MICROWAVE BACKSCATTER SPATIAL VARIATIONS IN RESPONSE TO LOW WINDS AND OCEAN FRONTS

David E. Weissman
Hofstra University
Department of Engineering
104 Weed Hall
Hempstead, New York 11549
phone: (516) 463-5546, fax: (516) 463-4939, e-mail: eggdew@hofstra.edu
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LONG-TERM GOAL

This program seeks to observe and interpret the causes and attributes of low sea surface roughness levels, of the short and centimeter wave spectrum, using microwave radar scatterometry under high resolution conditions. A better understanding is sought for observations made from slow flying airborne platforms (blimps and small aircraft) that display rapid and intense changes in the surface radar cross section, within kilometer sized areas. We need to better identify, distinguish among and separate those attributes associated with surface chemistry, hydrodynamics (short wave generation, breaking and turbulence), air-sea interactions and current.

SCIENTIFIC OBJECTIVES

Using microwave radar cross section measurements to observe spatial changes in surface roughness, we have begun to identify those situations which are affected by variations of wind speed, friction velocity, air and sea temperatures, heat and moisture fluxes, surface slicks and/or surface currents. The quantitative analysis of the absolute and azimuthal measurements of the microwave backscatter (V-pol and H-pol) is being used to separate and quantify many different processes that occur at low-to-moderate wind speeds.

APPROACH

Comparisons among measurements of the sea surface backscatter, wind speed, air and sea temperatures and friction velocity, heat and moisture fluxes were made from a manned airship platform off the Oregon coast in October 1993 during a month long field experiment. The broad objective of the experiment was to observe air/sea interactions with high spatial resolution and temporal coincidence of numerous sensors, in a coastal environment.

This study seeks to observe spatial and temporal changes for sea surface roughness within submesoscale areas, using a K_u-band dual polarized CW, microwave scatterometer radar. One mode of the 14 GHz CW radar provides a full 360^o azimuthal scan every 60 seconds (simultaneous H & V-pol) at incidence angles of 20^o,30^o and 40^o degrees. This omnidirectional data record senses the angular variation of the 1 to 3 cm capillary wave spectrum for each sweep. The radar observations are accompanied by a wide range of auxiliary sensors to monitor the properties of the sea surface and the boundary layer. The blimp platform enabled the measurements of surface conditions that displayed rapid spatial variations along its path. Among the most interesting observations was the frequent large amplitude drops and rises of the azimuthally averaged radar cross section (between 20^o and 50^o incidence angles) associated with

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wind variations in the range from 1 to 4 m/s. It appears that this observation is the minimum wind speed threshold for wave generation, which is being measured on the ocean for the first time after having been studied previously only in indoor wave tanks. Also detected were changes in the RCS associated with gradients of the sea surface temperature and/or air temperature within constant low wind regions.

WORK COMPLETED

The radar cross section and auxiliary physical data collected during the October 1993 blimp flights, in which the radar operates with an azimuthal scan mode, has been fully processed to quantitatively analyze all the coincident measurements. Studies of the depth of angular variation have also been conducted. The interpretation of these azimuthal quantities in terms of wind and other physical conditions is in progress. In addition, the azimuthally averaged cross section is continuously monitored, and evaluated. Numerous features have been identified which serve as evidence that the roughness is being influenced by additional effects, besides the equilibrium wind or boundary layer quantities.

RESULTS

New insight into the physical mechanism responsible scatterometer wind sensing at low wind speeds is being gained. While electromagnetic theory indicates its dependence on the short gravity and capillary wave spectrum, measurements show that the hydrodynamics of these scatterers is more complicated than expected, and that a threshold for wave generation influences these applications. The numerical parameters for the closed-form scatterometer model functions which are used to represent these relationships (for individual polarizations and incidence angles) imply that these are continuous and monotonic functions. However, the measurements analyzed in this study indicate that at the level of 2 m/s, the character of this relationship changes dramatically because sharp drops (or increases) in the RCS of approximately 15 dB are usually observed. One obvious interpretation is that the physical mechanism for short wave generation is very different below this threshold wind speed level. At present, no single dynamical model or theoretical explanation exists which explains the short wave properties below 2 m/s.

The results presented here show the magnitude of the decrease (or increase) in the average radar cross section, when the instrument travels into or out of a low wind area, to be similar to that seen in indoor wave tanks. Several issues and explanations associated with this situation have been discussed by Kahma & Donelan (1988) and Plant & Donelan (1996). The low wind regions may or may not be associated with gradients of air or sea surface temperatures. This implies that these are not associated with the small viscosity changes that occur with sea surface temperature variations.

An overall observation of both of these anomalous observations is that the coefficients for momentum flux, heat and moisture flux behave very differently under low wind conditions (less than 4 m/s), and they cannot be reliably estimated using extrapolations of their dependencies in the medium wind regime.

IMPACT/APPLICATION

The results of this experiment challenge the basis for microwave radar remote of ocean surface winds at low speeds. It is concluded that several surface variables can affect the short wave spectrum and other roughness parameters, and thereby the measured RCS. This makes the inversion process more problematic than expected, when estimating the surface wind is a primary goal. These results also bear on the behavior of the drag coefficient at low winds. Recent studies indicate that Cd can increase as the wind speed decreases, but with wide fluctuations in magnitude probably due to the multi-variable dependence of the short wave spectrum.

A new opportunity now exists for studying the hydrodynamics of the threshold of wind wave generation in the open ocean using microwave radar, after its demonstration in indoor wave tanks.

RELATED PROJECTS

This research program is in close partnership with the program of Dr. Wlliam Plant and his colleagues at the Applied Physics Laboratory of the University of Washington.

REFERENCES

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