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

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US CLIVAR Summit
Aug. 9, 2019
“Discovery” of wind response to mesoscale SSTs

a) TMI Sea Surface Temperature

b) QuikSCAT Wind Stress Magnitude with SST Overlaid

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

Oceanic forcing of the atmosphere on frontal and mesoscales.
Physics of the coupling: Modulation of MABL stratification

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

\[
-\langle u'w' \rangle = u_*^2 = \frac{\tau}{\rho_o}
\]
Spatially high-pass filtering is applied a priori. Positive regression coefficient is interpreted as the oceanic forcing of the atmosphere.
Cross-spectral analysis of the SST/10-m wind coupling at wavelengths, that shift to values between 0.2 and 0.8 m/s/°C within the /u1D4AA (10^3–10^4 km) range at 50.125 °S and 25.125 °S, and to between 0.8 and 1.8 m/s/°C at 0.125 °S. At wavelengths smaller than ∼100 km, spectra for all latitudes display /u1D6FE^2ab statistically similar to zero, a general increase of |Hab| as a function of frequency, and sharp /u1D703ab variations. Considering the ∼50 km spatial resolution of the microwave-based SST data used in the generation of the AVHRR + AMSR OISST product, this is likely the result of aliased SST variability at spatial scales smaller than ∼100 km (Reynolds and Chelton 2010).

The dispersion relation for first mode baroclinic oceanic waves are overlaid to the spectra in Fig. 2. At 50.125 °S (left column), the solid black lines highlight the dispersion relation from the standard linear Rossby wave theory, given by /u1D714 = k/1FD /((k^2 + R) - 1^2), where /u1D6FD is the meridional variation...
Ocean current effects on wind stress

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

The GS current manifest in reverse in wind stress
Effect of surface current on wind stress

\[ \tau = \rho_a C_D (W - U)^2 \]

AVISO: JJAS climatology

When ocean current is included in the bulk formula

- 117 cm²/s²
- 166 cm²/s² (+42%)

When eddy current is filtered out

- 179 cm²/s² (+53%)

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

(a) SST [°C]

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

Ogawa et al. 2012. GRL
Remotely atmospheric circulation response

Strong Kuroshio SST front strengthens the storm track in the west and pushes northward in the downstream.

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Kuwano-Yoshida et al. 2017. JCLI

— Is this a robust response?
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.
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

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 intercomparison 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)