P4.15 POLAR WIND RETRIEVALS USING THE ADVANCED MICROWAVE SOUNDING UNIT

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1. INTRODUCTION

Wind measurements derived from satellite data are most valuable over the oceanic regions where few surface and radiosonde stations exist. This lack of observational data extends over all latitudes, from the tropics to the poles. Key et al. (2003) report that horizontal winds in polar regions estimated from satellite data have the capability to increase the accuracy of numerical model forecasts, illustrating the need for improved wind observations in these data sparse regions.

In this paper, a method to retrieve horizontal wind fields over the polar regions using temperature profiles derived from satellite data is presented. The technique was originally developed for use in tropical cyclone research, and has been used to analyze midlatitude cyclones as well.

A discussion of the method used to compute the wind field from vertical temperature profiles derived from satellite data is given in Section 2. The results from a specific case are given in Section 3. Finally, Section 4 presents a summary and avenues for future work.

2. METHODOLOGY AND DATA

2.1 Determination of the Wind Field from Vertical Temperature Profiles

The technique used to derive wind fields over the poles follows the technique applied to tropical cyclones (Kidder et al. 2000; Demuth et al. 2004) and to midlatitude cyclones (Dostalek 2004). Starting with a specified height field, in this case the GFS (Global Forecast System) model 100-hPa analyzed height, the vertical temperature profile computed from satellite data can be used in the downward integration of the hydrostatic equation to derive the height field as a function of pressure. In this step the thicknesses of the atmospheric layers are computed using the assumption of a constant lapse rate within the layer instead of a constant temperature within the layer. Once the height field is known, the streamfunciton of the nondivergent component of the wind can be computed using a balance condition (i.e. geostrophic, linear, nonlinear). The streamfunction is related to the nondivergent component of the horizontal wind by $\vec{v} = \hat{k} \times \nabla \psi$.

2.2 Temperature Retrieval

In the present work, the vertical temperature profiles are computed from a retrieval technique (Goldberg 1999) which uses microwave radiances from the Advanced Microwave Sounding Unit (AMSU), which flies aboard NOAA's current polar-orbiting satellite series. Microwave data is particularly useful in the retrieval of temperature profiles in that liquid water clouds and thin ice water clouds are essentially transparent to microwave radiation. Only heavily precipitating clouds, or clouds with a high ice crystal concentration significantly attenuate microwave radiation (Jones 1989).

The AMSU instrument is actually two instruments, AMSU-A and AMSU-B. The channels of AMSU-A are primarily used for the generation of temperature profiles, while the channels of AMSU-B are primarily used for moisture profiling. The retrieval technique used here employs only radiances from AMSU-A. The technique produces temperatures at 40 pressure levels from 0.1 to 1000 hPa for each of the 30 footprints in a scan line. The nadir footprint size of the AMSU-A instrument is 50 km.

For the development and initial testing of the wind retrieval technique, 81 swaths of data over the Arctic north of 60º N from 2-17 December 2004 were acquired from the NOAA-15 and NOAA-16 polar-orbiting satellites. In order to validate the results, radiosonde profiles

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from 20 stations were also collected during this same time period.

3. EXAMPLE FROM 17 DECEMBER 2004

In order to introduce some initial results, data from a 17 December 2004 NOAA-16 orbit were analyzed. The orbit (Fig. 1) passed over the Arctic around 0015 UTC. The 0000 UTC 100-hPa analysis from the GFS model was therefore used as the upper boundary condition.

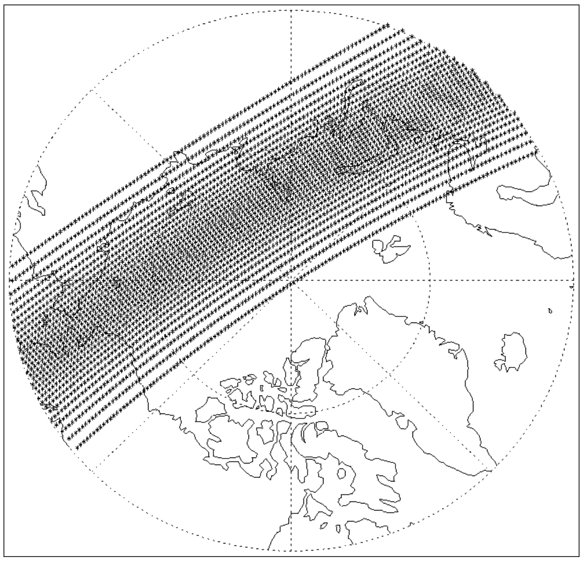

Fig. 1. AMSU footprints over the Arctic of the NOAA-16 orbit of 0015 UTC 17 December 2004.

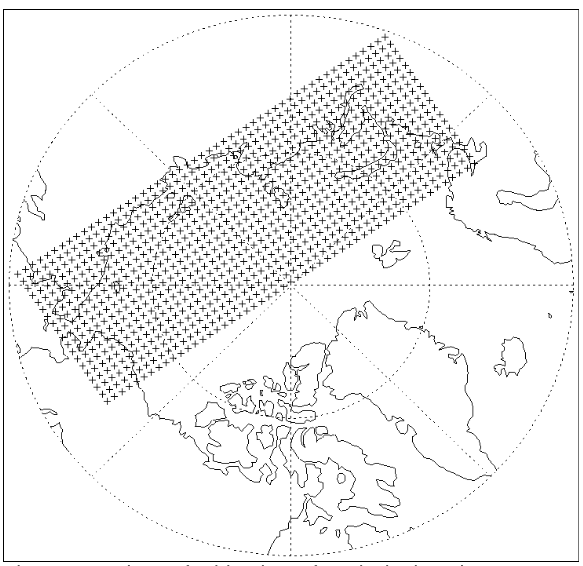

Fig. 2. Locations of grid points of analysis domain.

The analysis domain (Fig. 2) is a polar stereographic projection rotated along the AMSU data swath, and consists of a 51x19 array of points. The temperatures retrieved from the satellite data were fitted to the analysis grid using a Barnes analysis (Koch et al. 1983). Bilinear interpolation was used to interpolate the 100-hPa heights from the GFS model to the analysis grid.

The 500-hPa height field, along with the 500-hPa geostrophic winds was computed for the initial evaluation of the technique. The GFS model 500-hPa height analysis and geostrophic winds were used for comparison. A more

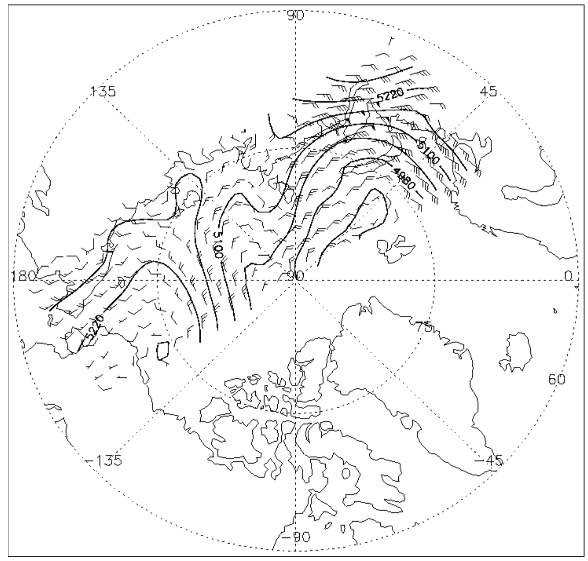

Fig. 3. GFS analysis of 500-hPa heights and geostrophic winds on 0000 UTC 17 December 2004. Height contours every 60 m. Half wind barb represents 2.5 ms^{-1}, full wind barb 5 ms^{-1} and a pennant 25 ms^{-1}.

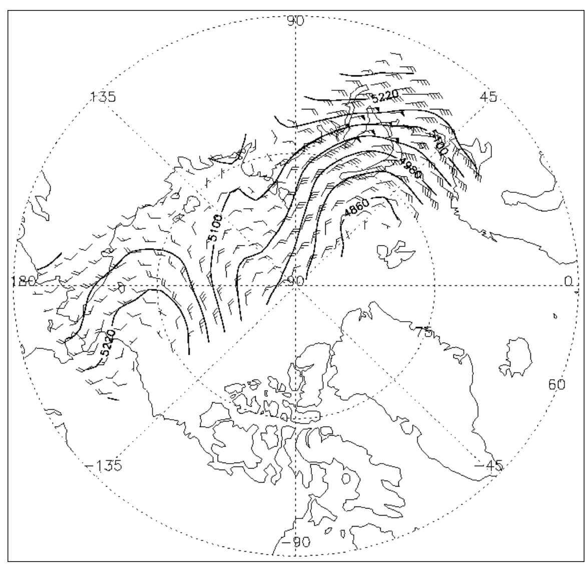

Fig. 4. Derived 500-hPa heights and geostrophic winds for 0015 UTC 17 December 2004. Height contours and wind barbs are as in Fig. 3.

meaningful evaluation of the technique would come with the comparison to radiosondes; such a comparison will be done in the future.

The GFS 500-hPa height field and geostrophic winds (Fig. 3) show a ridge along 75º N from north of Alaska to around 135º E. A trough is present over Russia, between 45º E and 90º E and around 70º N. Within this trough is a shortwave near 66º N and 60º E. As is expected, the greatest height gradient (and therefore wind speed) is associated with the trough. For clarity and in order to eliminate edge effects, wind barbs are plotted for every other row and column of the analysis grid, with the outermost rows and columns omitted.

The computed height and wind fields (Fig.4) show the same general pattern as the model analysis. Some differences, however, do exist. The small cyclonic circulation near 63º N and 177º E present in the GFS analysis was not seen in the retrieved winds. A small ridge just north of 60º N and near 67º E produced anticyclonically curved height and wind fields in the GFS analysis. This feature was also absent in the computed heights and winds. Further comparison can be made by plotting the difference between the computed height and geostrophic wind fields and the GFS-analyzed height and geostrophic wind fields (Fig. 5). The height difference field indicates that there is an overall negative bias in the computed height field. This observation is confirmed by a statistical analysis of the height difference, which shows a bias of -29 m. Systematic height differences will not affect the analysis of geostrophic wind, as the wind field is related to the gradient of the height field. Some structure in the height difference field does exist, however, and the largest gradients are found in the vicinity of the trough and shortwave over Russia. The maximum wind speed difference was computed as 16 ms^{-1}.

4. Summary and Future Work

A wind retrieval technique based on vertical temperature profiles derived from AMSU-A radiances has been applied to the Arctic. The method uses the temperature profiles in the downward integration of the hydrostatic equation from 100 hPa. The resulting heights can then be used in a balance equation to retrieve the wind field at various pressure levels. In the example given here, the 500-hPa heights and geostrophic winds were computed and compared to the 500-hPa heights and geostrophic winds from the GFS analysis. Overall, the agreement between the fields was quite good, although a systematic negative height bias was observed.

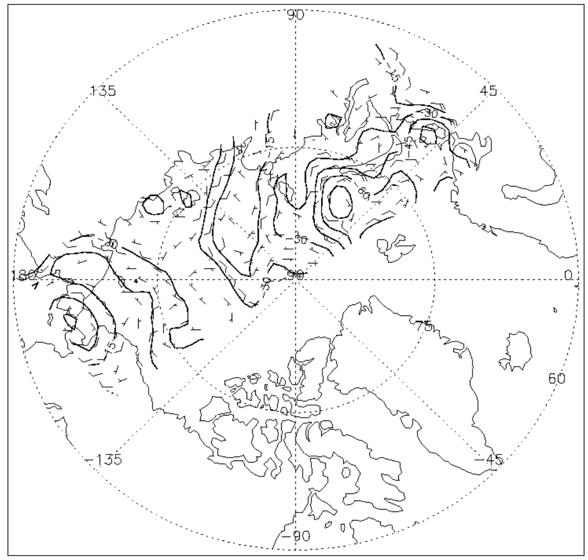

Fig. 5. Difference between the computed 500-hPa height and the GFS 500-hPa height analysis, with the difference in geostrophic winds plotted as wind barbs. Contour interval every 15 m and wind barbs as in Fig. 3.

Future work will consist of comparisons between derived fields radiosonde measurements. This comparison will, of course, be more informative of the quality of the wind retrieval technique than comparison to a model analysis. For the comparison to radiosonde winds a more accurate balance condition, the nonlinear balance (Charney 1955), will be used. Also, the possibility of using the Advanced Tiros Operational Vertical Sounder (ATOVS) (Reale 2001, 2002) data will be investigated. The ATOVS product suite uses radiances from both the AMSU instrument as well as the HIRS (High Resolution Infrared Radiation Sounder) instrument, and also contains a vertical moisture profile retrieval. The ATOVS data are NESDIS' (National Environmental Satellite, Data, and Information Service) operational polar-orbiting satellite product.

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