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

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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)

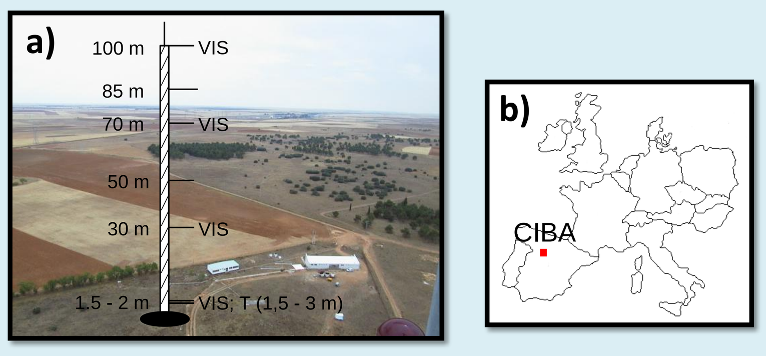

Figure 1. Aerial view from the top of the 100-m mast at CIBA and graphical representation of 100-m tower. b) CIBA location.

- 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

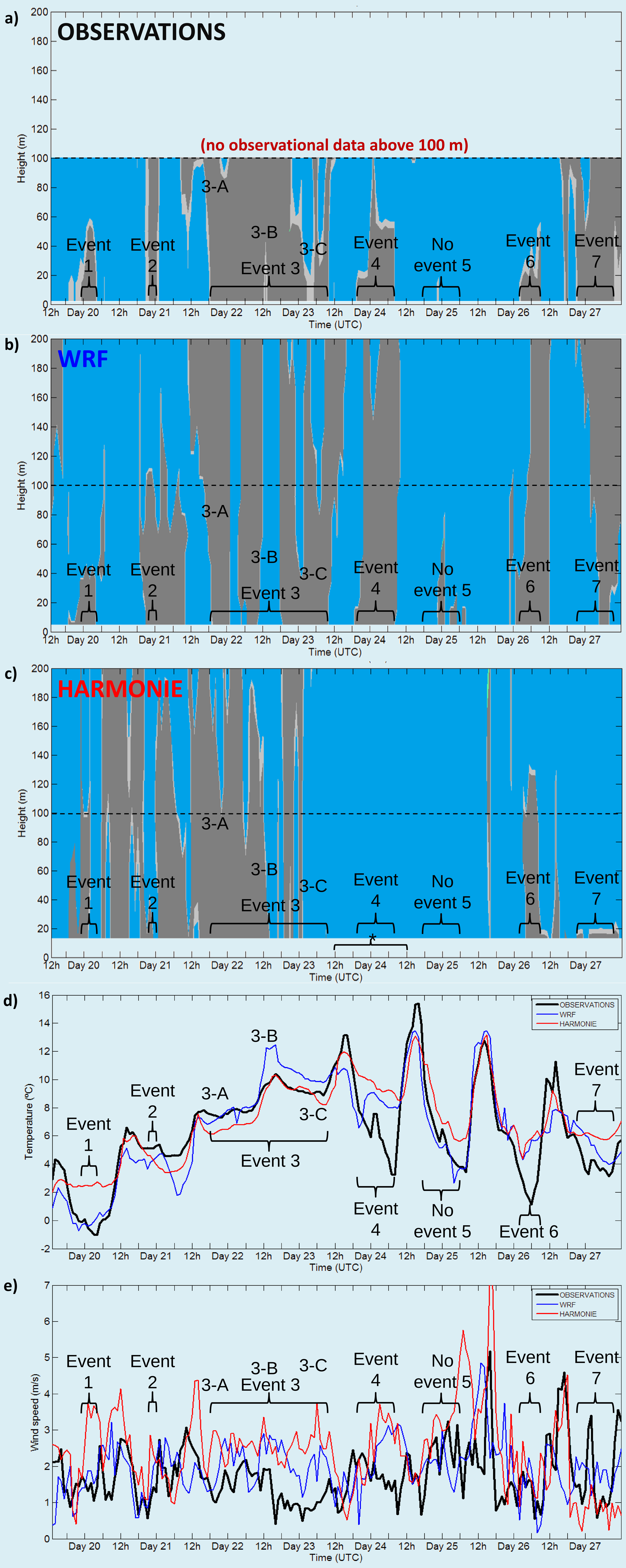

Figure 2. Observed (a) and simulated fog by WRF (b) and HARMONIE (c). 2-m temperature (d) and 10-m wind speed (e) from observations (black) and from WRF (blue) and HARMONIE (red).

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.

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