Equal frequency of stratospheric sudden warmings in El Nino and La Nina

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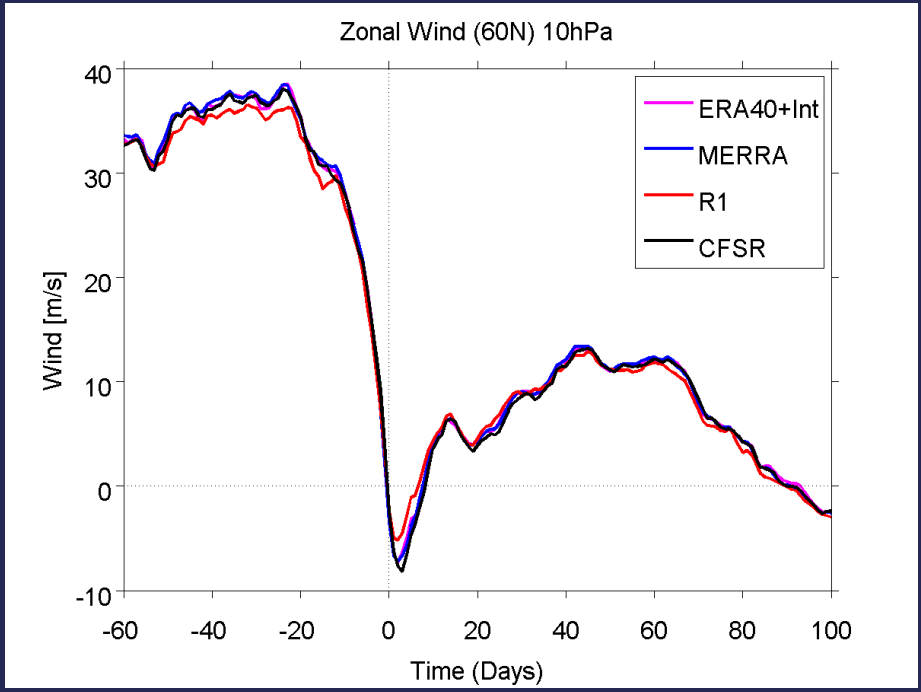
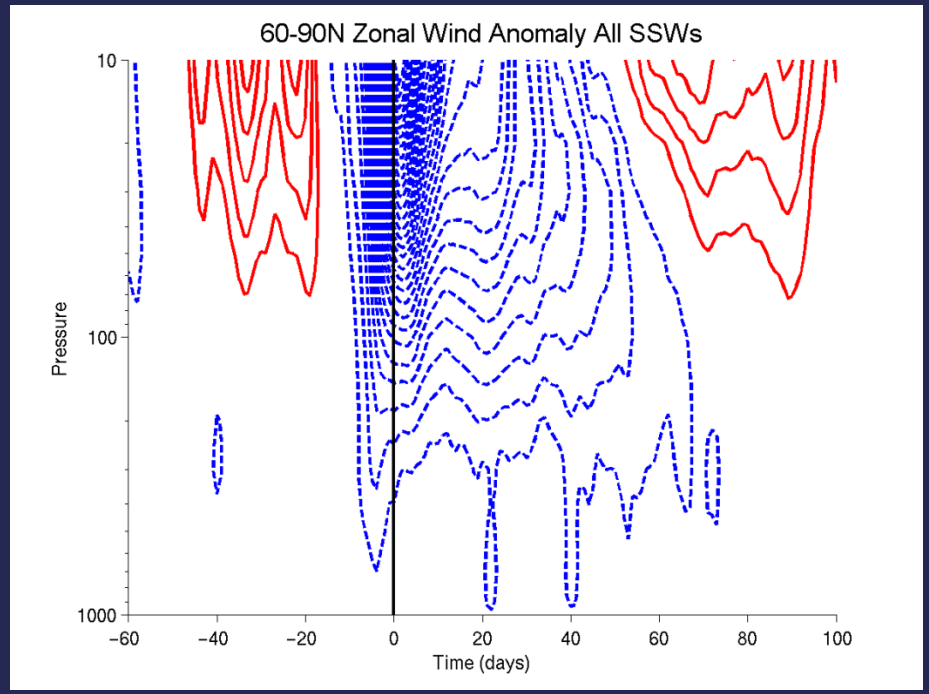
Stratospheric Sudden Warmings

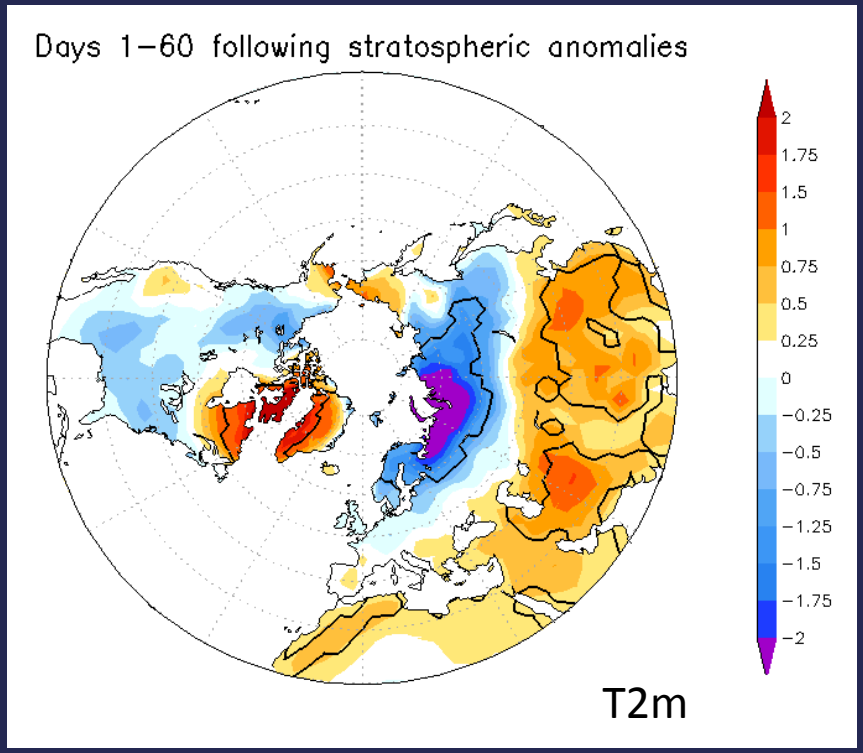
- **Dramatic reversal of the polar vortex winds during NH wintertime, often followed by anomalies that propagate downward to the troposphere 10-60 days later**



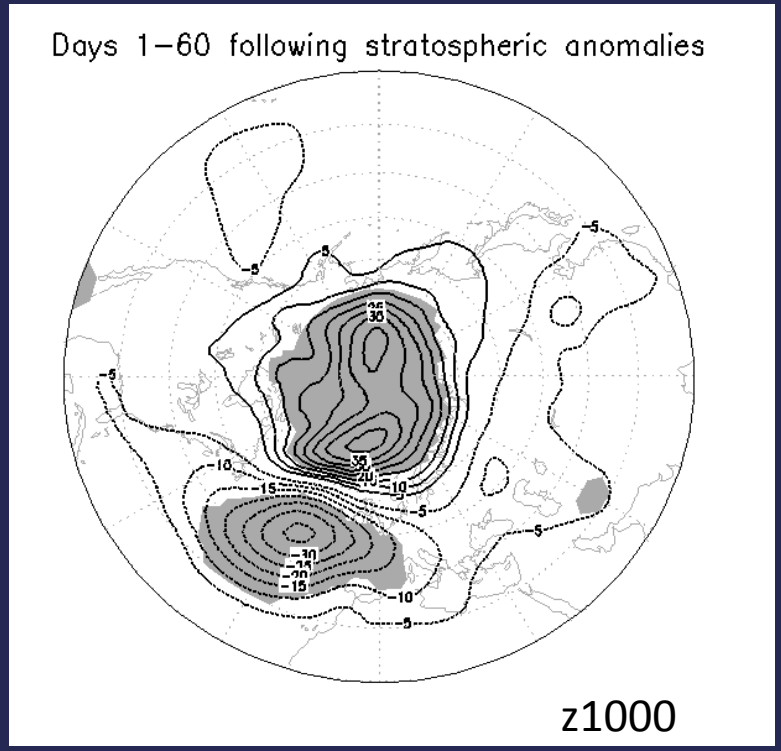


Stratospheric Sudden Warmings

- **Can have significant impacts on surface climate in NH winter**
- **Strong (-) NAO: extreme cold outbreaks, Arctic warming**



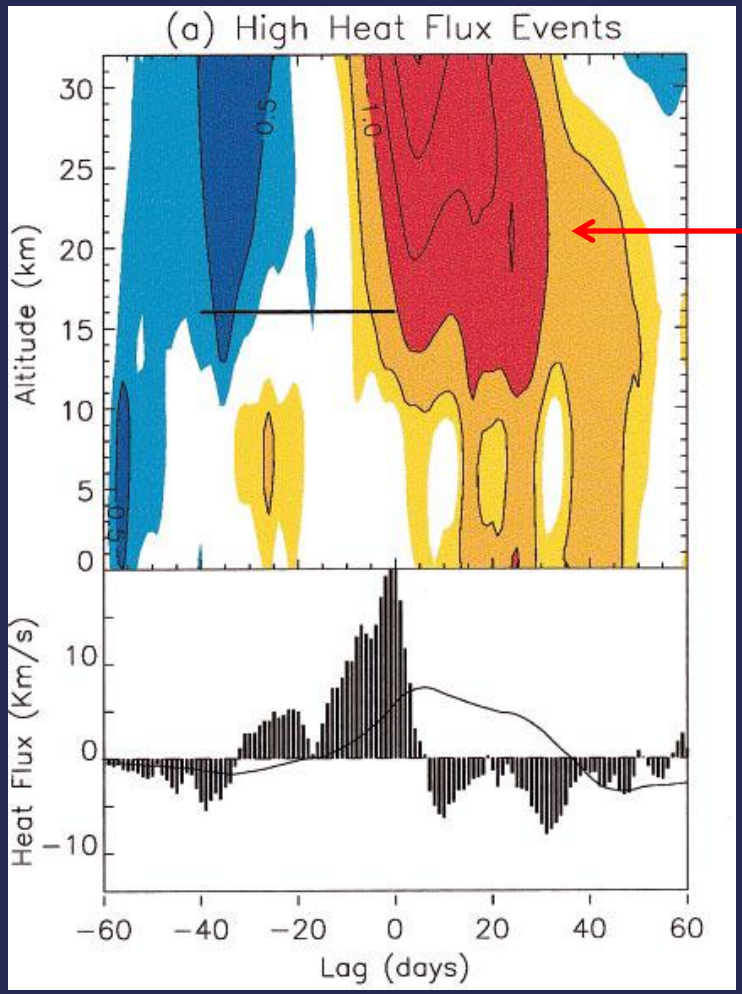
As in Thompson et al. 2002, updated through 2011



Being able to forecast these events could improve intraseasonal to seasonal prediction!
SO…. What causes them to occur?

Stratospheric Sudden Warmings

- **Driven by tropospheric planetary-scale waves propagating vertically into the stratosphere and breaking at high-latitudes**



(-) NAM

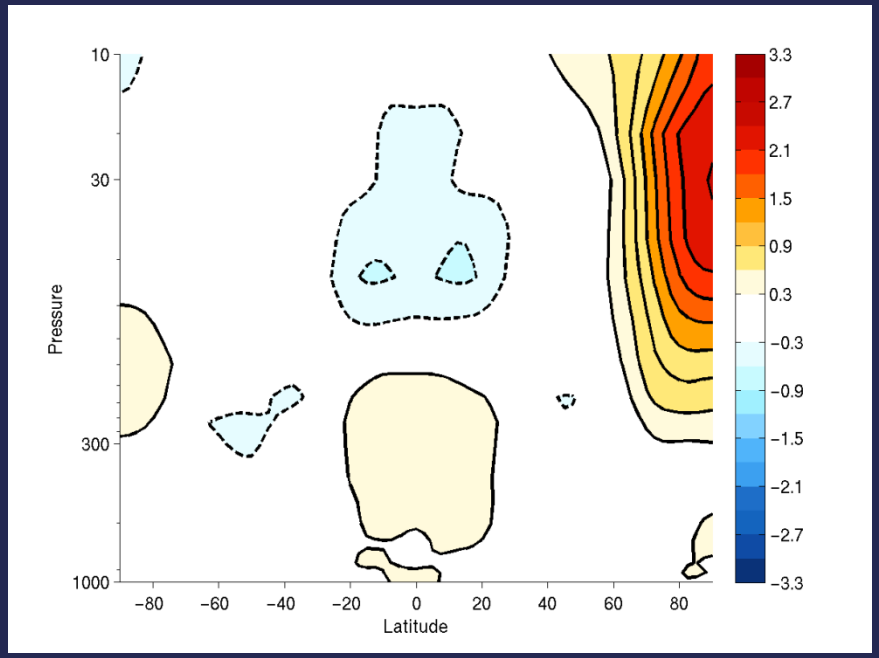
Processes which drive planetary scale waves, like ENSO, may therefore be associated with changes in the frequency of SSWs.

How does ENSO impact the stratosphere?

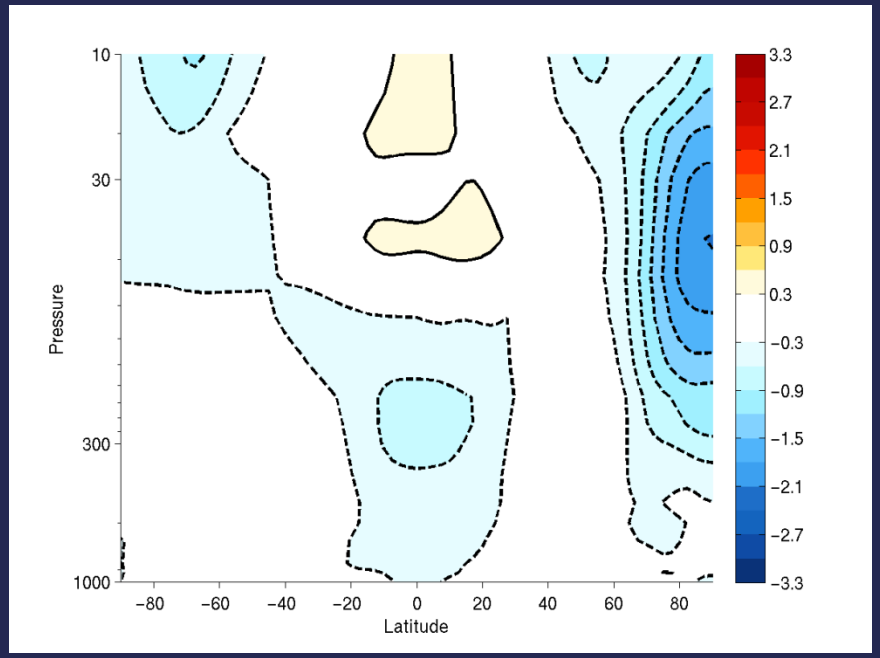
Polvani and Waugh 2004

ENSO's impact on the Stratosphere

El Nino



La Nina

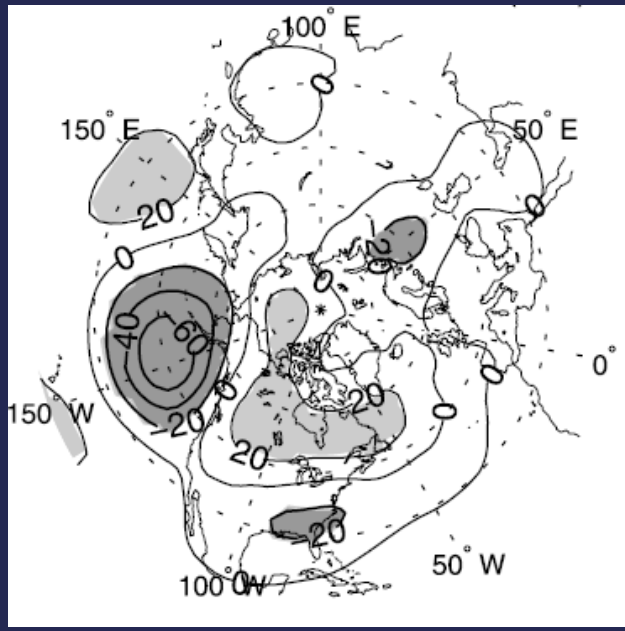


DJF Temperature composites [K]
1958-2009, NCEP-NCAR reanalysis

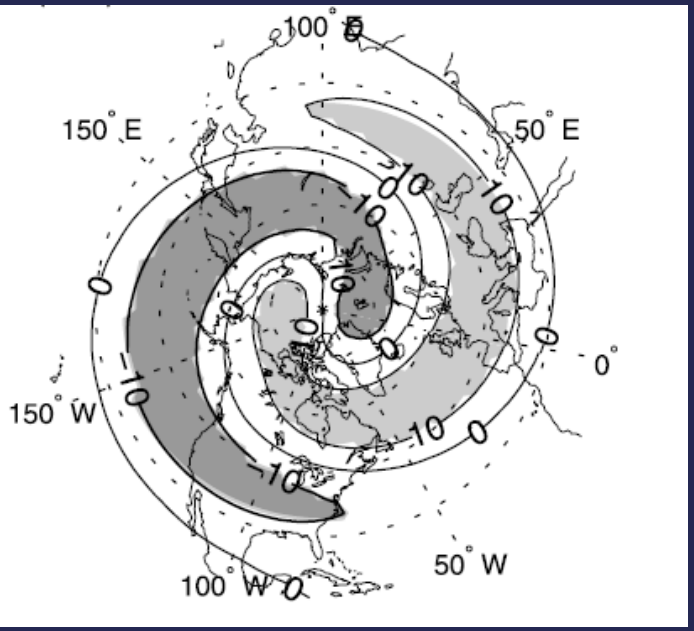
Presumably, the warmer temps during El Nino are associated with stronger wave driving in the seasonal-mean, which weakens the vortex and warms the stratosphere.

El Nino z500

Anomaly composite



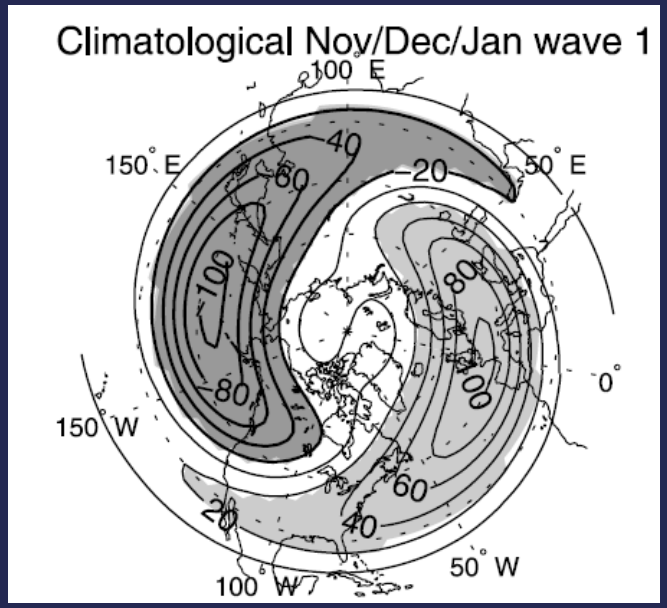
Wave-1 component



Because El Nino reinforces climatological wave 1, planetary wave driving of the vortex increases.

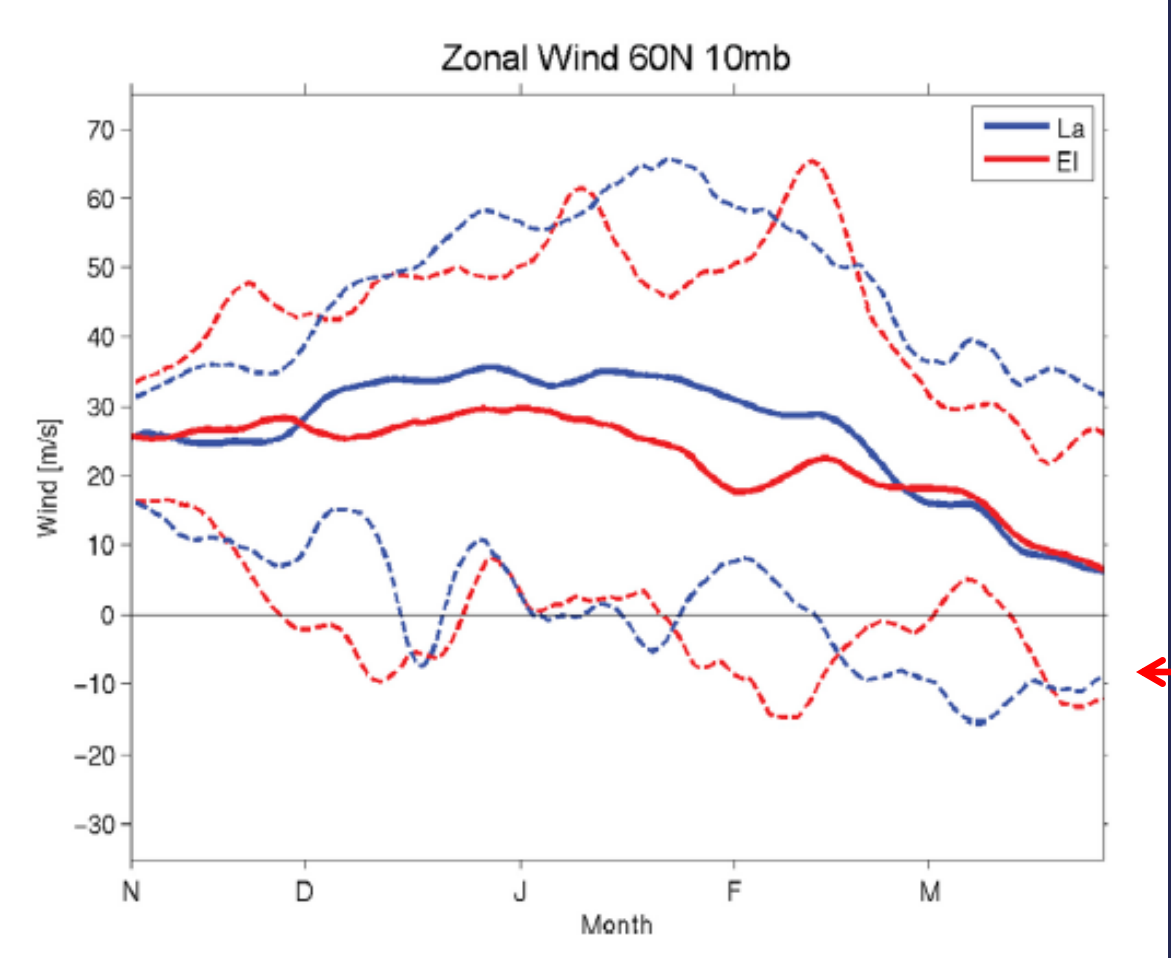
La Nina has the opposite effect, since it's associated with an anomalous high over the Pacific region.

But do extreme wave driving events that lead to SSWs ever occur during La Nina?



Garfinkel and Hartmann (2008)

ENSO and SSWs



Mean winds are weaker during El Nino relative to La Nina, but extreme wind anomalies are similar in each phase.

ENSO and SSWs

Table 2a. SSWs for El Niño, La Niña, ENSO-Neutral, and All Winters (Defined by the NDJFM-Mean)[a]

	1958–2010			1979–2010		
	Number of Winters	Number of SSWs	SSWs per Winter	Number of Winters	Number of SSWs	SSWs per Winter
El Niño	18	13	0.72	10	6	0.60
La Niña	18	14	0.78	10	10	1.0
Neutral	17	7	0.41	12	5	0.42
All	53	34	0.64	32	21	0.66

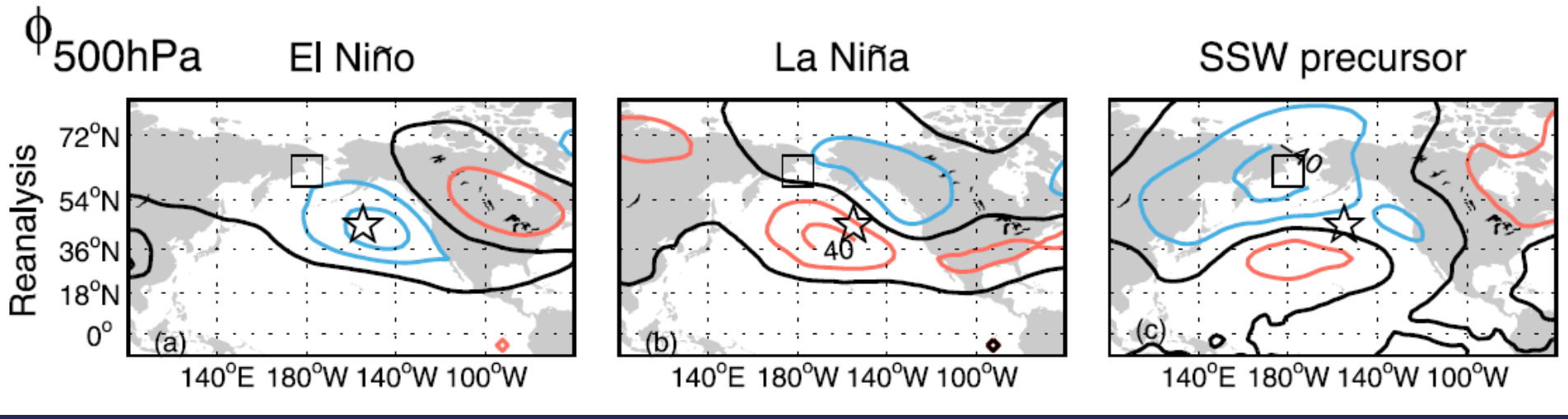
Butler and Polvani 2011, GRL

El Nino and La Nina have equal frequency of SSWs in the historical record.

Why do SSWs occur during La Nina as often as during El Nino if the La Nina teleconnection in the Pacific presumably interferes with wave amplification into the stratosphere?

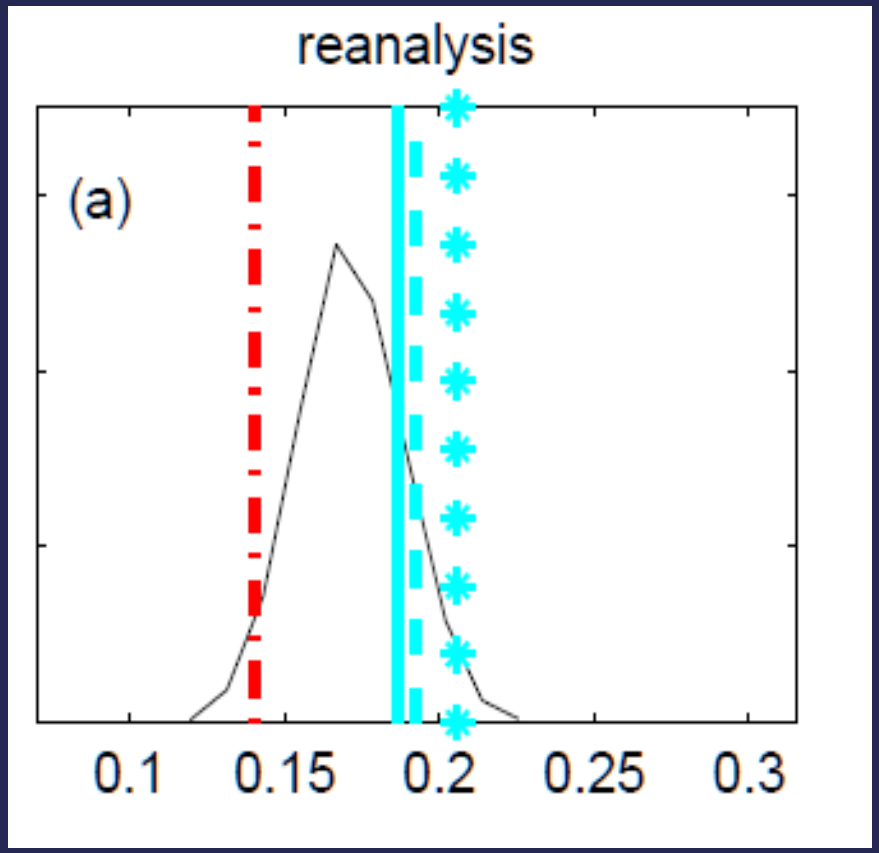
ENSO teleconnections and SSW precursors

From *Garfinkel et al. 2012*, JGR



While El Nino is associated with a trough in the North Pacific, and La Nina is associated with a ridge, both teleconnections are associated with low height anomalies in the SSW precursor region (marked by the square).

Frequency of Extreme Lows in SSW precursor region

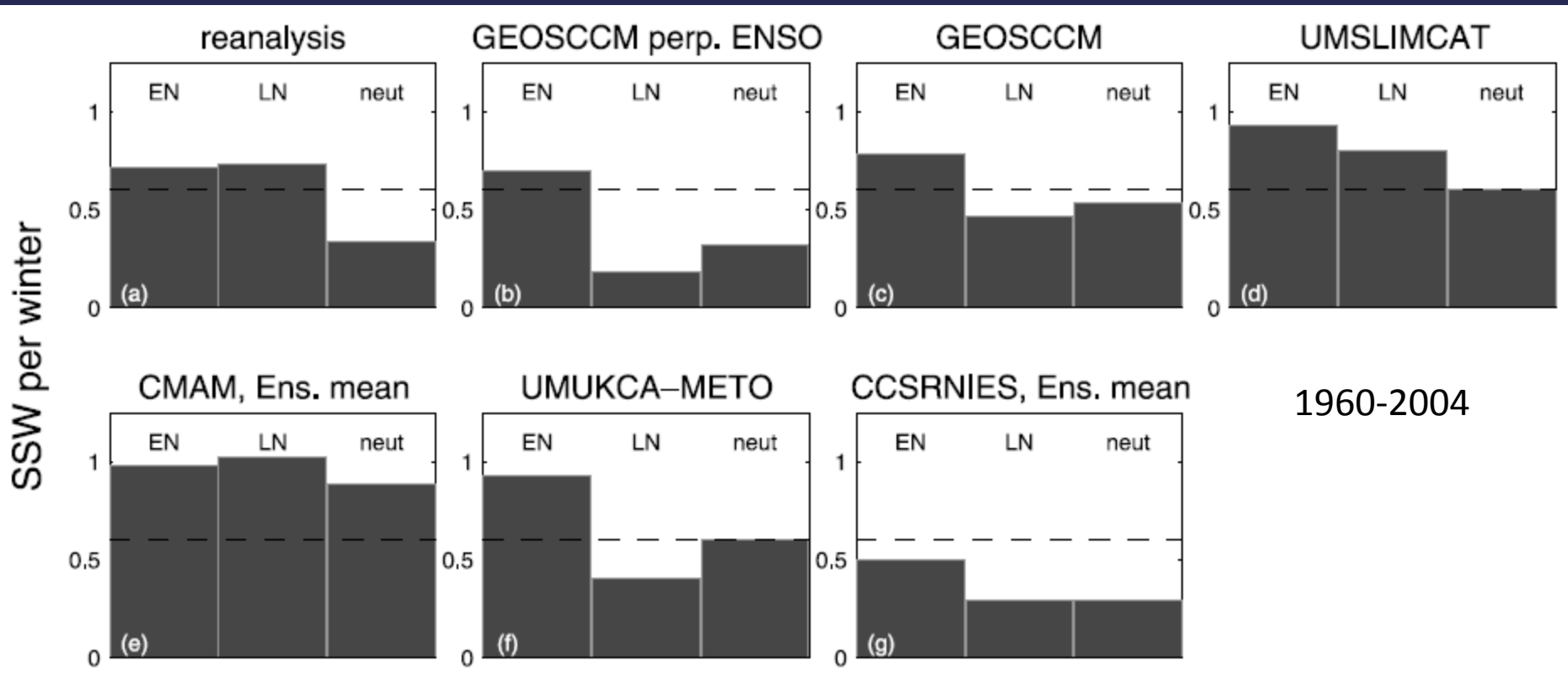


Frequency of height anomalies exceeding -120m in SSW precursor region. Neutral = red line, El Nino = dashed line, La Nina = solid line, strong La Nina = asterisks

Extreme negative anomalies in the SSW precursor region occur nearly equally often in La Nina and El Nino, and less often in neutral ENSO, consistent with SSW frequency.

Can this relationship explain the difference between SSW frequency and ENSO in chemistry climate models as well?

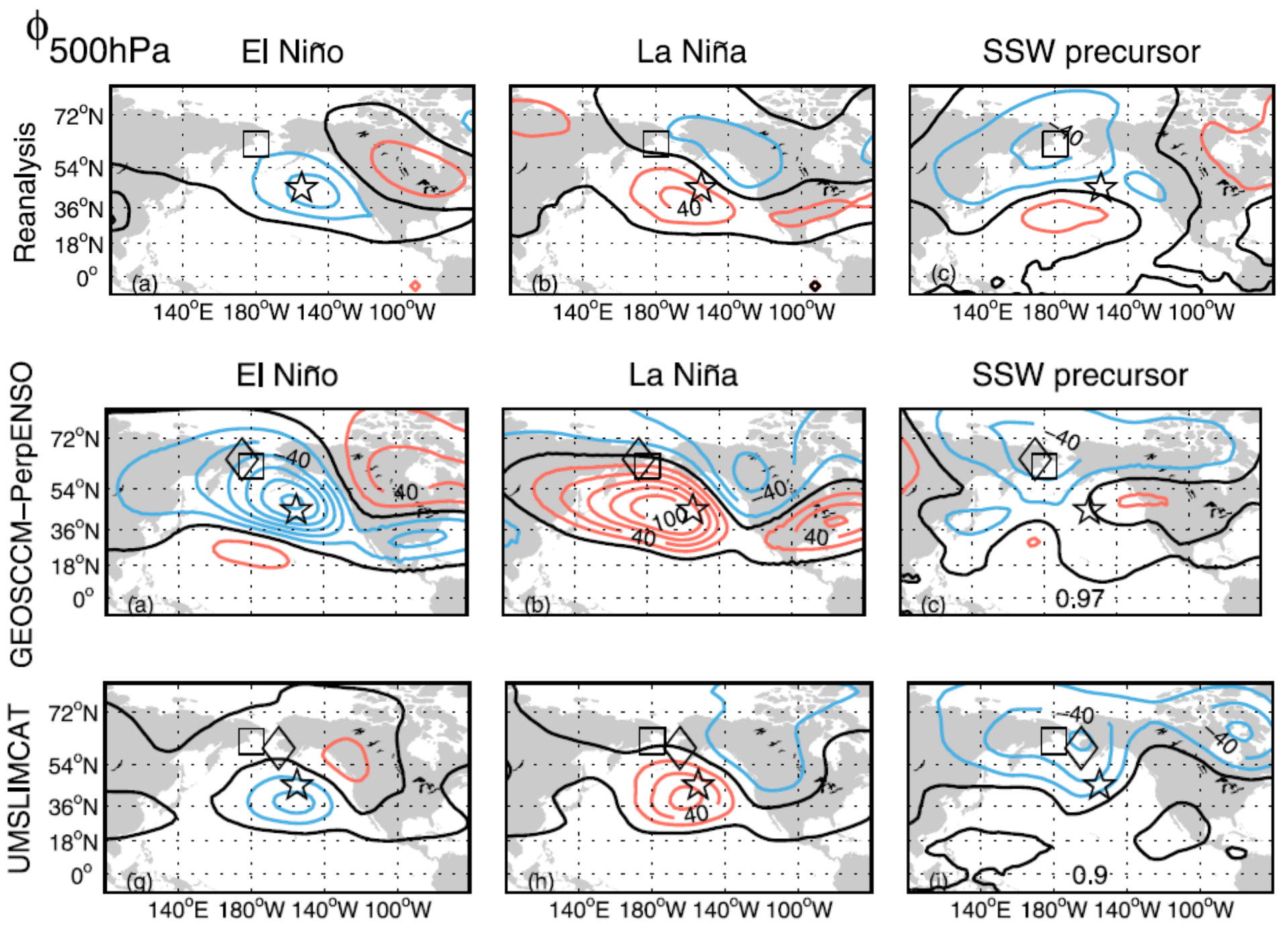
ENSO's impact on SSWs in models



1960-2004

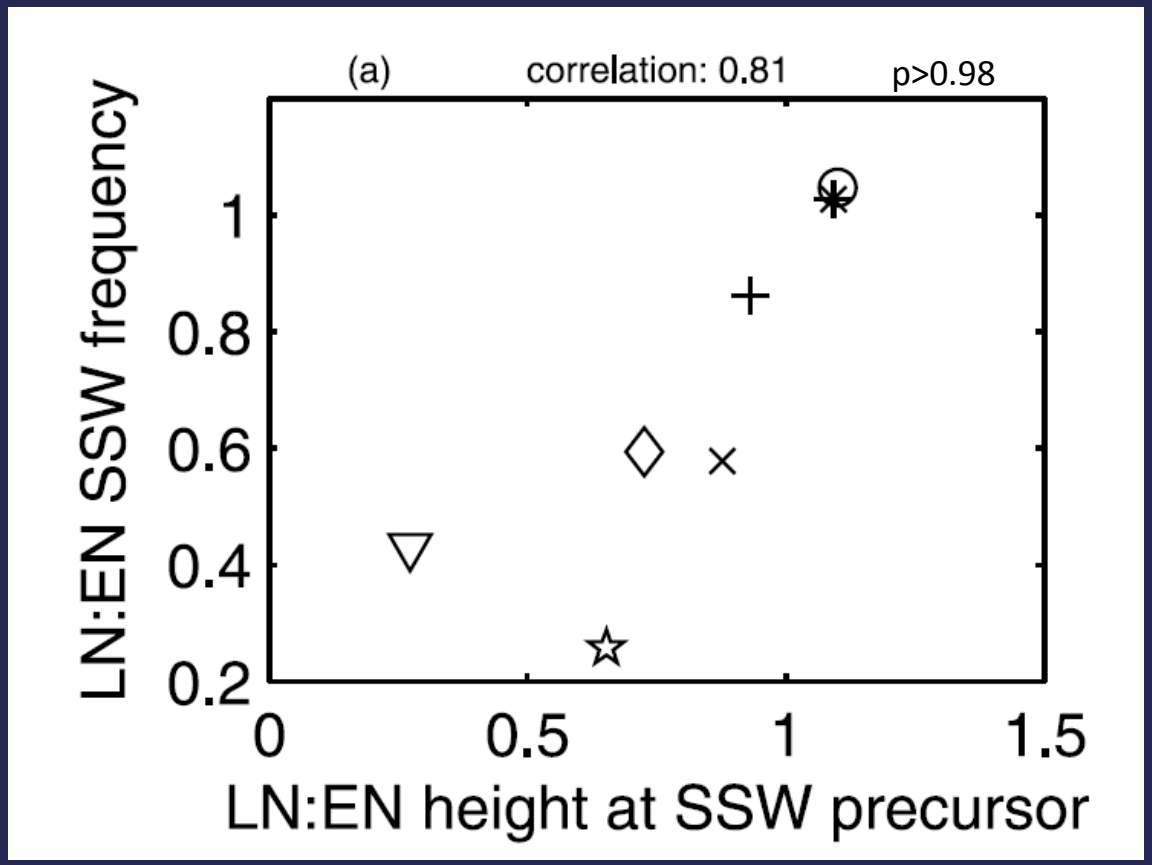
From *Garfinkel et al. 2012*, JGR

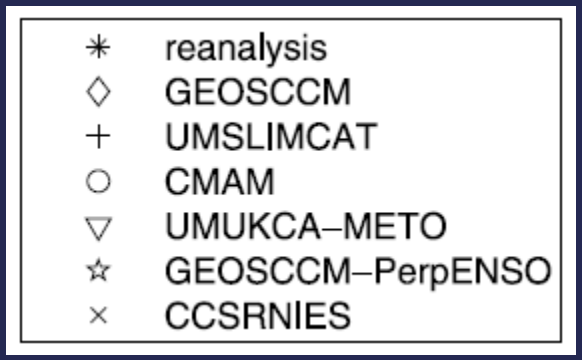
Though El Nino enhances SSW frequency in most models, the impact of La Nina varies wildy- e.g., the SSW freq is enhanced in UMSLIMCAT and CMAM, but reduced in GEOSCCM, UMUKCA-METO, and CCSRNIES. Can the location of the ENSO teleconnections in these models explain the SSW frequency response?



From *Garfinkel et al. 2012*, JGR

SSW frequency is closely related to extreme negative anomalies in precursor region

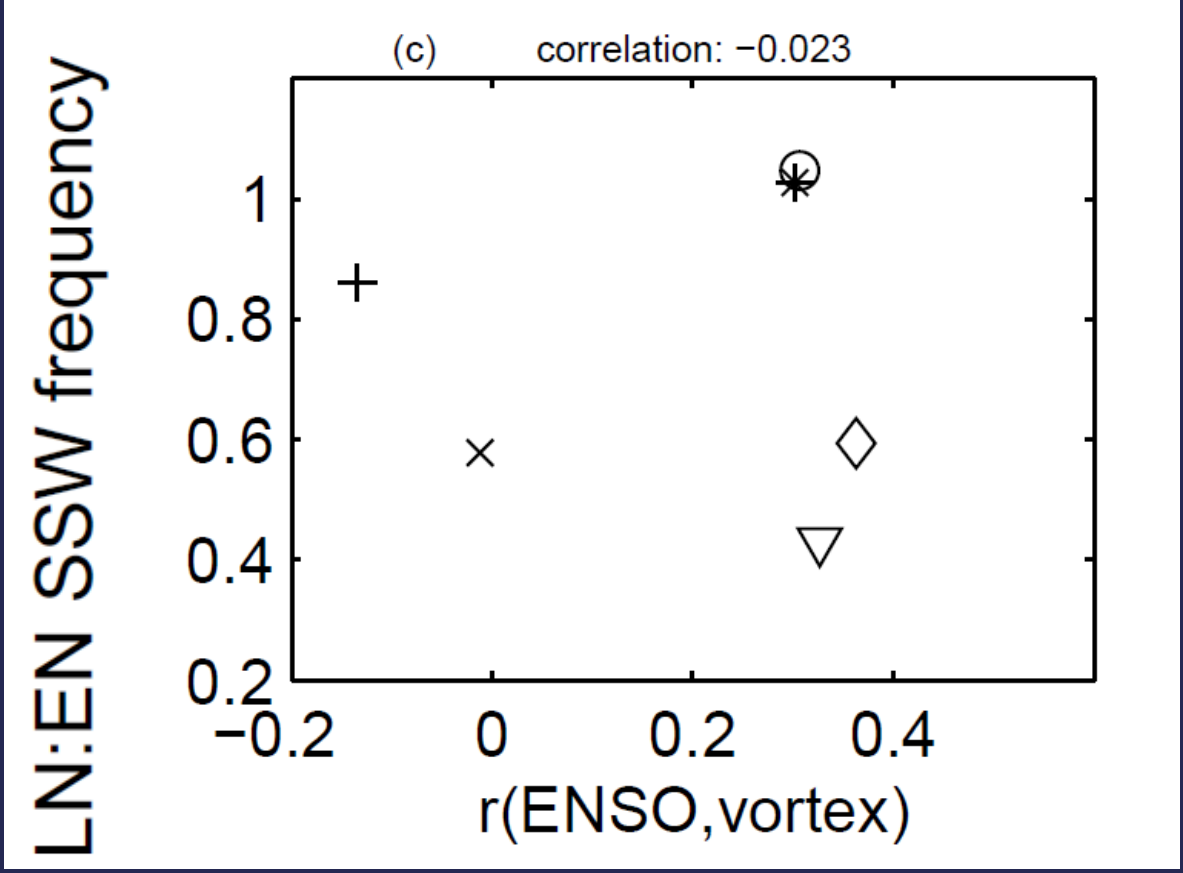


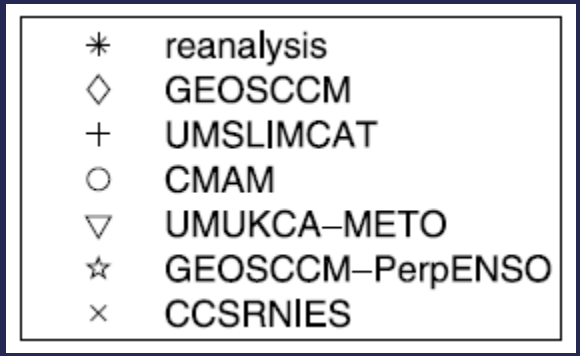


Inter-model variability in EN and LN SSW frequency is related to inter-model variability of the extreme negative height anomalies in the SSW precursor region

From *Garfinkel et al. 2012*, JGR

No relationship between ENSO impact on seasonal mean vortex and SSW frequency





Models/data with a large seasonal mean impact from ENSO do not necessarily have a large SSW response to ENSO, and vice versa

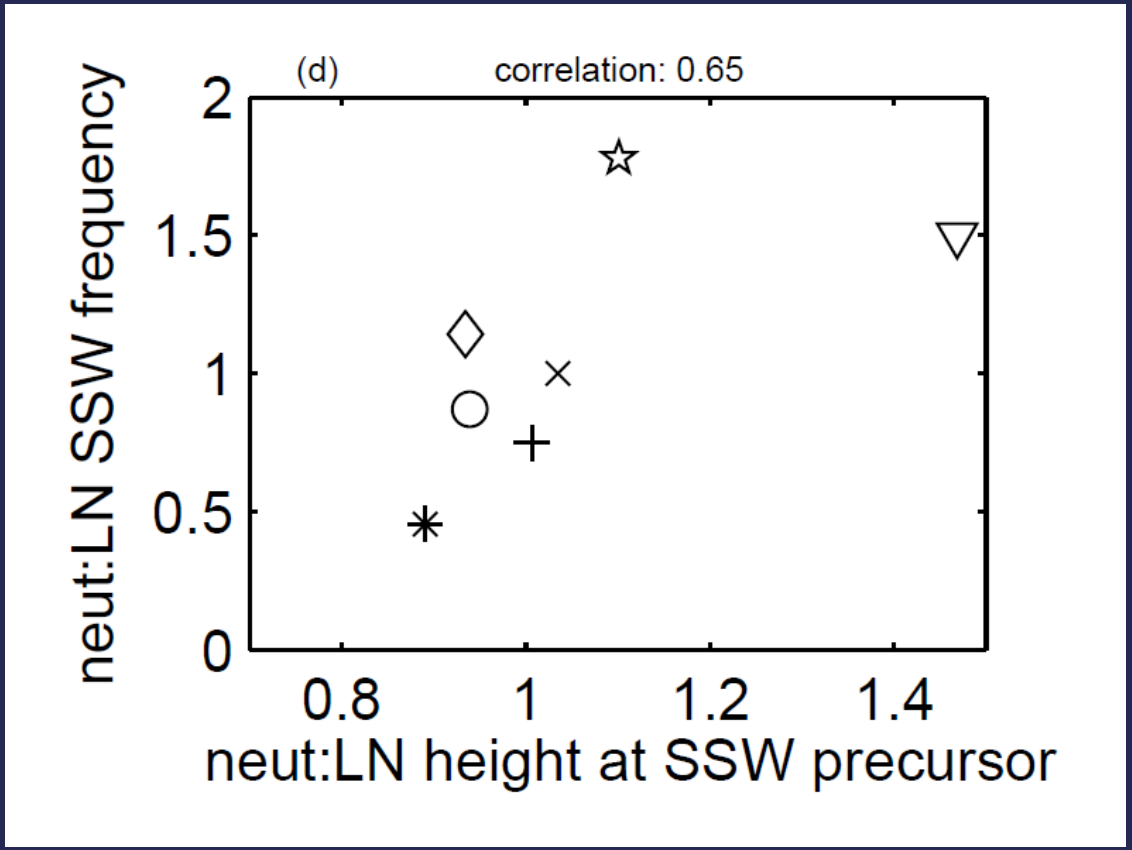
From *Garfinkel et al. 2012*, JGR

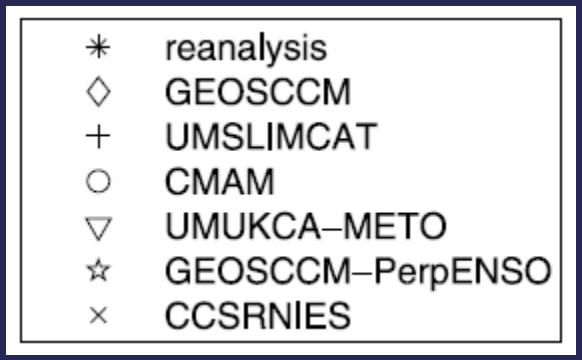
Conclusions

- **SSW frequency during different phases of ENSO is related to the subpolar extent of ENSO teleconnections.**
- **Frequency of extreme negative anomalies in SSW precursor region largely determines SSW frequency for a given dataset/model simulation.**
- **Response to an external forcing, like ENSO, of the seasonal mean stratospheric vortex may not be indicative of the response of extreme stratospheric events.**

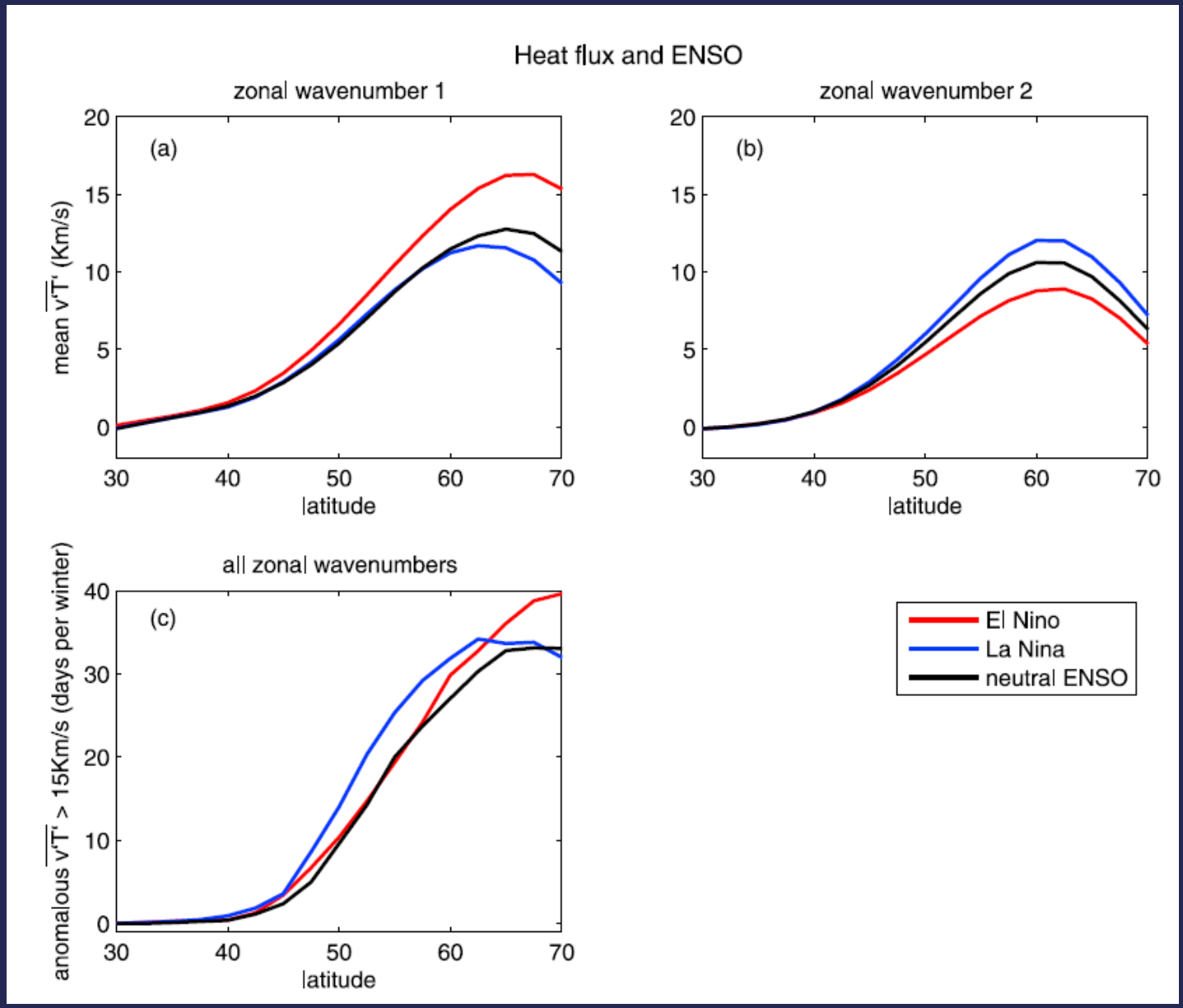
Garfinkel, C.I., A.H.Butler, D.W. Waugh, M.M. Hurwitz, and L.M. Polvani, Why might SSWs occur with similar frequency in El Nino and La Nina winters? J. Geophys. Res., 117, doi: 10.1029/2012JD017777, 2012.

SSW frequency during neutral ENSO winters is also tied to negative anomalies in SSW precursor region

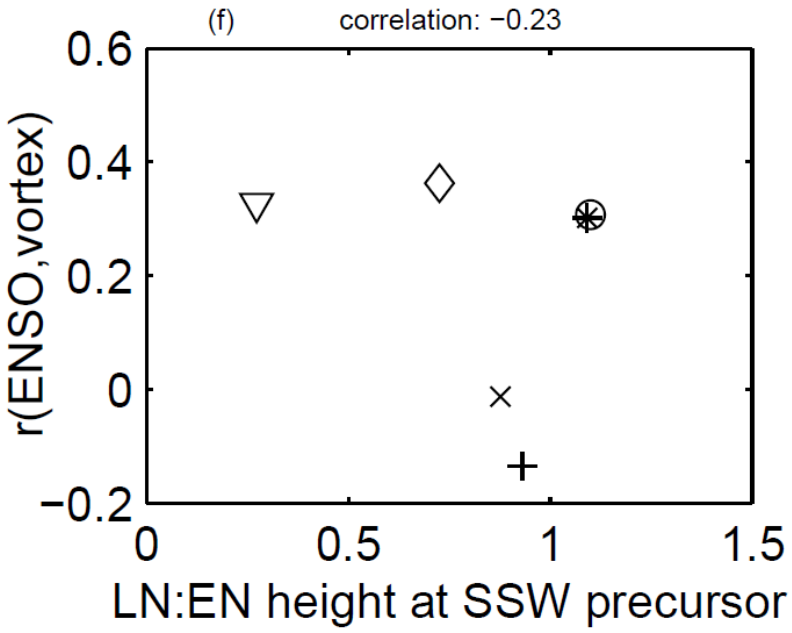


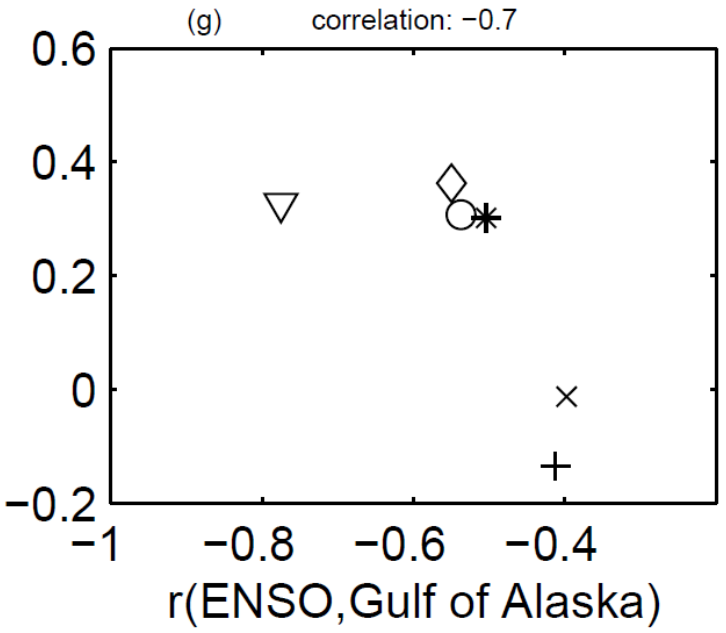


From *Garfinkel et al. 2012*, JGR


Heat flux and ENSO
zonal wavenumber 1
zonal wavenumber 2
all zonal wavenumbers
(a)
(b)
(c)
mean v'T' (Km/s)
anomalous v'T' > 15Km/s (days per winter)
latitude
El Nino
La Nina
neutral ENSO

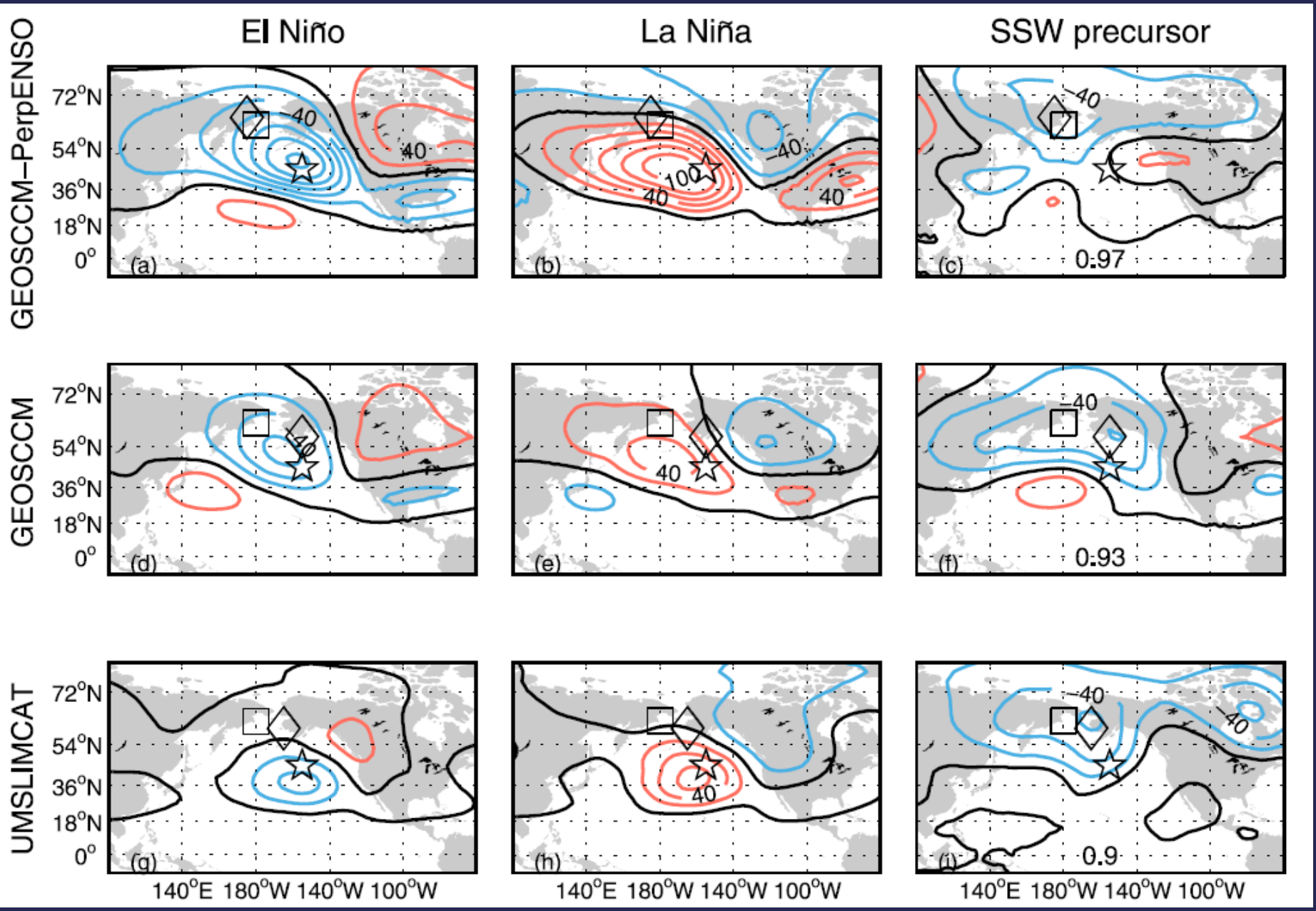
Understanding Seasonal Mean Response to ENSO

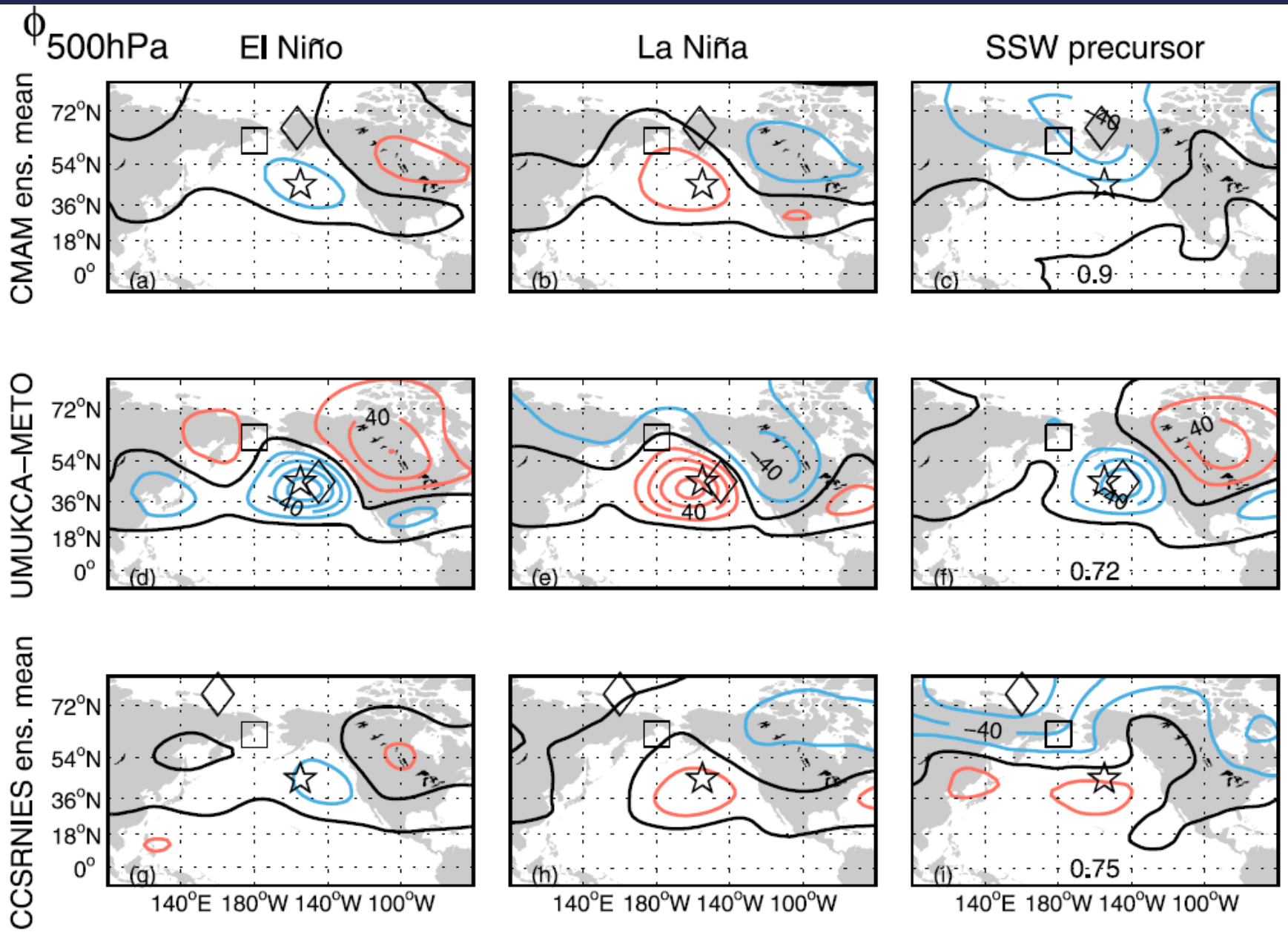


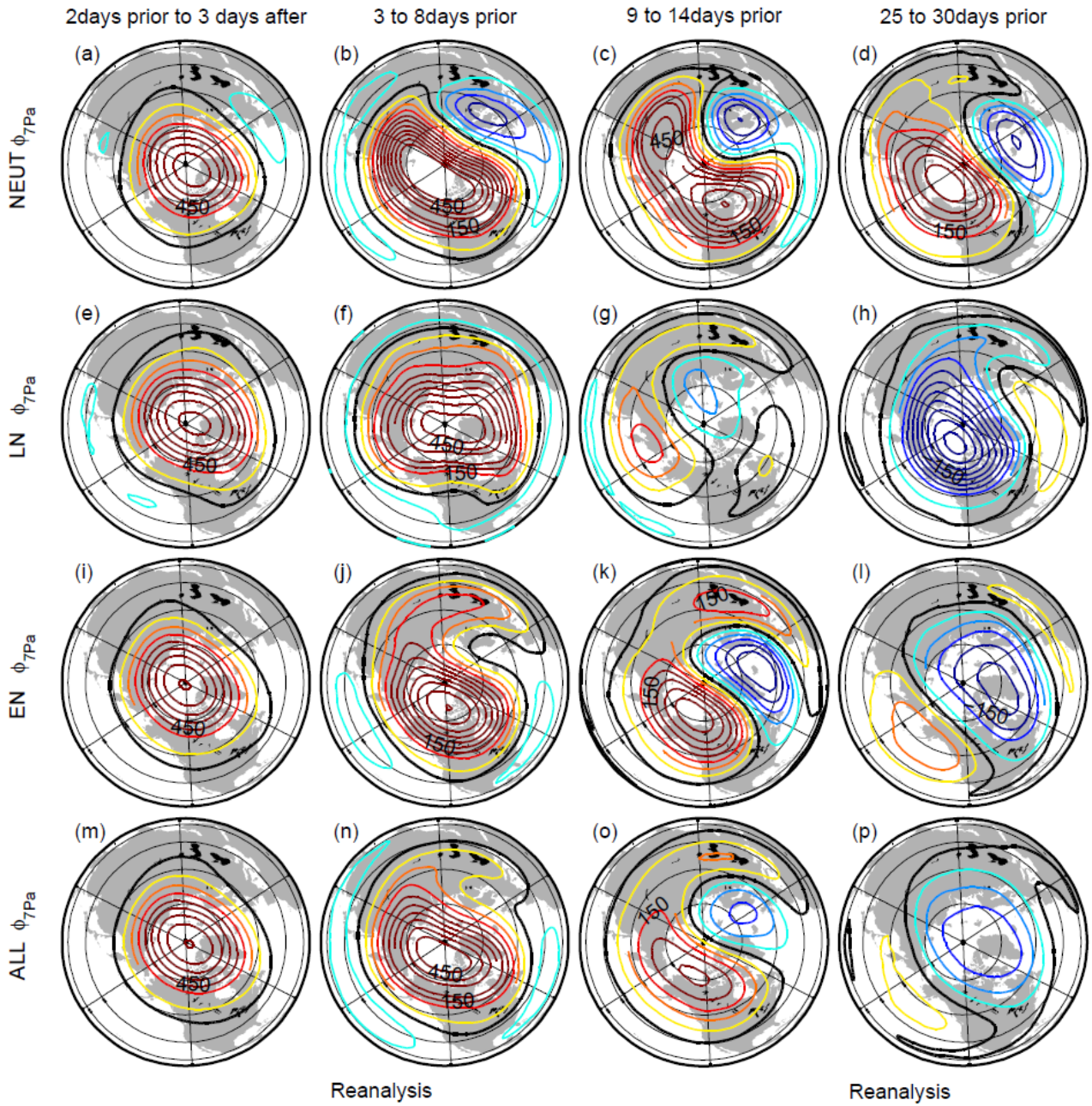


- reanalysis
- GEOSCCM
- UMSLIMCAT
- CMAM
- UMUKCA−METO
- GEOSCCM−PerpENSO
- CCSRNIES

•Seasonal mean response is more closely related to strength of teleconnections in Gulf of Alaska.


El Niño
La Niña
SSW precursor
GEOSCCM–PerpENSO
GEOSCCM
UMSLIMCAT
72°N
54°N
36°N
18°N
0°
140°E 180°W 140°W 100°W
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
40
100
0.97
0.93
0.9


ϕ500hPa
El Niño
La Niña
SSW precursor
CMAM ens. mean
UMUKCA–METO
CCSRNIES ens. mean
72°N
54°N
36°N
18°N
0°
140°E 180°W 140°W 100°W
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
40
−40
0.9
0.72
0.75



Split vs displacement frequency is similar in EN and LN.

Slight wave 2 signature during LN in the troposphere.