GUIDELINES FOR MANAGING CHANGES IN CLIMATE OBSERVATION PROGRAMMES

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THE WCDMP "GUIDELINES" SERIES

In recognizing the need for National Meteorological Services (NMHSs) to improve their climate data and monitoring services, the WMO' Commission for Climatology (CCl) placed a high priority on the distribution of guidelines for the NMHSs.

Within the World Climate Data and Monitoring Programme, under the Open Programme Area Group (OPAG I) on Climate Data and Data Management the Expert Team on Observing Requirements and Standards for Climate initiated the preparation of this guidelines Document. These guidelines are intended to provide managers and operators, including within NMHSs a set of recommended procedures and practices in managing changes in the observational programmes to best maintain the required integrity of climate records.

It should be kept in mind that this Technical Document, like the other technical documents published under the WMO WCDMP series, is intended to provide guidance in the form of best practices that can be used by Members. Because of the diversity of NMHSs, with respect to size and stage of technological development, it may not have a significant utility for specific Members. However, this document does cover a wide range of guidance that should provide some form of assistance to every Member.

Guidelines for Managing Changes in Climate Observation Programmes

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Introduction

Evolving capabilities of climate monitoring platforms and instrumentation and their impacts on data usability are inevitable. Fundamental to maintaining the integrity of data and information pertaining to a climate monitoring program then, is to manage the associated changes.

[1] Environment Canada, Downsview, Canada
[2] Environment Canada, Downsview, Canada
[3] Environment Canada, Downsview, Canada

Managing change within a climate monitoring program strives to maintain the intercomparability of the climate record throughout the change process. It is critical to meeting the needs of climate research, applications, and services users, as well as those of the policy community. Unlike observations taken solely to support the preparations of forecasts and warnings, the availability of a continuous, uninterrupted climate record is the basis for many important studies involving a diverse array of climatological communities of which the need for homogeneous climate datasets is of utmost importance.

These Guidelines aim to provide managers and operators of climate monitoring networks with a set of recommended procedures/practices by which change can be managed in the observational programs in a manner that best maintains the required integrity of the climate record. Not included in the scope of these Guidelines are recommended procedures and practices for the analysis of output data streams, including homogeneity analysis, nor details on requirements of climate observing networks. These subjects are amply covered by the WCDMP Guidelines on Metadata and Homogeneity (Aguilar, E. et al., 2003), and the Guidelines on Climate Observational Networks and Systems (Plummer, N. et al., 2003), respectively, and readers requiring further information on either of these subjects should refer to these documents.

Instigators of Change

Changes such as replacement of sensors, location or sighting of instruments are realities of an evolving program and are essential for program longevity. For example, the need to upgrade or replace an individual sensor or the entire suite of sensors at a particular location can be planned (e.g., a modernization effort that introduces newer technologies or more appropriate sensors) or unplanned as a result of a loss of a sensor due to breakage/damage, premature aging, or theft. Over time, observations at staffed sites may also react to changes in individual observers due to illness, attrition, loss of motivation, or replacement by Automatic Weather Stations (AWS). Additionally, changes to the local characteristics of an observing site which changes the observing footprint of the location (e.g., addition of a new building), or the need to move sensors due to local land use changes are also factors that need to be considered when managing change at observing locations.

The change from manual to AWS observations poses a particular problem. Objective or deterministic weather elements such as temperature, pressure, relative humidity and precipitation observed by AWS are comparable or superior to those taken by humans. Establishing transfer functions either through parallel observations or through alternative approaches are imperative in order to ensure that data continuity can be defined. In the case of subjective weather elements, however, AWS cannot replicate human observations nor should it be expected to do so. One problem with AWS observations speaks to the continuity of data sets; while in the short-term AWS observations promote a savings vis-à-vis the need to have on-site observers; it also tends to lead to a loss of trained local observers. In developing nations where budgets are quite limited, any maintenance problems with an AWS, without sufficiently trained backup observers, can lead to long periods of time with no observations until such time that the AWS can be repaired.

As noted earlier, site relocation may be necessary due to urban or natural development that renders the original site no longer available or unsuitable for climate observations. Buildings being erected or dismantled, industrial or residential development and trees being planted or removed may abruptly or insidiously alter the environment perceived by the instruments.

Change can also be the result of a switch in the intent of the observing program (e.g., from research or forecast support to climate) or observational practices.
In Canada, a notable shift in observational practice includes the evolution of Climatological Day. Before there was any kind of national weather guidelines, various weather observers made up their own rules and practices for recording weather phenomena until it was recognized that

standardization was needed in order to collect data with comparable results. For primary stations, a Climatological Day starts and ends at the same hour of two consecutive days (i.e. begins with 0600 GMT observations on Day 1 and ends at the 0600 GMT observation on Day 2). Depending on the element, the observation may be credited to Day 1, as is the case for maximum temperature and precipitation, or Day 2 for most other elements. Climatological Day for observations reported by volunteers are exceptions. These observations are reported at approximately 0800 LST and 1700 LST and depending on the element, the observation is credited to the previous day, as in the case of the 0800 LST report for minimum temperature and occurrence of weather, or the calendar day (i.e. all other elements).

Effects of Change

Changes can result in a temporal break in the record or a discontinuity caused by the monitoring program change rather than any change in the climate. From a user's perspective, the break or discontinuity can mask the true climate and/or trends or other changes in the climate.

The effects of changes to site situation and deterioration are reflected in the temperature observations reported from a site situated in Vernon, British Colombia, Canada. When tested against a reference series, this site demonstrated definitive steps or breaks in data continuity. Investigation of the station inspection reports indicated that these discontinuities could be easily associated with changes in site aspect in 1957 when the screen was detached from the observer's house and set in the lawn and in 1981 when it was again resituated and levelled. A significant discontinuity also occurred following the cleaning, repainting of the screen and replacement of thermometers in 1991. (see Figure 1).

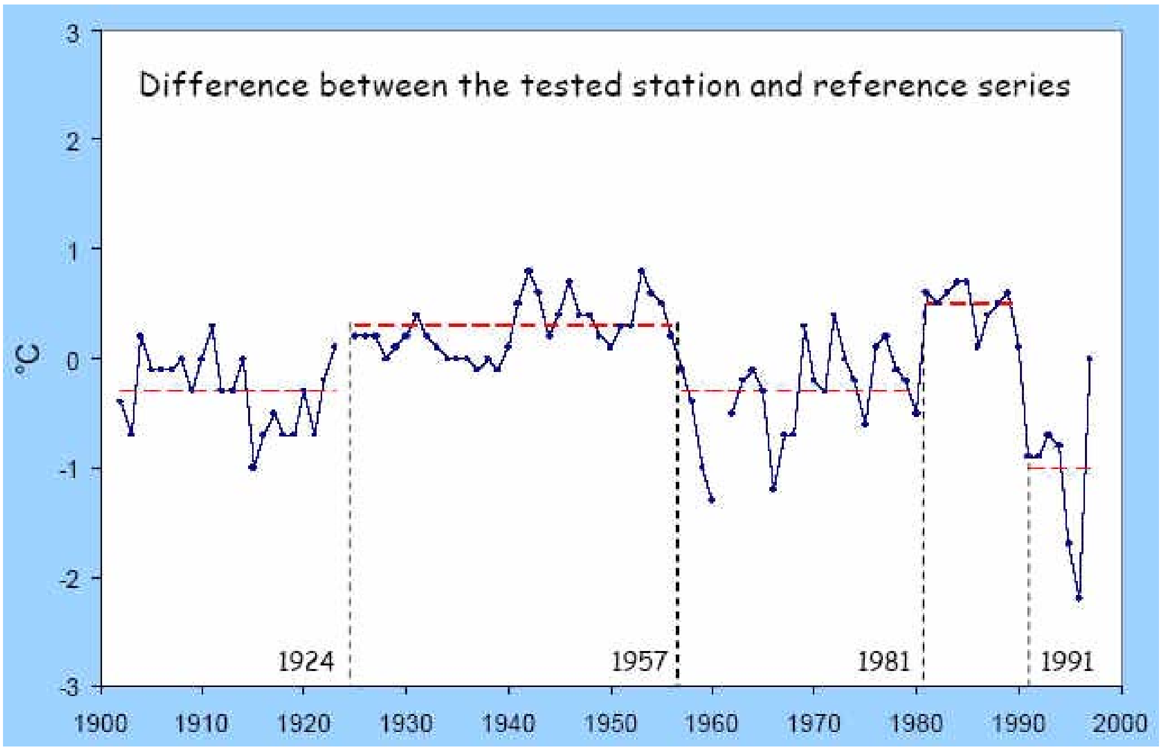

Figure 1: Hatch lines show data discontinuities at the Vernon, B.C. site. In 1957 the observation screen removed from the observer's house and installed in a grassy area of his lawn. The screen was further adjusted in 1981 to a more level area. In 1991, the screen was washed, painted and the thermometers were replaced.
As presented by Lucie Vincent, Homogenization of Temperature in Canada at the Workshop on Climate Data Homogenization, Marriot Eaton Centre Hotel, Toronto, Canada, April 19-21, 2004.

Further examples of effects of change:

1) The shift from manual to automatic precipitation gauges in the 1970s: automatic gauges report total precipitation and do not distinguish between rain and snow. In this case, instrumentation change did not affect a data discontinuity but essentially an information loss – no more snowfall observations. For Toronto Bloor Street, (a shift from manual to Geonor/Alter shield) this became a significant issue for providing advise to snow removal contractors. To accommodate this specific user need, manual snow measurements are reported by seasonal contract.

2) Shift from manual to AWS: elements such as presence of weather, visibility, ceiling, etc. Manual observations of these elements are subjective and may encompass a large field of vision. These elements should not be evaluated in the same context as observations from AWS which are discrete and reflect a limited observation field.

3) Benefits of change: improved data availability and timeliness, greater consistency, and improved response time to address site problems.

Managing Change

The need for effectively managing change is reflected in the Global Climate Observing System (GCOS) Climate Monitoring principles (see http://www.wmo.ch/web/gcos/Publications/gcos-73.pdf). These basic principles, adopted in paraphrased form by the Conference of the Parties to the UN Framework Convention on Climate Change through Decision 5/CP.5 of COP-5 at Bonn in November, 1999) are fundamental to ensuring the effective operation and management of climate monitoring systems in terms of remaining true to meeting users' needs.

Following these guidelines, Canada has adopted the following general practices for planned modernization of the climate monitoring program:

1) In an attempt to ascertain the impacts of change before implementation, all sensors and systems are tested and evaluated. Operations for old and new observing platforms are measured over space and time. When introducing a change, aim for as many similarities as possible (e.g. same site exposure, same procedures, and same sensors) in both old and new set-ups for at least one and preferably two years. Observations should be archived for both situations during the overlap period for approval, disapproval or deferral of change. Thorough testing and evaluation prior to installation should significantly ameliorate the transition from old to new set-up by establishing and documenting expected differences.

2) Measures should be taken to preserve the operation of historically uninterrupted stations and/or observing systems whenever possible to provide a baseline or reference standard. For example, in Canada the longevity of a pristine weather site (Beatrice, Ontario, in operation since the 1860s) was in jeopardy as the property owner was positioned to sell and there was no guarantee that prospective buyers would be amenable to retaining an observing site on their property. A portion of the property containing the weather site was purchased at market value from the land-owner in order to preserve its availability for continued parallel operations for more than two years.

3) Enforced periodic re-evaluation of station siting, exposure, calibrations and operational procedures should be completed every six months. Although these should be inherent with station inspections, they are often overlooked in favour of completing maintenance checks.

4) A national 'audit' or review of all stations at specified periods or frequency (i.e. 5 to 10 years) is recommended to ensure that station inspections, operations and documentation are completed to standards.

In addition, Canada has developed a change management process for the orderly introduction of new sensors, equipment etc. through the creation of a Change Management Board comprised of operational monitoring program representatives and representation from the research and data archiving communities. It provides an opportunity for network planners, operational managers and monitoring stakeholders to discuss long-term climate needs. The Board acts as a clearinghouse for all proposed monitoring system changes to ascertain implications, and should include cost-benefits. It serves as a focal point for decisions, ensuring that change requests are evaluated and processed and that through consensus a resolution is reached in a timely manner.

Successful application of a Change Management Board relies heavily on a clear and transparent change request process (submission form, instructions, and supporting information) which is readily available and understandable for potential proponents of change. All requests for changes related to climate monitoring are reviewed and evaluated; all systems, instruments, algorithms, procedures, processes and related documentation that influence the collection, processing, reporting and archiving of observations from the meteorological and climatological networks are within the scope of the change management process. This includes the climate data archive where database management changes may impact climate monitoring systems. If necessary, further analysis or investigations are commissioned.

Excluded from the scope of the Change Management Board is the operational management of the monitoring systems. Neither are network density and distribution decisions, which are the responsibilities of the network management committees themselves.

Finally, documentation of all approved changes to systems, configurations and specified applications for use as a reference in reviewing change requests must be maintained. Any changes or deviations from the documented approvals must be considered a new change and must be challenged through the Change Management Board's process.

Importance of Metadata

Seldom is metadata more important than when documenting network changes. Search and discovery metadata for data access, or basic site information, which generally includes station identifiers, name, latitude, longitude, elevation, start and end dates is insufficient to identify the history of the station and the impacts that changes may have had upon it.   Complete metadata should include a full account of the station from its onset date to the present. All changes to the site, such as site exposure, instrument changes including height above ground, calibrations, inspection visits, data adjustments, and quality control applications are all imperative for proper scientific decisions and judgments pertaining to data utility. Metadata should not preclude information derived form historical documents such as observing practices manuals, station inspection reports, government policies, resource and funding programs, even local newspapers.

Inherent to the problems of collecting and coordinating metadata is its management and maintenance. Present day technology for database warehousing of digitized metadata has the added benefit that metadata can be accessed, linked to observational data, as well as transferred. To facilitate metadata population, applications to directly ingest or derive as much metadata as possible from routine operations, such as station inspections, into the database should be developed. Network-wide observation policies and practices, calculation algorithms, quality control procedures, data adjustments, units, data formats, etc. should also be maintained to supplement the database management system. All database metadata can and should be easily mapped to an accepted descriptive metadata standard, such as ISO 19115 to broaden its accessibility to the climatological community.

Another problem facing metadata users is the inaccessibility of valuable information or data contained in their original medium. Historical documents such as observation reports or station inspection reports still in paper format need to be protected from deleterious effects of frequent use. Unfortunately, financial implications and sheer volume often prevent the digitization or transfer of these assets to mediums, such as scanned PDF or TIFF formats. At the very least, historical documents should be inventoried and properly conserved until such time as their information content can be transferred to a medium which supports multiple users access.

Metadata needs to have the same level of commitment as observed data. Incomplete, outdated, or inaccurate metadata can be as detrimental, indeed in some cases worse, than no metadata at all. Regular reviews of metadata content for confirmation and accuracy should be part of regular operations. Support to investigate new metadata sources, information management technologies and information sharing capabilities should be ongoing in an effort to make accessible and preserve the historical investment in the data collected.

Finally, with respect to metadata since it was noted that sighting of station instrumentation with respect to various structures and surfaces is quite important to maintaining a homogeneous set of observational data, it thus becomes critical to conclusively determine how much of any potential regional change in observed air temperatures might be due to land-use changes at the site itself (Davey and Pielke, 2005). As Davey and Pielke point out, such changes may include local-scale urban development around the site, changes in local vegetation characteristics, etc. Therefore, it is critical for at least 5 photographs, one of the temperature sensor, the other from the four cardinal directions (north, east, south, and west), and other as necessary in order to fully document important site characteristics.

This is an effort being undertaken in the U.S. by the National Climatic Data Center (NCDC) on behalf of the U.S. Historical Climate Network of 1221 sites; the estimated cost for initially gathering this photographic metadata is estimated at a $46 (US) per site for a total initial cost of $56K (US). A photographic documentation checklist used by NCDC is included in Appendix A. There are obvious costs for storing and keeping the data updated, but it is believed that such photographic input is a key part of the overall station metadata file. The U.S. GCOS Program, based at NCDC, is also investigating helping to create such a photographic metadata record on behalf of the approximately 1000 GCOS Surface Network stations as this is considered to be an important aspect of NCDC's role as a GCOS Lead Data Center. The cost for this effort is significantly higher (approximately $1.4M (US), but will be done over a longer period of time in the context of other activities such as the 3 GCOS Technical Support Projects (TSP) that currently operate in the Pacific Islands, Caribbean/Central America, and South and East Africa regions. For example as the TSPs make maintenance site visits they will take photographs of the GSN station configuration. As other opportunities avail themselves, NCDC will continue to add to this data base effort.

Effective Change Management Approaches

From the perspective of maintaining the integrity of the climate record through change, the best practice is to run the previous and the new systems/sensors in parallel. A parallel observation program allows for the identification of the necessary transfer functions, thus minimizing/eliminating the impact of the change on the climate record. This approach works best where change is planned or at least predictable.

Changes, however, are not always planned but may be forced (decisions made by others), the result of insufficient funding (leading to termination of parts of the observation program or an inability to run a parallel observation program), or due to unforeseen circumstances (e.g. natural or human-caused disasters). Where parallel observations are neither possible nor practical, other practices or approaches such as paired observations, or modelling or homogeneity based methods will need to be introduced to re-establish the integrity of the climate record.

Parallel observations – the preferred approach

The parallel observing approach works best for those changes which are planned rather than forced. The objective is to retain the original set-up and to establish the new configuration in a manner that maintains as much as possible of the old set-up: same location, procedures, and sensors; and to document in the associated metadata, those elements of the new set-up that have changed. Parallel operations on-site of the old and new climate observing program/system for an overlap period prior to decommissioning the original set-up is considered the best option for managing change (according to the GCOS Monitoring Principles).

This parallel observing approach allows for the identification and documenting of impacts and to assist potential users in the derivation of correction (relationship) factors needed to adjust data for homogeneity with the previous record. The length of the period of parallel observations should be defined based on consideration of the climate and the need for the two systems to operate in parallel through the range of climate of the site (i.e. all climate seasons and/or reasonable coverage of climatic range). A statistical approach could be used whereby the uncertainties are calculated for each of the monthly adjustment values. A decision could then be made to terminate the parallel program when, for example, enough comparison data have been collected to determine that the uncertainties on the monthly adjustments are within ±0.2°C at the 95% confidence level. From an operational perspective, economics and other operational considerations (e.g. availability of staff, land, and the feasibility of maintaining the operation of the old set-up) will often be limiting factors in defining the duration of the period of parallel observations. The extra demands these place on already stretched financial and human resources budgets should be considered in light of the information gain that an overlap period affords data usability. The goal should be to extend the length of the overlap period for a minimum of one and preferably two years.

Equally important to maintaining this parallel set of observations is the establishment and maintenance of the associated metadata for the old and the new set-ups. These two sets of metadata, including the dates and timing of the change, will help users and researchers understand the basis for any homogeneity based adjustments and allows for future considerations of the validity of those corrections in light of new information or developments.

It is also essential that both sets of observations be archived during the overlap period. Depending on the archiving system, archiving two sets of observations from the same site may require special designation for either the old or new set-up in order for both sets to be archived and retrieved in the future.

Associated Costs:

From a human resources perspective this approach will require maintaining two set-ups at each site undergoing the change. This means that at each site during the parallel observing period, staff will need to budget time for inspections of two systems, as well as time for making the necessary repairs and/or replacement of defective equipment comprising the two set-ups. This additional requirement will further exacerbate any existing human resources concerns that would result from the conversion to a new set-up (e.g., site and system establishment and associated training). There are some relatively small additional human resource requirements associated with archiving and quality controlling the additional set of observations generated by the parallel observations.

As the original set-up already exists, financial costs associated with its operation, including travel to and from the site by technical staff for inspection and maintenance, can to some degree be reflected in the original budget. However, it should be noted that additional equipment comes with more sparing requirements and a higher risk of equipment failure and thus potentially increasing time and costs associated with repair.

Financial costs are also accrued with the establishment of a parallel observing set-up for the new equipment, sited in an appropriate location with supportive infrastructure. For some sensors (e.g., precipitation, wind), the location of the individual sensors cannot be shared or require more space and more infrastructure (e.g., towers and cables). Not only are these additional financial costs, but acquisition of additional space may not be feasible, thereby operating a parallel program may be constrained. Individual sites may incur specialized costs such as those associated with leasing additional land, requirements for a special maintenance contract with the land owner, maintenance provider or observers (e.g. to maintain a good environment around the site), de-commissioning costs to return a site back to its original state post observing program completion, or deconstruction costs to remove certain site structures obstructing a second set of observational equipment (e.g., fences and/or concrete structures). Costs could also be incurred through recruitment and training of new observers to handle the additional workload.

Examples:

The Australian Bureau of Meteorology[4] has been conducting a parallel (or comparison) observation program, especially for its Reference Climate Stations, since the mid-1990s. This was prompted by the replacement of manual stations by automatic weather stations and concerns for the homogeneity of the climate record. Comparison data exists at about 31 sites as of September 2005 with daily rainfall, dew point and maximum and minimum temperatures being the priority climate variables. While the aim of the program has been to capture parallel observations over a two-year period, more than five years of data have been collected at many of these sites.

Table 1 provides an estimate of the direct costs associated with the parallel observations program at 31 Australian sites over a two-year period. Most of the costs are associated with maintaining two manual observations per day for the priority variables. The total direct cost is about $506K Aus ($382K US) with an average cost of around $16.3K Aus ($12.3K US) per site. Table 2 provides an estimate of the indirect costs and, because the comparison data do not accrue real value until they are put to use, these include data analysis costs. These total indirect costs amount to about $43K Aus ($32K US).

It is possible to incur much larger costs at individual sites. The costs associated with the leasing of land could be high and there may be requirements to establish a special maintenance contract with observers (e.g. to maintain a good environment around the site). De-commissioning costs can be high due to increasingly stringent environmental requirements and the need to return a site back to its original state. Costs may also be elevated by the need to remove certain structures on the site, e.g. fences, concrete slabs. Costs could also be incurred in recruiting and training new observers if needed.

In summary, there are some significant costs associated with a parallel observations program in Australia. However, when comparing those costs with the Bureau of Meteorology's total expenditure to capture observational data ($89M Aus per year in 2003/04) and manage the climate database ($5M Aus per year) then the expenditure on helping to preserve the homogeneity of the climate record is only 0.3% of the total to collect and manage the data over a two year period. Money well spent!

[4] Acknowledgment: Many thanks to Neil Plummer, (National Climate Centre, Bureau of Meteorology), Helmut Abt (Observations Program, Bureau of Meteorology) and Regional Observation Manager colleagues for providing some costings, as provided in Table 1. Special thanks to Rod Hutchinson, Margaret Kaskin and Dr Blair Trewin (National Climate Centre) for also assisting.

Component Description	Unit cost ($Aus)	Quantity	No. Sites	Total Cost ($Aus)
1. Inspections	200	1	31	6,200
2. Communications	0.15	40150	31	6,022
3. Site de-commissioning - One off	1,500	1	31	46,500
4. Allowances				444,638
5. Instrument replacement	200	0.4	31	2,480
6. Total				*505,840*

Table 1. *Estimated direct costs for the Australian Bureau of Meteorology's parallel observation programme. These are based on comparison observations at two times (0900 and 1500 Local Standard Time) from two stations at 31 locations over a two-year period. The following information has been used in the calculations: Inspection costs include salary, transport and incidentals; Communications costs are for data transmission; Site de-commissioning includes the inspection costs as well an allowance that additional time or additional funds for contractors may be necessary; Allowances are payments made to cooperative observers; and Instrument replacements costs assume that one thermometer is replaced once in 5 years.*

Component Description	Total Cost ($Aus)
1. Administrative	3,462
2. Data management	5,500
3. Data analysis and reporting	33,750
4. Total	*42,712*

Table 2. *Additional costs incurred through the Australian Bureau of Meteorology's parallel observation programme. The following information has been used in the calculations: Administrative overhead costs include setting up new station numbers, establishing arrangements with observers, administering payments, stationary and writing instructions; Data management costs include an assumption of data entry required for 5 of the 31 sites, metadata entry for 31 sites and the incremental costs of managing the additional data in the database; Data analysis and reporting costs have been costed assuming the work would take a Meteorologist 4.5 months to analyse all of the data and produce a report.*

Cost estimates are also available from detailed costing estimates for operation of Canadian climate reference network sites. These estimates have been derived as part of the efforts underway towards modernization of the Canadian reference climate network and in support of efforts related to the move from human observers to automated systems at a number of the climate reference sites.

In the case of parallel (and also paired) observations at the same site, there are no significant additional annual costs associated with utilities (electricity and water). Additional annual costs, however, are associated with communication and IT support ($1,150 CAN per site); inspection, repair and sparing ($11,060 CAN per site) with the assumption of 5% sparing and 10% emergency trips for repair; and for monitoring performance and real-time QA/QC ($290 CAN per site). There are additional annual cost associated with time required to undertake routine inspections and maintenance of additional systems ($1,365 CAN per site) assuming a travel and inspection period of two days per site. In the case where for occupational health and safety concerns, an associate (junior technical staff) is required to accompany an inspector during a routine inspection and maintenance visit to an isolated site, annual costs ($2,493 CAN per site) can be significantly higher (e.g. costs associated with additional travel to remote locations).

Paired observations

When parallel observations are not feasible or possible, as in the case where change is forced as a result of damaged or lost equipment, loss of access to a site, or actions by partners or land owners, or after the fact (i.e. those where the original set-up is no longer available or cannot be re-established), an alternative approach is to reproduce, as much as possible, the old set-up and then undertake paired observations using a co-located new set-up or a number of closely-located observing sites with the new set-up. As in the parallel observation approach, the duration of the period of paired observations should be as long as possible spanning the full range of climatic seasons (i.e. one to two years or when the uncertainties on the monthly adjustments are considered low enough – see previous section).

A paired observation program requires co-location of at least two set-ups; one an approximation of the original set-up and one as the new set-up. In cases where the homogeneity of the original set-up, new set-up and the environment are similar, one original set-up co-located with a new set-up can be used to develop the necessary correction (or relationship) factors for a number of similar locations.

This paired observation approach, although not as effective as the parallel observation approach, does offer a viable option towards maintaining continuity of record. Correction (relationship) factors can be derived from these paired observations allowing the observations collected under the new set-up to be connected to those collected under the former original set-up.

Short-comings of this approach are related to duplicating the original set-up, including finding and maintaining an original suite of sensors, and replicating the system configuration, observing program and environment (building and vegetation). In terms of a conversion from a manual to an AWS observing program, duplicating the original set-up may be completely impractical, and thus using a paired observational approach will not be possible. In addition, the availability and feasibility of re-establishing and maintaining a large number of original set-ups may be prohibitive.

Associated Costs:

The paired observation approach does require additional effort and therefore additional financial and human resource expenditures. These additional expenditures would be similar to those incurred through the parallel observation approach (see examples under parallel observations). Additional costs, however, would be incurred as a result of having to re-establish after the fact the original set-up. These costs include those required to support the additional demands on technical staff, including the need to acquire and ensure the operation (e.g., ensuring proof of operability, retrofitting and repair) of the original set of sensors and re-establishing the original set-up, including appropriately siting the sensors and establishing the required infrastructure. As in the case of the parallel observation approach, limitation related to space (availability or access to the additional space) can add to the costs and/or limit the applicability of this approach

Modelling or Homogeneity based approach

An alternative to the two observational approaches is to model the data collected through the original setup (i.e. model recording properties of formerly used sensors relative to nearby/neighbouring sensors) and compare them with data being collected by the new setup. Although not as sound an approach as the two observational approaches, this modelling approach does result in the establishment of a climatologically-based relationship that can then be used to homogenize the data being collected using the new setup with that collected using the original setup.

Homogeneity testing procedures have been developed for detecting artificial steps in climatological time series due to station relocation, changes in instrumentation, changes in observers and in observing procedures. These procedures are based on statistical methodologies; they require a large amount of observations from the tested site and several neighbouring stations, and they only provide rough estimates of the values that simulate homogeneity. They are adequate for adjusting past records, but for the future, the best approach is to have co-located instruments collecting concurrent daily observations for a period of least two but preferable five years and to develop mathematical relations to derive adjustment values.

When parallel observations are impossible homogeneity testing can be applied with an understanding of the limitations of the procedures. Estimate accuracy is directly proportionally to the number of neighbouring stations that are used (at least three to five stations) for the derivation. These stations should be in close proximity to the test site and represent a similar climate regime. For temperature, a neighbouring site can be located as far as 20 to 30 km depending on the topography of the area, but for precipitation, neighbour sites should be as close as only a few kilometres. The selected set of neighbouring stations should remain constant through the change and be expected to remain constant for a period of at least two or more subsequent years. The data provided during this period is necessary to construct a relationship model that is valid for the range of climates experienced at the target site(s). The longer the post-change period, the more confidence can be given to the validity of the relationship.

Techniques used to select the set of neighbouring stations and to develop the relationship model should be those used in homogeneity studies (Vincent, L.A. et al., 2002). The model should account for the differences in variables measured on an interval scale such as temperature, from those measured on a proportional scale such as precipitation.

Once a model has been developed, the data collected under the new setup can be adjusted to match that collected under the original setup. Adjustment factors can be obtained by calculating separate averages on the difference or ratio series for the period prior to the change and after the change. The obtained means are compared by calculating their ratio or difference and the obtained factor is applied to the post-change data. Adjustments should be corroborated with metadata to the extent that the metadata are considered reliable and complete.

Current studies have shown that homogeneity procedures are reliable for producing good estimates for annual and monthly temperatures but the error becomes larger for daily values, and in particular for extremes. Homogeneity testing has been applied to other climate elements such as pressure and relative humidity to identify steps in seasonal time series but adjustment procedures need to be further established. For precipitation, it is difficult to apply a homogeneity procedure since the spatial variability of precipitation is very high; however on-going research attempts to address this problem. It is also worth noting that there is not yet a definitive approach for any variable and therefore there will always be the need to review the evaluation of the data and the adjustments made. As such, it is very important to preserve the raw data and to document in the associated metadata all procedures applied to adjust the data.

In addition to applicability in terms of variables, data availability to build the relationship model may be limited. In locations where observational networks are sparse or retaining original setups at neighbouring sites is not possible, it is difficult to construct the necessary relationship model. In the latter case, a combination of parallel or paired and model approaches may be possible and may reduce the overall costs of managing a large scale change.

Associated Costs:

In terms of capital investment and human resources, associated costs are somewhat less than the two observational approaches and may be the only viable option. There is no need to maintain two sites and as long as the neighbouring sites are continuing, there are no additional network operational costs. The only costs are those associated with establishing, running and updating a relationship model and maintaining the associated metadata. Costs associated with this approach are dependent on the experience of the people involved, time and data availability and the climate element being modelled.

Cost considerations include the following[5]:

- An experienced climatologist familiar with the climatology of the area and a computer scientist familiar with statistical algorithms are essential. Both should be well trained in using modelling or homogeneity testing procedures.
- Daily observations for at least 25 years prior and five years after the changes from the site in question and from neighbour stations are needed with little missing values.
- In terms of computing power, the statistical analysis and modelling can be done on a personal computer with the proper statistical software installed.
- Detailed metadata for all the sites and equipment involved is required, including instrument type, observers, time of observations, locations, observing programs and description of the surrounding environment.

The Australian experience suggests that early efforts on the modelling or homogeneity approach have been time-intensive and costly. For example, the development of the first all-Australian rainfall (Lavery et al., 1997) and temperature (Torok and Nicholls, 1996) homogenized datasets each involved around two years of scientific development from a trained climatologist. (The latter dataset was developed as part of a PhD). The effort included: the collection and inventorying of metadata; development of statistical inhomogeneity detection and adjustment techniques; data collection and analysis, including applying adjustments to time series; documenting and reporting. The total cost to the Australian Bureau of Meteorology in developing a homogenized dataset is around $180,000 AUS[6] (or $135,000 US). Aside from associated observational costs, the effort involved in updating and maintaining this dataset is around six months work for a climatologist every three to five years, i.e. $45,000 AUS (or $34,000 US).

Conclusions

The practical goal of climate monitoring is to have consistent, continuous data for long periods of time. Long-term consistency generally does not exist so to simulate continuity, potential biases due to changes extraneous to that of climate change need to be managed. The main conclusions of these guidelines are:

- The integrity of the climate record is of utmost importance and ways and means do exist to preserve it from degradation
- Efforts need to be undertaken to ensure that there is a proper understanding of both the legitimate need for observational integrity and of the associated costs and benefits.
- Implementation of a change management process is essential to document decisions related to the change process and to ensure that the desired results have been achieved and to provide a forum for better understanding of the associated costs and benefits of the change process.
- Practicality and affordability suggest that in a large number of cases a combination of parallel and modelling approaches would most likely be achievable.
- Prudent stewardship of observational resources is central to long-term climate monitoring and to examine the effects of climate variability and change on life and property.

References

[5] Acknowledgment: Many thanks to Lucie Vincent of the Meteorological Service of Canada, Environment Canada for providing the costing/resources information for the modelling or homogeneity approach.

[6] Costs estimated by Neil Plummer (Bureau of Meteorology, Australia) and include corporate overheads as well as salaries and equipment.

Aguilar, E., Auer, I., Brunet, M., Peterson, T.C. and Wieringa, J., 2003: WCDMP No. 53, WMD/TD No. 1186: Guidelines on climate metadata and homogenization. World Meteorological Organization, Geneva, Switzerland.

Davey, C. and Pielke, R.A., 2005: Microclimate Exposures of Surface-Based Weather Stations: Implications for the Assessment of Long-Term Temperature Trends. Bulletin of the American Meteorological Society, 86, 497-504.

Plummer, N., Allsopp, T. and Lopez, J.A., 2003: WCDMP No. 52, WMO/TD 1185: Guidelines on climate observations networks and systems. World Meteorological Organization, Geneva, Switzerland.

Lavery, B., Joung, G. and Nicholls, N., 1997: An extended high-quality historical rainfall dataset for Australia. Australian Meteorological Magazine 46(1), 27-38.

Mekis, É. and Hopkinson, R., 2004: Derivation of an improved snow water equivalent adjustment factor map for application on snowfall ruler measurements in Canada. Proceedings of the 14th Conference on Applied Climatology, Seattle, Washington, American Meteorological Society.

Mekis É. and Hogg, W.D., 1999: Rehabilitation and analysis of Canadian daily precipitation time series. Atmosphere-Ocean, 37, 53-85.

Metcalfe, J.R., Routledge, B. and Devine, K., 1997: Rainfall measurement in Canada: changing observational methods and archive adjustment procedures. J. Climate, 10, 92-101.

Milewska, E.J. and Vincent, L.A., 2005: The effect of modernization of climate reference networks on continuity of daily maximum and minimum temperature observations. Proceedings of the13th Symposium on Meteorological Observations and instrumentation. June 20-24, Savannah, Georgia.

Milewska, E.J. and Hogg, W.D., 2002: Continuity of Climatological Observations with Automation - Temperature and Precipitation Amounts from AWOS (Automated Weather Observing System). Atmosphere-Ocean, 40(3), 333-359.

National Monitoring Change Management Board (NMCMB) Charter, issued by T. Allsopp, Meteorological Service of Canada, 2002, Downsview, Canada.

Peterson, T.C., Easterling, D.R., Karl, T.R., Groisman, P., Auer, I., Boehm, R., Plummer, N., Nicholls, N., Torok, S., Vincent, L., Tuomenvirta, H., Salinger, J., Forland, E.J., Hanssen-Bauer, I., Alexandersson, H., Jones, P. and Parker, D., 1998: Homogeneity adjustments of in situ climate data: a review. International Journal of Climatology, 18, 1493-1517.

Torok, S.J. and Nicholls, N., 1996: A historical annual temperature dataset for Australia. Australian Meteorological Magazine 45(4), 251-260.

Vincent, L.A., Zhang, X., Bonsal, B.R. and Hogg, W.D., 2002: Homogenization of daily temperatures over Canada. Journal of Climate, 15, 1322-1334.

Vincent, L.A., 1998: A Technique for the identification of inhomogeneities in Canadian temperature series. Journal of Climate, 11, 1094-1104.

Wang, X. L., 2005: Has Canada Experienced More Frequent Adverse or Fair Weather since 1953? Submitted to Journal of Geophysical Research.

Wang, X. L., 2003: Comments on “Detection of Undocumented Changepoints: A Revision of the Two-Phase Regression Model”. Journal of Climate, 16, 3383-3385.

World Meteorological Organization (Series) No. 488: Guide on the global observing system, 1989, Geneva, Switzerland.

World Meteorological Organization (Series) No. 100: Guide to Climatological Practices, Second edition, 1983, Geneva, Switzerland.

World Meteorological Organization WMO-No.8: Guide to Meteorological Instruments and Methods of Observation, Sixth edition, 1996, Geneva, Switzerland.

World Meteorological Organization WMO-No.544: Manual on the Global Observing System, Volume 1 (Annex V to the WMO Technical Regulations) Global Aspects, 1981, Geneva, Switzerland.

Appendix A

Photographical Documentation Checklist for USCRN Site Annual Maintenance Visit

☐ Photos taken By: ______________________ Date: ___________

Photos should be made when there is good visibility at 100 meters. On clear days, the pictures should be taken as close to noon as possible. File names should include the compass direction where appropriate. Archive file format is jpg. Photos MUST be taken in order listed below so they will properly be labelled and created.

1) Four Ipix taken at ten meters from the tower fence at the four points of the compass. Each Ipix should have an aligned compass in the center label area. The 186-degree image shots will be part of the official archive. **If the annual site visit uncovers significant change, these shots are to be retaken.**

   Photo 1: North: start with S, end with N
   Photo 2: East: start with W, end with E
   Photo 3: South: start with N, end with S
   Photo 4: West: start with E, end with W

2) At least four general site views that represents the most informative overall perspective. Two of the photos should be taken with the camera angle perpendicular to a line drawn between the DFIR and the tower, with the margin of sky no more than 1/3 of the height of the photo, and the station comprising 75% of the image. To be retaken at each annual site visit and photos placed in the archive.

3) From a position four meters west of the tower and starting at due south, nine still photos taken every 22.5 degrees clockwise to due north denoting objects within 100 meters and their heights. Stitch photos into a single 180-degree image. **To be retaken at each annual site visit and photos placed in the archive.**

   Start with S, SSW, SW, WSW, W, WNW, NW, NNW
   End with N

Object:	Distance:
Object:	Distance:
Object:	Distance:
Object:	Distance:
Object:	Distance:

4) From a position four meters east of the tower and starting at due north, nine still photos taken every 22.5 degrees clockwise to due south denoting objects within 100 meters and their heights. Stitch photos into a single 180-degree image. **To be retaken at each annual site visit and photos placed in the archive.**

   Start with N, NNE, NE, ENE, E, ESE, SE, SSE,
   End with S

Object:	Distance:
Object:	Distance:
Object:	Distance:
Object:	Distance:
Object:	Distance:

Location of original photos:
After photos are edited, properly saved, and sent to NCDC, they will be stored in file cabinet in Gabrielle's office. NCDC will receive cd with all photos. Photographer will receive cd with all photos.

Listing of Additional Objects and Distance:

Object:	Distance:
Object:	Distance:
Object:	Distance:
Object:	Distance:
Object:	Distance:
Object:	Distance:

REPORTS PUBLISHED IN THE

WORLD CLIMATE DATA PROGRAMME (WCDP)/

WORLD CLIMATE DATA AND MONITORING PROGRAMME (WCDMP) SERIES

WCDP-1 WMO REGION III/IV TRAINING SEMINAR ON CLIMATE DATA MANAGEMENT AND USER SERVICES, Barbados, 22-26 September 1986 and Panama, 29 September 3 October 1986 (available in English and Spanish) - (WMO-TD No. 227)

WCDP-2 REPORT OF THE INTERNATIONAL PLANNING MEETING ON CLIMATE SYSTEM MONITORING, Washington DC, USA, 14-18 December 1987 - (WMO-TD No. 246)

WCDP-3 GUIDELINES ON THE QUALITY CONTROL OF DATA FROM THE WORLD RADIOMETRIC NETWORK, Leningrad 1987 (prepared by the World Radiation Data Centre, Voeikov Main Geophysical Observatory) - (WMO-TD No. 258)

WCDP-4 INPUT FORMAT GUIDELINES FOR WORLD RADIOMETRIC NETWORK DATA, Leningrad 1987 (prepared by the World Radiation Data Centre, Voeikov Main Geophysical Observatory) - (WMO-TD No. 253. p. 35)

WCDP-5 INFOCLIMA CATALOGUE OF CLIMATE SYSTEM DATA SETS, 1989 edition (WMO-TD No. 293)

WCDP-6 CLICOM PROJECT (Climate Data Management System), April 1989 (updated issue of WCP-I 1 9) - (WMO-TD No. 299)

WCDP-7 STATISTICS ON REGIONAL NETWORKS OF CLIMATOLOGICAL STATIONS (based on the INFOCLIMA World Inventory). VOLUME II: WMO REGION I - AFRICA (WMO-TD No. 305)

WCDP-8 INFOCLIMA CATALOGUE OF CLIMATE SYSTEM DATA SETS - HYDROLOGICAL DATA EXTRACT, April 1989 - (WMO-TD No. 343)

WCDP-9 REPORT OF MEETING OF CLICOM EXPERTS, Paris, 11-15 September 1989 (available in English and French) - (WMO-TD No. 342)

WCDP-10 CALCULATION OF MONTHLY AND ANNUAL 30-YEAR STANDARD NORMALS, March 1989 (prepared by a meeting of experts, Washington DC, USA) - (WMO-TD No. 341)

WCDP-11 REPORT OF THE EXPERT GROUP ON GLOBAL BASELINE DATASETS, Asheville, USA, 22-26 January 1990 - (WMO-TD No. 359)

WCDP-12 REPORT OF THE MEETING ON HISTORICAL ARCHIVAL SURVEY FOR CLIMATE HISTORY, Paris, 21-22 February 1990 - (WMO-TD No. 372)

WCDP-13 REPORT OF THE MEETING OF EXPERTS ON CLIMATE CHANGE DETECTION PROJECT, Niagara-on-the-Lake, Canada, 26-30 November 1990 - (WMO-TD No. 418)

Note: ***Following the change of the name of the World Climate Data Programme (WCDP) to World Climate Data and Monitoring Programme (WCDMP) by the Eleventh WMO Congress (May 1991), the subsequent reports in this series will be published as WCDMP reports, the numbering being continued from No. 13 (the last 'WCDP" report).***

WCDMP-14 REPORT OF THE CCl WORKING GROUP ON CLIMATE CHANGE DETECTION, Geneva, 21-25 October 1991

WCDMP-15 REPORT OF THE CCl EXPERTS MEETING ON CLIMATE CODE ADAPTATION, Geneva, 5-6 November 1991 - (WMO-TD No. 468)

WCDMP-16 REPORT OF THE CCl EXPERTS MEETING ON TRACKING AND TRANSMISSION OF CLIMATE SYSTEM MONITORING INFORMATION, Geneva, 7-8 November 1991 - (WMO-TD No. 465)

WCDMP-17 REPORT OF THE FIRST SESSION OF THE ADVISORY COMMITTEE ON CLIMATE APPLICATIONS AND DATA (ACCAD), Geneva, 19-20 November 1991 (also appears as WCASP-18) - (WMO-TD No. 475)

WCDMP-18 CCl WORKING GROUP ON CLIMATE DATA, Geneva, 11-15 November 1991 (WMO-TD No. 488)

WCDMP-19 REPORT OF THE SECOND CLICOM EXPERTS MEETING, Washington DC, 18-22 May 1992 - (WMO-TD No. 511)

WCDMP-20 REPORT ON THE INFORMAL PLANNING MEETING ON STATISTICAL PROCEDURES FOR CLIMATE CHANGE DETECTION, Toronto, 25 June, 1992 (WMO-TD No. 498)

WCDMP-21 FINAL REPORT OF THE CCI WORKING GROUP ON CLIMATE DATA AND ITS RAPPORTEURS, November 1992 - (WMO-TD No. 523)

WCDMP-22 REPORT OF THE SECOND SESSION OF THE ADVISORY COMMITTEE ON CLIMATE APPLICATIONS AND DATA (ACCAD), Geneva, 16-17 November 1992 (also appears as WCASP-22) - (WMO-TD No. 529)

WCDMP-23 REPORT OF THE EXPERTS MEETING ON REFERENCE CLIMATOLOGICAL STATIONS (RCS) AND NATIONAL CLIMATE DATA CATALOGUES (NCC), Offenbach am Main, Germany, 25-27 August 1992 - (WMO-TD No. 535)

WCDMP-24 REPORT OF THE TENTH SESSION OF THE ADVISORY WORKING GROUP OF THE COMMISSION FOR CLIMATOLOGY, Geneva, 20-22 September 1995 (also appears as WCASP-34) - (WMO-TD No. 711)

WCDMP-25 REPORT OF THE FIFTH SESSION OF THE ADVISORY COMMITTEE ON CLIMATE APPLICATIONS AND DATA (ACCAD), Geneva, 26 September 1995 (also appears as WCASP-35) - (WMO-TD No. 712)

WCDMP-26 REPORT ON THE STATUS OF THE ARCHIVAL CLIMATE HISTORY SURVEY (ARCHISS) PROJECT, October 1996 (prepared by Mr M. Baker) - (WMO-TD No. 776)

WCDMP-27 SUMMARY REPORT OF THE MEETING OF THE THIRD SESSION OF THE CCl WORKING GROUP ON CLIMATE CHANGE DETECTION, Geneva, 26 February - 1 March 1996 - (WMO-TD No. 818)

WCDMP-28 SUMMARY NOTES AND RECOMMENDATIONS FOR CCI-XII FROM MEETINGS CONVENED TO PREPARE FOR PUBLISHING THE FIFTH AND SIXTH GLOBAL CLIMATE SYSTEM REVIEWS AND FOR A PUBLICATION ON THE CLIMATE OF THE 20TH CENTURY, July 1997 - (WMO-TD No. 830)

WCDMP-29 CLIMATE CHANGE DETECTION REPORT - REPORTS FOR CCI-XII FROM RAPPORTEURS THAT RELATE TO CLIMATE CHANGE DETECTION, July 1997 (WMO-TD No. 831)

WCDMP-30 SUMMARY NOTES AND RECOMMENDATIONS ASSEMBLED FOR CCI-XII FROM RECENT ACTIVITIES CONCERNING CLIMATE DATA MANAGEMENT, July 1997 (WMO-TD No. 832)

WCDMP-31 REPORTS FOR CCI-XII FROM RAPPORTEURS THAT RELATE TO CLIMATE DATA MANAGEMENT, July 1997 - (WMO-TD No. 833)

WCDMP-32 PROGRESS REPORTS TO CCl ON STATISTICAL METHODS, July 1997 (prepared by Mr Christian-Dietrich Schönwiese) (WMO-TD No 834)

WCDMP-33 MEETING OF THE CCl WORKING GROUP ON CLIMATE DATA, Geneva, 30 January - 3 February 1995 - (WMO-TD No. 841)

WCDMP-34 EXPERT MEETING TO REVIEW AND ASSESS THE ORACLE-BASED PROTOTYPE FOR FUTURE CLIMATE DATABASE MANAGEMENT SYSTEM (CDBMS), Toulouse, France, 12-16 May 1997 - (WMO-TD No. 902)

WCDMP-35 REPORT OF THE ELEVENTH SESSION OF THE ADVISORY WORKING GROUP OF THE COMMISSION FOR CLIMATOLOGY, Mauritius, 9-14 February 1998 (also appears as WCASP-47) - (WMO-TD No. 895)

WCDMP-36 REPORT OF THE MEETING OF THE CCl TASK TEAM ON CLIMATE ASPECTS OF RESOLUTION 40, Geneva, Switzerland, 10-1 1 June 1998 - (WMO-TD No. 925)

WCDMP-37 REPORT OF THE MEETING OF THE JOINT CCl/CLIVAR TASK GROUP ON CLIMATE INDICES, Bracknell, UK, 2-4 September 1998 - (WMO-TD No. 930)

WCDMP-38 REPORT OF THE MEETING OF THE WMO COMMISSION FOR CLIMATOLOGY (CCl) TASK GROUP ON A FUTURE WMO CLIMATE DATABASE MANAGEMENT SYSTEM (CDMS), Ostrava, Czech Republic, 10-13 November 1998 and FOLLOW-UP WORKSHOP TO THE WMO CCl TASK GROUP MEETING ON A FUTURE WMO CDMS, Toulouse, France, 30 March-1 April 1999 - (WMO-TD No. 932)

WCDMP-39 REPORT OF THE MEETING OF THE CCl WORKING GROUP ON CLIMATE DATA, Geneva, Switzerland, 30 November-4 December 1998 - (WMO-TD No. 970)

WCDMP-40 REPORT OF THE MEETING ON CLIMATE STATISTICS, PRODUCT DEVELOPMENT AND DATA EXCHANGE FOCUSING ON CLICOM 3.1, Geneva, 25-29 January 1999 - (WMO-TD No. 971)

WCDMP-41 PROCEEDINGS OF THE SECOND SEMINAR FOR HOMOGENIZATION OF SURFACE CLIMATOLOGICAL DATA, Budapest, Hungary, 9-13 November 1998 (WMO-TD No. 962)

WCDMP-42 REPORT OF THE MEETING OF EXPERTS ON THE CLIMATE OF THE 20TH CENTURY, Geneva, 26-30 April 1999 - (WMO-TD No. 972)

WCDMP-43 REPORT OF THE TRAINING SEMINAR ON CLIMATE DATA MANAGEMENT FOCUSING ON CLICOM/CLIPS DEVELOPMENT AND EVALUATION, Niamey, Niger, 03 May-10 July 1999, (WMO-TD No. 973)

WCDMP-44 REPRESENTATIVENESS, DATA GAPS AND UNCERTAINTIES IN CLIMATE OBSERVATIONS, Invited Scientific Lecture given by Chris Folland to the WMO Thirteenth Congress, Geneva, 21 May 1999 - (WMO-TD No. 977)

WCDMP-45 WORLD CLIMATE PROGRAMME - WATER, DETECTING TREND AND OTHER CHANGES IN HYDROLOGICAL DATA, Zbigniew W. Kundzewicz and Alice Robson (Editors) - (WMO-TD No. 1013)

WCDMP-46 MEETING OF THE WMO CCl TASK GROUP ON FUTURE WMO CLIMATE DATABASE MANAGEMENT SYSTEMS (CDMSs), Geneva, 3-5 May 2000 (WMO-TD No. 1025)

WCDMP-47 REPORT ON THE ACTIVITIES OF THE WORKING GROUP ON CLIMATE CHANGE DETECTION AND RELATED RAPPORTEURS, 1998-2001 (May 2001, updated from March 2001) (WMO-TD No. 1071)

WCDMP-48 REPORT OF THE FIRST SESSION OF THE MANAGEMENT GROUP OF THE COMMISSION FOR CLIMATOLOGY (Berlin, Germany, 5-8 March 2002) (also appears as WCASP-55) (WMO-TD No. 1110)

WCDMP-49 REPORT ON THE CLICOM-DARE WORKSHOP (San José, Costa Rica, 17-28 July 2000); 2. REPORT OF THE INTERNATIONAL DATA RESCUE MEETING (Geneva, 11-13 September 2001) (WMO-TD No. 1128)

WCMDP-50 REPORT OF THE CLIMATE DATABASE MANAGEMENT SYSTEMS EVALUATION WORKSHOP (Geneva, 11-13 September 2001) (WMO-TD No. 1130)

WCDMP-51 SUMMARY REPORT OF THE EXPERT MEETING FOR THE PREPARATION OF THE SEVENTH GLOBAL CLIMATE SYSTEM REVIEW (7GCSR) (Geneva, 16-19 September 2002) (WMO-TD No. 1131)

WCDMP-52 GUIDELINES ON CLIMATE OBSERVATION NETWORKS AND SYSTEMS (WMO-TD No. 1185)

WCDMP-53 GUIDELINES ON CLIMATE METADATA AND HOMOGENIZATION (WMO-TD No. 1186)

WCDMP-54 REPORT OF THE CCl/CLIVAR EXPERT TEAM ON CLIMATE CHANGE DETECTION, MONITORING AND INDICES (ETCCDMI) (Norwich, UK, 24-26 November 2003) (WMO-TD No. 1205)

WCDMP-55 GUIDELINES ON CLIMATE DATA RESCUE (WMO-TD No. 1210)

WCDMP-56 FOURTH SEMINAR FOR HOMOGENIZATION AND QUALITY CONTROL IN CLIMATOLOGICAL DATABASES (Budapest, Hungary, 6-10 October 2003) (WMO-TD No. 1236)

WCDMP-57 REPORT OF THE RA V DATA MANAGEMENT WORKSHOP (Melbourne, Australia, 28 November-3 December 2004) (WMO-TD No. 1263)

WCDMP-58 GUIDELINES ON CLIMATE WATCHES (WMO-TD No. 1269)

WCDMP-59 REPORT OF THE MEETING OF THE RA I WORKING GROUP ON CLIMATE MATTERS (Dakar, Senegal, 22 – 24 February 2006) (WMO-TD No. 1351)

WCDMP-60 GUIDELINES ON CLIMATE DATA MANAGEMENT (WMO-TD No. 1376)

WCDMP-61 THE ROLE OF CLIMATOLOGICAL NORMALS IN A CHANGING CLIMATE (WMO-TD No. 1377)

WCDMP-62 GUIDELINES FOR MANAGING CHANGES IN CLIMATE OBSERVATION PROGRAMMES (WMO-TD No. 1378)