

# Climate change indices



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## Introduction

For decades, most analyses of long-term global climate change using observational data have focused on changes in mean values. Several well-respected datasets of monthly station temperature and precipitation data provide quite good coverage across the globe. Analysing changes in extremes (e.g. the number of days exceeding the 90th percentile of minimum temperature observations), however, requires long-term digital

daily data. Unfortunately, such data are not readily available internationally for large portions of the world. In the 2002 "global" analysis by Frich *et al.* (2002), almost no analysis of extremes was possible for most of Central and South America, Africa and southern Asia. However, a concerted series of efforts to remedy that situation is underway.

## Role of an international expert team (ET)

Two complementary efforts to enable global analysis of extremes are being coordinated by the joint WMO Commission for Climatology (CCI)/World Climate Research Programme (WCRP) Climate Variability and Predictability (CLIVAR) project's Expert Team on Climate Change Detection, Monitoring and Indices (ETCCDMI). Detailed information on the ET is available at <http://www.clivar.org/organization/etccd>. Members of the Expert Team come from all continents and encompass a wide range of expertise in the field of climate change. The author is not a member of the ET but works closely with it as chair of the CCI Open Programme Area Group (OPAG) on the Monitoring and Analysis of Climate Variability and Change to which the ET belongs. As all ET members are volunteers with full-time jobs, the focus of their work must be on what they can coordinate, recommend or inspire, rather than do themselves.

One of the ET's activities is international coordination of a suite of climate-change indices derived from daily data which focus primarily on extremes. The development of the indices involves not only ET members but also numerous other scientists working with daily climate data. By setting an exact formula for each index, analyses done in different countries or different regions can fit together seamlessly.

A total of 27 indices are considered to be core indices. They are based on daily temperature values or daily precipitation amount. Some are based on fixed thresholds that are of relevance to particular applications. In these cases, thresholds are the same for all stations.

Other indices are based on thresholds that vary from location to location. In these cases, thresholds are typically defined as a percentile of the relevant data series. The definitions of the 27 indices and the formulas for calculating them are available from <http://cccma.seos.uvic.ca/ETCCDMI>. This Website also provides the FORTRAN code for calculating the indices from daily data and a user-friendly software package to calculate the indices. This software package, called RClimDex, uses the free software R (see <http://www.r-project.org> for more information), which is a language and an environment for statistical computing and graphics.

Analysis software does not, however, perform without data. In many parts of the world, enough daily data have been digitized to contribute to an analysis but institutions are reluctant to share them. This is a difficult problem to address. The solution proposed by the ETCCDMI's predecessor was to hold regional climate-change workshops modelled after the Asia Pacific Network workshops (Manton *et al.*, 2000; Peterson *et al.*, 2001). Two were held in 2001 and, in view of the experience gained, the ETCCDMI decided to hold a series of other such workshops to cover all areas of the globe.

## Regional workshop concept

The workshops bring together participants from as many countries as possible across an area for a combination of seminars and hands-on analyses of the daily data they bring

with them. Through this process, a workshop “recipe” has been created. The workshops start with overview seminars, describing the reasons for holding the workshops and how the climate of the region is projected to change. The participants then describe the climate of their countries and the station data they bring with them.

The hands-on analysis starts with quality control (QC). RCLimDex has several QC checks. Some identify specific data points as outliers. For these tests, each data point that is potentially a problem is examined. Based on data before and after, as well as the understanding of the climate of the region, the data are edited if the problem is obvious (e.g. 182° changed to 18.2°); set to missing if it is clearly a problem with unknown solution; or kept if deemed probably valid. With each change or acceptance of an outlier, a record of the decision and the reasons behind it is made in the QC log file. The second stage of QC involves evaluating numerous detailed graphs of daily data to detect evidence of possible quality issues with the data. An example of this would be an impossibly long period of time with zero precipitation. This problem can arise because many countries do not record zero precipitation, so missing values must initially be assumed to be zero.

The next stage of analysis is to conduct homogeneity assessments. Homogeneity adjustments of daily data are complex and difficult to make well (Aguilar, 2003). The focus on homogeneity is therefore to identify significant problems. When the homogeneity-testing software identifies a likely problem, the participant consults station history metadata, if available, to understand why. Non-climatic jumps in the time series have resulted in some stations not being used in the indices analyses or used only for the period after the discontinuity.

***The work described in this article is the result of the collaborative effort of many individuals, who have been supported in this endeavour by their home institutions. Unfortunately, they are too numerous to be mentioned here by name. WMO, through its Expert Teams, provides the structure and coordination so that these volunteers may make these accomplishments.***

Once QC and homogeneity testing have been accomplished, the calculation of the indices is quite simple. One of the benefits of doing this at a regional workshop is the synergy of immediately being able to see how results compare across borders. The participants create a short presentation of what the analysis is indicating about changes in extremes for each country. Similar results that span country borders verify the robustness of

the analysis. Participants have found this workshop product quite useful when they return home.

The last part of the workshop looks to the future. This includes user feedback and advice for future workshop organizers. Discussing how to improve the available Global Climate Observing System (GCOS) Surface Network (GSN) data, now that the participants clearly understand the value of being able to compare analyses across country borders, is also relevant. Lastly, the participants discuss how to make the results of the analyses started at the workshop useful for climate-change assessments. This includes deciding who will lead the writing of multi-authored peer-reviewed journal articles, making the time-series of the indices available to other researchers, and the data themselves available to other researchers (the author list includes all participants who bring data contributing to the analysis).

So far, none of these workshops has been able to release time-series of daily data. There has been great success, however, in reaching agreement to release the indices and some success in encouraging the release of data from GSN stations to the GSN



*Regional Climate Change Workshop in Brazil, August 2004*

Archive Centre. For each of these series of workshops, peer-reviewed journal articles on changes in extremes in the regions are either in preparation or have already been submitted and the indices prepared to contribute to the global indices paper.

## The workshops

The previous incarnation of the ETCCDMI, a CCI/CLIVAR Working Group, also addressed indices and regional climate change and held two workshops in 2001. The first was in the Caribbean, where 18 of the 21 National Meteorological Services participated. This workshop resulted in the release of daily data, indices, a meeting report, and a 17-author peer-reviewed journal article on how the climate in the region is changing (Peterson *et al.*, 2002). The second workshop was held in Casablanca, Morocco, for various African countries (Easterling, 2003).

The ETCCDMI sought to improve and extend those workshops to cover more of the world. Financial support was a limiting factor but adequate resources have become available to hold five workshops.

## Summary

This series of regional climate-change workshops is achieving several important objectives. In regions where data are not readily accessible, a suite of climate-change indices that focus primarily on extremes has been

**Regional workshops on climate change indices are "a very good beginning for regional cooperation".**

## The workshops

### Southern Africa

Cape Town, South Africa,  
31 May-4 June 2004

### Southern South America

Maceio, Brazil, 9-14 August  
2004

### Middle East

Alanya, Turkey, 4-9 October  
2004

### Central America and northern South America

Guatemala City, Guatemala,  
8-12 November 2004

### South-Central Asia

Pune, India, 14-19 February  
2005

produced and made available. The analyses would gain increased credibility by being reproducible with the release of the data. The strong focus on quality control and homogeneity testing (the results of which are being released), however, make it possible to evaluate the analysis independently, even without the digital data.

Training scientists in these countries may not have been the driving goal, but the workshops have definitely had a major capacity-building aspect, as outside experts worked closely with regional participants on data analyses, provided them with user-friendly software, and introduced them to a free statistical package. The capacity building has, in turn, helped foster a greater appreciation of the importance of long-term *in situ* data and this has resulted in renewed efforts at

digitizing historical records, as well as fulfilling GSN data-exchange goals.

These workshops are making a clear contribution to our understanding of how climate extremes are changing around the world. In addition to the in-depth peer-reviewed regional papers, the indices analysed at each of the workshops are contributing to two global extremes papers. Thanks largely to these workshops, these papers will indeed be global. Together, they will make a significant contribution to the upcoming Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

Lastly, as one participant wrote after the Middle East workshop, they are "a very good beginning for regional co-operation".

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Regional Climate Change Workshop in Turkey, October 2004



*Regional Climate Change  
Workshop in Guatemala,  
November 2004*

Town, South Africa; the Federal University of Alagoa, Brazil; the Turkish State Meteorological Service; the National Institute of Seismology, Vulcanology, Meteorology and Hydrology, Guatemala, and the Regional Committee for Water Resources of the Central American Isthmus (Costa Rica); and the Indian Institute of Tropical Meteorology (Pune)

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