Coupled ocean-atmosphere interaction mediated by the ocean mesoscale eddies in the Northwest Tropical Atlantic Ocean

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NBC rings:
7-14 km/day for ~100 days

ECCO2 ocean state estimate
Hypotheses

1. Mesoscale ocean current and SST cause significant spatio-temporal variations (sub-monthly and sub-100-200 km) in the momentum, heat and moisture fluxes.

2. This ocean-forced variability in air-sea fluxes influences the vertical mixing and wind work on the ocean and drives atmospheric boundary layer and cloud responses.
Specific Questions and Approaches

1) How well does the numerical model with the COARE bulk flux algorithm reproduce the observed fluxes on oceanic mesoscale?
   — Simulated vs. observed air-sea fluxes across the fronts & Pre-cruise modeling experiments.

2) What are the controlling factors on the spatial structure and temporal variability of the observed air-sea fluxes?
   — Various 1D and 3D sensitivity experiments. Develop a diagnostic metric.

3) How does the resulting air-sea flux variability impact the atmospheric boundary layer, and what are the critical feedback mechanisms?
   — Long-term mesoscale-resolving coupled experiments
HYCOM SST and Surface current, Jan-Feb 2012

Significant eddy-wind interactions?

Strong surface current and eddy activity under the steady northeasterly trade winds
Mesoscale SST alters the vertical mixing in the ABL

- 1-D turbulent boundary layer process
- A shallow and rapid adjustment (~hrs)
Eddy-SST impacts on surface wind

DJFM High-pass filtered CORR(SST,WS)

100 km zonal highpass filter

2000-2009 DJFM daily
QuikSCAT WS and
NOAA-OI SST

Seo 2017
Imprints of surface current in wind stress curl

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

correlation: wind stress curl and surface voriticity; 1993-2015 DJFM

1993-2015 DJFM

ERA-I wind stress

AVISO geostrophic current
Air-sea interaction over an idealized NBC ring

\[ \tau = \rho_a C_D (W - U)^2 \]
Air-sea interaction over an idealized NBC ring

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

SST-wind coupling

SST-wind: small change in wind work, affect the eddy propagation
Air-sea interaction over an idealized NBC ring

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

SST-wind coupling: small change in wind work, affect the eddy propagation

Current-wind coupling: negative eddy wind work, damp the eddy activity

SST-wind coupling

Current-wind coupling
Quantifying the impacts of air-sea coupling

~1° downstream shifts of the Great Whirl without the SST-wind coupling

Significant EKE damping effect (26%) by the current-wind coupling

~1° downstream shifts of the Great Whirl without the SST-wind coupling

Seo 2017, JCLI
Scripps Coupled Ocean-Atmosphere Regional (SCOAR) Model

Seo et al. (2007; 2014; 2016, JCLI)

http://hseo.whoi.edu/scoar/

Scale-selective air-sea coupling

Physics of air-sea coupling and impacts on upper ocean mixing and stratification

Upscaling effects on regional precipitation patterns

Surface meteorology (U10, V10, SLP, T2, Q2, Q_{sw}, Q_{lw}, Pr) → Surface forcing (T_x, T_y, Q_{net}, Pr, Q_{sw})

COARE

WRF

SST & Surface current

ROMS

Unsmoothed SST

300 km smoothed

300 km

Outer 10 km domain (d01)

Nested 3-km domain (d02)

Nested 5-km domain (d03)

Downscaling

Upscaling

Orinoco

Amazon
Exploring sampling possibilities

5km WRF-ROMS test simulations Jan-Feb 2012

Stationed at 9°N, 52°W
Exploring sampling possibilities
5km WRF-ROMS test simulations Jan-Feb 2012

Repeat sampling across the front at ~2kt

January 2012
Collaborations

- Coordinated experiments with LES and submesoscale-resolving modeling (e.g., McWilliams, Renault, Sullivan)
  - Use common sets of model physics. Share the input and forcing data.

- Effect of wave coupling in the air-sea fluxes
  - Refine and test the wave-based formulation in the COARE against the wave properties and flux measurements
Thanks
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