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Improved Global CO_2 Flux Estimates Derived From Satellite Data

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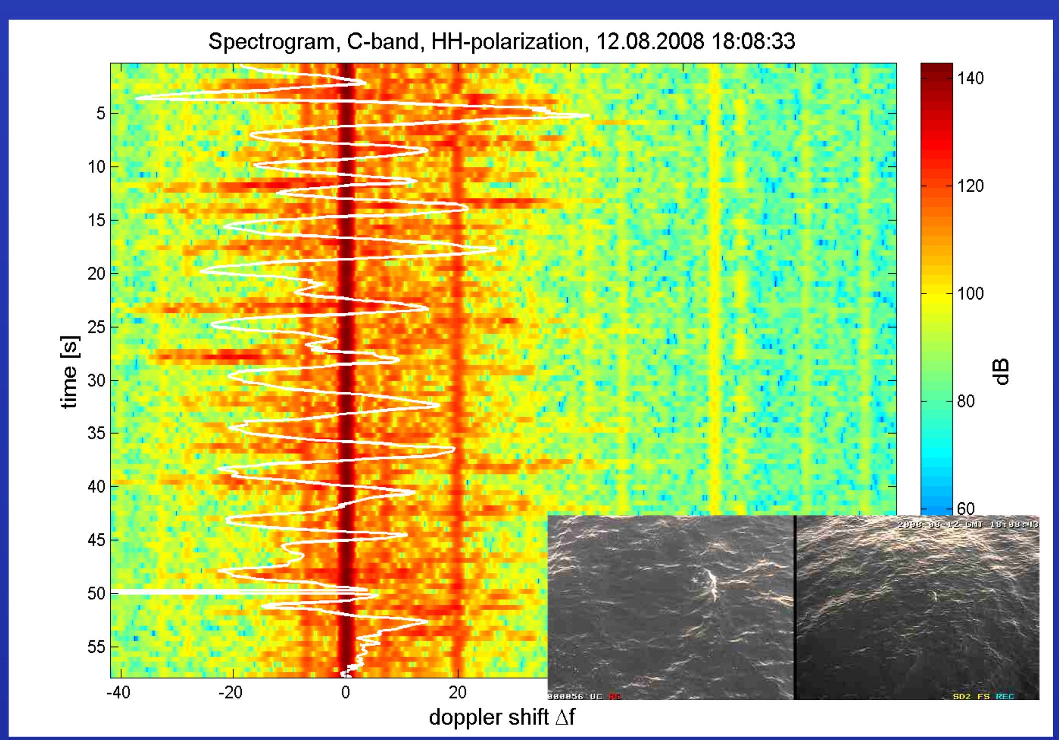
Abstract. Long-term scatterometer measurements are required to analyze seasonal variations of the wind-dependent radar backscattering from the ocean surface, and its link to the gas transfer velocity at the ocean-atmosphere interface. Therefore, our Multi³Scat measurements on FINO2 will be continued, and the continuously acquired data will be analyzed to find a direct link between the ocean radar backscatter and measured CO_2 fluxes. Since small-scale turbulence in the upper water layer plays an important role for gas fluxes, our investigation will include an analysis of those processes that enhance or reduce turbulence (e.g., wave breaking and marine surface films, respectively).

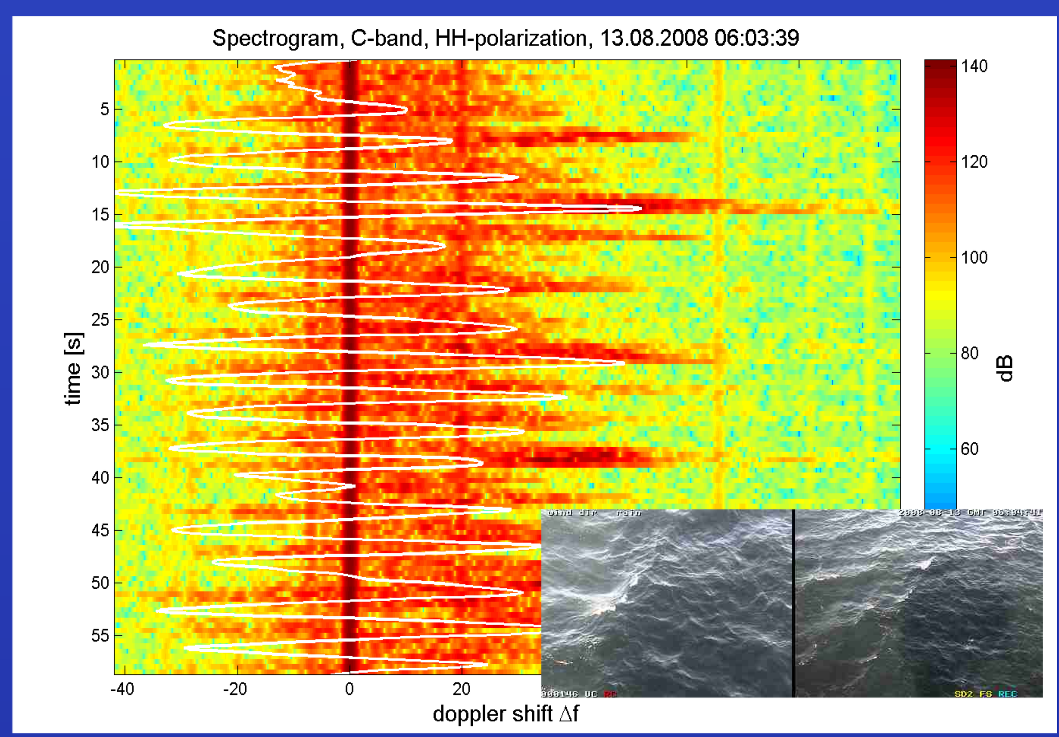
Our previous studies have revealed a 0.6 m/s bias of QuikScat winds with respect to ERS winds. While this is a global average, regional variations have been found that will be studied in more detail, also using data from new spaceborne scatterometers (aboard Oceansat-2 and Metop-A). The results, along with those from the scatterometer experiments and the analysis of high-resolution synthetic aperture radar (SAR) sensors such as the German TerraSAR-X or the Japanese PALSAR, will be used to provide important supplementary information during the cruise of RV Meteor in the Equatorial Atlantic.

Multi³Scat on FINO-2

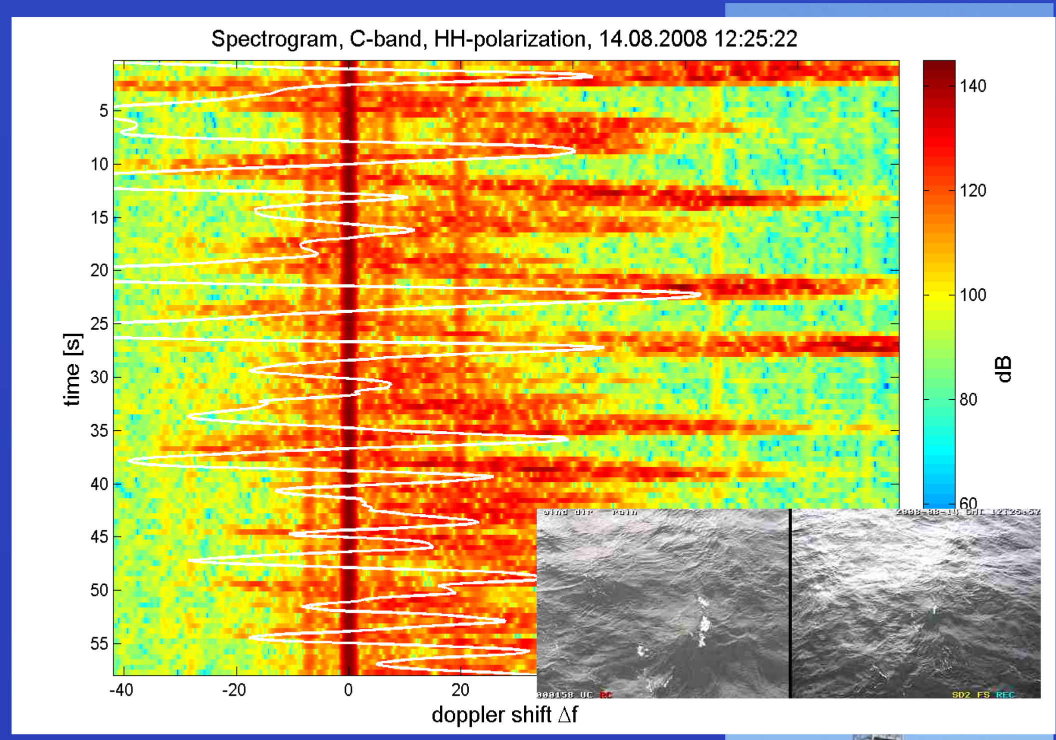
Wave breaking enhances the turbulence in the upper water layer, produces air bubbles, and therefore increases the gas transfer velocity significantly. Our goal will be to identify, and to quantify, breaking wave events through a thorough analysis of the Multi³Scat data from FINO-2. Three spectrograms are shown to demonstrate the effect of wave breaking on the backscattered radar signal. The data were acquired by Multi³Scat at C band, HH polarization, at different wind and wave conditions: From August 12 to 14, the wind speed increased from 7 m/s to 13 m/s (the wind direction was changing only slightly). Along with the increase in wind speed the frequency of wave breaking events increased, thus leading to an increased radar backscatter and Doppler shift.



Added to each panel are digital images of the radar footprint, which were taken simultaneously by a video camera mounted at the antenna frame. The solid white line added to each spectrogram represents the average grayscale values of the video images.

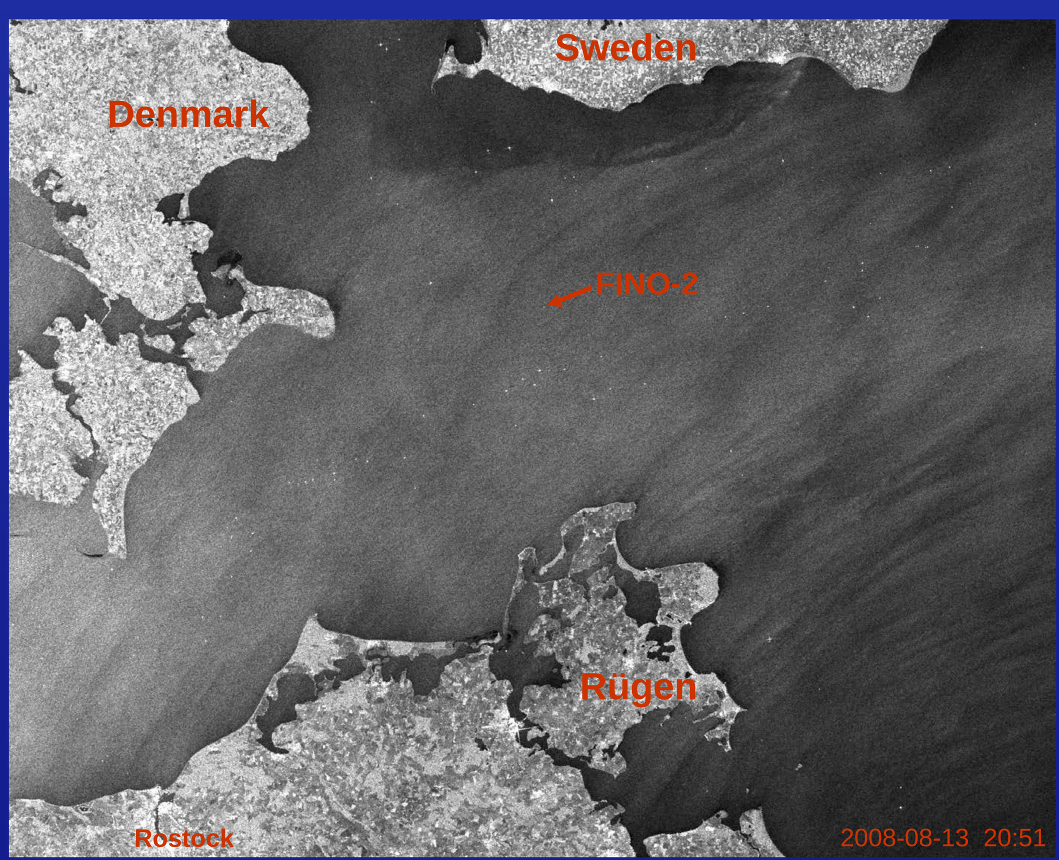


Both wind speed and sea state were moderate on August 12 (lower left panel), resulting in a moderate overall radar backscattering and low Doppler shifts. On August 13 (middle panel), the wind speed had increased to 11 m/s, but the sea state was still moderate. Thus, the radar backscattering from the small-scale (Bragg-) waves had strongly increased, but the undulation frequency and the Doppler shift variations remained moderate.



On August 14 (upper right panel), the wind speed was still high (13 m/s), but the sea state had grown significantly. As a result, the radar backscattering is as strong as on the day before, but the wave-induced undulation has changed: the undulation frequency is lower, and ist amplitude is higher.

These examples demonstrate the effect of wind and waves on the nature of the backscattered radar signal.



SAR Image Analyses

In order to complement our continuous scatterometer measurements on FINO-2, we will analyze high resolution data from spaceborne Synthetic Aperture Radar (SAR) sensors. As an example, an Envisat ASAR image of the Western Baltic Sea is shown on the left, which was acquired on August 13, 2008, at 2051 UTC. The image size is 195 km × 156 km, the pixel resolution is 75 m × 75 m. The location of FINO-2 is marked by the red arrow. High image brightness values correspond to a high radar cross section measured by ASAR (e.g., land, ships, or FINO-2); low brightness values correspond to a low radar cross section (e.g., wind streaks and wind shadowing off the coasts).

ASAR images of the FINO-2 site are regularly acquired and will be analyzed with respect to spatial variations in the radar cross section, and their dependence on the sensors' resolution: Multi³Scat data will be compared with high-resolution SAR data (with pixel sizes of o(6 m)), and medium-resolution SAR data will be compared with the gas flux measurements on FINO-2 and with low-resolution scatterometer data from spaceborne sensors. Thus, the SAR image analyses will help linking the scatterometer measurements performed at different scales (i.e., from FINO-2 and from satellites).
In addition, SAR data from the Meteor cruise in the Equatorial Atlantic will be analyzed.

Reference Data Set of Global CO_2 Fluxes

In order to derive similar global CO_2 fluxes from the QuikSCAT and the ERS wind speeds it is crucial to intercalibrate the two wind fields. Compensating for the observed bias is a first step, but the regional variations in the observed differences between QS_new and ERS-1 wind fields (see the right figure) need to be also taken into account.

The analyses of global wind fields will be extended, firstly, by including scatterometer data from other satellite missions such as the European MetOp and the Indian Oceansat-2, and secondly, by comparing ERS and QuikSCAT wind speeds to model wind speeds from NCEP and ECMWF.

Our global CO2 flux estimates will be refined by substituting the climatology of $dpCO_2$ from Takahashi et al. [2002] by numerical model results of global monthly mean fields of $dpCO_2$ for the entire period of interest (from 1991 onward).

Global Level-1B scatterometer data (i.e., normalized radar cross sections) will we used to derive improved global CO_2 flux estimates using the results from our experiments on FINO-2.

Reference:

Hinrichs, I., M. Gade, and D. Stammer (2009), Global time series of CO_2 fluxes across the ocean surface derived from spaceborne scatterometer data. In preparation.