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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Numerical modeling and analysis of the effect of Greek complex topography on tornado genesis" *by* I. T. Matsangouras et al.

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The authors would like to thank the Reviewer for providing insightful comments on the manuscript, allowing us to improve its scientific and presentation quality Our reply to the reviewer's comments follows:

Comment: The setup of the experiment should be better justified. For example, the reason why domain D3 was chosen is not clear enough. I would suggest that an appropriate reference should be made so that it is explained further. Reply: The domain D3 with a fine grid-spacing of 1.333km was employed in order to provide a more re-

alistic representation of topography and the atmospheric flow in the areas of interest which were characterized by complex terrain. Mass et al. (2002) showed that increasing model resolution generally leads to improved simulations of precipitation in regions with complex terrain. This is due to a better representation of the surface features and the smaller-scale features. Similarly, Colle and Mass (1998, 2000a, 2000b) performed high resolution modeling studies of windstorms, a flooding event and gap flow with grid spacings down to 1km – 1.33km. In general, their simulations improved as the grid-spacing decreased and many of the mesoscale features were more realistically simulated. Following the suggestion of the reviewer, a reference was made in the revised article.

Colle B.A., C.F. Mass (1998) Windstorms along the western side of the Washington Cascade Mountains. Part I: A high-resolution observational and modeling study of the 12 February 1995 event. Mon. Wea. Rev., 126, 28–52. Colle B.A., C.F. Mass (2000a) High-resolution observations and numerical simulations of easterly gap flow through the Strait of Juan de Fuca on 9–10 December 1995. Mon. Wea. Rev., 128, 2398–2422. Colle B.A., C.F. Mass (2000b) The 5–9 February 1996 flooding event over the Pacific Northwest: Sensitivity studies and evaluation of the MM5 precipitation forecasts. Mon. Wea. Rev., 128, 593–617. Mass, C., D. Ovens, K. Westrick, B. Colle (2002) Does increasing horizontal resolution produce more skilful forecasts? Bull. Amer. Meteor. Soc., 83, 407–430.

Comment: ECMWF's ERA-Interim reanalyses with resolution of 12 Km was used to initialize the model on the external domain. Since the jump in resolution is large, I would recommend you explain why you did not use a different model (COSMO-GR7, SKIRON). Reply: This study employed the ECMWF's ERA-Interim reanalysis with a resolution of 0.75x0.75 for initial and boundary conditions while the coarse grid of our model (WRF) exhibited a grid-spacing of 12km x 12km. Regarding the resolution jump from 0.75x0.75 to 12kmx12km: Beck et al. (2004) studied the impact of different one–way nesting strategies on precipitation simulations over the European Alps with the

LAM ALADIN model. The LAM was forced by initial and lateral boundary data derived from ERA40 reanalyses with 120 km horizontal grid-spacing. They examined the dynamical downscaling of ERA40 data to 12 km grid-spacing with a large resolution jump of 10:1 over complex terrain. Their results indicated that "the considered nesting strategies are comparably successful in terms of precipitation simulation, despite the large resolution jump (120 to 12 km) involved". Liu et al. (2012) investigated the sensitivity of WRF rainfall using different domain settings and various storm types. They concluded that "moderate downscaling ratios of 7:1, 5:1 and 3:1 were found to perform better with the WRF model in giving more reasonable results than smaller ratios". Papadopoulos et al. (2011) applied a downscaling procedure to reproduce high resolution historical atmospheric records across the Mediterranean region. They employed the POSEIDON weather forecasting system with a horizontal grid increment of 0.1x0.1 (about 10km). The forcing was provided by ERA40 reanalyses at a horizontal grid spacing of 1.125x1.125 latitude/longitude. Finally, it is mentioned that model output that resulted from resolution jumps higher than 5:1 (and up to 10:1) have been successfully used at various peer-reviewed articles of the international literature such as Galanis et al. (2006), Louka et al. (2009), Zoras et al. (2010), Katsafados et al. (2011), Stathopoulos et al. (2013). The abovementioned articles have been included in the revised version of the paper. The reviewer suggests the use of COSMO-GR7 and SKIRON as a modeling tool instead of WRF. WRF can be integrated at any desired horizontal resolution. In this study, the resolution jump between the input ERA-Interim reanalyses and the external grid of our model was between 5.5:1 and 7:1 (in longitude and latitude, respectively). The above brief literature review showed that downscaling ratios higher than 5:1 (and up to 10:1) have been used successfully at various studies during the last decade. In addition, reviewer suggestion motivated authors for a future work, regarding the evolution of examined diagnostic indices in numerical simulation, with research partners using COSMO-GR7 and SKIRON numerical models.

Beck A., B. Ahrens, K. Stadlbacher (2004) Impact of nesting strategies in dynamical downscaling of reanalysis data. GEOPHYSICAL RESEARCH LETTERS, 31, L19101,

doi:10.1029/2004GL020115. Galanis G., P. Louka, P. Katsafados, I. Pytharoulis and G. Kallos 2006: Applications of Kalman filters based on non-linear functions to numerical weather predictions. Annales Geophysicae, 24, 2451-2460 Katsafados P., E. Mavromatidis, A. Papadopoulos and I. Pytharoulis, 2011: Numerical simulation of a deep Mediterranean storm and its sensitivity on sea surface temperature. Natural Hazards and Earth System Sciences, 11, 1233-1246. DOI: 10.5194/nhess-11-1233-2011 Liu J., M. Bray, D. Han (2012) Sensitivity of the Weather Research and Forecasting (WRF) model to downscaling ratios and storm types in rainfall simulation. Hydrological Processes, 26, 3012-3031. DOI: 10.1002/hyp.8247 Louka P., G. Galanis, N. Siebert, G. Kariniotakis, P. Katsafados, I. Pytharoulis and G. Kallos 2008: Improvements in wind speed forecasts for wind power prediction purposes using Kalman filtering. Journal of Wind Engineering and Industrial Aerodynamics, 96, 2348-2362. DOI: 10.1016/j.jweia.2008.03.13 Papadopoulos A., G. Korres, P. Katsafados, D. Ballas, L. Perivoliotis, K. Nittis (2011) Dynamic downscaling of the ERA-40 data using a mesoscale meteorological model. Mediterranean Marine Science, 12/1, 183-198. Stathopoulos C., A. Kaperoni, G. Galanis, G. Kallos (2013). Wind power prediction based on numerical and statistical models. J. Wind Eng. Ind. Aerodyn., 112, 25-38. Zoras S., V. Evagelopoulos, I. Pytharoulis and G. Kallos, 2010: Development and validation of a novel-based combination operational air quality forecasting system in Greece. Meteorology and Atmospheric Physics, 106, 127-133. DOI: 10.1007/s00703-010-0058-z

Comment: You modified the topography only in the domain D3 while you used initial and boundary conditions for this domain which is calculated without removing the orography. I suggest you include some appropriate references to sustain your choice. Reply: The methodology used for the removal of the topography has also been followed at various numerical studies in the international peer-reviewed literature: Miao et al. (2003) in order to examine the influence of topography on the sea breeze over eastern Spain, performed an experiment (using RAMS model) identical to the control run but with a homogeneous flat terrain in grid 2 only i.e. their inner fine grid (please see page 164, right column of their paper). Koletsis et al. (2009) performed a numerical study of a downslope windstorm in northwestern Greece using MM5 model. In page 181 they state that "in addition to the control run, two sensitivity simulations were performed with modified topography height of Grid 3 (i.e. their inner fine grid), while all the rest of the setup characteristics were identical to the control simulation". Koletsis et al. (2010) performed a numerical study using MM5 model in order to investigate the interaction of northern wind flow with the complex topography of Crete Island. In page 1117 they state that "in addition to the control run, a sensitivity simulation was performed with modified topography of Grid 3 (i.e. their inner fine grid), while all the rest of the setup characteristics were exactly the same to the control simulation". Chiao et al. (2004) employed MM5 model with three nested domains of 45-, 15-, and 5-km horizontal resolution, in order to study the orographic forcing of heavy precipitation. "To test the effect of upstream mountains, they performed a simulation without the Ligurian Apennines as well as without the mountains of Corsica and Sardinia (NAPN) on 15- and 5-km domains, while keeping everything else identical to the CTRL" (page 2186, right column). It is mentioned that Corsica and Sardinia were included in their 45- and 15-km domains (i.e. D01 and D02), but not in the 5-km domain (D03). Chen et al. (2010) in their numerical study (with WRF model) used 4 nested domains of 36km, 12km, 4km and 1.33km and followed a procedure similar to the one of Chiao et al. (2004) in their experiment without Taiwan's topography. "In order to examine the Taiwan orographic effects on the occurrence of the heavy rainfall over southwestern Taiwan, they performed a sensitivity test without Taiwan's topography (NT) on 12-, 4-, and 1.33-km grid spacing simulations, while keeping everything else identical to the control run." (page 241, right column). Chen et al. (2011, 2013) in their numerical study (with WRF model) followed a procedure similar to the one of Chiao et al. (2004) in their experiments without topography (please see page 600 of Chen et al. 2011 and pages 316-322 of Chen et al. 2013). In all these experiments the topography was not removed in the coarse grid.

These references (appearing below) have been added in the revised version of the

paper in order to justify the methodology we followed. Finally, the inner grid would be forced with fields that are calculated using the normal orography in all methodologies that appear in the literature, i.e. no matter if the topography was removed in the inner or in all grids. This happens in experiments with modified topography even if only one grid is utilized (i.e. even without any nested grids). For example Moscatello et al. (2008) investigated the effect of Atlas mountains on the development of a Mediterranean "Hurricane" using only one grid in the area of these mountains. In page 4381, they state that "To test the importance of the Atlas Mountains in producing a lee-side cyclone (phase 1), EXP-1 is performed with the same grid configuration and numerical set up employed in the control run, but without the Atlas Mountains. Initial and boundary conditions are those provided by ECMWF fields at all pressure levels (including those below mountains) interpolated onto the WRF model vertical levels, which have been modified after setting the height of the orography to zero over Africa.". In all the abovementioned studies (with one or multiple grids) the normal orography was present in the initial conditions of all grids.

Chen C.-S., Y.-L. Lin, W.-C. Peng, C.-L. Liu (2010) Investigation of a heavy rainfall event over southwestern Taiwan associated with a subsynoptic cyclone during the 2003 Mei-Yu season. Atmos. Research, 95, 235-254. Chen C.-S., Y.-L. Lin, N.-N. Hsu, C.-L. Liu, C.-Y. Chen (2011) Orographic effects on localized heavy rainfall events over southwestern Taiwan on 27 and 28 June 2008 during the post-Mei-Yu period. Atmos. Research, 101, 595-610. Chen C.-S., Y.-L. Lin, H.-T. Zeng, C.-Y. Chen, C.-L. Liu (2013) Orographic effects on heavy rainfall events over northeastern Taiwan during the northeasterly monsoon season. Atmos. Research, 122, 310-335. Chiao S., Y.-L. Lin, M.L. Kaplan (2004) Numerical study of the orographic forcing of heavy precipitation during MAP IOP-2B. Monthly Weather Review, 132, 2184-2203. Koletsis I., K. Lagouvardos, V. Kotroni, A. Bartzokas (2009) Numerical study of a downslope windstorm in Northwestern Greece. Atmos. Research, 94, 178-193. Koletsis I., K. Lagouvardos, V. Kotroni, A. Bartzokas (2010). The interaction of northern wind flow with the complex topography of Crete Island – Part 2: Numerical study. Nat. Hazards

Earth Syst. Sci., 10, 1115-1127. doi:10.5194/nhess-10-1115-2010 Miao J.-F., L.J.M. Kroon, J. Vila-Guerau de Arellano, A.A.M. Holtslag (2003) Impacts of topography and land degradation on the sea breeze over eastern Spain. Meteorol. Atmos. Phys., 84, 157-170. DOI 10.1007/s00703-002-0579-1 Moscatello A., M.M. Miglietta, R. Rotunno (2008) Numerical analysis of a Mediterranean "Hurricane" over Southeastern Italy. Monthly Weather Review, 136, 4373-4397

Comment: Minor Points: The use of English in this paper is not competent enough and the paper as a whole may not have a satisfactory effect on the target reader. Even though you make an attempt to use appropriate format, information and ideas are inadequately organized and there are basic errors which may not always hinder meaning but may make language sound unnatural. In view of the fact that you are not a native speaker of English, it would be recommended that you get professional help. Reply: We have performed a substantial revision in language and the paper is under review by a native English speaker. In additional, we have taken into account all recommended corrections that the reviewer suggested.

Finally we would like to thanks the Reviewer for his/her time and his/her valuable comments that improved the quality of our paper and illustrated more clearly our results.

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 2, 1433, 2014.