

Blockings and Upward Planetary-Wave propagation into the stratosphere

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Controversy about SSWs and Blocking highs

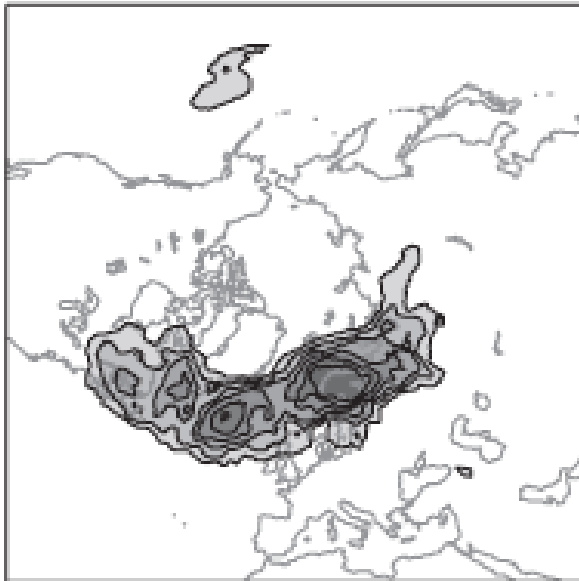
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 - “An SSW tends to be associated with blocking highs.”

However, there has been controversy about their linkage.

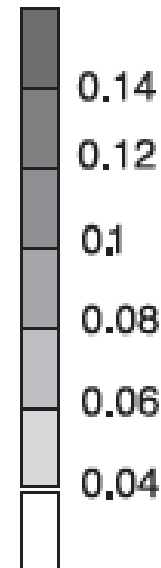
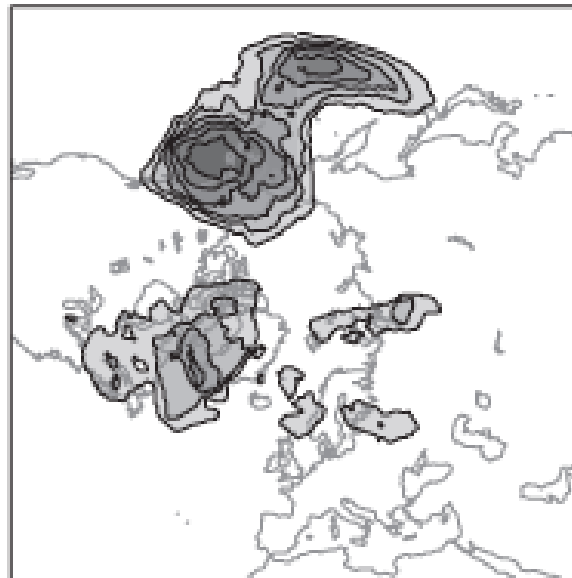
- Blockings lead SSWs.
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- SSWs lead blockings.
 - Labitzke (1965), Koder and Chiba (1995), Mukougawa and Hirooka (2004)
- Their relationship is statistically insignificant.
 - Taguchi (2008)

Blocking frequency before SSWs

Before Displacement
type SSW (wave 1)



Before Split type
SSW (wave 2)



Martius et al.
(2009, GRL)

Martius et al. (2009) and Woollings et al. (2010)

- Blockings tend to be observed over particular domains.
 - ✓ Displacement SSW ← Ridge of climatological wave 1
 - ✓ Split SSW ← Ridge of climatological wave 2

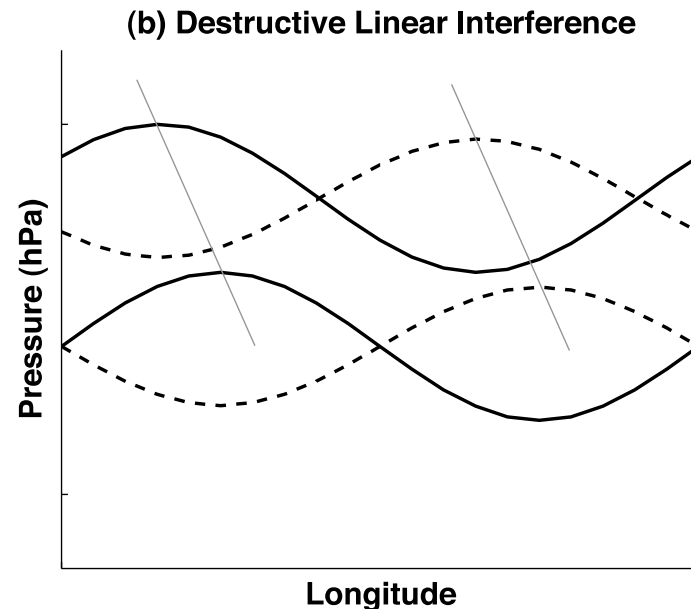
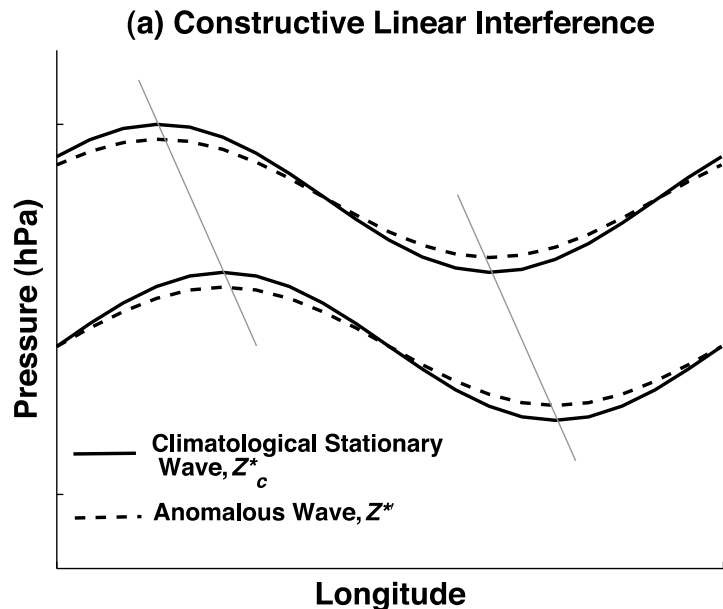


Importance of interference

Linear interference

(a) Constructive

(b) Destructive



Smith & Kushner
(JGR, 2012)

If stationary and anomalous waves are

- a) In phase \rightarrow constructive interference \rightarrow wave amplification
- b) Out of phase \rightarrow destructive interference \rightarrow wave suppression

Quantifying linear interference

- Eddy heat flux can be used as a measure of upward PW propagation.
- Anomaly of this flux may be decomposed as follows;
(DeWeaver & Nigam 2001; Nishii et al. 2009; Fletcher & Kushner 2011)

$$\begin{array}{ccccc} \text{Eddy heat flux anomaly} = & \text{nonlinear} & + & \text{linear interference} \\ [V^*T^*]_a & [V_a^*T_a^*]_a & & [V_a^*T_c^* + V_c^*T_a^*] \end{array}$$

Aim of this study

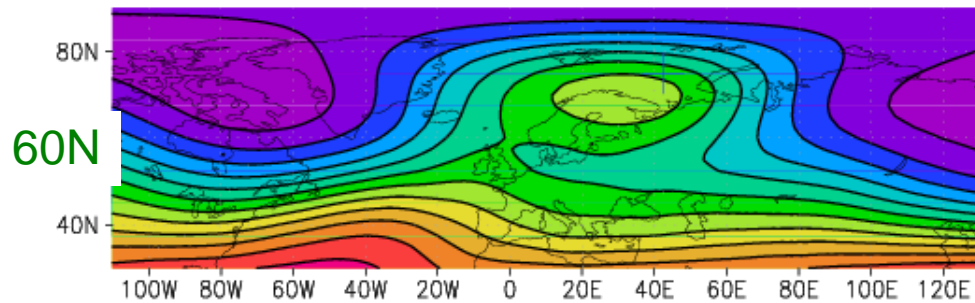
To quantify these decomposed terms in association with blockings all over the northern hemisphere

Used data and Analysis method

- JRA-25 reanalysis
- Winter (NDJFM) of 1979-2008
- Blocking highs
 - Large-amplitude events of submonthly-scale height anomalies at the 250-hPa level.
- Detect and composite largest 30 blockings around each grid point of reanalysis data.
- 100-hPa eddy heat flux ($[V^*T^*]$) is used as a measure of upward PW into the stratosphere.
 - Averaged over extratropics ($>45^\circ\text{N}$).

Example; blockings over Northern Europe

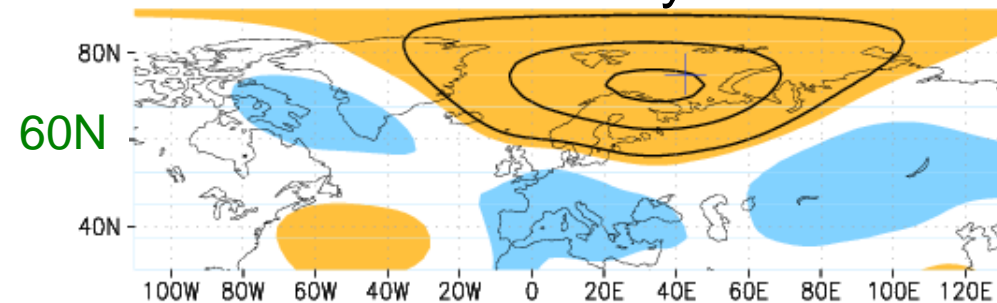
250hPa height



- Meandering of jet
- Cut off high

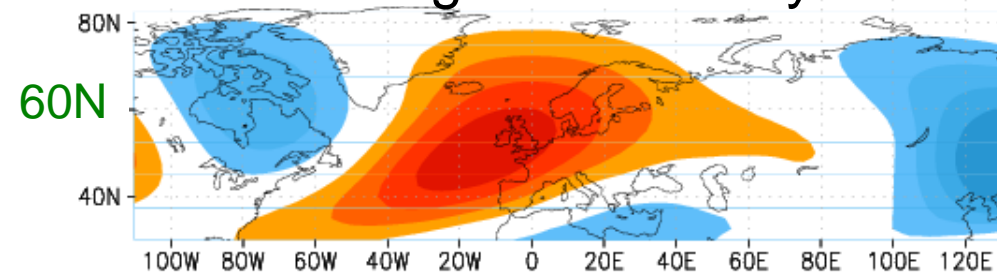
➡ Characteristics of blocking

Anomaly



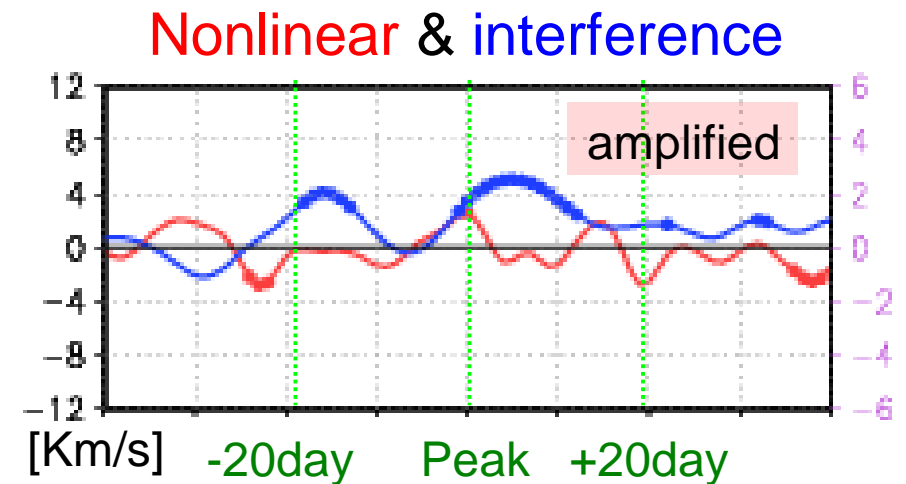
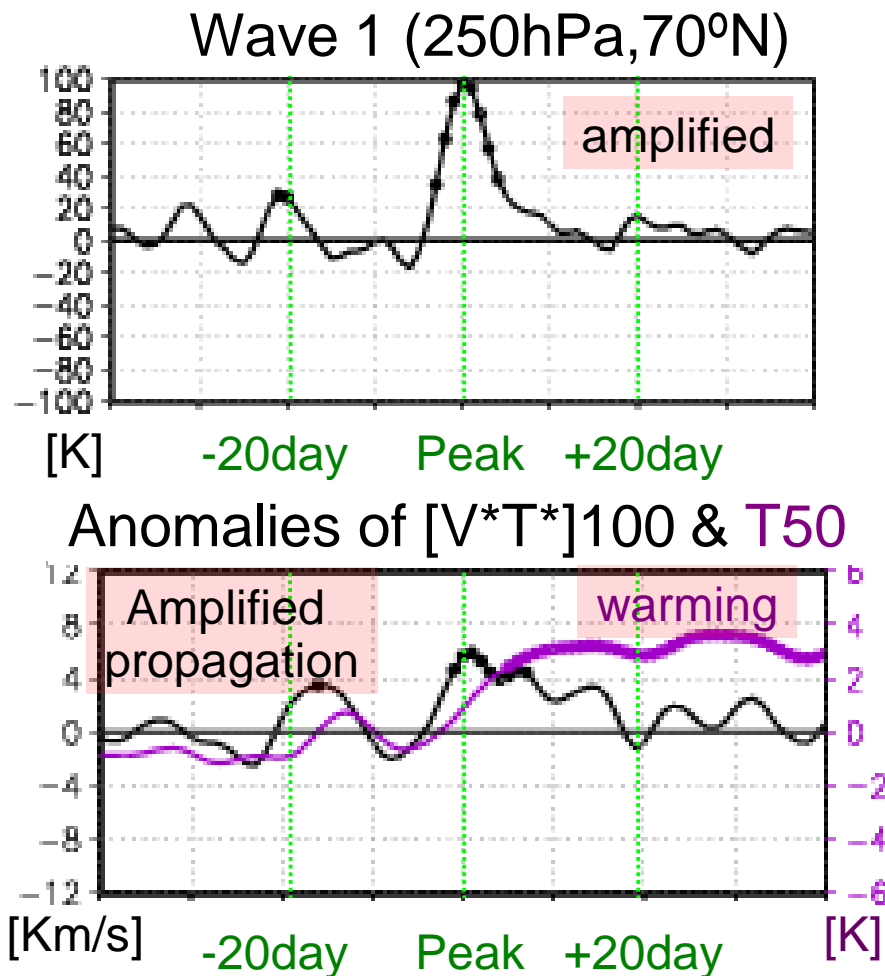
Blocking over climatological ridge

Climatological Planetary Wave



Constructive interference

Example; time series on blockings over Northern Europe



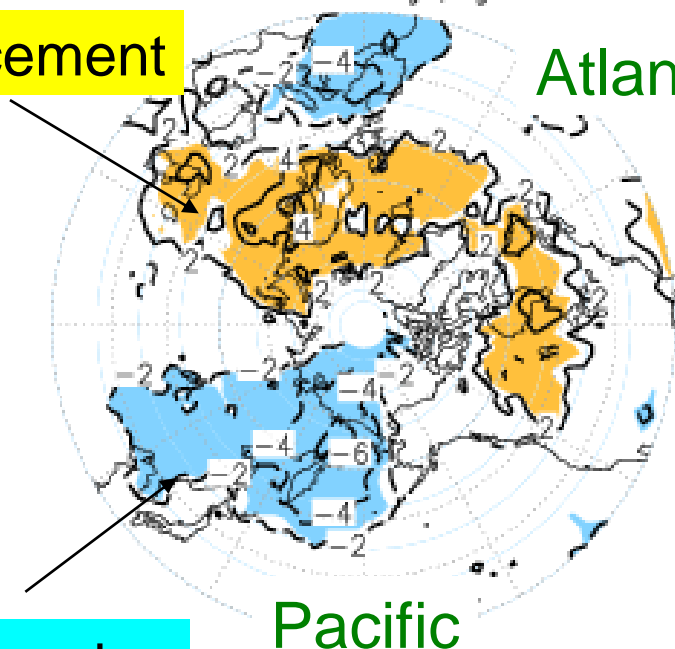
- **Interference term** contributes positively to the enhancement of upward wave propagation
- Amplification of wave 1 and upward wave to strato.
- Warming of polar strato.

Upward planetary-wave propagation changes associated with blockings for each grid point

Eddy heat flux anomaly

enhancement

Atlantic

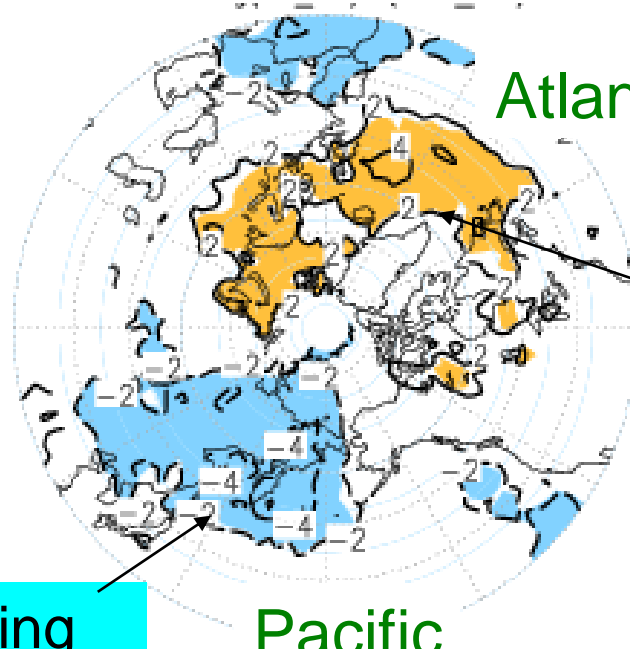


Pacific

suppression

Strato. polar T tendency (T50)

Atlantic



warming tendency

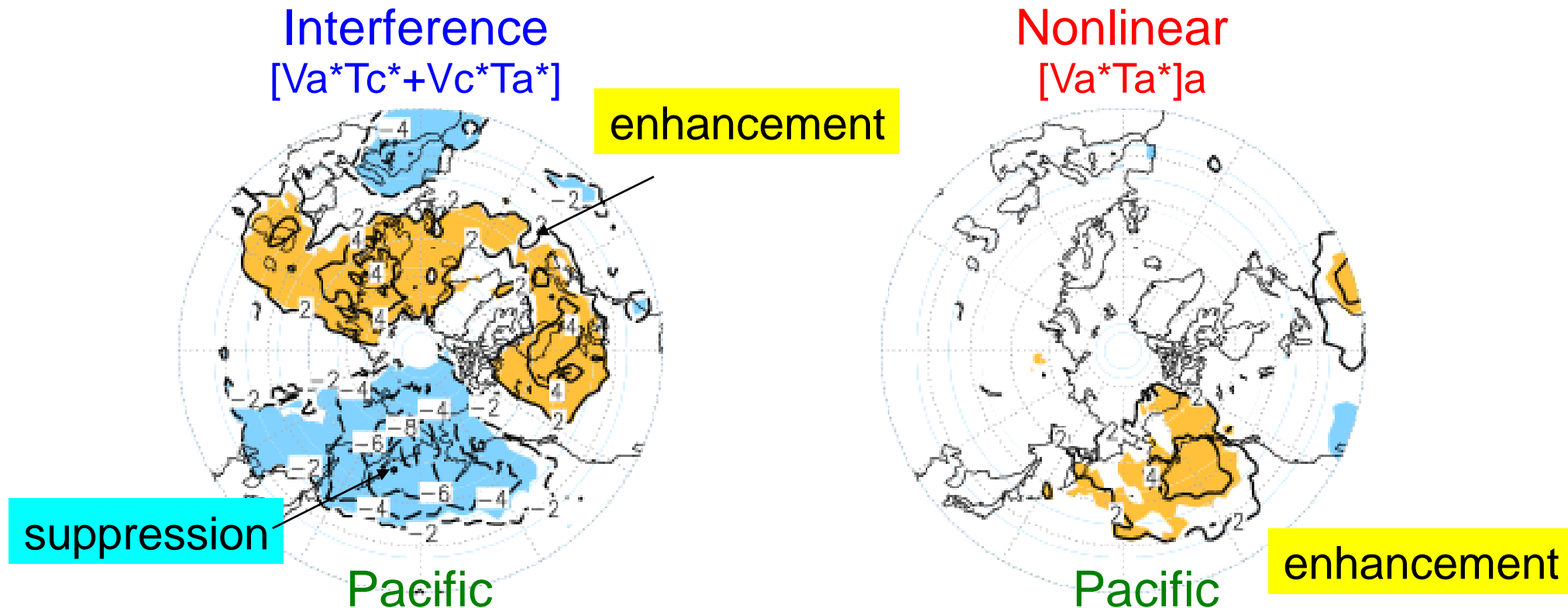
cooling tendency

Pacific

Assign average of $[V \cdot T^*]_a$ for +1~+10 day

- Blockings over **North America, Atlantic and Europe** tend to **enhance** upward wave propagation and **warm** the polar strato.
- Blockings over **Western Pacific and the Far East** tend to **suppress** upward wave propagation and **cool** the polar strato.

Decomposition into interference and nonlinear

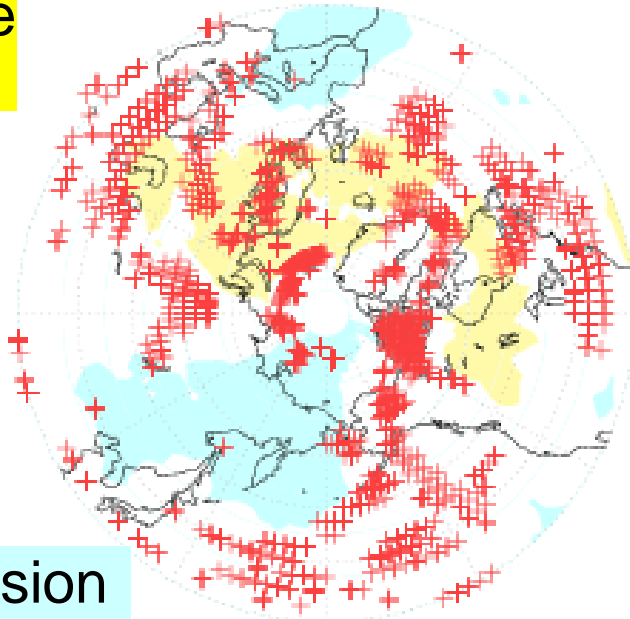


- **Interference term** contributes dominantly to total flux at most of locations.
 - An exception is over Eastern Pacific and Alaska
 - **Nonlinear term** cancels **interference term**

Blockings before stratospheric extreme events

SSW events

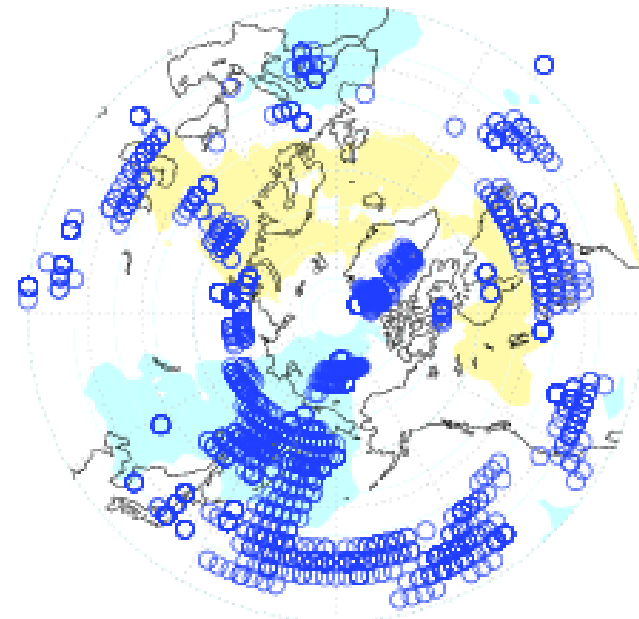
enhance
ment



suppression

- Blockings observed before 20 **SSW events**
- Observed where waves are **intensified** (yellow), except for eastern North Pacific
- Avoid where waves are **suppressed**

Vortex Intensification events

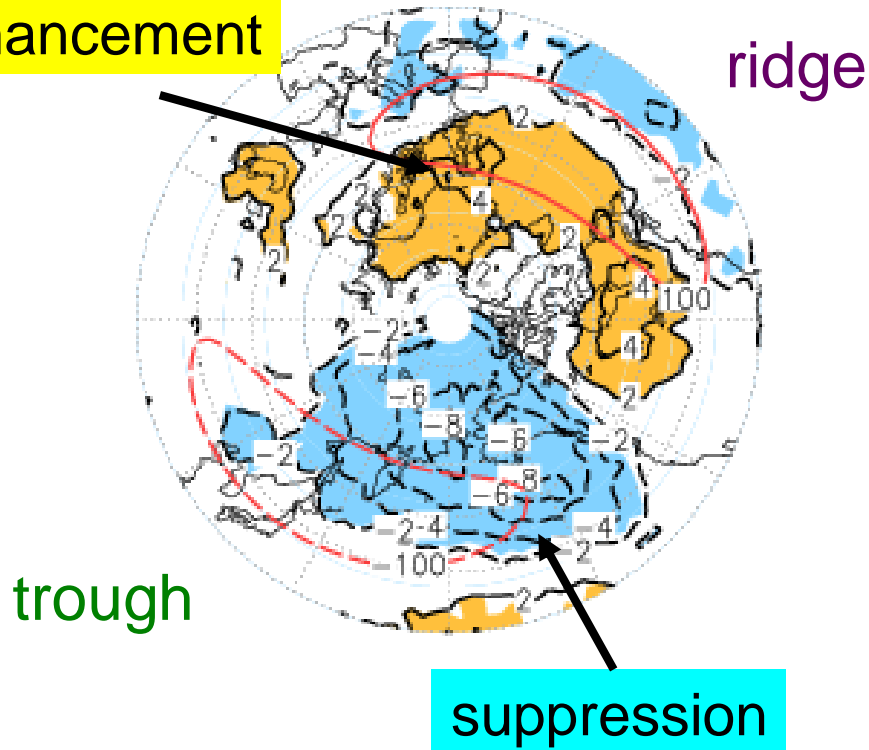


- Blockings observed before 15 **VI events**
- Observed where waves are **suppressed**
- Avoid where waves are intensified (yellow)

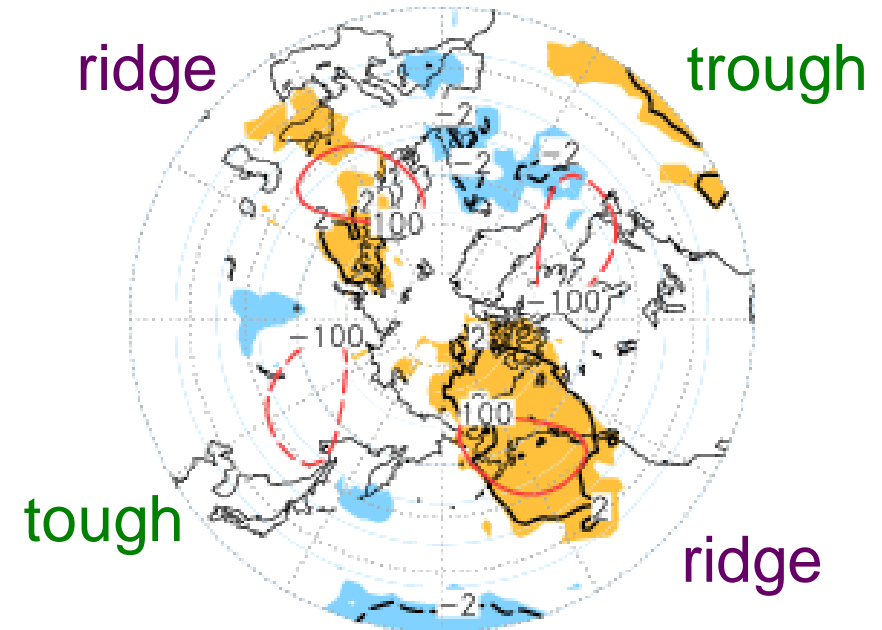
Wave 1 and 2 components of interference term

Wave 1

enhancement



Wave 2

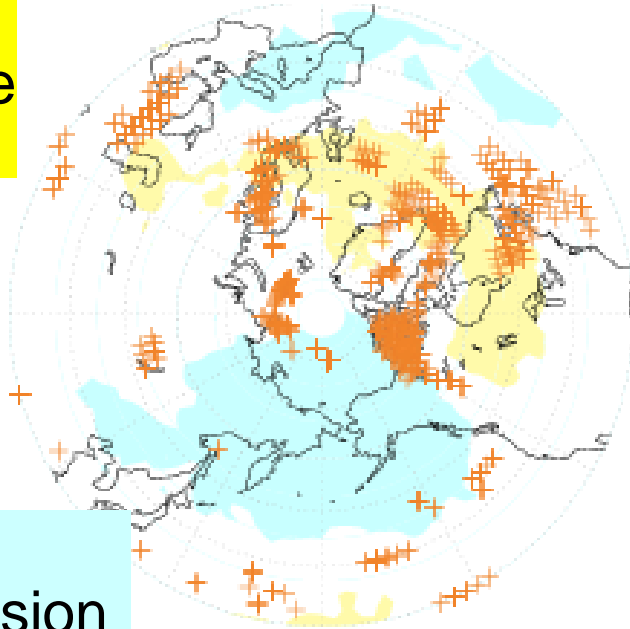


- Blockings over climatological-mean ridge (trough) tend to enhance (suppress) upward wave propagation of corresponding wave components.

Blockings before displacement and split SSW

Displacement (wave 1)
SSW events

Wave1
enhance
ment

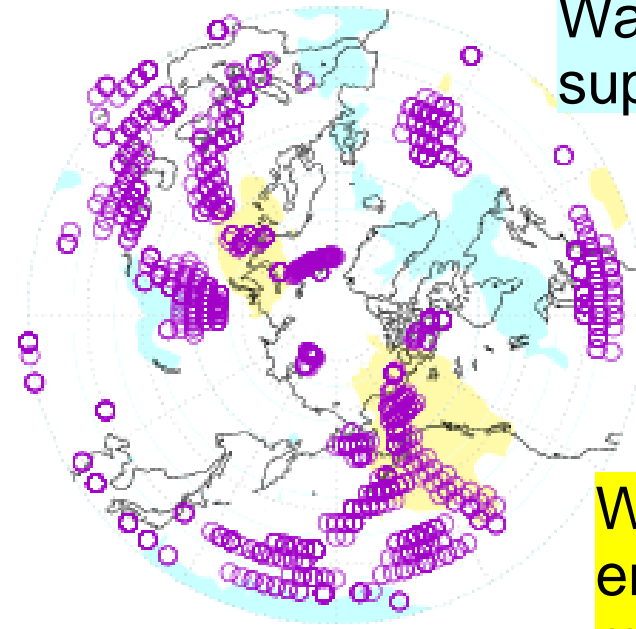


Wave1
suppression

- Blockings observed before displacement SSW
- Observed where wave 1 is intensified (yellow)

Split (wave 2)
SSW events

Wave2
suppression



Wave 2
enhance
ment

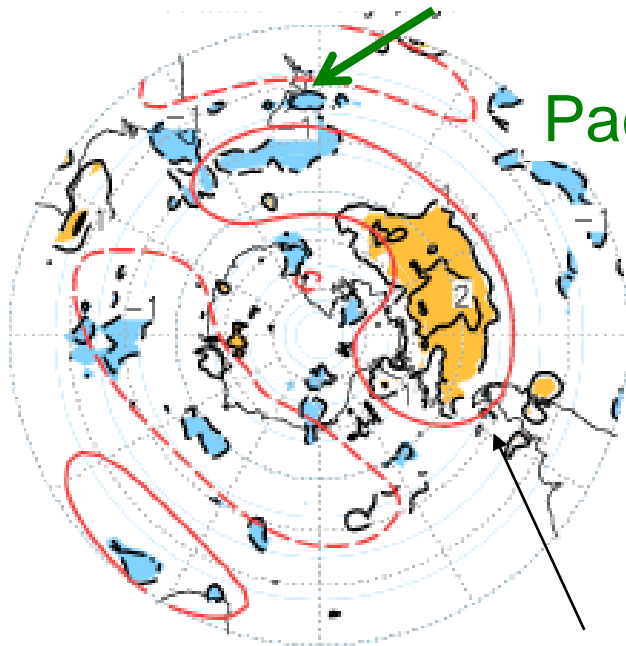
- Blockings observed before split type SSW
- Observed where wave 2 is intensified (yellow)

Blockings over the southern hemisphere in winter

Eddy heat flux anomaly

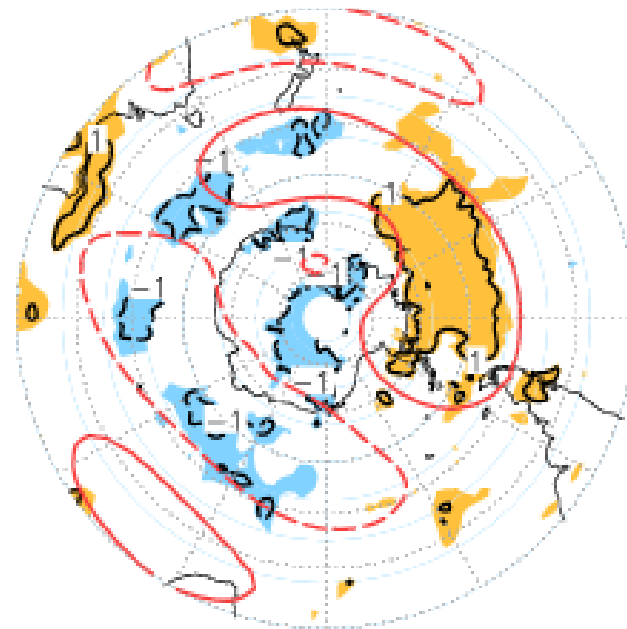
New Zealand

Pacific



enhancement

Interference
 $[V_a * T_c + V_c * T_a]$



MJJAS
1959-2012
50 events
JRA55

- Blockings over the Southeastern Pacific tend to enhance upward PW propagation
 - **Interference term** contributes to this enhancement

Conclusions

- Blockings tend to amplify or suppress upward PWs through constructive or destructive interference between blockings and climatological PWs.
- We confirmed this by quantifying the effect of the interference for typical blockings all over the northern and southern hemispheres.

Most of this talk are from

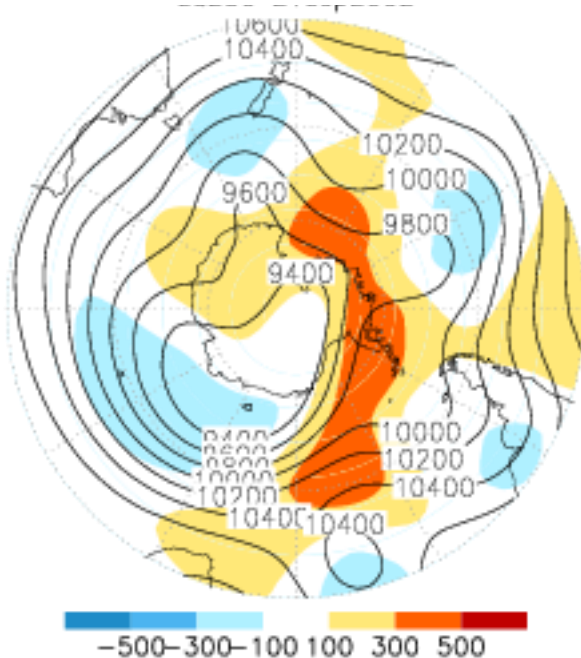
*Nishii, Nakamura, and Orsolini (2011), Journal of Climate,
“Geographical dependence observed in blocking high influence on the
stratospheric variability through enhancement and suppression of
upward planetary-wave propagation”*

An SSW in 2002 in the SH

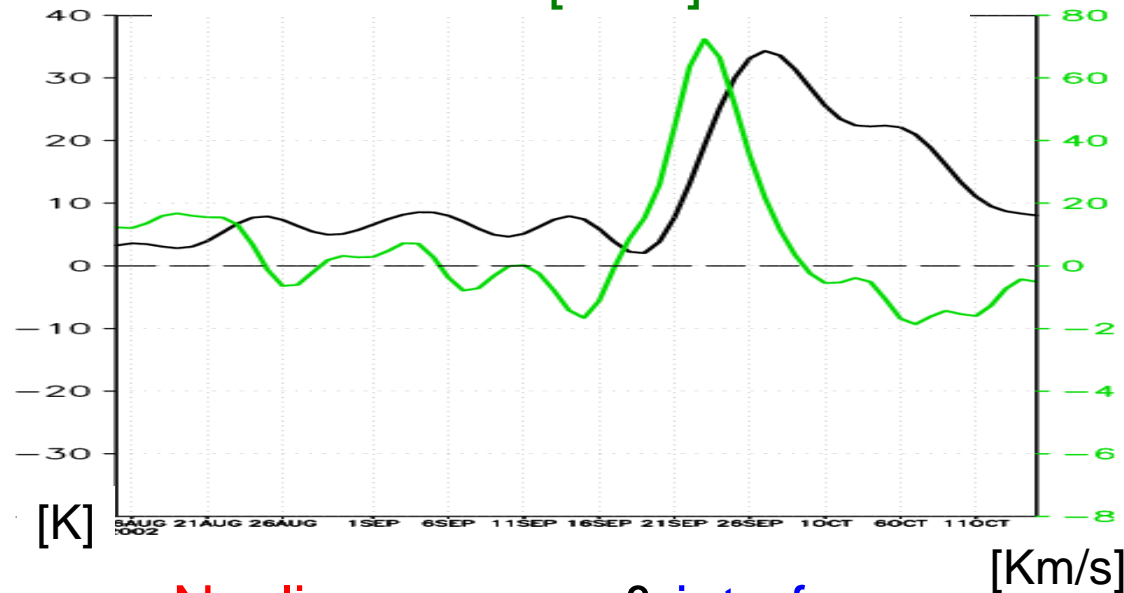
Non-linear term dominated over interference term.

Blocking was observed to the south of S. America and S. Atlantic
 ← Where interference term does not have significant anomaly

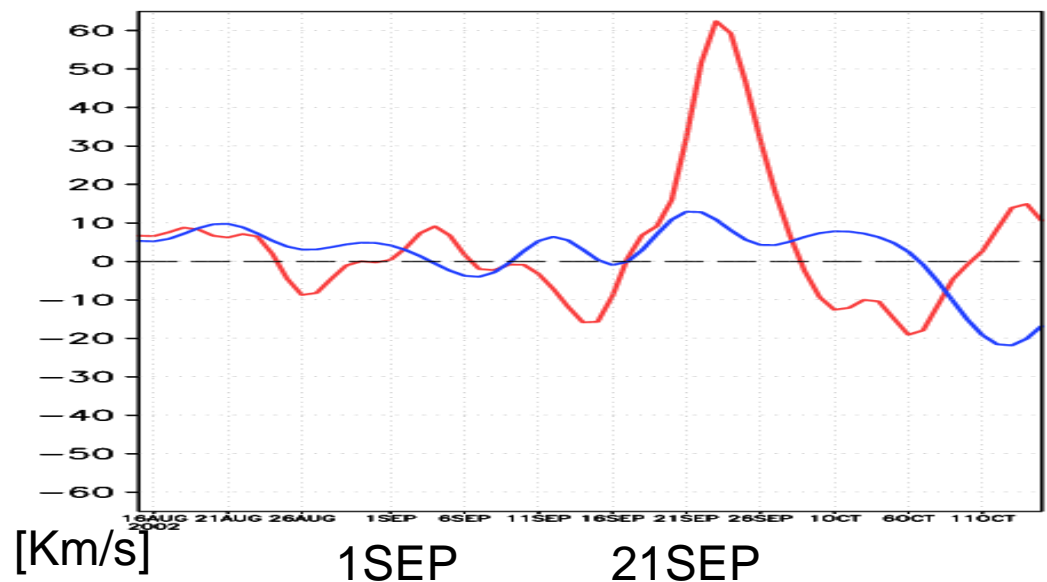
Z250 19~23 SEP average



Anomalies of $-[V \cdot T^*]100$ & Ta50



Nonlinear anom. & interference

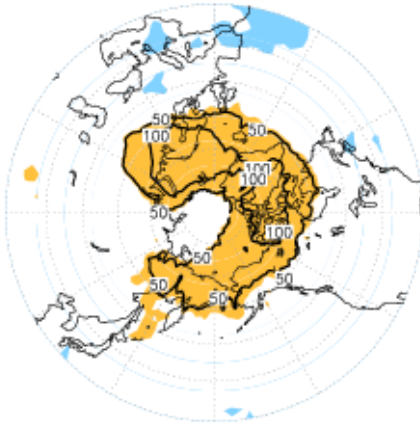


Amplitude anomaly of tropospheric wave component associated with blocking

Amplitude anomaly
along 70N (250hPa)

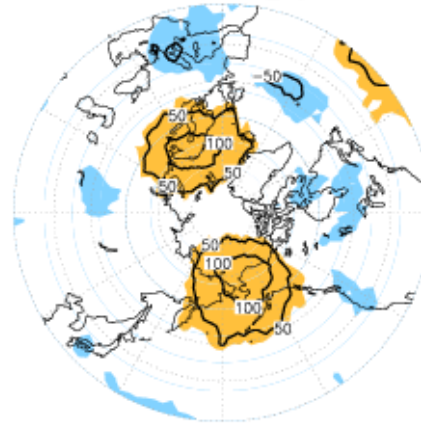
wave 1

z250amp1.70N_lag0



wave 2

z250amp2.70N_lag0



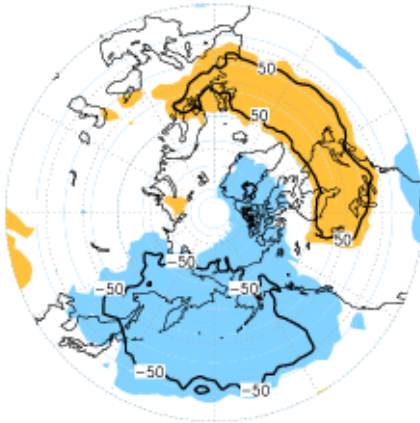
wave 3

z250amp3.70N_lag0

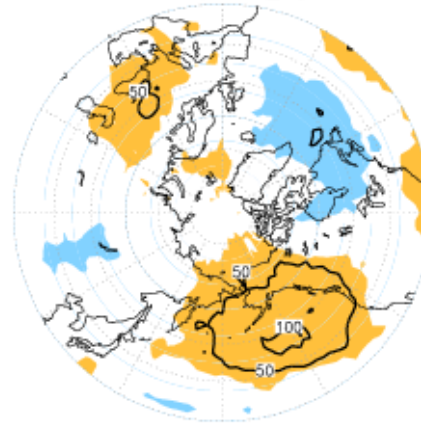


Amplitude anomaly
along 50N (250hPa)

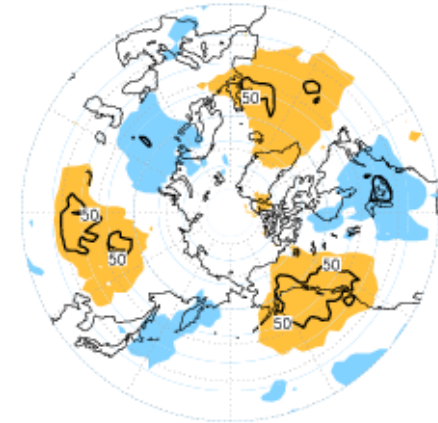
z250amp1.50N_lag0



z250amp2.50N_lag0

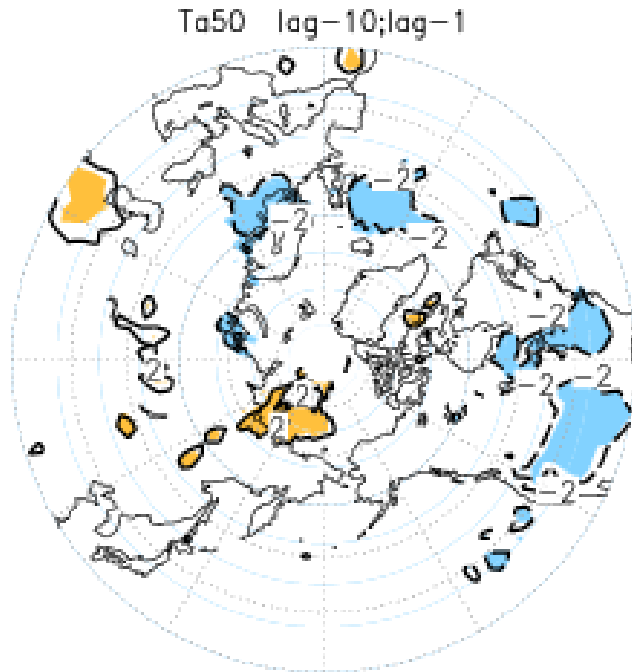


z250amp3.50N_lag0



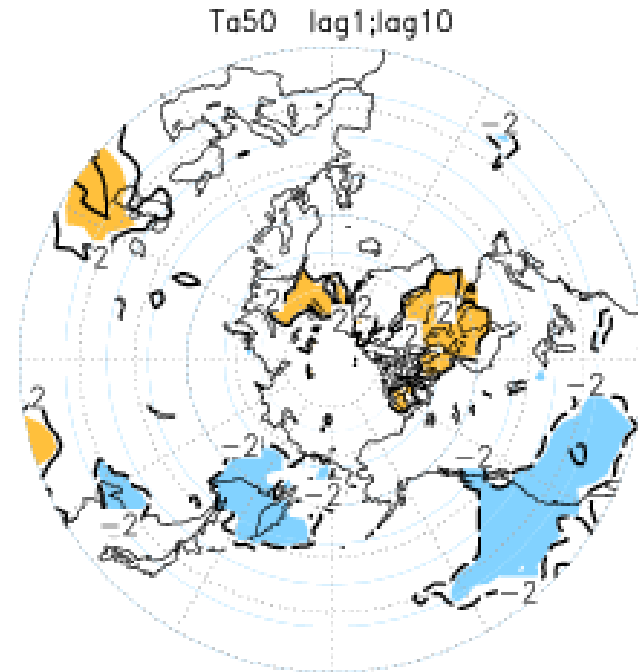
Stratospheric polar temperature anomaly before and after blocking peak

Polar T50 anom before



Assign average of Ta50 for -10~-1 day

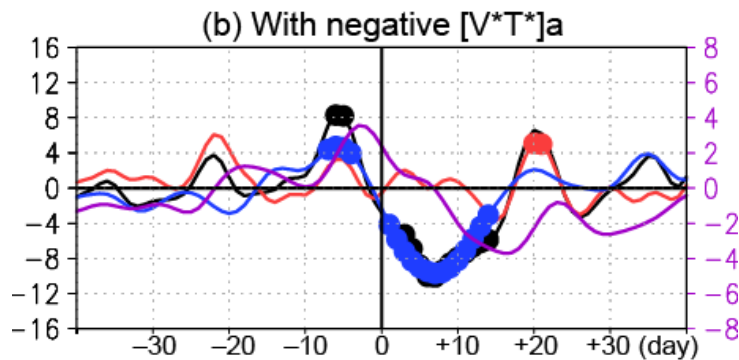
Polar T50 anom. after



Assign average of Ta50 for +1~+10 day

Blockings over eastern North Pacific

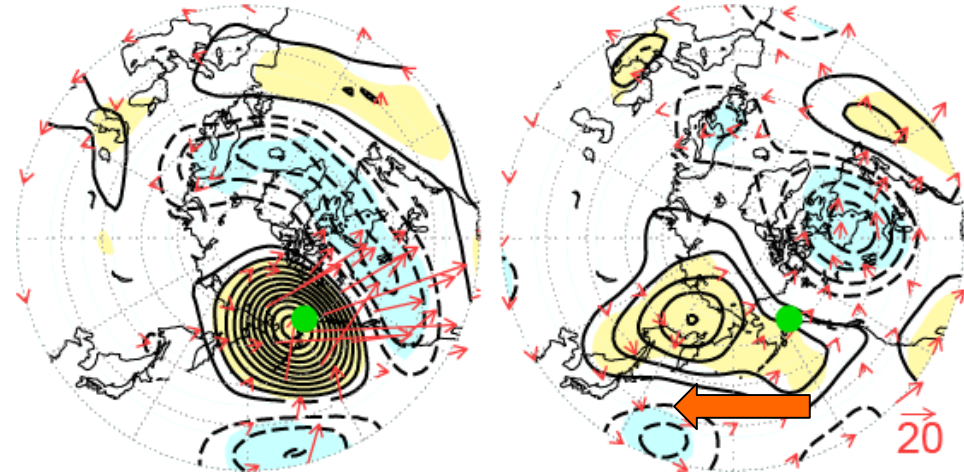
10 blockings accompanying PW suppression
← Move westward



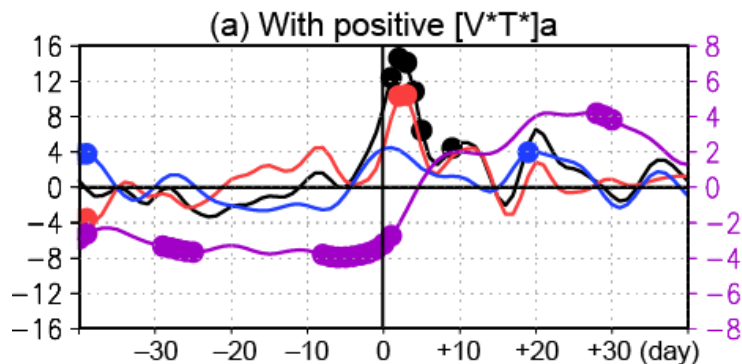
250hPa height anomaly

peak

+5 day

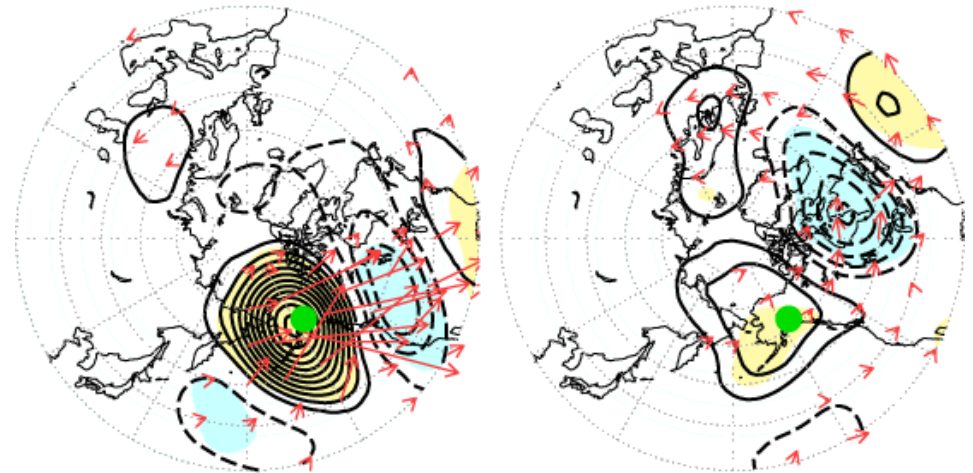


10 blockings accompanying PW amplification
← do not move



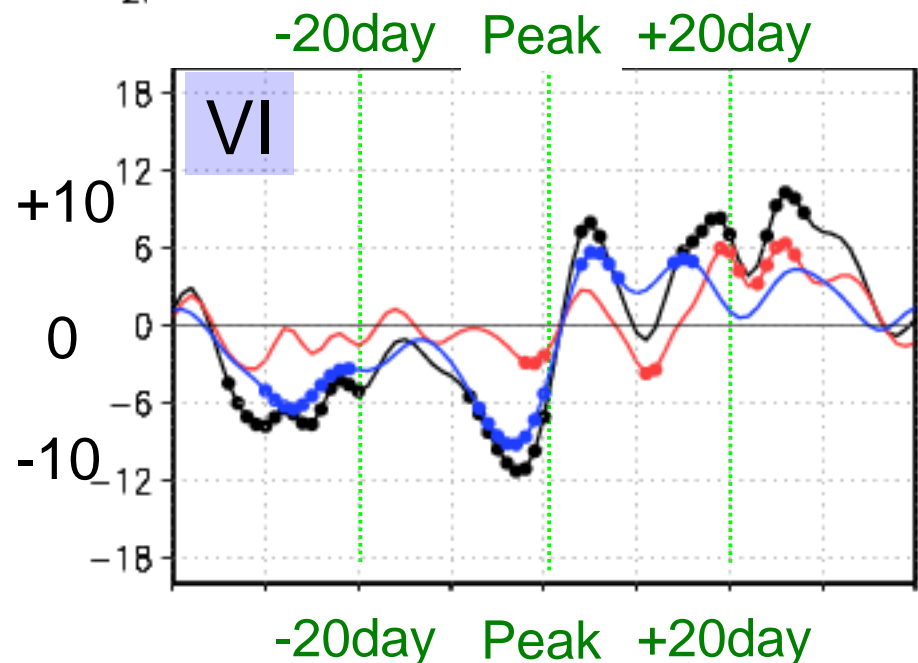
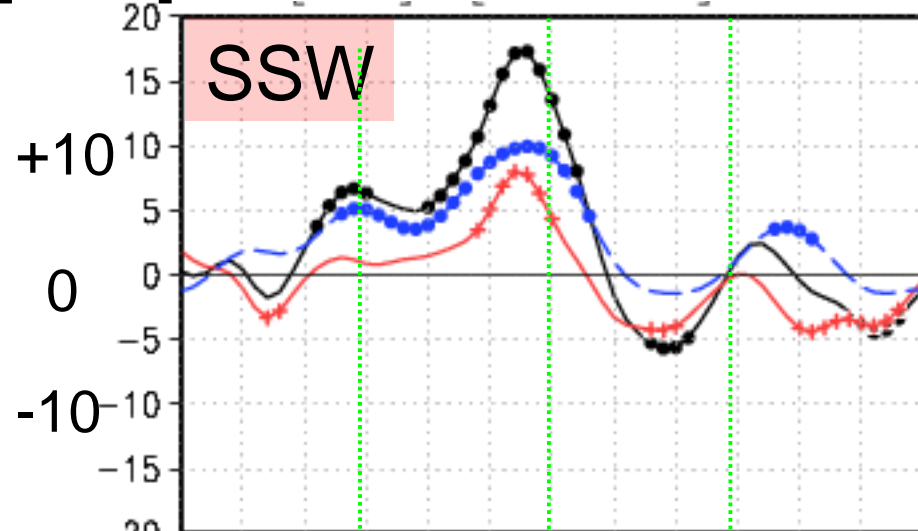
peak

+5 day



Composite of total, interference, and non-linear terms before stratospheric extreme events

$$[V^*T^*]a = \text{interference} + \text{nonlinear}$$



- Before SSW,
 - Long wave-forcing more than 20 days.
 - **Interference** and **non-linear** terms are comparable
 - **Nonlinear** term can not be ignored for the occurrence of SSW.
- Before VI, **interference** primarily contributes to the suppression

Consistent with Smith & Kushner (2012,JGR)

Controversy about SSWs and Blocking highs

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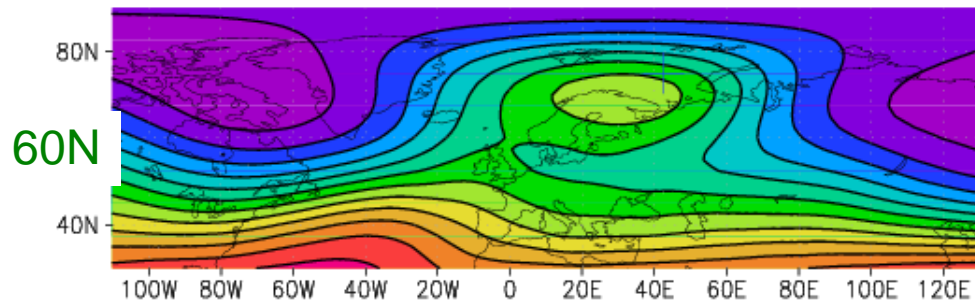
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Aim of this study

To quantify these decomposed terms in association with blockings all over the northern hemisphere

Example; blockings over Northern Europe

250hPa height

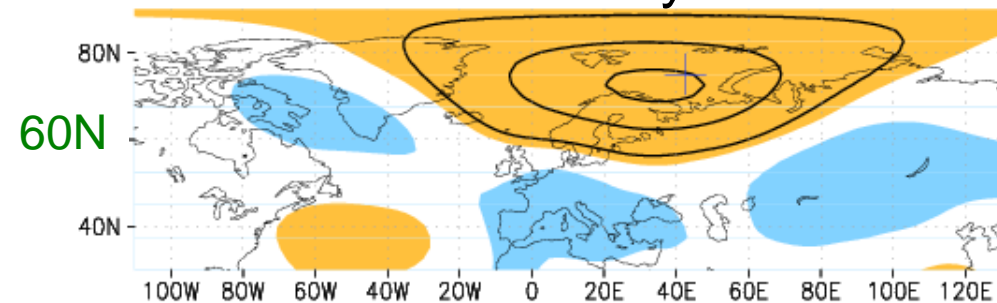


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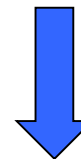


Characteristics of blocking

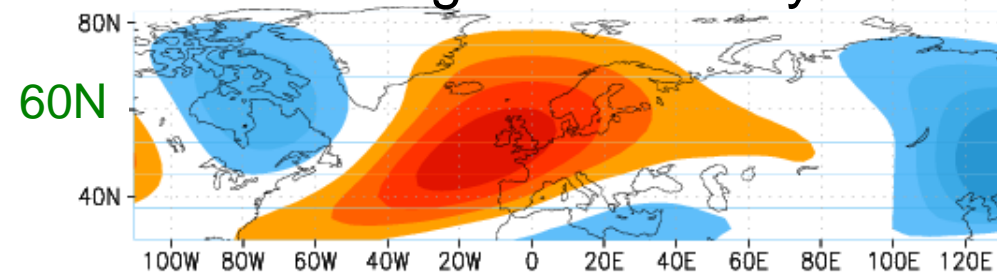
Anomaly



Blocking over climatological ridge



Climatological Planetary Wave



Constructive interference