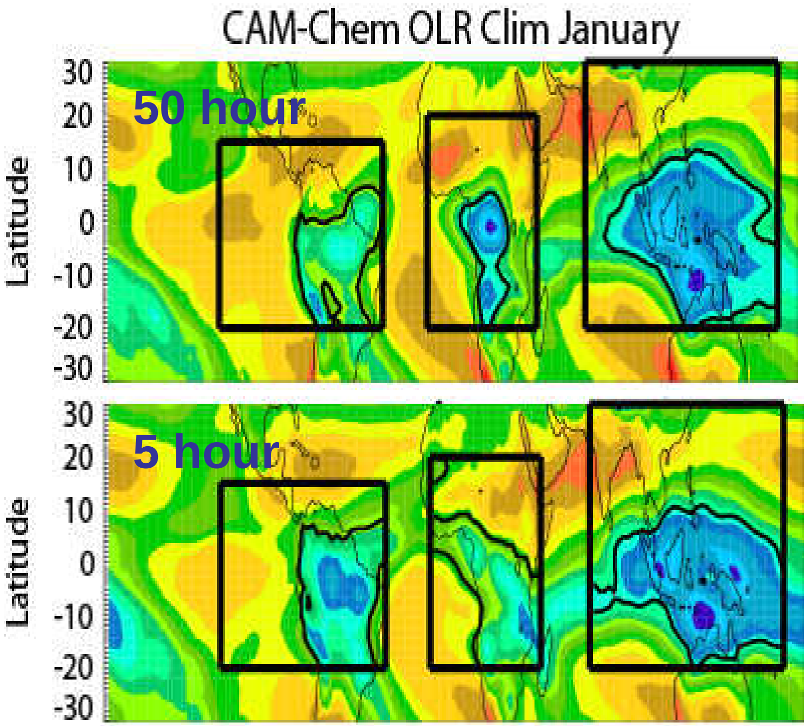


Convective mass fluxes over Africa and Indonesia are greatly reduced with 5 hour nudging.

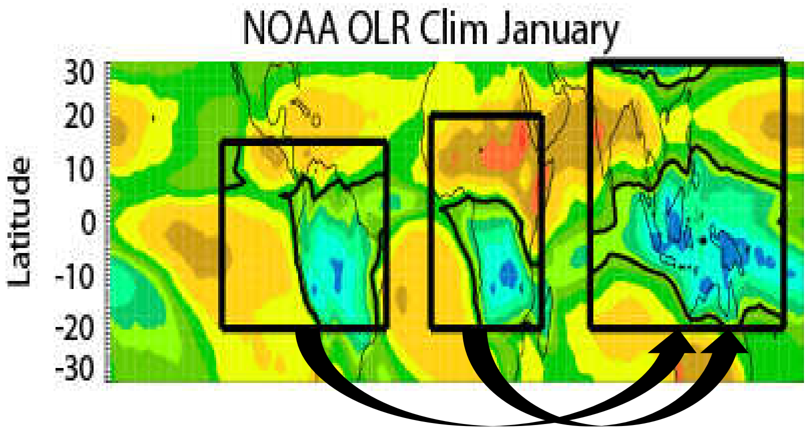
MLS IWC measurements suggest comparable convective depth and intensity over South America and Africa, with stronger convection over Indonesia in January. This is more consistent with the 5 hour nudging.

Convection is Strongly Dependent on the Nudging Timescale

Model OLR

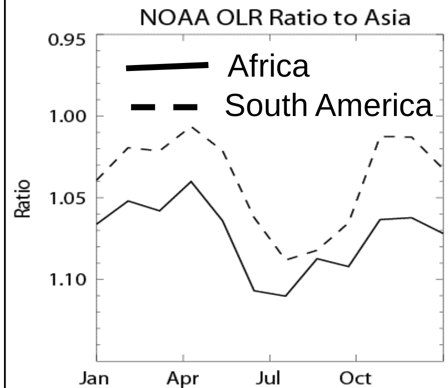


OLR Observations



The model OLR is also more consistent with observations when 5-hour nudging is used.

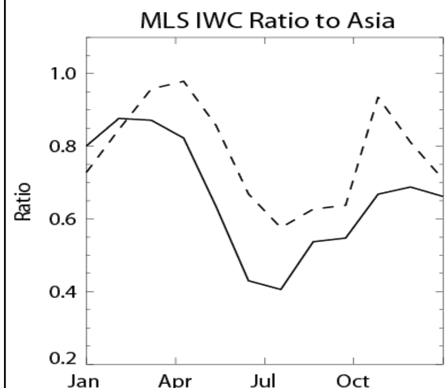
Observed Regional Ratios of Vertical Transport Tracers



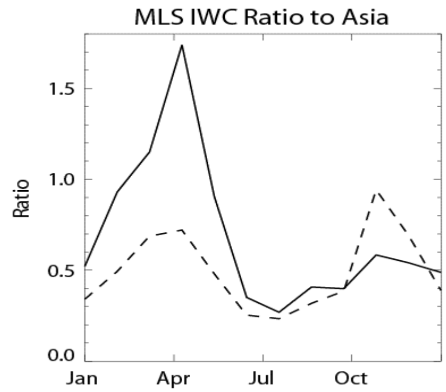
Observed Ratios of Vertical Transport Tracers over Africa and South America to Asia

OLR and 215 hPa IWC show a consistent picture that suggests that vertical transport over Asia > South America > Africa throughout the year.

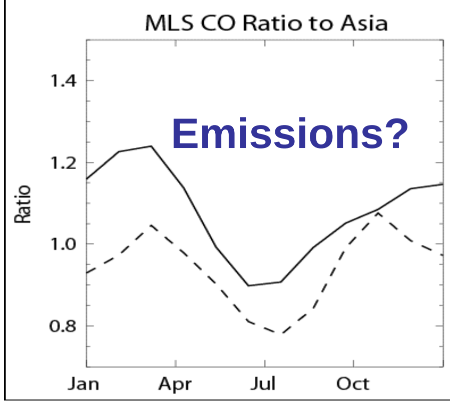
215 hPa

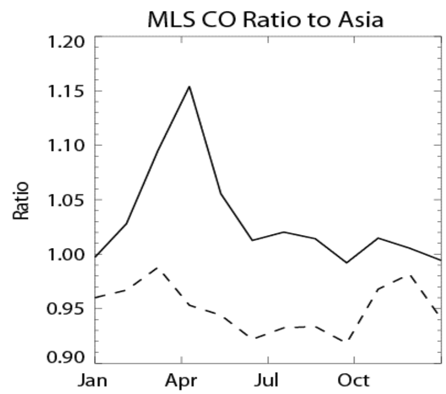


100 hPa



The ratio of South America and Africa to Asia peaks during Mar-Apr and Nov-Dec, with minimum values during the monsoon season

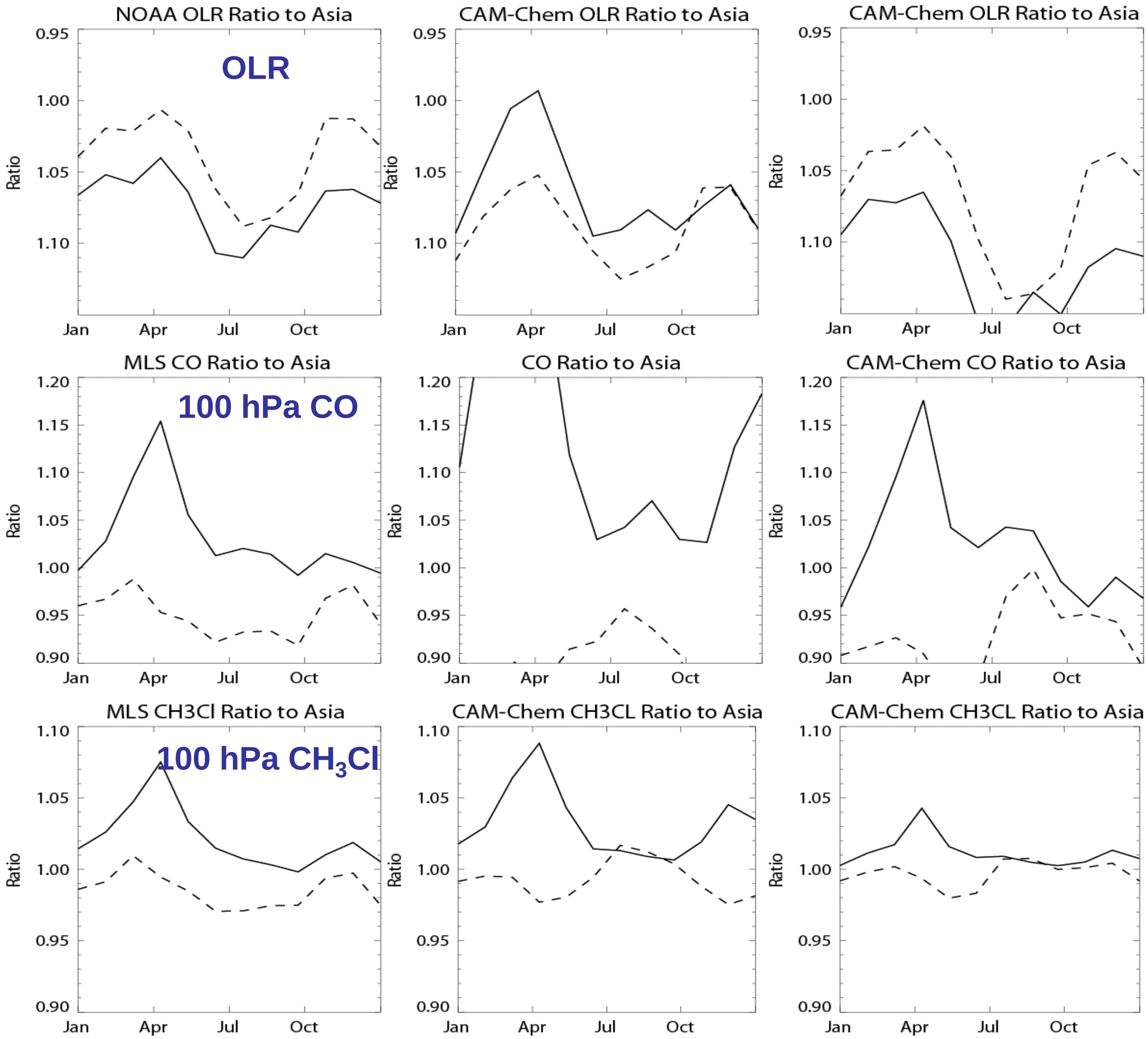




At 100 hPa, IWC, CO and CH_3Cl show quite a different picture than OLR, with the strongest vertical transport over Africa during April. Vertical transport over Africa penetrates deeper into the UTLS than over the other regions

Observed vs Modeled Regional Ratios

Observations | **50 Hour** | **5 Hour**



The 5 hour nudging improves the model regional ratios compared to the observations for every tracer except CH_3Cl

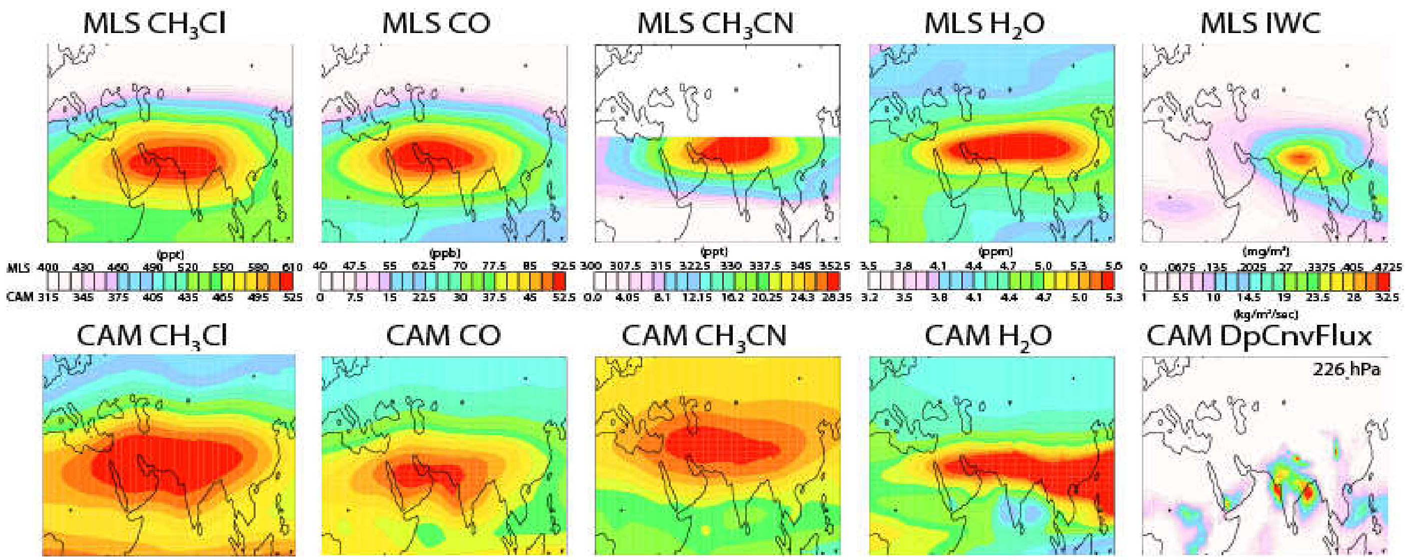
In both model versions, CH_3Cl over South America has a different seasonal relationship to Asia than observed – this suggests an issue with the seasonality of South American emissions

Asian Summer Monsoon Anticyclone – 100 hPa Climatologies

July Climatologies (2005-2012) at 100 hPa

MLS v3.3

50 hour



Note different scales for measurements and model

Model trace gas concentrations in the ASM anticyclone are lower than observed (in some cases much lower) and gradients are much weaker

Model H_2O maximum values extend too far eastward and do not show a closed anticyclone signature

The model's deep convective mass flux has maximum values over the East and West coasts of India

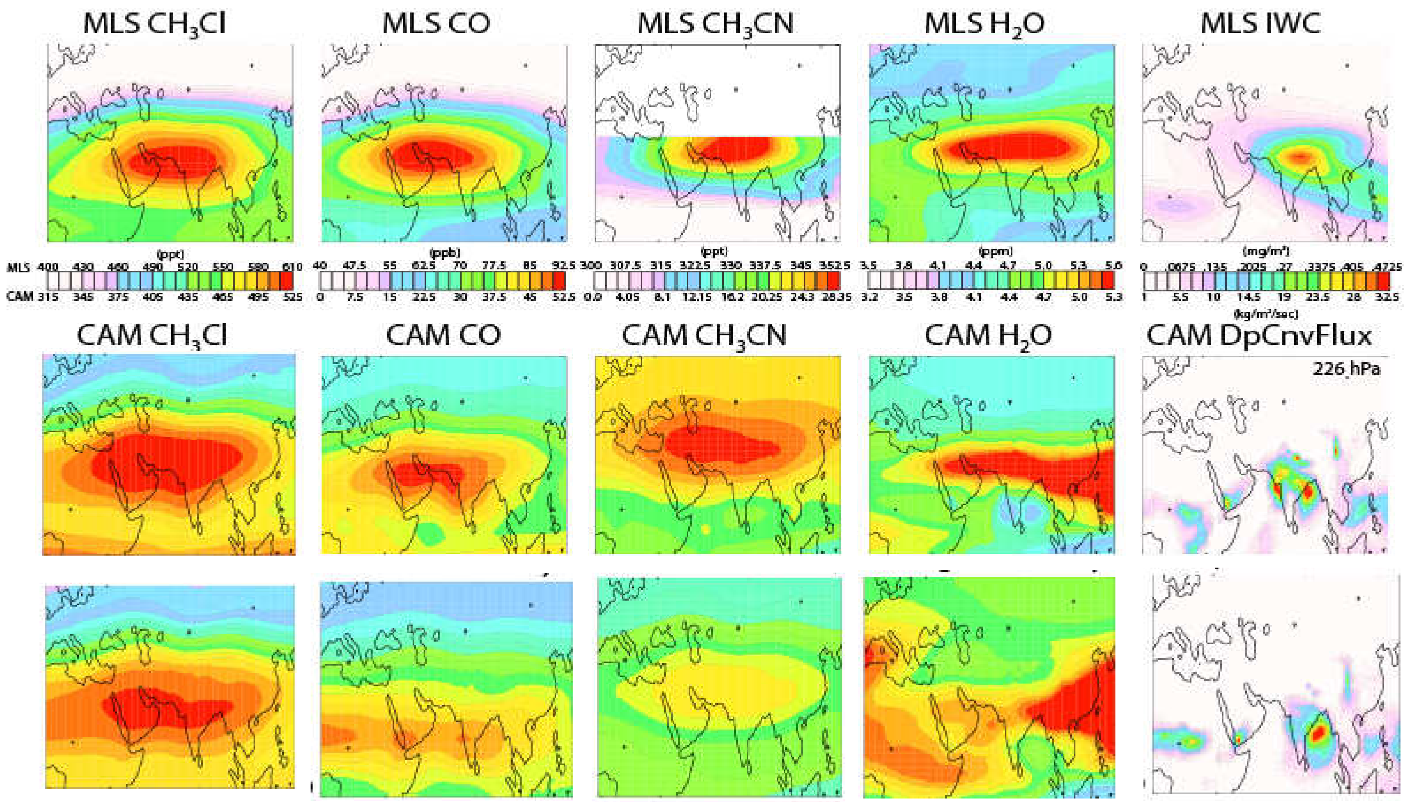
Asian Summer Monsoon Anticyclone – 100 hPa Climatologies

July Climatologies (2005-2012) at 100 hPa

MLS v3.3

50 hour

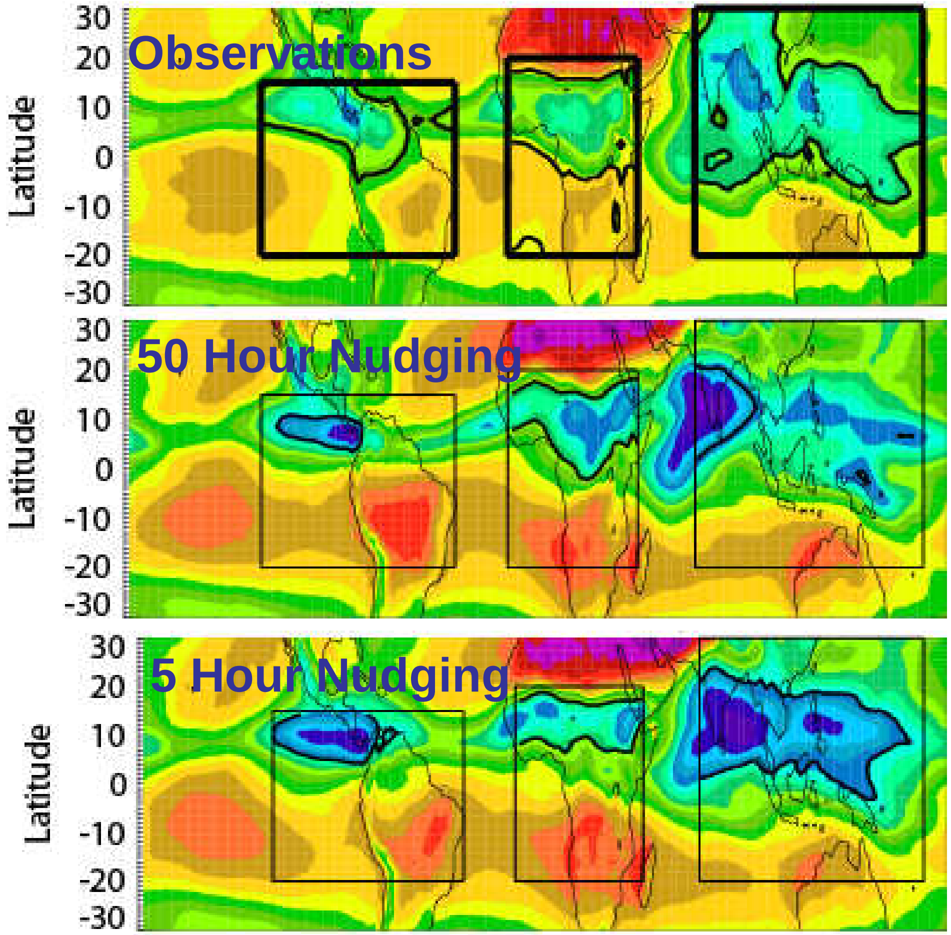
5 hour



Note different scales for measurements and model

5 hour nudging shifts the convective region to the Bay of Bengal, but the ASM anticyclone is not as well represented, especially for CO and H_2O

Asian Summer Monsoon – July OLR



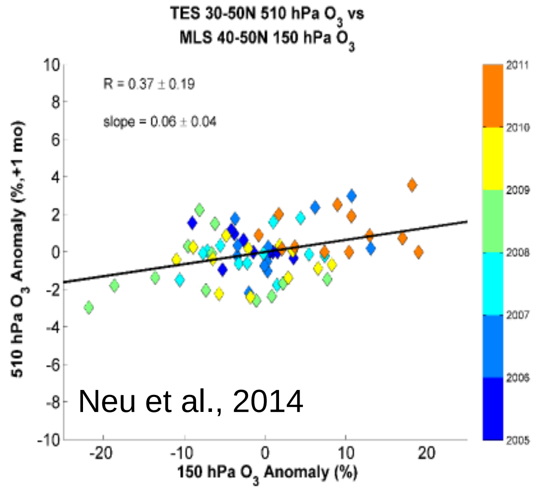
Comparison to OLR observations suggests that ASM convection is better with 5 hour nudging

So why does the 5 hour version degrade the quality of the ASM anticyclone?

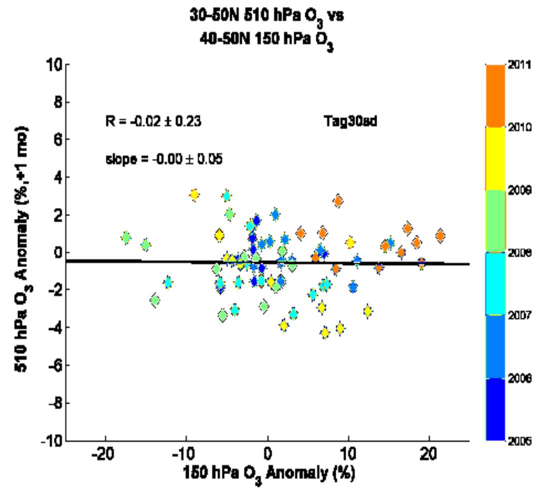
WACCM Nudging Timescale: Dependence of Tropospheric Ozone Variability on the Stratosphere

Tropospheric Ozone vs Stratospheric Ozone

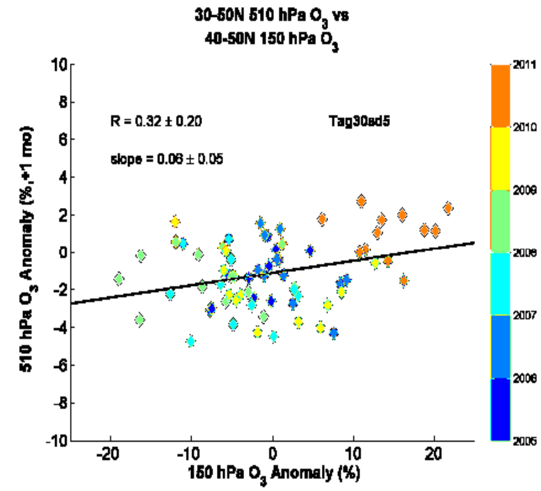
Observations



WACCM-SD 50 hour

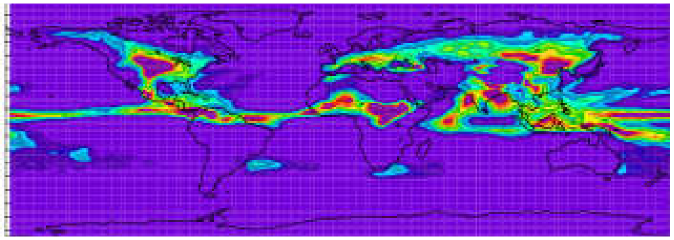


WACCM-SD 5 hour

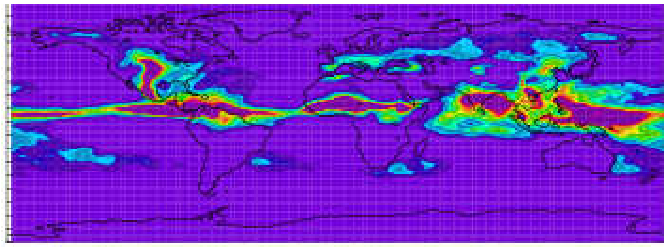


390 hPa Deep Convective Mass Fluxes for June

CAMChem-SD 50 hour



CAMChem-SD 5 hour



SD reproduces observed stratospheric ozone variability well, but, unlike FR, does not capture the observed NH relationship between stratospheric and tropospheric ozone.

Using a 5-hour nudging timescale reduces convection over the summertime continents and greatly improves the SD performance on this metric, but degrades the overall performance in the stratosphere.

Summary and Next Steps

- The model convective mass fluxes are very sensitive to the nudging timescale. The differences in convection lead to large differences in upper tropospheric composition for some species.
- Comparison to observations tends to indicate that 5 hour nudging gives more realistic convection, which is consistent with other anecdotal findings that tropospheric composition is better simulated with 5 hour nudging.
- The ASM anticyclone, however, appears to be better simulated with a longer nudging timescale.
- Likewise, analysis of WACCM output against observations has shown that the optimal nudging timescale for the stratosphere is ~50 hours.
- These results suggest that a height-dependent nudging timescale may be necessary to accurately simulate both tropospheric and stratospheric processes (or perhaps that the suite of variables being nudged should be reconsidered).
- We are redoing analysis with the MLS averaging kernels and sampling pattern; preliminary analysis indicates the results are not strongly affected.