Wave-Modulated Air-Sea Fluxes and Ocean Surface Turbulence

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Ocean surface processes, and air-interaction in general, have recently received increased attention as it is now accepted that small-scale surface phenomena can play a crucial role in the air-sea fluxes of heat, mass and momentum, with important implications for weather and climate. Yet, despite good progress in recent years, the air-sea interface and the adjacent atmospheric and marine boundary layers have proven to be difficult to measure in all but the most benign conditions. This has led to the need for novel measurement techniques to quantify processes of air-sea interaction. Here we present optical and infrared techniques aimed at simultaneously studying multiple aspects of the air-sea interface and air-sea fluxes. The instrumentation was tested and deployed during several field experiments from *R/P FLIP* and Scripps pier. We show that these techniques permit the detailed study of the ocean surface temperature and velocity fields and therefore heat flux and ocean surface turbulence.

It is well-known that ocean surface waves may support momentum transfer from the atmosphere to the ocean, but the role of the waves in heat transfer has been ambiguous and poorly understood. We present evidence that there are surface-wave-coherent components of both the sensible and latent heat fluxes. We present data from three field experiments that show modulations of temperature and humidity at the surface and at 10-14 m above the surface, that are coherent with the surface wave field. We show that the phase relationship between temperature and surface displacement is a function of wind speed. At 10-12 m elevation we found wave-coherent heat transfer of O(1) W m^{-2}, dominated by the latent heat transfer, and wave-coherent fractional contributions to the total heat flux of up to 7%. For the wind speeds and wave conditions of these experiments, which encompass the range of global averages, this wave contribution to total heat flux is comparable in magnitude to the atmospheric heat fluxes commonly attributed to the effects of greenhouse gases or aerosols. We expect the wave-coherent heat transfer to decay with height so that measurements at O(10) m elevation may underestimate the contribution of the wave-induced heat flux to the air-sea heat flux.

Using active and passive IR imaging techniques we measure the surface velocity field, including both wave-orbital motion and turbulence. We find modulations of the surface turbulence by the longer wind-waves and discuss results in the context of available theory and laboratory experiments.