METEOROLOGY

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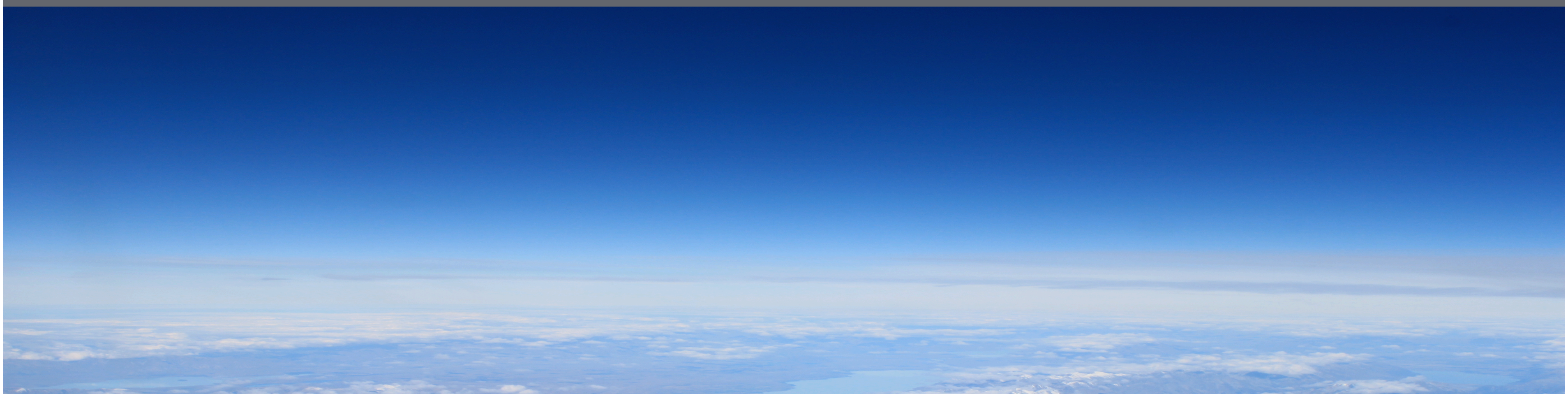
OZONE DATABASE IN SUPPORT OF CMIP6



Michaela I. Hegglin, University of Reading UK

Jean-François Lamarque, NCAR US
Neal Butchart, MetOffice UK
Veronika Eyring, DLR GE
David Plummer, CCCma CA

IMPORTANCE OF OZONE FOR CLIMATE

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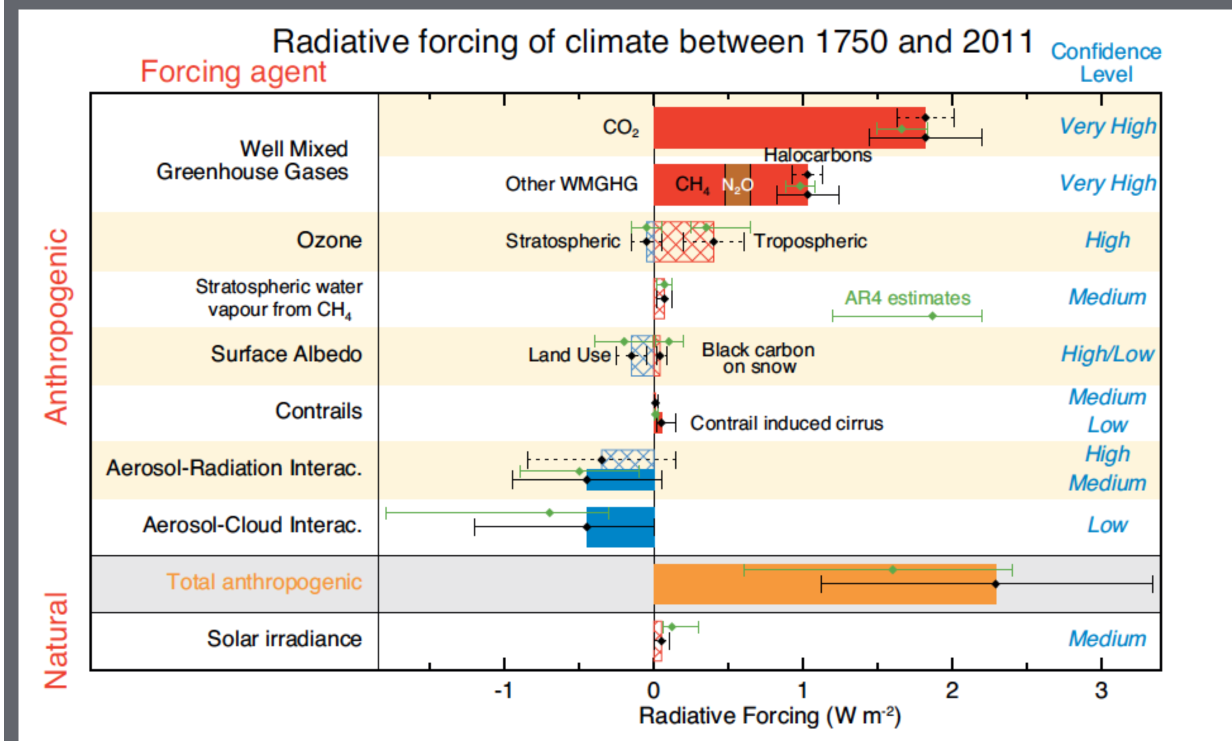
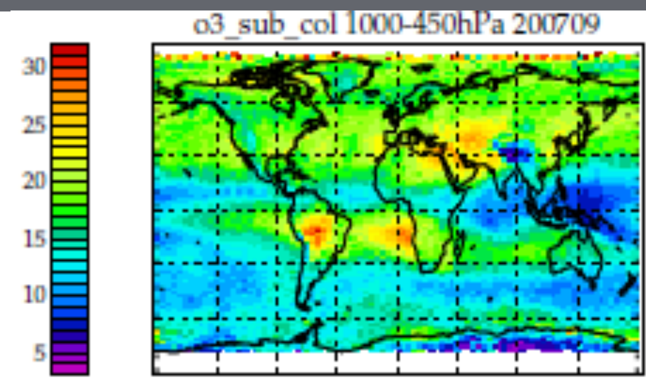
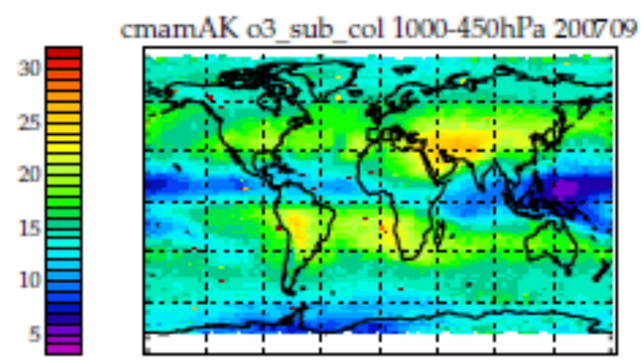
- Tropospheric ozone constitutes the third-most important GHG contribution to radiative forcing since 1750, after CO_2 and CH_4.
- 3D-distribution important to capture regional forcing and consequent effects on dynamics.



IPCC AR5, *2014*

GOME2



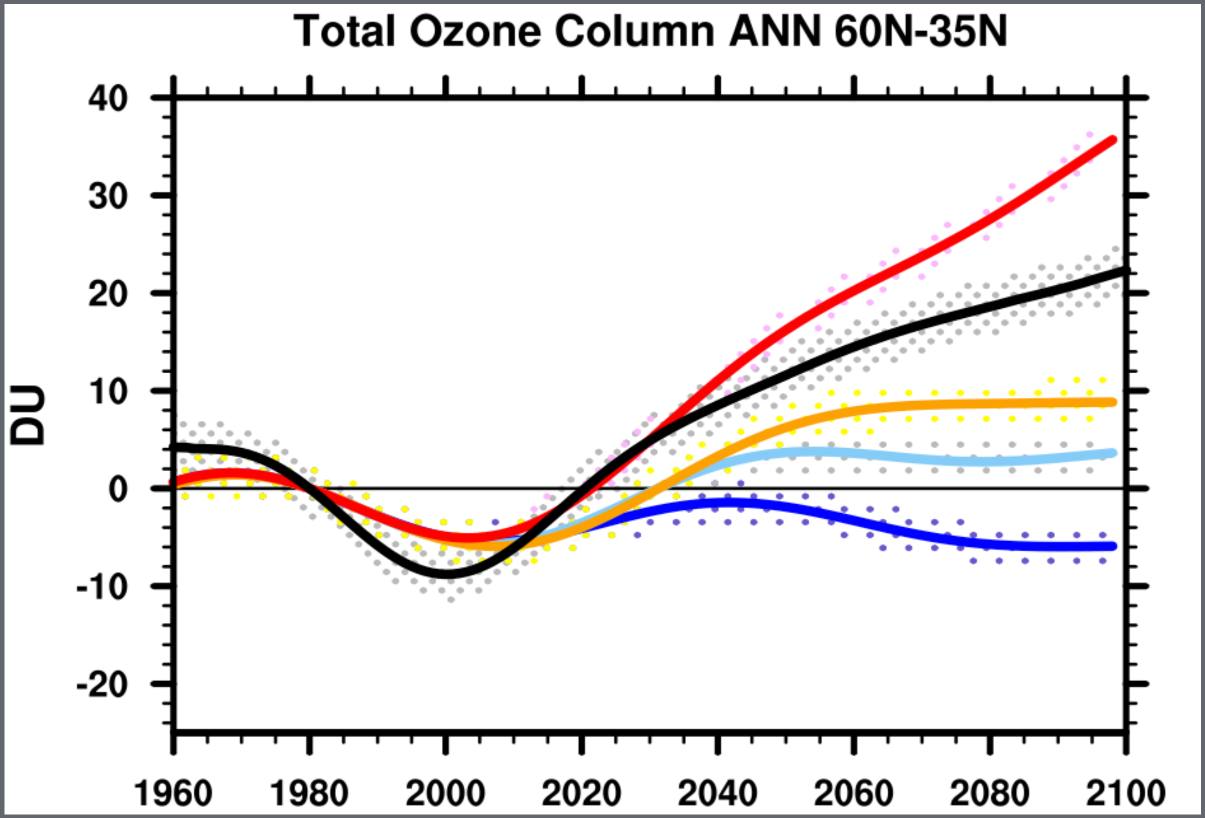


CMAM w/AK

(Figure courtesy Georgina Miles, see CCMI poster)

RCPs AND TOTAL COLUMN OZONE

- Mix of future GHG emissions will determine the state of the ozone layer (with CH_4 and N_2O having opposing effects on stratospheric ozone chemistry).



WMO, 2014 after
Eyring et al., 2013

RCP8.5
MMM A1B
RCP6.0
RCP4.5
RCP2.6

INDIRECT EFFECT OF OZONE DEPLETION ON SURFACE CLIMATE

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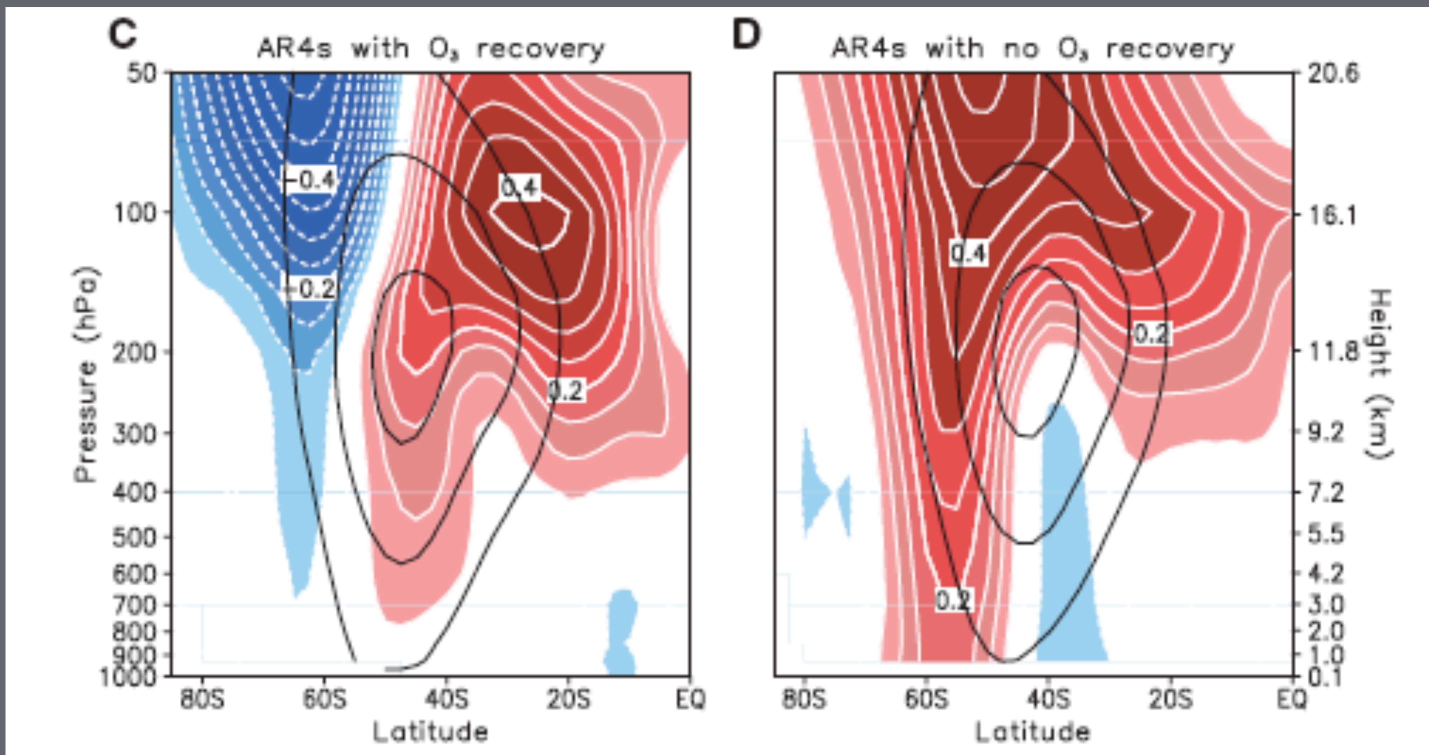
- The Antarctic ozone hole has altered the temperature structure of the atmosphere, thereby affecting also the distribution of winds.



units m s^{-1} dec^{-1}

Son et al., *Science 2008*

OZONE RECOVERY MITIGATES CLIMATE EFFECTS

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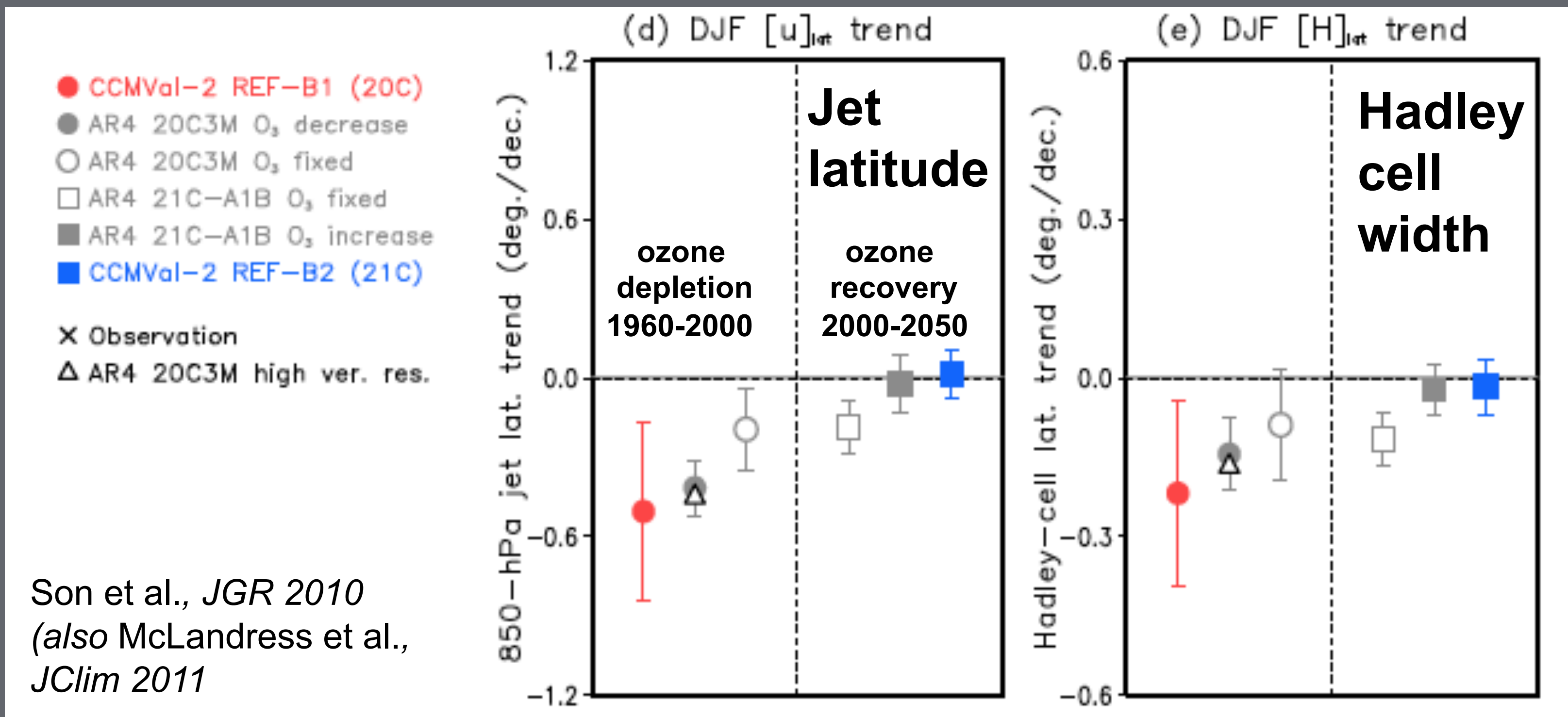
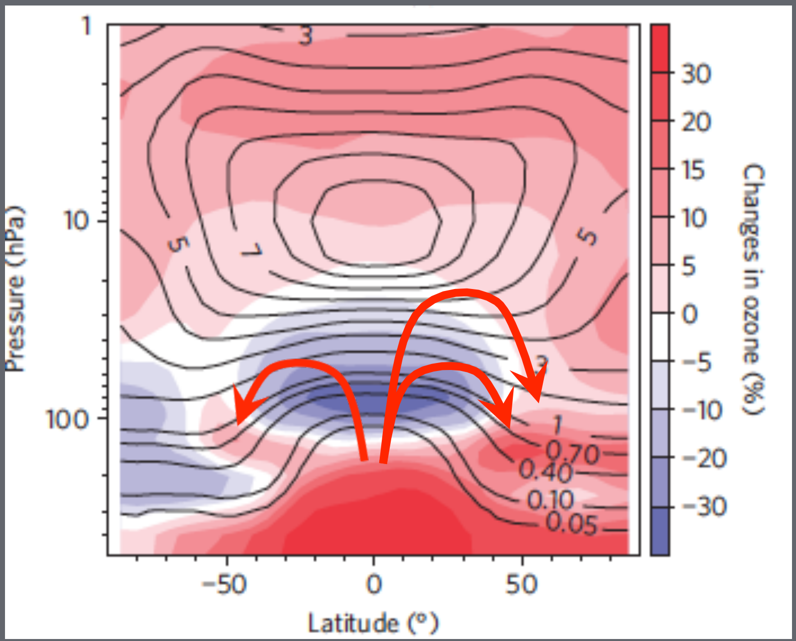
- The ozone hole thereby affects tropospheric surface climate during austral summer even outside SH high latitudes, including the tropics.



- The ozone-hole induced surface wind changes have potential implications for ocean circulation and carbon uptake (Cai & Cowan, *J Clim* 2007; Lenton et al., *GRL* 2009)

CHEMISTRY-CLIMATE COUPLING

- Climate change is expected to lead to a strengthening of the stratospheric Brewer-Dobson circulation, which affects ozone and also other trace gases.



Hegglin and Shepherd, *Nature Geoscience 2009*

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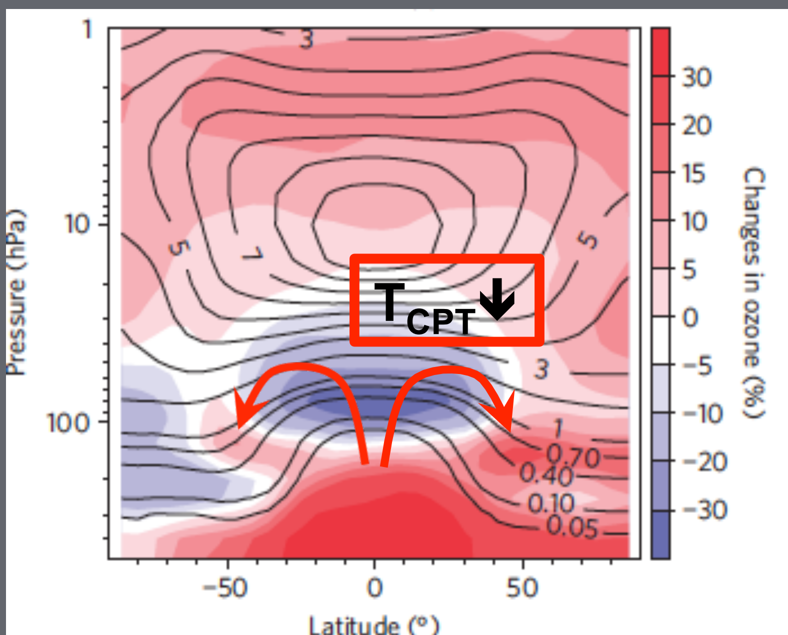

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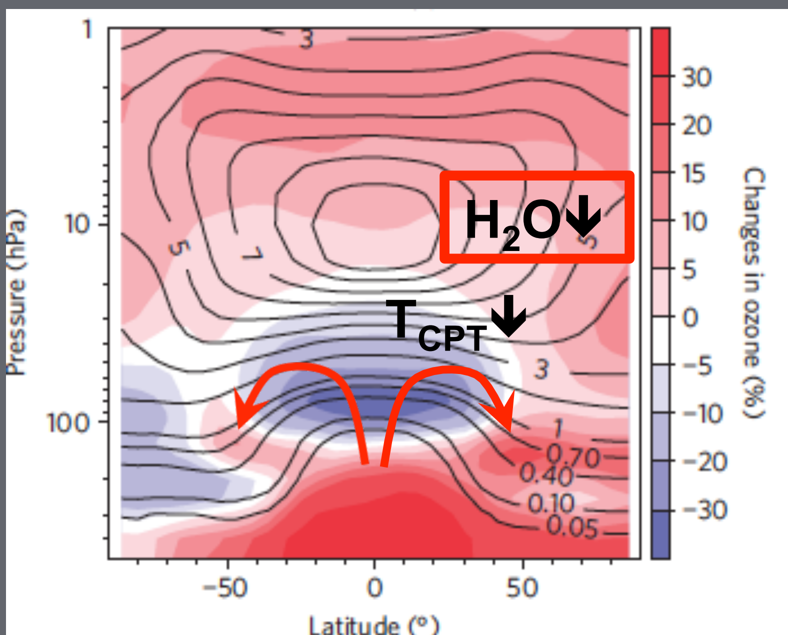

Hegglin and Shepherd, *Nature Geoscience 2009*

CHEMISTRY-CLIMATE COUPLING

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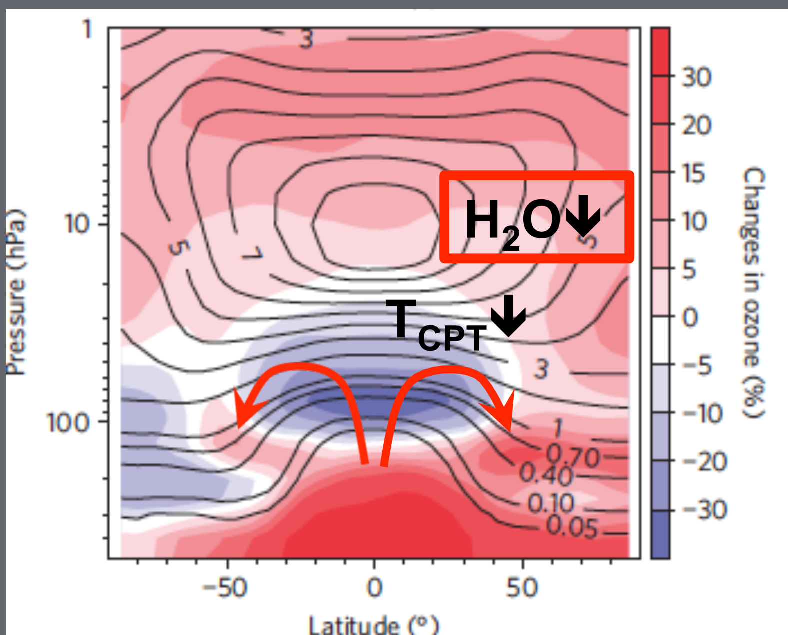
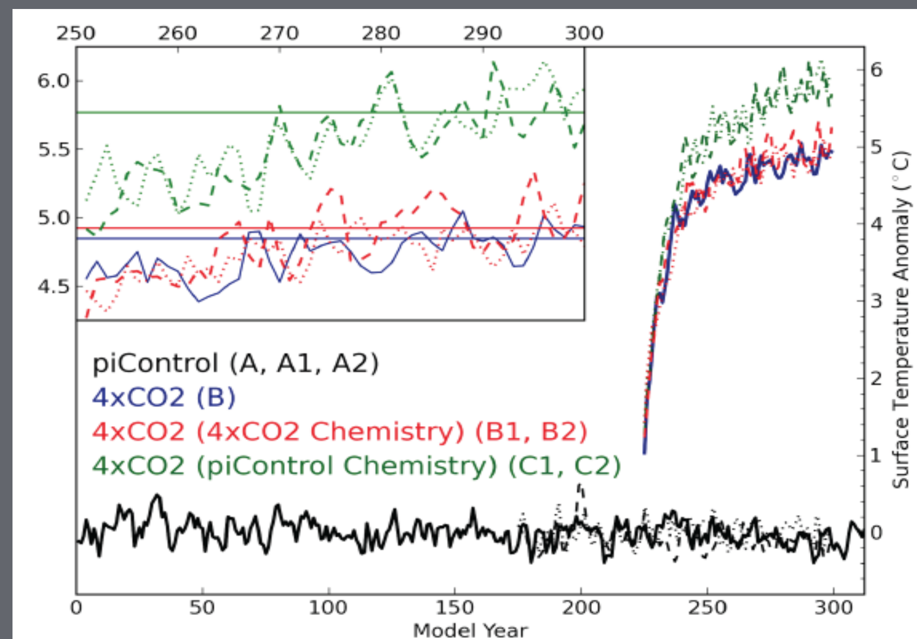
- Climate change is expected to lead to a strengthening of the stratospheric Brewer-Dobson circulation, which affects ozone and also other trace gases.
- The predicted decrease in water vapour would lead to a weaker surface temperature response to GHG forcing.



Hegglin and Shepherd, *Nature Geoscience 2009*



Nowack et al., *Nature Climate Change 2014*

IMPORTANCE OF STRATOSPHERIC H_2O

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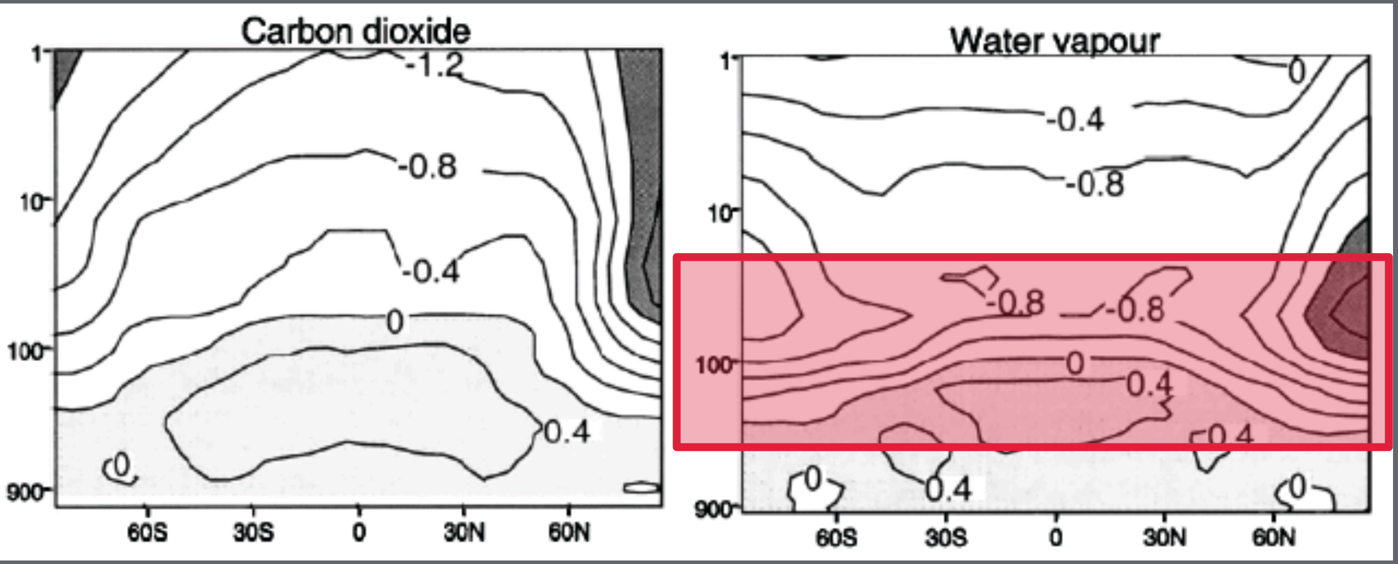
- Water vapour is the most important natural greenhouse gas in the atmosphere and provides a positive feedback to the climate forcing from CO_2.
  - A stratospheric water vapour trend of 0.4 ppmv/decade (as was apparently observed over Boulder) over 1980-1997 would have led to global surface warming that was 44% of that from CO_2 alone.
  - The assumed constant water vapour increase induces a strong latitudinal structure in the cooling of the stratosphere → important for dynamical feedbacks



Changes are largest in the UTLS

Forster & Shine, *GRL* 1999

PAST EFFORTS

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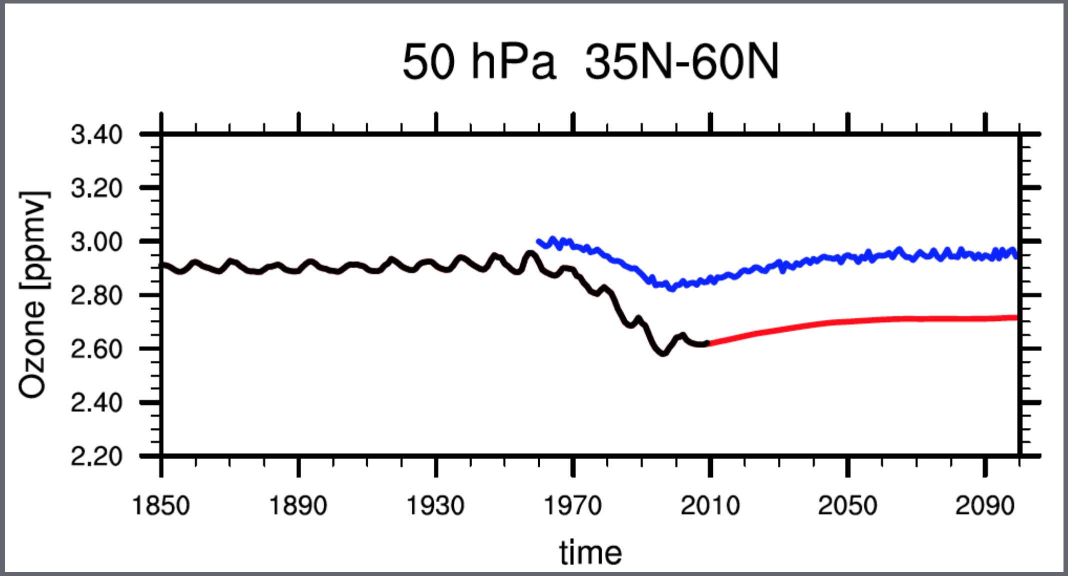
- IGAC/SPARC ozone data base by *Cionni et al.* (2011)
  - Merged fields from models with either stratospheric or tropospheric chemistry.
  - Only one emission scenario into the future.
  - Some unphysical behaviour was introduced by merging with observations.



- Update required with CCMI models that include coupled stratosphere-troposphere resolving chemistry.

APPROACH TO CREATE DATABASES

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- Need to produce ozone (and stratospheric water vapour) timeseries for Earth-system models without interactive chemistry.

1) CCMI ozone forcing database:
  - Tropospheric and stratospheric ozone fields (1000-0.01 hPa)
  - 5-day averaged (pentad) timeseries between 1850 and 2100
  - Set of comprehensive stratosphere-troposphere resolving chemistry-climate model simulations
    - Historical emissions and different emission scenarios (low, middle and high)
    - Envisage scaling approach to be adaptable to new emissions scenarios.

2) Also suggested, CCMI water vapour forcing database:
  - Stratospheric water vapour fields only (tropopause-0.01 hPa)
  - Monthly timeseries between 1850 and 2100
  - Same base simulations as for ozone described above.

- No merging with observations, but rigorous evaluation of models with observations and weighting according to performance metrics.

HOW COMPLEX TO MAKE IT?

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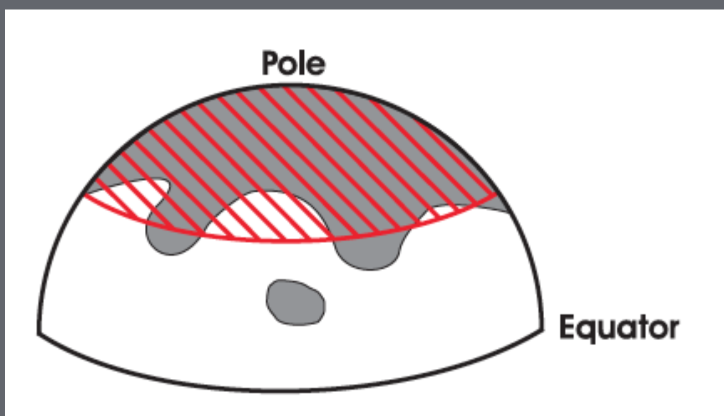
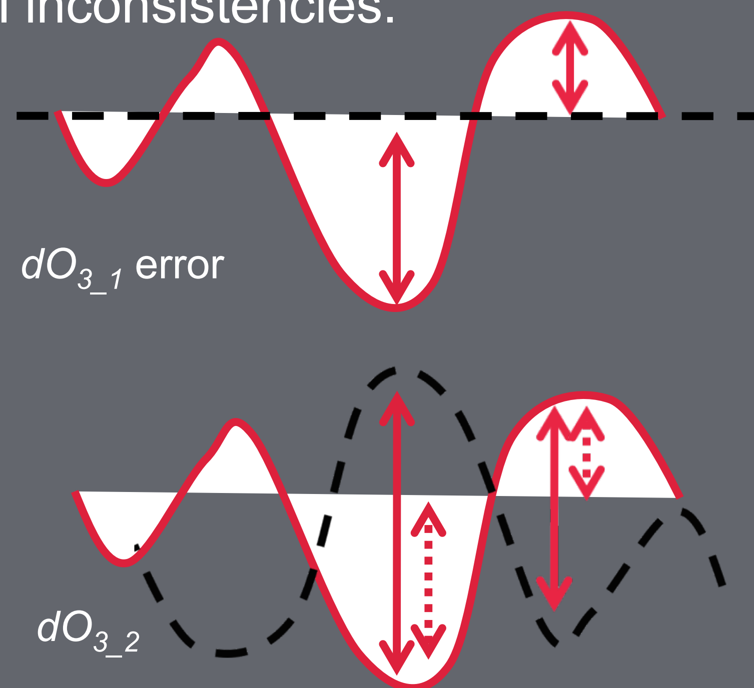
- *Approach is to keep it as simple as possible.* If you want full complexity you should be running a fully interactive model.
- In the stratosphere, the longitudinal structure arises from the dynamics, so imposing it would lead to dynamical inconsistencies.

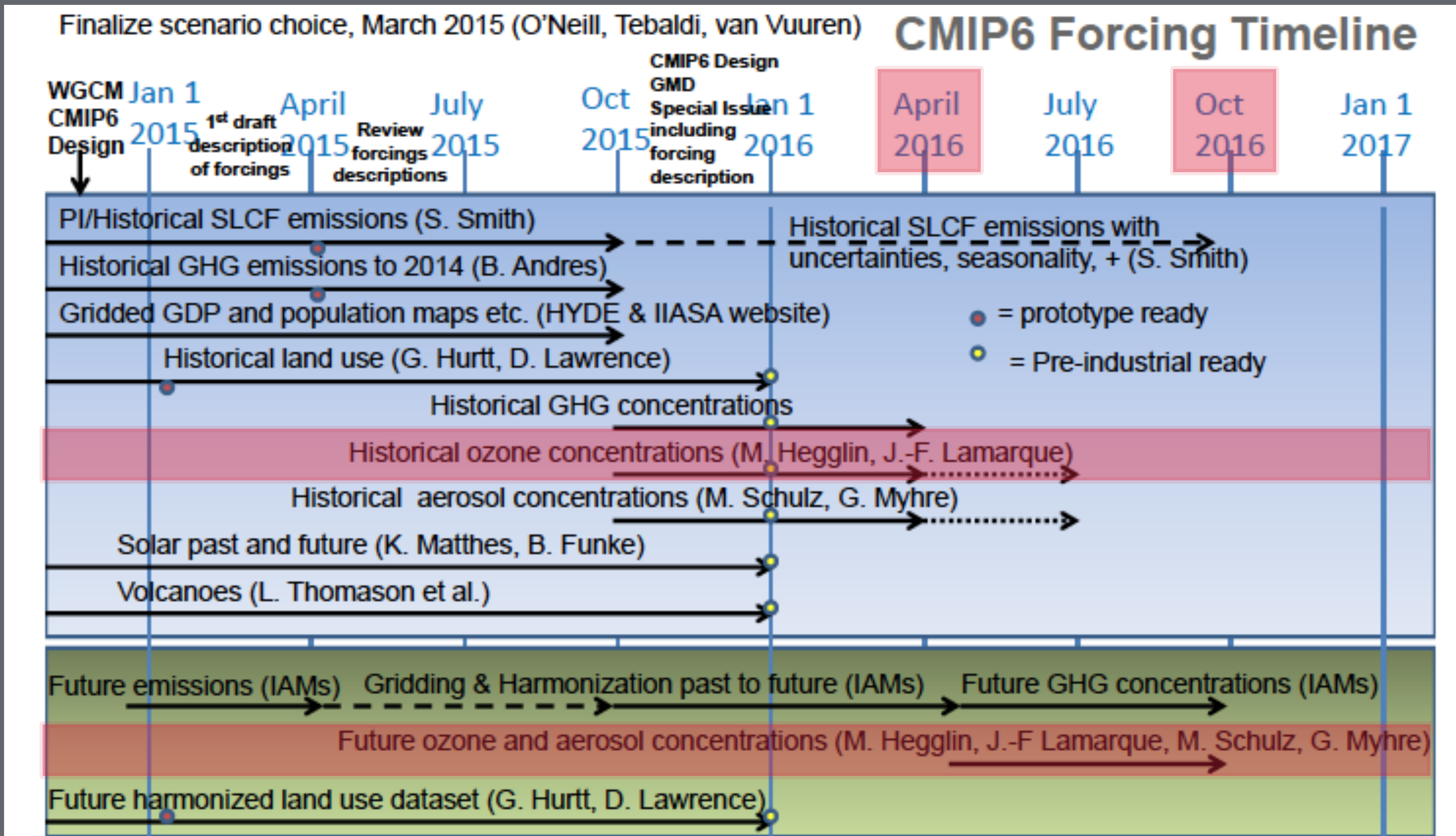




- Solar cycle?
- No QBO.

$dO_{3\_1} << dO_{3\_2}$

TIMETABLE


Finalize scenario choice, March 2015 (O'Neill, Tebaldi, van Vuuren)
CMIP6 Forcing Timeline
WGCM CMIP6 Design
Jan 1 2015
1st draft description of forcings
April 2015
Review forcings descriptions
July 2015
Oct 2015
CMIP6 Design GMD Special Issue including forcing description
Jan 1 2016
April 2016
July 2016
Oct 2016
Jan 1 2017
PI/Historical SLCF emissions (S. Smith)
Historical SLCF emissions with uncertainties, seasonality, + (S. Smith)
Historical GHG emissions to 2014 (B. Andres)
Gridded GDP and population maps etc. (HYDE & IIASA website)
= prototype ready
= Pre-industrial ready
Historical land use (G. Hurtt, D. Lawrence)
Historical GHG concentrations
Historical ozone concentrations (M. Hegglin, J.-F. Lamarque)
Historical aerosol concentrations (M. Schulz, G. Myhre)
Solar past and future (K. Matthes, B. Funke)
Volcanoes (L. Thomason et al.)
Future emissions (IAMs)
Gridding & Harmonization past to future (IAMs)
Future GHG concentrations (IAMs)
Future ozone and aerosol concentrations (M. Hegglin, J.-F Lamarque, M. Schulz, G. Myhre)
Future harmonized land use dataset (G. Hurtt, D. Lawrence)

SUMMARY AND OUTLOOK

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- Pre-publication of data fields via CCMI webpage.
  - 1850 fields to be posted by 31 December 2015.
    - Will allow for 'tuning' model response in historical reference state.
  - Historical simulations to be posted by April 2016.
  - Future simulations to be posted by October 2016.
  - NetCDF files with common format
- Publication in ESSD with citable doi-number attached to the database.
  - Meta-data will also be made available.
  - Historical and future fields to be published by 31 December 2016.
- Contributions/input from more CCMI modelling teams welcome!
  - Please email m.i.hegglin@reading.ac.uk to get involved.

STRATOSPHERIC GHG DISTRIBUTIONS & CLIMATE

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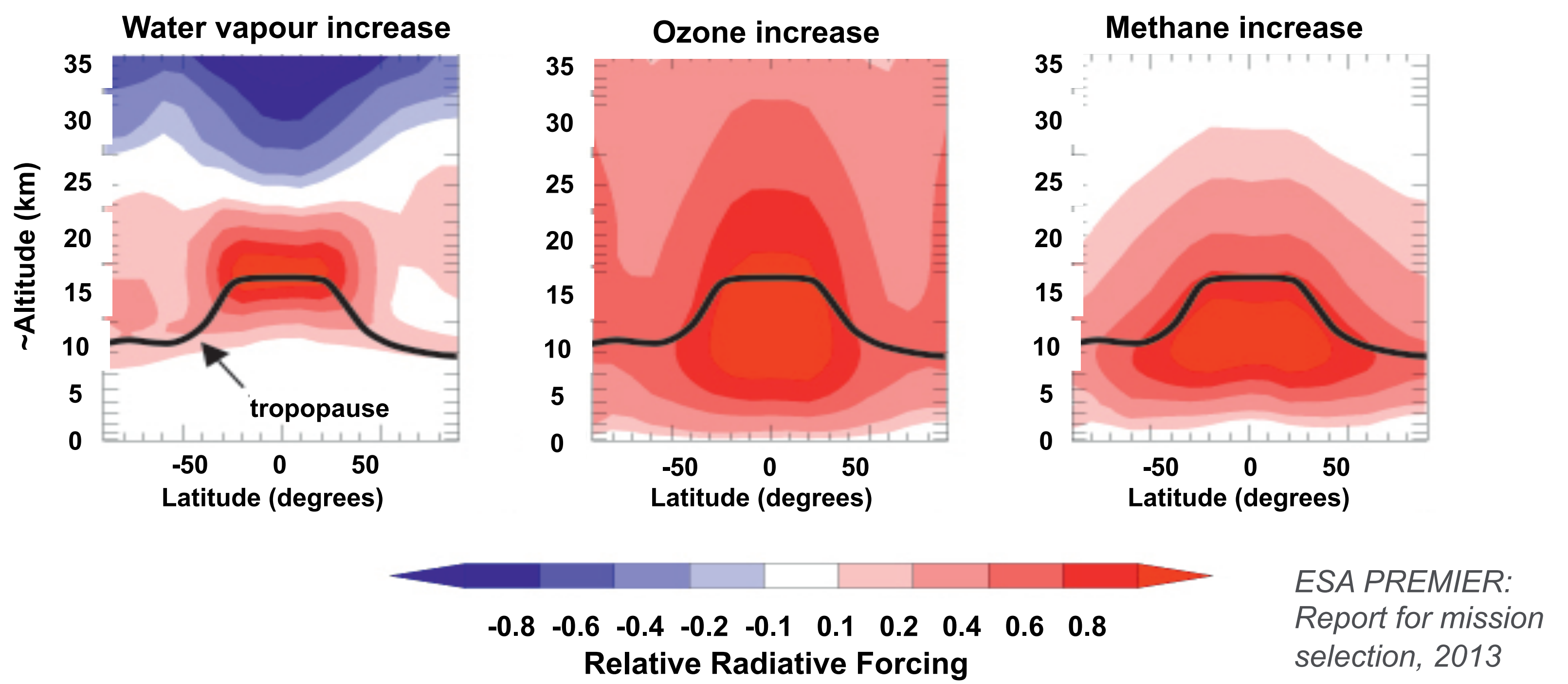
- Long-lived GHGs in the stratosphere affect both local temperatures and surface climate → *IPCC*



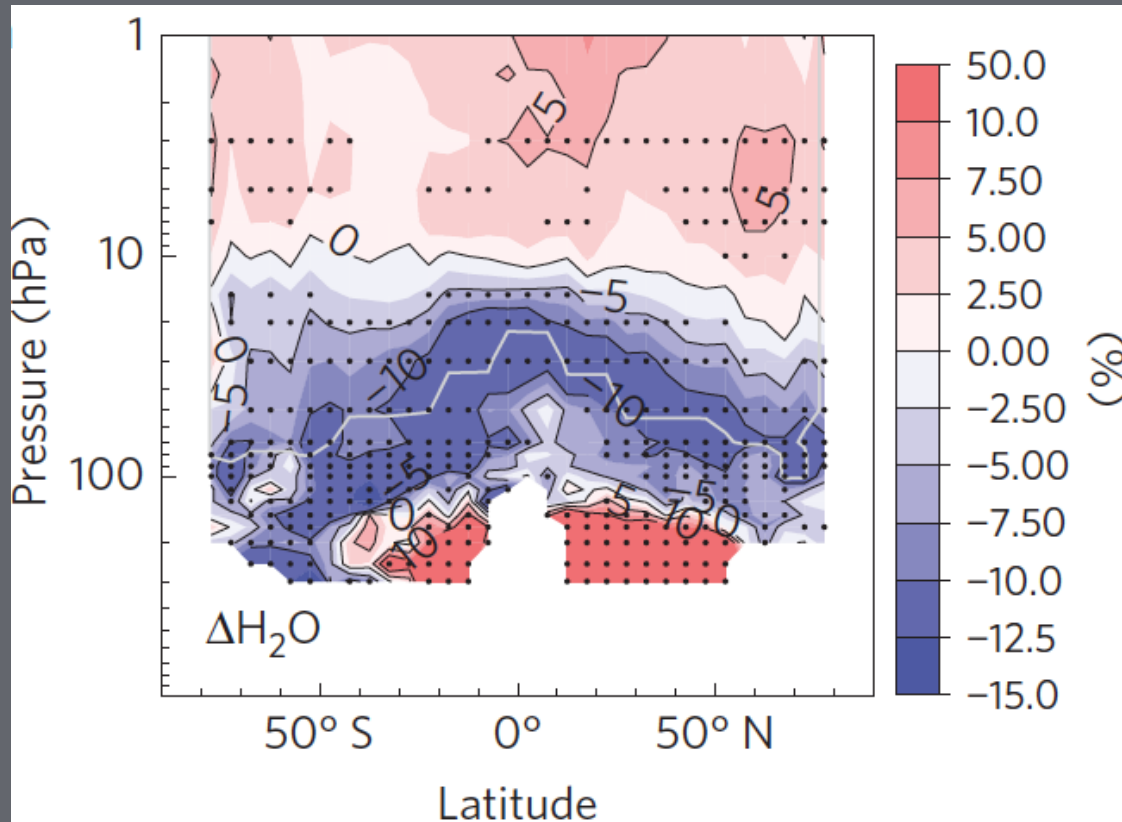
ESA PREMIER: Report for mission selection, 2013

- GHGs contribute to warming of surface climate.
- In the stratosphere, most GHGs lead to a local cooling.
- Dynamical feedbacks from chemistry-climate coupling extend to the surface.

STRATOSPHERIC H_2O CHANGES
(late 1980s to 2010)

Hegglin et al., *Nature Geoscience 2014*

- Trends in the lower to mid stratosphere are seen to be negative, not positive as would be inferred from the Boulder record!
- In the upper stratosphere, the trends are positive.
- The vertical structure in the changes indicates structural changes in the Brewer-Dobson circulation.



IMPORTANCE OF HALOCARBONS AND FLUORINATED SPECIES

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- Long-lived tracers can be used as age-of-air indicators.
- Trends derived from MIPAS SF_6 measurements between 2002-2010 for example indicate a slowing of the stratospheric circulation.
- Difference from Hegglin et al. (2014) is explained by a difference in the time periods considered.

→ Note, need for long-term observational records!

Stiller et al., *ACP 2012*