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TECHNICAL NOTE

Impact on NCEP Numerical Weather Forecasts of Omitting Marine Ship and Fixed Buoy Reports

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OPC CONTRIBUTIONS

No. 1. Burroughs, L. D., 1987: Development of Forecast Guidance for Santa Ana Conditions. National Weather Digest, Vol. 12 No. 1, 7pp.

No. 2. Richardson, W. S., D. J. Schwab, Y. Y. Chao, and D. M. Wright, 1986: Lake Erie Wave Height Forecasts Generated by Empirical and Dynamical Methods -- Comparison and Verification. Technical Note, 23pp.

No. 3. Auer, S. J., 1986: Determination of Errors in LFM Forecasts Surface Lows Over the Northwest Atlantic Ocean. Technical Note/NMC Office Note No. 313, 17pp.

No. 4. Rao, D. B., S. D. Steenrod, and B. V. Sanchez, 1987: A Method of Calculating the Total Flow from A Given Sea Surface Topography. NASA Technical Memorandum 87799., 19pp.

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No. 11. Esteva, D. C., 1987: The Editing and Averaging of Altimeter Wave and Wind Data. Technical Note, 4pp.

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Abstract

To investigate impact of surface marine data gathered from conventional in-situ measurements such as ships and fixed buoys on NCEP numerical weather forecasts, three parallel global data assimilation experiments have been conducted. The first experiment includes all operationally available marine surface data from ships, fixed buoys, drifting buoys, C-M stations, and satellite surface wind data that are routinely used in the NCEP numerical weather forecasting operations. This experiment is treated as a control run to evaluate results of the other two experiments which consist of one without the use of any data from surface ships only, and the other without any data from fixed buoys only. These global data assimilation experiments were run for a period of 15 days, starting 0000 UTC, May 27, 1997, and ending 0000 UTC, June 15, 1997. Based on 10 cases of forecasts and based on the standard statistics of anomaly correlations, forecast errors of mean sea level pressures and 10 meter vector winds, it is concluded that elimination of ships and fixed buoy data in the NCEP global data assimilation systems causes some degradation in the short range numerical weather forecasts. The negative impact is seen to be more significant over the Northern Hemisphere where there are more ship and fixed buoy data, than that over the Southern Hemisphere where these types of surface marine data are not as many. These results are in contrast with those obtained earlier from a previous impact study, which found a negative impact on NCEP numerical forecasts due to elimination of surface drifting buoy data, with the impact being more significant over the Southern Hemisphere than that over the northern Hemisphere.

1. Introduction

During the last decade or so, there has been a great increase in the amount of remotely sensed ocean surface wind observations from Special Sensor Microwave Imager (SSM/I) of the Defense Meteorological Satellite Program (DMSP), and from scatterometer of the Earth Remote Sensing Satellite (ERS-1/2). Observations from the SSM/I contain ocean surface wind speed information while those from the scatterometer of the ERS-1/2 contain both wind speed and direction. Before these satellite ocean surface wind data were used operationally for numerical weather prediction at the National Centers for Environmental Prediction (NCEP), they have been extensively tested in the NCEP global data assimilation systems. The test results have shown that use of these data leads to a positive impact on numerical weather prediction (see e.g., Yu et al, 1996, and Yu et al, 1997). Further, with the operational use of these satellite surface wind observations comes an important and practical question. Are these satellite surface wind data capable of replacing the conventional surface data such as ship and fixed buoy reports as well as drifting buoy data for numerical weather prediction? In a previous paper (Yu, 1996), the effect of drifting buoy data on NCEP numerical weather forecasts was investigated. This study now investigates the impact of ship and fixed buoy data on the NCEP global data assimilation systems.

There are generally about 600 to 700 marine surface ship data and about 530 fixed buoy data available for use in analyses during each NCEP global atmospheric data assimilation cycle, depending on the analysis time. Table 1 shows mean data counts for various types of surface marine data used in 0000, 0600, 1200, and 1800 UTC cycles of the NCEP global data assimilation operations. Note that while there are more ship reports than fixed buoy data over the global oceans, the fixed buoy data are believed to be more complete in reporting all of the surface marine meteorological parameters, and are in general of better quality than ship reports. From Table 1, it should be noted also that the numbers of ships in each analysis cycle are comparable to those of the drifting buoys, except that there are more ships data in the Northern Hemisphere than those in the Southern Hemisphere, whereas the opposite is true for the drifting buoy data (see Yu, 1996). Furthermore, unlike drifting buoy data which contain mainly sea level pressure information, marine ship and fixed buoy data contain sea level pressure, wind speed and direction, and temperature and humidity reports. The differences in the data characteristics among these three types of surface marine observations undoubtedly will lead to differences in the impact on the NCEP numerical weather analyses and forecasts. In Section 2, a brief description is given on the NCEP operational global data assimilation system used in this study, with the design of three parallel experimental runs for conducting the impact test of these ship and fixed buoy reports. Results on the three parallel run experiments are presented in Section 3 to assess the impact of ship and fixed buoy data, and where appropriate those on the impact of the drifting buoy data reported in Yu (1996) will also be discussed.

2. The Experimental Design

The NCEP T62 global data assimilation system, details of which were given in Kanamitsu (1989) and Kanamitsu et al (1992), was used to investigate the impact of the ship and drifting buoy data on analyses and forecasts. Basically, the assimilation system consists of a forecast model and an analysis scheme. The forecast model is a global spectral forecast model of triangular truncation with 62 waves for the horizontal spectral resolution. In the vertical it has 28 sigma layers. The forecast model includes identical parameterization of such physical processes as convection, precipitation, radiation, and boundary layer physics as those employed in the NCEP operational forecast T126 model. The assimilation experiment is proceeded by a six hour forward integration of the forecast model, starting from the beginning of the data assimilation period, to produce first guess fields of winds (u,v), temperatures (T), and specific humidity (q). The observations within a +/ - 3 hour window are then used to update the first guess fields and complete the analyses. This process of a six hour model forecast followed by an analysis update is repeated four times a day, once every six hour interval.

Three parallel global data assimilation experiments have been carried out to test the impact of surface ship and fixed buoy data on NCEP numerical weather analyses and forecasts. Exp. A includes all operationally available data from conventional (such as ship and fixed buoy data) and remote sensing sources. Thus it is treated as the control run against which the impact of excluding other data sources will be measured by running the models in parallel. In Exp. B all surface ship data are excluded, while in Exp. C all fixed buoy data are omitted. For this study a total of 15 days of data assimilation was conducted for the impact of ship and fixed buoy data, starting 0000 UTC May 27, 1997, and ending 0000 UTC, June 10, 1997. Furthermore, for each of the global data assimilation experiments, a five day forecast was made at the 0000 UTC cycle of the daily data assimilation. The forecasts valid at 24, 48, 72, 96, and 120 hours of the forecast cases are used for comparison between the parallel run systems. Standard statistics of anomaly correlations based on a total of 10 cases of forecasts are calculated for the parallel forecasts. In addition, forecast errors of sea level pressures and 10 meter winds with reference to mid-latitude deep ocean buoys and tropical TOGA buoys for the parallel forecasts are compared.

3. Results of the Parallel Experiments

3a. Impact of Ship Data on NCEP Numerical Weather Forecasts

The Northern Hemisphere 1000 mb anomaly correlations for Day 5 forecasts are shown in Figure 1a. From Figure 1a, it is clear that the elimination of ship reports are seen to have some negative impact for Day 5 forecast in the Northern Hemisphere. When compared to the mid-latitude deep ocean buoys (Table 2a and Table 2b), and when compared to the Northern tropical TOGA buoy data (see Table 3a), the negative impact over the Northern Hemisphere due to elimination of ship data can be further detected from the larger mean sea level pressure errors and larger 10 meter wind errors in the forecasts of up to 120 hours.

The impact over the Southern Hemisphere due to elimination of ship data is not as clearly indicated as that over Northern Hemisphere. The 1000 mb anomaly correlations of Day 5 forecasts over the Southern Hemisphere (see Fig. 1b) show a small difference between the two parallel forecasts. The elimination of ship data in the data assimilation and forecast experiments seems to provide a rather inconclusive answer about the impact of these data over the Southern Hemisphere. This conclusion is further substantiated by the comparison of the mean sea level pressure forecast errors and 10 meter wind forecast errors between the two parallel forecasts with reference to TOGA buoys over the Southern Hemisphere (see Table 3b).

3b. Impact of Fixed Buoy Data on NCEP Numerical Weather Forecasts

Results of the parallel experiment on the impact of fixed buoy data are very similar to and consistent with those of the parallel experiment conducted to investigated the impact of ship data. This is not too surprising in view of the fact that both the ship and buoy data are of the same data types. That is, both ships and fixed buoys contain wind speed and wind direction, temperature, and humidity information, except that fixed buoy reports are in general of better quality than the ship data, in term of observation errors and data completeness. The Northern Hemisphere 1000 mb anomaly correlations for Day 5 forecasts are shown in Figure 2a. From Figure 2a, it is clear that the elimination of fixed buoys reports are seen to have some negative impact for Day 5 forecast in the Northern Hemisphere. The negative impact over the Southern Hemisphere due to elimination of fixed buoy data is not as clearly indicated as that over Northern Hemisphere. The 1000 mb anomaly correlations of Day 5 forecasts over the Southern Hemisphere (see Fig. 2b) show a small difference between the two parallel forecasts. The elimination of fixed buoy data in the data assimilation and forecast experiments seems to provide a rather inconclusive answer about the impact of these data over the Southern Hemisphere. This finding is consistent with that arrived at from results on the impact of ship data discussed previously in 3a.

As alluded earlier that the fixed buoy data are of better quality than the ship reports in general, the elimination of fixed buoy data should lead to a greater negative impact over the

Northern Hemisphere, when compared to the results of the impact of the ship reports. This is indeed the case, and is shown in Fig. 3a. Over the Southern Hemisphere, the difference in the negative impact by the elimination of the ships and fixed buoy reports is very small and not significant at all (Fig. 3b).

3c. Impact of Drifting Buoy Data on NCEP Numerical Weather Forecasts

The results discussed above are in good contrast with those of a previous investigation on the effect of drifting buoys on NCEP numerical weather forecasts (Yu, 1996). Unlike the impact of ships, the elimination of drifters causes an insignificantly small negative effect on the Northern Hemispheric forecasts, but the negative impact is more detectable in the Southern Hemisphere. To facilitate comparison between the impact of these two types of surface marine data on NCEP forecasts, Figure 4 shows similar plots of the anomaly correlations as in Figure 1 from the drifting buoy study by Yu (1996) for the period of 0000 UTC, July 15, 1997 to 0000 UTC, July 24, 1997. The results constitute 10 cases of forecasts, and are quite typical of the forecasts during the whole month of July in that investigation (Yu, 1996). The difference in the impact between these two marine surface data on NCEP forecasts is clearly attributable to the difference in the data characteristics between the ships and drifting buoys discussed earlier.

4. Summary and Conclusions

With the operational use of great numbers of satellite ocean surface wind data from SSM/I and ERS-2 during the recent years in major operational weather forecast centers over the world, the role that conventional marine surface data from ships, fixed buoys, and drifting buoys play in numerical weather operations is being constantly challenged. The question is: can these satellite surface wind data replace the conventional marine surface data ? That is, how essential are those conventional marine surface data such as those from ships, fixed buoys, and drifting buoys in numerical weather prediction ? To answer this question, Yu (1996) in a previous study discusses the effect of drifting buoy data on NCEP forecasts. This paper examined the question of the effect of ship and fixed buoys data on NCEP numerical weather prediction.

Three parallel global data assimilation experiments were conducted to accomplish the impact investigation. In the first parallel run, the analyses and forecasts were made without the use of ship data, and in the second parallel run without the use of fixed buoy data. In the third parallel run, the analyses and forecasts were made using all the ship and fixed buoy data as in the daily NCEP numerical weather forecasting operations, thus serving as the control run results against which those from the first and second parallel runs were compared. The global data assimilation experiments were conducted for a period of 15 days, starting 0000 UTC, May 27, 1997, and ending 0000 UTC, June 15, 1997. Based on 10 cases of forecasts and based on the standard statistics of anomaly correlations, and forecasts errors of mean sea level pressures and 10 meter vector winds, it is concluded that elimination of ship and fixed buoy data causes some degradation in the forecasts. The negative impact is seen to be more significant over the Northern Hemisphere where there are more ship and fixed buoy data, than that over the Southern Hemisphere where ship and fixed buoy data are not as many. These results are in contrast with those of the impact study of drifting buoys reported in Yu (1996), where the negative impact on NCEP forecasts due to elimination of drifting buoy data is more significant over the Southern Hemisphere than that over the northern Hemisphere.

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Table 1. Mean data counts available for indicated model run cutoff times after 0000, 0600, 1200 and 1800 UTC as a function of data type for March 1995. Time windows is +/- 3 hours.

	0000 UTC	0600 UTC	1200 UTC	1800 UTC
Marine Ships	678	627	701	656
C-Man Platform	319	322	313	311
Fixed Buoys	540	536	535	529
Drifting Buoys	567	658	795	740

Table 2a. Mean sea level pressure forecast errors (mb) for the period 0000 UTC, May 27, 1997 to 0000 UTC, June 5, 1997 with reference to Northern Hemisphere mid-latitude ocean buoys.

Forecast Hours	No. of buoy Observations	Exp.A (Operational)		Exp.B (Without Ship Data)	
		RMS	Bias	RMS	Bias
24	373	1.75	0.24	1.95	0.36
48	373	2.37	0.39	2.86	0.47
72	385	3.46	0.31	3.75	0.26
96	385	4.07	0.12	4.43	0.18
120	385	4.36	-0.38	4.72	-0.32

Table 2b. Mean RMS vector wind errors (m/sec) for the period 0000 UTC, May 27, 1997 to June 5, 1997 with reference to Northern Hemisphere mid-latitude deep ocean buoys.

Forecast Hours	No. of Buoys	Exp.A (Operational)	Exp.B (Without Ship Data)
24	373	3.54	3.77
48	373	4.73	4.95
72	385	5.67	5.93
96	385	6.06	6.48
120	385	6.41	6.93

Table 3a. Mean RMS vector wind errors (m/sec) for the period 0000 UTC, May 27, 1997 to 0000 UTC, June 5, 1997 with reference to Northern Hemisphere TOGA buoys.

Forecast Hours	No. of Buoys	Exp.A (Operational)	Exp.B (Without Ship Data)
24	134	3.43	3.78
48	134	3.65	3.91
72	138	3.81	4.06
96	138	4.16	4.25
120	138	4.28	4.51

Table 3b. Mean RMS vector wind errors (m/sec) for the period 0000 UTC, May 27, 1997 to 0000 UTC, June 5, 1997 with reference to Southern Hemisphere TOGA buoys.

Forecast Hours	No. of Buoys	Exp.A (Operational)	Exp.B (Without Ship Data)
24	123	3.79	3.93
48	123	3.82	3.88
72	125	4.06	4.23
96	125	4.12	4.28
120	125	4.45	4.57

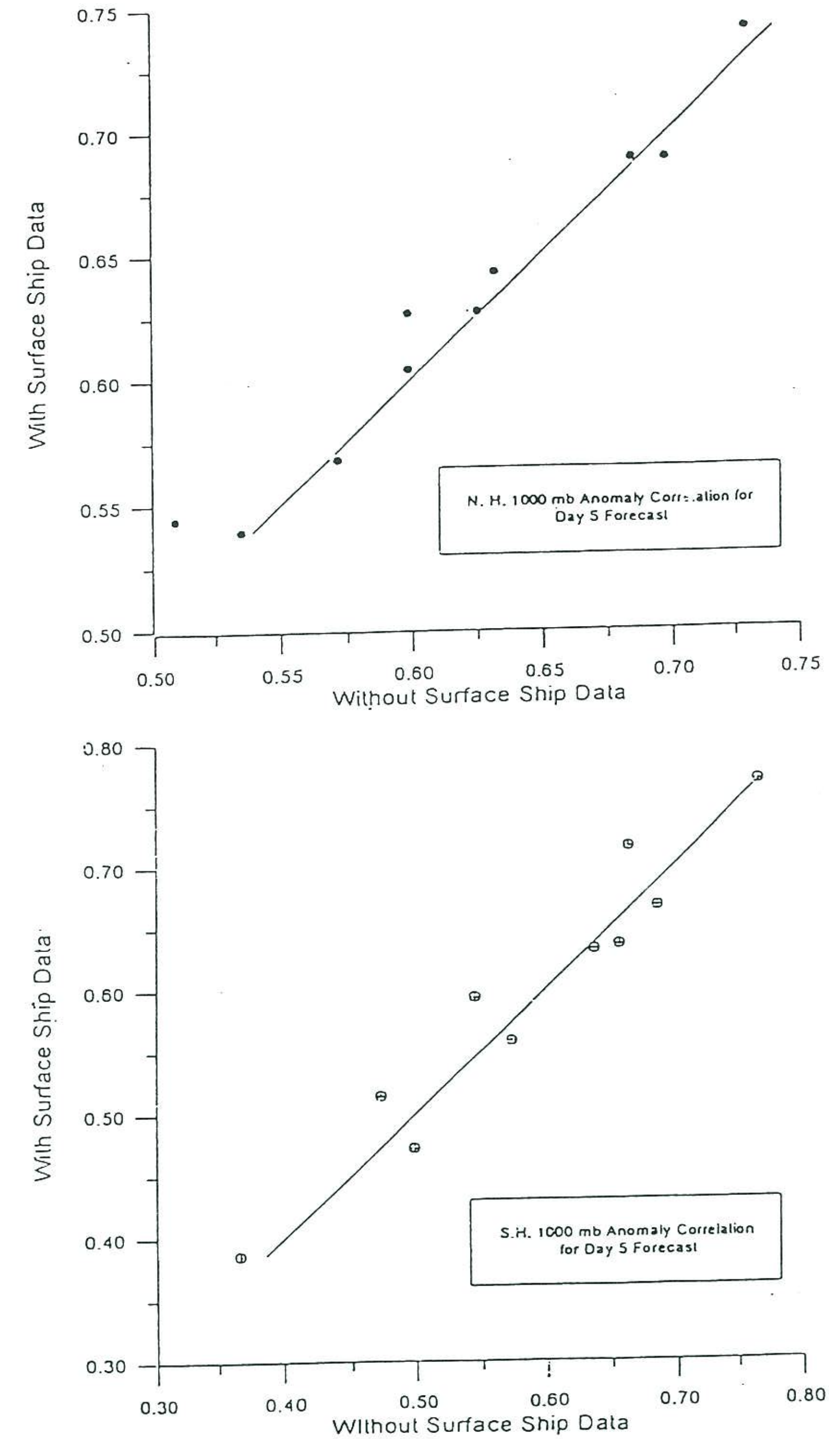


Fig. 1. 1000 mb anomaly correlations for Day 5 forecasts over the Northern Hemisphere (Top panel), and the Southern Hemisphere (Bottom panel) based on a two-weeks of global data assimilation and forecast experiments designed to test the impact of surface ship data, starting 0000 UTC, 27 May 1997, and ending 0000 UTC, 10 June 10, 1997. The values of the anomaly correlations plotted on the figure are based on 10 cases of five-day forecasts initiated on the 0000 UTC cycle of each day from May 27 to June 5, 1997.

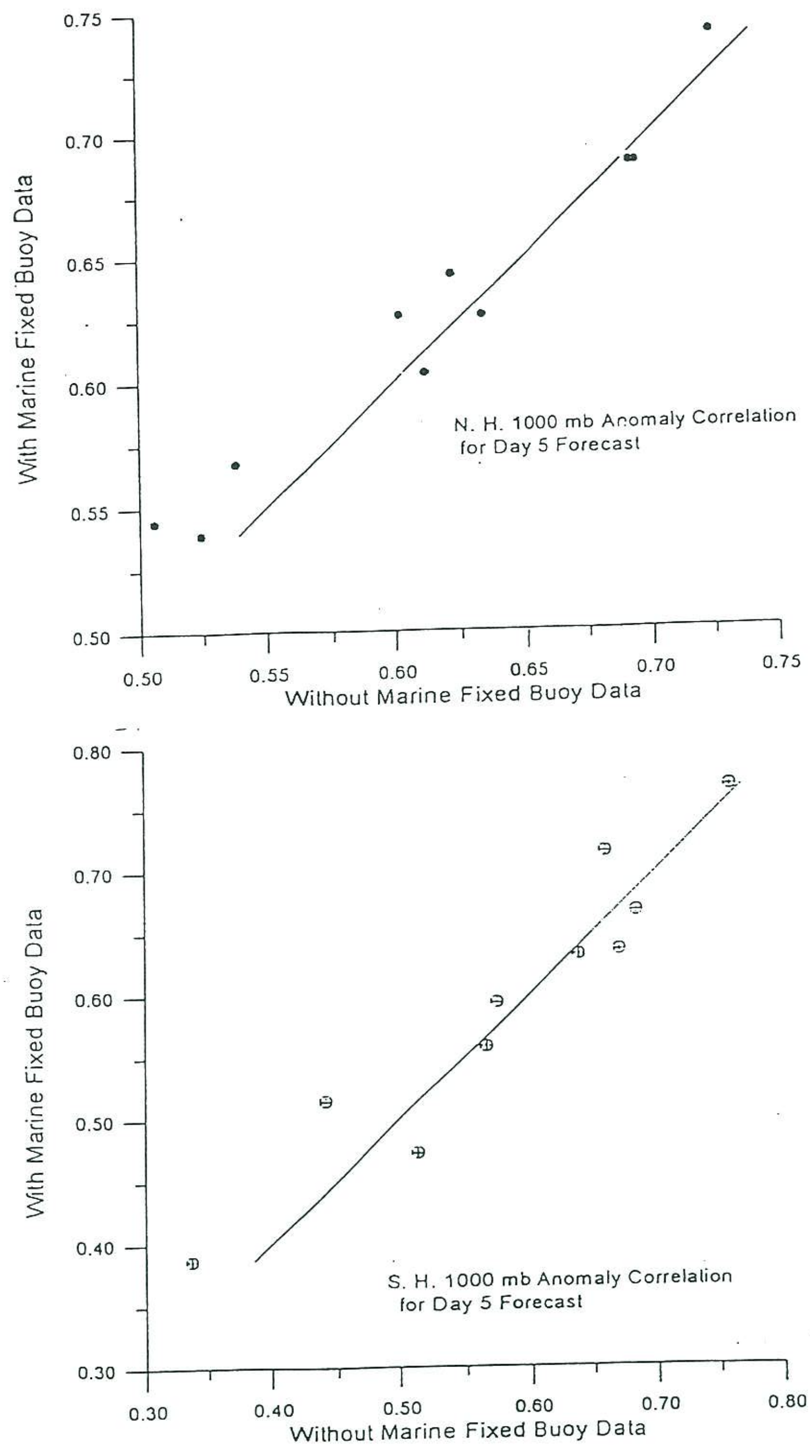
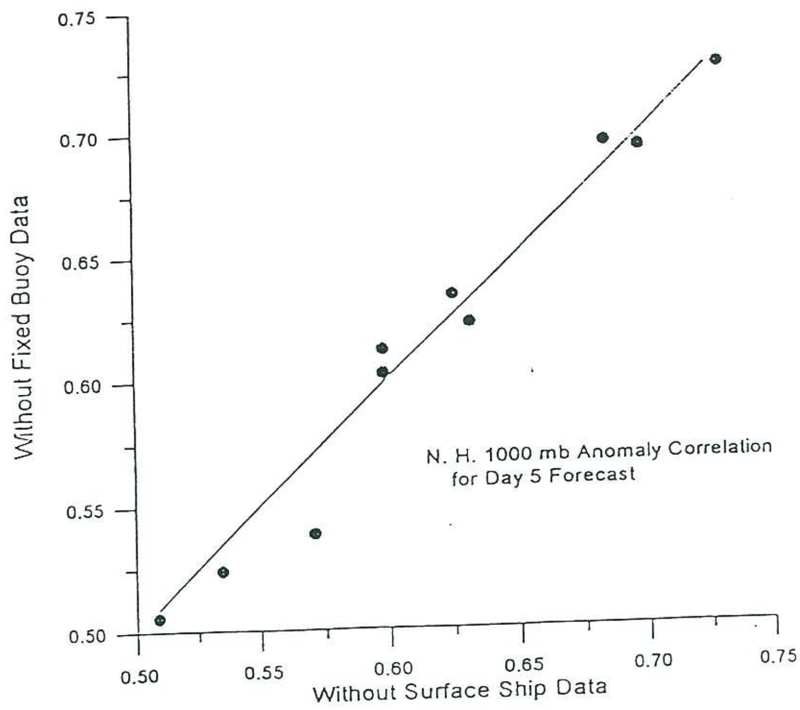


Fig. 2. 1000 mb anomaly correlations for Day 5 forecasts over the Northern Hemisphere (Top panel), and the Southern Hemisphere (Bottom panel) based on a two-weeks of global data assimilation and forecast experiments designed to test the impact of fixed buoy data, starting 0000 UTC, 27 May 1997, and ending 0000 UTC, 10 June 10, 1997. The values of the anomaly correlations plotted on the figure are based on 10 cases of five-day forecasts initiated on the 0000 UTC cycle of each day from May 27 to June 5, 1997.



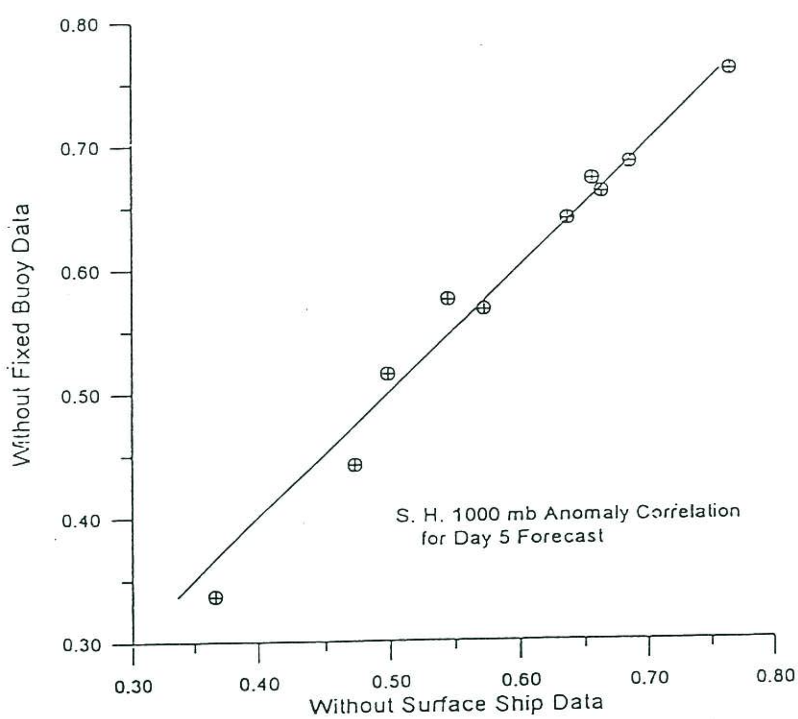


Fig. 3. 1000 mb anomaly correlations for Day 5 forecasts over the Northern Hemisphere (Top panel), and the Southern Hemisphere (Bottom panel) based on a two-weeks of global data assimilation and forecast experiments designed to test the impact of surface ship and fixed buoy data, starting 0000 UTC, 27 May 1997, and ending 0000 UTC, 10 June 10, 1997. The values of the anomaly correlations plotted on the figure are based on 10 cases of five-day forecasts initiated on the 0000 UTC cycle of each day from May 27 to June 5, 1997.

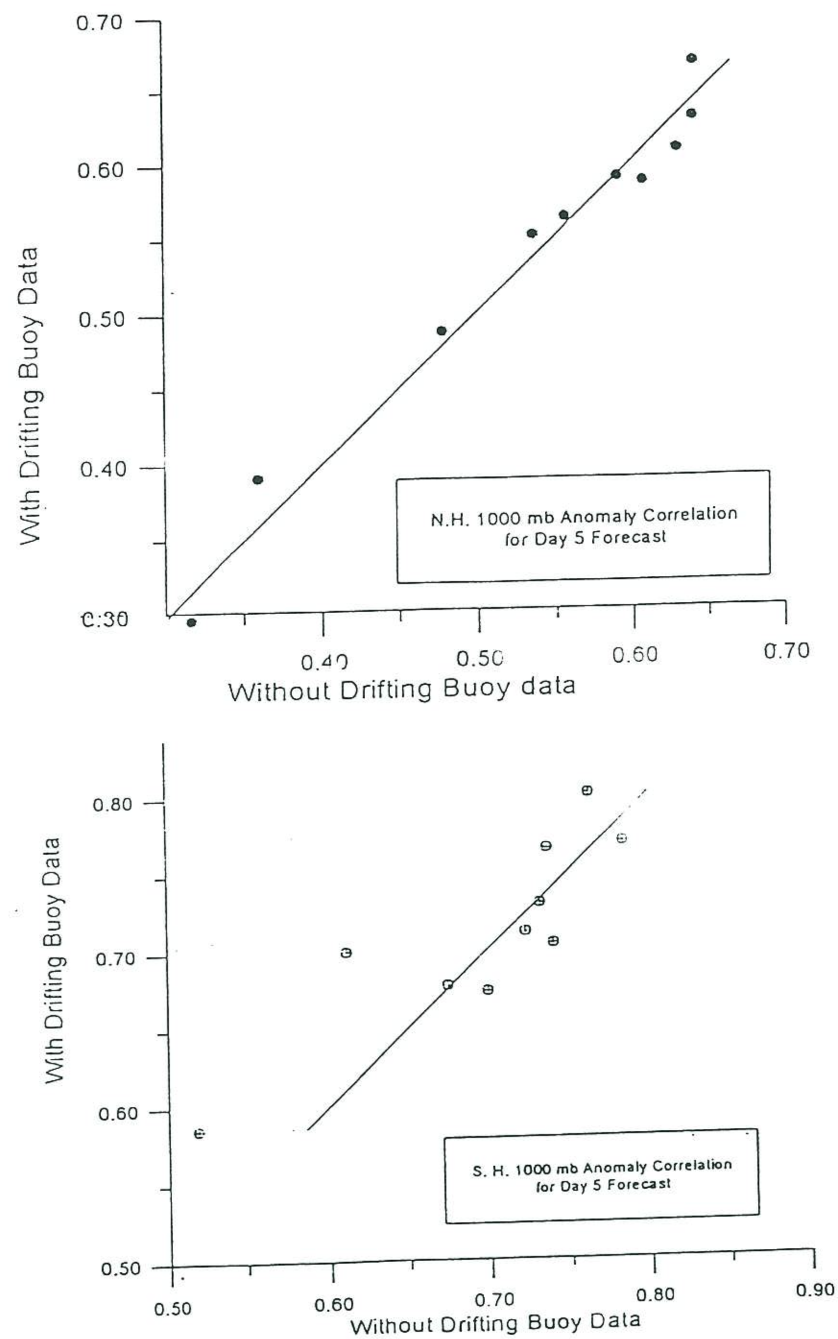


Fig. 4. 1000 mb anomaly correlations for Day 5 forecasts over the Northern Hemisphere (Top panel), and the Southern Hemisphere (Bottom panel) based on one month global data assimilation and forecast experiments designed to test the impact of surface drifting buoy data, starting 0000 UTC, 1 July 1996, and ending 0000 UTC, 31 July, 1996. The values of the anomaly correlations plotted on the figure are based on 10 cases of five-day forecasts initiated on the 0000 UTC cycle of each day from July 15, 1996 to July 24, 1996.

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