SEA SURFACE ROUGHNESS INFLUENCE ON SALINITIES OBSERVED WITH AN AIRBORNE L-BAND MICROWAVE RADIOMETER: MODEL INTER-COMPARISONS, VALIDATION AND IMPLICATIONS FOR SATELLITE SALINITY RETRIEVAL.

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1. INTRODUCTION

L-band microwave satellites SMOS and Aquarius, to be launched in 2009 and 2010, respectively, will determine Sea Surface Salinity (SSS) remotely in the deep ocean with a precision of 0.2 psu and resolution of order 100 km. However, the accuracy of the resulting SSS retrievals will depend crucially on corrections for the effects of Sea Surface Roughness (SSR). Roughness elevates L-band emission above that predicted by 'flat sea' emissivity models [1] by amounts comparable with those produced by typical salinity variations.

Surface roughness is influenced by capillary and short-period waves generated by the wind and wave-wave interactions over short time scales, larger wind-driven waves and breaking wave events that develop over intermediate time scales, and swell which is generated remotely [2]. Additional influence comes from sources that are not directly wind-driven, such as ocean currents and turbulence. A fair estimate of the wind-driven wave spectrum can be obtained from empirical models forced by vector winds. Emission enhancement above the level flat surface value results from tilted wind-wave facets exceeding the electromagnetic wavelength (6 cm for C-band, 21 cm for L-band), diffuse contributions near the Bragg scale, comparable with the wavelength and, in high wind conditions, white caps and foam. Short, Bragg scale, contributions are rarely represented in spectral models.

We report the results of two airborne STARRS field campaigns, VIRGO, conducted offshore from the coast of Virginia off the Chesapeake Bay Mouth and over the Gulf Stream, and COSSAR conducted in the northern Gulf of Mexico, off the Mississippi River delta. During these campaigns, brightness temperature data were acquired from the STARRS L-, C- and IR-band radiometers and in order to derive physical sea surface temperature, roughness and salinity. Our preliminary analysis [3] concentrated on evaluating independent measures of SST from the C-band radiometer. We extend that work here to assess the performance of possible L- and C-band empirical roughness correction models for use in salinity retrieval algorithms.

2. INSTRUMENTS AND METHODS

2.1. Instrumentation

The 6-beam STARRS L-band radiometer operates within a 24 MHz wide protected band, centered at a frequency of 1.4 GHz. The 15 deg wide antenna beams point downward to either side of the aircraft at +/- 7, 22 and 38 degree incidence angles. The C-band radiometer, with a single 20 deg wide beam pointing to nadir senses emission within 6 channels of frequency 5.2, 5.6, 5.9, 6.2, 6.6 and 7.1 GHz. The nadir-viewing IR radiometer measures thermal emission in the 8-14 and 9.6-11.5 micron bands. An integrated GPS receiver and 2-axis gyro provide UTC time and position, and aircraft attitude, respectively. For typical aircraft altitudes of 2600 m, the six L-band beams have 700-1100 m wide footprints spanning a 5.2 km swath.

2.2. Logistics

During VIRGO and COSSAR, STARRS was flown over NOAA NDBC weather buoys equipped with temperature, wind and wave measuring instrumentation. The flights approached these from various directions, altitudes and distances off shore. The altitude range of 3000-300 m corresponded to L-band beam spot sizes of 1.2–0.1 km, which gave progressively finer resolution in the STARRS/buoy roughness calibrations, to help determine the effects of spatial inhomogeneities in the wind/wave fields.

2.3. Methods

The wave spectra obtained from the NDBC buoy data only capture swell and longer wind-driven wave components. Results from previous experiments using a drifting wave buoy equipped with a short-wavelength measuring wire gauge and laser scanning system [4] are being used to extrapolate the spectra to higher wave numbers, to more fully cover wavelengths influencing L-band emissivity. The drifting buoy measured waves of length 1cm – 1m, which spans the Bragg scale. A variety of SSR emissivity models is being used, including two-scale and SSA/SPM asymptotic models. Initial model runs have been made using various empirical wave spectra, provided with the original model implementations. The models are now being modified to use our observed wave spectra, and the results are being used to validate the STARRS L and C-band observations, and NDBC buoy data.

3. RESULTS

Once validated against in situ buoy data, the STARRS C-band radiometer should provide an independent measure of SSR to be used to correct the L-band salinity retrievals. This approach is preferred because, unlike the L-band instrument, the C-band features multiple frequencies facilitating separation of environmental influences such as SST [3], enhanced sensitivity to roughness, and reduced sensitivity to salinity variations. The approach is analogous to using the Aquarius L-band scatterometer as an independent measure of the radar backscatter (and hence emissivity), of the surface, although the observing mechanisms (emission versus reflection) and frequency (C versus L-band) differ. The use of C-band for this purpose, is challenging, however, since sensitivity to wind-induced roughness is relatively low at wind speeds under 10 ms^{-1}, due to reduced white cap and foam coverage. During the STARRS flights, the C-band measurements provided a continuous record of multi-channel brightness temperatures. These are being used to develop roughness estimates for correlation with the L-band measurements to produce a measure of the roughness effect that is independent of the models under test. The L-band roughness correction models will thus be inter-compared and assessed against a C-band reference model. The best performing L-band models will be used to correct the STARRS L-band SSS retrievals for roughness influence.

4. CONCLUSIONS

Alternative L-band roughness correction models are being assessed against an empirical C-band roughness correction model. The 'best' L-band models will be applied to the STARRS L-band data to retrieve salinity in the presence of varying intensities of surface roughness. It is anticipated that the results of this study will assist in selecting appropriate roughness correction algorithms for retrieving SSS from the SMOS and Aquarius satellite data streams. The work will thus provide a basis for ongoing performance assessment of the baseline L-band scatterometer system (Aquarius) and independent wind/wave products (SMOS), under various sea states.

6. REFERENCES

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