Project of Strategic Interest NEXTDATA

WP 1.1 – High-altitude Climatic Observation System and Climate Station Network
(WP leader: Paolo Cristofanelli)

Deliverable D1.1.A. Implementation of the background observation network: identification of instrumentation to be acquired, identification of real-time data delivery/early warning services and their integration within international programme. Identification of guidelines for the harmonization of measurement protocols, data analysis, QA/QC procedures including the reference to common calibration scales and reference methodologies (e.g. GAW-WMI, ICOS, ACTRS)

Table of Contents

1. Introduction

As reported by the executive plan, the NextDATA project will aim at creating a climate observational network in mountain and remote areas, based on climate observatories for the monitoring of meteo-climatic conditions and atmospheric composition (Fig. 1). The network for monitoring the background atmospheric composition comprises five high-mountain atmospheric observatories: Monte Cimone (CMN, Northern Apennines, the only WMO/GAW global station in Italy; 2165 m), Plateau Rosa (PRS, Western Alps, WMO/GAW regional station; 3480 m), Col Margherita (MRG, Eastern Alps; 2550 m), Monte Portella (CMP, Central Apennines; 2912 m), and Monte Curcio (CUR, Southern Apennines, WMO/GAW regional station; 1796 m). In addition to these observatories, the WMO/GAW regional stations Capo Granitola (south-western Sicily, CGR) and Lampedusa (LMP), although not high-altitude sites, will provide complementary information on the background conditions of the Mediterranean Basin.

The project activity, aimed at monitoring the background atmospheric conditions, is based on the upgrade and support to already existing atmospheric observatories, managed by different research organizations and CNR institutes. Several of these observatories are already part of international projects/research programme for the monitoring of Essential Climate Variables (ECVs). More specifically, in the framework of the WMO/GAW activity, observations of greenhouse and reactive gases are carried out at Plateau Rosa, Monte Cimone, Monte Curcio, Capo Granitola and Lampedusa (Table 1). Moreover, Plateau Rosa, Monte Cimone and Lampedusa are also included among the potential sites included to the European Research Infrastructure ICOS (Integrated Carbon Observation System), a pan-European research infrastructure which provides harmonized and high precision scientific data on carbon cycle and greenhouse gas budget and perturbations. Measurements of physical properties of atmospheric aerosols are performed at Mt. Cimone, Mt. Curcio, Capo Granitola and Lampedusa (Table 1) with Mt. Cimone as being also part of ACTRIS (Aerosols, Clouds and Trace gases Research Infrastructure) project, leading to ACTRIS-RI, a pan-European initiative consolidating actions amongst European partners producing high-quality observations of aerosols, clouds and trace gases. Col Margherita and Mt. Curcio were part of GMOS (Global Mercury Observation System), a global observing system providing comparable monitoring data on mercury levels in air and marine ecosystems in the Southern and Northern Hemispheres aiming to support the Minamata Convention (Arts. 19 and 22). These measurements constitute the basis for a more effective integration between observations carried out at these 7 measurement sites.

To contribute to the implementation of the background observational network, a list of devices, fundamental for the Italian contribution in international projects and useful for the implementation of a National observational network in mountain and remote areas, will be provided in this Deliverable. With the aim of strengthening the national support to international programme, a list of real-time data delivery/early warning services will be defined.

Particular attention will be devoted to the homogenization of the different ECVs measurement protocols, with a special emphasis for the observatories still in a start-up phase or not fully

integrated in international programs. The implementation of international harmonized protocols and methodologies will increase the competitiveness of the research activities carried out at these observatories. Moreover, common procedures for data creation and Quality Assurance/Quality Check (QA/QC) will be implemented; these are useful also for the measuring activities already belonging to international programs. At present, although well-defined Standard Operation Procedures exist for the different ECVs, the QA/QC procedures at each observatory are often (still) characterized by a low level of automation and not fully standardized. To integrate the different observatories into a proper network, and to activate near-real time services for data publication, the current standardization and harmonization level need to be improved, by defining in a uniform way the measurement guidelines and the QA/QC procedures.

Currently, the National research system is lacking a centralization of data recorded at these atmospheric observatories, which then need to be retrieved (often only in part) directly from the websites of the research institutions, or from the database of each measuring program. For this reason, NextDATA aims in providing a single national entry point for the time series of the ECVs recorded at these atmospheric observatories.

Figure 1. Geographical location and pictures of the monitoring stations belonging to the atmospheric background observational network supported by the NextDATA project.

ECV	Reference programmes	Monitoring station						
		PRS	***MRG***	***CMN***	***MGR***	***CUR***	***CGR***	***LMP***
CO_2	**WMO/GAW**	X		X		X	X	X
CH_4		X		X		X	X	X
N_2O	**ICOS-RI**			X				X
SF_6				X				
CFCs				X				
HCFCs	**WMO/GAW**			X				
HFCs				X				
CO				X		X	X	X
O_3		X	X	X	X	X	X	X
SO_2				X		X	X	
NO				X		X	X	
NO_2				X		X	X	
Particle scattering				X			X	
Particle absorption	**WMO/GAW**			X			X	
Particle size distribution	**ACTRIS**			X	X	X	X	
Particle concentration				X		X	X	
Coarse particle size distribution				X		X		
AOD				X				X
Total O_3	**WMO/GAW**							X
UV radiation						X		X
Meteorological parameters	**WMO/GAW**		X	X	X	X	X	X
Solar radiation			X	X	X	X	X	X
Atmospheric Hg	**GMOS**		X			X		

Table 1. List of Essential Climate Variables (ECVs) collected at the atmospheric background monitoring observatories (PRS: Plateau Rosa; MRG: Col Margherita; CMN: Monte Cimone; CMP: Monte Portella/Campo Imperatore; CUR: Monte Curcio; CGR: Capo Granitola; LMP: Lampedusa). Grey cells indicate the measuring activities that are already part of the WMO/GAW program.

2. Implementation of the observational network for monitoring the background environmental-climatic conditions

The observational network for monitoring the background environmental-climatic conditions aims to contribute at international projects and programmes: e.g. GAW-WMO, ACTRISI and ICOS-RI. The first goal of the NextDATA Project is to contribute, during its activity period, in supporting the operation of the atmospheric background stations. This will be accomplished by strengthening the observation and technical equipment, by sharing and disseminating standard methodology and SOPs for the observed ECVs, by implementing common automatic systems for the quality assurance/check (QA/QC) and for the data reporting.

2.1 Upgrade of measurement systems

During the early phase of NextDATA, a list of scientific questions (SQ) was provided to address the scientific activity within the Project (Deliverable D1.1.1). Among these, SQ1 and SQ3 stressed the importance of setting-up an observing system based on remote atmospheric observatories to contribute in obtaining more accurate operational atmospheric composition monitoring and forecasting by using near-real time data and in understanding the role of short-lived climate forcers (especially black carbon) in regulating the regional and global climate. Obtaining more and more accurate information about SLCF variability and emissions was recently stressed by WMO/GAW as follow up if the Paris Agreement. In June 2015, the 17th World Meteorological Congress requested a plan for an Integrated Global Greenhouse Gas (GHG) Information System (IG3IS). In December 2015, the UNFCCC nations forged the Paris Agreement, codifying the idea of nationally determined contributions (NDCs). Improved scientific understanding of the SLCF and "well-mixed" GHG is a key step to create policy-relevant information regarding climate change mitigation and adaptation at national and international frameworks. For these reasons, the integration of the observational network for monitoring the background environmental-climatic conditions was based on the double concept of creating a national system for the prevision of NRT data information about SLCF and GHG. To this aim, efforts must be carried out (1) to increase the number of measurement sites for the ECV of interest to (2) to implement technical solution for NRT quality assessment and delivery of data at the selected measurement sites.
In the following, we report, for selected measurement sites, indications about the instrumentation to acquire to strength the observational capacity of the stations as a function of integration within international programme or within the NextDATA background observational network. In agreement, with the executive plan, NextDATA will support the implementation of measurement programme at the Mt. Cimone WMO/GAW Global Station as well as the at the other background stations within NextDATA.

Monte Cimone (CMN)
To guarantee an efficient contribution of CMN observations in the framework of WMO/GAW, it is necessary to upgrade the system for the continuous observations of CO and CH_4 at the CNR "O. Vittori" Observatory, part of the Mt. Cimone WMO/GAW Global Station. Indeed, the systems currently in operation (GC-FID "Agilent 6890N" and Thermo Tei48C-TL NDIR) are not able, due to their age and technical limitations, to guarantee the data quality objective (±2 ppb for CO and CH_4)

and the data coverage requested by WMO/GAW. To optimize the implementation activity, a system based on the "Cavity Ring Down Spectroscopy - CRDS" has been selected to be installed at this station. This system is characterized by relatively low need of manpower and functional costs in respect to other techniques. This will also optimize the overall management of the measurement activity at this remote station. Moreover, the use of a CRDS system for multiple gas measurements, will also allow to reach the technical requirements requested in the framework of the ICOS European Research Infrastructure and described in the document "ICOS Atmospheric Station Specifications" (Laurent, August 2017, V2.01). This will promote the integration of the Mt. Cimone observatory within this pan-European research infrastructure. To reach the high ICOS requirements also the implementation of a new system for the remote management of calibrations based on the use of a 10-way multivalve is necessary, together with the use of mixture standards produced by the ICOS calibration laboratory and traced back to WMO/GAW central calibration standards (NOAA-GMDL). Moreover, to this aim is also necessary to upgrade the meteorological measurements by using sensors with low uncertainty on the 1-minute time resolution. Thus, in agreement with ICOS and WMO (Cimo) guidelines, new meteorological sensors for the continuous observations of air-temperature, relative humidity and atmospheric pressure must be implemented at Mt. Cimone.

During the first implementation phase of the NextDATA Project, an automated system for summer measurements of Aerosol Optical Depth (AOD) has been implemented at M. Cimone, following the WMO/GAW guidelines (see www.isac.cnr,it/cimone/sunphoto). However, the atmospheric profiling component is still limited at this station. Thus, a further implementation of atmospheric profiling capacity at Mt. Cimone is strategic both for interpretation of the atmospheric processes and atmospheric compound variability, and for the consolidation of the participation within international programme. To reinforce the capability of trace gas monitoring and the contribution to the Copernicus Atmosphere Monitoring Service and to ACTRIS, it is of paramount importance to upgrade the DOAS (Differential Optical Absorption Spectroscopy) system already in use at Mt. Cimone. To this aim, the DOAS system in use at Mt. Cimone since 1996 (developed by CNR-ISAC), has been substituted with a state-of-art system developed by CNR-ISAC in collaboration with Evora University (Portugal). In the current configuration (zenith-sky mode), this new DOAS system is able to perform simultaneous measurement of total column amount of O_3, NO_2, BrO, SO_2 e IO. To obtain the vertical profiles of these ECVs, the system must be implemented with a technical device for implementing the MAXDOAS (Multi-AXis DOAS) methodology. Thanks to the coupling of a camera able to scan the atmosphere and by the treatment of observed data with a radiative transfer model, it can be possible to obtain quantitative information of vertical distribution of the observed trace gases. The ultimate goal of this activity must be the international recognition of this measurement system within international networks. This must be done by the participation in intercomparison exercises and measurement campaigns, with the ambiguous goal to include the Mt. Cimone station within NDACC - Network for the Detection of Atmospheric Composition Change.
To strength the integration of Mt. Cimone within ACTRIS, it is mandatory to upgrade the system for the continuous observations of sub-micrometer aerosol size distribution, in order to carry out realiable measurement in stable conditions of flows, temperatures and relative humidity. To this aim the current DMPS (Differential Mobility Particle Sizer) system must be converted and upgraded to a SMPS (Scanning Mobility Particle Sizer) with an automatic adjustment of aerosol and flows. This will allow Mt. Cimone to be compliant with the most recent WMO/GAW

guidelines for the execution of particle size distribution measurements (WMO/GAW Aerosol Measurement procedures, Guidelines and Recommendations, 2nd Edition, GAW Report No. 227)

Col Margherita (MGR)

At Col Margherita, located at the border between Trentino and Alto Adige regions, not far from Passo San Pellegrino, since 2013 is working an atmospheric observatory managed by CNR-IDPA. This observatory was installed to perform continuous observation of atmospheric mercury (Hg) and related deposition (wet and dry). Originally, these observations were started in the framework of the GMOS (Global Mercury Observation System) EU-Project and were co-located with observations of meteorological parameters, solar radiation and snow level. The site location and the sampling system by which the station is currently equipped are suitable for the execution of atmospheric composition observations (especially for reactive gases). The station still presents some limitations related to the relatively small space available for the instrumentation and some problems related to the provision of continuous electrical power and lightning discharge. The station is unmanned with no scientific or technical personnel working in-situ. It can be reached after a 2-hour trip by car from the CNR-IDPA HQs in Venice.

For these reasons, with the purpose of upgrade the observation capability at this station, "state-of art" instrumentation characterized by a low need of manpower and characterized by well-assessed standard operation procedures (SOPs) must be considered, together with an upgrade of the electrical system of the station (e.g. UPS and technical solutions to limit black-out and lightning impacts). To integrate the station within the NextDATA background observational network and support the research programmes already on-going, it is necessary to upgrade the sensors for meteorological parameters and solar radiation. Then, measurement programmes concerning atmospheric composition variables must be further implemented. In particular, starting continuous measurements of short-lived climate forcers (a key topic within NextDATA, see Deliverable 1.1.1) like ozone and black carbon, can represents a strategic implementation for this station. These observations are already widely performed among the observatories part of NextDATA: this represents a strong point for a successful implementation of MRG station, taking into account the possible sharing of experience, technical knowledge and materials. Moreover, starting SLCF observations at MRG would effectively contribute to a better investigation of their variability and emissions on National and European scales, in agreement with the roadmap traced for the Paris Agreement. This would also represent a support for implementation of science-service by the provision of NRT data to international initiatives (e.g. CAMS-Copernicus).

Monte Portella (CMP)

The station of Monte Portella is situated in the locality of the same name in the National Park of Abruzzo. The station is owned by University of Chieti which, as well as coordinating the scientific research activities of projects to which the station is affiliated, also directly performs most of the measurement and monitoring programmes undertaken at the station. Located at 2401 m altitude, on the crest of Monte Portella in the National Park of Abruzzo, the measurement station has a strategic role in the study of atmospheric conditions at high altitude in the Mediterranean Basin.

- Variability of greenhouse and reactive gases in the atmosphere due to both natural and anthropogenic factors.
- Variability of physico-chemical properties of aerosol in the atmosphere due to both natural and anthropogenic factors.

The experimental equipment is hosted inside an insulated shelter, provided with a sloping roof in order to avoid, in winter, an excessive accumulation of snow which pose a risk of damage to the equipment. The shelter houses approximately 3 m^2 for scientific instrumentation, in good part already occupied by the equipment in operation at the station. The station is powered by a 220 V 3kW electric line that originates from the nearby shelter "Duca degli Abruzzi". The station is equipped with a system to ensure continuity (UPS) of instruments for about 120 min in case of blackout and with a radio connection to ensure an internet link to the station, allowing remote access to systems for data acquisition and transfer (also in almost real time/NRT).
The laboratories also have special sampling heads for air sampling aimed to trace gas and aerosol properties monitoring. In particular, a unified sampling system has been installed, for air samples to be used for the continuous analysis of greenhouse gas and reactive gas variability. The system, developed under NextDATA, complies with the guidelines of the Global Atmosphere Watch program of the WMO. In particular, the system consists of a Pyrex and Teflon© collection head, with a flow capacity of over 40l/s guaranteed by a turbine. Currently, this sampling system is used for the measurements of surface ozone by means of a UV-abortpion analyser (Thermo 49i).
The meteorological measurements have been carried out by an integrated weather station that is currently not working. This must be replaced as soon as possible to support the interpretation of atmospheric composition data and QA/QC procedures finalized to the data flagging. As for the Col Margherita station, taking into account the not easy accessibility to the station (especially during winter) and the limited power available for the measurement programmes, here we suggest the implementation of “state-of art” instrumentation characterized by a low need of manpower and characterized by robust standard operations. In particular, in the future the implementation of aerosol light-absorption (equivalent black carbon) measurements by using multi-angle absorption photometer (MAAP) or Aethalomters could be strategic for a more effective integration of the station within the NextDATA background network and within international programme or project.

Lampedusa (LMP)
The atmospheric observatory on the island of Lampedusa has been operational since 1997, when measurements of UV radiation and total ozone were started. Many additional instruments were added since then, and Lampedusa now contributes to different international measurement networks (GAW/WMO, ICOS, ACTRIS, EMSO, AERONET, MWRnet, NOAA cooperative air sampling network) with continuous observations of many atmospheric parameters. These include greenhouse gases, some reactive gases (CO and surface O3), meteorological parameters, aerosol, radiation, etc. Within NextData we expect to implement new measurement protocols and update some instruments to allow the full integration within developing measurement networks (e.g., ICOS and ACTRIS). A relatively large set of data (meteorology, greenhouse gases, surface O_3,, AOD, total ozone, UV radiation) is provided to the NextDATA database.

2.2 Identification of real-time data delivery/early warning services and integration within international programme

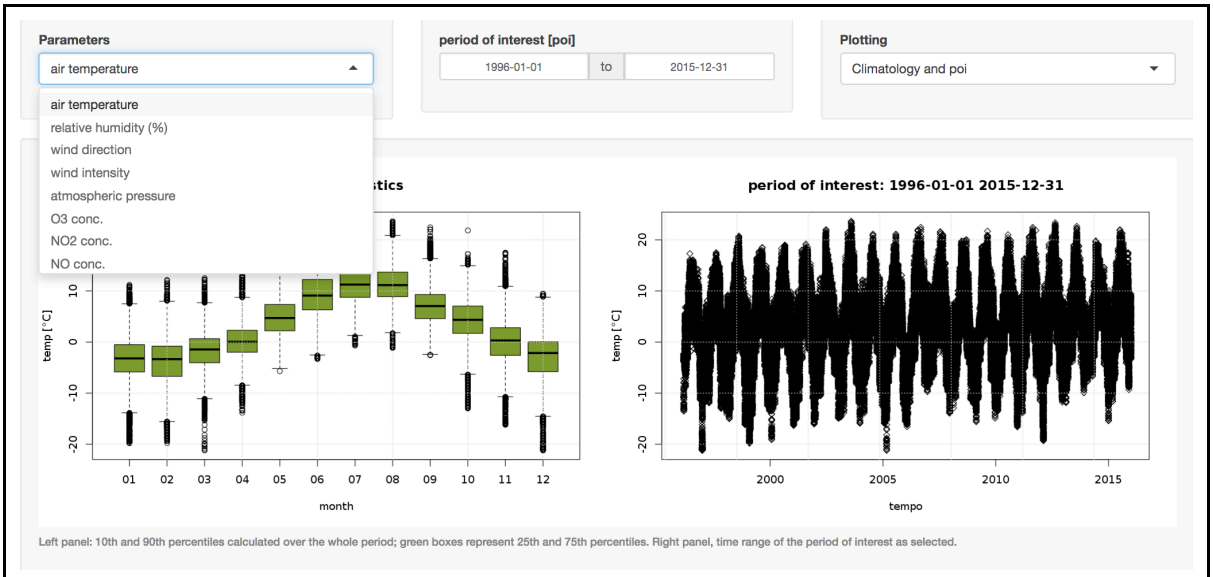
Specific services for the near-real time delivery and repository of data collected by some of the background atmospheric stations have been already activated in the framework of NextDATA and by other programme (es. GMOS, I-AMICA) devoted to strength the atmospheric observation capability in Italy. In the framework of NextDATA, we already activated (from PRS and CMN) NRT data delivery towards CAMS-Copernicus for reactive gases, towards GAW-NRT/ACTRIS for a subset

of aerosol parameters and towards WMO SDS-WAS for coarse particle number concentration(for CMN). NRT data delivery services were already implemented in the framework of the I-AMICA (from CUR and CGR) and GMOS (from MRG and CUR) network. Our goal is to further integrate and extend these services to other stations and ECVs before the end of NextDATA lifetime. To increase the integration of the background station within a National network, for a sub-set of ECV, we will implement automatic services to flag and format the data, in agreement with the WMO/GAW guidelines. These services, will be activated for MRG (surface O_3 and meteorological parameters), CMN (reactive gases, aerosol properties, AOD and meteorological parameters), CMP (surface O_3, aerosol size distribution and meteorological parameters), CUR (reactive gases, aerosol properties), CGR (reactive gases, aerosol properties) and LMP (surface O_3). These services will create a preliminary quality-assessed data-base also suitable for the activation of *near real-time data delivery/early warning* to external users.
In particular, we will support and implement the *near real-time data delivery/early warning* already activated in the framework of NextDATA. With the purpose of on-line verification of model forecast, we will extend the number of stations providing NRT delivery of reactive gases (O_3, CO, SO_2 and NOx) data to CAMS-Copernicus, with a special emphasis on O_3 and CO. Moreover, we will implement for CGR and CUR, the NRT data deliver experimental service concerning aerosol properties currently activated for CMN towards GAW-NRT/ACTRIS.
We will define the criteria for implementing an automatic system for the NRT detection of Sharan dust transport events based on near-surface observations of aerosol properties (aerosol size distribution, absorption and scattering coefficient) at different measurement sites integrated with the outputs from atmospheric model simulation. Moreover, we will implement an operational version of the STEFLUX code, already developed in the framework of NextDATA (*Putero, D., Cristofanelli, P., Sprenger, M., Škerlak, B., Tositti, L., and Bonasoni, P.: STEFLUX, a tool for investigating stratospheric intrusions: application to two WMO/GAW global stations, Atmos. Chem. Phys., 16, 14203-14217, https://doi.org/10.5194/acp-16-14203-2016, 2016*), to routinely identify the occurrence of stratospheric intrusion events at the high-altitude stations of the background network (Plateau Rosa, Col Margherita, Monte Cimone and Monte Curcio).

2.3 Data access

As mentioned in the introduction section, at the moment a single entry point for accessing the data of ECVs recorded by the background measurement stations does not exist. An important step for the integration of the network is to create a system by which data can be discovered, visualised and downloaded by external users. To this aim, we intend to implement the already existing MOVIDA (MonteCimone On-line VIsualization and Data Analyses) system (http://www.isac.cnr.it/cimone/data-access) to host and publish the time series of ECVs recorded by all the measurement stations part of the observational network (MOVIDA "Multistat").
MOVIDA is developed in R language by using shiny package (i.e. https://shiny.rstudio.com/) for plotting and data downloading. A linux virtual machine was dedicated to this application, which is installed on linux machine with an public IP.
The system for the data download is implemented and presented on the GUI (Graphical User Interface). It provides files in CSV format easy to import in the most common scientific technical computing languages (R, Matlab, Octave, Scilab, Julia, Python).
MOVIDA represents an "easy-to-use" and very intuitive web resource by which also not experts (e.g. high-school student or teachers, university student, citizens) can have access to the time series of ECVs over the Italian territory. Besides providing access to data time series, MOVIDA

represents a web resource by which external users can run some basic statistical analyses on the time series for each ECV and over flexible period of interests. Thanks to the packages Shiny (shiny.rstudio.com) and Openair (Carslaw and Ropkins, 2012), it is possible to plot raw data, average (on different time scales: daily, monthly and yearly) as well as to perform smoothing of time series to obtain information about long-term tendencies.
A preliminary version of MOVIDA "Multistat", is currently under development and it is available in the development environment at CNR-ISAC, see http://shiny.bo.isac.cnr.it:3838/plot-multistats/).



MOVIDA graphical web interface for the Italian Climate Observatory "O. Vittori". It is available - with free access to the dataset - at http://www.isac.cnr.it/cimone/data-access.

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3. Definition of guidelines to harmonize the measurement methodologies, protocols, QA/QC procedures, including the adoption of common reference calibration scales (e.g. GAW-WMO, ICOS, ACTRIS)

3.1 General approach

NexDATA aims to contribute in facilitating and strengthen the Italian contribution to international projects and programmes, e.g. WMO/GAW, ACTRIS-RI, ICOS-RI.
To this aim, for the background measurement stations, it is fundamental to implement the guidelines defined by the reference international programs for each observed ECV. In the next section, as a function of the different ECV focal areas, we will report the most update guidelines for each reference programme/project, together with the references to the calibration scales to be adopted.
The quality assessment system proposed in the framework of NextDATA for the background measurement network is based on the WMO/GAW approach:

1) Network-wide use of only one reference standard or scale;
2) Full traceability to the primary standard of all measurements;
3) Implementation of data quality objectives (DQOs) defined by the reference programs/projects;
4) Establishment of guidelines on how to meet these quality targets, i.e., harmonized measurement techniques based on Measurement Guidelines (MGs) and Standard Operating Procedures (SOPs);
5) Execution of round-robin exercises within the network for some key parameters;
6) Development of common procedures for the data validation to favour the timely submission of data submission to the international reference project/programme and to NextDATA archives.

In particular, in the framework of WP11, we propose a common approach for the data validation (data flagging) and for the format of data to be submitted to NextDATA archives and to the reference international programs/projects. Indeed, taking into account the large amount of data recorded by the measurement stations for the continuous monitoring of atmospheric composition, it is not feasible to carry-on the validation/flagging of data by the so-called “visual inspection” and by manual manipulation of data files. For these reasons, here we propose to develop and implement automatic procedures for data verification and formatting. The implementation of such an automatic procedures will represent a powerful resource to help the researcher in spending more time for the scientific purposes and not for data verification and formatting. Besides making faster the data creation process and favoring a timely data submission, the adoption of standardized validation procedures will also assure a more subjective flagging of data as well as the possibility to trace back the actions which leaded to data validation (i.e. data revisions will be easier).

Basically, the raw data (typically collected with a frequency of 1 minute) produced by each single instrument (often recorded with acquisition system not standardized among the different stations), will be elaborated – by using R scientific software codes – to harmonize the data format,

the flags and the data reduction (averaging) requested by the international reference programmes/projects (see next Tables).
In addition, such procedures, developed in the framework of NextDATA, will produce daily, monthly, seasonal and annual reports useful for the principal investigators of each stations for the data verification and data reporting. Annex 1 reports some examples of these reports preliminary which are currently produced by our pre-operational procedures applied to the surface ozone observations carried out at the Global Station WMO/GAW of Mt. Cimone.
Once finalized, the developed routines will be made available to whole scientific community.

Such routines have to be implemented on general criteria, but at the same time they can be adapted to each measurement sampling site:

- *Diagnostic/instrumental checks*: the internal instrumental parameters are considered (e.g. sampling flow, source light intensity, etc) and flagged on the basis of plausibility values. The data flag will be also defined according to the different instrumental status (e.g. sampling, zero, span,…).
- *Plausibility checks*: identification of measurement periods with measured values exceeding the expected variability. Such values depend by ECV, its typical variability and the sampling site feature.
- *Variability checks*: verification of the variability with time of the observed ECV. Basing on the considered ECV and depending by the site characteristics, a range for minimum and maximum ECV variability (i.e. rate of change by time) is defined (typically on hourly basis).
- *Comparison among parallel/simultaneous observations*: if available at the same measurement site, the time series of the considered ECV will be compared in order to point out possible anomalies.

The definition of data flags is based on the flagging system defined in the framework of WMO/GAW. Especially for reactive gases, physical aerosol properties and AOD, the data flagging is defined in agreement with guidelines provided by EBAS (operated by NILU) as WMO/GAW World Data Center for Aerosol and Reactive Gases. They can be found at http://ebas-submit.nilu.no/Submit-Data/List-of-Data-flags.

For greenhouse gases and carbon monoxide, the data flagging is defined in agreement with guidelines provided by the World Data Center for Greenhouse Gases (operated by JMA). They can be found on "Revision of the WDCGG Data Submission and Dissemination Guide" (GAW Report No. 188), https://www.wmo.int/pages/prog/arep/gaw/documents/GAW_188_web_20100128.pdf.

3.2 Reactive gases

Surface ozone, nitrogen oxides (NO and NO_2), sulphur dioxide and carbon monoxide are the reactive gases addressed in the NextDATA activites. For each of them, below are reported the referent guide lines.

- **Surface ozone**

Reference program: WMO/GAW; *guidelines:* GAW Report No. 209, Guidelines for Continuous Measurements of Ozone in the Troposphere

- **Nitrogen oxides**
  Reference program: WMO/GAW; *guidelines:* WMO/GAW Expert Workshop on Global Long-term Measurements of Nitrogen Oxides and Recommendations for GAW Nitrogen Oxides Network, GAW Report No. 209, GAW Report No. 232, Report of the WMO/GAW Expert Meeting on Nitrogen Oxides and International workshop on the Nitrogen Cycle
- **Sulphur dioxide:**
  Reference program: WMO/GAW; *guidelines:* line guida ancora non definite
- **Carbon monoxide**
  Reference program: WMO/GAW e ICOS-RI (only for ICOS stations), *guidelines***:** GAW Report No. 192, Guidelines for the Measurement of Atmospheric Carbon Monoxide/ICOS Atmospheric Station Specification, Version 2.01 - August 2016

Such guidelines identify the standard calibration scales to be implemented to participate within the international initiatives. In the table below, the reference Laboratory for such standard calibration scales are reported:

ECV	**Calibration Center**
Ozone	NOAA-ESRL/EMPA
NO	NPL
SO2	-
CO	NOAA-ESRL/EMPA

Currently, a Calibration Central Laboratory is not yet defined for SO_2 in the framework of WMO/GAW. Nevertheless, NPL, which provides standard mixtures for other reactive gases, can provide certificated mixtures for SO_2 useful for the measurements in background conditions.

3.3 Greenhouse gases

Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), halogenated greenhouse gases (CFCs, HFCs) are the greenhouse gases addressed in the NextDATA tasks.

- **Carbon dioxide**
  Reference program: WMO/GAW and ICOS[1]; *guidelines*: 17th WMO/IAEA meeting on Carbon Dioxide, other greenhouse gases and related tracers measurements techniques (GGMT-2013), GAW Report No. 213; ICOS Atmospheric Station Specification (V02.1 – August 2016)[1]

- **Methane**
  Reference program: WMO/GAW and ICOS[1]; *guidelines:* 17th WMO/IAEA meeting on Carbon Dioxide, other greenhouse gases and related tracers measurements techniques (GGMT-2013), GAW Report No. 213; ICOS Atmospheric Station Specification (V02.1 – August 2016)[1]

- **Nitrous oxide (N_2O) and Sulphur hexafluoride (SF_6)**
  Reference program: WMO/GAW; *guidelines:*: 17th WMO/IAEA meeting on Carbon Dioxide, other greenhouse gases and related tracers measurements techniques (GGMT-2013), GAW Report No. 213.

The reported guidelines identify the standard calibration scales to be implemented to participate within the international initiatives. In the table below, the reference Laboratory for such standard calibration scales are reported:

ECV	Calibration Center
CO_2	NOAA-ESRL/MPI-Jena[1]
CH_4	NOAA-ESRL/MPI-Jena[1]
N_2O	NOAA-ESRL/MPI-Jena[1]
SF_6	NOAA-ESRL

[1] For the ICOS (PRS, CMN, LMP) measurements station only

3.4 Aerosols physical properties

- **Aerosol Light Absorption, Aerosol Light Scattering**
  Reference program: WMO/GAW; *guidelines:* WMO/GAW Standard Operation Procedures fir in-situ measurements of aerosol mass concentration, light scattering and light absorption, GAW Report No. 200
- **Particle size distribution**
  Reference program: WMO/GAW; *guidelines:*WMO/GAW Aerosol Measurement procedures, Guidelines and Recommendations, 2nd Edition, GAW Report No. 227
- **Particle number concentration**
  Reference program: WMO/GAW; *guidelines:*WMO/GAW Aerosol Measurement procedures, Guidelines and Recommendations, 2nd Edition, GAW Report No. 227
- **Aerosol Optical Depth (AOD)**
  Reference program: WMO/GAW; *guidelines:*WMO/GAW Aerosol Measurement procedures, Guidelines and Recommendations, 2nd Edition, GAW Report No. 227

The reported guidelines identify the standard calibration scales to be implemented to participate within the international initiatives. In the table below, the reference Laboratory for such standard calibration scales are reported:

ECV	Calibration Center
Aerosols physical properties	WCCAP-TROPOS (ACTRIS/WMO)
AOD	PMOD/WRC

3.5 Total ozone and UV radiation

- **Total ozone**
- *Reference program:* WMO/GAW, *guidelines:* WMO/GAW The Tenth Biennial WMO Consultation on Brewer Ozone and UV Spectrophotometer Operation, Calibration and Data Reporting, WMO/GAW Report No. 176, 2007.

- **UV radiation**
  Reference program: WMO/GAW, *guidelines:* Standard Operating Procedures (SOPs) for Spectral Instruments measuring Spectral Ultraviolet Irradiance, WMO/GAW Report n. 212, 2014.

ECV	**Calibration Center**
Total ozone	WMO/Environment Canada
UV radiation	PMOD/WRC; NIST

3.6 Meteorological parameters and solar radiation (ancillary)

- **Meteorological parameters:**
  Reference program: WMO; *guidelines:* WMO guide to meteorological instruments and methods of observation. WMO-No. 8 (2014 edition)
- **Solar radiation**
  Reference program: WMO; *guidelines:* WMO guide to meteorological instruments and methods of observation. WMO-No. 8 (2014 edition

D11A – ANNEX 1

Operational QA/QC pre-products

This Annex presents the preliminary products that will be implemented in the framework of NextDATA to support QA/QC procedures and automatic reporting processes for the stations part of the "observational network for monitoring the background environmental-climatic conditions".

These operational QA/QC preliminary products (here defined as pre-products) are created or updated on a daily basise by using specific routines based on R software. Some specific function of the" Open Air" package (see Carslaw, D.C. and K. Ropkins, (2012). openair — an R package for air quality data analysis. Environmental Modelling & Software. Volume 27-28, pp. 52–61) were also used.

The definition of data flags is based on the flagging system defined in the framework of WMO/GAW. Especially for reactive gases, physical aerosol properties and AOD, the data flagging is defined in agreement with guidelines provided by EBAS (operated by NILU) as ACTRIS and WMO/GAW World Data Center for Aerosol and Reactive Gases. They can be found at http://ebas-submit.nilu.no/Submit-Data/List-of-Data-flags.

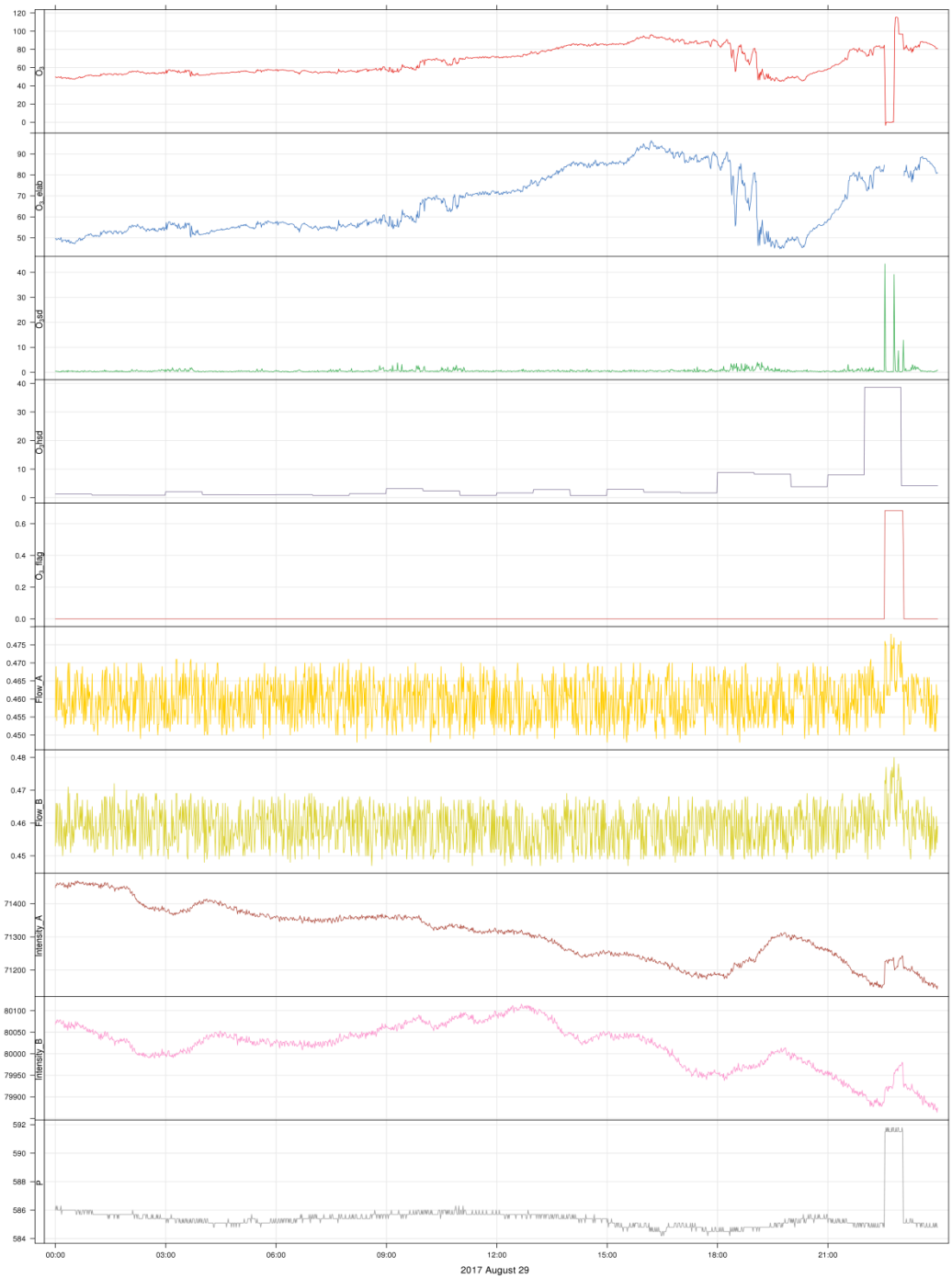
For greenhouse gases and carbon monoxide, the data flagging is defined in agreement with guidelines provided by the World Data Center for Greenhouse Gases (operated by JMA). They can be found on "Revision of the WDCGG Data Submission and Dissemination Guide" (GAW Report No. 188), https://www.wmo.int/pages/prog/arep/gaw/documents/GAW_188_web_20100128.pdf.

In the following pages, we will show, the operational QA/QC pre-products for the surface ozone measurements carried out at the WMO/GAW Global Station at Mt. Cimone, used as "test" site for the setting-up of these procedures.

DAILY PRODUCT

Description: This product is based on automated plot generated each day using native time resolution of data. They provide to the station PI information about ECV raw and pre-validated ("elab") data, together with internal instrumental parameters and automatic flags.

Aim: The main purpose is to have a daily diagnostic about measurement status as well as a high-resolution quick-view of ECV variability.



Here we present a preliminary example about surface ozone observed at CMN. Each plots reports: raw data, pre-valid data, data flags, 1-minute standard deviation, 60-minute standard deviation, internal flows (A and B), internal lamp intensities (A and B), internal pressure.

MONTHLY PRODUCT 1

Description: This product is based on automated plot generated each day using native time resolution of data as well as averaged data. They provide to the station PI information about ECV pre-validated and averaged-flagged (Lev 2) data, together with internal instrumental parameters and automatic flags.

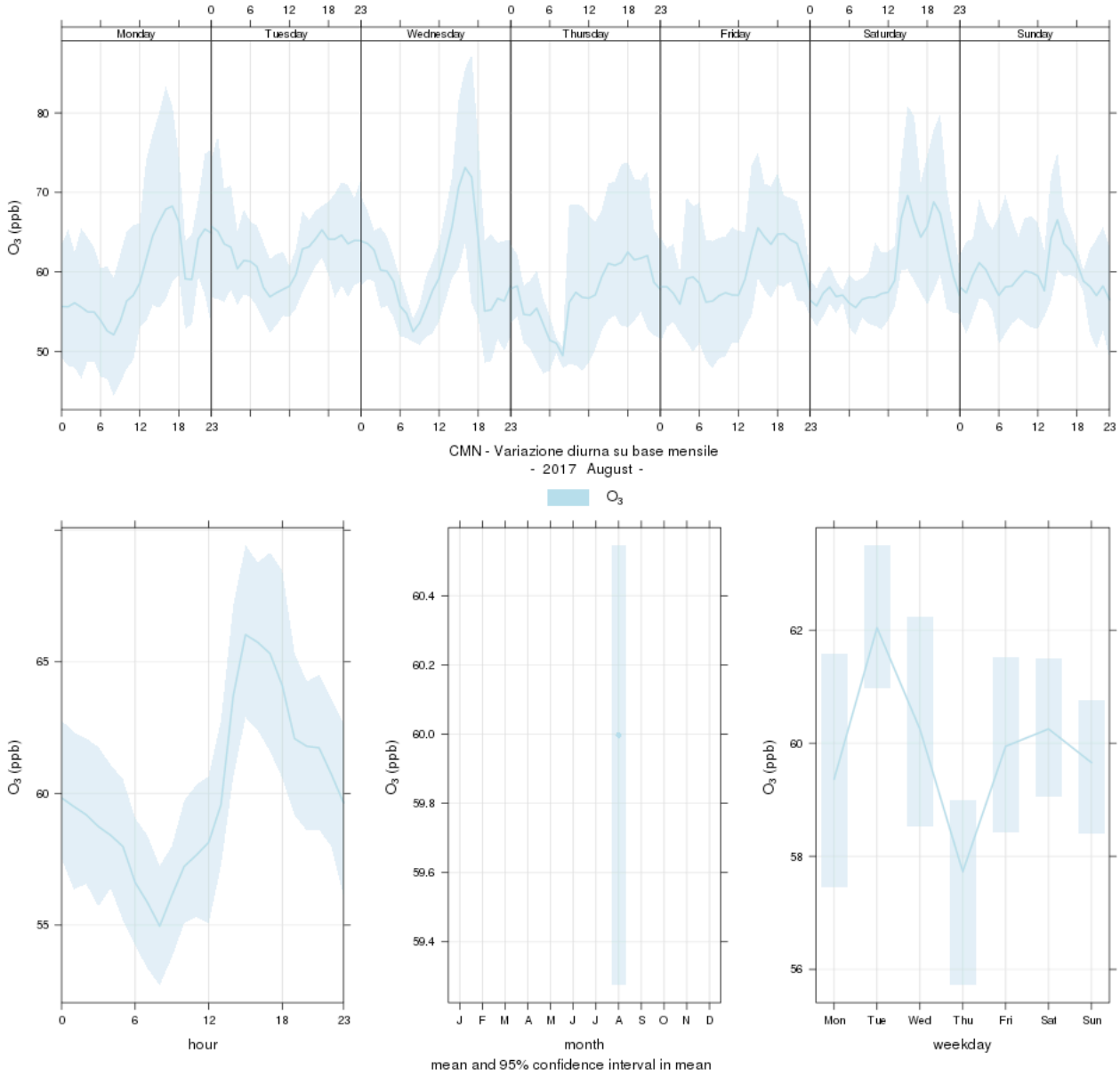
Aim: The main purpose is to have a medium-term diagnostic about instrumental status as well as a picture of pre-validated ECV data. It also provides a basic statistical table for pre-validated ECV data. This would help in pointing out medium-term instrumental drift able to affect measurements.

Here we present a preliminary example about surface ozone observed at CMN. Each plots reports: Level 2 data, , data flags, internal flows (A and B), internal bench temperature ,internal lamp temperature, internal lamp intensities (A and B).

MONTHLY PRODUCT 2

Description: This product is based on the use of R "OpenAir" package (timeVariation function ,see Carslaw, D.C. and K. Ropkins, (2012). openair — an R package for air quality data analysis. Environmental Modelling & Software. Volume 27-28, pp. 52–61*)* on Level 2 pre-validated data.

Aim: It provides to the station PI information about typical diurnal or daily variability of the selected ECV. The main purpose is routine data reporting and QA/QC (identification of anomalous behaviors).

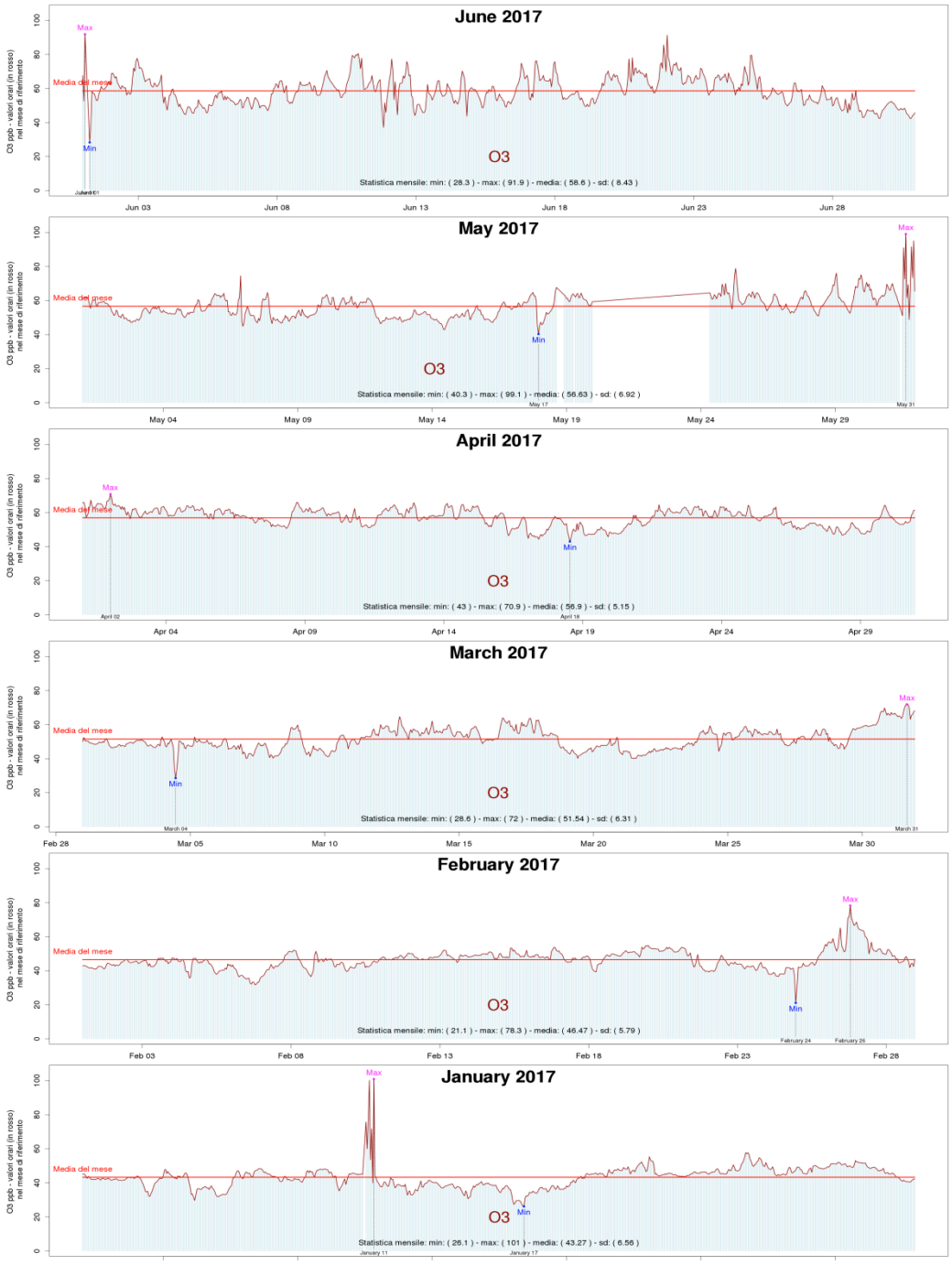


Here we present a preliminary example about surface ozone observed at CMN. The plot shown at the top shows the diurnal variation of average concentrations (shaded areas denote the 95% confidence interval) for all days of week of the selected month. The plot at the bottom-left provides the average diurnal variability of the selected ECV over the entire month. The plot at the bottom-right provides the weekly averaged concentrations of the selected ECV.

MONTHLY PRODUCT 3

Description: This product is based on automated plot generated month-by-month using pre-validated and averaged data (Level 2).

Aim: The main purpose is to have a medium-term diagnostic about pre-validated ECV data also useful to detect the occurrence of "special" events. To this aim, for each month, a line referencing to the average value as well as indication of the minimum and the highest pre-validated ECV values are provided.

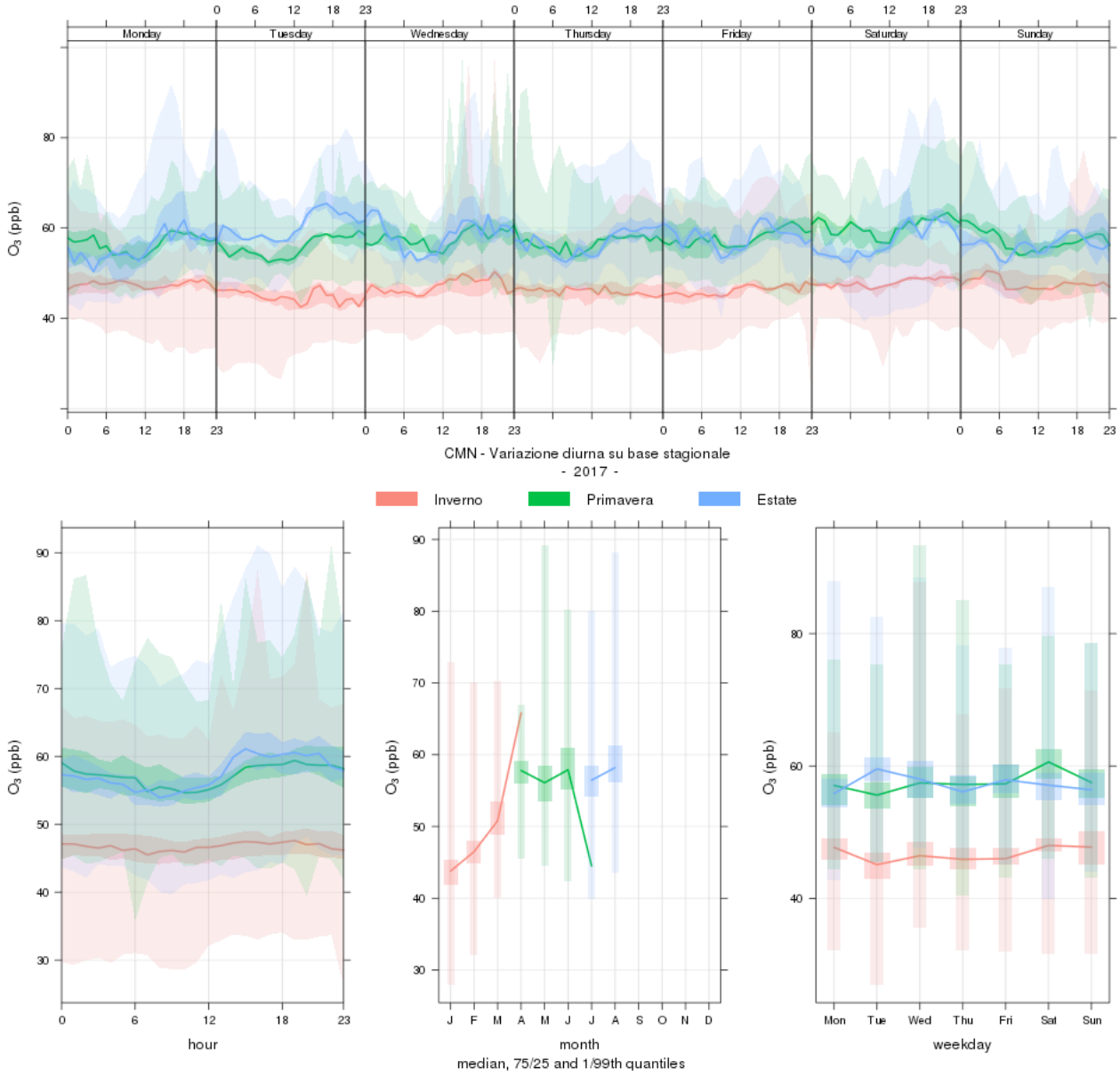


Here we present a preliminary example about surface ozone observed at CMN. Each plots report Level-2 data together with mean average value (red lines) and the minimum/maximum value observed during the selected months.

SEASONAL PRODUCT

Description: This product is based on the use of R "OpenAir" package on Level 2 pre-validated data.

Aim: It provides to the station PI information about typical diurnal or daily variability of the selected ECV. The main purpose is the operational data reporting and QA/QC (identification of anomalous diurnal behaviors potentially due to instrumental problems).

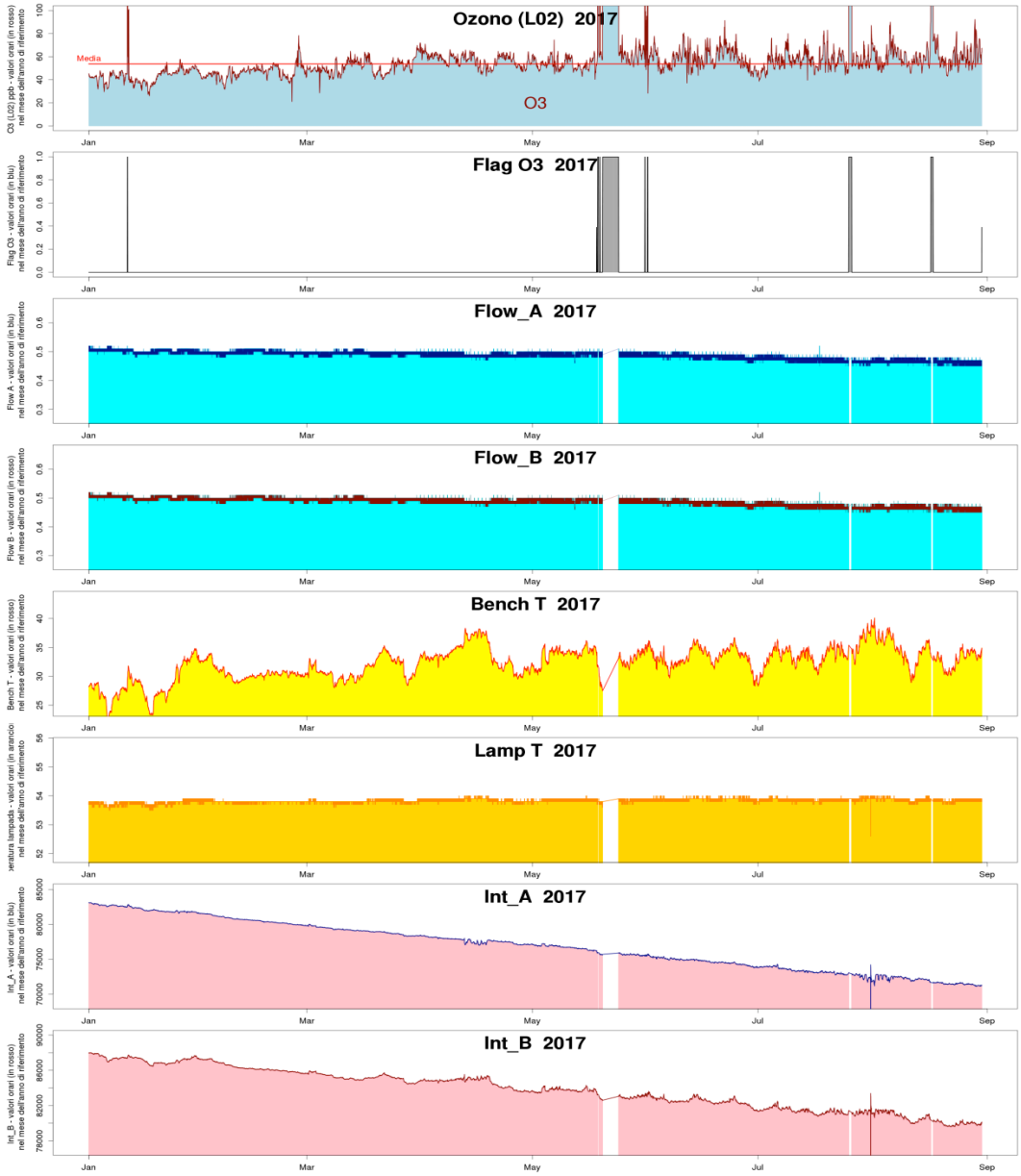


Here we present a preliminary example about surface ozone observed at CMN. The plot shown at the top shows the diurnal variation of average concentrations (shaded areas denote the 95% confidence interval) for all days of week of each season (colored scale). The plot at the bottom-left provides the average diurnal variability of the selected ECV over the entire seasons. The plot at the bottom-center provides the monthly mean concentrations of the selected ECV. The plot at the bottom-right provides the weekly averaged concentrations of the selected ECV.

ANNUAL PRODUCT 1

Description: This product is based on automated plot generated daily by using pre-validated and averaged data (Level 2).

Aim: The main purpose is to have a medium-term diagnostic about pre-validated ECV data also useful to detect the occurrence of "special" events. Moreover also internal instrumental parameters are plotted for QA/QC purpose. This would allow the station PI to timely detected possible instrumental changes or drifts occurring over several months.

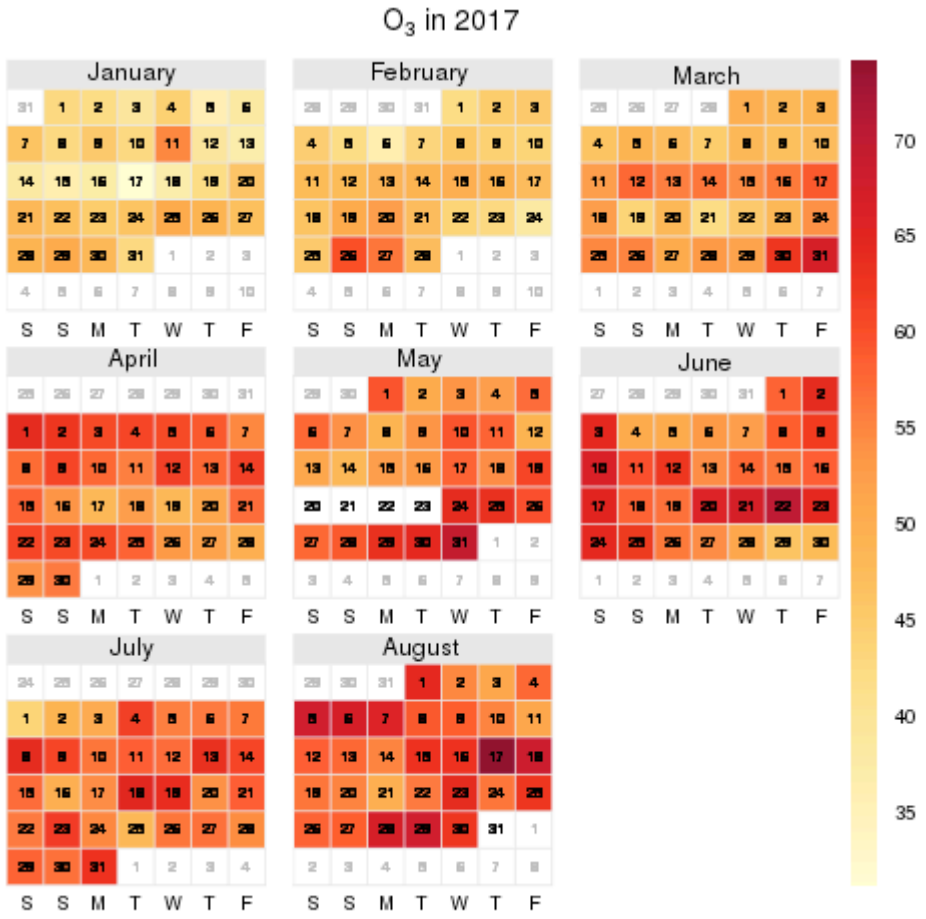


Here we present a preliminary example about surface ozone observed at CMN. Each plots report, for the whole year, Level-2 data, flags, internal flows (A and B), internal bench temperature ,internal lamp temperature, internal lamp intensities (A and B). Some statistical information about ECV variability and number of valid data are provided.

ANNUAL PRODUCT 2

Description: This product is based on the use of R "OpenAir" package (calendarPlot function ,see *Carslaw, D.C. and K. Ropkins, (2012). openair — an R package for air quality data analysis. Environmental Modelling & Software. Volume 27-28, pp. 52–61*). on Level 2 pre-validated data.

Aim: It provides to the station PI information about daily values along the year of the selected ECV. The main purpose is operational data reporting and a quick-look about ECV data availability at the station.



Here we present a preliminary example about surface ozone observed at CMN.