Impact of Size Distribution Assumptions in a Simple Microphysics Scheme on the Representation of Moist Processes

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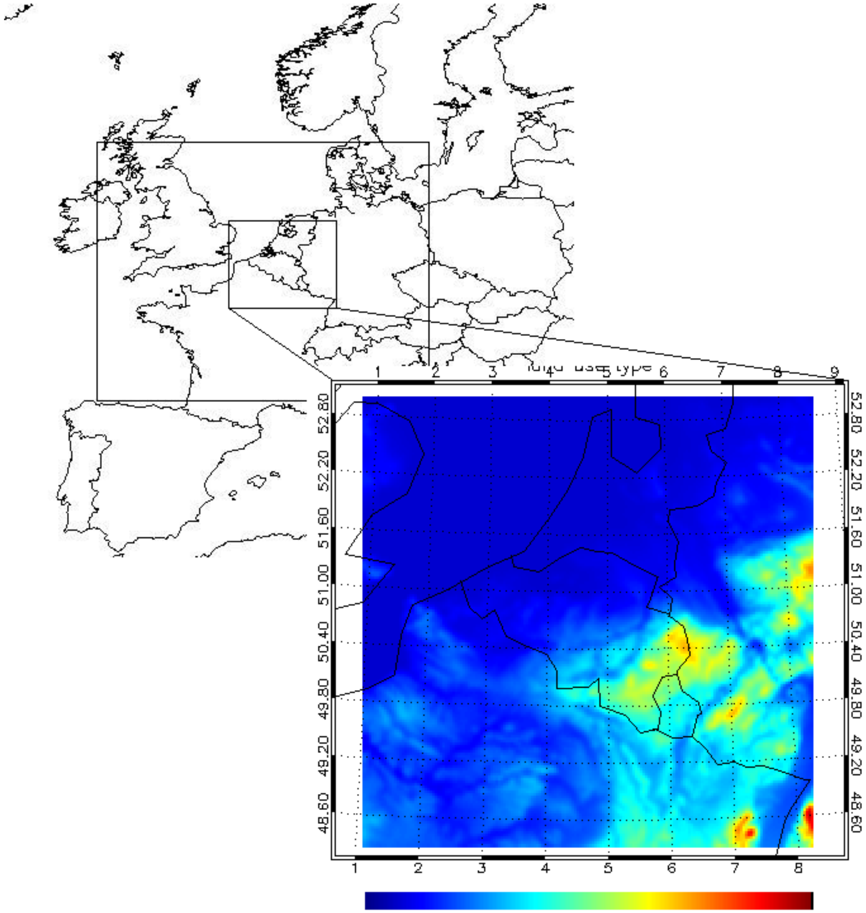
Materials and Methods



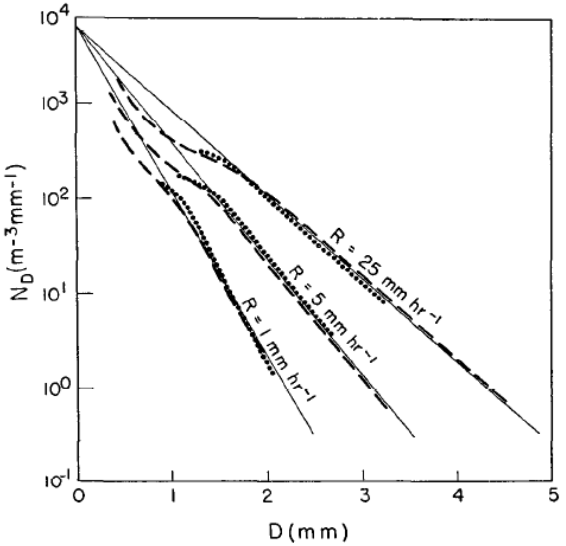
Advanced Regional Prediction System (ARPS)

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
- Lin-Tao microphysics (including rain, snow, hail, cloud ice, cloud water)
- 1.5-order TKE turbulence scheme
- Leap-frog time stepping

Materials and Methods: microphysics parameterization

- *One-moment (3rd: q_x) bulk microphysical scheme (Lin et al. 1983)*
- *Exponential size distribution assumptions are assumed for all precpitating hydrometeors (rain, snow and hail):*



$$N_x(D) = N_{0x}\exp(-\lambda_x D_x)$$

where N_{0x} is the constant intercept parameter and λ_x is the slope parameter:

$$\lambda_x = \left(\frac{a_{mx} N_{0x}\Gamma(b_{mx}+1)}{\rho q_x}\right)^{1/(b_{mx}+1)}$$

where a_{mx} and b_{mx} are the constants of the m-D relation: $m_x = a_{mx} D^{b_{mx}}$ for constant density spheres ($a_{mx}=\pi/6$ and $b_{mx}=3$)

Materials and Methods: microphysics parameterization

- *Experiments overview:*

		CONTROL	DH	DG	GH	GG
RAIN	Nor	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)*	$0.07106(10^3 \rho q_r)^{0.648}$ *(Zhang et al. 2008)*	$0.07106(10^3 \rho q_r)^{0.648}$ *(Zhang et al. 2008)*
SNOW	Nos	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)*
	λs	$\left(\frac{\pi \rho_s N_s}{\rho q_s}\right)^{0.25}$ *(Lin et al. 1983)*	$\left(\frac{0.0069 N_{0s} \Gamma(2+1)}{\rho q_s}\right)^{1/(2+1)}$ *(Cox 1988)*	$\left(\frac{0.0069 N_{0s} \Gamma(2+1)}{\rho q_s}\right)^{1/(2+1)}$ *(Cox 1988)*	$\left(\frac{0.0074 N_{0s} \Gamma(2.1+1)}{\rho q_s}\right)^{1/(2.1+1)}$ *(Locatelli and Hobbs. 1974)*	$\left(\frac{0.0074 N_{0s} \Gamma(2.1+1)}{\rho q_s}\right)^{1/(2.1+1)}$ *(Locatelli and Hobbs. 1974)*
	Vs	$\frac{152.93\Gamma(4+0.25)}{6\lambda_s^{0.25}}\left(\frac{\rho_0}{\rho}\right)^{1/2}$ *(Locatelli and Hobbs. 1974)*	$\frac{148.07\Gamma(0.527+2+1)}{\lambda_s^{0.527}\Gamma(2+1)}$ *(Cox 1988)*	$\frac{148.07\Gamma(0.527+2+1)}{\lambda_s^{0.527}\Gamma(2+1)}$ *(Cox 1988)*	$\frac{209.60\Gamma(0.28+2.1+1)}{\lambda_s^{0.28}\Gamma(2.1+1)}$ *(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)*
HAIL	No h	0.0004 *(Federer and Waldvogel 1975)*	0.0004 *(Gilmore et al. 2004)*	4.000 *(Gilmore et al. 2004)*	0.0004 *(Gilmore et al. 2004)*	4.000 *(Gilmore et al. 2004)*
	λh	$\left(\frac{\pi \rho_h N_h}{\rho q_h}\right)^{0.25}$ *(Lin et al. 1983)*	$\left(\frac{\pi \rho_h N_h}{\rho q_h}\right)^{0.25}$ *(Lin et al. 1983)*	$\left(\frac{0.0702 N_{0h} \Gamma(2.7+1)}{\rho q_h}\right)^{1/(2.7+1)}$ *(Locatelli and Hobbs. 1974)*	$\left(\frac{\pi \rho_h N_h}{\rho q_h}\right)^{0.25}$ *(Lin et al. 1983)*	$\left(\frac{0.0702 N_{0h} \Gamma(2.7+1)}{\rho q_h}\right)^{1/(2.7+1)}$ *(Locatelli and Hobbs. 1974)*
	Vh	$\frac{\Gamma(4.5)}{6\lambda_h^{0.5}}\left(\frac{4g\rho_h}{3C_D\rho}\right)^{1/2}$ *(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)*

Materials and Methods: microphysics parameterization

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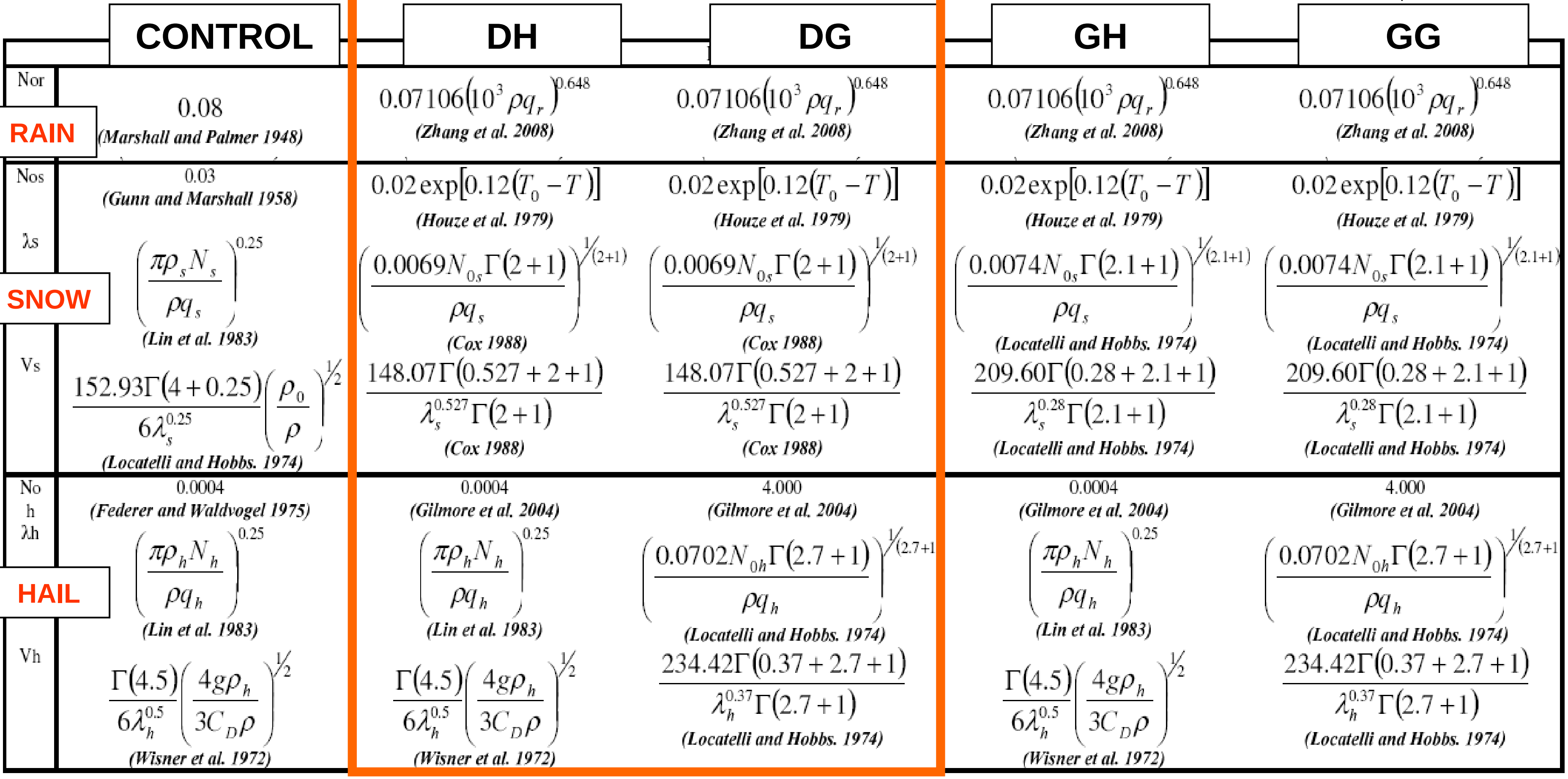

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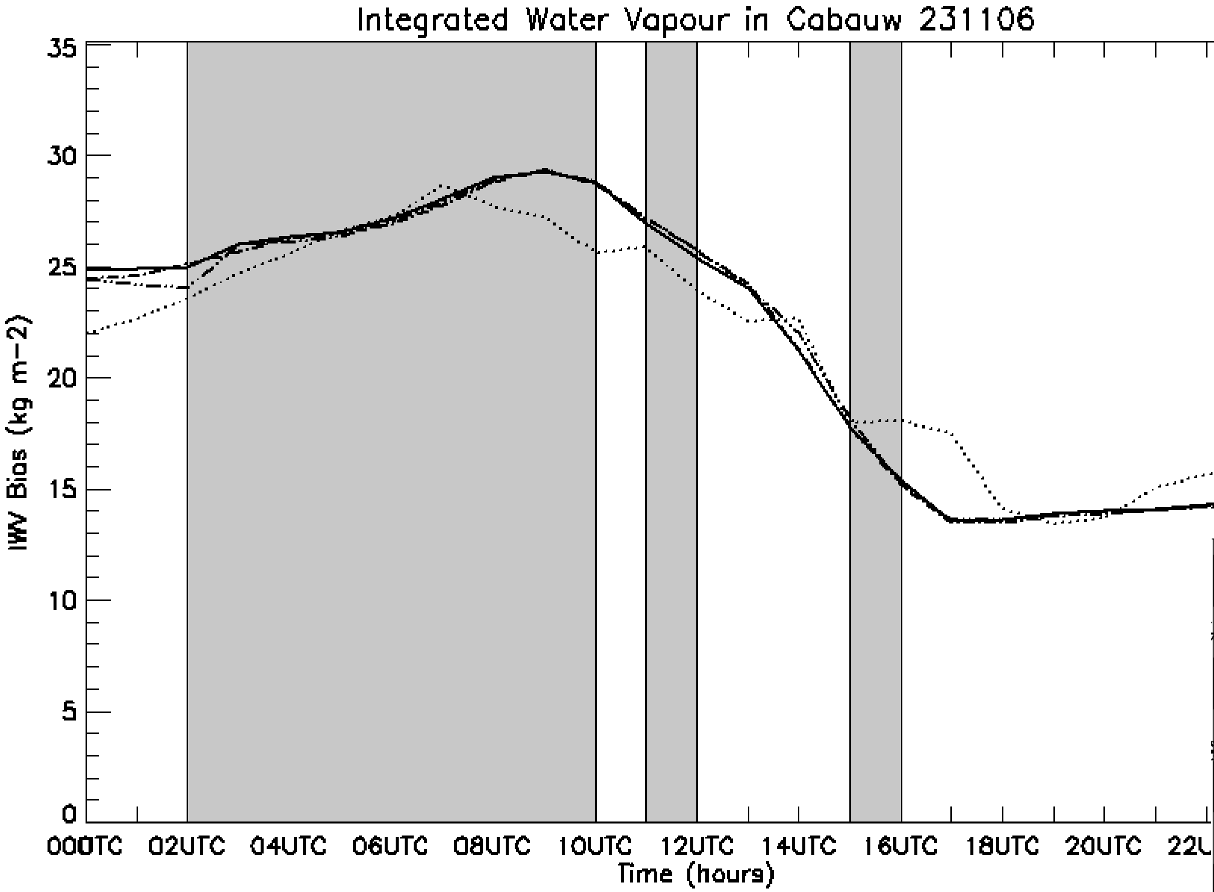
Case 23 November 2006

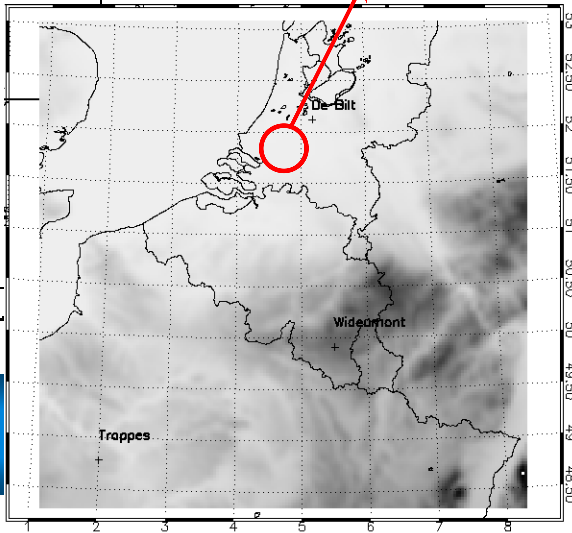
Results: Radiometer – water vapour

- *Integrated water vapour – comparison radiometer data (Cabauw)*



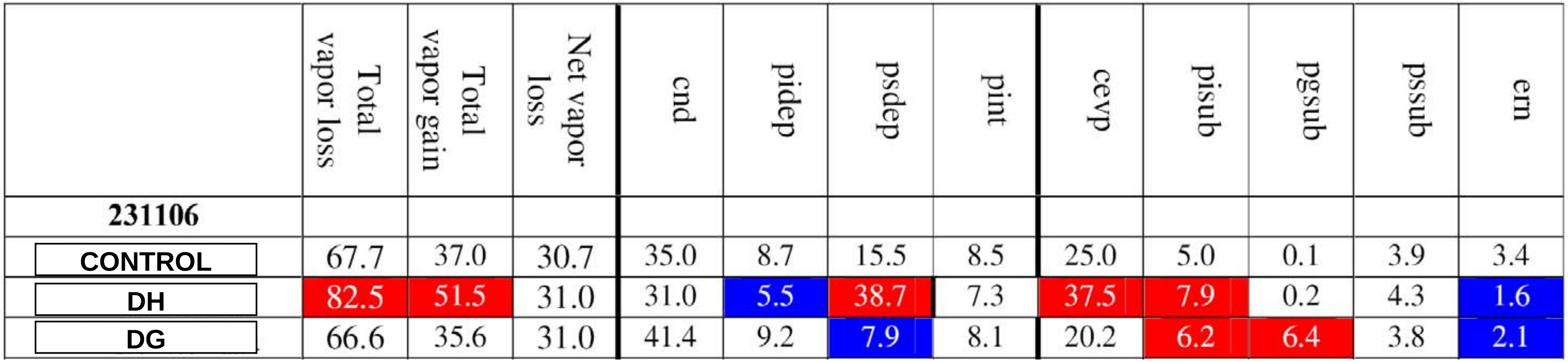
———	CONTROL
···········	RADIOMETER
–·–·–·–	DH
–··–··–	DG

Cabauw



Results: Soundings – water vapour

- *Water vapour – microphysical budget*



231106	Total vapor loss	Total vapor gain	Net vapor loss	cnd	pidep	psdep	pint	cevp	pisub	pgsub	pssub	ern
CONTROL	67.7	37.0	30.7	35.0	8.7	15.5	8.5	25.0	5.0	0.1	3.9	3.4
DH	82.5	51.5	31.0	31.0	5.5	38.7	7.3	37.5	7.9	0.2	4.3	1.6
DG	66.6	35.6	31.0	41.4	9.2	7.9	8.1	20.2	6.2	6.4	3.8	2.1

Results: MSG – cloud water, ice and snow

- *Cloud optical thickness – modelled and observed*

23 November

MSG

30.5

DH

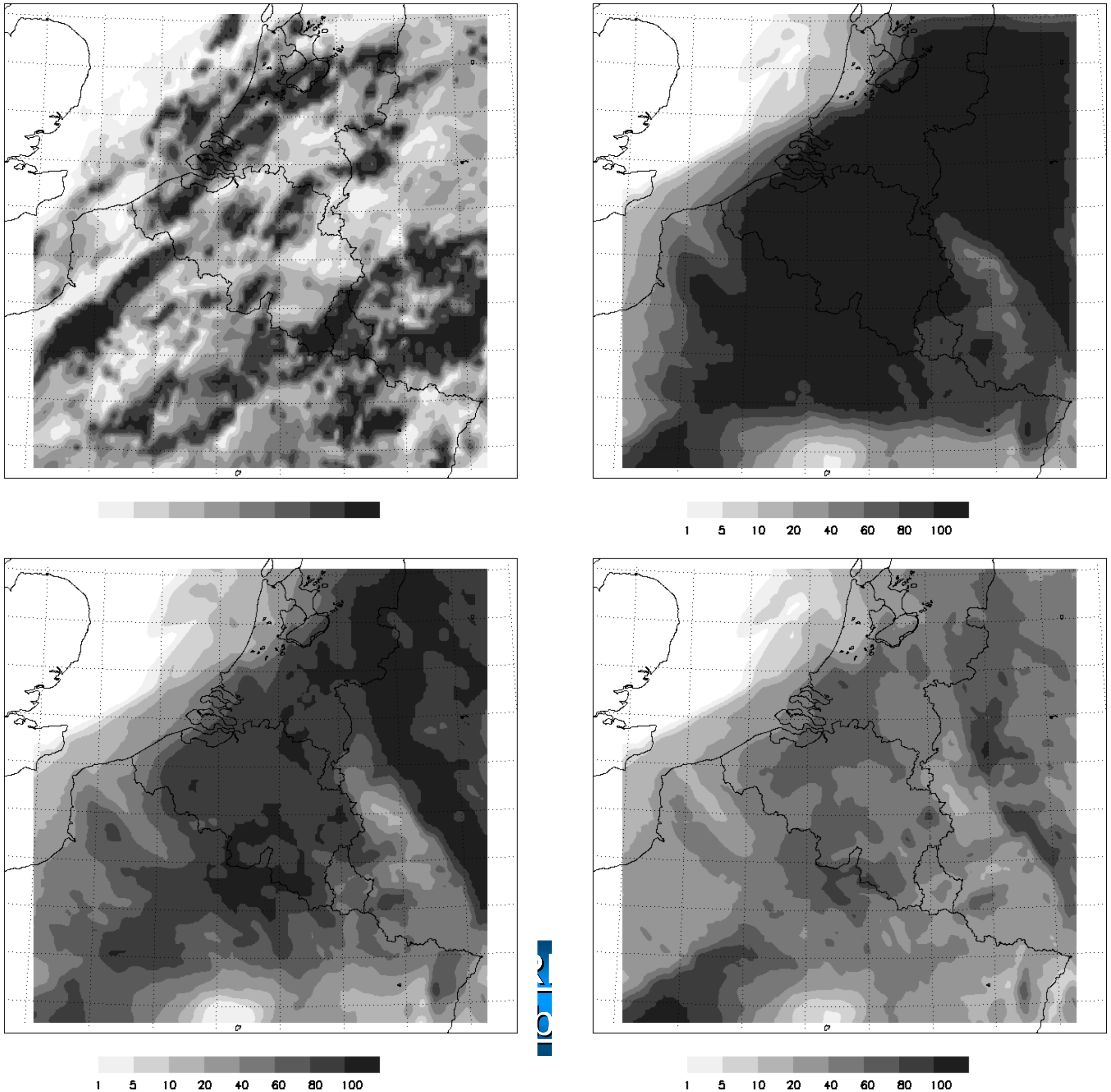
77.5

CONTROL

64.4

DG

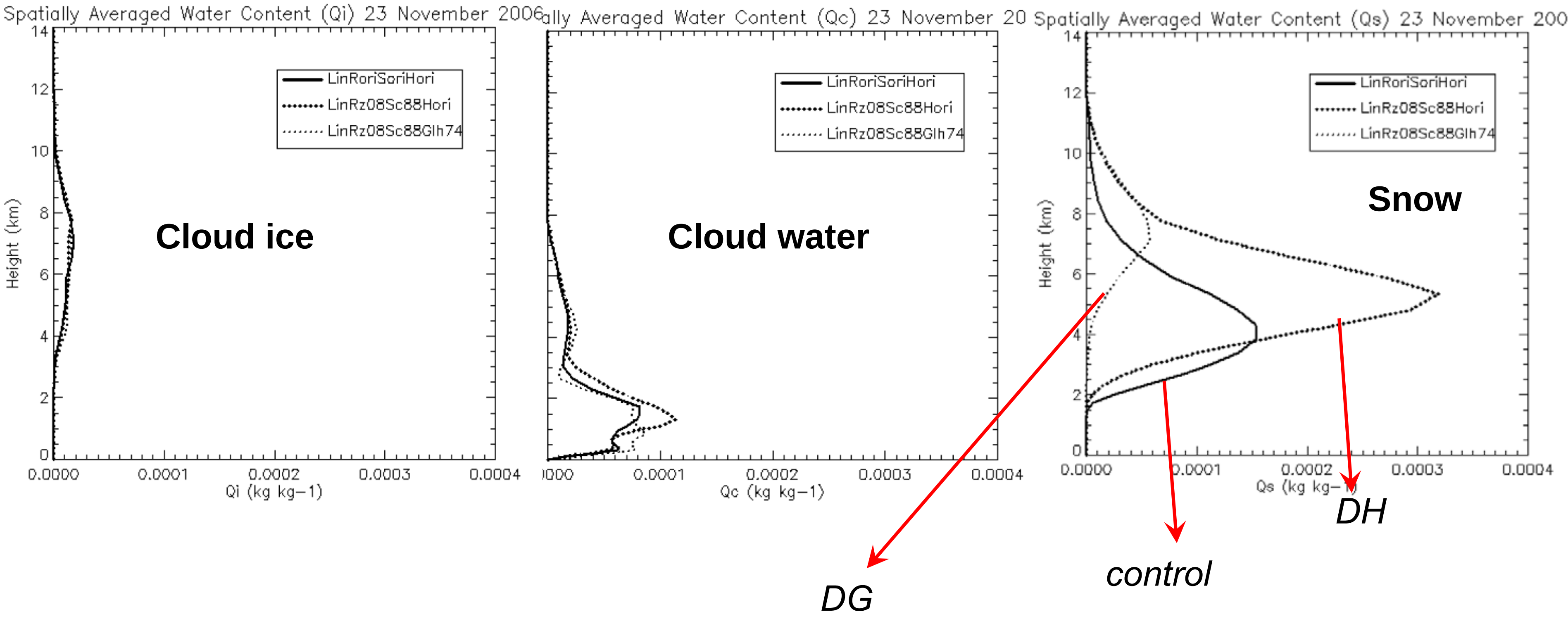
43.1



Results: MSG – cloud water, ice and snow

- *Hydrometeor vertical profiles*

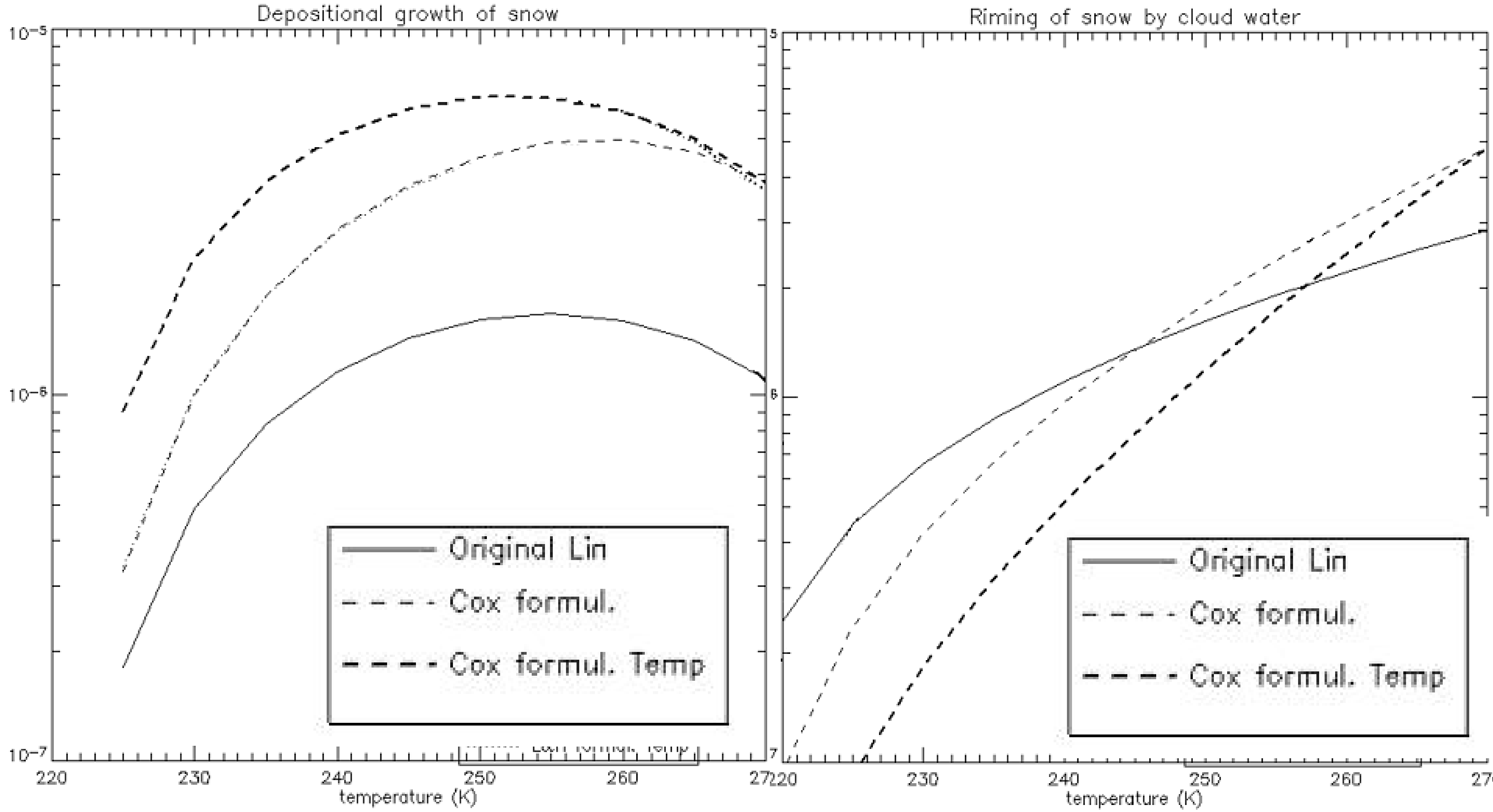
<u>23 November</u>



Results: MSG – cloud water, ice and snow

- *Depositional growth and riming growth of snow*

23 November



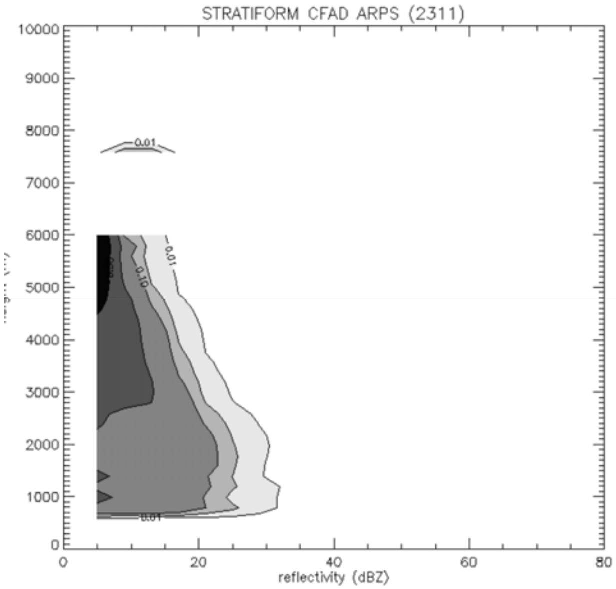
Results: Radar – snow, hail and rain

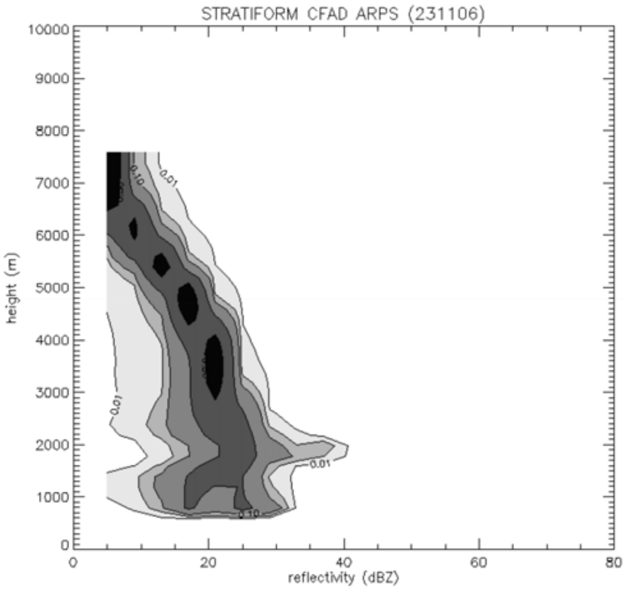
- *Radar reflectivity – modelled and observed*

23 November

RADAR

40.8



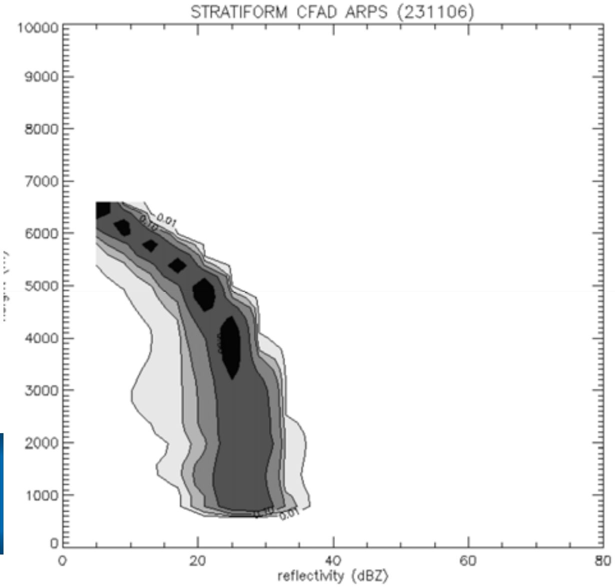


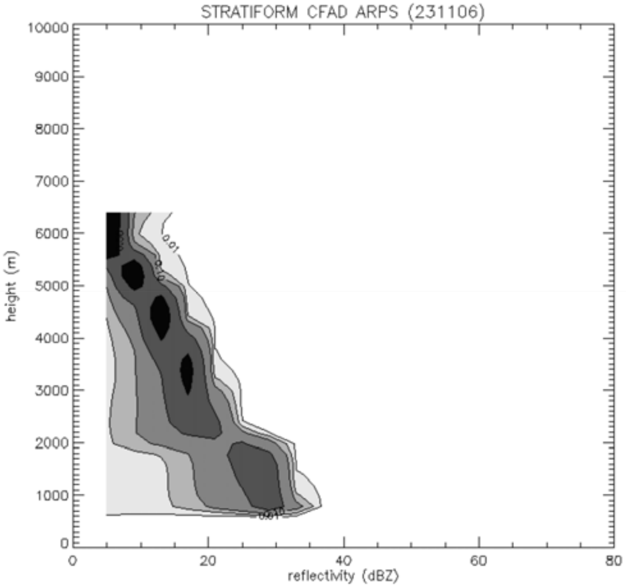
CONTROL

42.0

DH

37.2





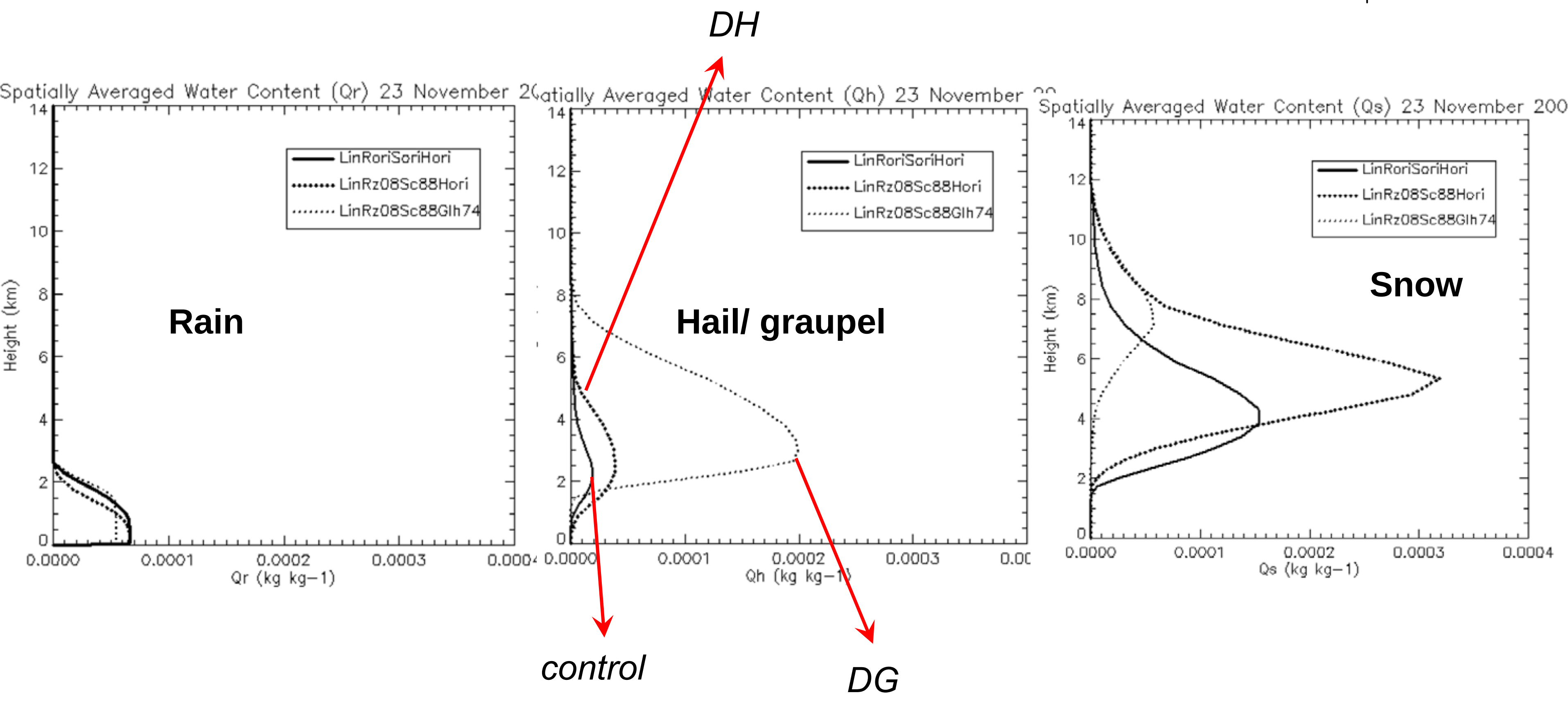
DG

35.6

Results: Radar – snow, hail and rain

- *Hydrometeor vertical profiles*

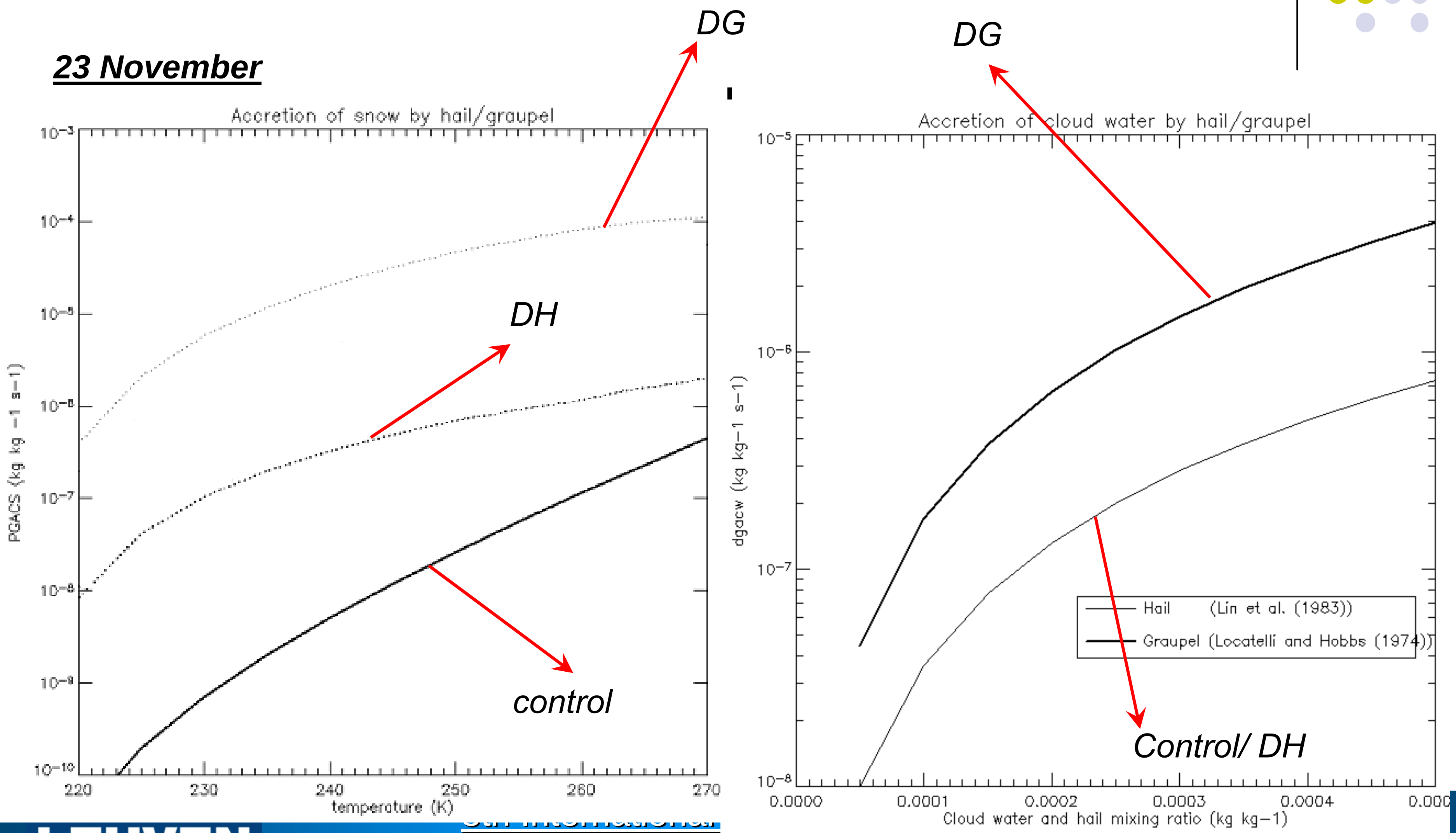
23 November



Results: Radar – snow, hail and rain

- *Collection of snow and cloud water by hail/ graupel*

23 November



Results: Radar – raing gauge surface rain

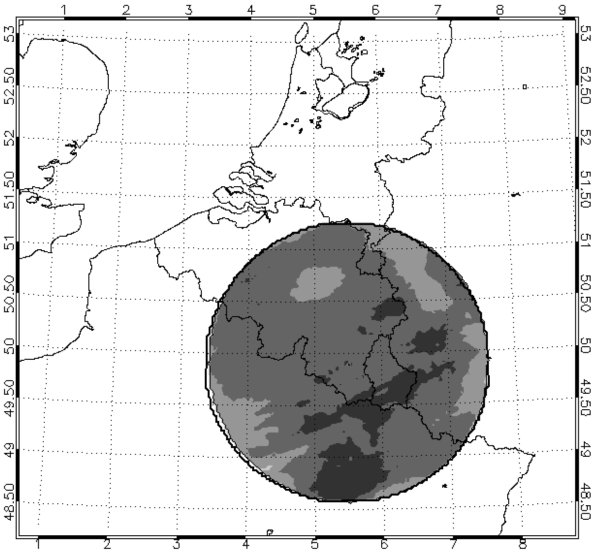
- *Surface precipitation – modelled and observed*

23 November

OBSERVED

11.4 mm

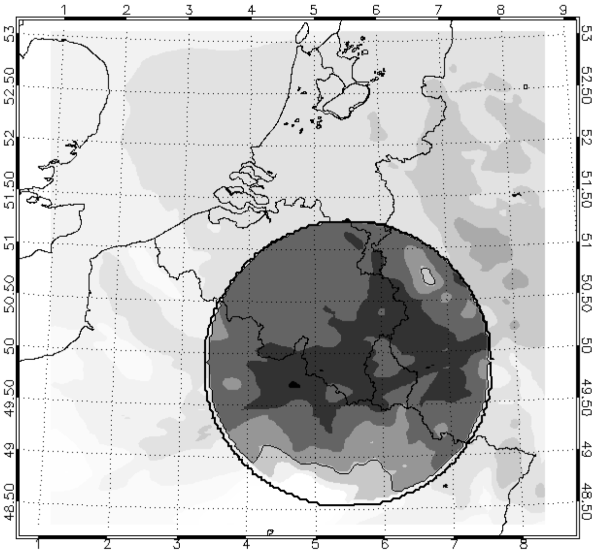
(-)



CONTROL

12.6 mm

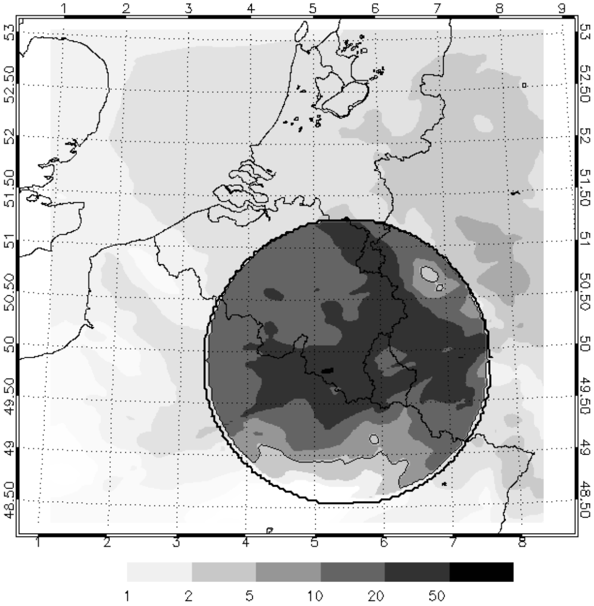
(41.9 %)



DG

13.9 mm

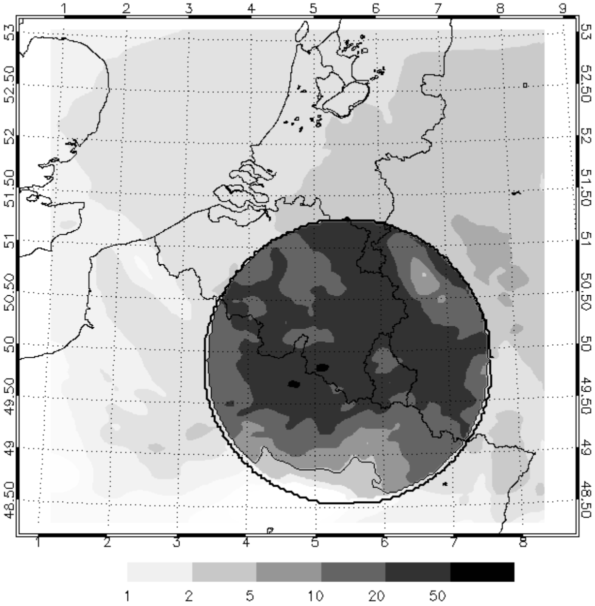
(47.2 %)



DH

16.4 mm

(46.1 %)



SR
tol

Results: Shear-driven convective case

- *Strongly positive IWV bias, net vapour loss becomes less in the GH (15%) and GG (25%) experiments*

- *Overestimated cloud optical thickness, only slightly improved in GG experiment*

- *More realistic CFAD's and maximum reflectivity when using large hail*

- *Overestimated surface precipitation, but improved QPF in all experiments; no large difference between graupel and hail, in contrast to Gilmore et al. (2004)*

Conclusions and outlook

- *The overestimated surface precipitation could probably be due to excessive glaciation, but this needs to be verified against observational data*
- *This study points to the strong need for microphysical schemes including both hail and graupel for operational use of mesoscale models*
- *Both snow and hail formulations are important in convective and stratiform simulations*
- *This study stresses the need for high resolution remotely sensed observation data for model evaluation.*
- *We will look in more detail to the influence of the microphysics experiments on the storm dynamics in the convective cases, comparing our experiments with more simple set ups such as in Gilmore et al. (2004)*
- *We will perform a long term analysis (one summer season) to see if current insights can be confirmed for more cases*