DATA QUALITY CONTROL PROCEDURES IN ALPINE METEOROLOGICAL SERVICES

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1 Introduction

Data Quality Control (DQC) is defined as all those operational procedures that will be routinely followed during the normal operation of the meteorological monitoring system to ensure that the measurement process is working properly. It consists of examination of data (in stations and in data centres) in order to detect errors, so that data may be either corrected or deleted. These procedures include periodic calibration of instruments, site inspection, data screening, data validation, and preventive maintenance.

In the past little attention was given to DQC, believed to be less important than the improvement of numerical weather prediction and data assimilation techniques, and considered a less 'glamorous' topic. Quite early, though, it was recognized that the insufficiency of the quality controls applied to the observations was an obstacle to the quality of the analysis, also crucial for the skill of numerical forecasts. Since the eighties more effort has gone in the study and formalization of quality control procedures, though most of the work has been tied to the assimilation of data in numerical models, and so mainly to the observations exchanged through the Global Telecommunication System (GTS) of the World Meteorological Organization. See, for example, Gandin (1989), ECMWF (1984) and references therein.

Weather data meant for GTS, sampled normally at a synoptic scale, have well codified quality requirements, both in station/instrument location and in data processing. This is not necessarily the case for denser, subnational, β- or γ-mesoscale networks, often managed by regional or provincial institutions.

Data exchange at a smaller scale, nowadays both technically feasible and fundamental (it's the scale of local area numerical forecasts and of severe weather alerts), is severely hampered by the dishomogeneity in data quality.

The hope is that in the context of sovraregional projects as Meteorisk and FORALPS better knowledge can be gained of the operational procedures of neighbouring institutions, and that this in turn will lead to a more standardized quality level and to easier exchange of meteorological information.

This report, written in the context of the INTERREG IIIB project FORALPS, aims at assessing the state of meteorological data quality control procedures in the organization and institutions which, in the Alpine Space, have functions of Meteorological, Civil Protection, or Hydrographic Services. The structure of the document is as follows: Chapter 2 summarizes, at least qualitatively, WMO reccomandations on data quality control, highlighting if possible peculiarities of small scale meteorological monitoring. Chapter 3 contains the results of the survey on data quality control procedure in mesonetworks, with more attention and space given to FORALPS' Project Partners and Alpine Space institutions. Further chapters contain an effort to establish a common terminology for reference in the context of FORALPS project and of the present report (Chapter 4), and the scheme of the interviews performed where possible (Chapter 5).

2 WMO guidelines on data quality control

This chapter contains a qualitative review of WMO recommendations on quality control procedures, with a section dedicated to smaller scale meteorological monitoring.

2.1 *General guidelines*

2.1.1 *Weather data for international exchange*

The World Meteorological Organization (WMO, 1981) prescribes that certain quality control procedures must be applied to all meteorological data for international exchange.

WMO (1982) prescribes that quality control must be applied by meteorological data-processing centres to most kinds of weather reports exchanged internationally, to check for coding errors, internal consistency, time and space consistency and physical - climatological limits. The same document specifies the minimum frequency and times for quality control.

WMO (1989) gives general guidance on procedures and emphasizes the importance of quality control at the station. A detailed description of the procedures that may be used by numerical analysis centres is given in WMO (1993).

Quality Control starts with a careful design, selection and test of the prototype Automatic Weather Station network before acquiring, installing and operating it. Considerable errors can be avoided by proper siting and exposure of weather stations, though this subject is out of the scope of the present report.

To ensure the good quality of data it is necessary to establish and use continuously good maintenance, repair and calibration procedures (as good instrument maintenance is, particularly for small centres, one of the best assurances of quality). This done, it is still highly advisable to establish procedures for automatic quality control of both weather station and data recorded, keeping in mind that quality requirements are a function of the sensor performance and of the environmental condition, and that it is not possible to determine a priori which controls are appropriate for the measurement of a specific variable.

The work which has to be done in a data centre on data quality control is also very important. Data should be checked in real time or as close to it as possible, at each point where they are received. It is also advisable to apply the same urgent checks to all data, even to those that are not used in real time, because later quality control will be less effective. If automation is available it should be used, but effective quality control is possible without computers, or only partly assisted by computing procedures or facilities.

The checks that have already been performed on data at the stations must usually be repeated at data centres, in a more elaborate form, usually making use of automation and additional information. Data centres have access to data from the whole network. This means that a spatial check is possible, against observations from surrounding stations or against analyzed or predicted fields.

If errors are found data should be either rejected or corrected, either by reference back to the source or at the data centre.

2.1.2 *Automatic weather stations*

During the Meeting of Geneva, Switzerland, 13-16 October 2004 a specific proposal on Quality Control Procedures for data from Automatic Weather Stations has been presented (Zahumensky, 2004), approved and finally published in both the Guide to Meteorological Instruments and Methods of Observation (WMO, 1996) and in the Guide on Global Data Processing System (WMO, 1993).

The main guidelines of the accepted proposal recognize two levels of real-time quality control of data from automatic weather stations:

– Quality control of raw data.
– Quality control of processed data.

Quality control of raw data has to be performed at the station-site. This level of control is relevant during acquisition of data and should eliminate errors of technical devices such as sensor malfunction, instability and interference, in order to reduce potential corruption of processed data. There are two possible checks:

– Plausible value check, whose aim is to verify if the values are within the acceptable range limits.
– Check on a plausible rate of change, whose aim is to verify unrealistic jumps in values. The check is best applicable to data of high temporal resolution, because the correlation between the adjacent samples increases with the sampling rate.

The second check is partly performed at automatic weather stations, partly at a Data Processing Centre. It can include a comprehensive checking of temporal and internal consistency, the evaluation of biases and long-terms drifts of sensors and modules, etc..

The quality control of processed data implies different checks:

– Plausible value check;
– Time consistency check, to verify the rate of change of instantaneous data;
– Internal consistency check, based on the relation between measured parameters.

In addition, more extended control procedures should be applied at the Data Processing Centre. These include comprehensive checks against physical and climatological limits, time consistency checks on longer measurement periods, checks on logical relations among a number of variables, statistical analysis of data, etc..

2.2 *WMO guidelines for sub-synoptic meteorological networks*

The Thirteen Session of the Commission for Instruments and Methods of Observation (CIMO) recognized the need to include in the WMO Guide to Instruments and Methods of Observation (WMO, 1996) a new chapter on Urban Observations: guidance on the observation of meteorological elements in urban areas. A report (Oke, 2004) has been therefore prepared and scheduled for publication.

There is a growing need for meteorological observation conducted in urban areas. At the same time meteorological services have difficulty in taking into account urban observations, because most urban sites make it impossible to conform to the standard guidelines for site selection and instrument exposure given in the WMO Guidelines.

Despite the complexity and inhomogeneity of urban environments, useful and repeatable observations can be obtained. When establishing an urban station, the rigid guidelines for climate stations are often inappropriate. It is necessary to apply guiding principles rather than rules, and to retain a flexible approach. This often means different solutions for individual atmospheric quantities and may mean that not all observations at a site are made at the same place.

The report in particular underlines the need to fully appreciate the different scales of urban climate (micro-scale, local-scale, meso-scale) as these differently impact meteorological phenomena and measurements methods.

- Micro-scale (from 1 m to hundreds meters): standard climate station recommendations of WMO Guidelines are designed to standardize all sites (use of a standard height of measurements, a single surface, minimum distance to obstacles, and little horizon obstruction) in order to avoid micro climatic effects, because the data may be used to assess climate trends at larger scale. Urban stations, as standard stations, should also avoid microclimate influences, but this is hard to achieve.
- Local-scale (from 1 km to several km): standard climate stations are designed to monitor at this scale. This includes landscape features (topography), and excludes micro-scale effect. In urban areas we have to average the climate of neighbourhoods with similar types of urban development. The result will be an integration of a characteristic mix of micro-climatic effects.
- Meso-scale (from tens km in extent) A city influences weather and climate at the scale of the whole city. A single station is not able to represent this scale.

The three scales mentioned above are horizontal scales, but also the different vertical scales must be kept in account. In fact an essential difference between the climate of urban areas and that of rural ones is that in cities the vertical exchanges of momentum, heat and moisture does not occur at a plane surface, but in a layer of a significant thickness called Urban Canopy Layer. This has to be taken into account for the comprehension of the vertical profiles of meteorological variables (including air temperature, humidity, wind speed) and the behavior of turbulent fluxes. Observations of fluxes and standard variables are of significant utility and permit to characterize the underlying local scale environment.

A last section in this WMO Report is devoted to the special requirements for the documenting metadata in urban environments. Because the environment of urban station changes frequently, metadata (and their frequent update) are as important as the meteorological data gathered. The full and accurate documentation of station metadata is absolutely essential for any station to ensure the final data user has no doubt about the conditions in which data have been recorded, gathered and transmitted, in order to extract accurate conclusions from their analysis. In particular special urban characteristics, such as local environment's historical events, need to be included in the metadata.

3 Regional implementation of data quality control procedures

This chapter contains the results of the survey on the procedures active in regional meteorological service in order to guarantee the quality of observations. The focus of this report is the Alpine Space area, but side information on the procedures implemented on other mesonetworks, when available, has been considered interesting for comparison and reference purposes, and so included in the report. In particular Nordic Countries (Denmark, Iceland, Finland, Norway and Sweden) have an original method for data quality control, as they codify the human component of the validation procedure.

3.1 *Nordic countries*

There is a need for improvement on automatic control methods, but even with the best control methods, some observations must always be checked manually. For this reason the Nordic countries have their own manual control system, called Human Quality Control (Andrese et al., 2003; Rissane et al., 2000). The objective of these countries is to develop a common Nordic Human Quality Control system, in order to save resources, improve data quality and make quality control more effective than it is today.

The quality control system consists of two main parts: automatic quality control methods and manual quality control methods. Ideally it should not be necessary to correct data with manual control methods. However, experience has shown that manual controls can be extremely important:

- in many cases station-values flagged as probably erroneous may turn out to be correct when spatial controls are performed later on;
- automatic methods point out possible erroneous observations, but are unable to estimate the correct observation values;
- in weather situations which may be of particular importance because of their rarity or severity, automatic spatial methods (which normally are able to produce parameter values for a station based on observed values from the neighbouring stations) may change correct values into incorrect ones;
- as yet, automatic correction methods have been developed only for some meteorological parameter. For several other parameters, corrections or interpolations have to be done manually.
- spatial automatic methods perform adequately for relatively flat homogeneous areas, but may be unreliable in areas with rough topography;
- manuals controls contribute to the evaluation of how the automatic controls work.

Staff involved in Quality Control uses many different information sources, such as reference stations, neighbouring stations, geographic and topographic data, climatological data, radar and satellite information, etc.. It is impossible to construct a perfectly accurate quality control system, but it is possible to reduce the number of automatically mis-flagged observations in the database by a rational and effective manual control. A future Manual Quality Control System will mainly depend on well designed interactive visualization tools:

– error lists, which should be for preference short and practical.
– spatial controls based on comparisons with neighbouring stations. It should be possible to visualize all kinds of data in tables, geographically on maps and graphically in time series. The comparison can be done on the weather, on the local climate, on the diurnal changes, on the parameters values etc. Useful tools are: satellite pictures, radar pictures, lightning recordings, model calculations, climatological information, time series, …
– dynamic coupling between Map, Graph and Table: this will permit, during a manual control, to compare and to choose between different interpolation methods in order to get a suggested value before the correction is done.

The main objective of the Nordic Countries is to maintain the highest desirable quality of data. For this reason, recommendations are given for a Manual Human Quality Control System that improves on automatic control methods; that automates some of the present Manual Quality Controls procedures (allowing the persons involved in quality control work to make quick decisions based on relevant and easily accessible information); and that allows daily manual control close to the observation time (in order to make it as rational and effective as possible).

3.2 *Alpine area*

In the following paragraphs different observation networks of the Regions of the Alpine area are discussed with as much detail as is available, and their procedures for storing and checking data sets are shortly presented. The information collected and summarized is referred to October 2005, and is mainly obtained by the organizations' web pages and by spot interviews following the survey scheme reproduced at the end of this report.

The aim is to assess the state of the art in DQC procedures implemented on meso-networks of the Alpine area. As an increasing amount data is being exchanged between organizations outside the GTS, for example in Interreg projects, the need for a more precise knowledge of how observations are obtained and processed becomes more pressing.

From even a cursory overview, the strong dishomegeneity in dimensions, functions, and resources of the unit institutions that compose the Alpine area is apparent, mainly in the Italian territory. Austria, Switzerland and Slovenia are National Meteorological Services (NMS) and so have a centralized structure for dealing with data control and storage. This of course has strong consequences on data treatment, as NMS are bound, at least on the GTS stations of their networks, to the well codified requirements of the WMO, and generally keep a higher level of quality assurance on the whole station network. Smaller centres rely more on preventive maintenance than on a-posteriori quality control, whereas the medium size Regional Meteorological Services can have very different observation networks and so very different approaches.

The following tables summarize the survey's results. Table entries are: nationality and region; number of stations and area covered (to give a feel of network dimension and station density); name of institution responsible for the observing network and contact person or office; meteorological parameters measured in the majority of stations (abbr.: Temperature - T, rainfall - P, wind direction and speed - WD and WS, total solar radiation - Rad, pressure - p, relative humidity - RH); parameters measured only in some stations; quality control procedures, manual and automatic, where the temporal indication refers to how frequently it is performed, not to the aggregation of the data on which it is performed (where possible it is specified in the text).

3.2.1 *Austria*

Austrian data control and storage is done at national level by the Wien section of ZAMG, the National Meteorological Service. Station and data management is divided in two sections: one for real time, with roughly 375 stations (comprising also synoptic GTS stations), and one for climatological stations (roughly 100).

Real time quality control is done 24 hours a day on half hourly data by operators aided by automatic DQC procedures. Periodic controls are performed daily, both manually and automatically, on various time spans. Some stations are manned, some other are automatic and measure all standard parameters plus snow height and snow fall (except for hydrological and climatic stations). Some climatic stations also measure phenological parameters (soil temperatures, radiations, etc).

Data are not public, but some stations' hourly values are published on the web-site. Annual values are saved on DVD's, and a yearly publication is issued on CD.

Country/Region			Austria/all
No. of stations/ Surface			$\sim 480/83.858km^2$
Contact information:			
institution			ZAMG - Wien
contact person			Dr. Andreas Reisenhofer
Measured parameters:			
in most stations			T P Rad RH WD WS p Snow
only in some			soil T, observers.
Quality Control:			
	hourly	daily	periodic
manual	Yes	Yes	Yes
automatic			
logical tests	Yes	Yes	Yes
climatological tests	Yes	Yes	Yes
variability tests	Yes	Yes	Yes
internal consistency	...	...	...
spatial consistency	...	...	...

Figure 1. Basic information about data quality control procedures in Austria.

3.2.2 *Valle d'Aosta, Italy*

Valle d'Aosta is a small regional administrative division, consisting of a single province, all in mountainous territory. The Regional Meteorological Service has its own monitoring network, which consists of about 20 automatic stations measuring the main meteorological parameters. Real-time hourly and daily data are regularly published on web-site, before validation, and stored in a central data base.

DQC consists on a monthly manual invalidation of the most evident erroneous values, performed on the data collected in the month before. Other 34 stations are accessible to, but not owned by, the RMS. Data from these stations cannot be published or stored in the database, but is used as source of further information. These stations are mainly of hydrographic origin, so that in most cases the only parameters available are precipitation and temperature.

Country/Region	Italia/Valle d'Aosta		
No. of stations/ Surface	$\sim 20/3.263 km^2$		
Contact information:			
institution	RAVA - Regione Autonoma Valle d'Aosta		
contact	Protezione Civile - Giulio Contri		
Measured parameters:			
in most stations	T P Rad RH WD WS p		
only in some	Snow-height		
Quality Control:			
	hourly	daily	periodic
manual	No	No	Yes
automatic			
logical tests	No	No	No
climatological tests	No	No	No
variability tests	No	No	No
physical checks	No	No	No
spatial consistency	No	No	No

Figure 2. Basic information about data quality control procedures in Valle d'Aosta.

3.2.3 *Provincia Autonoma di Trento, Italy*

Trento is a Province, but with Region-like functions as regards civil protection and meteorology. Meteotrentino is the provincial meteorological service, and its network consists of about 80 automatic stations. The bulk of it (~60 stations) have been recently acquired from the Hydrographic Service, and mainly measure temperature and precipitation. The network is at present being redesigned.

Real-time data (in hourly aggregation format and not validated) are regularly published on the web-site, together with the data of the last 24-48 hours. All data are regularly stored without validation in a central data base. There is no daily control of the data, but periodic checks on past data are performed, though not regularly, by manual control of the most evident erroneous values for specific parameters.

Country/Region	Italia/Provincia di Trento		
No. of stations/ Surface			$\sim 80/6.206km^2$
Contact information:			
institution			Meteotrentino
contact person			Andrea Piazza
Measured parameters:			
in most stations			T P Rad RH WD WS p
only in some			Snow-height
Quality Control:			
	hourly	daily	periodic
manual	No	No	Yes
automatic			
logical tests	No	No	No
climatological tests	No	No	No
variability tests	No	No	No
internal consistency	No	No	No
spatial consistency	No	No	No

Figure 3. Basic information about data quality control procedures in Trentino.

3.2.4 *Provincia Autonoma di Bolzano, Italy*

Similar in organization to Trento, Bolzano is a province with independent functions in civil protection and meteorology. The Meteorological Service of Alto Adige manages a network of ~40 complete automatic stations. The MS is part of the Hydrographic office, with function of civil protection and of hydrological and snow monitoring; some stations of recent installation measure therefore also snow height and net radiation. There is a classification of the network in hydrological, snow, and meteorological subnetworks. The snow-monitoring stations are grouped in high and low altitude stations, and instruments differ in the two groups. Several historical manual station are also present in the network, with coincident automatic ones. Real-time, raw, half hourly data are published on the web and stored in a central database. Validation consists on a monthly manual and automatic control on temperature, precipitation and snow-height of the preceding month (maximum and minimum daily temperature, daily accumulated precipitation, daily snow-height). The corrected values are also stored in the database.

Country/Region	Italia/Provincia di Bolzano		
No. of stations/ Surface	$\sim 40/\ 7.400 km^2$		
Contact information:			
institution	Ufficio Idrografico		
contact person	Alexander Toniazzo		
Measured parameters:			
in most stations	T P Rad RH WD WS p		
only in some	Snow-height, Net radiation		
Quality Control:			
	hourly	daily	periodic
manual	No	No	Yes
automatic			
logical tests	No	No	Yes
climatological tests	No	No	Yes
variability tests	No	No	Yes
internal consistency	No	No	...
spatial consistency	No	No	...

Figure 4. Basic information about data quality control procedures in Alto Adige/ South Tyrol.

3.2.5 *Lombardia, Italy*

The Regional Meteorological Service was born in January 2004, including the older mountain weather centre located in Bormio.

The regional network is the fusion of different subnetworks designed in different times with different purposes (agricultural, air quality, hydrology...). Each network has a characteristic sensor set. In particular, an experimental PBL network measures turbulent fluxes, and agro meteorological stations measure soil temperatures and leaf moisture. Hydrological station have mainly thermometers and rain gauges, but the majority of the stations have a complete set of instruments. Work is underway to redesign and homogenize the station network, and to implement automatic DQC procedures to support human validation of data.

Country/Region	Italia/Lombardia		
No. of stations/ Surface	261/ 23.861km^2		
Contact information:			
institution	SMR - ARPA Lombardia		
contact person	Mauro Valentini		
Measured parameters:			
in most stations	T P Rad RH WD WS p		
only in some	Snow, Net rad., Turb. flux, soil T.		
Quality Control:			
	hourly	daily	periodic
manual	No	Yes	Yes
automatic			
logical tests	No	Yes	No
climatological tests	No	Yes	No
variability tests	No	Yes	No
internal consistency	No	No	No
spatial consistency	No	No	No

Figure 5. Basic information about data quality control procedures in Lombardia.

3.2.6 *Piemonte, Italy*

The development of the regional meteo-hydrographic network has started in 1988, to respond to different monitoring needs (of which main importance was given to intense event forecasting and monitoring). The automatic meteo-hydrographic network consists of pluviometric, meteorologic and hydrologic stations, with a very high spatial density. Rain gauges, for example, have an average spatial frequency greater than 1 in 50 km^2. The automatic station network, managed by the Regional Meteorological Service, is integrated by manual stations for snowheight measures, two meteorological radars, a wind profiler, a radio sounding, an MTP5 radiometer, two automatic radiosounding systems and about 10 unmanned present weather stations.

Twice daily an automated quality control procedure is applied to raw data. Once a month a more complete, both automatic and manual, quality control is performed on the daily data, which is then checked again by the operators before the annual publication on CD.

Country/Region	Italia/Piemonte		
No. of stations/ Surface	$\sim 400/25.399 km^2$		
Contact information:			
institution	SMR - ARPA Piemonte		
contact person	Roberto Cremonini		
Measured parameters:			
in most stations	T P Rad RH WD WS p		
only in some	Snow height, current weather		
Quality Control:			
	hourly	daily	periodic
manual	No	No	Yes
automatic			
logical tests	No	Yes	Yes
climatological tests	No	Yes	Yes
variability tests	No	Yes	Yes
internal consistency	No	Yes	Yes
spatial consistency	No	No	No

Figure 6. Basic information about data quality control procedures in Piemonte.

3.2.7 *Liguria, Italy*

Liguria's regional meteorological service, Meteoliguria, manages ~120 automatic weather stations, though not all complete, connected by radio to a central control system that manages data acquisition, validation and storage. The station network has been redesigned between 2002 and 2003, integrating stations from different sources. Fifty mechanichal stations (T, P, river level gauge) and a meteorological radar managed by the regional service in collaboration with Piemonte complement the monitoring system.

The automatic stations have different acquisition times, but all acquire data at least every 30 minutes. Every two hours raw data are passed through automatic quality control routines and written on the data base. Controls are on thresholds and internal consistency, but work is underway to improve the tests. Periodic manual controls of the quality of data are also performed before issuing publications involving the observations.

Country/Region			Italia/Liguria
No. of stations/ Surface			$\sim 120/5.416 km^2$
Contact information:			
institution			Meteoliguria
contact person			Elisabetta Trovatore
Measured parameters:			
in most stations			T P
only in some			WD WS ...
Quality Control:			
	hourly	daily	periodic
manual	No	No	Yes
automatic			
logical tests	Yes	Yes	No
climatological tests	Yes	Yes	No
variability tests	No	No	No
internal consistency	Yes	Yes	No
spatial consistency	No	No	No

Figure 7. Basic information about data quality control procedures in Liguria.

3.2.8 *Veneto, Italy*

The regional meteorological service of Veneto has two centres: Teolo issues generalistic forecasts for the whole region, and Arabba specializes in snow and mountain weather forecasts. The integrated meteorological monitoring network counts a meteorological radar and a network of automatic weather stations, this last composed of purely meteorological stations (mainly in the Vicenza and Belluno provinces), hydro-meteorological stations and agrometeorological stations. The mountain meteorology centre of Arabba manages nearly 20 more station that also measure snow related parameters.

Automated data control procedures run nightly, also to enable maintenance early the following morning.

Country/Region	Italia/Veneto		
No. of stations/ Surface	$\sim 200/\ 18.264 km^2$		
Contact information:			
institution	Centro Meteorologico di Teolo		
contact person	Francesco Rech		
Measured parameters:			
in most stations	T P Rad RH WD WS p		
only in some	Soil T., leaf wetness		
Quality Control:			
	hourly	daily	periodic
manual	No	Yes	...
automatic			
logical tests	No	Yes	Yes
climatological tests	No	Yes	Yes
variability tests	No	Yes	Yes
internal consistency	...	...	...
spatial consistency	...	...	...

Figure 8. Basic information about data quality control procedures in Veneto.

3.2.9 *Friuli Venezia Giulia, Italy*

The Regional Meteorological Service of Friuli Venezia Giulia, OSMER (Osservatorio Meteorologico Regionale), manages a small but dense and efficient meteorological observation network, composed of nearly 100 automatic weather stations, a meteorological radar, hail pads and a volunteers observer project (also partially funded through FORALPS project).

The quality of observations is guaranteed by programmed periodic and corrective maintenance of the stations and by a thorough, semiautomatic system for collection, control, transmission and storage of the weather data (Giaiotti, 1998).

Country/Region	Italia/Friuli Venezia Giulia		
No. of stations/ Surface	$\sim 100/\ 7.845 km^2$		
Contact information:			
institution	OSMER		
contact person	Stefano Micheletti		
Measured parameters:			
in most stations	T P Rad RH WD WS p		
only in some	Soil T, Leaf wetness, Snow height		
Quality Control:			
	hourly	daily	periodic
manual	No	Yes	Yes
automatic			
logical tests	No	Yes	Yes
climatological tests	No	Yes	Yes
variability tests	No	Yes	Yes
internal consistency	No	Yes	Yes
spatial consistency	No	Yes	Yes

Figure 9. Basic information about data quality control procedures in Friuli Venezia Giulia.

3.2.10 *Slovenia*

Slovenia's National Meteorological Service is hosted by the Environmental Agency (EARS - Environmental Agency of the Republic of Slovenia), and manages automatic stations, synoptic GTS stations and classical climatological stations. The network is composed of ~60 automatic stations (of which some ecological or hydrological with meteorological instruments), of 13 synoptic GTS stations, and ~200 manned climatological stations with daily observations.

DQC on the automatic stations' data is performed both automatically and manually, daily, for a few of the most relevant parameters measured. Controls consist in logical, climatological, variability, internal and spatial consistency tests, and are applied on half hourly aggregation. Classical climatological data is checked monthly using daily values.

Work is underway to redesign the software used for data quality management (from Fortran to web based and open source tools).

Country/Region			Slovenija/–
No. of stations/ Surface			$\sim 74/20.273km^2$
Contact information:			
institution			EARS
contact person			Zorko Vicar
Measured parameters:			
in most stations			T P Rad RH WD WS p
only in some			Soil T, Leaf wetness, Snow height
Quality Control:			
	hourly	daily	periodic
manual	No	Yes	Yes
automatic			
logical tests	No	Yes	Yes
climatological tests	No	Yes	Yes
variability tests	No	Yes	Yes
internal consistency	No	Yes	Yes
spatial consistency	No	Yes	Yes

Figure 10. Basic information about data quality control procedures in Slovenia.

3.2.11 *Switzerland*

Switzerland has four main centres for meteorological observations (Locarno, Geneva, Payerne, Zurich), but all observations are transmitted, controlled and stored at the Zurich centre. As MeteoSwiss is a National Meteorological Service, it manages both GTS observations and mesoscale stations.

The network is operational with 80 manual stations since 1863. Today 25 stations continue as manual (three daily observations of main parameters), but the network is mostly composed of automatic weather stations (115 stations measure main parameters every 10 minutes) and of manual precipitation observations (340 manual stations give daily values of rain and snowfall).

MeteoSwiss has developed a software and a database architecture for processing and storing meteorological and climatological data. The main software modules for data processing and control are: "Calc and check" module (for flagging suspicious data); a module with an enlarged set of tests to verify and correct erroneous values; an interactive module, for all the cases which cannot be treated automatically (Grüter et al., 2005).

Country/Region			Schweiz/–
No. of stations/ Surface			173/ 41.285km^2
Contact information:			
institution			MeteoSwiss
contact person			...
Measured parameters:			
in most stations			T P Rad RH WD WS p
only in some			Snow height, Snow fall, soil T, observers
Quality Control:			
	hourly	daily	periodic
manual	No	Yes	Yes
automatic			
logical tests	Yes	Yes	Yes
climatological tests	Yes	Yes	Yes
variability tests	Yes	Yes	Yes
internal consistency	Yes	Yes	Yes
spatial consistency	Yes	Yes	Yes

Figure 11. Basic information about data quality control procedures in Switzerland.

4 Automatic data quality tests

A systematic analysis and classification of automatic tests that can be performed on weather observations is above the scope of this report. Even so, a problem arises when trying to exchange information on operational DQC procedures, because even common (and simple) tests and algorithms do not have a standard and accepted name. For example, testing an observation against neighbouring ones, called buddy check by some (Gandin, 1989), is reported as internal consistency check by others (WMO, 1993) and as spatial control by yet other Services (Pavan et al., 2003).

The purpose of this chapter is to clarify, by means of a classification and some examples, what is meant by the terms used in the summary tables of Section 3.2 and, when possible, to illustrate what terminology has been found in the literature.

Plausibility checks: WMO (1996) groups as tests of the plausibility of a measure all checks of the observed value against instrument range, measurement range, and climatologically plausible values. The tests can be implemented as sequential checks, as part of a decision algorithm (Gandin, 1989), or as contributing to a plausibility index (Giaiotti, 1998). The robustness of the tests obviously varies. In this report we have divided the most robust ones, resulting in immediate rejection of data (called logical) and the climatological ones, which can be implemented with various degrees of refinement depending on the depth of the statistical study of the measured values and of the flagging procedures.

Temporal consistency checks: also called variability tests. (1) The measured rate of change of a meteorological parameter is checked against a maximum physically acceptable temporal gradient or against a maximum climatological plausible gradient in a specified time interval. (2) The measured rate of change between two consecutive measures is tested against a minimal required variability in a certain period, also called dead band range. In this report we have grouped all the temporal consistency test under the name variability tests used by some authors (Grüter et al., 2005).

Internal consistency checks: WMO (1996) lists under this category all tests of the consistency of the different parameters measured at the same site, as, for example, non zero rain with relative humidity below a threshold value.

Spatial consistency checks: as, for example, buddy checks, difference from an interpolated value or residuals from a analyzed field. These test are routinely implemented by national or sovra-national meteorological services which need to initialize models (ECMWF, 1984) or which in any case routinely produce analyzed fields (Steinacker et al., 2000).

5 Survey scheme

1. How many automatic weather stations your organization is responsible for?
2. Are the stations classified in any way? If yes, with what criteria?
3. Your meteorological network is made only of automatic weather stations or also of manned weather stations? In which proportion?

Automatic	…
Manned	…

4. Which parameters do the stations measure?
   (a) in all the stations?
   (b) in more than 50 of the stations?
   (c) only in some?
   (d) with different frequencies?

Temperature	…
Precipitation	…
Relative humidity	…
Solar radiation	…
Pressure	…
Wind speed and direction	…
Other	…

6. Are the quality control procedures run once daily or more frequently?
7. Quality control is:
   (a) automatic
   (b) manual
   (c) partly automatic, partly manual
8. If any, which kinds of automatic controls are implemented:
   (a) logical
   (b) climatological
   (c) temporal (variation and persistence)
9. Which data undergo a quality control?
   (a) All measured parameters?

(b) Only some? Which ones ?

Temperature	YES	NO
Precipitation	YES	NO
Relative humidity	YES	NO
Solar radiation	YES	NO
Pressure	YES	NO
Wind speed and direction	YES	NO
Other	YES	NO

(c) What temporal aggregation do the data passing through DQC have?

Hourly	YES	NO
Daily	YES	NO
Monthly	YES	NO
Other	YES	NO

(d) Which time interval is checked?

Only data from the day before	YES	NO
Data recorded up to: …	YES	NO
…	…	…

10. After the first quality control, the data undergo other tests or controls on longer time periods?
11. If yes, with what frequency?
    (a) monthly
    (b) yearly
    (c) other (which?)
12. How is periodic quality control performed?
    (a) automatically
    (b) manually
    (c) both
13. How are the data stored?
    (a) only before quality control
    (b) only after quality control
    (c) quality controlled data and unchecked data together

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