The climate impact of past changes in halocarbons and CO_2 in the tropical UTLS region

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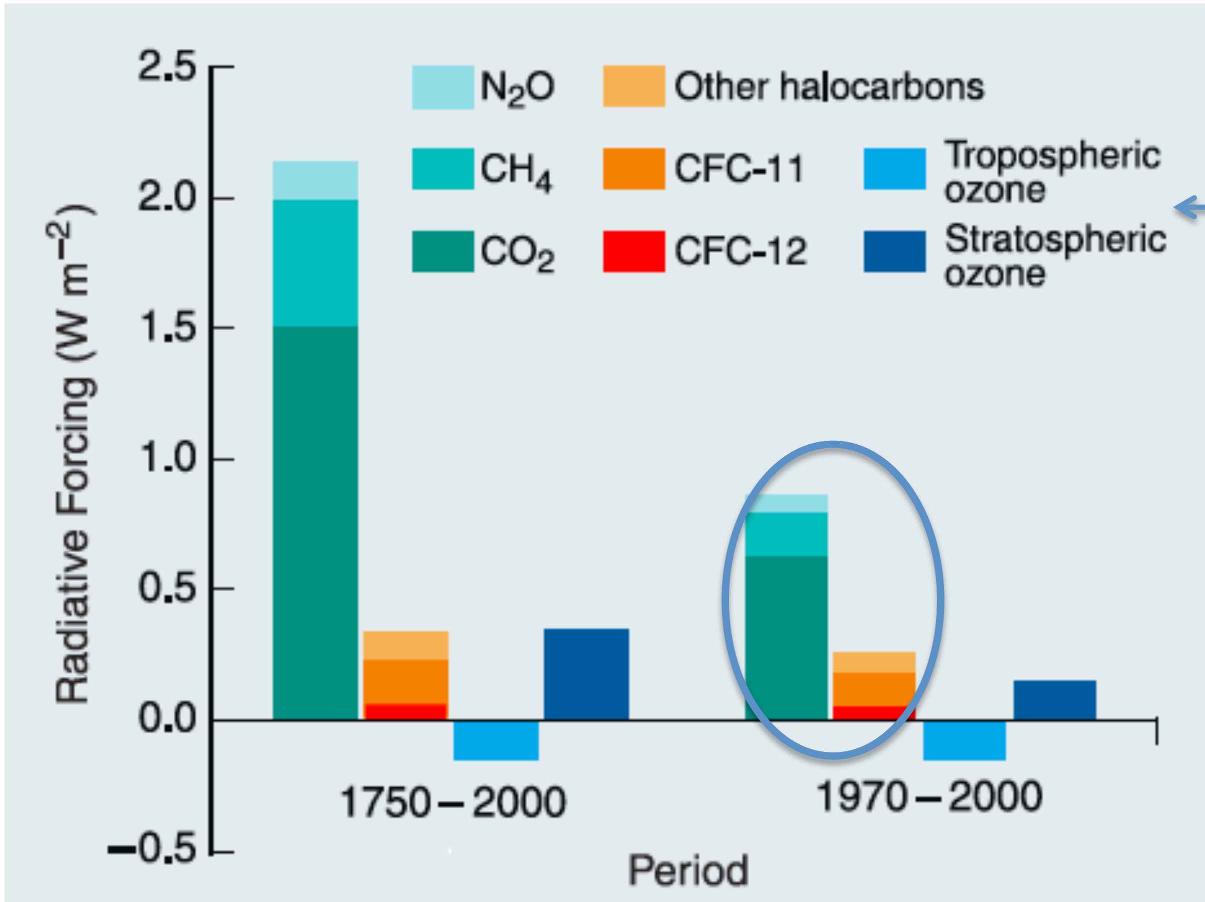
Based on paper by McLandress, Shepherd, Reader, Plummer & Shine (2014, J. Clim.)

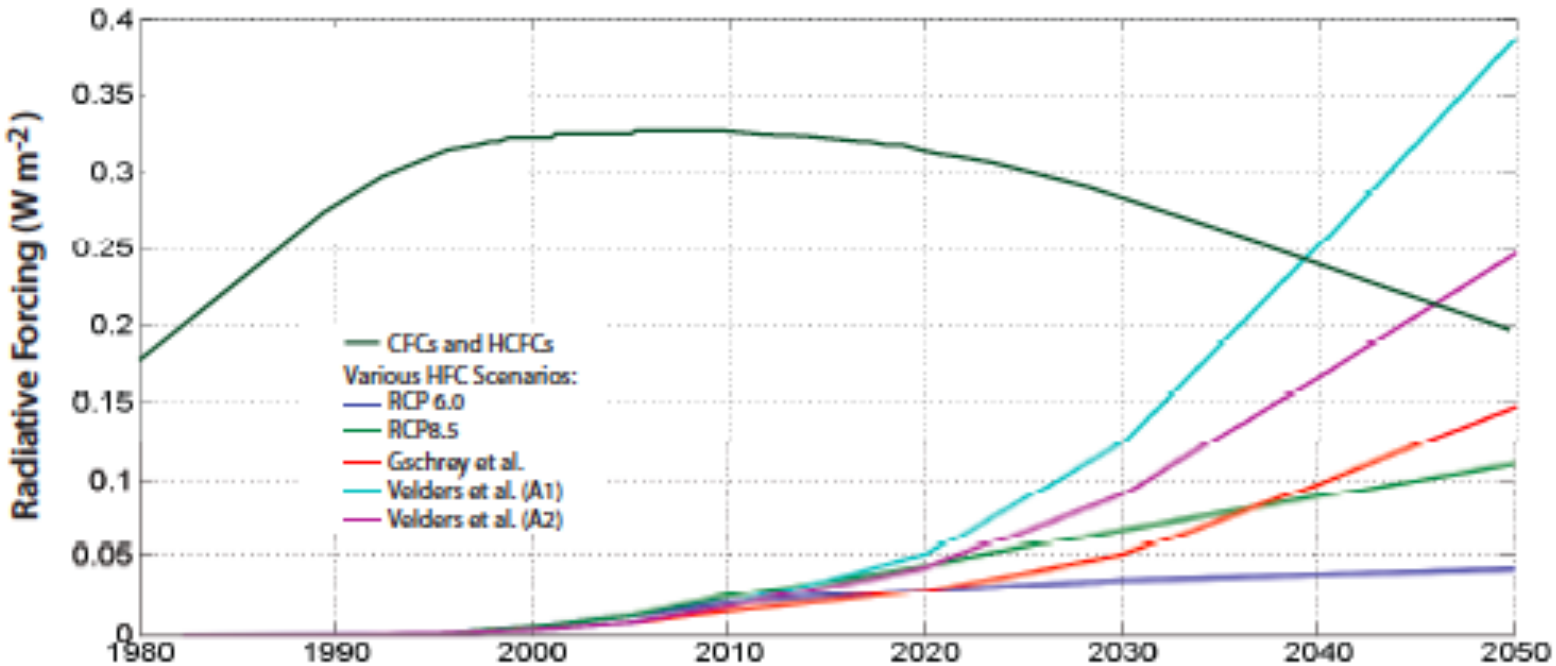
- Halocarbons represent a very significant fraction of the GHG radiative forcing, especially over the 1970-2000 period



N.B. Typographical error!

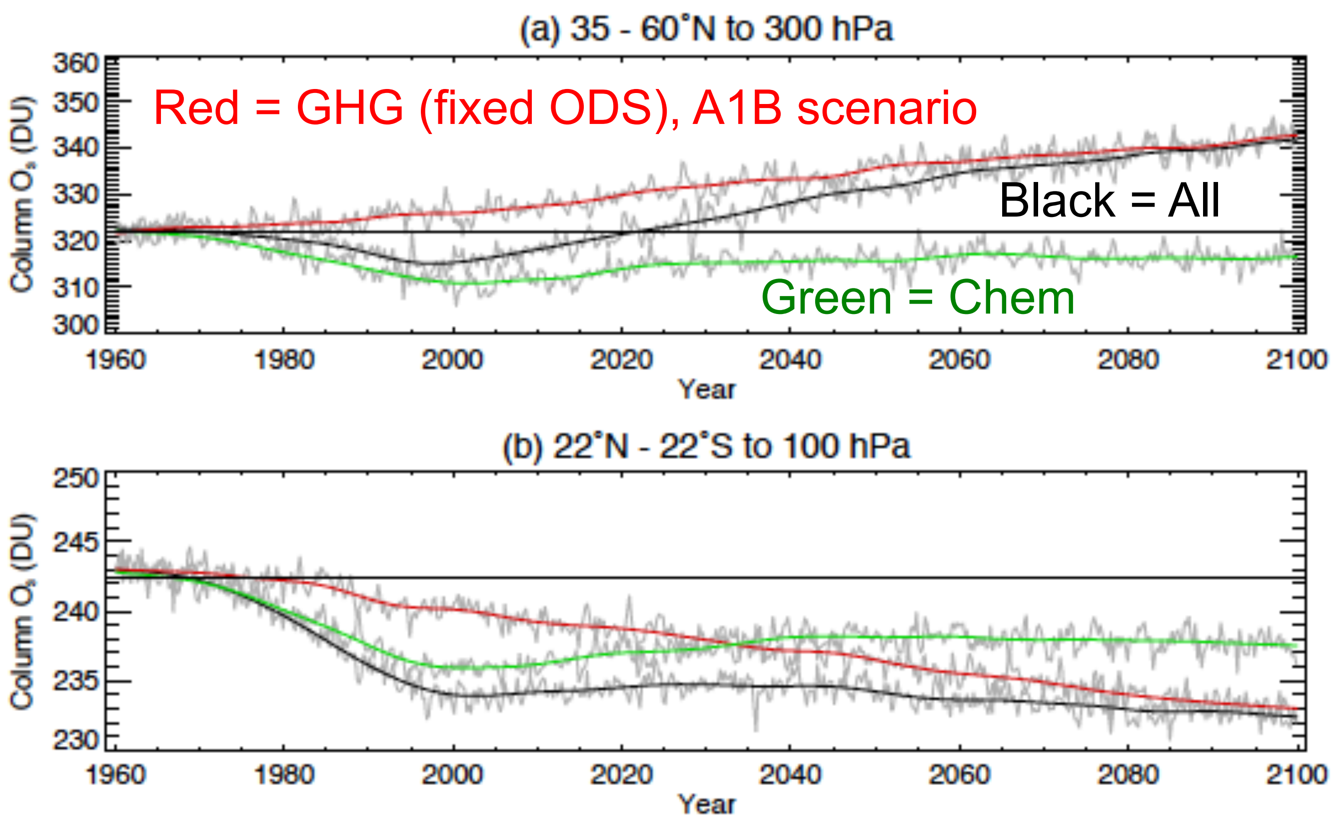
Chapter 1 of IPCC/TEAP Special Report on Ozone and Climate (2005)

- The future radiative forcing from HFCs could well exceed that of the ODS halocarbons at their max



From *Assessment for Decision-Makers* of 2014 WMO/UNEP Ozone Assessment

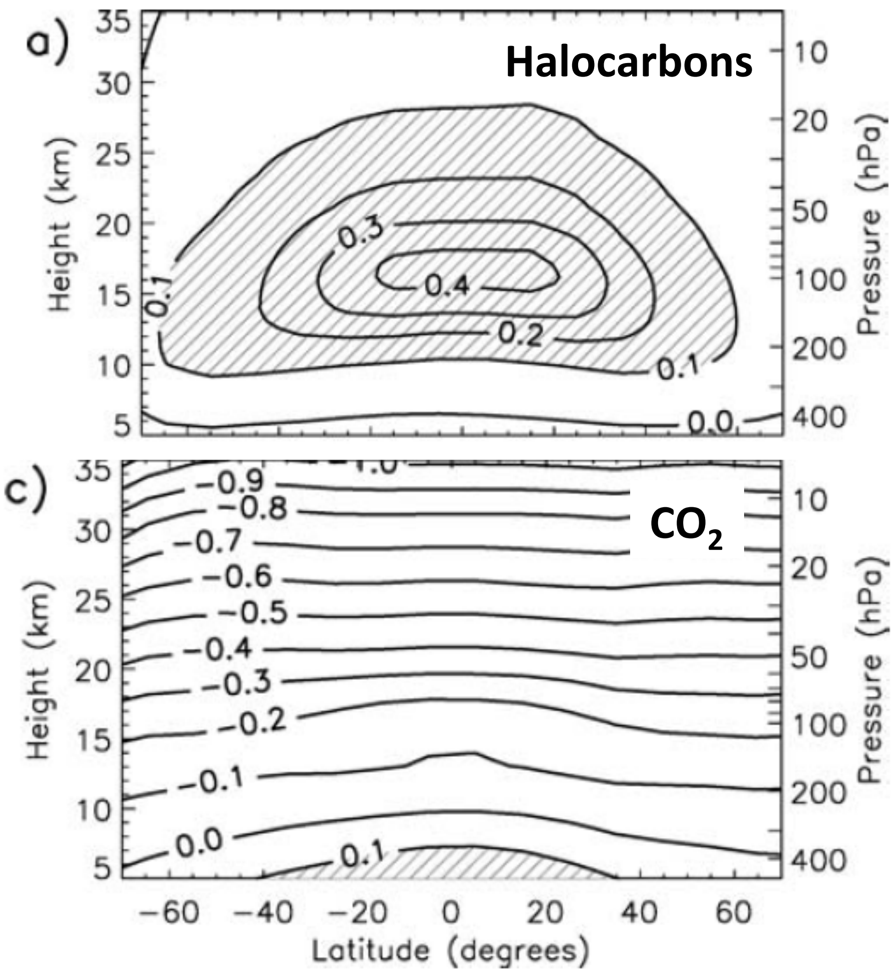
- The standard approach in the stratospheric CCM community (and Ozone Assessment) to attribution of ozone changes is to distinguish between ODS (chemical) and GHG (radiative) effects
  - Not quite logical, since (most) halocarbons affect both!



GHG-induced mid-latitude increase and tropical decrease result from strengthened Brewer-Dobson circulation

Plummer et al. (2010 ACP)

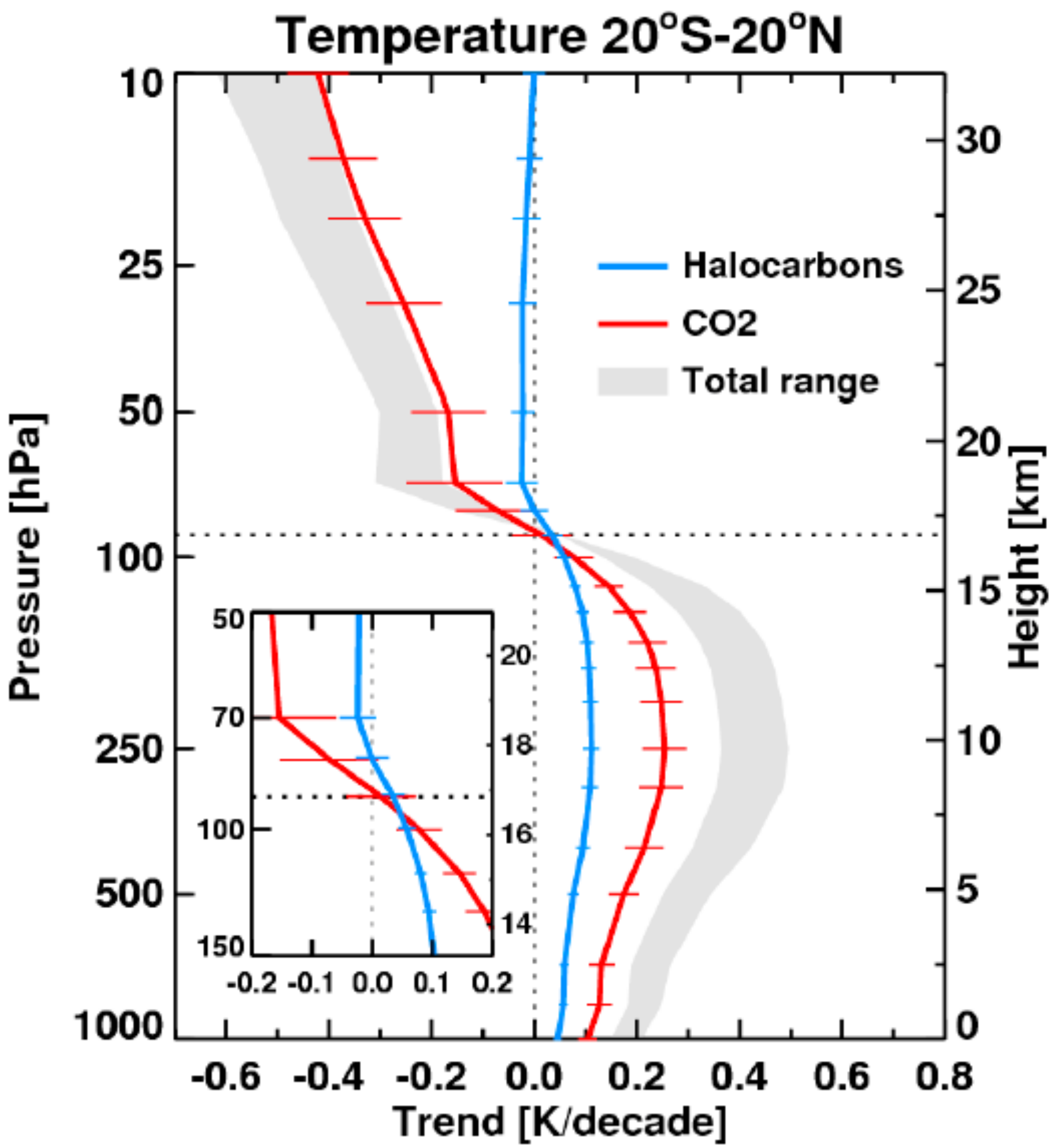
- Halocarbons are expected to preferentially warm the tropical upper troposphere/lower stratosphere (UTLS), so could have quite a distinct effect on tropical upwelling and tropical ozone



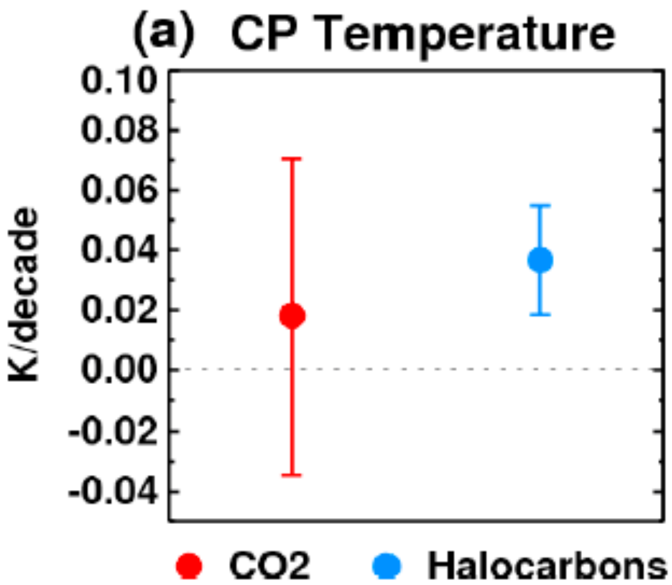
And also, of course, on stratospheric water vapour!

The effect of halocarbons on climate has not previously been quantified in a coupled setting with a chemistry-climate model

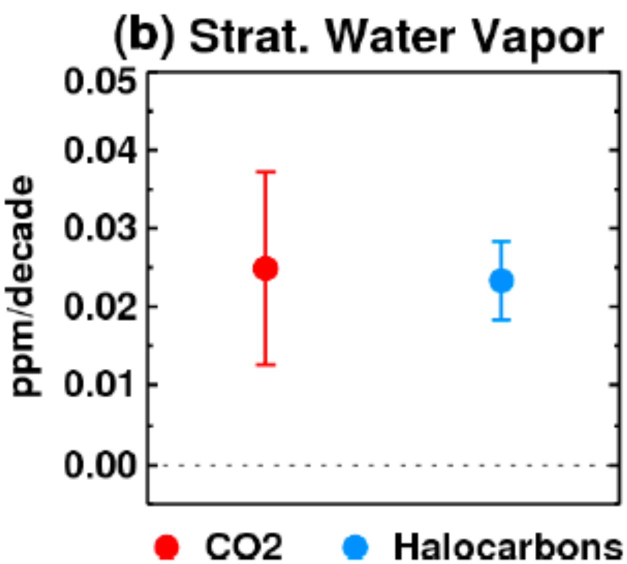
FDH calculations by Forster & Joshi (2005 Clim. Change)

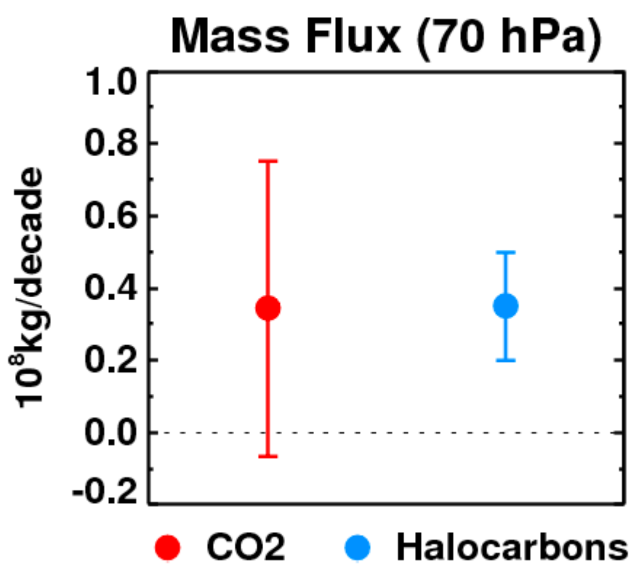


- The CMAM response over 1960-2010 to *radiative* changes in halocarbons does not show the expected warming in the tropical lower stratosphere
  - Suggests important feedbacks
- There seems to be more leverage on the tropical cold-point tropopause (dotted line) than from CO_2

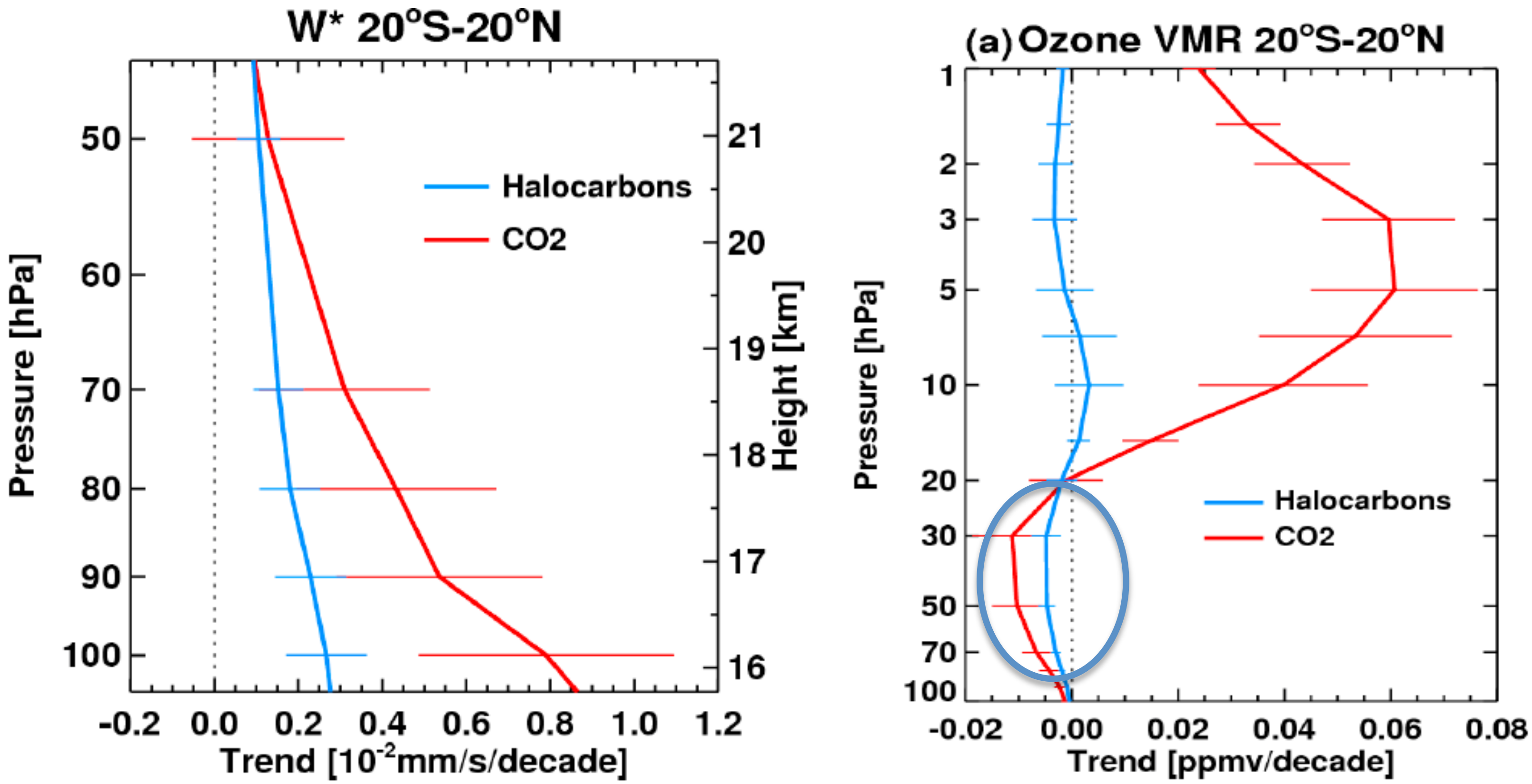


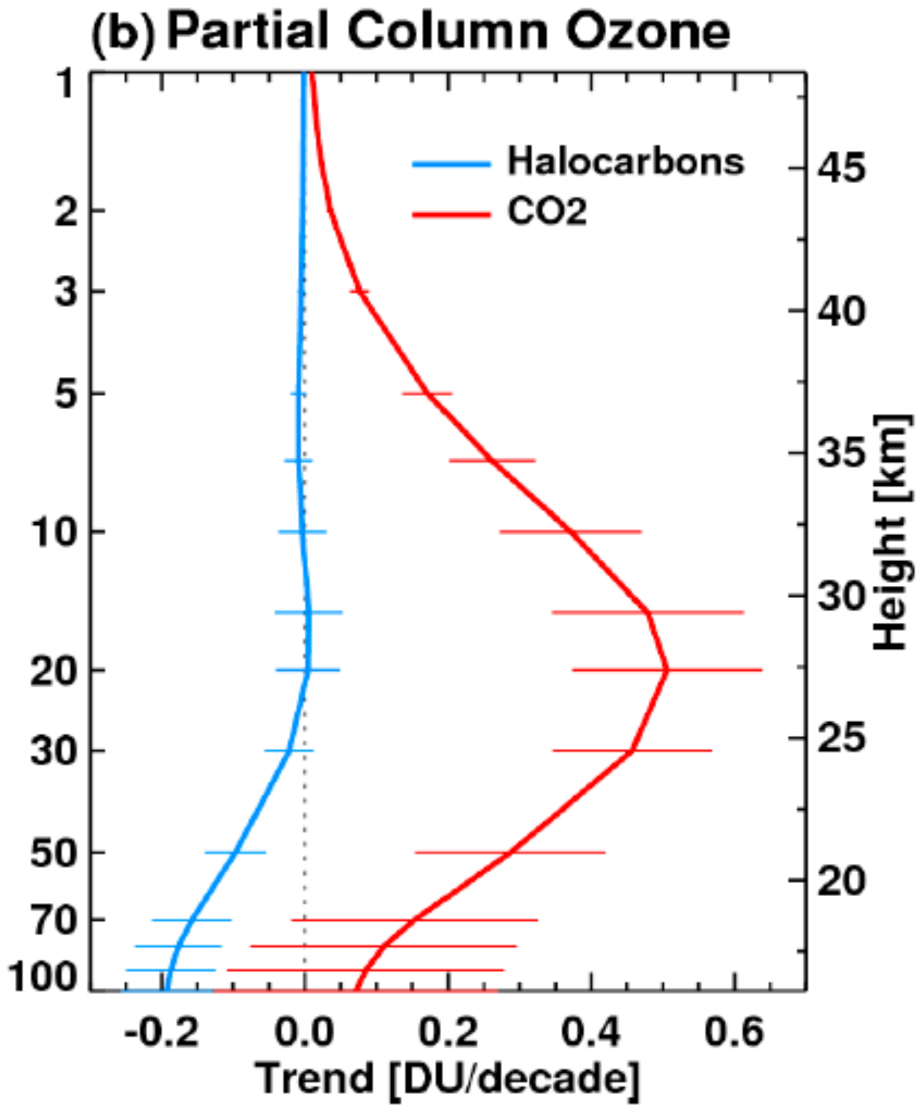
- Over 1960-2010, CFCs had a comparable effect on many aspects of stratospheric climate to that of CO_2 (vs 40% for surface and upper tropospheric warming)
  – Has important implications for past vs future



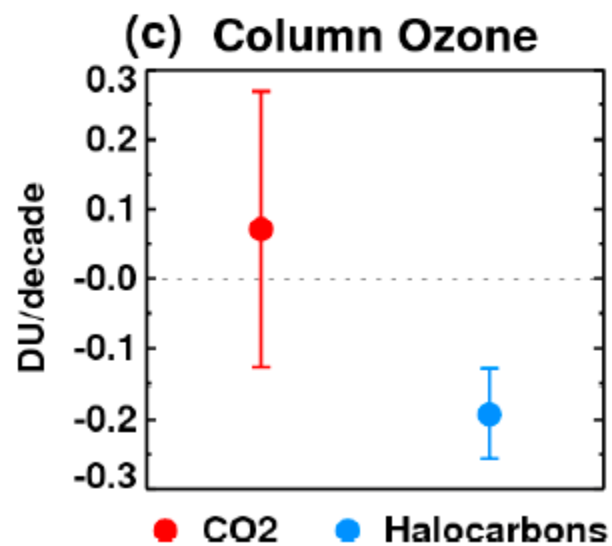


- The strengthened tropical upwelling decreases ozone in the tropical lower stratosphere
- However in the case of CO_2 (but not halocarbons), upper stratospheric cooling increases ozone in that region

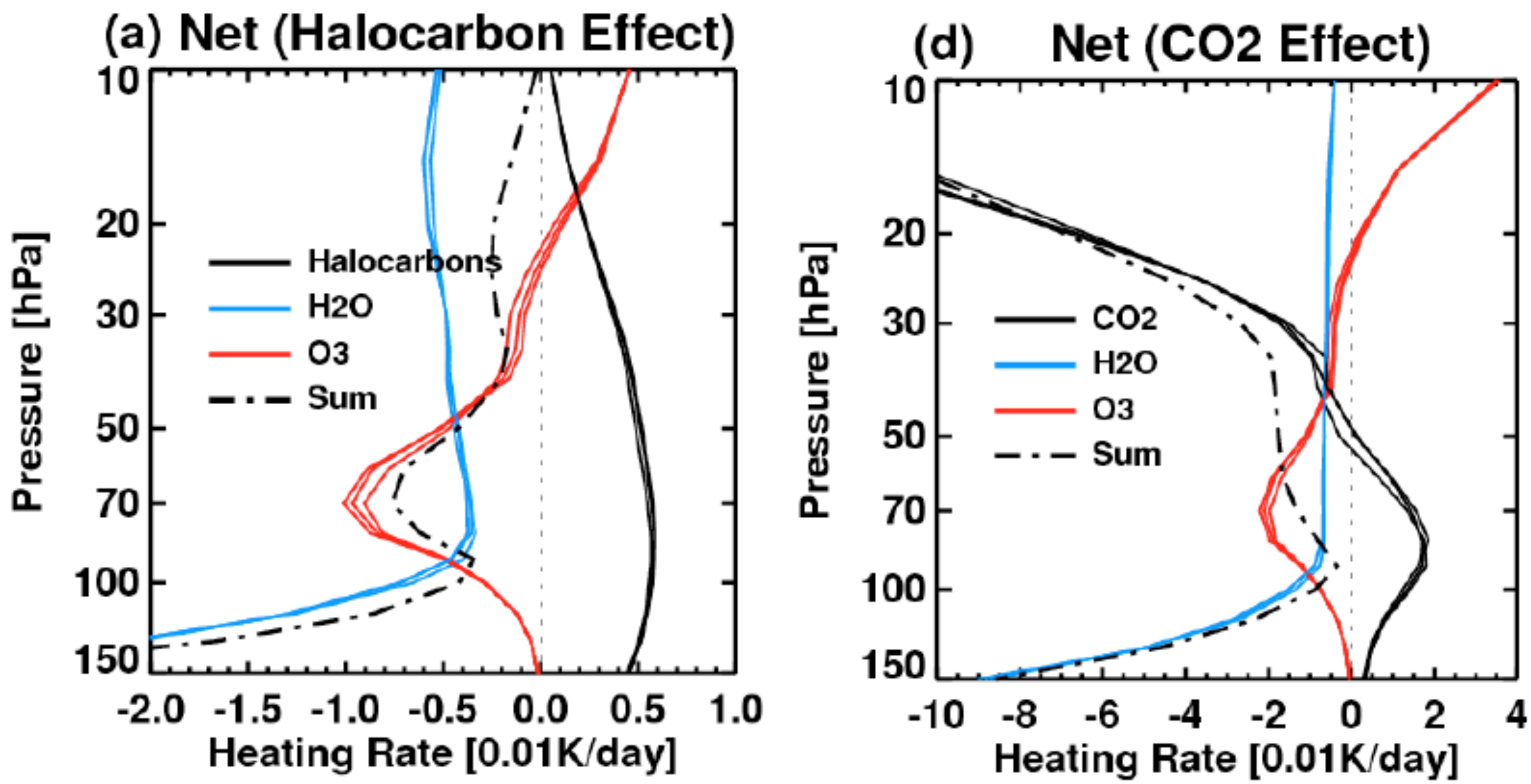




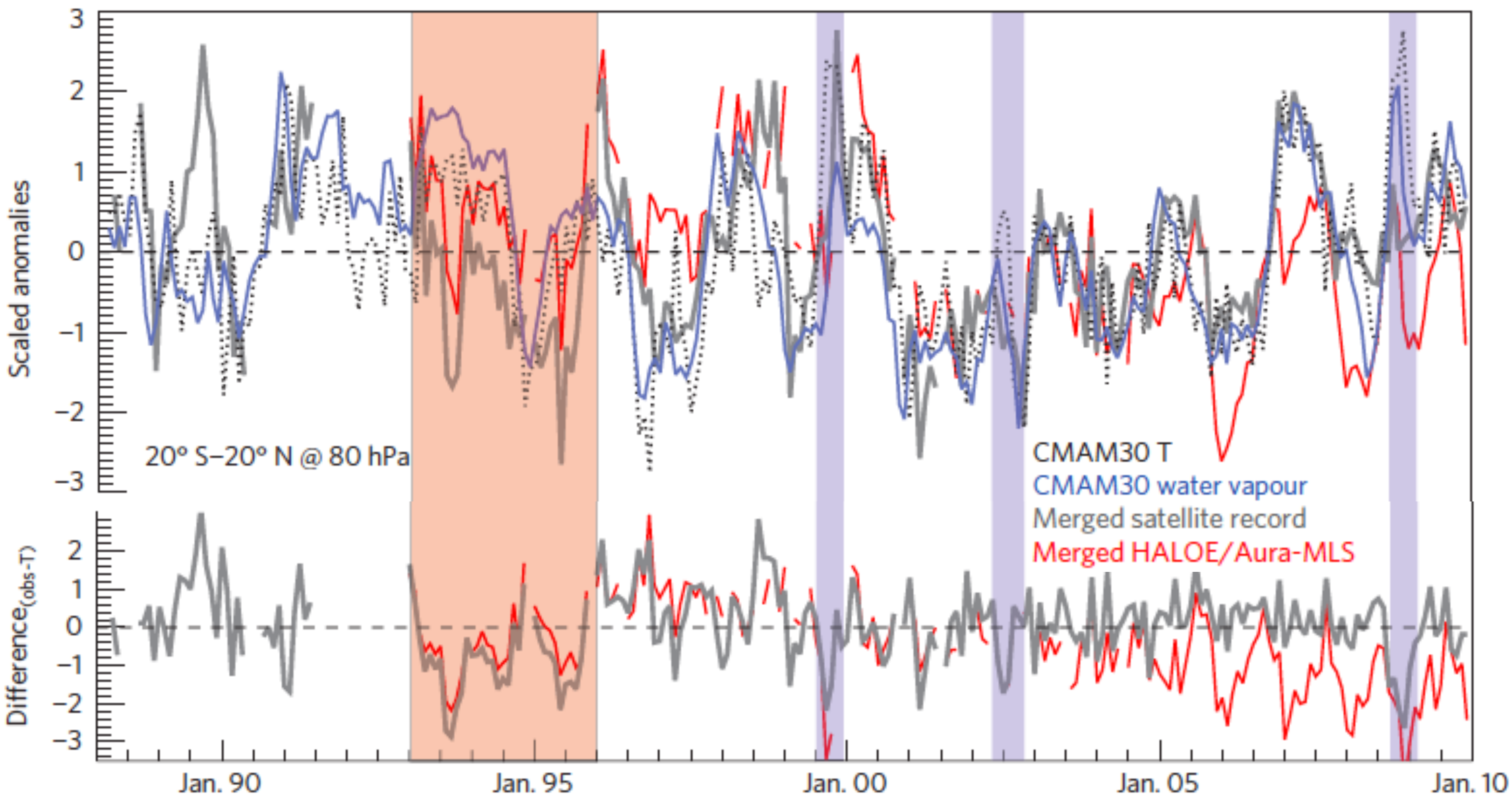
- Thus, CO_2 increases lead to *more* tropical column ozone, while halocarbon increases lead to *less*
  - Similar for other WMGHG
- Future tropical column ozone depends on the mix of GHG in the scenario



- Together, the cooling from lower stratospheric water vapour increases and from ozone decreases more than offsets the warming from halocarbons (figures show instantaneous heating rates)
- Water vapour and ozone feedbacks are similarly important in the response to CO_2 (right)



- These negative feedbacks may help explain the lack so far of an observed increase in lower stratospheric water vapour



Hegglin et al. (2014 Nature Geosci.)

Conclusions

- Halocarbons exert a stronger influence on the tropical tropopause region than on surface climate, relative to other GHG
  - Comparable to that of CO_2 over the 1960-2010 period
- Feedbacks from water vapour and ozone are significant, and nullify the expected stratospheric warming from halocarbons
  - These feedbacks also very important for the response to CO_2
- Strengthened tropical upwelling (Brewer-Dobson circulation) reduces tropical lower stratospheric ozone (as observed), which preferentially cools the tropical cold-point tropopause
  - May help explain the lack so far of any water vapour increase in the observations; also reduces stratospheric H_2O feedback
- Stratospheric column ozone is increased by increased CO_2, but decreased by increased halocarbons (or other WMGHG)
  - Future of tropical column ozone depends on GHG scenario