Improvement of clouds and quantitative precipitation forecast during convective and stratiform intense precipitation events on convection-resolving scales

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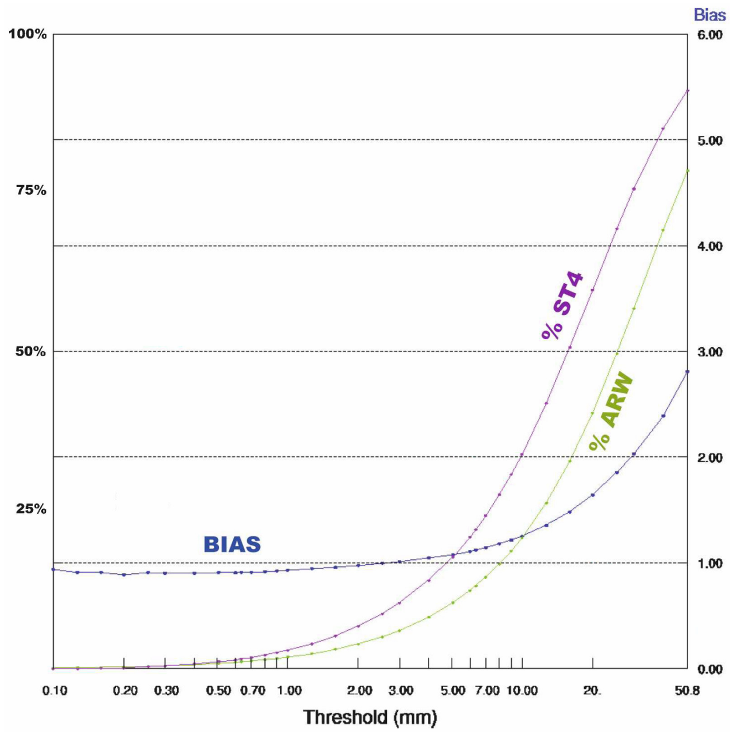
RMI

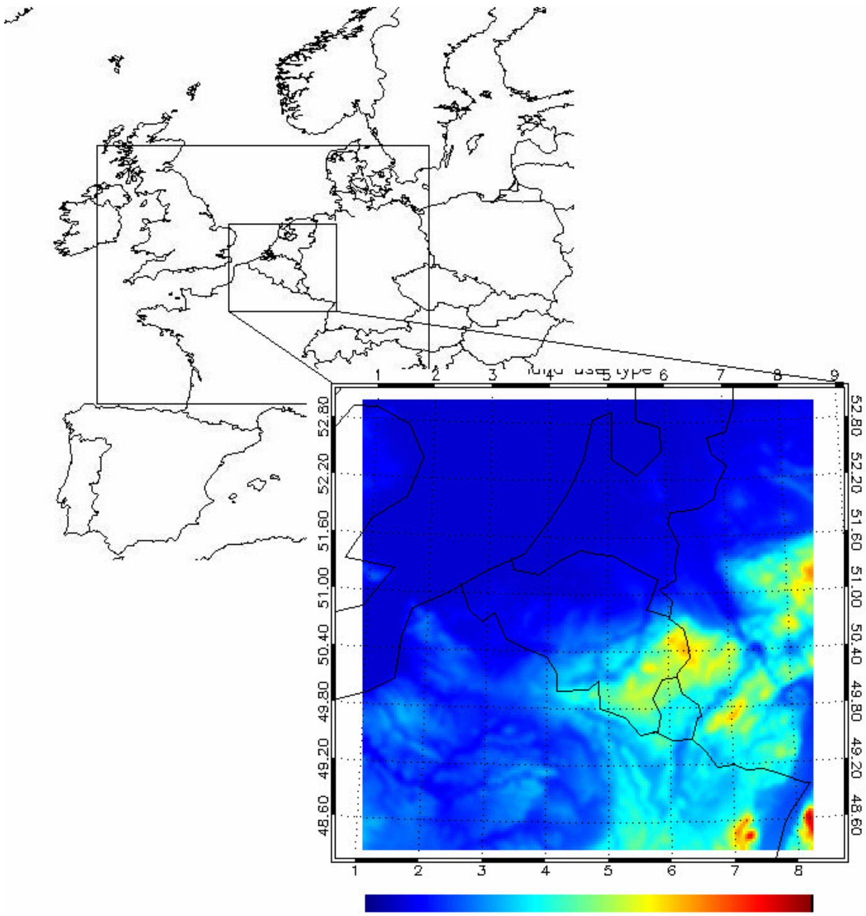
Motivation



Weisman et al. 2008

Systematic positive precipitation bias associated with deep convection in many models operated with explicit convection

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

	ExpH	ExpHSR	ExpGSRstrat
N_{0R}	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	$\left(\frac{\pi \rho_r N_{0r}}{\rho q_r}\right)^{0.25}$	$\left(\frac{\pi \rho_r N_{0r}}{\rho q_r}\right)^{0.25}$	$\left(\frac{\pi \rho_r N_{0r}}{\rho q_r}\right)^{0.25}$
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)*
N_{0S}	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)*
λ_S	$\left(\frac{\pi \rho_s N_s}{\rho q_s}\right)^{0.25}$ *(Lin et al. 1983)*	$\left(\frac{0.0074 N_{0s}\Gamma(2.1+1)}{\rho q_s}\right)^{1/(2.1+1}$ *(Locatelli and Hobbs. 1974)*	$\left(\frac{0.0069 N_{0s}\Gamma(2+1)}{\rho q_s}\right)^{1/(2+1)}$ *(Cox 1988)*
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)*	$\frac{209.60\Gamma(0.28+2.1+1)}{\lambda_s^{0.28}\Gamma(2.1+1)}$ *(Locatelli and Hobbs. 1974)*	$\frac{148.07\Gamma(0.527+2+1)}{\lambda_s^{0.527}\Gamma(2+1)}$ *(Cox 1988)*
N_{0H}	0.0004 *(Federer and Waldvogel 1975)*	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)*	$\left(\frac{0.0702 N_{0h}\Gamma(2.7+1)}{\rho q_h}\right)^{1/(2.7+1)}$ *(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)*

Two composites (of 15 cases each):

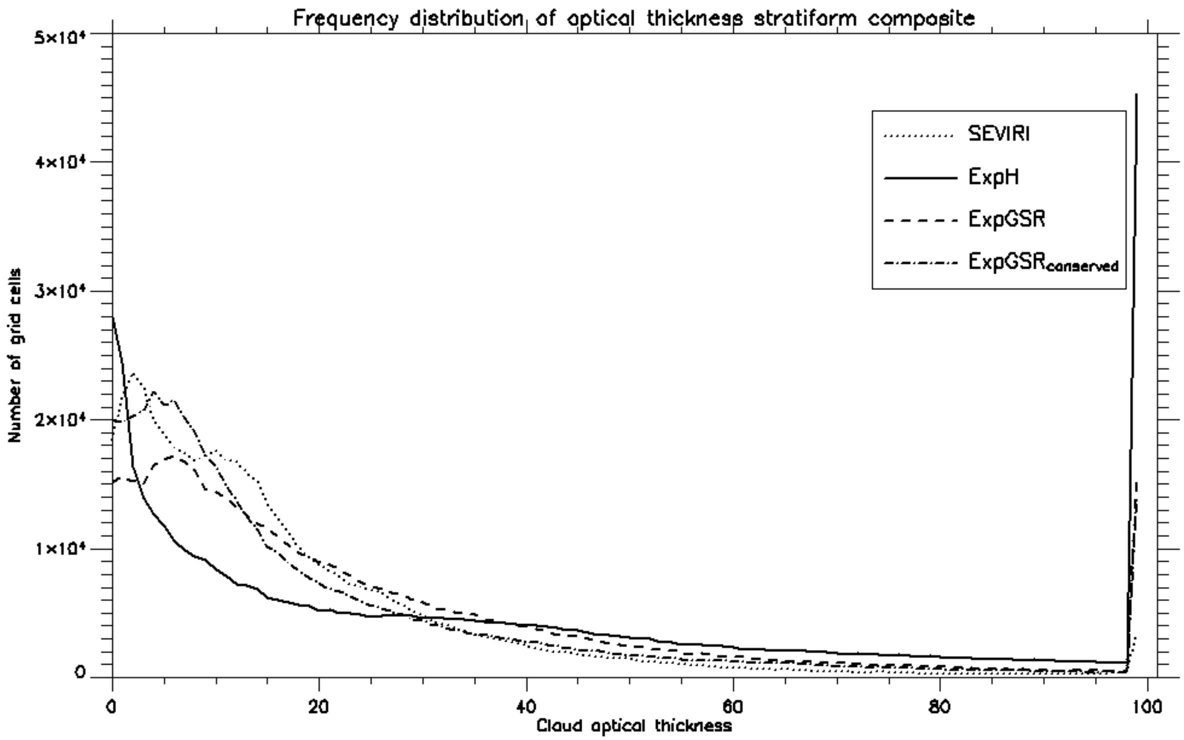
stratiform: ***ExpH, ExpGSR$_{strat}$ and ExpGSR$_{stratcons}$***

convective: ***ExpH, ExpHSR and ExpHSR$_{cons}$***

Verification of cloud optical thickness and surface precipitation

Results: Cloud optical thickness (stratiform composite)

Verification against CM-SAF SEVIRI COT



$$\bar{\tau} = -\mu \ln\left(1/N \sum_i \exp(-\tau_i/\mu_i) \right)$$

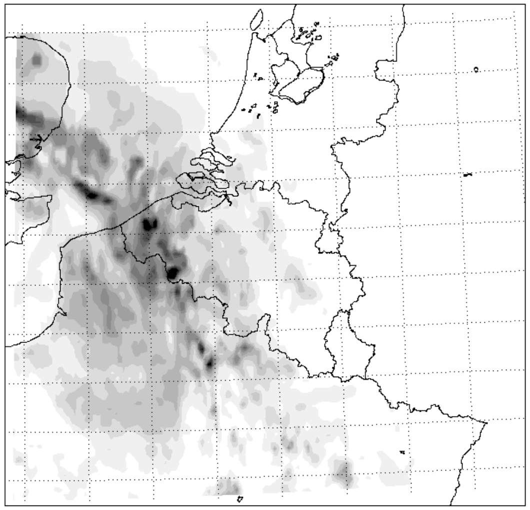
	Mean COT
SEVIRI	3.6
ExpH	3.1
$ExpGSR_{strat}$	3.7
$ExpGSR_{stratcons}$	3.5

Results: Cloud optical thickness (convective composite)

Verification against CM-SAF SEVIRI COT: example 7th May 2006 case (1200 UTC)

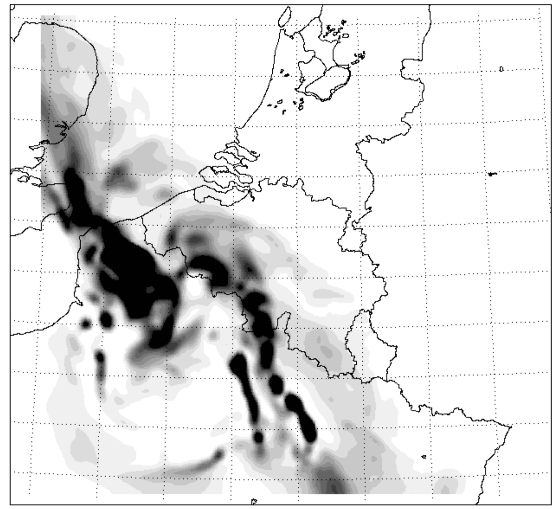
Observed:

3.2



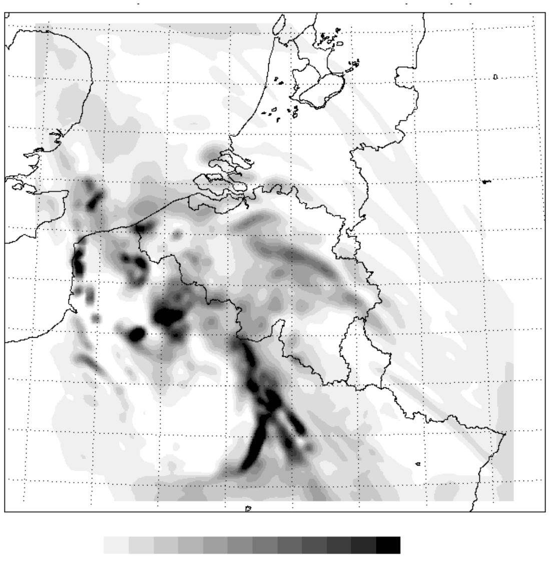
ExpH

2.6



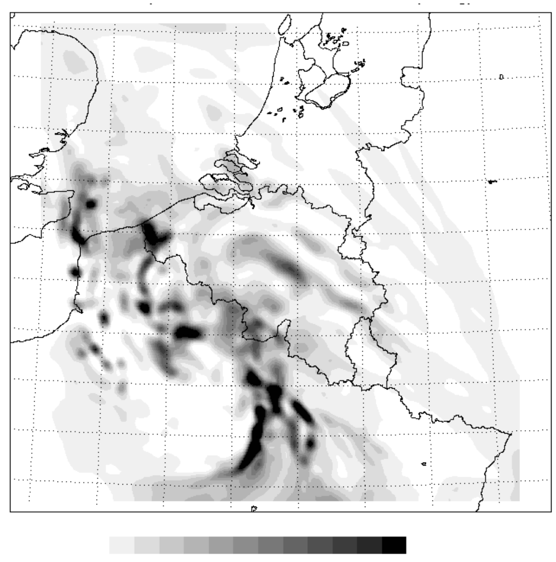
ExpGSR$_{strat}$

3.2



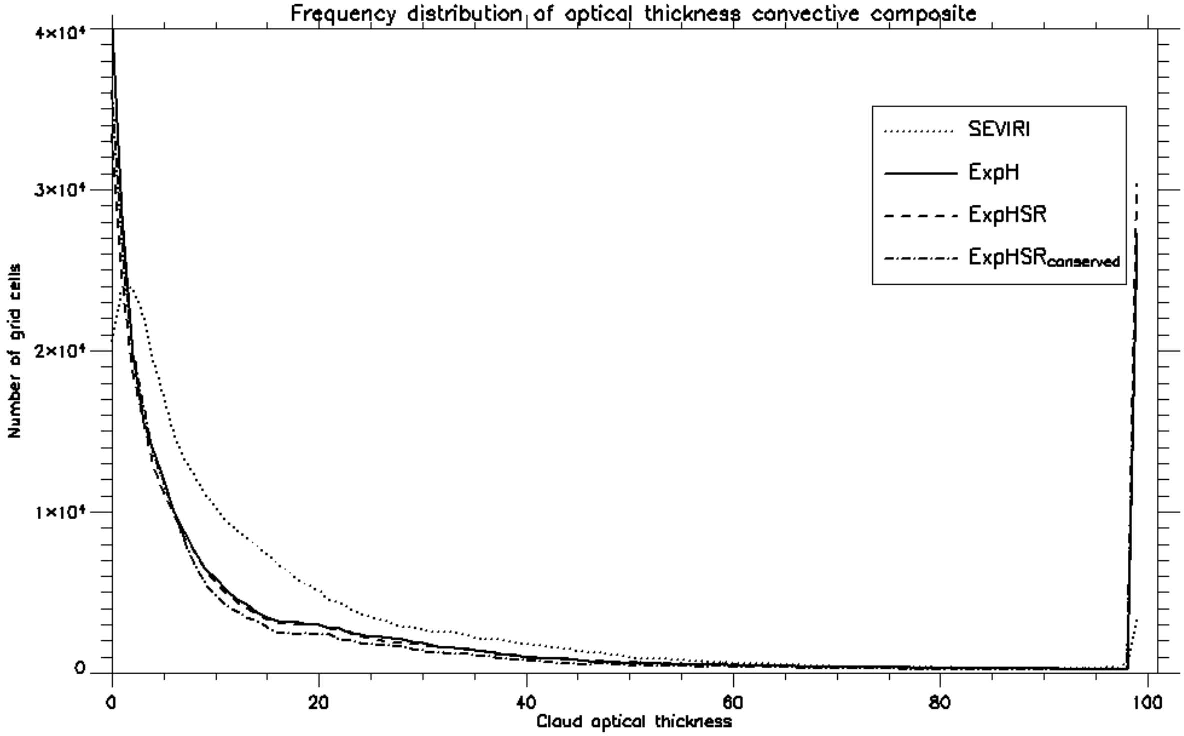
ExpGSR$_{stratcons}$

3.1



Results: Cloud optical thickness (convective composite)

Verification against CM-SAF SEVIRI COT



$$\bar{\tau} = -\mu \ln\left(1/N \sum_i \exp(-\tau_i/\mu_i) \right)$$

	Mean COT
SEVIRI	3.1
ExpH	2.7
ExpHSR	2.7
$ExpHSR_{cons}$	2.6

Results: Cloud optical thickness (convective composite)

Verification against CM-SAF SEVIRI COT: example 30th May 2006 case (1400 UTC)

Observed:

3.2

ExpH

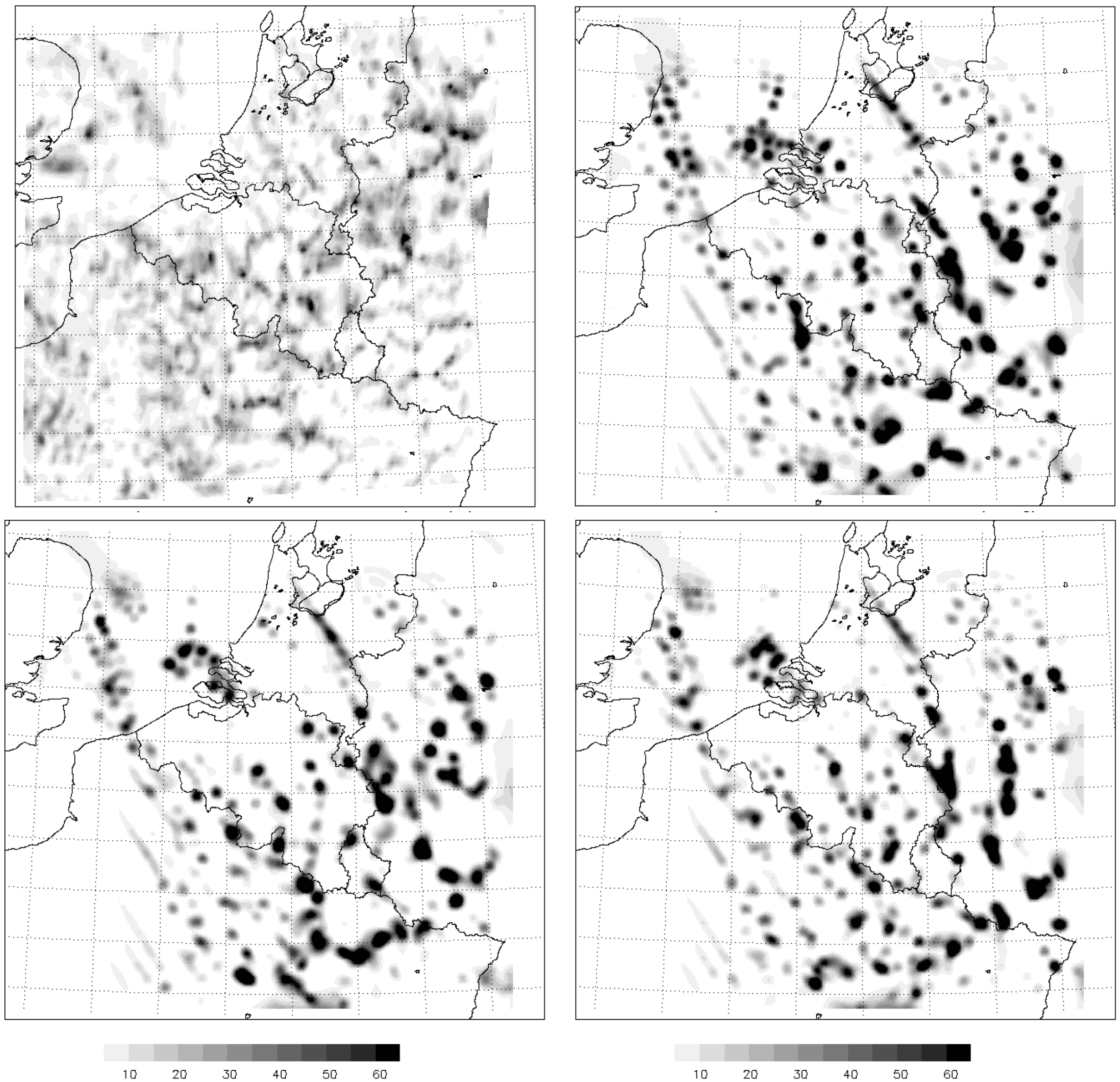
2.8

ExpHSR

2.8

ExpHSR$_{cons}$

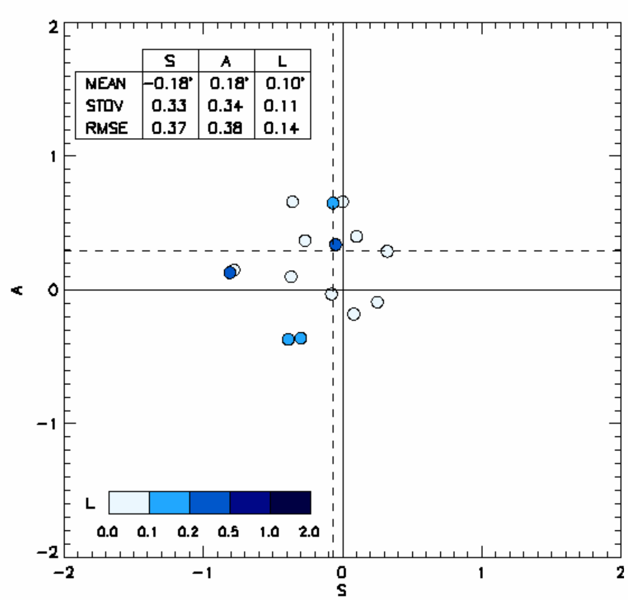
2.8



Results: Surface precipitation (stratiform composite)

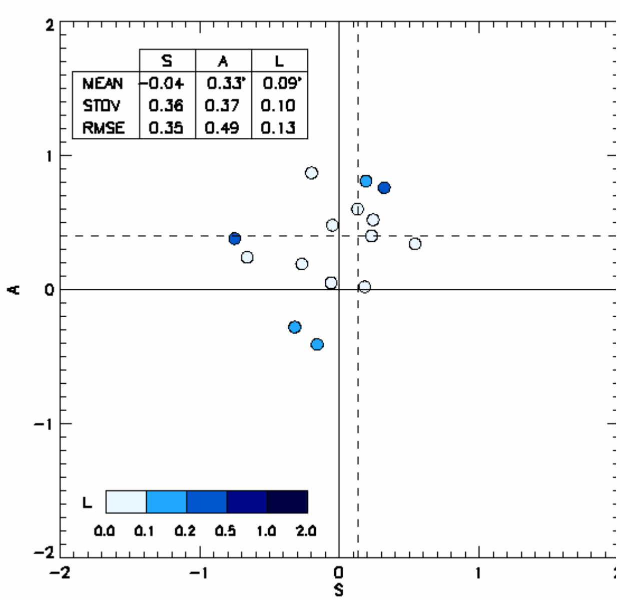
Verification against RMI rain gauge – radar merged surface precipitation (SAL)

ExpH



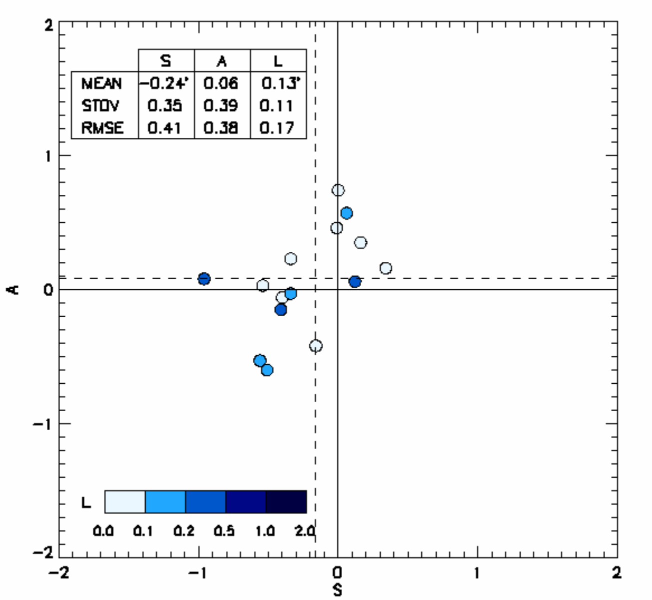
8.4 (60.7) mm

ExpGSR$_{strat}$



9.7 (56.1) mm

ExpGSR$_{stratcons}$



7.7 (49.2) mm

Observed: 6.6 (39.1) mm

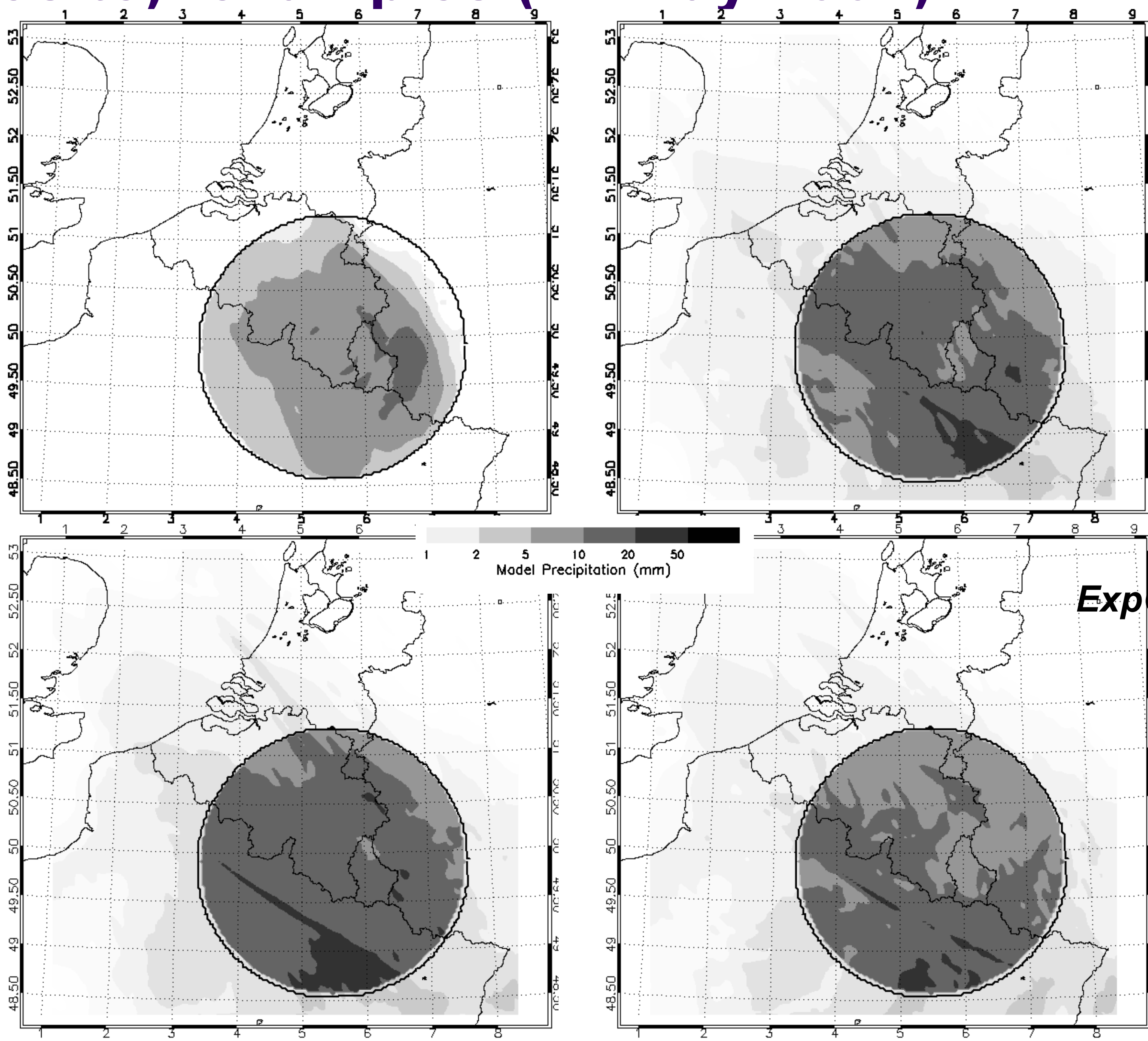
Results: Surface precipitation (stratiform composite): examples (17 May 2007)

Observed:

4.4 (13.3) mm

ExpH

8.7 (26.7) mm



$ExpGSR_{strat}$

11.1 (41.5) mm

$ExpGSR_{stratcons}$

9.6 (29.3) mm

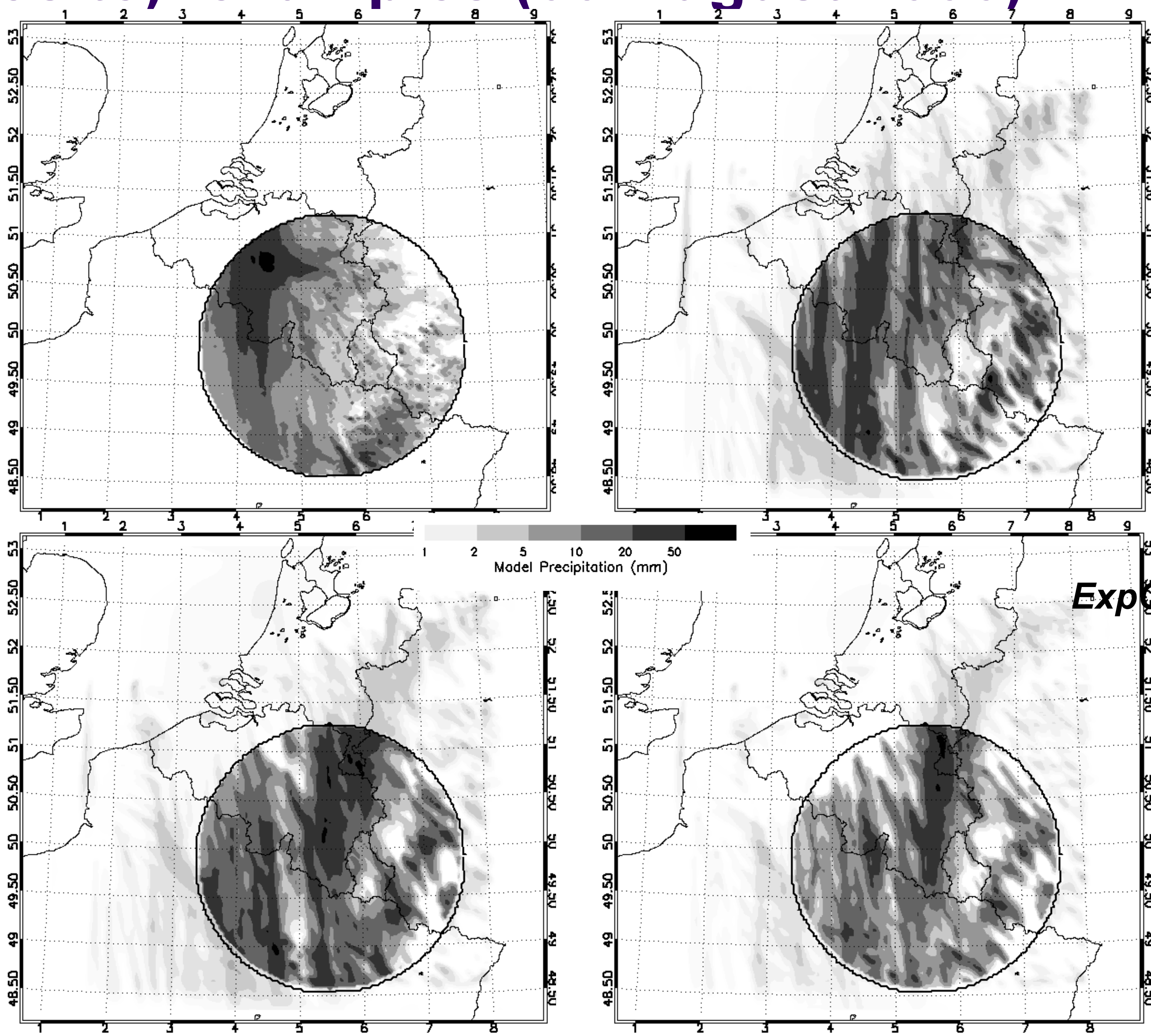
Results: Surface precipitation (stratiform composite): examples (03 August 2006)

Observed:

7.6 (62.7) mm

ExpH

10.1 (72.3) mm



$ExpGSR_{strat}$

11.3 (74.8) mm

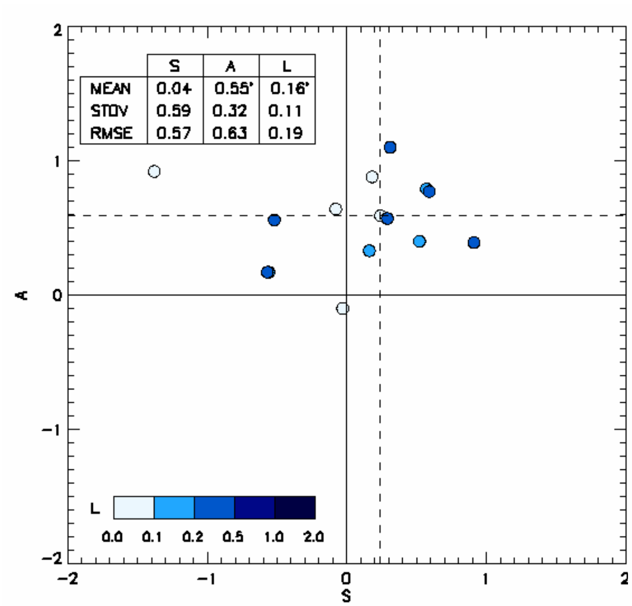
$ExpGSR_{stratcons}$

7.3 (69.6) mm

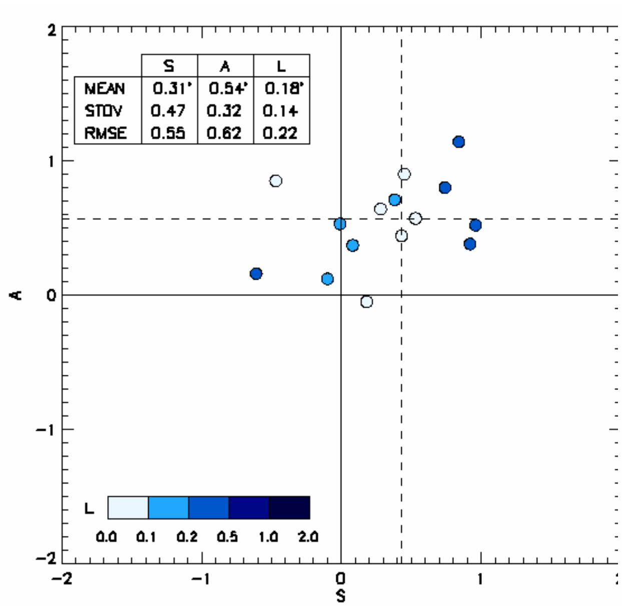
Results: Surface precipitation (convective composite)

Verification against RMI rain gauge – radar merged surface precipitation (SAL)

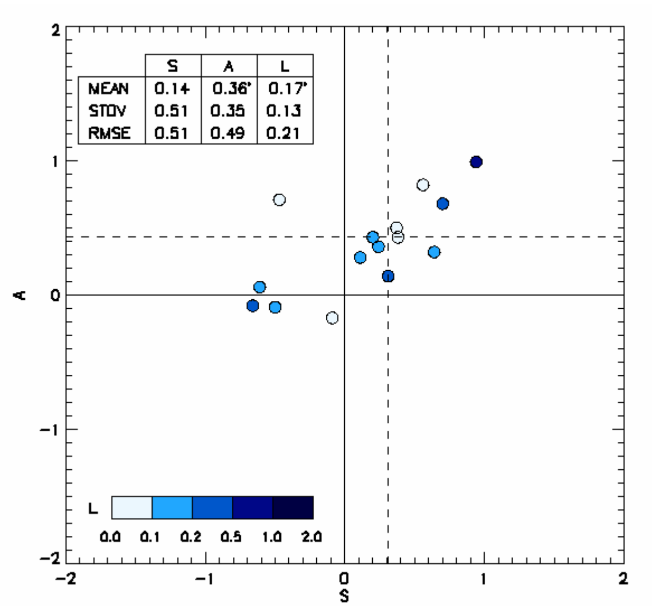
ExpH



ExpHSR



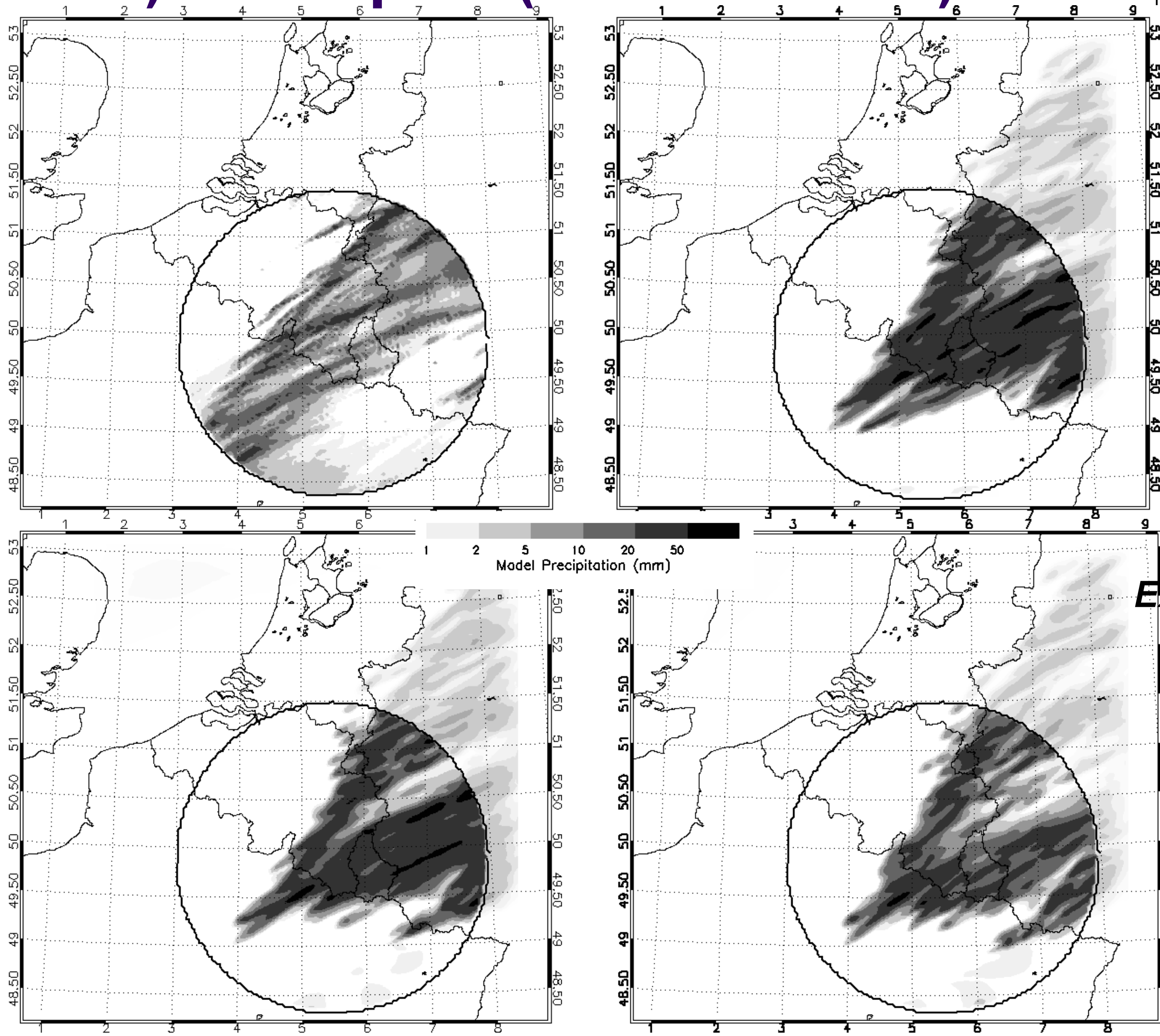
ExpHSR$_{cons}$



9.5 (101.3) mm ***9.5 (88.2) mm*** ***7.7 (72.8) mm***

Observed: 5.3 (55.9) mm

Results: Surface precipitation (convective composite): examples (22 June 2008)



Observed:

3.7 (44.1) mm

ExpH

8.6 (68.2) mm

ExpHSR

7.9 (74.0) mm

ExpHSR$_{cons}$

5.8 (63.8) mm

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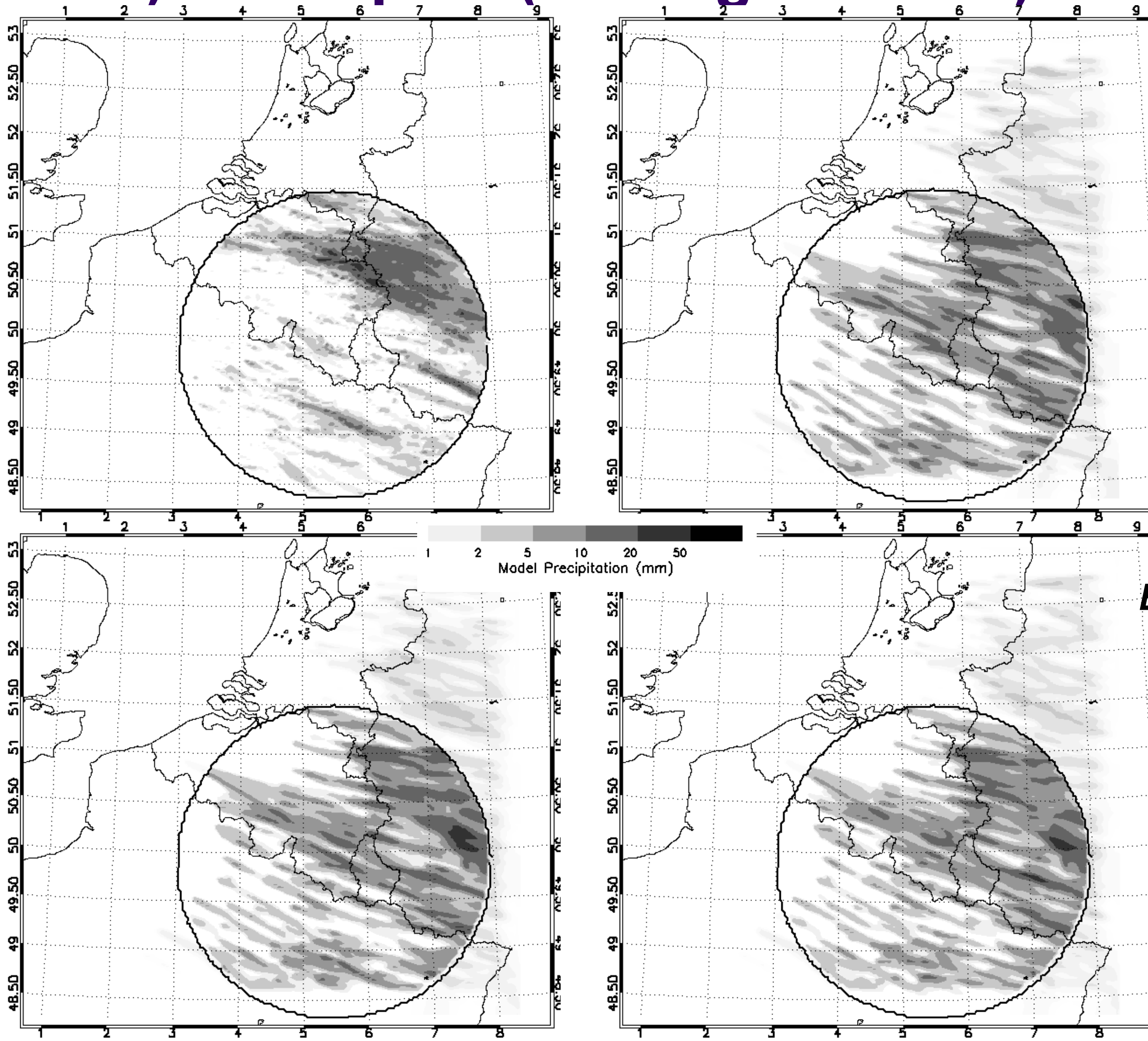
Results: Surface precipitation (convective composite): examples (27 August 2006)

Observed:

2.2 (32.0) mm

ExpH

3.3 (27.5) mm



ExpHSR

3.1 (27.6) mm

ExpHSR$_{cons}$

3.2 (28.3) mm

Conclusions

- ***Inclusion of graupel leads to significant improvement of the cloud optical thickness distribution and the mean transmission through the clouds during stratiform events.***
- *Surface precipitation in stratiform events is negatively influenced by more realistic size distribution assumptions, unless a method is applied to conserve water mass.*
- *More realistic rain and snow size distributions during convective events have no impact on cloud optical thickness. There are too much very thick and very thin clouds.*
- *Surface precipitation during convective events is not affected much by rain and snow size distribution assumptions. Most significant effect is found in supercell-cases. Conserving water mass improves the surface precipitation characteristics considerably.*

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