Elevated Stratopause Events in the Current and a Future Climate: A Chemistry-Climate Model Study

J. Scheffler[1], **B. Ayarzagüena**[2], Y. Orsolini[3,4], U. Langematz[1]

[1] Institut für Meteorologie, FU Berlin, Germany; [2] University Exeter, UK;
[3] Norwegian Institute for Air Research, Kjeller, Norway; [4] University of Bergen, Norway

Introduction

The polar winter stratopause is controlled by the residual circulation (RC) which in the mesosphere is controlled by gravity waves (GWs) whose propagation is influenced by planetary waves (PWs). During a sudden stratospheric warming (SSW), the propagation conditions for PWs and GWs are modified which changes the driving of the RC by wave dissipation and thus its strength and directions. Due to these changes in the RC, a large vertical displacement of the stratopause can occur after some SSWs (e.g. [1]). When the polar vortex re-establishes, the RC is rebuilt at lower mesospheric heights and the stratopause re-establishes at these heights.

Model and Method

The simulations were performed with the ECHAM/MESSy Atmospheric Chemistry (EMAC) model [2] in T42L39 configuration with the model top at 0.01 hPa.

simulation	GHGs	ODSs	years
REF2000	OBS	OBS	38
REF2095	A1B	A1	39

Natural forcing by solar variability and volcanoes are not included, an average QBO was used.

SSW definition: $\overline{u}$ at 60°N < 0 & $T_{90-60} > 0$ at 10 hPa .

Stratopause detection: $dT/dz(z_0) > 2K/km$ and $dT/dz(z_0+1) \geq dT/dz(z_0)$.

ESE definition: The strongest 5% of daily changes in stratopause height.

SSW-only events: SSWs that were not followed by an ESE.

Detected events

simulation (# of winters)	REF2000 (38)	REF2095 (39)
All SSWs (in %)	31 (81)	33 (85)
ESEs (in %)	11 (29)	17 (44)
SSWs-only (in %)	20 (52)	16 (41)
split/displ for ESEs	0.38	0.31
split/displ for SSWs-only	0.25	0.6

Conclusion

We have shown that the EMAC CCM is able to reproduce the main characteristics of ESEs. Persistent tropospheric forcing is more relevant for ESEs than its wavenumber decomposition. ESEs are projected to be more frequent and persist for a shorter period of time at the end of the 21st century.

Acknowledgements

This work was funded by the DAAD within a German Norwegian project and the BMBF within the project MiKlip - FASTO3. We would like to thank the North-German Supercomputing Alliance (HLRN) for computing time and support.

ESEs in EMAC

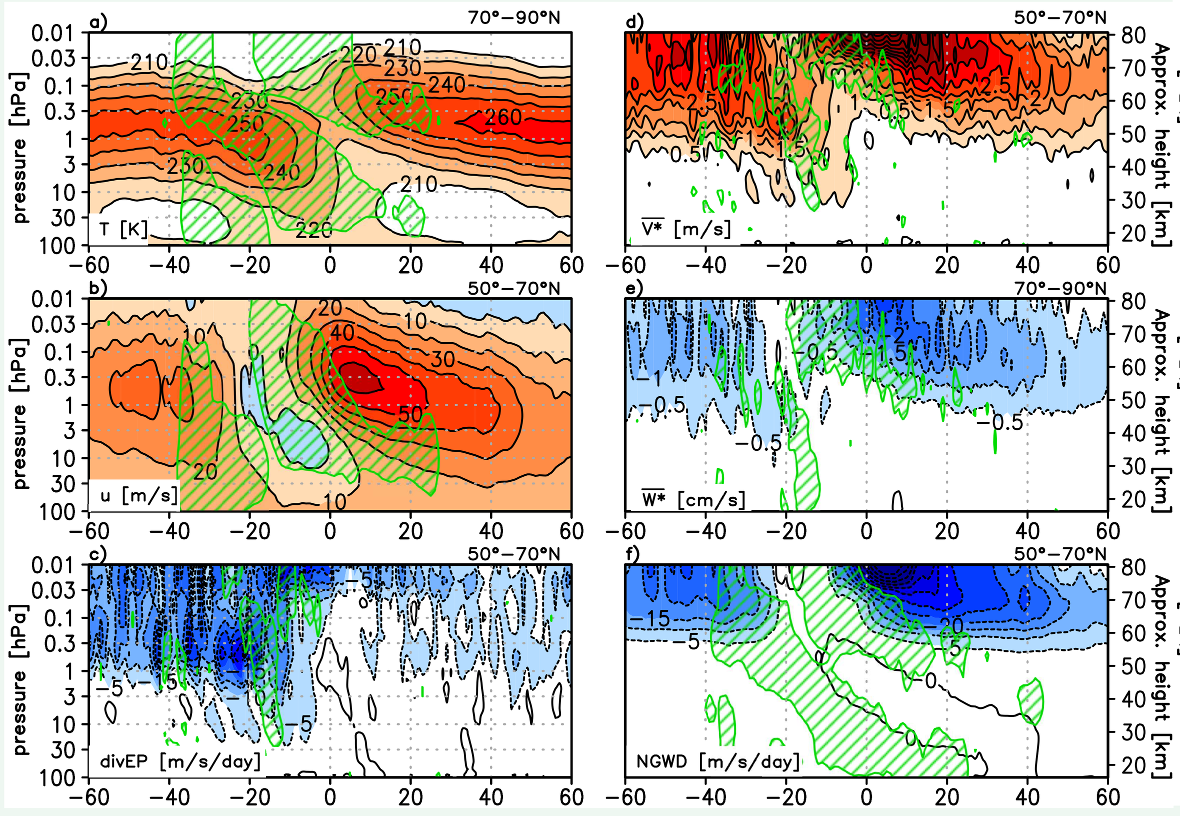

Figure 1: *ESE composit for REF2000 simulation. Green hatching: area statistically significantly different from SSW-only events at a 95% confidence level.*

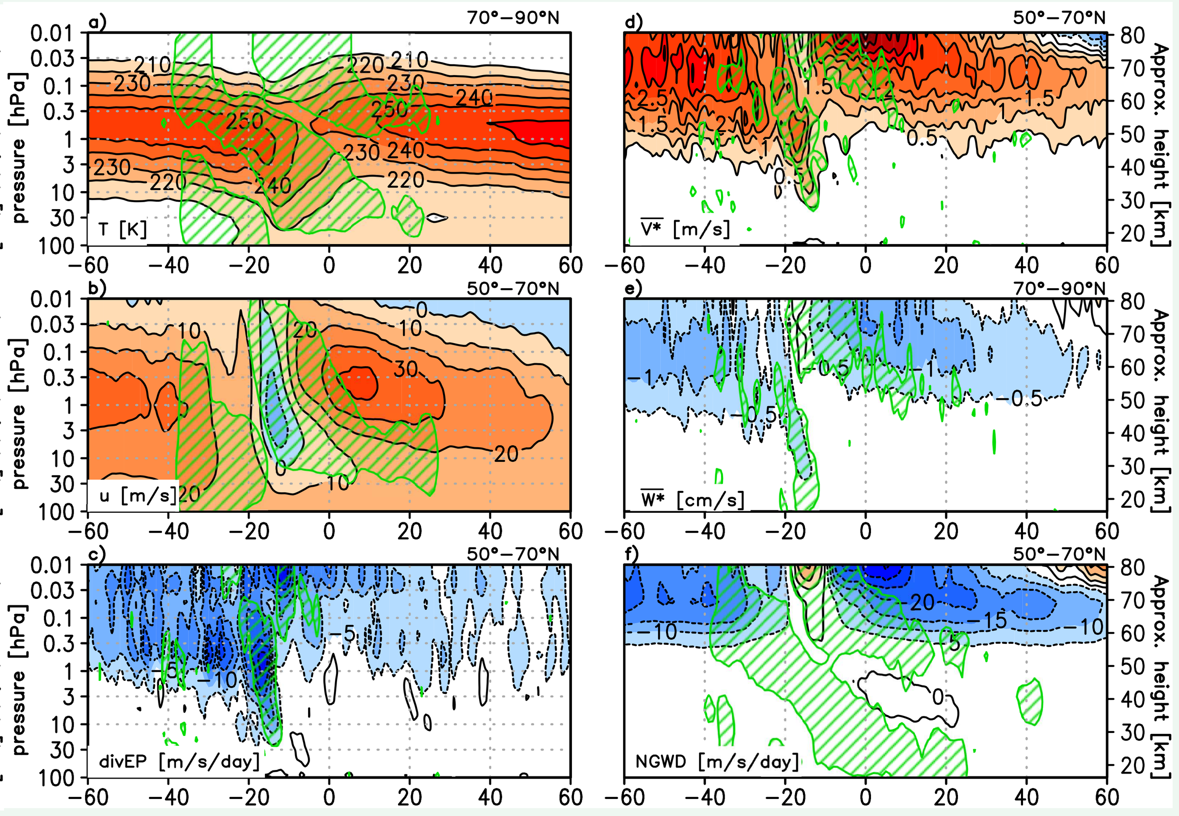

Figure 2: *As Fig.1, but for SSW-only composit.*

- **State of the polar vortex before events:** polar vortex in climatological state before ESEs, but weakened before SSW-only events
- **Tropospheric forcing:** weaker but more persistent forcing by PWs for ESEs.
- **Evolution of temperature and wind structures during events:** slower downward propagation of structures, longer reversal of zonal-mean zonal wind in the lower stratosphere (LS) for ESEs;
  more abrupt and simultaneous wind reversal in stratosphere and lower mesosphere for SSW-only events.
- Prior and after ESE, RC mainly driven by GWs, around ESE onset by PWs and GWs

Future changes in ESEs

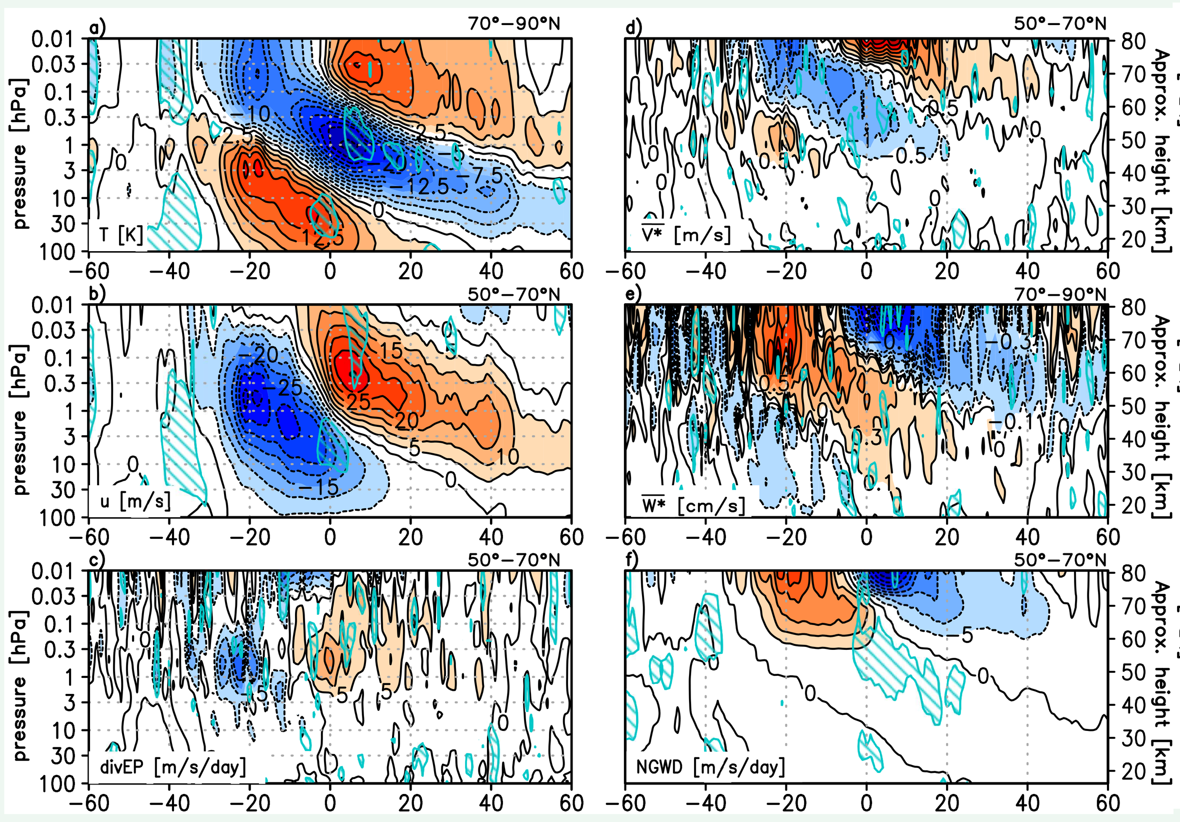

Figure 3: *As Fig. 1, but for anomalies from the daily mean climatological field. Blue hatching: anomalous ESE composite for REF2000 significantly different from REF2095.*

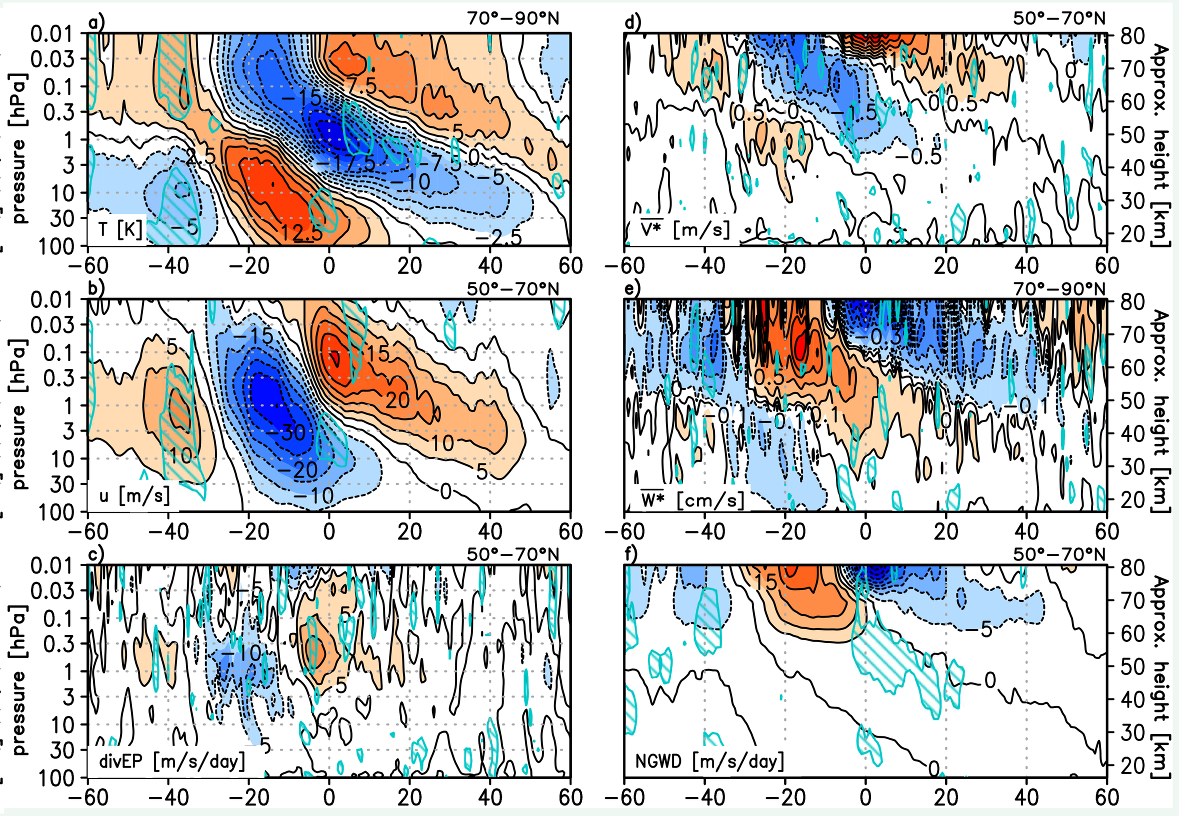

Figure 4: *As Fig. 3, but for ESEs in the REF2095 run.*

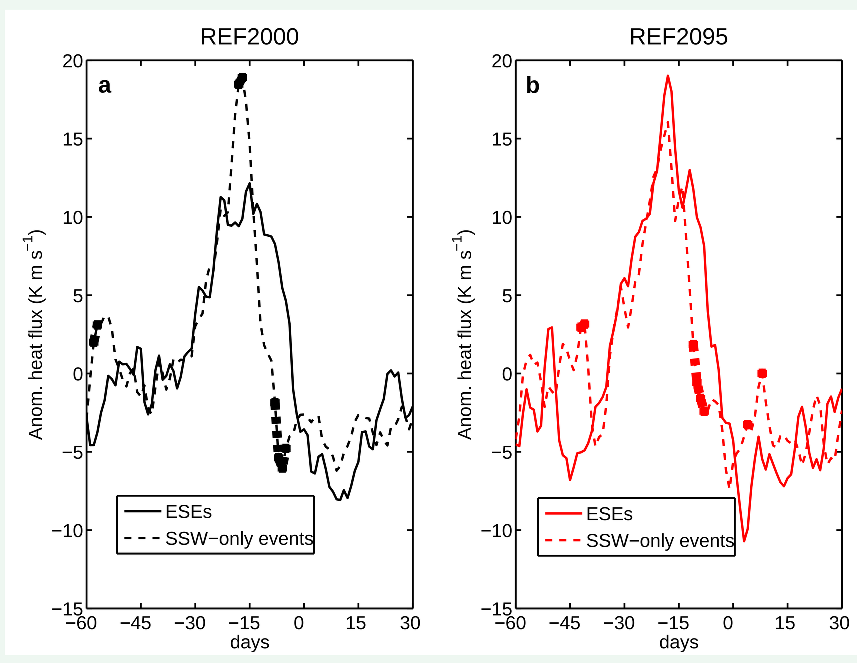

Figure 5: *Composite daily heat flux anomaly [K/ms] average between 45° and 75° N at 100 hPa around the date of the ESE for (a) the REF2000 and (b) the REF2095 run. Thick lines: ESE values are significantly different from SSW-only values at 95% confidence level.*

- **State of the polar vortex before events:** future ESEs preceded by strong polar vortices, reflected in negative tropospheric forcing -45 to -30 days prior to the ESE onset
- **Tropospheric forcing:** stronger but shorter tropospheric forcing for ESEs → stronger deceleration of ESEs
- **Evolution of temperature and wind structures during events:** positive temperature anomalies prior to ESE onset descend faster and ESEs are shorter
- Strong easterlies affect NGW filtering resulting in a weaker and short anomalous eastward circulation in the USLM → stratopause descends to a lower altitude

References

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SHARP 2016 February 16 - 19, Berlin contact: janice.scheffler@met.fu-berlin.de