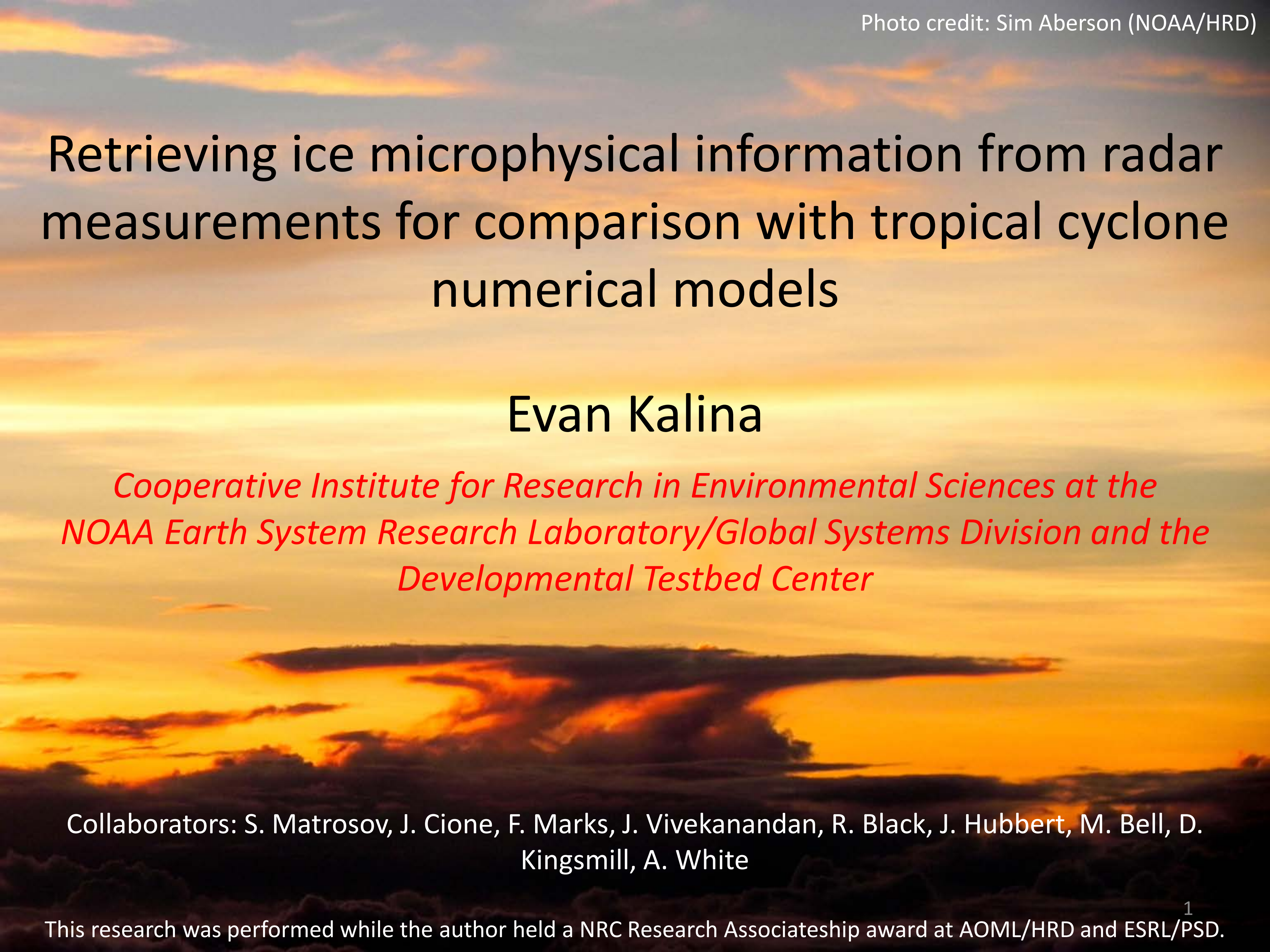


Photo credit: Sim Aberson (NOAA/HRD)

Retrieving ice microphysical information from radar measurements for comparison with tropical cyclone numerical models

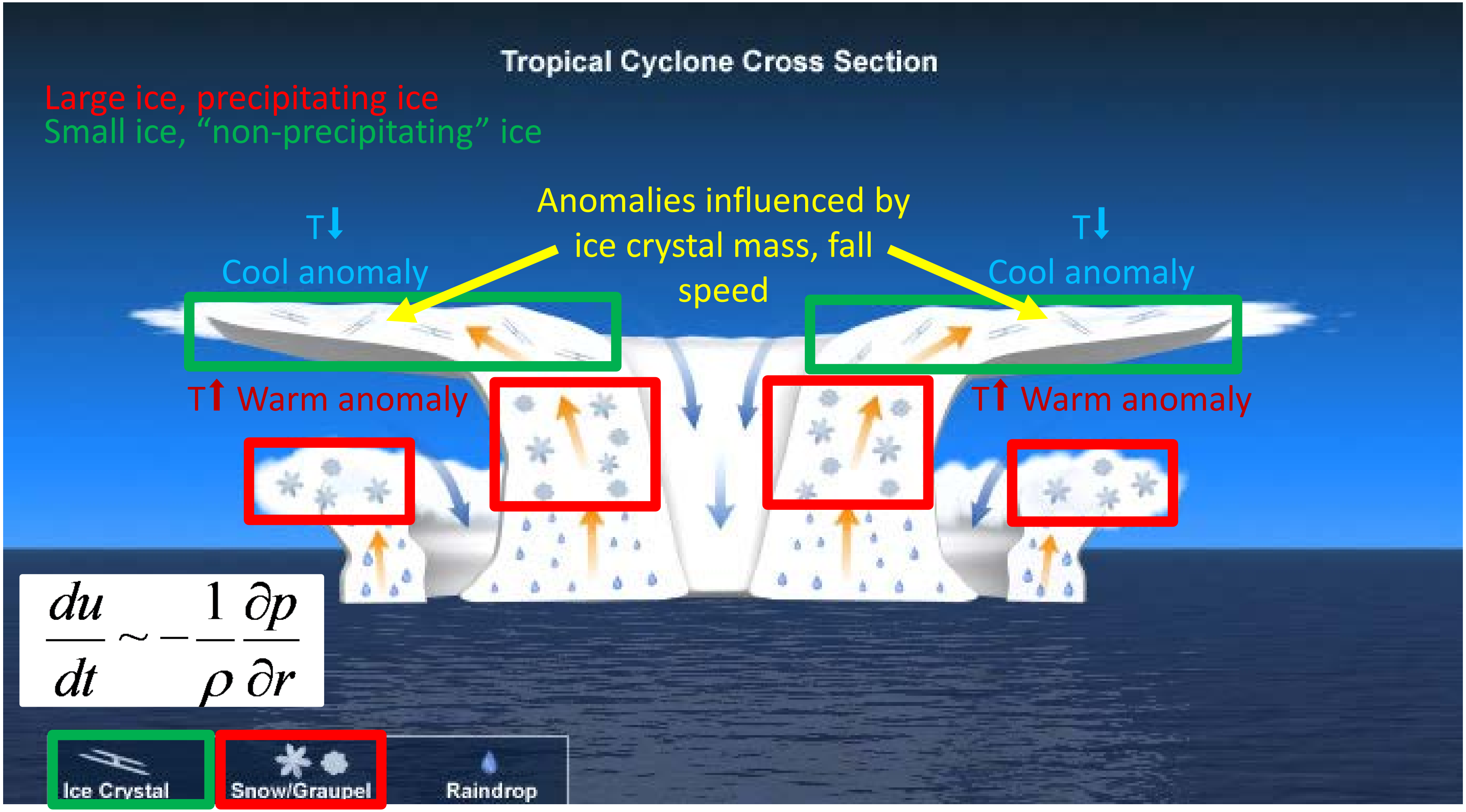
Evan Kalina

Cooperative Institute for Research in Environmental Sciences at the NOAA Earth System Research Laboratory/Global Systems Division and the Developmental Testbed Center

Collaborators: S. Matrosov, J. Cione, F. Marks, J. Vivekanandan, R. Black, J. Hubbert, M. Bell, D. Kingsmill, A. White

This research was performed while the author held a NRC Research Associateship award at AOML/HRD and ESRL/PSD.

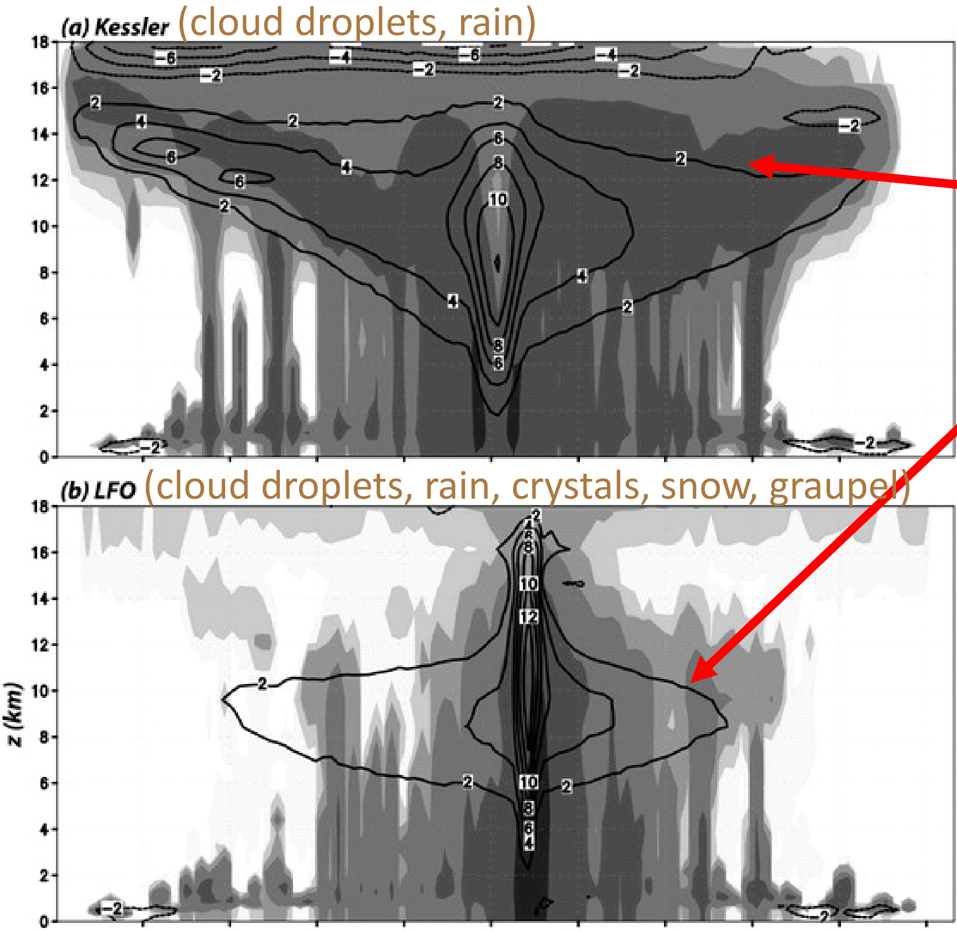
Ice crystal properties linked to tropical cyclone structure through cloud-top radiative budget



See Fovell et al. (2009) for more information

Background image courtesy of UCAR/COMET

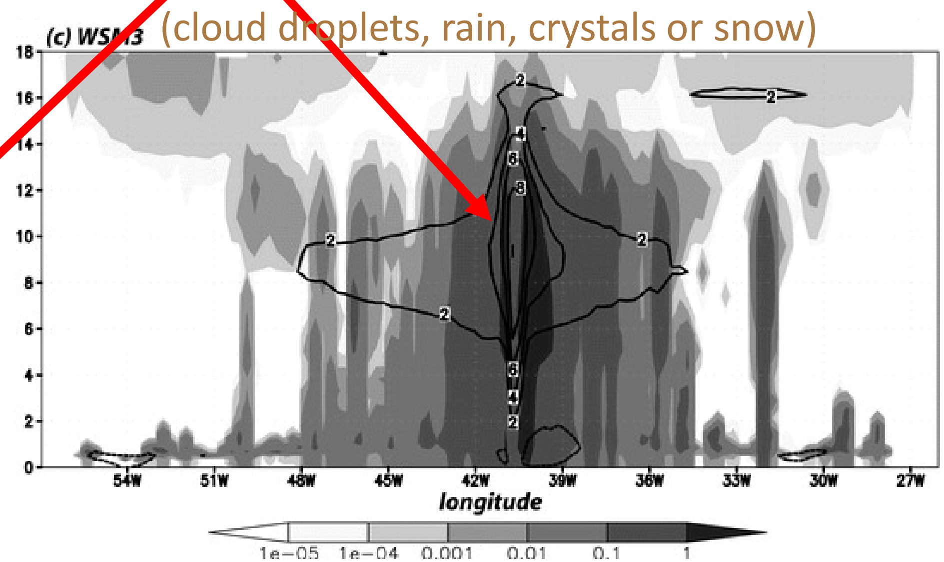
Horizontal extent, thickness of simulated TC anvil heavily dependent on microphysics scheme (Fovell et al. 2009)



Fill: Total condensate

Contours: Virtual potential temperature perturbation

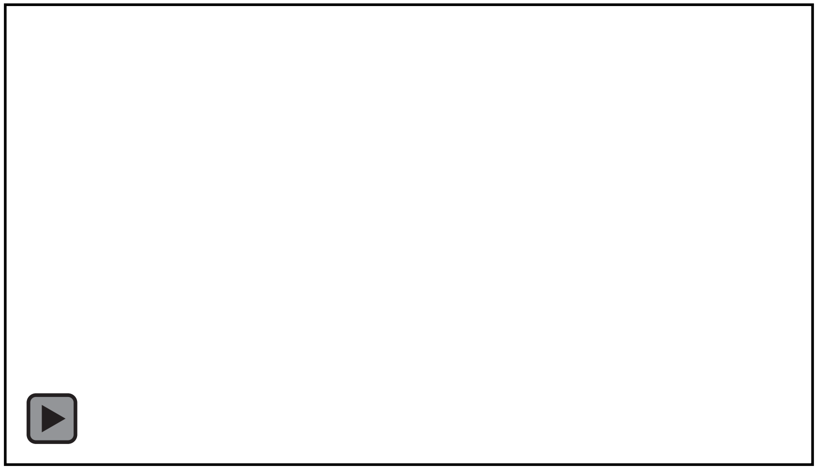
Drastic differences in anvil size, TC thermal structure

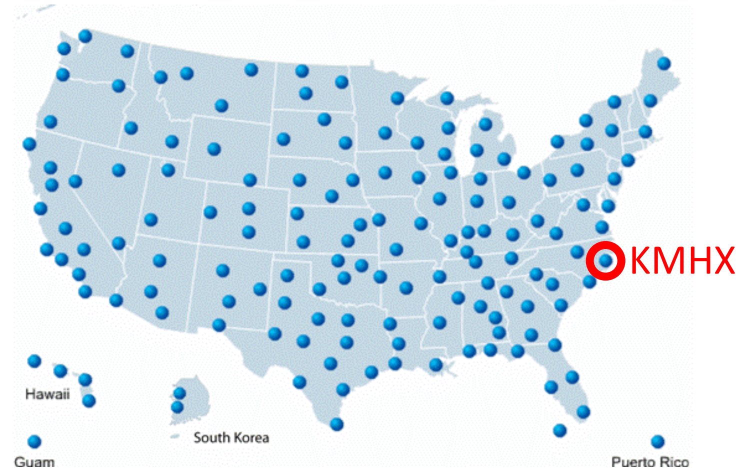


Which scheme is correct, if any?
Need observations of ice fall speeds and masses for model validation

Vertically-pointing radar and dual-polarization scanning radar: unique TC microphysics insights

Dual-polarization radar: •Particle shape •Particle type •Ice water path •Melting layer height

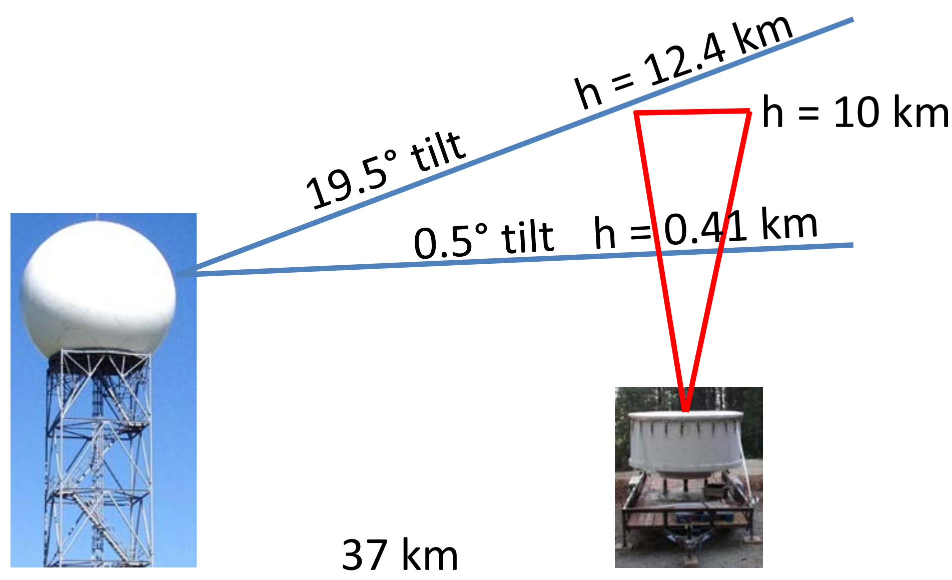




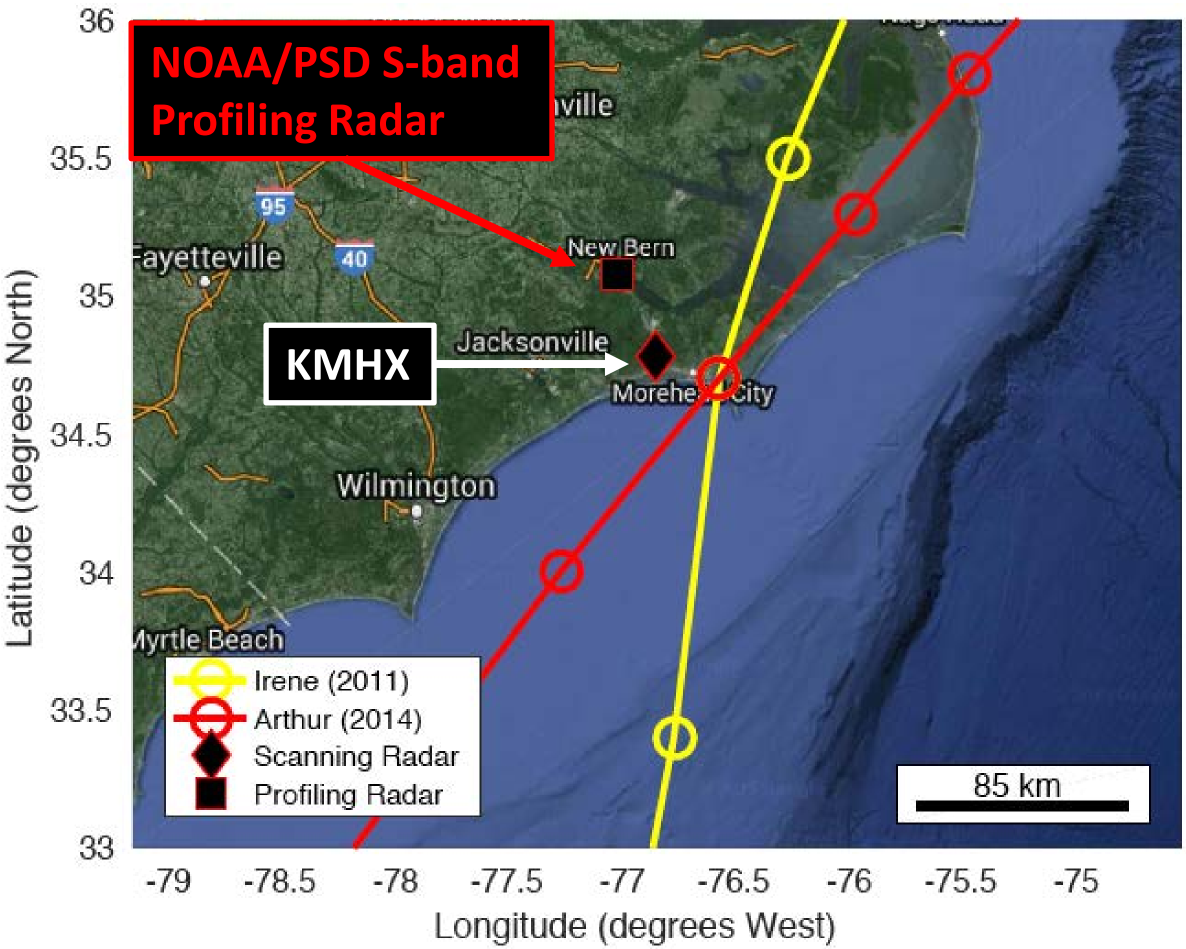
S-band vertically pointing radar (New Bern, NC):
•Reflectivity •Fall speed

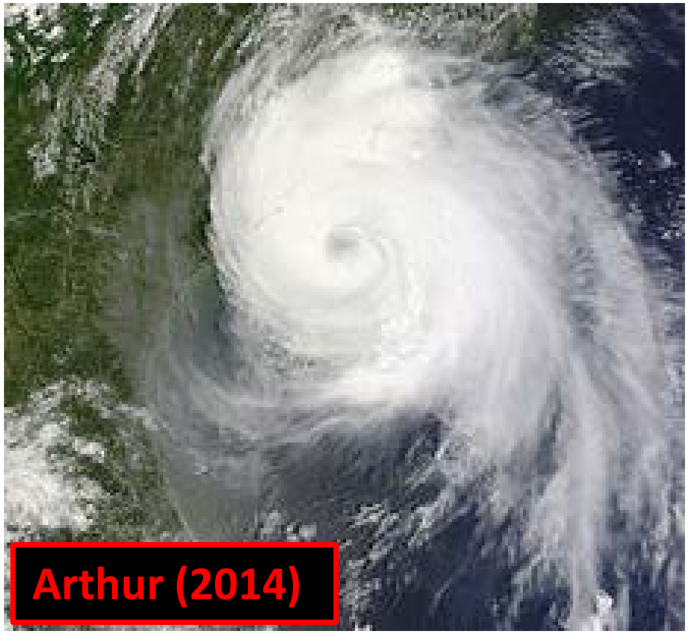

Image credit: NOAA/PSD)

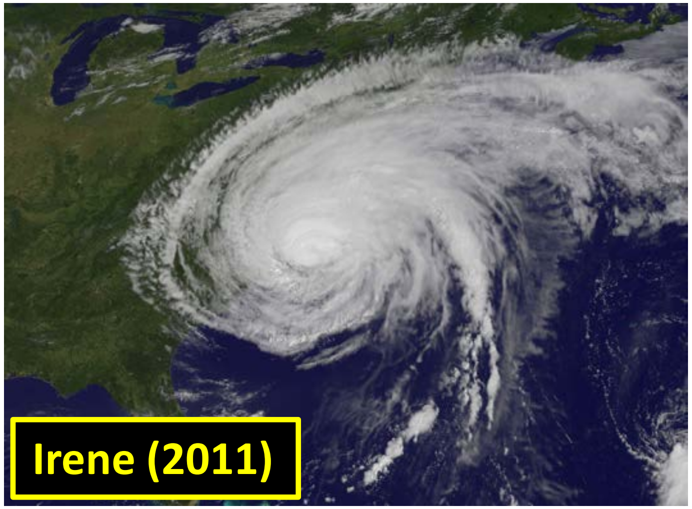
Combine data from these two instruments:

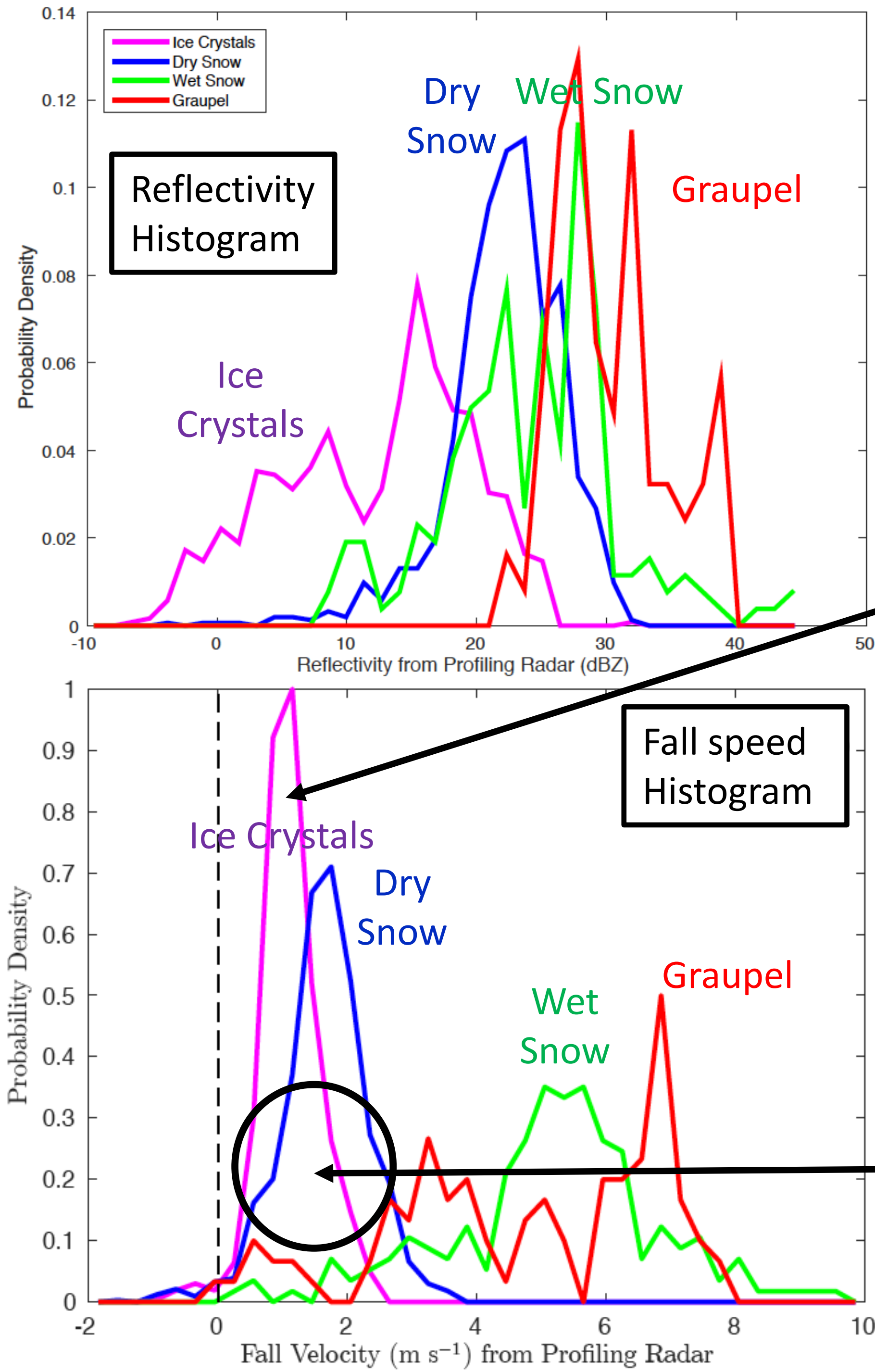


Arthur (2014): 85-kt winds, Irene (2011): 75-kt winds
Both passed within 30 km of KMHX radar site









~11 "rainy" hours at the New Bern profiler allow us to quantify the reflectivity and fall speed of the scanning radar's ice species

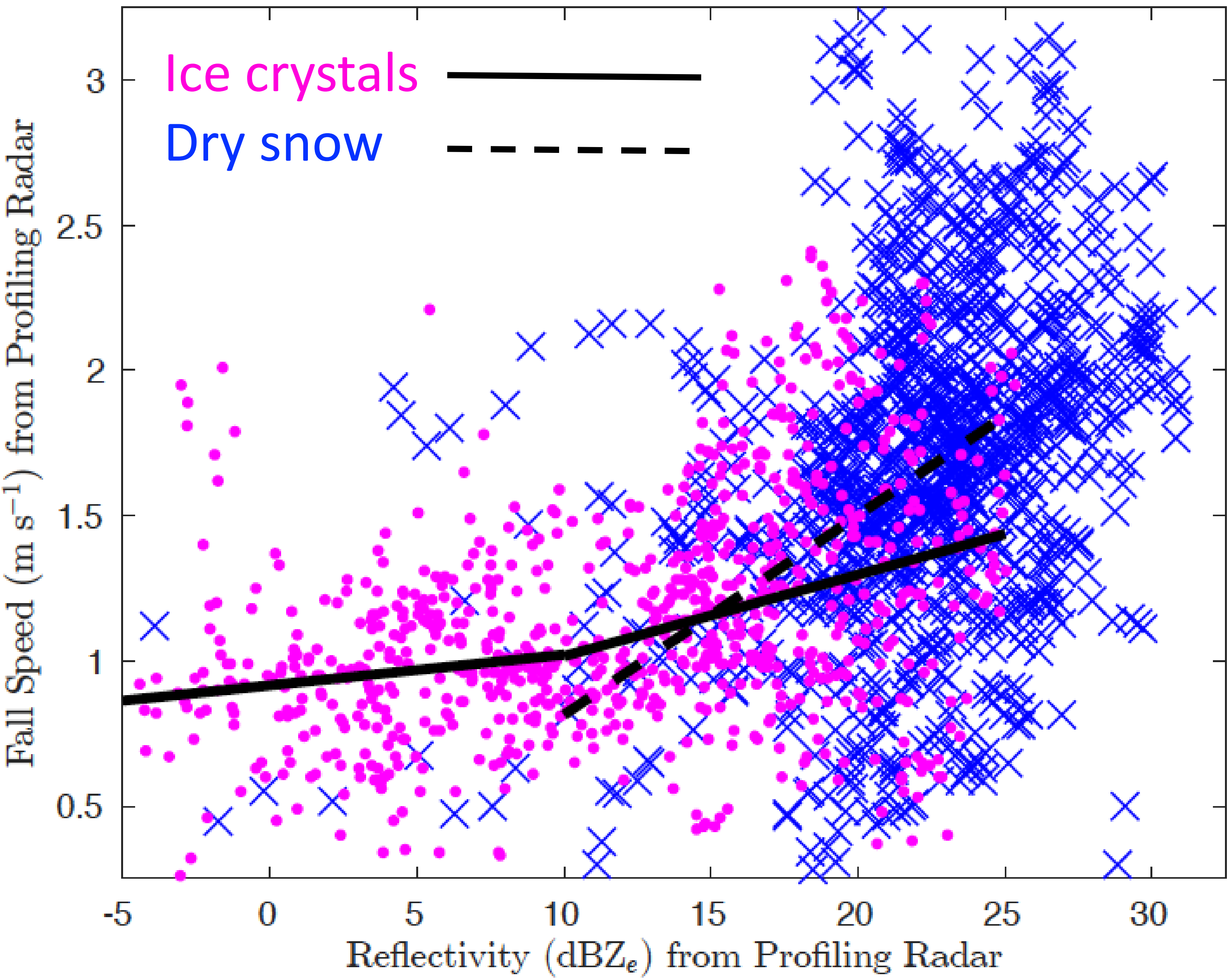
As particle size/riming increase, reflectivity and fall speed also increase.

Radar sees mostly descending ice crystals (air motion + fall speed). Detection limit is ~0.25 m s^{-1}.

These distributions can be compared with model output. Is the model microphysics realistic?

Considerable overlap between ice crystals ("small ice") and dry snow ("large ice"). Can the radar tell the difference?

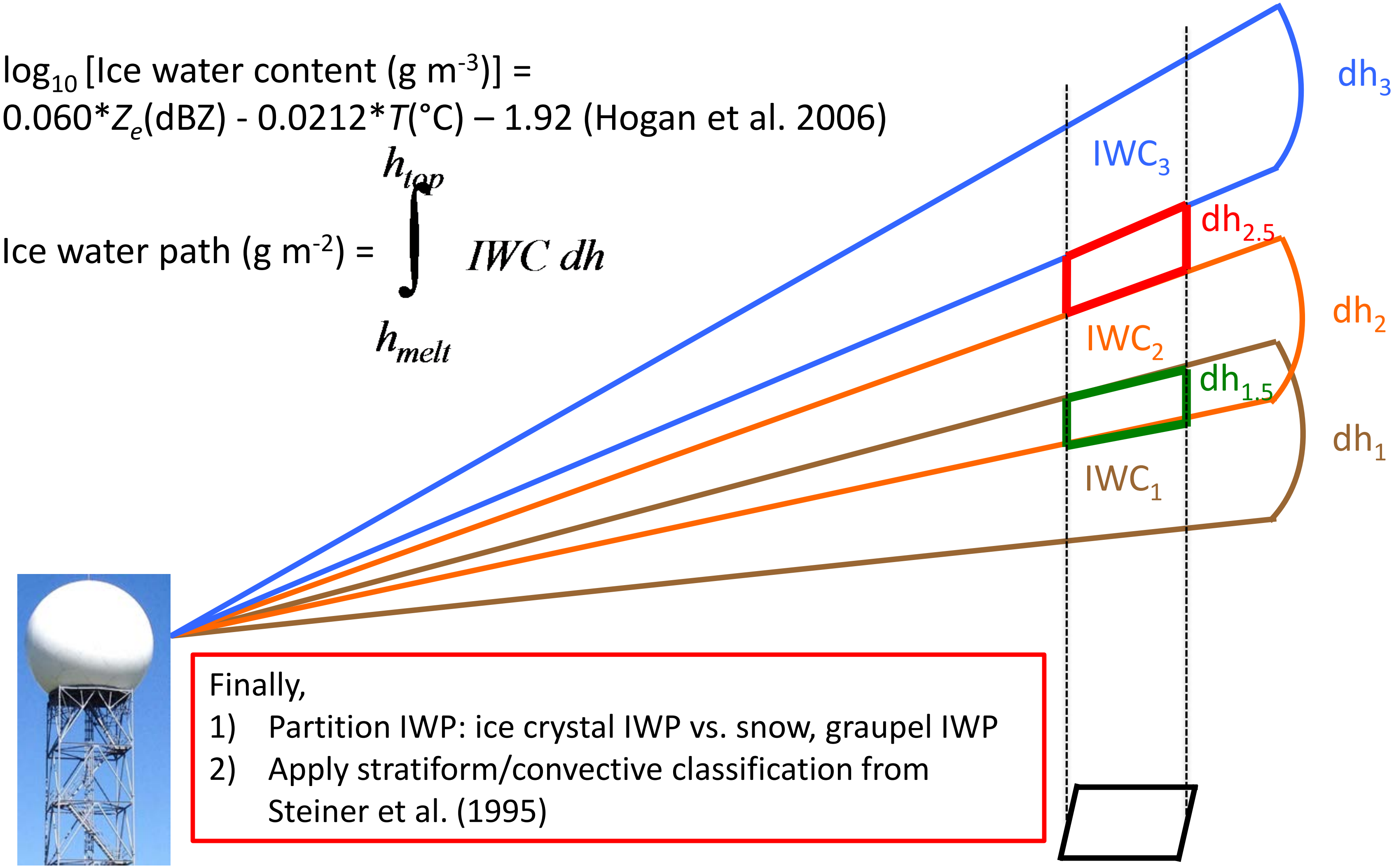
Ice crystals and dry snow have different reflectivity-fall speed relationships.
This gives us confidence that the radar is identifying two microphysically distinct particle types.



We use the Matrosov (2015) method to estimate ice water path

$\log_{10}$ [Ice water content (g m^{-3})] = $0.060 * Z_e(\text{dBZ}) - 0.0212 * T(°\text{C}) - 1.92$ (Hogan et al. 2006)

$$\text{Ice water path (g m}^{-2}\text{)} = \int_{h_{melt}}^{h_{top}} IWC \, dh$$



Finally,
1) Partition IWP: ice crystal IWP vs. snow, graupel IWP
2) Apply stratiform/convective classification from Steiner et al. (1995)

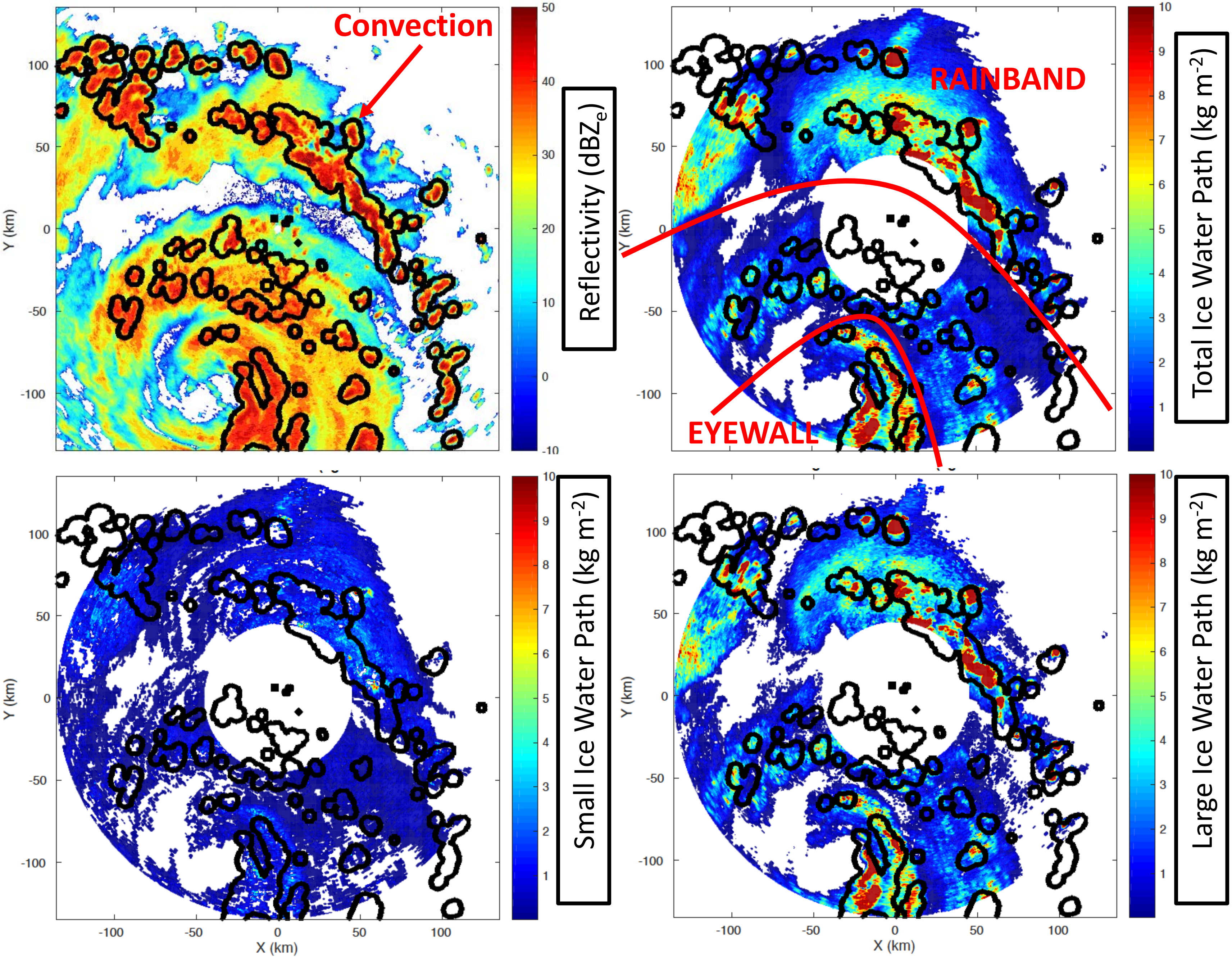
Want: Ice water path for this radar grid cell

Ice water path =

$IWC_1 * dh_1 + IWC_2 * dh_2 + IWC_3 * dh_3 - 0.5 * (IWC_1 + IWC_2) * dh_{1.5} + 0.5 * (IWC_2 + IWC_3) * dh_{2.5}$

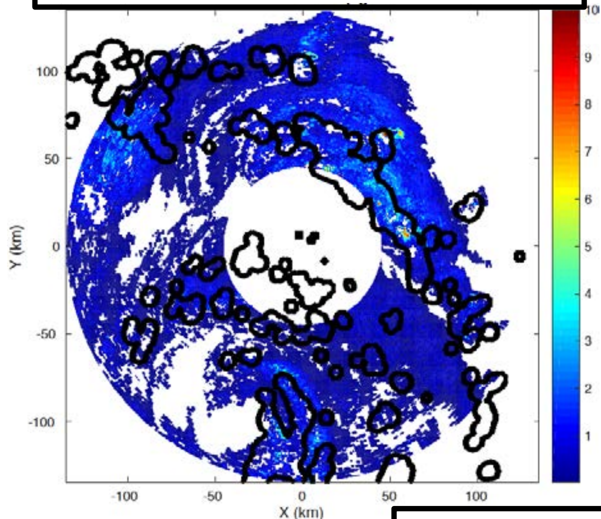
Ice water path largest in eyewall, rainband, and near convection

Convective-Stratiform Algorithm: Steiner et al. (1995); Total IWP: Matrosov (2015)



Convection is a sufficient - but not a necessary - condition for having a small IWP fraction mostly < 0.5

Small Ice Water Path (kg m^{-2})



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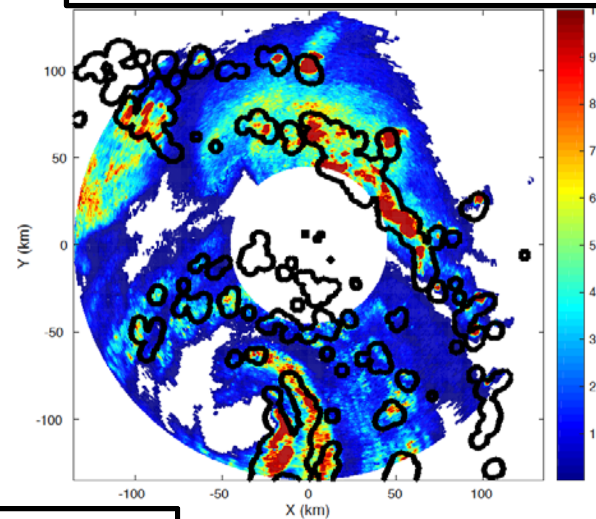
Total Ice Water Path (kg m^{-2})



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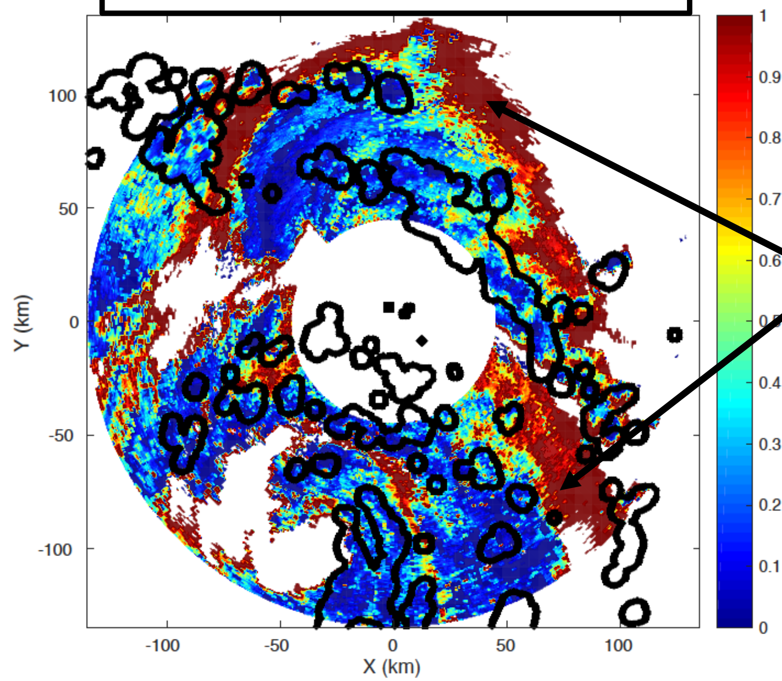
Small Ice Water Path Fraction

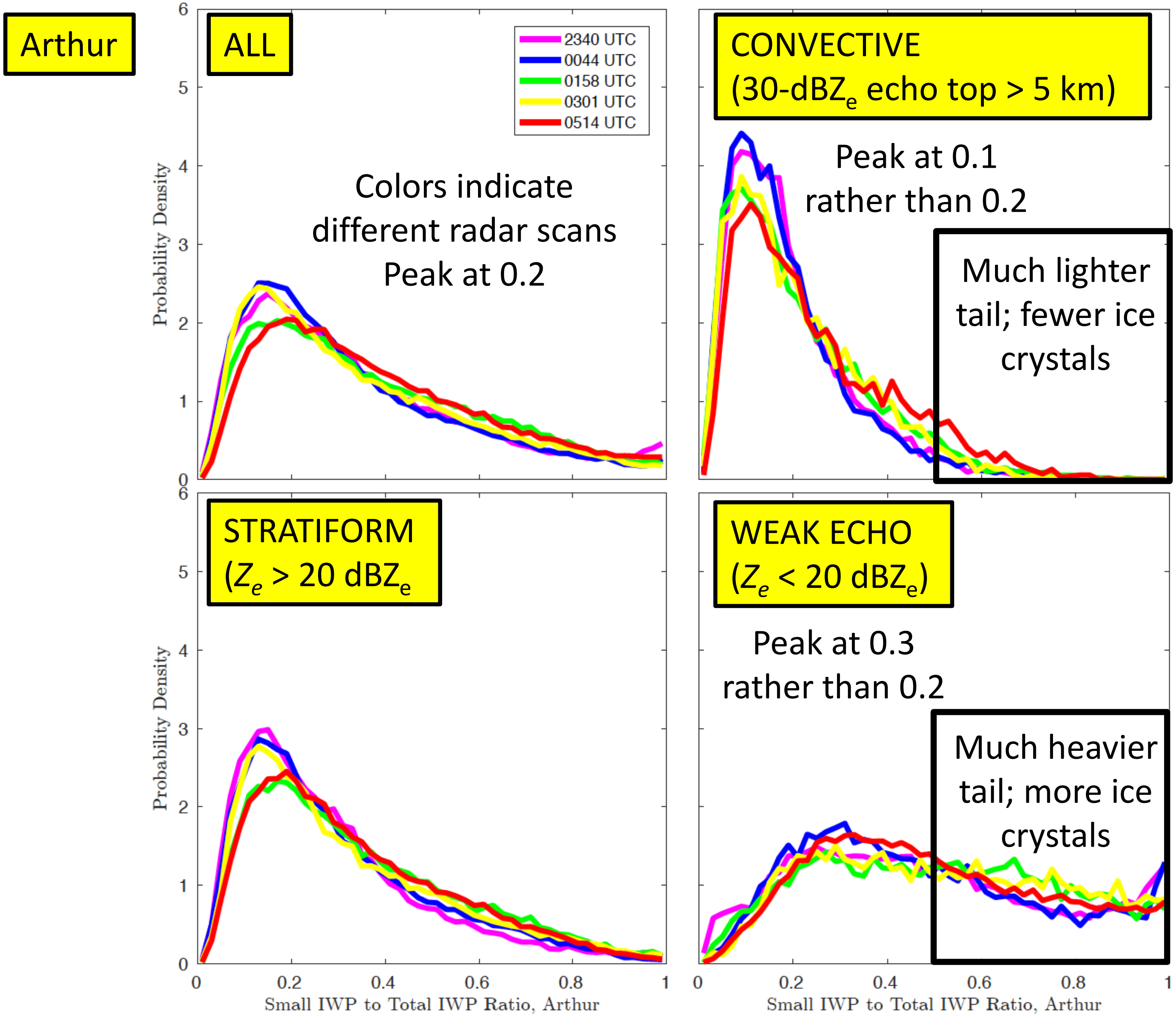


Mostly ice crystals

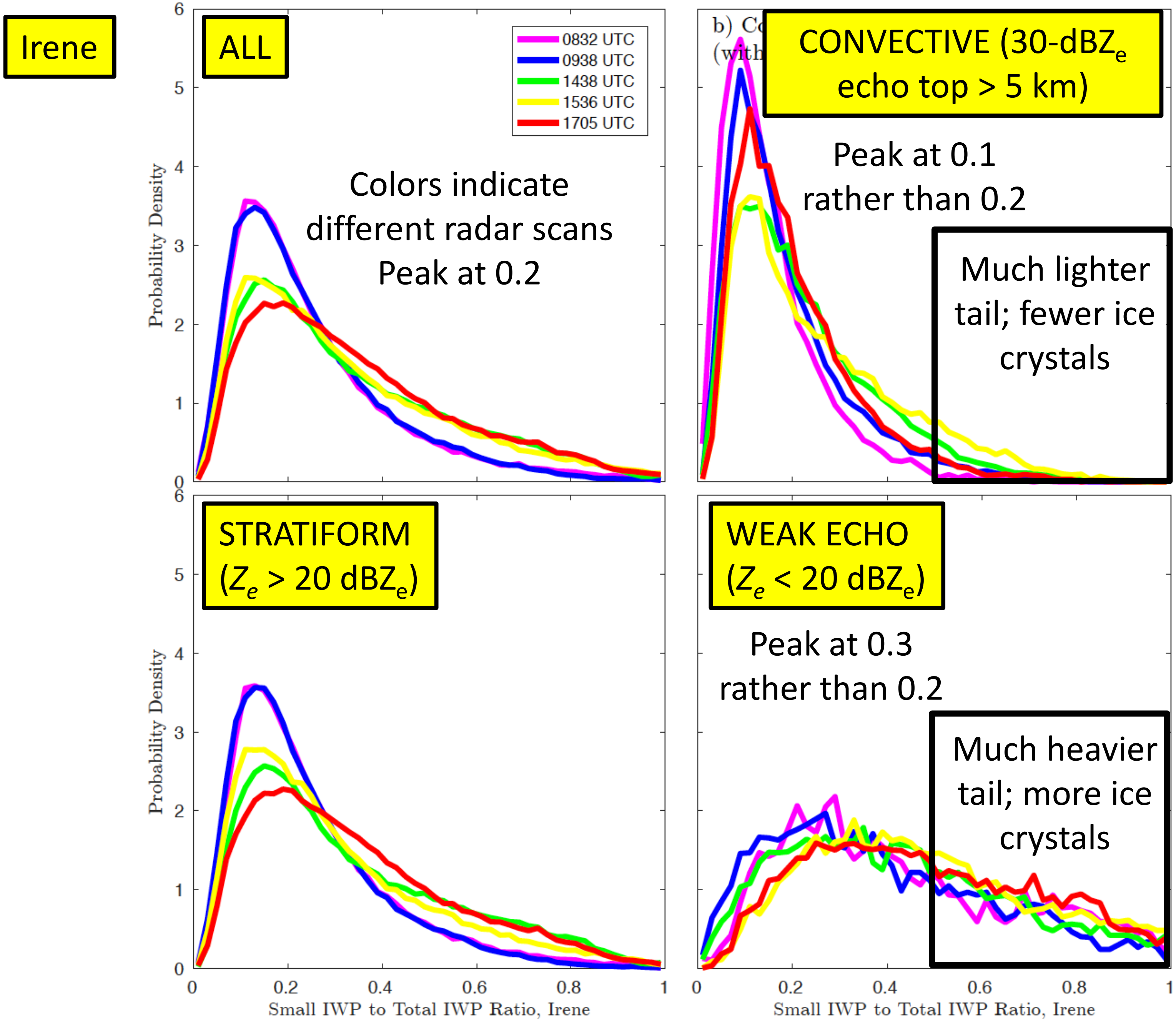
Mostly ice crystals at edges of precipitation shield in rainband, moat

Mostly snow

Small ice water path fraction PDF depends on the precipitation character



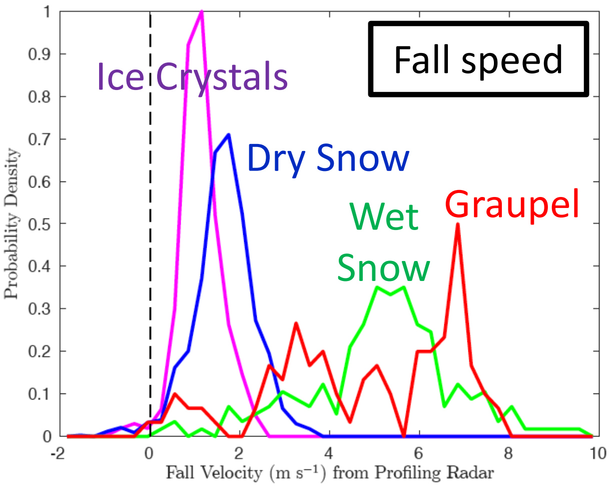
Distributions from Irene share similar characteristics with those from Arthur



Summary and conclusions

1. From slowest to fastest falling, the scanning radar identifies four ice species of relevance to TCs: ice crystals, dry snow, wet snow, and (small amounts of) graupel.

2. The ice crystals seen by the radar are precipitating, but at a slower rate than the other ice species (~1 m s^{-1} versus 2-10 m s^{-1}). Sensitivity limit: ~0.25 m s^{-1}



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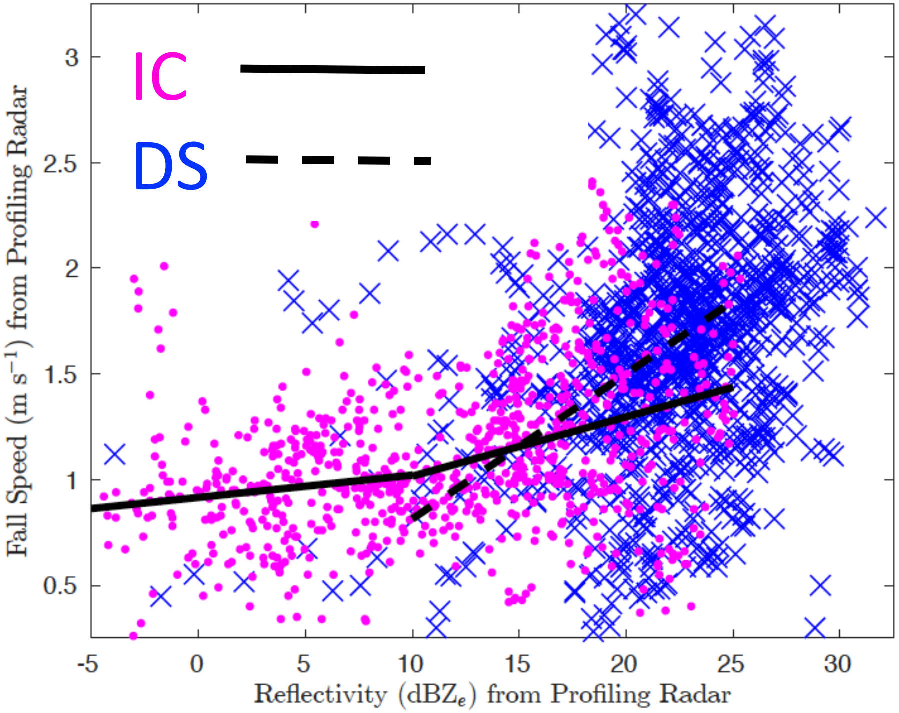

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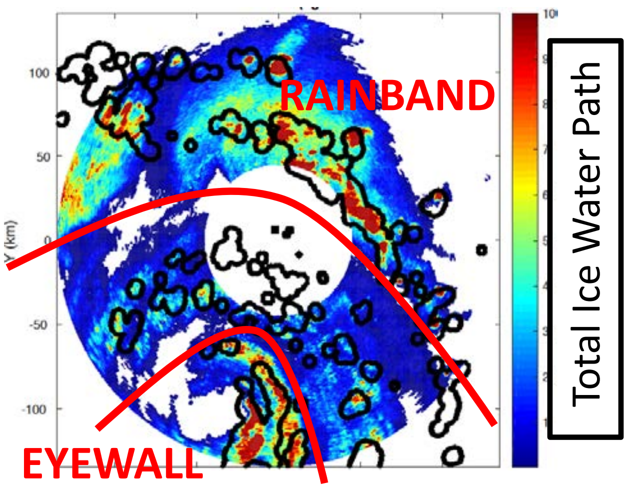

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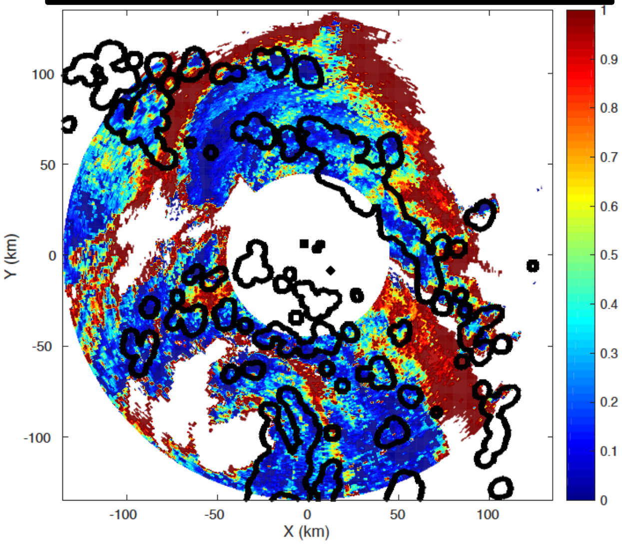

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6. PDFs of the small-to-total ice water path fraction peak between 0.1–0.3.

7. Intense convection PDF peaks at ~0.1, with a lighter tail. Weak precipitation peaks at ~0.3, with a heavier tail.

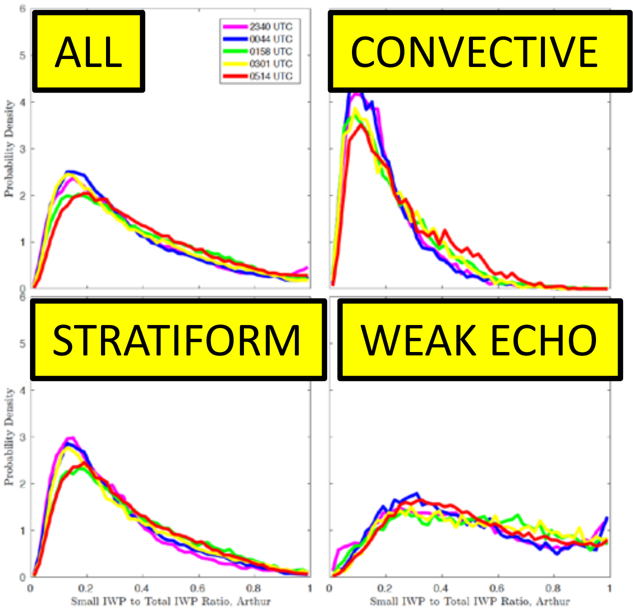

Photo credit: Sim Aberson (NOAA/HRD)

Thank You!

For more information, please see our paper in AMS JAMC:

Kalina, E. A., S. Y. Matrosov, J. J. Cione, F. D. Marks, J. Vivekanandan, R. A. Black, J. C. Hubbert, M. M. Bell, D. E. Kingsmill, and A. B. White, 2017: The ice water paths of small and large ice species in Hurricanes Arthur (2014) and Irene (2011). *J. Appl. Meteor. Climatol.*, in press.