High-Resolution NWP in Canada and the Impact of a Multi-Moment Microphysics Scheme

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OBJECTIVES OF PRESENTATION:

1. **Overview of Environment Canada's high-resolution NWP**
   • Canada's contribution to MAP D-PHASE

2. **The cloud scheme used in the high-resolution grids**
   • some advantages of the multi-moment approach
   • case 1: severe convection
   • case 2: orographic precipitation

Environment Canada's operational model:

Global Environmental Model (GEM)

- non-hydrostatic, fully compressible
- semi-implicit; semi-Lagrangian
- various possible grids configurations:
  - global, uniform grid (33 km)
  - global, non-uniform grid (15 km over North America)
  - limited-area version (GEM-LAM)

GEM-LAM (2.5 km)

- experimental windows only
- MAP D-PHASE
- 2010 Winter Olympics (Vancouver, Canada)

MAP D-PHASE

- Fourth phase of the **Mesoscale Alpine Project** (MAP), a Swiss-led project that evaluated high resolution numerical guidance in the Swiss Alps Demonstration of Probabilistic Hydrological and Atmospheric Simulation of flood Events in the Alpine region
- 2nd WWRP Forecast Demonstration Project

MAP D-PHASE – Models:

DOP Limited-Area Ensemble Prediction Systems (5)

ARPA – Italy (CLEPS [16: 10km])
ARPA – Italy (CSREPS [16: 10km])
UK Met – England (MOGREPS [24: 25km])
INM – Spain (INMSERPS [20: 27km])
DWD – Germany (PEPS [X: 7km])

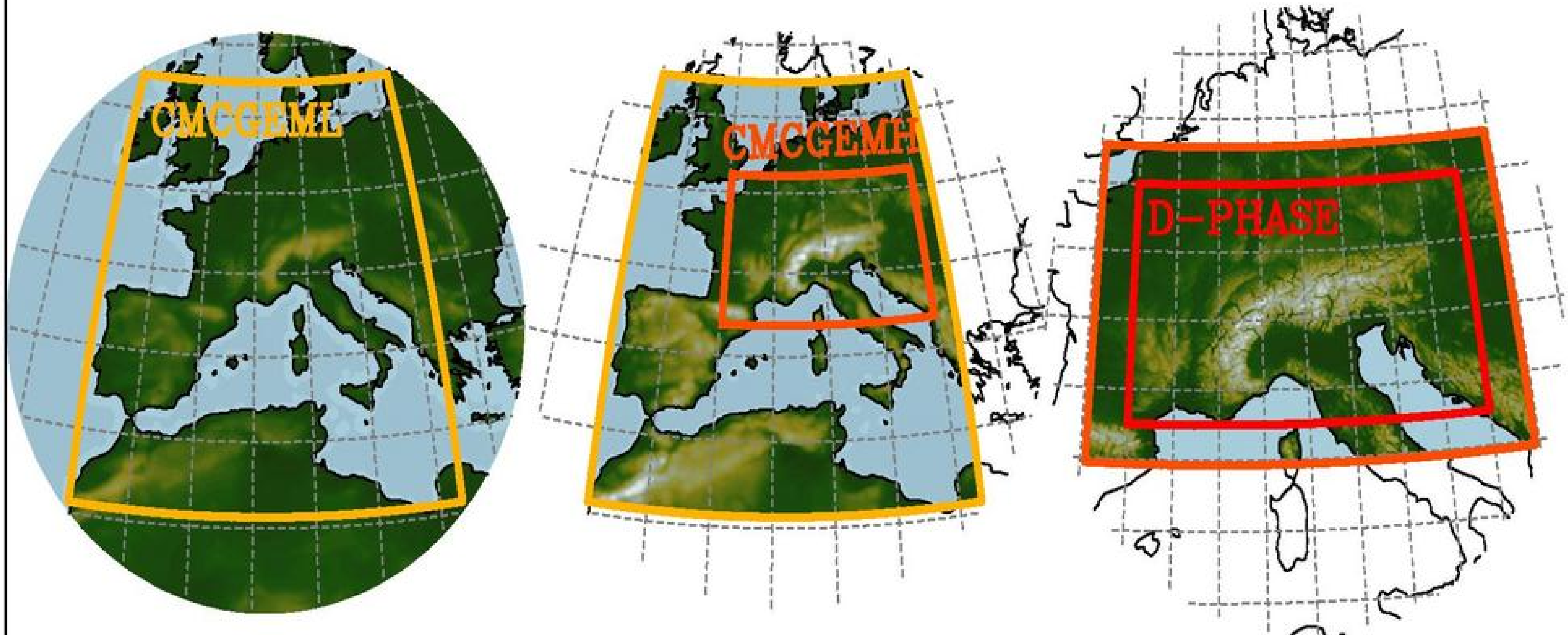
DOP High Resolution Ensembles (1)

DWD – Germany (MPEPS [5: ~2])
AROME - France
CMCGEM – Canada
COSMOCH2 – Switzerland
ISACMOL2 - Italy
LMK - Germany

DOP High Resolution Deterministic Models (11)

MeteoSwiss – Switzerland (COSMO [7,2.2])
U.Hohenheim – Germany (MM5 [10,3.3,1.1])
Meteo-Fance – France (AROME [11, 4.4])
ARPA – Italy (COSMO [7,2.8])
CNMCA – Italy (COSMO [7,2.8])
DWD – Germany (COSMO [7,2.8])
CNR – Italy (MOLOCH [2.2])
ARPA – Italy (BOLAM/MOLOCH [7,2.2])
APAT – Italy (BOLAM [33,11])
IMK – Germany (MM5 [50,15,3.75])
IMK – Germany (WRF [60,20,5])
ZAMG – Austria (ALADIN [9.6])
CMC – Canada (GEM [15, 2.5])

Canadian Domains for MAP D-PHASE



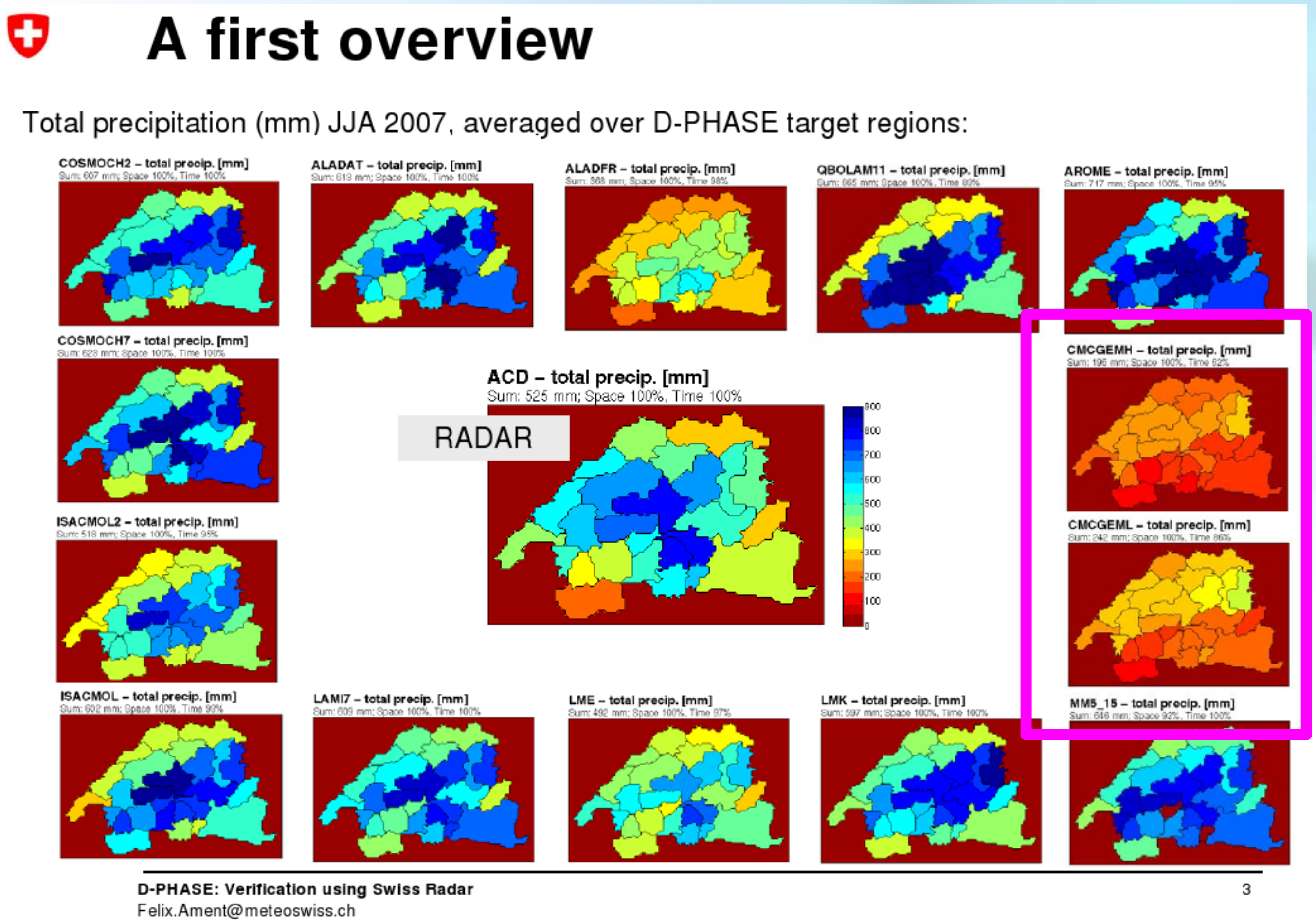
Meso-Global	CMCGEML	CMCGEMH
GEM Global Model	GEM LAM Driving Model	GEM LAM High Resolution
Grid Spacing: 35 km	Grid Spacing: 15 km	Grid Spacing: 2.5 km
Range: 240 h	Range: 24 h	Range: 18 h

Canadian Contribution to D-PHASE

- Model: GEM (LAM version)
- Summary of configuration:

	GEM Driving Model	High Resolution Model
Horizontal Grid (km)	15 km	2.5 km
Vertical Levels (#)	48	48
Domain size (#x;#y)	174; 199	600; 413
Step length (s)	300 s	60 s
Orography Growth (h)	4 h	4 h
PBL Scheme	Moist TKE	Moist TKE
Convective Scheme	Kain-Fritsch	–
Explicit Cloud Scheme	Milbrandt-Yau (1-moment)	Milbrandt-Yau (1-moment)
Roughness Reduction	no	yes

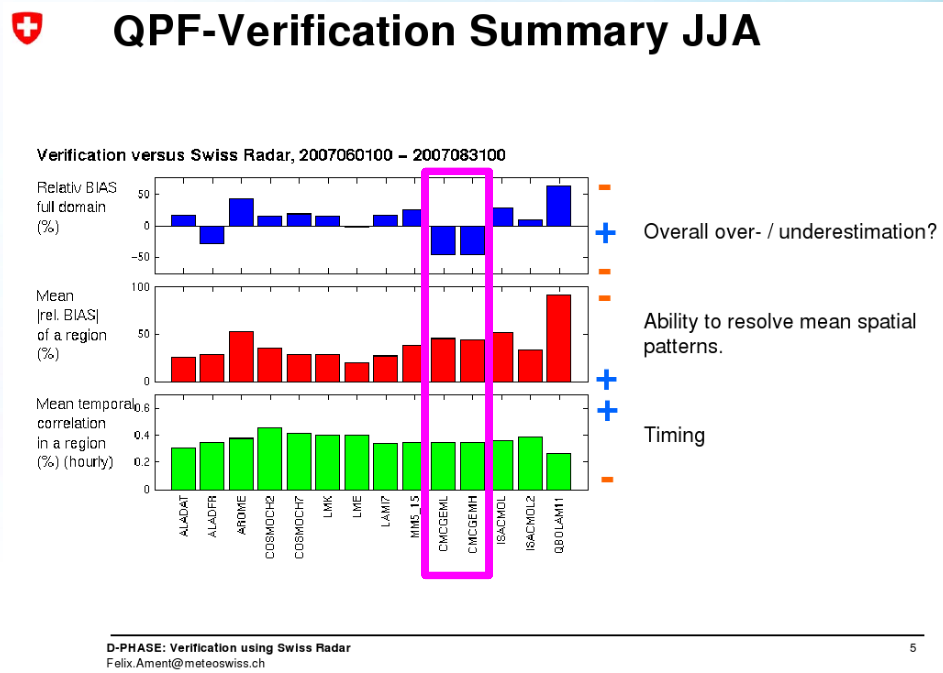
Precipitation Verification



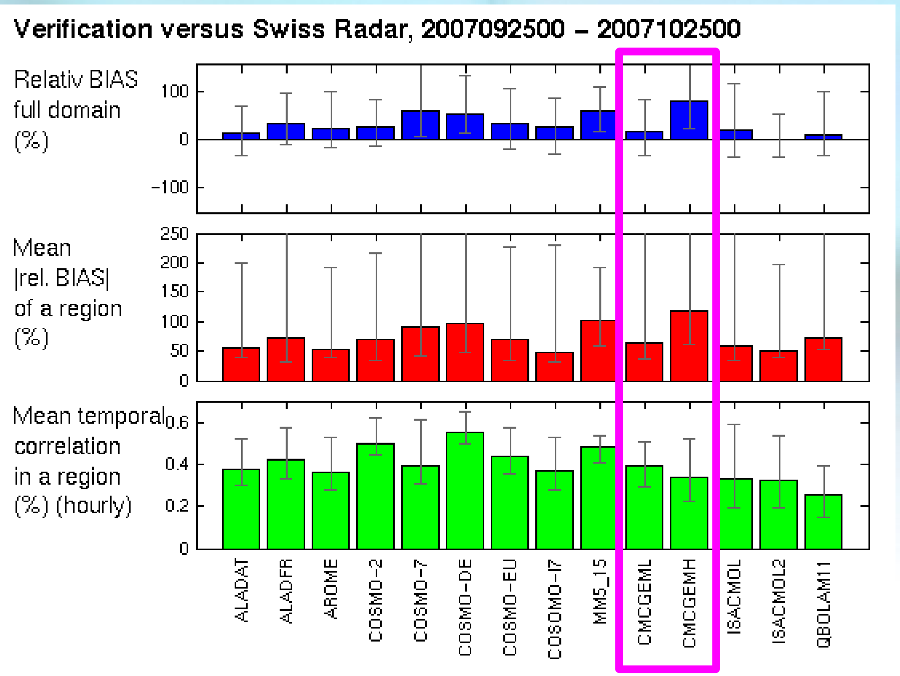
The GEM driving (**CMCGEML**) and high resolution (**CMCGEMH**) forecasts <u>too dry</u> for the JJA period compared to both observations and the other D-PHASE models.

Precipitation Verification

Radar Verification for JJA



Radar Verification for October



A 50% domain-averaged underprediction bias (JJA) has been replaced with an October overprediction bias following upgrade to microphysics scheme – further sensitivity testing will be beneficial

Milbrandt-Yau Multi-Moment Scheme *

FULL EXPERIMENTAL VERSION:

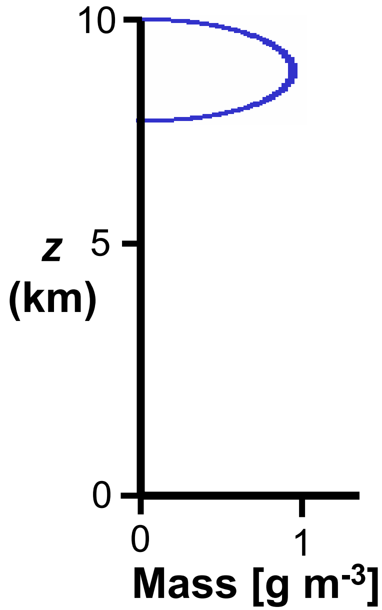
- Six hydrometeor categories:
  - 2 liquid: **cloud** and **rain**
  - 4 frozen: **ice**, **snow**, **graupel** and **hail**
- ~50 distinct microphysical processes
- Warm-rain scheme based on Cohard and Pinty (2000a)
- Ice-phase based on Murakami (1990), Ferrier (1994), Meyers et al. (1997), Reisner et al. (1998), etc.
- **Diagnostic-α_x** relations added for **double-moment***
- **Predictive equations for Z_x** added for **triple-moment***

*Milbrandt and Yau (2005a,b) [*J. Atmos. Sci.*]

Analytic bin model calculation:

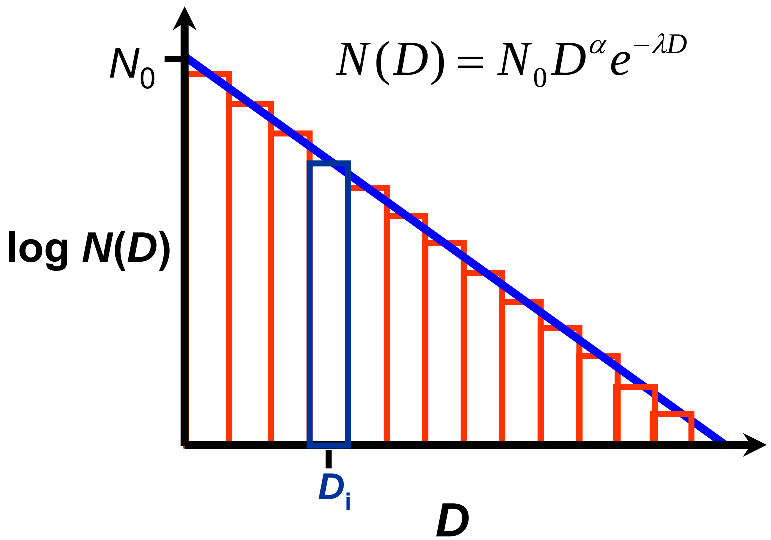
(1D column)

1. Prescribe $Q(z)$:



2. Compute $N(D_i, z)$:

[from a prescribed distribution]



3. Compute locations of each particle after sedimentation for time t:

For every size bin i:

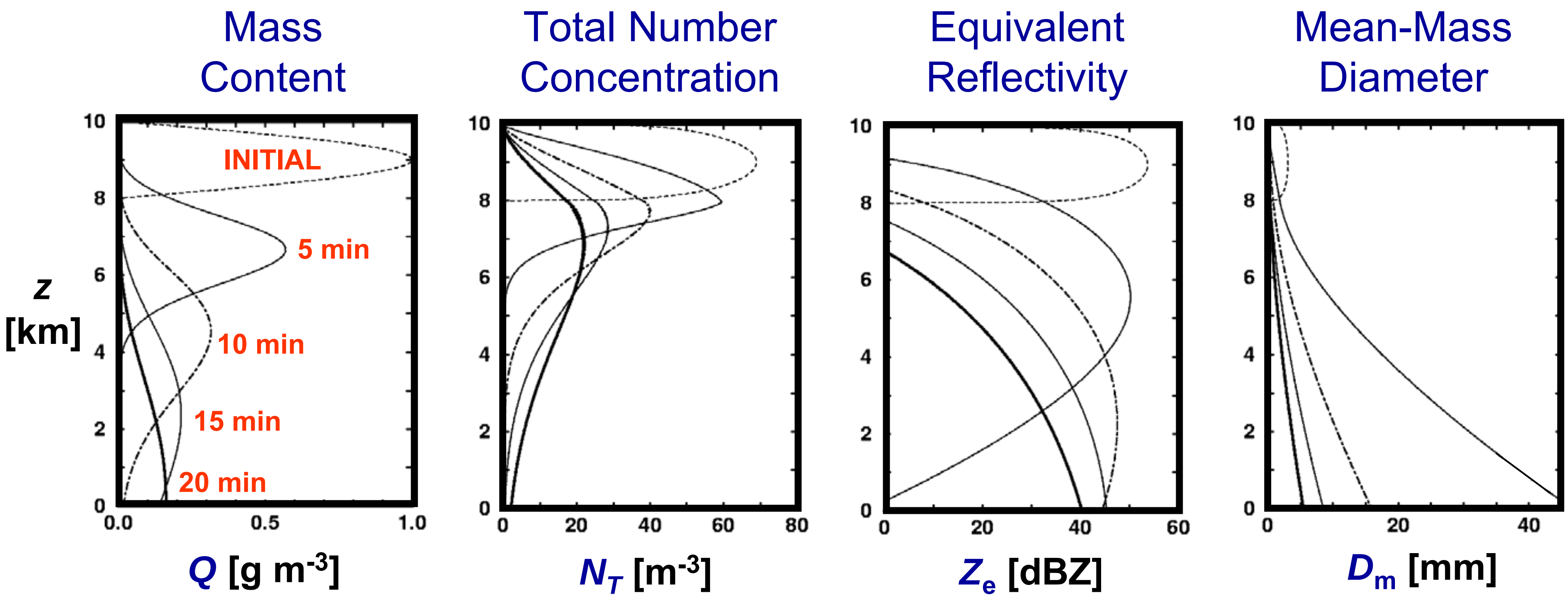
$$V_i(D_i) = aD^b$$

$$z_i(t) = z_i(0) - V_i(D_i) \cdot t$$

SEDIMENTATION:

Analytic bin model calculation:

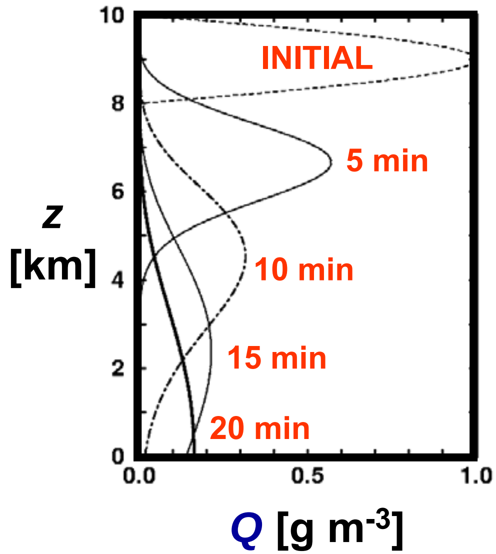
(1D column)



Contours every 5 min

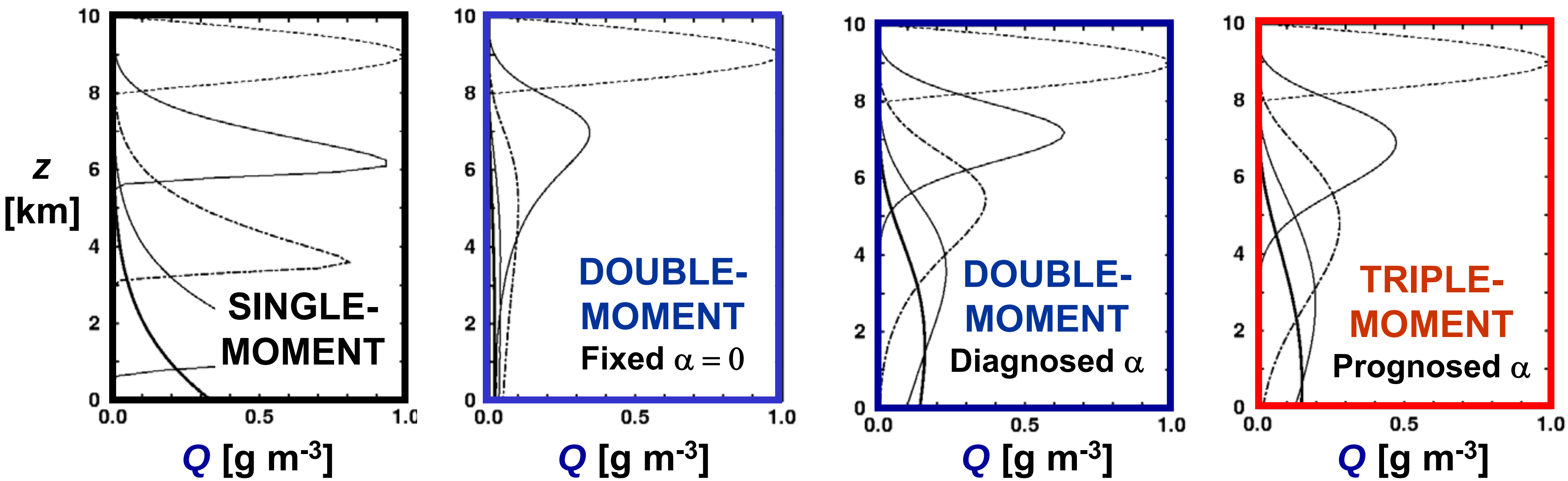
SEDIMENTATION: *BULK SCHEME vs. ANALYTIC*

Analytic model:



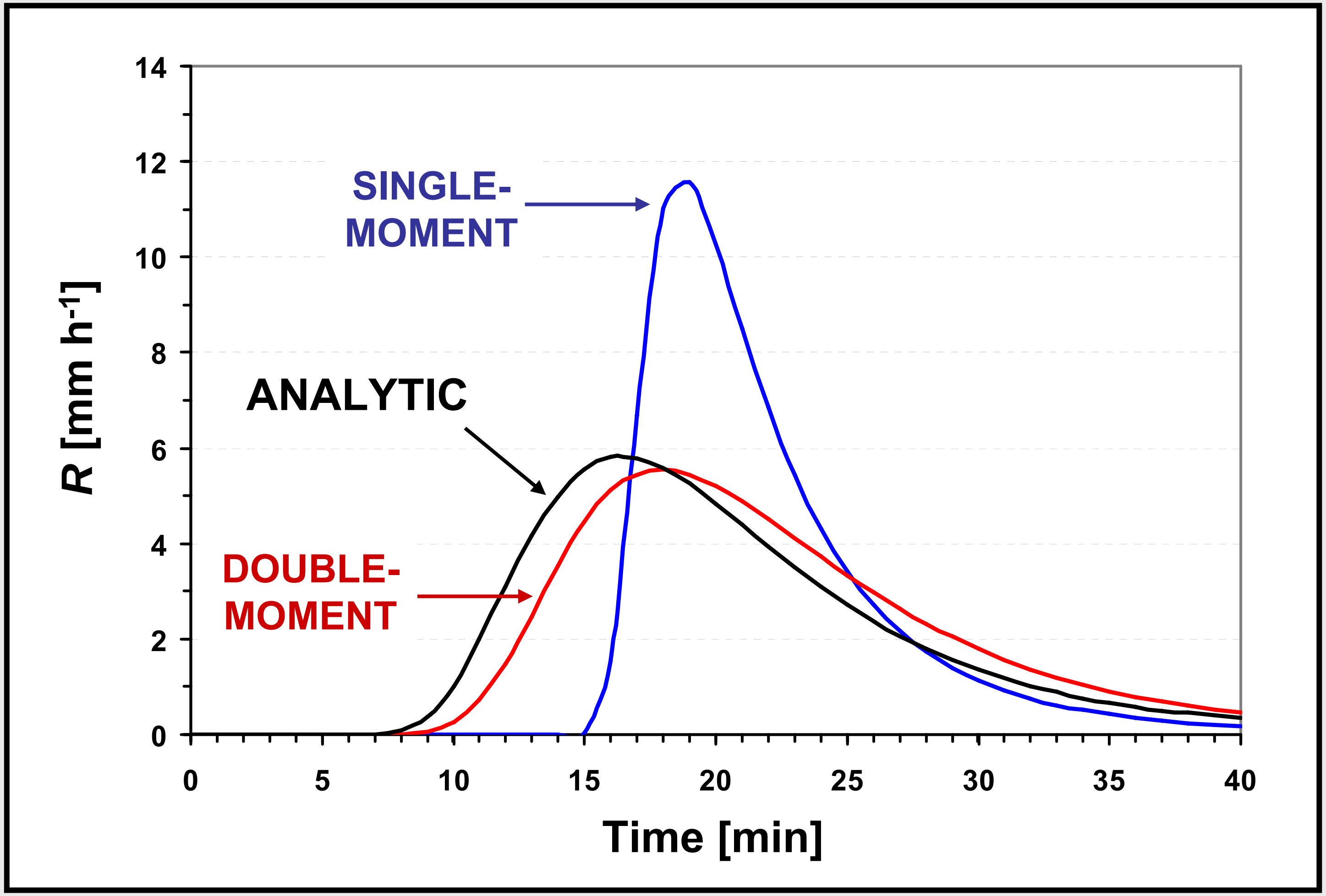
Mass Content

Bulk schemes:



Instantaneous <u>SURFACE PRECIPITATION RATE</u> (*R*)

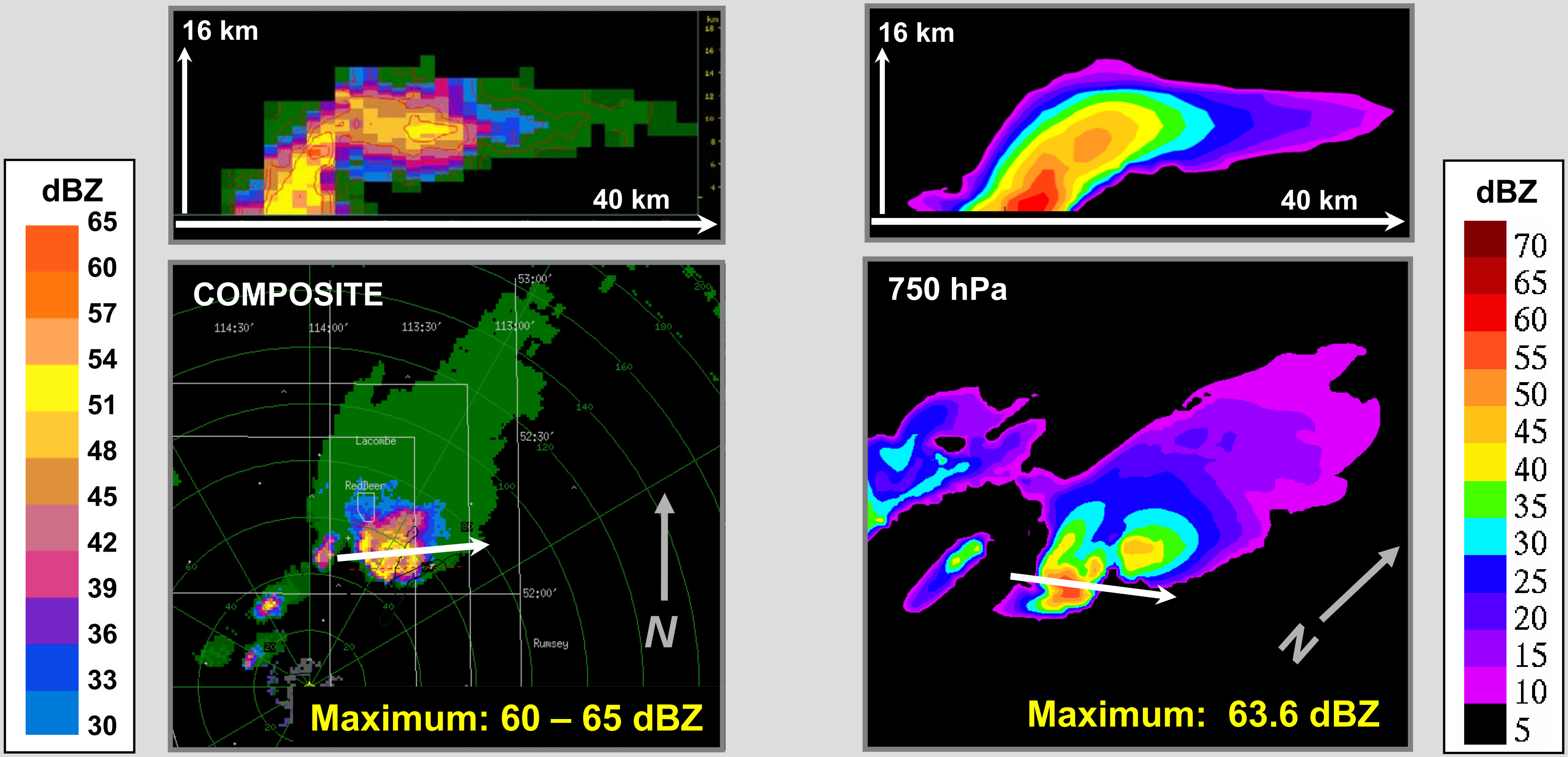
Due to Sedimentation Only in 1D:



CONTROL SIMULATION: Storm Structure: REFLECTIVITY

RADAR:
0030 UTC [6:30 pm]

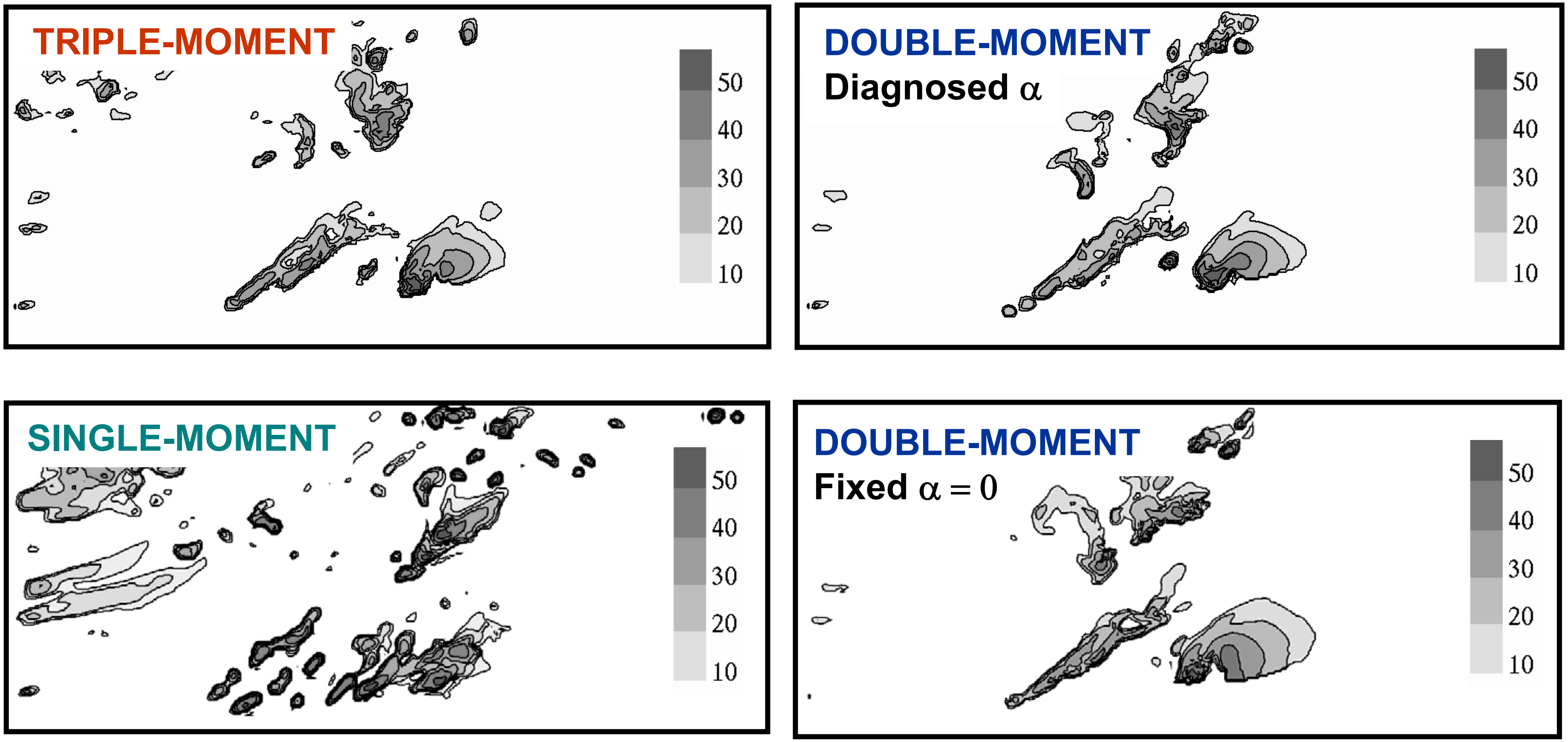
1-km SIMULATION:
4:30 h [6:30 pm]



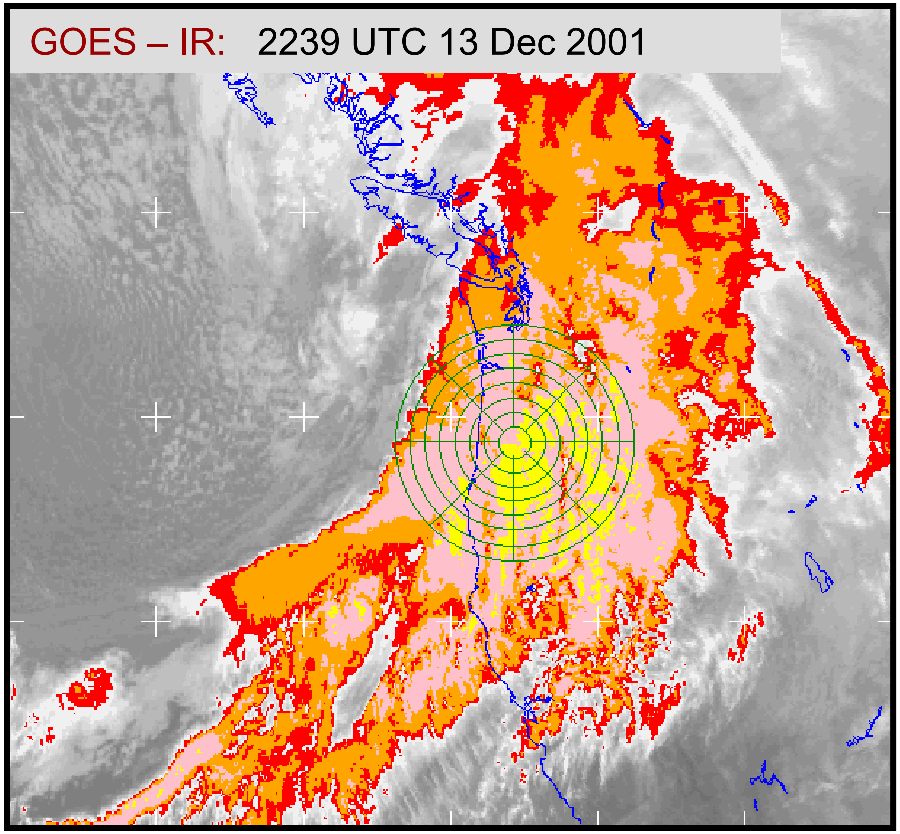
SENSITIVITY EXPERIMENTS: Equivalent Reflectivity from Hail

700 hPa:

Z_{eh} [dBZ]



13-14 Dec 2001 case during IMPROVE-2:



Characteristics:

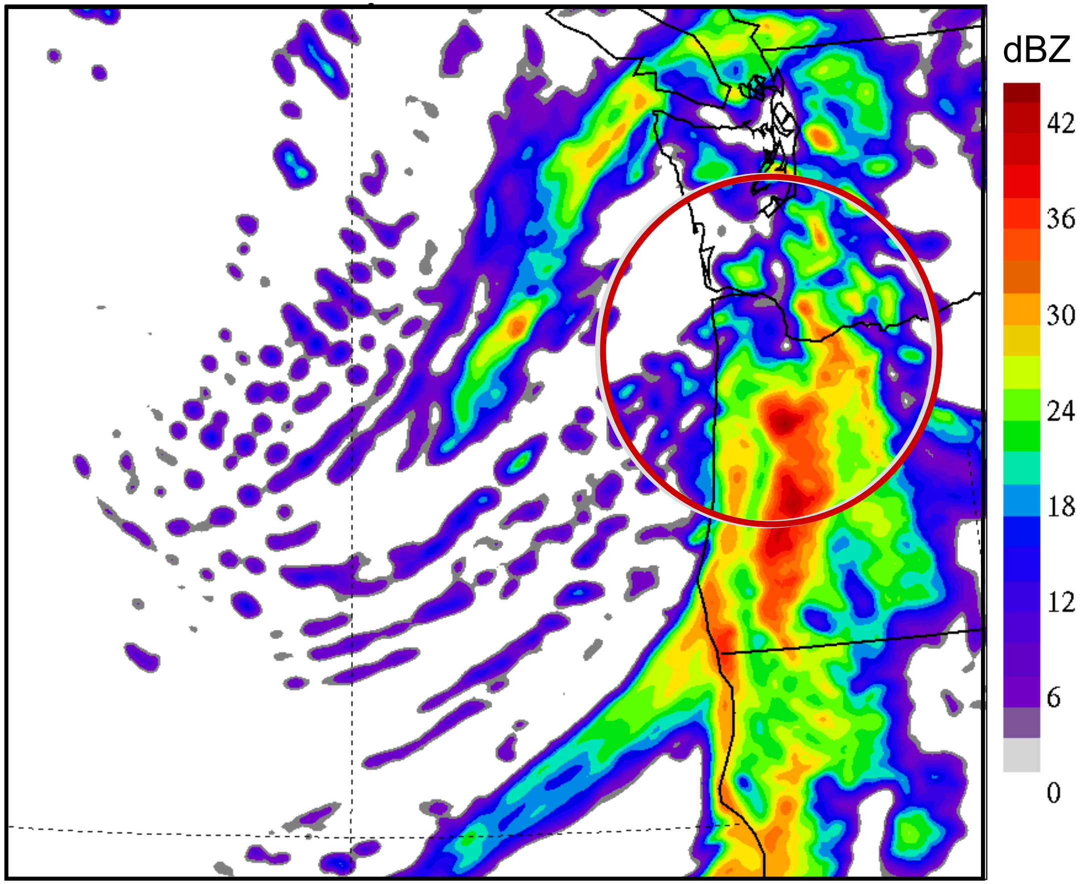
- large-scale baroclinic system
- strong low-level cross-barrier flow

Precipitation in IOP region:

- prefrontal showers;
- moderate to heavy stratiform rain (associated with mid-level baroclinic zone);
- surface frontal rain-band;
- transition to sporadic showers

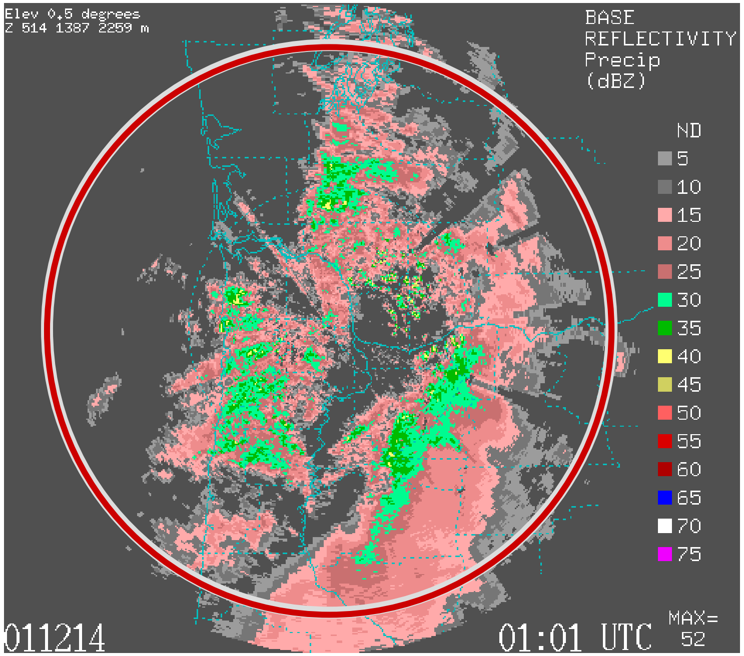
MC2 RUNS: **4-km, Triple-Moment**

Composite of Total Equivalent Reflectivity
(maximum value in column)



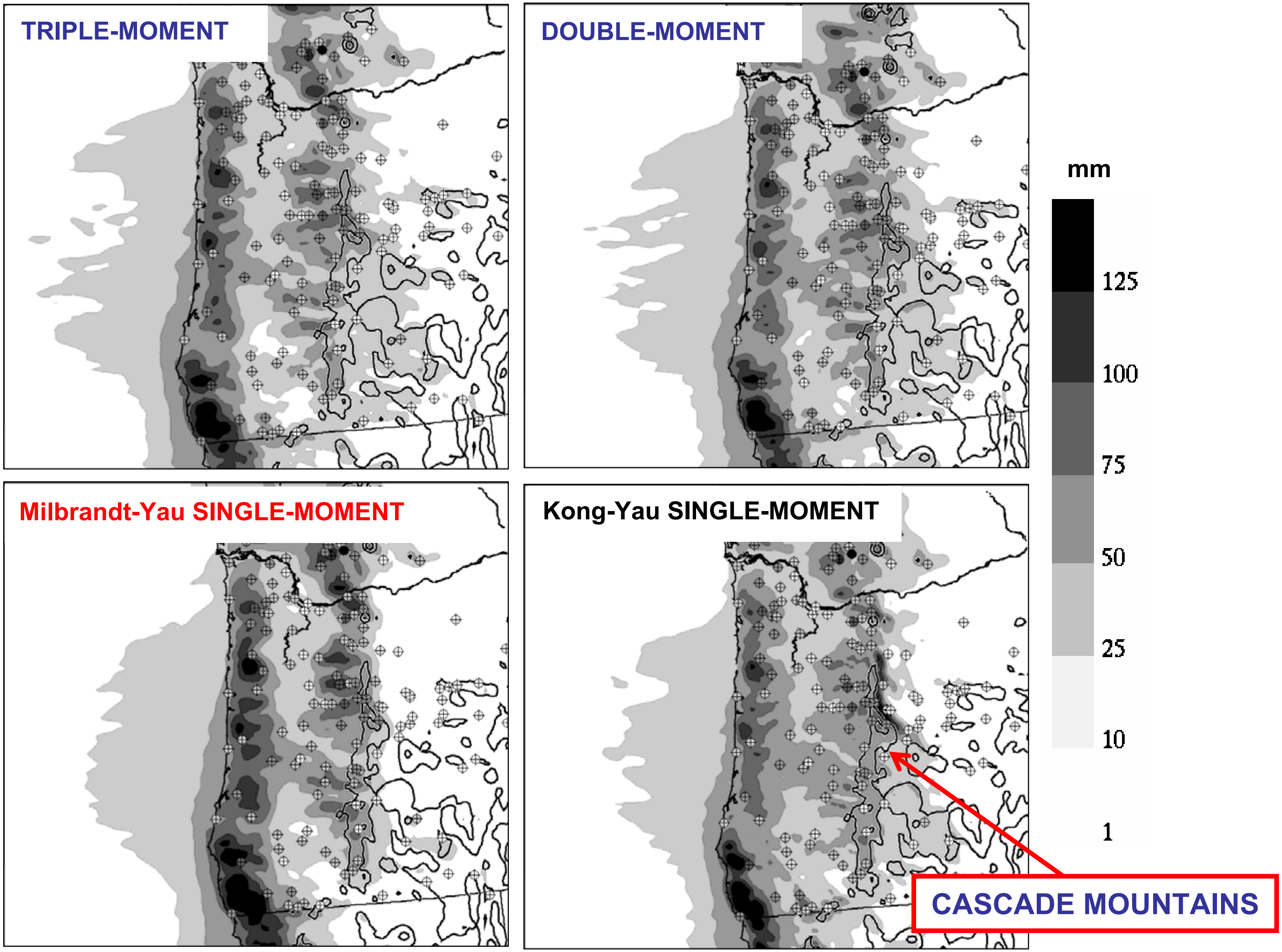
11 hour fcst valid 01:00Z December 14 2001

Portland Radar
PPI (0.5 deg)

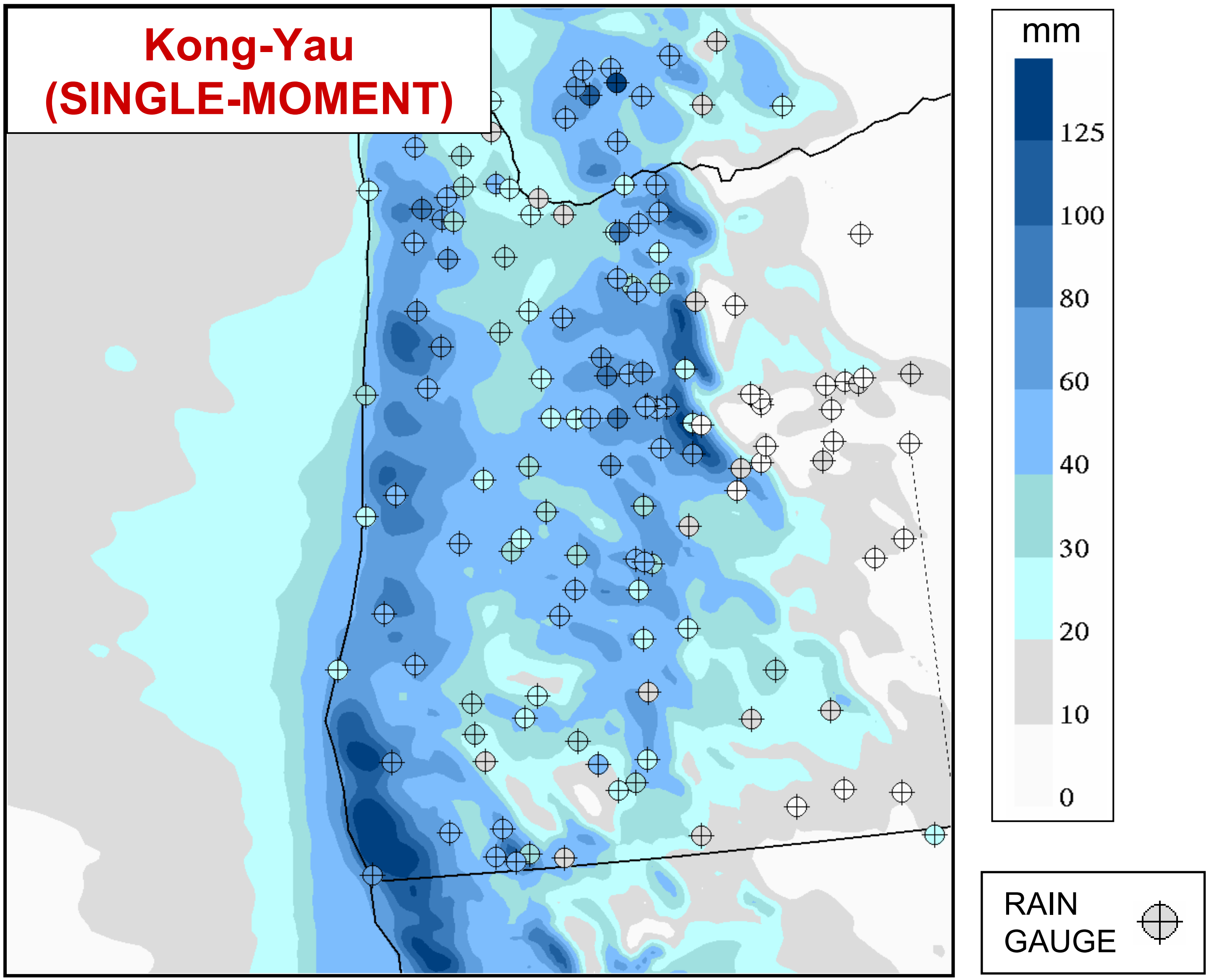


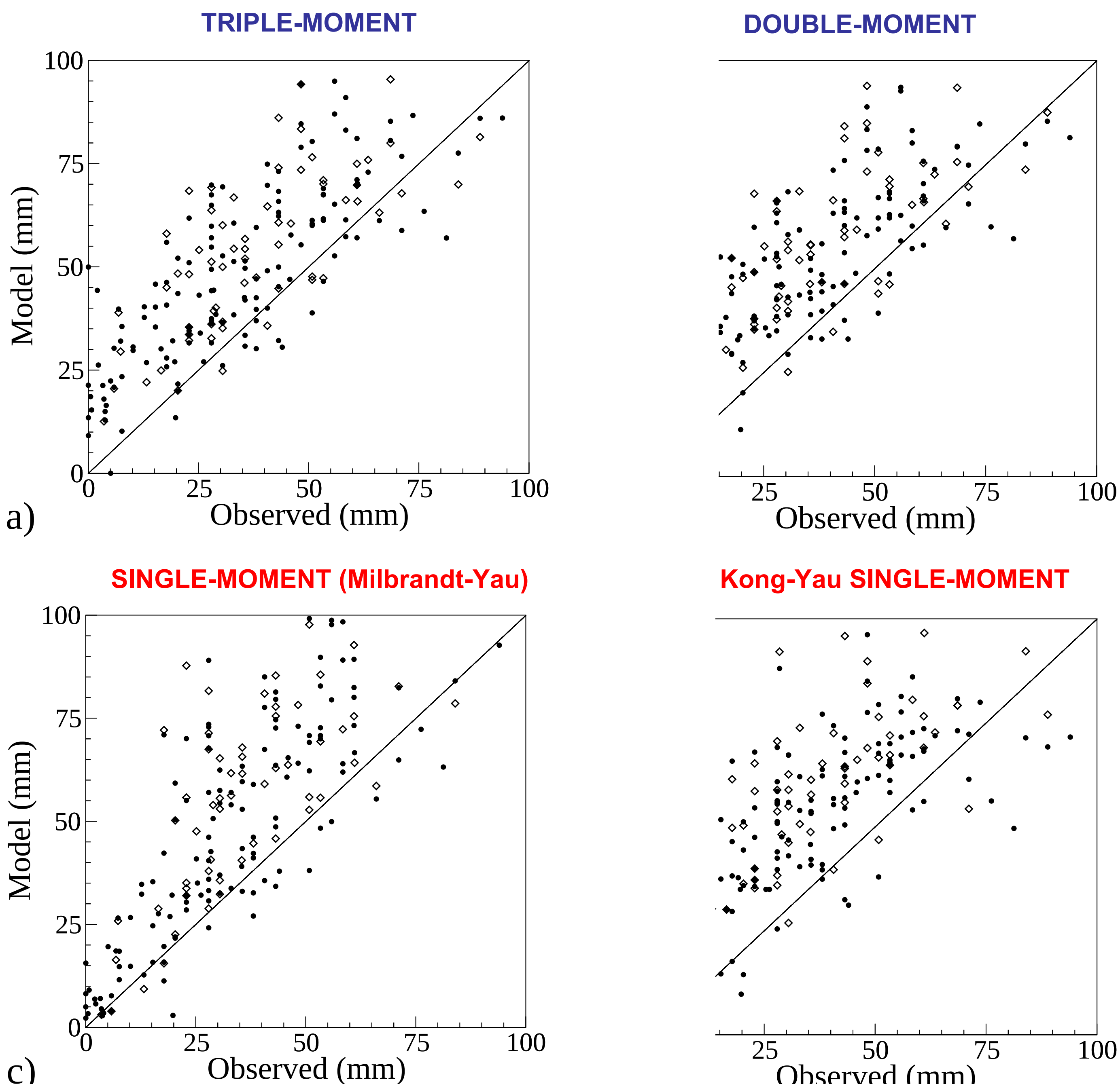
Range ring: 200 km radius

QPF: 4-km simulation, 18-h [1400 – 0800 UTC]

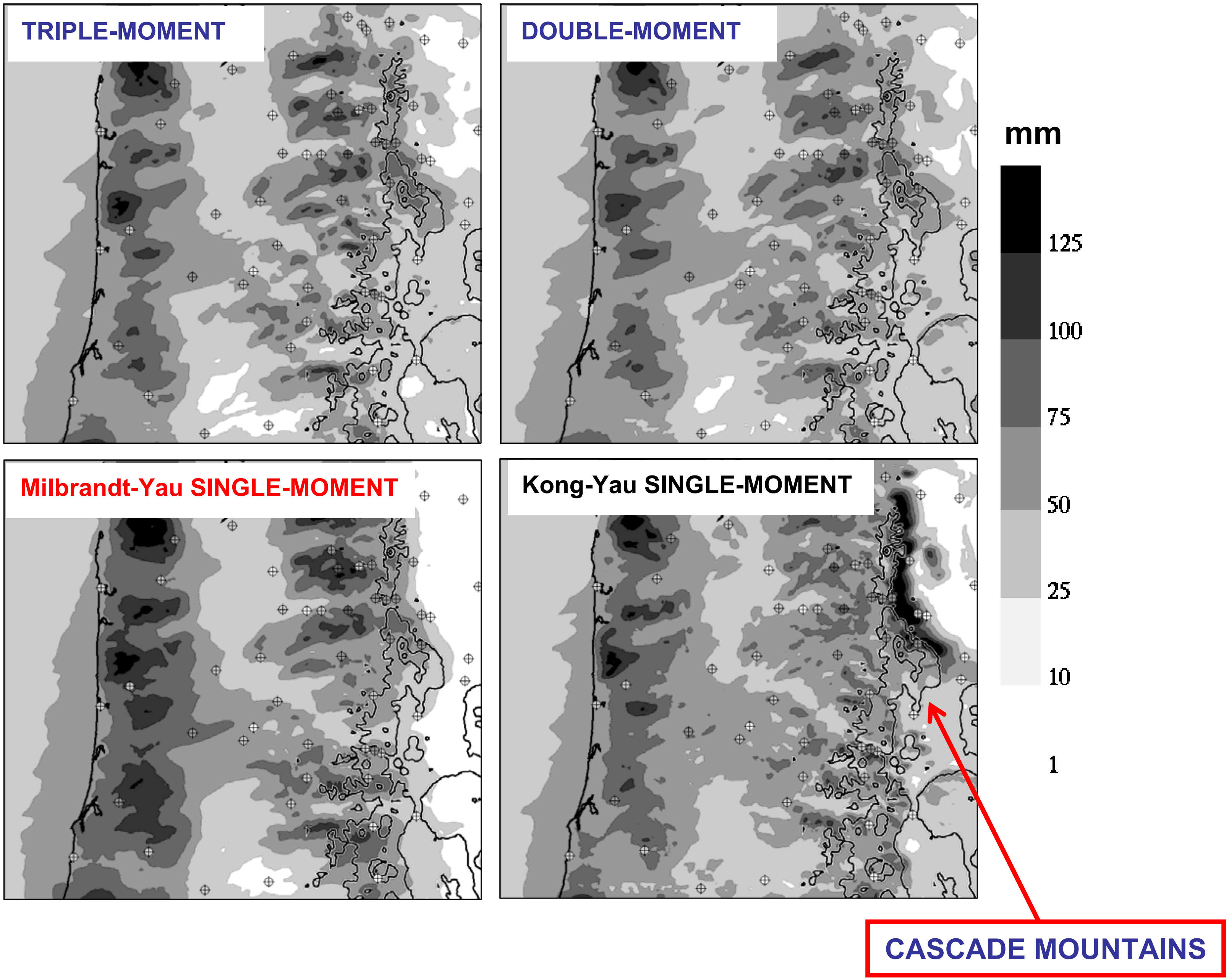


QPF: **4-km simulation, 18-h** [1400 – 0800 UTC]

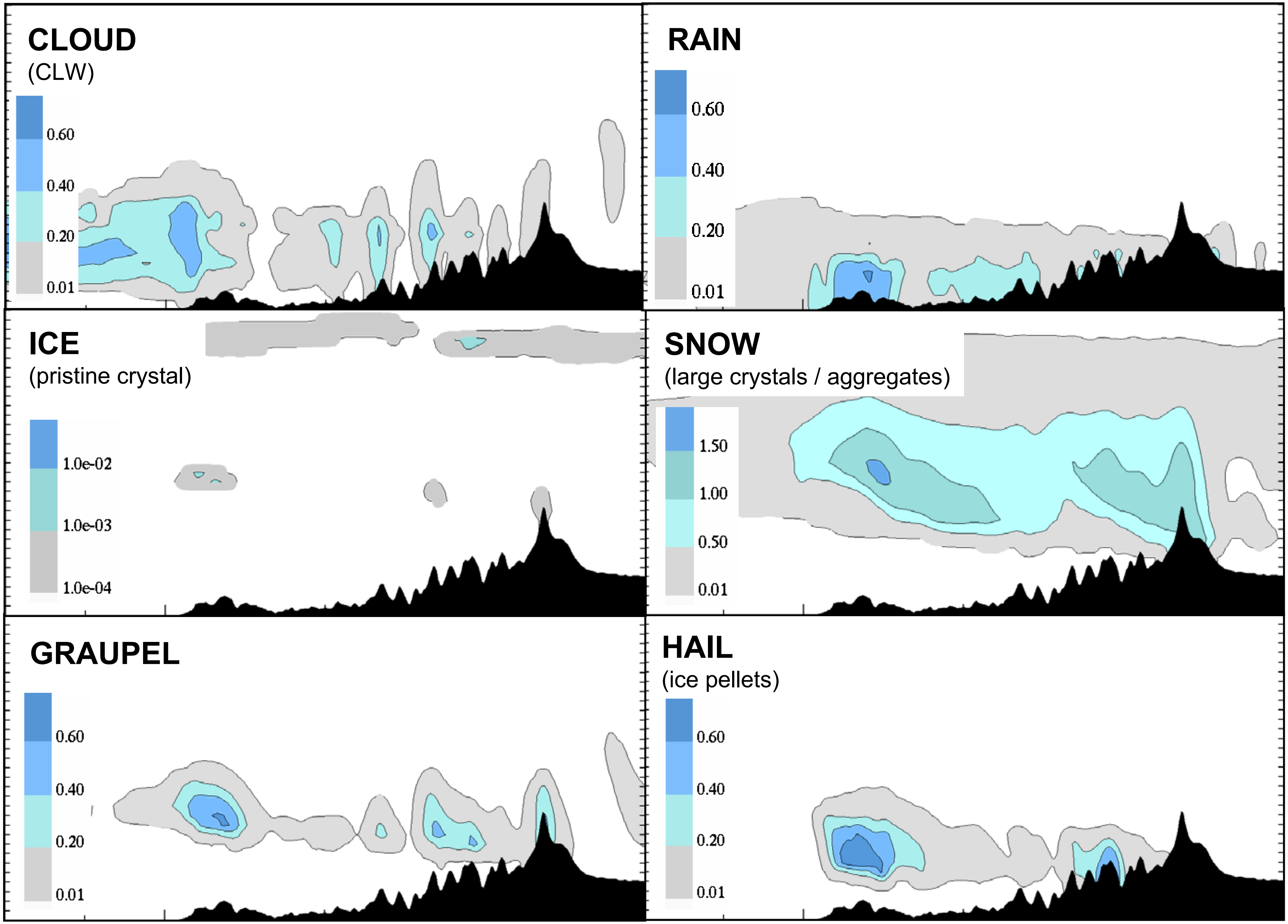



TRIPLE-MOMENT
DOUBLE-MOMENT
SINGLE-MOMENT (Milbrandt-Yau)
Kong-Yau SINGLE-MOMENT
Model (mm)
Observed (mm)
0
25
50
75
100
a)
c)

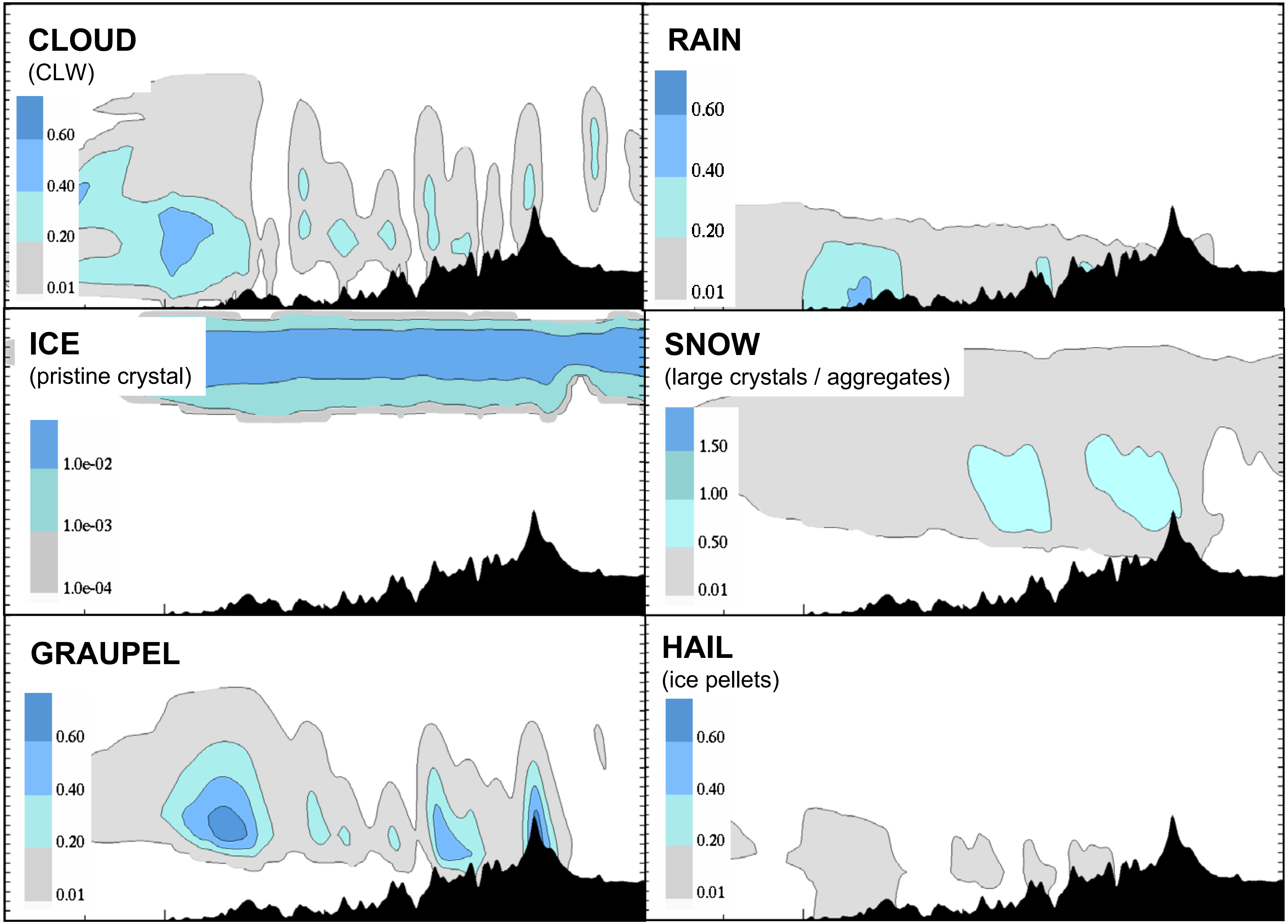
QPF: 1-km simulation, 18-h [1400 – 0800 UTC]



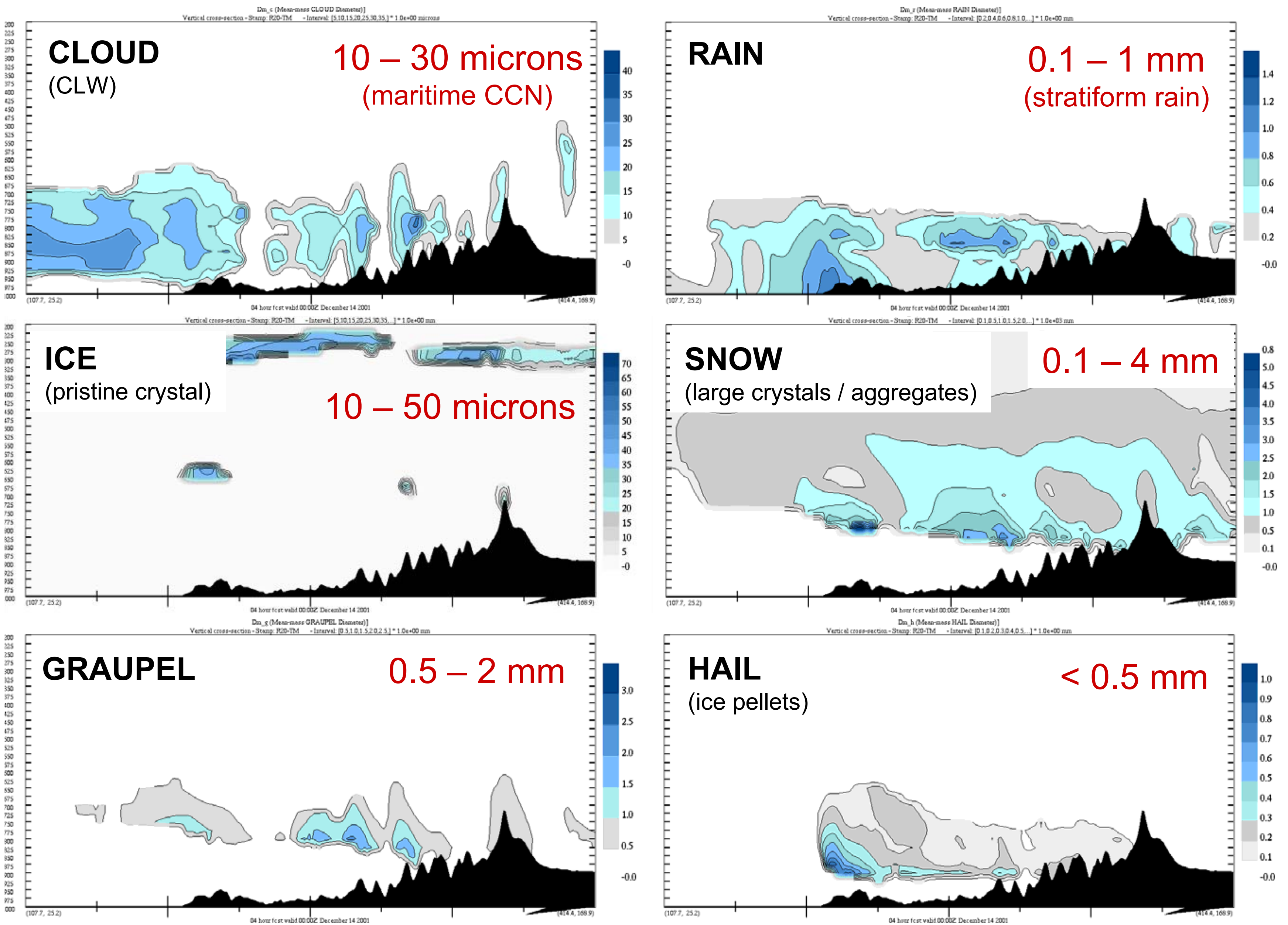
MICROPHYSICS: 1-km, Triple-Moment MASS CONTENTS [g m^{-3}]



MICROPHYSICS: 1-km, Single-Moment [g m^{-3}]



MICROPHYSICS: 1-km, Triple-Moment — Mean-Mass Diameters



Milbrandt-Yau Multi-Moment Scheme

CURRENT OPTIMZED VERSIONS :

Single-moment version

- Six hydrometeor categories
- Single-moment (Q_x) for each
- Cost is ~ 5% additional total CPU time (vs. current 4-category scheme)
- **To be implemented in the GEM-LAM 2.5-km experimental domains early 2008**

Double-moment version

- Six hydrometeor categories
- double-moment (Q_x, N_x) for each [fixed-α_x]
- Cost is ~ 18% additional total CPU time (vs. current scheme)

Milbrandt-Yau Multi-Moment Scheme

UPCOMING VERSION:

Prototype cloud scheme for the 2010 Winter Olympics

Operational version *

CLOUD single-moment (Q_c,)
RAIN double-moment (Q_r, N_r) [diagnostic-α_r]
ICE/SNOW double-moment (Q_i, N_i) [hybrid category]
GRAUPEL single-moment (Q_g)
HAIL double-moment (Q_h, N_h) [diagnostic-α_h]

Expected Cost: < 15% additional total CPU time (vs. current scheme)

DANKE