Spatial metrics that facilitate the comparison of radar reflectivity values within landfalling tropical cyclones

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Motivation

- TC intensity forecasting uses spatial organization of clouds (Dvorak 1975)

- Yet visual inspection commonly used to assess forecast or simulation success for spatial extent of storm/high rainfall regions (e.g. Gentry and Lackmann 2010, Davis et al. 2008)

- Verification statistics only compiled for TC track and intensity

- Need exists for technique to quantify spatial patterns to compare across multiple observational datasets or with/among simulations

- Geographers measure space!
Objectives

- Present set of metrics that measure spatial distribution of radar reflectivity values for tropical cyclones

- Compare observed WSR-88D reflectivity values with simulated reflectivity from WRF simulations for a landfalling hurricane (Isabel 2003)


- Tomorrow: Stephanie Zick details the WRF simulations from our second *MWR* manuscript

- Only 5 metrics here but many more are possible
WSR-88D Mosaic

- Sites within 600 km of storm center
- Level II reflectivity
- Preprocessing, coordinate transformation, projection
- Reflectivity values placed onto 3 km x 3 km x 0.5 km grid
- Highest value retained, Cressman interpolation to fill gaps
- Horizontal slice at 3.5 km

Technique profiled in Tang and Matyas (2016) J Tech
Identifying Reflectivity Regions

Every 30 min. 1800 18 Sept. – 0900 19 Sept.

- Contours drawn along edges of reflectivity values
- Converted into polygons
- Calculations of area and centroid location relative to storm center
- Identification of the largest polygon
- Calculation of spatial metrics
  - Utilized metrics from Geography, Marine Science, Atmospheric Science, Landscape Ecology
5 Spatial Metrics

- 2 metrics for largest polygon of 20 dBZ regions

- 3 metrics include all reflectivity regions; calculated separately for each reflectivity threshold
Comparing Metrics Across Reflectivity Thresholds

Closure

Dispersion

Fragmentation

• All significantly correlated with time save 35 and 40 dBZ fragmentation
• 20, 25, 30 dBZ significant correlated – stratiform precipitation
• 35 and 40 dBZ significantly correlated – convective rainfall
Vertical Wind Shear, Storm Motion, Topography

- Topography: increased closure 0300 - 0700?
- Centroids of 20 dBZ reflectivity regions located 35°-55° left of shear vector; shifted from 5° right to 20° left of storm motion vector
- As ET progresses, closure, circularity, solidity should decrease; dispersion, fragmentation should increase
Moisture Conditions as Isabel Experienced ET

- As moisture decreases, closure/solidity should decrease and dispersion/fragmentation should increase.
- Matyas (2017): 45 mm TPW extending from deep tropics contributes to high rainfall.
- Throughout, western edge of 45 mm co-locates with edge of outermost rainband.
- Future work to investigate these moisture tails.
Comparisons with WRF Simulations (20 dBZ)

Tiedtke and Kain-Fritsch Cumulus Schemes
WRF 6-class single moment and Morrison 2-M Microphysics
Acronyms: TS, TM, KFS, KFM

Strongest Correlations with WSR:
• TS/TM: circularity and closure
• KFS/KFM: dispersion and fragmentation

Take Home Messages:
• KF too circular, lacks outer rainbands
• T too spread out and fragmented but outer rainbands match well
Comparisons with TRMM 3B42 Data

- Spatial metrics useful to compare WSR-88D reflectivity regions to TRMM 3B42 rain rate regions
- Dispersion exhibited best results and strongest correlations with storm and environmental conditions
- All metrics strongly correlated with $V_{\text{max}}$ (-0.7 or 0.8) expected (Dvorak 1975)
- Also statistically significant correlations with moisture across the board
- Correlations with shear weaker, not significant for circularity
Conclusions and Future Research

• Spatial metrics separate stratiform and convective regions
• As Isabel made landfall and underwent ET, rainfall regions became less solid, enclosed less of the circulation center, and became more fragmented and dispersed
• Storm shape sensitive to convective parameterization in WRF
• Dispersion: good metric across varying spatial scales (e.g., TRMM 3B42)

• Add displacement for improved correlation with vertical wind shear (Zhou and Matyas, in revision JAMC)
• Consider orientation to identify possible topographical influences
• Calculate closure over multiple radial distances to separate inner core and outer rainbands (Matyas 2015 IHC conference)
References


• Matyas, C. J. 2015 Measuring gaps in tropical cyclone rainbands using Level II radar reflectivity data, delivered at the 69th Annual Interdepartmental Hurricanes Conference, March 3, Jacksonville, FL.


