Guide to National Climate Monitoring Products

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# Summary

National Climate Monitoring Products (NCMPs) are simple summaries of the weather and climate conditions in a particular country over a particular period of time. for example, average monthly temperature anomalies for Australia from 1900 to the present. NCMPs are already routinely used in some countries to monitor the changing climate with interest from policymakers, scientists, the media and other sectors. NCMPs are also routinely used in reports that summarise regional and global climate conditions, such as those produced by WMO Regional Climate Centres as well as by WMO, and thus attract regional and global interest.

In order to enhance climate monitoring efforts around the world and the production of NCMPs in a consistent manner to allow direct comparisons of regional and global climate summaries and synthesis reports, the WMO Commission of Climatology decided to define and suggest a short list of NCMPs to be produced by members on a regular basis. These products will also help to track the change and variability in the climate of each country that produces them. The six NCMPs defined in this guidance are designed to provide a consistent, basic set of climate monitoring indices.

The first two NCMPs detailed in this document measure anomalies (departures from the long-term average) of mean temperature and precipitation. The use of anomalies rather than absolute values provides an advantage in comparing records of varying lengths, as well as being more amenable to spatial interpolation, thus providing more robust measures of change over time.

The next three NCMPs are the Standard Precipitation Index (SPI), which describes drought and other precipitation extremes in a standard way, and the numbers of warm days and cold nights, which capture the frequency of moderate extremes of daily temperature. Each of these five NCMPs is presented as an average across the whole country. The sixth NCMP, station records, is intended to alert people to new temperature and precipitation records at individual stations.

The detailed guidance below describes how each NCMP is defined and provides a method for calculating them. This document also provides some additional background information.

# 1 Introduction and context

Due to the impact of changing climate conditions on society and ecosystems, countries around the world have created a variety of climate monitoring products at different spatial and temporal scales. National Climate Monitoring Products (NCMPs) are products that specifically summarise climate conditions at a national scale and show how current climate conditions compare with the past.

NCMPs are useful within a country, raising awareness and understanding of the effects of climate variability and change, as well as the importance of national monitoring networks and services. At an international level, they aid the synthesis of multi-national information to provide a broad, global view of climate variability and change. Such summaries are routinely published in high-profile annual publications such as the WMO Statement on the Status of Global Climate[[1]](#footnote-2) and the Bulletin of the American Meteorological Society’s State of the Climate reports[[2]](#footnote-3). Standardised indices of climate change have also been used in the Intergovernmental Panel on Climate Change’s periodic assessment reports.

Currently, a wide variety of climate monitoring products are produced around the world and there are many inconsistencies between the methods used by different countries. Inconsistencies make comparisons between products difficult or impossible, which limits their usefulness. To address this problem, the WMO Commission for Climatology decided to define and suggest a short list of NCMPs which could help to bring consistency in such products. A task team was convened under OPACE2 – on climate monitoring and assessment – of the CCl in order to achieve this. The task team defined the NCMPs and initiated the guidance which has been finalised by the expert team, convened in 2014.

The aim of this document, which is the result of the work of the WMO CCl OPACE2 Task Team on NCMPs and Expert Team on NCMPs, is to describe this list of standard NCMPs that can be produced consistently and easily by most countries. By having clearly defined NCMPs, it should be possible for countries with fewer resources to focus their efforts on a small number of products that have wide applicability and interest.

The following sub-sections describe each standard NCMP and provide the background necessary to understand them. A detailed software specification is provided in an Annex, which precisely describes all calculation steps to enable NMHSs to develop their own software. Software will be made available in due course for those who decide to use it.

## 1.1 Base period

In order to assess how climate is changing, it is useful to have a consistent base period against which those changes can be assessed. Such a base period is often referred to as a climate normal. For operational climate monitoring, the WMO guidance on the calculation of normals recommends a rolling 30-year period, updated every 10 years, with the most recent period being 1981-2010. This period is adopted here for the calculation of NCMPs. Further discussion of the reasons for this choice are given in the appendix. In the following text, 1981-2010 will be referred to as the *base period*. The base period is used to calculate average conditions, typical variability and to define typical distributions.

## 1.2 NCMP 1: mean temperature anomaly

NCMP 1 is mean temperature anomaly. An anomaly is simply the difference of the measurement from the base-period average. Here, this is the country-average mean-temperature anomaly calculated for the month, season or year. Mean temperature is a standard metric used to monitor climate change and is widely used in monitoring reports. It is a measure of overall warmth or cold, but does not distinguish between high maximum temperatures and high minimum temperatures. The variability of mean temperature anomalies vary from place to place and, in some places, from season to season: for example in the UK, temperature variability is typically higher during winter months than summer months.

## 1.3 NCMP 2: total rainfall anomaly

NCMP 2 is the total rainfall for the month, season or year expressed both as a percentage of the base-period average for the same period and as a simple difference (anomaly) from the base-period average. Precipitation percentage and anomaly are both standard metrics used to monitor climate change. In areas where average rainfall is low, large percentages can be recorded at individual stations due to very localised rainfall. Although the technique used to interpolate the data partly accounts for uneven spatial sampling, there could be problems in countries with sparse measuring networks. This issue is partly offset by also including the average anomaly within the NCMP report.

## 1.4 NCMP 3: standardized precipitation index

NCMP 3 is the standardized precipitation index (SPI). This is a percentile-based measure of the country-average standardized rainfall anomaly. SPI[[3]](#footnote-4) is a standard metric used to monitor rainfall and drought. Standardization means that the SPI is adapted to the climatic conditions at a particular station; it is a way of comparing the “unusualness” of rainfall at stations from different climatic zones within a country and between countries, where the mean and variability of rainfall might differ substantially. For example, an SPI of 2 or higher indicates this amount of rainfall occurs around 5% of the time, regardless of local conditions.

## 1.5 NCMP 4: warm days

NCMP 4 is the warm days index. This is a measure of the country-average percentage of days that exceeded the 90th percentile of the base period distribution for maximum temperatures, i.e., days that would have fallen in the warmest 10% of days during the base period. The number of warm days is a standard ETCCDI (Expert Team on Climate Change and Detection Indices[[4]](#footnote-5)) index and is widely used. It is sensitive to high impact events such as heat waves and is relevant to the seasonally-varying climatic conditions at each station. It is a way of comparing stations from different climatic zones within a country and between countries. This NCMP captures some information about moderate extreme temperature events over a significant fraction of the country.

## 1.6 NCMP 5: cold nights

NCMP 5 is the cold nights index. This is a measure of the country-average percentage of days that fell below the 10th percentile of the base period distribution i.e. nights that would have fallen in the coldest 10% of nights during the base period. The number of cold days is a standard ETCCDI (Expert Team on Climate Change and Detection Indices[[5]](#footnote-6)) index and is widely used. It is sensitive to high impact events such as cold waves and is relevant to the seasonally-varying climatic conditions at each station. It is a way of comparing stations from different climatic zones within a country and between countries. This NCMP captures some information about moderate extreme temperature events over a significant fraction of the country.

## 1.7 NCMP 6: temperature and precipitation records

This product gives a simple count of the number of stations that report highest or lowest on daily maximum temperature, minimum temperature and precipitation records. The aim is to flag the most exceptional extreme events.

## 1.8 Strengths, caveats and limitations of NCMPs

By providing country-level information, NCMPs have some obvious limitations and strengths. The most obvious limitation is that a country is not usually a single climatic unit. Climates can vary within a country, sometimes to a great extent. Thus, region-specific information will be lost in calculating NCMPs, particularly when averaging rainfall over large areas. Balanced against this is the fact that NCMPs, by averaging out local variations in temperature and precipitation, will increase the signal-to-noise ratio for detecting changes in climate over time. Long, historical records, which provide context for current conditions, are important for understanding these changes. In addition, aggregating information across a larger area can reduce the effect of measurement error and provide a more reliable basis for understanding long term change.

While a country is not a coherent climatic unit, it is a coherent psychological and administrative one. People across society are used to thinking at this level for many other indicators: Gross Domestic Product, crop production, population changes, and other indicators are routinely calculated and discussed with great interest at the national level. The guidance provided here could easily be adapted to provide information for different climatic zones within a country to complement the understanding and production of NCMPs.

Care must be taken when comparing an NCMP to output from a climate model. It is necessary to consider whether the phenomena being measured is exactly comparable to that being modelled. The use of percentile based observed indices are more readily compared to modelled fields. Differences can arise when the order of aggregation (from station data to NCMP) is rearranged and these differences can be marked if the indices are calculated before the gridding, rather than after.

This guidance does not explicitly address uncertainty. All indices are subject to uncertainty that arises from many sources, such as undetected errors in the data, measurement limitations (e.g., where data are rounded to the nearest whole degree), representative error (for example, where siting of instruments is not representative of the wider area), poor spatial sampling (where the network is too sparse of spatially biased), unidentified station moves or instrumentation changes, software errors, limitations of the interpolation techniques, etc.

However, various strategies are possible for assessing uncertainty in NCMPs, some of which are described briefly here. Sensitivity to the choice of interpolation method could be tested by using other methods. Uncertainty in the interpolation could also be assessed by separating the stations into two groups, one used for the interpolation, the other to test that the interpolation was effective. The uncertainty of the country-average NCMP could be assessed using “jack knifing” whereby the NCMP is calculated multiple times on different subsamples of the data. The resulting spread of estimates gives an estimate of the uncertainty.

A thorough uncertainty analysis is beyond the scope of this initial guidance, but could be considered in the future.

# 2 National focal points for NCMPs

With WMO letter of 10 November 2015, ref.: OBS/WIS/DMA/NCMP, Members were invited to nominate a focal point for NCMP as per the following Terms of Reference:

* To collaborate with ET NCMP on identifying existing national sources for climate monitoring products and related capacities as well as related training and capacity building needs;
* To raise awareness of the NMHS staff and other relevant stakeholders on the need for and the importance of NCMP;
* To facilitate the calculation of NCMPs including its dissemination via agreed protocols;
* To prepare and submit feedback to ET NCMP on the challenges and the need for improvement emanating from the preparation and dissemination of the NCMPs.

The focal points for NCMPs are expected to have knowledge about national climate data and monitoring activities. A basic knowledge of statistics would be advantageous, but is not essential.

It would be advantageous for the focal points to be acquainted with this document and its annex relating to the calculation of the NCMPs.

# 3 Generating the NCMPs

The basic procedure, which is common to the first five NCMPs, is to calculate a set of monthly indices for each station used in the calculation, then interpolate the station values for each month using Ordinary Kriging to obtain a spatially-complete analysis on a regular grid. The spatially-complete analysis is then averaged across the area covered by the country to calculate the NCMP for that month. In this way, a time series is built up month by month that can be used to examine climate change over time and to place each month into historical context.

The basic steps for calculating NCMPs 1–5 are:

1. Quality control the daily temperature and precipitation data
2. Consider homogeneity of the data
3. Generate the indices
4. Calculate the variogram for each index
5. Interpolate the data for each index
6. Average each index across the country
7. Output the NCMP

Note: NCMP 6 simply reports daily temperature and precipitation records and is described separately.

Detailed instructions for calculating the indices and performing the interpolation is provided in the annex on software specification. The following sections describe the pre-processing that is necessary, and then provides a walkthrough of steps 3-7 using the particular example of Australian precipitation. For countries with only a single station or limited station networks, see section 3.7.

## 3.1 Quality control (QC)

Quality Control (QC) is an important step in any data analysis. The aim of QC is to ensure that the data are not contaminated with values that are badly in error and that they meet the basic requirements of the analysis.

The definition of general methods for quality control is beyond the remit of the ET-NCMP and this guidance. However, it is recommended that the data are quality controlled prior to their use in calculating NCMPs. The ET-NCMP has developed a package for Quality Controlling data which can be used to aid with quality control of the data.

It should be noted that no quality control procedure is perfect and that certain kinds of data error are not immediately apparent from a first processing. Data and output should be checked after each substantial stage of the processing.

## 3.2 Homogenisation

A key difficulty in accurately assessing long-term trends is that instrumental observations of rainfall and temperature may be influenced by non-climate related factors over time. Non climate related influences include the relocation of observing can stations, changes in exposure due to changes in the environment surrounding the station and changes in observing practices can change, automation of the observations. If not accounted for, tor instrumentation. hese changes can lead to non-climatic artefacts in the data and affect the estimated long-term trends. The process of assessing and reducing the effect of non-climatic changes is known as homogenisation.

Homogenisation is complex and difficult and is outside of the remit of the ET-NCMP and this guidance. However, it is recommended that data are homogenised prior to the calculation of NCMPs. An alternative is to assess the homogeneity of each station and use only those sections of the station data that appear free from inhomogeneities. The RH-test software[[6]](#footnote-7), used in the ETCCDI workshop, can be used to assess the homogeneity of the station data, but there are many other methods.

## 3.3 Calculating the station indices

The indices form the basis for the next stages. There are five different indices that need to be calculated. Each index needs to be calculated separately for each station. In the example for Australia, the stations used to illustrate the steps of calculating the NCMPs are shown in ***Figure 1***. The data have already been quality controlled and homogenised.



*Figure 1: map of station locations for data taken from the AcornSAT data set for Australia. The AcornSAT data set is a daily temperature and precipitation dataset with state of the art quality control and homogenisation applied to it. Each of the red lozenges represents a station in the AcornSAT data set.*

## 3.4 Calculating a variogram

A variogram describes how much you expect the index (mean temperature anomaly, for example) to change as you move away from a location. It is found by plotting half the squared difference in the index at all pairs of stations as a function of the distance between them and then averaging the differences into regular bins. This is called the empirical variogram. It is always positive and is typically small for small separations and larger for large separations. Example empirical variograms for the stations from ***Figure 1*** are shown in black in ***Figure 2***.

In order to perform the interpolation, we need a function that can be used to give an estimate of what the variogram would be for any separation. This is found by fitting a particular functional variogram model to the empirical variogram. The functional variograms fitted to the data are also shown in ***Figure 2*** as red lines. A separate variogram model has to be calculated for each index and for each calendar month, hence there are 12 panels in ***Figure 2***. The 12-monthly variograms show that precipitation variability changes with the seasons. The empirical variogram (in black) often starts to drop at large separations. This is normal and it is only the first part of the variogram – the rise and plateau – that we are trying to model with the functional variogram (in red).

A reliable variogram model can only be calculated if there are more than 10 stations. Countries with fewer than 10 stations will either have to use a pre-calculated variogram, or use shared data from neighbouring countries. For countries with a single station or limited network, see section 3.7.



*Figure 2: sample variograms for Australian precipitation for each month from January (top left) to December (bottom right). The black line is the empirical variogram. The red line is the functional variogram The average difference is small for small separations and increases as the separation of the stations increases.*

## 3.5 Interpolating the data

An optimal method of estimating the national average of an index (mean temperature anomaly, for example) is to spatially interpolate the station based indices across the respective country. The method recommended in this guidance is called Ordinary Kriging[[7]](#footnote-8) and is widely used in geostatistics. This method naturally accounts for the uneven distribution of stations and provides a reasonable, though not perfect, estimate of what the index would be at intermediate locations. Here we will use Ordinary Kriging to estimate the value of the index at points on a regular grid, which covers the country. ***Figure 3*** shows an example interpolated field of precipitation anomalies for January 2010 for Australia. The interpolated fields are generally somewhat smoother than might be expected based on the individual station records.



*Figure 3: Map showing station locations (black lozenges) and the interpolated precipitation anomalies (mm) for January 2010 for Australia.*

## 3.6 Averaging the index

The final step in the calculation of the NCMPs is to calculate the area average. This is achieved by excluding all grid cells that fall outside the country’s borders (you can see in ***Figure 3*** that there are areas outside of Australia that have interpolated values. These must be excluded before calculating the Australian NCMP) and then calculating an area-weighted average of those that remain. The interpolation and averaging steps should be repeated for every month for which data are available from at least one station. In this way a time series of the NCMP, such as that shown in Figure 4, can be built up.



*Figure 4: time series of the example NCMP2, country-average precipitation anomalies for Australia. The monthly series is shown in the top panel in black and the annual series is shown in the lower panel in black. The official Australian Bureau of Meteorology series are shown in red for comparison purposes.*

## 3.7 Countries with a single station or limited networks

For countries with a limited network of stations, there are a number of possible ways of calculating an NCMP. Stations from neighbouring countries could be used, where this is an option, to supplement the station network within the country. The calculation of the variogram and interpolation would proceed as described above. An alternative is to use standard forms of the functional variogram, in consultation with the ET-NCMP.

Where a country has a single station, an using data from neighbouring stations is not an option, the area-average for the country for a particular month (season or year) will be equal to the value of the index at the station for that same period.

## 3.8 NCMP 6 temperature and precipitation records

NCMP 6 is intended to capture some of the more extreme events that occur within a particular month. The number of stations with records exceeding 30 years in length which record a station record for daily Tmax are counted. Similar counts are made of stations which record a record for daily Tmin and of daily total precipitation.

The focal point should have access to the names and locations of the stations reporting record temperatures or precipitation as well as the date on which the record was broken.

NCMP 6 is intended to indicate that particularly extreme events have occurred, but cannot, on its own, give a well rounded account of what happened. The focal point, should be able to provide further context for such events.

## 3.9 Output of the NCMPs

Once the NCMPs 1–5 are calculated, the results need to be output in a standard format. The exact format is described in the software specification in the Annex.

# 4 Production and dissemination

The NCMPs are designed to be compared, and to form the basis of ongoing climate monitoring activities nationally and internationally.

## 4.1 Initial Production

When the NMCPs are first calculated it will be necessary to calculate the NCMP for every month for which station data are available. The procedure for this is described in detail in the Annex. Once the NCMPs have been calculated once, it is possible to save certain parts of the processing to speed up the regular updates. The variograms need only be calculated once and can then be reused, unless major changes are made to the historical data used to calculate them. Values for the NCMPs once the are calculated will not usually need to be recalculated unless, again, there are major changed made to the historial data that were used to calculate them.

## 4.2 Annual updates

It is intended that NCMPs initially be updated annually, moving to a more timely update schedule – monthly or seasonal – as expertise improves and as the process is made more efficient.

When performing annual updates, it is necessary to check whether the base period has changed. At the time of writing the base period is 1981-2010, but when this period is updated to 1991-2020, the NCMPs will need to be recalculated from the beginning.

## 4.3 Monthly or seasonal updates

When performing monthly or seasonal updates, it is necessary to quality control and process only a limited number of months – typically those that have been added since the last update. Usually this will be a single month or season, but in cases where processing of the data (such as quality control) takes longer, it might be necessary to reprocess several months at a time. It is not necessary to recalculate the variogram for regular updates unless there have been major changes to station data during the base period.

## 4.4 Irregular updates

Updates might be desirable at times other than those described above. For example, recalculation of the NCMPs is recommended when large changes (revisions, additions or deletions) are made to the station data or network, or if there are improvements to the way that homogenisation, or quality control are done. Homogeneity should be rechecked periodically. Finally, there might be occasional updates to this guidance or software derived from it, which would necessitate a recalculation of the NCMPs.

## 4.5 Dissemination

The exact details of dissemination have not yet been determined. Detailed guidance will be provided at a later stage.

## 4.6 Data to be transmitted

The format for each NCMP is given in the Annex. It contains, the following information that is necessary for understanding the NCMPs.

* Year
* Month
* Country
* NCMP indicator [1, 2, 3, 4, 5 or 6]
* NCMP value with units implied by the format.
* For NCMP 2, the value of the interpolated precipitation anomaly (which is given in addition to the precipitation percentage of normal).
* For NCMP 6, the counts of stations exceeding daily records.
* The number of stations reporting each element used that month to calculate the NCMP.
* The number of stations with each homogenization flag [0, 1, 2].
* The number of stations with each quality flag [0, 1].
* Base period. This will be 1981-2010 in all cases.
* Version of the software or guidance used to calculate the NCMP

## 4.7 Auxiliary data

In addition to the main data, the method described above will produce many intermediate products that could be useful for the NCMP focal point and other users of NCMPs. It might help to think of the implementation of the above method as giving a set of general purpose tools, which are used to create the NCMPs but which could have wider applicability.

Up-to-date sets of station indices would be one simple output that may be of interest to the ETCCDI and the Expert Team on Sector Specific Indices (ETSCI). Spatial maps of the indices are generated at the interpolation step These can be used to assess the quality of the interpolated fields, but these could be saved out in a consistent format, such as NetCDF, or output as images in a standard format (png, eps, pdf). The location of the stations is also of interest. In conjunction with maps of the indices, station location will give an idea of any spatial bias, outliers, as well as the spatial extent of unusual events.

## 4.8 Dissemination via NCMP focal points

The exact mechanisms for dissemination are yet to be determined.

# 5 Appendix

## 5.1 Task Team on National Climate Monitoring Products

The membership of the TT-NCMP who defined the six NCMPs, produced working prototypes and initiated the guidance document was:

John Kennedy, Met Office, UK

Ladislaus Chang’a, Tanzania Met Agency, Tanzania

Olga Bulygina, Russian Federal Service for Hydrometeorology and Environmental Monitoring, Russian Federation.

Mesut Demircan, Turkish State Meteorological Service, Turkey

Deke Arndt, National Oceanic and Atmospheric Administration National Climate Data Center, USA.

Andrew Watkins, Bureau of Meteorology, Australia

Mohammed Semawi, Jordanian Meteorological Department, Jordan.

In addition, the team laid out a framework for dissemination of the products and a skeleton plan for capacity building via workshops and standardised software.

## 5.2 Notes on the choice of base period

In order to ensure that NCMPs produced by different countries are consistent, it is necessary to choose a fixed time period as a basis for the comparison.

The WMO guidelines suggest a dual approach with 1961-1990 used as a fixed period for climate change studies and a rolling 30-year period, updated every ten years for other activities such as climate monitoring. The current monitoring normal is therefore 1981-2010. However, it should be noted that this period is not currently used consistently across all agencies.

For NCMPs there is a choice to be made between 1961-1990 and 1981-2010. There are a number of things to consider when making this decision

1. Because of the way that the NCMPs are calculated, it is only possible to use stations that were reporting for the majority of the base period.
2. To get the most accurate assessment of current conditions, it is necessary to have access to the largest possible number of currently operating stations.
3. In order to understand how current conditions relate to the long term context, it is necessary to have access to stations that have been operating for a long period of time. The length of the period will depend on what is being monitored, but conventionally, a minimum period of 30 years is used.
4. NCMPs must be useful with the ecosystem of other current WMO initiatives.

Stations networkschange with stations opening, closing and moving. Stations that are currently reporting are more likely to have a continuous record back to 1981 than they are to have a continuous record back to 1961. Choosing the more recent, 1981-2010 baseline would therefore maximise the number of currently operating stations that can be used in the NCMP calculation and provide a more accurate assessment of current conditions.

On the other hand stations that were reporting in the late nineteenth or early twentieth century are more likely to have a complete record for 1961-1990 than they are for 1981-2010. Therefore, choosing an earlier base period could maximise the use of long station records and extend the NCMPs further back in time. On the other hand, it could also reduce the number of stations available for monthly updates as long-running stations are more likely to have closed since 1990. Having fewer stations will lead to a less accurate estimate of current conditions, which is detrimental to the aim of the NCMPs which is to monitor current climate.

Initially, the preference ought to be for the 1981-2010 base period. This would ensure the most accurate estimate of current conditions and an NCMP record extending back to at least 1981. The 1981-2010 base period is also more relevant to recent conditions, and will align better with other applications of NCMPs within the Global Framework for Climate Service as well as for applications in seasonal forecasting.

Long series are important, however and countries are encouraged to digitize paper records which can extend the calculation of accurate NCMPs further back in time.

## **6 Glossary**

Anomaly – difference from the long-term average.

ETCCDI – Expert Team on Climate Change Detection and Indices.

ETNCMP – Expert Team on National Climate Monitoring Products

ETSCI – Expert Team on Sector Specific Indices

NCMP – National Climate Monitoring Product

SPI – Standardised Precipitation Index

RCC – Regional Climate Centre.

WMO – World Meteorological Organisation

CCl – Commission for Climatology

OPACE – Open Panel of Climate Experts

1. WMO Annual Statements, <http://www.wmo.int/pages/prog/wcp/wcdmp/statement.php> [↑](#footnote-ref-2)
2. BAMS State of the Climate reports, <https://www.ncdc.noaa.gov/bams> [↑](#footnote-ref-3)
3. <http://www.wamis.org/agm/pubs/SPI/WMO_1090_EN.pdf> [↑](#footnote-ref-4)
4. Expert Team on Climate Change and Detection Indices <http://www.wcrp-climate.org/unifying-themes/unifying-themes-observations/data-etccdi> [↑](#footnote-ref-5)
5. Expert Team on Climate Change and Detection Indices <http://www.wcrp-climate.org/unifying-themes/unifying-themes-observations/data-etccdi> [↑](#footnote-ref-6)
6. Aguilar, E., I. Auer, M. Brunet, T. C. Peterson, and J. Wieringa (2003), Guidelines on Climate Metadata and Homogenization,WCDMP 53, WMO-TD 1186, 55 pp., World Meteorol. Organ., Geneva, Switzerland. [↑](#footnote-ref-7)
7. Reference document needed [↑](#footnote-ref-8)