Synergistic Impact of Aerosols and Clouds On Photochemistry in GMI: A First Look

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Objectives

- To **compare** the radiative effects of aerosols [*Martin et al.,* 2003] verus clouds [*Liu et al.,* 2006] on trop photochemistry
- To **assess** the synergistic impact of aerosols and clouds on global & regional trop photochemistry

GMI Model Experiments

- Tropospheric full-chemistry model; driven by DAO, GISS II', fvGCM, and GEOS4-DAS meteorological fields (4^ox5^o);
- Photolysis rate calculation: **Fast-J** [*Wild et al.,* 2000];
- Monthly mean dry aerosol mass (offline) from GOCART; AOD calculated from the mass concentration, extinction efficiency, and particle mass density [*Martin et al.,* 2003];
- Cloud optical depth and cloud fraction from met fields;
- GMI model simulations:
  - ✓ With aerosols, with clouds
  - ✓ Without aerosols, with clouds
  - ✓ With aerosols, without clouds
  - ✓ Without aerosols, without clouds

Model Representations of the Vertical Coherence of Clouds

- **LIN:** Linear Assumption [Wild et al., 2000] (GMI standard))

$$\tau_c' = \tau_c \cdot f$$

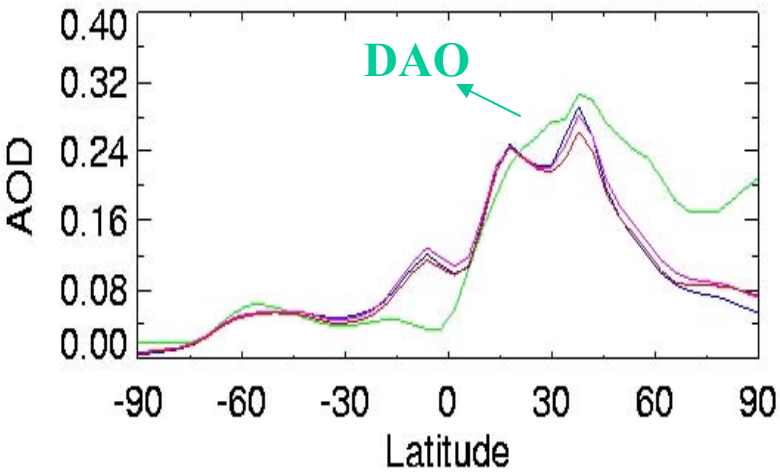
grid-scale OD in-cloud OD cloud fraction

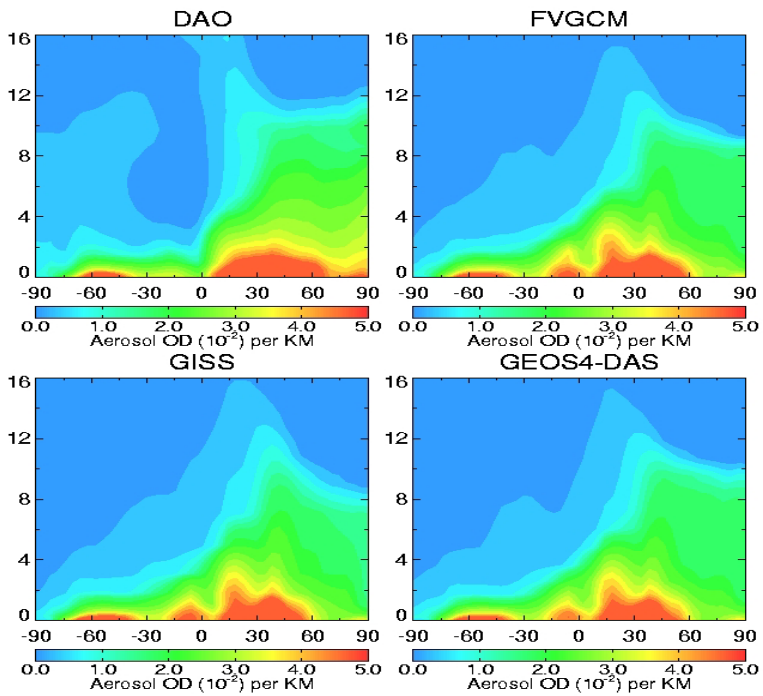
- **RAN:** Approximate Random Overlap [Briegleb, 1992]

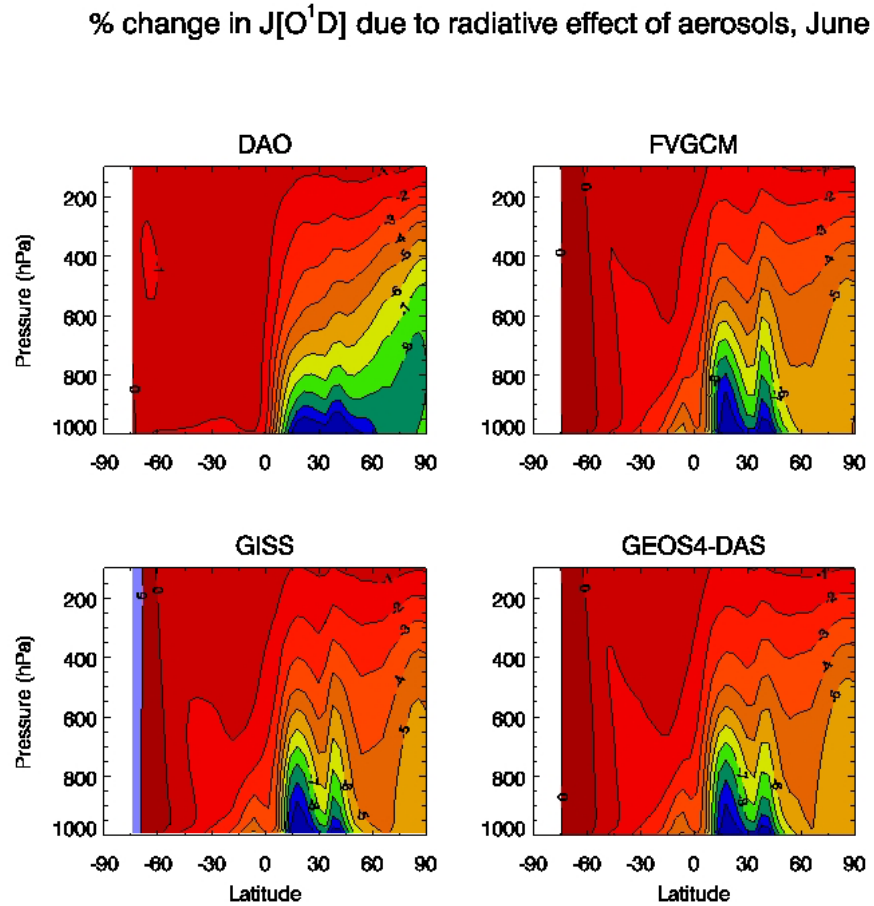
$$\tau_c' = \tau_c \cdot f^{3/2}$$

In terms of cloud effects on J[O^1D] and J[NO_2], on average, RAN and Maximum-Random Overlap differ by only ~2% throughout the troposphere [Liu et al., 2006].

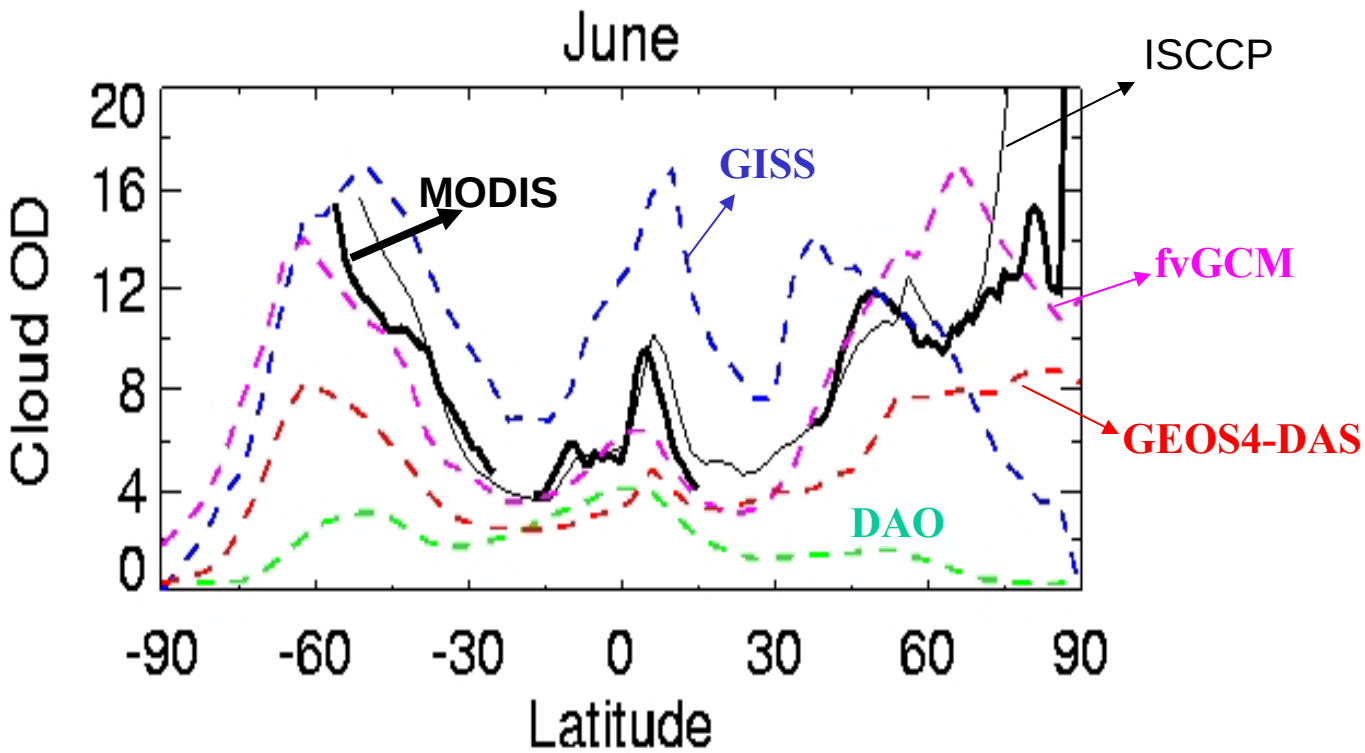
AOD and Effect on J[O^{1}D] (June)







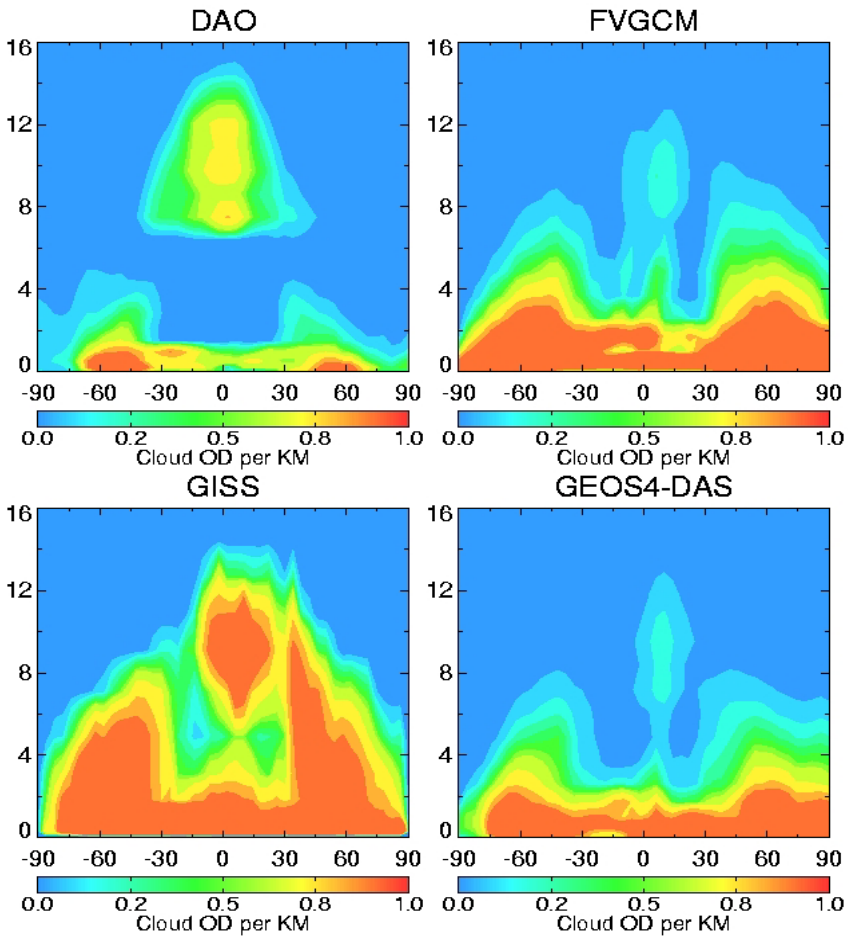
Monthly Zonal Mean Cloud Optical Depth (June)



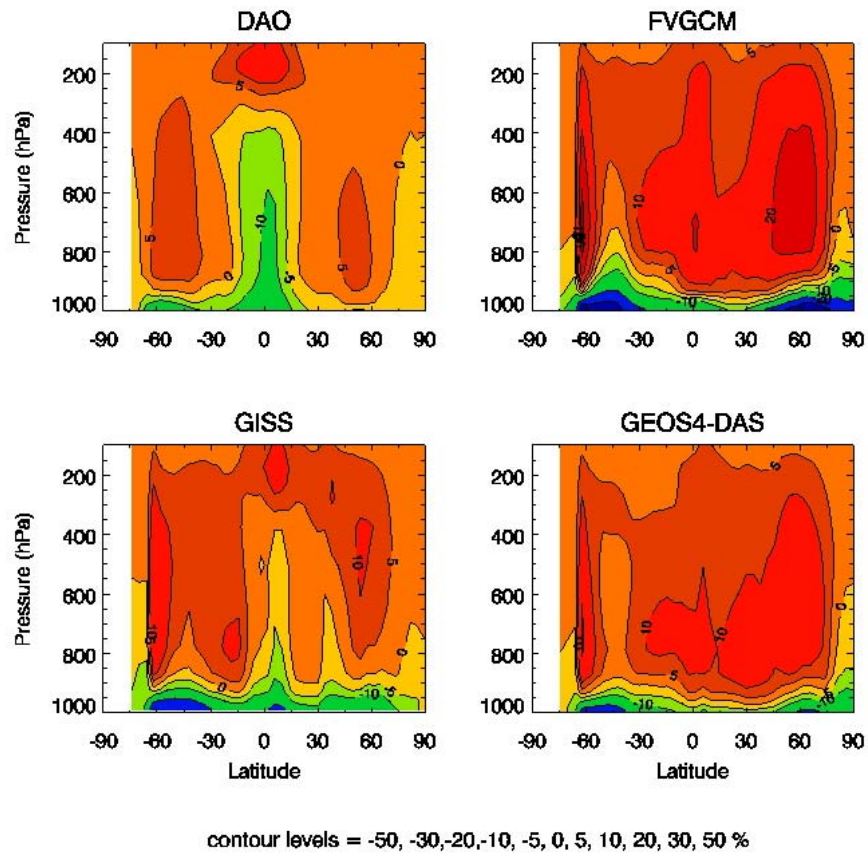
fvGCM column CODs are overall most close to MODIS and ISCCP CODs.

Cloud Optical Depth and Effect on J[O^{1}D] (June)

cloud optical depth

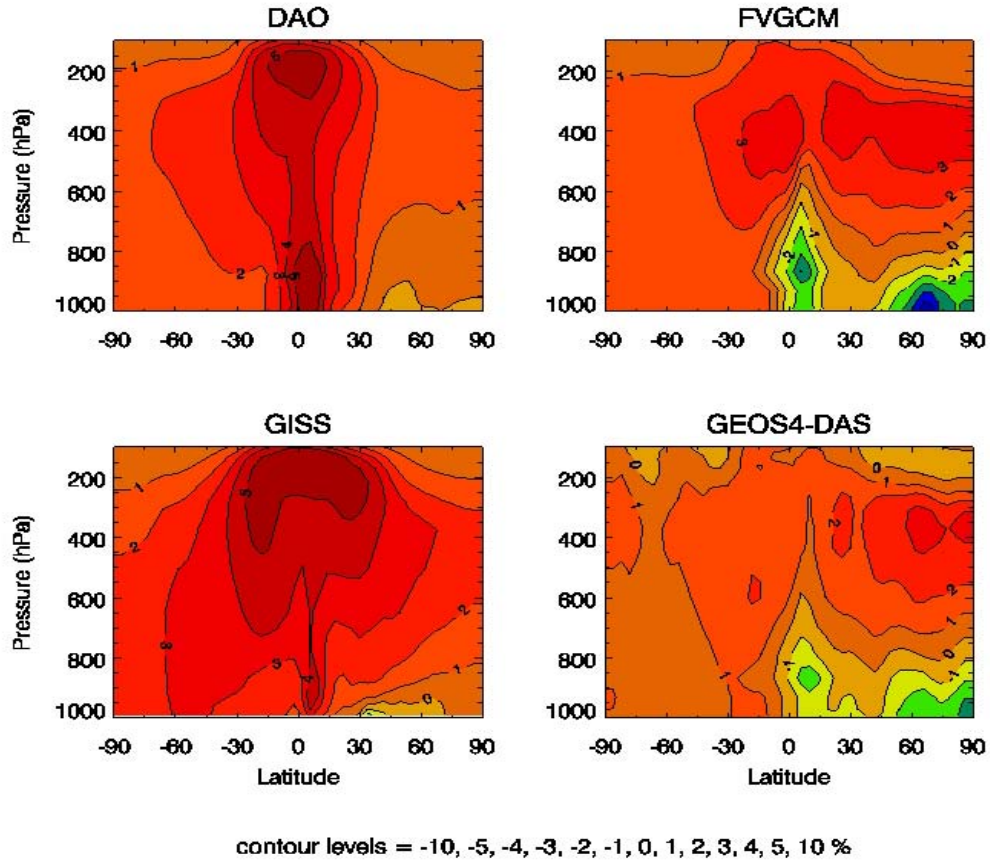


% changes in J[O^{1}D] (LIN)



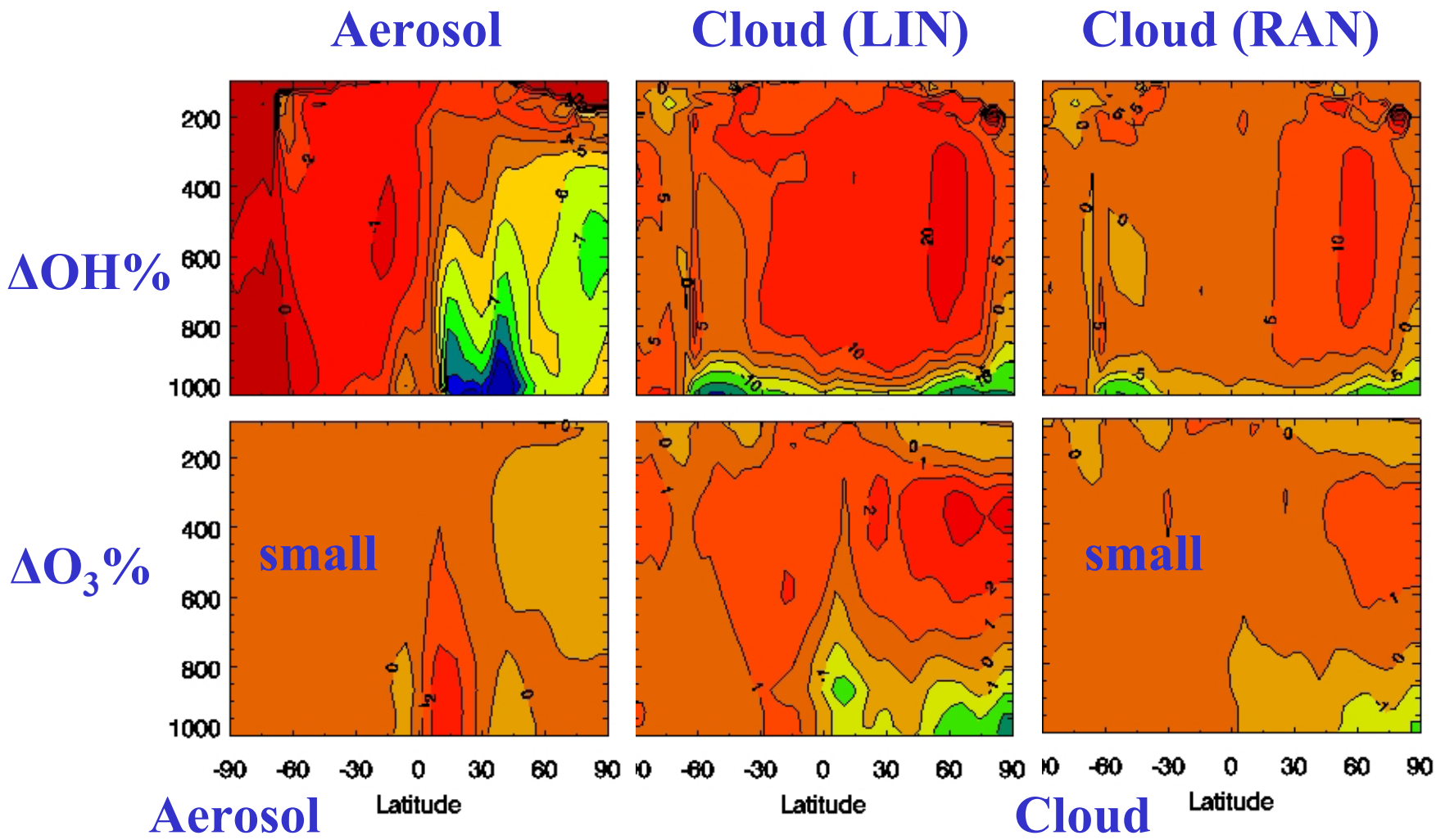
Tropical UT: optically much thinner in fvGCM / GEOS4-DAS

Radiative Effects of Clouds on Ozone (% changes in ozone, LIN, June)



- **Effects on tropical UT O_3: ~5% or less for all met/cloud fields; using RAN (vs LIN) for cloud overlap yields even lower effects.**
- **Sensitivity similar to results from GEOS-Chem driven by GEOS-3 [Liu et al., 2006], but much less than those from MOZART-2 (~20-30%) [Tie et al., 2003].**

Radiative Effects of Aerosols vs Clouds on OH and O_3
GEOS4-DAS, June



Aerosol

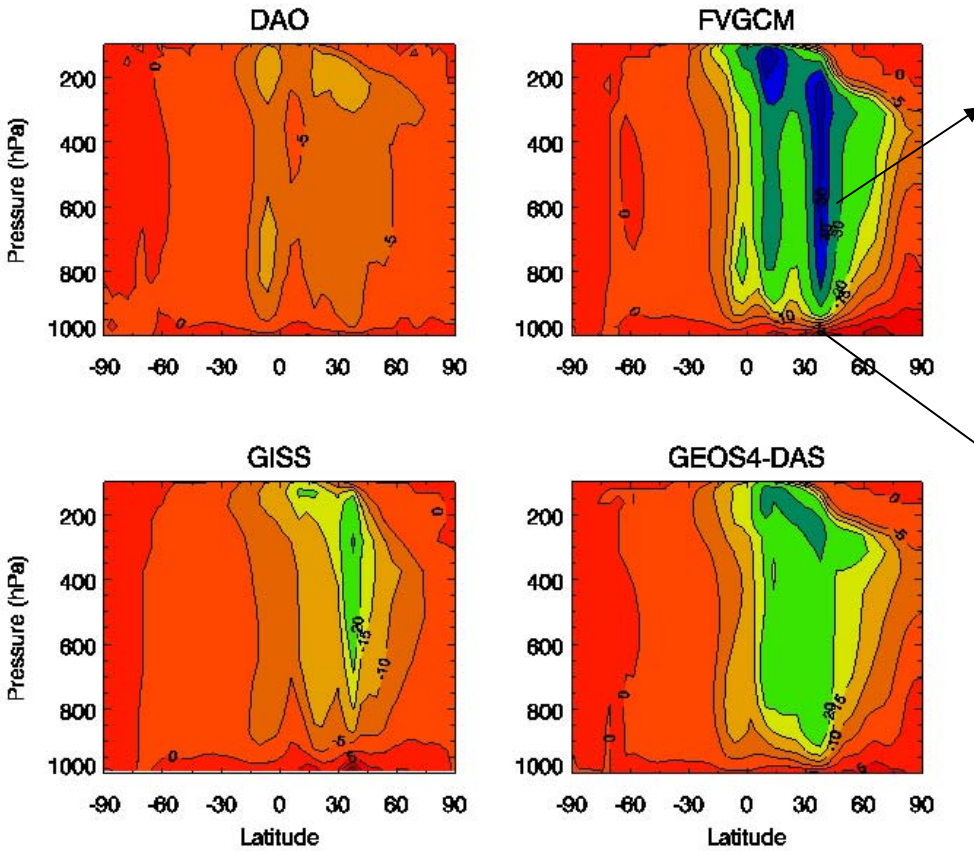
- Decrease OH throughout trop;
- Effects comparable to those of clouds near surface at NH mid-latitude;
- Small effect on global ozone.

Cloud

- Enhance (reduce) OH above (below) low level thick clouds;
- Vertical distributions (high clouds) are highly uncertain among models;
- Small effect on global ozone.

Effect of Clouds on Aerosol Radiative Impact on OH (June)

$(OH_{aero} - OH_{noaero})_{cloudy} - (OH_{aero} - OH_{noaero})_{clear}$



contour levels = -60, -50, -40, -30, -20, -15, -10, -5, -0, 5, 10, 15, 20 e-16 VMR

Negative values:
The aerosol effects are <u>enhanced above</u> the low level thick clouds over those under cloud-free conditions.

Positive values:
The aerosol effects are <u>reduced below</u> the low level thick clouds over those under cloud-free conditions.

- **Less synergy between cloud and (absorbing) aerosols in DAO/GISS is partly due to optically thicker clouds in UT.**
- **<u>Regional</u> analysis of the synergistic effect is to be conducted.**