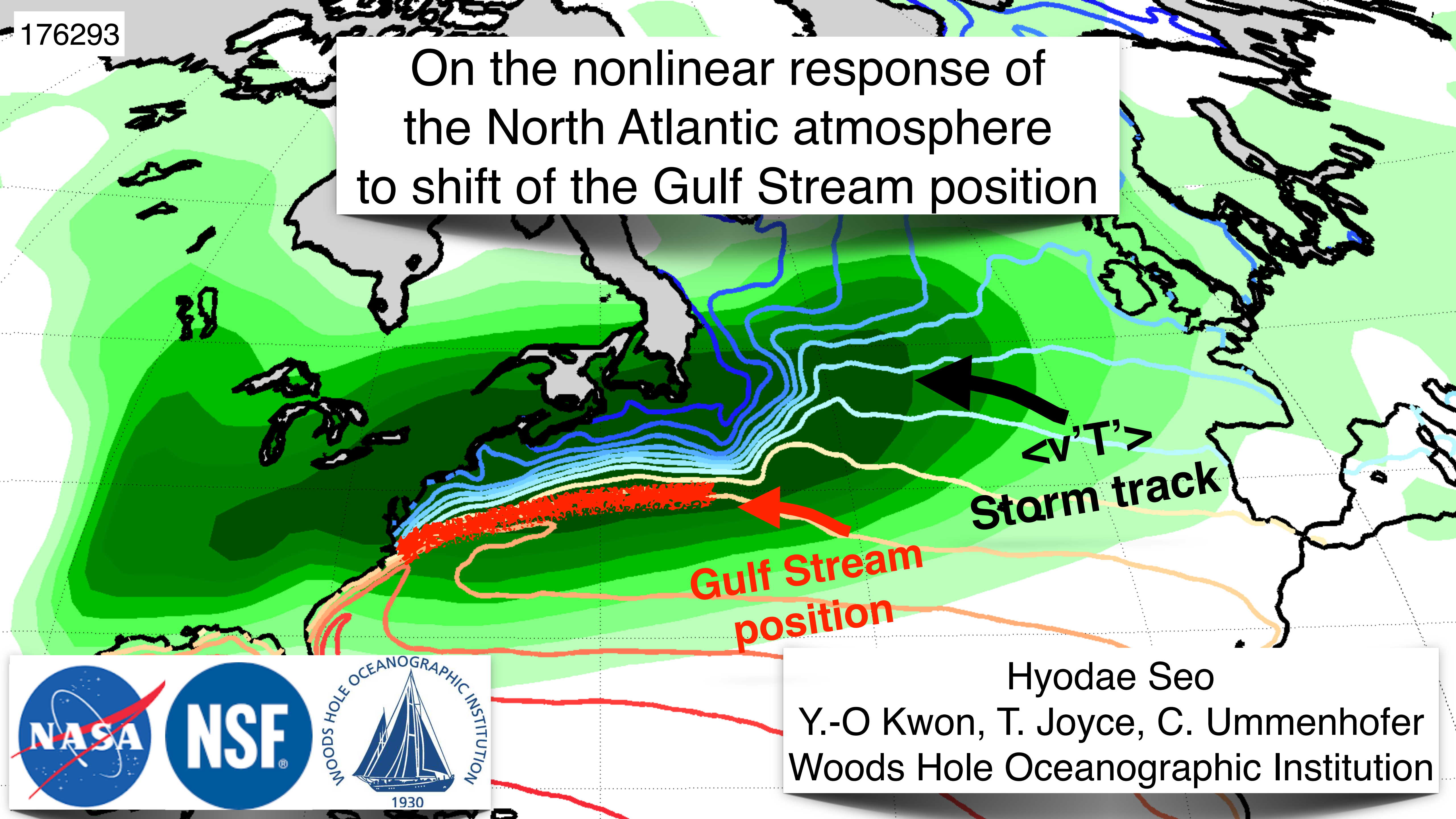


On the nonlinear response of the North Atlantic atmosphere to shift of the Gulf Stream position



$\langle V'T \rangle$
Storm track

Gulf Stream position

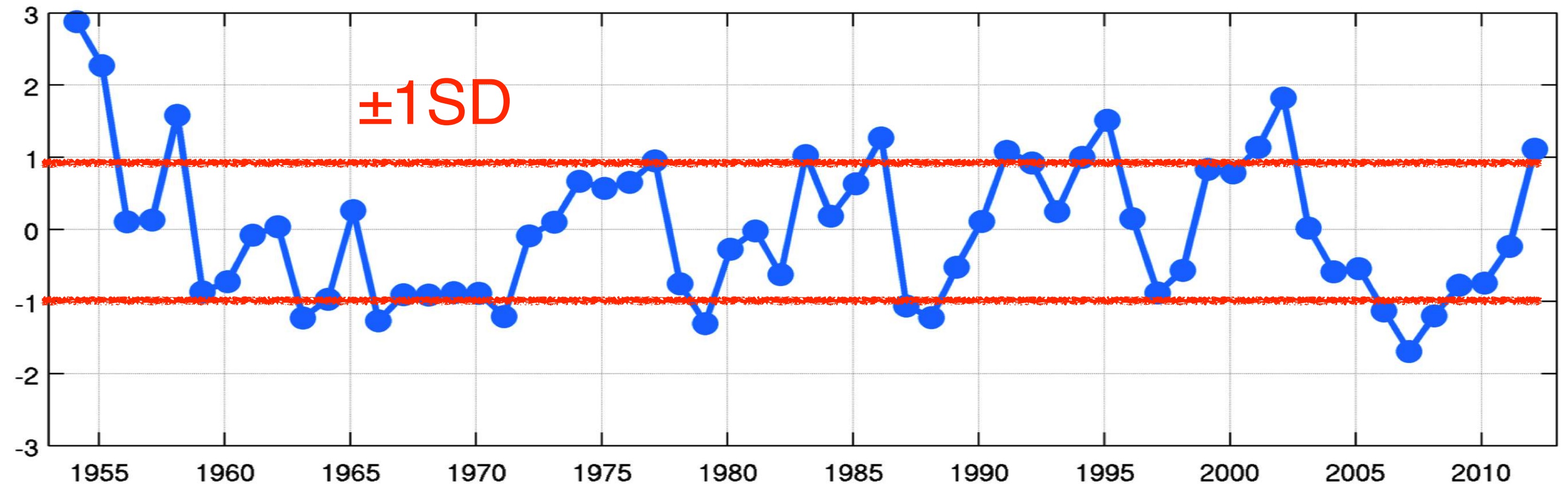
Hyodae Seo
Y.-O Kwon, T. Joyce, C. Ummenhofer
Woods Hole Oceanographic Institution



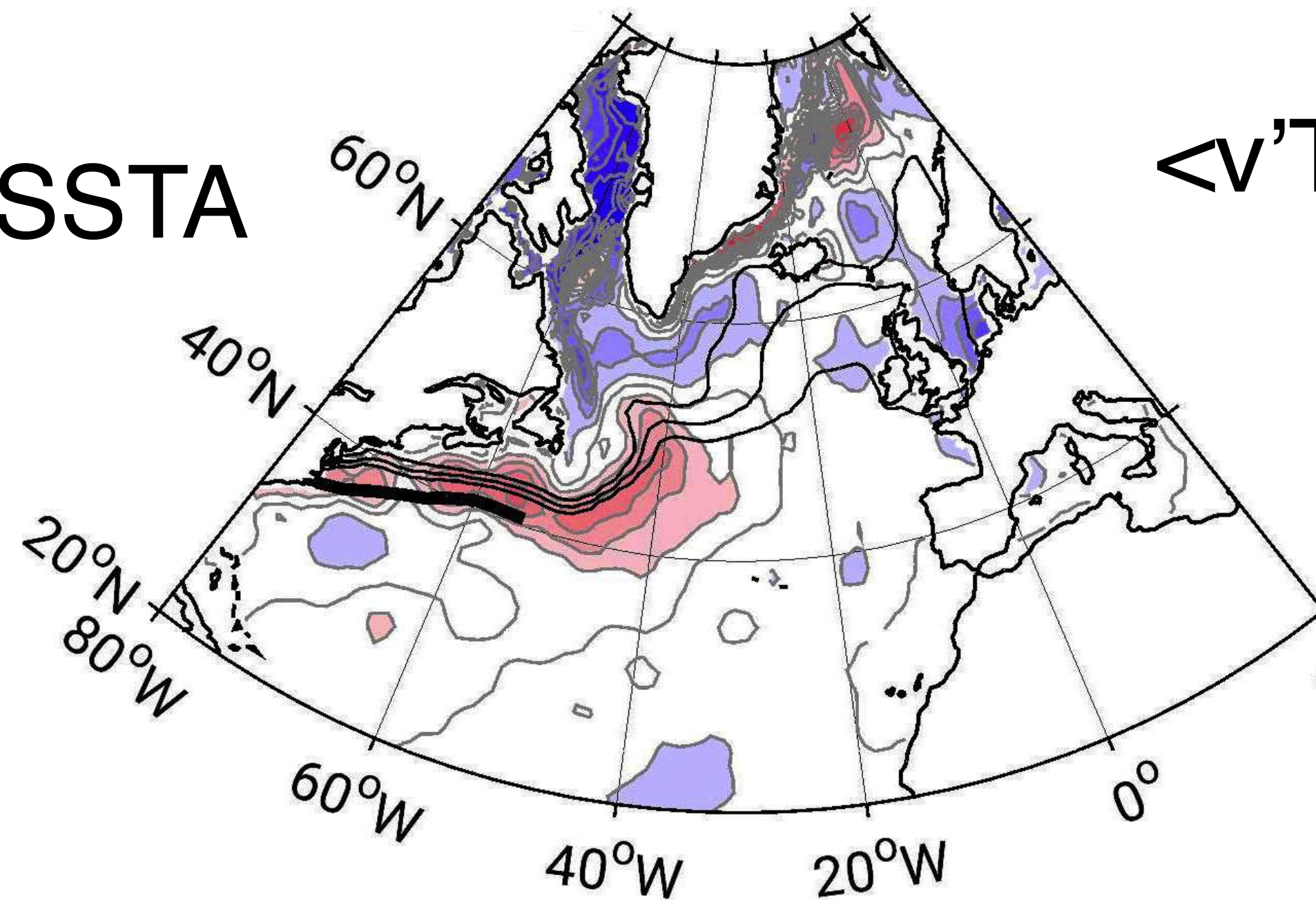
Observed responses to winter Gulf Stream position

— **Linear regression** when JFM GSI leads by 1-yr

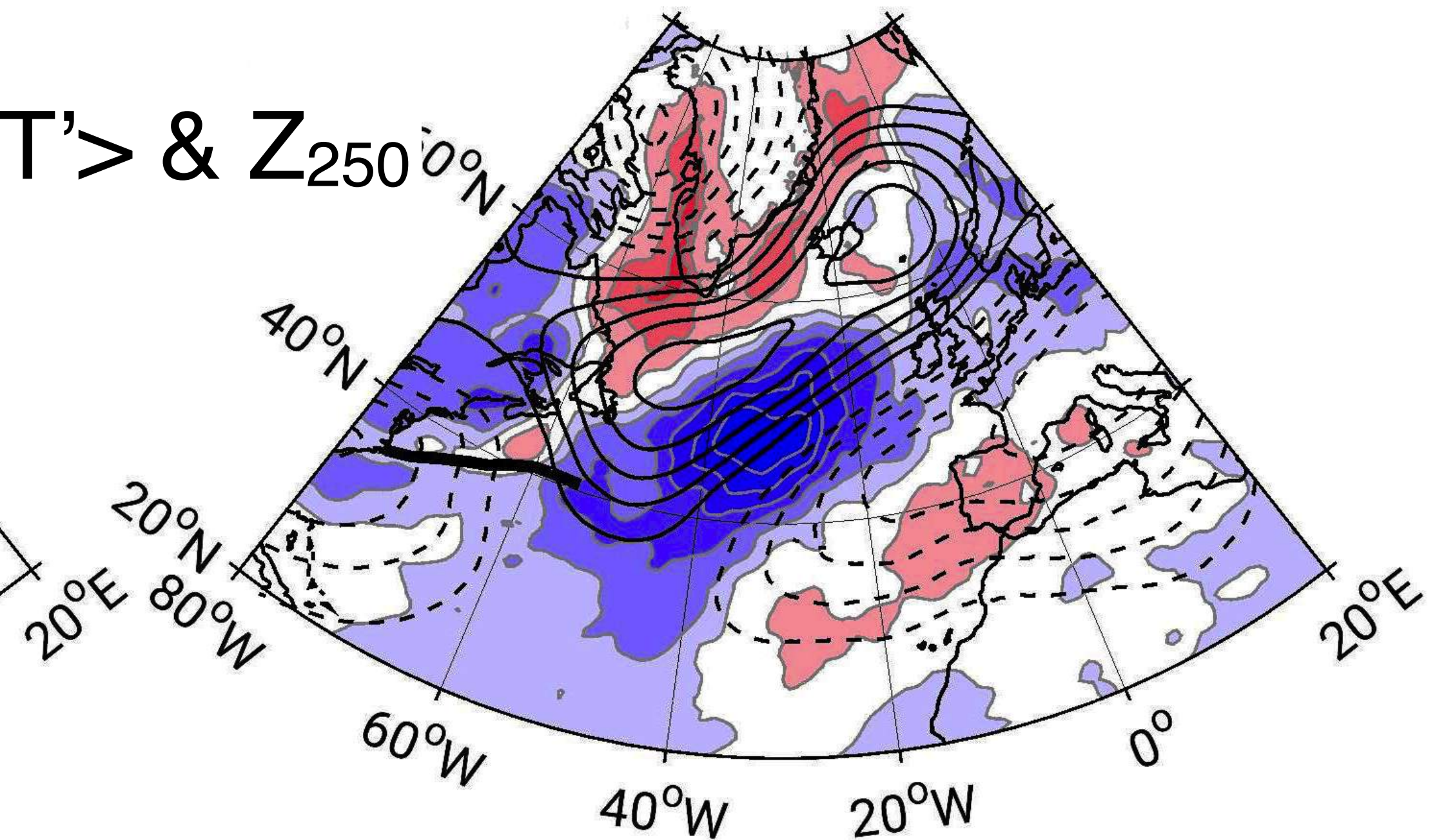
**Normalized
GS index**
based on T-200m
Joyce et al. 2000



regressed SSTA



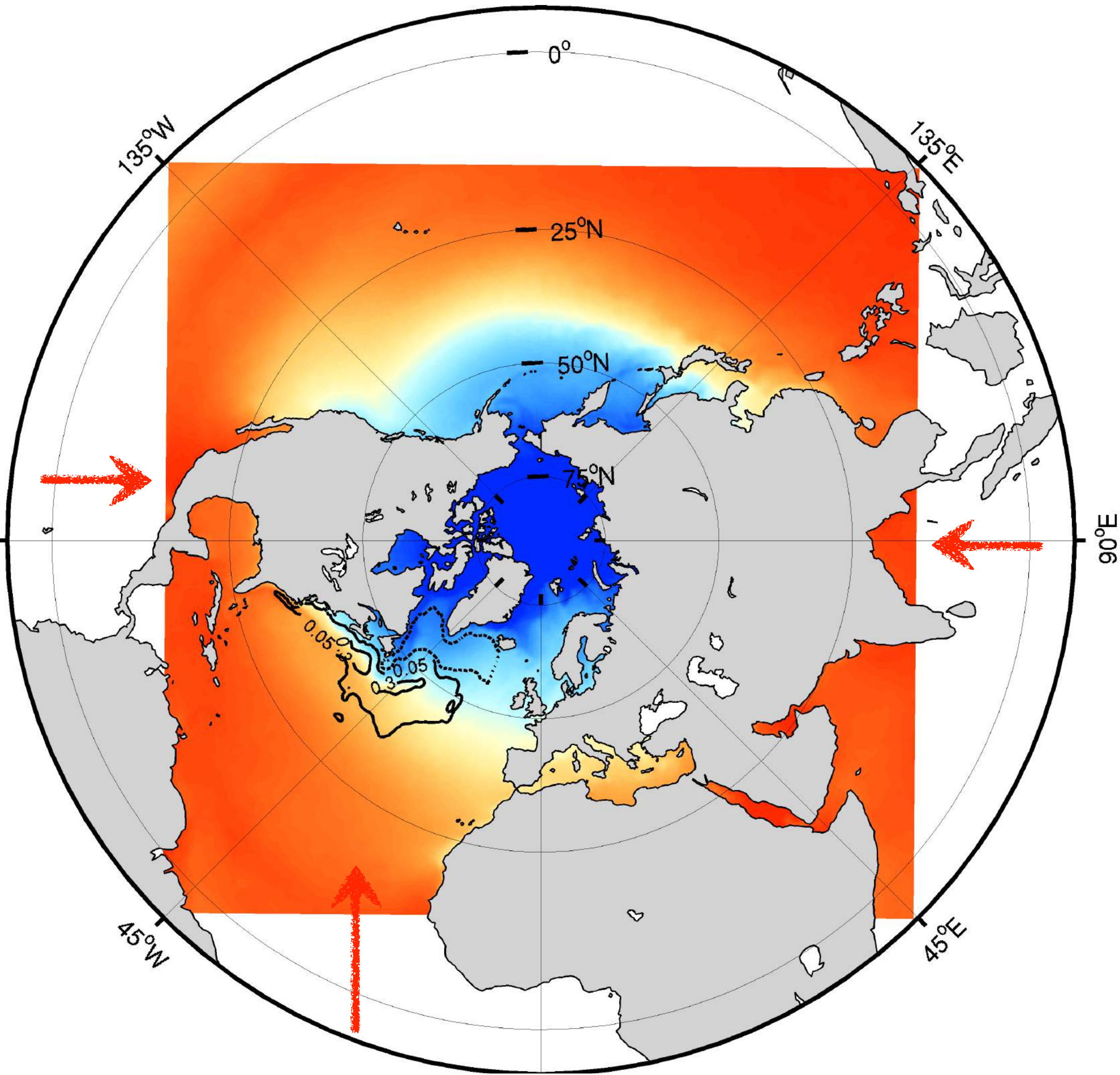
$\langle v'T' \rangle$ & Z_{250}



Kwon and
Joyce 2013

Modeling atmospheric response to shift in GS position

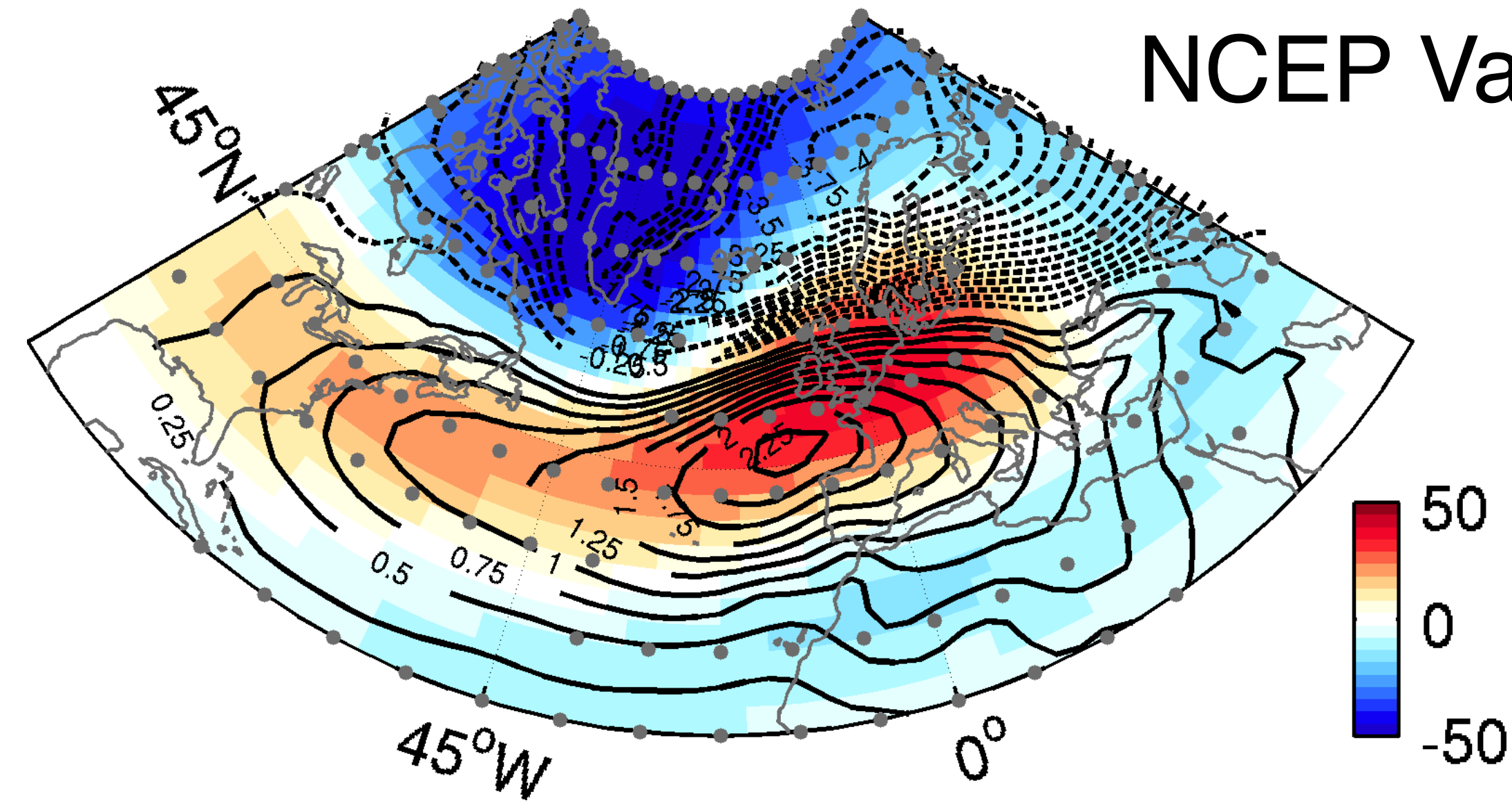
WRF 40-km Nov-Apr



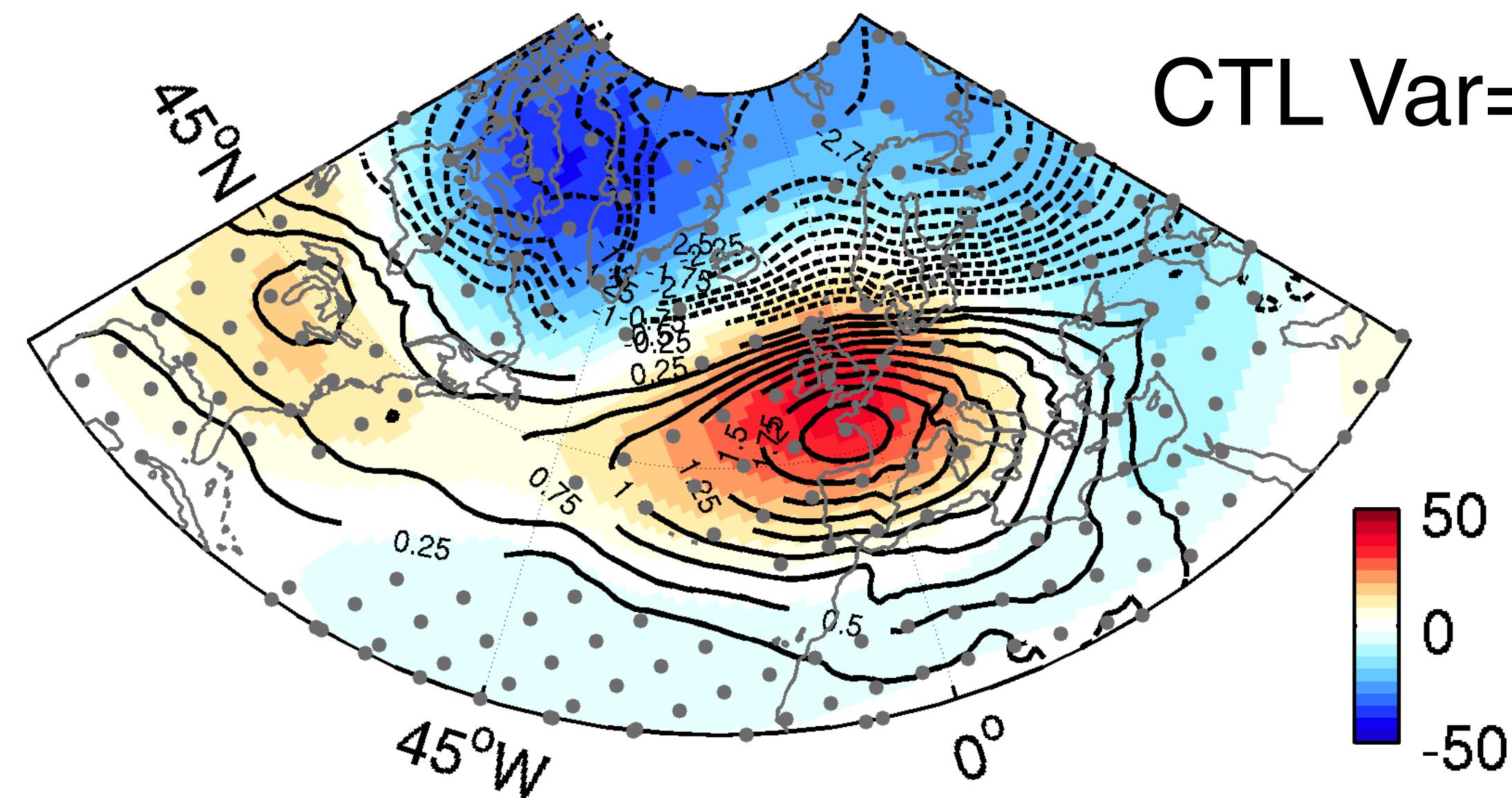
BCs; NCEP & SST climatology

Z₂₅₀/SLP EOF1

NCEP Var=32%



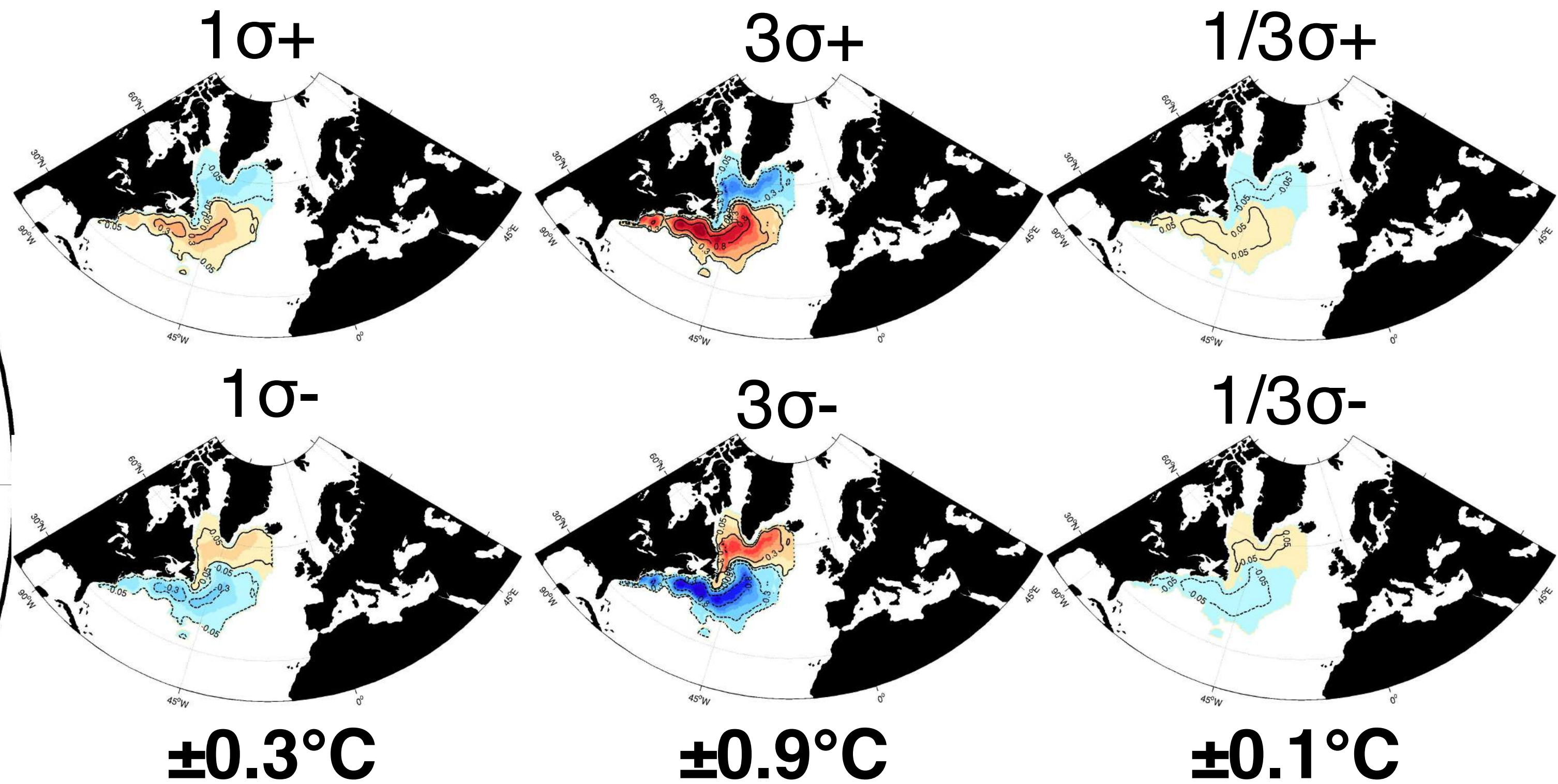
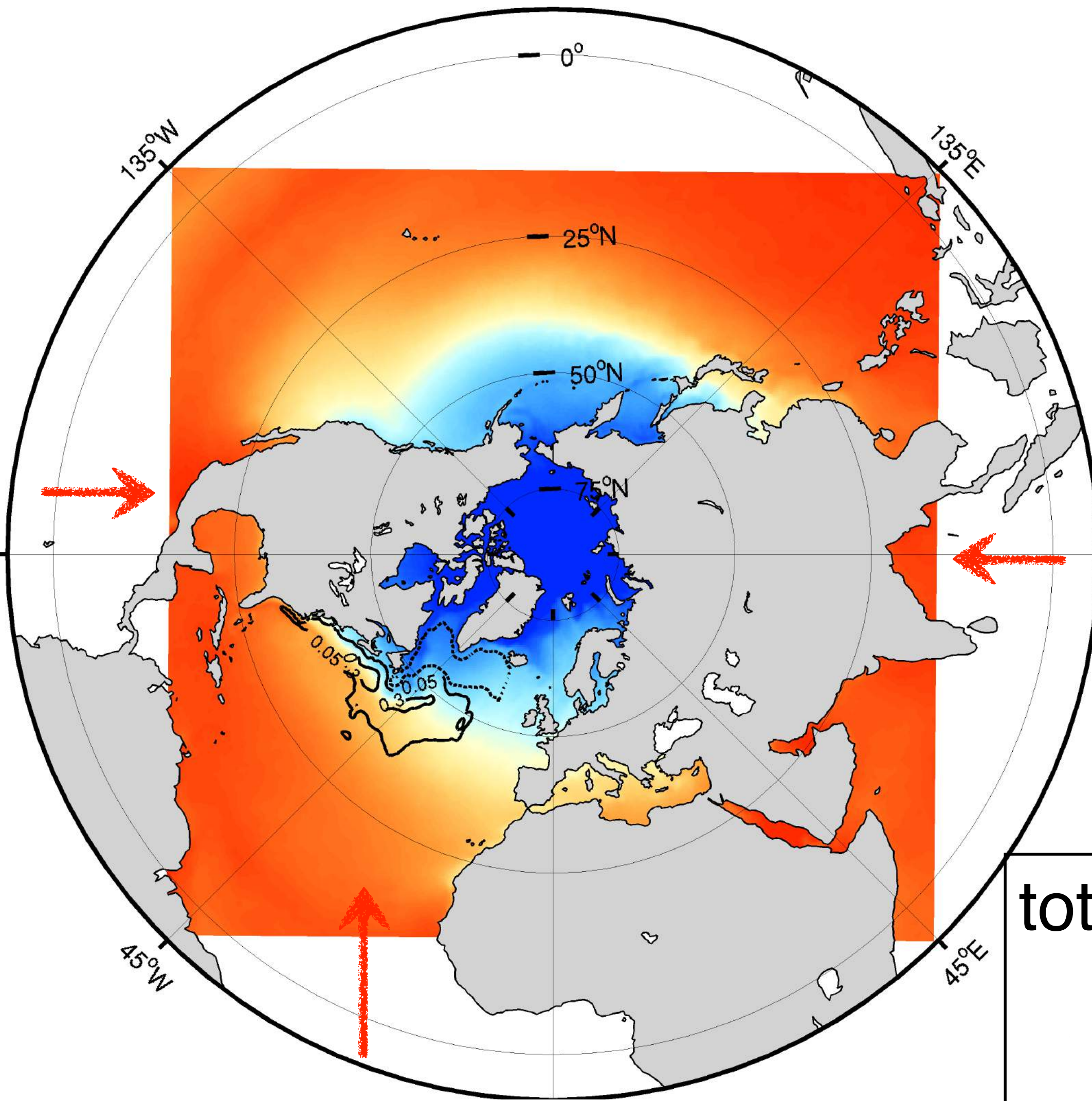
CTL Var=31%



Modeling atmospheric response to shift in GS position

WRF 40-km Nov-Apr

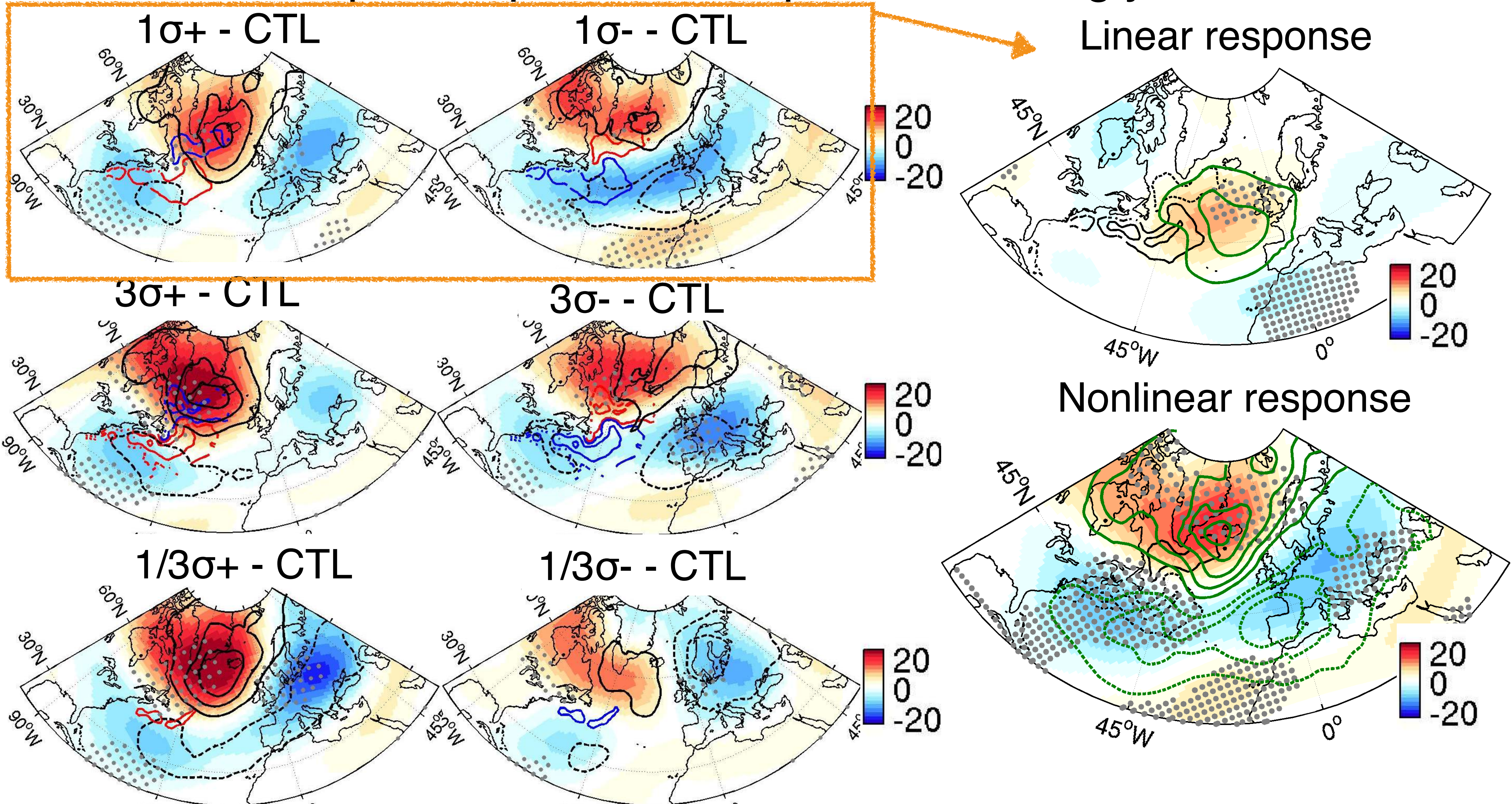
SST perturbation experiments



| | |
|--------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| total response = 1σ+ - CTL 1σ- - CTL | linear = $\frac{1}{2} \times (1\sigma+ - 1\sigma-)$ nonlinear = $\frac{1}{2} \times [(1\sigma+ - CTL) + (1\sigma- - CTL)]$ |
|--------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|

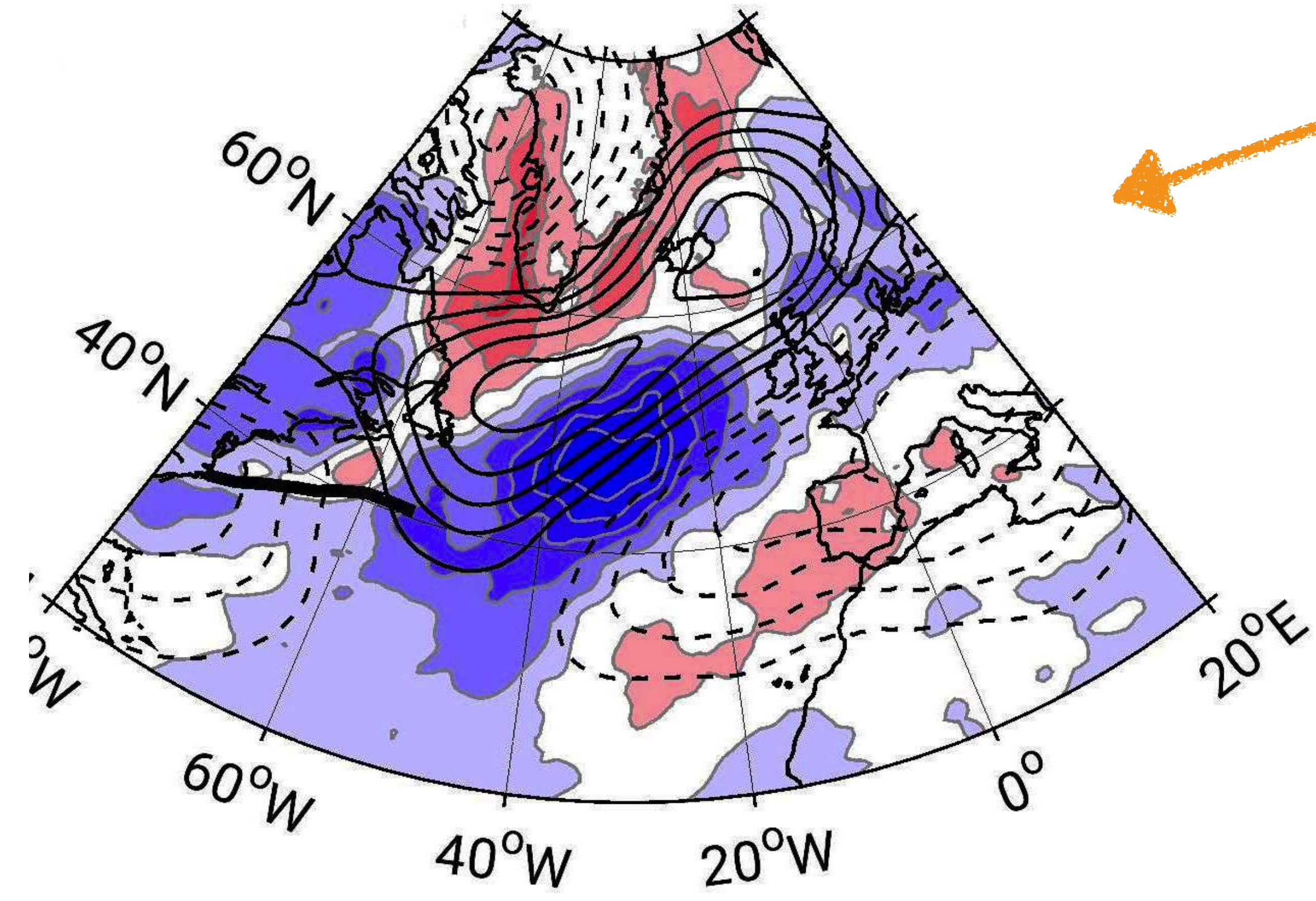
BCs; NCEP & SST climatology

Z₂₅₀/SLP quasi-equilibrium responses: Strongly nonlinear

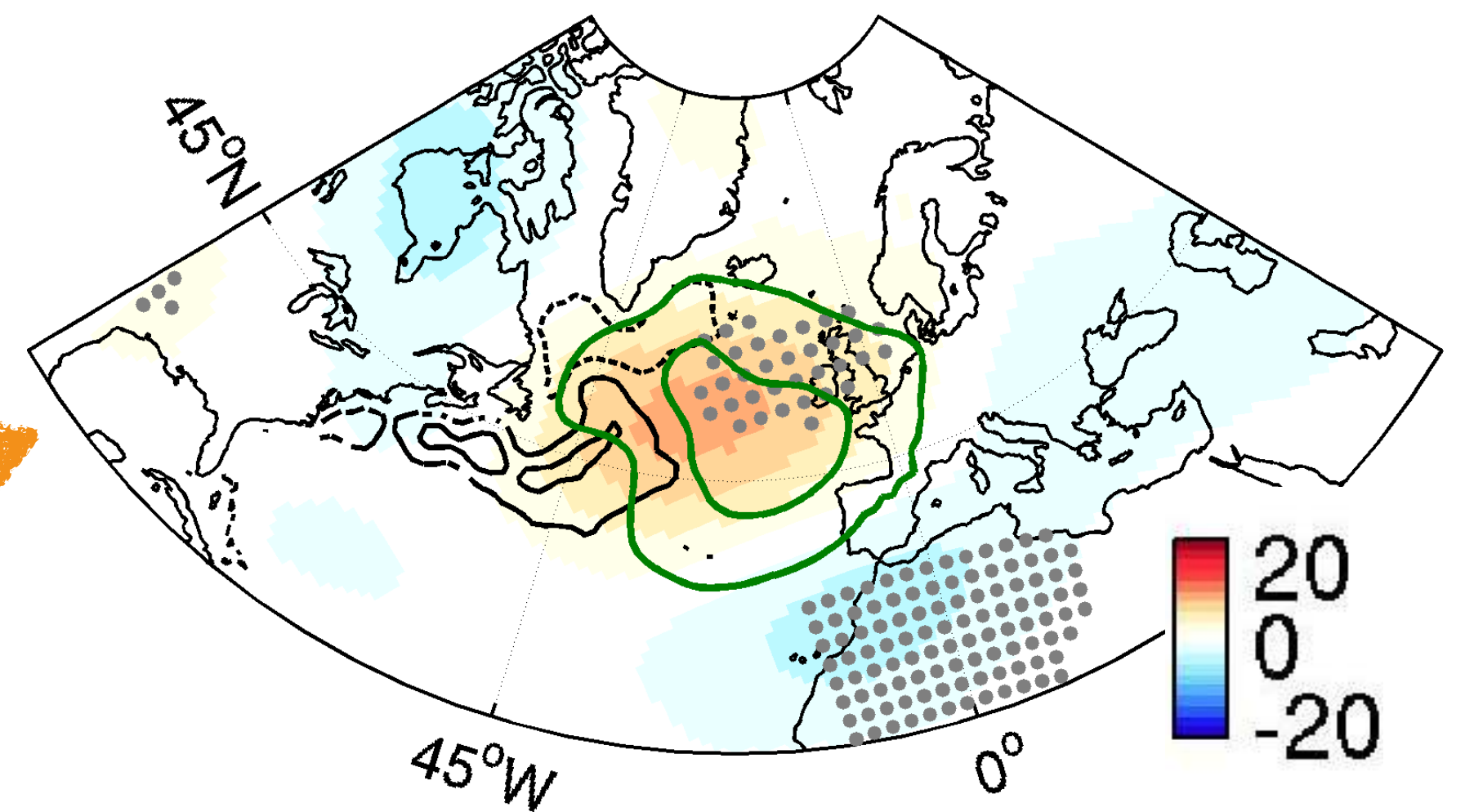


Z₂₅₀/SLP quasi-equilibrium responses: Strongly nonlinear

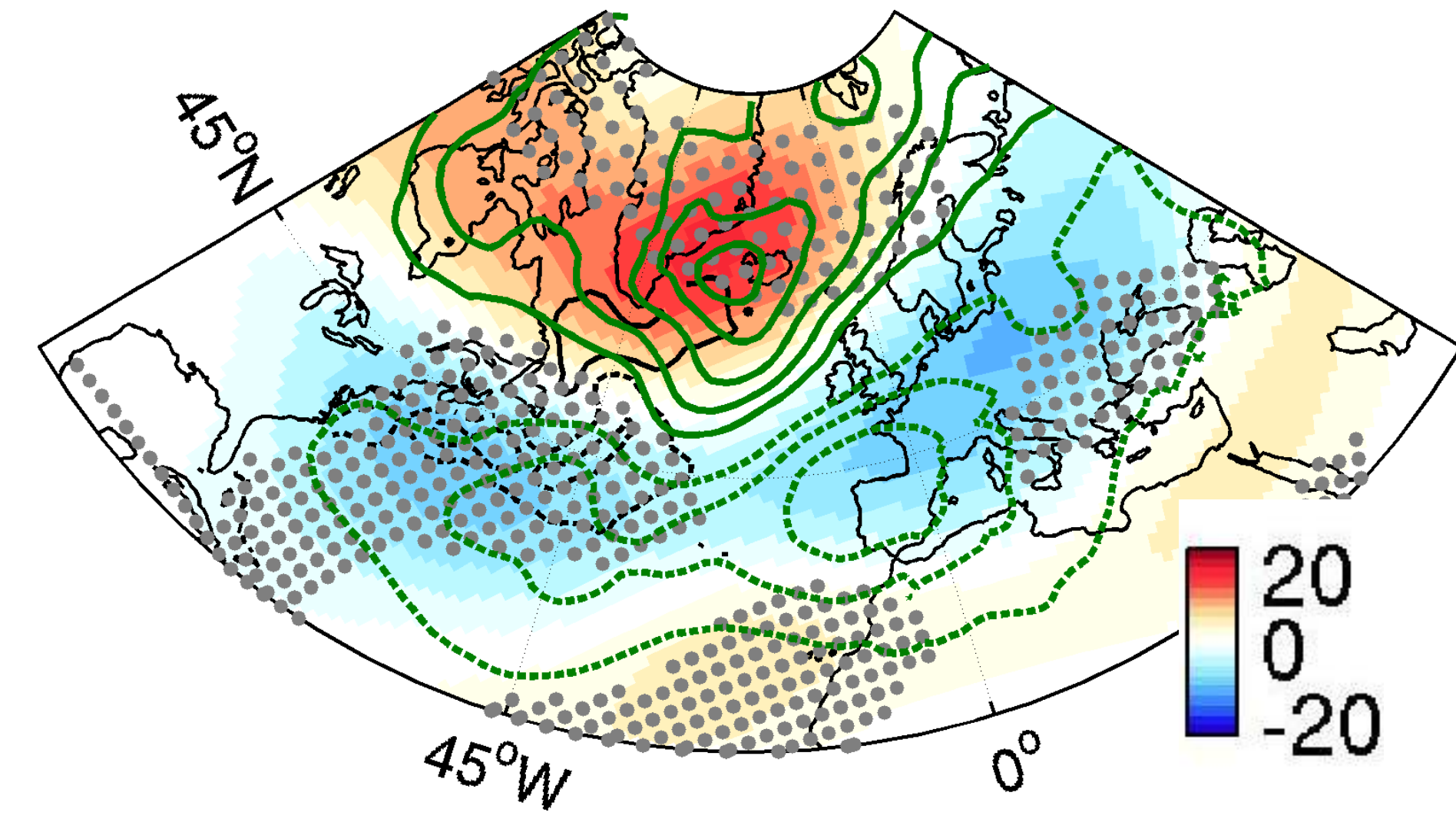
Recall
observed response in $\langle v'T' \rangle$ & Z₂₅₀
based on **linear regression**



Linear response



Nonlinear response

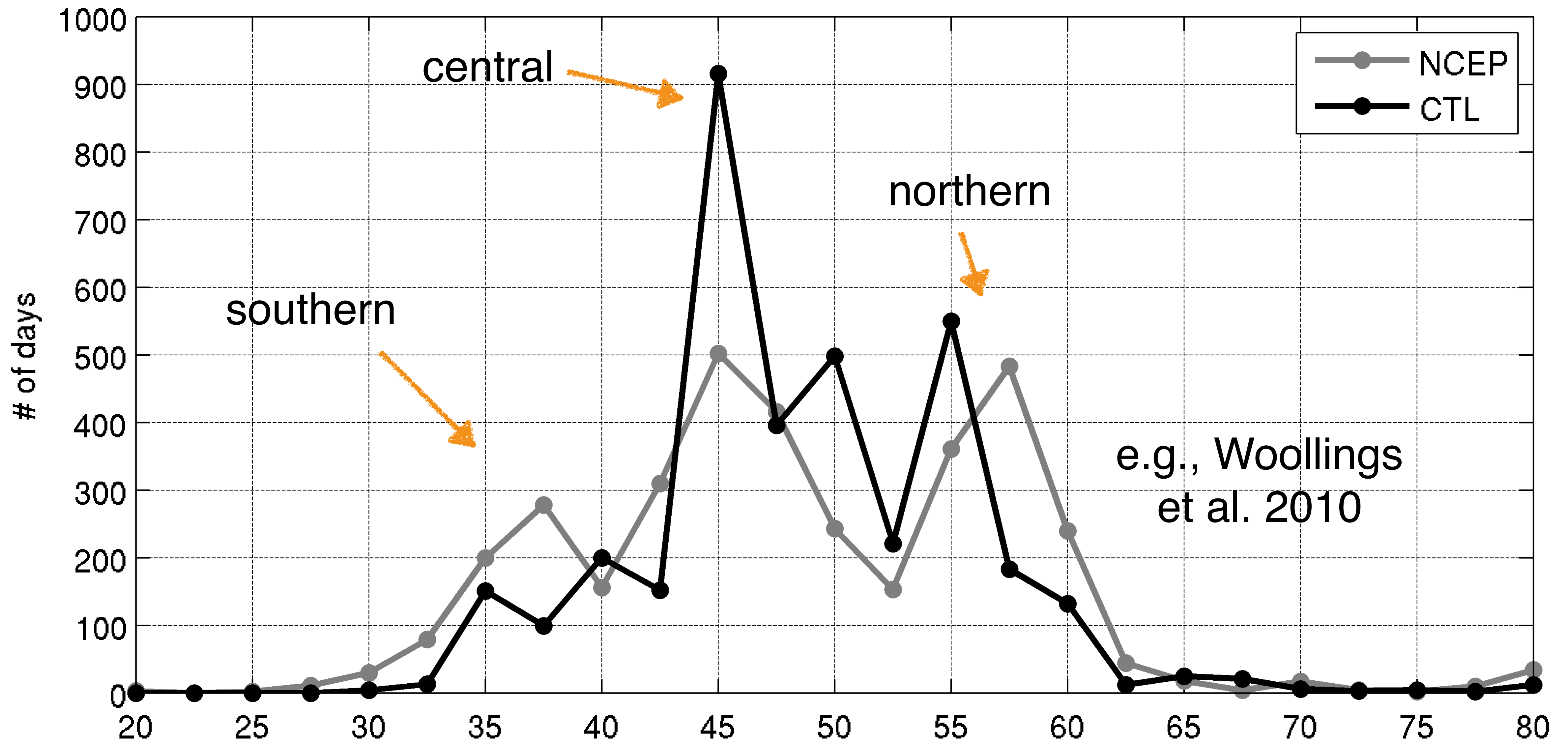


Kwon and Joyce 2013

Dynamical adjustment processes leading to
NAO-like nonlinear response?

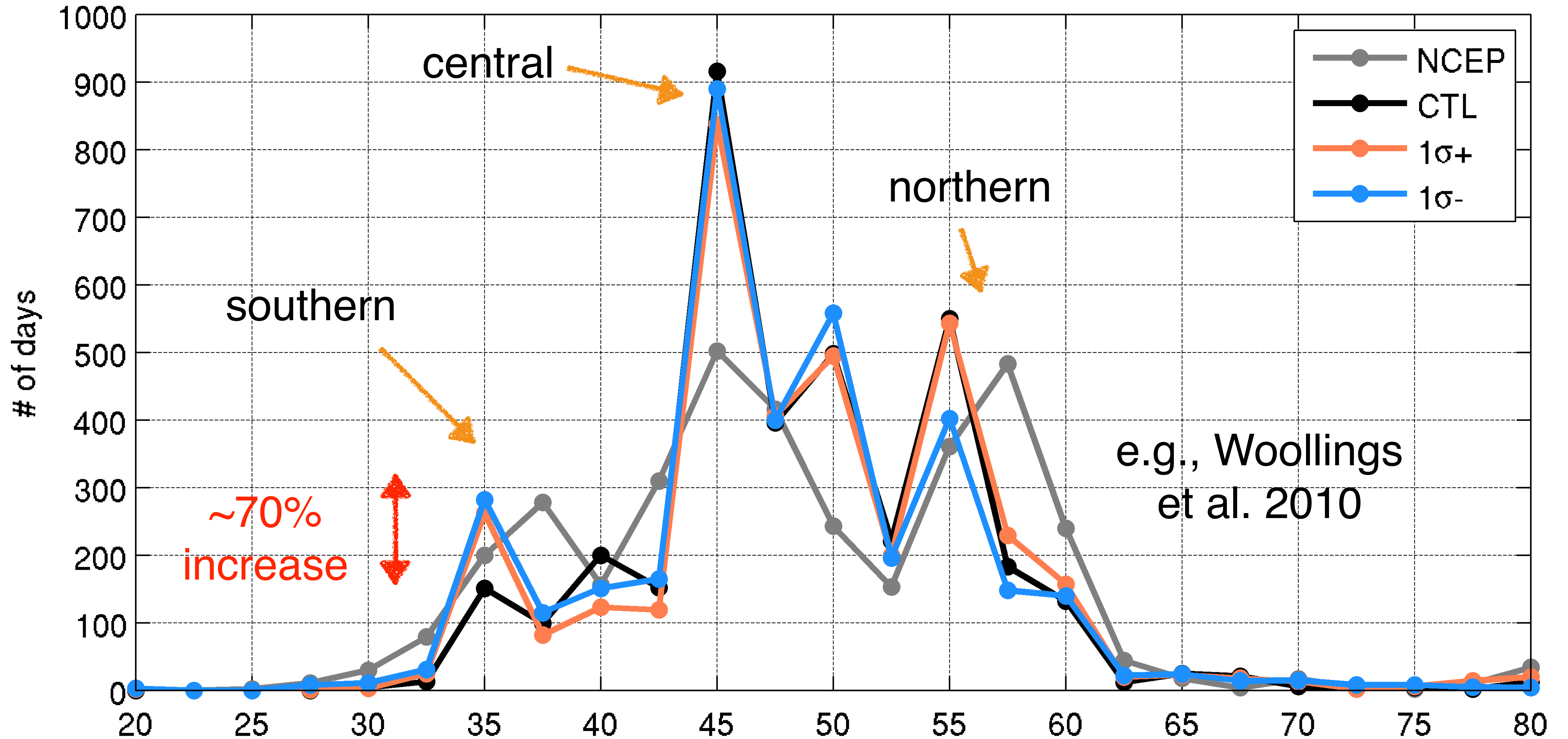
Position of the North Atlantic eddy-driven Jet

Jet latitude histograms (60°W-0°E, U₈₅₀, DJF)



Increased southerly location of the eddy-driven jet

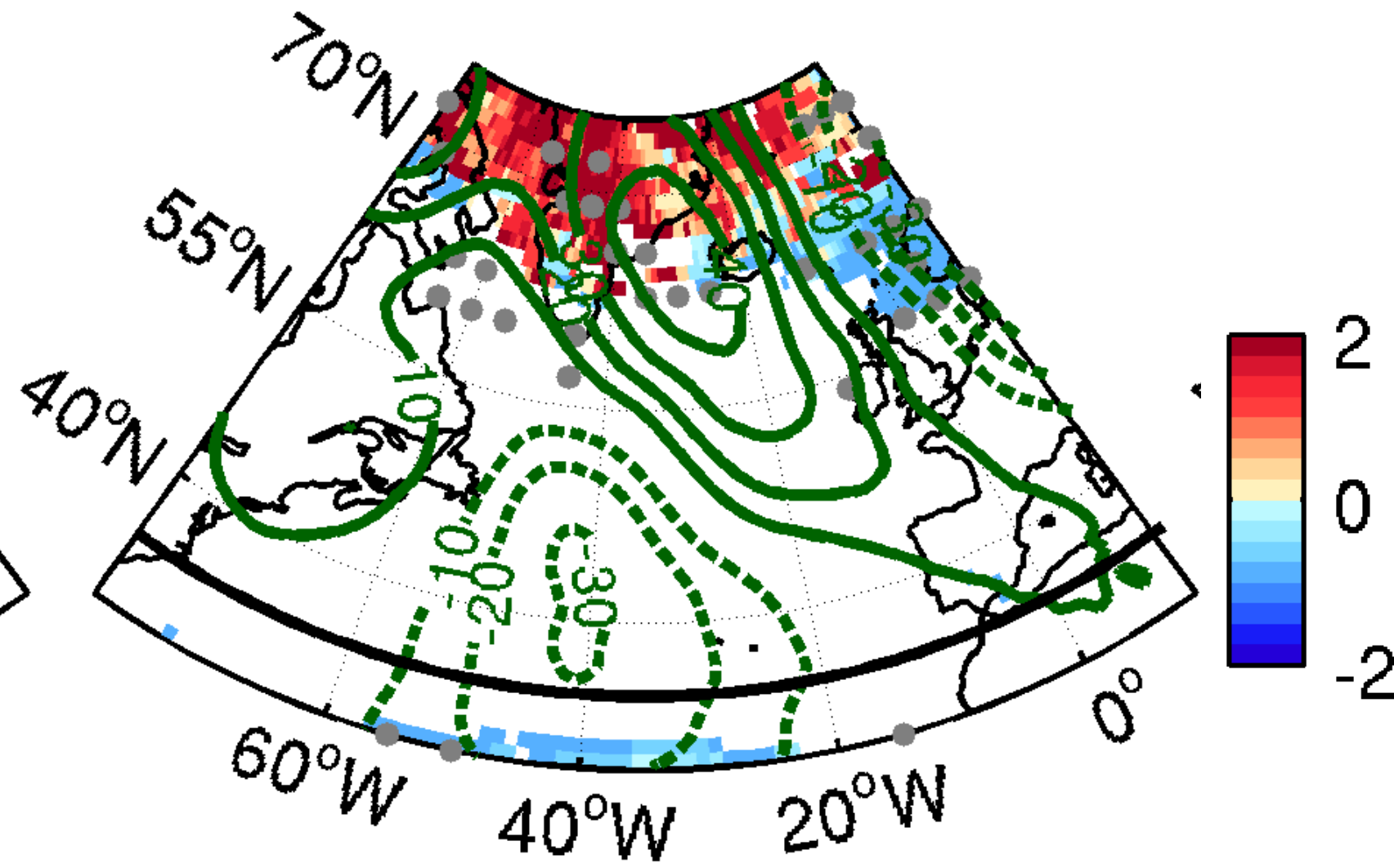
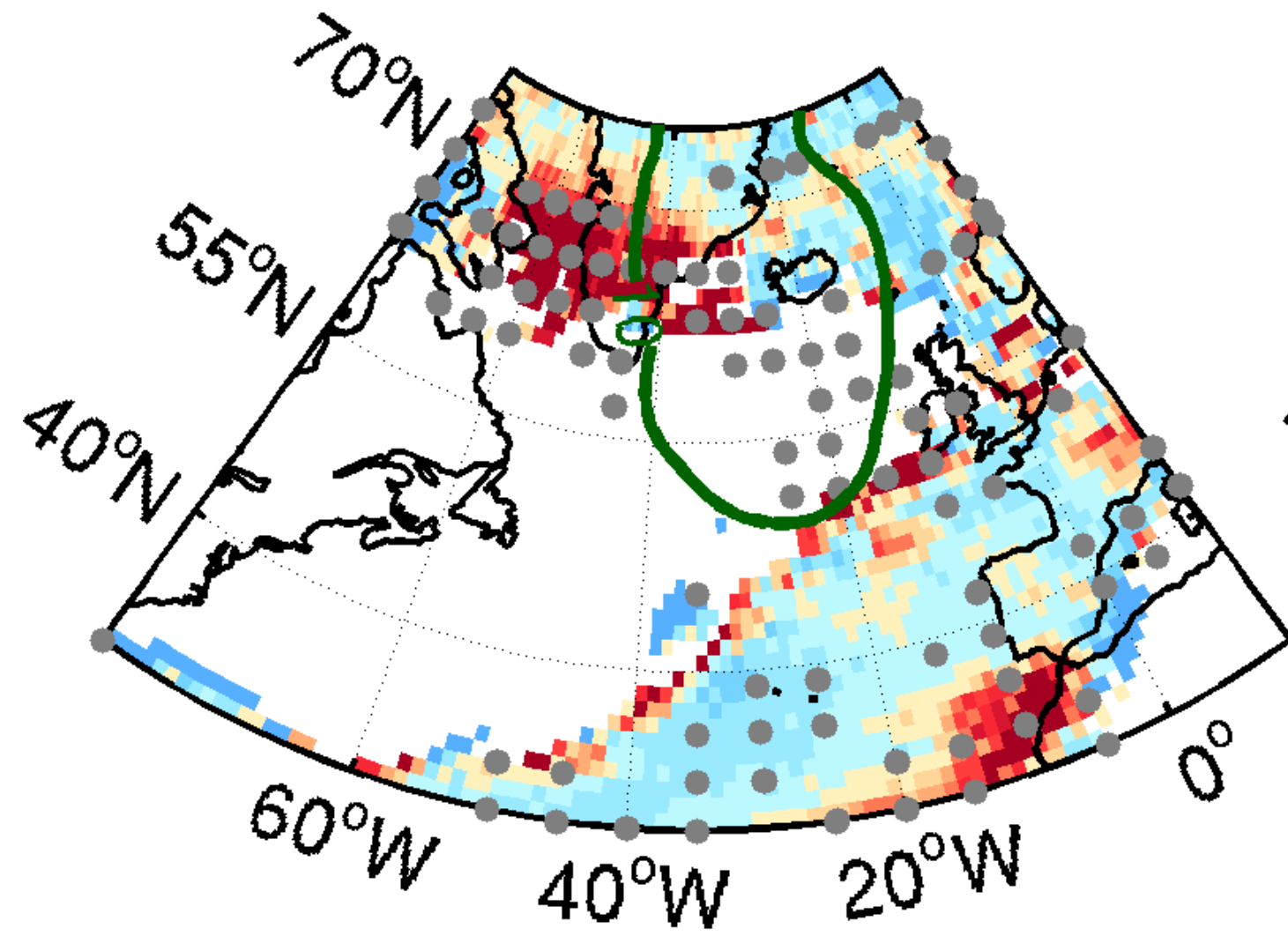
Jet latitude histograms (60°W-0°E, U₈₅₀, DJF)



High-latitude blocking and jet latitude

Ratio: $1\sigma+$ /CTL

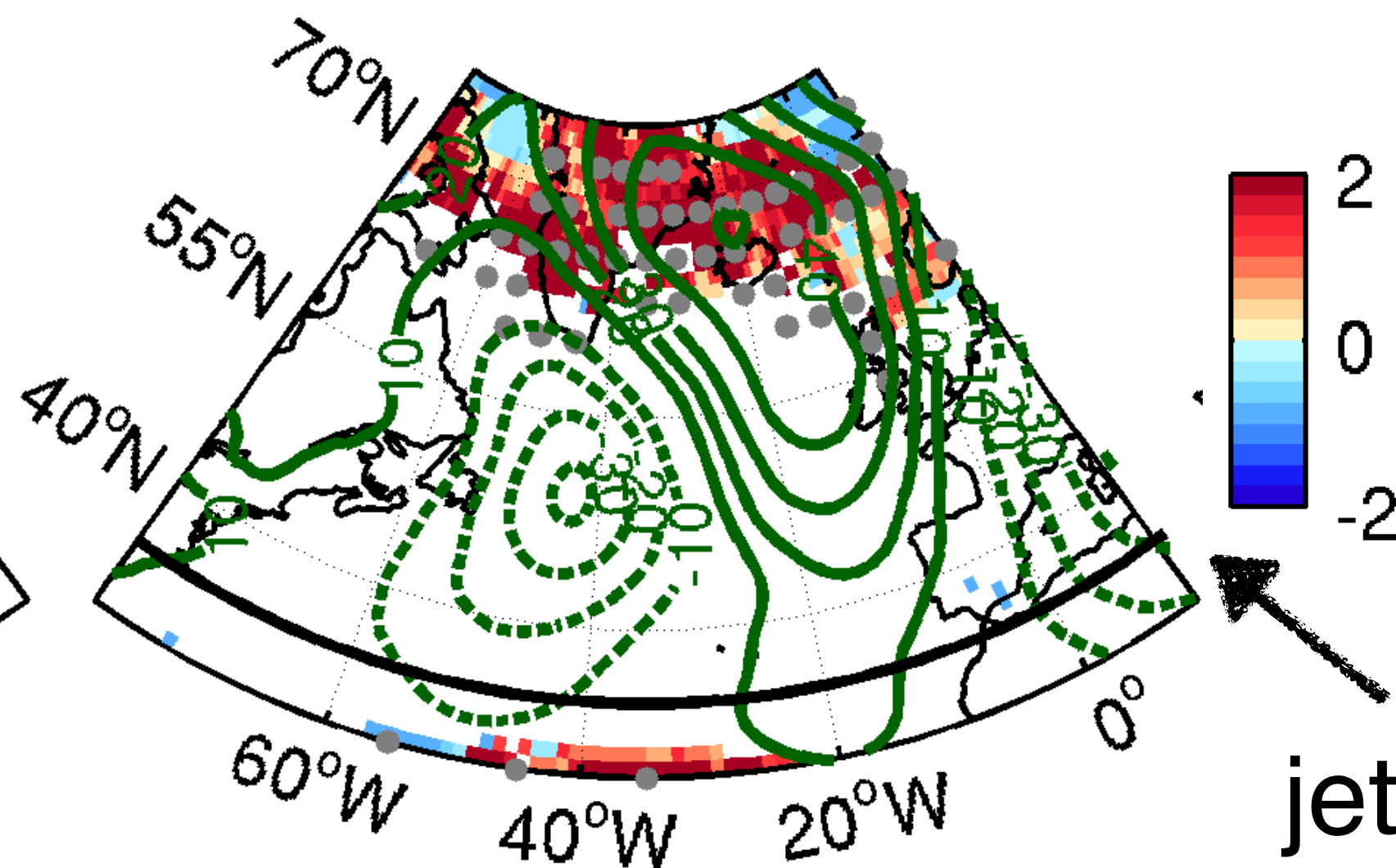
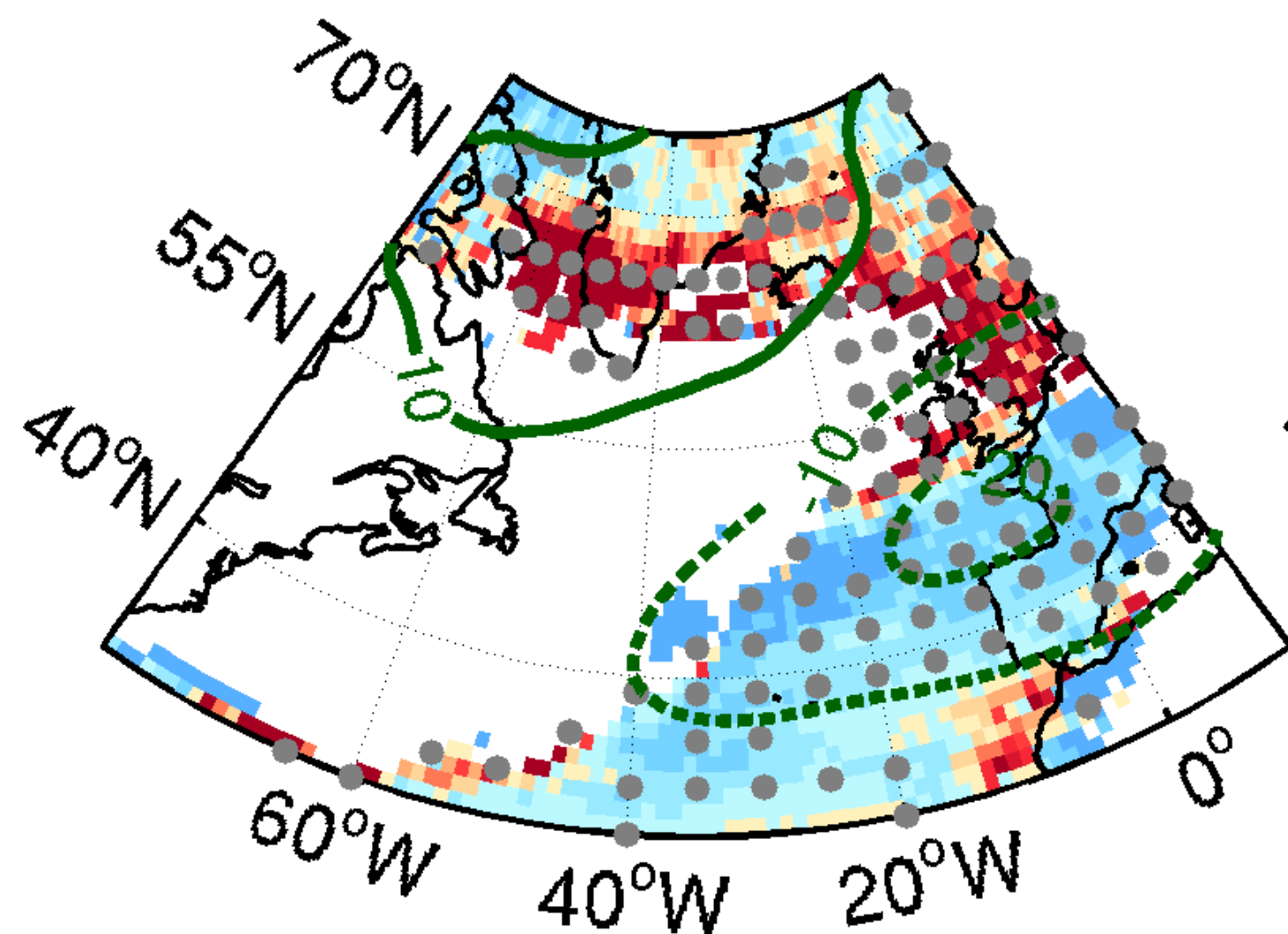
$1\sigma+$ /CTL when jet is @ 35N



Twice as many blocking occurrences in the high latitudes (cyclonic wave breaking events)

Ratio: $1\sigma-$ /CTL

$1\sigma-$ /CTL when jet is @ 35N



Reinforces the southerly location of the jet

blocking index
Scherrer et al.
2006

jet location

What maintained the high-latitude blocking ridge?

– Transient eddy vorticity flux convergence

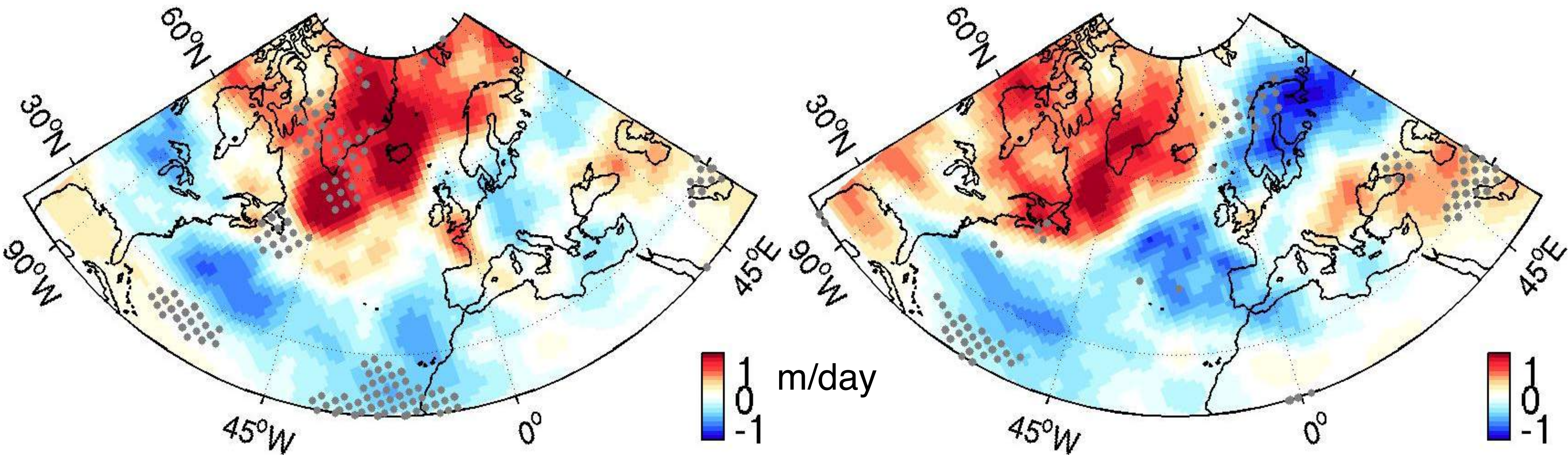
$$\left(\frac{\partial Z_{250}}{\partial t}\right)_{\text{HFT}} = \frac{f_0}{g} \nabla^{-2} [-\nabla \cdot (\overline{v' \zeta'} + \overline{v} \zeta' + \overline{v'} \zeta)]$$

Nakamura et al. 1997

1 σ + - CTL

($\partial Z_{250}/\partial t$)_{HF} response

1 σ - - CTL



What maintained the high-latitude blocking ridge?

– Transient eddy vorticity flux convergence

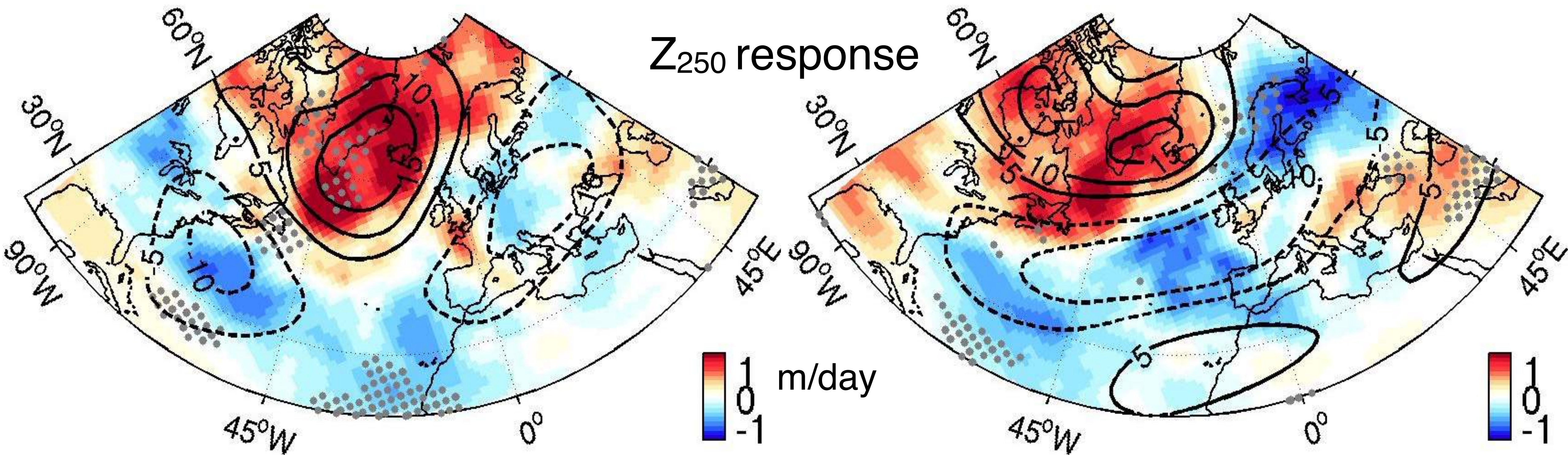
$$\left(\frac{\partial Z_{250}}{\partial t}\right)_{\text{HFT}} = \frac{f_0}{g} \nabla^{-2} [-\nabla \cdot (\overline{v' \zeta'} + \overline{\bar{v} \zeta'} + \overline{v' \bar{\zeta}})]$$

Nakamura et al. 1997

1 σ + - CTL

($\partial Z_{250}/\partial t$)_{HF} response

1 σ - - CTL



Nonlinearity of the circulation anomalies in NCEP?

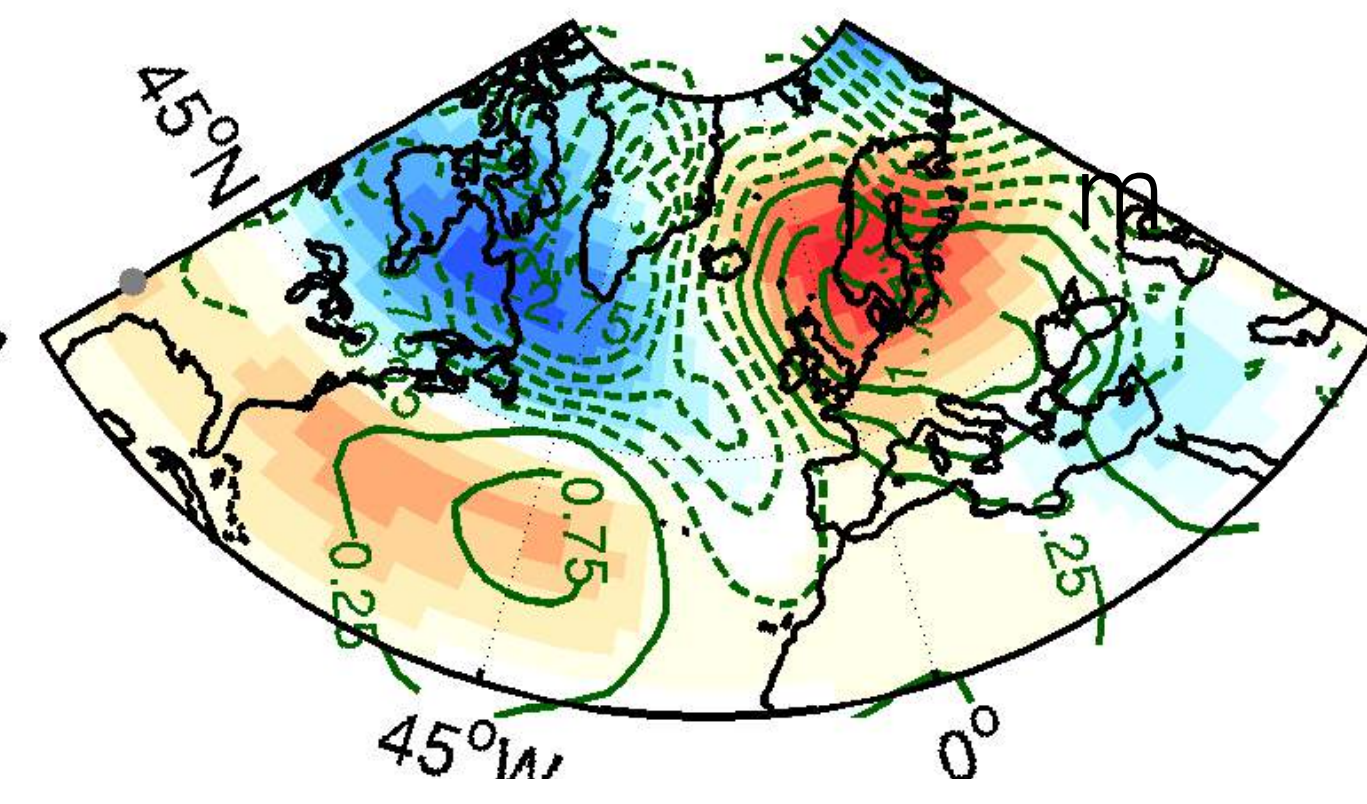
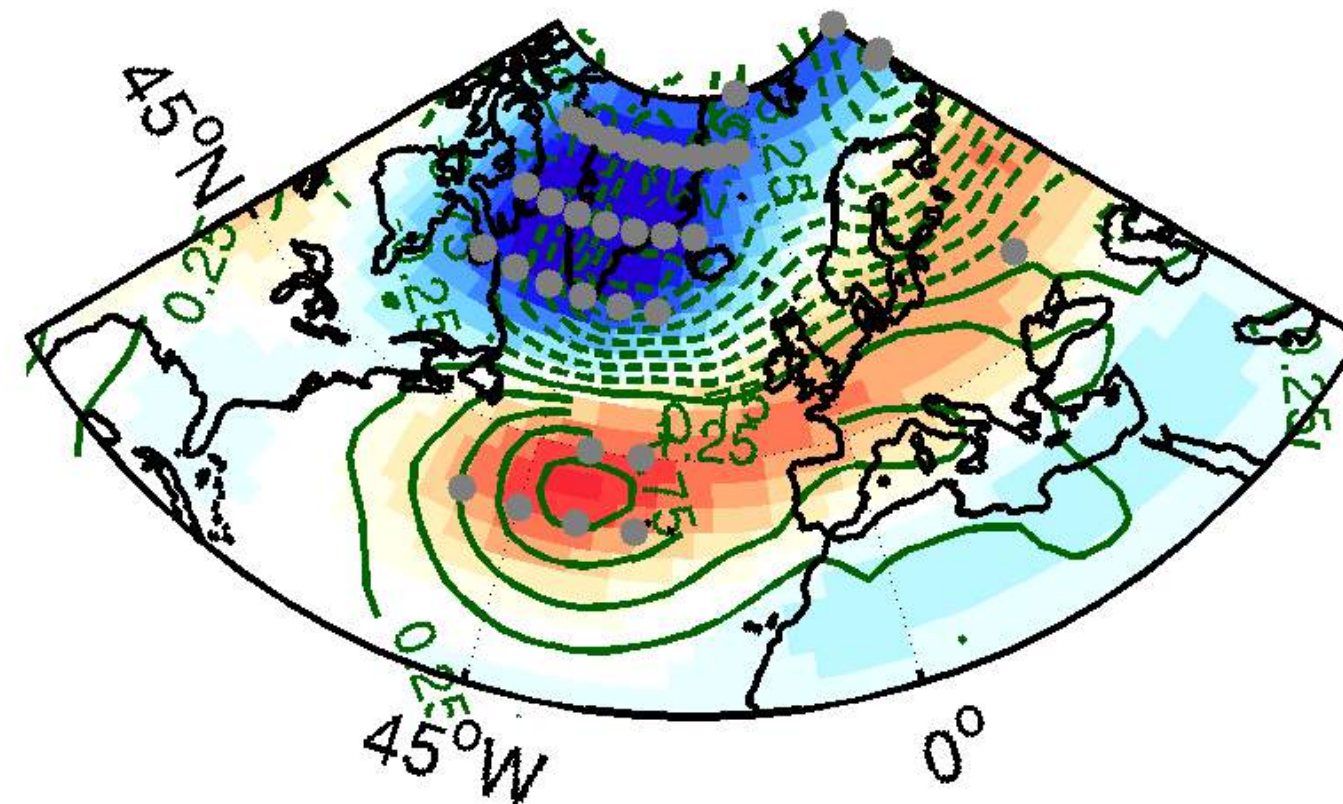
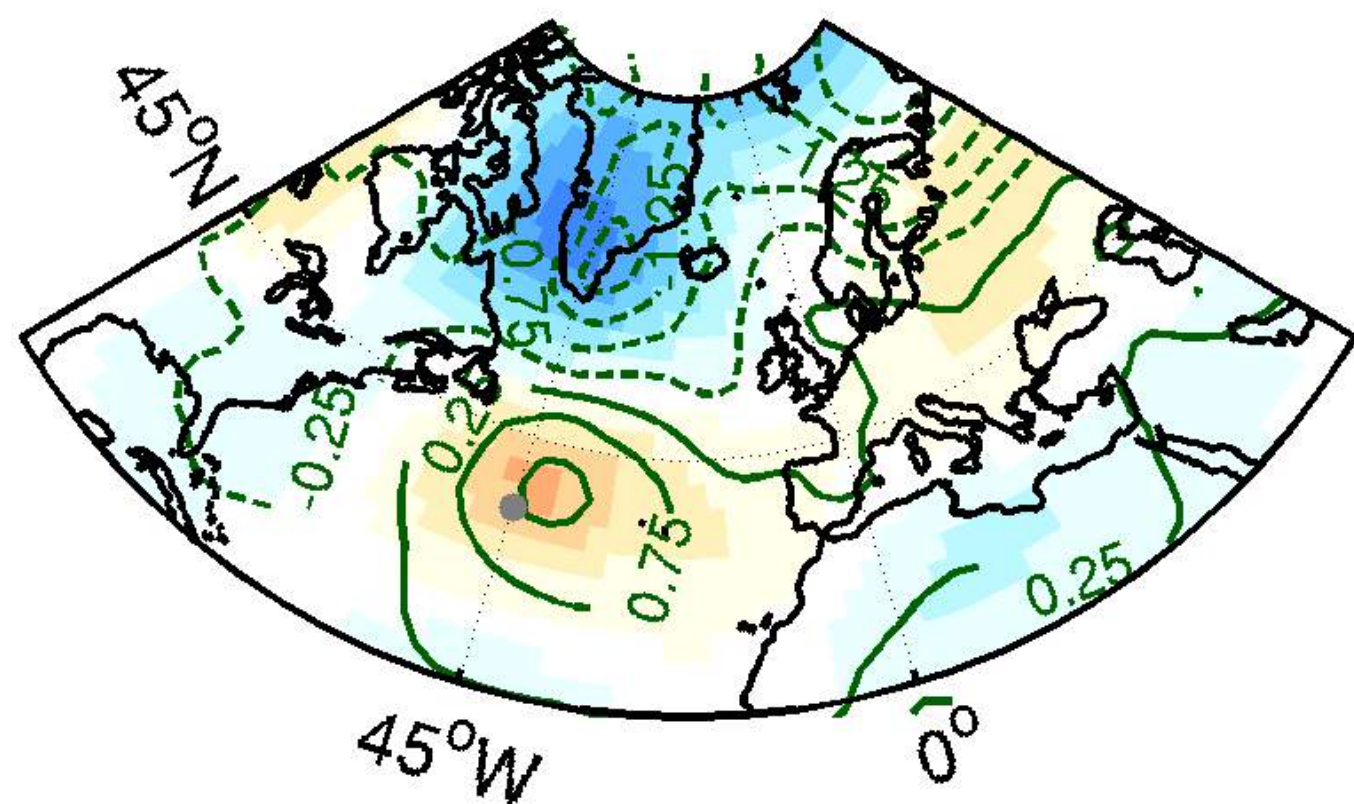
— Composite NCEP Z_{250} /SLP when GSI leads by 1-yr

GSI > +1/3 σ N=16

GSI > +1.0 σ N=10

GSI > +5/4 σ N=5

**GS
northward**

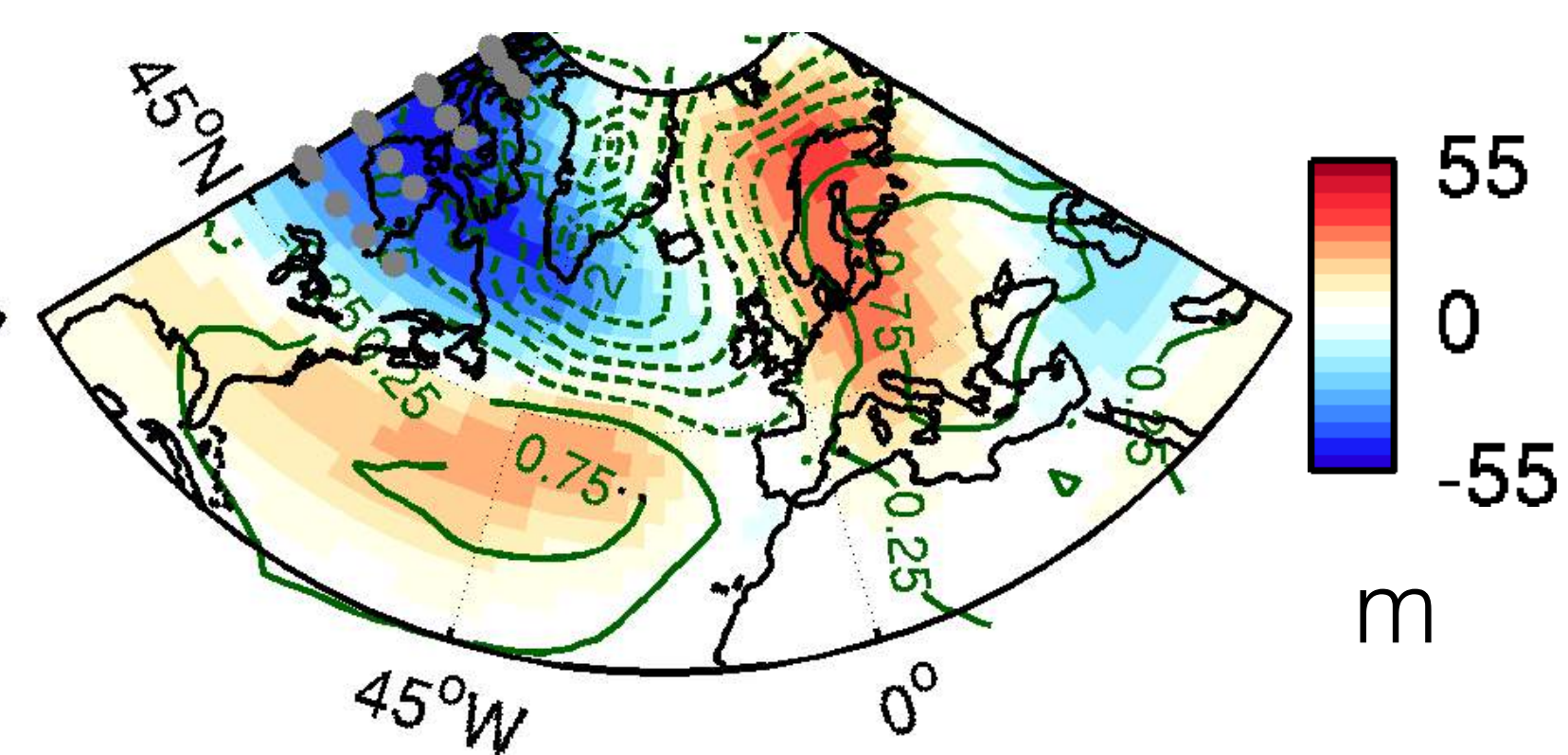
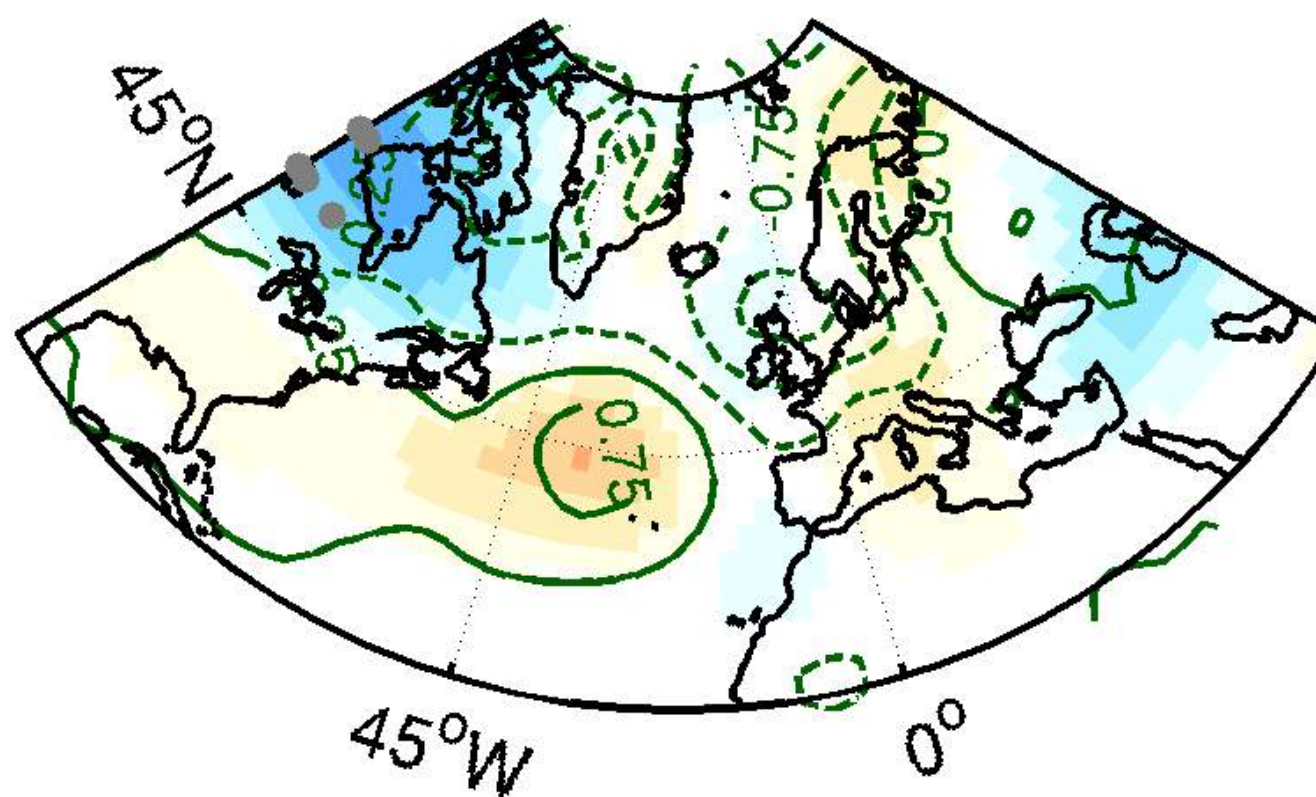
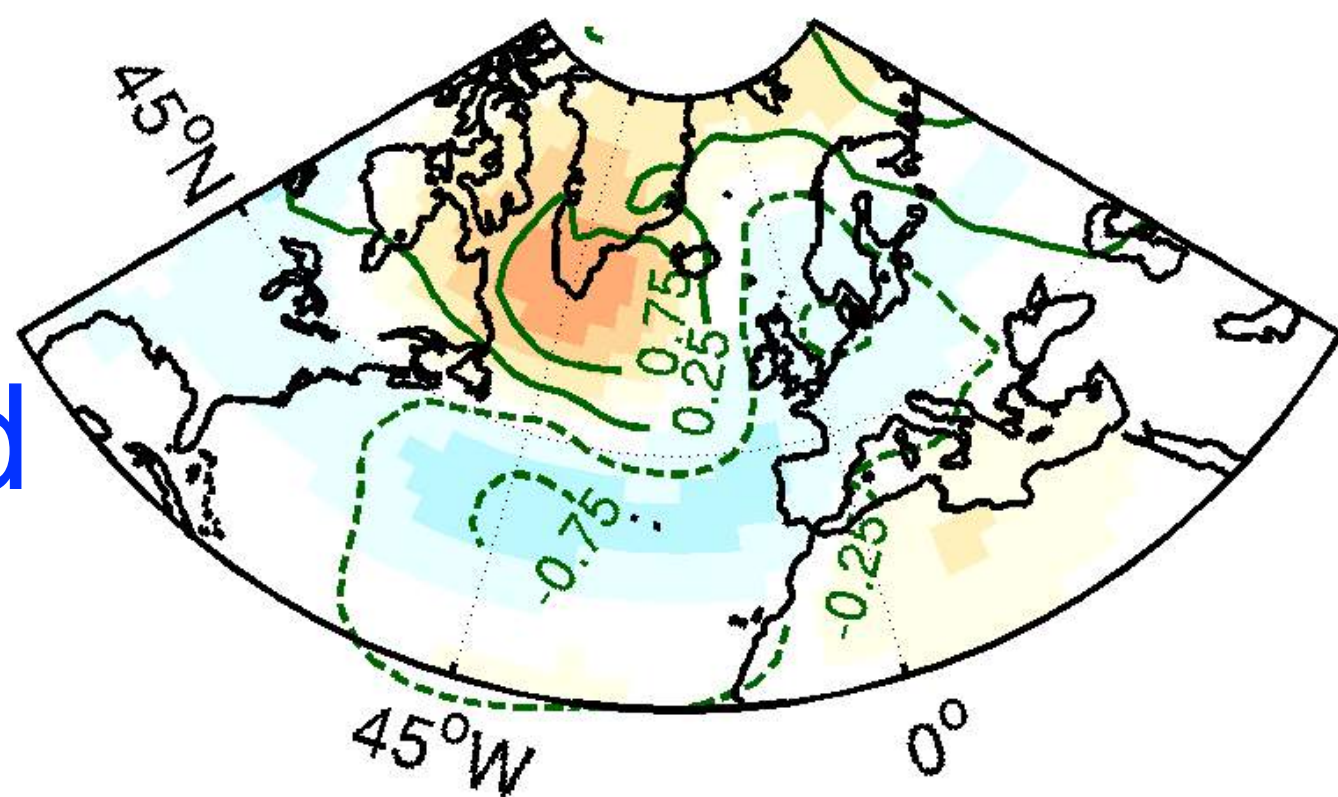


GSI < -1/3 σ N=25

GSI < -1.0 σ N=12

GSI < -5/4 σ N=8

**GS
southward**



Linear response with a moderate shift of GS

But, the response ceases to be linear as the shift becomes large

Summary and Discussion

Predominant nonlinear response to various GS shift scenarios

- Resembles the NAO, the leading mode of internal variability
- Nonlinear response is associated with
 - Increased southerly occurrence of the NA eddy-driven jet
 - Increased blocking frequencies near Greenland
- The high-latitude blocking ridge is maintained by barotropic feedback by transient eddies
- Observational analysis also suggests some asymmetry.

Thanks!
hseo@whoi.edu