Reply to Anonymous Referee #1 (30 March 2015)

The present paper describes three events of heavy rain in Valencia region, considering simulations performed with RAMS. Also, some sensitivity experiments are performed by changing the SST in some specific regions along the parcel trajectory ending in the precipitation area. In this way, the Mediterranean sub-regions that could have affected more deeply the precipitation amount and distribution are identified.

This new strategy to perturb the SST field is able to determine the regions that may have played a key role in the development of the torrential rain and then to investigate just the effect of that specific area in the model results. This approach is very interesting and could be applied also to other region in the Mediterranean basin. However, the potentiality of this idea is not fully exploited in the present manuscript version, thus I recommend the authors to improve the discussion in some points.

The authors wish to thank the reviewer valuable comments and considerations about our paper. Heading into the final version of the paper we will consider Them and include answers or explanations to your questions or suggestions.

We agree that our idea is not fully exploited in this paper as this is our first approach, coming from the first author doctoral thesis. In this sense, our future plans are to update our SST data base and perform new simulations for a higher number of events in the Valencia region and to extend, if possible, to other Mediterranean regions.

MAJOR POINTS:

- According to Figure 4, for each run the modifications with respect to the control run are not limited to a small area: for example along the coast of Algeria, none of the runs has a SST structure similar to panel (a). Thus, how did you modify the SST field? This point is very important, and it is never clearly explained in the manuscript;

Mediterranean sea surface temperature spatial and temporal behaviour have been studied in the first author doctoral thesis *"Ciclogénesis intensas en la cuenca occidental del Mediterráneo y temperatura superficial del mar: Modelización y evaluación de las áreas de recarga"* (available in spanish at http://hdl.handle.net/10803/83620. In that work a cluster analysis on SST data was conducted to identify regions with homogeneous characteristics and behaviour over the 1982-2009 period. Once those regions were identified, this information was used in the numerical simulations of three rain events in the Valencia region.

In most cases, clusters (defined from SST values) correspond to well defined spatial areas values but in some cases distant, usually smaller, areas corresponding to similar SST values were identified as belonging to the same cluster. In this situation, there was usually a bigger, clear area and some smaller locations apart from the main one. For every SST cluster/region geographical coordinates for any grid point were known; then SST gridded data were modified by prescribing a 10ºC value to the exact location of each cluster point.

After SST modification, these data were assimilated into RAMS model. The model assimilation process uses the higher resolution original SST gridded data and transforms to the lesser resolution model grid. This assimilated data is shown in figure 4 for September 1989 event, and in the corresponding figures for the rest of simulations. The different panels show the RAMS assimilated SST after original SST data modification. Additionally, some "noise" could have been added by RAMS interpolation between adjacent modified and preserved SST data areas. We think this could explain the differences the reviewer appreciates in SST maps in figure 4. More detailed SST maps can be found in the before mentioned work by Pastor.

Following modification will be introduced in the final paper to deal with your suggestion:

P 1366, lines 7-9:

*"For all this simulations, perturbation of SST consists in prescribing a 10 C constant value for the whole area in order to minimize air–sea exchanges while the air mass travels across the area."*

will change to:

*"For all this simulations, perturbation of SST consists in prescribing a 10 C constant value on selected areas, briefly described in section 2.1 (a more detailed SST areas description can be found in Pastor (2012), please also see additional material for SST data and clustering used on each model run), while retaining original data in the rest of the Mediterranean, in order to minimize air–sea exchanges while the air mass travels across the area. Modified SST fields are then assimilated into RAMS model grids for each simulation."*

Please, also find a supplement figure with the actual SST values and clustering for the three rain events simulated. The location of clusters determines the areas of modified SST. This will be available in the paper final version as additional material.

- For each case, a comparison with precipitation observations is suggested, otherwise it is not possible to understand how reliable the control simulations are;

A more detailed meteorological description of the three rain events can be found in the following papers, cited in the text:

- September 1989: *Pastor, F., Estrela, M., Peñarrocha, D., and Millán, M.: Torrential rains on the Spanish Mediterranean coast: modeling the effects of the sea surface temperature, J. Appl. Meteorol., 40, 1180–1195, 2001. 1360, 1364, 1367*

- October 2000: *Homar, V., Romero, R., Ramis, C., and Alonso, S.: Numerical study of the October 2000 torrential precipitation event over eastern Spain: analysis of the* *synoptic-scale stationarity, Ann. Geophys., 20, 2047–2066, doi:10.5194/angeo20-2047-2002, 2002. 1369*

- October 2007: *Pastor, F., Gómez, I., and Estrela, M. J.: Numerical study of the October 2007 flash flood in the Valencia region (Eastern Spain): the role of orography, Nat. Hazards Earth Syst. Sci., 10, 1331–1345, doi:10.5194/nhess-10-1331-2010, 2010. 1359, 1364, 1371*

Nevertheless, a figure showing observed precipitation (from AEMET database) will be added as supplement material, so the reader can compare control simulation results. Generally speaking, RAMS control simulations reproduce fairly well spatial distribution of precipitation but fails in reproducing accumulated values, especially by underestimating maximum values.

The following text will be added in the final version:

*"Although in this work we do not intend to evaluate the accuracy of the modeling results (for more detailed model evaluation see Pastor et al. (2001) and Pastor et al. (2010)), we have to note that, in general terms, RAMS control simulations reproduce fairly well spatial distribution of precipitation but fails in reproducing accumulated values, especially by underestimating maximum values. An observed precipitation map for each event is available as supplement material to aid for a comprehensive evaluation of model results."*

- Page 1369 L3-5: the motivations for the shift from offshore to onshore should be better motivated; is a convergence line present in CTLA, that no longer appears in A1?
Can you add a figure to better comment on this point? Similar considerations apply to the other cases;

Please find, as supplement material, a figure with equivalent potential temperature and vertical velocity cross sections at the latitude of rain area for the September 1989 event. In CTRLA simulation a strong vertical ascent is found over the sea offshore that moves onshore for A1. For the rest of simulations vertical movements are weak or almost inhibited.

- End of Section 3.1, P 1370 L20: some comments are missing about the connection among trajectories and SST modifications: in other terms, which change in SST is relevant for precipitation? Those along the trajectories? This is discussed in the Conclusions, but it should be explicitly stated already during the comment of each case;

Short comments have been added about trajectories in each case for the final text.

- From Figures 4, 8, 12, it appears that some interpolation in SST is done along the border between the modified and the unmodified regions, but this is not mentioned in the text;

Original SST data come in a high resolution (4 km) grid that is assimilated into the lesser resolution model grid. This assimilation includes some interpolation in order to build an homogeneous and relatively smooth data set. Abrupt, too high, SST changes between adjacent model grid points could lead to model numerical instability. SST fields shown in figures 4, 8, 12 are the RAMS assimilated data.

A distinction should in figure captions be made to clearly state which SST is shown.

Figure captions will change from:

*"SST used for RAMS model initialization on the simulation of ... event"*

to

*"RAMS model SST fields for the simulation of ... event"*

- P 1367 L20: is SST the climatological map? Or is the monthly map just for August 1989? This is not clear from the manuscript. Also, why not using the measured value before the episode? Again, how do you select the exact shape of the area where the SST has to be changed? Similar considerations apply to the other cases;

For the sake of clarity this will be more clearly stated in the final version text and the exact SST maps for each simulation will be added as additional material.

For every simulation the SST used correspond to the actual monthly average. In the case of the September 1989 the SST data used are from August 1989. As the cluster/area definition was build from monthly data we decided to use it on the simulations. In future work, best SST images close to the event could be used, with some work to fill data gaps due to cloudiness.

Regarding the modified area selection and the modified text, please see the answer in a prior question.

Please, also find a supplement figure with the actual SST values and clustering for the three rain events simulated.

- Figures 3, 7, 11: from what level do the trajectories start from? To what level do they arrive at?

At the time of computing trajectories we were mostly interested at surface levels as, from previous works cited in the paper, orography plays an important role as trigger mechanism. All the plotted trajectories (HYSPLIT and RAMS) are computed at surface level, ending at 100 m above ground level. We were interested in the trajectories closer to the sea where air-sea heat and moisture exchanges occur.

We also computed HYSPLIT trajectories ending 500-1000 m above ground level over the rain area; in this cases, starting levels ranged from 500 to 1500 m and its path across the Mediterranean was very similar to that on surface level.

- P 1374 L5: “the simulation with less change respect to the control simulation in both spatial distribution and rainfall amounts is the one when the most remote area across the air mass trajectory (Gulf of Tunis and Libyan coast) modifies its SST, being also the one with highest SST values”: Figure 8 shows that in such a simulation the SST is also modified near the Balearic island, which could affect significantly the results; please explain better this point;

Yes, this simulation was one of the cases when, apart from the main area in Tunis and Libyan coasts) there was a small one to the south of the Balearic islands belonging to the SST cluster. We computed HYSPLIT trajectories from the days previous until the end of the rain event (18-26). As trajectories only run across southern Balearic sea before 20 october, we consider that, as the air mass trajectories run to the north of Majorca island, the effect of this area on the model simulation was not as important as the rest of mediterranean areas.

- Abstract: introduce also here what you mean with recharge areas;

Rephrased to reflect the meaning of "recharge areas"

- Page 1359 Line 4: “favours both its own and differentiated meteorological . . .”: the sentence is not clear;

Rephrased to *"The particular configuration of the Western Mediterranean area, an almost closed sea surrounded by high mountain ranges and little water mass exchange with other seas, determines its own meteorological (Millan, 2005a, 2005b, Palau2014) and oceanic (Bethoux1999,Robinson2001) dynamics and behaviour"*

- P 1360 L25: about the role of heat/moisture exchange from a modelling point of view, please consider also the following two papers: - Moscatello, A., M. M. Miglietta and R. Rotunno (2008), Numerical analysis of a Mediterranean “hurricane” over southeastern Italy, Monthly Weather Review, 136, 4373-4397; - Rainaud, R., Brossier, C. L., Ducrocq, V., Giordani, H., Nuret, M., Fourrié, N., Bouin, M.-N., Taupier-Letage, I. and Legain, D. (2015), Characterization of air–sea exchanges over the Western Mediterranean Sea during HyMeX SOP1 using the AROME–WMED model. Q.J.R. Meteorol. Soc., doi: 10.1002/qj.2480

Citations of those papers are now included

- P 1360 L28: please consider that the exact trajectory can be important for air-sea exchanges also because it controls the time the air mass remains above the sea surface and air-sea interaction can work;

Change:

*Depending on the air mass trajectory prior to the rain event, air–sea interaction could be more or less intense because of the temperature difference between sea surface and the atmosphere.*

to

*Depending on the air mass trajectory prior to the rain event, air–sea interaction could be more or less intense because of the temperature difference between sea surface and the atmosphere and due to the time during that exchanges can develop.*

- P 1361 L2: rephrase “could be identified, that information” instead of “could be established that”

Changed

- P 1361 L8, P 1366 L7, P 1366 L23: “these” -> “this”

Changed

- P 1362 L10: delete “who”

Deleted

- P 1364 L25: why is LEAF-2 prescribed with a homogeneous soil texture?

For the simulations run on this, and other works, at Fundación CEAM we benefit of prior work with RAMS on different fields, ranging from meteorology to pollutant dynamics applications. Based on the previous experience on using RAMS we chose model configuration that has been previously tested

One of those works (cited in the text) is the one from

Pérez-Landa, G., Ciais, P., Sanz, M. J., Gioli, B., Miglietta, F., Palau, J. L., Gangoiti, G., and Millán, M. M.: Mesoscale circulations over complex terrain in the Valencia coastal region, Spain – Part 1: Simulation of diurnal circulation regimes, Atmos. Chem. Phys., 7, 1835–1849, doi:10.5194/acp-7-1835-2007, 2007.

In this work LEAF-2 configuration was studied in order to obtain reliable RAMS results for wind and temperature fields. Please find below an excerpt from this article related to RAMS model configuration.

*We thus initialized soil moisture and soil temperature during the campaign by running RAMS coupled to LEAF-2 over the two largest domains (Fig. 1a) for two months preceding the campaign, guided by a smooth data assimilation (FDDA) of the AVN fields. For simplicity, we prescribed LEAF-2 with a homogeneous soil texture of the clay-loam type. The soil column at each grid point is subdivided into 11 layers down to a* *depth of 2 m. The soil moisture was initialized with a uniform profile at a value of 0.38 m 3 /m 3 . The initial soil temperature profile is obtained by subtracting from the surface air temperature a value of 2.3 ◦ C in the top soil, which linearly decreases down to a decrease of 1 ◦ C in the bottom soil. The soil variables obtained in RAMS for 1 July 2001 were compared to the AVN global analysis data. Soil temperatures were similar in both simulations, except for those regions where differences in model orography are important (not shown). Soil moisture from AVN was drier than in RAMS for the 0–10 cm layer, and for 10–200 cm (Fig. 3). The RAMS results show their highest moisture values in mountainous regions, probably due to the effect of convective precipitation which the global AVN model could not resolve. Other differences in AVN vs. RAMS soil moisture fields must also be attributed to their different land surface schemes, which may induce different soil moisture dynamic ranges (see e.g., Koster and Milly, 1997).*

*The use of a 2-month model spin-up to initialize our high resolution simulation could be disputed, when compared with other more complex schemes employed in mesoscale models (e.g. Smith et al. 1994). However, initialized in this way, RAMS showed good skills in simulating wind and temperature fields during the campaign (Sect. 5 and Perez-Landa et al., this issue).*

But, of course, a realistic soil texture would be an improvement for future simulations.

- P 1365 L5: whose -> which

Changed

- P 1367 L10: the location of Valencia region should be indicated in a map (maybe Fig. 3?)

Changed figure 3 to locate Valencia region and Alicante

- P 1367 L16: add a comment about Fig. 2b otherwise please remove it;

Figure is now referenced in the text

- P 1367 L28: "of" instead of "reaching"

Changed

- P 1370 L19: "and" instead of "to"

Changed

- P 1370 L23: what do you mean with "equivalent potential fields"?

A typo mistake, should be "equivalent potential temperature fields"

- P 1370 L26: a decrease in dew point temperature determines lower humidity content: do you mean “a decrease in difference between dew point and temperature”?

It was a mistake when writing, changed from

*"a decrease in dew point temperature determines lower humidity content"*

to

*"a decrease in equivalent potential temperature determines lower humidity content"*

Please find a supplement figure with equivalent potential temperature cross sections at the latitude of rain area for the October 2000 event.

- P 1371 L6: for non-Spanish readers: please show where Alicante province is;

Changed figure 3 to locate Valencia region and Alicante

- P 1371 L23: mm instead of L;

Changed

- P 1371 L27: as instead of than;

Changed

- P 1373 L2: The following sentence is not clear: “In both modes, differentiated areas were found presenting similar qualitative features across the whole study period”

Changed to
*"In both modes (winter and summer), areas presenting similar qualitative features, regarding spatial extent and SST values, were found throughout the whole study period"*

- P 1374 L5: “where” instead of “when”

Changed

- P 1375 L9: “The determination of sea areas that contribute to the development or intensification of heavy rain events in the Mediterranean countries can be used as a prognosis and monitoring tool”: the way how this tool should work is not clear and three case studies are not enough to draw any general conclusion.

We agree with the reviewer that three events are not enough to draw general conclusion. This paper was conceived as a first approach to a new methodology for the evaluation and analysis of SST role in torrential rains in a Mediterranean region. In this sense, our future plans are to update our SST data base and perform new simulations for a higher number of events in the Valencia region and to extend, if possible, to other Mediterranean areas.

If Mediterranean areas acting as main contributors to the development of torrential rain could be established, monitoring of SST values and/or anomalies in this areas could be an indicator of potential risk of torrential rains or floods, in the presence of synoptic conditions prone to this type of events.

Change

*"The determination of sea areas that contribute to the development or intensification of heavy rain events in the Mediterranean countries can be used as a prognosis and monitoring tool".*

to

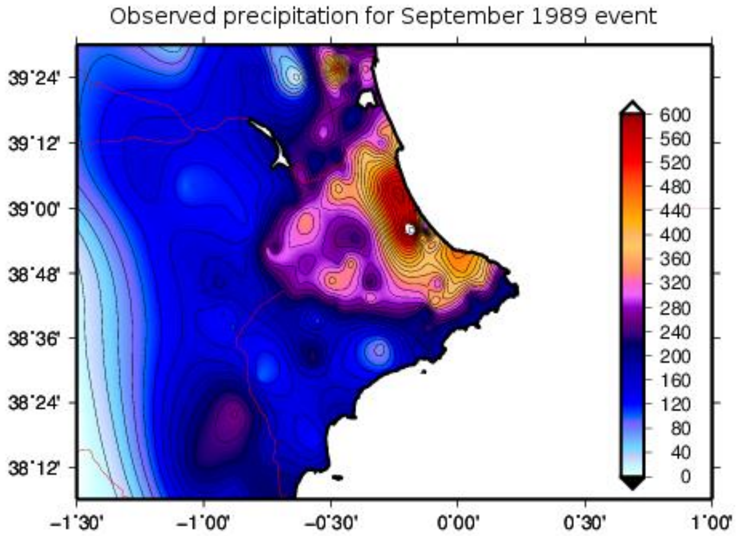
*"The determination of sea areas that contribute to the development or intensification of heavy rain events in the Mediterranean countries could be used as a prognosis and monitoring tool by monitoring SST anomalies and/or values in such areas".*

Figure 1: what is the meaning of the colors in the right panel?

Colors in the right panel stand for the clusters found for SST data; clusters identify region with similar SST values. Number of clusters can be different for any SST monthly data set. Figure has been modified to add a scale for clusters but it has to be noted that same color does not mean same SST range/value for different figures.

Table 1: why the rate in Time is 2 between grid 1 and 2, and 2 and 3, while in DX is it 3?

As explained before, previous experience in RAMS model configuration has led us to some common configuration schemes for different RAMS applications. In previous experiences we tried different grid sizes, timestep and number of grids. The RAMS configuration used in this work seemed us adequate to simulate heavy rain events in our region.


Observed precipitation for September 1989 event
39˚24'
39˚12'
39˚00'
38˚48'
38˚36'
38˚24'
38˚12'
−1˚30'
−1˚00'
−0˚30'
0˚00'
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600
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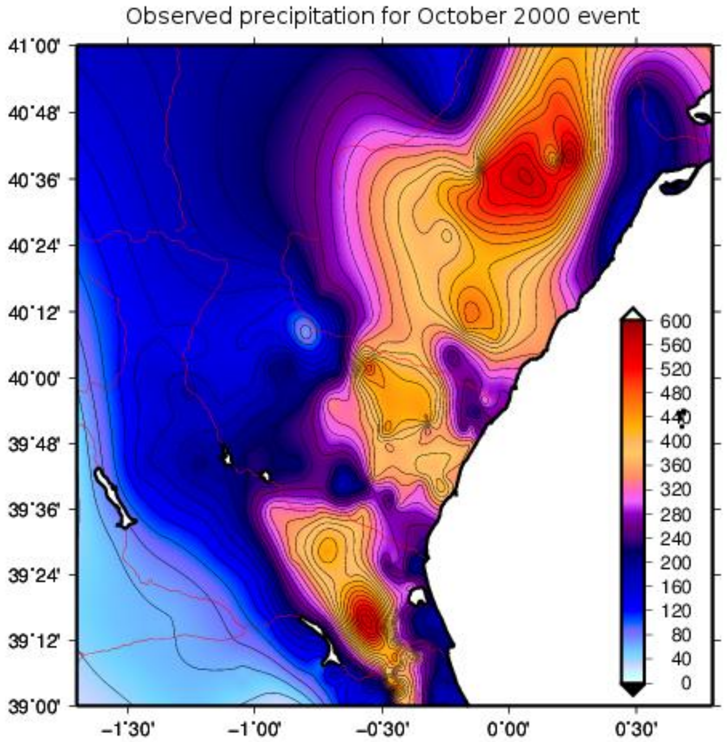
Observed precipitation for October 2000 event
41˚00'
40˚48'
40˚36'
40˚24'
40˚12'
40˚00'
39˚48'
39˚36'
39˚24'
39˚12'
39˚00'
−1˚30'
−1˚00'
−0˚30'
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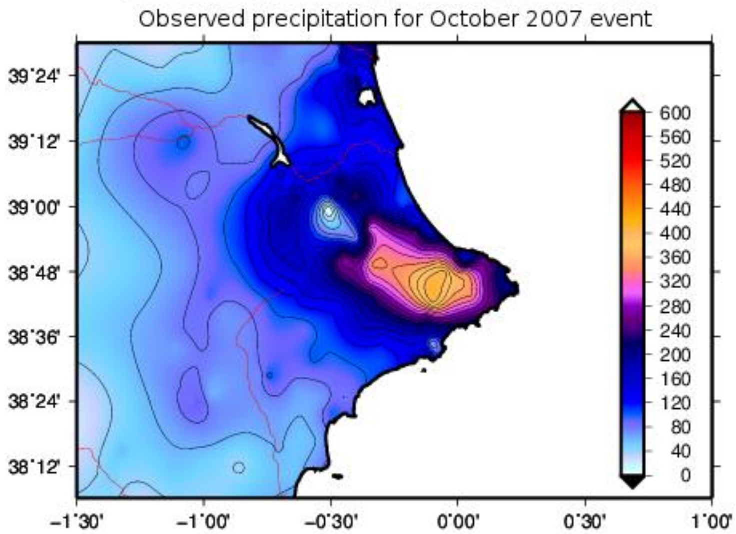
Observed precipitation for October 2007 event
39˚24'
39˚12'
39˚00'
38˚48'
38˚36'
38˚24'
38˚12'
−1˚30'
−1˚00'
−0˚30'
0˚00'
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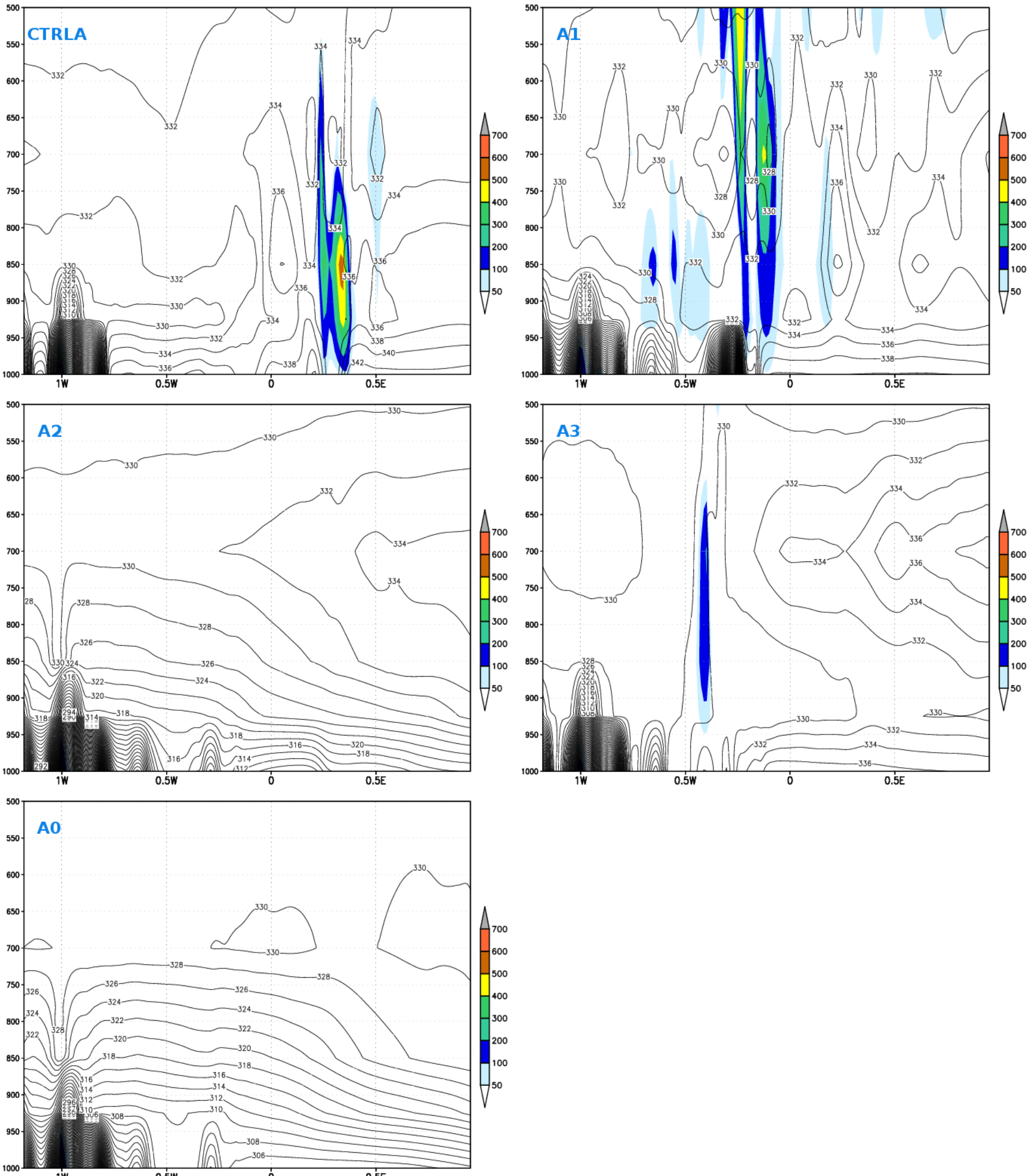
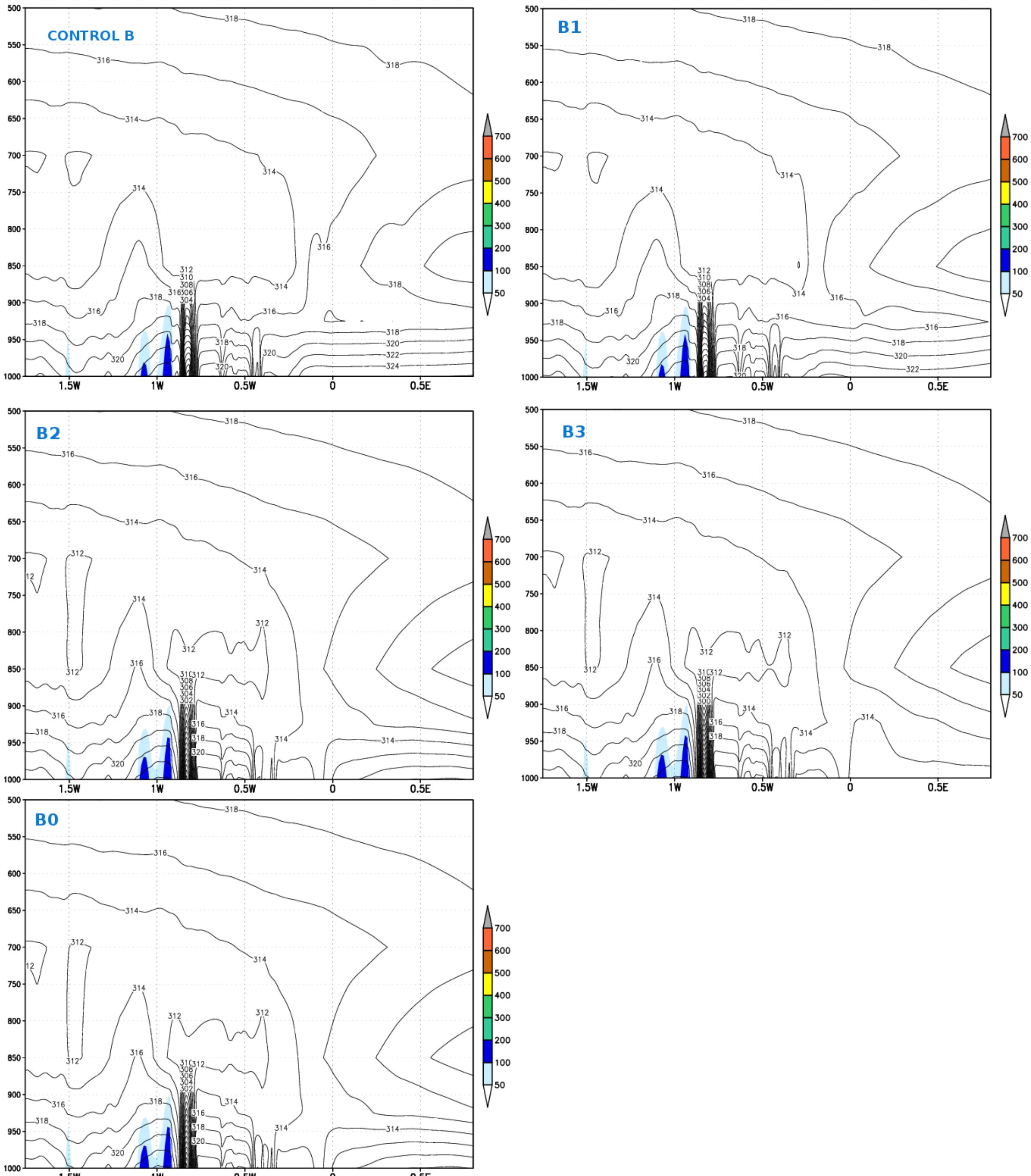
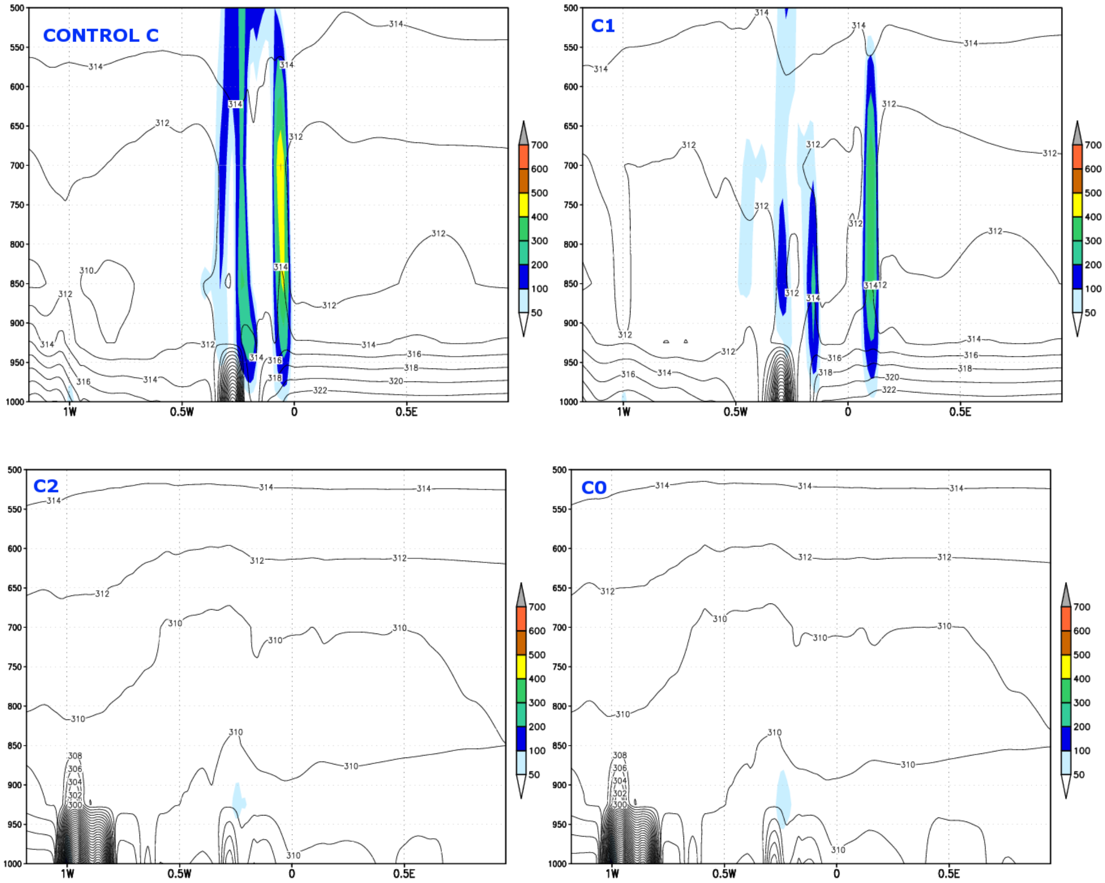



Vertical velocity (cm/s) and potential temperature (K) cross-section at 38.9N for the September 1989 event




Vertical velocity (cm/s) and potential temperature (K) cross-section at 39.9N for the October 2000 event




Vertical velocity (cm/s) and potential temperature (K) cross-section at 38.9N for the October 2007event

Sea surface temperature and clustering for the three RAMS model simulations