An Example of Wind Observing System Change Influencing the Climate Record

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Goal & Issues

• Interest: How big are biases in fluxes associated with common assumptions?
  • On what time scales will these biases seriously alter assumptions

• Goal: Estimate the change in Pacific Ocean latent heat fluxes (LHF) due to the change from ship winds to satellite winds – assuming they are treated in the same manner
  • For NWP assimilation, both types of winds are treated as earth relative
  • I will focus on the difference due to waves (swell and wind waves).

• Goal: Assess the influence of synoptic or finer scale variability on LHF
  • That is, differences from fluxes based on monthly averaged inputs
  • Wave-related variability is ignored in this part of the study
Many Air/Sea Interaction Processes
- Most are strongly influenced by stress -
Caveats

- Wave portion of analysis is based on theory – observations and not sufficient
- The one thing flux modeler agree on is that they disagree on how to model wave influence
  - There is a wide range of proposed mechanisms for how waves modify surface fluxes.
- Flux models used to study waves
  - Model used herein is Bourassa (2006):
Preliminary data form the SWS2 (Severe Wind Storms 2) experiment.

- The drag coefficients for high wind speeds are large and plentiful.
- The atypically large drag coefficients are associated with rising seas.
- Many models underestimate these fluxes.
- Spread is much bigger than expected from observational errors.
How Do Waves Enter The Picture?

• The surface turbulent stress and LHF are usually parameterized as

\[ \tau = \rho C_D U_{10}^2 \]

\[ L = \rho L_v C_E (q_{10} - q_{sfc}) U_{10} \]

• This form can be more accurately written as

\[ \tau = \rho C_D \left| U_{10} \right| U_{10} \]

\[ L = \rho L_v C_E (q_{10} - q_{sfc}) \left| U_{10} \right| \]

• It can be further improved in terms of surface relative wind vectors:

\[ \tau = \rho C_D \left| U_{10} - U_{sfc} \right| (U_{10} - U_{sfc}) \]

\[ L = \rho L_v C_E (q_{10} - q_{sfc}) \left| U_{10} - U_{sfc} \right| \]

• Does a scatterometer respond to \( U_{10} \) or to \( U_{10} - U_{sfc} \)?


• *Bentamy et al.* (2001, *JTech*) indicate there is also a dependence on wave characteristics.

• *Bourassa* (2006, *WIT Press*) showed that wave dependency can be parameterized as a change in \( U_{sfc} \).
Observed (x) and Modeled (y) Friction Velocity ($u_*$)

- Large and Pond (1981)
- Smith (1988)
- Taylor and Yelland (2001)
- Bourassa (2006)
The percentage change in surface relative winds is roughly proportional to the change in energy fluxes.

The percentage change squared is roughly proportional to changes in stress.

The drag coefficient also changes by about half this percentage.

\[
\frac{\mathbf{v}_A - \mathbf{v}_C}{|\mathbf{v}_A|} \rightarrow \frac{\mathbf{v}_W}{|\mathbf{v}_A|}
\]

From Kara et al. (2007, GRL)
Wave Induced Changes in LHF

- Examples from snapshots (6 hourly time steps)
- Input data:
  - WaveWatch3 (WW3) winds and waves
  - ECWMF temperatures and humidities

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Example of Results
Change in LHF Due to Waves: March 1999

Waves Decrease LHF

Waves Increase LHF

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Monthly Averaged Changes in LHF: Two Examples

- January 2003 (left) and June 1999 (right)
- One persistent feature is a reduction of heat transfer from the western Pacific warm pool to the atmosphere
- The roughly 5 Wm$^{-2}$ across basin difference is important for studies of decadal variability, and possibly for ENSO

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Submonthly Contribution to Average LHF

- $L$ is determined through a bulk formula.
  \[ L \approx \overline{\rho L_v C_E \bar{U}(q_{sfc} - \bar{q})} \]
  - Where the overbar indicates a monthly average
  - There is considerable controversy about that accuracy of this averaging
- A more accurate approach is to calculate the flux at each time step then average these fluxes:
  \[ L \approx \overline{\rho L_v C_E U(q_{sfc} - q)} \]
- If we apply Reynolds averaging this equation becomes
  \[ L = \overline{\rho L_v (C_E + C'_E) (U + U')(q_{sfc} - q'_{sfc} - q + q')} \]
  - If we assume density variations are not important, this equation becomes
    \[ L = \overline{\rho L_v C_E \bar{U}(q_{sfc} - \bar{q})} + \overline{\rho L_v (C'_E U'(q' - q'_{sfc}) + U C'_E (q' - q'_{sfc}) + (q' - q'_{sfc}) C'_E U')} \]
- Following examples of monthly biases are based on ECMWF reanalysis.
  - Plots bias from using monthly averaged flux input data
  - They do not include wave information

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Bias in Monthly Latent Heat Flux

(1) latent heat flux determined from 6 hourly data and
(2) latent heat flux determined from monthly averaged input

Monthly climatology computed for 1978-2001

Figures show: (1) minus (2)

Probably under-estimated for the Southern Ocean

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Bias in Latent Heat Flux (Wm$^{-2}$)
Thanks to Paul Hughes and Ryan Maue

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Summary

- Synoptic scale variability in regional latent heat fluxes and flux related variables can be large (>50 Wm\(^{-2}\) in some regions).
  - Particularly down wind of continents and by western boundary currents.
  - Implies heat fluxes in the Southern Ocean will be underestimated.
- In the tropics, sub-monthly variability - **ignoring waves** – can exceed 20Wm\(^{-2}\); however, it is typically <10 Wm\(^{-2}\).
- Monthly averaged tropical **wave related** variability is more wide spread:
  - Tends to reduce LHF by roughly 5Wm\(^{-2}\) in the Western tropical Pacific Ocean
  - Slightly increases LHF in the Eastern tropical Pacific Ocean
  - Could be of interest on ENSO time scales and longer.
- Similar magnitude and spatial distribution to what some people call the global warming signal.
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