# Microphysics Parameterization Changes Based on Observational Studies

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# Motivation

- New observational, theoretical and laboratory studies are leading to new parameterization formulas in bulk microphysics schemes
  - Heymsfield, Schmitt, Bansemer and Twohy: Improved representation of ice particle masses based on observations in natural clouds (JAS, 2010)
  - Heymsfield and Westbrook: Advancements in the estimation of ice particle fall speeds using laboratory and field measurements (JAS, 2010)

# Mass-Diameter Relation

Heymsfield et al. (2010) use data from 6 field programs

- Tropical/convective: CRYSTAL-FACE (Florida), NAMMA (Africa), TC4 (Costa Rica)
- Mid-latitude/stratiform: ARM SGP 2000, AIRS-2 (Canada), C3VP (Canada)

# Mass-Diameter Relation

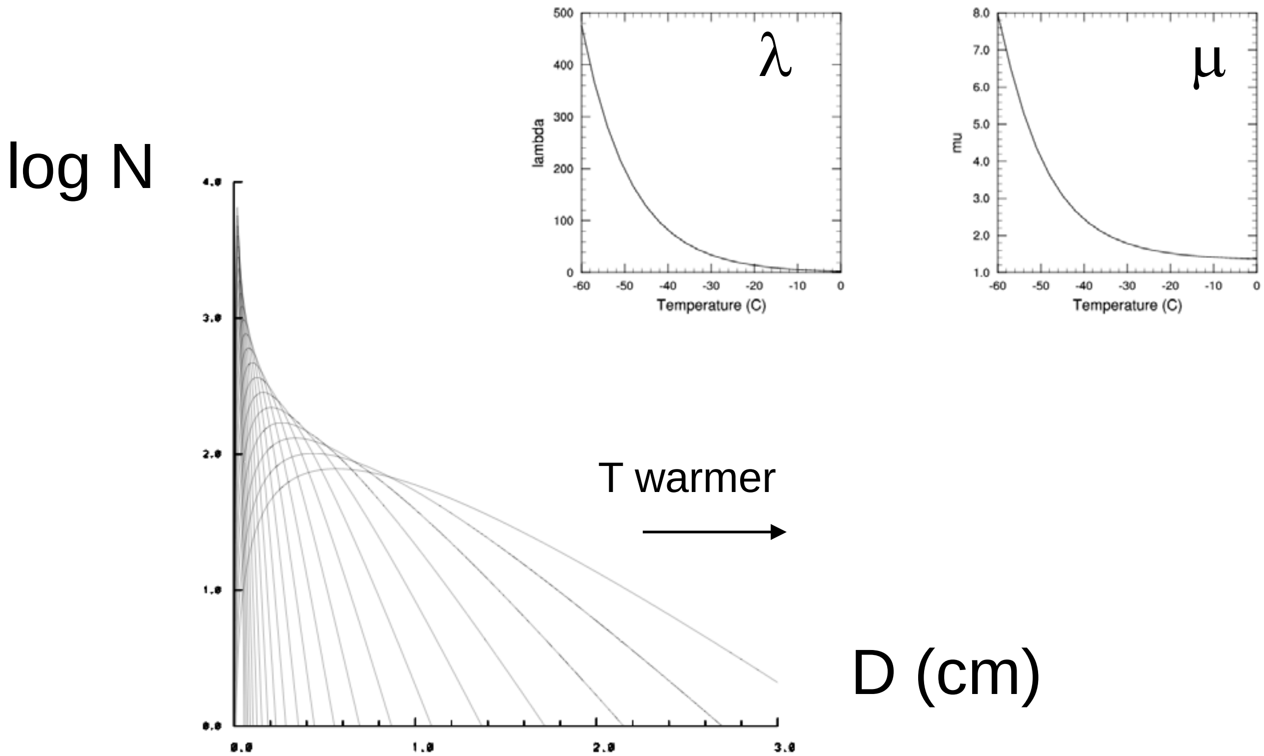
- Particle Size Distribution (PSD) derived from observations is a temperature dependent gamma distribution of the form

$$N = N_0 D^{\mu} \exp(-\lambda D)$$

where $\mu$ is a cubic fit to $\lambda$, and $\lambda$ is an exponential function of temperature

- Note that this PSD is only a function of T not ice water content (IWC)

# Gamma PSD for different T



# Mass-Diameter Relation

- Fitting IWC measurements to probe size data using this PSD yields a fit over a range of median-mass diameters and temperatures from 0ºC to -60ºC. For the complete dataset, the following function is optimal

$$m_g = 0.00528 D_{cm}^{2.1}$$

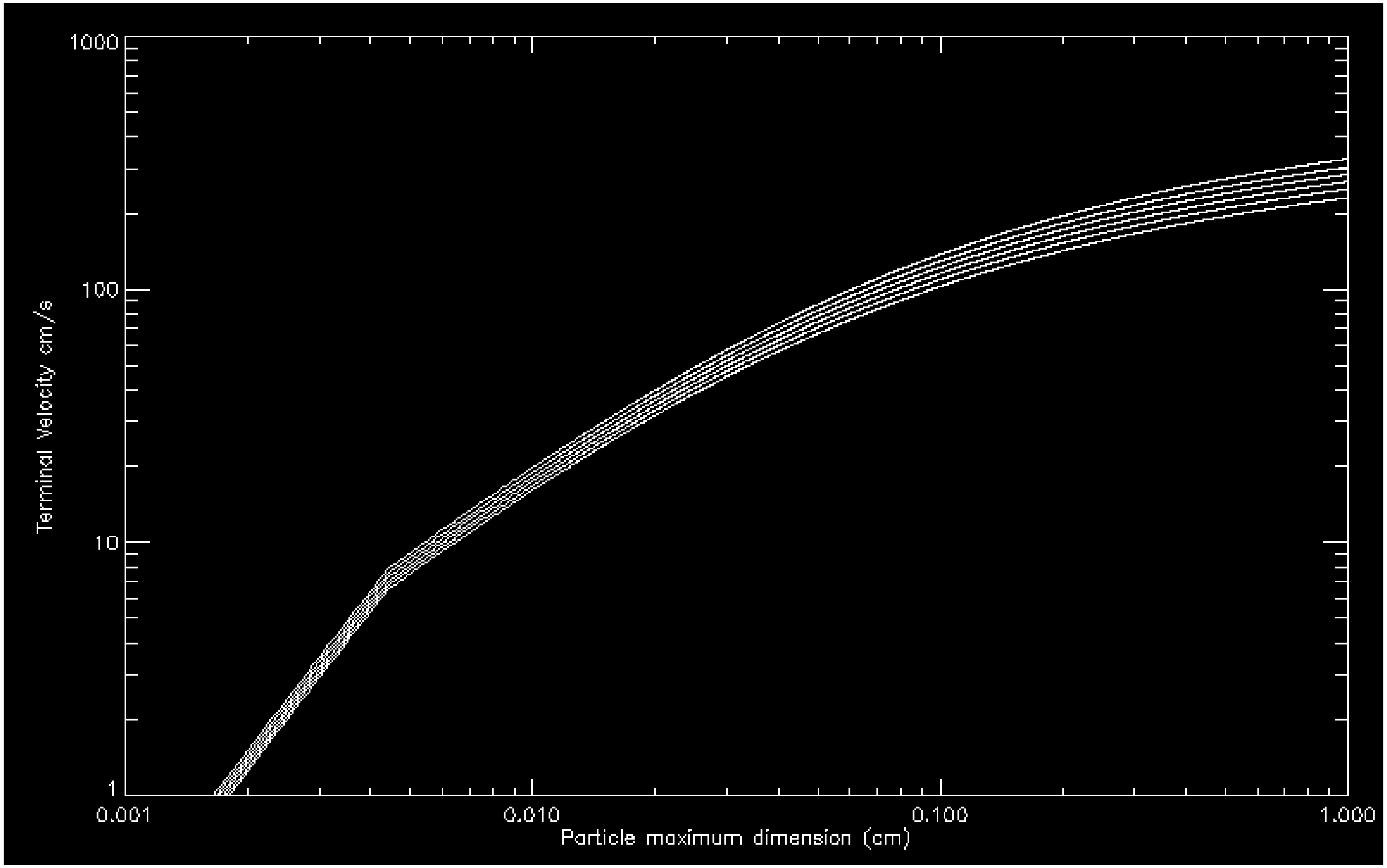
# Fallspeed-Diameter Relation

- Heymsfield and Westbrook (2010)
  - Use drag coefficient ($C_d$) that accounts for attached boundary layer ($D+\delta$) as a function of Reynolds number (Re)
  - Introduce a new form of Best number ($X^* \equiv C_d^* \, Re^2$) that has lab-derived effect of particle sub-circular cross-sectional area factor ($A_r$) on drag
  - These allow derivation of a new Re(X*) and hence

$$v_t = Re\ \eta \,/\, \rho_{air}\, D$$

  - Note that the $v_t$ (D) relation is not of the form $aD^b$

# Log-log $V_t$ versus D for various T

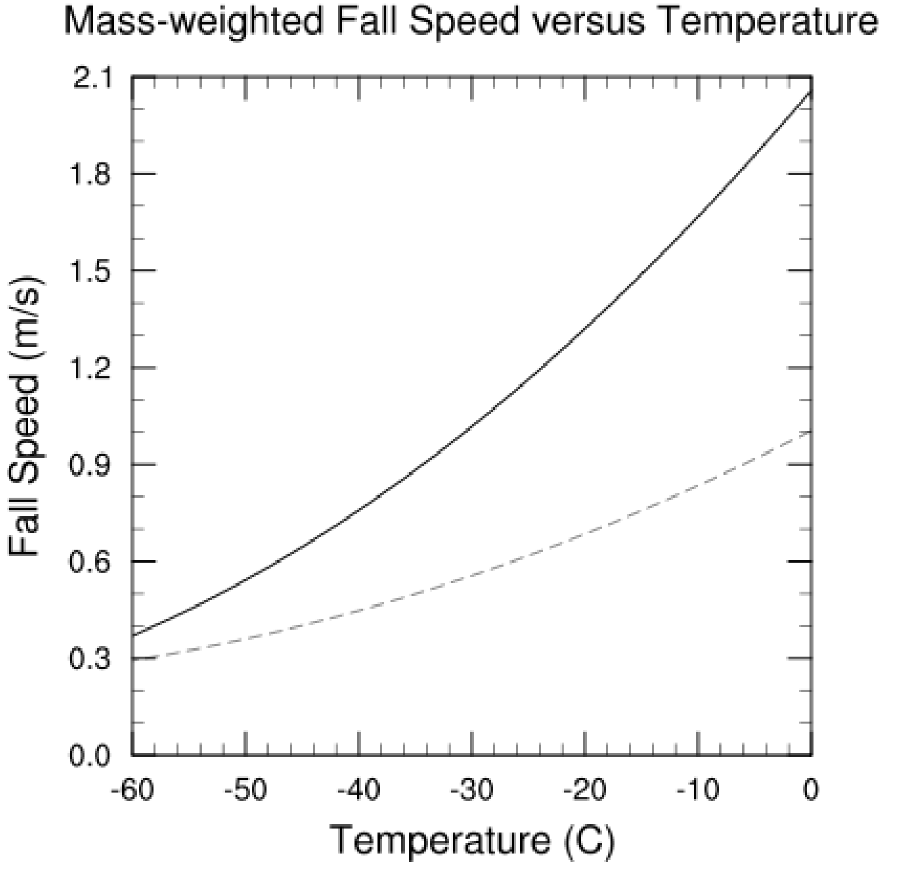


# Mass-Weighted Fallspeed

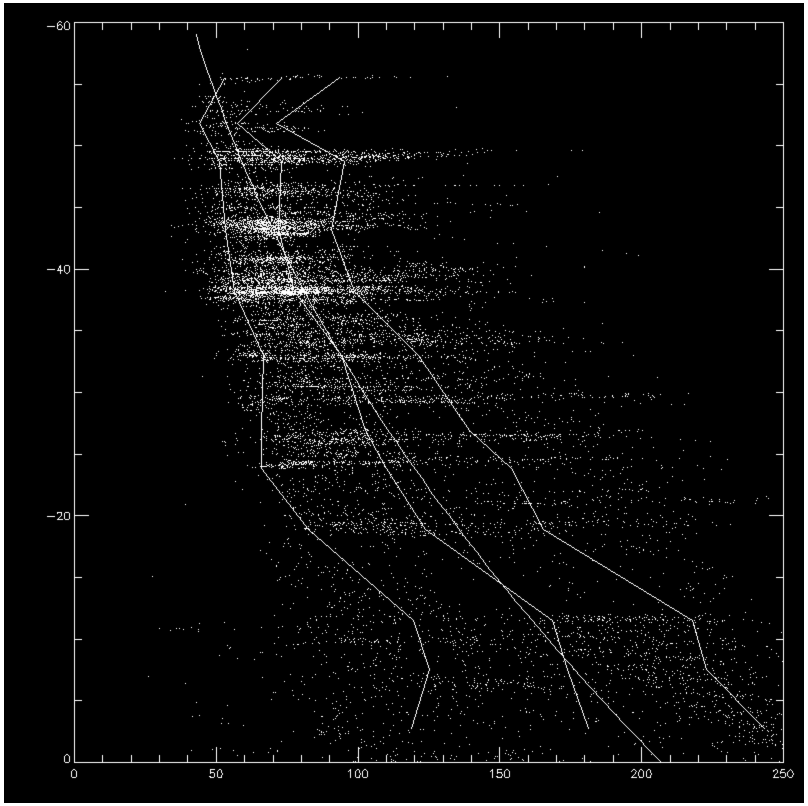
- In microphysics parameterization the mass-weighted fall speed ($\boldsymbol{V_t}$) is required
  - Mass-weighted particle $v_t$ (D) is integrated numerically over the particle size distribution for each temperature
  - $A_r$ also taken to be function of D from field data
- $\boldsymbol{V_t}$ is fitted as a quadratic function of T separately for the tropical/convective and mid-latitude/stratiform datasets
- Since the PSD is self-similar for different IWC at a given T, a unique feature of this scheme is that $\boldsymbol{V_t}$ is not a function of IWC, only T

# Mass-Weighted Fallspeed

Convective (solid)
Stratiform (dashed)

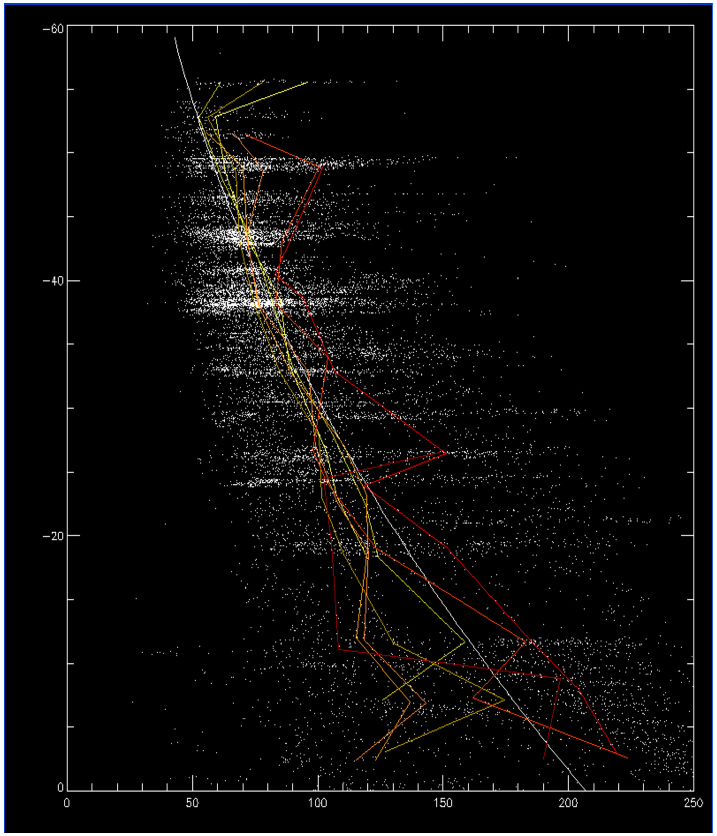


# Temperature versus Fallspeed




- Observations seem to support this relation, but there is some spread
- Is this due to neglecting IWC?

# Temperature versus Fallspeed




- Different IWC (lines) show no trend
- Fallspeed seems not to be correlated with IWC (also from separate scatter plot, not shown)
- This supports idea of temperature-only function

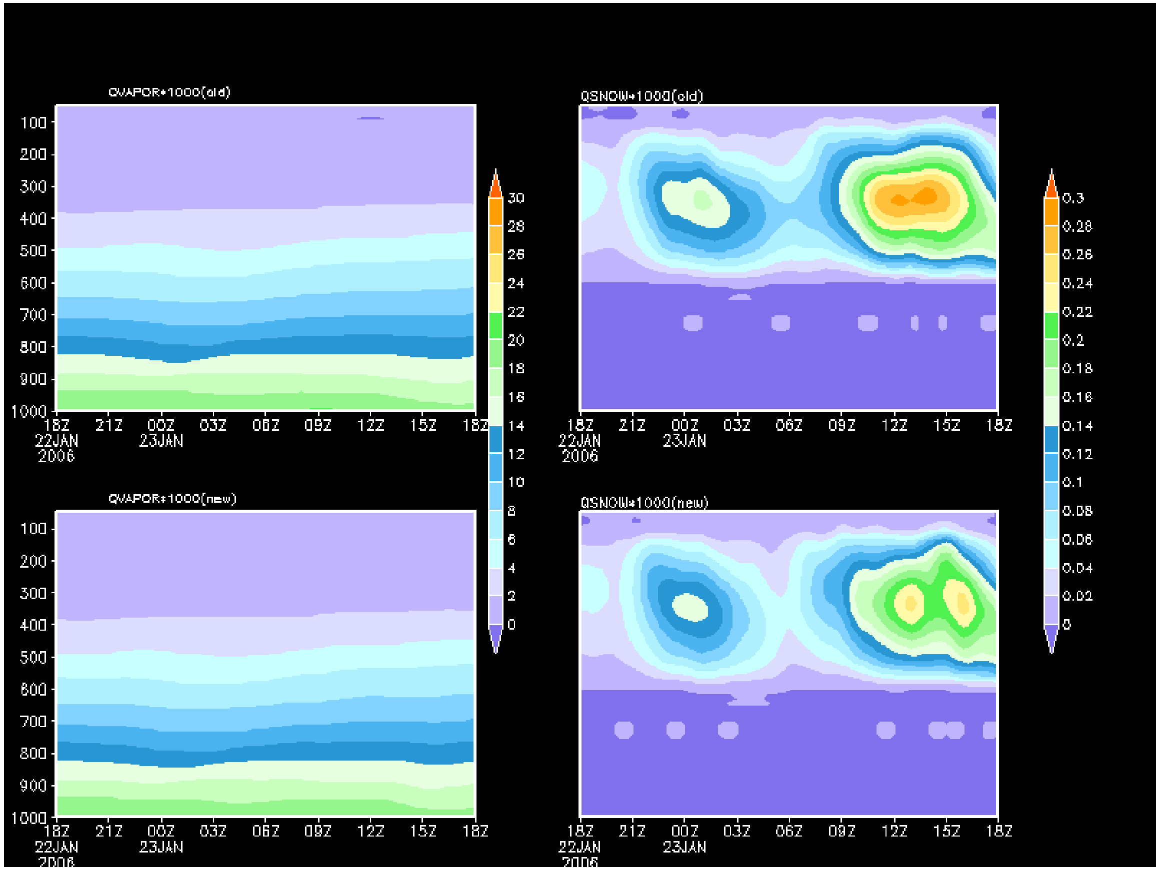
# Initial Implementation in WRF

- Fall speed (convective formula) added to WSM6 microphysics option (not yet other aspects of size distribution)
- Replaces mass-weighted fall speeds from exponential distribution for snow and mass-diameter relation for mean ice crystal diameter
- Since it is independent of IWC, we can just treat ice and snow fallspeeds independently
- Tests on hi-res 1 km 22-23 Jan 2006 TWP-ICE case

# 22/12Z-23/18Z precip rate 3 km domain

QuickTime™ and a
BMP decompressor
are needed to see this picture.

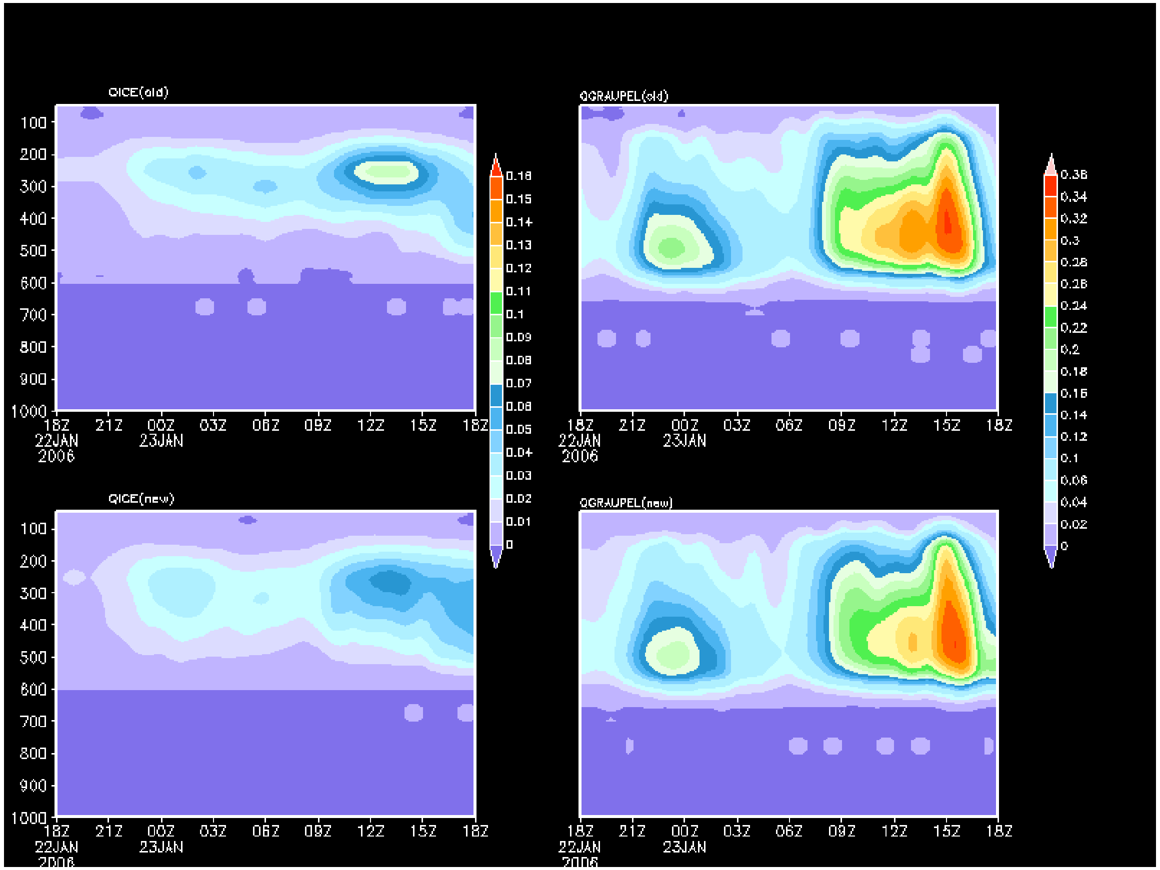
# Comparison: Domain-mean vapor and snow versus time




old

new

# Comparison: Domain-mean ice and graupel versus time




old

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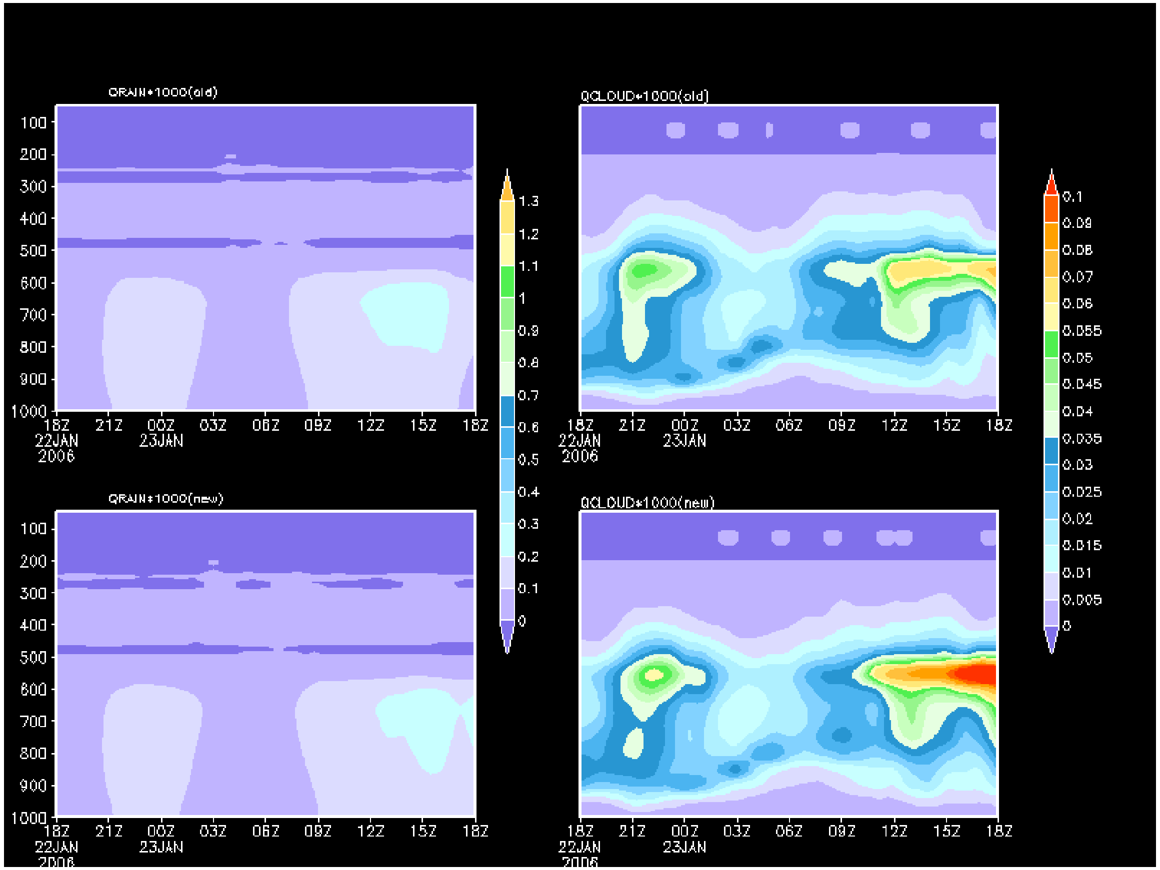
# Comparison: Domain-mean rain and cloud water versus time




old

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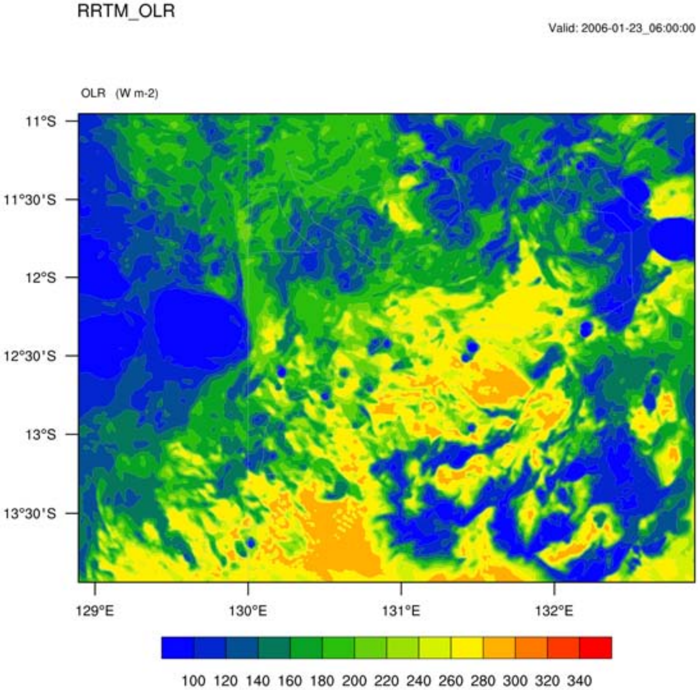
# Comparison OLR

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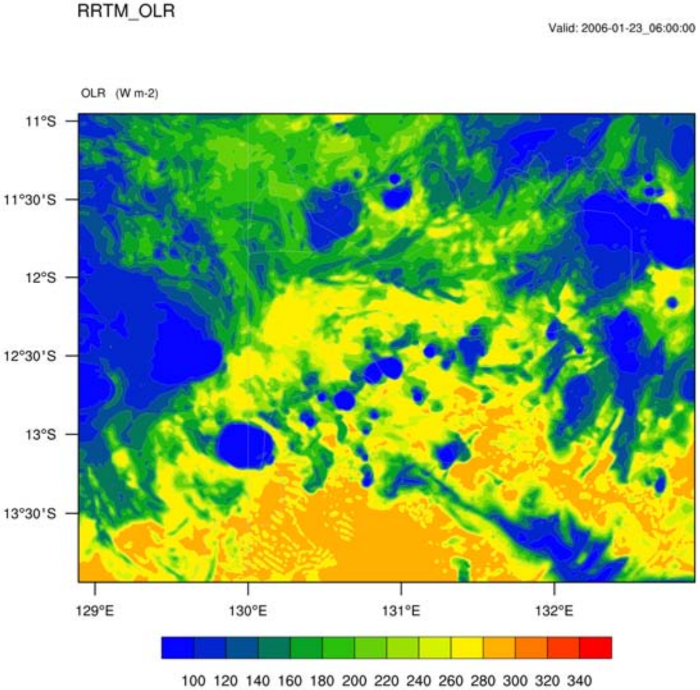


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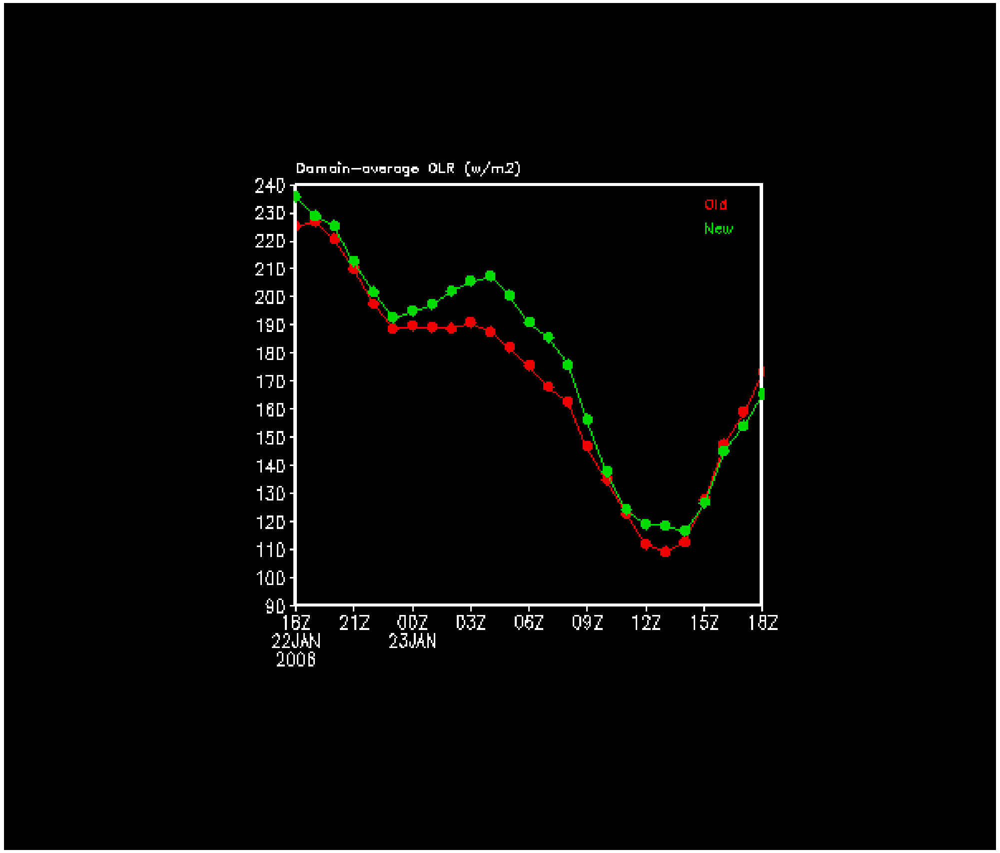
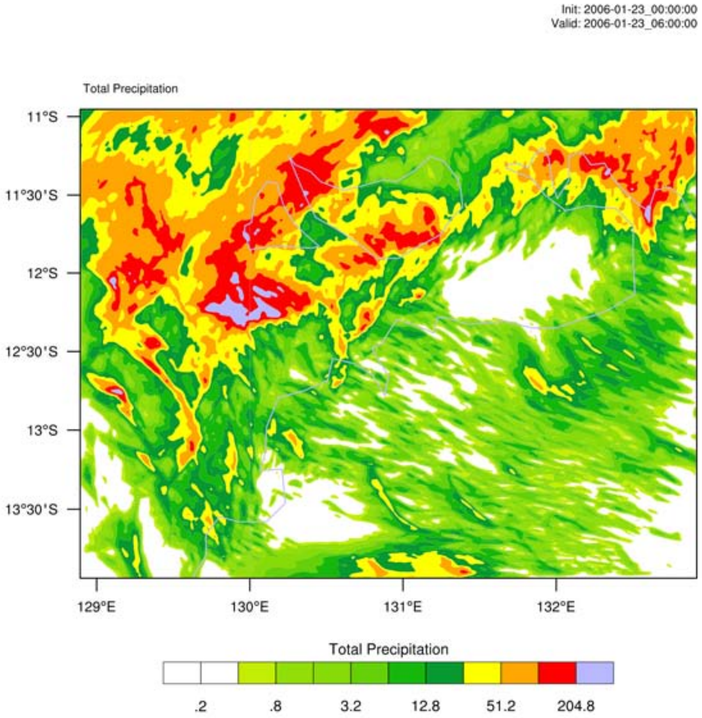
# Domain-averaged OLR versus time



# Comparison 12-hr Precipitation

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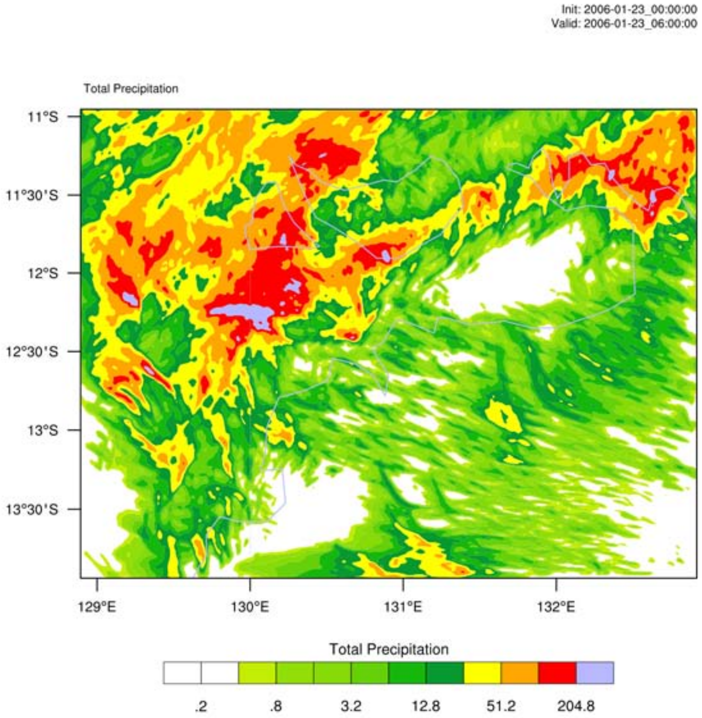
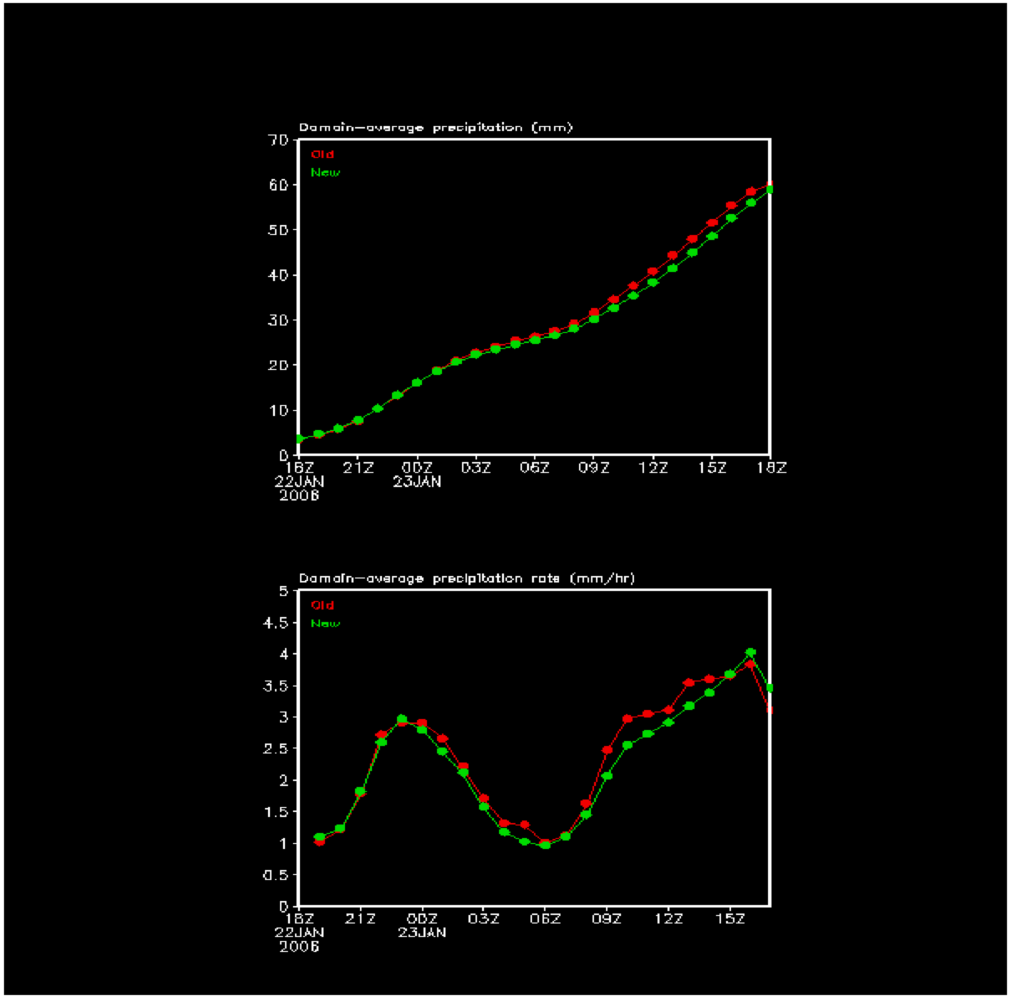



new

# Domain-averaged precip accumulation and rate versus time



# Summary and Further Work

- Need to evaluate differences against observations
- New fall speeds differ with height leading to
  - Less mean hydrometeor mass suspended
  - Small effect on rainfall
  - Increased OLR effect despite lower ice mass
- Further implementation
  - Apply PSD for microphysical processes that generally depend on particle sizes and fallspeeds
  - Radiation scheme should also be unified to use the same PSD and ice particle properties

# Suitability for GCMs

- By being a unified scheme for addressing the PSD and fallspeeds of all non-rimed ice, this can be the basis of a relatively cheap single-moment bulk scheme in climate models with non-rimed ice and snow particles represented by a single array
- It has been derived from observation-based size distributions combined with lab and theoretically-based particle fallspeeds