Taking the Microphysical Fingerprints of Storms with Dual-Polarization Radar

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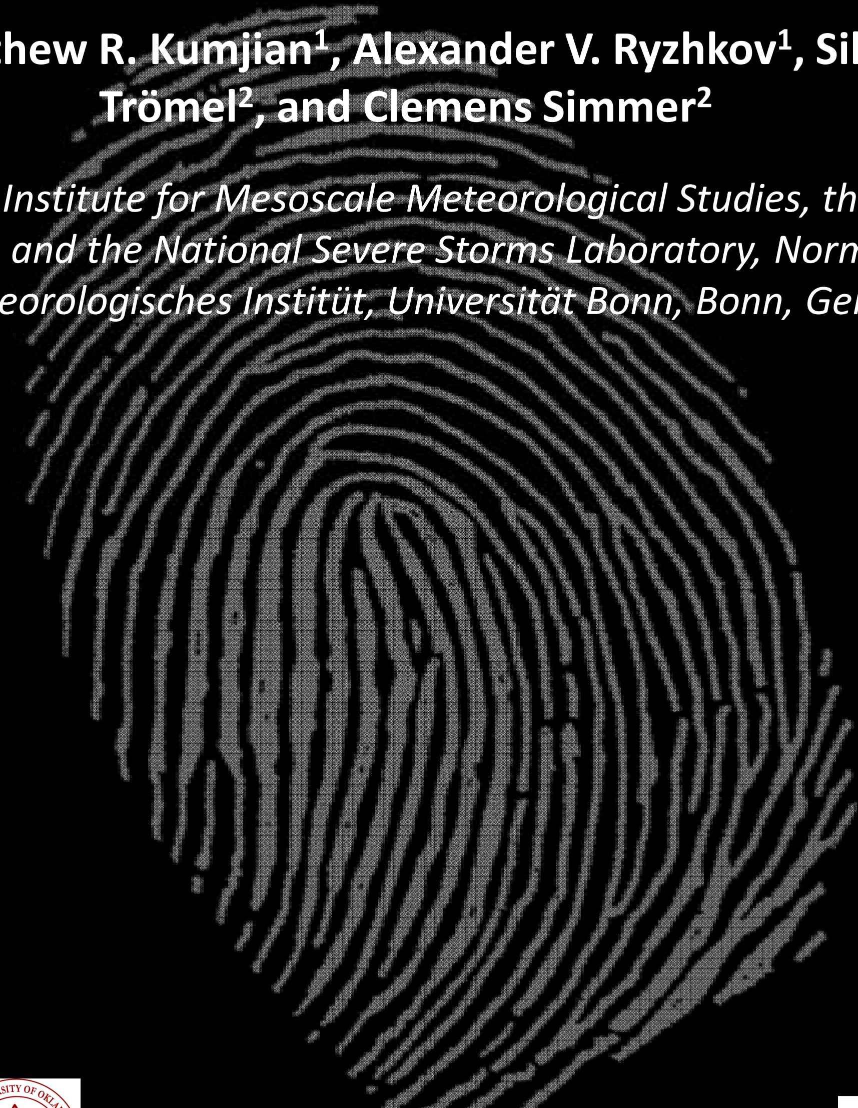
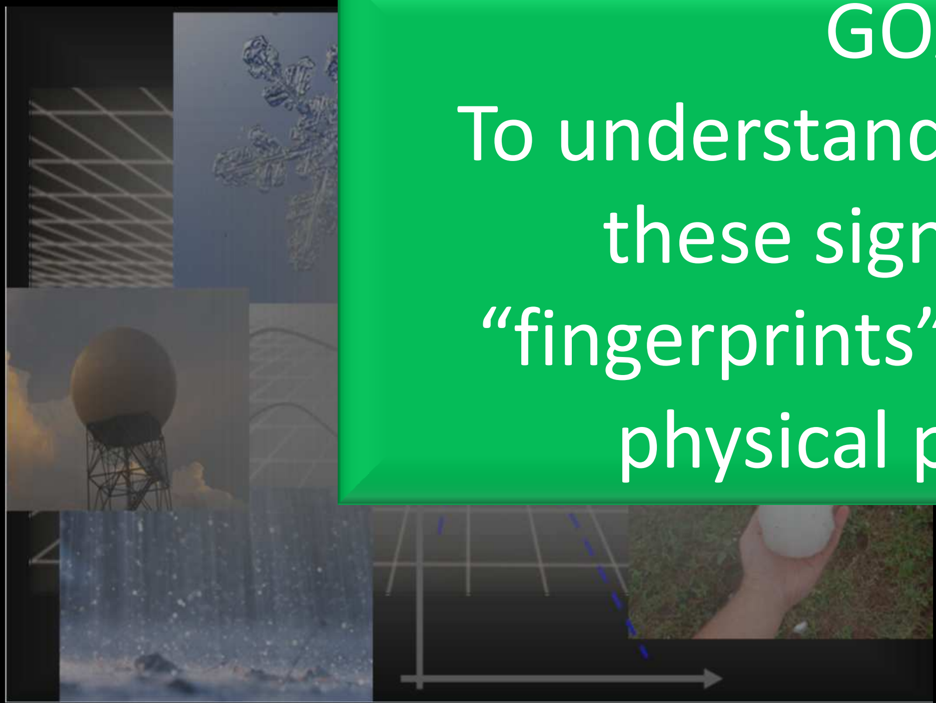


ERAD 2012 – Toulouse, France
26 June 2012

Microphysical Fingerprints?

Precipitation processes affect hydrometeors and their distributions during their lifetimes, including phase changes, particle growth, and mass redistribution.



GOAL:
To understand and quantify these signatures or "fingerprints" for different physical processes

ubsequent

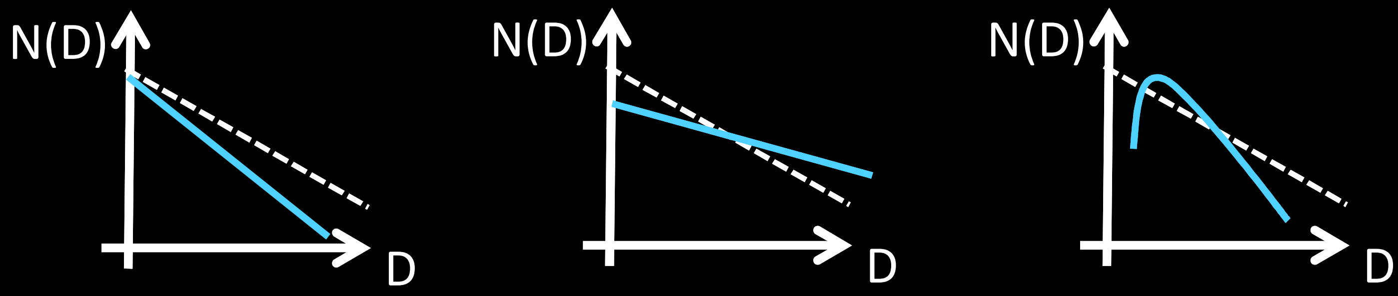
- Aggregation of snowflakes
- Breakup of raindrops
- Coalescence of raindrops

These processes affect the observed polarimetric radar variables in predictable ways.

Toolkit

- Microphysics models

Bulk parameterizations



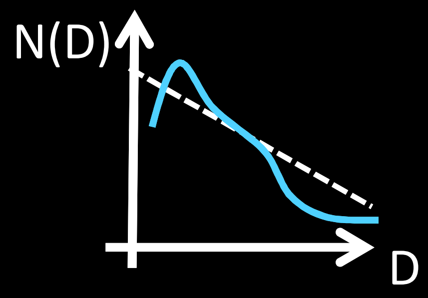
- ✔ **More general**
- ✔ **Coupled to a dynamical model**
- ✔ **Computationally cheaper**

- ✗ **Relevant physics obfuscated**
- ✗ **Assumes a PSD *a priori***
- ✗ **Employs simplified physics**

Toolkit

- Microphysics models

Simplified explicit bin models



- ✔ Does not assume a PSD *a priori* – all "bins" vary independently
- ✔ Physics are clear (experimenter has full control)
- ✔ Physics treated explicitly

- ✗ Less general; idealized
- ✗ Generally not coupled to a dynamical model
- ✗ Computationally much more expensive

We adopt the philosophy of the simple bin model approach

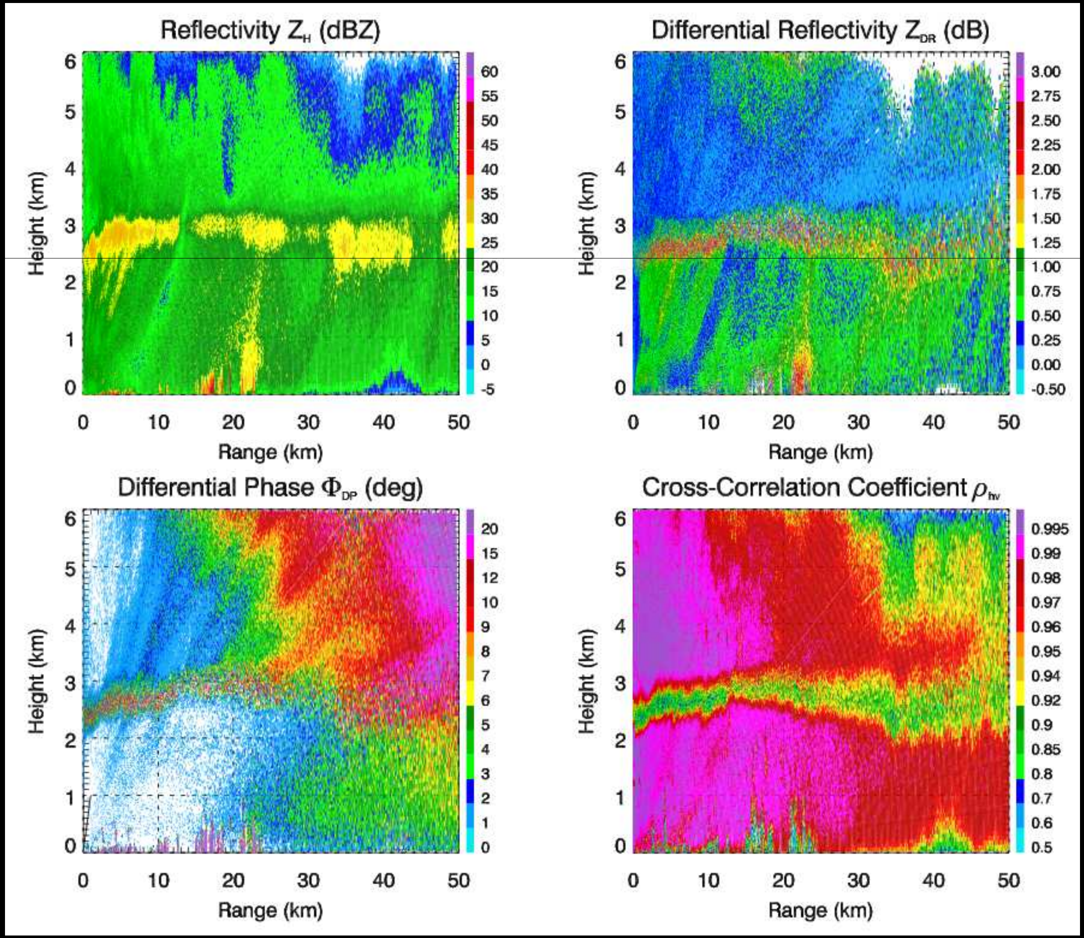
Toolkit

- Microphysics models
- Electromagnetic scattering calculations
- Thought experiments
- Radar observations (preferably, genuine RHI scans)

Precipitation Processes

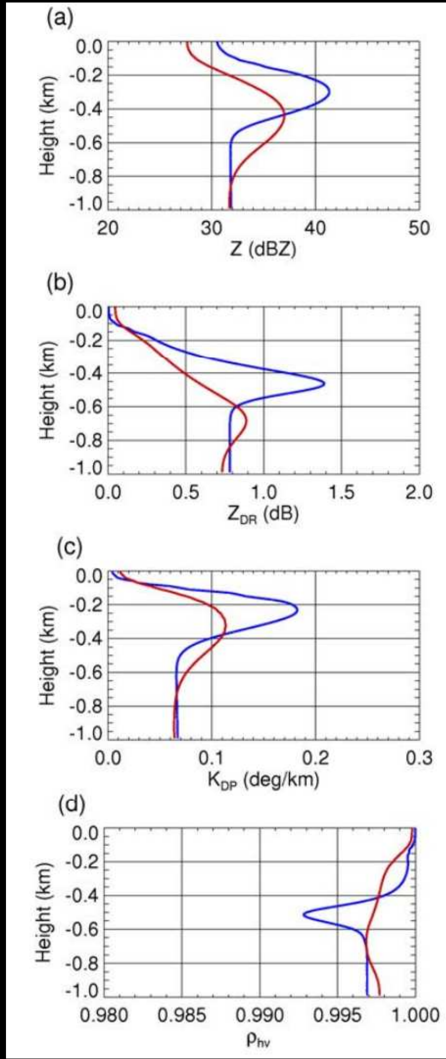
Melting of ice particles

- Our investigations of precipitation physics with polarimetric radar started with studies of the melting layer.



Melting of Ice Particles

Ryzhkov et al. (ERAD 2008) simulate profiles of the polarimetric variables for melting snow, demonstrating the impact of riming on the resulting "bright band" signatures.



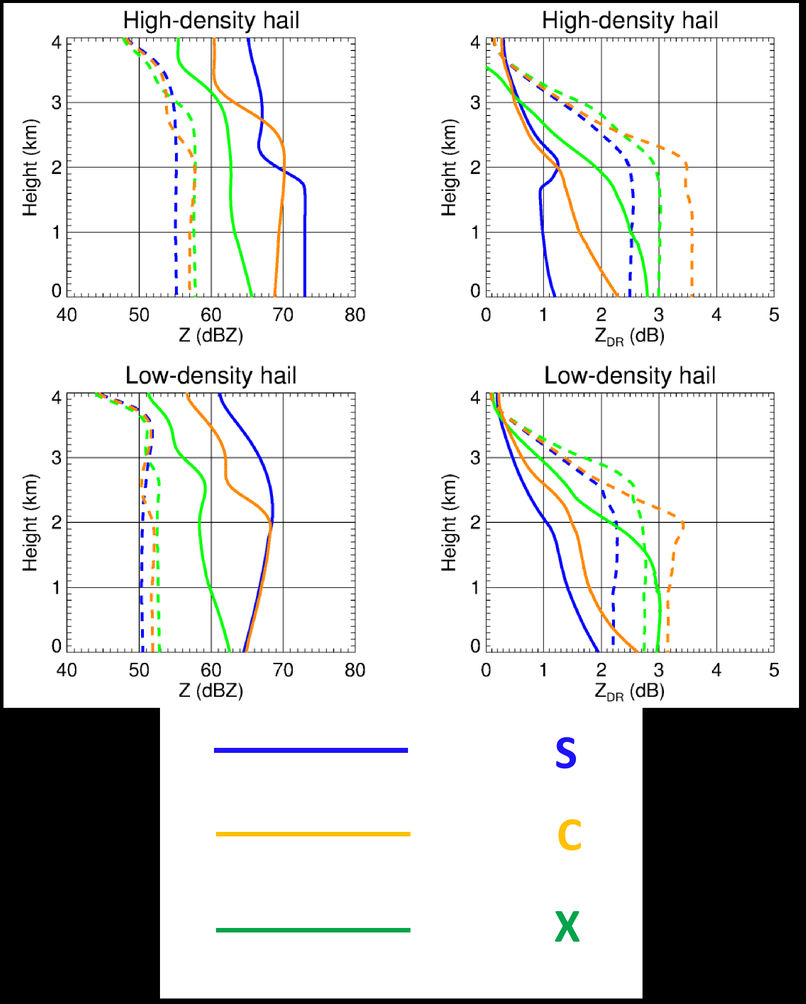
Unrimed snow

Rimed snow

Riming increases the density of snow, thereby increasing particle fall speeds and prolonging melting.

Melting of Ice Particles

Melting of hail can be thought of as the upper limit of prolonged melting owing to higher density ice. (In many cases, the hail reaches the ground before entirely melting!)



(Adapted from yesterday's talk by A. Ryzhkov et al.)

Melting of Ice Particles

To summarize pictorially:

Z_H Z_{DR} K_{DP} ρ_{hv}

Size sorting of raindrops

- Developed simple bin models describing pure raindrop fallout and size sorting owing to wind shear. In addition to the explicit treatment of sedimentation, it is treated using one-, two-, and three-moment parameterizations.

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The Impact of Size Sorting on the Polarimetric Radar Variables

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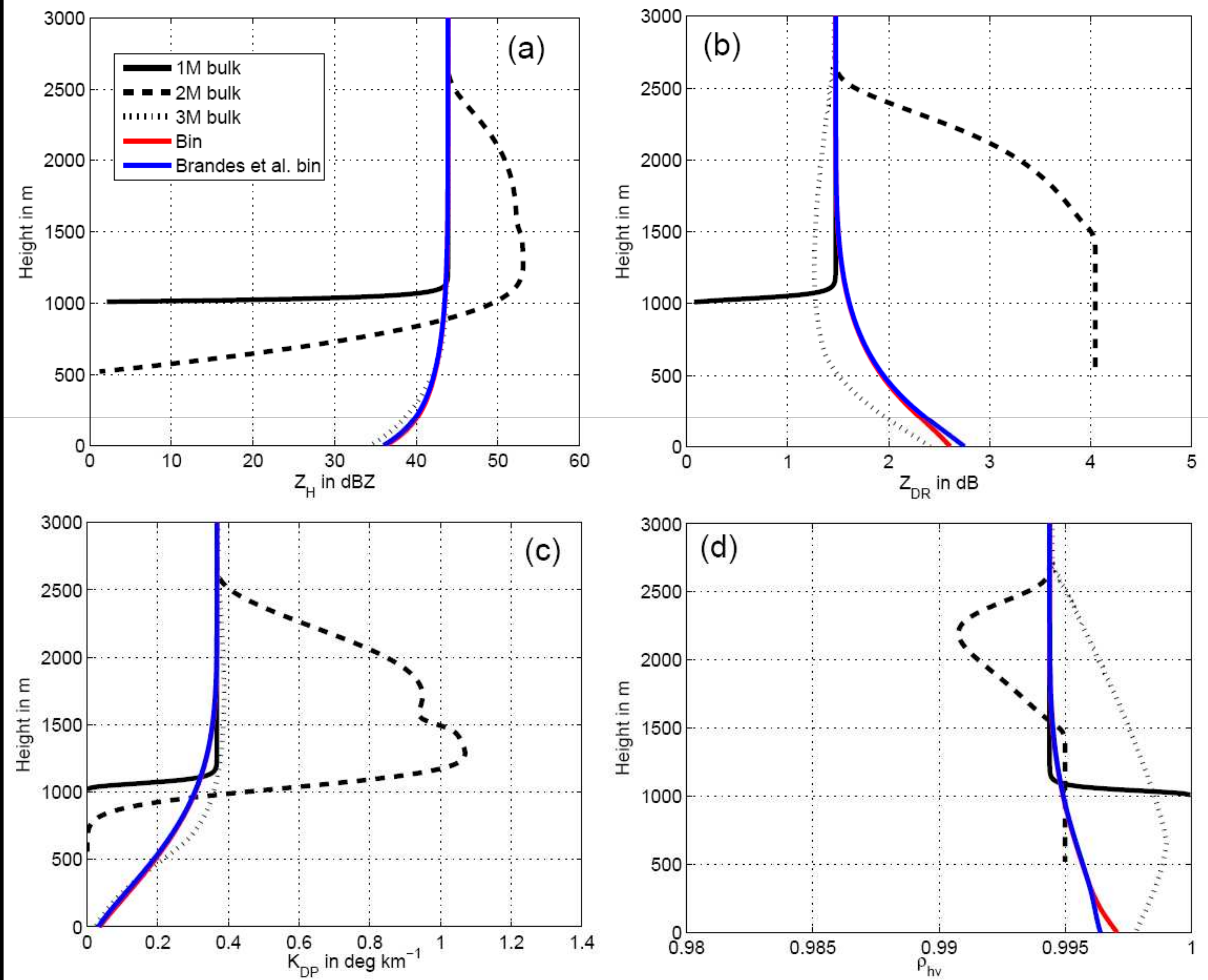
Kumjian and Ryzhkov, JAS, June 2012

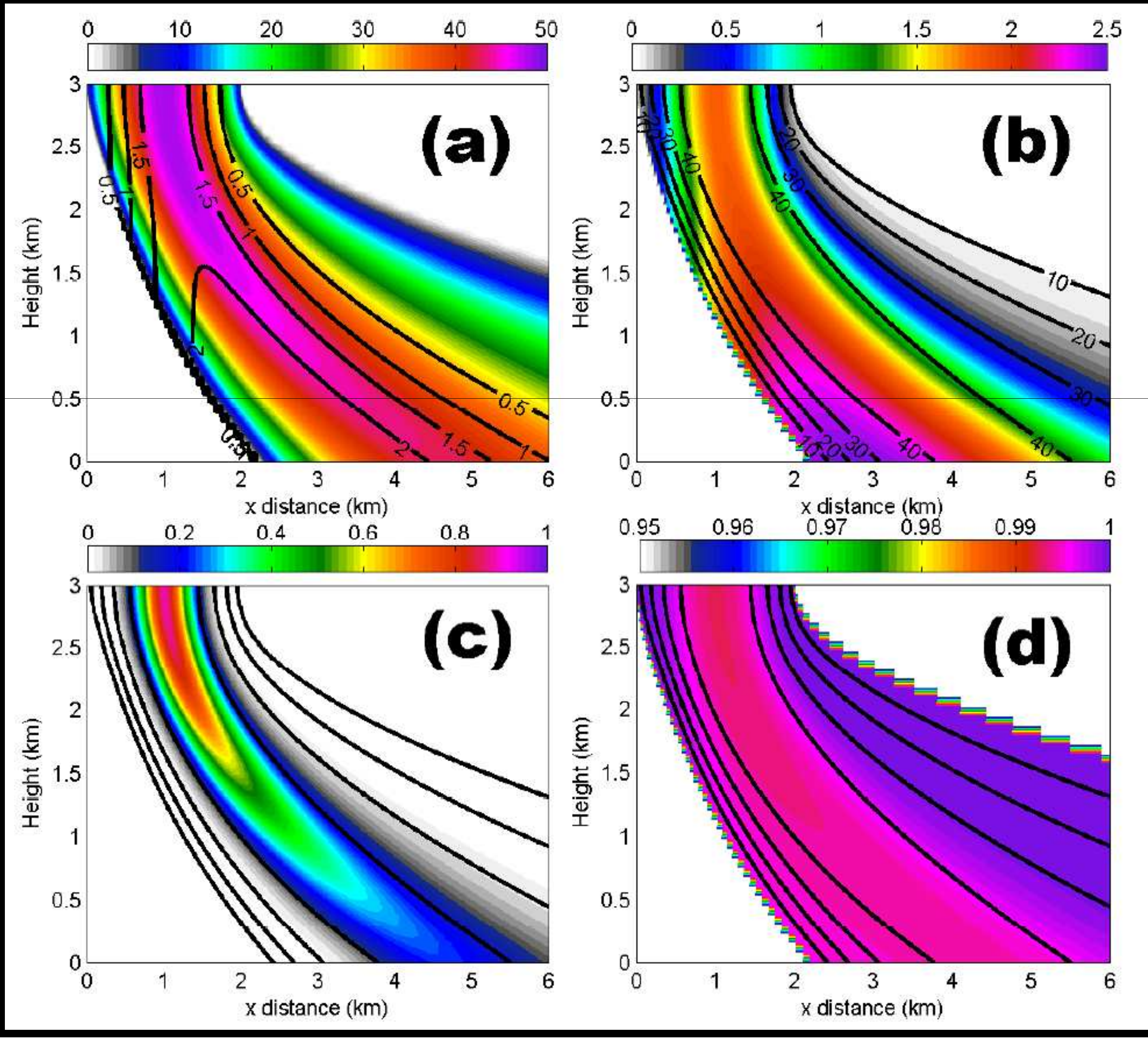
Size sorting of raindrops

t = 333 s



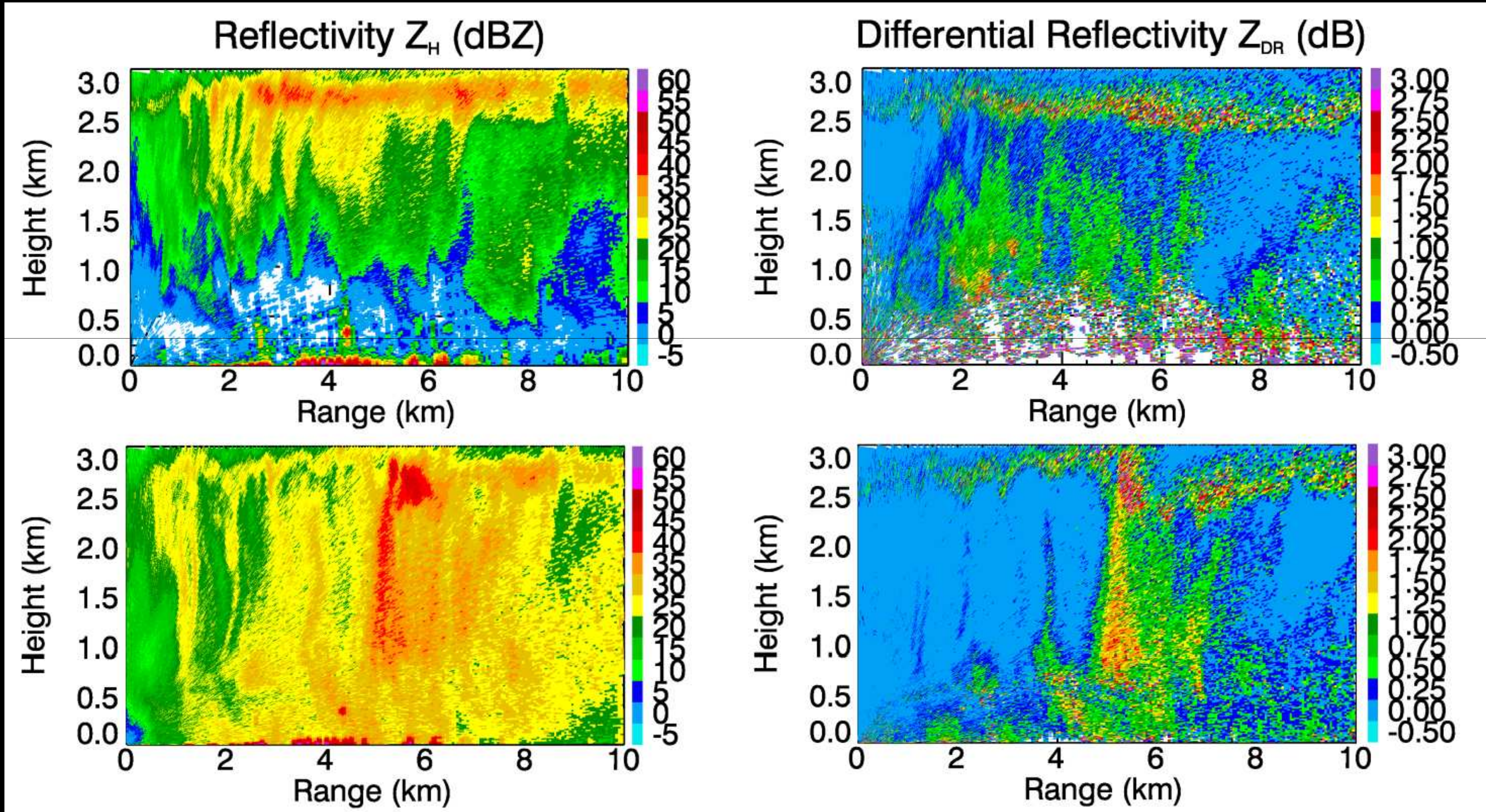
Size sorting of raindrops

Rainshaft model – encountering wind shear



Size sorting of raindrops

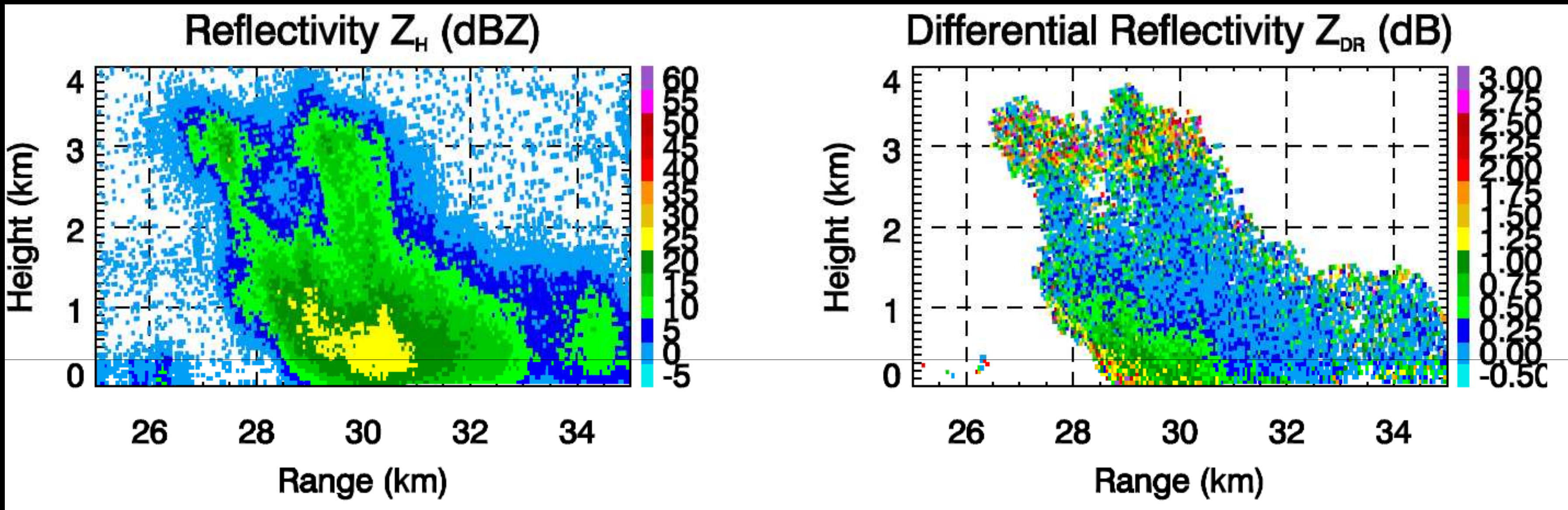
What about the observations?

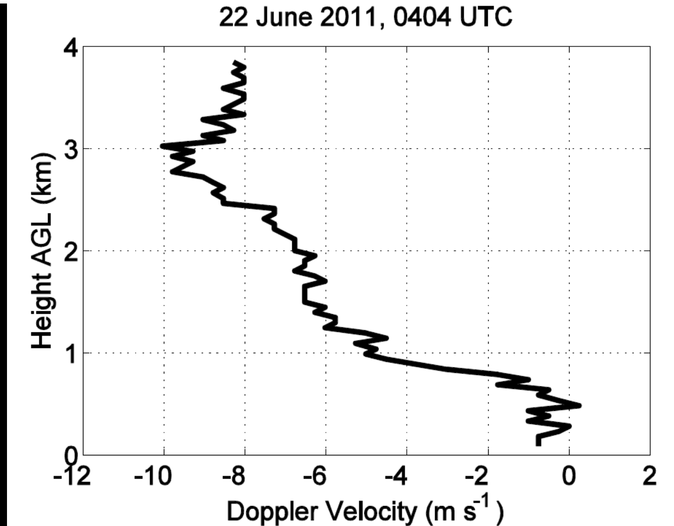


BOXPOL (Bonn, Germany) on 22 June 2011.

Size sorting of raindrops

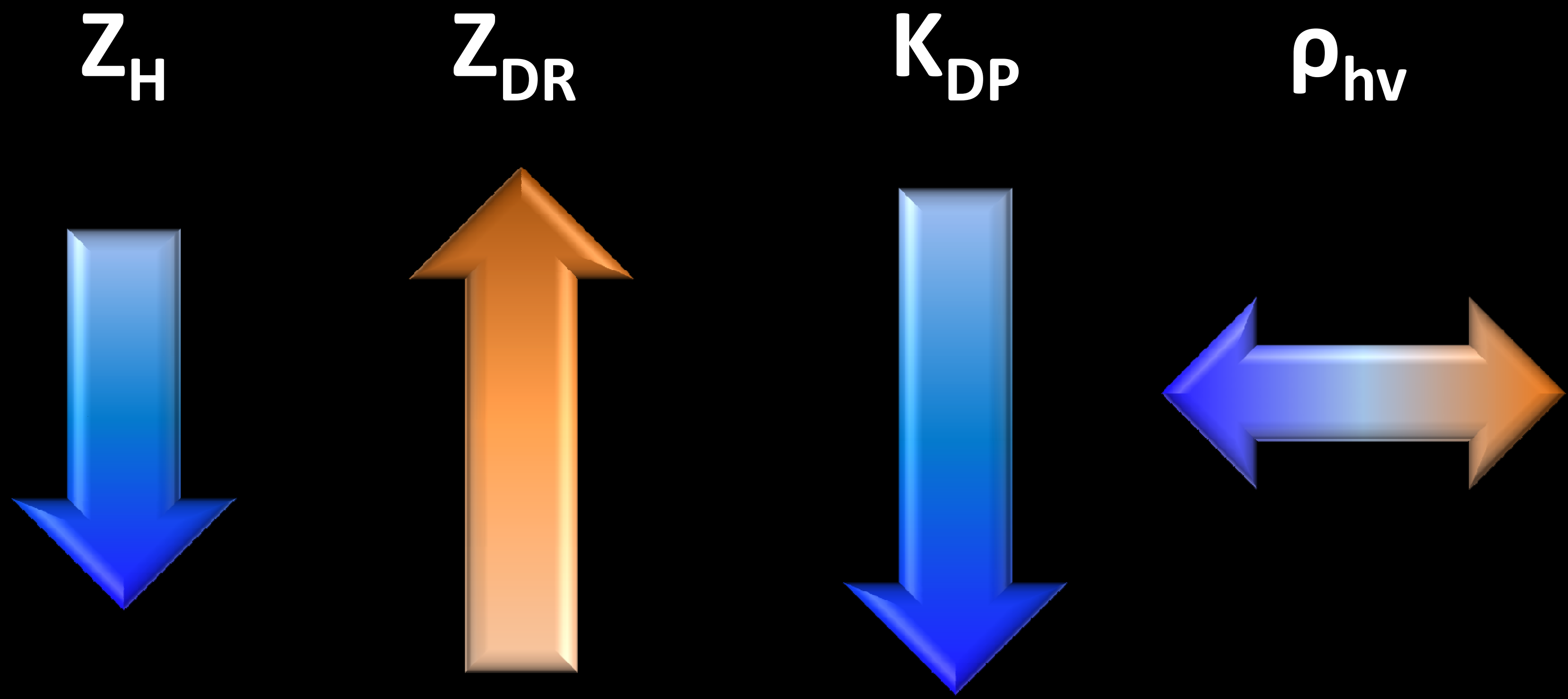
What about the observations?





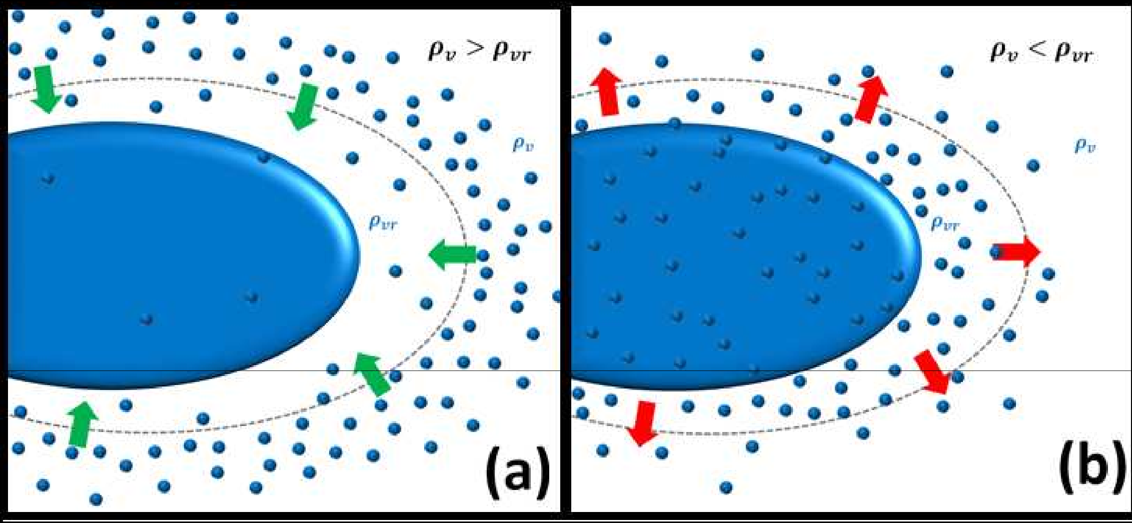
Size sorting of raindrops

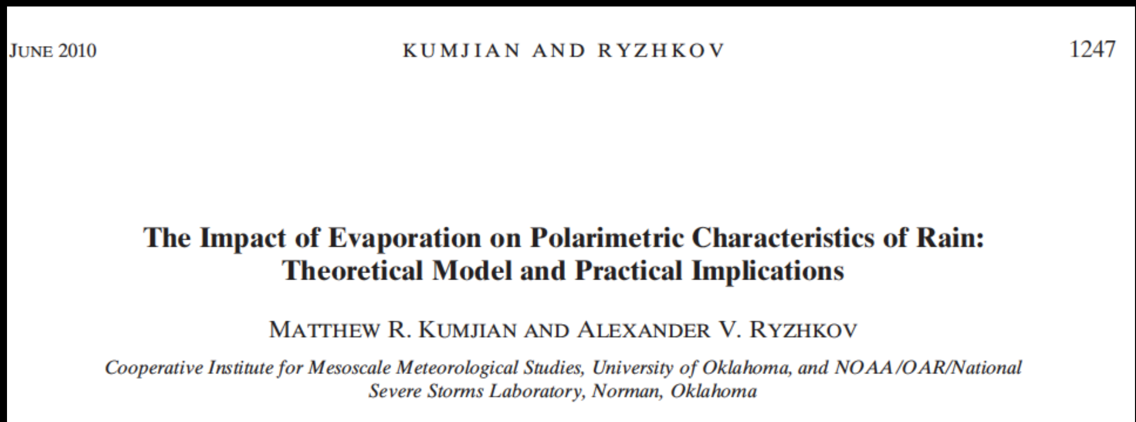
To summarize pictorially:



Evaporation of raindrops

- Developed an 1D explicit bin model describing pure raindrop evaporation.





JUNE 2010 KUMJIAN AND RYZHKOV 1247

The Impact of Evaporation on Polarimetric Characteristics of Rain: Theoretical Model and Practical Implications

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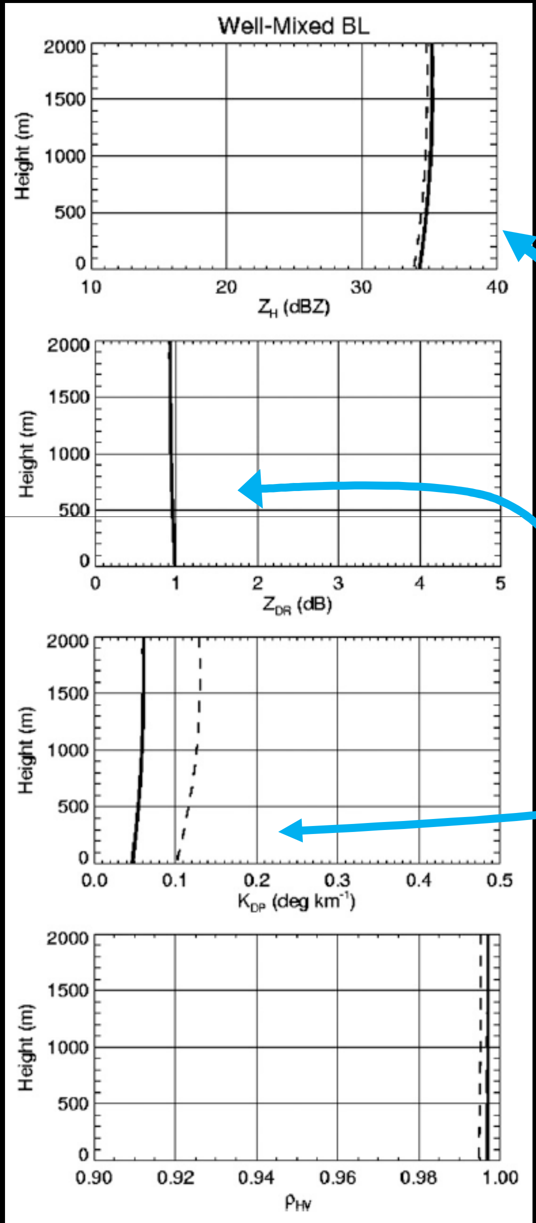
Kumjian and Ryzhkov 2010, JAMC

Evaporation of raindrops



Marshall-Palmer DSD aloft, 3-km deep “mixed layer” with surface temperature of 30 °C and surface relative humidity of 70%

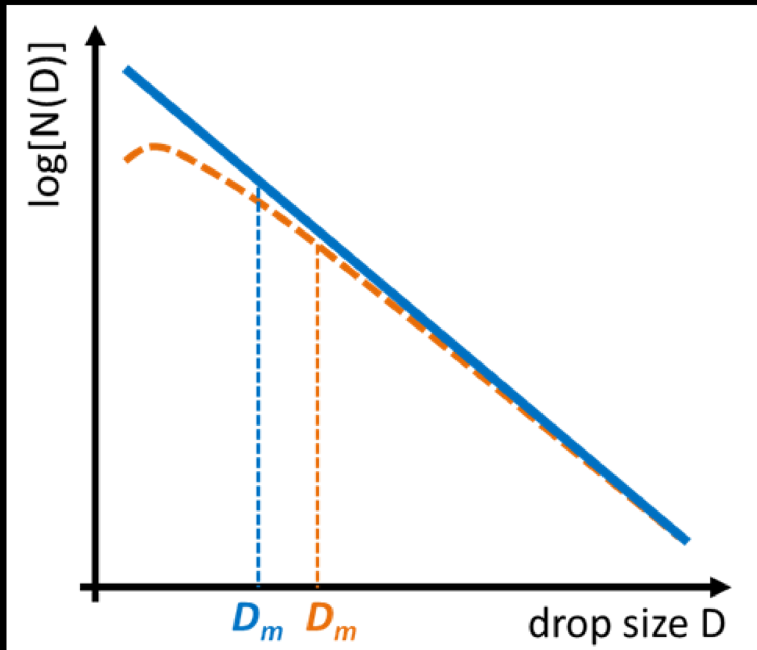
Decreases in Z_H and K_{DP}, but an *increase* in Z_{DR}.

Evaporation of raindrops

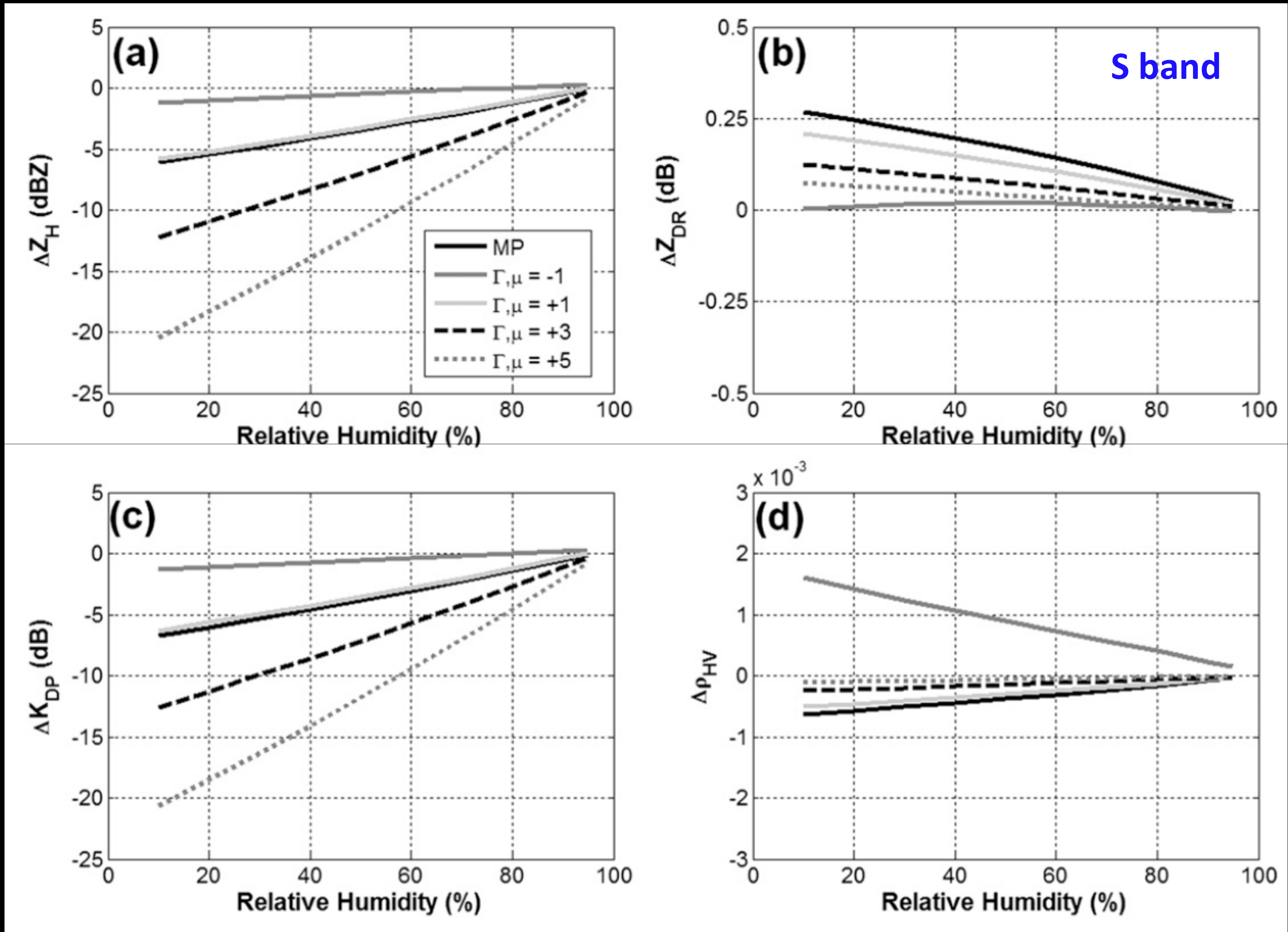
Why the *increase* in Z_{DR} if all drops are losing mass?

Rate of change of drop size is inversely proportional to drop size *r*; thus, smaller drops are depleted more rapidly than larger drops

$$r\frac{dr}{dt} = \frac{S-1}{F_K + F_D}$$



Evaporation of raindrops



Idealized 2-km deep isothermal layers with constant RH (abscissa)

Evaporation of raindrops

What about the observations?

Borowska et al. (2011) investigated one month of light rain using data from BOXPOL radar, located in Bonn, Germany. Their results are consistent with the theoretical model described here. Notably,

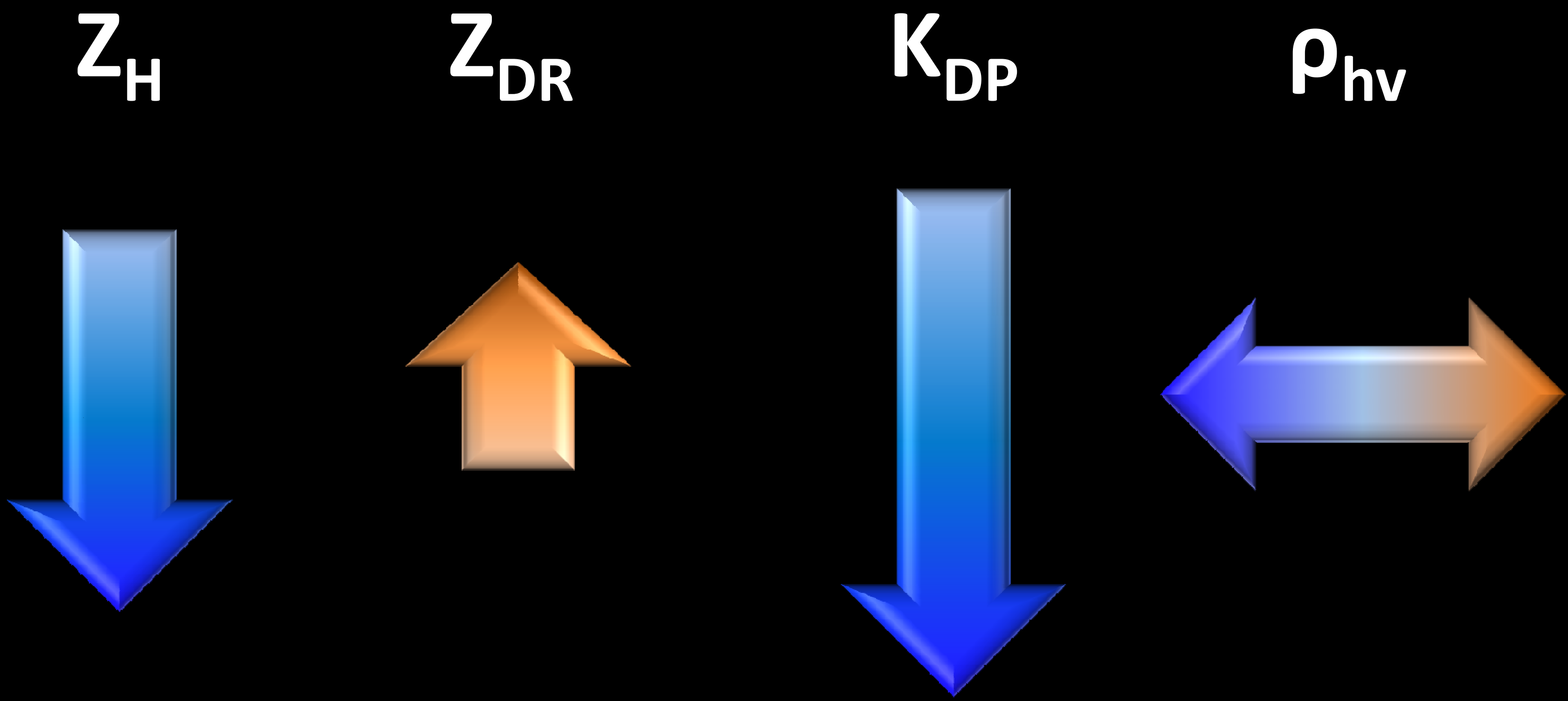
- Z_{DR} is found to be larger at lower levels, despite having a smaller radar-derived rain rate.

- The decrease in K_{DP} was more substantial

- Using median environmental conditions from Bonn during that period, the evaporation model predicts a 22% decrease in K_{DP}. Their observations showed a 20% decrease in K_{DP}.

Evaporation of raindrops

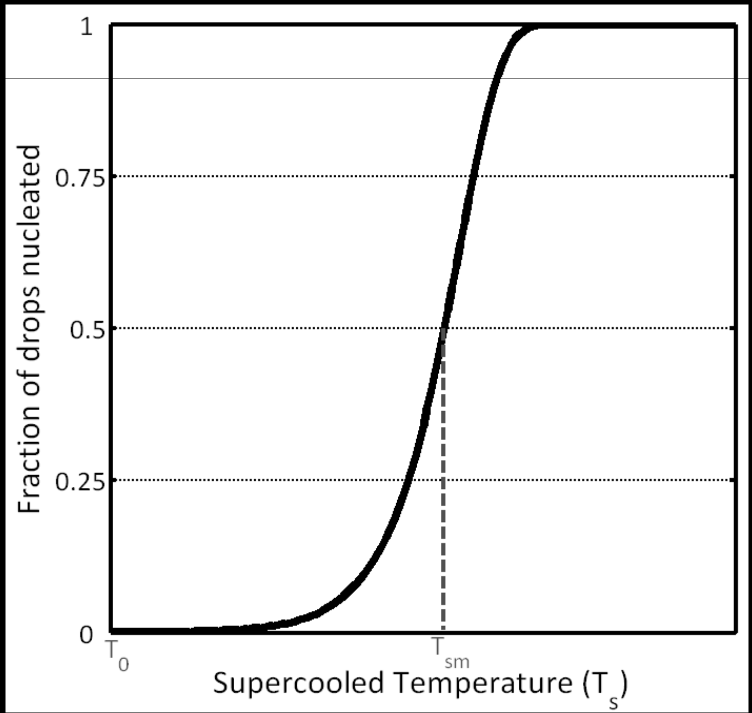
To summarize pictorially:



Freezing of raindrops

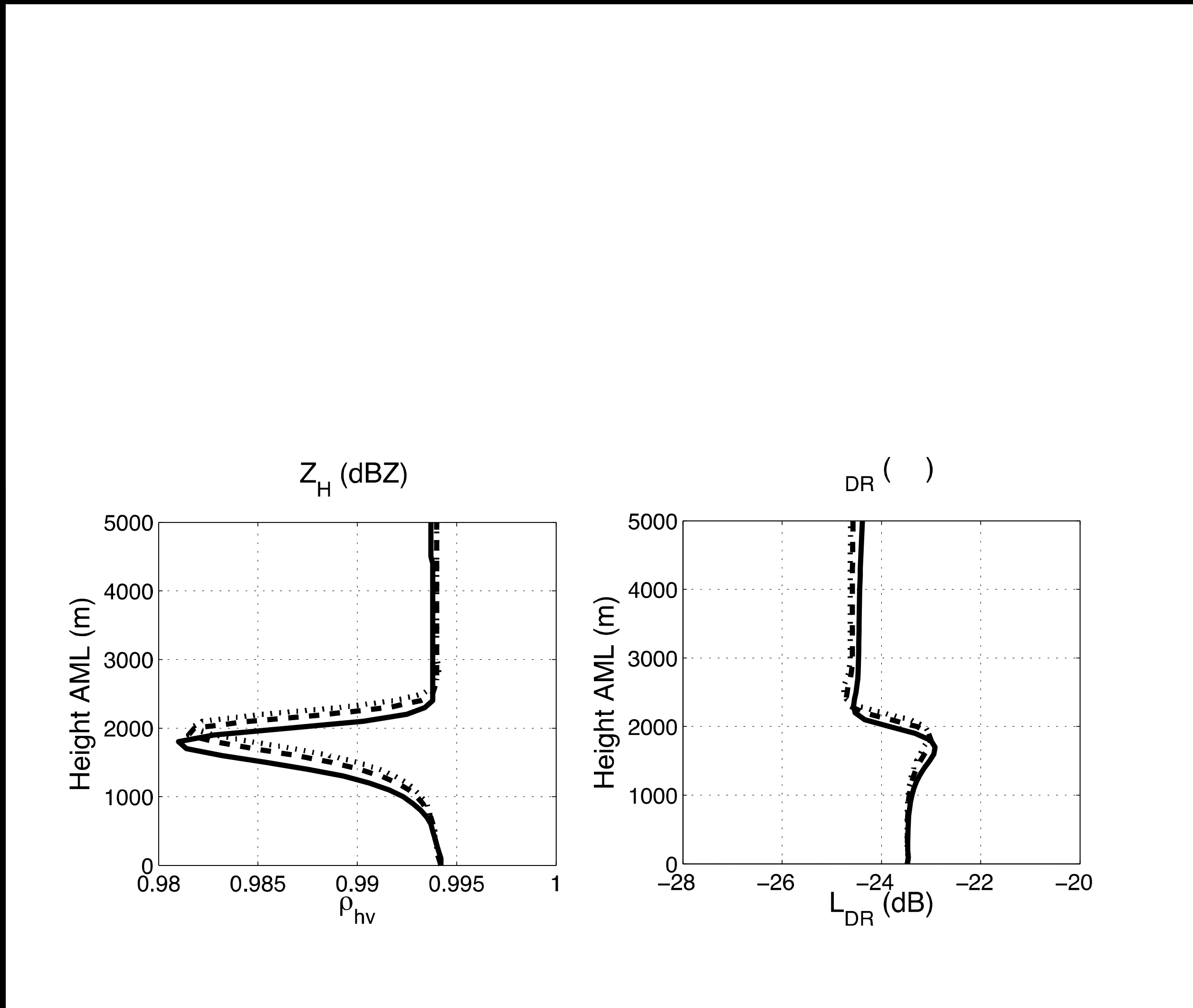
- Developed a one-dimensional column model describing raindrops being lofted by a convective storm updraft. The drops undergo stochastic nucleation followed by deterministic freezing.

- The median nucleating temperature is determined following Bigg (1953). A probability distribution function can be derived following (among others) Pruppacher and Klett (1997).



Kumjian et al. 2013, conditionally accepted at JAS

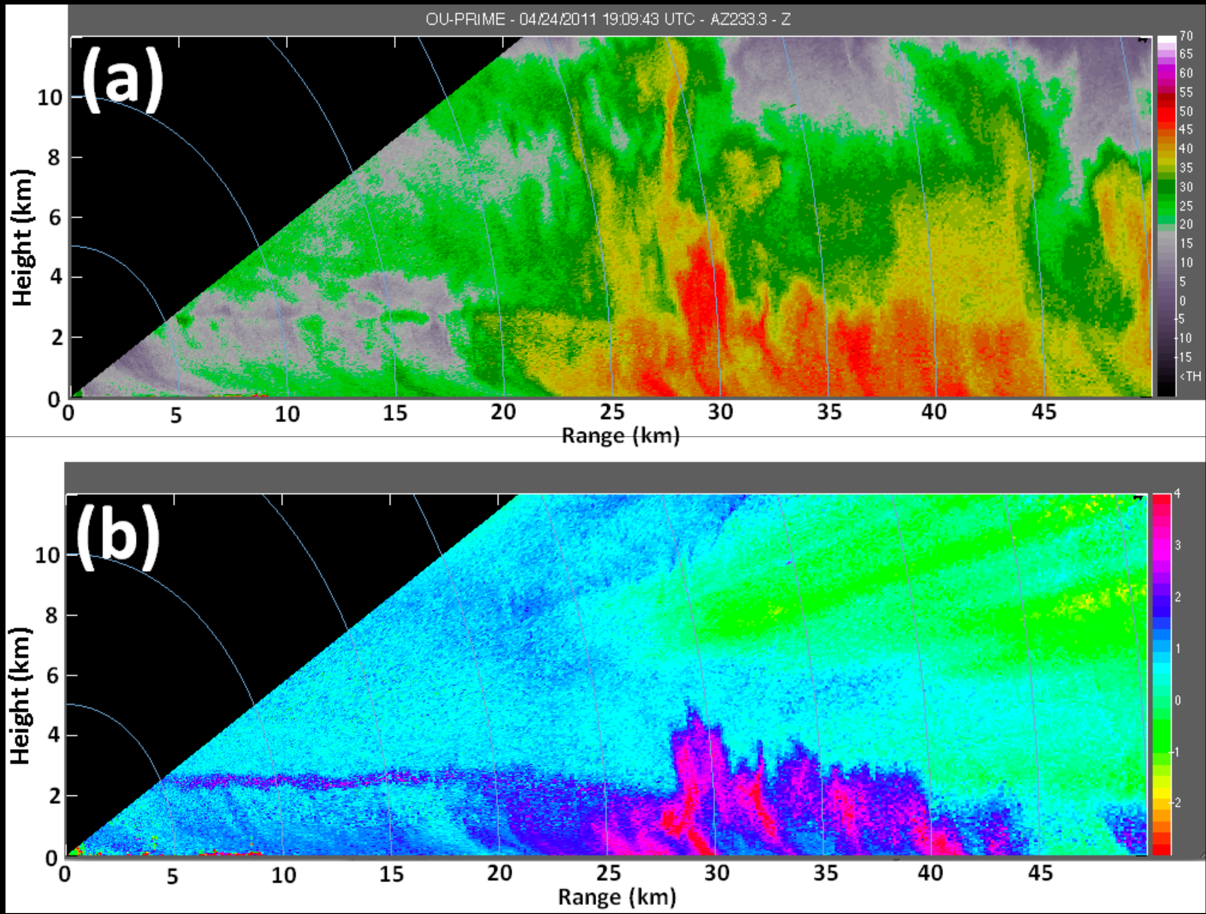
Freezing of raindrops



Vertical profiles of the polarimetric radar variables computed from the model, for three different updrafts.

Freezing of raindrops

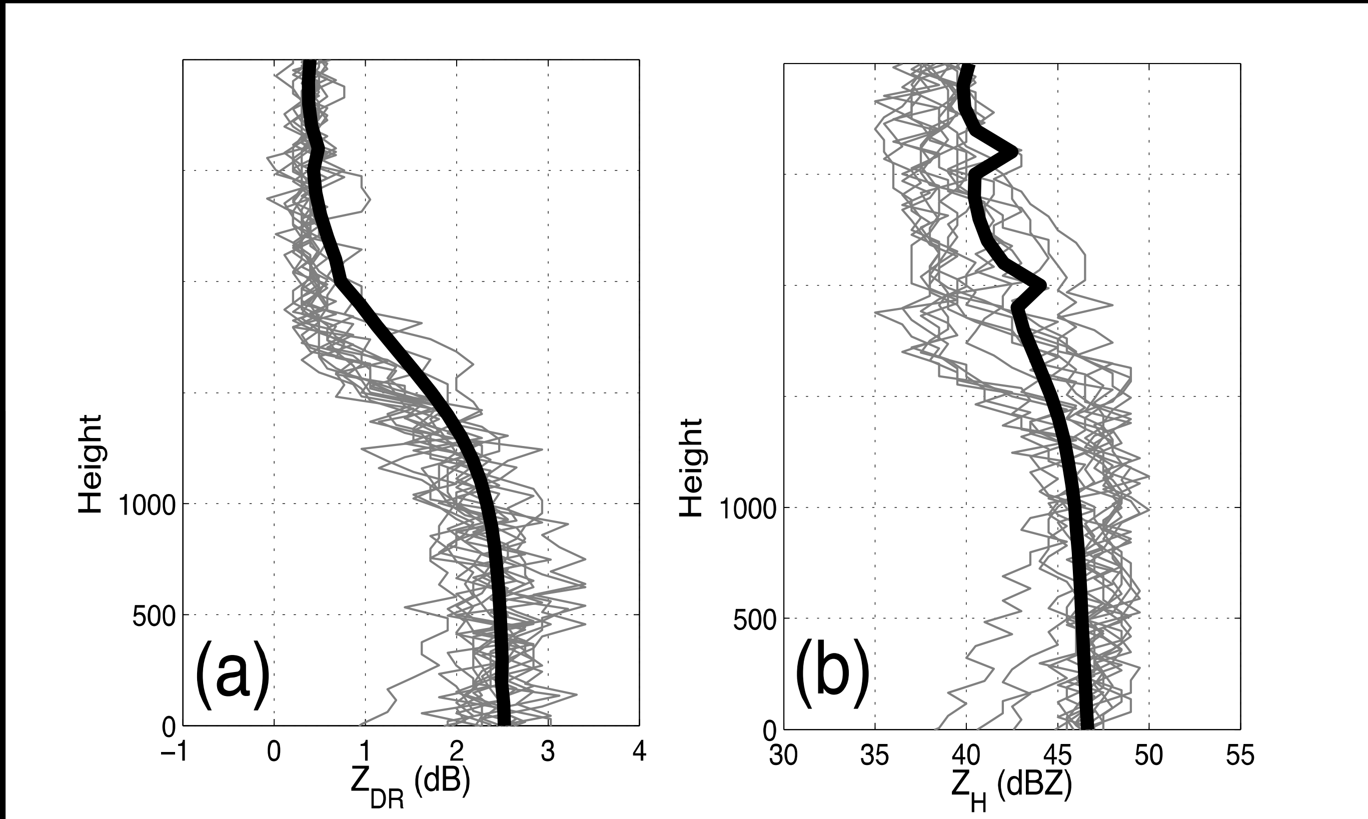
What about the observations?



OU-PRIME data collected on 24 April 2011. Courtesy of Boonleng Cheong, Guifu Zhang, and the ARRC.

Freezing of raindrops

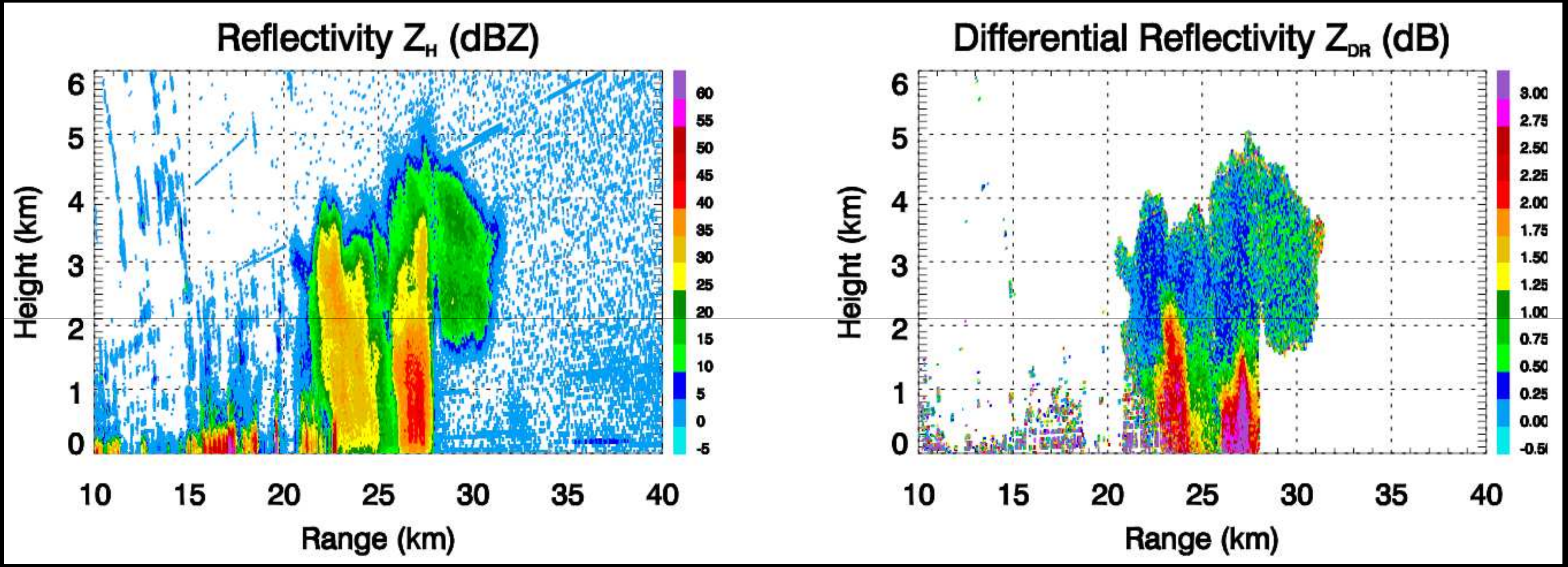
What about the observations?



Gray curves are observed profiles through the Z_{DR} column, black curves are the modeled profiles.

Freezing of raindrops

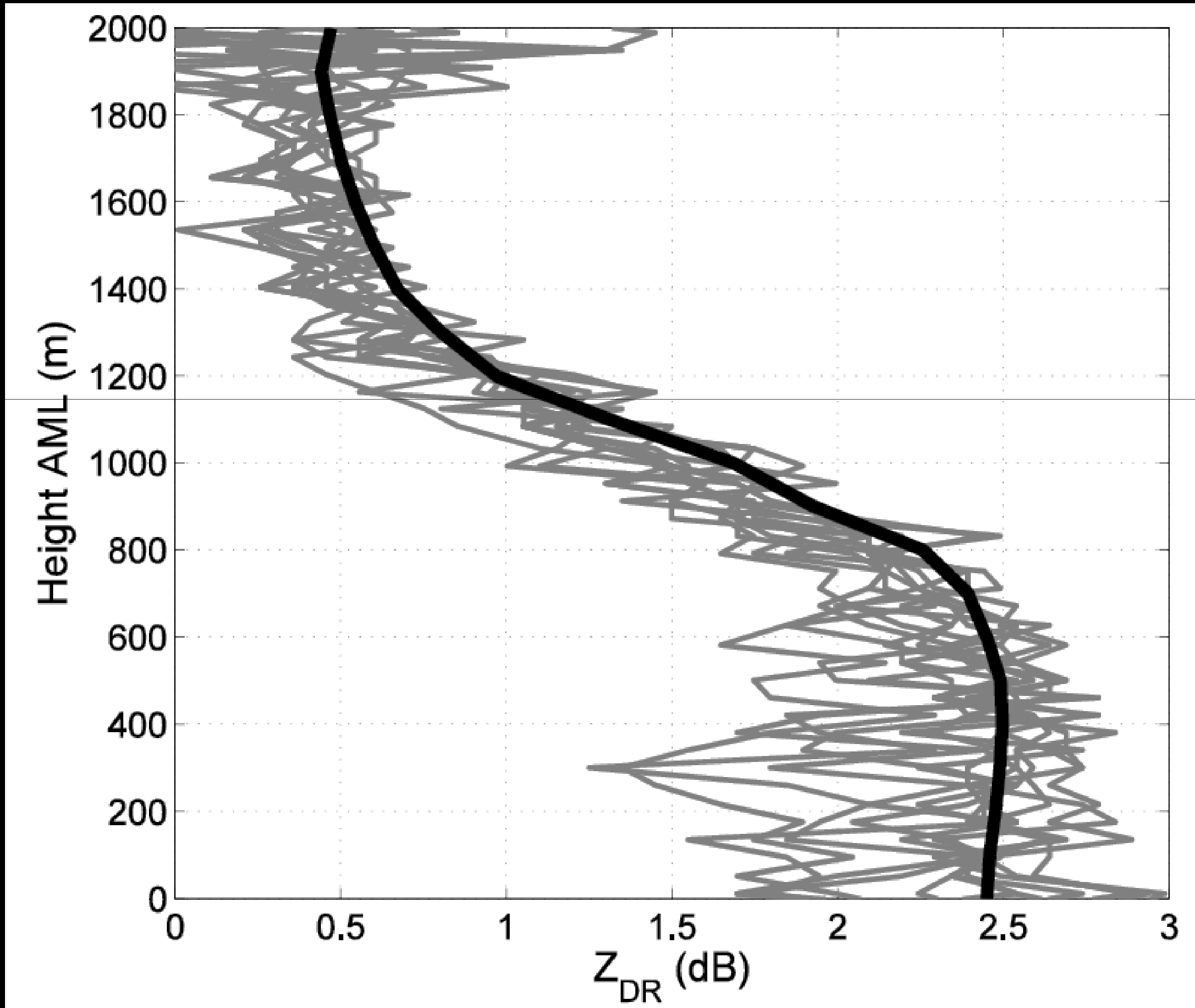
What about the observations?



Data from BOXPOL, collected on 24 June 2011. Courtesy of the Meteorological Institute at the University of Bonn.

Freezing of raindrops

What about the observations?



Freezing of raindrops

To summarize pictorially:

Z_H Z_{DR} K_{DP} ρ_{hv} L_{DR}

Summary

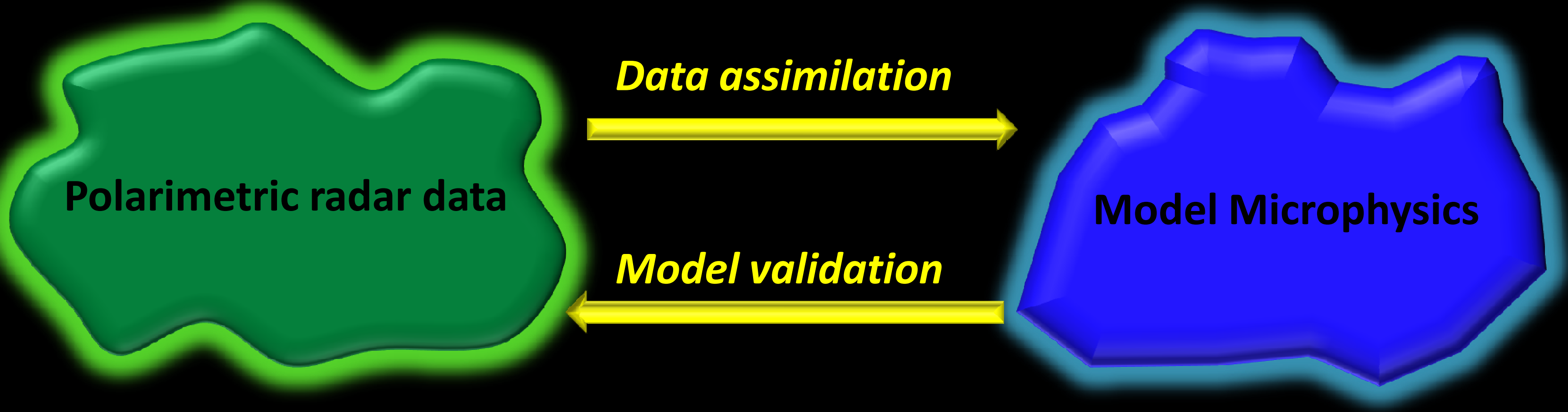
	Z_H	Z_{DR}	K_{DP}	ρ_{hv}
Size sorting	↓	↑	↓	↔
Evaporation	↓	↑	↓	↔
Coalescence	↑	↑	↑	↓
Breakup	↓	↓	↓	↑
Freezing	↓	↓	↓	↓
Aggregation	↑	↓	↓	↑
Melting/ Wet Growth	↑	↑	↑	↓

Summary

- Understanding how certain processes affect the polarimetric radar variables will allow us to better interpret observed data in a variety of storms. Such knowledge also opens the doors for pure microphysics research using remote sensing techniques.

- Direct comparisons between observations and bin/bulk model output can help identify deficiencies in parameterizations, as well as aid in the refinement and validation of such schemes.

- The link between polarimetric radar observations and model microphysics schemes must be fully understood and improved for efficient and effective blending of these tools (e.g., polarimetric radar data assimilation).



Great thanks to ERAD 2012 for providing me with the opportunity to travel to and participate in this conference.

Questions?

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