# DEVELOPMENT OF SCATTEROMETER-DERIVED RESEARCH QUALITY SURFACE PRESSURE FIELDS 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 unprecedented coverage of the Southern Ocean (Fig. 1). SeaWinds on QuikSCAT has been used to determine high-quality surface wind speed and direction (Bourassa et al. 1997, Freilich and Dunbar 1999; Bourassa et al. 2001), and in turn, surface pressure (Harlan and O'Brien 1986; Brown and Levy 1986; Brown and Zeng 1994; Zierden et al. 2000). This study has two goals. First, is demonstration that the scatterometer can be effectively used to calculate high-resolution, research-quality surface pressure fields without thousands of buoys. Second, is demonstration that the scatterometer has an impact on existing analysis covering the Southern Ocean.

## 2. DATA

The data to be used were processed with the Ku-2000 model function that has been shown to result in 60% of the QSCAT-1 uncertainties (Bourassa et al. 2001). Radiometer data from other sources were used to flag cells potentially contaminated by precipitation and were not considered in the analysis. NCEP reanalysis was used to initialize the pressure field and update boundary conditions. The analysis data are available on a 2.5° global grid at 6-hour intervals. Global Telecommunications System (GTS) data received past the window for NWP processing will be used as comparison data for validation. Errors in both the satellite pressures and in the GTS pressures must be considered. The technique of Kent et al. (1998) could be used, for example.

## 3. METHODOLOGY

Geostrophic vorticity may be calculated from an initial (analysis) pressure field using the centered difference form of

$$(\zeta^{A}{}_{ij})_g = (\rho \boldsymbol{f}_j)^{-1} \quad {}^{2}\boldsymbol{p}_{ij} + (\beta_j/\rho \boldsymbol{f}_j^{2})\, \partial \boldsymbol{p}_{ij}/\partial \boldsymbol{y}$$

where $\boldsymbol{p}$ is sea-level pressure and ρ is taken to be a constant (1.225 kg $m^{-3}$). This value of vorticity is blended with the satellite vorticity using a variational method (Zierden et al., 2000). Before blending, however, the satellite vorticity must be converted to its geostrophic equivalent. First, a "reduction-rotation" method is used to relate the satellite vorticity ($\zeta^S$) to a gradient equivalent (Clarke and Hess 1975; Harlan and O'Brien 1986). Theoretical considerations (Brown and Zeng 1994) suggest a scaling factor of 1.5 and a cyclonic rotation factor of 18° for neutral stability, which will be used in this study. The gradient vorticity is then adjusted to its geostrophic equivalent using a method inspired by Patoux and Brown (2001) and Endlich (1961). The gradient wind equation can be written as

$$\boldsymbol{V}_g = \boldsymbol{V}(1+\boldsymbol{V}/\boldsymbol{fR}) = \boldsymbol{V}\,(1+\boldsymbol{Ro})$$

where $\boldsymbol{Ro}$ is the Rossby number. If the flow is steady, it can be shown that

$$\boldsymbol{Ro} = 1/\boldsymbol{fV}^2\, [(\boldsymbol{u}^2\, \partial \boldsymbol{v}/\partial \boldsymbol{x} - \boldsymbol{v}^2\, \partial \boldsymbol{u}/\partial \boldsymbol{y}) - \boldsymbol{uv}(\partial \boldsymbol{u}/\partial \boldsymbol{x} - \partial \boldsymbol{v}/\partial \boldsymbol{y})]$$

Terms involving time derivatives of the wind field can be included to get the full trajectory curvature, but Patoux and Brown (2001) obtain good results without these time dependent terms. The gradient wind adjustment is performed in the swath, and then both the satellite and analysis geostrophic vorticities are transferred to a regular 0.25° earth-aligned grid.

The variational method minimizes the cost function $\boldsymbol{F}$ to find the solution fields $\boldsymbol{p}_{ij}$ and $\zeta_{ij}$,

$$\boldsymbol{F}(\boldsymbol{p}_{i,j}\,,\ \zeta_{i,j}\,,\ \lambda_{i,j}) \ = \ \Sigma_i\, \Sigma_j\, [\lambda_{i,j}\, \boldsymbol{H}_{i,j} + K_\zeta/2\ \boldsymbol{M}_{i,j}^{\ 2} + \boldsymbol{K}_E/2\ \ \boldsymbol{G}_{i,j}]$$

where $\lambda_{ij}$ is a Lagrange multiplier, $\boldsymbol{H}_{ij}$ is the strong contraint or model, $\boldsymbol{M}_{ij}$ is the data misfit, $\boldsymbol{G}_{ij}$ is the weak constraint or regularization, and $\boldsymbol{K}_\zeta$ and $\boldsymbol{K}_E$ are Gaussian precision moduli. The model takes the form

$$\boldsymbol{H}_{i,j} \ = \ (\rho \boldsymbol{f}_j)^{-1}[\ \ {}^{2}\boldsymbol{p}_{i,j} \ - \ (\beta_j/\boldsymbol{f}_j)\, \partial \boldsymbol{p}_{i,j}/\partial \boldsymbol{y}] \ - \ \zeta_{i,j}$$

The data misfit takes the form

$$\boldsymbol{M}_{i,j} \ = \ \zeta_{i,j} \ - \ \zeta^*_{i,j}$$

where $(\zeta^*{}_{ij})_g$ takes on the satellite value, $(\zeta^{S}{}_{ij})_g$, inside the swath and the initial value, $(\zeta^{A}{}_{ij})_g$, outside the swath. The regularization is simply a minimization of the geostrophic kinetic energy

$$\boldsymbol{G}_{i,j} \ = \ (2\rho^2\, \boldsymbol{f}_j^{2})^{-1} \quad \boldsymbol{p}_{i,j} \bullet \ \ \boldsymbol{p}_{i,j}$$

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Minimization of the cost function reduces to solving

$$(\rho \boldsymbol{f_j})^{-1}[\;\;{}^{2}\boldsymbol{p}_{i,j} - (\beta_j/\boldsymbol{f_j})\,\partial \boldsymbol{p}_{i,j}/\partial \boldsymbol{y}] - (\boldsymbol{K}/2\rho \boldsymbol{f_j})\,(\boldsymbol{p}_{i,j} - \boldsymbol{p}_{0i,j}) = \zeta^*_{i,j}$$

where $\boldsymbol{K} = \boldsymbol{K}_E/2\boldsymbol{K}_\zeta$. This may be solved using successive overrelaxation.

## 4. RESULTS AND VALIDATION

Extensive calculations and validation are being performed at this time. Once completed, the two goals stated in the introduction will be evaluated.

## 5. ACKNOWLEDGEMENTS

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**FIG. 1.** Typical daily coverage of SeaWinds over the Southern Ocean.