Project of Strategic Interest NEXTDATA

Scientific Report
for the reference period: 01 - 01 - 2014 / 31 - 12 - 2014

WP 2.5 Archive of numerical simulations and projections

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CMCC

1. Scheduled activities, expected results and Milestones (as indicated in the Executive Plan)

For the third year of the Project (2014), the following activities were planned:

- to continue the production of global and regional numerical simulations targeted at the areas of interest for the Project, with particular reference to the Mediterranean, Alpine and HKKH regions;
- to complete the implementation and integration of high-resolution, limited area, non-hydrostatic numerical models and to perform simulations of the dynamics of climate and of the environment in mountainous areas with complex terrain;
- to carry out feasibility studies of long (secular) simulations of climate variability in the Mediterranean region: analysis of the capability of available regional models to reproduce the observed decadal scale signals in the Mediterranean basin;
- to continue the archiving of modelled climate data, with particular focussing on the Mediterranean, Alpine and HKKH regions;
- to contribute to the design of the Project Portal with special attention to the accessibility of the modelled climate data;
- to continue the work on stochastic downscaling with various activities, mainly aimed at the production of future scenarios of precipitation at high resolution in north-western Italy;
- to start generating high-resolution climate data, applying the downscaling techniques to observations and model outputs at low resolution (both spatial and temporal);
- to start a comparison of different downscaling techniques (dynamic, statistical and stochastic), in order to understand the characteristics and limits of applicability in different and specific case studies;
- to arrange a WP partner meeting to discuss and coordinate the production of climate scenarios and the access to numerical output data.

2. Deliverables expected for the reference period

D2.5.4: First version of the archives of global and regional climate simulations available on the data servers of the partner institutions.

3. Activities which have been actually conducted during the reference period

During the third year of the Project, all partners have contributed to the full achievement of the objectives of the WP and in particular to the completion of Project Deliverable D2.5.3. In addition, all partners have contributed to the production of new data sets and new high-resolution numerical simulations for the areas of interest of the Project, such as the Mediterranean area, the Alpine region and HKKH.
The following paragraphs summarize the partner contributions to the WP activities in 2014.

3.1 Research activities

Global and regional high-resolution numerical modelling
ISAC-CNR has continued numerical experiments aimed at tuning the new version v.3 of the EC-Earth model at standard resolution T255L91/ORCA1. Tuning efforts by ISAC-CNR have allowed to release in 2014 the new version EC-Earth v 3.1. Recent tuning activities have been focused on testing the sensitivity of EC-Earth radiative fields and Reichler and Kim (2008) performance indices to different parameters that affects convection, entrainment rates, precipitation, and other various water-cycle-related features. Several AMIP runs (6 years each) where performed. This effort identified a setting of the parameters which has produced better values of TOA net shortwave and longwave fluxes, longwave cloud forcing and net surface heat flux.

ISAC-CNR has performed a high-resolution climate simulation for the European CORDEX domain, using the non-hydrostatic Weather Research and Forecast (WRF) model v 3.4.1, at 11 km resolution. The model has been integrated with boundary conditions from the ISAC-CNR CMIP5 EC-Earth simulation. Two simulations have been performed: the historical period (1979-2005) and the projection period 2006-2050, using the RCP4.5 radiative forcing. This activity has been performed using computing resources provided by the LRZ Supercomputing Center. The WSM6 microphysical parameterizations of the Kain-Fritsch convective scheme were used. A preliminary study, aimed at determining the best choices in terms of parameterizations, particularly in terms of the ability of the simulations in reproducing precipitation over complex topography in the Greater Alpine Region, was completed in 2014. To this end, a series of simulations at 0.11° and 0.04° were performed in the EURO-CORDEX domain, forced by ERA-Interim boundary conditions, in the period 1979-2009. The simulation results have been compared with available high-resolution observational gridded precipitation data sets.

In the framework of the scientific questions raised within the NextData Project, ENEA has conducted extensive analysis to assess the capability of existing regional simulations in reproducing decadal signals. In particular, as a first step, the ENSEMBLES (Christensen and Christensen) regional runs driven by ERA40 reanalysis for the period 1961-2000 have been evaluated. The ENSEMBLES dataset will be considered as a reference for forthcoming analyses of new regional simulations performed within the CORDEX framework and made available on the NextData data portal.

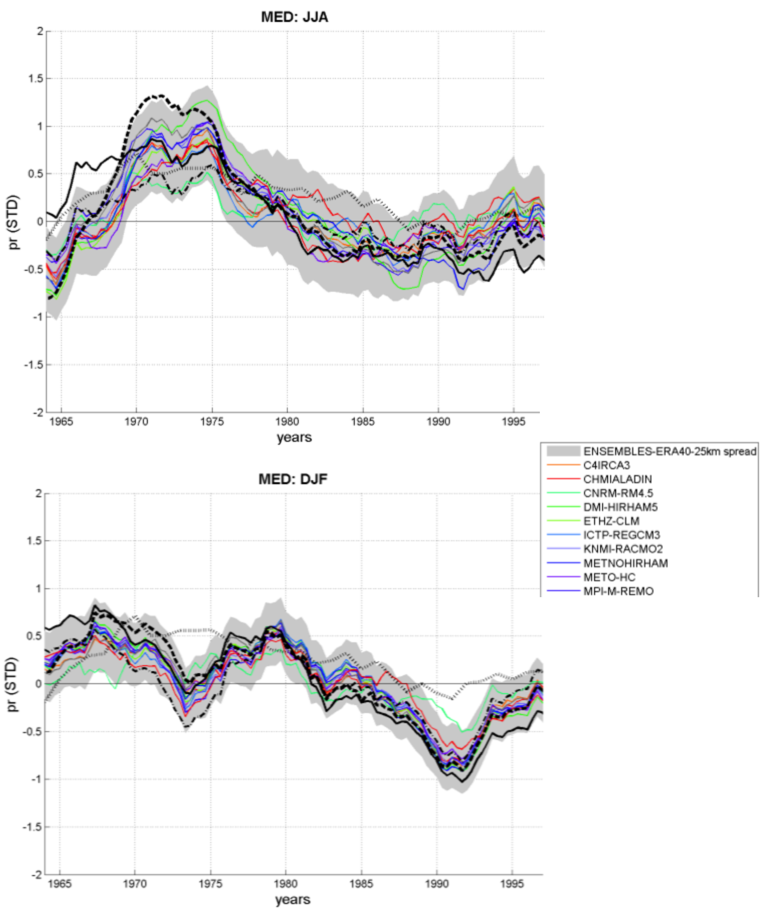

Fig. 1. Observed and ENSEMBLES simulated long term climate anomalies over a Mediterranean box (LON: 10W- 40E; LAT: 30N-48N) for the period 1961–2000. We show the precipitation anomalies (Pr, land-only; STD units) based on CRU, EOBS, ERA40 and ENSEMBLES-ERA 40 simulations (legend on the right) for JJA (top) and DJF (bottom). The SNAO index (normalized units) is also reported for reference. Mean anomalies relative to 1961–2000 with a 7-year running mean are shown.

The capability of ENSEMBLES ERA40 regional runs in reproducing anomalies of summer and winter precipitation over a Mediterranean box (only land points LON: 10W- 40E; LAT: 30N-48N) is shown in Figure 1, where the SNAO index (Mariotti and Dell'Aquila, 2011) is shown as a proxy of the large scale decadal signal. Some observational datasets (CRU, EOBS, ERA40 reanalysis) are also shown. The ENSEMBLES regional simulations appear to be generally able to reproduce the large-scale decadal variability signals. These preliminary results suggest to further deepen this study, taking into account the new regional runs performed in the CORDEX and MedCORDEX programs.

In the course of year 2014, CMCC has implemented the COSMO-CLM atmospheric model at 0.02° (~2.2 km) horizontal resolution in a domain comprising the Alpine region. To this aim, a series of sensitivity tests to different model parameters have been conducted in order to identify the best setting, which produces the most realistic 2 m temperature and precipitation in the Alpine area for the period March 1979 - February 1981. Specifically, twelve sensitivity runs have been performed by nesting the 0.02° COSMO-CLM version in a coarser simulation of the same model configuration at 0.072° (about 8km) integrated with ERA Interim Re-analyses boundary conditions. Each of the 12 runs corresponds to a different combination of physical and numerical parameters with a particular attention on parameters related to the microphysics of the precipitation processes. The performances of the 12 model configurations have been evaluated comparing the simulated Alpine temperature and precipitation with different observational datasets, such as EOBS, EURO4M, Veneto and Emilia Romagna data sets. Besides, areas characterized by different orographic features have been considered: a region at high altitude (>1000 m asl) and low altitude (<300 m asl), and the territory of Veneto and Emilia Romagna regions.
Figure 2 reports the orography, the domain of the simulations and the test case areas considered.

Figure 3 shows the 2-meter temperature bias for each simulation on the high altitude test case. From the results, the 0.02° simulations appear to perform generally better than the 0.0715° ones. In particular, the lowest bias is found for the 0.02° simulation where the height of boundary layer has been modified.

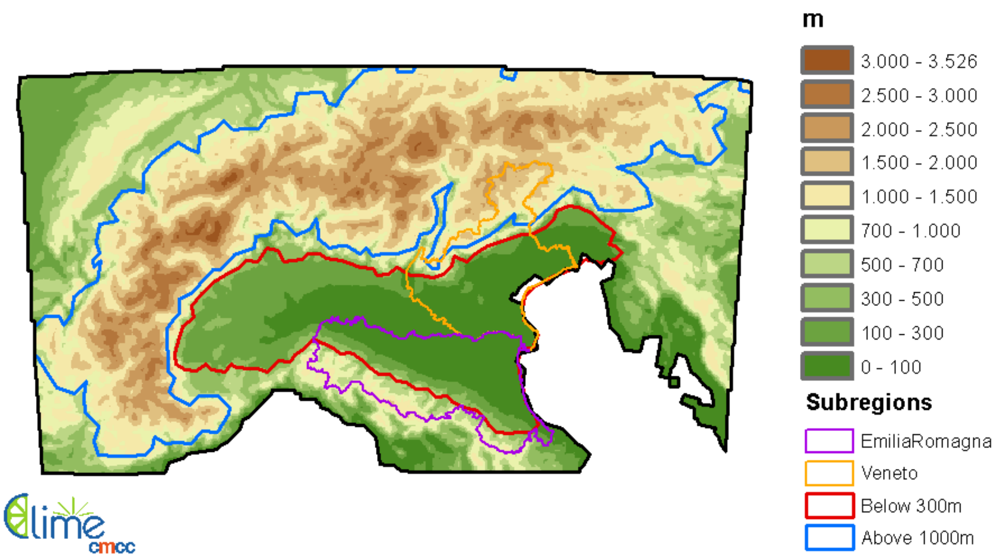

Fig. 2. Orography of the simulation domain at 0.02° of horizontal resolution and test case areas.

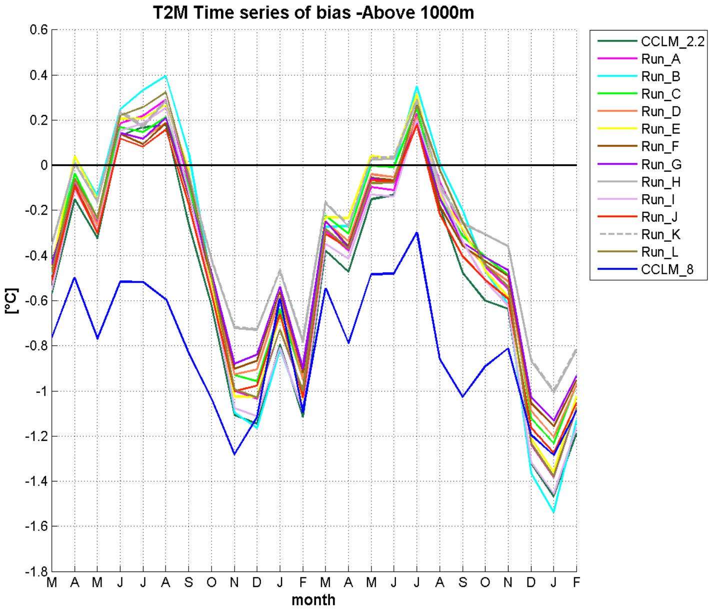

Fig. 3. Monthly mean 2-meter temperature bias with respect to the EOBS data for the high altitude test case area for each of the 12 sensitivity test performed.

As for the presence of bias in climate simulations, CMCC has conducted an extensive analysis of the most suitable techniques for the estimation and correction of systematic errors in order to improve the climate data produced by numerical models used in impact assessments. In particular, two studies have analyzed the strengths and weaknesses of three techniques of bias correction widely adopted in the literature: linear-scaling, quantile mapping and MOS analogs. In the first work, Zollo et al. (2014) adopt as a case the landslide of Orvieto and the bias correction techniques are thus applied on a punctual scale, while in the second study (Zollo et al., 2015) the bias correction methods are applied to the Po river basin.

The results obtained indicate that the techniques of Bias Correction are necessary tools for the application of the data produced by climate models to impact assessment studies. Moreover, in general, the best results are obtained, in both cases, with the technique of "quantile mapping". On this basis, a third research work has been conducted (Villani et al., submitted), where the performances of different types of the "quantile mapping" method (distribution derived transformations, parametric transformations, empirical quantiles) have been explored.

Furthermore, CMCC has performed an analysis aimed at assessing the statistical properties (annual cycle, decadal and interannual variability, geographical distribution, trends) of the Mediterranean Tropical-like Cyclones (MTLC or Medicanes) in the climatology of the past sixty years, and to estimate how such properties could respond to climate change. Cavicchia and von Storch (2013) showed that a numerical model implemented at high resolution (10 km) over the Mediterranean basin and driven by boundary conditions derived by a large scale reanalysis dataset is able to reproduce a number of observed Medicane cases previously studied in the literature. Exploiting such method, together with an objective detection algorithm specifically designed to single out their features and developed within NextData, it has been possible to study the statistical properties of Medicanes in a systematic way. Specifically, it was found that Medicanes are formed mostly during the cold season in the western Mediterranean and in the region extending between the Ionian Sea and the northern coast of Africa. The environmental factors related with the formation of Medicanes have been analyzed, finding that the triggering of Medicanes requires a sufficiently large difference between the sea surface temperature and the temperature in the upper atmospheric layers, a low wind shear, high moisture content, and high low-level vorticity.

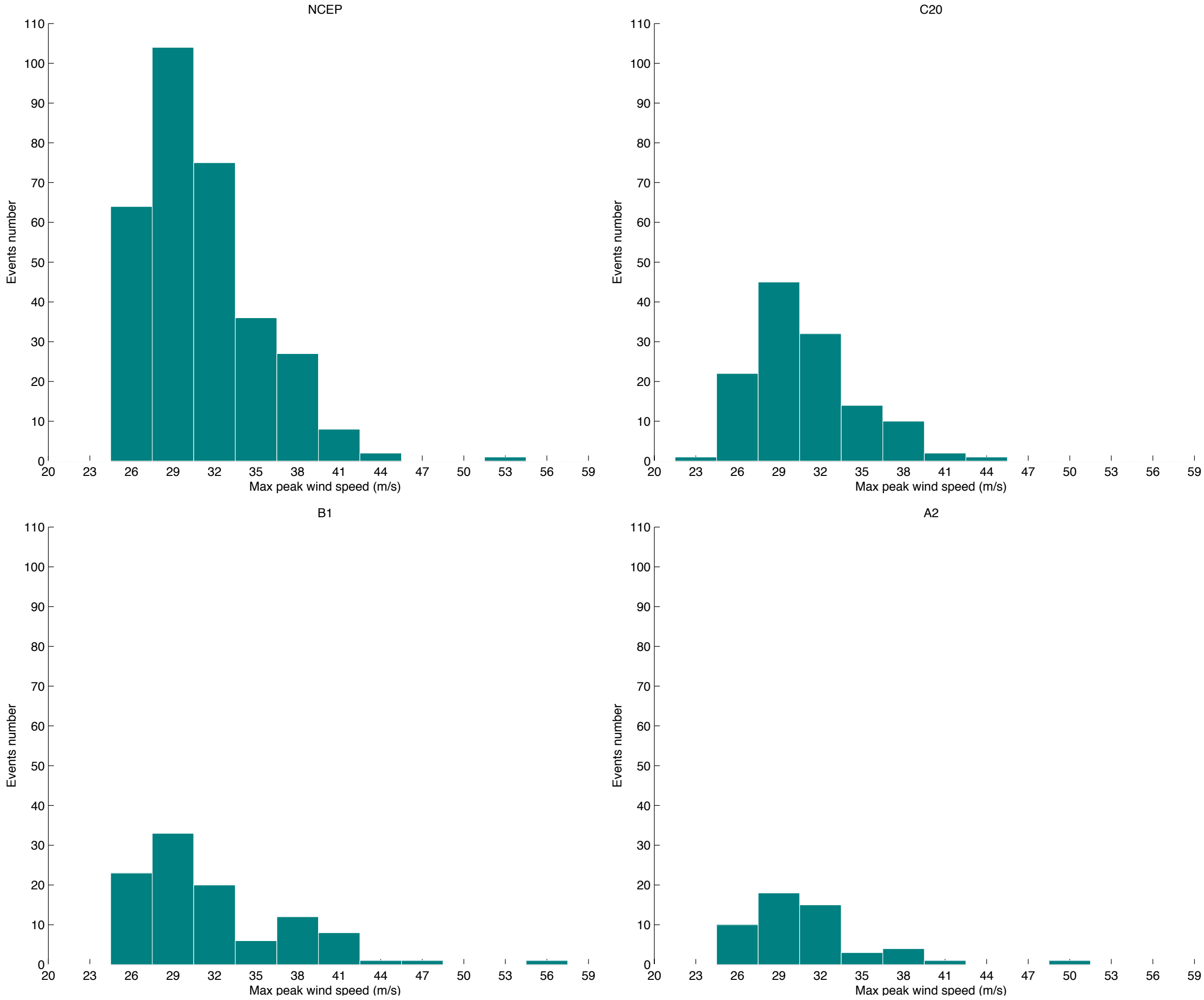

Fig. 4. Intensity of simulated Mediterranean tropical-like cyclones in downscaled NCEP reanalysis (top left), simulated 20th century climate (top right) and climate scenarios B1 (bottom left) and A2 (bottom right), from Cavicchia et al. (2014).

Applying the same downscaling procedure to the atmospheric fields produced by a global circulation model, forced with different future climate scenarios greenhouse gas concentration, we estimate the impact of climate change on the statistics of Mediterranean tropical-like cyclones (Cavicchia et al., 2014).
We find that in the last three decades on the present century (2070-2100), the number of mesoscale storms in the Mediterranean showing tropical-like features is projected to decrease, as a consequence of the lower frequency of environmental configurations favorable for their formation. On the other hand, the percentage of such storms reaching a high intensity shows a tendency towards a moderate increase (Figure 4). The robust assessment of changes in Medicane intensity requires, however, further investigation based on a larger sample of simulated events, and on the analysis of the physical mechanisms involved in MTLC intensification. Finally, the setup and evaluation of the new CMCC regional ocean-atmosphere coupled model for the Mediterranean region has been completed. Specifically, the setup of the coupling between the atmospheric limited area model COSMO-CLM v 4.8.21 (horizontal resolution 0.44°; 45 vertical sigma levels) and the ocean model NEMO v 3.4 MFS (1/16° horizontal resolution; 71 vertical levels) through the Oasis3 coupler has been completed and carefully tested. A series of test simulations, evaluating the sensitivity of the model to different cloud, convection and albedo parametrizations have been performed. The model has been used to perform current climate simulations and will be used, within NextData, to

produce climate change projections for the Mediterranean basin area, according to the MedCORDEX protocols.

High-resolution data from dynamical, statistical and stochastic downscaling

ISAC-CNR started the application of the RainFARM stochastic downscaling procedure to WRF and PROTHEUS historical and scenario simulations in the Noce river basin in Alto Adige, Italy. Available raingauge datasets have been collected and used for initial validation.

A study has been started comparing the RainFARM downscaling procedure with an alternative method based on multifractal cascades in North-Western Italy, using data from EURO4-APGD datasets and raingauges from Piemonte Italy for validation.

ISAC-CNR tested and validated different bias-correction methods for precipitation applied to data from climate scenario simulations with the ICTP RegCM4 model, for the Greater Alpine Region domain. EURO4M-APGD, HISTALP and E-OBS data were used for calibration. Three different methods (based on a simple proportional bias correction and on quantile mapping) were explored, validating in particular indices of extreme precipitation.

In order to provide a methodology to contrast dynamical downscaling output against in situ observations, ENEA compared the output of simulations (performed with the ENEA-PROTHEUS model integrated with ERA40 boundary conditions) with 40 years of data from 64 weather stations from the Italian National Air Force network. Climatic zones have been identified by using the Ward's method (Ward, 1963) for cluster analysis for minimum, maximum surface temperature and rainfall. The model is able to generate realistic spatial patterns of the observed clusters, although with different skills, depending on the considered variable. The closest match between model and observations is for the case of daily minimum temperature. The maximum temperature shows an unrealistic summer peak for most of the clusters. Consistently, the model produces also too many strong warm events during summer. The model shows also a tendency to overestimate total rainfall especially during spring and early summer. The frequency and intensity of extreme events is well captured in the case of minimum temperature for Alpine and mountain weather stations.

CMCC has performed a comparison between different methods of statistical and dynamic downscaling for the generation of precipitation fields at sub-daily time scales. Based on the results obtained in recent studies (eg. Lu and Quin, 2014), a stochastic model for the production of sub-daily pattern of precipitation, derived from daily observations, has been developed and tested. In the model, the statistics associated with the precipitation values observed every 24 and 48 hours are used to estimate the parameter of the Bartlett-Lewis Rectangular Pulse Model. Then, using a proportional control algorithm based on the previously identified parameters, it is possible to estimate the values of precipitation in time scale consistent with the reference statistics. The stochastic model was then applied to a case study (to estimate changes in peak flow flood in the basin of the river Secchia, associated with different scenarios of climate change), using as input the data of daily precipitation provided by a regional climate model and post-processed through appropriate techniques of "bias correction" (developed within the NextData Project). The results of these studies are collected and discussed in a paper in preparation.

3.2 Applications; technological and computational aspects

At ISAC-CNR, long spin-up integrations of EC-Earth 3.1 have been performed for current-day anthropogenic forcing conditions (910 years) and for year 1850 conditions (1800 years), using CMIP5 forcing data, in order to allow the system to reach an equilibrium state. The final states of these integrations have been stored as restart files for the model and will serve as a basis for future experiments. The new initial conditions files are available on the ISAC-CNR web server (http://sansone.to.isac.cnr.it/ecearth/init/). The results from the tuning

experiments have been post-processed and analyzed in terms of performance indices, global mean values, atmospheric and oceanic time-series.
Datasets from a series of experiments with the Earth System Model of Intermediate Complexity (EMIC) PlaSim have been stored and made available. In particular experiments included a historical transient run under CMIP5 GHG forcing for the period 1850-2005 and two perennial year 2000 and year 1850 runs. The resolutions were T21 and T42 (coupled with a simple Mixed-Layer ocean) and T21 (coupled with the LSG (Large Scale Geostrophic) ocean module). The model outputs were compared with results from the EC-Earth model, an ensemble of CMIP5 GCM and with observational datasets.
The RainFARM downscaling procedure software has been further developed, implementing the D'Onofrio et al., 2014 procedure and allowing to write directly an ensemble of stochastic downscaling outputs in netcdf format.
Raingauge datasets for the Noce river basin (Alto Adige) have been collected, controlled and validated.
The THREDDS server previously installed on the ENEA workstations has been maintained and updated. New regional high resolution oceanic simulations driven by ERA40 re-analyses, produced by ENEA group, have also been made available.
During the third year of the Project, CMCC has updated and improved its "NextData Platform". The platform is a rather complex infrastructure, whose main objective is to make available climate data from numerical simulations to a broad range of potential users. In the design phase of the platform, special emphasis has been given to the following key requirements:

- efficiency, scalability and transparent access to large volumes of scientific data;
- uniformity in the metadata manager with similar platforms deployed at the data server of the other partners in the Project;
- implementation of a "data centric" approach, making available the same data through different services that offer complementary functionality.

From the logical point of view, the CMCC Data Platform consists of a "set of services" implemented on a virtual infrastructure. Therefore, all available services are hosted on virtual machines and can be grouped into the following broad categories:

- services "general purpose": HTTP / FTP
- services "domain-based" such as, for example:
  - OPeNDAP / THREDDS;
  - ESGF data node.

To allow the implementation of the "data centric" approach described above, all of the data are stored in a data repository shared with the multiple virtual machines that implement the various services. In addition, the Thredds Data Server (TDS) prepared for the needs of NextData has been completely updated. The new TDS is now hosted on a new virtual machine, specifically designed and configured for that need and implemented with the following software packages: Apache Tomcat (v. 7.0.41) and TDS (v. 4.3). The service is available at the following URL: http://nextdata.cmcc.it:8080/thredds.

3.3 Formation

Supervision of a Ph.D. starting in January 2013 of the "Scuola di Dottorato in Scienze della Natura e Tecnologie Innovative" of the University of Torino on climate downscaling and land-vegetation-atmosphere interaction processes.

Supervision of a Ph.D. starting in March 2013 of the "Scuola di Dottorato in Fluidodinamica" of the Politecnico di Torino on paleoclimate simulations and precipitation in EC-Earth.

Supervision of a second cycle degree thesis ("Laurea Magistrale" – University of Torino) on historical climate modeling with the Plasim climate model.

Supervision of a second cycle thesis ("Laurea Magistrale" – University of Torino) on the comparison of Stochastic Rainfall Downscaling methods.

Supervision of a first cycle thesis (Univ. of Torino) on numerical simulation of convective processes.

Co-Supervision of a Ph. D. (University of Genova) starting in January 2014 on High-resolution non-hydrostatic simulations of extreme rainfall events ion complex orography.

Co-Supervision of a Laurea Magistrale degree in Mathematics at the Seconda Università di Napoli on stochastic downscaling of sub-daily precipitation (tutor Prof. Di Serafino; co-tutor Dr Guido Rianna).

3.4 Dissemination

Course XXII of the Alpine Summer School: Dynamics, Stochastics and Predictability of the Climate System, Valsavarenche, Valle d'Aosta, Italy, 9-18 June, 2014,.
The course has seen the participation of 16 lecturers and of 46 students (http://www.to.isac.cnr.it/aosta_old/aosta2014/index.htm).

3.5 Participation in conferences, workshops, meetings

International meeting with EC-Earth contributors/users, Lund, Sweden, 29-30 September 2014.

International meeting with EC-Earth contributors/users, Reading (ECMWF), 3-4 February 2014.

CAVICCHIA L.: The new coupled regional climate model of the Mediterranean basin: COSMO-NEMOMed (oral presentation). *CLM Community Assembly*, Frankfurt, Germany, 2-4 September 2014.

CALMANTI S., DELL'AQUILA A., MAIMONE F., PELINO V.: Evaluation of climate patterns in a regional climate model over Italy using long-term records from SYNOP weather stations and cluster analysis (oral presentation). *87th Congress of the Società Geologica Italiana*, Milan, 12 September 2014.

VEZZOLI R., DEL LONGO M., MERCOGLIANO P., MONTESARCHIO M., PECORA S., TONELLI F., ZOLLO A.L.: Hydrological simulations driven by RCM climate scenarios at basin scale in the Po River in Italy (oral presentation). *IAHS 2014*, Bologna, Italy.

AGNETTI A., DEL LONGO M., PECORA S., VEZZOLI R., ZENONI E.: Hydrological modeling and data assimilation in water resources assessment (oral presentation). *IAHS 2014*, Bologna, Italy.

CACCIAMANI C, MERCOGLIANO P., PECORA S., SCHIANO P., TIBALDI S., VEZZOLI R.: Hydrology and Climate Change Scenarios in the Po River Basin (oral presentation). *EU-Water Center First Annual Conference Climate Changes and Water Security in the Po River Basin*, Parma, Italy.

VEZZOLI R., RIANNA G., ZOLLO A.L., MERCOGLIANO P., VILLANI V., ZENONI E., PECORA S.: A stochastic approach to the assessment of climate change impacts on the flood peaks distribution*. XXXIV National Congress of "Idraulica e Costruzioni Idrauliche", IDRA 2014*, Bari, Italy.

SCOCCIMARRO E., GUALDI S., VILLARINI G., BELLUCCI A., ZAMPIERI M., NAVARRA A.: Extreme precipitation events over the Euro-Mediterranean region: projections dependance on daily/sub-daily time scale definition (oral presentation). *MedClivar International Conference*, Ankara, 23-25 June 2014.

ZAMPIERI M., SCOCCIMARRO E., and GUALDI S.: Observed snowfall and river discharge trend and low-frequency variability over Alps (oral presentation). *MedClivar International Conference*, Ankara, 23-25 June 2014.

CAVICCHIA L., GUALDI S., VON STORCH H.: Mediterranean tropical-like ciclone in present and future climate (oral presentation). *MedClivar International Conference*, Ankara, June 23-25 2014.

ZAMPIERI M., SCOCCIMARRO E., and GUALDI S.: Observed snowfall and river discharge trend and low-frequency variability over Alps (oral presentation). *15th Conference on World Lake*, Perugia, 4-6 settembre 2014.

CAVICCHIA L., SANNA A., GUALDI S., ODDO P., ZAMPIERI M. The CMCC regional coupled model system (oral presentation). *8th HyMex General Assembly*, Valletta (Malta), 15-19 September 2014.

ZAMPIERI M. and GUALDI S.: Certainties and uncertainties in river discharge predictions over the Iberian Peninsula in the next decades (oral presentation) at the *Final SCARCE International Conference*, Terragona, Spain, 15-22 October 2014.

European Geosciences Union (EGU), *General Assembly 2014*, Vienna, Austria, 27 April - 2 May 2014:

PIERI A., VON HARDENBERG J., PARODI A., and PROVENZALE A.: High-resolution retrospective precipitation climatology for the Euro-CORDEX domain with the Weather Research and Forecast model (poster - *EGU2014* - 12501).

PIERI A., VON HARDENBERG J., PARODI A., and PROVENZALE A.: Role of resolution and of sub-grid parameterizations in modeling precipitation over the Euro-CORDEX domain with the Weather Research and Forecast model (poster - *EGU2014* - 12628).

PALAZZI E., VON HARDENBERG J., TERZAGO S., AND PROVENZALE A.: The CMIP5 picture of current and future precipitation in the Karakoram-Himalaya (talk - *EGU2014* - 6355).

DAVINI P., VON HARDENBERG J., FILIPPI L., AND PROVENZALE A.: Impact of the removal of the Greenland Ice Sheet on the Northern Hemisphere climate in a high-resolution GCM (poster - *EGU2014* - 7567).

ZAMPIERI M., SCOCCIMARRO E., GUALDI S.: Observed snowfall and river discharge trend and low-frequency variability over Alps (talk - *EGU2014* - 6655).

CAVICCHIA L., H.VON STORCH, GUALDI S.: Mediterranean Tropical-like Cyclones: Present and Future, (talk - *EGU2014* - 6655).

SCOCCIMARRO E., GUALDI S., BELLUCCI A., ZAMPIERI M., NAVARRA A.: Heavy precipitation events over the Euro-Mediterranean region in a warmer climate: results from CMIP5 models (talk - *EGU2014* - 3967).

4. Results obtained during the reference period

4.1 Specific results (Data libraries, Measurements, Numerical simulations, etc)

Initial conditions for EC-Earth 3.1 at T255L91, from spin-up simulations with current-day anthropogenic forcing conditions (910 years) and for year 1850 conditions (1800 years), using CMIP5 forcing data.

Diagnostic outputs from several tuning experiments with EC-Earth 3.1, available on a server at ISAC-CNR (http://sansone.to.isac.cnr.it/ecearth/diag).

Datasets from a series of experiments with the Earth System Model of Intermediate Complexity (EMIC) PlaSim for a historical transient run under CMIP5 GHG forcing for the period 1850-2005 and two perennial year 2000 and year 1850 runs.

The raw output of WRF climate integrations at 0.04° and at 0.11° have been postprocessed extracting the main variables of interest (such as tas, pr, hurs, uas, vas, and t,q,u,v at selected levels). The transfer of these variables onto the NextData storage area at CINECA has been completed for a subset of these variables. Precipitation and temperature datasets have been transferred and converted in a format suitable for distribution.

Validated raingauge datasets for the Noce basin, Alto Adige are available on ISAC-CNR servers.

Calibrated bias-corrected daily precipitation datasets, based on ICTP RegCM4 simulations for the GAR, for the period 1970-2005 and for the scenario 2006-2050, were prepared and are available.

Climate simulations of the Euro-Mediterranean region produced with coupled and uncoupled, regional, high resolution, models. The simulations were conducted according to the protocol of the MedCORDEX programme and will be used to investigate climate variability of the basin and the signal of climate change projected according to the scenarios under the protocol.

Very high resolution climate simulations carried out with the COSMO-CLM implemented 0.02° (about 2.2 km) on the Alpine region.

4.2 Publications

PALAZZI E., VON HARDENBERG J., TERZAGO S., PROVENZALE A., (2014, in press): The CMIP5 picture of current and future precipitation in the Karakoram-Himalaya. *Climate Dynamics*. DOI: 10.1007/s00382-014-2341-z.

TERZAGO S., VON HARDENBERG J., PALAZZI E., and PROVENZALE A., (2014): Snowpack changes in the Hindu-Kush Karakoram Himalaya from CMIP5 Global Climate Models. *J. Hydrometeorol*. DOI:10.1175/JHM-D-13-0196.1, 15 (6), 2293-2313.

FILIPPI L., PALAZZI E., VON HARDENBERG J. AND PROVENZALE A., (2014, in press): Multidecadal Variations in the Relationship between the NAO and Winter Precipitation in the Hindu-Kush Karakoram. *Journal of Climate*. DOI:10.1175/JCLI-D-14-00286.1,.

TURCO M., LLASAT M.C., VON HARDENBERG J. and PROVENZALE A., (2014): Climate change impacts on wildfires in a Mediterranean environment. *Climatic Change* 125, 369–380.

D'ONOFRIO D., PALAZZI E., VON HARDENBERG J., PROVENZALE A., CALMANTI S., (2014): Stochastic Rainfall Downscaling of Climate Models. *J of Hydrometeorology* 15 (2), 830-843.

PIERI A., VON HARDENBERG J., PARODI A., PROVENZALE A., (2014): Sensitivity of precipitation statistics to resolution, microphysics and convective parameterization: a case study with the high-resolution WRF climate model over Europe. *Journal of Hydrometeorology*, sub judice.

CALMANTI S., DELL'AQUILA A., MAIMONE F., PELINO V., (2014): Evaluation of climate patterns in a regional climate model over Italy using long-term records from SYNOP weather stations and cluster analysis. *Climate Research*. DOI: 10.3354/cr01256.

DI BIAGIO V., CALMANTI S., DELL'AQUILA A., RUTI PM., (2014): Northern Hemisphere winter midlatitude atmospheric variability in CMIP5 models. *Geophysical Research Letters* 41 (4), 1277-1282.

VEZZOLI R., DEL LONGO M., MERCOGLIANO P., MONTESARCHIO M., PECORA S., TONELLI F., ZOLLO A.L., (2014): Hydrological simulations driven by RCM climate scenarios at basin scale in the Po River in Italy. Proceedings of *ICWRS2014*, Bologna, Italy, IAHS Red Book 364 (ISI).

ZOLLO A.L., RIANNA G., MERCOGLIANO P., TOMMASI P., COMEGNA L., (2014): Validation of a simulation chain to assess climate change impact on precipitation induced landslides. *Landslide Science for a Safer Geoenvironment*, pp. 287-292.

CAVICCHIA L., STORCH H.V., GUALDI S., (2014): Mediterranean Tropical-Like Cyclones in Present and Future Climate, *J. Climate*, 27, 7493-7501.

4.3 Availability of data and model outputs (format, type of library, etc)

Diagnostic outputs of the EC-Earth model are available at the web site: http://sansone.to.isac.cnr.it/ecearth/diag/

New initial conditions are available at http://sansone.to.isac.cnr.it/ecearth/init/ in netcdf format. Outputs of the EC-Earth model and reference climate datasets are available on the ISAC-CNR thredds server at http://sansone.to.isac.cnr.it:8080/thredds/catalog.html in netcdf format.

All climate data from global modelling included in the NextData census (D2.5.1) have been made available by the WP2.5 partners, according to the protocols defined in the work-package and related to Project Deliverables D2.5.4. The data are accessible through the Project portal at: http://www.nextdataproject.it/?q=en/content/model-data.

4.4 Completed Deliverables

D2.5.4: First version of the archives of global and regional climate simulations available on the data servers of the partner institutions.

5. Comment on differences between expected activities/results/Deliverables and those which have been actually performed.

No significant differences have occurred during the third year between the planned activities and those actually performed.

6. Expected activities for the following reference period

In agreement with the Executive Plan of the Project, during the fourth year the following activities are expected to be conducted:

- to complete numerical simulations of global and regional climate scenarios in the areas of interest of the Project, with particular reference to the Mediterranean regions, Alps and HKKH;
- to continue the storing of the results from the high-resolution, non-hydrostatic model simulations, for climatic and environmental dynamics in mountain areas (in particular the Alpine region and for HKKH) and make available the data on the Project server;
- to continue the feasibility studies for long simulations (secular) of climate variability in the Mediterranean area: analysis of decadal variability and low frequency in the regional climate projections until 2100 in the Mediterranean region;
- to contribute to the creation of the final version of the General Portal of the Projec;
- to continue the activities of statistical and stochastic downscaling of climate scenarios and to make the data available for impact assessment studies;
- to arrange a WP partner meeting (in addition to the annual meeting of the Project) targeted to the discussion of the results obtained by the numerical simulations conducted in the WP and the coordination of studies and publication of their results.

Project of Strategic Interest NEXTDATA

Scientific Report
for the reference period 01-01-2014 / 31-12-2014

WP2.5 Special Project / Pilot Study P4: RECCO

Development of ensembles of regional climate change scenarios, with focus on variability, extremes and uncertainties in areas of complex topography.

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1. Scheduled activities, expected results and Milestones (as indicated in the Executive Plan)

The original executive plan is summarized hereafter.

P4-WP1. Completion of additional simulations (more GCMs, more model configurations) for the Mediterranean and South Asia domains, possibly complemented by additional runs for the South America, Central America and Africa domains. The set of new simulations are discussed within the NextData consortium and finalized.

P4-WP2. The scenario simulations (RCP 4.5) will be run for the timeslices 2041-2050 and 2071-2080. The set of simulations will be analysed and discussed within the NextData consortium and the first part of analysis performed.

P4-WP3. Continuation of the elaboration of the test runs and analysis of the key items for high-resolution runs; simulations in the HKKH area for different months representative of the seasonal variability; possible comparison with observations and WRF outputs and analysis.

After the re-modulation of the activities due to the extension of the duration for NextData Project, the working schedule was re-programmed in the new executive plan for next years 2014-2016 as follows:

- continuing to produce numerical simulations both at the global and regional scales focused on the areas of interest, in particular:
  - for the MED-CORDEX area, simulations with RegCM and WRF can be performed and compared in order to study the problem connected to the overestimation of precipitation when using numerical resolutions of the order of 12 km;
  - for the Asian area (INDIA) already under study with RegCM, it is planned to perform a common study on a limited area with both WRF and RAMS models in order to investigate and evaluate the underestimation of precipitation characteristic of the NE sector;
  - for the Himalaya area, it is planned to perform simulations with RegCM at 12 km resolution and with WRF at 0.11° resolution. RAMS simulations could contribute performing a zoom on the Khumbu-valley area;
  - for the HKKH area, the same assessment and evaluation could be performed as described above for the Himalaya area.
- Using the local-scale, non-hydrostatic models for the simulation of the meteorological and environmental dynamics over the mountainous areas of interest, carrying on the stochastic downscaling through different activities, in particular:
  - to identify 'case studies' for reproducing short-term episodes that are of interest for comparing the typical 'meteo' and 'climate' simulation outputs;
  - to possibly perform RegCM simulations including aerosols for the period of interest;
  - to carry on the comparison between different downscaling techniques, statistical and stochastic, in order to study their characteristics and their applicability limitations in the case studies.
- Finalizing the setup and releasing of the content for the numerical data archive for the areas and periods of interest.
- Organizing workshops and meetings of the researchers involved in the Project with the aim of integrating the different modelling activities.

2. Deliverables expected for the reference period

After the re-modulation of the activities due to the extension of the duration for NextData Project, the Deliverables were also re-assigned to a different schedule, as in the following table. For the reference period, deliverables coded as D2.5.R.1, which include reports referred as P4.1.1, P4.1.2, P4.2.1, P43.1, are expected.

Deliverable		P4-WP	Delivery date (Month)	REMODULATED DELIVERY SCHEDULE	Nature
D2.5.R.1	**P4-D1.1**	**1**	**20**	**31.12.2014**	Report describing the data transferred to the NextData Archive.
	P4.D1.2	**1**	**20**	**31.12.2014**	Report summarizing the main findings from the analysis of the available simulations.
	P4.D2.1	**2**	**20**	**31.12.2014**	Report on the analysis of the preliminary simulations, with illustrative examples. Archives of simulation outputs, made available for the WP4 activity.
	P4.D3.1	**3**	**20**	**31.12.2014**	Report on the analysis of the preliminary and test simulations, with illustrative examples.
D2.5.R.2	**P4.D1.3**	**1**	**32**	**31.12.2015**	Report describing the additional simulations completed and eventual results from a preliminary analysis of these experiments.
	P4.D2.2	**2**	**32**	**31.12.2015**	Preliminary report on the scenarios simulations. Archives of simulation outputs, made available for the WP4 activity.
	P4.D3.2	**3**	**32**	**31.12.2015**	Report on the specific results of the simulations performed in the different areas. Archives of simulation outputs, made available for the WP4 activity.
D2.5.R.3	**P4.D1.4**	**1**	**38**	**30.06.2016**	Report describing the new data transferred to the NextData Archive.
	P4.D1.5	**1**	**38**	**30.06.2016**	Report summarizing the main findings from the analysis of the new simulations.
	P4.D2.3	**2**	**38**	**30.06.2016**	Report on the numerical simulations and conclusive analysis.
	P4.D3.3	**3**	**38**	**30.06.2016**	Report on the numerical simulations and conclusive analysis. Archives of simulation outputs, made available for the WP4 activity.
D2.5.R.4	**P4.D4.1**	**4**	**44**	**31.12.2016**	Comprehensive report detailing and discussing the comparison between observed and simulated fields for all simulations performed.
	P4.D4.2	**4**	**44**	**31.12.2016**	Datasets of observations (meteorological stations and satellite) and predicted fields publicly available as benchmark studies for NextData community.

3. Activities which have been actually conducted during the reference period

3.1 Research activities

The work program of the RECCO Project is organized in Units and Work Packages (P4-WP), depending on the different modelling activities, which will merge in the conclusive and comprehensive WP4 "Evaluation and joint analysis of simulation results".
Therefore, the description of the activities is mostly structured by Unit and P4-WP.

Unit 1, ISAC-CNR, P4-WP2.

The P4-WP2 research activities, undertaken in cooperation by Dr. J. von Hardenberg, Dr. A. Pieri and Dr. A. Parodi, have been focused on the execution, at the LRZ supercomputing center in Germany (Gauss-EXPRESS Project pr45de), of a set of control runs for the period 1979-2009 using ERA-Interim reanalysis and reference WRF model configurations derived during the first year of activity of P4-WP2, with reference to the target year 1979.
Precipitation is one of the most crucial meteo-climatic variables affecting the environment and the human societies. In particular, estimating the expected impact of climate change on hydrometeorological risk, ecosystem functioning, permafrost thawing, snow and glacier melt and water availability requires precise quantitative precipitation estimates with high spatio-temporal resolution (Giorgi, 2006; Fowler and Wilby, 2010). For these reasons, we have explored the role of microphysical and convective parameterizations in the WRF model applied to the Euro-CORDEX (Chu et al., 2010) domain (22° W - 45° E and 27° - 72° N at 0.11° horizontal resolution) down to a spatial resolution of 0.037° (about 4 km) in the two-way nested "Inner European Region" (IER) domain, comparing against precipitation values from observation and reanalysis datasets. Furthermore, monthly and daily statistics have been analysed for the period 1979-1998 with special attention to the Great Alpine Region (GAR; a smaller region within the IER extending 4° - 19° N and 43° - 49° N) as representative of complex topography and orographic lifting processes.

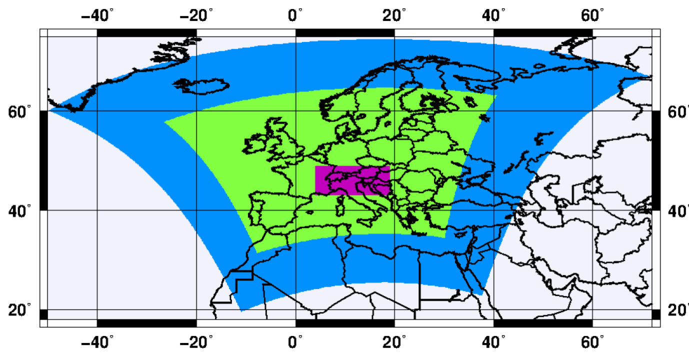

Fig. 1. Outermost domain (0.11°, blue), innermost domain (IER, 0.037°, green) and purple (Great Alpine Area, GAR).

The final objective has been to determine the best RCM configuration for reproducing precipitation climatology and to assess strengths and weaknesses of the modeling approaches. Model sensitivity (Tab. 1) to the convection scheme was tested for the Kain-Fritsch CAPE removal time scale closure (KF; Kain and Fritsch (1990) and for the Betts-Miller-Janjic adjustment-type closure (BMJ; Betts (1986)), and we investigated the suitability of explicit (no parameterized) convection in the inner domain. Such a "grey-zone" resolution still remains an open question in the field. Sensitivity to microphysics implied three different schemes: the WRF Single-Moment 6-Class Microphysics (WSM6, Hong and Lim (2006)), the Thompson et al. (2004) and the Morrison and Gettelman (2008) closures. They are all 6-class including vapor, cloud water, rain, cloud ice, snow and graupel, and represent mixed-phase processes. The two-moment Thompson scheme predicts, in addition to mixing ratios, also number concentrations for ice and rain, while the Morrison parameterization does likewise and further predicts number concentrations for snow and graupel.

Exp. ID	Grid	Microphysics	PBL/Conv. scheme
kt11	0.11°	Thompson	Kain-Fritsch
km11	0.11°	Morrison	Kain-Fritsch
kw11	0.11°	WSM6	Kain-Fritsch
bt11	0.11°	Thompson	Betts-Miller-Janjic
et04	0.037°	Thompson	*explicit*

Tab. 1. Details and ID of the different numerical simulations performed with WRF. Convective schemes are indicated by 'k' for Kain-Fritsch and 'b' for Betts-Miller-Janjic scheme. Microphysics parametrizations are indicated by 't' for Thompson scheme, 'm' for Morrison scheme and 'w' for the WSM6 scheme. The last two integers indicate the horizontal resolution of the simulation.

The results show, in terms of rainfall climatology, that systematically all numerical simulations produce annual precipitation means significantly larger than the gridded precipitation datasets (Tab. 2). With respect to E-OBS dataset, the high-resolution simulation with explicit convection (et04) shows the lowest average precipitation excess in both the IER domain and GAR region. For non-explicit convection runs, the best performing are those with the BMJ scheme.

Run	IER	GAR
kt11	2.68 (46%)	3.67 (24%)
km11	2.60 (42%)	3.57 (21 %)
kw11	2.70 (48%)	3.79 (28%)
bt11	2.43 (33%)	3.34 (13%)
et04	2.29 (25%)	3.09 (4.7%)
erai	2.01	2.73
cru	1.89	2.82
eobs	1.83	2.58
gpcc	1.95	2.70
merra	1.86	2.37
histalp	—	2.95

Tab. 2. Averages over the nested domain, limited to land surfaces, of the average rainfall rate (in mm/day) for the different observational datasets and the different WRF configurations used in the present study. The percentage differences from the E-OBS dataset for IER, and from the HISTALP dataset for GAR, are reported in brackets.

All simulations create likewise positive precipitation biases over all areas with complex orography (i.e., the large mountain chains) compared to observational datasets. The et04 run slightly reduces excess precipitation over eastern Europe and the Alps. Nevertheless, caution must be taken when interpreting these, as the quality of the E-OBS dataset is limited over some mountainous areas due to scarcity of measurements.

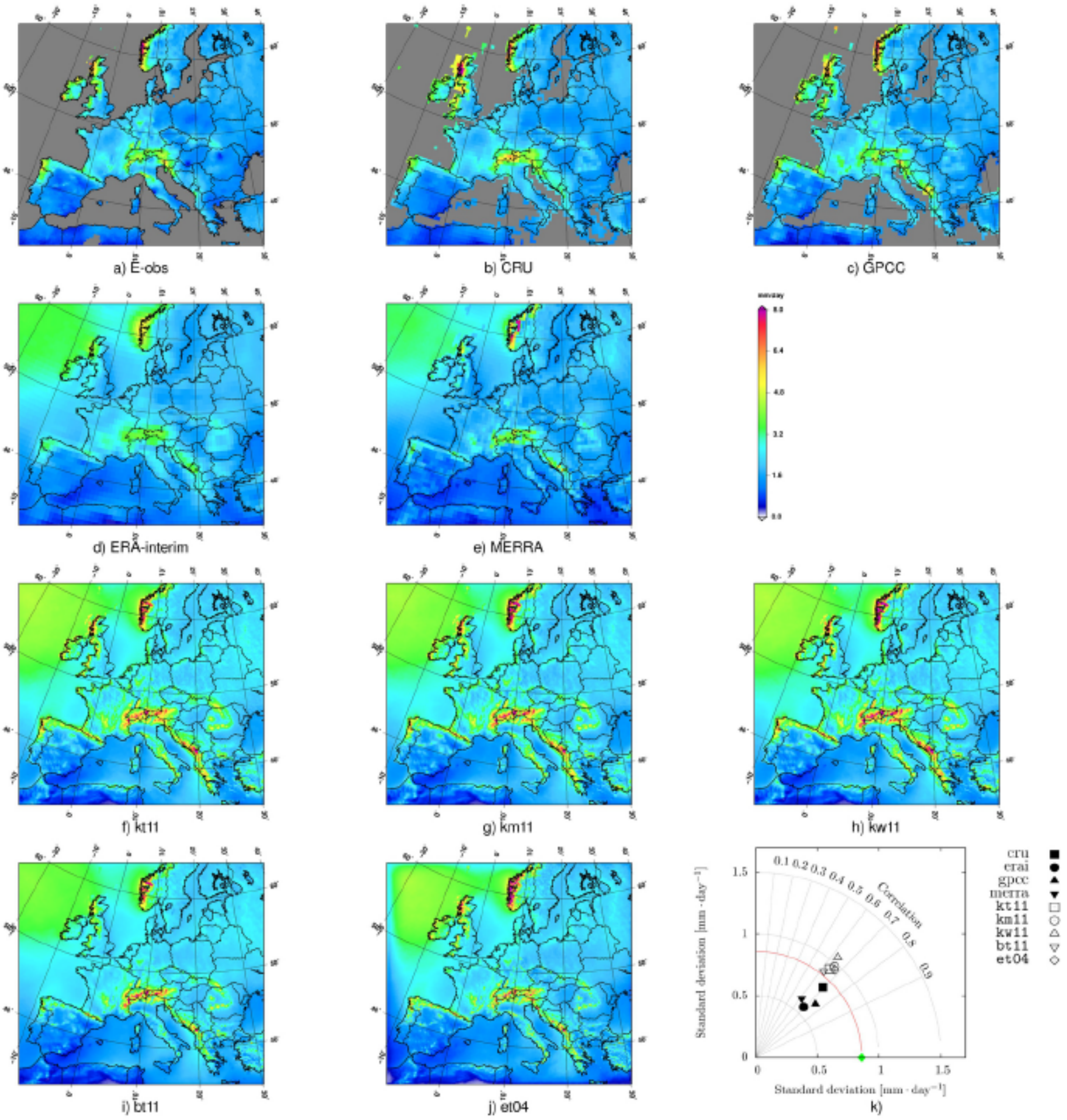

Fig. 2. Total precipitation rate averaged over the period 1979-1998 for different observational datasets (panels a{e) and all numerical experiments performed in this study (panels f-j). The lower right panel (k) shows the Taylor diagram corresponding to the various experiments and datasets; E-OBS was chosen as the reference dataset

It is found that, especially for summer, the et04 run outperforms those with an active parameterization, evidencing that particularly in the months when convection dominates, the model already characterizes better this phenomenon at that resolution without the aid of a convection closure (Fig. 3).

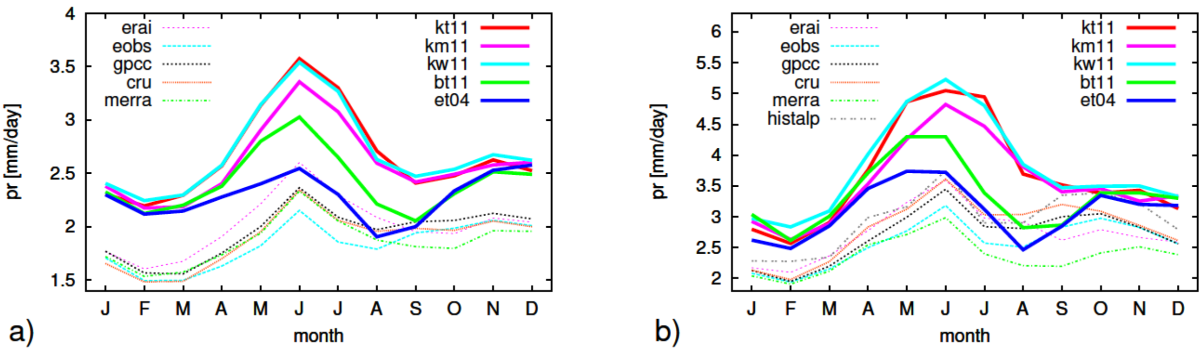

Fig. 3. Monthly precipitation climatologies for period 1979-1998 averaged over (a) the European domain (IER); (b) the Greater Alpine Region. Comparison between all numerical simulations and the observational data.

Analysing now the data specifically for the GAR region, we observe the same pattern of better performance of the et04 run with respect to others: excess over the Alps and deficit in the Ligurian Appennines are both widely corrected. Also, summer rainfall biases over the Alps are particularly sensitive to the convective closure, and the BMJ scheme run defeat those with KF.

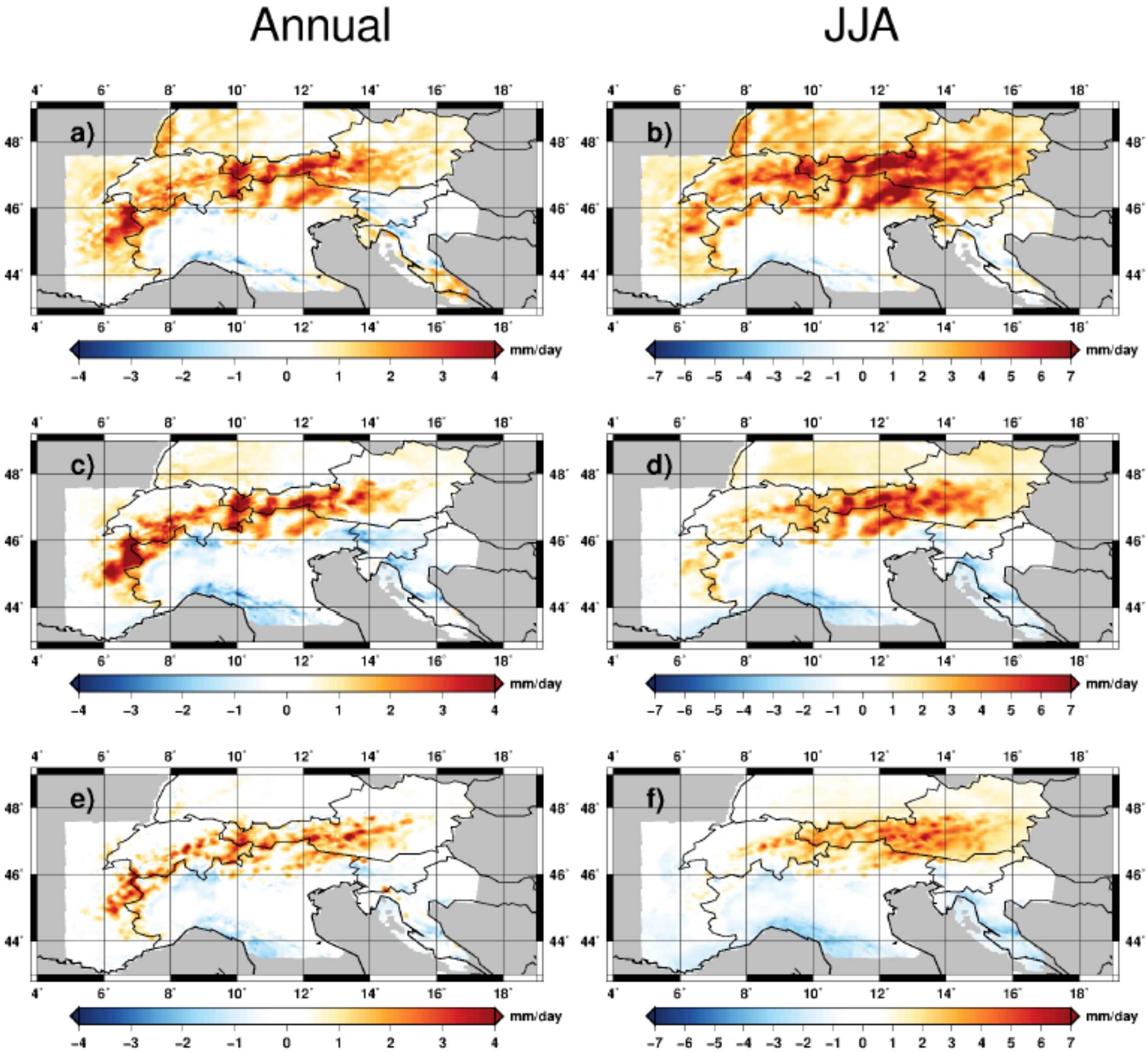

Fig. 4. Differences in the precipitation climatology over the Greater Alpine Region between WRF and the EURO4M-APGD dataset. Annual mean: (a) kt11 ; (c) bt11; (e) et04. Summer mean (JJA): (b) kt11; (d) bt11; (f) et04.

Concerning intense precipitation events, results largely show large overestimations of heavy precipitation days for the period 1979-1998 by all simulations except et04, that captures well the spatial distribution of the heavy precipitation events as characterized by E-OBS (Fig. 5). In some cases, these simulations at 0.11° predict almost twice the frequency of observed intense events. The comparison of the probabilities of exceedance of precipitation thresholds for the daily rainfall rate on the GAR region between observation and model runs provides mixed results. The high-resolution et04 run agrees well with observations in most seasons, but in winter it overestimates EURO4M while the aggregated et04 to 0.11° is closest to observations.

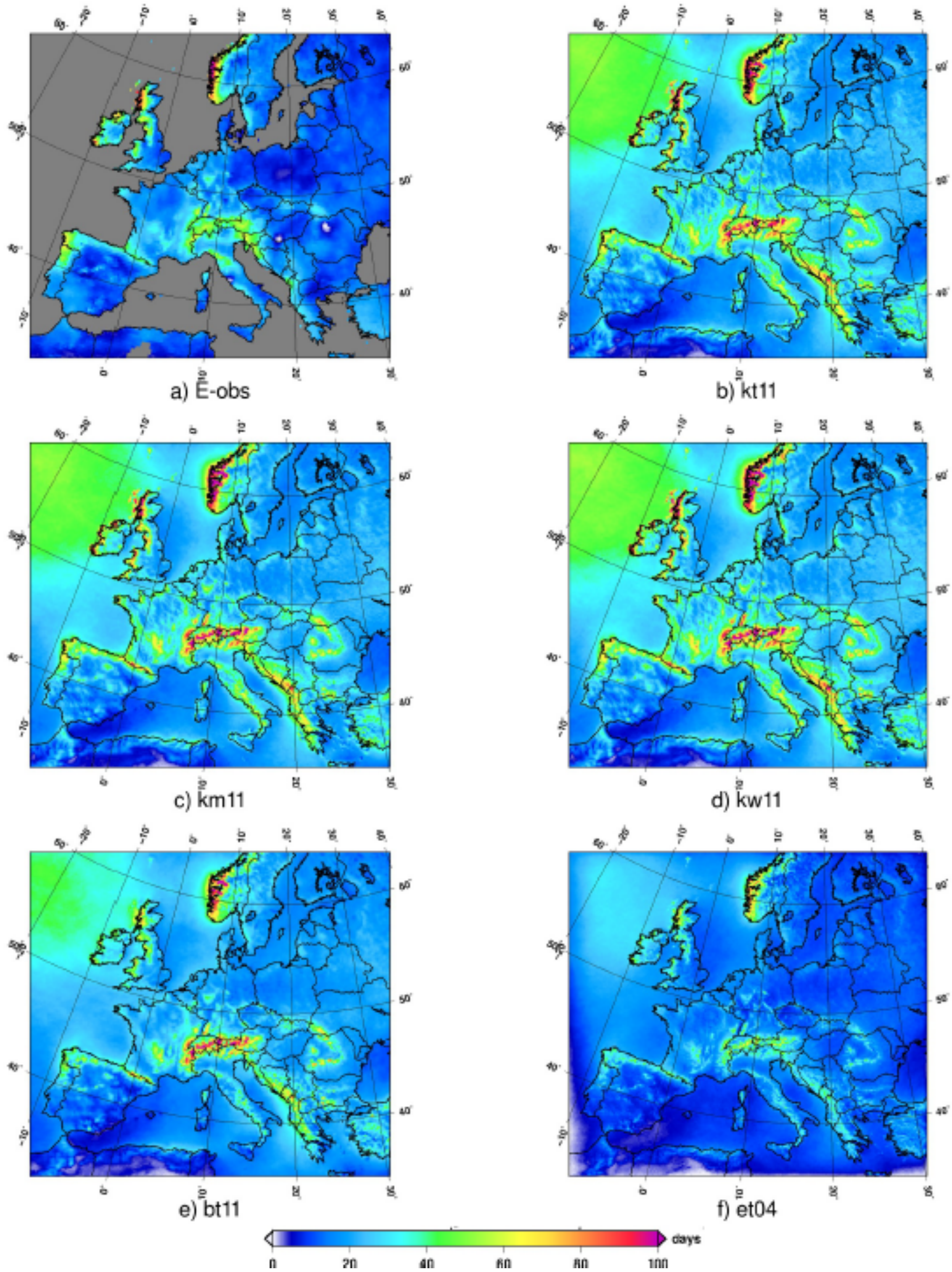

Fig. 5. Number of days with heavy precipitation (> 10mm) for the period 1979-1998.

Unit 1, ISAC-CNR, P4-WP3.

The work of Unit 1 in P4-WP3 is contributing to the physical understanding of the changes in climatological regimes over the NextData regions of interest. Details are given in the Report related to Deliverable P4.3.1. In the frame of RAMS modelling activities, it was planned to perform high-resolution (cloud-resolving) simulations for specific complex topography areas to investigate relevant physical and dynamical processes over the mountainous areas of the Hindu Kush-Karakorum-Himalaya (HKKH). The results have been evaluated using available observations and will be released to the NextData data storage. In the first phase of RAMS modelling activities, a thorough review of the specialized literature on high-resolution simulations in highly complex terrain was conducted. This allowed identifying the critical aspects of performing simulation of the atmospheric circulation in very inhomogeneous topographical conditions. Thanks to the analysis of results from the literature, it was possible to establish the guidelines for the sensitivity analysis to carry on with RAMS simulations in the framework of the RECCO Project. As a second activity, past RAMS simulations in the Italian Alps, performed in the Frejus area, were collected and a database is under preparation. These runs were later analysed to provide specific guidelines for RAMS configuration to be used in other areas of interest for NextData, such as the HKKH. These results are discussed in the Report P4.3.1. Here we present some details and illustrative examples of simulations performed in the HKKH area, focusing on their sensitivity to grid resolution, orography representation, level of the microphysics parameterization, and to some numerical aspects. We chose a reference case characterized by a flood event that was previously studied. The critical episode occurred in year 2010: during the week 24-31 July 2010 an unexpected heavy rain and a flood occurred. This episode has been studied and linked with other critical events, for example heat waves in Russia. In the RAMS model, the two-way nesting procedure allows optimising the interaction between the different scales. The simulations were thus configured using four nested grids with a horizontal grid resolution of 64 km, 16 km, 4 km and 1 km, respectively: the main outer one covers a wide domain, where the main large scales topographical features of the HKKH region are included. The next two intermediate grids zoom over the area of interest and they are chosen to be compatible with the main local topographic features. The last domain, having the highest resolution, is focused over the HKKH area where the observation stations were selected for the NextData Project. In the Pakistan area, the activities are focused on the Central Karakorum National Park (on Baltoro Glacier). In this region, three Automatic Weather Stations are installed. We also considered seven stations of the Pakistan Meteorological Department (PMD) (see Table 3). The initialisation of the RAMS model is provided by the *European Centre for Medium Range Weather Forecast* (ECMWF) with a resolution of 0.5 degrees (that is, at our latitudes, about 50 km). In fact, as input to RAMS, the large-scale 3D meteorological fields give the initial conditions and also the boundary conditions that drive the model during the simulation by means of the nudging technique.

In the selected period, we performed simulations for two cases, as follows:

- *One-day case*: 21 July 2010.
- *One-week case*: 24-31 July 2010.

Tab. 3. Coordinates of the measuring stations in HKKH area

CODE	***NAME***	***LON (°E)***	***LAT (°N)***	***HEIGHT (m)***	***GRIDS***
8	Askole	75.815	35.681	3015	1,2,3,4
9	Urdukas	76.286	35.728	3926	1,2,3,4
10	Concordia	76.514	35.744	4700	1,2,3,4
14	Astore	74.9	35.33	2168	1,2,3
15	Skardu	75.68	35.30	2317	1,2,3
16	Gupis	73.40	36.17	2156	1,2
17	Chitral	71.83	35.85	1498	1,2
18	Gilgit	74.33	35.92	1460	1,2,3
19	Bunji	74.63	35.67	1372	1,2,3
20	Chilas	74.10	35.42	1250	1,2

The "one-day case" run.

A one-day (21 July 2010) case study has been carried out in order to perform some tests on the sensitivity to the smoothing of topography. In RAMS, the flag ITOPSFLG controls the type of processing of topographic data from input files is.

We have four topography options:

- *Average Orography:* a conventional mean is computed (ITOPSFLG = 0).
- *Silhouette Orography*, both the conventional mean and a silhouette average are computed. While the conventional average preserves total terrain volume above sea level, the silhouette average adds mass by filling in valleys. It is used to maintain the effective mean barrier height that air must rise to when crossing a topographic barrier such as a ridge. The conventional average lowers this barrier height, particularly when the barrier height is poorly resolved. (ITOPSFLG = 1)
- *Envelope Orography*: an envelope topography scheme is used. It is an alternative method of attempting to preserve barrier heights (ITOPSFLG = 2).
- *Reflected Envelope Orography:* a reflected envelope topography scheme is used and it aims at preserving both barrier heights and valley depths. Naturally, this method leads to the steepest topography in RAMS, while still filtering the shortest wavelengths (ITOPSFLG = 3).

We analyzed the resulting topography for all cases and then we performed two simulations, one with a “smooth” option (ITOPSFLG=0, Case_top0) and the second one with a “complex” option (ITOPSFLG=3, Case_top3). The obtained results have been used for an intercomparison exercise between simulations dealing with different scheme of orography.

We used the RAMS post-processing REVU (*RAMS Evaluation and Visualization Utilities*) in order to read the output meteorological variables. We used the option “GRAB” which reads (lat-lon) coordinates of the station, specified in input file, then it transforms them in metric coordinates which are transformed in latitude and longitude again. By means of this method, we verified that in the last step the station coordinates are just a bit different with respect to the real ones, supplied in input, and as a consequence also the station altitude changes. In particular, in complex terrain, this effect is emphasized and the change in altitude has to be clearly taken into account.

We report the simulated temperature comparison between two simulations (Case_top0 and Case_top3) at NextData Askole station.

The difference in the temperature values are computed as $\Delta T = T_{Case\_top0} - T_{Case\_top3}$

For Askole’s station (located at 3000 m a.s.l.), we found different altitudes in the four grids using REVU option “GRAB”:

grid 1: 4351 m; grid 2: 4380 m; grid 3: 4465 m; grid 4: 3431 m

In Figure 6, regarding the two different orography schemes, we plot the ΔT temporal trend for each grids. The differences between temperature values are less enhanced in grids 1 and 2, where the values have been extracted at comparable altitudes, than in grids 3 and 4. In grid 3, ΔT is almost nearly positive, therefore $T_{Case\_top0} > T_{Case\_top3}$. In grid 4, the trend is different: ΔT is negative for about 18 hours and then it becomes positive $T_{Case\_top0} > T_{Case\_top3}$.

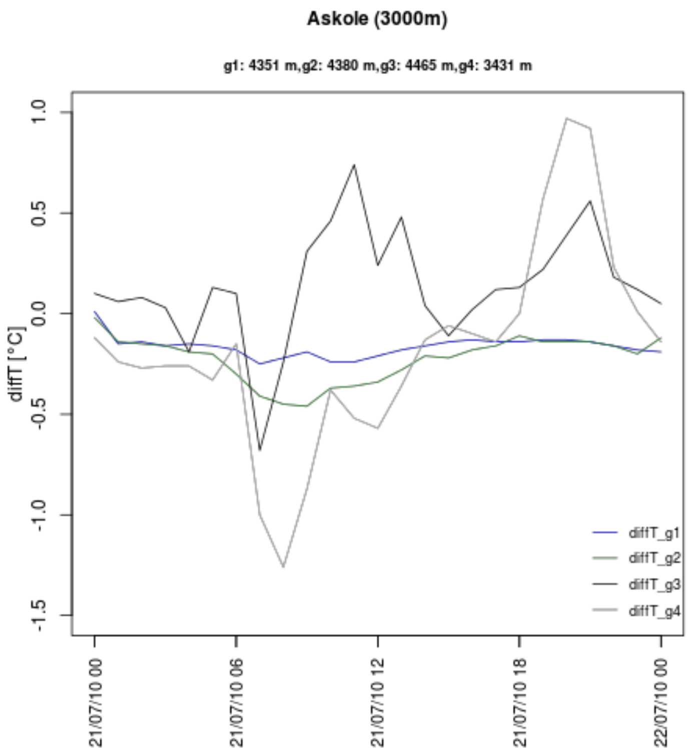

Fig. 6. Comparison between simulated ΔT temporal evolutions in the four grids, in NextData Askole station.

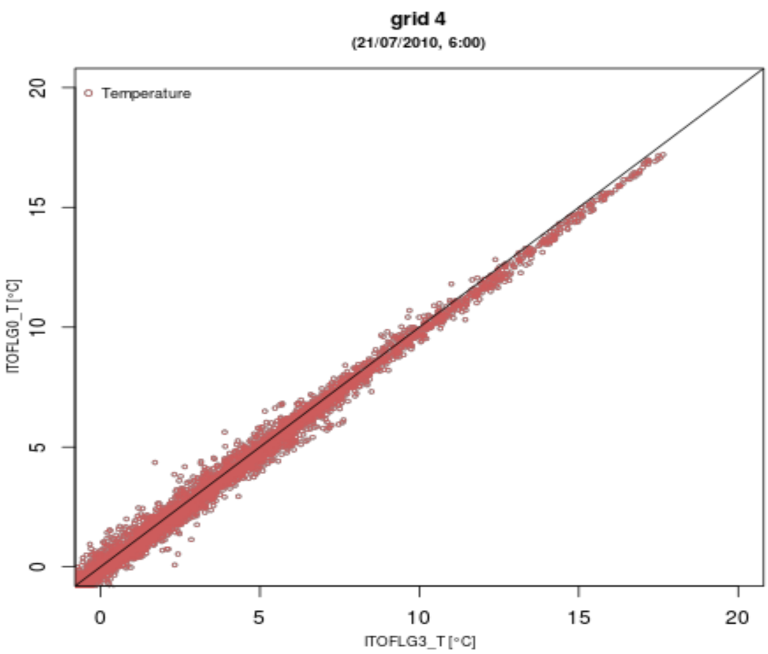

Fig. 7. Simulated temperature scatter plot for grid 4, using two different orography schemes.

In Figure 7, we show a comparison between the simulated temperature, for grid 4, using the two different orography schemes. In general, we notice a certain scatter in the data, of the order of ±1°C, up to about 10 °C. Above this temperature value, the simulation with more "complex" orography provides higher values than the one with a smoother orography scheme. These examples, supported by a deeper analysis of the cases for which we refer to Report D3.1, show that the smoothing of the orography has a not negligible effect on the reproduction of the meteorological fields. When possible, a more realistic representation of the topographical characteristics, which means a lower level of smoothing, should be applied.

"One-week case" run.

In the one-week case, we selected the "*Reflected Envelope Orography"* topography scheme (ITOPFLG=3) and both a complete microphysics parameterization (LEVEL=3), which includes all kind of precipitation processes (named as TestW_1), and a simplified microphysics parameterization (LEVEL=2), where only condensation of water vapour to cloud water is computed and no other forms of liquid or ice water are considered (named as TestW_2).

For the TestW_1 case we performed and analysed three types of simulation:

- a complete "continuous" simulation from 24 to 31 July 2010
- a 36-hours simulation in the same week, in order to test the effect of the spin-up time
- an "irregular" simulation from 24 to 31 July 2010, during which the RAMS run was intentionally interrupted and restarted through the "HISTORY" option, which uses the previously saved output files to carry on the simulation. This was done in order to test the reliability of the restart procedure: the atmospheric and soil prognostic variables are read from an analysis state file, which was written by the model on a previous run, before the interruption or, as in our case, at an hour in which the model has been stopped.

The first simulation represents the flood case study; numerical issues have been evaluated by means of the other two cases. In fact, we show that these aspects may influence the model outcome. Test_W2 case was run as a complete "continuous" simulation, to investigate the effect of the microphysics parameterization when compared to Test_W1 case.

To present the results of the simulations of the atmospheric processes and meteorology, in the following we focus our discussion on the comparison between the model predictions and observations at the surface.
The comparisons are here presented for the PMD stations because the measurements are available only for these stations. In particular, for each period, we compared the simulated temporal evolution of the temperature with daily-observed maximum and minimum values. For the other NextData stations, we analysed wind speed, temperature and relative humidity trends, respectively, in order to highlight possible inaccuracy.
A point-to-point agreement between observed and predicted data cannot be expected and a good result is obtained when the mean trend of measurements is reproduced by the simulated variables. In general, to produce the simulated fields at a specific surface station, it is possible to interpolate on its location the values simulated at the grid points surrounding it, considering also a vertical interpolation from the closest model levels to the height of the site.
Since we are dealing with highly complex topography and landuse heterogeneity, in particular when considering a 1 km grid resolution, we decided to plot the predicted data of the first model level (about 24 m high) at the four grid points around the station, in order to highlight the possible differences due to the different altitudes of the points (the altitudes of two near grid points may change even for several meters).
We extracted the output simulated fields from RAMS analysis files at the four grid points around the considered station (SW=South-West, NW=North-West, SE=South-East, NE=North-East), using the REVU option "DUMP".

In Figure 8, we show the comparison between the simulated temperature trends, using the two different microphysics schemes (TestW_1 and TestW_2 cases) at Askole station. In particular we considered the SW point (3841 m) for grid 1 and the SW point (3215 m) for grid 2.
In both graphs, we observe that the simulated temperature trends practically superpose until the 28th of July 2010 at 12:00, then they start differentiating. The values of TestW_1 case (green curve) are higher than for the TestW_2 case (blue curve). In particular in grid 4, simulated temperature values for TesW_1 show a different trend compared to the ones calculated for TestW_2. The latter maintains the classic daily temperature cycle: computed values about 15 °C early in the morning and peaks of 20-25 °C at noon. Since only the microphysics parameterization is different in the two runs, the perturbation in the temperature occurring in the last days of the simulation for TestW_1 is clearly linked to the intense precipitation event, occurring between the 29/07 and 01/08, as in next Figure 9.

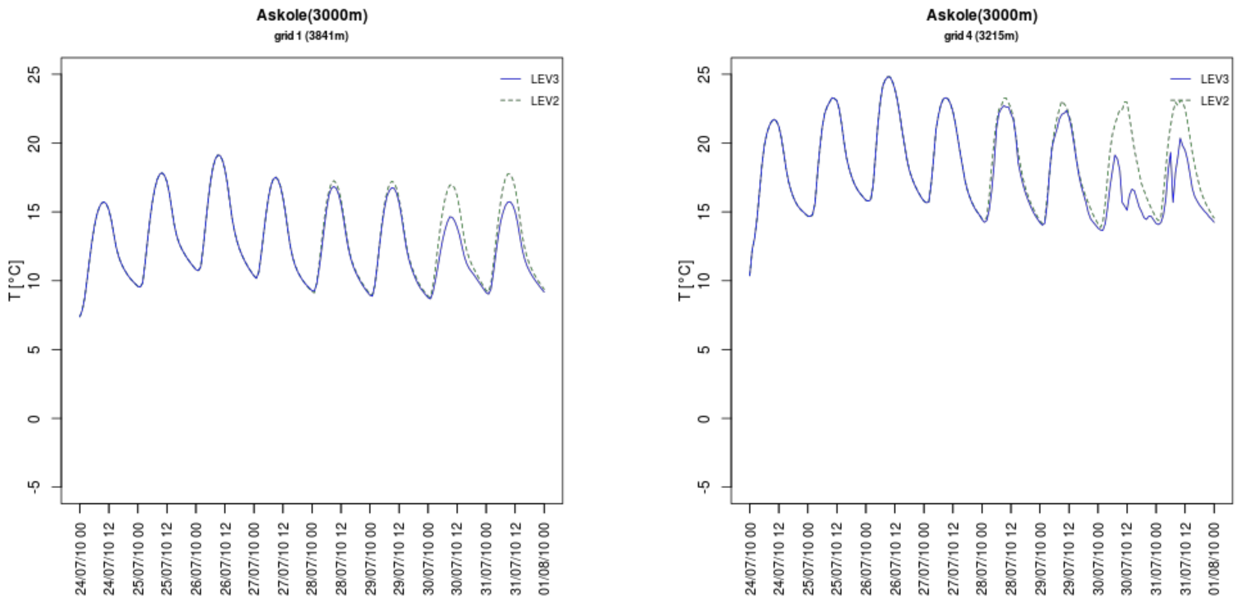

Fig. 8. Askole station. Comparison between simulated temperature trends, using two different microphysics parameterization, in one grid point for grid 1 (left) and for grid 4 (right).

Regarding temperature and precipitation compared to the available observations, we report as example the plots for PMD Skardu station for grid 3. It was possible to extract the simulated values only for grid 3, because the station coordinates are located outside the other nested grids. In this case, the latitude of the station coincides with the latitude of a grid point, therefore only two grid-points where the longitudes are the closest to the station one, are considered.
In Figure 9, we compare simulated temperature trend against daily-observed maximum and minimum values at Skardu station. Considering the relatively coarse horizontal resolution of grid 3, that is 4 km, the predicted temperature daily evolution is satisfactory at the grid points around the station. In particular, some measured peaks and minimum observed values are well reproduced.
In Figure 9 we compare also the resolved surface precipitation trend against mean daily-observed values at Skardu station. RAMS is able to partially catch the event but underestimates the measurements and does not reproduce correctly the observed maximum, occurring on the 30th of July 2010.

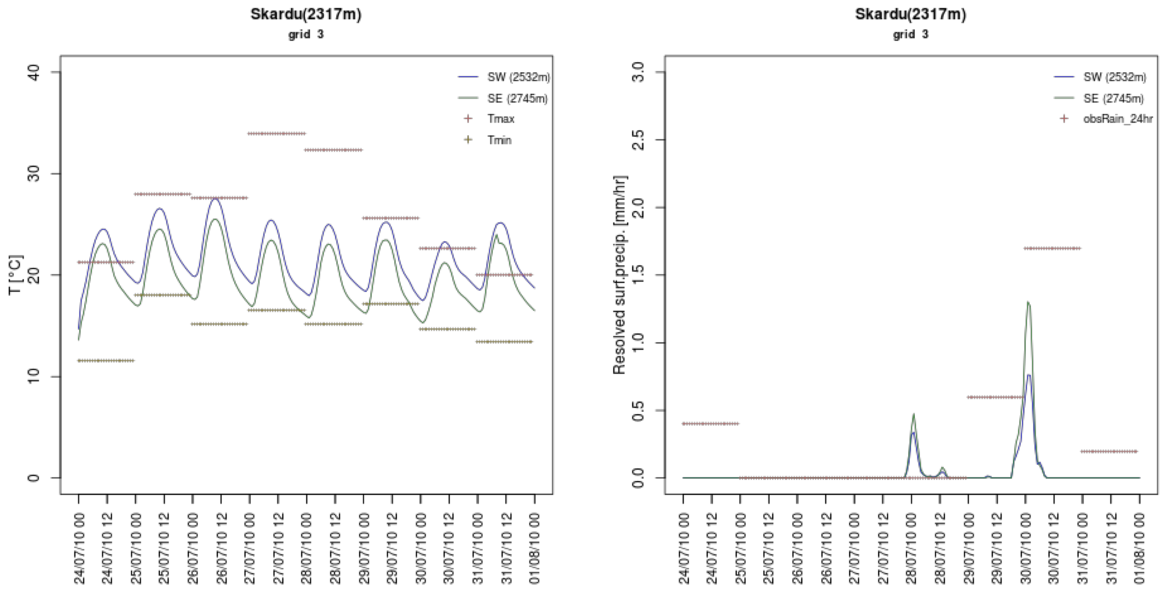

Fig. 9. Skardu station, Grid 3. Time evolution of the simulated temperature (left) and precipitation (right) at the two grid points closest to the station, compared to the corresponding observed daily averages.

Referring to the numerical tests performed for TestW_1 case, here we just cite that (1) not negligible differences were found in the time development of the meteorological variables for a shorter spin-up time, for the 36-hours test; (2) the output fields tend to diverge when operating with the model in the 'restart' procedure: in our knowledge, this aspect was never investigated before and needs a thorough discussion since it is a procedure commonly adopted. Details of these analyses are available in Report P4.3.1.

Unit 2, ICTP, P4-WP1.

Research activities during the NextData reference period have been focused on the completion and analysis of the simulations made with the regional model RegCM4 over the interested areas of the Project, over the Mediterranean basin (MED-CORDEX) and over the Asian region (INDIA).

As scheduled in the executive plan, regional numerical simulations targeted to the areas of interest of the Project were completed, in particular:

- as part of the MED-CORDEX domain, six regional climate simulations with RegCM at 50km were assessed over the Mediterranean region. The following factors were intercompared:
- driving GCMs as boundary conditions;
- two model physics settings: convection scheme and irrigation;
- always for MED-CORDEX domain, two simulations at 12 km of resolutions were carried out, driven by ERA-Interim and RegCM scenario simulation at 50 km;
- for the Asia region (INDIA), a simulation over all the South Asia domain at 25 km driven by ERA-Interim reanalysis from 1979 up to 2012.

Relevant data will be then transferred to the NextData archive. Referring to the Milestone and Deliverable: the data were transferred and the analysis was completed.

Hereafter, a more detailed description of the main results is presented.

For MED-CORDEX, six RegCM4 (50 km) simulations were assessed in total over the domain, driven by different GCMs for the scenario RCP8.5. From the analysis of these simulations the following factors has been found to be most prominent: for temperature, the largest contributions to differences across model projections were due to the driving GCMs and the presence of irrigation; for precipitation the use of different convection schemes had also a comparable effect. We also found that the contributions of different factors changed across geographical regions and showed temporal trends throughout the 21st century. The synergy term, when not negligible, mostly acted in counterbalancing differences across the individual factor contributions, suggesting the presence of negative feedback responses in the model (see publication: Torma and Giorgi, 2014).

Another study (submitted to JGR: Atmospheres) focuses on only over the Alpine region where high resolution and high quality dataset is available at 5 km resolution.

4 GCMs providing the boundary conditions for the 5 RCM simulations at 50km and the same 5 RCMs at 12 km of resolution were used for this study. GCMs as part of the CMIP5 while the RCM simulations were provided by EURO-and MED-CORDEX initiatives at 0.44 and 0.11. Only ALADIN and RegCM is from MED-CORDEX. All the results were interpolated onto the following common grids: 1.32,0.44 and 0.11. The main results are:

- RCMs produce substantial added value over complex topography regions;
- increasing resolution improves the simulation of precipitation spatial patterns and extremes;
- RCMs are important tools to study climate processes over regions with complex topography.

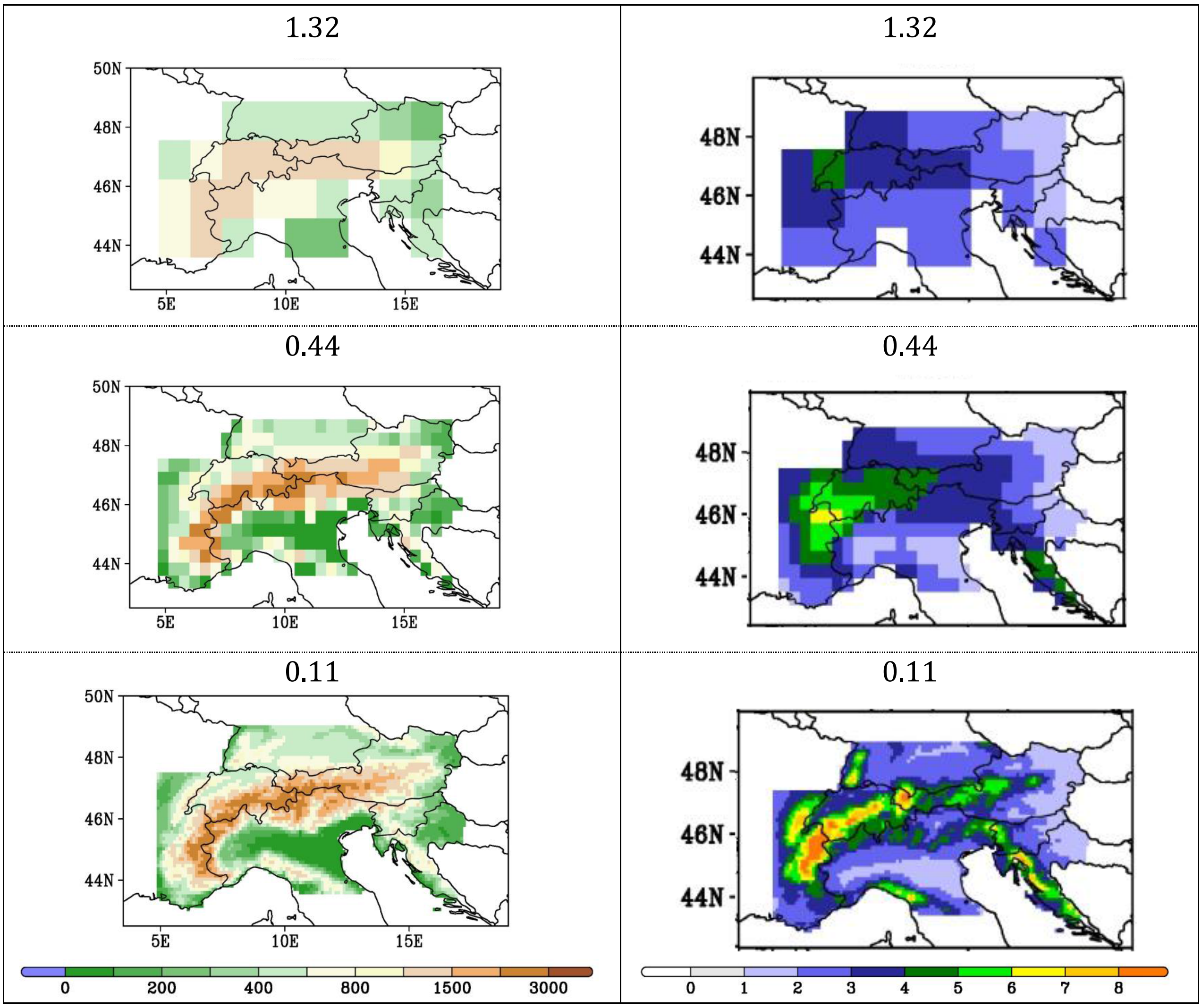

Figure 10: (left column) Topography for the Alpine analysis region at the three resolutions: 1.32°, 0.44° and 0.11° (unit in meter); (right column) Example of the different pattern of precipitation at the three different resolutions for the winter season (December-January-February)

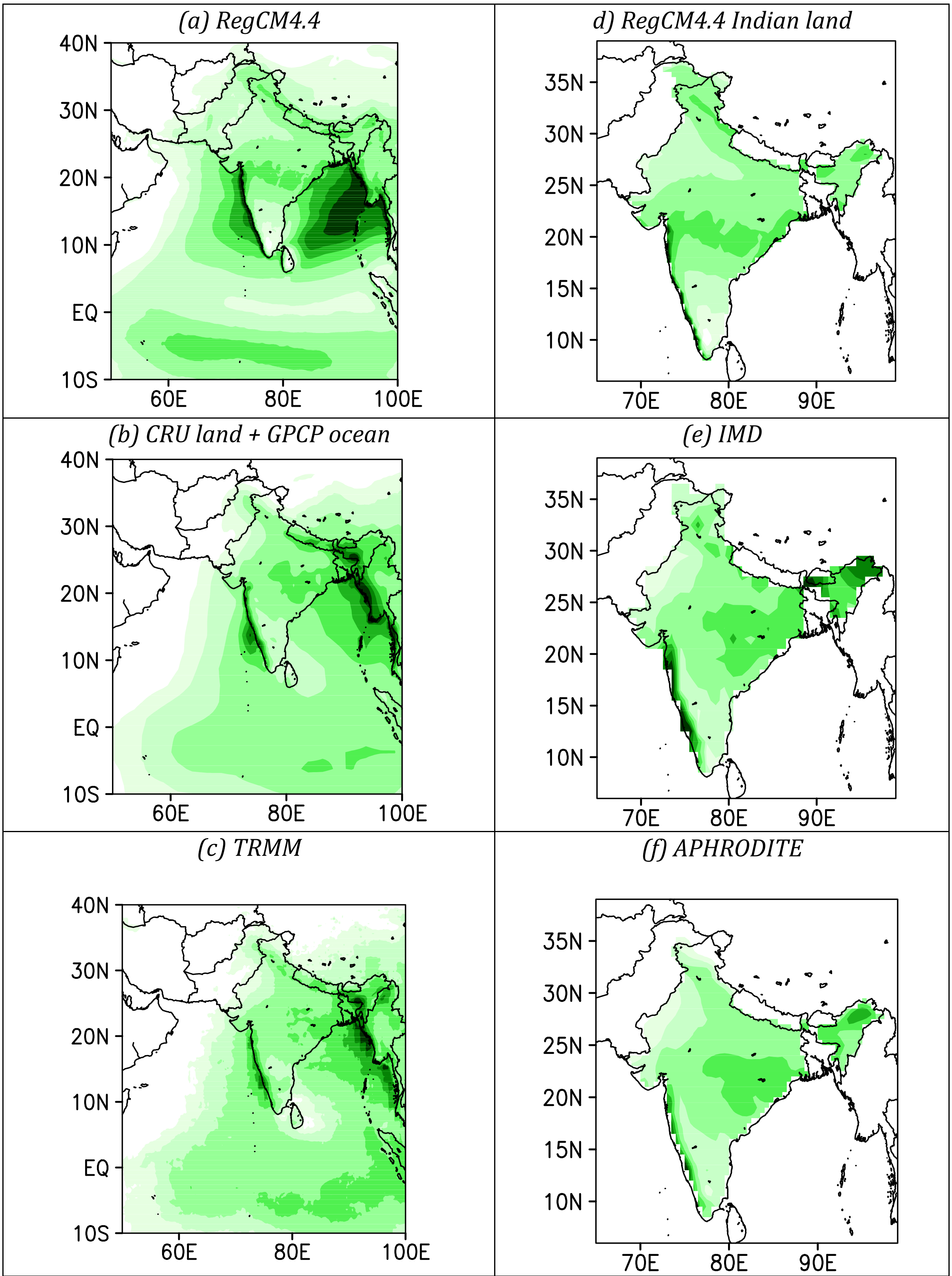

Fig. 11.Precipitation maps (mm/day) from 1980 up to 2012 for (a) RegCM4.4, (b) CRU over land and GPCP over ocean, (c) TRMM from 1998-2006, (d) RegCM4.4 only over Indian land, (e) IMD (Indian Meteorological Department), (f) APHRODITE.

In Figure 10 are reported: in the left column the topography for the Alpine analysis region at the three resolutions: 1.32°, 0.44° and 0.11°;on the right column an example of the different pattern of precipitation at the three different resolutions for the winter season (December-January-February) derived from the GCM and RCM (0.44 and 0.11 degree) ensembles, respectively. A new high-resolution regional climate simulation over the CORDEX South Asia has been performed with RegCM4.4 at 25 km of resolution using the ERA-Interim boundary conditions. The simulated results are compared with the monthly mean surface observations for temperature and precipitation over the entire domain.

The rainy season during the June-July-August-September (JJAS) over India shows a bigger improvement using a different parameterization of the MIT-Emanuel convection scheme for land and ocean. Another big improvement has been found with the UW PBL scheme. The monsoon precipitation over the Indian continent is reasonably represented as shown in Figure 11, where the RegCM precipitation has been compared with different observations.

Unit 3, CINECA, P4-WP2,3.

CINECA is the only one Supercomputing Center in Italy and therefore provides services related to the "enabling" of codes towards HPC Tier-0 and Tier-1 computing platforms.

In particular, in the activity planned for RECCO CINECA was involved in the development of WRF and WRF-CHEM simulations on Tier-0 platform FERMI (located at CINECA BO).

As for the activity of "sensitivity analysis" for RAMS, preliminary testing of the parallel version was developed on PLX platform (now GALILEO); more massive simulations are expected within the next period.

Unit 4, IMAA-CNR, P4-WP4.

The IMAA-CNR has already:

- processed ground based and satellite remote sensing observations of clouds and precipitation and it is ready to make all the data available to the Project partners (mostly already publicly available from other international databases of the observations networks in which CNR-IMAA is participating).
- retrieval of clouds and rain rate from satellite observations.
- routine evaluation of the main European mesoscale weather models (ECMWF, MetOffice, MeteoFrance, ….).

3.2 Applications; technological and computational aspects

<u>Unit 1, ISAC-CNR, P4-WP3.</u>

The analysis of the computational aspects related to the spin-up time and to the restart procedures can be of reference for the meteorological modelling community.

<u>Unit 2, ICTP; P4-WP1</u>

A new tagged version of the model has been released in December and it will not be changed anymore. The development of the model will focus on the new setting of the model from a non-hydrostatic to hydrostatic model.

3.3 Formation

<u>Unit 2, ICTP; P4-WP1</u>.

A workshop was conducted in May 2014 on the latest version of the RegCM system, RegCM4.4. This workshop included both theoretical classes and tutorial/laboratory sessions. About 90 students participated to this workshop. In addition, a student was invited to ICTP for a period of 9 months to carry out tests with the new version of the model under the supervision of ICTP scientific staff.

3.4 Dissemination

<u>Unit 2, ICTP; P4-WP1</u>.

The RegCM model is a free and public code and it is maintained for community use. The outputs from the CORDEX simulations are available for community use, particularly for impact studies.

3.5 Participation in conferences, workshops, meetings

Laura Mariotti attended the
- EGU conference in Wien, April 27 to May 2, 2014,
- the *RECCO Meeting* in Turin, June 26, 2014
- and the *The future of the Italian geosciences* conference in Milan, September 11, 2014.

Filippo Giorgi attended
- *the RECCO Meeting* in Turin, June 26, 2014
- and the *The future of the Italian geosciences* conference in Milan , September 11-12, 2014.

Silvia Trini Castelli and Alessia Balanzino attended the
- *NextData meeting* in Rome, June 3-4 2014
- and the *RECCO Meeting* in Turin, June 26, 2014 and

KRANZLMÜLLER D., VON HARDENBERG J., PARODI A., PIERI A.B., & PROVENZALE A., (2014): EXtreme PREcipitation and Hydrological climate Scenario Simulations (EXPRESS-Hydro Project), *High Performance Computing in Science and Engineering*, Garching, Munich, 2014, Editors S. Wagner, A. Bode, H. Satzger, M. Brehm, Bayerische Akademie der Wissenschaften.

PIERI, A., VON HARDENBERG, J., PARODI, A., & PROVENZALE, A., (2014): Role of resolution and of sub-grid parameterizations in modeling precipitation over the Euro-CORDEX domain with the Weather Research and Forecast model. In *EGU General Assembly Conference* Abstracts, 16, 12628.

PIERI A., VON HARDENBERG J., PARODI A., & PROVENZALE A., (2014): High-resolution retrospective precipitation climatology for the Euro-CORDEX domain with the Weather Research and Forecast model. In *EGU General Assembly Conference* Abstracts, 16, 12501.

4. Results obtained during the reference period

4.1 Specific results (Data libraries, Measurements, Numerical simulations, etc.)

Unit 1, ISAC-CNR, P4-WP3.

Numerical simulations up to 1 km resolution on the Italian Alpine and HKKH areas are available with their related outputs. They can be used as reference case studies and as a basis for further analysis and investigation.

Unit 2, ICTP; P4-WP1

The post-processing of the CREMA simulations (2013) is still on going and the data will be transferred onto the NextData archive.

Unit 4, IMAA-CNR, P4-WP4.

- Ground based observations of Essential Climate Variables for the study of aerosol, clouds, precipitation and radiation (available since 2004).
- Output of the main European mesoscale weather models retrieved over the CNR-IMAA Atmospheric Observatory (CIAO), in cooperation with Cloudnet (www.cloud-net.org).
- Systematic in-situ radiosounding providing vertical profiles of PTU and wind along with their uncertainty budget obtained using the GRUAN data processing (GCOS Upper-Air Reference Network).
- Rain rate estimation retrieved for all AMSU overpasses over Italy since 2008 available for the Project activities (including the whole Alps domain)
- Rain gauge data provided by CIAO station and by the whole network available in Basilicata region (waiting for the data from the regional agency ALSIA) for the validation model output over the Appennino region.

4.2 Publications

VON HARDENBERG J., PARODI A., PIERI,A.B., & PROVENZALE A., (2015): Impact of Microphysics and Convective Parameterizations on Dynamical Downscaling for the European Domain. In Engineering Geology for Society and Territory-Volume 1 (pp. 209-213). Springer International Publishing.

PIERI A., VON HARDENBERG J., PARODI A., & PROVENZALE A., (2015 submitted): Sensitivity of precipitation statistics to resolution, microphysics and convective parameterization: a case study with the high-resolution WRF climate model over Europe. *Journal of Hydro-Meteorology*.

RICCIARDELLI E., CIMINI D., DI PAOLA F., ROMANO F., AND VIGGIANO M: A statistical approach for rain class evaluation using Meteosat Second Generation-Spinning Enhanced Visible and InfraRed Imager observations. *Hydrology and Earth System Sciences*, in review.

Submitted to Climatic Change Special Issue 2014:

COPPOLA ET AL.: The bias and climate change signal in the Phase I CREMA ensemble.

GIORGI ET AL.: Changes in extremes and hydroclimatic regimes in the CREMA ensemble projections.

MARIOTTI ET AL.: Seasonal and intraseasonal changes of African monsoon climates in 21st century CORDEX projections.

DASH ET. AL.: Projected Seasonal Mean Summer Monsoon over India and Adjoining Regions for the 21st Century.
FUENTES FRANCO ET AL.: Changes in inter-annual variability of precipitation over Southern Mexico and Central America from RegCM4 CORDEX projections and their relationship to Sea Surface Temperature.

DIRO ET AL.: Tropical cyclones in a regional climate change projections with RegCM4 over the CORDEX Central America domain.

DA ROCHA ET AL.: Interannual variability associated with ENSO: present and future climate projections of RegCM4 for South America-CORDEX domain.

LLOPART ET AL.: Climate change impact on precipitation for the Amazon and La Plata basins.
<u>*Submitted to Atmospheric Science Letters*</u>

TORMA ET AL.: Assessing the contribution of different factors in regional climate model projections using the Factor Separation method.

<u>*In preparation*</u>

TRINI CASTELLI S., BALANZINO A., (2015): Numerical experiments with RAMS model in highly complex terrain. To be submitted to Environmental Fluid Mechanics

4.3 Availability of data and model outputs (format, type of library, etc)

<u>*Unit 1, ISAC-CNR; P4-WP3.*</u> Output from RAMS simulations over HKKH area, in RAMS-specified HDF5 format, to be adjusted to NectCDF format established in the NextData protocol.

<u>*Unit 2, ICTP; P4-WP1.*</u> Output from the CORDEX simulations are in NetCDF format following the NextData protocol.

<u>*Unit 4, IMAA-CNR, P4-WP4.*</u> All the data are available on both the CNR-IMAA data archive and on the open access database of the observing networks in which CNR-IMAA is actively participating (Cloudnet, AERONET, EARLINET, GRUAN, …). Data are in NetCDF format.

4.3 Completed Deliverables

D2.5.R.1, including:

P4.1.1: Report describing the P4-WP1 data transferred to the NextData Archive.
P4.1.2: Report summarizing the main findings from the analysis of the available P4-WP1 simulations.
P4.2.1: Report on the analysis of the preliminary WRF simulations, with illustrative examples, identifying the critical issues related to simulations in the two study regions. Simulations outputs in archives and available for the P4-WP4 activity.
P4.3.1: Report discussing the critical issues for high-resolution and complex-terrain simulations and the analysis of the preliminary RAMS runs over the HKKH area.

5. Comment on differences between expected activities/results/Deliverables and those which have been actually performed.

Some delay in the original schedule, due to a late delivery of the budget in 2013 that prevented activating research grants in due time, are now overcome both thanks to the activity of the granted collaborators and because of the re-modulation of the research plan related to the prolongation in time of NextData Project.
The missed delivery of the budget for the year 2014 is now seriously threatening the prosecution of the RECCO research activity, since it will be not possible to renew the research grants to the young researchers and collaborators. This implies that it will not be possible to continue and complete most of the modelling activity, which have been mostly care of the young RECCO associate researchers. As a consequence, large part of the research activity will be heavily delayed in the best case, or even cease at all. In such case, RECCO Special Project results will be heavily affected and the research programme will probably not be pursued and finalized as planned in the original proposal. Also, the training and formation of young researcher in course will be heavily compromised.

6. Expected activities for the following reference period

P4-WP1. For the interested areas Himalaya and HKKH are in program a series of simulations with RegCM at 12 km of resolution.

P4-WP2. The set of scenario simulations (RCP 4.5) will be completed and the modelling output will be delivered to the NextData database

P4-WP3. On the basis of the results from RAMS simulations performed over the HKKH area, new case studies are planned:
(1) further simulations over the same domain in HKKH, but referring to another period: 20 August 2012 – 20 October 2012. This case study is related to the experimental campaign "PAPRIKA", during which high-pollution episodes occurred and were studied. The rationale of this study is to provide high-resolution simulated fields of the meteorological variables that can be of support to investigate the flow dynamics and turbulence determining the air pollutant dispersion.
(2) simulations over another domain in the Khumbu Valley (Nepal), located in the central part of the Himalayan range and including the area of Sagarmatha National Park. Here, a network of Automatic Weather Stations provides data since 1994 at different altitudes. The main goal of this set of simulations is to better understand and interpret the transport processes in the valley, investigating the role of the mountain/valley circulation for the transport of pollutant between the boundary layer and the free atmosphere. The choice of the episodes of interest and related periods for the simulations, included between the 2006 and 2001, is still under evaluation.

For **P4-WP2** and **P4-WP3** activities, more massive WRF, WRF-CHEM and RAMS simulations are expected within Project targets and in the framework of ISCRA B, C and PRACE calls.

For **P4-WP4**: to provide satellite, ground based and in situ observations of the atmosphere thermodynamics and the related retrieved products; to identify observations and products relevant for the modelling activities.