GEOSCCM simulations of the Antarctic ozone hole changes due to continuing CFC-11 emissions

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Goddard Earth Observing System Chemistry-Climate Model (GEOSCCM)

Model – the NASA Goddard GEOS-5 Chemistry Climate Model (GEOSCCM):

- 3-D Chemistry Climate Model with detailed tropospheric-stratospheric chemistry from the Global Modeling Initiative (GMI) chemical mechanism (Nielsen et al., 2017)
- has an internally generated QBO (Hurwitz et al., 2011)
- includes a 11-year solar cycle

CFC-11 simulations:

- Building off of the GEOSCCM contributions to SPARC Chemistry-Climate Modeling Initiative (CCMI) and 2018 WMO Ozone Assessment

  (2° x 2° horizontal resolution, 72 vertical layers, surface to 0.01 hPa, 80km)

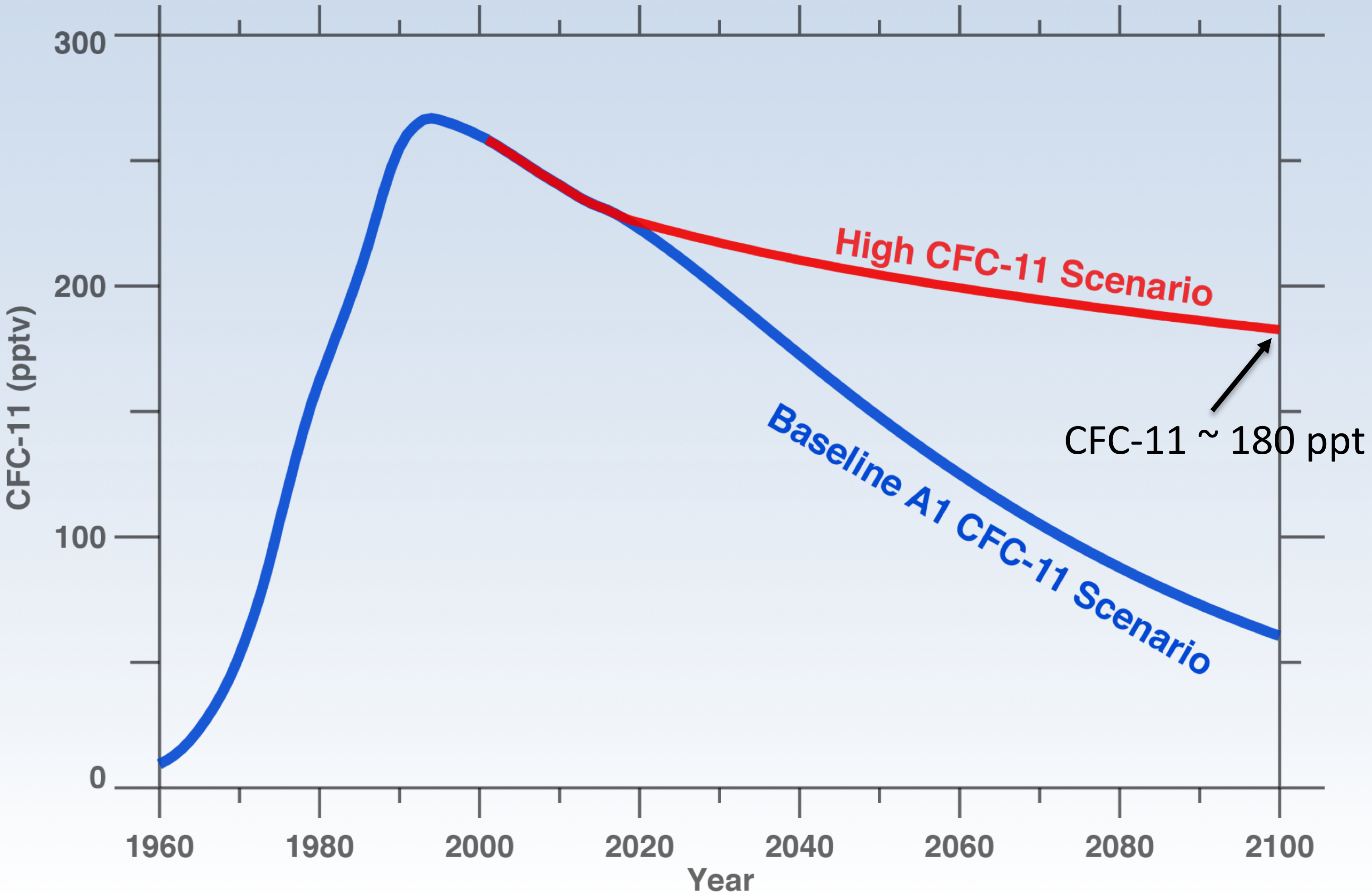
→ baseline: forced with WMO-2014 A1 Ozone Depleting Substances (ODS) , RCP 6.0 Greenhouse Gases (GHG) scenarios

→ CFC-11 high scenario using constant 72.5 Gg/yr emissions for 2018-2100

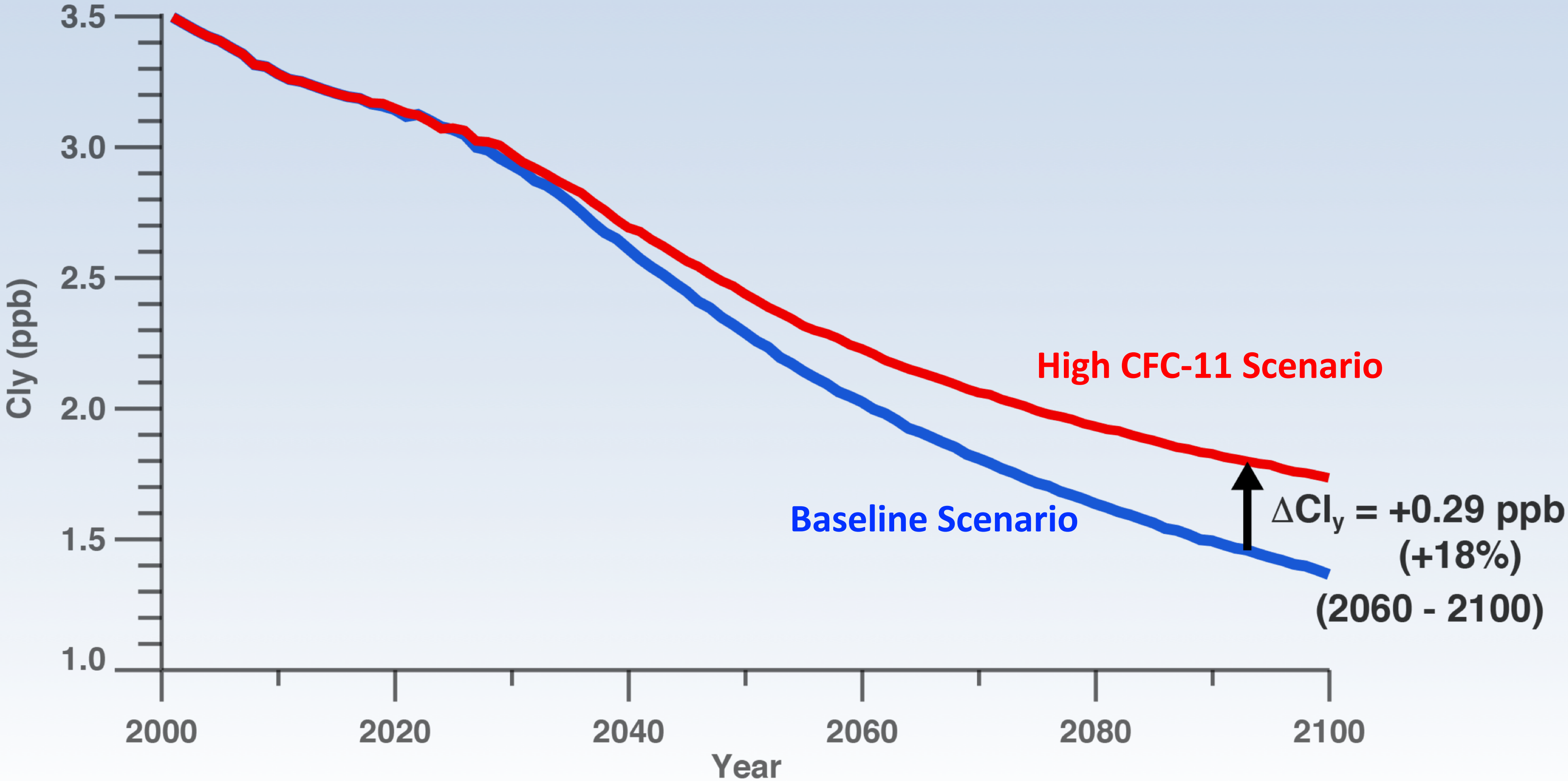
CFC-11 Scenarios

Baseline: WMO 2014 A1 Scenario

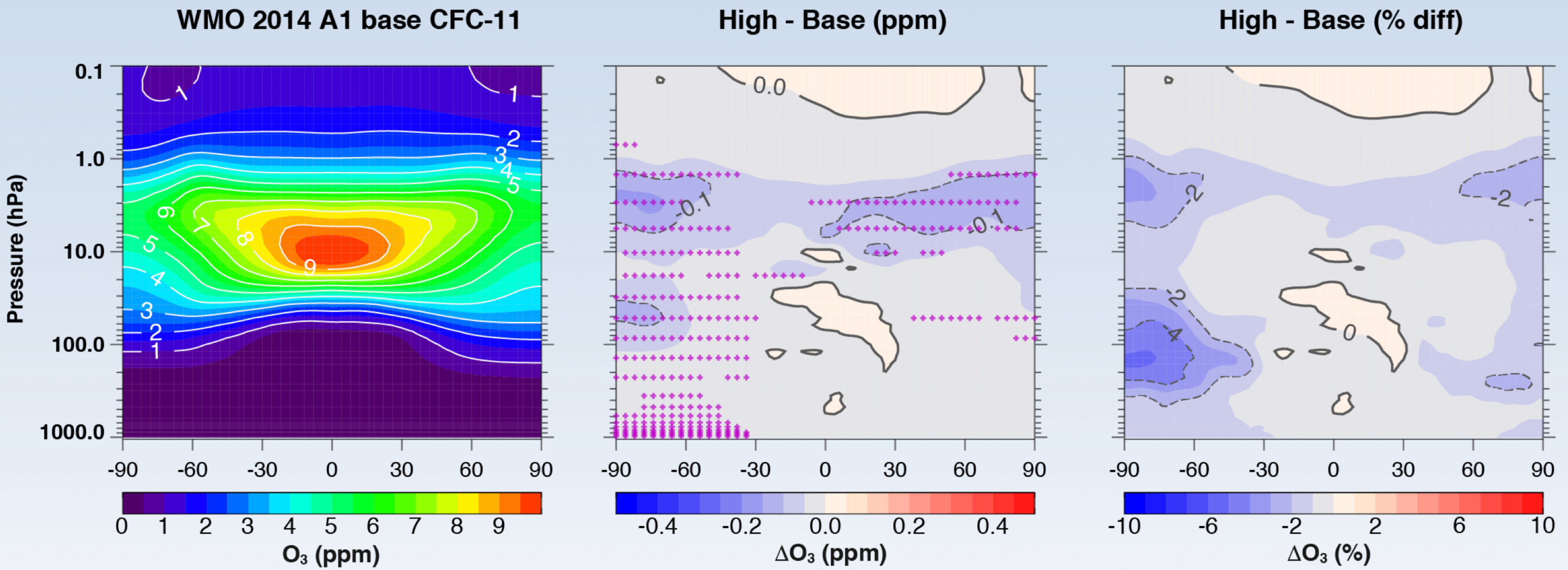
High CFC-11 Scenario: Continued emissions of 72.5 Gg/yr for 2018 - 2100



Impact on stratospheric inorganic chlorine (Cl_y)

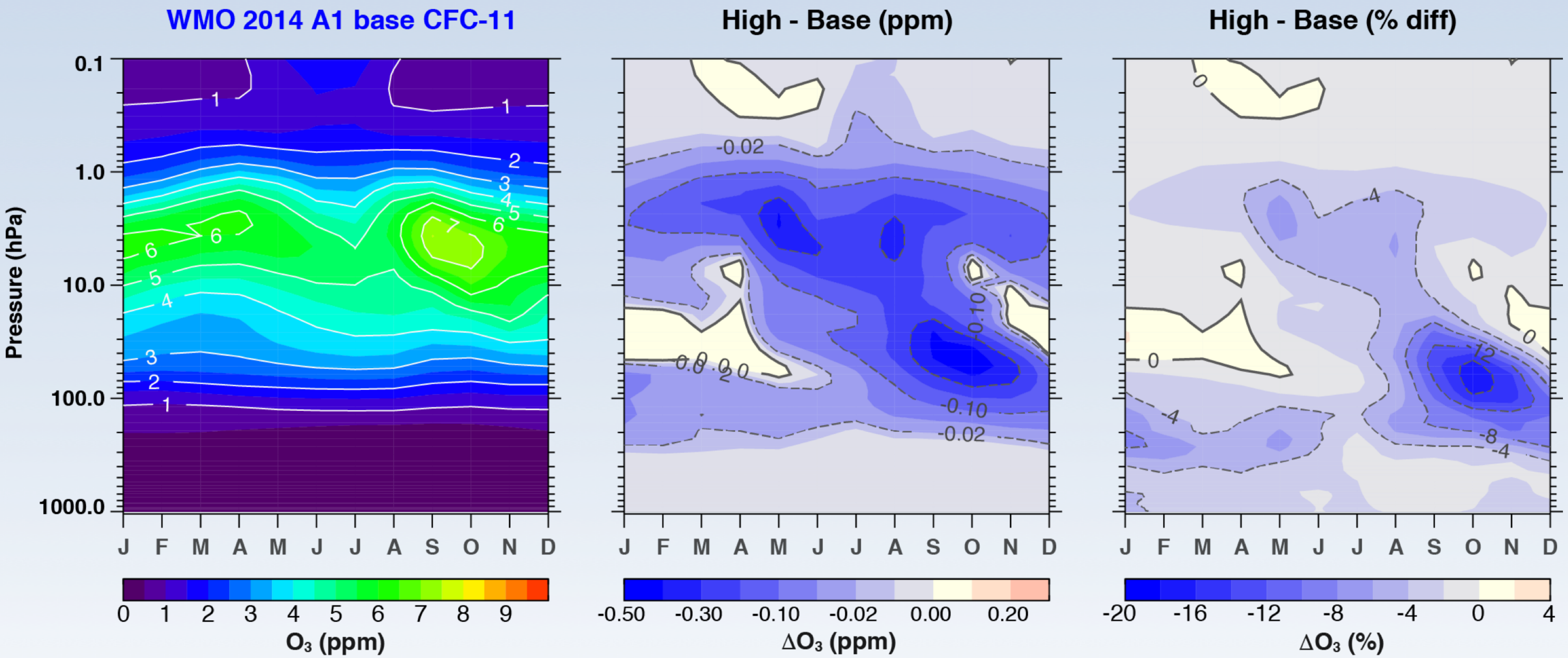


Impact on atmospheric O_3 (2060-2100 annual mean)

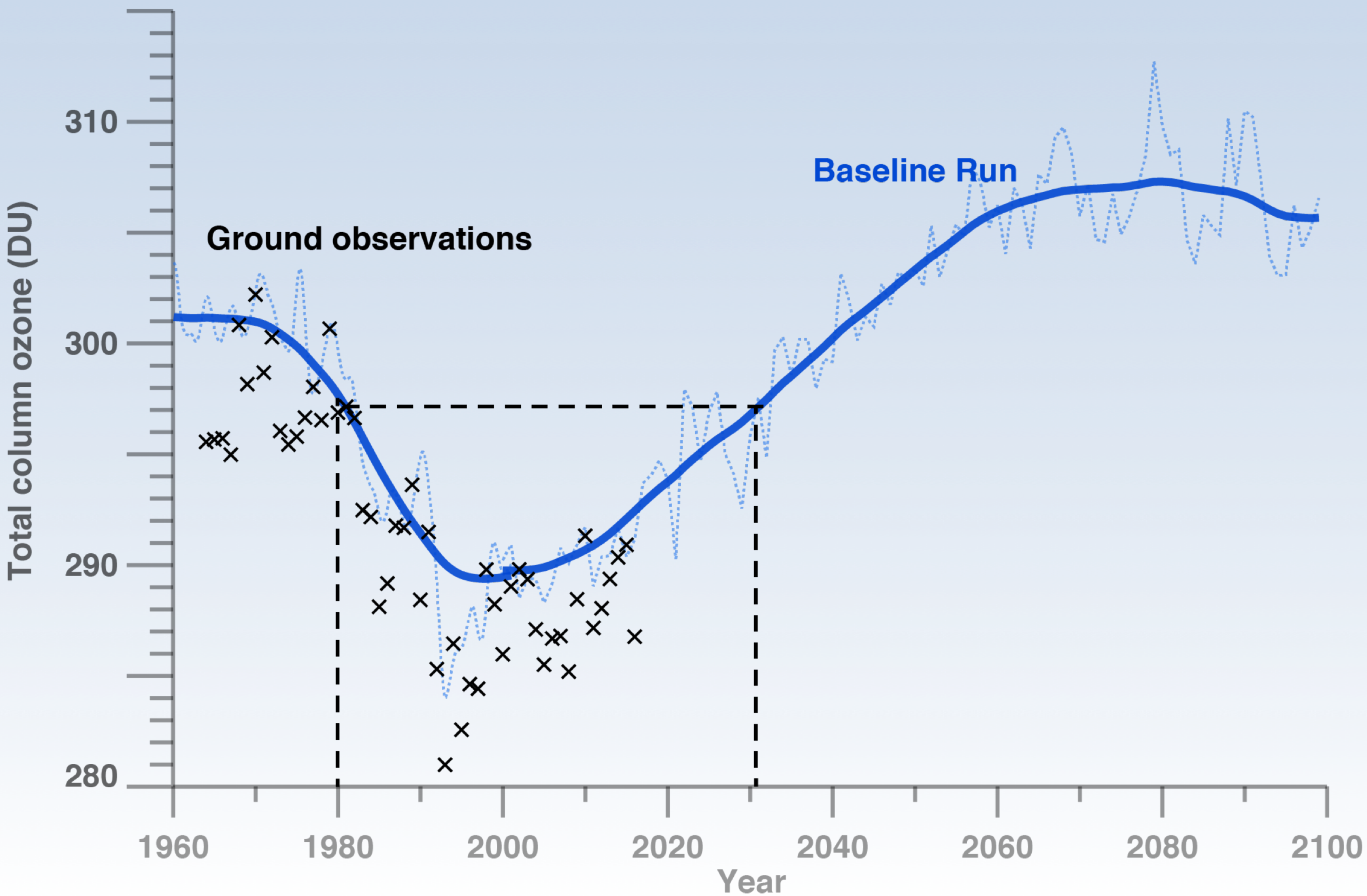


Significant response

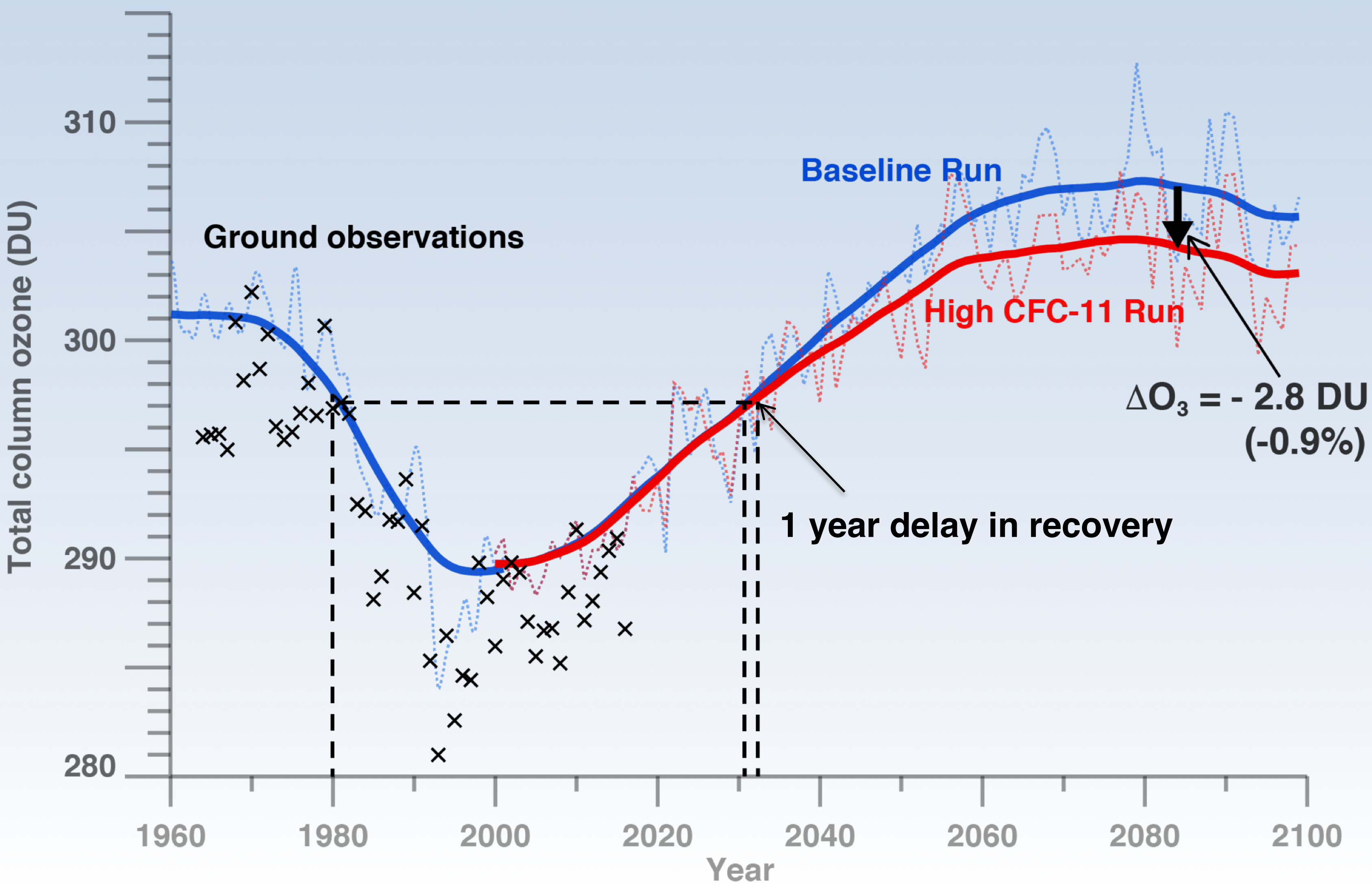
Impact on Antarctic ozone: Seasonal variation



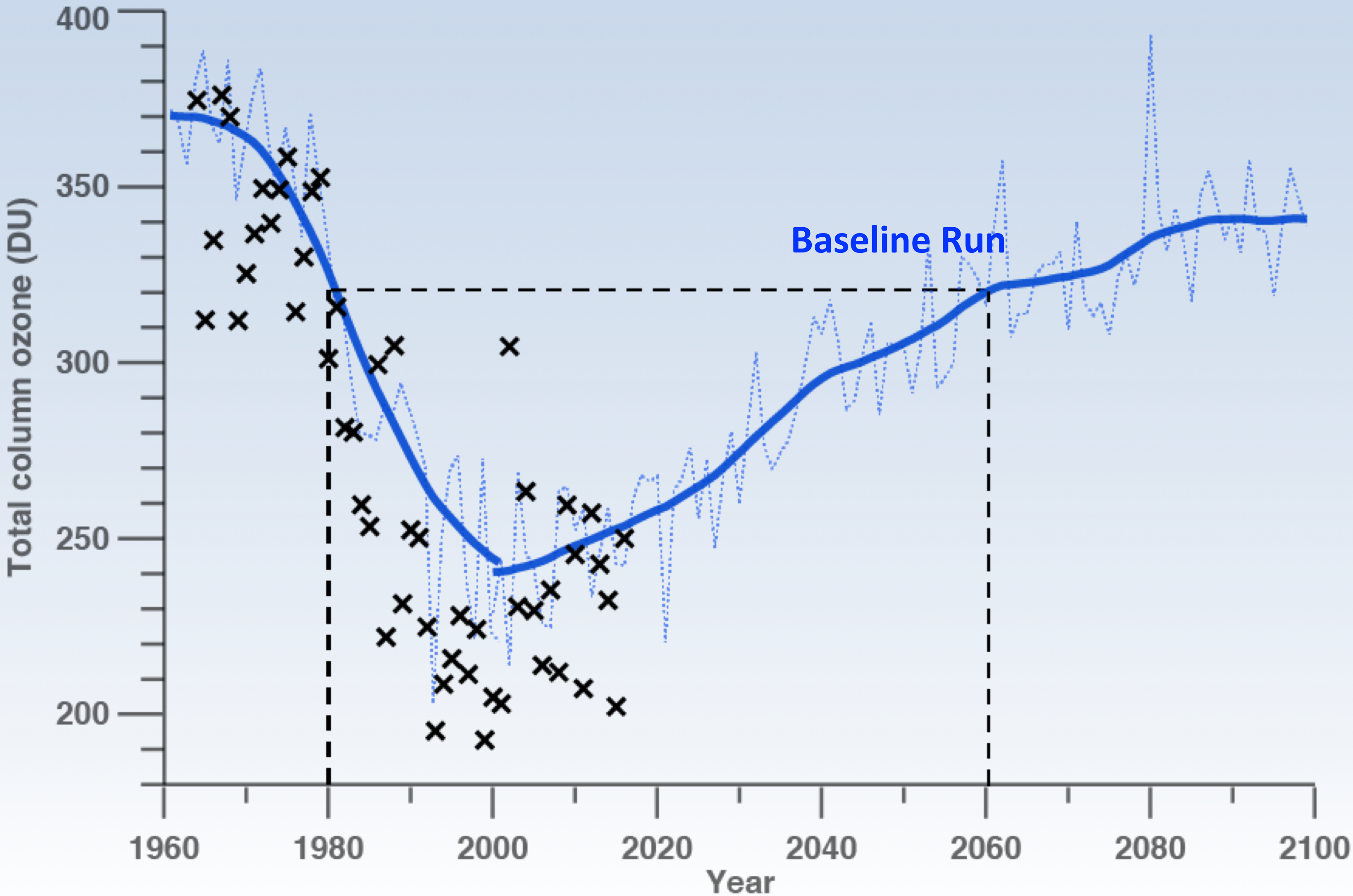
Impact on global ozone (90ºS-90ºN)



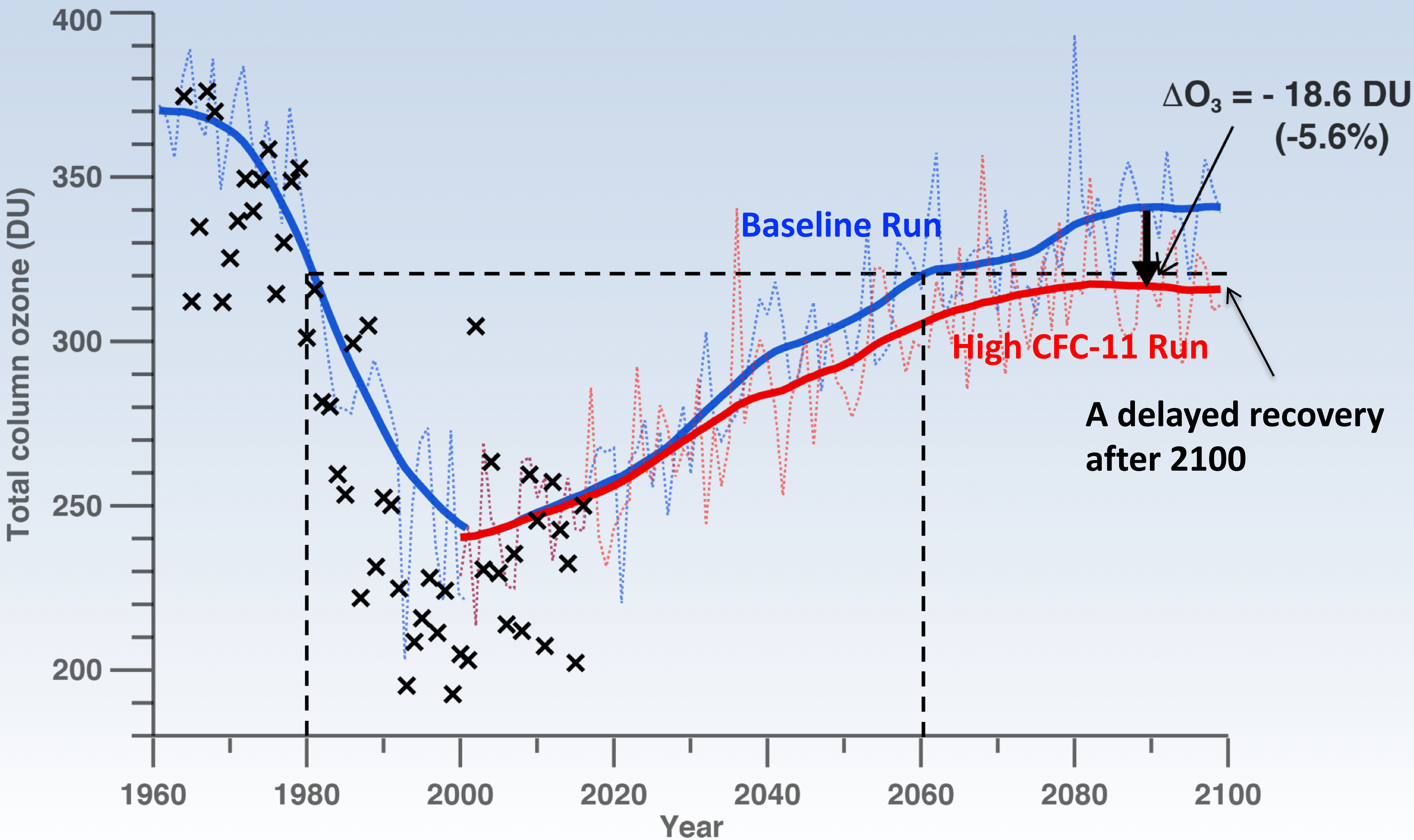
Impact on global ozone (90ºS-90ºN)



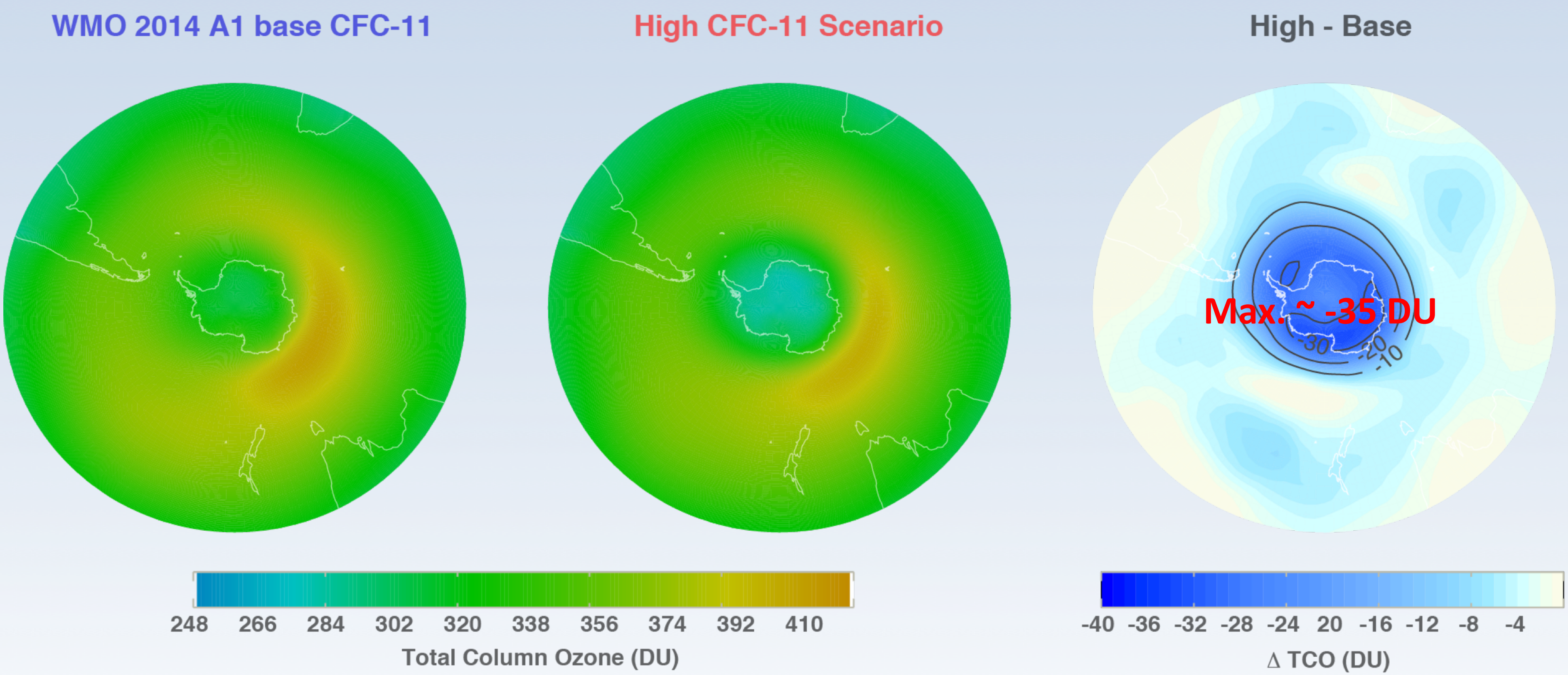
Impact on Antarctic ozone



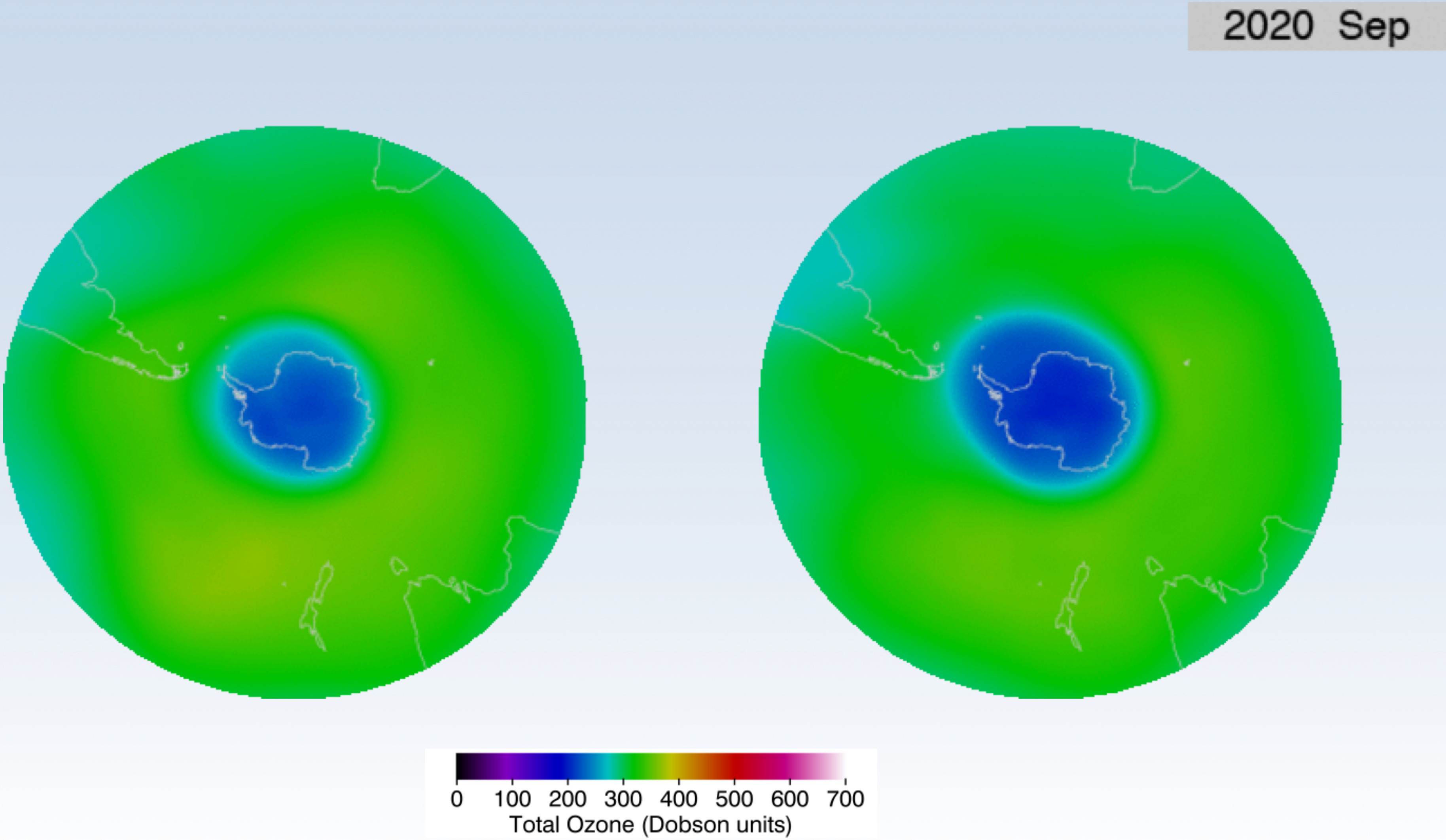
Impact on Antarctic ozone



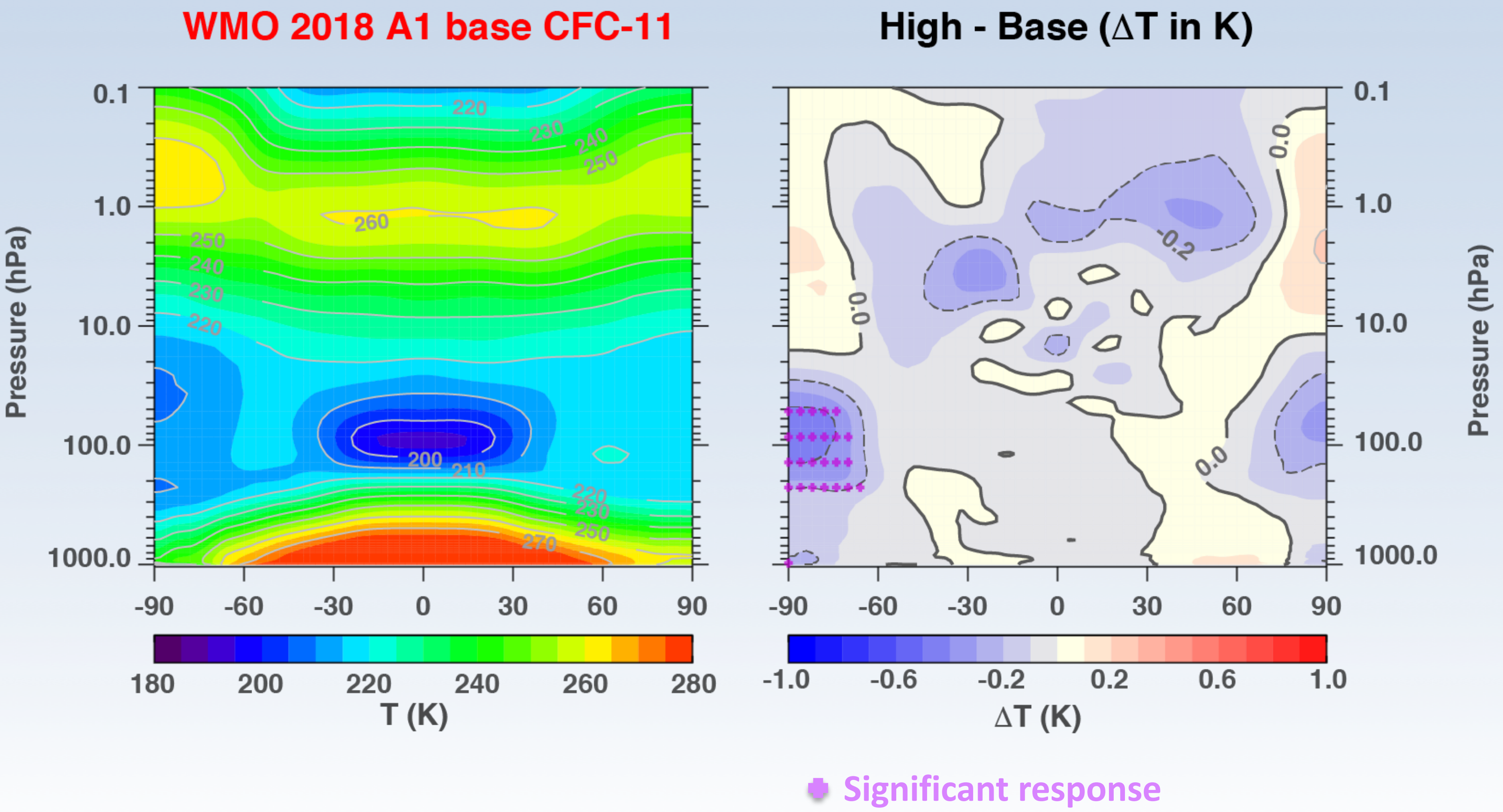
Antarctic Total Column Ozone (TCO) September 2080-2100 mean



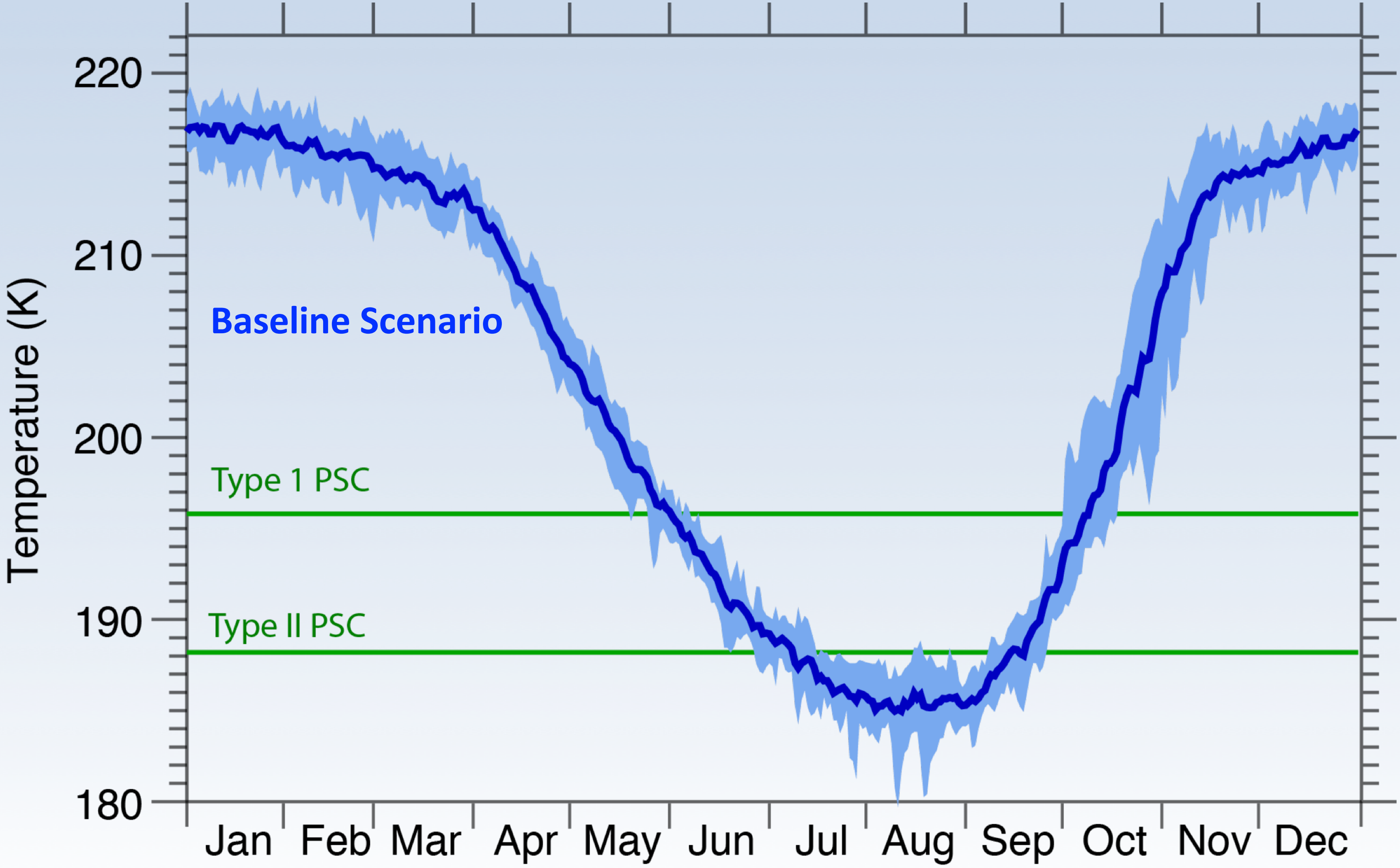
Antarctic Sep TCO animation



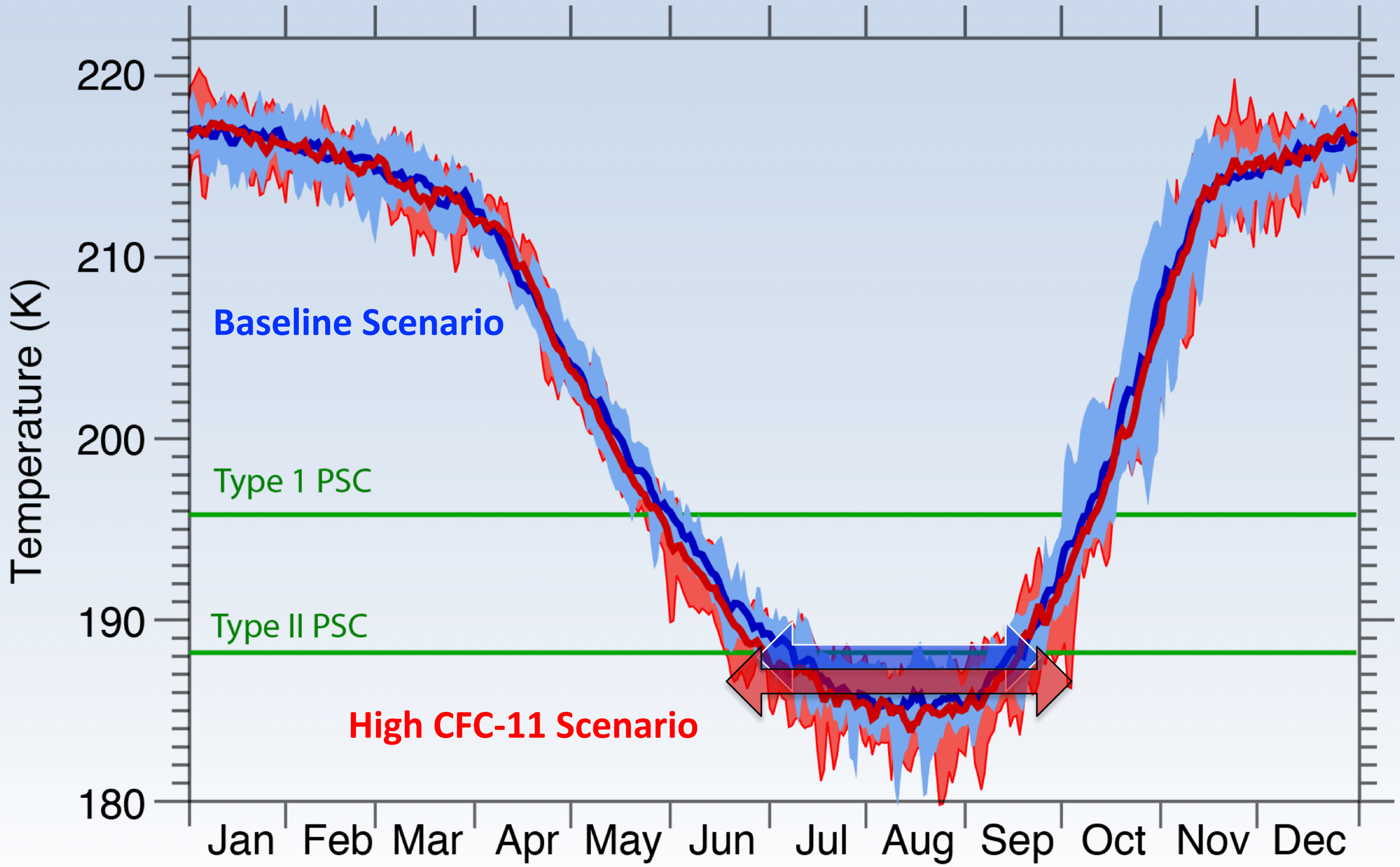
Impact on atmospheric temperature (2060-2100 annual mean)



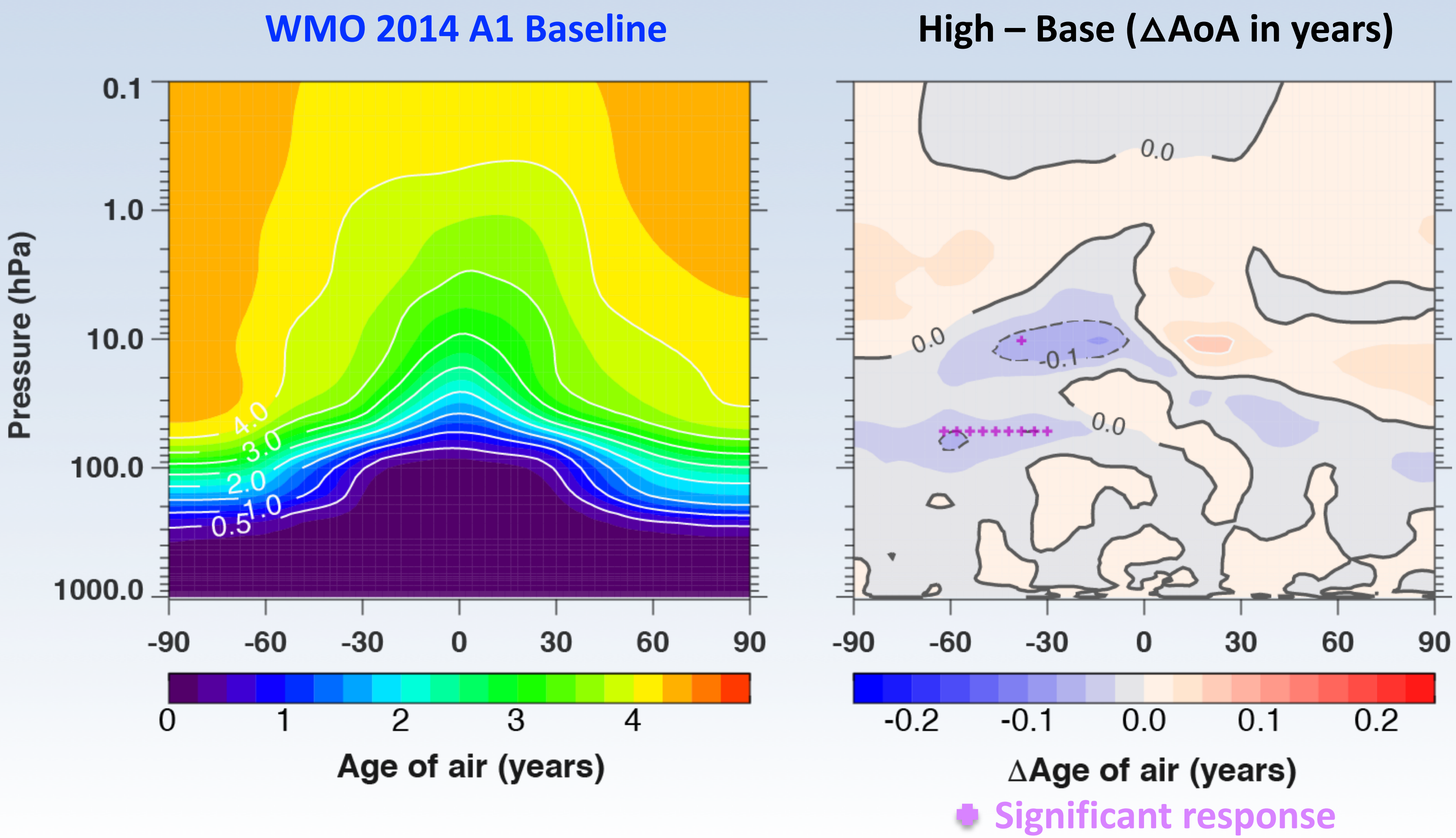
Antarctic lower stratospheric minimum temperature



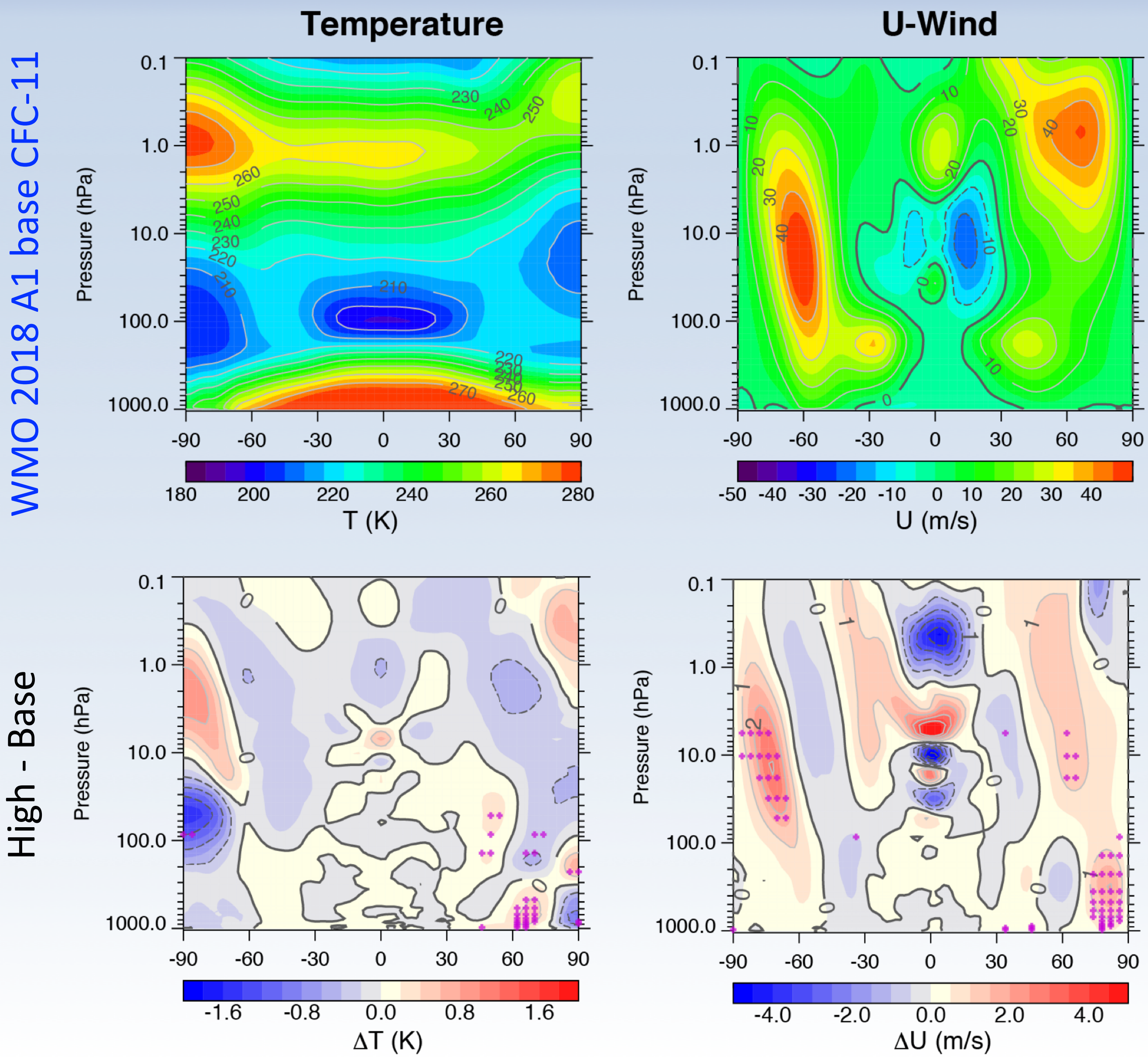
Antarctic lower stratospheric minimum temperature



Impact on atmospheric circulation (Annual mean age of air)



Temperature and U-wind in October



- colder in ozone hole due to enhanced ozone loss, reduced UV heating
- warmer in upper strat above ozone hole due to descent/dynamical response to ozone hole (Stolarski et al., 2006)
- corresponding U-wind change (stronger jet)

Summary

Assuming constant 72.5 Gg/yr emissions from present to 2100:

- CFC-11 decline is significantly slowed and surface abundance remains above 180 ppt by 2100
- Cly concentration will increase by ~0.3 ppb (~20% increase) between 2060-2100
- Global TCO between 2060-2100 will decrease by 0.7%
- Antarctic TCO between 2060-2100 will decrease by ~6%
- The Antarctic ozone hole will be present till the end of the century and ozone will not recover to the 1980 level by 2100
- Significant impacts on the Antarctic stratospheric temperature, the S. Hemispheric jet strength, and the Brewer-Dobson circulation

Backup slides

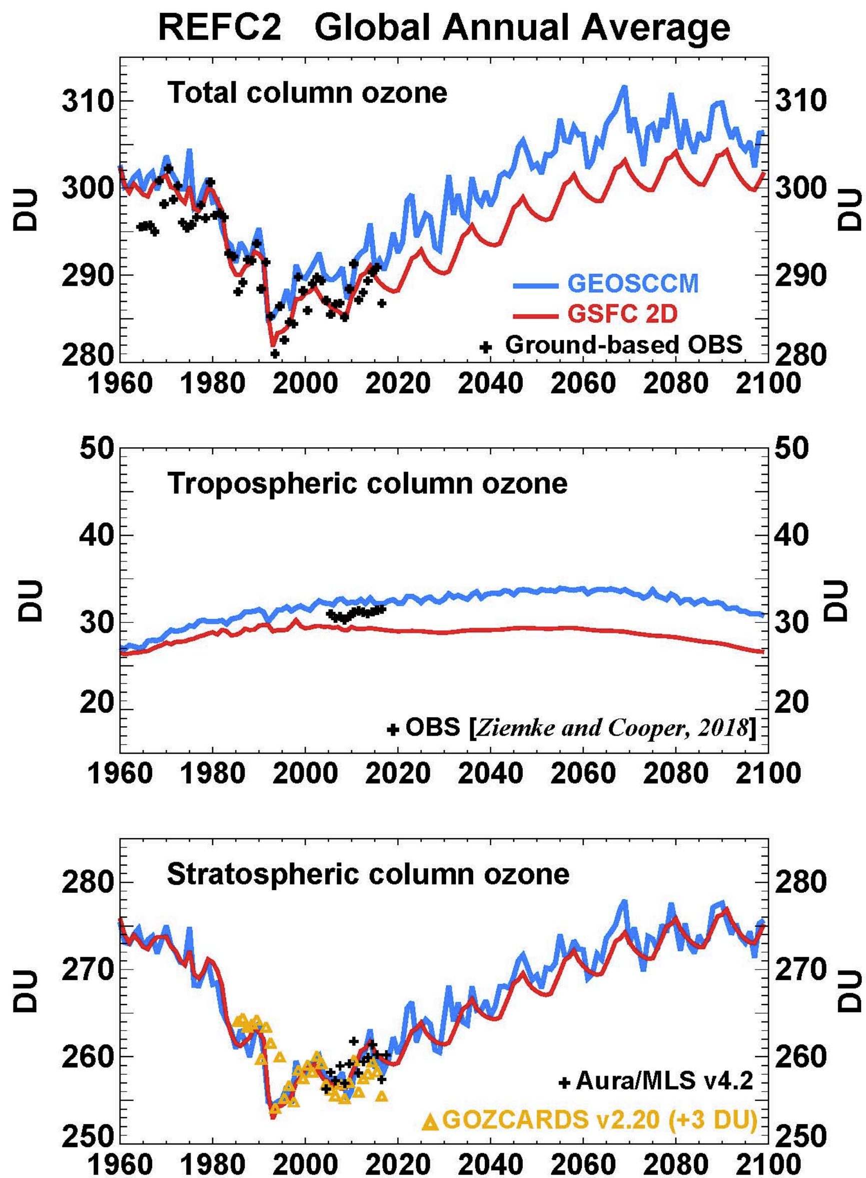
GSFC2D comparison with GEOSCCM

- **REFC2 total ozone, 1960-2100 incudes:**
  - baseline (A1) ODS scenario
  - past stratospheric aerosol changes
  - past and future solar cycle variations

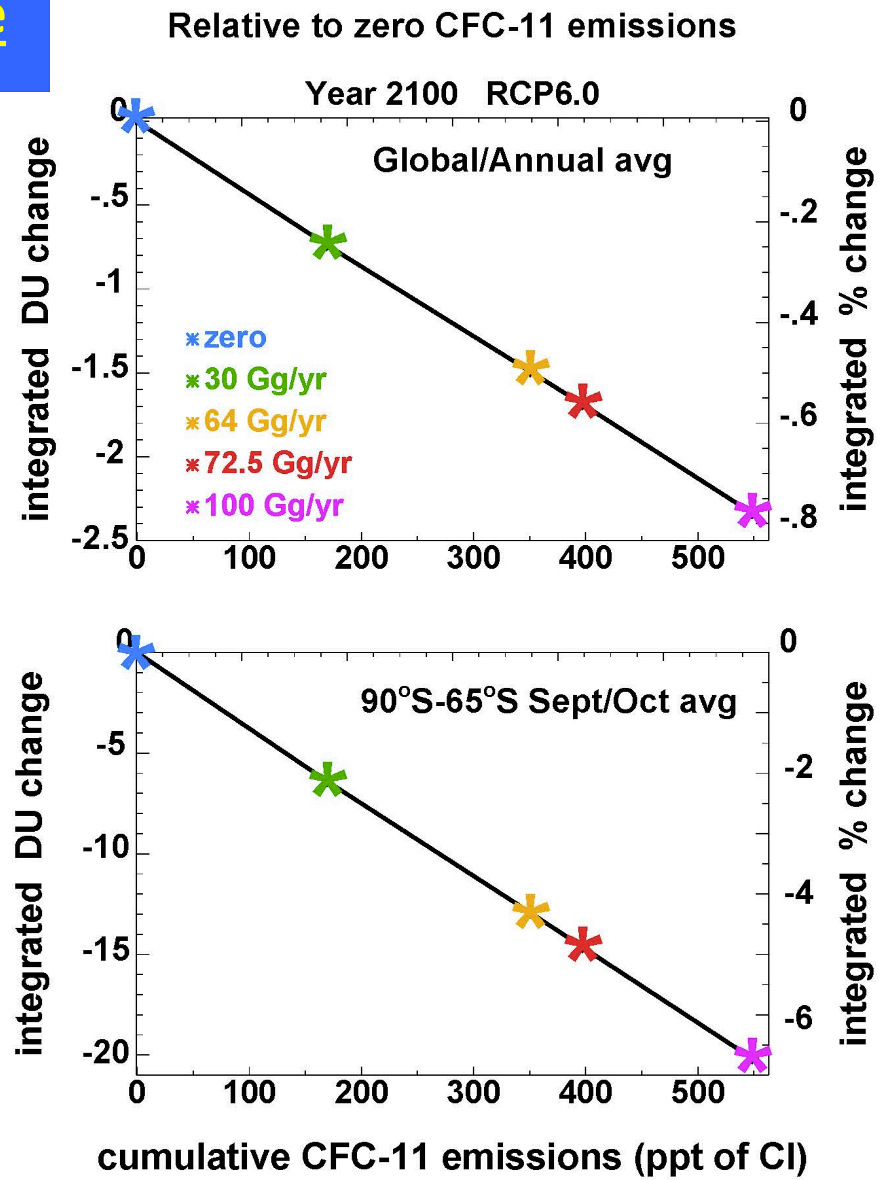
- GSFC2D compares mostly well with observations and GEOSCCM

- GSFC2D 3-5 DU lower than GEOSCCM during 21st century
  - due to tropospheric ozone differences
  - incomplete tropospheric chemistry in GSFC2D

- stratospheric column ozone very similar, including rate of past ozone decline and future recovery



Linearity of Ozone Response



Sensitivity (per 100 ppt emission of chlorine):

Global annual = -0.44 DU (-0.15%)

Antarctic spring = -3.6 DU (-1.4%)

(baseline EESC = 2300 ppt in 2100)