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Interactive comment on "Evaluating intense precipitation in high-resolution numerical model over a tropical island: impact of model horizontal resolution" *by* N. Yu

N. Yu

yunansh@hotmail.com

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General response: We highly appreciate the comments of the reviewer. The current manuscript has been improved based on your criticisms. Actually, we have carried out many numerical experiments in order to understand the impacts of domain size, nesting method, turbulence scheme, convection scheme, shallow convection scheme, topographic resolution, initial conditions and model horizontal resolution. We are convinced that the model resolution has a great significant impact on rainfall simulations during this rain event. The 1 km grid spacing is necessary to resolve well the topography if the island (see Figure a), the evaporation and the cold pool blocked by mountains, which are critical factors to yield such intense precipitations. For a sake of simplicity, we just presented the impact of model resolution and of relevant microphysical process in the manuscript. Nevertheless, the discussions about the other model configurations are welcome and the others results may be presented in a further paper.

1. The difference in simulation results might be related to the domain size and the change of the method of nesting from 1-way to 2-way and not to the spatial resolution of the models grid.

Regarding the domain size, we have tested 90X90, 180X180 at 8 km resolution (with convection parameterization), 360X360, 180X180, 90X90 at 4 km resolution (with and without convection parameterization), 360X360, 180X180, 90X90 at 2 km resolution. All these numerical experiments showed similar characteristics: 1) the maximum rainfall is under-estimated 2) the position of intensive rainfall is displaced (too close to the mountains). The most important point is that we could not see the cold pool in those coarse resolution simulations. We cannot present the results of all these simulations in the article. But we have added a sentence in the section 2.2 to sum up the results of these simulations.

Regarding the nesting method, we tested both 1-way and 2-way methods. However, the results showed that its impact on rainfall simulation is less important than the model resolution. The 1-way nesting method yields an overall slight underestimation of rainfall. For such extreme event, we think that strong convection triggered by the topography has important influence on the energy and water vapor balance at large scale. That is the reason why we use the 2-way nesting method in this study. We agree that the numerical experiment at 1 km (or 500 m) resolution in the same domain without nesting technique should be better to understand the impact of model resolution. However, our computer and financial support is not enough for such high-cost numerical experiments. Additionally, the coarse resolution of the analysis (8 km) is also an obstacle to run such 1 km or 500 m experiments.

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2. Each change in the configuration can be regarded as a disturbance experiment or another realisation. Due to sensible dependence on initial conditions this might lead to another weather situation. This has not been excluded.

This is true. We have run several sensitivity tests at 2 km and (nested) 1 km resolution using different initial conditions (27 January 2011 00:00, 27 January 2011 06:00 and 27 January 2011 12:00). The results showed that the differences due to the initial conditions were less significant than those due to model resolution. All numerical experiments starting after the 27 January 00:00 showed no significant improvement in rainfall simulation for this case study.

3. In general, the physical parameterisations of turbulence and convection are not independent on the spatial resolution of the model. The relation of grid scale and physical parameterisations is not discussed and not proof is given that the results shown are not dominated by differences in model physics.

Regarding the turbulence scheme, at 2 km (or 4 km) resolution, since the horizontal resolution is not enough to resolve large gradients, we selected the quasi-1D (Bougeault and Lacarrère 1989) scheme. While in the high resolution simulations (1 km and 500 m), in order to well resolve the turbulence sources by shear in all three spatial dimensions, the three-dimensional turbulent fluxes scheme (Redelsperger et Sommeria 1981), is used. A detailed discussion about this point can be found in Honnert et al. (2011)

To our knowledge, 4 km is the grey zone for the convection parameterization. In this study, the convection parameterization is inactive for all numerical experiments. It is assumed that deep convection is resolved explicitly. In fact, when we activate the convection scheme (at 8 km 4 km and 2 km resolutions), we got some very strange rainfall simulation (even at 2 km resolution). We have investigated these results with Peter Bechtold. It seems to me that, a lot of work needs to be done in the future to better take into account the relationship between grid size and convection parameterization.

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This issue is out of the scope of the current study.

4. The frequency of the update of the boundary conditions every 6h and the constant vertical resolution might have an impact on the simulation results, in particular for small domains and high resolutions.

Thank you for these interesting comments. The setup of different vertical resolution between parent and nested domains is not allowed in the numerical model MesoNH. Based on recent research (Aligo et al. 2009), we selected a vertical resolution configuration with high resolution in the surface layer (about 20m).

We agree that the frequency of the updates of the boundary conditions has certainly great impacts on rainfall simulation. But our parent domain is relatively small (as you mentioned) due to the limitation of computer resource, therefore we hope that the analysis can provide as much as possible information about the large scale circulation (especially provide the position and intensity of the depression near the island as shown in Figure 1). This is the reason why we update the boundary conditions every 6 hours. Given the size of the father domain and the main flow speed, updating boundary conditions every 6 hours is reasonable when focusing on precipitation over La Réunion.

5. The vertical crossection shown in Fig. 11 exhibits a typical space scale of the convective cells of 10-20 km. The grid scale of 2km should resolve these structures. A scale analysis of the processes necessary to be simulated explicitely is missing and a proof that this cannot be represented by a 1km grid scale resolution.

We agree that the convective cell shown in Fig.11 is larger than 2 km grid spacing. However, the key point of this study is that the “cold pool” and “land breeze” is poorly simulated by the 2km resolution model. These two features are confirmed by the meteorological observations and well simulated in the 1 km resolution model. Without the “cold pool” and “land breeze”, even if the 2km grid spacing is much smaller than the convective cells, there is no such convective cell in simulations.Therefore, we believe that even if the convection scale is 10-20km, the grids scales below 2km are still needed for the accurate representations of the orography and physical processes, especially for La Reunion Island with complex topography.

6. A summary of results already published is found in the section conclusions rather than in the introduction.

We have moved this part in to the introduction.

7. At many places qualities like "precise" or "reliable" are used instead of quantities.

We have replace these expressions by quantitative descriptions.

8. The difference between grid scale and effective model resolution is not considered at all. Thus the grid scale of 50m needs not to resolve turbulence and 1km the convective motion.

This is a very interesting comment. The dynamics of the MesoNH is based on Eulerian explicit schemes. A recent case study (Ricard et al. 2013) showed that the effective resolution of Meso-NH remains around 4–6Δx for horizontal grid spacings between 2.5 km and 250 m. The choice of the turbulence scheme is based on the study of Honnert et al. (2011). We agree that it is interesting to further investigate this question.

9. The effect of the domain size on the simulation results is not discussed. In particular the domain for the 1km and 500m simulations is very small.

The 1 km and 500m nested domains are used to take into account the triggering and the reinforcing of the convection by the island topography, which cannot be represented in 4-km and 2-km runs. That is the reason why we selected a small domain around the island. We admit that a larger parent domain will be better (as we mentioned in the question 4). We added a sentence in the manuscript to mention the limit of the research due to small domain.

10. The update of the boundary conditions every 6h is inappropriate for convection permitting and resolving simulations.

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First, our study focuses on the very local event, situated at La Réunion. The rationale for our experimental setup is the following :

-initial conditions and regional-scale boundary conditions are provided by high-resolution regional analyses every 6 hours; this is the best picture of the large-scale situation we can have in this part of the world ;

-a large-scale domain (D1) is forced by these analyses as boundary conditions ; the boundaries of this large-scale domain are sufficiently far away from La Réunion to avoid boundary effects ;

-the small-scale domain (D2) is really focused on La Réunion.

This is the best configuration we may develop for studying and modeling high-resolution event over La Réunion. As mentioned above, we cannot make the 2 km resolution (parent) domain larger due to computer limitation and we need the analysis to provide the large circulation information. The update of the boundary conditions every 6h was also used in many past studies, such as Costa et al (2010), Couto et al.(2012), Luna et al. (2011) and Trapero et al. (2013).

11. A reference for the the 2-way-coupling mode is missing.

We have added the nesting reference (Stein et al. 2000) in the section 2.

3. Technical corrections

The language needs to be improved.

A special language editing will improve the language.

The Figure captions and axis descriptions are not always complete

We completed them. Thank you.

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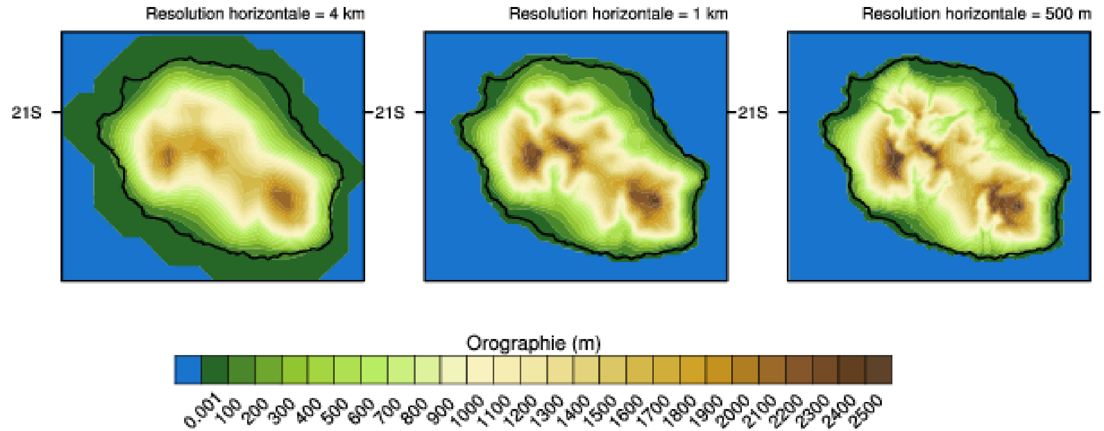

Fig. 1. La Réunion orography as seen by the 4-km, 1-km and 500-m simulations

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