Revised Centroid Method

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The revised centroid method was developed as a upgrade to and replacement for the HWRF-X nest motion algorithm due to its problems handling terrain noise or nearby storms. The HWRF-X algorithm would get caught on sharply peaked mountains due to mean sea level pressure (MSLP) noise caused by explicitly resolved gravity waves. In addition, being a centroid algorithm, if two low pressure systems were present in a domain, the algorithm would follow the centroid of the two until one became much stronger. Then it would jump to the stronger storm. This phenomenon came to be known as "Julia jumping" due to Hurricanes Julia and Igor in 2010 causing this problem repeatedly. Furthermore, high-pressure systems near the tropical cyclone would cause the centroid to stay at the mass centroid of those: on the opposite side of the tropical cyclone from the high-pressure system.

As with the HWRF-X centroid method, the revised centroid method tracks the centroid of a function of MSLP, but the weighting is no longer mass, rather a function of mass that more highly weights the lowest pressures. In addition, an MSLP noise removal algorithm is used, and only data within a circle at the domain center is used.

The scalar P_{ref} is a reference pressure (currently set to 1013 mbar) used to determine how much mass is shifted by the cyclone. All MSLP values $P_m < P_{ref}$ within R km of the nest center are considered (current 250 km), with the exception of any gridpoints considered "noisy" and any gridpoints within n_n gridpoints (L1 norm or "Manhattan" distance) of a "noisy" gridpoint.

1 Noise Removal

A gridpoint is considered noisy if it falls in one of these categories:

1. $P_m(i,j) < P_{min}$ where $P_{min} = 850$ mbar, currently
2. $P_m(i,j) > P_{max}$ where $P_{max} = 1030$ mbar, currently
3. $\left|\frac{\partial P_m}{\partial dNE}\right| > \partial P_{max}$ where $\partial P_m ax = 0.6\ Pa/km$, currently, and NE is the rotated NE direction
4. $\frac{\partial P_m}{\partial dSW} > \partial P_{max}$ where $\partial P_m ax = 0.6\ Pa/km$, currently, and SW is the rotated SW direction

NE and SW directions are used for computational efficiency.

After the entire grid is analyzed for noise, an iterative algorithm is executed. For each "noisy" gridpoint in the grid, the four adjacent gridpoints (in the i and j directions) are marked as "noisy." That is then repeated up to n_n times, currently set to 2.

Lastly, all gridpoints within 9 points of the nest Y (rotated north and rotated south) boundaries are discarded, and all points within 6 of the nest X (rotated east and rotated west) boundaries are discarded. This is to prevent nest movement related boundary noise from interfering with centroid detection after rapid successive nest moves.

2 Distance

Only points within R km of the grid center are used, which requires a calculation of grid center distance. This is done during nest re-initialization after every nest move since the rotated latitude-longitude projection causes the relative point locations to change each time. Distance to the grid center is calculated using the NMM DX and DY arrays, under a local flat earth approximation for each gridpoint:

$$r^2(i,j) = (DX(i,j) * (i - i_{center} + (mod(j,2)*2-1)))^2 + (DY * (j - j_{center}))^2 \quad (1)$$

where $mod(x)$ is the integer remainder function. The $r^2(i,j)$ is then compared against R^2.

3 Centroid Calculation

A centroid X and Y locations x_c and y_c of the final area A under consideration are calculated based on discretizing this pair of equations:

$$x_c = \int_A x \left(\frac{P_{ref} - P(x,y)}{P_{ref}} \right)^b dA \tag{2}$$

$$y_c = \int_A y \left(\frac{P_{ref} - P(x,y)}{P_{ref}} \right)^b dA \tag{3}$$

due to the non-rectangular shape of A, that corresponds to the following discrete equations:

$$x_c = \sum_A i \left(\frac{P_{ref} - P(x,y)}{P_{ref}} \right)^b n_j(i) \tag{4}$$

$$y_c = \sum_A j \left(\frac{P_{ref} - P(x,y)}{P_{ref}} \right)^b n_i(j) \tag{5}$$

where $n_j(i)$ is the number of points in the j direction in the i th column after noise removal, and $n_i(j)$ is the number of points in the i direction in the j th column after noise removal. The b exponent is set to 0.5 currently. A value of 1 would be mass weighting.

Note that x_c and y_c are real numbers. They are then rounded to the nearest *parent* gridpoint location to decide whether it is time to move the nest. The nest moves if the centroid has moved 2 parent j gridpoints, or 1 parent i gridpoint, or both.

4 Failsafes

Several failsafe mechanisms are built in to the WRF-NMM mediation layer now to prevent unsafe moves. In particular, movement will be disabled if a domain's child would leave leave the domain or enter its coral area (5 gridpoint boundary region). In addition, a domain's movement will be disabled if it would enter its parent's coral region.