Impacts of surface currents on derived scatterometer wind at Ku and C band

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This work comes under the OVWST project “Determining geophysical impacts on scatterometer wind stress accuracy,” and Jim Edson will be presenting additional work on Wednesday afternoon.
Overview

• What do we know-- or what do we think we know?
• Effect of currents on QuikSCAT - buoy residuals at 2 buoys
• Spatial case study of QuikSCAT and currents using models
• Currents and ASCAT - buoy residuals
• Currents altimeter wind (briefly)
Scatterometry and currents

• According to the model [Bourassa 2006], we expect that QuikSCAT should follow the kinematic boundary condition, i.e.:

\[ U(z) - U_s = \frac{u_* a}{\kappa} \left[ \ln \frac{z}{z_0} + \phi(z, z_0, L) \right] \]

• But:
  o the few existing studies focus mostly in the equatorial region
  o and/or use only climatological currents
  o or non-surface currents (10m depth)
  o and don’t quantitatively validate the model

Dickinson et al. 2001; Kara et al. 2007; Kelly et al. 2005; Quilfen et al. 2001;
5-Day Interval Ocean Surface Currents (meter/sec)
Centered on May 2 2011

Mean

1.0 meter/sec (0.514 m/s = 1 knot)

NESDIS/NOAA

May 7 2011

http://www.oscar.noaa.gov/datadisplay/oscar_latlon.php
Dickinson et al. 2001, *Comparisons between the TAO buoy and NASA scatterometer wind vectors*

**Fig. 4.** Effect of ocean currents on NSCAT winds. (a) NSCAT-2 winds (eastward is up). (b) Currents at a depth of 10 m measured from TAO buoys. (c) The difference between TAO buoy and NSCAT-2 vectors at the ocean surface. The difference between the TAO and NSCAT-2 wind speeds is significantly correlated with the component of the ocean currents in the direction of the buoy winds.
Scatterometry and currents

- So:
  - it is hard to find a study that quantifies this in a global sense
  - to get to the physics, need a lot of data, not just in the equatorial regions, but also in coastal regions to examine tidal signals
  - and given that there is so much emphasis now on dual-frequency work, what about C-Band?
- We should also keep in mind that many wave-current interactions occur within the footprint of our sensor: even if they don't show up in the data, it doesn't mean they aren't happening
The Gulf of Maine
In Situ Data

- Focused on two Gulf of Maine Ocean Observing System (GoMOOS) Buoys
  - Buoy N (number 44024 at 42.31 N, -65.93 E)
  - Buoy L (number 44038 at 43.62N, -66.55 E)
- Winds from RM Young anemometers at 4m, corrected to 10m neutral winds using COARE 3.0
- Surface currents from Aanderaa RCM9 meters at 2 m depth
  - $u' = |u| \cdot \cos(\phi_{\text{buoycurr}} - \phi_{\text{buoywind}})$
- Also provide air and water temperatures, relative humidity, atmospheric pressure, etc.
Other Data

• **Satellite:**
  - QuikSCAT: L2 25 km and 12km (PO.DAAC); UHR (D. Long); collocations according to Plagge et al. 2009
  - ASCAT collocations from Anton Verhoef (KNMI): 12 km and 25 km at buoy N; 25 km at buoy L
  - Altimeter: Jason-1,-2, and Envisat

• **Models:**
  - Atmosphere: 9 km WRF (UNH and AER, Inc)
  - Finite Volume Community Ocean Model (FVCOM) circulation model (Dr. Chen at UMass)
QuikSCAT and buoy wind speed residuals vs. projected current

- Dashed line indicates $y = -x$
- Weighted LS fit
QuikSCAT and buoy wind speed residuals vs. projected current

- Binned (UHR QS - buoy L and N) wind speed (m/s) vs. $u'$
  - Weighted LS fit
  - Black dashed line indicates $y = -x$
  - $N=5286$

- Binned (12km QS - buoy L and N) wind speed (m/s) vs. $u'$
  - Weighted LS fit
  - Black dashed line indicates $y = -x$
  - $N=4487$

- Binned (25km QS - buoy L and N) wind speed (m/s) vs. $u'$
  - Weighted LS fit
  - Black dashed line indicates $y = -x$
  - $N=2540$
Is it following the kinematic boundary condition?

- Relationship for speed residuals very close to 1:1
- If QuikSCAT is truly responding to the kinematic boundary condition, can we make this response any clearer?
- Might there be a difference at light wind for instance?
  - Expected errors: 5 m/s and below there are larger QS-buoy residuals for all resolutions in the Gulf of Maine [Plagge et al 2009]
  - Physics: perhaps fully coupled wind-wave situation not developed
  - Differences in drag coefficient parametrization at speeds below 4 m/s (viscous effects and surface tension)
- Might expect masking due to stability effects: magnitude of these could easily be greater
Is there a speed dependence?

- Low
- Moderate
- High(er)

Weighted LS fit

Black dashed line indicates $y = -x$
Those were speed residuals. What about direction?

Binned (UHR QS - buoy L and N) wind dir (deg) vs. $u'$

$y = (2.22 \pm 2.33)x + (1.44 \pm 0.76)$

Binned (12km QS - buoy L and N) wind dir (deg) vs. $u'$

$y = (1.10 \pm 2.21)x + (4.35 \pm 0.75)$

Binned (25km QS - buoy L and N) wind dir (deg) vs. $u'$

$y = (-2.98 \pm 2.59)x + (5.36 \pm 0.91)$

weighted LS fit
Spatial patterns

http://app2.iris.usm.maine.edu/gulfofmaine-censusdev/wp-content/images/circulation/fig4.jpg
Spatial case study: Dec 26-27 2008
ASCAT

- C-band (5.255 GHz)
- Does the different frequency mean a different response to currents/current shear?
- Notes:
  - Collocations provided by Anton Verhoef
  - No 12 km data at buoy L due to swath patterns
  - Some missing temperature data at buoy N means that some buoy winds are not stability-corrected
25km ASCAT and buoy N winds

red dots indicate instances of missing buoy water temperatures, meaning the 10m buoy wind was created using law-of-the-wall only; this will be remedied in future.

black dashed line indicates $y = -x$
(25km ASCAT-buoy N) wind speed vs. current

ASCAT 25km - buoy wind speed vs uprime for buoy N

$y = -0.39x + 0.31$

weighted LS fit

black dashed line indicates $y = -x$
(25km ASCAT-buoy N) wind speed vs. current

- **ASCAT Bspd<5, (25km - buoy N) wspd (m/s) vs uprim**
  - N=264
  - $y = (-0.62\pm0.29)x + (-0.26\pm0.08)$

- **ASCAT 5<Bspd<=10, (25km - buoy N) wspd (m/s) vs uprim**
  - N=464
  - $y = (-0.19\pm0.14)x + (0.34\pm0.05)$

- **ASCAT Bspd>10, (25km - buoy N) wspd (m/s) vs uprim**
  - N=167
  - $y = (-1.11\pm0.36)x + (0.88\pm0.10)$

The black dashed line indicates $y = -x$. The plots show weighted LS fit.
12km ASCAT and buoy N winds

red dots indicate instances of missing buoy water temperatures, meaning the 10m buoy wind was created using law-of-the-wall only; this will be remedied in future.

black dashed line indicates $y = -x$
(12km ASCAT-buoy N) wind speed vs. current

ASCAT 12km - buoy wind speed vs uprime for buoy N

N = 772
Corr. coeff = -0.155

\[ y = -0.41x + 0.40 \]

weighted LS fit

black dashed line indicates \( y = -x \)
(12km ASCAT-buoy N) wind speed vs. current

black dashed line indicates $y = -x$

weighted LS fit
Surface-relative altimeter winds

- Jason-1,-2, Envisat
- We want to check if the response is less than kinematic 1:1 due to the longer waves included in altimeter backscatter (this would be similar in off-nadir radiometry) [Vandemark et al 1998]
- Note: This may not be a representative case, as the dynamic range of waves in the location of buoy N is somewhat limited, and certainly doesn't represent the global ocean
Altimeter and buoy N

(Alt - buoy windspeed) vs. uprime, buoy N

N = 284
Corr. coeff = -0.19496

\[ y = -0.86x + 0.12 \]
Altimeter and buoy N: low wave height and neutral stability

Rule: $\text{WVHT} \leq 1$ & neut.: $(\text{Alt} - \text{buoy N wspd})$ vs. $u'$

$N = 48$

Corr. coeff = -0.3973

$y = -0.98x + 0.86$
Conclusions and future work

• QuikSCAT-- overall-- follows the kinematic boundary condition for all resolutions at two coastal buoys
• The effect of currents on QuikSCAT wind speed can be seen spatially as well
• ASCAT appears to have a weaker response
• Altimeter may be following kinematic condition despite longer waves

• Can we explain what is happening at low wind speeds?
• Can we retrieve any further information by sorting by z/L or another stability-related parameter?
• Can we determine why Ku-band and C-band seem to have such a different response?
  o Is this universally true or somehow related to the dynamics at our test site?
UNH air-sea discus buoy (ASID) for eddy covariance momentum, mass, and latent heat flux under ASCAT - ongoing in G. Maine

Key features

- Offshore with good ASCAT overpass data
- Synchronized 20 Hz data for hourly flux estimates using:
  - Licor H₂O and CO₂ (Li7500)
  - Direct covariance flux system
- Solar powered for long-term continuous operation
- 3-D near surface current data
- 2-D gravity wave spectra
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- Ernesto Rodriguez and NASA’s Graduate Student Researchers Program
- Anton Verhoef at KNMI
- Hui Feng at UNH
- Rich Signell at USGS
- Dr. Chen at UMass

Questions? Suggestions? Comments?
Extra slides
Bourassa’s [2006] model

\[ U(z) - U_s = \frac{u_* a}{\kappa} \left[ \ln \frac{z}{z_0} + \phi(z, z_0, L) \right] \]
for both buoys it does look like there are directional differences, especially between low and high winds
Spatial case study: 16-17 Mar 2009
25km ASCAT and buoy L winds

- Black dashed line indicates $y = -x$
(25km ASCAT-buoy L) wind speed vs. current

ASCAT 25km - buoy L wind speed residual vs uprime

weighted LS fit

black dashed line indicates $y = -x$