Some Recent Results obtained with NASA's GEOS-4 DAS

Steven Pawson[1], Mark. R. Schoeberl[2],
Arlindo da Silva[1], Ivanka Stajner[1],
Wei-Wu Tan[1], Kryzstof Wargan[1]

[1] Global Modeling and Assimilation Office, NASA GSFC
[2] Earth Sciences Directorate, NASA GSFC

ECMWF Workshop, June 23-26, 2003

Overview of talk

1. Why assimilate?
2. Ongoing work in NASA's Global Modeling and Assimilation Office (GMAO)
3. Constituent modeling using assimilated data (chemistry-transport models, CTMs)
4. Causes of excessive mixing in assimilated data
5. Implications

1. Why assimilate?

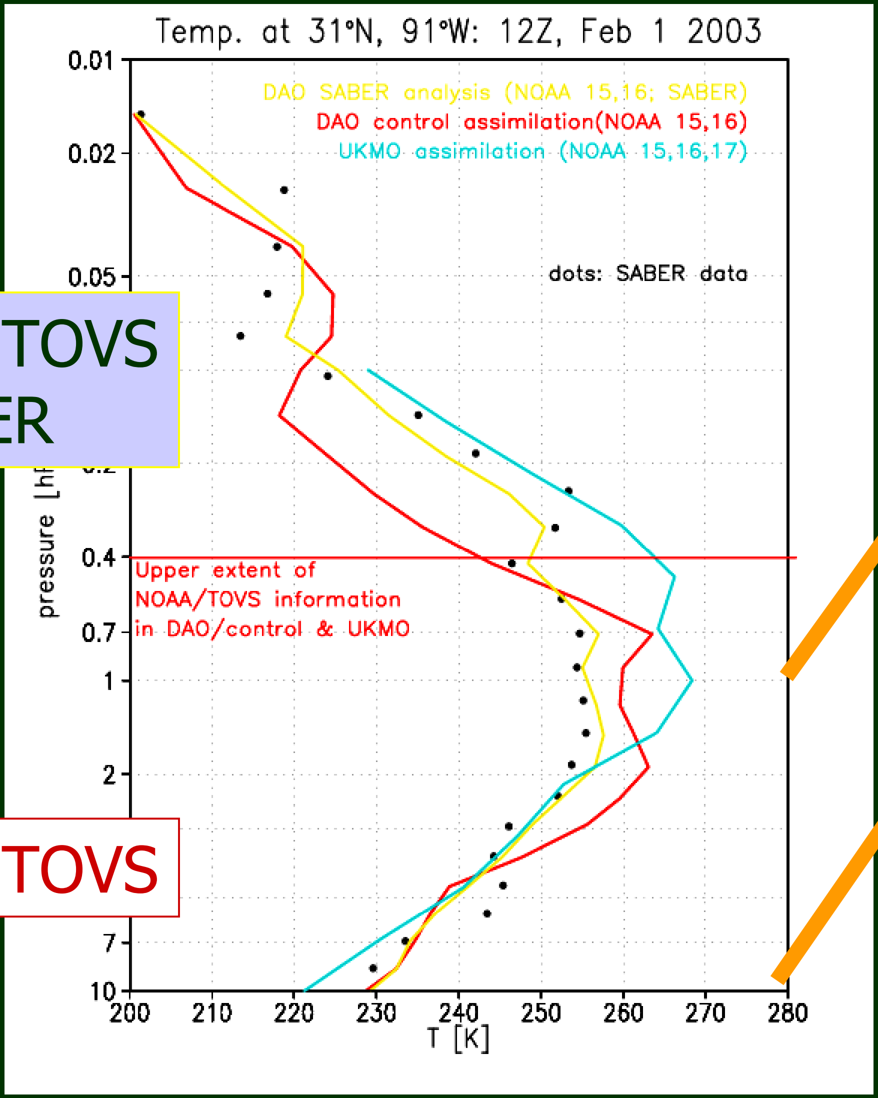
- Better knowledge increases understanding:
  - Combine characteristics/advantages of many data types
  - Improve understanding of processes & parameterization
  - Careful model-data fusion needed to maximize benefits
- Specific for upper troposphere and stratosphere:
  - Nadir-versus-limb sounding?
  - Use of space-based upper tropospheric water?
- Interpretation of constituent measurements:
  - Real observations need "real" state for interpretation
  - Limitation: transport by analyzed meteorology

2. Assimilation in GMAO

- Meteorological DAS: GEOS-4
  - FVGCM (Lin-Rood dynamics, CCM3 physics)
  - PSAS (observation-space analyses)
  - Nadir-sounders (TOVS)
  - Cloud-track winds, scatterometers, TPW, ...
  - Impact of SABER data (TOVS info content)
- Ozone DAS: off-line with chemistry
  - TOMS, SBUV – standard data input
  - Impact of MIPAS data
- Some thoughts about water

Assimilation of SABER limb-sounder temperatures

Limb sounders can have substantial impact



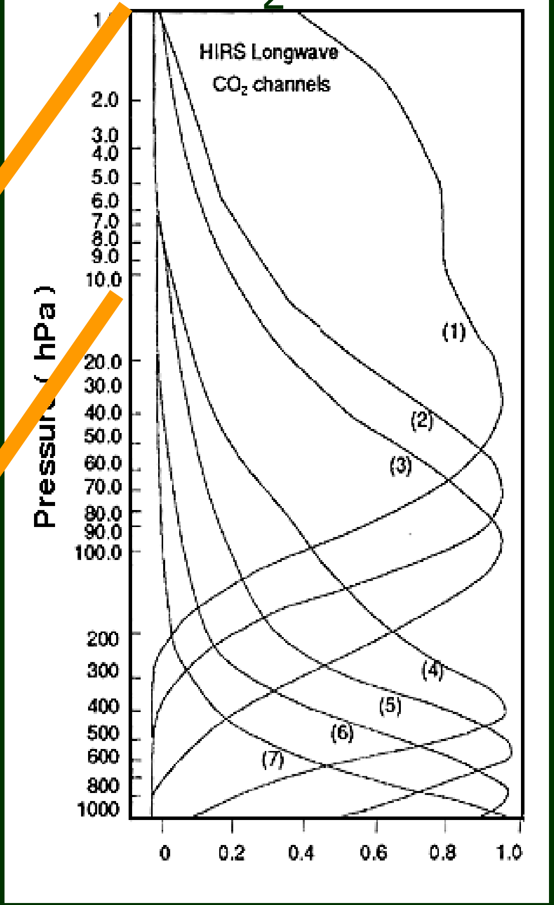
GEOS-4: TOVS and SABER

UKMO

GEOS-4: TOVS

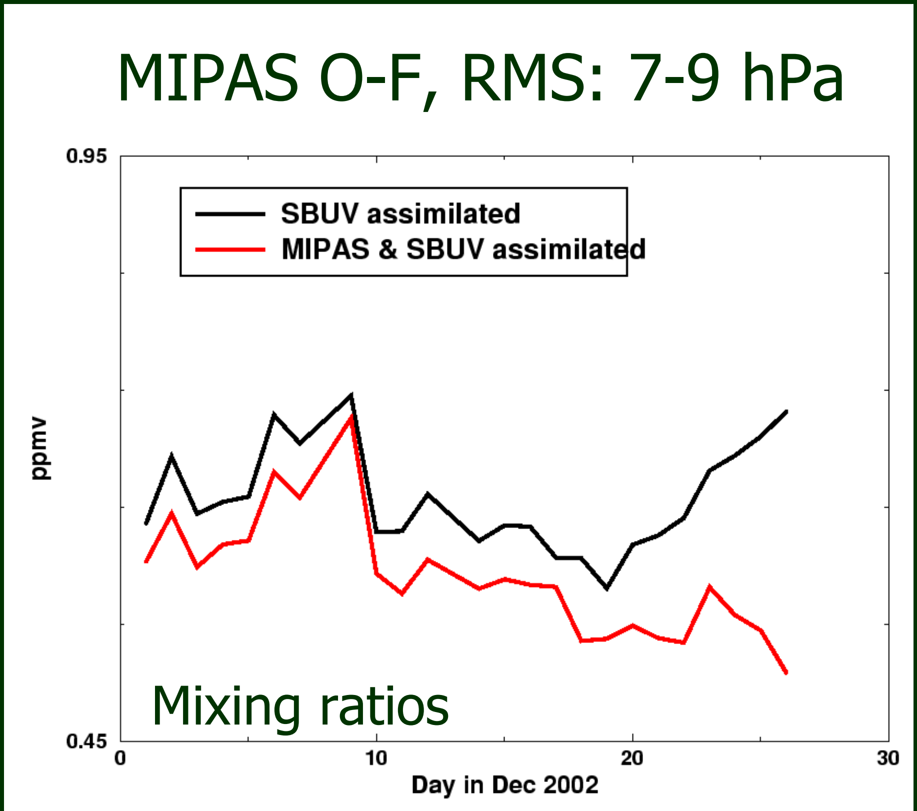
Limited vertical information in TOVS

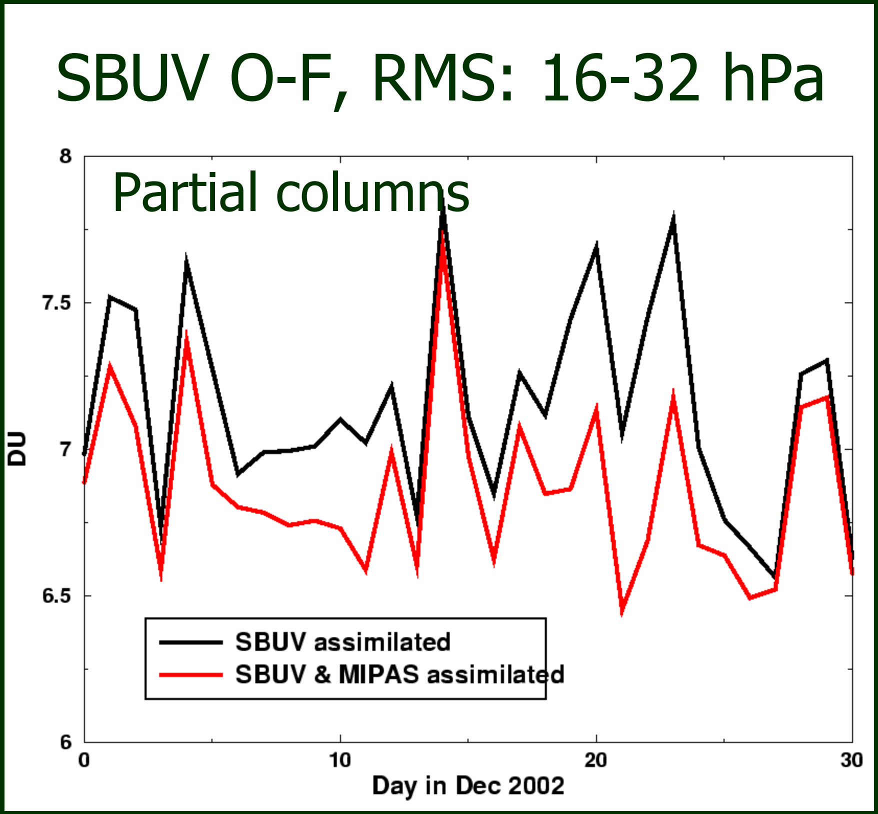
TOVS CO_2 channels



SABER data courtesy Marty Mlynczak, LaRC
da Silva et al., work in progress

MIPAS O_3 assimilation: O-F statistics (Dec. 2002)

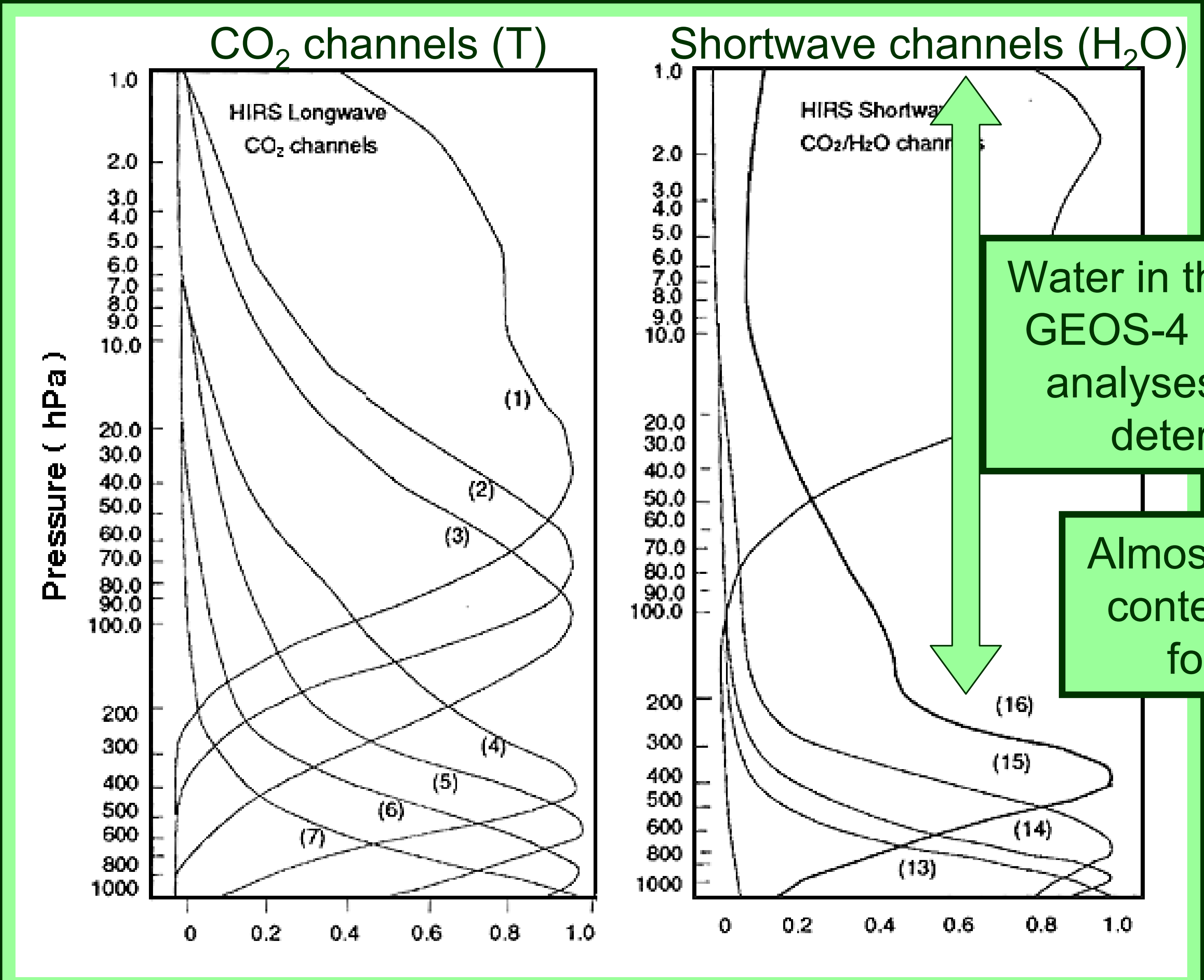




- Global O-F RMS values for MIPAS & SBUV both improve (decrease) when MIPAS data are assimilated
- Chi^2 statistics indicate that the reported MIPAS standard deviations may be too small

Wargan et al., work in progress

Information content of TOVS: water



Water in this region of GEOS-4 (and other) analyses is model determined

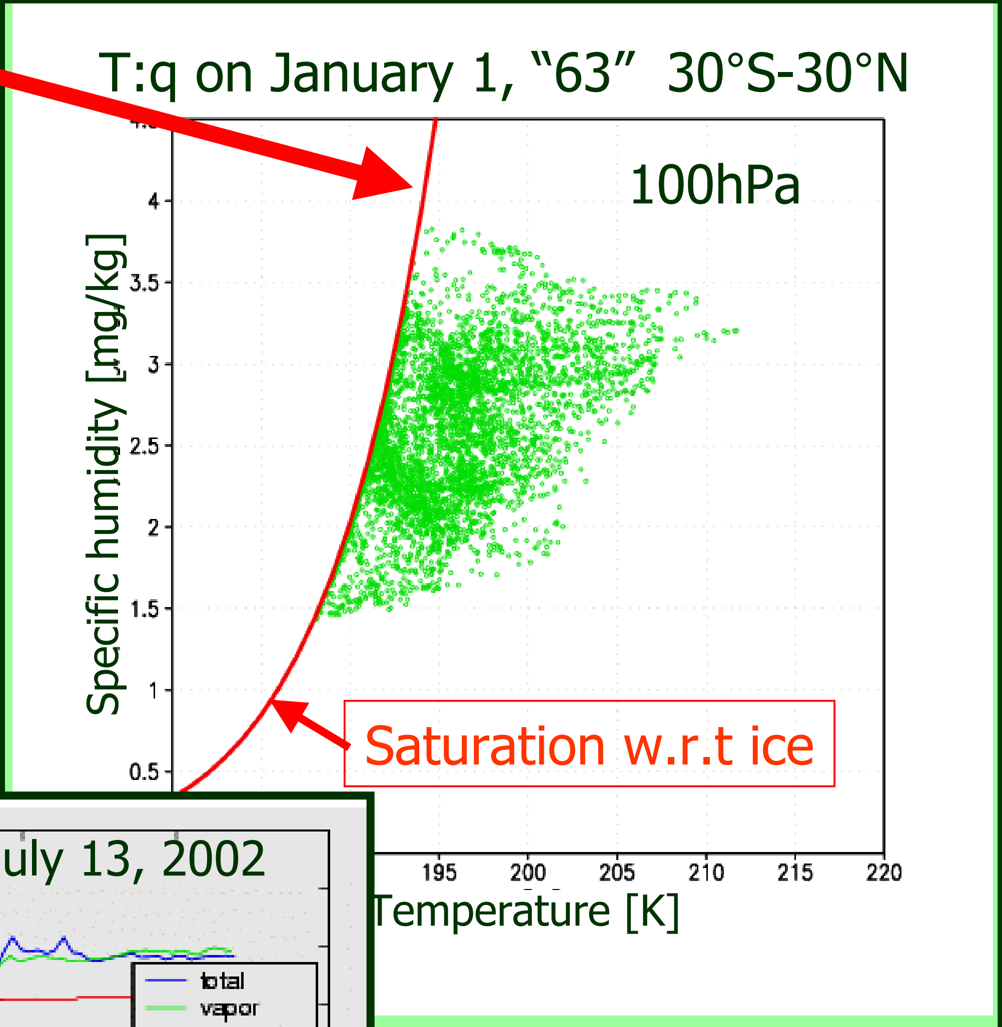
Almost no information content about water for p<300hPa

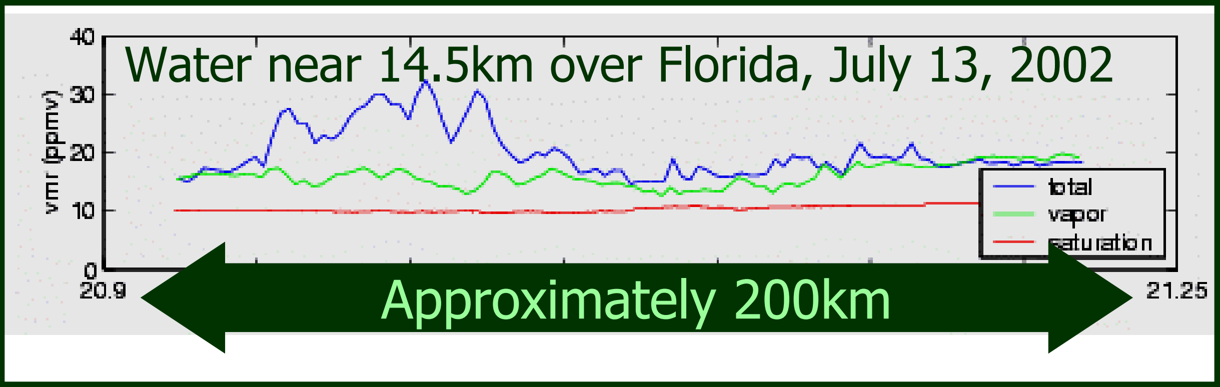
Assumption of “model physics” (CCM3)
Illustration with a T:q scatterplot from the model

No supersaturation

<u>Resolved scales:</u> saturation & dehydration synonymous: cirrus forms and the cloud water precipitates out

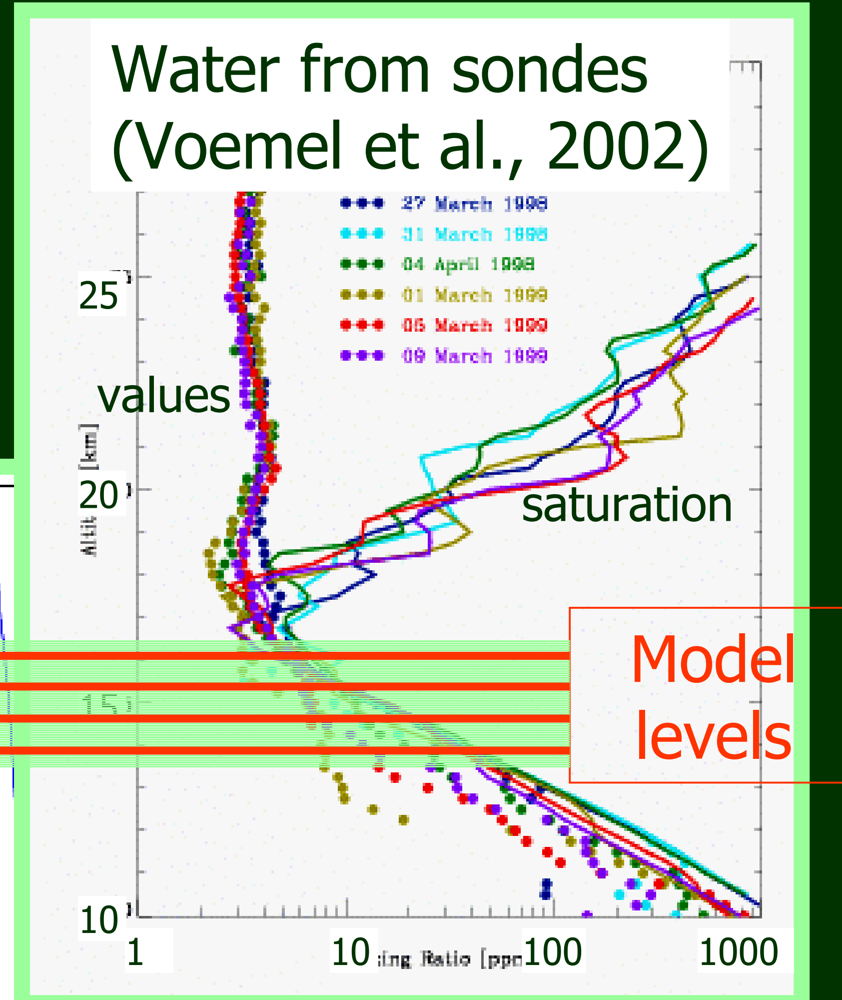
<u>Sub-grid scales:</u> cloud starts to form at 80% saturation; 100% cloud at saturation

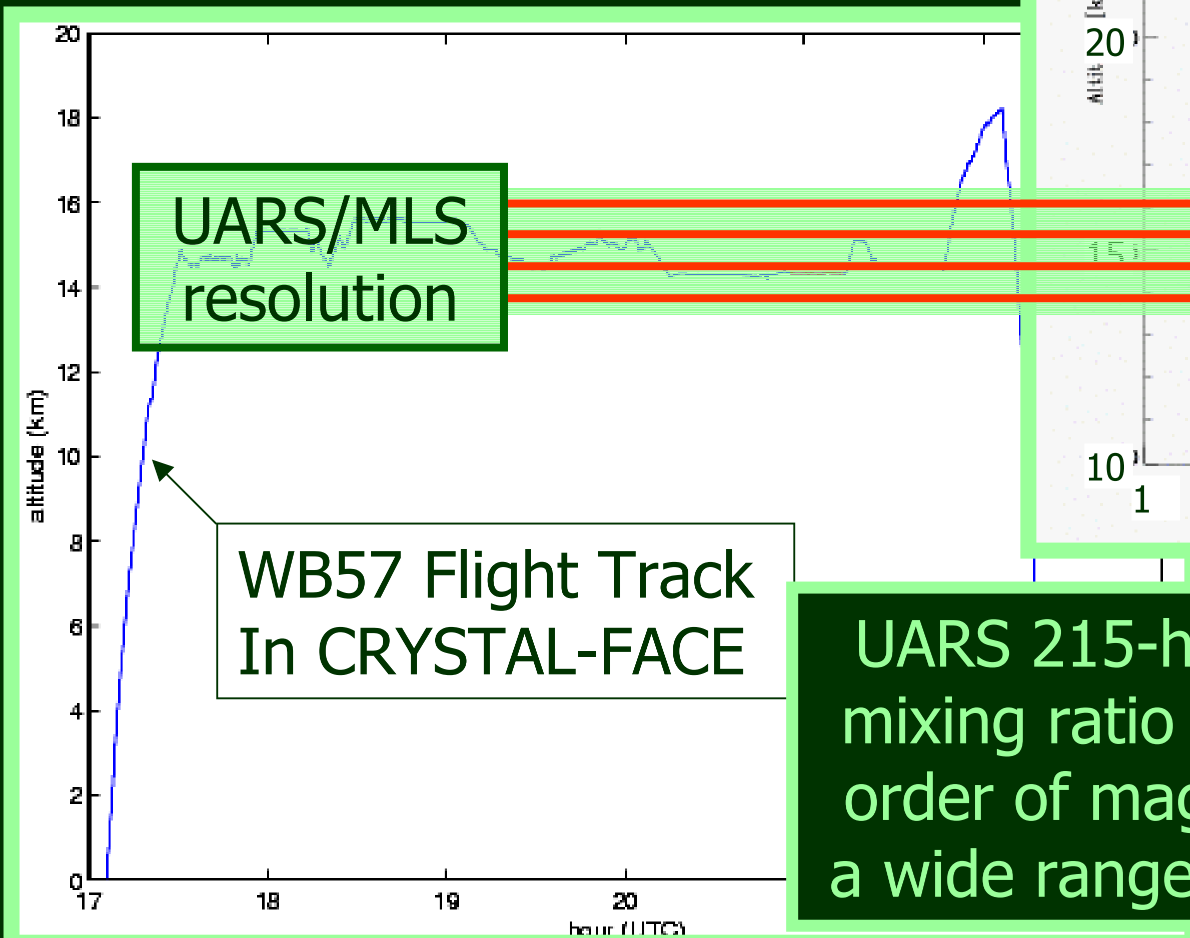




CRYSTAL-FACE observations from E. Weinstock

Upper tropospheric water: vertical resolution from sonde, aircraft & satellite. A challenge for assimilation



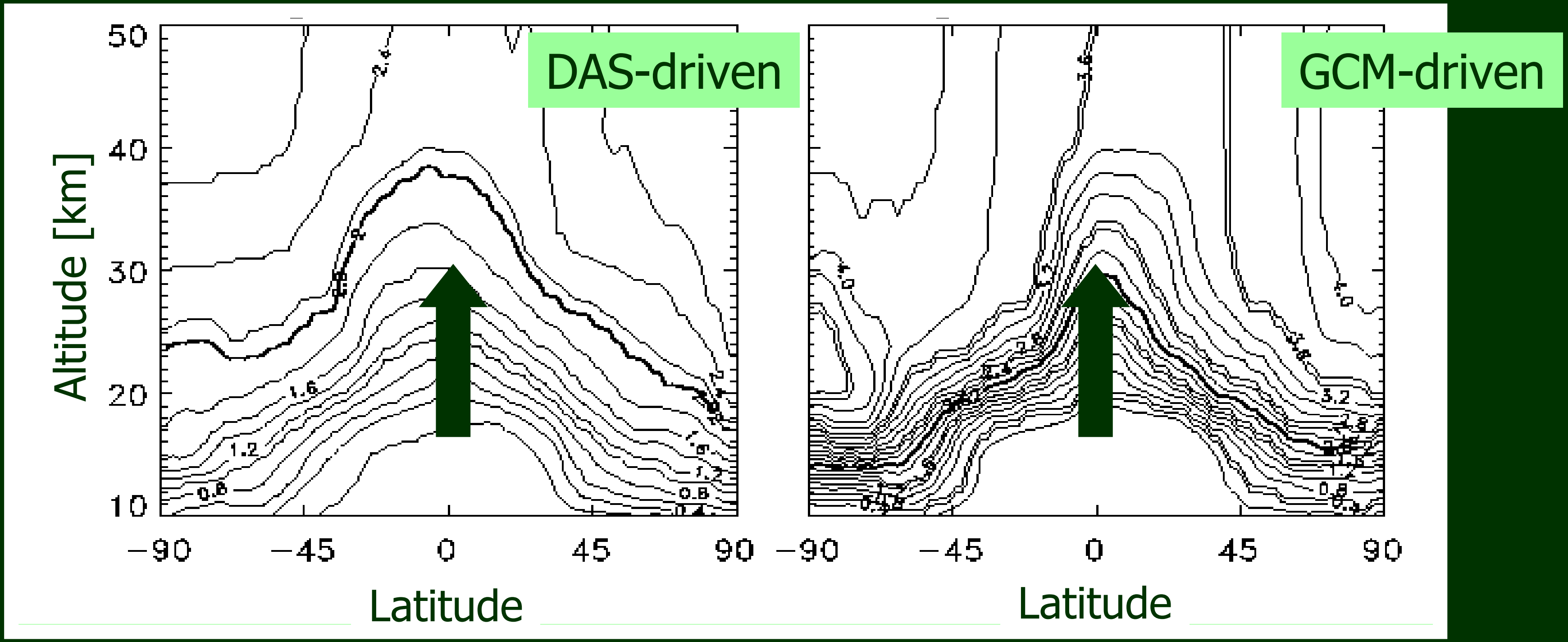


UARS 215-hPa layer (~3km deep): mixing ratio decreases by about an order of magnitude & profile spans a wide range of rel. humidity values

3. Assimilation-driven CTMs

- About a decade of experience using CTMs driven by successive versions of GEOS-DAS
- Lin-Rood code provides highly accurate representation of large-scale transport
- Improvements in meteorological assimilations have benefits for CTMs
- What is the "limit" of success?
- GCM-driven transport may offer insight, given the high quality of present simulations

"Age of Air:" long-lived tracer with surface source, weak decay



- Determined "off line" using DAS- or GCM-driven winds
- Tropical ascent and weak meridional mixing lead to "bulge"
- Subtropical barrier much stronger in GCM than in DAS
- GCM values in better agreement with observations

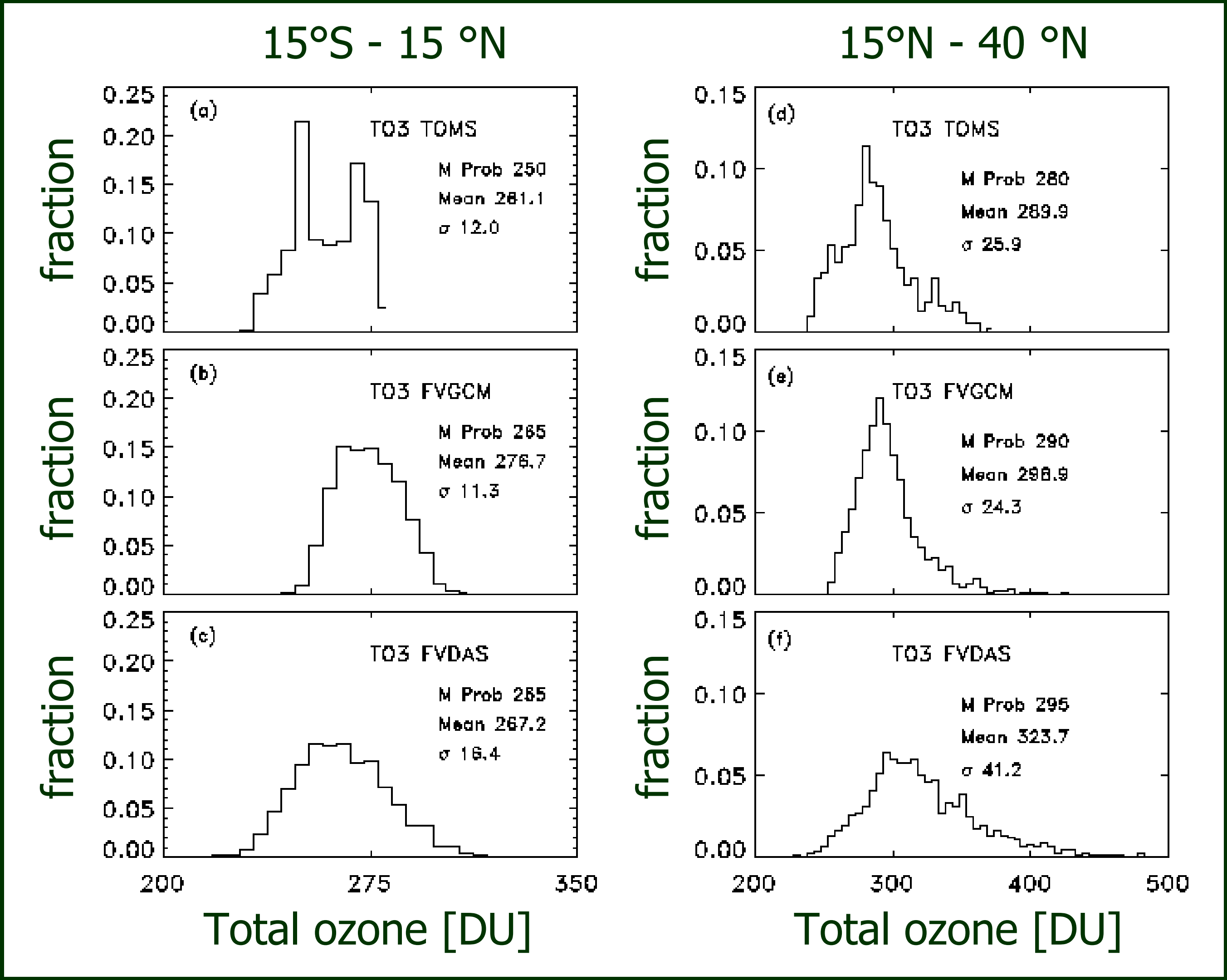
Douglass, Schoeberl, Rood and Pawson (2003)

PDFs of total ozone: observations & CTM

TOMS obs.

GCM-driven
- Means displaced
- Half-width ok

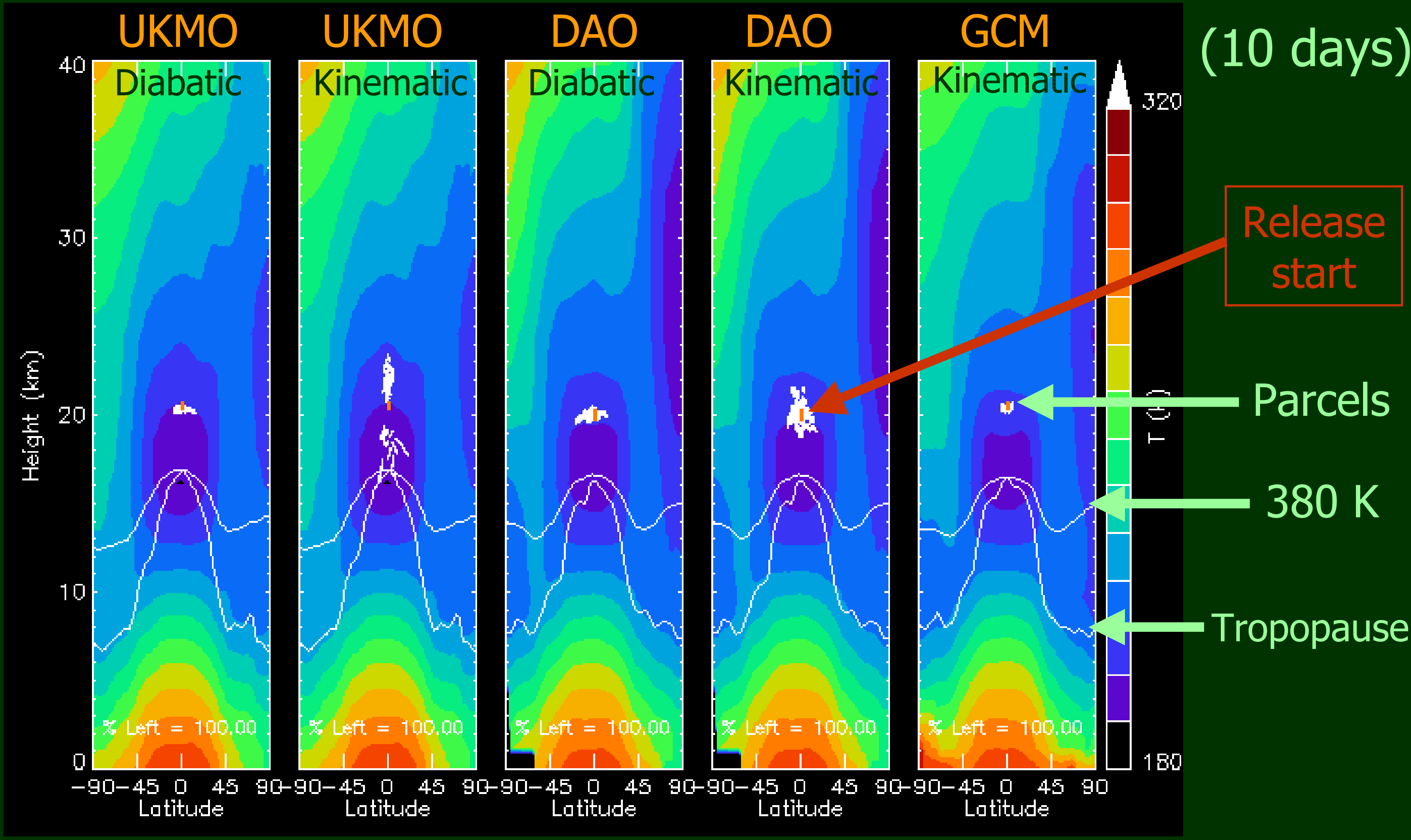
DAS-driven
- Means displaced
- Spread too wide



Too much tropical-extratropical mixing in DAS

Douglass, Schoeberl, Rood and Pawson (2003)

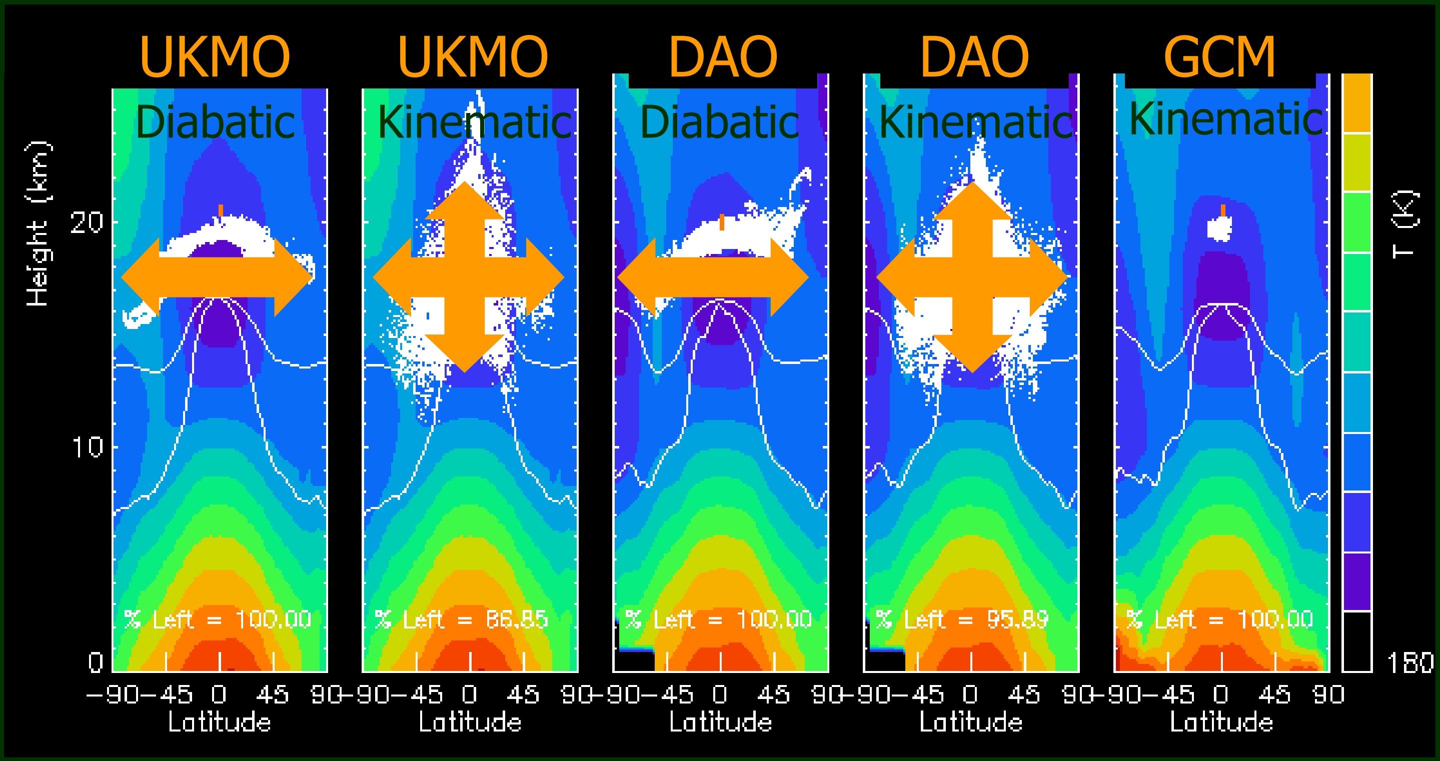
Three-dimensional trajectory calculations



Kinematic: 3D velocities used in trajectories
Diabatic: vertical motion from heating rates

Schoeberl, Douglass, Zhu and Pawson (2003)

Three-dimensional trajectory calculations



(50 days)

Kinematic: considerable vertical and horizontal dispersion
Diabatic: vertical dispersion reduced (smooth heating rates)

GCM shows very little dispersion, regardless of method used
Assimilated fields are excessively dispersive

Schoeberl, Douglass, Zhu and Pawson (2003)

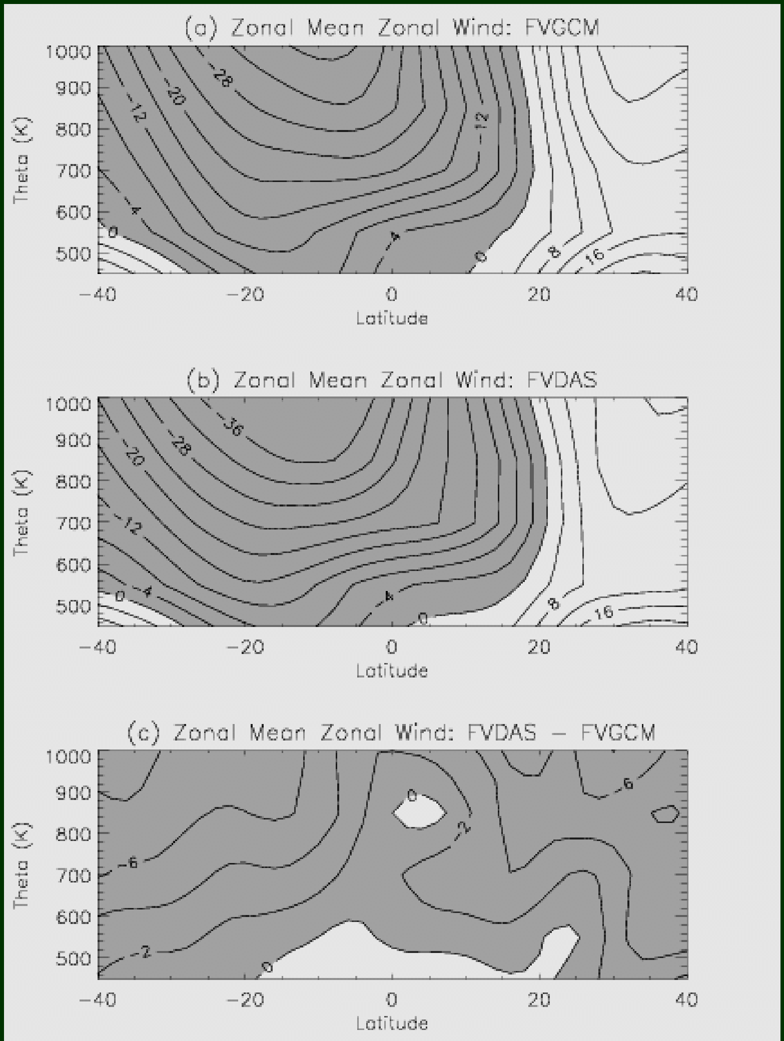
4. Causes of Excess Mixing

An attempt to quantify the links between data insertion and superfluous subtropical mixing using FVGCM and FVDAS

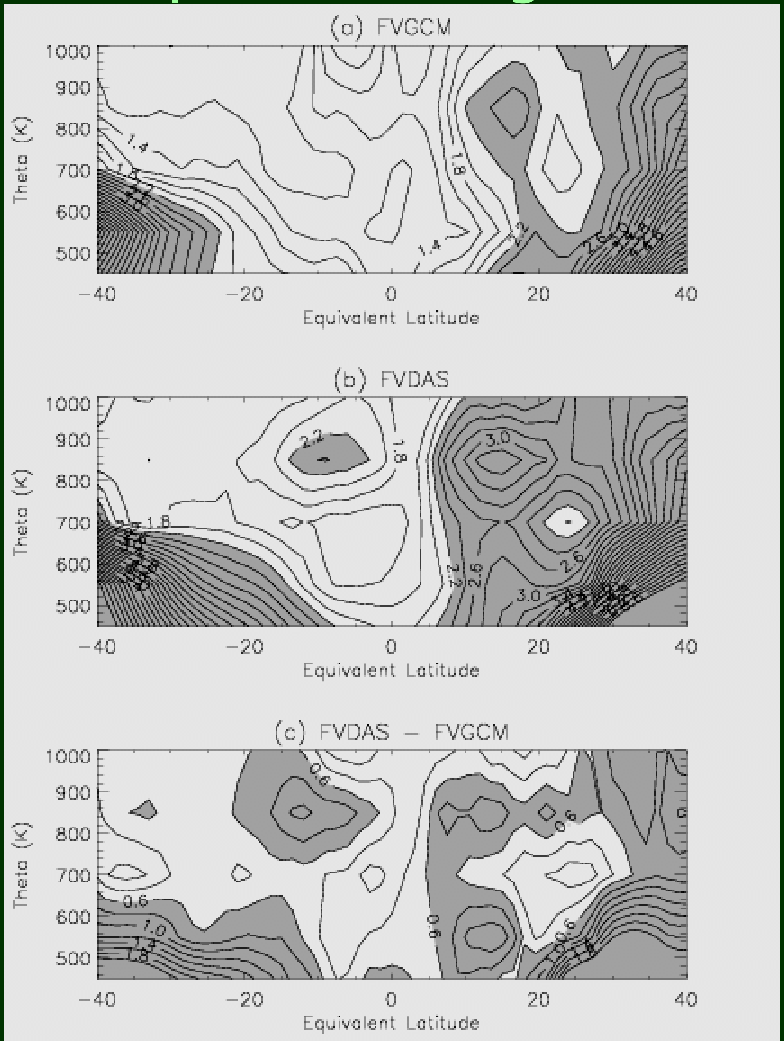
- January 1998: six-week model run and DAS
- Additional data-withholding experiments
- Trajectory calculations
- Equivalent length and “entrainment” into Tropics give quantitative measures of mixing

Characteristics of model and assimilation

Zonal-mean zonal wind



Equivalent length



FVGCM

FVDAS

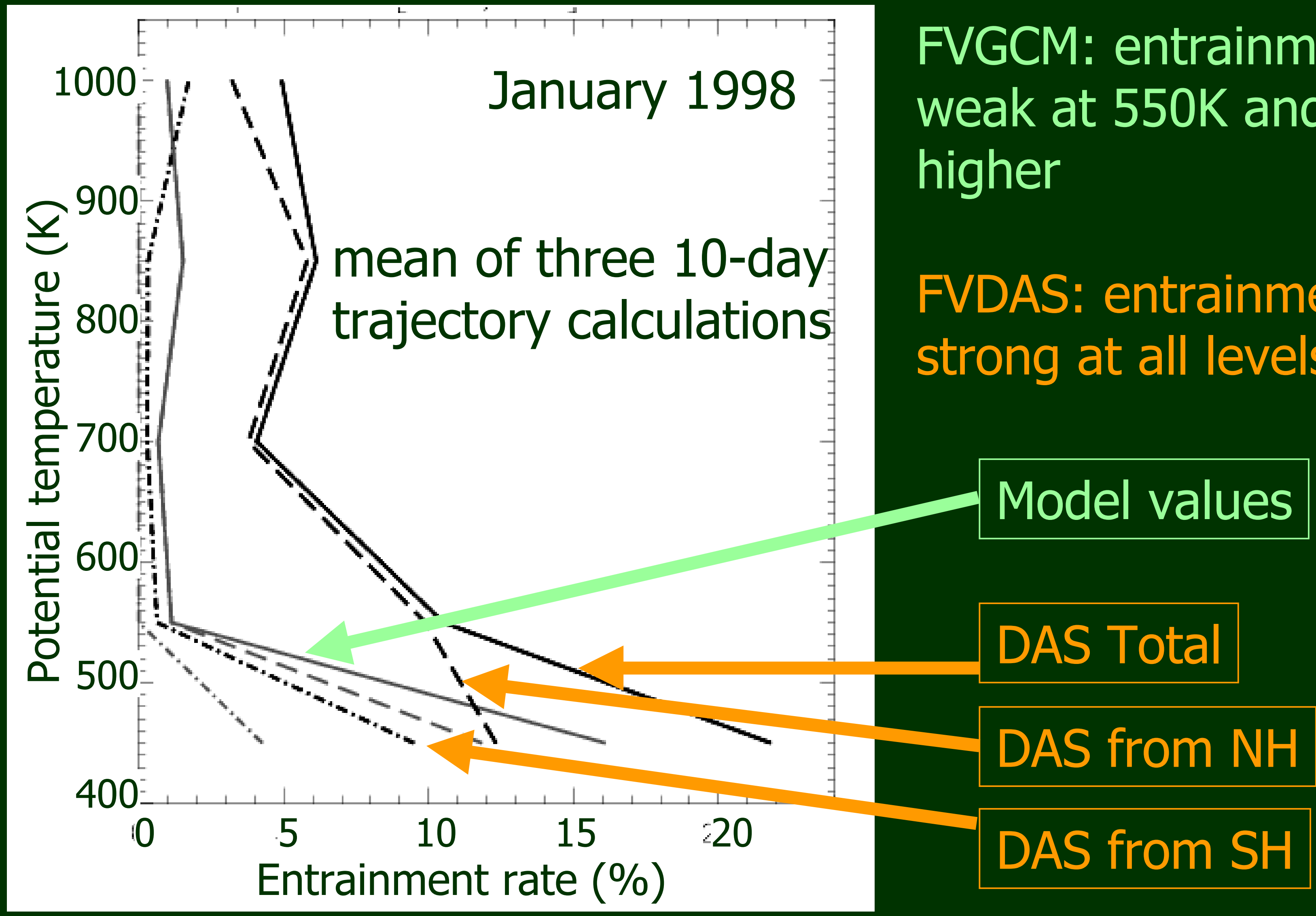
Difference

Small differences

Large differences

Tan, Geller, and Pawson (2003) in preparation

Transport into 10°S-10°N from outside 20°N/S



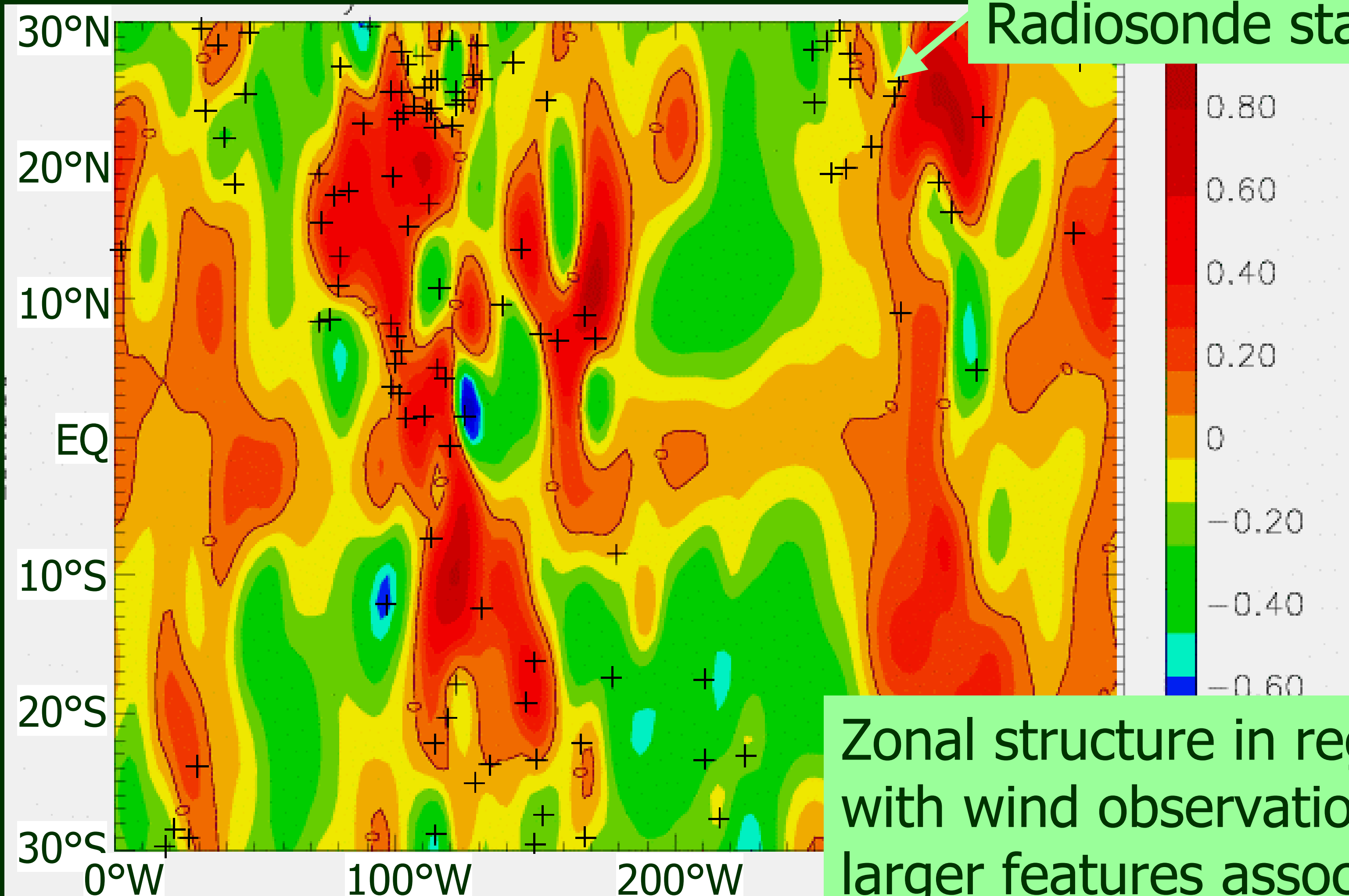
FVGCM: entrainment weak at 550K and higher

FVDAS: entrainment strong at all levels

Tan, Geller, and Pawson (2003) in preparation

Relationship between mixing and data insertion

Analysis increment for zonal velocity (January 1998, 30hPa)

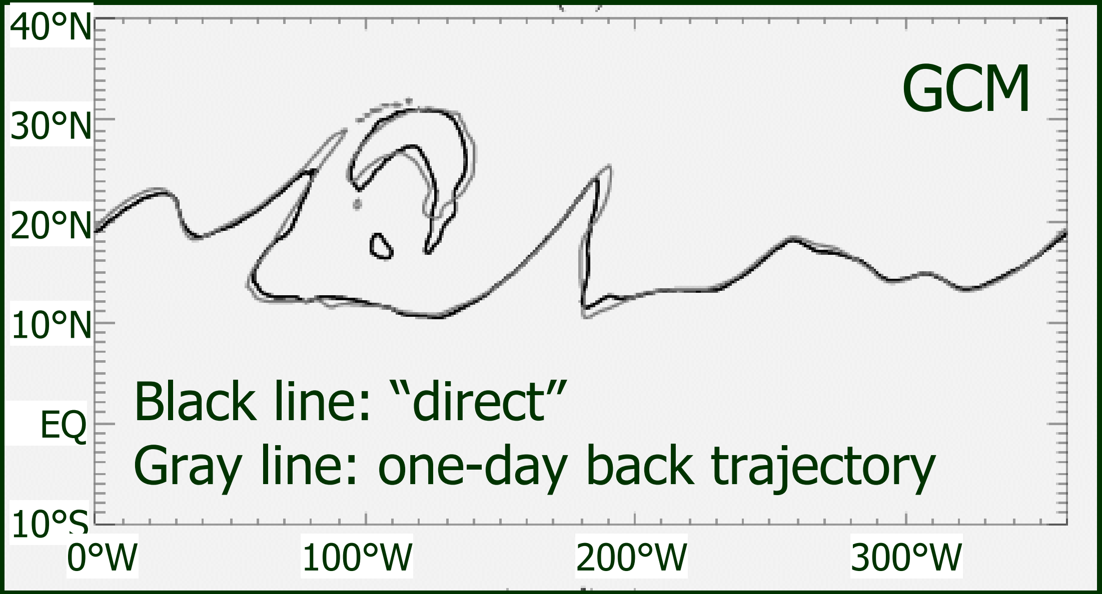


Radiosonde stations

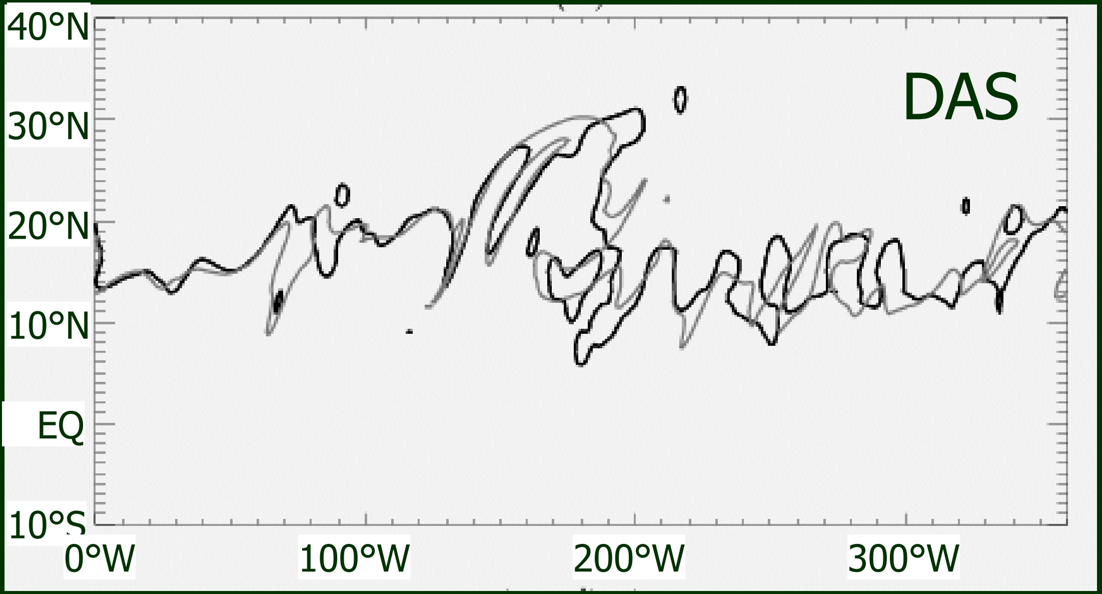
Zonal structure in regions with wind observations, larger features associated with TOVS data

Tan, Geller, and Pawson (2003) in preparation

Impact on potential vorticity: direct and trajectory



In the model run, the trajectory analysis reflects the temporal continuity of fields (differences arise from resolution and diffusive processes)



In the DAS, the noisy structure is evident, as well as the poor correspondence of the two contours, caused by non-conservative data insertion

Tan, Geller, and Pawson (2003) in preparation

5. Summary

- Limb-sounding temperature data (SABER) can be effectively combined with TOVS data
- Inclusion of MIPAS ozone, alongside SBUV, improves performance of ozone system
- Need good information about upper tropospheric water and clouds for improving models
- CTM studies using assimilated meteorology reveal excessive cross-barrier transport
- Local assimilation leads to noise and excessive transport near the sub-tropical barrier

Drawing Information From:

- A.R. Douglass, M.R. Schoeberl, R.B. Rood, S. Pawson: *Evaluation of transport in the lower tropical stratosphere in a global chemistry and transport model*. J. Geophys. Res., in press (2003).
- M.R. Schoeberl, A.R. Douglass, Z. Zhu, S. Pawson: *A Comparison of the lower stratospheric age-spectra derived from a general circulation model and two data assimilation systems*. J. Geophys. Res.,**108**, DOI 10.1029/2002jd002652 (2003).
- W. Tan, M.A. Geller, S. Pawson: *A Case Study of Excessive Subtropical Transport in the Stratosphere of a Data Assimilation System*, J. Geophys. Res., almost submitted (2003).