

Separating the stratospheric and tropospheric pathways of ENSO teleconnections

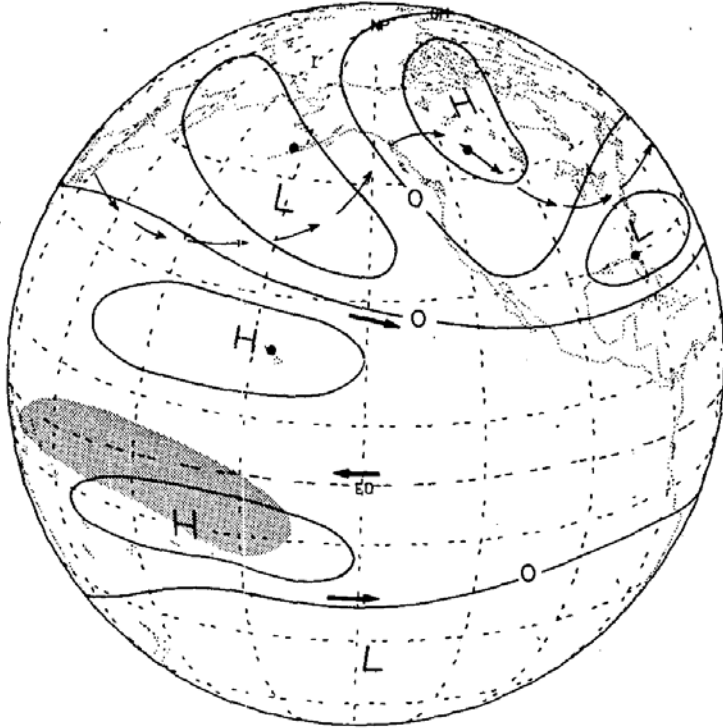
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ENSO Teleconnections in the NH

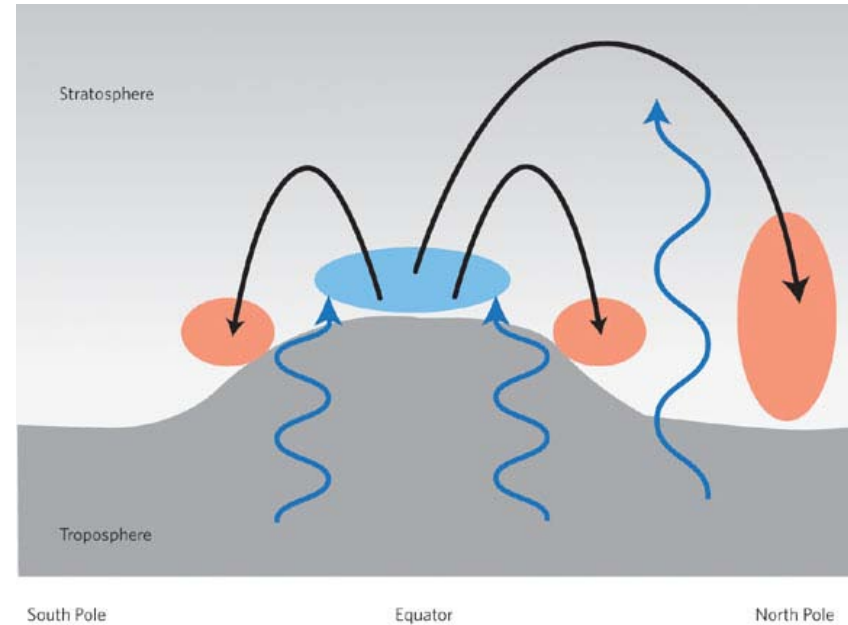


From Horel and Wallace 1981

- Major component of **seasonal climate** forecasts
- Canonical picture: Planetary wave train over Pacific, N. America
- Roughly **LINEAR**
- ENSO effects in N. Atlantic and Eurasia are not so clear...
- This is the **TROPOSPHERIC** pathway

ENSO response in the stratosphere

- Many studies have shown that ENSO also affects STRATOSPHERIC conditions
- Seasonal-mean response is LINEAR:
El Niño winter → strat is **WARM** & vortex weak
La Niña winter → strat is **COLD** & vortex strong

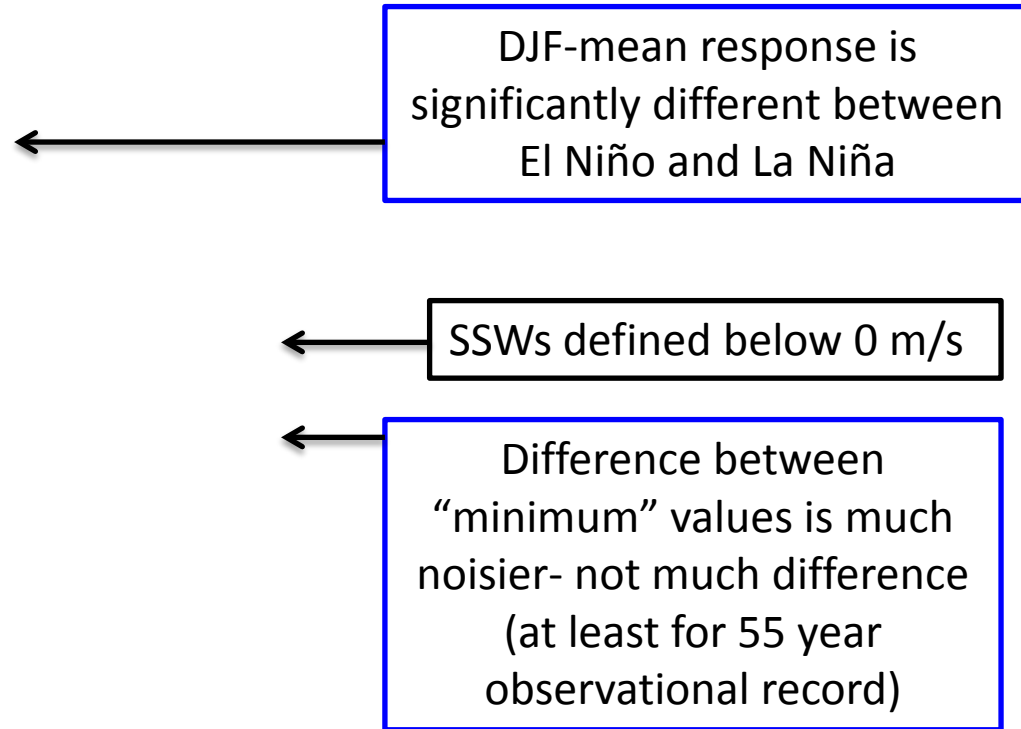


From Manzini 2009

[i.e., Toniazzo and Scaife 2006; Garcia-Herrera et al. 2006; Bell et al. 2009; Cagnazzo and Manzini 2009; Free and Seidel 2009; Li and Lau 2013...]

But, EXTREME stratospheric response is NON-LINEAR!

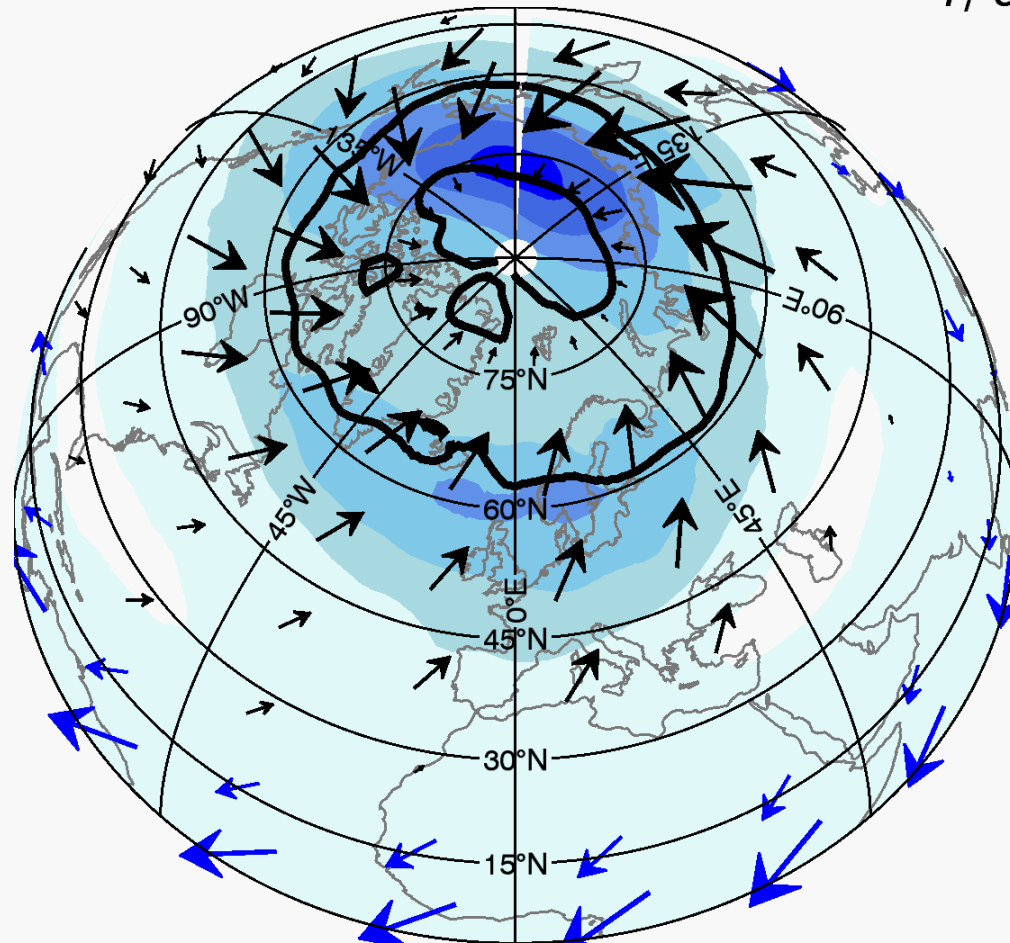
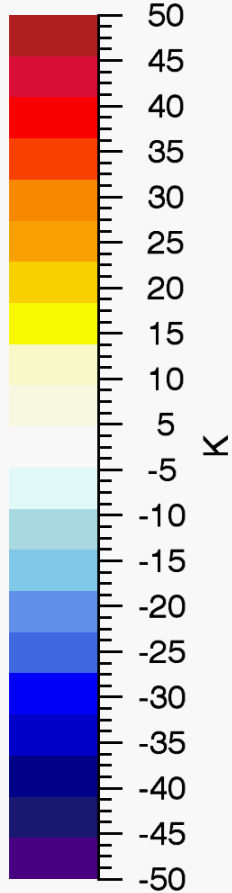
Observed SSW-ENSO relationship is NON-LINEAR



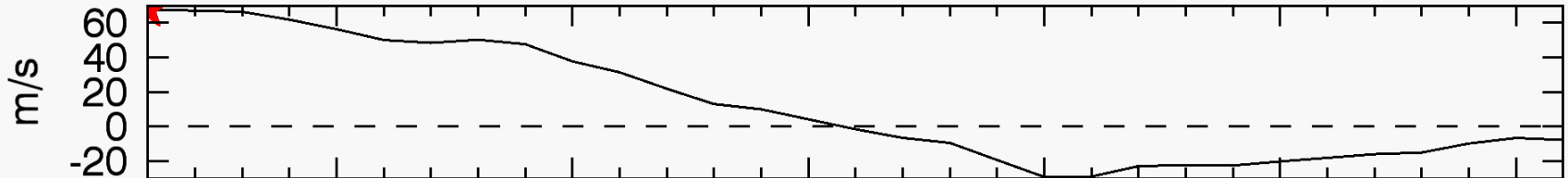
Garfinkel et al. 2012

Sudden Stratospheric Warmings (Example of a vortex split: January 2009)

1/ 9/2009

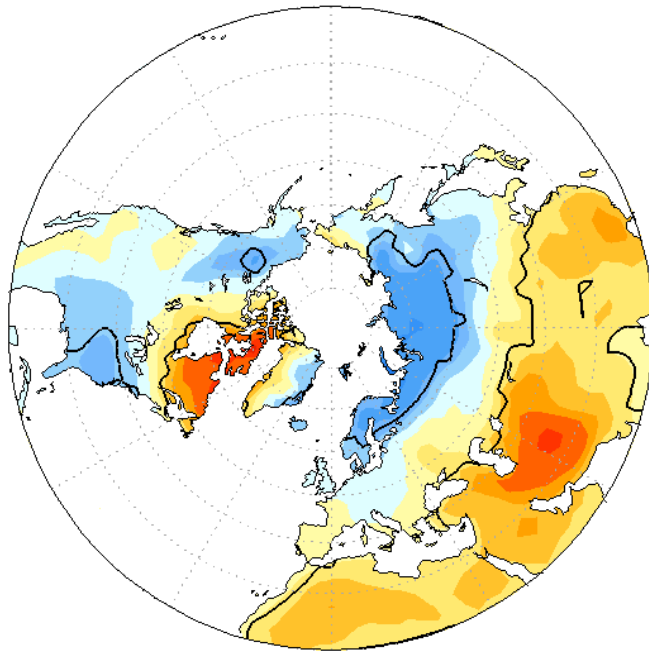


Zonal Wind 10hPa 60N

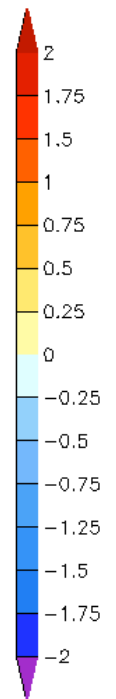
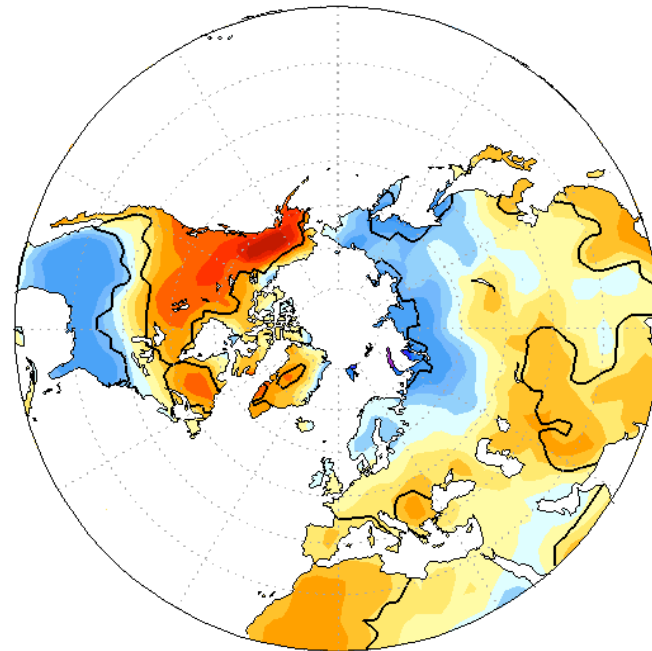


Surface climate response of SSWs vs ENSO

Days 1-60 after 35 SSWs

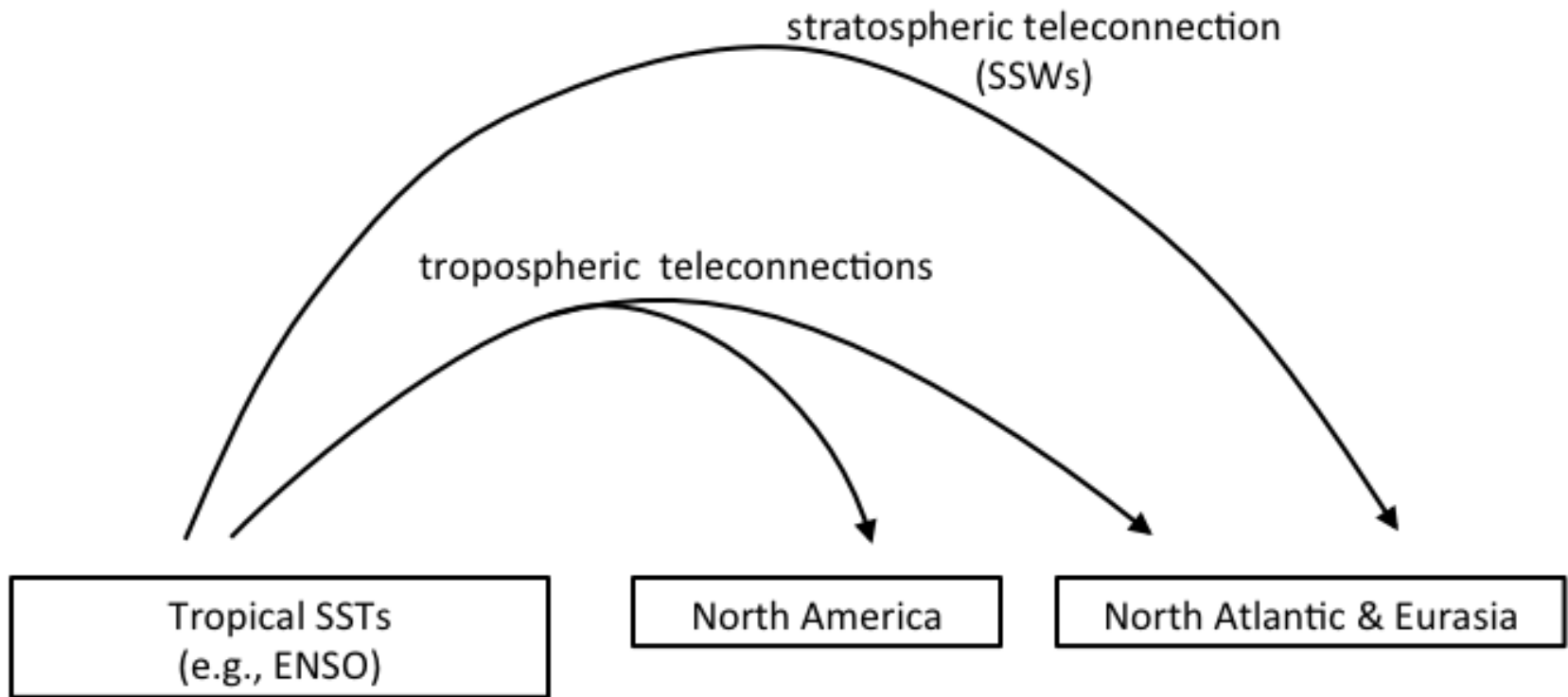


ENSO (NDJFM)



(see also *Thompson et al. 2002*)

Two distinct ENSO pathways....?



We need to **DISENTANGLE** ENSO from SSWs
to **DISTINGUISH** the two pathways....

The stratospheric pathway of ENSO

- A number of **modeling** studies, for example:
 - ✓ Bell et al., 2009, J. Climate
 - ✓ Newman and Sardeshmukh 2008, J. Climate
 - ✓ Cagnazzo and Manzini, 2009, J. Climate
 - ✓ Ineson and Scaife, 2009, Nature Geoscience
 - ✓ Li and Lau, 2013, J.Climate
- What's missing: clear **OBSERVATIONAL** evidence
 - ✓ This is our contribution (Butler, Polvani, and Deser, 2014, ERL)

What we did

- Use NCEP-NCAR reanalysis from 1958-2013
- Detect occurrence of **SSWs** using Charlton and Polvani (2007) definition
 - Wind reversal at 10 hPa and 60°N, Nov-Mar
- Use ERSST.V3B “Oceanic Nino Index” (ONI) over the Niño-3.4 region (5N-5S, 170-120W)
 - Define **El Niño/La Niña** winters as per NCEP/CPC index as +/- 0.5°C for 5 consecutive overlapping seasons

How many SSWs per ENSO phase?

SSWs (El Niño)	SSWs (La Niña)	SSWs (neutral)
30 Jan 1958	23 Mar 1965	16 Jan 1960
30 Nov 1958	17 Jan 1971	22 Feb 1979
08 Dec 1965	20 Mar 1971	29 Feb 1980
24 Feb 1966	24 Feb 1984	04 Dec 1981
27 Nov 1968	02 Jan 1985	02 Jan 2002
13 Mar 1969	22 Feb 1989	07 Jan 2004
02 Jan 1970	15 Dec 1998	07 Jan 2013
02 Feb 1973	25 Feb 1999	
23 Jan 1987	20 Mar 2000	
08 Dec 1987	11 Feb 2001	
14 Mar 1988	21 Jan 2006	
18 Jan 2003	22 Feb 2008	
24 Feb 2007	24 Jan 2009	
09 Feb 2010		
24 Mar 2010		

- 15 SSWs during El Niño
- 13 SSWs during La Niña
- Only 7 SSWs in neutral-ENSO
- 80% of SSWs occur in El Niño or La Niña winters!

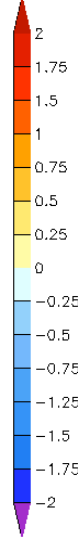
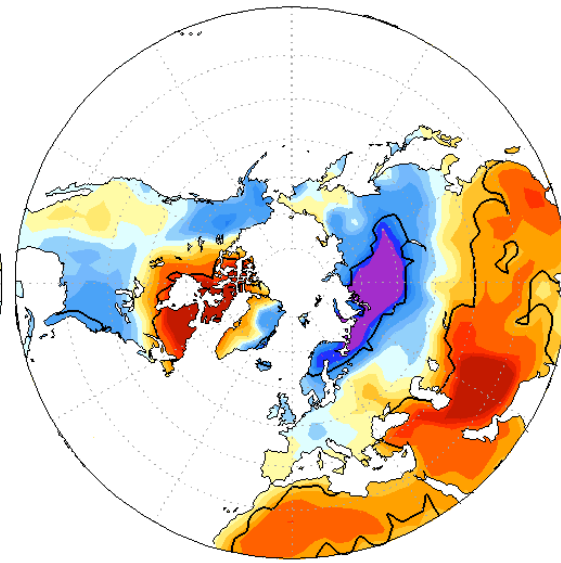
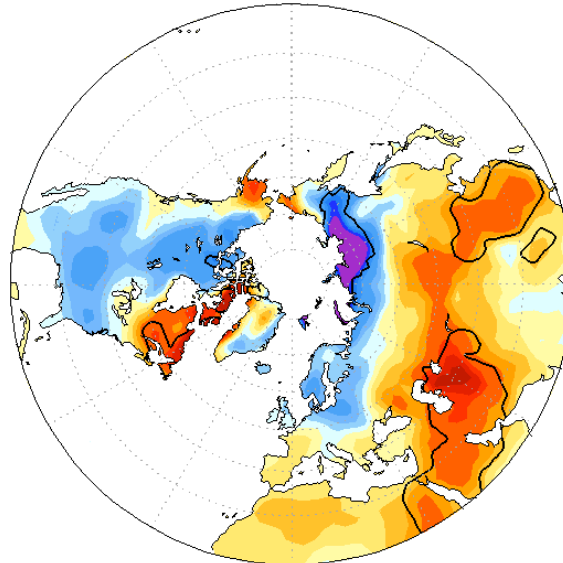
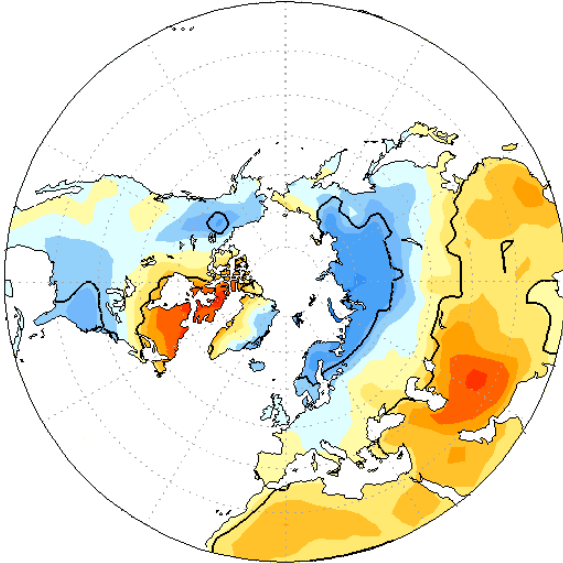
Does a stratospheric pathway exist??

SSWs
All winters

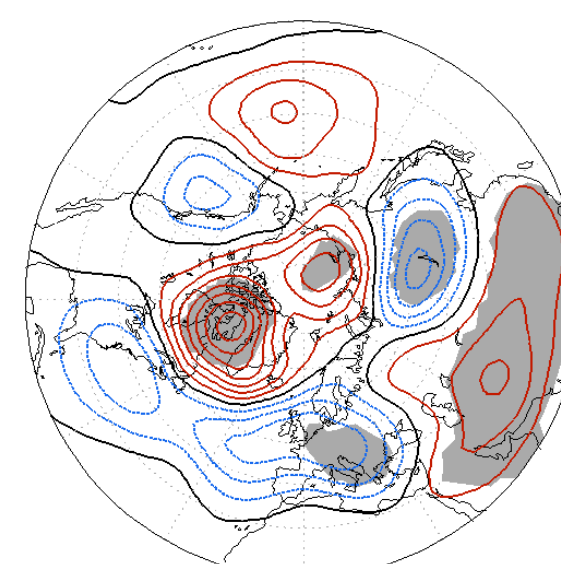
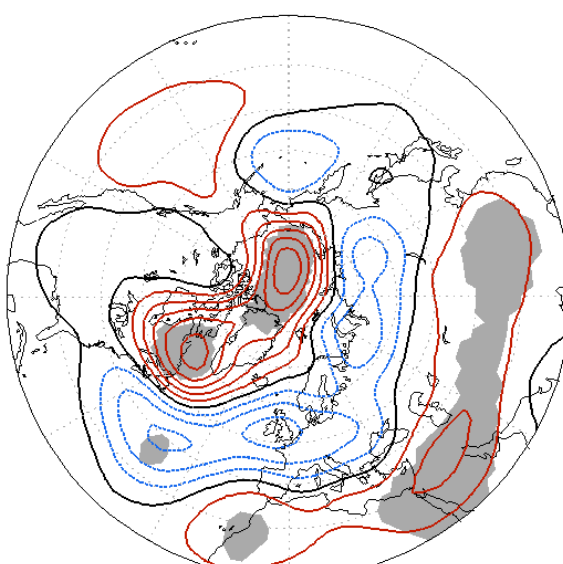
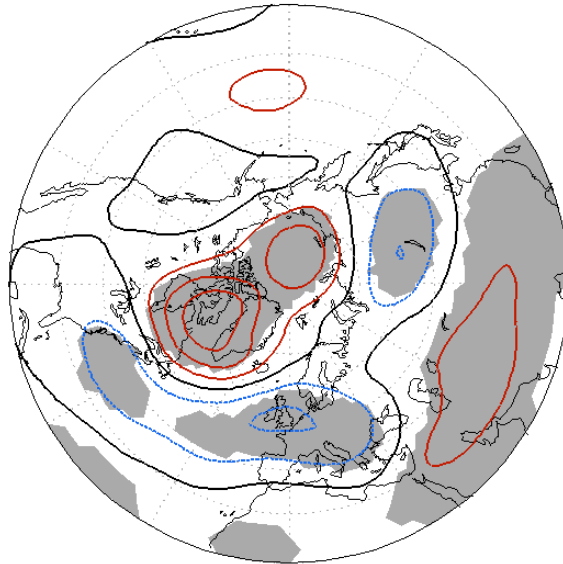
SSWs
neutral ENSO [7]

SSWs (El Niño) +
SSWs (La Niña)

Surface temperature



Z500



How many ENSO winters w/SSWs?

- 56 winters, approx 1/3 each El Niño, La Niña, neutral
- Overall frequency of SSWs: about 6 per decade
- But much **HIGHER** during **ENSO** winters
- More ENSO winters **WITH SSWs** than **WITHOUT**

The linear ENSO response

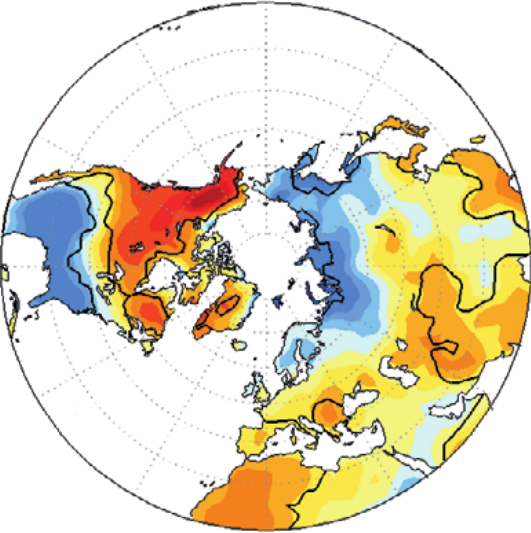
WITH AND WITHOUT THE STRATOSPHERIC PATHWAY

ENSO (El Niño – La Niña)

ENSO, with SSWs

ENSO, without SSWs

Surface temperature



Z500

The NON-linear ENSO response

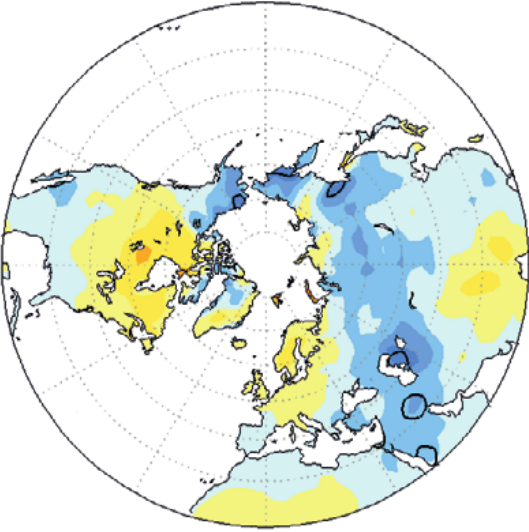
AND IMPACTS OF STRATOSPHERIC PATHWAY

ENSO (El Niño + La Niña)

ENSO, with SSWs

ENSO, without SSWs

Surface temperature



Z500

Conclusions

- The **stratospheric** pathway is very **important!**
 - Present in **60%** of ENSO winters
 - ENSO teleconnection with SSWs looks VERY DIFFERENT from teleconnection without SSWs, in terms of seasonal impact
- ENSO response over
 - N. America → **TROPOSPHERIC** pathway
 - N. Atlantic & Eurasia → **STRATOSPHERIC** pathway
- Knowledge of **stratosphere** could enhance **seasonal prediction** for the NAO and Eurasia

	All winters	Winters with SSWs	Winters without SSWs
NDJFM Eurasian surface temperature anomaly (K)			
All years	~ 0	-0.5	$+0.6$
El Niño	-0.4	-1.1	$+0.5$
La Niña	$+0.3$	$+0.2$	$+0.5$
Neutral	$+0.1$	-0.7	$+0.6$
JFM NAO index			
All years	0.00	-0.17	$+0.19$
El Niño	-0.26	-0.44	-0.01
La Niña	$+0.17$	$+0.12$	$+0.24$
Neutral	$+0.10$	-0.22	$+0.29$

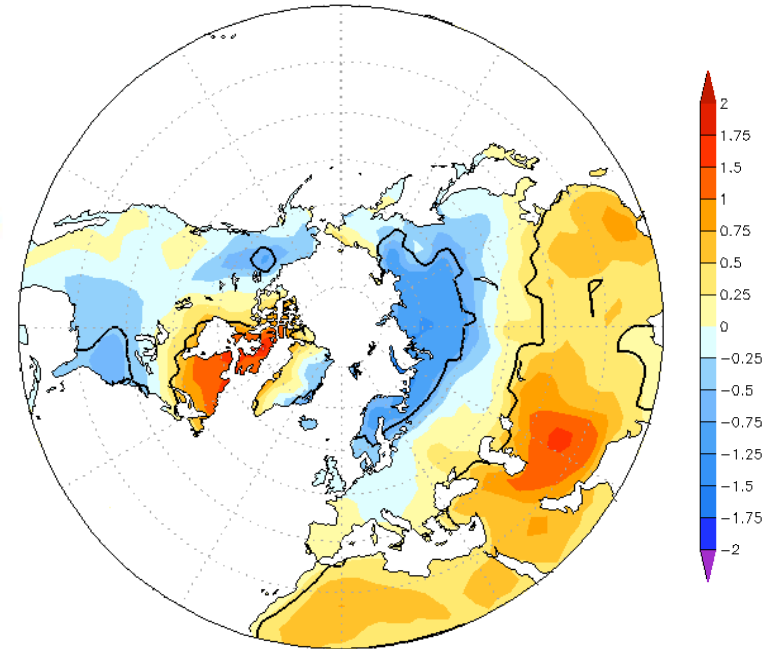
Surface impacts of SSWs

Annular Mode composite for 18 sudden warming events

Days 1-60 after 35 SSWs

[Baldwin & Dunkerton, 2001]

Baldwin and Dunkerton 2001



- Anomalous surface weather **1-2 months** after SSW
- Possibility of **longer range** forecasting

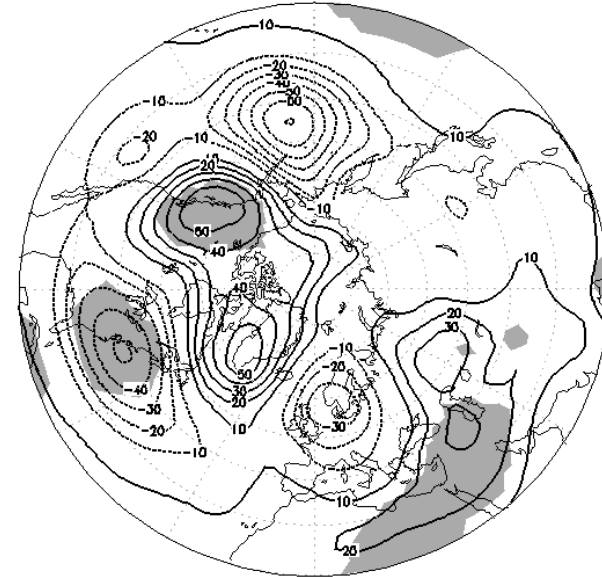
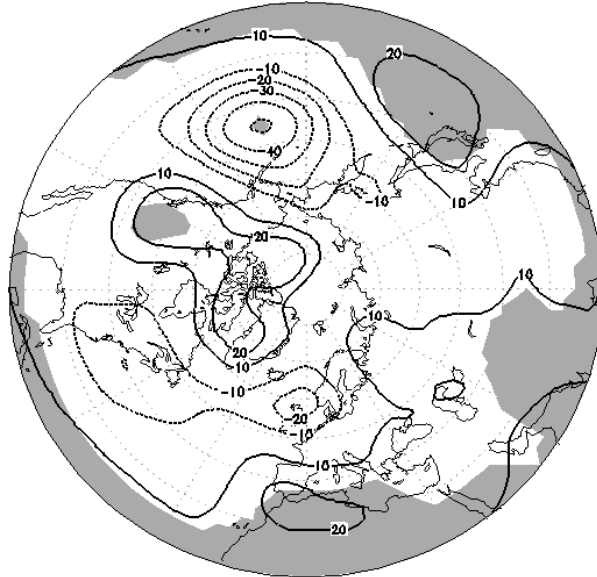
Dependence on ENSO threshold

Z500 (m)

ENSO (El Niño – La Niña)

ENSO, no SSWs

MODERATE



STRONG

