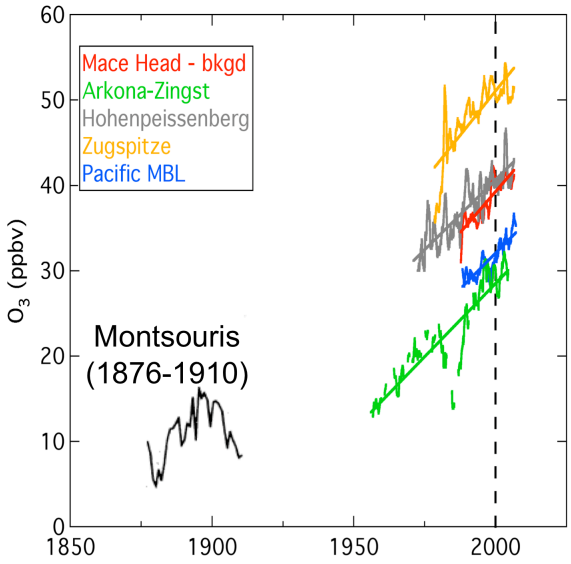
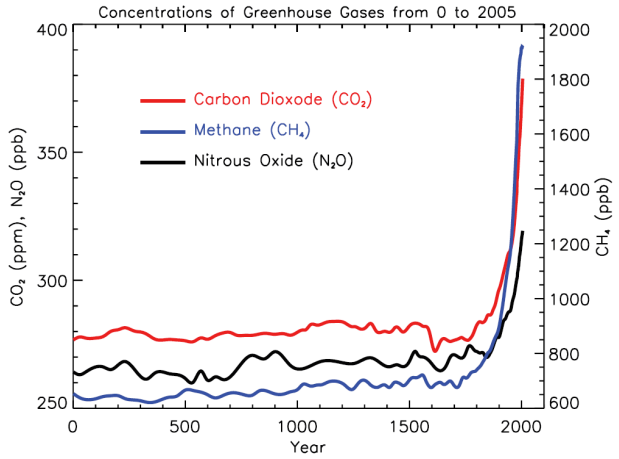
Single-forcing chemistry simulations of historical composition changes

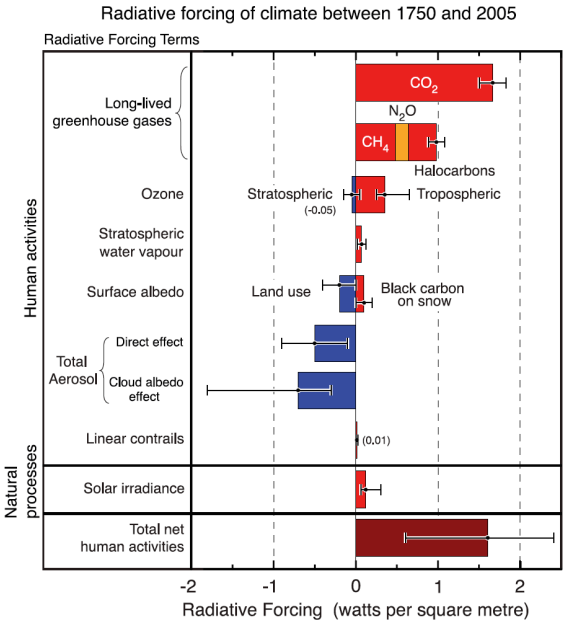
Jean-François Lamarque (NCAR)
Paul Young (NOAA)
Collaborators: A. Conley, D. Kinnison and F. Vitt

Changing atmospheric composition



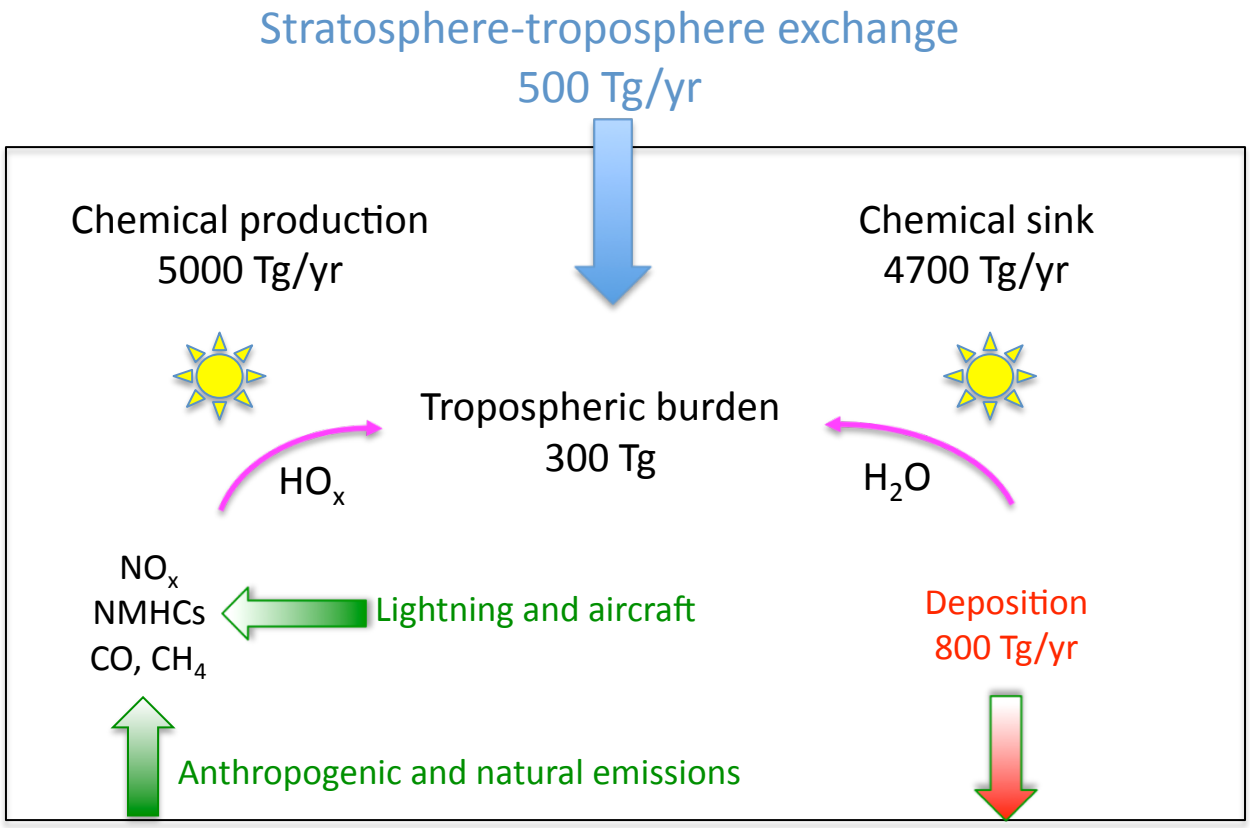
Surface ozone 1850-2000 from obs. Slide from D. Parrish.





Forster and Ramaswamy. AR4 Chapter 2

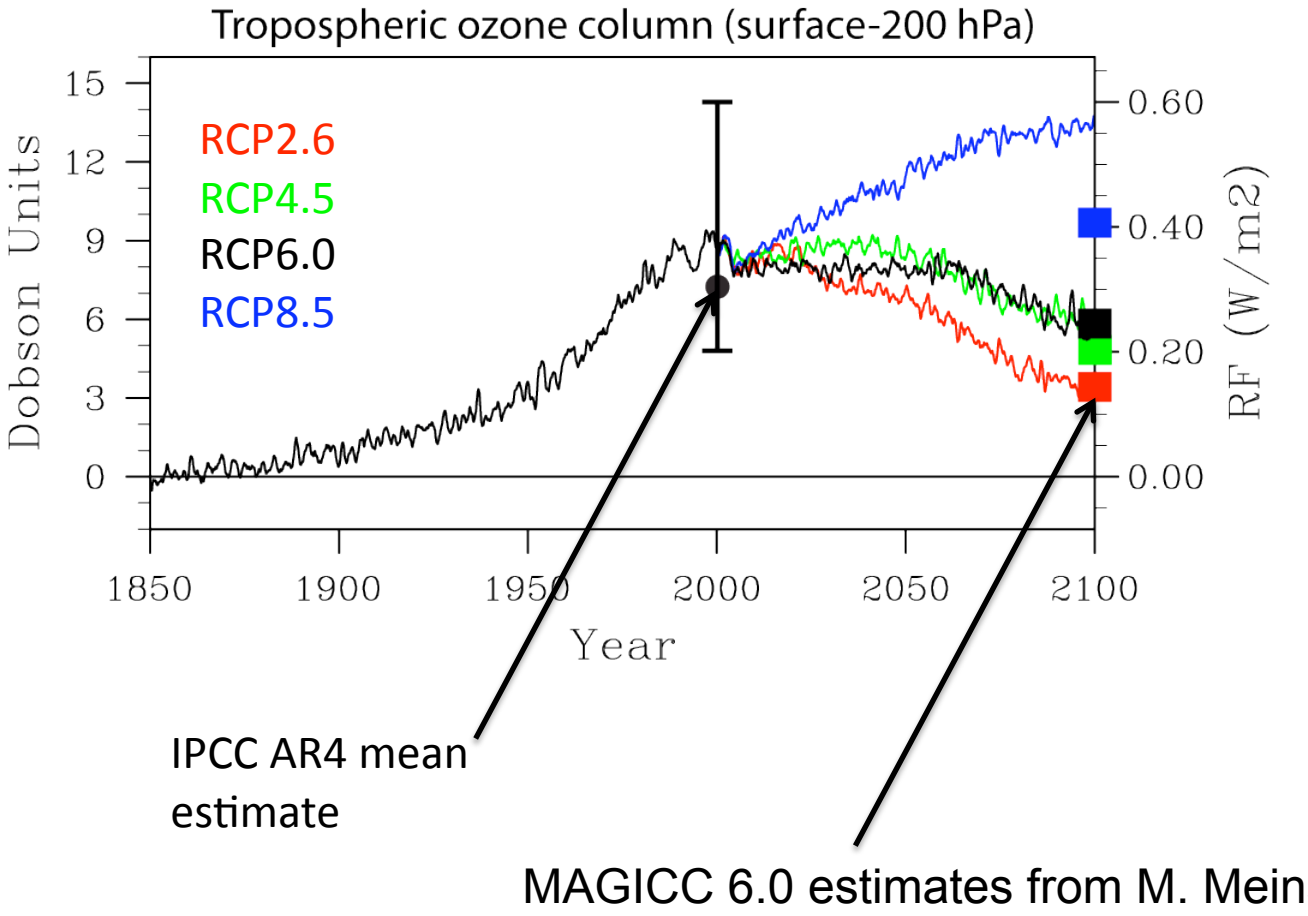
Present-day tropospheric ozone budget



Model: CAM3.5

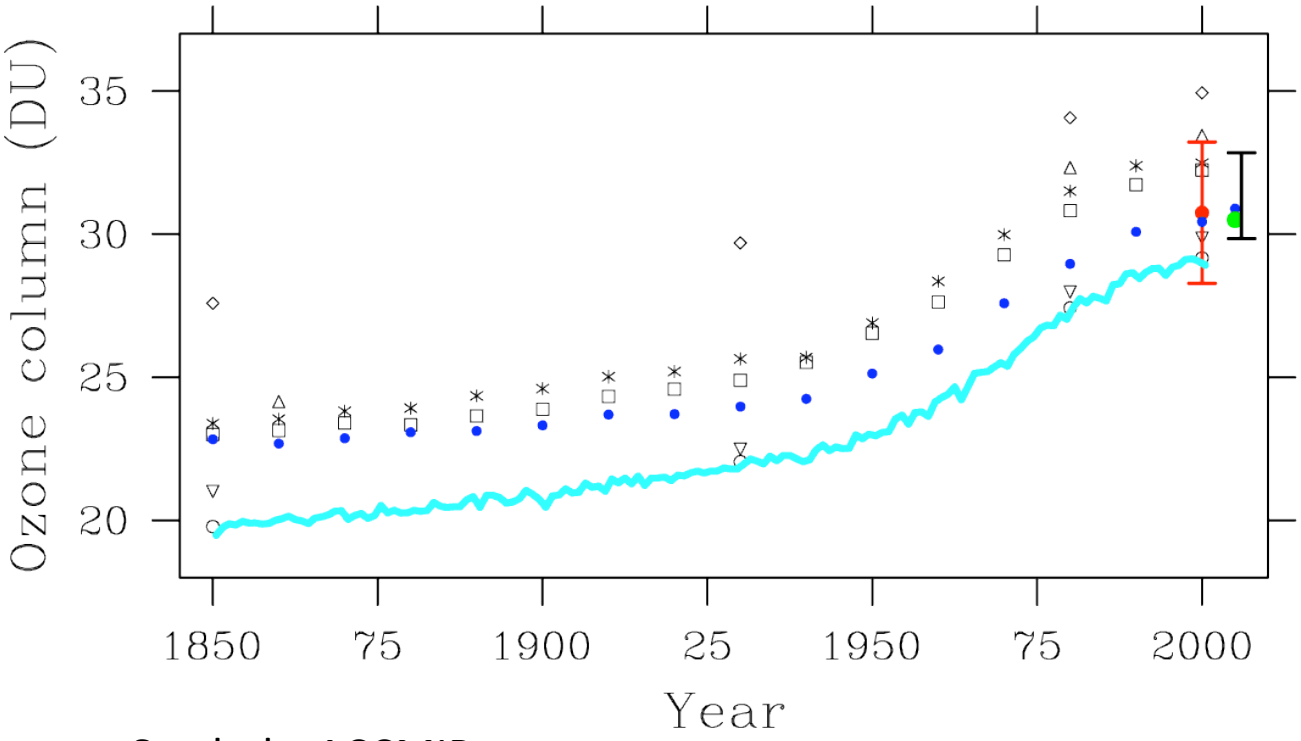
- Interactive tropospheric (reduced NMHCs) and stratospheric (including PSCs) chemistry
- Driven by sea-surface temperatures
- 1.9x2.5x26L (surface to ≈ 40 km)
- Continuous simulation 1850-2000 with time varying emissions (Lamarque et al., ACP, 2010) and surface concentrations (CH_4, CO_2, N_2O, CFCs; follows CCMVal recommendation)
- Participated in CCMVal-2: major shortcoming was a weak Antarctic ozone hole

Tropospheric ozone: 1850-2100



Lamarque et al., Climatic Change, 2011

Comparison to other model/obs



Symbols: ACCMIP runs

Red: ACCENT-AR4

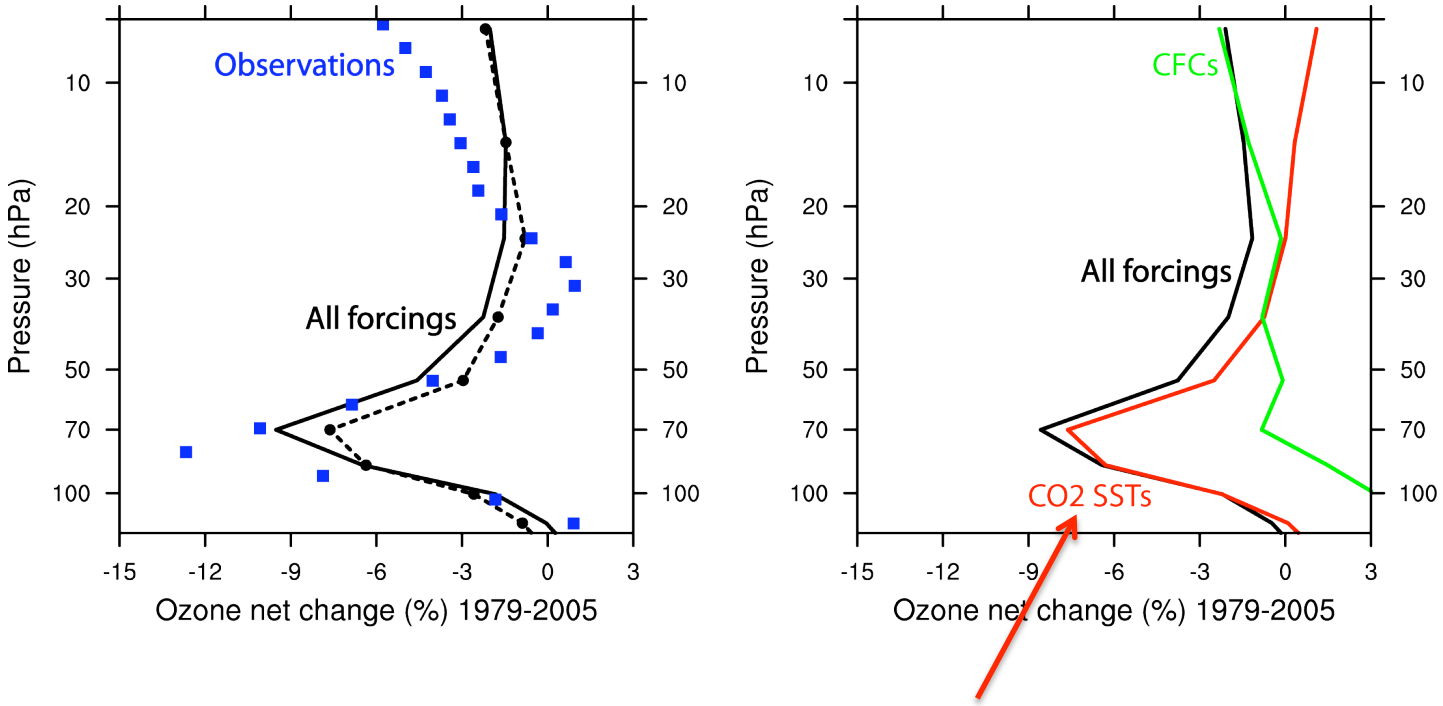
Blue: Kawase et al. (2011)

Green: OMI-MLS (Ziemke et al., 2011)

Black: TES

Cyan: CAM3.5

Previous single forcing experiments



Attribution of tropical lower stratospheric ozone trend to climate change

Lamarque and Solomon, J. Climate, 2010

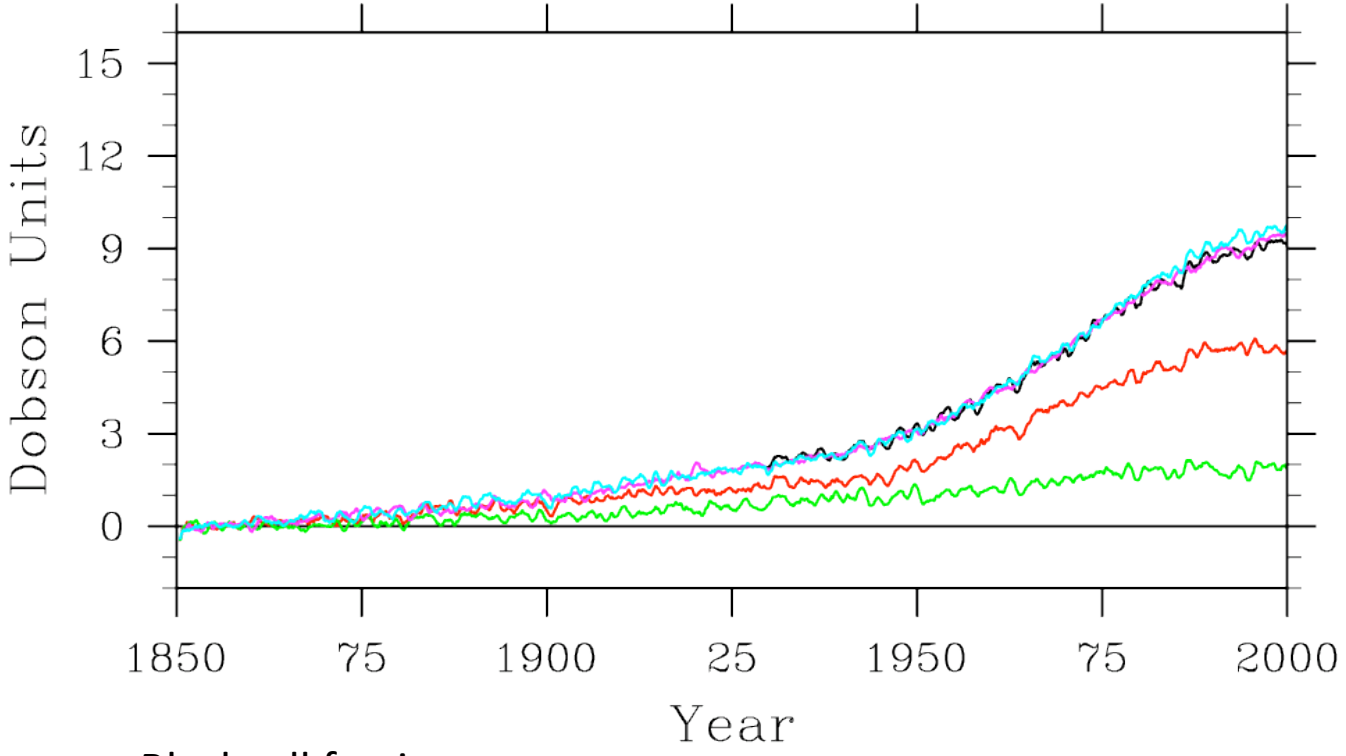
Single forcing simulations

1. All forcings
2. Same as 1. but with CH_4 fixed at 1850
3. Same as 1. but with emissions fixed at 1850
4. Same as 1. but with SSTs/CO_2 fixed at 1850
5. Same as 1. but with CFCs fixed at 1850

Diagnostics:

- Global tropospheric ozone burden
- Global ozone budget terms
- Residual circulation
- Radiative forcing
- Comparison to stations

Tropospheric ozone column



Black: all forcings

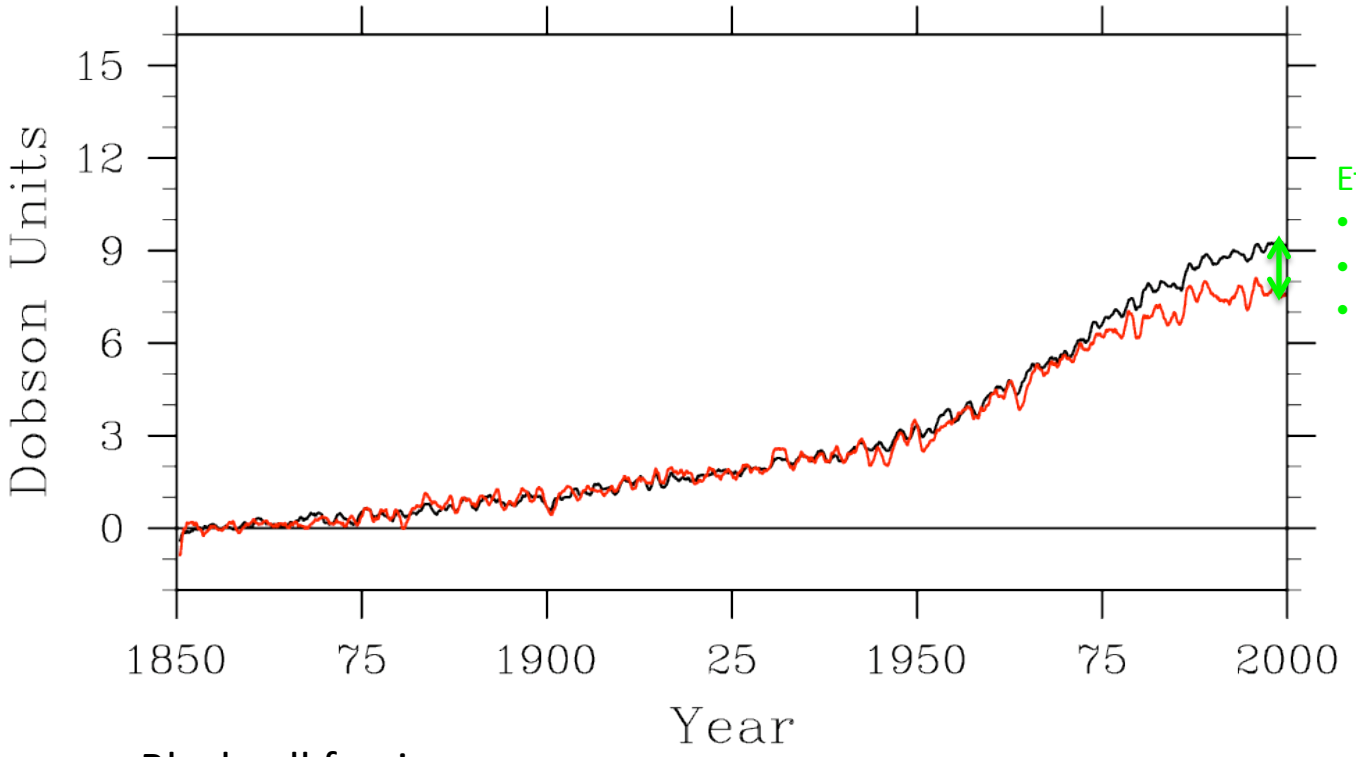
Red: 1850 CH_4

Green: 1850 emissions

Magenta: 1850 climate

Cyan: 1850 CFCs

Tropospheric ozone column

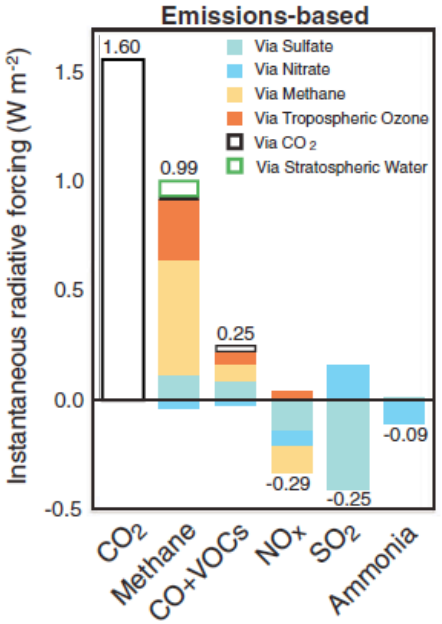


Effect of
- climate
- CFCs
- nonlinearities

Black: all forcings

Red: 1850 CH_4+1850 emissions

Tropospheric ozone radiative forcing

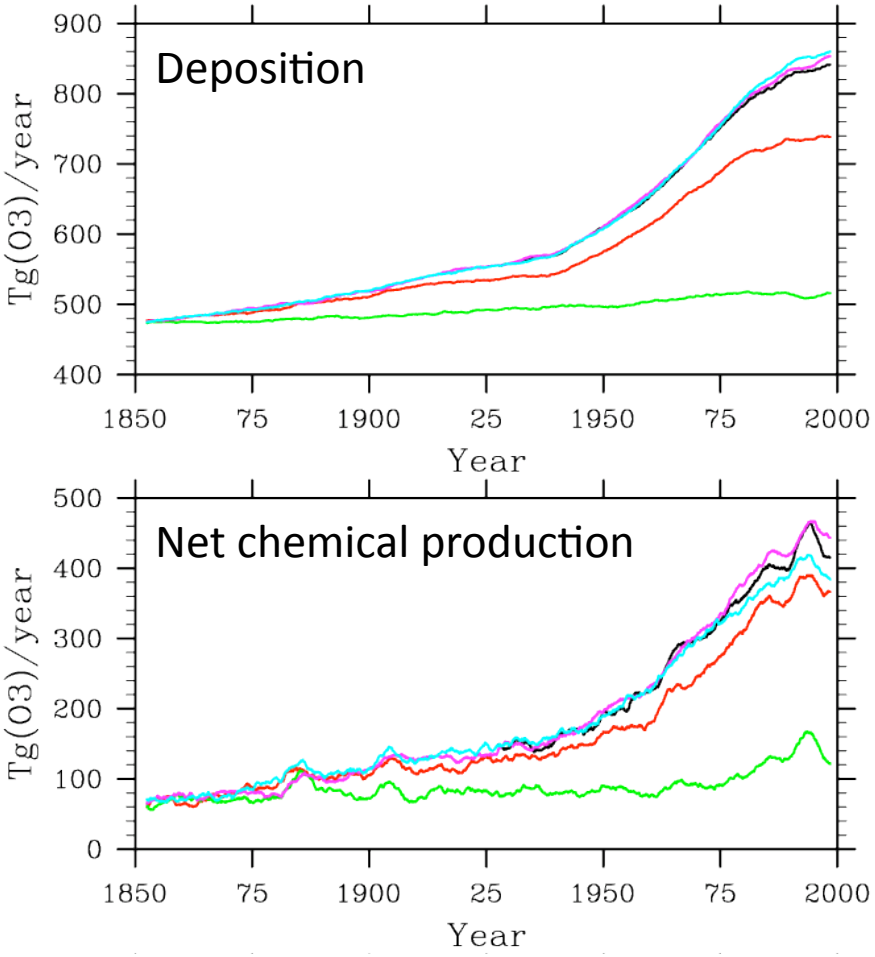


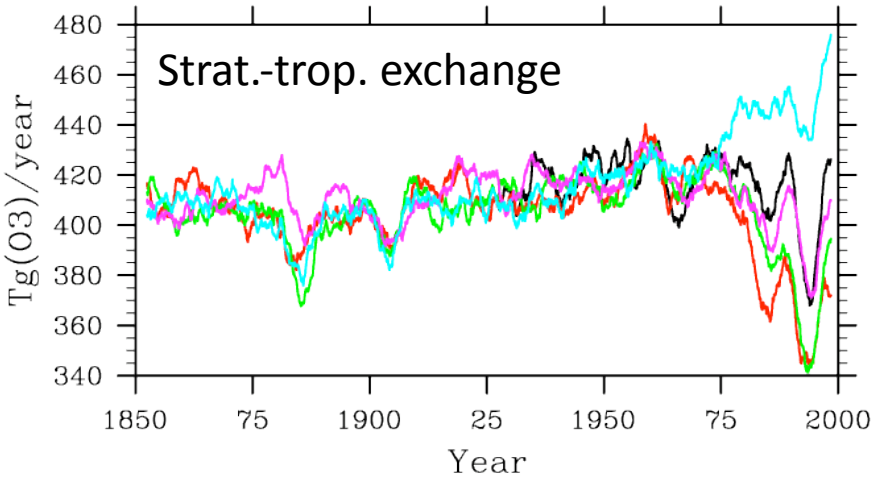
Shindell et al., 2009

Simulation	IRF (W/m^2)
1850-2000	0.342
From CH4	0.161
From emissions	0.281
From SST/CO_2	-0.013
From CFCs	-0.023

Non-additive by ≈ 0.06

Tropospheric ozone budget





Black: all forcings

Red: 1850 CH_4

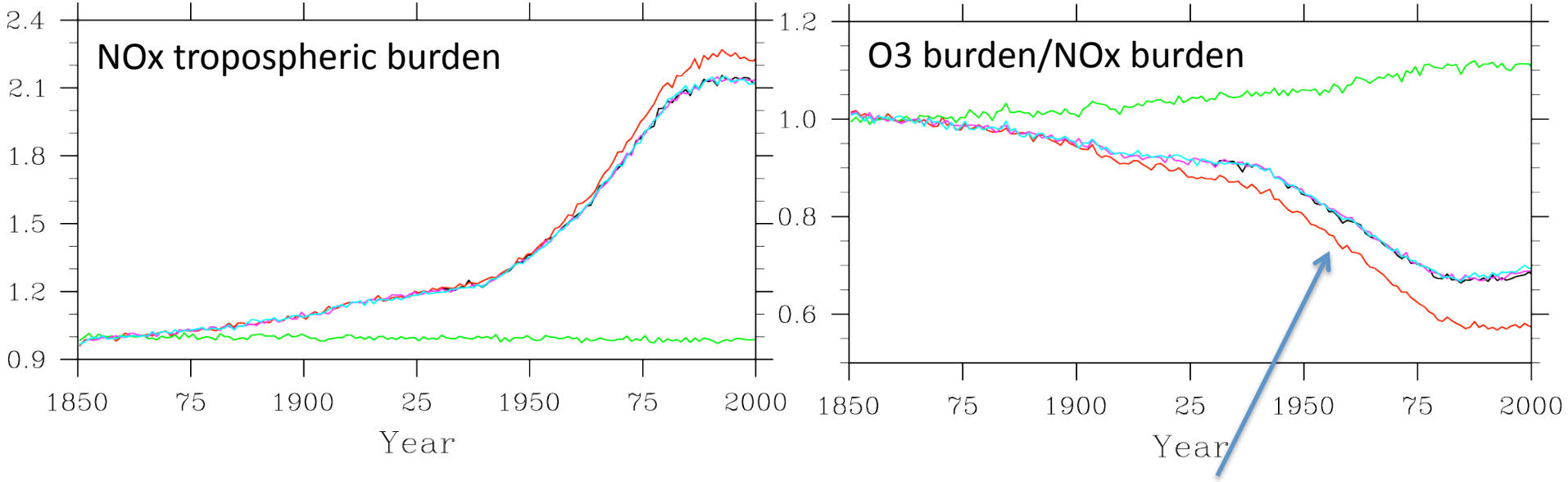
Green: 1850 emissions

Magenta: 1850 climate

Cyan: 1850 CFCs

Tropospheric NOx

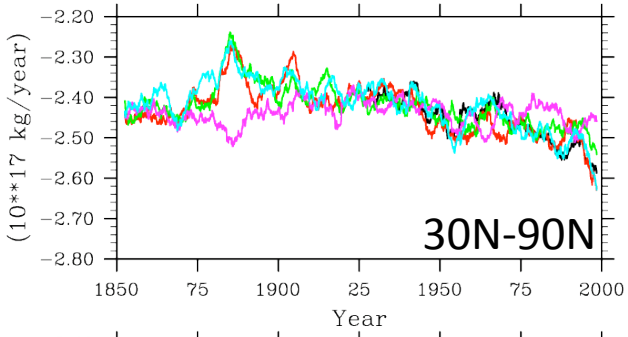
Values relative to 1850s average

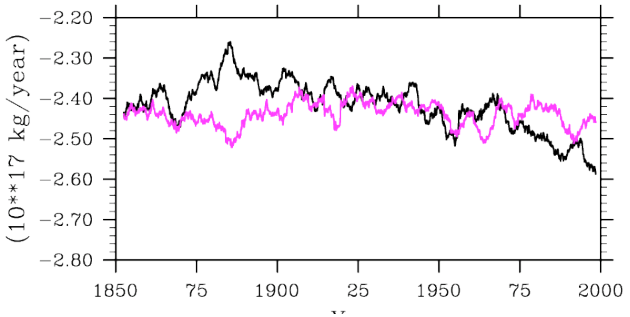


Black: all forcings
Red: 1850 CH_4
Green: 1850 emissions
Magenta: 1850 climate
Cyan: 1850 CFCs

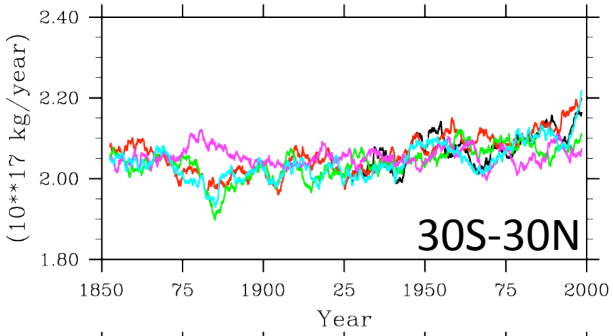
Ozone production efficiency going down with increasing NOx

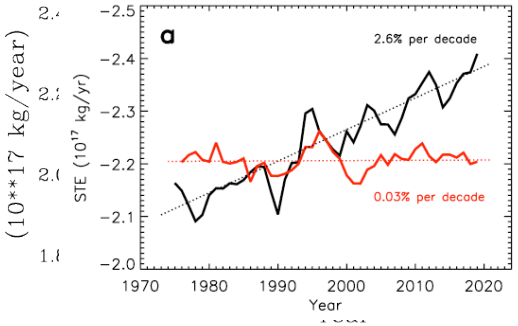
Mass flux across 100 hPa

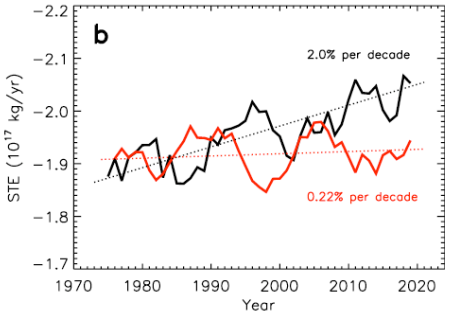




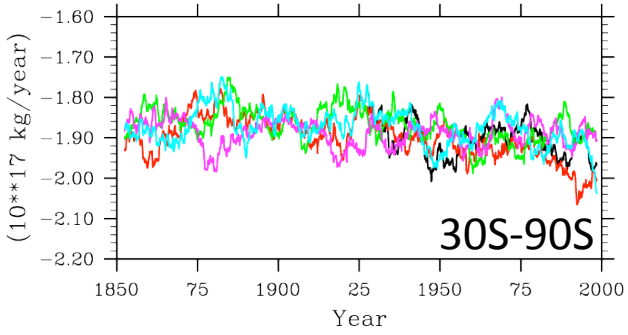
Olsen et al. (2006)

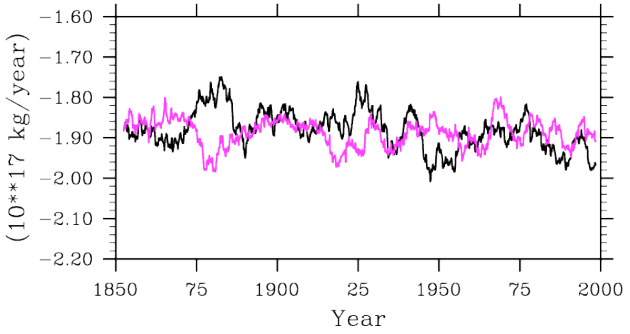




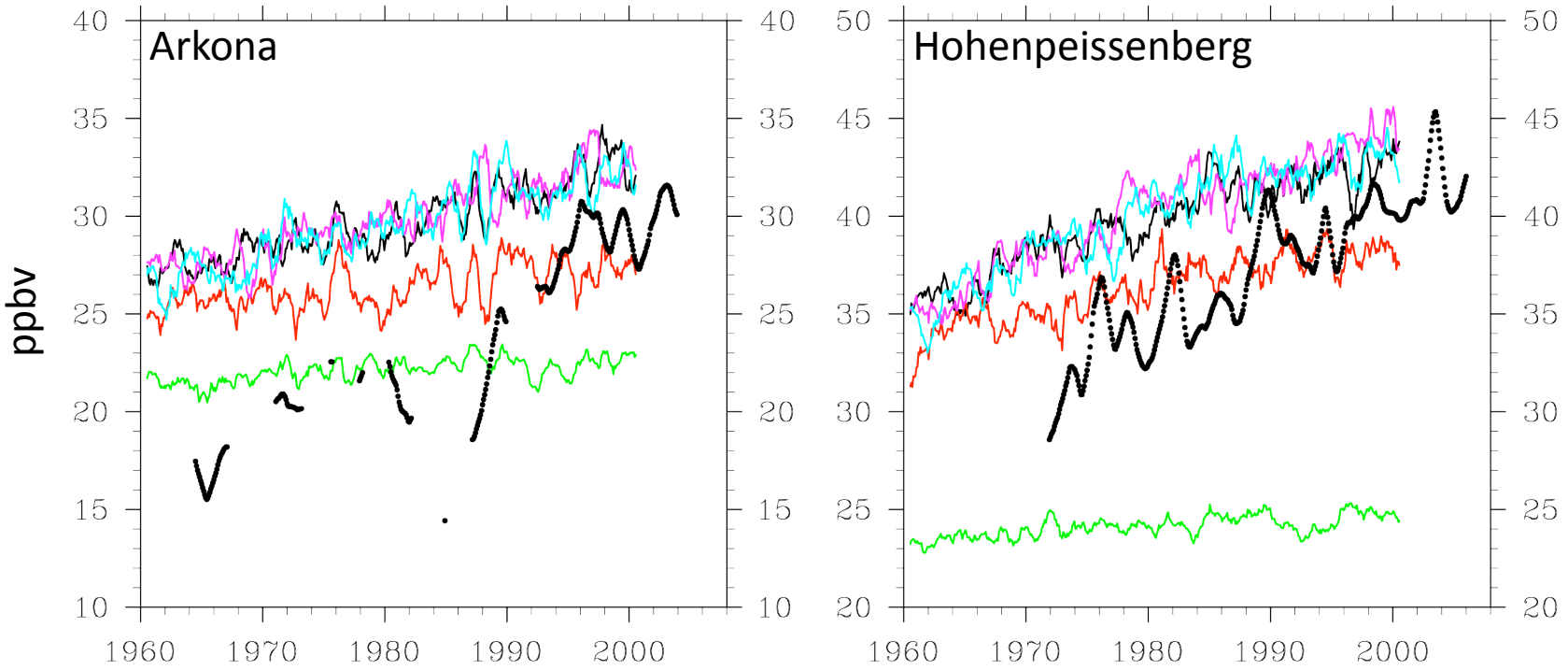


ons
ate





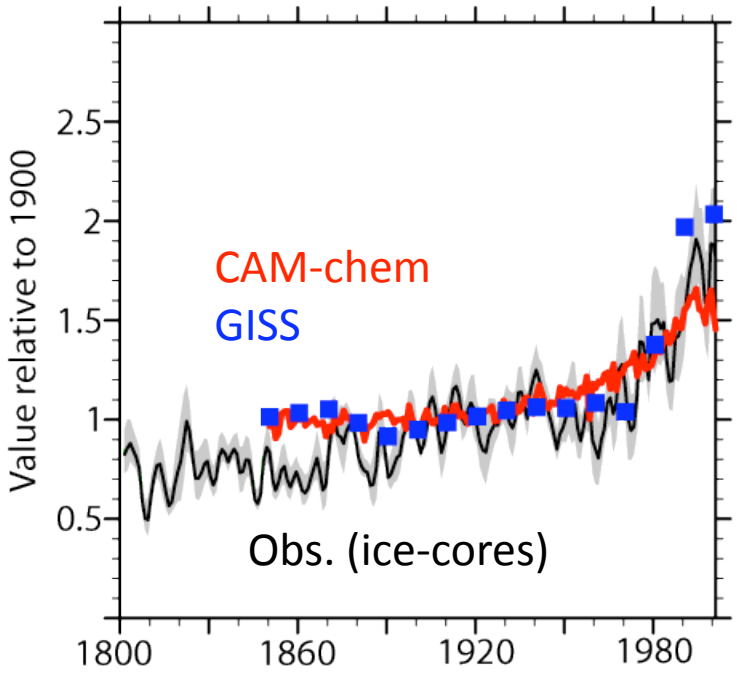
Long-term trend in surface ozone

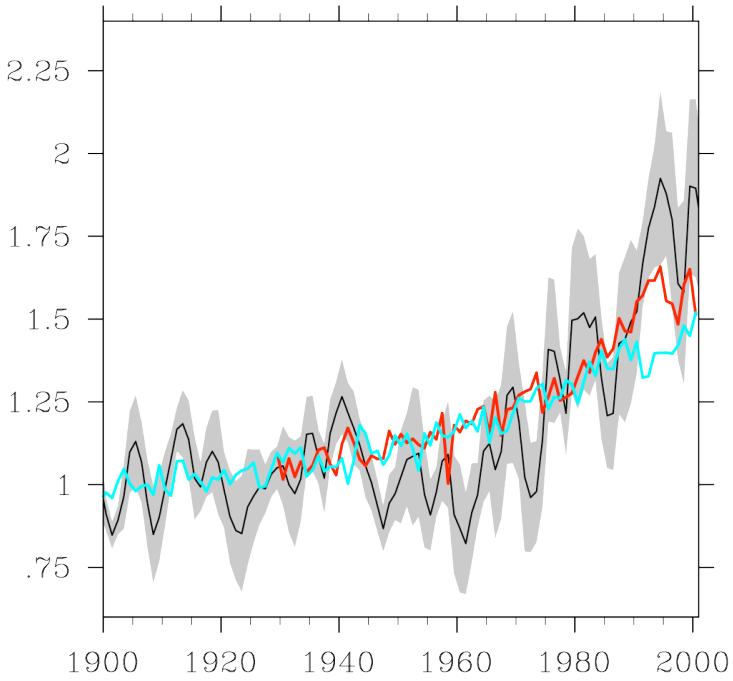


Data provided by D. Parrish (NOAA):
12-month running mean

Black: all forcings
Red: 1850 CH_4
Green: 1850 emissions
Magenta: 1850 climate
Cyan: 1850 CFCs

Attribution: Antarctic H_2O_2





Lamarque et al., GRL, 2011

Red: all forcings

Cyan: 1850 CFCs

Summary

- Performed 5 single-forcing simulations of relevance to tropospheric and stratospheric ozone
- Change in anthro/bb emissions (NOx/CO/ VOCs) is the largest contributor to tropospheric ozone increase
- Residual circulation in the LS displays no trend in the no-CC simulation