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Modeling Tropospheric Impacts of the Arctic Ozone Depletion 2011

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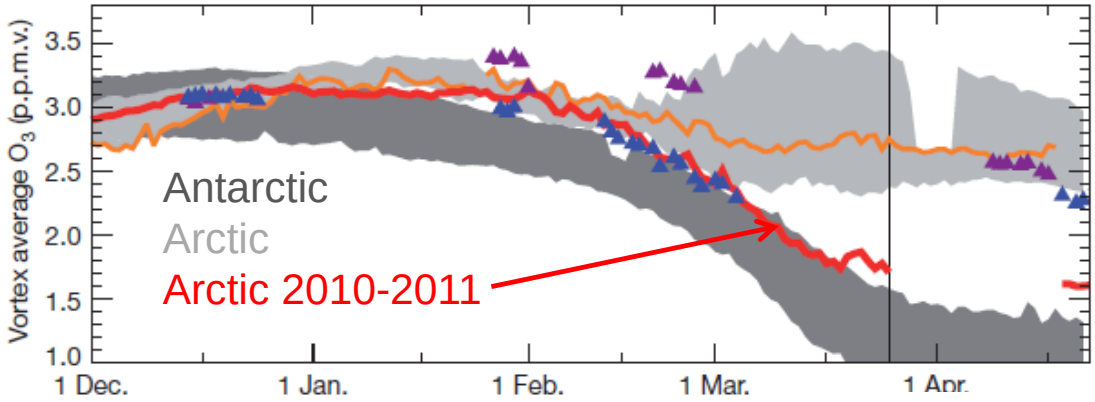
Stratospheric ozone and troposphere

- There is a strong two-way coupling between stratospheric and tropospheric circulation anomalies
- Ozone anomalies impose radiative forcing which can alter stratospheric and tropospheric circulation
  - ✓ In the Southern Hemisphere, Antarctic ozone hole caused a poleward shift of the tropospheric jet during summer over the last three decades
- The largest ozone depletion in the Arctic occurred in spring 2011
- Did Arctic ozone depletion 2011 impact the tropospheric circulation?

Arctic winter/spring 2011

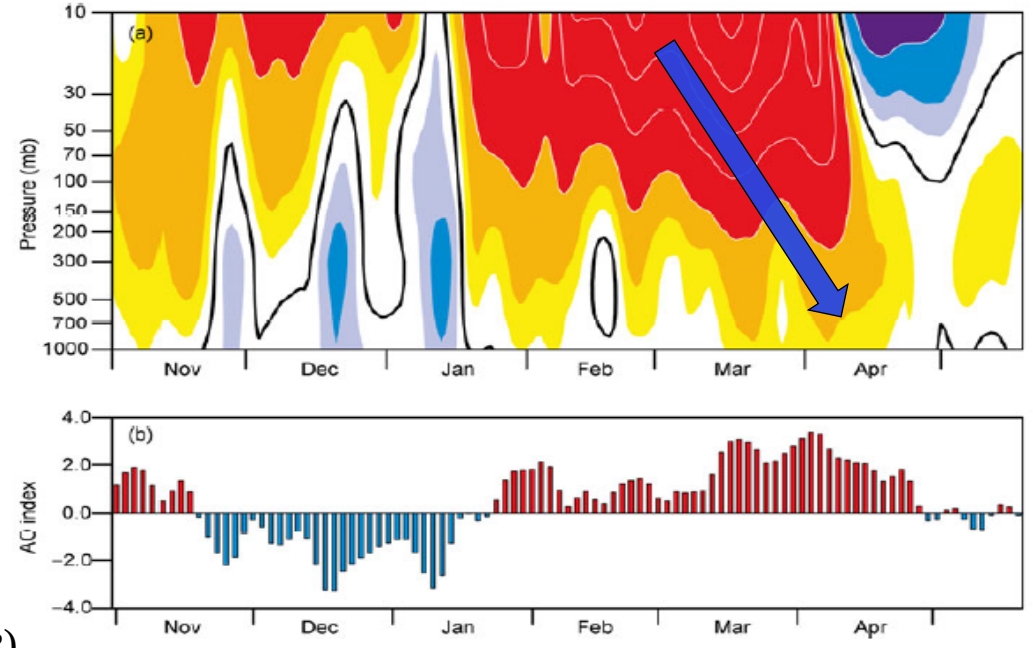
Ozone



(*from Manney et al. 2011*)

- Arctic ozone in 2011 was well below typical Arctic values and almost reached the Antarctic values

NAM index



- Polar vortex was very strong from January to early April (see e.g. Manney et al. 2011, Hurwitz et al. 2011, Strahan et al. 2013)
- Tropospheric circulation was characterized by positive NAO/NAM anomalies
- April NAO/NAM indexes was record large in NOAA/CPC records since 1950 (2.48/2.27 std)

(*from Hu and Xia 2013*)

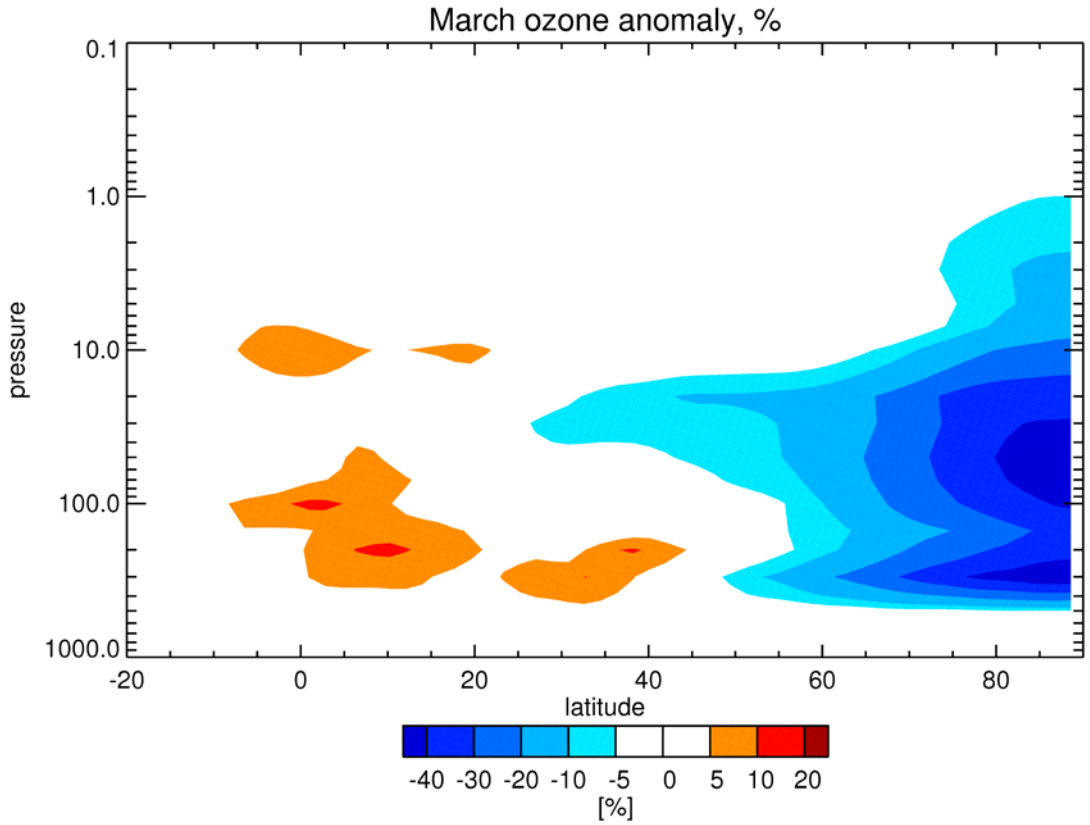
Model experiments

Four experiments with **AGCM ECHAM5** (T63L47) model:

	Duration	SST/SIC	O3
CONTR	50 years	AMIP2 climatology	Fortuin-Kelder climatology
R-O3	50 runs from Sep 1 to Apr 30	As in CONTR	Fortuin-Kelder + MERRA 2010/2011 anomaly
R-SST	50 runs from Sep 1 to Apr 30	AMIP2+HadISST 2010/2011 anomaly	As in CONTR
R-ALL	50 runs from Sep 1 to Apr 30	AMIP2+HadISST 2010/2011 anomaly	Fortuin-Kelder + MERRA 2010/2011 anomaly

Results reported in Karpechko, Perlwitz and Manzini, submitted to JGR

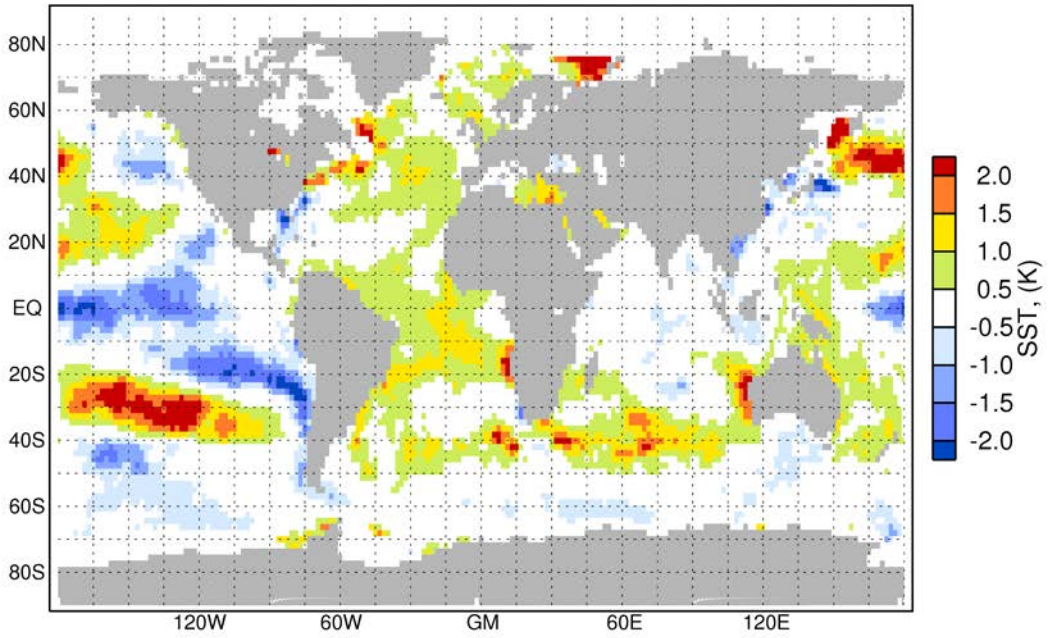
Prescribed ozone anomaly



- Prescribed ozone anomalies include both chemistry and transport effects
- Prescribed anomaly peaks in mid-March, about two weeks earlier than the observed one → the dynamical response may also be expected earlier

Prescribed SST anomaly

January-March



- La Niña conditions
- Positive SST anomalies in sub-polar Pacific (see Hurwitz et al. 2011,2012)

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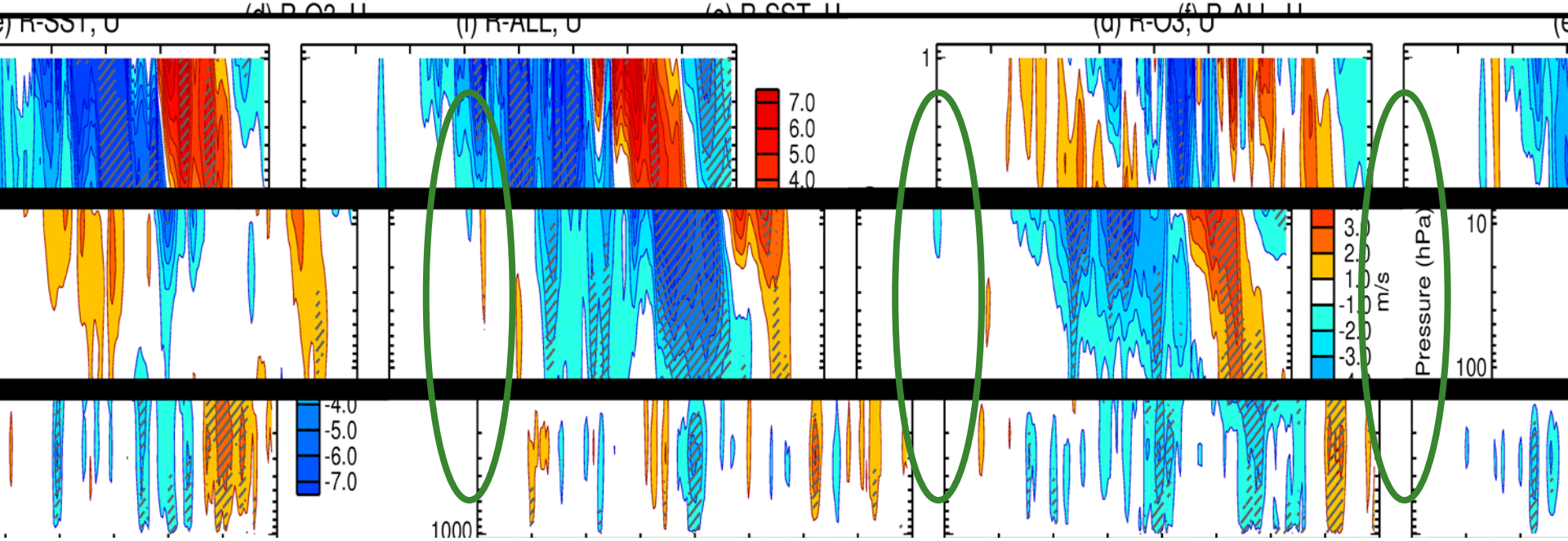
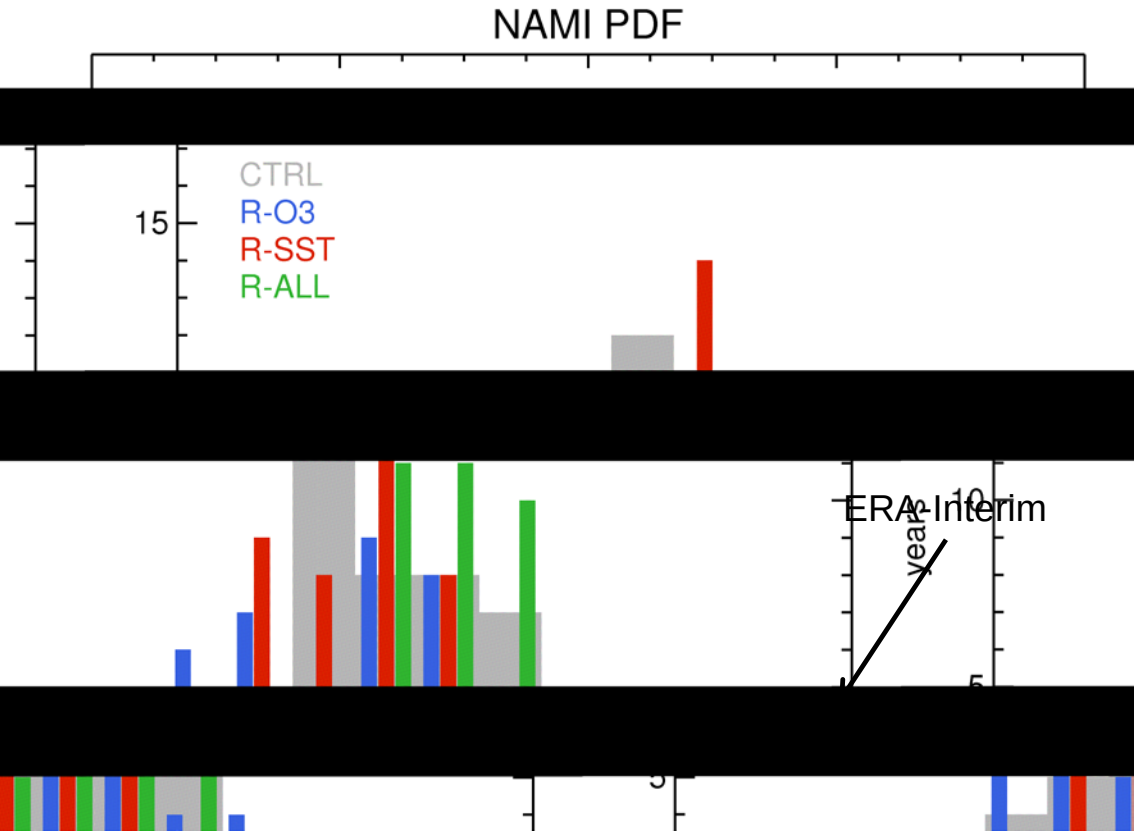
Mid-latitude (50°-70°N) zonal wind response



- Strengthening of the westerly stratospheric winds and downward anomaly propagation to the troposphere in March/April is simulated in all experiments
- The strongest response is simulated in the R-ALL experiment
  - ✓ *R-ALL response is stronger than the sum of R-O3 and R-SST, ask for more details*
- E.g. the mid-March/mid-April response at 1000hPa: R-O3 -0.02m/s; R-SST 0.17m/s; **R-ALL 0.33m/s**

500-hPa NAM response, mid-March/mid-April

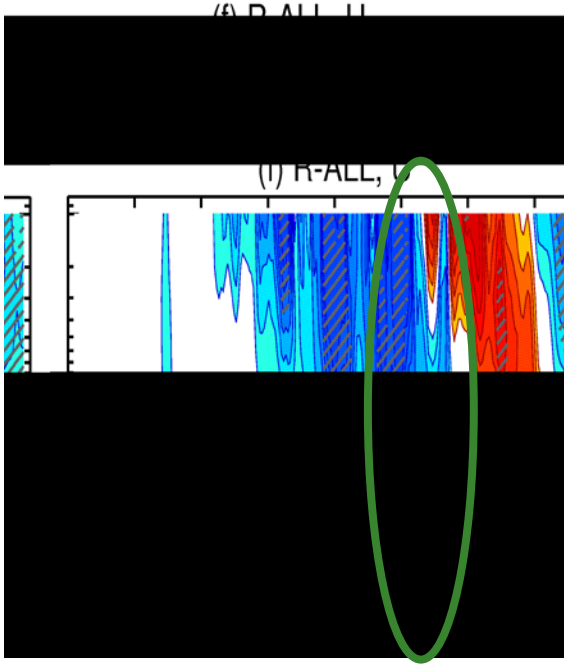


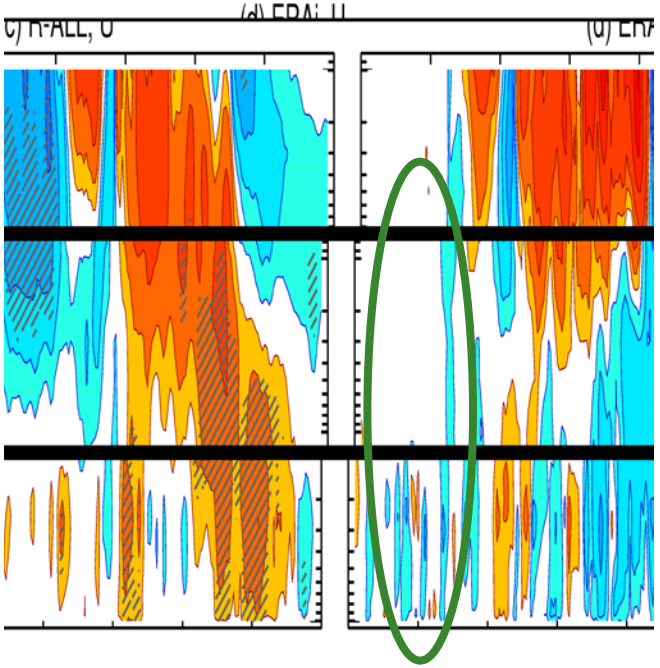
Mean and extreme NAM responses

	Mean	<-1σ years	>1σ years
CONTR	-	8	9
R-O3	0.04 (0.85)	10	11
R-SST	0.17 (0.38)	3	8
R-ALL	**0.45 (0.03)**	5	15

- Significant month-lasting positive NAM response is only simulated in R-ALL
- The probability of large positive NAM events (>1σ) is strongly enhanced in R-ALL.
- The observed event is >2σ. Which conditions do enhance the probability of extreme events?

Extreme NAM events





- Forced positive NAM signal appears in lower stratosphere/troposphere in mid-March
- During most extreme simulated positive NAM events, a positive NAM signal *pre-existed* in lower stratosphere/troposphere before mid-March, as did happen in winter/spring 2011

Summary

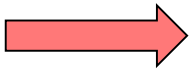
- A record large positive tropospheric NAM event was observed in April 2011 following the occurrence of the record large Arctic ozone depletion

- ECHAM-5 forced by the observed ozone anomaly simulates only weak tropospheric circulation response

- When the model is forced by both ozone and lower boundary (SST/SIC) anomalies, a significant, month-lasting shift of the tropospheric circulation towards a positive NAM phase, and increased probability of occurrence of large positive NAM events are simulated

- R-ALL response is stronger then the sum of R-O3 and R-SST

- Extreme magnitude of the observed tropospheric NAM event was likely related to a preconditioning



Prediction of extreme tropospheric anomalies such as that in April 2011 requires models that include interactive stratospheric ozone chemistry