JP2.10 DEVELOPMENT OF SCATTEROMETER-DERIVED RESEARCH-QUALITY SURFACE PRESSURES FOR THE SOUTHERN OCEAN

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## 1. INTRODUCTION

The scarcity of observations over the oceans has long frustrated meteorological research in the Southern Hemisphere. Launched in 1999, the SeaWinds scatterometer on the QuikSCAT satellite provides surface wind speed and direction over the Southern Ocean at high spatial resolution (nominally 25 km) and with unprecedented coverage (99% per day). These surface winds have been useful to oceanographers in forcing ocean models, but surface winds are relatively difficult for meteorologists to interpret and digest. Surface pressures are a more useful product for most meteorologists. This paper has two goals. First is demonstration that scatterometer winds can be used to objectively calculate surface pressures. Second is demonstration that the scatterometer data has an impact on existing analysis covering the Southern Ocean.

## 2. DATA

The SeaWinds data are available on a 25x25 km grid aligned with the satellite track. The SeaWinds data were processed with the Ku-2001 model function that has been shown to result in 60% of the QSCAT-1 uncertainties (Bourassa et al. 2002). Radiometer data from other satellites were used to flag cells potentially contaminated by precipitation. Radiometer data are considered correct where available, but these data are often unavailable. Flagged cells were not considered in the analysis. The NCEP/NCAR reanalysis (NCEPR) is used as the background pressure field for the variational method. The reanalysis data are available on a 2.5º global grid at 6-hour intervals. Linear interpolation in time is used to obtain a pressure field corresponding to the time of the QuikSCAT overpass. The NCDC TD1129 marine observations are used as the comparison data. Nearly all of the observations are ship borne. Although these observations may have entered the NCEPR, their effect is small as evidenced by their small correlation with the NCEPR ($r^2$ = 0.35, n = 25 721).

## 3. METHODOLOGY

Endlich et al. (1981) were among the first to derive surface pressures from scatterometer winds. Wind measurements were objectively analyzed onto a regular grid. The nonlinear balance equation was then solved to yield surface pressures. Reasonable results were obtained, although their work suffered from the deficiency of not accounting for the atmospheric boundary layer. The boundary layer was accounted for in the work of Brown and Zeng (1994) who inverted a boundary layer model with scatterometer winds as a lower boundary condition. A pressure field was found with the constraint that it minimized the difference between the geostrophic wind defined by the pressure field and the winds retrieved from inverting the boundary layer model. One weakness of their method was that winds retrieved from the model were closer to gradient winds than to geostrophic winds. This weakness can be removed by applying a gradient wind adjustment (Patoux and Brown 2002).

The method used in this study was originally developed by Harlan and O'Brien (1986), improved by Zierden et al. (2000), and further improved by Hilburn et al. (2002). This method uses a variational approach to smoothly blend geostrophic vorticity derived from scatterometer winds with geostrophic vorticity from an existing sea-level pressure analysis. This method accounts for the boundary layer in a simple way that assumes neutral stratification and barotropic conditions. Although these assumptions seem crude, they eliminate the need for upper air or temperature data, which are likely to be seriously inaccurate in the most interesting cases when the scatterometer differs greatly from the existing analysis. Brown and Zeng (1994) found no more than a 2-hPa change in pressures when baroclinity and stratification were included than when barotropic and neutral conditions were assumed. The method used here also enjoys the strength of not requiring any iteration when applying the gradient wind adjustment (in contrast to Patoux and Brown 2002).

## 4. VALIDATION

The region used for validation is 30-70ºS for the 20-day period 1-20 June 2000. Calculations were performed with individual scatterometer swaths contained within a box extending 5º beyond the maximum and minimum longitude points of the swath. All observations falling within this box and within 3 hours of the satellite overpass are used for validation. The observation locations are given at a resolution of 0.1º and the scatterometer-derived pressures are on 0.25º grids. Bilinear interpolation was used to interpolate from the 0.25º grid to the observation location. Thus, the co-location radius was 0.15º latitude ~ 17 km and 3 hr.

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It was found that the NCEPR had a bias of -1.45 hPa and an RMS difference (uncertainty) of 15.10 hPa compared to the observations. The scatterometer-derived pressures had a bias of -3.00 hPa and an RMS difference of 13.96 hPa compared to the observations. So, for all 25 731 observations, the scatterometer-derived pressures have a little less uncertainty, but a little more bias than the NCEPR sea-level pressures. Two factors complicate the interpretation of these results. First is that ship captains tend to avoid storms (Fig. 1) where the scatterometer-derived pressures make the largest improvement over the NCEPR. Second is that for these statistics to be meaningful, the comparison data would need to be very close to the truth. Analysis assuming imperfect comparison data was also performed and is described below.

Using the techniques in Tolman (1998) one can estimate the expected value of the true model uncertainty for a range of estimated mean observational uncertainties. Doing so, one finds the scatterometer-derived pressures are about 1.5 hPa more accurate than the NCEPR. In order to obtain an estimate of both the scatterometer-derived pressure uncertainty and the observed pressure uncertainty, a “bin-average analysis” (BAA) was used (Tolman 1998). A BAA is performed on the actual data, and then a BAA is performed on synthetic data generated using a range of uncertainties. Since reproducibility of the BAA is a necessary condition for accurate error estimation, the BAA gives an idea of both the observed and the scatterometer-derived pressure uncertainties. One finds that at least an 8 hPa uncertainty in both the observed and scatterometer-derived pressures is needed for the synthetic BAA to resemble the real BAA. Although these numbers are high, the many sources of uncertainty should be remembered: the problematic nature of analysis in the Southern Hemisphere, barometer height corrections, dynamic pressure effects, and uncertainty introduced from the collocation.

## 5. CASE STUDY

While the statistics presented in the last section would seem to imply that the scatterometer-derived pressures make only a small improvement upon the NCEPR overall, there are many instances where the NCEPR misses storms entirely and the scatterometer-derived pressures are a large improvement (as much as 20 hPa). An example will be given in this section. Note that the missed storms are not in the middle of the Pacific, but are very close to land. The relative proximity of such systems to land highlights the importance that they be identified and tracked using scatterometer-derived pressures.

The example begins on 7 June with a storm that has formed between Australia and Antarctica (Fig. 2). In three days this storm moves eastward by about 30° (Fig. 3). The NCEPR has begun to recognize this system about to crash into New Zealand, but has a central pressure 16 hPa higher than the scatterometer pressure field. Four days later (Fig. 4) after passing New Zealand the NCEPR represents the system much better; however, the NCEPR has missed a system (Fig. 5) that formed just downwind of New Zealand. This cycle begins again with another system forming in the region between Australia and Antarctica (Fig. 6). This system, however, dives southward (Fig. 7) and continues to elude the NCEPR. The existence and location of these storms was also verified with Australian Bureau of Meteorology GMS IR imagery. Other cases of missed storms were also typical between Africa and Antarctica.

## 6. CONCLUSIONS

This work has demonstrated that the SeaWinds on QuikSCAT winds can effectively be used to objectively calculate high-resolution surface pressures. The pressures were validated in comparison to in situ observations. Overall, the scatterometer-derived surface pressures were a small improvement over the NCEPR, which is used as the technique’s background field. This improvement is understated because the comparison data under-sample storms. Instances are found where the NCEPR missed storms entirely and the scatterometer-derived pressures are a large improvement (as much as 20 hPa).

## 7. ACKNOWLEDGEMENTS

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## 8. REFERENCES

Bourassa, M. A., D. M. Legler, J. J. O’Brien, and S. R. Smith, 2002: SeaWinds validation with research vessels. *J. Geophys. Res.*, in press.

Brown, R. A., and L. Zeng, 1994: Estimating central pressures of oceanic midlatitude cyclones. *J. Appl. Meteor.*, **33**, 1088-1095.

Endlich, R. M., D. E. Wolf, C. T. Carlson, J. W. Maresca, Jr, 1981: Oceanic wind and balanced pressure-height fields derived from satellite measurements. *Mon. Wea. Rev.*, **109**, 2009-2016.

Harlan, J., Jr., and J. J. O'Brien, 1986: Assimilation of scatterometer winds into surface pressure fields using a variational method. *J. Geophys. Res.*, **91**, 7816-7836.

Hilburn, K. A., M. A. Bourassa, and J. J. O'Brien, 2002: Development of scatterometer-derived research-quality surface pressures for the Southern Ocean, *J. Geophys. Res.*, in review.

Patoux, J., and R. A. Brown, 2002: A gradient wind correction for surface pressure fields retrieved from scatterometer winds. *J. Appl. Meteor.*, **42**, 133-143.

Tolman, H. L., 1998: Effects of observation errors in linear regression and bin-average analysis. *Q. J. R. Meteorol. Soc.*, **124**, 897-917.

Zierden, D. F., M. A. Bourassa, J. J. O'Brien, 2000: Cyclone surface pressure fields and frontogenesis from NASA scatterometer (NSCAT) winds. *J. Geophys. Res.*, **105**, 23 967-23 981.

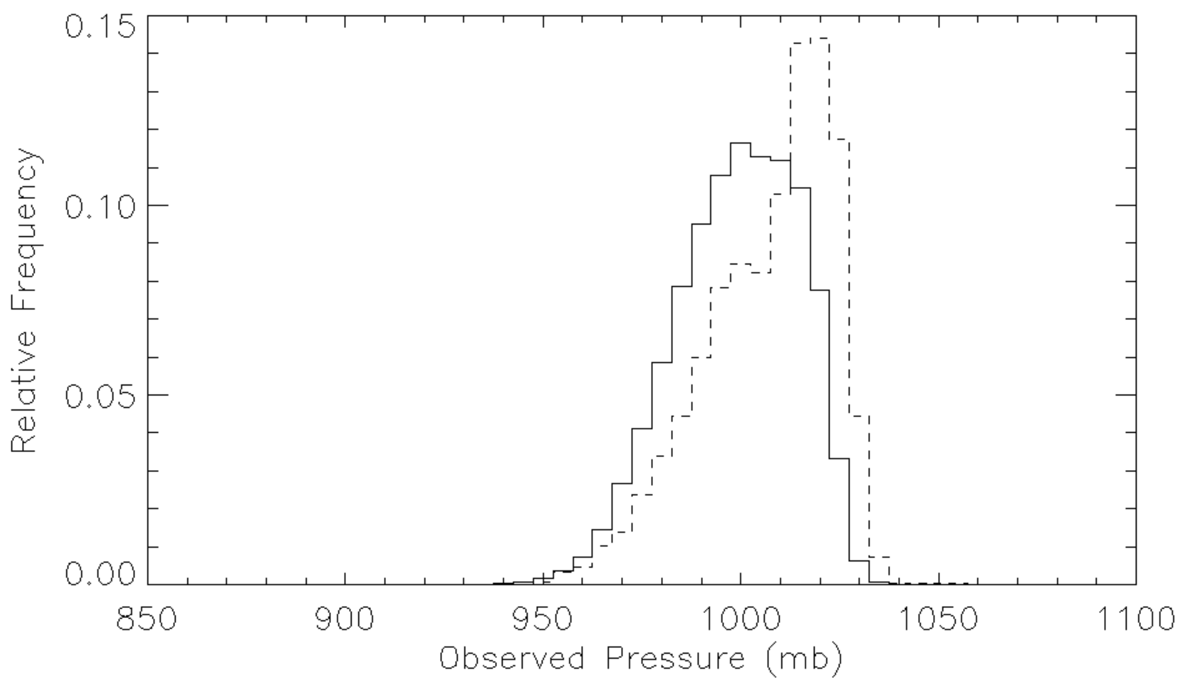


FIG. 1. Histograms for all calculated pressure points (solid) and observation pressure points (dashed). It can be seen that all the calculated pressure points include low pressures not found at the validation (observation) points.

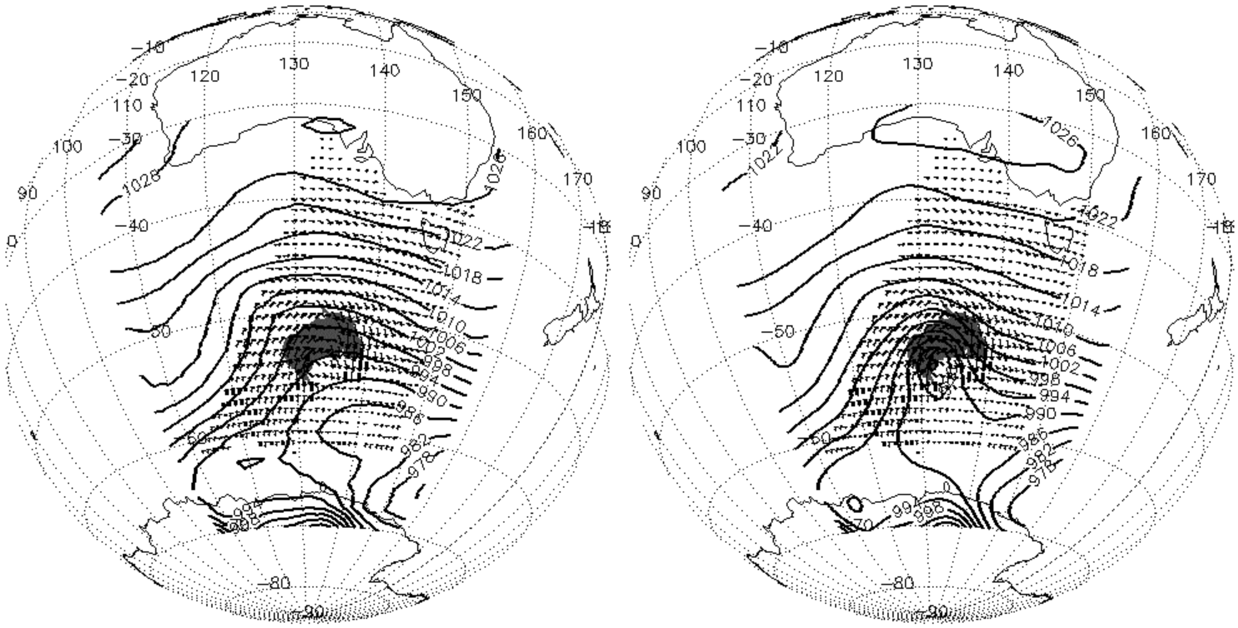


FIG. 2. SeaWinds winds (greater than 35 kts shaded) with NCEPR pressures (left) and calculated pressures (right; CP (central pressure): 982 hPa) for 7 June 2002. The southern limit of the swath indicates the location of the ice edge.

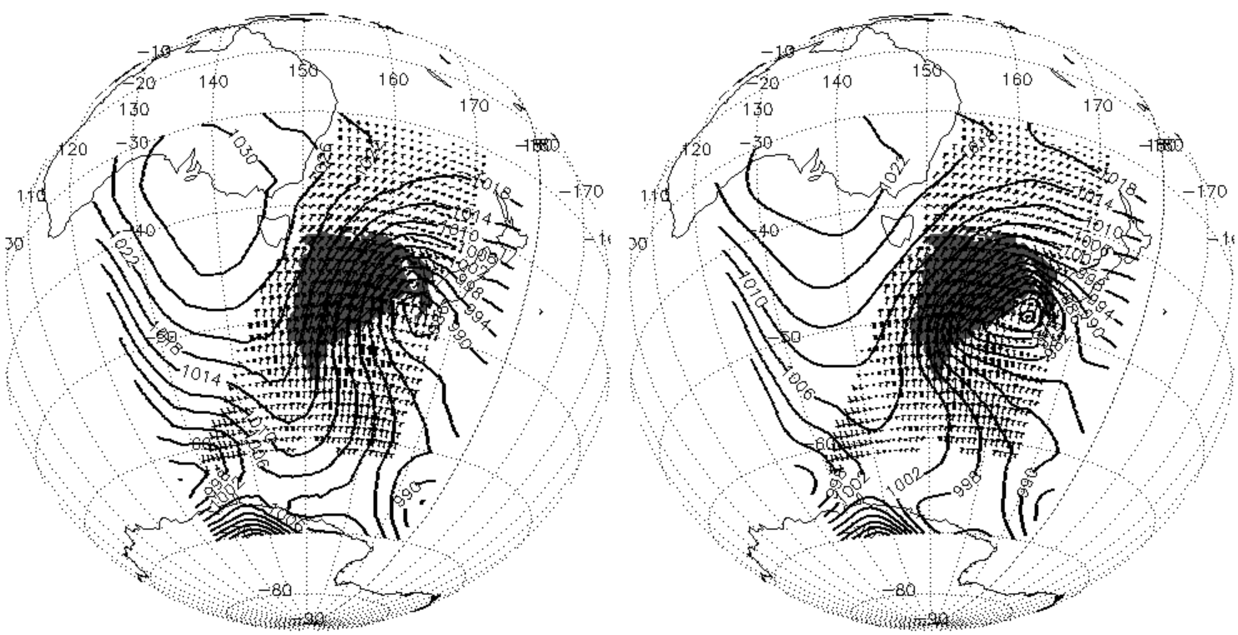


FIG. 3. SeaWinds winds (greater than 35 kts shaded) with NCEPR pressures (left; CP: 986 hPa) and calculated pressures (right; CP: 966 hPa) for 10 June 2002.

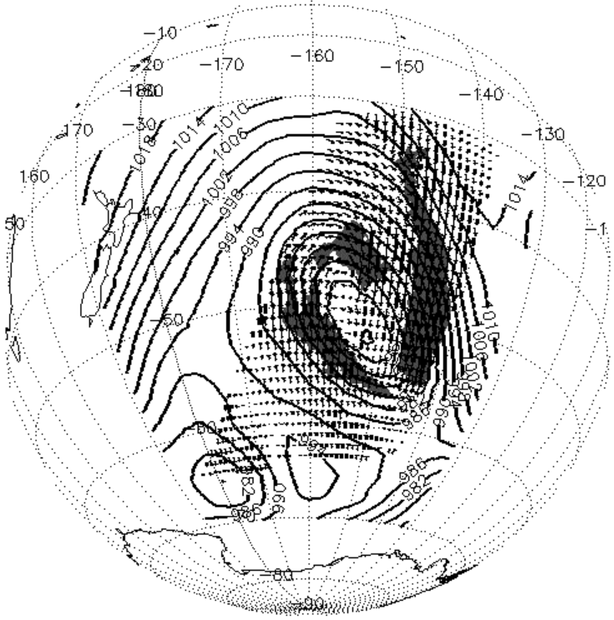

FIG. 4. SeaWinds winds (greater than 35 kts shaded) with NCEPR pressures (left; CP: 962 hPa) and calculated pressures (right; CP: 970 hPa) for 14 June 2002.

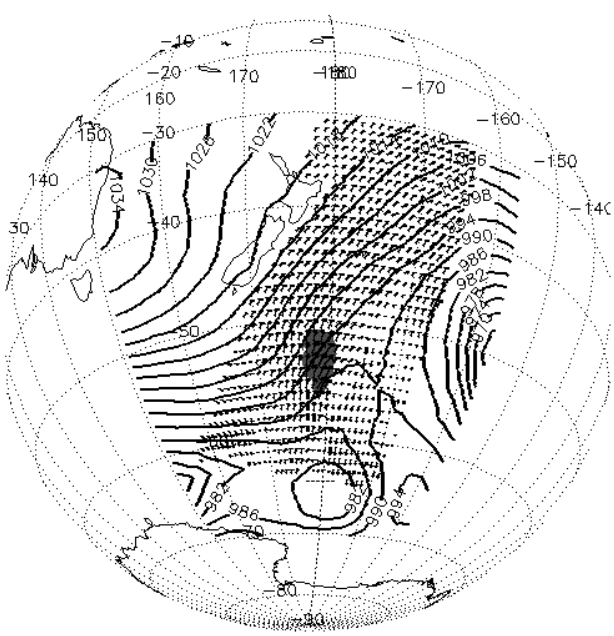

FIG. 5. SeaWinds winds (greater than 35 kts shaded) with NCEPR pressures (left) and calculated pressures (right; CP: 978 hPa) for 14 June 2002.

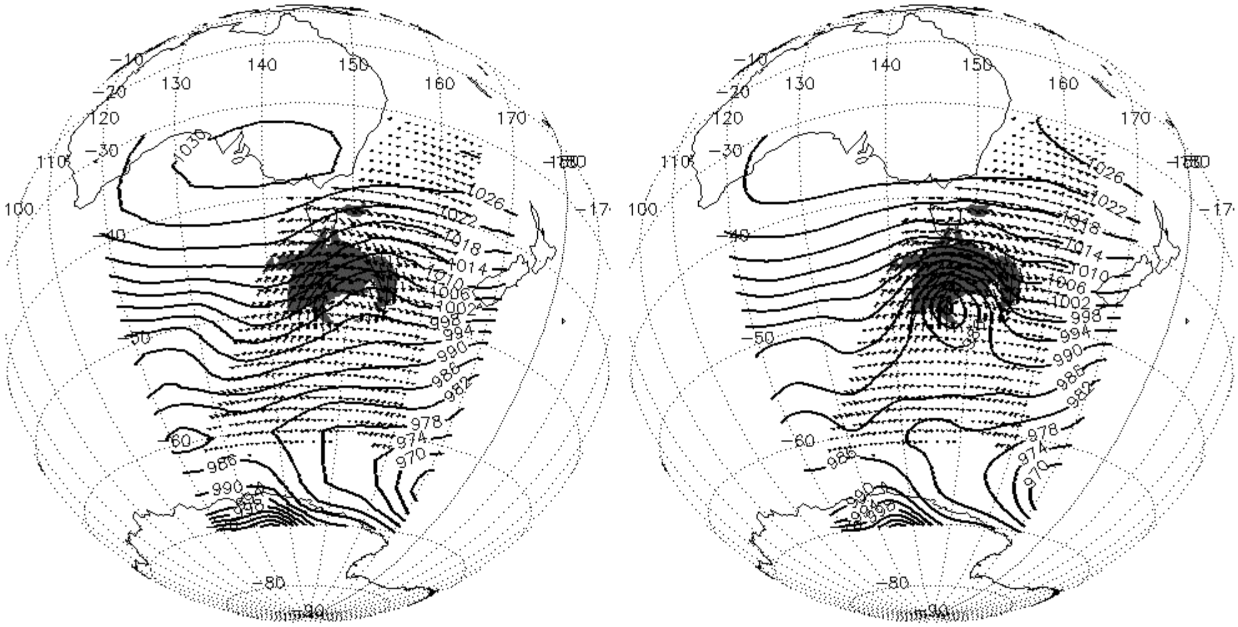


FIG. 6. SeaWinds winds (greater than 35 kts shaded) with NCEPR pressures (left) and calculated pressures (right; CP: 978 hPa) for 17 June 2002.

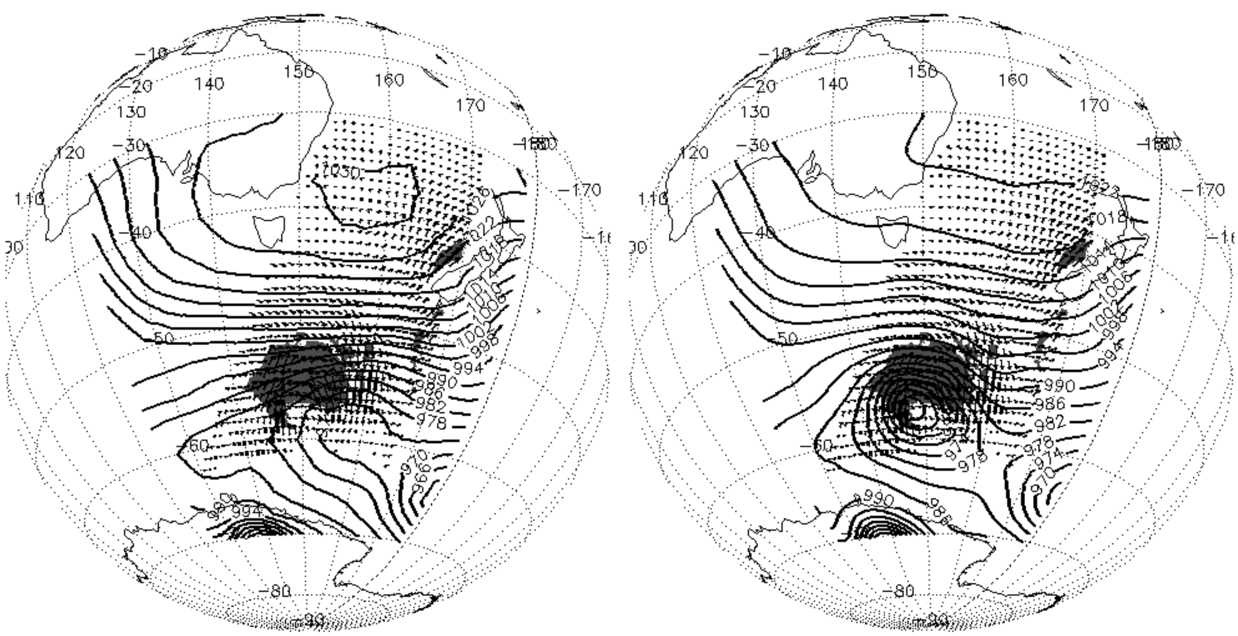


FIG. 7. SeaWinds winds (greater than 35 kts shaded) with NCEPR pressures (left) and calculated pressures (right; CP: 958 hPa) for 18 June 2002.