VALIDATION OF ATMOSPHERIC HEAT BUDGET PARAMETERS IN THE WESTERN INDIAN SECTOR OF THE SOUTHERN OCEAN

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Abstract:

The work reports validation of numerical weather forecasts (NWF), QuikSCAT-based wind speed and AMSR-E sea surface temperature (SST) for the surface atmospheric boundary layer in the Indian sector of the Southern Ocean under the International Polar Year. The database consists of wind speed, air temperature, relative humidity, sea level pressure collected along the ship route from Durban (32.4°S, 30.4°E) to India Bay (62.4°S, 18°E) and from Prydz Bay (69.35°S, 76.17°E) to Mauritius (20.15°S, 57.48°E) during February - March 2007. The NCEP-NCAR and ECMWF meteorological data have been validated. Both the NWFs overestimate mean sea level pressure by -5 to -12 mb; the root mean square difference (RMSD) ranges from 1.7 to 2.3 mb. The validation of air temperature yields a RSMD of 0.8°C and the correlation exceeds 0.9. The relative humidity from NWFs is underestimated by 3%. The validation of QuikSCAT-based wind speed yields a root mean square difference (rmsd) of 1.4 m/s. The validation of AMSR-E SST is found to be highly significant with high correlation of 0.9 and yields a RMSD of 0.7°C. The comparison of sensible and latent heat fluxes estimated from in situ data and that from NCEP-NCAR and ECMWF yields RMSD in the range 17-19 and 38-42 Wm-2, respectively, with ECMWF data being poorly correlated to the in situ data than the NCEP-NCAR product. There is no significant difference in the turbulent heat flux estimated by Liu-Katsaros-Bussinger and Kondo's algorithm.

1. INTRODUCTION

The Southern Ocean (SO) is an important component of global climate system. Its circumpolar current, forced dominantly by zonal winds, plays a crucial role in the global transport of mass, heat and momentum, and transports climate signals from one ocean basin to another, and heat, moisture, and momentum exchange between the ocean and atmosphere; for example, in the Antarctic Zone, south of the Antarctic Polar Front, approximately 300 PW of heat is lost to the atmosphere (Keffer and Holloway, 1988). This mechanical forcing influences ocean circulation, water mass formations, mixed layer dynamics, Ekman mass and heat transport between mid- and low-latitudes, as well.

The understanding of physical processes in the SO has been hampered since it is under-surveyed by the traditional (ship) observations due to its remoteness and inclement weather. However, the lack of data is not the only factor that has prevented a detailed study of the meteorological and ocean dynamics in SO, validation of the available data in the SO is another major factor. In particular, the variables that enter the air–sea heat flux equations have large uncertainties in the SO because of the limited availability of in situ data. Thus, one challenge is to determine whether the existing measurements provide a research quality data.

In this work, we analyzed the meteorological data recorded from the AWS mounted on the ship along its track. Our interest is to validated these air-sea heat flux variables in the lower atmospheric boundary layer (ABL), monitor their variability and relate these changes to the underlying oceanic thermohaline structure, considering atmosphere-ocean as a coupled system. The data was collected during the 26th Indian Antarctic Expedition on board Emerald Sea from Durban (32.4ºS, 30.4ºE) to India Bay, Antarctica (70.05°S, 12.45°E) during 9 - 14 February (Track-1) and from Prydz Bay, Antarctica (69.35°S, 76.17°E) to Mauritius (20.15°S, 57.48°E) during 19 - 26 March (Track-2). This validation will serve as pre-launch benchmark information of the ABL conditions in SO to India's scheduled launch of OCEANSAT-2 carrying a payload of scatterometer and Ocean Color Monitor in the later half of 2008.

2. DATA AND METHODS

In this work we analyzed wind speed (Ws), air temperature (Ta), sea surface temperature (SST), relative humidity (Rh), and sea level pressure (MSLP) which were recorded at every three hourly interval from 32°S to the sea-ice edge. Ws was measured using the RM Young wind monitor (accuracy: ±0.3 m s^{-1}). Ta and Rh were recorded using a PRT probe and a sensor equipped with capacitive polymer H-chip (make: Vaisala Inc.), respectively; the accuracies of which are temperature dependent. A digital barometer was used to record the atmospheric pressure (make: Vaisala Inc., accuracy: ±0.3 hPa at 20°C), from which MSLP was obtained by accounting for the measurement height. The meteorological data have been adjusted to a height of 10 *m* above the sea surface by using log-layer profiles (Liu *et al.*, 1979). Using these data and SST obtained from XBT and XCTD profiles, sensible (Qs) and latent heat flux (Qe) were estimated using two bulk flux algorithms (Liu et al., 1979; Kondo, 1975). In this work, positive Qs and Qe indicate the surface heat loss to the atmosphere.

For the validation, six hourly (00, 06, 12 and 18 GMT) numerical weather forecasts (NWF) of Ta, Rh, MSLP from NCEP-NCAR (Kalnay et al., 1996) and ECMWF (Gibson et al., 1997), with a spatial resolution of 2.5°×2.5°, were collocated with the in situ data by a linear interpolation in space and time. Ws from SeaWinds scatterometer flown on the QuikBird satellite (QuikSCAT) was retrieved by using the Ku-2001 geophysical model function (http://www.ssmi.com/qscat; Wentz et al., 2001). The SST data from the Advanced Microwave

Scanning Radiometer (AMSR-E) on board the NASA's Aqua satellite (http://www.ssmi.com/amsr) have been compared with that from 26th expedition and January-April 2006 cruise. We employ the microwave measurements (Ws and SST) since the persistent cloud cover over SO does not degrade their E by using linear interpolation in space and time between the satellites's ascending and descending passes.

3. RESULTS AND DISCUSSION

Figure 1 shows the validation results for NCEP and ECMWF data. Each panel shows the regression to the data points represented by the grey line, the 1:1 line represented by the black line and the correlation coefficient, r which is significant at 1% level determined by using two-tailed student's t test (Till, 1974).

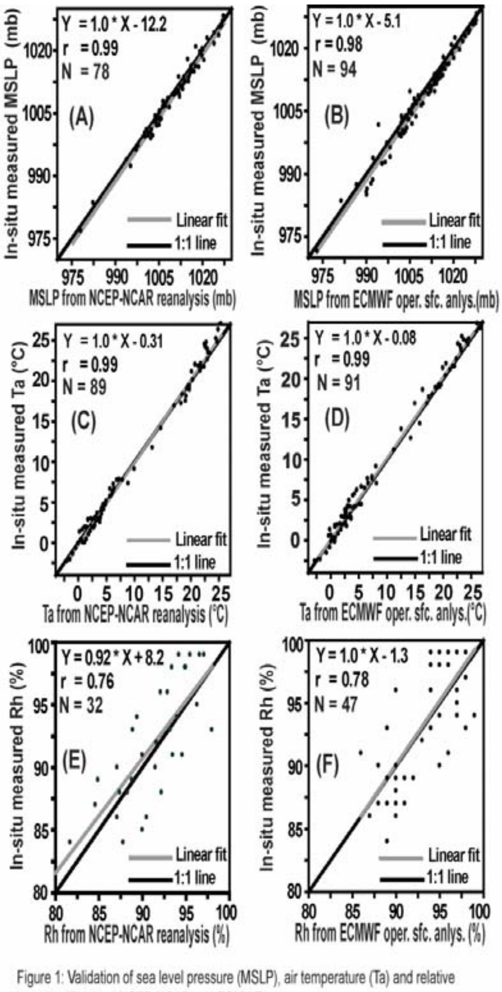


Figure 1. Validation of sea level pressure (MSLP), air temperature (Ta), and relative humidity (Rh) from NCEP-NCAR and ECMWF products.

The validation of the MSLP from NCEP-NCAR yields a RMSD of 1.7 mb and the regression shows a high r exceeding 0.9 (Fig. 1A). On the other hand, the validation of the ECMWF MSLP yields a RMSD of 2.3 mb and a high r (0.98) (Fig. 1B). The regression further confirms the overestimation of MSLP by the NWFs by a factor ranging from -5 to -12 mb. The validation of accuracies, except in the raining conditions. The root mean square difference (RSMD) between the AMSR-E SST and that from the Reynold's data is reported to be 0.76°C for June to August 2002 (Wentz et al., 2003). The in situ SST was collocated with that from AMSR the Ta from NCEP-NCAR gives a RMSD of 0.78°C and yields a high r (0.99) (Fig. 1C). The comparison of ECMWF Ta with that from in situ data yields a RMSD of 0.85°C and the correlation is found to be highly significant (r = 0.99) (Fig. 1D). The negative intercept in the regression equation suggests that both the NWFs overestimate Ta. The validation of Rh from NCEP-NCAR yields a RMSD of 3%, and the regression equation confirms that the NWF underestimate Rh by about 8% (Fig. 1E). The correlation coefficient is found to be 0.76. Similarly, the validation of Rh from ECMWF yields a RMSD of 3%, which indicates that the later underestimates Rh (Fig. 1F), and the regression is significant (r = 0.76).

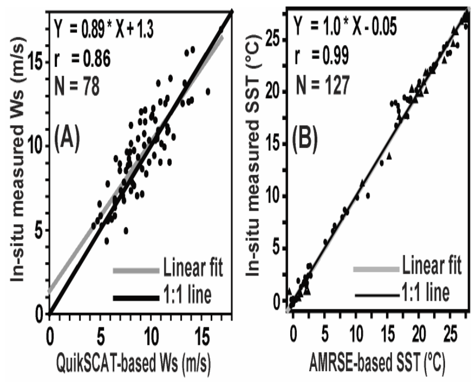


Figure 2. Validation of QuikSCAT wind speed (Ws) and AMSR-E sea surface temperature (SST).

The validation of Ws from QuikSCAT yields a RMSD of 1.4 m s-1 (Fig. 2A), which is close to the value of 1.99 m s-1 obtained by Yuan (2004), and closer to the RMSD of 1.93 m s-1 averaged over the entire SO (Atlas et al., 1999). The positive intercept in the regression equation suggests that the QuikSCAT underestimates Ws by 1.3 m s-1; moreover the regression shows a high correlation coefficient (r = 0.86). The validation of the SST from AMSR-E yields a RMSD of 0.7°C (Fig. 2B). The correlation coefficient (r = 0.99) confirms that AMSR-E SST agrees well with the in situ data.

The validation of Qs estimated from NCEP-NCAR data yields a RMSD of 17 Wm-2 (Fig. 3A). The linear fit shows a high correlation coefficient (r = 0.81), which suggests that there is insignificant difference between the two data. On the other hand, a comparison of ECMWF Qs and that from in situ data yields a RMSD of 19 Wm-2, and a poor correlation of 0.52, as 83% of the data points cluster near zero in the range of ±25 Wm-2 (Fig. 3B). The validation of Qe from NCEP-NCAR yields a RMSD of 38 Wm-2 (Fig. 3C) and the regression provides a correlation coefficient of 0.84. On the other hand, the validation of Qe from ECMWF yields a RMSD of 42 Wm-2 (Fig. 3D) and the regression yields a correlation coefficient of 0.62. It has been pointed out that ECMWF turbulent fluxes are underestimated globally due to deficiency in the model physics (Renfrew et al., 2002).

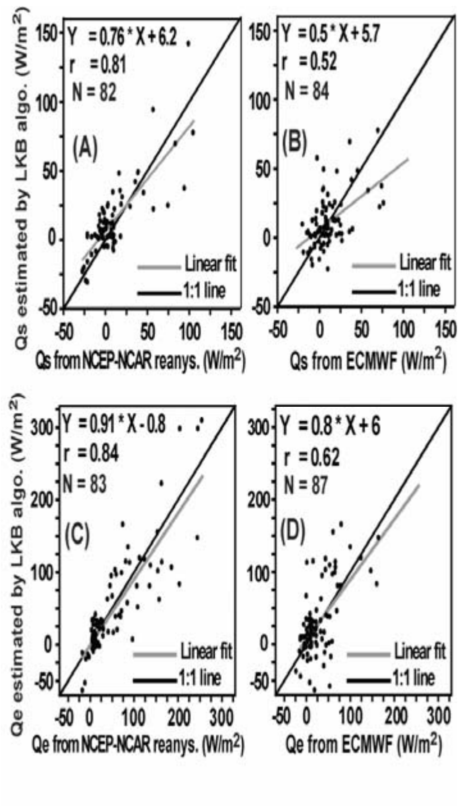
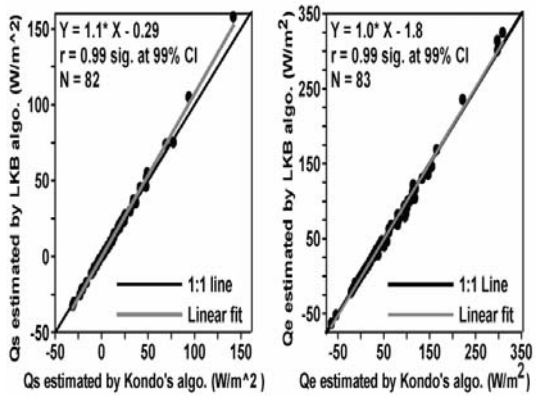


Figure 3. Validation of sensible heat (Qs) and latent heat flux (Qe) estimated from NCEP-NCAR and ECMWF products using the algorithm of Liu et al., 1979)



(A) (B)

Figure 4: Comparison of sensible (Qs) and latent heat flux (Qe) by using LKB and Kondo's algorithm.

A comparison of Qs and Qe estimated by using LKB and Kondo's bulk flux algorithms is shown in Figure 4. Computation yields a RSMD of -0.7 Wm-2 with standard deviation of 2.5 Wm-2 for Qs (Fig. 4A). On the other hand, a RMSD of 1.1 Wm-2 and standard deviation of 5.4 Wm-2 were obtained for Qe (Fig. 4B). The fit to the data point is highly significant with a high correlation. In brief, these statistics suggest that the variations in the estimates of Qs and Qe made by the two algorithms are insignificant.

4. CONCLUSIONS

The validation suggests that the NWFs overestimate MSLP, project lower Rh and fail to capture sporadic events in the mid-latitudes. QuikSCAT Ws is underestimated by about 1.3 ms-1 and the comparison with in situ data yields a RMSD of 1.4 ms-1. The validation of AMSR-E SST is found to be highly significant ($r > 0.9$) and yields a RMSD of 0.7°C. The comparison of Qs and Qe from NWFs yields RMSD in the range 17-19 and 38-42 Wm-2, respectively, with ECMWF data being poorly correlated to the in situ data than the NCEP-NCAR product. There is no significant difference in the turbulent heat flux estimated by LKB and Kondo's algorithm.

REFERENCES

Atlas, R., S. C. Bloom, R. N. Hoffman, E. Brin, J. Ardizzone, J. Terry, D. Bungato, and J. C. Jusem, 1999, Geophysical validation of NSCAT winds using atmospheric data and analyses, J. Geophysical Research, 104, pp. 11405–11424.

Dong, S., S. T. Gille, J. Sprintall, and C. Gentemann, 2006, Validation of the Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E) sea surface temperature in the Southern Ocean, J. Geophysical Research, 111, C04002, doi:10.1029/ 2005JC0 02934.

Gibson, J. K., P. Kallberg, S. Uppala, A. Hernandez. A. Nomura, and E. Serrano, 1997, ECMWP reanalysis project report series, 1: ERA description, ECMWE Reading, U.K, pp. 77.

Kalnay, E., and Coauthors, 1996, The NCEP/NCAR 40-year reanalysis project, Bull. American Meteorological Society, 77, pp. 437 – 471.

Keffer, T., and G. Holloway (1988), Estimating Southern Ocean eddy flux of heat and salt from satellite altimetry, Nature, 332, 624–626.

Liu, W. T., K. Katsaros, and J. A. Businger, 1979, Bulk parameterization of air-sea exchanges of heat and water vapor including the molecular constraints at the surface, J. Atmospheric Science, 36, 1722-1735.

Renfrew, I. A., G. W. K. Moore, P. S. Guest, and K. Bumke (2002), A comparison of surface layer and surface turbulent flux observations over the Labrador Sea with ECMWF and NCEP reanalyses. J. Physical Oceanography, 32, 383–400.

Till, R. (1974), Statistical methods for the earth Scientist- an introduction, The Macmillan Press Ltd., London, pp. 154.

Wentz, F. J., D. K. Smith, C. A. Mears, and C. L. Gentemann (2001), Advanced algorithms for QuikSCAT and SeaWinds/ AMSR, Paper presented at IGARSS'01, Inst. of Electr. and Electron Eng., Sydney, N. S. W., Australia.

Wentz, F. J., C. Gentemann, and P. Ashcroft (2003), On-orbit calibration of AMSR-E and the retrieval of ocean products, 83rd AMS Annual Meeting, AGU, Long Beach, CA.

Yuan, X. (2004), High-wind speed evaluation in the Southern Ocean, J. Geophysical Research, 109, D13101, doi: 10.1029/2003JD004179.

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