Reply to
Interactive comment on "The radiative impact of desert dust on orographic rain in the Cevennes–Vivarais area: a case study from HyMeX" by C. Flamant et al.
from Anonymous Referee #1

We thank the Referee for his time and his constructive comments. We have complied with most of the proposed changes.
In the revised version of the manuscript, we now thank the referees explicitly in the Acknowledgement section.
In the following, our point by point replies to the Referee's comments are in red.

General comments:

The authors present the results of quite a large research effort: A case study on the radiative impact of desert on convective precipitation in complex orography in the Mediterranean. In a first step, combined measurements with two water-vapor and aerosol Raman lidars, an airborne water vapor DIAL, sun-photometers, different types of satellite instruments (MODIS, SEVIRI), and ground-based networks of meteorological stations are used for the verification of a convection-permitting mesoscale dust model. Second, model runs with and without dust are compared. It turns out that the impact of the dust on the simulated convective precipitation is weak in this case. Finally, the authors give an outlook for future refinements of related research activities. That the impact of dust is weak (ñmarginalò) in this case should not be taken as a weak point of the manuscript. On the contrary, the science community needs in the same way the publication of a study if the result is a weak impact as it needs the publication of the result if the impact should be large.

The manuscript is well written. The discussion is mostly clear (see specific comments below for details). The conclusions seem all justified.

Thus, I recommend accepting the manuscript after minor revisions.

Specific comments:
Title: The title seems to suggest that the impact is significant. As this is not the case here, I suggest that you write it clearly already in the title, e.g., ñWeak/marginal radiative impact of desert dust on convective precipitation in complex terrain: A case study in the Cevennes-Vivarais area from HyMeXò or similar
We have discussed this aspect with the co-authors. We feel that if we add the word ñweakò or ñmarginalò to the title, this will likely diminish the curiosity of the scientific community for the paper and, hence, lower its impact. Our point is that, even though, this is one of very few studies dealing with the direct radiative impact of dust on Mediterranean convective systems (and we do show this weak impact), researchers might not take the time to read it if ñweakò is stated in the title. Furthermore, the title should reflect the topic of the paper, and not the content/resulté
Hence, we decided not to change the title.

Section 2.4.: Aoshima et al. (2008) used a BT threshold of 250 K instead of 230 K. Maybe this would fit better? Please comment.
The value of 230 K is used to assess the presence of deep convective clouds top in the CV area, mostly based on visual inspection of Figs 10 through 12. Hence, using a value of 250 K instead of 230 K does not change the main points made in the discussion. This point is now made in the paper. The reference has been added as well.

Section 3: Does RTTOV include the effect of the dust in the model? Please comment.

The dust effect is not taken into account in RTTOV version 8.7. It is marginal in the BTs (about a few K for the window channels, see e.g. Chaboureau, J.-P., P. Tulet, and C. Mari, 2007: Diurnal cycle of dust and cirrus over West Africa as seen from Meteosat Second Generation satellite and a regional forecast model, Geophys. Res. Let., 34, L02822, doi:10.1029/2006GL027771).
This information has been added in Section 3. The reference has been added as well.

Section 5, first paragraph: Please quantify ñrather lowòetc.
Agreed. We have added ñ(less than 0.2 at 550 nm)ò to the sentence to quantify what was meant here.

Page 22464, line 21: I think ñoverall complex structure : : : wellò is overstating the result. How about ñThe general structure of the dust plume is reproduced by the simulation: : :ò
Agreed. The sentence has been modified as suggested.

Page 22464: Can you comment on the differences between WALI and AERONET data?
The analysis of the AERONET data has been revisited, using co-located WALI data. We paid particular attention to the detection of thin elevated clouds by looking at the lidar data up to the tropopause. We have identified many instances when thin homogeneous and likely widespread cirrus clouds that are difficult to detect and screen out in the AERONET processing. Hence in the revised version of the manuscript, we have carefully removed the cloud-polluted AODs. You will see that the agreement is now much better between WALI and AERONET on 18 October (see revised Figure 5 at the bottom of the Response). Thanks for pointing this out.

Page 22465, line 7: ñis also simulated deeper: : :ò?
Agreed. That ñobservedò has been replaced by ñsimulatedò in the sentence.

Figure 5 and 6: I think it would be very interesting to show the clouds which are detected by the lidars and compare them with the clouds in the model runs. Are there clouds the BASIL data in the morning of the 18 above 3 km? Are there no clouds in the WALI data?
There are indeed very few clouds observed in Menorca by the lidar between 0 and 4.5 km amsl (i.e. the altitude range shown in Fig. 5 and 6): clouds were observed at the top of the marine boundary layer from 17 to 19 October, and are most clearly identified prior to the arrival of the dust event (see Fig. 11 of Chazette et al., 2014 in AMT). A second layer of more intermittent clouds was also observed above the dust plume (i.e. above 3.5 km amsl on 18 October and above 3 km amsl on 19 October). The clouds produced rain which is responsible for the data gaps on these days. The cloud layers are well represented in the Meso-NH DUST simulation using a cloud condensate mixing ratio of 0.005 g kgī 1 (contours in new Figure 5 at the end of this Response).

Similarly, we have added a cloud mask on the BASIL data shown in Figure 6. There are indeed much more clouds in Candillargues than there is in Menorca. Thanks to the cloud mask, we now evidence that the larger values of extinction (in excess of 0.25 km-1) are caused by the presence of clouds, e.g. at the top of the boundary layer at the beginning of the dust event on 18 October, as well as at the top of the dust plume later on. The Meso-NH simulation also shows the presence of a thick cloud condensate layer at the top of the boundary layer, which looks more contiguous than in the observations, as well as the clouds above 3 km amsl, as in Menorca. Overall, the addition of the cloud mask overlaid on the lidar observations is clearly beneficial to the reader as it helps segregating between clouds and dust, and helps emphasizing that the Meso-NH extinctions associated with the dust plume are in good agreement with their lidar counterpart.

Hence we have modified the figures according to the refereeõs comments. Thanks for suggesting this.

Page 22466: I am confused by the selection of the locations taken for the model data for the comparisons. You write that both were ñthe best match obtained with the LEANDRE 2 observed dust plumeò. Do you mean ñmoisture fieldò in the case of ñdryó? But why ñdryó? How do you determine ñbest matchó?

Yes, absolutely, we mean ñmoisture fieldò in the case of the comparison between the observed and simulated water vapor mixing ratio profiles. Thanks for picking this up, this is now modified in the text.

The label ñdryò was just a reference to the fact that we had identified a drier layer separating the marine PBL from a moist layer aloft (as discussed in the paper page 22466, lines 23-25 in the original version of the manuscript).

The ñbest matchò is obtained by minimizing the difference between the lidar-derived water vapor mixing ratio and backscattering coefficient profiles, averaged over the cross-sections shown in Fig. 7a and 7c, and the Meso-NH profiles from a given grid point. Because we do not expect the simulation to give the best comparison at the exact location of the observations, we have compared systematically all Meso-NH profiles in the vicinity of the observations (within a distance of 150 km) and selected the profile with the smallest difference. This is now mentioned in the text, for the sake of clarity.

Page 22468, line 8: ñunambiguouslyò seems too strong for me here. How about ñgenerallyò and ñespecially in the upper part of the dust layeró?

Agreed. The sentence has been modified as suggested.

Page 22471, line 17. ñto reproduce realisticallyò is too strong for me here; this would mean near perfect agreement. I suggest ñto simulate the most intense: : :ò

Agreed. The sentence has been modified as suggested.

Figs. 2, 3, 11, 12: It is difficult to distinguish the precipitation values in Fig. 2 as the dots are so small and all green-blue in the VR area. But anyway you show the zoom in the VR area in Fig. 3. Therefore, I suggest that you omit the precipitation plots of Fig. 2. The temporal relation to the SEVIRI data is anyway not given (average versus snapshot). But also the SEVIRI plots in Fig. 2 are redundant with the SEVIRI data in Fig. 11 and 12. I thus suggest that you show SEVIRI data in Fig. 2 and the corresponding model data in Figs. 11 and 12. In addition to the DUST images in Figs. 11 and 12, I would be interested to see the NODUST images too.

Figure 2: we believe that the sub-figures showing 24-h accumulated precipitations are useful as they show that the episodes of interest are indeed located on the southern part of the Massif Central, i.e. the Cevennes, and nowhere else. We have made the dots bigger.

There is little redundancy between Figs 2, 11 and 12. In fact only Fig. 2b and Fig. 11c are redundant. In the revised version of Figure 2, we have modified the MSG images to avoid this redundancy. We have selected the MSG/SEVIRI images based on our analysis of the brightness temperature in the CV area. We are now showing for each day, the SEVIRI image for which brightness temperature is smallest on the CV area.

Finally, we have added the brightness temperature issued from the NoDUST simulation in Figure 11 (on 17/10 at 15, 18, 21 UTC and 18/10 at 00 UTC) and Figure 12 (19/10 at 15, 18, 21 UTC and 20/10 at 00 UTC). These plots are now discussed in the text.

Technical corrections:

Please introduce BT (page 22459, line 9) and use it throughout. In figure 10 you write TB (caption and panels).

Please note that BT is already defined on page 22455 line 12.

We have corrected the caption and y-axis label in Figure 10. Thanks for picking this up.

You write ñdusty forecastò which sounds a little bit odd to me. I suggest just ñdust forecastò.
Agreed. We have modified ñdustyò into ñdustò throughout the text (7 occurrences).

Page 22460, line 2: ñsubgridò
Corrected.

Page 22460, line 18: ñThen, dust data at the end: : :ò
Corrected. « data » has been added.

Page 22461, line 6: Delete ñuseò
Corrected.

Page 22461, line 14: ñprecipitationò
Corrected.

Page 22466, line 5 and 19: ñcarried outò
Corrected.

Page 22466, line 25: The reference ñBerhendt et al. 2011ò is missing. I guess you mean Behrendt et al., 2011 (which is also missing)?
Yes we meant Behrendt et al., 2011. The reference has been added.

Page 22468, line 1: ñboundariesò instead of ñenvelopò?
Agreed and modified.

You write several times ñhighlightò (e.g., page 22468, line 18). I would prefer ñshowò, ñpresentò etc.
There were 11 occurrences of ñhighlightò. We now use ñshowò, ñpresentò, ñevidenceò, etc.. but we have kept 3 ñhighlightò for the sake of diversity.

Page 22480: ñoverlaidò
Agreed. 2 occurrences were corrected.

Page 22489: ñblack boxò
Corrected.

References:
Aoshima et al., 2008: Statistics of convection initiation by use of Meteosat rapid scan data during the Convection and Orographically-induced Precipitation Study (COPS). Meteorol. Z. 17: 921ï 930.

Behrendt et al., 2011: Observation of convection initiation processes with a suite of state-of-the-art research instruments during COPS IOP8b, Q. J. Roy. Meteor. Soc., 137, 81ï 100, doi:10.1002/qj.758, 2011.

We also have updated the Vié et al. reference to:
Vié, B., J.-P. Pinty, S. Berthet, and M. Leriche, LIMA (v1.0): a two-moment microphysical scheme driven by a multimodal population of cloud condensation and ice freezing nuclei, Geosci. Model Dev. Discuss., 8, 7767-7820, doi:10.5194/gmdd-8-7767-2015, 2015

Updated Figures

Figure 2: Left column: 24-h rainfall amounts (from 00 UTC) derived from rain gauge measurements on (a) 17 October, (c) 18 October and (e) 19 October 2012. The thick black line delineates the CV area (2-5°E/43.2-45.5°N). Right column: Brightness temperature at 10.8 εm derived from SEVIRI at (b) 2300 UTC on 17 October, (d) 1200 UTC on 18 October and (f) 0600 UTC of 19 October 2012. The white line delineates the CV area.

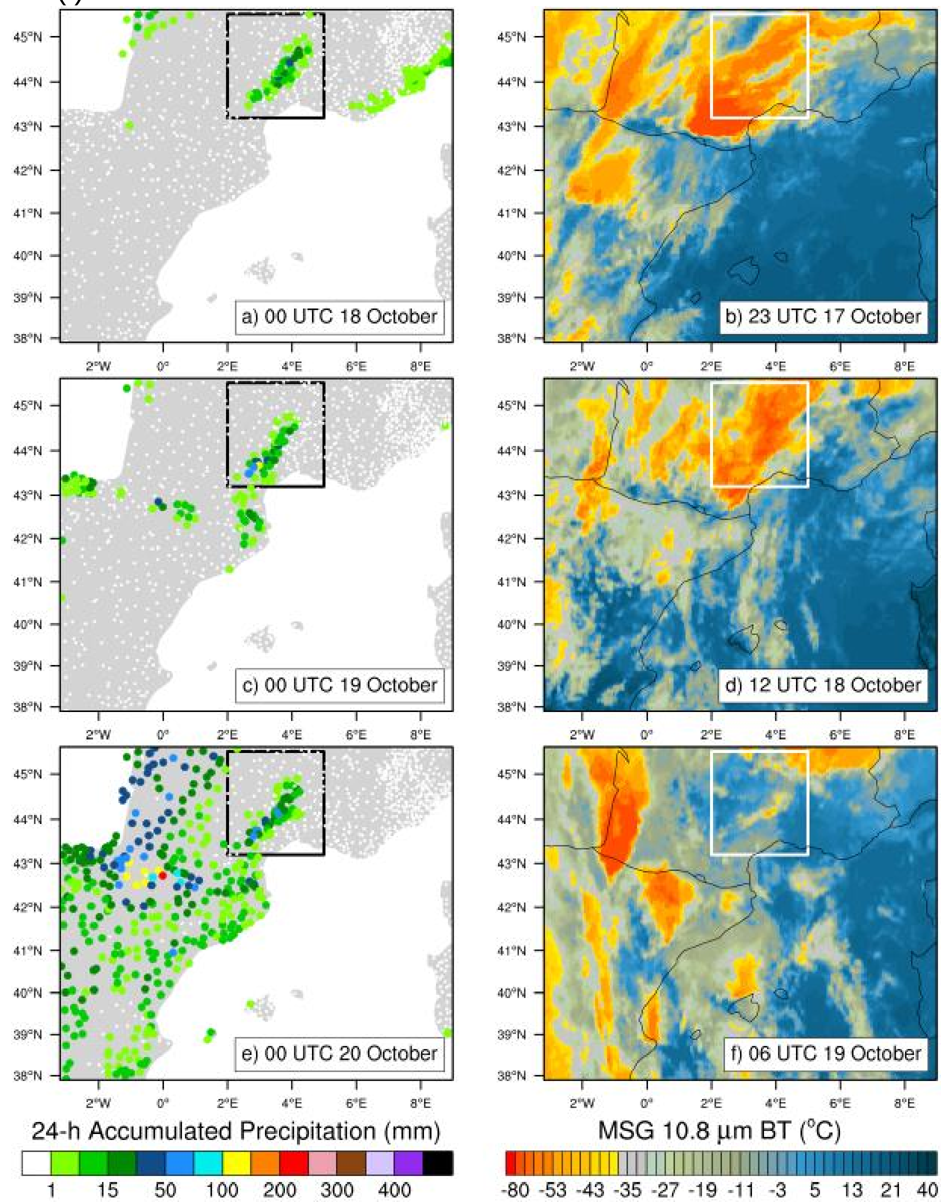

Figure 5: Time-height series of extinction coefficients derived from (a) WALI at 355 nm and (b) the Meso-NH DUST simulation ï valid for the spectral range 0.25-0.44 εm ï over Menorca between 0000 UTC on 17 October and 0000 UTC on 20 October 2012. Data gaps in (a) appear in white and are due to rain. (c) and (d) Same as (a) and (b), but for water vapor mixing ratio. The cloud layers in the Meso-NH DUST simulation are shown using a cloud condensate mixing ratio of 0.005 g kgï1(white contours in (b) and black contours in (d)). (e) AOD evolution for the same time period as derived from WALI (blue solid line), AERONET (at 340 nm, black solid line), MODIS (grey solid line) and the Meso-NH DUST simulation (red solid line). Error bars on the AOD retrievals are ±0.03 and ±0.02 for AERONET and WALI retrievals, respectively.

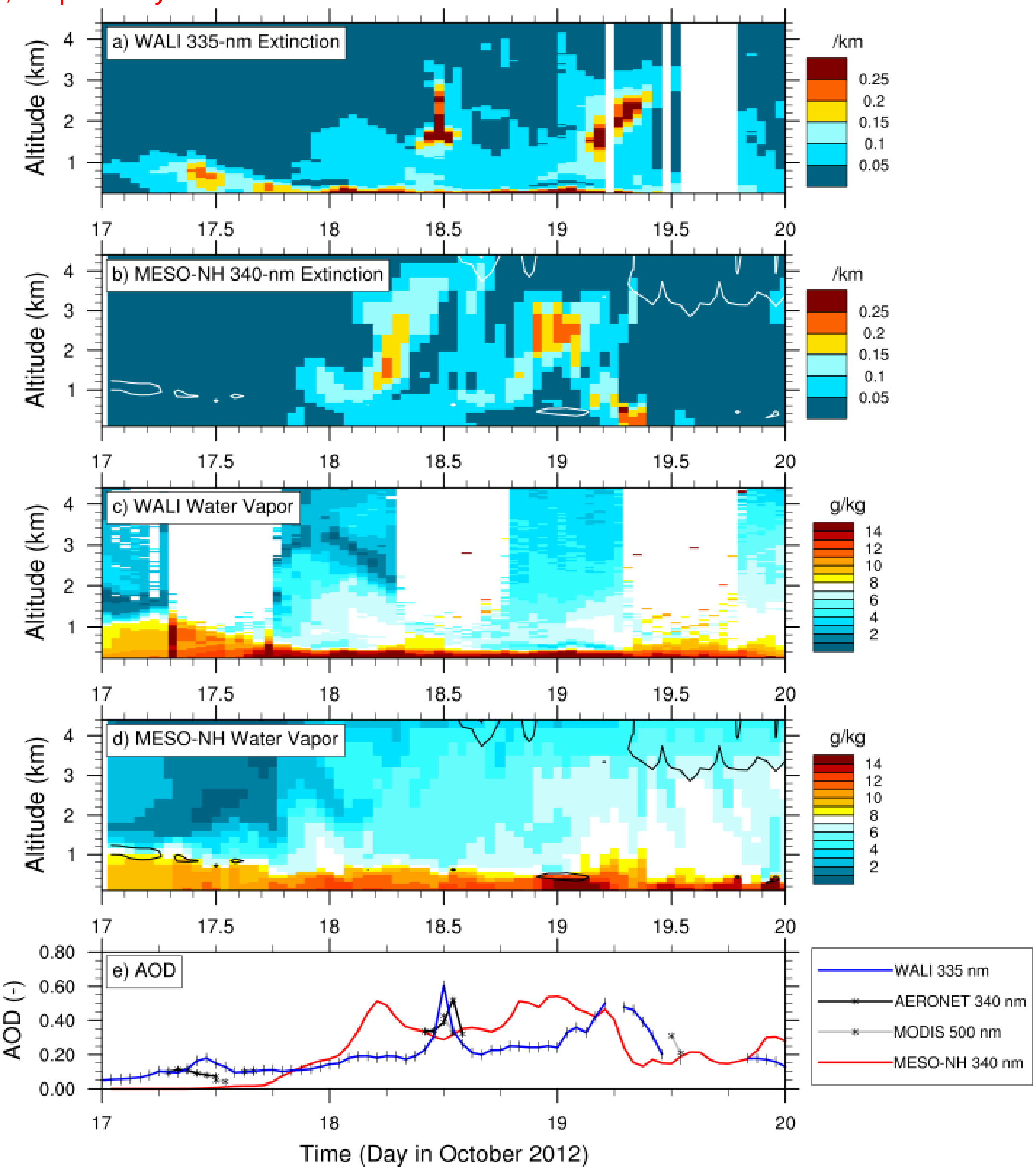

Figure 6: Time-height series of extinction coefficients derived from (a) BASIL at 355 nm and (b) the Meso-NH DUST simulation - valid for the spectral range 0.25-0.44 µm over Candillargues between 00:00 UTC on 17 October and 00:00 UTC on 20 October 2012. Missing BASIL data appears in white. (c) Same as (b), but for dust aerosol concentration derived from the Meso-NH DUST simulation. (d) and (e) Same as (a) and (b), but for water vapor mixing ratio. The cloud mask in (a) and (c) is based on the BASIL extinction coefficient, using a threshold of 0.25 $km^{-1}$. Hence, the presence of clouds is shown by the white contours in (a) and the black contours in (d), respectively. The cloud layers in the Meso-NH DUST simulation are shown using a cloud condensate mixing ratio of 0.005 $g\ kg^{-1}$(white contours in (b) and black contours in (d) and (e)).

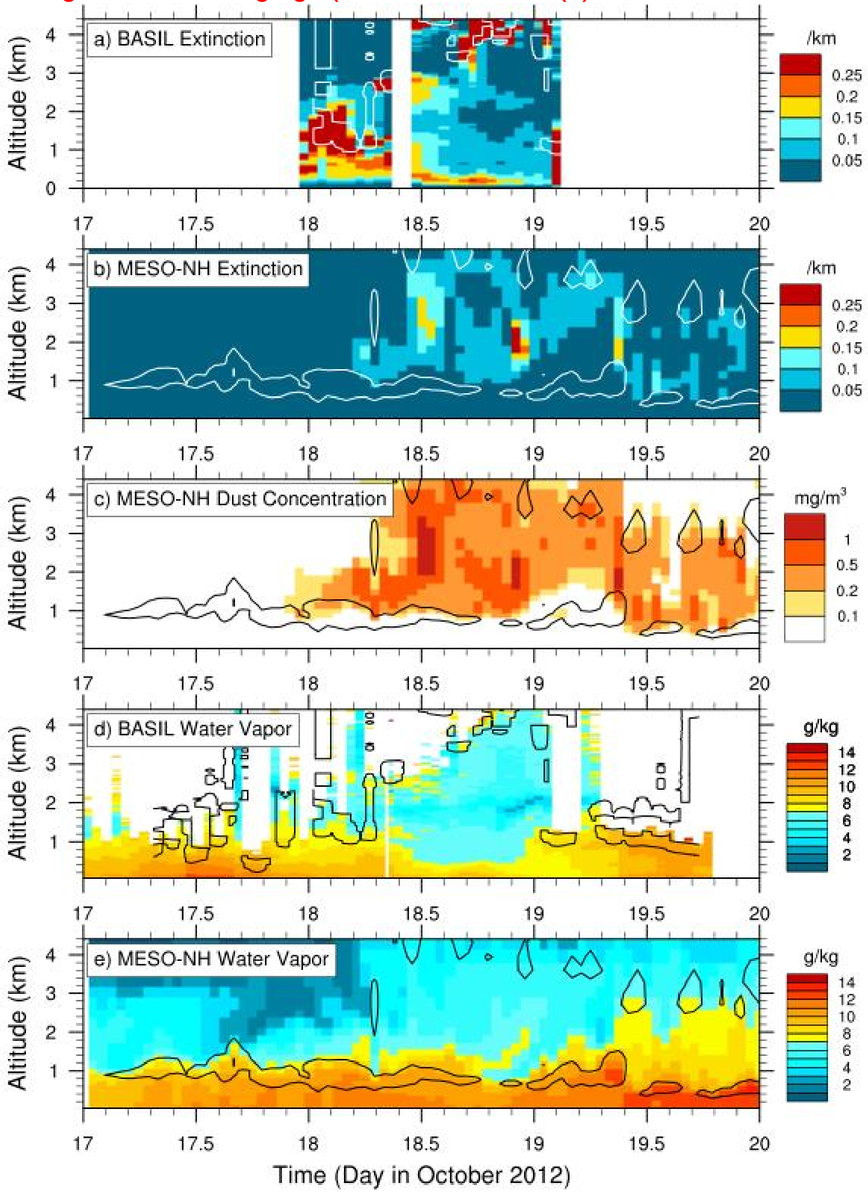

Figure 10: **(a)** 3 hourly evolution of the maximum MuCAPE difference (dashed blue line) in the CV domain and MuCAPE difference averaged over the CV domain (solid red line) between the DUST and NODUST from 00:00UTC on 17 October to 00:00UTC on 21 October 2012. **(b)** Same as **(a)**, but for the temperature difference at 2.5 km a.m.s.l. **(c)** same as **(b)**, but at 500 a m.s.l. **(d)** 3 hourly evolution of the minimum 10.8 εm BT in NODUST (dashed blue line) and in DUST (solid red line) in the CV domain. The dotted line is the minimum BT in the CV area observed with SEVIRI. **(e)** Same as **(d)**, but for the 10.8 εm BT averaged over the CV domain.

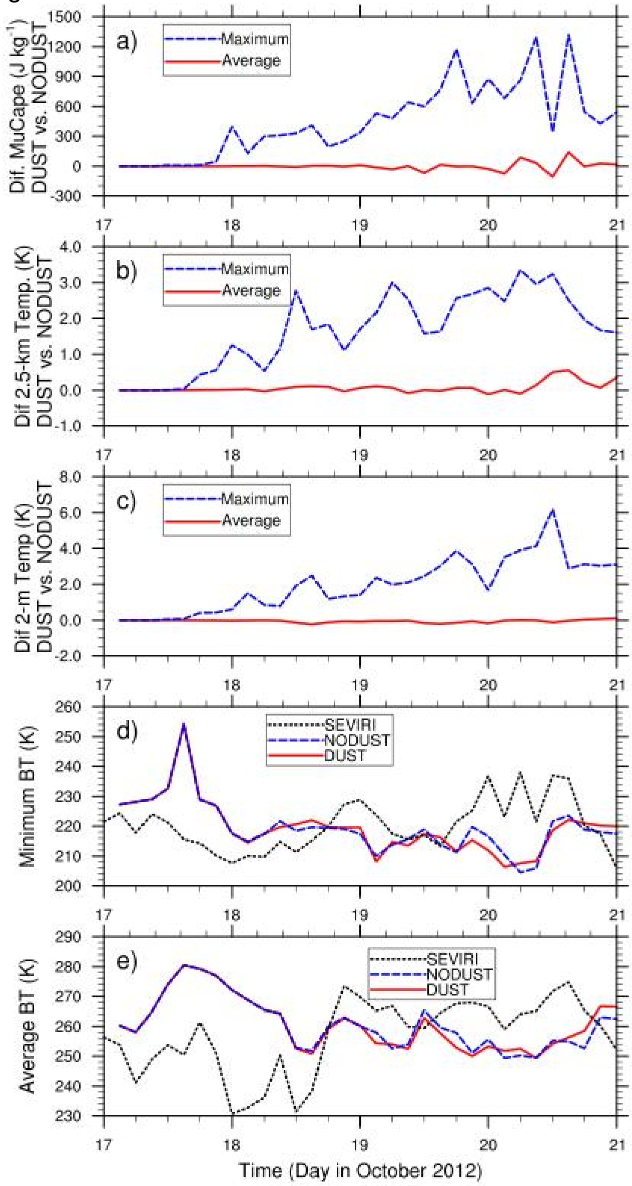

Figure 11: Top row: 3 hourly field of BT at 10.8 εm between 15:00UTC on 17 October and 00:00UTC on 18 October 2012. Middle row: same as top row, but for BT extracted from DUST. Bottom row: same as middle row, but for BT extracted from NODUST. The white box shows the CV area.

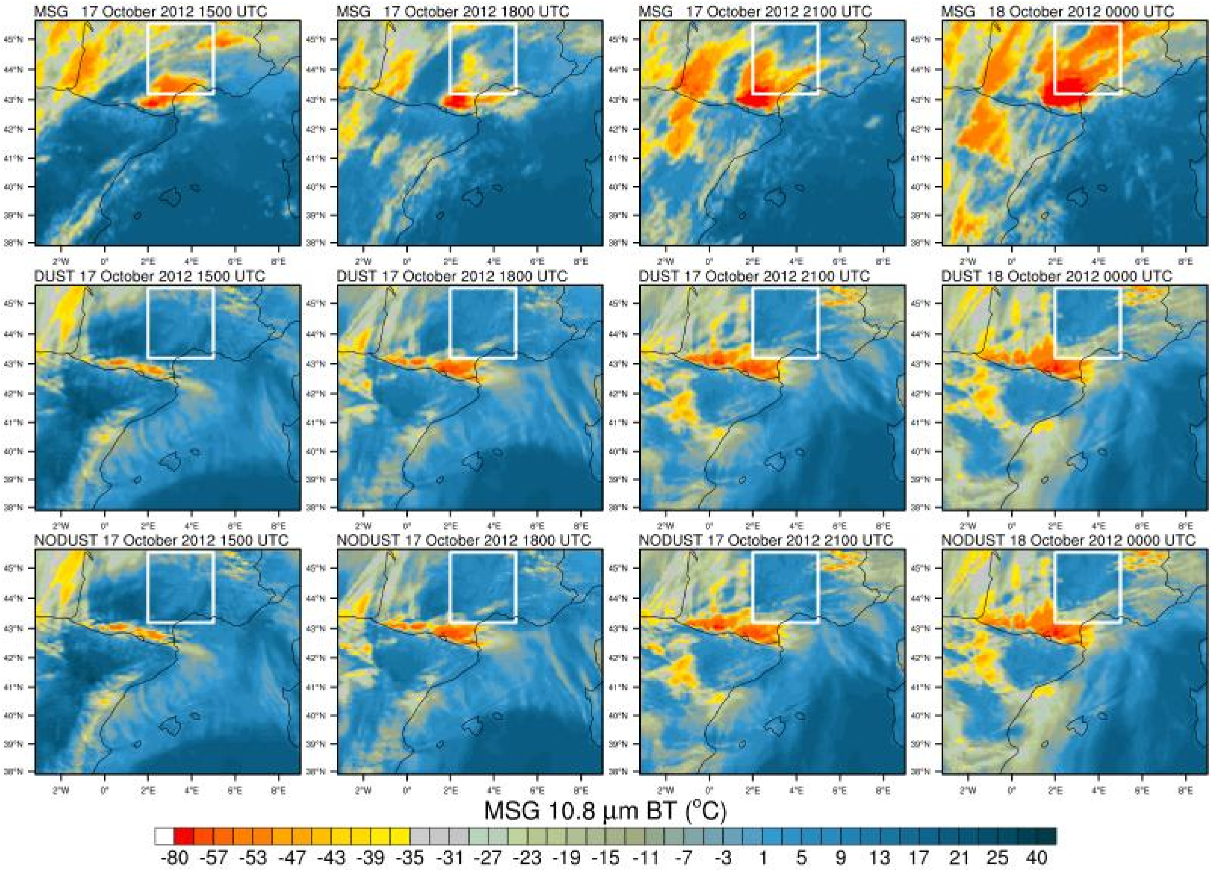

Figure 12: same as Fig. 11, but for the afternoon of 19 October.