

IMPROVED SSM/I WIND SPEED RETRIEVALS AT HIGHER WIND SPEEDS

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ABSTRACT

Limitations in making SSM/I wind speed retrievals at higher wind speeds ($w > 15$ m/sec) are investigated and the primary sources of error identified. Whitecaps and foam give rise to systematic changes in the empirical transfer functions which are used in making SSM/I wind speed retrievals at higher wind speeds. The addition of the 85GHz(V) channel is shown to improve retrievals at higher wind speeds from the SSM/I. A new hybrid retrieval approach has been developed which combines a modified neural network (NN) architecture (including 85GHz channel) and modified training procedures with an independent correction for a residual systematic error in the transfer function which occurs at higher wind speeds. This hybrid approach has resulted in a weighted, bias-corrected NN algorithm with five inputs (the "OMB" algorithm). Applied to matchup data used in deriving previous SSM/I wind speed algorithms, this algorithm yields a bias < 0.2 m/sec and an rms difference < 1.75 m/sec for all wind speeds and weather conditions encountered in the matchup database, and a bias of ~ 0.7 m/sec and an rms difference of ~ 2.8 m/sec for wind speeds > 15 m/sec. The OMB algorithm is capable of generating wind speeds up to 25- 27 m/sec. It also yields an average gain in coverage of $\sim 15\%$, and significantly higher gains in coverage for individual synoptic events. This algorithm also reveals detailed structure in the patterns of surface wind speed not produced by other retrieval algorithms. It has been preliminarily validated using data from both the F10 and F13 SSM/I instruments. Finally, the application of surface winds retrieved using the OMB algorithm to atmospheric and oceanic forecast models is discussed.

1. INTRODUCTION

Ocean surface winds are required by operational marine forecasters to produce accurate surface weather analyses over the global oceans, and by atmospheric modelers for assimilation into global and regional weather forecast models. Since the late 1970's, both active and passive microwave radiometers aboard polar-orbiting satellites have been used to infer wind speed and, in some cases, wind direction over the ocean. Algorithms which have been developed to infer surface wind speed for these instruments such as the SMMR and the SSM/I, however, have been seriously limited in their ability to infer wind speeds under conditions of high atmospheric moisture or for wind speeds greater than ~ 15 m/sec. Because active synoptic weather systems, which are usually characterized by relatively high levels of moisture and higher-than-average wind speeds, are of primary interest to the operational forecasting community, it is important to develop wind retrieval algorithms which are “robust” both with respect to atmospheric moisture and wind speed.

Neural networks (NNs) have recently been used to develop wind speed retrieval algorithms based on brightness temperatures (TBs) received from the SSM/I flown aboard the DMSP satellites [Stogryn et al., 1994; Krasnopolsky et al. 1994, 1995]. Krasnopolsky et al. [1995; referred to as KBG, hereafter] developed a single, extended-range NN algorithm (SER NN) together with a wind speed retrieval flag based on cloud liquid water path (LWP) which retrieved wind speeds up to ~ 17 m/sec for moisture levels up to ~ 0.5 kg/m² with a small bias and an rms error of less than 1.7 m/sec.

Based on our previous work in establishing an acceptable rain flag criterion for the SER NN, we are approaching the upper limit for making SSM/I wind speed retrievals at higher levels of atmospheric moisture. However, it is likely that further refinements to the threshold value of 0.5 kg/m^2 can still be made when a more extensive database is created which includes significantly more matchups under high moisture conditions.

Another limitation of existing SSM/I wind speed retrieval algorithms is that they are primarily restricted to retrieving wind speeds with acceptable accuracy only up to 15 - 20 m/sec. Often, high wind speed events are accompanied by high levels of moisture (e.g., hurricanes), which preclude the possibility of making successful retrievals because the moisture threshold is exceeded. For lower levels of moisture, however, processes at the ocean surface which directly affect the emissivity of the air-water interface establish an upper limit for retrieving surface wind speed. In particular, as wind speed increases, wave breaking occurs which produces whitecaps and foam. Eventually, when the ocean surface becomes completely obscured by foam, microwave emissions from the surface no longer change as wind speed increases. Therefore, an additional physical limitation in retrieving SSM/I wind speeds, based on the wind speed itself exists, which limits the range of SSM/I wind speed retrievals to the interval $(0, w_{max})$. It is difficult to estimate the value of w_{max} from theoretical considerations alone; however, observational estimates indicate that this threshold occurs in the vicinity of 30 m/sec [Bortkovskii, 1987; Monahan and Mac Niocaill, 1986; Swift, 1990]. Clearly, based on these estimates, significant improvements can still be made to existing NN algorithms by extending their range of applicability from (0,16-17) m/sec, to (0,25-30) m/sec. In what follows, we describe a new NN algorithm with extended wind speed retrieval capabilities.