Assimilation of occultation data

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Outline

- Brief review of examples from literature
- Validation of assimilated constituents
  - Statistical comparisons
  - Four-day wave
- Assimilation of constituents
  - Sparse data
  - Importance of error modeling, quality control
  - Local analyses/local impact of data
  - Regional constraint in global analyses: polar ozone from our recent work
- Conclusions, recommendations

Roles of occultation data in assimilation systems

- **Validation**: profiles with high vertical resolution provide excellent data sets for validation of three-dimensional assimilated fields (meteorological and constituents)

- **Assimilation**: Occultation data provide sparse profiles - it is hard to constrain global fields through assimilation of sparse data

Validation of assimilated constituents

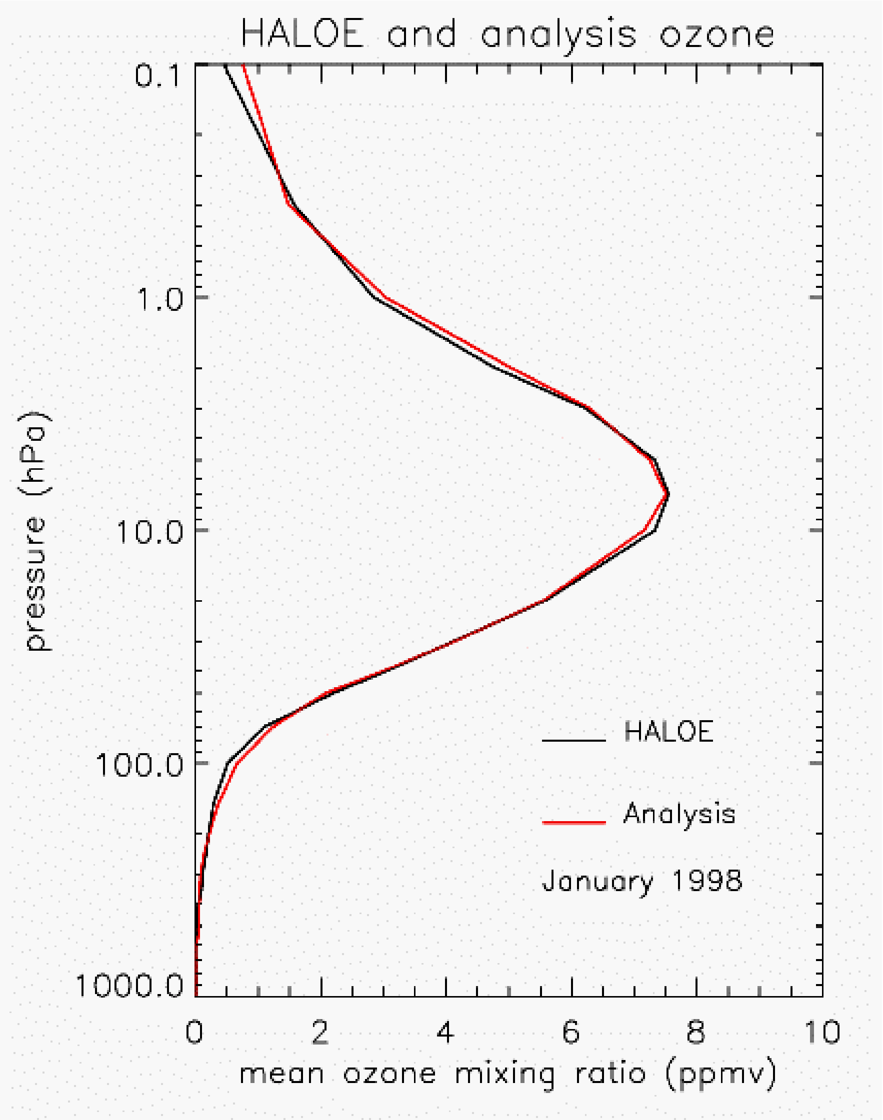
Statistical properties of constituent distribution in occultation data (**HALOE** or **ATMOS**) and assimilated constituent fields are compared:

- **Stajner** I, Riishojgaard LP, Rood RB,The GEOS ozone data assimilation system: Specification of error statistics Q J ROY METEOR SOC 127 (573): 1069-1094 Part A APR 2001
- **Errera** Q, Fonteyn D, Four-dimensional variational chemical assimilation of CRISTA stratospheric measurements J GEOPHYS RES-ATMOS 106 (D11): 12253-12265 JUN 16 2001
- **Struthers** H, Brugge R, Lahoz WA, et al. Assimilation of ozone profiles and total column measurements into a global general circulation model J GEOPHYS RES-ATMOS 107 (D20): Art. No. 4438 SEP-OCT 2002

Process-based evaluation (comparison with **POAM** data):

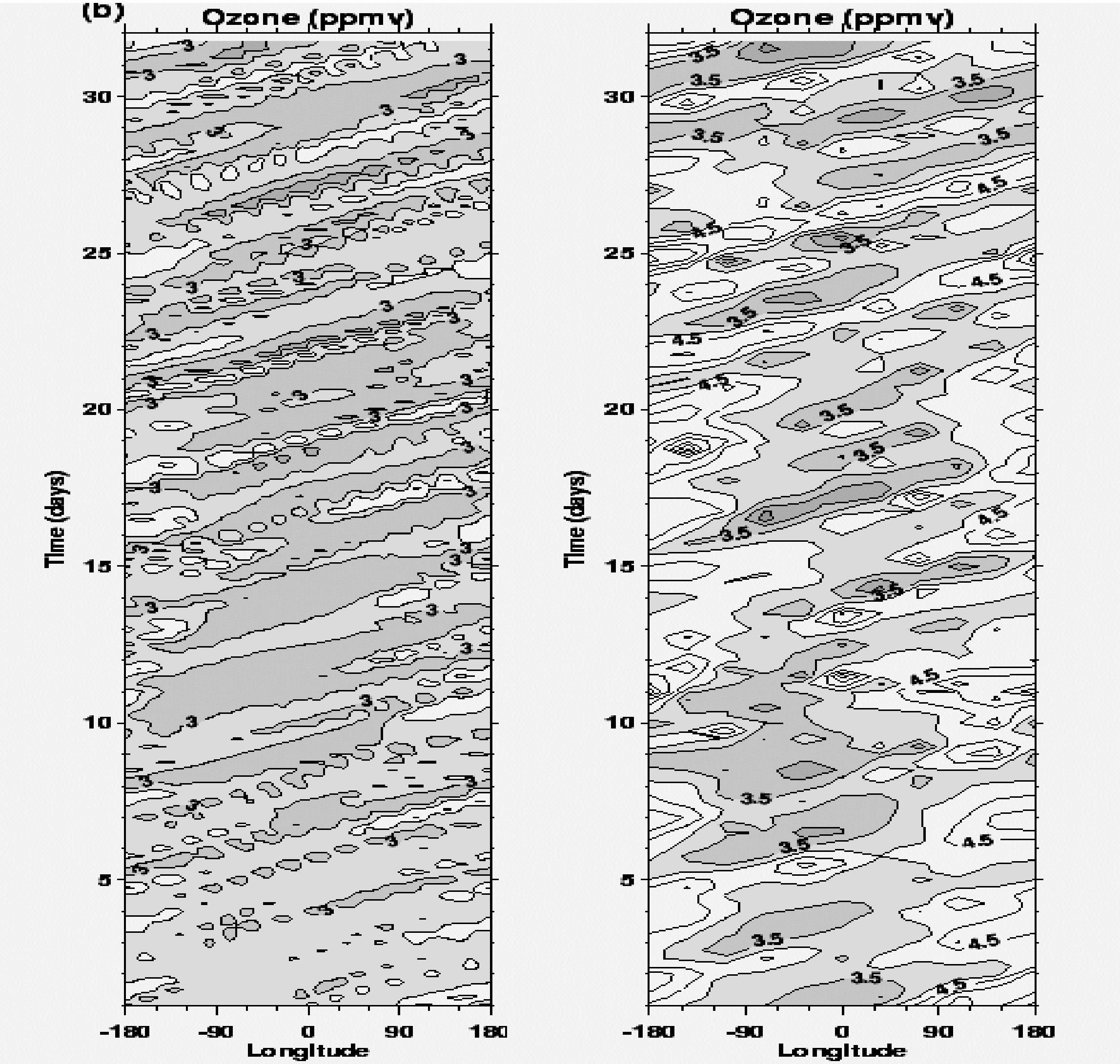
- **Coy** L, Stajner I, DaSilva AM, et al. High-frequency planetary waves in the polar middle atmosphere as seen in a data assimilation system J ATMOS SCI 60 (24): 2975-2992 DEC 15 2003

Statistical comparisons



- GEOS ozone assimilation fields are compared to **HALOE** profiles. GEOS assimilation used TOMS total columns and SBUV stratospheric partial columns to constrain ozone in a three-dimensional transport model (Stajner et al).
- Mean of HALOE profiles (black) is compared with collocated assimilated ozone (red).

Four-day wave



- Timeseries of GEOS assimilated ozone (left) and **POAM** observations (right) at 2 hPa are compared for July 1998.
- A 4-day wave that was analyzed by Coy et al. dominates the variability in both fields.

Assimilation of constituents

HALOE methane:

- **Menard** R, Chang LP, Assimilation of stratospheric chemical tracer observations using a Kalman filter. Part II: chi(2)-validated results and analysis of variance and correlation dynamics MON WEATHER REV 128 (8): 2672-2686 Part 1 AUG 2000

HALOE ozone, methane, water vapor, and hydrochloric acid - tracer-tracer correlations preserved:

- **Chipperfield** MP, Khattatov BV, Lary DJ Sequential assimilation of stratospheric chemical observations in a three-dimensional model J GEOPHYS RES-ATMOS 107 (D21): Art. No. 4585 NOV 2002

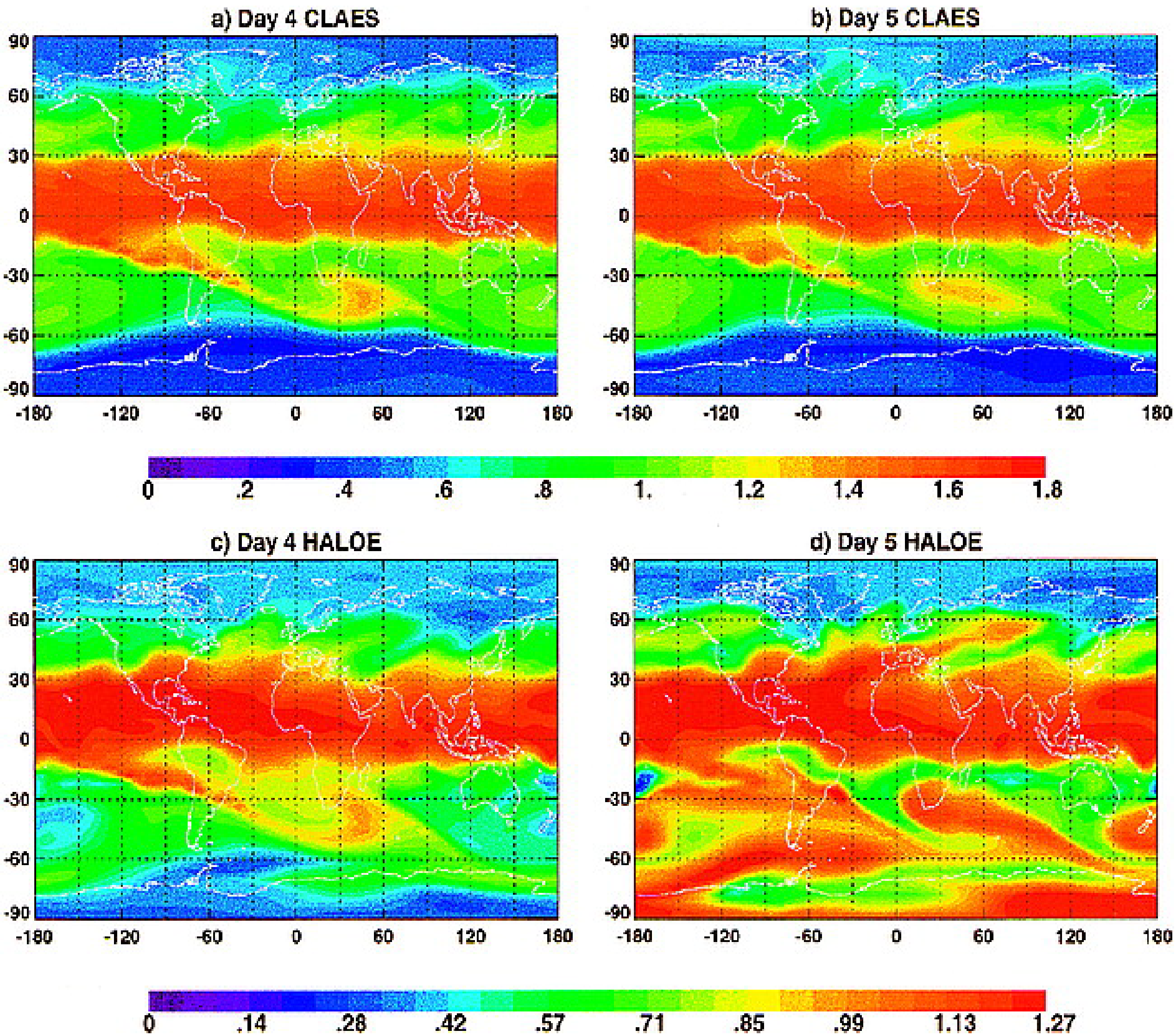
14 species from ATMOS – diurnal cycle and unobserved species studied:

- **Lary** DJ, Khattatov B, Mussa HY Chemical data assimilation: A case study of solar occultation data from the ATLAS 1 mission of the Atmospheric Trace Molecule Spectroscopy Experiment (ATMOS) J GEOPHYS RES-ATMOS 108 (D15): Art. No. 4456 AUG 7 2003

SAGE aerosol (evaluation of the dataset prior to assimilation – QC criteria):

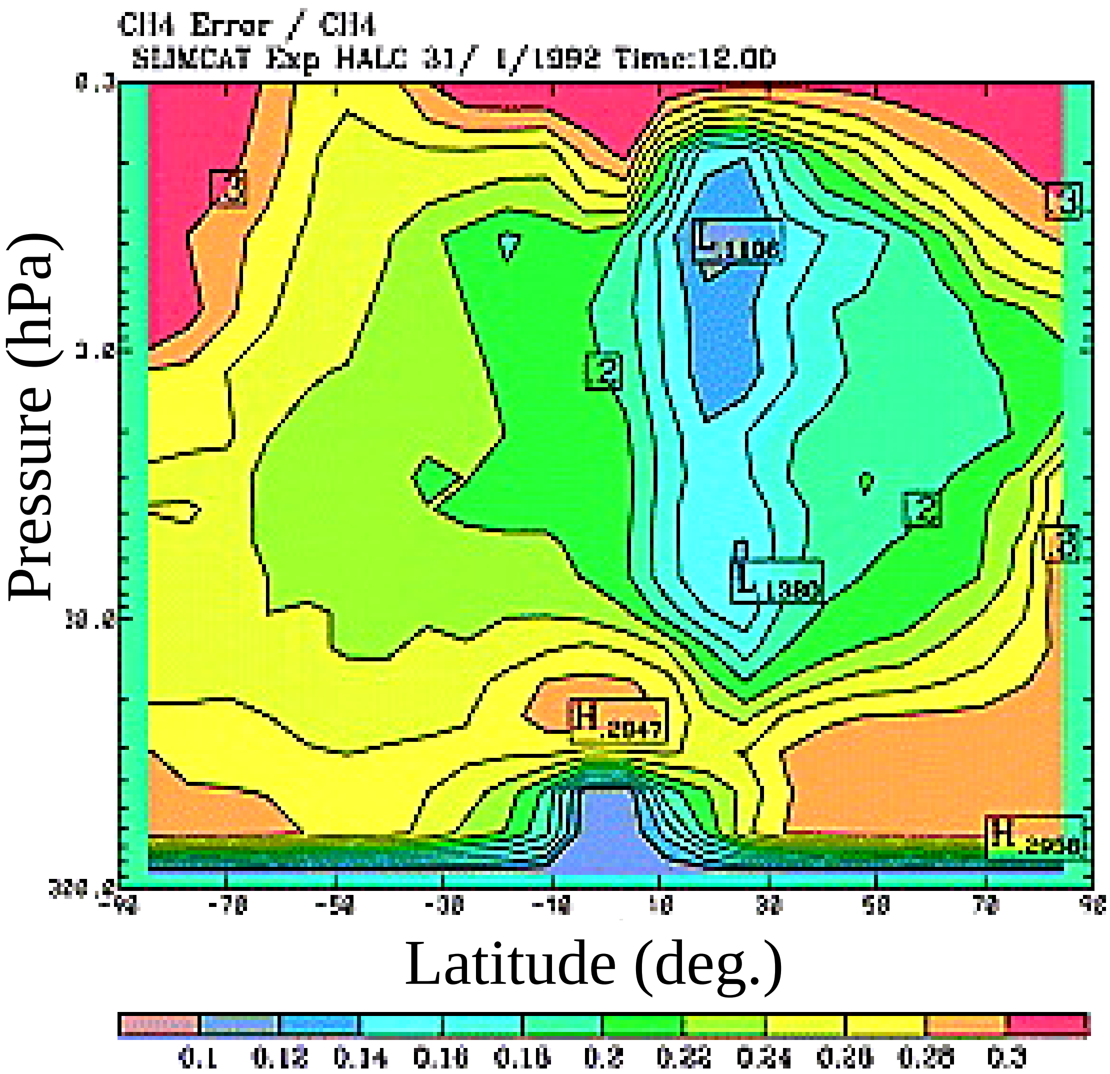
- **Antuna** JC, Robock A, Stenchikov G, et al. Spatial and temporal variability of the stratospheric aerosol cloud produced by the 1991 Mount Pinatubo eruption J GEOPHYS RES-ATMOS 108 (D20): Art. No. 4624 OCT 17 2003

Importance of error modeling



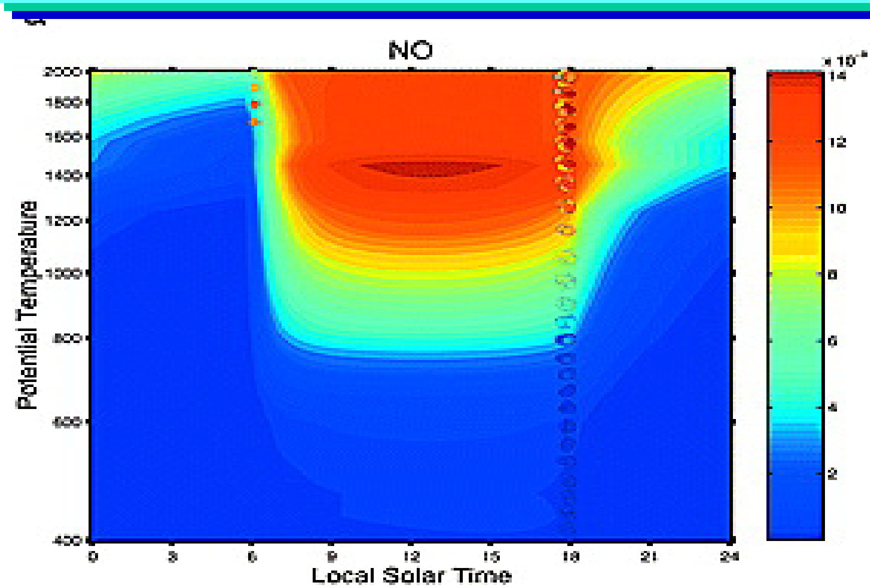
- Methane from CLAES (top) or **HALOE** (bottom) was assimilated for 5 days using Kalman Filter into a 2-dim. model on the 1100-K isentropic surface.
- HALOE data were available in the Tropics and around 72 N.
- CLAES data are available between 80S and 34N.
- With simple models for initial error covariances and without model error, the Kalman filter results for sparse HALOE data are not reliable, leading to unrealistic methane distribution (Menard et al).

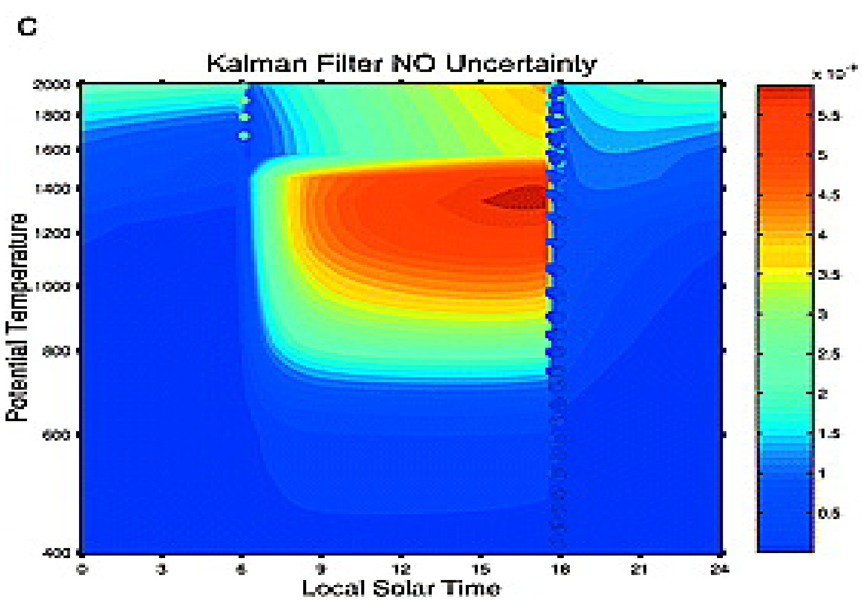
Local impact of data



- **HALOE** O_3, CH_4, H_2O, and HCl were assimilated into a 3-dim. chemical transport model.
- Zonal mean of the relative error in methane is shown after one month of assimilation.
- HALOE measurements at this time are around 20°N, where the analysis errors are reduced (Chipperfield et al).

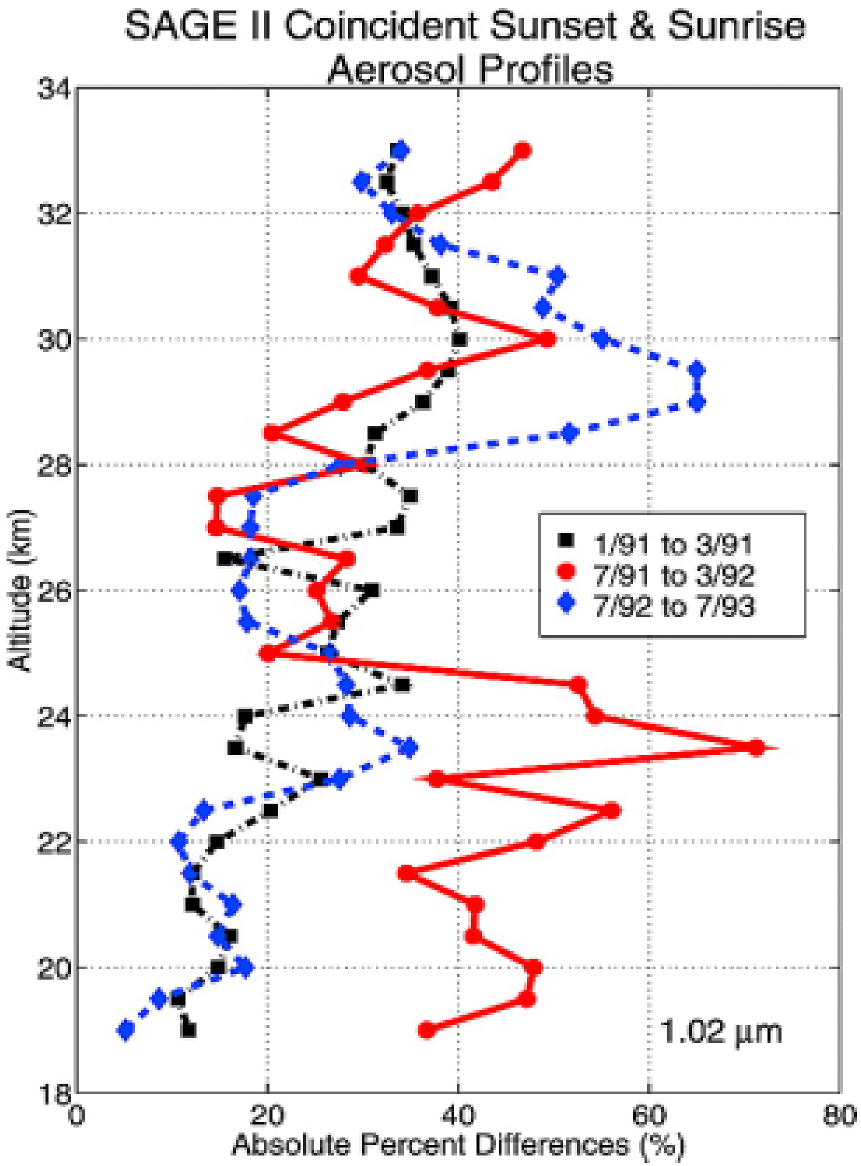
Local analyses





- One "profile" with equivalent potential vorticity latitude of 38°S is constrained through assimilation of nearby observations of 14 species by **ATMOS**.
- A full chemistry model is used to reconstruct the diurnal cycle in constituents and unobserved species from sunrise/sunset observations.
- The analysis error computed by the assimilation scheme decreases following the data insertion in the sequential Kalman filter scheme (Lary et al).

Quality control of data

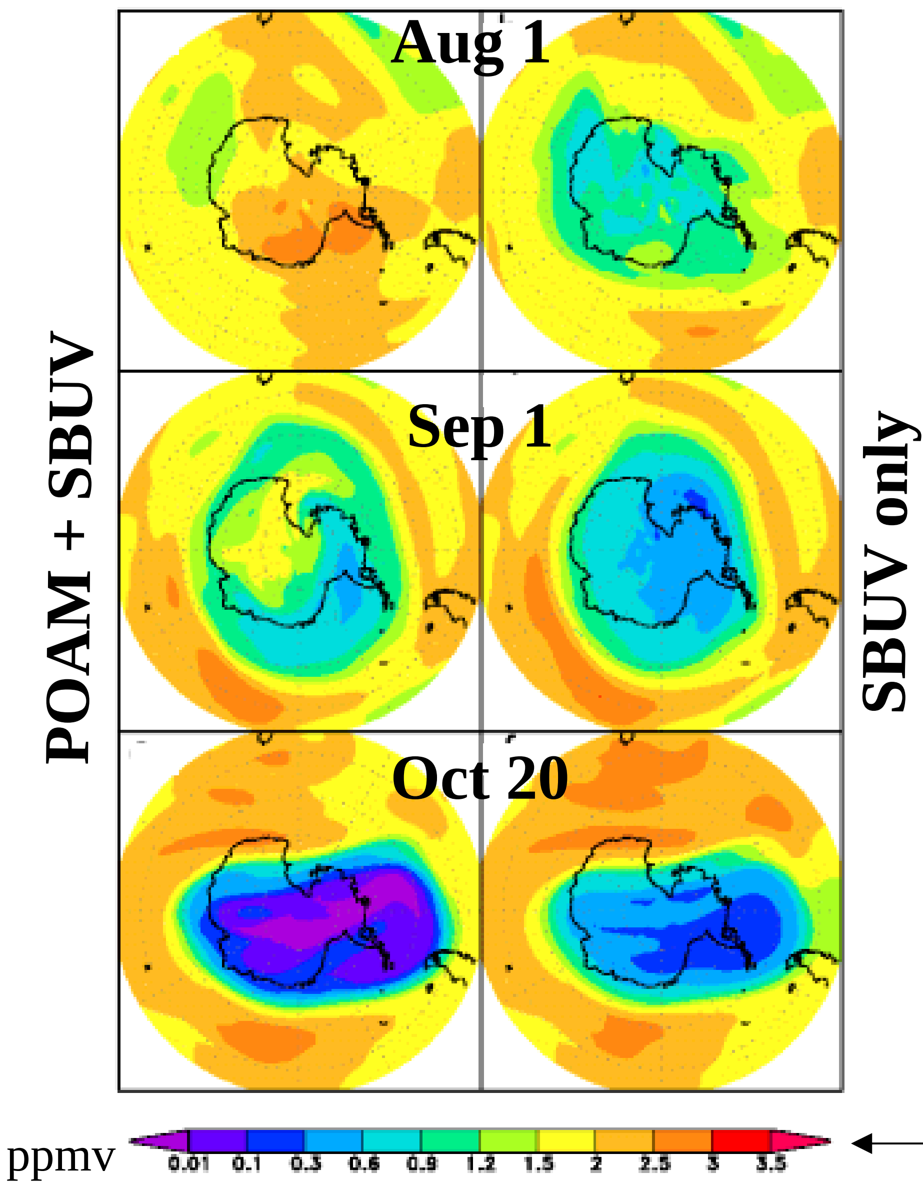


- In preparation for assimilation of **SAGE** aerosol profiles, they were inter-compared and compared with lidar measurements. Aerosol errors and spatio-temporal variability were evaluated.
- Large differences are seen below 25 km in the period after Mt. Pinatubo eruption (red).
- The findings are planned to be used in the quality control scheme in the assimilation of SAGE aerosol data (Antuna et al).

Regional constraint in global analyses

- HALOE data provides local constraints in global analyses. Data sparseness is an issue.
- **Polar ozone:**
  - Ozone assimilation often uses nadir measurements (TOMS, SBUV, TOVS, GOME) with limited resolution in the lower stratosphere, and no BUV measurements in the polar night.
  - Assimilation of IR or microwave limb sounders (MLS, MIPAS) helps to constrain polar ozone distribution.
- **Can POAM data be used in assimilation to constrain ozone distribution in polar regions?**

Polar ozone: impact of POAM

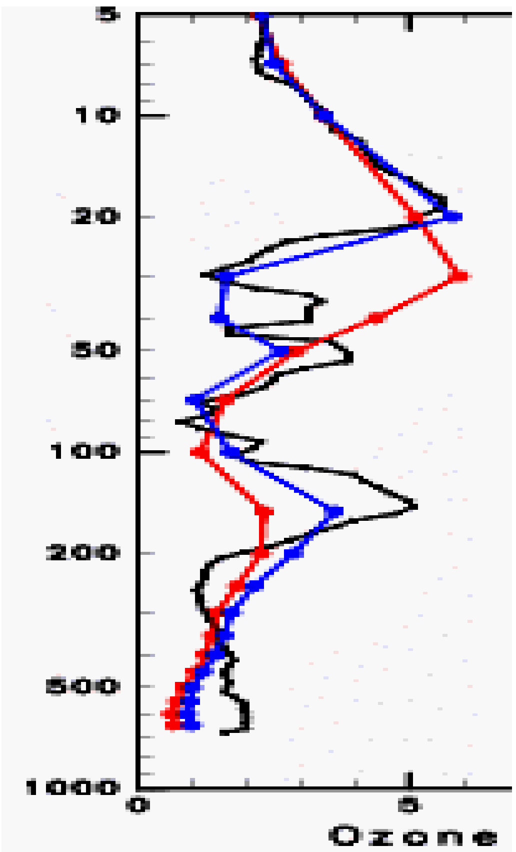


- Snapshots at 70 hPa for three days in year 1998 are shown for two assimilations: with POAM (left) and without POAM (right).
- Impact of POAM data is seen throughout the Antarctic vortex.
- A progression from a higher ozone within the vortex in wintertime, over a gradual loss near the vortex edge in springtime, to the full depletion later in the spring is seen.

← Note nonlinear scale

Assimilation vs sonde at S. Pole

19980928



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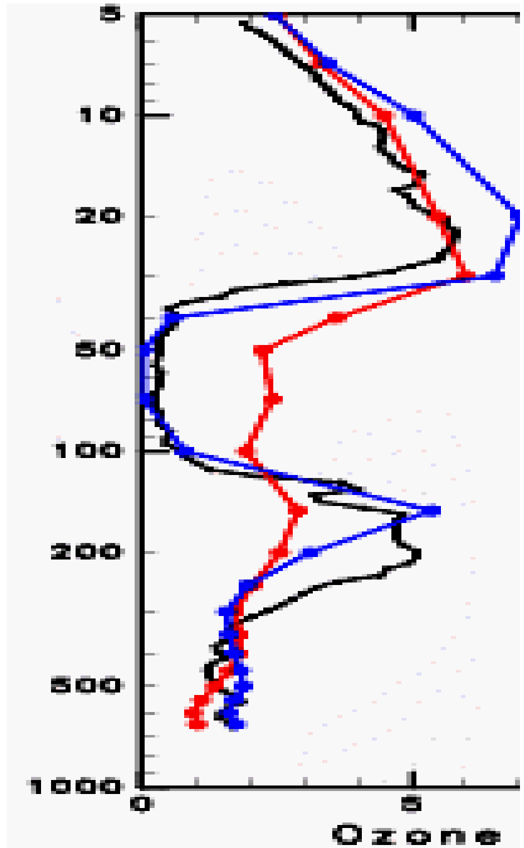
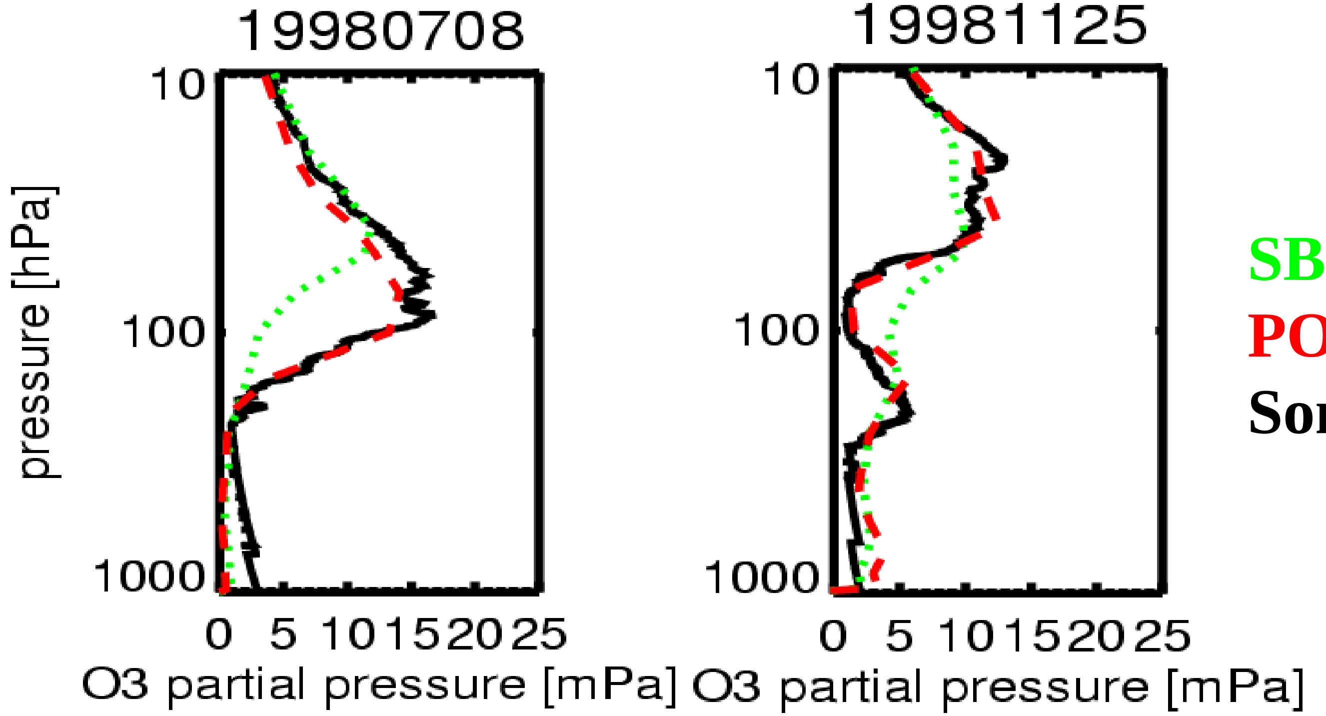


SBUV assim
POAM+SBUV assim
S. Pole ozone **sonde** (mPa)

GMAO assimilation of SBUV/TOMS ozone has long data voids in polar night regions.

- Profile shape in the “ozone hole” is better constrained with POAM data (even the double minima on 9/28).

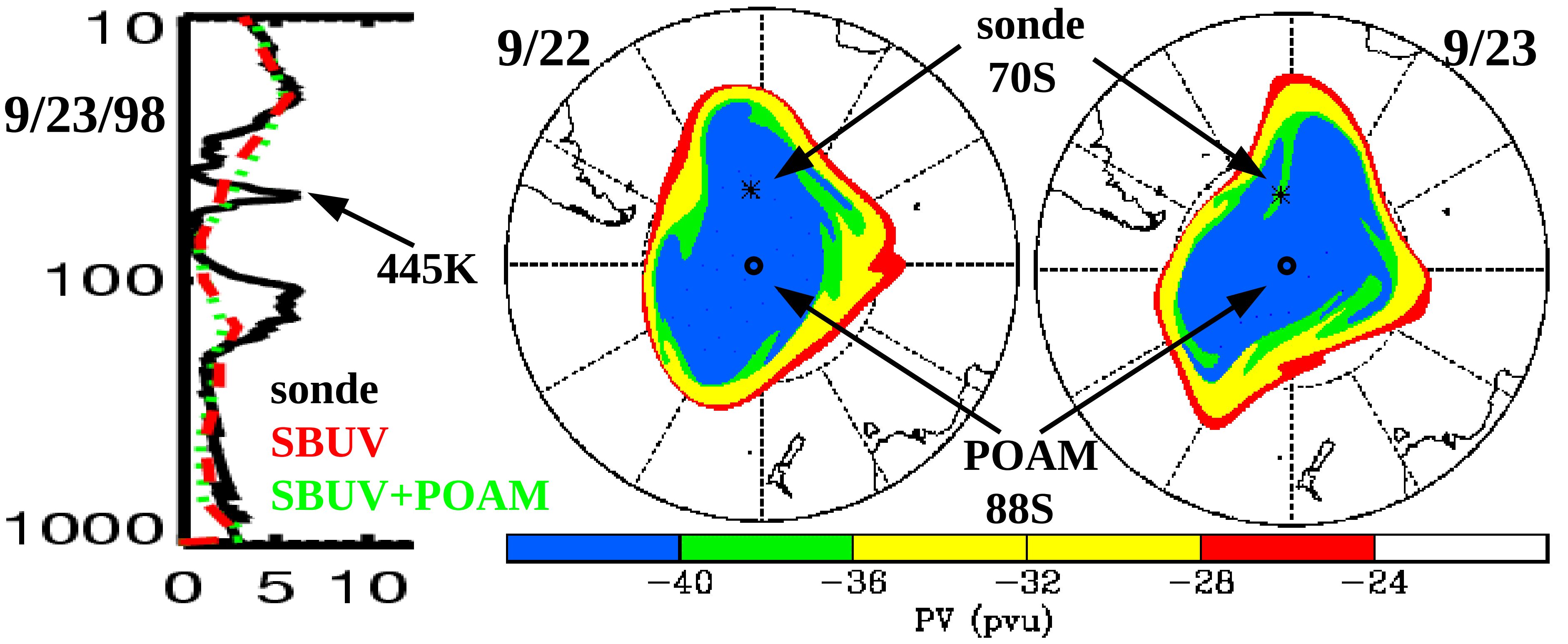
Assimilation vs sonde at Neumayer



SBUV assim.
POAM+SBUV assim
Sonde at 70S

- **POAM** assimilation captures wintertime accumulation (left) and springtime depletion (right) of ozone.
- In the lower stratosphere the agreement with Neumayer sonde profiles improved substantially.

Lamina at Neumayer



- A shallow laminar feature is generated at the inner edge of the vortex (Moustaoui et al QJ 2003).
- This lamina is not observed by POAM (which is at 88S), and it is not seen in assimilation.

Conclusions

Solar occultation data:

- Excellent validation data sets
- Limited spatial and temporal coverage poses challenges in assimilation
- Assimilation of long-lived species or over limited regions was successful
- In assimilation need to carefully model errors and interpret results in the context of the limited spatial coverage of measurements

Conclusions, continued

Assimilation of POAM ozone:

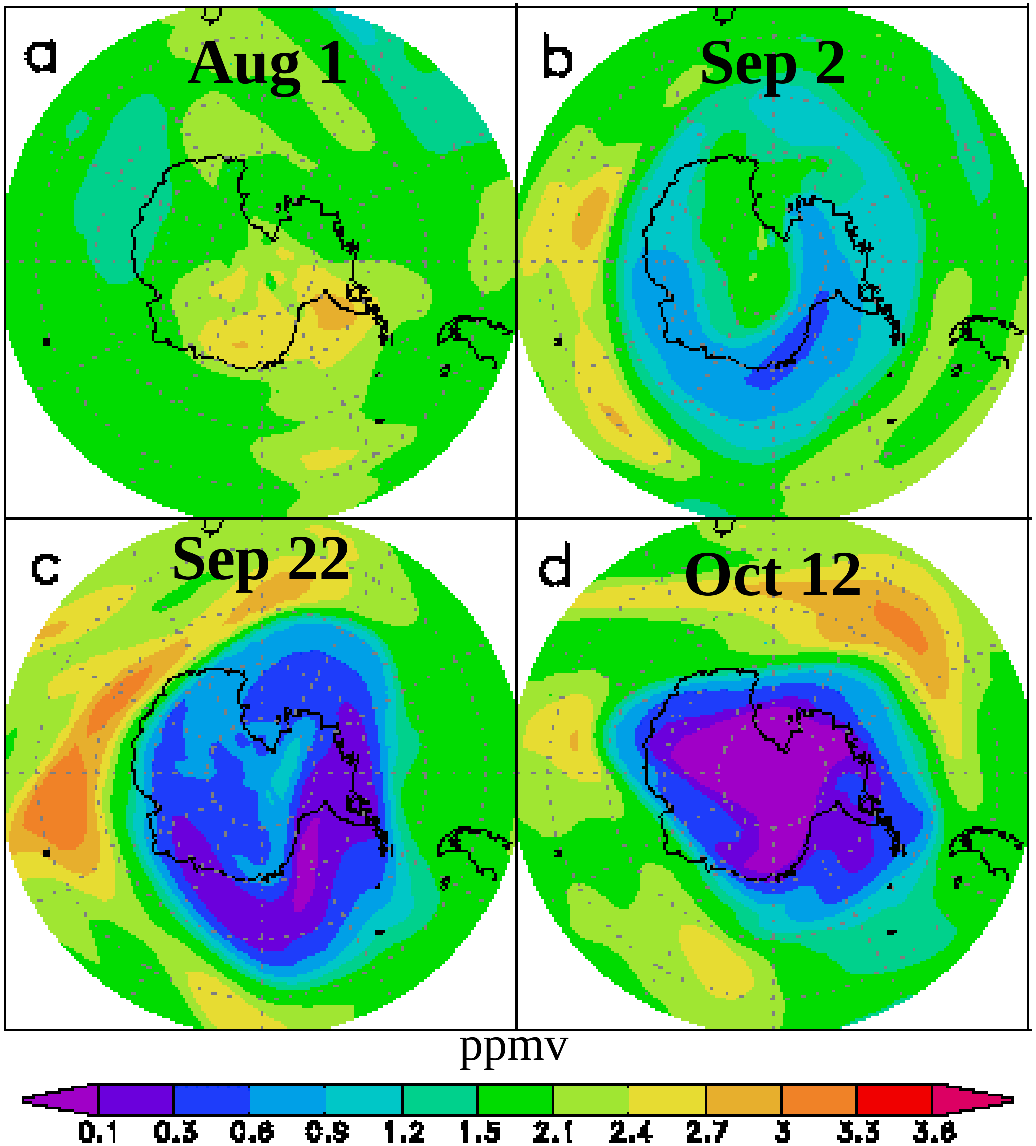
- A large impact was seen in the polar night, throughout the Antarctic vortex.
- Qualitative improvements were seen in the evolution of the polar ozone distribution in comparison with SBUV-only assimilation.
- The agreement between independent ozone sondes and assimilation improved substantially.
- Near-real time availability of POAM data would likely increase their role in ozone assimilation.

Extra slides

Assimilation of occultation data

We review applications of solar occultation data in the assimilation of atmospheric constituents. Solar occultation data are invaluable in evaluation and validation of global assimilated constituent fields, which are often obtained by assimilation of operationally available data from nadir viewing instruments. A limited coverage of occultation data presents challenges when they are assimilated. We highlight these challenges and ways of overcoming them in the assimilation framework. With sparse data sets several issues in error modeling, representativeness, and how well the global fields are constrained need to be addressed. Examples from assimilation of long-lived and active chemical species will be given. The examples range from global two- or three-dimensional systems, over imposing additional regional constrains in global systems, to assimilation into a single model profile. Their success indicates benefits of assimilation of historical occultation data. However, many constituent assimilation systems, especially for ozone, are running in near-real time, and even providing forecasts. The use of occultation data in assimilation would likely increase if they were available in operational, near-real-time fashion.

Regional constraint in global analyses



- We assimilated **POAM** and SBUV ozone to constrain polar regions.
- Snapshots at 70 hPa for four days in year 1998 are shown.
- A progression from a higher ozone within the vortex in wintertime, over a gradual loss near the vortex edge in springtime, to the full depletion in late spring is seen.

- **Evaluation of transport**
- **Sparling** LC Statistical perspectives on stratospheric transport REV GEOPHYS 38 (3): 417-436 AUG 2000
- **Rood** RB, Douglass AR, Cerniglia MC, et al. Seasonal variability of middle-latitude ozone in the lowermost stratosphere derived from probability distribution functions J GEOPHYS RES-ATMOS 105 (D14): 17793-17805 JUL 27 2000

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- **Pierce** et al - ozone
- **Robock** et al – stratospheric aerosols
- **Antuna** JC, Robock A, Stenchikov G, et al. Spatial and temporal variability of the stratospheric **aerosol** cloud produced by the 1991 Mount Pinatubo eruption J GEOPHYS RES-ATMOS 108 (D20): Art. No. 4624 OCT 17 2003
- **Stajner** et al - ozone

Evaluation of transport processes

Validation of assimilated winds used in the chemistry and transport models

Statistical properties of constituent distribution in occultation data and models are compared:

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