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Enhanced air-sea CO_2 flux due to water-side convection

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In the global carbon cycle, the total exchange of CO_2 at the sea surface is important, due to a lack of detailed understanding of the controlling processes it is currently not very accurately described. The exchange of CO_2 between the ocean and the atmosphere is controlled by the air-sea difference in partial pressure of CO_2 (ΔpCO_2) at the surface and of the efficiency of the transfer processes. The partial pressure at the water surface is controlled by biological, chemical and physical processes in the water. The efficiency of the transfer processes is determined by the resistance to the transfer in the atmosphere as well as in the ocean. Since the diffusivity of CO_2 is much greater in the atmosphere than in the water, the largest resistance to the CO_2 transfer is by molecular diffusion and turbulent mixing in the aqueous boundary layer. The efficiency of the transfer processes is expressed by a transfer velocity, k. The transfer velocity is usually described by a quadratic or cubical wind speed dependence.

Direct flux measurements using the eddy-covariance method shows that the CO_2 transfer velocity is also a function of the mixed-layer depth of the water and, to a lesser degree, of the stratification of the atmosphere. The transfer velocity is significantly enhanced by a large mixed-layer depth, the enhancement increasing also as the surface cooling increases. This means that for strongly convective conditions in the water the transfer velocity of carbon dioxide increases significantly. The impact of mixed layer depth is expressed by the convective velocity scale of the water (analogous to atmospheric convective scaling).

Enhancement due to convection is important to capture for the diurnal cycle of air-sea fluxes. But large air-sea temperature differences (indicating the presence of water-side convection) also occurs due to advection of air masses. Specifically in small, or mid-size water basins, in the vincinity of a coast or in areas with large horisontal temperature gradients. We here investigate the importance for intermediate wind speeds. The impact during higher wind speeds is not analysed due to lack of data, it is possible that water-side convection is important also for higher winds-speeds.

The addition due to convection can be added to the traditional transfer velocity (k_U) as $k = k_U + k_c$, where k_c here is expressed as a function of the water-side convective velocity. In the presence of water-side convection, the resistance in the water is small. Then the relative importance of the atmospheric resistance increases and atmospheric processes must be taken into account.