The response of tropospheric circulation to perturbations in lower stratospheric heating

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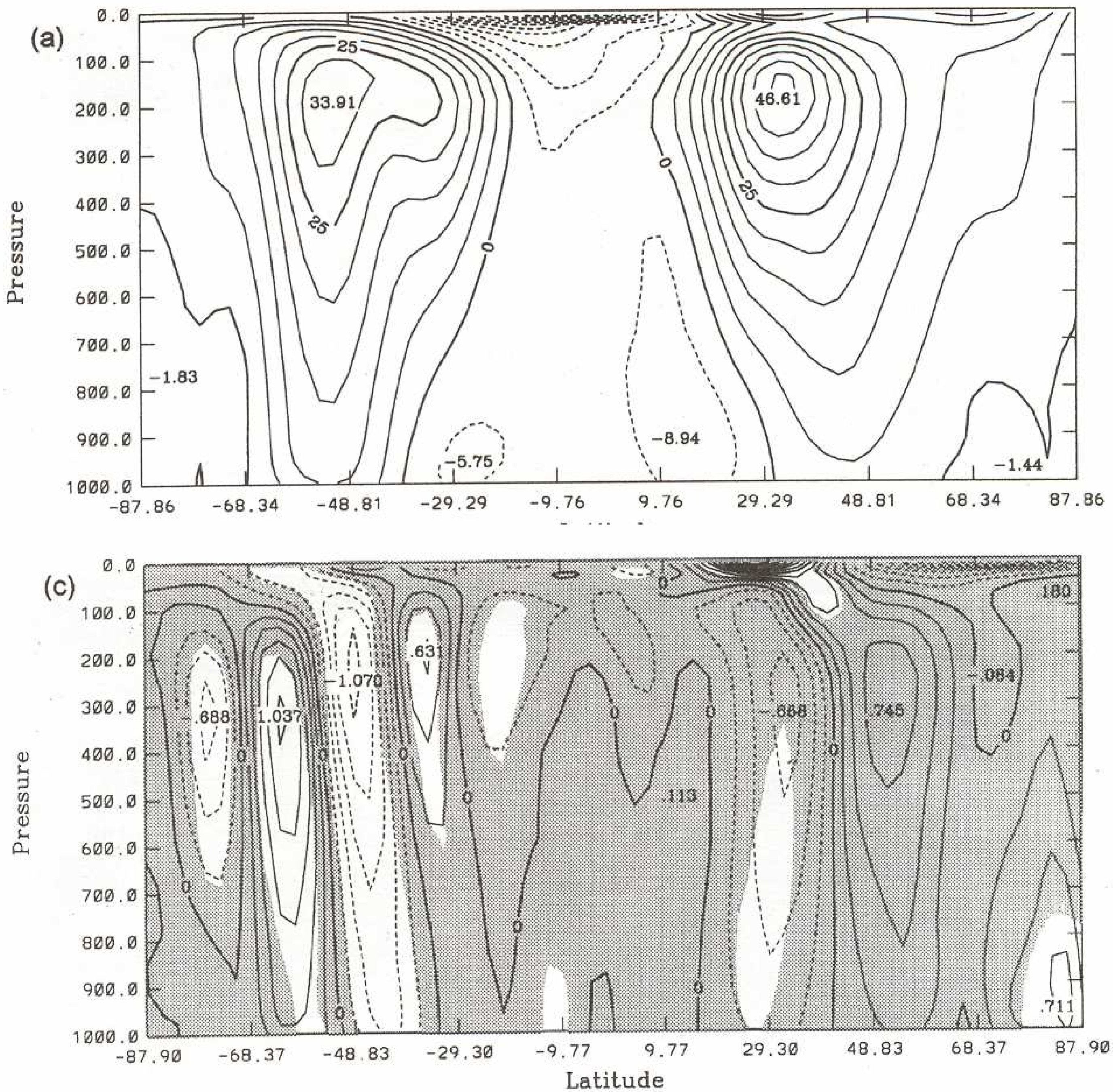
Outline

- GGM studies of response to solar UV.
- Sensitivity experiments.
- Comparison of model results with observational data.
- Understanding the response using a "dynamical core" model.

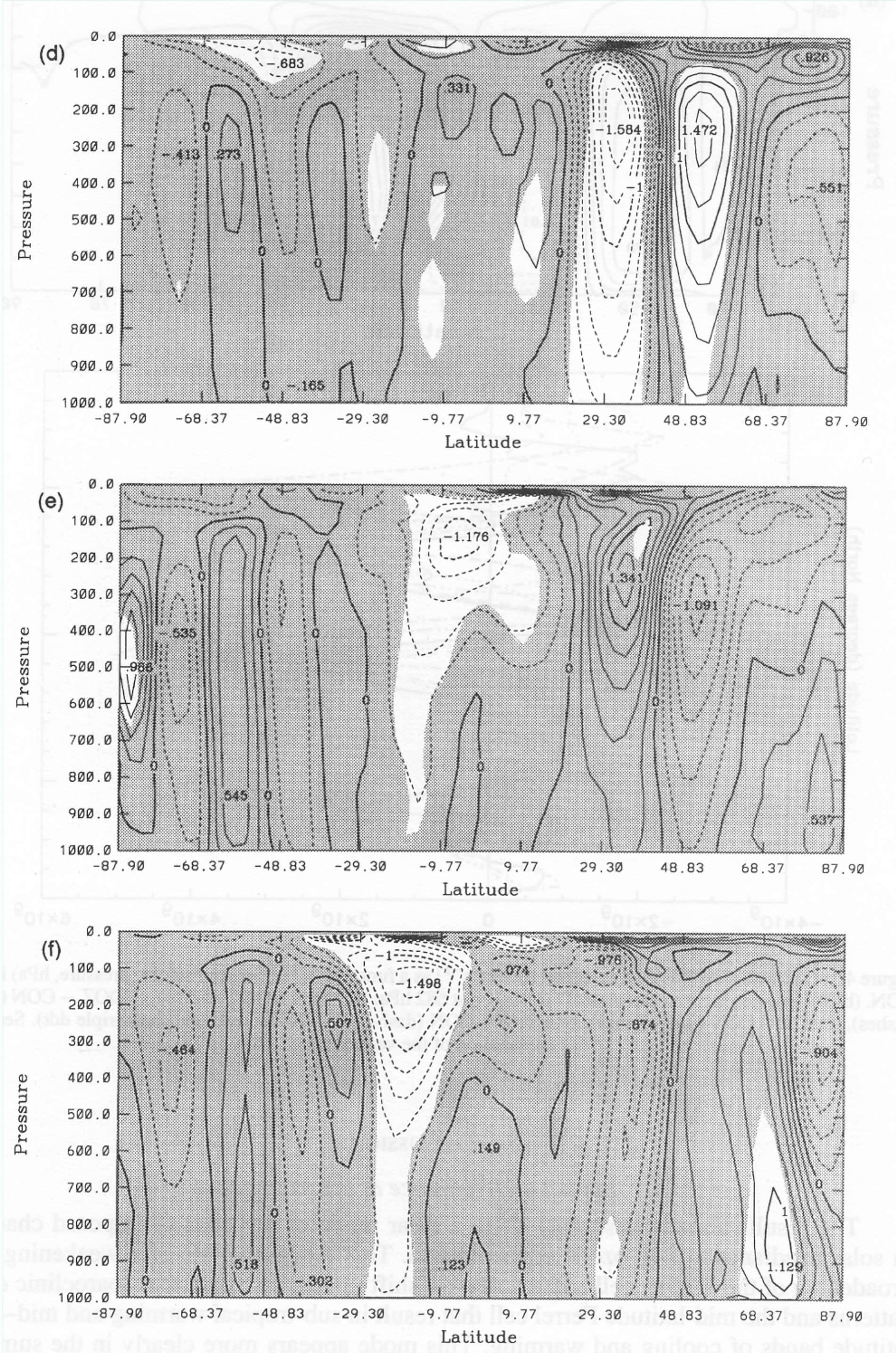


UGCM zonal wind

solarmax-solarmin

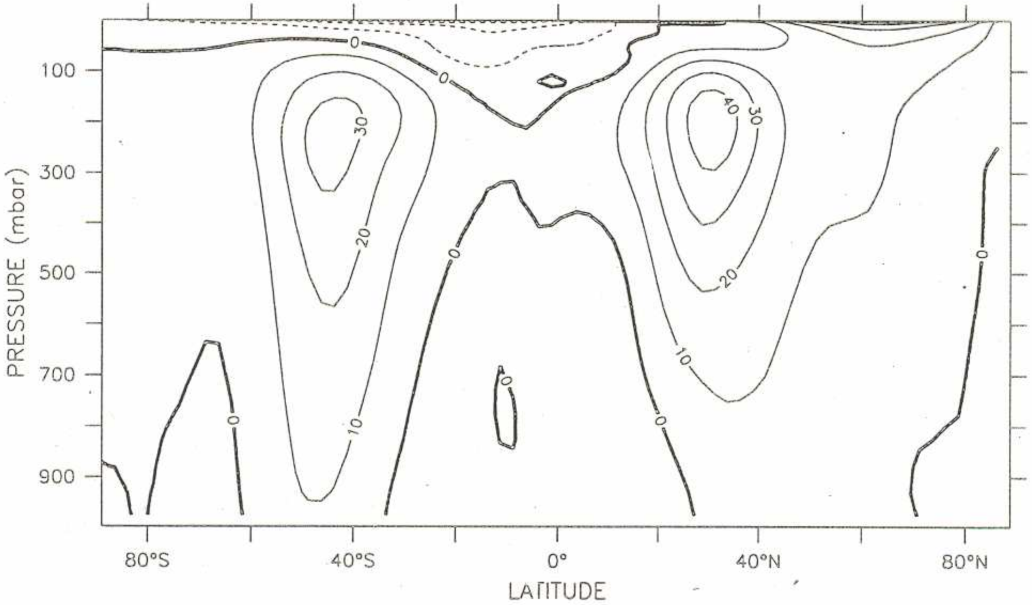
(2D model ΔO_3)

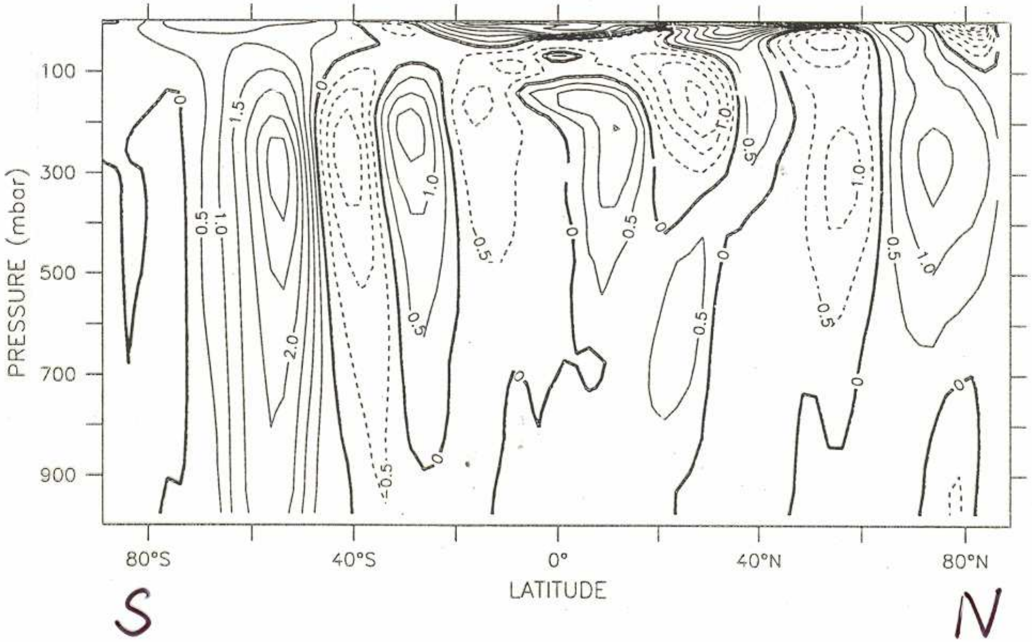
Haigh (Science1996; QJRMS1999)



Further UGCM solarmax-solarmin zonal wind results

Haigh (1999)

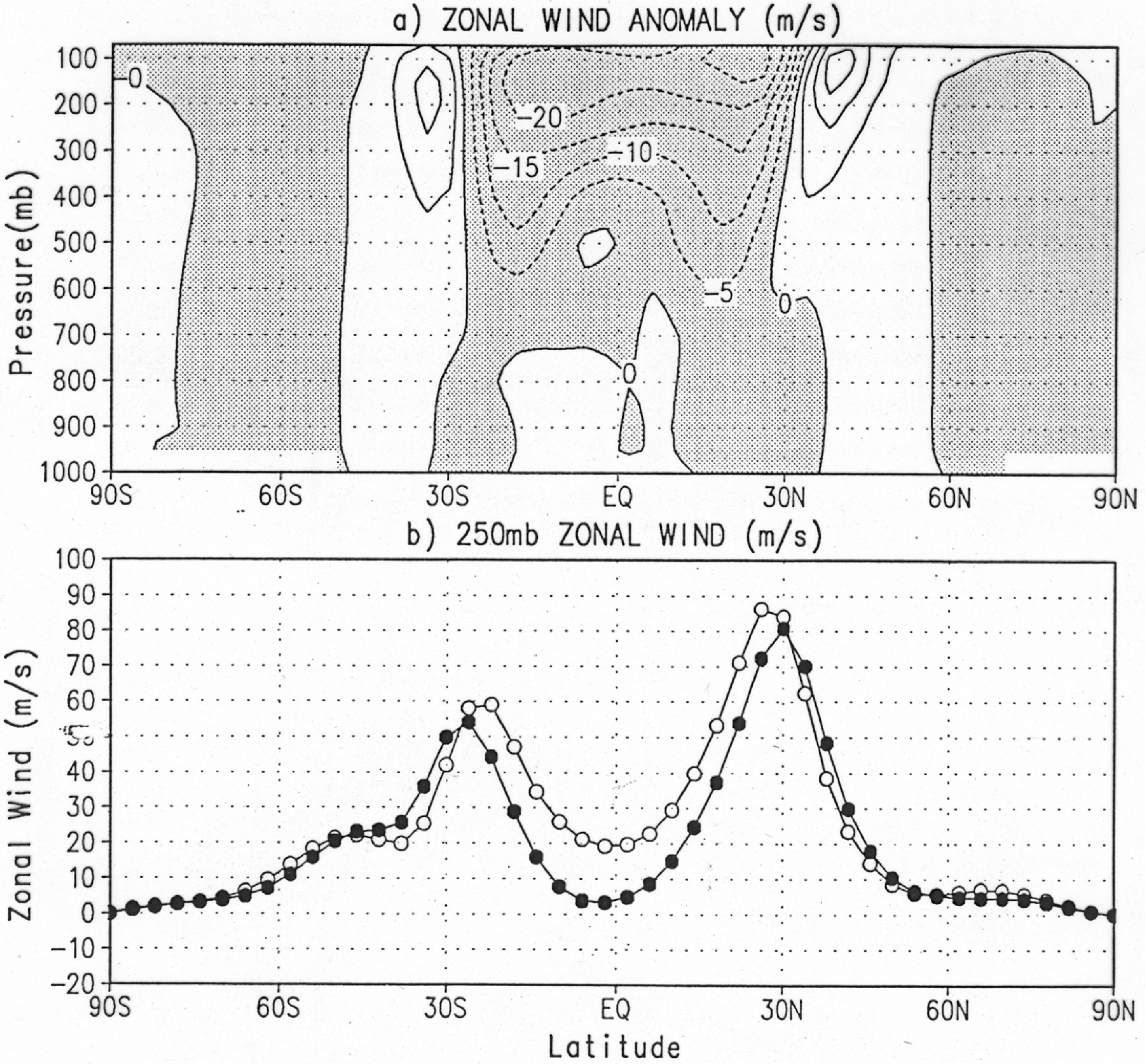




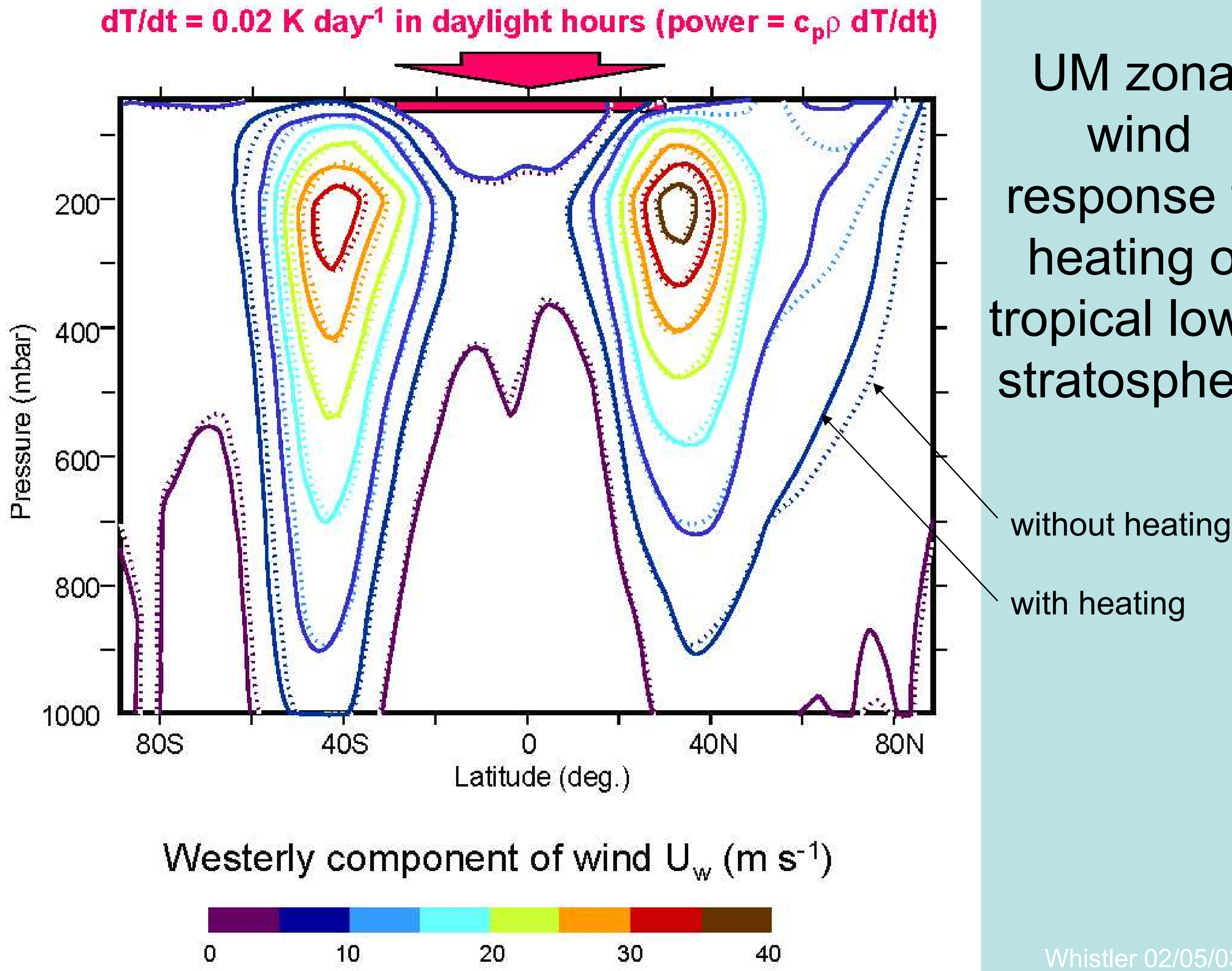
UM zonal wind

solarmax-solarmin

Larkin et al (2000)

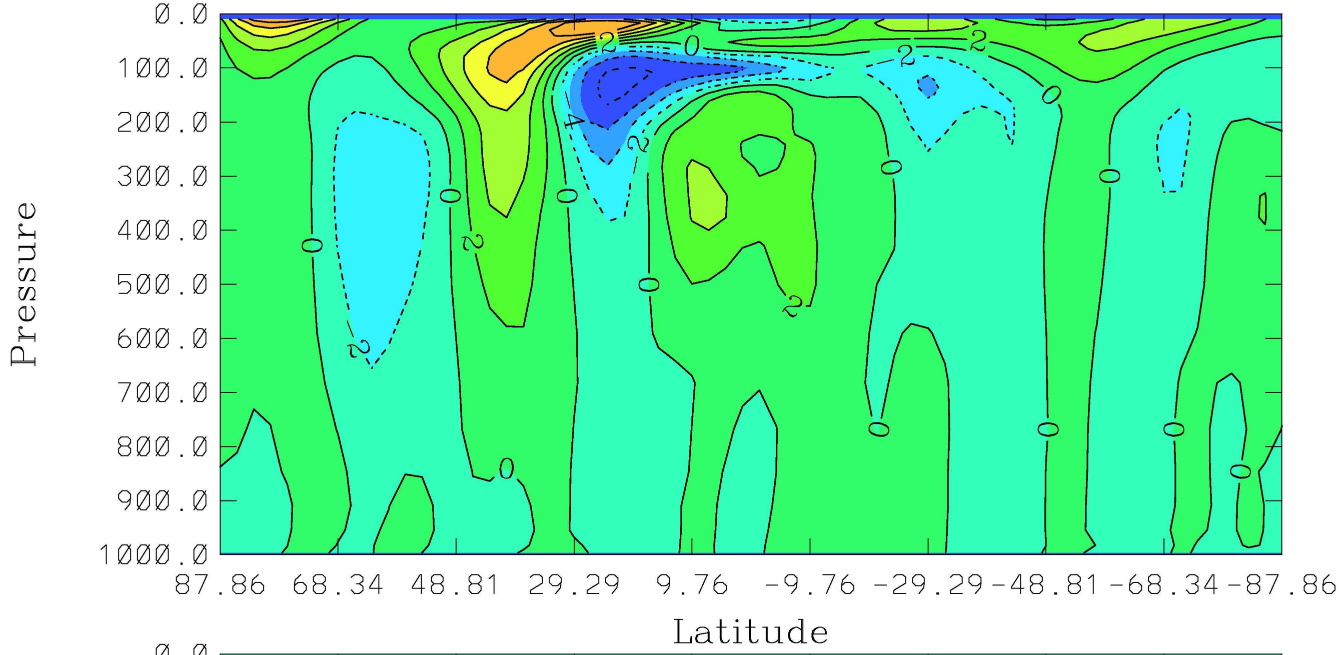


Hou (2000) GCM response to "artificial" delta O_3

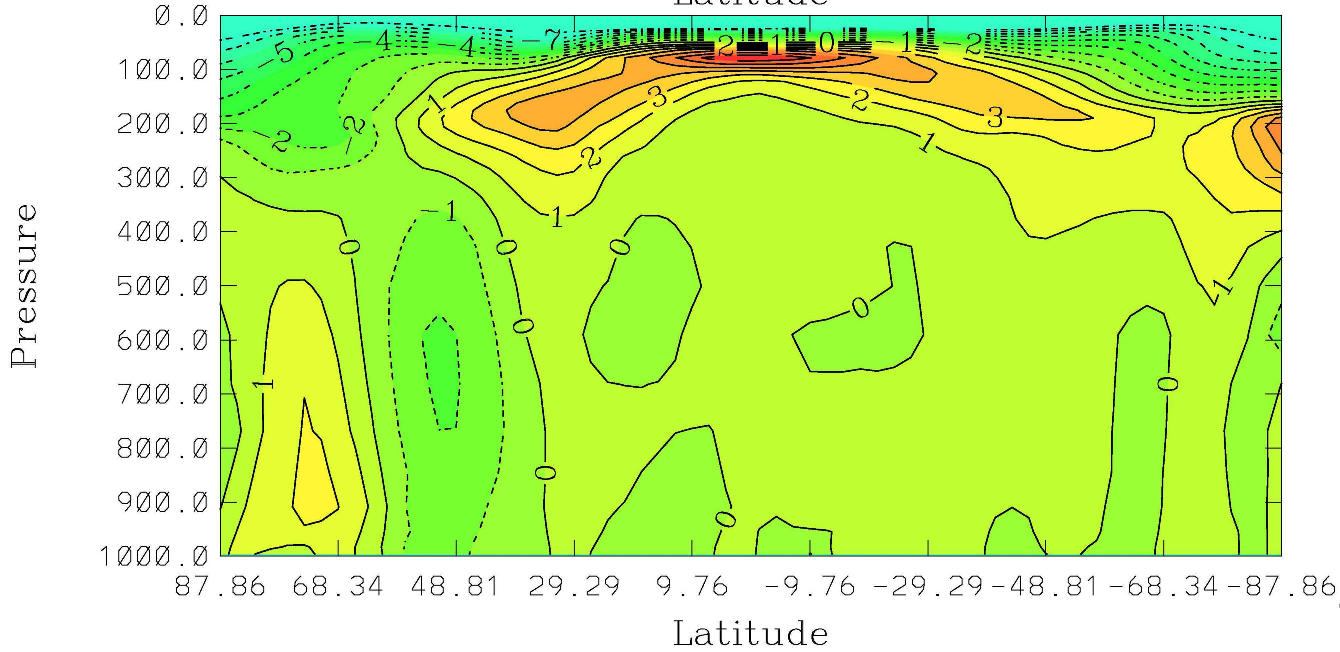


UM zonal wind response to heating of tropical lower stratosphere

UGCM O_3 downward shift experiment

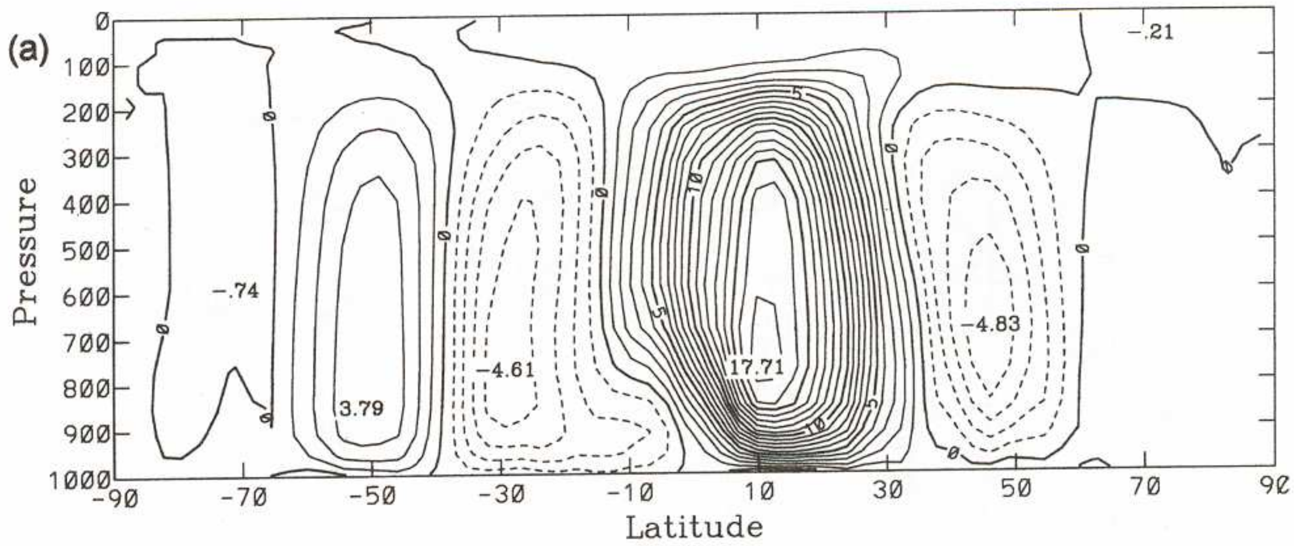


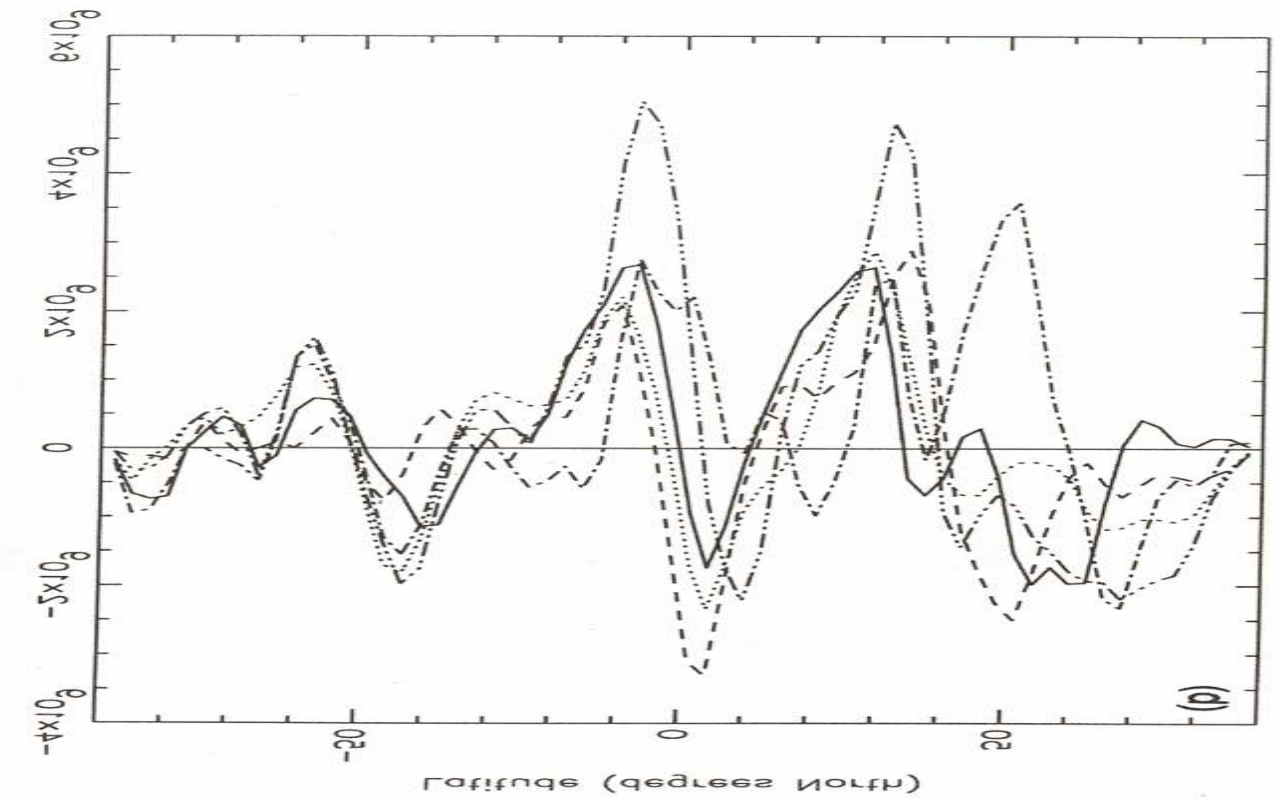
Δ u (m s^{-1})



Δ T (K)

Thuburn & Craig (2000)



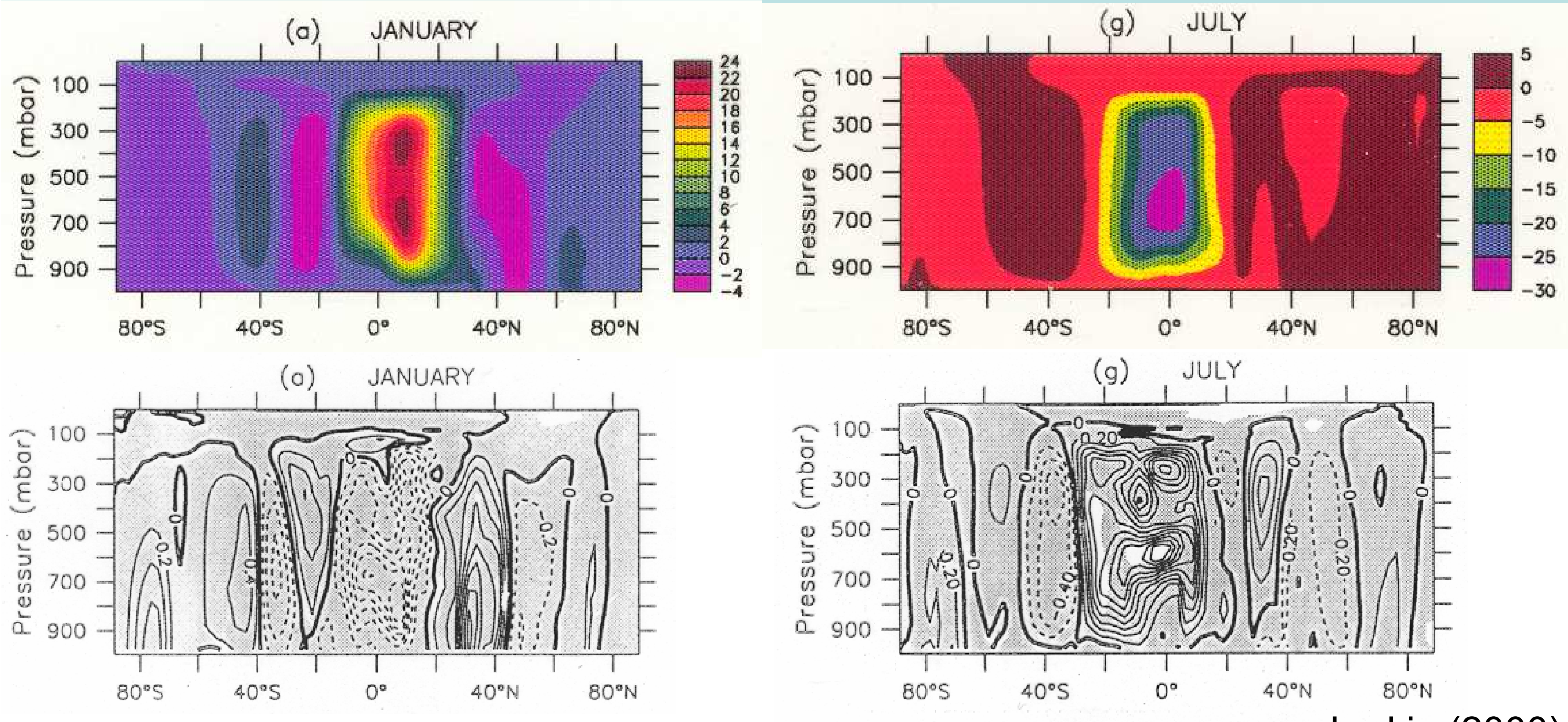


UGCM mean meridional circulation

change in MMC
at 682hPa

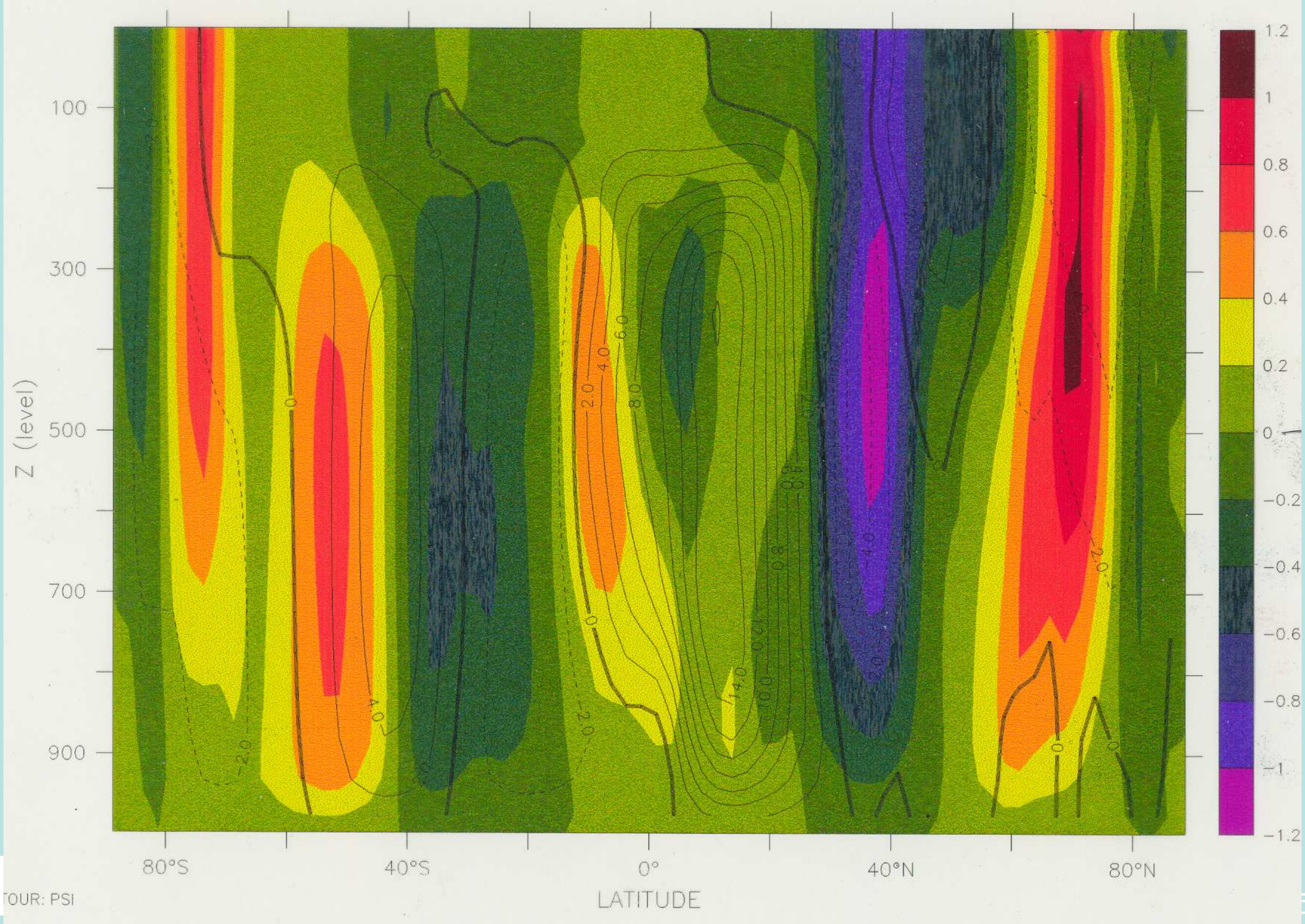
Haigh (1999)

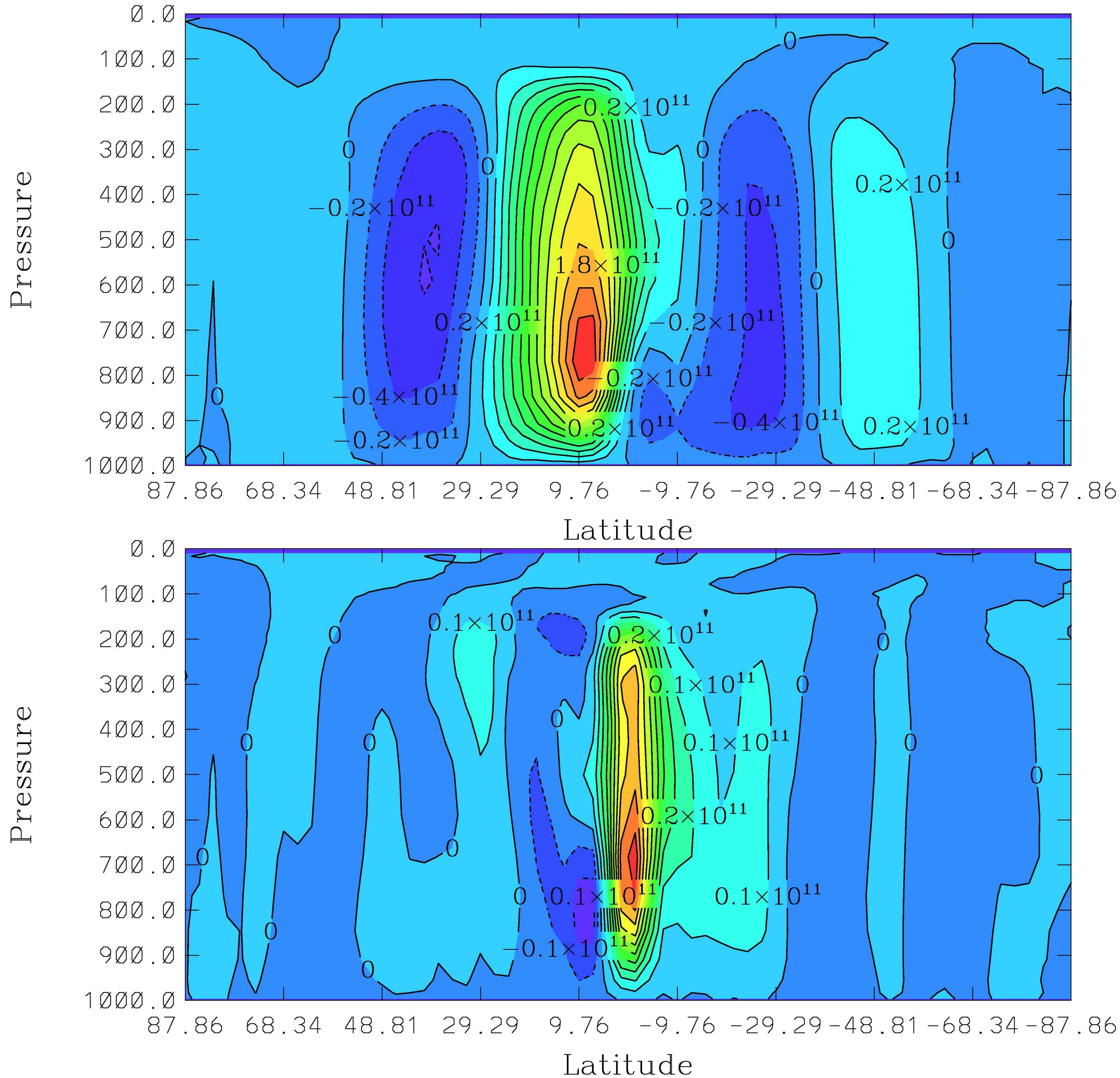
UM mean meridional circulation



Larkin (2000)

UM mean meridional circulation (tropical heating experiment)





UGCM mmc

Δ mmc due O_3 shift

Multiple regression of observational data

$$y(x,t) = \sum_i \beta_i(x) f_i(t) + noise$$

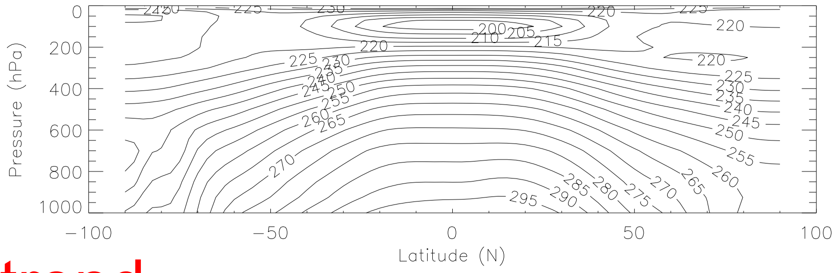
- $y(x,t)$ are data
- $f_i(t)$ is time-dependent climate factor i

10 factors are taken into account:

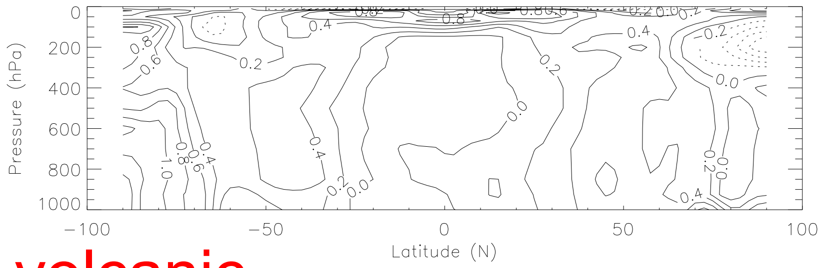
trend
solar irradiance
volcanic aerosol
ENSO
NAO
QBO
amplitude & phase of annual cycle
amplitude & phase of semi-annual cycle

Regression results: NCEP Tbar

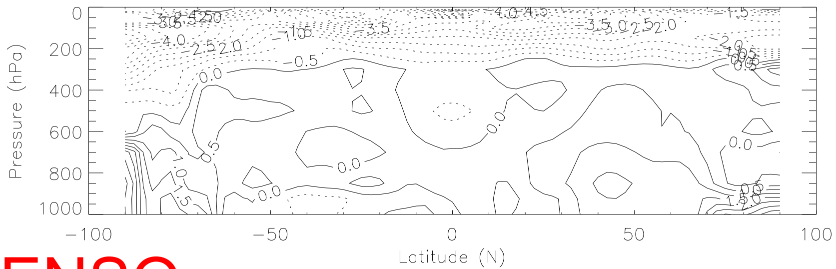
mean



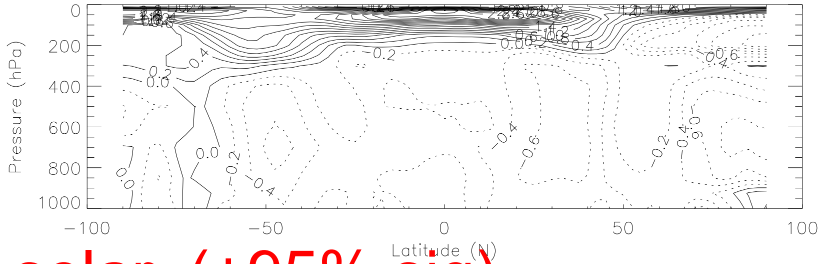
solar



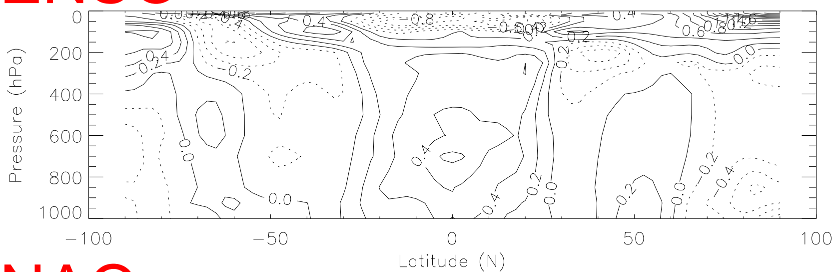
trend



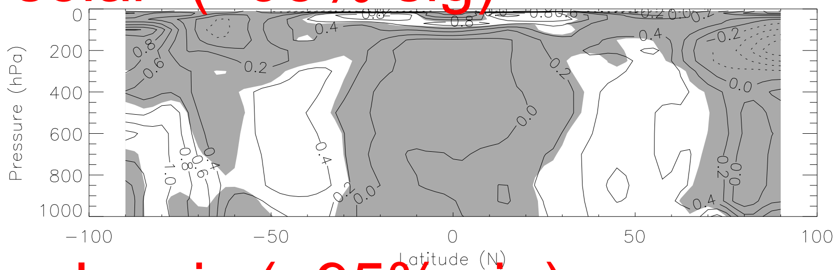
volcanic



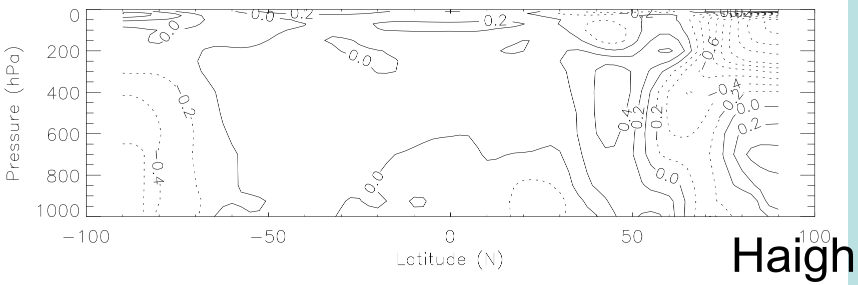
ENSO



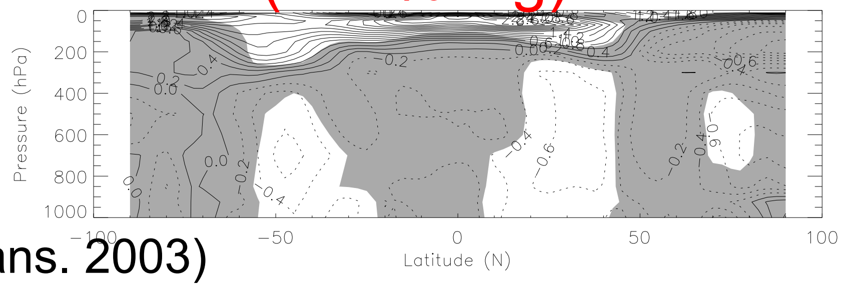
solar (+95% sig)



NAO



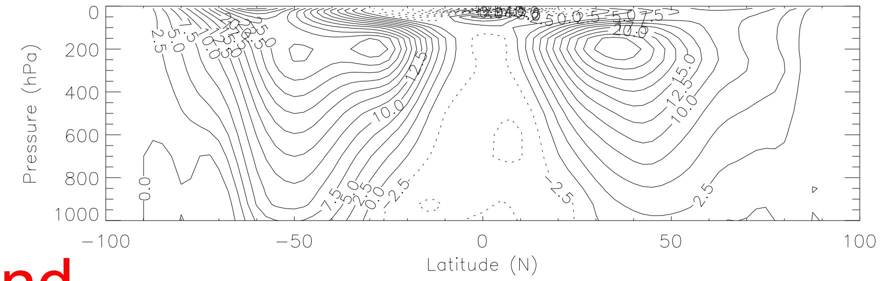
volcanic (+95% sig)



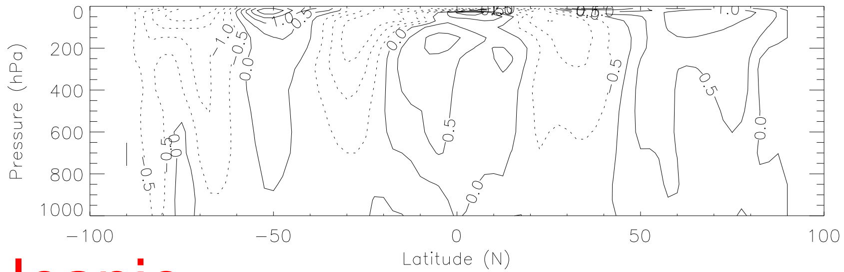
Haigh (Phil.Trans. 2003)

Regression results: NCEP ubar

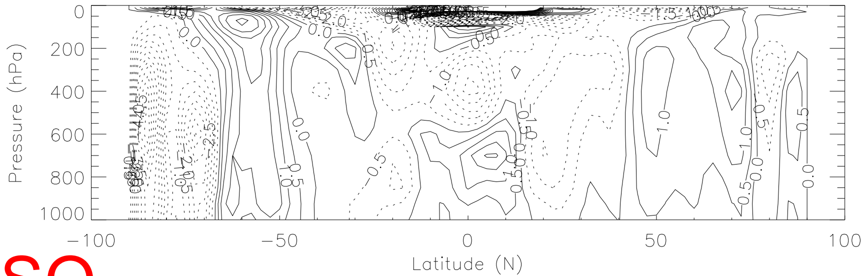
mean



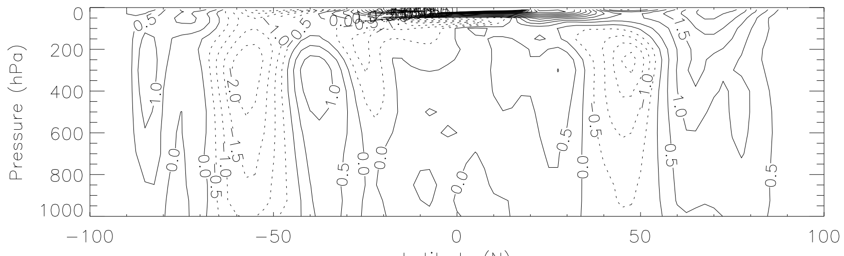
solar



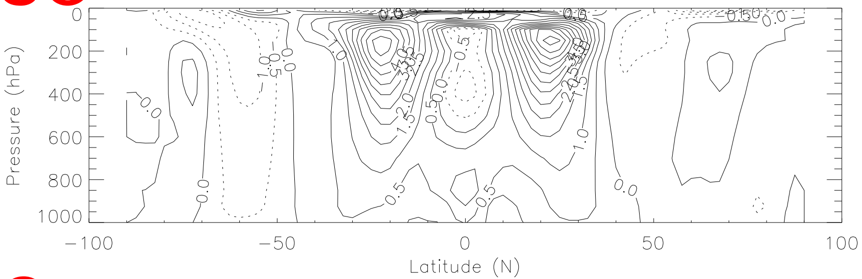
trend



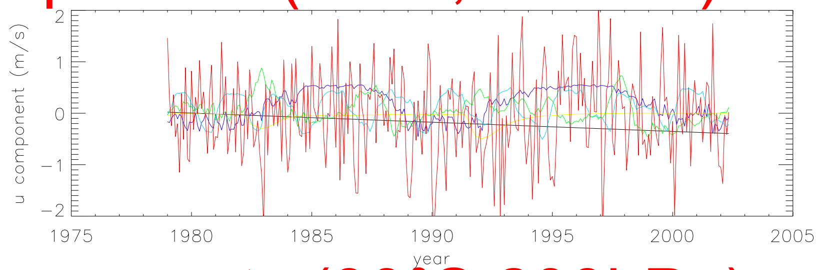
volcanic



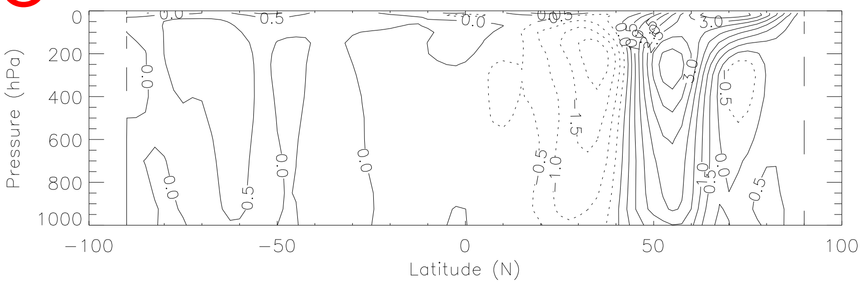
ENSO



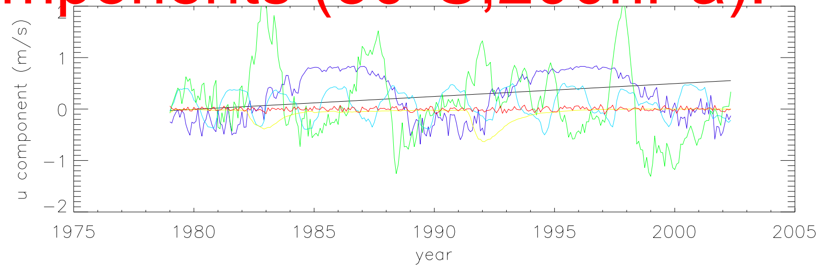
components(35°N,200hPa)



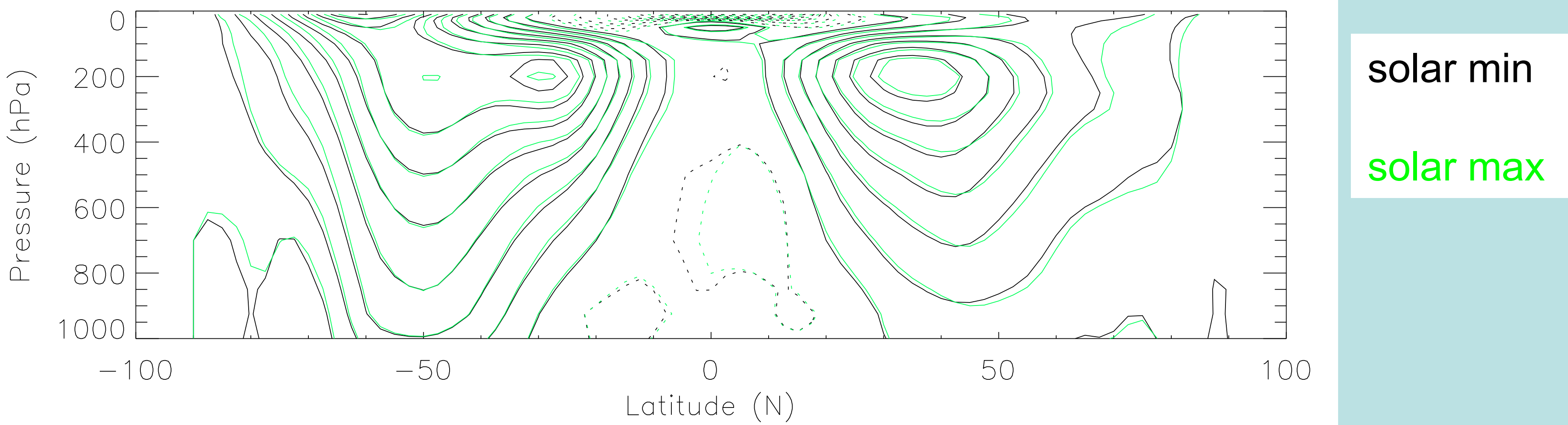
NAO

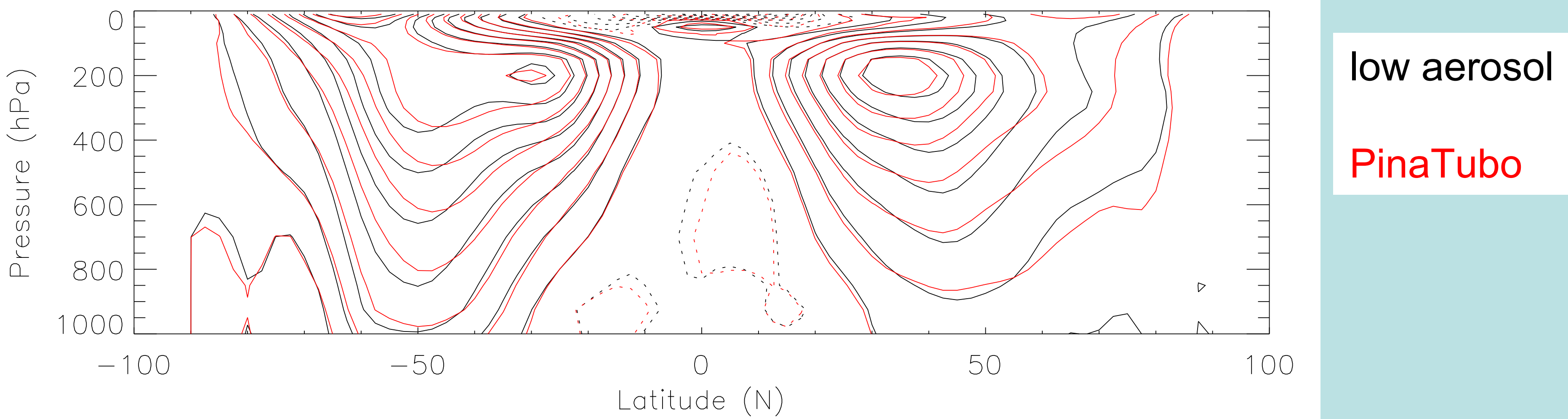


components (30°S,200hPa).



NCEP ubar regression results





Dynamical core model experiments

As Held and Suarez (1994):

Full dynamics T42 L20. No orography.

Newtonian cooling (equinoctal radiative equilibrium temperatures). Rayleigh friction.

All experiments involved heating the lower stratosphere:

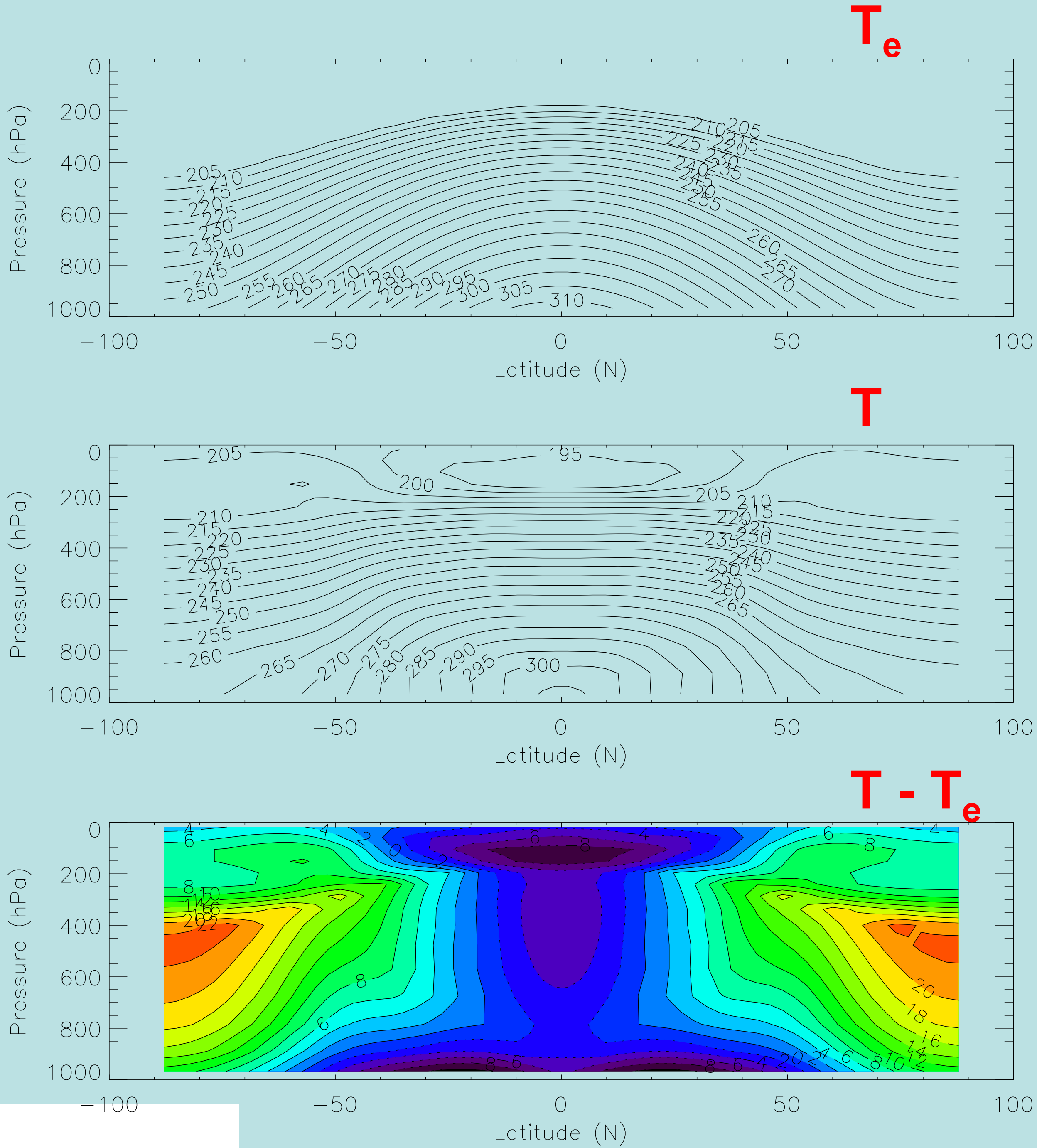
- 1K at all latitudes
- 1K at equator, $\cos^2$(lat) variation
- 5K at all latitudes
- 5K at equator, $\cos^2$(lat) variation

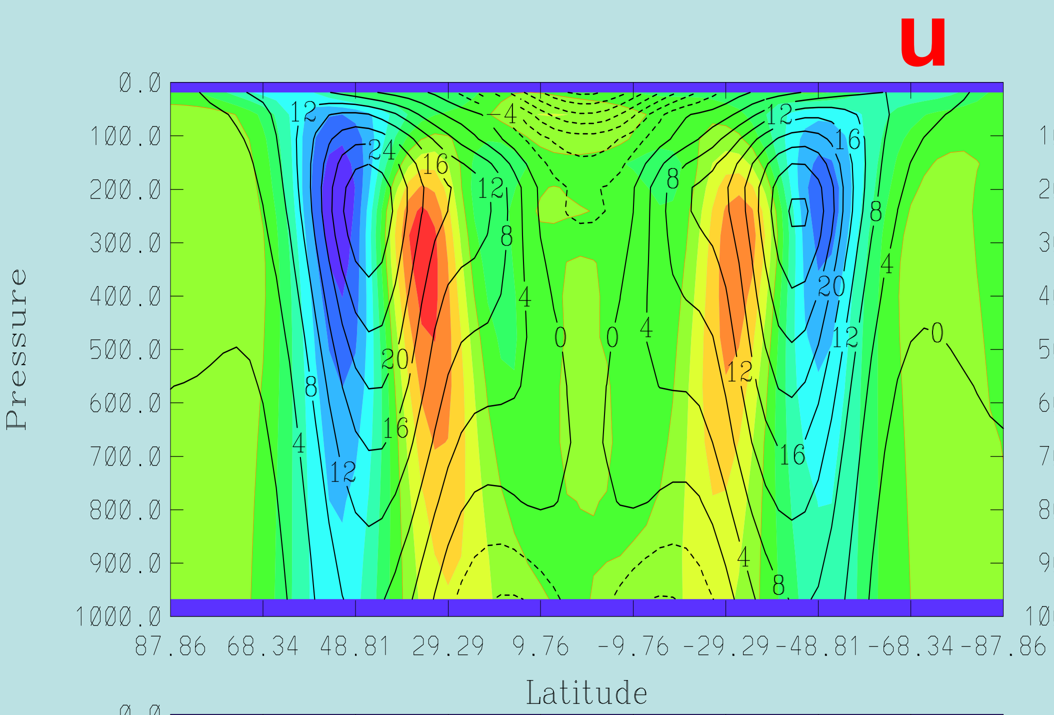
All runs 1200 days.

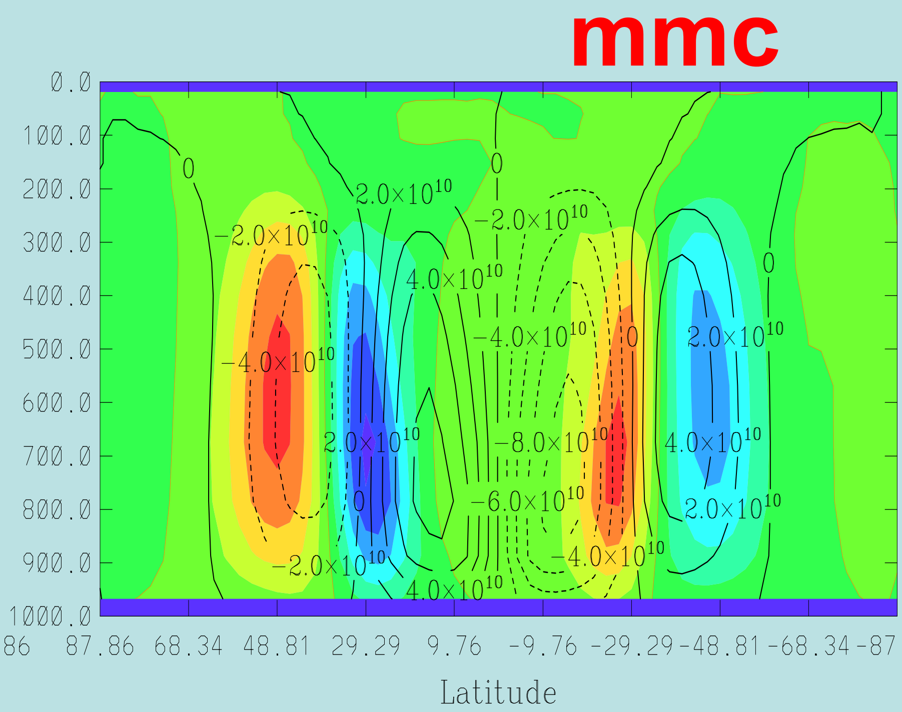
Temperatures

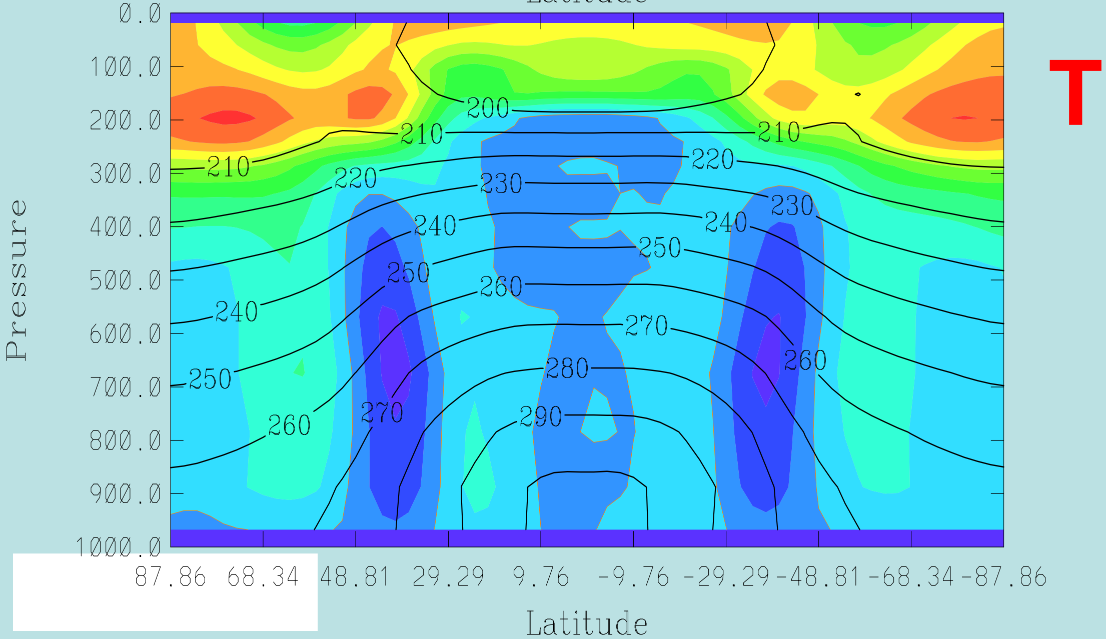
rad. eq.

control run



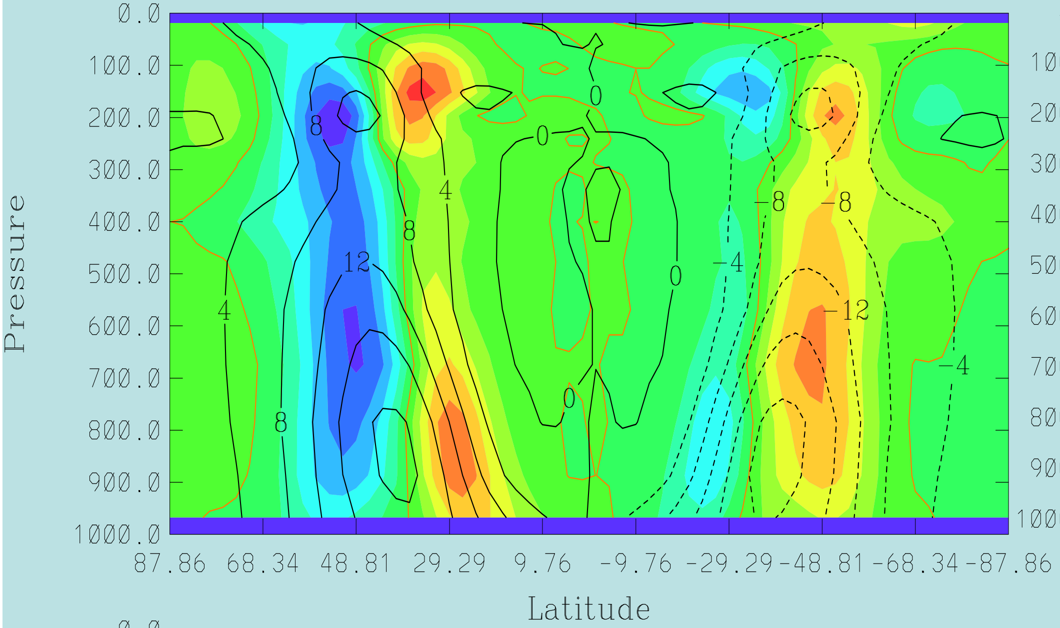




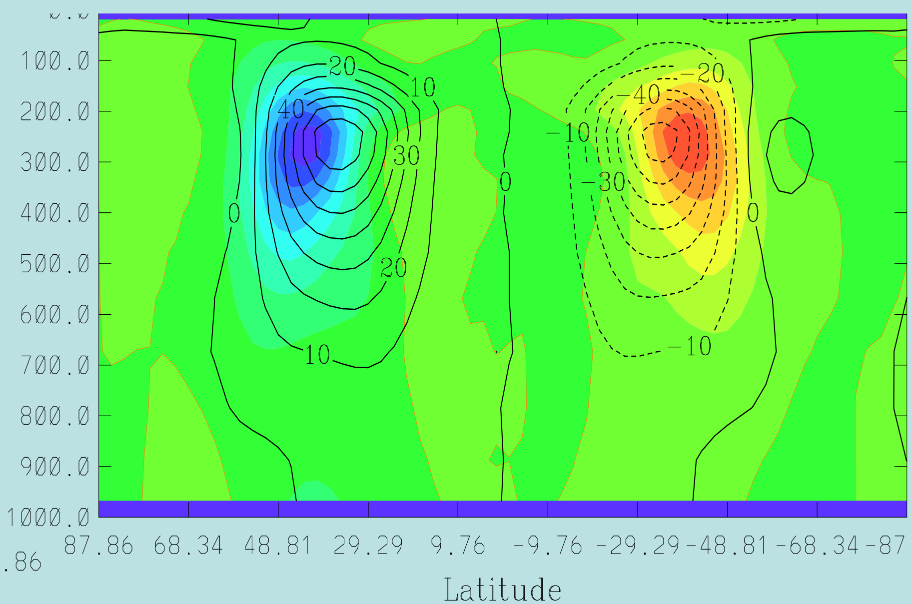


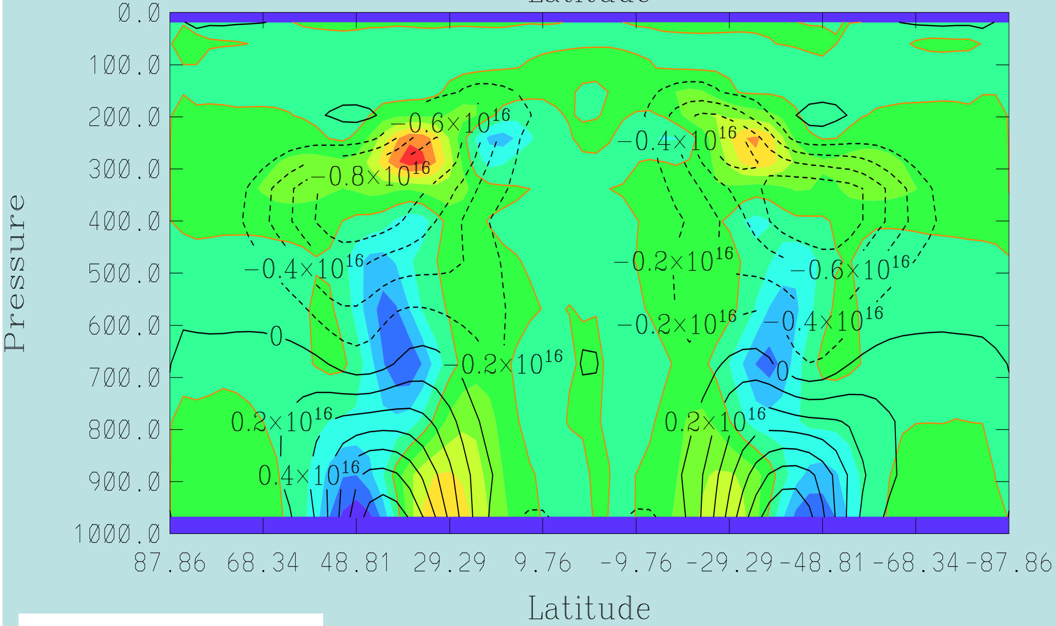
Uniform heating expt

v'T'



u'v'

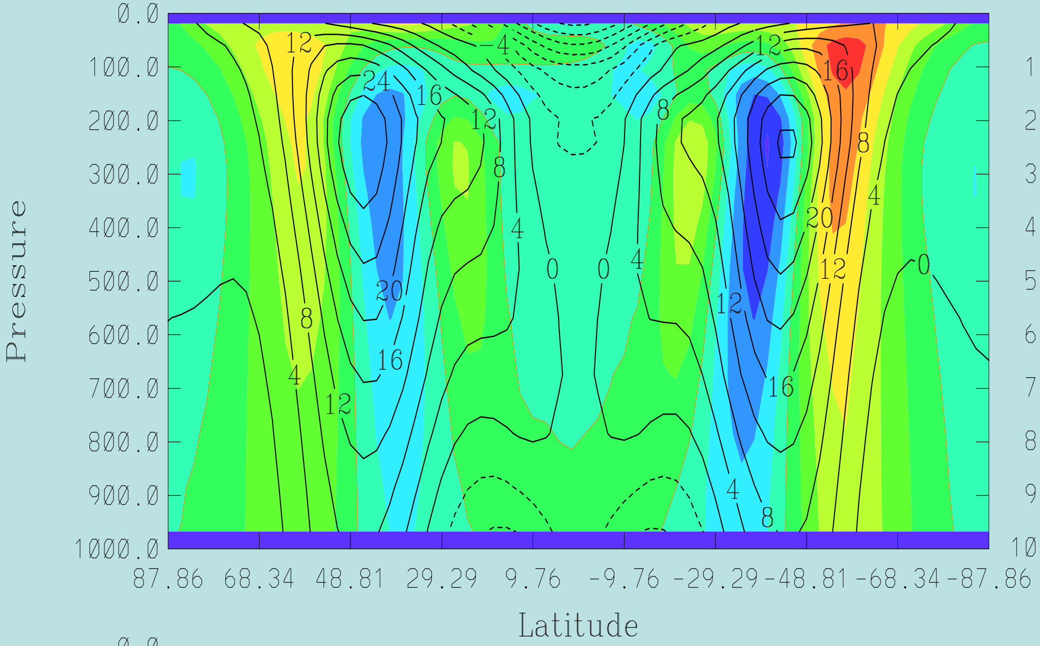




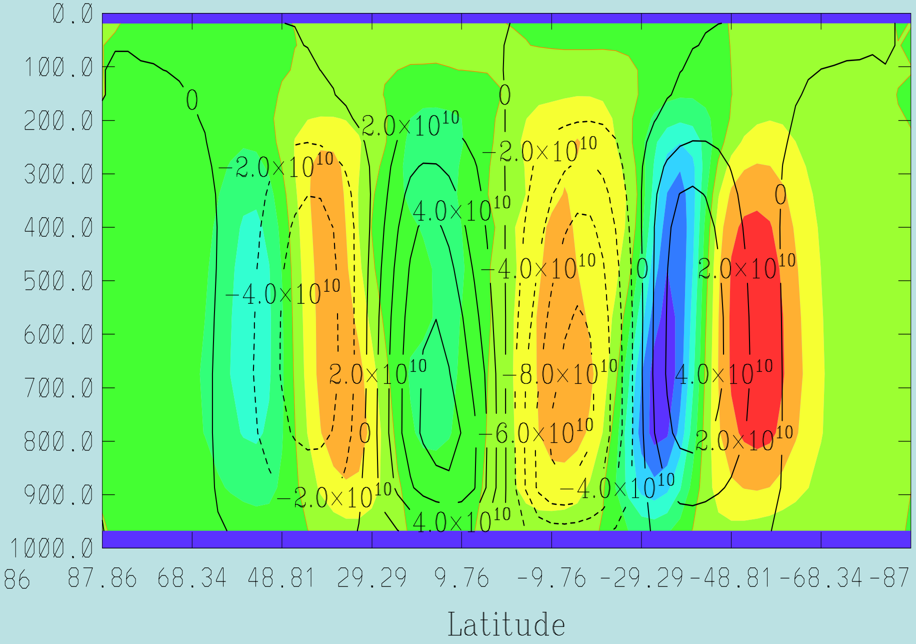
∇.F

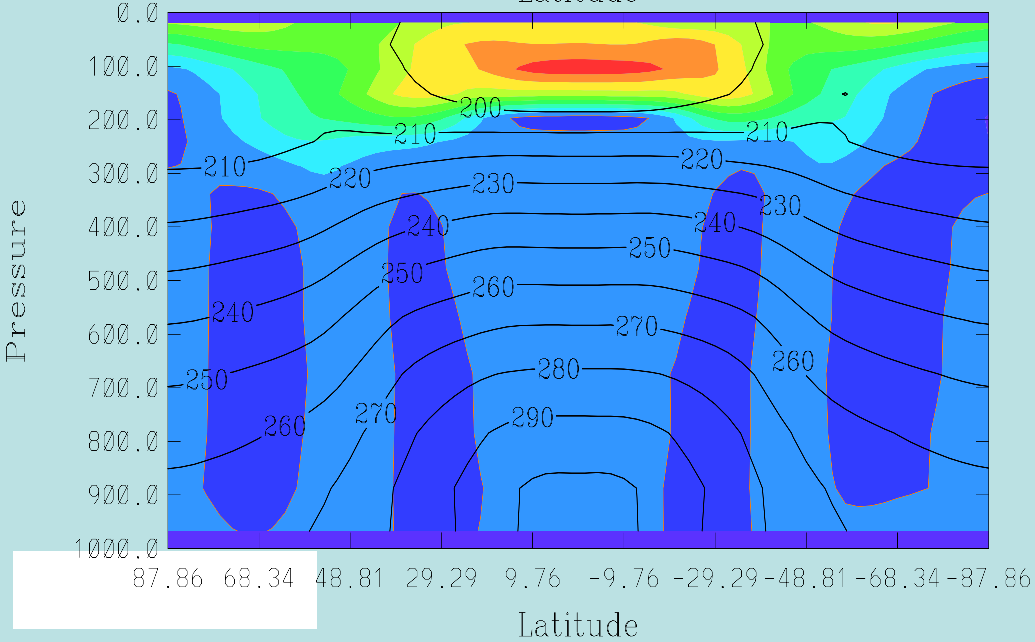
Uniform heating expt

u



mmc

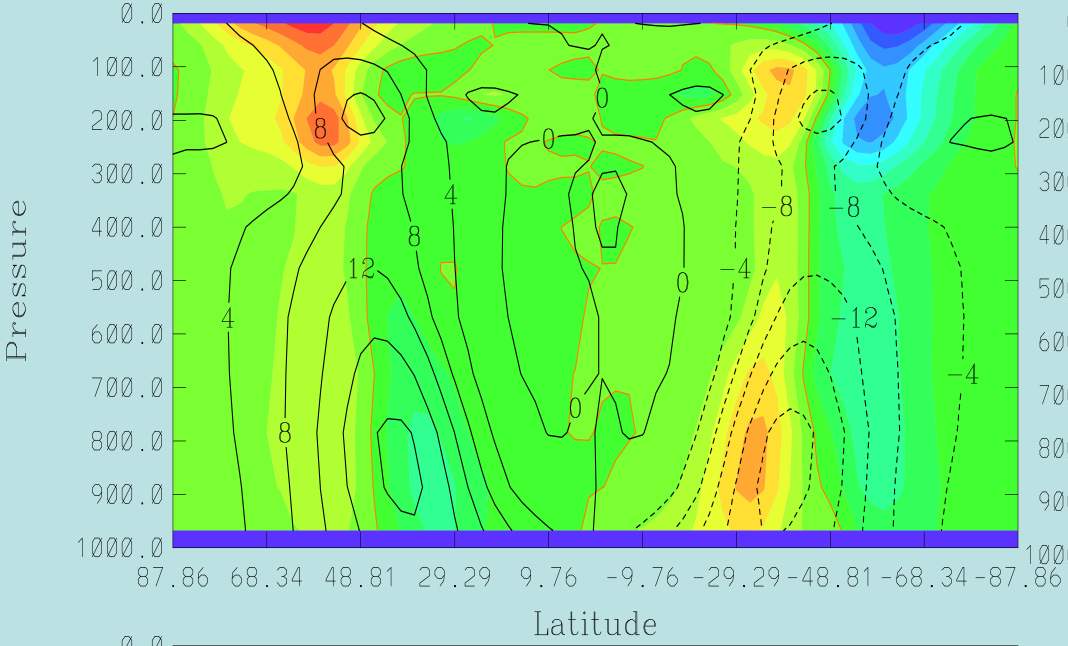




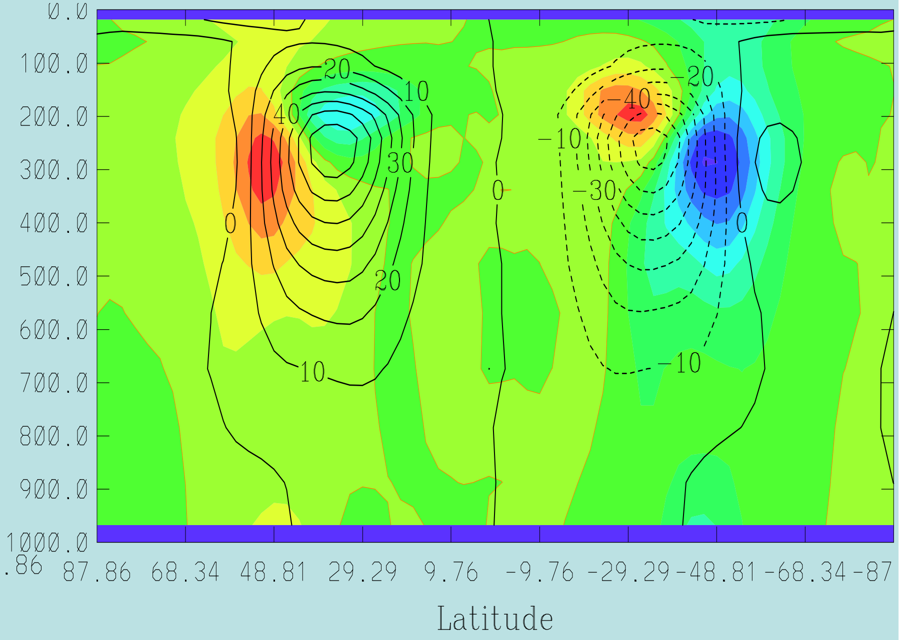
T

$\cos^2$(lat) heating expt.

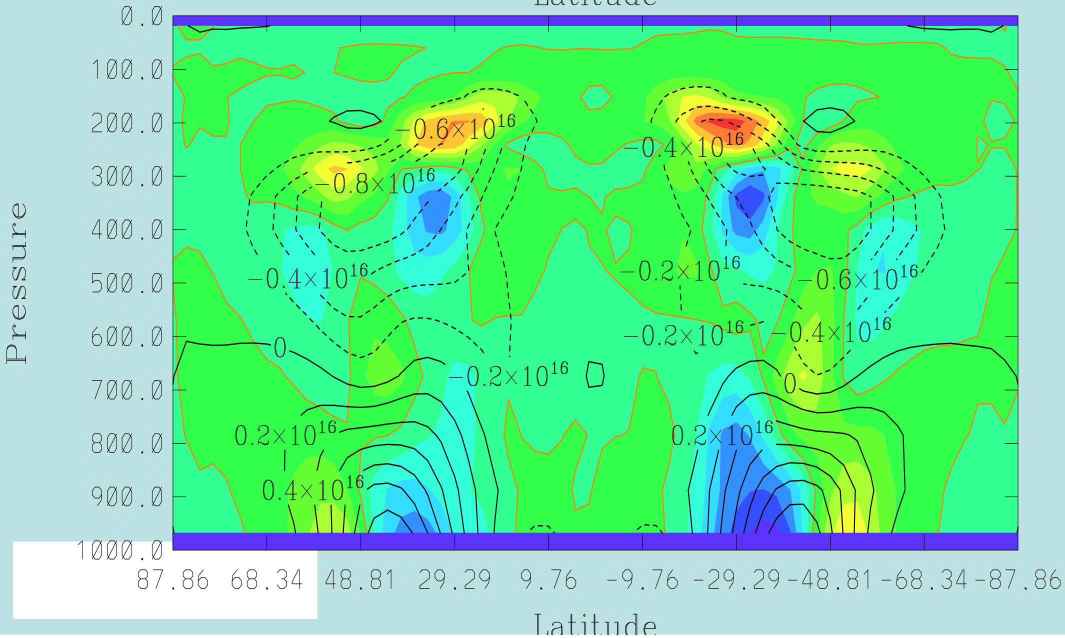
v'T'



u'v'



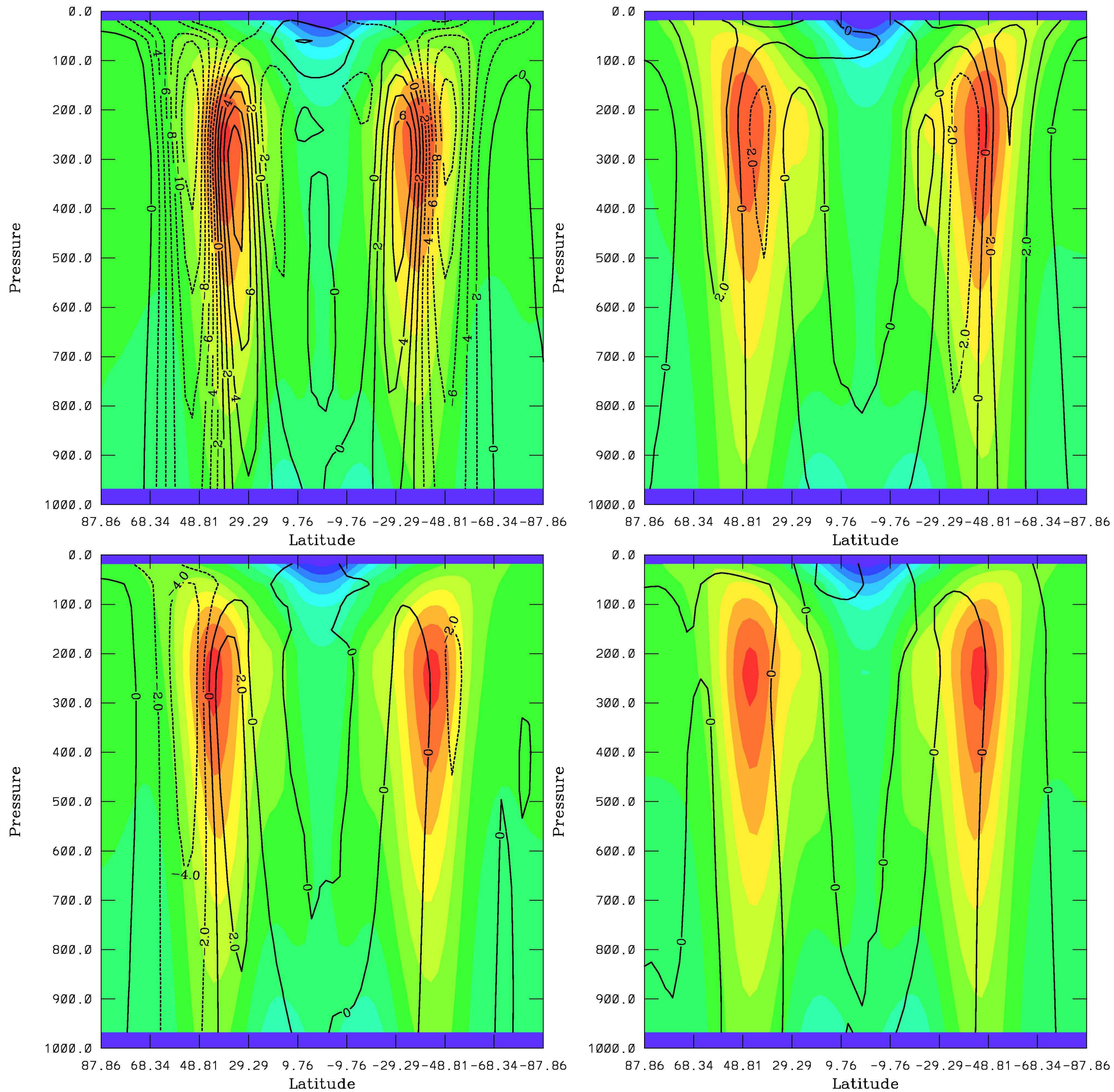
∇.EPF



$\cos^2$(lat) heating expt.

uniform heating | cos²(lat) heating

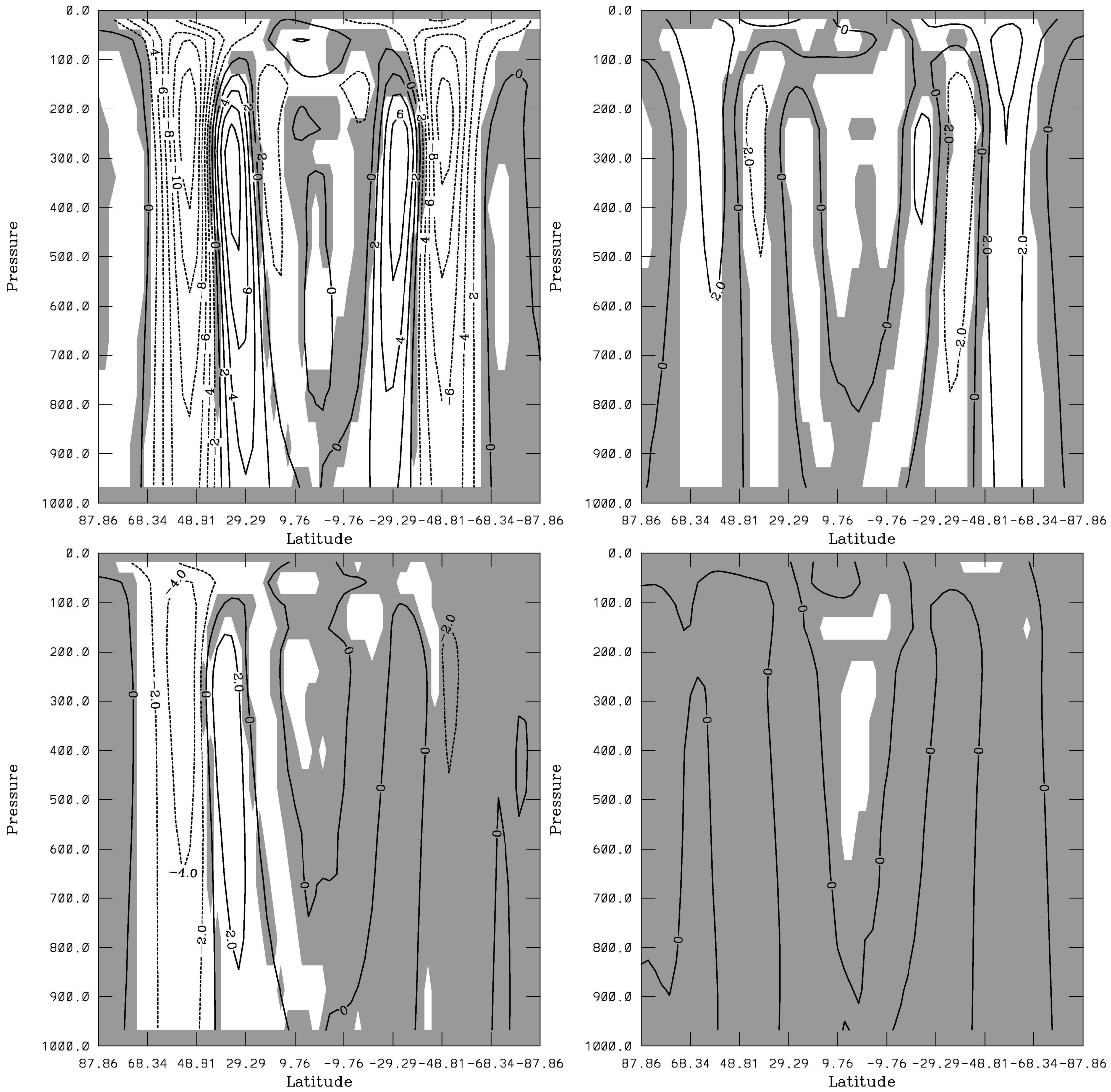
ubar



5K heating

1K heating

uniform heating cos^2(lat) heating



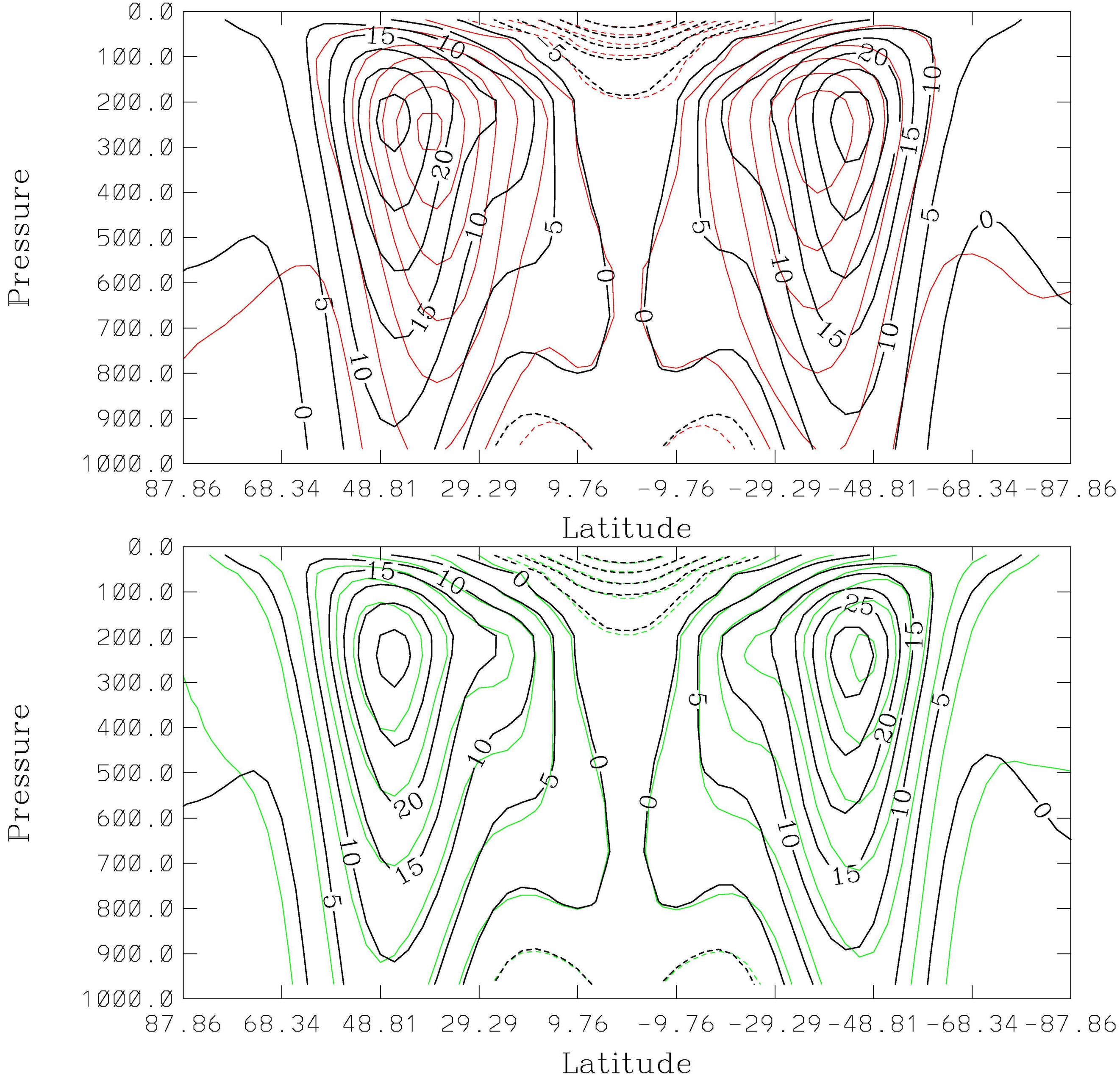
ubar

5K heating

shaded areas not statistically significant at 95% level

1K heating

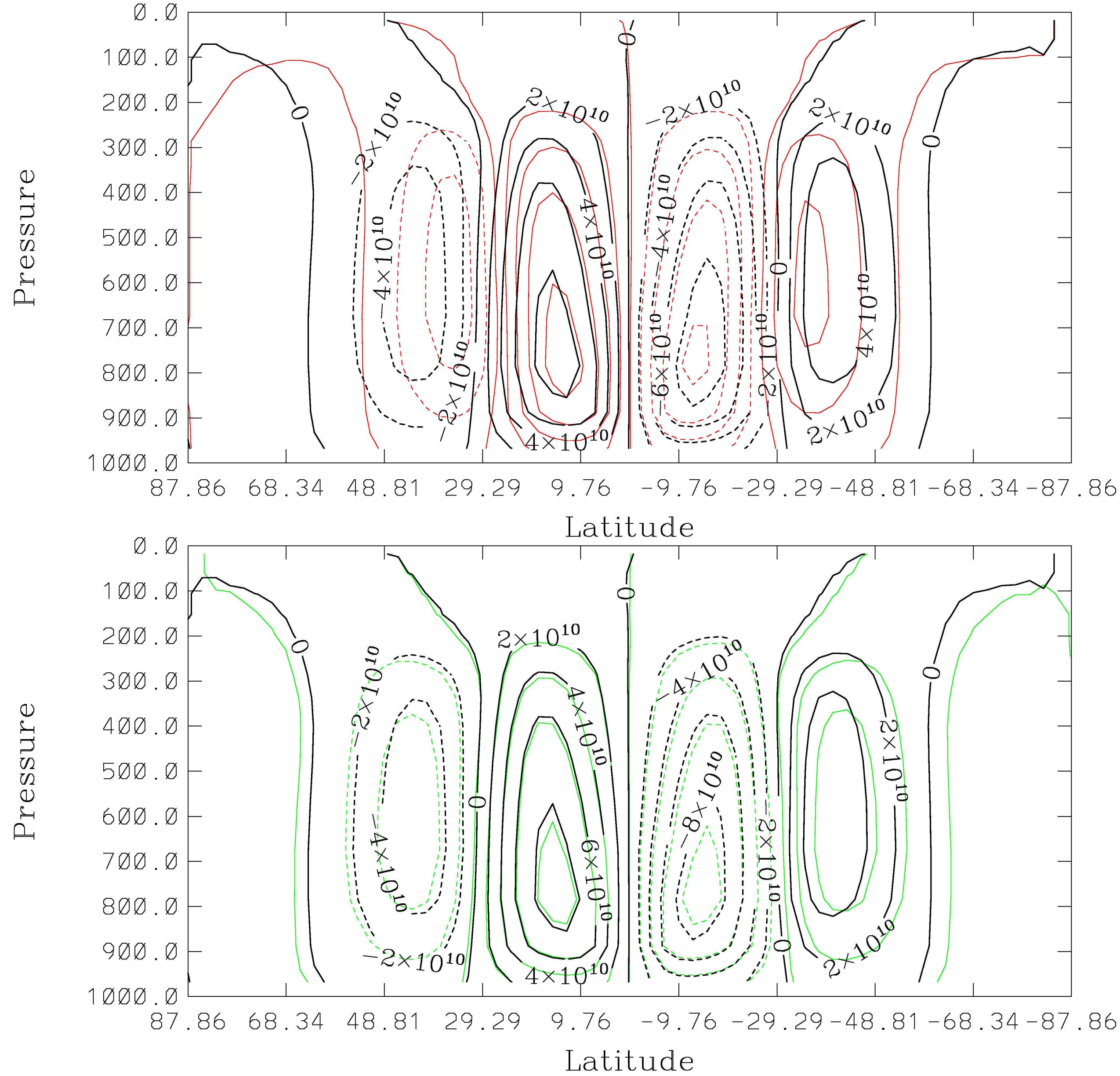
ubar



control

uniform heating

$\cos^2$(lat) heating

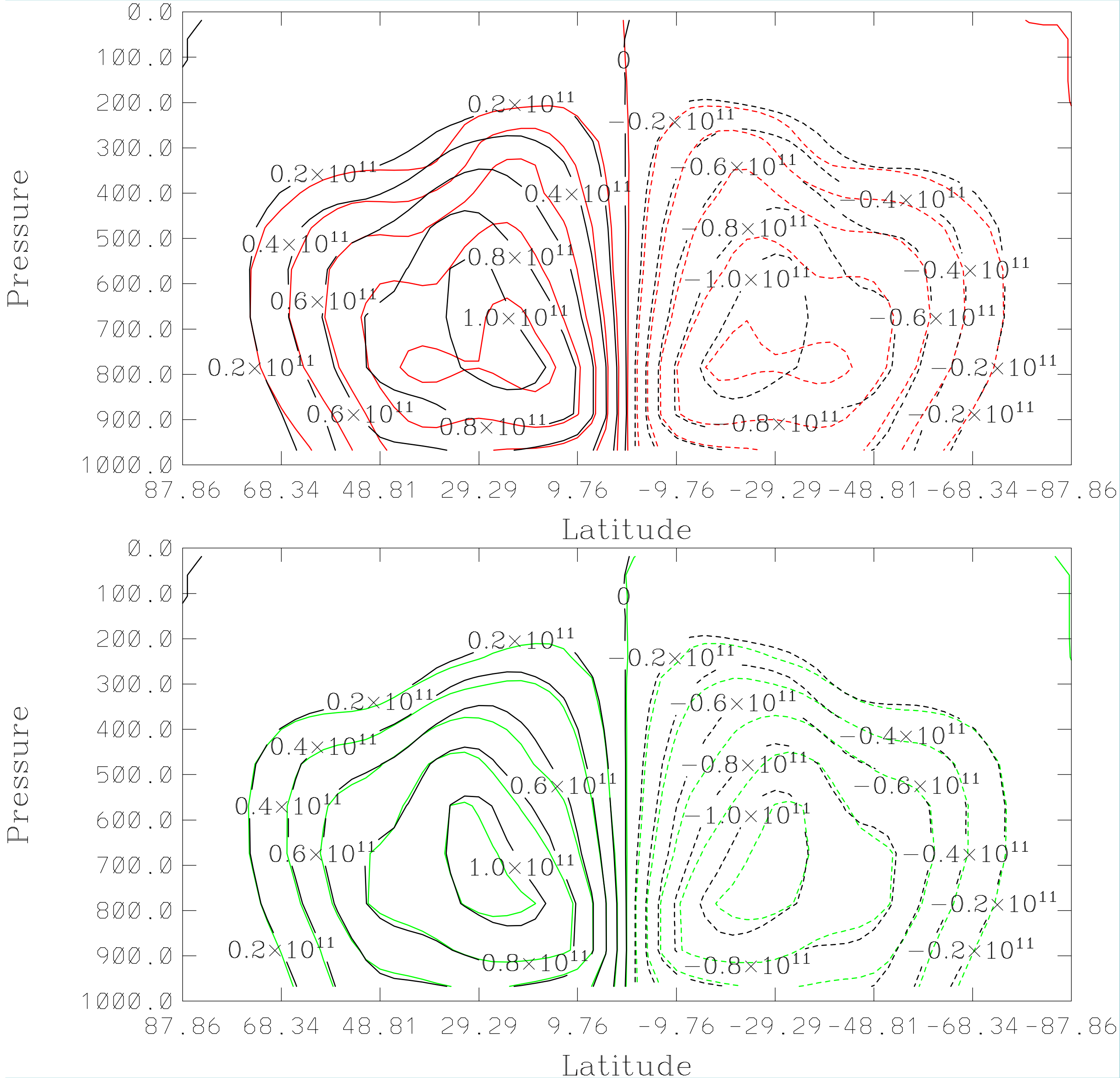


mean meridional circulation

control

uniform heating

$\cos^2$(lat) heating



TEM residual circulation

control

uniform heating

$\cos^2$(lat) heating

Conclusions - I

- Model simulations show a characteristic pattern of response to enhanced solar UV: the sub-tropical jets weaken & move poleward, the Hadley cells weaken.
- The same patterns, with similar magnitudes, are found in multiple regression studies of observational data.

Conclusions - II

- Results from a simplified model suggest that:

  (a) Heating of the lower stratosphere tends to weaken the sub-tropical jets as a result of reduced eddy activity.

  (b) The distribution of the heating in the stratosphere determines any shift in position of the jets.