The Influence of Boundary Layer Dynamics and Thermodynamics on the Diagnosis of Near-Surface Wind Speed by Synthetic Aperture Radar

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LONG-TERM GOALS

Procedures have been developed which employ Monin-Obukhov and mixed layer similarity theory to produce Obukhov length (L), convective velocity scale, buoyancy flux, and a stability corrected wind speed from SAR-derived neutral wind imagery (Young and Sikora, submitted to *Monthly Weather Review*, 1998). These procedures are based on the variance and spectral shape of the neutral wind imagery. It is hypothesized that there is a static stability / mean wind speed limit in the usefulness of these techniques. The long term goals of the current research are to thoroughly test and document the usefulness of the above-mentioned SAR-MABL techniques under varying degrees of Bulk Richardson Number (R_b) in order to quantify and account for these potential problems.

OBJECTIVES

Convection in the marine atmospheric boundary layer (MABL) manifests itself as distinct coherent structures, such as kilometer-scale three-dimensional thermals. Momentum transfer from the convective MABL to the sea surface results in centimeter-scale sea surface roughening beneath and down-mean-wind of the bases of thermal downdrafts. In contrast, the sea surface beneath and down-mean-wind of the bases of thermal updrafts is less perturbed on the centimeter-scale. Microwave radar imagery of the sea surface, such as synthetic aperture radar (SAR), can reveal the existence of the convective MABL via a characteristic kilometer-scale mottled backscatter pattern that results from this sea surface roughening pattern (Sikora et al. 1995).

The aforementioned SAR imagery can be converted to neutral wind imagery using a standard transfer function. Two methods have been previously presented which employ Monin-Obukhov and mixed layer similarity theory to produce L, convective velocity scale, buoyancy flux, and a stability corrected wind speed from the SAR-derived neutral wind imagery (Young and Sikora, submitted to *Monthly Weather Review*, 1998). These procedures are based on the variance and spectral shape of the neutral wind imagery (based on the above-mentioned mottling).

The ability of SAR to reveal the existence of convection via the mottling is, among other things, a function of the MABL static stability (air-sea virtual temperature difference) and mean wind speed (R_b), equation 1);

$$R_b = \frac{(g/\overline{\theta}_v)(\overline{\theta}_{vz} - \overline{\theta}_{v0})}{2(\overline{u}_z / z)^2} \qquad 1)$$

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Here $\overline{\theta}_v$ is mean virtual potential temperature which is measured at height *z* and the surface (*z=0*) and $\overline{u}_z$ is the mean wind speed at height *z*.

In the presence of MABL convection, it is reasonable to expect that as the static stability and mean wind speed change, mottling variability will also change. An increase or decrease in MABL static stability will cause a corresponding decrease or increase in mottling variability, all else being equal. An increase or decrease in mean wind speed will cause a corresponding decrease or increase in mottling variability, all else being equal. It is therefore reasonable to expect that there is a static stability / mean wind speed limit in SAR's ability to detect the presence of MABL convection. This limit is when the mottling variability approaches zero but when the *in situ* observations indicate the MABL is still convective, not neutral.

In short, it is hypothesized that SAR is not a perfect convection finder. This poses a potentially serious problem when employing SAR for the above mentioned MABL techniques. The objective of the current research is to test this hypothesis.

APPROACH

The current research employs portions of twelve Radarsat passes acquired by The Johns Hopkins University Applied Physics Laboratory Ocean Remote Sensing Group. The meteorological conditions during the collection of these images cover a wide range of air-sea temperature difference and wind speed. This SAR imagery is being cross referenced with collocated *in situ* data from buoys and C-MAN stations, supporting remote sensing observations such as Advanced Very High Resolution Radiometer data, and operational numerical weather prediction model analyses. This collection of collocated data is being undertaken by Midshipman 1/C John Bleidorn under the supervision of the principal investigator. This collocated data will be used to diagnose R_b at different locations within each SAR overpass. This *in situ* data will also be used as input for the bulk flux algorithm described in Fairall et al. (1996) to calculate *L*. Corresponding measures of *L* will be calculated using the previously mentioned SAR techniques. Note that R_b is approximately equal to *z/L* for statically unstable conditions. The accuracy of the SAR-derived estimates of *L* under varying degrees of R_b will be quantified by direct comparison with the *in situ*-derived *Ls*.

WORK COMPLETED

From STATEMENT OF WORK of original proposal:

Task 1. Select appropriate SAR imagery from in-house collection at The Johns Hopkins University Applied Physics Laboratory (JHUAPL).
Who: Principal Investigator
Time: Summer 1998
Status: Completed

Task 2. Cross reference SAR imagery with collocated in situ, remote sensing, and modeling data.
Who: Midshipman 1/C John Bleidorn and Principal Investigator
Time: Summer and Fall 1998
Status: Nearing Completion

RESULTS

The current research is ongoing. Preliminary results are expected by Spring 1999 per STATEMENT OF WORK of original proposal. These preliminary results will be presented at the *13th Symposium on Boundary Layers and Turbulence*, Dallas, TX, 10-15 January 1999.

However, the principal investigator has co-authored a related paper with G. S. Young of Pennsylvania State University that was recently submitted for publication (see **PUBLICATIONS** below). This paper summarizes the above-mentioned SAR-MABL similarity theory techniques. This paper also presents results of the techniques from sensitivity tests and real data tests on SAR imagery over the Gulf Stream on a low wind day.

IMPACT/APPLICATIONS

The above-mentioned SAR-MABL similarity theory techniques have the potential to provide accurate MABL wind and flux measurements at a very high resolution. Verification of the usefulness of these techniques is important to those communities that would benefit from their implementation. These communities include synoptic-scale and mesoscale operational numerical weather prediction, global ocean wave prediction, and observational air-sea interaction.

TRANSITIONS

Because results are limited at the time of this writing, the above-mentioned potential applications of the current research have not yet been realized.

RELATED PROJECTS

The current research is natural progression of that presented in Sikora et al. (1995), Sikora et al. (1997), Young and Sikora (1998) and Young and Sikora (submitted to *Monthly Weather Review*, 1998) (ONR Grants N00014-90-J-4012, N00014-92-J-1585, N00014-93-1-0252, N00014-96-1-0375 and N00014-96-1-0978). The principal investigator is coordinating his research with the principal investigators of the previously mentioned ONR-funded research. In addition, the principal investigator has a burgeoning collaboration with Pierre Mourad of the University of Washington Applied Physics Laboratory and Bernie Walter of Science Applications International Corporation who have supplied the principal investigator with a Radarsat image of the Bering Sea.

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Young, G. S. and T. D. Sikora, Inferring Marine Atmospheric Boundary Layer Properties from Spectral Characteristics of Satellite-borne SAR Imagery; Part II, Current Relative Wind Speed and Turbulence Statistics. Submitted to *Monthly Weather Review*, 1998.

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IN-HOUSE/OUT-OF-HOUSE RATIOS

100 % of the work is out-of-house.