Project of Strategic Interest NEXTDATA

Scientific Report for the reference period **01/01/2012-31/12/2012**

WP 2.6: Portal for access to data and pilot studies on data use (resp. A. Provenzale, CNR-ISAC)

Partners: CNR-ISAC, URT Ev-K2-CNR, CMCC, CASPUR, ICTP, ENEA

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

Definition of the characteristics of the General Portal for accessing the databases and the archives generated during the project, and of the methods for the harmonization of the procedures for accessing the various subarchives that will be included in the portal. First annual meeting of all researchers and technicians involved in the project to discuss the needs of data access and to define the pilot studies to be completed during the project.

Beginning of the first pilot studies, which include: (a) Analysis of water resources in the Himalaya-Karakorum and 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) preparation of a multi-secular historical climate simulation for the Mediterranean area.

Organization of a structure of summer schools at doctoral and post-doctoral level, devoted to the analysis of climate and environmental change in the mountain environment and the dynamics of the high altitude areas.

Milestone M2.6.1 (PM12): Preliminary results of the first Pilot Studies.

2. Deliverables expected for the reference period

The Deliverable D2.6.1 (PM12): "Report on the results of pilot studies", due at the end of the first year, has been completed.

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

3.1 Research activities

The characteristics of the General Portal for accessing the data have been defined, as illustrated in detail below.

The research activities related to the pilot studies (a)-(d) of the first year started immediately after the beginning of the project. The detailed description of the research activities is given in the individual reports of the various pilot studies in the following. The pilot study on the multi-secular climatic simulation for the Mediterranean area (e), as scheduled, started only at the end of the first year and it will be the subject of a detailed report at the end of the second year.

The start-up meeting of the participants in the NextData project was held at the Department of Earth and Environment (DTA), CNR Rome, on 23 January 2012, and the annual meeting of the project was held in the same location on 17 October 2012. In the course of the first year, we organized several specific workshops for the various pilot studies and for the definition of the project web site and the General Portal. As indicated in the Executive Plan, the effective implementation of the General Portal and of the associated archive interoperability has been the object of a specific public call which has been published by the DTA, by CNR-URP and on the project web site.

New pilot studies were identified, such as the compilation of a new inventory of Italian glaciers and the analysis of climate change impacts on mountain ecosystems.

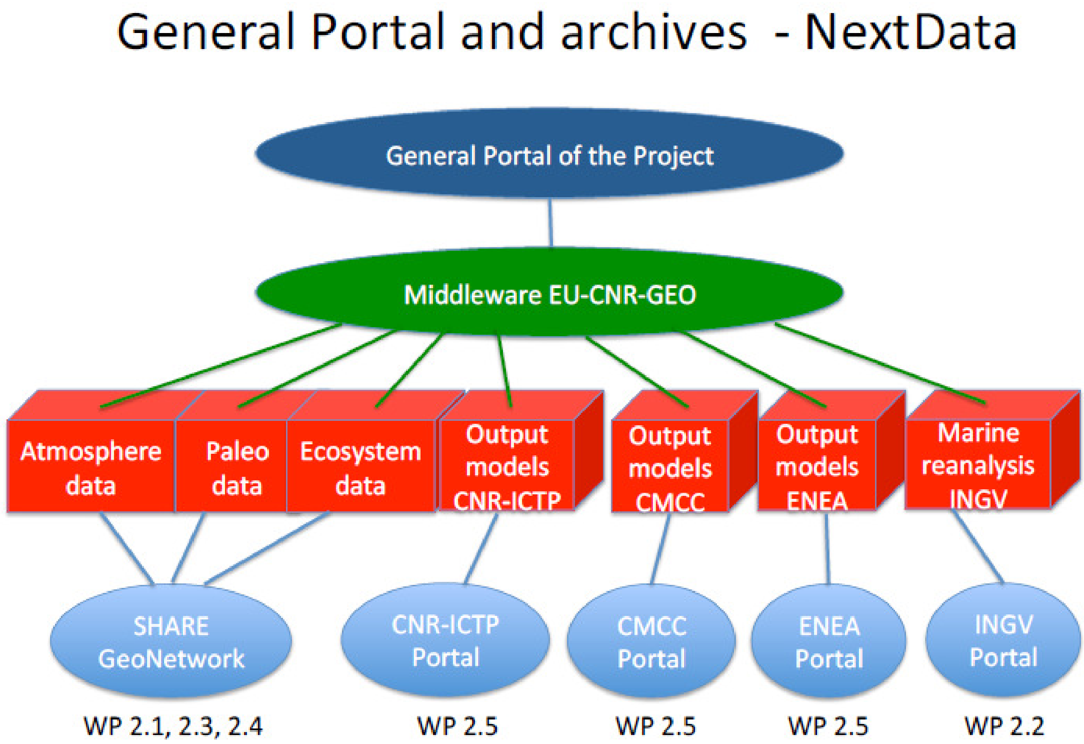
Mutual agreements and MoU are ongoing between the NextData project and several international initiatives, such as the HyMeX programme, the European Climate Research Alliance (ECRA) and the GEO/GEOSS Programme.

3.2 Applications; technological and computational aspects

The web site of the NextData project was designed and is open to public access, at the address www.nextdataproject.it. The web site will include a direct link to the General Portal, which is currently under construction and will be open to the participants at the end of the second year of the project.

The main characteristics of the General Portal have been identified. The General Portal will have two main archives, one for the ground and field data and metadata (based on SHARE GeoNetwork) and one for gridded data (reanalyses and numerical simulations) which will use THREDDS servers. During the first year, the strict collaboration between some of the project partners (CNR-ISAC, URT Ev-K2-CNR, CMCC, CASPUR) has led to the definition of the characteristics of the data portals that will be implemented by the WP partners and that will form the backbone of the General Portal, contributing also to the harmonization of the methodologies for archiving and accessing the data that will be made available through the portals.

The General Portal will include an intermediate *Middleware* layer, based on the GEOSS type of approach and which will be able to access both the thematic portals which will be activated by the various project partners and directly the data and metadata archives. Overall, the NextData Project will provide an important Italian contribution to the International Programme GEO/GEOSS. The figure below schematically illustrates the structure of the NextData General Portal. The existence of different archives and thematic portals for the numerical simulations (WP2.5) is due to the need of avoiding huge data transfers (of the order of hundreds of Terabytes); for this reason, the simulation data will be kept at the institutional archives of the partners which generated them. By contrast, the field and measurement data (including paleoclimatic data) will be stored in a single server, which will be mirrored by at least another server (presumably hosted at CNR).



The implementation of the General Portal has been the object of a public call open to CNR Institutes and non-CNR partners, which was published on the web site of the project, by the CNR-URP and by DTA on 20 November 2012. The call will close on 25 January 2013 and the proposals will be selected in February and March 2013.

In addition, there were several technological and numerical developments, a pre-requisite for the pilot studies. CMCC has developed a coupled ocean-atmosphere regional model, implemented at high resolution for the Mediterranean area. The coupled model is formed by the COSMO-CLM model as atmospheric component and by the NEMO-MFS as oceanic component. Currently, the atmospheric component COSMO is implemented at horizontal resolutions of about 50 and 25 km, but in the continuation of the project this resolution will be further increased up to about 14 km. As for the ocean component, on the other hand, the Mediterranean Sea NEMO-MFS model is implemented at a horizontal resolution of about 6.7 km, with 71 vertical levels. This regional coupled model for the Mediterranean area will be used to perform the simulations planned for the pilot studies. In collaboration with the other partners of the WP, CMCC has also started the implementation of a series of experiments aimed at the reconstruction of the past Mediterranean climate and its variability and at the production of climate projections for the future, extending the set of simulations that were already conducted with the CMCC-MED model in the framework of the CIRCE EU Project. CNR-ISAC has continued the implementation and development of the global climate model EC-Earth and the analysis of the outputs. CNR-ISAC and ICTP have analyzed the outputs of the regional simulations for the Himalaya-Karakoram area produced by ICTP with the RegCM regional climate model. CNR-ISAC has developed a framework for high-resolution non-hydrostatic simulations by using the WRF model with resolution from 22 km down to 3.5 km, nested into ERA-Interim reanalyses and global scenarios produced by EC-Earth, to provide the outputs needed for the pilot studies.

3.3 Formation

Four Post-Doc research fellowships, three Post-Laurea fellowships and one Doctorate fellowship were activated on themes related to the pilot studies of the NextData project.

One Master Thesis on precipitation in the Hindu-Kush - Karakoram - Himalaya was completed.

NextData supported the organization of the course "Climate, aerosols and the cryosphere", XX course of the International School "Fundamental Processes in Geophysical Fluid Dynamics and the Climate System", June 2012, Valsavarenche (AO). The XXI course of the same school, entitled "Climate Change and the Mountain Environment" is being organized for June 2013 as an initiative of the NextData project. This represents the first step towards the creation of a permanent structure for doctoral and post-doctoral courses and schools on climate change and the mountain environment.

3.4 Dissemination

The Project of Interest NextData was presented at various scientific meetings and to the general public. The project was presented at the Academy of Sciences of Torino, at the Lincei Academy in Rome, at the Nepal Academy of Sciences and Technology (NAST), at the Italian State TV (RAI Parlament), at ICIMOD (Nepal), at the European Climate Research Alliance (ECRA), at the University of Barcelona, at the meeting of the International Group of Funding Agencies (IGFA), to representatives of the Belmont Forum, at the World Bank and at the InterAmerican Development Bank in Washington. The NextData project has been indicated as an important Italian contribution to the international programme GEO/GEOSS. The NextData project was presented in various public lectures in schools and museums. The volume "What is Global Warming" is being translated into English for the free distribution to schools in Nepal (Himalaya) and North Pakistan (Karakoram). Representatives of the project have participated in several public conferences on climate change in the mountains, presenting the NextData project.

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 pilot studies.

4. Results obtained during the reference period

4.1 Specific results (Databases, Measurements, Numerical simulations, etc)

The results of the pilot studies are detailed in the individual reports.

4.2 Publications

In the first period, two papers have been submitted to the scientific literature. Both have been accepted for publication and are currently in press.

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

The deliverable D2.6.1, due at the end of the first 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 delays from the activities foreseen in the Executive Plan.

6. Expected activities for the following reference period

First version of the General Portal and opening of the Portal to the researchers involved in the NextData Project. Contact with the private sector to stimulate the use of the data collected during the project by industries and enterprises. Annual meeting of all researchers and technicians involved in the project, open by invitation to scientists from outside the project, to all groups which are providing data and to specific representatives from the private sector. Final results of some of the pilot studies on the impact of climate change on the mountain environment. Start-up of new pilot studies, including: (a) Measurement and analysis of precipitation in high-elevation regions; (b) analysis of the effects of climate and environmental change on health in the HKKH; (c) multi-secular simulations of the Mediterranean climate for comparison with sediment and ice core data; (d) effects of climate change on mountain ecosystems; (e) response of Alpine glaciers to climate change. Organization of two meetings of the researchers involved in the pilot studies, to assess progress and determine data storage strategies. Continuation of the formation activities and of the summer school on the mountain environment. "Mid term" meeting for the possible modification of some of the project strategies. Activation of new public calls for specific themes related to the pilot studies (in particular, on mountain ecosystems and the hydrological cycle in mountain areas). General reports on the activities, dissemination by public conferences and articles. The work to archive, harmonize and provide climate data through the data portals will continue, as a contribution to the General Portal of the project. The production of global and regional numerical simulations as designed in the context of the pilot studies planned within the project will be continued. The analysis and characterization of the mechanisms of climate variability and the investigation of how these might be altered by the anthropogenic climate change will be continued.

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

1. Scheduled activities, expected results and Milestones

This report describes the activities included in the pilot study "Water Resources in the Himalaya-Karakorum (HKKH) and interaction between monsoon and mid-latitude disturbances" (responsible: Dr. Elisa Palazzi, CNR-ISAC), foreseen within the Work Package 2.6. This pilot study uses the observational and climate model data provided by the project to analyse precipitation patterns, seasonality and long-term trends in the Hindu-Kush Karakoram Himalaya (HKKH) region (highlighting the different regimes in the western and eastern stretches of the HKKH) and to study the interaction between mid-latitude western disturbances and the tropical monsoon circulation in the HKK (Hindu-Kush Karakoram) region, in order to contribute to impact studies on current and future water resource availability in the Karakoram and in the Himalayas.

2. Deliverables expected for the reference period

Contribution to the project deliverable D2.6.1 with the results of the pilot study: "Water Resources in the Himalaya-Karakorum and interaction between monsoon and mid-latitude disturbances". We provide an overview of the results obtained during the first project year concerning the study of precipitation in the HKKH region, in particular of winter precipitation in HKK carried on mid-latitude westerly disturbances. The deliverable is structured into three sections and a conclusive section which summarizes the progress and outcomes of this pilot study during the first year of activity. The first section describes the study of current and future precipitation in the HKKH region which we have performed making use of various gridded observational datasets, reanalysis data and the output of a state-of the art Global Climate Model (EC-Earth).
The second section focuses on the western portion of the HKKH domain (the HKK) and makes use of in-situ meteorological data (in particular precipitation and temperature records) from individual stations spread over the upper Indus basin (UIB) region to analyse the horizontal and vertical variability of precipitation and temperature in northern Pakistan and their long-term trends at the locations of the individual stations.
The third section describes the synoptic scale circulation affecting northern Pakistan in summer and winter making use of back-trajectory analyses and presents a preliminary study of the western weather pattern tracks from the Atlantic/Mediterranean to the Karakoram region.

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

3.1 Research activities

An analysis of precipitation in the HKKH region has been performed in the first half of the year, using several datasets from different observational archives and from the output of the global climate model (GCM) EC-Earth (the EC-Earth simulations have been performed at CNR-ISAC). In particular, the study considers data from different archives based on in-situ gridded station data (the APHRODITE, CRU, GPCC datasets), satellite data (TRMM), merged in-situ/satellite data (GPCP archive), reanalyses (ERA-

Interim) and the precipitation output from the EC-Earth GCM. A detailed description of these datasets, their use and the results obtained in this study can be found in the project deliverable D2.6.1, as well as in the peer-reviewed paper "Precipitation in the Hindu-Kush Karakoram Himalaya: observations and future scenarios", by Palazzi E., von Hardenberg J, and Provenzale A., accepted for publication in the Journal of Geophysical Research. Two specific sub-regions in the HKKH (shown in Fig. 1), which differ for circulation patterns, precipitation distribution and amounts and, by consequence, glacier behaviour and dynamics have been identified: the HKK (Hindu Kush-Karakoram) and the Himalaya regions. In fact, the complex topography, circulations patterns and climatic responses in different parts of the HKKH range make a global description of these mountain areas scarcely useful and suggest a division into sub-regions.

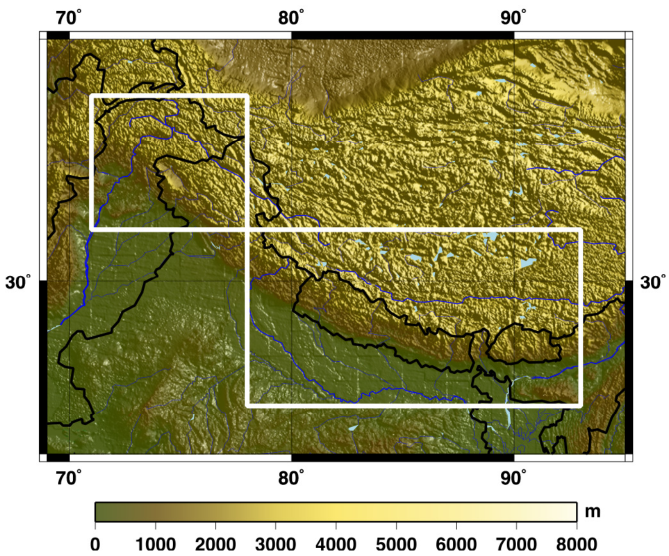


Figure 1. Map of the study area and the HKK (West) and Himalaya (East) domains.

Our analysis is focused on precipitation seasonality, interannual variability and long-term trends (the contribution of rain and snow is identified, when possible). The capability of the various datasets to reproduce precipitation characteristics has been evaluated and their biases and issues have been analyzed; the EC-Earth model has been validated against the observations and a process-oriented evaluation has been performed. As an example, Fig. 2 shows the multiannual mean (1998-2007) of summer (JJAS) precipitation over the region between 69°-95°E and 23°-39°N from the APHRODITE, CRU, GPCC, TRMM, GPCP, ERA-Interim and EC-Earth model datasets. All datasets coherently reproduce the key features of summer precipitation in the HKKH region: precipitation is concentrated over the eastern stretch of the Himalaya and decreases from south-east to north-west along the Himalayan chain. Mountain regions in northern Pakistan are quite dry during summer, reaching a maximum precipitation of about 3-4 mm/day.

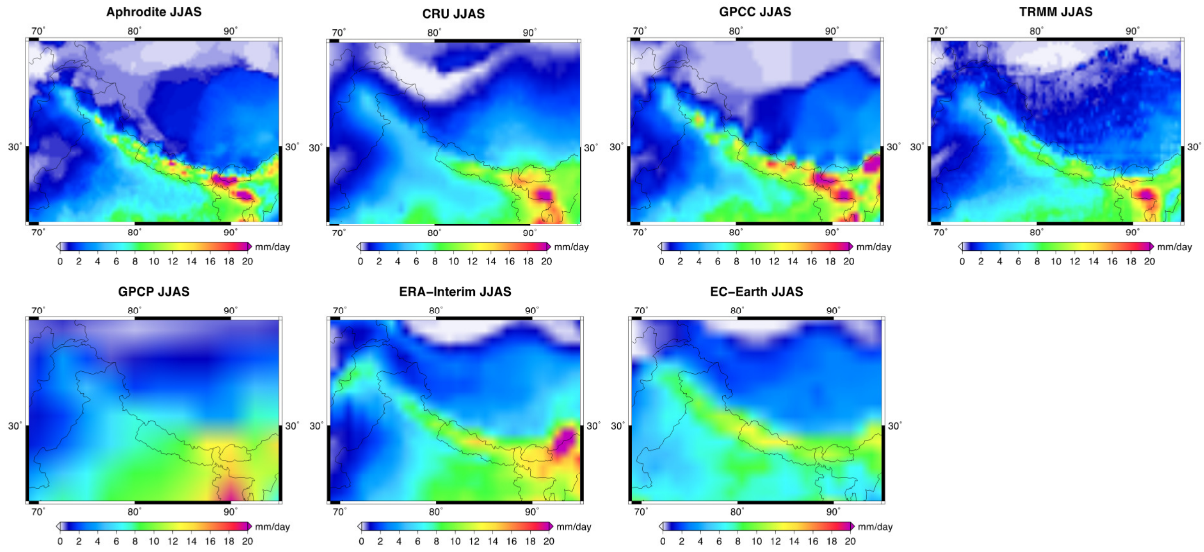


Figure 2. Multiannual mean (1998-2007) of summer (JJAS) precipitation over the region between 69°-95°E and 23°-39°N from the APHRODITE, CRU, GPCC, TRMM, GPCP, ERA-Interim and EC-Earth model datasets.

The mean annual cycle of precipitation over HKK and Himalaya (not shown here, see deliverable D2.6.1) is coherently reproduced by the various datasets. In the HKK it is characterized by a bimodal precipitation distribution, reflecting the wintertime precipitation associated with the western weather patterns and the impact of the summer monsoon. In the Himalaya, the dominant source of precipitation is the summer monsoon, leading to a unimodal precipitation distribution peaked around July. The precipitation time series from the various datasets in the time period 1950-2010 reproduce, in spite of the biases between the datasets, the interannual precipitation variability in a coherent way. None of the datasets shows statistically significant trends in the HKK during winter. In the Himalaya during summer, a statistically significant decreasing trend is observed from the analysis of the longest datasets (APHRODITE, CRU and GPCC). Outputs from EC-Earth indicate a positive summer precipitation trend in this region, opposite to what is revealed by the observations: a possible explanation for the discrepancy between the decreasing trend in the observations and the increasing monsoon precipitation simulated by EC-Earth is that the model does not correctly reproduce the complex effect of the recent increase of atmospheric aerosols resulting from the combustion of fossil fuels in Asia.

Projections made with EC-Earth under two different emission scenarios, RCP 4.5 and RCP 8.5, show for RCP 4.5 that the historical increasing precipitation trend in the Himalaya during summer is predicted to continue until about 2050, starting a slight decrease from that time on. In the RCP 8.5 scenario, summer precipitation is found to increase throughout the century, associated with an increasing trend in the intensity of rainfall events, a slight reduction of the number of rainy days. In this scenario, the recently introduced "hydroclimatic intensity index (HY-INT)" is also found to increase, indicating a transition towards more episodic and intense monsoonal precipitation. HY-INT is defined as the product of the average precipitation intensity (in mm/day) and the average dry spell length (in days), both normalized to their values in a reference time period. The HY-INT index is sensitive to increases in both quantities which define it and has been found to be an ubiquitous signature, in several regions of the world, of twenty-first century global warming. Overall, our results agree with most current climate model projections giving an increase in wet extremes, in the length of dry periods and in precipitation in the Indian monsoon by the end of the 21st century, as a result of atmospheric moisture build-up due to increased greenhouse gases and consequent temperature increase. Future projections in the HKKH region should be further verified with climate models interactively resolving temporally varying radiative and thermodynamical effects of various aerosol species.

During the second half of the year, a complementary activity has been performed by CNR-ISAC and Ev-K2-CNR in collaboration with the Pakistani Institute of Information Technology (Abbottabad), consisting in the analysis of the spatial (horizontal and vertical) and temporal variability of temperature and precipitation in the mountainous region of northern Pakistan from in-situ station data. This activity benefits from the availability of the following data:

1) hourly-resolution temperature and precipitation data measured at two high-altitude stations installed on the Baltoro glacier (Karakoram range); we have analysed the data collected at these stations during the first five years of operation
2) daily- and monthly-resolution temperature and precipitation data from fourteen other stations (seven stations are managed by the PMD and the other ones by the Pakistani Water and Power Development Authority - WAPDA) spread over northern Pakistan and located at different altitudes.

The geographical distribution of the in-situ stations employed in this study are shown in Fig. 3.

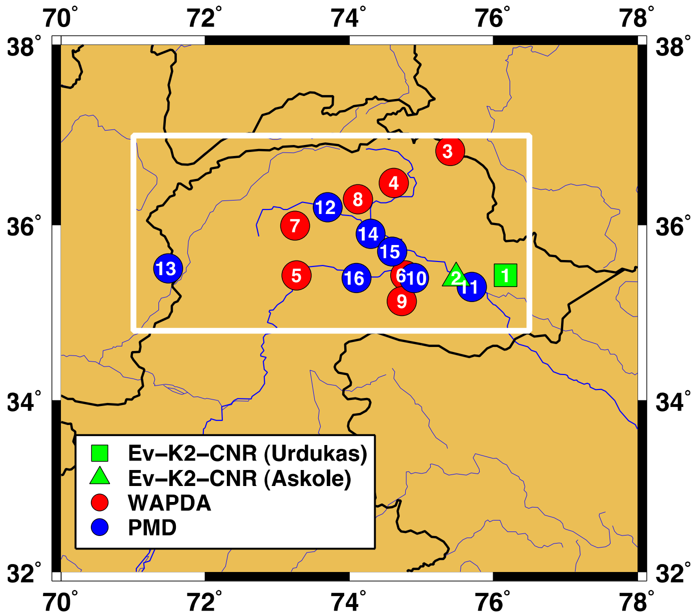


Figure 3. Geographical distribution of the sixteen in-situ stations employed in this study: Ev-K2-CNR (green), WAPDA (red) and PMD (blue).

We have analysed long-term trends in total precipitation, precipitation intensity and maximum, minimum and mean temperature from the longest records among the ones which were available (PMD records). Our results show an overall decline in summer mean and minimum temperature and increase in winter mean and maximum temperature, as well as an increase in winter precipitation, consistently with the studies reported in the current literature. Exploiting the data availability at the various stations, after assessing the spatial coherency of temperature and precipitation across the upper Indus basin region, we have analysed the dependence of temperature and precipitation on the elevation (shown in Fig. 4). The linear fit of the data gives a temperature lapse rate for the region in winter (Fig. 4, panel a) and summer (panel b) of -6.8 °C 100 m^{-1} and -7.7 °C 100 m^{-1}, respectively, very close to the standard moist adiabatic lapse rate for the atmosphere (-6.5 °C 100 m-1) as defined by the

International Civil Aviation Organization (ICAO). In spite of the horizontal distance of stations and the presence of mountain barriers, seasonal temperatures exhibit spatial coherency across the UIB region, so that one can expect that the high horizontal correlation between stations may be reflected over much shorter vertical distances. The seasonal precipitation lapse rates shown in Figs. 4c and 4d indicate that precipitation increases with altitude until about 3,000 m (well visible in summer), while it decreases from that altitude upwards. On the other hand, we expect an underestimation of precipitation measured at the highest elevations, due to the undercatch of solid precipitation by rain gauges.

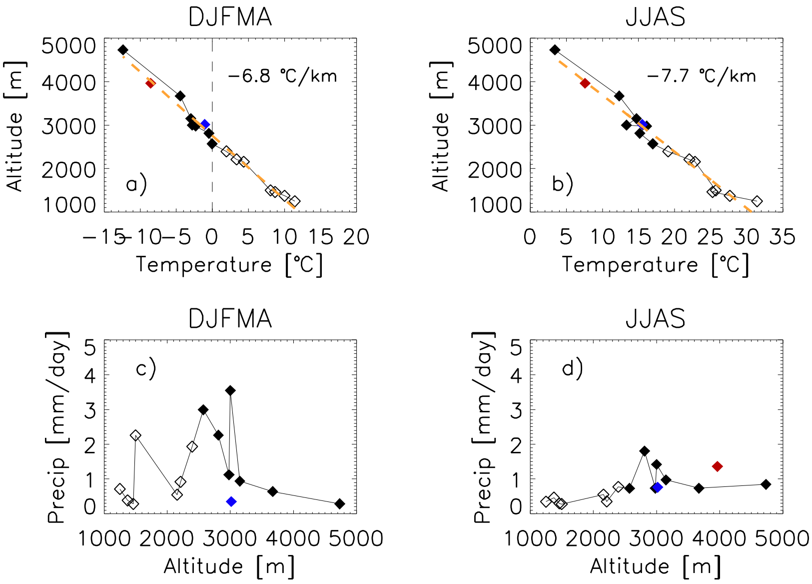


Figure 4. Winter (a,c) and summer (b,d) temperature (a,b) and precipitation (c,d) lapse rates derived from the measurements at the Askole (blue), Urdukas (red), PMD (empty rhombus symbols), and WAPDA (filled symbols) stations.

The in-situ precipitation measurements have also been used to assess the seasonal precipitation climatology in northern Pakistan and to define the contribution of winter and summer precipitation to the annual budget. The mean precipitation annual cycle at the various sites is shown in Fig. 5 (a e b). Panel c shows the spatially-averaged precipitation annual cycle over the white box shown in Fig. 3, calculated from five gridded precipitation archives, namely, APHRODITE, GPCP, GPCC, CRU and TRMM. Beyond the differences in the monthly precipitation amounts at the individual stations, owing to their geographical position, altitude, wind exposure, a feature that emerges clearly from Fig. 5 is that, during a mean year, winter (December to April) precipitation generally dominates over summer (June to September) precipitation.

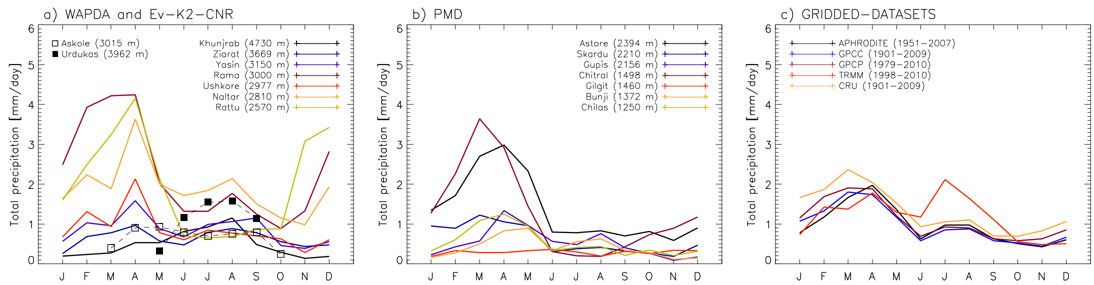


Figure 5. Mean annual cycle of precipitation inferred from (a) WAPDA and EV-K2-CNR observations, (b) PMD observations, and (c) the five gridded datasets indicated in the legend.

To investigate the properties of the synoptic-scale circulation affecting the mountain regions of northern Pakistan, we analyse 6-days-long back trajectories with the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) Model (http://ready.arl.noaa.gov/HYSPLIT.php). Trajectory calculations are based on the operational Global Data Assimilation System (GDAS) produced by the United States National Centres for Environmental Prediction (NCEP) with a horizontal resolution of 1°x1°. HYSPLIT back-trajectory ensembles, providing the geographic location and altitude of air parcels with 1-hour resolution along each path, have been calculated for ten different receptor points centred at 35.73°N-76.29°E and shifted by ± 0.75° at 100 m above ground level (a.g.l) and 500 m a.s.l., representative of the mountain area of northern Pakistan. The runs were performed for the years 2005-2009, more or less covering the time period of measurements at the Askole and Urdukas AWS which we have analysed, for summer and winter seasons. Based on the inspection of the Urdukas and Askole precipitation data in the period 2004-2009, Fig. 6 shows the air-mass back trajectories actually associated with precipitation events that occurred at the target area, reaching northern Pakistan during summer and winter. The region of northern Pakistan is predominantly prone to a westerly synoptic-scale circulation which brings precipitation in the Karakoram during winter. Winter precipitation represents the main nourishment for the Karakoram glacier systems in the accumulation period.

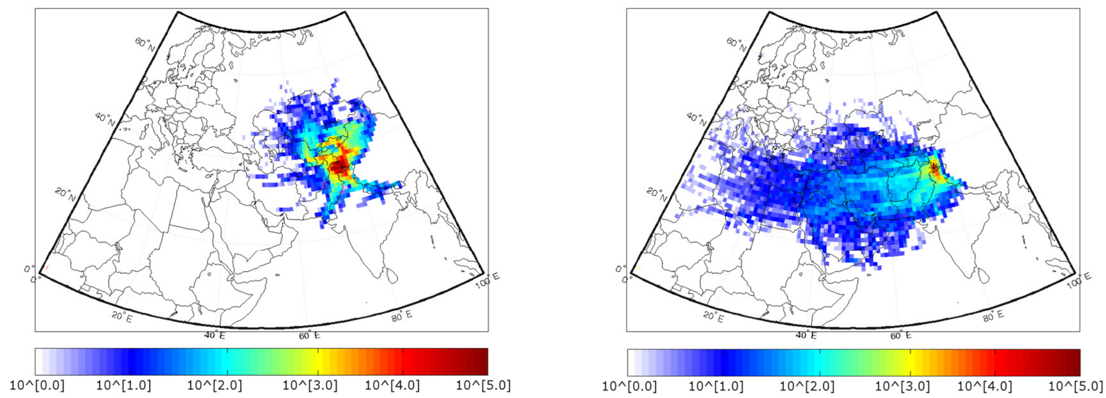


Figure 6. Air-mass back-trajectories associated to precipitation events over Northern Pakistan. The coloured logarithmic scale indicates the number of back-trajectory points for summer (left column plots) and for winter (right column plots).

A more detailed analysis of the mechanisms associated to western weather patterns has started. To give an idea of the trajectories followed by these disturbances, Fig. 7 shows the precipitation during three different winters obtained from satellite TRMM daily data, plotted as a function of the longitude (x-axis) and time (November to March, y-axis). The displayed longitudes, from 30°E to 80°E, include a region from the eastern Mediterranean to the HKK. Precipitation is averaged over the latitude band from 30°N to 40°N. The westerly disturbances appear as non-homogeneous rainy systems. Their intensification east of about 40°E could suggest that an input of extra moisture from other sources than Mediterranean, i.e., the Caspian and Arabian Sea and the Persian Gulf, could be of importance. The picture obtained from TRMM data is consistent with the one obtained from ERA40 reanalyses and EC-Earth model data (not shown here).

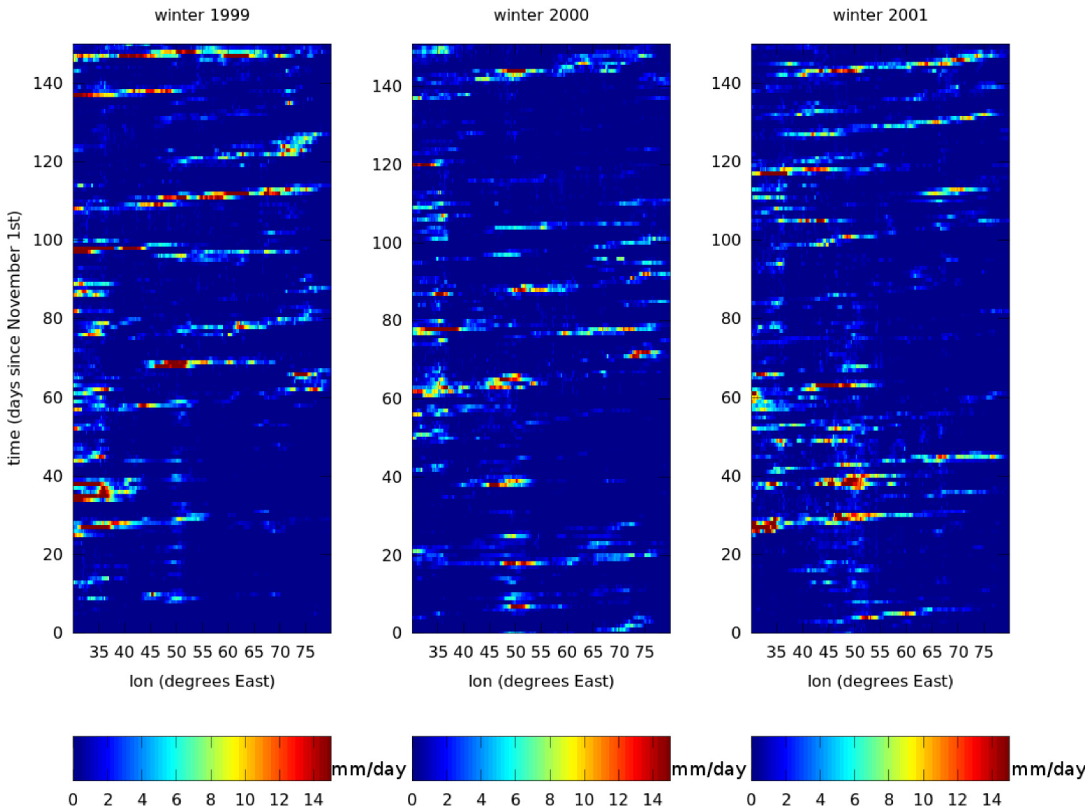


Figure 7. TRMM daily precipitation averaged over latitudes from 30°N to 40°N, plotted as a function of longitude (from 30°E to 80°E) and time for winters (NDJFM) 1999, 2000 and 2001 (left to right).

3.2 Applications; technological and computational aspects

Databases of ground and gridded precipitation data.

3.3 Formation

- A research grant position for the analysis of changes in the Indian monsoon has been opened.
- We will supervise the research program of a PhD student (Dr. Luca Filippi) on the role of mid-latitude disturbances on winter precipitation in the Karakorum and the relationship with teleconnection patterns.

3.4 Dissemination

A seminar entitled "Climate, glaciers and water in the Karakoram range" was presented by the person in charge of this pilot study in the framework of the "XX Alpine Summer School" organised by CNR-ISAC at Valsavarenche (AO) from June 20 to 28, 2012, focused on "Climate, aerosols and the Cryosphere".

3.5 Participation in conferences, workshops, meetings

The results of the research activities performed so far in the framework of this pilot study have been presented at various scientific workshops and conferences:
- ECRA (European Climate Research Alliance) workshop: "Changes in the hydrological cycle", CNR, Rome, 5-6 March 2012.
- Workshop: "Orographic Precipitation and Climate Change", NCAR, Boulder, 13-15 March 2012.

- European Geosciences Union (EGU) General Assembly 2012, Vienna, 22-27 April 2012.
- Workshop: "Contribution of science and cooperation to the sustainable development of the Central Karakorum National Park", Islamabad, 4-7 June 2012.

4. Results obtained during the reference period

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

We have analysed precipitation data from various gridded archives (as described in Sect. 3.1), characterized by different spatial and temporal resolutions, for the two specific sub-regions of the entire HKKH range, as mentioned above. For each sub-region and each dataset the following information has been produced (in the form of NetCDF files):
- Spatial average of precipitation over the HKK and Himalaya at the original spatio-temporal resolution of the considered dataset as well as at the monthly resolution.
- Precipitation over the HKK and Himalaya (pixel by pixel) at the original spatio-temporal resolution of the considered dataset as well as at the monthly resolution.
When possible, the separate contribution of rain and snow has been evaluated.

We have analysed temperature and precipitation data from sixteen in-situ stations spread over the upper Indus basin region and we produced time series of these variables at the time-resolution of the original data and at monthly resolution. Correlation matrices between the climatic records (temperature and precipitation) at the various locations have been computed (to asses the spatial coherency of temperature and precipitation across the UIB region) and are available, together with values of temperature and precipitation lapse rates in northern Pakistan.

We have calculated the North Atlantic Oscillation (NAO) index specifically for the EC-Earth model and the ERA40 and ERA-Interim reanalyses, to be used in the next months to analyse the correlation between the NAO phase and winter precipitation in the HKK region.

4.2 Publications

On October 5, 2012, we have submitted the revision of a paper entitled "Precipitation in the Hindu-Kush Karakoram Himalaya: observations and future scenarios" by Elisa Palazzi, Jost von Hardenberg, and Antonello Provenzale, submitted to JGR. On December, 4, the paper was accepted for publication in JGR.

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

- Spatial average of precipitation over the HKK and Himalaya at the original spatio-temporal resolution of the various dataset employed and at the monthly resolution.
- Precipitation over the HKK and Himalaya (pixel by pixel) at the original spatio-temporal resolution of the employed dataset and at the monthly resolution.
- Precipitation trends averaged over the HKK and Himalaya sub-regions and spatial maps of precipitation trends.
- Precipitation and temperature trends at the locations of sixteen in-situ station in the upper Indus basin region.

- Monthly North Atlantic Oscillation index for the EC-Earth model and the ERA40 and ERA-Interim reanalyses.

4.4 Completed deliverables

Our contribution to the deliverable D2.6.1 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.

6. Expected activities for the following reference period

We expect to continue the analysis of the interaction between the mid-latitude western weather patterns and the tropical circulation associated to the Indian monsoon in the HKKH region. In particular, we will focus our analysis on the link between the NAO phase and 1) evaporation and humidity patterns over a region extending from the Atlantic to the Karakoram and 2) winter precipitation in the Karakoram, to better understand where evaporation occurs and western weather patterns pick up the moisture leading to precipitation in the HKK region. We will use various datasets including observations from satellite and gridded archives, reanalysis data and the outputs of the EC-Earth global climate model.

Pilot Study 2.6.b: Analysis of the changes in terrestrial biodiversity in areas of high altitude in the north-western Italian Alps (resp. Ramona Viterbi, Gran Paradiso National Park)

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

Identification, collection and analysis of previous data on terrestrial biodiversity in the western Italian Alps. Implementation of new monitoring campaigns.

2. Deliverables expected for the reference period

Deliverable D2.6.1: Report with the results of the first year of the pilot study.

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

3.1 Research activities

The following activities have been carried out:

- ✓ Authorization from the Parks for the access to the data coming from the previous monitoring campaigns (2007-2008), in order to analyse biodiversity patterns and to develop model simulations. Such data are now available for the comparison with the data collected inside the NextData project (2012-2013).
- ✓ Preparation of biological datasets. Databases are ready for the inclusion in the General Portal. For each type of biological data we chose the metadata, needed for their precise identification.
- ✓ Statistical analyses of biological datasets coming from the monitoring activities of 2007-2008. Such data have been analysed to describe biodiversity patterns in mountain ecosystems and to identify the most vulnerable habitats and species.
- ✓ Conduction of new field campaigns (April-October 2012) to monitor and measure terrestrial faunal biodiversity in the Gran Paradiso National Park (PNGP), in the Veglia-Devero Natural Park (PNVD) and in the Orsiera Natural Park (PNOR). Sampling activities have been carried out to provide presence/absence and relative abundance data of species belonging to seven taxa: Lepidoptera Rhopalocera (butterflies), Orthoptera, birds, surface-active macro-arthropods (Coleoptera Carabidae, Coleoptera Staphylinidae, Araneae, Formicidae).
- ✓ Collection of micro-climatic conditions, through the positioning of temperature data-logger (iButton DS1922), one per each sampling station and macro-environmental (topographic variables) and micro-environmental (percentage of land coverage and estimate of floristic diversity) conditions.
- ✓ Preparation of the data collected during the field season (April-October) and upgrade of the databases.
- ✓ Analysis and identification of the samples collected during field session (not finished yet).
- ✓ Start of the arthropod biomass measurements, both in term of weight and volume, along the altitudinal gradients and development of a working protocol that will be applied to the analysis of all the arthropods contained in the pitfall traps;
- ✓ We are performing model simulations of the biological datasets (years 2007-2008) using the MaxEnt software package.

3.2 Applications; technological and computational aspects

The specific needs of biological data and metadata archives have been discussed and compared with the structures needed for the atmospheric and climate data.

3.3 Formation

On February 2012 a Post-Doc fellowship was activated, on biodiversity monitoring and data analysis. On June 2012, two Post-Laurea fellowships on biodiversity monitoring and data analysis were activated.
Researchers and rangers of the Parks attended internal courses, concerning:
methods for monitoring animal biodiversity in mountain ecosystems;
courses for the identification of the species belonging to the studied taxa.

3.4 Dissemination

- ✓ Lecture to graduate students at the University of Genova - Savona campus (May 2012).
- ✓ Lecture at the Regional Museum of Natural Sciences in Torino on biodiversity in mountain areas (July 2012).
- ✓ Public conference in PNGP (Soana Valley - Summer 2012).
- ✓ Lectures on the progress of the monitoring activities to the Park wardens (Summer 2012).
- ✓ Public events, connected to 90th birth of PNGP (May-December 2012).

3.5 Participation in conferences, workshops, meetings

- ✓ Workshop "Biodiversity value - Regional Observatory of Biodiversity: an active conservation tool" - Aosta, 22/5/2012 - Poster: "A multi-taxa approach to study mountain ecosystems: developing an exportable, long term monitoring programme".
- ✓ Conference "Trans-border days of technical-scientific exchange - Generalised Biological Inventory Mercantour/Maritime Alps" - Barcelonette, 17-18/9/2012 - Oral Communication: "Monitoring animal biodiversity in N-W Italian Alps: a multi-taxa approach".

4. Results obtained during the reference period

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

- Organisation of the data coming from the previous monitoring campaigns (2007-2008) in a database, useful for statistical analyses and for the comparison with the data that we are being and will be collected in the framework of NextData (2012-2013).
- Statistical analysis of the data coming from the campaigns of 2007-2008 showed that species richness and community composition of arthropods are highly influenced by micro-climate conditions, suggesting their potential vulnerability to changes in temperature. Moreover, we observed that the alpine belt, in comparison with belts located at lower altitudes, presents lower values of species richness, but a higher percentage of species of conservation concern (e.g., microtherm species, highly specialized species with low dispersal capability, rare).

- Conduction of new field campaigns to measure terrestrial faunal biodiversity in three selected protected areas in the north-western Italian Alps. Monitoring has been carried out by the three CNR-ISAC research fellows, helped by Park wardens and technicians (6 from PNGP, 3 from PNOR, 2 from PNVD) and by students from University of Torino, Pavia and Parma (for a total of 5 students). We report here below the sampling efforts for the field activities:

- Lepidoptera Rhopalocera (butterflies), monitored through linear transect, one per month from May to September, for a total of 375 linear transects, distributed over 78 working days;
- Orthoptera, monitored through linear transect, with 3 repetitions during mid July and mid September for a total of 225 linear transects, distributed over 49 working days;
- birds, monitored through point counts, with 2 repetition per plots, for a total of 150 point counts, distributed on 52 working days during mid April and July;
- surface-active macro-arthropods (Coleoptera Carabidae, Coleoptera Staphylinidae, Araneae, Formicidae), monitored through pitfall-traps. The number of traps set per station was 5, for a total of 375 traps. The number of temporal collections is 10 per station, for a total of 130 working days. Number of obtained traps for the analysis is 3750;
- Microclimatic conditions through the positioning of 75 temperature data-loggers (iButton DS1922), for 150 days with a total of 3600 temperature data collected for each logger;
- Macro and micro environmental conditions, through field monitoring for a total of 15 days;

- Analysis and identification of the samples collected during field session. We have performed 20% of the analysis.
- Measurements of arthropod biomass, both in terms of weight, and in terms of volume. We have completed 50 % of the analysis.
- Concerning the model simulation of the biological datasets (years 2007-2008) using the MaxEnt software, three temperature scenarios and three environmental predictors were selected and are now ready for future simulations.

Databases

The databases, coming from monitoring activities contain the list of species, with data on relative abundance, for each taxon and each sampling plot. At the moment, only the database of birds is completed. For the other taxa, databases still need the identification of collected specimens.

The data of temperature collected by the data logger are now stored in a database.

4.2 Publications

The following paper: “Patterns of biodiversity in the northwestern Italian Alps: a multi-taxa approach" by R. Viterbi, C. Cerrato, B. Bassano, R. Bionda, A. von Hardenberg, A.Provenzale, G. Bogliani, is currently in press on the journal *Community Ecology*.

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

The data from the campaigns of 2007-2008 are available. The data from the 2012 field campaign have been processed for birds, climatic and environmental conditions. The other data will be processed and made available in the coming months.

4.4 Completed deliverables

Report of the first year of activities of the pilot study.

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

The execution of field monitoring activities has been carried out in line with the Executive Plan.

6. Expected activities for the following reference period

The following activities are planned for the next reporting period:

- ✓ Check of suitability and effectiveness of the databases for the General Portal, both in terms of used metadata and in terms of information accessibility;
- ✓ Processing of the data coming from the 2012 campaign for inclusion in the data archive;
- ✓ First comparison of collected data for some taxa (coming from field work in 2012) with biological data coming from previous monitoring campaigns (2007-2008), to detect variations in biodiversity patterns and to compare real data with the models run under temperature increase scenarios;
- ✓ Simulation of the response of terrestrial faunal biodiversity in the north-western Italian Alps to temperature changes;
- ✓ End of the analysis and identification of the samples collected during field session;
- ✓ End of the measurements of arthropod biomass, both in term of weight and volume.

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

1. Scheduled activities, expected results and Milestones

This pilot study aims at estimating the changes in the hydrological cycle, in particular in the snow cover and water resources availability in high altitude areas, focusing on the Alps and the Hindu-Kush Karakorum Himalaya (HKKH) mountains.
The existing data from surface measurement networks and the new ones obtained during the project are analyzed. The development and implementation of statistical and dynamical snow models will allow to obtain estimates of recent and future changes in the snow persistence and depth in high altitude areas.

2. Deliverables expected for the reference period

Contribution to the project deliverable D2.6.1 with the results of the present pilot study.

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

3.1 Research activities

This pilot study aims at providing projections of the snowpack characteristics (depth, snow density and areal cover) in the mountain areas of interest of the project, for different climate change scenarios, using both global and regional models.
A key step in the study is to determine the methodology that allows to obtain the most reliable snow projections. For this, two different modeling approaches have been identified.

The first approach is to directly use the snow projections provided by the climate models (i.e. EC-Earth), possibly after application of a suitable downscaling procedure. The advantage is that the atmospheric and the surface-snow modules are interactive and therefore snow change feedbacks on climate can be properly represented.

A second possibility is to use physical/empirical models (i.e. H-Tessel, UTOPIA, degree-day models) in off-line mode. In this approach the snow model is forced by the atmospheric variables produced by the climate model. In this case, the surface-atmosphere feedbacks cannot be represented but, on the other hand, it is possible to calibrate the snow models and, presumably, represent the snow dynamics more accurately for the region of interest.

We are following both approaches, with the aim to determine which is the most effective comparing the results to the available data.

Concerning the first approach, the snow dataset of the Global Climate Model EC-Earth referring to the historical period 1850-2005 and the projections until 2100 for the scenario RCP4.5 have been collected. The available variables of interest for this study are the snow depth expressed as snow water equivalent and the snow density. From these data, it is possible to reconstruct the snow depth on a global scale, with a spatial resolution of 1,125°, corresponding to about 130 km at midlatitudes.
We estimated the EC-Earth accuracy in describing the present climate, specifically for

the snow variables. Since EC-Earth dataset is composed by gridded data, the natural basis of comparison is another gridded dataset. The present state-of-the-art is the ERA-INTERIM reanalysis (ECMWF), a set of global analysis that assimilates observed data and covers the period since 1979. For a selected case study also the ECMWF analysis product has been considered.

In this study the attention has been focused on the mid-latitudes, in particular the area that extends from Portugal to Japan and that includes the Alps and the Hindu-Kush Karakoram Himalaya (HKKH) mountain ranges (Figure 1).

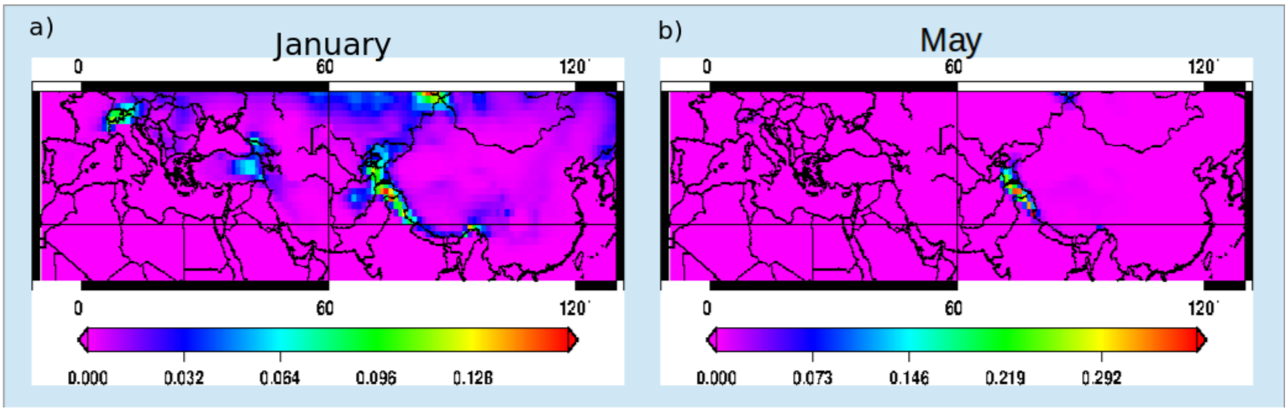


Figure 1. Climatological average snow depth in January (a) and May (b) from the EC-Earth dataset over the period 1979-2009.

The analysis of the average snow depth characteristics on a monthly basis allows to determine the variability of solid precipitation, the accumulation and the persistence of snow on the surface throughout the year. It also allows to highlight the differences between climatic subregions in the area of interest. The comparison of the average snow depth in January and May (Figure 1) shows that in the Alps the maximum snow accumulation occurs in winter, afterwards the snow depth decreases and in May the surface is almost totally snow free. On the contrary, in the HKKH region, due to the higher average altitude, the accumulation continues even after the winter months and reaches a maximum in spring.

The EC-Earth maps of monthly average snow depth in the period 1979-2009 have been compared to the corresponding ERA-Interim reanalysis dataset, in order to find their relative accuracy. An inconsistency has been found in the Karakoram region, at the border between Pakistan and China, in the area of the Baltoro glacier (Figure 2). With mean length of 62 km and an area of 640 square kilometers approximately the Baltoro glacier is one of the largest glaciers in the world. Within 20 km there are K2, the highest mountain in the region, and three other peaks above 8,000 m s.l.m..
In this area ERA-Interim estimates about 7 meters of snow water equivalent, while EC-Earth values are about an order of magnitude lower. This significant difference is recorded throughout the year, regardless of the month. Figure 2 shows the maps for January.

The Baltoro area is occupied by a large and deep glacier, where a considerable amount of snow and ice is stored. On the other hand the amount of water equivalent estimated by ERA-Interim is very high, considering that it refers to an average value over an area 75x75 km wide. A priori we can not say which of the two datasets best represents the real situation, so it is necessary to compare these results with other independent datasets. To our knowledge no historical long-term snow-depth series is available for

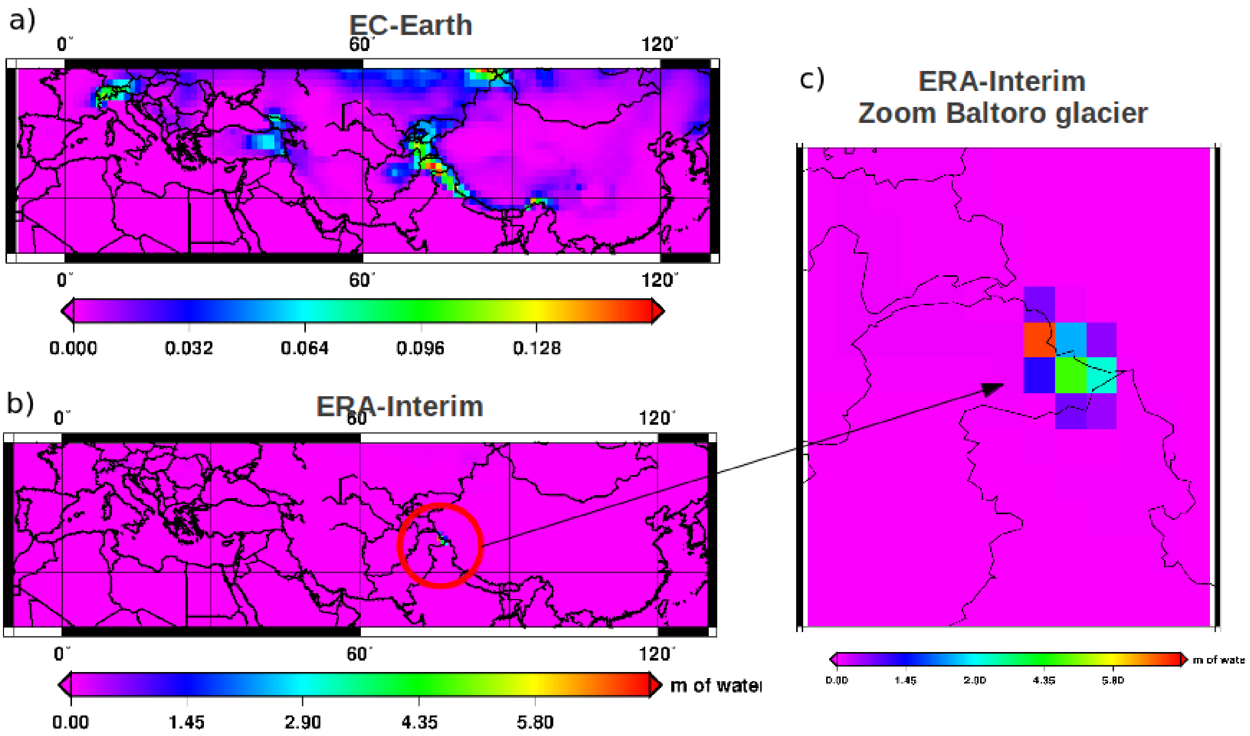


Figure 2. Monthly average snow depth, expressed in meters of water equivalent, according to EC-Earth (a) and ERA-Interim (b) over the period 1979-2009. ERA-Interim presents a maximum in the Baltoro area (c) of about one order of magnitude higher than EC-Earth.

the Baltoro region due to its impervious and uneasily accessible mountains. Recently some sparse nivo-meteorological observations have been performed during specific measurement campaigns organized through high altitude expeditions. Among them there is the campaign of the international project PAPRIKA that sampled 3 snow-pits to study the snowpack characteristics along the vertical, from the snow surface to the soil. The maximum snow depth observed in these 3 observations was about 8 m and the average density was 400 kg/m^3, corresponding to a 3.2 m snow water equivalent. We point out that this measure is of the same order of magnitude of ERA-Interim estimate, however, it is very difficult to infer the spatial representativeness of this data and further measurements in that area will be necessary to draw a reliable conclusion.

A further investigation allowed to compare the EC-Earth and ERA-Interim results with the ECMWF analysis product, a gridded dataset obtained by assimilation of the observed data. We considered the snow depth field in a winter day (on February 1, 2012, Figure 3) to assess the order of magnitude of this variable in the Baltoro area. In the specific grid point, the analysis presents about 8 meters of water equivalent, in better agreement with the ERA-INTERIM dataset, to be compared with EC-Earth which seems to underestimate the snow depth.

Excluding the Baltoro area to which we will address further research, we compared the monthly maps of EC-Earth with ERA-INTERIM using the same scale. In order to evaluate the relationship between each pair of maps, we plotted the EC-Earth pixel values in function of the ERA-INTERIM ones. Figure 4 shows the scatterplot for the months of January, April and August.

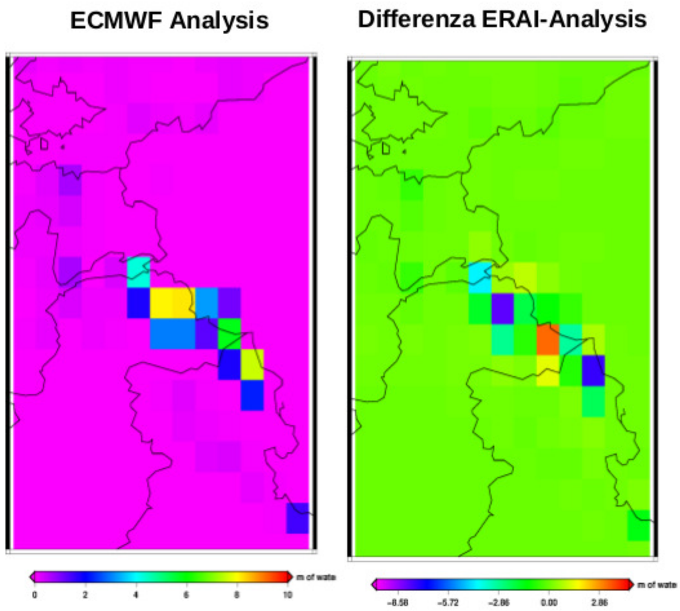


Figure 3. ECMWF analysis referring to the snow depth in the Baltoro area on February 1, 2012 (left) and difference between ERA-Interim and the analysis (right).

The correlation between the two climatologies strongly depends on the season. In January the correlation coefficient is R^2=0.60 and EC-Earth tends to underestimate the snow depth compared to ERA-INTERIM. In April, the correlation between the two datasets decreases (R^2=0.4) and EC-Earth overestimates the snow thickness. In August, the two datasets are uncorrelated, in particular EC-Earth wrongly identifies snow cover in most of the area of study.
In conclusion, the analysis of the historical period 1979-2009 shows that in winter/spring EC-Earth and ERA-INTERIM snow climatologies are comparable, while in summer EC-Earth is not able to reproduce correctly the spatial distribution of the snow depth. These results on the EC-Earth accuracy in the control period should be taken into account when interpreting future snow projections.

The snow projection can be obtained also using off-line snow models, forced by the atmospheric variables produced by the climate model. Literature research allowed to identify the physical and empirical models that simulate the temporal evolution of the snowpack, i.e. the accumulation, transformation and fusion processes, using the meteorological variables. These distributed models can be applied to simulate the evolution of the snow depth spatial distribution.

The physical models reproduce the exchange processes between surface and atmosphere and they are based on the energy and hydrological balance equations at Earth's surface. These models can have different degrees of complexity, but they generally require several input variables, such as temperature, pressure, humidity, precipitation, wind direction and wind speed, solar radiation and they are demanding from the point of view of the computing resources. On the other hand, they can reproduce many of the snow processes and the snow related variables (snow depth, density, water equivalent, snow temperature at various depths, etc ...).

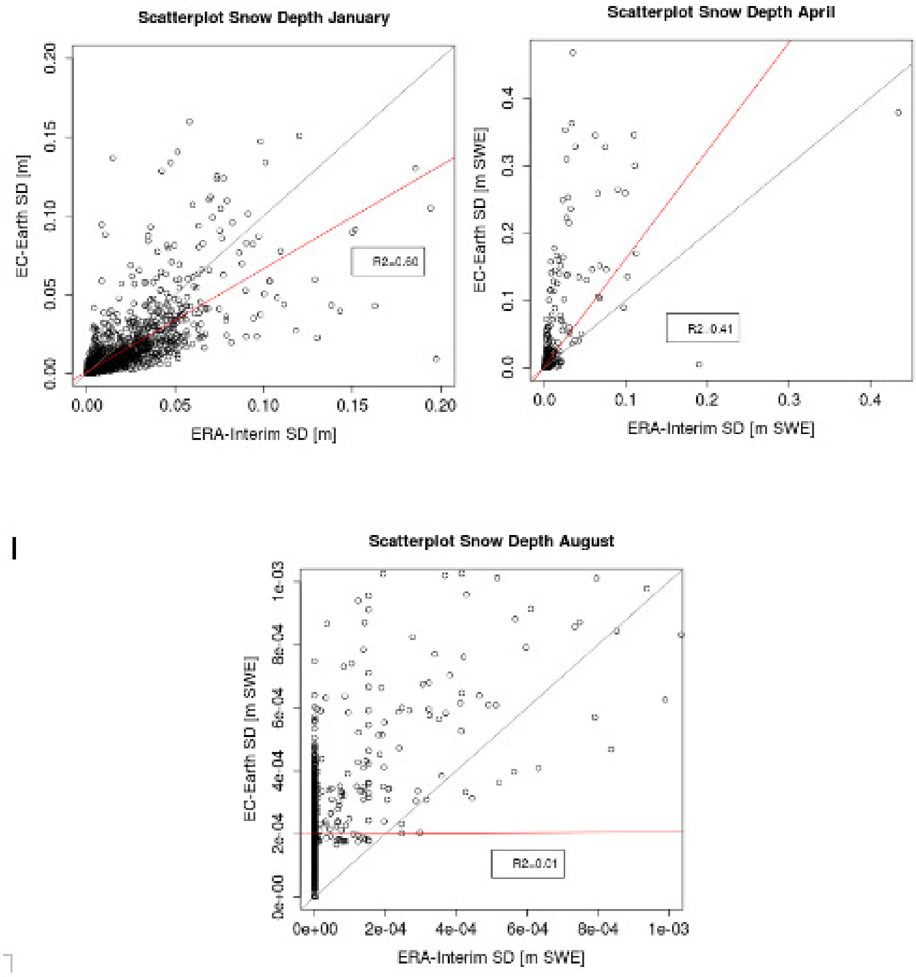


Figure 4. Scatterplot of the average monthly snow depth in EC-Earth vs. ERA-INTERIM in January, April and August (clockwise order) in the area of study. The Baltoro area has been excluded from the analysis.

Empirical models estimate the solid precipitation fraction and the amount of melted snow through empirical relations between temperature and precipitation, which are usually the only two input meteorological variables needed. These models, although very simple, may be able to reproduce with good accuracy the snow dynamics and they have the advantage of requiring only two easily available input variables, and few computational resources. After a literature search we identified different physical (UTOPIA, CHTESSEL, FEST, GEOTOP, ACHAB-Snow) and empirical (SNOW17 ETI) models and we studied the related articles. We focused on the UTOPIA model as it was immediately made available by the developers of the University of Torino. Recently we acquired also CHTESSEL, the model currently operational at the ECMWF and integrated into EC-Earth. These two models have been installed on a computer at CNR-ISAC in Torino and they are now available for simulations. We also established contacts with the CIMA Research Foundation of Savona to obtain the ACHAB-Snow surface model, that will be made available shortly.

The research that we are pursuing aims at comparing the different models and at assessing their accuracy in different geographical contexts, both Alpine and extra-Alpine. Initially, we carried out simulations based on surface stations data. In the Piemontese Alps there are 10 nivo-meteorological stations that measure all the necessary variables (Table 1) and their data have been requested to the managing agency ARPA Piemonte.

Stazioni	Quota [m slm]	Disp. dati
Passo del Moro	2820	1988
Sestriere Banch.	2480	2003
Sestriere Alpette	2250	2003
Colle Bercia	2200	1996
Clot della Soma	2150	1996
Limone Pancani	1875	2006
Rifugio Mondovì	1760	1997
Pragelato	1620	2002-2010/07
Prerichard	1353	1990
Settepani	1300	2003
Ponzone Bric B.	773	1989

Table 1. List of the nivo-meteorological stations of the ARPA Piemonte network that are fully instrumented, elevation and period of data availability. The station of Limone Pancani was activated in 2006 and has the shortest record, the others are operating at least since 2003.

Figure 5 (left) shows a snow depth simulation at Colle Bercia station (2200 m a.s.l.) obtained using the UTOPIA model. It can be seen that the model adequately reproduces the snowfall and melting processes, with a tendency to underestimate snowfall in the case of intense events, but we have to remind that the amount of solid precipitation is determined in UTOPIA from heated rain gauges measurements. These instruments are designed for measuring the liquid precipitation and they tend to underestimate solid precipitation. In fact their resistor is not able to melt quickly enough the snow that tends to accumulate and to obstruct the lens, producing a remarkable underestimation during intense events. Thus, the deviation between the UTOPIA simulation and the real snow depth may be partly due to the quality of the initial precipitation data rather than

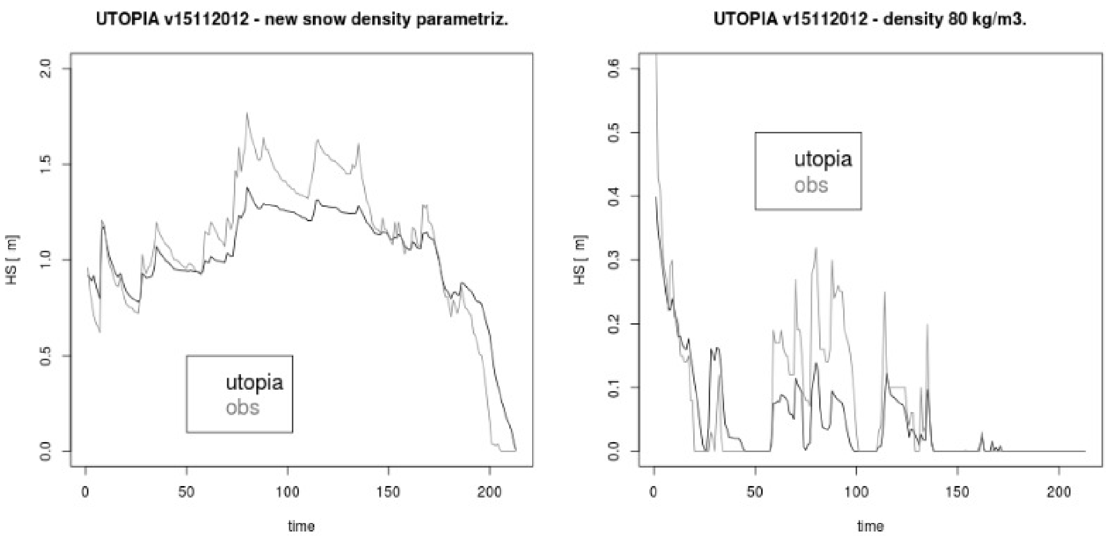


Figure 5. UTOPIA-simulated snow depth (black line) and observation (gray line) in Colle Bercia (left) and Prerichard (right) stations in the Piedmontese Alps, starting from November, 1 2003 until May, 31 2004.

uniquely to an internal problem of the model. The complete snow melting simulated by UTOPIA occurs about 7 days later than the observations, thus the model tends to retain snow longer.

The same analysis was performed for the Prerichard station, located at 1353 m above sea level (Figure 5, right). UTOPIA faithfully reproduces the processes in the early snow season and, similarly to the case of Colle Bercia, it underestimates the solid precipitation during snowfalls exceeding 20 cm.

We carried out some tests also on two Siberian meteorological stations:
Ogurtsovo 54 ° 54 'N lat., 82 ° 57' E long, altitude 133 m above sea level
Kostroma 57 ° 46 'N lat., 40 ° 56' E long.; 126 m

the complete datasets are freely available online
(http://rp5.ru/Weather_archive_in_Ogurtsovo
http://rp5.ru/Weather_archive_in_Kostroma).

Simulations have been performed using 30' time series from January, 1 1978 until December, 31 1983. The results are shown in Figure 6: in Ogurtsovo UTOPIA simulations reproduce quite well the observed signal throughout the period considered with the exception of the 1979-80 season, when the snowfall is underestimated by approximately 30 cm.

The best results are obtained in the station of Kostroma where there is a good agreement between the real and the reconstructed signal. In this case UTOPIA reproduces the observed data with high accuracy.

After the encouraging results obtained with Utopia on sample stations, in the near future other snow models will be tested and evaluated through a comparative analysis to determine their relative accuracy.

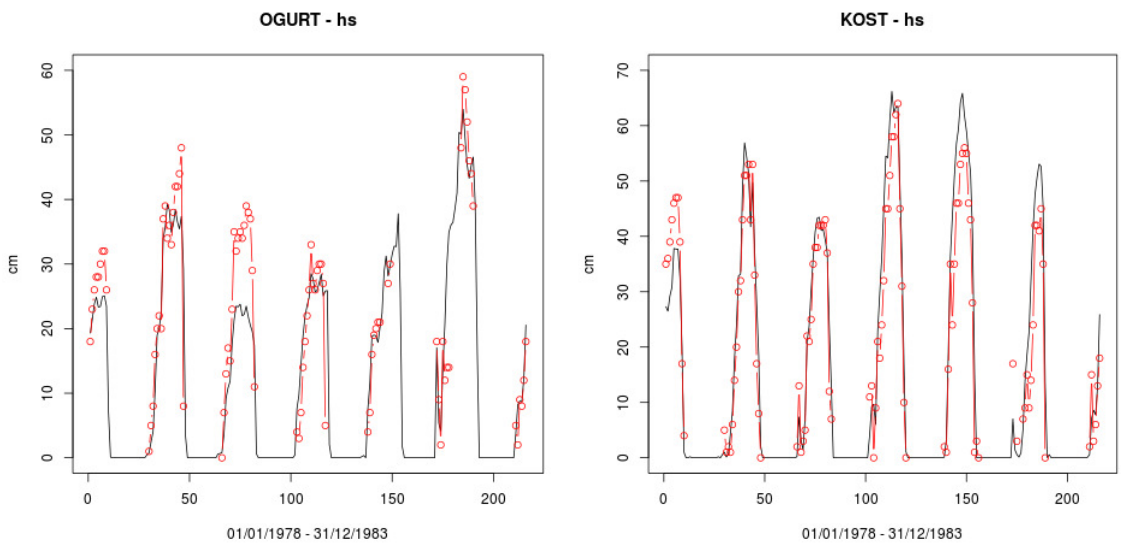


Figure 6. Time evolution of the snowpack simulated by UTOPIA (black line) and observed (red line with circles) in Ogurtsovo (left) and Kostroma (right) stations (Siberia), from January, 1 1978 until December, 31 1983.

In the framework of this pilot study, CMCC has developed and initiated a series of analyses investigating the mechanisms of snow precipitation variability in the Alpine area and their effects on the hydrological cycle in the region. To this purpose, an analysis of the observed long-term discharge time-series of the Rhine, the Danube, the Rhone and the Po rivers has been performed. These rivers are characterized by different seasonal cycles reflecting the different climates of the Alpine basins. Despite the intensive water management in this region, we found common features in the timing of the spring discharge in the basins. All time-series display a statistical significant tendency of anticipating the spring discharge (Figure 7), that is consistent with the general warming trend of the Alps. The low-frequency variability of the spring peak phase shows some similarities among the rivers. Timing of spring discharge appears to be correlated with the spring temperature over the Alps.

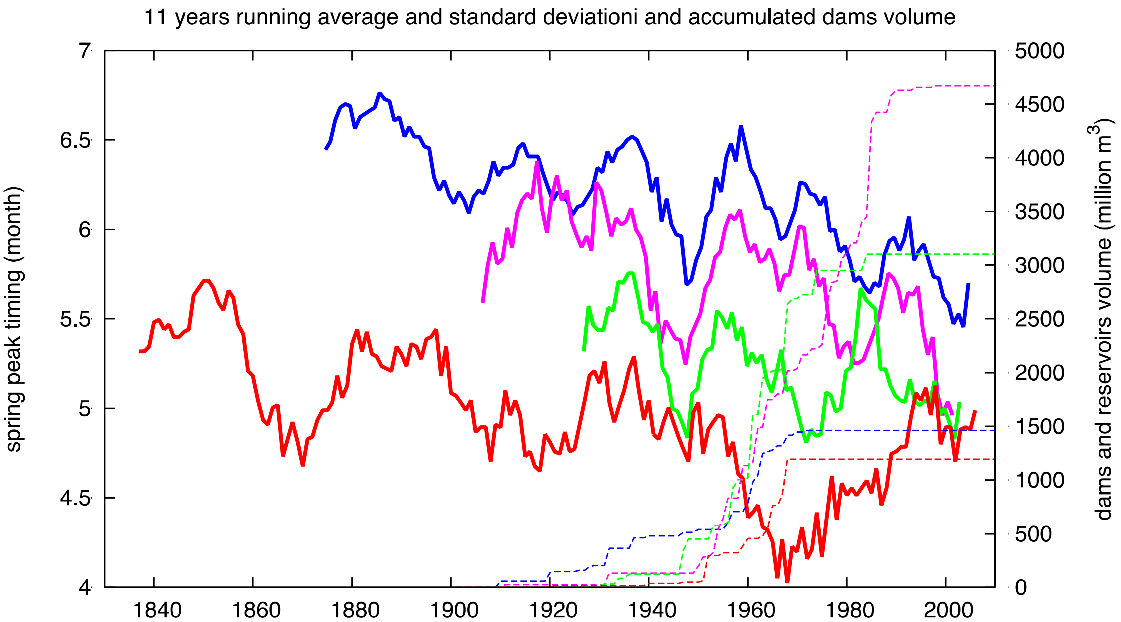


Figure 7: 11 years running mean phases time series of the fitting functions. Dashed lines represent the accumulated dam and managed reservoirs volume in the basins upstream the stations.

A paper illustrating and discussing the results found in this analysis is in preparation.

In addition, a series of numerical experiments with a limited-area, non-hydrostatic atmospheric model (COSMO) implemented with high-resolution have been designed and initiated. The goal of these exepriments is to explore with a numerical model the mechanisms underpinning the observed variability.

3.2 Applications; technological and computational aspects

The source code of UTOPIA and CHTESSEL, two land surface process models for the simulation of the snow dynamics, have been obtained through agreements with the institutions that developed them, respectively, the University of Torino and the European Centre for Medium-Range Weather Forecasts (ECMWF) in Reading. These softwares have been installed on a computer of the CNR-ISAC Torino and the first numerical experiments have been performed. CMCC has developed a coupled ocean-atmosphere regional model, implemented at high resolution for the Mediterranean area. The coupled model is formed by the COSMO-CLM model as atmospheric component and by the NEMO-MFS as oceanic component.

3.3 Formation

None in this period.

3.4 Dissemination

None in this period.

3.5 Participation in conferences, workshops, meetings

Participation in the conference "MEDCLIVAR - The climate of the Mediterranean region: understanding its evolution and effects on environment and societies" held in Madrid from 26 to 28 September 2012.

CNR-ISAC organized two workshops inviting the developers of UTOPIA and CHTESSEL models in Torino, in order to share the knowledge on the models theory and the practical experience in using the programs. On December 14, 2012 in Aosta we attended a meeting to define the collaboration with the CIMA Reserch Foundation and ARPA Valle d'Aosta on the comparison of snow models.

4. Results obtained during the reference period

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

We have analysed snow datasets from the various gridded archives (as described in Sect. 3.1), over midlatitudes, especially for two specific sub-regions, the Alps and the entire HKKH range. For each sub-region and each dataset we produced NetCDF files containing snow depth over the Alps and HKKH at the original spatio-temporal resolution of the considered dataset as well as at the monthly resolution.

In particular, the monthly mean snow depth fields obtained by the global climate model EC-Earth have been evaluated over the period 1979-2009 and compared to the ERA-Interim reanalysis. The comparison over the Alps and the Hindu-Kush - Karakorum - Himalaya (HKKH) region has been completed and will be soon integrated using the output of the regional climate models.

In addition to gridded data, we collected also surface station meteorological data (temperature, precipitation, humidity, wind intensity and direction, solar radiation, etc ...) in several observation sites in the Alps, to be used for the estimation of the temporal variability of the snow depth, density and water equivalent.

4.2 Publications

None in this period.

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

- Snow depth over the Alps and the HKKH at the original spatio-temporal resolution of the various dataset employed and at the monthly resolution.

- Nivo-meteorological surface station data for some sites in the Piedmontese Alps.

- Temporal evolution of snow depth simulated by UTOPIA, in several location in the Piedmontese Alps.

4.4 Completed deliverables

The contribution from this pilot study has been included in deliverable D2.6.1..

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.

6. Expected activities for the following reference period

In the near future a meteorological dataset with surface stations measurements will be collected in order to test the snow models in several Alpine sites. In addition to Piedmontese stations, we will include the new meteorological observation site of Torgnon (Aosta), equipped with innovative instruments such as the OTT rain gauge, which gives higher reliability in the snowfall measurement. The preparation of the dataset will require particular attention both during the data quality control, necessary to identify and filter the erroneous data, and in the gap-filling phase, essential since the models need continuous time series.
The obtained dataset will be the benchmark to test and compare the performances of different physical/empirical snow models. Since the objective of this pilot study is to carry out simulations with snow models driven by the output of global/regional climate models, we will have to work on gridded data at low spatial resolution. So we will study the sensitivity of the snow models to the degradation of the spatial resolution of the initial data. We plan to carry out simulations with different types of input data, of gradually decreasing “quality", starting from (i) the ideal case when all input data are available (measurements provided by the fully equipped weather stations), then (ii) the case when only the main variables are provided (data from standard meteorological stations) and the others are estimated directly by the models through their own parametrizations, and finally (iii) using interpolated datasets with low spatial resolution and larger uncertainty. This survey will identify the models that provide the best estimates when the input data are forced by low spatial resolution. These models will be used to produce the snow projections for the following decades.

Pilot study 2.6.d: Effect of aerosols in high altitude areas
(Resp. Jost von Hardenberg, CNR-ISAC)

1. Scheduled activities, expected results and Milestones

This pilot study aims at defining aerosol effects in mountain areas, including direct radiative effects, indirect thermodynamics and precipitation microphysics effects, as well as effects linked to the deposition of black carbon and dust on snow-covered surfaces. Particular attention will be devoted to the Himalaya-Karakorum region, where a strengthening of the measurement network in the framework of the NextData project will allow to obtain a quantiative characterization of the impact of aerosols on the mountain environment.

2. Deliverables expected for the reference period

Deliverable D2.6.1: Report with the results of the first year of the pilot study. The deliverable first summarizes and discusses the main physical mechanisms involving aerosols in climate and their role in high-altitude areas, in particular the Hindu-Kush Karakorum Himalaya region (HKKH). Effects and feedbacks linked to the deposition of black carbon and dust on snow-covered surfaces are discussed and recent literature is summarized. The main part of the deliverable focuses on a description of numerical modelling results for the HKKH area, using a regional climate model (the RegCM4 model) and presents a comparison in terms of aerosol optical depth (AOD) with available satellite and reanalysis datasets.

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

3.1 Research activities

In the framework of the pilot study aerosol optical depth (AOD) reproduced in the HKKH region by a regional climate model (the RegCM4 model run by ICTP) has been compared with satellite observations (MODIS-Terra) and with an aerosol reanalysis product provided by the MACC project (Monitoring Atmospheric Composition and Climate). The model was run for a regional domain including the Indian subcontinent defined for the CORDEX project. Two present-day simulations (2000-2009) are available with boundary conditions provided by ERA-Interim reanalyses and by the global model EC-Earth run created for CMIP5 by CNR-ISAC. A future scenario timeslice in the period 2040-2050 has been created using EC-Earth boundary conditions for the RCP 4.5 emission scenario.

The ability of the model in reproducing AOD distributions and their seasonality has been assessed by comparing climatological averages over the entire simulation domain and, more in detail, over the HKKH region, with the MODIS and MACC spatial climatological distributions. Fig. 1 reports an example of such a comparison for the summer monsoon season (JJAS), averaged over the years 2003-2009, common to all datasets, with ERA-Interim boundary conditions for RegCM. The analysis confirms that in winter RegCM is capable of reproducing to a large extent the amplitude and the spatial distribution of the optical depth of aerosols in this area, with a good reproduction of a low over the Tibetan plateau and of a higher AOD at the southern feet of the Himalayas, mainly associated with anthropic pollution. In summer we find a good reproduction of a severe maximum of AOD centered over the border between Pakistan and India, even if with an offset in the position of the maximum which is located farther east.

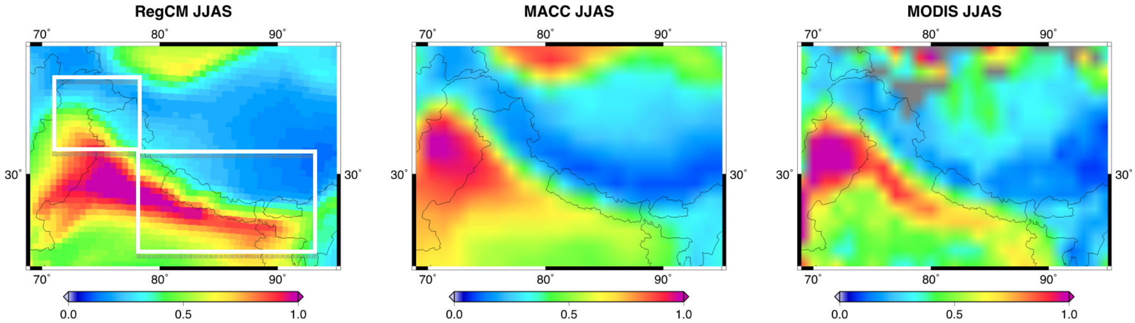


Fig. 1. Comparison over the HKKH of AOD in the visible band simulated by the RegCM4 model with Era-Interim boundary conditions with AOD (at 550 nm) reproduced by the MACC and by MODIS, in the summer monsoon season (JJAS). The white boxes in the left panel indicate the regions over which regional averages over HKK and Himalaya have been computed.

Experimentation with a dynamical dust scheme used in the model has allowed to assess the role of an accurate representation of dust emissions from the local desert areas (mainly the Thar desert) in order to represent correctly this maximum during the monsoon season.

A more detailed view of seasonal fluctuations over the two focus areas of the Hindu-Kush-Karakorum (HKK) in the west and over the Himalaya in the east, is obtained by defining two boxes enclosing these areas (shown in Fig 1). A comparison of the monthly climatology of AOD (Fig. 2) with MODIS and MACC shows very good agreement in the average AOD in summer, while in winter (from October to February) RegCM reports a significantly higher AOD. Similarly to the two observational databases, RegCM reaches a maximum in July for the HKK. In the Himalaya region MACC and MODIS show a significant difference during all year, which can be attributed to a higher estimate of AOD over the Tibetan plateau in MODIS. While from December to May RegCM AOD maintains itself between these two observational datasets, in summer it reports higher values, which are associated with higher AOD over northern India, associated with high dust sources and transport in the monsoon season.

Timeseries of AOD averages over these same regions (Fig. 3) show that in the HKK RegCM reproduces well the observed variability and the timing of some extremes of AOD, particularly compared to MODIS. Some high extremes of AOD in winter find no correspondence in the observational and reanalysis datasets. These may be associated with episodes of long-range transport of dust and anthropogenic pollutants which have to be investigated further. In the Himalayas RegCM presents a more irregular timeseries compared to the two observational datasets and is not able to capture some extreme high values observed in summer, particularly by MODIS.

Analysis of deposition fluxes of light-absorbing aerosols (black carbon and dust) confirms the importance of dust deposition mainly during the monsoon summer season on the southern flanks of the HKKH. The RCP 4.5 future scenario (for 2040-2050) shows a possible decrease in winter BC deposition, mainly associated with a decrease in the scenario of east-Asian anthropogenic emissions. The model also forecasts a significant decrease in dust activity affecting the Himalayas, both in summer (from the Thar desert) and in winter (from the Gobi desert). The associated changes in long-range transport patterns and in wind climatology have to be further investigated, together with possible impacts on snow albedo and local radiative forcing.

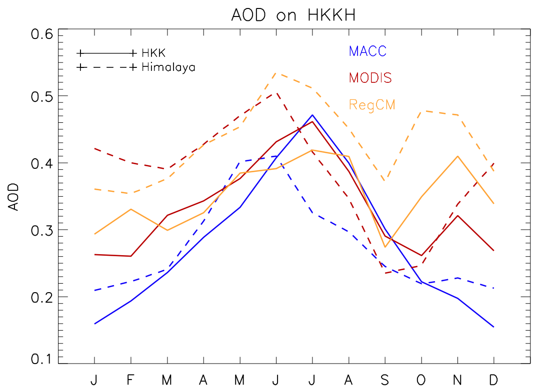


Fig. 2. Monthly climatology of AOD for the HKK and Himalaya boxes defined in fig. 1.

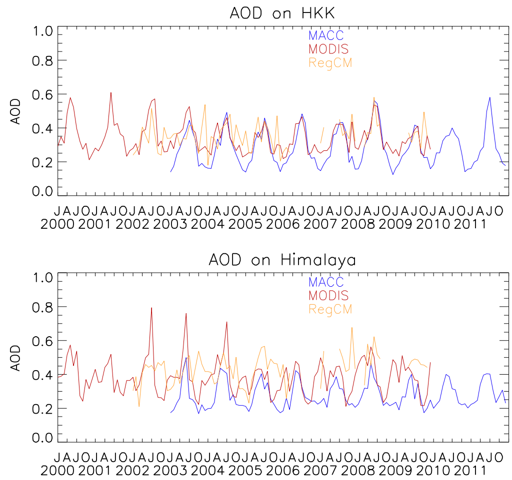


Fig. 3. Timeseries of monthly AOD for the HKK and Himalaya boxes

3.2 Applications; technological and computational aspects

Starting from the EC-Earth model outputs, specific boundary condition files have been prepared for the periods 1960-2005 (historical) and 2006-2050 (RCP 2.6, RCP 4.5, RCP 8.5) and transmitted to ICTP in order to be used for the production of model simulations with a hydrostatic regional climate model for the HKKH focus area.

CNR-ISAC has worked in close collaboration with ICTP providing large-scale aerosol concentration boundary conditions, consistent with those used in EC-Earth simulations, to be used for the regional climate model runs. In particular CAM 3.5 aerosol concentrations have been recovered, together with SO2 concentration fields, originally not distributed by IIASA.

The output of the RegCM model simulations provided by ICTP have been transferred both to CASPUR and CNR-ISAC. Preliminary analysis performed both at CNR-ISAC and ICTP on a first version of the simulations has allowed ICTP to improve the initialization of snow cover, the dynamical parametrization of dust generation and issues in aerosol transport, leading to an improved final set of model results.

The output of existing climate simulations performed by CNR-ISAC at CASPUR using the ECHAM-HAM 5.5 model, including the aerosol dynamics and transport module HAM2, have been collected and made available in a centralized archive at CNR-ISAC.

A plotting tool has been developed in order to allow fast and easy production of spatial distribution maps of gridded netcdf data, based on the GMT package (Generic Mapping Tools). The developed tool, under the form of a unix command allows the flexible generation of spatial maps, providing different projections, selection of areas and different color maps. This tool has been used for the AOD analysis in this pilot study.

3.3 Formation

CNR-ISAC organized the XX edition of the Alpine Summer School, held in Valsavarence, Valle d'Aosta, Italy, from 20 to 28 June 2012, titled "Climate, Aerosols and the Cryosphere" (http://www.to.isac.cnr.it/aosta_old/aosta2012/index.htm). The course presented the current state-of-knowledge concerning the effect of short-lived species, in particular light absorbing aerosols, on climate with an emphasis on our current state of knowledge as well as future mitigation strategies. The course discussed the specific links between short-lived species in particular aerosol and their absorbing components and the cryosphere dynamics, with a focus on the Hindu-Kush-Karakorum-Himalaya, a region where radiative forcing from aerosols is expected to have a significant impact. The course addressed also the more practical issues linked to impact, adaptation and mitigation of global changes. The school saw the participation of 13 lecturers among the leading experts in the world on these topics and over 30 graduate students.

3.4 Dissemination

None in the reference period.

3.5 Participation in conferences, workshops, meetings

Scientific results developed in the framework of this pilot study have been presented in the following workshops and conferences:

- Aerosol modelling results with two global models (ECHAM-HAM and TM5) have been presented at the European Geosciences Union (EGU) General Assembly 2012, Vienna, 22-27 April 2012.

- Discussion of modelling strategies and presentation of scientific results at the Paprika modelling meeting at CNR-ISAC Torino on 2-3 April, 2012 and at the General meeting of the Paprika-Italy project, CNR-ISAC, Torino, 30.11.2012.

- 3rd International Conference on Earth System Modelling 17-21 September 2012, Hamburg, Germany.

4. Results obtained during the reference period

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

For this pilot study we analysed a series of numerical simulations (present-day, with ERA-Interim and EC-Earth boundary conditions, and the RCP4.5 scenario) performed with the RegCM4 regional climate model. These simulations have been stored at CNR-ISAC, ICTP and CASPUR. The analysis results are described in detail in the corresponding deliverable D2.6.1 and the available output data and further details on the model are described in the deliverable D2.5.1.

AOD data from the Moderate Resolution Imaging Spectro radiometer (MODIS) aboard the Terra satellite starting from 2000 were recovered and archived at CNR-ISAC. Specifically the Aerosol Cloud Water Vapor Ozone Daily L3 Global 1Deg CMG collection products were used. In addition AOD data from the MACC (Monitoring Atmospheric Composition and Climate) project, have been recovered and archived, starting from 2003.

Global aerosol simulations performed with the model ECHAM-HAM have been performed for a series of different anthropogenic forcing datasets and archived at CNR-ISAC. Further details on the ECHAM-HAM simulations are provided in deliverable D2.5.1.

In-situ measurements of AOD from the global network AERONET for the HKKH region have been retrieved and stored at CNR-ISAC.

4.2 Publications

The paper "Asian Monsoon and the Elevated-Heat-Pump Mechanism in Coupled Aerosol-Climate Model Simulations" by Miriam D'Errico, Chiara Cagnazzo, Pier Giuseppe Fogli, William K. M. Lau and Jost von Hardenberg is currently in preparation.

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

The model data outputs provided by ICTP from the RegCM model for the historical period (2000-2009) and for the RCP 4.5 scenario (2040-2050) have been transferred to CNR-ISAC and to CASPUR and are available on the THREDDS dataserver (TDS) provided by CASPUR/Cineca:
(https://bl102.caspur.it:8443/thredds/catalog/NextData/ICTP/RegCM/India-CORDEX/EC-Earth_BC/historical/catalog.html).
The output files are monthly netcdf files and give for each aerosol type the instantaneous concentrations and burden, the average deposition fluxes (drydep, rainout, washout), emissions fluxes and the dry deposition velocity. Outputs of AOD and of radiative forcings are also available, together with atmospheric data, surface data and radiative data. The data on the TDS are distributed over subfolders "3hr", "6hr", "day" and "mon" based on their timebase. The surface data (e.g temperature at 2m, precipitation etc) are available at 3hr time intervals. Daily statistics such as e.g. daily maximum temperature are available at daily time intervals. All other files/variables are available as snapshots at 6hr frequency. For user convenience CNR-ISAC also created daily averages (in subdirectory "day") and monthly averages ("mon") of all files.

4.4 Completed deliverables

The deliverable D2.6.1 has been completed with the results for the first year of activity of this pilot study.

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.

6. Expected activities for the following reference period

The comparison between the model simulations and observations will be extended to available local in-situ observational datasets. In particular AOD and Angstrom parameter measurements available from the AERONET network will be compared. The analysis will also be extended to other chemical and physical aerosol parameters (such as the aerosol absorption coefficient, concentrations, scattering coefficient, number size distribution, PM1, PM2.5 e PM10) available from the EBAS database parameters and directly from CNR-ISAC, measured at the Nepal Climate Observatory - Pyramid ABC site (Nepal) and measured at sites in the Karakoram range. Particular interest will be in the analysis of BC and dust long-range transport in the model, identification of source areas and their deposition on snow and ice.