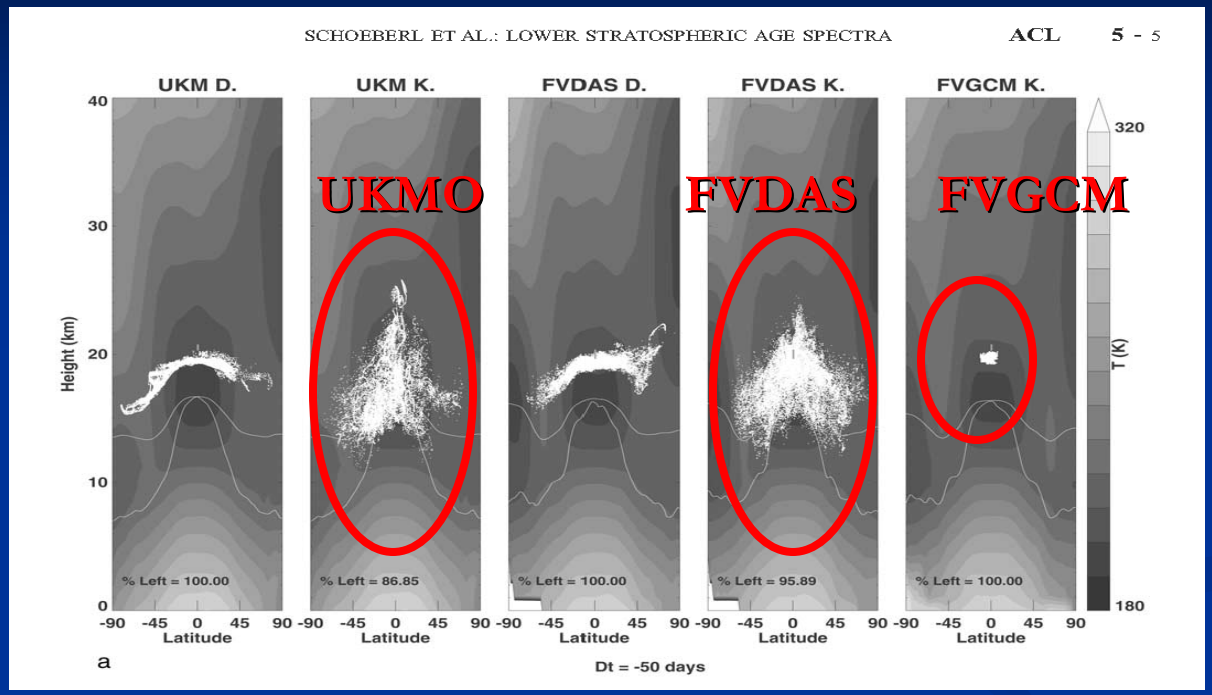
Do GEOS-4 forecast met fields have improved stratospheric circulation?

Susan Strahan & Steve Steenrod
Goddard Earth Science & Technology Center (GEST)
University of Maryland, Baltimore County
NASA/GSFC

Why are we looking at forecast products?



Mark Schoeberl's 2003 paper, using a trajectory model to compare various assimilated met products, nicely demonstrates the problem.

- In the bad old days, we used assimilated met products when we wanted simulations to match an observation period (e.g., an ER-2 mission or UARS data).
- There were lots of problems with simulations lasting more than a few weeks – noisiness in the DAS fields spoiled the descent in the vortex and the isolation of the tropics (e.g., Tan et al., 2004).

Why are we looking at forecast products?

Answer 1: Because there is (was?) a lot of room for improvement in GEOS-DAS stratospheric transport.

Answer 2: A number of recent studies using ECMWF forecast met product show improved age of air and/or STE, particularly compared to their old 3D-var products (e.g. ERA-40).

Meijer et al., GRL, 2004
Scheele et al., ACP, 2005
Bregman et al., ACP, 2006
van Noije et al., JGR, 2006
Monge-Sanz et al., GRL, 2007

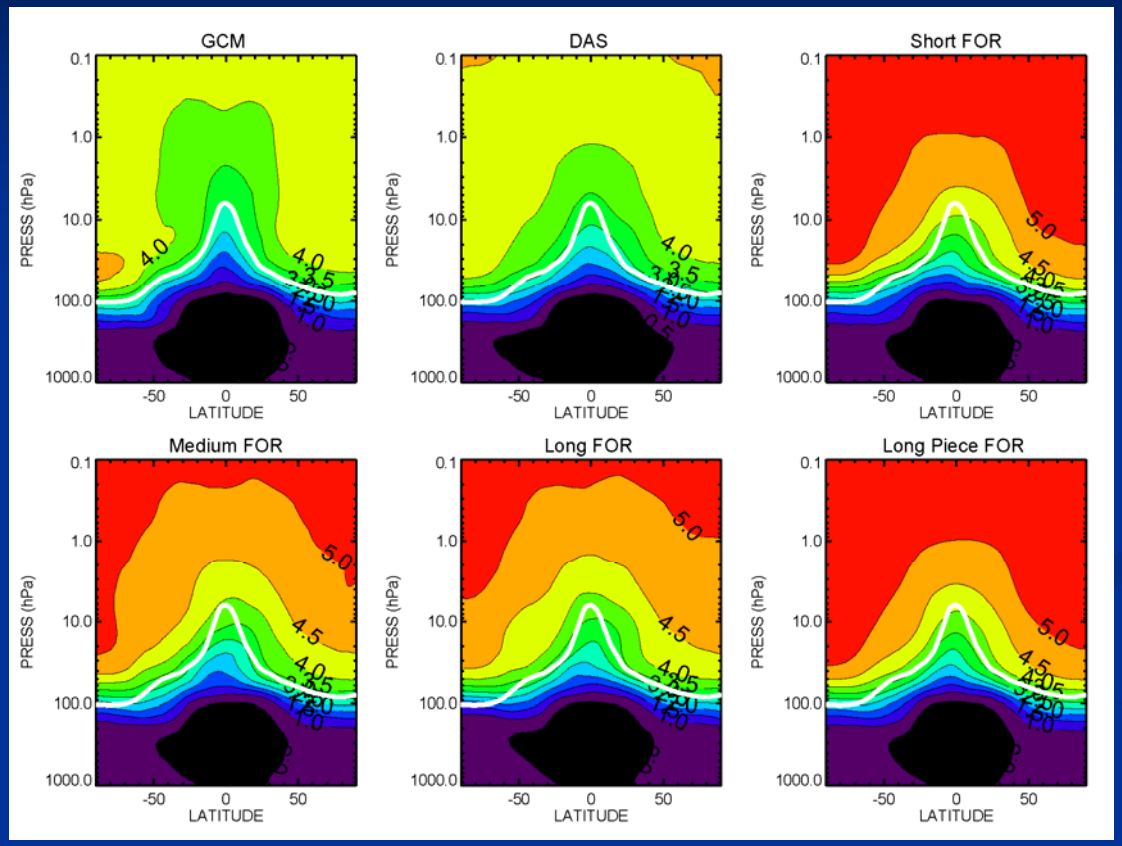
GMI-CTM experiments to evaluate stratospheric transport in forecast met products

Six CTM age of air experiments, 2x2.5 horizontal, 42 levels vertical:
Age tracer is released at the two lowest model levels for the first month of the simulation, 10°S-10°N. It is removed upon contact with the surface. The simulations are each run for 20 years.

1. GCM – The GEOS-4-GCM (the 'gold standard')
2. DAS – GEOS-4-DAS, time-averaged (over 3-hr intervals) – AURA2
3. Short Forecast – 12-hr forecast segment, 12-24Z post-analysis.
4. Medium Forecast - 12-hr forecast segment, 60-72Z post-analysis
5. Long Forecast – 12-hr forecast segment, 108-120Z post-analysis
6. Long Piece Forecast – 60-hr forecast segment, 12-72Z post-analysis

All non-GCM met fields used cover the period July 1, 2004 to June 30, 2005
Forecast products are also time-averaged, but over a 6-hr period.

GMI-CTM experiments: Mean Age in Six Experiments



There are two ways to make the stratosphere old:

1) slow down the circulation (e.g., have slower tropical ascent),

2) have a leaky tropical pipe that allows old air from high latitudes to re-enter and recirculate.

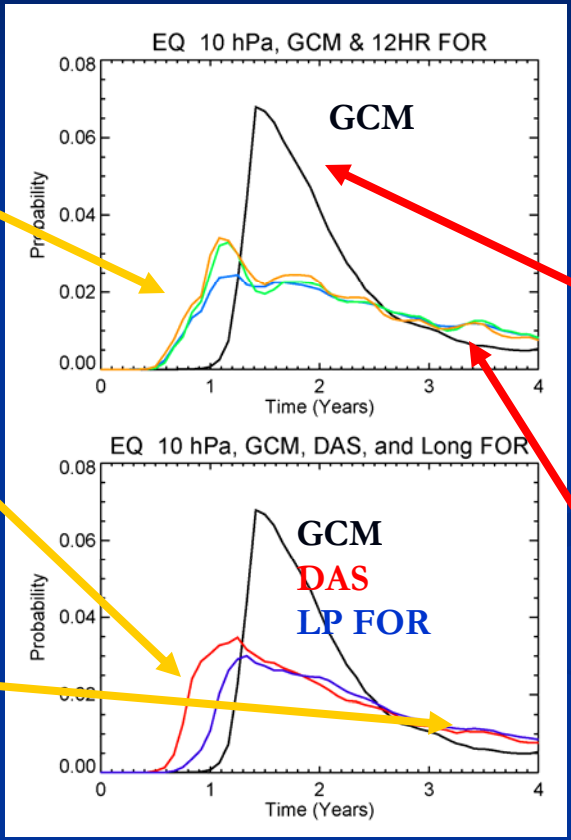
- The GCM has the youngest stratosphere. We also know it has lots of excellent transport characteristics, e.g., good transport barriers.
- The DAS looks more like the GCM than the forecasts do.
- All runs have similar mean age in the Antarctic vortex, so that doesn't help!

Age Spectra in the Tropics: Ascent Rate & Recirculation

12-hr forecasts: they arrive early and not suddenly.

The DAS has a more sudden arrival than the forecasts (less diffusive transport).

All non-GCM spectra have long tails, which means recirculation and older age. Only Long Piece FOR has a slower ascent rate.



It is the latest to arrive (slowest ascent).

It has the highest peak (least diffusive transport on its way here).

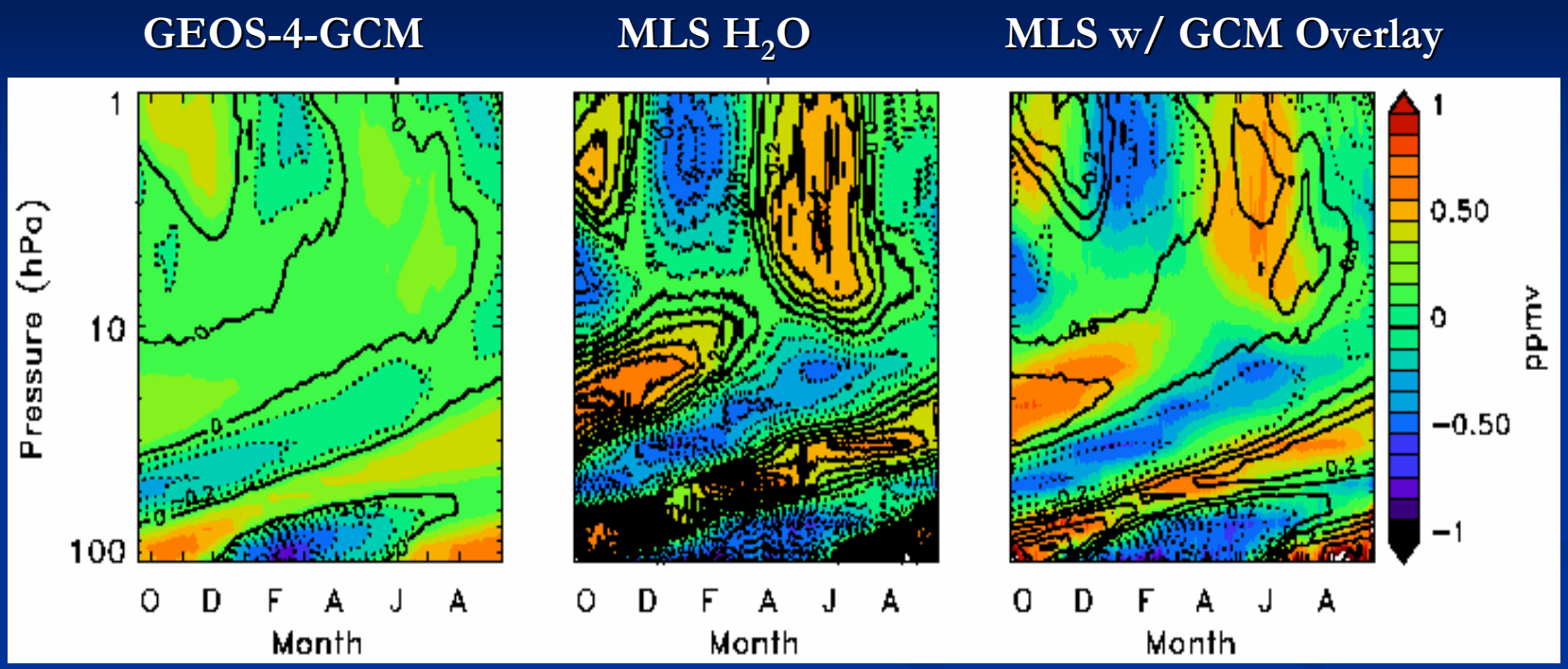
The modal peak arrives suddenly (i.e., transport is not diffusive).

The tail decreases faster than all others (less recirculation.)

The GCM tropical spectrum is in sharp contrast to the DAS and all forecasts.

How do we know the GCM is best? It's got a great H_2O-vapor tape recorder!

The 'tape recorder' seen by Aura MLS (Anne Douglass)

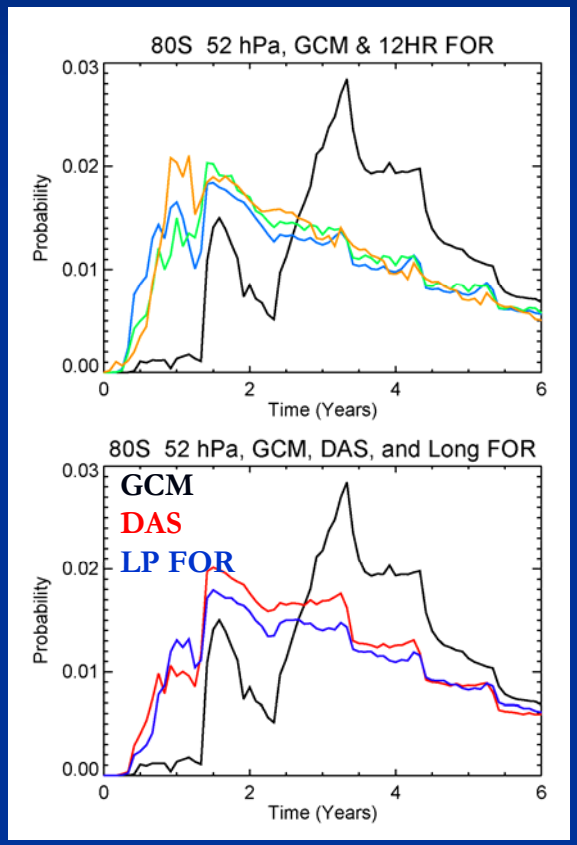


Qualitative comparison of model with obs shows realistic
rate of ascent and
decrease in the tape recorder amplitude with height.

Weak amplitude, correct phase of simulated semi-annual oscillation (10-1 hPa)

Conclusion: the GEOS4-GCM strength of the upwelling and isolation between 10 and 100 hPa match observations.

Age Spectra in the Antarctic Vortex: similar mean age, very different pathways of transport



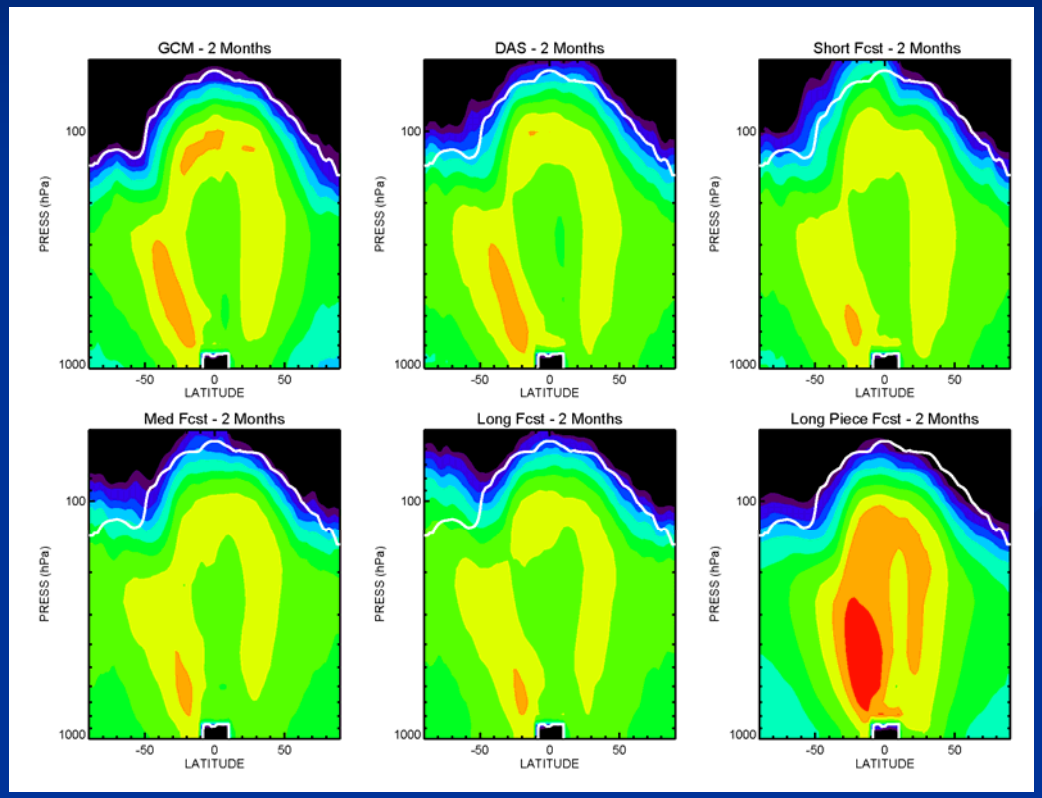
In the GCM (black), it takes air several years to find its way to the Antarctic lower stratosphere (peak at 3.3 years).

The 12-hr forecasts have a modal peak in the first year!

The DAS and Long Piece FOR do a little better.

The GCM and Long Piece FOR have the same mean age here (4.5 years). Only the GCM would be able to produce high Cly in its vortex because descent is an important transport pathway. All the forecasts (and the DAS) have too much young (low Cly) air entering the Antarctic high latitudes.

A pseudo trajectory expt: age tracer distributions (2 months)



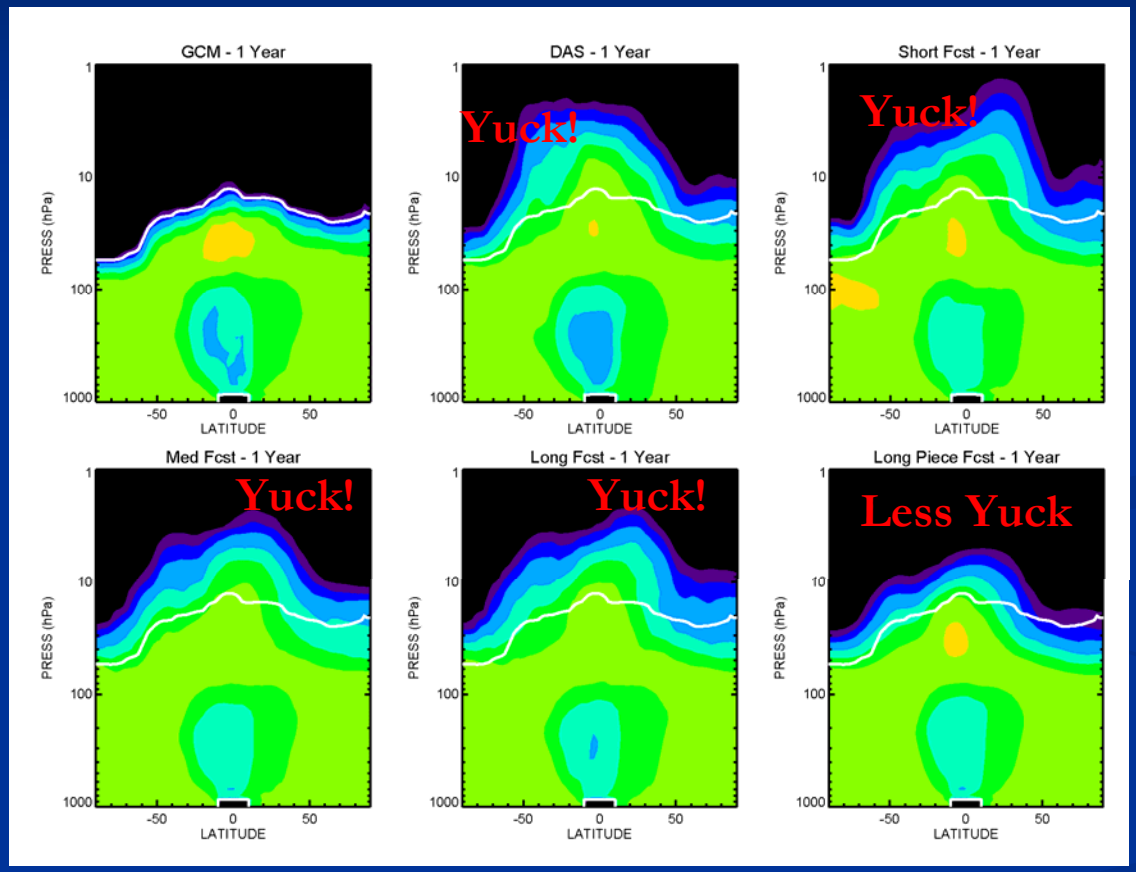
All age of air simulations start with a clean atmosphere.

The thick white line is the 0.001 age mixing ratio from the GCM after 2 months.

The medium and long forecasts transport gobs of air to the SH mid and high latitudes.

Only the Long Piece forecast does NOT show excessive vertical transport in the tropics.

Age Tracer Distributions after 1 year



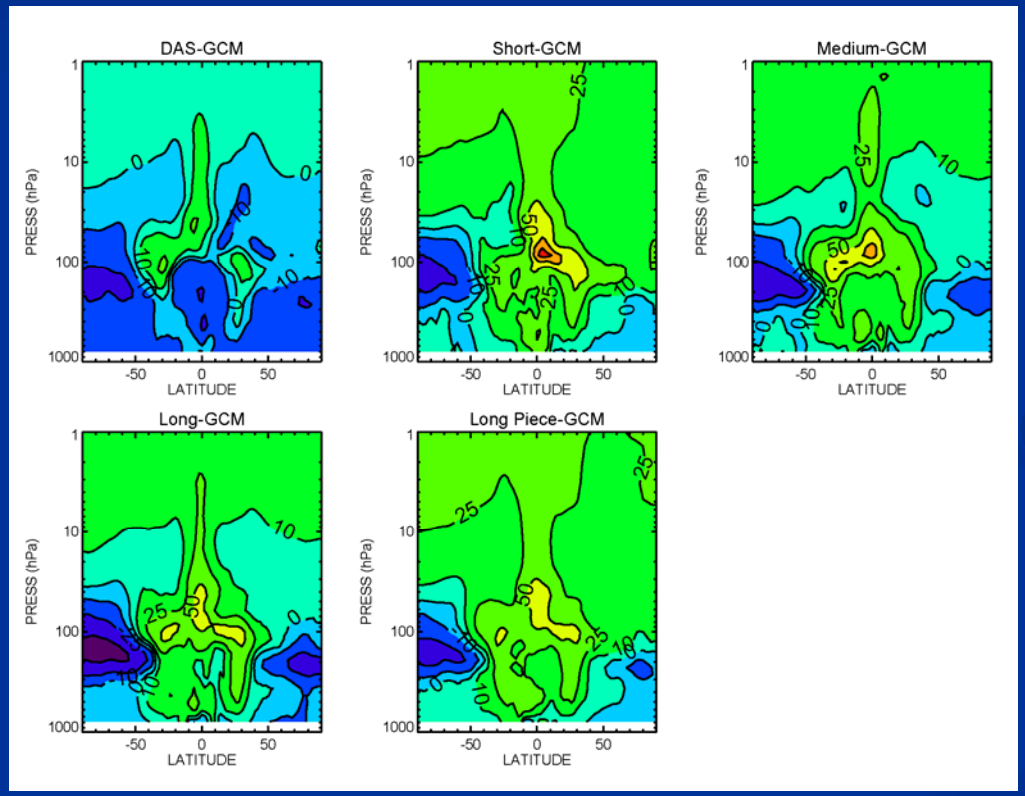
The time-averaged DAS may have slightly better vortex isolation, and its tropical pulse has diffused less, but after 1 year it looks about as bad as the 12-hr forecasts.

The Long Piece forecast has improved circulation compared to the DAS.

I wouldn't want to use anything but the GCM for long simulations.

Difference in mean age compared to the GCM Expt (%)

The trouble spots: tropical ascent and poleward horizontal transport in the LS.



The DAS shows the smallest differences compared to the GCM.

Jolting the CTM with discontinuous met fields (i.e., pieced forecasts)…

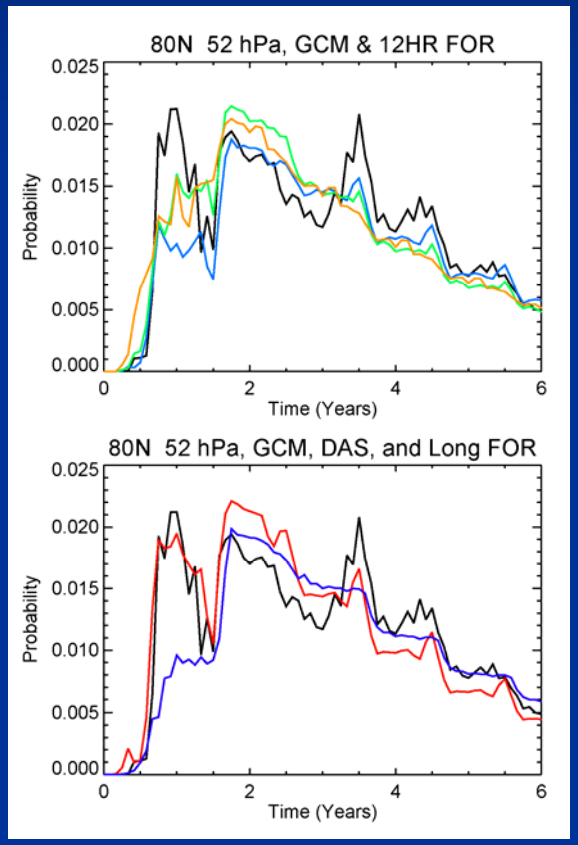
- causes mixing
- ruins transport barriers
- allows recirculation into the tropical pipe, making the stratosphere old.

GMI-CTM experiments: Conclusions

Time-averaging (TA) of DAS fields is a HUGE improvement over the old instantaneous fields. Age of air with TA-DAS products is much closer to the GCM age than in the bad old days (see Pawson et al., accepted JGR, 2007).

In the stratosphere, forecast met products are NOT an improvement over time-averaged DAS met fields.

Using long piece forecasts (e.g. 60 hrs) rather than 12-hr segments results in 5x fewer jolts to transported species. The Long Piece forecast had slower tropical ascent than the 12-hr forecasts or the TA-DAS, but recirculation (i.e. poor barriers) is still a big problem. Frequent jolts = bad circulation.

Forecast fields take 10X the effort to process (one 5-day forecast every 12 hours). If they are worth using, it's up to the tropospheric community to demonstrate this.

Age Spectra in the Arctic Vortex: it's OK to be young