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COMMISSION FOR BASIC SYSTEMS
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INTEGRATED OBSERVING SYSTEMS

ITEM: 6

**SECOND AD HOC IPET-OSDE WORKSHOP ON
OBSERVING SYSTEM NETWORK DESIGN**

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GCOS MATERIALS THAT COULD BE USED FOR DEVELOPING OSND GUIDANCE MATERIAL

(Submitted by Jay Lawrimore (USA))

SUMMARY AND PURPOSE OF DOCUMENT

The document provides information on GCOS materials and other materials associated with climate monitoring and networks that could be used for developing OSND guidance consisting of the intermediate layer of general guidance that lies between the WIGOS OSND Principles and the lower layers of guidance/documentation that apply / will apply to the individual observing system components of WIGOS.

ACTION PROPOSED

The Meeting is invited to note the information contained in this document when considering its recommendations.

Appendix: A. Climate Monitoring and Design Document Summary Items
B. Observing Network Documents

DISCUSSION

Several reports, correspondence, and related papers written over the past decade provide information that could be helpful in developing Observing System Network Design (OSND) guidance that lies between the WIGOS OSND Principles and the lower layers of guidance/documentation that apply or will apply to the individual observing system components of WIGOS. A list of pertinent documents is included below and notes of interest from each are included in Appendix A. These include information on metadata and data management, station siting and continuity, tiered design, and other associated information.

Guidelines on Climate Observation Networks and Systems; WMO/TD No. 1185. Available at http://www.wmo.int/pages/prog/wcp/wcdmp/wcdmp_series/index_en.html .

Guidelines on Climate Metadata and Homogenization; WMO/TD No. 1186. Available at http://www.wmo.int/pages/prog/wcp/wcdmp/wcdmp_series/index_en.html .

Observing Weather and Climate from the Ground Up: A Nationwide Network of Networks. Available at <http://www.nap.edu/catalog/12540/observing-weather-and-climate-from-the-ground-up-a-nationwide> .

Comments from William Wright (ICG-WIGOS) on a draft WIGOS discussion paper regarding Externally-Sourced data

Report from Expert Team on National Networks and Observations in Support of Climate Activities (OPAG on Climate Data and Data Management). Available at <http://www.bom.gov.au/wmo/climate/ccl/opag1.shtml> .

Report on Automated Versus Manual Surface Meteorological Observations – Decision Factors. Available at <http://www.bom.gov.au/wmo/climate/ccl/opag1.shtml> .

CCI Guidelines on Data Management, Version 5.0. Available from <http://www.bom.gov.au/wmo/climate/ccl/opag1.shtml> .

In addition, links to documentation is included in Appendix B that comprise a spectrum of operational networks including a reference climate network, an automated meteorological network, a national network supported by manual observations, and a network that provides externally sourced observations. This documentation for existing networks may serve as a reference for observing system network design.

APPENDIX A

CLIMATE MONITORING AND DESIGN DOCUMENT SUMMARY ITEMS

Guidelines on Climate Observation Networks and Systems; WMO/TD No. 1185

Network density and station distribution depend on the particular application. National climate networks should be able to provide a satisfactory representation of the climate characteristics of the country.

The rate of spatial and temporal variation for meteorological elements varies by element. For example, the network density requirement for characterizing temperature is usually much less than precipitation. WMO provides density criteria guidelines for climatological networks.

Additional approaches include various objective analysis techniques and methodologies for specific applications. The simplest approach would be to identify homogeneous climatic regions and ensure that each region is adequately sampled. More sophisticated methods would examine the particular characteristics and merits of the available stations (e.g. Peterson et al. 1997, Collins et al. 1999) or use objective analysis to aid network selection (e.g. Daley 1993, Jones and Trewin 2000).

In designing climate networks, there should be strong recognition, that to be most cost effective, these networks can and should support other applications and purposes as well. For example, in some countries, reference climate stations also provide valuable information in real time for weather forecasting and agrometeorological applications. Even Ordinary Climatological Stations, measuring daily temperature and precipitation and snow cover (if applicable), can provide low cost data for nowcasting and forecast verification if the data are reported on a timely basis.

National networks, especially those intended for detection of climate trends, variations and changes, must be equipped with standard, approved instrumentation. A process or plan should be in place to ensure that occurs in an orderly way.

First, a careful determination of stakeholder requirements must occur through consultation. These include requirements for uncertainty (accuracy), resolution and range, robustness, and suitability for the intended operating environment. For example, are they suitable for operating in cold climates? Do they retain their accuracy in extreme temperature conditions?

The process (Fig. 6.1) should include a review of performance requirements against manufacturer specifications, laboratory testing against a reference standard traceable to a national primary standard to determine uncertainty and repeatability, and engineering quality and design. The test and evaluation process should include field-testing in operational environments. This usually requires having multiple test sites and a test period of one year to capture the expected range of climatic conditions and to acquire a statistically significant dataset. The field test plan must be carefully designed to determine performance under various measurement ranges and environmental conditions. Field-testing could include comparisons to calibrated field reference standards (when available), identical model products (functional precision) and other sensors/systems currently in operational use.

An observation site should be representative of the climatic regime for which it is intended. Sites on steep slopes, in hollows, in proximity to pronounced features such as buildings, topographical influences, for example, ridges, should be avoided. Otherwise, the site becomes representative of local features only.

Stations measuring baseline or background atmospheric composition, specifically those part of the GAW program have very stringent siting criteria – no significant change in land use practices within 30-50 km of the site and minimal effects of local and regional air pollution (WMO 2003).

Stations should be on a level piece of ground (to the extent possible) and should be well exposed, away from obstacles and obstructions that could influence the observation including instrument

performance. A general rule often employed is that the distance of any obstacle from the instrument gauge should be 2 to 4 times the height of the object above the gauge. Anemometers require even more exposure, the distance of any obstruction being prescribed as at least 10 times the height of the obstruction (WMO 2003). These restrictions may sometimes require splitting of the site, example, the anemometer location being some distance from the rest of the instrumentation.

When selecting station sites, network planners and administrators should consider locations where there is a high probability that exposure is unlikely to change over the long term and that the site is secure through long-term agreements, leases or ownership.

Factors such as security, care-taking, power, protection against flooding, etc. must also be taken into account. Many NMHSs develop instrument compound guidelines that prescribe sensor location and proximity to one another, buffer zones and security fencing. Underlying surfaces could include short-cropped well-maintained grasses or gravel.

NMHSs are strongly encouraged to have network installation guidelines and procedures in effect, including those provided by manufacturers for specific equipment. It is critical that instrument pads are well seated and leveled, that trenching for power and signal cables follow prescribed directions. Under some extreme conditions, such as some arctic or sub-arctic locations, where freeze/thaw cycles can produce ground slumping or upheaval, gravel beds are prescribed for the instrument compound.

Performance Measurement: It is also important to measure performance on a program- or network basis. In effect, these are measures of the health of a program in terms of quality, effectiveness and efficiency. Measures could include frequency and character of observational errors, reporting percentages, completeness, timeliness – e.g., what is the percentage of observations received by collection centers within prescribed time frames? They could also include percentages of time that standards are attained – for example, the percentage that national radiosonde balloon releases reach prescribed heights. Life cycle management metrics could include information on how often routine station inspection and maintenance occurred within prescribed frequency of visits, the number of unscheduled maintenance trips, how often systems were replaced within prescribed timeframes, numbers of repairs, etc.

Guidelines on Climate Metadata and Homogenization; WMO/TD No. 1186

Good metadata are needed to ensure that 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.

Meteorological data are influenced by a wide variety of observational practices. Data depend on the instrument, its exposure, recording procedures and many other factors. There is a need to keep a record of all these metadata to make the best possible use of the data. This guide identifies the minimum information that should be known for all types of stations.

Complete metadata describe the history of a station since its establishment to the present and hopefully onwards to the future.

A good metadata archive helps the NMHSs in asset management and other administrative procedures, as data existences and observing conditions are kept in good order. It also can be said that good metadata helps society to gain a better understanding of weather and climate related processes, as well as climate change.

Minimum metadata requirements:

Station Identifiers; Name, Aliases, WMO Code or station number, station number in other networks, opening/closing dates, type of station, station contact.

Geographical Data; Lat/Lon, Elevation above Mean Sea Level, Relocations

Local Environment; Updated mapping, Toposcale map, Radiation horizon mapping, Photos in all compass directions and updated a minimum of annually, Microscale map of instrument enclosure and updated as changes occur.

Local land use/land cover; At different scales it is recommended to keep track of several attributes. Mesoscale (1km to 30km) account in metadata for proximity and size of large water surfaces, urbanized areas, mountain ranges. Toposcale (100m to 2km) terrain slope, forests, crops, other roughness, nearby obstacles such as trees or buildings, proximity to irrigation. Sketches providing this information are often recommended.

Instrument Exposure; Obstacles, Ground Cover.

Type of instruments; e.g., Instrument manufacturer, Model of instrument, with size and identification, Output type and sensitivity, Transducer type (if applicable), Response time (if applicable).

Instrument mounting and sheltering; Height above surface, description of shelter, degree of interference from other instruments/objects such as an artificial heat source or a ventilator.

Data recording and transmission; type of recording, signal transport.

Observing practices; Observer, Observed Elements, Observing times, Routine maintenance, corrections made by observer.

Data processing; Units, Special Codes, Calculations, Quality Control, Homogeneity Adjustments, Data recovery.

General Historical Network Information; Changes in sheltering and exposure, Changes in mean calculations, observation hours and daylight saving times, Units of observed elements and data accuracy, Urbanization and land-use changes, Introduction of Automatic Weather Stations or new types of instruments, Changes in quality control, homogenization and data recovery procedures.

Observing Weather and Climate from the Ground Up: A Nationwide Network of Networks (US National Academy of Sciences)

Meteorological observations at the mesoscale play a vital role in promoting the health, safety, and economic well-being of our nation. Although the federal role in weather and climate information services is pivotal, a number of state and local governments, universities, and private sector interests have developed and deployed dense networks of meteorological observing systems, known as “mesonets.” The advent of inexpensive digital electronics and high bandwidth communications lowered barriers to investment and enabled literally thousands of small businesses, Fortune 500 corporations, agricultural producers, recreation providers, and many others to enter the field of mesoscale observations, driven by a wide range of missions and markets at various investment levels.

Despite this widespread participation, all is not well. National priorities demand ever more detailed meteorological observations at much finer spatial and temporal resolutions than are widely available today. These priorities include tracking atmospheric dispersion of chemical, biological, and nuclear contaminants from industrial accidents and terrorist activities, as well as smoke dispersion monitoring and prediction for wildfires, prescribed burns, and seasonal agricultural fires; more extensive air quality forecasting, high-resolution “nowcasting,” and short-range forecasting of high-impact weather; high-resolution weather information for aviation, surface transportation, and coastal waterways; and support to regional climate monitoring.

The report offers steps that can be taken to affect near-term improvements in U.S. mesoscale observations and the investments that could be made to strengthen capability over the longer term. Although many of the recommendations specify actions to be taken by the federal sponsors of the report, federal agencies alone are unlikely to satisfy the breadth of national needs for mesoscale data. Therefore, the recommendations specifically address the broader community of private, public, and academic partners.

An overarching national strategy is needed to integrate disparate systems from which far greater benefit could be derived and to define the additional observations required to achieve a true multi-purpose network that is national in scope.

The Committee envisions a distributed adaptive “network of networks” (NoN) serving multiple environmental applications near the Earth’s surface. Jointly provided and used by government, industry, and the public.

A NoN cannot deliver a net benefit to users unless comprehensive metadata are supplied by all operators.

Several steps are required to evolve from the current circumstance of disparate networks to an integrated, coordinated NoN. First, it is necessary to firmly establish a consensus among providers and users that a NoN will yield benefits in proportion to or greater than the effort required to establish it.

The new elements of a NoN are twofold: (1) the provision of services and facilities that enable individually owned and operated networks to function, more or less, as one virtual network, and (2) the provision of new observing systems or facilities to enable national objectives.

A number of recommendations were made in the report.

Stakeholders, including all levels of government, various private-sector interests, and academia should collectively develop and implement a plan for achieving and sustaining a mesoscale observing system to meet multiple national needs.

To ensure progress, a centralized authority should be identified to provide or to enable essential core services for the network of networks.

Essential core services include but are not limited to

- definition of standards for observations in all major applications,
- definition of metadata requirements for all observations,
- certification of data for all appropriate applications,
- periodic “rolling review” of network requirements and user expectations,
- definition and implementation of data communication pathways and protocols,
- design and implementation of a data repository for secure real-time access and a limited period for post-time access,
- generation of a limited set of products based upon the raw observations, most notably, graphical presentations of data fields and analyses thereof,
- pointers to more sophisticated products generated externally, such as analyses produced from a short-term model prediction and multiple observation sources,
- pointers back to data providers, where more products and services are available,
- establishment of a link to the National Oceanic and Atmospheric Administration’s (NOAA’s) National Climate Data Center (NCDC) for archival of selected data, as deemed appropriate by NCDC,
- development and provision of software tools and internet connectivity for data searches, information mining, and bulk data transmissions,

- development and provision of a limited set of end-user applications software, which would enable selection of default network data configurations for major applications as well as tools for creation of custom network data configurations, and
- provision of a data quality checking service with objective, statistically based error-checking for all major categories of data, including manual intervention and feedback to providers.

The centralized authority should require metadata of every component in an integrated, multi-use observing system.

A national design team should develop a well-articulated architecture that integrates existing and new mesoscale networks into a national “network of networks.”

The national network architecture should be sufficiently flexible and open to accommodate auxiliary research-motivated observations and educational needs, often for limited periods in limited regions.

Federal agencies and partners should employ testbeds for applied research and development to evaluate and integrate national mesoscale observing systems, networks thereof, and attendant data assimilation systems. Among other issues, testbeds should address the unique requirements of urbanized areas, mountainous terrain, and coastal zones, which currently present especially formidable deficiencies and challenges.

Existing surface observations and observing platforms associated with road and rail transportation, as appropriate, should be augmented to include World Meteorological Organization (WMO)-standard meteorological parameters. Conversely, existing WMO-standard meteorological observing stations near highways and railways should be augmented, as appropriate, to meet the special needs of the transportation sector.

The stakeholders should commission an independent team of social and physical scientists to conduct an end-user assessment for selected sectors. The assessment should quantify further the current use and value of mesoscale data in decisionmaking and also should project future trends and the value associated with proposed new observations. Upon implementation and utilization of improved observations, periodic assessments should be conducted to quantify the change in mesoscale data use and its added societal impact and value.

Comments from William Wright (ICG-WIGOS) on a draft WIGOS discussion paper regarding Externally-Sourced data

From a climate perspective, for certain activities, most notable climate change monitoring, a very high standard of observational practice and metadata is required. However, many climate services do not need this level of exactness, although continuity and length of data is important in most cases. This brings in the concept of tiered networks – certain applications such as catchment mapping of rainfall require a high density of observations, rather than a few points with high-end gauges. For this sort of application, crowd-sourced data is ideal. A challenge for the climate program is to establish some kind of system that grades ESO’s in terms of reliability (accuracy, siting, metadata etc), and maps these to climate services.

Many amateur weather observers (e.g., members of the storm-chasing fraternity) take great pride in their observations, and arguably in some cases perform better than co-op observers. Other countries have organised systems for non-NMHS observers to contribute their observations, e.g., CoCoRAHS in the US; WoW in several countries. And the Bureau has often had requests from external people to advise on best-practice and recommended systems.

There would seem to be great potential to harness this enthusiasm – one ideal solution would be to better harness (in Australia’s case) Bureau retirees and even current employees. For instance current high quality rainfall observations from a part of Victoria that represents an important catchment area, yet is poorly served by conventional observations.

This would be further enhanced if the enthusiastic amateurs were equipped with proper instrumentation and taught how to service and maintain it.

In many areas crowd-sourced observations may be the only available observations, and can still provide very useful data.

“One set of standards ...cannot meet the needs across all applications”. This is the tiered approach. For many purposes a subset of high quality stations for high-end monitoring and for reference purposes, interspersed with a denser network of ESOs, yields good results. Importance of maximising metadata, is true. If you can evaluate the reliability of an observation, you can make an informed judgement on what that observation can and can't support.

Data management. It is strongly recommended that external data are flagged as such within Data Management systems, to avoid the sorts of problems that go with possibly lower-quality data. These data also need to be linked to information on any restrictions placed on the data. Data from private providers may have immediate commercial sensitivity, but less so after a period of time. In that case, submission of data at a later, less sensitive time would be of potential value, especially to climate services that in general have a less immediate time-frame. This “sunset clause” approach is adopted by the Water program within the Bureau.

As NMHS decrease the number of manual observers, the ability to provide visual and phenomena observations declines also (albeit to some extent automated sensors may replace these, but it is not known how well these replicate the missing observations). Therefore, more crowd-sourcing of things like hail, dust, thunderstorms, strong wind bursts etc greatly assist certain climate services, incl those to the insurance industry, horticulture planning etc. And phenomena such as frost can be very localised yet significant to agriculture and other applications.

Filling in gaps. A group of rapporteurs is being set up within OPACE 1 to investigate the potential to obtain more observations from data sparse regions such as Africa. One suggestion is to equip local people with low cost raingauges and encourage submission of their data via mobile phones.

Report from Expert Team on National Networks and Observations in Support of Climate Activities (OPAG on Climate Data and Data Management)

The use of automated systems is replacing traditional stations in developed countries. Network designers need to consider unanticipated maintenance problems from a technical and cost standpoint for countries in economic transition.

The presence of automated systems takes away from the local knowledge required to maintain the engagement of local observers and meteorological services.

The need for training (maintenance in addition to all other aspects) needs to be a part of network design and deployment.

Long and homogeneous climate series are in key roles in climate change studies, and special care is required when changing instrumentation or automating these series. An overlap between the old and new systems is necessary, at least one year.

Report on Automated Versus Manual Surface Meteorological Observations – Decision Factors

For many applications, automated weather stations (provided they are well-maintained and life-cycle managed), offer important advantages in terms of data quality and reliability. They have also been used to increase network densities, reporting frequencies and elements observed, especially in remote and largely unpopulated regions where access is difficult. They also can augment manned stations both as observer aids and during hours when no observer is on duty.

Lower labor costs may reduce or even reverse the cost payback.

Lack of adequate supporting infrastructure may pose obstacles to implementing AWSs. Simplistic cost comparisons based on one-time only capital and installation costs can be misleading. Automation initiatives must consider factors such as user requirements, operating environments and all costs associated with the life-cycle management of the autostations. AWSs can enhance systematic observing through increased sampling and reporting frequencies and additional data elements. Very high investment costs, however, may preclude some NMHSs from automating some data parameters that human observers provide. Examples include sky cover, obstructions to visibility and precipitation type identification.

Unless the NMHS has the capacity to respond effectively to outages, it can expect increased data loss (especially in remote locations).

There are many considerations for whether to retain manual observations or install an automated system. Examples include - Are the stations located in places with labour markets that can provide the necessary skills to carry out manual observations at an affordable price? What resources does the NMHS have or need to acquire to maintain automated systems? See the 9 major questions in this document.

The meteorological variables that present the largest hurdles for automated measurement are those that are directly related to human perception of a physical parameter. Because reporting protocols for parameters such as sky cover, horizontal visibility and present weather consider the characteristics and limitations of human senses, AWS often report differently than a human would under identical conditions. In cases where the aviation sector is a client, service providers must carefully consider their needs in developing an automation strategy. Replacing manual observation programs with automated observations requires a thorough change management process e.g. testing, evaluation, implementation planning, user education, and documentation.

It is extremely important that key stakeholder groups such as climatologists, regulators, forecast production managers, data managers, etc, liaise closely with observation program managers during the requirements and subsequent planning phases to ensure that their needs are thoroughly considered before implementation starts. This communication should form part of a change management process that is recommended for any NMHS planning changes to its observation programs.

The cost of implementing an autostation varies greatly. Factors include:

- Which parameters will the station report? What standards and requirements apply?
- What site preparation is needed to establish a suitable instrument compound and bring in required utilities, e.g. electrical power, telephone or satellite communications?
- Is the site in an isolated location where it is expensive to ship supplies and obtain services?

It is incumbent upon the NMHS to consider operational requirements and related budgetary costs when planning for the implementation of autostations. AWS networks, like any manned observation program, should be sustainable, life-cycle managed, operated and maintained to defined standards and operating procedures.

Automated observations introduce many changes that affect the way data is managed for both operational and archiving purposes. For example, automation presents an opportunity to acquire data at higher temporal resolutions. While it may not cost significantly more to collect this additional data, managers will have to assess whether it adds downstream ongoing and/or development costs to activities such as telecommunications, processing and data storage and to assess such costs in relation to user requirements and competing priorities.

CCI Guidelines on Data Management, Version 5.0

This document provides information on best practice climate data management with some emphasis on building knowledge and capacity, particularly in support of the transition to a modern

climate database management system. It includes the skills, systems and processes needed to be in place to ensure that operations are sustained.

Database management is an integral part of network design. If done correctly it will ensure not just the long-term preservation of data but also near real-time collection and access. This is a lengthy document. Some items of interest to network design include the following.

Database needs to be designed for the appropriate purpose – near real-time meteorological work will mainly be accessed synoptically. Climate data accessed for period of record – storage will be different.

Metadata structures are more complex than data – follow standard metadata model for climate data – extension of WMO Core Metadata Standard?) The ability to support the standard model is a desirable characteristic of data management systems.

Key entered systems should validate data as they are entered – catch errors early and recommend alternate values.

Systems should be designed to decode WMO standard formats (SYNOP, CLIMAT, etc.) directly into a climate database.

Metadata documentation and management

A detailed treatment of station specific metadata can be found in the report “Guidelines on Climate Metadata and Homogenization” (WMO 2003b) in the World Climate Data and Monitoring Programme series of publications.

An important general point in this context is that the innate structure of the metadata in an ideal system will be considerably more complex than the innate structure of the climate data itself.

The associated metadata, which is needed to fully interpret the data, could include such things as the:

- Reference date used by the database (GMT, time zone, others);
- Quality which has been ascribed to the observation;
- History of the values ascribed to the meteorological parameter and any associated flags;
- Instrument used to record the observation, together with more fine detail on its own maintenance programme, tolerances, internal parameters, etc;
- Name of the observer;
- Full details of the station and its history;
- Programme of observations in effect at the time and its history;
- the inventory of the elements stored in the database, their units, their boundaries; and
- Topographical and ground-cover details of the site, information on surrounding trees, buildings, etc, and how these have changed with time.

It will also require the ability to store graphics associated with stations in a network (site plans, photos, possibly images of old documents, etc). This is not conceptually complex, but has implications for, in particular, the hardware to be used in order to capture and reproduce a range of images, and the underlying software to be used as the database management system.

Data may also be the subject of homogenisation work, which is intended to remove from a data set all influences other than those from the underlying climate. Data that has been the subject of such exercises has a need for additional associated metadata, in order to accurately represent the nature of the homogenisation work. Homogenised data sets should be a product of the CDMS and never considered as a replacement.

Data Acquisition

The overheads associated with running a network could be reduced if the NMHS were to use the station networks of similar institutions such as universities, local utilities, and private companies. In these cases all relevant climate data should be collected and it is highly desirable that the NMHS should be granted full use of all the climate data, without restriction, as if it were its own data. Appropriate contractual, or ‘Memorandum of Understandings’, between the NMHS and other organisations may need to be drafted and signed at senior management level.

Data Entry

Data collection should be as close to the source as possible. Automated stations including stations which have some manual observations, and partially automatic weather stations should collect their climate data and error messages on site and transfer these electronically to the data management system, possibly via another database system. Manually observed data should be collected and captured on-site and transferred as soon as possible to the CDMS. (e.g., daily observations transmitted daily instead of monthly).

Data quality is likely to be improved. • While the cost for data transmission will increase, the human effort for quality control will likely decrease and there will be greater opportunities from improved access to more data; and • Technical errors will be detected much faster.

For data capture, a system that checks the constraints and data type for each parameter before it ingests the values into the database is recommended.

An important job of the data manager is to estimate data storage requirements, including estimating future growth. Account must be taken of the additional information to be included in data records (e.g. QC flags, original messages, date/time of record update), metadata needs and any redundancy necessary to ensure that databases can be restored. Estimating future growth will be difficult but it is worth keeping in mind that many NMHSs are now archiving 1 and/or 10 minute AWS data and that non-traditional climate data (e.g. soil moisture, vegetation indices) are very important for climatologists. The storage requirements for remotely sensed and oceanographic data are generally very large.

Data Exchange

There are perhaps four categories of climate data to consider from the data exchange viewpoint:

- Real-time or near-real-time data exchanged over the GTS, and for which timeliness is vital;
- Delayed-mode datasets which may be composites of the above but which are limited in terms of QC;
- Delayed-mode datasets which have had extensive QC and possibly homogeneity analysis applied; and
- Other products (e.g. Satellite imagery, metadata, climate monitoring and prediction products, climate indices, national / regional / global analyses and climatologies, outputs from global climate models).

For the first of these, WMO standard formats have been defined. CLIMAT and CLIMAT TEMP are the 'climate-specific' ones, while others - notably SYNOP, PILOT, TEMP and Marine message formats - are relevant to climate work. Details on these can be found in WMO (1995). For the others, there are formats defined for data interchange (for example, HDF and NetCDF) but these are at a higher level of generality and are not, per se, 'self-describing'.

Data administration and monitoring

As has been emphasized in Section 3.1, data managers need to ensure that their systems and data are managed in a way that satisfies user (or business) needs. Consequently, systems and processes need to be put in place to check that the data being managed conform to the expectations of users. A useful way of doing this is to establish and monitor a carefully selected set of performance indicators that reflect the standards expected by data managers.

Data flow problems should be identified and corrected before there are any consequences for climate data users.

Any monitoring indicators developed should be associated with target values which allow for measurement of performance against user needs.

Monitoring needs to ensure databases are:

- Comply with the relevant national and international guidelines in respect of spatial density, frequency and length of record;
- Subject to appropriate quality control;
- Of acceptable quality;
- Made readily available in digital form; and
- Stored optimally in terms of security and accessibility.

The systems and processes in place should provide real-time alerts to business critical activities. This may include alerts to missing data during times where high profile climate products are

produced (e.g. for government ministers) or where data are being provided to clients who are paying an urgency-fee for the service.

APPENDIX B

OBSERVING NETWORK DOCUMENTS

Documentation for existing networks can serve as a reference for observing system network design. The following provides documentation for a spectrum of networks including a reference climate network, an automated meteorological network, a national network supported by manual observations, and a network that provides externally sourced observations.

US Climate Reference Network: A complete set of documentation for the gold standard of climate networks is available at <http://www.ncdc.noaa.gov/crn/docs.html> . This includes functional requirements, test and evaluation, demonstration phase, site information and acquisition, commissioning plan, and field maintenance plan.

NOAA/NWS Automated Surface Observing System (ASOS) program documentation is available at <http://www.nws.noaa.gov/asos/> . This includes a variety of technical reports on instrumentation, change management, station information and the ASOS Users Guide (<http://www.nws.noaa.gov/asos/aum-toc.pdf>) .

Functional Specifications for Automatic Weather Stations in THE STATE-OF-THE-ART OF INSTRUMENTS AND AUTOMATED SURFACE OBSERVING SYSTEMS (ASOS) - https://www.wmo.int/pages/prog/www/IMOP/meetings/Surface/ET-STMT1_Geneva2004/Doc4.1%282%29REV1.pdf .

Measurements at Automatic Weather Stations (Draft for CIMO-16 Approval); http://www.wmo.int/pages/prog/www/IMOP/publications/CIMO-Guide/Provis2014Ed/Provisional2014Ed_P-II_Ch-1.pdf .

NOAA/NWS Cooperative Observer Program documentation is available at <http://www.nws.noaa.gov/om/coop/> .

An example of an external source observing program is the **Community Collaborative Rain, Hail and Snow Network** (CoCoRaHS) at www.cocorahs.org .
