WACCM simulations of the mean circulation linking the mesosphere and thermosphere

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trace species transport in the middle atmosphere

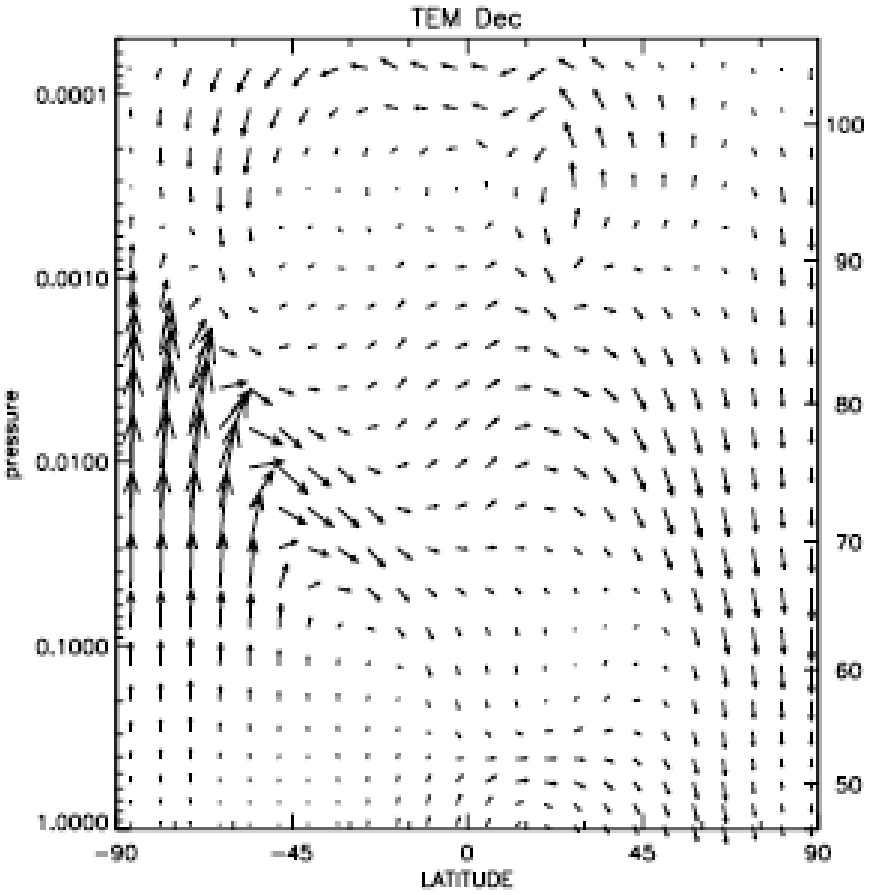
- wave driven mean circulation (transformed Eulerian mean = residual circulation), includes mass transport by resolved waves and GWD
- eddy diffusion from unresolved parameterized gravity waves
- molecular diffusion, including species-dependent net vertical drift
- chemical eddy transport by resolved waves (different from mass transport)

- FOCUS TODAY: transformed Eulerian mean circulation determined from monthly mean output (1960-2005)

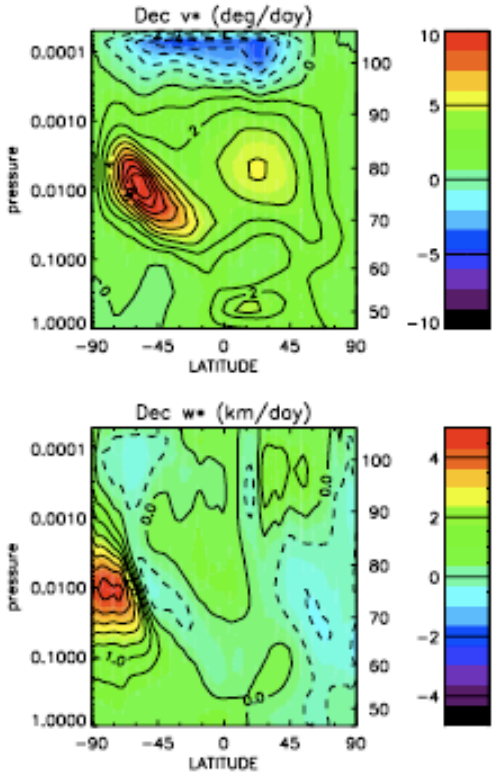
v* and w* vectors, December mean 1960-2005

winter to summer
w* strongest
away from poles

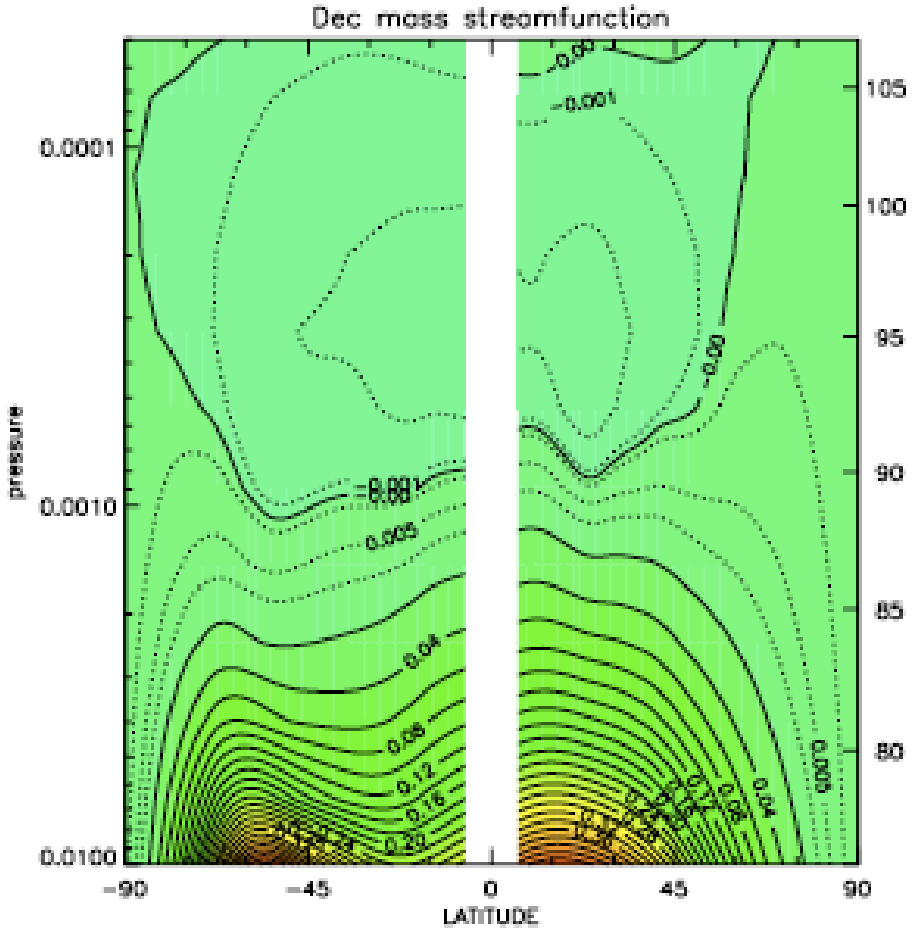
summer to winter
w* strongest
near poles



magnitudes of v* and w*



mass streamfunction, December mean 1960-2005

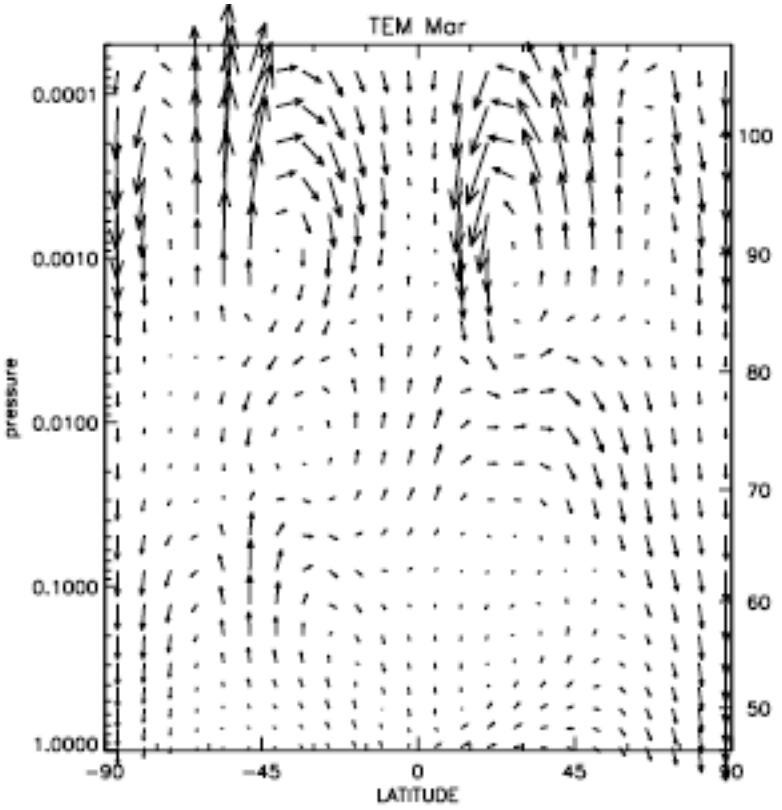


<u>air parcels transported by TEM</u>

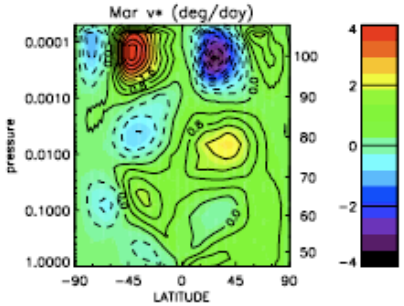
- polar winter air originates in
  - summer mesosphere
  - summer thermosphere
- diffusion moves air across streamlines

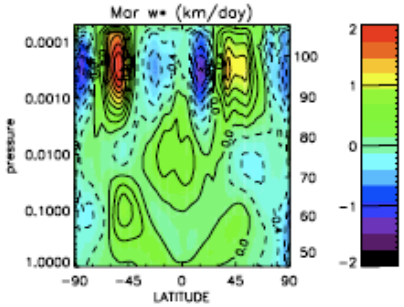
NOTE: These are instantaneous streamlines – they change with the seasonal cycle as the air parcels are being transported.

for comparison: equinox TEM & mass streamfunction

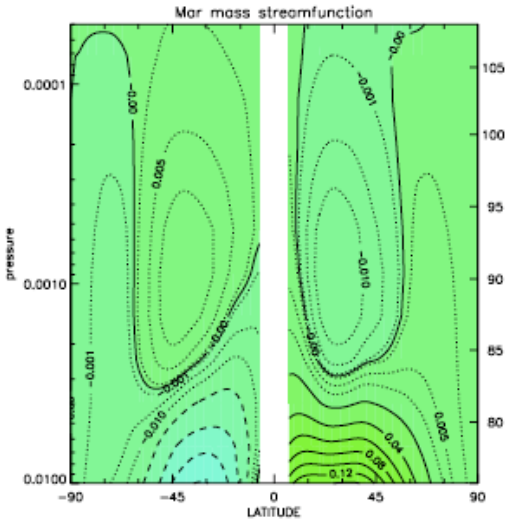


downward at both poles throughout MLT





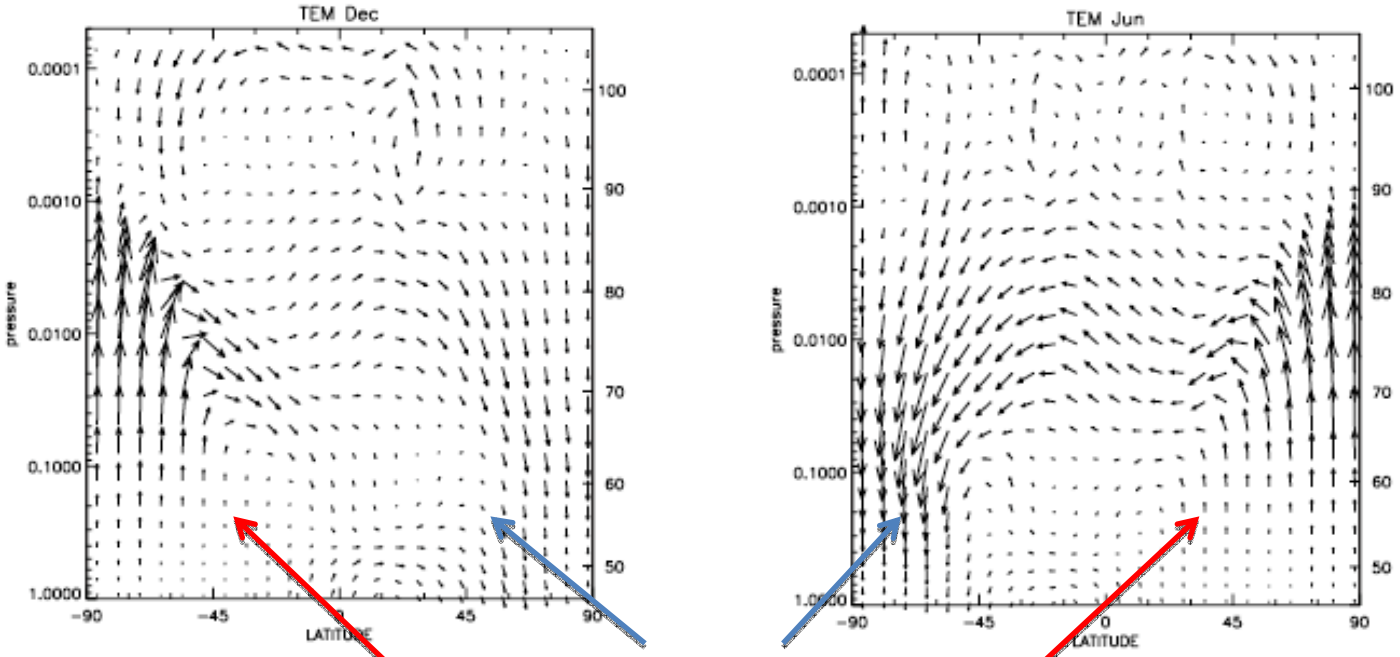
(Dec ranges are 10 deg/day and 5 km/day)



hemispheric comparison

December

June

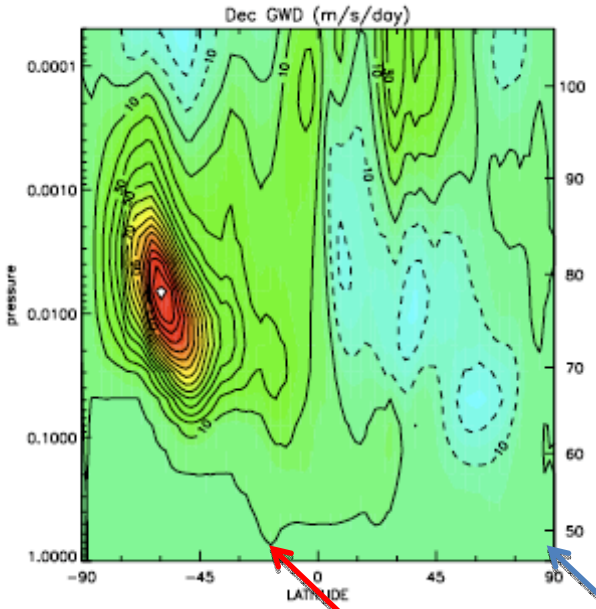


in winter, SH is stronger

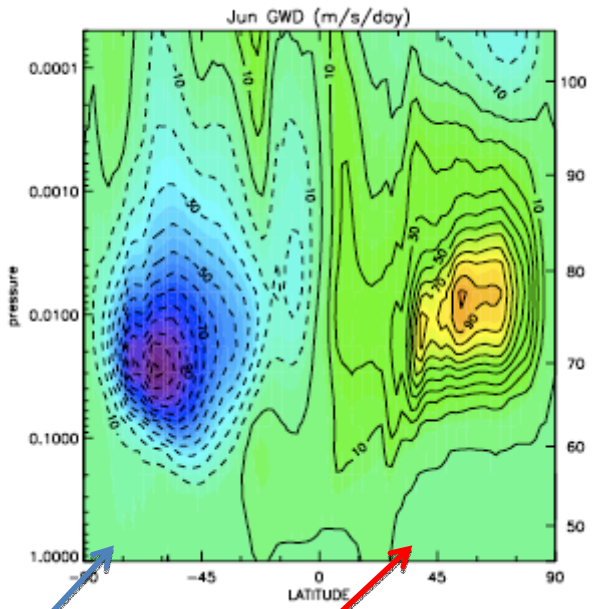
in summer, SH is stronger

the reason: gravity wave drag

December



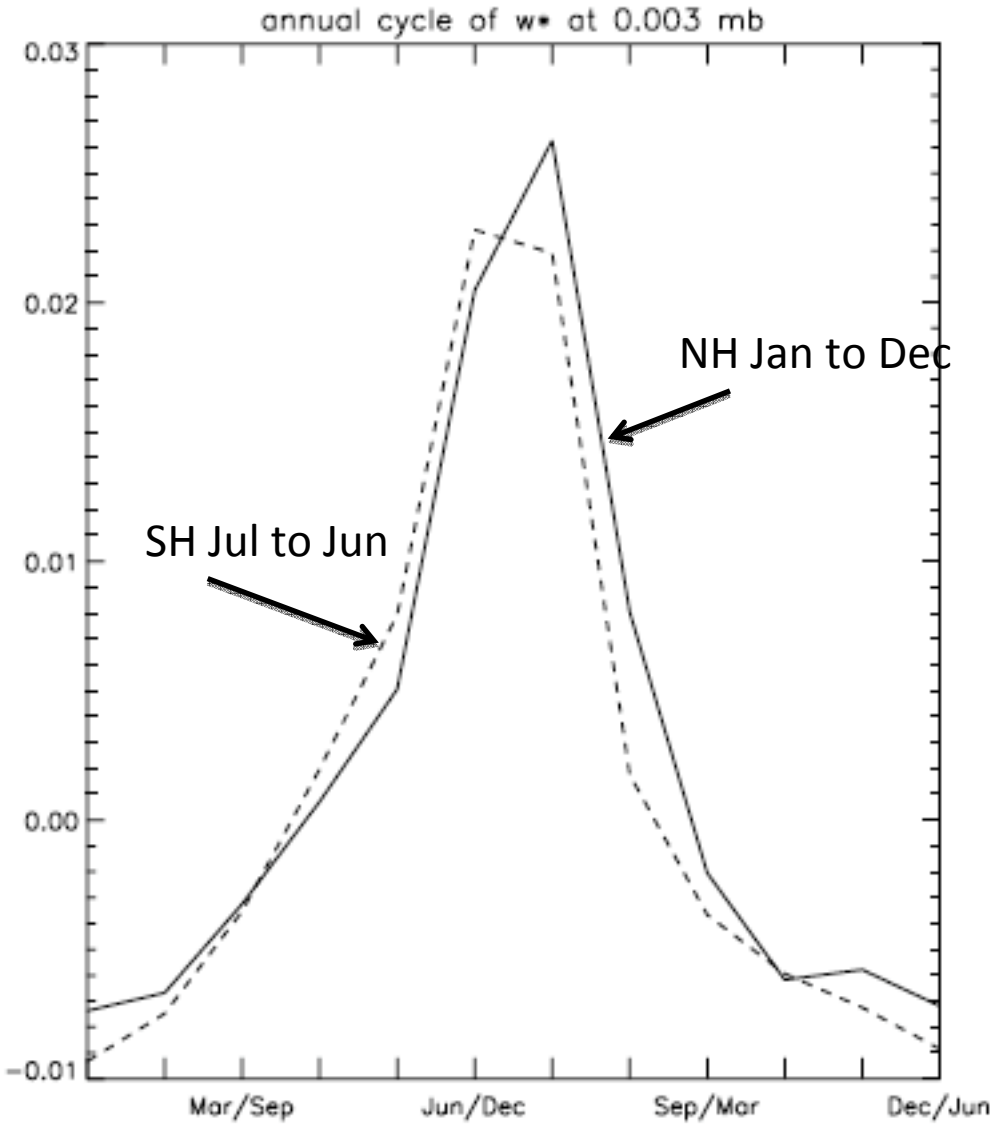
June



SH is stronger in winter

SH is stronger in summer

hemispheric differences in timing



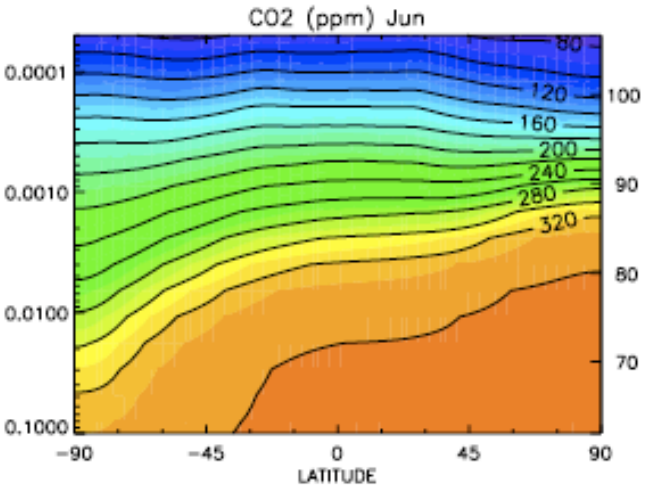
based on monthly mean data

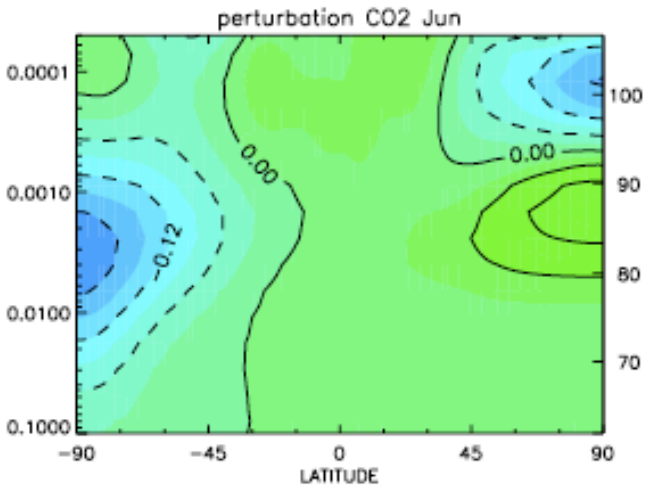
winter max (downward) similar
- NH December
- SH June

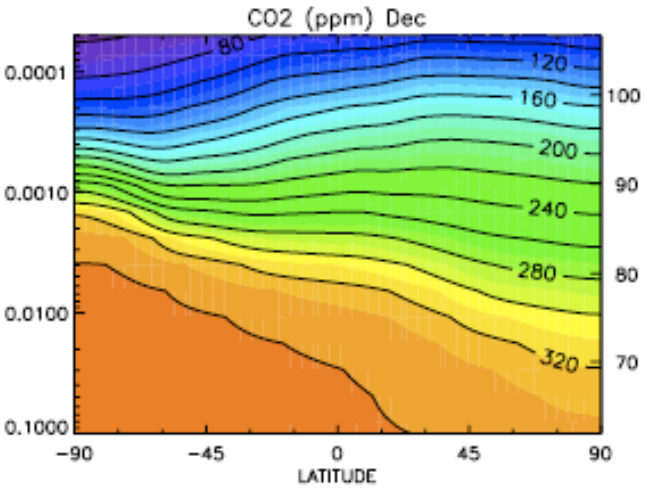
summer max (upward) offset
- NH July
- SH December

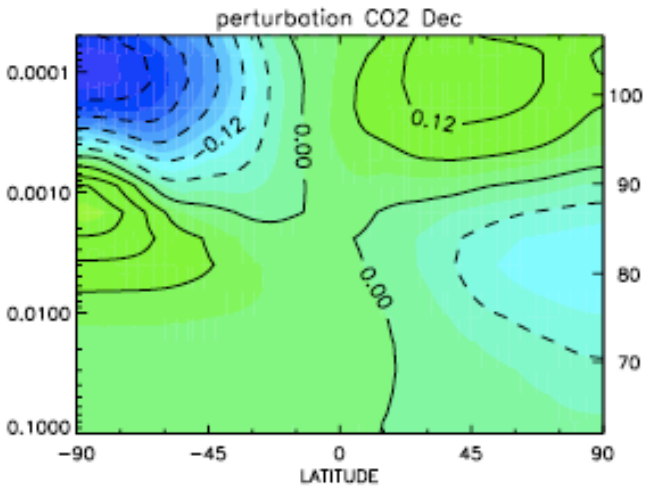
equinoxes also offset
- SH earlier than NH

impact on trace species distributions: CO_2







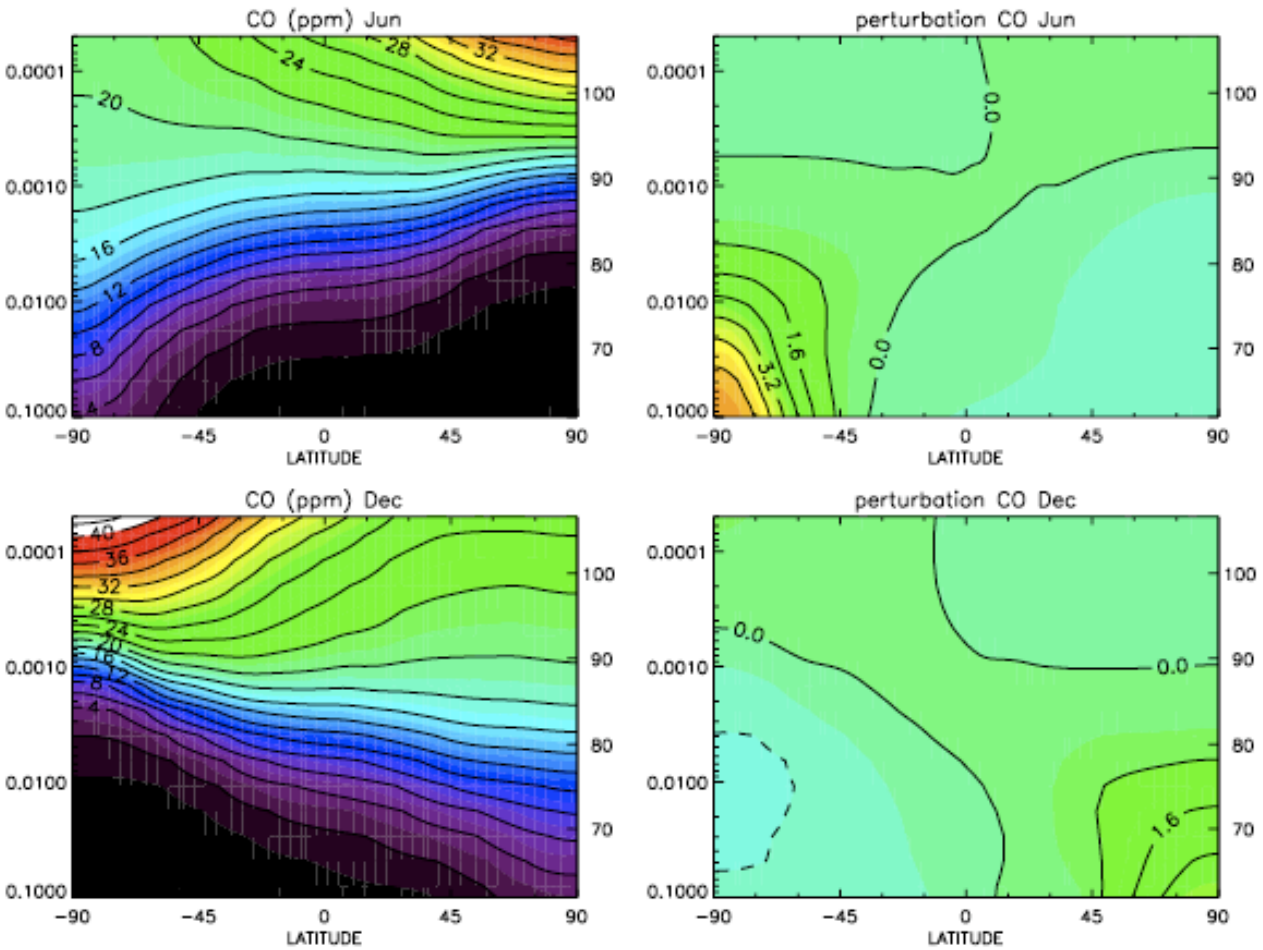


fractional perturbation from global mean

checkerboard pattern of perturbation illustrates reversal of circulation cell

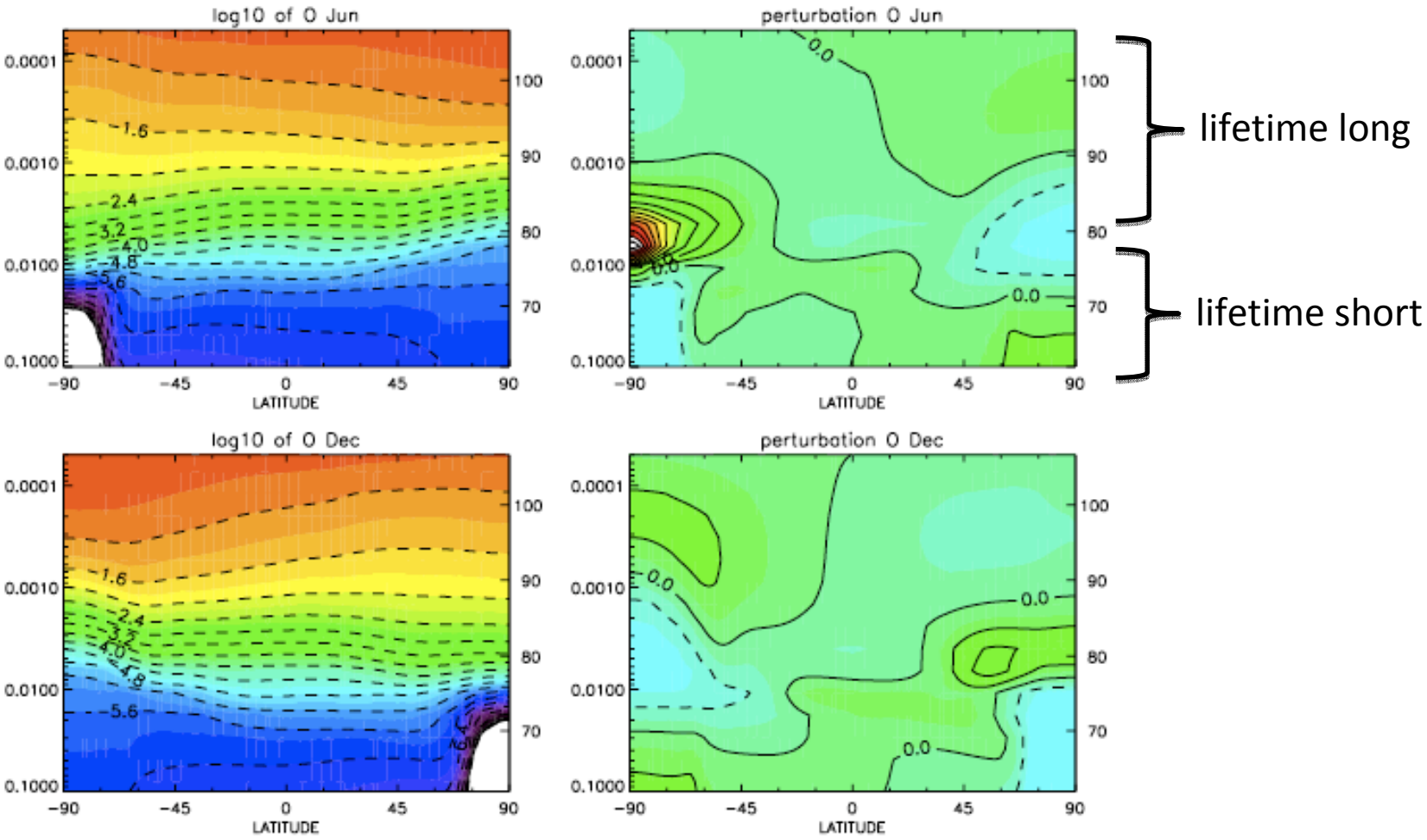
larger perturbations in SH
max≈30%

likewise for CO distribution



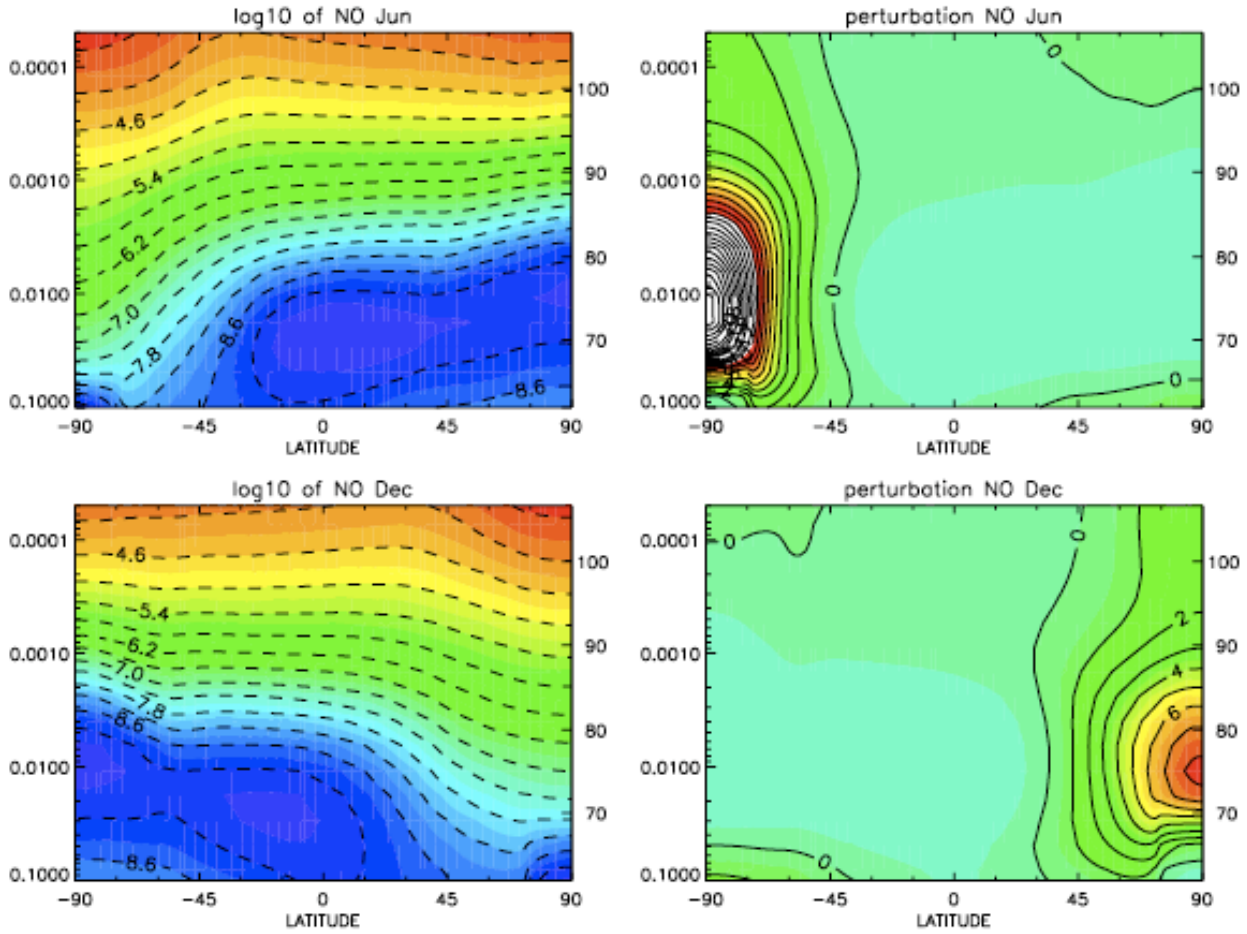
largest perturbations in SH
max≈500%

and for O distribution



largest perturbations in SH
max≈500%

but NO does not have a checkerboard pattern

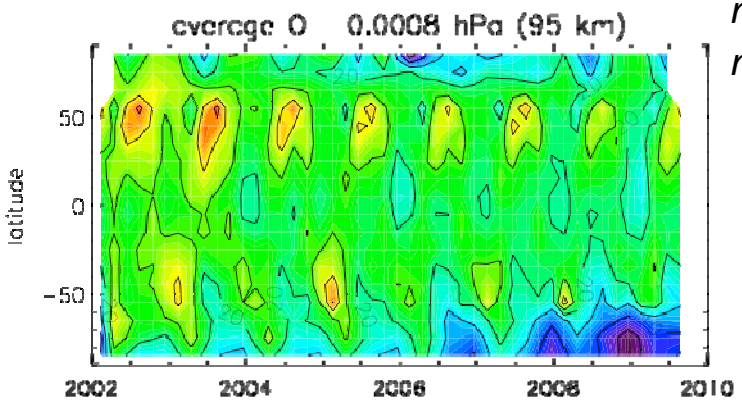


largest perturbations in SH
max≈3000%

comparison of WACCM and SABER O at 2 levels

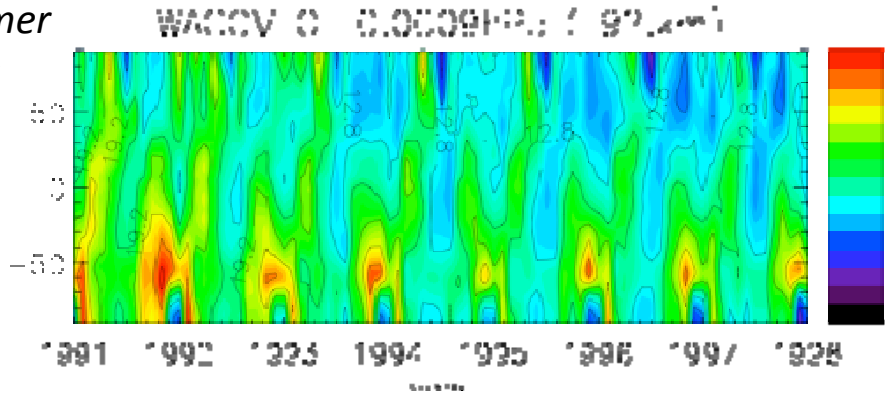
latitude x time (multiyear)

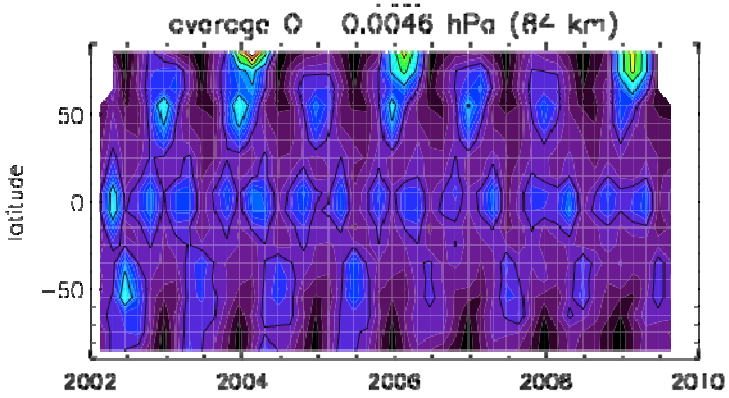
SABER



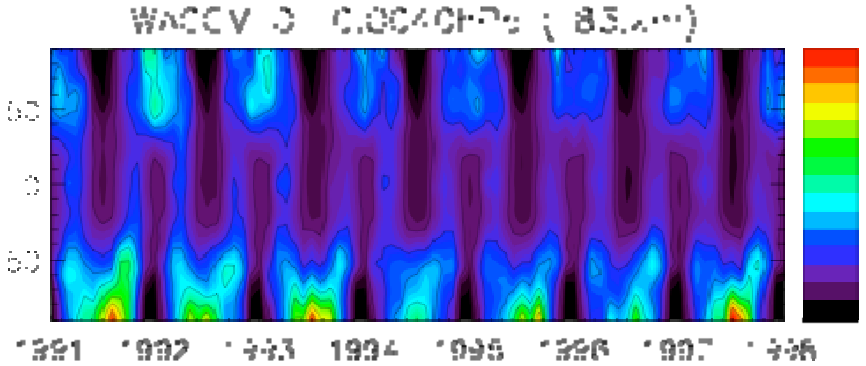
max in summer midlatitudes

WACCM





max at winter pole



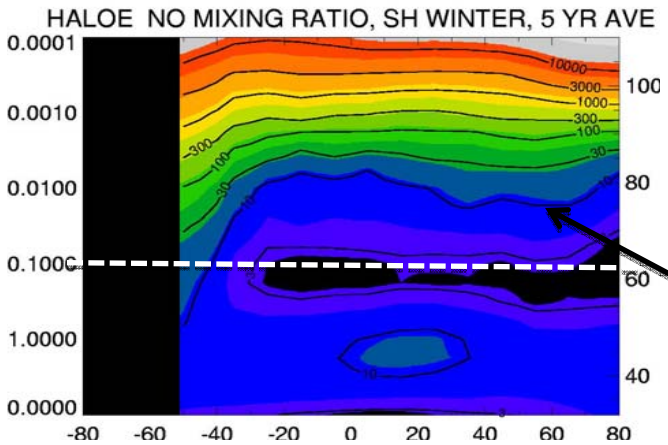
more O in NH

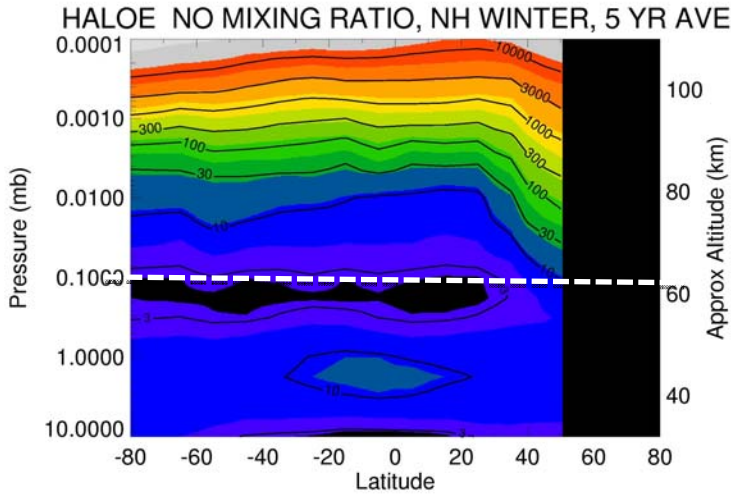
more O in SH

➡ Basic seasonal cycle is OK but hemispheric difference is backwards.
REASON: not known

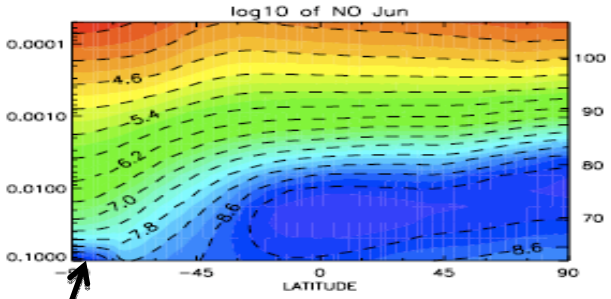
comparison of WACCM and HALOE NO

HALOE (from Siskind's tutorial)

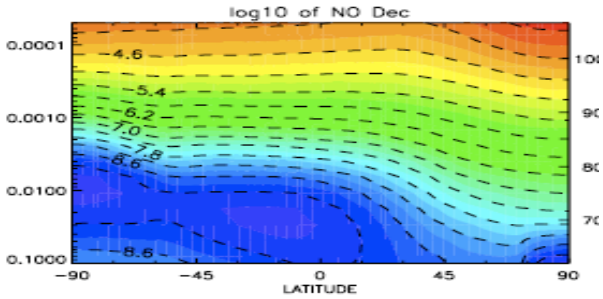




WACCM

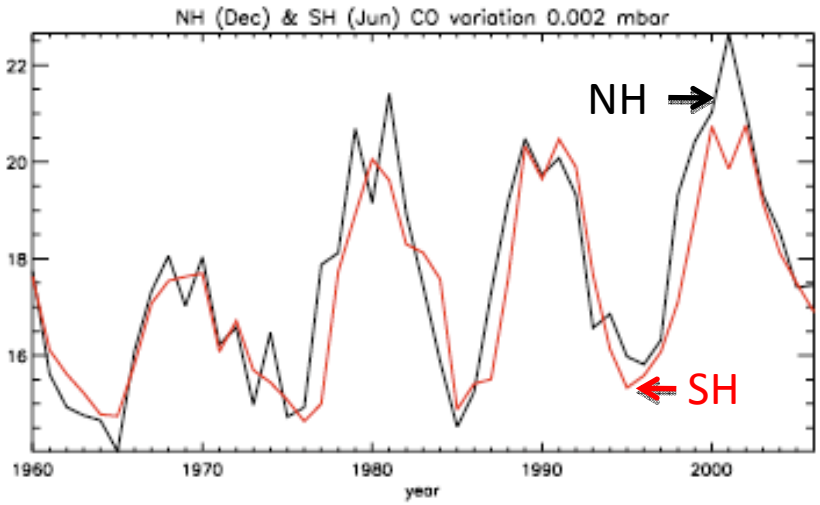


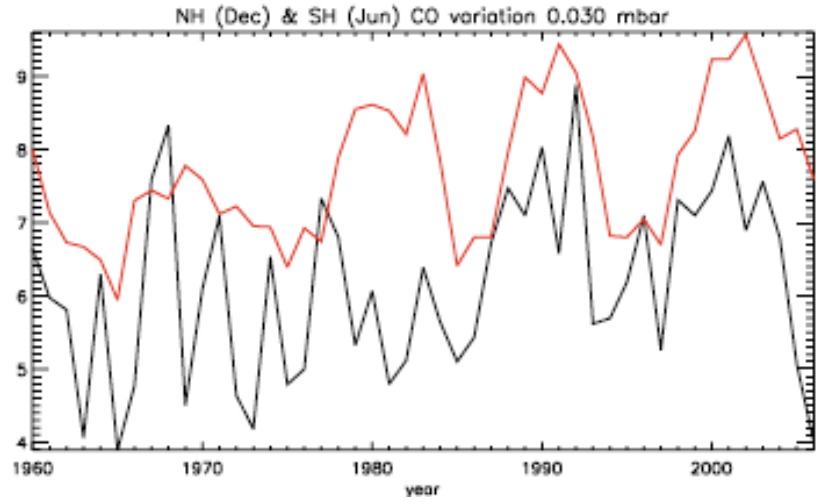
10 ppb => -8



Model downward extent of NO in winter less than in obs.
Altitude of minimum is too high.
Hemispheric differences in the right direction (SH stronger).

interannual variability of CO (winter solstice lat>80˚)





<u>winter in MLT</u>

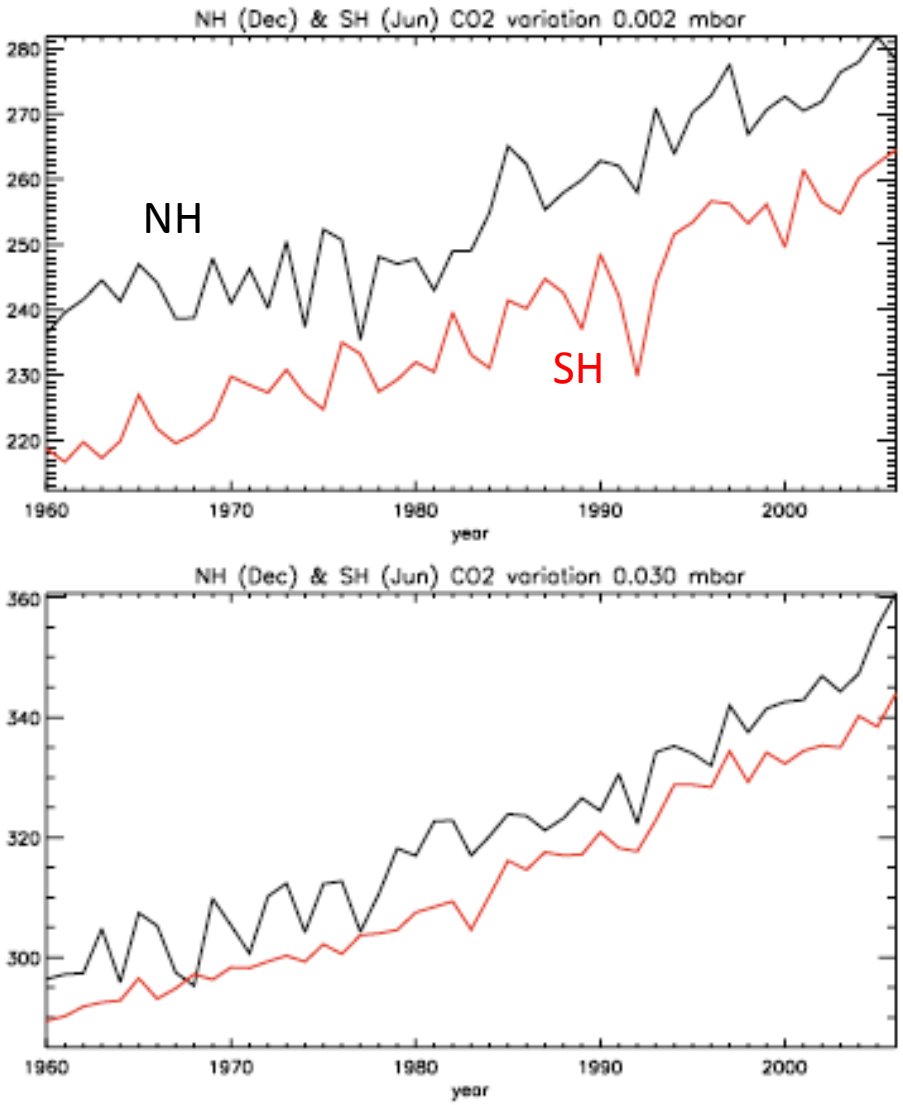
- variability dominated by solar cycle
- source of CO is CO_2 photolysis
- positive trend due to increase in CO_2

<u>winter in middle mesosphere</u>

- solar cycle still dominant in SH
- masked by additional interannual variation in NH

cf. schematic of Randall et al 2007 for NOx:
SH: perturbations from forcing are maintained in downwelling
NH: variable dynamics dominates over signal from forcing

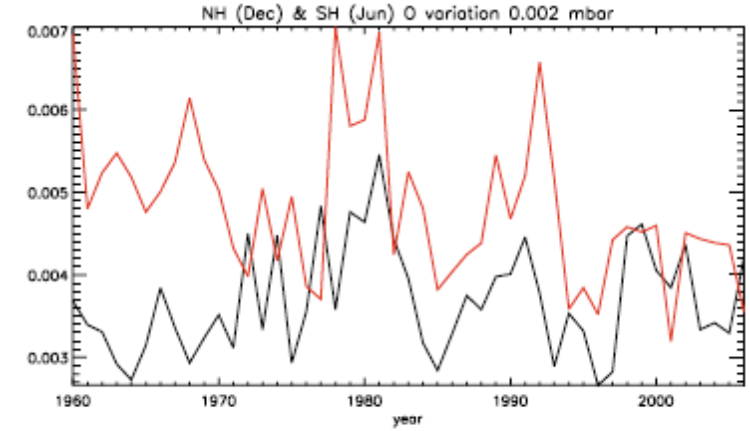
interannual variability of CO_2

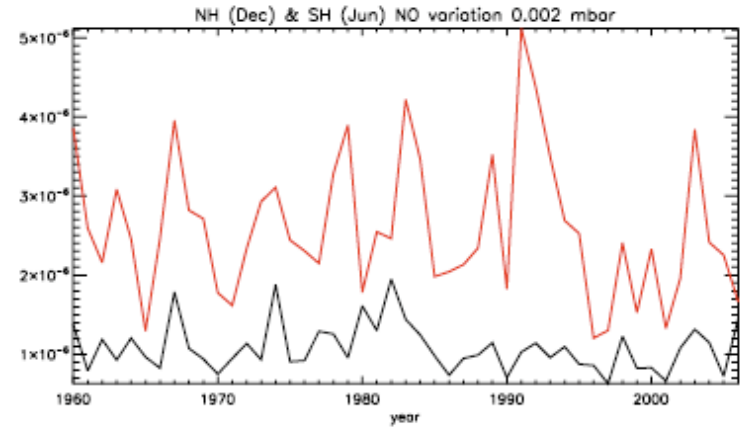


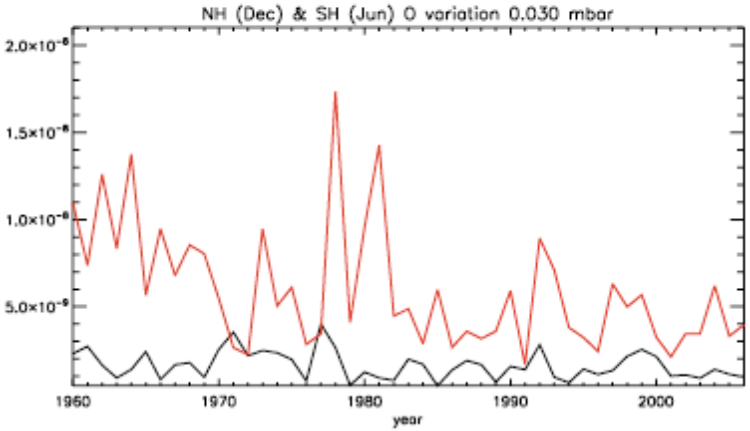
- trend dominates variability in both hemispheres
- NH more variable, particularly at lower altitude

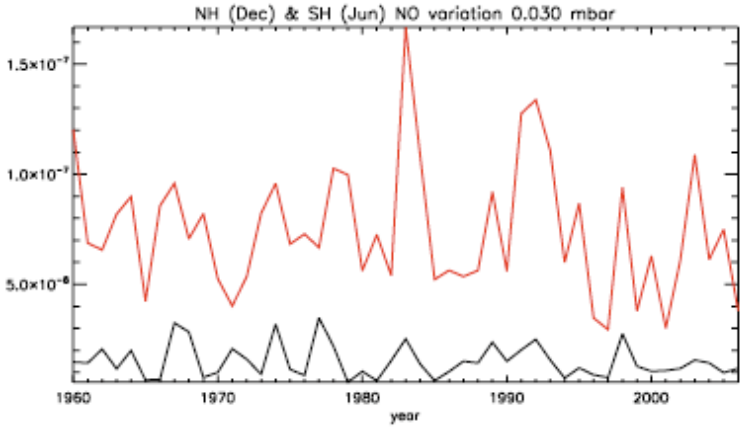
more CO_2 in NH winter

interannual variability of O and NO









winter mixing ratios consistently higher in SH

WACCM transformed Eulerian mean circulation

- solstices: summer to winter flow, max at ~80 km; winter to summer flow above 95-100 km
- solstices: sinking in winter, rising in summer below ~90-95 km; opposite above
- circulation is stronger in SH (summer and winter) due to stronger gravity wave drag
- distributions of trace species with strong vertical gradients indicate that the mean transport is an important factor
- comparison of O with SABER obs indicates a good simulation of the seasonal cycle but a discrepancy in the hemispheric difference
- comparison of NO with HALOE obs indicates a weaker circulation near 0.1 hPa but hemispheric difference agrees
- possible contributors to WACCM/SABER O discrepancy:
  - problems with SH stratospheric jet and GW filtering and/or other forcing of the circulation in WACCM
  - errors in SABER and/or WACCM O
  - unusual NH dynamics during three of the winters the SABER observation period (Jan 2002-present)