Project of Strategic Interest NEXTDATA

Deliverable D1.1.5
Report describing the activities, data transfer to archives and to the General Portal

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Within WP1.1, the in-situ activities of mountain meteo-climatic measurements in the regions of interest (Italian Apennines, Hindu-Kush Karakoram Himalayas, Rwenzori) were continued (Tab. 1). The Automatic Weather Station (AWS) network in the Khumbu valley (Himalayas) were upgraded by using new acquisition systems. The AWS at Mt. Stanley (Rwenzori) was implemented by upgrading the acquisition system. Data analyses were carried out for meteorological measurements in Himalayas as well as for atmospheric composition data in Nepal (Kathmandu) and in Pakistan (Deosai Plateau). The status of station (AWS) operations, data validation and data transmission to the NextData archives are described in the Annex 1.
It should be clearly stated that the funds expected for 2014 have not been received till today, leading to a significant limitation of the planned scientific activities.

Measurement site	Country/Continent		Class	Elevation (m a.s.l.)
Osservatorio Portella del Gran Sasso (central Apennines)	Italy	Europe	ATM	
SusKat Observatory (Kathmandu valley)	Nepal	Asia	ATM	1,250
Pyramid Laboratory Observatory (Khumbu valley, Himalayas)	Nepal	Asia	AWS	5,050
Pheriche (Khumbu valley, Himalayas)	Nepal	Asia	AWS	4,258
Namche Bazaar (Khumbu valley, Himalayas)	Nepal	Asia	AWS	3,560
Lukla (Khumbu valley, Himalayas)	Nepal	Asia	AWS	2,660
Kala Patthar (Khumbu valley, Himalayas)	Nepal	Asia	AWS	5,600
Changri Nup Station (Khumbu valley, Himalayas)	Nepal	Asia	AWS	5,700
Urdukas (Baltoro glacier, Karakorum)	Pakistan	Asia	AWS	3,926
Askole (Baltoro glacier, Karakorum)	Pakistan	Asia	AWS	3,015
Concordia (Baltoro glacier, Karakorum)	Pakistan	Asia	AWS	4,700
Deosai Plateau (Karakorum)	Pakistan	Asia	ATM	4,000
Mt. Stanley (Elena glacier, Rwenzori)	Uganda	Africa	AWS	4,700

Tab 1. Measurement stations (AWS, ATM: observatories for atmospheric composition measurements) supported by NextData.

1. Activities in Nepal

1.1 Meteorological observations in Himalayas

The activities carried out in the Himalayan areas are located mainly in Nepal, thanks to the presence of the International Pyramid Laboratory-Observatory, installed by Ev-K2-

CNR in 1990, at 5,050 m a.s.l. in collaboration with the Nepal Academy of Science and Technology. This facility represents a strategic logistic base for supporting monitoring activities carried out along the Khumbu Valley, in the region of Mt. Everest, where the AWS network (Tab. 1) and the GAW/WMO Nepal Climate Observatory Pyramid (see WP1.2) are located.
During 2014, in-situ calibration and checking activities were performed using the "travelling standard" AWS-QC (Automatic Weather Station for Quality Check). During 2014, intercomparison exercises were carried out at the Lukla AWS (2660 m a.s.l.) and at the Pyramid AWS (5050 m a.s.l.) allowing the identification of possible sensor malfunctioning or drifts. Overall, the Lukla AWS was compared with the travelling reference AWS-QC for 20 days and the Pyramid AWS for 10 days (for more details see the Deliverable D1.1.6). These comparison periods were necessary to operate during days of completely clear sky in order to assess the quality of the radiometer data. During 2014, the instrumental equipment of the AWS-QC has been re-calibrated. The solar short-wave radiation sensor, after being tested at the reference site of Lampedusa (thanks with the collaboration with ENEA-UTMEA), was recalibrated at the WMO World Radiation Centre – PMOD in Davos (Switzerland).
During the reference period, the data transmission system was upgraded: four AWSs (Kala Patthar, Changri Nup, Pyramid and Pheriche) are currently operating in near-real time mode. A huge work has been carried out in the Himalayas by the Ev-K2-CNR URT to harmonise the acquisition protocol of the AWS working along the Khumbu Valley: at the end of the autumn campaign, data acquisition systems were harmonized (in terms of acquisition time frequency and file format) for all the AWS working along the Khumbu Valley. ISAC-BO completed the validation of the 2010 – 2012 data series recorded at the nine AWS in Nepal and Pakistan (see Annex 1). The validated data were provided to the Ev-K2-CNR URT for the submission to the NextData archives (by way of the Geonetwork system). In addition, ISAC-BO elaborated, for a sub-set of historical AWS in Nepal (Lukla, Namche, Pheriche and Pyramid), a "meteorological atlas" with the purpose to provide reference climatological information for each of the measurement stations. Only the data flagged as "good" have been considered for this analysis. For each AWS the atlas contains information on the (i) seasonal and monthly wind roses for four time slots of the day, and (ii) monthly and yearly time series of temperature, relative humidity, atmospheric pressure, wind speed, precipitation and solar radiation.
A preliminary investigation about the long-term (2000 – 2012) variations of these meteorological parameters (except wind direction) has been carried out for these selected stations (see Annex 2).

1.2 Contribution to the ABC-SusKat Project: atmospheric composition measurements in Kathmandu and data analysis.

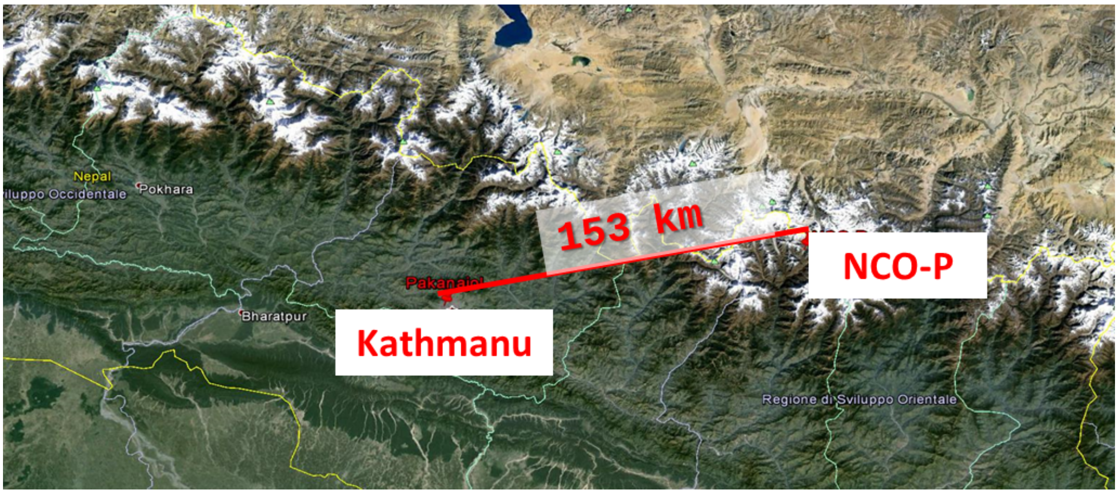

Fig. 1. Geographical location of Kathmandu and NCO-P along the Himalaya region.

As part of the International collaboration activities within the Suskat (Sustainable Atmosphere for the Kathmandu Valley) Project, the observations and the study of the atmospheric composition at the Observatory "Pakanajol" continued during the reference period. ISAC-CNR, in collaboration with the Ev-K2-CNR URT staff, continuously verified the correct execution of the measurements (ozone, black carbon equivalent, size distribution of particles, integrated particle count, meteorology, solar radiation) to timely point out and fix instrumental problems. In particular, the ISAC-CNR staff analysed the day-to-day variations of the different monitored parameters, by interacting with the local Nepali staff. On March 2014, the PM10-PM1 measurements have been suspended while only sporadic measurements by the Condensation Particle Counter (CPC) were performed due to a series of instrumental failures (the instrument has been sent back to Italy for maintenance). In May 2014, the ozone analyser was compared against a calibrated analyser. Even if this comparison was not designed to obtain a calibration curve, it revealed that the Pakanajol analyser performs in very good agreement respect to the reference instrument. The data obtained for the period February 2013 - January 2014 were submitted to NextData archives by way of the GeoNetwork system.

At ISAC-CNR, the analysis of the data collected at the Pakanajol Observatory were prosecuted in order to study the processes affecting air quality and Short - Lived Climate Forcers (SLCF) behaviour at the Kathmandu hot-spot and in the Himalayas. In particular, the results concerning the comparison of the SLCF measurements at Pakanajol with the concurrent observations at NCO-P were presented at the EGU 2014 General Assembly in Vienna. Specifically, the different SLCF seasonality (see Fig. 3) at the two locations was used to investigate the different perspectives of the Atmospheric Brown Cloud phenomenon (emissions vs transport) between the Himalayas and the foothills.

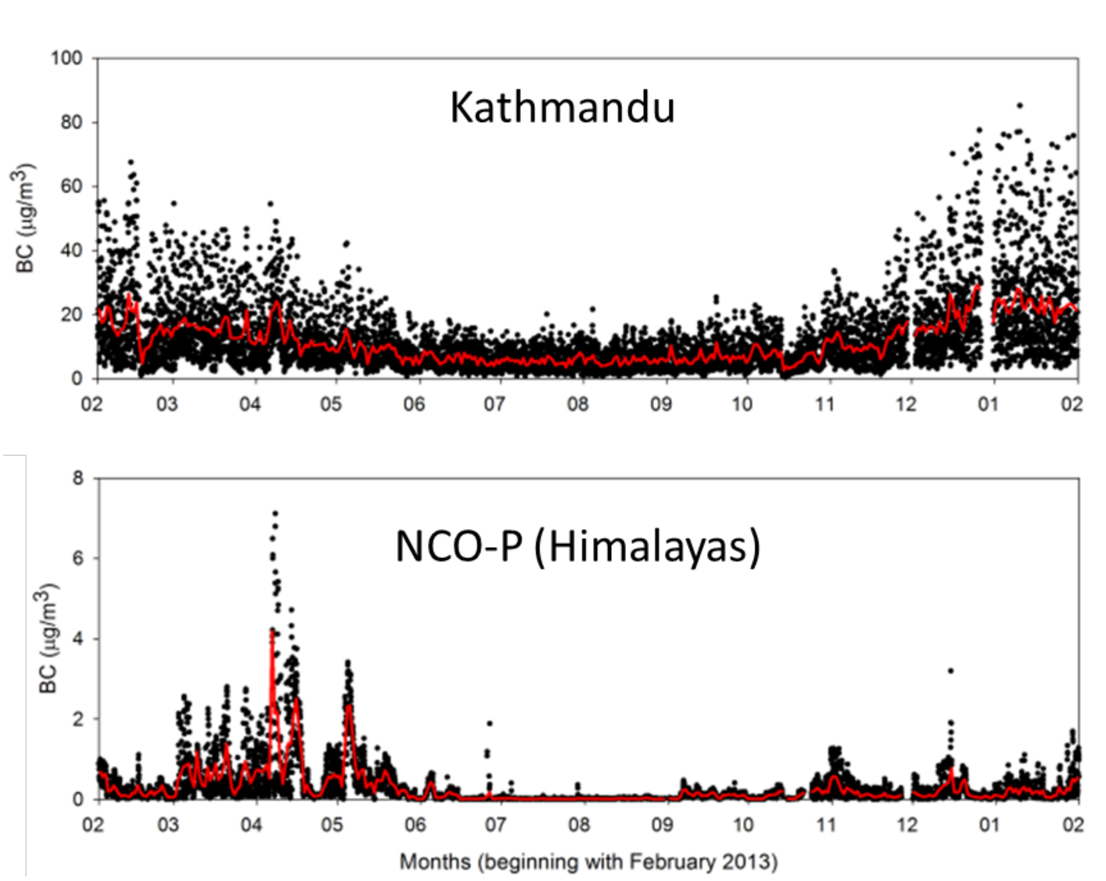

Fig. 3. ***Upper plate*: hourly mean values of eqBC at Kathmandu-Pakanajol. *Bottom plate*: hourly mean values of eqBCat NCO-P. Red lines represent daily mean values.**

At Pakanajol, the following average mean values were obtained for the period February 2013 – January 2014: BC = 11.6 ± 10.7 μg/m^3, O_3 = 27.0 ± 21.3 nmol/mol, Accumulation particle number = 505.1 ± 372.3 cm^{-3}, Coarse particle number = 3.3 ± 2.4 cm^{-3}, total integrated particle number = 11.6 ± 12.0*10^3 cm^{-3}. As showed for BC and O_3 (Figure 4), highest concentrations observed during pre-monsoon (MAM) and winter (DJF).

At Kathmandu, during pre-monsoon, no linear correlation (r = -0.08) between O_3 and eqBC exists (Figure 5) when considering daily values. This probably indicates that, besides local anthropogenic emissions, a significant role in determining the day-to-day O_3 variability is likely played by photochemistry and atmospheric dynamics (possible entrainment of O_3 from free troposphere/residual layers within valley PBL).

As shown by Putero et al. (2014), eqBC concentrations in Himalayas are significantly affected by fire emissions occurring at regional scale. With the aim of investigating the possible influence of these processes on the Kathmandu SLCF variability, we analysed the temporal behaviour of eqBC at Pakanajol as a function of open fire occurrence over South Himalayas, as deduced by the analysis of the MODIS satellite fire data-set (product: MCD14ML). We found almost no correlation between eqBC at Kathmandu and the number of fires in the Himalaya foothills (r = 0.11) at Pakanajol, suggesting that the eqBC variability at this site is mainly influenced by other anthropogenic emissions such as traffic and domestic uses. Nevertheless, some eqBC peaks (red bars in Figure 6) were superimposed with periods of high fire activities, possibly indicating that some specific pollution events can be affected by open fire emissions. More work is needed to better assess this point.

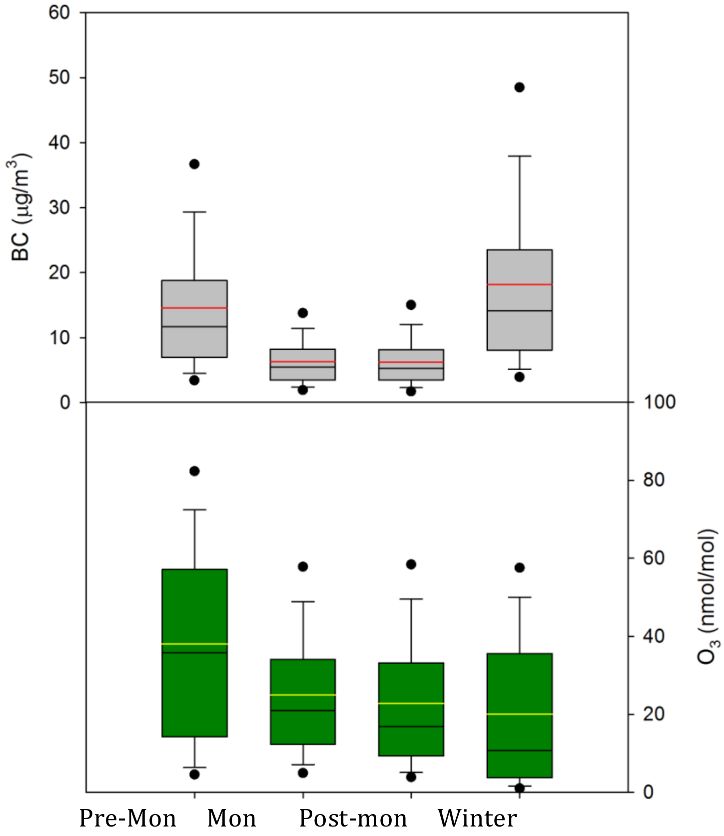

Fig. 4. Box and whisker plots representing basic statistical parameters (percentiles and average values) for BC (upper plate) and O_3 (bottom plate) at the Suskat Station at Pakanajol.

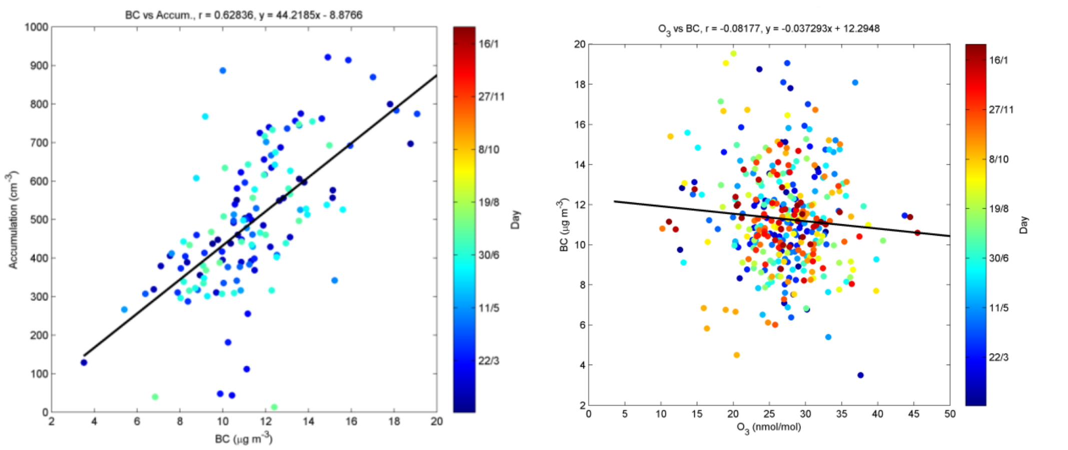

Fig. 5. Correlation study between daily value of eqBc and accumulating particle (left) and eqBc and O_3 (right) during the pre-monsoon. The coloured bars denote the calendar day of measurements.

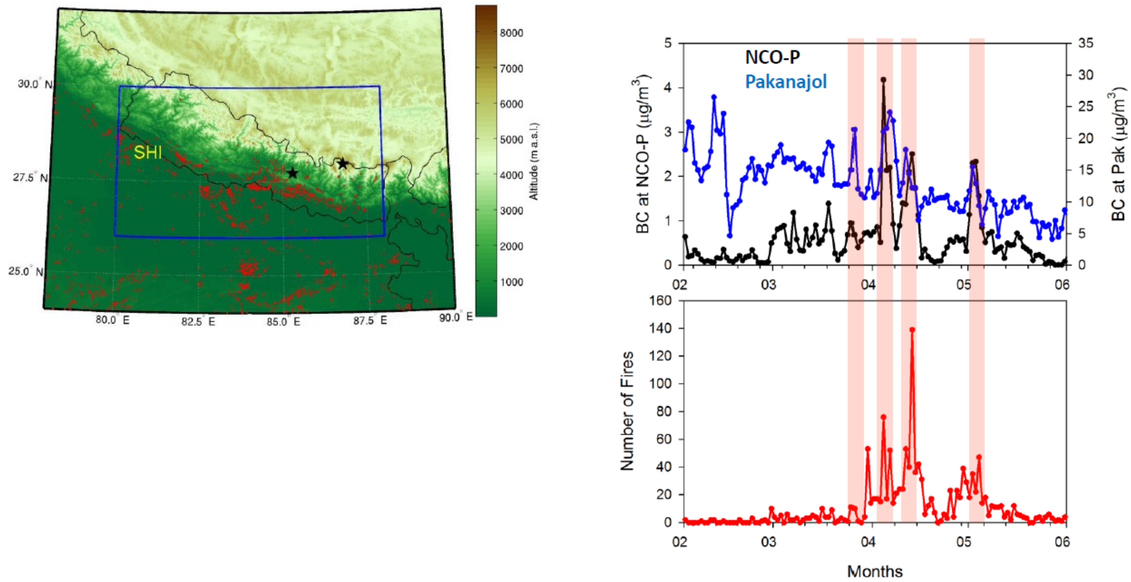

Fig. 6. Daily average values for eqBC at Pakanajol (blue) and NCO-P (black) as well as the number of MODIS fires (red) over the analysed spatial domain (top left). Red bars denote possible fire events able to influence eqBC at Kathmandu.

2 Activities in Pakistan

As pointed out by the WP1.1 Activity report, the research activities carried out in Pakistan were related to the maintenance of the three AWSs at Askole, Urdukas and Concordia (Baltoro Region) and to data validation. In June 2014, the Ev-K2-CNR URT personnel carried out one field campaign during which technical interventions to the AWSs were performed. ISAC-CNR validated the meteorological and radiometric data for the period 2010 – 2012 (see Annex 1). Data were sent to the Ev-K2-CNR URT for the submission to the NextData archives by way of the Geonetwork system.

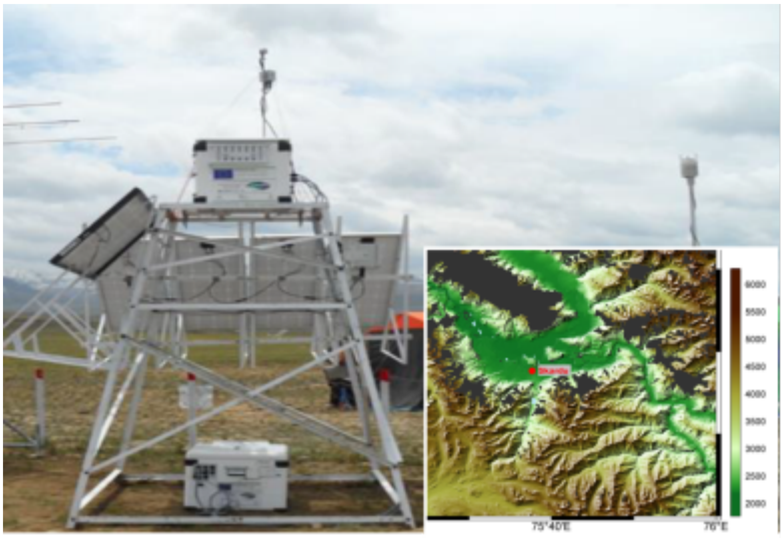

Fig. 7. The Remote Climate Station installed at the Deosai Plateau in Pakistan. A trellis is used to reduce the possibility that the Station is covered by snow accumulation.

ISAC-CNR validated the atmospheric observation data recorded by the Atmospheric Observatory in the Deosai region (surface ozone, equivalent BC, aerosol size distribution, meteorological parameters). A Remote Climate Station (i.e. an improved version of the transportable system used in the Summer 2012 experimental campaign) was installed at the Deosai Plateau (4200 m a.s.l.) on Summer 2013, in collaboration with the Pakistan Meteorological Department (PMD) and the Water And Power Development Authority (WAPDA) to obtain the first information on SLCF variability and typical levels at the Deosai region (Figure 7). This represents a contribution to the ABC-UNEP Project, since until now no scientific permanent experimental activities were performed in the Karakorum region. Unfortunately, due to the harsh environmental conditions and technical instrumental problems, poor data coverage characterised the period November – December 2014 (Figure 8). Even if the observing system was installed on a trellis at 2.5 m from the ground, the snow covered the solar panels preventing the accumulation of energy to power the station. However, atmospheric composition was recorded almost continuously (especially for ozone and particle number concentration) from January to March 2013, providing the first hints about typical springtime SLCF levels and variability in this region. Validated data were submitted to NextData archives by way of the Geonetwork system.

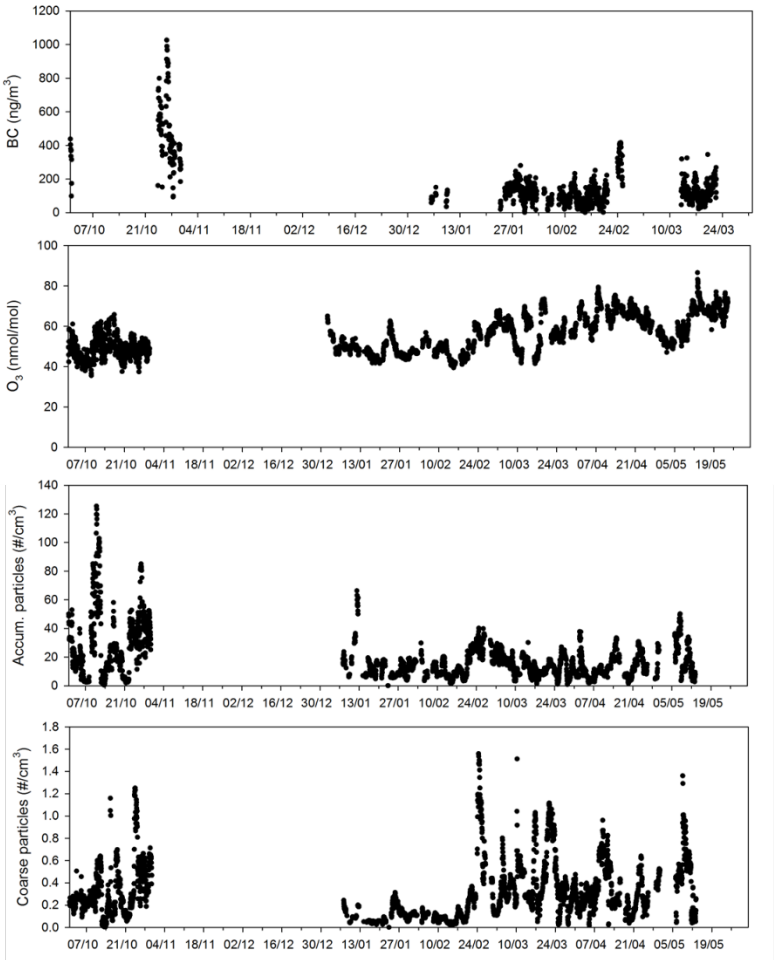

Fig. 8. Hourly mean value of SLCFs (ozone, eqBC, accumulation and coarse aerosol number) recorded at the Deosai Observatory from October 2013 to may 2014.

During the reference period, technical activities to reinforce this measurement site were planned, but, due to the lack of scheduled funds, we cannot be able to do any actions to fix the technical problems pointed out during the first months of experimental activity.

3 Activities in Africa

3.1 Meteorological observations at Rwenzori Mountains

In Uganda, the URT Ev-K2-CNR performed a maintenance campaign at the Rwenzori measurement site (4.700 m a.s.l.) to upgrade the AWS acquisition system: the software was modified to fulfil WMO guidelines. ISAC-CNR validated the data series from January to December 2013. Data were submitted to URT Ev-K2-CNR to be included in the NextData archives by way of the Geonetwork system.

Fig. 9. The AWS installed at Mt. Stanley (Rwenzori) on January 2013.

4. Activities in Italy

4.1 Alps

In Italy, URT Ev-K2-CNR performed preliminary activities for the installation of a new AWS on the top of Mt. Bianco mountain. On Autumn 2014, a base was built at 4.720 m a.s.l. where a new AWS is supposed to be installed when the meteorological conditions will be favourable. The AWS, which feasibility plan was already defined during the first year of the Project, is equipped by:

- thermo-hygrometer Vaisala HMP155;
- anemometer Young Wind Monitor 05103 (Alpine Version);
- barometer Vaisala PT330;
- radiometer Kipp&Zonen CNR4;
- nivometer Sommer USH-8;
- total pluviometer OTT Pluvio2;
- WebCam MOVIX (Umbria Meteo).

Once installed, the AWS will be managed by URT Ev-K2-CNR and ARPA Valle d'Aosta. The scientific goals were related to the improvement of the regional weather observation network at high altitudes and to enlarge the availability of high quality meteorological data at high altitude for model validation/verification.

4.2 *Apennines*

The Monte Portella station (42°26'52.96" N, 13°33'02.41", elevation 2401 m a.s.l.) on the Gran Sasso chain (Central Italy), was installed at the beginning of July 2012: continuous measurements of meteorological parameters and atmospheric composition started since July 19, 2012. The observed parameters are: temperature, relative humidity, pressure, velocity and wind direction, O_3, NO_x and particle size distribution (University of L'Aquila allows real time transfer of data to a local server. A webpage with information about the station and 5-min updated data can be found at the following link: http://www.aquila.infn.it/lif/high-altitude-observatory.html).
Due to the lack of the scheduled funds, the planned activities were significantly reduced. ISAC-CNR provided to the University of L'Aquila a state-of-art surface O_3 UV-analyser (Thermo 49i) to be installed at the station. Moreover, the ISAC-CNR staff realized the system for the execution of automatic zero/span daily check.

Database availability:

- High-mountain network AWS: see Annex 1.
- Deosai Plateau, Pakistan (October 2013 – May 2014): O_3, eqBC, aerosol number size distribution (280 nm <Dp< 20 mm), meteorological parameters, solar radiation (measurement status: ongoing; format: WMO/GAW WDCGG/WDCA; status: validated data; data provider: URT Ev-K2-CNR, data access: **Geonetwork**);
- Kathmandu – Pakanajol Station (February 2013 – January 2014): surface O_3, eqBC, total particle number concentration (20 nm ≤ Dp< 3 m 3 3 l particle number concentration (20 nm ^{2} Dp< Dp< 10 m 10 PM_{10}, $PM_{2.5}$ (only February – March 2013), PM_1 (April – December 2013), meteorological parameters, global short-wave solar radiation; (measurement status: ongoing; format: WMO/GAW WDCGG/WDCA; status: validated data; data provider: ISAC-BO, URT Ev-K2-CNR; data accessibility: **Geonetwork**).

Project of Strategic Interest NEXTDATA

Scientific report
for the reference period 01 – 01 – 2014 / 31 – 12 - 2014

WP 1.1 High altitude climate observation system

WP Cordinator: Paolo Cristofanelli

Partners: URT Ev-K2-CNR, CNR-ISAC

ANNEX 1
STATUS OF DATA AVAILABILITY
FROM THE AWS NETWORK

*This document reports the status of data availability for the Automatic Weather Station (AWS) operating within the scientific activities of WP1.1. Availability is intended to describe the status of data transmission to NextData General Portal by their submission to the Geonetwork system (see WP2.1) in January 2015. When data are still not present in the NextData archives, the modality for data access is indicated***.**

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Himalaya AWS – 1

Station	Parameters	Measurement period	Availability of validated data
AWS Pyramid *Data resolution: 60-min*	Atmospheric Pressure	1994 - ongoing	2002 - 2012
	Air Temperature		
	Relative Humidity		
	Wind Speed		
	Wind Direction		
	Precipitation		
	Global Radiation	2000 - ongoing	2002 - 2012
	Incoming Shortwave	2002 - ongoing	2002 - 2012
	Outgoing Shortwave		
	Incoming Longwave		
	Outgoing Longwave		
	Soil Temperature 5 cm	2002 - 2012	2002 - 2010
	Soil Temperature 20 cm		
	Soil Heat Flux		
	Soil Moisture		
	Snow Depth		
AWS Pheriche *Data resolution: 60-min*	Atmospheric Pressure	2001 - ongoing	2002 - 2012
	Air Temperature		
	Relative Humidity		
	Wind Speed		
	Wind Direction		
	Precipitation		
	Global Radiation		
AWS Namche *Data resolution: 60-min*	Atmospheric Pressure	2001- ongoing	2002 - 2012
	Air Temperature		
	Relative Humidity		
	Wind Speed		
	Wind Direction		
	Precipitation		
	Global Radiation		

Himalaya AWS – 2

Station	Parameters	Measurement period	Availability of validated data
AWS Lukla *Data resolution: 60-min*	Atmospheric Pressure	2002 - ongoing	2002 - 2012
	Air Temperature		
	Relative Humidity		
	Wind Speed		
	Wind Direction		
	Precipitation		
	Global Radiation		
	Incoming Shortwave	2007 - ongoing	2007 - 2012
	Outgoing Shortwave		
	Incoming Longwave		
	Outgoing Longwave		
	Soil Temperature 5 cm	2007-2012	2007-2010
	Soil Temperature 20 cm		
	Soil Heat Flux		
	Soil Moisture		
AWS Kala Patthar *Data resolution: 10 min*	Atmospheric Pressure	2008 - ongoing	2008 - 2012
	Air Temperature		
	Relative Humidity		
	Wind Speed		
	Wind Direction		
	Precipitation		
	Global Radiation		
	UVA Radiation		
AWS ChungriNup *Data resolution: 30 min*	Air Temperature	2010 - ongoing	2010-2012
	Relative Humidity		
	Wind Speed		
	Wind Direction		
	Incoming Shortwave		
	Outgoing Shortwave		
	Incoming Longwave		
	Outgoing Longwave		

Himalaya AWS – 3

Station	Parameters	Measurement period	Availability of validated data
AWS Colle Sud *Data resolution: 10 min*	Station Pressure	2008-2011	***Upon request to the data provider***
	Air Temperature		
	Relative Humidity		
	Wind Speed		
	Wind Direction		
	Global Radiation		
	UVA Radiation		

Karakorum AWS

Station	Parameters	Measurement period	Availability of validated data
AWS Concordia *Data resolution: 60-min*	Atmospheric Pressure	2011 - ongoing	2012
	Air Temperature		
	Relative Humidity		
	Wind Speed		
	Wind Direction		
	Precipitation		
	Incoming Shortwave		
	Outgoing Shortwave		
	Incoming Longwave		
	Outgoing Longwave		
	Snow Depth		
AWS Askole *Data resolution: 60-min*	Atmospheric Pressure	2005 - ongoing	2005 - 2012
	Air Temperature		
	Relative Humidity		
	Wind Speed		
	Wind Direction		
	Precipitation		
	Global Radiation		
AWS Urdukas *Data resolution: 60-min*	Atmospheric Pressure	2004 - ongoing	2004-2012
	Air Temperature		
	Relative Humidity		
	Wind Speed		
	Wind Direction		
	Precipitation		
	Incoming Shortwave	2011 - ongoing	2011-2012
	Outgoing Shortwave		
	Incoming Longwave		
	Outgoing Longwave		
	Snow Depth		

Rwenzori AWS

Station	Parameters	Measurement period	Availability of validated data
AWS Elena Glacier *Data resolution: 60-min*	Atmospheric Pressure	2006 - 2009 2013 - ongoing	2006 - 2009 2013: ***Upon request to the data provider***
	Air Temperature		
	Relative Humidity		
	Wind Speed		
	Wind Direction		
	Precipitation		
	Global Radiation		
	Precipitation	2013 - ongoing	***Upon request to the data provider***
	Incoming Shortwave		
	Outgoing Shortwave		
	Incoming Longwave		
	Outgoing Longwave		
	Snow Depth		

Project of Strategic Interest NEXTDATA

Scientific report
for the reference period 01 – 01 - 2014 / 31 – 12 - 2014

WP 1.1 High altitude climate observation system

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ANNEX 2
LONG TERM CLIMATOLOGY AND TREND ASSESSMENT IN THE KHUMBU VALLEY – PRELIMINARY RESULTS

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Introduction

In the following, climatology and preliminary trend analyses for 4 AWSs of the Khumbu Valley in Nepal (Pyramid, Pheriche, Namche and Lukla) are described. For Pyramid (5050 m a.s.l.) the available period is 2000-2012, for Pheriche (4300 m a.s.l.) and Namche (3600 m a.s.l.) 2001-2012 and for Lukla (2700 m a.s.l.) 2002-2012.

Pyramid and Pheriche are the highest elevation stations and they are characterized by colder and drier conditions with respect to Namche and Lukla. At those highest sites, wind speed is generally higher between March and May (Pre-Monsoon), the period of the year when also solar radiation values are higher, and in June. June to September is the wettest and rainy period of the year, characterized by the monsoon activity: rainfall represents about 80-90% of the total accumulated annual precipitation. During the Monsoon period and in Winter (December to February) the solar radiation values are the lowest of the year. The post-Monsoon period (October and November) is a transition period characterized by intermediate meteorological conditions.

Here below is a list of the abbreviations that are used to indicate the various meteorological parameters:

- Tmin, Tavg, Tmax are the minimum, average and maximum Temperature, respectively;
- RHmin, RHavg, RHmax are the minimum, average and maximum Relative Humidity;
- Pmin, Pavg, Pmax are the minimum, average and maximum Pressure;
- WSmin, WSavg, WSmax are the minimum, average and maximum Wind Speed;
- RADmin, RADavg, RADmax are the minimum, average and maximum Solar Radiation.

In the following, we report the analysis results for the each AWS. This analysis is based on monthly mean values which were calculated if at least a coverage of 75% on hourly data was available. Long-term trends were evaluated on a monthly basis by using a linear fit over the AWS measurement periods.

The statistical significance of the computed trends was assessed by using a t-student test on the slope values of the linear fitting. The following meaning of "trend" and "tendency" is adopted here: "trend" is used to indicate the presence of slope values significantly different from zero (at the 90% confidence level); "tendency" is used to indicate the slope values that do not appear to be statistically different from zero.

Pyramid – Climatology

Minimum temperatures ranged from -12°C (January and February) to 2°C (July).
Maximum temperatures ranged from -3°C (January and February) to 7°C (July).

Relative humidity ranged between 10% and 50-60% (December and January). On July and August, both minimum and maximum RH values ranged around 90-100%.

Pressure: lower values (548-552 hPa) in Winter and higher values at the end of the Monsoon season (September, values between 553 and 555 hPa).

Wind Speed are always rather low with mean values around 2.3-2.4 m/s in January-February and May-June and lower values (around 1.8-2.0 m/s) during the remaining Monsoon months and on the Post-Monsoon.

Solar Radiation: mean daily values were higher on the Pre-Monsoon and in June (around 260 W/m^2). The lowest values (about 200 W/m^2) were observed during the other months on the Monsoon and in November, December and January. Similar pattern are observed for the maximum daily values. November, December, January and February are characterized by Solar Radiation values around 800-900 W/m^2. Values greater than 1000 W/m^2 characterize the Pre-Monsoon season and are also found in June, while values around 1000 W/m^2 characterize the period between July and October.

Precipitation: It is important to underline that the only months having enough data coverage (at least 75% of total) are July, August and September, making it difficult to perform robust analyses for the other periods of the year. Monsoon is the only wet period of the year: it is characterized by a mean accumulated precipitation of about 366 mm. The total monthly mean accumulated precipitation is higher than 130 mm on July and August, and around 50 mm on June and September when rainy days are about 2/3 of the total. The rest of the year is poorly populated of precipitation data flagged as "good".

Pyramid – long-term trend

Temperature: mainly negative tendencies for Tmax (except in March, April and December) and positive tendencies for Tmin (except in June). Significant negative trends for Tmax are found in August and October while positive significant trends for Tmin are found in December. Positive tendencies are found for Tavg in March, April, September, November and December, while the remaining months showed negative tendencies.

Relative Humidity: always negative tendencies except for the November and December RHmin. Significant negative trends for:

- RHmin in August and September;
- RHmax from February to June and in October and December;
- RHavg in March and from August to October.

Pressure: always negative tendencies except in May and for Pmin and Pavg in August. Significant negative trends only in October.

Wind Speed: mainly negative tendencies. Significant negative trends only in May (when data coverage is less than 75%) and December for WSmax.

Solar Radiation: data coverage exceeding 75% only in October and December.

- WSavg: positive tendencies in March, April, July, August, September and December, negative tendencies for the rest of the year. Positive significant trends in February, negative significant trends in October;
- WSmax: positive tendencies except in May. Significant positive trends in jJuly, September and December.

Precipitation: Negative tendencies of the number of rainy days were observed in the monsoon season, while positive (negative) tendencies for accumulated precipitation were detected in June and September (July). August is the only month showing a significant negative trend for accumulated precipitation.

Pheriche – Climatology

Minimum temperatures ranged from -12°C (January and February) to 5°C (July and August). Maximum temperature: ranged from 2°C (January and February) to 12°C (June, July and August).

Relative humidity ranged from 20-30% (RHmin) and 80% (RHmax) in December-January to 90-100% (both RHmin and RHmax) in July and August.

Pressure showed the lowest values (602-605 hPa) on January and February and the highest on October (607 - 610 hPa).

Wind Speed mean values were around 3-4 m/s all over the year with no clear seasonal cycles.

Solar Radiation mean daily values were characterized by the peak values on the Pre-Monsoon and on June (higher than 250 W/m^2). The lowest mean daily values (less than 200 W/m^2) were measured in November, December and January. Maximum daily Solar Radiation values present similar patterns as Mean daily values. April, May and June have the higher values - around 1100 W/m^2 – while November, December and January showed the lowest RADmax values (800 W/m^2).

Precipitation: It is important to underline that the only months having enough data coverage (at least 75% of total) are July, August and September, making it difficult to perform robust analyses for the other periods of the year. Monsoon is the only wet period of the year: it is characterized by a mean accumulated precipitation of about 388 mm. The total monthly mean accumulated precipitation is higher than 120-130 mm on July and August, around 50 mm in June and 80 mm in September

Pheriche – long-term trend

Temperature: mainly negative tendencies were detected. Positive tendencies were detected for Tmin in December and January, April and may and in November for Tmin and Tavg. Significant negative trends for Tavg ad Tmax were detected in June, August and September.

Relative Humidity: mainly negative tendencies were detected except that for RHmax in April and May, RHavg in April - June and RHmin in May - August.
Significant negative trends were detected for:

- RHmin in December;
- RHmax from August to December;
- RHavg in October and December.

Pressure: always negative tendencies were detected except that for Pmax in May, August and January. Significant negative trends were detected only in June and July.

Wind Speed: negative tendencies were observed for WSmin (except in May). For WSavg and WSmax mainly positive tendencies have been observed in the first half-year (except in May and for WSavg in February), opposite tendencies in the second half-year except in December. Positive significant trends found for WSavg in April, while negative significant trends were detected for WSavg and WSmax in September and August.

Solar Radiation: mainly positive tendencies were detected for RADavg (except in March, May, October and November). Mainly negative tendencies were detected for RADmax (except in February and December). Significant positive trends were detected for RADavg in February and December, significant negative trends for RADmax from March to June.

Precipitation: no statistically significant trends were detected for the monsoon months (for which at least 50% of data coverage was available). Positive tendencies for the number of rainy days were detected (except that in July). Positive tendencies were detected also for accumulated precipitation in July and in September. Negative tendencies, instead, were detected in June and August accumulated precipitation.

Namche – Climatology

Minimum temperatures ranged from -5°C (January) to 9°C (July).
Maximum temperatures ranged from 3°C (January) to 14°C (June to August).

Relative humidity: the lowest RHmin values (about 30%) in December and January. RHmin ranged from 90% to 95% in the Monsoon season RHmax values higher than 90% all over the year.

Pressure was characterized by the lowest values (660-664 hPa) in January and February, and in June. The highest values were observed in October (~ 666 hPa).

Wind Speed average monthly values are about 2-3 m/s all over the year. The highest WSavg values characterized the Pre-Monsoon season.

Solar Radiation mean daily values peaked in April and May (higher than 270 W/m^2). These values decrease sharply since the beginning of the Monsoon season below 200 W/m^2 (170-180 W/m^2 between July and September).

Precipitation: the Monsoon season was the wettest period of the year with a mean accumulated precipitation of about 710 mm. July and August mean accumulated precipitation was about 260 mm and 210 mm, respectively. September and June averaged accumulated precipitation was around 130 mm. In July and August almost all days were rainy days, while in June and September about 83% of the days were affected by rain precipitation.

Namche – Long-term trend

Temperature: negative tendencies were detected for Tmax, while positive tendencies were mostly detected for Tmin (except that in January, March and August). For Tavg, February, May, September, November and December showed positive tendencies, while the remaining 7 months had negative tendencies. Significant negative trends were detected only for Tmax in June and for Tavg/Tmax in August.

Relative Humidity always showed negative tendencies except for RHmin in April and for RHmax in May. Significant negative trends were detected for:

- RHmin in February, March and from July to October;
- RHmax in February, March and from October to December;
- RHavg from February to April and from June to October.

Pressure: significant negative trends were detected for all the months and all the parameters (Pmin/Pavg/Pmax).

Wind Speed: for this parameter mostly negative tendencies were detected. Only for WSmin/WSavg/WSmax in October, and WSmin in May and June, positive tendencies were detected. The only positive significant trend has been detected for WSmin in July. Significant negative trends were detected for WSmin in Winter, for WSavg in January and for WSmax in November.

Solar Radiation: positive tendencies were observed for all the months and the parameters (RADavg/RADmax). Significant positive trends were detected for RADavg in January - April, in July and in October - December. As for RADmax, a significant positive trend was detected only in July.

Precipitation: No significant trends were observed. Positive tendencies have been observed for the number of rainy days except in September and March. Negative tendencies were detected for the accumulated precipitation except in September, April and May. The only statistically significant negative trend in the accumulated precipitation has been detected in October.

Lukla – Climatology

Minimum temperatures ranged from 0°C (January) to 13°C (July and August).
Maximum temperatures ranged from 10°C (January) to 19-20°C (Monsoon season).

Relative humidity showed the lowest values of RHmin (about 50%) in Winter, March and April. The highest RHmin values (about 90%) were found in July. RHmax values (equal or higher than 95%) were observed all over the year.

Pressure: the lowest values (747-750 hPa) were observed during the Monsoon from June to August. The highest values were observed in the Post-Monsoon months (751-753 hPa).

Wind Speed: WSavg values are rather low (about 1-1.5 m/s) all over the year. The higher WSavg values characterized the Pre-Monsoon, while the lowest ones the monsoonal months between June and August.

Solar Radiation daily average values peaked in the Pre-Monsoon (190-210 W/m^2), while the lowest values characterized the Monsoon season, with mean values lower than 140 W/m^2 in July and August.

Precipitation: Average accumulated precipitation was about 310 mm in June, 340 mm in September and about 700 mm in July and August. It should be remembered, however, that July, August and September have a data coverage lower than 50%.

Lukla – long-term trend

Temperature: significant positive trends were detected for Tmax, except that in September. As for Tavg, positive tendencies were observed (except that in January), while for Tmin prevailing negative tendencies were detected (except that in May and July). Significant positive trends were detected for Tavg in June, July and December. It should be noted that the months between July and September have data coverage lower than 50%.

Relative Humidity: prevailing negative tendencies were detected except that for RHmax in November and ,January, RHavg in April and RHmax/RHavg in May. Significant negative trends were detected for:

- RHmin, RHavg, RHmax in February, June and October;
- RHmax in March and August.

It should be noted that the months between July and October have a data coverage lower than 50%.

Pressure: mostly significant negative trends were detected. In particular, the most significant results were the negative trends in July, January - March and October - December. Significant negative trends were detected for Pavg/Pmax in June. Positive tendencies were detected only in August (all parameters) and for Pmin in September. It should be noted that August and September have a data coverage lower than 50%.

Wind Speed: prevailing negative tendencies were detected for WSmin (except that in March). Significant negative trends were detected for WSmin in Winter. For WSmax/WSavg significant negative trends were detected (except that for WSavg in July). It should be noted that from March to October good data are less than 50% of the total.

Solar Radiation: for RADavg positive tendencies were detected (except that in May). These tendencies were significant (i.e. trends) in Winter. As for RADmax, significant negative trends have been found in March, April and November. Positive tendencies were detected for RADmax in the remaining months (statistically significant in December).

Precipitation: the low data coverage prevented any calculation of trends or tendencies for rain precipitation at Lukla.