MEETING OF THE
Expert Team on WORLD DATA CENTRES
(JMA, Tokyo, Japan, 21-23 January 2014)

QA/QC Procedures at WDCs

(submitted by Van Bowersox, with contributions by Anatoly Tsvetkov)

"The details and history of local conditions, instruments, operating procedures, data processing algorithms and other factors pertinent to interpreting data (i.e. metadata) should be documented and treated with the same care as the data themselves." (WMO 2002, GCOS Monitoring Principles).

"The primary objective of the GAW Quality Assurance system is to ensure that the data in the WDCs are consistent, meet GAW data quality objectives (DQOs), and are supported by comprehensive metadata." (WMO/GAW report 142 – Strategy for the Implementation of the Global Atmosphere Watch Programme, 2001-2007)

1. Introduction

Environmental measurement programmes begin with the identification of an environmental phenomenon and the need to better understand the causes and consequences of that phenomenon. For the atmospheric phenomena addressed by the GAW Programme, the measurements may be used to discern the geographic extent of an environmental problem or changes in the spatial extent of the problem over years or even decades. The data also may be used to identify sources of pollutants, gases and particles that degrade air quality either directly or indirectly, once released to the atmosphere. Adequately comprehensive measurements might even be used to infer mechanisms of atmospheric chemical transformations or pollutant scavenging by clouds, precipitation, or turbulent transfer processes. Certainly a fundamental use of GAW data is to document the direct exposure of plant and animal communities, terrestrial and aquatic ecosystems, and humans to air pollutants or to the potential for damaging secondary effects of air pollutants, such as decreased phytoplankton productivity or increased incidence of skin cancer due to UV-B exposure.

Central to GAW is the capacity to report measurements that have a known or definable level of quality. This requires effective QA/QC, central to which is a set of DQOs that define in quantitative and qualitative terms the overall level of uncertainty acceptable to scientists using the measurements to test hypotheses or to decision-makers using the measurements to formulate or evaluate policy.

Quantitative DQOs set numerical limits on accuracy. To meet a quantitative DQO, the bias and precision of a measurement must be equal to or less than a specified limit. Limits can be fixed numerical (i.e., absolute) values or percentage (i.e., relative) values. Chemical concentrations, state variables, lengths, volumes, and masses lend themselves to quantitative DQOs. Another environmental variable that lends itself to a quantitative DQO is the dimensional, temporal, or spatial completeness of a variable. An example is the requirement that there be 328 days (i.e., 90%) of precipitation measurements to meet the DQO for ensuring a 'representative year' of precipitation measurements.

Qualitative DQOs specify qualities of representativeness or comparability that cannot readily be quantified. Measuring airborne chloride concentrations 50 meters from an oceanic shoreline would yield concentrations heavily influenced by seasalt. Such a measurement represents only a very narrowly defined location, perhaps the surrounding few tens of meters. In general, GAW seeks measurements that are 'regionally representative', meaning measurements that are representative of the surrounding few hundreds of kilometers. Qualitative DQOs are often supplemented by one or more specifications or rules that set criteria of acceptability. These criteria may outline acceptable locations for collecting samples, acceptable equipment and procedures for collecting samples or making measurements, acceptable methods for handling and analyzing samples, and acceptable standards for validating measurements. Together these criteria address qualities that ensure that the data are representative. It follows that two data sets from a given location, each acquired with equipment and procedures that meet the criteria for being 'representative', should be 'comparable', as well. Indeed, side-by-side measurements are encouraged as a means to evaluate the conditions for measurement representativeness and comparability.

Complementing the measurements and observations, GAW data must be supported by metadata sufficient to identify the data provider and, as a minimum, the geographic location of the measurements. Understanding the data and facilitating its interpretation often requires additional metadata, including instrument make/model, instrumental settings, measurement methods, analytical procedures, detection limits, etc. Data centres are charged with maintaining metadata that is comprehensive and supports the use of GAW data.

Each of the GAW WDCs is responsible for a different set of measurements supported by relevant comprehensive metadata. Each set of measurements has unique DQOs that define limits of acceptability. This document summarizes the existing QA/QC procedures at each of the WDCs.

2. WDCPC

2.1. Objectives

- Assure the harmonization of measurements conducted globally by various regional and national programmes.
- Enable quantification of patterns and trends in the composition of atmospheric precipitation at global and regional scales.
- Improve the understanding of biogeochemical cycles of major chemical species.
- Faciliate global assessments of acid deposition and investigate long-range transport from major source areas.
- Provide the data needed for evaluating effects of acid deposition to major ecosystems (e.g., coastal and sensitive areas) and for developing control measures.

2.2. **Data Quality Objectives**

2.2.1. Quantitative

- Precipitation Measurement Completeness ≥ 90%: percentage of the summary period (e.g., season, year) for which valid standard gauge measurements are reported.
- Precipitation Chemistry Completeness ≥ 70%: percentage of precipitation during a summary period for which valid precipitation chemistry measurements are available.
- Analytical Chemistry Measurements: overall laboratory accuracy expressed in absolute (e.g., pH) or relative values.

Table 1. DQOs for GAW Precipitation Chemistry Measurements

Measurement	DQO
pH (pH units)	± 0.07
Conductivity (µS/cm)	± 7%
Acidity/ Alkalinity (µmole/L)	± 25%
Sulfate (mg/L)	± 7%
Nitrate (mg/L)	± 7%
Chloride (mg/L)	± 10%
Ammonium (mg/L)	± 7%
Calcium (mg/L)	± 15%
Magnesium (mg/L)	± 10%
Sodium (mg/L)	± 10%
Potassium (mg/L)	± 20%

2.2.2. Qualitative

- Sites for precipitation sampling must be 'regionally representative'. Guidelines for site locations include separation distances from point sources (e.g., power plants), population centers, line sources (e.g., highways), agricultural sources (e.g., cattle feedlots), parking lots, chemical storage facilities, sewage treatment plants, active geothermal sites (e.g., volcanoes), and natural emission sources such as shorelines, dust flats, etc. Separation distances are specified in the *Manual for the GAW Precipitation Chemistry Programme* (WMO/GAW report 160). Accompanying these guidelines are on-site requirements that address equipment installation including separation, allowable vegetation height, separation from buildings, trees, and other obstructions, and site security and accessibility (see WMO/GAW report 160).
- Sites must measure precipitation amounts with a standard gauge. Standard gauges are specified by the National Meteorological and Hydrological Service (NMHS) of each country.
- Sites are expected to sample precipitation for chemical analysis using a wet-only precipitation sampler designed to be open only during precipitation. Automated samplers are preferred, though manually-operated wet-only samplers are acceptable if open only during precipitation. 'Bulk samplers' that are open continuously are strongly discouraged. Data from bulk samplers are acceptable only under two conditions: (1) samples are collected every day, and (2) the NMHS verifies that dry deposition is negligible by, for example, demonstrating equivalence with wet-only data.
- Providers report only valid data. Invalid data result from the operational failure of the standard gauge or precipitation sampler, samples that are not handled according to standard operational procedures in the field or laboratory, and samples that are too contaminated for a valid analysis. Contaminants are substances not scavenged by precipitation, either during its formation or falling. Examples include bird feces, insect or plant debris, hair, clothing fibers, etc.
- The WDCPC reports only valid data. Every data set a provider submits to the WDCPC undergoes a set of checks: (1) sample dates and times are checked to ensure continuity of sampling; (2) chemical analytical measurements must be within pre-specified limits (e.g., 9 > pH > 2); (3) anion-cation balances must meet the criteria in Table 2; and (4) conductivity balance must meet Table 3 criteria.

Table 2. Criteria for Anion-Cation Balance.

Anions + Cations (µe/L)	**Acceptable Ion Difference (%)**
$\leq$ 50	$\leq$ ($\pm$ 50)
> 50 $\leq$ 100	$\leq$ ($\pm$ 30)
> 100 $\leq$ 500	$\leq$ ($\pm$ 15)
> 500	$\leq$ ($\pm$ 10)

Table 3. Criteria for Conductivity Balance

Measued Conductivity (µS/cm)	**Acceptable Conductivity Difference (%)**
≤ 5	≤ (± 50)
> 5 ≤ 30	≤ (± 30)
> 30	≤ (± 15)

The WDCPC communicates with data providers to resolve problems identified by these checks. For problems that cannot be resolved, data record(s) may be invalidated.

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2.3. **Metadata**

Table 4 lists the metadata that supports the precipitation chemistry data submitted by GAW data providers to the WDCPC.

WMO/GAW WORLD DATA CENTRE for PRECIPITATION CHEMISTRY (WDCPC)

Report for Major Inorganic Ions in Precipitation (version 2014)

Date of Report (dd-mm-yyyy)	Principal Contact (name)	Principal Contact (e-mail address)

The WDCPC will provide the metadata in Parts 1 through 5, below, when precipitation chemistry data for the station indicated in Part 3 is requested. Scientists and other data users are expected to acknowledge the data provider by using the citation in Part 1.

Part 1. Agency Information

(Provide a citation for the precipitation chemistry data provided by your agency. This is how scientsts and others will cite your agency in publications.)

Global Atmsophere Watch, World Data Centre for Precipition Chemitry Data, 2014, data provided by:

Part 2. Laboratory Information

Laboratory ID Number	Measurement	Analysis Method	Measurement	Analysis Method	Detection Limit	Units
	pH		Sulfate **as** SO_4^{2-}			mg/L
	Conductivity		Nitrate **as** NO_3^-			mg/L
	Acidity		Ammonium **as** NH_4^+			mg/L
			Fluoride			mg/L
			Chloride			mg/L
			Sodium			mg/L
			Potassium			mg/L
			Calcium			mg/L
			Magnesium			mg/L

Part 3. Station Information

GAW ID	Country	Station Name	Location		
			Latitude (xx.xxxx)		<== Indicate N or S
			Longitude (xxx.xxxx)		<== Indicate E or W
			Elevation (m.a.s.l.)		

Part 4. Sampling Instrumentation

Standard (Precipitation) Gauge			Precipitation Chemistry Collector		
Manufacturer	Model	Wind Shield	Manufacturer	Model	Area of Orifice

Part 5. Sampling Protocol

Period (check one or describe)		Type (check one or describe)		Sample Preservation
daily		automated wet-only		(List all that apply-examples include: filter/filter type, chloroform, refrigeration, other-describe)
weekly		manual wet-only		
monthly		bulk (continuously open)		
other (describe below)		other (describe below)		

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3. WRDC

3.1. **Quality Checks at the WRDC**

- Physically meaningful limits
- Follow up Control according to WRDC procedures applied to daily and monthly totals
- Checks of calculated and actual totals
- Checks of hourly and daily values in the within setup ranges
- Control of exceedings above TOA values
- Control of values higher than those of probabilistic and climatological levels
- Control of correlation: data of neighbour sites
- Homogeneity Analysis (HA)
- Build up of Metadata for 1500 Stations from paper archive by the end of 2012

3.2. **Metadata Elements at WRDC**

- STATION IDENTIFIERS
    - Local Code
    - WMO Code
    - Name and aliases
    - Active/Closed
    - Beginning/End Date
- GEOGRAPHICAL DATA
    - Latitude
    - Longitude
    - Elevation
    - Dates of relocation
- LOCAL ENVIRONMENT
    - Local land use/land cover
    - Instruments exposure
    - Skyline diagrams
- STATION INSTRUMENTATION AND MAINTENANCE
    - Instrument Sheltering and Mounting
    - Type of recording
    - Calibration results
    - Special Maintenance/Faults
- DATA PROCESSING
    - Units
    - Special codes
    - Algorithms
    - Calculations
    - QC applied? (yes/no)
    - Homogenization applied? (yes/no)
- HISTORICAL EVENTS Changes in the social, political and institutional environment

3.3. **Symbols and Abbreviations used**

Symbols	Instruments
CDI	Bellani pyranometer
KZ	Kipp and Zonen pyranometer
PSP	Eppley precision spectral pyranometer
TB/R/	bimetallic actinograph
TT	thermoelectric pyranometer
TT/E/	Eppley pyranometer
TT/EKO/	EKO pyranometer
TT/IS/	SODECO integrated pyranometer
TT/M/	M-80 pyranometer
TT/MG/	Moll-Gorczynsky pyranometer
TT/S/	stellar pyranometer
TT/SN/	Sonntag pyranometer
SR-75	Spectrolab SR-75 pyranometer
NIP	Normal incidence pyrheliometer
BT/F/	Funk net pyrradiometer
BT/GD/	Gier and Duncle net pyrradiometer
BT/M/	M-10 net pyrradiometer
BT/S/	Schulze net pyrradiometer
BT/SF/	Suomi-Franssila net pyrradiometer
BT/./	other designs of net pyrradiometer
SS/A/	automatic heliographe
SS/C/	Campbell-Stokes sunshine recorder
SS/CE/	CIMEL Fibre optique sunshine recorder
SS/CS/	Casella sunshine recorder

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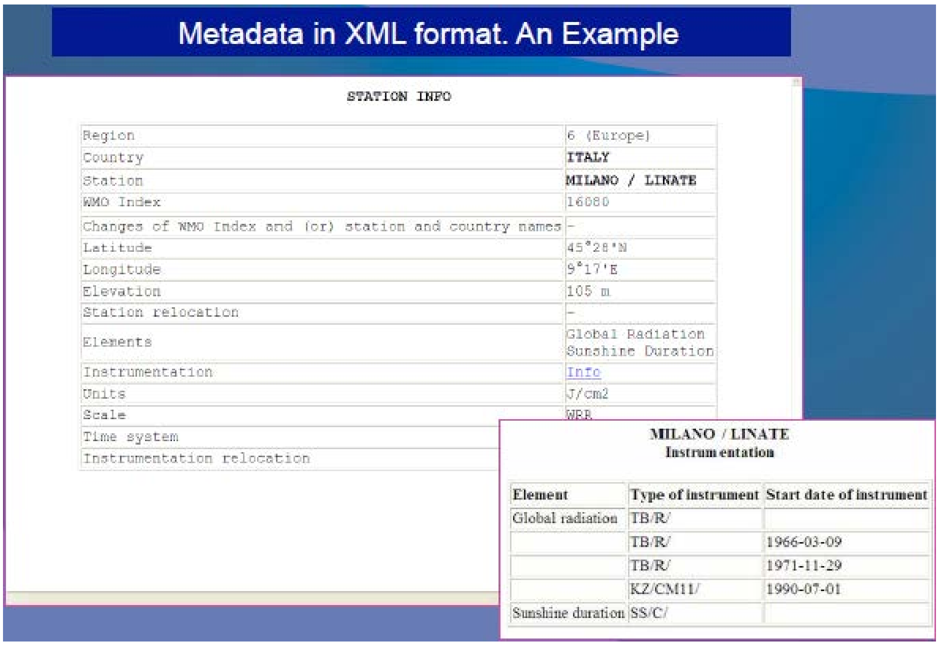
SS/EKO/	EKO sunshine recorder
SS/FO/	Fibre optique sunshine recorder
SS/H/	Haenni-type sunshine recorder
SS/J/	Jordan sunshine recorder
SS/PREDE/	PREDE sunshine recorder
SS/SONI/	SONI sunshine recorder
KZ/CSD/	Kipp and Zonen CSD sunshine sensor
+ -	information on instrument type is not available at WRDC



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