Response to Referee 2

We would like to thank Reviewer 2 for his/her careful reading of our paper, and for his/her remarks that will help enhancing the clarity of the main ideas. We did our best to take them into account as explained below. Reviewer comments are reproduced in italic text. Our answers are in plain text.

Specific comments

1. P1803, L15: The sentence starting with "Several studies..." does not fit in here.

We recognize that this sentence is misleading here. We propose to modify with "AROME-France, from which AROME-WMED is derived, leaves a large part of Mediterranean Sea out of its domain. As several studies have shown the importance of an accurate description of the moist low-level flow (that feeds meso-scale convective systems which can result in heavy precipitating events over the Mediterranean Sea, Duffourg and Ducrocq, 2011; Bresson et al., 2012; Ricard et al., 2012), we choose to extend further south the AROME-WMED domain (Fig. 1). In addition, AROME-WMED ran..."

2. P1810, L8-9: The authors state that the data from the balloons were discarded when they encountered strong updrafts. Please give more details why the data cannot be used.

The BLPBs (constant volume balloons) do not have the same sampling strategy than radiosoundings which basically collect one set of data per time unit (1 or 2 seconds). The BLPB sampling strategy is meant for horizontal drift : the measurement system yields one set of data (P, T, Hu) every 30 seconds (let call these raw data). Each set of raw data is derived from a series of a dozen of individual measurements that are averaged. These internal measurements are not available outside the gondola and are not transmitted to ground.

This strategy does not allow to capture very sudden changes such as those encountered in convective updrafts. For example, balloon B26 (Figure 4, top frame) ended its flight in a very rapid updraft that uplifted the balloon by more than 2500m in less than 10 minutes !

Moreover the data to be assimilated in AROME WMED had to be representative of larger scale/time features that the 30s raw data produced by the BLPBs. To achieve this representativeness issue, raw data were averaged every 20 minutes approximately. To guarantee the consistency of such data the averaging was performed only over periods corresponding to stable flight. So when the BLPBs underwent transient vertical excursions (sudden change of flight level before returning to the nominal flight level), these part of the data-set where not assimilated.

The paragraph below will be inserted in the text :

"Only data from stable parts of the flights were used to generate this special dataset, which has been derived from raw BLPB data by time filtering. Some balloons ascended rapidly when encountering strong up-drafts which were generated by deep convection. The data corresponding to these rapid vertical variations were discarded. The sampling pace of the BLPBs is not meant to capture very rapid changes in the measured parameters."

3. P1813, L22-24: The authors just describe that the bias is positive during night-time and negative during day-time. Some ideas about the origin of this diurnal cycle would help the reader here.

A possible explanation of the origin of the positive temperature bias is given further in the text for figure 8 (p 1815 l 2-9). "This positive bias in 2 m temperature of AROME-France during night-time is well known and it is due to the excessive coupling of the scheme between the surface and the lowest level of the model. The Masson and Seity (2009) surface scheme tends, in fact, to overestimate the surface temperature at night-time during summer. The delay in the increase in temperature at 2m during summer in day-time (i.e. at 12:00UTC in Fig. 8c and d) is also well known but not yet explained." We propose to add the following sentences : "The positive bias in 2 m temperature during night-time is the result of an excessive coupling of the Masson and Seity (2009) scheme between the surface and the lowest level of the model. The negative bias during day-time corresponding to the delay in the temperature increase is also well known but remains yet to be explained."

4. Figs. 7, 15: I wonder why the relative humidity is analyzed. As it is linked to temperature, the errors are coupled as obvious from the opposing diurnal cycle. I would recommend to analyze the 2-m specific humidity instead.

You are right, RH is not the best indicator for moisture because it is linked to temperature, however, the observations provide only relative humidity and we do not perform the conversion from RH to q in our scores.

5. The case study at the end is very interesting but too short in my opinion. A few comments on possible reasons for model deficiencies or more details about the relevant processes responsible for this heavy precipitation event would be useful.

We tried to expand the case study by introducing more details about the genesis of the heavy precipitation event and possible reasons for model deficiencies. We tried to supplement the case study by detailing the genesis of the precipitations and try to explain the model deficiency. The section should be modified as following (added comments are in bold).

An example of strong precipitation simulation by AROME-WMED is given with IOP8. IOP8 is a case of deep convection associated with a mesoscale convergence line (Ducrocq et al., 2014) which occurred on 28–29 September 2012 in Southern Spain. Heavy rainfall during IOP8 caused severe damages which resulted in 13 casualties in Andalusia and Murcia (southern Spain, neither of these areas is a specific HyMeX target but they are included in the AROME-WMED domain). The synoptic situation was characterized by an upper level cut-off low over southern Portugal at 00:00UTC on 28 September (Fig. 19a), which first affected Andalusia, then progressed eastward to finally reach eastern Spain at 12:00UTC on 29 September (Fig. 19**). In the north easterly flank of the cut-off low, where there is upwards forcing, favouring the triggering of the convection, low level depression and convergence were created, reinforcing the convection and heavy precipitation. The low-level convergence zone shifted from inner Andalusia (at 06:00UTC on 28 September) to Catalonia at 12:00UTC on 29 September.** Most of the heavy precipitation that fell on the Murcia region was caused by a mesoscale convective system between 10:00 and 13:00UTC on 28 September. It was generated along this convergence line between the warm and moist easterly low-level flow in the Balearic basin and the rapid westerly low-level flow between southern Spain and North Africa, in the Alborean basin (Fig. 20a and b). This convergence line is located ahead of the deep upper level trough (Fig. 19b). **Both progressed north eastwards passing over Valencia and reaching the north of the Balearic Islands at 00:00UTC on 29 September (Figs. 19c and 20c). They finally reached Catalonia on 29 September 12:00UTC.**

The measured amount of daily precipitation exceeded 200 mm in Andalusia and in Murcia (28 September, Fig. 21a). Another precipitation maximum was observed in the Valencia area. Worthy to be mentioned, AROME-WMED was able to forecast accurately the 24 h accumulated precipitation amount (Fig. 21b) at 24 h and even at the 48 h forecast range (Fig. 21c). At the 24 h range, the Andalusia precipitation maximum is indeed underestimated, it has a very small horizontal extension, located at around 37N and 4 W (Fig. 21b). Also to be noted that the 48 h precipitation forecast from 27 September 00:00UTC seems to be better than the 24 h one as it isolates three precipitation maxima over Andalusia, the Murcia area and in Valencia, even though the first two precipitating areas are not precisely located as compared to observations.

The analysis of the 1-h precipitation accumulation in the observations showed that heavy precipitation over Andalusia at 5 °W 36.5 °N occurred as soon as 27 September 21:00UTC. In AROME-WMED forecast from 28 September 00:00UTC the corresponding system is located more westerly with lower values of rainfall (up to 15 mm/1h) instead of more than 50 mm/1h in the observations. In that case, AROME-WMED model had difficulty in reproducing heavy precipitation in the early 4h forecast ranges. Noteworthy to mention that this area is close to the boundary of the model domain and contains few assimilated data.
This wrong location of the meteorological system is illustrated when comparing the SEVIRI brightness temperature observations against the simulations from the 9 h forecast starting on 28 September 2012 00:00UTC and from the 33 h forecast starting on 27 September 2012 00:00UTC (Fig. 22). At first sight, the low brightness temperature values over Spain, especially in the Andalusian area and the Murcia region are higher in the simulation than in the observations (Fig. 22a). They are associated with two convective systems present over these areas. The system over Murcia is associated with low values around -60 C. The brightness temperature simulation from the 9 h forecast indicates that the system is less developed and extended (Fig. 22b) over the Andalusia region. In the 33 h forecast simulation, the system over Andalusia is less intense, its spatial coverage is smaller than in the observations (Fig. 22c). The Murcia system is also shifted to the north-east and is located over the coast instead of in-land.

For 29 September 2012, the maximum values of rain accumulated between 24 and 48 h are overestimated (Fig. 23a and c) and located over the Cévennes Vivarais area and the south-west of Catalonia. In the 24 h forecast range (Fig. 23c), the maximum is lower than at day-2 forecast and more centred over Catalonia as displayed by the observations (Fig. 23a). The brightness temperature simulation for 29 September 2012 at 06:00UTC shows that the system over Catalonia is more developed and extended over land in the 30 h simulation than in the 6 h one and in the observations (Fig. 24). **The persistence and the stationary position of the convective system in the 24-30-h forecasts lead to an overestimation of precipitation over Catalonia in the first 6-h on 29 September.**
For 29 September 12:00UTC, the global ARPEGE model (not shown) and AROME-WMED (Fig. 25) forecast too much warm air over the Balearic Islands and Catalonia. This feature is associated to a low with two minima off-shore the Var region (south-east of France) and over the Balearic Islands in the 36 h forecast (not shown), which leads to overestimate precipitation on 29 September over Catalonia. The system over south-east of France is already established in 6 h forecast simulation and is ahead compared to the observations (Fig. 24a). Finally, the convective system affecting Liguria is present in the 30 and 6 h simulations, even though the associated brightness temperatures are lower than in the observations.

To summarize, AROME-WMED is able on this case to simulate more than 150 mm/24h even if the location and the temporal evolution are not perfect.

Minor technical or textual comments
1. P1802, L9: observation instruments -> meteorological instruments
Correction accepted.

2. P1803, L13: Meteo-rologique -> Meteorologique
Correction accepted.

3. P1803, L20: The authors state that due to the domain covered by AROMEWMED, it is better suited for HyMeX. This is clear, since it was developed especially for this project. Thus, this remark can be omitted.
The paragraph has been reworded (cf specific comment 1) and the remark has been removed.

4. P1803, L26: COPS stands for: Convective and Orographically-induced Precipitation Study

This has been added in the text. Moreover, as suggested by Referee 1, we will add an appendix including all acronyms.

5. P1804, L2: Please give some more details for ALADIN-France.

We will include details on ALADIN-France "which was at the time the operational regional Météo-France model, taking its lateral boundary conditions from ARPEGE and its initial state from a three-dimensional variational data assimilation (3D-Var) scheme (Fischer et al. 2005)."

6. P1804, L15: mobile platforms

Corrected.

7. P1804, L18: Please explain the abbreviation ECMWF.

The explanation of ECMWF acronym has been added: European Centre for Medium-range Weather Forecasts.

8. P1805, L26: ...of grid points are covered...

Corrected.

9. P1806, L7: ...model so as to avoid ... -> model to avoid

"so as" removed.

10. P1806, L11: Please exchange performed with initialized or started.

Performed has been change in started.

11. P1808, L20: estimation of the estimation -> estimation of the

Modification made.

12. P1810, L24: Please explain IASI.

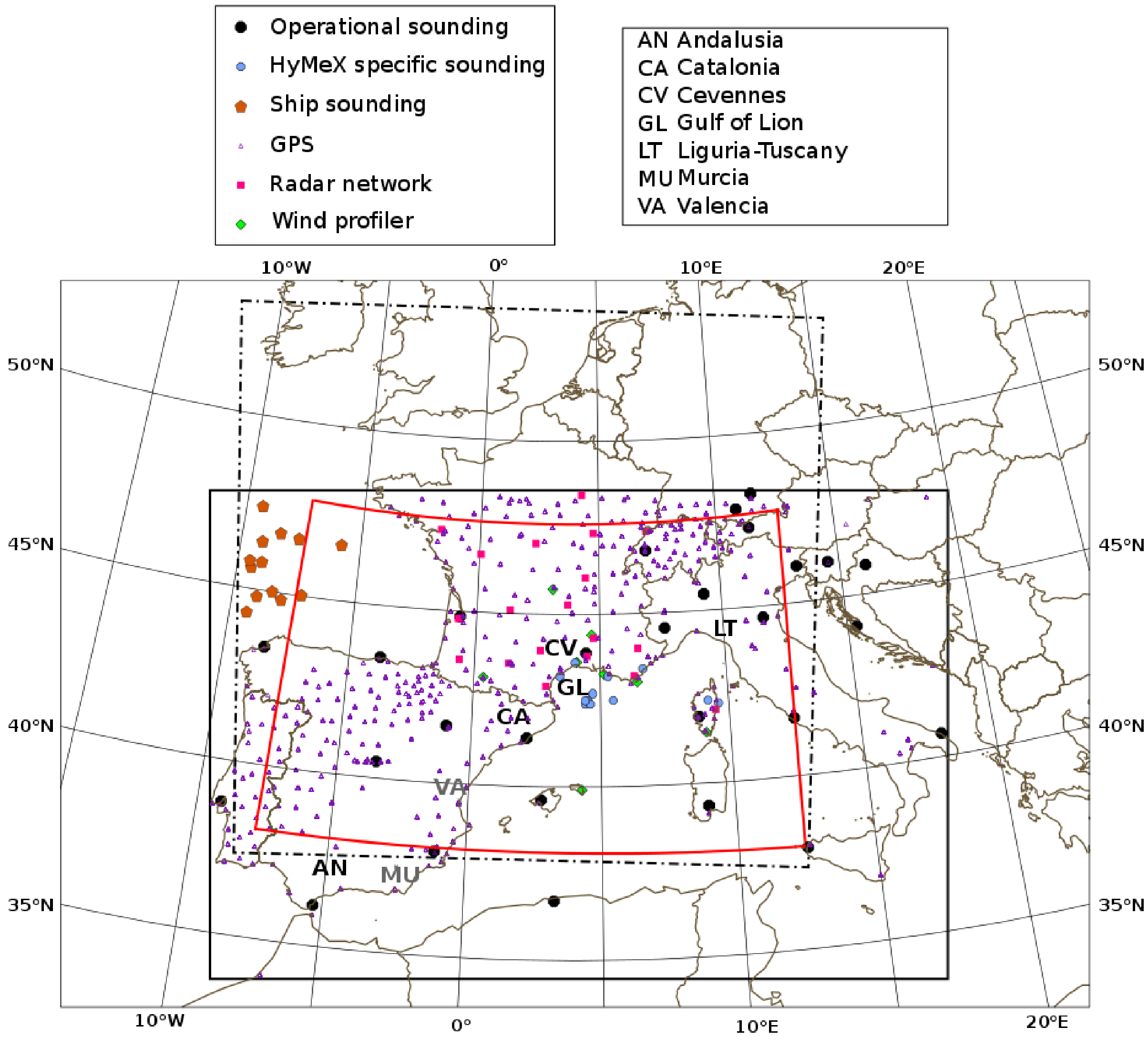
IASI stands for Infra-red Atmospheric Sounding Interferometer. It has been specified in the text.

13. P1812: Please explain CAPE and HOC.

CAPE has been replaced by convective available potential energy and HOC by HyMeX Operational Centre.

14. P1813, L4: A rectangle showing the common area could be inserted in Fig. 1.

This rectangle has been added in figure 1, which has been also enlarged.



15. P1815, L12: ... from the HyMeX database
Corrected

16. P1815, L13: ...had been subject to...
Corrected

17. P1815, L17: ...if one 1 h datum was missing... -> if one 1 h interval was missing
Corrected

18. P1815, L21: no SYNOP nor climatological -> neither SYNOP nor climatological
Corrected

19. P1816, L1: The closer to 1 the ETS is, the better is the prediction.
Corrected

20. P1820, L11: ... the Intensive Observation Period....
Corrected

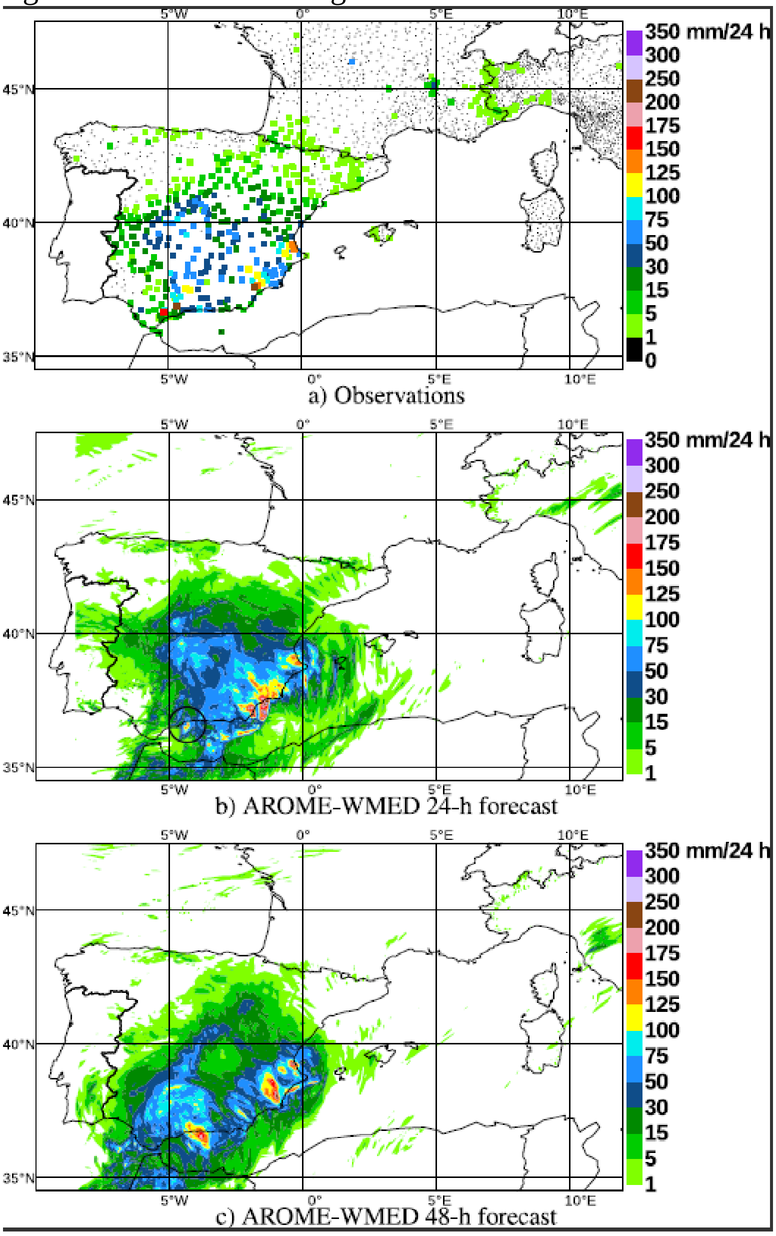
21. P1820, L20: Fig. 19b
“b” has been added.

22. P1820, L22-25: This sentence is too long and confusing, please rephrase.

This long sentence will be modified as following: “It was generated along a convergence line between the warm and moist easterly low-level flow in the Balearic basin and the rapid westerly low-level flow between southern Spain and North Africa, in the Alborean basin (Fig. 20a and b). This convergence line was located ahead of the deep upper level trough (Fig. 19b).”

23. P1821, L7: The Andalusia precipitation maximum could be marked with a circle in Fig. 21b.

A black circle has been added in Fig 21b to highlight the Andalusia precipitation maximum. The figure has been also enlarged.



a) Observations

b) AROME-WMED 24-h forecast

c) AROME-WMED 48-h forecast

24. P1821, L10: ...are not located precisely as compared to observations... -> are not located precisely at the observed locations.

Corrected.

25. P1822, L22: Once the field campaign was over...

Corrected

26. Please enlarge the size of the following figures: 1, 6-8, 12, 15, 20-25

We agree that the size of the figure is not adequate in the landscape format. We enlarged Figures 1, 6, 7, 8, 12, 15 and 21. However, if this was not enough, we propose to interact with the editor to propose the adequate size.

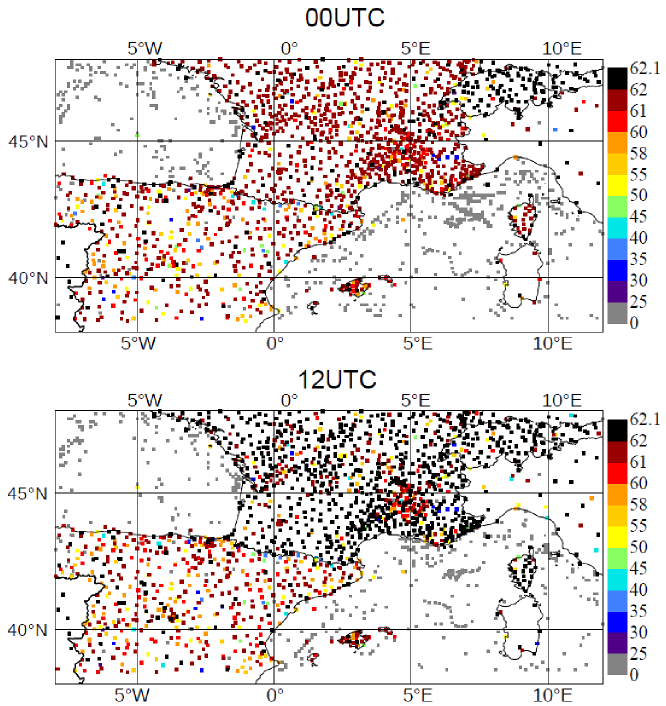


Fig 6:

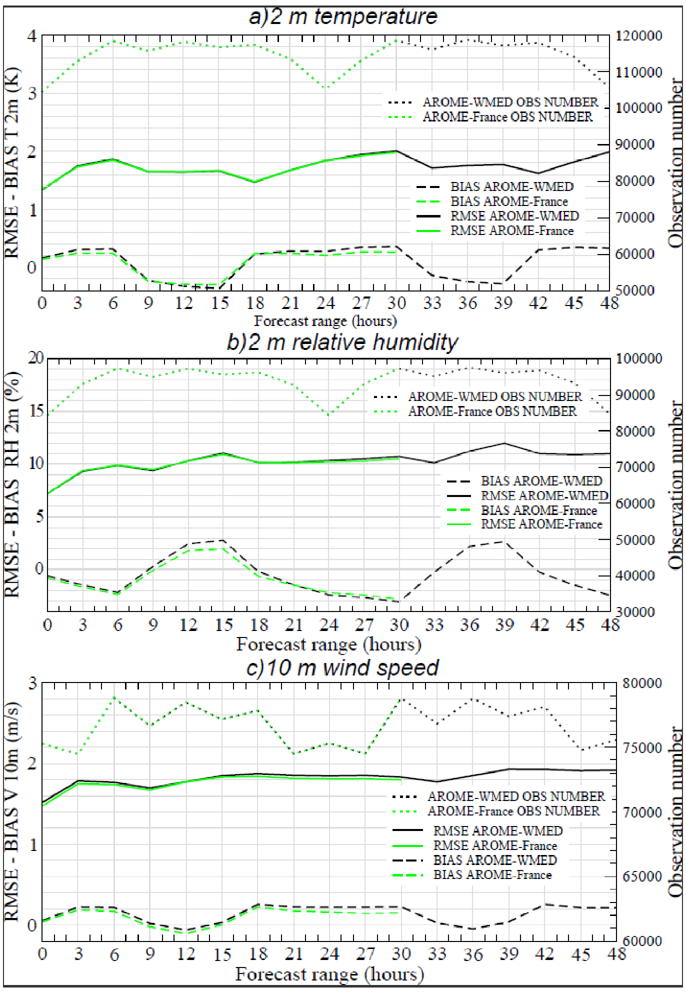


Fig 7:

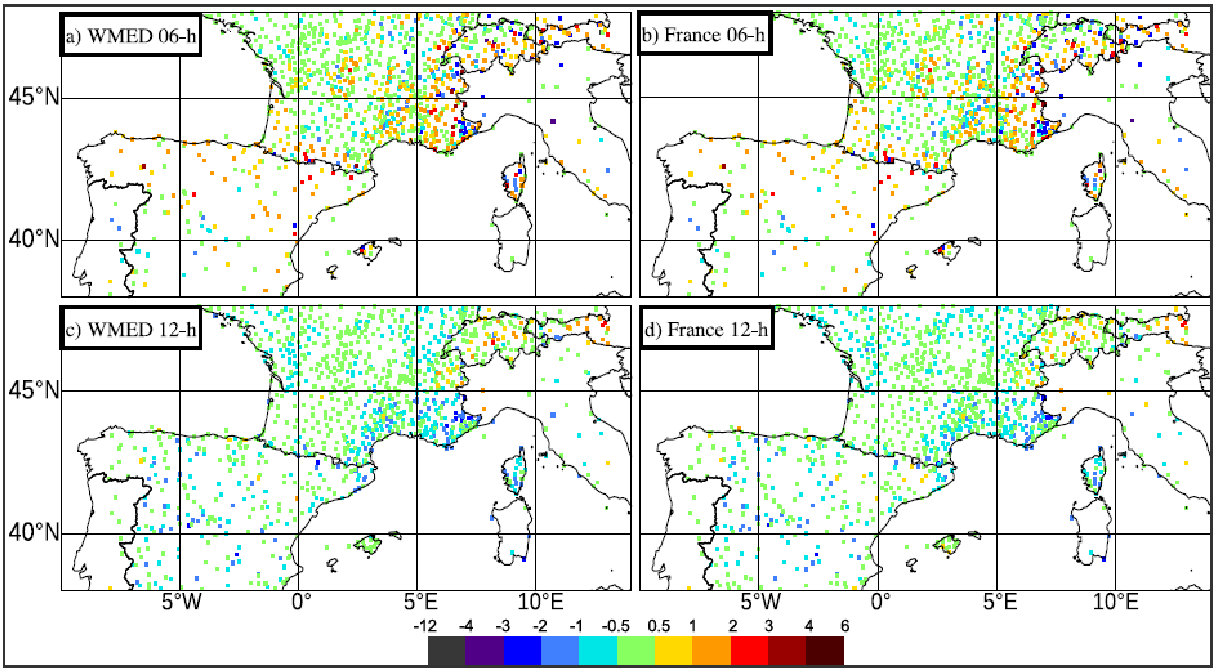

a) WMED 06-h
b) France 06-h
c) WMED 12-h
d) France 12-h
45°N
40°N
5°W
0°
5°E
10°E
-12 -4 -3 -2 -1 -0.5 0.5 1 2 3 4 6

Fig8a:

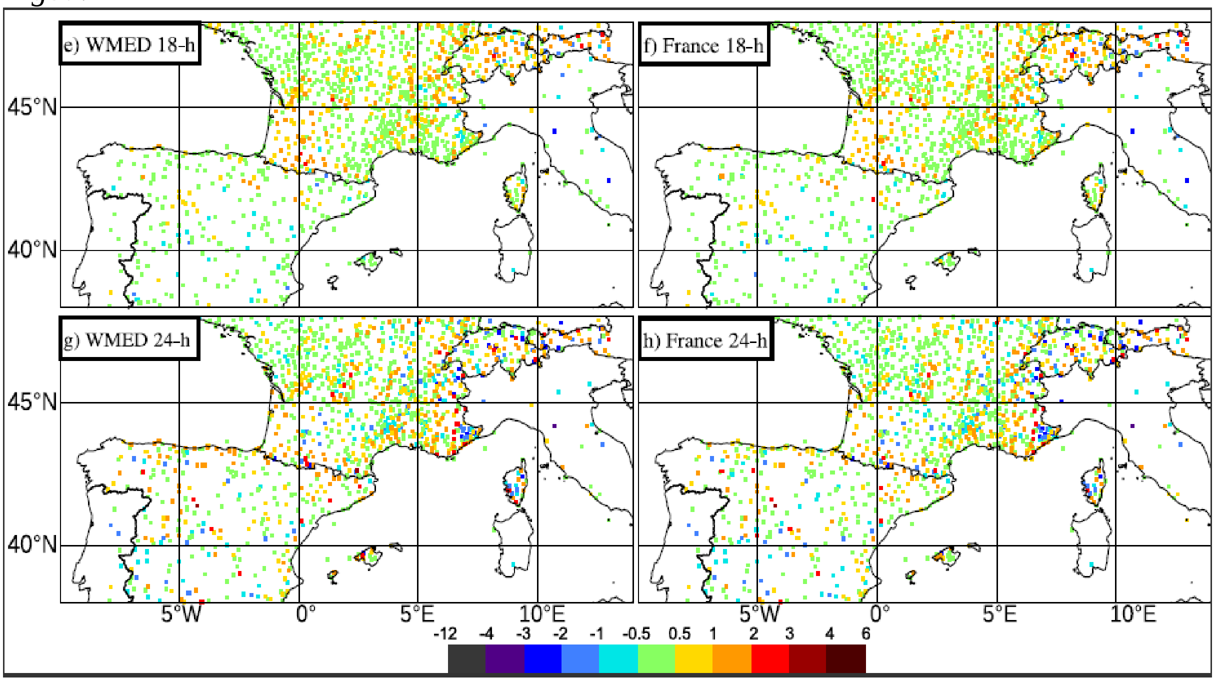
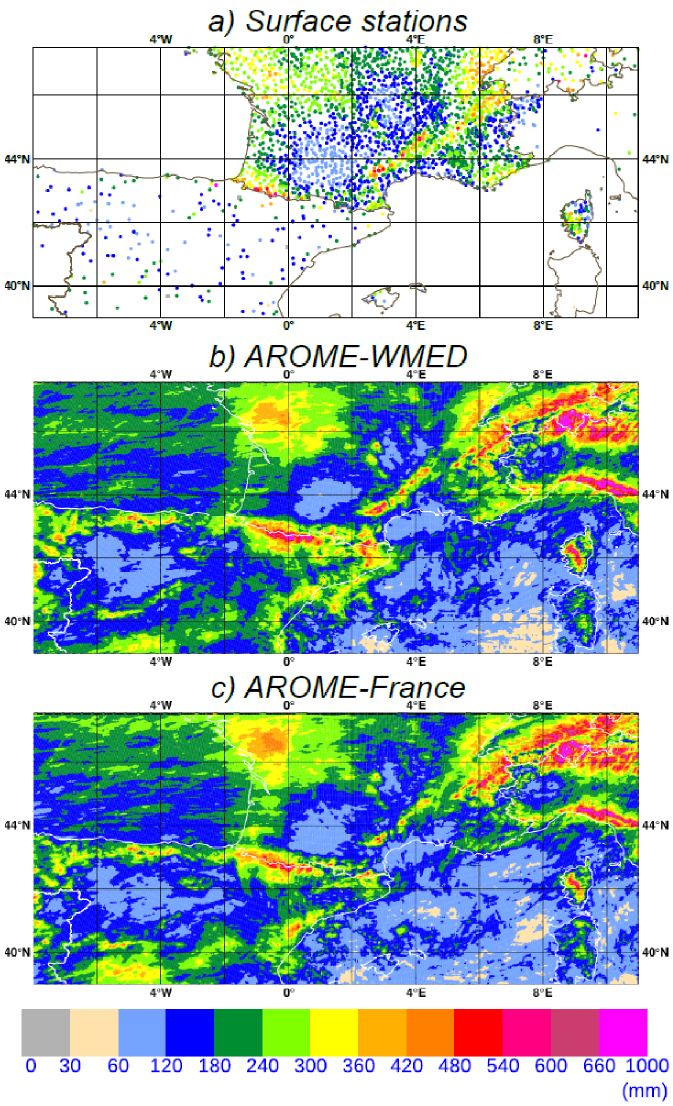

e) WMED 18-h
f) France 18-h
g) WMED 24-h
h) France 24-h
45°N
40°N
5°W
0°
5°E
10°E
-12 -4 -3 -2 -1 -0.5 0.5 1 2 3 4 6

Fig8b



a) Surface stations
b) AROME-WMED
c) AROME-France
4°W
0°
4°E
8°E
44°N
40°N
0
30
60
120
180
240
300
360
420
480
540
600
660
1000
(mm)

Fig12:

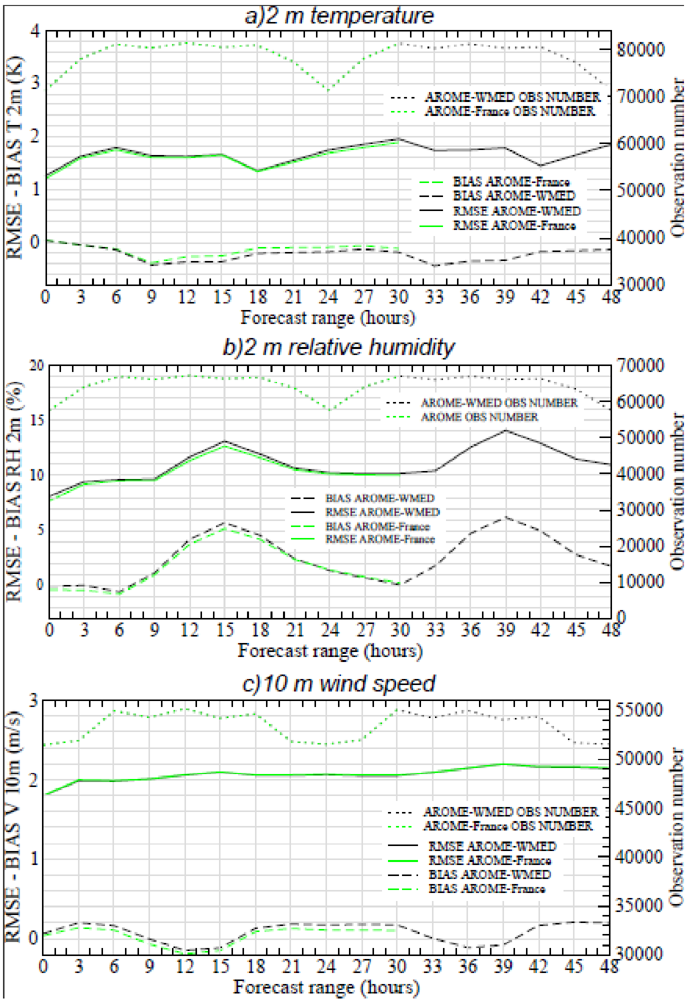

a)2 m temperature
RMSE - BIAS T 2m (K)
Observation number
AROME-WMED OBS NUMBER
AROME-France OBS NUMBER
BIAS AROME-France
BIAS AROME-WMED
RMSE AROME-WMED
RMSE AROME-France
Forecast range (hours)
b)2 m relative humidity
RMSE - BIAS RH 2m (%)
Observation number
AROME-WMED OBS NUMBER
AROME OBS NUMBER
BIAS AROME-WMED
RMSE AROME-WMED
BIAS AROME-France
RMSE AROME-France
Forecast range (hours)
c)10 m wind speed
RMSE - BIAS V 10m (m/s)
Observation number
AROME-WMED OBS NUMBER
AROME-France OBS NUMBER
RMSE AROME-WMED
RMSE AROME-France
BIAS AROME-WMED
BIAS AROME-France
Forecast range (hours)

Figure 15

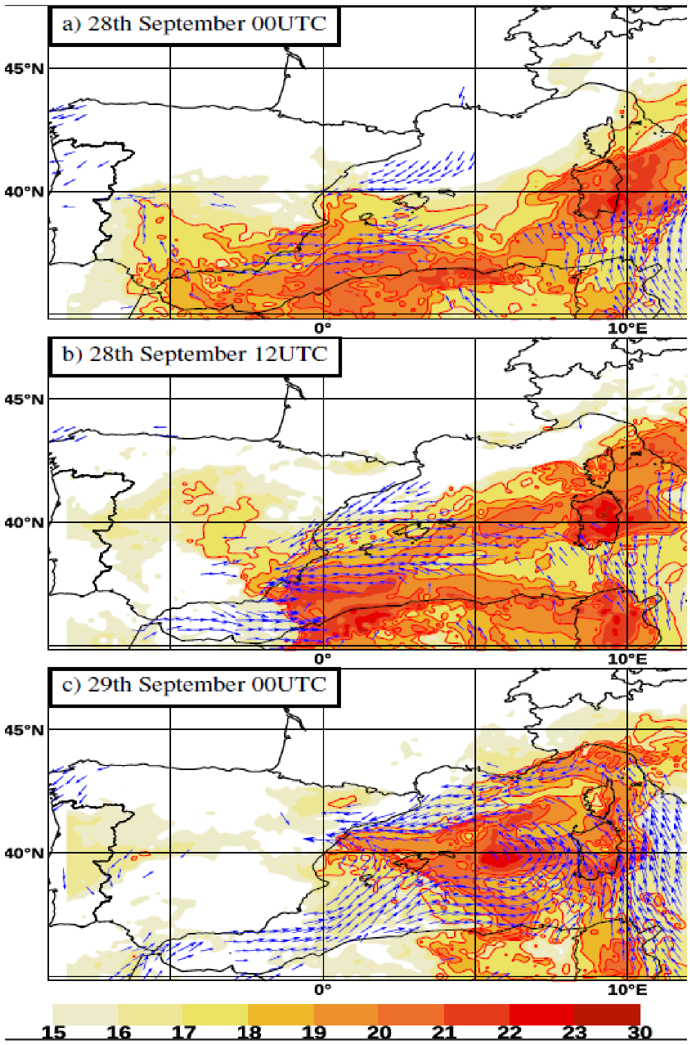
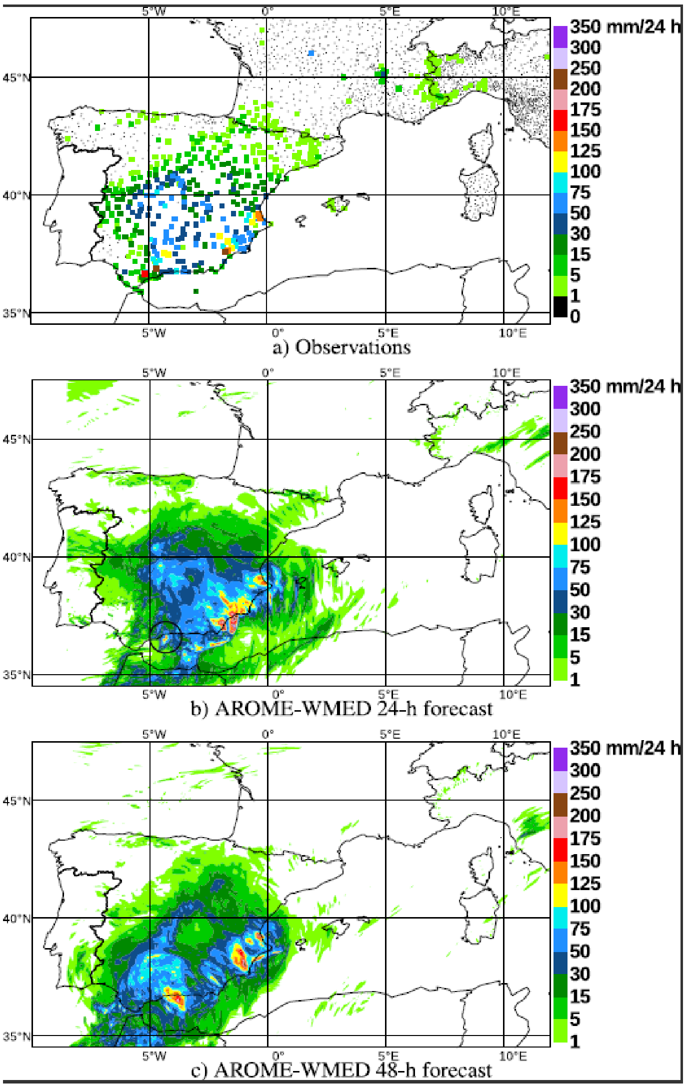

a) 28th September 00UTC
45°N
40°N
0°
10°E
b) 28th September 12UTC
45°N
40°N
0°
10°E
c) 29th September 00UTC
45°N
40°N
0°
10°E
15 16 17 18 19 20 21 22 23 30

Figure 20



5°W
0°
5°E
10°E
45°N
40°N
35°N
350 mm/24 h
300
250
200
175
150
125
100
75
50
30
15
5
1
0
a) Observations
b) AROME-WMED 24-h forecast
c) AROME-WMED 48-h forecast

Figure 21

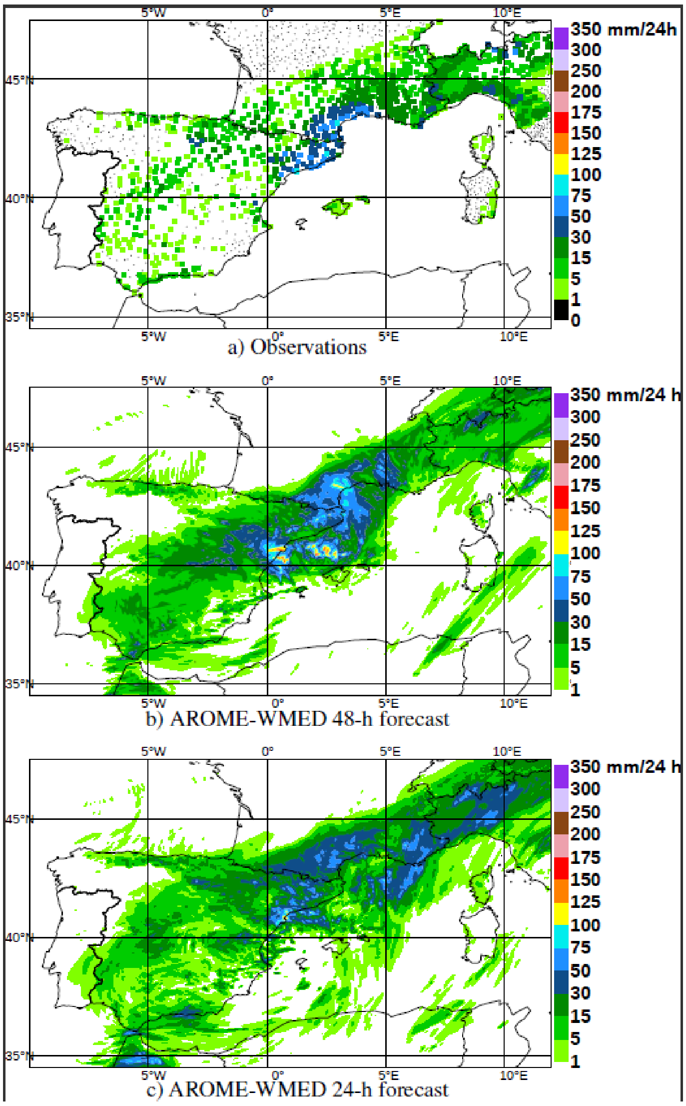

5°W
0°
5°E
10°E
45°N
40°N
35°N
350 mm/24h
300
250
200
175
150
125
100
75
50
30
15
5
1
0
a) Observations
350 mm/24 h
b) AROME-WMED 48-h forecast
c) AROME-WMED 24-h forecast

Figure 23

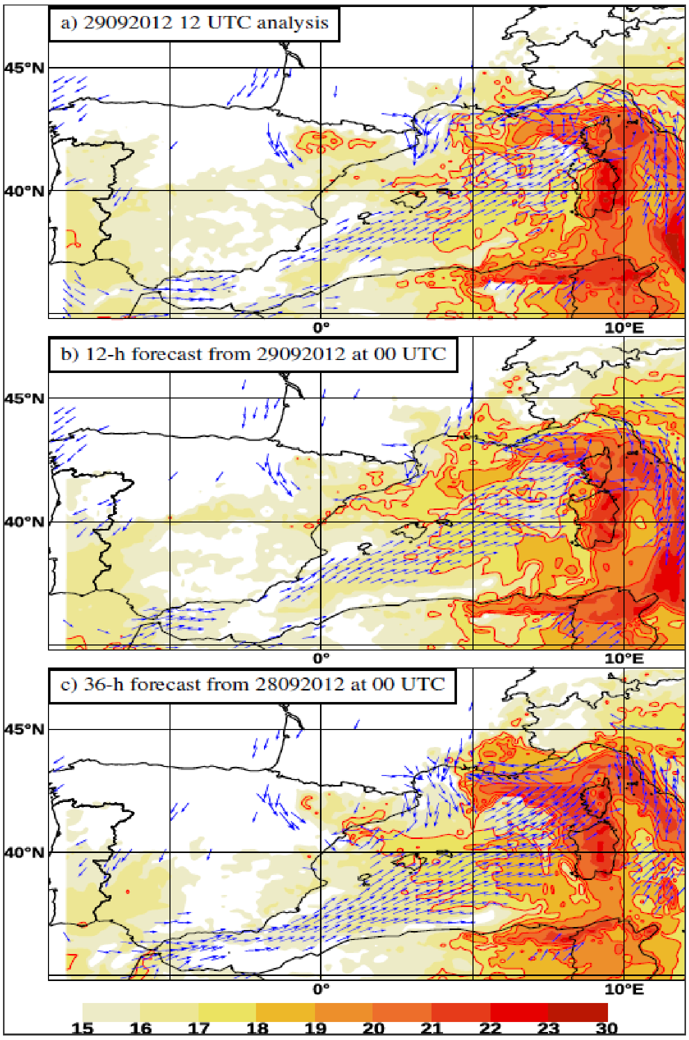


Figure 25

27. Fig. 2: SD -> Standard deviation

Corrected

See below for figure 22 and figure 24.

28. Fig. 7: text on Figure a) 2m temperature at -> 2m temperature; please write out SD in the caption

Corrected.

29. Fig. 12: AROME-WMED simulates much more precipitation on the Spanish coast south from the Pyrenees than AROME-FRANCE. The authors should add a comment on that.

We will mention that a maximum was also found in AROME-WMED over the north east of Catalonia. “Another maximum is present over the north-east of Catalonia in AROME-WMED, while the maximum over the Valencia area is larger in AROME-France than in AROME-WMED.”

30. Figs. 22 and 24: Please use the same colourbar ranges for observed and simulated brightness temperatures to facilitate the comparison.

The colour bar has been modified in both figures and is identical for the 3 panels.

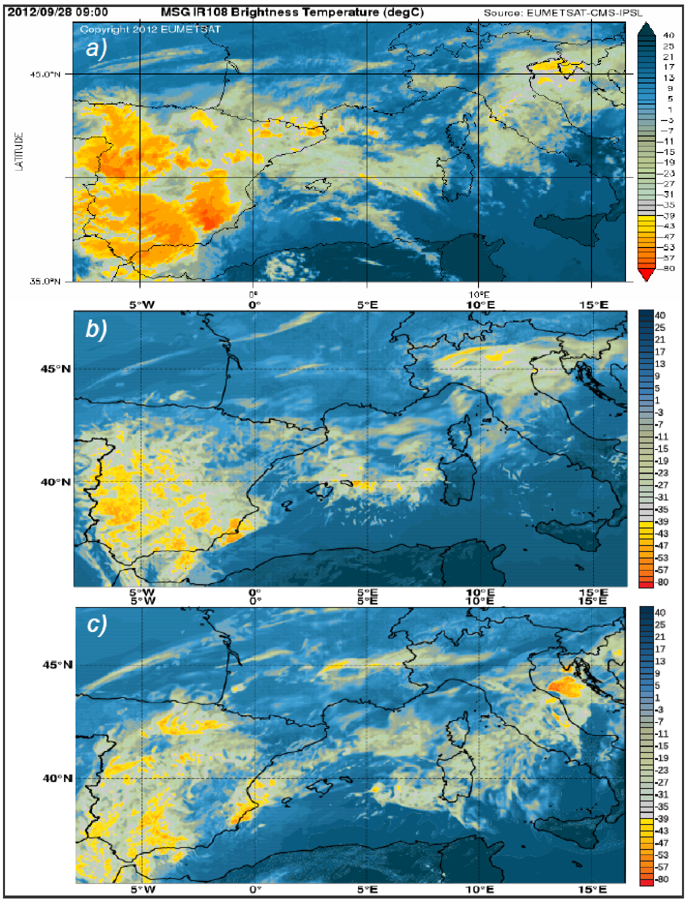

2012/09/28 09:00
MSG IR108 Brightness Temperature (degC)
Source: EUMETSAT-CMS-IPSL
Copyright 2012 EUMETSAT
a)
b)
c)
45°N
40°N
5°W
0°
5°E
10°E
15°E

Fig 22:

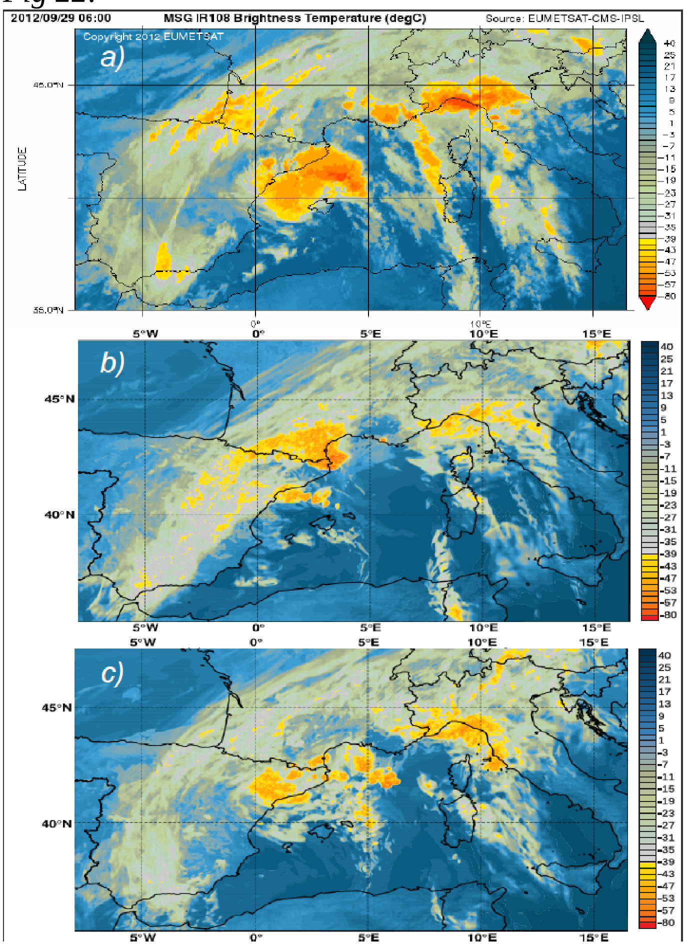

2012/09/29 06:00
MSG IR108 Brightness Temperature (degC)
Source: EUMETSAT-CMS-IPSL
Copyright 2012 EUMETSAT
a)
b)
c)
45°N
40°N
5°W
0°
5°E
10°E
15°E

Fig 24: