Project of Strategic Interest NEXTDATA

Scientific Report for the reference period 01- 01- 2013 / 31- 12- 2013

WP 2.6 Pilot studies on data use, dissemination and project coordination

WP Coordinator:
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Authors are indicated in the description of the individual Pilot Studies

1. Scheduled activities, expected results and Milestones

WP 2.6 is devoted to carry out pilot studies, to collate and disseminate their results and to the project management. The planned activities for this WP, as they were specified in the Project Executive Plan, concern the following aspects:

- organisation of meetings of the researchers involved in the pilot studies to assess the progresses and determine data storage strategies;
- continuation of the formation activities related to the project topics and dissemination by public conferences and articles;
- organisation of a "Mid term" meeting for the possible modification of some of the project strategies and of a general meeting of the researchers and personnel involved in the project;
- activation of a new call for pilot studies (in particular, on mountain ecosystems);
- preparation of general reports on the project activities in the second year;
- preparation of a short documentary movie on climate change and the alpine ecosystems;
- activation of contacts with the private sector, to stimulate the use of the data collected during the project by industries and enterprises;
- continuation of the ongoing pilot studies on (a) analysis of changes in water resources in the Himalaya-Karakorum and of the interaction between monsoon and mid-latitude perturbations; (b) analysis of the changes in terrestrial biodiversity in areas of high altitude in the north-western Italian Alps; (c) estimation of the changes in snow cover and the hydrological cycle of the Alps and the Apennines; (d) effect of aerosols in high altitude areas; (e) multi-secular historical climate simulation for the Mediterranean area and comparison with paleoclimatic proxy data, to obtain a climatological history of Italy in the last one thousand years;
- start of new pilot studies related to the Special Projects activated during the second year: (f) measurement and analysis of precipitation in high-elevation regions; (g) response of Alpine glaciers to climate change; (h) high-resolution climatological information for mountain areas for a 30-yr reference period; and (i) effect of climate change on Alpine plant species germination.

2. Deliverables expected for the reference period

D2.6.2: Report on the results of the pilot studies in the second year.

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

3.1 Research activities

The selection of the Special Projects presented at the NextData calls of the end of 2012 finished in early 2013, and the accepted projects started their activities in 2013. In October 2013, new calls for other Special Projects were issued. The accepted proposals start their activities in early 2014.

The research activities related to the pilot studies (a), (b), (c) and (d) started at the beginning of the first year, and of the pilot study (e) on the multi-secular climatic simulation for the Mediterranean area, started at the end of the first year. All these studies continued in the second year.

The research activities of the pilot studies (f), (g), and (h), related to the newly-activated Special Projects started in the second year.

The detailed description of the research activities related to each pilot study (except for pilot study (b) and (i), see item 5 below) is given in the individual reports of the various pilot studies reported in the Appendix.

3.2 Applications; technological and computational aspects

There have been several technological and numerical developments during the second year, mostly documented in the WP2.5 report and Deliverable, a fundamental pre-requisite for carrying out the activities foreseen in the Pilot Studies and for the fulfilment of the specific Pilot Study objectives. In fact, the research performed within each Pilot Study has exploited the availability of a great amount of numerical data produced during the project as a result of the global and regional climate model simulations. The Pilot Studies are based on datasets other than the model simulation outputs as well. For example the gridded observation-based datasets and reanalysis data have been widely employed for the study of precipitation and snow pack in the Hindu-Kush Karakoram Himalaya region, see Pilot Studies (a) and (c). From 2013, the realization of the NextData General Portal is included in the new WP2.7. The WP2.6 continues to update the project web site and the availability of data and numerical results from thematic archives. In 2013, several internal workshops and project meetings on specific themes were organized, and a general project meeting was held in November 2013.

3.3 Formation

Five Post-Doc research fellowships and two Boursaries were activated/continued on themes related to the pilot studies of the NextData Project.

One Bachelor Thesis entitled “Climate Change as simulated by an Earth System Model of Intermediate Complexity” was completed in October 2013.

NextData supported the organization of the course "Climate Change and the Mountain Environment ", XXI course of the International School "Fundamental Processes in Geophysical Fluid Dynamics and the Climate System", Valsavarenche (AO), June 2013.

NextData supported the organization of the course “The Fluid Dynamics of Climate”, coordinators: A. Provenzale, K. Fraedrich. International Centre for Mechanical Sciences, Udine, Italy, 26-30 August 2013.

3.4 Dissemination

The Project of Interest NextData was presented at various scientific meetings and to the general public.

Lectures on climate dynamics, University of Budapest, January 2013.

Meeting of the GEO Ecosystems Task at ISRE35, Beijing, 21 April 2013.

Annual assembly of LTER-Italy, Bologna, 8 May 2013.

CNR Open Access meeting, Rome, 9 May 2013.

Presentation at the annual meeting of the Italian Glaciological Committee, Gressoney (AO), 5 July 2013.

Presentation at WCRP, WMO, Geneva, 10 July 2013.

International Conference High Summit, Lecco, October 2013.

Presentation at COP 19, Warsaw, November 2013.

IGFA-Belmont Forum, Cape Town, December 2013 (The Scoping Workshop of the Belmont CRA "Mountains as sentinels of change" is being organized for June 2014, supported by the NextData Project).

A short documentary movie by M. ANDREINI and P. FIORATTI has been produced, which describes some of the essential aspects of high mountain ecosystems and focuses on the specific adaptations to the high altitudes. The movie, in Italian and English, is available at the NextData Web Site.

The volume "What is Global Warming?" by A. PROVENZALE, E. MANGHI, A. LOSACCO and G. D'ANNA, printed in Italy by Editoriale Scienza, has been translated into English and printed in Nepal for free distribution in some of the mountain schools in Nepal e Pakistan, to celebrate the "World Environment Day 2013".

3.5 Participation in conferences, workshops, meetings

The activities of the Pilot Studies were presented at different scientific meetings as discussed in the individual reports for the individual Pilot Studies.

4. Results obtained during the reference period

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

The results of the Pilot Studies are detailed in the individual reports.

4.2 Publications

The volume "Il mutamento climatico. Processi naturali e intervento umano" (in Italian) has been published. This book originates from a workshop with the same title organized in 2012 by the Academy of Sciences of Torino. The publication of the volume has been promoted by the Academy of Sciences of Torino, with the support of ISAC-CNR and of NextData.

The results in terms of peer-reviewed publications are detailed in the individual reports (Appendix).

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

Described in the individual reports for the pilot studies.

4.4 Completed deliverables

Deliverable D2.6.2, due at the end of the second year, has been completed.

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

We have not met specific problems or had significant delays from the activities foreseen in the Executive Plan. We decided to include the research activities of the pilot study (b) "analysis of the changes in terrestrial biodiversity in areas of high altitude in the north-western Italian

Alps” and (i) "Effect of climate change on Alpine plant species germination" in the newly-introduced WP 1.7 “Mountain ecosystems and biodiversity”. Therefore, the results of these Pilot Studies are not included in the present report (see the report of WP1.7 and associated Deliverable).

6. Expected activities for the following reference period

Conclusion of the Pilot Studies that started in the first year, continuation of the Pilot Studies that started in the second year, start of new Pilot Studies associated with the Special Projects presented at the calls of October 2013. Organisation of two project meetings and one conference open to the scientific community. Dissemination actions. Strengthening of international links, through participation in the activities of GEO-GEOSS and support to the new initiative GEO-GNOME: GEO Global Network for Observations and information in Mountain Environments. participation in the activities of the Collaborative Research Action of the Belmont Forum "Mountains as Sentinels of Change".

Appendix: Results of the Pilot Studies

Pilot Studies and authors:

2.6a: Analysis of water resources in the Himalaya-Karakoram and interaction between monsoon and mid-latitude perturbations

Lead author: Elisa Palazzi (CNR-ISAC).
Contributors: S. Terzago, L. Filippi, J. von Hardenberg, A. Provenzale (CNR-ISAC).

2.6c: Estimation of the changes in the hydrological cycle, snow cover and water availability in high altitude areas.

Lead author: Silvia Terzago (CNR-ISAC)
Contributors: E. Palazzi, J. von Hardenberg, A. Provenzale (CNR-ISAC); C. Cassardo (University of Torino, Dept. of Physics), U. Morra di cella, E. Cremonese (ARPA VdA).

2.6e: Multi-secular historical climate simulation for the Mediterranean area and comparison with paleoclimatic proxy data, to obtain a climatological history of Italy in the last one thousand years

Lead author: Elisa Palazzi (CNR-ISAC).
Contributors: J. von Hardenberg, A. Provenzale (ISAC-CNR); F. Toselli (University of Torino).

2.6f (Special Project P2): NextSnow - Measurement and analysis of precipitation in high-elevation regions

Lead author: Vincenzo Levizzani (CNR-ISAC).
Contributors: S. Laviola, E. Cattani (CNR-ISAC); U. Morra Di Cella, E. Cremonese (ARPA-VdA); R. Rudari, S. Gabellani (CIMA Foundation); P. Claps, F. Laio, P. Allamano, A. Libertino (Polytechnic of Torino – DIATI); S. Ferraris, D. Canone, M. Previati (Poltechnic and University of Torino – DIST); C. Cassardo, S. Ferrarese (University of Torino, Dept. Physics); S. Fratianni, F. Acquaotta, D. Garzena, L. Perotti (University of Torino – Dept. Earth Sciences).

2.6g (Special Project P3): Database for reconstructing the spatial-temporal evolution of the Glacial Resource in the Italian ALPs over the last 100 years in the Framework of the NextData Project (DATAGRALP)

Lead author: Marta Chiarle (CNR-IRPI)
Contributors: C. Baroni, A. Carton, M. Chiarle, M. Giardino, G.Mortara, G. Nigrelli, L. Perotti, M. C. Salvatore (CNR-IRPI, CGI).

2.6h (Special Project P7): High Resolution Climate Information for Mountain Areas (HR-CIMA)
Lead author: Michele Brunetti (CNR-ISAC).
Contributors: A. Bertolini, M.Brunetti, C. Simolo (CNR-ISAC); Maurizio Maugeri (University of Milan, Dept. Physics).

Pilot study 2.6a: Analysis of water resources in the Himalaya-Karakoram and interaction between monsoon and mid-latitude perturbations (Coordinator: Elisa Palazzi, CNR-ISAC)

1. Scheduled activities, expected results and Milestones

This report describes the continuation of the activities carried out during the first year in the framework of the pilot study on "Analysis of water resources in the Himalaya-Karakorum and interaction between monsoon and mid-latitude perturbations", part of the Work Package 2.6. During the second year we have extended the study on precipitation in the HKKH region based on the analysis of different kinds of observations and the precipitation data from one state-of-the-art global climate model, the EC-Earth GCM run at CNR-ISAC, to an ensemble of thirty-two models included in the Climate Model Intercomparison Project Phase 5 (CMIP5) dataset. The second main activity of the second year has been focused on a more detailed investigation of the synoptic origin of winter precipitation in the Karakoram area (western HKKH), making use of both observations and reanalysis data.

2. Deliverables expected for the reference period

Contribution to the project Deliverable D2.6.2 with the results obtained during the second year of the pilot study: "Analysis of water resources in the Himalaya-Karakorum and interaction between monsoon and mid-latitude perturbations". Two main activities will be presented and the main results summarized in this report, to be better and deeper described in the specific Deliverable on this pilot study. One activity has been focused on the assessment of the skill of a set of thirty-two state-of-the-art global climate models participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5) in simulating precipitation in the HKKH region. In particular, we have considered the ability of these models in reproducing the "historical" precipitation annual cycle and long-term trends by comparing their output with two long observational data sets, providing data since 1901. We have then studied the future precipitation trends under two different emission scenarios (RCP 4.5 and RCP 8.5) for a long time period, and the precipitation changes between future and historical conditions. For all these analyses we have considered separately a western and eastern portion of the whole HKKH range, namely the HKK (Hindu-Kush Karakoram) and the Himalaya regions, affected by different circulation patterns and characterized by different precipitation climatologies. The second main activity in this pilot study concerns the investigation of the origin of winter precipitation in the western portion of the HKKH region, i.e., in the HKK area, where winter precipitation represents the most important nourishment for the Karakoram glacier systems. Therefore, the Deliverable is structured into two sections, describing the two main activities outlines above, and a conclusive section which summarizes the progress and outcomes of this pilot study during the second year of activity.

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

3.1 Research activities

The two main research activities performed during the second year are summarized here below together with an overview of the main results we obtained. We refer to the Deliverable 2.6.2a for the details and for the bibliography reported in the text and in Table 1.

3.1.1 The CMIP5 view of current and future precipitation in the Karakoram-Himalaya

Processes affecting precipitation in the HKKH and surrounding regions are very complex, owing to the variety of meteoclimatic regimes and interaction of local and large-scale circulation systems (see also section 3.1.2), resulting in large variability and lack of spatial coherence in the observed precipitation trends (Solomon et al., 2007). Two main sub-regions, prone to the influence of different circulation patterns, can be distinguished in the HKKH region. The western Hindu-Kush Karakoram (HKK) areas are largely exposed to the arrival of westerly perturbations bringing precipitation during winter/early spring and are less affected by the monsoon circulation, while the eastern Himalayan counterpart is prone to the summer monsoon precipitation (Syed et al, 2006; Yadav et al, 2012). During the first project year we analysed various precipitation datasets including satellite rainfall estimates, reanalysis data, gridded in situ rain gauge data, and a merged satellite and rain gauge climatology, to study precipitation at the seasonal scale in terms of area averages over the HKK and the Himalaya sub-regions. We compared the observation-based and reanalysis data to the output of the EC-Earth v2.3 model, run by ISAC-CNR, to evaluate the extent to which this specific GCM was able to reproduce precipitation patterns, seasonality, and long-term behaviour in the two sub-regions of the HKKH and to evaluate future precipitation trends under different forcing conditions (Palazzi et al., 2013). During the second year we have extended the previous model analysis to an ensemble of thirty-two GCMs participating in the World Climate Research Program (WCRP) Coupled Model Intercomparison Project Phase 5 (CMIP5), in order to provide an overview of their performance in simulating the current and future (out to 2100) climatology of precipitation in the HKKH region, discuss the spread among the various models and highlight some of the factors responsible for differences in model simulations and projections. It is well known that the precipitation simulated by GCMs in mountains areas are affected by large uncertainties because the controls of topography on precipitation are still not properly represented in these models, mainly owing to their coarse resolution. In the monsoon-controlled regions, moreover, the precipitation is also strongly influenced by aerosol particles through both direct and indirect effects.

We have analysed the output of the historical (1870-2005) and scenario (2600-2100) simulations of thirty-two CMIP5 models, whose main characteristics - spatial resolution, number of vertical levels in the atmosphere, representation of the aerosol indirect effects and one key reference, are summarized in Table 1. It is worth underlying that some of these climate models share a common lineage and are not really independent of each other, either because they share a common dynamical core (in particular the same atmospheric model) or they are developed in the same centre.

Comparison of models with the observations is a necessary step for evaluating the performances of climate models and a prerequisite for critically analysing their future projections. Here we employ two long precipitation datasets going back in time to 1901. One is the Climate Research Unit (CRU) product, consisting of monthly gridded fields of precipitation from 1901 to 2009 over land areas with a spatial resolution of 0.5° latitude-longitude; the other is the Global Precipitation Climatology Centre (GPCC) full data reanalysis (GPCC_FD), providing data from 1901 to 2010 and consisting of monthly precipitation data at 0.5° spatial resolution.

Tab. 1. The CMIP5 models used in this study. For the models including the indirect aerosol effects, we indicate in brackets whether the secondary aerosol effect is represented, in addition to the first one. Starred entries indicate the models in which the aerosol module is fully interactive.

Model ID	Resolution Lon×Lat° Lev	Institution ID	First/second indirect aerosol effect	Key reference
bcc-csm1-1-m	1.125×1.125L26 (T106)	BCC	No	Wu et al (2013)
bcc-csm1-1	2.8125×2.8125L26 (T42)	BCC	No	Wu et al (2013)
CCSM4	1.25×0.9L27 (T63)	NCAR	No	Meehl et al (2012)
CESM1-BGC	1.25×0.9L27	NSF-DOE-NCAR	No	Hurrell et al (2013)
*CESM1-CAM5	1.25×0.9L27	NSF-DOE-NCAR	No	Hurrell et al (2013)
EC-Earth	1.125×1.125L62 (T159)	EC-EARTH	No	Hazeleger et al (2012)
FIO-ESM	2.8125×2.8125L26 (T42)	FIO	No	Song et al (2012)
GFDL-ESM2G	2.5×2L24 (M45)	GFDL	No	Delworth et al (2006)
GFDL-ESM2M	2.5×2L24 (M45)	GFDL	No	Delworth et al (2006)
MPI-ESM-LR	1.875×1.875L47 (T63)	MPI-M	No	Giorgetta et al (2013)
MPI-ESM-MR	1.875×1.875L95 (T63)	MPI-M	No	Giorgetta et al (2013)
*CanESM2	2.8125×2.8125L35 (T63)	CCCMA	Yes / No	Arora et al (2011)
CMCC-CMS	1.875×1.875L95 (T63)	CMCC	Yes / No	Davini et al (2013)
CNRM-CM5	1.40625×1.40625L31 (T127)	CNRM-CERFACS	Yes / No	Voldoire et al (2013)
*CSIRO-Mk3-6-0	1.875×1.875L18 (T63)	CSIRO-QCCCE	Yes / No	Rotstayn et al (2012)
*GFDL-CM3	2.5×2L48 (C48)	GFDL	Yes / No	Delworth et al (2006)
INM-CM4	2×1.5L21	INM	Yes / No	Volodin et al (2010)
IPSL-CM5A-LR	3.75×1.89L39	IPSL	Yes / No	Hourdin et al (2013)
IPSL-CM5A-MR	2.5×1.2587L39	IPSL	Yes / No	Hourdin et al (2013)
IPSL-CM5B-LR	3.75×1.9L39	IPSL	Yes / No	Hourdin et al (2013)
*MRI-CGCM3	1.125×1.125L48 (T159)	MRI	Yes / No	Yukimoto et al (2012)
CMCC-CM	0.75×0.75L31 (T159)	CMCC	Yes / N/A	Scoccimarro et al (2011)
FGOALS-g2	2.8125×2.8125L26	LASG-CESS	Yes / N/A	Li et al (2013)
*HadGEM2-AO	1.875×1.24L60	MOHC	Yes / N/A	Martin et al (2011)
*ACCESS1-0	1.875×1.25L38 (N96)	CSIRO-BOM	Yes / Yes	Bi et al (2013)
*ACCESS1-3	1.875×1.25L38	CSIRO-BOM	Yes / Yes	Bi et al (2013)
*HadGEM2-CC	1.875×1.24L60 (N96)	MOHC	Yes / Yes	Martin et al (2011)
*HadGEM2-ES	1.875×1.24L38 (N96)	MOHC	Yes / Yes	Bellouin et al (2011)
*MIROC5	1.40625×1.40625L40 (T85)	MIROC	Yes / Yes	Watanabe et al (2010)
*MIROC-ESM	2.8125×2.8125L80 (T42)	MIROC	Yes / Yes	Watanabe et al (2011)
*NorESM1-M	2.5×1.9L26 (F19)	NCC	Yes / Yes	Bentsen et al (2013)
*NorESM1-ME	2.5×1.9L26	NCC	Yes / Yes	Bentsen et al (2013)

The mean annual cycle of precipitation, averaged over the years 1901-2005 (2006-2100) for the historical (future) climate, is shown in Figure 1 for the Himalaya (a) and HKK (b) regions.

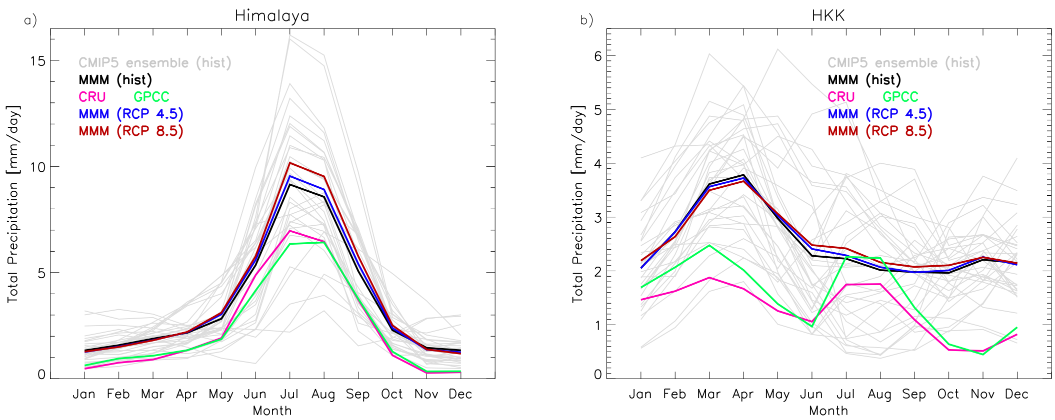

Fig. 1. Mean annual cycle of precipitation in the Himalaya (a) and HKK (b), calculated as the multi-annual average over the years 1901-2005 (historical period) for each CMIP5 model (grey lines) and for their multi-model mean (MMM, black line). The solid blue and red lines represent the mean annual cycle of precipitation over the years 2006-2100 in the RCP 4.5 and the RCP 8.5 future scenarios, respectively, for the CMIP5 MMM.

Each grey line indicates the output of a single model member, the multi-model mean (MMM) is shown with the black solid line, while CRU and GPCC observations are shown with the pink and green lines, respectively. With respect to CRU, the CMIP5 MMM indicates an overestimation of the simulated precipitation all over the year in both the HKK and Himalayan regions, a positive bias which is commonly found in the precipitation simulated by the state-of-the-art GCMs over high-elevated terrains. The same model bias is found with respect to GPCC data, except for July and August precipitation in the HKK region. In both regions, the model spread relative to the multi-model mean is large, indicating that the models do not converge in their representation of the historical precipitation annual cycle. Despite this, all models reproduce one-modal precipitation annual cycles in the Himalayan region, even if the various distributions are differently wide and have different amplitudes, while the model disagreement is much more serious in the HKK region, where annual cycles with very different characteristics are simulated. A hierarchical clustering analysis, using a standard Euclidean distance as a distance metric, has been applied to group the various models based on their output in terms of precipitation annual cycle in the HKK region, so assuming no a priori knowledge about the features of any model. Using the simplest rule of thumb to set the number of clusters, the procedure allowed to determine four model clusters in the HKK region: the mean annual cycle of precipitation for each of the four clusters is shown in Fig. 2.

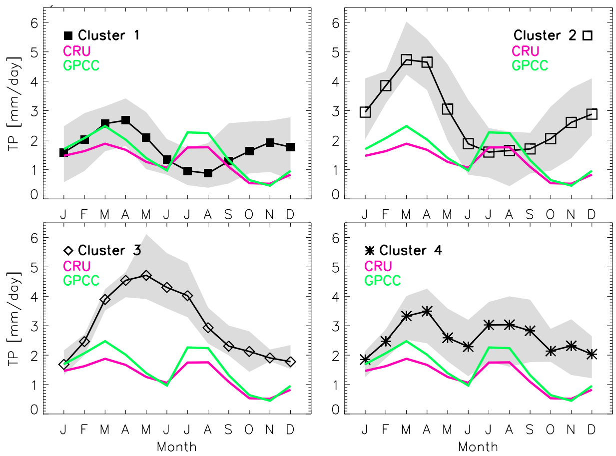

Fig. 2. Mean annual cycle of precipitation in the HKK simulated by all models within each cluster (the grey shaded areas indicate the variability range of the models) and by their MMM (black lines with symbols). The CRU and GPCC observations are shown with the pink and green lines, respectively.

Models in the first and in the second cluster simulate very few amounts of precipitation during Summer compared to Winter/early Spring. The models in the third cluster display a wide precipitation distribution, with high precipitation values from February to September and one peak around May; precipitation values are strongly overestimated with respect to the CRU and GPCC observations. Finally, models in the last show a precipitation annual cycle with two main peaks in late-Winter and in Summer, reflecting the two main seasonal precipitation sources in the HKK region, in overall agreement with the CRU and GPCC observations, and a third lower maximum in November (it is worth highlighting, however, that the main contribution to the third Autumn maximum comes from one single model results, MRI-CGCM3). The spatial resolution of this models cluster is either 1.125° or 1.25°, except for the NorESM1-M and NorESM1-ME models which have a coarser resolution (2.5°).
Figure 1 also shows the mean precipitation annual cycle averaged over the years 2006-2100 in the RCP 4.5 and RCP 8.5 scenarios with the blue and red lines, respectively, obtained by averaging all CMIP5 models. The CMIP5 MMM indicates higher precipitation in the future with respect to the historical precipitation average, from about May to October in the Himalayan region, with higher values for the RCP 8.5 than for the RCP 4.5 scenario, especially in the

warmest months. In the HKK region from about February to May, future precipitation appears to be close to or slightly lower than the present-day value in both scenarios, while from about May to November future precipitation is slightly higher than the historical one, particularly in the RCP 8.5 scenario. We refer to the Deliverable of this pilot study for the discussion about the simulations of the long-term seasonal precipitation trends in the HKK and Himalayan region in both historical and future decades; these results are not discussed here for brevity.

In order to analyse in detail how precipitation may change in the near and farther future, we compared averages over the periods 2021-2050 and 2071-2100 with a 1971-2000 present-day reference period.

In Fig. 3 we show the seasonal-mean percentage precipitation change in 2021-2050 relative to 1971-2000 (left column) and in 2071-2100 relative to 1971-2000 (right column) simulated by each GCM in the Himalaya region. The results obtained in the RCP 4.5 (RCP 8.5) scenario are shown with the grey (black) histograms: filled histograms are used for the models giving statistically significant differences between future and historical average conditions. A consistent number of models display statistically significant precipitation changes in 2021-2050 relative to 1971-2000 in the Himalaya during Summer (top left panel of Fig. 3), either in the RCP 4.5 or RCP 8.5 scenario or in both scenarios. For all these models (except HadGEM2-AO in the RCP 4.5 scenario) the simulated change is positive, indicating that the GCMs simulate a wetter future in this region and season. Positive and statistically significant precipitation changes (ranging from less than ~10% to ~80% in the RCP 8.5 scenario) are also found in 2071-2100 relative to 1971-2000 for almost all models: only three GCMs (CMCC-CMS, MPI-ESM-LR, MPI-ESM-MR), built on the same atmospheric model, provide positive but insignificant precipitation changes, while only one model (FIO-ESM) simulates significantly drier future conditions.

Therefore, the CMIP5 models overall simulate a positive precipitation change in both the near and far future with respect to the historical (1971-2000) precipitation. A less clear signal emerges for winter precipitation changes in the Himalaya. Only five models simulate statistically significant negative changes in 2021-2050 relative to 1971-2000, either in the RCP 4.5 and RCP 8.5 scenarios, while one model gives a positive, significant change. The number of GCMs simulating either positive or negative significant changes increases when the precipitation changes are evaluated in 2071-2100 relative to 1971-2000, with a slight prevalence towards a drier future under the RCP 8.5 scenario.

The model picture of precipitation change in the HKK region (not shown) indicates wetter conditions in Summer in both 2021-2050 and 2071-2100, relative to 1971-2000, as well as positive winter precipitation changes in the nearest future. However, it is worth pointing out that only a few models simulate statistically significant changes. The model picture of winter precipitation change in 2071-2100 relative to 1971-2000 in the HKK is not homogeneous: a few models show significant wetter future conditions, a few others simulate a drier future (especially under the RCP8.5 scenario). Overall, with respect to the Himalaya region, in the HKK a larger number of GCMs simulate no significant seasonal precipitation changes.

2. The synoptic control of winter precipitation in the Karakoram

The Hindu-Kush Karakoram (HKK) is located at the western edge of the Himalayan range, and it is exposed to two main circulation patterns - the Indian monsoon and the mid-latitude westerlies, mainly known as Western Weather Patterns (WWPs). The different circulation patterns lead to different precipitation climatology in the western and eastern portions of the mountain chain. The HKK in the west, in particular, receives precipitation both in Winter, carried on WWPs originating from the Mediterranean/Atlantic regions, and in Summer due to the monsoon. As a result, precipitation in HKK is characterized by a bimodal annual cycle. WWPs are primarily responsible for the build-up of seasonal snow cover in the Karakoram, constituting an essential water reserve and source for several river basins.

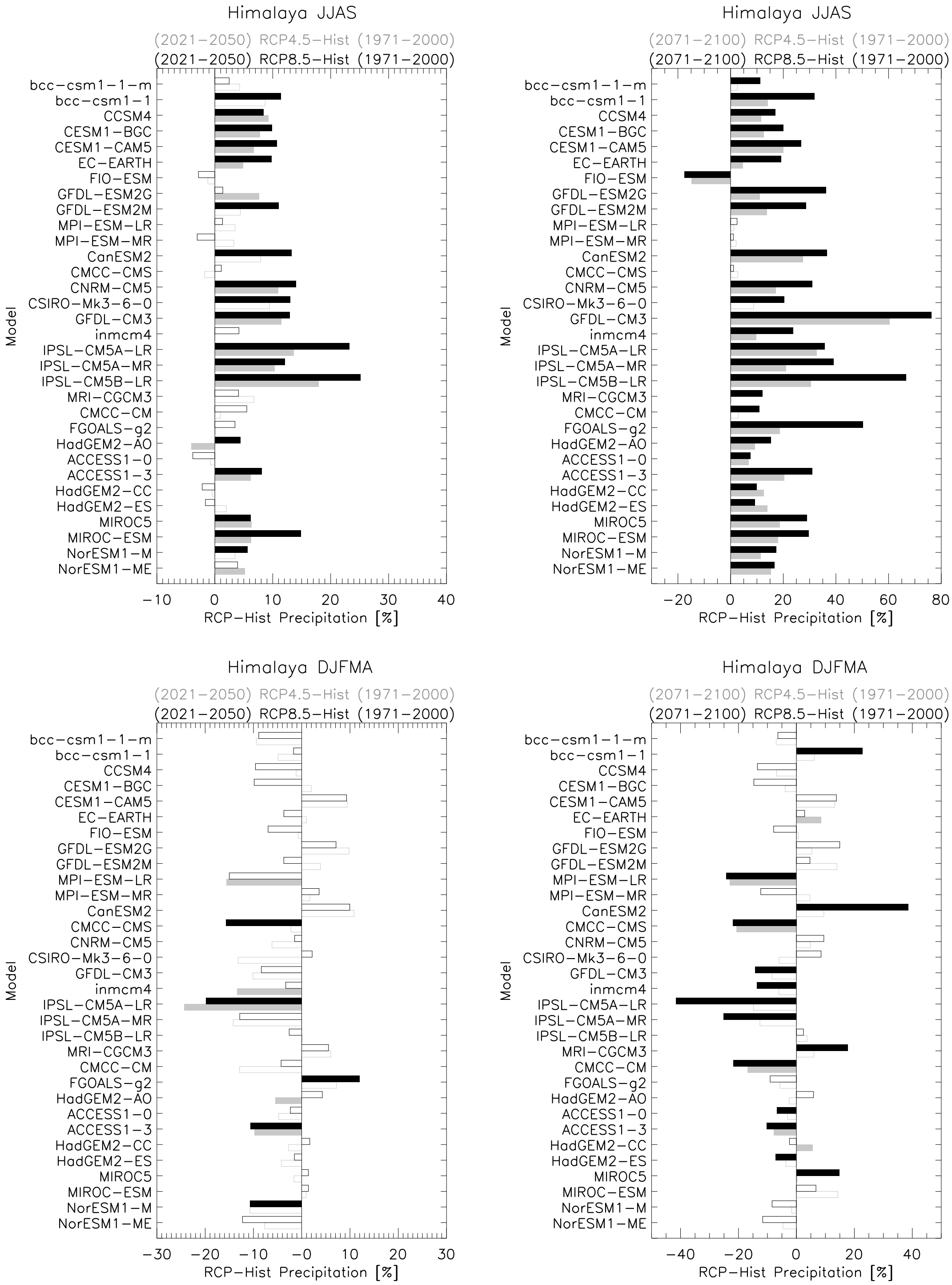

Fig. 3. Percentage change in summer (top) and winter (bottom) precipitation in the Himalaya in 2021-2050 (left column) or over the period 2071-2100 (right column) and the precipitation averaged over the historical reference period 1971-2000. For the models displaying statistically significant precipitation changes we use filled histogram.

The North Atlantic Oscillation (NAO) has been indicated as an important factor affecting winter/spring precipitation in the Karakoram region. Previous studies have indicated that winter precipitation and NAO are correlated with above (below) than normal precipitation over the HKK area during the positive (negative) NAO phase. The main goal of our research was to identify the synoptic-scale processes that are responsible for the observed correlation between NAO and winter precipitation in HKK. To this purpose, we used an ensemble of precipitation datasets, including three gridded archives based on the interpolation of in-situ rain gauge measurements (GPCC, CRU and APHRODITE), TRMM satellite observations and the ERA40 reanalysis.

First of all, we illustrate in Fig. 4 the space-time propagation of westerly systems showing, as an example, the meridionally-averaged daily precipitation for the 2001 winter season for TRMM (left) and ERA40 (right), plotted as a function of longitude and time. Precipitation is averaged over the latitude band from 30°N to 45°N, while longitude ranges from the Mediterranean basin to the HKK region. Western Weather Patterns appear as intermittent rainy systems propagating eastward, with alternating intensified and weakened precipitation, with a marked association with orographic features (see, for example, the intensified precipitation at about 50°E and 75°E, corresponding to the mountain regions of western Iran and the HKK, respectively). The figure also shows that the number of systems reaching the longitudes corresponding to the HKK region is higher during February-March than December-January and, as a consequence, conspicuous precipitation amounts in this area occur during late winter. The main features of WWP tracks are qualitatively captured by precipitation from TRMM and ERA40. TRMM shows slightly lower precipitation values over the Atlantic and higher values over the Mediterranean and the Middle East (up to about 50°E), while ERA40 shows a peak in total precipitation at HKK longitudes, between about 70°E and 80°E. This enhanced precipitation is not visible in the TRMM data, probably owing to the fact that the snow component of precipitation is neglected in the satellite estimates.

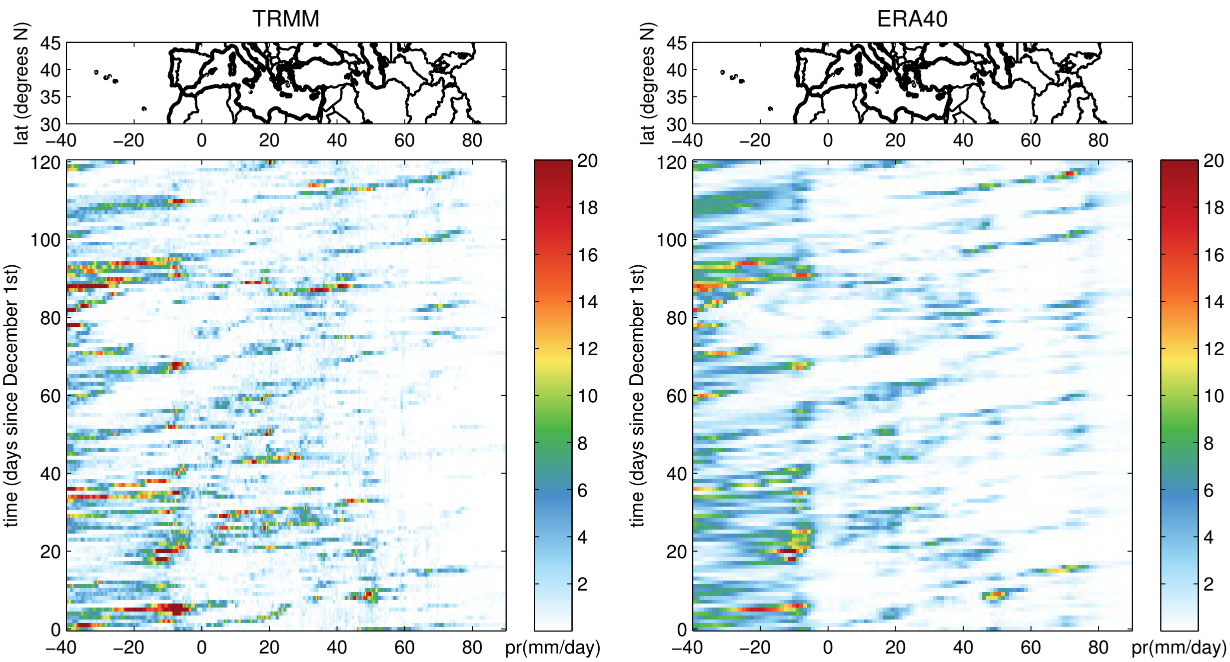

Fig. 4. Top: Maps showing the region considered in the analysis. Bottom: Daily precipitation in Winter 2001, from TRMM (left) and ERA40 (right) averaged over the latitudes from 30°N to 45°N, plotted as a function of longitude and time.

In Fig. 5 we show the correlation pattern (only statistically significant correlations are displayed) between the NAO and precipitation during Winter (December to March, DJFM), across a wide area covering both the Atlantic/European sector and South-East Asia, for the CRU, GPCC, APHRODITE and ERA40 datasets. Strong positive NAO phases tend to be associated with above-average precipitation over northern Europe in Winter, and below-average precipitation over southern and central Europe, while opposite patterns of precipitation anomalies are observed during strong negative NAO phases: this is the typical and well known European precipitation dipole associated with the NAO phases.

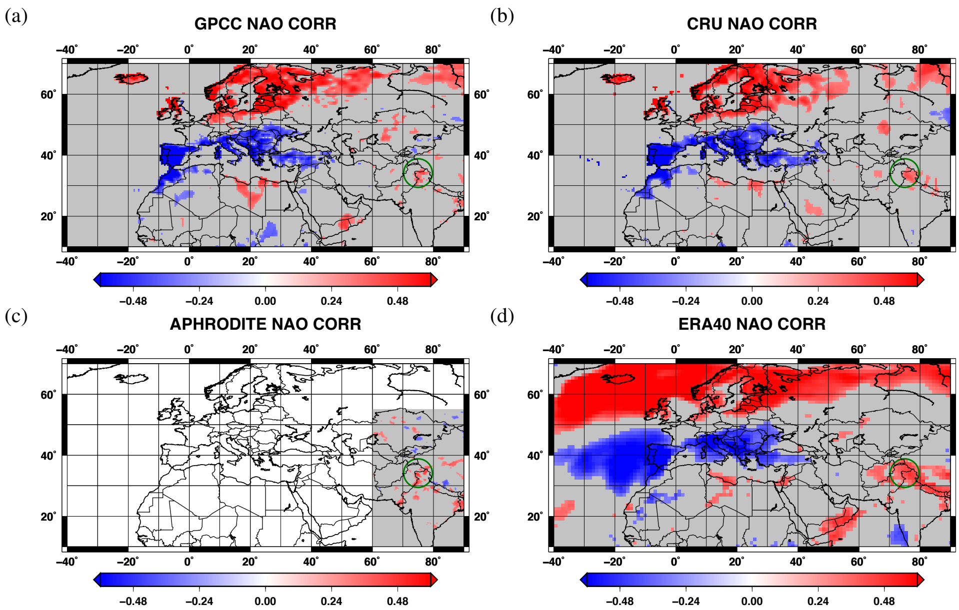

Fig. 5. Correlation coefficients between NAOI and winter precipitation from (a) GPCC, (b) CRU, (c) APHRODITE and (d) ERA40. Colours indicate statistically significant correlations at the 95% confidence level. Non-significant correlations are marked in grey. The green circle highlights the area of positive correlation centred on HKK.

Another area displaying statistically significant positive correlations in all datasets, though with some differences in spatial extent, is located at the border between north-eastern Pakistan and north-western India. Compared to the observation-based datasets shown in the figure, ERA40 exhibits significant positive correlations over a broader area encompassing central and northern Afghanistan and Pakistan, and the greater Himalayan chain. This could be due to a signature of the underestimation of total precipitation in the observations, leading to an underestimation of the significance of the NAO-precipitation correlation signal when using datasets based on gridded observations.

We used the ERA40 data to estimate the mean moisture transport in DJFM, integrated vertically from 250 to 1000 hPa, in order to identify the major sources of the humidity transported to the HKK region in Winter. The transport vectors superimposed on the spatial map of the significant correlations between the NAO and the intensity of moisture transport (the modulus of the transport vector) are shown in Fig. 6a. Moisture, originating mainly from the northern Arabian Sea and the Red Sea, is transported towards the HKK region through the Persian Gulf. The figure suggests that a comparatively smaller moisture contribution comes from the Mediterranean area, though, on average, moisture from the Mediterranean deviates north-eastward, mainly affecting the regions north of the HKK. The relatively small transport of Atlantic humidity over the Sahara region deviates southward before reaching the Red Sea, contributing minimally to the moisture channel from the Arabian area to the HKK region. Positive and negative NAO composites of moisture transport are shown in Figs. 6b and 6c: the main differences between the two pictures occur in the Mediterranean region, where the overall transport is weaker during the positive NAO phase. In this region, however, moisture transport has an important southward component during the positive NAO phase. As a result, a fraction of the Mediterranean humidity reaches the Arabian area and flows into the main moisture channel from there to the HKK. The intensity of moisture transport from the Arabian area to Pakistan is significantly larger during the positive NAO phase, consistently with the correlation analysis discussed above. The difference between positive and negative NAO composites of precipitable water obtained from ERA40, shown in Fig. 6d, is consistent with the considerations drawn for moisture transport. The Mediterranean region is characterized by a negative anomaly, which is mainly caused by the weaker advection of moisture from the Atlantic (Hurrell, 1995). Positive anomalies are instead found over the southern and south-western side of the greater Himalayan chain, a region located south of the area where significant NAO-precipitation correlations are found in ERA40. This supports the view that moisture transport during the positive NAO phase sustains wetter than normal conditions in this region, with a tendency of moisture to accumulate and to generate larger precipitation amounts over the slopes of the Himalayan range.

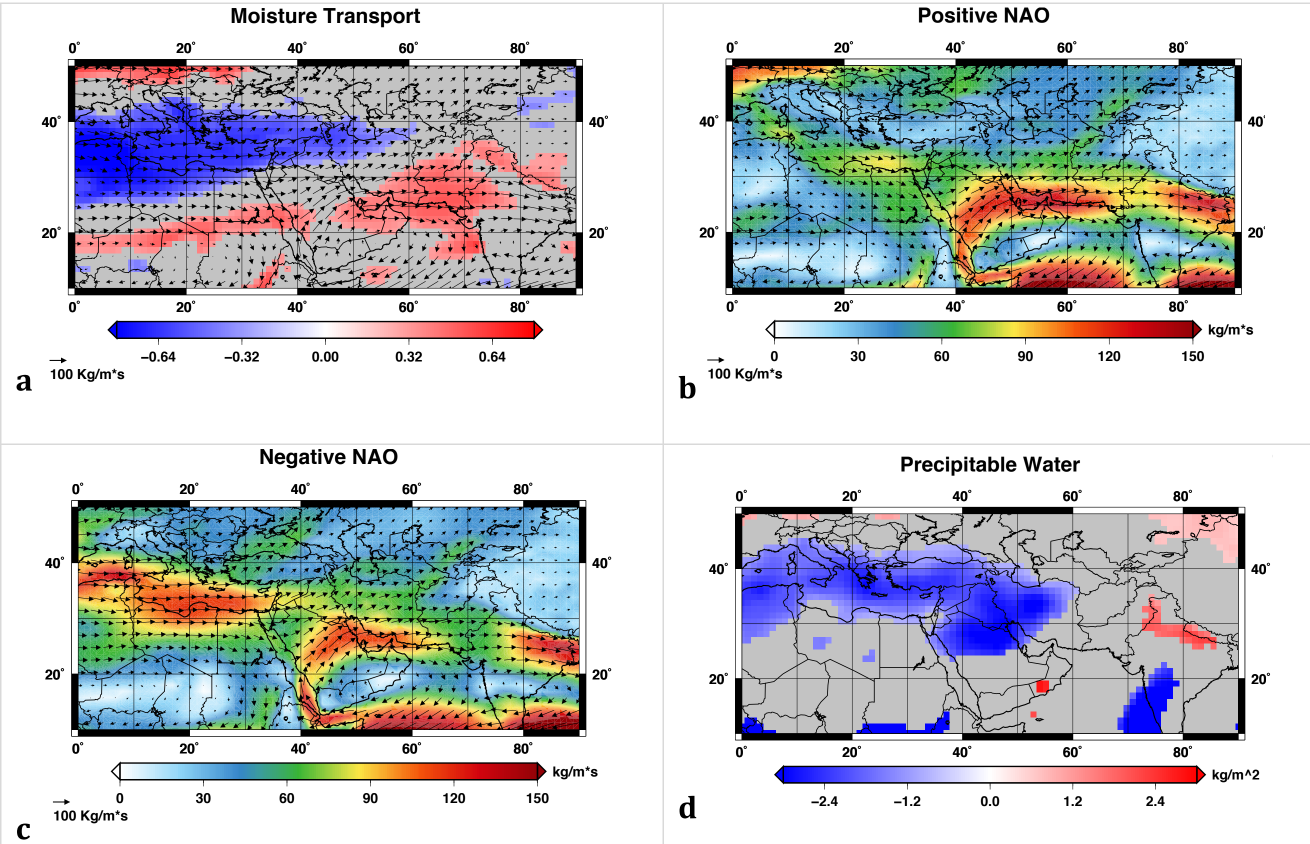

Fig. 6. a) Mean moisture transport during Winter (vectors) and correlation coefficients between NAOI and the intensity of moisture transport (colour map). Colours are used for statistically significant correlations at the 95% confidence level, grey indicates non-significant correlations. b) Composites of moisture transport (vectors) and intensity of moisture transport (colour map) for positive NAO winters. c) Same as b) for negative NAO winters. d) Difference between the positive and the negative NAO composites of precipitable water.

We tried to identify the processes associated with lower-tropospheric moisture transport. Since water vapour essentially resides in the lower troposphere below 500 hPa, the lower-level atmospheric circulation is expected to contribute significantly to the vertically integrated total moisture transport. Similarly to what shown in Fig. 6a for moisture transport, the mean DJFM wind fields at 775 hPa for the ERA40 reanalysis, superimposed on the spatial map of the significant correlations between the NAO and the intensity of 775 hPa winds (not shown here for brevity) highlight the role that the lower tropospheric circulation plays for the transport of moisture toward the HKK. However, wind is not the only variable influencing moisture transport. In Fig. 7 we show the difference between the positive and the negative NAO composites of evaporation: during the positive NAO phase, enhanced evaporation occurs from the Red Sea, the Persian Gulf, the northern Arabian Sea and the south-eastern Mediterranean. Moisture from these sources converges over the Arabian Peninsula and is transported towards Pakistan, giving a major contribution to atmospheric moisture in the HKK. The evaporation signal from the Red Sea, the Persian Gulf and the northern Arabian Sea is associated with coherent signals in surface wind speed and sea surface temperature (not shown here). During the positive NAO phase, ERA40 shows high surface wind speed over the Red Sea, the Persian Gulf, and the northern Arabian Sea, as well as high sea surface temperatures in a portion of the northern Arabian Sea, roughly corresponding to the area where the wind speed signal is not significant. Although it could be difficult to associate the surface wind anomalies with the changes in the upper level circulation, owing to the strong influence of surface conditions, a link between the two seems reasonable. Our results suggest that the dominant path through which the NAO could induce higher evaporation is the intensification of surface winds.

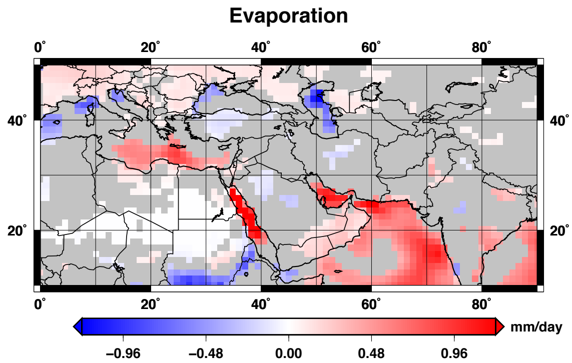

Fig. 7. Difference between the positive and the negative NAO composites of evaporation.

3.2 Applications; technological and computational aspects

During the second year, we did not produced new model simulations for the HKKH region with the EC-Earth Model, but used the EC-Earth Model (v2.3) outputs previously generated and analysed the CMIP5 Model outputs available at the Program for Climate Model Diagnosis and Intercomparison (PCMDI) web page (http://cmip-pcmdi.llnl.gov/cmip5/).

3.3 Formation

We are supervising the research program of a PhD student (Dr. Luca Filippi) working on the role of mid-latitude disturbances on winter precipitation in the Karakoram and the relationship between precipitation in the Karakoram and teleconnection patterns.

3.4 Dissemination

A seminar entitled “Precipitation in HKKH and Western Weather Patterns" was given by the person in charge of this Pilot Study in the framework of the “XXI Alpine Summer School” on “Climate Change and the Mountain Environment” organized by ISAC-CNR at Valsavarenche (AO) from June 18 to June 28, 2013.

3.5 Participation in conferences, workshops, meetings

The results of the research activities performed during the second year were presented at the following scientific workshops, conferences and other meetings:

E. PALAZZI, P. CRISTOFANELLI, A. A. TAHIR, E. VUILLERMOZ, P. BONASONI, and A. PROVENZALE: Climatic characterization of Baltoro glacier (Karakoram) and northern Pakistan from in-situ stations. *EGU 2013*, April, 07-12, 2013 (poster presentation) (Presentation of the results obtained during the first project year).

L. FILIPPI, E. PALAZZI, J. VON HARDENBERG, and A. PROVENZALE: Western weather patterns and winter precipitation in the Hindu-Kush Karakoram. *EGU 2013*, 7-12 April, 2013 (poster presentation).

FILIPPI et AL.: An application of the EC-Earth model to study the effects of the NAO on winter precipitation in the Hindu-Kush Karakoram. *International meeting with EC-Earth contributors/users* held in Lisbon, 16-17 April, 2013.

PALAZZI et AL.: Current and future precipitation in the Karakoram-Himalaya and the role of western weather patterns, at the *28th Himalayan Karakorum Tibet Workshop & 6th International Symposium on Tibetan Plateau 2013 (HKT-ISTP-2013)*, Tübingen, Germany, 22-24 August, 2013.

4. Results obtained during the reference period

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

We have analysed the monthly precipitation output of an ensemble of CMIP5 GCM simulations producing, for each model and for the multi-model ensemble mean (MMM), the following data (available as NetCDF files):

- Spatial average of monthly and seasonal (DJFMA, JJAS) precipitation over the HKK and Himalaya boxes. All spatial averages over the boxes were computed by weighting the original model grid values (at the native resolution) by the fraction of each grid cell with an elevation greater than 1000 m a.s.l. (to account for high-elevation areas only) and included inside a box, evaluated using the 1-km Digital Elevation Model from the Global Land One-km Base Elevation (GLOBE) Project (Hastings and Dunbar 1999).
- Monthly and seasonal precipitation for each pixel encompassing the HKKH range, at the native spatial resolution of the models

4.2 Publications

PALAZZI, E., J. VON HARDENBERG, and A. PROVENZALE (2013): Precipitation in the Hindu-Kush Karakoram Himalaya: Observations and future scenarios. *J. Geophys. Res. Atmos.*, 118, 85–100, doi: 10.1029/2012JD018697.

PALAZZI, E., J. VON HARDENBERG, S. TERZAGO and A. PROVENZALE: The CMIP5 picture of current and future precipitation in the Karakoram-Himalaya, in preparation for *Climate Dynamics*.

FILIPPI, L., E. PALAZZI, E., J. VON HARDENBERG, AND A. PROVENZALE: Synoptic control of winter precipitation in the Hindu-Kush Karakoram, in preparation for *Journal of Climate.*

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

- Spatial average of monthly precipitation over the HKK and Himalaya sub-regions, for each GCM and for the MMM.
- Monthly and seasonal precipitation over the HKK and Himalaya regions (pixel by pixel) at the original spatial resolution of the GCMs.
- Seasonal precipitation trends for each GCM and for their MMM, averaged over the HKK and Himalaya sub-regions

4.4 Completed Deliverables

The contribution to the Deliverable D2.6.2 has been completed.

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

We have not identified particular problems or significant deviations from the activities planned in the Executive Plan for the second year.

6. Expected activities for the following reference period

Future work will address the causes of the temporal variability of the NAO-precipitation correlation in the HKK and will consider its possible modifications in different climate change scenarios.

Pilot study 2.6c: Estimation of the changes in the hydrological cycle, snow cover and water availability in high altitude areas.
(Coordinator: Silvia Terzago, CNR-ISAC)

1. Scheduled activities, expected results and Milestones

This pilot study aims at estimating the climate change effects on the snow resources and the hydrological cycle in high altitude areas through the analysis and interpretation of the existing snow cover and snow depth data and the new data obtained during the project. A further aim is to study, develop and implement physical and dynamic snow models in order to obtain estimates of the recent and future changes in the persistence and depth of the snowpack in mountain areas.

2. Deliverables expected for the reference period

Deliverable D2.6.2: Report on the results of the second year.

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

3.1 Research activities

The aim of this Pilot Study is to provide projections of the snow characteristics (depth, water equivalent and extension of the coverage) in different climate change scenarios, using both Global Climate Models (GCMs) and Regional Climate Models (RCMs) nested in the global models. In order to achieve this goal, two different modeling approaches have been identified:

- We use the projections of the snow variables provided by a climate model: in this case the surface-snow module is interactive with the atmosphere and therefore the feedbacks of the snow cover changes on the climate (e. g. the snow-albedo feedback) are correctly represented.
- We use physical and empirical models (e. g. CH-TESSEL, UTOPIA, ETI, ACHAB-Snow, Geotop) in off-line mode, forced by the atmospheric variables produced by the climate models. In this case the effects of the feedbacks between soil and atmosphere cannot be represented but, on the other hand, it is possible to calibrate the snow models and presumably obtain a more reliable representation of the snow dynamics.

Regarding the first approach, i.e. the direct analysis of the snow projections provided by climate models, we considered the most up-to-date Global Climate Models output archive, the Coupled Model Intercomparison Project Phase 5 (CMIP5), freely available on the web http://cmip-pcmdi.llnl.gov/cmip5/. This archive provides, for each model, an ensemble of historical runs for the period 1850-2005 and the future projections for the period 2006-2100, in different climate change scenarios at global scale. Among all models, we selected those providing the variable "snow depth", thus 26 models out of the total. Their spatial resolution ranges between 0.75° and 2.8° longitude. For each of them we considered the area of the Hindu Kush Karakoram Himalaya (HKKH, Figure 1), which hosts the largest and highest mountain range in the world. This area has been subdivided into two climatically homogeneous sub-regions: 1) the Hindu-Kush-Karakoram (HKK) where precipitation is mainly due to the perturbations carried by westerly winds and occurs mainly in winter months, and 2) the Himalaya (H) where precipitation is related to the monsoons and therefore occurs mostly between June and September. As this study aims to explore snow characteristics at high altitudes we focused on the area higher than 1000 m above sea level.

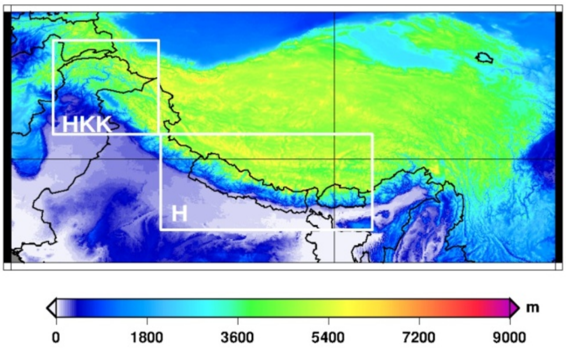

Fig. 1. Altitude in meters above sea level of the study area. The two sub-regions, Hindu Kush-Karakoram (HKK) and Himalayas (H) are highlighted by white boxes.

First, we examined how the Global Climate Models represent the thickness of the snowpack at monthly and seasonal scale in the HKKH region. In this area, the comparison between the models and the real characteristics of snow cover is limited by the almost total absence of observational snow depth data. We then used the ERA-Interim/Land reanalysis and 20th Century Reanalysis as a reference for the "ground truth". We found that the models with high spatial resolution (0.75-1.25°) are generally in better agreement with the reanalysis than those at lower spatial resolution. The former show a snow depth peak on the Karakoram area and decreasing values moving towards the Himalayas and the Tibetan plateau (Figure 2).

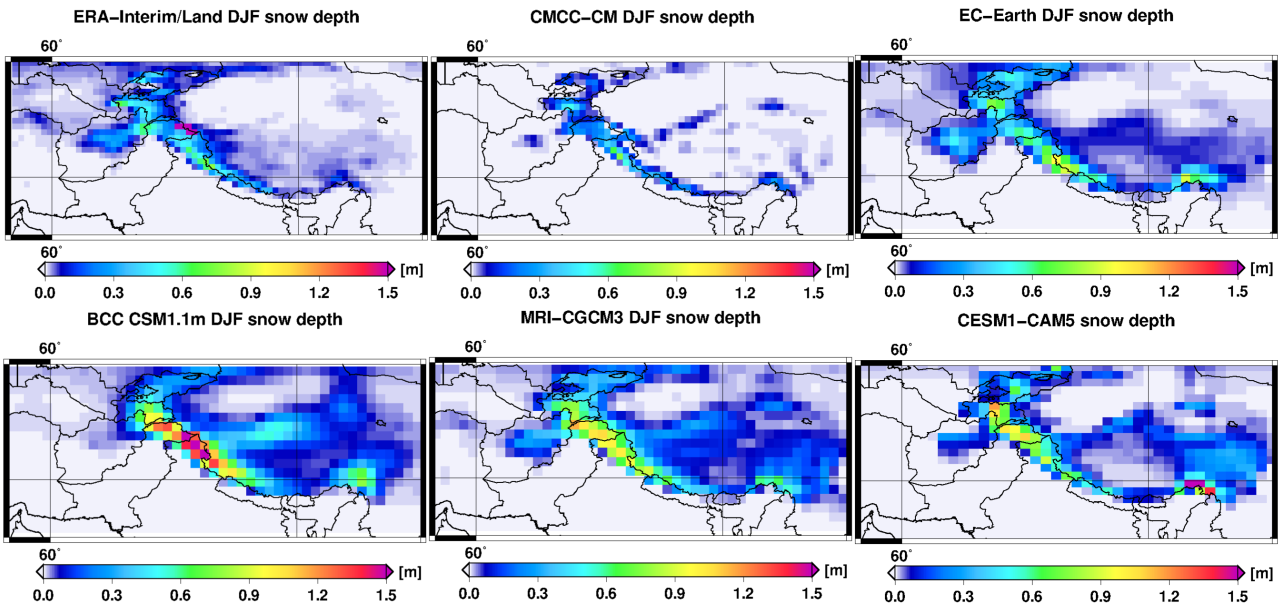

Fig. 2. Average winter snow depth in the Hindu-Kush-Karakoram-Himalayas according to the high resolution (higher than 1.25° longitude) Global Climate Models compared to the ERA-INTERIM/Land reanalysis.

The analysis of the GCMs' snow depth seasonal cycle (i.e. the evolution of the snowpack thickness during the period from September to August) shows a unimodal snow depth distribution with a maximum in February/March in both HKK and Himalaya regions, and, on average, an overestimation of the snow depth compared to the ERA-Interim/Land reanalysis, as well as a non-negligible spread among the models.

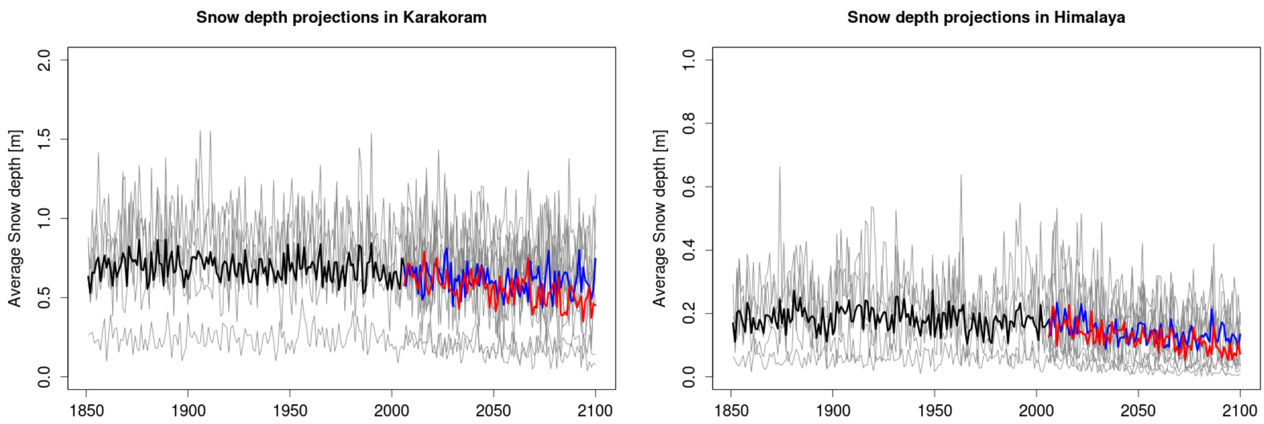

Fig. 3. Average thickness of the winter snowpack during the historical period 1850-2005 and the future projections until 2100 in the scenarios RCP4.5 (blue) and RCP8.5 (red) according to the high-resolution CMIP5 GCMs. The values refer to the areal average over the Hindu-Kush Karakoram (left) and the Himalaya (right) mountains above 1000 m a.s.l..

We assessed the interannual variability of the winter snow thickness in the historical period and the projections in the future scenarios of climate change RCP4.5 and RCP8.5 (Figure 3). The future climate projections indicate a significant decrease of snow depth ranging between 8% and 28% in HKK and between 30% and 50% in the Himalayas depending on the considered scenario, RCP4.5 and RCP8.5 respectively. In the Himalayas we expect also an earlier snow melting, starting in February instead of March, with possible consequences on the seasonal distribution of melt water in downstream regions.

The second research approach, as mentioned earlier, aims at representing the snowpack temporal evolution by means of several physical and empirical models forced by the atmospheric variables produced by the large-scale climate models. This approach allows to tune and to optimize the snow models to obtain more accurate performances, the drawback is that these simulations are performed in off-line mode, so the soil-atmosphere feedbacks are not represented.

Climate models provide meteorological variables at considerably lower spatial and temporal resolution compared to those registered by weather stations and generally used to validate snow models. So we analysed the reliability of the snow simulations depending on the "quality" and the spatial/temporal resolution of the meteorological input. In other words we carried out simulations with different types of input data with gradually decreasing quality, and in particular we analysed (i) the ideal case with high-quality and validated data registered in a fully instrumented weather stations, then (ii) the case of standard station data, consisting of the main meteorological variables (the other variables are estimated internally by the models' parameterizations), and finally (iii) the case of interpolated datasets with low spatial and/or temporal resolution and greater uncertainty in the measurements. The goal is to identify the models that provide the best estimates even if they are forced with input data at lower spatial resolution.

Through a collaboration with ARPA Valle d'Aosta we obtained the snow-meteorological dataset of the observation site of Torgnon. This site is fully equipped with up-to-date instruments such as the OTT rain-gauge and it is maintained in order to obtain reliable measurements. Torgnon is thus an ideal site providing high quality measurements.

We also considered snow-meteorological datasets collected in weather stations with standard instruments, such as Colle Bercia located at 2200 m above sea level and providing data since 2003. In such cases, a preliminary analysis was carried out to verify the data quality, in particular regarding precipitation measurements that are particularly critical at high altitude. We found that the reliability of the precipitation input is crucial to obtain a good estimate of the seasonal variability of the snow depth.

The two stations mentioned above have been used to test and compare two physical models: the University of Torino land-surface Process Interaction model in the Atmosphere (UTOPIA) and the Hydrology-Tiled ECMWF Scheme for Surface Exchange over Land (CHTESSEL).
Figure 4 (left) compares UTOPIA and CHTESSEL simulations of the snowpack evolution in Torgnon, and the observed data, recorded through an ultrasonic snow gauge. UTOPIA provides a good estimate of the snowpack characteristics, and its output is very close to the observations. CHTESSEL tends to underestimate the snow depth, mainly due to the excessive melting simulated at the beginning of the snow season. Figure 4 (right) shows the same plot for Colle Bercia station (2200 m a.s.l.). In this case the models adequately reproduce the snowfall and the melting processes but with a tendency to underestimate snowfall in the case of intense events.

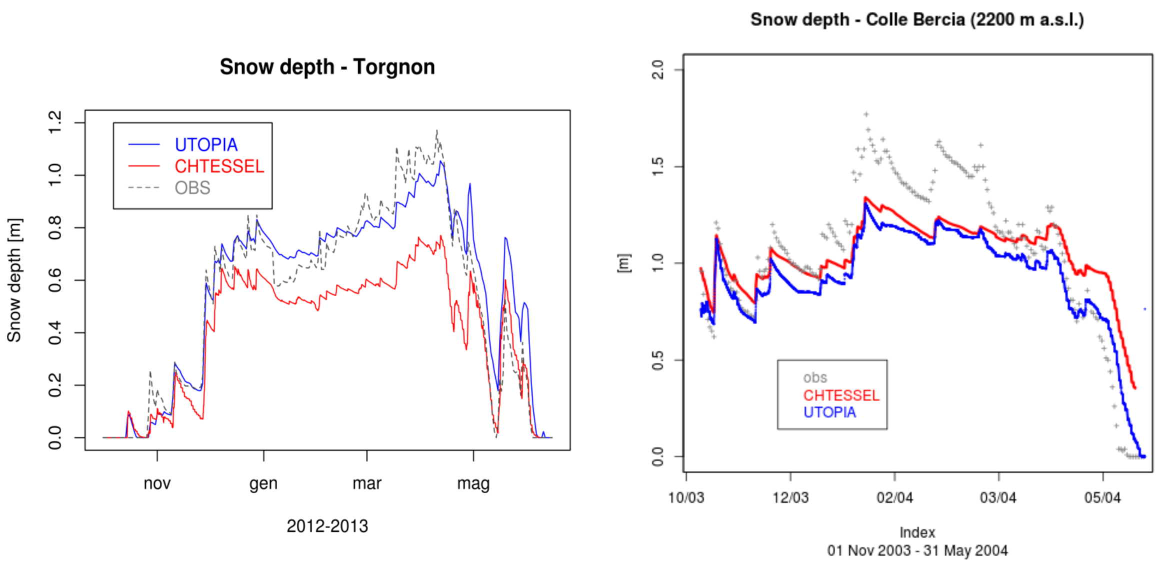

Fig. 4. UTOPIA (blue) and CHTESSEL (red) snow depth simulations compared to the observations (grey) in the stations of Torgnon (left) and Colle Bercia (right), located in the Aosta Valley and Piedmont Alps respectively.

The underestimation may be due to the fact that the amount of solid precipitation is determined from heated-rain-gauge measurements. This instrument is designed for measuring liquid precipitation and it tends to underestimate solid precipitation. In fact the resistor is not able to melt quickly enough the snow that then accumulates and obstructs the cup, producing a remarkable underestimation during intense events. Thus, the deviation between the simulations and the real snow depth may be partly due to the quality of the initial precipitation data rather than uniquely to an internal problem of the model. The total melting of the snowpack simulated by UTOPIA is 7 days delayed compared to the observations while CHTESSEL does not melt completely the snowpack.
These preliminary results show that the quality of the input data is crucial to obtain a good estimate of the seasonal variability of the snowpack, so it will be necessary to develop appropriate techniques for validation and correction of the measurements, in particular those of precipitation. This theme will be developed within the Special Project P2.

3.2 Applications; technological and computational aspects

The analysis, the comparison and the relative and absolute validation of both Global Climate Models and Land Surface schemes, with respect to their ability to represent the snowpack characteristics, have highlighted the strengths and weaknesses of each model. The results can be applied in the field of climate modeling, for improving and developing the parameterizations of the physical processes used within the models.

3.3 Formation

During the second year we organized two meetings with the developers of the CH-TESSEL and Achab Snow Models, at the European Centre for Medium-Range Weather Forecasts (ECMWF) in Reading and the CIMA Foundation in Savona respectively, in order to learn how to run such models. We also took part in the following schools:

- ECMWF Training Course 2013 "Parameterizations of subgrid physical processes", 22 April - 2 May, Reading (UK).
- XXI Alpine Summer School "Climate change and the mountain environment", Valsavarenche (Italy), 18-28 June 2013.

3.4 Dissemination

The results of this pilot study were presented during the XXI Alpine Summer School "Climate Change and the Mountain Environment" Valsavarenche (Italy), 18-28 June 2013.

3.5 Participation in conferences, workshops, meetings

The results of this pilot study were presented during the following national and international meetings:

Mountain Under Watch 2013: Observing Climate Change in the Alps, Forte di Bard, Aosta, Italy, 20-21 February.

International EC-Earth meeting, Lisbon, Spain, 16-17 April 2013.

European Geosciences Union General Assembly 2013, Vienna, Austria, 7-12 April 2013.

28° Himalayan Karakorum Tibet Workshop and 6th International Symposium on Tibetan Plateau Joint Conference, Tuebingen, Germany, 22-24 August 2013.

First Annual Conference of the Società Italiana per le Scienze del Clima: "Climate change and its implications on ecosystem services and society", Lecce, Italy, 23-24 September 2013.

4. Results obtained during the reference period

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

The data derived from processing the Global Climate Models outputs, the validated snow-meteorological datasets derived from the surface stations network, together with the results of the Land Surface models simulations, will be made available at the end of the analysis.

4.2 Publications

TERZAGO S., VON HARDENBERG J., PALAZZI, E., PROVENZALE, A.: Snow depth changes in the Hindu-Kush Karakoram Himalaya from CMIP5 Global Climate Models, submitted to *Journal of Hydrometeorology*.

TERZAGO S., VON HARDENBERG J., PALAZZI, E., PROVENZALE, A. (2013): Snow depth in the "Third Pole": how do CMIP5 models represent it? - *Proceedings of the First Annual Conference of the Società Italiana per le Scienze del Clima: "Climate change and its implications on ecosystem services and society"*, Lecce, Italy, 23-24 September 2013, , pp 110-118.

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

We stored in CNR-ISAC servers the following data:

- Snow depth simulations of all the Global Climate Models included in the CMIP5 experiment. The dataset cover the historical period 1850-2005 and future simulations for the period 2006-2100 under the two scenarios RCP4.5 and RCP8.5.
- ERA-Interim/Land reanalysis dataset and the 20th Century Reanalysis at global scale.
- Snow-meteorological dataset for the considered observation sites.
- Dataset of the simulated snowpack evolution obtained with CH-TESSEL and UTOPIA land surface models.
-

4.3 Completed Deliverables

Contribution to D2.6.2 with the results of the pilot study in the second year.

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

No deviations from the scheduled activity.

6. Expected activities for the following reference period

Simulations of Global Climate Models have low spatial resolution compared to the scale needed to study the effects of climate change in areas with complex terrain such as the Alps and the HKKH. In particular, the physical phenomena related to the hydrological cycle and the dynamics of the snowpack are typically characterized by scales of the order of few kilometres. We will study and apply both dynamic and stochastic downscaling techniques to reach resolutions comparable to those required for the description of such processes.

We will develop a modeling chain in which the output of Global Climate Model EC-Earth, currently available at CNR-ISAC, are dynamically downscaled to ~30 km resolution using different Regional Climate Models such as PROTHEUS, RegCM, WRF, etc. The obtained fields will be further downscaled to a scale of a few kilometres through statistical downscaling techniques (i.e. RainFARM) in order to produce high-resolution climate projections for high altitude areas.

Pilot study 2.6e: Multi-secular historical climate simulation for the Mediterranean area and comparison with paleoclimatic proxy data, to obtain a climatological history of Italy in the last one thousand years (Coordinator: Elisa Palazzi, CNR-ISAC)

1. Scheduled activities, expected results and Milestones

This report describes the beginning of the activities related to the pilot study "Multi-secular historical climate simulation for the Mediterranean area and comparison with paleoclimatic proxy data, to obtain a climatological history of Italy in the last one thousand years", part of the Work Package 2.6. As scheduled, we have performed a twofold activity. One has been focused on the identification and retrieval of a number of observed data that will be used to calibrate and validate the paleoclimate models/data, especially for the European/Italian region. The other has been focused on the identification and use of one climate model particularly suitable to perform paleoclimate simulations owing to its intermediate complexity. The first experiments performed with this model, outlined in this report and presented with more detail in the correspondent Deliverable, were aimed at reproducing the global climatic conditions occurred in the last ~150 years in response to the variable CO_2 forcing.

2. Deliverables expected for the reference period

Contribution to the project deliverable D2.6.2 with the results obtained during the first year of the pilot study: "Multi-secular historical climate simulation for the Mediterranean area and comparison with paleoclimatic proxy data, to obtain a climatological history of Italy in the last one thousand years".

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

Two main activities have been conducted during the second year in the framework of this pilot study. On the one side, we performed global simulations of the last 150 years climate with an Earth system model of intermediate complexity, the Planet Simulator (PlaSim). On the other side we identified, downloaded and began to analyse the available climate datasets useful for the calibration/validation of paleoclimatic data, in support to the activities of WP1.4, WP1.5 and WP1.6, focused on paleoclimatic reconstructions from marine and terrestrial archives and lake sediments. The research activities are summarized here below and better described in the Deliverable D2.6.2 associated to WP 2.6.

3.1 Research activities

a) Simulations of the last 150 years climate with PlaSim

The Planet Simulator (PlaSim) is an Earth system Model of Intermediate Complexity (EMIC) that was developed at the Meteorological Institute of the University of Hamburg and can be used to run climate and paleoclimate simulations for time scales up to 10 thousand years, due to its medium complexity and associated less intensive computing requirements.

Compared to other state-of-the-art EMICs (Claussen, 2002), PlaSim has a more complex atmospheric model (the Portable University Model of the Atmosphere, PUMA) based on the moist primitive equations conserving momentum, mass, energy and moisture and including,

as in the most comprehensive general circulation models (GCMs), all atmospheric processes, but with the limitation of less sophisticated parameterizations (Fraedrich et al., 2005).
The atmospheric model in PlaSim can be coupled to different ocean models besides using climatological sea surface temperatures (SST). These ocean models can be a mixed-layer ocean or the large-scale geostrophic ocean (LSG, Maier-Reimer et al., 1993). Besides the atmospheric and oceanic parts, a land surface model with biosphere and a module representing sea ice can also be included. A complete description of how the coupling between the various components is realized can be found in the PlaSim User Guide (http://www.mi.uni-hamburg.de/fileadmin/files/forschung/theomet/planet_simulator/downloads/PS_UsersGuide.pdf).

Before running PlaSim over paleoclimatic time scales, we decided to test the model ability in simulating the climate response to the CO2 forcing over the last ~150 years and, in particular, in reproducing the observed trend in temperature and changes in total precipitation from 1850 to 2005, which is commonly referred to as the "historical period" in the state-of-the-art climate model simulations. We tested different PlaSim configurations and spatial resolutions. We opted for including atmosphere-ocean coupling, testing both a mixed-layer (ML) approach and coupling with the LSG ocean model; we did not include vegetation and sea ice modules in this preliminary stage.
In particular, we run PlaSim at two horizontal resolutions, T21 and T42 corresponding to about 5.6° and 2.8° respectively. We performed two different kinds of climate simulations:

1. Perpetual runs, aimed at generating average climate conditions for two years, namely 1850 and 2005, representative of a different CO2 forcing, by running the model for 30 years (PUMA + ML at T21 and T42) and for 500 years (PUMA + LSG, at T21 only) by maintaining the appropriate CO2 forcing for 1850 (285 ppmv CO2) and for 2005 (379 ppmv CO2). We called these runs "Perpetual 1850" and "Perpetual 2005" simulations.

2. Transient runs, aimed at generating a multi-year historical simulation, using both ocean model configurations and both atmospheric resolutions, from 1850 to 2005 (156 years), using the historical atmospheric concentrations of CO2 available as global mean time series from the website at IIASA http://tntcat.iiasa.ac.at/RcpDb/.

The PlaSim outputs have been analysed in terms of

- Annual and seasonal time series of either global mean averages of surface temperature and total precipitation or averages over different latitudinal bands;
- zonal means of surface temperature and total precipitation;
- mean temperature and precipitation annual cycle;
- spatial maps of the multiannual mean of annual or seasonal surface temperature and precipitation.

We decided to focus our evaluation of the PlaSim simulations by comparing the model outputs mostly to the historical simulations from other state-of-the-art global models: 1) the EC-Earth GCM (Hazeleger et al., 2012) version 2.3, run at CNR-ISAC, and 2) an ensemble of Coupled Model Intercomparison Project Phase 5 (CMIP5) GCMs, available at the Program for Climate Model Diagnosis and Intercomparison (PCMDI, http://cmip-pcmdi.llnl.gov/cmip5/). In addition, we have used the GPCP observation-based gridded dataset for the precipitation comparison.
In this report we indicate with "EC-Earth 1850" or "EC-Earth 2005" the average output of two twenty-years long simulations performed with the EC-Earth model for the periods 1850-1869

and 1986-2005, respectively, to be compared with the “Perpetual 1850” and “Perpetual 2005” PlaSim simulations. We use the term “GPCP 2005” to indicate, in the same way, the average output of GPCP in the period 1986-2005.

As an example, Figure 1 shows the spatial maps of the multiannual mean annual temperature obtained from the perpetual 2005 PlaSim simulations (PUMA+ML at T21 and T42, PUMA+LSG at T21) and from the EC-Earth 2005 simulation. In order to better highlight the differences between the three PlaSim simulations and EC-Earth we show in Fig. 2 the spatial map of the temperature difference between EC-Earth and the three PlaSim outputs.

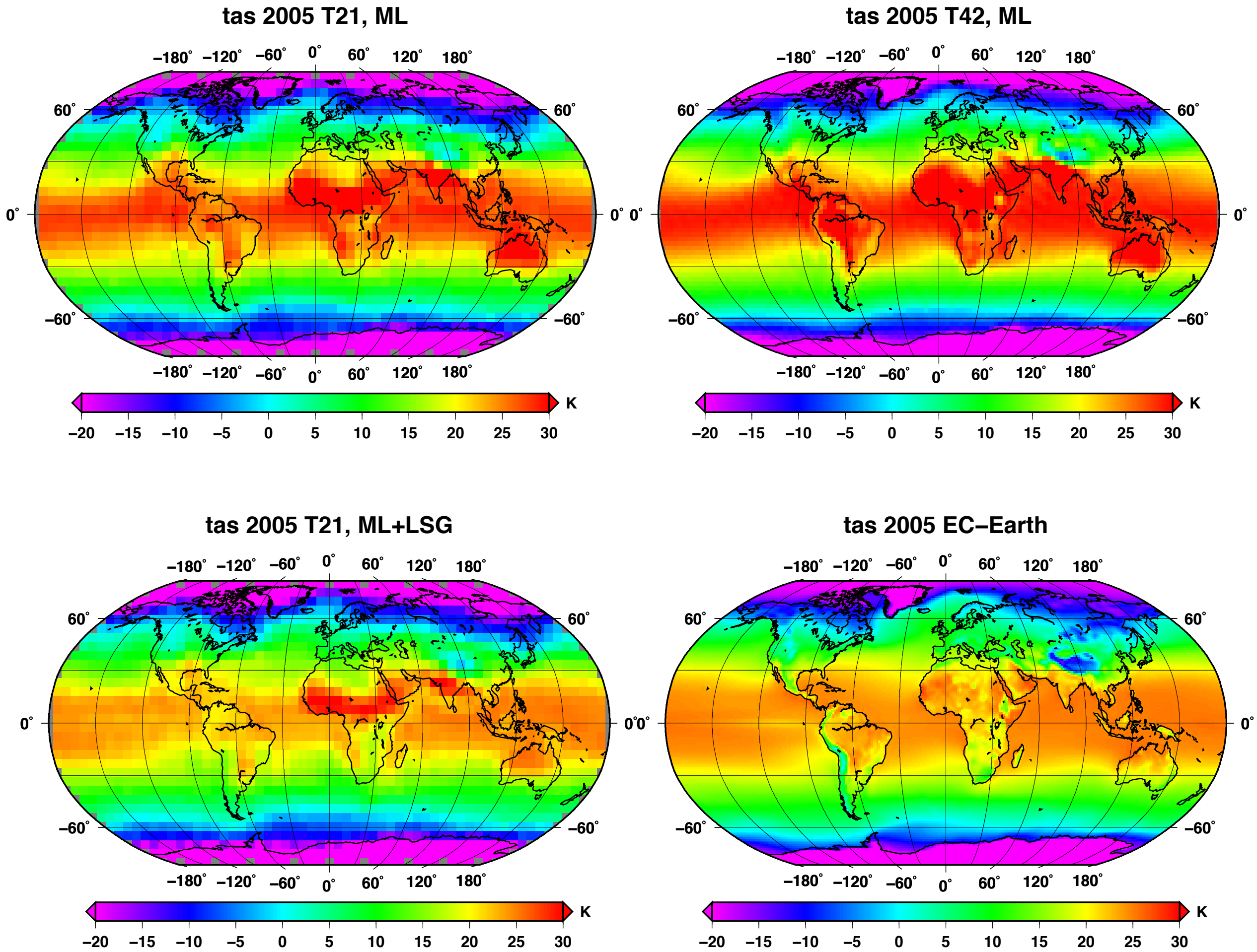

Fig. 1. Spatial maps of 2005 surface temperature obtained from the “perennial 2005” PlaSim simulation at T21 (left column) and T42 (top right panel) spatial resolutions, with PUMA coupled to the ML ocean (top panels) or to LSG (bottom left). The spatial map of the EC-Earth 2005 temperature (multi-annual mean average over the years 1986-2005) is shown in the bottom right panel for comparison.

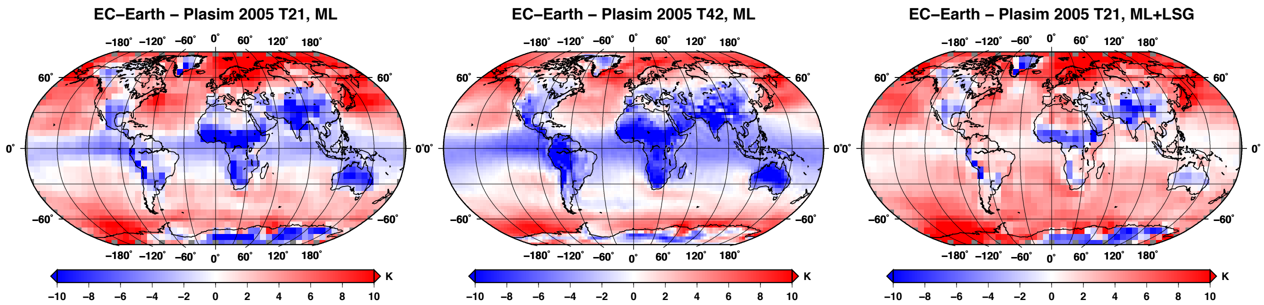

Fig. 2. Spatial maps of 2005 surface temperature difference between EC-Earth and Plasim (perennial 2005 simulation at T21, T42 with PUMA coupled to the ML ocean and at T21 with PUMA coupled to LSG, from left to right).

EC-Earth exhibits a cold bias with respect to the PlaSim-ML simulations at both resolutions in the equatorial and tropical oceans, the Australian continent, overall in Africa, South-America, the Middle-East, the Indian sub-continent and the Tibetan Plateau. On the contrary, a warm bias of EC-Earth relative to the PlaSim-ML simulation is found in the mid-latitude and polar oceans. Compared to the PlaSim-LSG simulation, EC-Earth exhibits overall a warm bias except over the Indian sub-continent, the high-altitude regions of the Third Pole Environment, the Andes, and central Africa.

Figure 3 shows the same as Figure 1 but for the precipitation; in this case we also show for comparison the GPCP 2005 precipitation map (bottom right panel).
The two PlaSim-ML simulations (first row) exhibit much higher precipitation amounts around the equator than EC-Earth and GPCP, and also relative to the PlaSim-LSG simulation. All PlaSim simulations (particularly those performed with PlaSim-ML) do not display the double ITCZ structure found in EC-Earth (and also reproduced by most state-of-the-art GCMs) and in the GPCP observations.

In order to better highlight the spatial distribution of the temperature and precipitation change between 2005 and 1850 conditions, we have analysed the spatial maps of the difference between 2005 and 1850 temperature and precipitation, for the three PlaSim simulations and for EC-Earth (we do not show the maps here, see the D2.6.2 Deliverable).
Positive temperature differences between 2005 and 1850 conditions are found in the three PlaSim simulations and in EC-Earth almost everywhere. However, with respect to EC-Earth, all PlaSim simulations exhibit warmer conditions in the oceans between 30°S and 30°N latitude. This is particularly true for the PLASIM-ML simulation at T42 which, however, does not reproduce the same Arctic warming in 2005 relative to 1850 as the other PlaSim simulations and as the EC-Earth simulation.

We further evaluate the PlaSim simulations by analysing their outputs in terms of zonal means of surface temperature and total precipitation and by comparing them to the EC-Earth and GPCP (for precipitation) outputs. In Fig. 4 we show the zonal means of total precipitation from the various datasets. None of the PlaSim simulations reproduces the double-peak precipitation structure in the tropics, associated with the double ITCZ, which is seen in the GPCP observations and in EC-Earth. Both simulations where PlaSim is coupled to the Mixed-Layer ocean tend to overestimate precipitation between 10°S and 10°N, while the PlaSim+LSG simulation gives precipitation amounts more similar to the observed ones and to the ones simulated by EC-Earth.

Finally, in Fig. 5 we provide an example of the globally-averaged temperature time series, from 1850 to 2005, obtained with the PlaSim-ML simulations at T21 (green line) and T42 (black line), PlaSim-LSG at T21 (red line), EC-Earth (blue line) and an ensemble of CMIP5 models (grey lines). As mentioned above, the figure clearly shows the coldest temperatures simulated by PlaSim coupled to LSG at T21. The PlaSim-ML simulation at T21 is also below the range simulated by the CMIP5 models (included the EC-Earth Model) and lower than the PlaSim-ML simulation at T42. The latter is indeed well inside the CMIP5 Model ensemble and produces, compared to EC-Earth (for which a cold bias is known to exist) more "realistic" global mean surface temperatures.

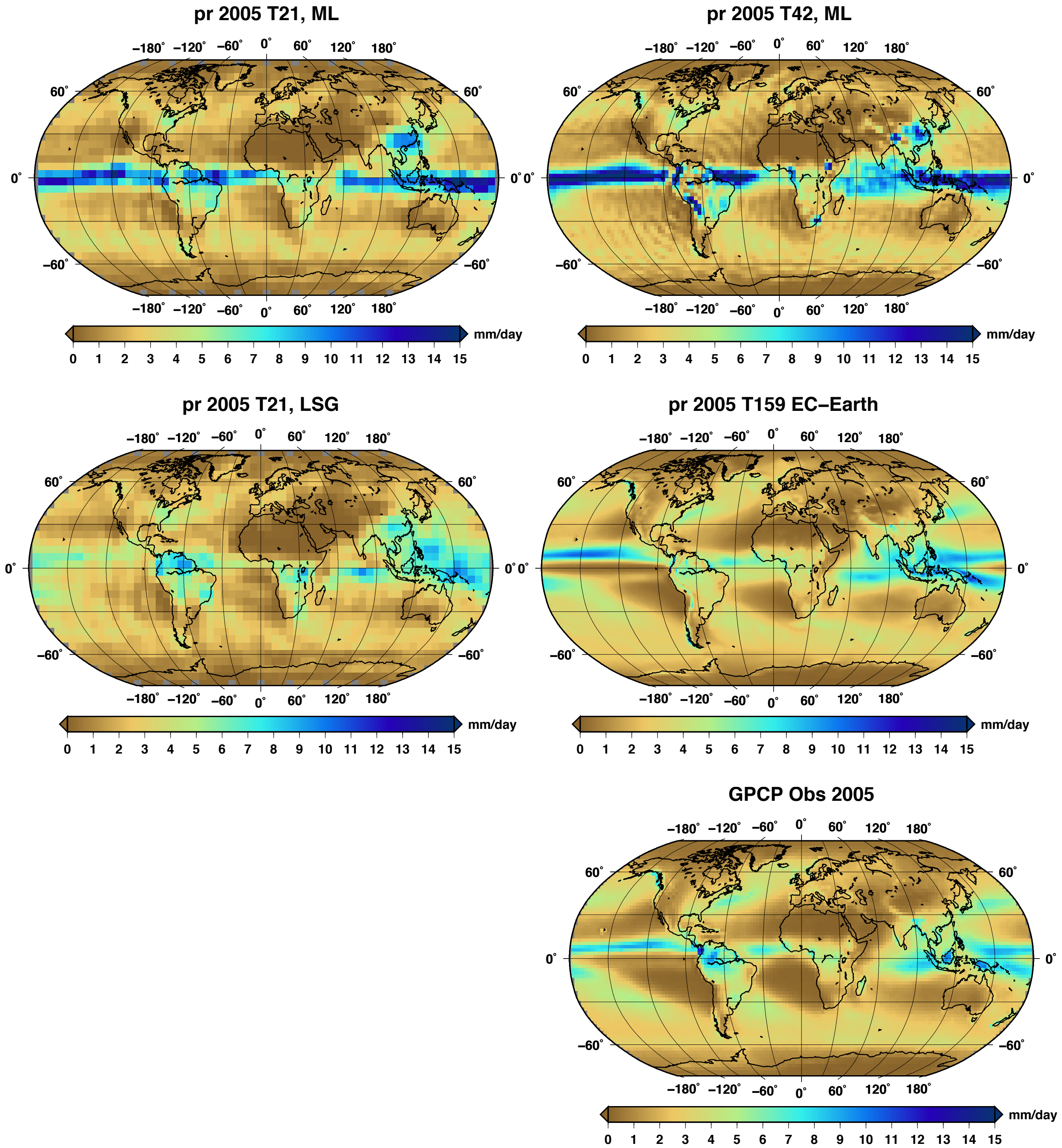

Fig. 3. The same as Fig. 1, but for total precipitation. The GPCP 2005 observation-based precipitation (2.5° spatial resolution) is also shown in the bottom right panel.

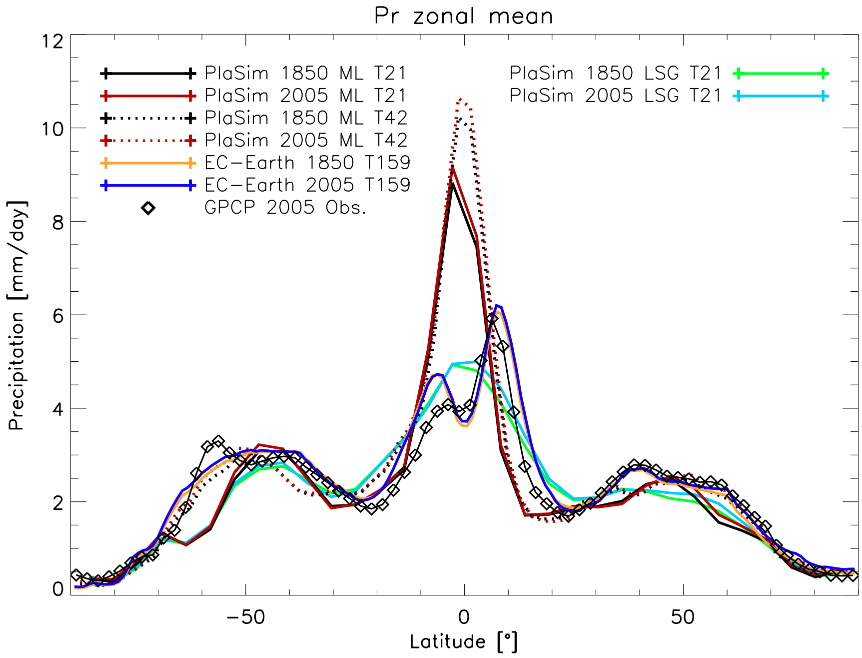

Fig. 4. Zonal mean plot of precipitation from the perennial Plasim simulations at the different resolutions and ocean model configurations, from EC-Earth and from GPCP 2005 data.

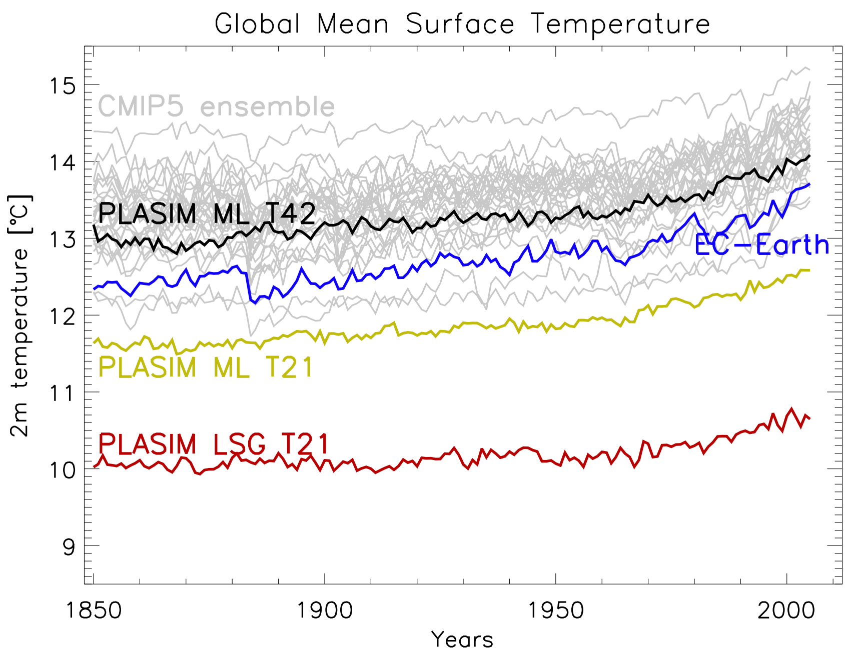

Fig. 5. Time series of global mean surface temperature from PlaSim (ML ocean), run at T21 (green) and T42 (black) resolutions, the EC-Earth model (blue) and the CMIP5 GCMs (light grey).

b) Climate datasets for the calibration/validation of Paleoclimate data

We have identified and collected the datasets that will be used to calibrate and validate the paleoclimate data. The variables of interest are (maximum and minimum) temperature and precipitation. Most datasets are based on the interpolation of station data, and sometimes they supply information on the underlying station data. Here below a list of the considered datasets.

- For the Greater Alpine Region (GAR): Alp_IMP, HISTALP, EURO4M-APGD

- For the European Sector: E-Obs

- For the globe: GHCN-CAM5, CRU_TS_32, GPCC,NO AA-CIRES-20C.

References

CLAUSSEN M., L. A. MYSAK, A. J. WEAVER, M. CRU- CIFIX, T. FICHEFET, M.-F. LOUTRE, S. L. WEBER, J. ALCAMO, V. A. ALEXEEV, A. BERGER, R. CALOV, A. GANOPOLSKI, H. GOOSE, G. LOHMANN, F. LUNKEIT, I. I. MOKHOV, V. PETOUKHOV, P. STONE, Z. WANG, 2002: Earth system models of intermediate complexity: closing the gap in the spectrum of climate system models*. Climate Dyn.* 18, 579–586.

MAIER-REIMER, E. MIKOLAJEWICZ U., and K. HASSELMANN, 1993: Mean circulation of the Hamburg LSG OGCM and its sensitivity to the thermohaline surface forcing*. J. Phys. Oceanogr.,* 23, 731–757.

FRAEDRICH K., E. KIRK, U. LUKSCH, and F. LUNKEIT, 2005: The Portable University Model of the Atmosphere (PUMA): Storm track dynamics and low frequency variability. *Meteorol. Zeitschrift,* 14, 735-745.

HAZELEGER W., WANG X., SEVERIJNS C., STEFAˇNESCU S., BINTANJA R., STERL A., WYSER K., SEMMLER T., YANG S., VAN DEN HURK B., VAN NOIJE T., VAN DER LINDEN E., VAN DER WIEL K., 2012: Ec-earth v2.2: description and validation of a new seamless earth system prediction model. *Clim. Dyn.* 39: 2611–2629, DOI 10.1007/s00382-011-1228-5.

3.2 Applications; technological and computational aspects

The intermediate complexity model PlaSim was installed and run and the generated outputs made available on dedicated archives for further post-processing.

3.3 Formation

Supervision of a Bachelor Thesis (at the University of Turin): "Climate Change as simulated by an Earth System Model of Intermediate Complexity", discussed in October 2013.

3.4 Dissemination

None in the reference period.

3.5 Participation in conferences, workshops, meetings

None in the reference period.

4. Results obtained during the reference period

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

Numerical simulations with the Earth System Model of Intermediate Complexity, PlaSim, run at different spatial resolution and different Ocean configurations. Perpetual simulations for two different years (1850 and 2005), characterized by different CO_2 forcing, and transient simulations have been performed.

4.2 Publications

None in the reference period.

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

Availability of the PlaSim temperature and precipitation outputs as NetCDF files. These files contain the global average and the average over different latitude bands of the two variables, in terms of annual, monthly, and seasonal means.

The following Temperature and Precipitation Datasets that will be used to validate/calibrate the paleoclimatic data, in support to the activities of WP 1.6 have been downloaded, preliminary post-processed and are available as NetCDF files: Alp_IMP, HISTALP, EURO4M-APGD (specifically for the Great Alpine Region, GAR), E-Obs (Europe), and GHCN-CAM5, CRU_TS_32, GPCC, NO AA-CIRES-20C (Global datasets).

4.4 Completed Deliverables

Our contribution to the Deliverable D2.6.2 has been completed.

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

We have not identified particular problems for the execution of the activities described in the Executive Plan for this Pilot Study. The modeling part has experienced a few deviations with respect to the original plans. In fact, once the model (PlaSim) to be used for performing paleoclimate simulations has been identified, as a first application we decided to test it over the last ~150 years rather than over the last millennium. On the other hand, this has allowed us to better explore the various model possibilities, in terms of coupling options and resolutions, and the parameter space. Such a knowledge will be useful for the prosecution of the activities and the use of PlaSim for performing longer simulations.

6. Expected activities for the following reference period

Multi-secular historical climate simulation for the Mediterranean area and comparison with paleoclimatic proxy data, to obtain a climatological history of Italy in the last one thousand years. For the model simulations, we plan to exploit both PlaSim (testing when possible other model configurations - for example incorporating the vegetation and sea ice modules – and coupling option), and the EC-Earth Global Climate Model (a fully coupled global climate model run at CNR-ISAC).

Pilot study 2.6f: Measurement and analysis of precipitation in high-elevation regions (Coordinator: Vincenzo Levizzani, CNR-ISAC)

1. Scheduled activities, expected results and Milestones

UR1 - CNR-ISAC. Development of the retrieval algorithm for snow cover and snowfall using passive microwave sensors on board NOAA and EUMETSAT satellites.
Milestone: 31/12/2013.

UR2 – ARPA-VdA. Production of meteorological datasets from two eddy-covariance and snow water equivalent (SWE) stations at high altitude in Valle d'Aosta.
Milestone: 01/07/2013.

UR3 – CIMA Foundation. Comparison of several physical and empirical snow cover models. Production of MODIS and H-SAF snow cover datasets over Valle d'Aosta and Piemonte. Collection of meteorological and snow data at Pian dei Corsi (900 m a.s.l.).
Milestone: none in the reference period.

UR4 - Polytechnic of Torino – DIATI. Validation and organization of the database of manual snow depth and density measurements. Modeling of the relationship between fresh snow SWE and ancillary variables and determination of the model uncertainties.
Milestone: 31/12/2013.

UR5 – Polytechnic and University of Torino – DIST – Flux measurements (water vapor and energy) on mountain slopes. Measurements of SWE and soil humidity using Time Domain Reflectometry (TDR) in different exposure conditions. Measurements of snow cover at high altitude. Investigations are carried out in cooperation with UR2 at high altitude in Valle d'Aosta.
Milestone: none in the reference period.

UR6 – University of Torino – Dept. Physics – Preparation of the meteorological database needed for running the UTOPIA model.
Milestone: 31/12/2013.

UR7 – University of Torino – Dept. Earth Sciences – Collection and analysis of homogeneous snow data from manual and automatic stations over long period (1961-2010). Preparation of datasets provided by the manual and automatic high altitude stations of the monitoring network of ARPA Piemonte. Snow cover estimates from satellite data will be provided.
Milestone: none in the reference period.

2. Deliverables expected for the reference period

UR1. Report on snow cover measurements using satellite sensors in the microwave.

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

3.1 Research activities

The research activities carried out during the reference period cover different aspects of the Pilot Project: datasets production, improvement of the retrieval models and tuning of numerical models.

UR2 worked on the preparation of datasets of meteorological measurements from the first of the two eddy-covariance stations of Torgnon (AO) and of SWE at high altitude in the Aosta Valley. These data represent a first and important contribution to the construction of a dataset of snow cover over the alpine region for climatology and hydrology applications. Their possible integration with the other data from Piemonte will provide to the project scientists a dataset of considerable length and high accuracy to be integrated with satellite data.

UR1 focused on the improvement of the Water vapor Strong Lines at 183 GHz (183-WSL) retrieval algorithm for precipitation and snow cover estimates. The activity mostly concerned the development of a new module for cloud classification based on sensitivity thresholds of microwave spectral channels. This new module improves the actual performance of the algorithm for precipitating cloud detection and snow covered terrain recognition. The validation activity planned in 2014 will further refine such approach through a comparison with ground based snow measurements.

UR3 has produced the snow cover dataset from MODIS and H-SAF satellite data and will be provided to the project during the first months of 2014. This product, together with in situ and helicopter measurements of UR2, will provide high resolution data of considerable length in order to start the verification of retrieval algorithms of snow cover (UR1) and the numerical model outputs (UR6). It will also represent a good basis for the model comparison that UR3 will conduct during 2014.

UR4 produced the fresh snow dataset at 65 stations at high altitude in the Aosta Valley and Piedmont together with in situ measurements of meteorological variables and snowpack characteristics. The dataset represents the basis for the studies in 2014 on the relationships between the characteristics of the snowpack and precipitating system structure.

UR5 has prepared the measurement site at Cogne (AO) to carry out ongoing measurements during the winter season 2013/2014. The measurements are performed using TDR (soil humidity and snow density), TIR (thermal infrared, soil and snow temperature) and eddy-covariance (sensible heat and vapor fluxes) techniques over very steep slopes highly exposed to solar radiation. Such measurements will allow for improvements of snow cover products in areas with considerable slope.

UR6 was active in two directions: a) preparation of input datasets for the UTOPIA model runs that will be used during 2014 over the areas covered by the project in the Aosta Valley, so as to make use of a homogeneous dataset over various stations in alpine areas, complete with the data necessary for the model runs, and b) verification of the parameterizations of the snowpack within the model (this activity was foreseen for a later stage in the project). Both the activities have not been completed yet, thus a slight delay of the first milestone and deliverable is foreseen for month 12.

UR7 has collected and climatologically analysed snow data from manual and automatic stations over long period (1961-2010) in Piedmont. In particular, the main activity concerned the quality control and homogenization of data to obtain reliable time series for the analysis of trends, climatic indexes and extreme events.

3.2 Applications; technological and computational aspects

None in the reference period.

3.3 Formation

No formation activity was planned in the reference period.

3.4 Dissemination

The NextSnow Project was presented at the meetings of the Global Energy and Water Exchanges Experiment (GEWEX). The project coordinator is a member of the GEWEX Hydroclimatology Panel (GHP, http://www.gewex.org/projects-ghp.html) within which a discussion is ongoing on the launch of a Regional Hydroclimatology Project (RHP) that will encompass various experiments on the water cycle in mountain regions: Himalaya, New Zealand, Colombian Andes, etc. NextSnow will represent a Pilot Project in this context bringing in science problems concerning the European alpine environment (Please note, however, that NextSnow is a Pilot Project funded for a very short period and thus, if Italy and CNR want to fully participate to the above mentioned GEWEX project, adequate funding needs to be ensured in order to enlarge the NextSnow temporal and spatial horizons).

3.5 Participation in conferences, workshops, meetings

AIGeo (Associazione Italiana di geografia fisica e geomorfologia) - V giornata nazionale dei giovani geomorfologi, Roma, 1-3 ottobre 2013.

ISSW 2013 - International Snow Science Workshop, Grenoble – Chamonix Mont-Blanc, 7-11 October 2013.

13th EMS / 11th ECAM, Reading, 9-13 September 2013.

4. Results obtained during the reference period

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

The project started in June 2013 and thus the first results are to be expected during the first semester of 2014. However, the Project URs have worked on the construction of datasets foreseen by the activities of the first year, in particular UR2, 3, 4 and 7. The datasets described in the paragraph 3.1 of the present report have reached a good level of maturity and will represent the basis of the activity during the next year of the project.

At the same time UR6 is now completing the input dataset for the UTOPIA model runs, an essential condition for the modeling activity in 2014.
UR1 has completed the improvements of the satellite-based microwave retrieval algorithm 183-WSL for the estimate of snow cover and snowfall.

4.2 Publications

ACQUAOTTA F., FRATIANNI S., TERZAGO S., FALETTO M., PROLA M.C. (2013): La neve sulle Alpi Piemontesi: Quadro conoscitivo aggiornato al cinquantennio 1961-2010. ISBN: 9788874791231, 97 pag.

COLOMBO N., FRATIANNI S., GIACCONE E., PARO L. (2013): Relationships among atmosphere-cryosphere-biosphere in a transitional glacial catchment (Sabbione Lake, North-Western Italian Alps). Proceedings ISSW 2013, pp. 1201-1207.

FRATIANNI S., TERZAGO S., FALETTO M., ACQUAOTTA F., PROLA M.C., BARBERO S. (2013): Snow climatological analysis and assessments of the extreme events in western Italian Alps. Proceedings ISSW 2013, pp. 1251-1255.

GARZENA D. (2013): Valutazione dei cambiamenti climatici sulle Alpi italiane nord–occidentali, attraverso l'uso di serie termometriche di lungo periodo 1961–2010. *Atti della v giornata nazionale dei giovani geomorfologi*. Aracne Edizioni, ISBN 978-88-548-6339-2, pp. 43-47, DOI:

10.4399/978885486339210.

GARZENA D., ACQUAOTTA F., FRATIANNI S. (2013): Assessment of climate change on North-West Italian Alps, through the use of long-term climatic series 1961-2010. *EMS Annual Meeting Abstracts,* 13th EMS / 11th ECAM, 9-13 September 2013, Reading.

TERZAGO S., FALETTO M., PROLA M.C., FRATIANNI S., CREMONINI R., BARBERO S. (2013): An innovative algorithm for unmanned validation of automatic snow depth measurements. Proceedings ISSW 2013, pp. 989-993.

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

Completed Deliverables

UR1. Report on the retrieval of snow cover from satellite microwave sensors (31/12/2013).

UR2. Dataset of high quality meteorological data at two stations at high elevation (Torgnon, Valle d'Aosta, 2100 m a.s.l.). Dataset of SWE over Valle d'Aosta (since 2005) (31/12/2013).

UR6. Input database for the snow cover model UTOPIA (31/12/2013, to be completed).

The other deliverables are expected in January 2014.

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

No significant differences between expected and completed activities are registered. However, please note that a certain level of difficulty was found in meeting the project deadlines. These difficulties are to be attributed to delays in funding availability and to bureaucratic burdens. In this sense, the groups have carried on their activities regardless of such difficulties and the coordinator wants to express a high degree of appreciation to each of the members of the project for their dedication.

6. Expected activities for the following reference period

The main activity in 2014 will focus on the using of the datasets made available during 2013 and their integration with other data that became recently available.

A meeting of all interested URs is being organized in February 2014 in Aosta in order to coordinate the handling of SWE and meteorological datasets over Valle d'Aosta made available by UR2, which coordinates the effort. These data will be the basis for validating the satellite retrieval products of UR1, for the model comparison of UR3, for the validation of fresh snow models of UR4, for the numerical modeling of UR6 and for the comparison with the products of UR7.
The 2014 activities can be summarized as follows:
UR1. Retrieval of snowfall using the 183-WSL algorithm over the western Alps and comparison with data over complex terrain. Verification of the satellite-based microwave snow cover product with data available within the project.
UR2. Increase the spatio-temporal coverage of the dataset over the Aosta Valley in terms of ground data and satellite data (MODIS). Snow cover modeling.
UR3. Experiment on comparing empirical and physical models of snow pack evolution over the Torgnon site in the Aosta Valley. Delivery of satellite measurement dataset from the MODIS sensor. Collection of meteo-hydrological data at the station of Pian dei Corsi.
UR4. SWE reconstruction for automatic measurement stations (equipped with a nivometer). Construction of a dataset of fresh snow SWE measurements over the western Alps.

UR5. Continuing measurement campaigns at high altitude and in different conditions of exposure to the solar radiation. Construction of the datasets.
UR6. Optimization of the UTOPIA mModel in terms of parameterizations of the snow cover (multi-layer coverage, slope, wind effects, others).
UR7. Continuing the collection and analysis of time series and datasets of snow cover and snowfall over the western Alps.

Pilot study 2.6g: Database for reconstructing the spatial-temporal evolution of the Glacial Resource in the Italian ALPs over the last 100 years in the Framework of the NextData Project (DATAGRALP) (Coordinator: Marta Chiarle, CNR-IRPI)

1. Scheduled activities, expected results and Milestones

The scheduled activities of the DATAGRALP Special Project, for the reporting period, consisted in:

- design and development of an integrated system for the management of numerical, textual, iconographic and geographic data related to the Italian glaciers. The system consists of a server-side database (PostgreSQL+PostGIS) connected to a web interface and to a GIS (QGIS). The system is developed using open source applications according to the GeoNetwork architecture of the SHARE Project, in coordination with the working group that will develop and manage the Portal of the NextData Project;
- completion of the list of multitemporal spatial data to be used by the participants to the project in charge of GIS activities;
- beginning of the acquisition phase of the main morphometric parameters of the Italian glaciers, for three specific time steps, to be performed in parallel for the three alpine sectors (Western, Central and Eastern Italian Alps): this phase was planned to take start with the drawing of glacial limits updated to 2006-2007 (from orthophotos accessible via WMS services of the National Cartographic Portal) and with the completion of the related attribute table.

The expected results in relation to this first part of activities were as follows:

- development of the integrated system for the management of the information on Italian glaciers in "beta testing", with the possibility to access the system from several work stations through a common web browser;
- list of multitemporal spatial data to be used by the participants to the project in charge of GIS activities;
- beginning of the acquisition phase of the main morphometric parameters of the Italian glaciers, starting from the outline of glacier extent in 2006-2007, and data enter into the system.

Milestones:

- On-line placing of the integrated system for the management of numerical, textual, iconographic and geographic data related to the Italian glaciers, in order to make it available to the participants to the project in charge of data entry.
- Completion of the list of multitemporal spatial data to be used by the participants to the project in charge of GIS activities.

2. Deliverables expected for the reference period

An integrated system for the management of numerical, textual, iconographic and geographic data related to the Italian glaciers, consisting of a server-side database (PostgreSQL+PostGIS) connected to a web interface and to a GIS (QGIS). The system has to be developed using open source applications and in coordination with the working group that will develop and manage the Portal of the NextData Project, and in agreement with the GeoNetwork architecture of the SHARE Project.

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

3.1 Research activities

The activities actually carried out during the reference period correspond to the activities scheduled for the same period:

- design and development of the integrated system for the management of the information related to Italian glaciers, which is the first Deliverable of the project. Particular attention has been devoted to the identification of low cost technological solutions, through a careful analysis of the most reliable free open source software for the management of information systems (database and GIS): the aim was to identify the best solutions for the needs of the project, in particular to ensure full interoperability between the system developed within DATAGRALP, on one side, and the portal of SHARE-NextData GeoNetwork, on the other side. The system has been installed on the server of CNR-IRPI-Turin and consists of a server-side database (PostgreSQL) in which the PostGIS extension was loaded, which is essential for the management of geographic data. Geographic data are produced and validated by means of a Geographic Information System client side, which is also free open source (QGIS), and then entered into the database using a simple procedure of file import (spit). The system, composed of PostgreSQL, PostGIS and QGIS, has been connected to a website, which has also been realized by means of free open source software (Apache http server, PHP). The website is already accessible, following a request of authentication, at the address http://dbirpi.to.cnr.it/datagralp/index.php (Figure 1).
  Data entry carried out up to now concerns the information necessary for the completion of the phase of "beta testing" of the system and more specifically: i) list of codes and names of glaciers, according to the Italian Glaciers Inventory (CNR-CGI, 1961-1962), ii) lists of terms describing the morphological characteristics of glaciers, as listed in the World Glacier Inventory; iii) list of mountain ranges, according to the traditional classification; iv) list of mountain ranges, according to the SOIUSA classification; v) lists of typologies related to the management of the information on glaciers, on changes in front position, on mass balances and on the attachments.
  From the early stages of database design, the persons in charge of the management of the SHARE GeoNetwork portal have been contacted, in order to ensure the interoperability of the two systems and to define appropriate hierarchies and types of metadata.
  Considered that, in order to achieve the objectives on schedule, data acquisition is carried out in parallel in the three alpine areas (Western, Central and Eastern Italian Alps), a set of documents of reference has been prepared to guarantee the homogeneity of data entered into the system; these documents include: i) definitions of the database fields and guidelines to data acquisition, ii) template shape files (areal, linear and punctual) for storing data in a GIS.
- Compilation of the list of multitemporal spatial data to be used by the participants to the project in charge of GIS activities.
- Start of the acquisition activity of the main morphometric parameters values of the Italian glaciers for 3 temporal steps, which began with the outline, from

orthophotos, in a GIS environment, of glaciers in 2006-2007 and with the completion of the related table of attributes.

The achievement of the objectives set for the reference period was possible thanks to the close cooperation among project partners, developed through a number of meetings, video conferences and constant e-mail exchange. The NextData Project coordinator and the responsible of the SHARE-GeoNetwork Portal were actively involved in the project. The contents of the most important meetings are summarized in the minutes and reports.

3.2 Applications; technological and computational aspects

Development of an integrated system for the management of the information related to the Italian glaciers. It can be accessed (under authentication) at the web address http://dbirpi.to.cnr.it/datagralp/index.php (Figure 1).

Fig. 1. Web interface of the Information Management System implemented within DATAGRALP.

3.3 Formation

During the reporting period, the following formation activities were carried out: two projects of formation and orientation have been activated, that involved two students enrolled in the BSc in Computer Science (Systems and Networks) for the duration of 4 months/person. The training project was titled "Design and implementation of a server-side database for an integrated and interoperable management system of information related to the alpine glaciers".

Concerning glaciological themes, three scholarships have been activated on the topic "Acquisition and processing of information relating to the glaciers of the Alpine sector: 1)

Piemonte-Valle d'Aosta, 2) Lombardia, 3) Triveneto" and one research grant on the topic "Tools and methods for the treatment of multi-temporal glaciological data in digital format".

3.4 Dissemination

The activities of the DATAGRALP Project have been presented in the following occasions:

- Annual Meeting of the Italian Glaciological Committee, Milan, 13 December, 2013;
- annual Meeting of the Cabina di Regia dei Ghiacciai Valdostani, Courmayeur, 29 November, 2013;
- general meeting of the NextData Project, Rome, 12 November, 2013.

3.5 Participation in conferences, workshops, meetings

No participation in conferences for the DATAGRALP Project in the reference period.

4. Results obtained during the reference period

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

The results obtained so far correspond to those expected for the reference period, as listed below:

- development of the management system of the information in "beta testing", available upon request of authentication at http://dbirpi.to.cnr.it/datagralp/index.php, and preparation of the documentation and guidelines for the successful implementation of the database;
- definition of multi-temporal data sets necessary for the subsequent activities;
- start of the acquisition activity of the main morphometric parameters values of the Italian glaciers, beginning with the outline, from orthophotos, in a GIS environment, of glaciers in 2006-2007 and with the completion of the related table of attributes.

4.2 Publications

None in the reference period.

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

No data available, because the data are being acquired and validated.

4.4 Completed Deliverables

Integrated system for the management of numerical, textual, iconographic and geographic data related to the Italian glaciers, consisting of a server-side database (PostgreSQL+PostGIS) connected to a web interface and to a GIS (QGIS). The system has been developed using open source applications and in coordination with the SHARE-GeoNetwork/NextData Portal.

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

Nothing to report.

6. Expected activities for the following reference period

The activities planned for the period 01/01/2014 - 31/12/2014 are:

- continuation of the Italian glaciers outline in 2006-2007;
- continuation of the compilation of the datasets of the main morphometric parameters of Italian glaciers, for three specific times (50s, 80s, 2006-07);
- supply the data input for the information management system;
- connection of the system with the SHARE-GeoNetwork/NextData Portal;
- activation of flows of validated information to the SHARE-GeoNetwork/NextData Portal, to be implemented at time intervals, according to the needs of the NextData Project.

Pilot study 2.6h: High-resolution climatological information for mountain areas for a 30-yr reference period (Coordinator: Michele Brunetti, CNR-ISAC)

1. Scheduled activities, expected results and Milestones

The activity planned for the first reporting period of the project is aimed at the realization of an inventory of monthly precipitation and temperature data available in digital form for the Italian Alpine region and surroundings. These data are the base for the realization of a 1961-1990 climatology at 30 arc-second of resolution for the Italian Alpine territory above 1500 m of elevation and for the construction of monthly data sets (at the same spatial resolution) for three case study areas (Gran Paradiso National Park, Stelvio National Park, Paneveggio and Pale di San Martino National Park) spanning the last decades. The availability and accessibility of these data shall be evaluated too.

Besides the data already available in digital form (to be found mainly in the archives of the regional environmental protection agencies of the regions belonging to the Alpine area), the necessity of new digitalizations will also be evaluated.
In addition to termo-pluviometric data, a set of pluviometric observations referred to very remote areas will be recovered by digitalizing some "nivo-pluviometric totalizer" data measured by the former National Hydrographic Service between 1920s and 1970s.
Besides the data required for the climatology construction, particular attention will be given to the recovery of long temporal series that will be used for the construction of the temporal component. To obtain a fruitful reconstruction of past climate variability for the three study areas and to provide, at the same time, an instrument useful also for future applications, it is necessary to realize a data set with the possibility to periodically update it in the future. To do this, it will be necessary to merge the former Hydrographic Service network (unfortunately abandoned in most regions) with the new regional networks.

2. Deliverables expected for the reference period

No Deliverables were planned for this first activity period.

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

3.1 Research activities

The research activity during 2013 focused on the inventory of monthly temperature and precipitation data already available in digital form for the Alpine region. These data will constitute the bases for the construction of the 1961-1990 30 arc-second climatology and the monthly data sets for the three study areas.

The three study areas have been identified in the Gran Paradiso National Park, Stelvio National Park, Paneveggio and Pale di San Martino National Park (the latter already defined in the proposal). The activity focalized to rescue the as long as possible temperature and precipitation series was focalized on these three areas to integrate the data already available in our archive.
Besides the data already available in digital form (to be found mainly in the archives of the regional environmental protection agencies of the regions belonging to the Alpine area), we also started a digitization activity with the aim of recovering a set of pluviometric

observations referred to very remote areas by digitalizing some “nivo-pluviometric totalizer” data measured by the former National Hydrographic Service between 1920s and 1970s. These data should be less biased by wind in snow and precipitation measurements.

3.2 Applications; technological and computational aspects

This research activity will lead to the realization of a database which will constitute the base for the application of the algorithm we realized for the construction of the high-resolution climatologies for the Italian Alpine area that, together with the interpolation of the anomalies of the longest temporal series that will be recovered (and that will be preventively homogenized), will permit the realization of the high-resolution data sets for the three study areas.

3.3 Formation

A one-year (extendible up to three years) research assistant contract started on 20 November 2013. The selected researcher was subsequently admitted (without grant) to the doctorate school in Models and Methods for Material and Environmental Sciences (XXIX cycle Academic Year 2013/2014) at the Modena and Reggio Emilia University.

3.4 Dissemination

During the first year of activity, the pilot study objectives and structure have been officially presented at the NextData Meeting held in Rome on July 18, 2013 (focused on the Paleoclimate research in NextData) and at the general NextData Meeting held in Rome on November, 12, 2013). The project objectives have been also presented to the Lombardia and Valle d’Aosta ARPA personnel involved/interested in these project topics.

3.5 Participation in conferences, workshops, meetings

“Paleo” NextData Meeting (18 June 2013).

General NextData meeting (12 November 2013).

4. Results obtained during the reference period

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

Activities are still in progress and, despite the delay in funding, the data inventory (the first planned deliverable) will be provided within February 2014 as planned in the proposal plan. The delay in the release of funds caused a delay in the signature of the agreement with the University of Milan, in charge of realizing a part of the archive, and in the call for an open position as research assistant (planned starting date for the contract 1st September 2013, actual starting date 20 November 2013).

4.2 Publications

None in the reference period.

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

None in the reference period.

4.3 Completed Deliverables

None in the reference period.

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

The delay in the release of funds caused a delay in the signature of the agreement with the University of Milan and in the call for an open position as research assistant: planned starting date for the contract 1st September 2013, actual starting date 20 November 2013.

6. Expected activities for the following reference period

We plan to conclude the inventory of monthly temperature and precipitation data available in digital form for the Italian Alpine area and surroundings. This will lead to the achievement of the objectives of Deliverable 1.1. (Inventory (table list) of monthly temperature and precipitation data available in digital form for the Italian Alpine area and surroundings) planned for month 9 (February 2014).

The quality control phase will then start: all the data will be checked for quality and consistency as far as their geographical location is concerned. Such checks will be performed by comparing each site's elevation with that of a 30-arc-second digital elevation model. This detailed data verification, though extremely time consuming, is very important to enhance the reliability of the stations elevation, as incorrect elevation values can introduce significant errors in the estimation of the relation between the meteorological variable and elevation, which represents the key-point of the model for the construction of high-altitude climatologies.

Finally, for all the available stations, the 1961-1990 monthly normals will be extracted (the choice of the 1961-1990 period is suggested by the wider data availability in that 30-year time window for Italy). This will lead to the achievement of Deliverable 2.1. (Registry (table with data) of stations' monthly climate normals (referred to 1961-1990), geographical coordinates and associated geomorphological parameters) planned for month 12 (May 2014).
The longest series, useful for the reconstruction of the temporal component, will be subjected to additional quality controls to ensure their homogeneity and, if necessary, they will be homogenized.
This will lead to the achievement of Deliverable 2.2. (Metadata (coordinates and quality flags) of long series that will be involved in the reconstruction of the temporal component) planned for month 15 (August 2014).

The activities aimed at the realization of the climatologies will then start.