Impact of size distribution assumptions on surface precipitation and storm dynamics during a low-topped supercell case

K. Van Weverberg [(1)]

N.P.M. van Lipzig [(1)], L. Delobbe [(2)]

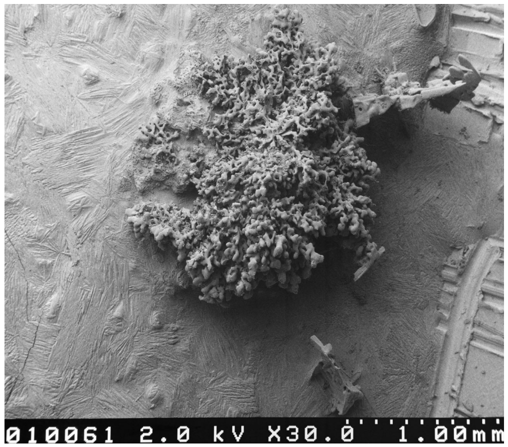
(1) Physical and Regional Geography Research Group, K.U.Leuven, Belgium

(2) Royal Meteorological Institute, Belgium

DEPARTMENT OF EARTH AND ENVIRONMENTAL SCIENCES
K.U.LEUVEN - BELGIUM

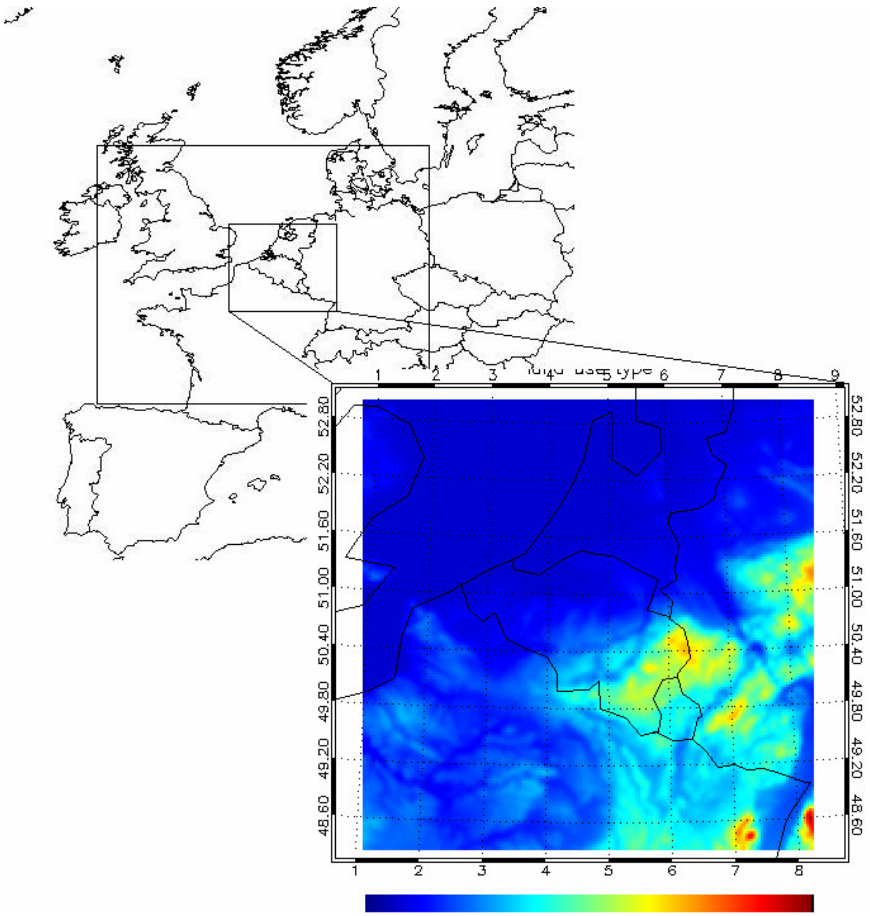
RMI

Motivation



- Contrasting findings in literature on the influence of the size distribution characteristics of the largest precipitating ice species in bulk one-moment schemes on thermodynamics and surface rain.
- Influence of other precipitation species rarely investigated
- Recently big influence found of the moisture advection on surface precipitation in models with explicit convection (Skamarock and Weisman 2009)

Materials and Methods



Advanced Regional Prediction System (ARPS)

Non-hydrostatic mesoscale model (Xue et al. 2000, 2001), developed at CAPS

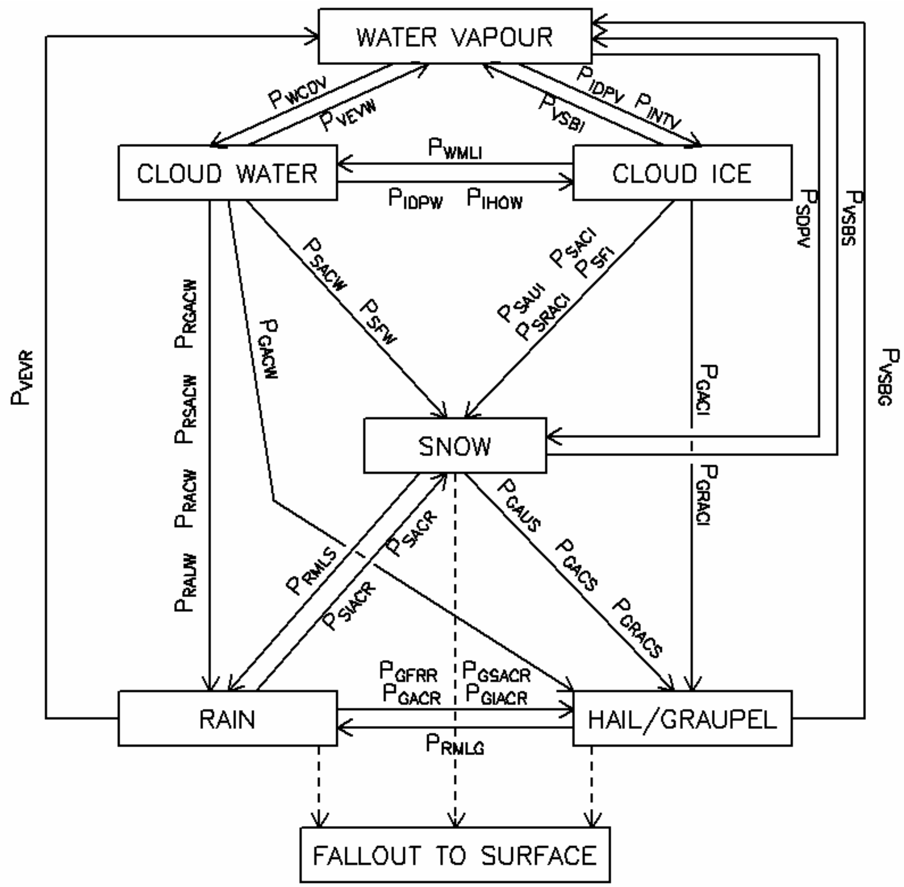
• Double one-way nested grid with successive grid resolution of 9 km and 3 km. Smallest model domain covers Belgium and boundary and initial conditions are derived from ECMWF operational analysis (0.25° resolution). Vertically compressed grid with 50 levels.

• No convection parameterization used in smallest domain, Kain-Fritsch convection parameterization in larger domain

• 1.5-order TKE turbulence scheme

• Land surface processes parameterized following Noilhan and Planton (1989)

Materials and Methods



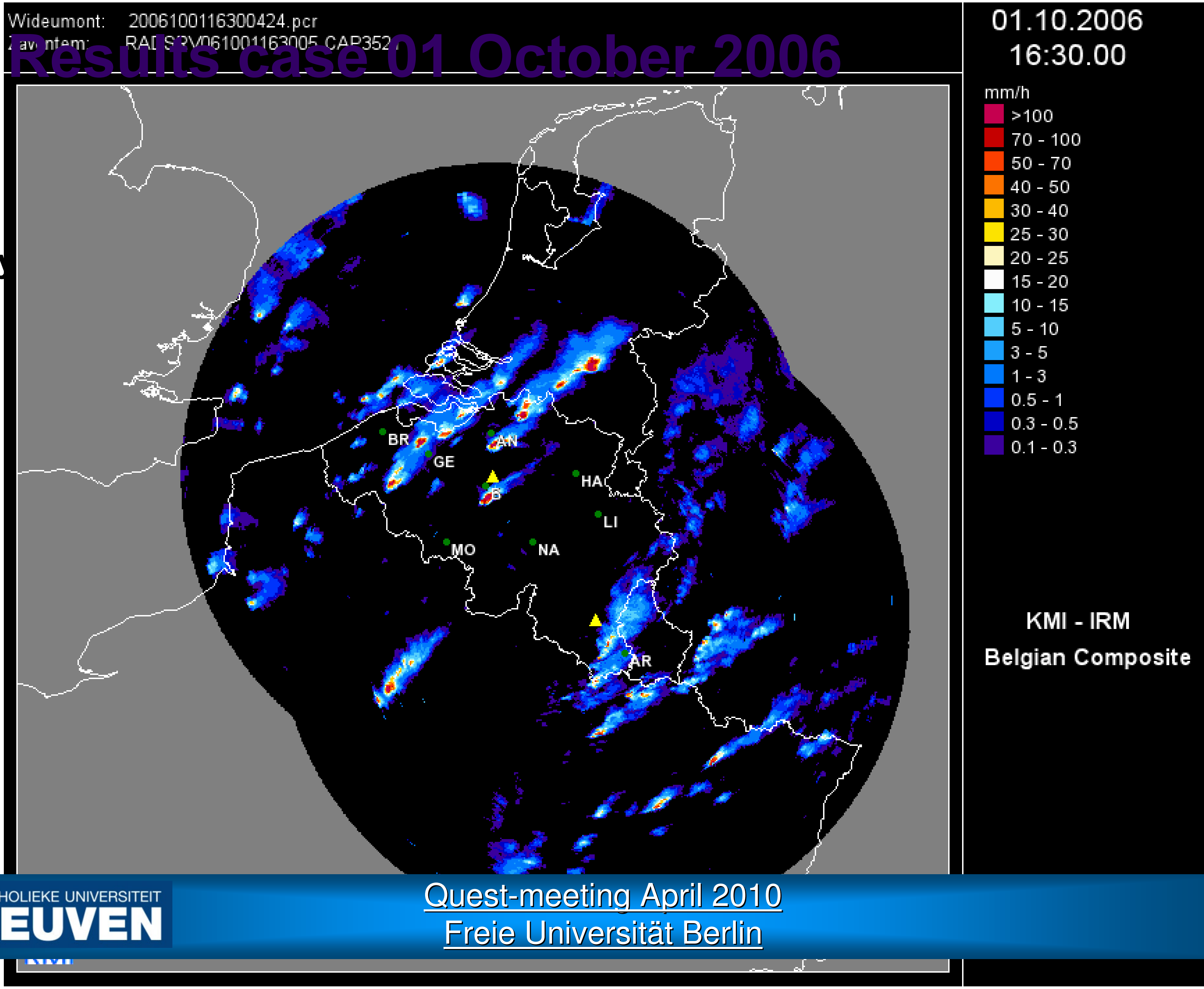
Advanced Regional Prediction System (ARPS)

Lin et al. (1983) one moment bulk microphysics scheme

Materials and Methods: microphysics sensitivity experiments

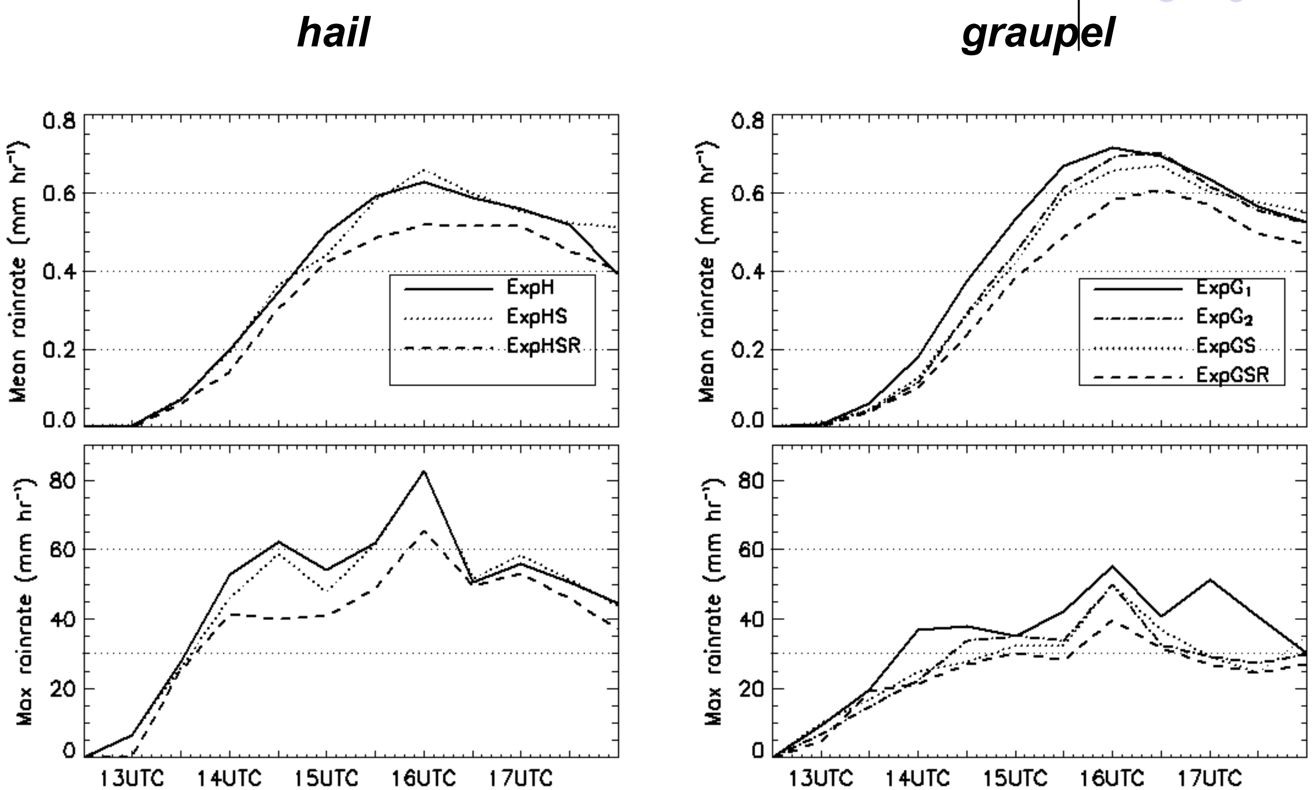
	ExpH	ExpG1	ExpG2	ExpHS	ExpGS	ExpHSR	ExpGSR
N_{0R}	0.08 *(Marshall and Palmer 1948)*	0.08 *(Marshall and Palmer 1948)*	0.08 *(Marshall and Palmer 1948)*	0.08 *(Marshall and Palmer 1948)*	0.08 *(Marshall and Palmer 1948)*	$0.07106(10^3\rho q_r)^{0.648}$ *(Zhang et al. 2008)*	$0.07106(10^3\rho q_r)^{0.648}$ *(Zhang et al. 2008)*
λ_R	$\left(\frac{\pi\rho_r N_{0r}}{\rho q_r}\right)^{0.25}$	$\left(\frac{\pi\rho_r N_{0r}}{\rho q_r}\right)^{0.25}$	$\left(\frac{\pi\rho_r N_{0r}}{\rho q_r}\right)^{0.25}$	$\left(\frac{\pi\rho_r N_{0r}}{\rho q_r}\right)^{0.25}$	$\left(\frac{\pi\rho_r N_{0r}}{\rho q_r}\right)^{0.25}$	$\left(\frac{\pi\rho_r N_{0r}}{\rho q_r}\right)^{0.25}$	$\left(\frac{\pi\rho_r N_{0r}}{\rho q_r}\right)^{0.25}$
V_R	$\frac{2115\Gamma(4+0.8)}{6\lambda_r^{0.8}}\left(\frac{\rho_0}{\rho}\right)^{1/2}$ *(Liu and Orville 1969)*	$\frac{2115\Gamma(4+0.8)}{6\lambda_r^{0.8}}\left(\frac{\rho_0}{\rho}\right)^{1/2}$ *(Liu and Orville 1969)*	$\frac{2115\Gamma(4+0.8)}{6\lambda_r^{0.8}}\left(\frac{\rho_0}{\rho}\right)^{1/2}$ *(Liu and Orville 1969)*	$\frac{2115\Gamma(4+0.8)}{6\lambda_r^{0.8}}\left(\frac{\rho_0}{\rho}\right)^{1/2}$ *(Liu and Orville 1969)*	$\frac{2115\Gamma(4+0.8)}{6\lambda_r^{0.8}}\left(\frac{\rho_0}{\rho}\right)^{1/2}$ *(Liu and Orville 1969)*	$\frac{2115\Gamma(4+0.8)}{6\lambda_r^{0.8}}\left(\frac{\rho_0}{\rho}\right)^{1/2}$ *(Liu and Orville 1969)*	$\frac{2115\Gamma(4+0.8)}{6\lambda_r^{0.8}}\left(\frac{\rho_0}{\rho}\right)^{1/2}$ *(Liu and Orville 1969)*
N_{0S}	0.03 *(Gunn and Marshall 1958)*	0.03 *(Gunn and Marshall 1958)*	0.03 *(Gunn and Marshall 1958)*	$0.02\exp[0.12(T_0-T)]$ *(Houze et al. 1979)*	$0.02\exp[0.12(T_0-T)]$ *(Houze et al. 1979)*	$0.02\exp[0.12(T_0-T)]$ *(Houze et al. 1979)*	$0.02\exp[0.12(T_0-T)]$ *(Houze et al. 1979)*
λ_S	$\left(\frac{\pi\rho_s N_s}{\rho q_s}\right)^{0.25}$ *(Lin et al. 1983)*	$\left(\frac{\pi\rho_s N_s}{\rho q_s}\right)^{0.25}$ *(Lin et al. 1983)*	$\left(\frac{\pi\rho_s N_s}{\rho q_s}\right)^{0.25}$ *(Lin et al. 1983)*	$\left(\frac{0.0074N_{0s}\Gamma(2.1+1)}{\rho q_s}\right)^{1/(2.1+1)}$ *(Locatelli and Hobbs. 1974)*	$\left(\frac{0.0074N_{0s}\Gamma(2.1+1)}{\rho q_s}\right)^{1/(2.1+1)}$ *(Locatelli and Hobbs. 1974)*	$\left(\frac{0.0074N_{0s}\Gamma(2.1+1)}{\rho q_s}\right)^{1/(2.1+1)}$ *(Locatelli and Hobbs. 1974)*	$\left(\frac{0.0074N_{0s}\Gamma(2.1+1)}{\rho q_s}\right)^{1/(2.1+1)}$ *(Locatelli and Hobbs. 1974)*
V_S	$\frac{152.93\Gamma(4+0.25)}{6\lambda_s^{0.25}}\left(\frac{\rho_0}{\rho}\right)^{1/2}$ *(Locatelli and Hobbs. 1974)*	$\frac{152.93\Gamma(4+0.25)}{6\lambda_s^{0.25}}\left(\frac{\rho_0}{\rho}\right)^{1/2}$ *(Locatelli and Hobbs. 1974)*	$\frac{152.93\Gamma(4+0.25)}{6\lambda_s^{0.25}}\left(\frac{\rho_0}{\rho}\right)^{1/2}$ *(Locatelli and Hobbs. 1974)*	$\frac{209.60\Gamma(0.28+2.1+1)}{\lambda_s^{0.28}\Gamma(2.1+1)}$ *(Locatelli and Hobbs. 1974)*	$\frac{209.60\Gamma(0.28+2.1+1)}{\lambda_s^{0.28}\Gamma(2.1+1)}$ *(Locatelli and Hobbs. 1974)*	$\frac{209.60\Gamma(0.28+2.1+1)}{\lambda_s^{0.28}\Gamma(2.1+1)}$ *(Locatelli and Hobbs. 1974)*	$\frac{209.60\Gamma(0.28+2.1+1)}{\lambda_s^{0.28}\Gamma(2.1+1)}$ *(Locatelli and Hobbs. 1974)*
N_{0H}	0.0004 *(Federer and Waldvogel 1975)*	4.000 *(Gilmore et al. 2004)*	4.000 *(Gilmore et al. 2004)*	0.0004 *(Federer and Waldvogel 1975)*	4.000 *(Gilmore et al. 2004)*	0.0004 *(Federer and Waldvogel 1975)*	4.000 *(Gilmore et al. 2004)*
λ_H	$\left(\frac{\pi\rho_h N_h}{\rho q_h}\right)^{0.25}$ *(Lin et al. 1983)*	$\left(\frac{\pi\rho_h N_h}{\rho q_h}\right)^{0.25}$ *(Lin et al. 1983)*	$\left(\frac{0.0702N_{0h}\Gamma(2.7+1)}{\rho q_h}\right)^{1/(2.7+1)}$ *(Locatelli and Hobbs. 1974)*	$\left(\frac{\pi\rho_h N_h}{\rho q_h}\right)^{0.25}$ *(Lin et al. 1983)*	$\left(\frac{0.0702N_{0h}\Gamma(2.7+1)}{\rho q_h}\right)^{1/(2.7+1)}$ *(Locatelli and Hobbs. 1974)*	$\left(\frac{\pi\rho_h N_h}{\rho q_h}\right)^{0.25}$ *(Lin et al. 1983)*	$\left(\frac{0.0702N_{0h}\Gamma(2.7+1)}{\rho q_h}\right)^{1/(2.7+1)}$ *(Locatelli and Hobbs. 1974)*
V_H	$\frac{\Gamma(4.5)}{6\lambda_h^{0.5}}\left(\frac{4g\rho_h}{3C_D\rho}\right)^{1/2}$ *(Wisner et al. 1972)*	$\frac{\Gamma(4.5)}{6\lambda_h^{0.5}}\left(\frac{4g\rho_h}{3C_D\rho}\right)^{1/2}$ *(Wisner et al. 1972)*	$\frac{234.42\Gamma(0.37+2.7+1)}{\lambda_h^{0.37}\Gamma(2.7+1)}$ *(Locatelli and Hobbs. 1974)*	$\frac{\Gamma(4.5)}{6\lambda_h^{0.5}}\left(\frac{4g\rho_h}{3C_D\rho}\right)^{1/2}$ *(Wisner et al. 1972)*	$\frac{234.42\Gamma(0.37+2.7+1)}{\lambda_h^{0.37}\Gamma(2.7+1)}$ *(Locatelli and Hobbs. 1974)*	$\frac{\Gamma(4.5)}{6\lambda_h^{0.5}}\left(\frac{4g\rho_h}{3C_D\rho}\right)^{1/2}$ *(Wisner et al. 1972)*	$\frac{234.42\Gamma(0.37+2.7+1)}{\lambda_h^{0.37}\Gamma(2.7+1)}$ *(Locatelli and Hobbs. 1974)*

Results case 01 October 2006



Results: surface precipitation

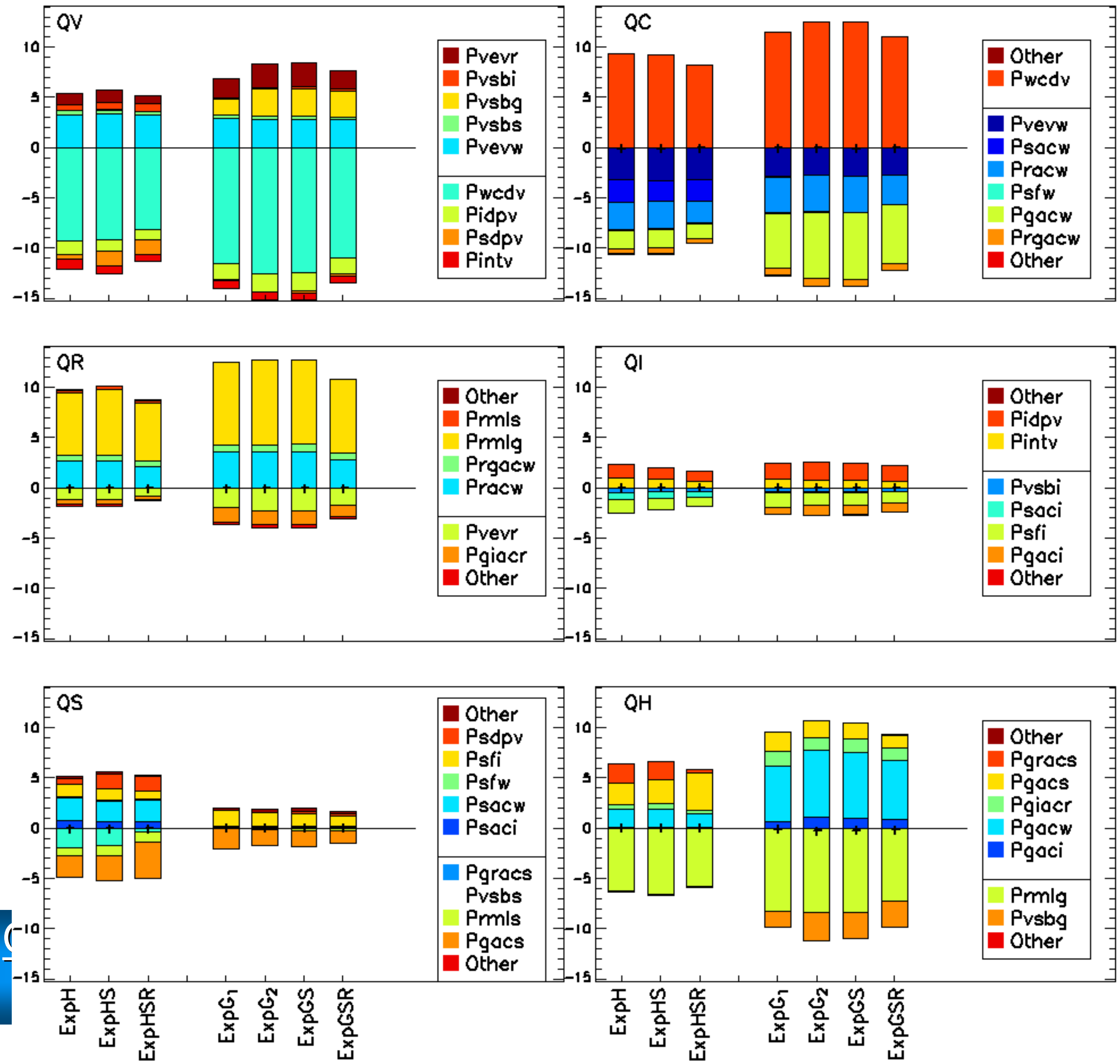
	Mean Precip (mm)	Max Precip (mm)
Radar	1.6	35.0
ExpH	3.1	42.5
$ExpG_1$	3.5	34.4
$ExpG_2$	3.4	37.0



Results: graupel – hail difference
Impact on microphysical conversions

$$PE = \frac{P}{Pwcdv + Pidpv + Psdpv + Pintv}$$

	Mean Precipitation (mm)	Max Precipitation (mm)	**Precipitation Efficiency**
Observed	1.6	35.0	
ExpH	3.1	42.5	**30.7**
$ExpG_1$	3.5	34.4	**28.6**
$ExpG_2$	3.4	37.0	**24.9**



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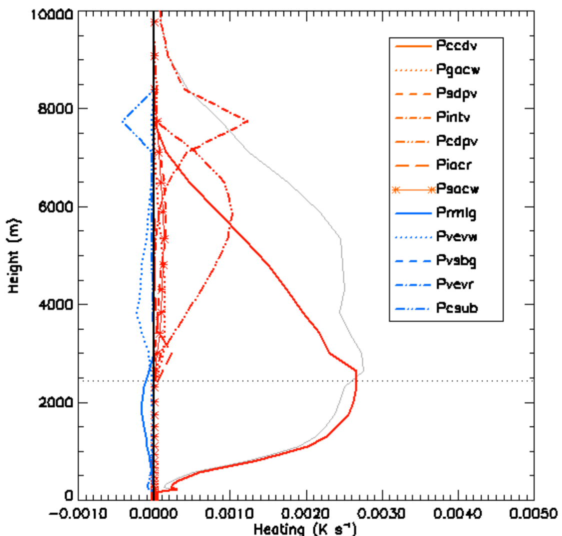
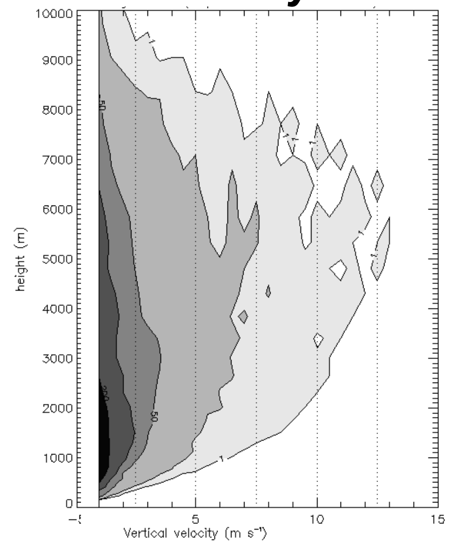
Results: graupel – hail difference

Impact on thermodynamics: updrafts

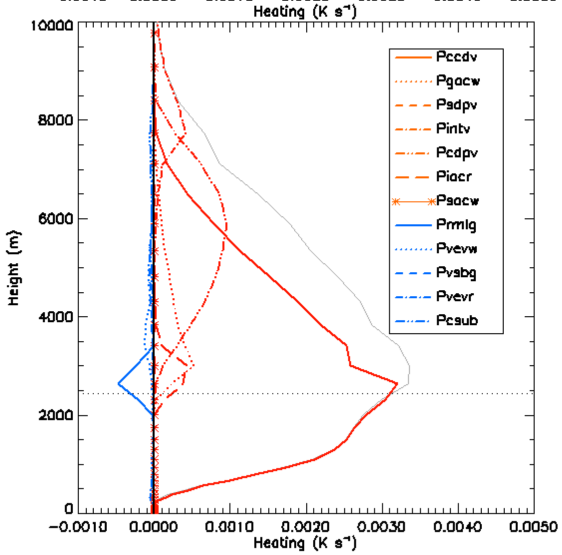
Total latent heating | ***Vertical velocity CFAD's***

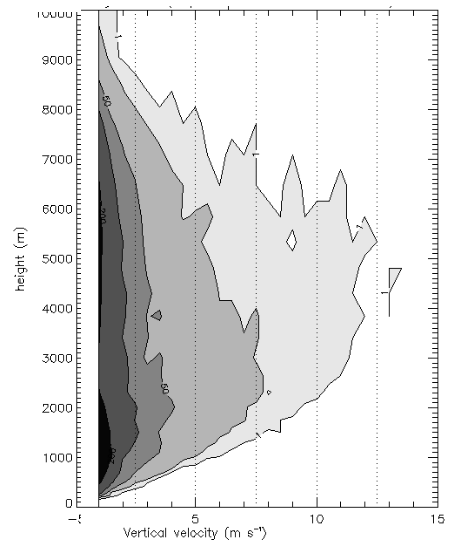
Hail
(2.4 m s⁻¹)





Graupel
(2.8 m s⁻¹)





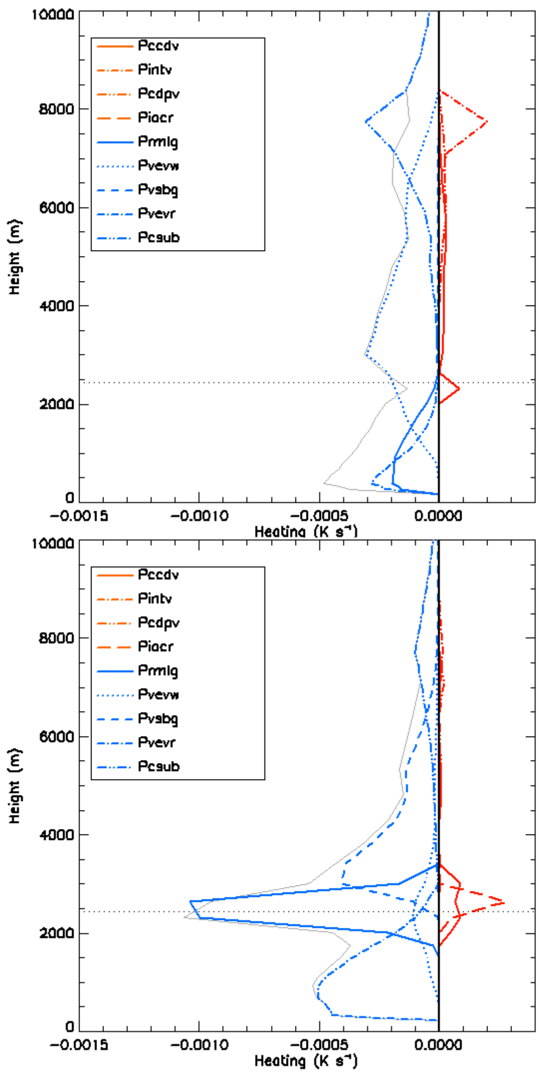
Results: graupel – hail difference

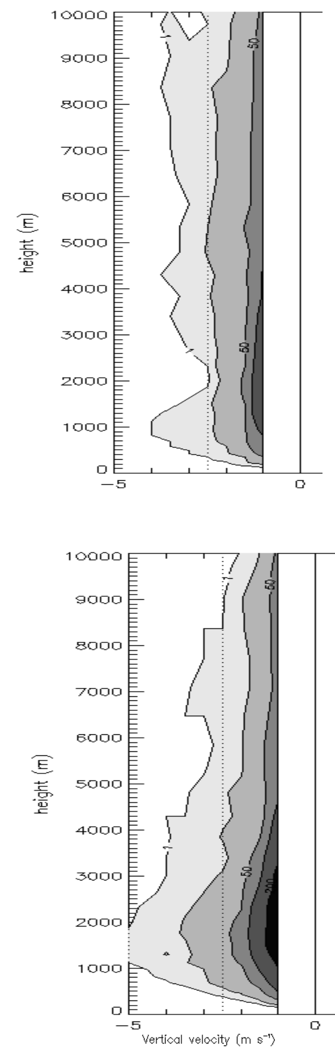
Impact on thermodynamics: downdrafts and cold pools

Total latent heating | ***Vertical velocity CFAD's***

hail

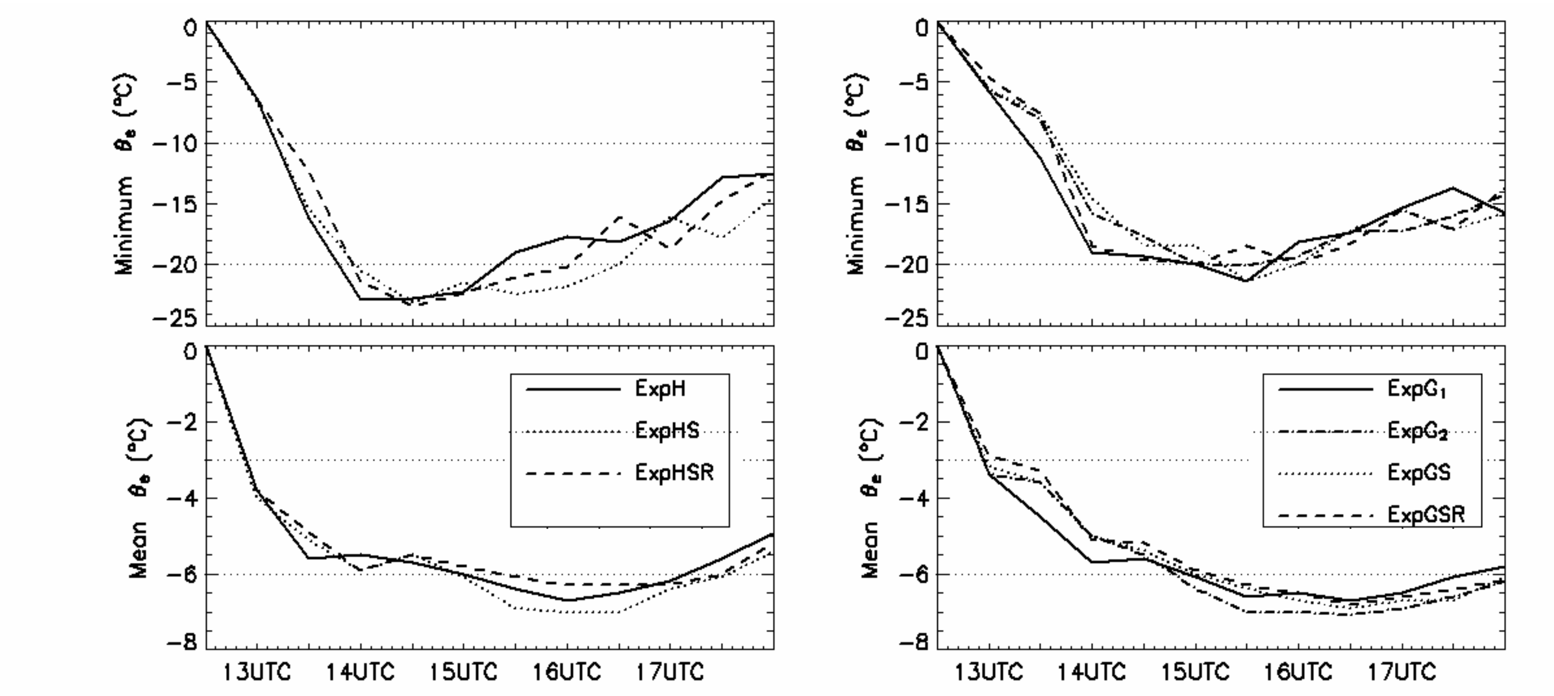
graupel





Results: graupel – hail difference
Impact on thermodynamics: downdrafts and cold pools

hail ***graupel***

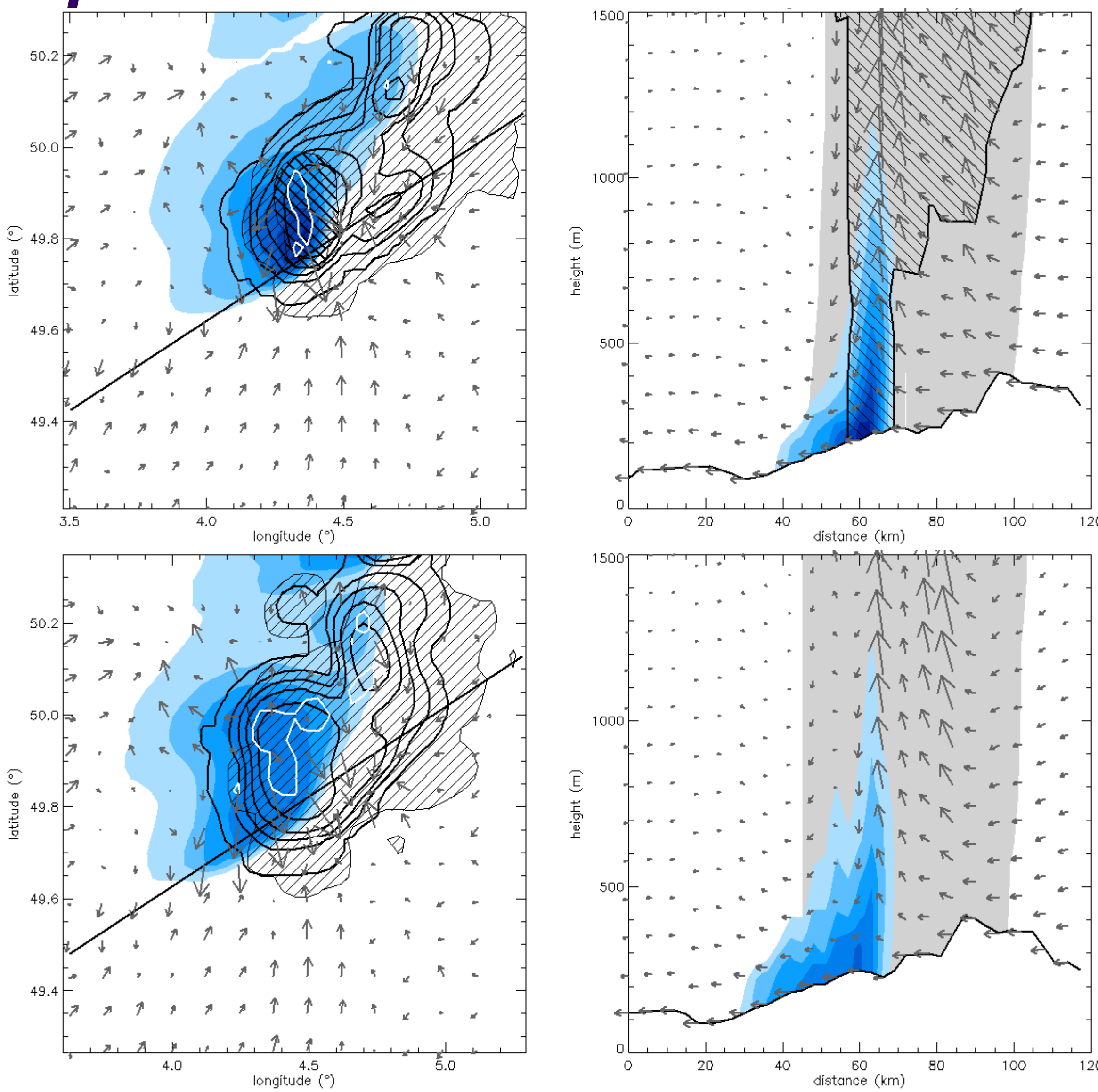


Results: graupel – hail difference

Impact on thermodynamics: downdrafts and cold pools

hail

graupel



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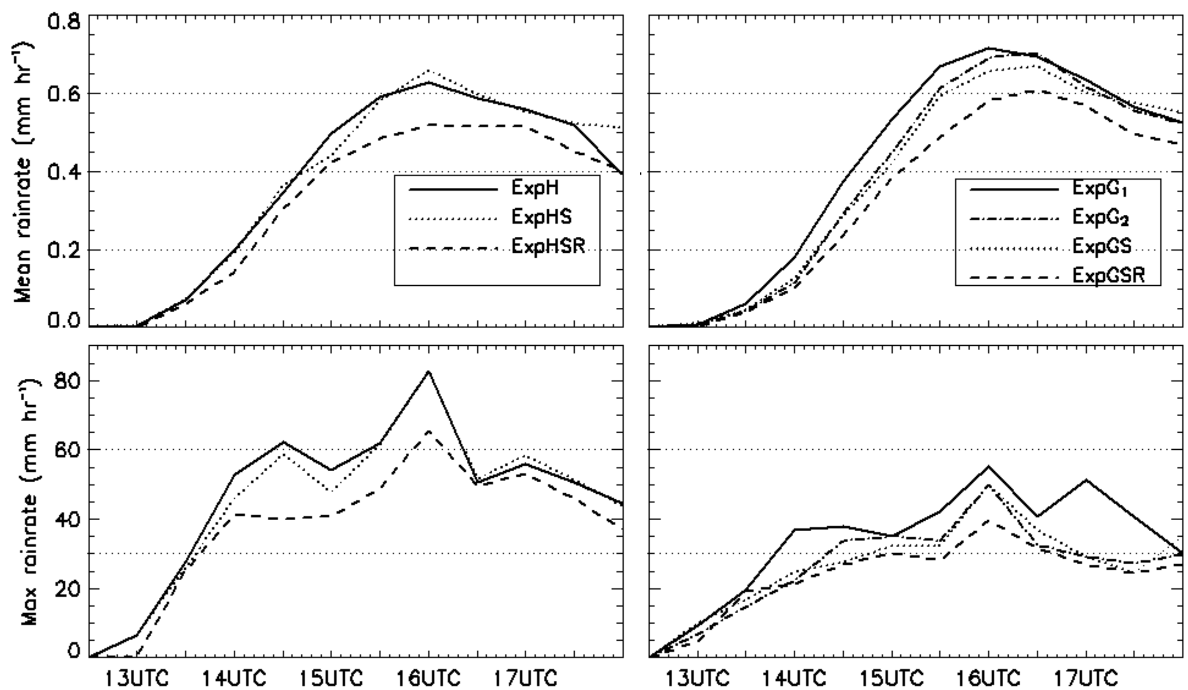
Results: influence of other hydrometeors

	Mean Precipitation (mm)	Max Precipitation (mm)	**Precipitation Efficiency**
Observed	1.6	35.0	
ExpH	3.1	42.5	**30.7**
$ExpG_1$	3.5	34.4	**28.6**
$ExpG_2$	3.4	37.0	**24.9**
ExpHS	3.0	42.0	**30.4**
ExpGS	3.3	44.7	**24.8**
ExpHSR	2.6	33.3	**30.9**
ExpGSR	2.7	28.5	**24.5**

hail ***graupel***



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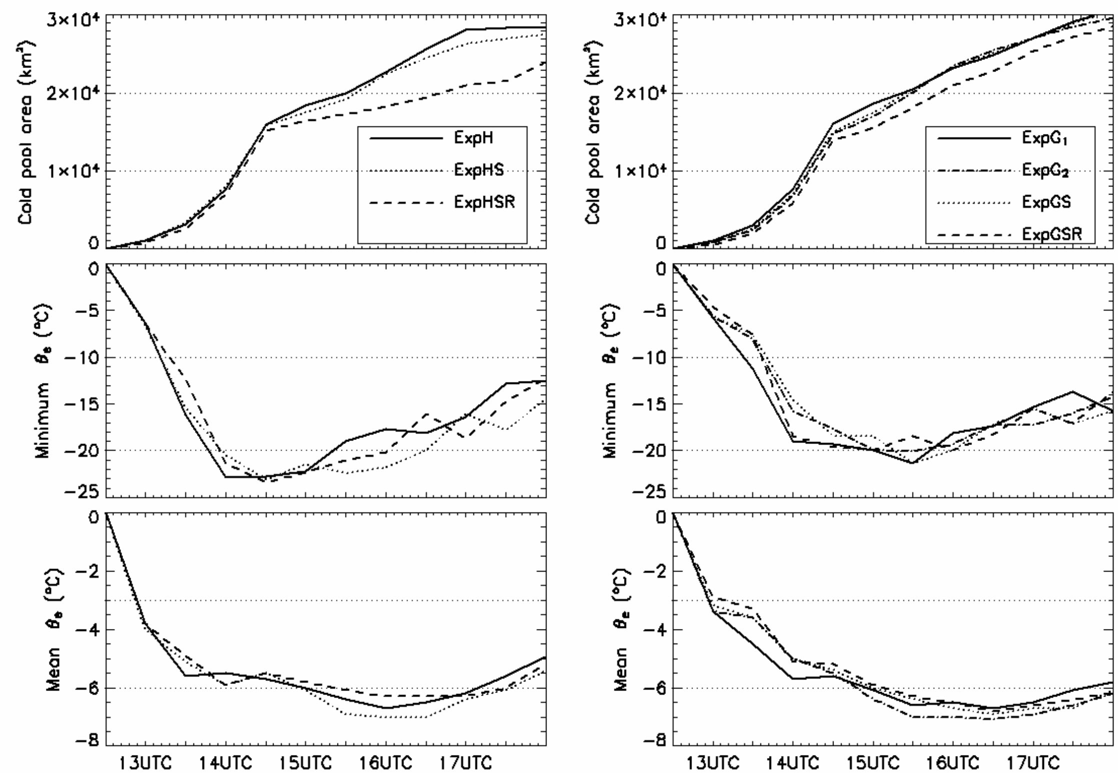
hail ***graupel***



Results: influence of negative mixing ratios, associated with finite-differcing in advection scheme

$$\frac{\partial q_x}{\partial t} = -\mathbf{V} \cdot \nabla q_x + Diff_x + P_x + \frac{1}{\rho}\frac{\partial}{\partial z}\left(V_x q_x \rho\right) + Z_x$$

Inaccuracies in the finite-differencing of the moisture advection

↓

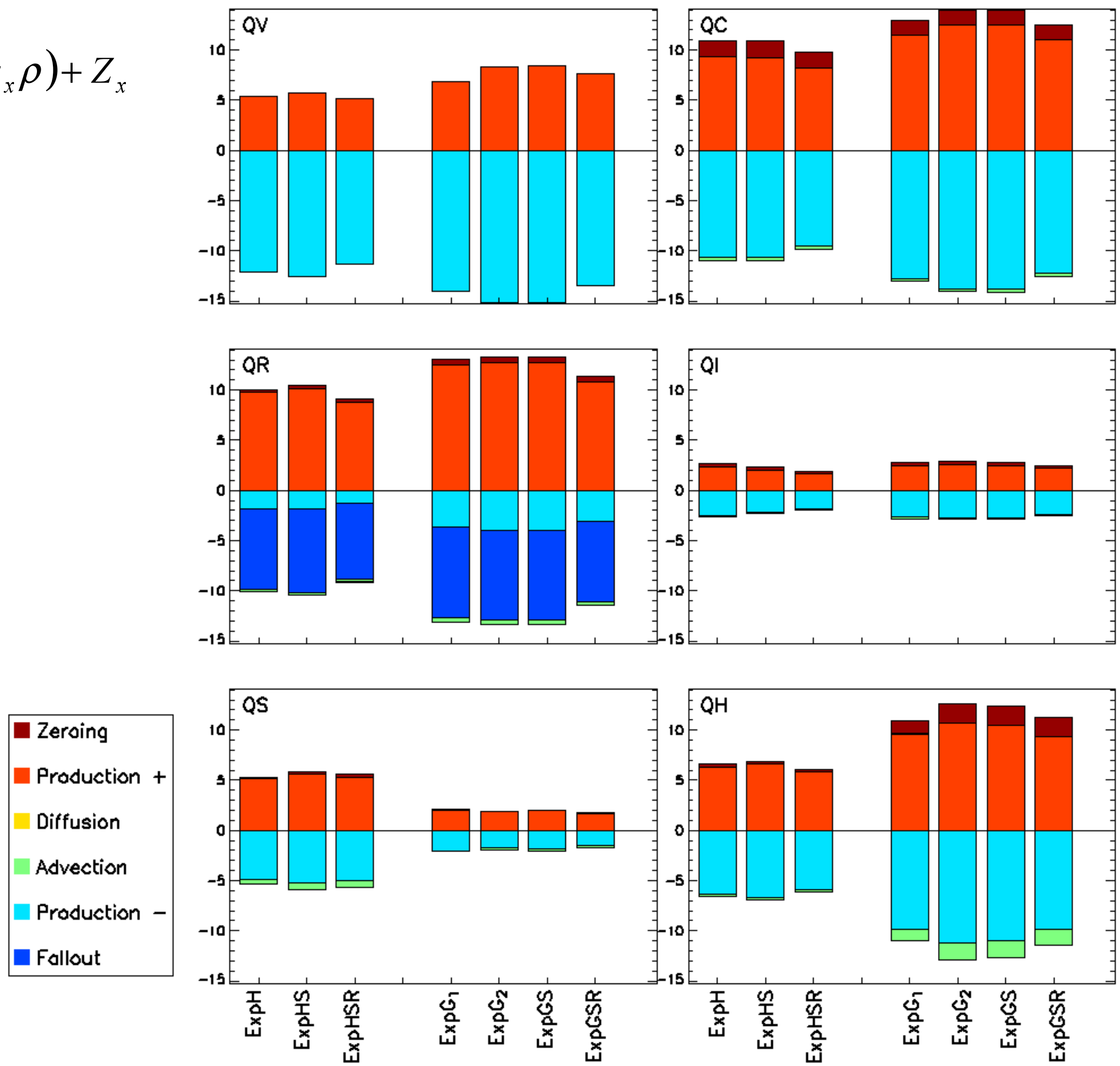
Negative mixing ratios near strong gradients

↓

Set to zero to have physical calculations in microphysics

↓

Artificial water added to the model

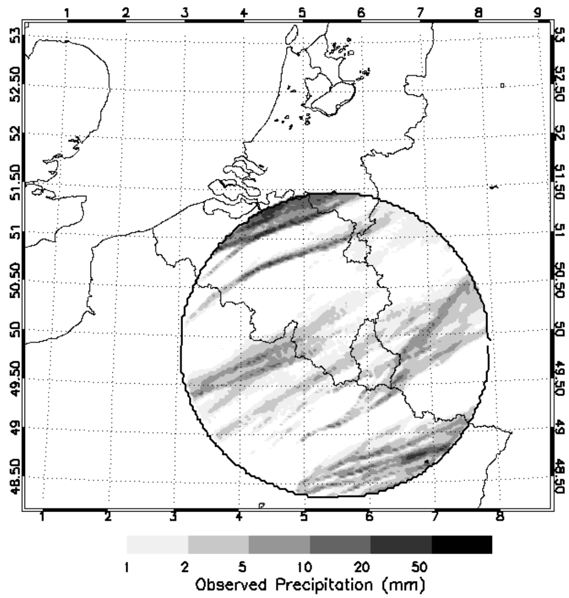


Results: influence of negative mixing ratios, associated with finite-differcing in advection scheme

Experiment: In each grid box and at each time step:

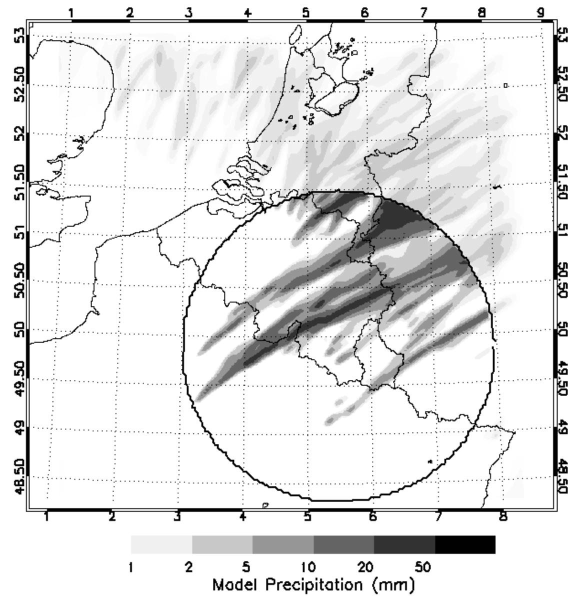
> ***artificially added water of all hydrometeors subtracted from water vapour source to keep the mass balance***

Radar



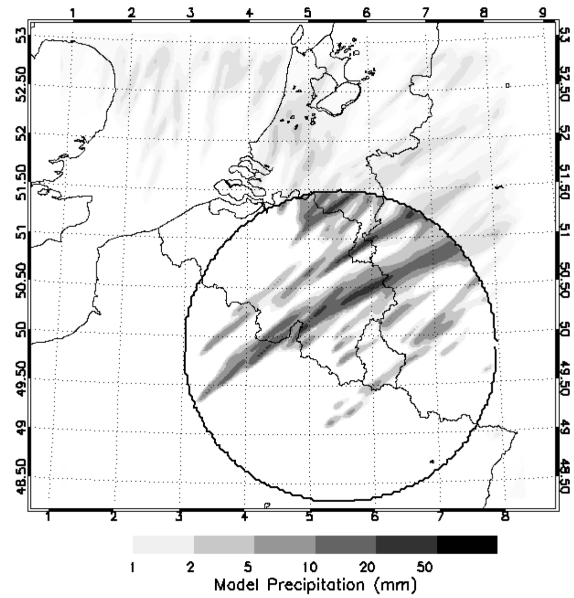
1.6 (35.0) mm

ExpHSR



2.6 (33.3) mm

ExpHSR$_{conserved}$



1.8 (31.5) mm

Conclusions

- *Differences associated with graupel – hail found in literature probably mainly associated with different environmental atmospheric conditions*

- *Vertical wind shear and storm depth important to explain those differences*

- *Graupel negatively influences precipiation efficiency, but positively influences thermodynamic conditions, leading to contrasting effects on surface precipitation*

- *Snow size distributions have little influence, rain size distribution most significantly affect domain average surface preciptiation by altering cold pool size.*

- *Very signficant effect amount of artificial water added to the model. Surface preciptiation is strongly improved when forcing the model to conserve water mass.*

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