Effect of the East/Japan Sea SST variability on the North Pacific atmospheric circulation

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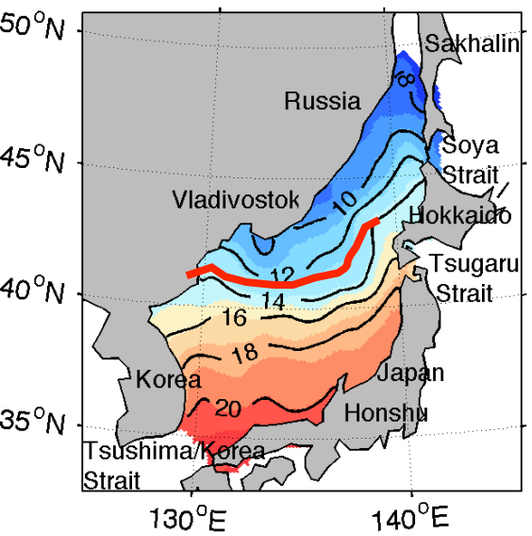
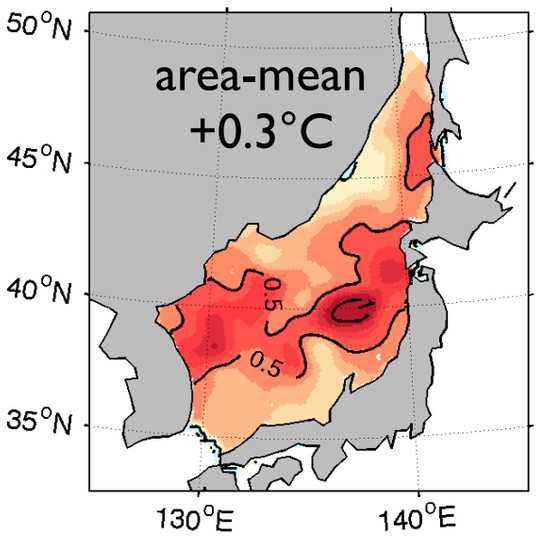
Seo et al. 2014: On the effect of marginal sea SST variability on the North Pacific atmospheric circulation. *JGR-Atmospheres*

Image: Cloud streets in the Sea of Japan captured by MODIS: http://modis.gsfc.nasa.gov/gallery/individual.php?db_date=2011-01-03

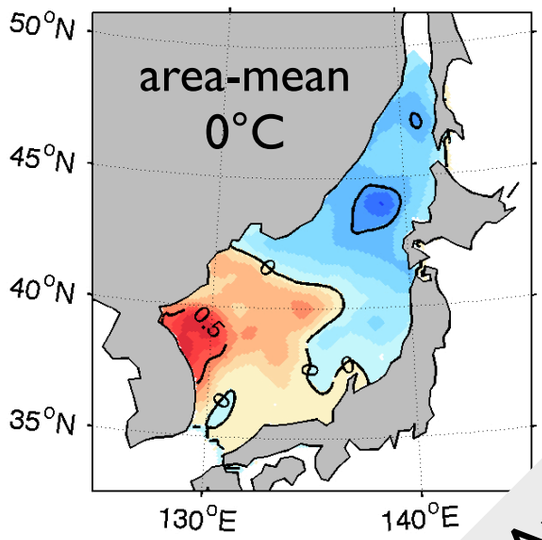
Winter Climatology



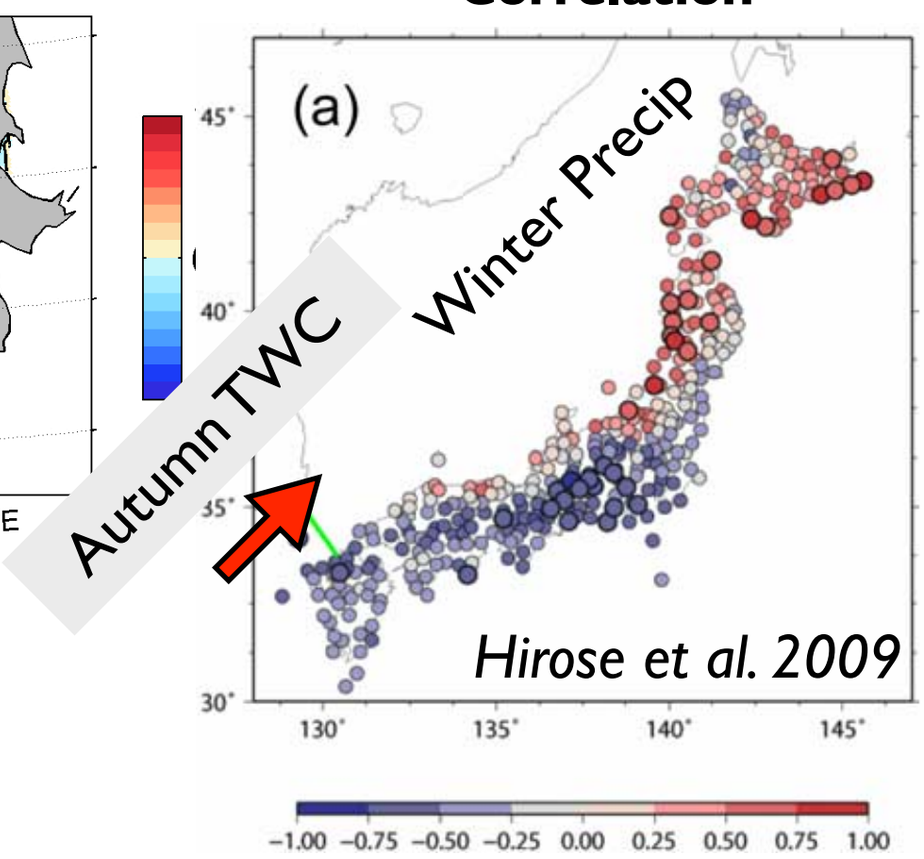
EOF1 42%



EOF2 18%

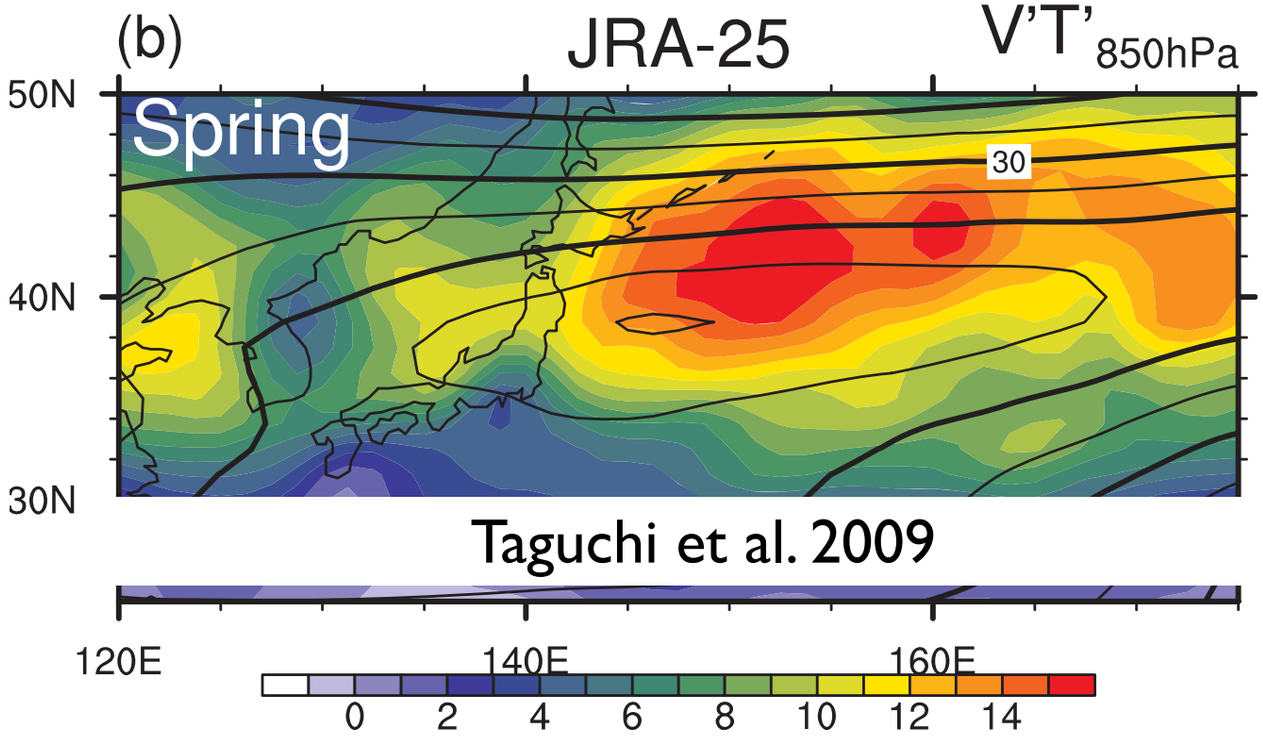


Correlation



- Two dominant modes of the winter SST variability
- Important for *regional* weather and climate.

Storm track climatology



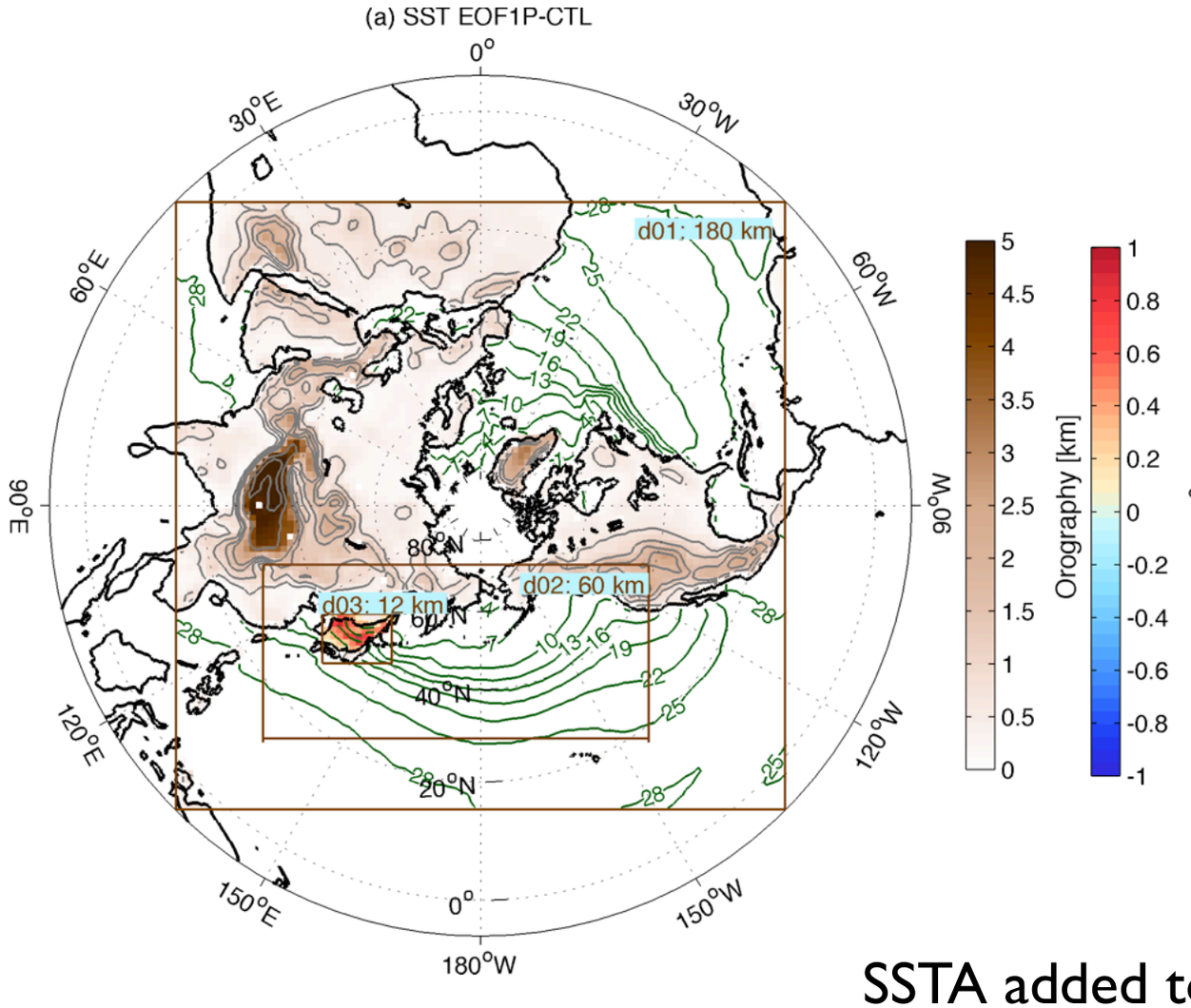
Taguchi et al. 2009

- Located upstream of the North Pacific storm track, EJS SST may be relevant to large-scale atmospheric circulation.

local and remote responses and their mechanisms

Hemispheric multi-nesting WRF model

as a way to study margina-sea interaction with the circumglobal atmosphere

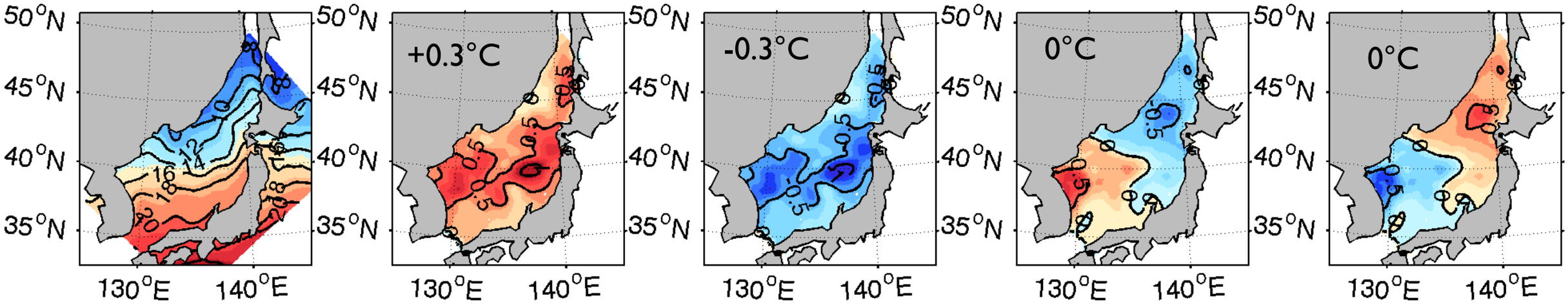


- Five sets of 6-month (NDJFMA) and 40 ensemble simulations:

- **CTL**: clim. SST
- **EOF1P, EOF1N, EOF2P, EOF2N**
- (+) and (-) SSTA to assess symmetricity in response

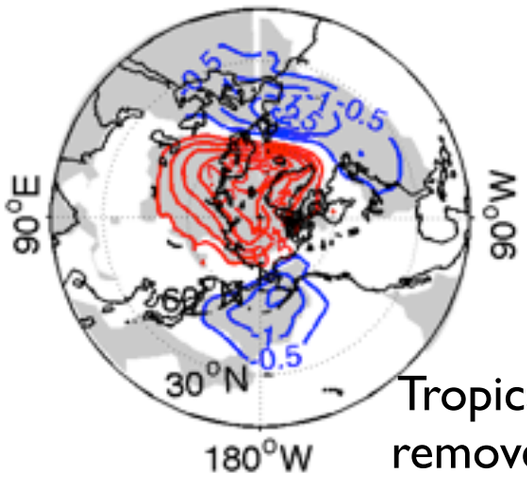
- Daily clim. SST and NCEP outside the EJS
- Forcing of opposite sign to assess the symmetricity

SSTA added to SST climatology

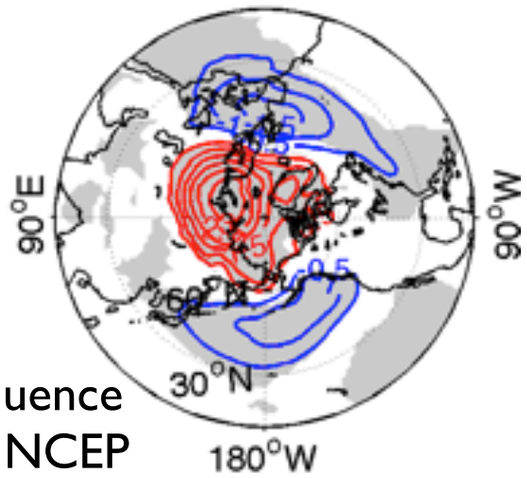


How well does the model capture key NH winter atmospheric variability?

EOF1 NCEP SLP 34%

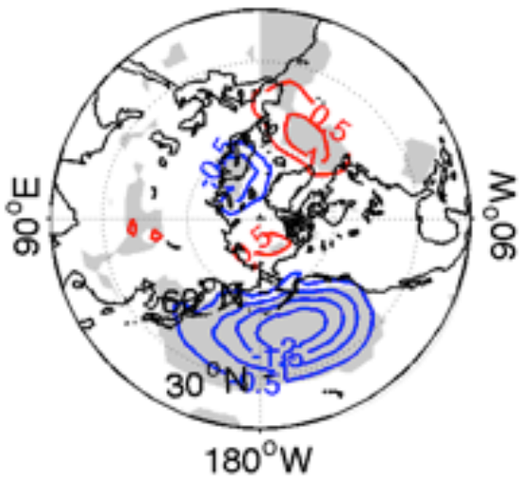


EOF1 CTL SLP 34%

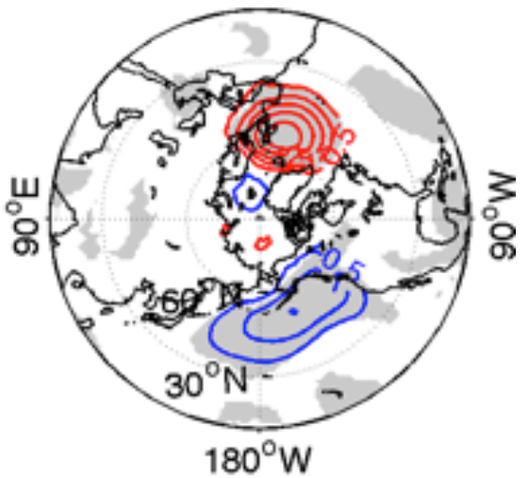


Tropical influence removed in NCEP

EOF2 NCEP SLP 14%



EOF2 CTL SLP 15%

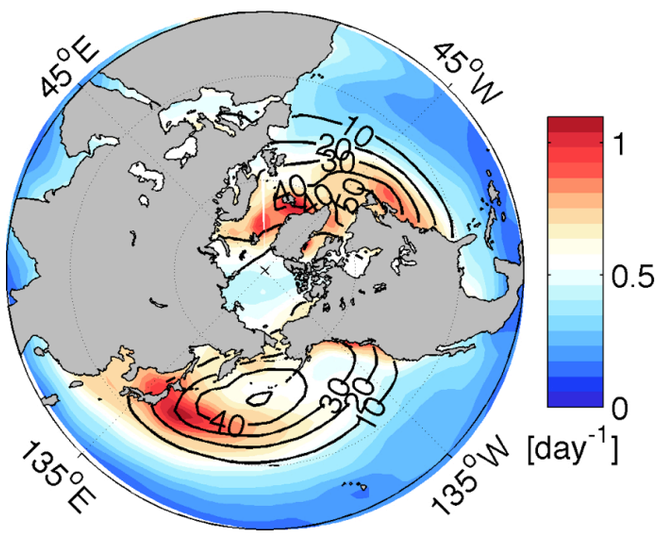


- Internal modes of variability is represented reasonably well in CTL;
  - the 1st mode; the AO
  - the 2nd mode: the Aleutian Low mode.

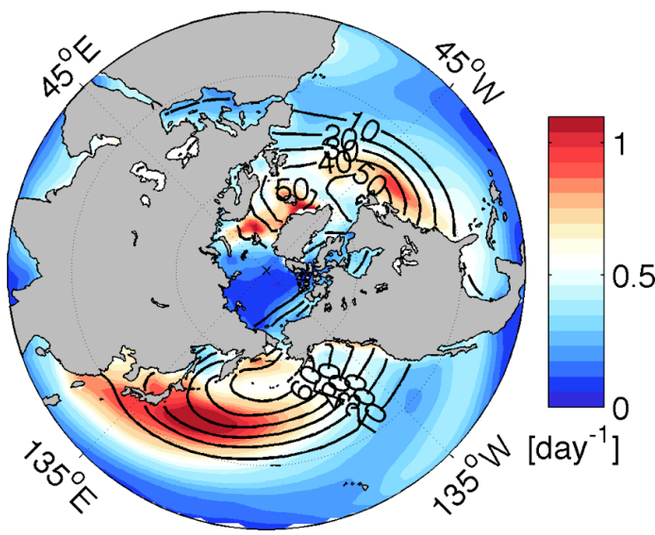
- The simulated climatological *Eady growth rate* (σ) and the storm track (2-8 day SLP variance) are reasonably realistic.

$$\sigma = 0.31 f \left| \frac{\partial \vec{v}}{\partial z} \right| \frac{1}{N},$$

NCEP NDJFMA σ

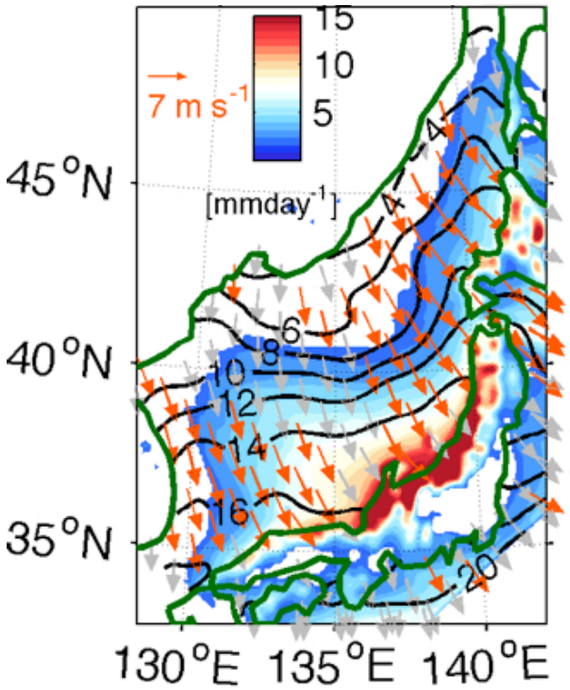


CTL NDJFMA σ

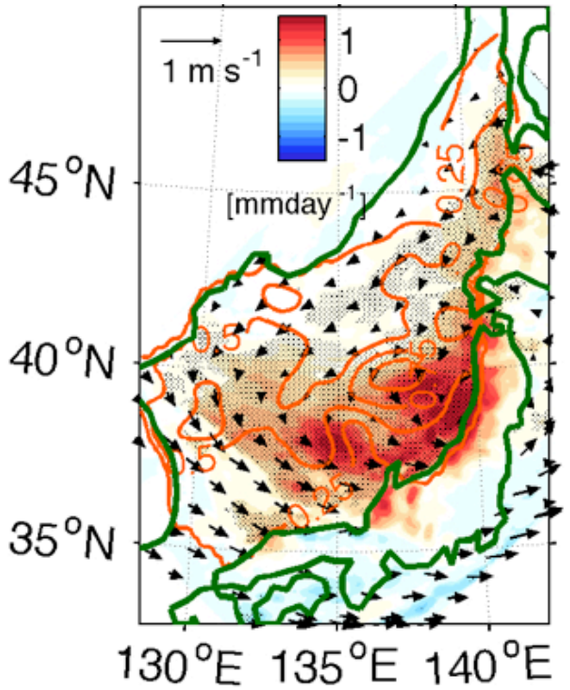


Response in the vicinity of diabatic forcing is linear:
Intra-basin SST pattern critical to local response

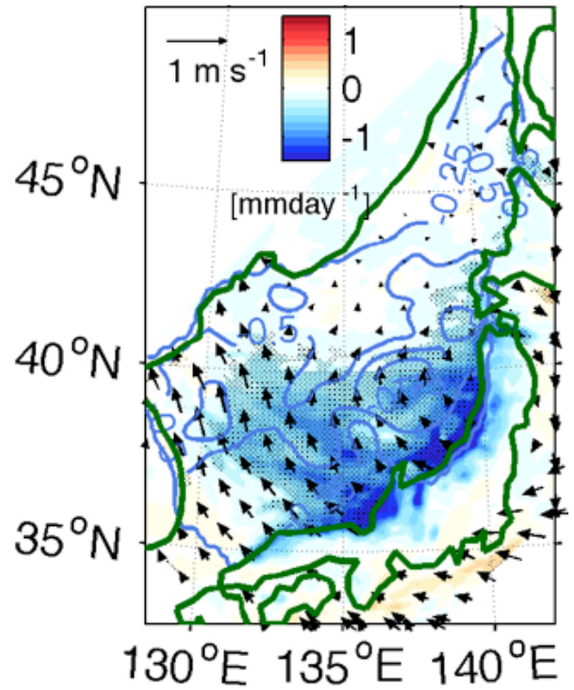
CTL



EOF1P-CTL

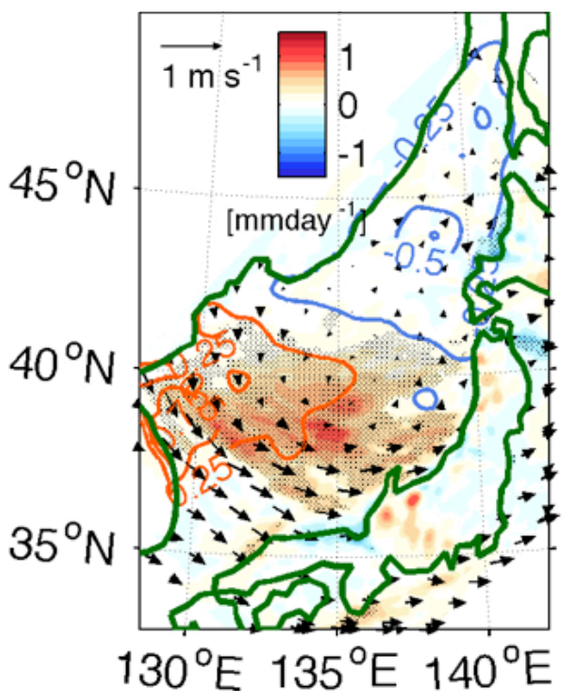


EOF1N-CTL

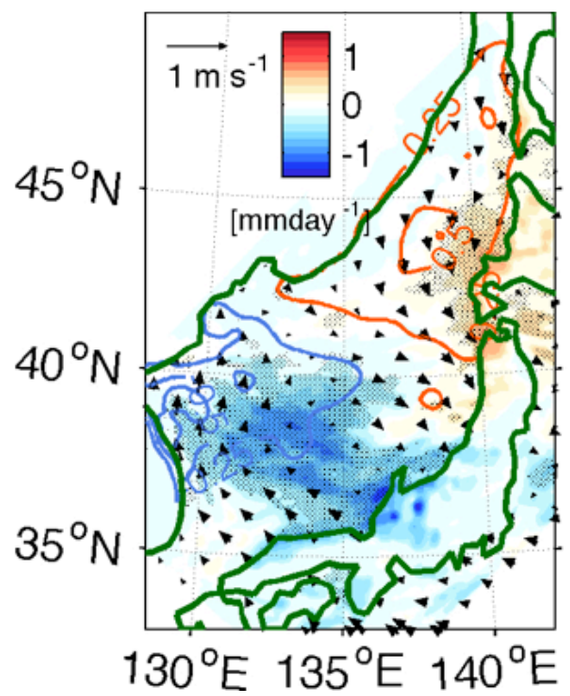


Response in NDJ mean precipitation and winds

EOF2P-CTL



EOF2N-CTL



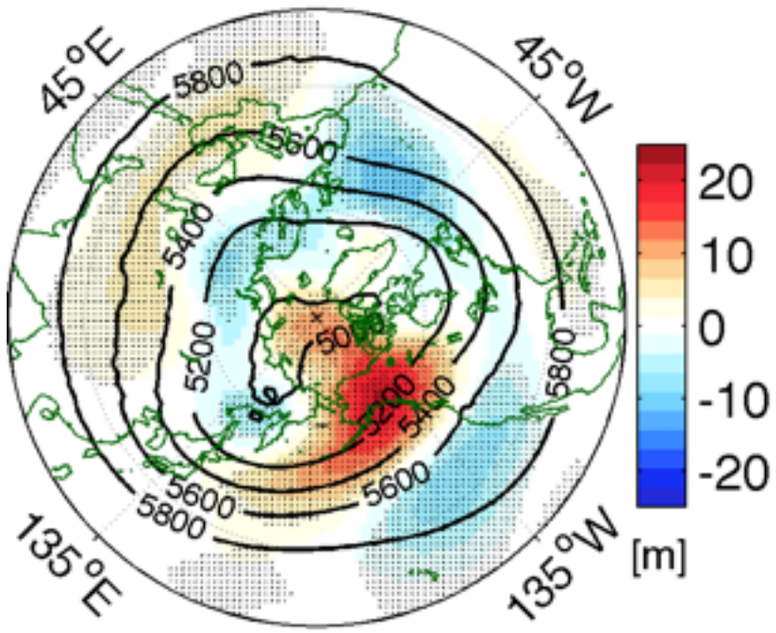
- Response is *symmetric* with respect to the polarity of SSTA:

➡ A quasi-deterministic response in the vicinity of anomalous diabatic forcing

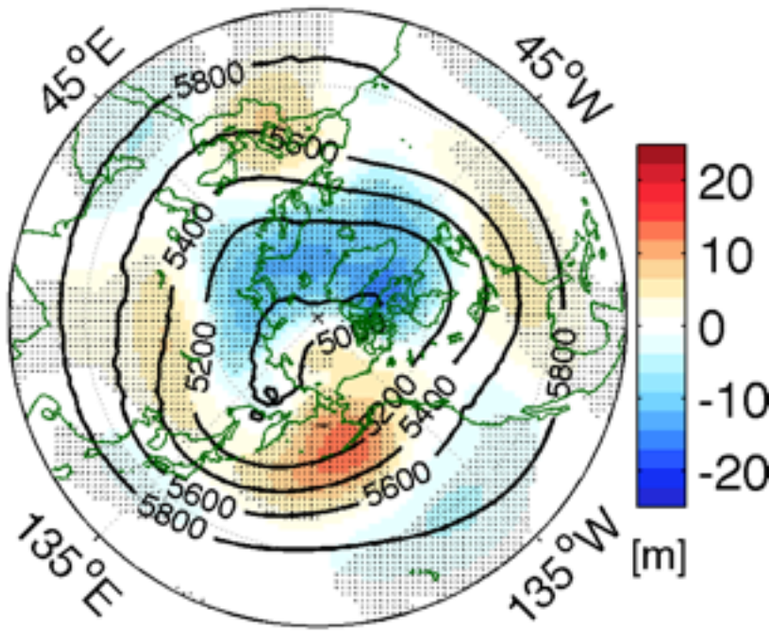
Remote response is *NOT linear*.

Response in NDJFMA mean Z500

EOF1P-CTL

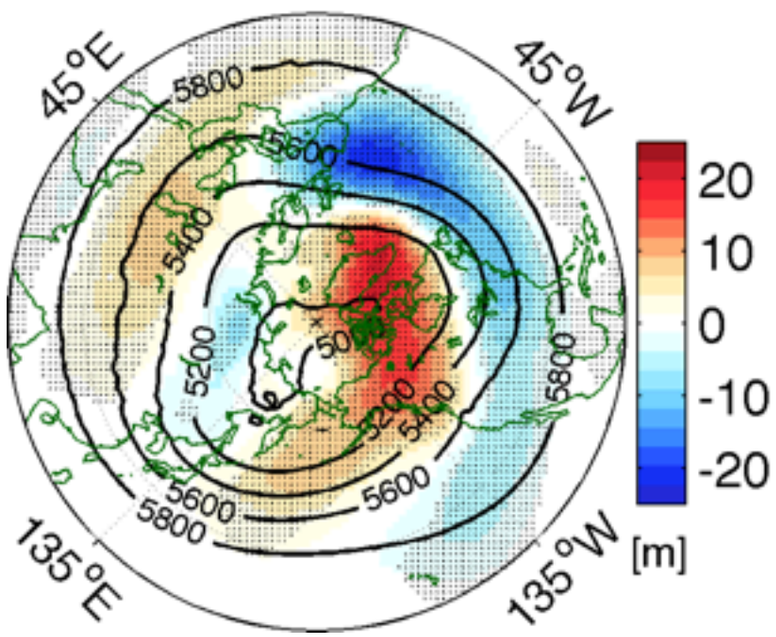


EOF1N-CTL

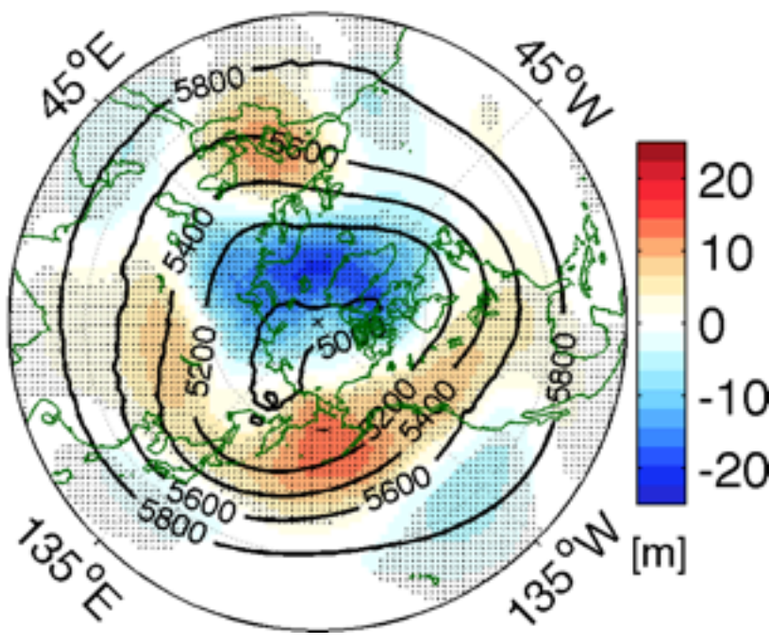


• Anomalous GoA ridge a characteristic equilibrium response pattern **independent of** SSTA.

EOF2P-CTL



EOF2N-CTL

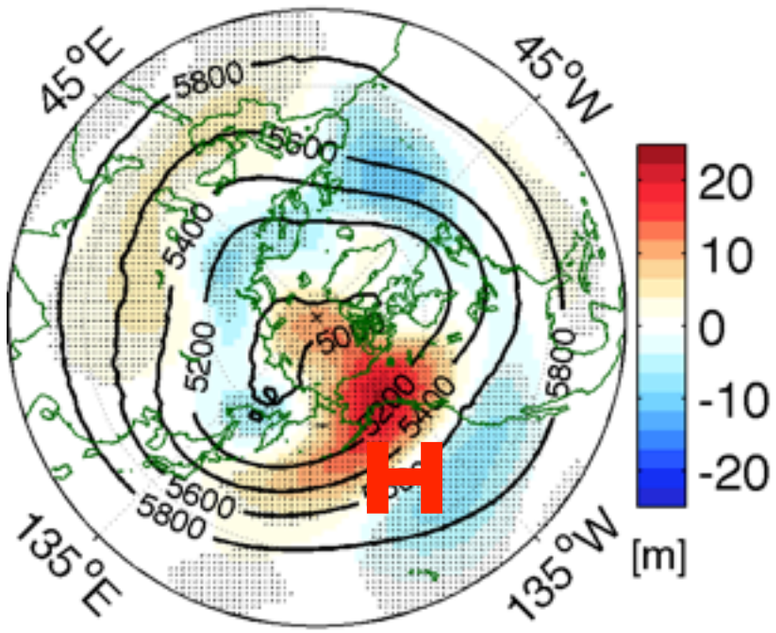


• Response of O(20m) is comparable to the classical AGCM studies forced with basin-scale SSTA of 2-3°C.

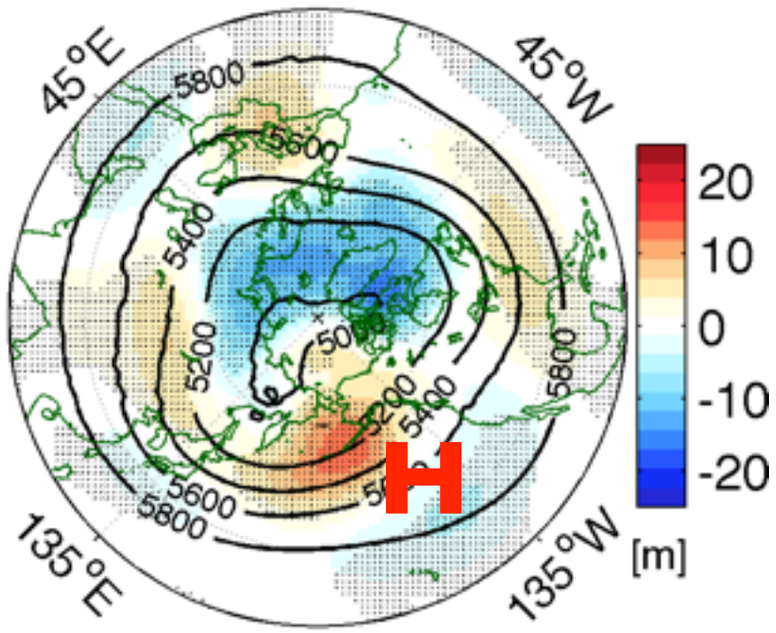
Remote response is *NOT linear*.

Response in NDJFMA mean Z500

EOF1P-CTL

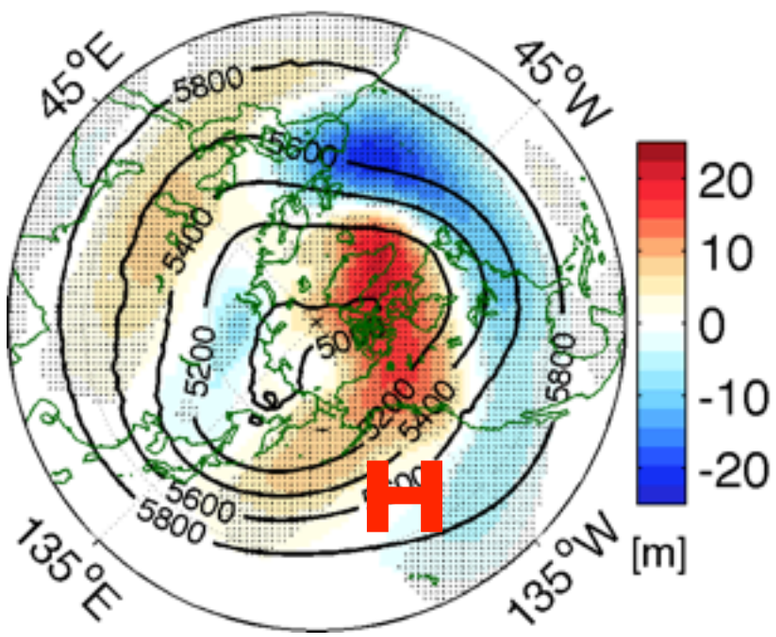


EOF1N-CTL

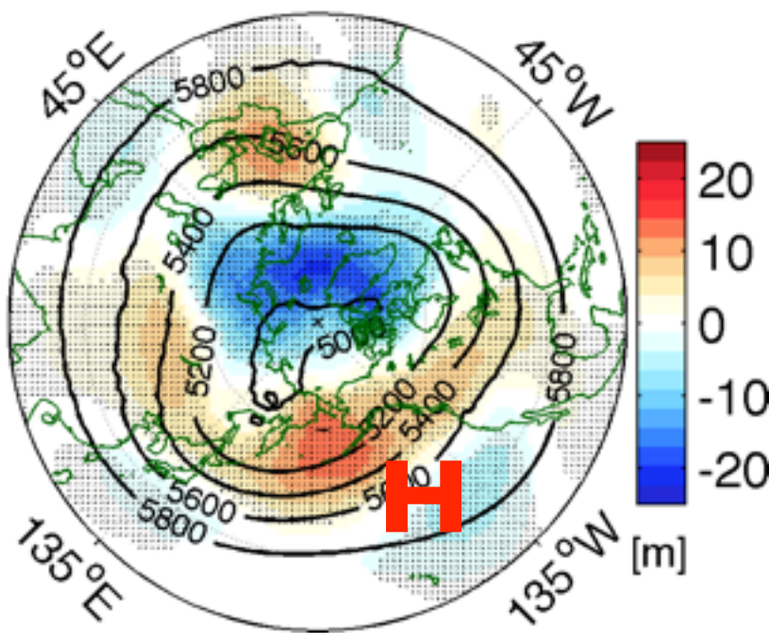


• Anomalous GoA ridge a characteristic equilibrium response pattern **independent of** SSTA.

EOF2P-CTL



EOF2N-CTL

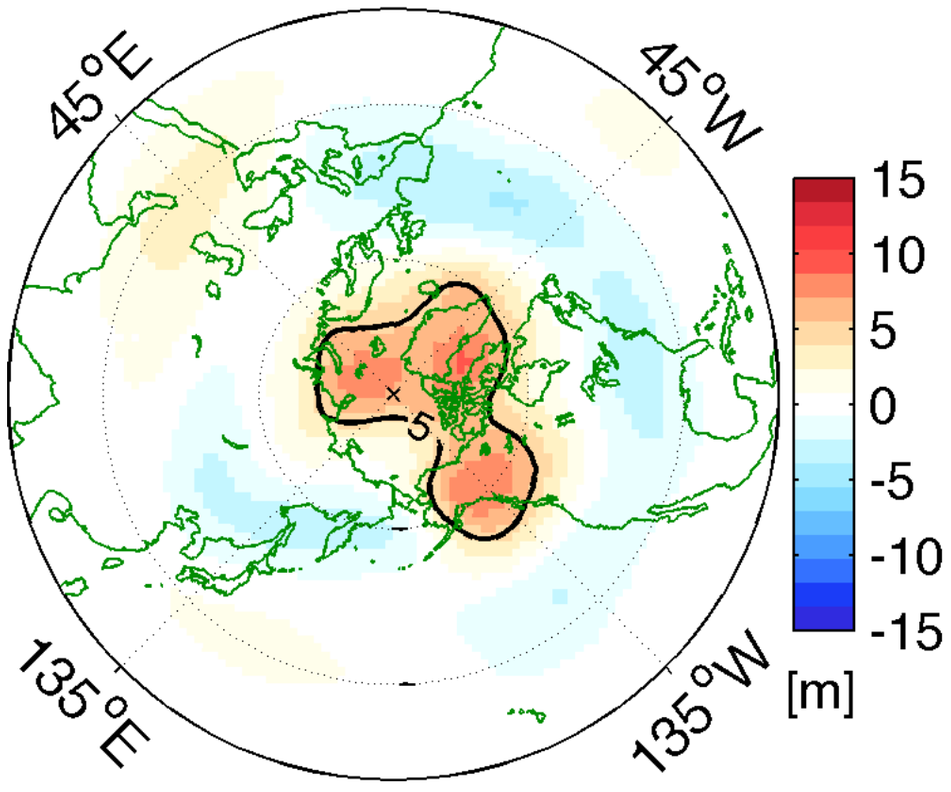


• Response of O(20m) is comparable to the classical AGCM studies forced with basin-scale SSTA of 2-3°C.

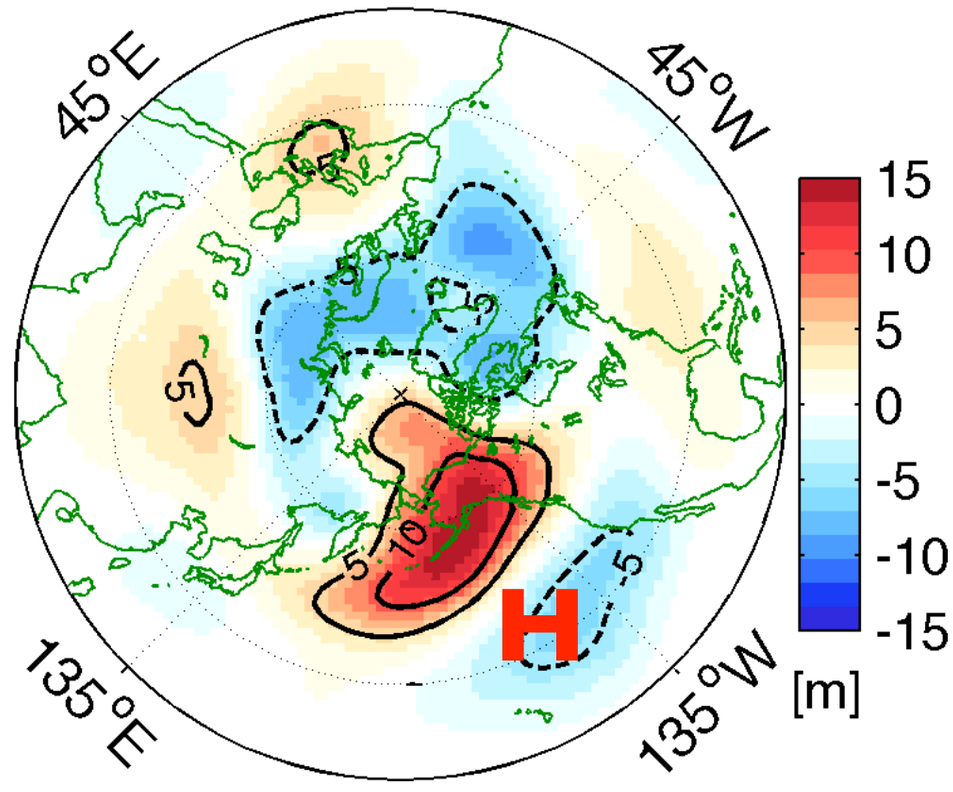
Confirming the anomalous downstream ridge is a nonlinear response

- The total response is partitioned into
  - R_S = ½ × (EOF1P - EOF1N)
  - R_A = ½ × [(EOF1P-CTL) + (EOF1N-CTL)]

EOF1 Symmetric Z500

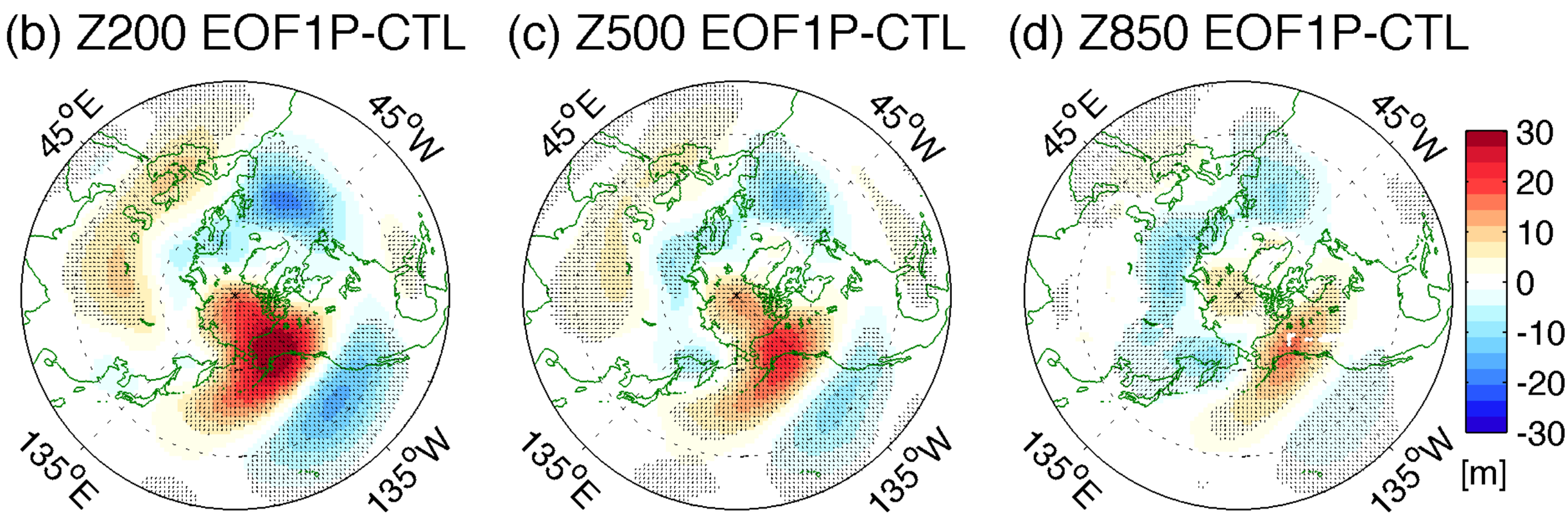


EOF1 Anti-symmetric Z500



- The ridge response strongly resemble the anti-symmetric component.
- Independent of SSTA, an equivalent barotropic ridge emerges as the dominant remote response pattern.

The anomalous ridge is a quasi-steady response
with an equivalent barotropic structure

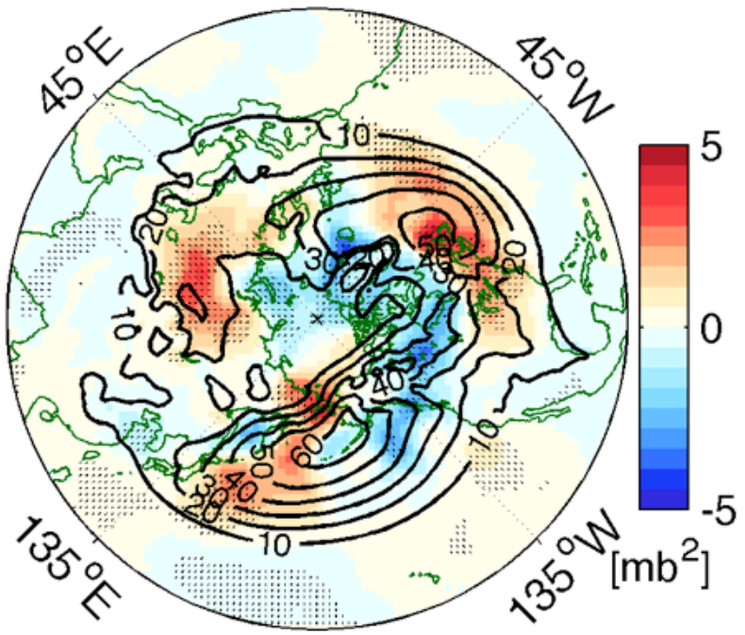


This anomalous ridge has a time-scale of 8-90 days

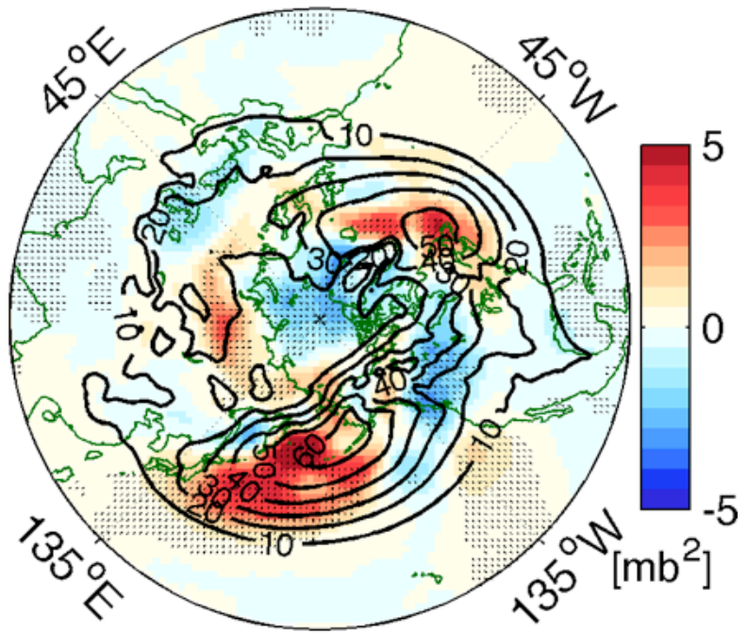
Enhanced ridge response accompanied by enhanced storm track

Response of the 2-8 day filtered SLP variance

EOF1P-CTL

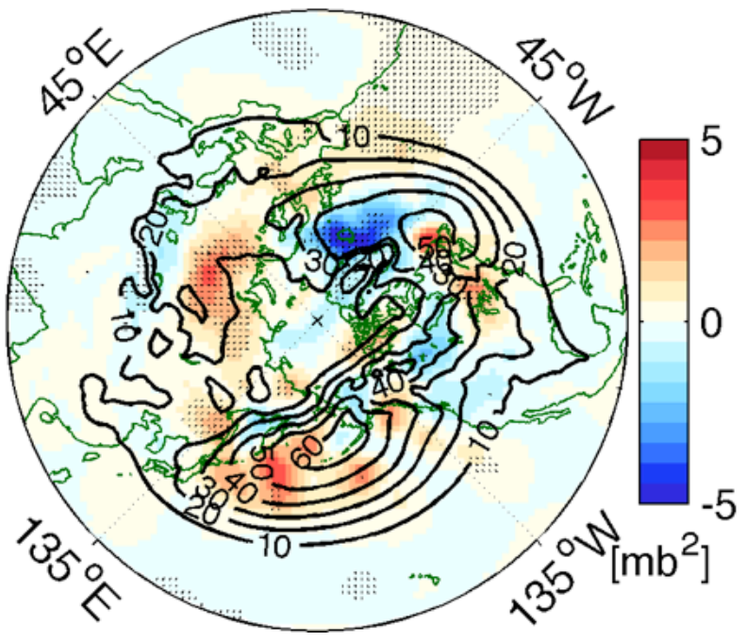


EOF1N-CTL

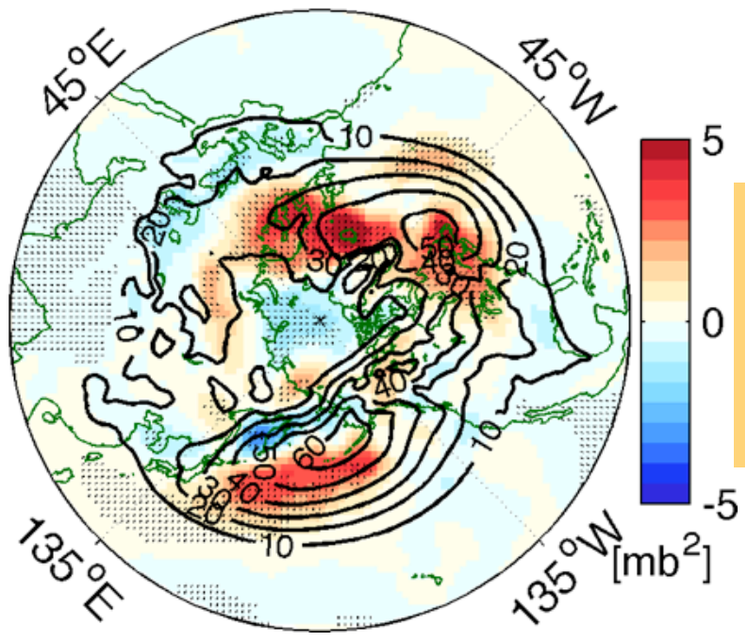


- Enhanced synoptic storm track variability in the upstream half.
- A hint of southward shift

EOF2P-CTL



EOF2N-CTL



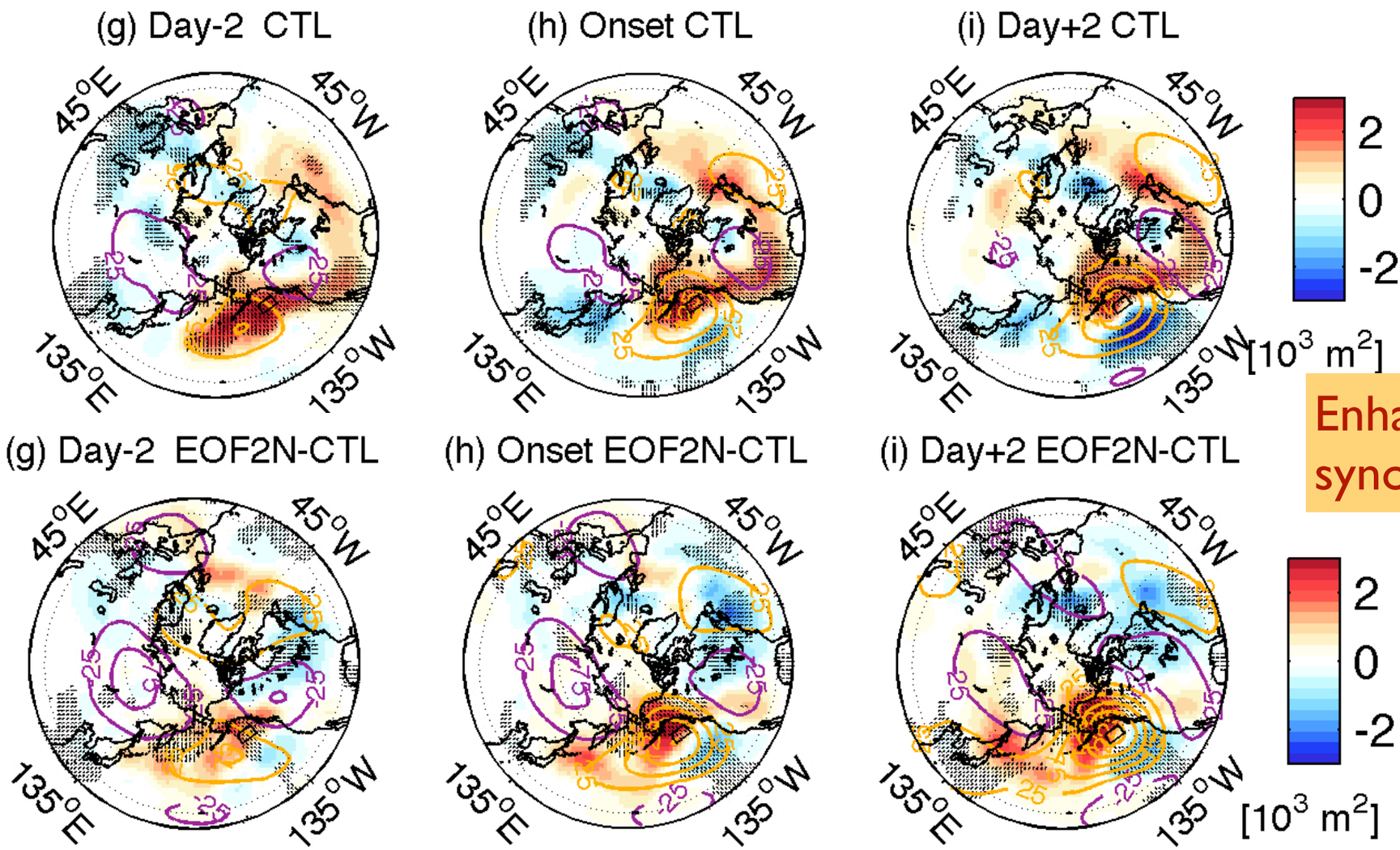
What is the connection bet'n the responses in blocking and storm track?

Intensified storm track activity prior to the onset of GoA blocking

Composite evolution of synoptic & intraseasonal variability against the blocking index

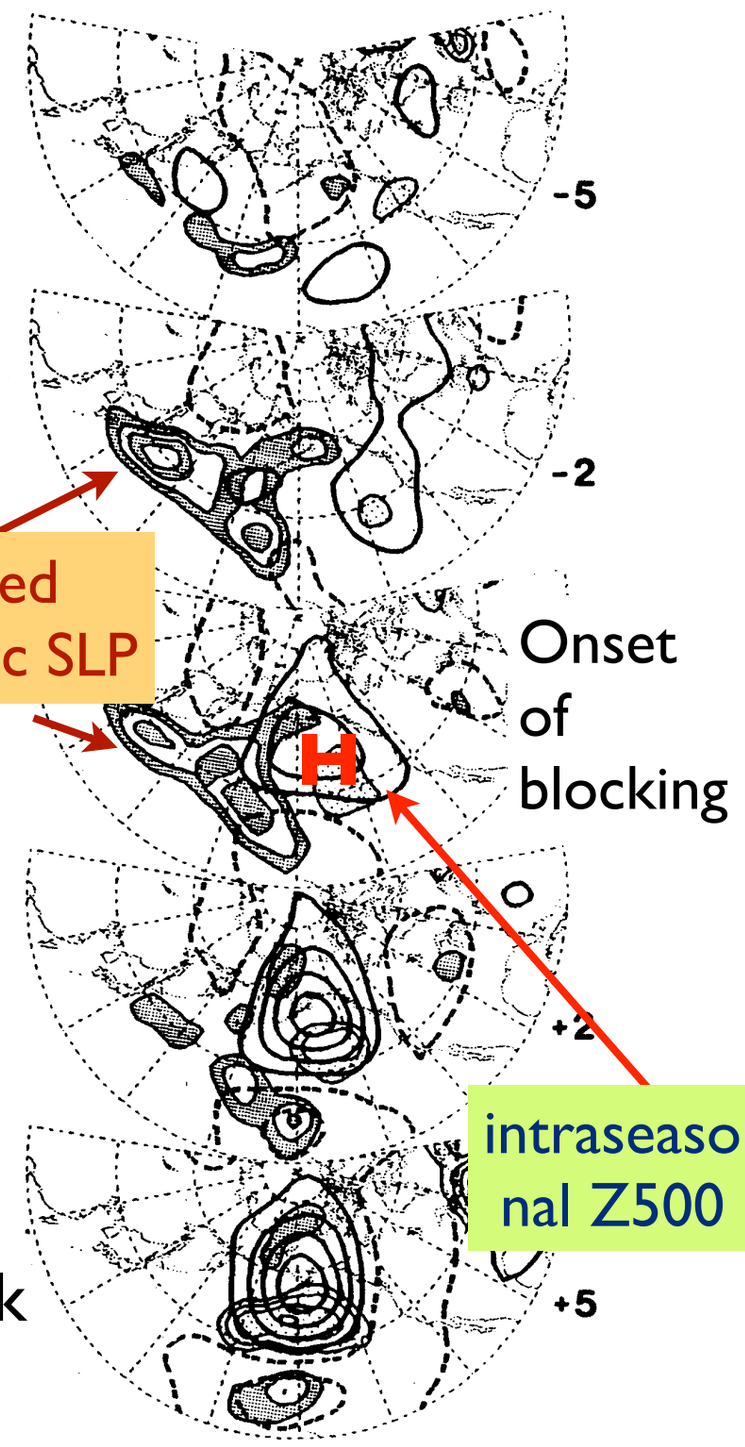
CTL

Day-2	Onset of blocking	Day+2



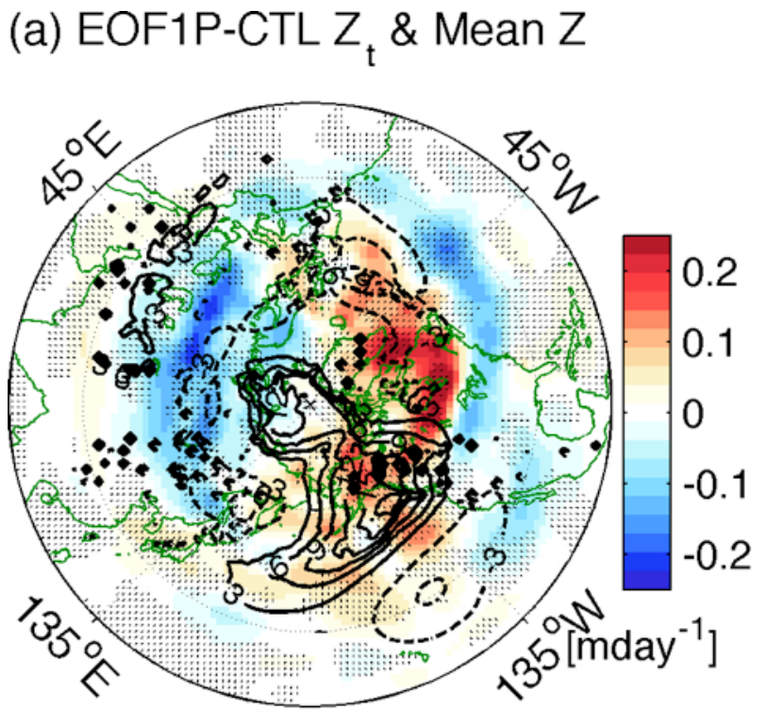
EOF2N-CTL

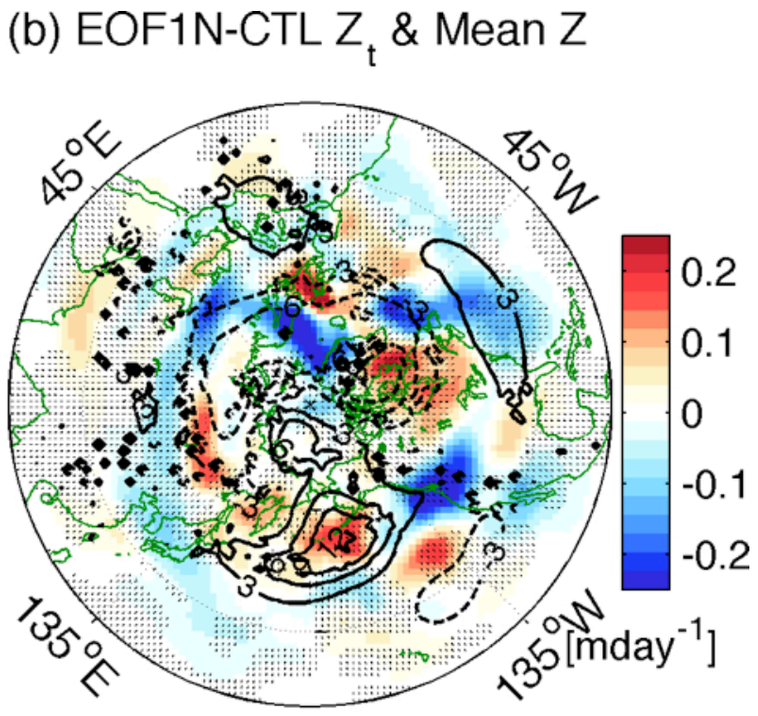
Nakamura and Wallace (1990)



- Enhanced baroclinic wave activity in the upstream storm track
- Preceding the ridge blocking ridge in the downstream.

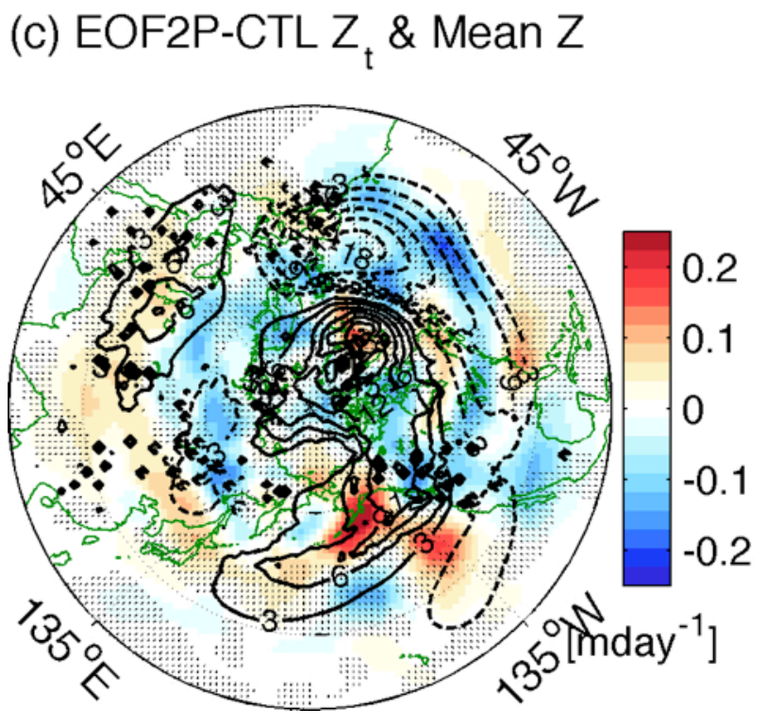
Synoptic eddy vorticity flux reinforcing blocking ridge response via convergence of transient eddy vorticity flux

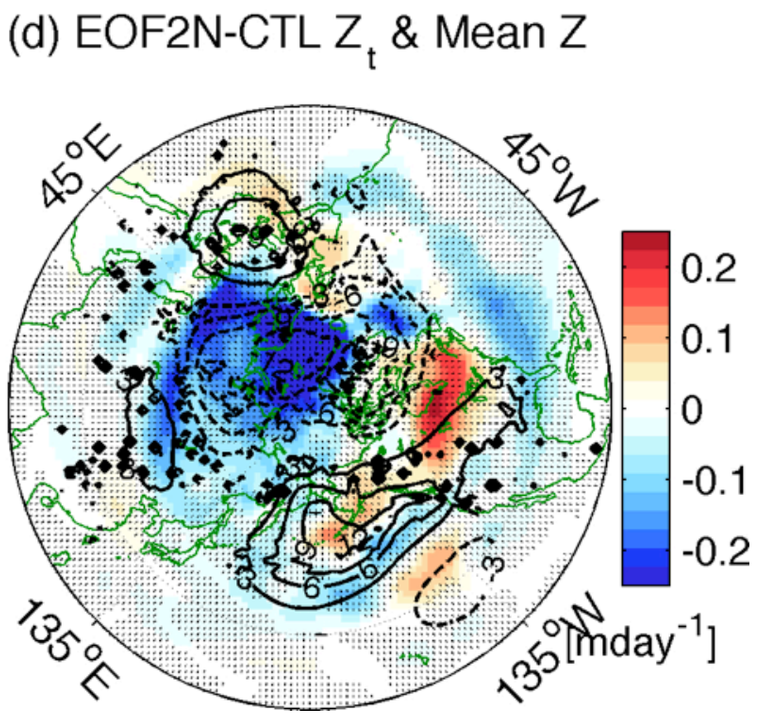




$$Z_t = (f/g)\nabla^{-2}\left[-\nabla(\overline{v'\zeta'})\right]$$

- Z_t (shading) spatially well corresponds to low-frequency blocking circulation (contours).





- $-\nabla(\overline{v'\zeta'})$ maintains low-frequency circulation anomaly.

Consistent with the AGCM studies forced with basin-scale SSTA (e.g., Kushnir et al. 2002)

Summary

What is the *characteristic atmospheric response pattern* to the EJS SST anomalies and the *generating mechanism*?

Local response: linear and symmetric w.r.t sign and pattern of SSTA

A *critical role* of the *intra-basin structure of the SSTA* in the wintertime regional atmospheric conditions.

Transient eddy vorticity flux convergence

turning the direct linear baroclinic response into an equivalent barotropic height tendency.

Remote response: Highly nonlinear *independent of SSTA.*

A potentially important element for the North Pacific climate variability

Thanks

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Seo et al. 2014: On the effect of marginal sea SST variability on the North Pacific atmospheric circulation. *JGR-Atmospheres*

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