Mesoscale Air-Sea Interactions

Atmosphere $\rightarrow$ wind & heat flux $\rightarrow$ Ocean
Atmosphere $\leftarrow$ SST $\leftarrow$ Ocean

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World's Oceans are full of mesoscale eddies and fronts!

- Tropical Instability Waves
- Coastal Upwelling
- Kuroshio
- Gulf Stream
- Antarctic Circumpolar Current
- Oyashio
- North Atlantic Current

AMSRE SST, June 1 2003
http://aqua.nasa.gov/highlight.php
Outline

1. Air-sea interaction on mesoscale vs large-scale?
2. Mechanism for mesoscale air-sea interaction?
3. Impact on the ocean and atmosphere?
4. Summary
Air-sea interaction at basin-scale
(slow and large scales)

SST and wind anomaly pattern related to NAO

Mean wind is westerly ➔

Mean wind is easterly ←

Kushnir et al. 2002

North Atlantic Oscillation

Stronger wind speed ➔
lower SST via mixing and turbulent flux

Negative correlation:
Atmosphere drives the ocean.
Air-sea interaction at oceanic mesoscale
(fast and short scales)

TRMM SST and QuikSCAT wind stress on 3 September 1999

Enhanced wind speed over higher SST!

Seo et al. 2007
Enhanced wind speed over warm SST
Reduced wind speed over cold SST
Positive correlation: Ocean drives the atmosphere.

How does the mesoscale SST influence the surface wind?
Eddies alter the stability of the lower atmosphere.

Increased wind

Decreased wind

Unstable boundary layer and increased mixing

Decoupled stable boundary layer

$-\langle u'w' \rangle = u_*^2 = \frac{\tau}{\rho_o}$
How do this coupling affect the ocean and atmosphere?

- **Wind curl** $\Rightarrow$ Ekman pumping $\Rightarrow$ Ocean circulation

- **Wind convergence and divergence** $\Rightarrow$ Atmospheric vertical motion and planetary-scale circulation

\[ W_{ek}' = \nabla \times \frac{\tau'}{\rho(f+\zeta)} \]

\[ w \approx \frac{1}{\rho_o} \left( \frac{\varepsilon_z}{\varepsilon^2 + f^2} \right) \nabla^2 SST \]

\[ \nabla \cdot \bar{u} \approx -\nabla^2 SST \]
Wind stress curl and divergence from satellites

Tropical Instability Waves

- Wind stress curl and convergence co-propagate with the front.
- Large-amplitude and persistence of the anomalies ➔
- Could be an important factor for dynamics of the large-scale ocean and atmosphere?

Animation from D. Chelton OSU
Impact on the ocean via Ekman pumping: western Arabian sea upwelling case from a coupled model

- Large Ekman pumping velocity induced by wind stress curls
  \[ W_{ek}' = \nabla \times \frac{\tilde{\tau}'}{\rho(f + \zeta)} \]
  - \(|W_{ek}/W| \sim O(1)|
  - A significant factor for evolution of eddies.

Seo et al. 2008
Impact on the atmosphere via vertical motion: Gulf Stream case from the observations

- Wind convergence (divergence) over warmer (colder) flank of the GS.
- Intense precipitation where wind converges.
- Vertical motion reaching all the way up to the tropopause!
- This will excite the planetary-scale Rossby waves and influence the atmospheric general circulation.

Minobe et al. 2008
Summary

SST variations associated with mesoscale eddies and fronts cause coherent perturbations in the atmosphere.

A ubiquitous feature observed throughout the World Oceans,

potentially important for mesoscale ocean dynamics and atmospheric circulation,

net effect on large-scale climate dynamics remains uncertain but is an active area of research.

In situ data, satellite observations and high-resolution climate models are all important tools to examine the dynamics of coupling and the effect on large-scale flows.
Thanks!

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References