# Mesoscale and frontal-scale air-sea interactions, physics, diagnostics, and impacts

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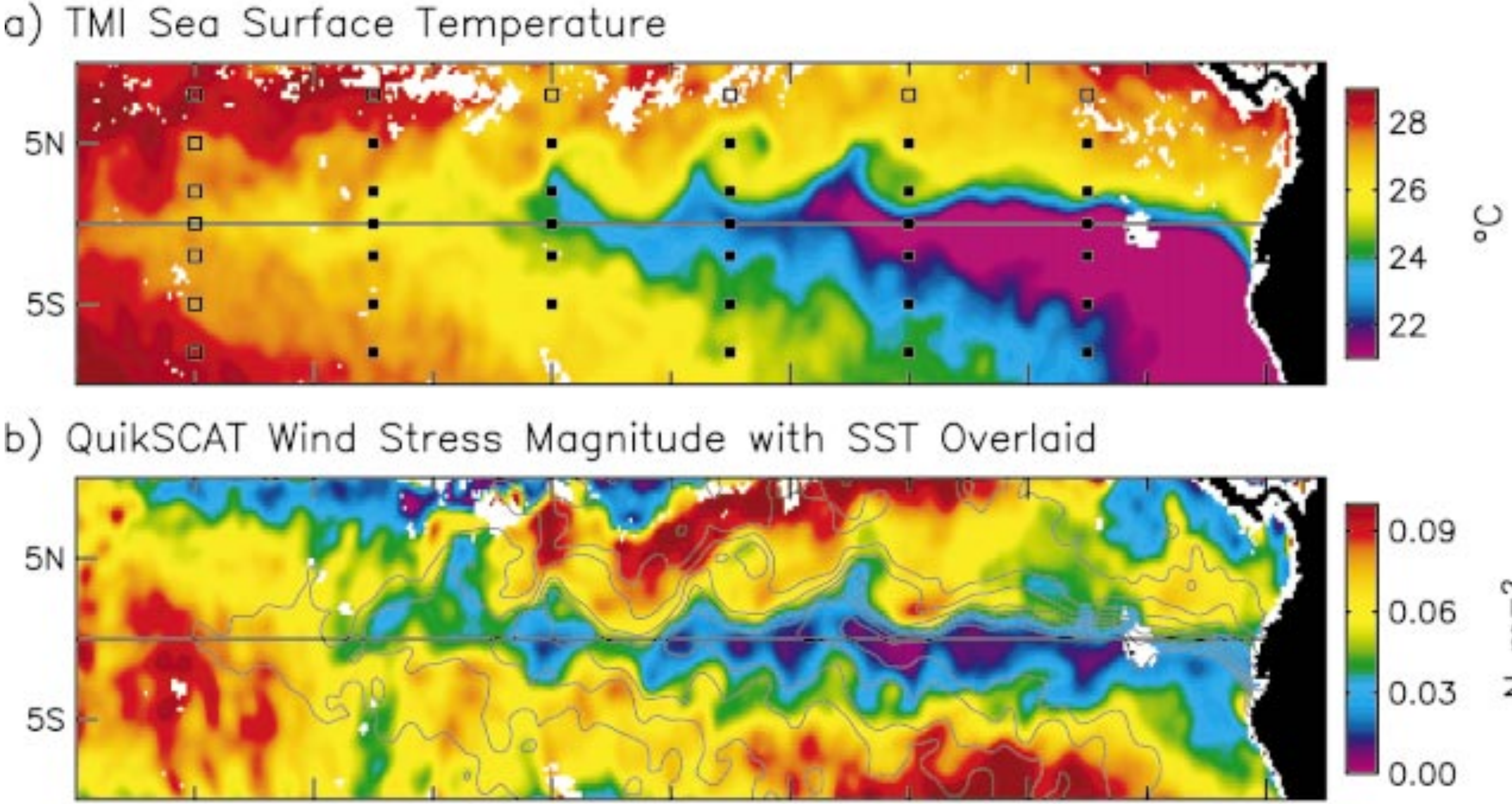
**PSMI Panel, WHOI**

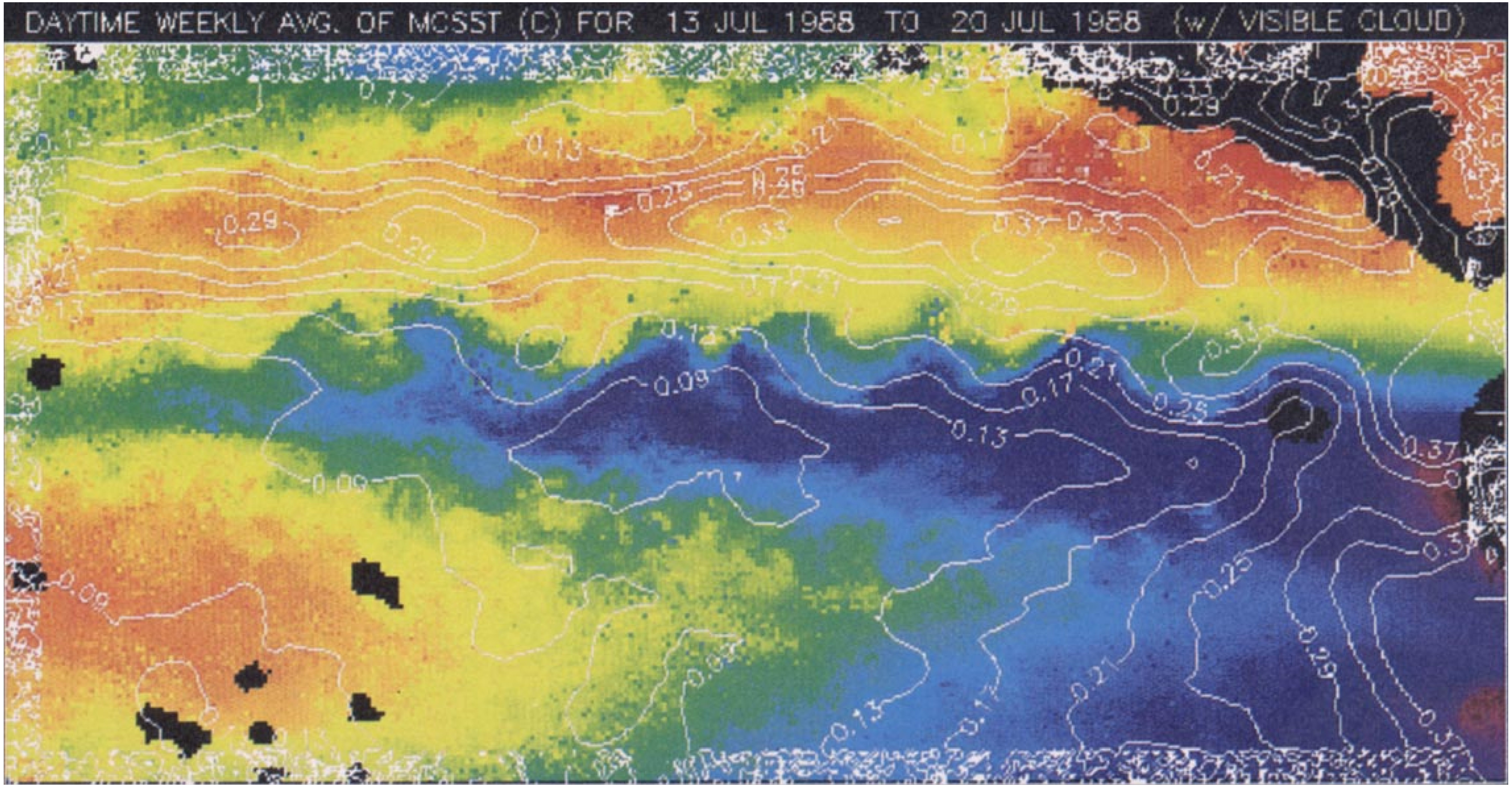
**US CLIVAR Summit**
**Aug. 9, 2019**

# “Discovery” of wind response to mesoscale SSTs




Chelton et al. 2001. JCLI

# Stratiform clouds response to the SST waves

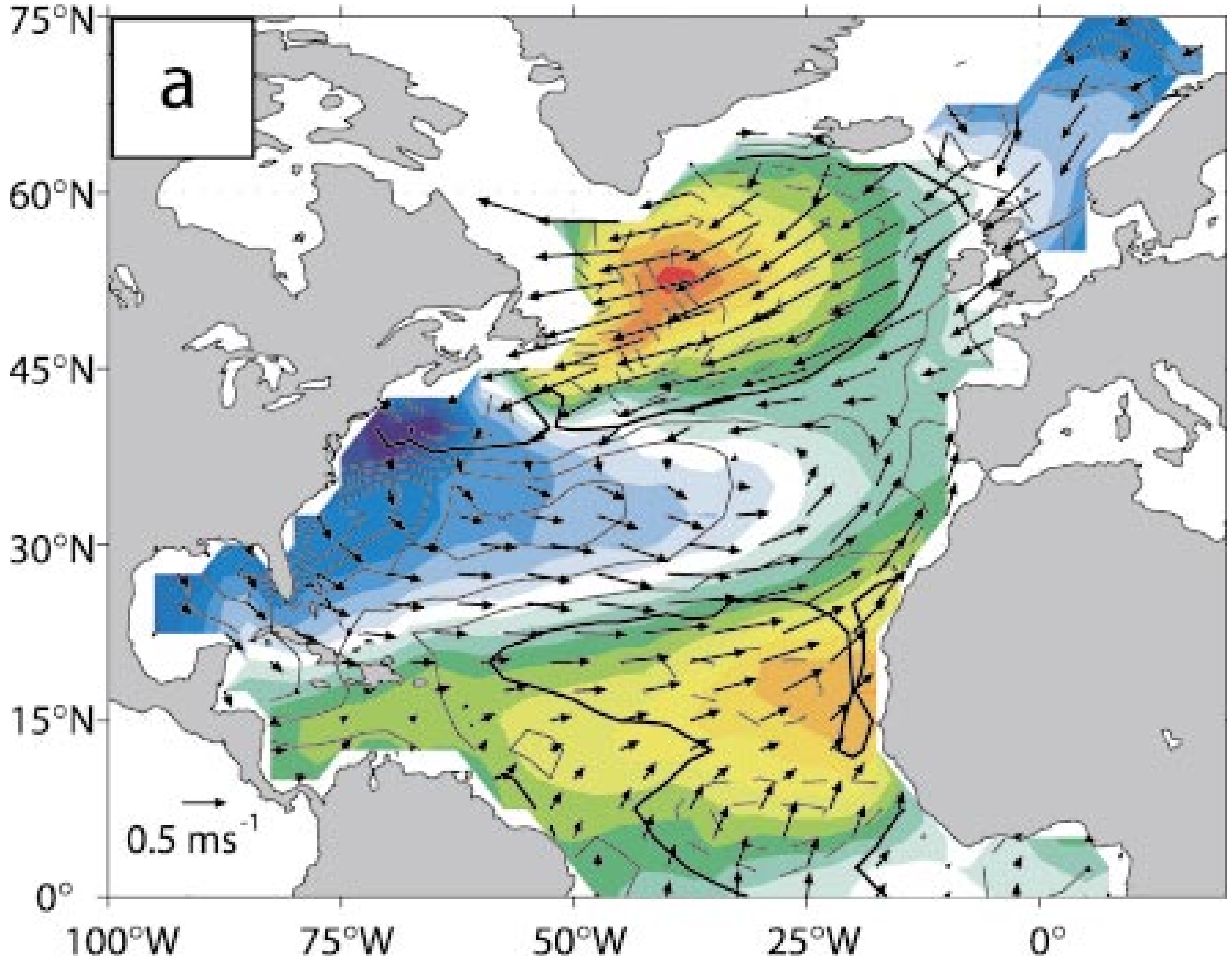



Estimate the changes in downward shortwave radiation fluxes of ~25 W/m² → 0.75°C / month (MLD=20m)

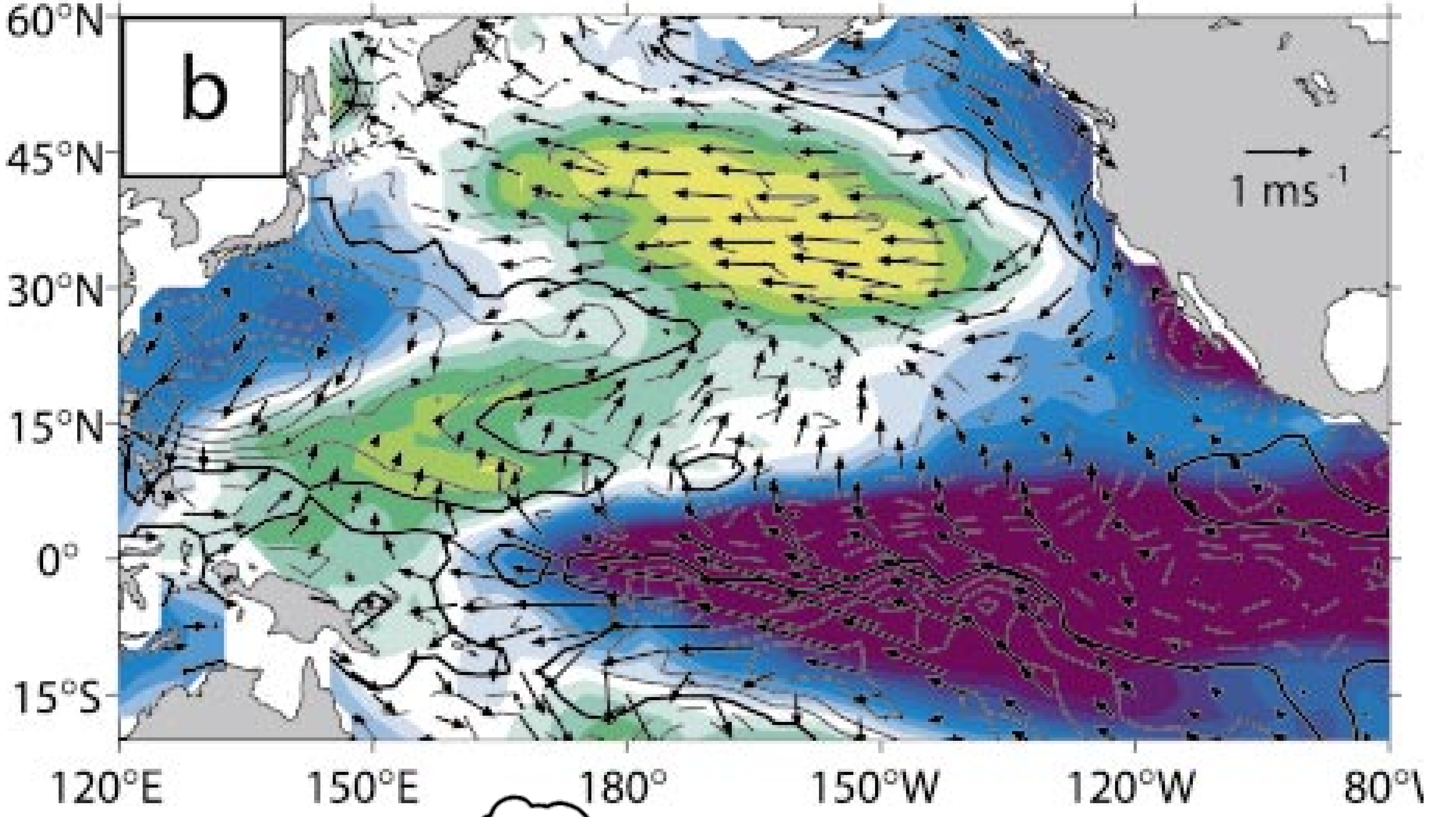
Deser et al. 1993 JCLI

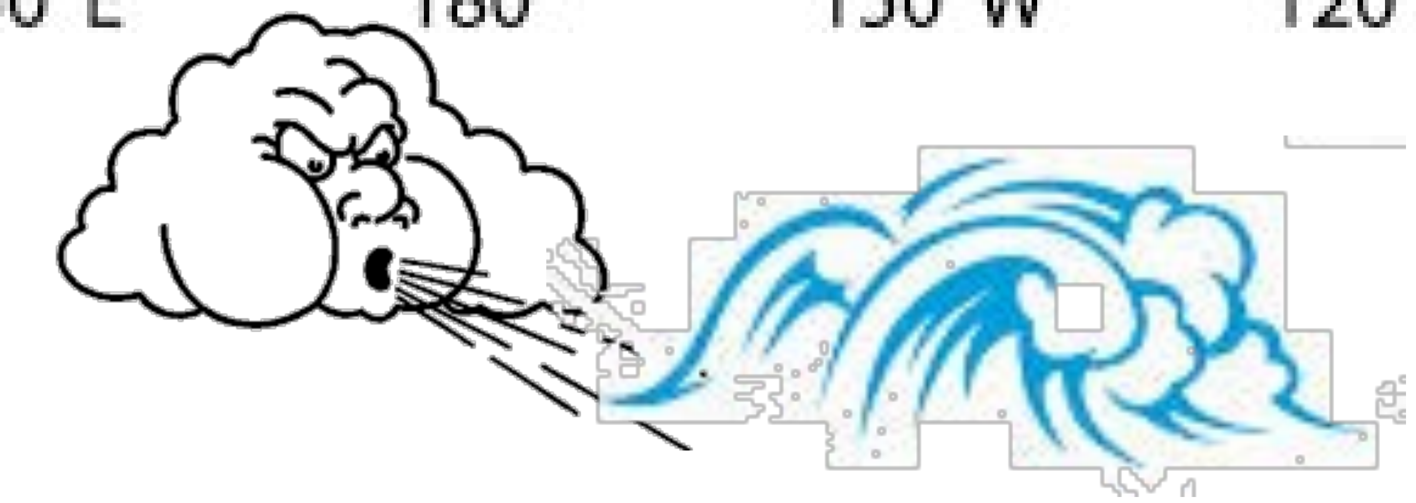
# Large-scale air-sea interactions?

North Atlantic Oscillation




Pacific Decadal Oscillation

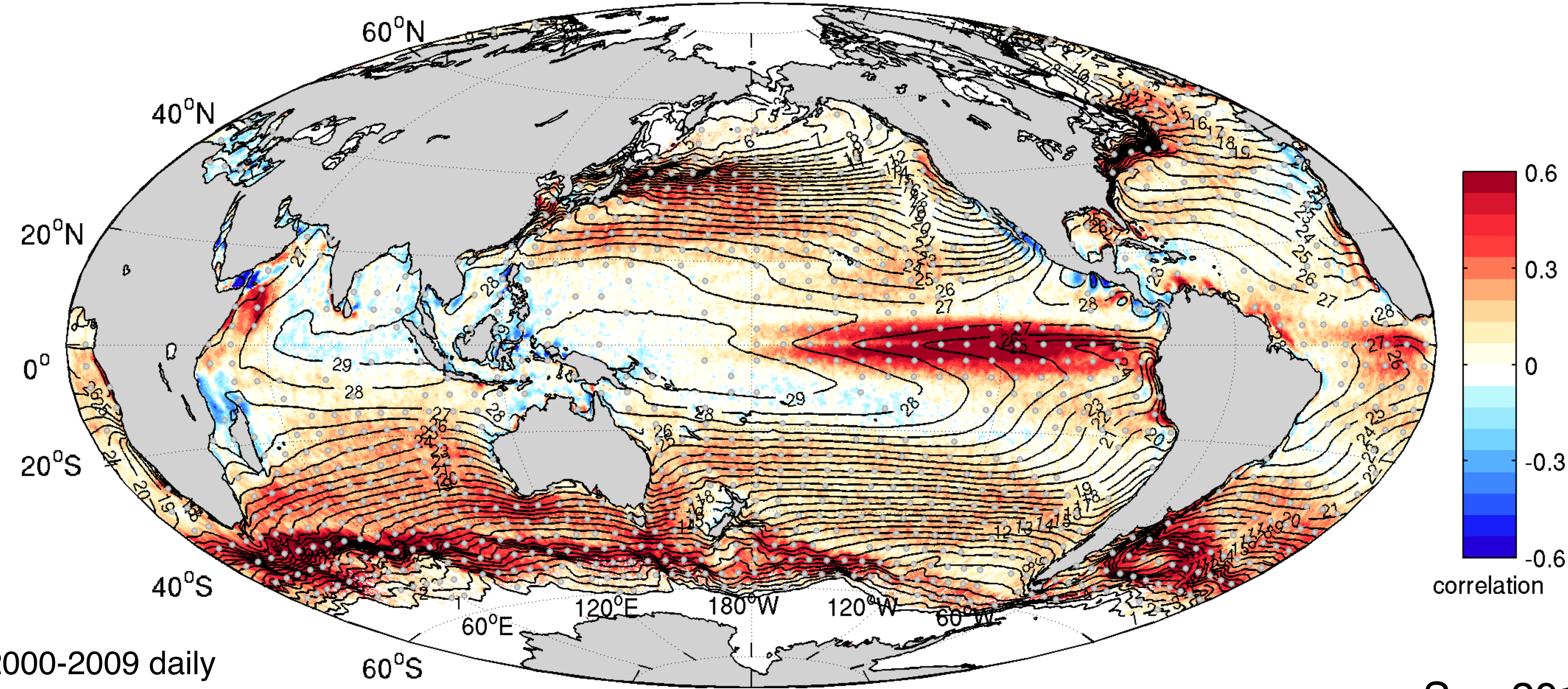


Kushnir et al. 2002. JCLI

# Eddy-mediated air-sea interaction

Spatial high-pass filtering applied to daily data to remove large-scale wind-SST relationship

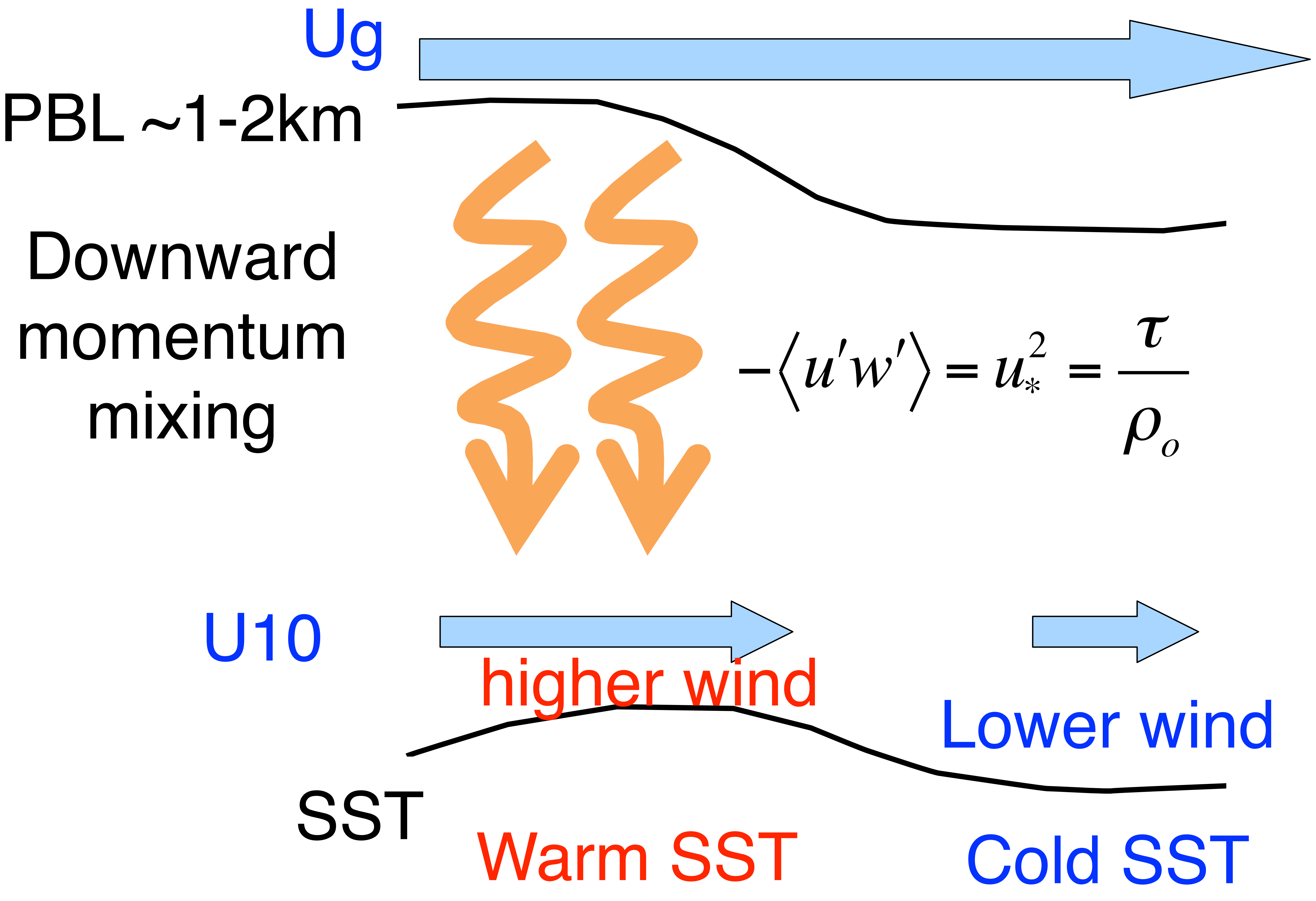


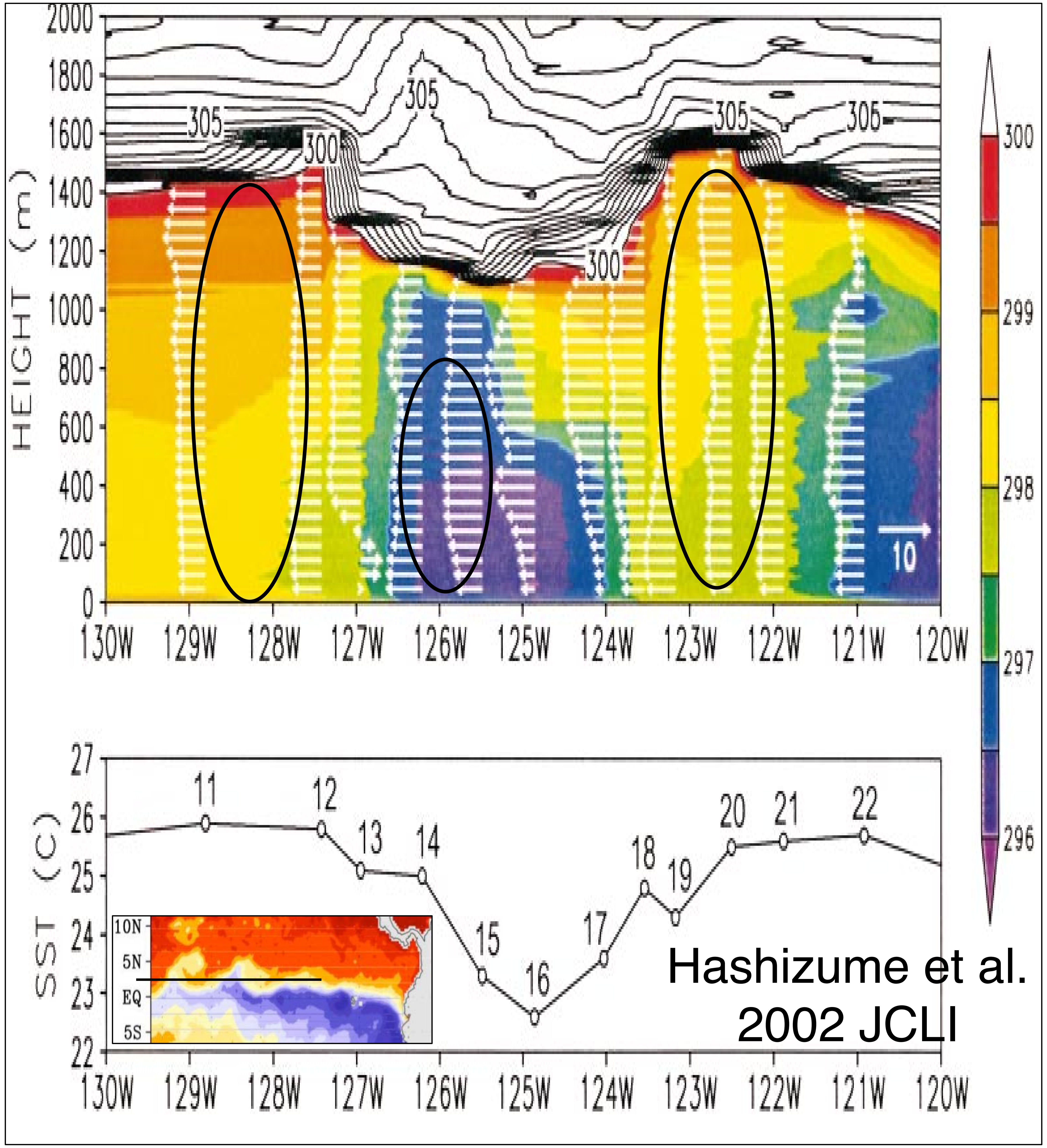

2000-2009 daily
QuikSCAT WS
NOAA-OI SST

Oceanic forcing of the atmosphere on frontal and mesoscales.

Seo 2017
JCLI

# Physics of the coupling: Modulation of MABL stratification

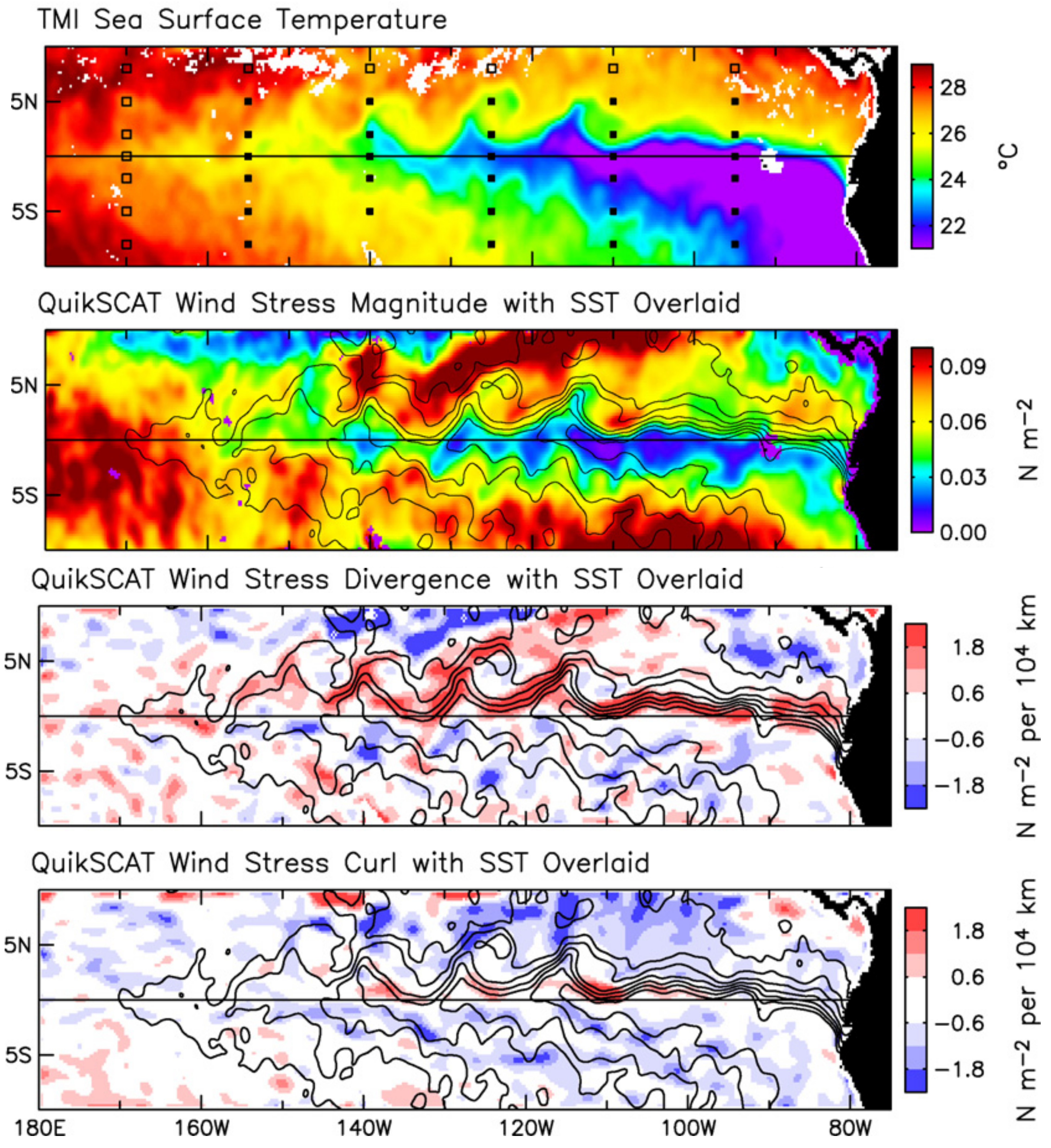


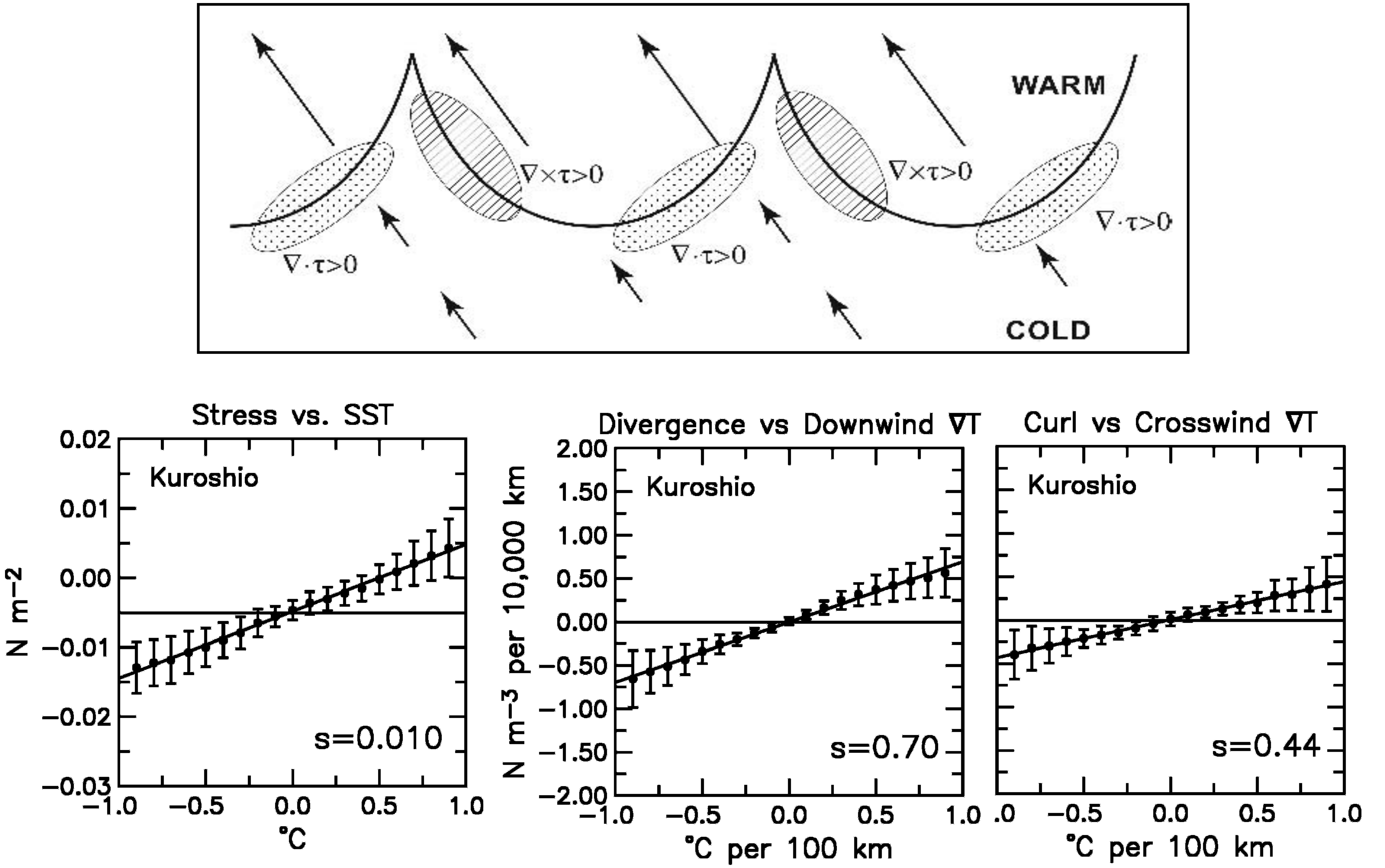




Hashizume et al. 2002 JCLI

- 1-D turbulent boundary layer process
- A shallow and rapid adjustment (~hrs)

# A linear-regression based diagnostic metic



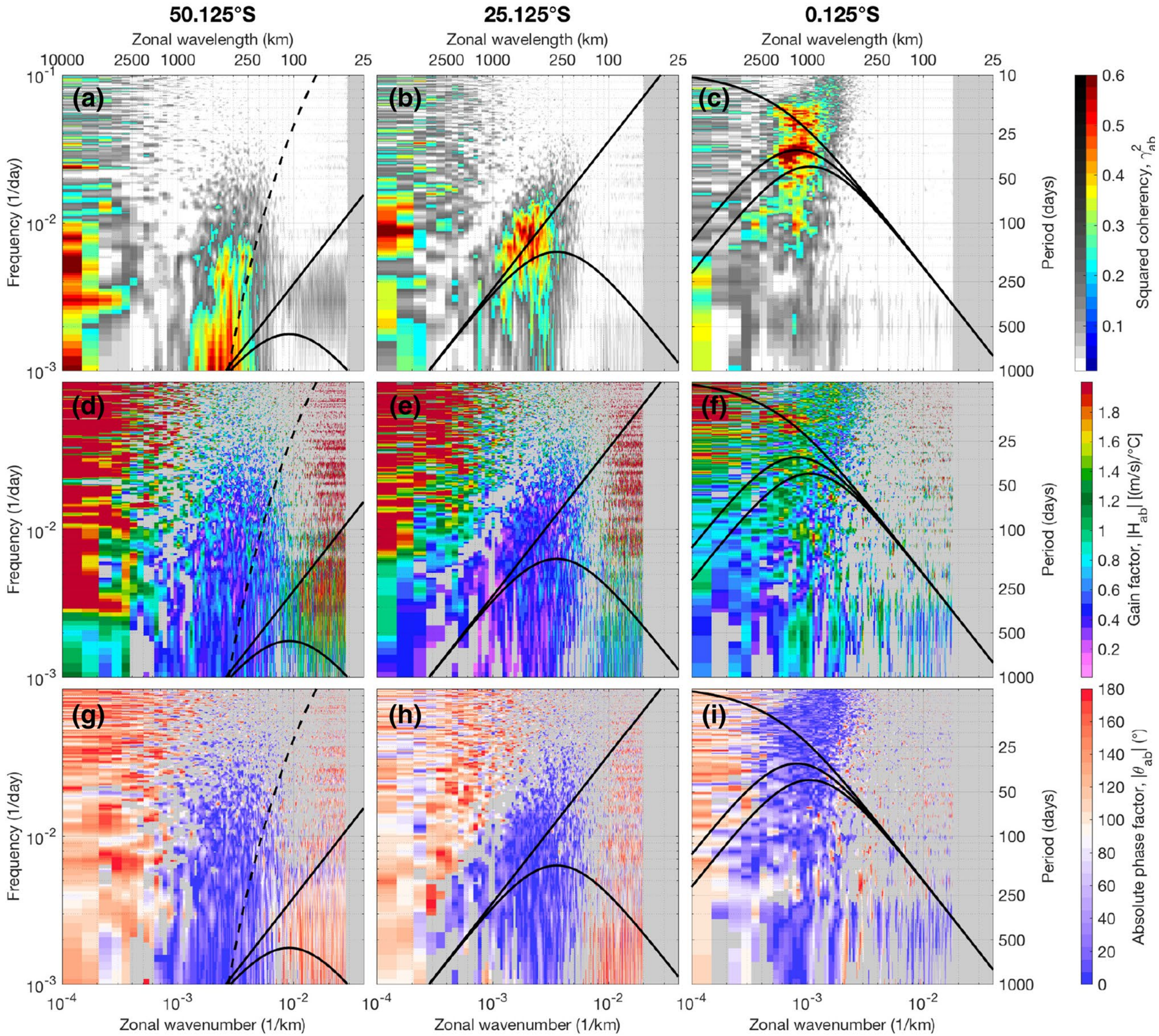

Maloney and Chelton 2010 JCLI

Spatially high-pass filtering is applied a priori.Positive regression coefficient is interpreted as the oceanic forcing of the atmosphere.

Coh²

Gain factor

Phase



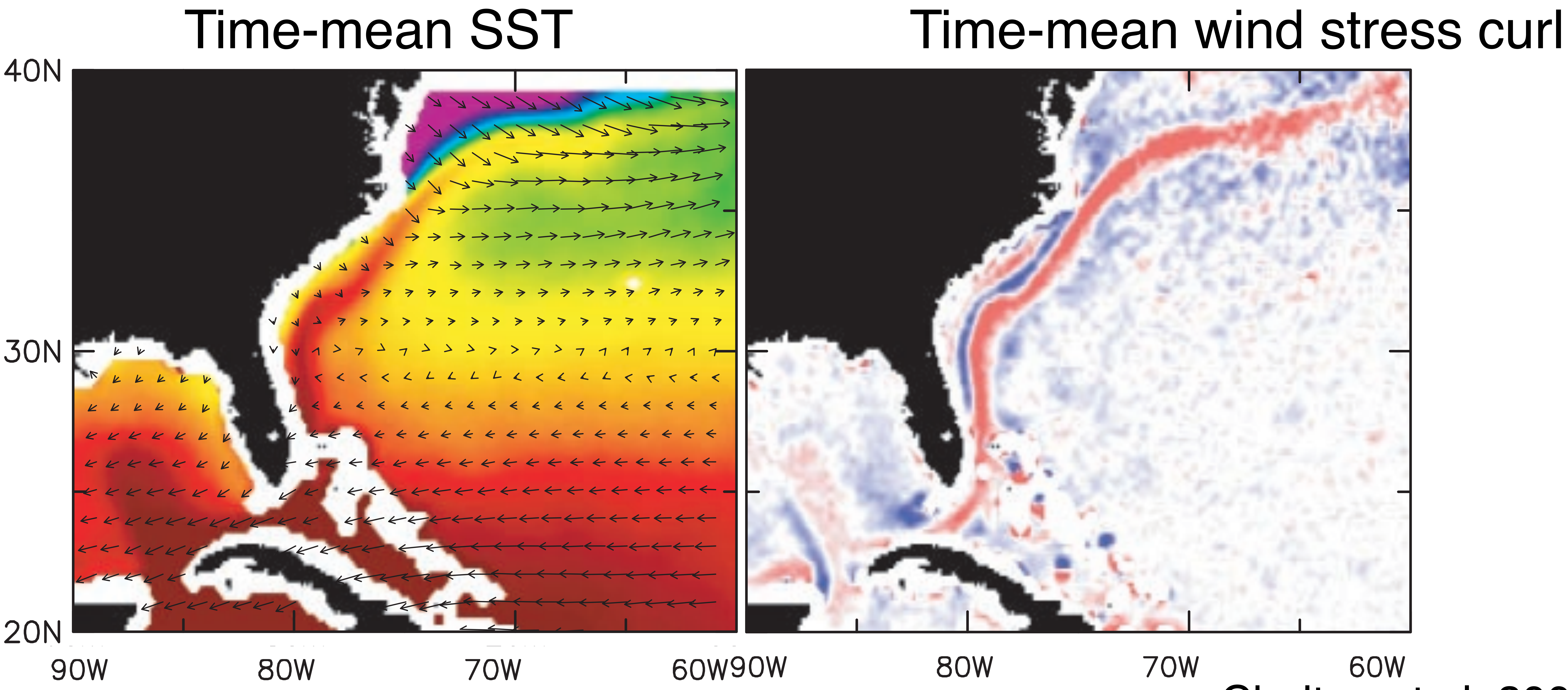

# Diagnostic based on spectral approach

A newer approach is to compute the squared coherence, transfer function, and phase between oceanic and atmospheric fields as a function of wavenumber and frequency

Laurindo et al. 2018 Clim. Dyn.

# Ocean current effects on wind stress

$$\tau = \rho_a C_D (\underline{W} - \underline{U})^2$$




The GS current manifest in reserse in wind stress

Chelton et al. 2004 Science

# Effect of surface current on wind stress

$$\tau = \rho_a C_D (\underline{W} - \underline{U})^2$$

AVISO: JJAS climatology

When ocean current is included in the bulk formula

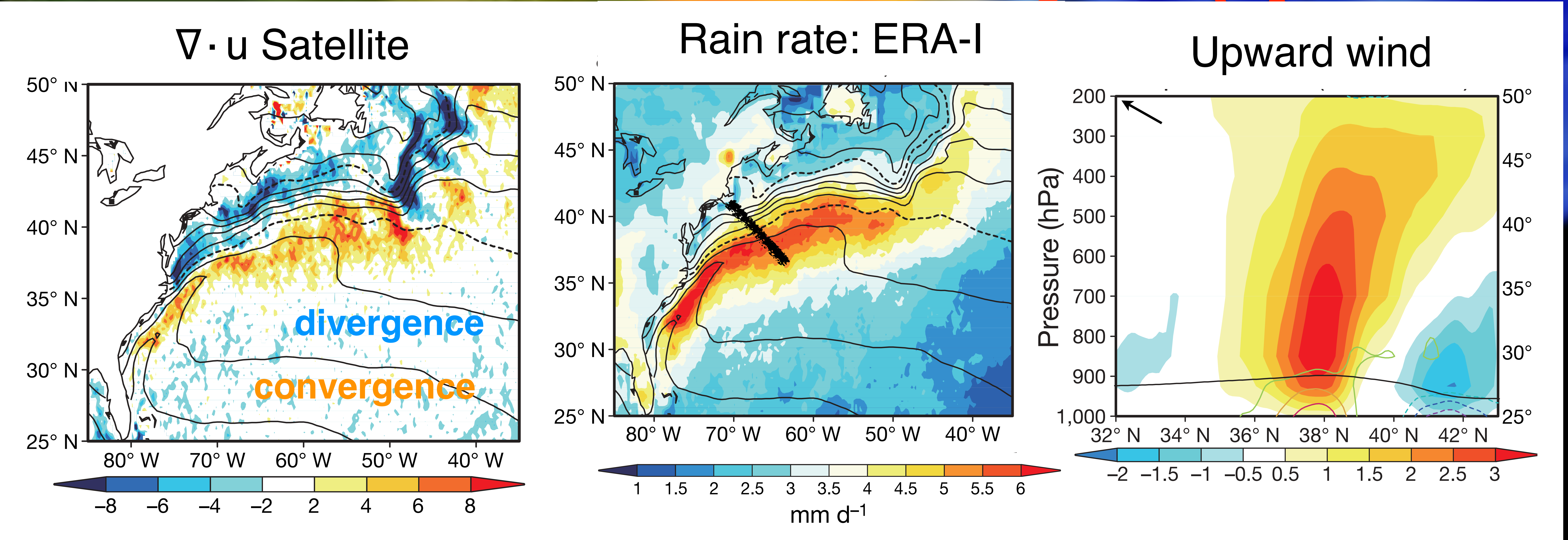
When eddy current is filtered out

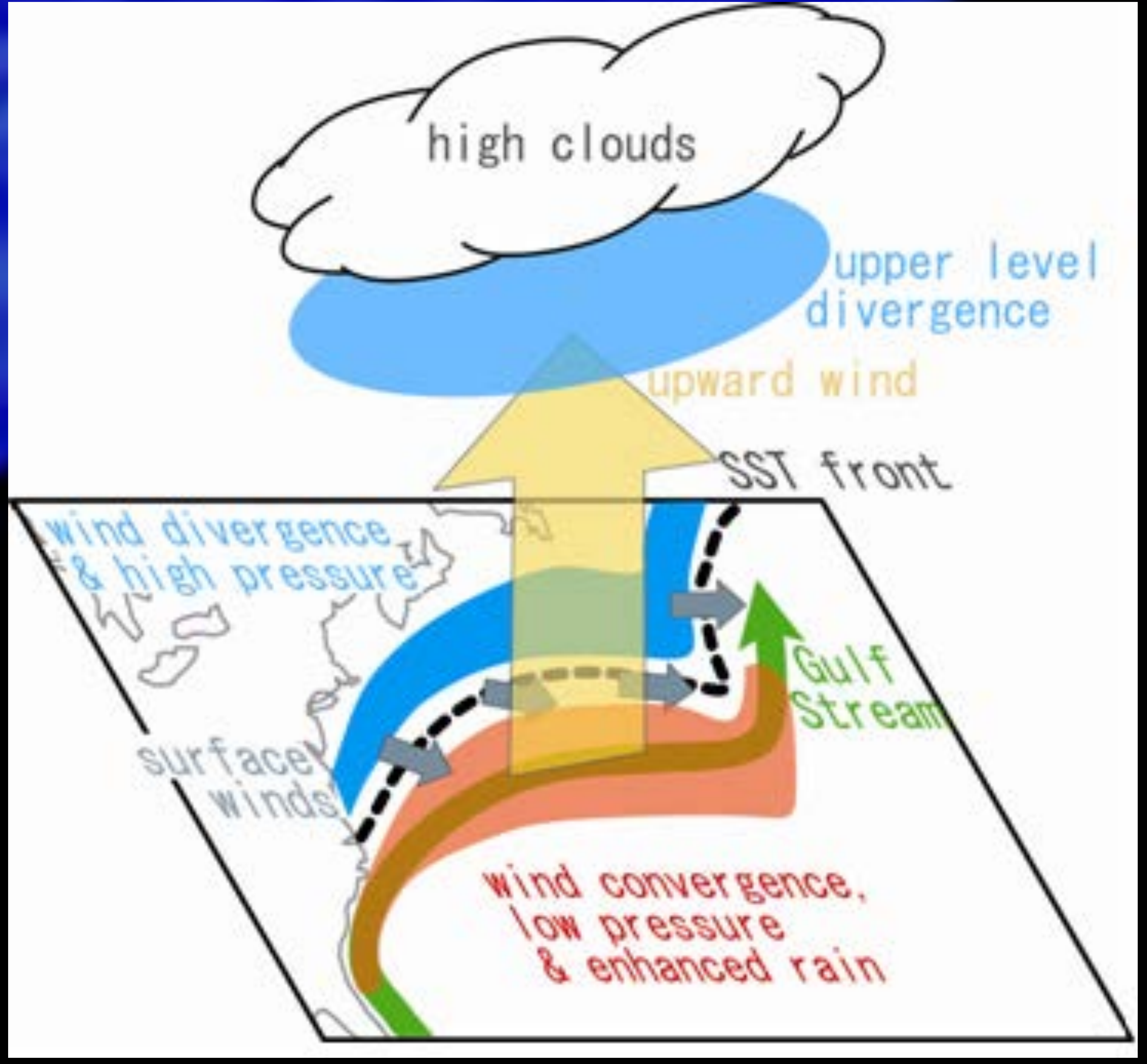
When the ocean current is ignored


Seo et al. 2016 JPO

# Deep response in the atmosphere


Minobe et al. 2008
Nature



# Northern Hemisphere atmospheric storm track climatology

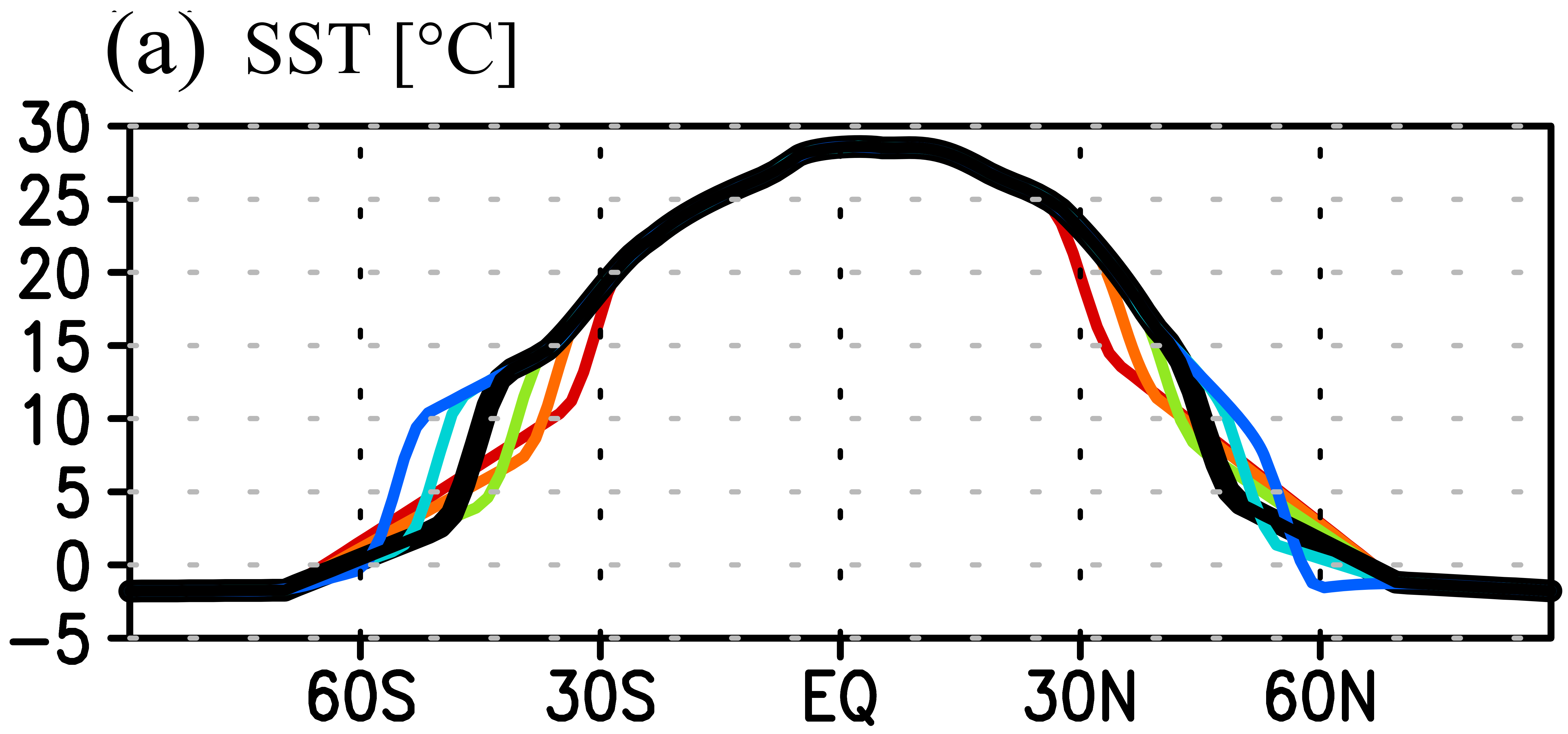

Growth rate of the extratropical cyclones
is proportional to low-level baroclinicity

$$\sigma = 0.31 \frac{g}{T} |\nabla T| / N$$

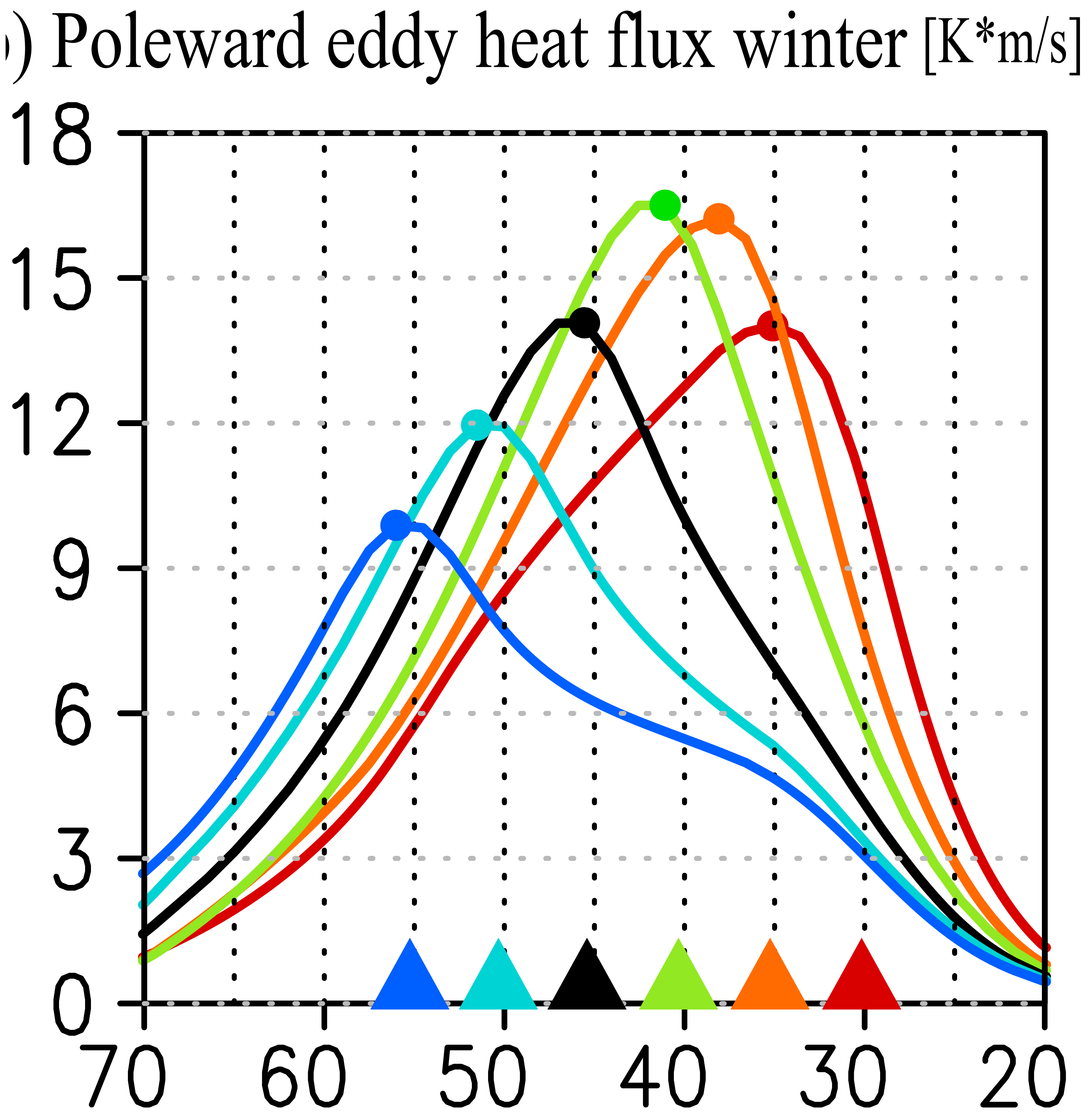
Storm track over the Kuroshio and Gulf Stream

Seo et al. 2014. JGR

# Local atmospheric response: Anchoring of storm tracks

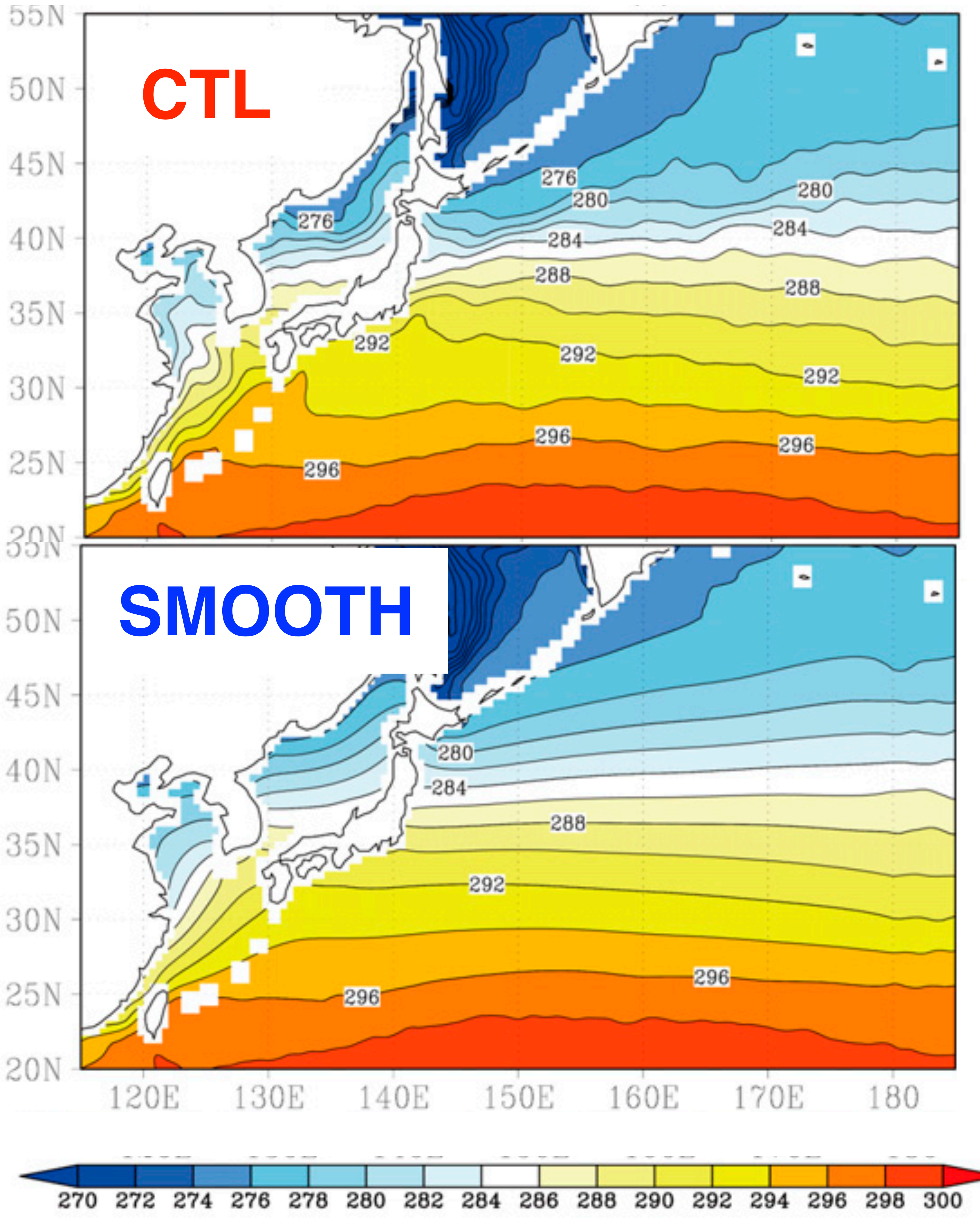


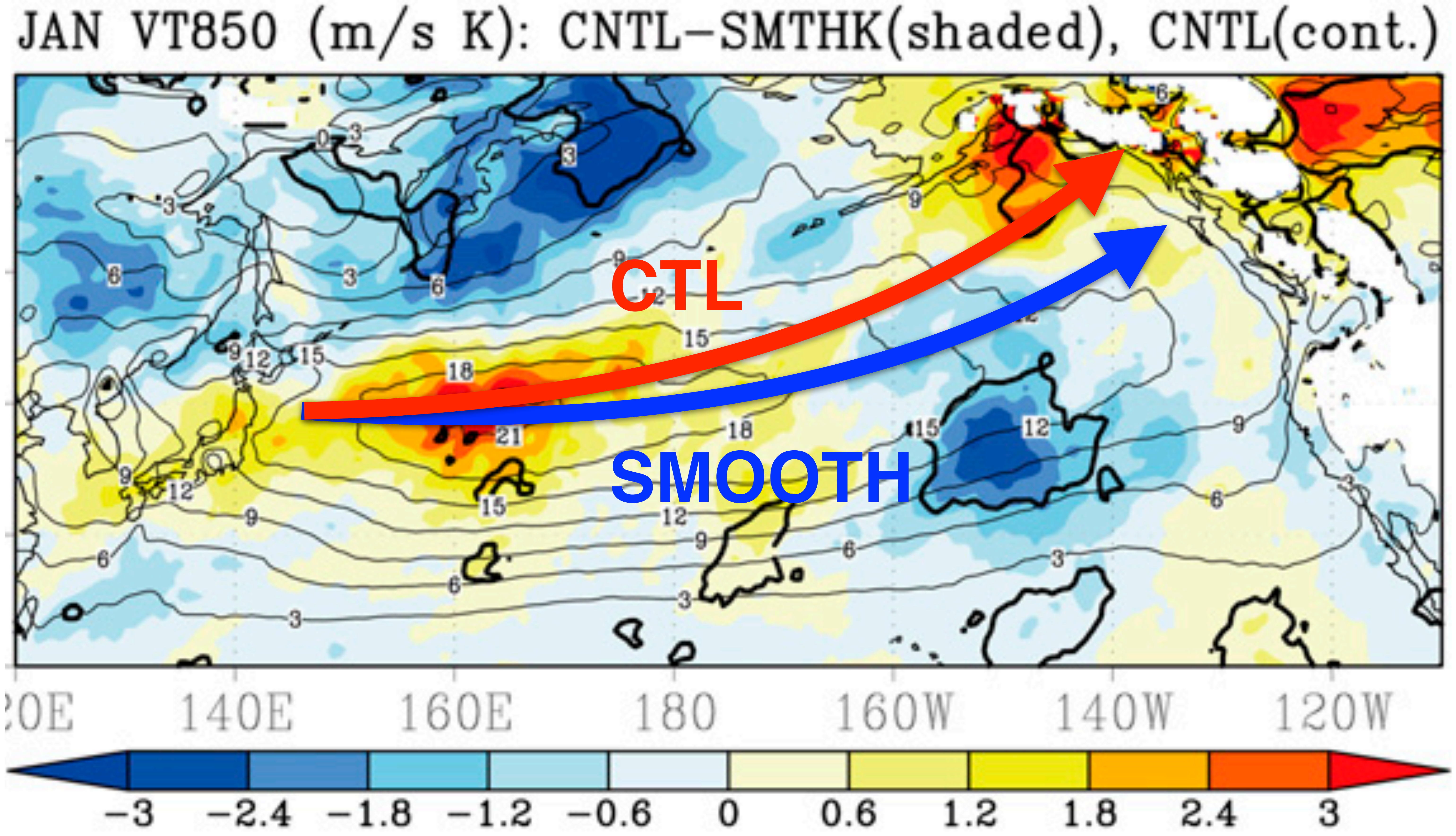

Idealized aqua-planet atmospheric general circulation model (AGCM) simulations forced by various locations of ocean front




Ogawa et al. 2012. GRL

# Remote atmospheric circulation response




Strong Kuroshio SST front strengthens the storm track in the west and pushes northward in the downstream.
— Is this a robust response?

Kuwano-Yoshida et al. 2017. JCLI

**Atmospheric GCM Response to Extratropical SST Anomalies: Synthesis and Evaluation***

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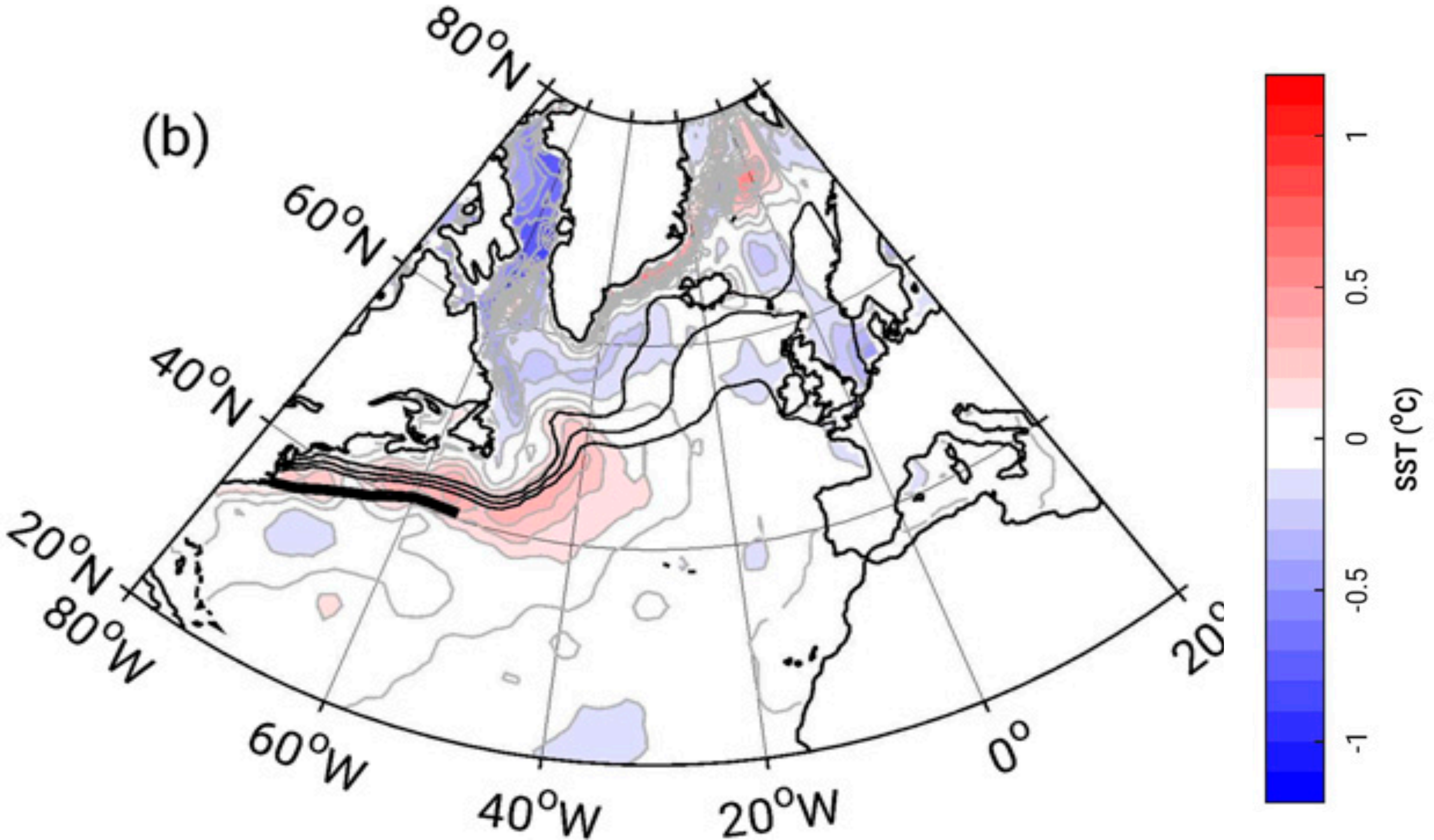
Kushnir et al. 2002 JCLI

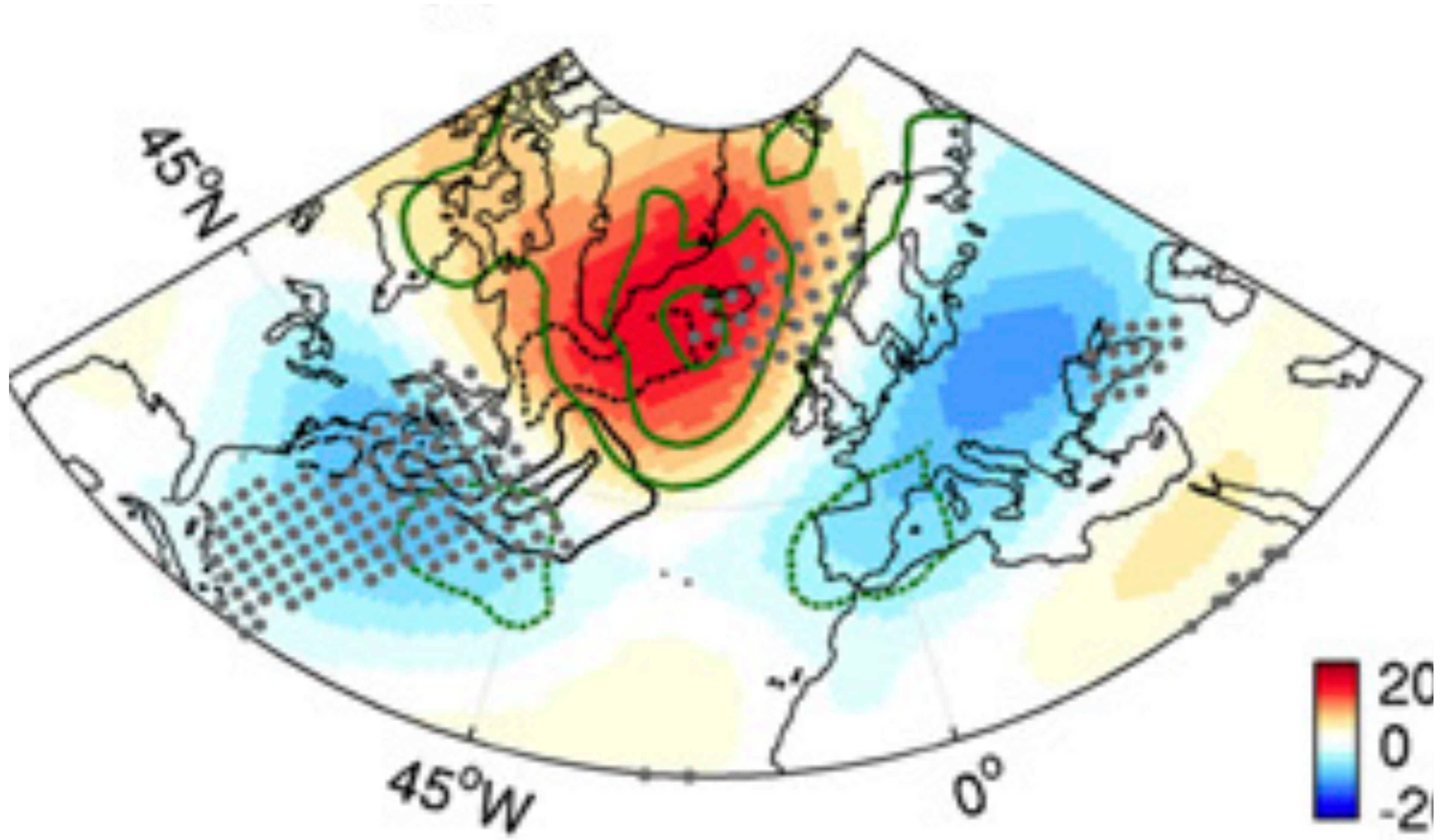
The observed standard deviation of 500-hPa heights on monthly to interannual timescales is of the order of 50–100 m. Thus, while it is possible for the response to an SST anomaly to provide a significant signal at the 500-

GCM responses to extratropical SST anomalies with realistic spatial sizes and amplitudes of up to a few degrees are on the order of 10–20 gpm $K^{-1}$ anomaly at 500 hPa. These values are in agreement with the-

SSTA associated w/ shift of the GS of ±1K

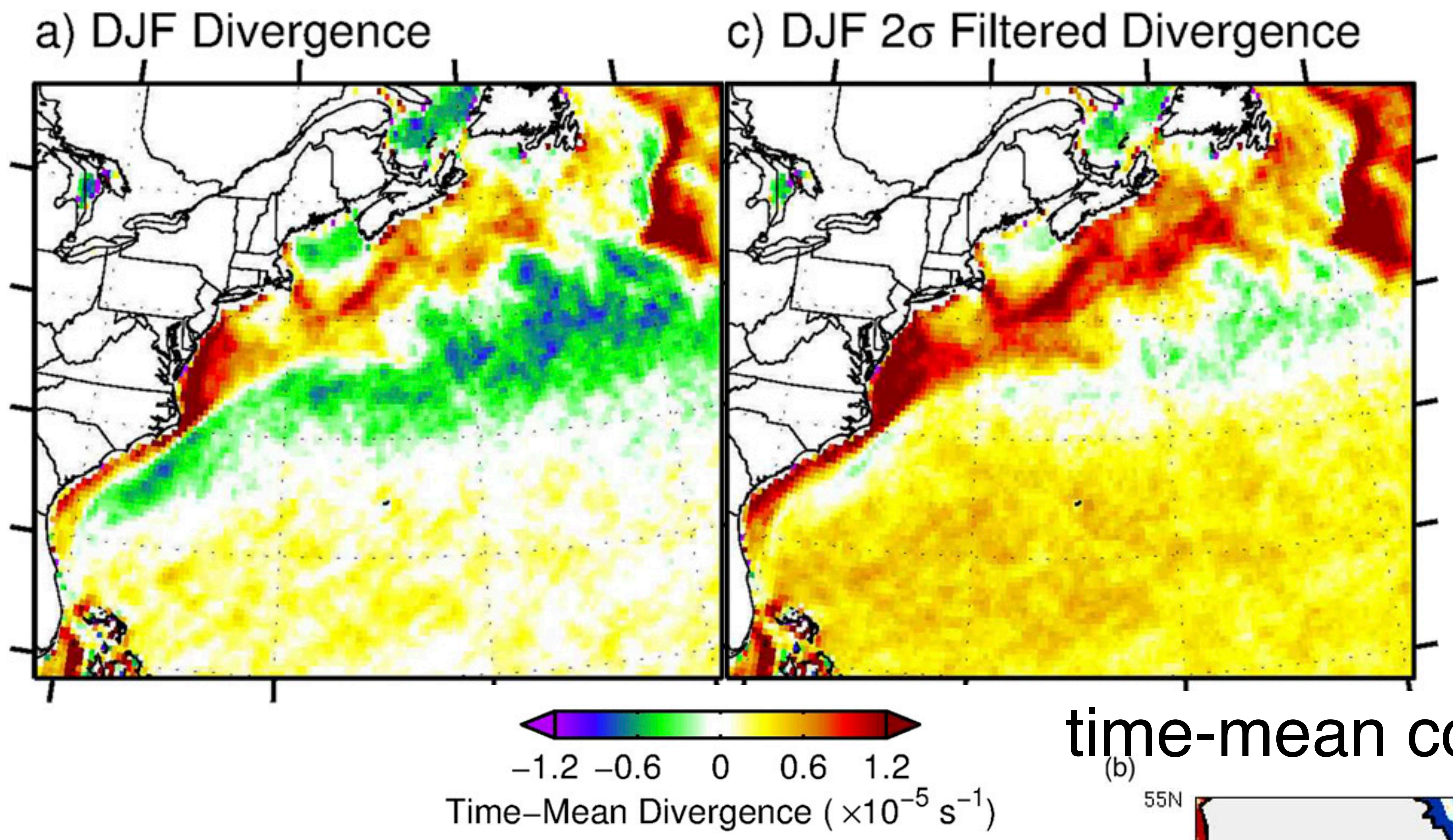



250hPa Z response of ±20m.




Seo et al. 2017 JCLI

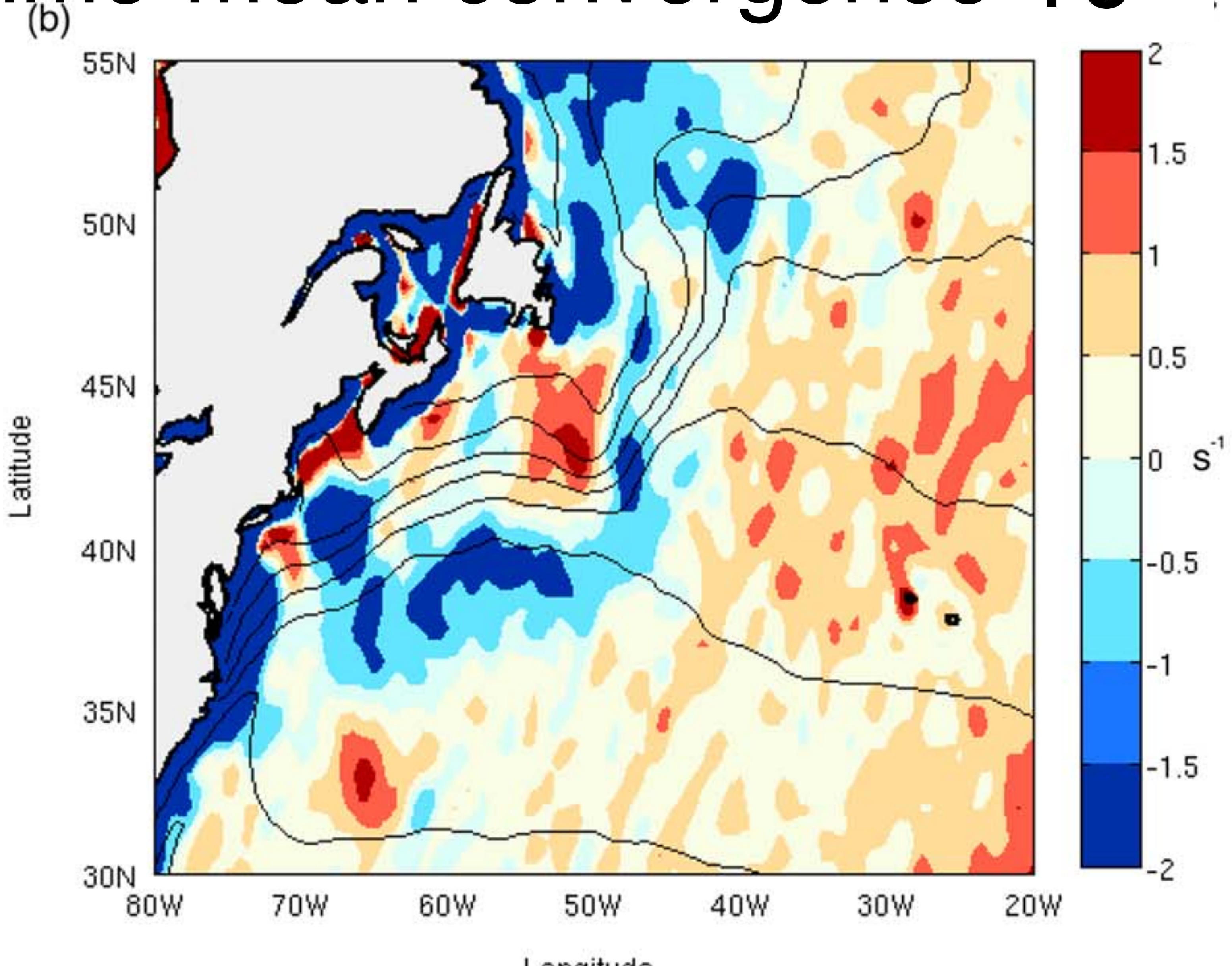
# Complications over the WBC regions



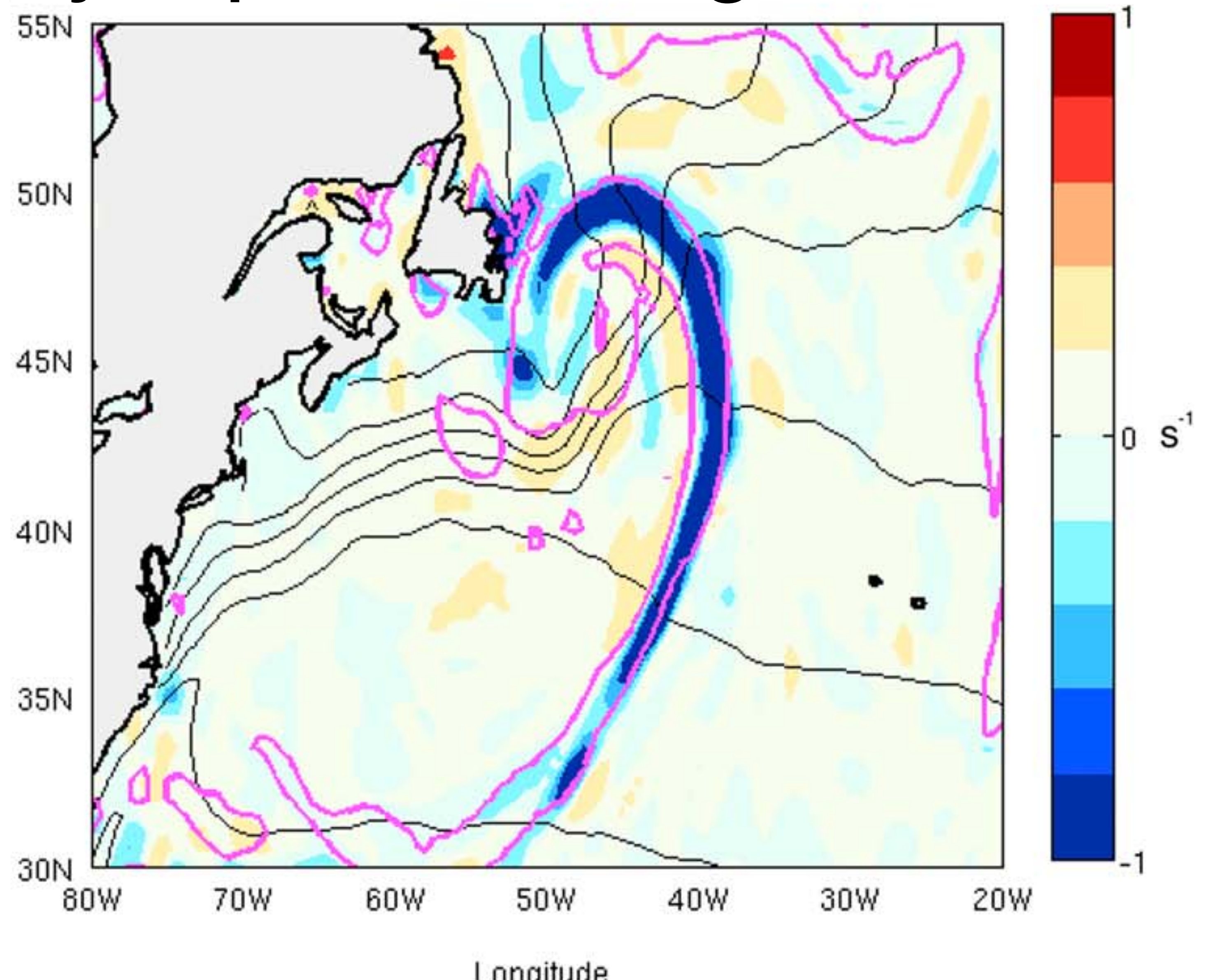

2σ filtering (4-5% of the data) removes the time-mean convergence over the GS front.

O'Neill et al. (2017) JCLI

time-mean convergence $10^{-6}$




synoptic convergence $10^{-4}$




Divergence associated with the continuous baroclinic waveguide >> the time-mean divergence.

Parfitt and Seo (2018) GRL

# Discussion Points

1. Improve understanding of the physics of air-sea coupling at increasingly small and transient scales.
2. Develop spatio/temporal-scale dependent diagnostic methods
3. Detect the eddy/front-forced midlatitude storm track variability from the intrinsic atmospheric internal variability
4. Quantify feedback mechanisms onto the ocean circulation/energetics, the large-scale atmospheric circulation, and the hydrologic cycle.
5. Guide in situ observational strategies and satellite remote sensing and coordinate modeling studies

# US CLIVAR Working Group on Mesoscale and Frontal-Scale Ocean-Atmosphere Interactions and Influence on Large-Scale Climate

- Construct a common modeling framework to diagnose the air-sea interaction
- Develop a strategy for a “Mesoscale Grand Challenge” multi-model inter comparison experiment.
- Guide in situ and satellite observations for optimum sampling of spatial and temporal scales for study of mesoscale air-sea interaction

**US WG members (Confirmed so far)**
Larry O’Neill (OSU) & Hyodae Seo (WHOI): Co-Chairs
Angeline Pendergrass (NCAR), Jim Edson (WHOI), Ben Kirtman (Univ. Miami), Baylor Fox-Kemper (Brown), Justin Small (NCAR), Kyla Drushka (UW-APL), Niklas Schneider (U. Hawaii), Qing Wang (NPS) Sarah Gille (Scripps) + *One OCB Person*

**International Members**
Lionel Renault (IRD, France)
Malcolm Roberts (UK Met Office)
Shoshiro Minobe (Hokkaido U, Japan