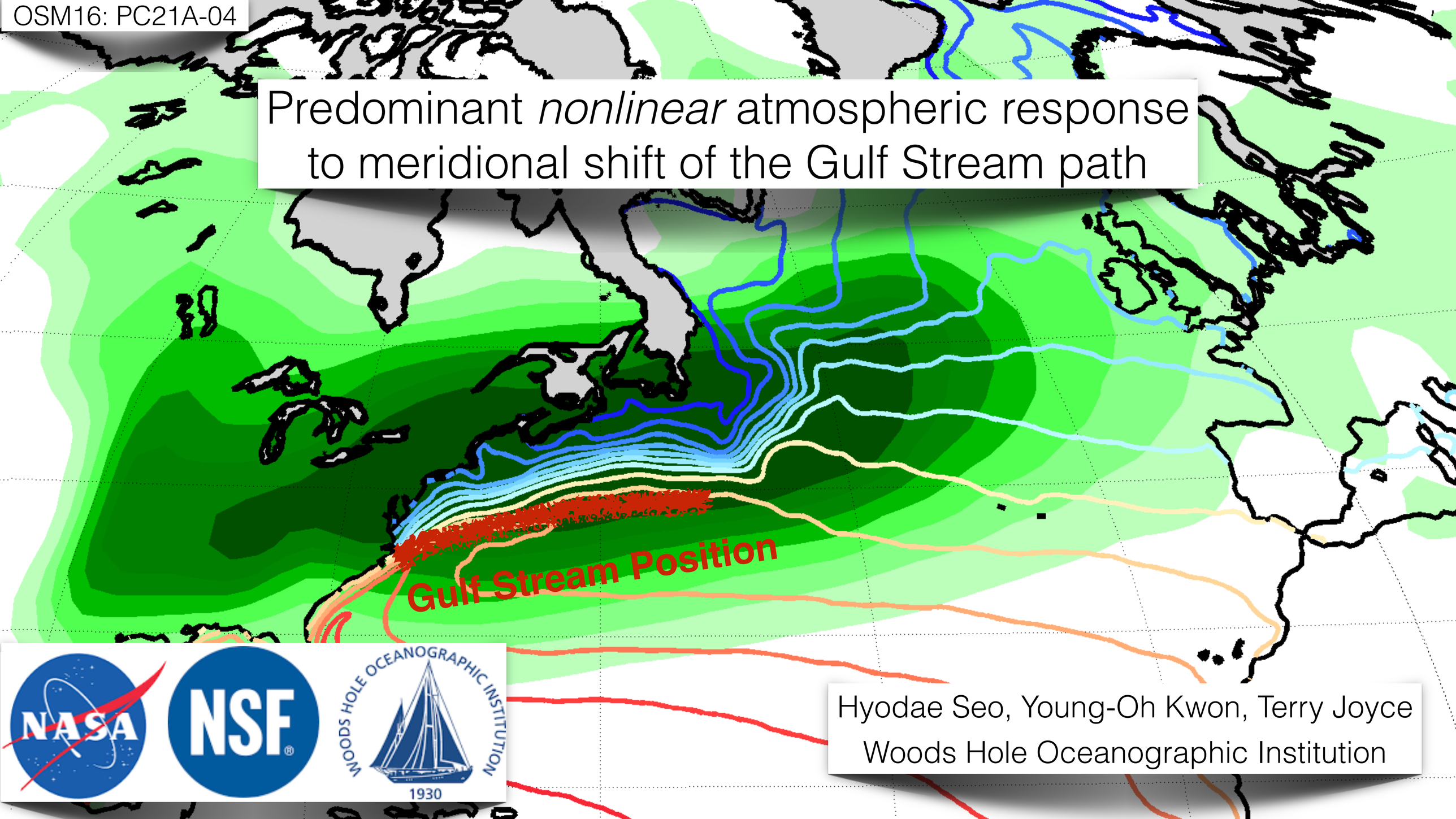
OSM16: PC21A-04

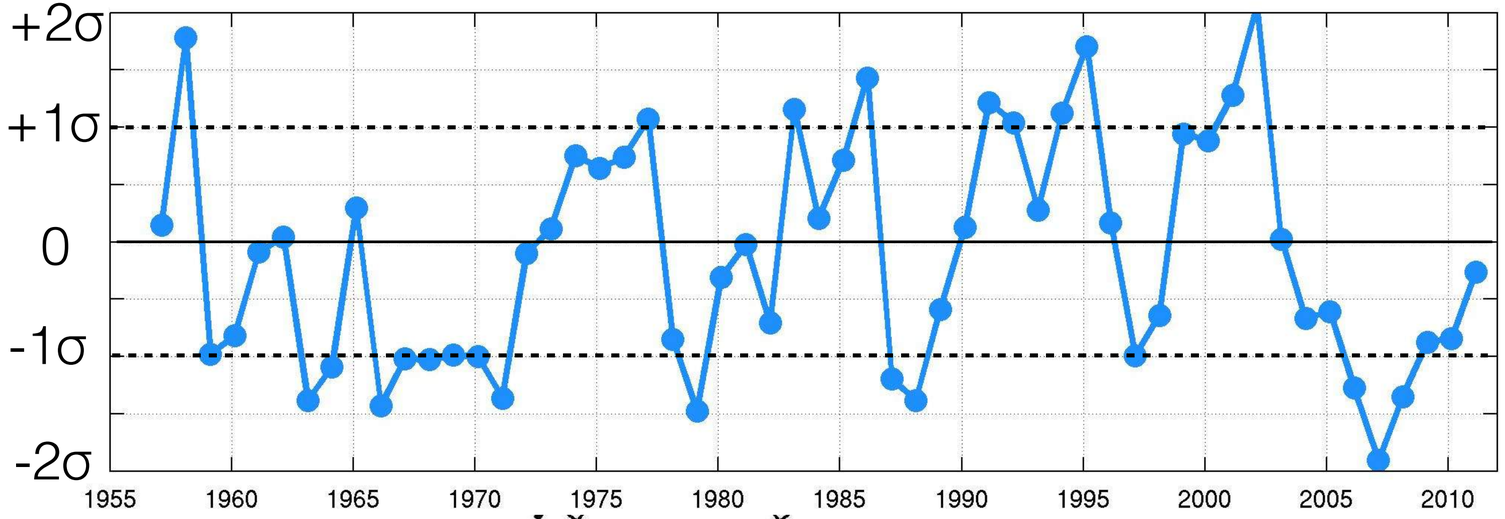
Predominant *nonlinear* atmospheric response to meridional shift of the Gulf Stream path



Hyodae Seo, Young-Oh Kwon, Terry Joyce
Woods Hole Oceanographic Institution

GSI and the associated SSTA

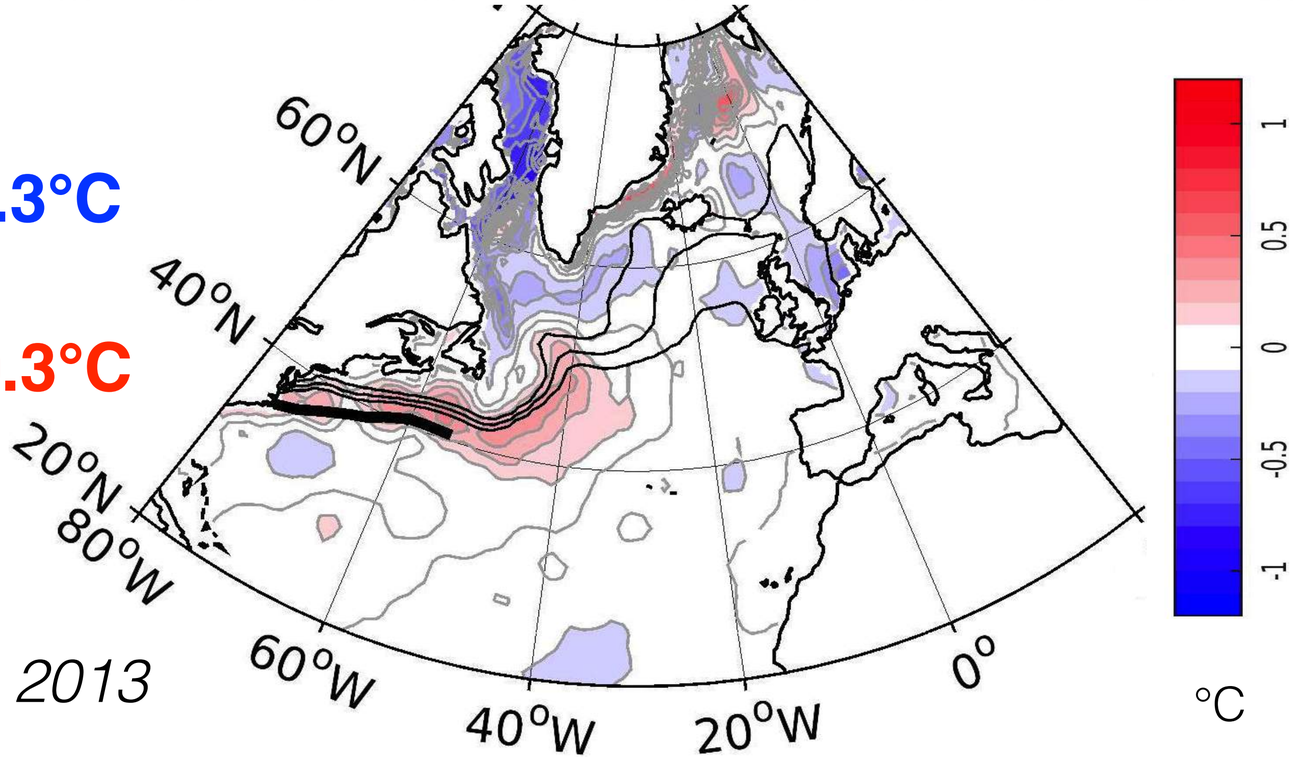
JFM Gulf Stream position
(15°C at 200m, 55-75°W)
Joyce et al. 2000



Linearly regressed
SSTA
when GSI leads by 1-yr

~-0.3°C

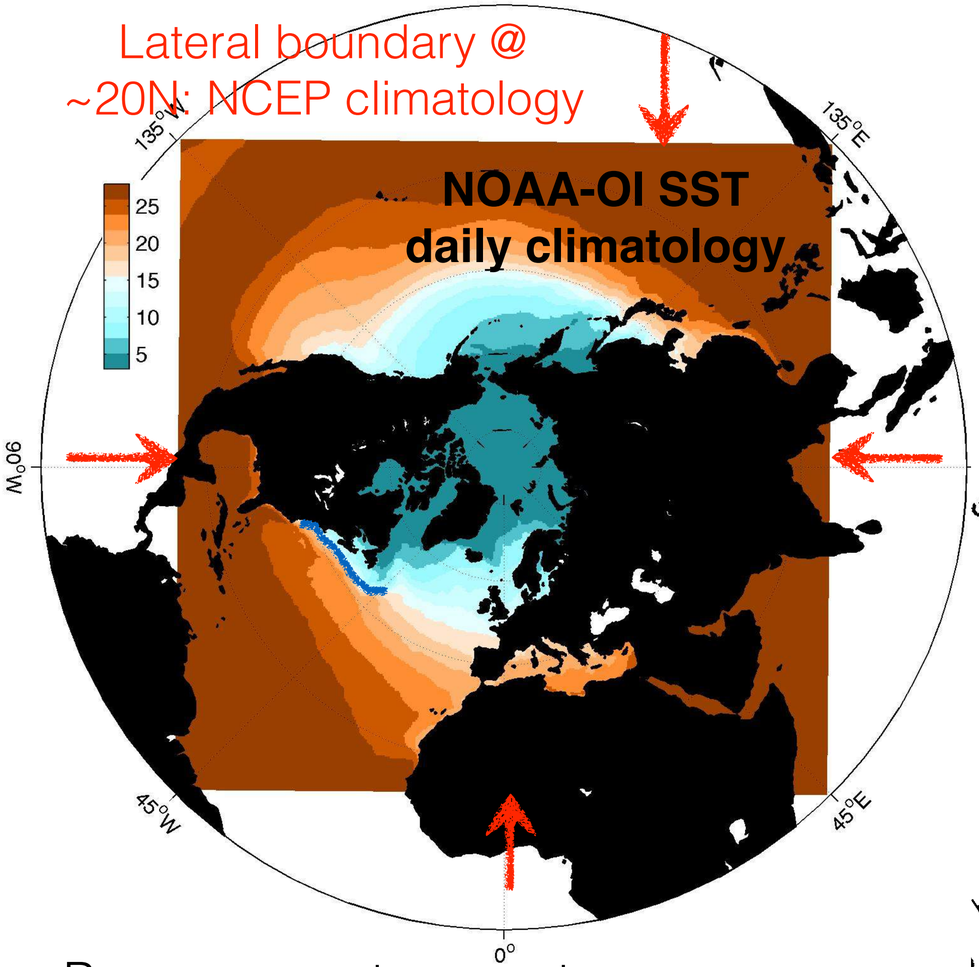
~+0.3°C



Kwon and Joyce 2013

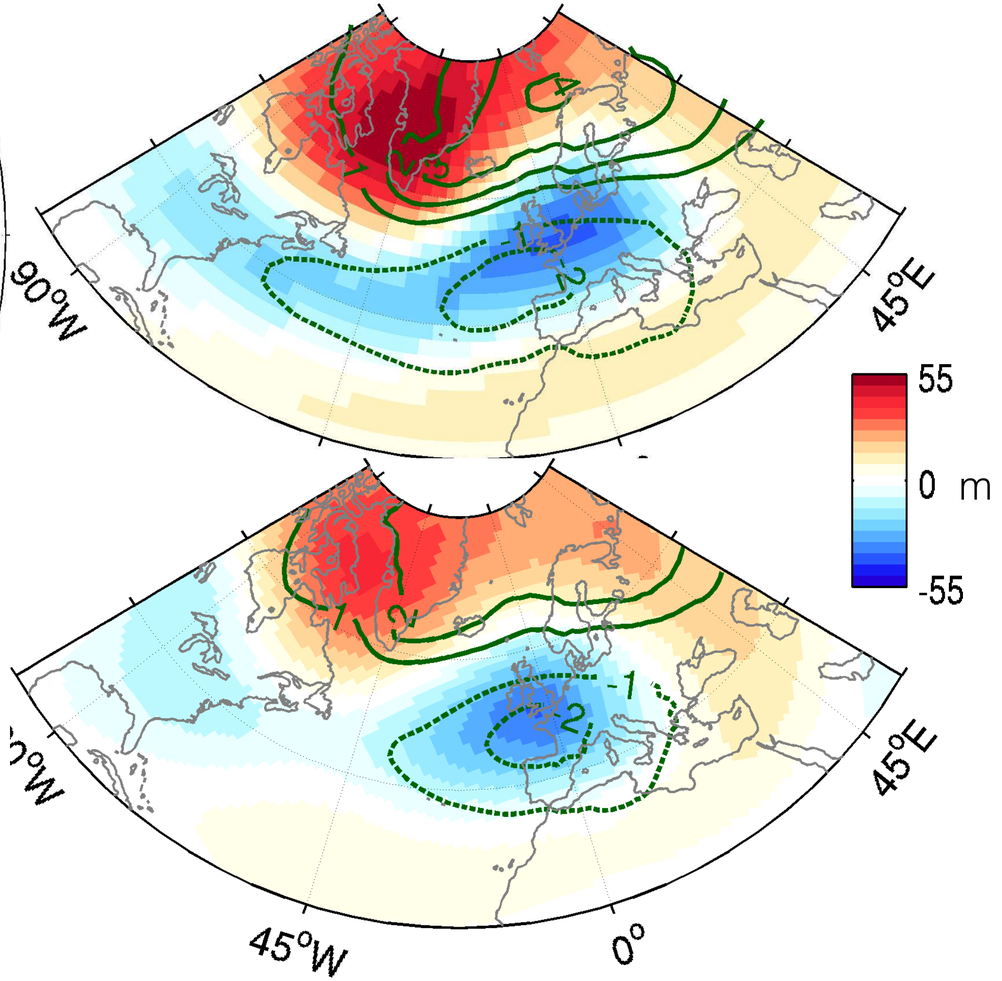
Identifying atmospheric response to GS-induced SSTA: Hemispheric WRF

40-km, 6-month (NDJFMA)



Exps	SST	N
CTL	daily climatology	40

NDJFMA Z_{250}/SLP EOF1



NCEP 40-yrs
(1971-2010)
Var=32%

Realistic level of internal variability in the model

CTL 40-ensemble members
Var=31%

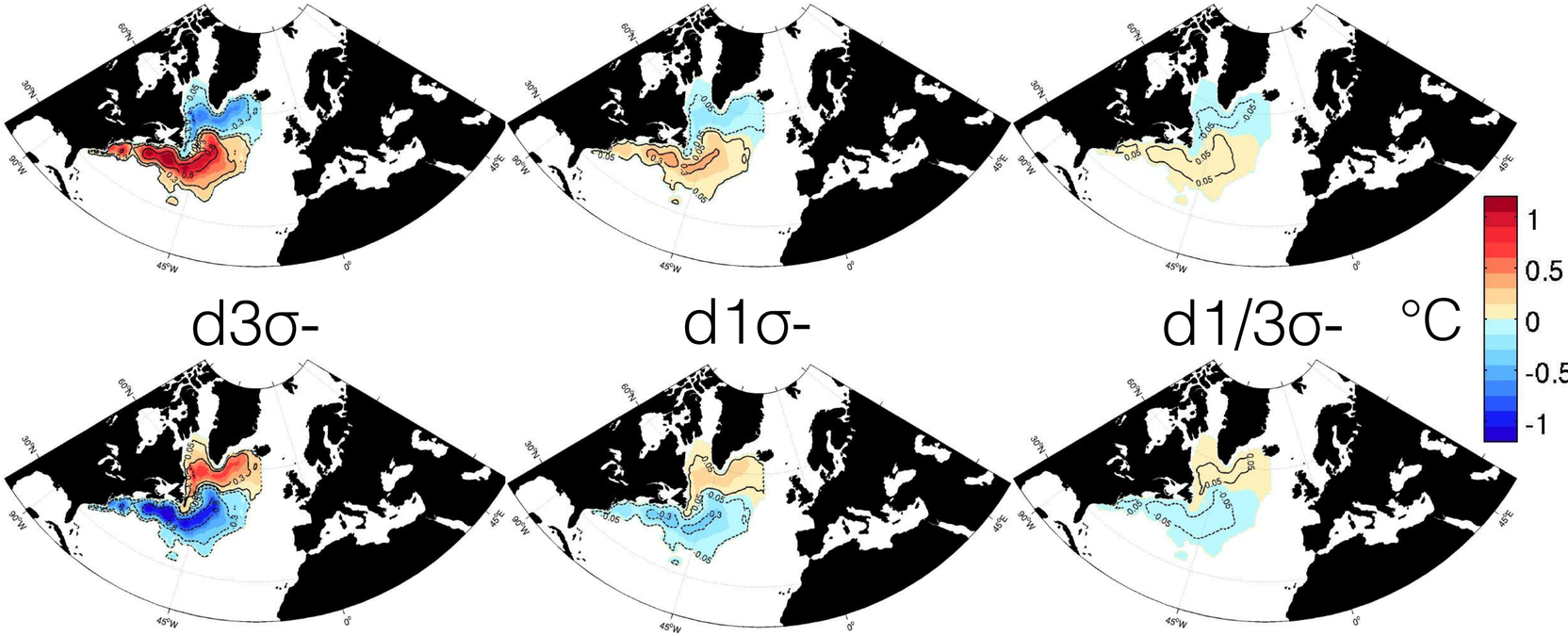
Processes not present:

- Tropical influence
- Interannual SST variability
- Thermodynamic O-A coupling

SST perturbation experiments

cf: GS smoothing for presence/absence (e.g., O'Reilly et al. 2015)

d3σ+ d1σ+ d1/3σ+



d3σ- d1σ- d1/3σ-

±0.9°C ±0.3°C ±0.1°C

Exps	SST		N
	amp	sign	
CTL	daily climatology		40
d1σ+	1σ	+	40
d1σ-	1σ	-	40
d3σ+	3σ	+	40
d3σ-	3σ	-	40
d1/3σ+	1/3σ	+	40
d1/3σ-	1/3σ	-	40

total response =
d1σ+ - CTL
d1σ- - CTL

symmetric (linear) = ½ × (d1σ+ - d1σ-)
asymmetric (nonlinear)
= ½ × [(d1σ+ - CTL) + (d1σ- - CTL)]

Strongly nonlinear equilibrium response independent of GS-SSTA

Z_{250}/SLP
NDJFMA

d1σ+ - CTL

d1σ- - CTL

d3σ+ - CTL

d3σ- - CTL

20
0
-20

- **Predominant asymmetric**
- **(nonlinear) response independent**

Linear

d1σ+ &

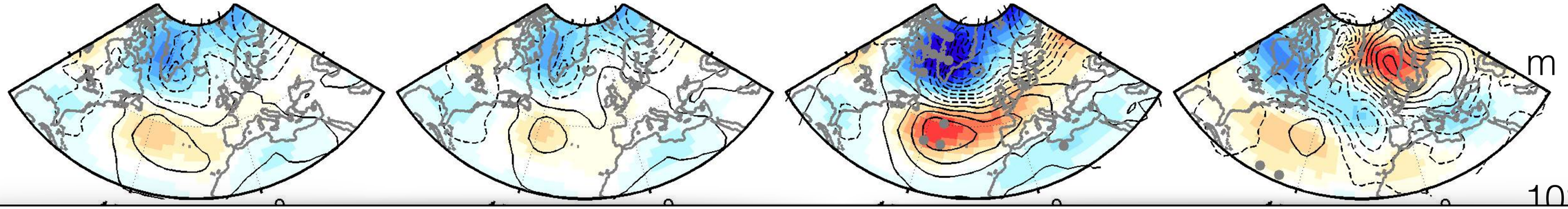
Linearly regressed
poleward eddy heat flux (MERRA)

Kwon and
Joyce 2013

Some nonlinearity in circulation anomalies in NCEP

— Composite NCEP (1971-2010) JFM Z_{250}/SLP *when JFM GSI leads by 1-yr*

GSI>+0.25σ N=16 GSI>+0.50σ N=15 GSI>+1.0σ N=9 GSI>+1.25σ N=4



10% level

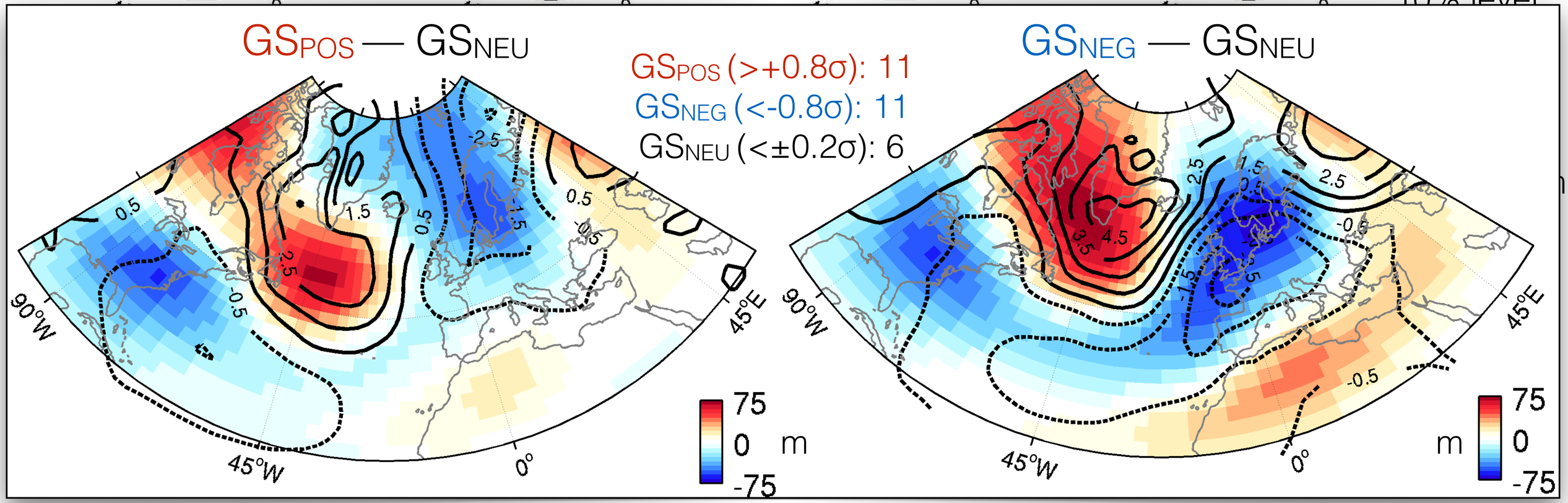
GS_{POS} — GS_{NEU}

GS_{POS} (>+0.8σ): 11

GS_{NEG} (<-0.8σ): 11

GS_{NEU} (<±0.2σ): 6

GS_{NEG} — GS_{NEU}



Two main questions:

#1. Why +ve blocking ridge?

Barotropic feedback by transient eddies (HF) +
Wave activity flux due to a stationary Rossby wave train (LF)
(e.g,. Nakamura et al. 1997)

#2. Why is the response nonlinear?

The blocking ridge maintained in part by anomalous vorticity flux convergence by transient eddies

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

Nakamura et al. 1997

primes: 8 day high-passed (HF); over-bars: 8-day low-passed (LF)

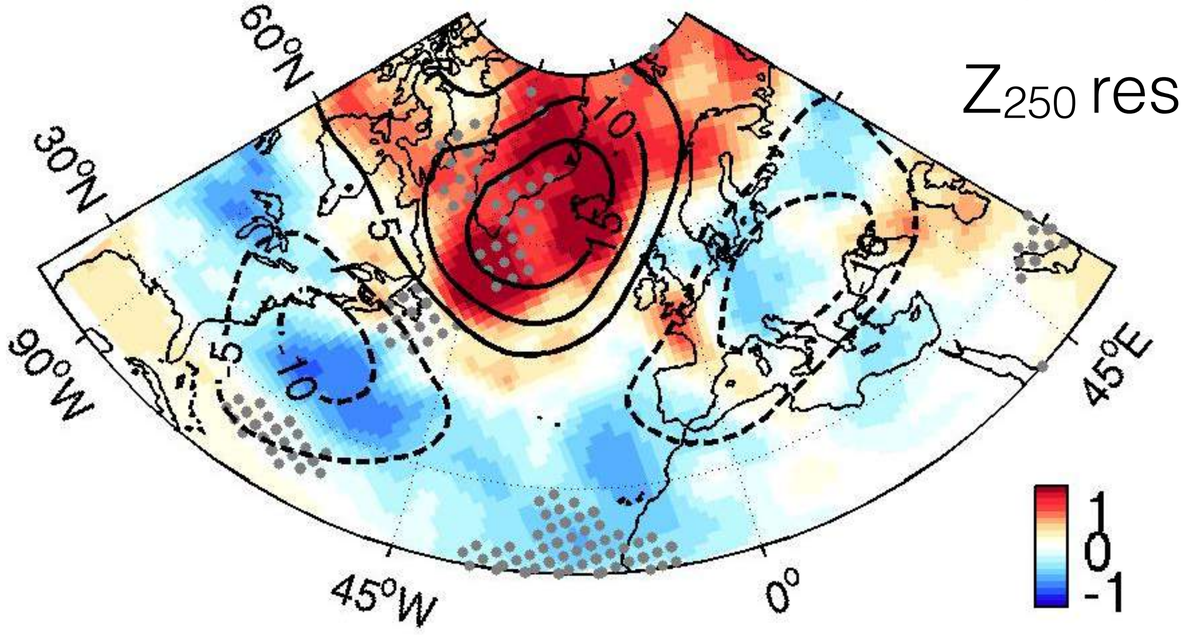
NDJFMA

d1σ+ - CTL

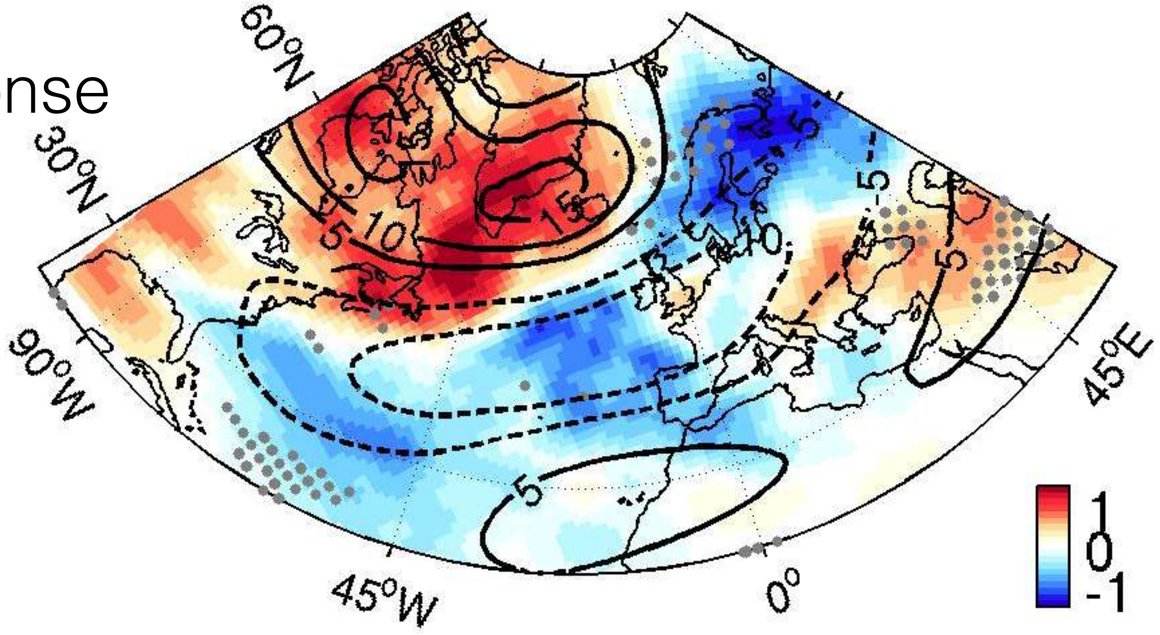
$(\partial Z_{250}/\partial t)_{HF}$ response

Z_{250} response

d1σ- - CTL



m/day



m/day

Contribution by the transient eddy feedback to Z_{250} high:

Lead/lag composites about the onset of a block

Blocking index at 40°W, 60°N
(Low-passed Z_{250} time-series)

composites

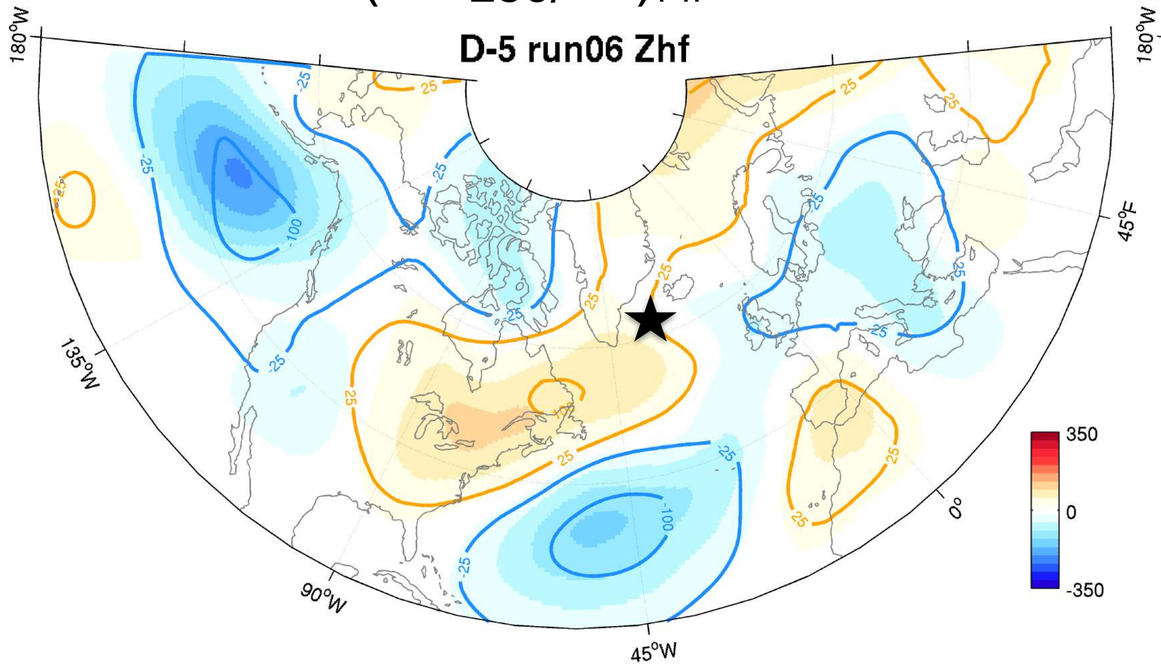
$(\partial Z_{250}/\partial t)_{HF}\Delta t$: shading
Low-passed Z_{250}: contours

Nakamura and Wallace 1990

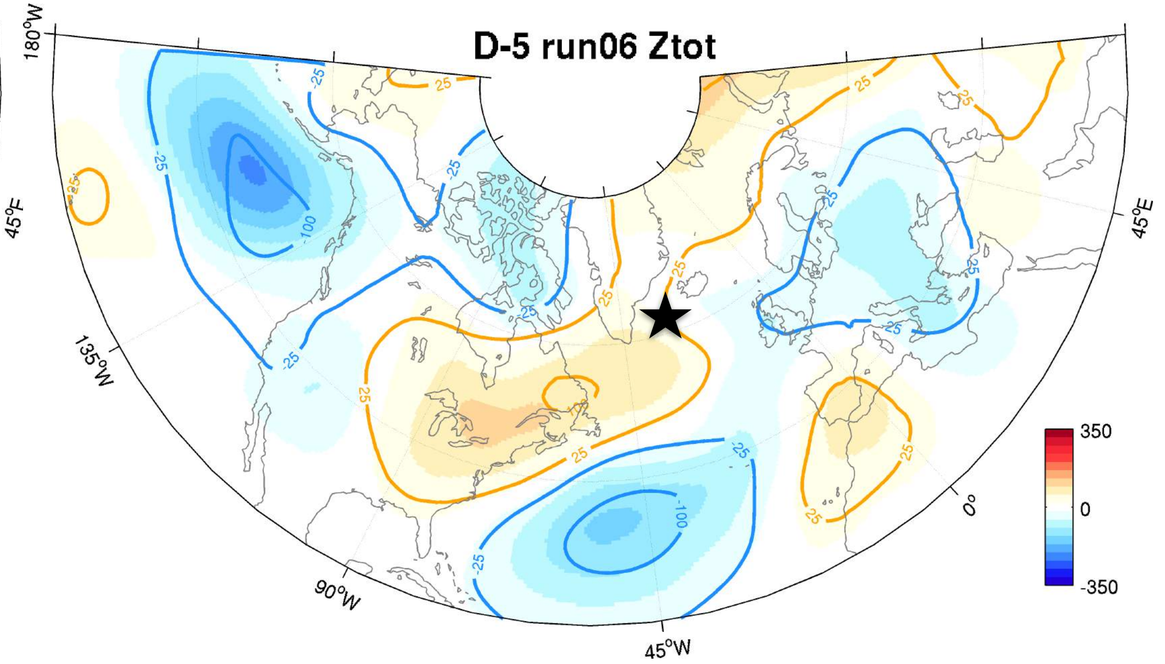
Day-5 (Initial) → Onset → Day+5

d1σ+ - CTL

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



$(\partial Z_{250}/\partial t)_{TOTAL}\Delta t$

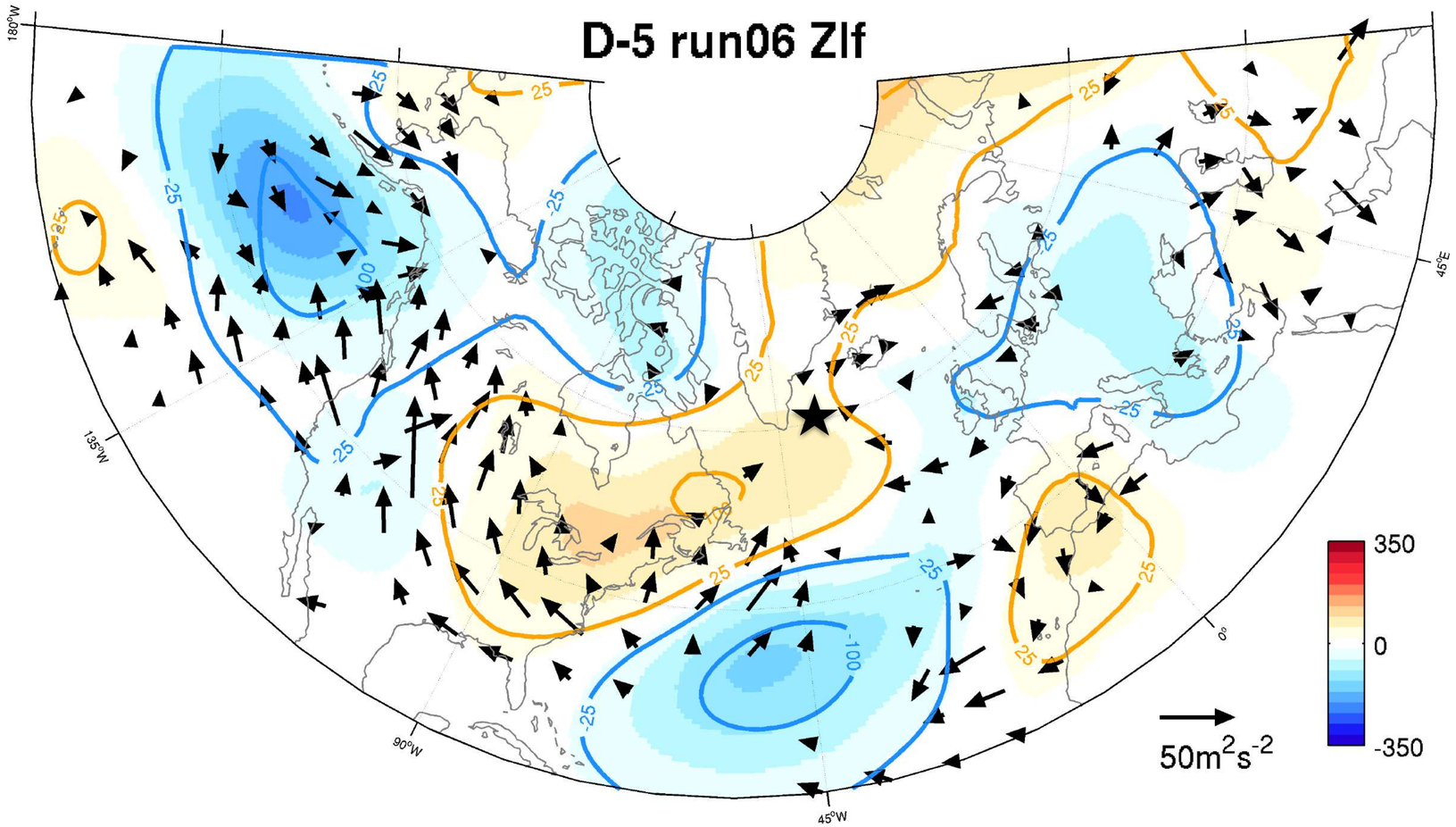


Transient eddy feedback contributes to the total height response by ~50%

The blocking ridge formation due to low-frequency dynamics

d1σ+ - CTL

TOTAL - HF ≈ $(\partial Z_{250}/\partial t)_{LF}\Delta t$



Apparent quasi-stationary wave signatures

Wave activity density flux convergence within the amplifying blocking ridge (Nakamura et al. 1997)

Wave activity flux calculation from http://www.atmos.rcast.u-tokyo.ac.jp/nishii/programs/index.html

Summary and Discussion

Predominant nonlinear response to various GS shift scenarios

— resembles the -ve NAO pattern, the leading mode of internal variability

- The blocking response is formed and maintained both by
  - HF: barotropic feedback by transient eddies (forced response)
  - LF: wave activity density flux associated with an incoming Rossby wave train (internal dynamics)

- Both HF and LF feedback processes are nonlinear.
  - The cause of the nonlinearity is under investigation.

- Observational analysis also suggests some asymmetry in the NA circulation

Thanks!

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