Attribution of Ozone Changes: Non-linear Interactions between Ozone Depleting Substances and Greenhouse Gases in the Past and the Near Future

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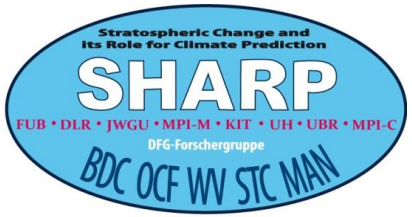
EGU General Assembly 2014
01.05.2014
Wien, Austria

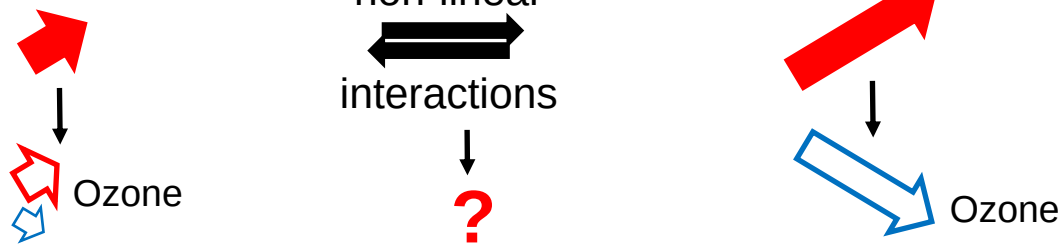


Introduction

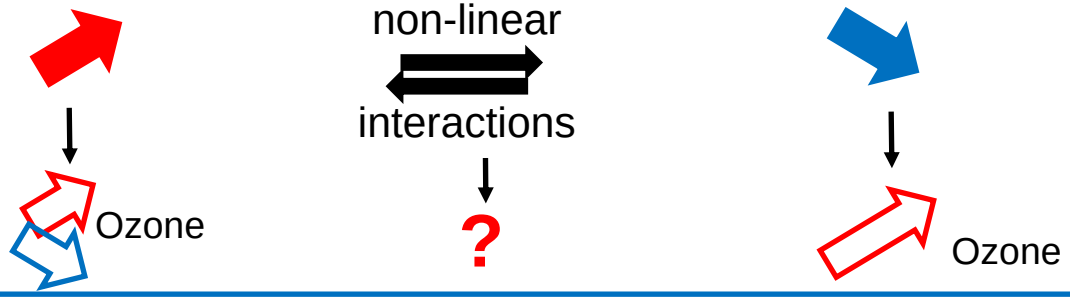
GHGs:
(Greenhouse gases)

ODSs:
(Ozone depleting substances)

Past:
1960-2000



Near Future:
2000-2045



Model Setup & Experiments

- Chemistry-Climate Model (CCM) **EMAC** v1.7 (ECHAM/MESSy Atmospheric Chemistry, *Jöckel et al., 2006; Roeckner et al., 2006*)

- Interactive chemistry module MECCA1 *(Sander et al., 2005)*

- Configuration:
  - FUBRad shortwave radiation scheme *(Nissen et al., 2007)*
  - Spectral **T42** resolution (2.8°x2.8°)
  - **39 model layers** (model top at 0.01 hPa)

- Prescribed sea surface temperatures (SSTs) and sea ice concentrations (SICs): MPI-OM *(Jungclaus et al., 2006)*

Model Setup & Experiments

Definition of sensitivity studies *(for details see Oberländer et al., 2013; Meul et al., 2014)* :

- **"Timeslice" experiments** over 20+ years (model run with fixed boundary conditions)
- GHGs: **Obs (past)** and **A1B scenario** *(IPCC, 2000)* **(future)**
- ODSs: **Obs (past)** and **adjusted A1 scenario** *(WMO, 2007)* **(future)**

Future

Name	GHGs (year)	ODSs (year)	SSTs/SICs (years)
REF2000	2000	2000	1995-2004 mean
REF2045	2045	2045	2040-2049 mean
GHG2045	2045	2000	2040-2049 mean
ODS2045	2000	2045	1995-2004 mean

Model Setup & Experiments

Total change between 2000 and 2045:

total := REF2045 – REF2000

Change due to GHG increase:

GHG:= GHG2045 – REF2000

Change due to ODS increase:

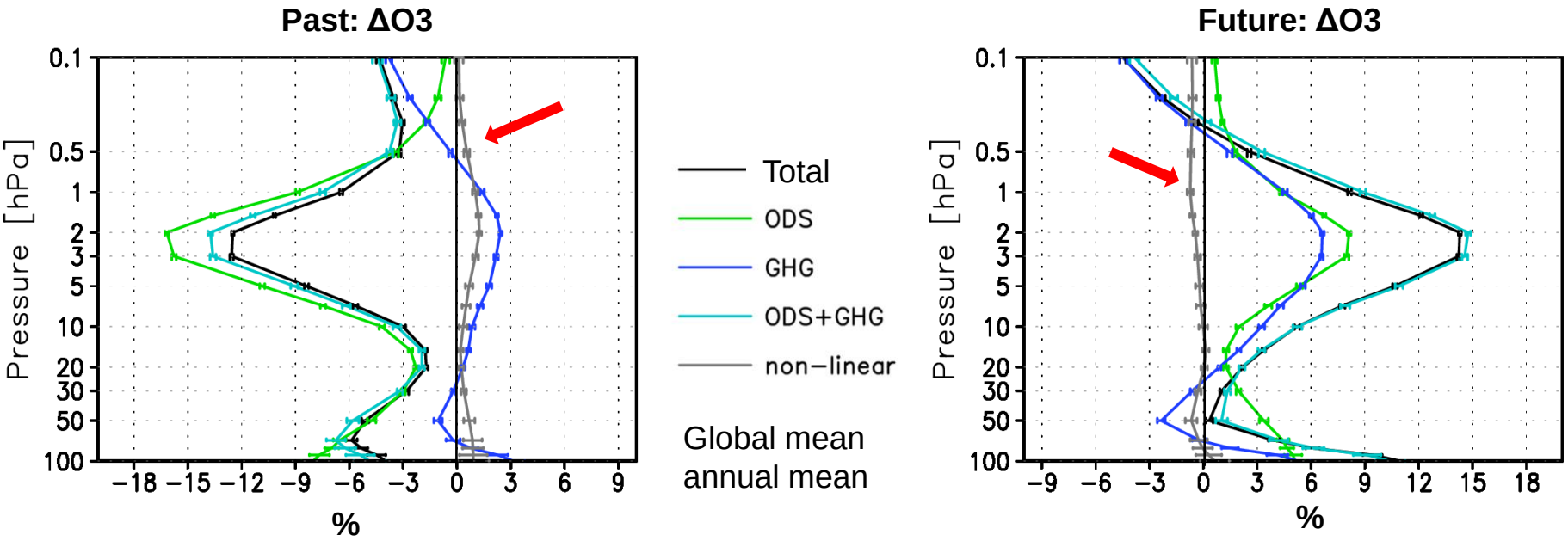
ODS:= ODS2045 – REF2000

Non-linear := total – (GHG + ODS)

in the stratosphere:

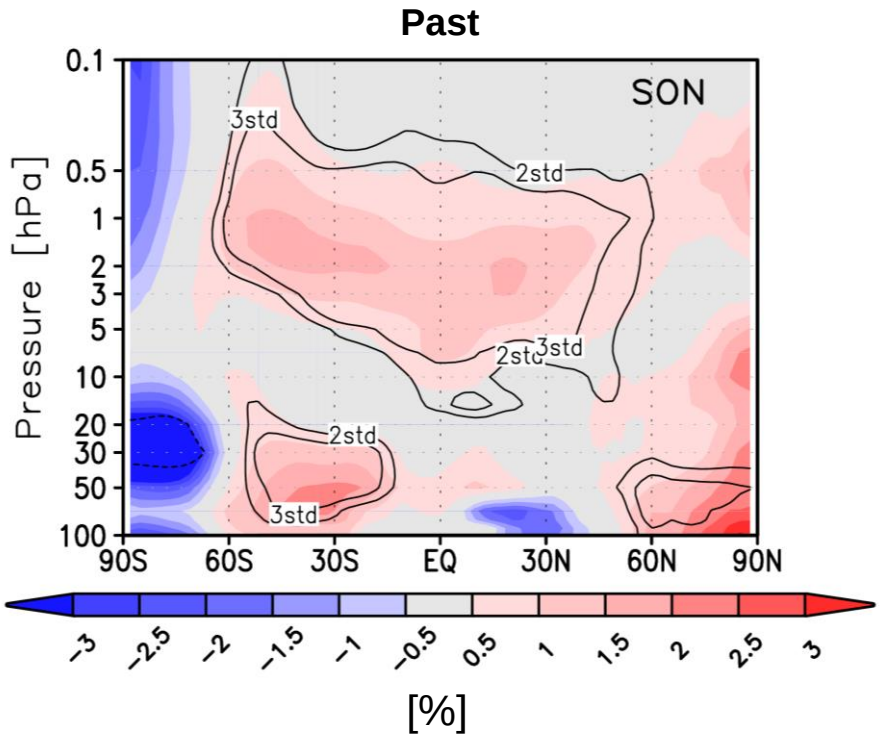
Analogously for the Past (1960 - 2000)

Ozone Changes and Non-linear Contribu



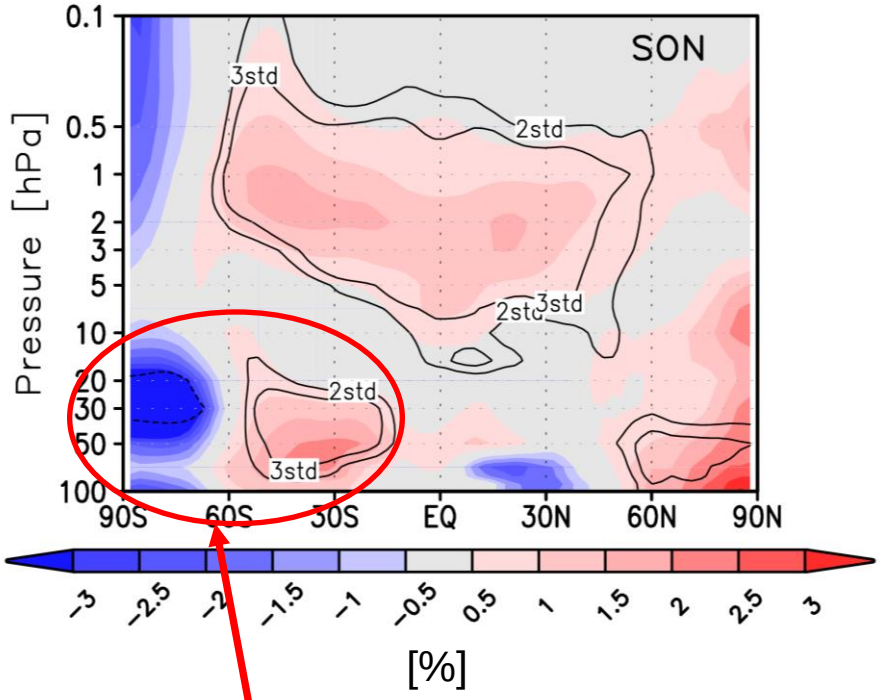
Small positive non-linear effect in the global mean annual mean ozone change in the past and negative non-linear effect in the near future.

Non-linear Contribution to Ozone Chang

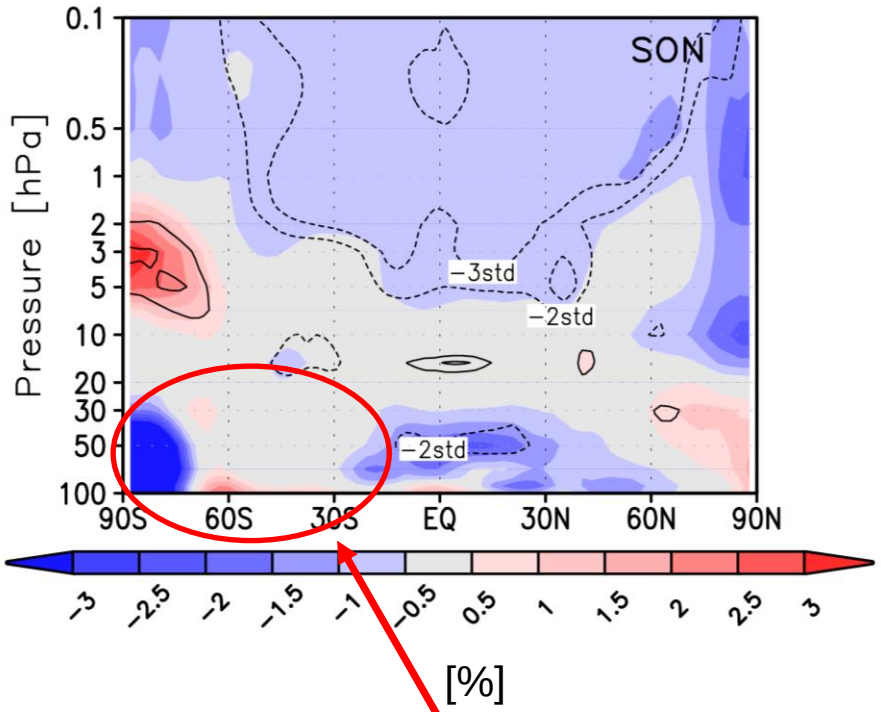


Non-linear Contribution to Ozone Chang

Past



Future



Attributed to **transport processes**:
Less ozone transport from mid to high latitudes due to non-linear interactions:
ODS increase → more persistent, less permeable polar vortex
GHG increase → increased ozone transport to high latitudes

No significant non-linear effect in the near future

For details to the attribution method see Garny et al., 2011; Meul et al., 2014

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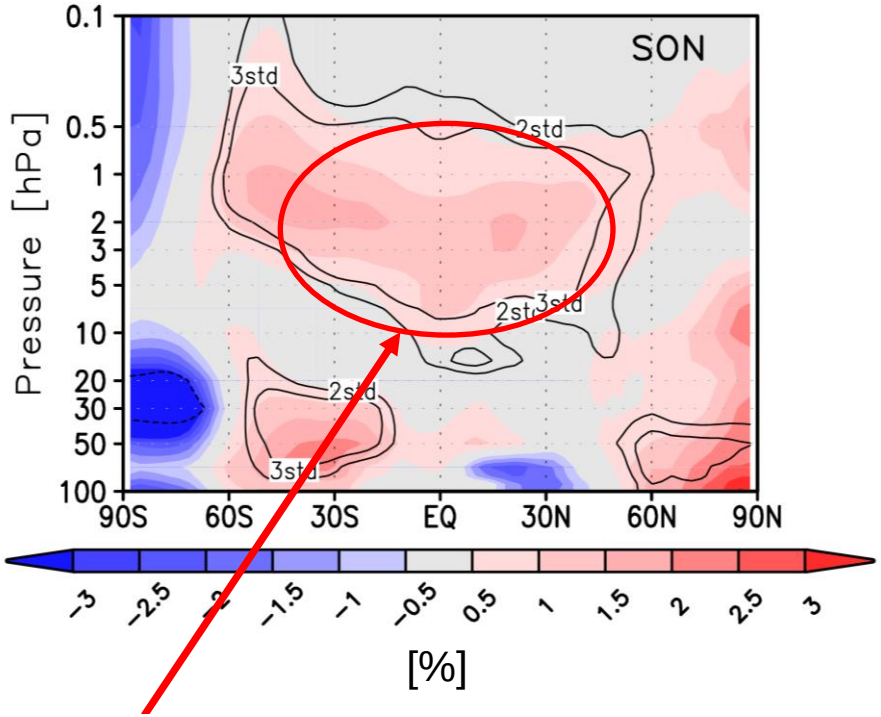
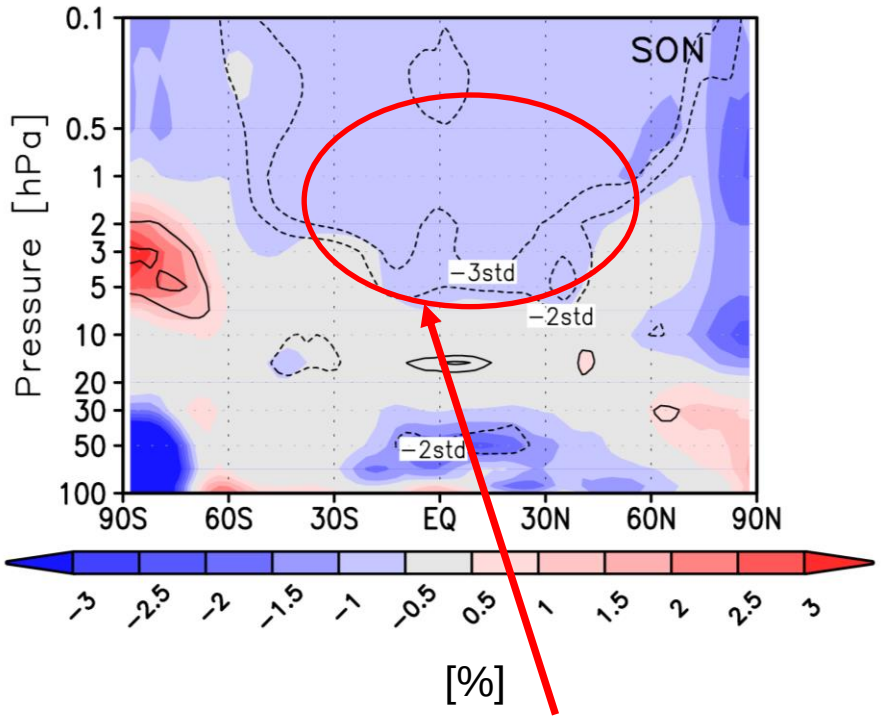
Non-linear Contribution to Ozone Chang

Past



Future



Attributed to **chemical processes**:
Largest non-linear effect in the catalytic ozone loss due to **ClOx**:
Less efficient ClOx cycle due to increased fraction of reservoir gases in Cly

Attributed to **chemical processes**:
Largest non-linear effect in the catalytic ozone loss due to **ClOx**:
ClOx cycle more efficient due to reduced fraction of reservoir gases in Cly

Why?

Past: Less ClOx radicals

Possible explanation:

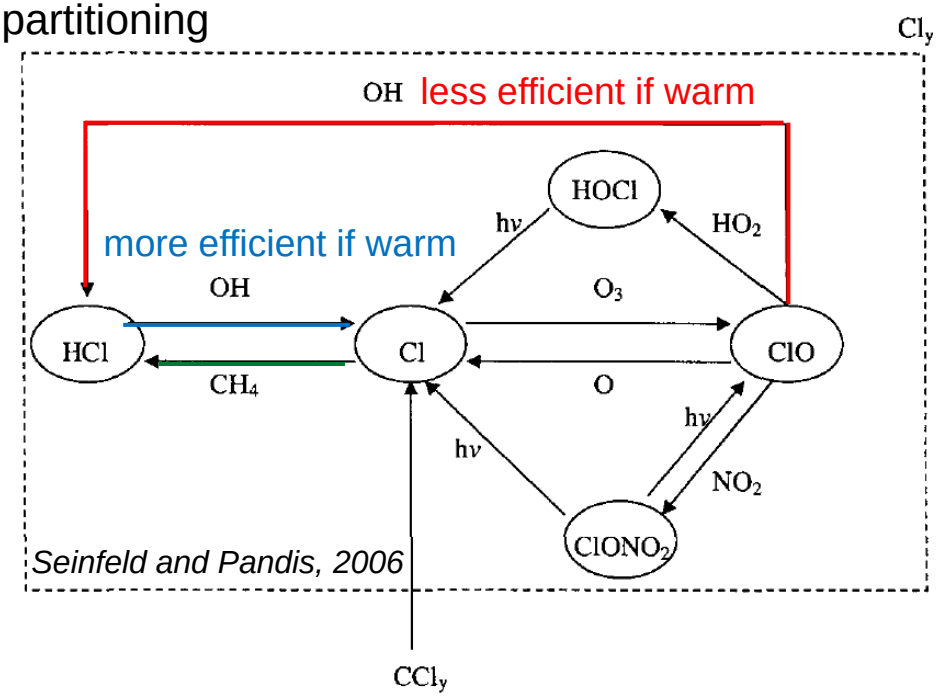
- Increase in CH4 concentrations:
  → more chlorine sequestered in HCl
- Lower temperatures if ODSs and GHGs change
  → affects temperature dependent reaction rates of reactions which influence the Cly partitioning

Future: More ClOx radicals

Possible explanation:

- Higher temperature and more HOx in the stratosphere if ODS and GHG change

→ affects temperature dependent reaction rates of reactions which influence the Cly partitioning



Summary

- Chemical non-linear interactions lead to a
  1) reduced upper stratospheric ozone loss in the past
  2) reduced upper stratospheric ozone increase in the near future

- Largest non-linear effects on the ClOx cycle, but also effects on the Chapman and the NOx cycle

- Dynamical non-linear interactions lead to
  1) a reduced ozone transport from mid to high latitudes in the southern hemispheric spring (SON) in the past
  2) no significant effect in the SH polar region in the near future

- Different non-linear processes in the recent past and the near future
- Accounting for non-linear effects on ozone in attribution studies

Thank you!