A NEURAL NETWORK FORWARD MODEL FOR DIRECT ASSIMILATION OF SSM/I BRIGHTNESS TEMPERATURES INTO ATMOSPHERIC MODELS

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A new neural network (NN) SSM/I forward model (FM) or geophysical model function (GMF) was developed which generates SSM/I brightness temperatures (BTs) at 19GHz (V and H), 22GHz (V), and 37GHz (V and H) given the wind speed (*W* in m/s), columnar water vapor (*V* in mm), columnar liquid water (*L* in mm), and *SST* (in °C). This OMBNNFM1 (Ocean Modeling Branch Forward Model number 1) has been developed to directly assimilate SSM/I BTs into atmospheric models. The NN SSM/I FM OMBNNFM1 has 4 inputs (*W*, *V*, *L*, and *SST*) one hidden layer (12 units), 5 main outputs (BT19V, BT19H, BT22V, BT37V, and BT37H), and also 20 auxiliary outputs which provide a 5 x 4 Jacobian matrix which is used in the process of direct assimilation of SSM/I BTs [1]. A FORTRAN program which implements the OMBNNFM1 is available upon request from the author.

OMBNNFM1 is an empirical GMF. About 3,000 buoy/SSM/I matchups for F11 instrument for clear plus cloudy conditions have been used for the FM development and about 3,000 for testing. Table 1 shows BT statistics for an independent F11 test set. The table contains statistics for five BTs (BT19V, BT19H, BT22V, BT37V, and BT37H), including minimum value, maximum value, mean value and standard deviation (σ_{BT}), together with these statistics for BTs generated by OMBNNFM1. The table also shows some statistics (bias, standard deviation (SD), and correlation coefficient (CC)) for the differences between SSM/I and FM-generated BTs.

Table 1. Test statistics for F11 BTs under clear + cloudy conditions. Columns 3 - 6 show statistics for the BTs per se (σ_T denotes standard deviation and each cell contains two numbers SSM/I / FM), and columns 7 - 9 for the difference between SSM/I and OMBFMNN1-generated BTs. SD denotes standard deviation, and CC denotes correlation coefficient.

Channel	Min BT	Max BT	Mean BT	σ_{BT}	Bias	SD	CC
19V	175.7 / 177.8	230.3 / 227.7	200.4 / 200.4	12.3 / 12.2	0.0	1.4	0.99
19H	96.7 / 99.7	184.8 / 181.2	136.6 / 136.6	18.9 / 18.8	0.0	2.5	0.99
22V	183.7 / 187.2	266.3 / 264.6	228.3 / 228.3	20.9 / 20.8	0.0	1.0	1.00
37V	199.4 / 201.4	243.3 / 242.3	216.5 / 216.5	8.8 / 8.7	0.0	1.4	0.99
37H	126.6 / 129.2	209.8 / 207.1	159.1 / 159.1	15.9 / 15.5	0.0	3.1	0.98

OMBNNFM1 was also validated for F10 SSM/I instrument and compared with a physically-based FM [2]. Table 2 shows BTs statistics for F10 validation set which consists of about 7,000 buoy/SSM/I matchups. Both OMBNNFM1 and physically-based models have been developed using the data from different instruments (F11 and F8 respectively).

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Table 2. Statistics for F10 BTs under clear + cloudy conditions. Columns 3 - 6 show statistics for the BTs per se (σ_T denotes standard deviation), and columns 7 - 9 for the difference between F10 SSM/I and FM-generated BTs. SD denotes standard deviation for the difference, and CC denotes correlation coefficient.

Channel	FM	Min BT	Max BT	Mean BT	σ_{BT}	Bias	SD	CC
19V	F10 SSM/I	174.4	230.5	200.9	12.4	N/A	N/A	N/A
	Phys.-based	175.6	224.7	199.6	12.2	1.2	2.4	0.98
	OMBNNFM1	177.6	227.3	200.2	12.0	0.7	1.7	0.99
19H	F10 SSM/I	95.4	184.7	138.2	18.9	N/A	N/A	N/A
	Phys.-based	98.6	178.6	137.1	18.3	1.1	3.9	0.98
	OMBNNFM1	99.7	181.4	136.0	18.4	2.2	2.6	0.99
22V	F10 SSM/I	180.3	263.7	228.1	20.7	N/A	N/A	N/A
	Phys.-based	184.9	261.6	227.9	20.9	0.2	2.3	0.99
	OMBNNFM1	186.8	263.4	227.7	20.6	0.4	1.2	1.00
37V	F10 SSM/I	199.5	243.6	217.3	8.9	N/A	N/A	N/A
	Phys.-based	198.8	236.3	214.9	8.2	2.3	2.4	0.96
	OMBNNFM1	201.2	241.9	216.2	8.5	1.0	1.6	0.98
37H	F10 SSM/I	124.9	209.3	160.2	15.7	N/A	N/A	N/A
	Phys.-based	125.5	196.4	156.4	13.9	3.8	4.8	0.96
	OMBNNFM1	129.6	206.9	158.6	15.1	1.6	3.1	0.98

For both F10 and F11 instruments, horizontal polarization channels 19H and 37H have highest SDs: ~3°K under clear + cloudy conditions (~2.5°K under clear) for OMBNNFM1. For the vertically polarized channels, the SDs are lower: ≤1.7°K under clear + cloudy conditions (≤1.6°K under clear). The same trend occurs for the physically-based FM; however, the SDs for the physically-based FM are systematically higher for all weather conditions and for all channels considered.

For the F10 instrument, biases for both FMs are also higher for horizontal polarization (especially for 37H). For all channels except at 19H and 22V, OMBNNFM1 has a smaller bias than the physically-based FM, and for 22V channel, both biases are small (< 0.4°K). These nonzero biases can be explained (at least partly) by the fact that both FMs have been developed using data from different satellites. The nonzero biases which these FMs produce, when applied to F10 data, may be due to slight calibrational errors or due to the ellipticity of the F10 satellite orbit. The wind directional signal may also contribute to this bias.

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