N84 27314

THE IMPACT OF SCATTEROMETER WIND DATA ON GLOBAL WEATHER FORECASTING

By

R. Atlas, W. E. Baker, E. Kalnay, M. Halem, P. Woiceshyn†, and S. Peteherych*
Goddard Laboratory for Atmospheric Sciences, NASA/Goddard Space Flight Center
Greenbelt, MD 20771
†Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109
*Atmospheric Environment Service, Downsview, Ontario M3H 5TA, CANADA

ABSTRACT

A series of experiments has been performed to assess the impact of Seasat-A scatterometer (SASS) winds on coarse resolution GLAS model forecasts. In general, the effect of objectively dealiased-SASS data is found to be negligible in the Northern Hemisphere. In the Southern Hemisphere the impact is larger and primarily beneficial when VTPR data is excluded. However, the inclusion of VTPR data eliminates the positive impact, indicating some redundancy between the two data sets.

1. INTRODUCTION

The Seasat-A satellite that flew for three months in 1978 provided a new source of data over the world's oceans for meteorological and oceanographic research. On board the satellite, an active microwave sensor known as the Seasat-A Satellite Scatterometer (SASS) measured capillary wave backscatter, which can be used to infer wind stress or surface wind velocity (Jones et al., 1978). The scatterometer provides high resolution winds, but each wind can have up to four possible directions. One wind direction is correct, and the rest are ambiguous or "aliases". Consequently, before an analysis can be made with the SASS winds the aliases must be removed.

Until recently only a few limited studies had been conducted to evaluate the usefulness of SASS data for numerical weather prediction. In a simulation study, Cane et al. (1981) found an improvement in the surface pressure forecast over the extratropics with SASS winds. However, their results are probably too optimistic because the assimilated winds did not contain an alias and were inserted at the lowest model level (nominally 945 mb). This underestimated the typical errors made in obtaining a 945 mb wind field from the ambiguous surface winds.

In studies with actual SASS data, Yu and McPherson (1979) designed an iterative procedure for alias removal and analyzed the resolved SASS winds with a global optimum interpolation scheme (Bergman, 1979). They found the effect of the SASS winds on the surface pressure analysis to be negligible over areas where ship reports are plentiful. However, large effects were noted over areas where ship reports are sparse.

In a later study, Yu and McPherson (1981) used SASS winds directly in the lower tropospheric wind analysis. They found large differences in the SASS and NOSASS (without SASS winds) wind and height analyses in the Southern Hemisphere after 48 h of assimilation. The differences in the Northern Hemisphere were much smaller. Similarly, the 72 h forecast differences were significant in the Southern Hemisphere, but very small in the Northern Hemisphere.

Using a variational approach to remove the ambiguity of the SASS winds, Hoffman (1982) found the resulting analysis within the SASS data swath to be a reasonable representation of the surface wind. However, Hoffman noted some deficiencies particularly near circulation centers which could be corrected by subjective intervention.

In this study, we examine the impact of SASS data on the GLAS analysis/forecast system. In Section 2, the objective analysis and assimilation of SASS winds is discussed. A scheme developed to objectively dealias the SASS data is discussed in Section 3. Section 4 presents the results of some analysis and forecast experiments, and a summary follows in Section 5.

2. OBJECTIVE ANALYSIS AND ASSIMILATION OF SASS WIND DATA

In this section we describe the analysis system developed for the evaluation of the usefulness of Seasat data for numerical weather prediction. A similar version was utilized in the evaluation of data from the FGGE observing systems (Halem et al., 1982).

2.1 Forecast Model

The forecast model is the 4° latitude by 5° longitude fourth order global general circulation model described by Kalnay-Rivas et al. (1977) and Kalnay-Rivas and Hoitsma (1979). It is based on an energy-conserving scheme in which all horizontal differences are computed with fourth-order accuracy. A two-dimensional (latitude and longitude) sixteenth order Shapiro (1970) filter is applied every 2 h on the sea level pressure, potential temperature, and wind fields. In this scheme, wavelengths longer than four grid lengths are resolved accurately without damping. Wavelengths shorter than four grid lengths, which would otherwise be grossly misrepresented by the finite differences, are filtered out while they are still infinitesimal.

2.2 Objectively Analysis Scheme

The objective analysis scheme, described in Baker (1983), employs a successive correction method (Cressman, 1959) utilizing the first guess provided by the model 6 h forecast from the previous analysis. Eastward and northward wind components, geopotential height, and relative humidity are analysed on mandatory pressure surfaces. Surface pressure and temperature are reduced to sea level and analyzed there. An intermittent analysis is performed every 6 h on batches of data grouped in a ± 3 h window about each synoptic time.

In the asimilation of the SASS wind data, the analysis procedure was modified from the way in which it was applied with the FGGE data (Halem et al., 1982). The various steps in the assimilation of SASS data involve objective dealiasing, optional subjective enhancement, objective analysis of the final dataset, and adjustment of the sea level pressure field by the surface wind field using the linear balance equation on the wind increments introduced by the analysis. The model is then integrated either 6 h to provide a first guess for the next dealiasing or for a few days in order to conduct data impact studies.

3. OBJECTIVE DEALIASING OF THE SASS WIND FIELD

A three-pass procedure was developed to objectively dealias the SASS wind field. The guess for the first pass over the data is provided by a 6 h prediction from the previous analysis by the GLAS fourth order model. The SASS wind vector which is selected from the possible aliases is the one nearest in direction to the first guess vector obtained by a bilinear interpolation of the four surrounding first guess vectors. The least ambiguous data points (two aliases) are handled in the first pass, with the more ambiguous cases (three or four aliases) handled in the second or third pass. This approach was adopted because of our experience in subjectively dealiasing SASS data which indicated that a more accurate SASS wind field could be produced by using resolved SASS vectors from data points with lesser ambiguity in subsequent dealiasing passes over data points with more ambiguity.

After the first pass over the SASS data, the resolved SASS vectors and available ship winds are analyzed by a successive correction method (SCM). The resulting surface wind analysis is utilized in resolving the SASS wind vectors in the second pass. The resolved SASS winds from the first two passes and the ship data are then analyzed as before, This analysis is then utilized in the third pass in a similar manner.

4. RESULTS OF ANALYSIS/FORECAST EXPERIMENTS

In this section we present the results of some analysis/forecast experiments with the Seasat data. Four assimilation experiments have been conducted from 0000 GMT 7 September 1978 to 1200 GMT 13 September 1978. The experiments began from initial conditions provided by the global operational Hough analysis (Flattery, 1971) of the National Meteorological Center (NMC) for 0000 GMT 7 September 1978.

The four assimilation experiments differed only with respect to the use of objectively dealiased SASS wind data or satellite temperatures from the vertical temperature profile radiometer (VTPR) on board NOAA-4. All other available conventional and satellite cloud track wind data were included in each of the asssimilation experiments. A total of 16 forecasts (four for each experiment) were generated from the initial conditions provided by the assimilation at 0000 GMT 9, 1200 GMT 13 September 1978. Extensions of these assimilation cycles and forecast cases as well as a fifth assimilation experiment using the subjectively enhanced SASS winds are planned for the near future.

The evaluation of SASS data impact concentrated on differences between the initial states which resulted from the assimilation of SASS winds and differences between numerical predictions made from these initial states. Initial state differences were evaluated by comparing pressure and wind field analyses produced with and without SASS data. Numerical predictions were evaluated objectively by S_1 scores and rms differences and by subjective comparisons.

4.1 Initial State Differences

For satellite observations of surface wind to have a significant impact on numerical weather prediction, substantial differences between the atmospheric state analyses produced with and without the data must occur. The surface wind observations should be consistent with the higher level analysis and low level mass field, and the forecast model should be sensitive to the low level wind modifications. Assimilation of scatterometer data can work in two ways to modify the analysis. First, it can modify the wind field directly and the mass field indirectly through balance adjustments to the wind increments. Second, these differences may be amplified at the next analysis time due to their effects on the first guess fields used for that analysis.

The magnitude of the initial state differences depends strongly on the amount of available conventional and satellite data. Thus, larger differences would be expected in the Southern Hemisphere than in the Northern Hemisphere and in the assimilation without VTPR data.

Comparisons of analyses produced by the four assimilation experiments (not shown) for the most part confirm this expectation. In the Northern Hemisphere, with or without VTPR data, the assimilation of SASS winds produced only modest (generally < 10 m sec^{-1}) vector wind differences from 1000-500 mb. Over most of the oceans there were neglible differences in sea level pressure and 500 mb geopotential height. Maximum 500 mb height differences of 64 m, covering not more than two mdoel grid points were occassionally observed. On the average, the central pressure of cyclones at sea level differed by .5 mb. The maximum difference in central pressure was 5 mb.

In the Southern Hemisphere, more significant differences occurred. For the assimilations with VTPR data included, vector wind differences of 10-20 m sec^{-1}, sea level pressure differences of 8-16 mb and 500 mb height differences of 64-98 m covered large regions of the extratropical oceans. The average and maximum central pressure differences for cyclones at sea level were 3 mb and 15 mb respectively. For the assimilation with VTPR data excluded substantially larger differences were observed.

4.2 Prognostic Differences

Both objective scores and subjective comparisons were used to evaluate the impact of SASS data on GLAS model forecasts of sea level pressure and 500 mb height. S_1 scores and rms differences were calculated for each of the 72 h forecasts at 24 h intervals using the NMC objective analysis for the same time as verification. For reasosn of brevity, onl S_1 scores averaged over all forecasts for North America and Europe (Fig. 5) and for South America and Australia (Fig. 6) are presented here.

Fig. 5 shows the average effect of the SASS data to be insignificant over North America and Europe. With VTPR data excluded, the impact of SASS winds is very slightly positive from 24-48 h and very slightly negative at 72 h. The inclusion of VTPR data results in improved predictions at 24 h and 48 h at 500 mb but degrades the 24 h and 72 h forecast skill at sea level and the 72 h skill at 500 mb. This degradation is larger in the forecasts which also included SASS data. Thus, in the cases with VTPR data, the impact of SASS winds is slightly negative at sea level and negligible at 500 mb throughout the 72 h period.

Fig. 6 shows that the effect of SASS data on forecasts for South America and Australia is highly dependent upon whether or not VTPR soundings were assimilated over the Southern Hemisphere oceans. When VTPR data is excluded, the impact of SASS winds is increasingly positive from 24-72 h at sea level; at

ORIGINAL PAGE IS
OF POOR QUALITY

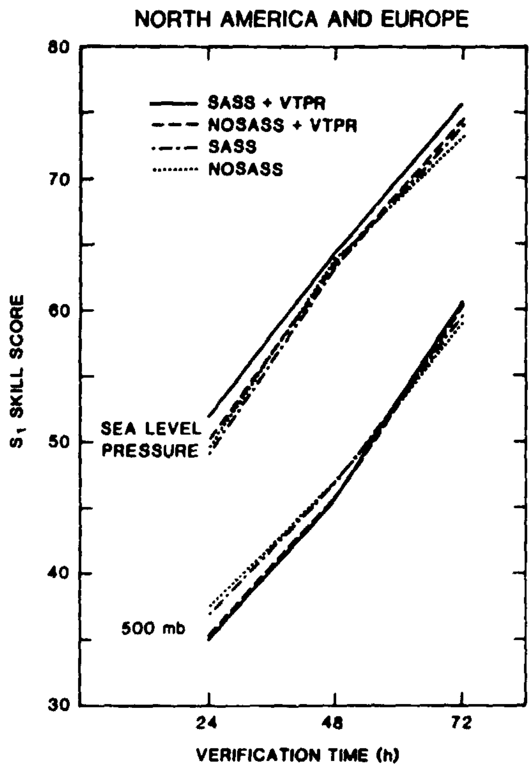

Fig. 1. S_1 scores for North America and Europe averaged over 4 forecasts.

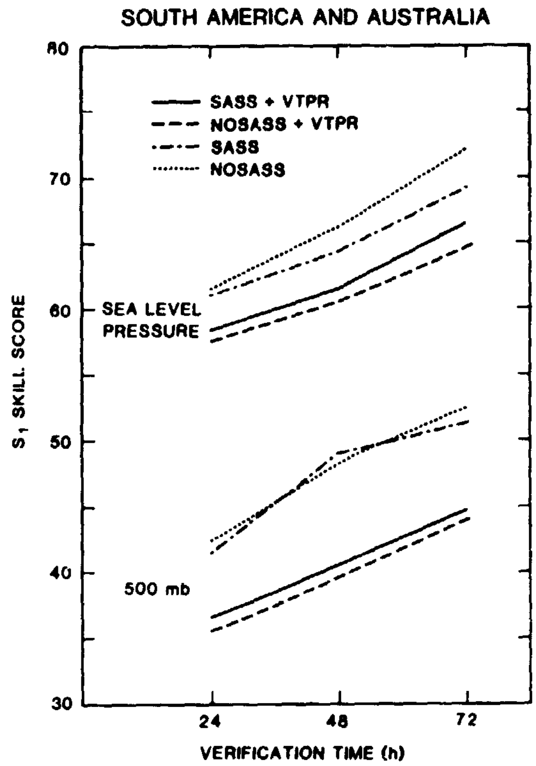

Fig. 2. Same as Fig. 1 for South America and Australia.

500 mb the effect is essentially negligible. It is very slightly positive at 24 h and 72 h and very slightly negative at 48 h. the inclusion of VTPR data in the Southern Hemisphere has a large beneficial effect. However, it improves the NOSASS predictions substantially more than the SASS forecasts. As a result, the impact of SASS winds is slightly negative at both sea level and 500 mb from 24-72 h.

For the subjective evaluation sea level pressure and 500 mb prognostic charts from the four experiments were compared with the NMC analysis over North America, Europe, South America and Australia. Comparisons were made at 12 h intervals and the SASS forecasts were classified as signficantly better, slightly better, the same, slightly worse, or significantly worse following the procedures described by Atlas et al., (1982).

Table 1 presents a summary of the subjective ratings. These results confirm the gnerally insignificant effect of SASS data over North America and Europe with only one prognostic chart being classified as significantly worse due to the combined effect of SASS and VTPR data. For South America and Australia, the effect of SASS data is larger but inconsistent. Both positive and negative impacts occur. The impact is largest and most beneficial when VTPR soundings are not assimilated.

Table 1. Subjective Evaluation of SASS Impact For Sea Level Pressure and 500 mb Height.

SASS Prognostic Charts	North Amer. & Europe		South Amer. & Australia	
	W/VTPR	W/O VTPR	W/VTPR	W/O VTPR
Significantly Better	0	0	1	3
Slightly Better	0	0	0	10
Same	71	72	65	50
Slightly Worse	0	0	4	3
Significantly Worse	1	0	0	2

5. SUMMARY

A series of assimilation/forecast experiments has been performed to assess the impact of Seasat-A scatterometer (SASS) winds on GLAS model forecasts. Four assimilation cycles were conducted from 0000 GMT 7 September to 1200 GMT 13 September 1978 which differed only with respect to the inclusion or exclusion of objectively dealiased SASS winds or VTPR soundings. four forecasts winds or VTPR soundings. Four forecasts from each assimilation were evaluated by objective measures and subjective comparisons.

In general, the results of this evaluation show a negligible effect of the SASS data in the Northern Hemisphere. In the Southern Hemisphere the impact is larger and primarily beneficial when VTPR is excluded. However, the inclusion of VTPR data effectively eliminates this positive impact, indicating some redundancy between the two data sets.

This study was limited by the coarse resolution of the analysis and forecast model, the lack of a detailed planetary boundary layer formulation in the model, the use of only objective dealiased SASS winds, the small number of forecast cases and others. We plan to investigate the importance of each of these factors in the near future.

6. ACKNOWLEDGEMENTS

The SASS wind data fields, utilized in this study were obtained from the Atmospheric Environment Service (AES) of Canada, courtesy of S. Peteherych. Subjective dealiasing and subjective enhancement of objectively dealiased winds at GLAS are being performed in collaboration with P. Woiceshyn (JPL), M. Wurtele (UCLA) and S. Peteherych. (AES). The authors benefited from discussions with each of the above investigators as well as with R. Hoffman, M. Cane, T. Yu and R. McPherson. Excellent technical assistance with the data processing and assimilation were provided by D. Edelmann, A. Pursch and D. Wallace. S. Postman, H. Bloom, J. Badner and R. Laplante participated in the subjective evaluation. L. Thompson typed the manuscript and L. Rumburg drafted the figures.

7. REFERENCES

Atlas, R., M. Halem, and M. Ghil, 1982: The effect of model resolution and satellite sounding data on GLAS model forecasts. Mon. Wea. Rev. 110, 662-682.

Baker, W. E., 1982: Objective analysis and assimilation of observational data from FGGE. Mon. Wea. Rev., 111. in press.

Bergman, K. H., 1979: Multivariate analysis of temperatures and winds using optimum interpolation . Mon. Wea. Rev., 107, 1423-1444.

Boggs, D., 1981: The Seasat scatterometer model function: The genesis of SASS1. Jet Propulsion Laboratory, Pasadena, California, 44 pp., [NTIS PD 622-230].

Cane, M. A., V. J. Cardone, M. Halem and I. Halberstam, 1981: On the sensitivity of numerical weather prediction to remotely sensed marine surface wind data: A simulation study. J. Geophy. Res., 86, 8093-8106.

Cressman, G. P., 1959: An operational objective analysis scheme. Mon. Wea. Rev., 87, 367-374.

Flattery, T., 1971: Spectral models for global analysis and forecasting. Proc. Sixth AWS Technical Exchange Conference, U. S. Naval Academy, Annapolis, Air Weather Service Tech. Rep. 242, 42-54.

Halem, M. E., Kalnay, W. E. Baker and R. Atlas, 1982: An assessment of the FGGE satellite observing system during SOP-1. Bull. Amer. Meteor. Soc., 63, 407-426.

Hoffman, R. N., 1982: SASS wind ambiguity removal by direct minimization. Mon. Wea. Rev., 110, 434-445.

Jones, W. L., F. W. Wentz and L. C. Schroeder, 1978: Algorithm for inferring wind stress from Seasat-A. J. Spacecraft and Pockets, 15, 368-374.

Kalnay-Rivas, E., A. Bayliss and J. Storch, 1977: The 4th order GISS model of the atmosphere. Beitr. Phys. Atmos., 50, 299-311.

Kalnay-Rivas, E. and D. Hoitsma, 1979: The effect of accuracy, conservation and filtering on numerical weather forecasting. Preprints Fourth Conference on Numerical Weather Prediction Silver Spring, Maryland, AMS, Boston, pp.302-312.

Yu, T. W. and R. D. McPherson, 1979: Surface pressure analysis using scatterometer derived wind data from the Seasat-A satellite. Preprints Fourth Conference on Numerical Weather Prediction, Silver Spring, Maryland, AMS, Boston, pp. 351-355.

Yu, T. W. and R. D. McPherson, 1981: Global data assimilation experiments with scatterometer winds from Seasat-A. Preprints Fifth Conference on Numerical Weather Prediction, Monterey, California, AMS, Boston, pp. 9-13.