Future changes in Elevated Stratopause Events

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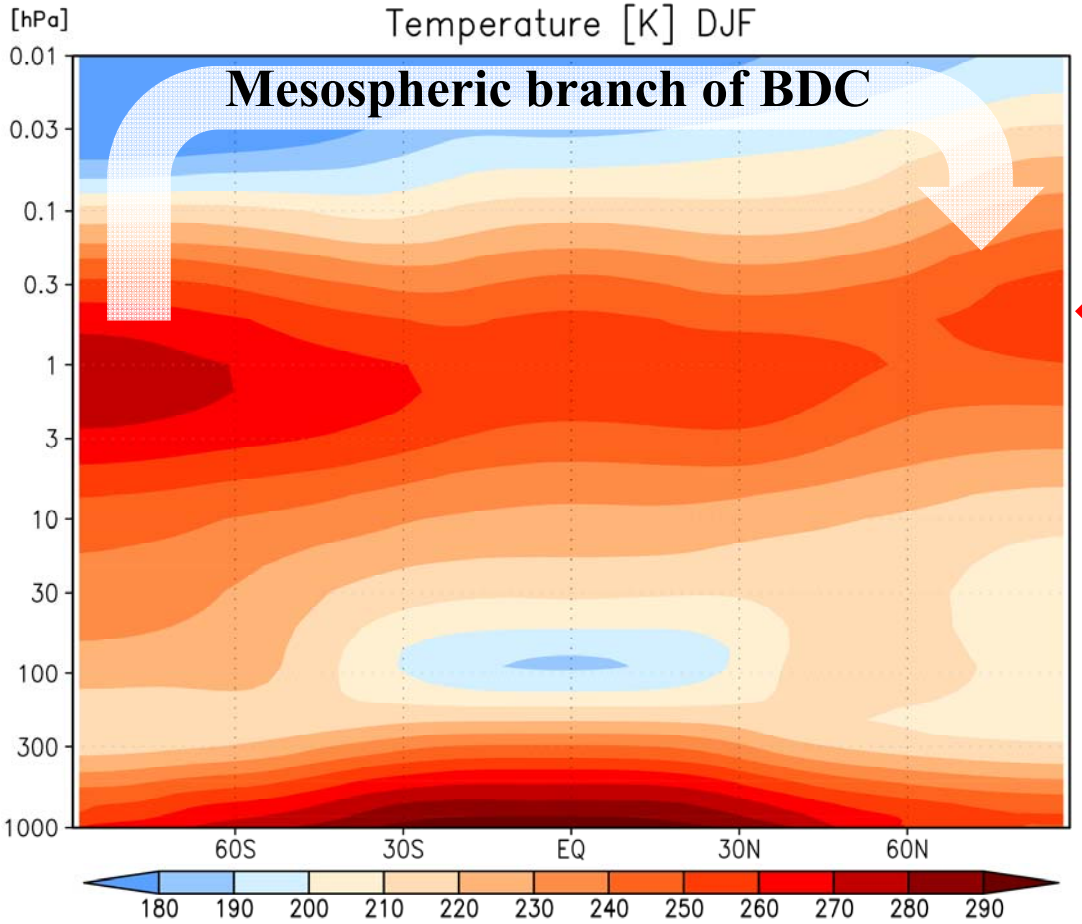
Formation of the stratopause

Summer hemisphere: UV absorption by ozone



Adiabatic heating

Winter hemisphere: Adiabatic heating by downward branch of BDC (*Hitchman et al.*, 1989)

Interaction of atmospheric layers

In winter hemisphere:

atmospheric layers coupled with each other

Mesospheric cooling

Elevated Stratopause Events (ESEs) ⇨

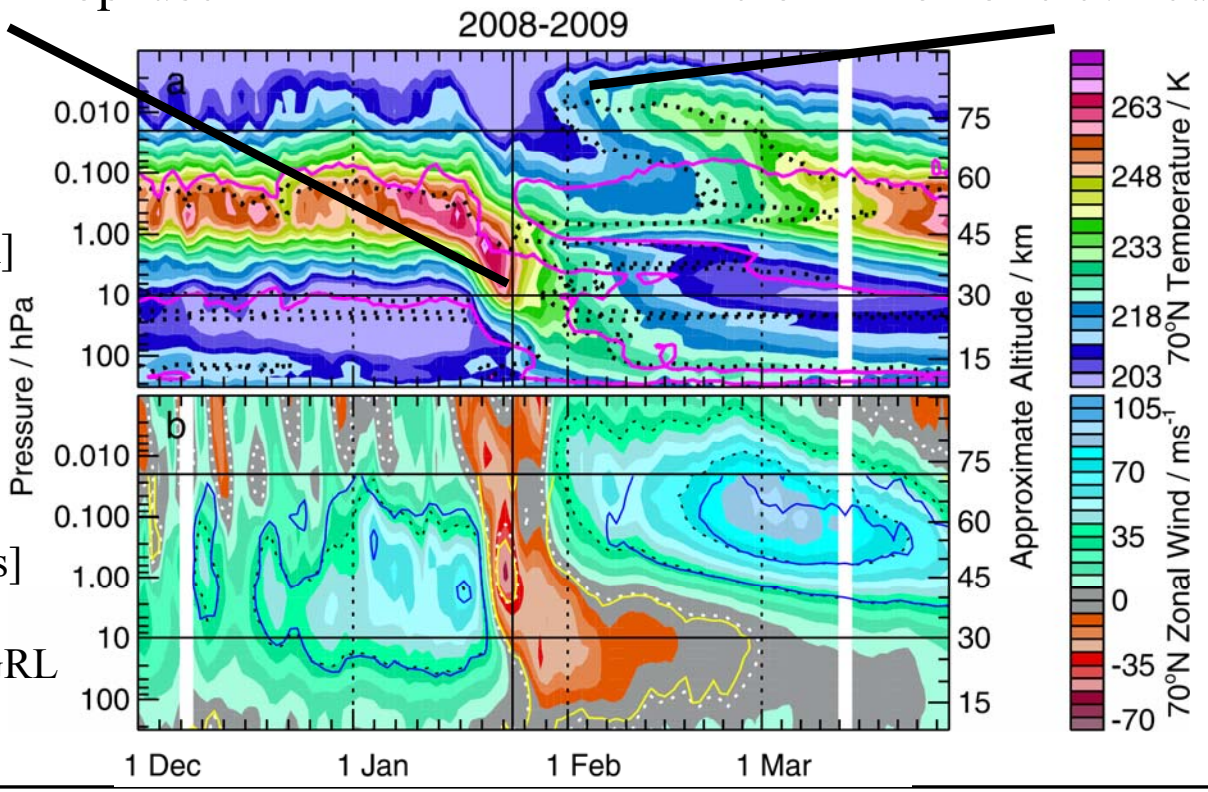
- After some SSWs (mostly prolonged SSWs)
- Large vertical displacement of stratopause into mesospheric heights

Sudden Stratospheric Warmings (SSWs)

What do we know about ESEs?

Plunging of old stratopause down to 30 km

Reformation of elevated stratopause near 75 km



Temperature [K]

Zonal Wind [m/s]

Manney et al., 2009, GRL

We adress the following question:

Will the characteristics of ESEs change in a changing climate?

Data

- ECHAM/MESSy Atmospheric Chemistry Model (EMAC) *(Jöckel et al., 2006)*
- Chemistry-Climate Model (CCM) with FUBRad-Radiation parameterisation *(Nissen et al., 2007)*
- Horizontal: T42 (2.8° x 2.8°), Vertical: L39 (1000 hPa – 0.01 hPa)

Simulation	Duration	GHG	ODS	SST/ SIC
REF2000	39 yr	2000	2000	1995-2004 (MPI-OM)
REF2095	40 yr	2095 (A1B scenario)	2095 (A1 scenario)	2090-2099 (MPI-OM)

Oberländer et al., 2013; *Meul et al.*, 2014

Methods

SSW: @ 10 hPa
ΔT (90°N – 60°N) > 0
At 60°N: $\bar{u} < 0$

ESE: @ 70°N-90°N
stratopause height Z
ΔZ > 99.5th percentile of daily ΔZ in NDJFM
New Z > climatological Z

	#SSW	#ESE	ΔZ [km]
REF2000	34	10	8.4
REF2095	40	17	9.7

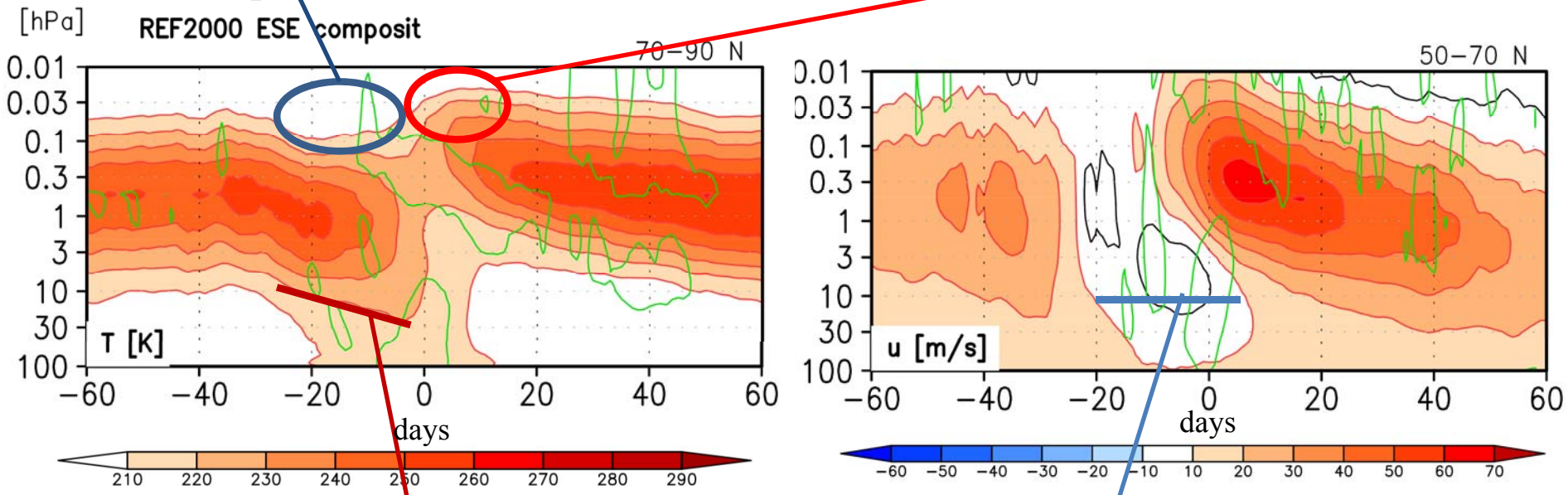
ESEs in EMAC

Long, strong mesospheric cooling

New stratopause built at higher altitude

Temperature [K] at 70-90°N

Zonal wind [m/s] at 50-70°N



Slow downward propagation of anomalies

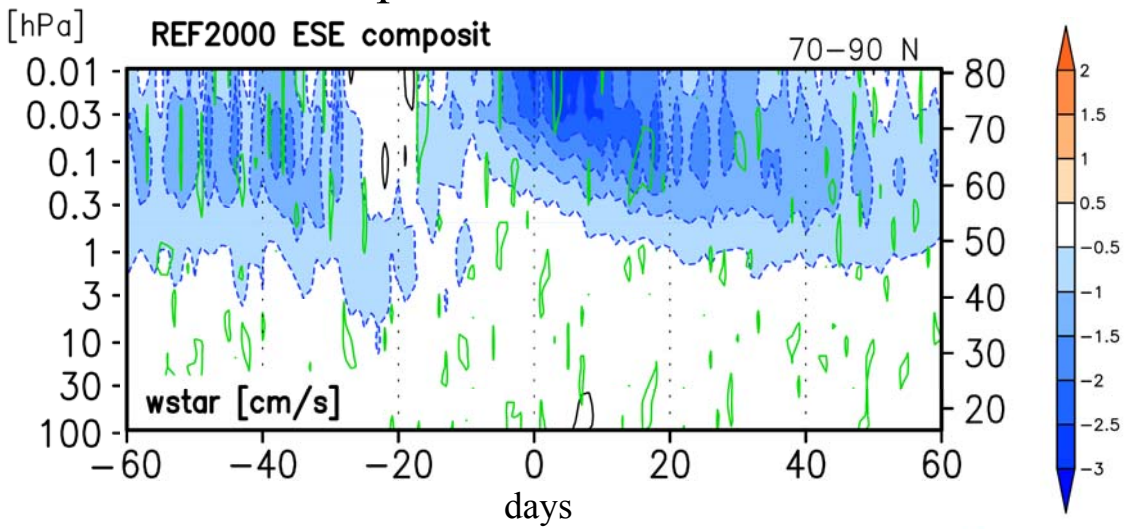
Prolonged SSW

95% statistically significant (Monte Carlo)

Residual circulation and wave driving

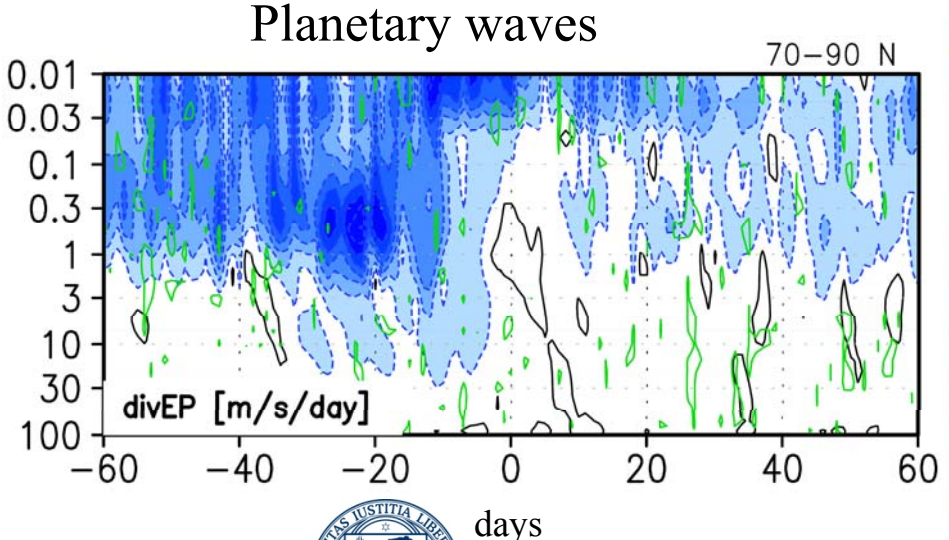
95% statistically significant (Monte Carlo)

Vertical component residual circulation

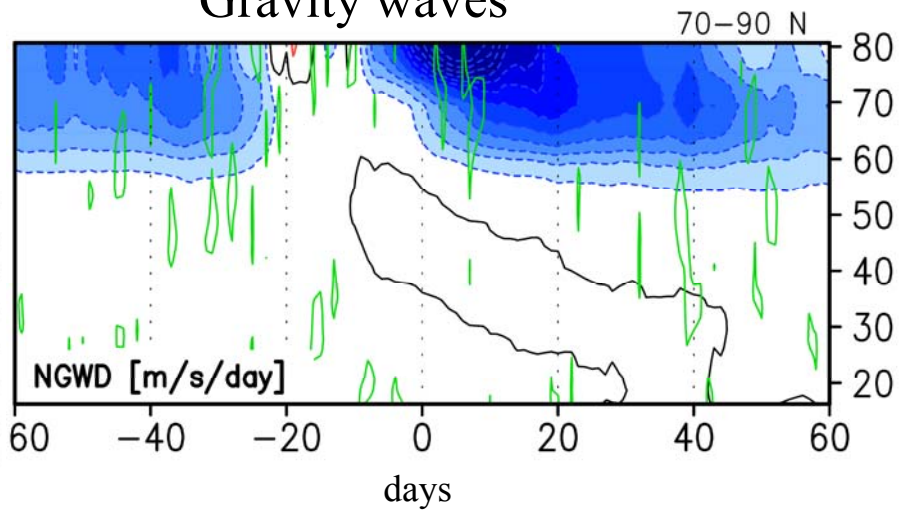


- new stratopause at higher altitude due to strong residual downward circulation
- residual circulation first driven by planetary waves, then gravity waves (e.g. Limpasuvan et al., JASTP 2012, Chandran et al., JGR 2013)

Planetary waves



Gravity waves

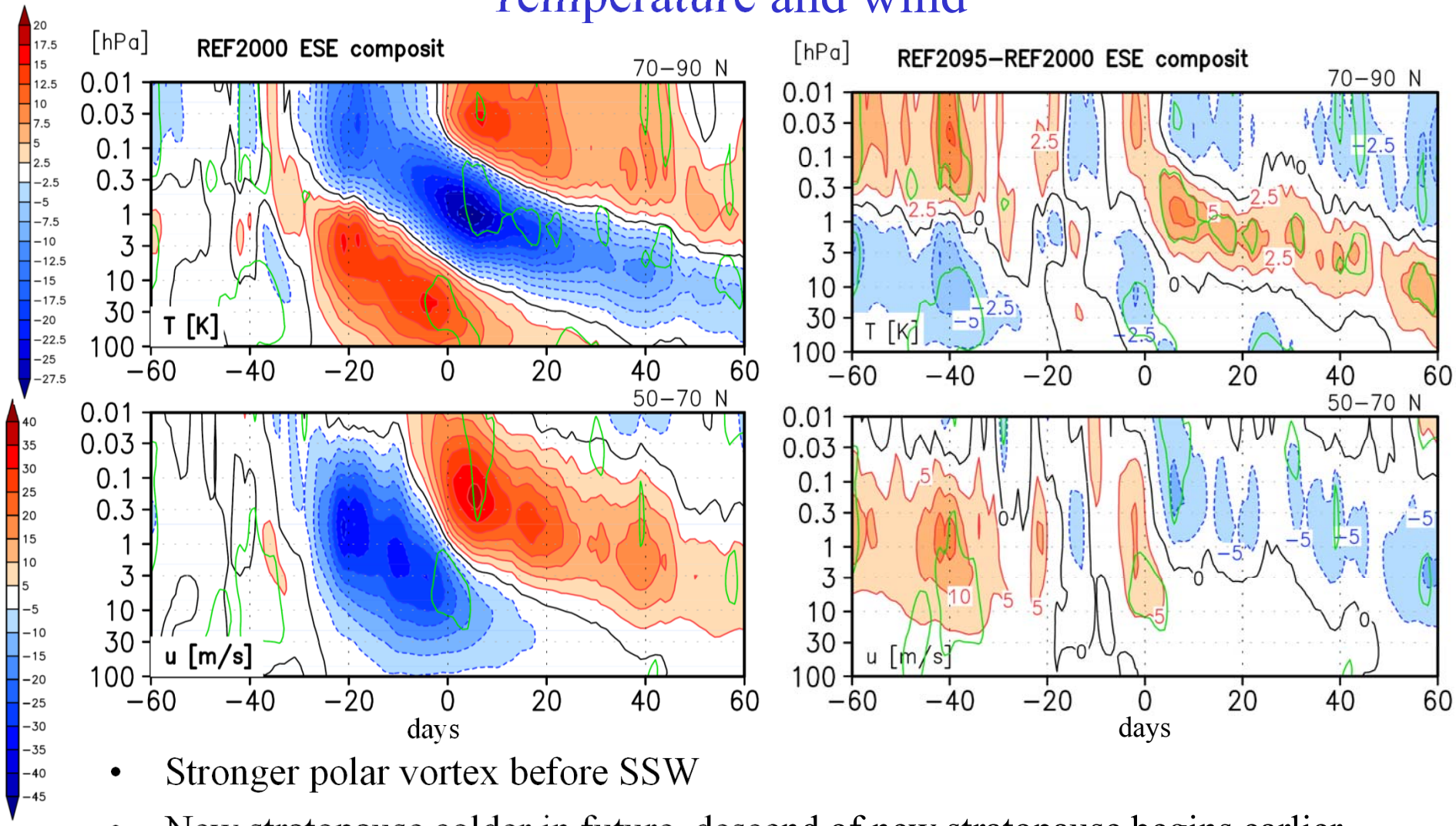


Present vs. Future

Results

95% statistically significant (ttest)

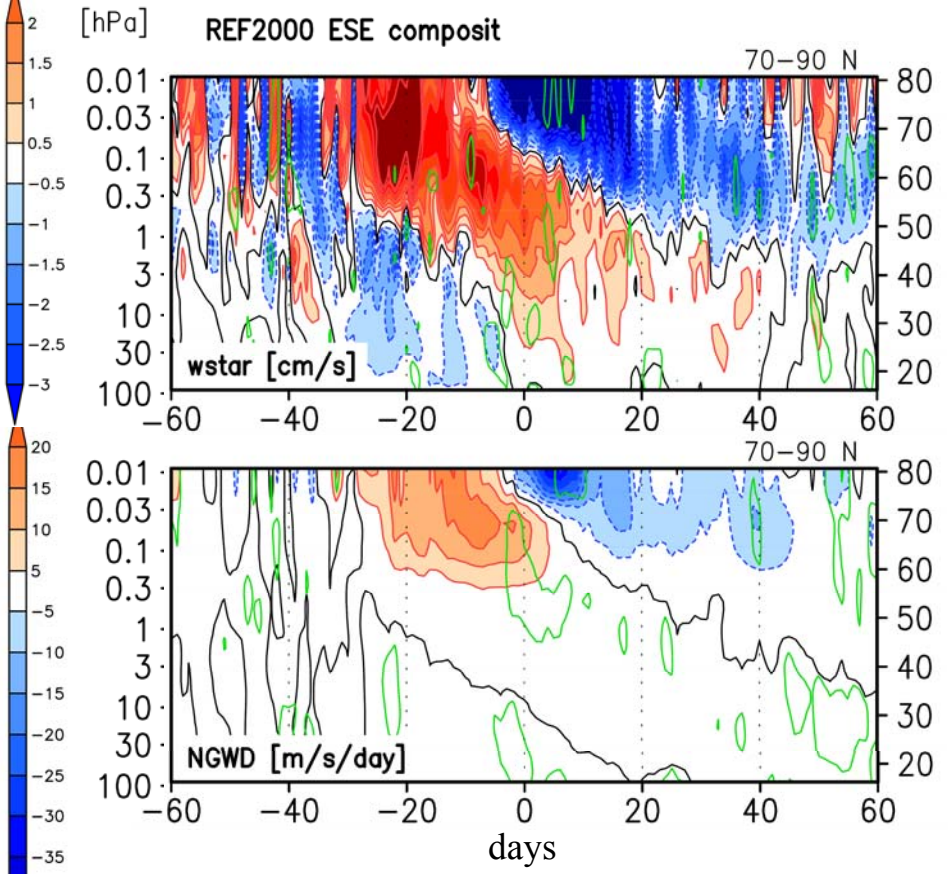
Temperature and wind

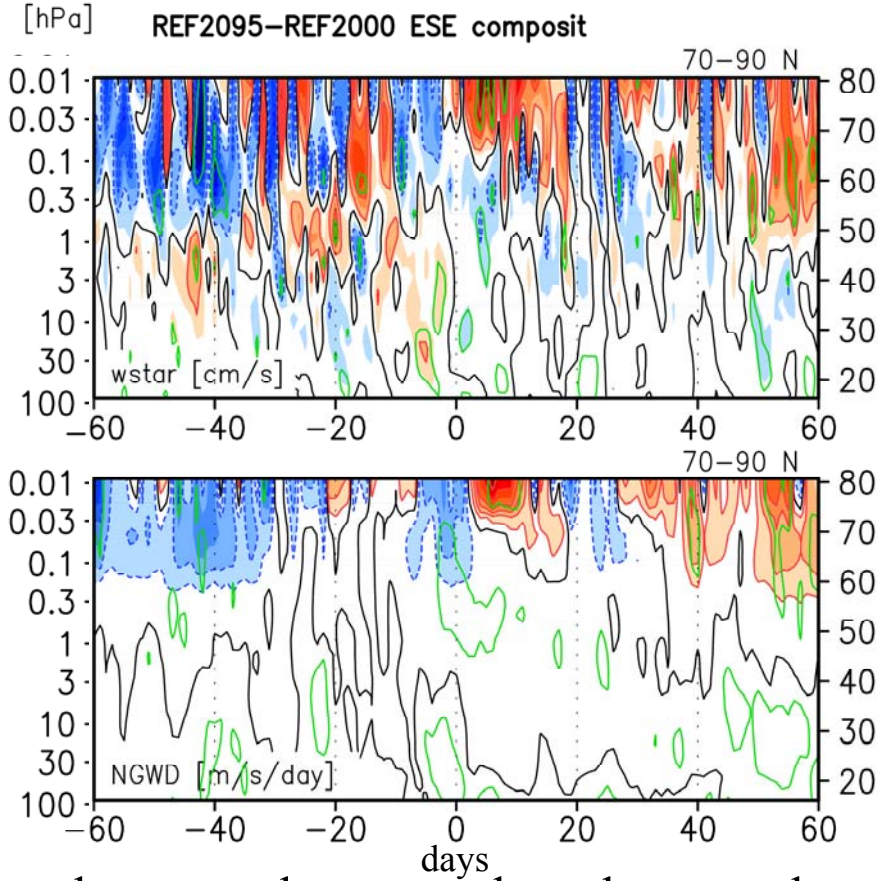


- Stronger polar vortex before SSW
- New stratopause colder in future, descend of new stratopause begins earlier

95% statistically significant (ttest)

Residual circulation and gravity waves





Weaker warming of new stratopause in future due to weaker anomalous downward circulation

Shorter anomalous wave forcing → shorter anomalous residual circulation → short duration of ESE

Summary

- EMAC can reproduce the typical characteristics of ESEs
  - Strong vortex before the SSW
  - Slow downward propagation of anomalies
  - Prolonged SSW
  - Strong mesospheric cooling

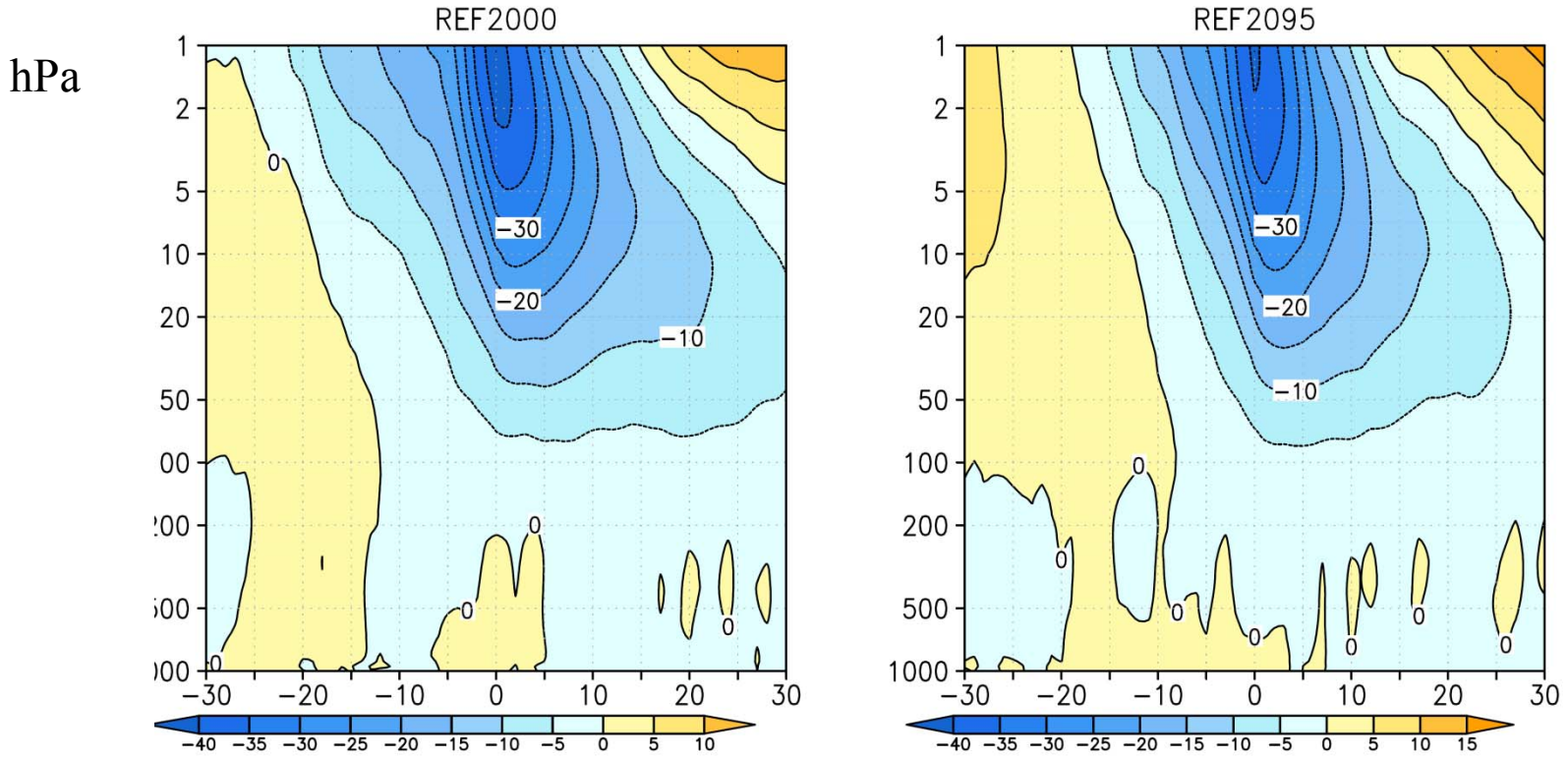
- Will the characteristics of ESEs change in a changing climate? -

No, but:

- stronger polar vortex before SSW with ESE
- Shorter duration of ESE

Thank you for your attention!

Anomalies of ū in 60°N

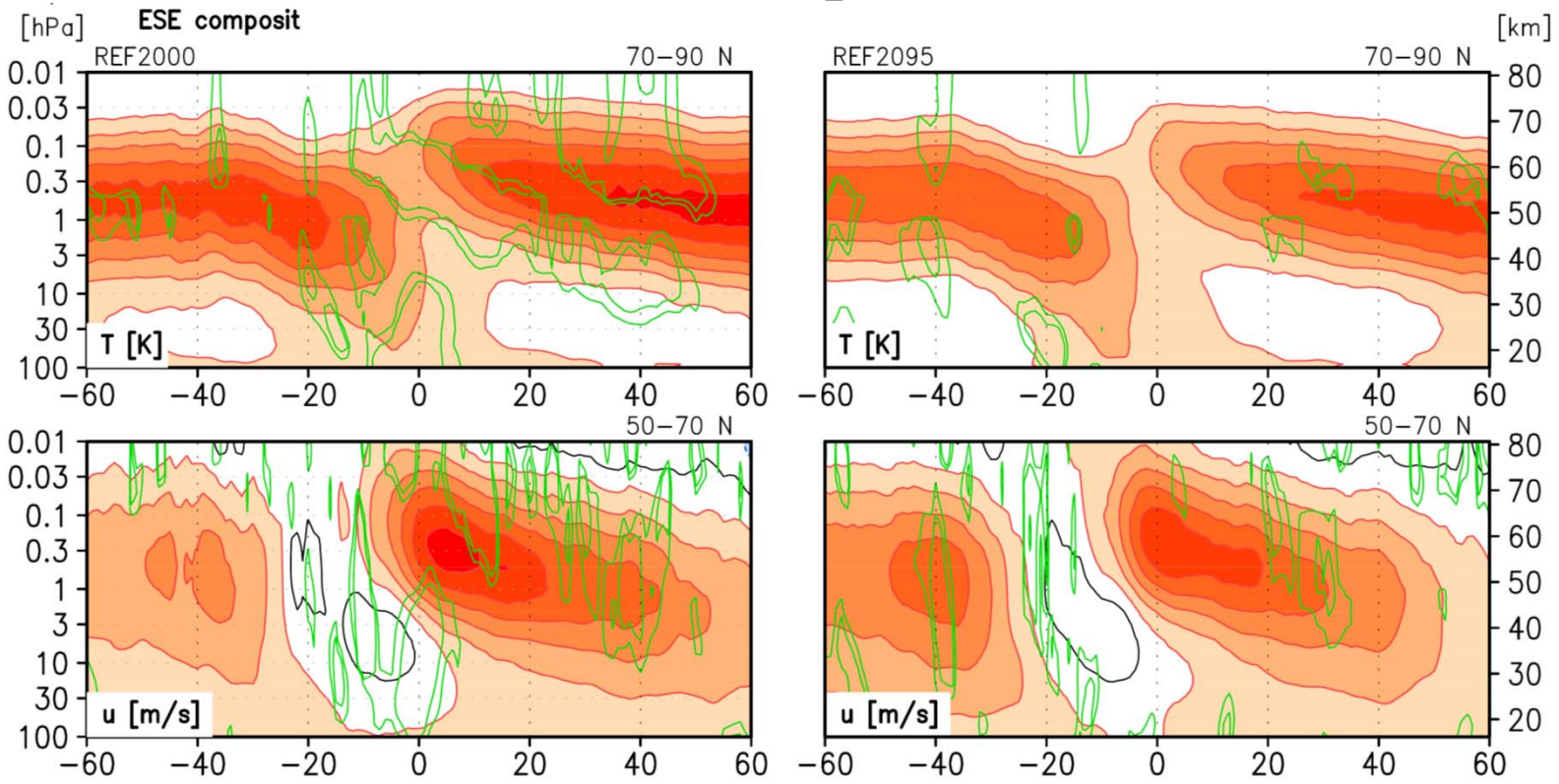


Days relative to SSW

Temperature and wind

ESE composits

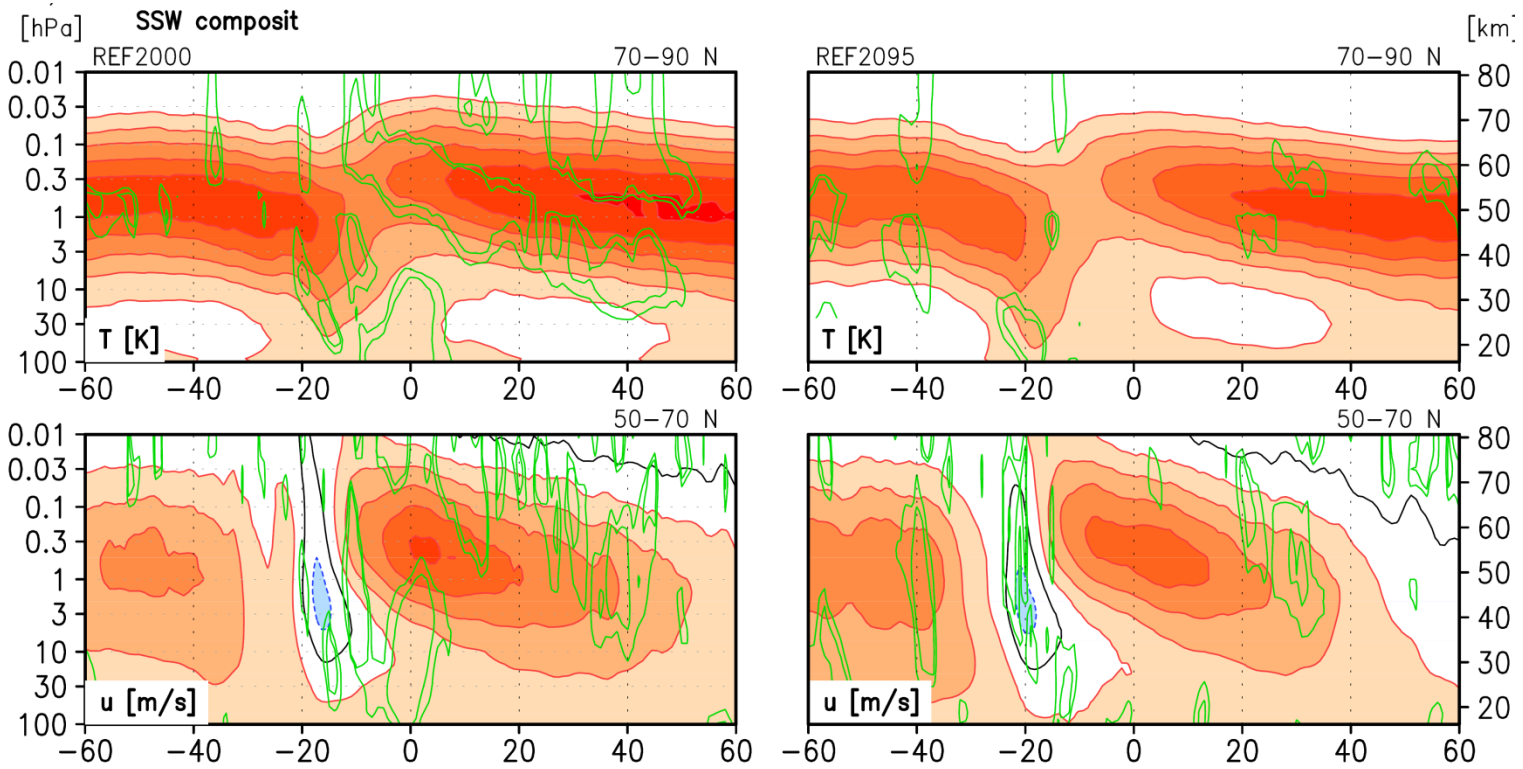
hPa



Days relative to SSW

Temperature and wind
SSW composits

hPa



Days relative to SSW