2.14 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). The scatterometer actively measures radar backscatter cross-section at multiple viewing geometries. This information 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 paper has two goals. First, this paper will demonstrate that the scatterometer can be effectively used to calculate high-resolution, research-quality surface pressure fields without thousands of buoys. Second, this paper will demonstrate that the scatterometer has an impact on existing analysis covering the Southern Ocean.

2. DATA

QuikSCAT is a sun-synchronous satellite with a period of 101 minutes. The SeaWinds scatterometer uses two conically rotating pencil beams operating in the Ku-band (13.402 GHz). Individual footprints are binned into 25x25 km cells with as many as 76 cells across the satellite swath. A "geophysical model function" relates the backscatter cross-section to the near surface wind velocity. 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. These flagged cells 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 2.5º global grid at 6-hour intervals. Drifting buoys are the comparison data for validation. While some of the buoys may have entered the NCEP reanalysis, their effect on the analysis should be sufficiently small to be ignored in validation.

3. METHODOLOGY

SeaWinds winds are located on a regular grid aligned with the satellite track. Relative vorticity may be calculated in the swath using centered differences. Using that vorticity is rotationally invariant, the winds are converted to cross-track (***v***') and along-track (***u***') components and derivatives are computed in along-track (***x***') and cross-track (***y***') directions. Delunay triangulation and interpolation (Renka 1982) transfers the satellite vorticity (ζ^S) onto a regular 0.25º earth-aligned grid.

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

$$\zeta^A{}_g = (\rho \boldsymbol{f})^{-1} \nabla^2 \boldsymbol{p} + (\beta/\boldsymbol{f})\, \boldsymbol{u}_g$$

where ***p*** is the sea-level pressure and ρ is taken to be a constant. 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. A "reduction-rotation" method is used to relate satellite vorticity (ζ^S) to a geostrophic equivalent ($\zeta^S{}_g$) (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 18º for neutral stability, which will be used in this study.

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

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

where $\boldsymbol{H}_{ij}$ is the strong constraint or model, $\boldsymbol{M}_{ij}$ is the data misfit, and $\boldsymbol{G}_{ij}$ is the weak constraint or regularization. The model takes the form

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

The data misfit takes the form

$$\boldsymbol{M}_{ij} = \zeta_{ij} - (\zeta^*{}_{ij})_g$$

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

$$\boldsymbol{G}_{ij} = (2\rho^2 \boldsymbol{f}_j^2)^{-1} \nabla \boldsymbol{p}_{ij} \bullet \nabla \boldsymbol{p}_{ij}$$

Minimization of the cost function involves taking

$$\partial \boldsymbol{F}/\partial \lambda_{ij} = \boldsymbol{H}_{ij} = 0 \tag{1}$$

$$\partial \boldsymbol{F}/\partial \zeta_{ij} = \boldsymbol{K}_\zeta \boldsymbol{M}_{ij} - \lambda_{ij} = 0 \tag{2}$$

$$\partial \boldsymbol{F}/\partial \boldsymbol{p}_{ij} = (\rho \boldsymbol{f}_j)^{-1}[\nabla^2 \lambda_{ij} + (\beta/\boldsymbol{f}_j)\, \partial \lambda_{ij}/\partial \boldsymbol{y}] + \boldsymbol{K}_E (2\rho \boldsymbol{f}_j)^{-2} \nabla^2 \boldsymbol{p}_{ij} = 0 \tag{3}$$

(3) has a solution of the form

$$\lambda_{ij} = (\boldsymbol{K}_E/4\rho \boldsymbol{f}_j)\, (\boldsymbol{p}_{ij} - \boldsymbol{p}_{0ij}) \tag{4}$$

where $\boldsymbol{p}_{0ij}$ is the homogeneous solution. The homogeneous solution satisfies

$$(\boldsymbol{K}_E/4\rho \boldsymbol{f}_j) \nabla^2 \boldsymbol{p}_{0ij} = 0$$

and λ=0 on the boundary implies $\boldsymbol{p}_{0ij} = \boldsymbol{p}_{ij}$. Substituting (4) into (2) gives

$$\zeta_{ij} = \zeta^*{}_{ij} + (\boldsymbol{K}/2\rho \boldsymbol{f}_j)\, (\boldsymbol{p}_{ij} - \boldsymbol{p}_{0ij}) \tag{5}$$

where $\boldsymbol{K} = \boldsymbol{K}_E/2\boldsymbol{K}_\zeta$. Putting (5) into (1) yields

$$(\rho \boldsymbol{f}_j)^{-1}[\nabla^2 \boldsymbol{p}_{ij} - (\beta/\boldsymbol{f}_j) \partial \boldsymbol{p}_{ij}/\partial \boldsymbol{y}] - (\boldsymbol{K}/2\rho \boldsymbol{f}_j)\, (\boldsymbol{p}_{ij} - \boldsymbol{p}_{0ij}) = \zeta^*{}_{ij} \tag{6}$$

(6) may be solved using an elliptic solver with second-order finite difference representations of the derivatives and subject to Dirichlet or Neumann boundary conditions.

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4. VALIDATION

Drifting buoys constitute the comparison data. The errors in both the satellite pressures and buoys must be considered. For example, the technique in Kent et al. (1998) could be used.

5. RESULTS/CONCLUSIONS

Results and conclusions will be presented at the meeting and will be available at www.coaps.fsu.edu/~hilburn/18IIPS/index.html.

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