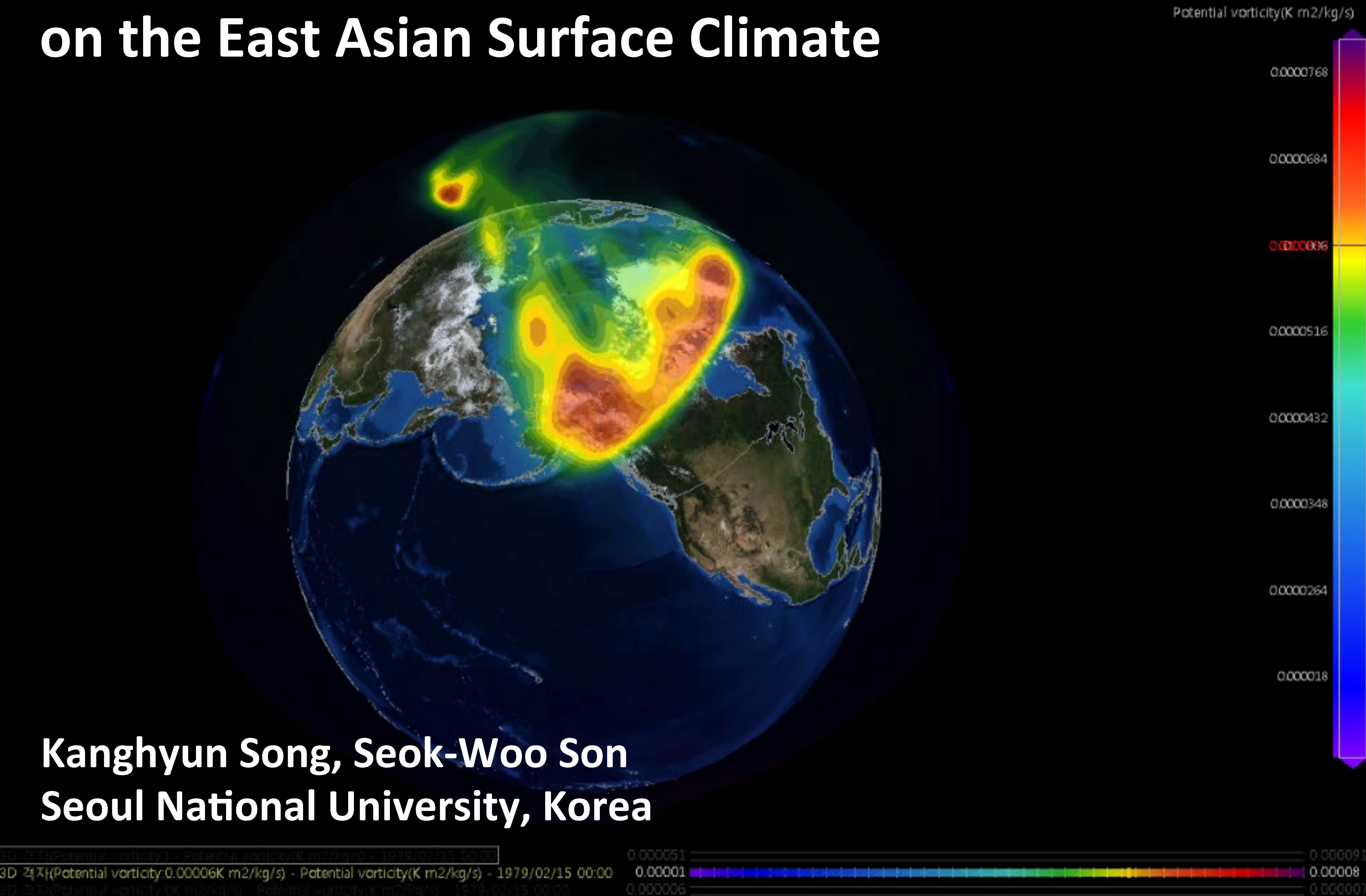
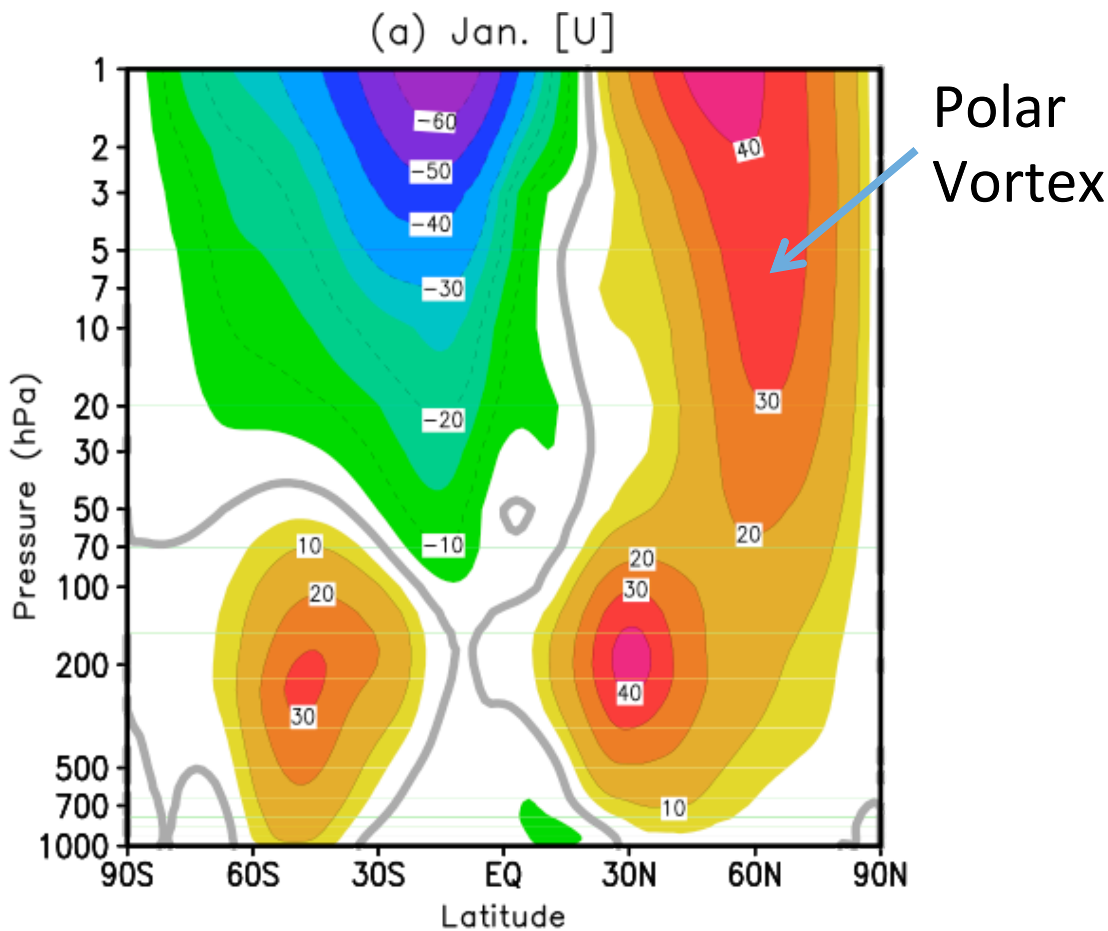
Impact of Stratospheric Sudden Warming (SSW) on the East Asian Surface Climate



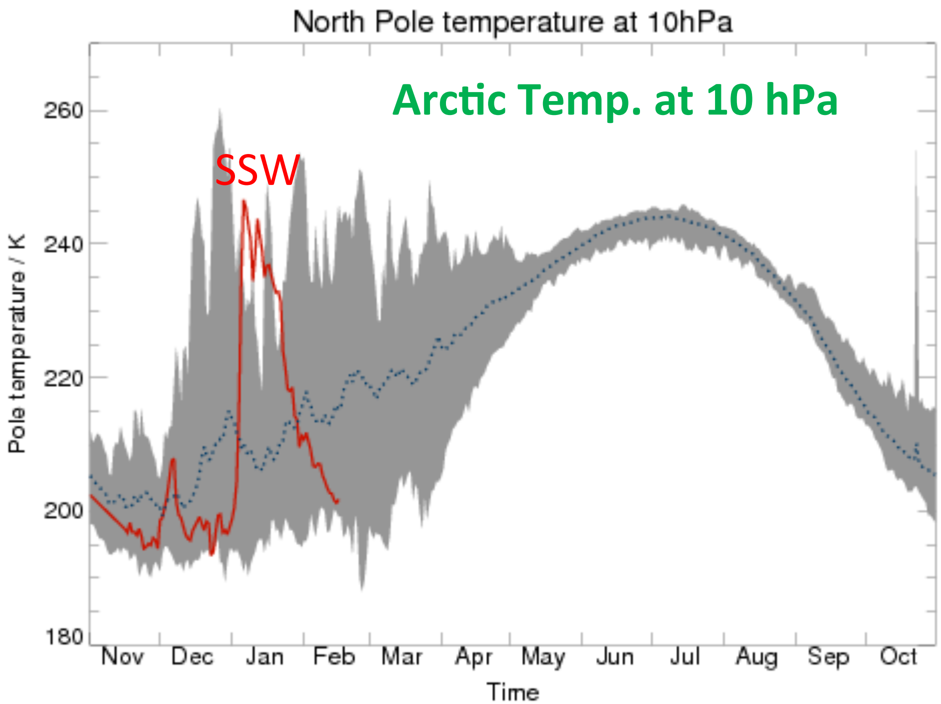
Kanghyun Song, Seok-Woo Son
Seoul National University, Korea

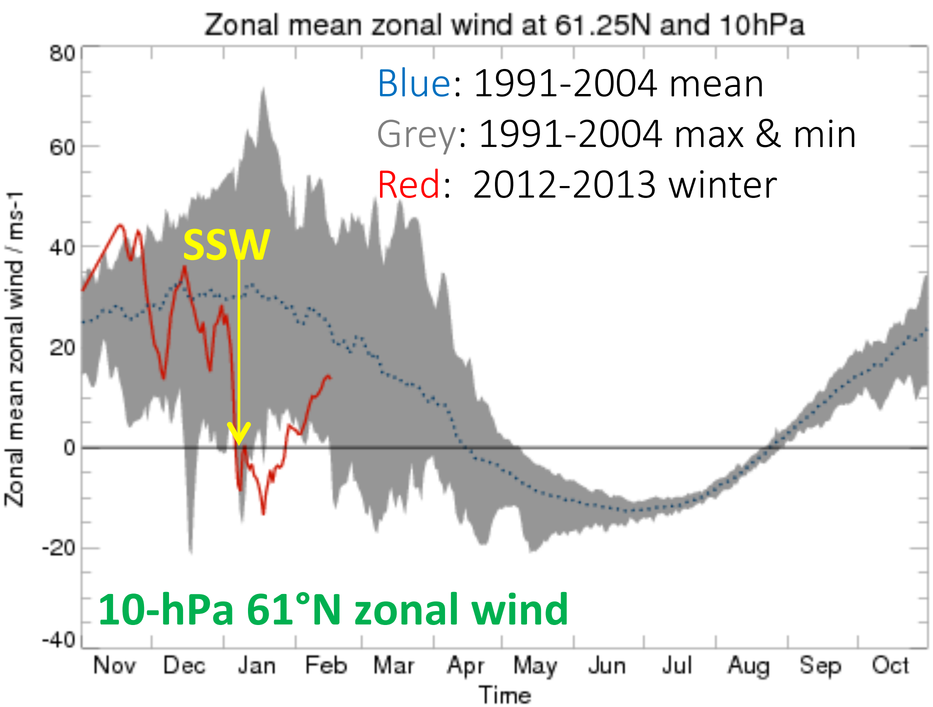


(a) Jan. [U]
Pressure (hPa)
Latitude
90S
60S
30S
EQ
30N
60N
90N
1
2
3
5
7
10
20
30
50
70
100
200
500
700
1000
-60
-50
-40
-30
-20
-10
10
20
30
40
Polar Vortex

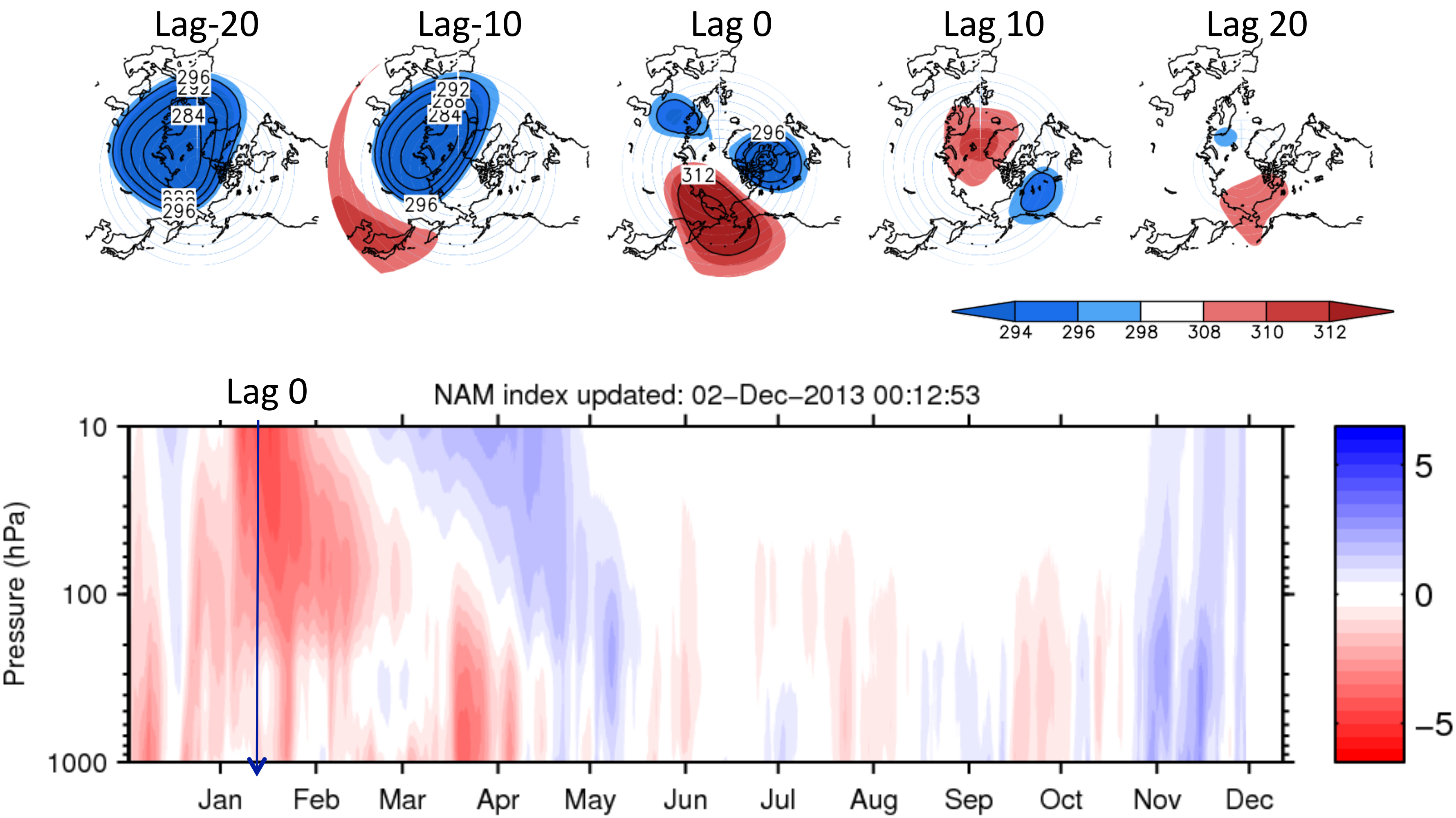
SSW: Jan. 7th, 2013

Arctic stratospheric temperature rapidly increases by extratropical wave driving, often resulting in zonal-wind reversal from westerly to easterly.





http://www.met.reading.ac.uk/research/stratclim/current/diagnostics.html



Stratospheric vortex is split into two daughter vortices and the associated NAM-index anomalies propagate downward in time.

Contents

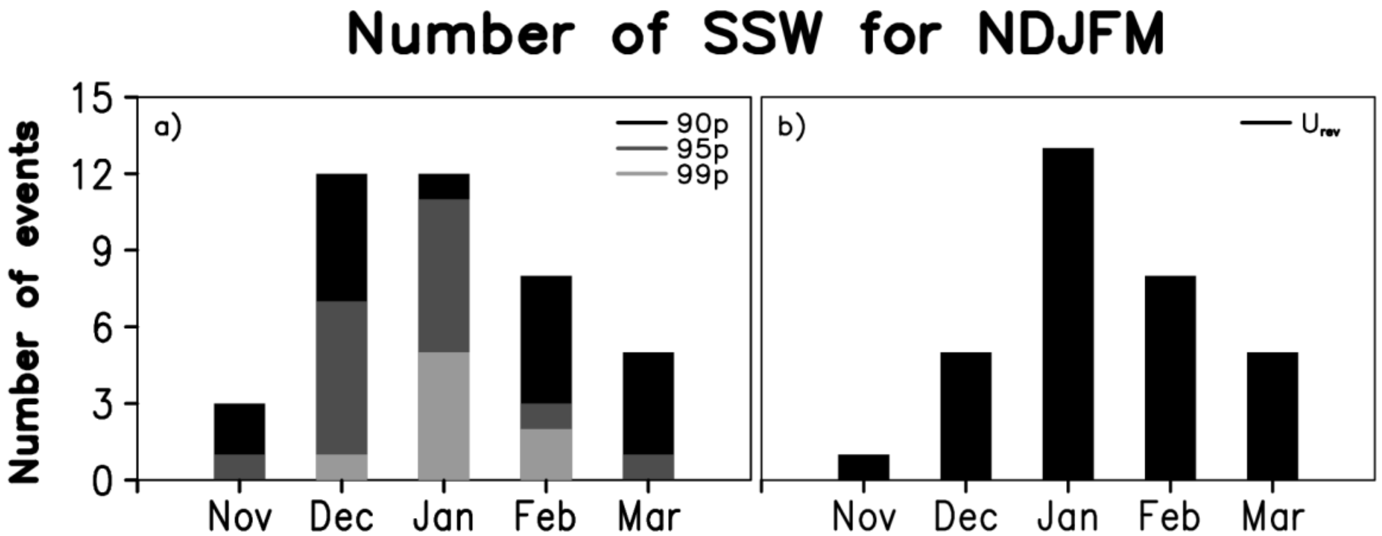
Impact of SSW on east Asian surface climate

Inter-annual variability of SSW

SSW prediction skill in an operational seasonal prediction model (KMA - GloSea5)

SSW Definition

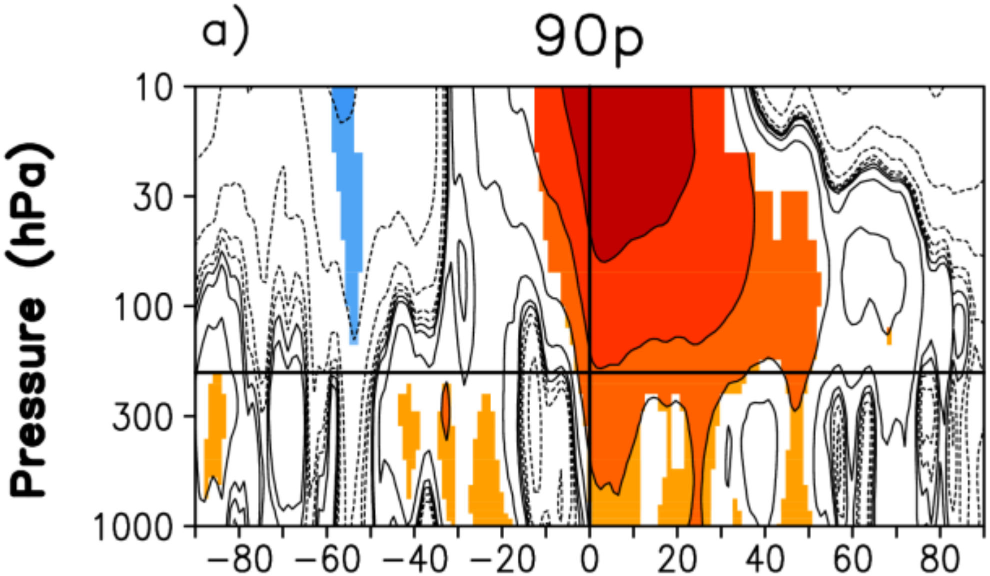
- Definitions: 90th percentile of polar-cap GPH (PCI), 60°N [u] reversal during mid-winter, etc. Typically evaluated at 10 hPa.
- 37 SSW events over 1958-2012 from JRA-55 data (90th percentile definition)



Song et al. (2015)

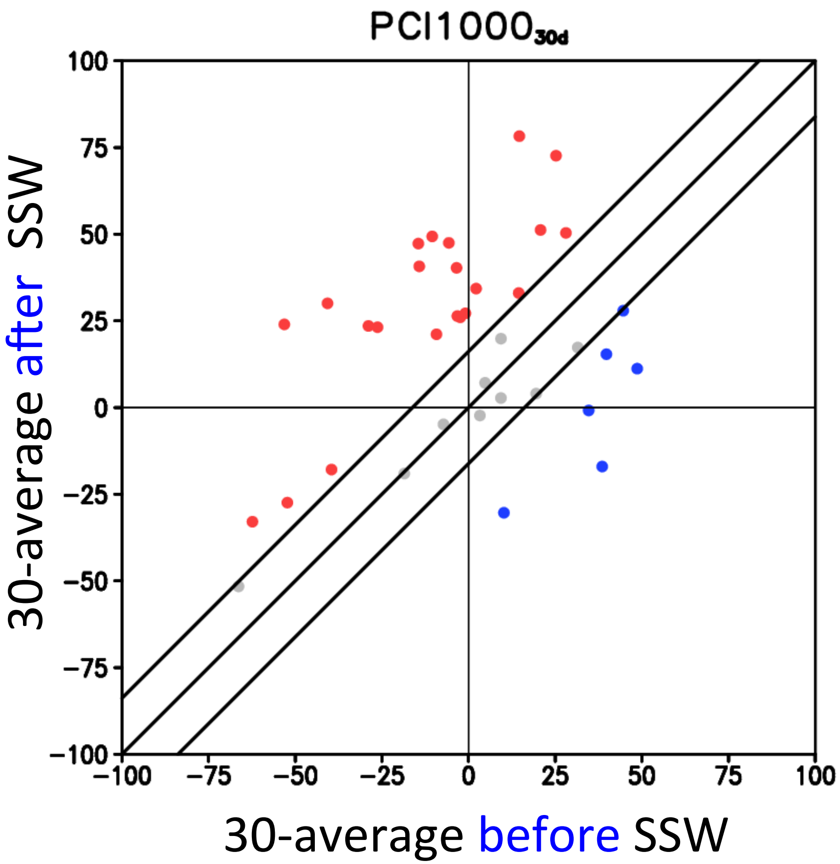
Surface Impacts

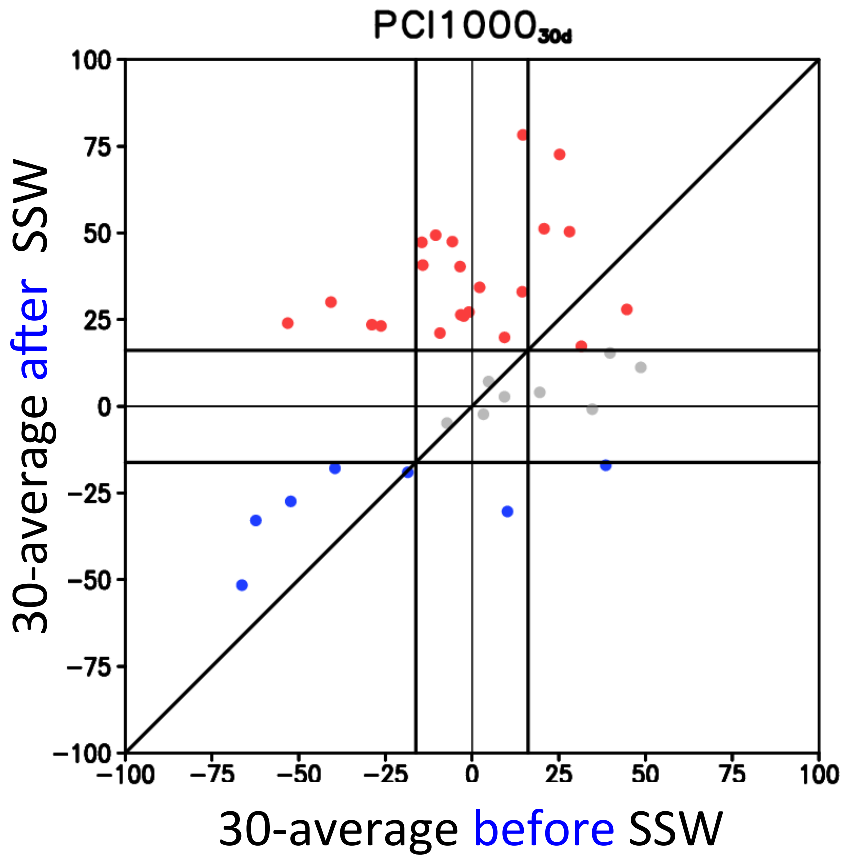
Polar-cap GPH anomalies ≈ −NAM index



Song et al. (2015)

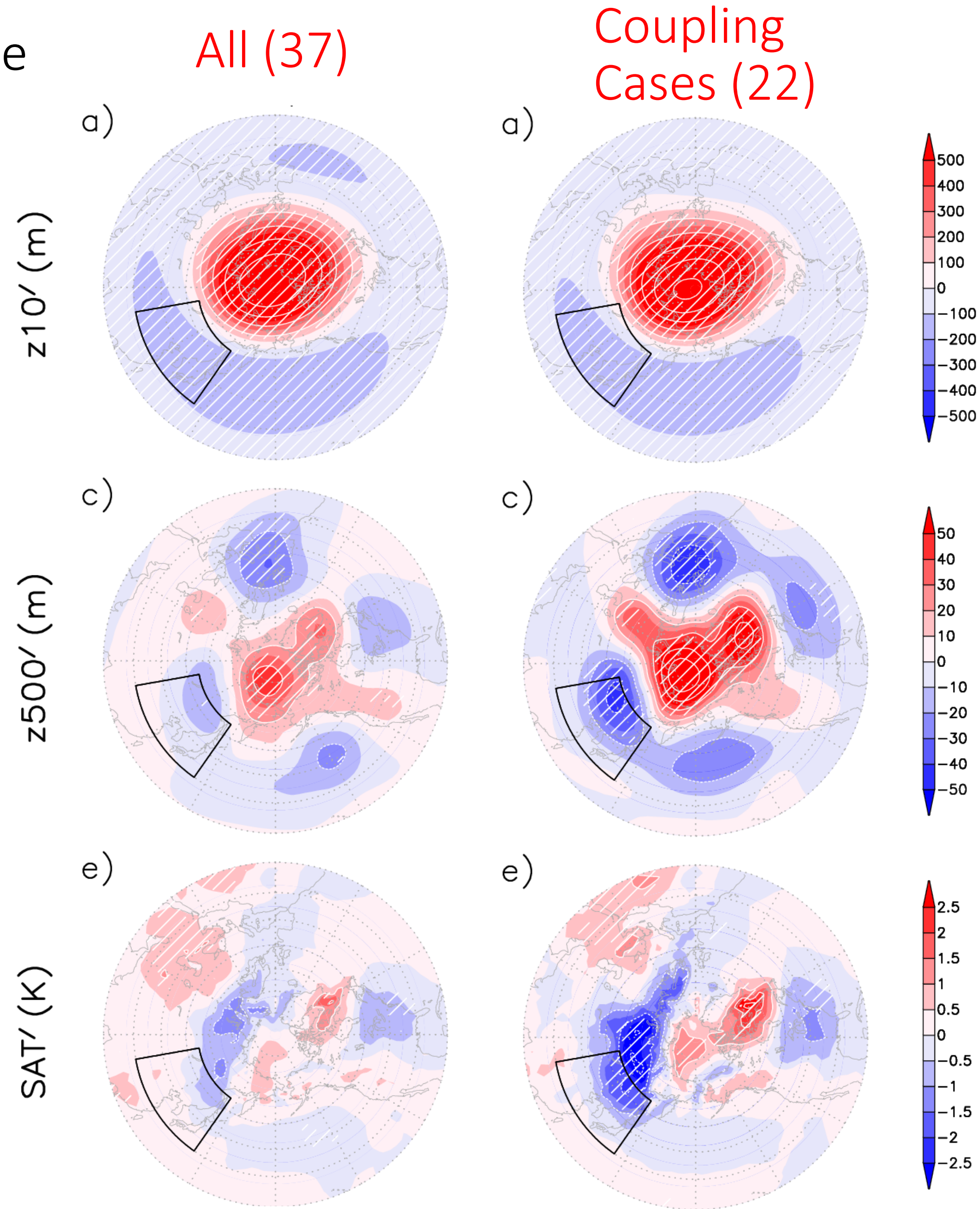
Surface Impacts: Coupled vs. Uncoupled Events



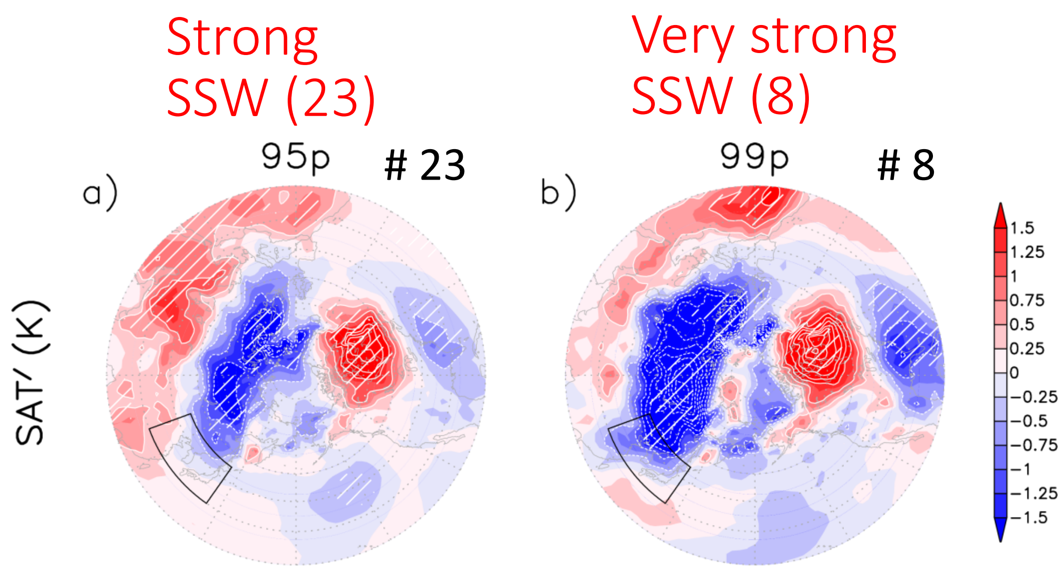


22 SSW events (60%) show more positive surface PCI (more negative surface NAM index) after the SSW; changes are larger than 0.5 standard deviation!

30-day average
after SSW



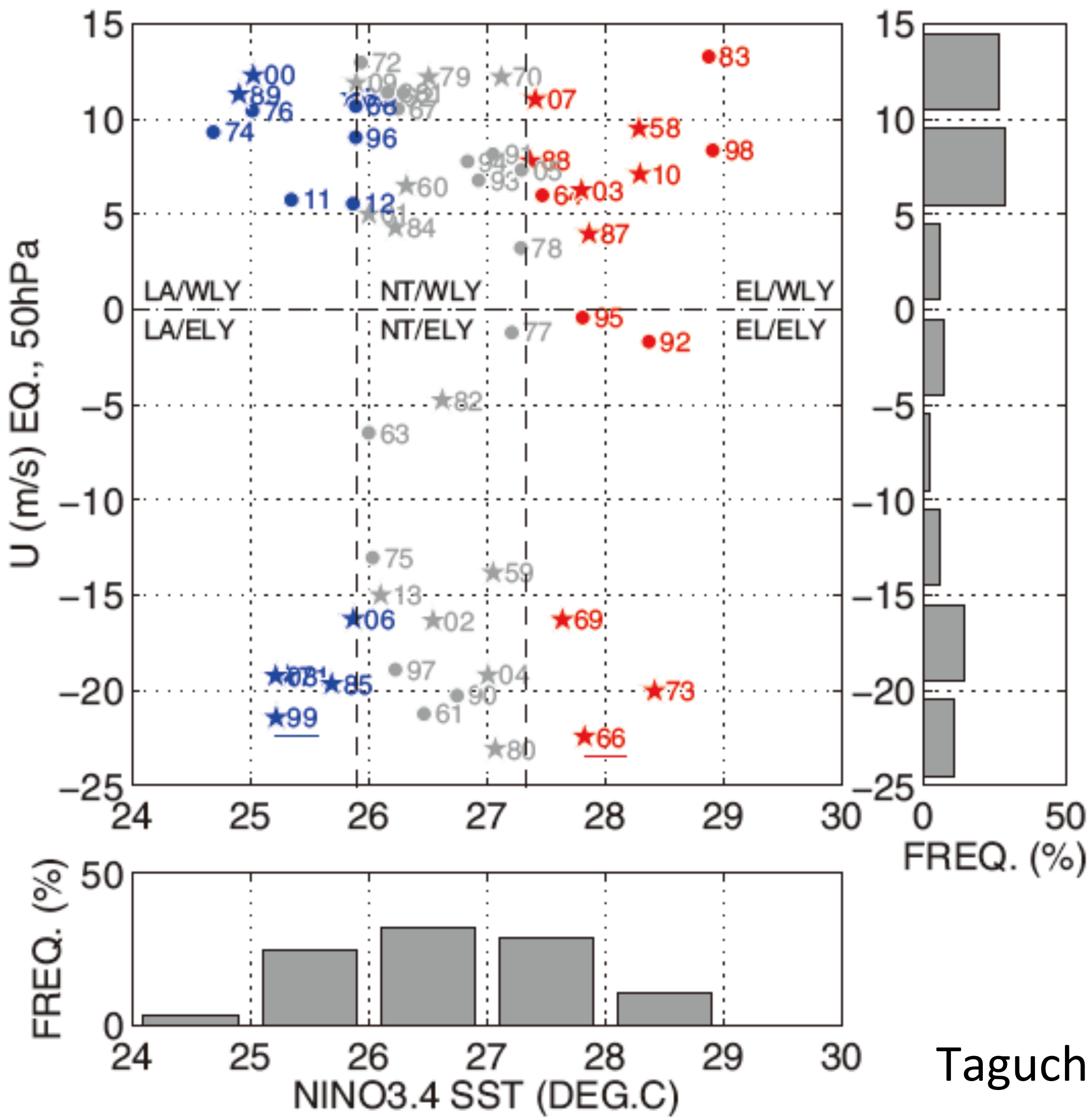
30-day average
after SSW



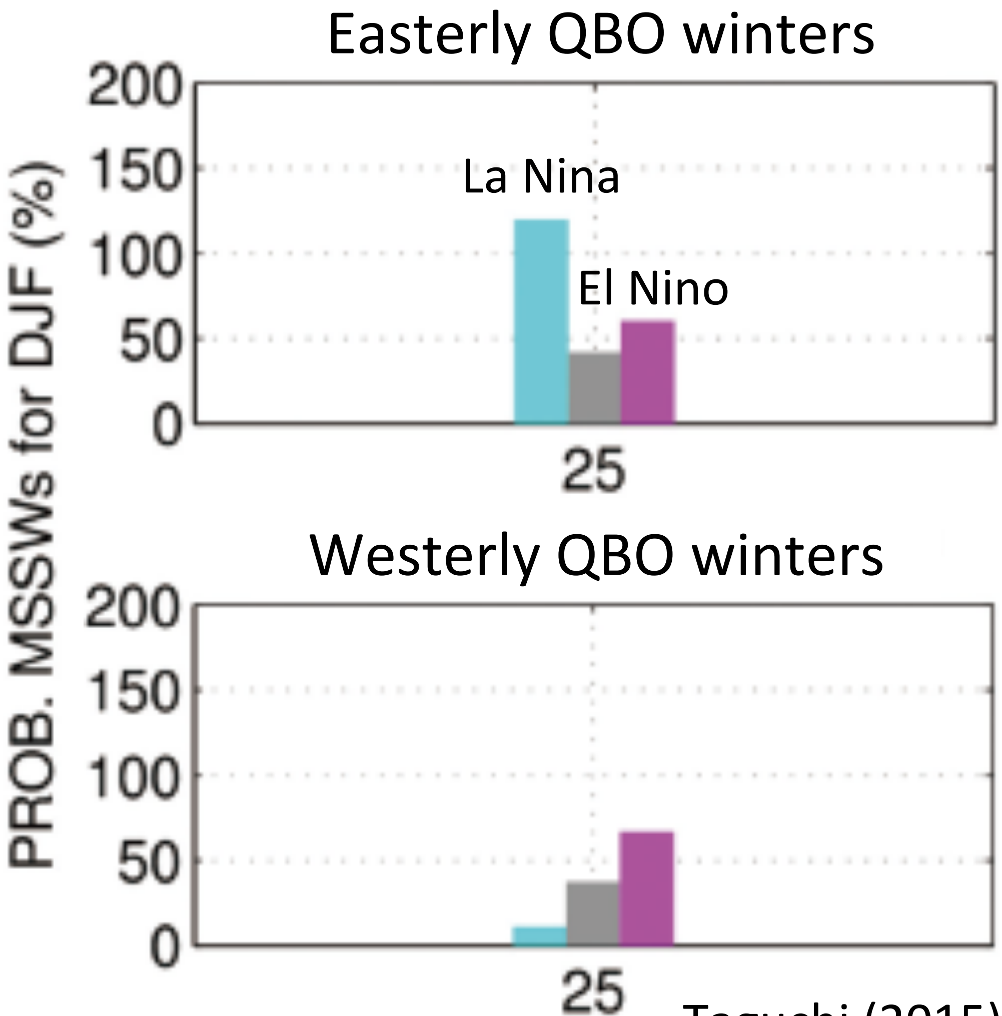
Song et al (2015)

Cold East Asia after SSW events; surface response is stronger for stronger SSW events.

Inter-annual Variability



Taguchi (2015)

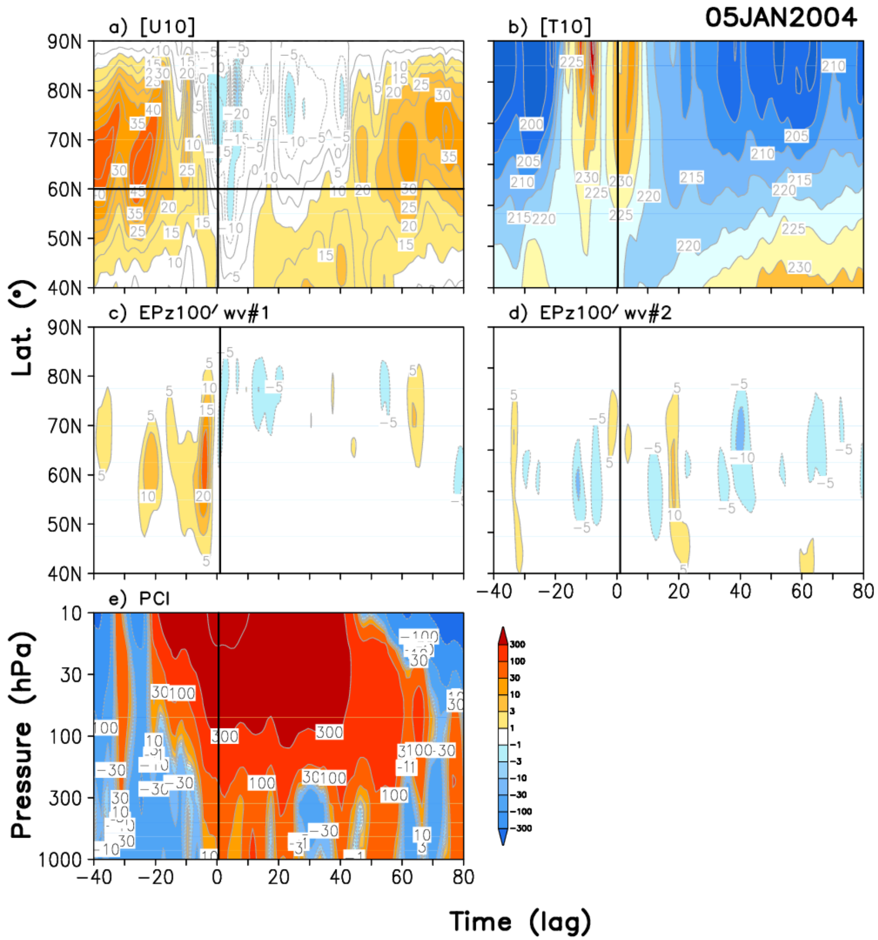


Taguchi (2015)

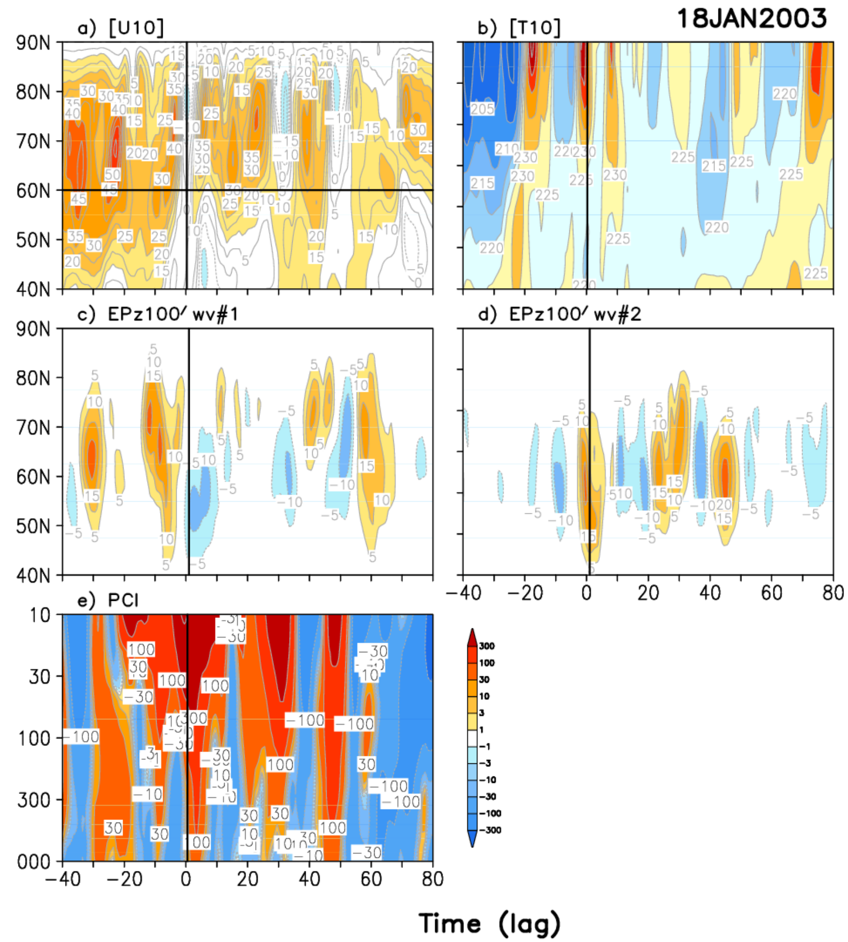
- More SSW events during ENSO years
- At least one SSW event during EQBO and La Nina winters (5 yrs)
- WQBO and El Nino years (2015 winter) tends to have more chances of SSW occurrence

SSW Prediction: Reference Cases

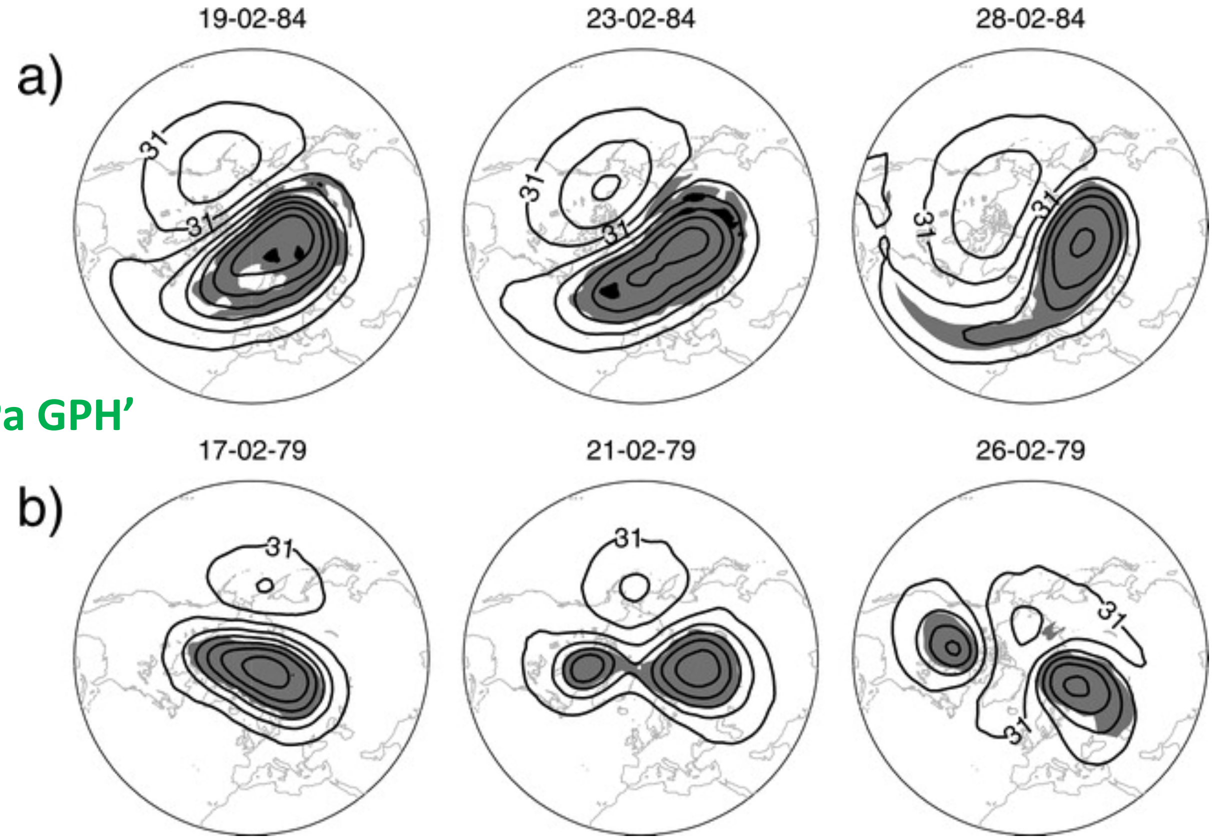
Displacement SSW (2004)



Split SSW (2003)



SSW: Displacement vs. Split SSW



Displacement SSW events may have different surface influence to Split SSW events (Mitchell et al., 2013).

2004 SSW Prediction: GloSea5

Displacement SSW
05JAN2004

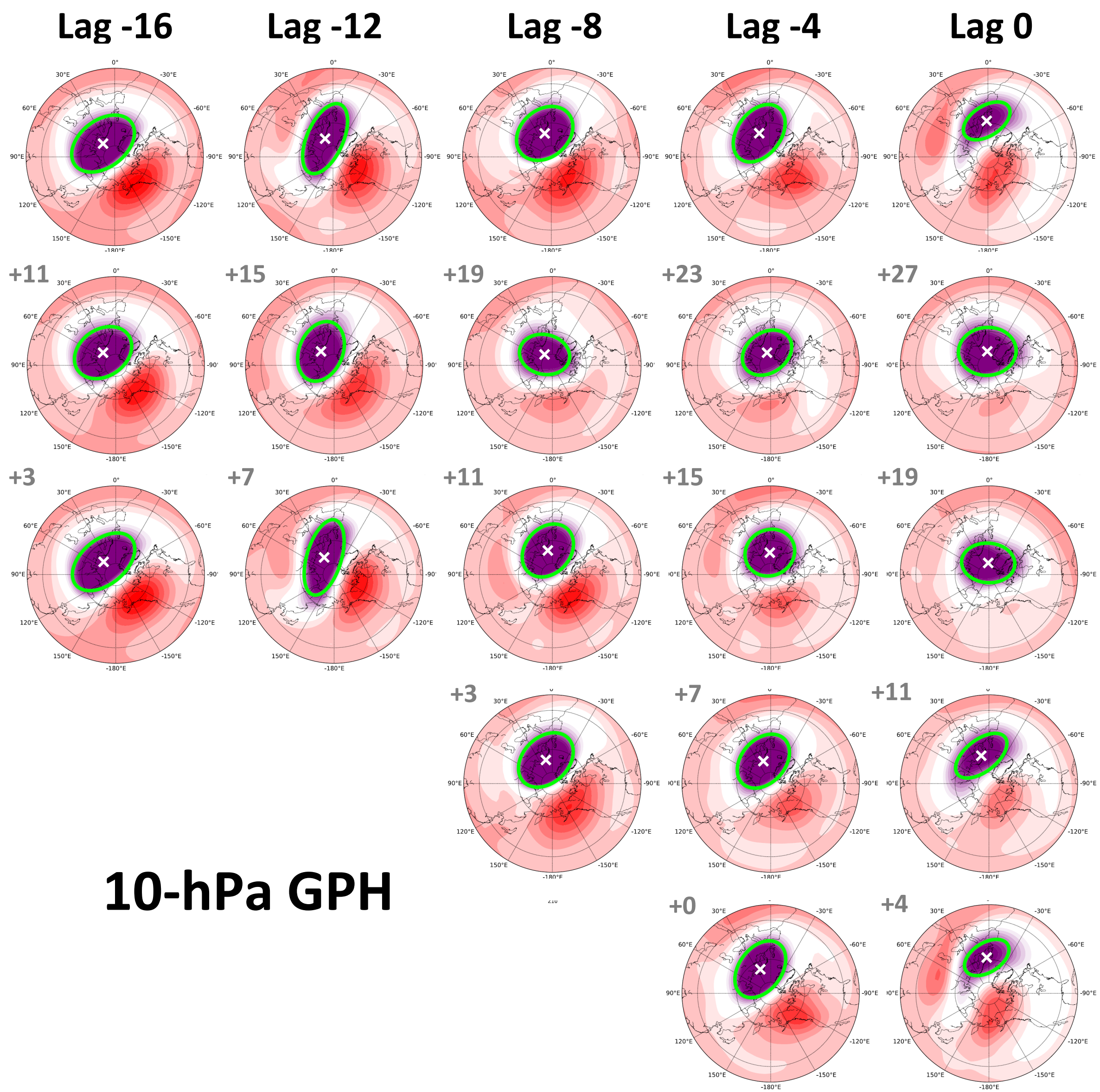
JRA-55

Initialized at
27 days
before SSW

19 days
before

11 days
before

4 days
before



2003 SSW Prediction: GloSea5

Split SSW
18JAN2003

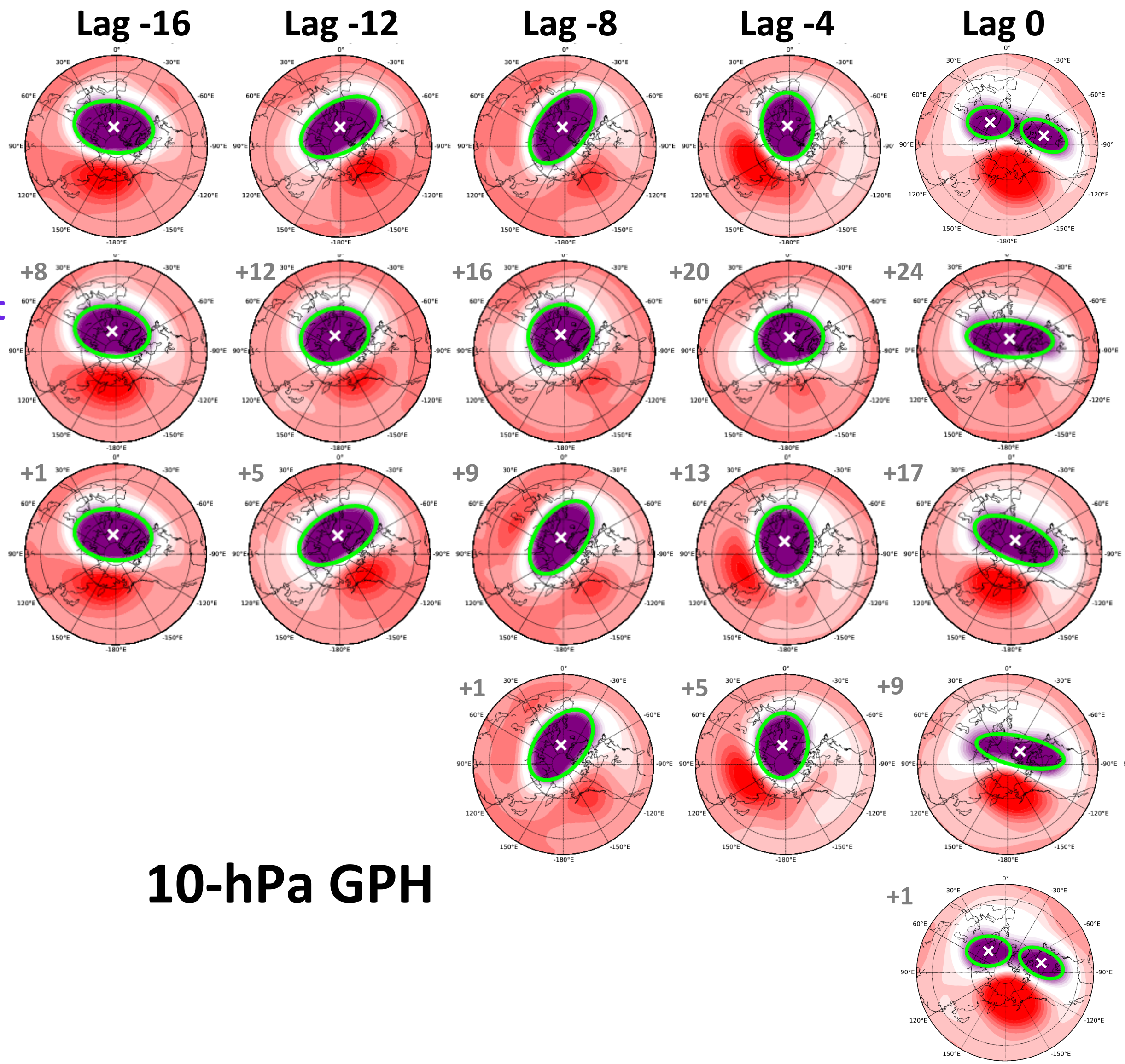
JRA-55

Initialized at 24 days before SSW

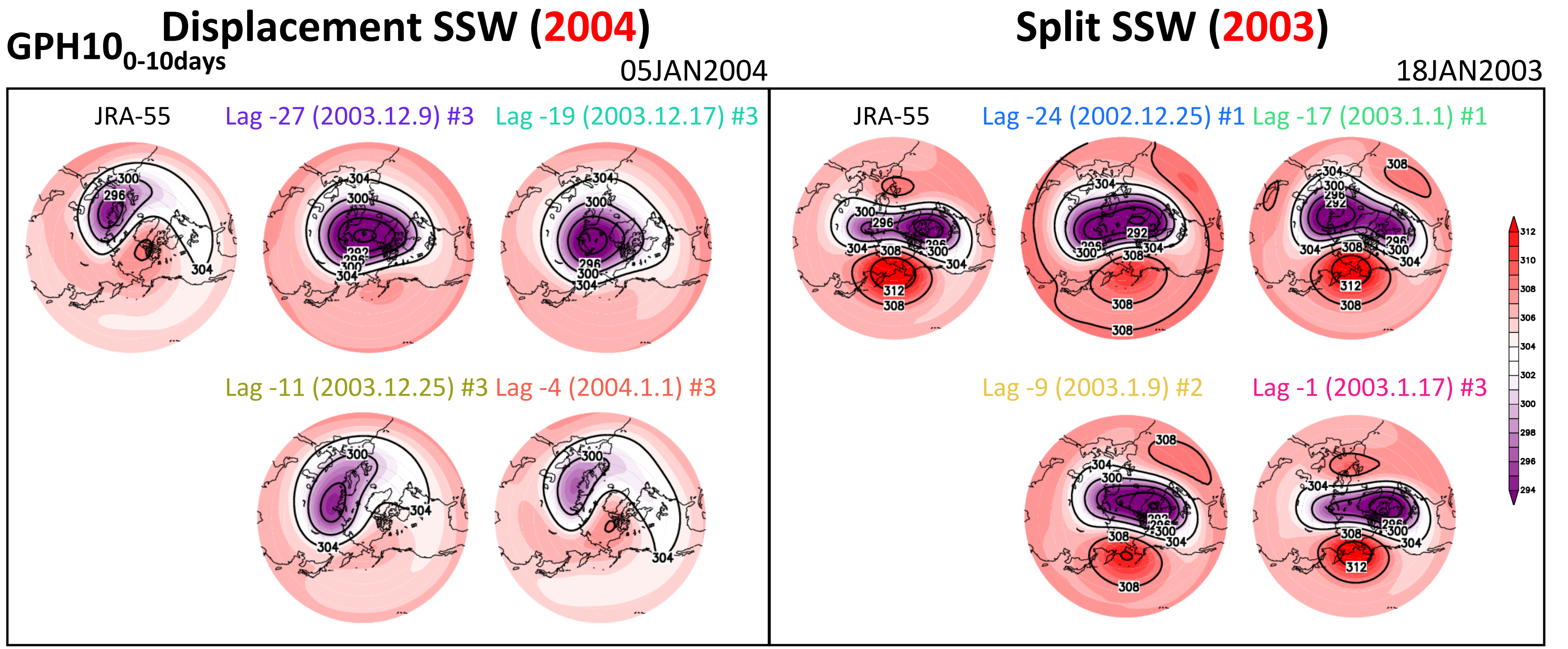
17 days before

9 days before

1 days before

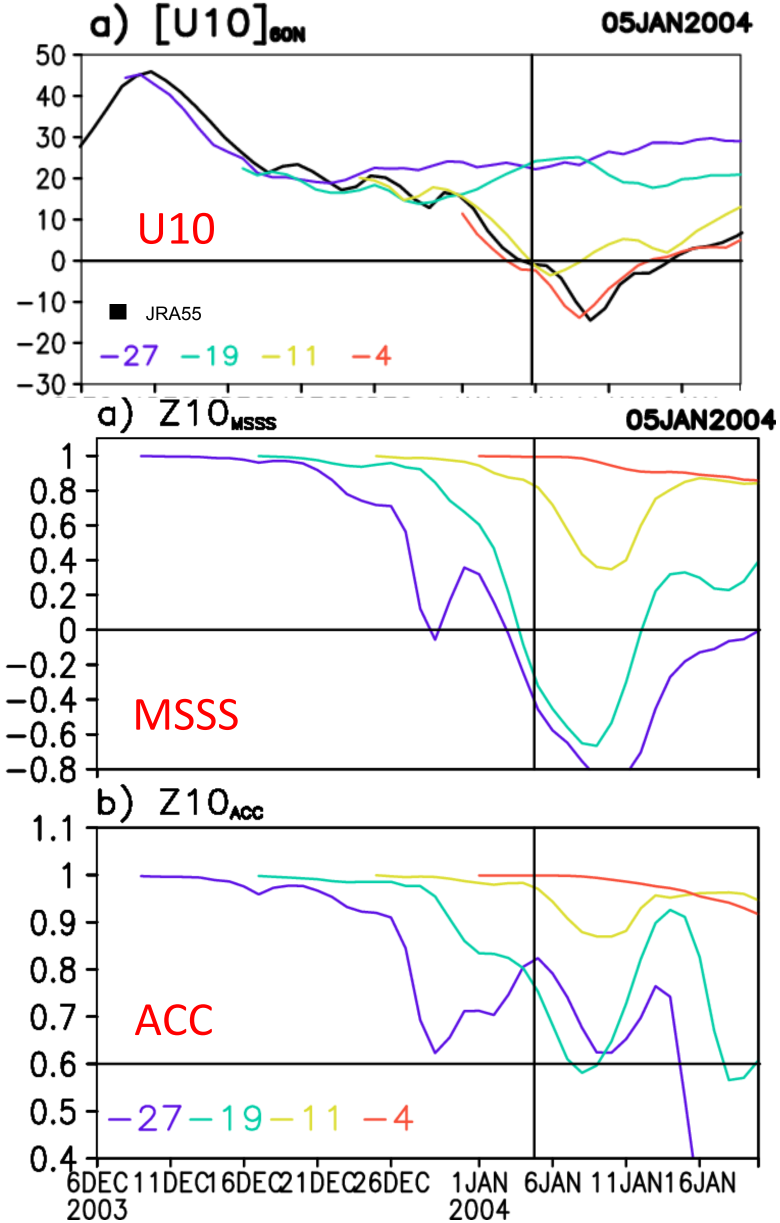


SSW Prediction Skill: GloSea5

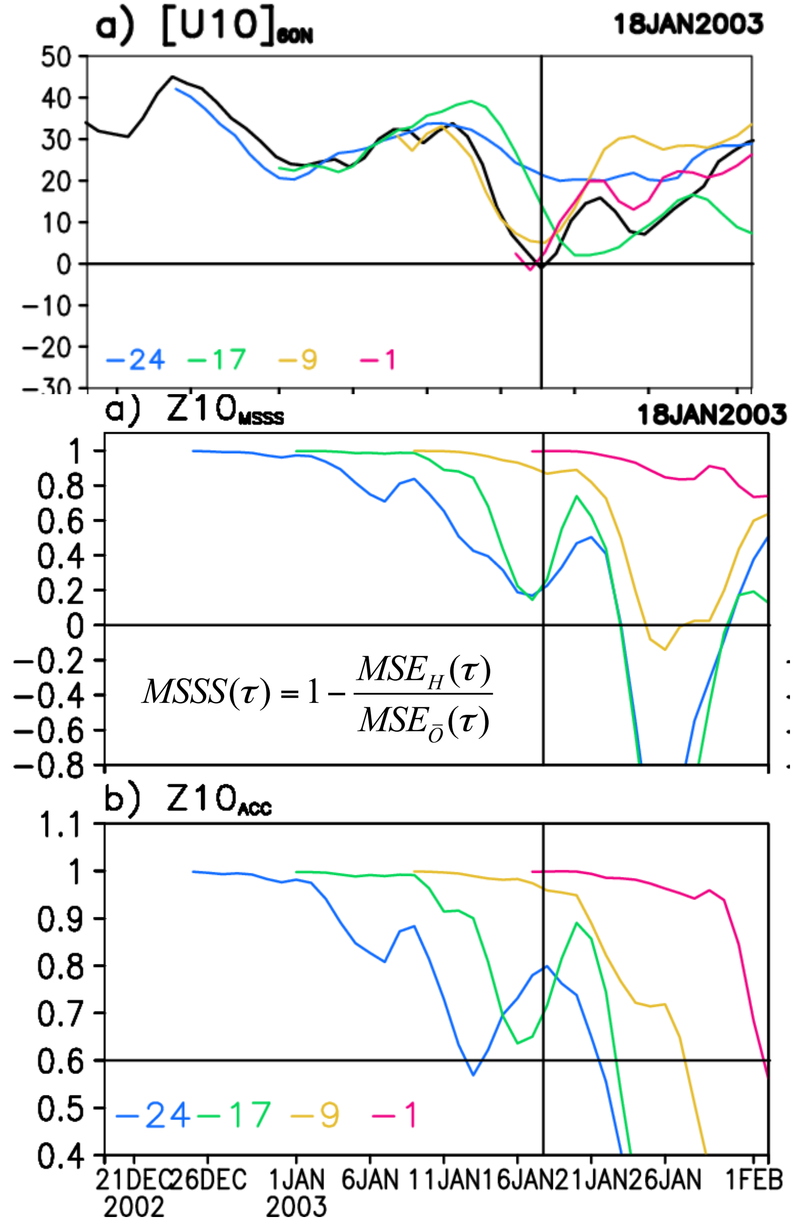


GloSea5 qualitatively predicts 2003 and 2004 SSW events with a maximum lead time of 11~17 days.

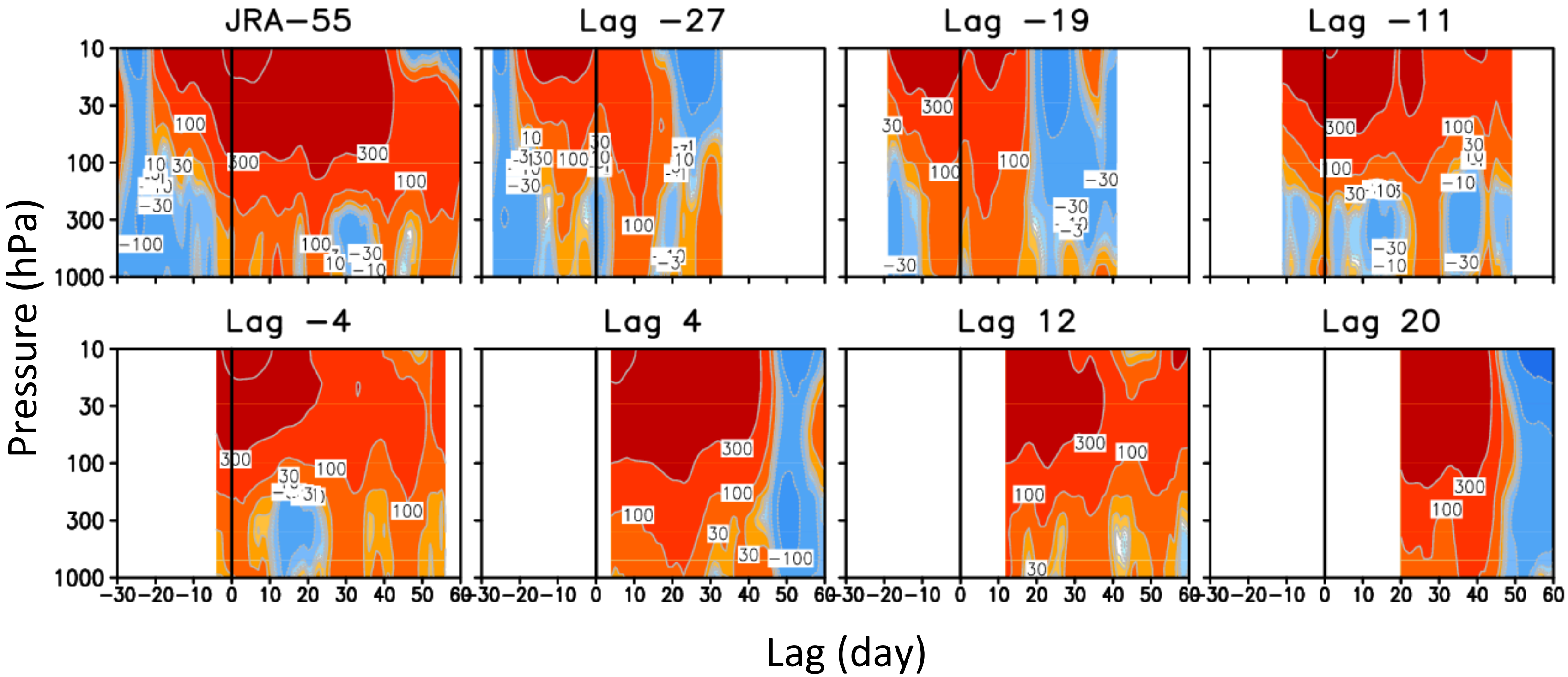
Displacement SSW (2004)



Split SSW (2003)

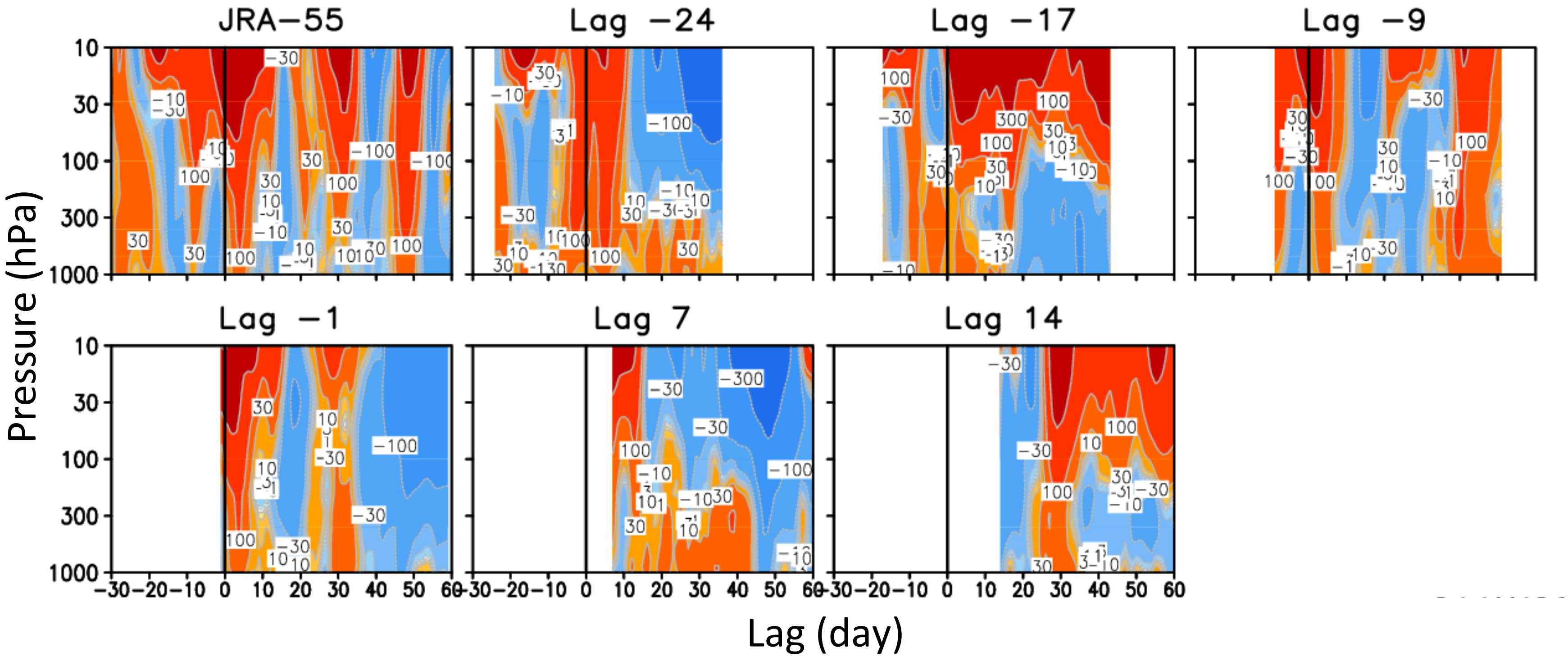


Displacement SSW (2004)

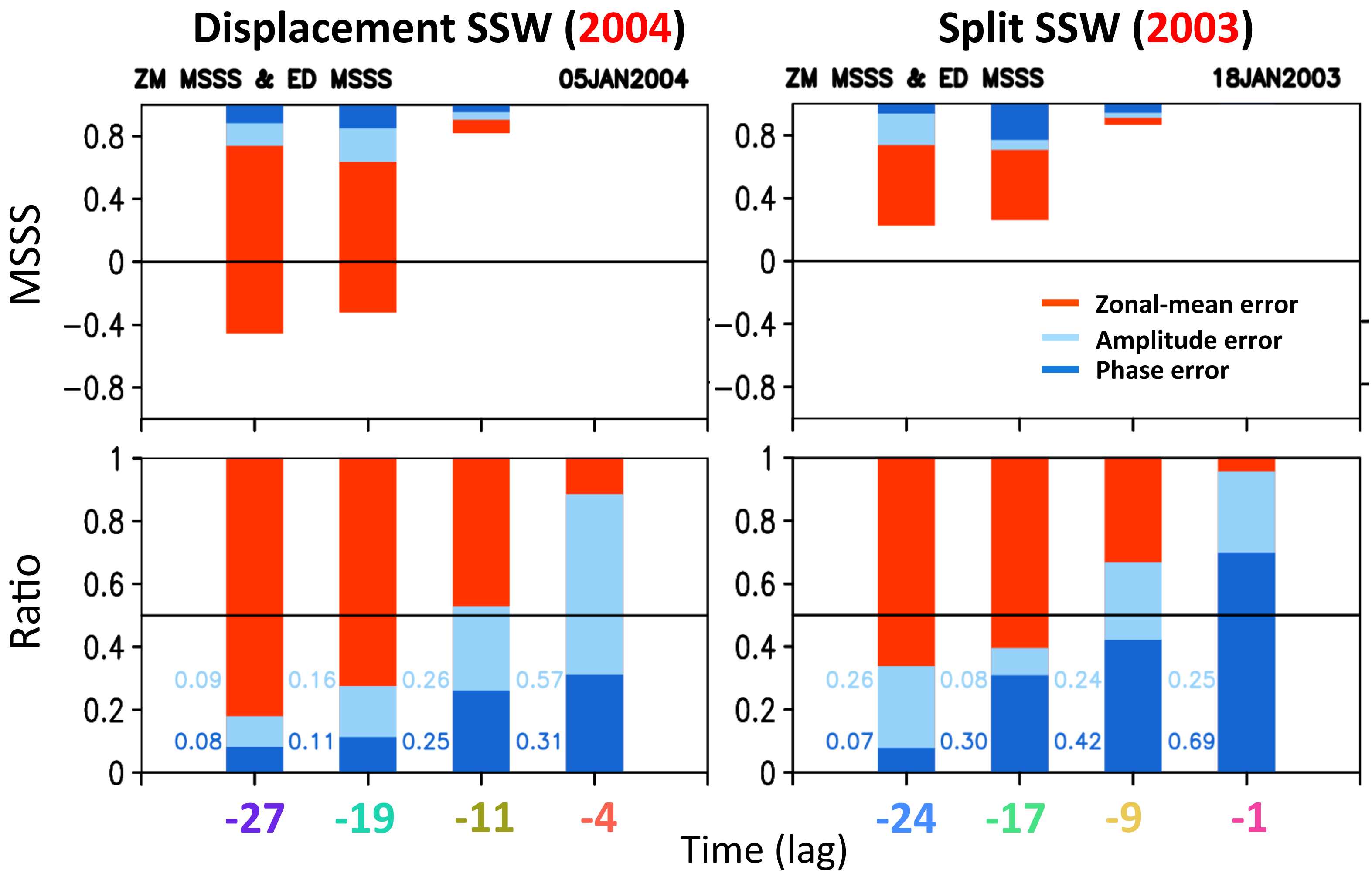


SSW-related downward propagation is also reasonably well predicted.

Split SSW (2003)



Sources of Prediction Errors



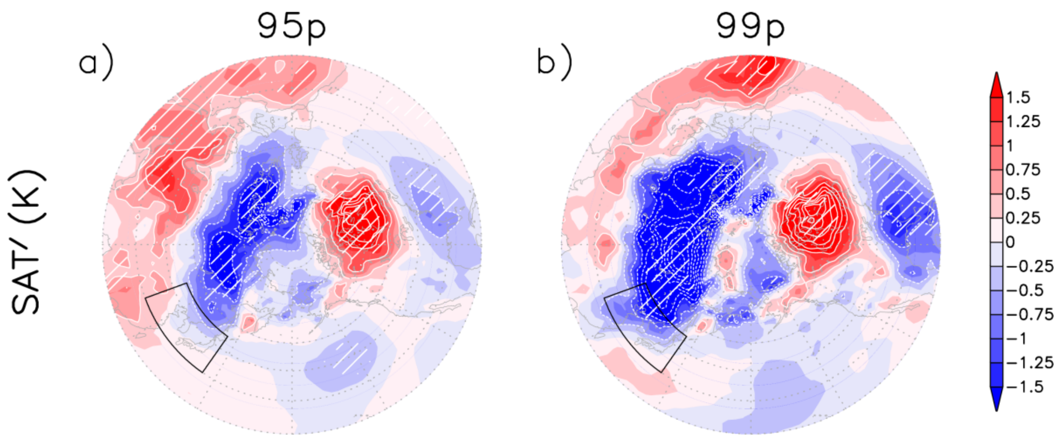
$$MSSS = [MSSS] + MSSS_{amp} + MSSS_{phs}$$

Recent 10 SSW Events

Case	Displacement SSW		Split SSW	
Urev	1998-12-15	15	1999-02-26	17
MSSS + ACC		15		17
Ratio of eddy (amp)		0.17 (0.02)		0.18 (0.02)
	2001-12-31	14	2001-02-11	17
		14		17
		0.48 (0.02)		0.32 (0.22)
	2004-01-05	11	2003-01-18	1*
		11		17
		0.27 (0.16)		0.8 (0.16)
	2007-02-24	0*	2006-01-21	20
		7		4
		0.32 (0.09)		0.73 (0.11)
	2008-02-22	13	2009-01-24	7
		5		7
		0.29 (0.04)		0.16 (0.09)
Mean		**13.25 days**		**15.25 days**
		10.4 days		**12.4 days**
		0.31 (0.07)		**0.43 (0.12)**
Predictability		**11.25 days**		**11.25 days**

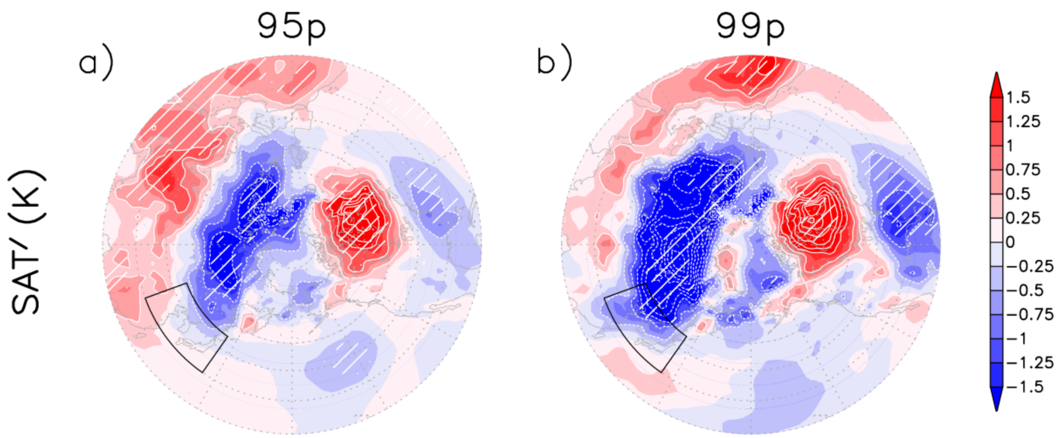
SSW can be predicted about 11-12 days in advance for both displacement and split SSW events.

Summary



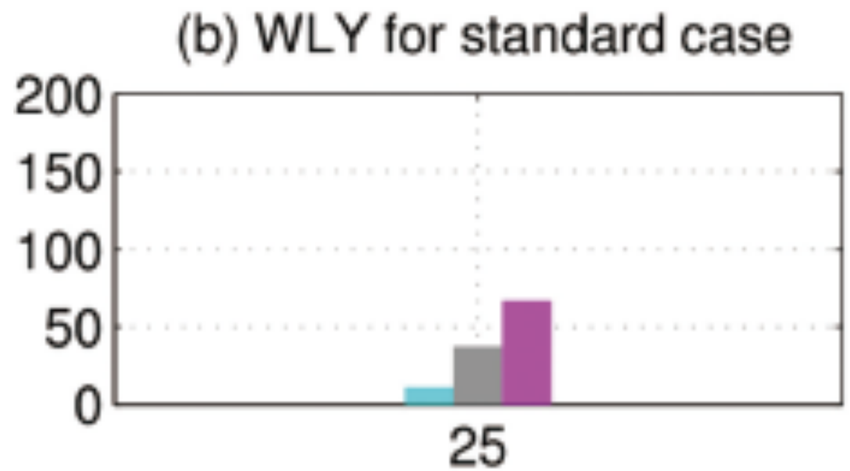
About 60% of SSW events cause a significant cooling and more frequent cold days in East Asia.

Summary

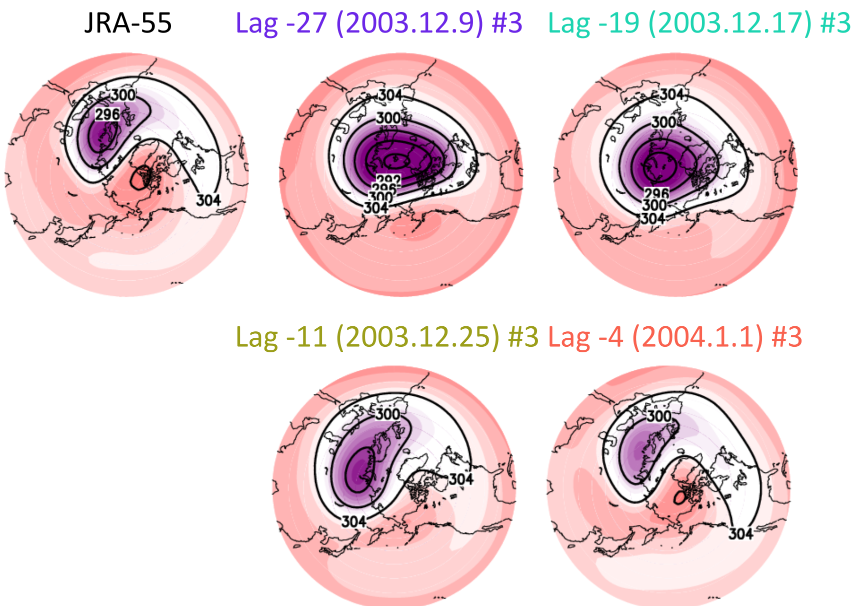


About 60% of SSW events cause a significant cooling and more frequent cold days in East Asia.

Statistically speaking, there is 60-70% chances of SSW in 2015 winter (WQBO and El Nino)

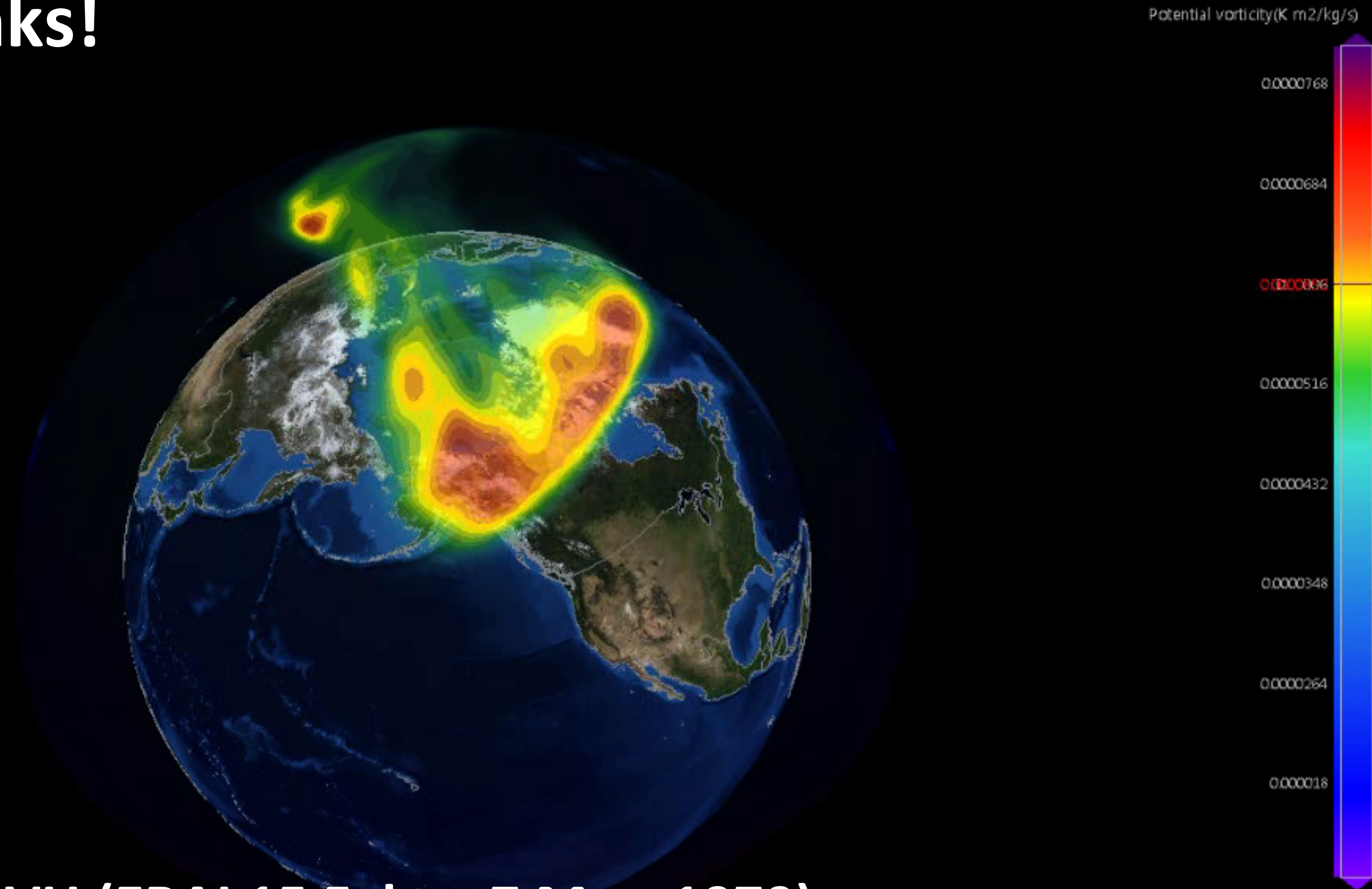


Summary



GloSea5 (operational seasonal prediction model of KMA) successfully predict SSW and the associated downward coupling with a maximum lead time of 11-12 days.

Thanks!



50-70 PVU (ERAI 15 Feb. – 7 Mar. 1979)

Year	Model	Event (SSW)	Predictability	Reference
1970	GFDL GCM	March 1965	2-day (captured only tendency)	Miyakoda et al. (1970)
1983	ECMWF	February 1979	10 - days	Simmons and Strufing (1983)
1985	UCLA GCM	February 1979	5 - days	Mechoso et al. (1985)
2004	JMA NWP	December 1998	30 - days	Mukougawa and Hirooka (2004)
2005	ECMWF	September 2002 (Antarctic)	7 - days	Simmons et al., 2005
2005	JMA NWP	December 2001	14 - days	Mukougawa et al., 2005
2006	NOGAPS-ALPHA	September 2002 (Antarctic)	5 - days	Allen et al., 2006
2007	ECMWF	Various	10 - days	Jung and Leutbecher, 2007
2007	JMA NWP	December 2003	9 - days	Hirooka et al, 2007
2009	NCEP SFSIE	Various	15 - days	Stan and Straus, 2009
2010	NOGAPS	January 2009	5 - days	Kim and Flatau (2010), Kim et al. (2011)
2010	HadGAM1	Various	9 - 15 days	Marshall and Scaife (2010)
2013	Met Office	January 2013	14 - days	Adam Scaife, pers. Comm., 2014
2013	GEOS-5	January 2013	5 - days	Lawrence Coy and Steven Pawson (http://gmao.gsfc.nasa.gov/researchhighlights/SSW/)

Tripathi et al. 2014QJ

Method: MSSS

$$MSSS(\tau) = 1 - \frac{MSE_H(\tau)}{MSE_{\bar{O}}(\tau)} = 1 - \frac{\frac{1}{n}\sum_{j=1}^{n}(H'_{j\tau} - O'_{j\tau})^2}{\frac{1}{n}\sum_{j=1}^{n}(O'_{j\tau} - \bar{O})^2}$$

$$\left(\frac{1}{n}\sum_{j=1}^{n} = \sum,\ H'_{j\tau} = H, O'_{j\tau} = O\right)$$

$$\left(\bar{O} = \sum O'_{j\tau} = 0\right)$$

$$= -\frac{\sum H^2}{\sum O^2} + 2\frac{\sum HO}{\sum O^2}$$

$$\left(r_{HO} = \frac{\sum HO}{\sqrt{\sum H^2 \sum O^2}}\right)$$

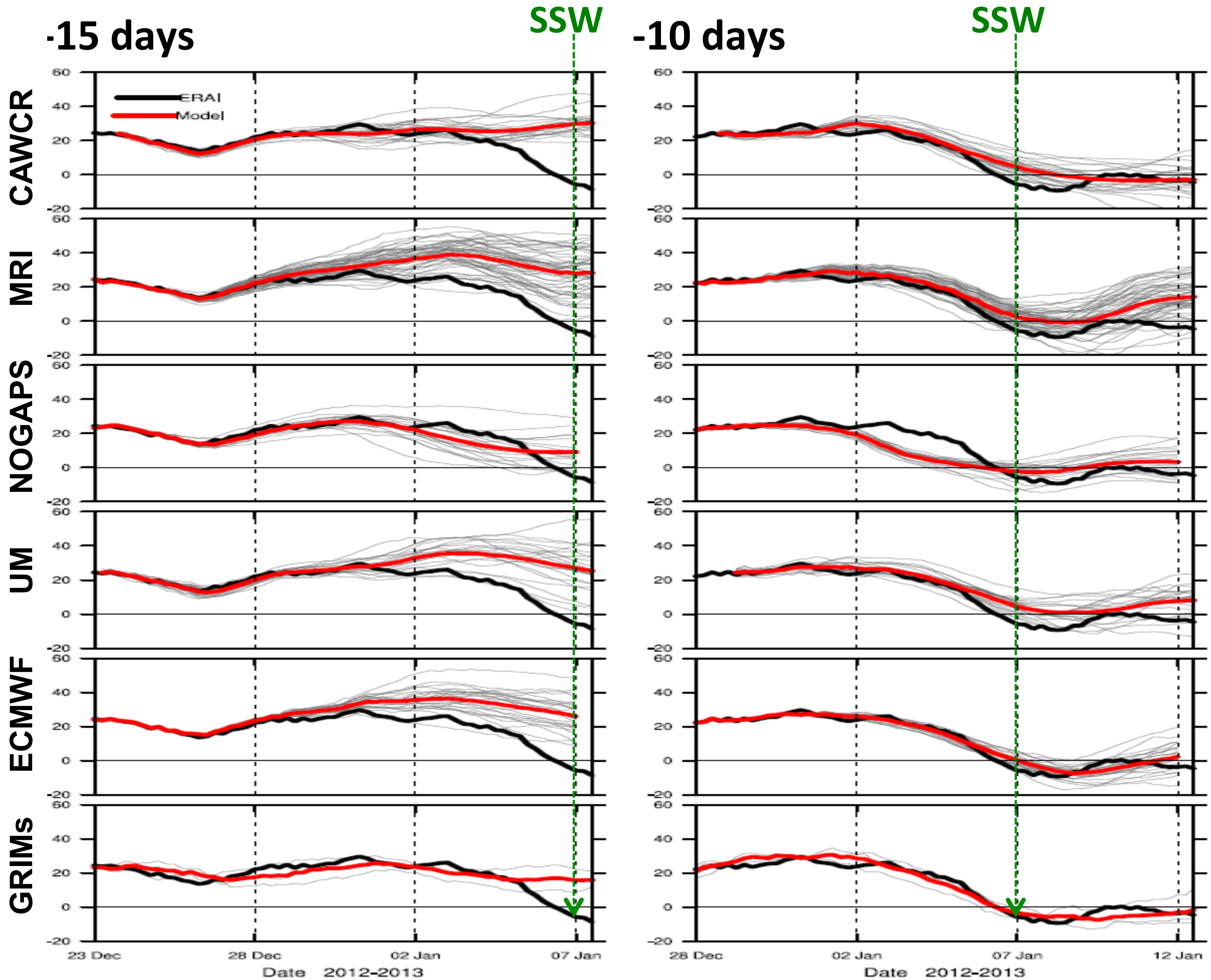
$$= -\frac{\sum H^2}{\sum O^2} + 2r_{HO}\sqrt{\frac{\sum H^2}{\sum O^2}}$$

$$\left(\begin{array}{l} s_H^2 = \frac{1}{n}\sum_{j=1}^{n}\left(H'_{j\tau}\right)^2 \\ s_O^2 = \frac{1}{n}\sum_{j=1}^{n}\left(O'_{j\tau}\right)^2 \end{array}\right)$$

$$= r_{HO}^2 - \left(r_{HO} - \left(s_H / s_O\right)\right)^2$$

ACC ***Conditional bias***

Results: SNAP Experiments



All SNAP models predict SSW about 10 days in advance.