METEOROLOGY

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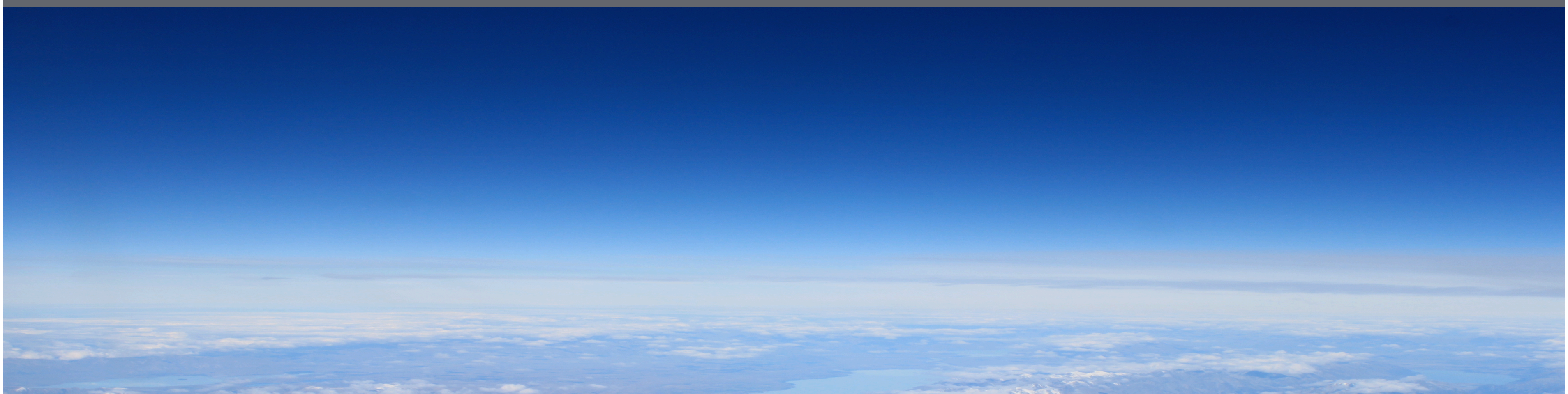
OZONE AND STRATOSPHERIC WATER VAPOUR DATABASES FOR CMIP6



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MOTIVATION

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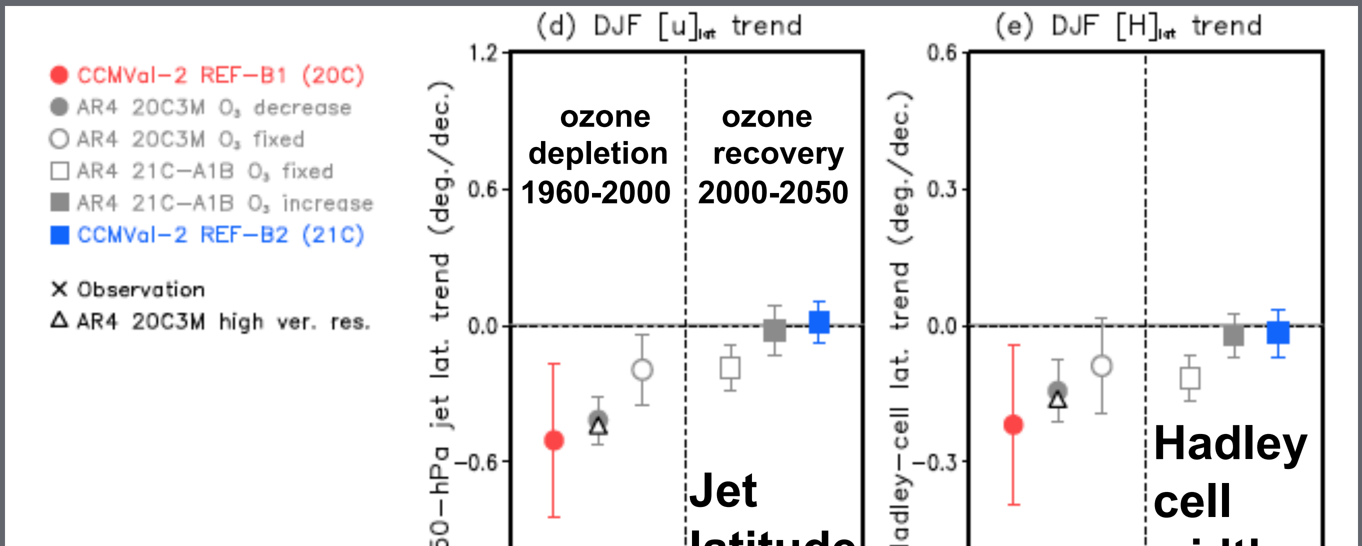
- A realistic representation of tropospheric and stratospheric ozone in climate models is crucial for reproducing past and predicting future trends in climate variables.
- The SH ozone hole has been shown to affect tropospheric surface climate during austral summer even outside SH high latitudes.
  - Changes have potential implications for ocean circulation and carbon uptake (Cai & Cowan, *J Clim* 2007; Lenton et al., *GRL* 2009)
  - Ozone recovery over the next few decades will mitigate SAM-related climate effects.



Son et al., *JGR 2010*

TROPOSPHERIC OZONE AND CLIMATE

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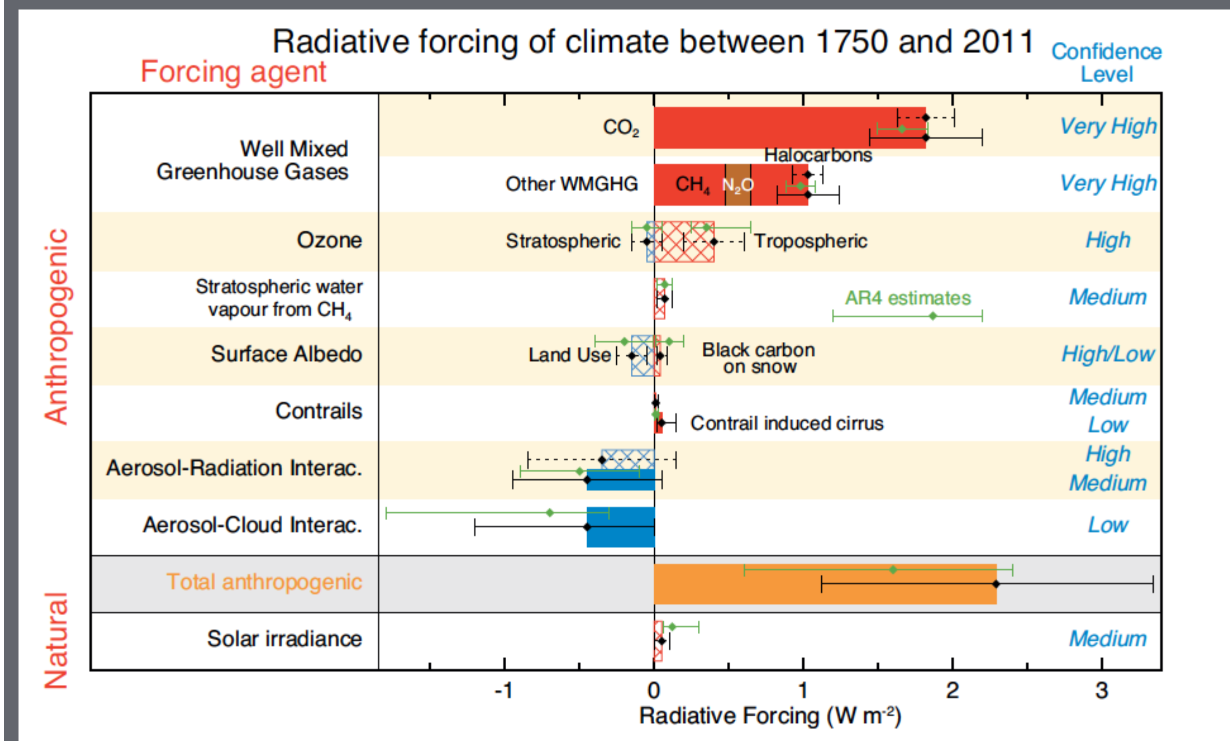
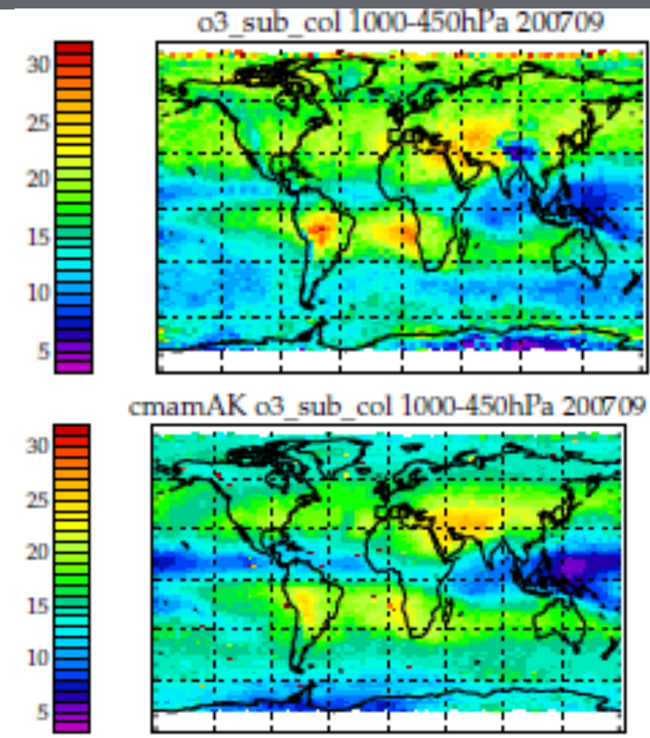
- Tropospheric ozone constitutes the third-most important GHG contribution to radiative forcing since 1750, after CO_2 and CH_4.
- 3D-distribution important to capture regional forcing and consequent effects on dynamics.

GOME2





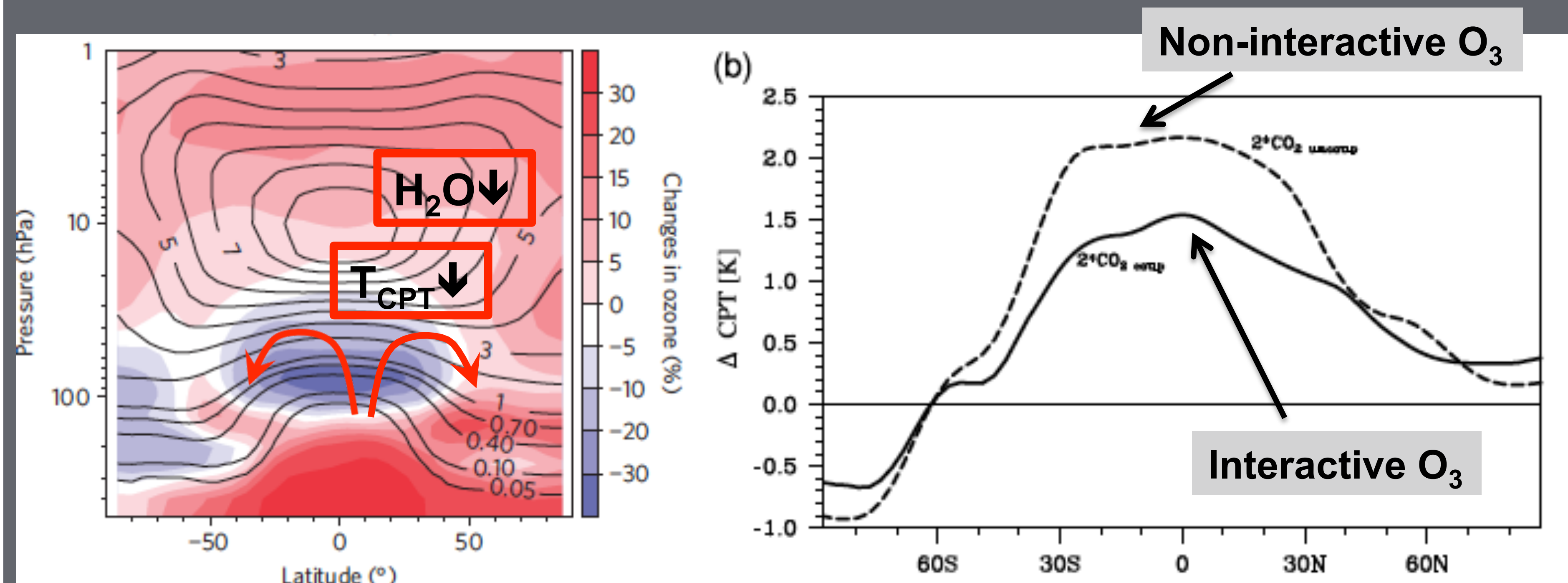
IPCC AR5, *2014*

(Figure courtesy Georgina Miles)

CMAM w/AK

STRATOSPHERIC H_2O AND CLIMATE

- Interactive ozone is important not only in the polar regions, but also in the tropics:
  - Climate change is predicted to lead to an increase in the Brewer-Dobson circulation, with associated decreases in tropical lower stratospheric ozone.
  - As a consequence, the expected stratospheric water vapour increase is also reduced, thereby reducing climate sensitivity.



Hegglin and Shepherd, *Nature Geoscience 2009*

Dietmüller et al., *JGR* 2014

CMIP 5 SITUATION

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- Due to the high computational demand, only 20% of CMIP5 models ran their simulations with interactive chemistry. 80% used prescribed ozone fields, of which ¾ used the IGAC/SPARC ozone database (Cionni et al., 2010).

Table 1. Summary of Features of the CMIP5 Models With a Focus on How They Treat Ozone Chemistry[a]

Modeling Center	Model	O_3 Chemistry Trop.	O_3 Chemistry Strat.	Prescribed Ozone Data Set	Main Reference	Main Reference for Ozone Chemistry Scheme or Offline Calculation	Group
Centre for Australian Weather and Climate Research, Australia	ACCESS1-0	P	P	C^1	[*Dix et al.*, 2012]	[*Cionni et al.*, 2011]	NOCHEM
	ACCESS1-3	P	P	C^1	[*Dix et al.*, 2012]	[*Cionni et al.*, 2011]	NOCHEM
Beijing Climate Center, China Meteorological Administration, China	BCC-CSM1.1	P	P	C^1	[*Wu*, 2012]	[*Cionni et al.*, 2011]	NOCHEM
	BCC-CSM1.1-M[b]	P	P	C^1	[*Wu*, 2012]	[*Cionni et al.*, 2011]	NOCHEM
College of Global Change and Earth System Science, Beijing Normal University, China	*BNU-ESM*	*SO*	*SO*	P^2		[*Lamarque et al.*, 2012; *Lamarque et al.*, 2010]	*CHEM*
Canadian Centre for Climate Modelling and Analysis, Canada	CanAM4	P	P	C^1_{modA}	[*von Salzen et al.*, 2013]	[*Cionni et al.*, 2011]	NOCHEM
	CanCM4	P	P	C^1_{modA}	[*von Salzen et al.*, 2013]	[*Cionni et al.*, 2011]	NOCHEM
	CanESM2	P	P	C^1_{modA}	[*Arora et al.*, 2011]	[*Cionni et al.*, 2011]	NOCHEM
National Centre for Atmospheric Research, USA	CCSM4	SO	SO	P^2	[*Meehl et al.*, 2012]	[*Lamarque et al.*, 2012; *Lamarque et al.*, 2010]	CHEM
Community Earth System Model Contributors	*CESM1(BGC)*	*SO*	*SO*	P^2	[*Gent et al.*, 2011]	[*Lamarque et al.*, 2012; *Lamarque et al.*, 2010]	*CHEM*
	CESM1(CAM5)	*SO*	*SO*	P^2	[*Gent et al.*, 2011]	[*Lamarque et al.*, 2012; *Lamarque et al.*, 2010]	*CHEM*
	CESM1(FASTCHEM)	I	I	-	[*Gent et al.*, 2011]	[*Cameron-Smith et al.*, 2006; *Hsu and Prather*, 2009]	CHEM
	CESM1(WACCM)	I	I	-	[*Calvo et al.*, 2012; *Gent et al.*, 2011]	[*Calvo et al.*, 2012; *SPARC-CCMVal*, 2010]	CHEM
Centro Euro-Mediterraneo per I Cambiamenti Climatici, Italy	CMCC-CM	P	P	C^1_{modB}	[*Vichi et al.*, 2011]	[*Cionni et al.*, 2011]	NOCHEM
Centre National de Recherches Meteorologiques, France	CNRM-CM5	I	I	-	[*Voldoire et al.*, 2012]	[*Cariolle and Teyssedre*, 2007]	CHEM

Eyring et al., *JGR* 2013

CIONNI ET AL. OZONE DATABASE

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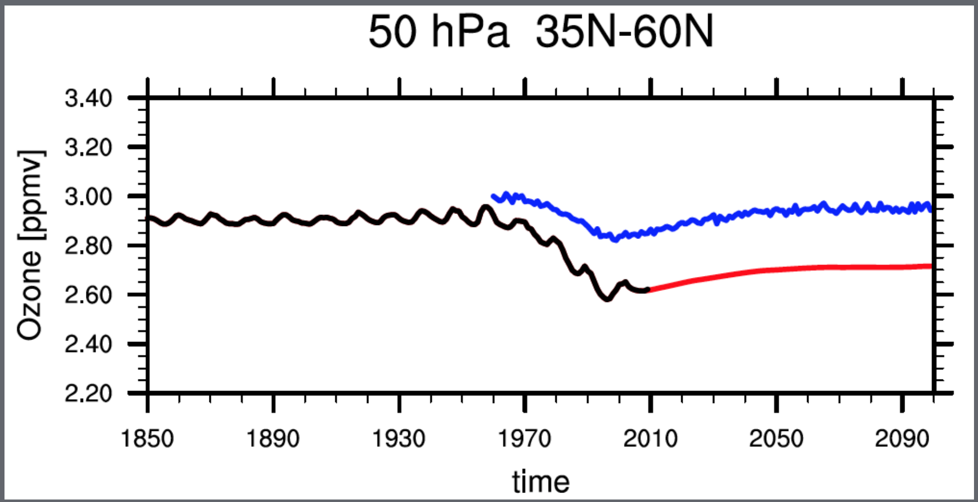
- CCMI will provide an update of the Cionni et al. database.
- Known weaknesses in the Cionni et al. database will be addressed:
  - Fields merged from models with either stratospheric or tropospheric chemistry.
  - Provided only one emission scenario into the future.
  - Showed some unphysical behaviour that was introduced by merging with stratospheric observations:
    - Not ‘deep’ enough Antarctic ozone hole.
    - No recovery from ozone depletion in the Northern midlatitudes.



CCMI OZONE DATABASE

- Will be produced with CCMI models that include comprehensive chemistry in both the stratosphere and troposphere.
- Ozone fields will extend from 1000 to 1 hPa.
- 3D monthly mean fields.
- Timeseries between 1850 and 2100:
    - 1850-2010: Historical emissions (two CCMI models CMAM & WACCM)
    - 2010-21000: Future emission scenarios (RPC2.6, 4.5, 6.0, and 8.5 from CCMI)
    - Envisage scaling approach to be adaptable to new emissions scenarios
- Will include solar cycle signal from HEPPA-SOLARIS.
- Will *not* include QBO signal.
- No merging with observations, but rigorous evaluation of models with observations and weighting according to key performance metrics.

CCMI OZONE DATABASE FIRST RESULTS

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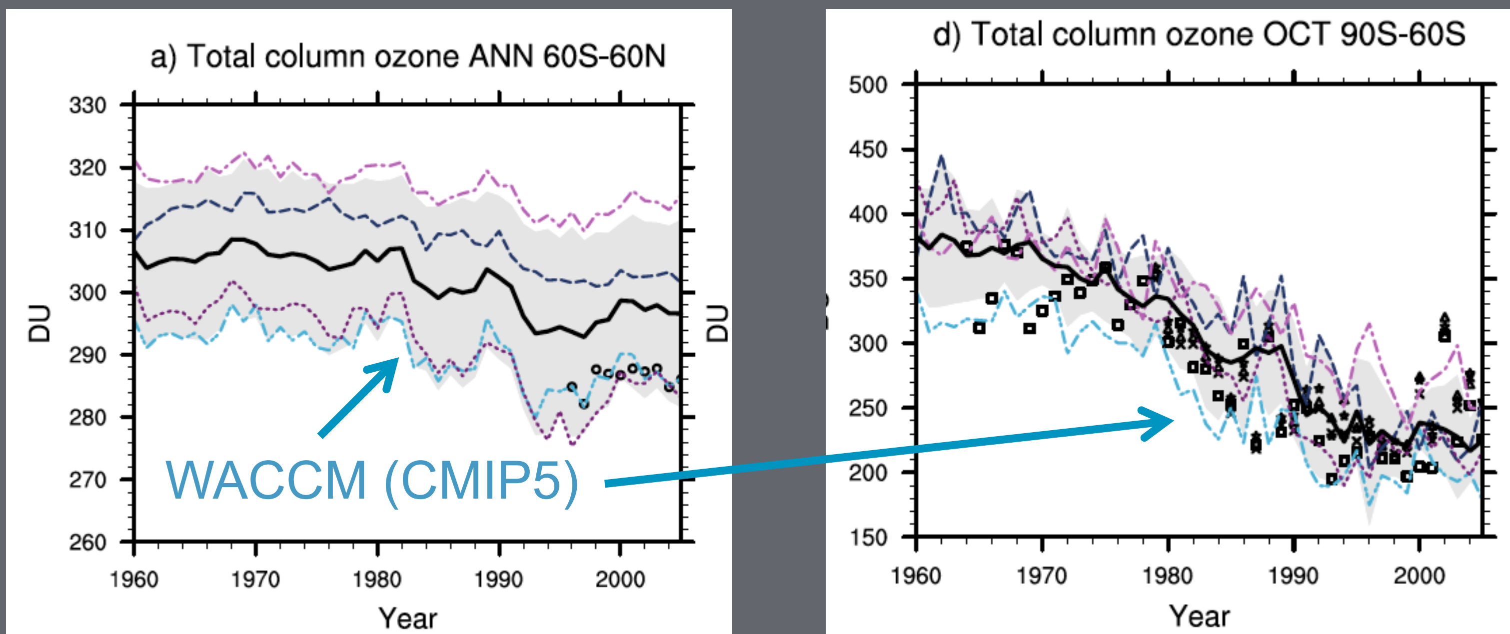

CCMI STRATOSPHERIC H_2O DATABASE

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- Following same approach as for ozone database.
- However, only stratospheric zonal mean fields will be provided.
- Only suggested for models with unrealistic stratospheric water vapour.

TIMELINE

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- Consistent with CMIP6 timeline.

Pre-publication of fields on CCMI webpage

Publication in ESSD

Dec 2015

1850 fields

Will allow for 'tuning' model response in historical reference state.

April to July 2016

Historical timeseries (1850-2010)

Oct 2016

Future scenarios (2010-2100)

Dec 2016

- Your comments/questions welcome!
  - Please email m.i.hegglin@reading.ac.uk
    - E.g. Decadal prediction folks, would you rather want more realistic fields using observations over the recent past?

EXTRASLIDES

TIMETABLE

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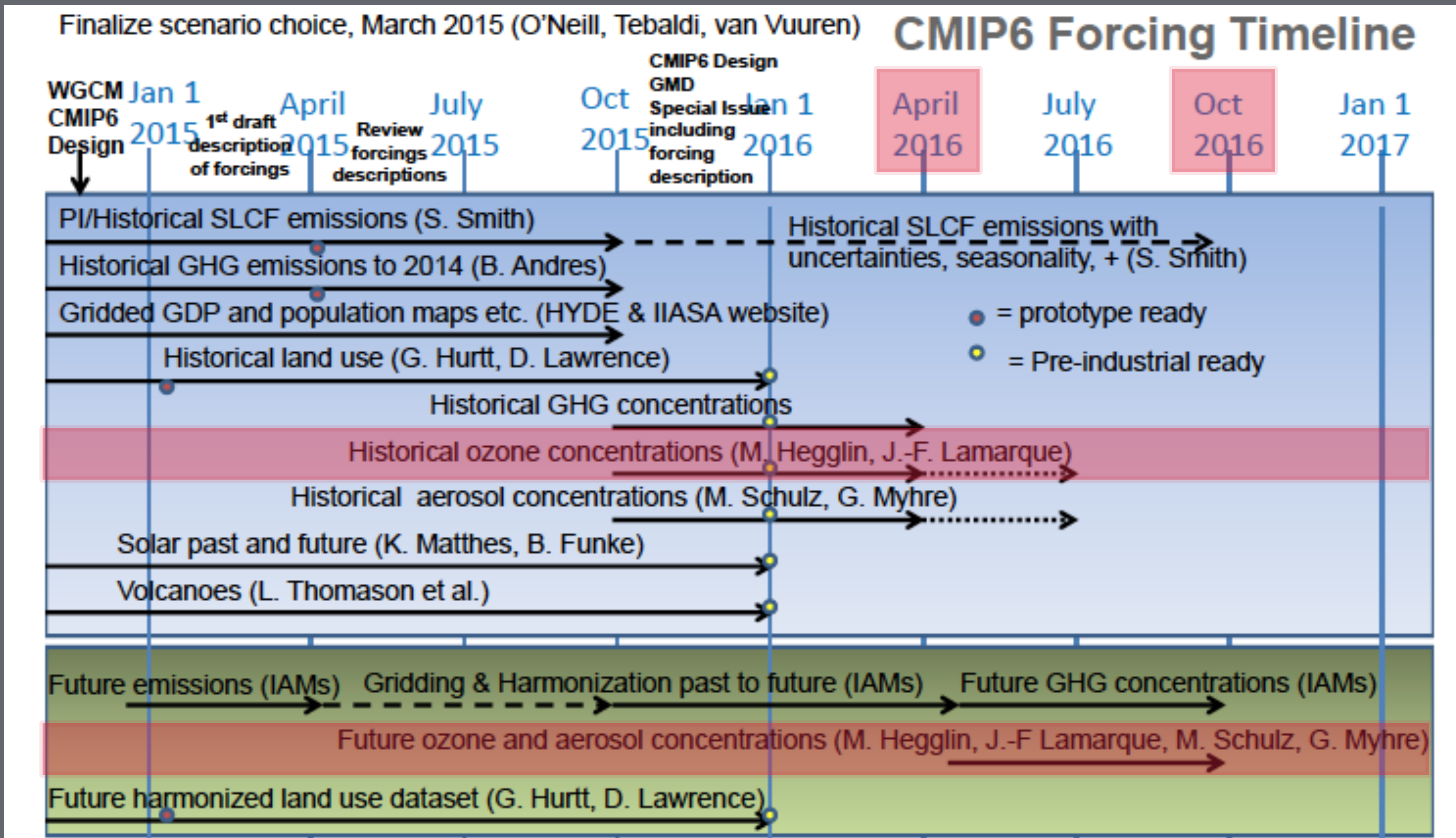
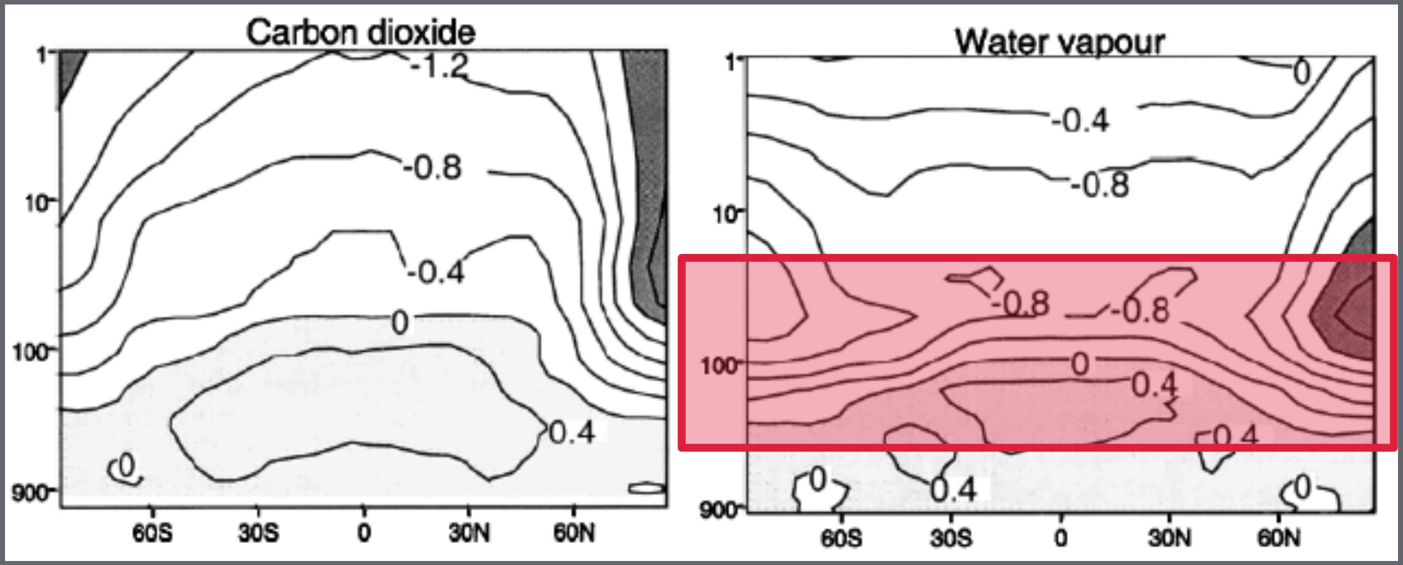


IMPORTANCE OF STRATOSPHERIC H_2O

- 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

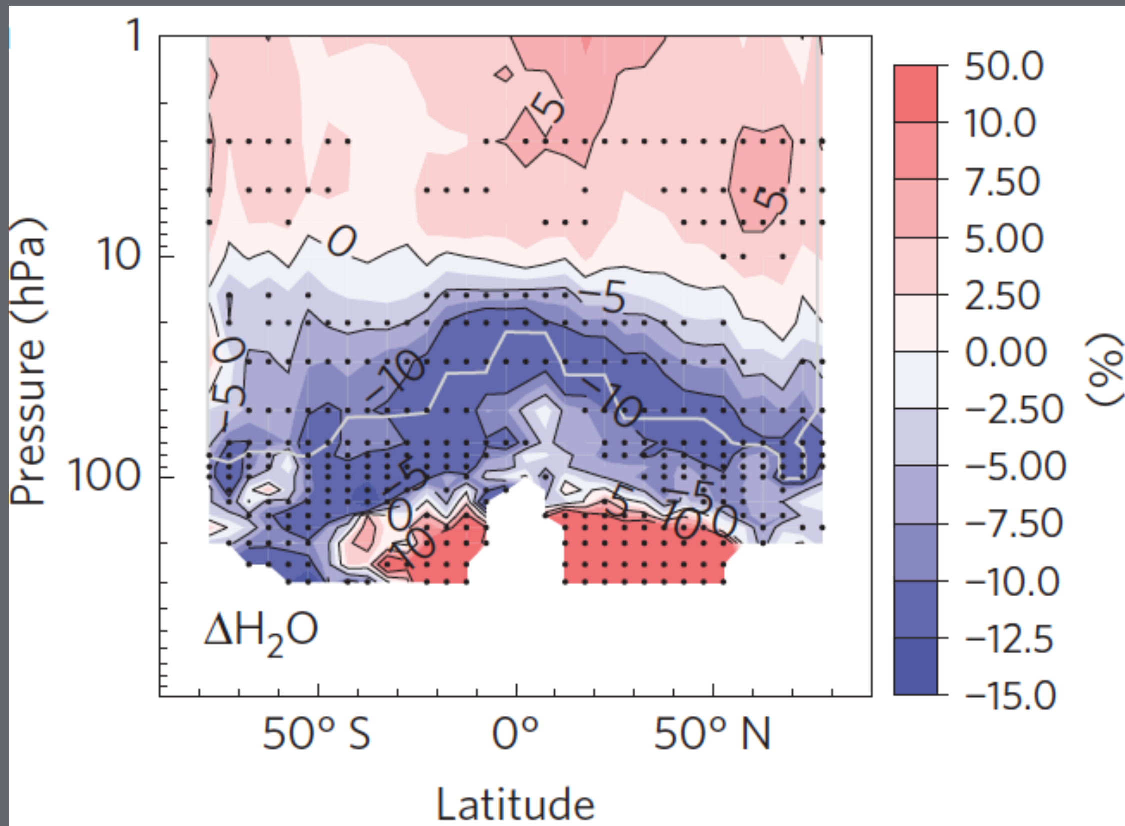


Forster & Shine, *GRL* 1999

STRATOSPHERIC H_2O CHANGES
(late 1980s to 2010)

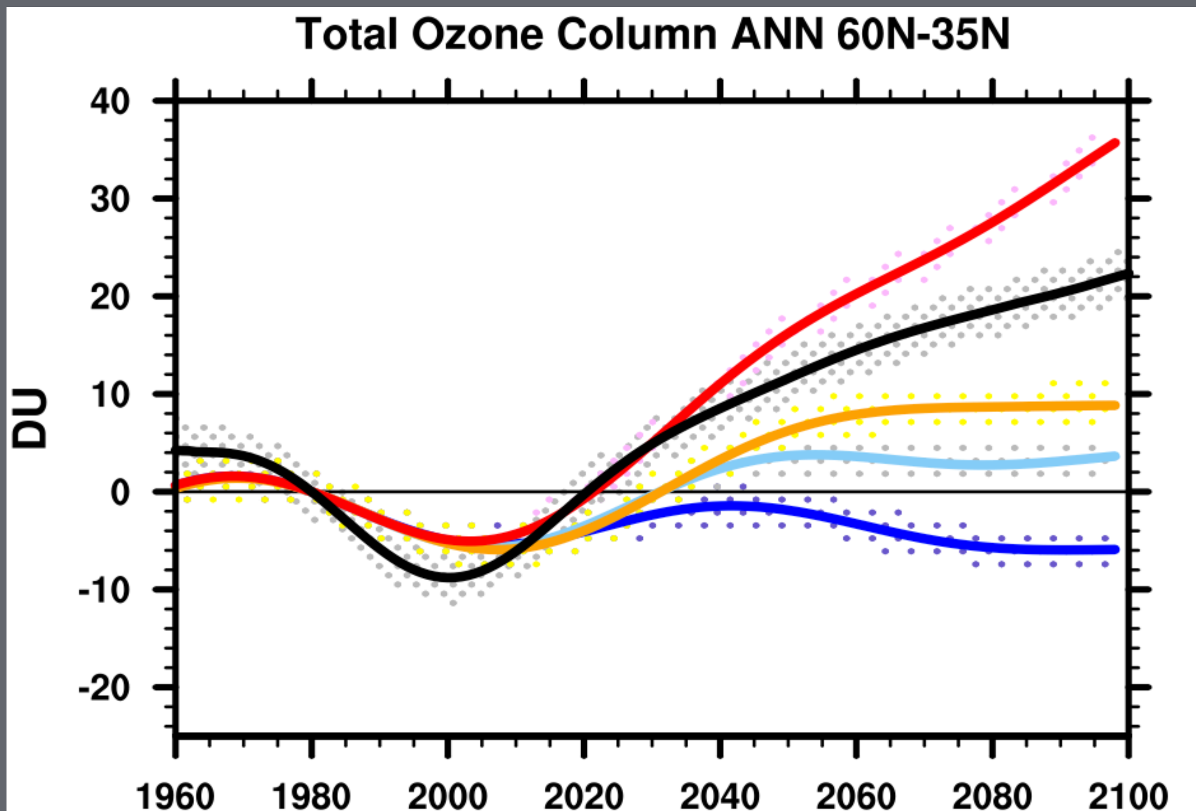
Hegglin et al., *Nature Geoscience 2014*

- 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.



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