Enabling Climate Information Services for Europe

Report

DELIVERABLE 5.4
Report on the impact of climatic change on water availability over the Sicily Region

Activity:	*WP5 – Water*
Activity number:	*Task 5.3 Water availability in Sicily, Italy*
Deliverable:	*Report on the impact of climate changes on water availability over the Sicily region*
Deliverable number:	*5.4*
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Summary

Sicily is located in the southernmost part of Italy and is the largest Italian region (about 26,000km^2). It is characterized by a heterogeneous terrain. Equally heterogeneous is the availability of water resources.

Our user (SIAS) therefore believes that the knowledge of the average rainfall climatology over the region at the adequate spatial resolution (due to the strong spatial gradients of precipitation characterizing the region) is extremely important. The user is also interested to have an indication on the possible evolution of precipitation for the next decades to support future planning concerning water resources.

1. Introduction

The strong spatial gradients of precipitation characterizing Sicily makes it necessary to study the rainfall climatology of this region at an adequate spatial resolution. Beside the knowledge of the present-day precipitation climatology, it is also very important to have an indication on the possible evolution of precipitation for the next decades. This allows supporting future planning concerning water resources.

Therefore SIAS (Servizio Informativo Agrometeorologico Siciliano) has a strong needing of climate services concerning Sicily high-resolution precipitation climatologies and required these product to the ECLISE community.

2. Description of the procedure

2.1 High-resolution precipitation reconstruction for past decades

We have recently developed a methodology to construct high-resolution precipitation grids (30-arc-second-resolution) over complex terrain (Brunetti et al., 2009; 2012) based on the anomaly method (New et al., 2000; Mitchell and Jones, 2005).

This method assumes that the spatio-temporal structure of the signal of a meteorological variable over a given area can be described by the superimposition of two fields: the climatological normals over a given reference period (i.e. the climatologies) and the departures from them (i.e. the anomalies). The former are basically linked to the geographical features of the territory and they can manifest remarkable spatial gradients. On the contrary, the latter are linked to climate variability and change and they are generally characterized by higher spatial coherence. On this assumption the two fields can be reconstructed in a completely independent way from each other and they can be based on different data sets. Such data sets have obviously to be constructed by the selection of the records fulfilling completely different criteria: for the anomalies the priority lies in data quality and in the availability of long records (in our case we aim at covering at least the last 50-60 years); for the climatologies the most relevant aspect is the availability of a large number of stations, whereas the records length is less relevant (it is sufficient to consider a 30-years period).

The second assumption of our research is that precipitation climatologies are linked to the physiographical features of the Earth's surface. Mountain ranges play an important role in modifying the atmospheric circulation on a wide range of spatial scales. As a consequence of this, the spatial distribution of the climatological average of precipitation amounts is strongly linked to topography, with the windward flanks of the mountain ranges receiving much more precipitation than the leeward ones, in the midlatitude. Anyway, the characteristics of the relationship between precipitation and elevation can vary appreciably depending on the steepness of the terrain and the slope orientation, among other factors. So, it is difficult to obtain a unique relationship between elevation and precipitation; but it is more rigorous to evaluate this relationship separately for each grid-cell of the domain, giving more importance to those nearby stations that have topographic characteristics similar to those of the grid-cell itself.

To do this we chose to evaluate the precipitation climate normals at the grid-cell location by estimating a "local" precipitation/elevation relationship by means of a weighted linear fit among the nearby stations, and attributing to the grid-cell the precipitation amount corresponding to its elevation on the base of the estimated relationship.

Such an assumption allows to join the predictive advantages of purely statistical techniques to the physical understanding of the processes determining the spatial distribution of the meteorological variables, which is typical of a geographical approach. This approach integrates the information contained in meteorological records with the one arising from digital elevation models (DEMs); it allows to recognize the link between the meteorological and the physiographical variables: this permits the construction of climatologies for a number of points of several orders of magnitude larger than the number of the available records.

The time-component (i.e. the interpolation of the anomalies onto the same grid-nodes of the climatology), because of the higher spatial coherence of the anomalies, is reconstructed with a more simple approach, based on an inverse distance weighting interpolation method with the addition of an angular weight to take into account the anisotropies in stations' spatial distribution.

This methodology has been applied to a set of 424 Sicily stations with monthly precipitation data and 129 additional stations located in southern and western Calabria. It allowed to obtain high-resolution fields both for precipitation climatologies and for the corresponding time-dependent anomalies (a subset of 225 quality checked and homogenised anomaly records was used). The superimposition of the two fields allowed to get high-resolution monthly virtual records for any point of Sicily. These records were obtained to calculate the 10-year average fields which are provided in deliverable 5.3.

2.2 <u>High-resolution future projections of precipitation</u>

Thanks to the robust high-resolution past reconstruction of precipitation for Sicily, it was possible to evaluate ENSEMBLES Regional Climate Models (RCMs) ability in reproducing precipitation in this very complicated area of the Mediterranean basin. In fact, due to the low spatial resolution of RCMs (25x25 km^2) the topography is poorly represented and its important effect on Sicilian precipitation not completely captured. As a consequence, even if the spatial coherence and the variability of precipitation at monthly scale is well reproduced, its absolute values are significantly biased and a bias-correction is necessary to make the model outputs more representative of real precipitation. Moreover, the RCMs' outputs must be downscaled onto the 1-km^2 resolution grid we realized for the past.

Four RCMs were taken into account: KNMI-ECHAM5, SMHI-ECHAM5, SMHI-BCM and SMHI-Had. We considered the historical run of the models forced by GCM and their future projections under the A1B scenario.

To compare RCMs outputs with observations, we upscaled the high-resolution 1961-1990 precipitation climatologies (produced in deliverable 5.3) to the RCM grid of 25x25 km^2. To do this, we averaged the precipitation of the 1-km^2 grid-cells falling into each RCM box (only land boxes with at least 400 1km^2 cells were considered) and compared these values with those of the RCMs averaged over the same 1961-1990 period. The historical runs forced by the GCM were considered to take into account the bias due both by RCM and GCM, because that is the bias we must correct for the future.

The RCMs present important biases when compared with observed data. Biases are a combination of both GCM and RCM difficulties in capturing the correct patterns (caused both by circulation and orographic effects) over Sicily, probably due to the rough topography of both GCMs and RCMs which under-represents the complexity of this island, with mountains exceeding 3000m asl (the Etna mountain) very close to the sea in the eastern and northern sectors of Sicily.

The best performing models (see figure 1 and 2) are KNMI and SMHI RCMs nested on the ECHAM5 GCM (the KNMI in particular). Biases are more spatially uniform in summer season than in winter season (figure 1), however their spatial patterns are more similar among the different RCMs in winter months, where almost all models present the same areas of under- and over-estimation of precipitation amount. On the contrary, in summer, there are models that underestimate precipitation (such as KNMI-ECHAM5) and other that significantly overestimate the amount (SMHI-BCM and SMHI-Had in particular).

Comparing KNMI-ECHAM5 with SMHI-ECHAM5 performances, and the three SMHI (nested on ECHAM5, BCM and Had) among themselves, it is evident that the source of the bias is a combination of both RCM and GCM errors. This evidence confirms that the historical run of each RCM forced by the GCM (instead of RCM forced by reanalysis) is the right calibration run to evaluate the bias correction to be applied to the future projection.

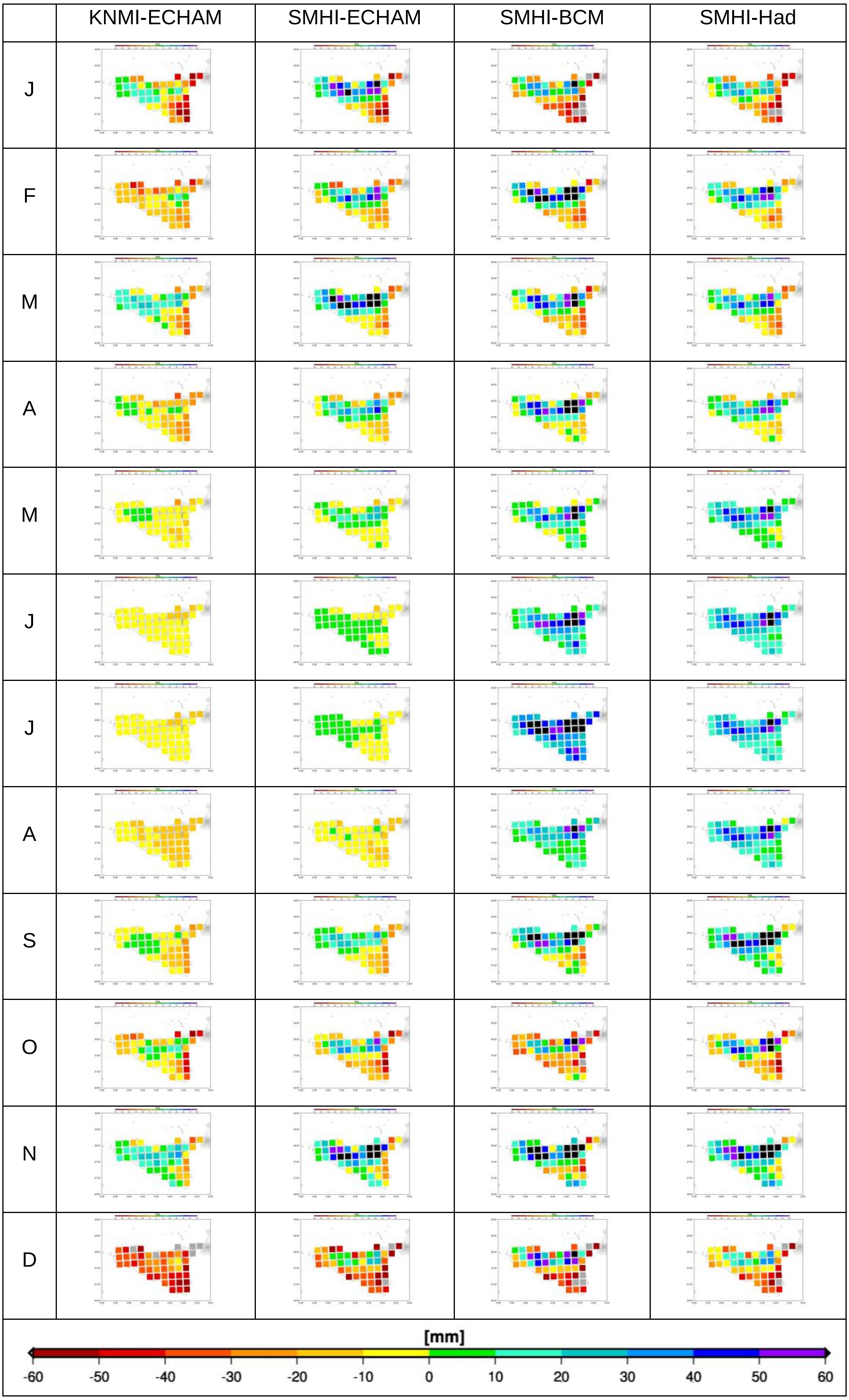

Figure 1. Difference between RCM 1961-1990 climatology estimated from the historical run (forced by GCM) and the observed 1961-1990 normal precipitation over Sicily.

To do this, each grid point monthly series of each model output (from the historical run to the future projection) has been converted into anomaly respect to its 1961-1990 mean annual cycle (multiplicative anomalies, obtained dividing by the 1961-1990 monthly normal). These series were then interpolated (as we already did with the historical homogenized stations' series) onto the same nodes of the 1km^2 resolution precipitation climatology produced in deliverable 5.3.

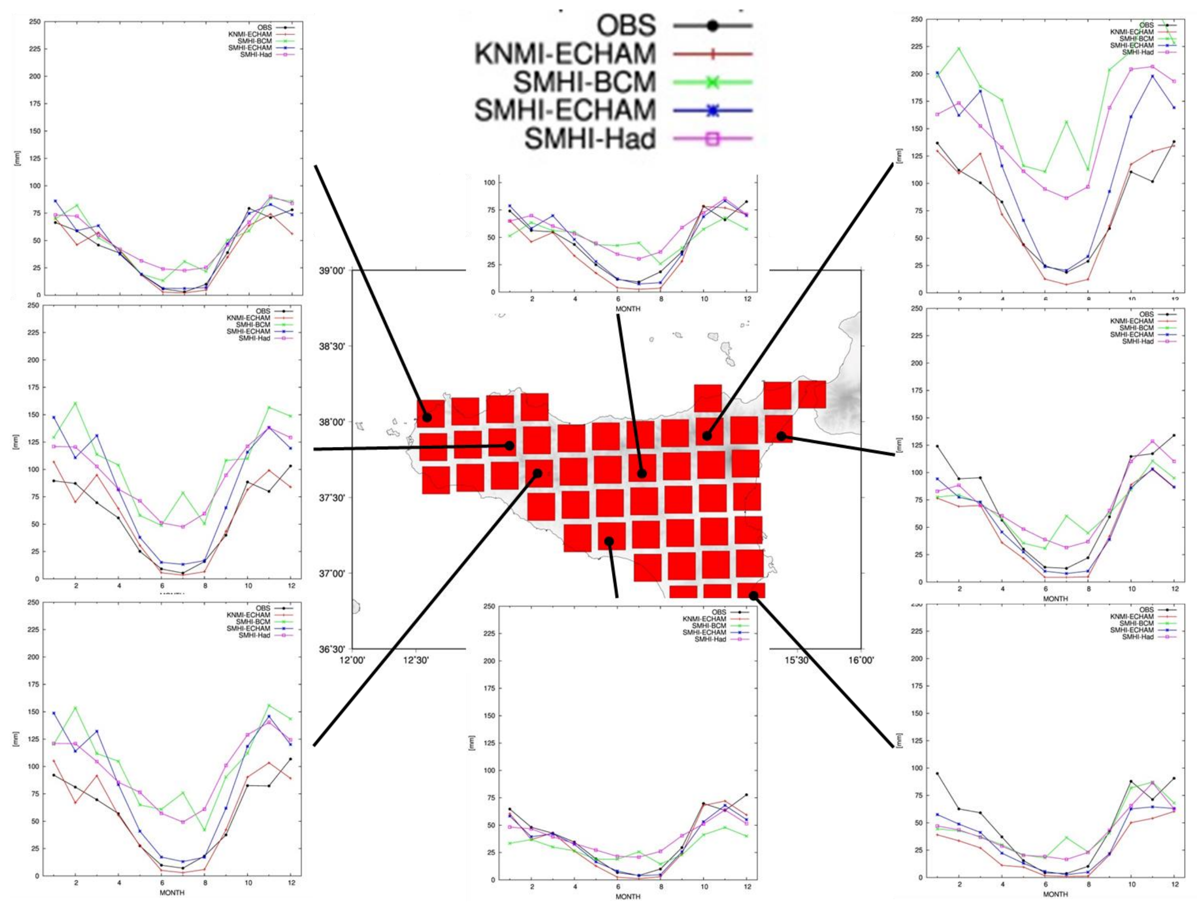

Figure 2. Comparison between RCM 1961-1990 mean annual cycle estimated from the historical run (forced by GCM) and the observed 1961-1990 mean annual cycle for precipitation over Sicily.

Finally, they were converted into absolute monthly precipitation by multiplying each series by the climate normal of the corresponding 1km^2 grid cell. In this way we obtained, for each model, a high resolution grid of bias-corrected monthly precipitation series for the 1951-2100 period.

Besides the single model outputs, we also produced a high resolution bias-corrected future projection by considering all the four models together to obtain an ensemble mean projection. In particular, the 1951-2100 monthly series of the four models converted into anomalies respect to the 1961-1990 period were considered together and interpolated onto the 1km^2 grid. Then, they were converted into absolute monthly precipitation by multiplying each series by the climate normal of the corresponding 1km^2 grid cell.

2. Conclusions

A methodology which allows to obtain virtual precipitation records for any cell of a high resolution grid covering the whole Sicily territory has been developed. The results allow both to describe the spatial distribution of precipitation over Sicily and to show the spatio-temporal behaviour of precipitation variability and change. These high resolution dataset has been used to validate the ENSEMBLES RCMs outputs over the past and to estimate the bias corrections to by applied to the future runs.

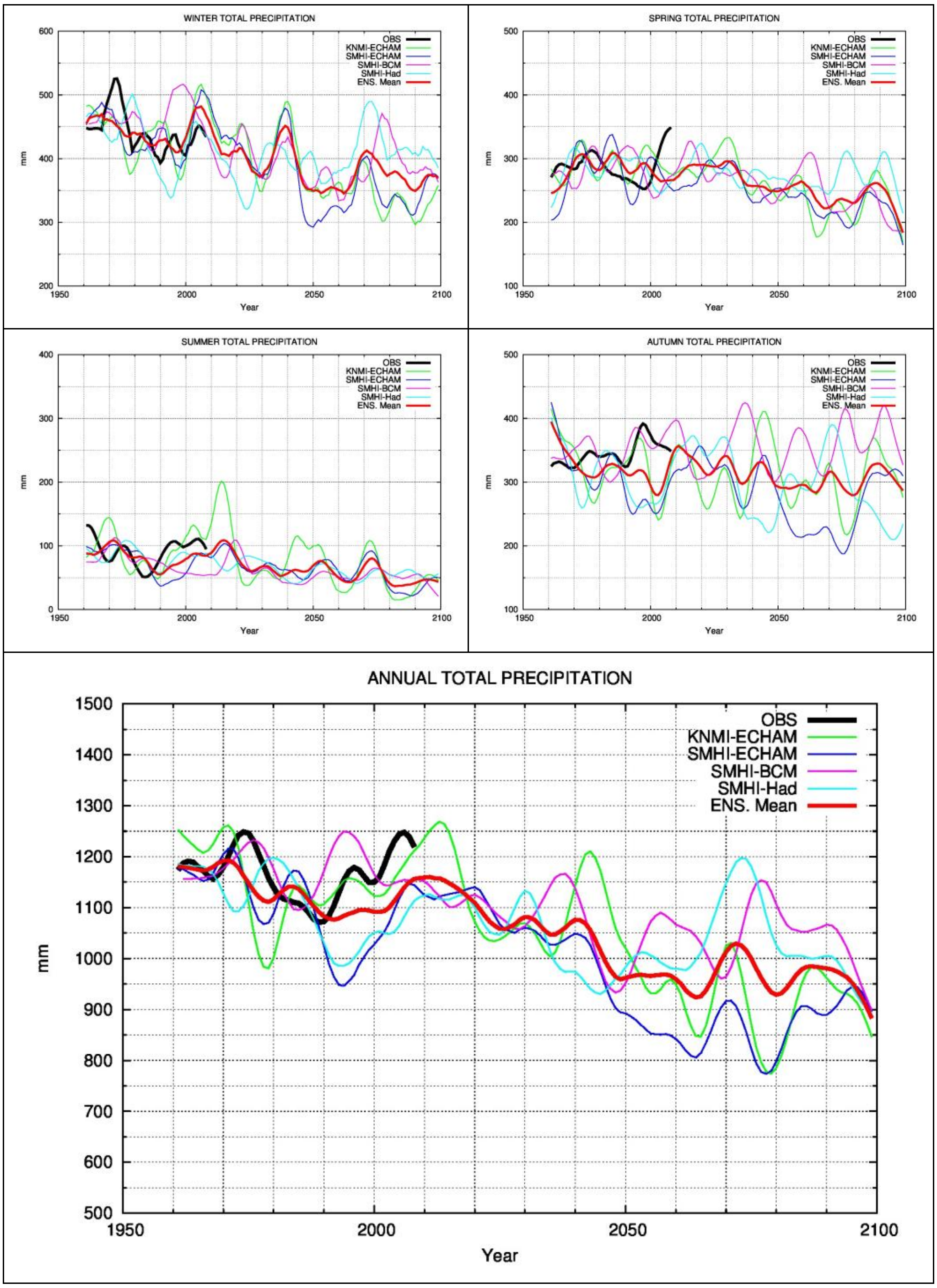

Figure 3. Temporal series of the seasonal and annual precipitation corresponding to the rainiest point of Sicily (14.7042,37.9458).

The final result consists of high resolution (1km^2) monthly precipitation data sets over Sicily for the 2001-2100 period for four RCMs and their ensemble mean.

In figure 3 the temporal series of the seasonal and annual precipitation corresponding to the rainiest point of Sicily (14.7042,37.9458) is shown as an example.

These data were provided to SIAS for the evaluation of future water availability for the Sicily region (see http://www.sias.regione.sicilia.it/ECLISE/).

In particular, in figure 4 the precipitation evolution in the future decades (2001-2050 and 2051-2100 means) are compared with the past observed precipitation (1951-2000) over the same 1-km^2 grid nodes.

It is evident a significant reduction of the total precipitation amount in future decades, mostly due to winter and spring seasons (see figure 5), and this will constitute a crucial information to be taken into account when planning future water management in the Sicily region.

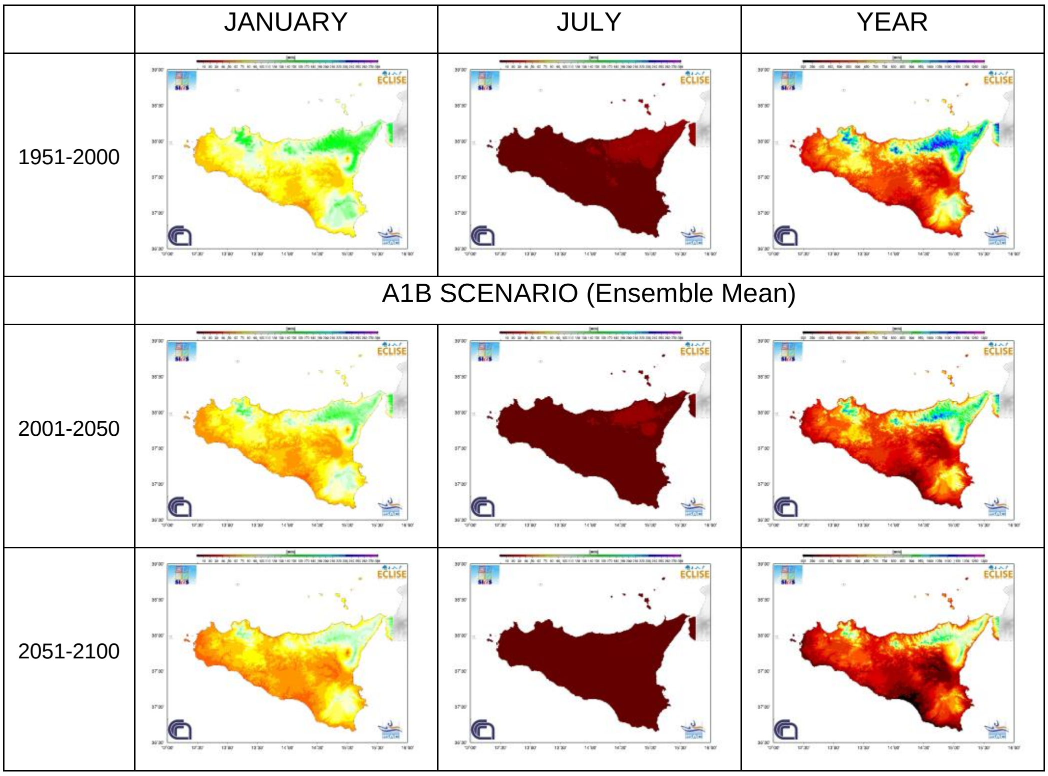

Figure 4. Comparison of future precipitation projections (in an A1B emission scenario) with past observed. The ensemble mean is obtained from four RCMs (KNMI-ECHAM5, SMHI-ECHAM5, SMHI-BCM, and SMHI-Had) downscaled onto a 1km^2 grid (more maps and results are available at www.isac.cnr.it/climstor/ECLISE-project.html).

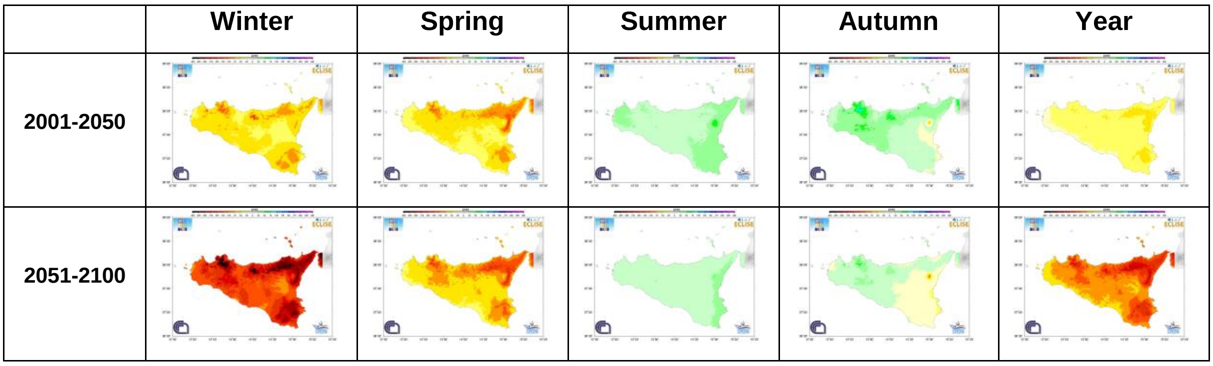

Figure 5. Seasonal and annual deviation from the 1951-2000 mean precipitation for the future sub-periods 2001-2050 and 2051-2100 for the ensemble mean.

These data will be used by SIAS as the base for the 2014-2020 PSR (Rural Development Plan) plan for Sicily (see http://www.psrsicilia.it/ for the 2007-2013 PSR).

References

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Mitchell, T.D., Jones, P.D., 2005. An improved method of constructing a database of monthly climate observations and associated high-resolution grids. Int. J. Climatol. 25, 693–712.

New, M., Hulme, M., Jones, P.D., 2000. Representing twentieth century space-time variability. Part 2: development of 1901–96 monthly grids of surface climate. J. Climate. 13, 2217–2238.

Links to concrete results:

http://www.eclise-project.eu/

http://www.sias.regione.sicilia.it/ECLISE/

http://www.isac.cnr.it/climstor/ECLISE-project.html

References to activity meetings:

The objectives of these maps have been presented at the ECLISE Kick-off meeting (De Bilt - 09 March 2011).

The methods and results have been presented at the First ECLISE meeting (Norrkhoping - 6-7 March 2012) and at the second ECLISE meeting (23-26 April 2013, Crete, GR).