WINDSAT: PASSIVELY MEASURING OCEAN VECTOR WINDS

Ian S. Adams, Peter W. Gaiser, Michael H. Bettenhausen, Li Li

Naval Research Laboratory
Washington, DC 20375

WindSat, aboard the Coriolis bus, was launched in January 2003 with the primary mission of evaluating the use of a polarimetric radiometer to provide measurements of the ocean surface wind vector and to serve as risk-reduction within the NPOESS program [1]. The use of polarization information beyond the principal polarizations (vertical and horizontal) is necessary for inferring ocean surface wind direction, with the polarization state described fully by the modified Stokes vector

$$\begin{bmatrix} T_v \\ T_h \\ U \\ V \end{bmatrix} \propto \begin{bmatrix} \langle E_v E_v^* \rangle \\ \langle E_h E_h^* \rangle \\ -2\mathrm{Re}\langle E_v E_h^* \rangle \\ 2\mathrm{Im}\langle E_v E_h^* \rangle \end{bmatrix}, \tag{1}$$

where E_v and E_h are the vertically and horizontally polarized electric fields, T_v and T_h are the vertically and horizontally polarized brightness temperatures, and U and V are the third and fourth Stokes brightness temperatures. To accurately retrieve wind direction, U and V must be calibrated so that uncertainties are below about 0.1 K [2]. In order to achieve these accuracies in the polarimetric channels, an ambitious calibration campaign was held after launch and additional calibration checks have been performed over the life of the mission. One particular component of the post-launch calibration exercises was a series of pitch maneuvers where the Coriolis was pitched $45°$ so that the WindSat field-of-view peered into deep space [3]. The pitch maneuvers confirmed that uncertainties of WindSat T_bs were within the pre-launch error budget, but the maneuvers uncovered some small along-scan biases.

Since the initial calibration period, NRL has worked to develop and refine a physically-based ocean retrieval algorithm [2]. The algorithm uses an optimal estimator to match measured brightness temperatures to a parameterized foward radiative transfer model. Recent improvements to this algorithm include an improved surface emissivity model for high wind speeds and an updated atmospheric radiative transfer model.

This paper will focus on the calibration of WindSat and the resulting vector wind products. The calibration corrections developed for WindSat will be reviewed, and special attention will be given to the results of the pitch maneuvers and how these results compare to other calibration analyses performed at NRL. Wind vector performance and utility will be described in detail [4], with a focus on the improvements to high wind retrievals [5, 6, 7]. This description will include an evolution of the ocean-surface vector wind products, highlighting the improvements from calibration and forward modeling. An overview of other applications of WindSat data, such as soil moisture retrieval [8], will also be presented.

1. REFERENCES

[1] P. W. Gaiser, K. M. St. Germain, E. M. Twarog, G. A. Poe, W. Purdy, D. Richardson, W. Grossman, W. L. Jones, D. Spencer, G. Golba, J. Cleveland, L. Choy, R. M. Bevilacqua, and P. S. Chang, "The WindSat spaceborne polarimetric microwave radiometer: sensor description and early orbit performance," *IEEE Trans. Geosci. Remote Sens.*, vol. 42, no. 11, pp. 2347–2361, Nov 2004.

[2] M. H. Bettenhausen, C. K. Smith, R. M. Bevilacqua, N.-Y. Wang, P. W. Gaiser, and S. Cox, "A nonlinear optimization algorithm for WindSat wind vector retrievals," *IEEE Trans. Geosci. Remote Sens.*, vol. 44, no. 3, pp. 597–609, Mar 2006.

[3] W. L. Jones, J.-D. Park, S. Soisuvarn, L. Hong, P. W. Gaiser, and K. M. St. Germain, "Deep-space calibration of the WindSat radiometer," *IEEE Trans. Geosci. Remote Sens.*, vol. 44, no. 3, pp. 476–495, Mar 2006.

[4] B. Candy, S. J. English, and S. J. Keogh, "Evaluation of hurricane ocean vector winds from WindSat," *IEEE Trans. Geosci. Remote Sens.*, vol. 47, no. 6, pp. 1632–1640, Jun 2009.

[5] I. S. Adams, C. C. Hennon, W. L. Jones, and K. A. Ahmad, "Evaluation of hurricane ocean vector winds from WindSat," *IEEE Trans. Geosci. Remote Sens.*, vol. 44, no. 3, pp. 656–667, Mar 2006.

[6] Y. Quilfen, C. Prigent, B. Chapron, A. A. Mouche, and N. Houti, "The potential of quikscat and windsat observations for the estimation of sea surface wind vector under severe weather conditions," *J. Geophys. Res.*, vol. 112, 2007.

[7] I. S. Adams, M. H. Bettenhausen, and P. W. Gaiser, "Passive microwave remote sensing of tropical cyclones," in *AMS 28th Conference on Hurricanes and Tropical Meteorology*, Orlando, FL, April 2008.

[8] L. Li, P. W. Gaiser, B.-C. Gao, R. M. Bevilacqua, T. J. Jackson, E. G. Enoku, C. Rüdiger, J.-C. Calvet, and R. Bindlish, "WindSat soil moisture algorithm and validation," *IEEE Trans. Geosci. Remote Sens.*, In press.