A NEW NEURAL NETWORK TRANSFER FUNCTION FOR SSM/I RETRIEVALS

V.M. Krasnopolsky[1], W. H. Gemmill[2], and L. C. Breaker[2]

A new neural network (NN) SSM/I transfer function (OMBNN3) which retrieves wind speed (W), columnar water vapor (V), columnar liquid water (L), and SST, using only satellite data (five SSM/I brightness temperatures) has been developed and compared with the current operational (GSW) [1] algorithm, NN algorithms developed earlier (OMBNN1 [2] and OMBNN2 [3]), and with a physically-based algorithm [4]. The new NN algorithm systematically outperforms all algorithms considered for all SSM/I instruments (F8, F10, F11 and F13), all weather conditions where retrievals are possible, and for all wind speeds in terms of wind speed retrievals. It also retrieves V and L with an accuracy close to that of a physically-based [4], the cal/val [5] (for V), and the Weng and Grody [6] (for L) algorithms, and produces low resolution SSTs with moderate accuracy. OMBNN3 demonstrates significantly better performance at higher wind speeds (and at higher latitudes) than previous NN-based algorithms. It generates wind speeds up to ~23 m/s for the available test data, and has a theoretical upper limit of about 32 m/s. Also, the retrieval accuracy for OMBNN3 does not depend significantly on the particular satellite and/or instrument.

Retrieving surface winds from the SSM/I has two physical limitations: (1) the level of moisture or cloud liquid water (CLW) in the intervening atmosphere, and (2) the extent of whitecaps and foam (WF) that covers the surface of the ocean. The transfer function becomes significantly nonlinear when CLW $\geq$ 0.1 kg/m^2, and virtually no signal reaches the sensor from the surface when CLW $\geq$ 0.5 kg/m^2 [2]. Secondly, the WF restriction also gives rise to nonlinear behavior of the transfer function at wind speeds higher than about 7-10 m/sec and also produces an upper limit in terms of the maximum wind speed which may be retrieved (~30-40 m/sec [3]).

The NN algorithm (OMBNN1) which we initially developed [2] covered the range of moisture levels $0 \leq$ CLW $<$ 0.5 kg/m^2. However, this algorithm still had high wind speed retrieval limitations, with the accuracy of retrievals dropping off significantly at wind speeds higher than 14-15 m/sec and in no case could it generate wind speeds >18 m/sec. An improved NN wind speed retrieval algorithm (OMBNN2) [3] retrieves wind speeds up to ~20 m/sec for CLW levels up to 0.5 kg/m^2. However, this algorithm requires a bias correction which is instrument dependent. The new OMBNN3 algorithm is based on a new hybrid retrieval approach which combines a modified NN architecture (5 inputs, 12 hidden units in one hidden layer and 4 outputs) and a modified training procedure. Applied to matchup data for three SSM/I instruments (F8, F10, and F11), this algorithm yields a bias < 0.3 m/sec and an rms difference < 1.8 m/sec for all wind speeds and clear plus cloudy weather conditions (see Table 1 for F10 statistics), and a bias of <1. m/sec and an standard deviation of <2.3 m/sec for wind speeds > 15 m/sec (Table 1). The OMBNN3 algorithm also yields an average increase in coverage of ~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, and

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[1] General Sciences Corp., Laurel, MD 20707, e-mail: wd21kv@sgi78.wwb.noaa.gov

[2] Ocean Modeling Branch, Environmental Modeling Center, National Centers for Environmental Prediction, Washington, D.C. 20233

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appears ready for operational testing. A FORTRAN program which implements the OMBNN3 algorithm is available upon request from V.M.K.

TABLE 1. Wind speed statistics for GSW [1], physically-based [4], OMBNN1 [2], OMBNN2 [3] and OMBNN3 algorithms for CLEAR plus CLOUDY conditions and separately for wind speeds > 15 m/sec. Columns 2 - 4 show statistics for the wind speeds per se, and columns 5 - 7 for the difference between buoy and algorithm-generated wind speeds. 6879 matchups from F10 matchup database were used. σ_w denotes standard deviation, SD denotes standard deviation for the difference, and CC denotes correlation coefficient.

TOTAL	Max W	Mean W	σ_w	Bias	SD	CC
Buoy	21.6	7.26	3.18	N/A	N/A	N/A
GSW	26.0	7.81	3.59	-0.55	2.15	0.80
Phys.-based	31.1	6.93	4.04	0.33	2.45	0.80
OMBNN1	16.4	6.42	2.53	0.85	1.74	0.84
OMBNN2	19.5	6.32	2.77	0.95	1.72	0.84
OMBNN3	22.5	7.57	3.18	-0.31	1.81	0.84

W > 15	Max W	Mean W	σ_w	Bias	SD
Buoy	21.6	16.8	1.51	N/A	N/A
GSW	26.0	17.1	2.95	-0.3	2.61
Phys.-based	31.1	16.2	3.31	0.6	2.88
OMBNN1	15.7	12.5	1.63	4.3	1.64
OMBNN2	19.5	13.9	1.78	2.9	1.93
OMBNN3	22.5	16.4	2.62	0.4	2.16

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