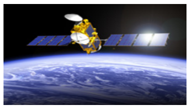
Combining altimetry and wave models to refine and apply measurements of wave slope variance



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I. Abstract

It is recognized that altimeter backscatter measurements at C and Ku-band provide the most directly accessible satellite measure of ocean wave slope variance. The slope variance represents integration over the entire gravity and gravity-capillary wave spectrum and its measure is closely coupled to wind-wave growth and dissipation and air-sea gas exchange as it is weighted towards high-frequency wavelengths. As part of our project goal to enhance synergy between wave modeling and altimetry, we revisit the development of a dedicated global model relating Jason C-band altimeter backscatter to the slope variance measured using in situ wave buoys. We also present recent comparisons between altimeter and wave model-derived slope variance estimates using operational WAVEWATCH III global ocean wave model output produced at IFREMER. Results from application of these data to NASA's Aquarius salinity mission will be shown, where wave model data are co-registered with L-band radiometer to investigate long and short wave impacts on brightness temperature, and the potential impact on derived salinity.

II. Objectives

Overall Framework

A. Develop calibrated total and long-wave mean square slope products using C and Ku-band altimeter backscatter and sea state measurements with buoy data as a reference

B. Apply these data to calibrate and inform ocean wind wave modeling for the high frequency portion of the predicted wind-wave spectra (wave dissipation)

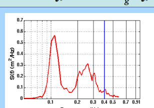
C. Use altimeter-informed wave model output in global applications – one example being the Aquarius salinity mission and its needed roughness correction

III. Slope variance via the altimeter and use in wave model development and validation

Altimeter + wave model efforts -

Following Gourrion et al. (2002) work with the T/P altimeters, we've developed a simple non-parametric model relating Jason-1(2) C-band altimeter backscatter and signficant wave height data to buoy-measured mean square slope (mss or s^2).

$$mss\_buoy \overset{\Delta}{=} \int_0^{k_{cut}} k^2 S(k)dk = \frac{(2\pi)^4}{g^2}\int_0^{f_{cut}} f^4 S(f)df = mss\_long$$



Example buoy-measured 1-D wave spectrum within our altimeter/buoy colocation database.

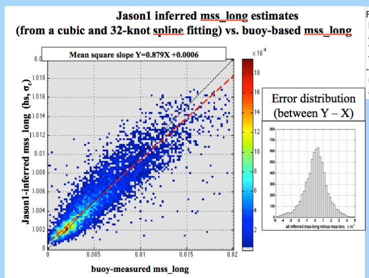


Fig. at left: Comparison between buoy and Jason-1 altimeter derived slope variance using a high frequency gravity wave cut-off of 0.4 Hz. The algorithm uses C-band backscatter and SWH data.

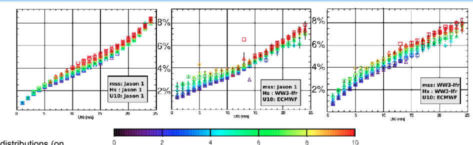
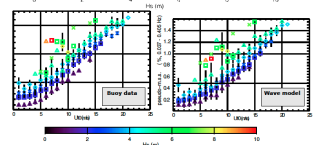


Fig. at right: comparison of mss distributions (on the vertical) as a function of wind speed (U10) and significant wave height (Hs) for the year 2008. **Top row**, for the global ocean, on the left is the distribution using only Jason data, but this means that the wind speed is not an independent estimate as it is derived from sigma0 and Hs using a geophysical model function. In the central plot, U10 is given by ECMWF analyses and on the right, mss and Hs are given by the wave model. The **bottom row** is for the buoy 46013, Central California using (a) the buoy data and (b) the wave model, using a high frequency cut-off at 0.4 Hz.



IV. Application : wave model predictions of mean square slope for use in Aquarius salinity measurements

The question: Does unresolved ocean long wave roughness (slope variance) lead to error in the Aquarius L-band radiometer salinity estimates?

Key altimeter role: The wave model data we are using is specifically trained/validated using global altimeter slope variance data – the only known global data source

Methods

- Coregister 3 hourly the above validated operational wave model data (including significant wav height, wave period and slope variances) with each Aquarius beam measurement
- Evaluate Aquarius L-band scatterometer and radiometer sea surface observations for varied wind and wave conditions to develop a model function and order of magnitude for long wave impacts
- Compare results with ESA SMOS project findings as well as AMSR-E and altimetry (under the project of S. Brown of JPL)
- Incorporate wave model data into the operational salinity retrieval algorithm

Preliminary Results

While early in the process of radiometer calibration, the data indicate some key features:

- the perturbation of the slope variance field due to long waves, when mapped globally (see below), shows fairly strong zonal variability that may indicate a systematic zonal error potential in the Aquarius salinity estimates
- the amplitude of such an error is partially inferred from the scatter plots of the radiometer and scatterometer measurements; it is apparent that increased slope variance at a given ocean wind speed below 7 m/s is causing increased emissivity and the observed variations translates to 0.1-0.2 psu error
- another important issue is the incidence angle variation (left to right in the figures) are not same for the scatterometer and radiometer measurements

Radiometer-measured emissivity at a given wind speed is increasing with total slope variance (at right):

- an expected result at both polarizations and all beams
- Δemiss increase of 0.001 -> ~ 0.1-0.2 psu salinity increase

Scatterometer-measured backscatter at a given wind speed is increasing with increasing total slope variance (at bottom right):

- the effect decreases slightly from the inner to outer beam (left to right)
- impact differences between radiometer and scatterometer are critical

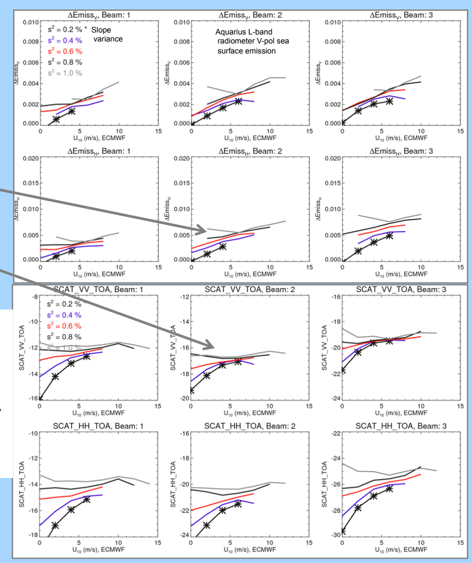


Fig. (Right): Aquarius satellite data averaged globally over the two week period of 25 Sep – 11 Oct. 2011 and plotted versus ECMWF wind speed and then bin averaged versus collocated wave model slope variance for :

a) Aquarius L-band radiometer measurements of rough surface emissivity (delta_emiss) at two polarizations (V-pol upper panel, H-pol lower) and three incidence angles (left to right)

b) Aquarius L-band scatterometer measurements of ocean backscatter (sigma0) at two polarizations (VV-pol upper panel, HH-pol lower) and three incidence angles (left to right)

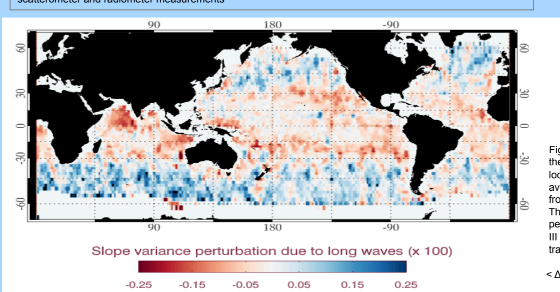


Fig (Left): Long-wave induced perturbation of the sea surface mean square slope for a given location – where perturbation is defined as the average deviation of mean square slope away from that due to wind over a two week period. The estimate is derived over a two week period , 25 Sep to 11 Oct using WAVEWATCH III model output along the Aquarius ground tracks.

$$\langle \Delta mss \rangle = \langle mss - mss_{wind}(U\_ecmwf) \rangle$$

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