The GEOS5-Replay Model: A promising tool for chemistry simulations

Susan Strahan
UMBC & NASA/GSFC
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Chemistry simulations with GEOS5-Replay

Replay is a capability built into the GEOS-5 System

- It runs online GMI Combo chemistry simulations using (GEOS) analyzed meteorology

- The chemistry calculation has no feedback on the meteorology.
- 'Regular' replay reads in analyzed fields every 6 hrs, then recomputes analysis 'increments' to update the meteorology every 30 minutes.
- Meteorological updates are frequent (every 30 minutes) compared to a CTM (3-6 hrs).
- Convective and diffusive transport are also recomputed every 30 minutes in Replay.

Chemistry simulations with GEOS5-Replay

Why is this of interest to our Community?

Preparation time for multi-year simulations using Replay is much shorter than for the GMI CTM.

- Replay ingests GEOS5 met fields exactly as they have been archived – no reprocessing or reformatting.
- A decadal simulation (e.g., tropospheric hindcast) now becomes feasible.
- The Replay simulation shown today uses MERRA met fields (0.5^ox0.67^ox72 levels) which were regridded online within Replay to 2^ox2.5^o.

How is this different from the Replay Results I showed last year?

This model is 'regular' replay. Last year, 'intermittent' Replay was shown. It had significant spurious transport generated by the way data was inserted into the forecast.

Compare 1-yr simulation of Replay with two GMI-CTM simulations

Compare MERRA Replay with GMI-GEOS4 (aka 'Aura4') and GMI-GEOS5.1 for 2005.

- All use GMI-Combo chemical mechanism
- All simulations run at 2°x2.5^{o}.
- Emission inputs very similar though not identical.
- Same source gas boundary conditions (e.g., CFCs, CH4, N2O)
- Replay uses 'default' lightning NO (an emission input) while the CTM uses Dale's parameterization.

Comparisons include

- Stratospheric differences in O3 and long-lived tracers
- Tropospheric differences for O3, NOx, and CO

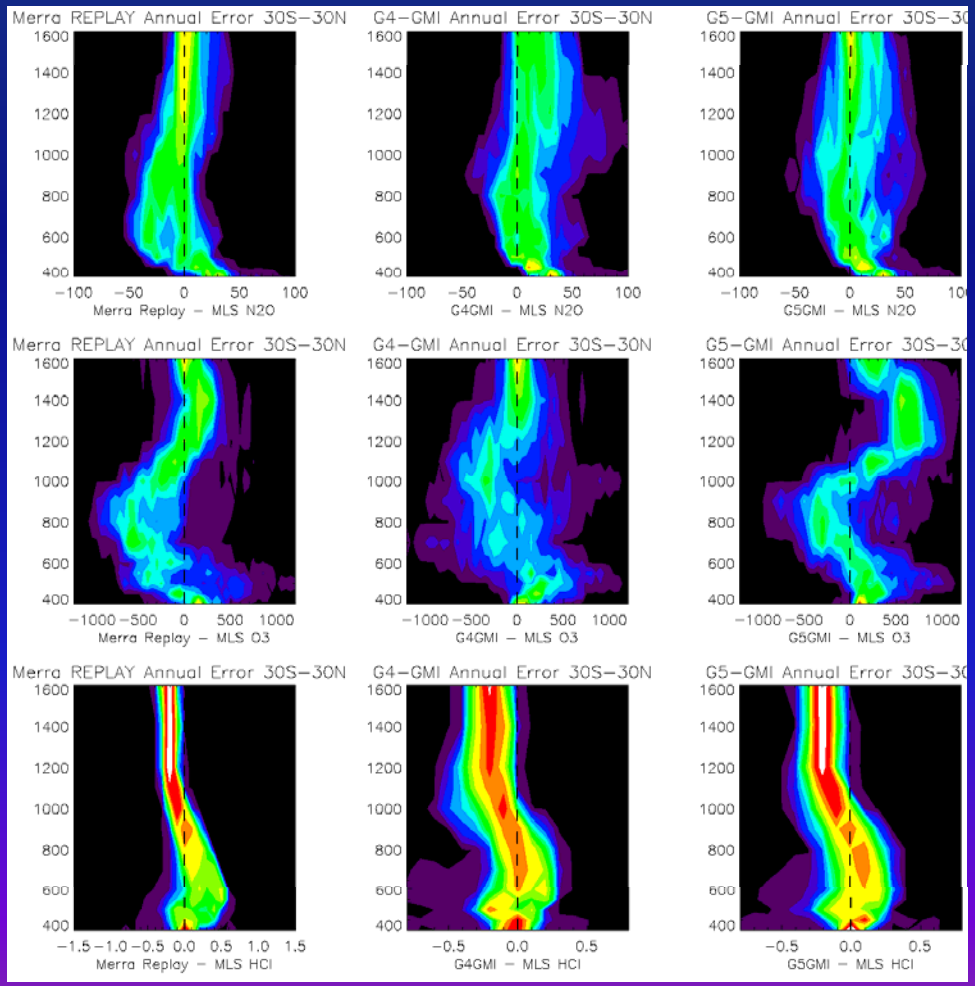
New Replay Run and GMI CTMs runs:
Tropical (30°S-30°N) Error Distributions 400-1600K, Model-MLS

Merra Replay **GMI-GEOS4** **GMI-GEOS5.1**

N2O

O3

HCL



Low bias in Replay tropical N2O suggests LS transport differences (Replay may have older air here).

Replay Upper Strat O3 is less biased than GEOS5.1. Lower O3 in the Replay Upper Strat may be responsible to lower O3 in the LS too.

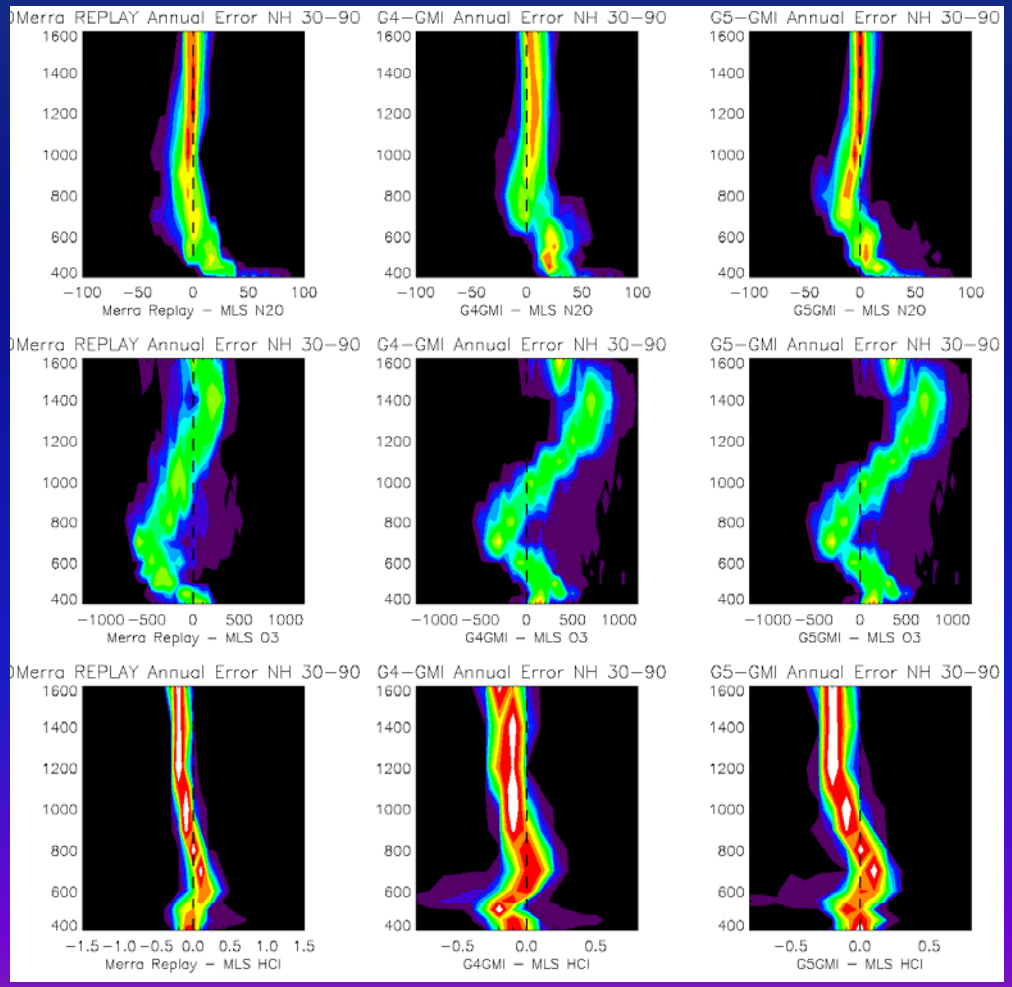
New Replay Run and GMI CTMs runs:
30-90ºN Error Distributions 400-1600K, Model-MLS

Merra Replay **GMI-GEOS4** **GMI-GEOS5.1**

N2O

O3

HCL



Replay N2O has overall smaller disagreements with MLS.

The shape of the O3 differences are similar for all models but the magnitude is smaller for Merra Replay.

O3 in the upper strat now agrees much better with MLS – due to improved temperatures.

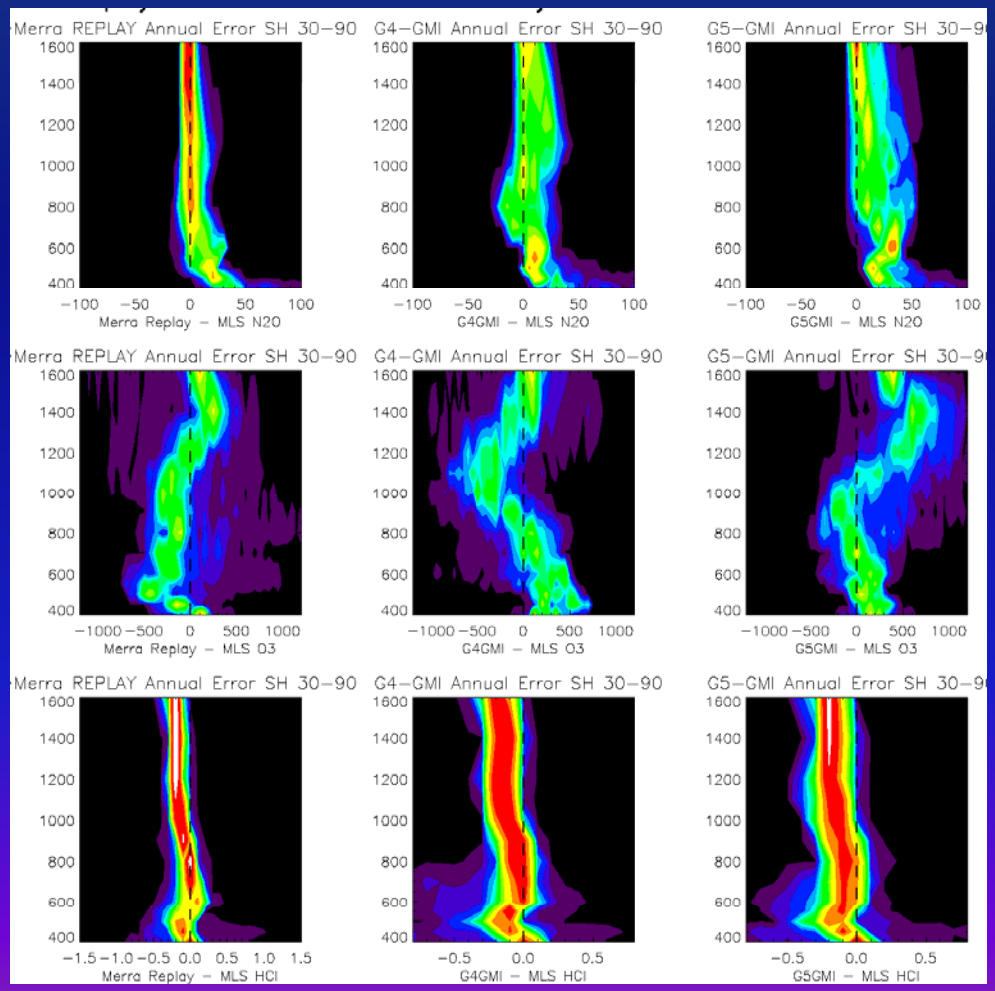
New Replay Run and GMI CTMs runs:
30-90ºS Error Distributions 400-1600K, Model-MLS

Merra Replay **GMI-GEOS4** **GMI-GEOS5.1**

N2O

O3

HCL



In the SH, Replay has smaller disagreements at all levels for N2O and O3 than either CTM simulation.

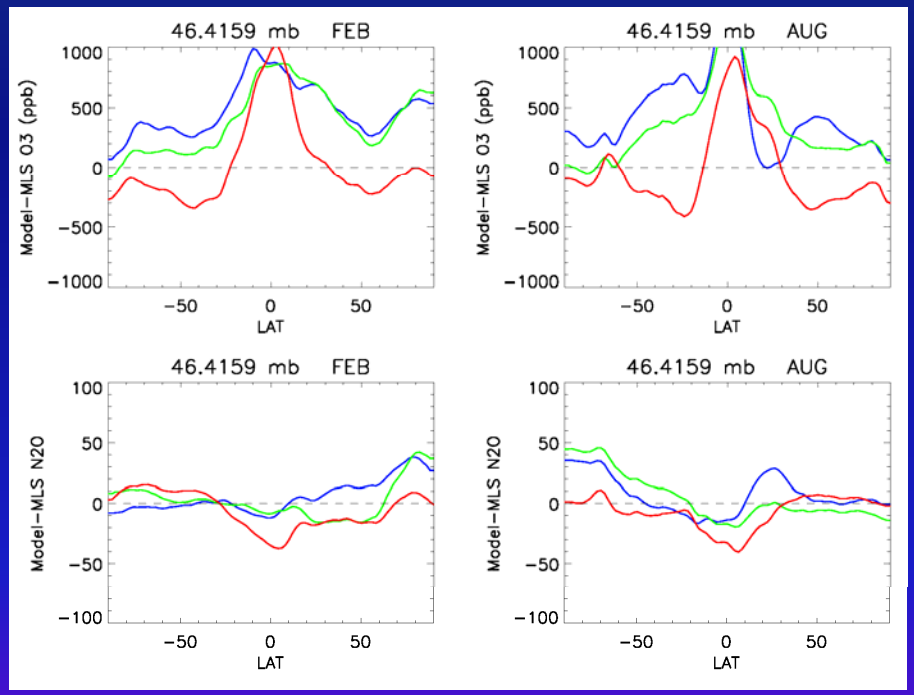
Overall, error distributions are narrower for Merra Replay. Less diffusive transport than in the CTM?

Example at 46 hPa: Models and MLS vs. Latitude
Tropical transport 'glitch' in all versions of assimilation?

GMI-GEOS4 **GMI-GEOS5** **Merra Replay**

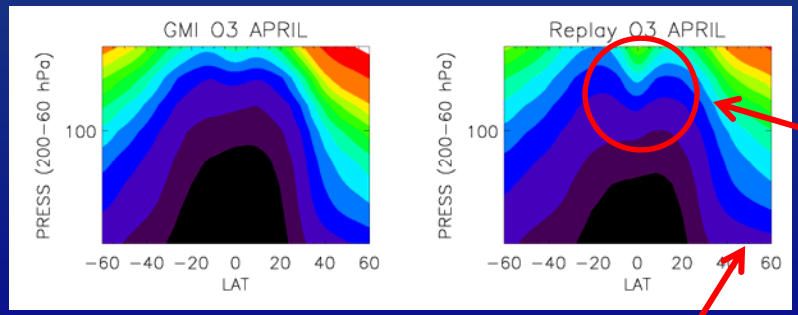
O3

N2O



All models show a similar shape as a function of latitude – maybe feature of the GEOS assimilation. This is true at many pressures – sometimes Replay agrees better, sometimes not.

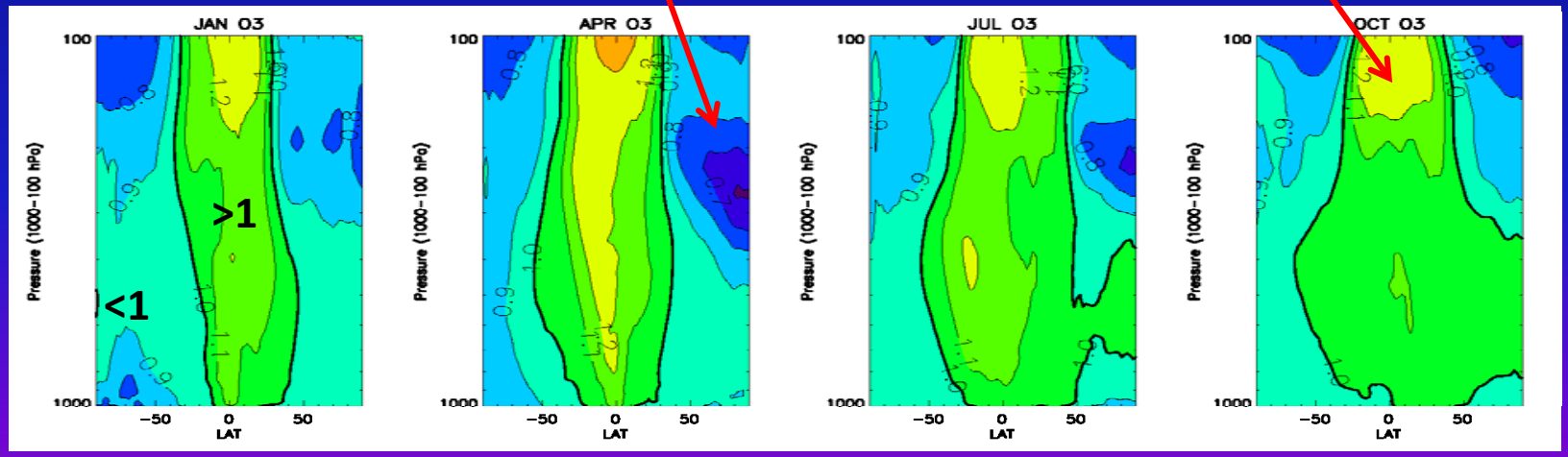
Zonal Monthly Mean UT/LS O3



MERRA tropical transport 'feature' creates high O3 here

Large differences near the tropical tropopause: Replay ~100 ppb higher than MLS O3.

This may be from lower O3 in Replay lower stratosphere (descent)



Ratio of Merra Replay/GMI-GEOS5.1 Monthly Mean O3

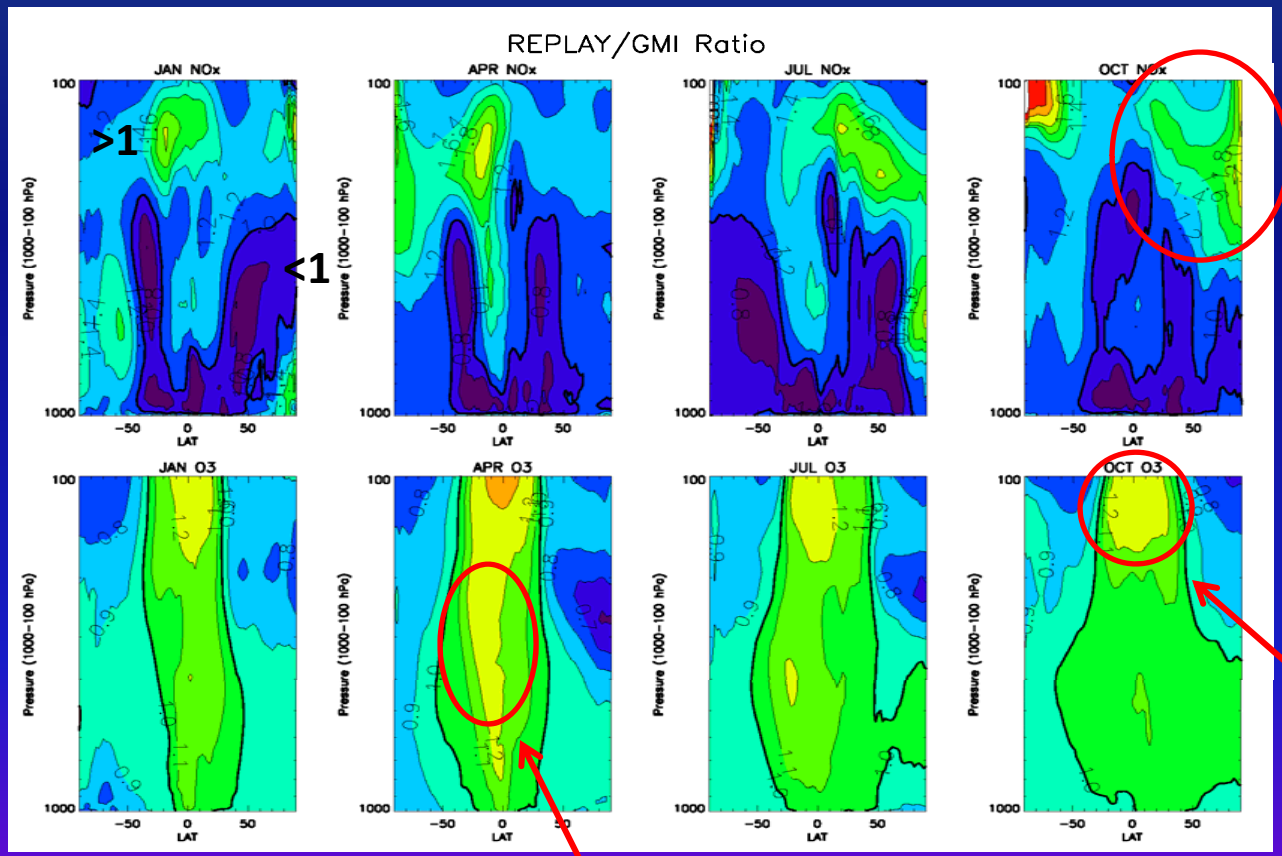
Replay reads in emissions for NO from lightning.

GMI lightning NO is based on GEOS5.1 meteorology and is calculated in the CTM.

Replay Lightning NO = 10 Tg/yr GMI Lightning NO = 6 Tg/yr

NO_x

O_3



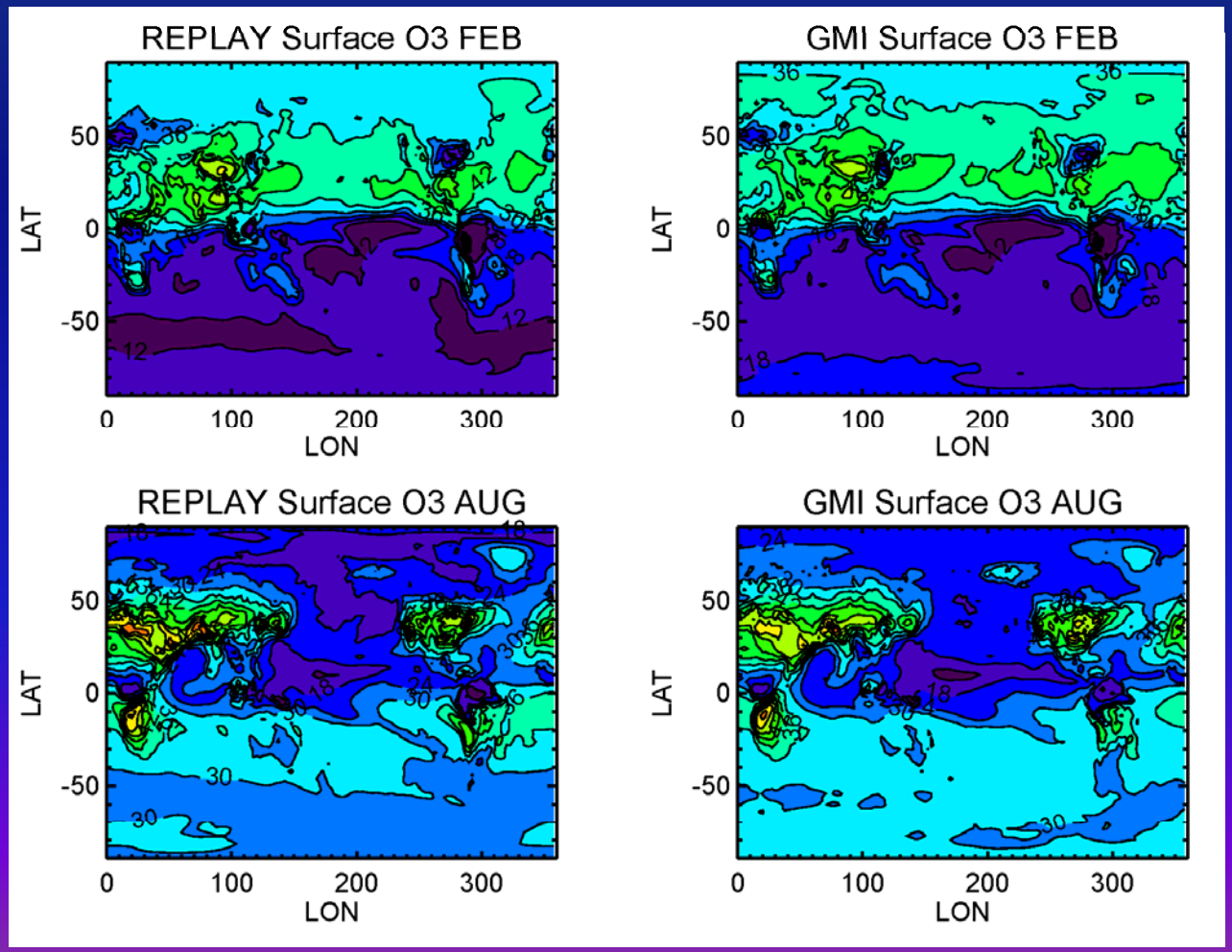
Higher Replay NOx in the high latitudes is consistent with higher NOx coming from the Replay LS

Higher O3 near 100 hPa is probably NOT due to lightning NO, but transport.

Higher Replay tropical tropospheric O3 is consistent with the region of higher lightning NO emissions.

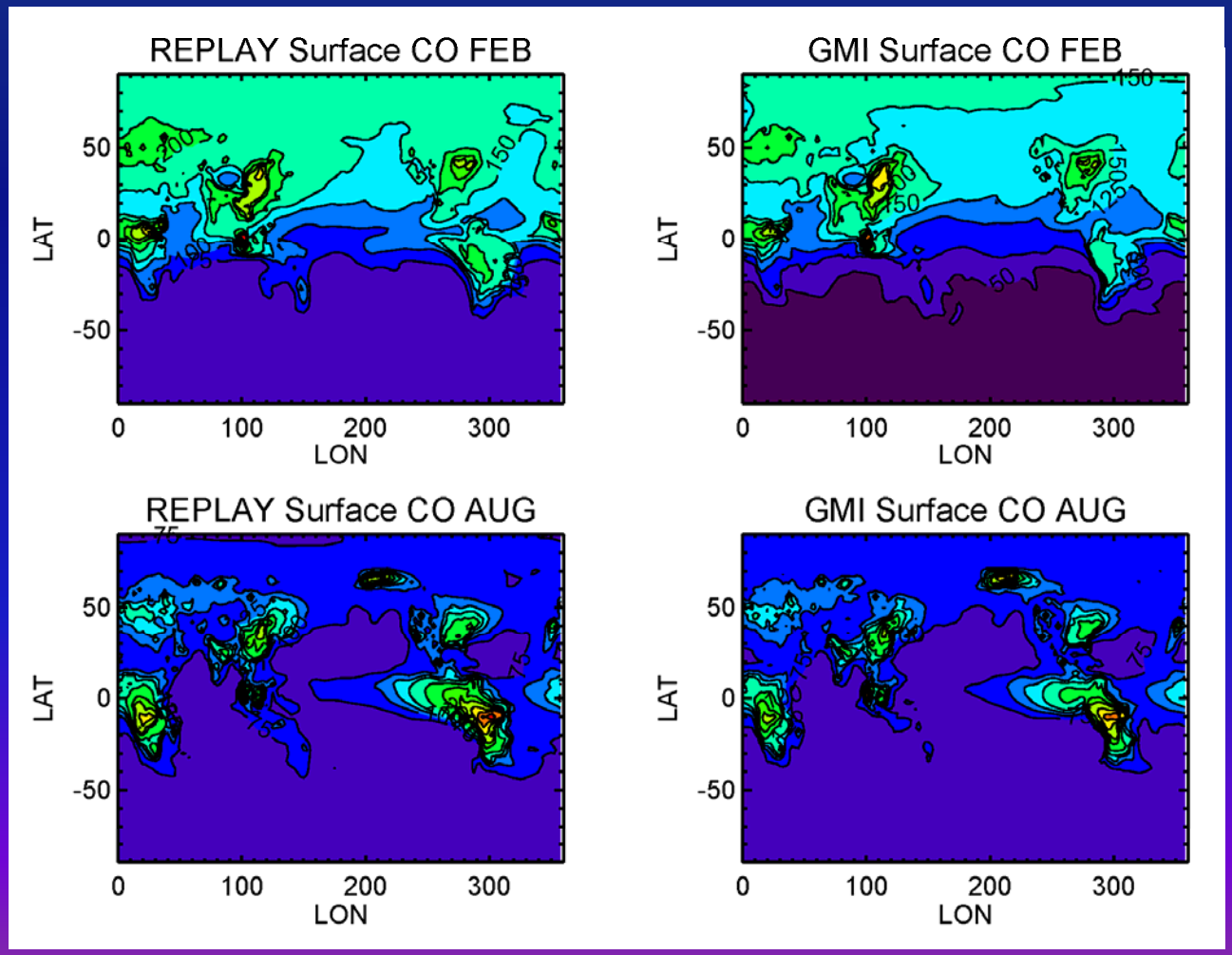
Surface O3: Very similar

GMI very slightly higher, consistent with greater strat O3 contribution



Surface CO: very similar emissions

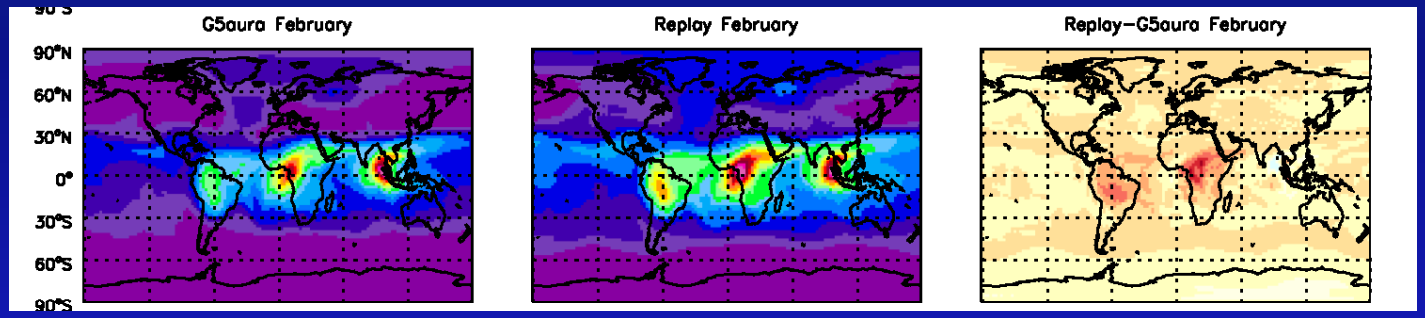
GMI slightly lower in NH winter, nearly identical in SH winter



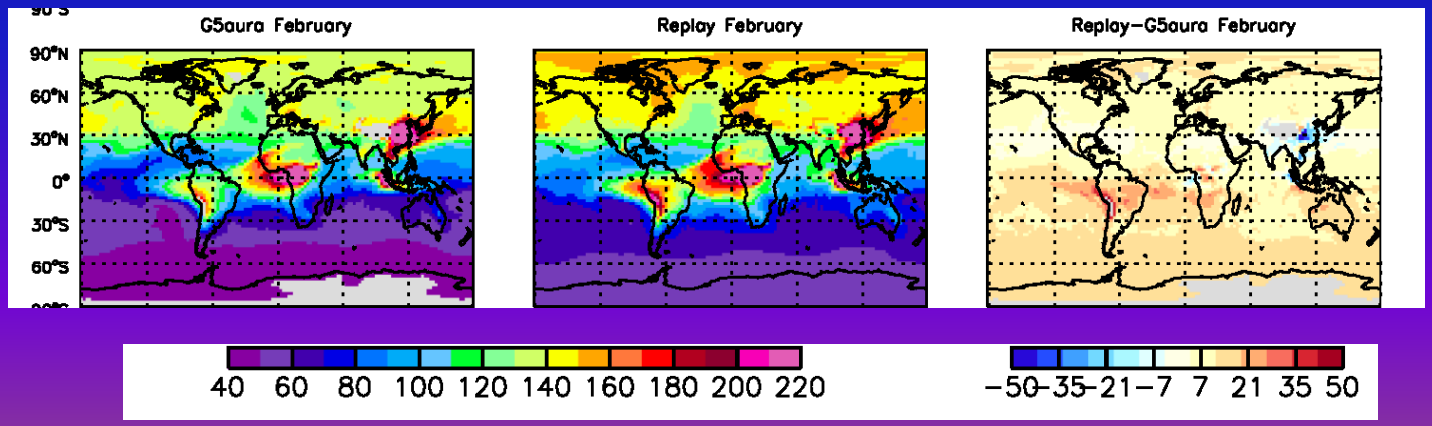
CO in the Upper and Lower Troposphere

Replay is slightly higher, especially over tropical source regions

200 hPa February CO



700 hPa February CO



Conclusions

MERRA Replay Stratospheric Transport Looks Good

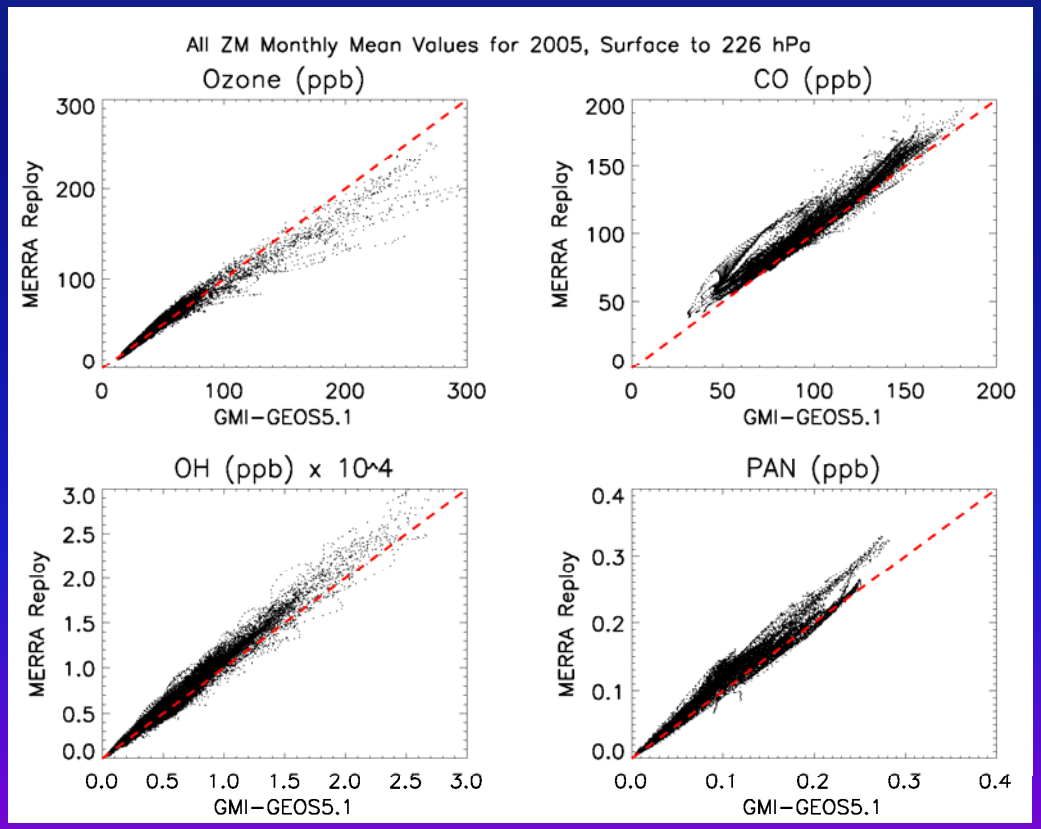
- O3 is overall less biased (upper strat temperature)
- N2O is better in some places
- Funny tropical transport 'feature', but other assimilation systems have this too (this is MERRA, not replay)
- Doug Allen will show good cross polar transport in Replay

No Showstoppers in the Troposphere

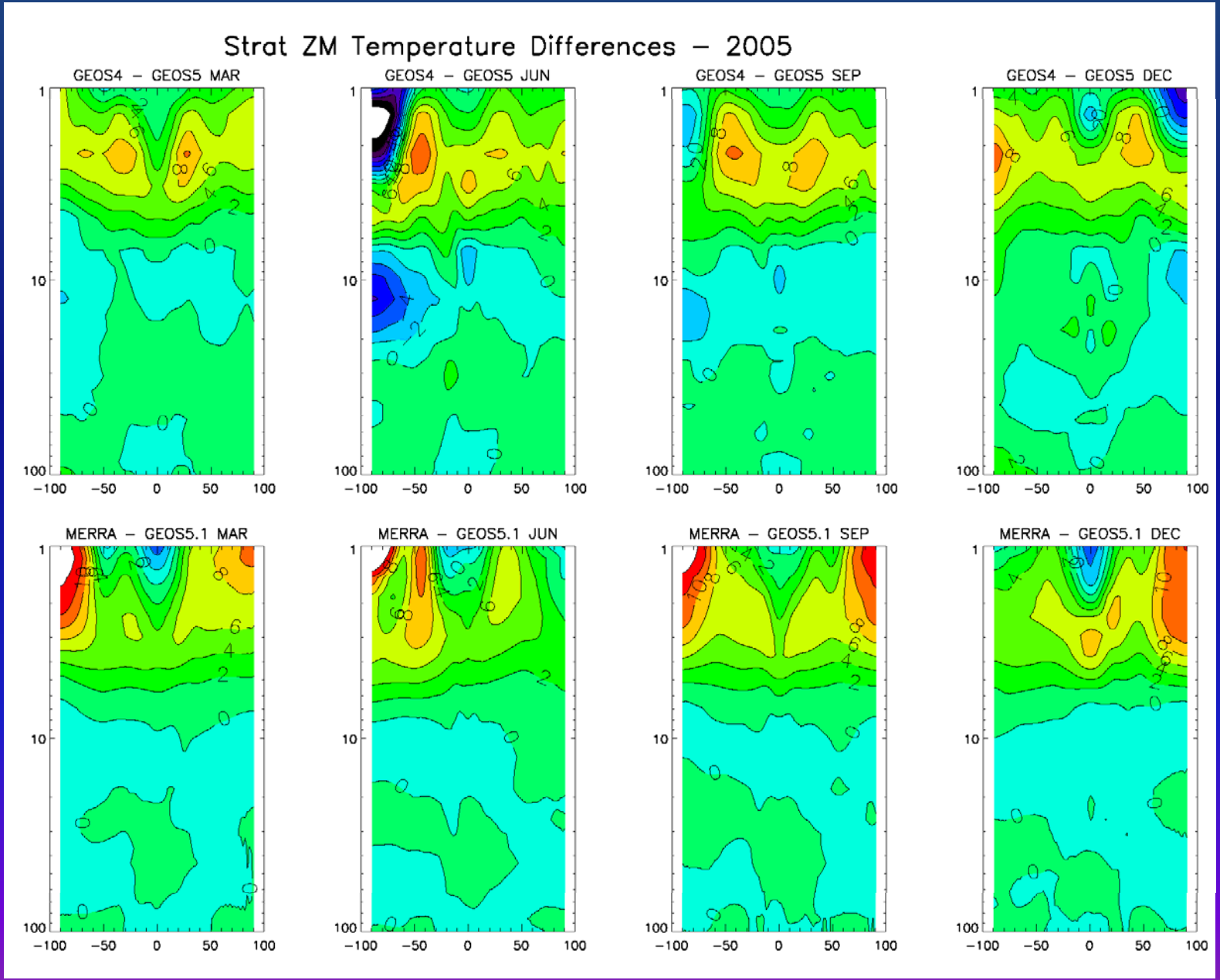
Right now, no online lightning NO param in Replay – stuck with old emissions and method (NO emissions not co-located with convection)

Replay has big advantage over the GMI CTM for GEOS5 simulations because no reprocessing or reformatting is needed!

Zonal Monthly Mean Tropospheric Composition 2005: O3, CO, OH, and PAN



r^2 is 0.94 to 0.98 for all.


Strat ZM Temperature Differences – 2005
GEOS4 – GEOS5 MAR
GEOS4 – GEOS5 JUN
GEOS4 – GEOS5 SEP
GEOS4 – GEOS5 DEC
MERRA – GEOS5.1 MAR
MERRA – GEOS5.1 JUN
MERRA – GEOS5.1 SEP
MERRA – GEOS5.1 DEC
1
10
100
−100
−50
0
50
100