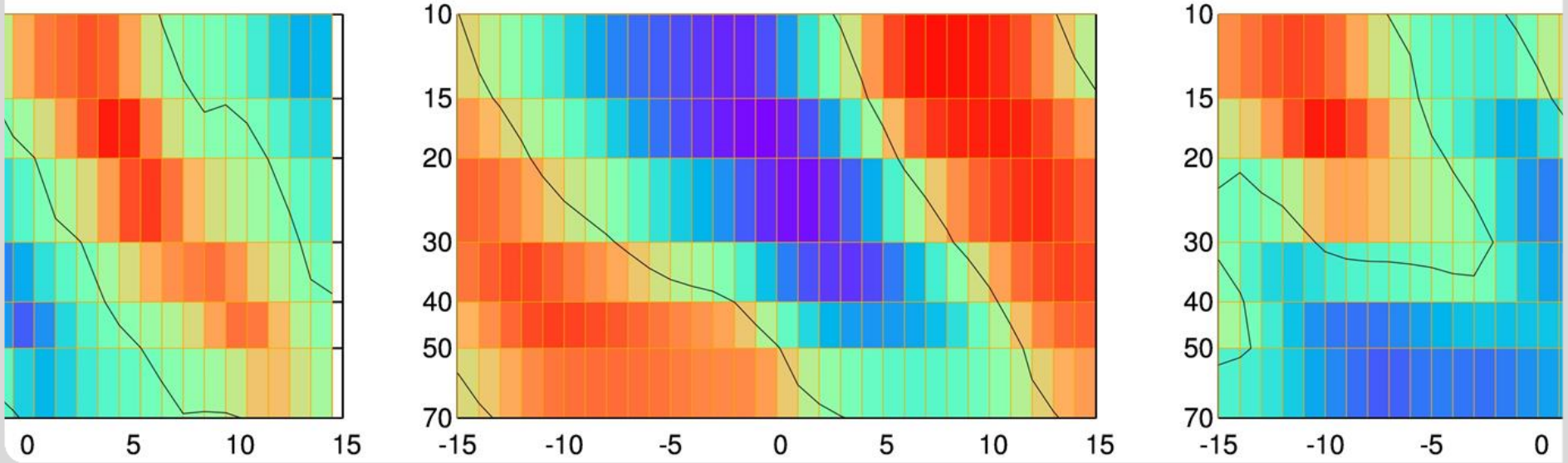
Karlsruher Institut für Technologie

Composition-Climate Interactions: The recent past

Peter Braesicke

IIMK-ASF

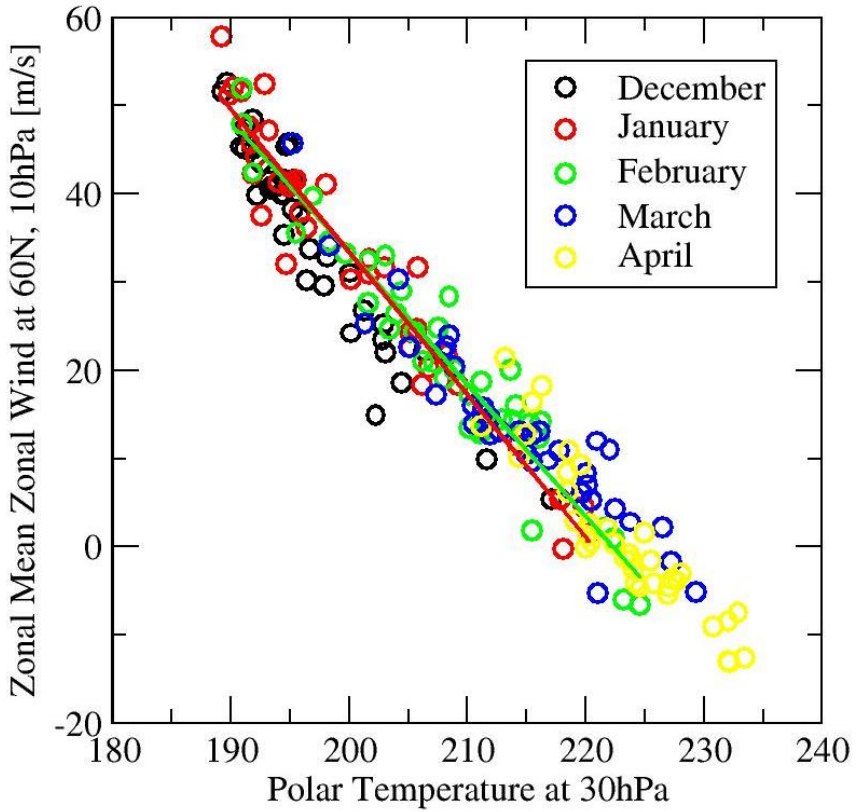


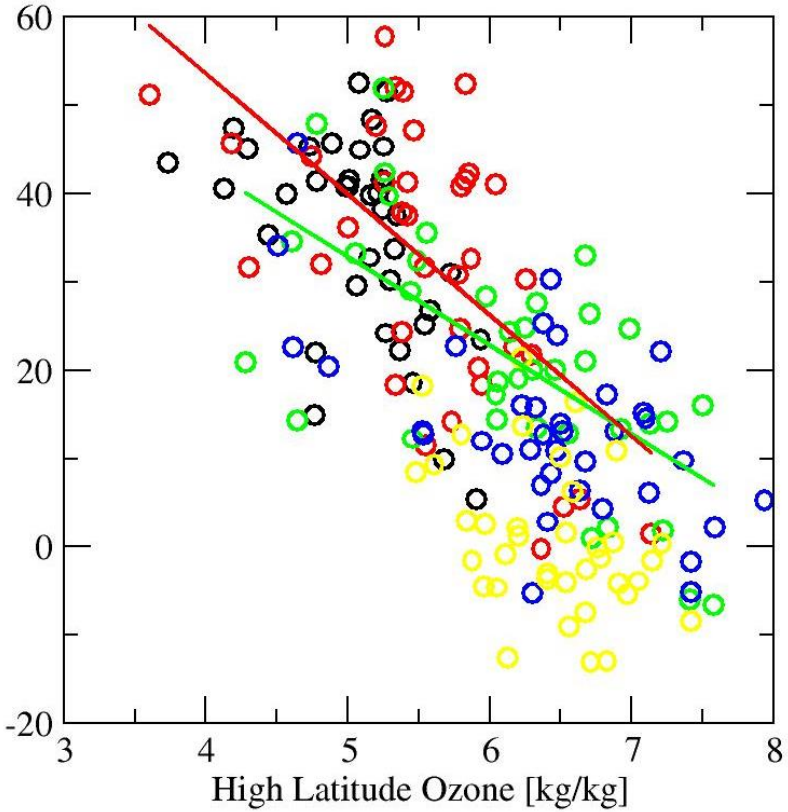
Structure

Composition-Climate Interactions
(with a focus on ozone and the Arctic)
(and in three parts)

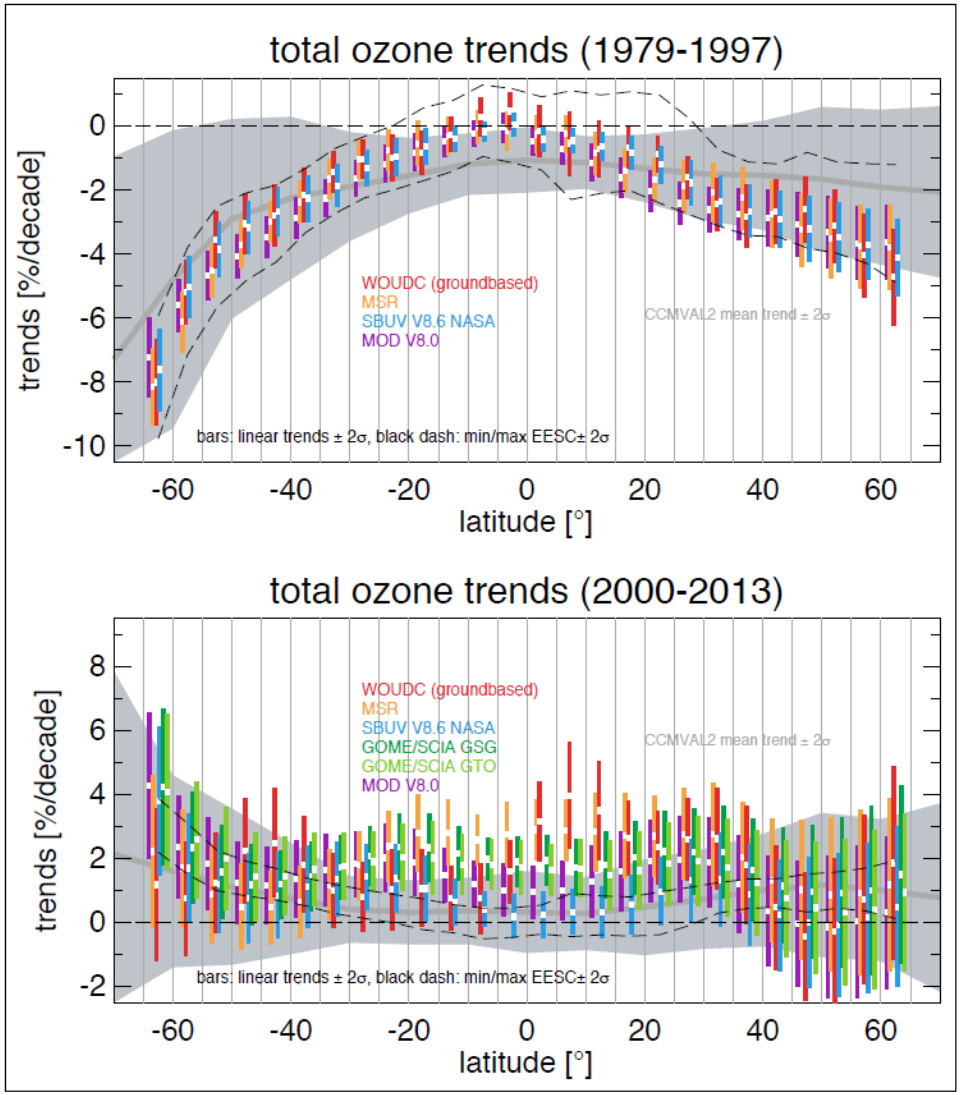
- Introduction
  - Structure of the atmosphere
  - Why does ozone matter?
  - Modelling the atmosphere
- The recent past
  - Observations (an aside: Antarctic climate change)
  - Simulations of the recent past
- Expectations for the future
  - Common sense (ozone recovery)
  - Projecting the future (surprises?)

Polar Meteorology and Ozone



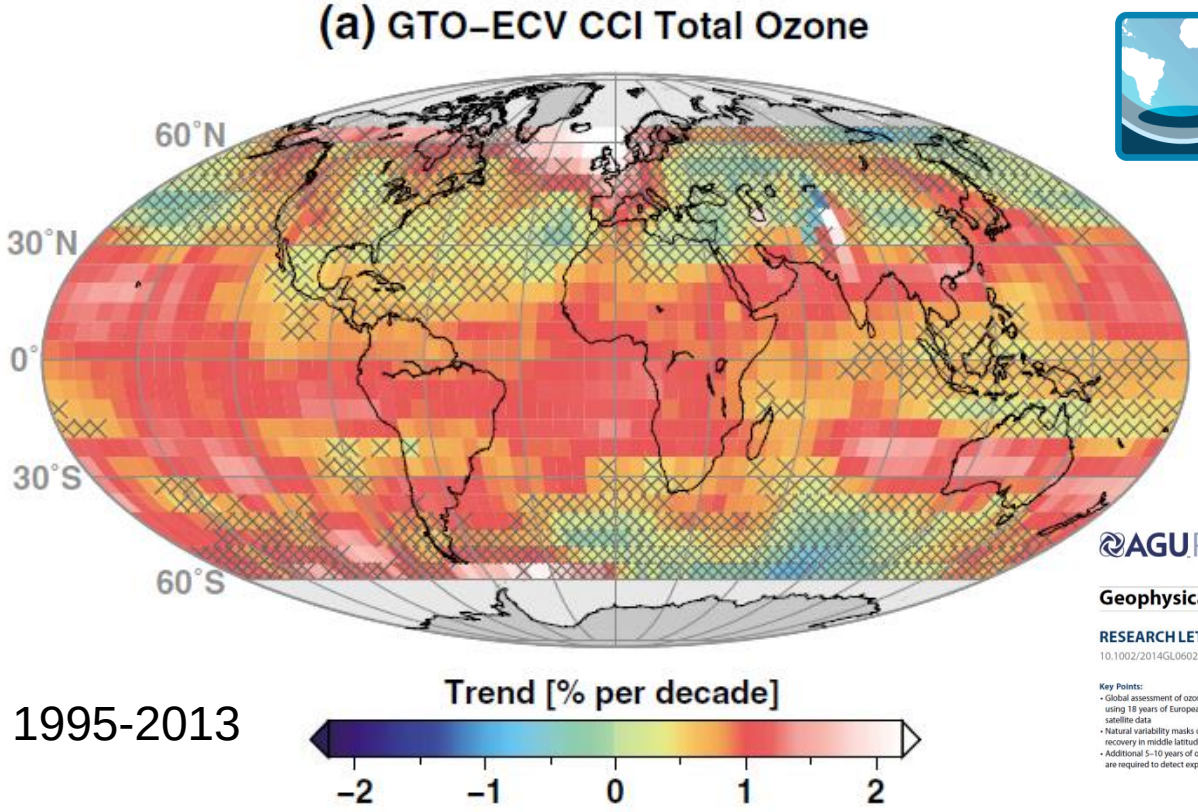


Zonal Mean Total Column Ozone Trends



Regional Total Column Ozone Trends

- Regional (trend) assessments are becoming more important.
- After the ozone assessment (2014) is before the next one …
- Example:



Grey crosses: not significant!

1995-2013


AGU PUBLICATIONS

Geophysical Research Letters

RESEARCH LETTER
10.1002/2014GL060212

A new health check of the ozone layer at global and regional scales

Key Points:
- Global assessment of ozone trends using 18 years of European satellite data
- Natural variability masks ozone recovery in middle latitudes
- Additional 5–10 years of observations are required to detect expected onset

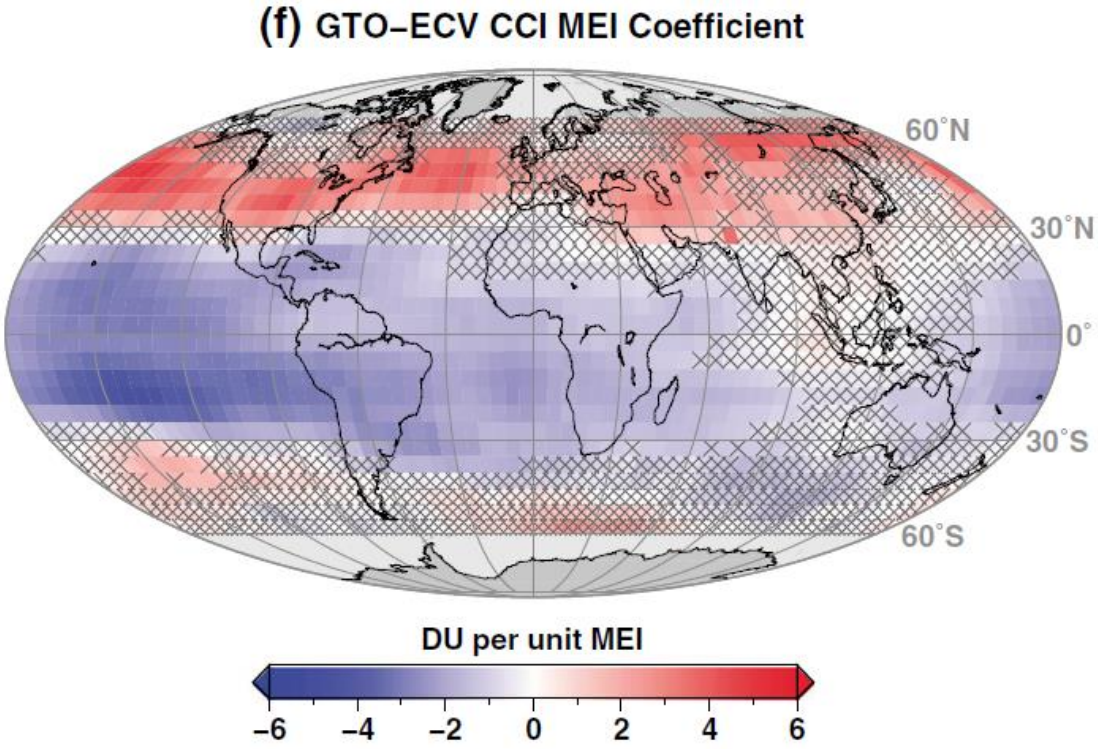
Melanie Coldewey-Egbers[1], Diego G. Loyola R.[1], Peter Braesicke[2], Martin Dameris[3], Michel van Roozendael[4], Christophe Lerot[4], and Walter Zimmer[1]

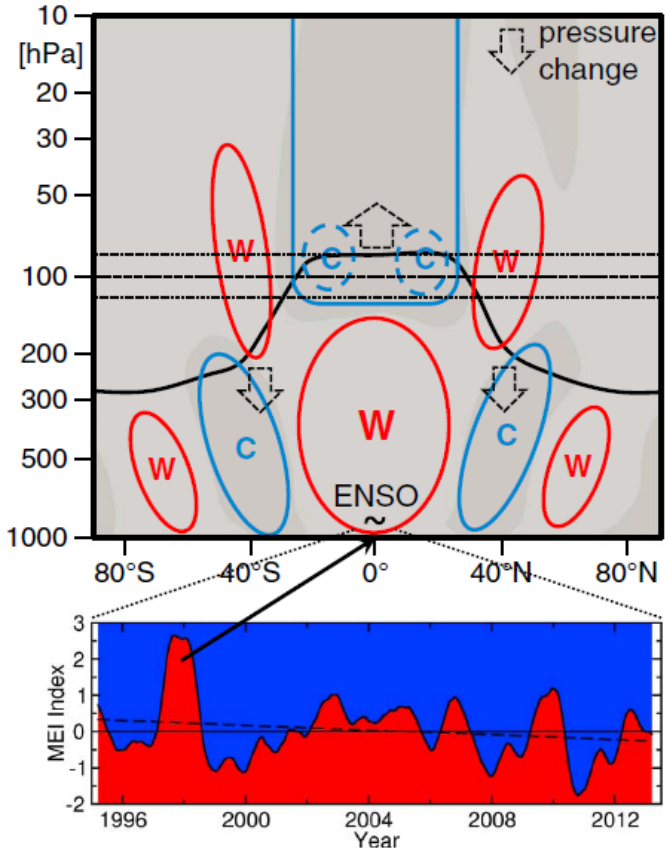
[1]Remote Sensing Technology Institute, German Aerospace Center, Weßling, Germany, [2]Karlsruhe Institute of Technology, Institute for Meteorology and Climate Research, Karlsruhe, Germany, [3]Institute for Physics of the Atmosphere, German Aerospace Center, Weßling, Germany, [4]Belgian Institute for Space Aeronomie BIRA-IASB, Brussels, Belgium

Coldewey-Egbers et al., GRL, 2014

Role of Natural Variability

- ENSO signal:



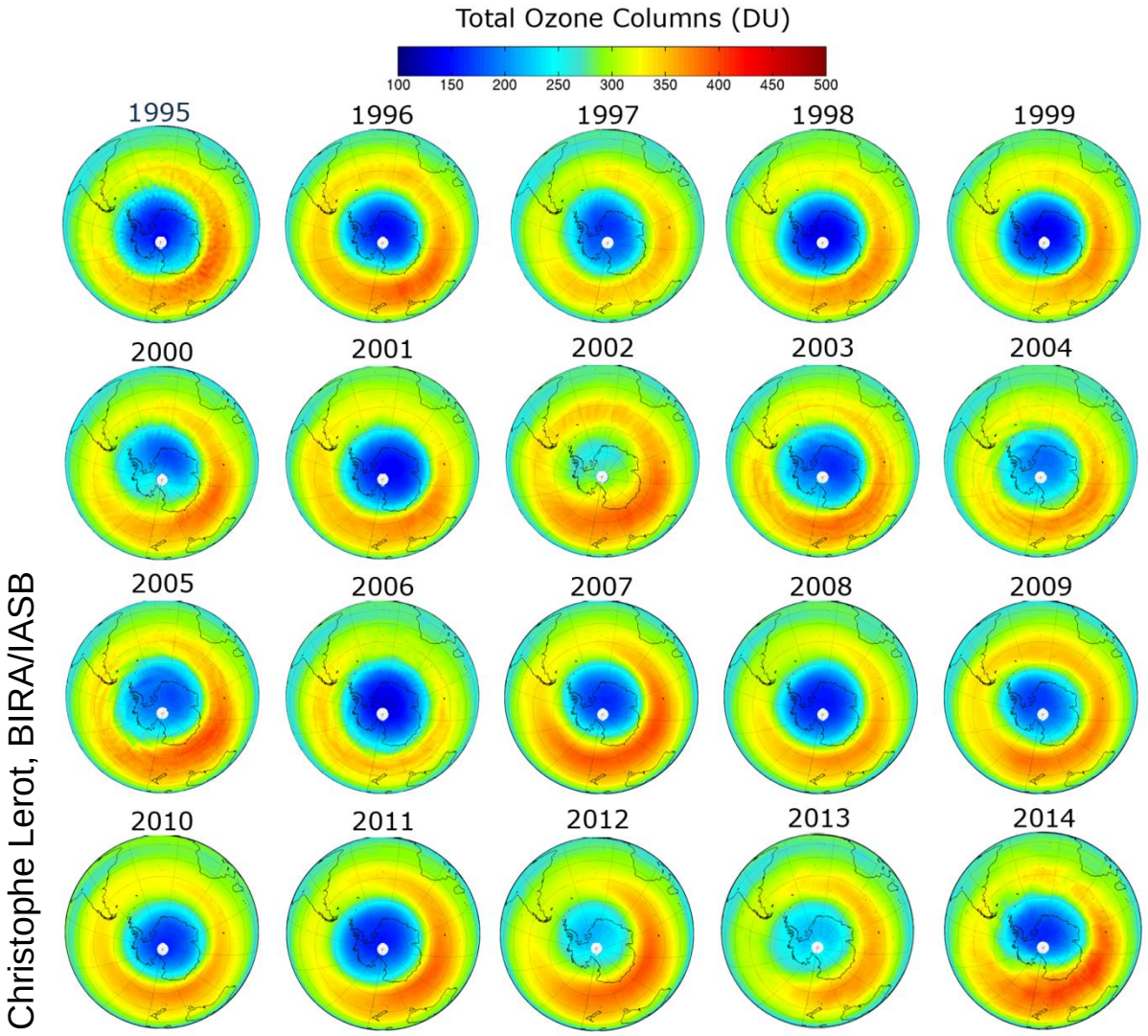


- Detection and attribution of natural variability is important!

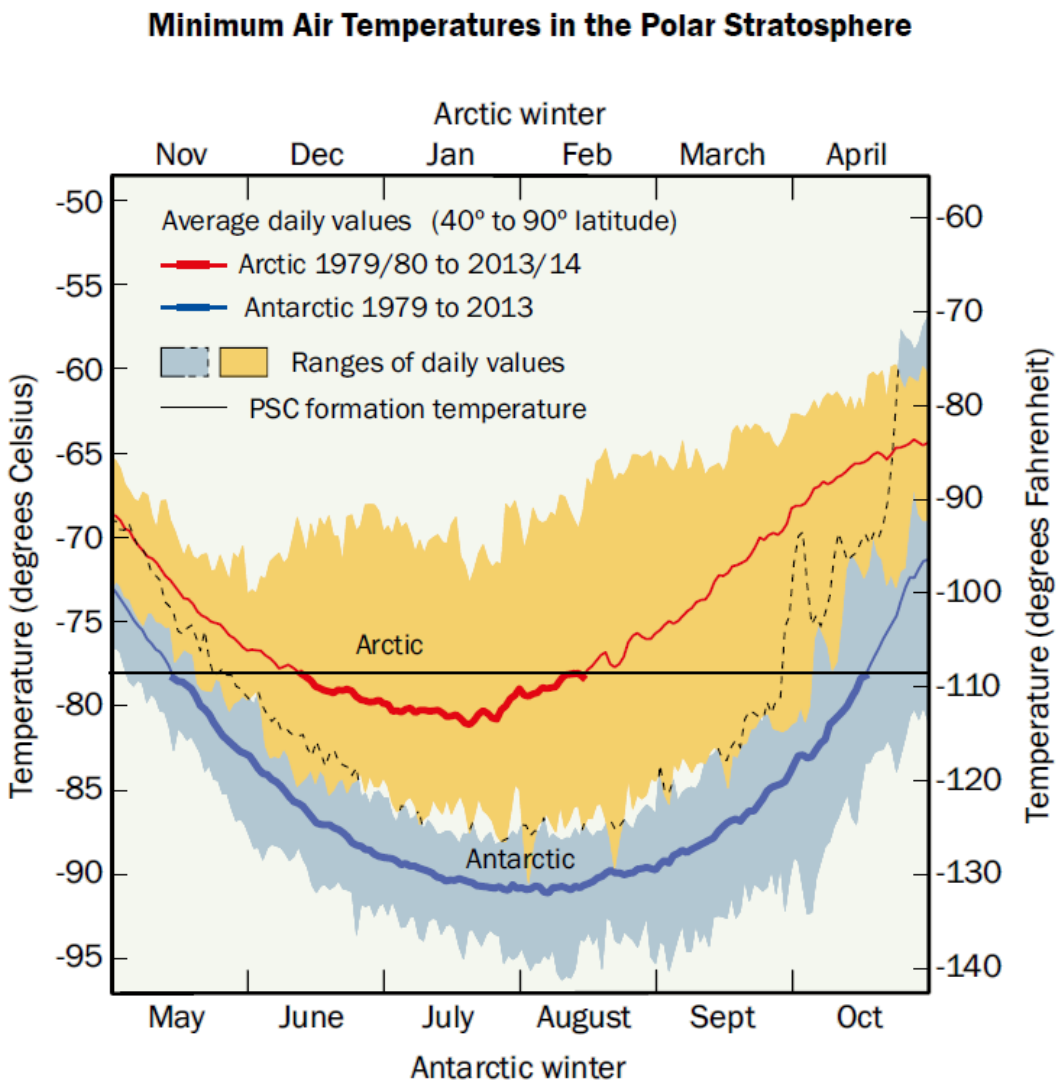
Coldewey-Egbers et al., GRL, 2014

Excursion to the Southern Hemisphere

ESA Ozone_CCI



Temperatures in PSCs



PSCs over Kiruna

WMO, 2014

Catalytic Ozone Destruction

PSCs allow the formation of ClO and BrO

Ozone Destruction Cycles in Polar Regions

Cycle 2

$$ClO + ClO \rightarrow (ClO)_2$$
$$(ClO)_2 + \text{sunlight} \rightarrow ClOO + Cl$$
$$ClOO \rightarrow Cl + O_2$$
$$2(Cl + O_3 \rightarrow ClO + O_2)$$

Net: $2O_3 \rightarrow 3O_2$

Cycle 3

$$ClO + BrO \rightarrow Cl + Br + O_2$$

or

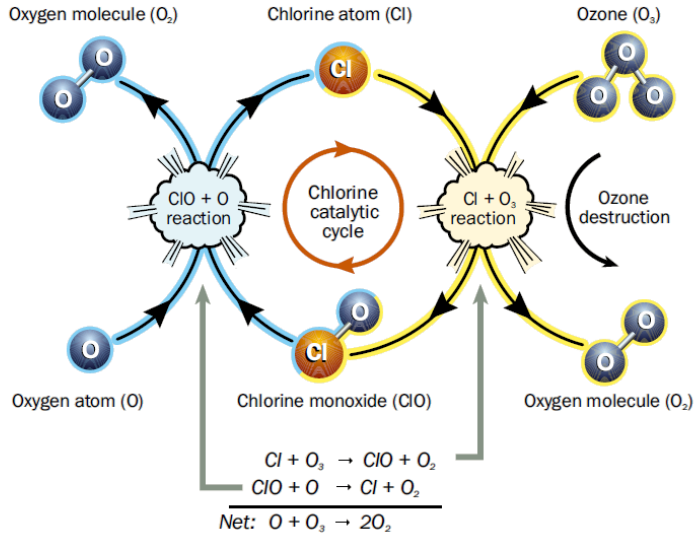
$$ClO + BrO \rightarrow BrCl + O_2$$
$$BrCl + \text{sunlight} \rightarrow Cl + Br$$

$$Cl + O_3 \rightarrow ClO + O_2$$
$$Br + O_3 \rightarrow BrO + O_2$$

Net: $2O_3 \rightarrow 3O_2$

WMO, 2014

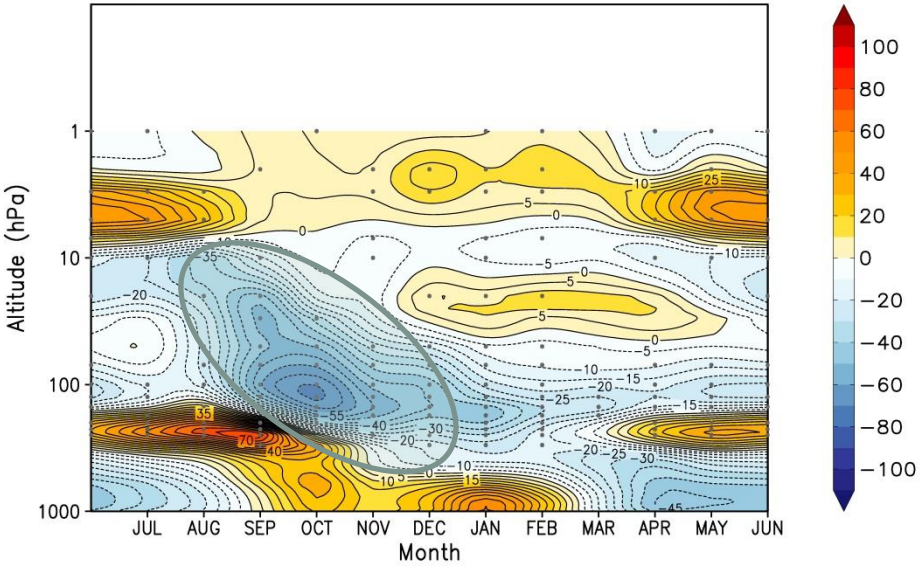
Ozone Destruction Cycle 1



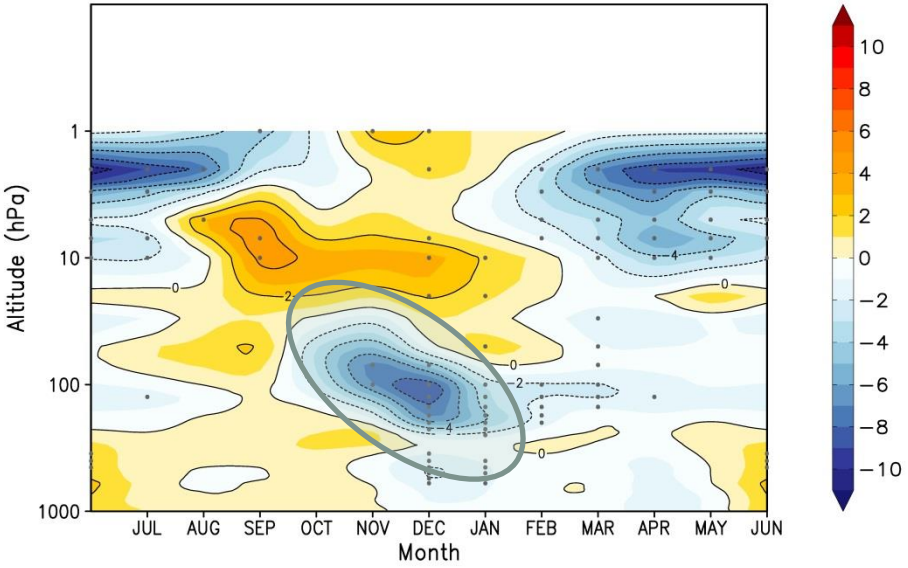
„Observed“ Ozone and Temperature Change

ERA-Interim Reality: Mean(1998 to 2002) - Mean(1979 to 1983)

Ozone Difference [%] – 90º-75ºS



Temp. Difference [K] – 90º-75ºS

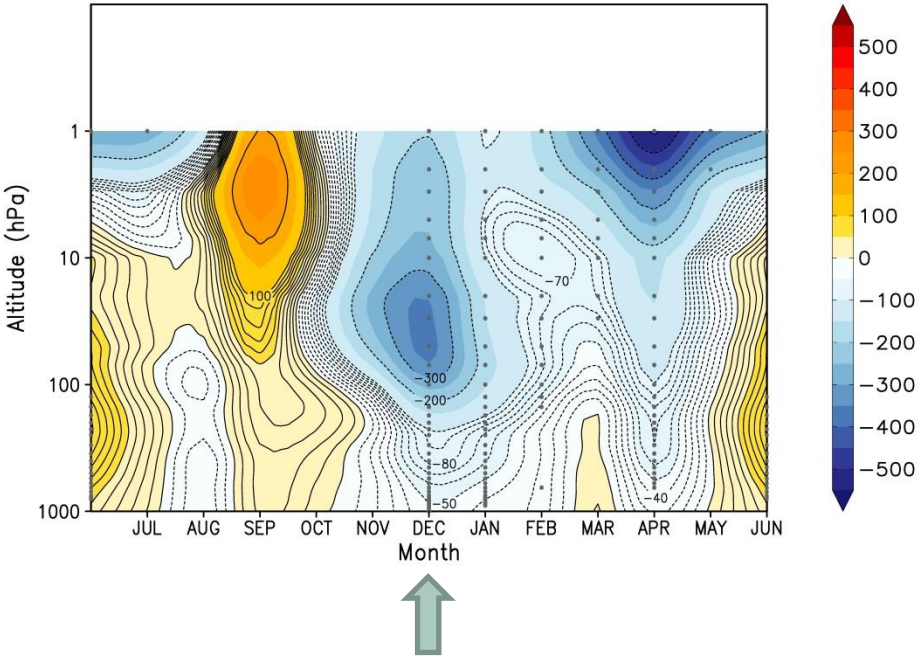


James Keeble

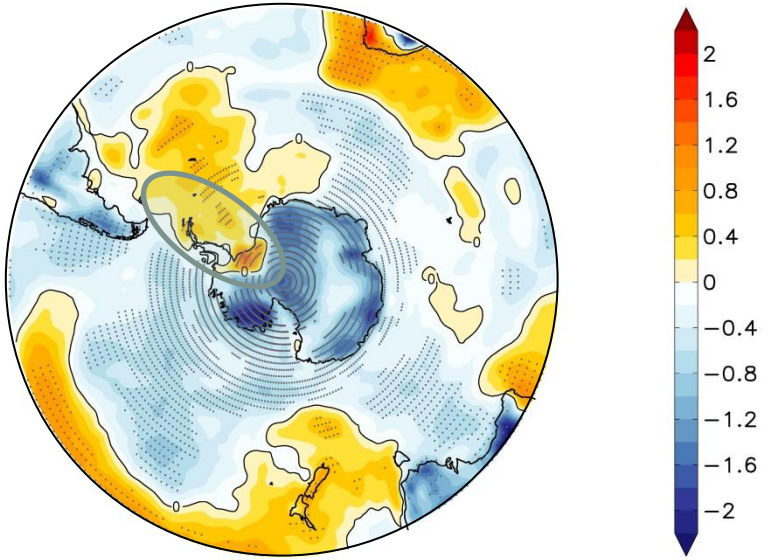
“Observed” circulation and surface changes

ERA-Interim Reality: Mean(1998 to 2002) - Mean(1979 to 1983)

Height Difference [m] – 90º-75ºS



Surface Temp. Difference [K]



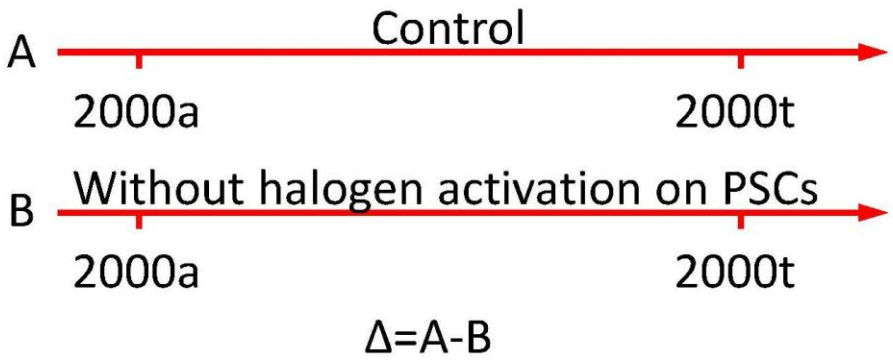
December

James Keeble

Understanding: Designing experiments

http://www.ukca.ac.uk/wiki/index.php/UKCA

Pair A: UMUKCA CheS



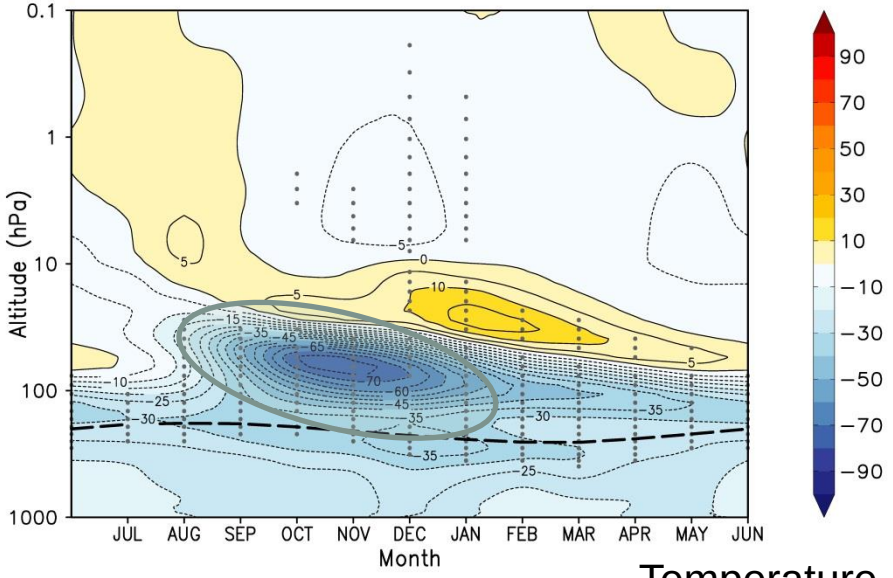
Model:
UMUKCA @ N48L60
3.75°x2.5°, 0 – 84km
CheS Chemistry (Look-up J)
CheST+ Chemistry (Fast-Jx)
Boundary conditions:
Hadley Centre SSTs/SI

Atmosphere
~~Ocean~~
Composition
Model

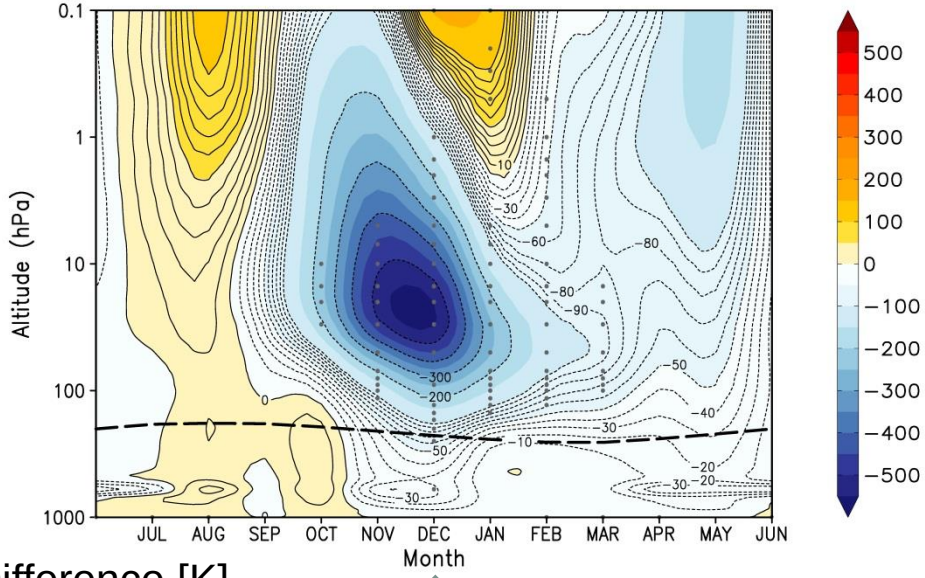
Time slices for 2000 conditions

Modelled ozone loss and response

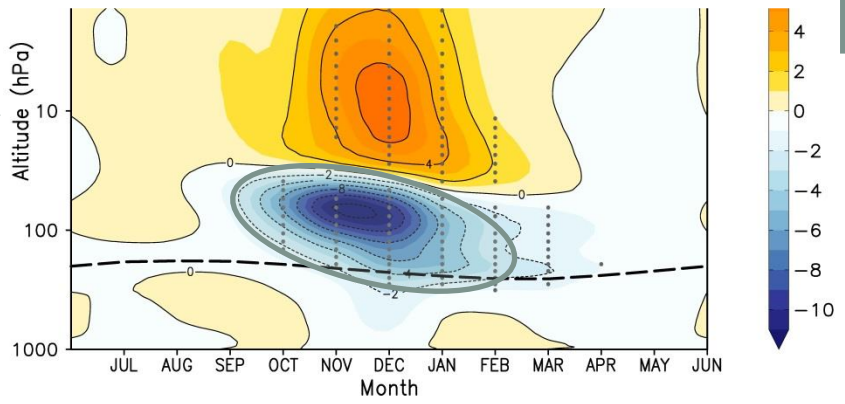
Ozone Difference [%] – 90º-75ºS



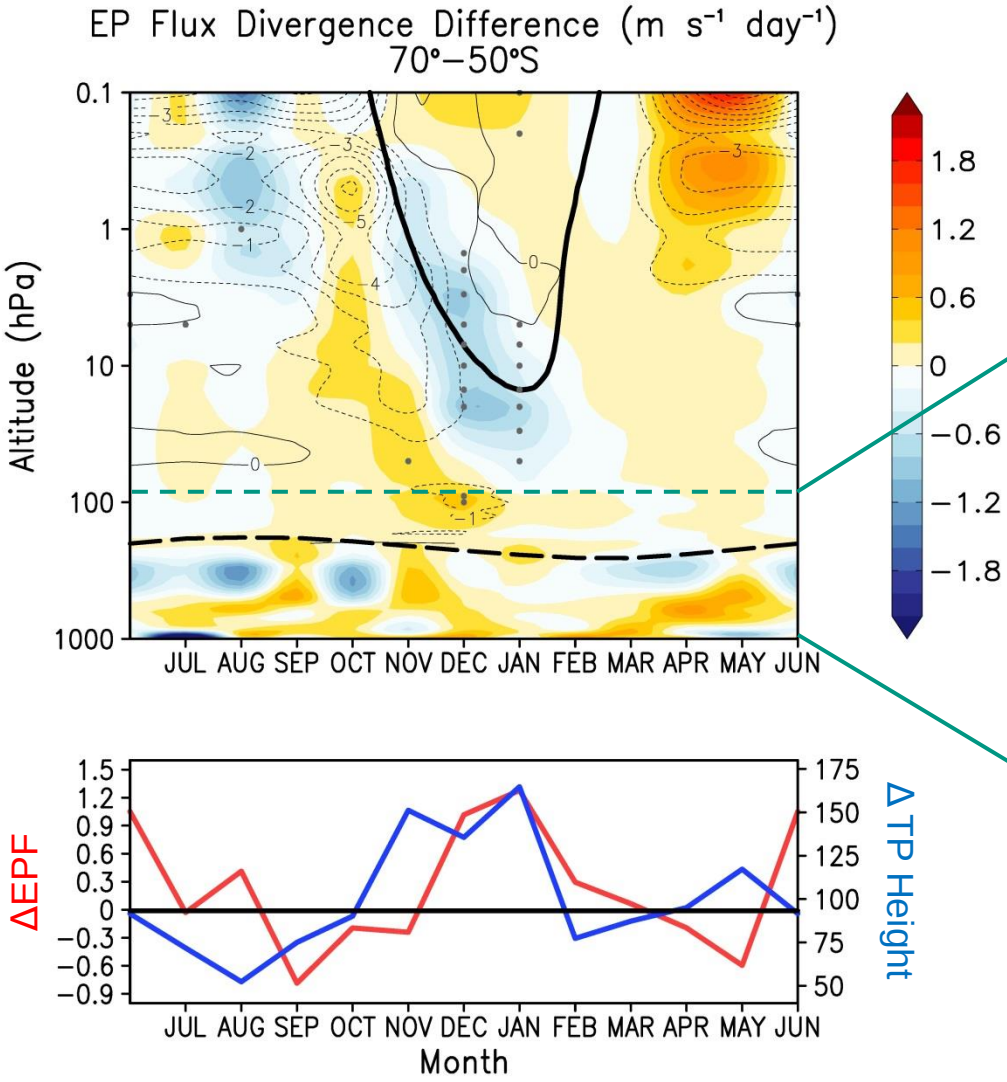
Height Difference [m] – 90º-75ºS

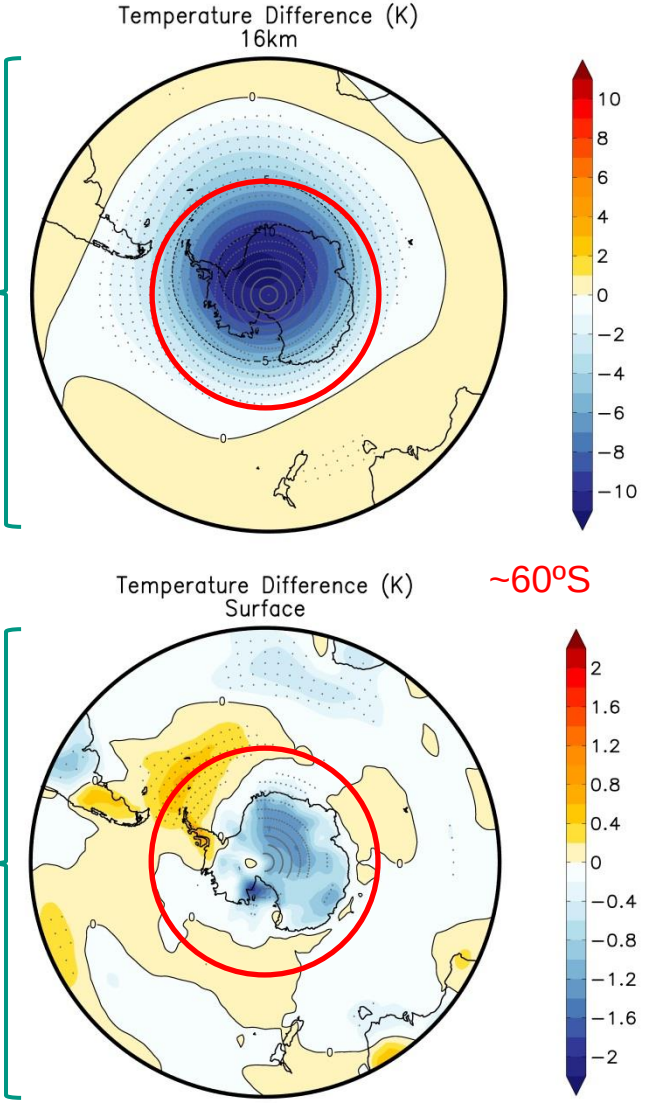


Temperature Difference [K]



Effects on surface climate

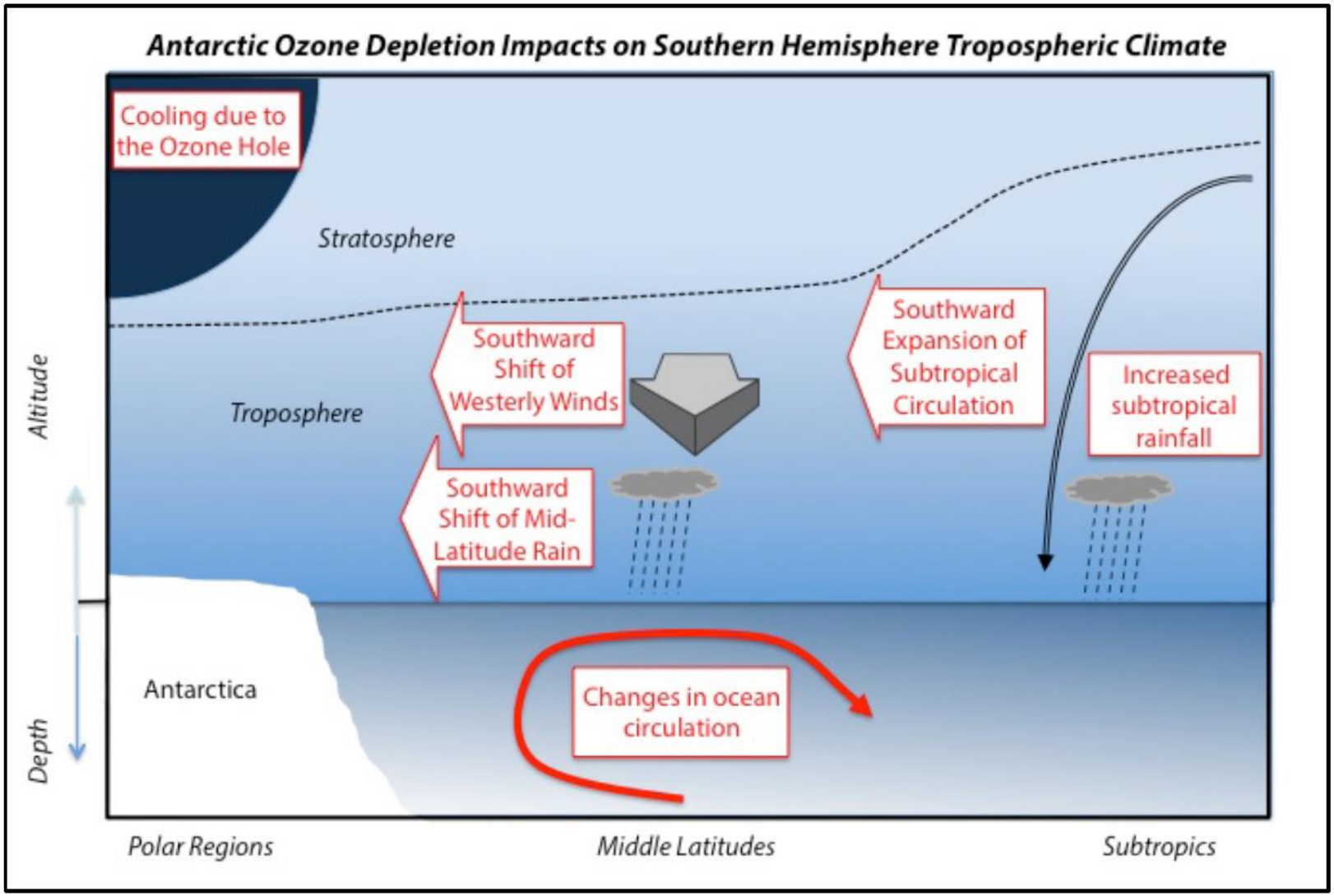




~60°S

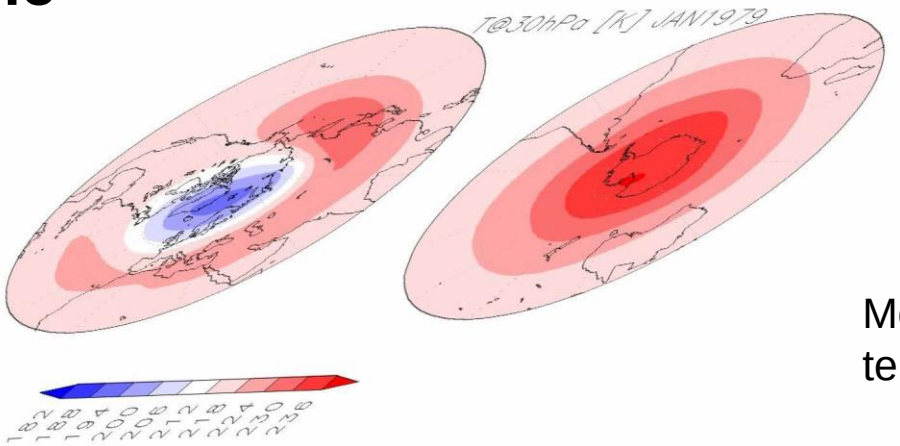
Keeble et al., ACP, 2014

Antarctic Ozone and Climate

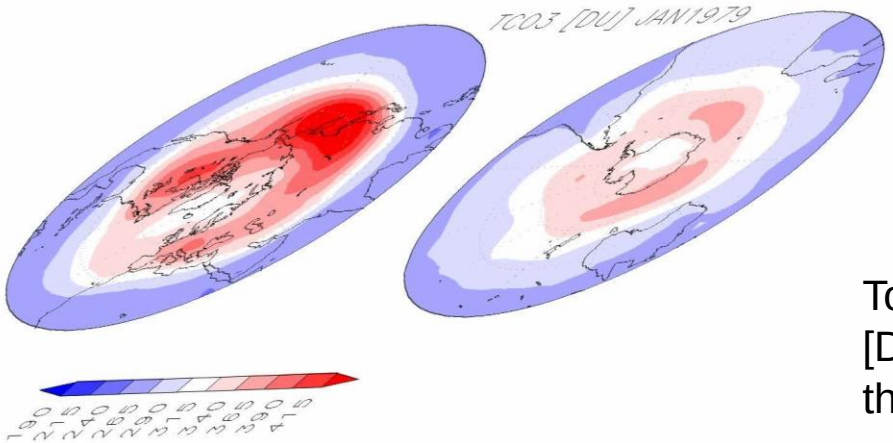


WMO, 2014

Movie Time

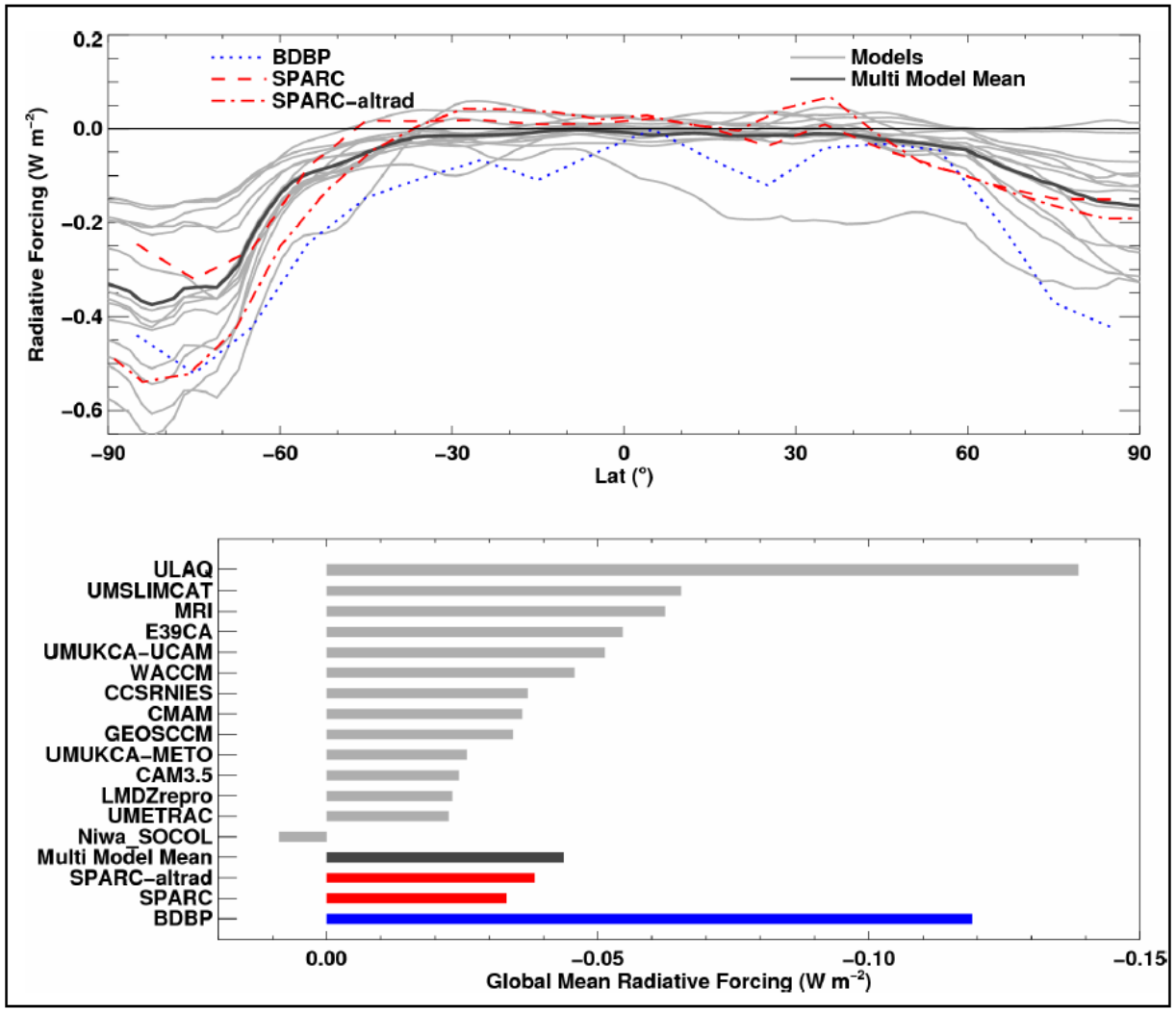


Monthly mean temperatures [K] at 30hPa



Total column ozone [DU] (integrated from the TOA to the surface)

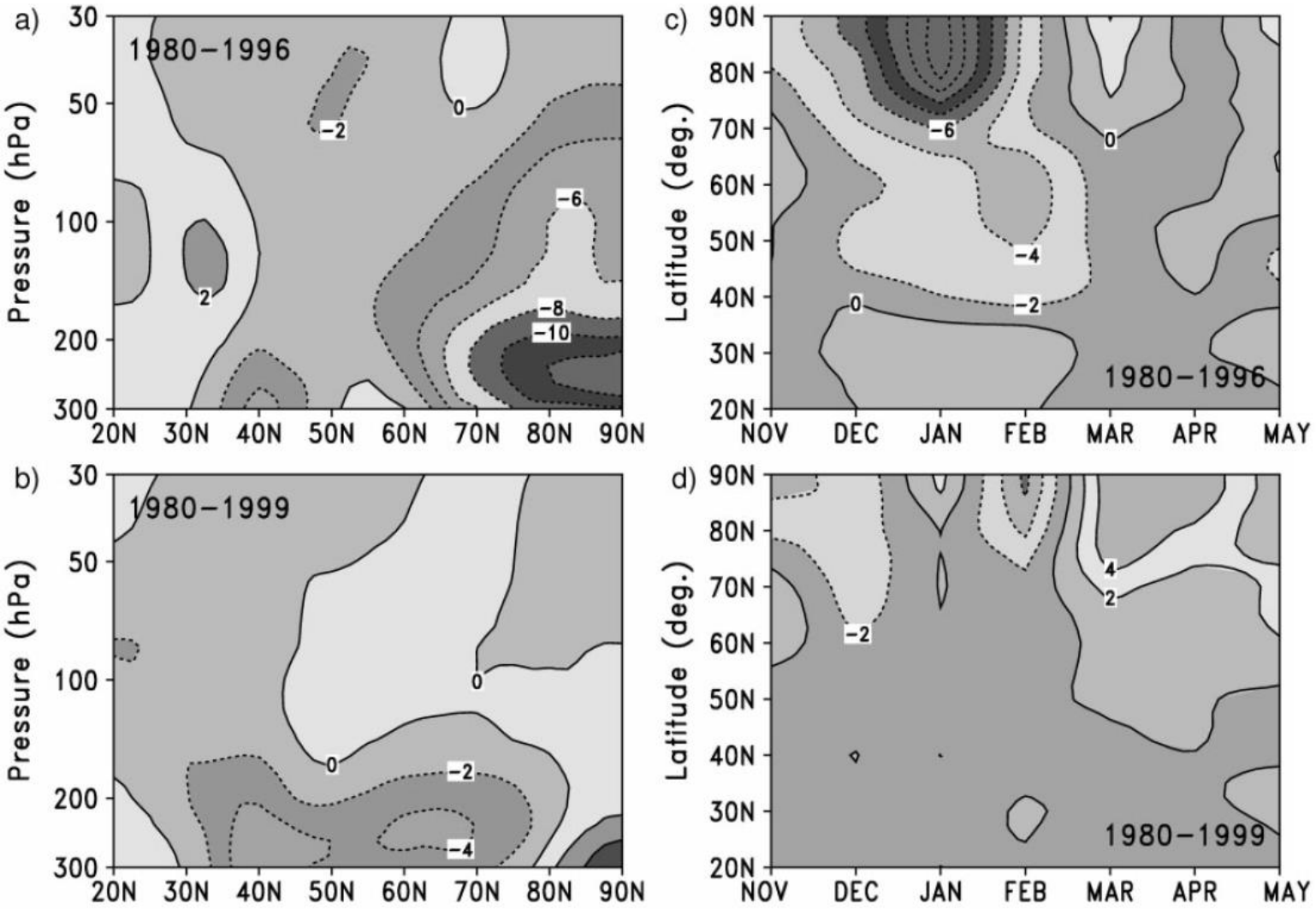
Radiative Forcing



WMO, 2014

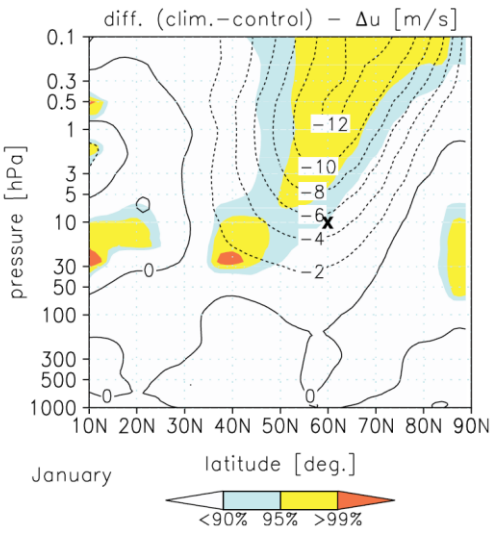
Annual mean radiative forcing due to stratospheric ozone changes between 1979–1981 and 1995–1997

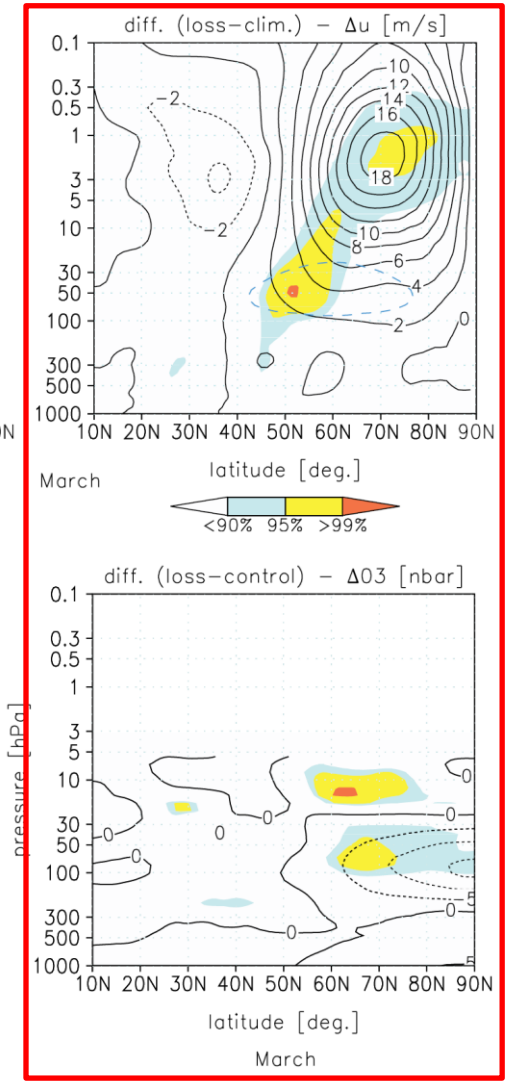
Modelled Ozone Trends

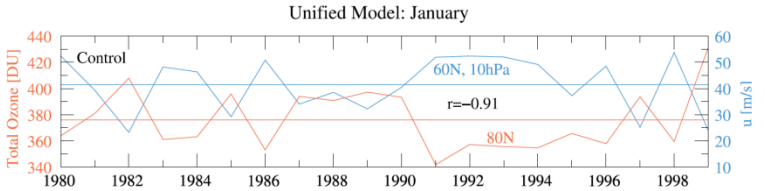


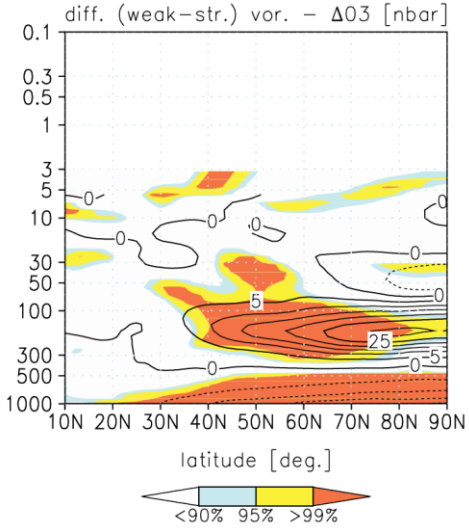
Braesicke and Pyle, QJRMS, 2004

Mid-Latitude Ozone Change



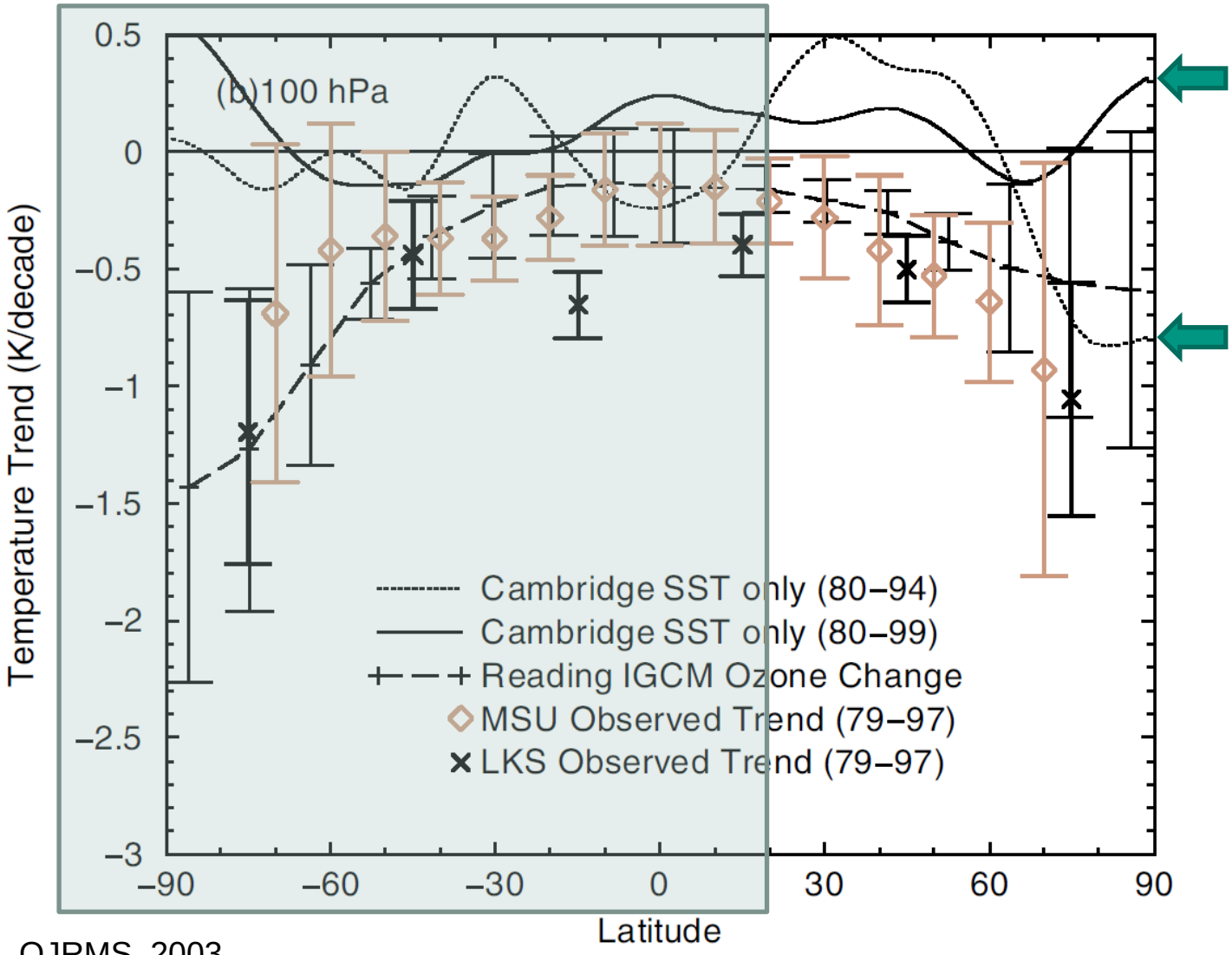






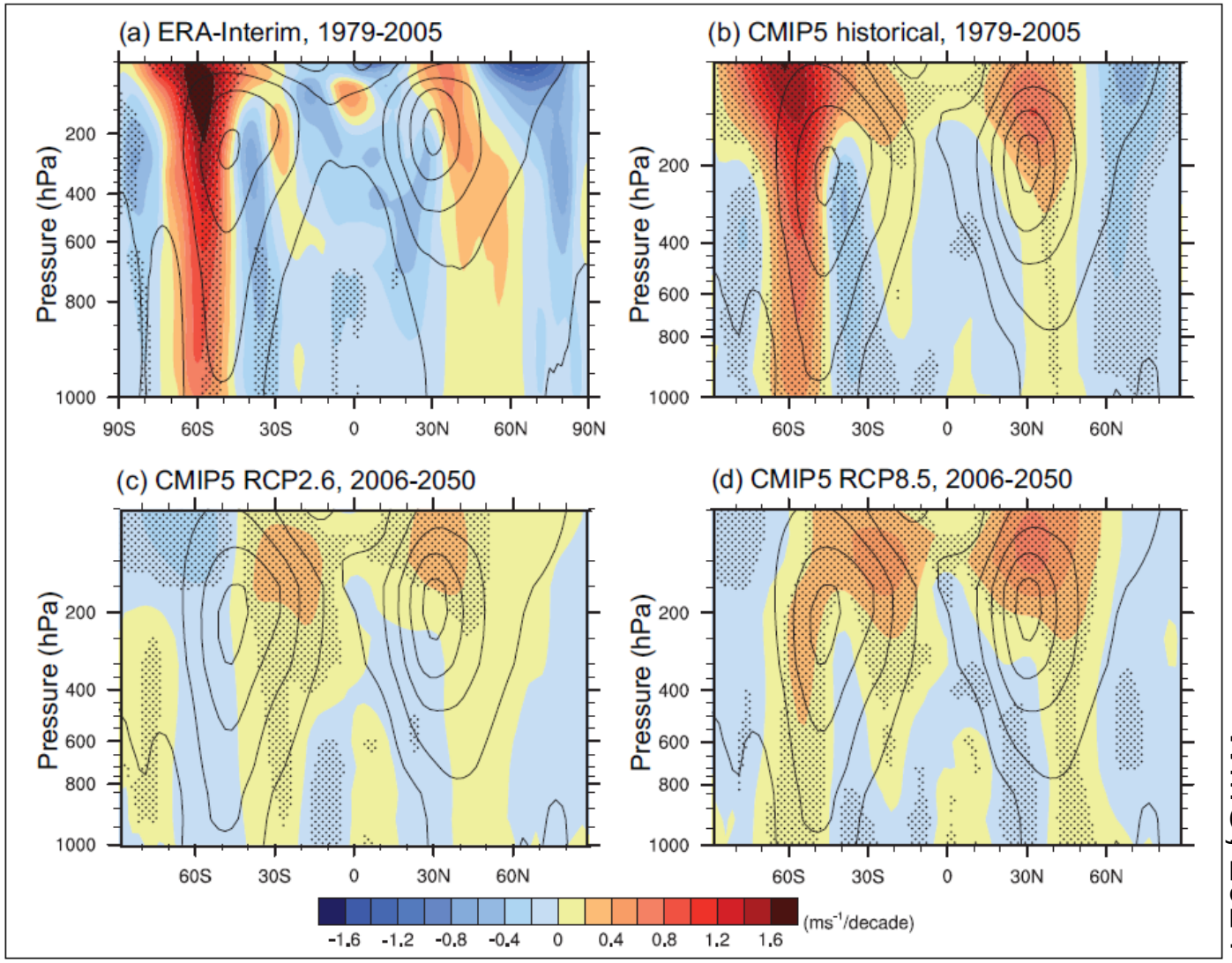
Braesicke and Pyle, GRL, 2003

Temperature Trends



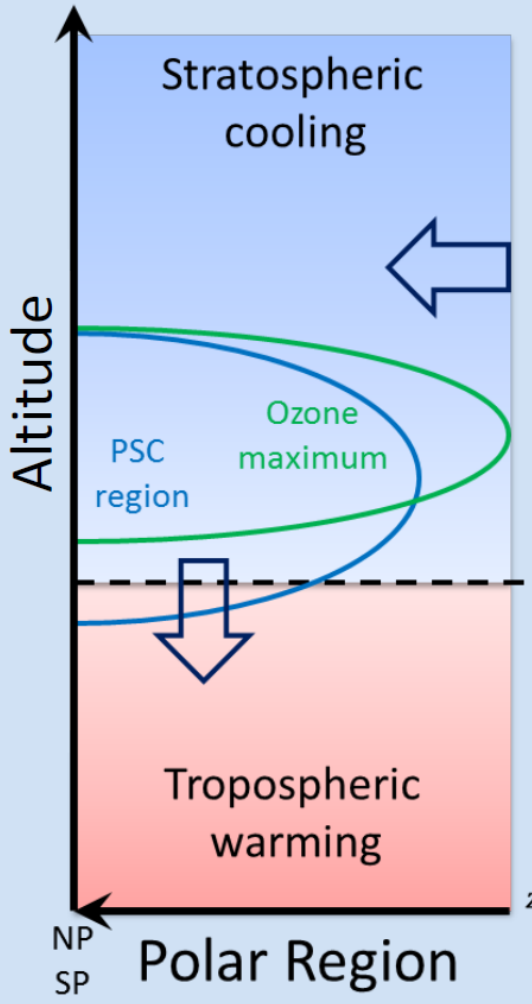
Shine et al., QJRMS, 2003

Jet Shifts



WMO, 2014

Ozone and Climate (Change)



ΔO_3

\+

GHG cause stratospheric cooling
→ Gas phase ozone destruction slows down
→ Ozone is increasing

\+

The abundance of **chlorine containing** species is decreasing
→ Less ozone is destroyed by chlorine chemistry
(sources are shrinking and transport removes chlorine from the stratosphere and redistributes ozone)

+/-

PSCs form below a threshold temperature:
In colder conditions more PSCs could be formed for longer
→ If more chlorine reservoirs can be activated ozone is decreasing
In warmer conditions less PSCs would be formed
→ Less chlorine activation would result in increasing ozone

$\int_{z=0}^{toa} O_3$

Total ozone: column integrated ozone
→ Is influenced by all mechanisms described above
Recovery: Total ozone is no longer affected by chlorine chemistry
Return: Total ozone reaches a value it had in the past (e.g. in 1980)

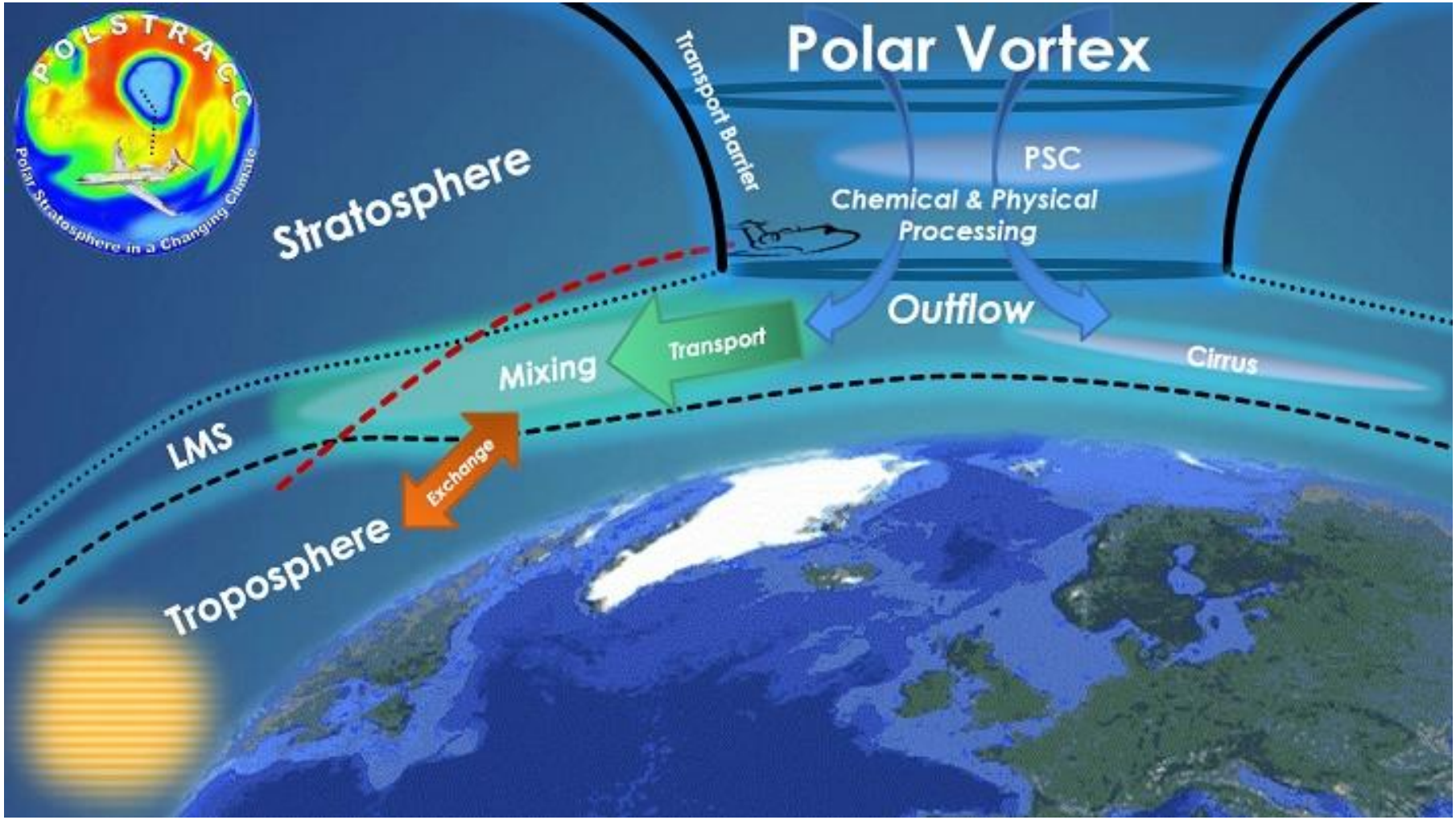
⇦ Poleward and downward transport

WMO, 2014

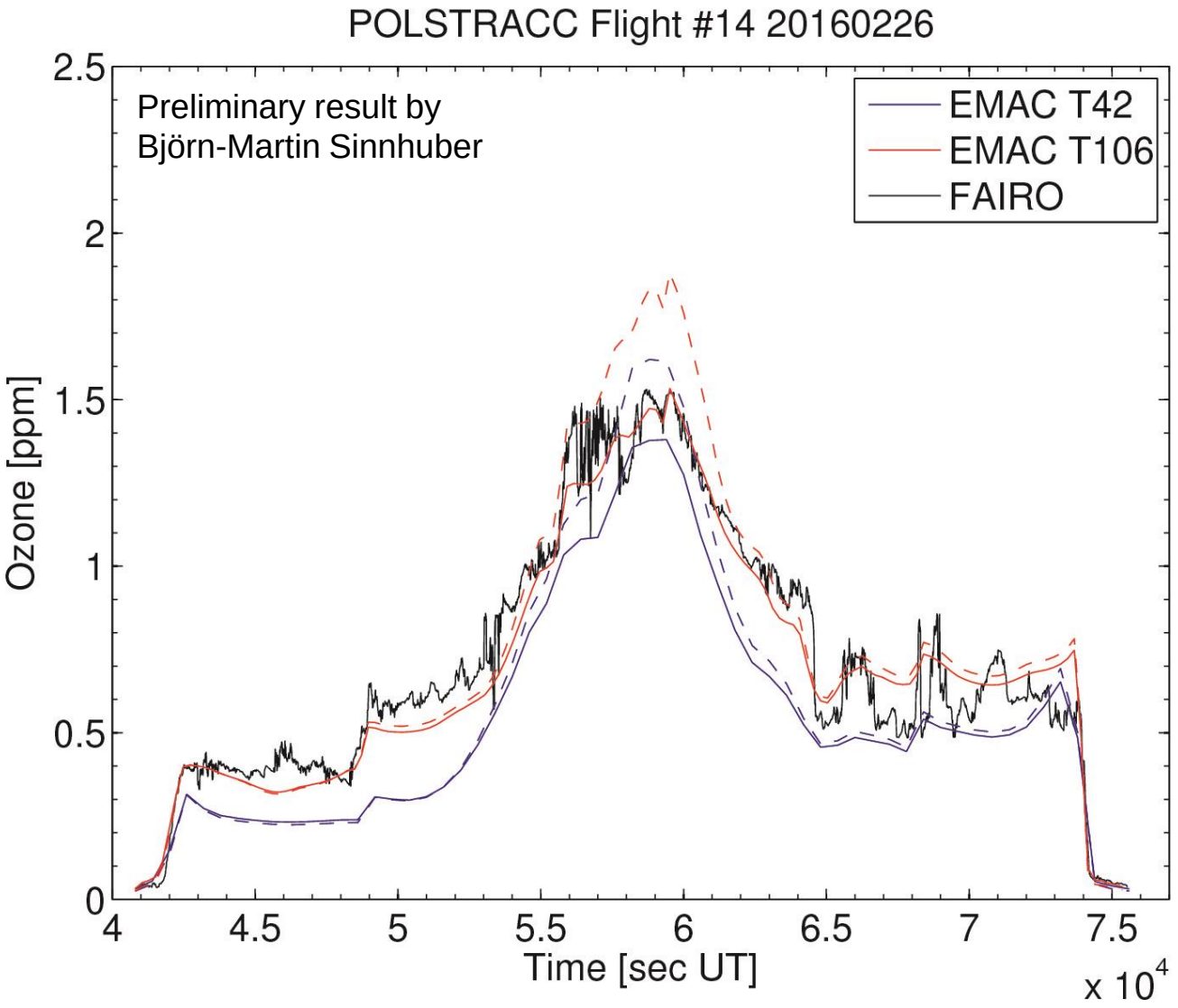
HALO Research Aircraft

Gimballed **L**imb **O**bserver for **R**adiance **I**maging of the **A**tmosphere (GLORIA)

POLSTRACC Winter 2015/16



The importance of model resolution



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Thank you for your attention!

QUESTIONS?

A GREAT WIND IS BLOWING, AND THAT GIVES YOU EITHER IMAGINATION OR A HEADACHE. *CATHERINE II OF RUSSIA (1729-1796)*