Some recent results obtained with NASA's GEOS-4 DAS

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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

Limited vertical information in TOVS

TOVS CO₂ channels

SABER data courtesy Marty Mlynczak, LaRC
da Silva et al., work in progress
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MIPAS O$_3$ assimilation: O-F statistics (Dec. 2002)

MIPAS O-F, RMS: 7-9 hPa

SBUV O-F, RMS: 16-32 hPa

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 $p<300$ hPa.
Assumption of “model physics” (CCM3)
Illustration with a T:q scatterplot from the model

No supersaturation

Resolved scales: saturation & dehydration synonymous: cirrus forms and the cloud water precipitates out

Sub-grid scales: cloud starts to form at 80% saturation; 100% cloud at saturation

T:q on January 1, "63° 30′S-30′N

Specific humidity [mg/kg]

Saturation w.r.t ice

Water near 14.5km over Florida, July 13, 2002

Approximately 200km

CRYSAL-FACE observations from E. Weinstock

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

Water from sondes (Voemel et al., 2002)

UARS/MLS resolution

Model levels

WB57 Flight Track
In CRYSTAL-FACE

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

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

Three-dimensional trajectory calculations

UKMO Diabatic
UKMO Kinematic
DAO Diabatic
DAO Kinematic
GCM Kinematic

(10 days)

Release start
Parcels
380 K
Tropopause

Kinematic: 3D velocities used in trajectories
Diabatic: vertical motion from heating rates
Three-dimensional trajectory calculations

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


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

FVGCM

FVDAS

Difference

Small differences

Equivalent length

Large differences

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

January 1998

mean of three 10-day trajectory calculations

FVGCM: entrainment weak at 550K and higher

FVDAS: entrainment strong at all levels

Model values

DAS Total

DAS from NH

DAS from SH

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


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

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:

