Error Characteristics of Scatterometer-Derived Vorticity as a Function of Spatial Scale

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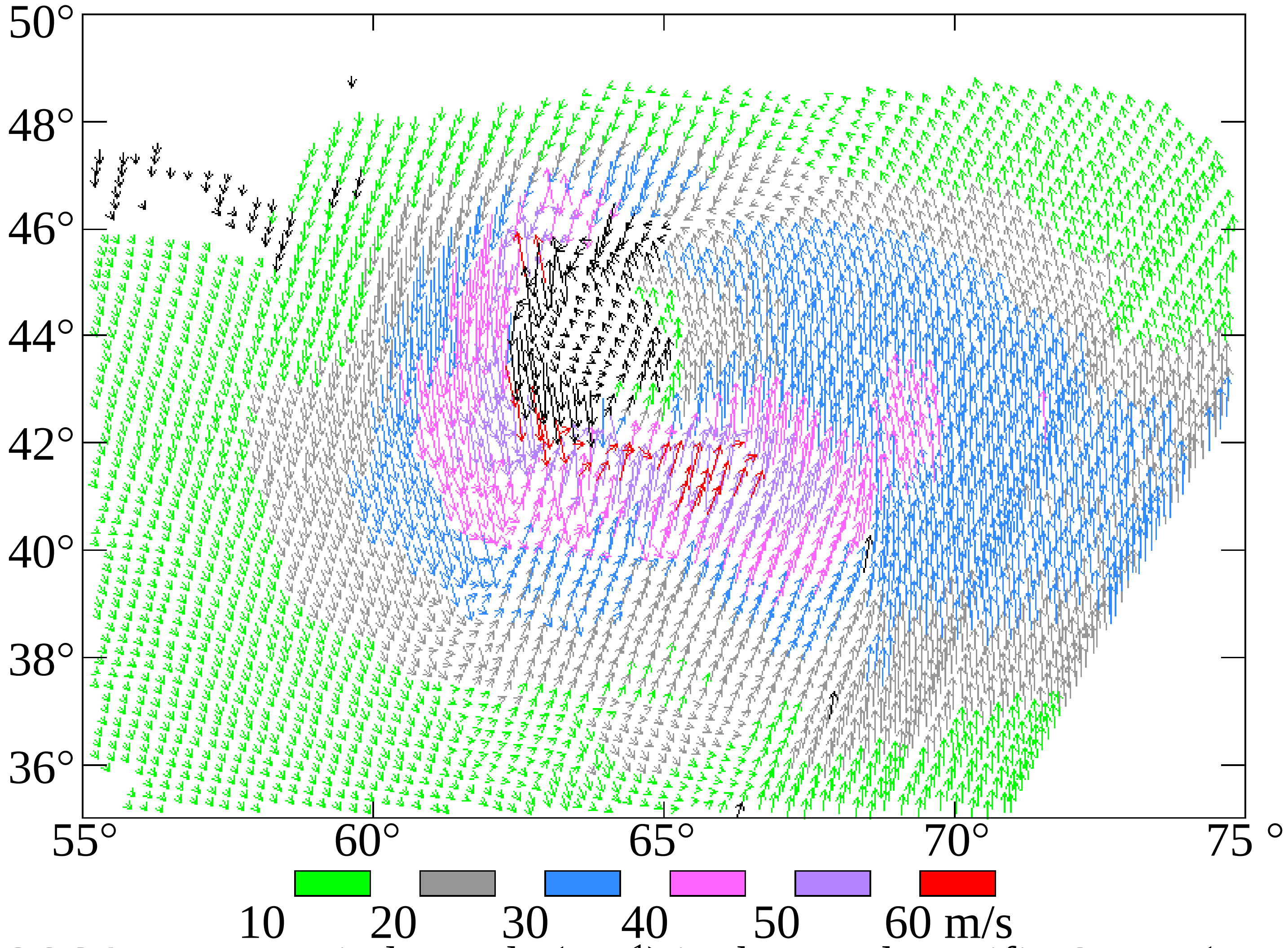
Motivations & Approach

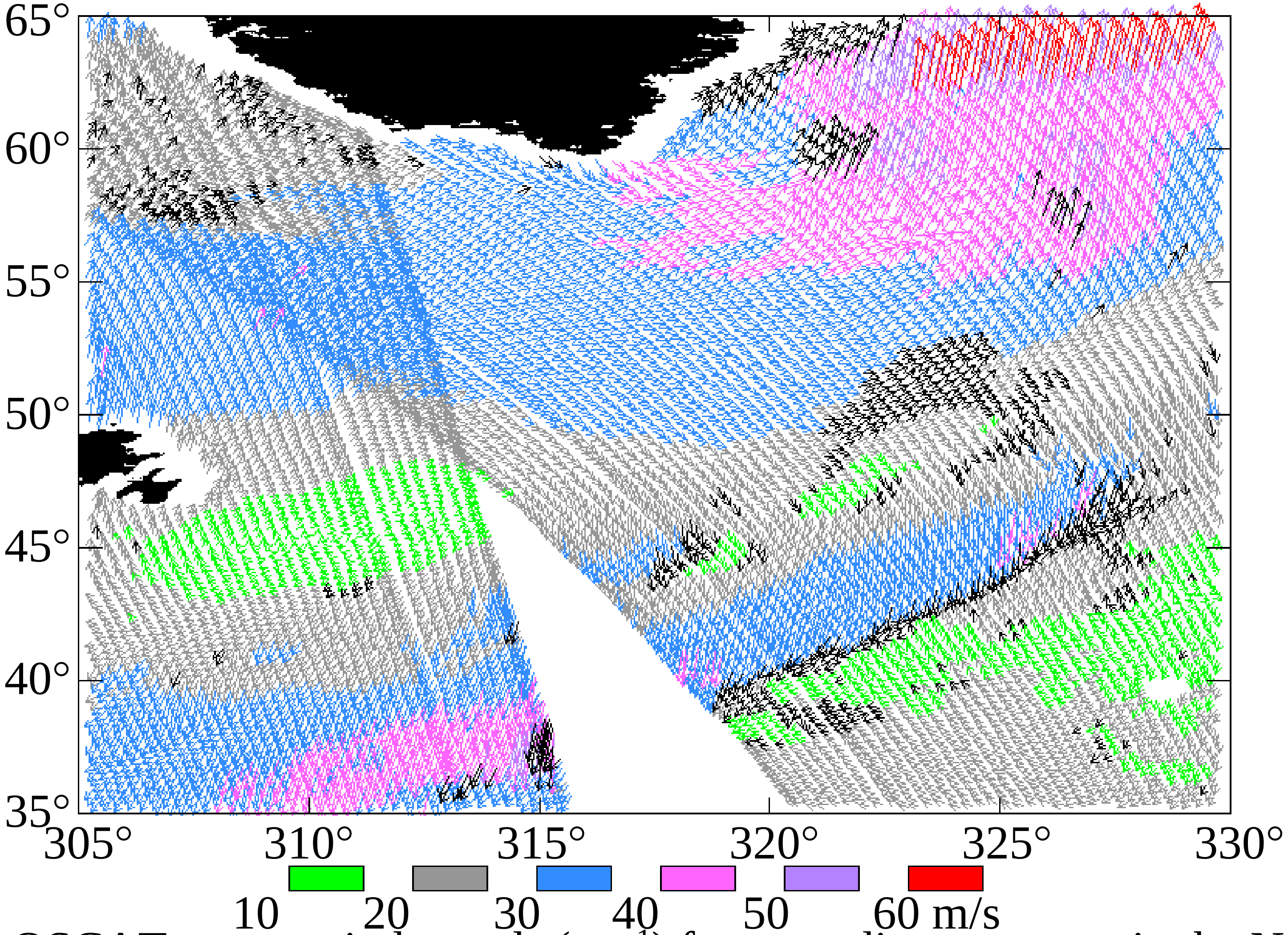
- Spatial derivatives (curl and divergence) of wind or stress are very important in regards to ocean forcing and convection in the atmosphere.
- I use curl as part of a detection algorithm for tropical disturbances.
- I want to characterize the errors (biase and noise) as a function of the spatial scale used in the calculation.

Warm Core Seclusion: Case 1



- QSCAT vector wind speeds (ms^{-1}) in the North Pacific Ocean (Dec. 24, 2004). Black vectors indicate serious rain contamination.

Warm Core Seclusion: Case 2



- QSCAT vector wind speeds (ms^{-1}) for two adjacent passes in the North Atlantic Ocean (Oct. 20, 1999 at 0701Z and 0842Z).

SeaWinds Data

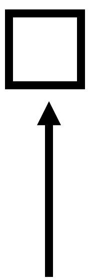
- Simplified version-3a of the Ku2001 product developed by Remote Sensing Systems (RSS).
  - Includes time, location, surface (10 m) wind speed, wind direction and rain-flag.
- 25 km grid spacing within a swath that's 1800 km wide
  - 76 vector wind cells across the swath.
  - The smallest area to calculate vorticity is 25km × 25km.
- Swaths are not perfectly gridded.
- Missing values:
  - Land contamination,
  - Outside the observational swath or
  - Serious rain contamination.
- Reduced accuracy of wind vectors due to rain. Leaves two options:
  - Develop a technique that is insensitive to rain-contaminated data or
  - Attempt to avoid using such data (done here).

Methodology

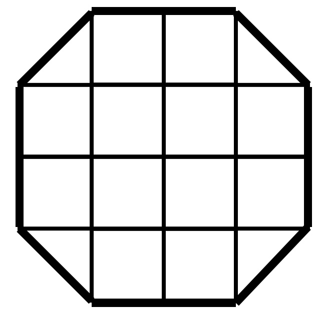
- Relative vorticity is then determined by dividing the circulation by the area.
  - $\zeta = C / A$
- Circulation is calculated as a line integral about a "shape" using the circulation theorem.
  - $C = \oint \mathbf{v} \cdot \mathrm{d}\mathbf{l}$
  - "shape" is dependent on available data: polygon (triangle, square …).
  - Linearly interpolate wind vectors between adjacent good obs.
  - Too many missing points on the "shape" perimeter (<80%) and the vorticity isn't calculated.
- Individual dot products along circumference of the "shape" using wind speed components and distance between data points.
  - $\mathbf{v} \cdot \mathbf{l} = 0.5\left(u_2 + u_1, v_2 + v_1\right) \cdot \left(x_2 - x_1, y_2 - y_1\right)$
  - Circulation is the sum of the dot products.

Methodology: Spatial Scale

- Only data on the perimeter of the shape contributes to the calculation.
- As the shape becomes larger, it becomes more circular.



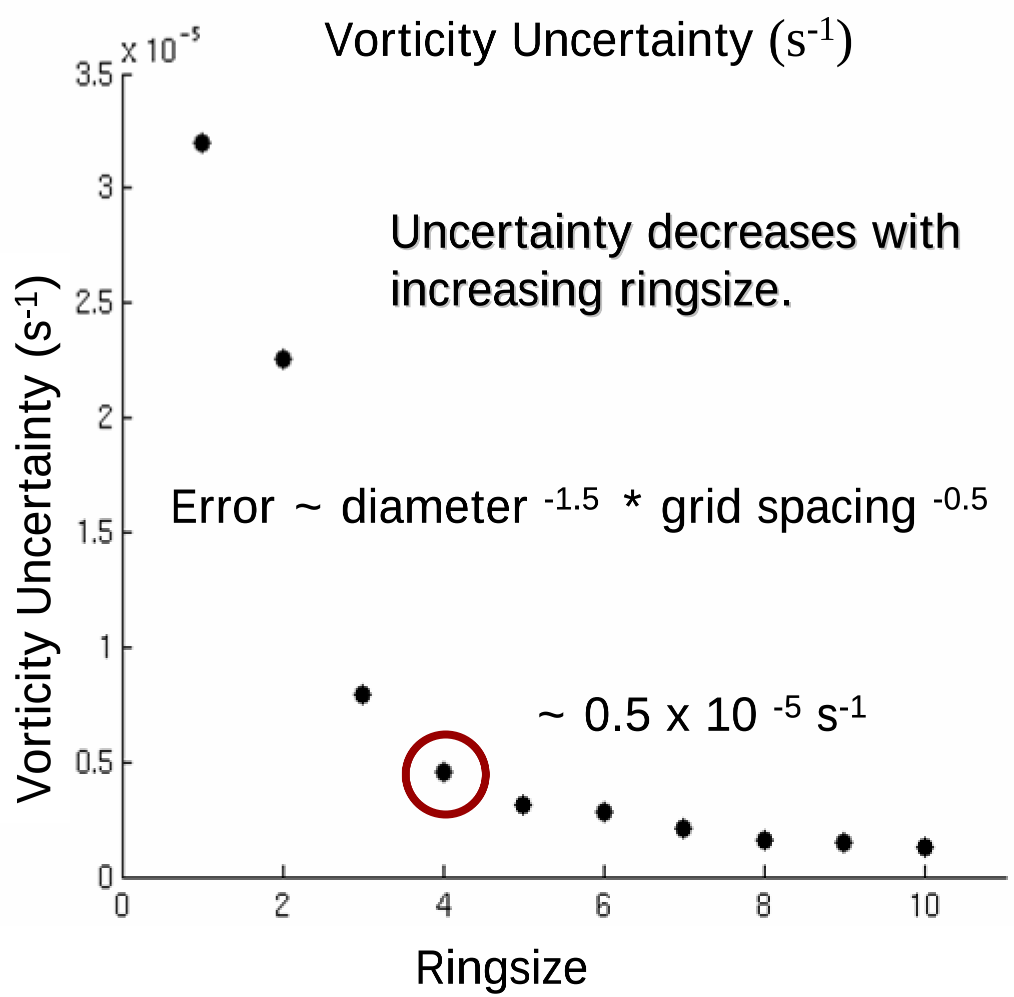
Ringsize 1



Ringsize 4

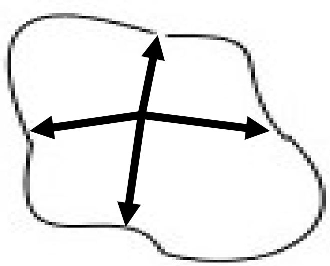
Observational Errors

- Random vector component errors:
  - Assessed several ways:
    - (Freilich 1997;
    - Stoffelen 1988;
    - Bourassa et al. 2003;
    - Freilich and Vanhoff 2006).
  - The conservative (large) estimate of **0.6 ms^{-1}** (Freilich et al. 1997) is used to determine an upper bound.



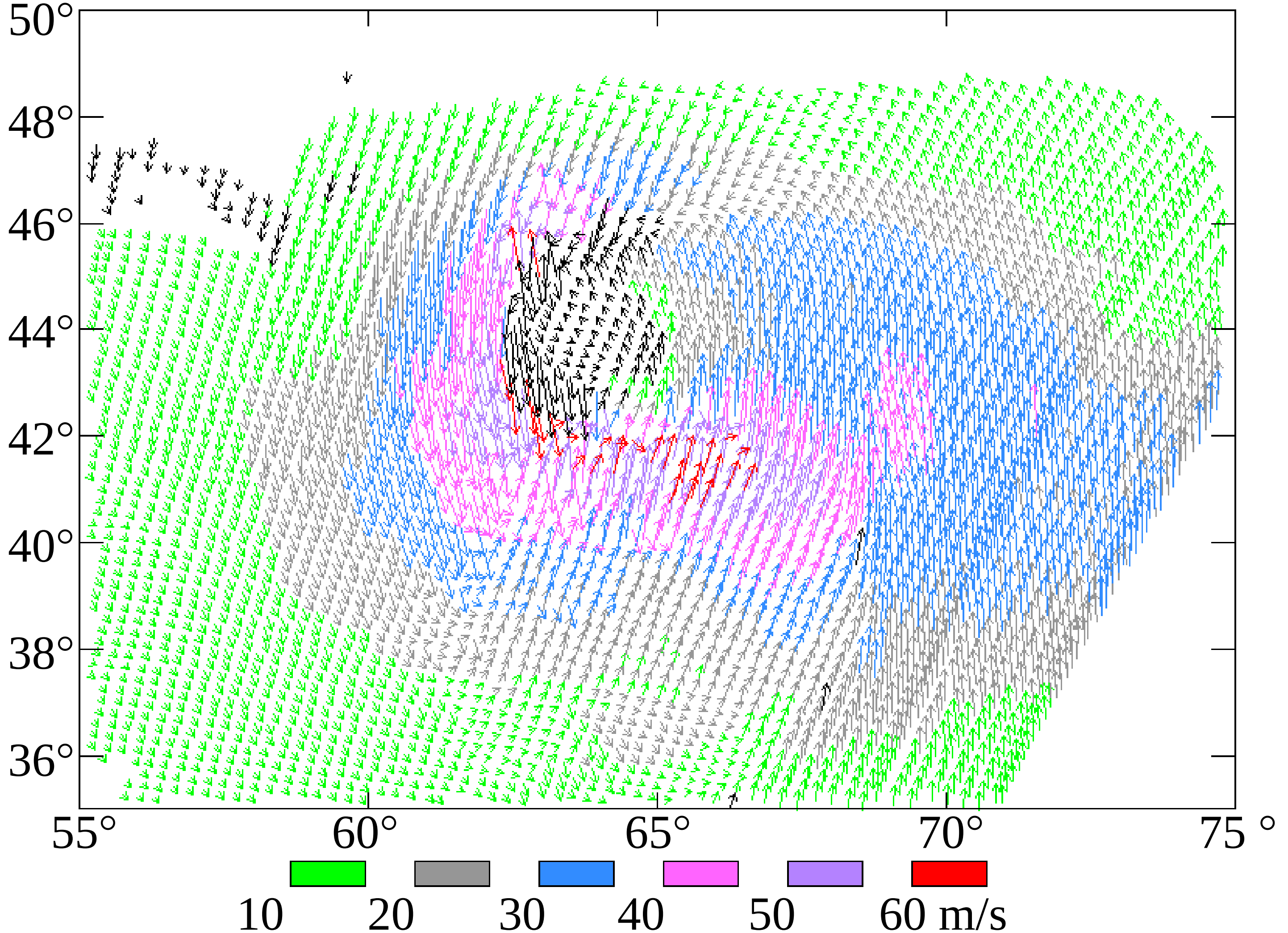
Observational Errors

- Ambiguity selection errors:
  - Associated with the process used to determine the best fit for the wind direction from the backscatter to the satellite.
    - Goodness of fit as a function of direction.



  - Most likely below 8 ms^{-1}.
  - Calculated RMS difference of vorticity:
    - ringsize (1-9) – ringsize (10)
    - wind speeds from 0.5 ms^{-1} to 19.5 ms^{-1} increasing by 0.5 ms^{-1}.
- Implies that the random vector error model accounts for most ambiguity errors

Warm Core Seclusion: Case 1



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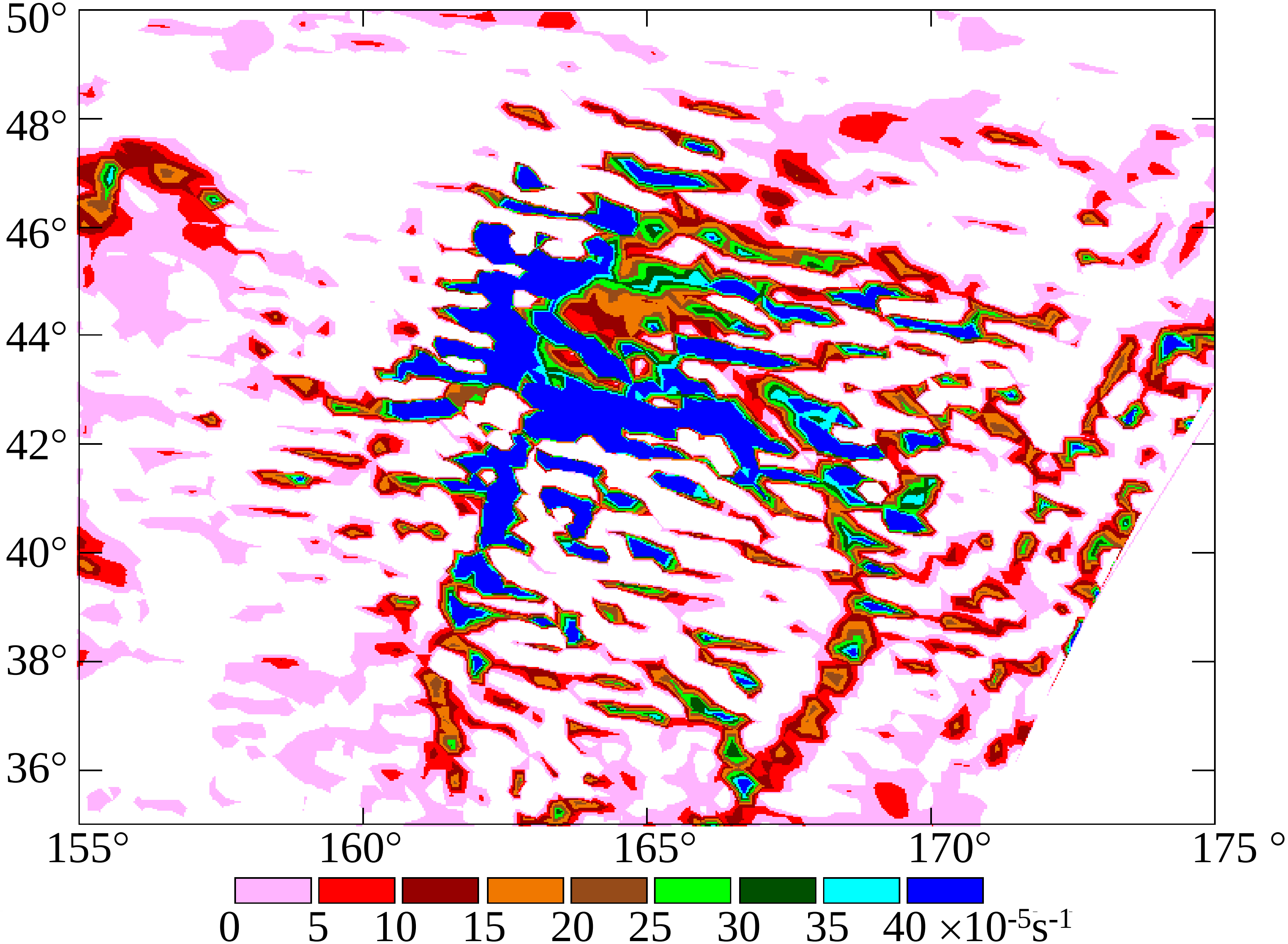
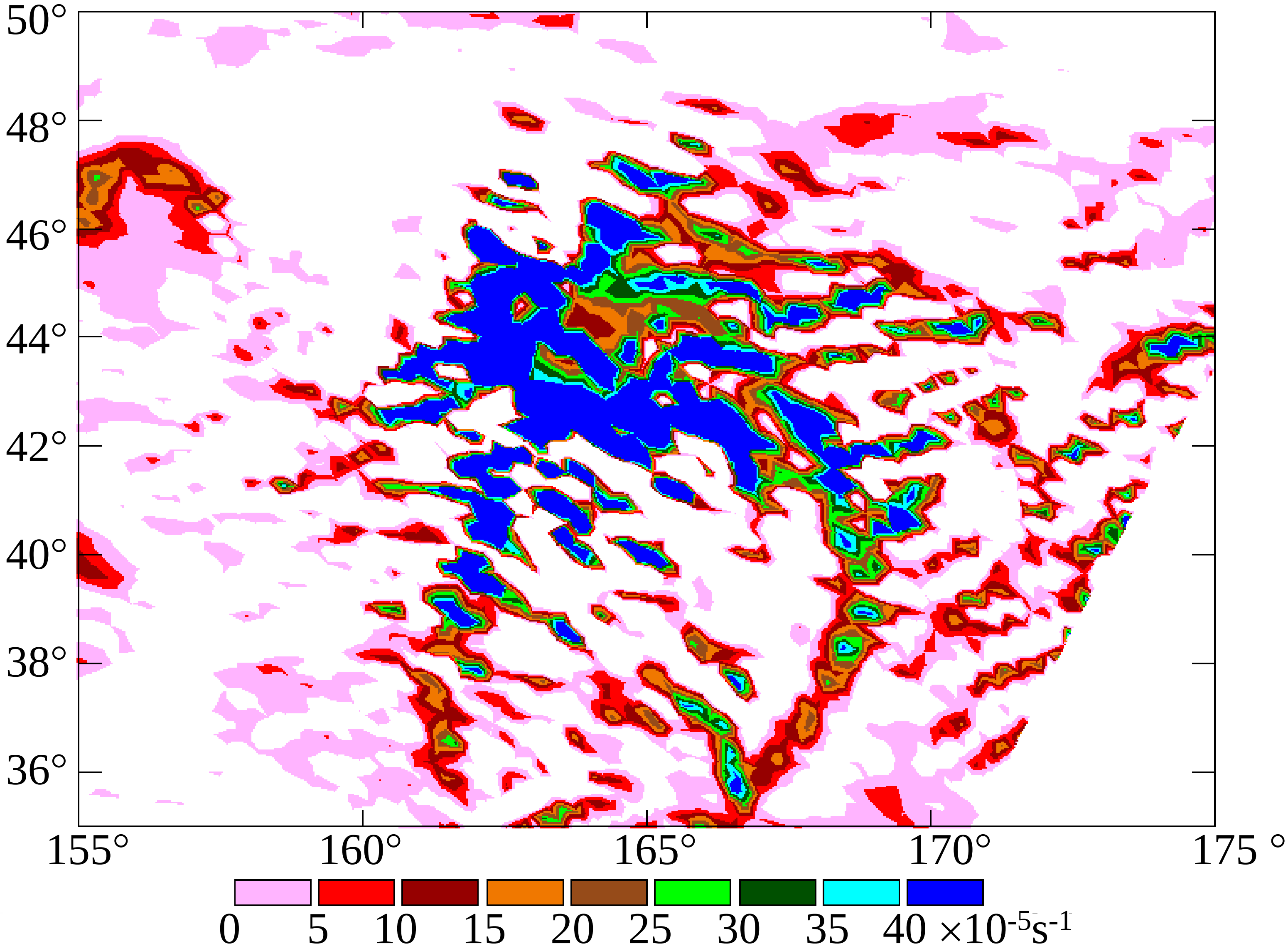
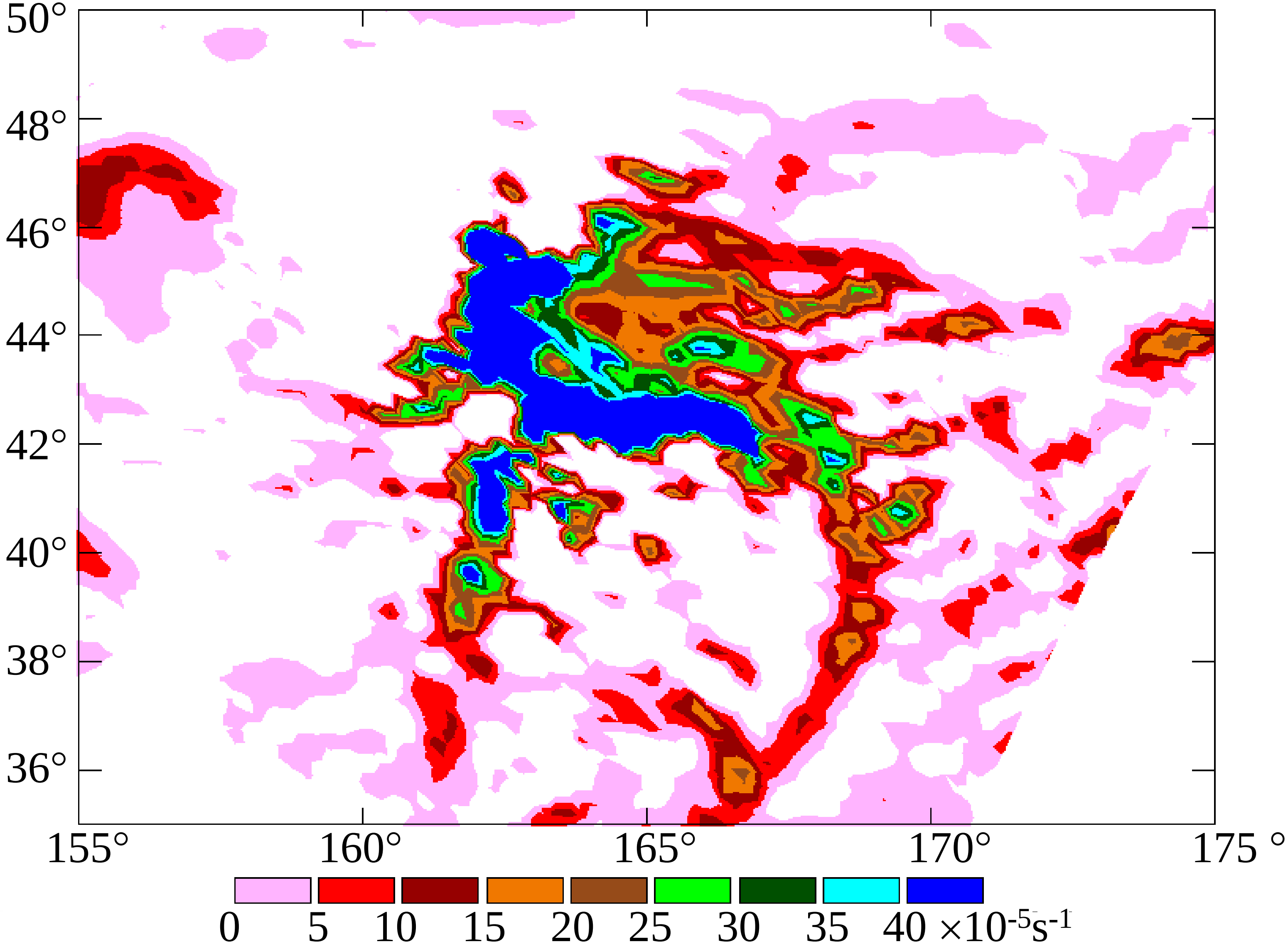
Swath-Based Vorticity: Case 1, 25km



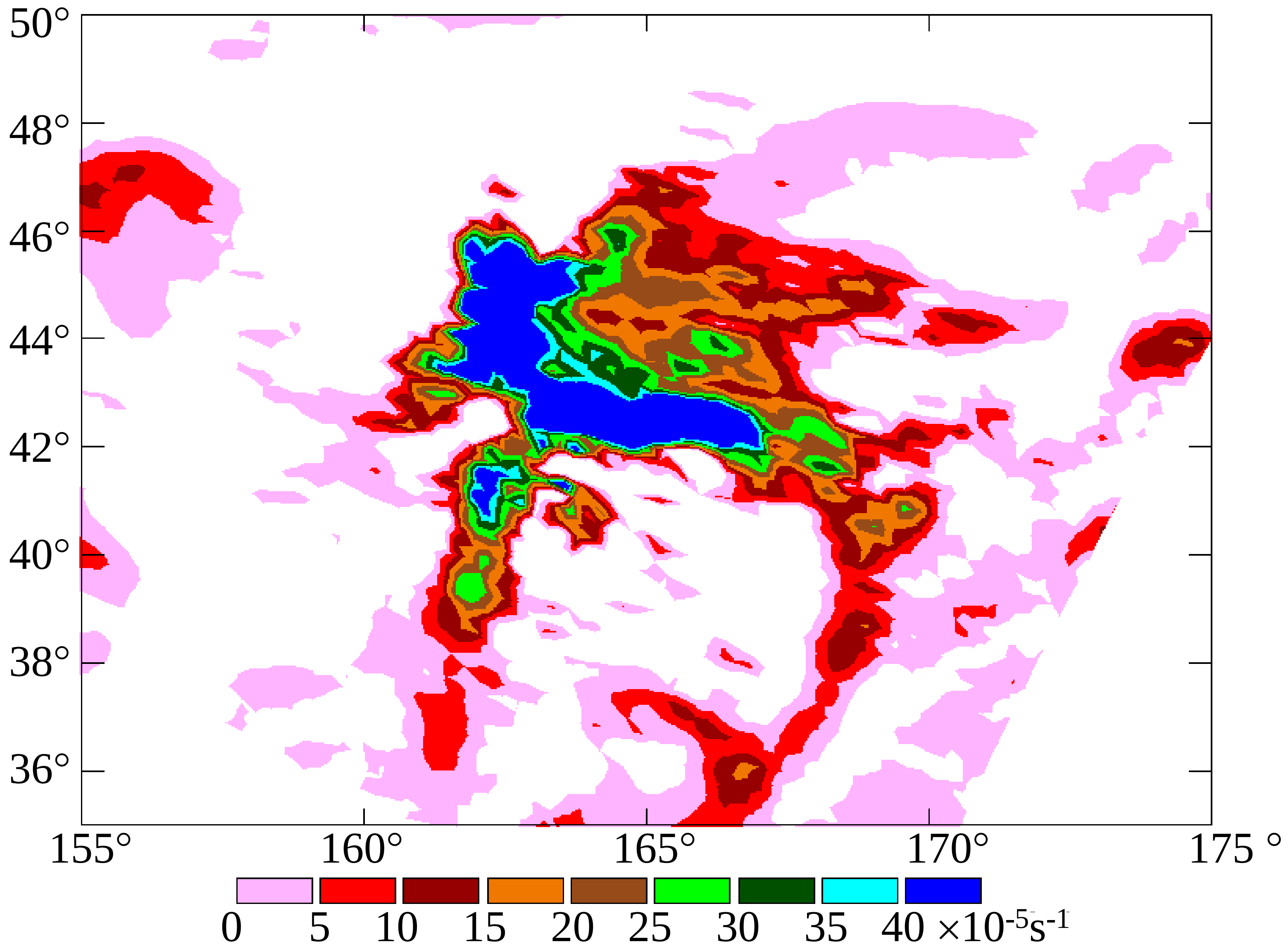
Swath-Based Vorticity: Case 1,   50km



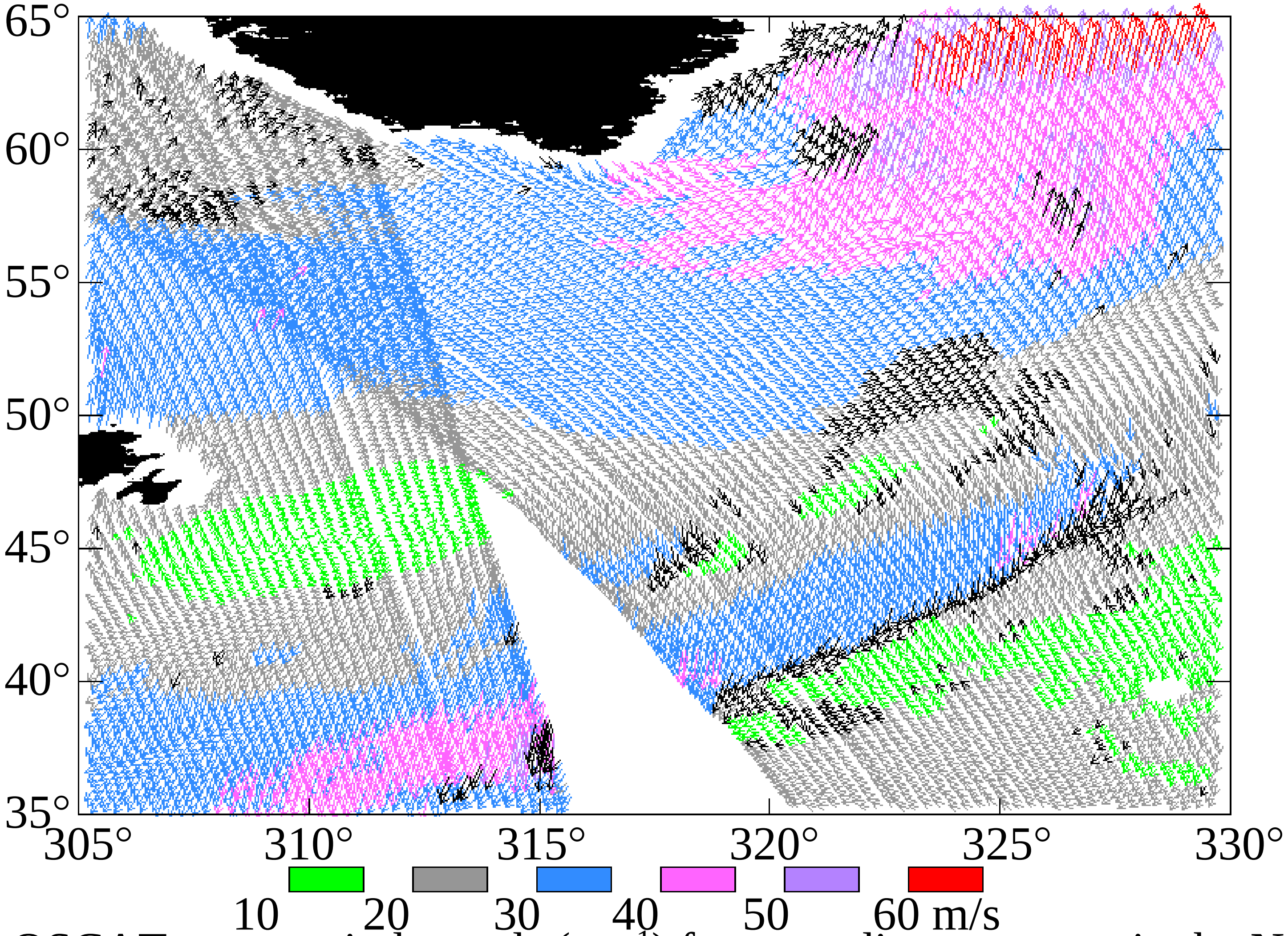
Swath-Based Vorticity: Case 1, 75km



Swath-Based Vorticity: Case 1, 100km

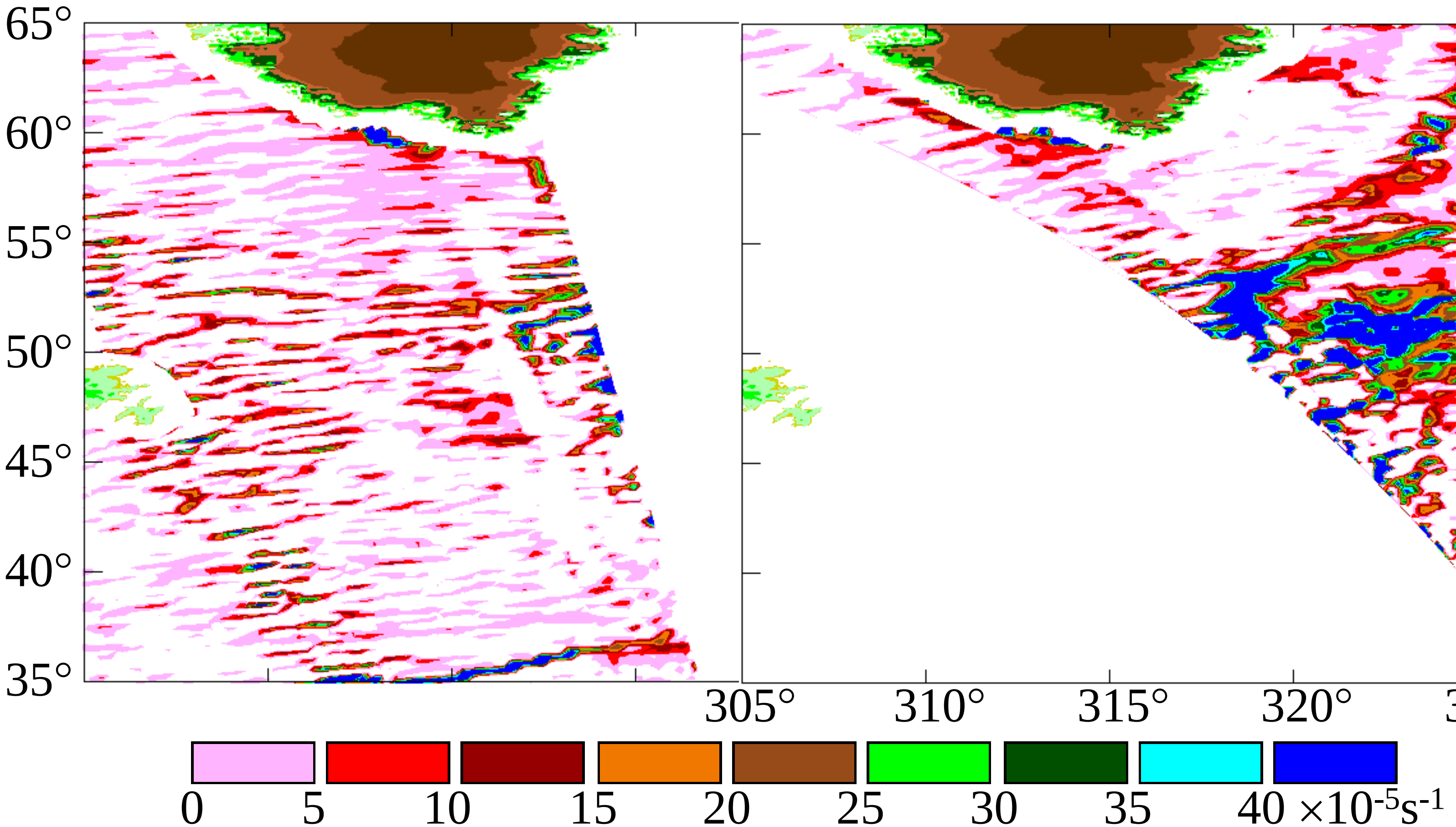


Warm Core Seclusion: Case 2

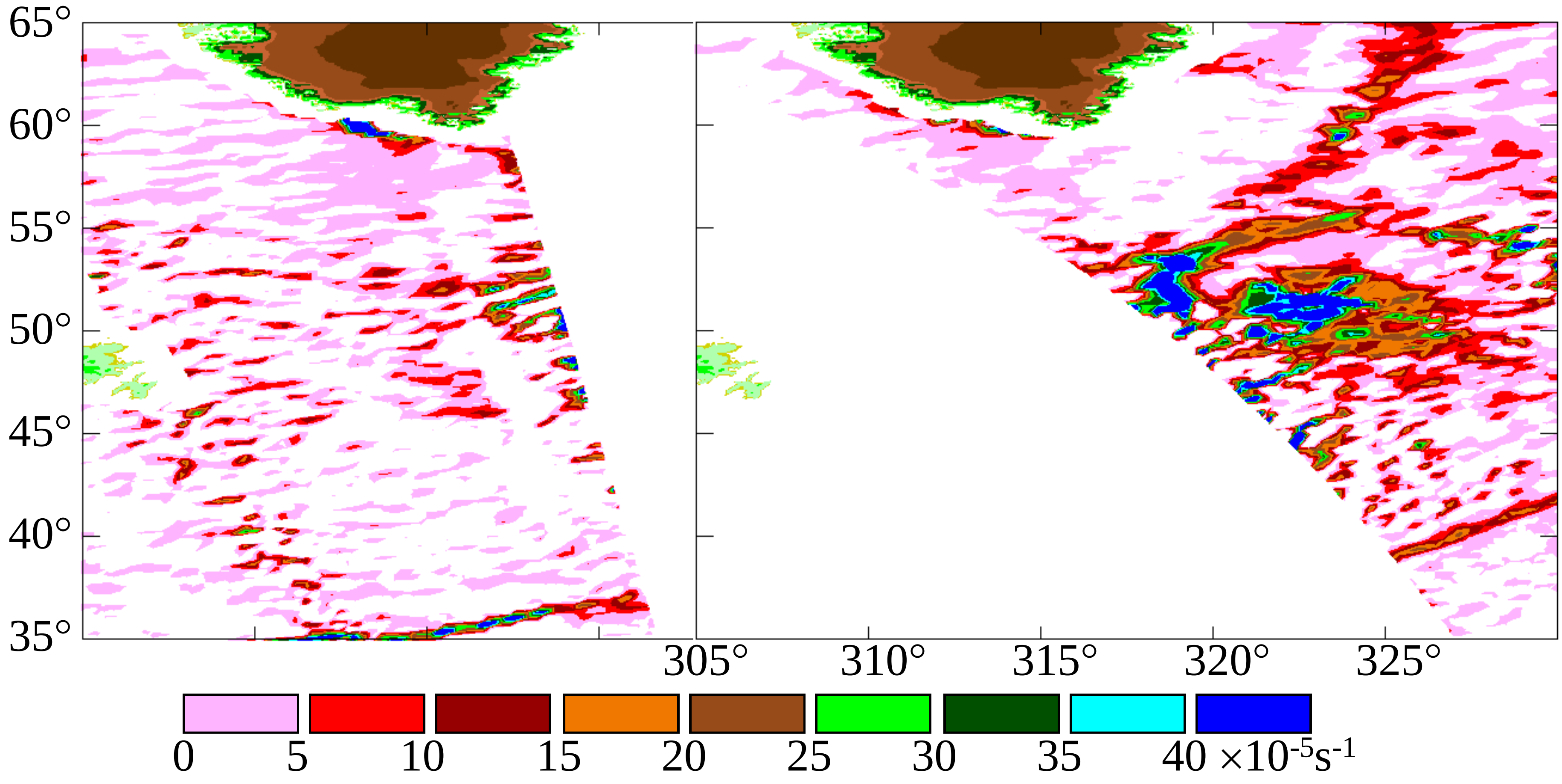


- QSCAT vector wind speeds (ms^{-1}) for two adjacent passes in the North Atlantic Ocean (Oct. 20, 1999 at 0701Z and 0842Z).

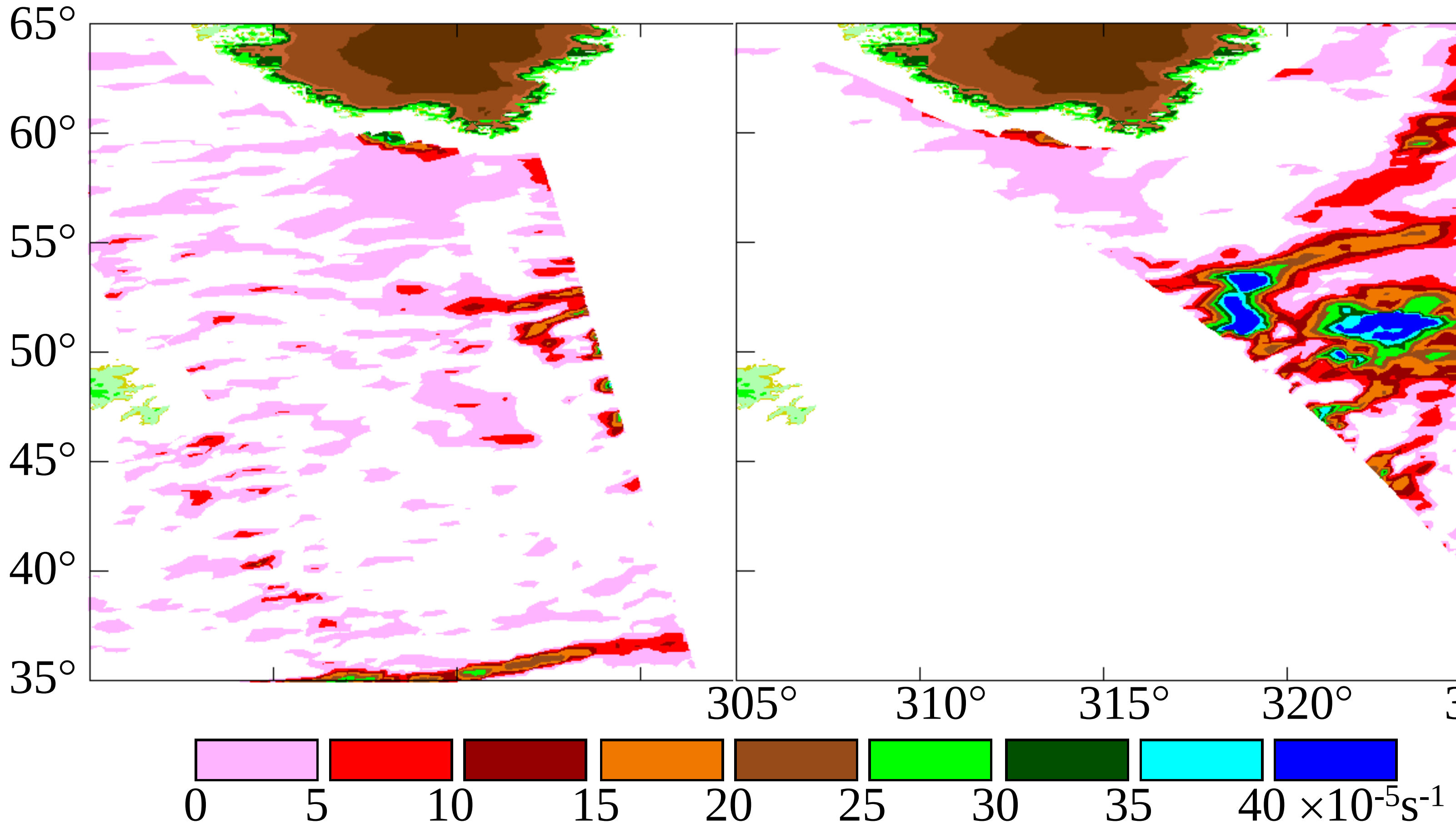
Swath-Based Vorticity: Case 2, 25km



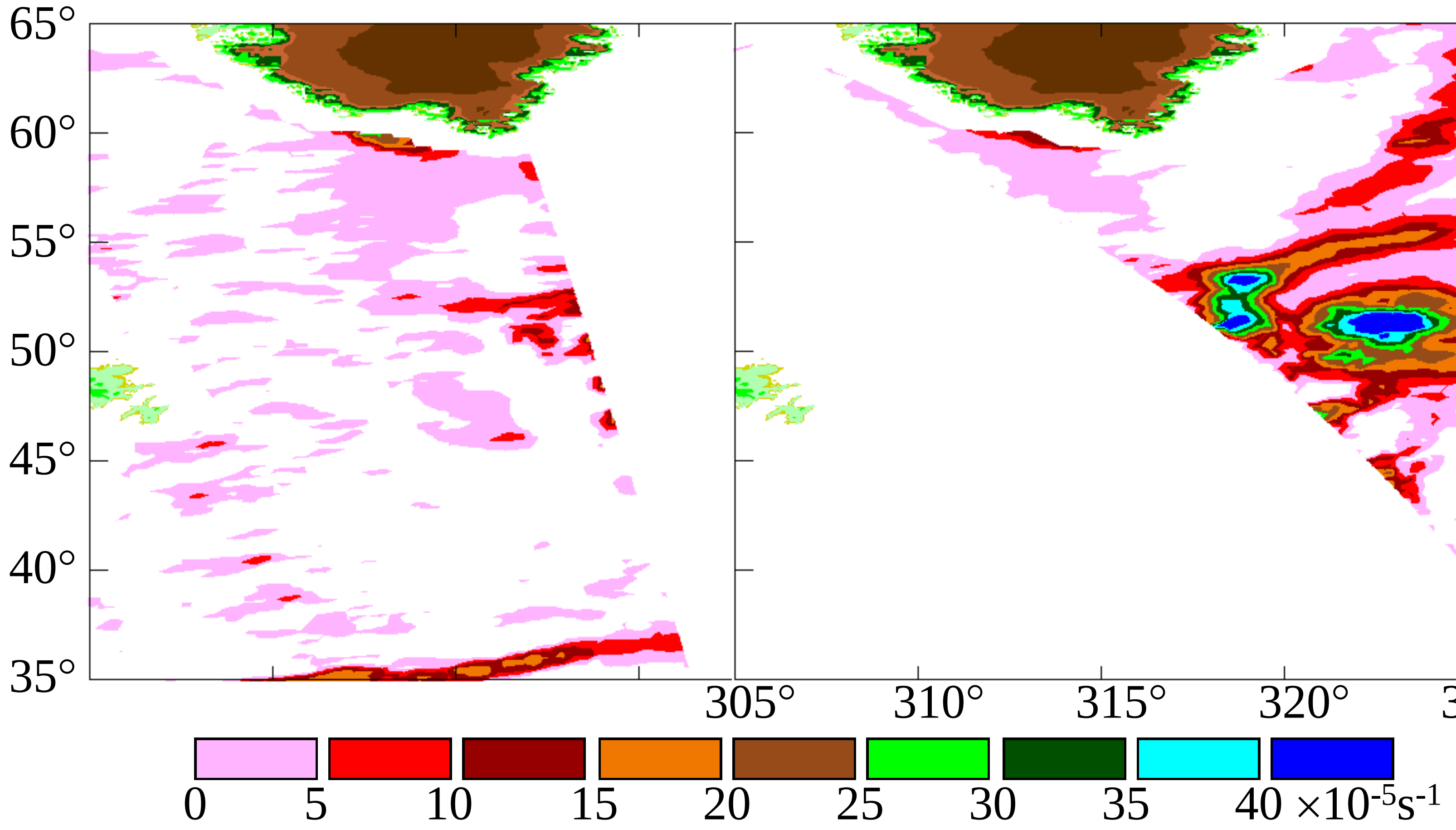
Swath-Based Vorticity: Case 2, 50km



Swath-Based Vorticity: Case 2,   75km

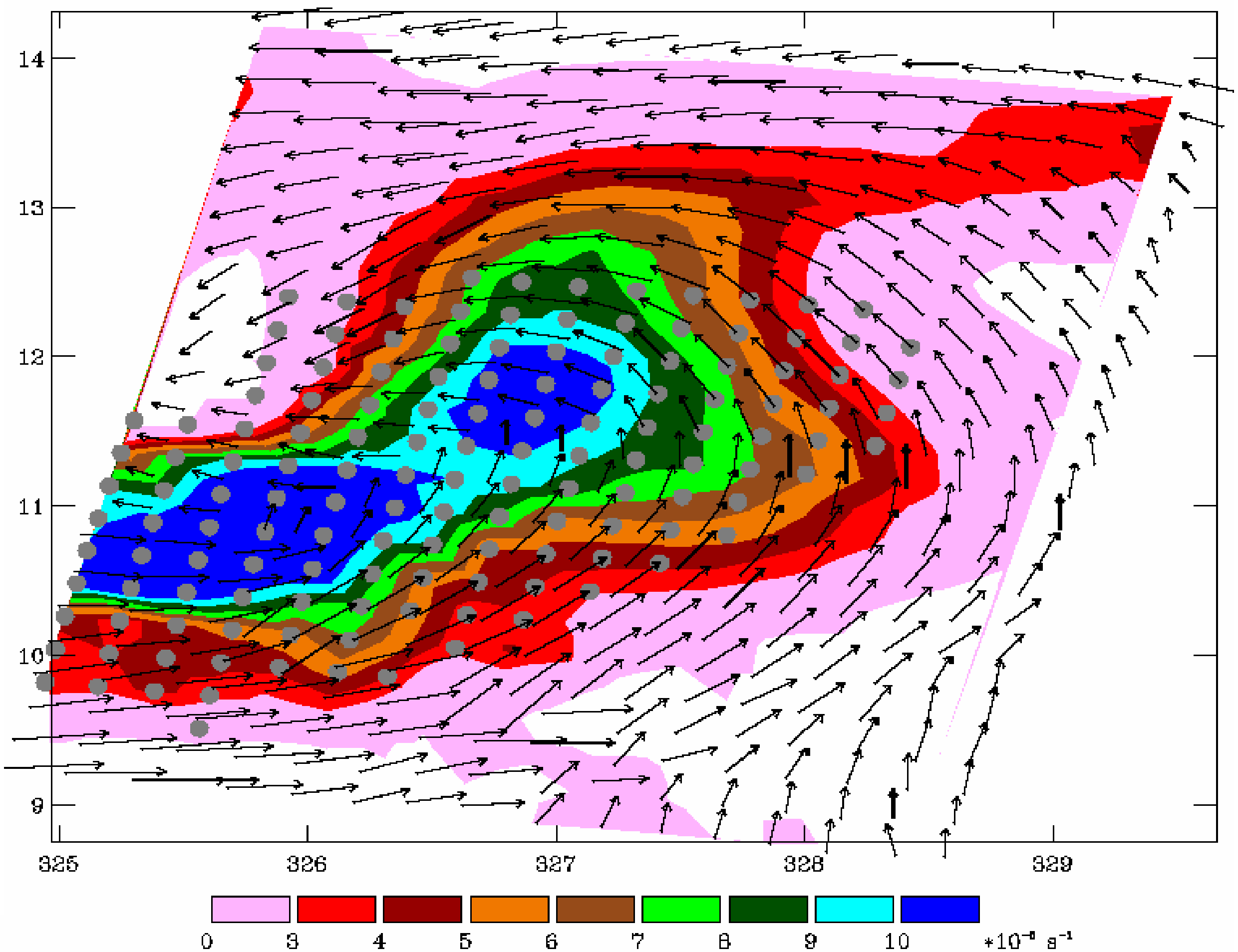


Swath-Based Vorticity: Case 2, 100km



What Causes The Suspicious Fine Scale Features?

- Leading possibilities
  - (1) Bourassa messed up the code!

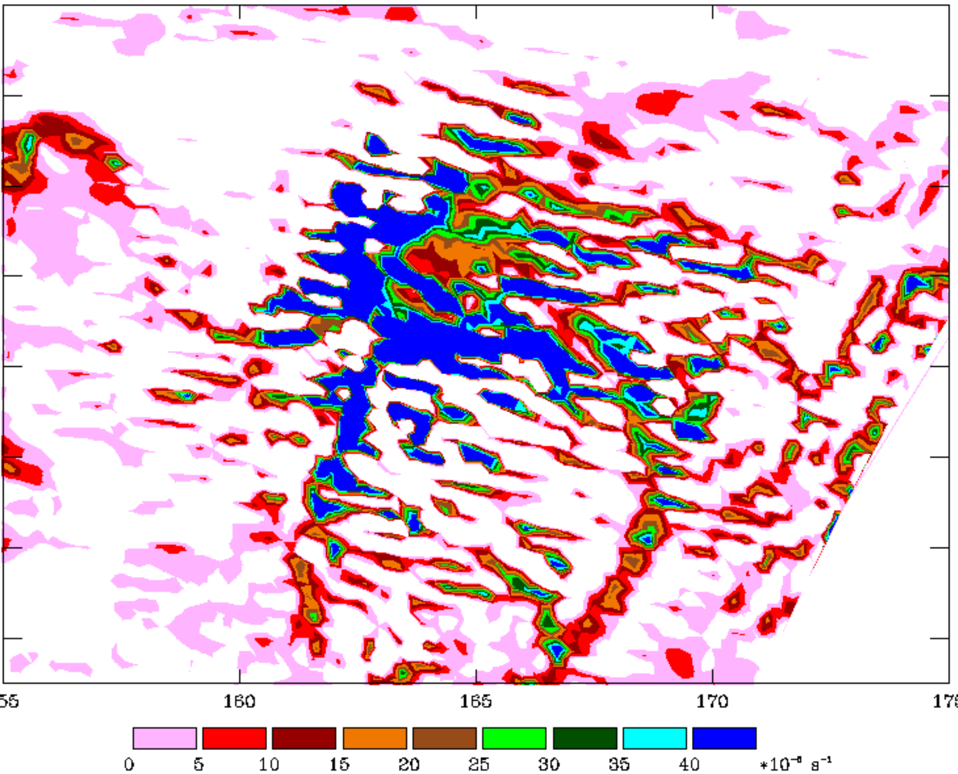


Not seen about tropical disturbances

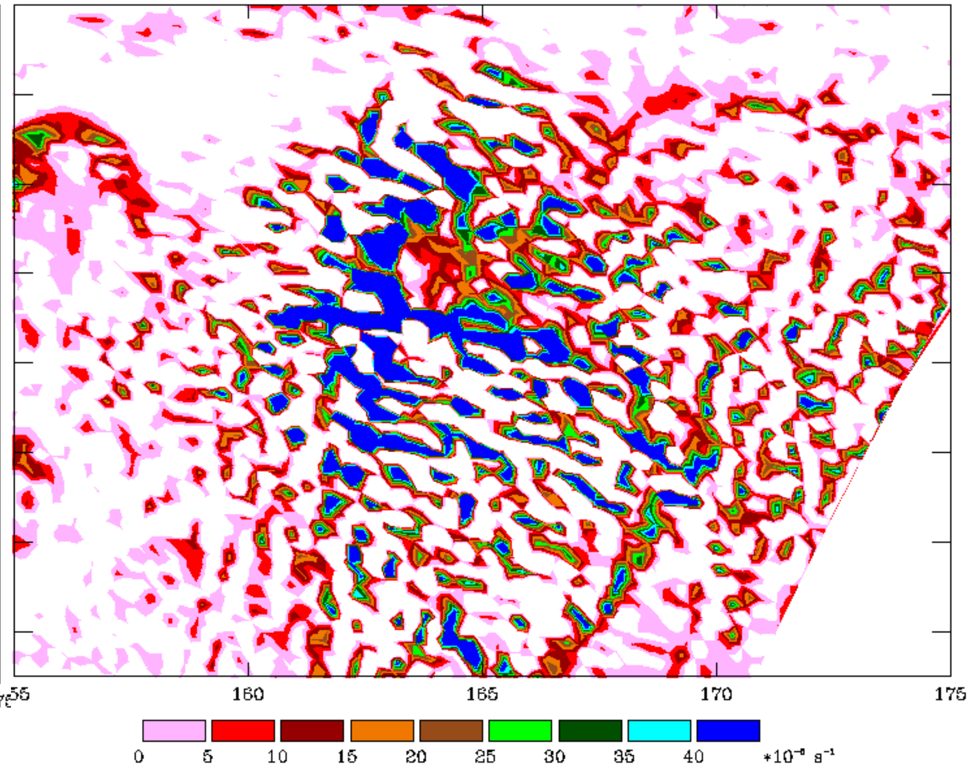
Until a much finer color bar is applied.

What Causes The Suspicious Fine Scale Features?

- Leading possibilities
  - (1) ~~Bourassa messed up the coding!~~
  - (2) RSS messed up the retrievals at high wind speeds.



RSS Retrieval



JPL Retrieval

What Causes The Suspicious Fine Scale Features?

- Leading possibilities
  - (1) ~~Bourassa messed up the coding!~~
  - (2) ~~RSS messed up the retrievals at high wind speeds.~~
  - (3) Truncation error associated with the assumption of a linear change in wind vectors between adjacent points.

Estimated Truncation Errors

- Error estimate is based on the mathematics of truncation errors

- As with the observational uncertainty, the area increases faster than the number of truncations, resulting in the diameter$^{-1.5}$ dependency.

- The dependency on grid spacing is much larger than for observation errors, and decreases for finer grid spacing.

- This type of uncertainty is going to be relatively small contribution for typical wind speeds, but becomes quite large for wind speeds >20ms^{-1}.

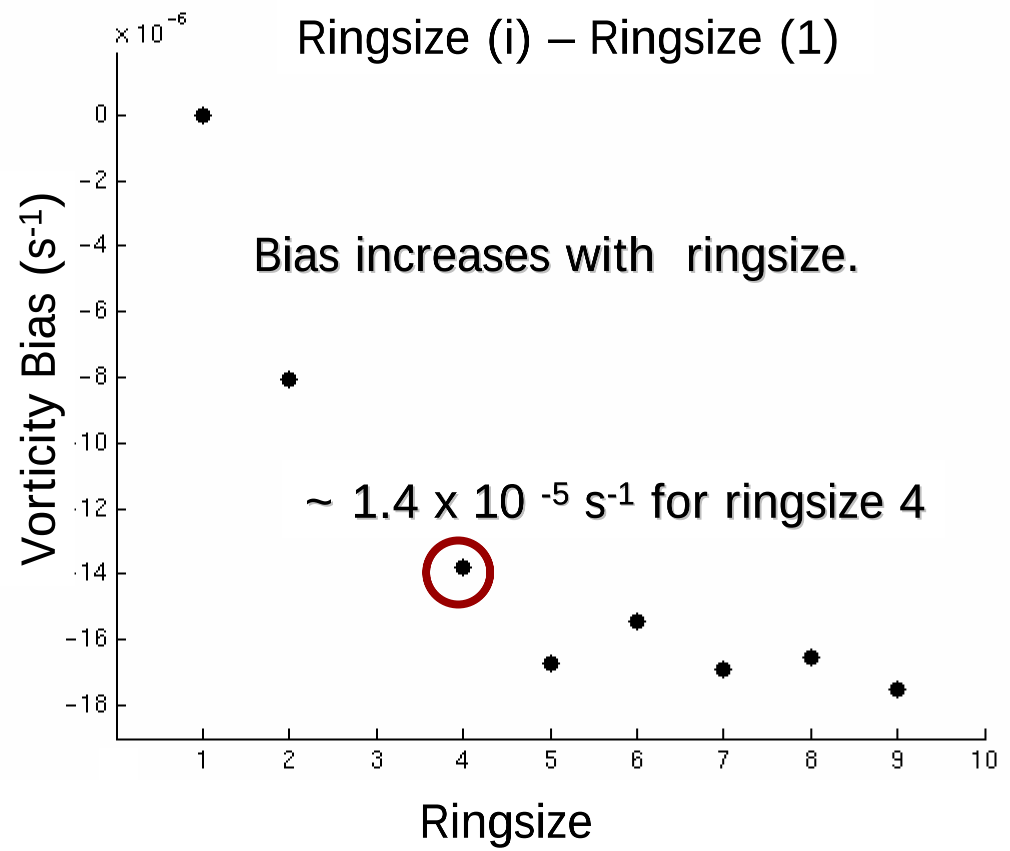
Uncertainty decreases with increasing ringsize.

uncertainty ~ diameter $^{-1.5}$ * grid spacing $^{1.5}$

Errors appear to be proportional to wind speed.

Bias: Spatial Averaging Error

- Examined tropical disturbances from 1 August - 31 October 1999.
- Change in vorticity relative to vorticity with ringsize 1.
- Bias as compared to ringsize 1:
  - smaller features not considered.
- Potential to 'over-smooth'.
- Different biases for other types of weather.



Conclusions

- Error characteristics of derived products need to be much better understood
- The larger the area over which vorticity (or curl of the stress) is determined, the larger the bias
  - particularly for low pressure systems (including fronts)
- Observational error is negligible for a 25km grid spacing
- Truncation error vastly dominates
  - Increasing resolution by a factor of ~5 will result in a truncation error that is of similar error to the observational error for high wind speeds!
  - Clearly a substantial advantage of XOVWM