View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Agencia Estatal de Meteorología

Exploring the formation and dissipation of radiation fog from observational data and numerical model results (WRF and HARMONIE)

C. Román-Cascón [1], C. Yagüe [1], G. Morales [2], G-J. Steeneveld [3], I. Bartolomé [1], M. Sastre [1], J. A. Arrillaga [1] and G. Maqueda [4]

(1) Depto. de Geofísica y Meteorología. Universidad Complutense de Madrid, Spain. (carlosromancascon@ucm.es); (2) AEMET. Madrid, Spain; (3) Meteorology and Air Quality Section. Wageningen University, The Netherlands; (4) Depto. de Astrofísica y Ciencias de la Atmósfera. Universidad Complutense de Madrid, Spain.

1. MOTIVATION & INTRODUCTION

NOT CORRECT FOG FORECASTING

FOG PHYSICAL PROCESSES NOT WELL UNDERSTOOD & NOT WELL PARAMETERIZED IN MODELS [1]

PROBLEMS!

FOG ONSET-DISSIPATION [2]
VERTICAL EXTENSION [3]
SHALLOW FOG [4]
} Some known model-problems

OBSERVATIONAL ANALYSIS OF A PERIOD WITH SEVERAL RADIATION-FOG EVENTS AT CIBA
Onset – Development – Dissipation

IN THIS STUDY

NUMERICAL MODELS EVALUATION
WRF vs. HARMONIE

2. DATA AND METHOD

OBSERVATIONAL ANALYSIS

CIBA[5]
(Research Centre for the Lower Atmosphere)

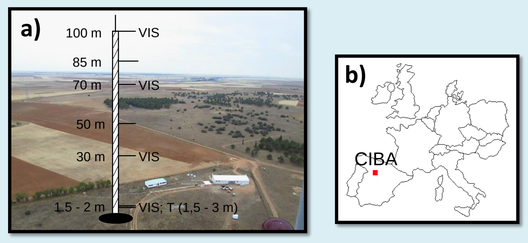


Figure 1. Aerial view from the top of the 100-m mast at CIBA and graphical representation of 100-m tower. b) CIBA location.

- Located at an extensive and homogeneous plateau in the Spanish Northern Plateau (*Montes Torozos* (41º 47'N, 4º 56'W, 840 m asl)).

- DATA from 2 towers (10-m and 100-m).
  - VISIBILIMETERS
  - TERMO-HIGROMETHERS
  - SONIC ANEMOMETER
  - ANEMOMETERS & WIND VANES

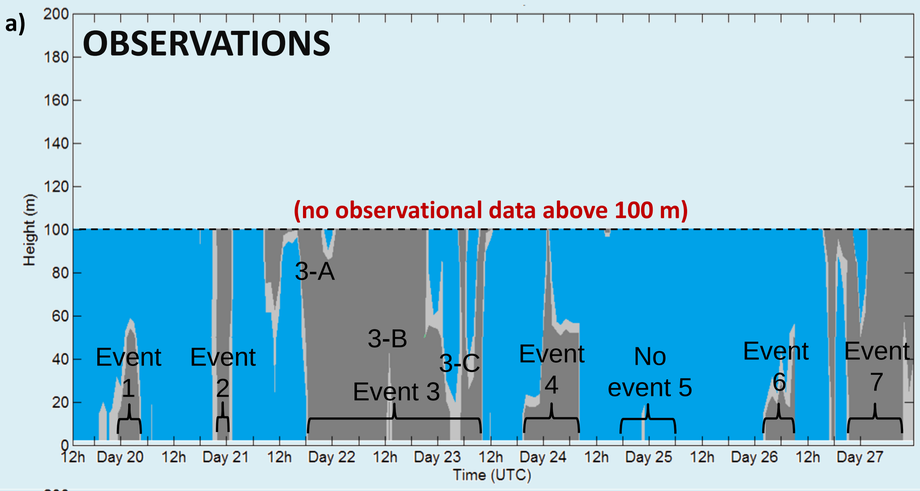
- Studied period: 19-27 Jan 2016, composed by several radiation-fog events with different features (thickness, duration, fog formation processes, temperature, etc.).

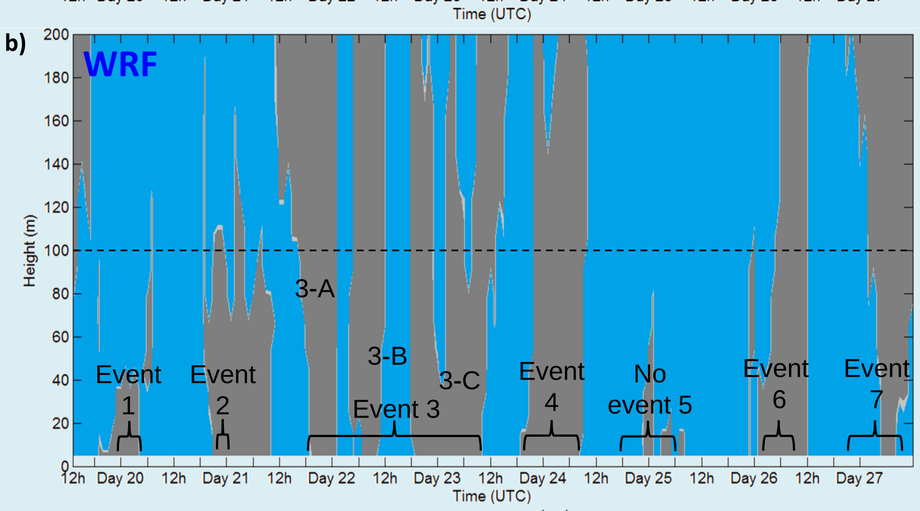
NUMERICAL MODELLING

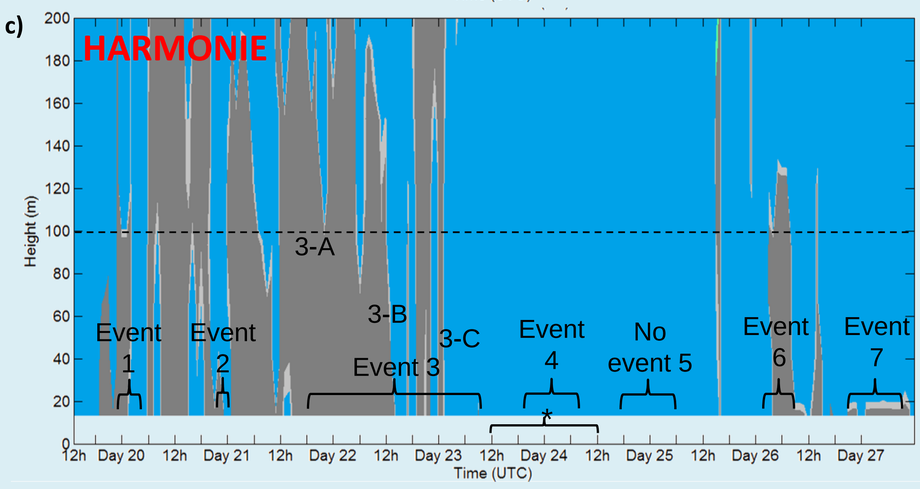
Table I. WRF and HARMONIE models configuration used in this work.

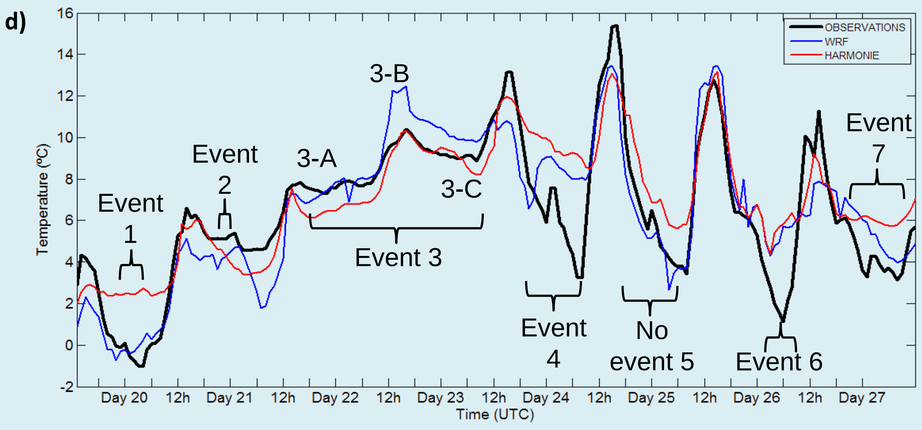
	WRF-ARW [6] 3.5.1	HARMONIE [7,8] (AROME configuration)
Brief description	Mesoscale model Research & Forecast	Mesoscale model Operational
Domain and horizontal resolution	1 domain (300 x 300 points around CIBA) 2.5 km grid	1 domain (Iberian Peninsula domain) 2.5 km grid
Initial conditions	NCEP 1º, 6 h	ECMWF forecast, 16 km
Vertical levels	50 vertical levels (8 levels < 100 m) (28 levels < 1 km)	65 vertical levels (4 levels < 100 m) (20 levels < 1 km)
Planetary Boundary Layer scheme	MYNN 2.5	Cuxart - Bougeault TKE
Radiation (SW/LW)	Dudhia / RRTM	ECMWF scheme
Land-surface scheme	Noah	SURFEX
Microphysics scheme	WRF Double-Moment 6-class	ICE-3

3. RESULTS









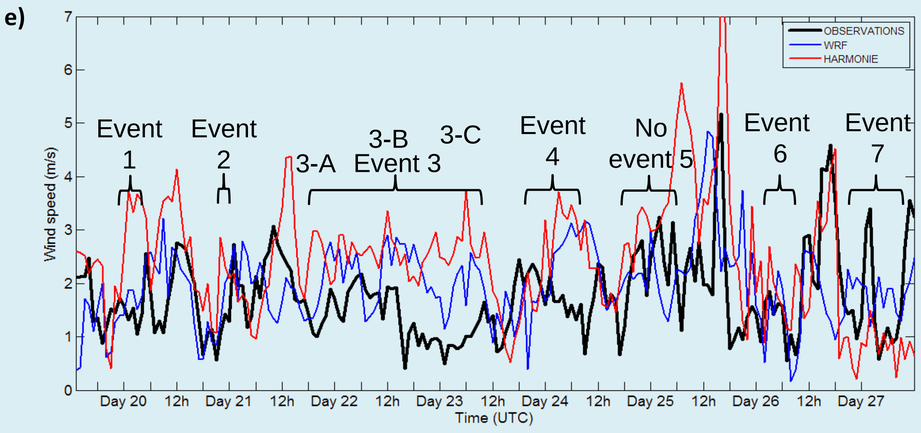


Figure 2. Observed (a) and simulated fog by WRF (b) and HARMONIE (c). 2-m temperature (d) and 10-m wind speed (e) from observations (black) and from WRF (blue) and HARMONIE (red).

FIGURE 2 INFO
- Hard grey color in figures a, b, c represents horizontal vis < 1 km and light grey 1 km < vis < 5 km approximately.
- Observed horizontal visibility obtained from BIRAL SWS-100 visibilimeters installed at 2, 30, 70 and 100 m agl.
- Horizontal visibility from WRF and HARMONIE calculated from liquid water content values (Kunkel, 1984 [9] formula).
- Results from models are a composition of 24-48 h reaches of daily simulations starting at 12:00 h (e.g. results from 24th Jan 12:00 to 25th Jan 12:00 are obtained from simulations started the 23rd Jan at 12:00).
- (*) HARMONIE data from 23rd Jan 12:00 to 24th Jan 12:00 corresponds to 0-24 h reach due to technical problems.
- Approximate sunrise at 07:40 UTC and sunset at 17:20 UTC.
- Observed value of temperature (d) calculated as the mean between 1,5 m and 3 m temperatures.

Table II. Observed and simulated fog hours (vis < 1 km) during the whole period. Hit rate and false-alarm rate for each model regarding fog simulation or not, taking into account horizontal visibility lower than 1000 m as fog.

	WRF	HARMONIE	OBSERVATIONS
Hours simulated with fog	83 h	80 h	63 h
Hit rate	65 %	56 %	--
False-alarm rate	33 %	35 %	--

Table III. Observed onset and dissipation time of each event and their respective biases from WRF and HARMONIE.

	EVENT 1	EVENT 2	EVENT 3	EVENT 4	EVENT 6	EVENT 7
ONSET time						
OBSERVED	00 UTC	22 UTC	19 UTC	20 UTC	03 UTC	22 UTC
WRF bias (h)	-5	-1	+1	-1	-2	+7
HARMONIE bias (h)	-5	-3	-24 (initial formation)	--	+1	-1
DISSIPATION time						
OBSERVED	04 UTC	00 UTC	10 UTC (+2d)	08 UTC	09 UTC	10 UTC
WRF bias (h)	0	+10	0 (final end)	0	+3	-2
HARMONIE bias (h)	-3	+38	-9	--	+6	+1

Table IV. Observed values of 2-m temperature and 10-m wind speed and biases from WRF and HARMONIE for each event. * No-event 5 values calculated from 18:00 UTC of day 24 to 06:00 UTC of day 25.

	EVENT 1	EVENT 2	EVENT 3	EVENT 4	NO- EVENT 5*	EVENT 6	EVENT 7
2-m temperature (mean)							
OBSERVED	-0.63	5.16	8.75	5.92	8.56	2.50	3.91
WRF bias	+0.47	-0.85	+0.74	+2.33	-1.03	+2.82	+1.13
HARMONIE bias	+3.16	-0.89	-0.54	+3.67	+0.52	+3.17	+2.07
10-m wind speed (mean)							
OBSERVED	1.38	1.25	1.32	1.80	2.18	1.25	1.55
WRF bias	+0.30	+0.56	+0.81	+0.43	-0.21	+0.05	+0.20
HARMONIE bias	+1.98	+1.17	+1.29	+0.90	+0.64	+0.56	-0.77

ANALYSING THE RESULTS…

EVENT 1

OBS – Nocturnal fog (formed after sunset and dissipated before sunrise).
WRF – Quite good simulation (earlier formation at lowest levels).
HAR – Fog simulated, but earlier onset and dissipation. Wrong fog the next afternoon. WS10 and T2 overestimated.

EVENT 2

OBS – Night, short-lived (< 3 h) and thick fog (> 100 m).
WRF – Correct fog onset, wrong (late) fog dissipation.
HAR – Wrong fog onset and wrong (very late) fog dissipation.

EVENT 3

3-A

OBS – Fog formed during the afternoon (cloud-base-lowering fog from low clouds), persistent and thick.
WRF – Correct fog formation (cloud-base-lowering fog process).
HAR – Wrong (too early) fog formation but model able to simulate persistent and thick fog. Earlier dissipation.

3-B

OBS – Persistent fog during daytime (only very short (1 h) and slight surface dissipation (mist)).
WRF – Wrong fog dissipation during daytime, model unable to simulate persistent fog. T2 and WS10 overestimated.
HAR – Wrong fog dissipation several hours during daytime (although more persistent fog than WRF). WS10 overestimated.

3-C

OBS – Fog still present and dissipated before midday. Shallow and variable thickness.
WRF – Correct fog dissipation and observed thickness behavior (although vertical extension overestimated).
HAR – Wrong dissipation of fog at midnight (too early).

EVENT 4

OBS – Fog formed during the afternoon, increasing thickness and dissipated after sunrise.
WRF – Correct simulation (onset and dissipation), although vertical extension overestimated. T2 and WS10 overestimated.
HAR – Fog not simulated by the model (0-24 h analysis*). T and WS overestimated (more than WRF).

NO EVENT 5

OBS – Fog not formed this day at CIBA (only one hour with mist). Similar but slightly windier than the day before (> 2 m/s).
WRF – Shallow and short-lived fog simulation (wrong, although possible patchy fog). Underestimation of WS10.
HAR – Fog not simulated by the model (correct simulation). Overestimation of wind speed and temperature.

EVENT 6

OBS – Shallow fog formed during night and dissipated after sunrise.
WRF – Correct fog onset and slightly late dissipation. Vertical extension overestimated. T2 overestimation.
HAR – Correct fog onset. Some difficulties to dissipate totally the fog during midday (very shallow fog). T2 overestimated.

EVENT 7

OBS – Cloud-base-lowering fog (thick) formed after sunset. Dissipation before midday.
WRF – Correct representation of cloud-base-lowering process. Late fog onset (surface) and slightly early dissipation.
HAR – Correct onset and dissipation but vertical extension underestimated (very shallow fog in lowest levels).

4. CONCLUSIONS

- Summary: Analysis of 8-day period in January 2016, composed of 7 fog events with different features at CIBA (Northern Spanish plateau). WRF and HARMONIE simulations are evaluated and compared to the observations.

- WRF-ARW produces in general slightly **better results** than HARMONIE.
- Better onset/dissipation time (WRF).
- Lower bias for 2-m temperature / 10-m wind speed (WRF).
- Better hit rate and false-alarm rate (WRF).

- Models fog-simulation features
- Both models able to simulate almost all fog events.
- Vertical extension overestimation.
- Problems to simulate day-time persistent fog.
- Good representation of cloud-base-lowering processes.

REFERENCES

[1] 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: 1121–1159.
[2] Steeneveld GJ., Ronda R., Holtslag A.A.M., 2015. *Boundary-Layer Meteorol.* 154: 265–289.
[3] Guedalia, D., Bergot, T., 1994. *Mon. Weather Rev.* 122: 1231–1246.
[4] Román-Cascón, C., Steeneveld, GJ., Yagüe, C., Sastre, M., Arrillaga, J., Maqueda, G., 2016. *Q. J. R. Meteorol. Soc.* 142: 1048-1063.
[5] Cuxart, J., Yagüe, C., Morales, G., Terradellas, E., Orbe, J., Calvo, J., Fernández, A., Soler, M., Infante, C., Buenestado, P., Espinalt, A., Joergensen, H., Rees, J., Vilà, J., Redondo, J., Cantalapiedra, I., and Conangla, L., 2000. *Boundary-Layer Meteorol.* 96: 337–37.
[6] Skamarock, W., Klemp, J., Dudhia, J., Gill, D., Barker, D., Duda, M., Huang, X.-Y., Wang, W., and Powers, J., 2008. *Tech. Rep.*, p. 113, doi:10.5065/D6DZ069T.
[7] Seity, Y., Brousseau, P., Malardel, S., Hello, G., Bénard, P., Bouttier, F., Lac, C., Masson, V., 2011. *Mon. Wea. Rev.* 139: 976–991.
[8] Brousseau, P., Berre, L., Bouttier, F. and Desroziers, G., 2011. *Q. J. R. Meteorol. Soc.* 137: 409–422.
[9] Kunkel, B. A., 1984. *J. Clim. Appl. Meteorol.* 23: 34–41.

ACKNOWLEDGEMENTS

This research has been funded by the Spanish Government (MINECO project CGL2012-37416-C04-02 and grant BES-2013 064585). The GR3/14 program (supported by UCM and Banco Santander) has also partially financed this work through the Research Group Micrometeorology and Climate Variability (No. 910437). Part of this work has been completed during a scientific stay of Carlos Román Cascón in Wageningen University through a WIMEK Research Fellowship. The contribution by G-J. Steeneveld has partly been sponsored by the NWO contract 863.10.010 (Lifting the fog). We would like to thank Dr. Peláez and Prof. Casanova for allowing us the entry to CIBA facilities.