SOPRAN 4.4

Towards an Empirical Relationship between the Normalized Radar Cross Section from and the CO_2-Flux across the Water Surface

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Summary: In the past, estimates of global CO_2 fluxes across the ocean-atmosphere interface were calculated using scatterometer-based wind speed data. Since the relationship between the normalized radar cross section (NRCS) at the water surface and the wind speed is error prone as is connection between wind speed and the CO_2 transfer velocity, the derived global CO_2 fluxes are also inaccurate. The aim of this project is to find an improved, direct relationship between the NRCS and the CO_2 transfer velocity. We present first results of this effort. To produce a surface CO2 flux reference data set for the period 1991 through 2007 we used historical global wind speed data from the ERS-1/2 scatterometers and Quikscat, together with global CO_2 partial pressure difference data from Takahashi et al. (2002). Starting in July 2008, routine scatterometer measurements, in parallel to gas transfer measurements, are performed from the platform FINO-2 in the Baltic Sea using the Multi³Scat instrument of the University of Hamburg. This experiment will provide a set of data, wich will be used to infer a direct relation between scatterometer data and surface CO_2 fluxes.

Approach

For calculating CO_2-fluxes across the air-sea interface it is essential to know the gas transfer velocity **k** which is a function of wind speed **u**. If not measured in situ, wind speed can be derived from the roughness of the sea surface. The normalized radar cross section (**NRCS**) measured by a scatterometer (see box below) is a measure of the roughness. Since both, the relation of the **NRCS** and **u** and the relation of **u** and **k** are rather inaccurate, we try to find a direct empirical relationship between **k** and **NRCS**. Figure 1 gives an overview of the approach.

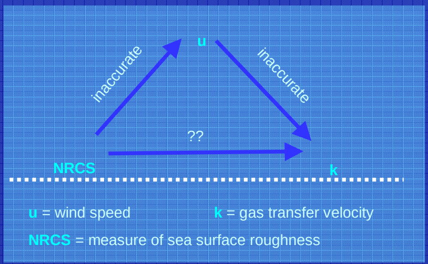


Figure 1:Schematic sketch of the relations of the NRCS, the wind speed and the gas transfer velocity.

CO_2 Reference data set

A reference data set of global CO_2 fluxes was created. The flux F of carbon across the air-sea interface, $F = k*s*\Delta pCO_2$, is the product of gas transfer velocity k, solubility s and the difference in CO_2 partial pressure between atmosphere and ocean ΔpCO_2. For calculating the flux, k was derived from wind speeds measured by scatterometers flown on the satellites ERS-1, ERS-2 and QuikScat. For $\Delta pCO2$ and s we used a climatology created by Takahashi et al., 2002. Besides monthly maps of CO_2-flux, monthly global netfluxes were calculated, shown in figure 2.

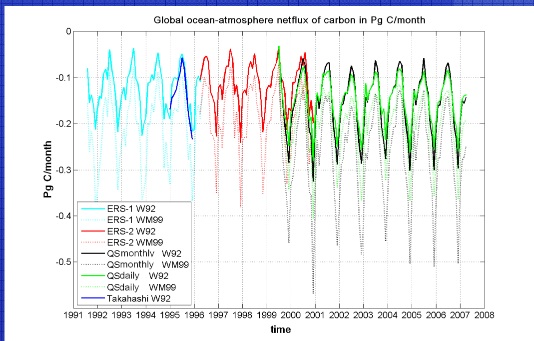


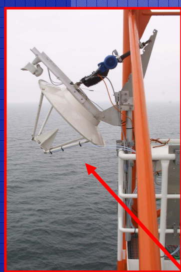
Figure 2:
Gobal CO_2 netfluxes calculated from the Takahashi climatology and the wind speeds. This figure shows negative netfluxes, that means a global flux of CO_2 into the ocean. A seasonal variation ist clearly visible. Considering the fact, that the Takahashi-climatology was designed only for one year, it is unlikely, that the global netfluxes calculated over a time period of several years represent the truth.

Scatterometer

A scatterometer is an antenna which emits electromagnetic waves (em- waves) and measures the backscattered power. The rougher the surface exposed to the em-waves, the higher the backscatter. Thus, scatterometers can measure the roughness of a surface, for example the sea surface.
The backscattered power is also dependant on the frequency and the polarization of the em-waves and the incident angle at which the em-waves hit the surface of the object.
The roughness of the surface is expressed by the dimensionless normalized radar cross section (NRCS) which characterizes the backscatter capacities of the surface, regardless of the emitted power of the antenna and the distance between the antenna and the object.
Spaceborne scatterometers are currently flown,for example, on the satellites ERS-2 (C-band) and QuikScat (Ku-band). They provide routinely global measurements of the NRCS of the sea surface. From the NRCS, geophysical model functions can calculate windvectors over the ocean.

The Multi³Scat

The scatterometer of the University of Hamburg, called Multi³Scat, was designed to work in five different frequency bands (L, S, C, X and Ku) and to be operated in different incident angles. The emitted em-waves are horizontally and vertically polarized.
So far, two similar systems are existing: one can be flown on a helicopter and, since July 2008, the other one is deployed on the research platform FINO-2 in the Western Baltic Sea, routinely measuring the sea surface backscatter.
Via a satellite internet connection the system can be controlled and random samples can be taken. The data recorded by the system are saved on external hard disks which need to be changed regularly.



The Multi³Scat of the University of Hamburg (platform version)

First results

As an example, a one minute long continous measurement of the backscatter is presented here. Figure shows the variation of the power spectral density in time. From the Doppler shift of the received signal it is clearly visible that the movement of the water surface had a stronger component towards and a weaker component away from the antenna. It can also be seen that the signatures alternate in time. This can be explained by the orbital movements of waves propagating towards the antenna.
Integrating the power spectral density over the time and the frequency range of the signal yields a measure of the sea surface backscatter during the time of the measurement. This in turn can be converted into the normalized radar cross section (NRCS) which can then, for example, be compared to an NRCS measured by a spaceborne scatterometer. A NRCS-time series will also be analysed together with a time series of CO_2 fluxes, in order to find an empirical relationship between the NRCS and the gas transfer velocity k.

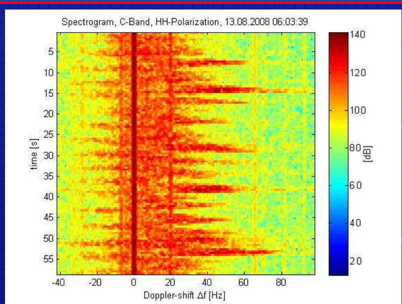


Figure : Variation of the power spectral density in time: positive Doppler-shift indicating a movement towards and negative Doppler-shift indicating movement away from the antenna.

FINO-2

This is a research platform located in the Western Baltic Sea (55°00' 25'' N, 13°09' 15'' E).