Conference Proceedings Paper

Sensitivity Analysis of Climate Change Projection to the Grid Size Resolution over Mediterranean

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Abstract: In this study the Weather Research and Forecasting (WRF) model is used to dynamically downscale NASA Goddard Institute for Space Studies (GISS) GCM ModelE simulations over the Mediterranean in order to assess the grid size selection effect on the estimated climate change in this region. Results are presented for Athens (Greece) and Rome (Italy), the biggest cities at the south-southeast Europe, which are located close to the sea. A multinesting approach is used with grid resolutions of 108 km, 36 km, 12 km, 4 km and 1.3 km. The NASA GISS GCM ModelE is used to simulate current and future climate using the RCP4.5 emissions scenario while WRF simulations are performed for October of 2010 and 2050. The sensitivity analysis assesses the estimated changes in temperature, precipitation and wind speed for the related cell in each grid that corresponds to the cities of Athens and Rome. The results show that increasing grid resolution significantly improves the spatial distribution of the examined parameters but does not add much value on the average projected change of the variable.

Keywords: climate change; sensitivity; grid size resolution; GISS; WRF; Mediterranean

1. Introduction

Global Climate Models (GCMs) are the primary tools used today in climate research. There are several modelling groups around the world using different GCMs in order to estimate the future changes in the climatic parameters over the globe. However, the ability of GCMs to simulate climate change at local and regional scales is limited by their coarse spatial resolution. To overcome this issue, regional climate models (RCMs) have been widely used for downscaling the GCM results. RCMs are forced by lateral boundary and initial conditions generated by a GCM to reproduce regional climatology and its variations in high resolution.

Iizumi et al. [1] assessed the climate downscaling as a source of uncertainty in projecting local climate change impacts and recommended the use of multi-downscaling models ensemble, for impact assessment and following adaptation strategy development. Leduc et al. [2] assesed the sensitivity to domain size with a regional climate model. They suggested, from the general point of view of performing seasonal climate simulations with a RCM, the domain size should be carefully chosen depending on the purpose of the study, the region of interest and the season.

Chan et al. [3] investigated if increasing the spatial resolution of a regional climate model improves the simulated daily precipitation.They concluded that there are improvements when model resolution is increased from 50 km to 12 km, while there is no further improvement when resolution icreased to 1.5 Km.

Lee and Hong [4] estimated the potential for adding value in the dynamical downscaling by increasing the spatial resolution of a RCM (50 km and 12.5 km). They found that the increased resolution of the RCM contributes to the improvement of simulated surface variables including precipitation and temperature. The increased resolution also contributes to capture the extreme weather conditions, such as heavy rainfall events and sweltering days. Moreover, the enhanced added value is more evident for the precipitation than for the temperature.

However, there are no studies, to the best or our knowledge, assesing the sensitivity of a climate change projection to the grid size resolution. The objective of this study is to assess the sensitivity of climate change projection to the grid size resolution over the Mediterranean since the complex topography and the vast coastlines of Mediterranean suggest a fine scale spatial variability of the climatic conditions. We focus on the cities of Athens (Greece) and Rome (Italy), the biggest cities at the south-southeast Europe, which are located close to the sea.

2. Method

The NASA Goddard Institute for Space Studies (GISS) GCM ModelE [5] is used to simulate current and future climate at a horizontal resolution of 2° × 2.5° latitude by longitude and 20 vertical layers (from surface to 0.1 hPa). Sea surface temperatures (SST) are calculated using model-derived surface energy fluxes and specified ocean heat transports. The GCM simulations cover the period from 1880 to 2050. Greenhouse gas concentrations up to 2008 are prescribed using ice-core measurements, while for the period 2009–2050 the GHG levels are supplied from the RCP4.5 emissions scenario. The Weather Research and Forecasting (WRF) model [6] is used to dynamically downscale NASA GISS GCM ModelE outputs in a multi nesting approach over the Mediterranean in order to assess the grid size selection effect on the estimated climate change in this region. WRF simulations are performed for October of 2010 and 2050, using six-hourly instantaneous outputs of physical parameters from the GCM. The dynamical downscaling approach that is used has the WRF model run in multinesting mode with grid resolutions of 108 Km, 36 Km, 12 Km, 4 Km and 1.3 Km as shown in Figure 1.

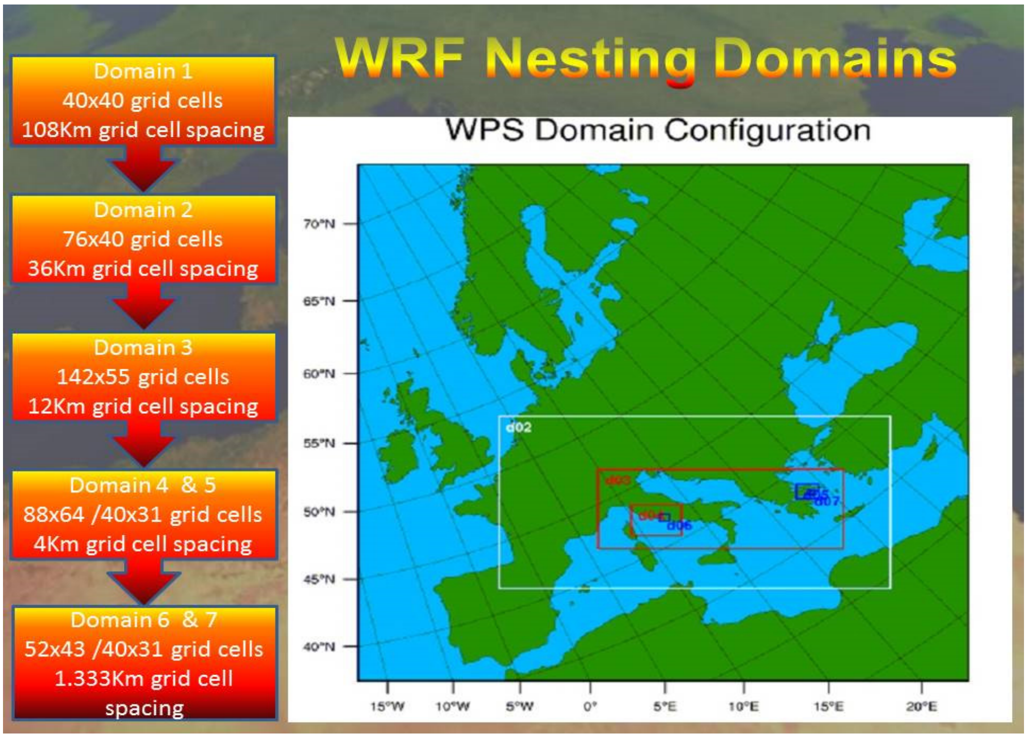


Figure 1. WRF multinesting domain configuration approach.

Spatial plots representing the distribution of the average change for all variables are created and the cities while the grid cell of each domain containing Athens and Rome is specified and the average values of each variable are extracted from it. The average change for all variables is then calculated. Comparison of the projected change values, concerning the two cities, at each resolution is then used for the assessement of the sensitivity of grid size resolution to climate change.

3. Results

3.1. Spatial Distribution

The spatial analysis, here, presents the spatial distribution of the changes as projected by the WRF model for temperature, precipitation and wind speed.

3.1.1. Temperature

The spatial distribution of the average temperature change in the grid resolution 36 Km × 36 Km is presented in the following Figure 2.

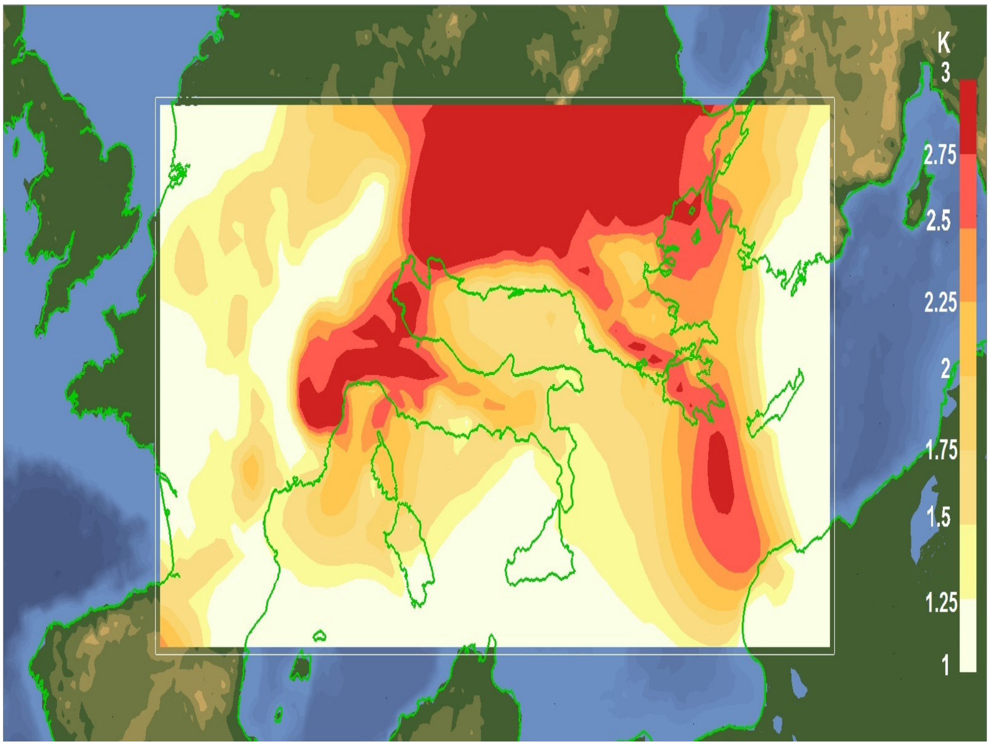


Figure 2. Spatial distribution of the average temperature change at 36 Km grid cell size.

In order to compare the spatial distributions of the average change, Figures 3 and 4 present the results for the different spatial resolutions for Athens and Rome.

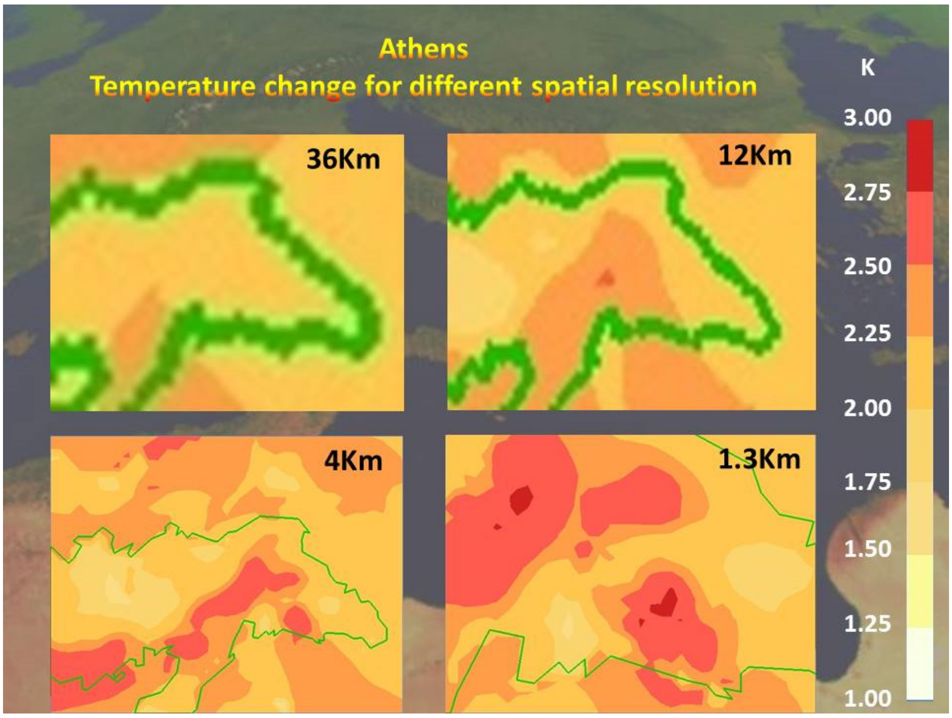


Figure 3. Spatial distribution of the average temperature change at 36 Km/12 Km/4 Km/1.3 Km grid cell size for Athens.

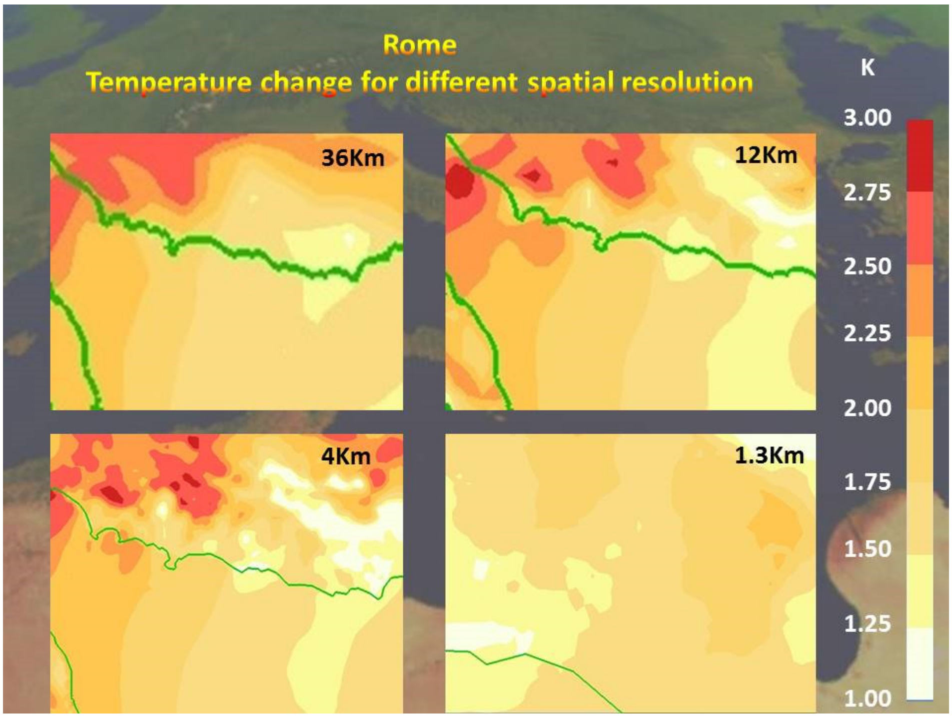


Figure 4. Spatial distribution of the average temperature change at 36 Km/12 Km/4 Km/1.3 Km grid cell size for Rome.

3.1.2. Precipitation

The spatial distribution of the average percentage change in the grid resolution 36 Km × 36 Km is presented in the following Figure 5.

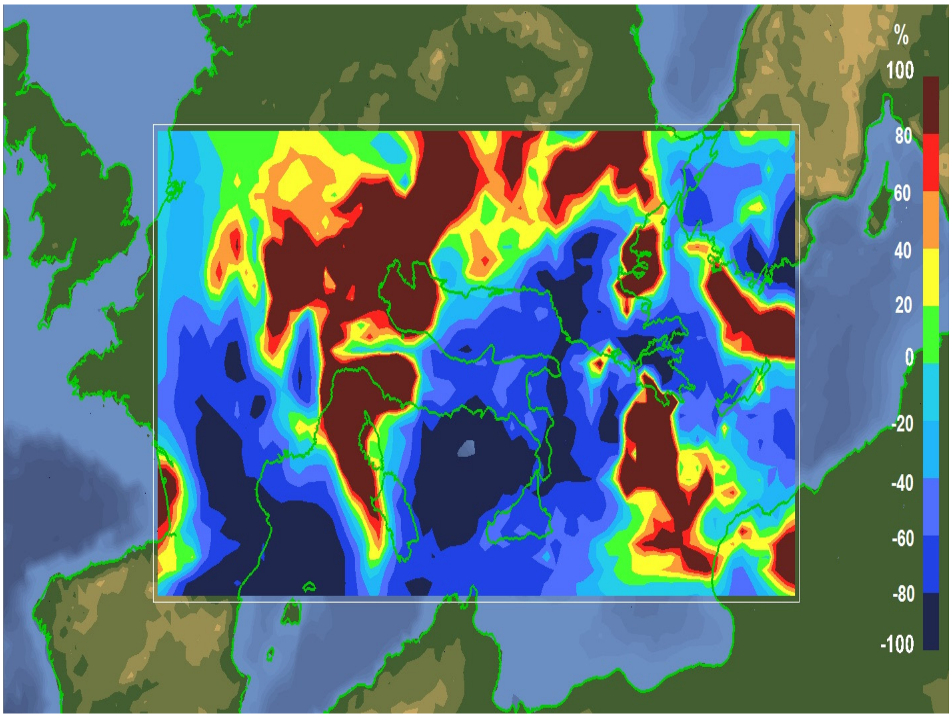


Figure 5. Spatial distribution of the average percentage precipitation change at 36 Km grid cell size.

In order to compare the spatial distributions of the average percentage change in precipitation, Figures 6 and 7 present the results for the different spatial resolutions for Athens and Rome.

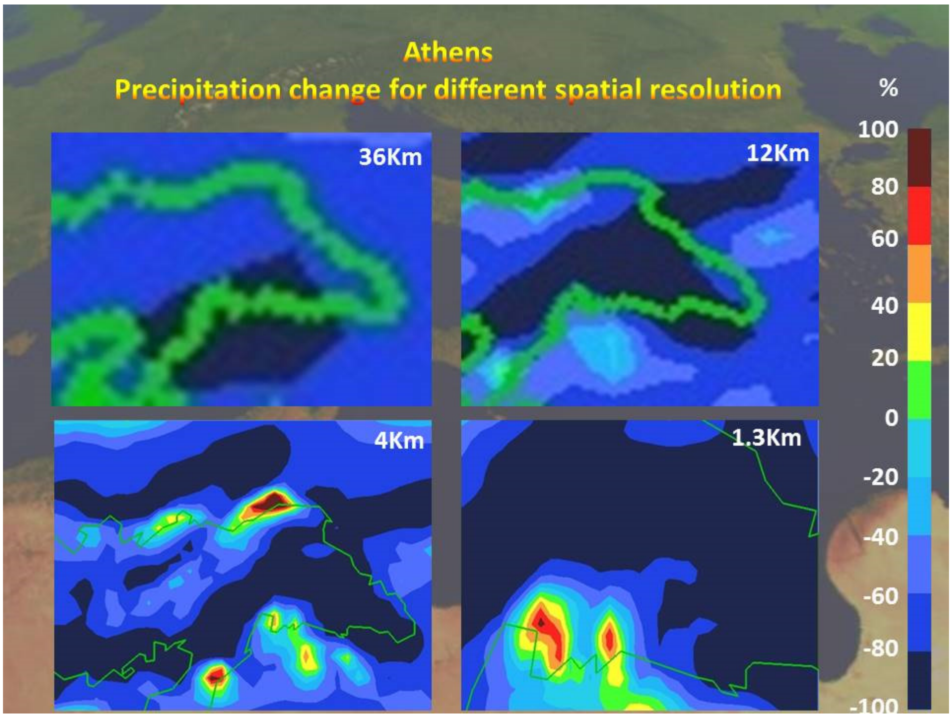


Figure 6. Spatial distribution of the average percentage precipitation change at 36 Km/12 Km/4 Km/1.3 Km grid cell size for Athens.

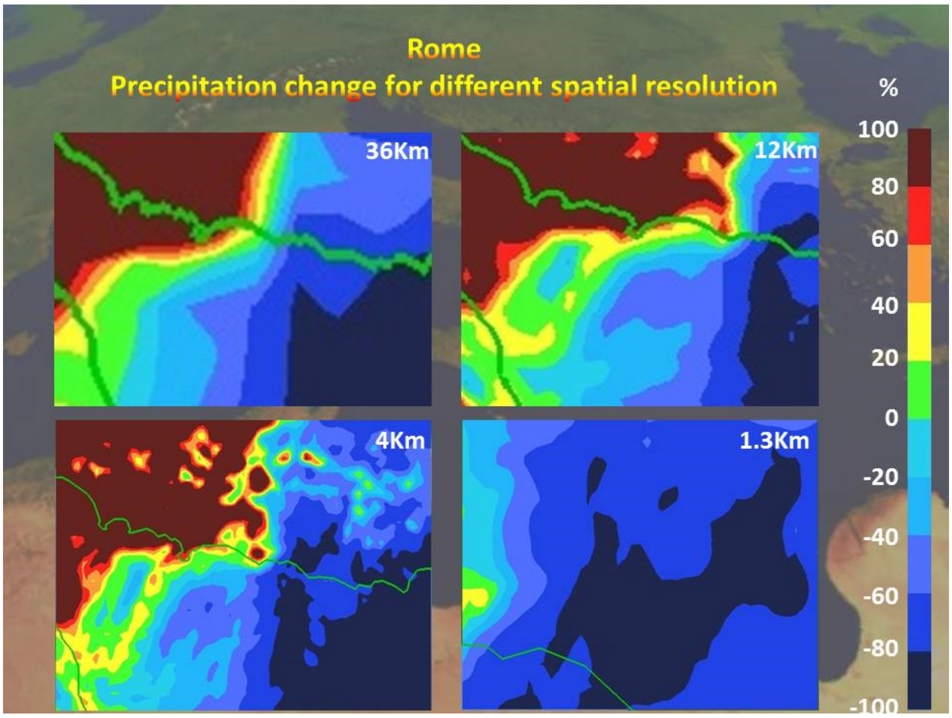


Figure 7. Spatial distribution of the average percentage precipitation change at 36 Km/12 Km/4 Km/1.3 Km grid cell size for Rome.

3.1.3. Wind Speed

The spatial distribution of the average change of wind speed in the grid resolution 36 Km × 36 Km is presented in the following Figure 8.

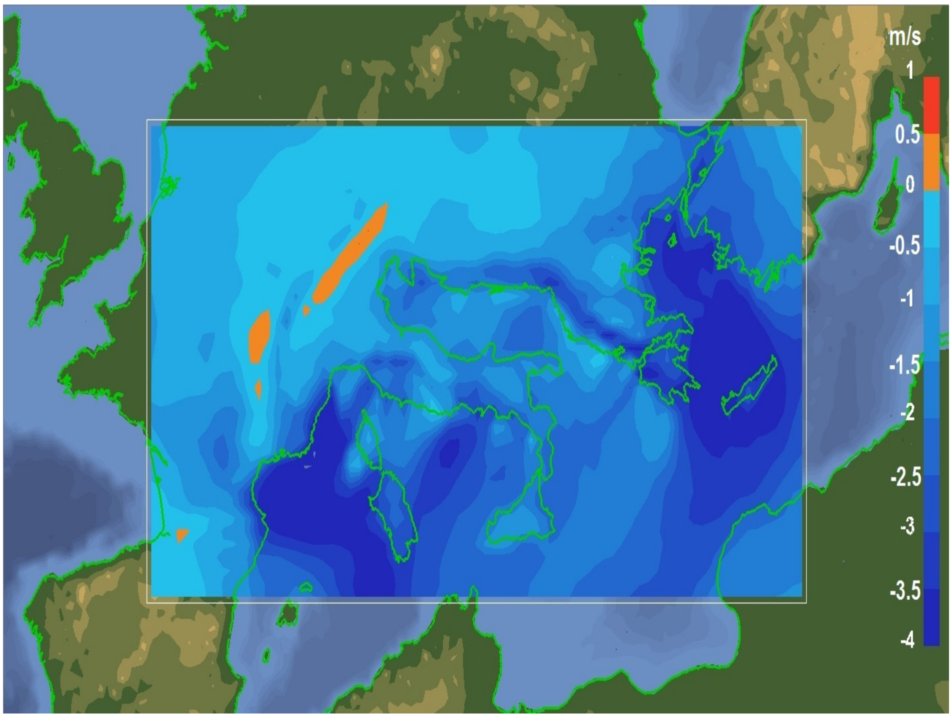


Figure 8. Spatial distribution of the average wind speed change at 36 Km grid cell size.

In order to compare the spatial distributions of the average change in wind speeed, Figures 9 and 10 present the results for the different spatial resolutions for Athens and Rome.

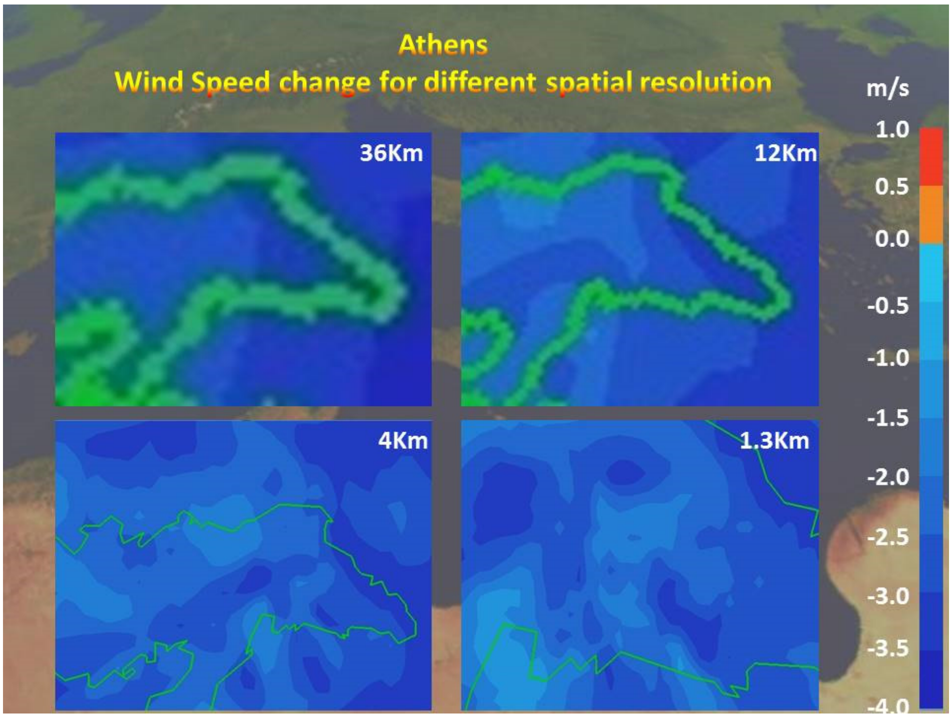


Figure 9. Spatial distribution of the average wind speed change at 36 Km/12 Km/4 Km/1.3 Km grid cell size for Athens.

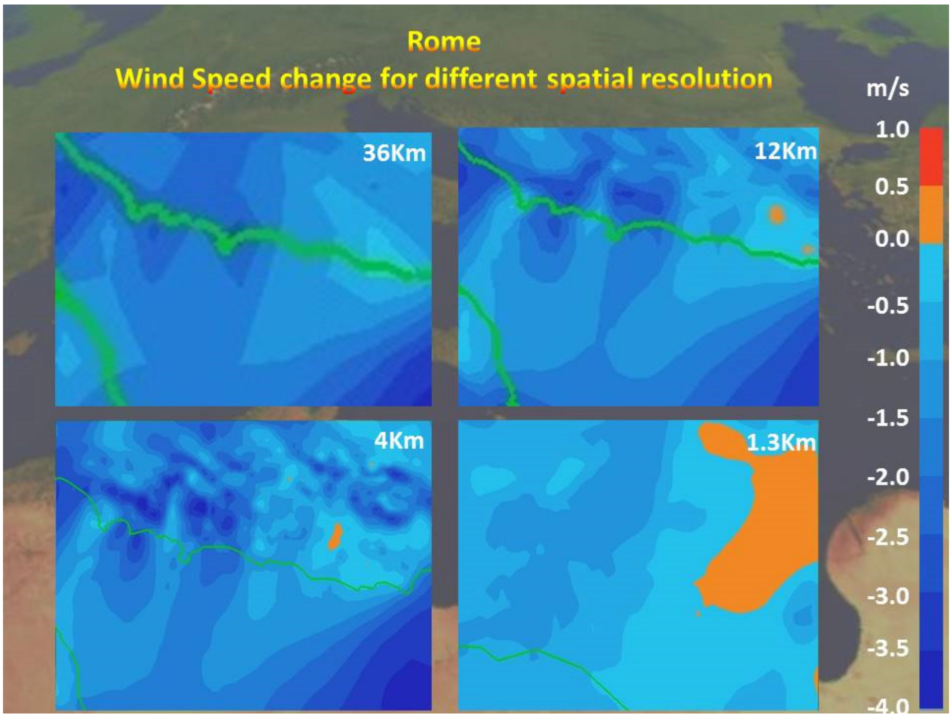


Figure 10. Spatial distribution of the average wind speed change at 36 Km/12 Km/4 Km/1.3 Km grid cell size for Rome.

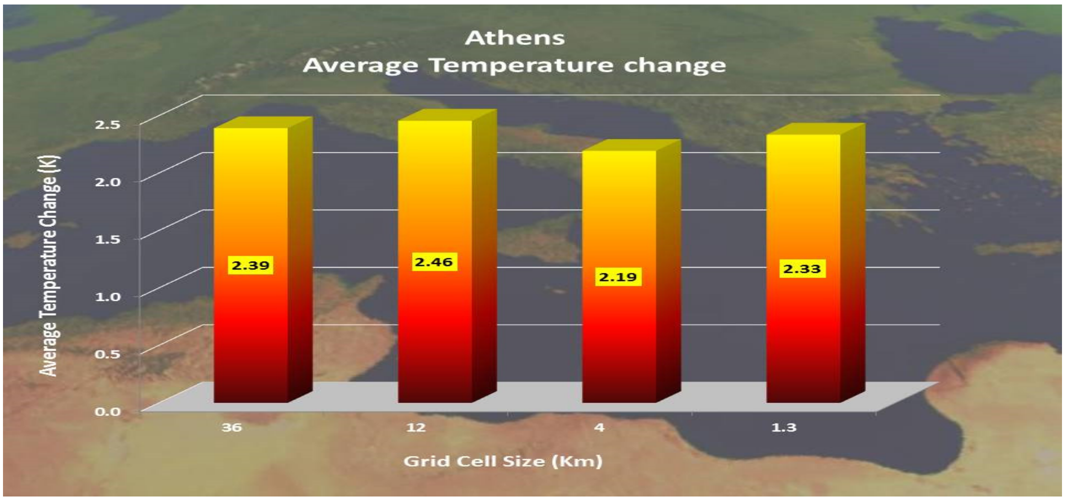
3.2. Average Change at Corresponding Grid Cell

3.2.1. Athens

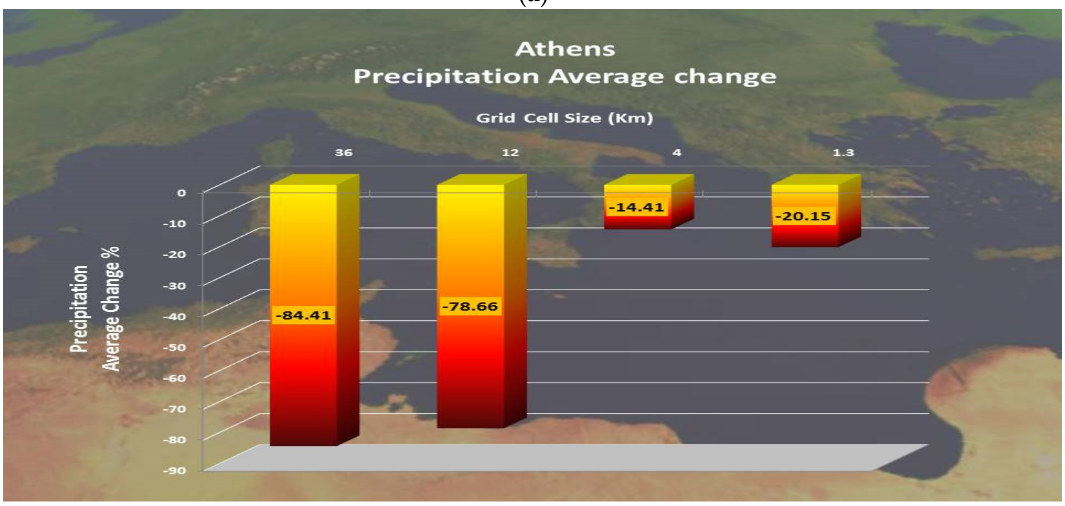
The average change of temperature, precipitation and wind speed for the city of Athens are presented in Table 1 and Figure 11. These values are refered to the grid cell that contains the city of Athens in each domain.

Table 1. Average change for temperature, precipitation and wind spead at the cell containing Athens for each grid.

Domain Grid Cell Size	Temperature Average Change	Precipitation Average Precentage Change	Wind Speed Average Change
36 Km	2.3912 K	−84.41%	−2.4293 m/s
12 Km	2.4561 K	−78.66%	−2.3861 m/s
4 Km	2.1938 K	−14.41%	−1.9891 m/s
1.3 Km	2.3346 K	−20.15%	−1.8403 m/s

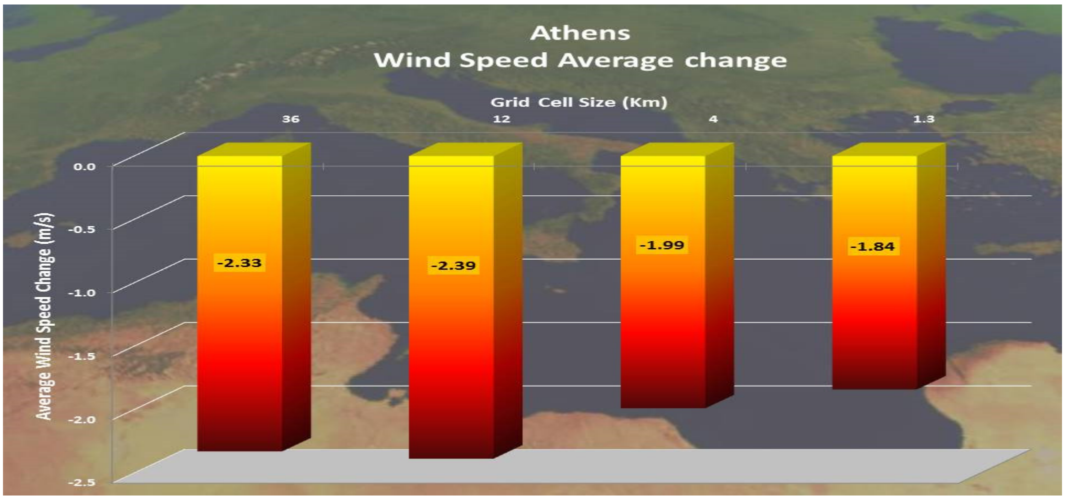


(**a**)



(**b**)

Figure 11. *Cont.*



(c)

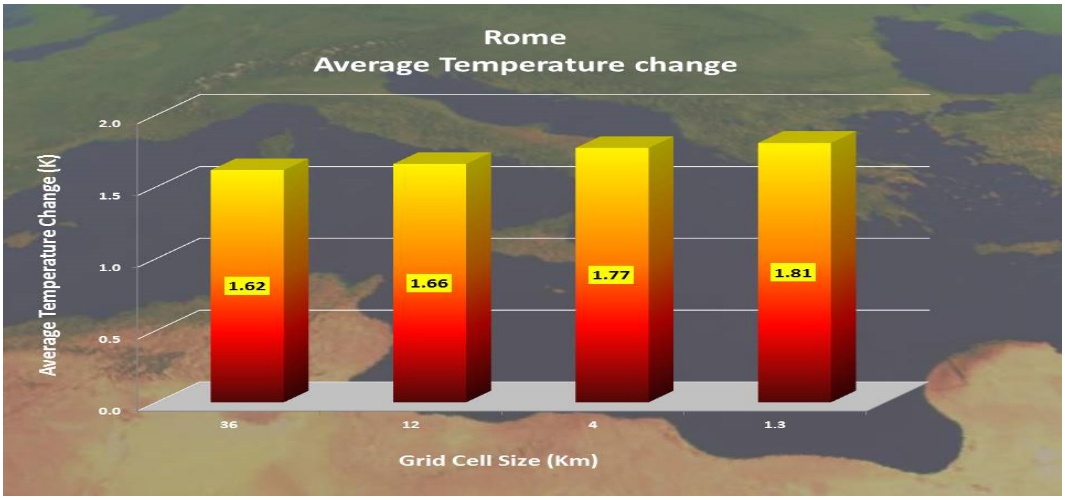
Figure 11. Average change for Athens (**a**) Temperature; (**b**) Precipitation %; (**c**) Wind Speed.

3.2.2. Rome

The average change of temperature, precipitation and wind speed for the city of Rome are presented in Table 2 and Figure 12. These values are refered to the grid cell that contains the city of Rome in each domain.

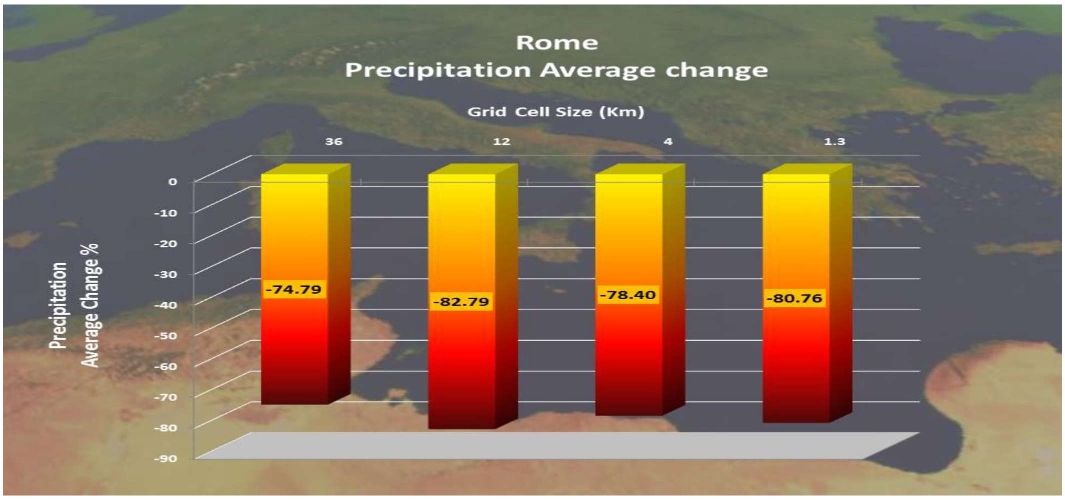
Table 2. Average change for temperature, precipitation and wind speadat the cell containing Rome for each grid.

Domain Grid Cell Size	Temperature Average Change	Precipitation Average Precentage Change	Wind Speed Average Change
36 Km	1.6166 K	−74.79%	−0.0237 m/s
12 Km	1.6595 K	−82.79%	−0.1971 m/s
4 Km	1.7710 K	−78.40%	−0.0345 m/s
1.3 Km	1.8061 K	−80.76%	−0.0952 m/s

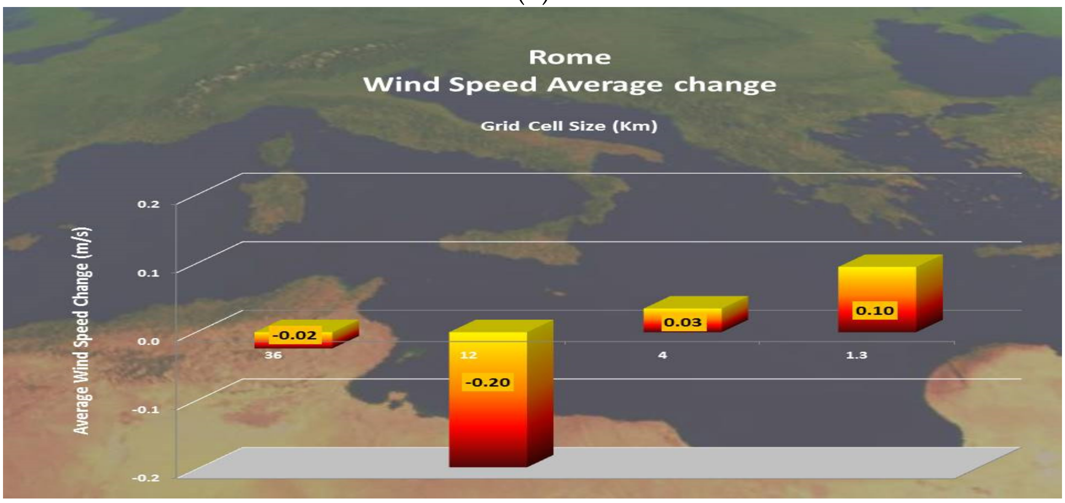


(a)

Figure 12. *Cont.*



(**b**)



(**c**)

Figure 12. Average change for Rome (**a**) Temperature; (**b**) Precipitation %; (**c**) Wind Speed.

4. Discussuon and Conclusions

The results from our simulations showed that increasing grid resolution greatly modifies the spatial distribution results increasing their detail. On the other hand, this increase in grid resolution does not significantly improve climate change results. The added value to the average change cannot be considered significant if we take into account the cost in prossessing power needed.

The significant difference between the average precipitation change concerning the grids of 4 Km and 1.3 Km over Athens, are probably caused by the complex terrain of the area.

The preliminary results presented here should be further investigated and longer term simulations are needed.

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Conflicts of Interest: The authors declare no conflict of interest.The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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