Analysis of Infrared Measurements of Microbreaking and Whitecaps

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LONG-TERM GOALS

The long-term goals of this research are to develop infrared techniques for oceanographic remote sensing and apply those techniques to air-sea interaction studies.

OBJECTIVES

The primary objective of this work is to evaluate an active IR technique for remote measurement of heat flux. The secondary objectives are to determine if skin temperature modulation by swell waves is caused by modulation of microbreaking, and to correlate microbreaking waves with radar backscatter.

APPROACH

Our approach has been to analyze data from field and laboratory experiments. The field experiments from which data were used are the Fluxes, Air-sea Interaction, and Remote Sensing, or FAIRS, Experiment that took place on the R/P FLIP in 2000 off Monterey CA and the GasEx01 cruise that took place on the NOAA R/V *Ronald H. Brown* in 2001 in the Equatorial Pacific. Laboratory data used in the analysis were taken in the wind-wave tank at the NASA Wallops Island Flight Facility. Graduate student Ruth Fogelberg analyzed the passive IR data from FAIRS. Postdoctoral fellow Mohamed Atmane analyzed the active IR data from FAIRS and GasEx01.

WORK COMPLETED

The data analysis for FAIRS and GasEx01 have been completed. A manuscript on the measurements of heat flux using the active technique has been submitted. Ruth Fogelberg completed her MS thesis using data from the FAIRS experiment. Postdoctoral fellow Mohamed Atmane analyzed the data from Wallops Island. Graduate student Kapil Phadnis has also worked on the laboratory data.

RESULTS

During the past year, our efforts focused primarily on analysis of the active infrared measurements. In the absence of downwelling solar radiation, the net air-sea heat flux, Q_{NET} may be written in terms of the heat transfer velocity, k_H, and the temperature difference between the surface skin layer and the bulk ocean water, ΔT as

$$Q_{NET} = -k_H \rho C_p \Delta T \qquad (1)$$

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14. ABSTRACT

The long-term goals of this research are to develop infrared techniques for oceanographic remote sensing and apply those techniques to air-sea interaction studies.

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where ρ and C_p are the density and heat capacity of seawater, respectively. Here the heat flux is defined as positive upward from the ocean to the atmosphere and $\Delta T = T_{skin} - T_{bulk}$. The active controlled-flux technique [*Haußecker and Jähne*, 1995; *Haußecker et al.*, 1995; *Jähne et al.*, 1989], or ACFT, was used to measure k_H and ΔT was measured using a radiometer and a thermistor. ACFT measures the decay rate of the temperature of a small patch of water surface that has been heated a few degrees using a CO_2 laser. This decay rate is then assumed to be equal to the surface renewal timescale, τ, so that a transfer velocity for heat, k_H, can be calculated using surface renewal theory.

The ACFT analysis technique developed by *Atmane et al.* [2003] was used to produce a temperature decay curve for each patch in an image sequence. These decay curves were then ensemble averaged and a decay timescale for each sequence was calculated using a Monte Carlo method. The inverse of this decay timescale was taken as the surface renewal rate and used to calculate k_H. The resulting heat transfer velocities referenced to a Schmidt number of 660, $k_H(660)$, using (1) are shown versus wind speed, U_{10}, in Figure 1. The overall agreement between the two experiments is excellent; especially when we consider that the measurements were made in widely separated geographic locations, from different platforms (stable platform versus moving ship), and under significantly different environmental conditions.

Figure 2 shows the ACFT-derived net heat flux given by (1), Q_{ACFT}, plotted versus the measured net heat flux Q_{NET} for all available nighttime data from both FAIRS and GasEx-01. During both FAIRS and GasEx-01, Q_{NET} was measured by J. Edson and W. McGillis (WHOI). For both data sets, the two measurements of net heat flux are correlated, with correlation coefficients of 0.60 and 0.51 for FAIRS and GasEx-01, respectively, based on the regression lines shown. The FAIRS data, which cover a wider range of stability conditions, are more scattered. Nonetheless, the correlation between these two independent data sets is striking and strongly supports the validity of (1) in parameterizing the net heat flux at the air-water interface.

IMPACT/APPLICATIONS

The results demonstrate our ability to use the active IR technique in the field and its potential to provide a remote measurement of the net heat flux. The successful field use of the active IR technique suggests the possibility for airborne applications to detect features with turbulence greater than the background.

RELATED PROJECTS

This project is related to a NSF grant that is a collaboration with W. Asher (APL-UW) studying gas transfer.

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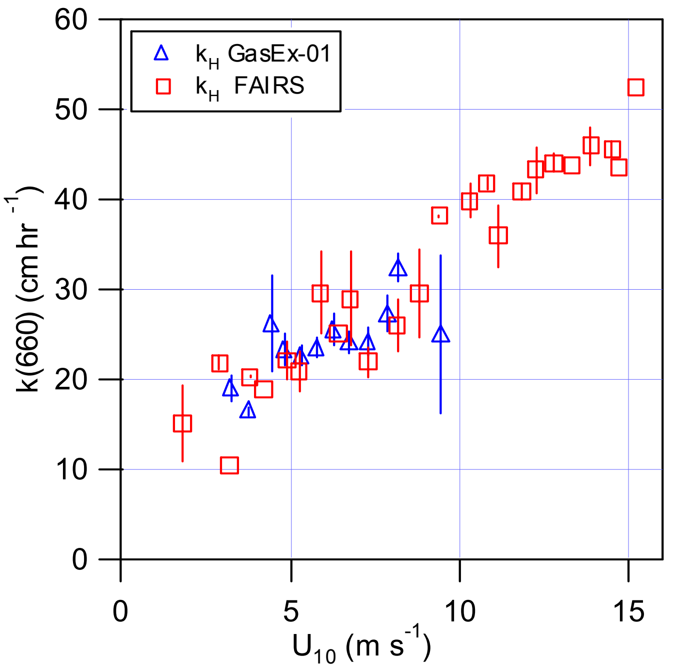

Figure 1. Heat transfe velocity, k_H(660), versus wind speed, U_{10} for FAIRS and GasEx01. For both experiments, k_H increases linearly with wind speed and there is good agreement between the experiments.

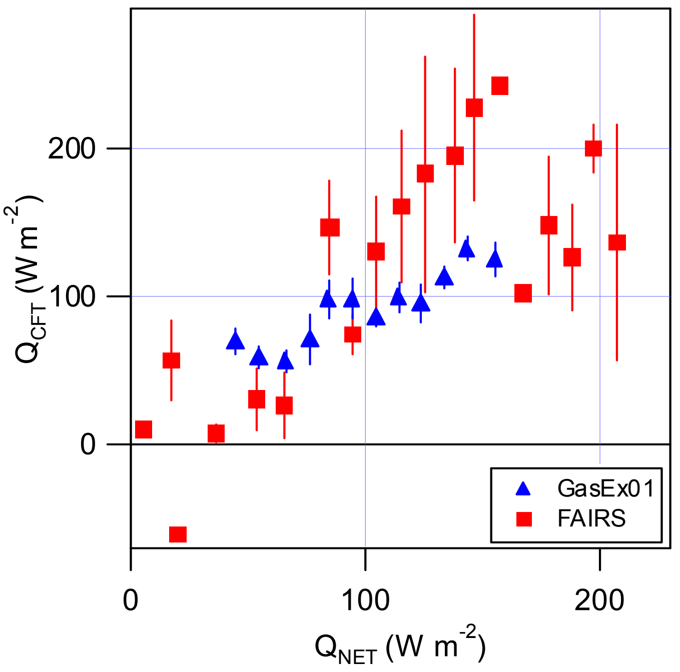

***Figure 2.** Net heat flux computed from ACFT, Q_{ACFT}, versus measured net heat flux, Q_{net}, for FAIRS and GasEx01. The data are correlated and there is good overlap between the data sets. There is more scatter at high value.*