HAIL MICROPHYSICS, AEROSOLS AND PARAMETERS OF ZDR COLUMNS

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MOTIVATION

***We answer the following questions*:**

1. **How does big hail form in hailstorms?**
2. **What is the mechanism of hail growth?**
3. **What is the relationship between hail size and aerosols?**
4. **What hydrometeors comprise the Zdr column?**
5. **What is the relationships between Zdr columns, hail and aerosols?**

NEW HUCM

A hail storm with hailstones up to several cm in diameter (Germany, 2006) is simulated at different aerosol concentrations using a new version of the Hebrew University Cloud Model (HUCM) with spectral bin microphysics. The model solves kinetic equations for 14 size distributions (43 bins) of the following hydrometeors:

1) Aerosols; 2) Liquid drops ; 3) Three types of ice crystals: plates, columns and dendrites

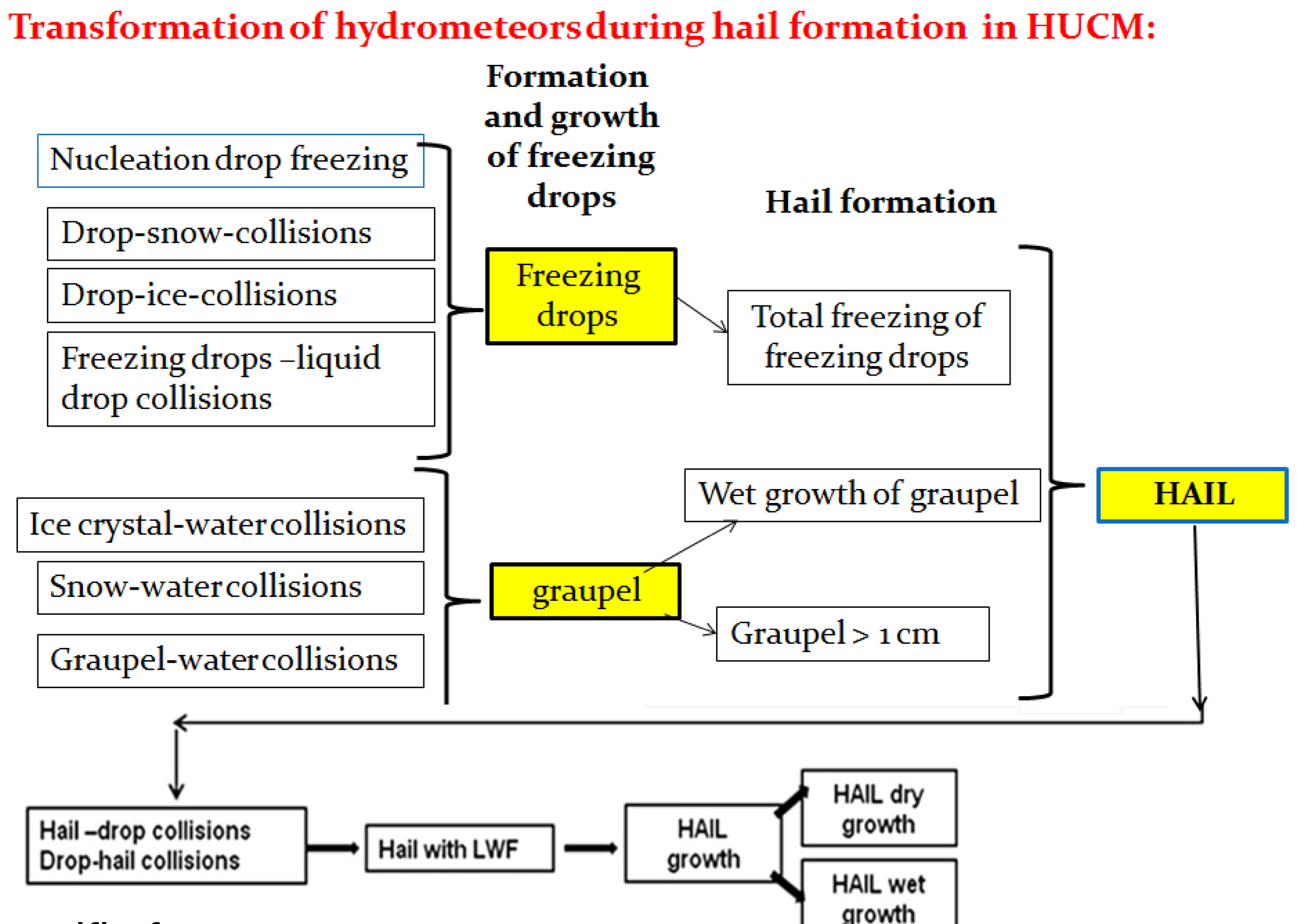
4) Snow (aggregates) and rimed mass in snow (T<0C) and liquid water in snow (T>0C);

5) Freezing drops and liquid water within freezing drops;

6) Graupel and liquid water within graupel;

7) Hail and liquid water within hail

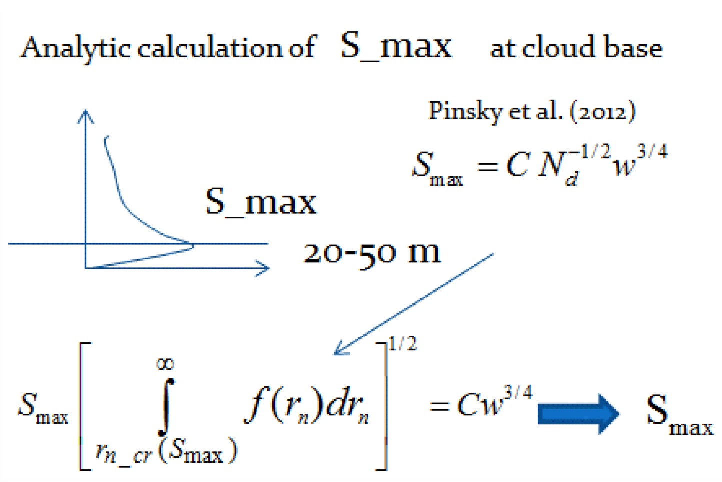
Transformation of hydrometeors during hail formation in HUCM:



Specific features:

a) Equation system for supersaturations over water and ice and equations for diffusional growth is solved with time step less than the drop relaxation time. Supersaturations change during time step.

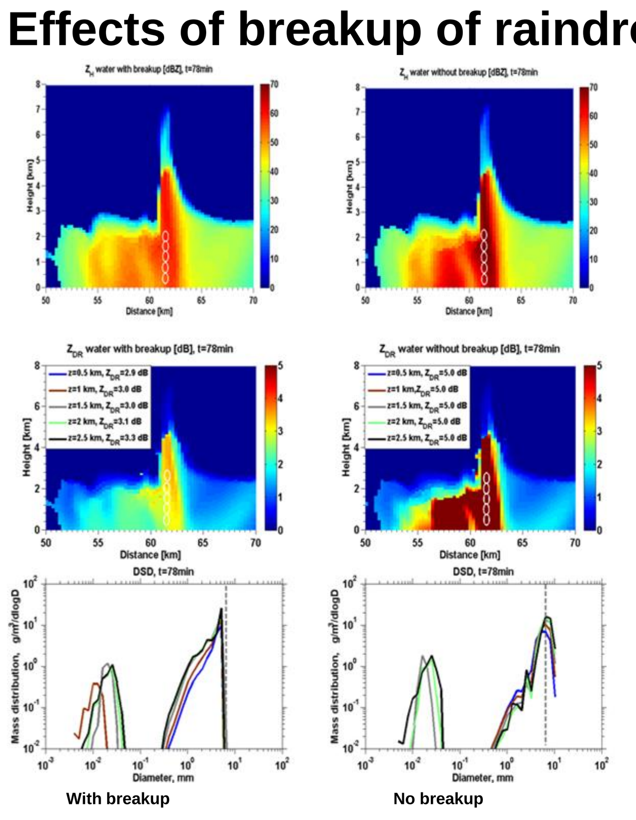
b) Nucleation at cloud base is performed using analytic calculation of supersaturation maximum



c) Snow density ρ_s is calculated. If $\rho_s > 0.2 g\ cm^{-3}$ snow ➔ graupel

d) Spontaneous breakup of raindrops (Kamra et al, 1991) :

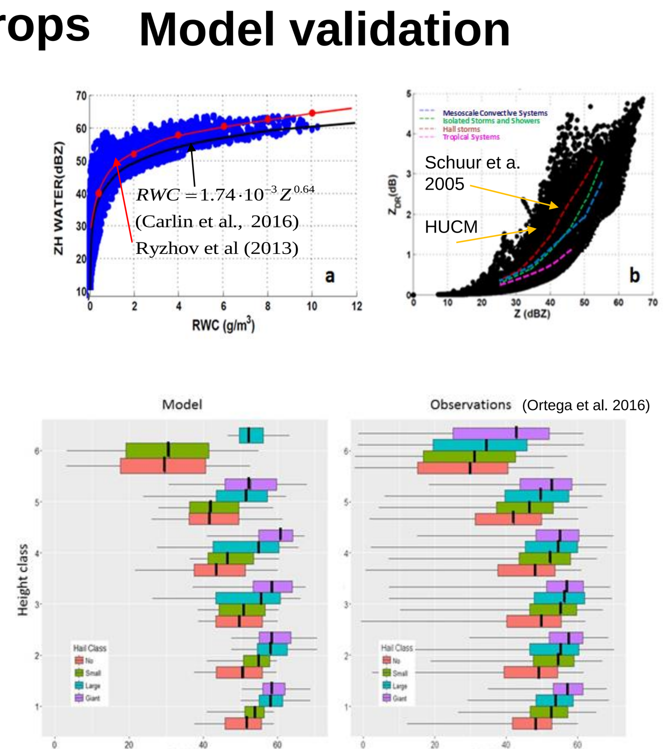
Effects of breakup of raindrops



Breakup eliminates rain drops with diameters of 9-10 mm

Breakup ➔ lower Z and Zdr

Model validation



Percentiles of radar reflectivity in different height classes for different hail size categories at the surface (giant, large, and small are marked purple, blue, and green, respectively) and for no hail (red) from model (left) and radar observations (right). The thick vertical line marks the median value of distributions. The left and right boundaries of the colored boxes correspond to 25th and 75th percentiles of the distributions. Radar quantities are calculated at S band.

POLARIMERTIC OPERATOR

POLARIMETRIC OPERATOR (Ryzhkov et al. (2011): Input: size distributions, aspect ratios, densities, variation of orientation angle, liquid fraction, rimed fraction. Output: Z, Zdr, Kdp, Rohv and other polarimetric parameters

Reflectivity	Differential reflectivity	
low Z_H	Z_{DR} = 0 dB	Cloud droplets
high Z_H	$Z_{DR} \approx 0$ dB • Close to spherical • Tumble during their fall	Graupel and dry hail
low Z_H	Z_{DR} > 0 dB	Snow
high Z_H	Z_{DR} > 0 dB	Raindrops
high Z_H	Z_{DR} > 0 dB	Wet hail

Multiphase particles:

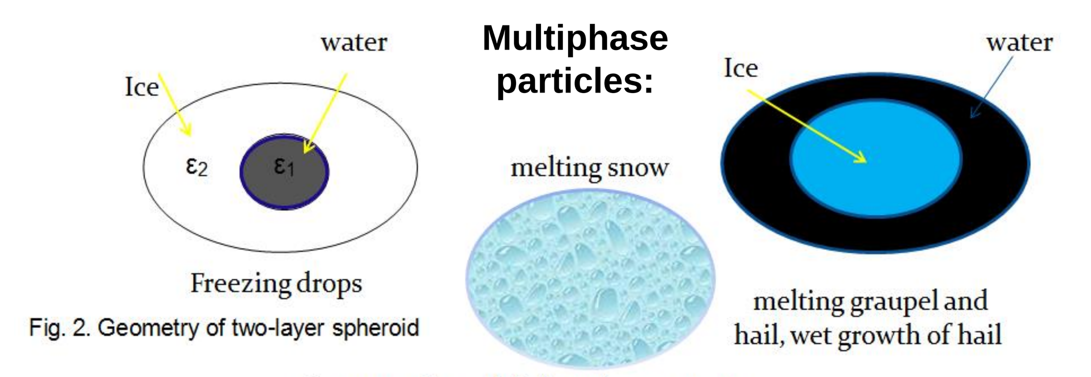
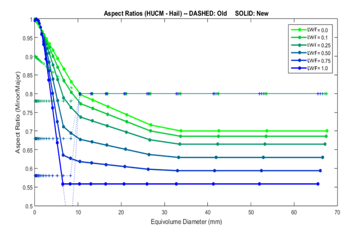


Fig. 2. Geometry of two-layer spheroid

Computation of dielectric constant ε as in Ryzhkov et al. (2011)



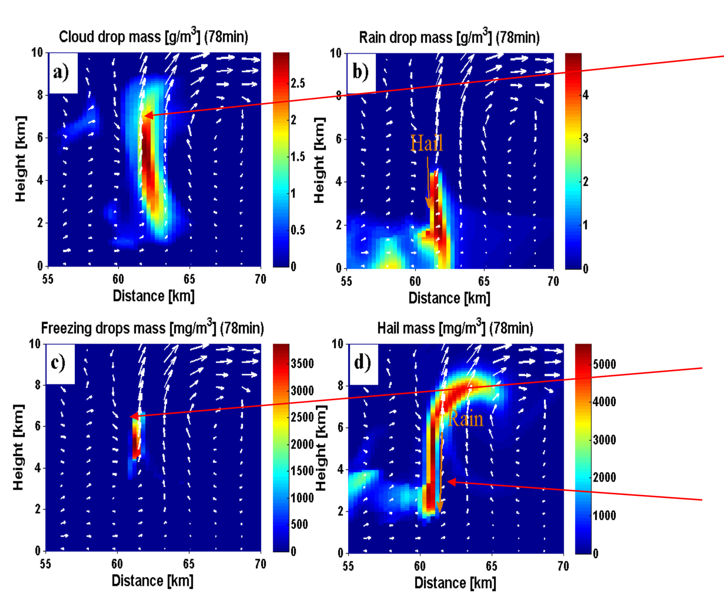
Dependence of aspect ratio of hail particles on equivalent spherical diameter at different liquid water fraction. Solid lines show the relation used in this study; dashed lines show the dependencies used by Kumjian et al (2014).

RESULTS

High CCN concentration

Low CCN concentration

Calculations are in C-band

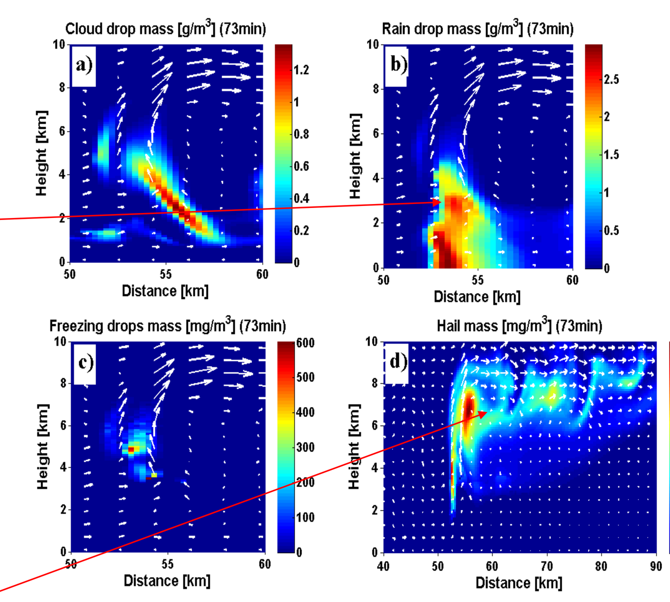


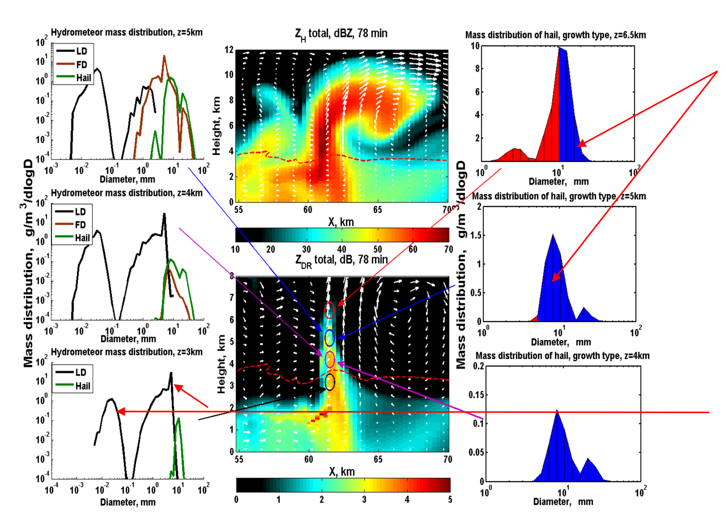
1)CWC is larger and reaches higher levels in polluted clouds;

2) In low CCN concentration a significant fraction of rain is warm rain.

3) Mass of freezing drops is larger in polluted air, due to accretion freezing drops ascent to higher levels than in clean air.

4) In polluted clouds hail growth by riming within narrow updraft zone. Hail falls along the edge of cloud updrafts. In clean air hail is smaller and spreads over large area



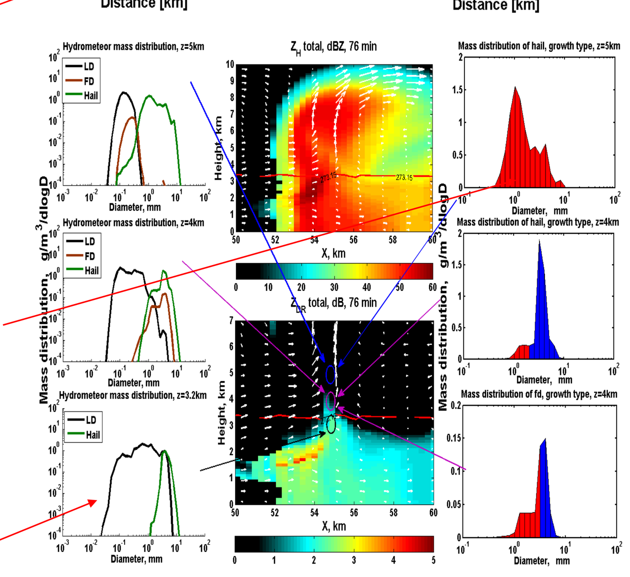


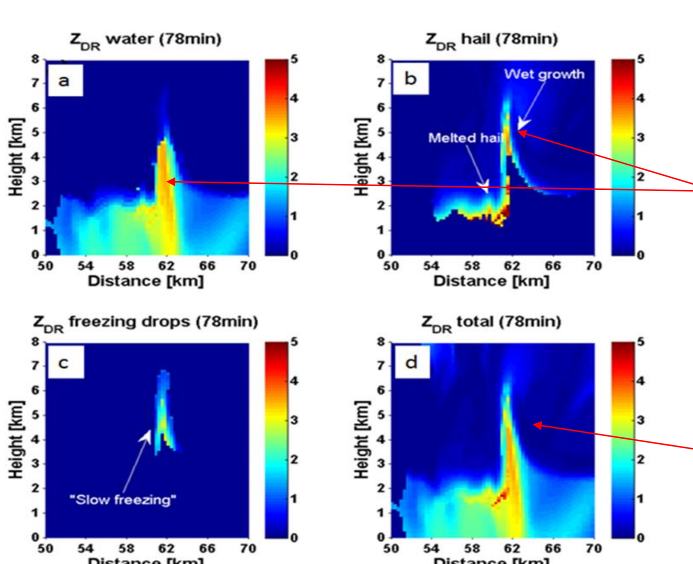
1) Zdr column in polluted cloud arises in cloud updrafts, where hail ascends and grows by accretion in wet growth (blue areas in size distribution). CWC is larger and reaches higher levels in polluted clouds.

2) In case low CCN concentration hail particles are small and grow in dry growth regime (red area in size distributions)

3) In polluted air drop size distribution contain clear two peaks: cloud droplets and raindrops. Raindrops penetrate updrafts during recycling.

4) In clean air drop size distribution does not contain small droplets





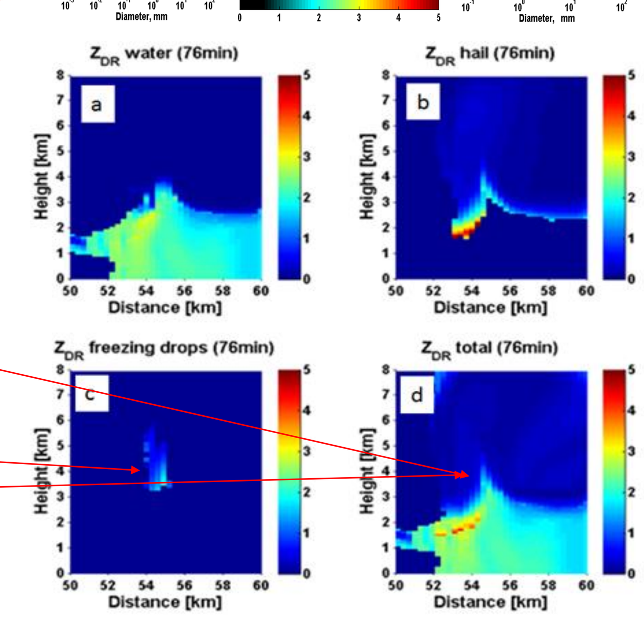
1) In polluted clouds Zdr colums form by raindrops and hail in wet growth regime up to high levels.

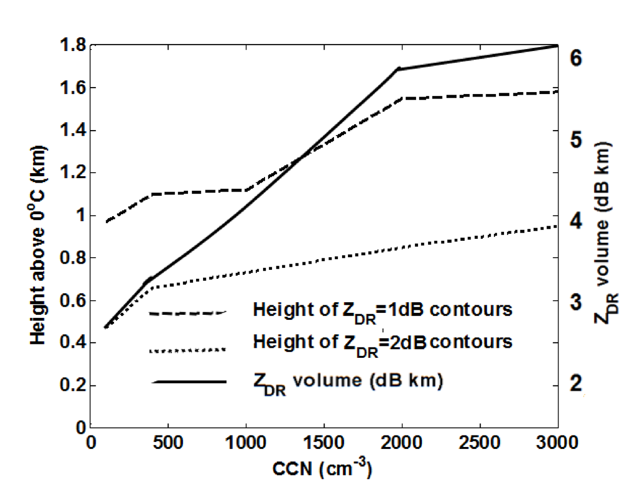
2) In clean air Zdr column are low and the values of Zdr are small.

This is because of low supercooled water mass in clean case.

Freezing drops freeze very fast.

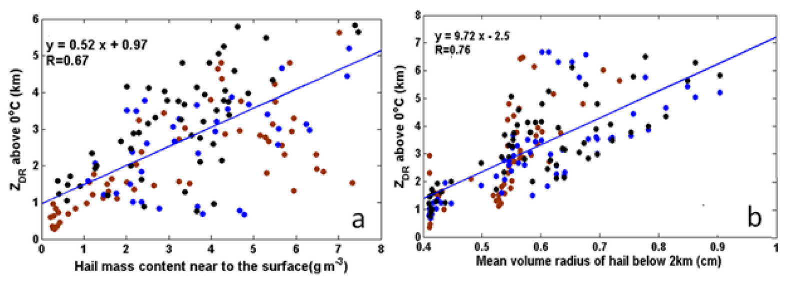
3. In polluted air Zdr columns are higher than in clean air





Dependencies of time-averaged heights of the maximal elevations of Z_{DR} = 1dB and Z_{DR} = 2 dB contours and time-averaged Z_{DR} column volume on CCN concentration determined at 1% of supersaturation. Zdr columns are higher in polluted (continental) air.

Some statistics:



The correlation between the maximal Zdr values above 0C level and the maximum hail mass content (left), and between the mean volume radius of hail near the surface (right).

Conclusions

1. More aerosols increase supercooled CWC ➔greater hail growth by riming➔ wet growth of hail column and maximum hail size at the surface

2. High liquid water fraction within hail can be associated with high ZDR.

3. Tall ZDR columns and high values of ZDR can be predictors of the mass and size of hail.

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