SPARC DAWG Workshop, October 2006

# On the use of CCMVal diagnostics for validating DA products

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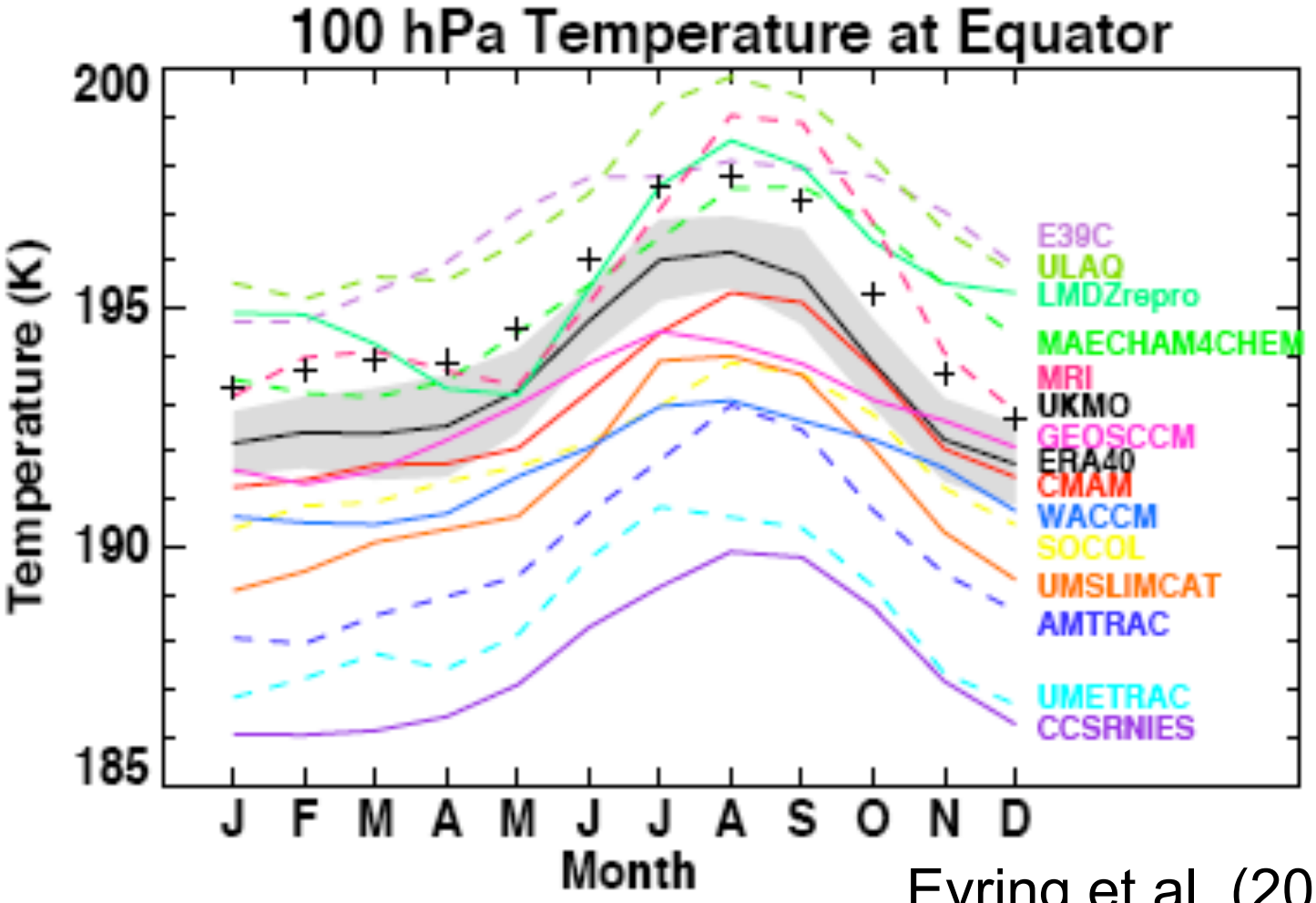
- SPARC CCMVal: process-oriented validation of Chemistry-Climate Models (CCMs)
- Concept is to identify robust diagnostic relationships between physical quantities, which are:
  - Important for ozone and climate
  - Understandable in terms of an underlying process
  - Well constrained by observations

- Diagnostics are divided into four categories:
  - Dynamics, transport, chemistry, radiation
- First workshop (Grainau 2003) led to initial table, published in Eyring et al. (2005 BAMS)
- Second workshop (Boulder 2005) refined the table (see Web site)
- Initial efforts have been focused around the 2006 WMO Ozone Assessment
  - Eyring et al. (2006 JGR)

- In some cases, CCMVal is looking to the SPARC DAWG to provide some understanding of which analyses it should trust for its validation




Eyring et al. (2006 JGR)

- But in other cases, the CCMVal validation data sets could be useful for validation of stratospheric analyses
- This will not be generally true for the dynamics diagnostics, but it will be so for the other categories — and especially for transport

- Examples of transport diagnostics

**TABLE 2. List of core processes to validate CCMs with a focus on their ability to model future stratospheric ozone.**

| Process | Diagnostic[a] | Variables | Data | References[b] |
|---|---|---|---|---|
| **Stratospheric transport** | | | | |
| **Subtropical and polar mixing barriers** | PDFs of long-lived tracers | $N_2O$, $CH_4$, CFC-11, etc.; potential vorticity (PV) | Satellite and in situ (aircraft, balloons) chemical measurements and meteorological analyses[c] | Strahan and Douglass (2004) |
| | Latitudinal gradients of long-lived tracers | | | Sankey and Shepherd (2003) |
| | Correlations of long-lived tracers | | | Sankey and Shepherd (2003) |
| | Phase and amplitude of tropical $CO_2$ or $H_2O$ annual cycle in lower stratosphere (tape recorder) | $CO_2$, $H_2O$ or idealized annually repeating tracer | Satellite and in situ measurements | Hall et al. (1999), Mote et al. (1996) |
| | Annual cycle of streamer frequency | Daily PV (maybe long-lived tracers) | Meteorological analyses[c] satellite measurements | Eyring et al. (2003), Waugh (1996), Waugh et al. (1997) |
| **Meridional circulation** | Mean age | Conserved tracer with linearly increasing concentration, $SF_6$ or $CO_2$ | In situ measurements | Hall et al. (1999), Waugh and Hall (2002) |
| | Correlation of interannual anomalies of total ozone and Planetary wave flux | Total ozone and heat flux at 100 hPa, zonal and monthly means | Satellite measurements, meteorological analyses[c] | Randel et al. (2002), Weber et al. (2003) |

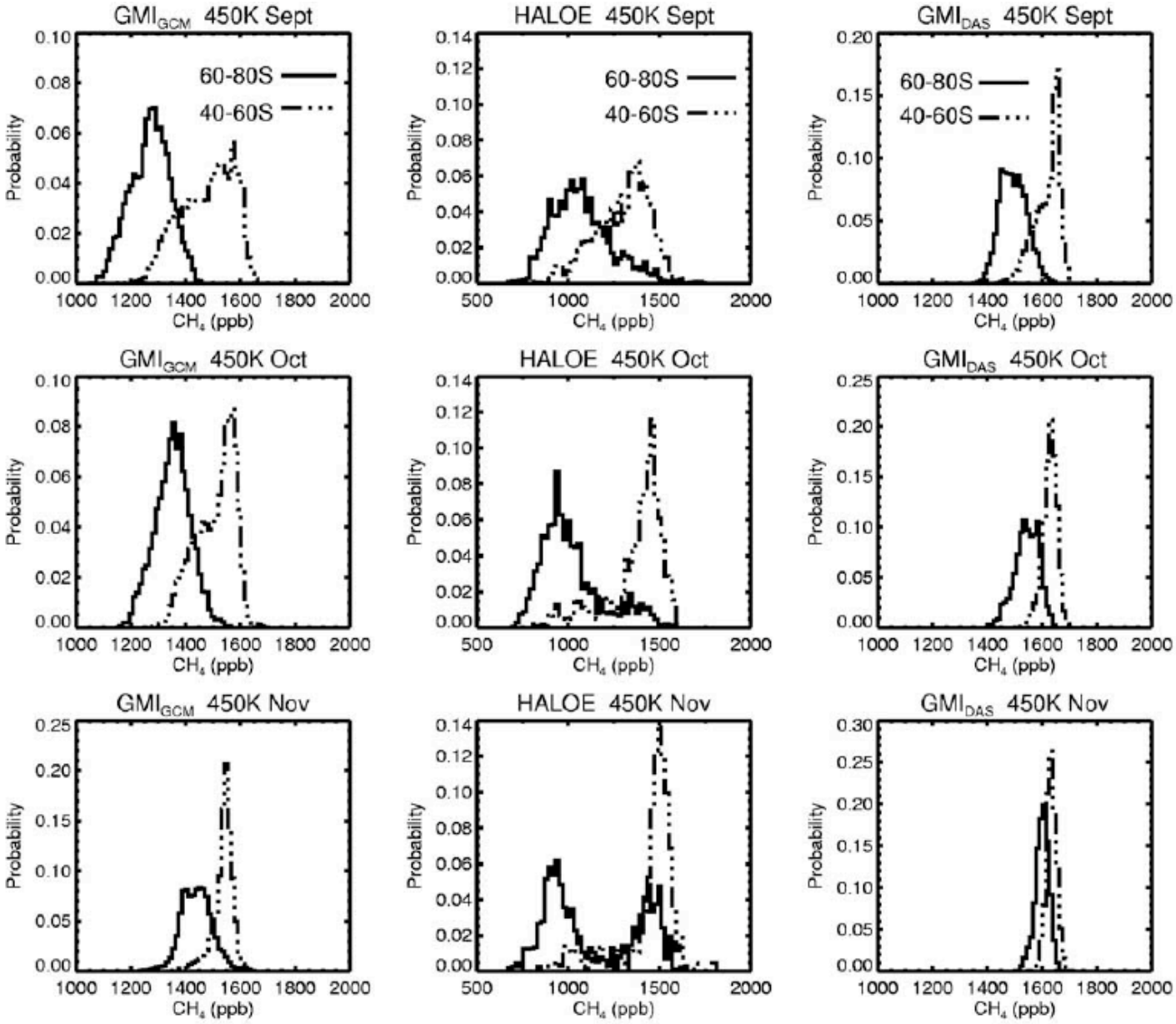
Eyring et al. (2005 BAMS)

- The current on-line table; for each diagnostic there will be links to a “cookbook” and a data source

| Process | Diagnostic* (Click for Description) | Variables | Contact | Ranking |
|---|---|---|---|---|
| **Subtropical and polar mixing barriers** | PDFs of long-lived tracers | $N_2O$, $CH_4$, CFC-11, etc.; Potential Vorticity (PV) | Susan Strahan | C |
| | Latitudinal gradients of long-lived tracers | | Veronika Eyring and Ted Shepherd | C |
| | Correlations of long-lived tracers | | Ted Shepherd | I |
| | Phase and amplitude of subtropical $CO_2$ (or $H_2O$) annual cycle in lower stratosphere (tape recorder) | $CO_2$, $H_2O$ or idealized annually repeating tracer | Neal Butchart and Darryn Waugh | C |
| **Meridional circulation** | Mean age | Conserved tracer with linearly increasing concentration, $SF_6$ or $CO_2$ | Darryn Waugh | C |
| | Correlation of interannual anomalies of total O3 and PW flux | Total ozone and heat flux at 100 hPa, zonal and monthly means | Paul Newman | C |
| | Vertical propagation of tracer isopleths | $H_2O$ or $CO_2$ or idealized annually repeating tracer (tropics), $CH_4$ or $N_2O$ (polar) | | U |
| **UTLS transport** | Vertical gradients of, and correlations between, chemical species in the extratropical UTLS | $CO_2$, $SF_6$, $H_2O$, CO, $O_3$, HCl | Peter Hoor and Laura Pan | I |
| | TTL structure and transport | Temperature, Ozone, LW Heating rates, SW heating rates | Andrew Gettelman | I |

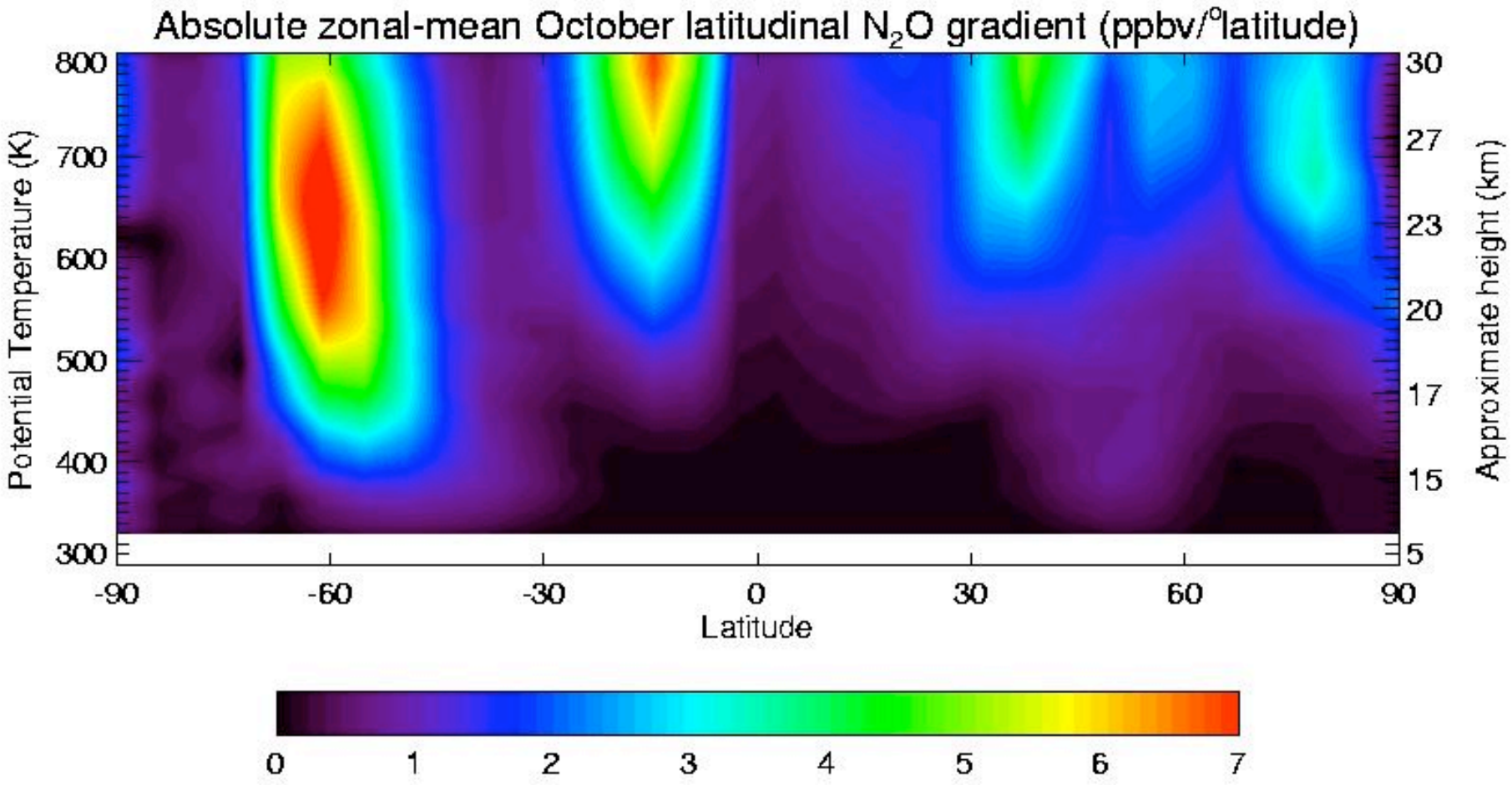
http://www.pa.op.dlr.de/CCMVal/CCMVal_EvaluationTable.html

- Evolution of $CH_4$ PDFs on 450 K surface in SH spring



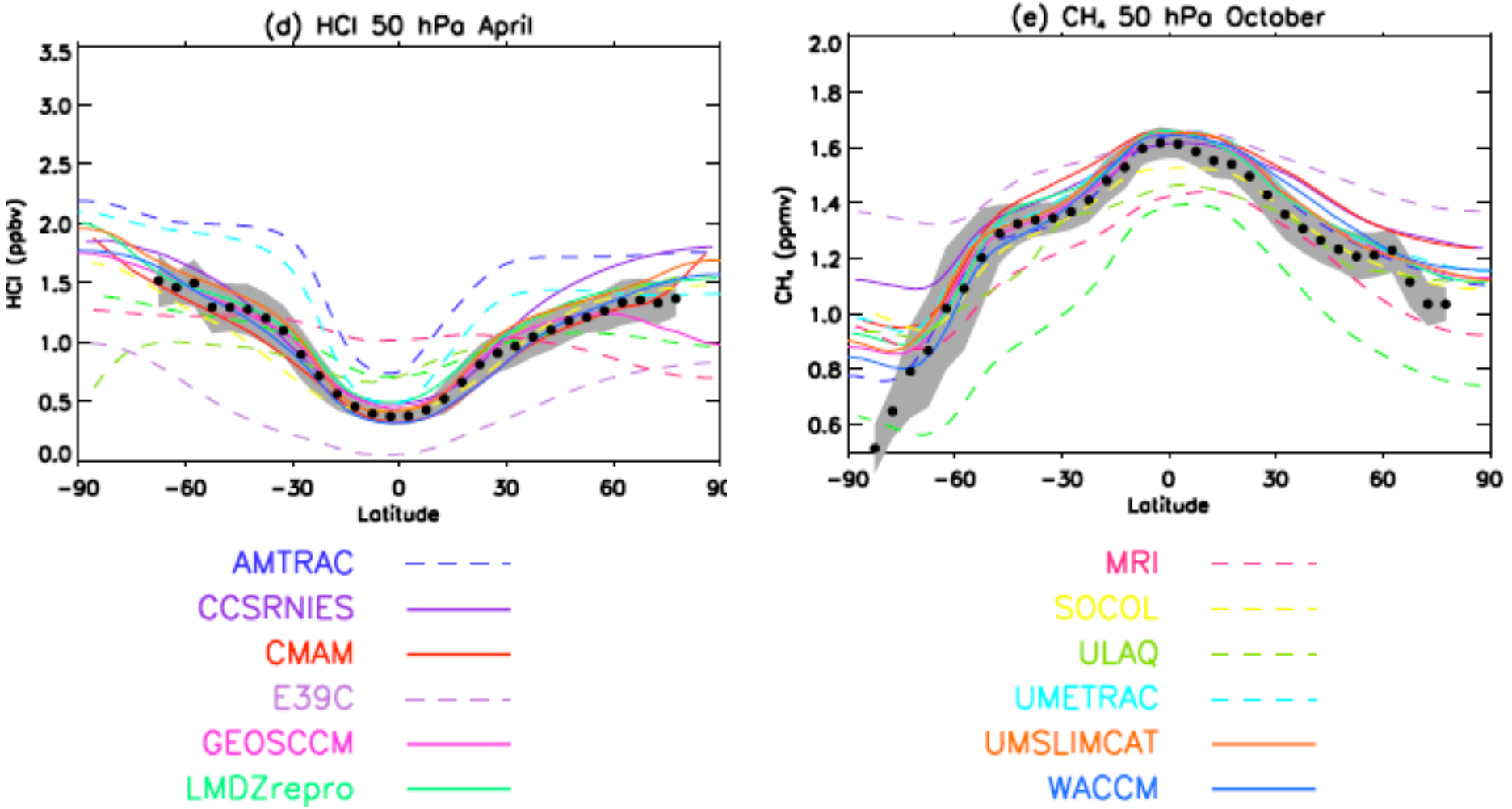

From Strahan & Douglass (2004 JGR)

- Latitudinal gradient of $N_2O$ in CMAM



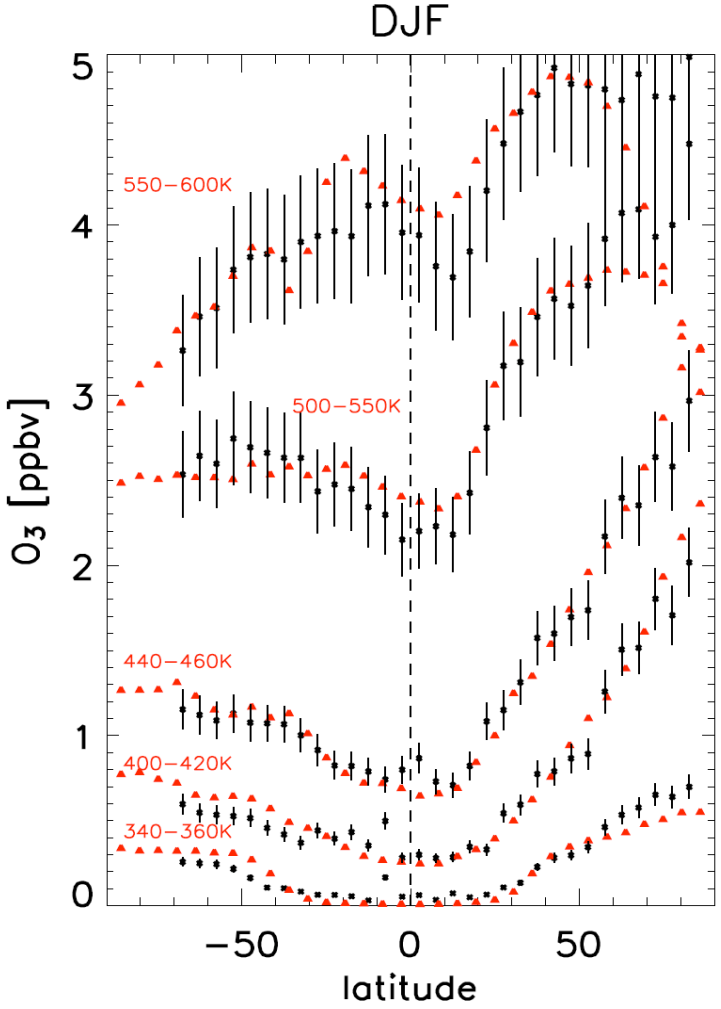

From Sankey & Shepherd (2003 JGR)

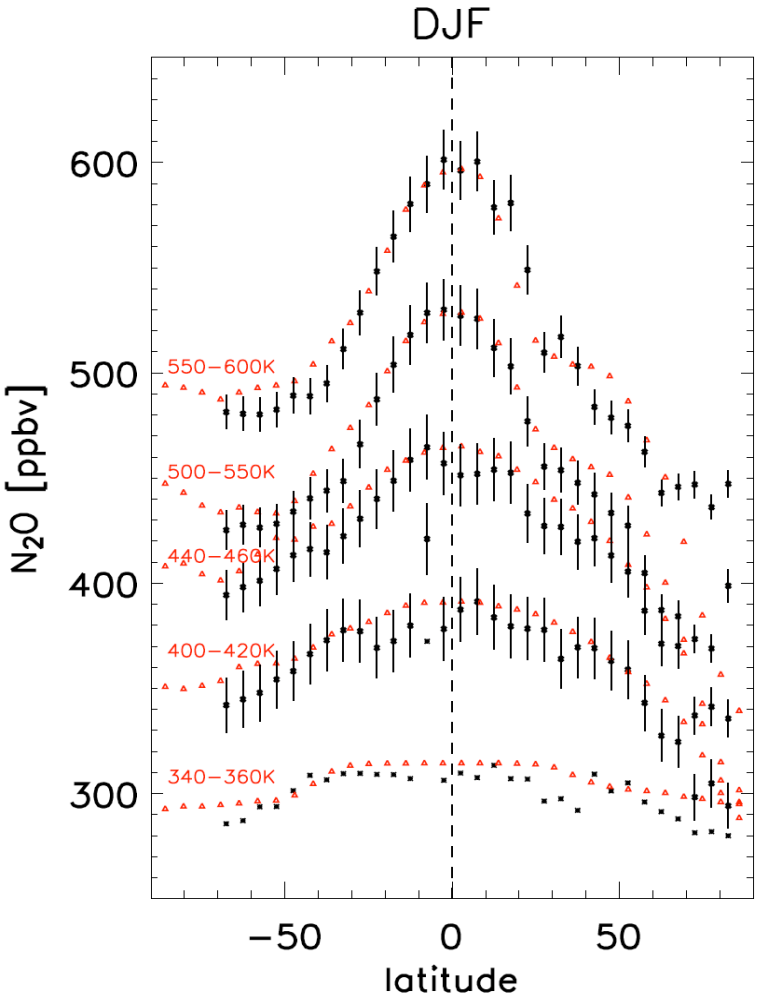
- Latitudinal profiles of HCl and $CH_4$ at 50 hPa, vs HALOE




From Eyring et al. (2006 JGR)

- The Canadian Middle Atmosphere Model (CMAM, red) is here compared with the ACE-FTS on SciSat-1 (black)

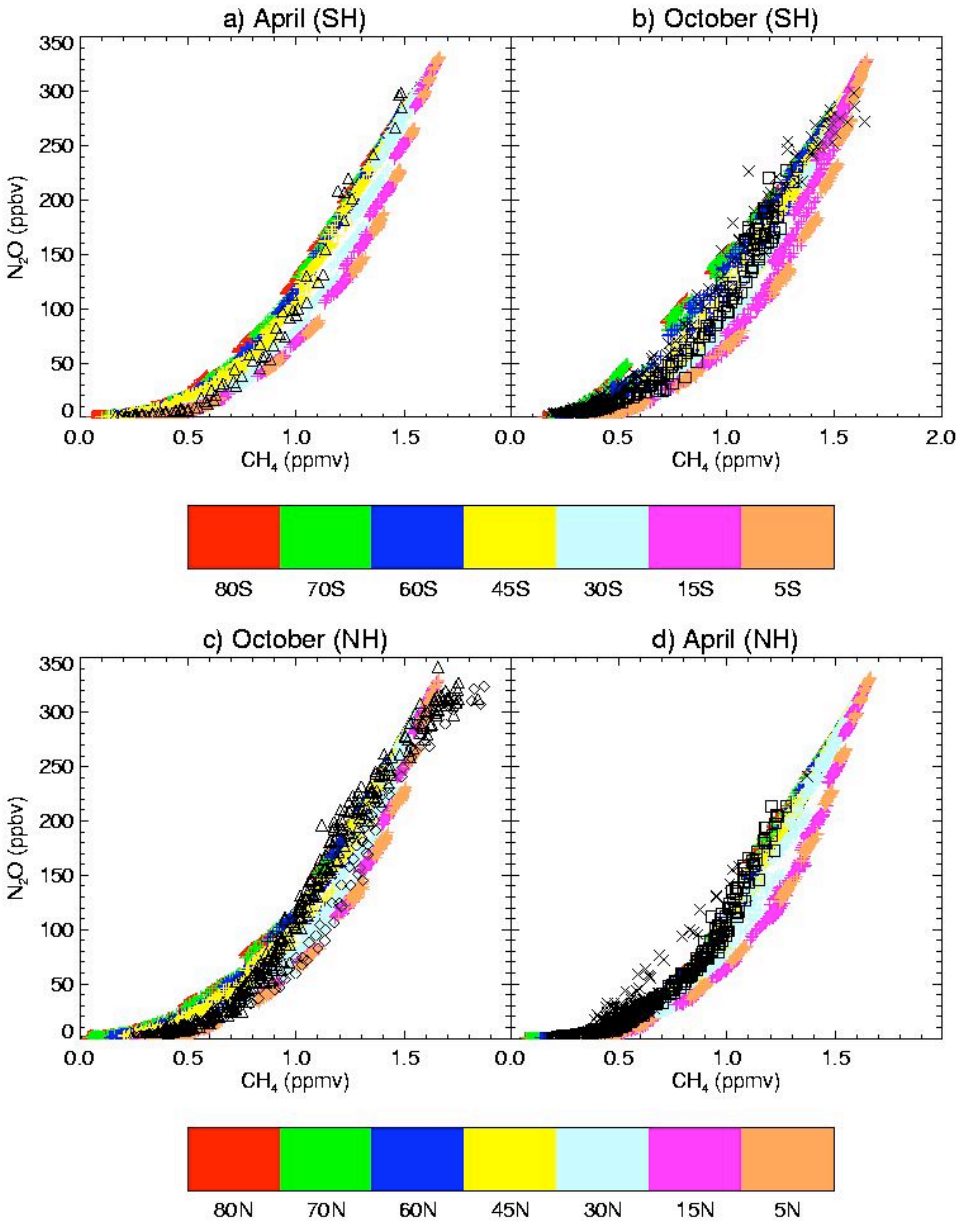



**N.B.** $N_2O$ is offset by 80 ppbv for each level

Figure courtesy of Michaela Hegglin, University of Toronto

- Correlation between $CH_4$ and $N_2O$: CMAM and ATMOS




Mixing establishes a compact correlation between long-lived chemical species

There is structure associated with mixing barriers

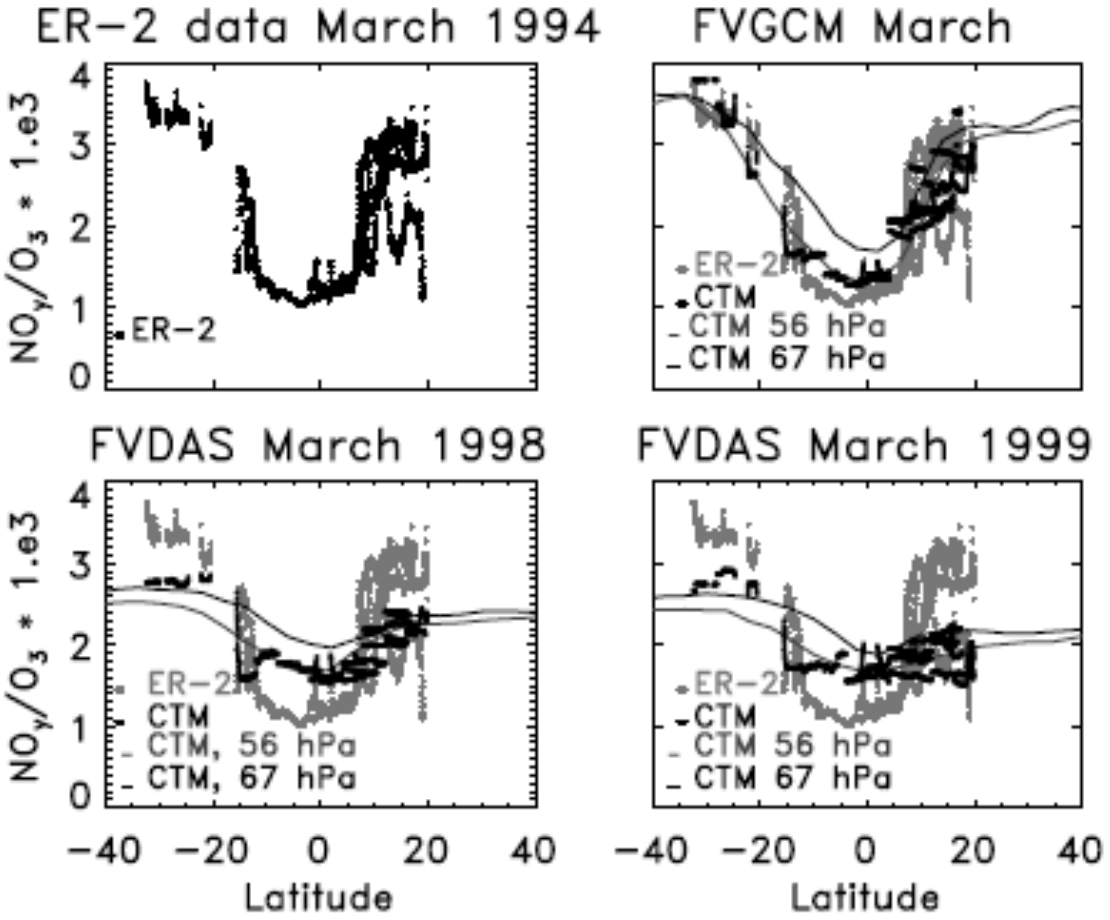
Single profiles give an "instant" climatology

CMAM agrees well with ATMOS measurements

Diamonds: Tropics; Squares: Midlatitudes
Triangles: High latitudes
Crosses: Vortex

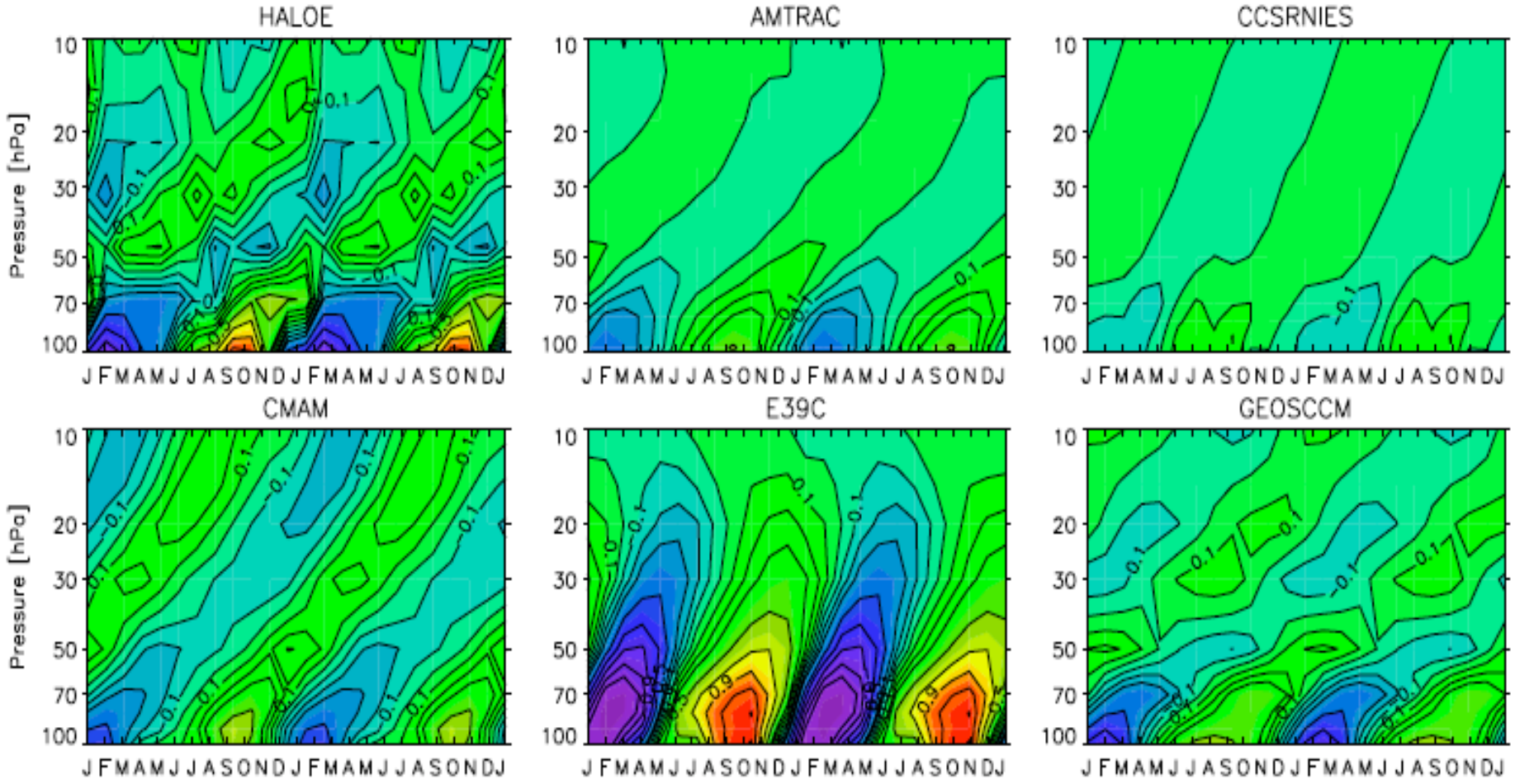
Sankey & Shepherd (JGR 2003)

- Another example: $NO_y/O_3$ ratios at ER-2 altitudes (~20 km)
  - The DAS-driven CTM destroys the strong horizontal gradients




From Douglass et al. (2003 JGR)

- The tropical tape recorder in HALOE and in CCMs

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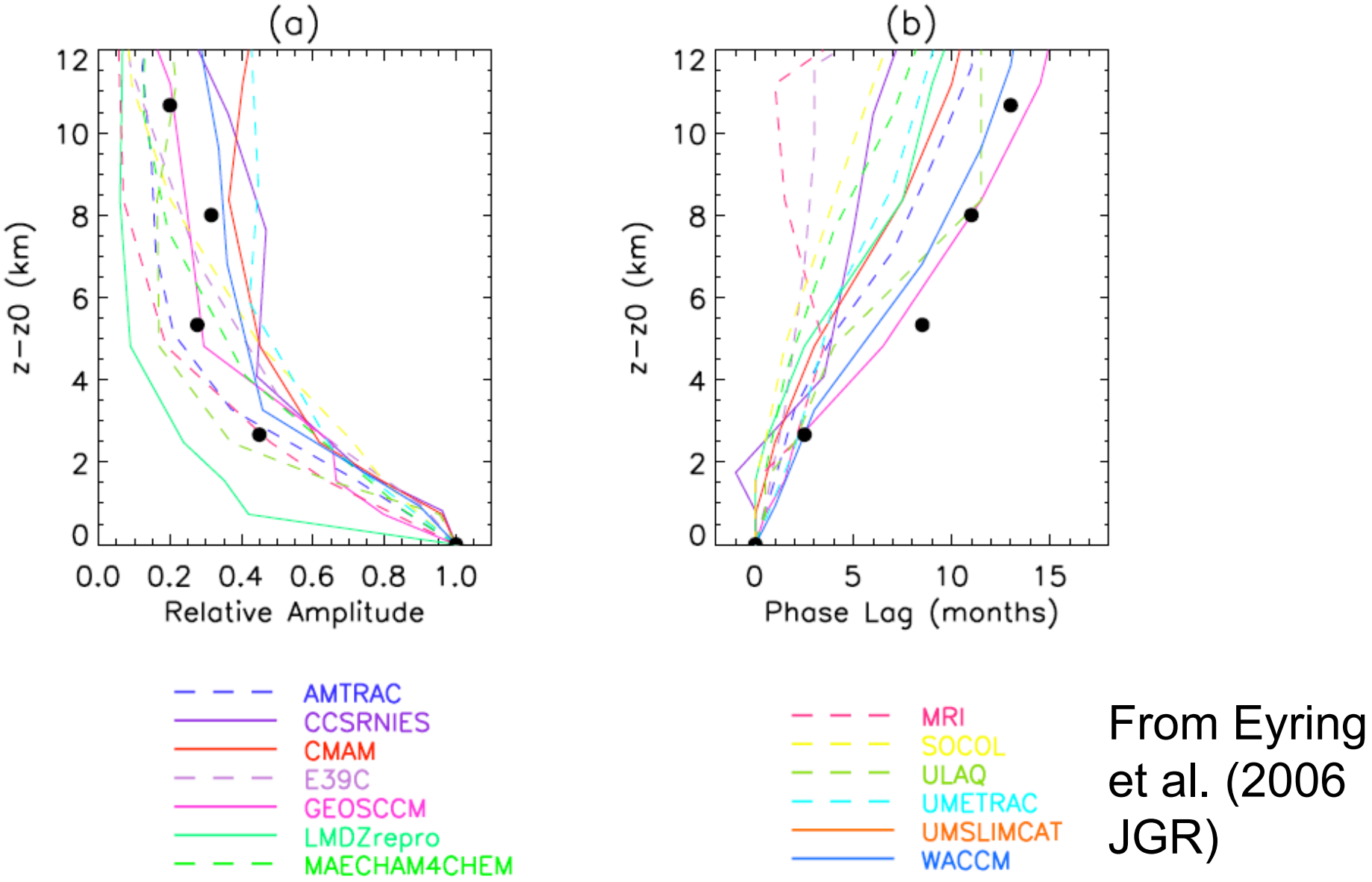
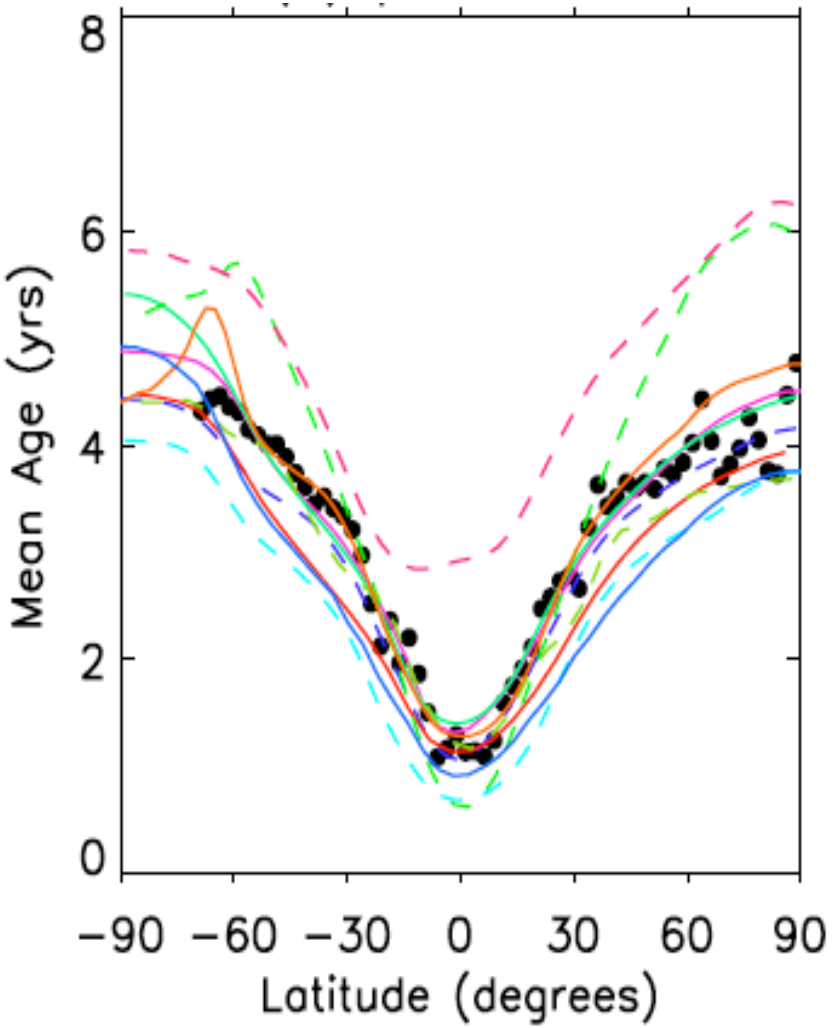


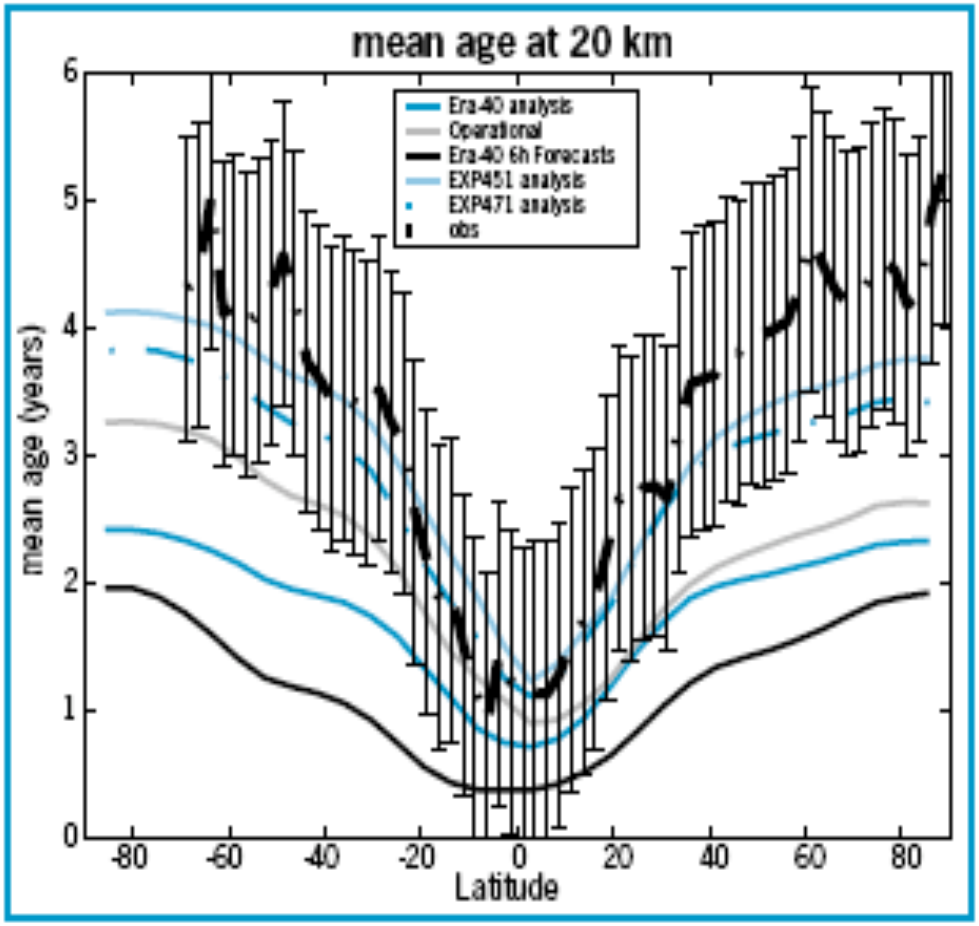

From Eyring et al. (2006 JGR)

- "Age of air" at 50 hPa for various CCMs
  - Observations (dots) are from ER-2 $CO_2$





From Eyring et al. (2006 JGR)

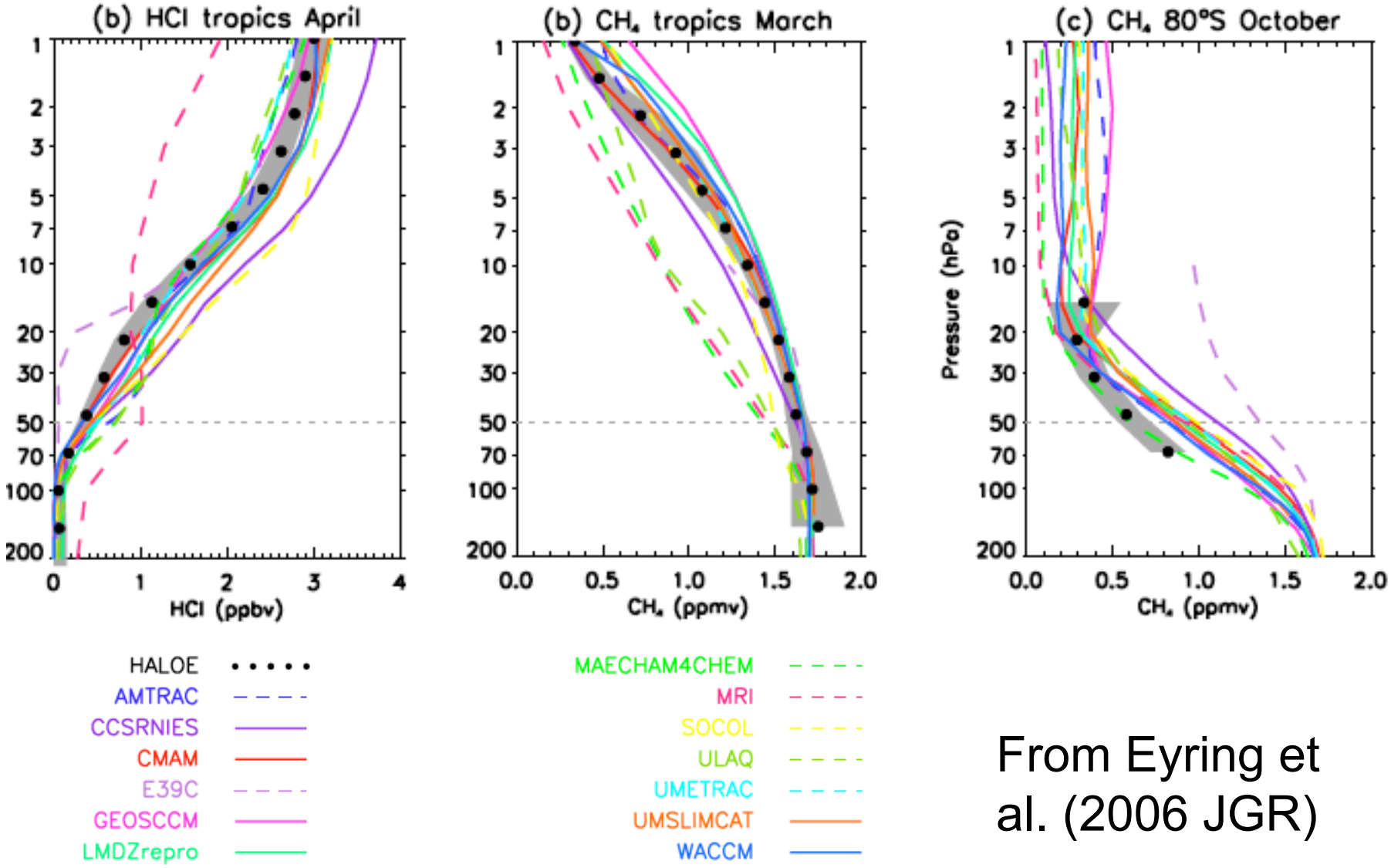



- Age of air from DAS-driven CTMs have usually looked pretty dreadful; but there have been some recent improvements

Figure from Beatriz Monge Sanz, University of Leeds

Published in SPARC Newsletter No. 26 (2006)

- Vertical profiles of HCl and $CH_4$

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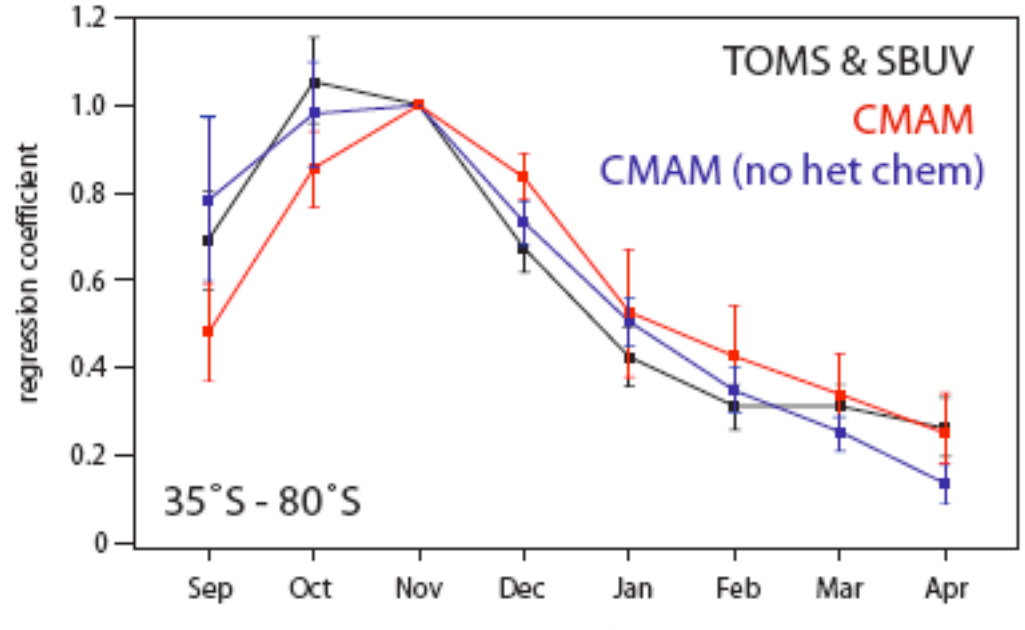
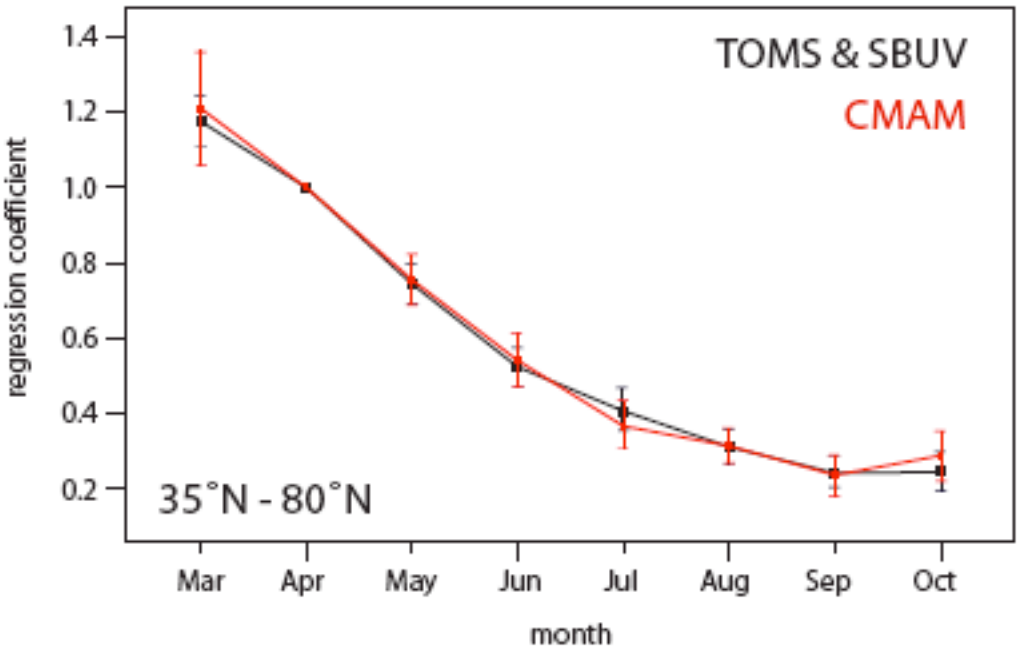


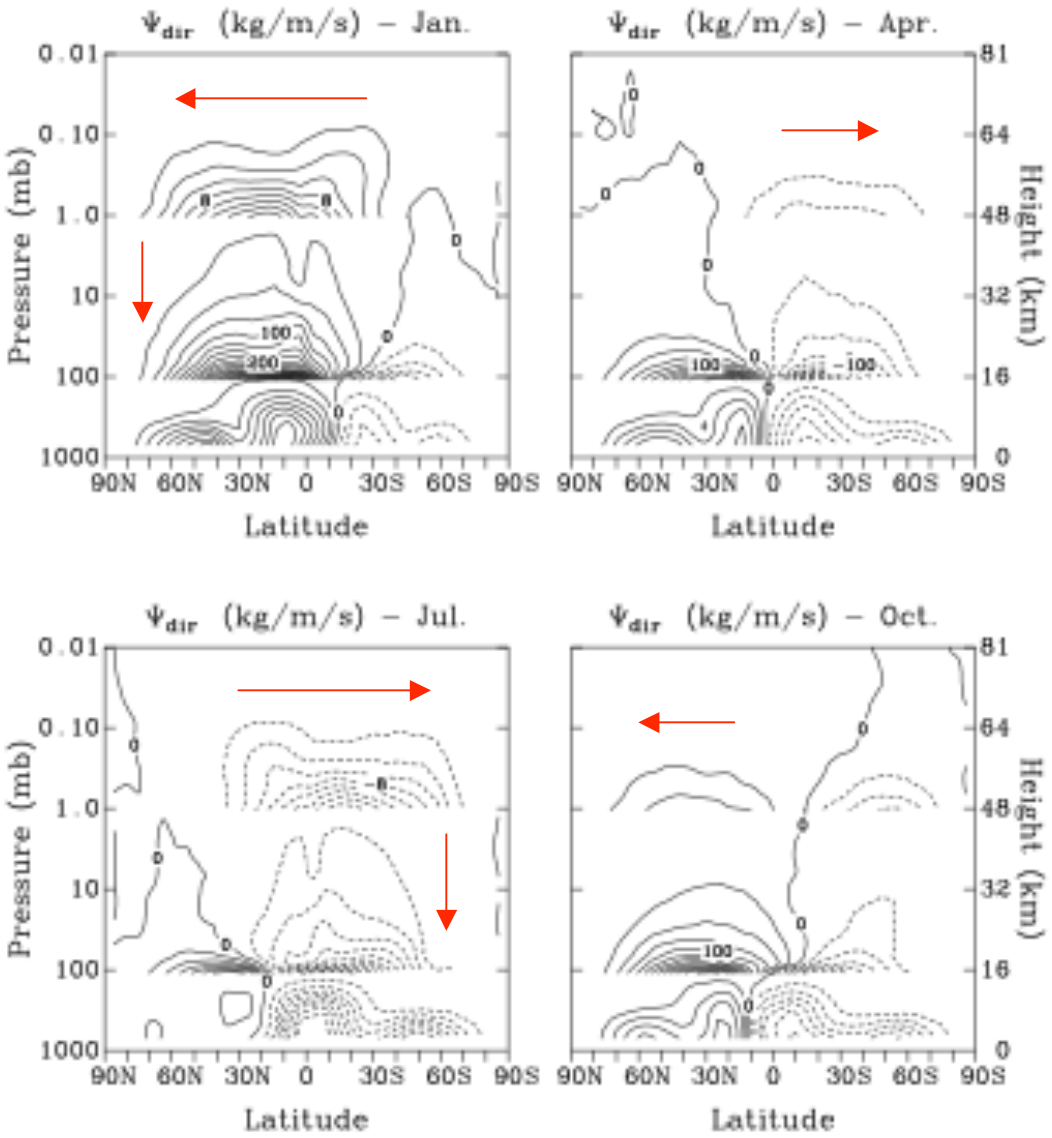

**Summertime photochemical decay of late-spring total ozone anomalies**

Regression coefficients with November (SH) and April (NH) anomalies

(see Fioletov & Shepherd, GRL 2003)

Tegtmeier & Shepherd (ACPD 2006)

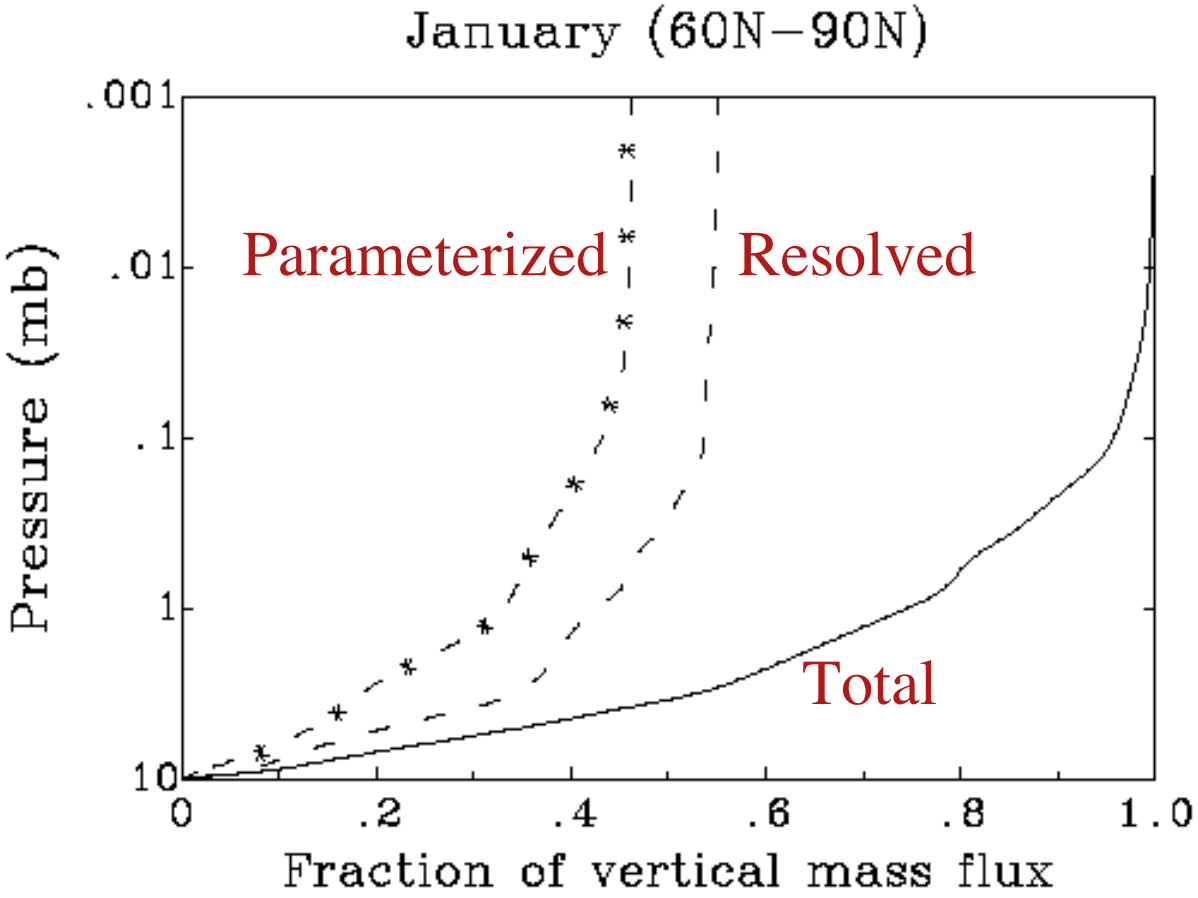
# Seasonal cycle of meridional (TEM) circulation in CMAM




We don't have "observations" of this, but it would be interesting to compare the TEM circulation in analyses with that inferred from diabatic heating

From Beagley et al. (1997 Atmos.-Ocean)

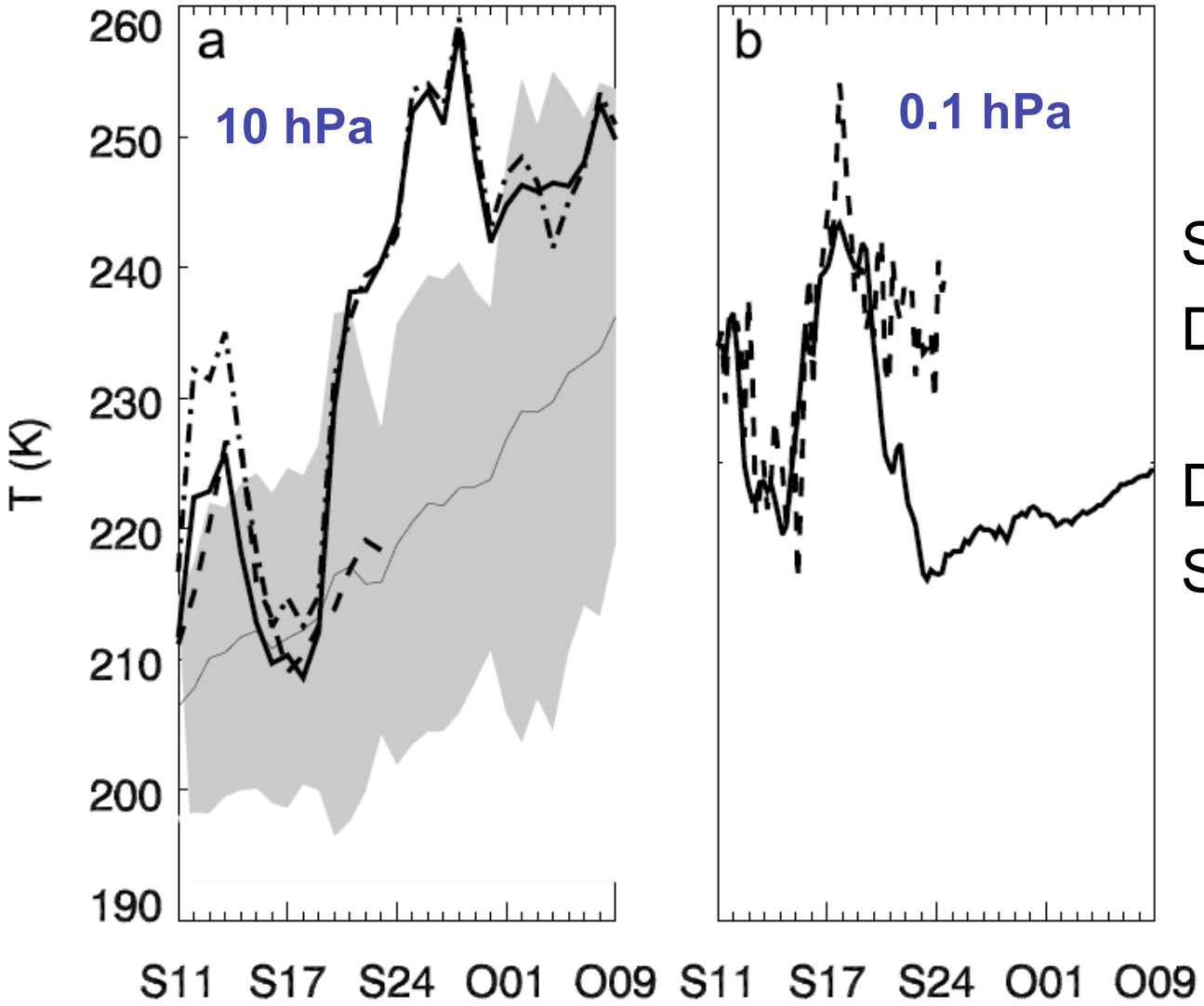
# Cumulative contribution of resolved and parameterized wave drag at various altitudes on polar downwelling at 10 hPa in CMAM with only orographic GW drag




Likewise, it would be interesting to compare this partitioning in CCMs and DASs

From Beagley et al. (1997 Atmos.-Ocean)

- Results from Ren, Polavarapu & Shepherd (GRL, subm.)
  - 2002 Antarctic SSW in the CMAM-DAS; *no mesospheric data*




**South Pole T**

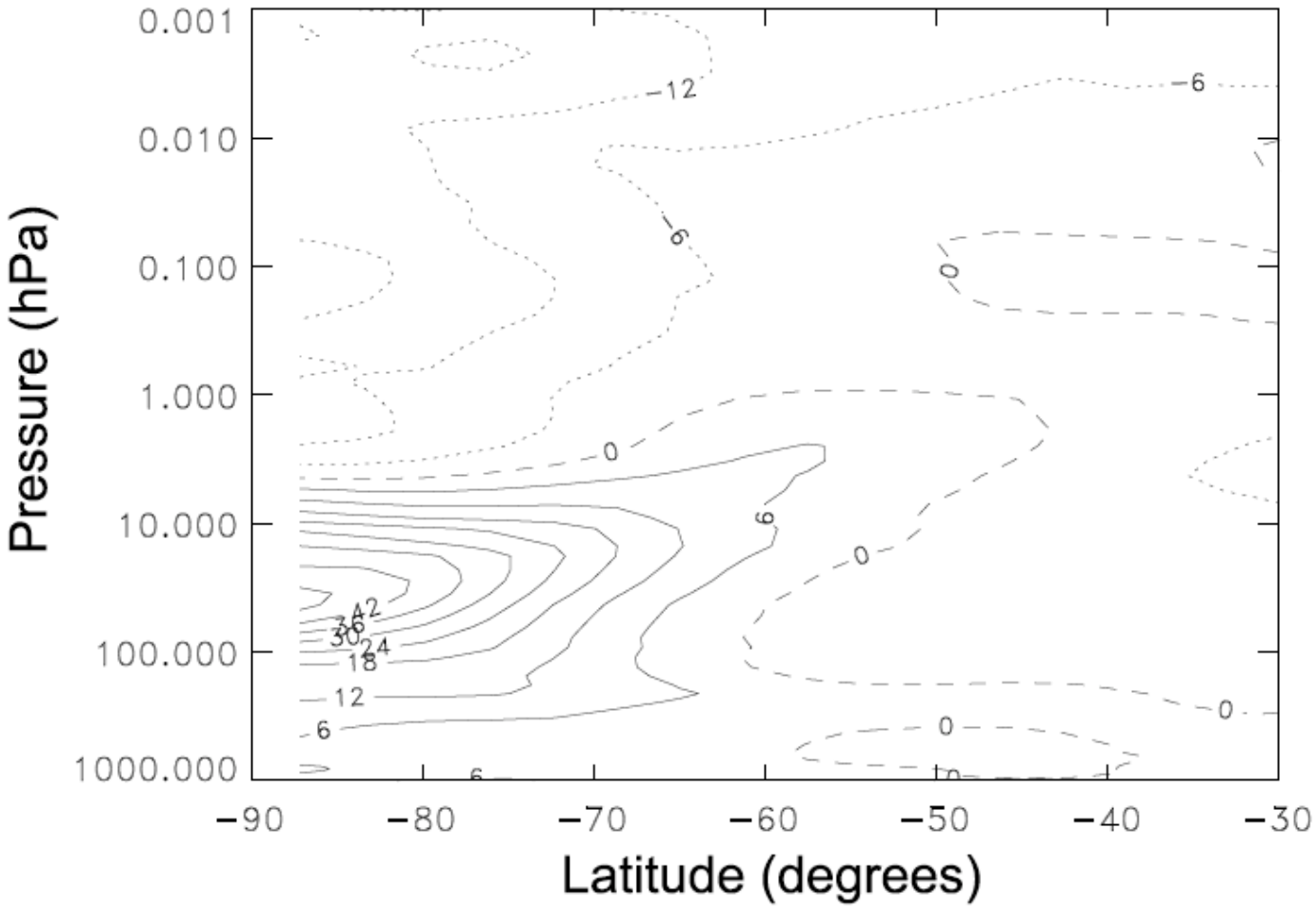
Solid: CMAM-DAS

Dashed: CMAM-DAS forecast

Dash-dot: Met O

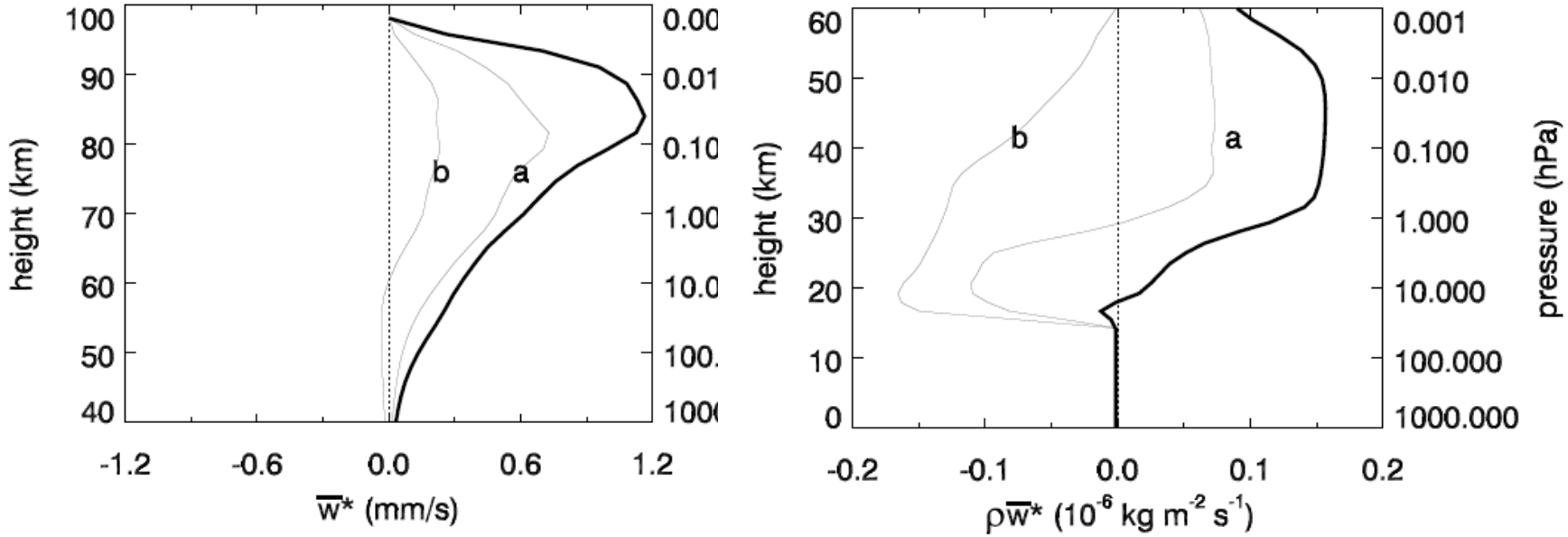
Shaded: Met O mean + 2$\sigma$ climatology (excluding 2002)

- Difference between analysis and forecast on Sept. 25 represents the impact of the stratospheric data
- There is widespread cooling in the polar mesosphere




From Ren et al. (GRL, submitted)

- The mesospheric cooling arises from anomalous polar upwelling from an eastward GWD anomaly
  - Mechanism was suggested by Holton (1983 JAS)
  - Magnitude and details of response will depend on the GW source spectrum
  - Raises prospect of constraining the latter




From Ren et al. (GRL, submitted)

# Summary

- CCMVal diagnostics (esp'ly of transport) will also be useful for the SPARC DAWG
  - We should use common validation data sets
  - Details and links are on the CCMVal web site
- For GWD, DAS analyses should provide useful information for CCMVal
  - Observations provide a strong constraint on filtering of GW fluxes, as the winds are then realistic
  - Allows a focus on errors in the source spectrum