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Air-sea gas transfer at hurricane wind speeds

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Measuring the transfer of trace gases across the air-sea boundary at hurricane wind speeds in the field is extremely challenging and dangerous. Therefore, the Kyoto High Speed Wind Wave Tank and the Miami SUSTAIN wind-wave tank with wind speeds between 7 and 78 m/s were used to measure the gas transfer velocities of a multitude of tracers (including He, SF6, and DMS) spanning a wide range of solubilities and Schmidt numbers. Results obtained from three different campaigns are presented, where gas transfer velocities were measured with sea water, fresh water as well as with fresh water containing trace amounts of Butanol (simulated sea water), which changes the bubble spectrum to be comparable to that of salt water.

A new regime, in which the gas transfer velocity increases stronger than the friction velocity to the third power, starting at a wind speed of around 35m/s was found. In fresh water, bubble-mediated gas transfer contributes at most one third to the total gas transfer velocity even for the gases with the lowest solubilities (He and SF6). But the same steep increase of the gas transfer velocity is found for moderately soluble volatile compounds, where bubble contribution is negligible. Therefore, this strong increase is not caused by bubble-induced gas transfer.

For simulated sea water and sea water, bubbles contribute up to two thirds to the total gas transfer for gases with low solubilities. However, for gases with dimensionless solubilities larger than one, bubble contribution is not significant. High-speed image sequences of the water surface at hurricane wind speeds give a first indication of the mechanisms taking place. The steep increase in the gas transfer velocity is likely caused by a combination of strongly enhanced turbulence at the water surface and the enlargement of the water surface itself by various processes such as bag breakup, projections and bubbles bursting through the water surface. Further investigations are required to quantify these processes and their contribution to gas transfer in more detail.