The Effect of Waves and Wave Breaking on IR SST (321sr) and Modulation of Skin Temperature by Ocean Swell Waves (AASERT)

Andrew T. Jessup
Applied Physics Laboratory
University of Washington
1013 NE 40th St.
Seattle, WA 98105
phone: (206) 685-2609 fax: (206) 543-6785 e-mail: jessup@apl.washington.edu

Award # N00014-93-1-1326

LONG-TERM GOALS

This research is to develop infrared remote sensing techniques to quantify exchange processes at the air-sea interface utilizing similarity scaling for the fluxes of heat, gas, and momentum. The primary focus is to understand the spatial and temporal evolution of the ocean thermal boundary layer through infrared detection of the bulk-skin temperature difference. We also address the development of laboratory and in situ calibration techniques, which are essential to making measurements of useful accuracy.

OBJECTIVES

The objectives for FY98 are (1) to develop infrared imaging techniques to investigate microscale wave breaking and (2) utilize those techniques to quantify the role of microscale wave breaking in surface roughness modulation at scales relevant to infrared and microwave measurements.

APPROACH

The approach is to use field and laboratory measurements to quantify the variability of IR SST and as a guide to modeling the effect of waves and wave breaking. In addition to the PI, key personnel are: Mr. Chris Zappa, graduate student, Ms. Christine Richardson, graduate student, and Dr. Ellen Lettvin, post-doctoral fellow.

WORK COMPLETED

Work over the past year has focussed on preparation for the laboratory and field experiments that will take place in FY99.

1. With graduate student Mr. Chris Zappa and Professor Harry Yeh (Dept. of Civil Engineering, Univ. of Wash.), we reported on the skin layer recovery of free-surface wakes [*Zappa et al., 1998*].

2. Two laboratory experiments have been completed. The first at the University of Washington Wind Wave Tank was devoted to simultaneous IR, radar, and sonar experiments in collaboration with W. J. Plant and P. H. Dahl. The second was a preliminary study of the modulation of skin temperature by long waves done at the NASA Wallops Island facility.

3. Preparations for the main laboratory measurement campaign at the NASA Wallops Island Air-Sea Interaction Facility have been completed. The measurement period is scheduled for November 1998.

Report Documentation Page					*Form Approved* *OMB No. 0704-0188*
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE **1998**		2. REPORT TYPE			3. DATES COVERED **00-00-1998 to 00-00-1998**
4. TITLE AND SUBTITLE **The Effect of Waves and Wave Breaking on IR SST (321sr) and Modulation of Skin Temperature by Ocean Swell Waves (AASERT)**					5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)					5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Washington,Applied Physics Laboratory,1013 NE 40th Street,Seattle,WA,98195**					8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)					10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**					
13. SUPPLEMENTARY NOTES **See also ADM002252.**					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**3**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

4. Preparation is ongoing for airborne measurements to be made in February 1999 using the NOAA Twin Otter during a pilot experiment for the Shoaling Waves DRI by W. J. Plant.

SCIENTIFIC RESULTS:

1. Skin Layer Recovery of Free Surface Wakes

The thermal signatures of free-surface wakes observed in the open ocean show that the recovery of the cool skin layer is related to the degree of surface mixing and to ambient environmental conditions. Wakes produced by two surface-piercing cables of O(0.01 m) in diameter are analyzed using infrared imagery. Under low wind-speed conditions when the swell and surface current were aligned, the wakes exhibited distinctive patchlike features of O(1 m) in diameter that were generated by the passage of individual waves. The time, t_*, required by the skin layer to recover from these disturbances is compared to the surface-renewal time scale τ used in heat and gas flux models. At low wind speeds, t_* is comparable to τ, but at moderate wind speed the agreement is poor. The spatial and temporal variations in the skin temperature of these wakes are related to a wave Reynolds number used to characterize the strength of the disturbance due to the waves. The recovery process is characterized in terms of the restoring internal energy flux, J_r, which is proportional to both the initial thickness and the thermal recovery rate of the skin layer and was found to be directly related to the strength of the surface disruption. Comparison of the wake results with laboratory and other field measurements of breaking waves implies that J_r is also a function of the net heat flux and background turbulence, which relate directly to the existing environmental conditions such as wind stress and sea state. Our results demonstrate that J_r may differ by several orders of magnitude, depending on the environmental conditions.

2. Laboratory Measurements of Microscale Wave Breaking

The preliminary measurements of skin temperature modulation by long waves were performed at the Wallops Island facility in preparation for the main experiment scheduled for November 1998. An Agema Radiance HS infrared imager was used to determine the modulation of microscale wave breaking by long waves. For a long wave frequency of 0.8-1.0 Hz and amplitude of 1-4 cm propagating with the wind, we observed significant modulation for winds greater than 5 m/s at a fetch of 5 m. When the long wave direction was opposite to the wind direction, the phase and character of the modulation changed significantly. Analysis of these preliminary results is ongoing and will be used in the design and execution of the main experiment.

IMPACT FOR SCIENCE

The potential significance of microscale breaking waves in radar backscatter has been indicated by recent efforts to model observations of microwave backscatter near grazing [*Trizna and Carlson*, 1996] and at large incidence [*Plant*, 1997]. Our previous results have shown that infrared techniques can be used to detect and quantify microscale wave breaking. The laboratory measurements will provided detailed information on the modulation of microscale wave breaking by long waves. The field measurements will provide the degree of microscale wave breaking that should lead to a quantiative evaluation of the role of microscale breaking waves in radar backscatter at large incidence angles.

RELATIONSHIP TO OTHER PROGRAMS OR PROJECTS

This work is related to a collaborative effort with Dr. W. E. Asher (APL-UW) to determine the role of microscale wave breaking in air-sea gas transfer. The relationship is that similar techniques and laboratory efforts are combined in order to reduce costs. During FY99, field measurements of microscale wave breaking will be made in conjunction with microwave measurements by Dr. W. J. Plant (APL-UW).

REFERENCES

Plant, W. J., A model for microwave Doppler sea return at high incidence angles: Bragg scattering from bound, tilted waves, *J. Geophys. Res.,102*, 21,131-146, 1997.

Trizna, D. B., and D. J. Carlson, Studies of dual polarized low grazing angle radar sea scatter in nearshore regions, *IEEE Trans. Geosci. Remote Sens., 34*, 747-757, 1996.

Zappa, C. J., A. T. Jessup, and H. Yeh, Skin layer recovery of free-surface wakes: Relationship to surface renewal and dependence on heat flux and background turbulence, *J. Geophys. Res., 103*, 21,711-722, 1998.

PUBLICATIONS

Zappa, C. J., A. T. Jessup, and H. Yeh, Skin layer recovery of free-surface wakes: Relationship to surface renewal and dependence on heat flux and background turbulence, *J. Geophys. Res., 103*, 21,711-722, 1998.