WRF physical options affecting simulations of radiation fogs: turbulence, microphysics and land-surface schemes

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1. INTRODUCTION

- Despite the well-known adverse effects of fogs over human life, its forecasting is one of the goals still not well achieved by the Numerical Weather Prediction (NWP) models. One of the reasons is because there coexist many processes acting together and affecting the fog cycle, being difficult to correctly parameterize them [1], [2]. Since the formation of radiation fogs starts from the surface, the effects of different land-use data sets and different land-surface schemes available in the Weather Research and Forecasting (WRF) [3] model have been investigated. Before this analysis, the impact of different microphysics (MP) and planetary boundary layer (PBL) schemes have been studied in order to select the best combination simulating the analyzed period, which was dominated by radiation fogs. A schematic view of the simulations procedure can be seen in Fig. 1. The setup of the simulations is shown in Fig. 2.

- The results of the simulations have been compared to observations from data available at CIBA (Research Centre for the Lower Atmosphere) site. This centre is located in the Montes Torozos, an extensive and homogeneous plateau specially suitable for the development of radiation fogs during winter. The studied period (3-15 January 2012) was characterized by high pressure systems over the western of Europe, and it led to more than 10 consecutive foggy days with different features (thickness, persistence during the daytime, vertical extension, freezing temperature values…).

- This poster is structured in 4 main boxes (PBL, microphysics, land use data sets and land-surface experiments). In each section, the observed fog (an approximation done from relative humidity measurements at 2 levels and temperature at 5 levels from 2 to 97m) have been compared to the Liquid Water Content (LWC) simulated by WRF at different heights (10, 35, 100 and 300m) (100 and 300m values are analyzed because the model usually tends to raise the fog as low clouds). Besides this comparison, measurements of relative humidity, temperature and mixing ratio have been compared to simulated values.

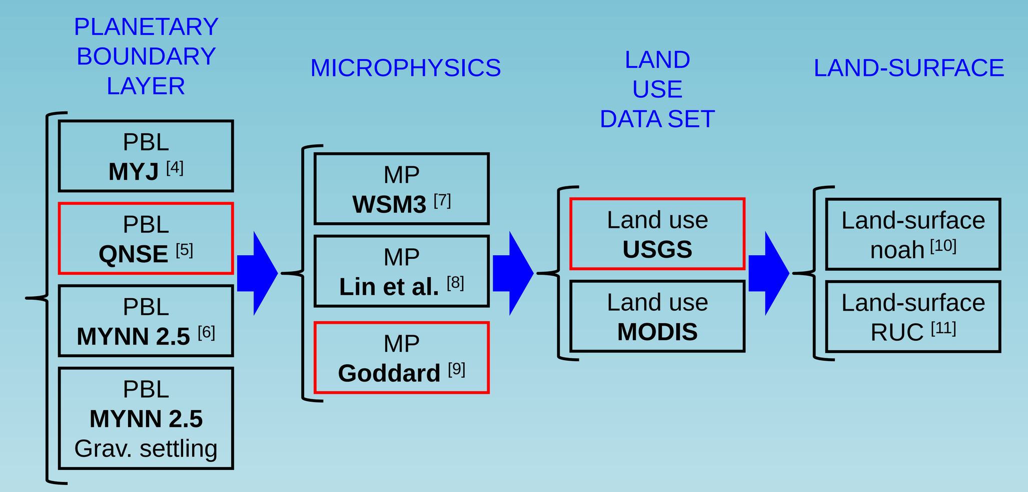

Figure 1. WRF-ARW simulations procedure (fixed scheme for next step marked as red).

WRF-ARW 3.3.1 setup

- **Horizontal domains -** 4 nested domains
- **Grid -** 27, 9, 3, 1 km
- **Boundary conditions -** NCEP, 1º, 6 hours
- **Vertical resolution** 50 levels "eta" (8 levels< 100 m) (28 levels< 1 km)
- **Time step** - 90 s
- **Spin up** -36 h (restart run)
- **SW radiation**- Dudhia (1998)
- **LW radiation** - RRTM

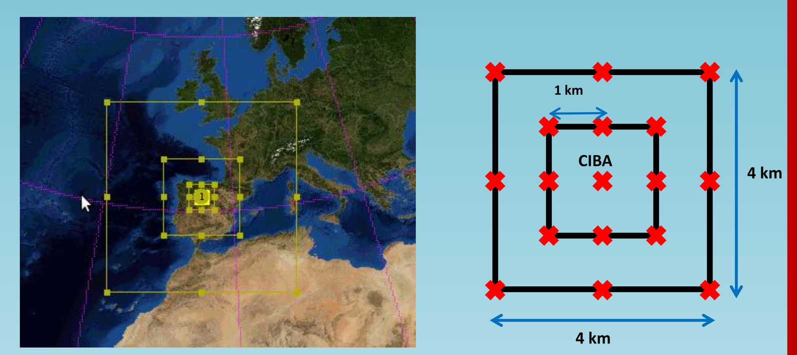

Figure 2. Simulations setup and map with the 4 nested domains centered at CIBA site. The third figure shows the 17 points used to average the simulated values of the different parameters (temperature, LWC, relative humidity…), i.e. 17 points have been used and not only one point.

2. PLANETARY BOUNDARY LAYER

WSM3, noah, USGS fixed!

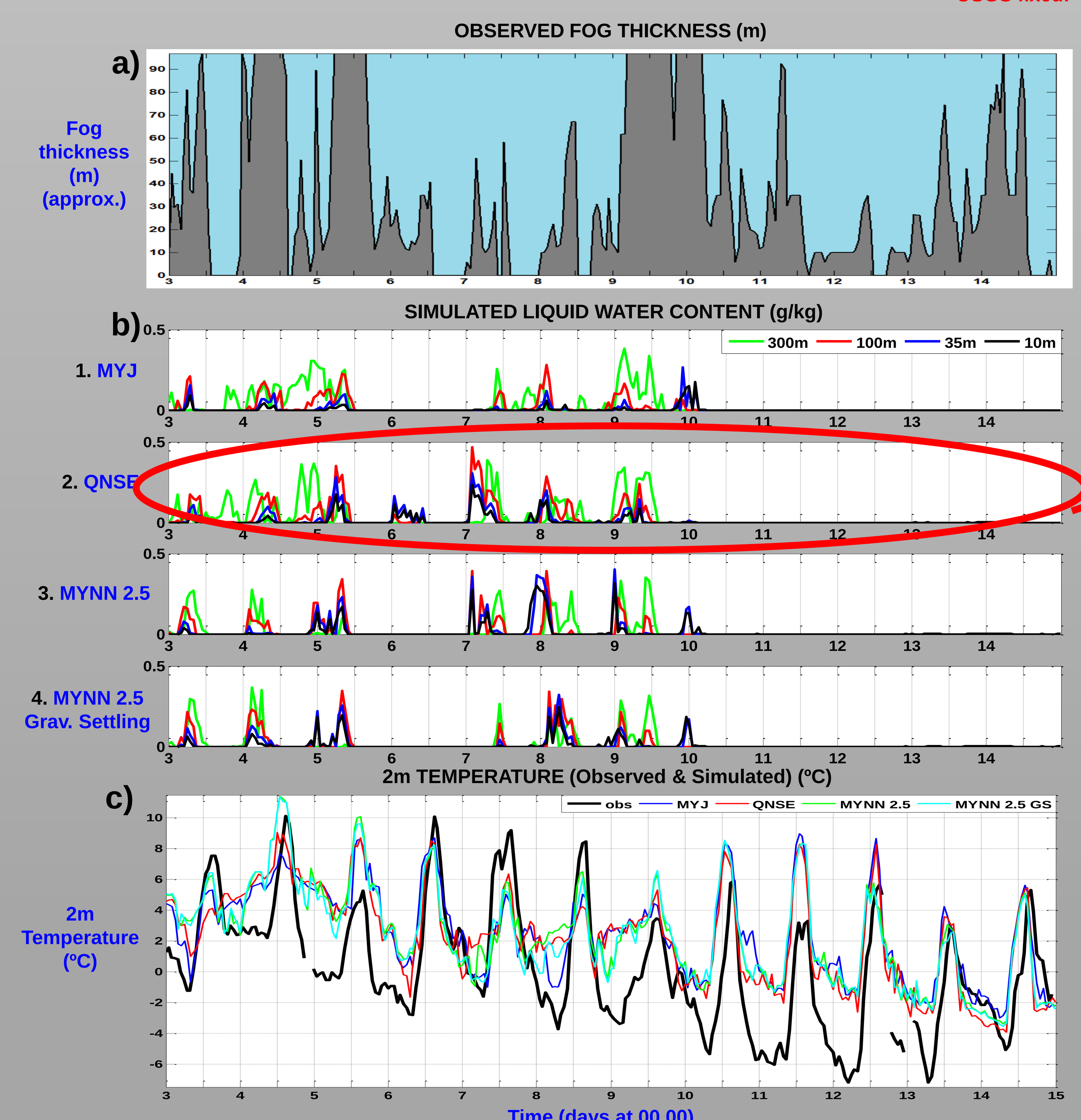

Figure 3. a) Observed fog thickness (m) (approximation). b) LWC simulated by WRF at 10m (black), 35m (blue), 100m (red) and 300m (green) for 4 different PBL options: 1=MYJ, 2=QNSE, 3=MYNN 2, 4=MYNN with gravity settling option. c) Observed temperature (black) and simulated temperature by 4 different PBL options: MYJ (blue), QNSE (red), MYNN 2 (green) and MYNN 2 GS (light blue).

- All schemes tend to elevate the fog in the vertical until 200-300m approximately.

- Most of fogs dissipated at midday by simulations (no well simulation of persistent fogs).

- None of the schemes simulated the fog at all for days 10, 11, 12, 13 and 14 (mainly shallow fogs related to strong thermal surface inversions).

- The model usually overestimate the temperature (specially minimum temperatures), being not able to reach the needed relative humidity values to produce condensation -> no LWC.

3. MICROPHYSICS

QNSE, noah, USGS fixed!

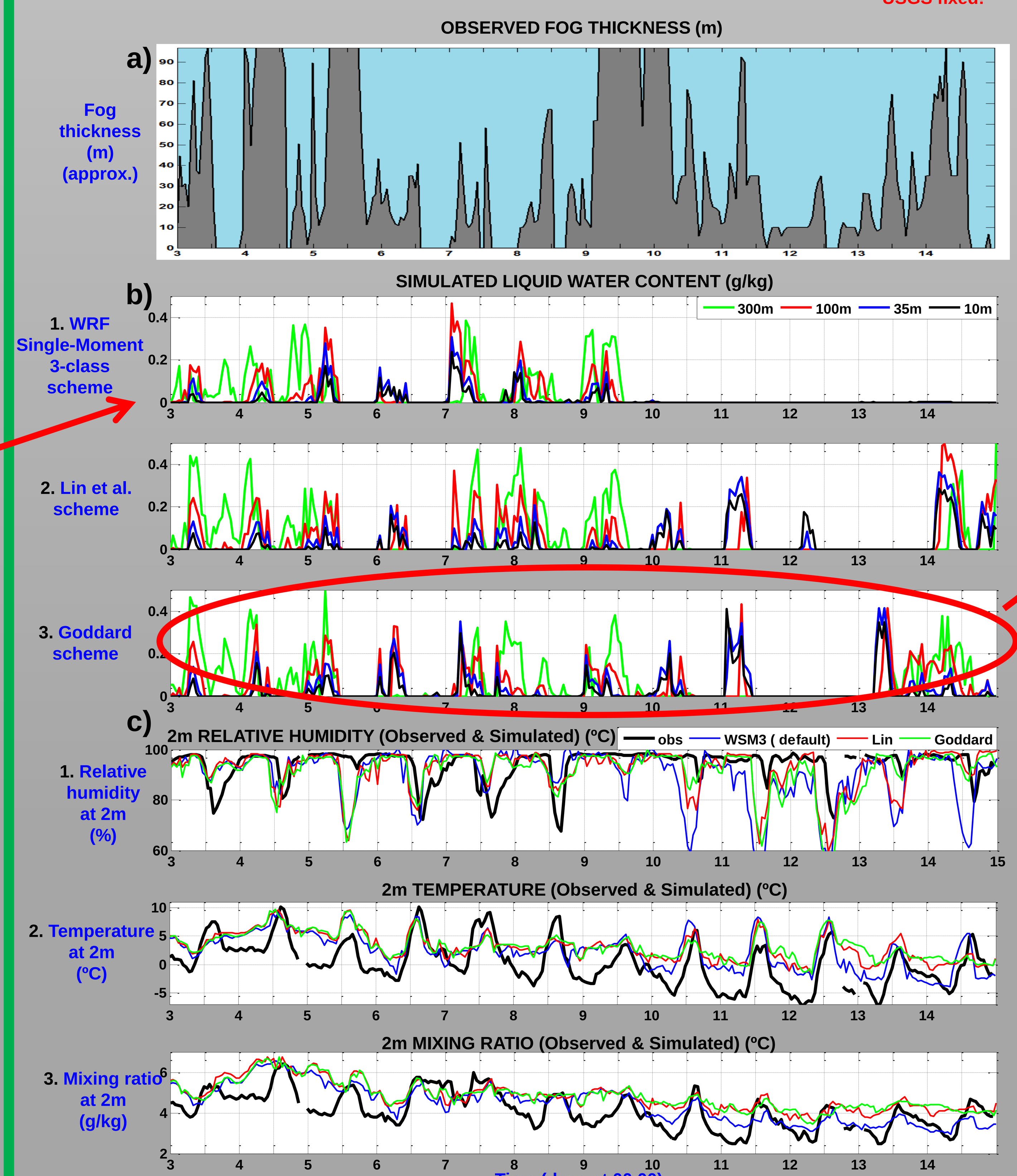

Figure 4. a) Observed fog thickness (m) (approximation). b) LWC simulated by WRF model at 10m (black), 35m (blue), 100m (red) and 300m (green) for 3 different microphysical schemes: 1=WSM3, 2=Lin et al., 3=Goddard scheme. c) Relative humidity (1), temperature (2) and mixing ratio (3) at 2m: observed (black) and simulated for 3 different microphysics options: WSM3 (blue), Lin et al. (red) and Goddard (green).

- For days 10, 11 and 14, the fog is now simulated using Lin et al. and Goddard schemes. Day 12 was also simulated by Lin et al. scheme and day 13 by Goddard scheme.

- Wrong simulation of temperature & mixing ratio -> relative humidity well simulated (2 ERRORS leading to a good prediction of the relative humidity and a good prediction of the fog).

4. LAND USE DATA SETS

QNSE, noah, Goddard fixed!

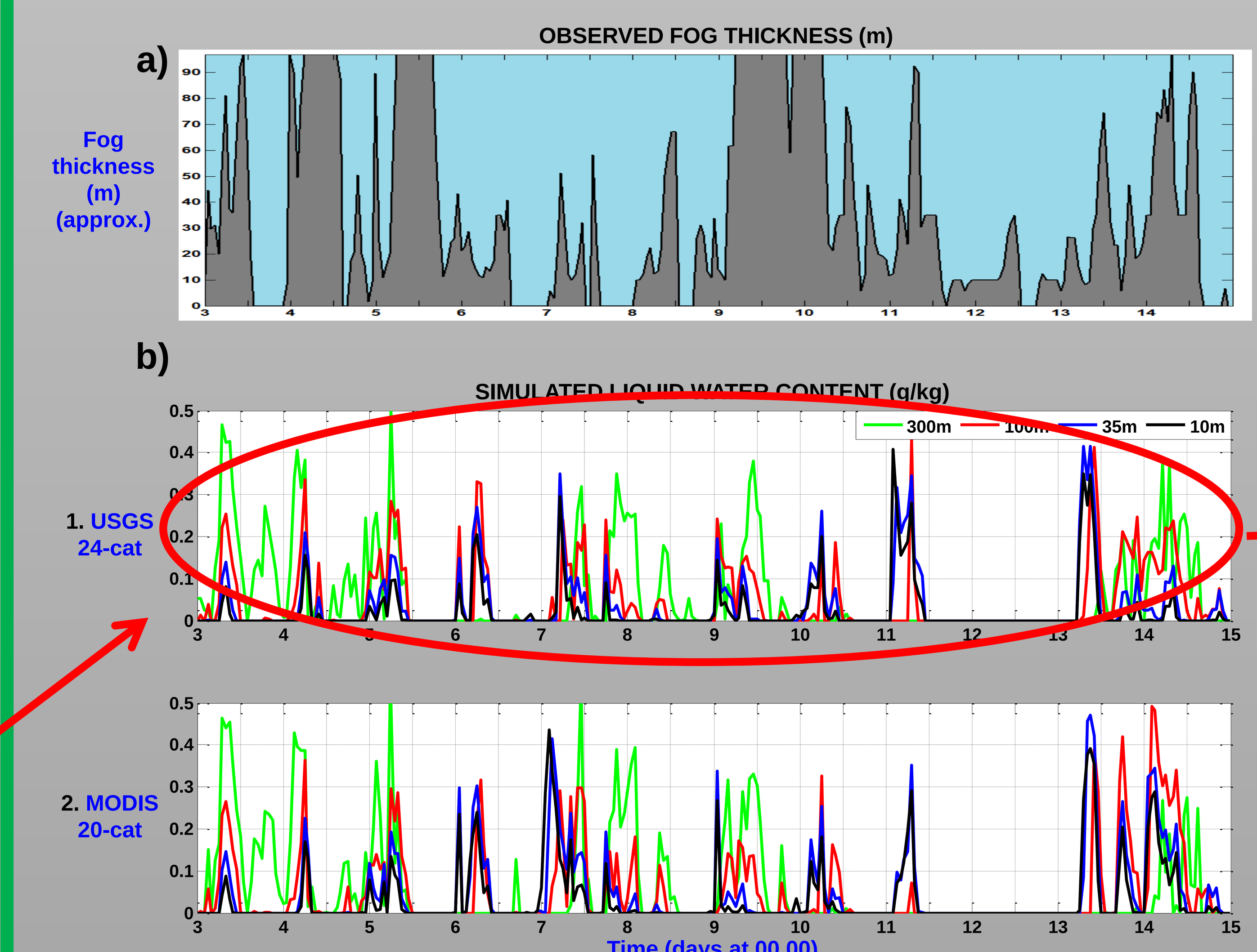

Figure 5. a) Observed fog thickness (approximation). b) LWC simulated by WRF model at 10m (black), 35m (blue), 100m (red) and 300m (green) using 2 different land-use data sets: 1=USGS and 2=MODIS

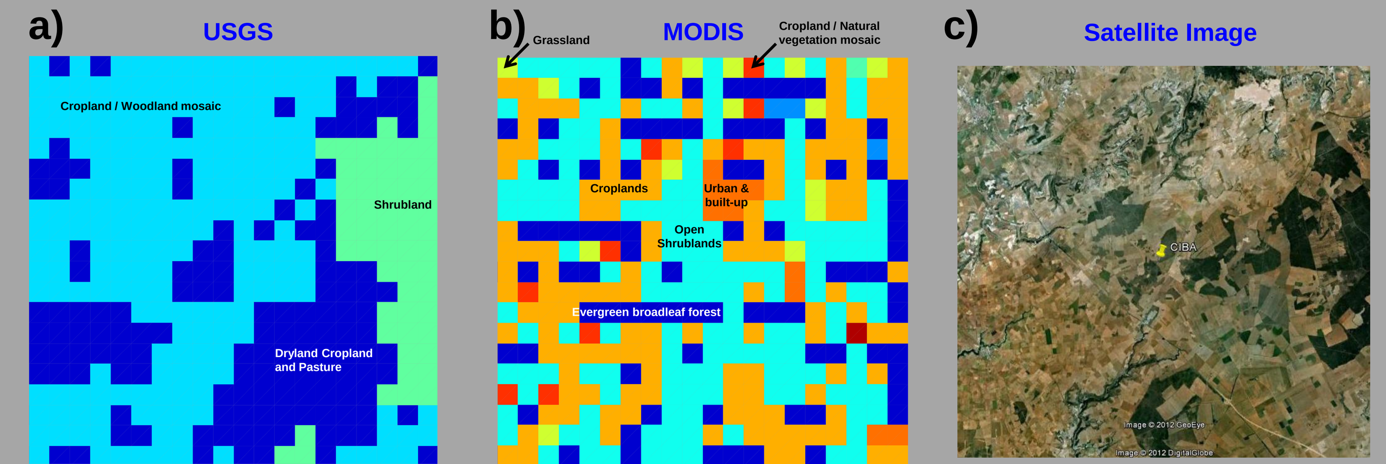

Figure 6. USGS (a) and MODIS (b) land-use at CIBA site (20 x 20 km). c) Satellite image of CIBA site (20 x 20 km) (from Google earth)

- There exist some differences between land uses at CIBA site between USGS 24-cat and MODIS 20-cat data sets (more homogeneity in USGS data set).

- The CIBA place is a very homogeneous terrain with mainly cropland and shrubland.

- However, no remarkable differences in simulated LWC using different land-use datasets.

5. LAND-SURFACE

QNSE, Goddard, USGS fixed!

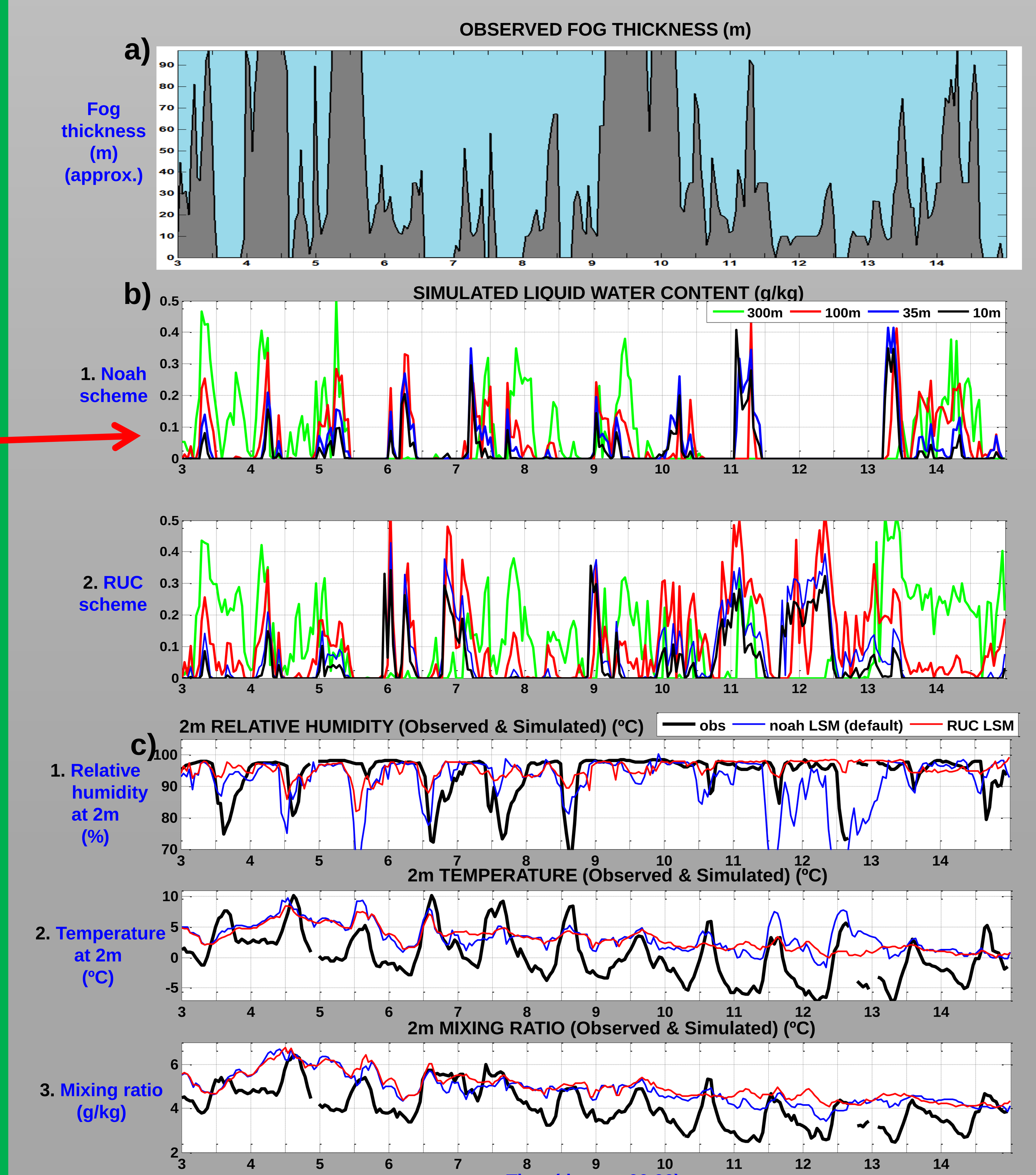

Figure 7. a) Observed fog thickness (m) (approximation). b) LWC simulated by WRF model at 10m (black), 35m (blue), 100m (red) and 300m (green) for 2 different land-surface schemes: 1=NOAH, 2=RUC. c) Relative humidity (1), temperature (2) and mixing ratio (3) at 2m: observed (black) and simulated for 2 different land-surface parameterizations: NOAH (blue) and RUC (red).

- Correct simulation of the fog (LWC) on day 12 using RUC. It includes improvements for snow and frozen soil conditions, as well as for stable situations. However, 2m temperature not well reproduced.

- Still incorrect prediction of temperature (overestimation) and mixing ratio (overestimation). Again two error leading to a correct prediction of LWC

6. CONCLUSIONS

- Radiation fogs are sensitive to WRF physical options:

PBL - QNSE and MYNN improved the fog prediction. Gravity settling option produced shallower fogs (usually more realistic) but also a faster dissipation (not good for persistent fogs).

MP - Lin et al. and Goddard microphysics schemes served to improve the fog forecasting (specially during days with shallow fogs and strong thermal inversion). Wrong prediction of temperature and mixing ratio.

LAND USE DATA SET - No important differences in LWC between USGS and MODIS land-use data sets, but differences in the definition of the CIBA site land uses.

LAND-SURFACE - RUC land surface model predicted the fog for day 12 (shallow fog , strong inversion and frost conditions day) (RUC specially designed for inversions and frost conditions–> BUT, 2m temperature not well predicted!

- More and detailed investigation is needed in order to separate PROCESSES involved in fog cycle.

7. ACKNOWLEDGMENTS

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8. REFERENCES

[1] Bergot T., Terradellas E., Cuxart J., Mira A., Liechti O., Mueller M. and Nielsen N. W. (2007): *J. Appl. Meteorol. Climatol.*, 46, 504.

[2] Gultepe I., Tardif R., Michaelides S. C., Cernak J., Bott A., Bendix J., Müller M. D., Pagowski M., Hansen B., Ellrod G., Jacobs W., Toth G. and Cober S. G. (2007): *Pure Appl. Geophys.*, 164 , 1121.

[3] Skamarock W., Klemp J., Dudhia J., Gill D., Barker D., Duda M., Wang W. and Powers J. (2008): NCAR Technical Note.

[4] Mellor G. L., and Yamada T. (1982): *Rev. Geophys. Space Phys., 20, 851–875.*

[5] Sukoriansky S., Galperinand B., Staroselsky I. (2005): *Physics of Fluids*, 17, 085107–1–28.

[6] Bougeault P. and Lacarrere P. (1989): *Mon. Wea. Rev. 117, 1872–1890.*

[7] Hong S-Y., Dudhia J., Chen S-H. (2004): *Mon. Wea. Rev*. 132, 103-120.

[8] Lin Y-L., Farley R.D., Orville H.D. (1983): *J. Appl. Meteorol. Climatol.*, 22, 1065-1092

[9] Tao W-K., Simpson J. and McCumber M. (1989): *Mon. Wea. Rev. 117, 231-235.*

[10] Pan H.L. and Mahrt L. (1987): *Boundary-Layer Meteorol 38, 185-202.*

[11] Smirnova, T. G., Brown J.M. and Benjamin S.G. (2000): *J. Geophys. Res.*, 105 (D3), 4077-4086.