Analyzing the location of TC rain bands relative to the storm center using metrics of dispersion and closure for changes in radial and tangential directions

hurricane.geog.ufl.edu

BCS 1053864

Corene J. Matyas: Department of Geography, University of Florida; Jingyin Tang: The Weather Company/IBM   Contact: Matyas@ufl.edu

Introduction

The rainfall produced by tropical cyclones (TCs) can cause devastating floods as seen during Hurricanes Harvey (2017) and Florence (2018). Many studies limit TC rainfall comparisons to calculation of areal coverage of rain rates, but this does not provide information about the spatial arrangement of the rain rates. Configurations of TC rain fields can vary according to environmental conditions and storm attributes and it is important to track their evolution so that different model projections can be compared. Weakening after landfall, increasing vertical wind shear, reductions in moisture, and baroclinic interactions should lead to less rainfall surrounding the circulation center (decreasing closure), and spreading of rainfall away from the storm center (increasing dispersion).

We compare rainband configurations for three U.S.-landfalling major hurricanes: Jeanne (2004), Harvey (2017), and Florence (2018). Although they all eventually transitioned into extratropical cyclones, their landfall locations, sizes, rates of de-intensification differed. As weakening of the primary and secondary circulations in a TC should correspond to decreases in rainband activity in the tangential and increases in the radial directions relative to the storm center, we calculate closure and dispersion for stratiform (20 dB*Z*) and convective (40 dB*Z*) regions detected by the WSR-88D network and compare rates of change in these storms. We also average the extent of 20 dBZ regions in each quadrant to determine the search radius needed and when rainbands are within radar range.

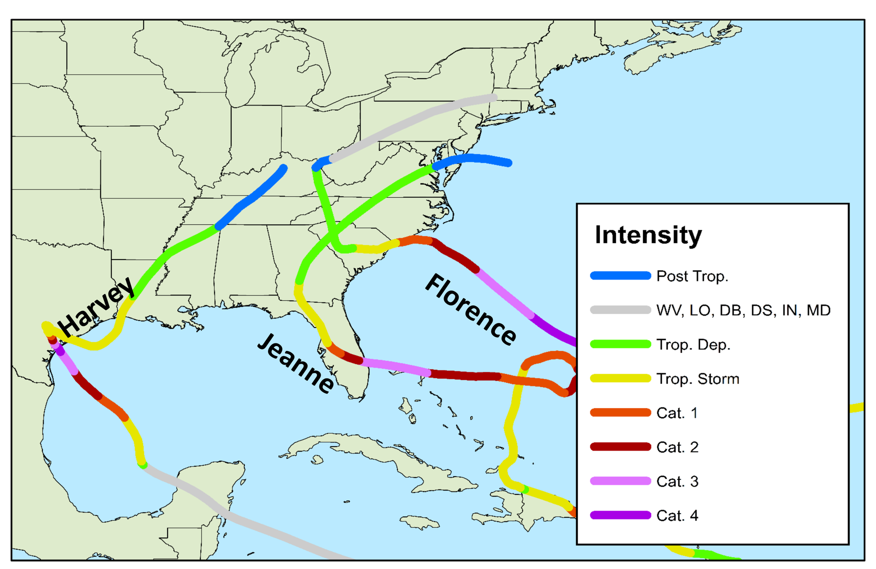


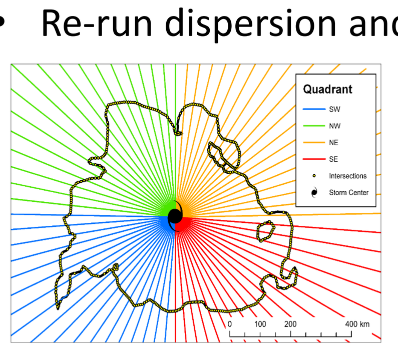
Fig. 1. Tracks of Harvey (2017), Jeanne (2004), Florence (2018) with color indicating intensity.

Event	Jeanne	Harvey	Florence
Landfall	2004-09-26 0400	2017-08-26 0600	2018-09-16 1115
Max. Intensity	0	-3	-65
Tropical Storm	14	12	13
Tropical Depression	38	114	55
Post Tropical	68	144	73

Table 1. Time of landfall and the no. of hours after landfall for key intensity thresholds.

Data and Methods

- Every 10 minutes, grid reflectivity at 1 km x 1 km x 500 m resolution (Tang and Matyas 2016)
- Using a GIS, contour reflectivity values, smooth, convert to polygons, and determine centroids
- Interpolate Best Track positions using splines to 10-min resolution
- Include polygons with centroids <500 km from TC center (Jiang et al. 2011)
- Calculate metrics using a 500 km search radius (Matyas et al. 2018)
- Examine extent each quadrant to determine customized search radius and when analysis can begin
- Re-run dispersion and closure with new radius and 50 km exclusion zone around storm center



Averaged extent in direction-relative quadrants (measured every 1°)

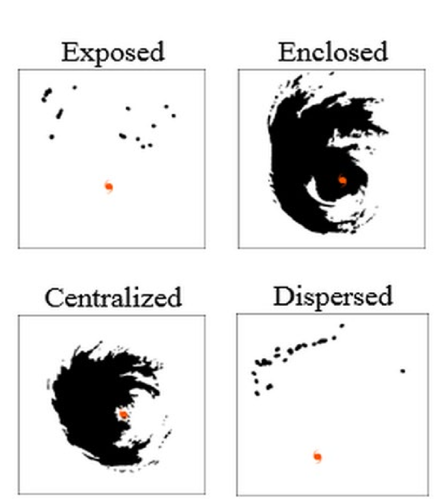
Closure:

$$C = \frac{\underline{\text{no. } 1^\circ \text{ angles intersecting polygons}}}{360}$$

Dispersion:

$$D = \sum_{i=1}^{NP} \frac{Area_i}{\sum_j^{NP} Area_j} \left(\frac{r_{centroid,i}}{r_{search}} \right)$$

r = radius; NP = number of polygons



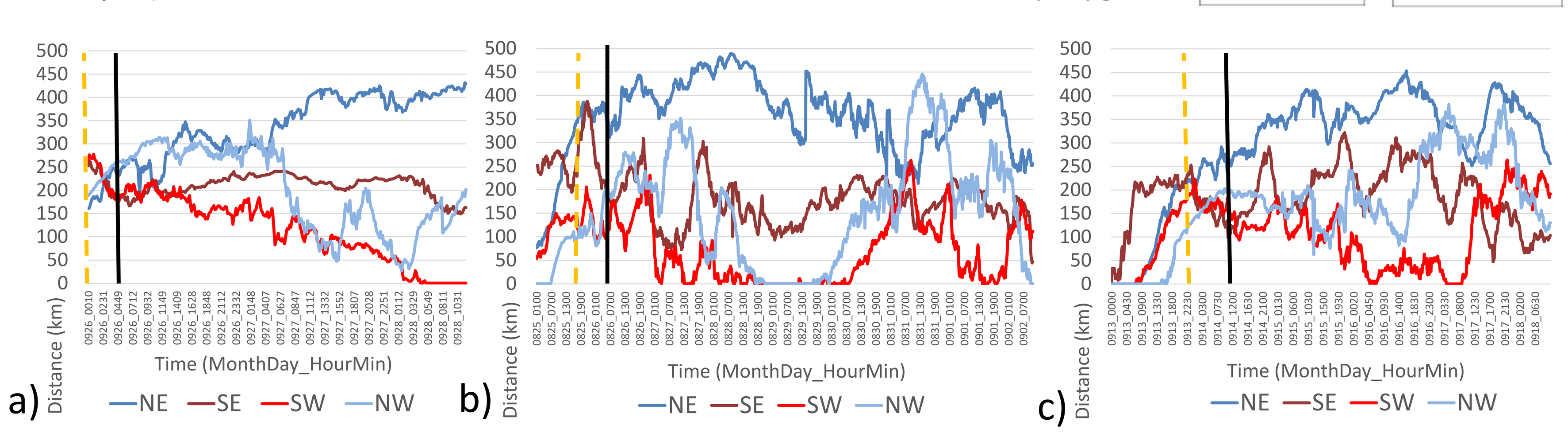


Fig. 2. Extent of 20 dB*Z* regions from center in each quadrant for a) Jeanne, b) Harvey, and c) Florence.

Reflectivity Mosaics at Landfall Time

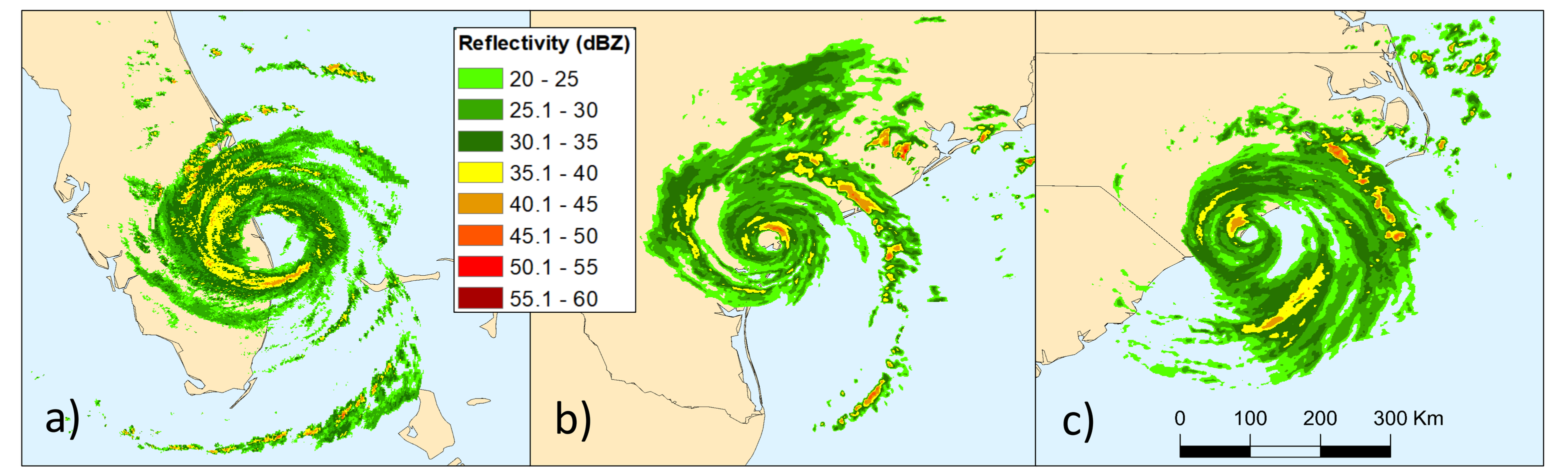


Fig. 3. At landfall, reflectivity at 3 km for a) Jeanne, b) Harvey, and c) Florence.

Table 2. Metric values for each storm at the time of landfall.

Metric	Jeanne	Harvey	Florence
Dispersion 20 dB*Z*	0.15	0.23	0.19
Dispersion 40 dB*Z*	0.29	0.34	0.38
Closure 20 dB*Z*	1.00	1.00	1.00
Closure 40 dB*Z*	0.31	0.12	0.14

- Harvey is more dispersed due to rainfall region extending north, Florence is in the middle due to the asymmetrical placement of the main polygon's centroid east of center, and Jeanne is the most compressed as its rainfall surrounds its center in a fairly symmetric manner.
- All have 20 dB*Z* regions completely encircling the eye.
- Jeanne has a large eyewall yet it encircles more of the storm's center accounting for the low 40 dB*Z* dispersion and high closure.
- Harvey and Florence have more convection in their outer rainbands than Jeanne.
- The 50 km exclusion zone doesn't consider the eyewall convection in H or F. Without this limitation, tangential coverage of 40 dB*Z* regions would be higher in these storms.

20 and 40 dB*Z* Polygons at 36 Hours Post-Landfall

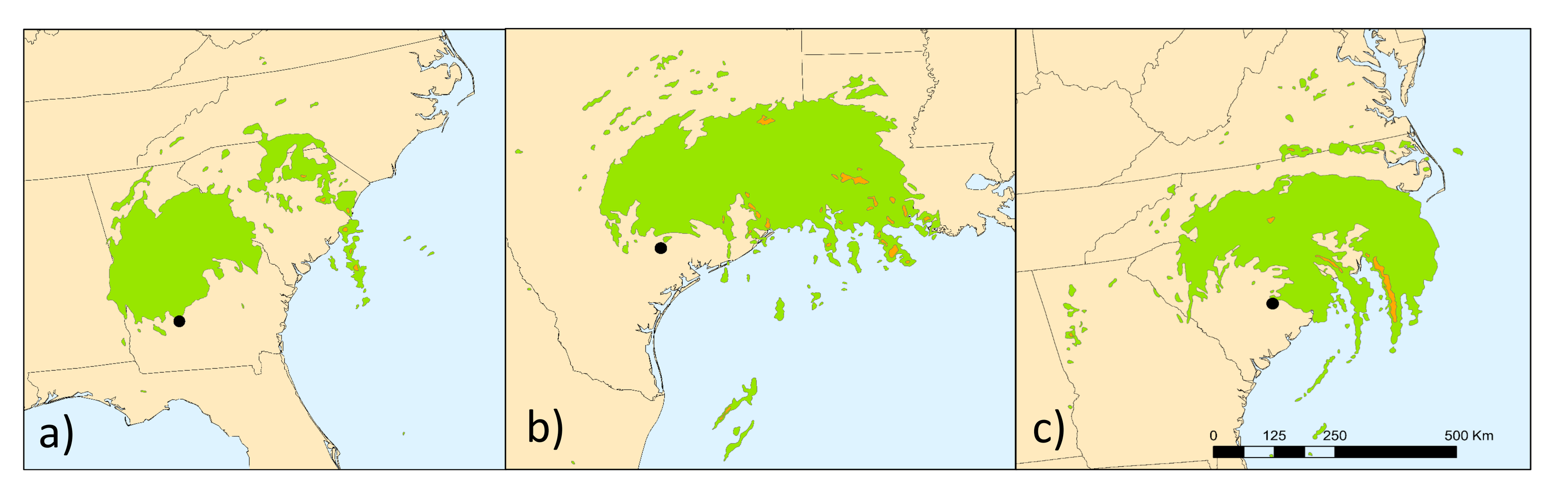


Fig. 4. At 36 h post-landfall, polygons enclosing 20 dB*Z* (green) and 40 dB*Z* regions (orange) for a) Jeanne b) Harvey, and c) Florence. Circulation center = black dot.

Table 3. Metric values for each storm at 36 h post-landfall.

Metric	Jeanne	Harvey	Florence
Dispersion 20 dB*Z*	0.39	0.57	0.38
Dispersion 40 dB*Z*	0.84	0.79	0.51
Closure 20 dB*Z*	0.69	0.67	0.78
Closure 40 dB*Z*	0.03	0.12	0.16

- Jeanne is weakest and has the least convection leading to low closure in 40 dB*Z*.
- Harvey is the most dispersed and has the most exposure for 20 dB*Z* regions as its rain fields are mainly northeast of center.
- Florence has a well-developed 40 dB*Z* region 250 km from center, thus it is the least dispersed as the majority of regions in Harvey and Jeanne are >400 km from center.

Comparison of Values Over Time, Relative to Landfall

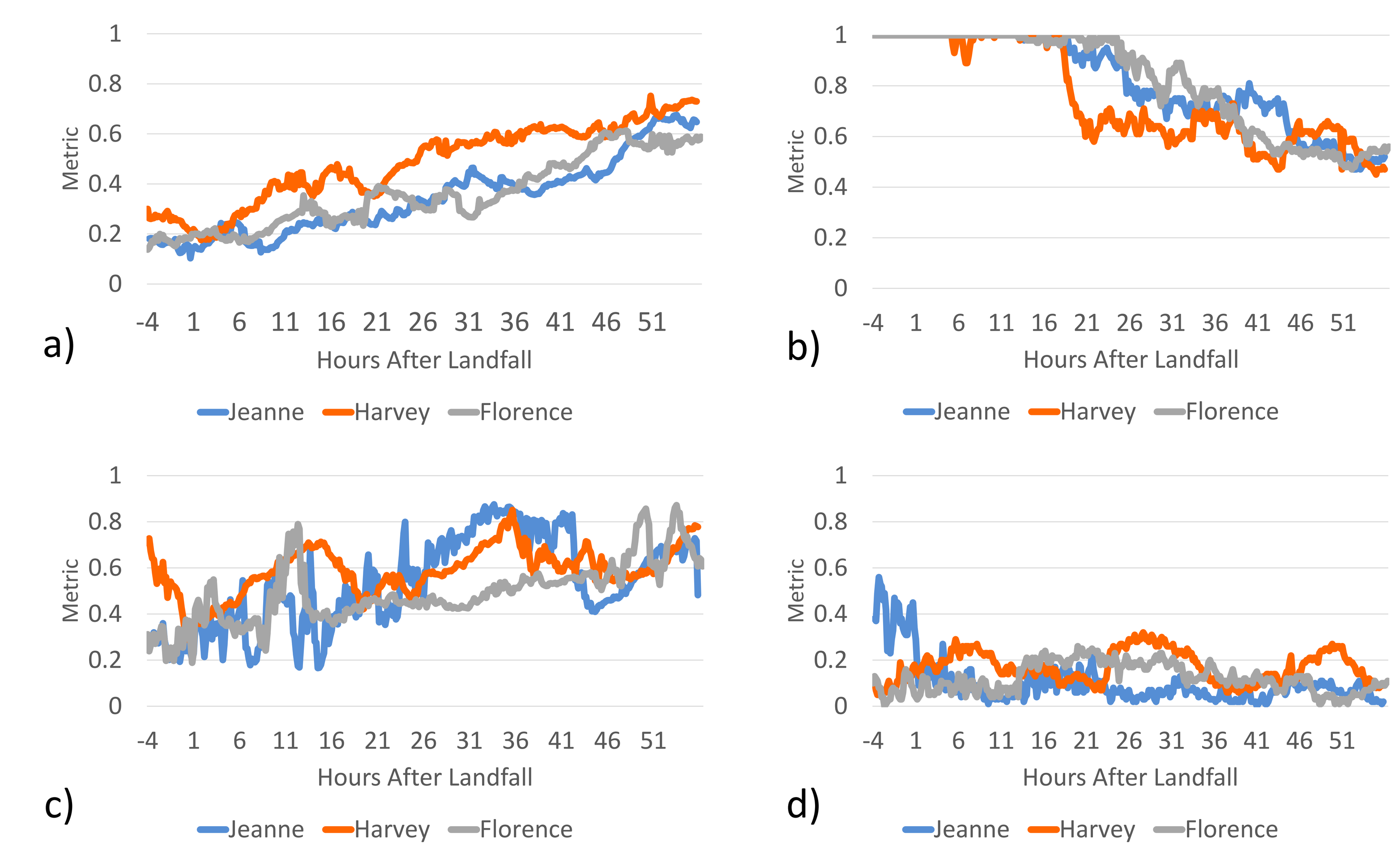


Fig. 5. a) Dispersion of 20 dB*Z*, b) closure of 20 dB*Z*, c) dispersion of 40 dB*Z*, d) closure of 40 dB*Z* regions with search radius of 50-450 km (J and F) and 50-500 km (H).

- 20 dB*Z* dispersion increased in all TCs at ~ 4 km per hour with R^2 values > 0.89; total increases were 180-220 km. Harvey was more dispersed overall.
- 20 dB*Z* values no longer completely encircled the center at 19 hours post-landfall for Jeanne and Harvey, but 24 hours post-landfall for Florence. This is about 6 to 12 hours after weakening to tropical storm intensity.
- Once values began to decline, 20 dB*Z* closure decreased at 4.1° and 5.4° per hour for Jeanne and Florence, with R^2 values > 0.86. Values bottomed out around 180°
- 40 dB*Z* regions were dispersed in the outer rainbands, which limits tangential extent.

Future Work: Examining Atmospheric Conditions

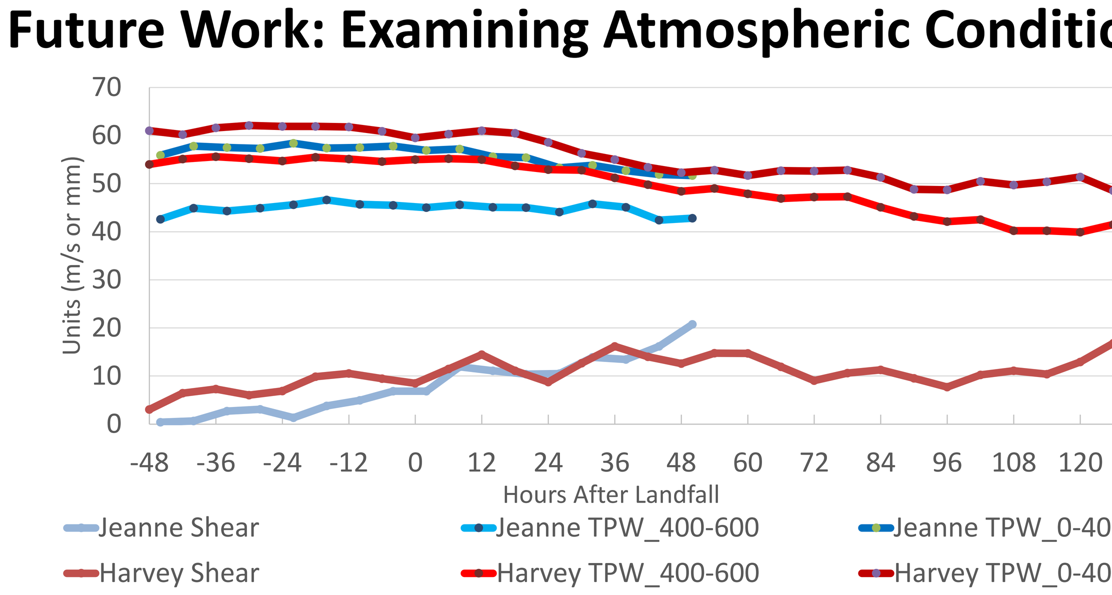


Fig. 6. SHIPS values of 200-850 hPa wind shear velocity and total precipitable water averaged 0 – 400 and 400-600 km from storm center for Jeanne (blue) and Harvey (red).

- SHIPS data (DeMaria et al. 2005) are not yet available for 2018.
- Before landfall, Harvey experienced stronger shear than Jeanne, with a vector more consistently from the southwest, which could account for more dispersion in Harvey.
- Total precipitable water averaged inside of 400 km and over an annulus 400-600 km away from storm center showed more moisture was available for Harvey than Jeanne. This could have limited the development of outer rainbands in Jeanne, leading to less dispersion near landfall.

References

- DeMaria, M., M. Mainelli, L. K. Shay, J. A. Knaff, and J. Kaplan, 2005: Further improvements to the Statistical Hurricane Intensity Prediction Scheme (SHIPS). *Weather and Forecasting*, **20,** 531-543.
- Jiang, H., C. Liu, and E. J. Zipser, 2011: A TRMM-based tropical cyclone cloud and precipitation feature database. *Journal of Applied Meteorology and Climatology*, **50,** 1255-1274.
- Matyas, C. J., S. E. Zick, and J. Tang, 2018: Using an object-based approach to quantify the spatial structure of reflectivity regions in Hurricane Isabel (2003): Part I: Comparisons between radar observations and model simulations. *Monthly Weather Review*, **146,** 1319-1340.
- Tang, J., and C. J. Matyas, 2016: Fast playback framework for analysis of ground-based Doppler radar observations using Map-Reduce technology. *Journal of Atmospheric and Oceanic Technology*, **33,** 621-634.