UNCERTAINTY IN SCATTEROMETER DERIVED VORTICITY

Mark A. Bourassa
COAPS & Department of Meteorology
Florida State University
Tallahassee, FL 32306-2840
E-Mail: bourassa@coaps.fsu.edu

The main goals of this project are to improve upon the scatterometer-based calculation of area averaged vorticity (referred to from this point as "vorticity") and to characterize errors in this technique. The major sources of error in the calculation of scatterometer-based surface vorticity are investigated and discussed. The strengths and weaknesses of the new and old methods (that focused on tropical systems) are discussed in terms of the improvements made upon earlier methods, as well as considerations of how accuracy might change for prospective satellite missions.

Working with QuikSCAT swath data poses several issues in attempting such a calculation. Swaths are not vertically aligned or in a perfectly gridded format and some data points may be missing (due to land contamination or being outside the observational swath) or rain contaminated. To account for this, the calculation technique is developed to work around such points, and outputs a missing value if there are insufficient good data points. Vorticity (ζ) is calculated at the center of a "shape", as defined by available data in the swath, using the circulation (C) about the shape and divided by the area (A) of the shape: $\zeta = C / A$. The circulation theorem is used to calculate the circulation: $C = \oint \mathbf{v} \cdot d\mathbf{l}$., where **v** is the velocity vector on the closed contour and **l** is an element tangent to the contour. The wind vector components are linearly interpolated between adjacent good observations. Then $\int \mathbf{v} \cdot d\mathbf{l}$ becomes $\sum \mathbf{v} \cdot \mathbf{l}$.

The shapes used in this study are approximations of circles. The finest spatial scale is a diameter of one grid spacing, which for QSCAT is 25km. This spatial scale is relatively noisy due to random errors associated with (1) observational noise and (2) truncation errors related to the linear interpolation between grid points. At the 25km scale, the 'circle' is approximated as a square and the results are equivalent to finite differencing in a swath-relative coordinate system. The in-swath vorticity is also calculated using a diameter of 25 to 250km diameter. The larger scale greatly reduces the noise at the expenses of reduced resolution and a bias associated with smaller scale features.

. The propagation of Gaussian distributed random errors can be used to estimate the contribution of observational errors to uncertainty (expressed as a standard deviation) in area averaged vorticity. The observational uncertainty in vorticity is defined as $\sigma_\zeta = \sigma_u \left(n_1 + 2n_2\right)^{0.5} / A$, where σ_u is the uncertainty in a vector wind component, n_1 represents the number of "non-diagonal" components of the area perimeter and n_2 represents the number of "diagonal" components of the area perimeter. The area increases more rapidly than the number of points on the perimeter of the area, therefore, the σ_ζ decreases as area increases.

The uncertainty can also be expressed in terms of diameter and the grid spacing, which might make the application more intuitive, particularly when considered for non-QuikSCAT applications. Consider that the number of points on the perimeter times the grid spacing is roughly equal to the length of the perimeter, which is proportional to the diameter. The area is proportional to the diameter squared: $\sigma_{\zeta} \approx 4\pi^{-0.5}\sigma_{u}D^{-1.5}\,\Delta x^{-0.5}$.

The uncertainty in vorticity (σ_{ς}) associated with truncation errors has a similar form, he uncertainty in wind related to truncation error (σ_T) is roughly proportional to the square of the length of each segment, which is roughly proportional to $(\Delta x)^2$. Therefore, σ_{ζ} is proportional to $(\Delta x)^{1.5}$: $\sigma_{\varsigma} \propto D^{-1.5}\,\Delta x^{1.5}$. As one would anticipate, finer grid spacing will reduce truncation errors, as will increasing the diameter of calculation area. However, increasing the area results in a vorticity averaged over a larger area, which has shortcomings associated with representation errors (over smoothing).

Spatial averaging errors come in to play when the wind vectors associated with an area averaged vorticity maximum are within the ring used in the vorticity calculations. The larger the ringsize, the more potential there is for a localized vorticity maximum to be missed. In the case of cyclonic systems, representation error tends to result in a negative bias (an underestimation of positive vorticity). Tropical disturbances from 01 August 1999 through 31 October 1999 were examined to estimate the bias and random errors associated with representation errors. These are systems typical of our applications. The bias shows the change in vorticity (centered at the same point) relative to the vorticity for a ringsize 1 (diameter of 25 km). The bias increases as ringsize increases, with a bias of approximately $1.5\text{x}10^{-5}$ s^{-1} for a ringsize 4 (diameter of 100 km). The magnitude of the bias doesn't decrease much beyond a ringsize 4, thus choosing a ringsize higher than 4 do little to increase the bias from this area assumption for this application. The bias typical of tropical disturbances and TDs ($1.5\text{x}10^{-5}$ s^{-1}) could impact on the application of finding tropical disturbances, since the detection threshold is slightly than three times larger ($5\text{x}10^{-5}$ s^{-1}) than the bias; however, and any bias was presumably factored into the threshold. Different biases will be typical of other types of weather (e.g., fronts or high pressure systems) and therefore the shown biases should not be assumed to apply to all situations.

Representation errors result in a negative bias (underestimation) when sampling cyclonic systems. In a more general sense, these three types of error should be considered in any study of satellite based vorticity. The truncation error is highly dependent on the variability in the satellite sampling pattern, and is likely to be quite different from instrument to instrument. An instrument, such as the proposed XOVWM, with five to 25 times the resolution (in one dimension) would greatly reduce the both truncation and representation errors.

Examples will be provided for each type of error, and the pros and cons of options to reduce there errors will be discussed.