

WEATHER PATTERNS OVER THE OCEAN RETRIEVED BY NEURAL NETWORK MULTI-PARAMETER ALGORITHM FROM SSM/I¹

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ABSTRACT

New opportunities are now available for "operational" weather analysis and forecasting due to the new SSM/I neural network algorithms providing accurate and detailed fields of meteorological variables over the ocean, as well as due to the extensive global coverage by the increased number of available satellites. Neural networks at NCEP have gone through an evolutionary phase to improve ocean surface wind speed retrievals. The current version of neural networks has been expanded into a system that retrieves simultaneously four geophysical parameters: ocean surface wind speed, columnar water vapor, columnar liquid water, and sea surface temperature. Although, these variables have already been retrieved by other techniques, it is the simultaneous retrieval that is unique about the new algorithm, allowing the information from one variable to contribute to the improvement of the other variables (e.g., improved accuracy of wind speed retrievals at high wind speed). In fact, those wind speed data were recently incorporated as a part of the Global Data Assimilation System. These variables, when viewed together, can provide internally consistent information about synoptic weather patterns over the oceans. Several examples are presented which demonstrate that significant meteorological features like fronts, convective areas, areas with high probability of precipitation can be identified and observed in SSM/I fields retrieved by the new algorithm.

1.0 INTRODUCTION.

Beginning in 1987, a series of Special Sensor Microwave/Imager (SSM/I) instruments have been launched through the Defense Meteorological Satellite Program (DMSP). SSM/I sensors do not measure meteorological variables directly, but measure brightness temperatures from the ocean surface passively, which can be converted into geophysical parameters using transfer functions (retrieval algorithms). With the three satellites in orbit F11, F13 & F14 (each provides coverage over a particular ocean area twice a day) and the fairly wide swath coverage for each of the satellites (about 1400 km), extensive high-resolution coverage is now available over many ocean areas where there was almost no data before. These satellites have substantially increased the amount of "real-time" meteorological data over the oceans, which are used subjectively, by marine meteorologists to improve ocean surface weather map analyses, and objectively, by numerical analyses systems to provide initial conditions for numerical weather prediction models.

Empirical retrieval algorithms have been developed separately for various geophysical parameters such as surface wind speed (Goodberlet, et al, 1989; Petty, 1993), columnar water vapor (Alishouse et al, 1990) and columnar liquid water (Weng and Grody, 1994). The empirical transfer function is usually derived from a high-quality data set that collocates in time and space the satellite brightness temperatures with buoy and/or radiosonde measured geophysical variables. A satellite vs buoy collocated matchup data set requires a large sample in order to be representative of the wide range of possible global meteorological events. For example, high wind speed events have been fairly rare in most matchup data set because of the collocation requirements. Winds speeds of gale force (> 17 m/s) or greater at a given time cover no more than 5 % of the global ocean surface. Some of the

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initially developed retrieval algorithms are based on a simple statistical technique such as linear regression and, as a result, have limited retrieval capabilities. In reality, careful evaluations of the retrievals over a period of time are required to determine the weaknesses in the transfer functions. That requires validating the data under a wide range of meteorological conditions. Such validations invariably show that the initial algorithms have serious limitations in providing good quality data over regions where weather conditions are actively developing. Hence the necessity to examine the possibility of making improvements to the transfer functions arises (Gemmill et al., 1996).

The purpose of this paper is to discuss the new data sets that are now made available for "operational" weather analysis and forecasting using the latest SSM/I neural network algorithm. This algorithm provides detailed and accurate fields of meteorological variables over the oceans and the coverage is extensive because of the number of satellites that are current in operation. As mentioned before, the new neural network algorithm derives surface wind speed, columnar water vapor, columnar liquid water and sea surface temperature simultaneously from SSM/I brightness temperatures. Although these parameters have already been retrieved separately by other techniques, it is the simultaneous retrieval by the NN's that is unique, allowing the information from one parameter to contribute to a better estimate of the other parameters. These parameters, when viewed together, can provide internally consistent information about synoptic weather patterns over the oceans than when only a single parameter is used.

The following sections will summarize our work on using neural networks to improve the retrieval of marine variables from the SSM/I sensor. In Section 2 we briefly review recent algorithm developments at NCEP. In Section 3 we discuss possible approaches to interpret the data fields derived from SSM/I. Section 4 presents several examples which show that significant meteorological features like fronts, convective areas, areas with high probability of precipitations can be identified and observed in SSM/I fields retrieved by the new algorithm.

2.0 WORK ON IMPROVEMENT OF ACCURACY OF SSM/I RETRIEVALS AT NCEP

Most algorithms designed originally for SSM/I retrievals retrieve one variable at a time. The original global algorithm for retrieving surface wind speed from SSM/I was developed by Goodberlet, et al in 1989 (GSW algorithm). This algorithm is a linear regression type and is limited to low moisture conditions because, above a certain threshold, moisture in the atmosphere makes the retrieval problem nonlinear. Further, there were no wind speed observations above the moderate range (> 18 m/s) available in the matchup data set used in the formulation of the algorithm, so the GSW algorithm could not be expected to perform well at high winds. Because of these limitations, wind speeds cannot be accurately determined with this algorithm in areas with significant levels of atmospheric moisture (e.g., in tropics) and cannot be retrieved at all under the more active and critical weather situations such as storms and fronts. Petty (1993) introduced a nonlinear correction to GSW algorithm (GSWP algorithm) which improves the accuracy of the wind speed retrievals in areas with higher level of the water vapor (in tropics). Recently this algorithm became operational for shared data processing.

Several algorithms have been developed for columnar water vapor (Alishouse 1990; Petty 1993) and columnar liquid water (Weng and Grody, 1994; Weng et al., 1997). However, all these algorithms (including wind speed algorithms) have been developed independently using their own different data sets. They were formulated without taking into account co-dependency of these parameters and without accounting for their physical relationships.

For the past five years, NCEP has been working on improving the accuracy of SSM/I satellite derived ocean wind speeds, columnar water vapor, and columnar liquid water for both marine meteorology applications and numerical weather prediction (NWP). A series of algorithms (see Fig. 1) has been formulated using neural networks (NNs), each one more complex and accurate than the previous one. Neural networks were chosen because they have been highly successful in dealing with nonlinear problems, and hence, seemed to be an appropriate method to pursue to deal with high moisture conditions in deriving wind speeds initially. In 1994 (Krasnopolsky et al, 1994; 1995a), an initial NN algorithm (OMBNN1) was formulated using the same satellite