# Comparing Wind Derivative Calculation Methods from Orbital Swath Winds

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## INTRODUCTION

Wind derivatives, such as vorticity and divergence, are important variables used to understand vertical motions in the atmosphere, and wind stress derivatives at the ocean surface are crucial for examining vertical circulations in the upper ocean. Calculation methods for vorticity and divergence from orbital swath wind products differ based on the gridding of winds used for the calculation, the smoothing of winds prior to calculation and the area over which winds are used in the calculations. These differences are examined herein using three different calculation methods for wind derivatives from QuikSCAT. The different calculation methods lead to differences in signal-to-noise relationships as shown in a wavenumber spectra analysis.

## OBJECTIVE

- Compare spatial wavenumber spectra for different wind derivative calculation techniques using orbital swath data to identify differences in noise characteristics with the effects of smoothing, gridding and the area used for individual point calculations.

## DATA

One Month: January, 2008

- NASA MEaSUREs: QuikSCAT Scatterometer Inter-Calibrated ESDR Level 2 Ocean Surface Equivalent Neutral Wind Vectors Version 1.0 (NASA PO.DAAC: QUIKSCAT_ESDR_L2_WIND_STRESS_V1.0)

## DERIVATIVE CALCULATION METHODS

### A. FINITE DIFFERENCING ON A UNIFORM GRID

Calculation Steps:

1. Smooth winds using a 2D loess half-power filter.
2. Interpolate L2 swath winds to a chosen uniform grid in x and y at the individual swath level.
3. Calculate derivatives through 1st order, centered finite differencing:

$$Vorticity = \frac{dv_i}{dx_i} - \frac{du_i}{dy_i} = \frac{v_{i+1} - v_{i-1}}{x_{i+1} - x_{i-1}} - \frac{u_{i+1} - u_{i-1}}{y_{i+1} - y_{i-1}}$$

One main advantage of this method is that the calculated derivatives will share a common grid as the input wind points that are first interpolated from the L2 grid, and the common defined grid can be used to combine multiple swaths for robust statistics. Example: O'Neill et al. (2015)

### B. FINITE DIFFERENCING ON AN ORBITAL GRID

Calculate derivatives through 1st order, centered finite differencing using the nearest neighboring points in the along- and cross-track directions.

This is the most simply applied derivative calculation method. Unlike method A, the calculated derivative point will not always lie on the L2 grid, as the grid itself is not always uniform in the along- and cross-track directions.

### C. CIRCULATION THEOREM METHOD

Calculation Steps:

1. A polygon shape of grid points surrounding a wind vector grid cell on the orbital swath is used to approximate a circle about which the winds are integrated to calculate the circulation of vorticity and divergence around the grid cell given by the equations below.

$$C_{vort} = \oint \boldsymbol{v} \cdot d\boldsymbol{l} = \sum_{i=1}^{n} \frac{1}{2}(u_{i+1} + u_i, v_{i+1} + v_i) \cdot (x_{i+1} - x_i, y_{i+1} - y_i)$$

$$C_{div} = \oint \boldsymbol{v} \times d\boldsymbol{l} = \sum_{i=1}^{n} \frac{1}{2}(u_{i+1} + u_i, v_{i+1} + v_i) \times (x_{i+1} - x_i, y_{i+1} - y_i)$$

2. Area averaged relative vorticity (***V***) and divergence (***D***) is calculated for the wind vector cell by dividing the respective circulation by the polygon area (***A***).

$$Vorticity = \frac{C_{vort}}{A}, \quad Divergence = \frac{C_{div}}{A}$$

This method has the advantage of using different areas over which the derivatives are calculated, which alters the signal-to-noise characteristics. More wind vector cells into consideration depending on the choice of ring size. Example: Bourassa and Ford (2010)

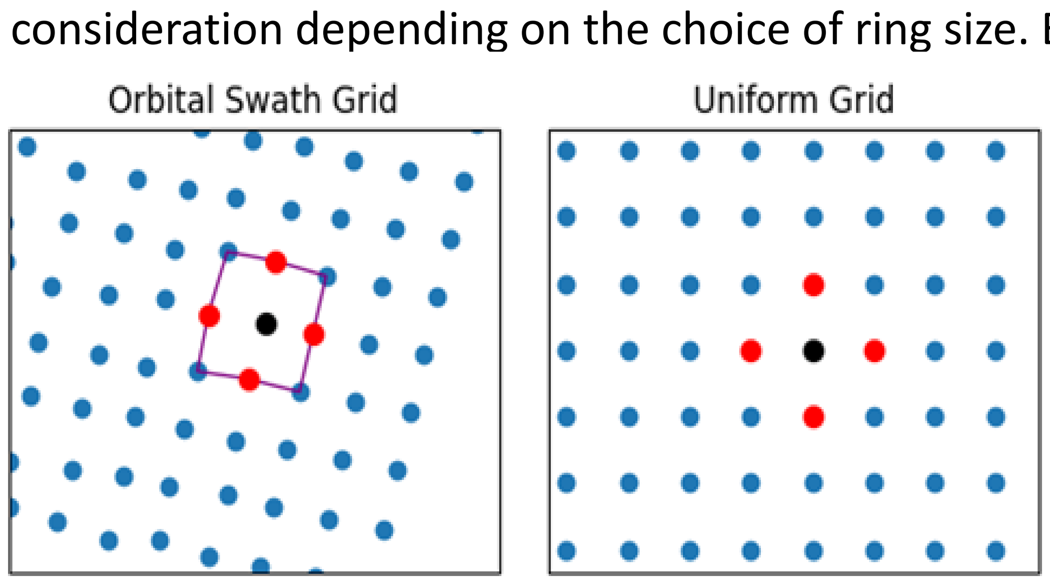


**Figure 1**. Left: Orbital swath grid used for methods B and C. Right: Uniform grid used for method A. Red dots indicate points used for centered finite differences. For method C, the purple line connects the points used in the line integral approach. With the 12.5km QuikSCAT data, this has a "ring size" of 25 km across (ring size 2).

## REFERENCES

Bourassa, M. A., & McBeth Ford, K. (2010). Uncertainty in scatterometer-derived vorticity.
O'Neill, Larry W., Tracy Haack, and Theodore Durland (2015). Estimation of time-averaged surface divergence and vorticity from satellite ocean vector winds.

## POWER SPECTRA DENSITY CALCULATION

- Specta were computed within the bounding boxes in the Atlantic shown in Fig. 1.

Calculation Steps

1. Within the bounding box, we found the longest "string" of non-missing values for each along-swath column meeting a minimum length of 1875 km.
2. Trim all of the strings to the same length.
3. Remove the linear trend from each string.
4. Use a fast Fourier transform to compute the spectra for each string.
5. Sum all of the spectrum for each string over the period of interest and compute the average spectra.

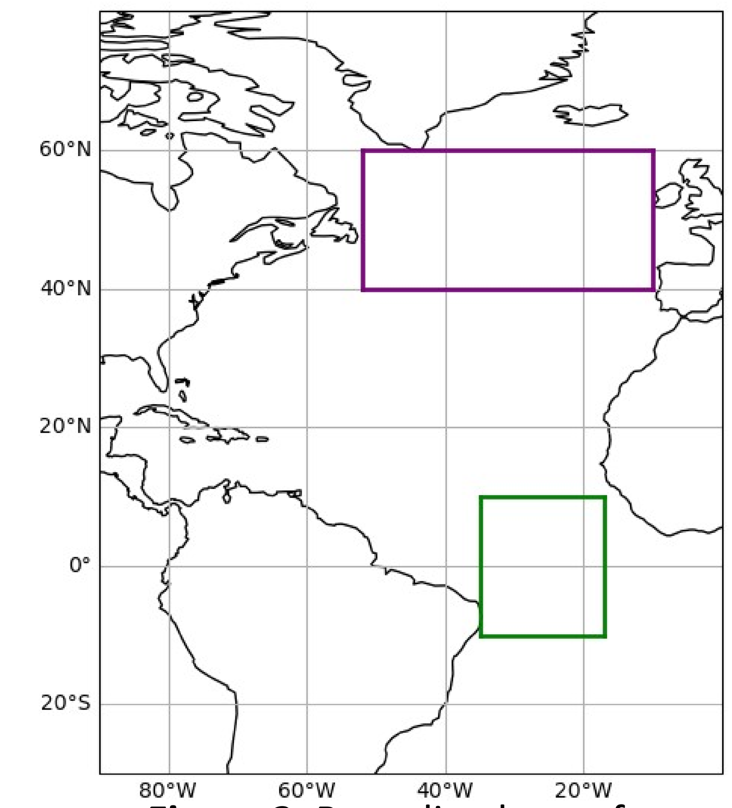


**Figure 2**. Bounding boxes for spectra comparisons.

## RESULTS: SPECTRA ANALYSIS

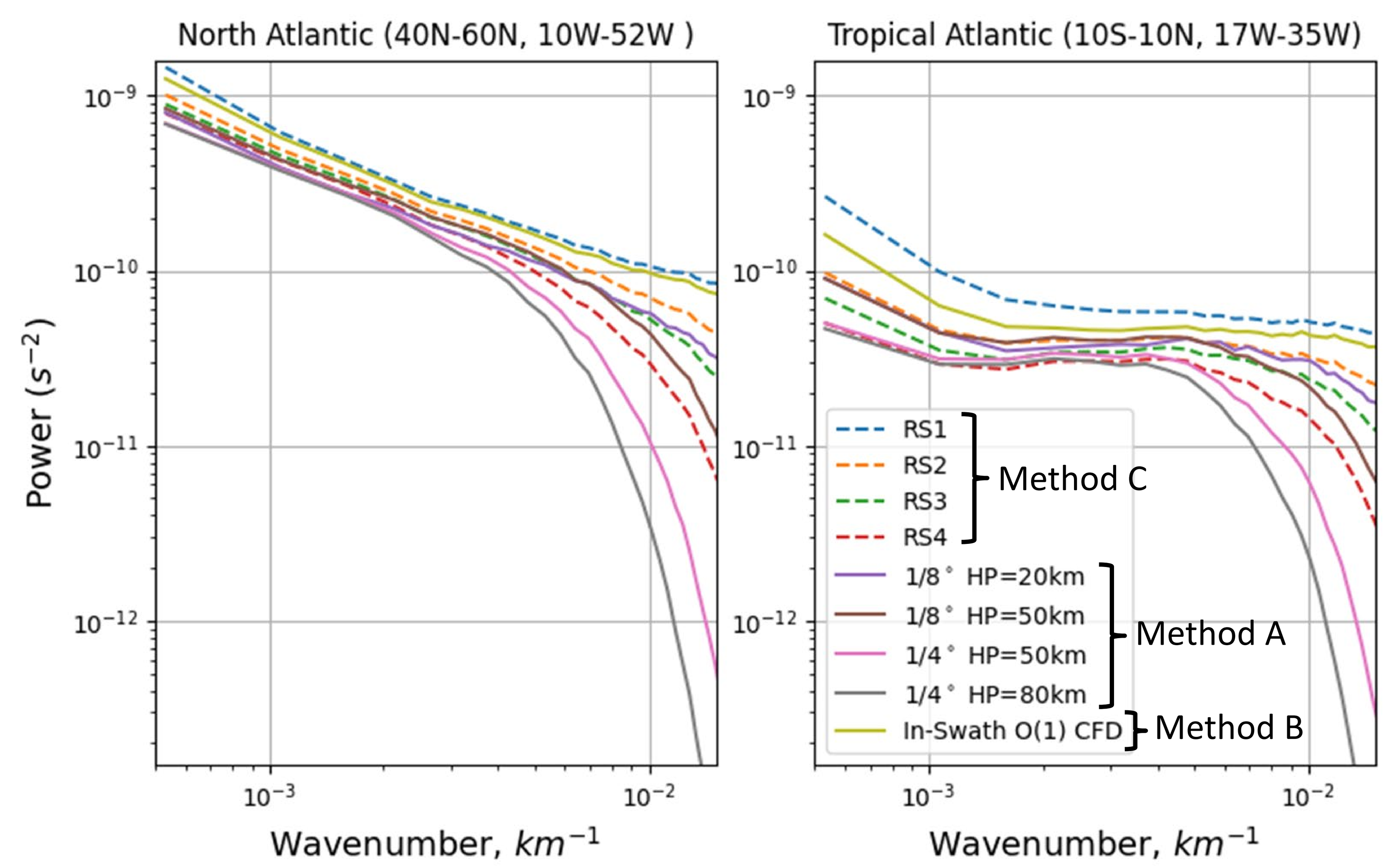


**Figure 3**. Spectra comparisons of vorticity for January 2008. RS1-RS4 are the ring sizes used with method C (see Fig. 1). The grid size and loess half-power filter cutoff limit are given for method A.

## GRIDDING EFFECTS

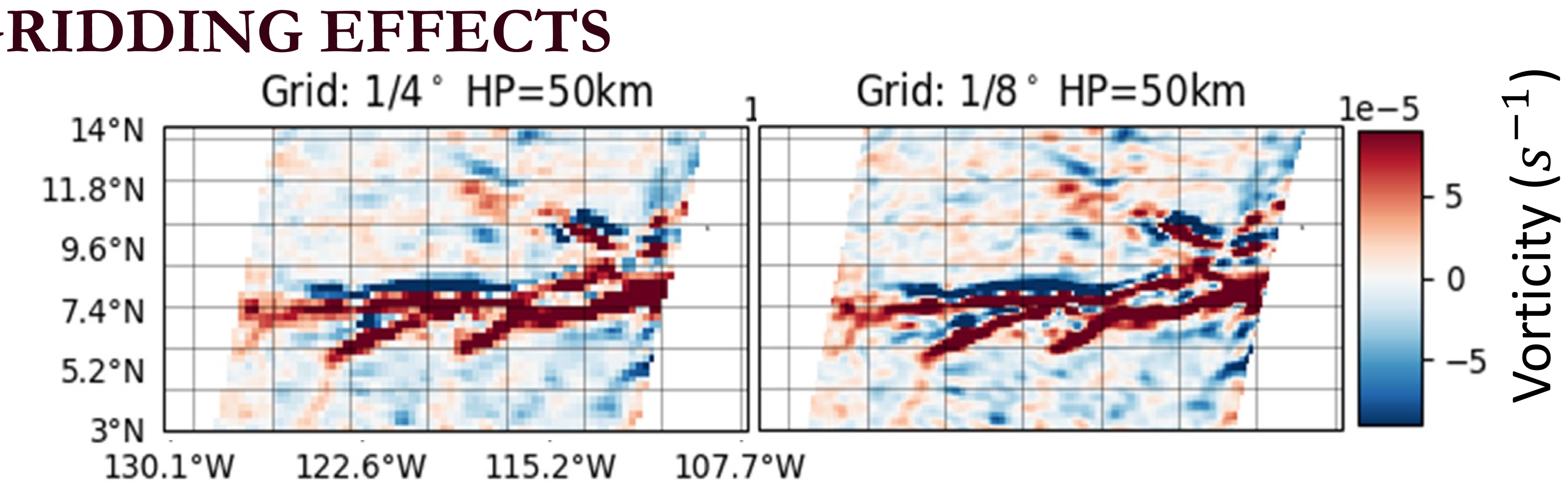


**Figure 4.** Wind vorticity calculated across the ITCZ using method A with different grid sizes. Compare the pink line in Fig.3 to the left image and the brown line to the right image.

- With the same smoothing filter, gridding has a large effect on the spectra. The ¼° spectra drops off from the main group of spectra on scales of 500-600 km, whereas the drop occurs on scales of 200-300 km for the 1/8° gridded vorticity.

## SMALL SCALE NOISE REDUCTION

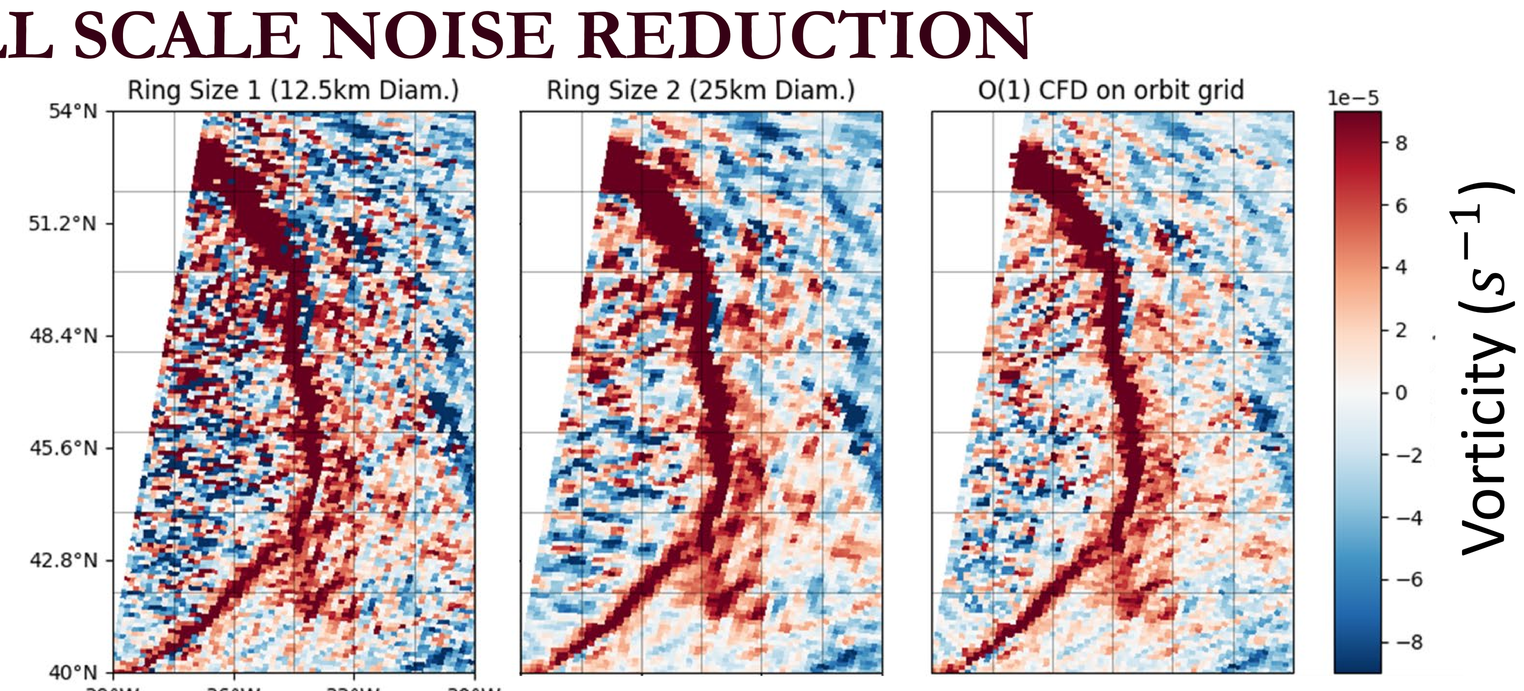


**Figure 5.** Wind vorticity calculated across a high latitude cold front using method C with ring sizes 1 (left) and 2 (center) and method B (right).

- The visible small scale noise drops off going from ring size 1 to 2 for method C, and is comparable to the noise from method B.

## DISCUSSION

The noise characteristics from three different derivative calculation methods for orbital swath winds were compared. Gridding at the commonly used ¼° scale leads to a large reduction in the small scale signal resolved. Small changes in gridding, prior to calculating the derivatives, leads to large changes in the spatial spectra at small scales, suggesting that careful consideration be given to the choice of calculation method dependent on the scale of the studied phenomena.

## ACKNOWLEDGEMENTS

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