Winter climate change and stratosphere-troposphere interaction

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Do stratospheric dynamics alter tropospheric climate change?

Shindell et al 1999
Positive AO response in strat-trop model only

Gillett et al 2002
No sensitivity to stratospheric resolution

Sigmond et al 2008
Positive AO response sensitive to GW parametrization

Huebener et al 2007
Stronger Atlantic storm track into Europe

Models and Experiments

Standard Model

Resolution: L38 N96
Lid: ~40km

Extended Model

Resolution: L60 N96
Lid: ~85km

Pre-industrial SST, Sea-Ice and CO_2
or
$4xCO_2$ SST, Sea-Ice and CO_2

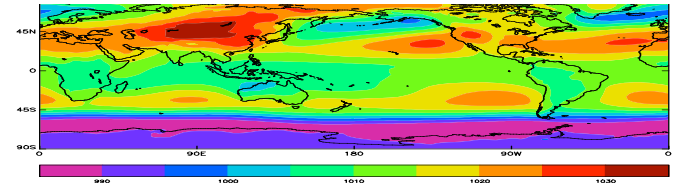
CTL L38
$4xCO_2$ L38

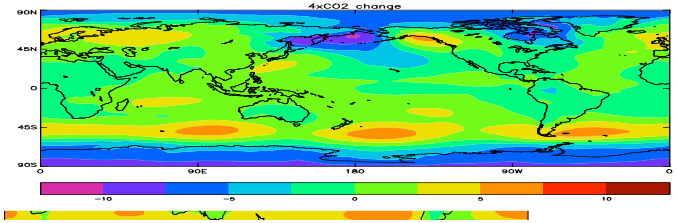
CTL L60
$4xCO_2$ L60

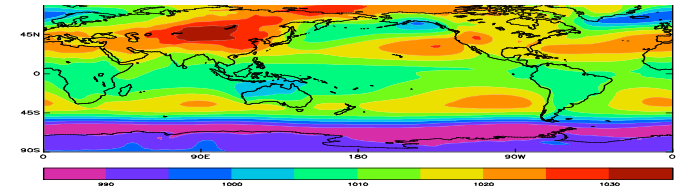
Preindustrial Winter Climate

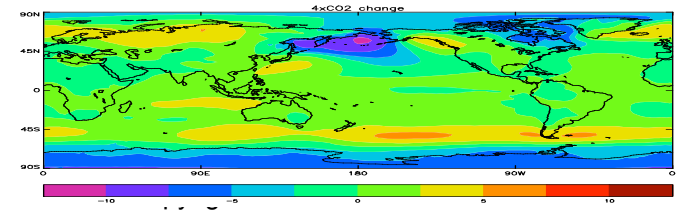
Met Office

Sea Level Pressure

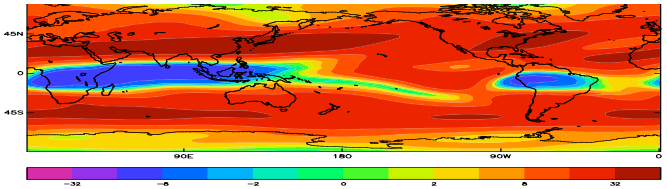


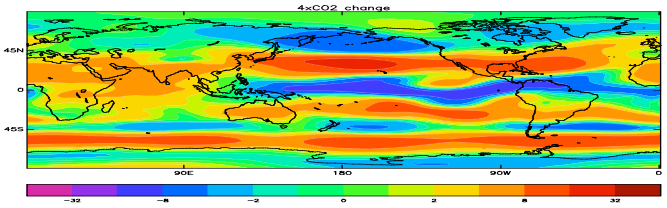


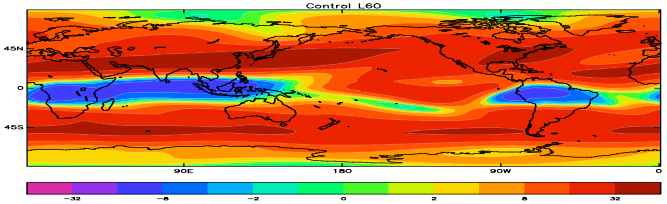


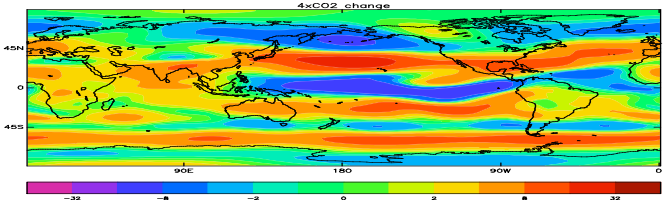


Tropospheric U wind





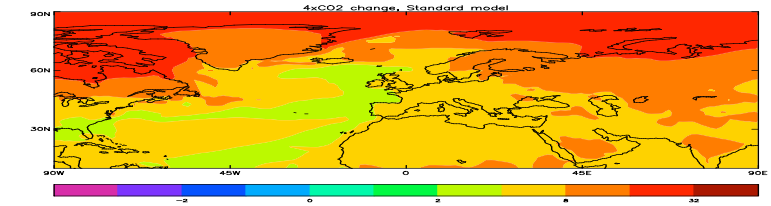




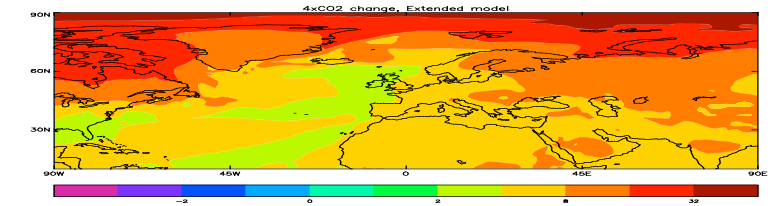
Standard Model

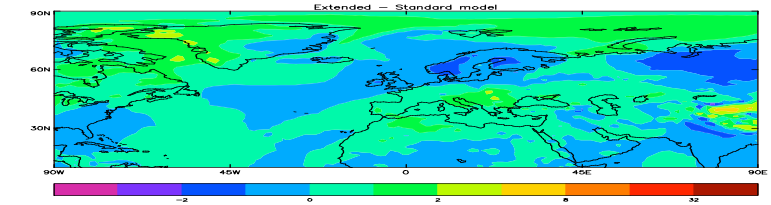
Extended Model

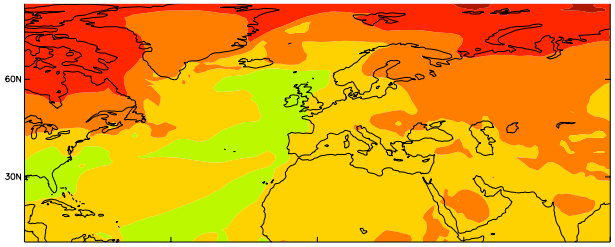
Winter Climate Change: 1.5m Temperature (K)



Standard Model



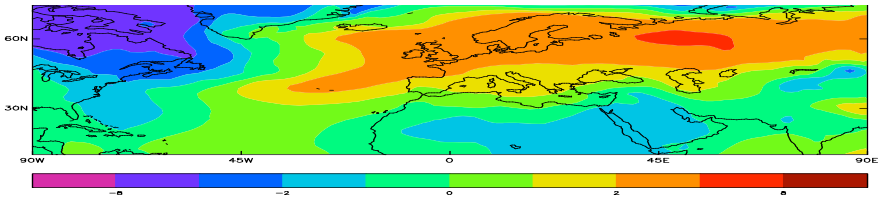


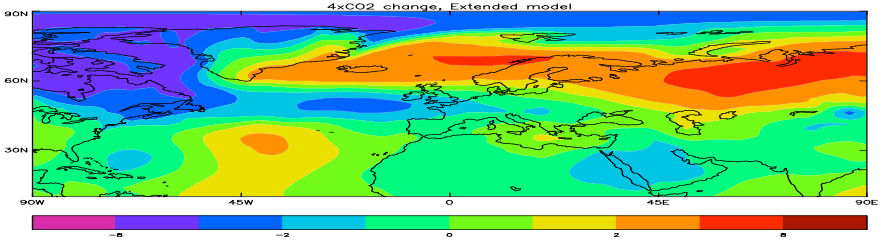


Extended Model

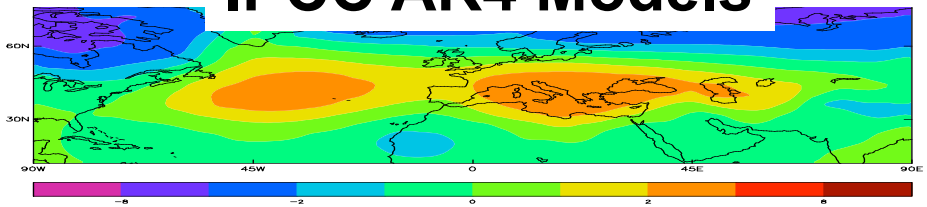
Winter Climate Change: Sea Level Pressure (hPa)

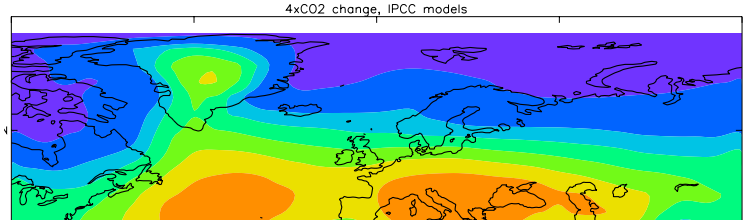
Standard Model



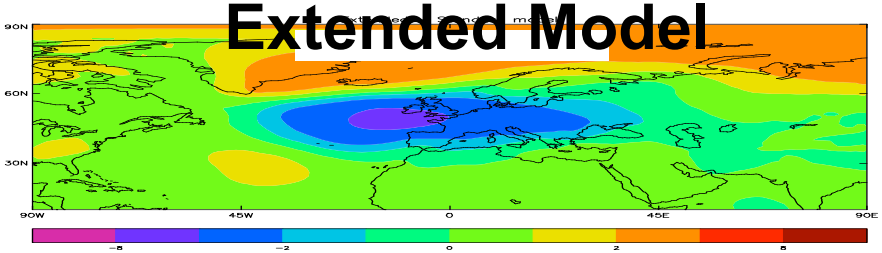


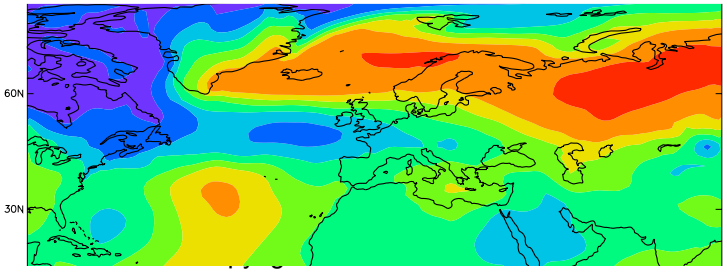
IPCC AR4 Models





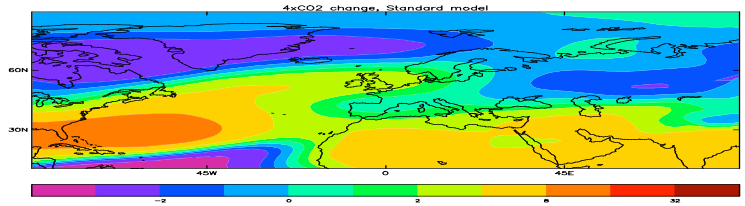
Extended Model

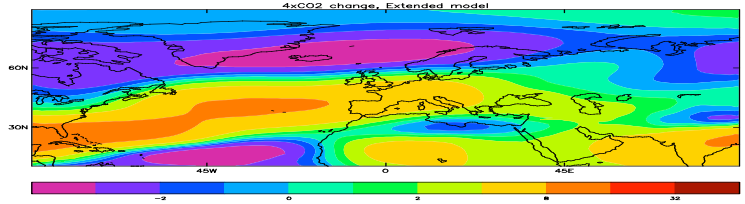


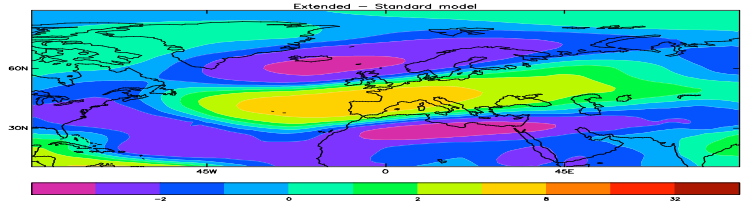


Winter Climate Change: 200hPa U (m/s)

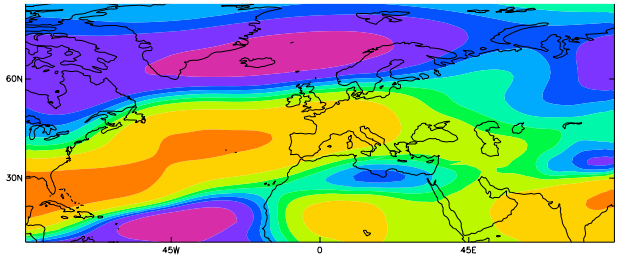
Standard Model



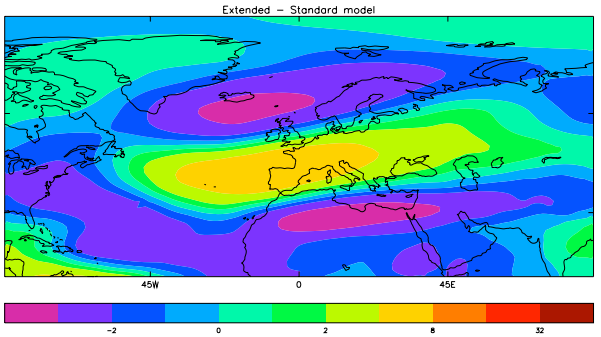




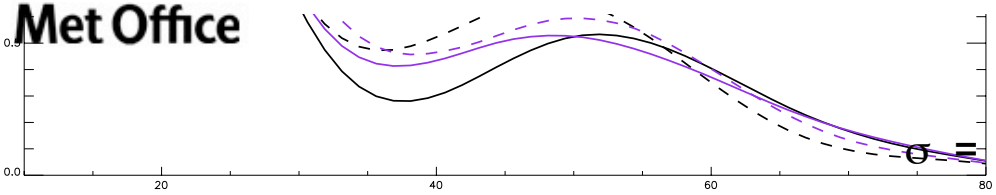
Extended Model



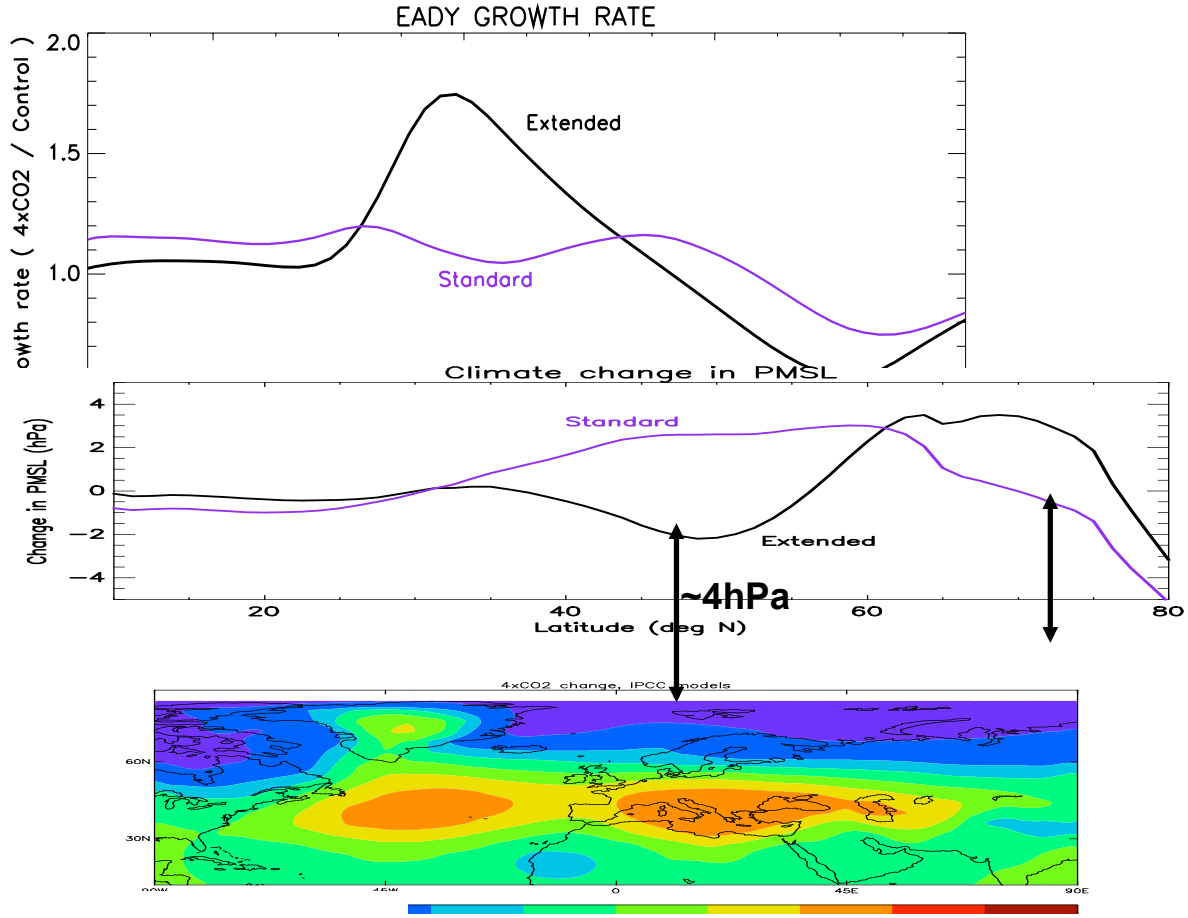
Extended - Standard



Baroclinic Eddy Response



$$\sigma = \frac{0.3 U_z f}{NH}$$

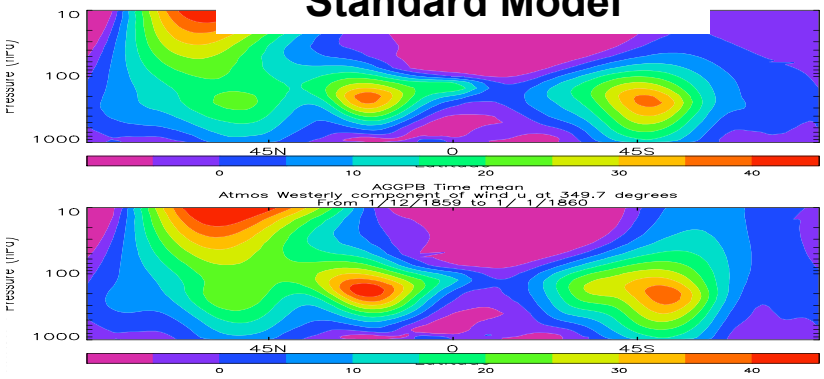


- **Very large increase in the Eady growth rate in the extended model**
- **Not present in the standard model**
- **Just S of the low pressure response in the extended model**

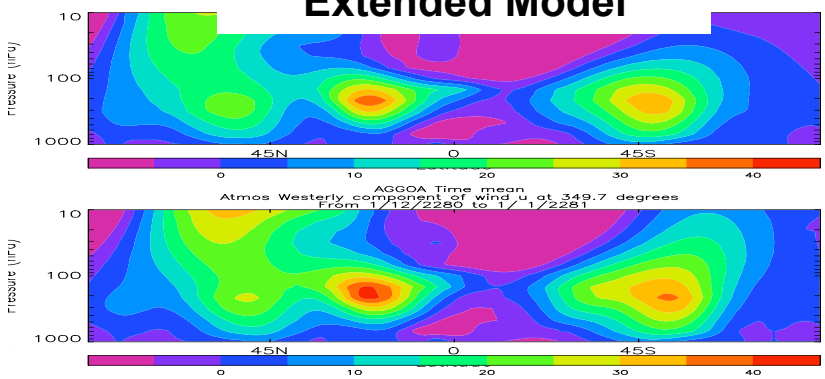
=> Enhanced cyclones and low P in mid lats

Zonal Wind Response (10W)

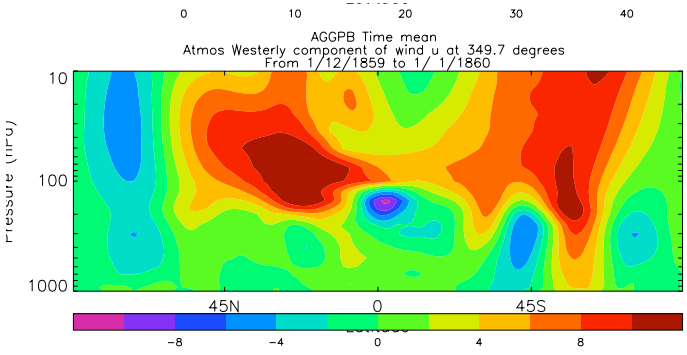
Standard Model



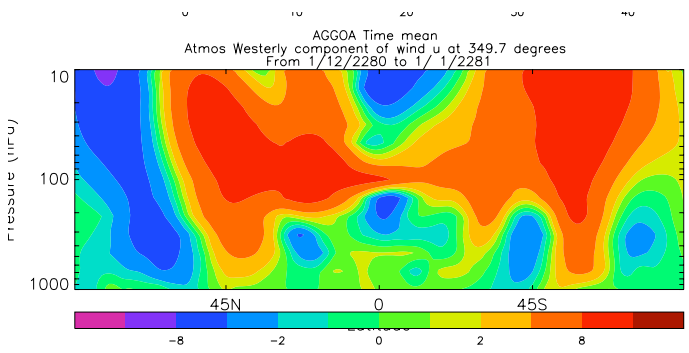
Extended Model



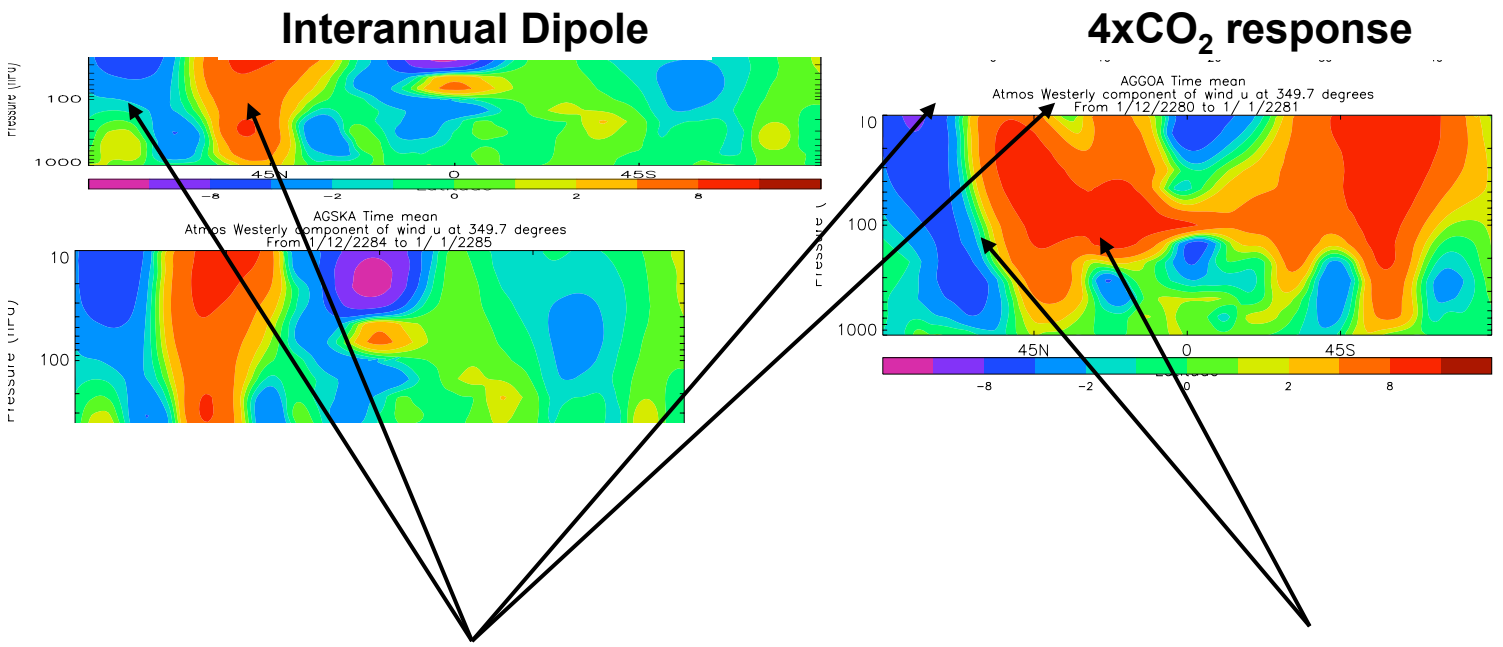
4xCO_2 response



4xCO_2 response



Causes of increased tropospheric shear



- **Stratospheric dipole interannual *and* climate timescales**
- **Extends into troposphere in both cases**

Changing stratospheric circulation

- Increased GHG forcing

=> Increased wave driving & meridional circulation

=> Weakened and equatorward shifted PNJ

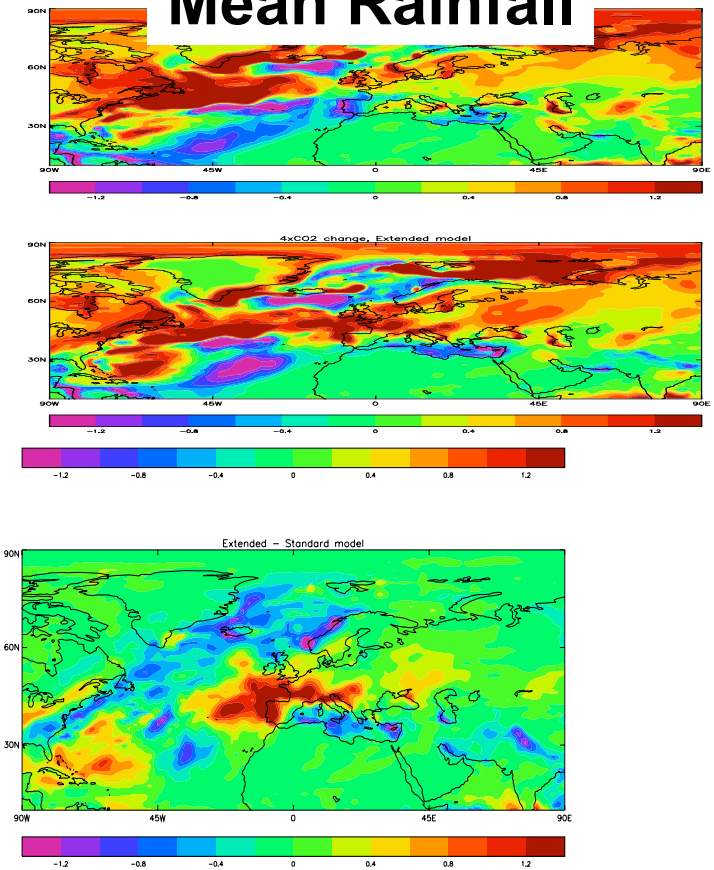
=> Stronger mid-latitude westerlies

=> Increased vertical shear in U in troposphere

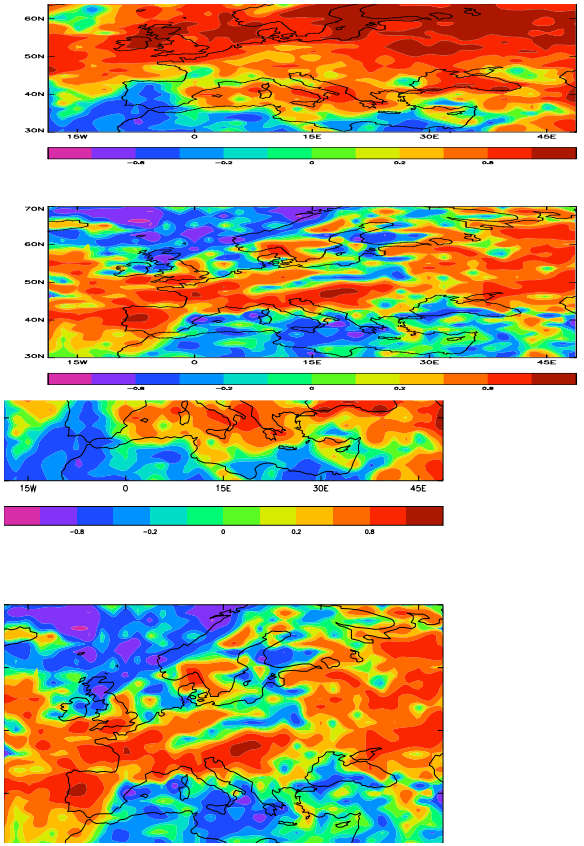
=> Greater tropospheric eddy growth

Rainfall Changes

Mean Rainfall



Frequency of Heavy Rainfall



Standard Model

Extended - Standard

Summary

- *Extended model shows dipole response in U*
- *Weak in standard model*
- *Changes in U_z => increased growth of baroclinic eddies*
- *Circulation changes exacerbate climate change in W Europe*

  more storms => larger increase in heavy rainfall events
- *Eliminated the role of the ocean*