Climate impacts of non-CO2 gases and aerosols and satellite measurements

Jean-François Lamarque (NCAR)

Climate forcing from non-CO_2

- Ozone (tropospheric/stratospheric)
- Methane
- N_2O
- CFCs/HCFCs/… (Montreal Protocol)
- Stratospheric water vapor
- Aerosols

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- ~~Stratospheric water vapor~~
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ACCMIP

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- Atmospheric Chemistry and Climate Model Intercomparison Project (IGAC/SPARC project), led by D. Shindell (NASA-GISS) and myself
- First full workshop in Toulouse, April 2011
- Second workshop in Pasadena, February 2012 (in collaboration with HTAP)
- Model output archival at BADC
- More information available at www.giss.nasa.gov/projects/accmip/

ACCMIP goals and participation

- Document & analyze the radiative forcing in CMIP5 simulations
- Evaluate underlying chemistry used for providing concentrations & depositions in CMIP5
- Participating models (output available now, * is CMIP5 model)
  - CCCma (Canada)
  - CICERO (Norway)
  - DLR-EMAC (Germany)
  - GFDL (USA)*
  - GISS (USA)*
  - LSCE (France)*
  - LLNL-NCAR (USA)
  - MeteoFrance (France)
  - NCAR CAM3.5 (USA)*
  - NCAR CAM5.1 (USA)
  - NIES (Japan)*
  - NIWA (New Zealand)
  - UKMO (UK)*
  - UEDI (UK)

Model simulations

Historical Simulations

Emissions/Configuration	1850	1890	1910	1930	1950	1970	1980	1990	2000
Emissions and SSTs/GHGs for given year	C	1	1	C	1	1	C	1	C
Year 2000 emissions/1850 SSTs & GHGs									C

Future Simulations

Emissions/Configuration	2010	2030	2050	2100
RCP 2.6		C	1	C
RCP 4.5	1	1	1	1
RCP 6.0	C	C	1	C
RCP 8.5		C	1	C
Year 2000 emissions/RCP 8.5 SSTs & GHGs		C		C

C = core, 1 = Tier 1, blank = not requested

- Long-term variations
- Role of climate/emission change
- Targets
  - Tropospheric ozone budget
  - Methane lifetime
  - Radiative forcing (including aerosols)
  - Nitrogen/sulfur deposition
  - Health/Agriculture impacts

Papers submitted (GMDD & ACPD)

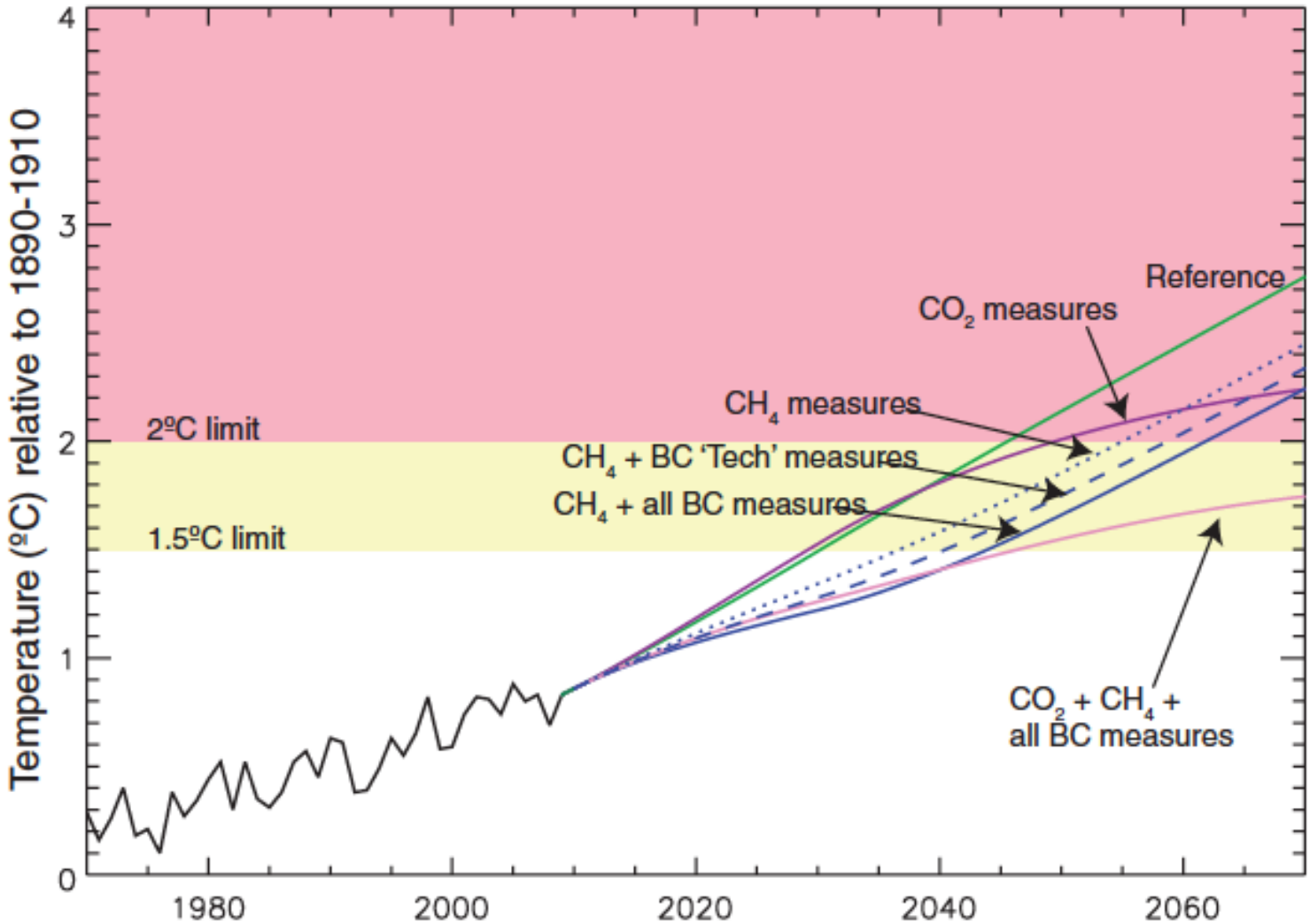
- ACCMIP overview and models, J.-F. Lamarque (NCAR)
- Ozone
  - Ozone budget, time evolution, Paul Young (NOAA ESRL)
  - Observation constraint on ozone radiative forcing , Kevin Bowman (JPL)
  - Ozone radiative forcing and attribution, David Stevenson (U. Edinburgh)
- Aerosols
  - Long-term changes in BC (based on ice cores), Yunha Lee (GISS)
  - Aerosol forcing, Drew Shindell (GISS)
- Methane
  - Future oxidation & methane, Apostolos Voulgarakis (GISS)

Papers in preparation/planned

- Nitrogen/sulfate deposition, F. Dentener (JRC)/J-F Lamarque (NCAR)
- Methane historical changes , V. Naik (GFDL)
- Convection and transport changes, R. Doherty (U. Edinburgh)
- Air quality/health
  - Role of climate change in air quality, Bill Collins (Met Office)
  - Surface aerosols, Steve Rumbold (Met Office)
  - Health (ozone/PM) impacts, Susan Anenberg (EPA)
  - Ozone impact on crop yields, Lisa Emberson (U. York)

METHANE

Climate benefits from methane reductions

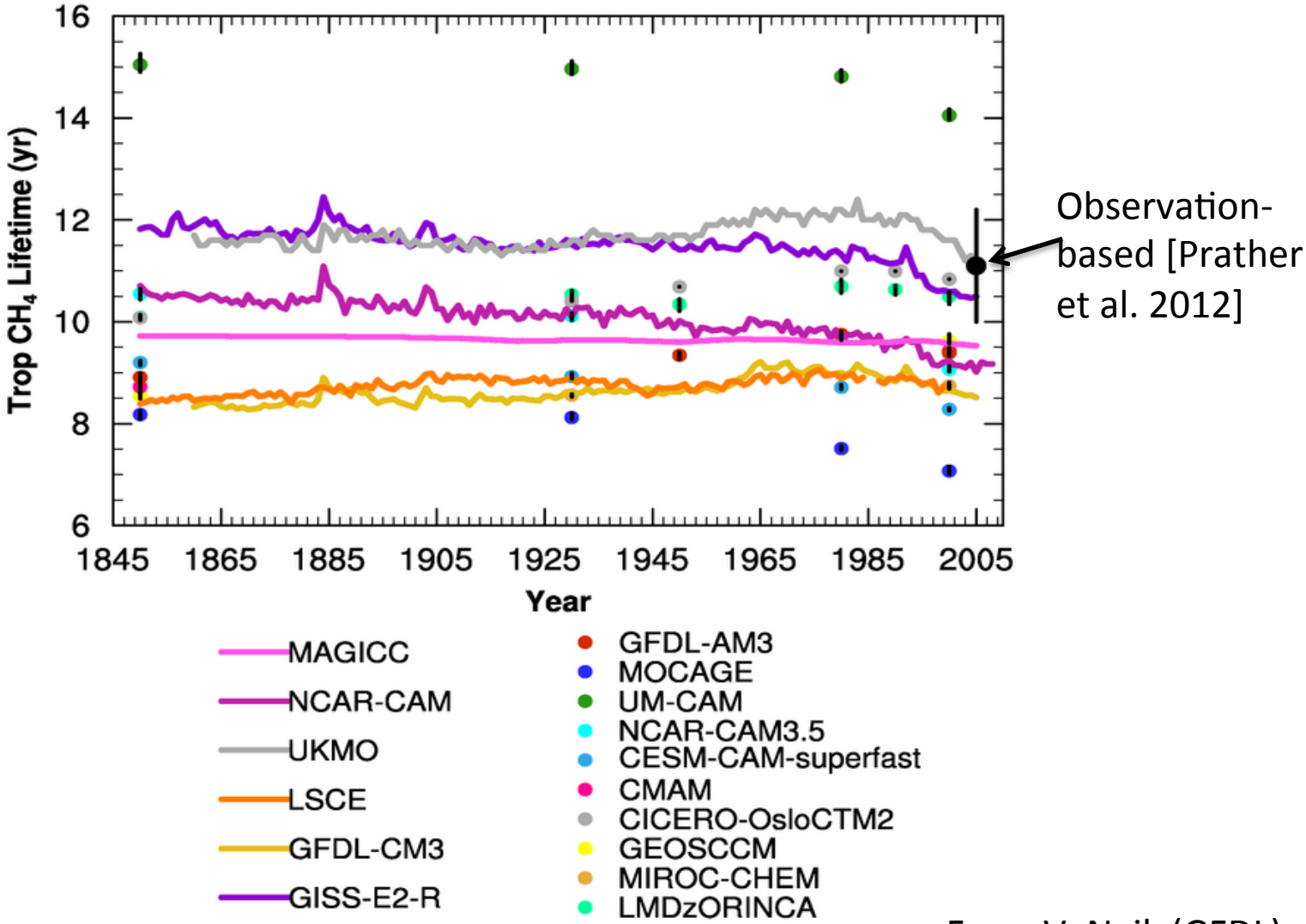


Reference

CH_4 measures

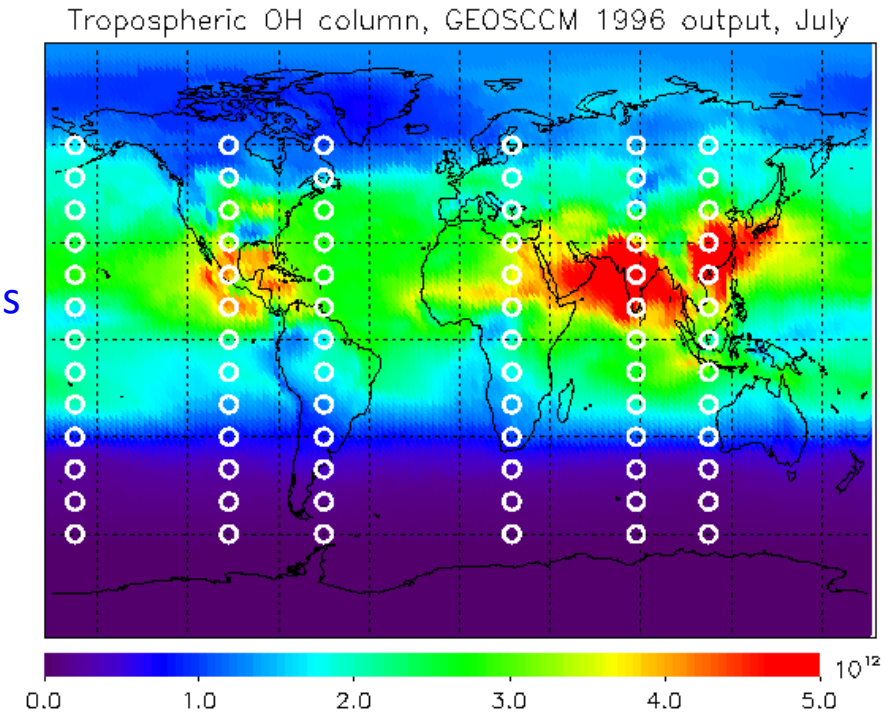
Shindell et al., Science, 2012

ACCMIP/CMIP5 Tropospheric (surface to 200 hPa) Methane lifetime



From V. Naik (GFDL)

Box model approach:
→ Characterize biases to inform Interpretation of CCMs
→ reduced vs. more complete mechanism
→inform lifetimes



Two sets of metrics will be developed:

$g_{RADICAL}$ based on how well CCM OH agrees with box model OH, considering uncertainties in the chemical mechanism

$g_{PRECURSORS}$ based on how well CCM O_3, CO, H_2O, NO_x, isoprene, formaldehyde, etc agree with observations, considering measurement variance

Approach modeled after Fast Chemistry evaluation used in CCMVal-2

Engagement of multiple box models strongly encouraged!

Notes:

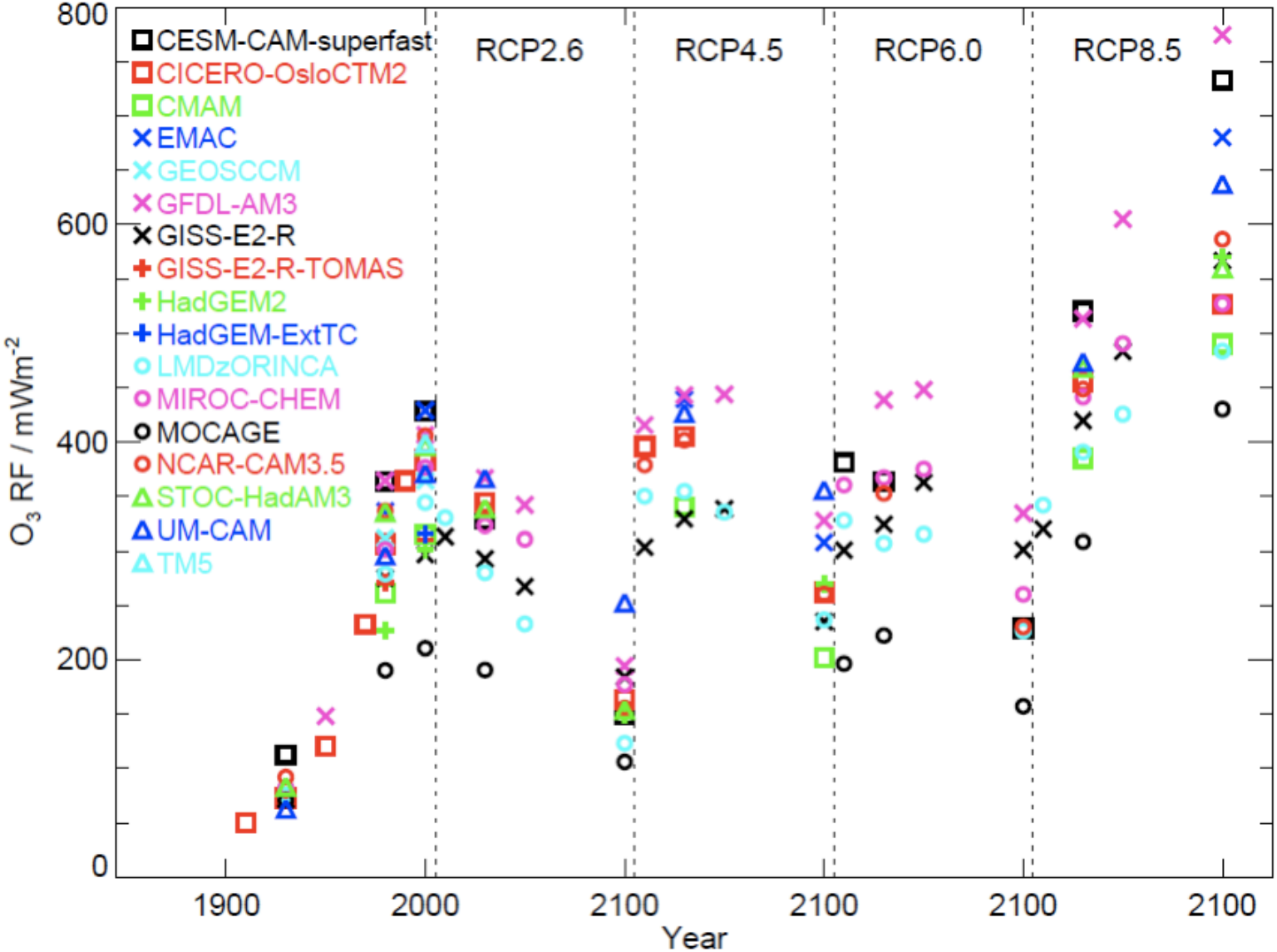
1. Fine for these "core dumps" to be archived on full lat/long grid
2. There has been a suggestion that rates of all reactions be saved on model internal time/alt grid
3. Observations of OH precursors in table is notional … there are many observations that should be considered
4. This occasional "core dump" will provide insight into CCM chemical mechanism for many other topics: NO_x/NO_y, BrO/Br_y, etc especially if all species are saved
5. CCM "restart files" could be route for obtaining this info

c/o R. Salawitch & J. Nicely

Environmental chamber constraints?

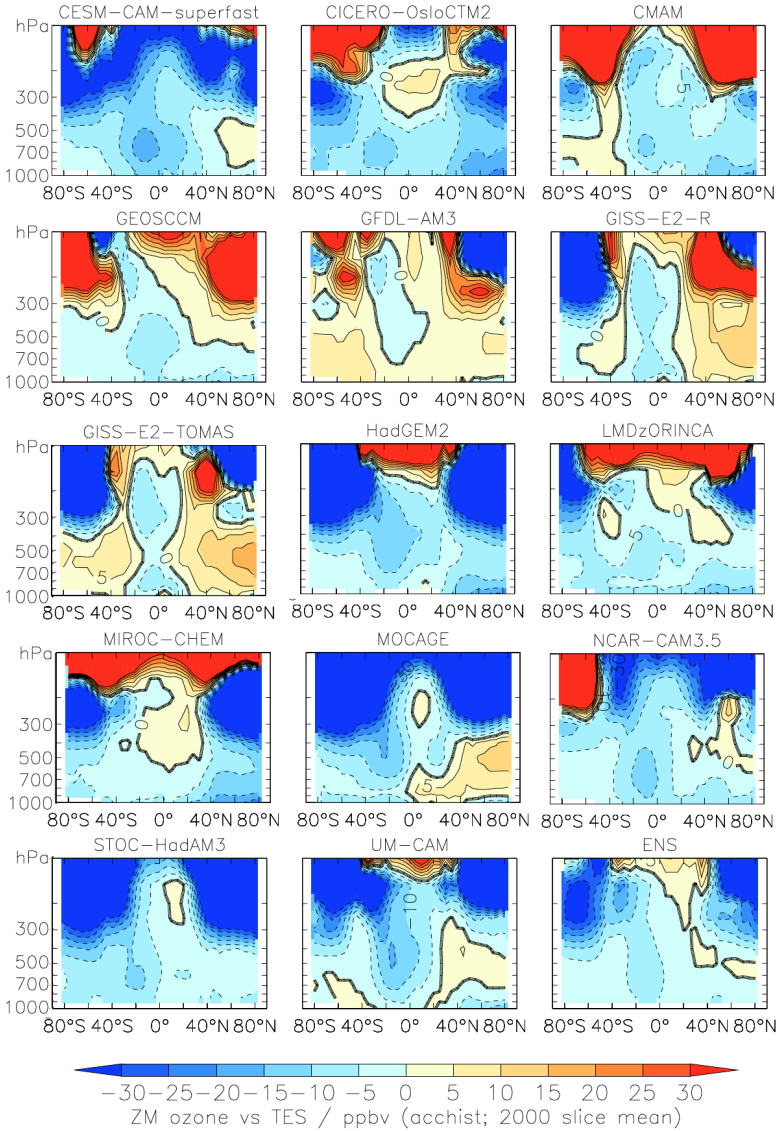
OZONE

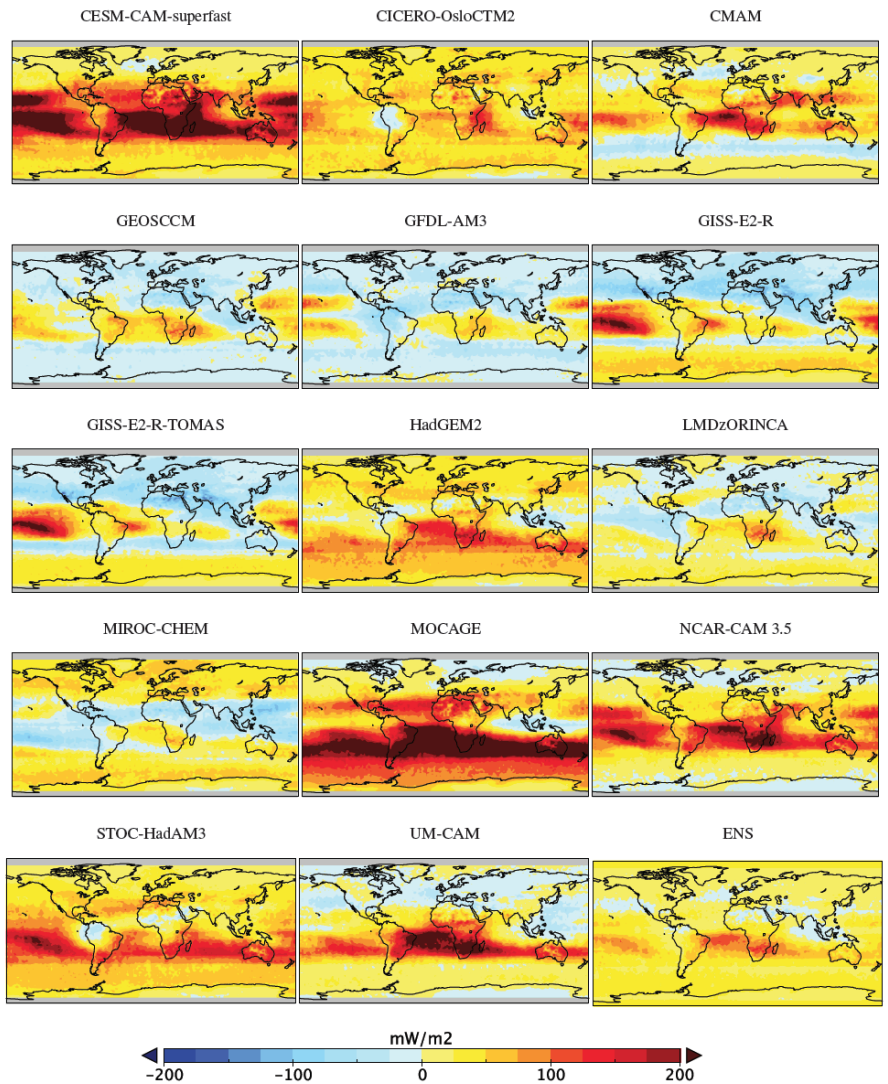
Time evolution of Trop. O3 RF since 1850



Stevenson et al., ACPD 2012

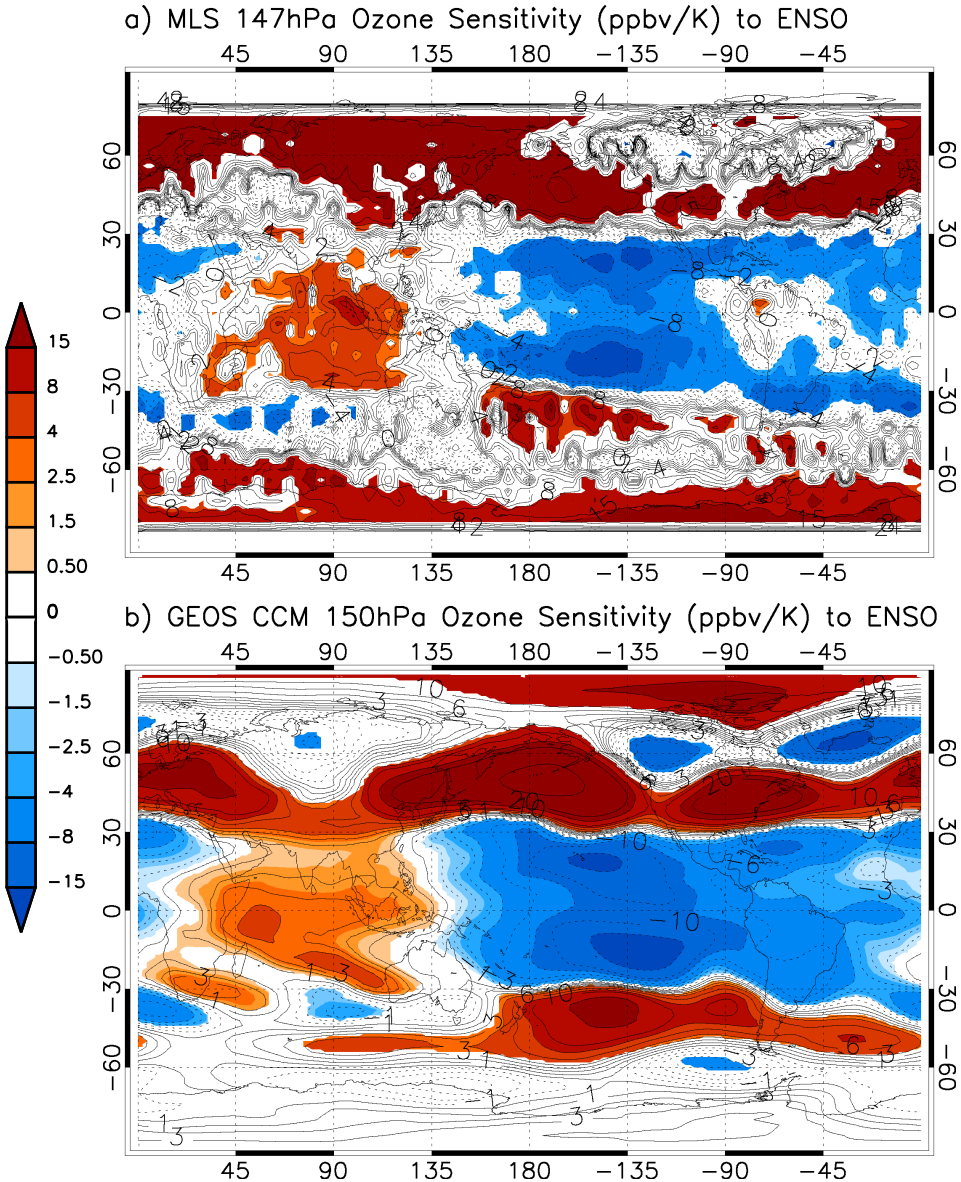
Tropospheric ozone against TES: concentration and RF

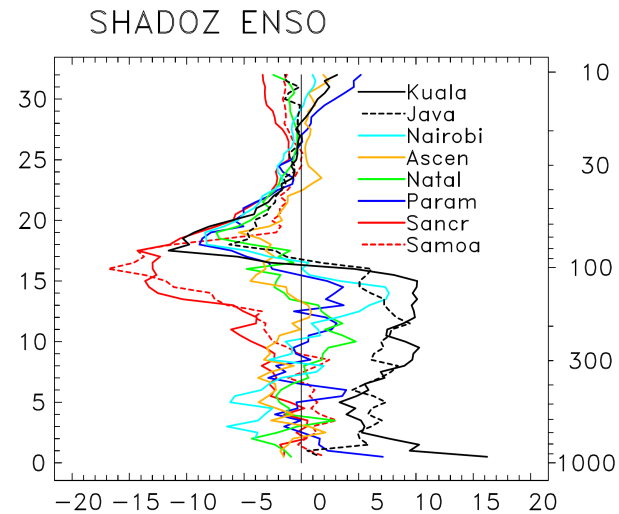




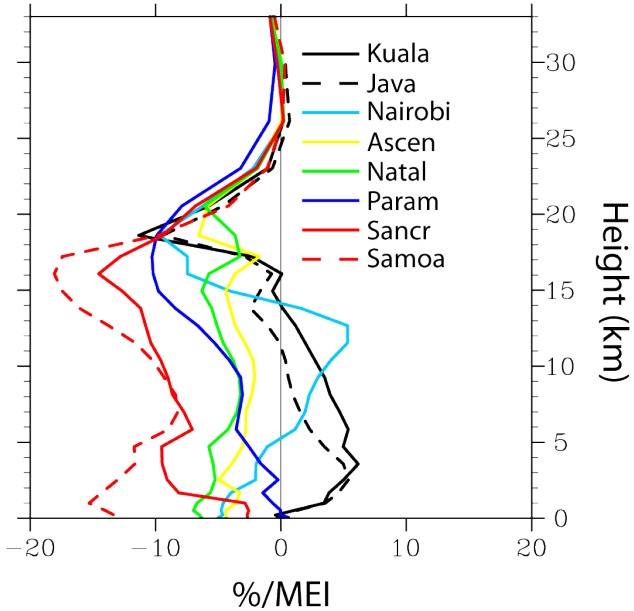
Bowman et al., ACPD, 2012

Ozone Sensitivity to ENSO





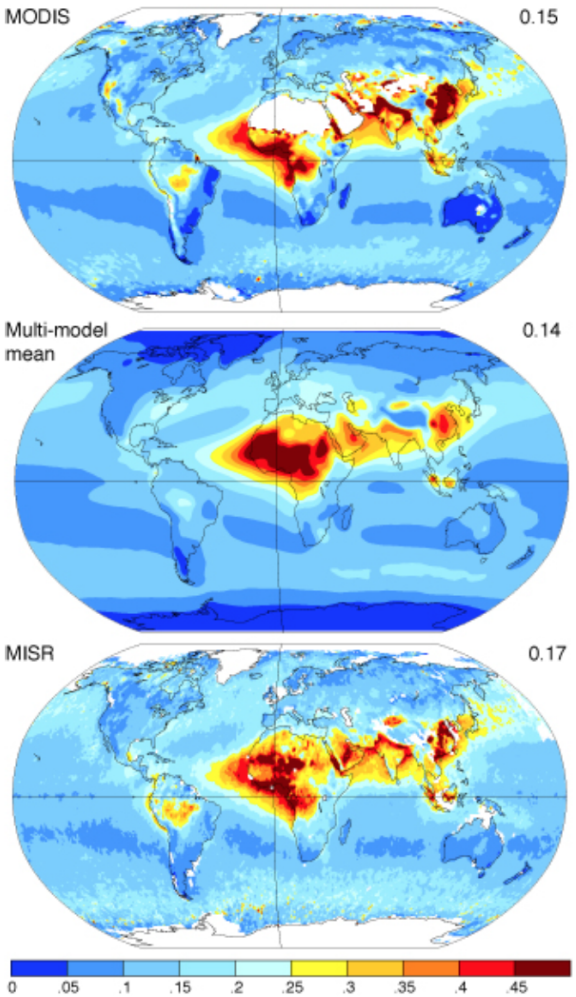
From Randel and Thompson, 2011

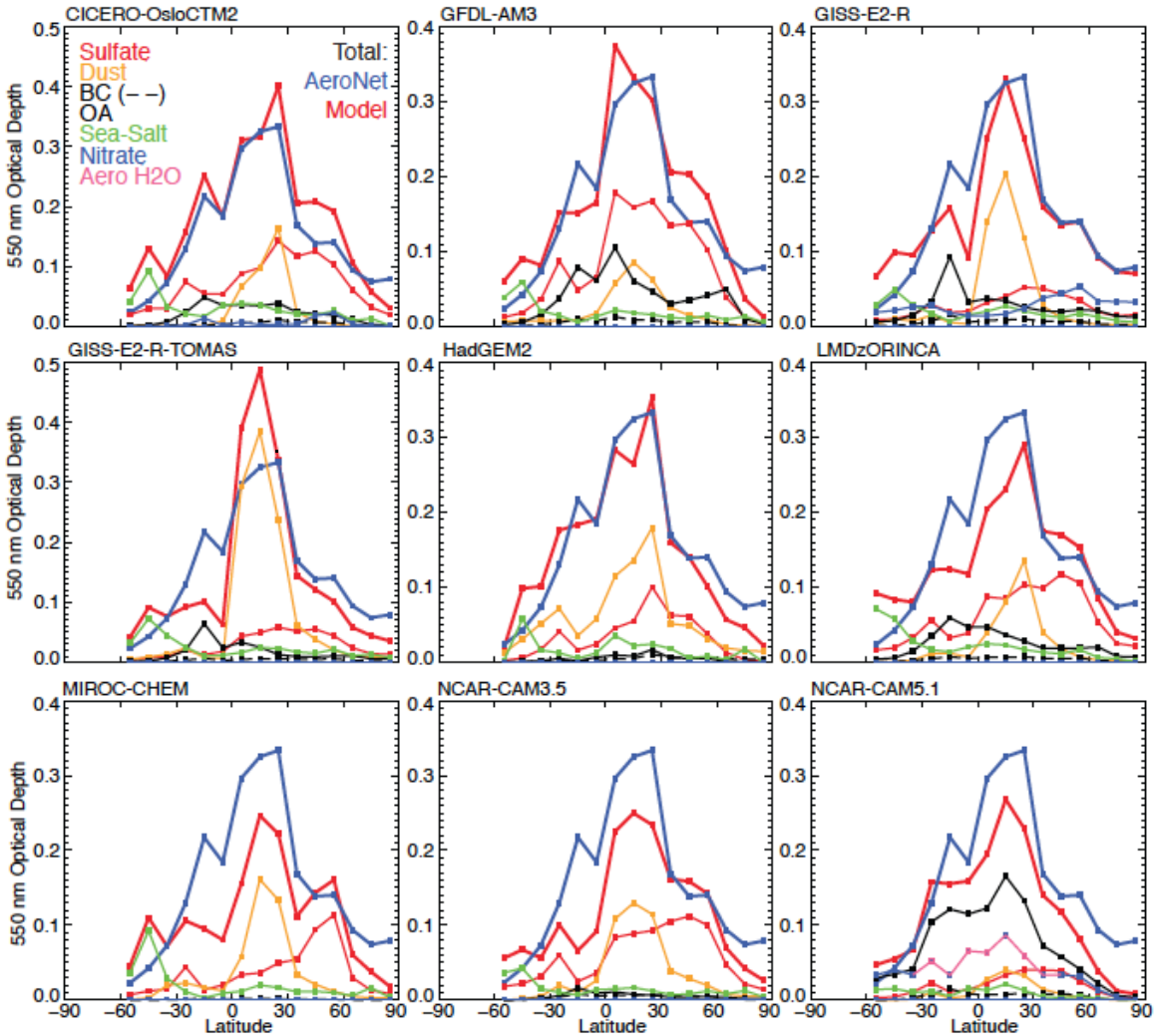


Slide from L. Oman, Davos, 2012

AEROSOLS

AOD 550nm

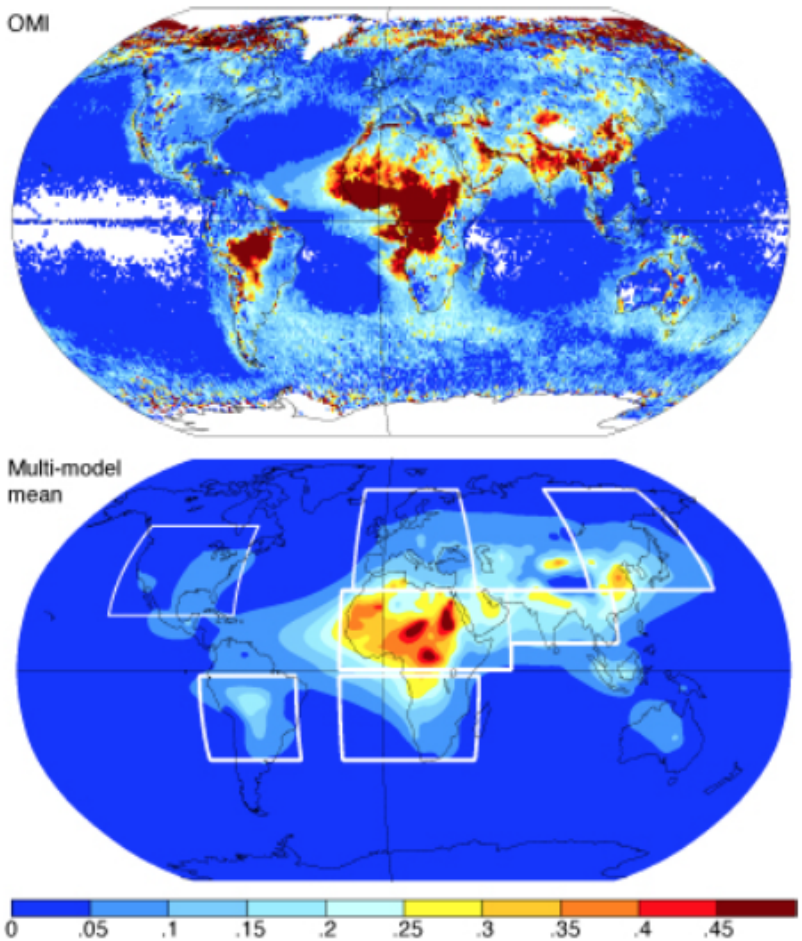




Shindell et al., ACPD, 2012

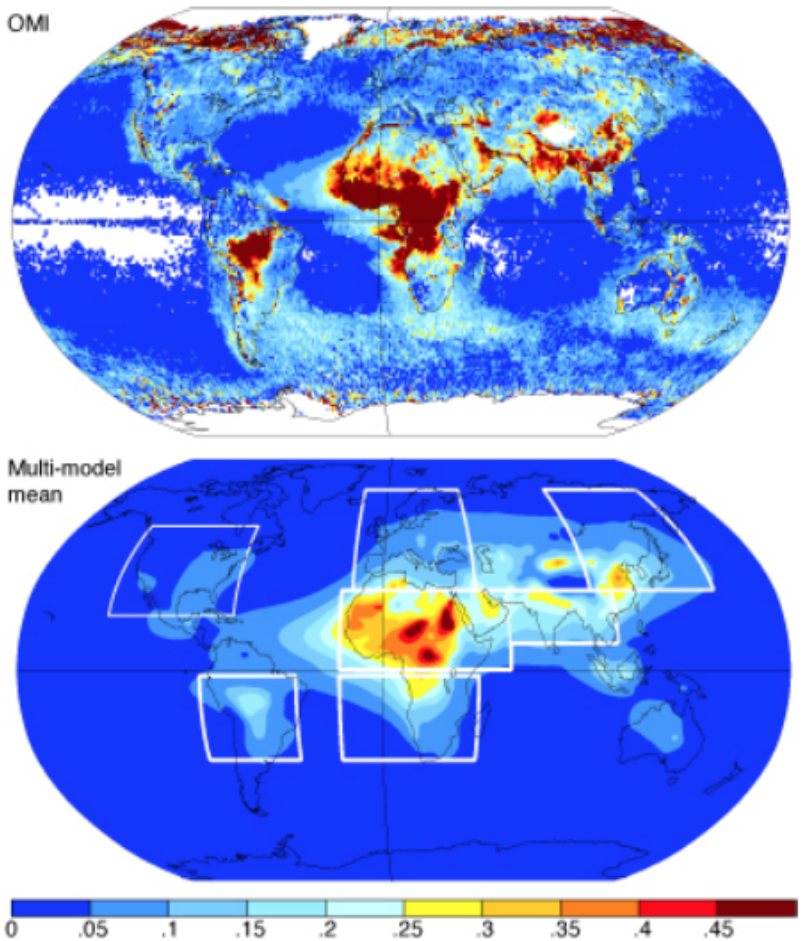
AeroNet data

AAOD from OMI (2005-2007)

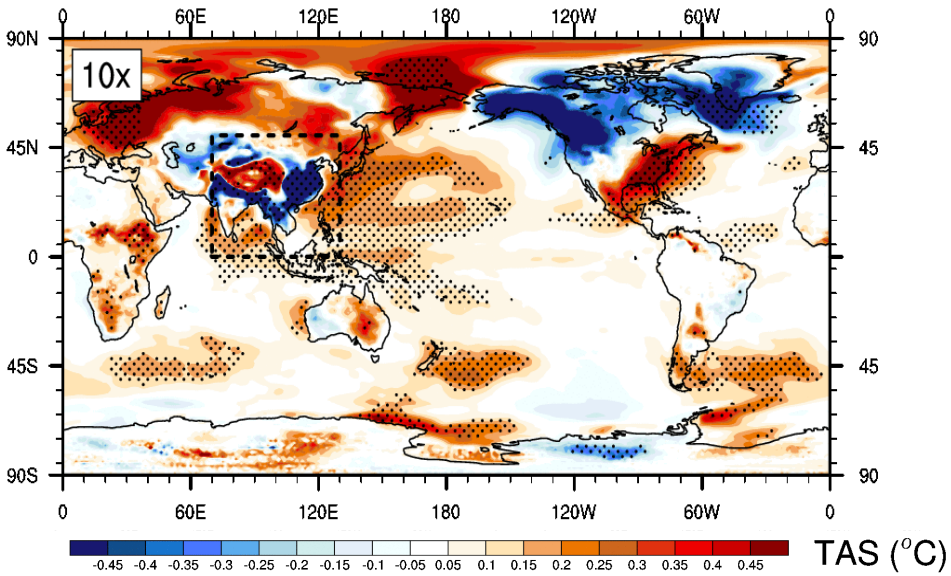


Shindell et al., ACPD, 2012

AAOD from OMI (2005-2007)

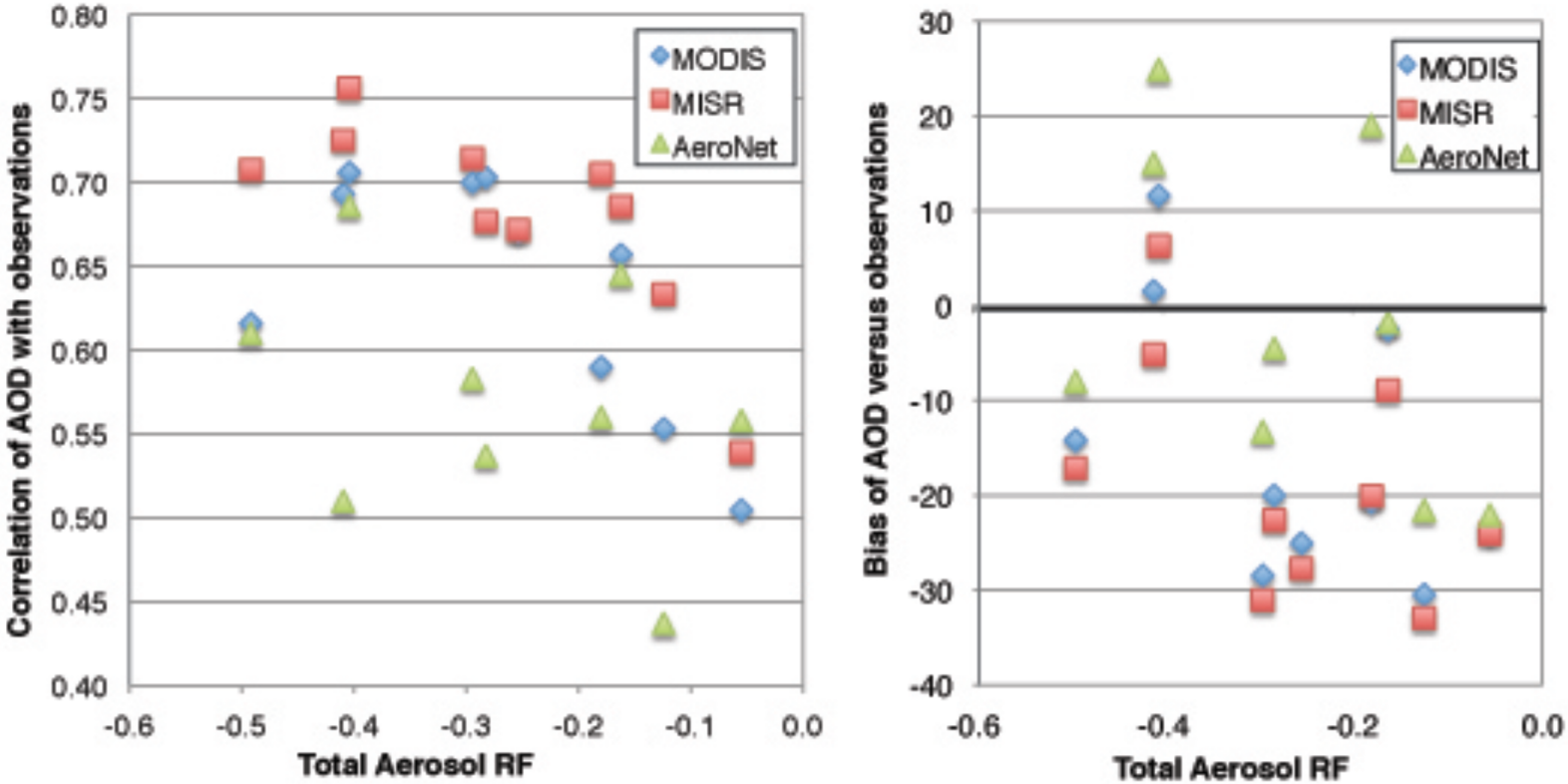


Shindell et al., ACPD, 2012



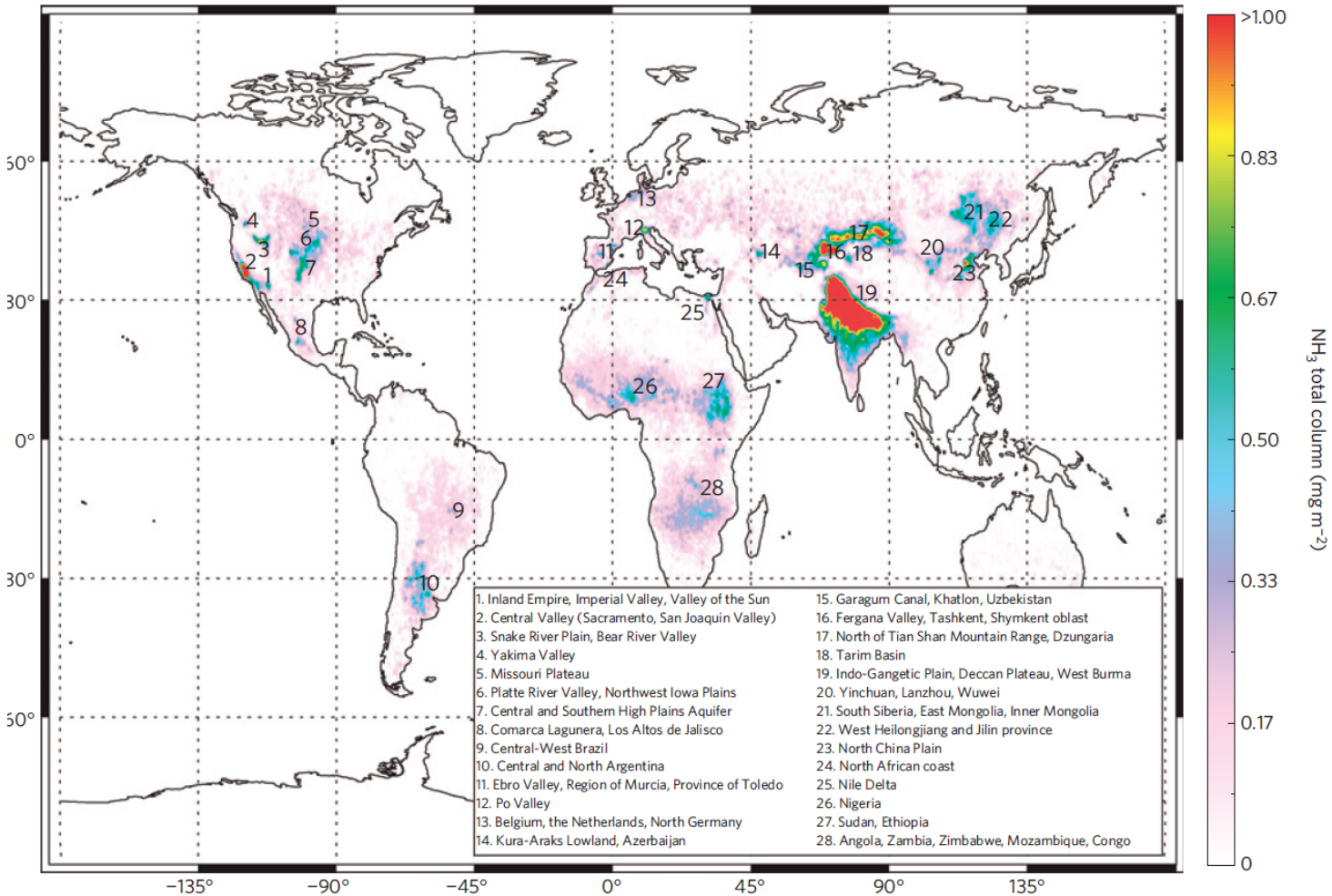
Teng et al., GRL, 2012

Skill impact on forcing



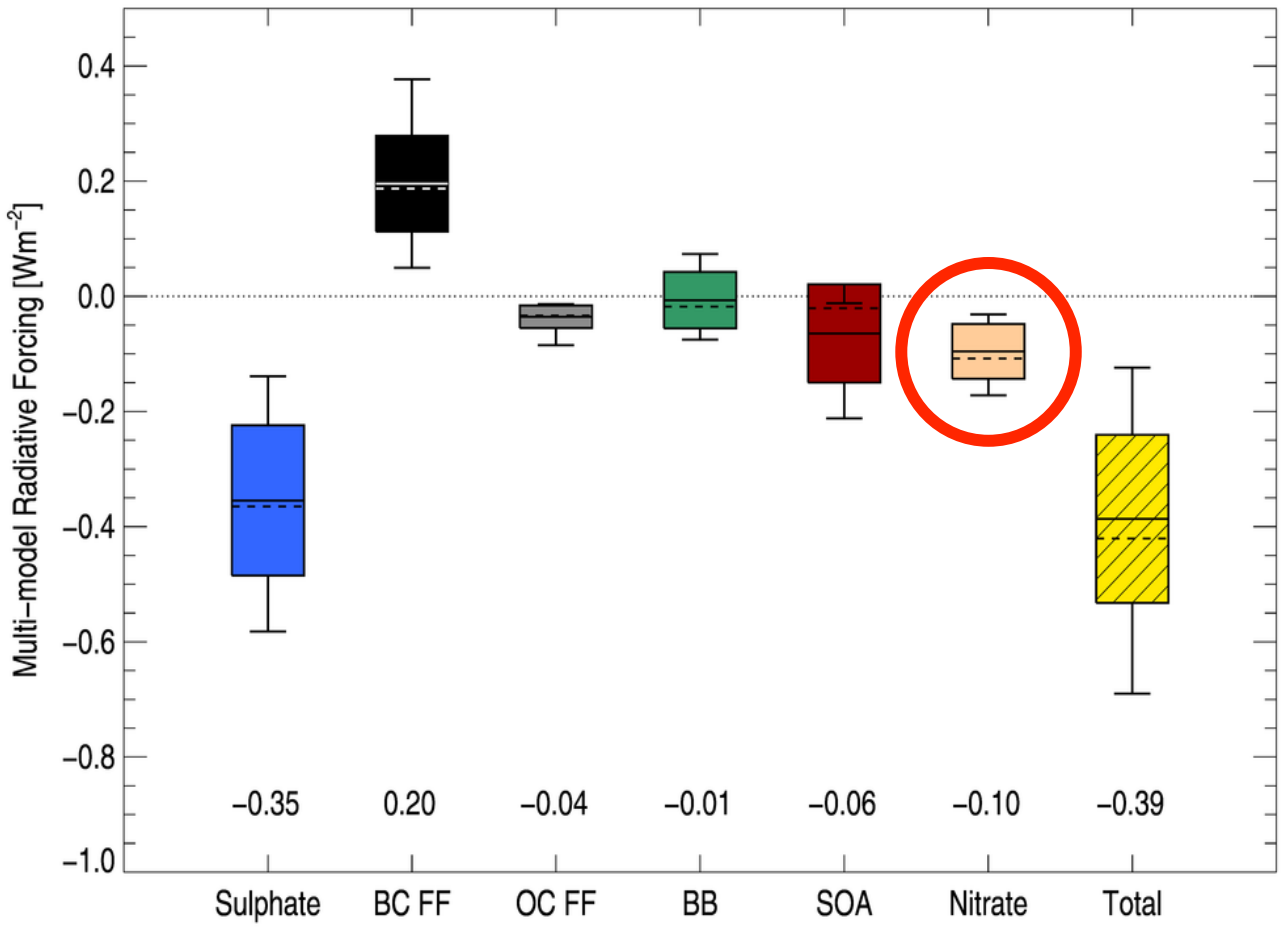
Shindell et al., ACPD, 2012

NH3 distribution



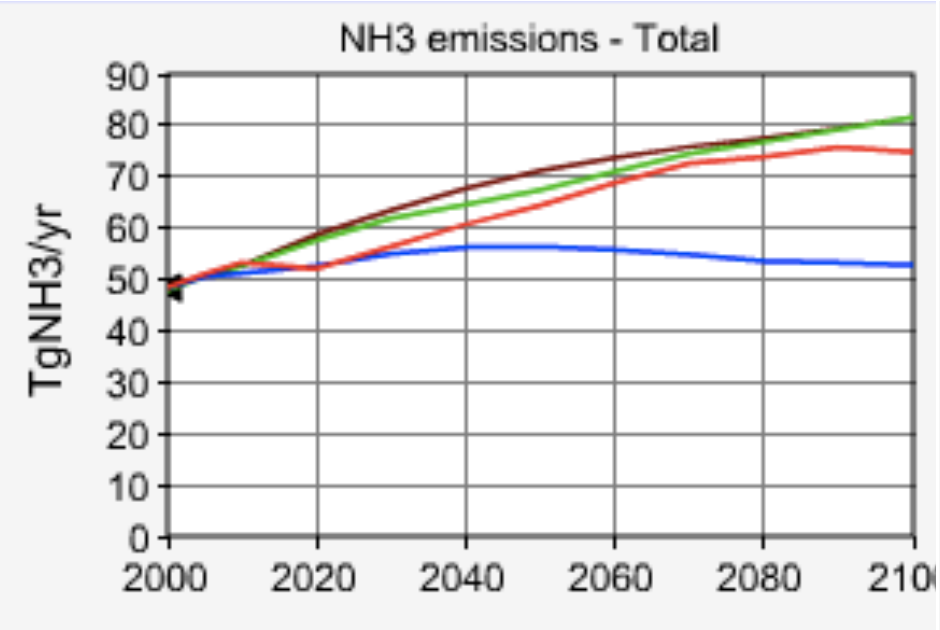
IASI instrument on MetOp satellite (Lieven et al., 2009)

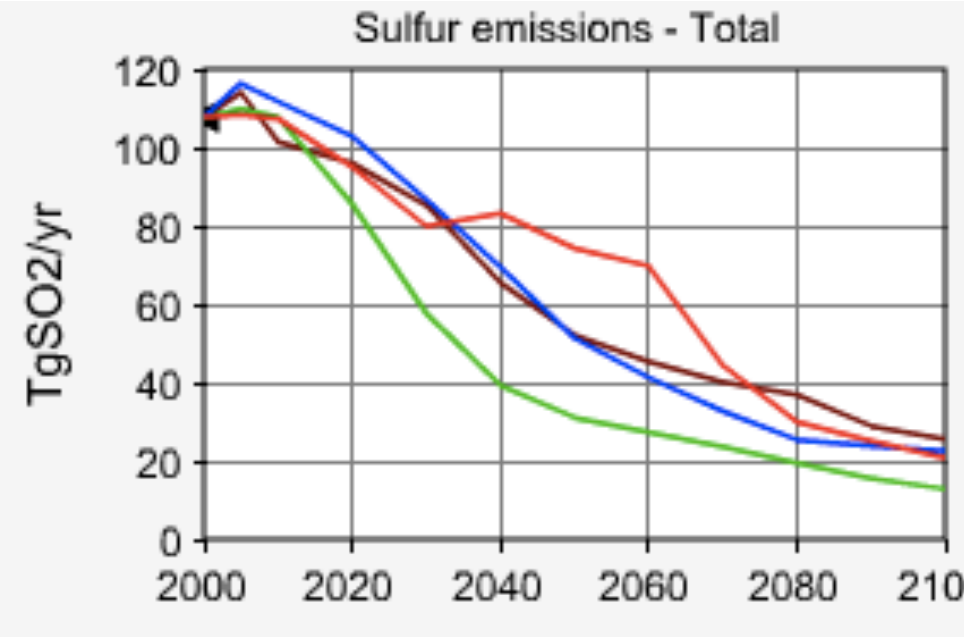
Present-day RF



Myhre et al., submitted, 2012

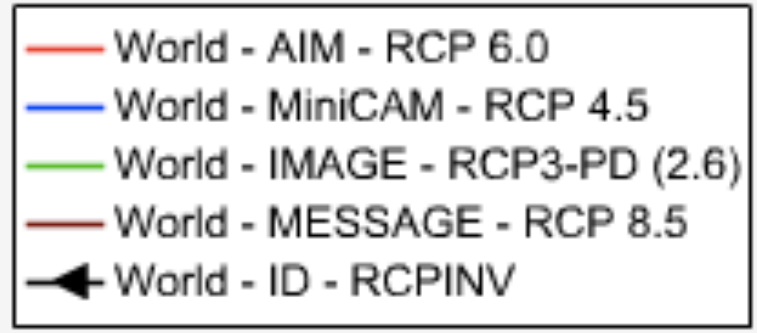
Future NH3 vs SO2?



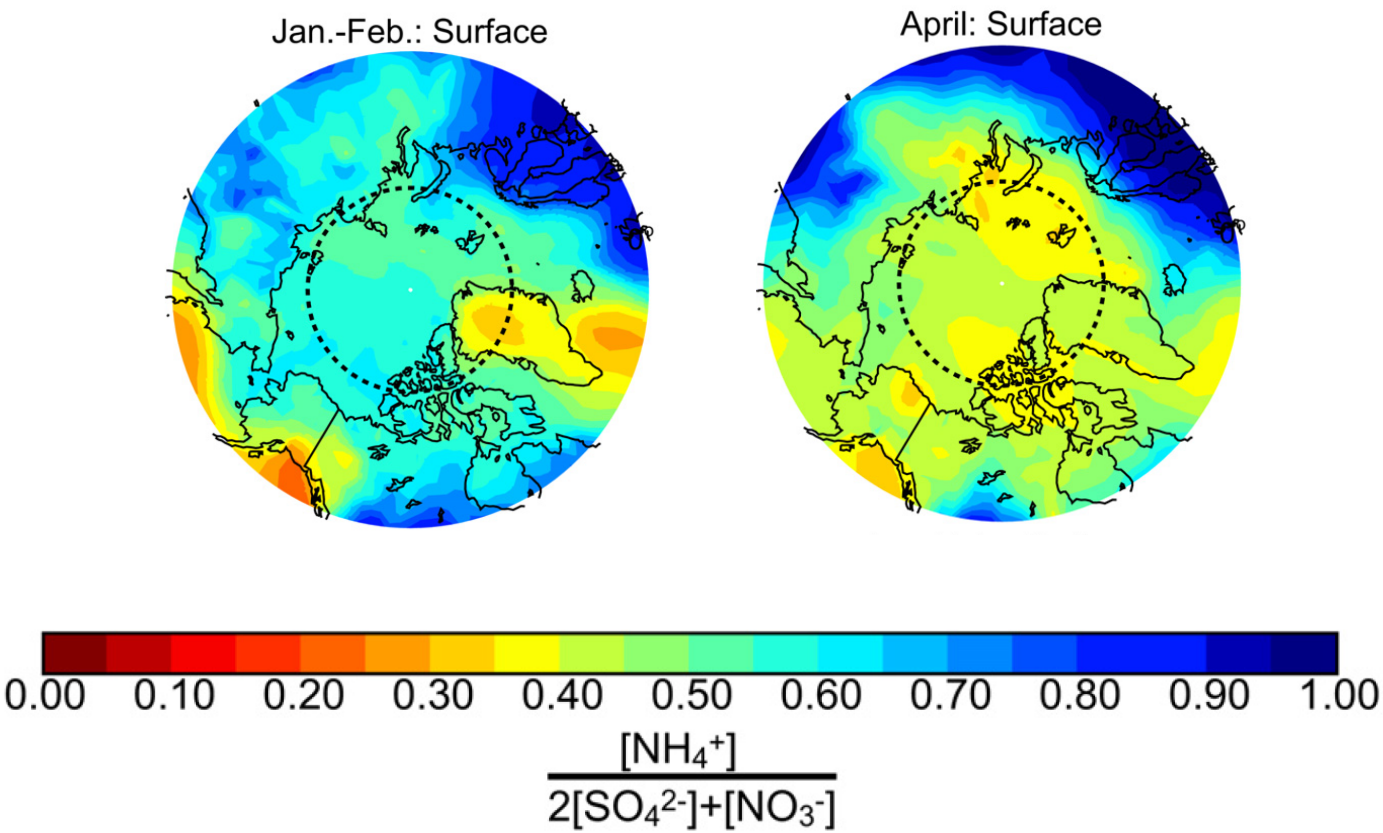


In the RCPs, anthropogenic emissions of all other aerosols are decreasing

=> increasing role of NH3



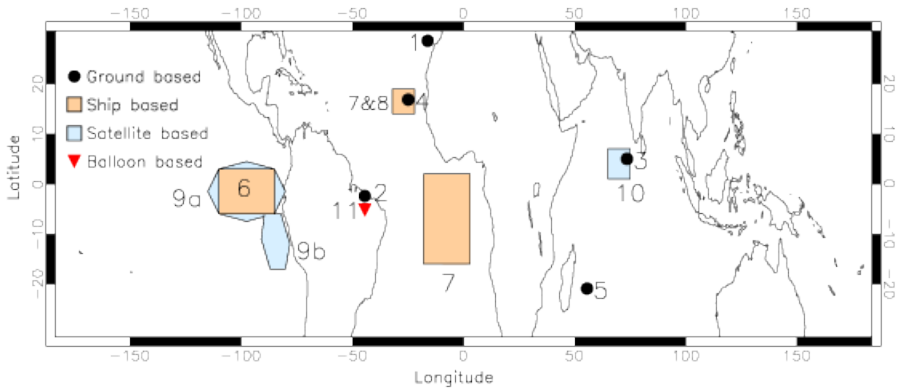
Acidity of deposition



Fisher et al., Atmos. Env., 2012

HALOGENS

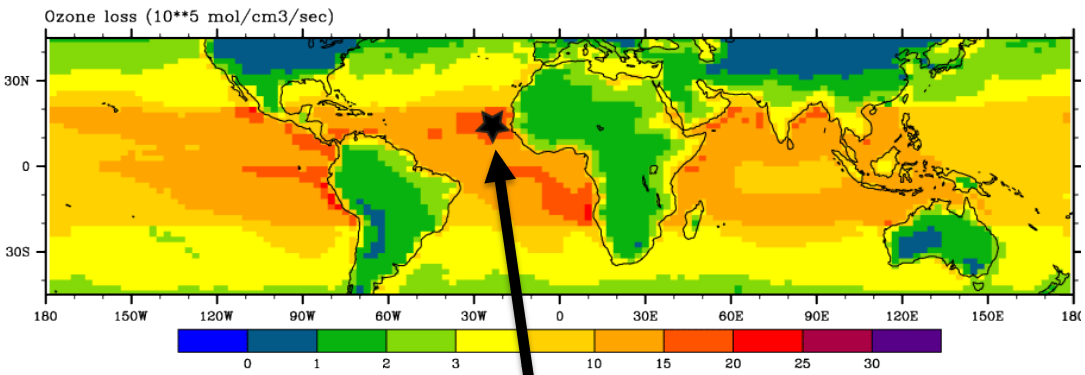
Regional measurements of IO & BrO



No. (species)	Daytime avg. mixing ratio (pptv)	
	Modelled	Observed
Ground based measurements		
1 (IO)	0.4	1.2
2 (IO)	0.7	<0.2 – 0.8
3 (IO)	1.0	~2.4
4 (IO, BrO)	1.0, 2.0	1.0, 2.0
5 (BrO)	0.8	<0.5
Ship based measurements		
6 (IO)	1.0	~3.5
7 (BrO)	0.8	<3.6
8 (BrO)	1.2	<3.0
Satellite based measurements		
9a (IO)	1.0	~3.3
9b (IO)	1.0	~3.3
10 (IO)	1.0	~2.4
Balloon based measurements		
11 (IO)	0.02	~0.1
11 (BrO)	0.5	~1.0

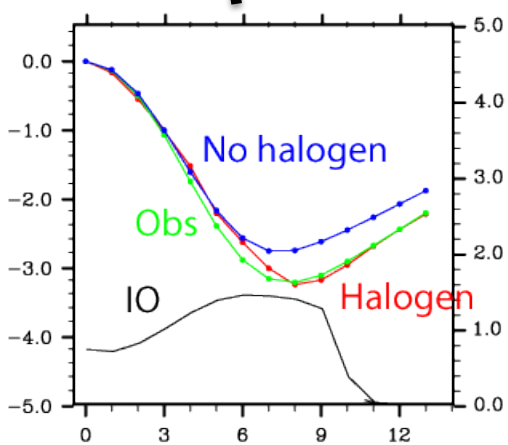
Saiz-Lopez et al., ACP, 2011

Ozone loss due to halogens



Surface layer loss

Ozone loss (ppbv)

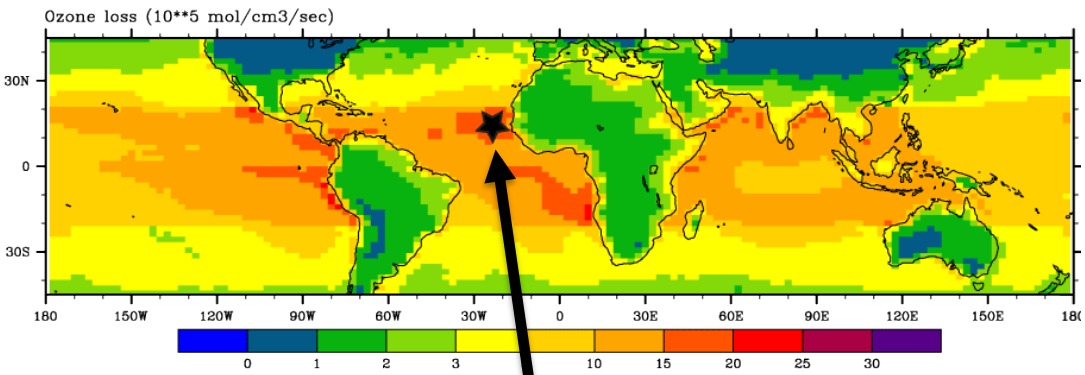


IO (pptv)

BrO≈2 pptv

Hours since ozone maximum

Ozone loss due to halogens



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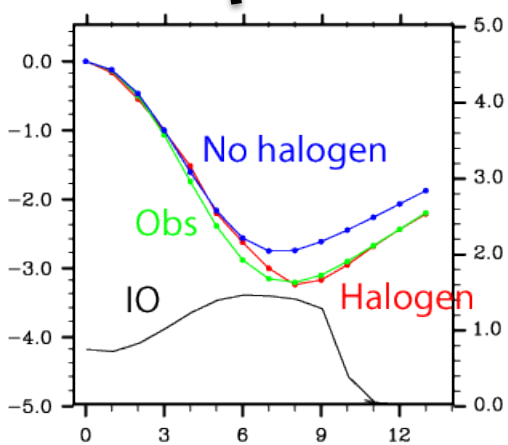

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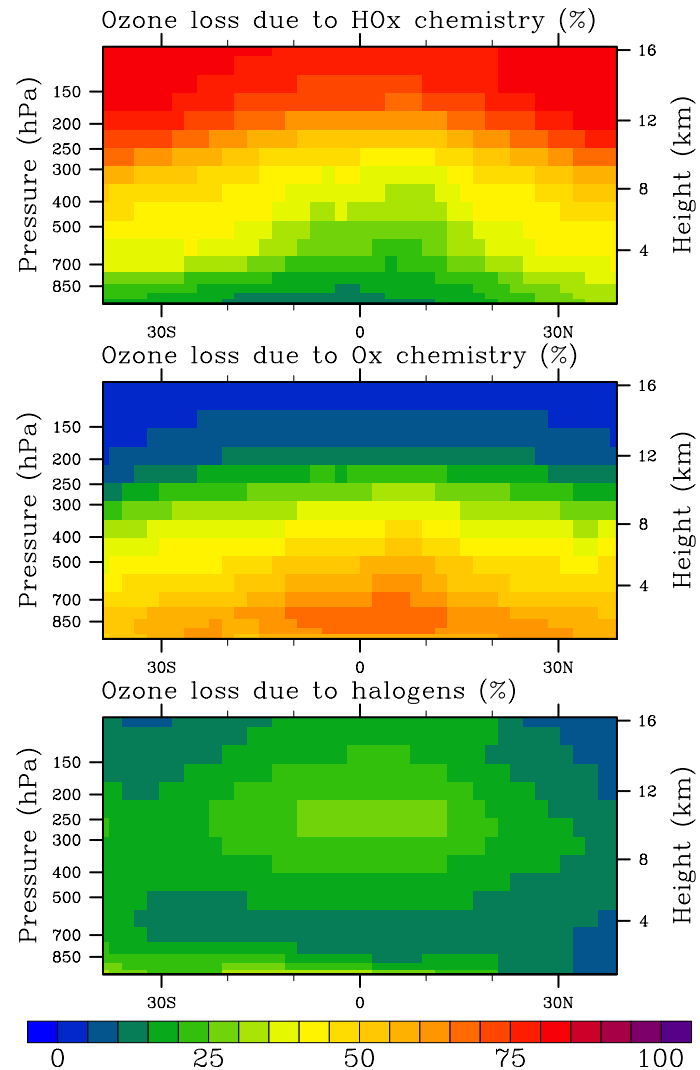
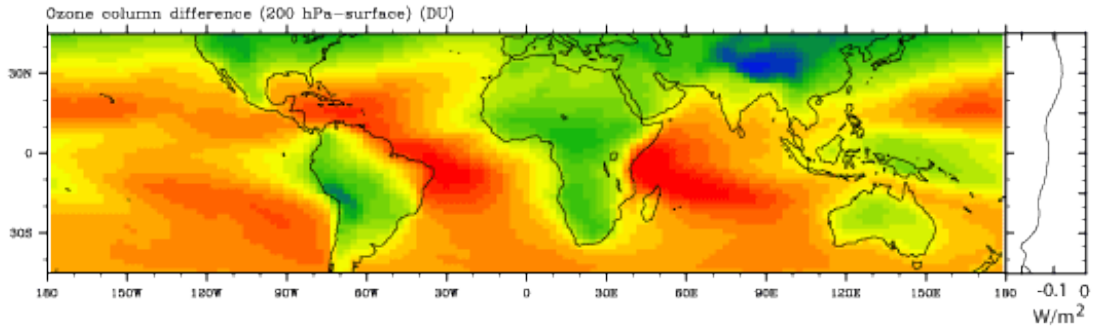
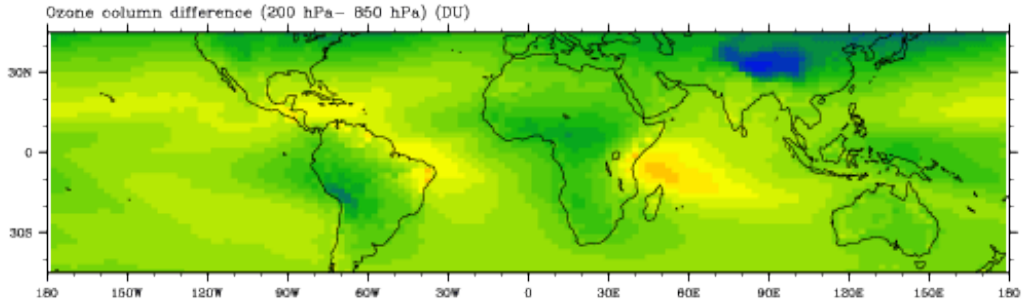


Zonal annual mean ozone loss fraction

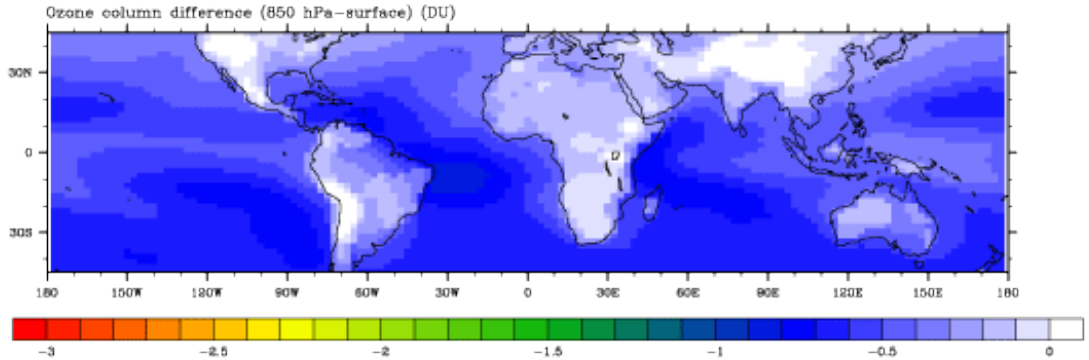
Decrease in tropical tropospheric ozone from halogen chemistry



200 hPa-surface



200 hPa-850 hPa



850 hPa-surface

Dobson Units

THANK YOU