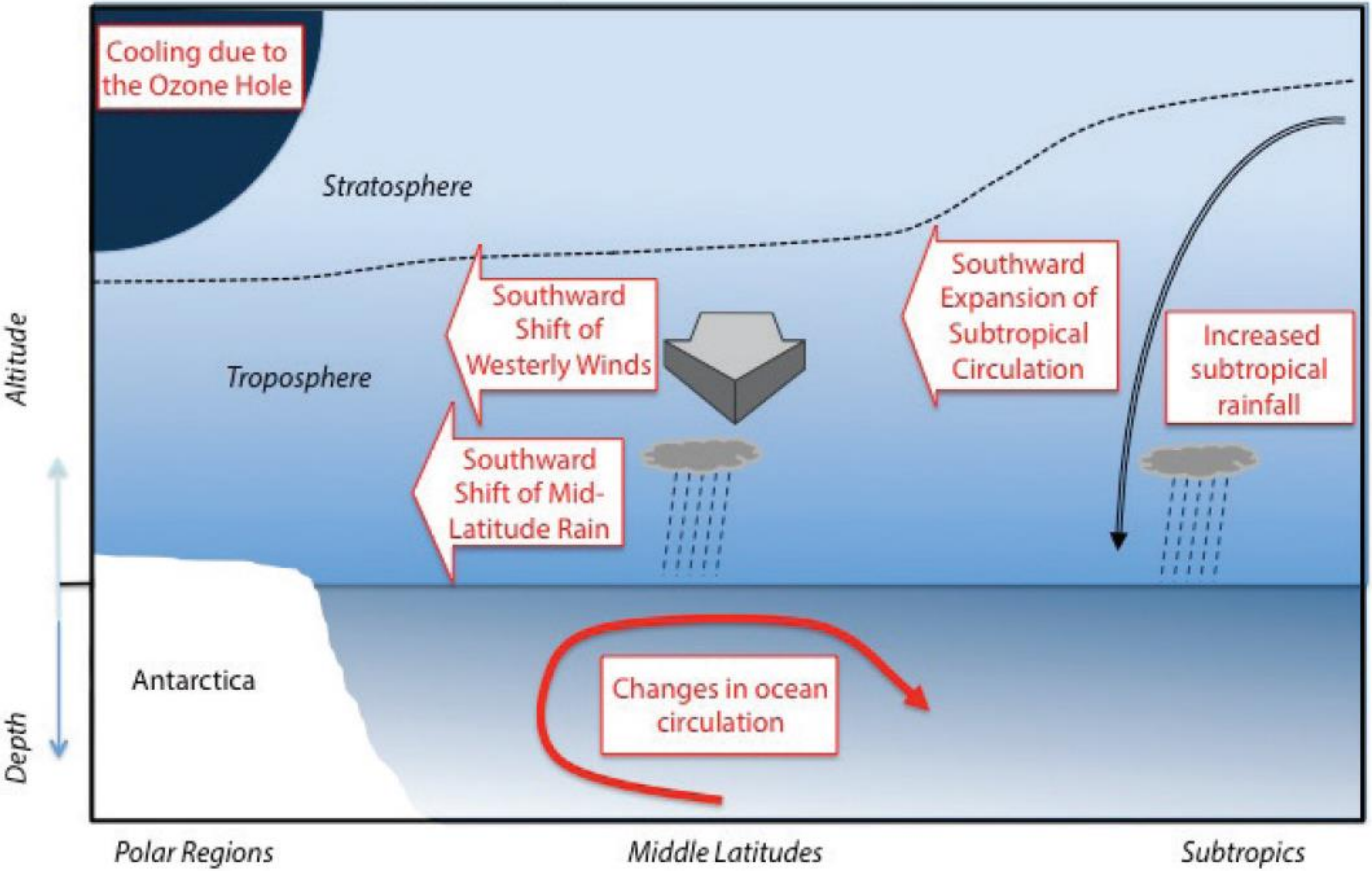
Impacts of historical ozone changes on climate in GFDL-CM3

Larry Horowitz (GFDL)

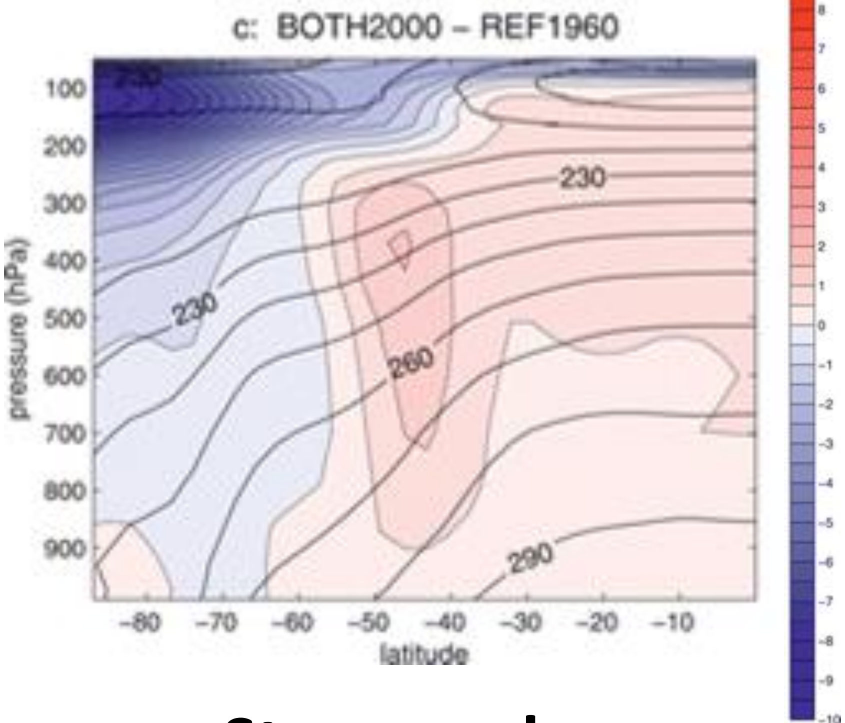
with: Vaishali Naik (GFDL), Pu Lin (CICS), and M. Daniel Schwarzkopf (GFDL)

Antarctic Ozone Depletion Impacts on Southern Hemisphere Tropospheric Climate



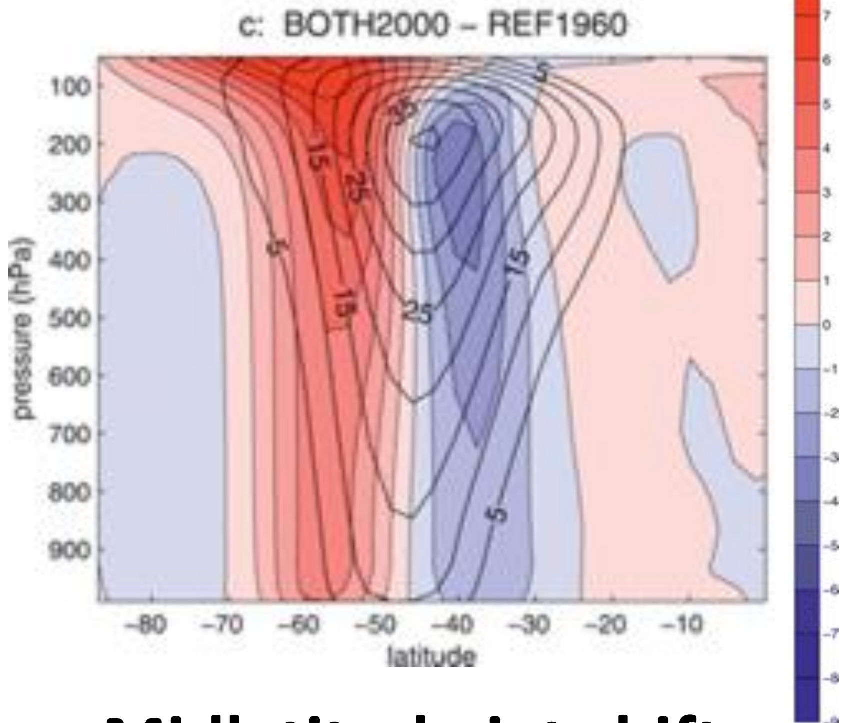
WMO (2014)
Figure ADM 5-1

Temperature (DJF)



Strong polar stratospheric cooling

Zonal Wind (DJF)



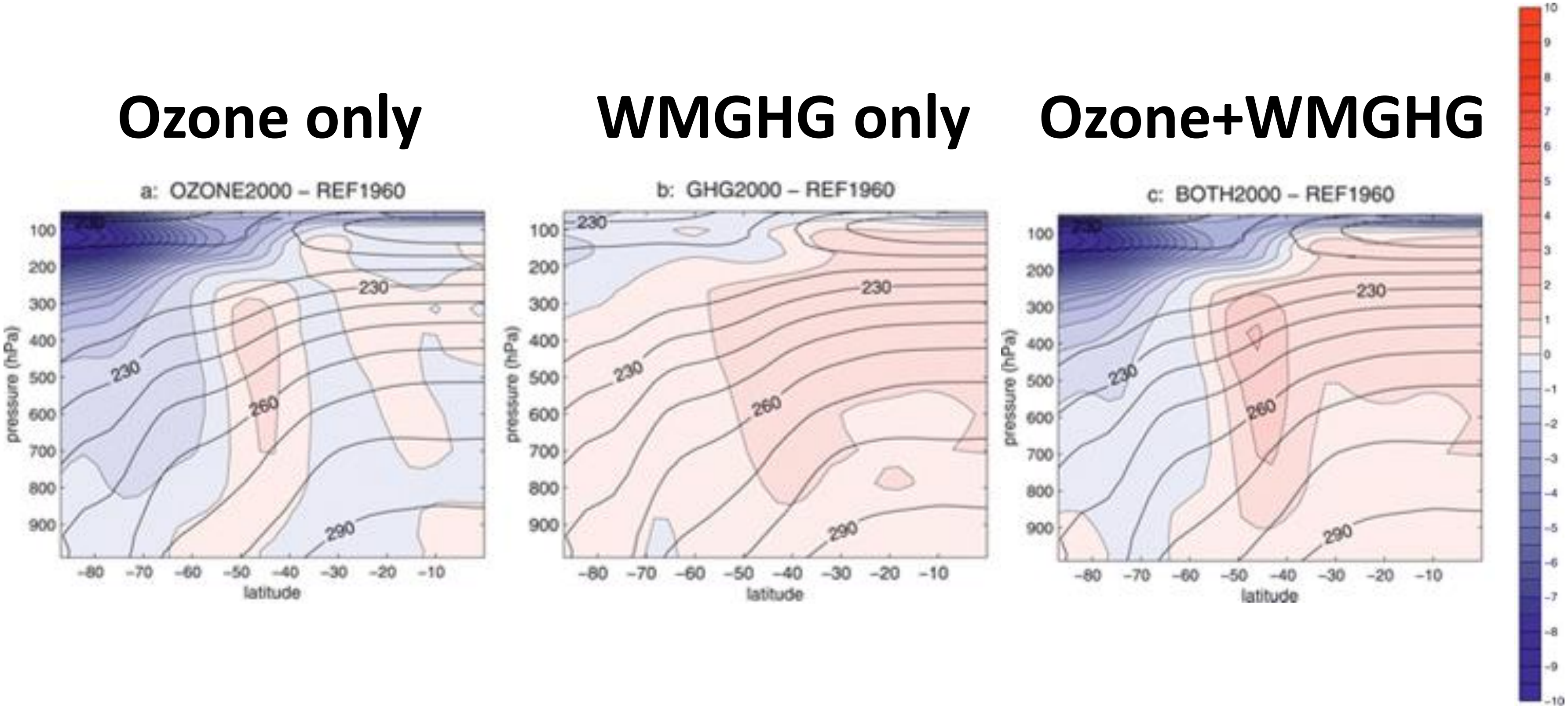
Midlatitude jet shifts poleward

Relative contributions of ozone and WMGHG?

Polvani et al. (2011)

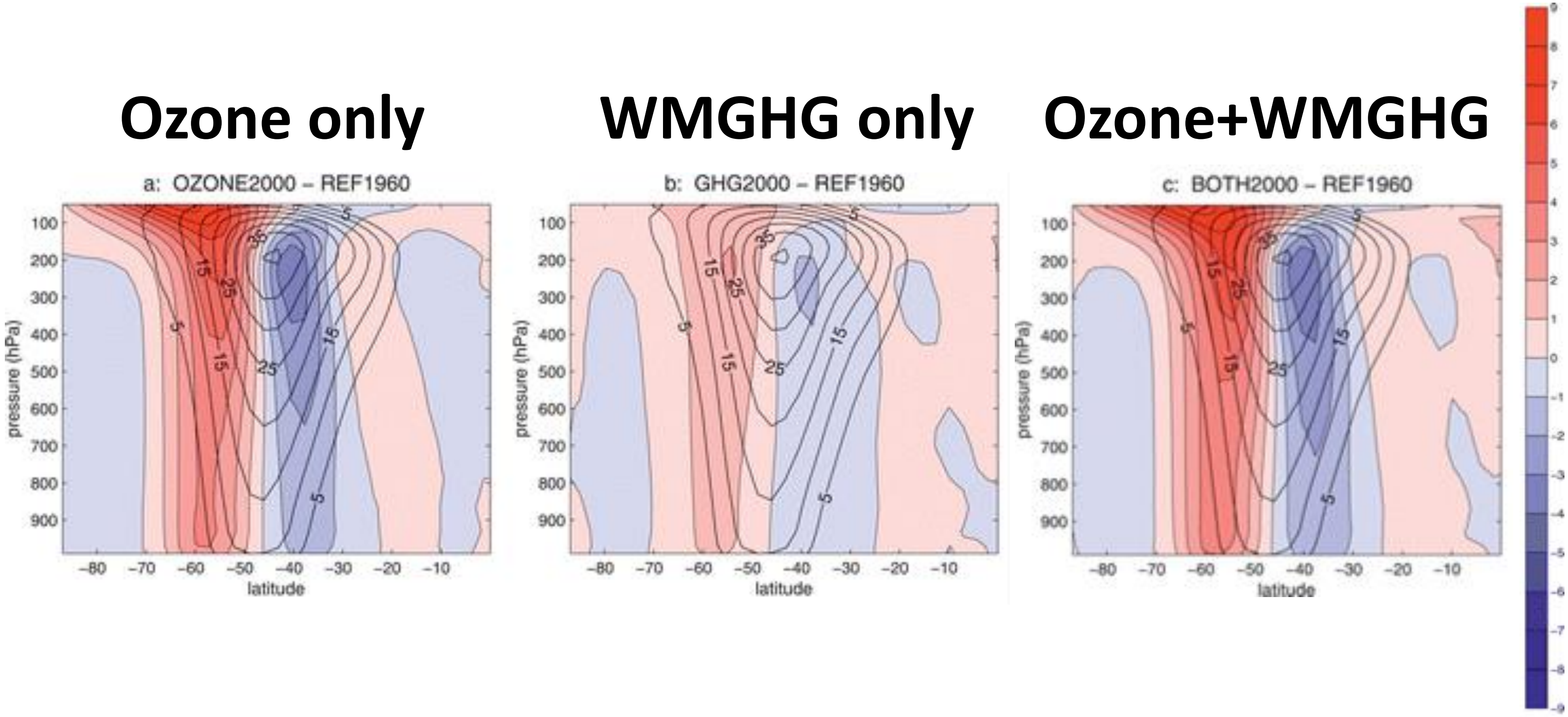
Ozone changes dominate temperature response

Ozone only | **WMGHG only** | **Ozone+WMGHG**



Polvani et al. (2011)

Ozone changes dominate jet shift

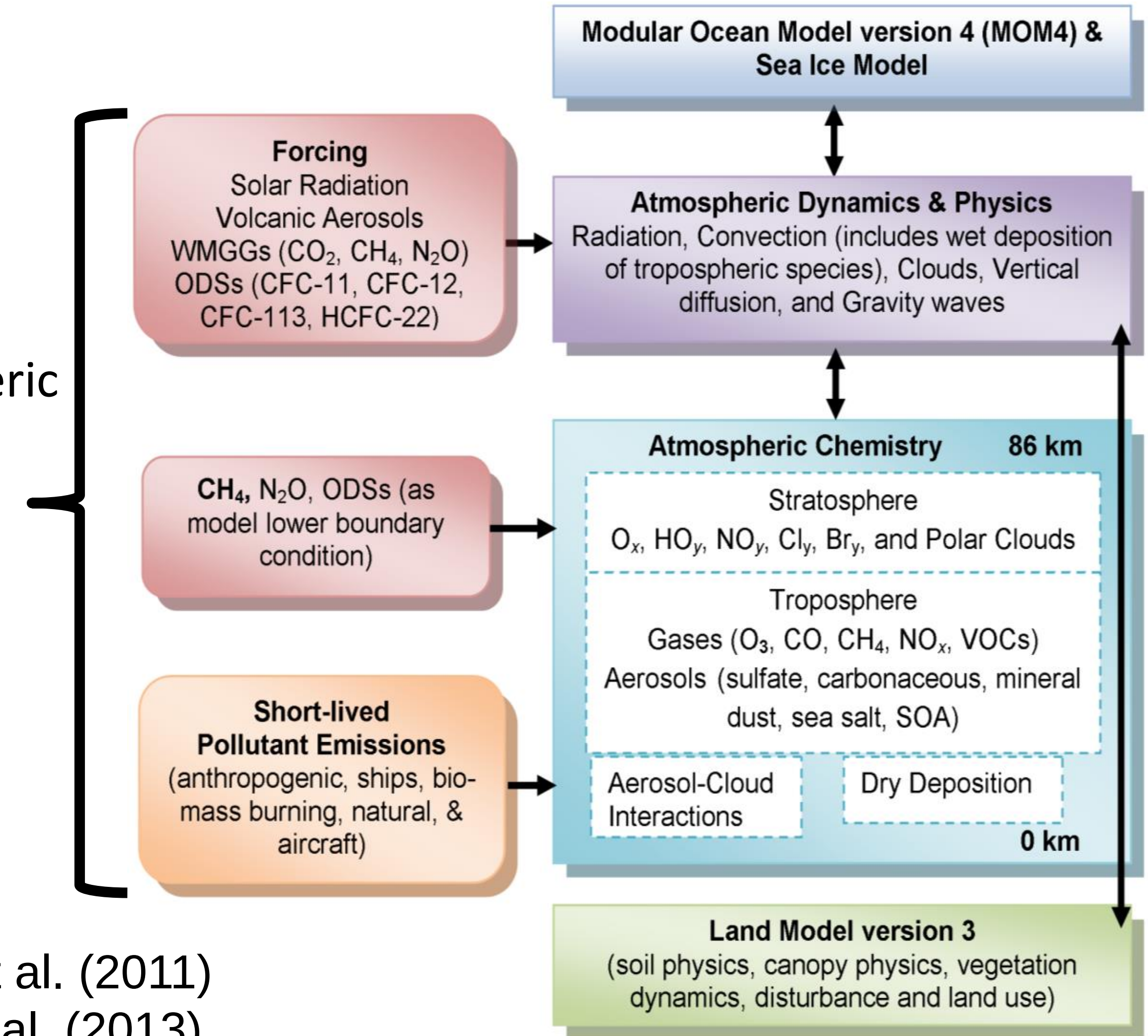


Polvani et al. (2011)

CM3 Coupled Climate Model

AM3

Atmospheric Model



Cubed sphere dynamical core

Putman and Lin (2007)

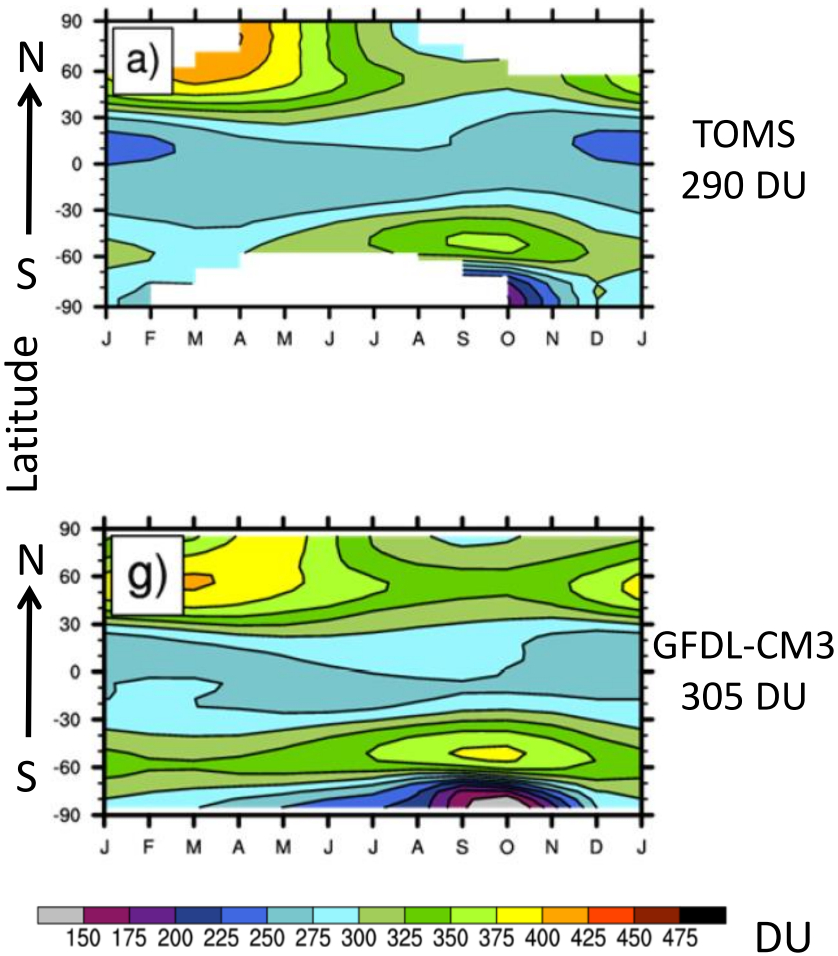
Designed to address:

- Chemistry-climate feedbacks
- Stratosphere-troposphere chemical and dynamical coupling (high model top)
- Aerosol-cloud interactions

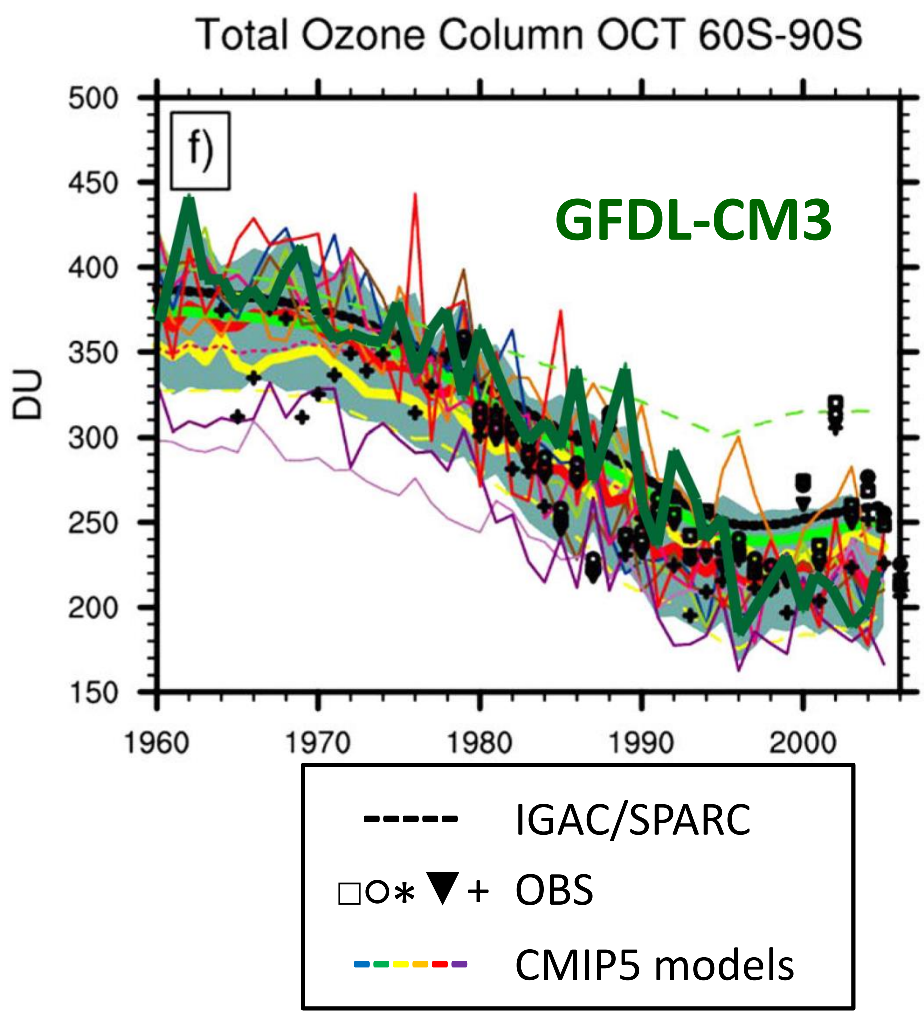
Donner et al. (2011)
Austin et al. (2013)
Naik et al. (2013)

Stratospheric ozone distributions and trends are generally well simulated

Ozone Column

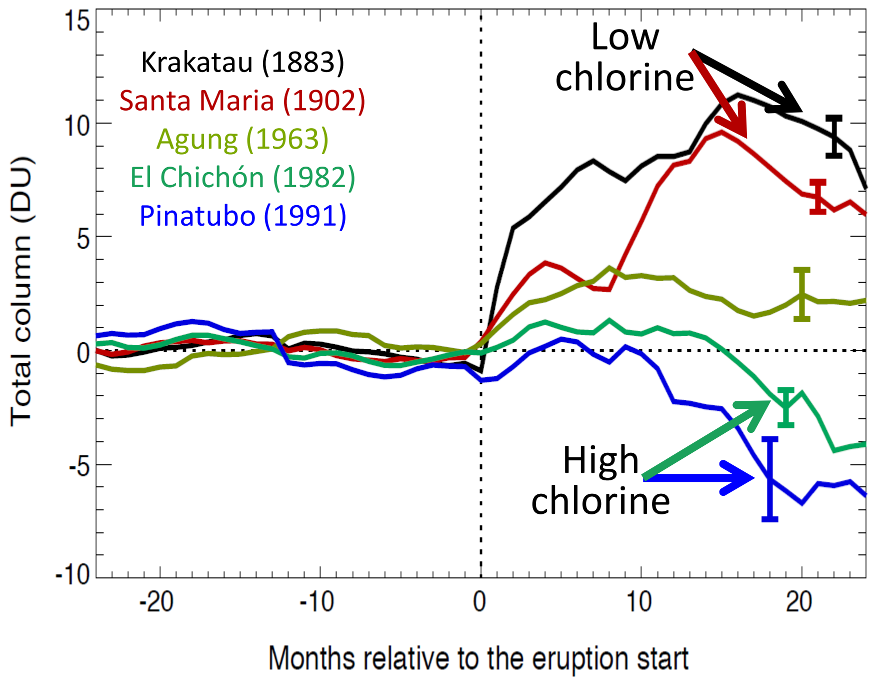


Development of Antarctic Ozone Hole



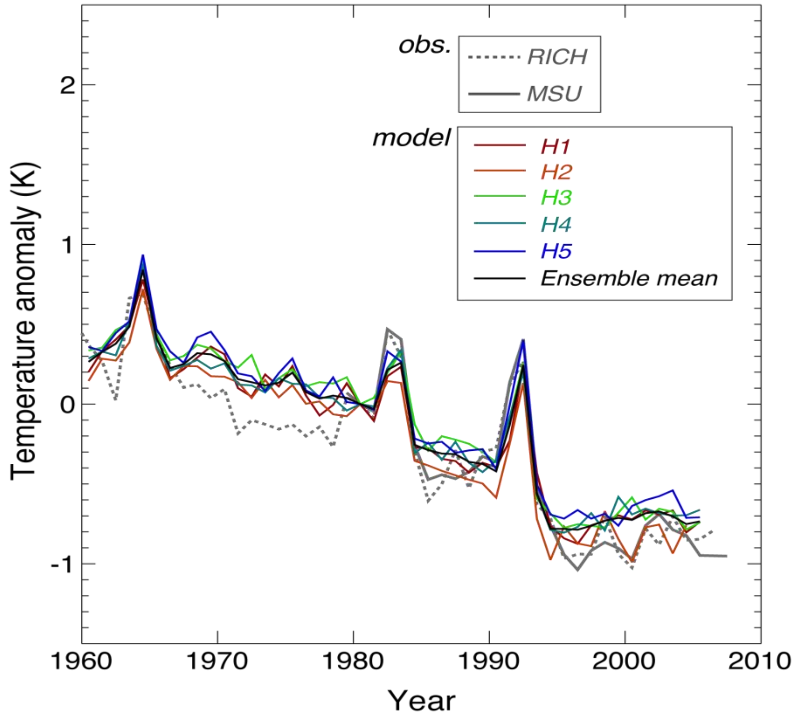
Stratospheric ozone and temperature respond strongly to volcanic eruptions

Ozone Column



Sign of ozone response to volcanic aerosols depends on atmospheric chlorine loading

Temperature

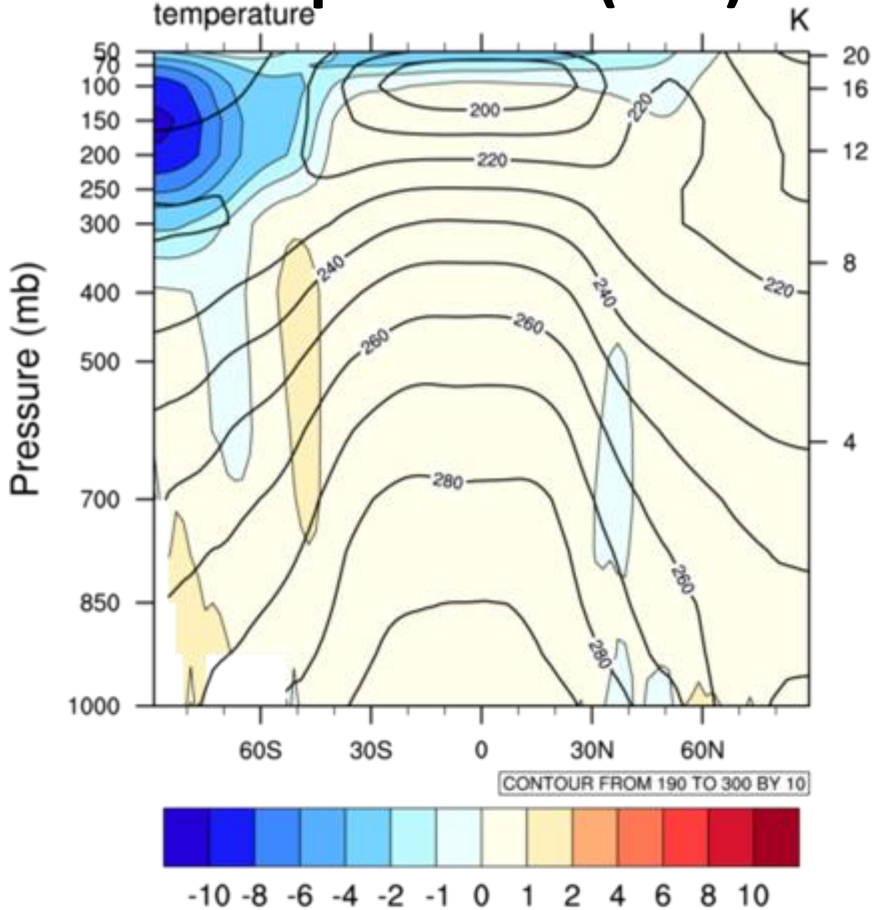


Post-volcanic warming and long-term cooling in stratosphere are well simulated by CM3

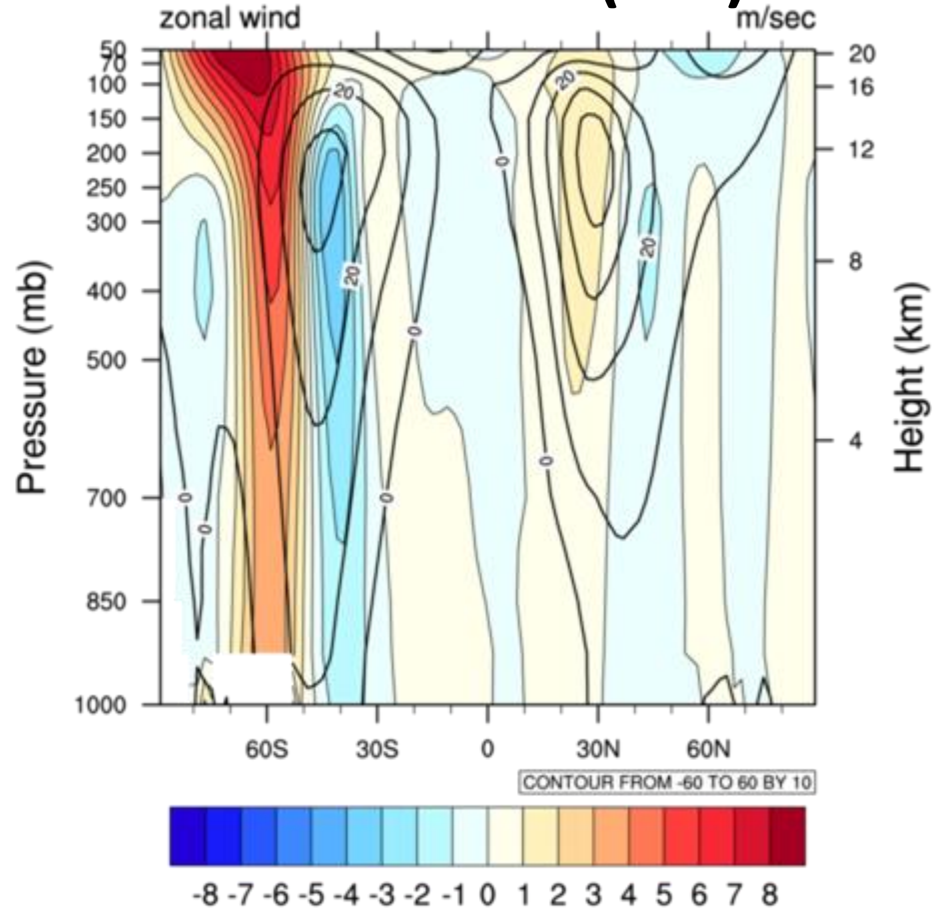
Austin et al., *J.Clim.* (2013); WMO (2014)

CM3 Historical Simulations (All Forcings)

Temperature (DJF)



Zonal Wind (DJF)

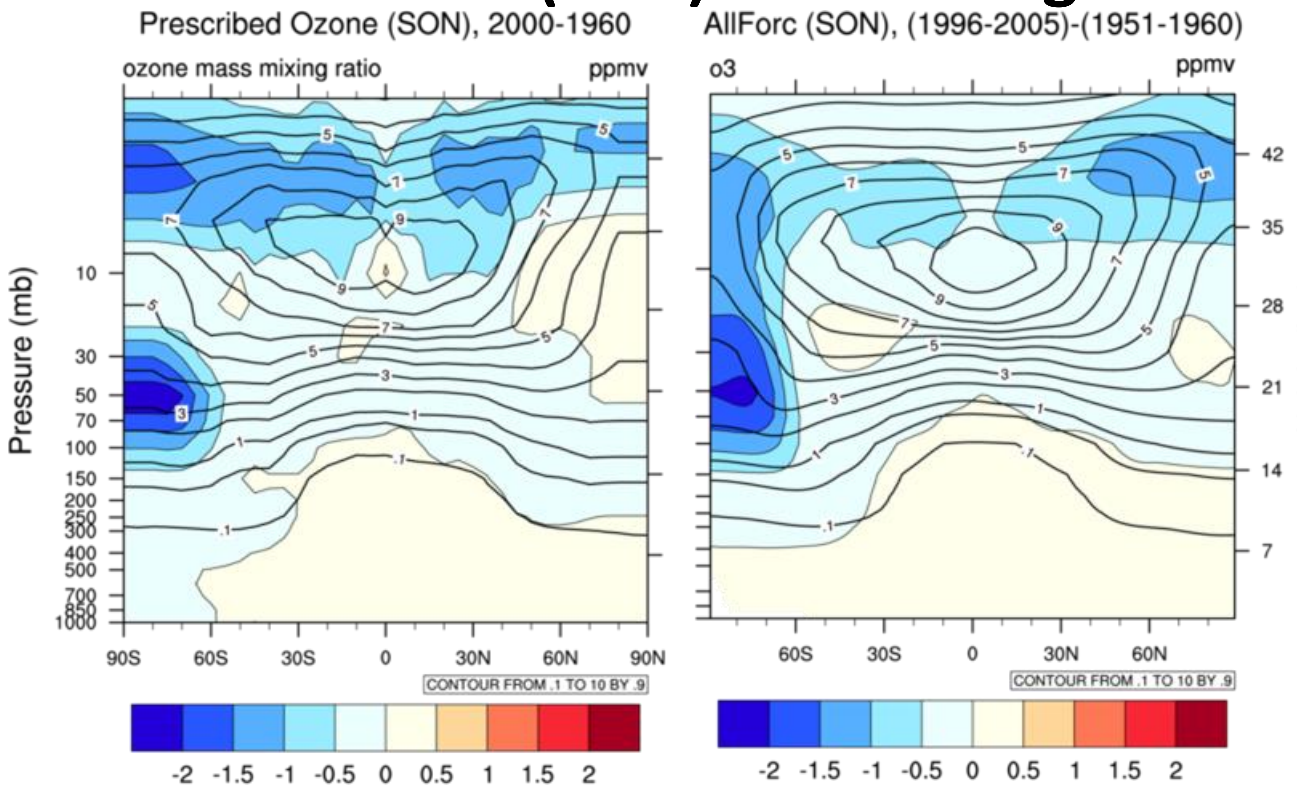


Colored contours show difference
present-day (1996-2005) minus 1950s (1951-1960)

Relative contributions of ozone and WMGHG?

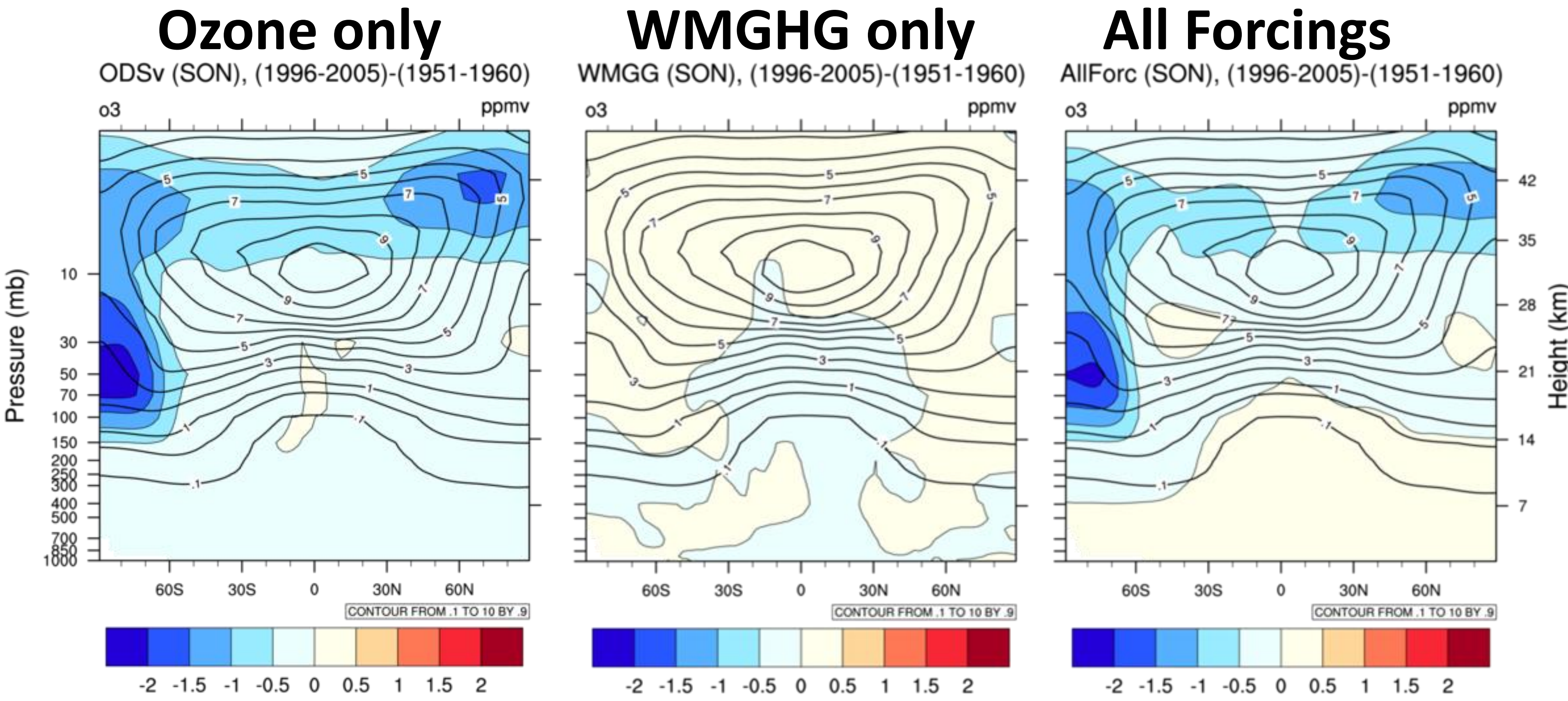
Ozone mixing ratio in CM3 (SON)

SPARC Dataset (OBS) **All Forcings**



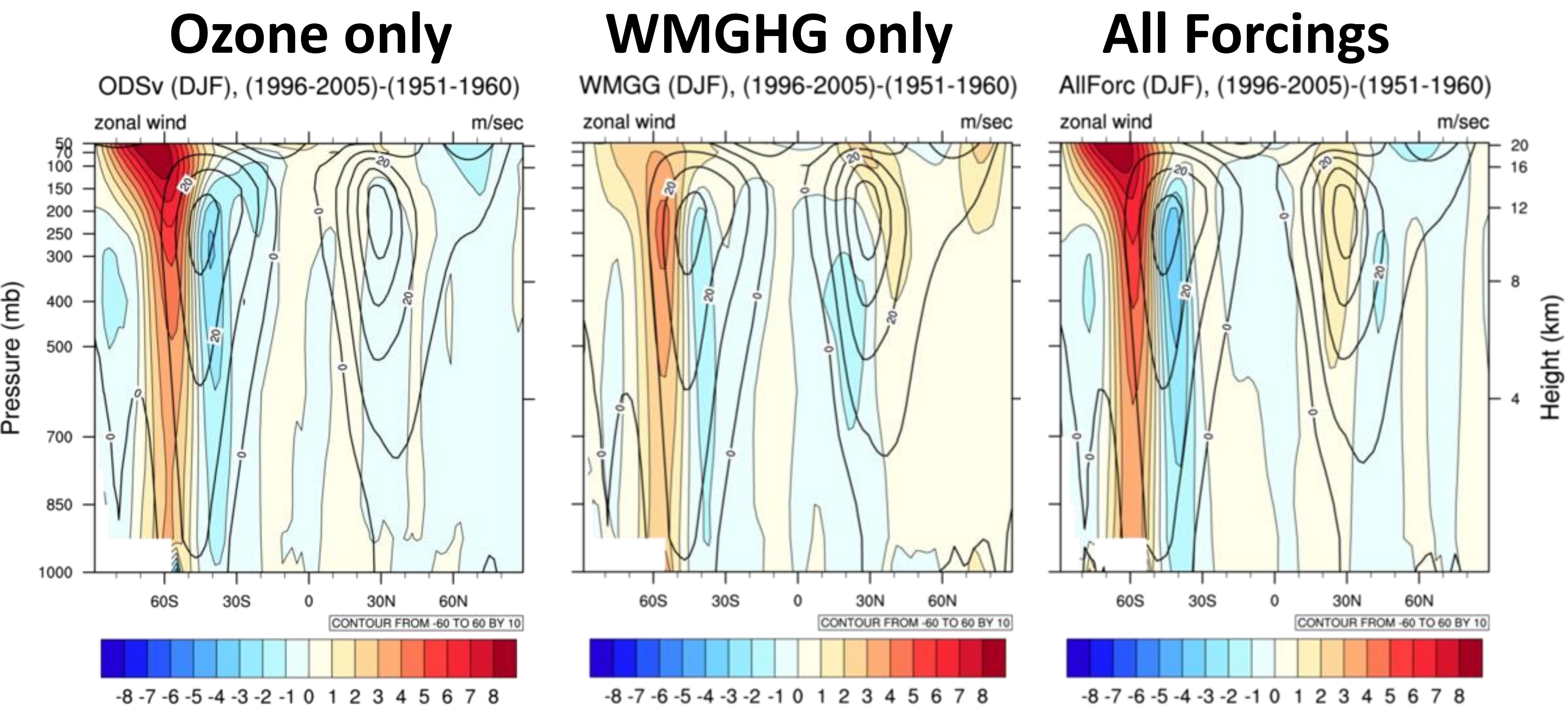
Historical changes in ozone well-simulated by CM3

Ozone mixing ratio in CM3 (SON)



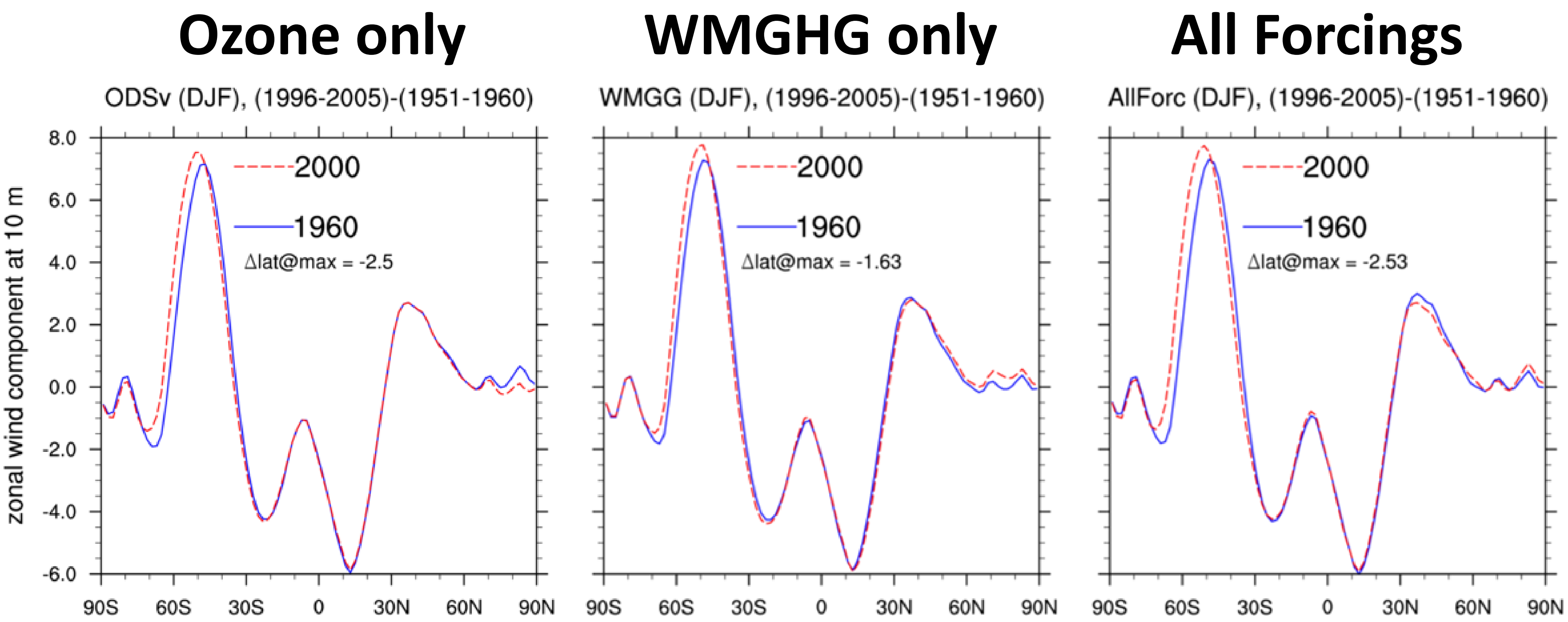
"Ozone only" experiment includes changes in ODS concentrations and uses background (1860) volcanic aerosols

Zonal winds in CM3 (DJF)



Circulation shifts more strongly in response to historical ozone depletion than to WMGHG increase

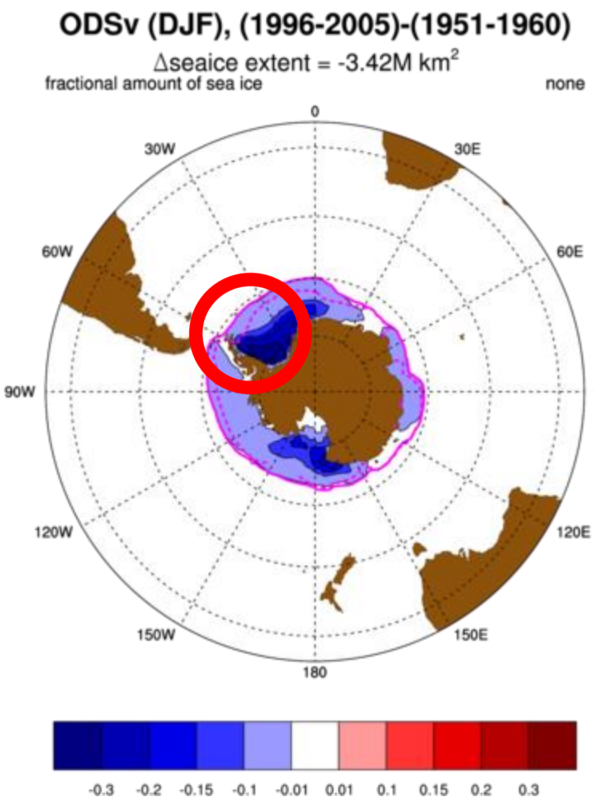
Surface winds in CM3 (DJF)

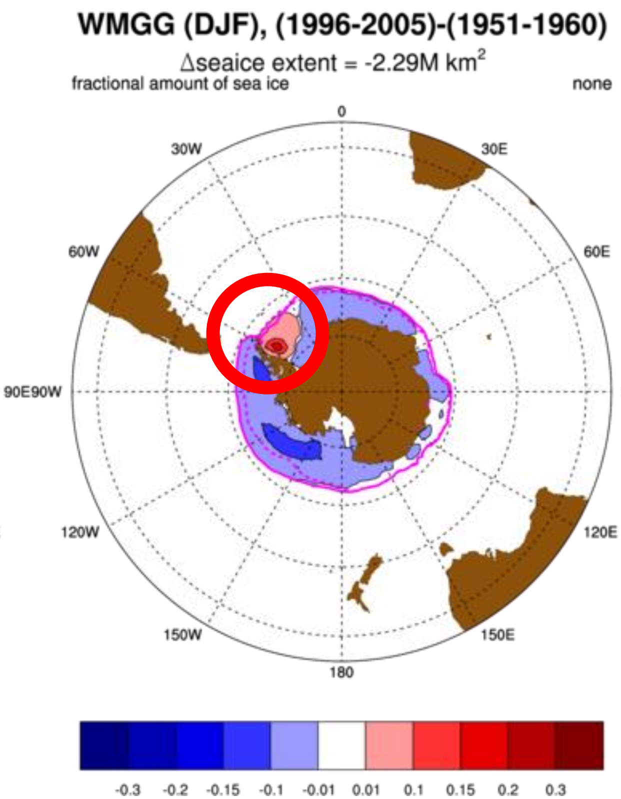


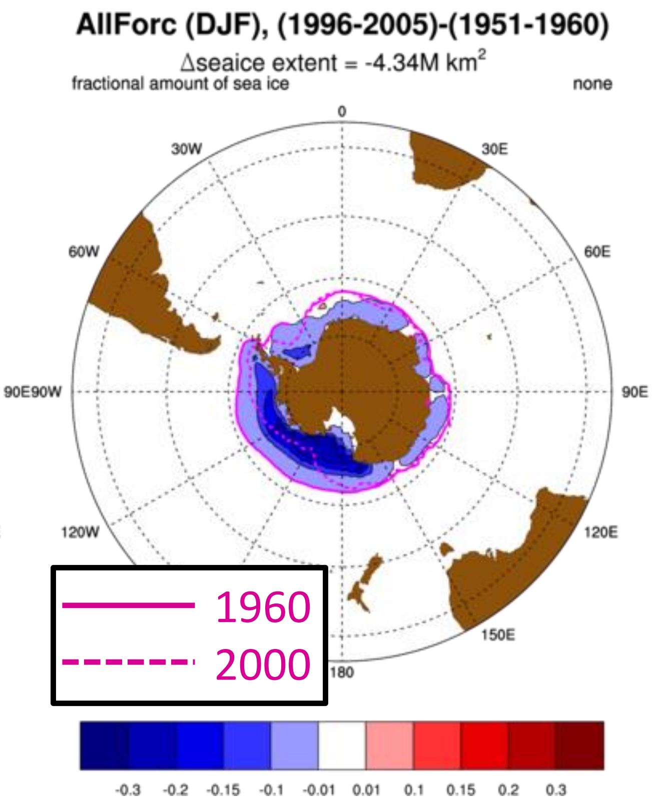
Poleward shift in surface winds in response to both ozone depletion and WMGHG increase (non-linear)

Sea ice in CM3 (DJF)

Ozone only | **WMGHG only** | **All Forcings**



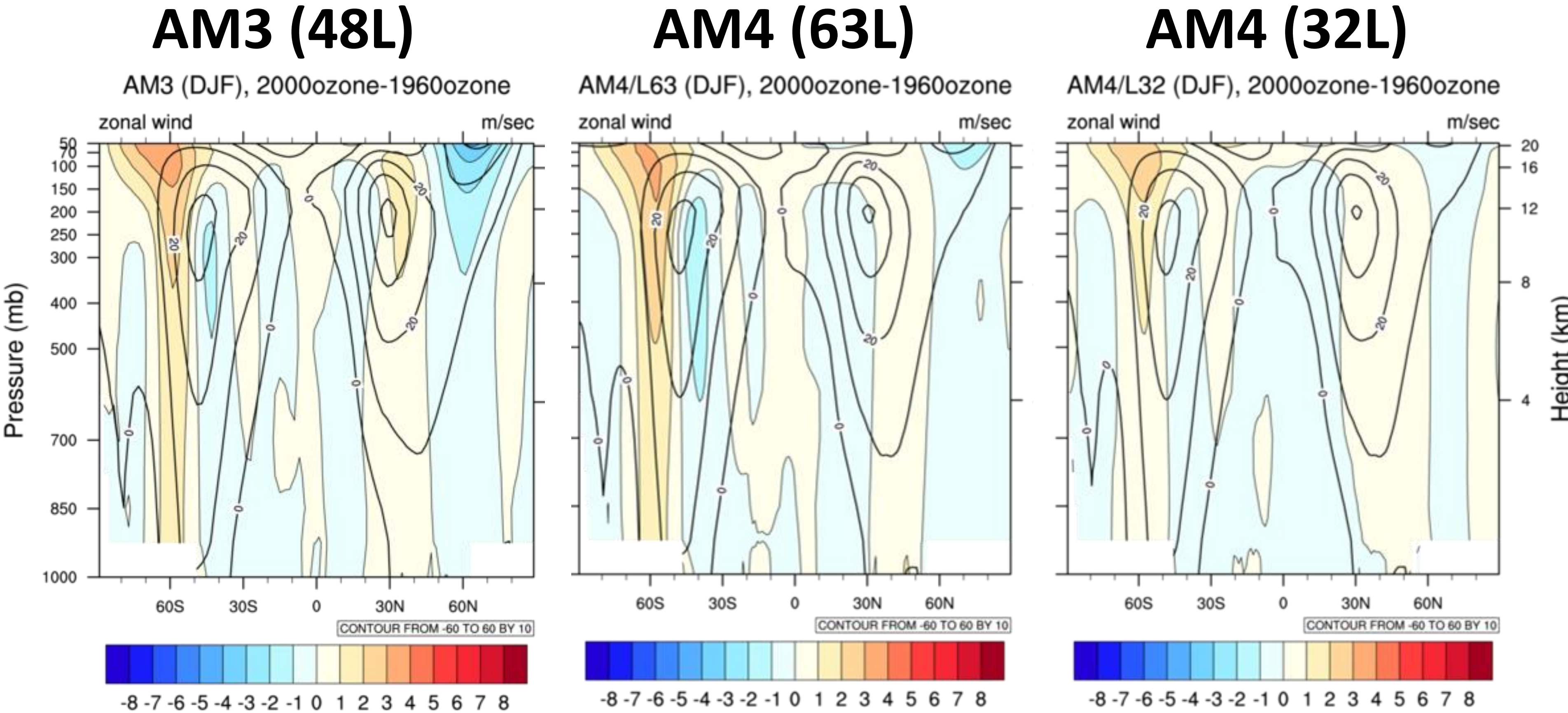




Stronger response of sea ice to ozone than to WMGHG

Sensitivity to model configuration

Zonal winds (DJF)



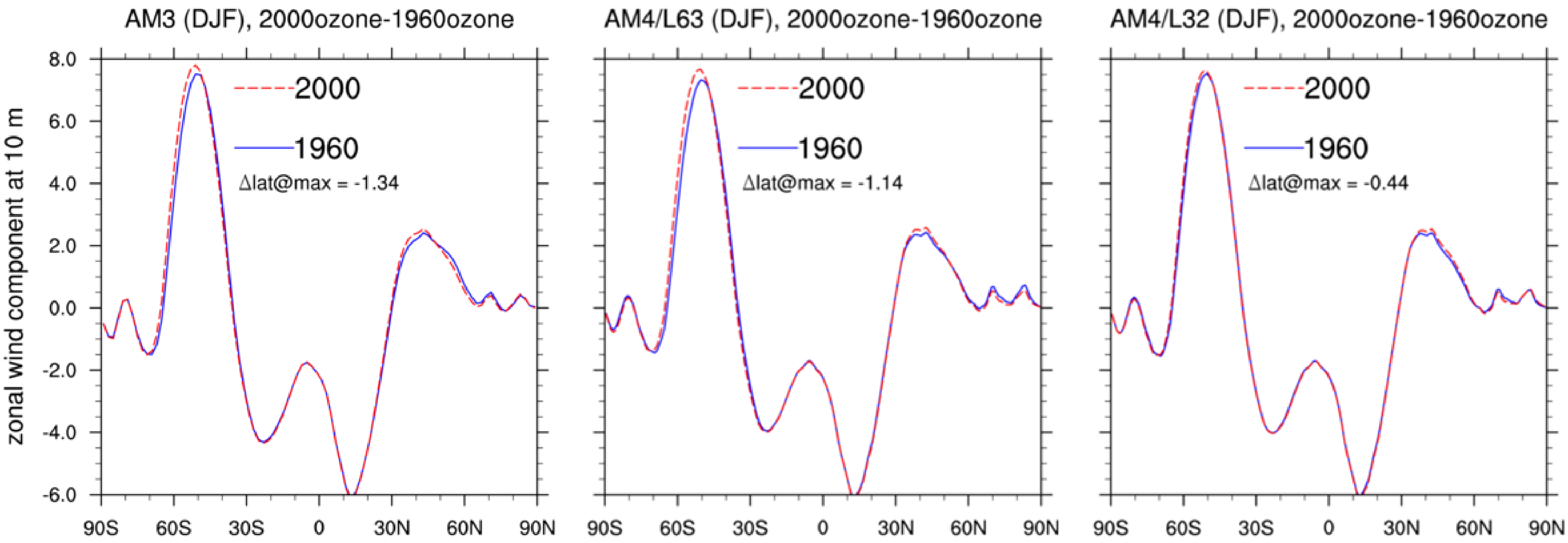
Atmosphere-only simulations with prescribed ozone change (2000 minus 1960)

Weaker tropospheric jet response in AM4 32L

Sensitivity to model configuration

Surface winds (DJF)

AM3 (48L) AM4 (63L) AM4 (32L)

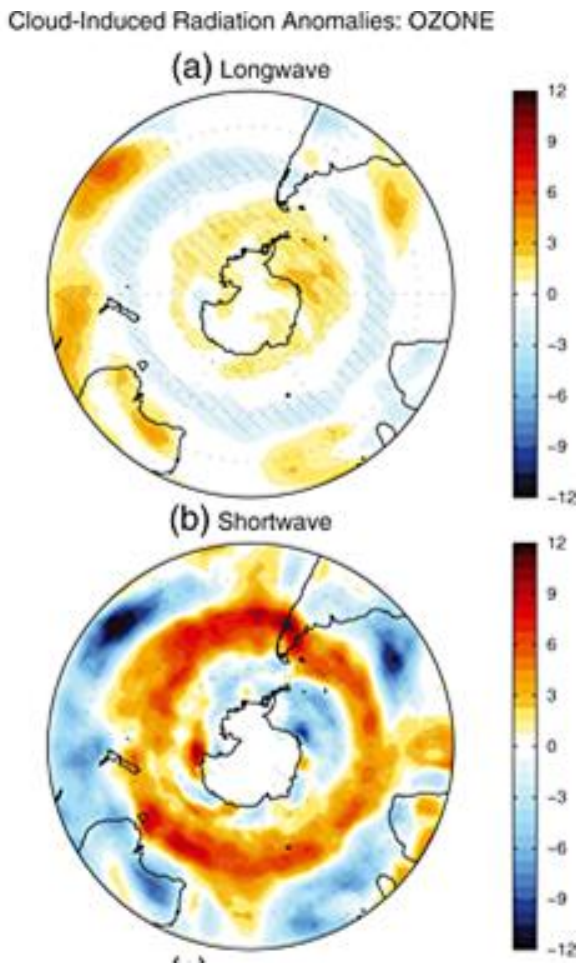


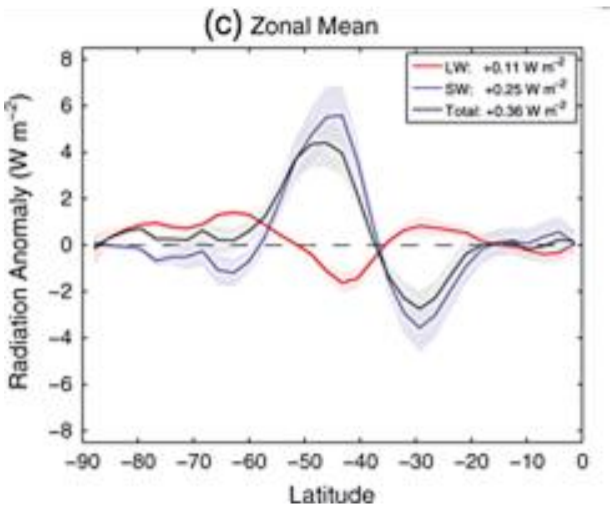
Atmosphere-only simulations with prescribed ozone change (2000 minus 1960)

Weaker surface wind shift in AM4 32L

Effective Radiative Forcing from Ozone

Cloud Radiative Forcing at TOA (DJF)





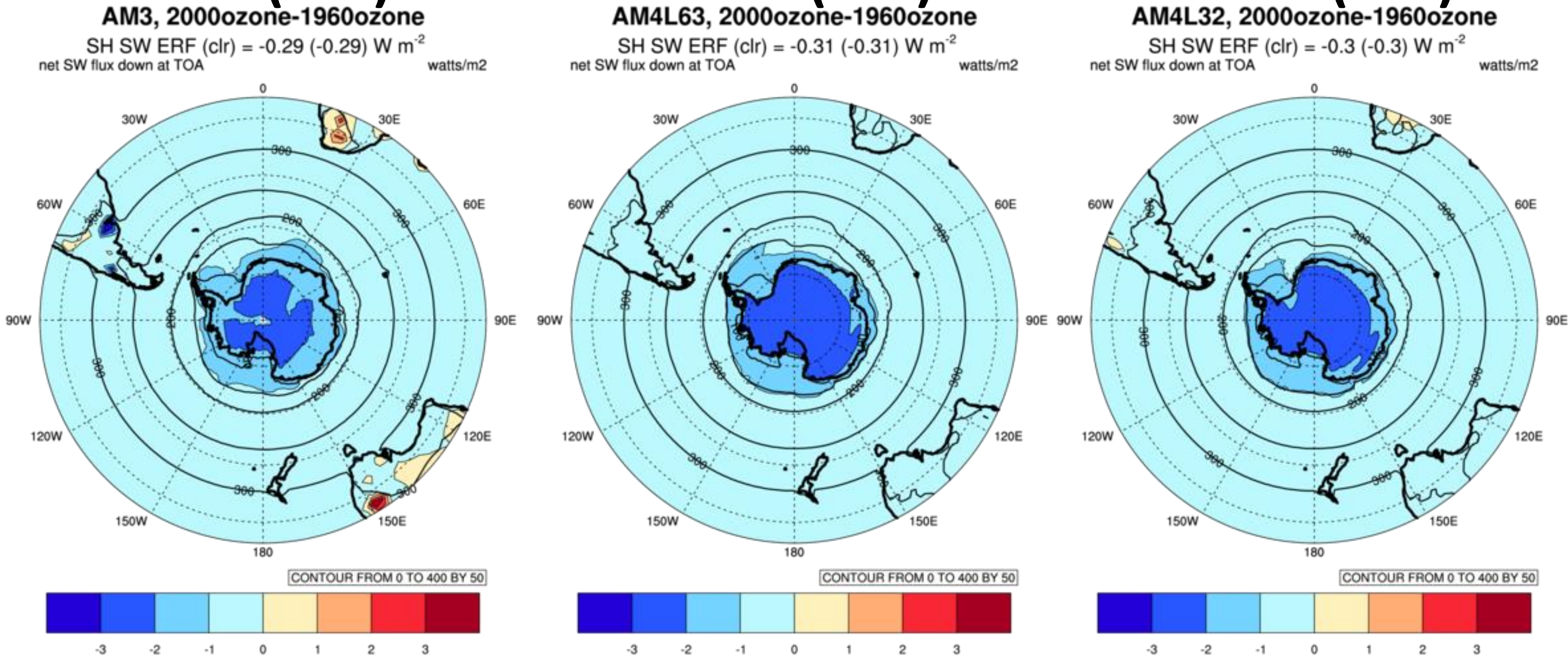
Compare response in CM3

Grise et al. (2013)

Effective Radiative Forcing from Ozone

Net Clear-Sky Shortwave Flux at TOA (annual)

AM3 (48L) **AM4 (63L)** **AM4 (32L)**



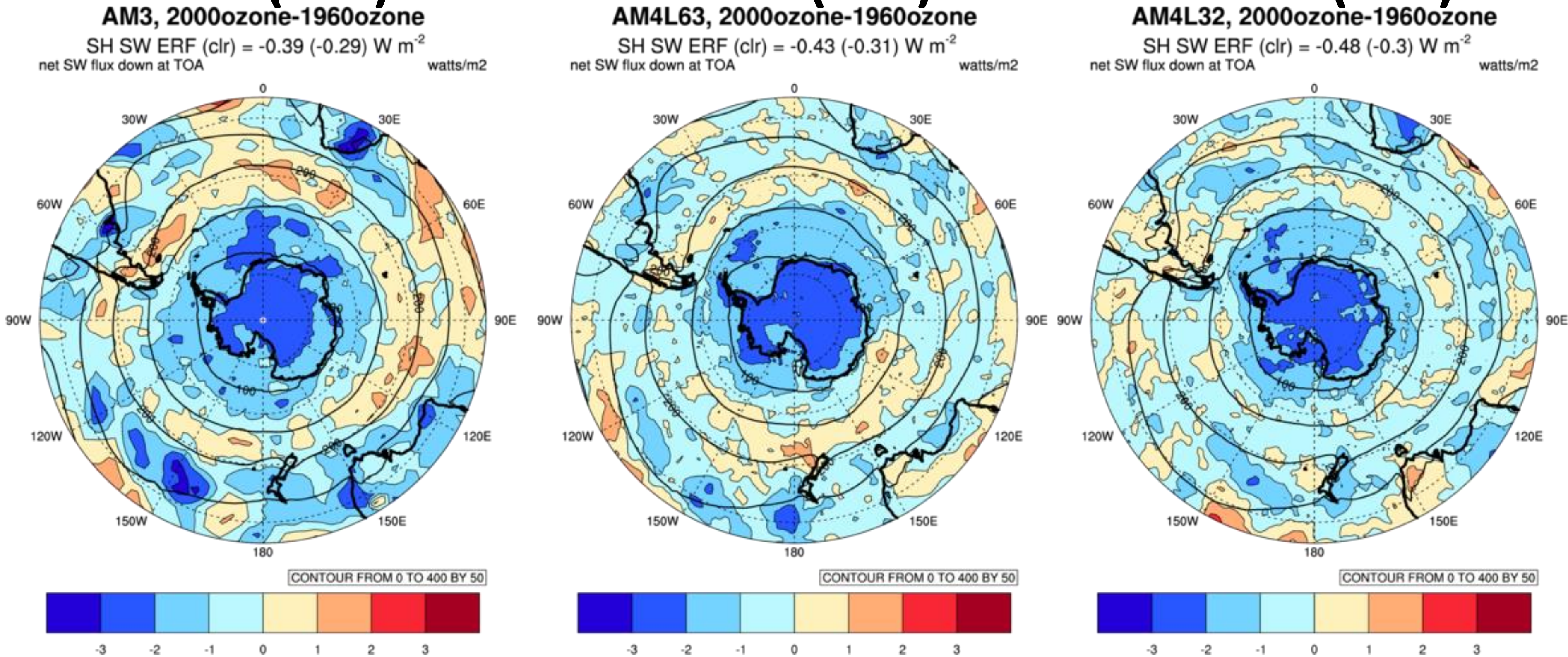
Simulations with prescribed ozone change (2000 minus 1960)

Strong clear-sky SW cooling over pole

Effective Radiative Forcing from Ozone

Net Shortwave Flux at TOA (annual)

AM3 (48L) | **AM4 (63L)** | **AM4 (32L)**



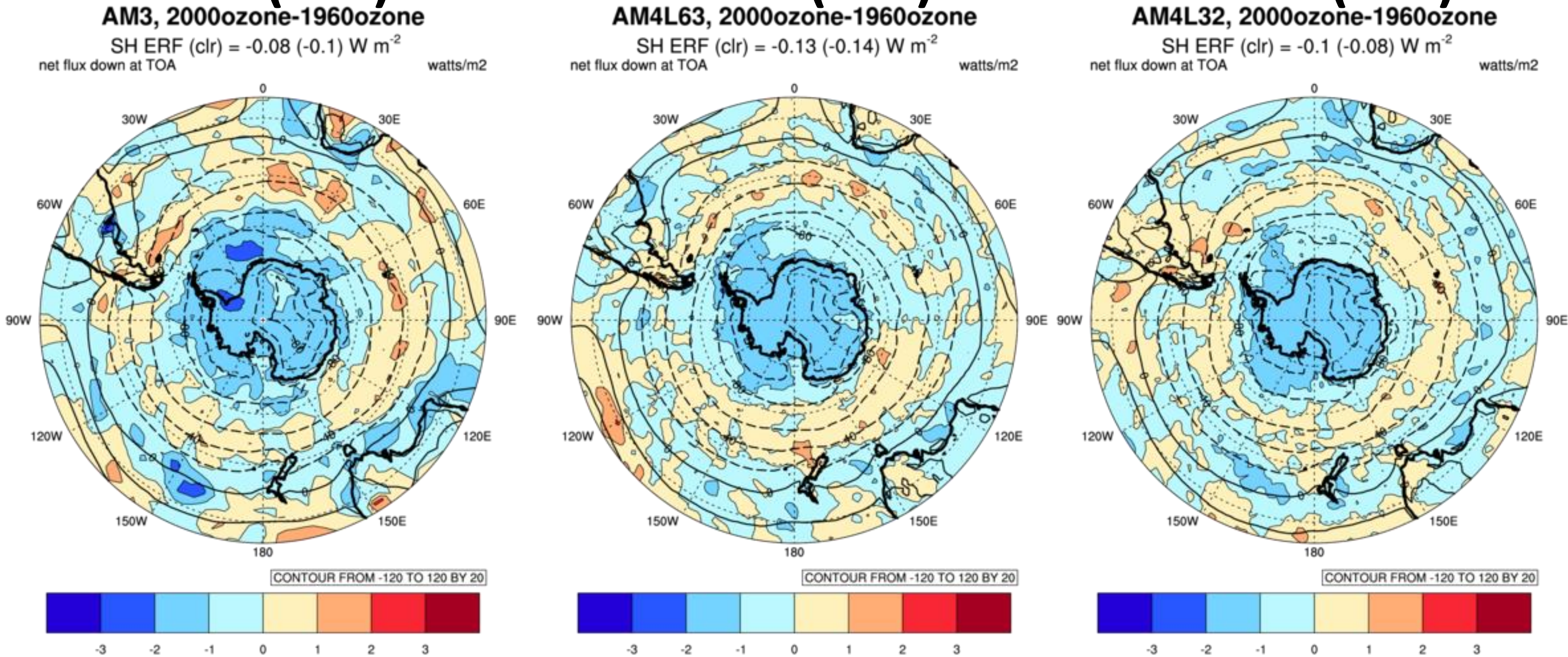
Simulations with prescribed ozone change (2000 minus 1960)

Strong cooling over pole, partially offset by SW mid-lat cloud warming

Effective Radiative Forcing from Ozone

Net Radiative Flux at TOA (annual)

AM3 (48L) | **AM4 (63L)** | **AM4 (32L)**



Simulations with prescribed ozone change (2000 minus 1960)

LW warming damps SW radiative effect

Conclusions

- **Strong poleward shift of SH summer jet in response to ozone depletion in GFDL-CM3**
- **Surface wind shift and intensification sensitive to model configuration (vertical resolution)**
- **Shortwave (direct+indirect) forcing damped by long-wave**
- **Sea ice decreases more strongly in response to historical ozone depletion than to WMGHG increase**

Caveat:

- **Only one ensemble member (CM3 coupled runs)**
- **Only one model**