Characterization of Rainfall C-Band Radar Response and Dual-Polarized Measurement for an Hailstorm Event in the Po valley

K. De Sanctis (1), M. Montopoli (1), F. S. Marzano (1,3), L.Molini (2), A. Parodi (2), F. Siccardi (2) and R. Ferretti (1),

1-Dipartimento di Fisica/CETEMPS,
University of L'Aquila,
L'Aquila, ITALY

2-CIMA
Università di Genova,
Savona, Italy

3-DIE
Università "La Sapienza",
Rome, ITALY

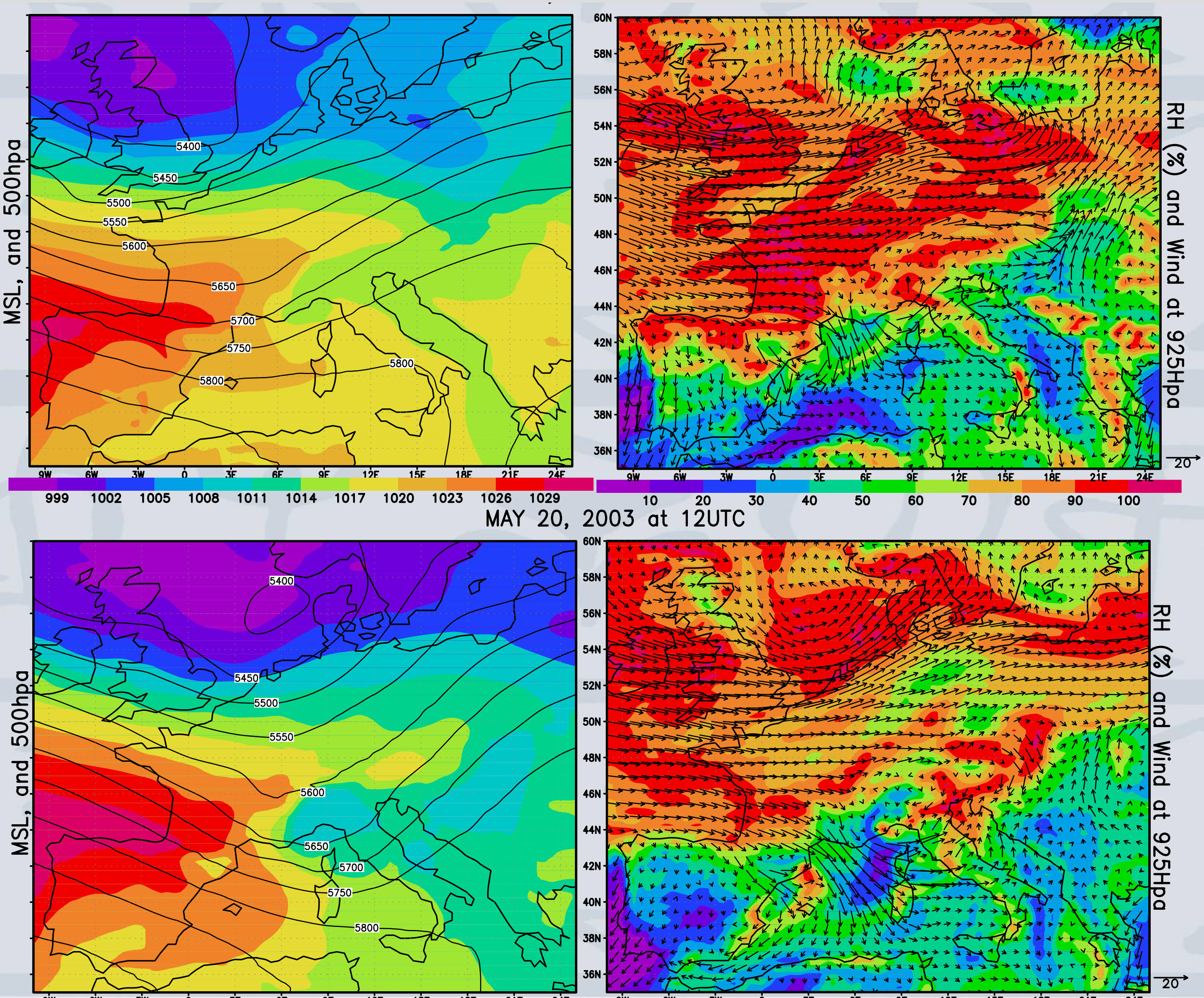
Work layout

Goal of the work: providing a contribution to the current scientific debate about the usefulness and reliability of high resolution numerical modelling of deep moist convective processes

- Are NWP models (COSMO-Model, MM5) sensitive to change on their microphysical/dynamical configurations? **PART I**
- Does high resolution allow to gain a deeper insight in the physics and dynamics of deep moist convection in this case? PART I
- Are the simulated 3D convective structures similar to those observed by radar? PART II
- Is the simulated atmospheric "background" consistent with the observed convection dynamics from a data assimilation viewpoint? PART II

Case study: hailstorm over Nor. Italy, 20 May 2003

During the night between 19 and 20 May 2003, a cold front coming from the North-West crossed the Alps causing a series of severe hailstorms over Emilia-Romagna and southern Veneto



Comparison between the simulated and observed 3D radar data

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Approach 1: intercomparison of both simulated (RSM-POL) and observed reflectivity fields (PPI of Gattatico and San Pietro Capofiume radars) so as to assess the reliability of model in reproducing deep convective weather conditions

Approach 2: intercomparison of both simulated and radar derived integrated water content for the whole hydrometeor species

Skill measure: Rousseau index (Barancourt et al. 1992; Giuli et al., 2003) and spectral decomposition

$$I_R^t = \frac{4 p_{11} p_{00} - \left(p_{10} + p_{01} \right)^2}{\left(2 p_{11} + p_{10} + p_{01}\right)\left(2 p_{00} + p_{10} + p_{01}\right)}$$

p11 : prev & oss > thr

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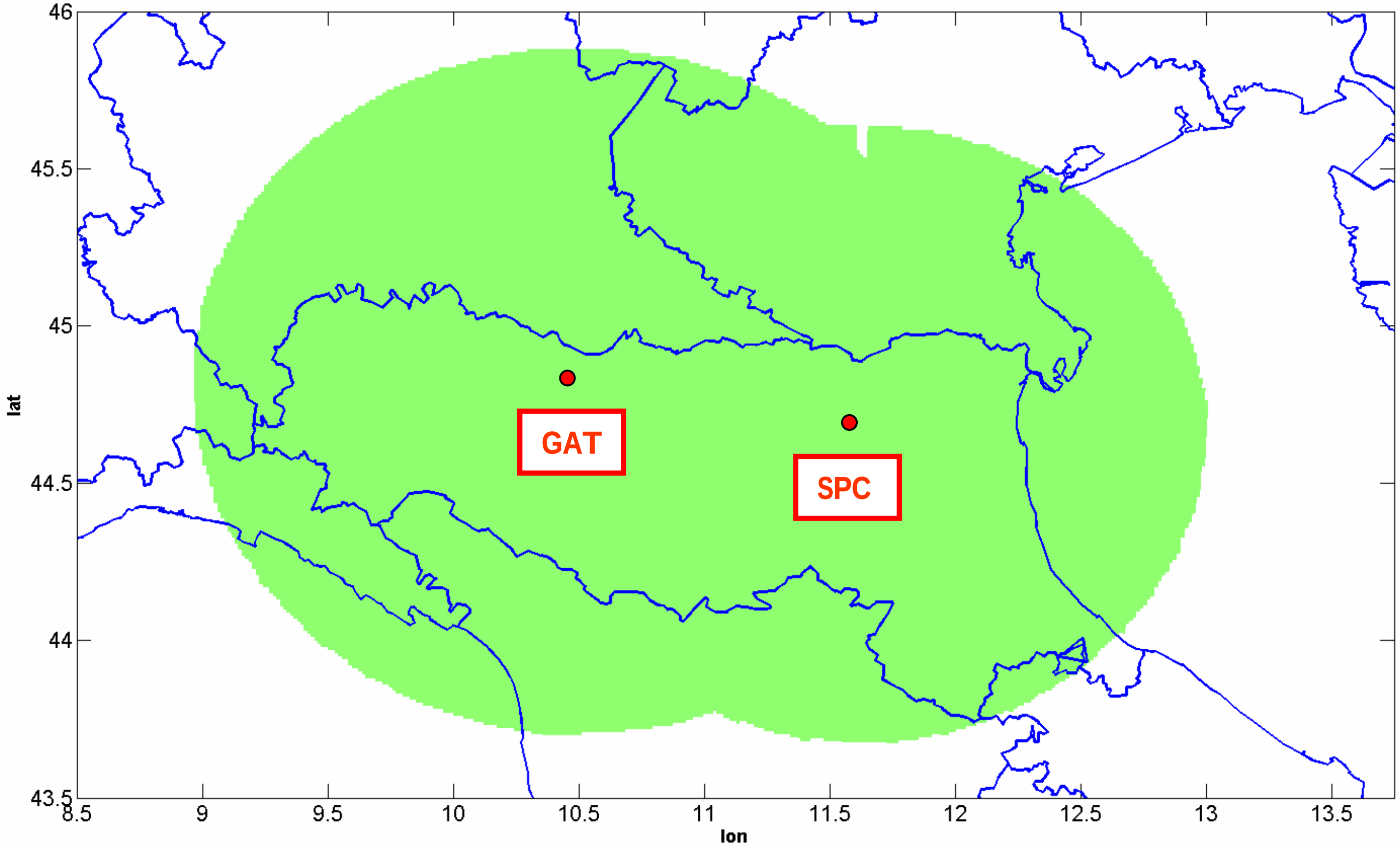
Radar observations (courtesy of ARPA-SIM)



Gattatico (GAT, left) and S. Pietro Capofiume (SPC, right) are two C-band polarimetric radars, with a maximum range of about 100 km owned by ARPA-SMR Emilia-Romagna. The distance between the two is about 90 km.

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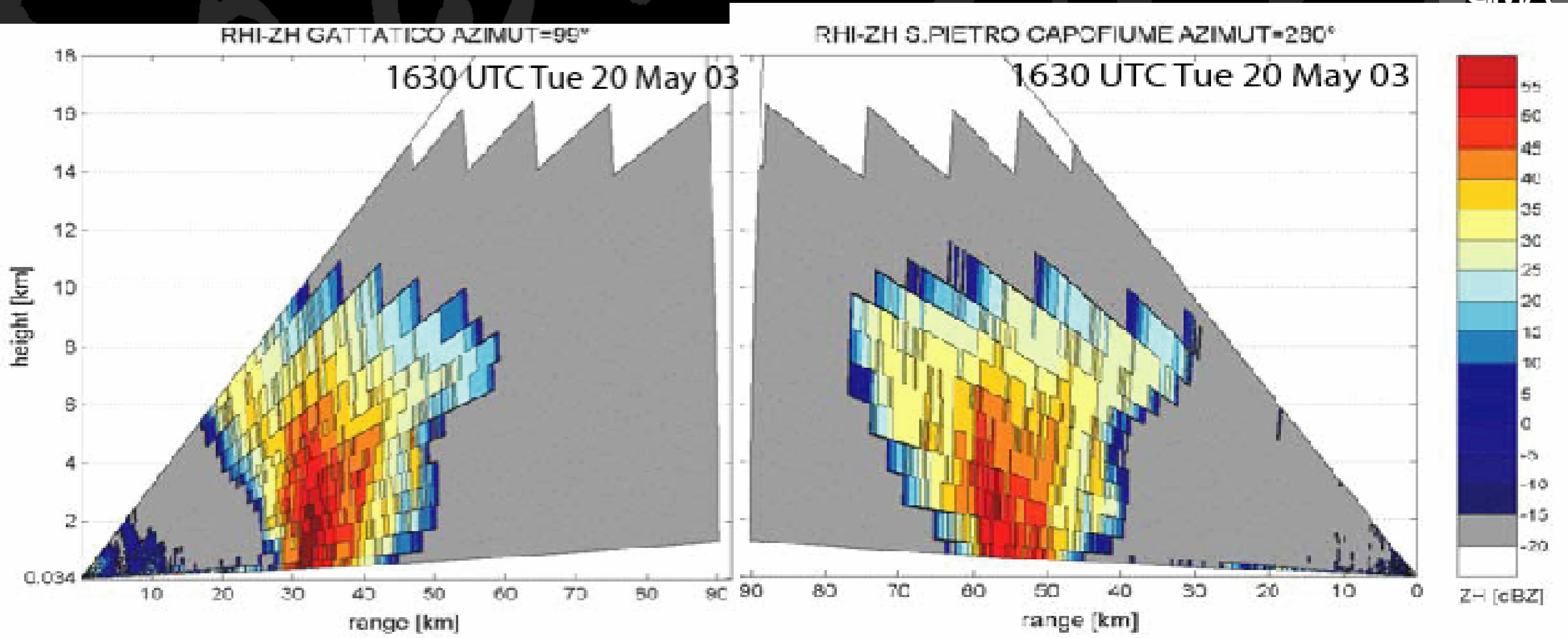
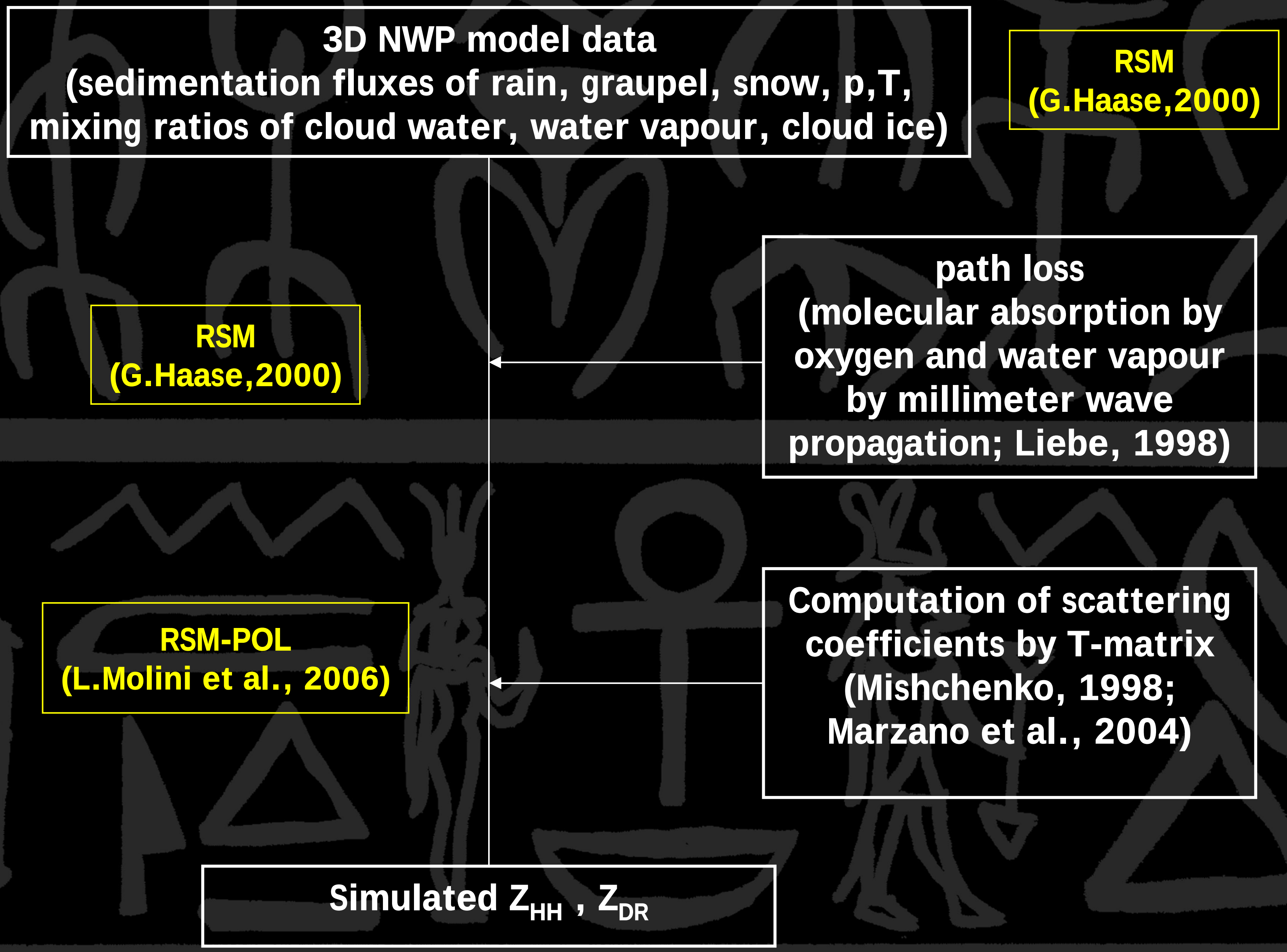
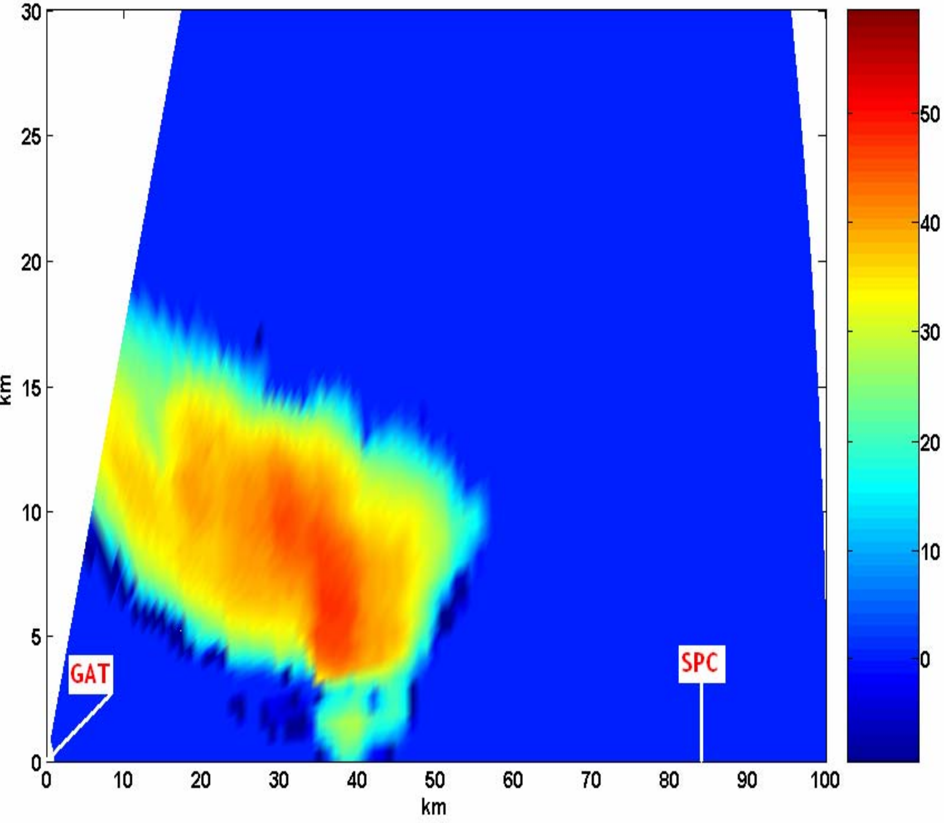


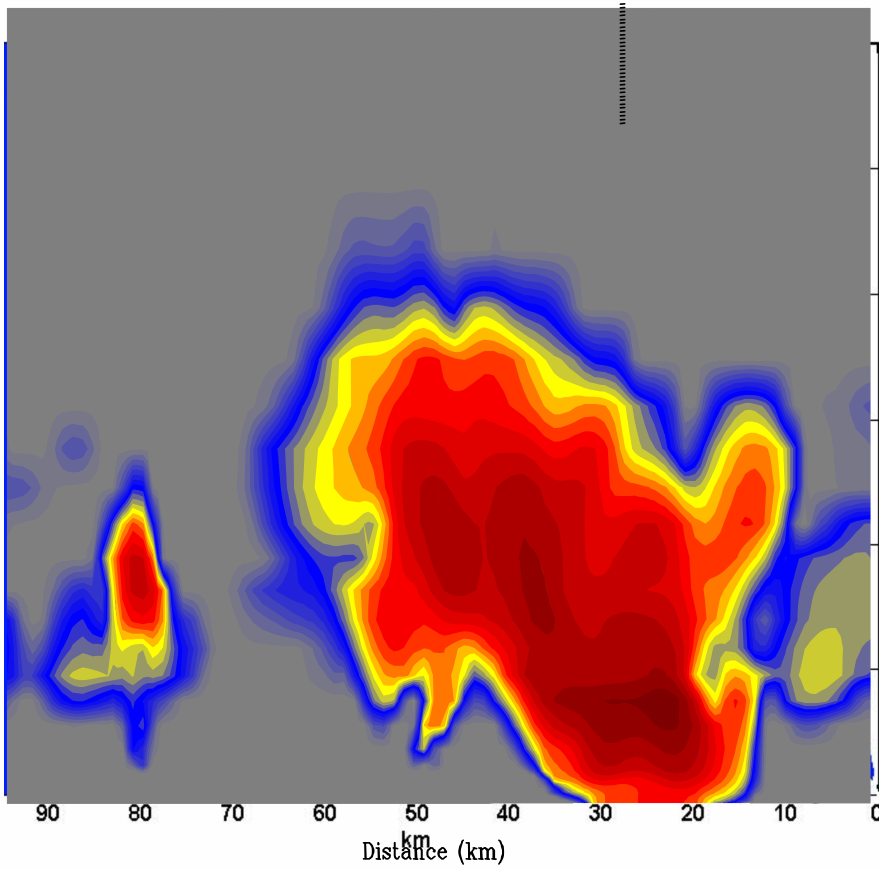
Vertical section (RHI) of copolar reflectivity Z_{HH} with respect to the line of sight between the two C-band radar systems in Italy on May 20, 2003 at 16:30.

Radar simulations: RSM-POL



RSM-POL





Vertical section (RHI) of copolar reflectivity Z_{HH} with respect to the line of sight between the two C-band radar systems on May 20, 2003 at 17:30 UTC simulated by means of the COSMO-LAMI/RSM-POL chain nested on the SETTING-3 COSMO-LAMI run *("light graupel").*

On the right, a RHI derived from MM5 reflectivity compuation model nested on SETTING-3 MM5 run (at 18.00)

Sensitivity to graupel particle properties

(density, number density intercept, velocity/size and mass/size distribution)

in COSMO-LAMI and MM5 simulations with a 3-category ice scheme with a 1km resolution

Setting	ρ_G (g/cm^3)	N_G^0 (m^{-4})	a[m$^{(1-b)}$*s^{-1}]	b	c[kg*m$^{(-e)}$]	e
1	0.2	$4*10^4$	442	0.89	169.6	3.1
2	0.2	$4*10^5$	442	0.89	169.6	3.1
3	0.2	$4*10^6$	442	0.89	169.6	3.1
4	0.4	$4*10^4$	93.35	0.50	209.44	3.0
5	0.4	$4*10^5$	93.35	0.50	209.44	3.0
6	0.4	$4*10^6$	93.35	0.50	209.44	3.0
7	0.9	$4*10^4$	140.03	0.50	471.24	3.0
8	0.9	$4*10^5$	140.03	0.50	471.24	3.0
9	0.9	$4*10^6$	140.03	0.50	471.24	3.0

Velocity-size relationship: $V_T=aD^b$

Mass-size relationship: $M=cD^e$

Heymsfield & Kajikawa, 1986
Lin et al, 1983
Reinhardt and Seifter, 2005

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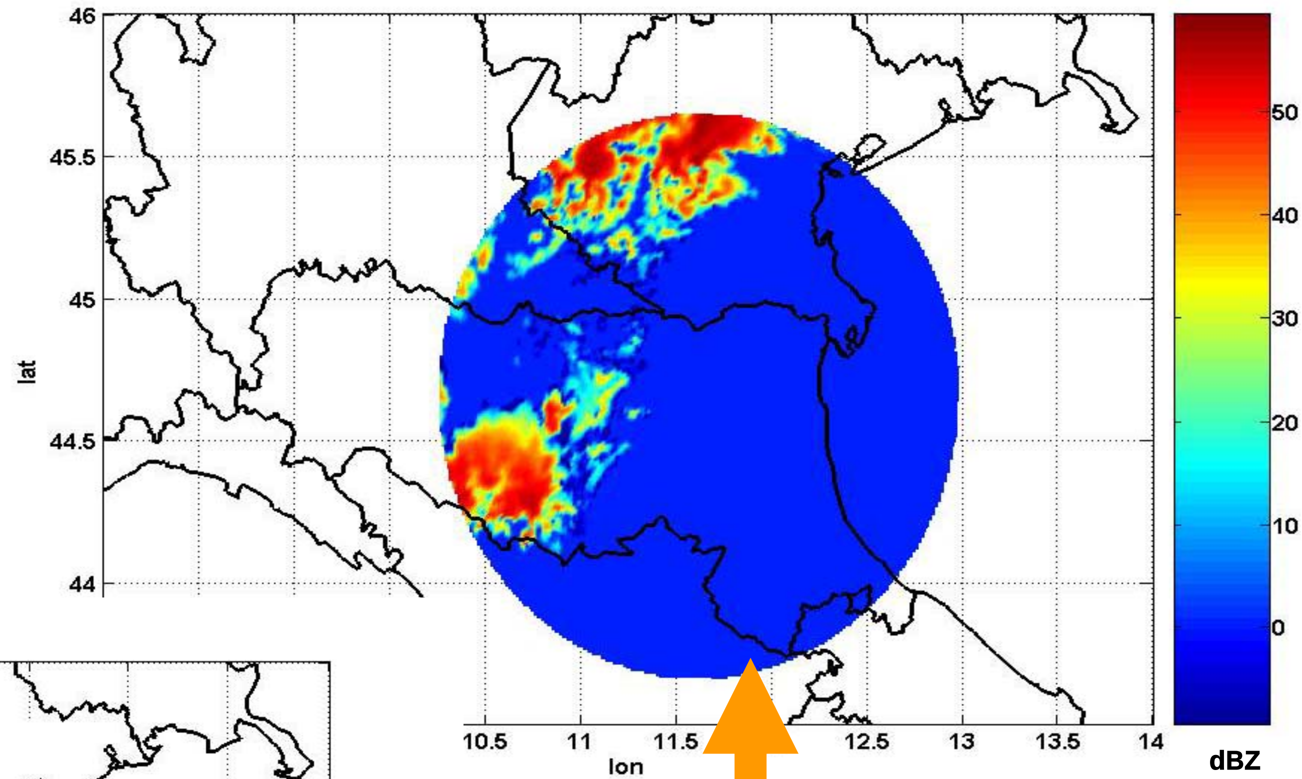
16.30 UTC

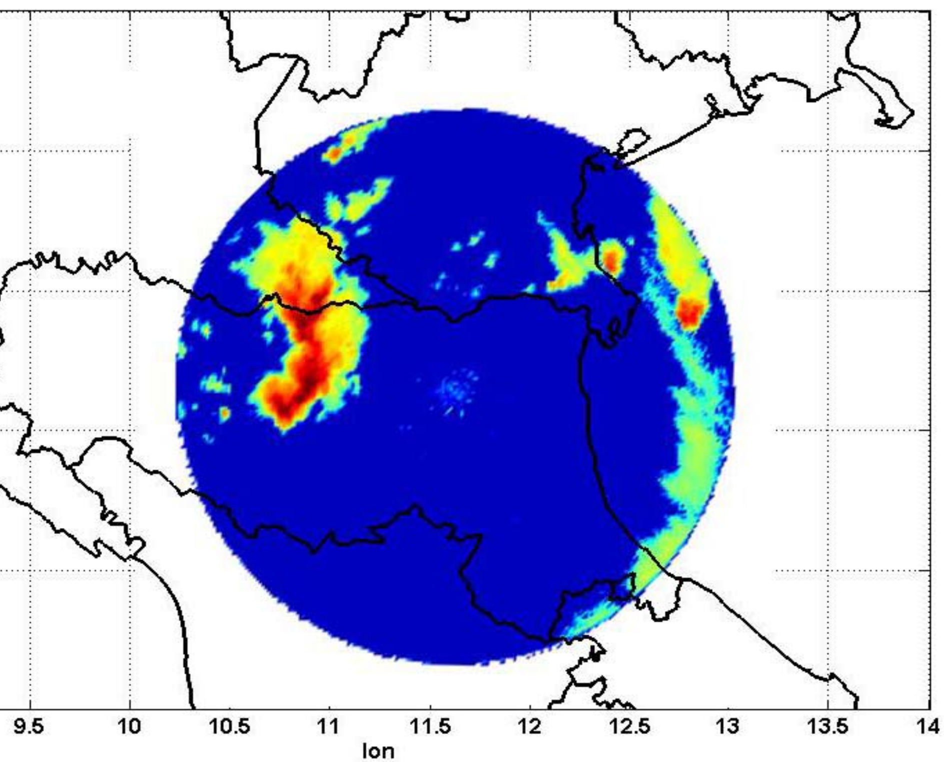
SPC radar

Elevation: 3°



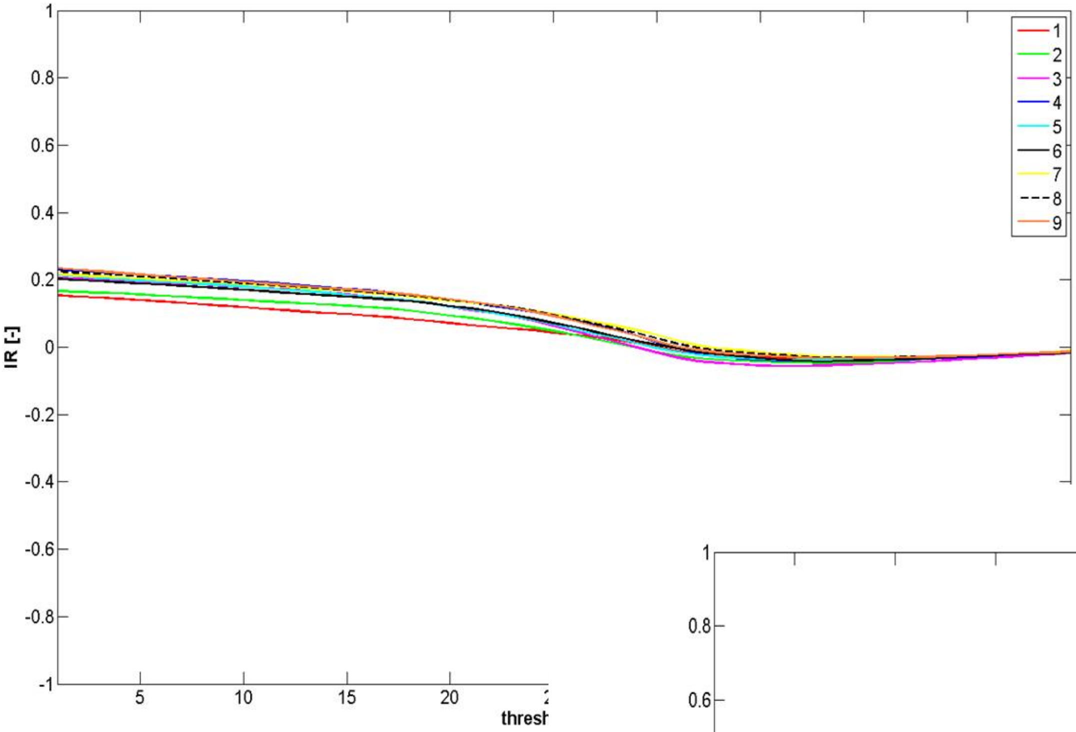
Simulated scan (setting 3)

Real scan



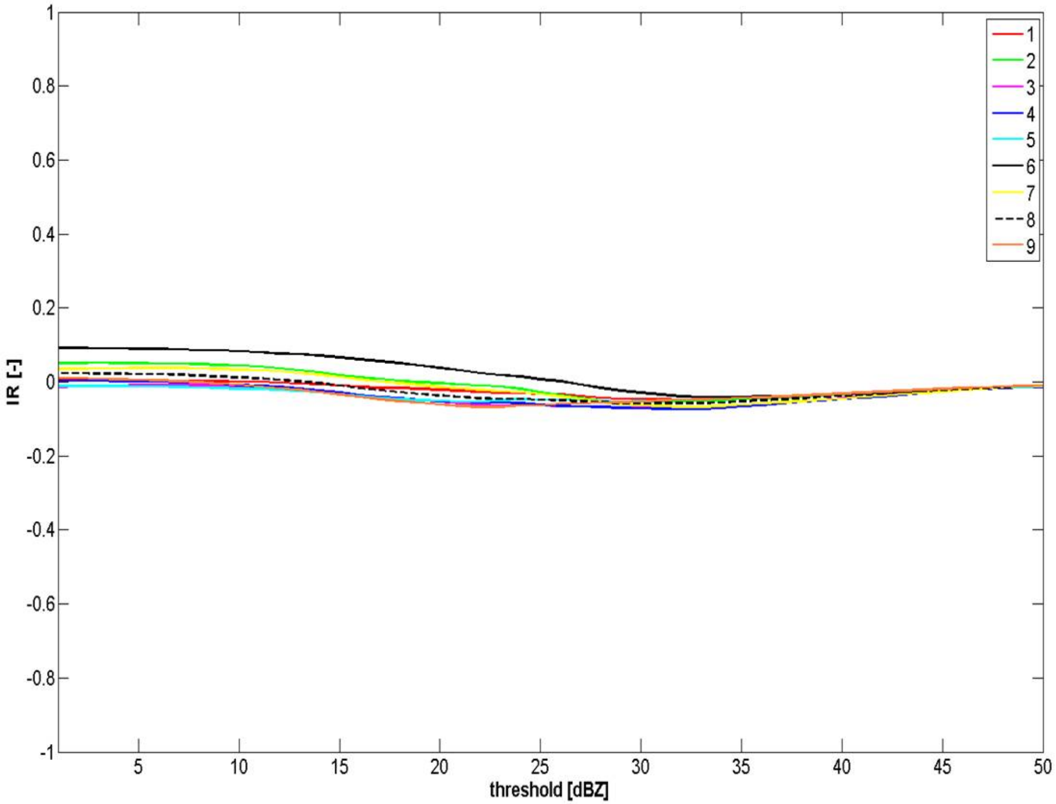
Rousseau Index
SPC

16-18 UTC

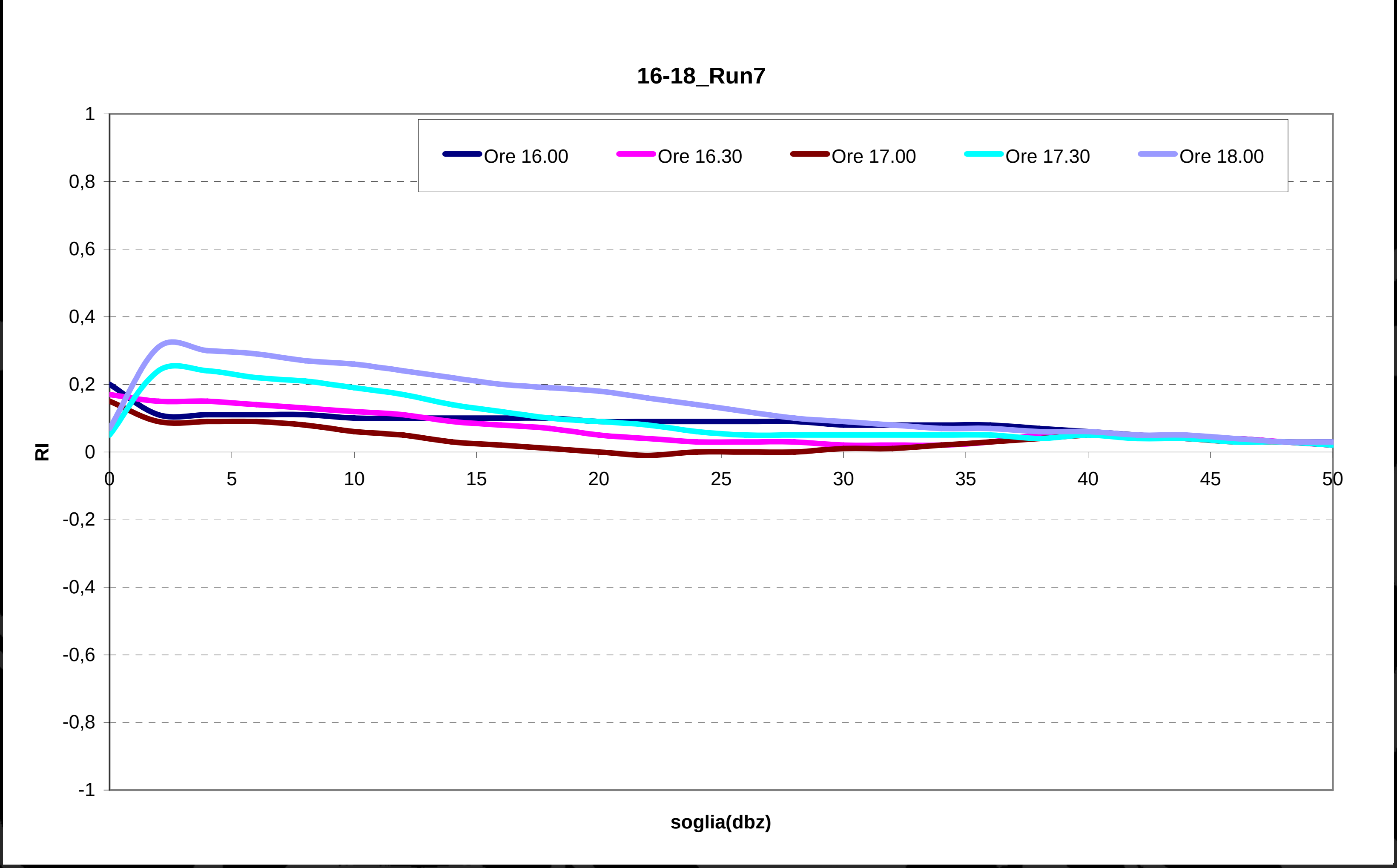


Rousseau Index
GAT

16-18 UTC



IR step by step computation (MM5)



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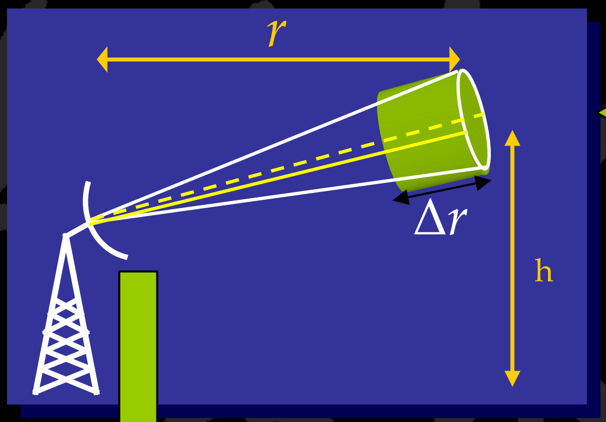
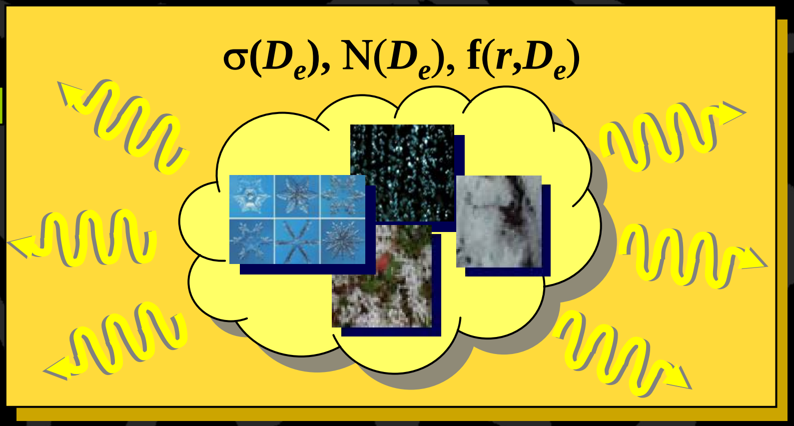
Water content estimate



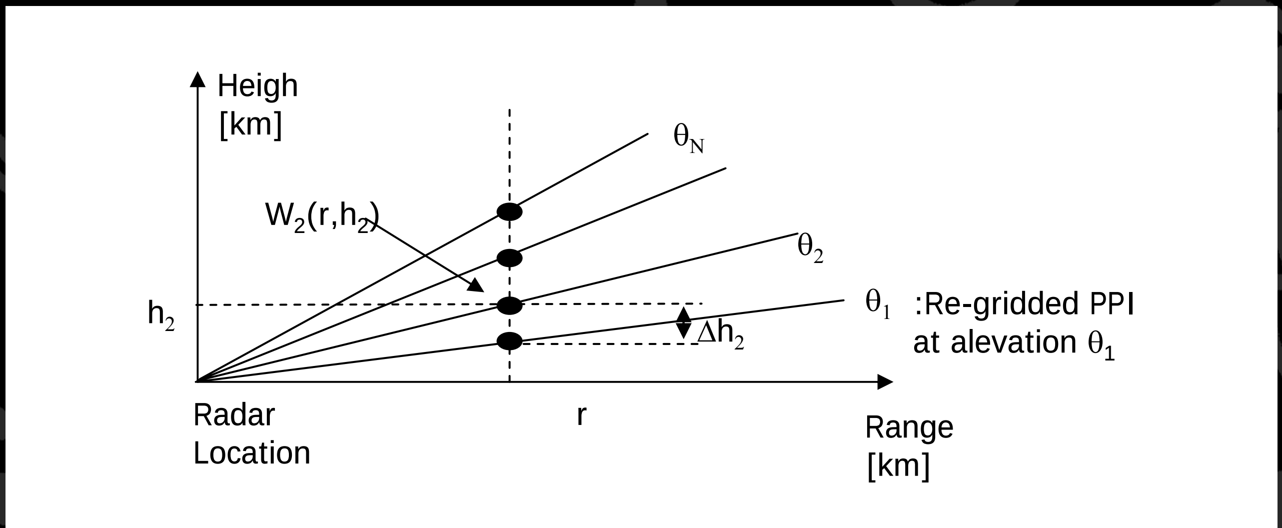


$$\mathbf{x} = \begin{bmatrix} Z_{hh} \\ Z_{dr} \end{bmatrix}$$

Power-law parameters *a*, *b* and *c* can be retrieved by a multiple linear regression techniques, applied to simulated L_w, Z_{dr} and Z_{hh} data. (Marzano et al.)

$$L_w \cong a Z_{hh}^{b} Z_{dr}^{c}$$

Integration over 11 PPI elevations (0°-17°)



Water content estimate

Large Drops	**(LD),**
Light Rain	**(LR),**
Medium Rain	**(MR),**
Heavy Rain	**(HR),**
Hail	**(H),**
Graupel/Small Hail	**(G/SH),**
Dry Snow	**(DS),**
Wet Snow	**(WS),**
Ice Crystals	**(IC),**
Drizzle Rain	**(DR),**
Wet Hail	**(WH),**
Wet Hail/Rain	**(WH/R),**

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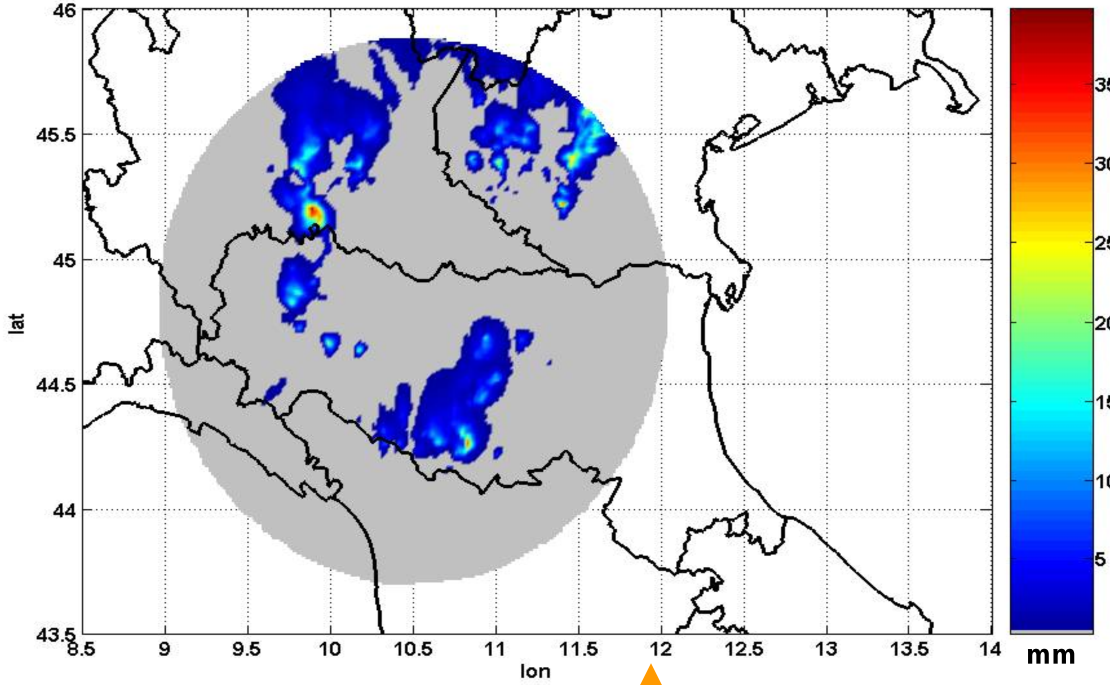
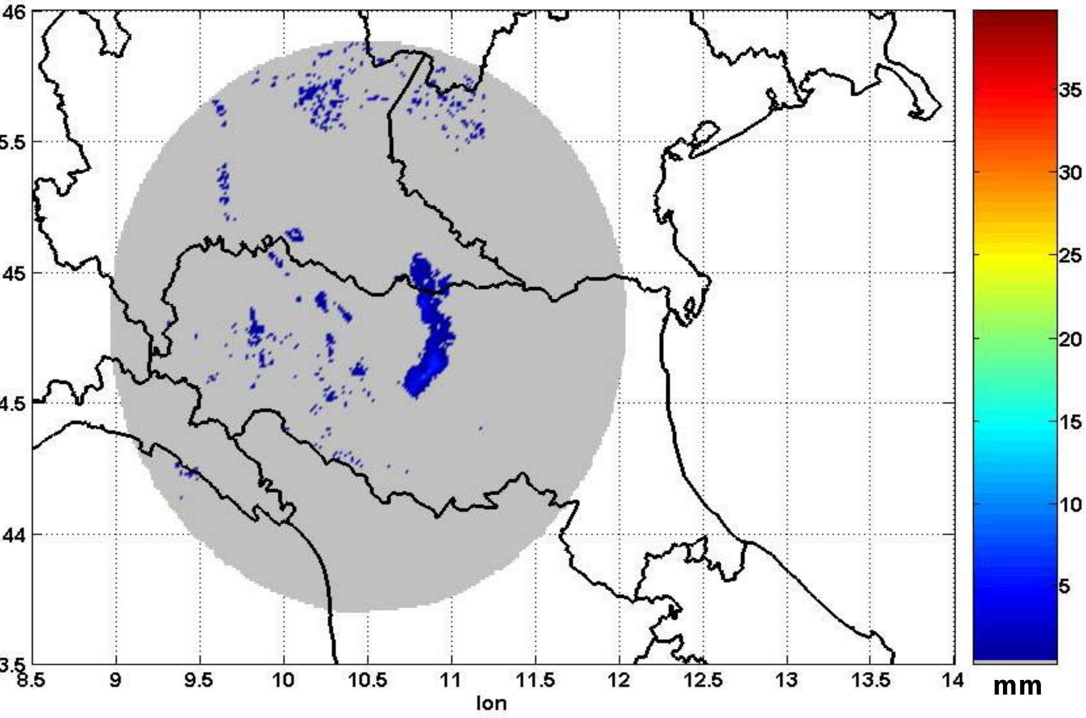
16.30 UTC

GAT radar

Water Content

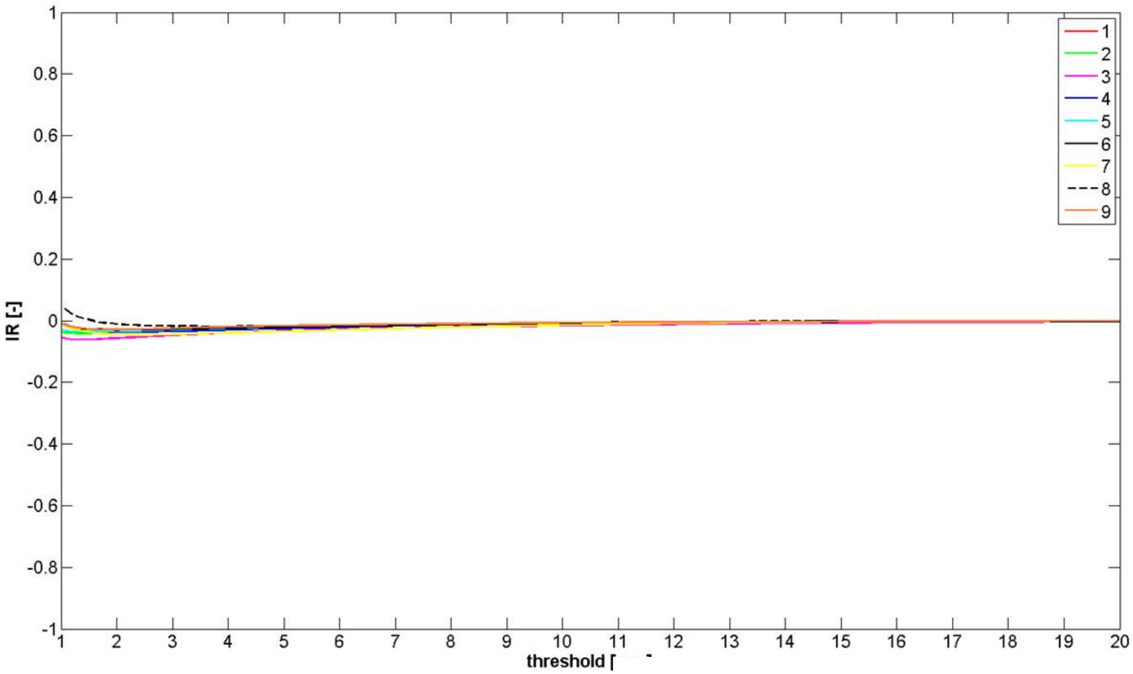




Simulated (setting 3)

Observed

The total columnar amount of water (rain, snow and graupel / hail) contained in the simulated atmosphere was 3-4 times higher that that retrieved from radar observations



Rousseau Index
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16-18 UTC

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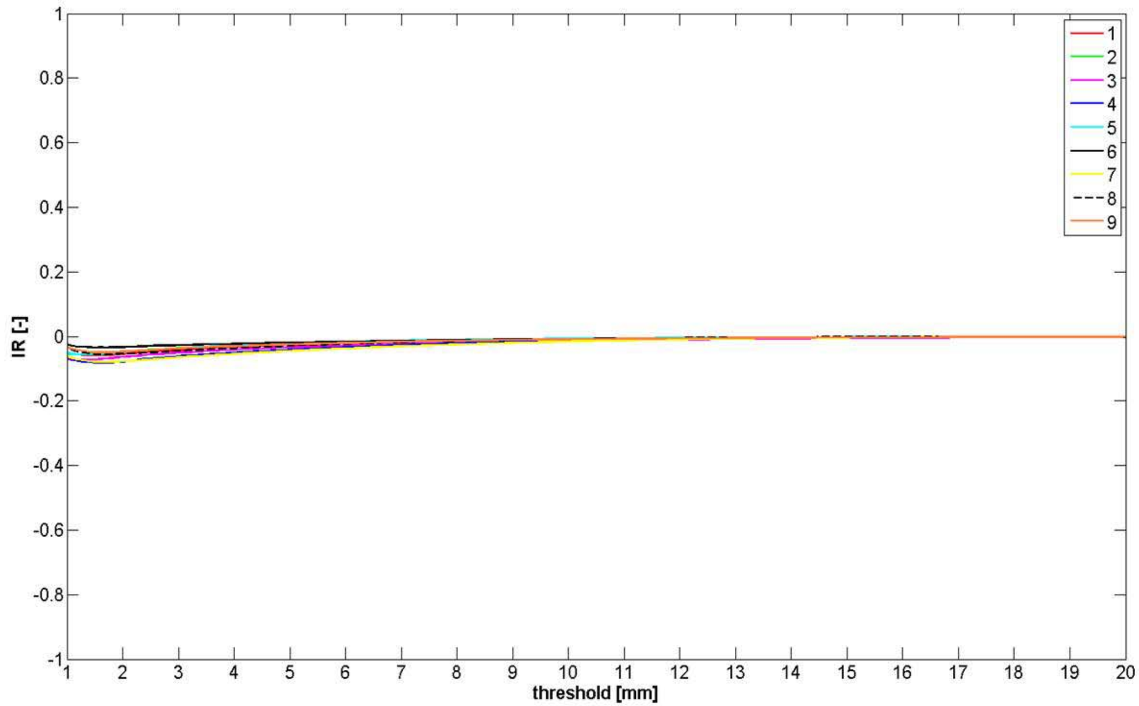
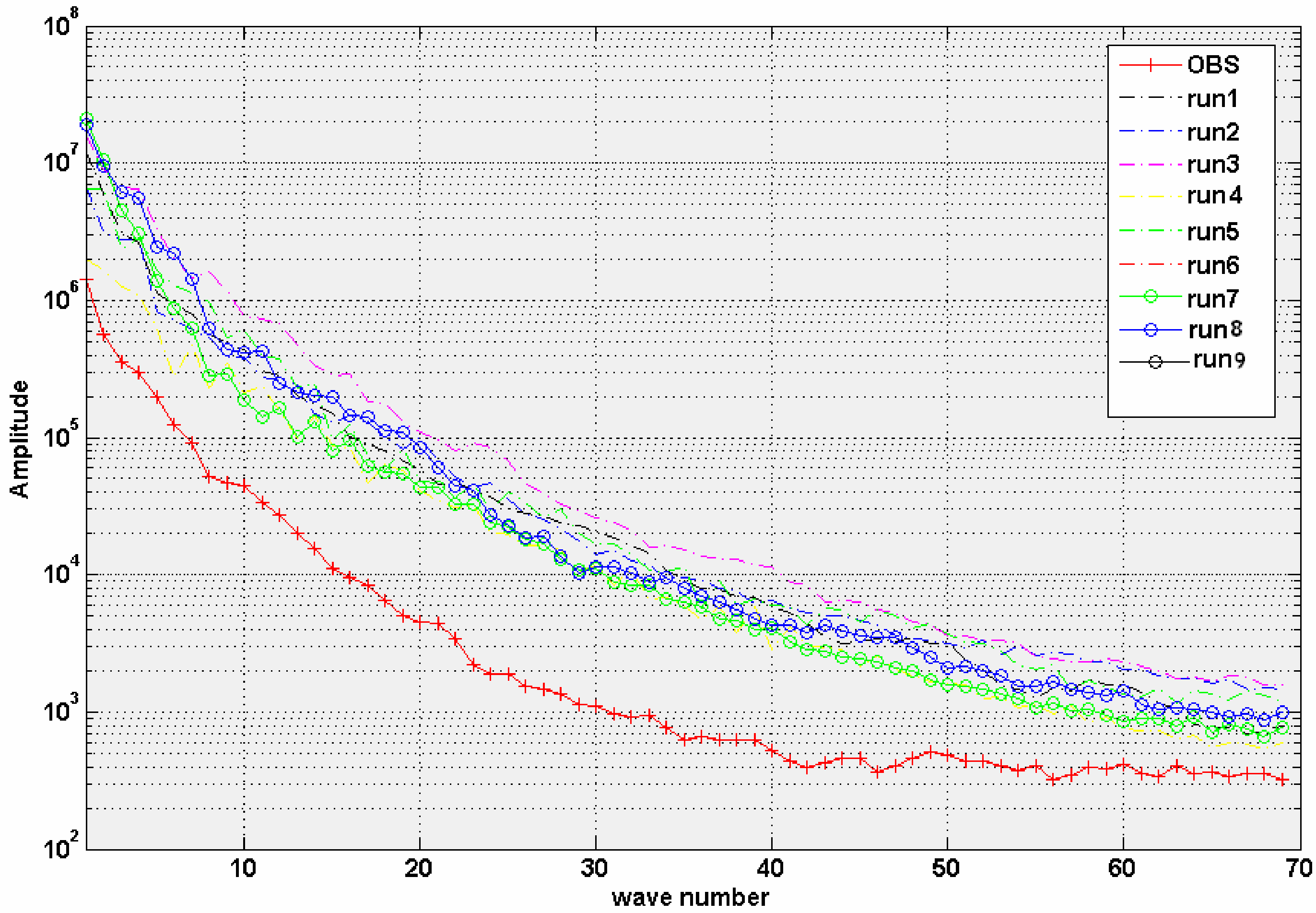


Spectral analysis



Mean spectra for both observed SPC water content (in red) and simulated (other colors)

Conclusions-PART I

both COSMO-LAMI and MM5 simulated cells exhibit a relevant sensitivity to changes in the graupel particle properties

At least one configuration produces hail at ground level

Open issue/Conclusions-PART II

Since both models, whatever it was the configuration, are able to provide realistic and plausible results, what is their forecast skill?

do the modelled scenarios agree with observations?

This study case seems to produce a negative answer to the question, for both NWP models, even in their best (hail at the ground) configuration

But...
Is this analysis too rigorous? Is RI too strict?
Are we asking too much to NWPs?

Several more study cases and results are needed

Thank you!

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