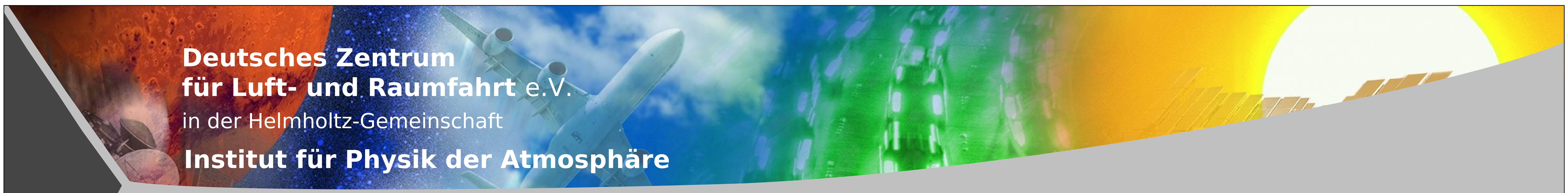

Hemispheric differences in the return of midlatitude stratospheric ozone to historical levels

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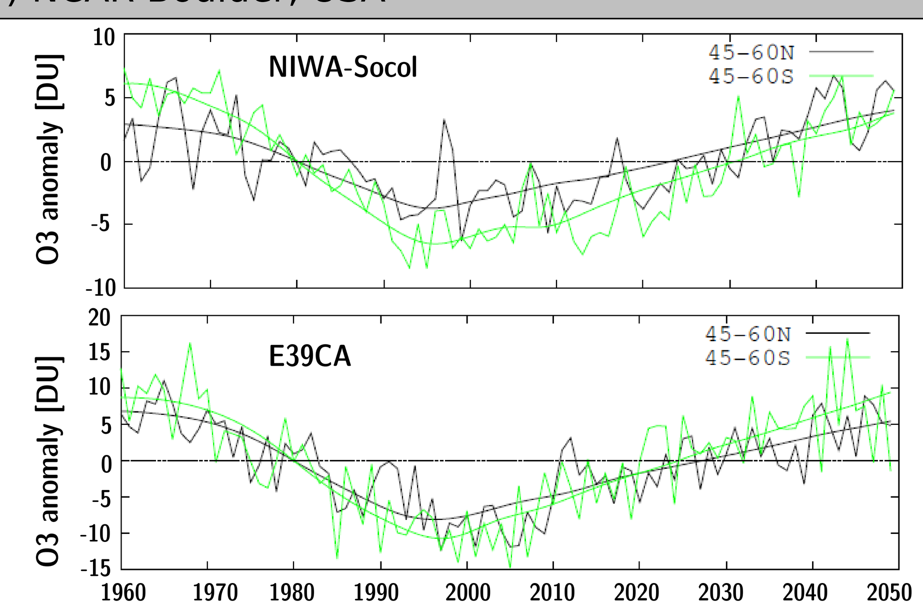
1. MOTIVATION

The return of stratospheric ozone to 1980 levels is projected to occur earlier in northern mid-latitudes than in southern mid-latitudes by many CCMs (WMO, 2010). These hemispheric differences are thought to be caused by different changes in transport in the two hemispheres. In this study, two CCMs are used: NIWA-Socol and E39CA. While the NIWA-Socol model does project different dates of return to 1980 values in the mid-latitudes of the two hemispheres, in E39CA the return dates are rather similar.

What is the cause for the earlier return of stratospheric ozone to 1980 levels in the NH in NIWA-Socol, and why does E39CA not show the hemispheric difference in the return dates?



Right: Timeseries of annual mean partial ozone column (100 to 10 hPa) anomalies relative to 1980, averaged over 45-60N (black) and 45-60S (green).

2. METHOD: Attribution of ozone changes *(For details see Garny et al., 2011, GMD)*

1.) Determination of tendencies due to transport and due to chemistry:

Production and destruction saved as model output

$$dO_3/dt = \text{Production} - \text{DestructionRate} \cdot O_3 + \text{Transport} \quad (1)$$

- Monthly O_3 tendency
- Monthly O_3 tendency due to chemistry
- Calculated as residual

2.) Attribution of year-to-year ozone changes:

Combining Equ. 1 for two periods p1 and p2 (here p1:mean 1960-69, p2: individual year) yields:

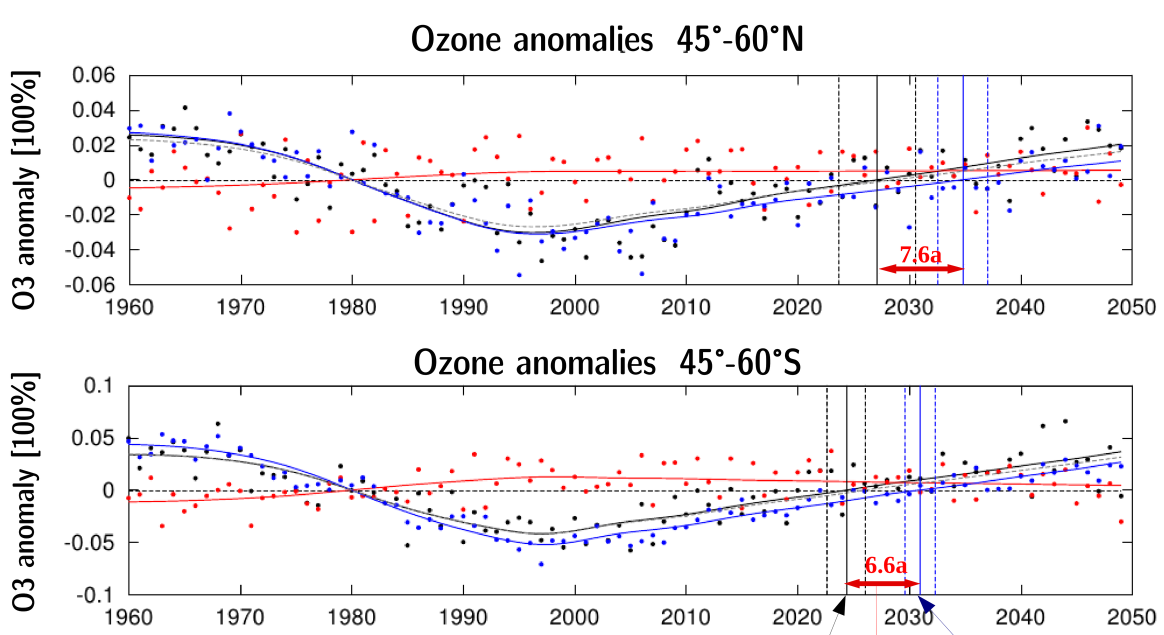
$$\frac{O_3^{p2}-O_3^{p1}}{O_3^{p1}} = \frac{D^{p1}-D^{p2}}{D^{p2}} + \frac{P^{p2}-P^{p1}}{P^{p1}+T^{p1}-\Delta^{p1}} + \frac{T^{p2}-T^{p1}}{P^{p1}+T^{p1}-\Delta^{p1}} + \frac{\Delta^{p1}-\Delta^{p2}}{P^{p1}+T^{p1}-\Delta^{p1}} + \delta D \times (\delta P + \delta T + \delta \Delta) \quad (2)$$

- Relative change in O3
- Relative change in O3 if only destruction rates would change
- ... if only production would change
- ... if only transport would change
- Term due to imbalance of ozone over the period (neglected)
- Non-linear term

3.) Apply linear regression to time series (including Trend + Cly + (QBO+Solar))

3. RESULTS

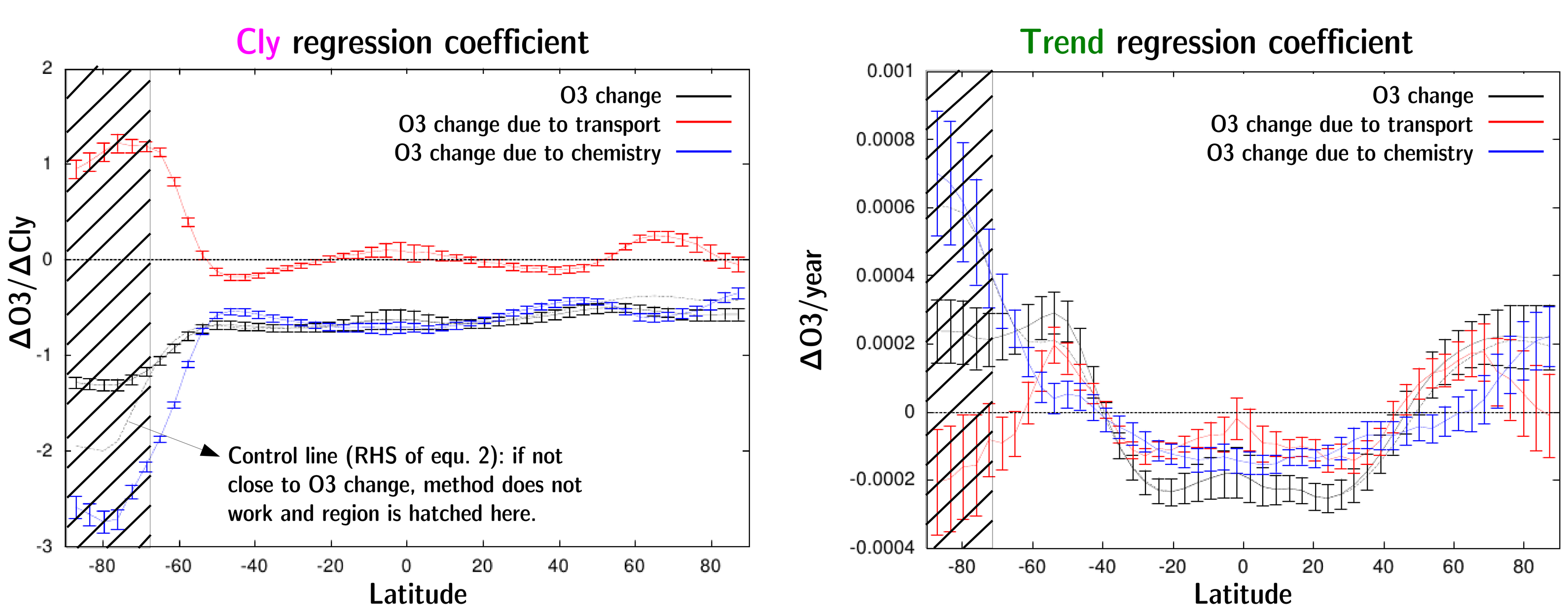
E39CA – Model without hemispheric differences



Anomalies in partial column ozone (100-10hPa) relative to 1980

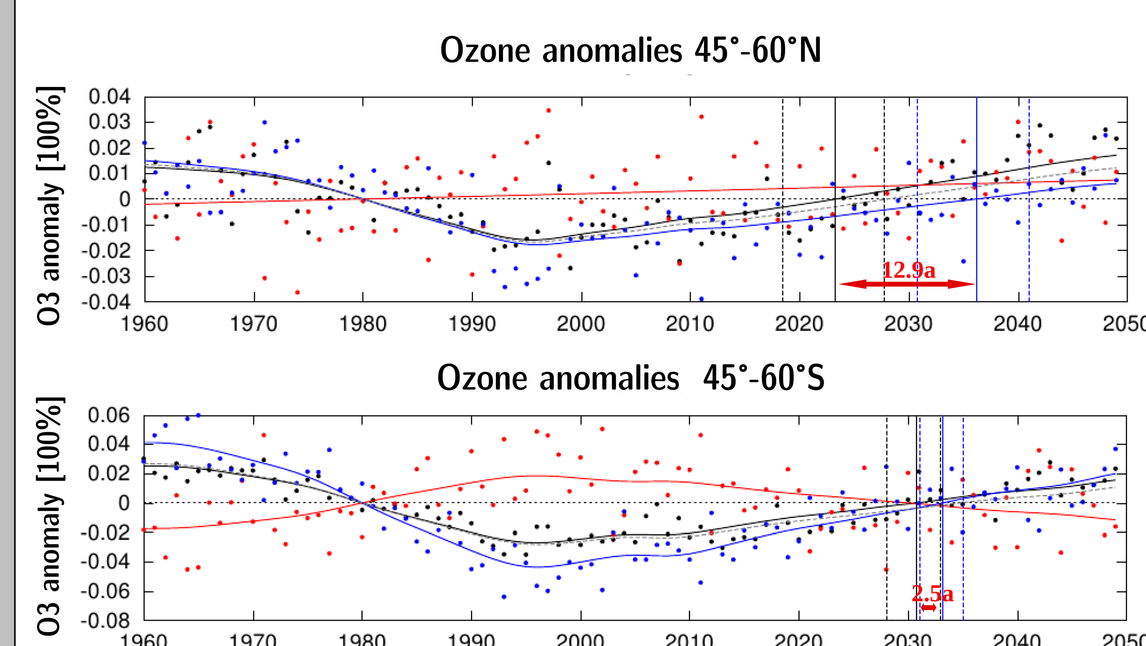
Dots: annual mean
Lines: regression fit

Black: ozone anomalies
Red: ozone anomalies caused by transport changes
Blue: ozone anomalies caused by chemistry changes



Regression coefficients of the fits of the partial column ozone time series at each latitude, showing the response to Cly changes and the trend (response to GHG changes). The error bars are the 1σ uncertainty on the coefficients. Cly increases cause ozone decreases, which are largely due to chemistry (blue), with some modifications by transport (red). There is a negative ozone trend in the tropics and positive in mid-latitudes, in large parts caused by transport changes.

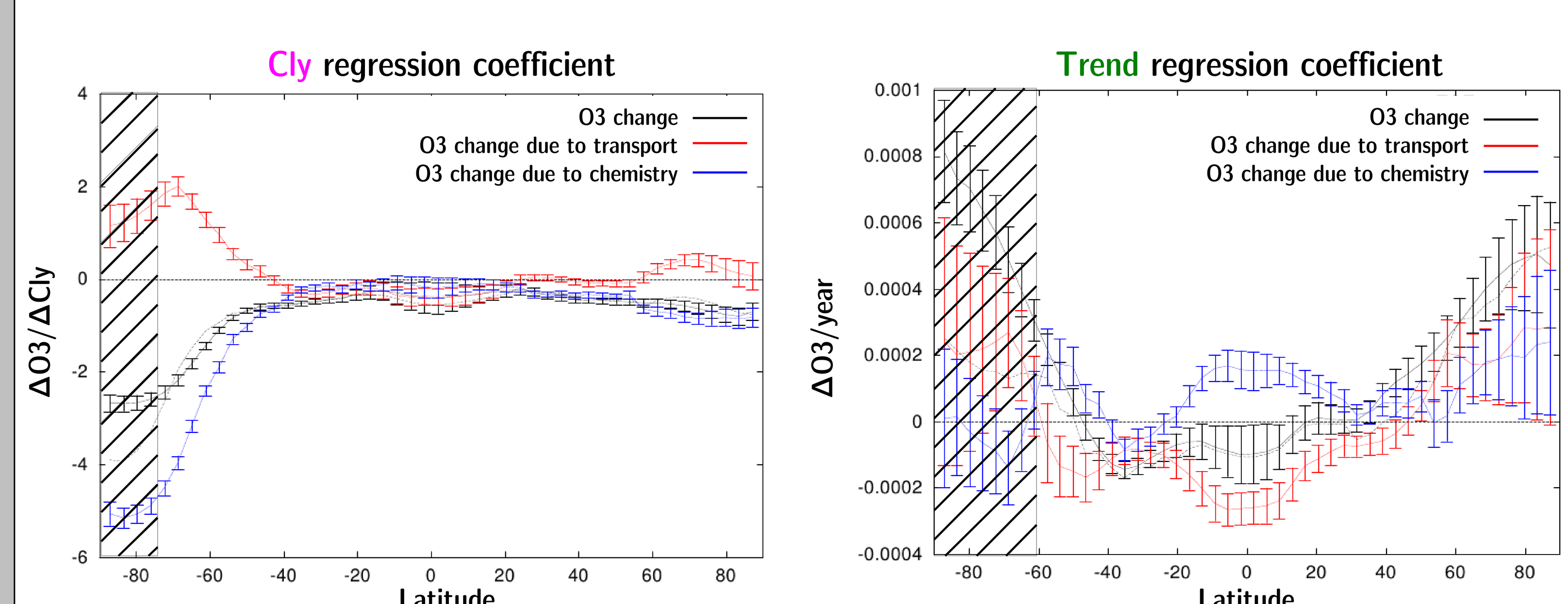
NIWA-Socol – Model with hemispheric differences



As in the left box but for NIWA-Socol.

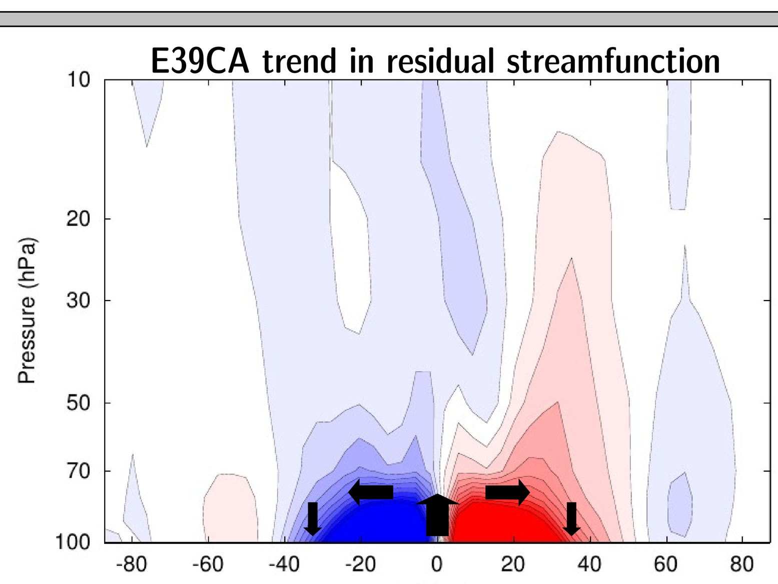
Difference in return dates NH-SH: 7.4 years

Difference in return dates NH-SH caused by transport: 10.4 years

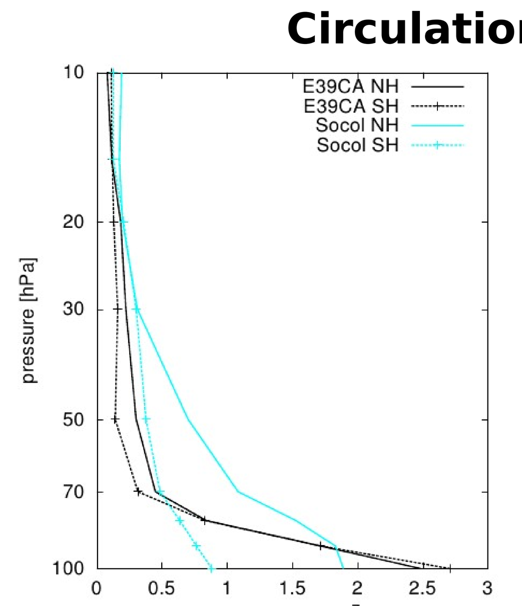


As on the left but for NIWA-Socol. The differences in Cly-coefficients between Niwa-Socol and E39CA are due to the absence of the layer above 10 hPa in E39CA. While there appears to be a negative trend due to transport in NIWA-Socol as in E39CA in the tropics, the influence of transport on ozone trends is positive only in the northern mid-latitudes in NIWA-Socol.

Circulation changes

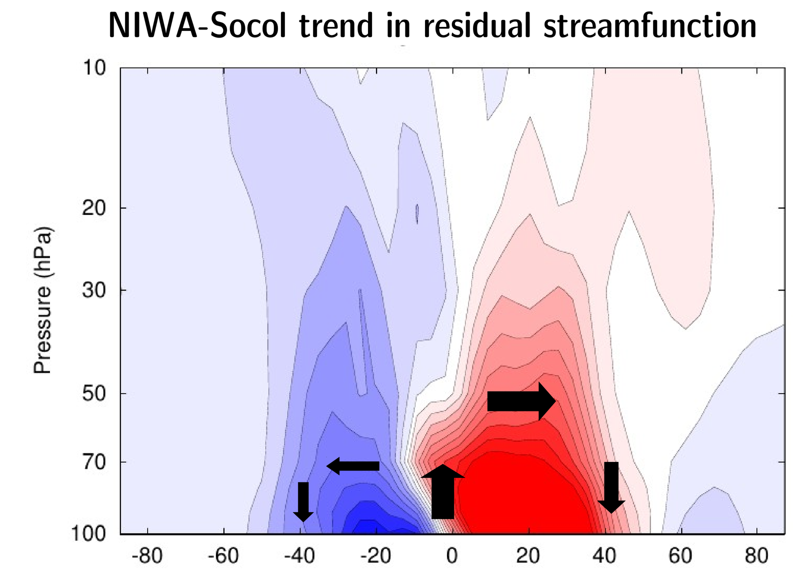


Linear trend over 1960 to 2049 in the streamfunction of the residual circulation, Positive values are shown in red, negative values in blue.



Left: Trends in the maximal strength of the residual streamfunction in the northern and southern hemisphere as a function of height.

In E39CA, the circulation changes are confined to the lowermost stratosphere, but are about the same in the NH and SH. In NIWA-Socol, the changes are higher-reaching, but overall weaker in the SH compared to the NH.



As on the left but for NIWA-Socol

4. CONCLUSIONS

Mid-latitude ozone **return dates are affected by transport changes.** Return dates are generally earlier compared to the case of chemistry changes only. In Niwa-Socol, the hemispheric differences in **transport changes cause the hemispheric differences in return dates.** In E39CA, transport effects on ozone are about equally strong in both hemispheres, leading to small hemispheric differences in return dates.

The hemispheric and inter-model differences in transport effects are **associated with differences in the residual circulation**. In E39CA, ozone trends are affected by transport changes in a similar magnitude as in NIWA-Socol despite the shallow circulation changes. However, E39CA **lacks hemispheric differences in the residual circulation trends which results in the absence of hemispheric differences in return dates**. We speculate that the deficit of more pronounced circulation changes in the NH in E39CA result from an improper gravity wave drag scheme.

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