Improving the integration of models and observations by predicting multiple ice particle properties

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Thanks to:
Wojciech Grabowski, Jerry Harrington, Anders Jensen, Jason Milbrandt, Kara Sulia

ASR Cloud Lifecycle WG breakout
November 6, 2013

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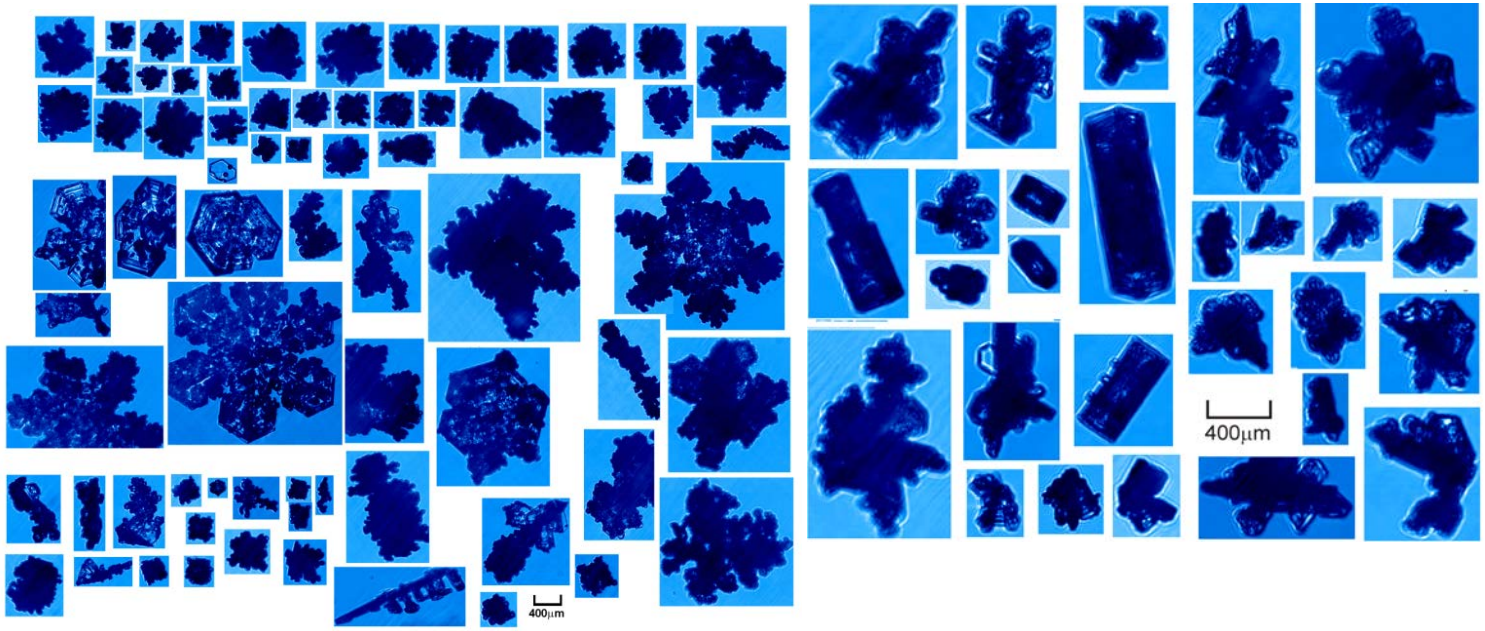
Microphysics schemes have traditionally represented ice using **pre-defined classes** (*cloud ice, snow, graupel, hail, etc.*) with **fixed properties** (bulk *density, V-D, etc.*).

Example of observed ice particles:



Photos c/o Alexei Korolev (ARMP, EC)

Some conceptual problems (specific to integration of models and observations):

1) cannot represent the continuum of particle properties that occurs in nature; instead properties in a grid cell depend on a (weighted) average of properties specified for each ice-phase class

   → *implications for radar simulators*

2) partitioning of ice mass among classes is often controlled by unphysical and/or poorly constrained thresholds and rates (e.g., ice autoconversion)

   → *threshold behavior and large sensitivity to conversion "processes" and may lead to difficulty in "fingerprinting" of specific microphysical processes*

Example: Riming in traditional schemes

Low riming rates:

Increase in bulk mass

SNOW
ρ_s = 100 kg m^{-3}
$V = a_s D^{bs}$

SNOW
ρ_s = 100 kg m^{-3}
$V = a_s D^{bs}$

High riming rates:

Increase in bulk mass

SNOW
ρ_s = 100 kg m^{-3}
$V = a_s D^{bs}$

SNOW +
ρ_s = 100 kg m^{-3}
$V = a_s D^{bs}$

GRAUPEL
ρ_g = 400 kg m^{-3}
$V = a_g D^{bg}$

Changes in particle properties are not smooth or clearly linked to riming rate!

A shift (in parameterization of ice phase)**:**

Representation using pre-defined *classes*
to
Prediction of particle *properties*

- Predicted rime mass fraction – Morrison and Grabowski (2008)
- Predicted graupel density – Mansell et al. (2010); Milbrandt and Morrison (2013)
- Predicted crystal axis ratio (habit) – Harrington et al. (2013); Sulia et al. (2013)
- Multiple predicted properties (P3-1C) – Morrison and Milbrandt (2013, in prep.)

Some conceptual advantages:

•avoids unphysical/poorly constrained thresholds for conversion between pre-defined ice-phase classes

→ *smooth evolution of particle properties which are directly linked to microphysical process rates*

•particle properties are real physical quantities that can be observed, conversion thresholds are not

→ *better linkage with observations*

→ *predicted particle properties can be utilized directly by instrument simulators (hydrometeor id's less useful for model comparison)*

Example: Riming in the new approach

ICE

Increase in bulk mass

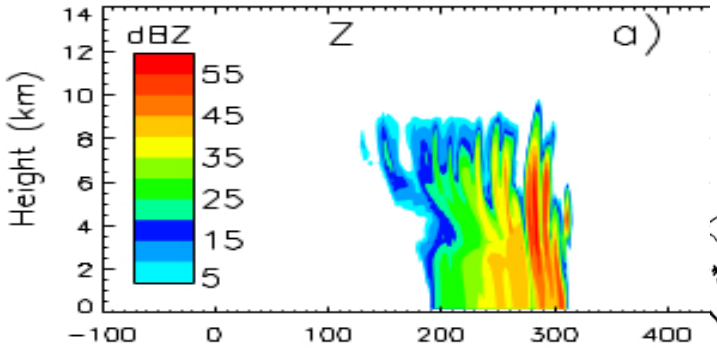
ICE

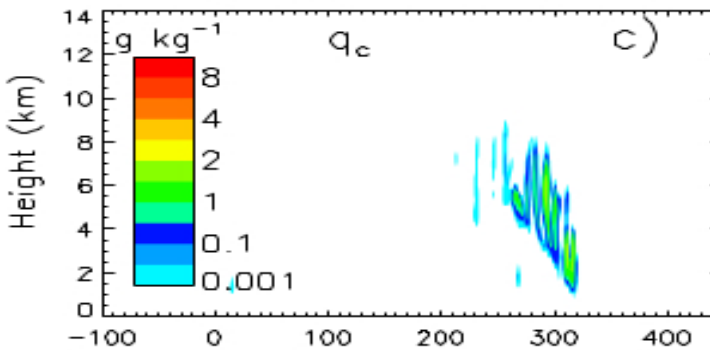
Change in predicted properties: **increase in *mean rime mass fraction, density, fallspeed***

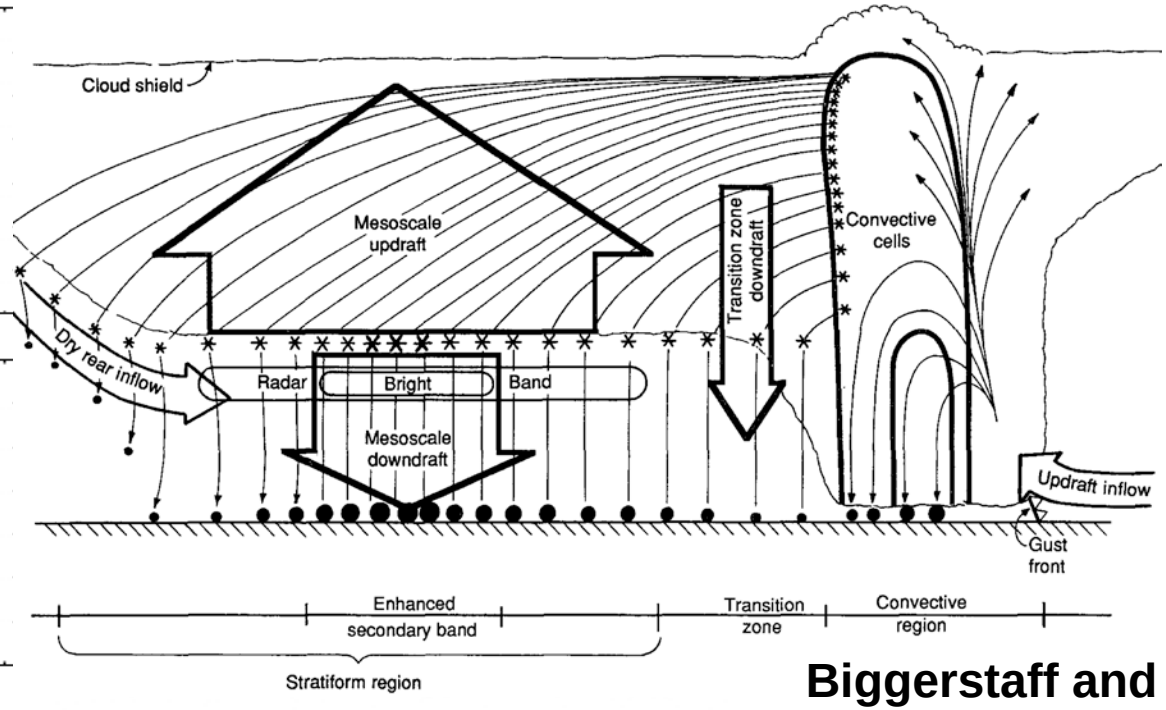
Changes in particle properties are smooth and directly linked to riming rate

WRF 2D idealized squall line

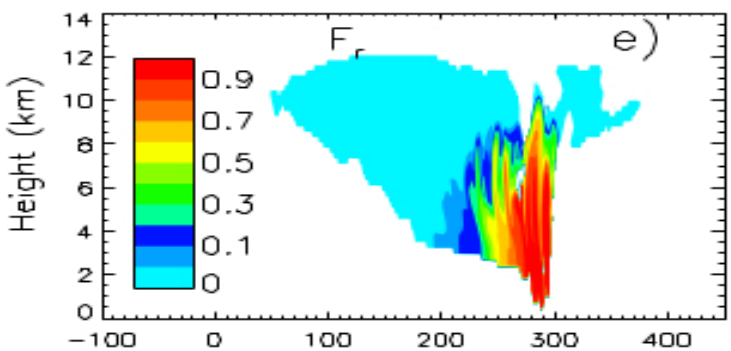
- WRFv3.4.1
- Dx = 1 km, 80 vertical levels, 500 x 20 km domain
- Weisman-Klemp initial sounding
- Convection initiated from a thermal
- No radiation or surface fluxes
- Moderate low-level environmental shear (12 m/s difference in 0 to 2.5 km horizontal wind)

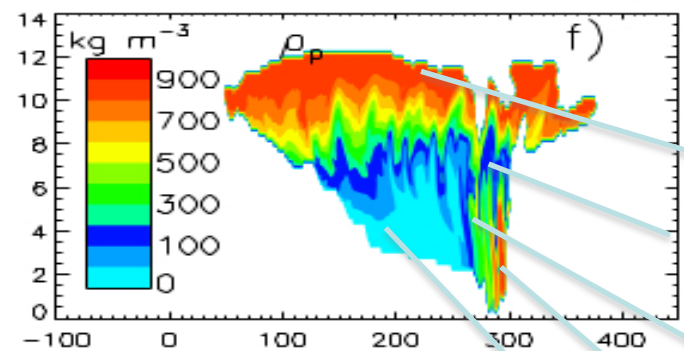


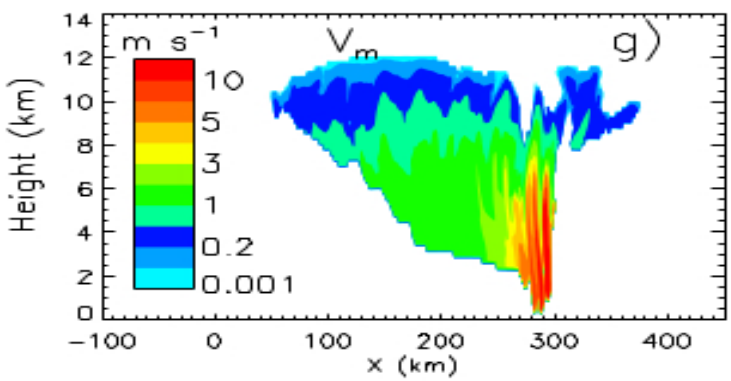


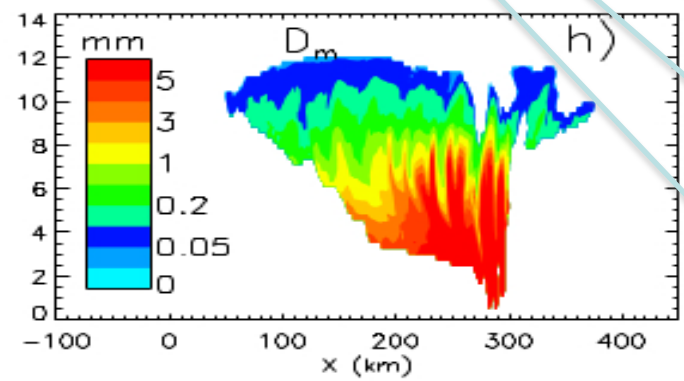


Biggerstaff and Houze (1991)









Small dense ice

Low-density graupel

Medium-density graupel

Hail

Large unrimed ice (aggregates)