

COMPARISON OF GEOSAT AND GROUND-TRUTH WIND AND WAVE OBSERVATIONS: PRELIMINARY RESULTS

Preliminary results of the Naval Research Laboratory's validation of the wind-speed and wave-height data derived from GEOSAT's radar altimeter indicate that the wind speeds determined by GEOSAT are slightly higher than the ground-truth data below 6 meters per second and slightly lower than the ground-truth data for wind speeds greater than 6 meters per second. The significant wave height values from GEOSAT compare favorably with the ground-truth data.

INTRODUCTION

The Naval Research Laboratory has been conducting a validation study of wave-height and wind-speed data derived from GEOSAT. Sensor Data Record tapes from APL were forwarded to the Naval Surface Weapons Center, Dahlgren, Va., where data were screened, and tidal and atmospheric corrections and precise ephemeris data were added. The result was an Intermediate Geophysical Data Record tape that was received by the Naval Research Laboratory for the validation study.

Problems associated with comparing satellite data, which are spatially variable, to ground-truth station data, which are temporally variable, are well known. However, such constraints are inherent in this validation study.

Ground-truth data were derived exclusively from the buoy network of the National Data Buoy Office (Fig. 1). Many of the buoys are located in deep water far enough from shore so that the effects of land and seafloor on waves are minimal. Conditions also provide ample fetch for the wind-driven surface. Buoy data from foreign sources will be presented later. Satellite passes within 80 kilometers of a ground-truth station and within 90 minutes of a ground-truth observation were used in the comparison. Data were classified as "excellent" (the satellite pass being within 25 kilometers of the ground-truth station and within 30 minutes of the ground-truth observation), "good" (25 to 60 kilometers, 60 minutes), and "fair" (60 to 80 kilometers, 90 minutes). Data outside the limits of 80 kilometers and 90 minutes were not used.

WIND-SPEED DATA COMPARISON

The comparison between ground-truth station and GEOSAT wind-speed values is shown in Fig. 2. "Excellent" data are represented by squares, "good" data by triangles, and "fair" data by circles. A linear regression analysis did not provide a significant difference between any of the three data sets. Essentially identical

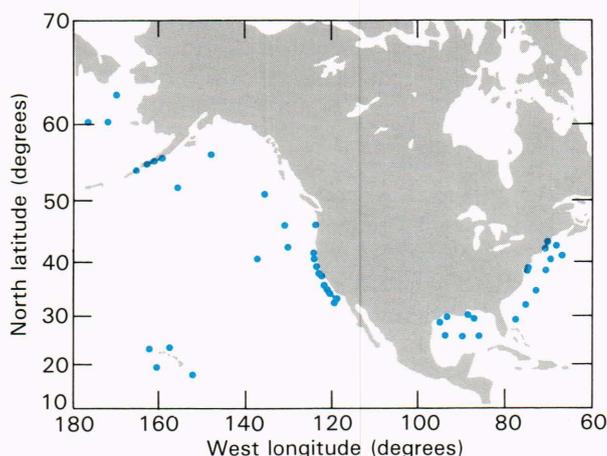


Figure 1—Buoy network of the National Data Buoy Office.

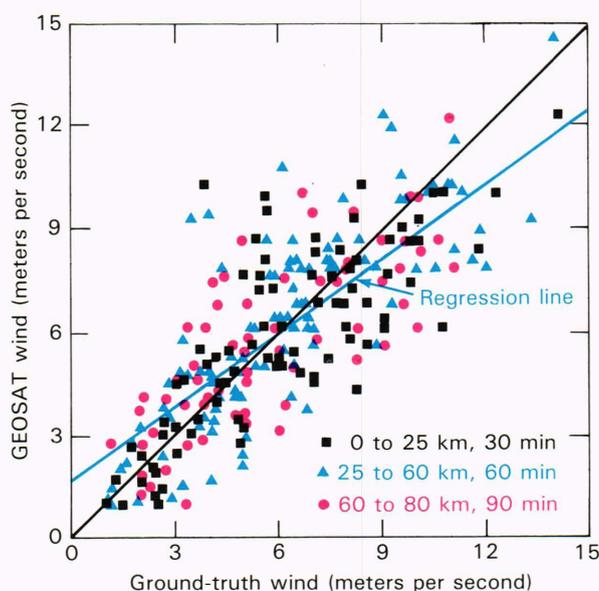


Figure 2—A comparison between GEOSAT and ground-truth station winds at 10 meters.

The authors are members of the Space Sensing Branch, Naval Research Laboratory, Washington, DC 20375.

“best-fit” lines and rms values were obtained for each data set when analyzed individually. The comparison used 276 data points with an rms error of 1.54 meters per second. From that limited data set, it appears that GEOSAT estimates are greater than buoy-measured speeds for wind speeds of less than 6 meters per second and that GEOSAT estimates are smaller than buoy-measured speeds for wind speeds of greater than 6 meters per second. However, based on the scatter seen in Fig. 2, the differences may not be statistically significant. Further analysis is being conducted to obtain comparison data for high-wind-speed conditions. Spatial variability is being studied to determine which comparisons may not be valid as a result of high variability along the satellite track line. Temporal variability at the ground-truth station itself is being assessed for each comparison to determine the validity of the comparison.

The algorithm used to determine wind speed¹ was based on 184 comparisons between GEOS-3 σ^0 and buoy wind-speed data. Buoy wind-speed data used by Brown et al., along with the curve used in their algorithm, are shown in Fig. 3. A similar plot of GEOSAT-observed σ^0 versus buoy wind data is shown in Fig. 4. The plots of the two databases, GEOS-3 and GEOSAT, are nearly identical when superimposed on one another.

An attempt was made to determine the effect of the off-nadir angle on the computation of GEOSAT wind speed. Comparisons between ground-truth and GEOSAT data were examined for the off-nadir angle range of 0.0 to 0.2, for each one-tenth-degree range from 0.2 to 1.1, and for greater than 1.1 degrees in order to determine whether the scatter of data points seen in Fig. 2 was a function of the off-nadir angle. There appears to be a correlation between the angle and poor wind-speed comparisons for angles greater than 1.1 degrees and a better comparison between GEOSAT and ground-truth data for angles of less than 0.4 degree. A histogram of off-nadir angles for the comparison data is shown in Fig. 5.

COMPARISON OF SIGNIFICANT WAVE HEIGHT DATA

Comparison values for the significant wave height between ground-truth stations and GEOSAT are shown in Fig. 6. Again, the same symbol convention is used for excellent, good, and fair data for the 332 data points in the comparison. Overall agreement between GEOSAT and ground-truth data was excellent. The first-order least-squares fit is shown in Fig. 6; it is very nearly the same as an identity line. The mean square error of the data set was 0.3 meter. This aspect of the satellite’s performance is extremely encouraging.

AIRCRAFT UNDERFLIGHTS

The GEOSAT satellite was underflown by the Naval Research Laboratory’s P-3 Orion aircraft, which was equipped with an Adaptive Wind/Wave Radar System. The system measures wave heights and wind speeds by analyzing the backscattered waveform. Interpretation is based on theoretical models of the effects of significant

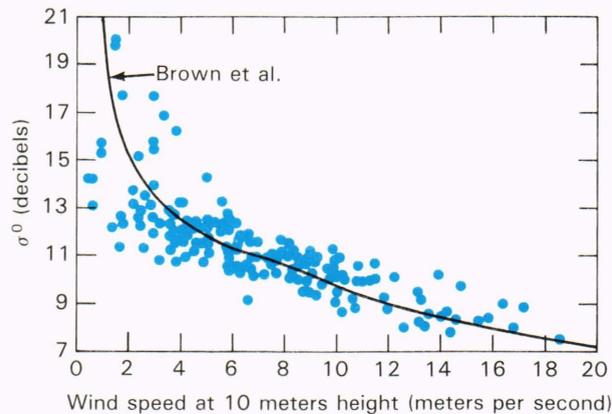


Figure 3—GEOS-3 σ^0 versus ground-truth wind speed at 10 meters. The solid curve is the Brown et al. wind model.¹

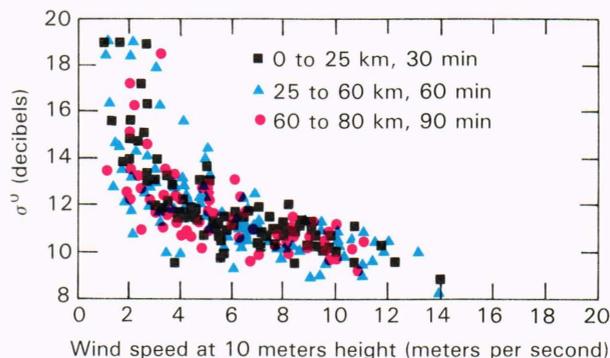


Figure 4—GEOSAT σ^0 versus ground-truth wind speed at 10 meters.

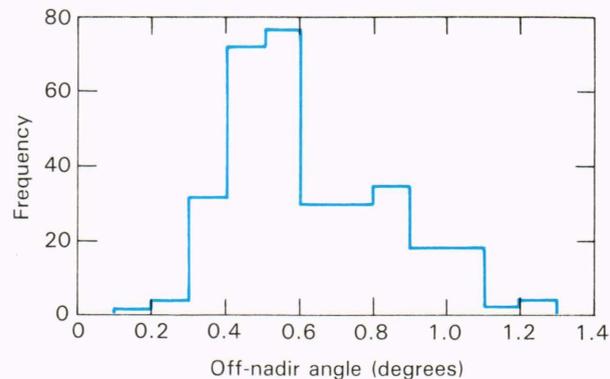


Figure 5—Histogram of GEOSAT off-nadir angles at the time of comparison between GEOSAT and ground-truth data.

wave height on the leading-edge slope and the effects of the rms sea-surface slope on the trailing-edge shape. The models include the radar system parameters of antenna beamwidth and pulse width.²

The comparison for an underflight of the satellite on April 24, 1985, when the satellite was passing over the Grand Banks of Newfoundland, is shown in Fig. 7. The track line was approximately 250 miles long. The aircraft flew at an altitude of 150 meters at a speed of about 100 meters per second, taking about 90 minutes to com-

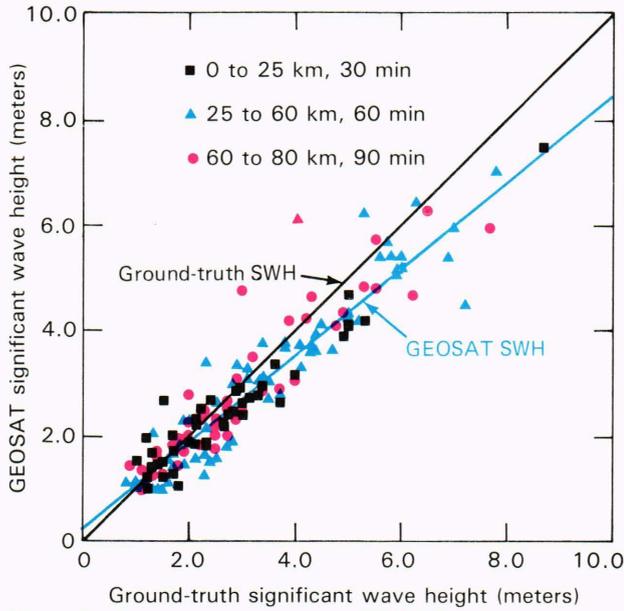


Figure 6—A comparison between GEOSAT and ground-truth significant wave height.

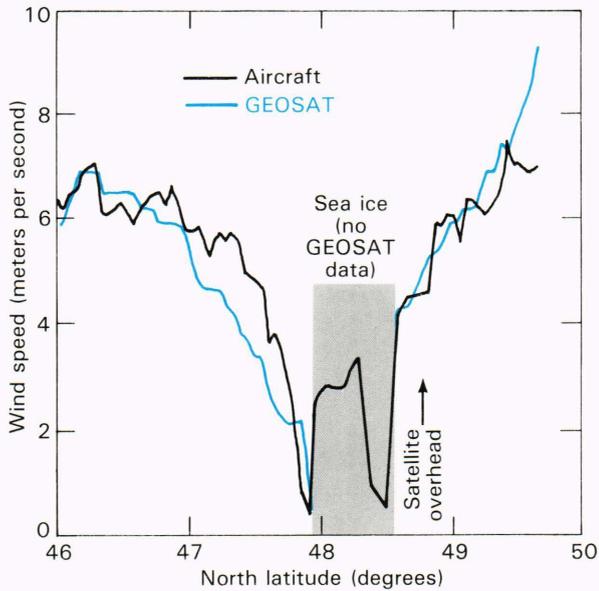


Figure 7—A comparison between GEOSAT and Adaptive Wind/Wave Radar System winds for April 24, 1985.

plete the transit. The satellite passed overhead about midway on the track line and took approximately one minute to cover the same distance. These data are in good agreement. Scattered sea ice was encountered along the track line, as is noted in Fig. 7. Since the footprint of the Adaptive Wind/Wave Radar System was about 150 meters, it was able to measure wind speed in the open wa-

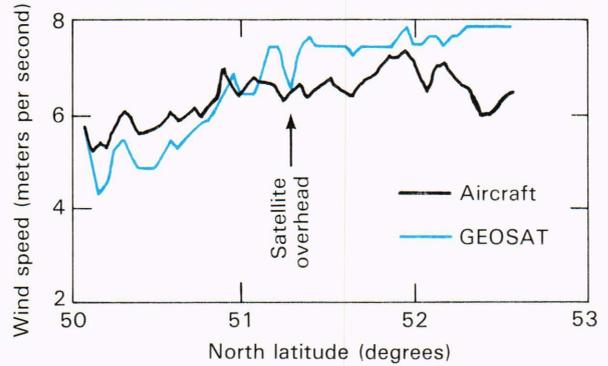


Figure 8—A comparison between GEOSAT and Adaptive Wind/Wave Radar System winds for August 13, 1985.

ter in the presence of the ice. However, since GEOSAT's footprint was about 4 to 5 kilometers (depending on sea state), GEOSAT gave no wind-speed data for that portion of the track line and flagged it as ice data.

Results of another underflight are shown in Fig. 8. Conducted on August 13, 1985, in the southern Indian Ocean, it provided results similar to those just described. Data from several other underflights are still being analyzed.

FUTURE WORK

Data from the Northern Hemisphere winter are being evaluated for higher wind and sea conditions, which will help define the nature of comparisons at the upper wind-speed limit. All indications are that significant wave-height data from GEOSAT are of excellent quality relative to available surface-truth information. Following a more extensive database, analytical effort, and study of the off-nadir angle, a determination will be made whether any changes are required in the wind algorithm.

Data from foreign sources are being evaluated to determine which are appropriate for wind-speed and significant wave-height validation. This is particularly important, not only with regard to GEOSAT, but in determining data quality for validating sensors to be flown on future Navy spacecraft. The experience gained in the GEOSAT validation will establish the operational viability of the remote sensing satellite data.

REFERENCES

- ¹G. S. Brown, H. R. Stanley, and N. A. Roy, "The Wind Speed Measurement Capability of Spaceborne Radar Altimeters," *IEEE J. Oceanic Eng.* **25**, 59-63 (1981).
- ²D. L. Hammond, R. A. Mennella, and E. Walsh, "Short Pulse Radar Used to Measure Sea Surface Wind Speed and SWH," *IEEE Trans. Antennas Propagat.* **25**, 61-67 (1977).