Using Shape Metrics to Compare Observed and Simulated Reflectivity During the Landfall of Hurricane Isabel (2003)

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hurricane.geog.ufl.edu

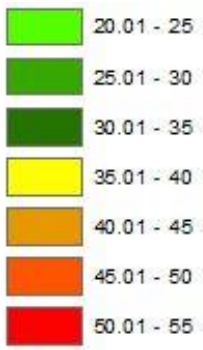
Thanks to Gary Lackmann and Michael Bell

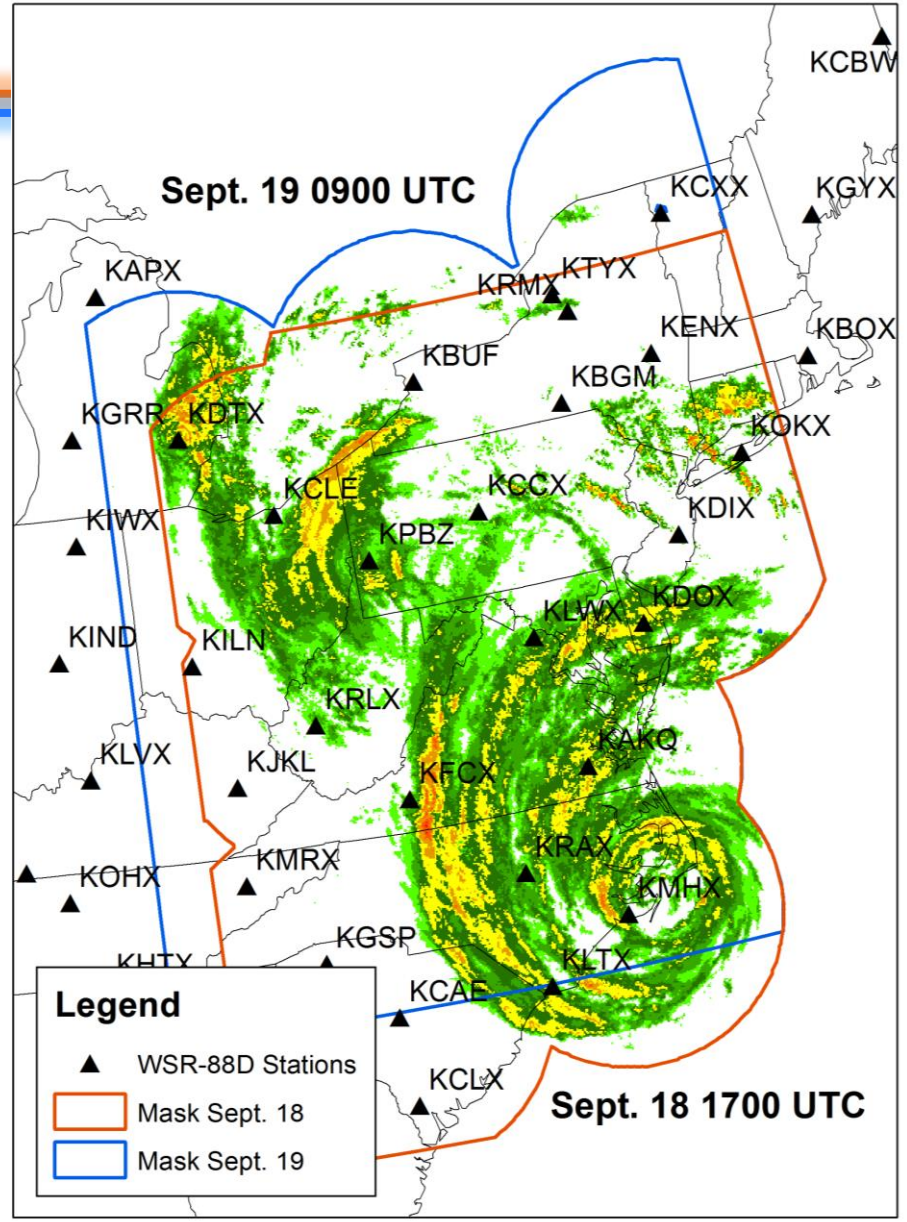
Overview and Objectives

- Compare observed radar reflectivity values (Tang and Matyas 2016) with simulated reflectivity from an ensemble of WRF models for a landfalling hurricane due to sensitivity to model physics (e.g., Davis et al. 2008; Fierro et al. 2009)
- Identify biases in reflectivity values
- Use shape metrics to compare spatial distribution of reflectivity values (Matyas 2007; 2009; 2010; Zick and Matyas, in revision)
- Case study: Hurricane Isabel (2003)

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)
Journal of Atmospheric and Oceanic Technology

WRF Ensemble (Cumulus)

	Cumulus Parameterization	BOTH are mass flux schemes & incl. shallow convection	Operational Models/ Research Studies
	Kain-Fritsch (Kain and Fritsch 1990; Kain 2004)	- Closure for (deep) convection based on CAPE - Cloud, rain, ice and snow detrainment - No momentum transport	COAMPS-TC 2010-14; NCAR-MMM Advanced Hurricane-research WRF (AHW) 2010; Davis et al. (2008); Gentry and Lackmann (2010)
***May* perform better**	**Tiedtke** (Tiedtke 1989; Zhang et al. 2011) → recommended for hurricane simulations in WRFv3.6.1 documentation	- Closure: CAPE - Cloud and ice detrainment - Includes momentum transport	NCAR-MMM AHW 2011-13; Torn and Davis (2012)

Mesoscale model configurations from: http://www.ral.ucar.edu/projects/hfip

WRF Ensemble (Microphysics)

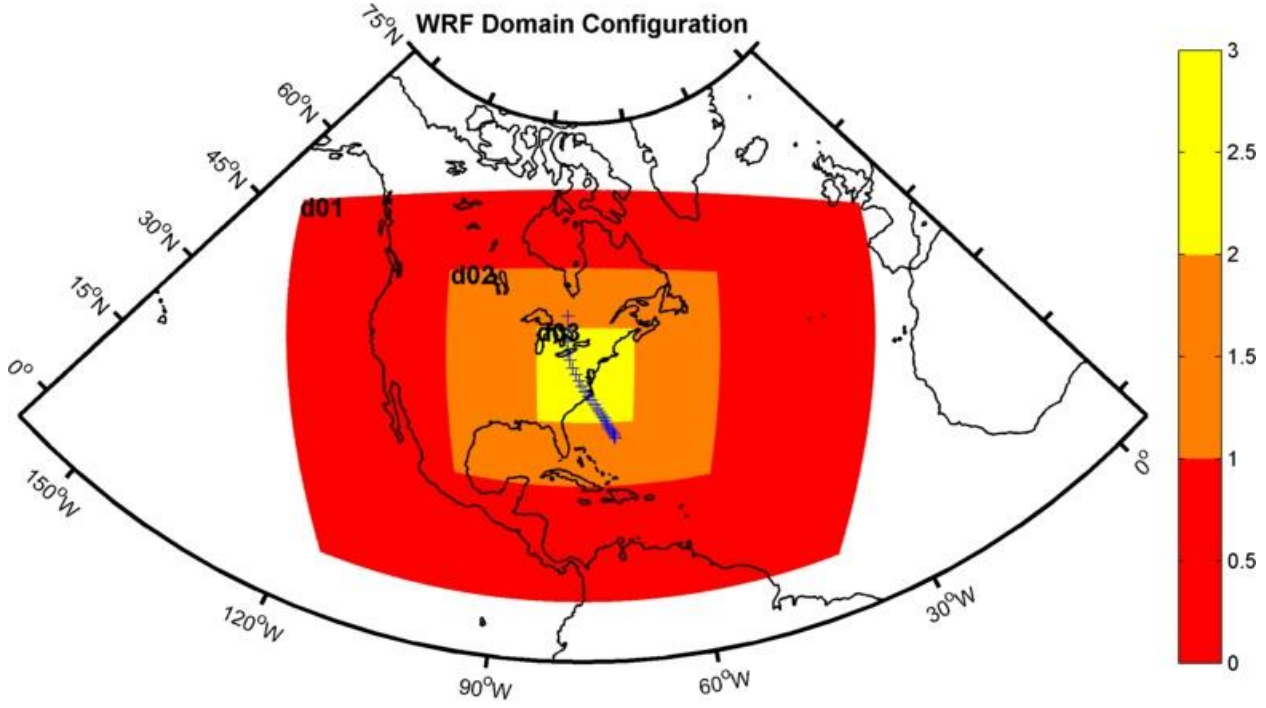
Increasing complexity

Microphysics Parameterization	Mass Variables	Number Variables	Operational Model/ Research Studies
WSM6 (Hong and Lim 2006)	Qv, Qc, Qr, Qi, Qs, Qg	-	NCAR-MMM AHW 2011-13; PSU WRF/EnKF 2011-14 Numerous TC research studies
WDM6 (Lim and Hong 2010)	Qv, Qc, Qr, Qi, Qs, Qg	Nn^+, Nc, Nr (Nn^+ = CCN number)	N/A Hurricane Nature Run (Nolan et al. 2013)
Morrison-2M (Morrison et al. 2009)	Qv, Qc, Qr, Qi, Qs, Qg	Nr, Ni, Ns, Ng	N/A Brown, Bell, and Frambach (2015) (use these 3 and more complex schemes)

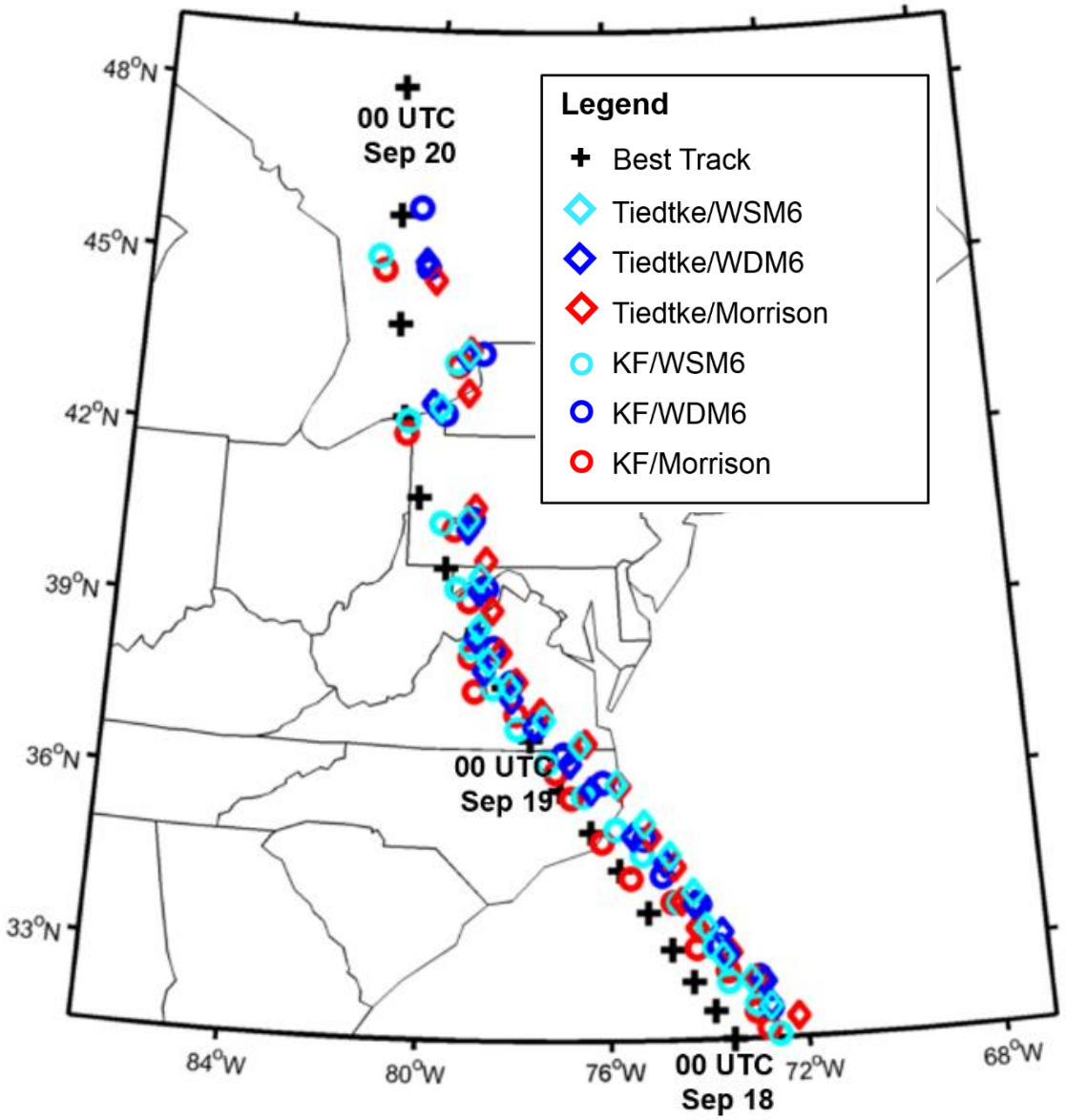
Mesoscale model configurations from: http://www.ral.ucar.edu/projects/hfip

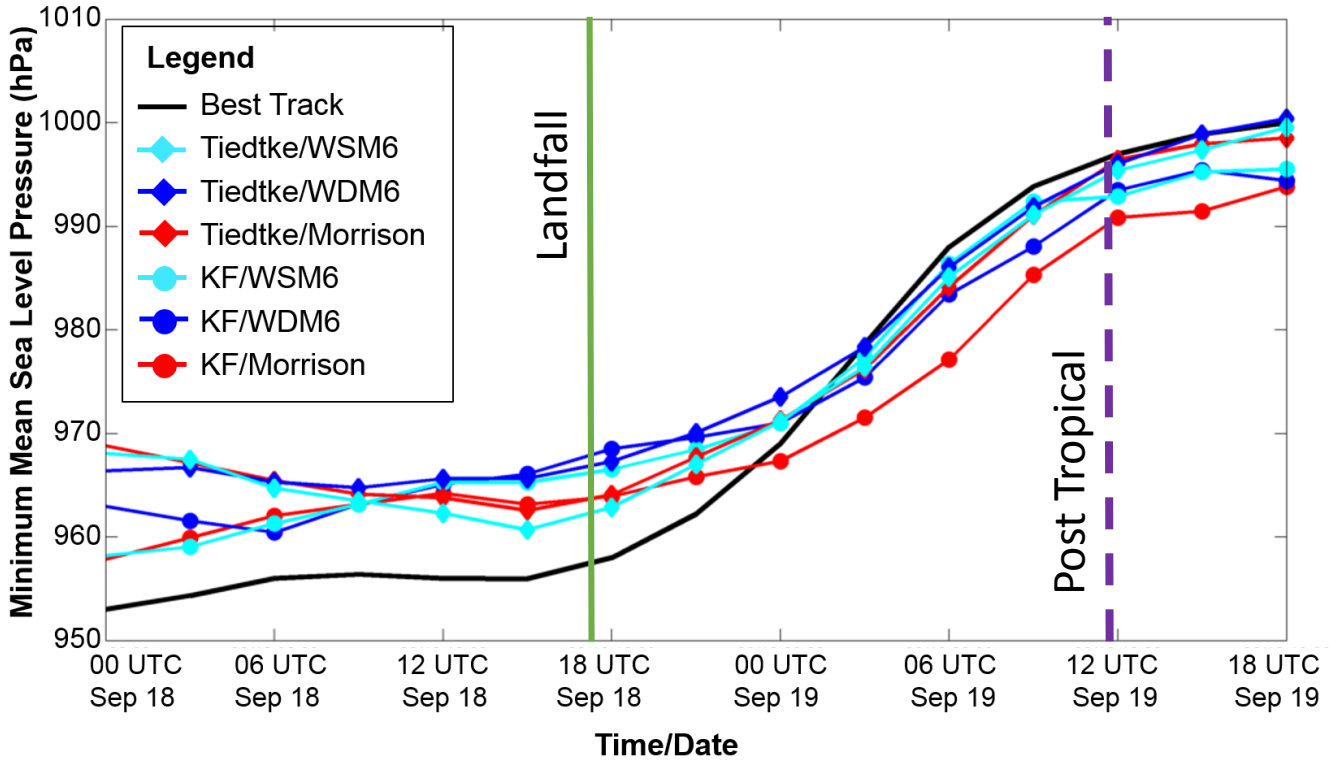
Weather Research and Forecasting (WRF) Model

WRF-ARW v3.6.1
Domain: 27 km (d01) → 9 km (d02) → 3 km (d03)
40 vertical levels with 2 hPa model top
Timing: d01 initialized 00 UTC Sep 16 2003
d02/3 initlzed 00 UTC Sep 17 2003
BT landfall: 17 UTC Sep 18 2003
all sims end: 18 UTC Sep 19 2003
Physics: YSU boundary layer
RRTMG longwave and shortwave radiation
Tiedtke (◊) & Kain-Fritsch (○) convection
(fully explicit on d03)
WSM6, **WDM6**, & **Morrison-2M**
microphysics
Ocean: SSTs prescribed

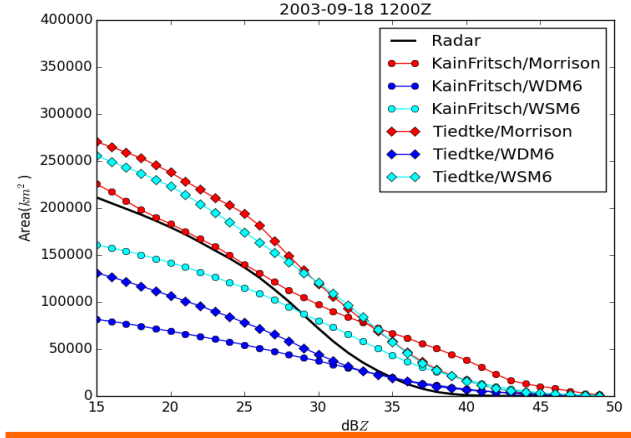


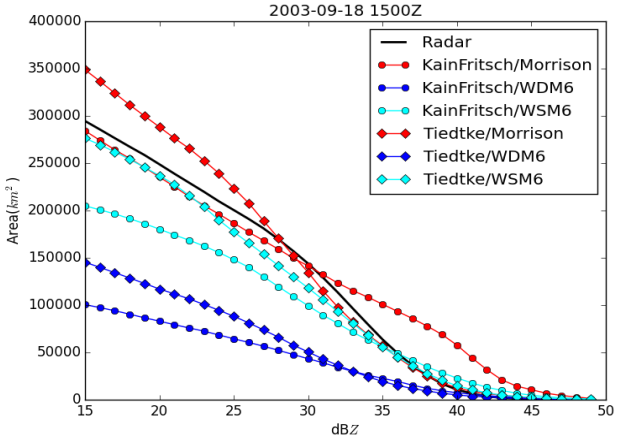
Position and Intensity Comparisons

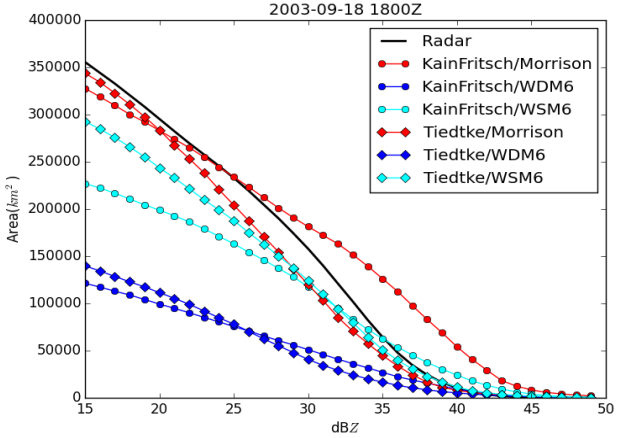


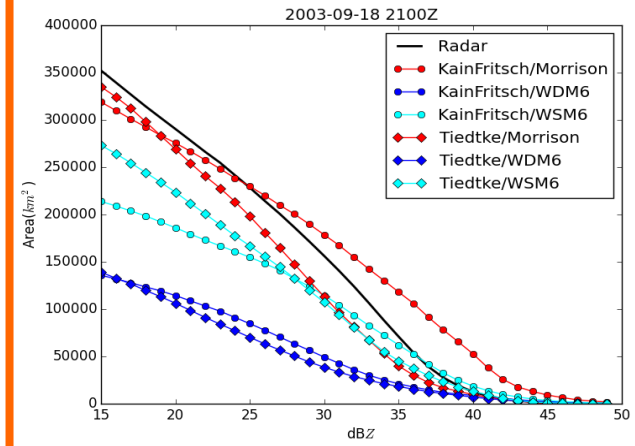


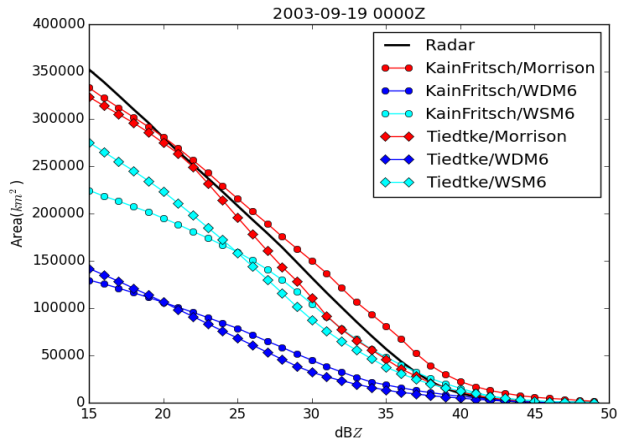
Reflectivity Areas (sq. km)

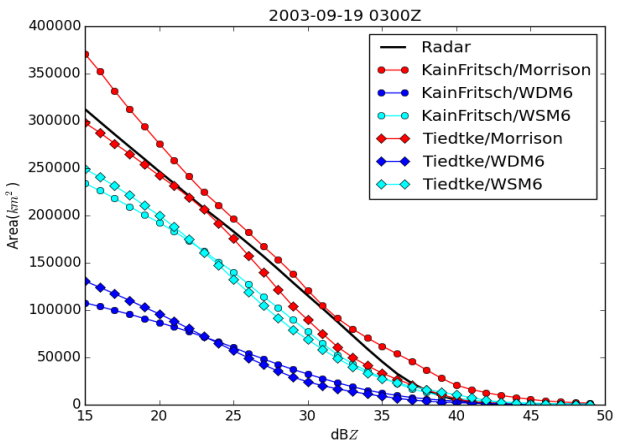


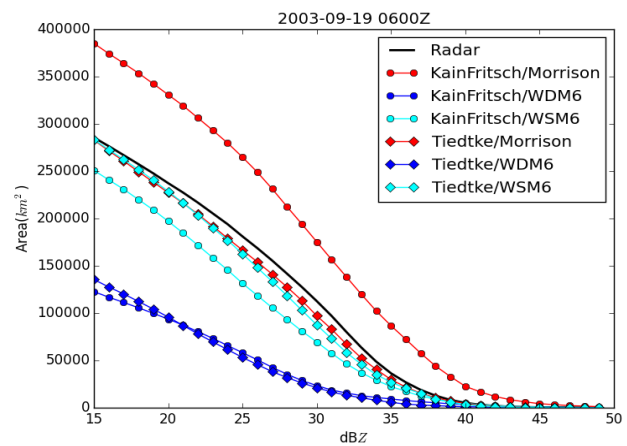


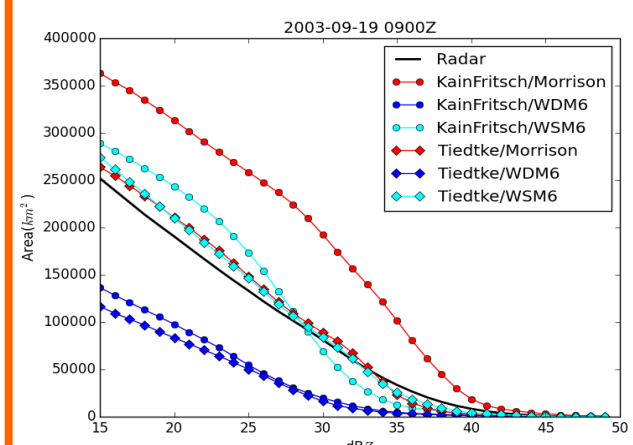


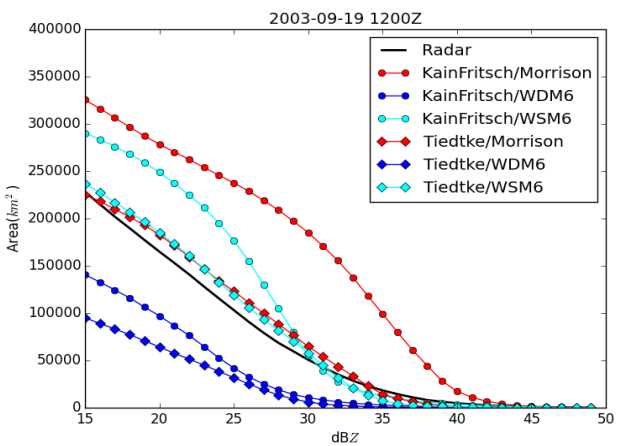












Reflectivity 1800 UTC

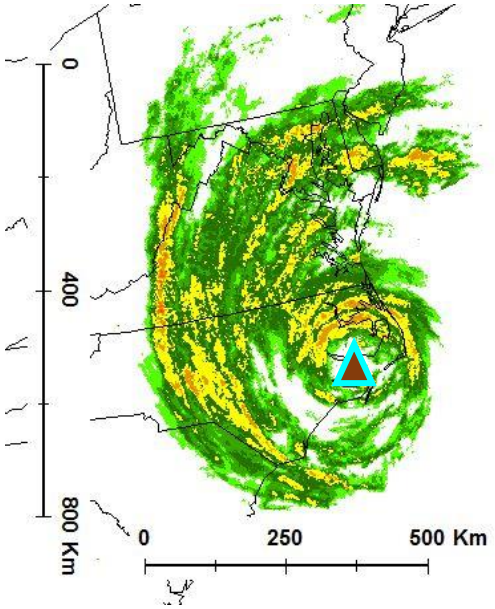
WSM6

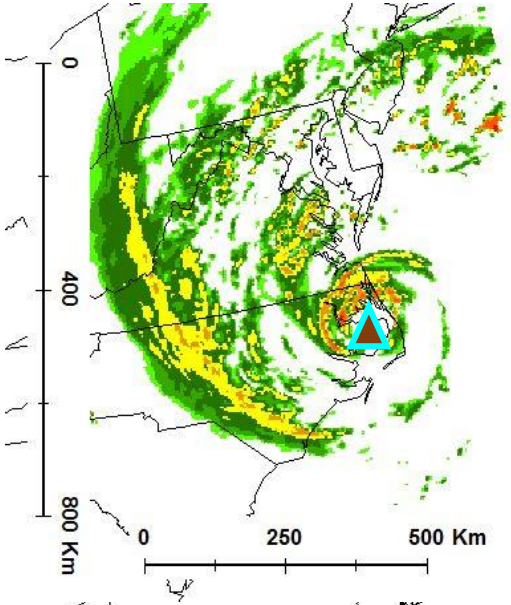
WDM6

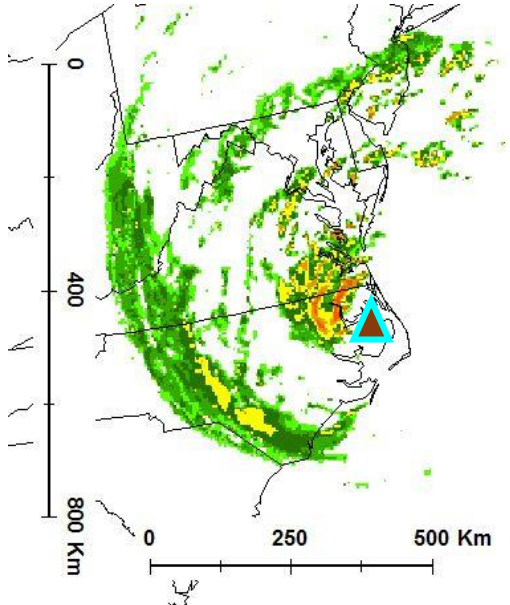
Morrison

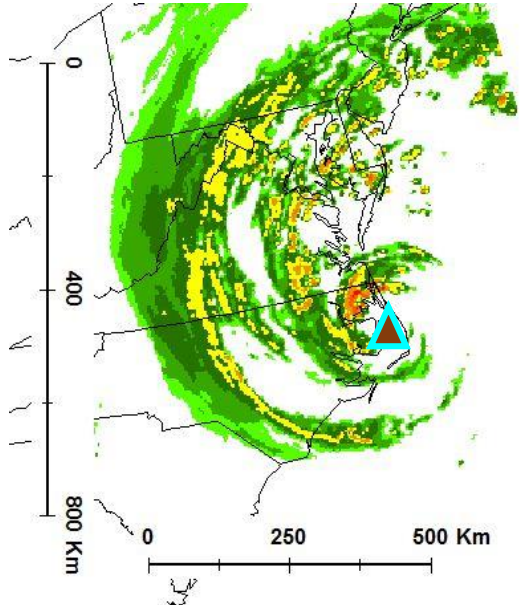
Tiedtke

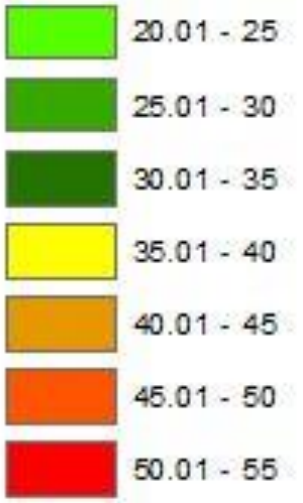
Kain-Fritsch

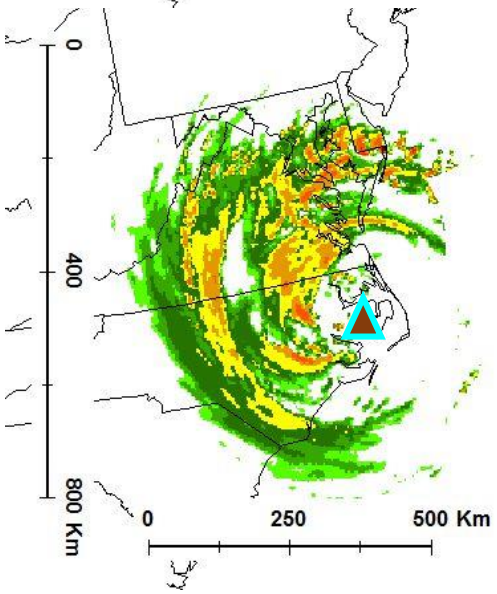


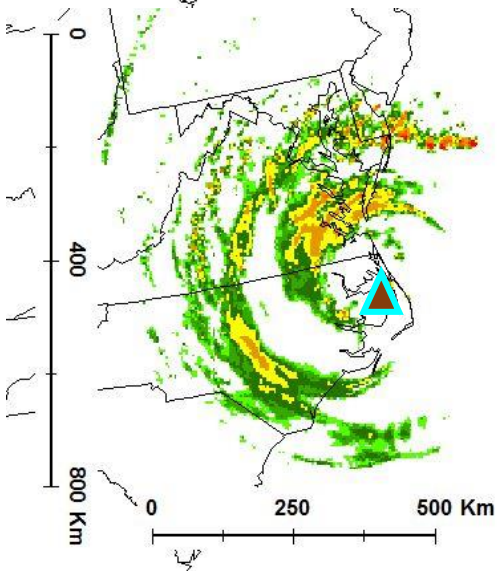


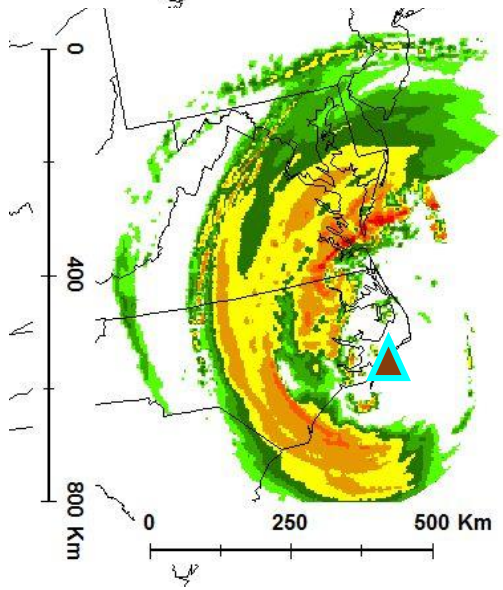












Reflectivity 0900 UTC

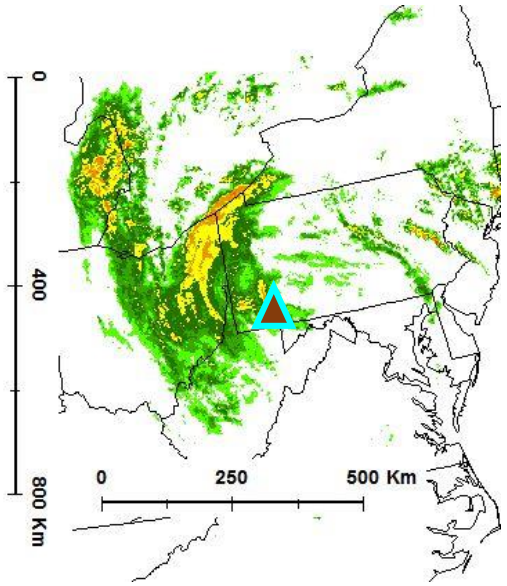
WSM6

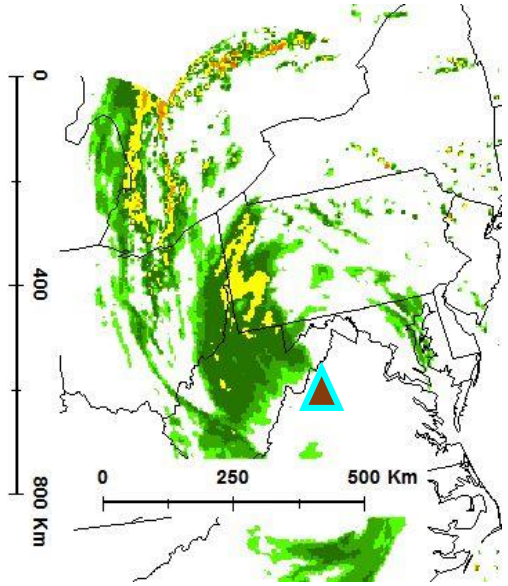
WDM6

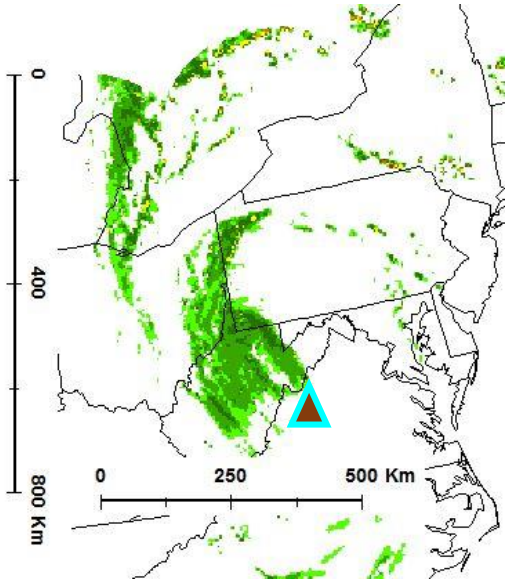
Morrison

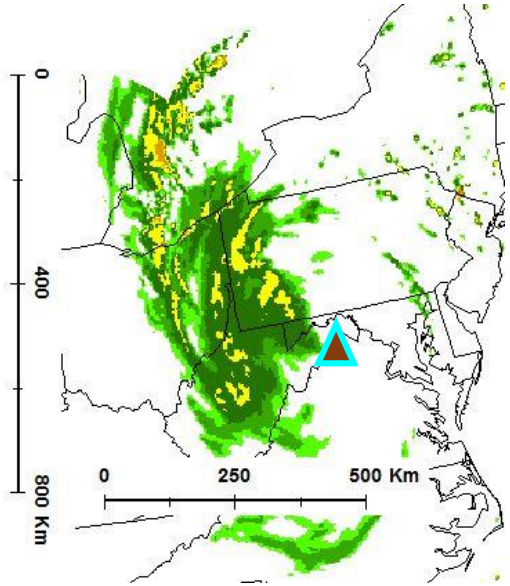
Tiedtke

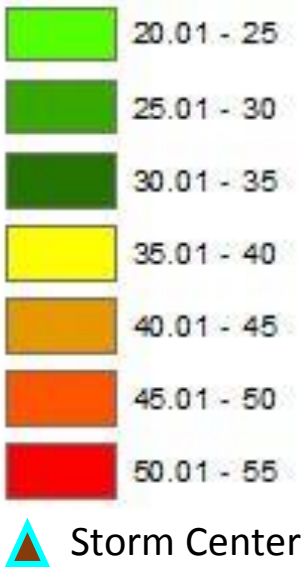
Kain-Fritsch

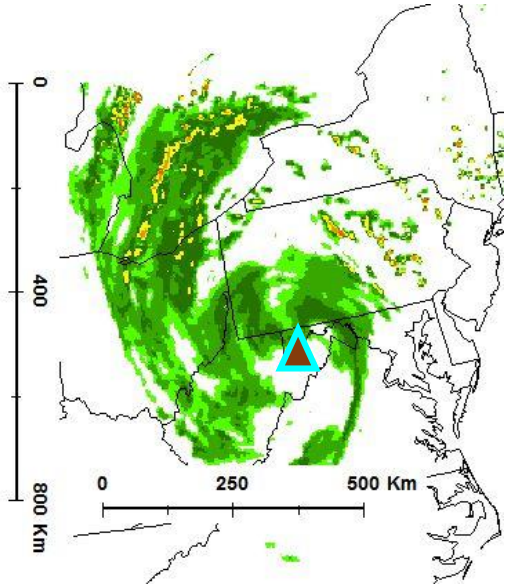


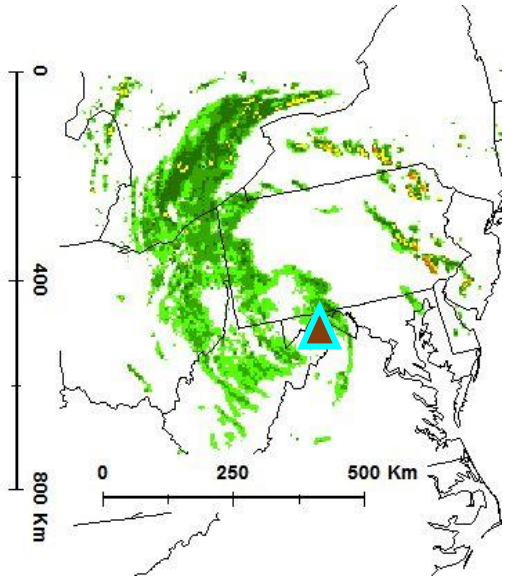


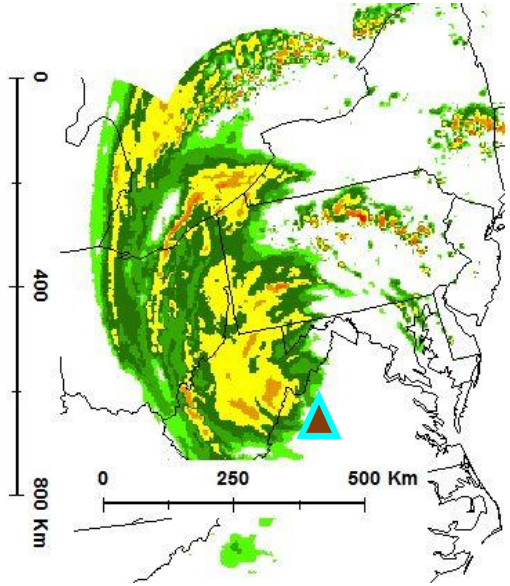












Reflectivity Bias

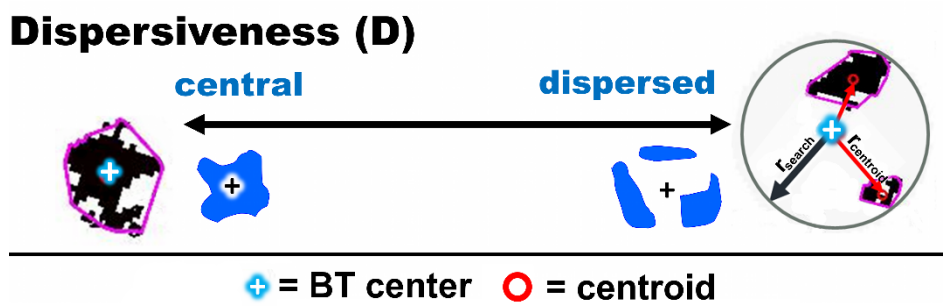
	T/ WSM6	T/ WDM6	T/ Morrison	KF/ WSM6	KF/ WDM6	KF/ Morrison
20	-2.3	-10.0	1.0	-7.1	-10.0	1.9
25	-1.9	-14.3	0.0	-6.3	-14.4	1.8
30	-1.4	-12.5	-0.4	-2.3	-13.6	4.0
35	-1.0	-7.1	-0.5	-0.8	-6.8	4.1
40	0.8	-3.1	1.4	1.8	-1.8	4.5
45	2.4	1.4	1.8	3.8	2.6	6.5
Average	***-0.6***	-7.6	***0.5***	***-1.8***	-7.3	***3.8***

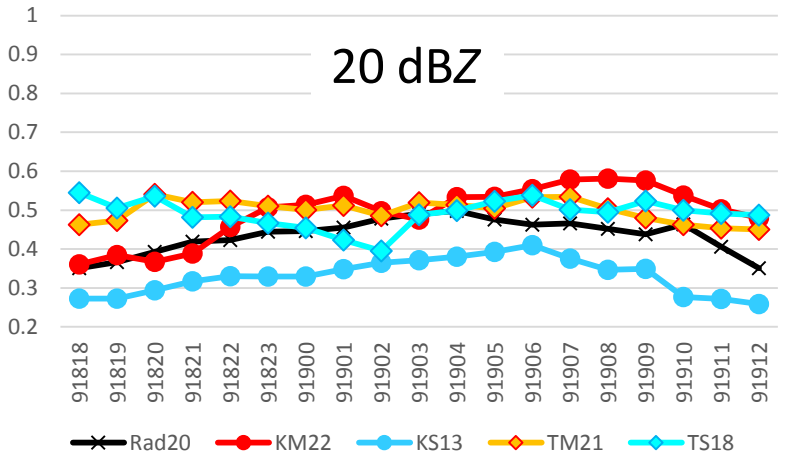
Dispersion Metric Results

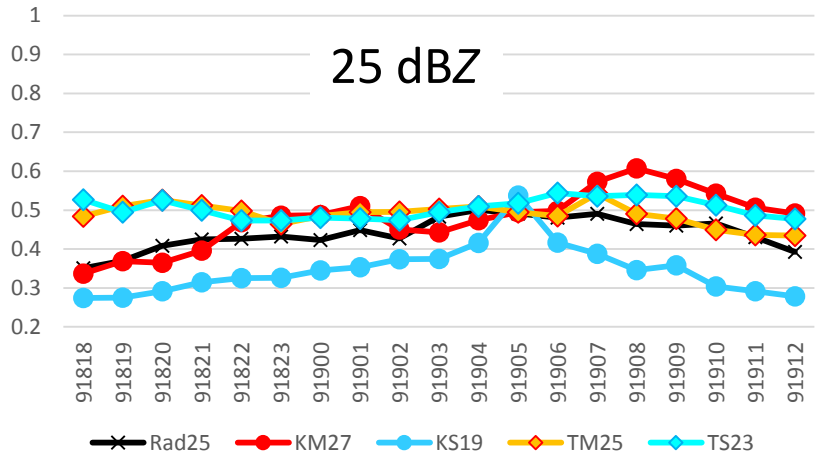
$$D = \sum_{i=1}^{NP} \frac{Area_i}{\sum_j^{NP} Area_j} \left(\frac{r_{centroid,i}}{r_{search}} \right)$$

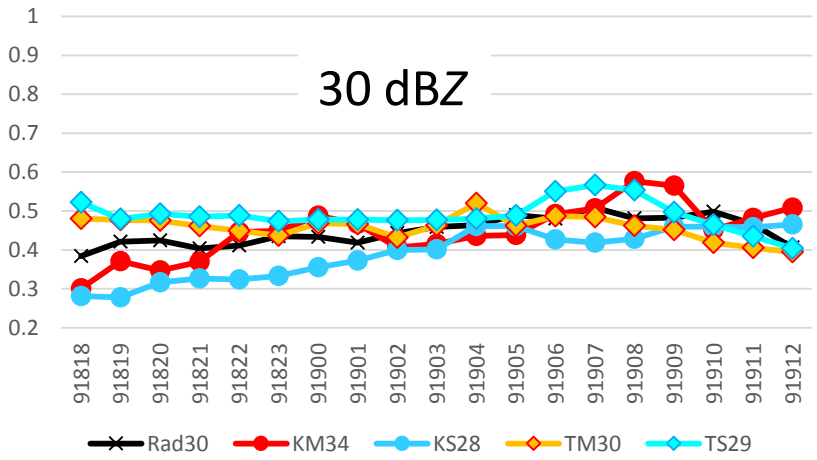
NP = number of polygons
r = radius
Search distance = 600 km

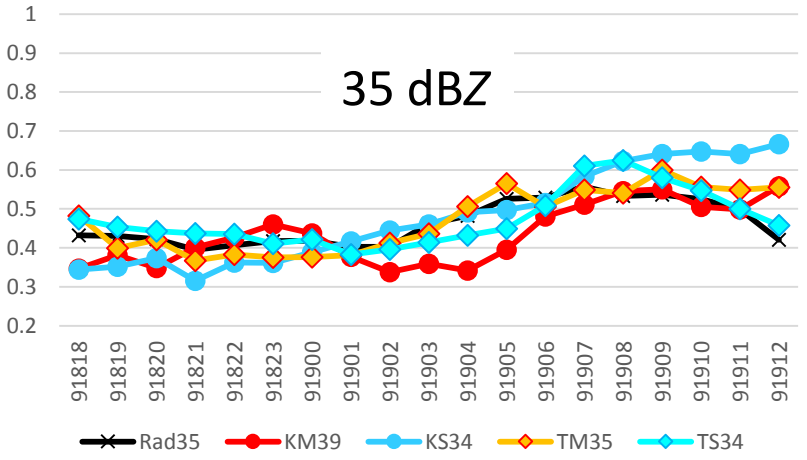
Zick and Matyas, in revision
Annals of the Association of American Geographers

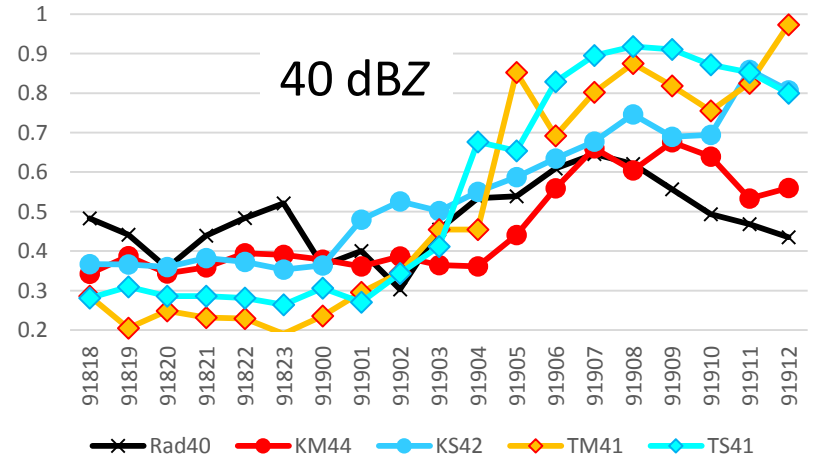






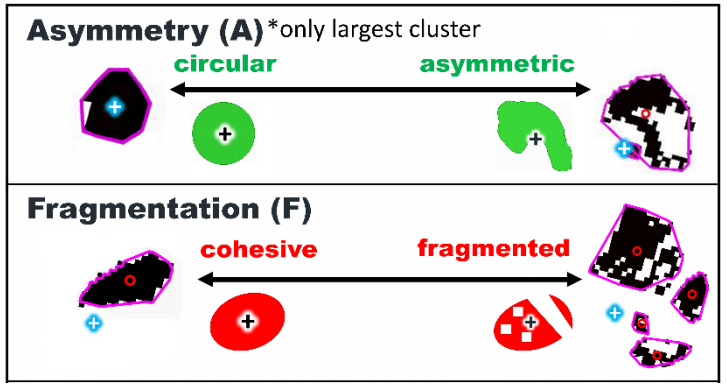






Conclusions and Future Research

- Reflectivity biases inconsistent through time and different reflectivity values
- Tiedtke handles intensity after landfall best, lowest reflectivity bias
- Both WDM6 have extremely low reflectivity values
- Kain-Fritsch Morrison over intensifies after landfall, too much convection
- Storm shape sensitive to convective parameterization



- Calculate additional shape metrics
- Explore rainfall totals
- Examine different altitudes
- Refine bias correction