ENHANCING MIDDLE EAST CLIMATE CHANGE MONITORING AND INDEXES

BY SERHAT SENSOY, THOMAS C. PETERSON, LISA V. ALEXANDER, AND XUEBIN ZHANG

Extreme climate events can have significant impacts on both natural and human systems, and therefore it is important to know if and how climate extremes are changing. Analysis of extremes requires long-term daily station data and, unfortunately, there are many regions in the world where these data are not internationally exchanged. The Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report (Folland et al. 2001) relied heavily on the multinational analysis of Frich et al. (2002). However, Frich et al. (2002) had no results from all of Central and South America, and most of Africa and southern Asia, including the Middle East.

To remedy this situation for the IPCC Fourth Assessment Report, the joint World Meteorological Organization Commission for Climatology/World Climate Research Programme (WCRP) project on Climate Variability and Predictability (CLIVAR) Expert Team on Climate Change Detection, Monitoring, and Indices (Zwiers et al. 2003) internationally coordinated a series of five regional climate change workshops and a set of indices for analyses of extremes.

Two workshops covered the Americas, one in Brazil and one in Guatemala. One workshop addressed southern Africa. A workshop in India involved south and central Asia, while the workshop for the Middle East sought to address the region from Turkey to Iran and from Georgia to the southern tip of the Arabian Peninsula. The latter workshop was funded by the U.S. State Department through the Global Climate Observing System (GCOS) as support for IPCC, and was hosted by the Turkish State Meteorological Service at their training center in the Mediterranean town of Alanya. Like the workshops before it, it used a basic workshop "recipe" that was initiated by the Asia Pacific Network workshops (Manton et al. 2001) and refined by the 2001 regional climate change workshops in the Caribbean (Peterson et al. 2002) and northern Africa (Easterling et al. 2003).

WORKSHOP ON ENHANCING MIDDLE EAST CLIMATE CHANGE MONITORING AND INDICES

WHAT: Scientists and data for the Middle East were brought together to produce the first area-wide analyses of climate extremes for the region
WHEN: 4–9 October 2004
WHERE: Alanya, Turkey

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WORKSHOP APPROACH. The key to a successful workshop is a collaborative approach between outside experts and regional participants. The participants here brought long-term daily precipitation and maximum and minimum temperature data, station history information, an understanding of their country's climate, and a willingness to analyze these data under the tutelage of outside experts. The outside experts brought knowledge of the crucial data and climate change issues, presentations to explain these issues, and user-friendly software to aid the analyses. Xuebin Zhang of Environment Canada wrote the workshop software to perform quality control (QC) on the data, test the time series homogeneity, and calculate the indices. This software is available online at http://cccma.seos.uvic.ca/ETCCDMI.

The first day of the five-and-a-half-day workshop was devoted to a series of introductory talks, which set the groundwork for the workshop, followed by participants giving a short presentation about the climate of their country and the station data they brought. Twelve scientists from 11 countries in the Middle East participated (see Table 1). A few countries chose not to participate in the workshop but later contributed data for the post-workshop analysis, including Saudi Arabia, Iraq, and Israel. In addition to the authors, the workshop team included Enric Aguilar (Universitat Rovira i Virgili de Tarragona, Spain) and Trevor Wallis (NOAA/National Climatic Data Center, United States).

QUALITY CONTROL. The hands-on data work started on the second day and continued to nearly the end of the workshop. After a seminar on the importance of quality control and a description of how to use the QC procedures in the workshop software, the participants started assessing the quality of their data. The QC involved carefully evaluating numerous detailed graphs of daily data to detect evidence of possible quality issues with the data as well as statistically identifying outliers. Each outlier or potential data problem was manually validated using information from the days before and after the event along with participants' knowledge of their own climate. With each change or acceptance of an outlier, a record of the decision and the reason behind it was made in the QC log file.

The third day of the workshop focused on climate data homogenization, again starting off with a seminar and followed by hands-on analysis. Adjusting daily data to account for discontinuities is very complex and difficult to do well, particularly for extreme values (Aguilar et al. 2003). Therefore, the workshop focused on identifying significant inhomogeneity problems. The software used a regression-based homogeneity test to detect significant discontinuities or shifts in the time series (Wang 2003). An example of the output from homogeneity testing software is shown in Fig. 1. When the homogeneity testing software identified a likely problem, the participant consulted station history metadata, if available, to understand why. Stations with nonclimatic jumps either were removed from the analysis or only the period after the discontinuity was used in later analyses.

INDEXES. After the data had been quality controlled and tested for homogeneity, they were ready for calculation of indices. The development of the indices calculated at the workshop involved not only members of the Expert Team, but also numerous other scientists, most notably Albert Klein-Tank (the

Table 1. List of workshop participants and their countries and data.

No.	Country	Participant	No. of stations brought	Starting year of data
1	Armenia	Mr. H. Melkonyan	2	1950
2	Azerbaijan	Ms. U. Tagiyeva	4	1970
3	Bahrain	Mr. N. Ahmed	1	1948
4	Georgia	Dr. N. Kutaladze	1	1966
5	Islamic Republic of Iran	Mrs. A. Taghipour	4	1961
6	Jordan	Mr. M. Semawi	5	1930
7	Kuwait	Mr. M. Karam Ali	1	1958
8	Oman	Mr. M. Al-Shabibi	5	1987
9	Qatar	Mr. Z. Al-Oulan	1	1976
10	Syrian Arab Republic	Dr. I. Khelet Mr. S. Hammoud	8	1965
11	Turkey	Mr. M. Demircan	14	1926

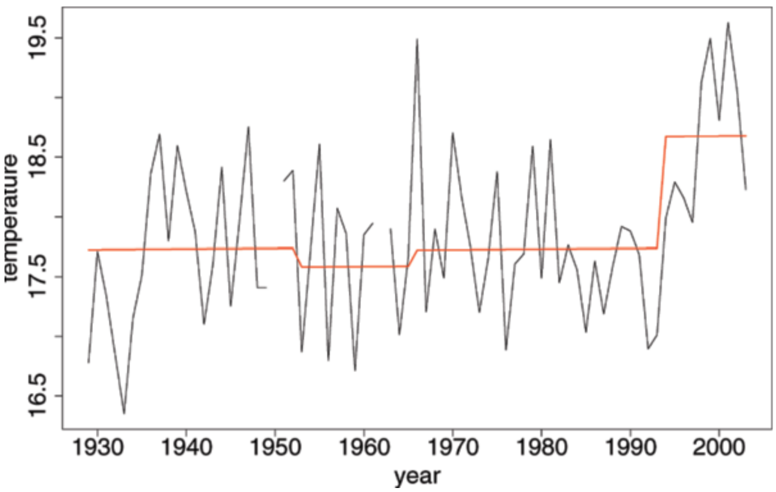

Fig. 1. Homogeneity test of annual minimum temperature for station Rize, Turkey. Years with less than 361 daily observations have been excluded from the analysis and are indicated as gaps in the annual minimum temperature time series (black line). The red line indicates the location and magnitude of possible step changes in the time series and the linear regression across the homogeneous sections between the possible step-change points. Not all possible step changes are statistically significant or supported by metadata. However, the discontinuity indicated by the large step change in the mid-1990s is not only statistically significant but also verified by the station history metadata, which indicates that the station relocated in 1995.

Netherlands), Lisa Alexander (United Kingdom), Byron Gleason (United States), Xuebin Zhang (Canada), and Gabriele Hegerl (United States). This continuing effort refined and improved the earlier suite of indexes described in Peterson et al. (2001) by using a bootstrap method of calculating values during the base period to prevent a discontinuity at its beginning and end (Zhang et al. 2005a). By setting an exact formula for each index, analyses done in different countries or different regions can fit together seamlessly. Table 2 lists the indices calculated at the workshop.

RESULTS. For the final hands-on working stage of the workshop, participants created presentations on how extremes were changing in their countries. The workshop software produced figures for each index at each station (e.g., Fig. 2), which the participants then used to illustrate their results. The presentations were made to workshop participants, and probably were repeated to colleagues when presenters returned home. One of the synergies gained at the workshop was an understanding that the results produced were more reliable if stations in neighboring countries showed the same change. Figures 3 and 4 show some results for the region as a whole that reveal coherent patterns of warming in minimum temperatures but a much more mixed pattern of change in precipitation. After the participants presented their results on how extremes are changing in the region, agreements needed to be reached on how to share this information with the scientific community. The first point of agreement was that we accepted Xuebin Zhang's offer to lead author a peer-reviewed paper of the results, with all the participants who brought data used in the analysis acting as coauthors (Zhang et al. 2005b). All participants readily agreed to provide Zhang with their indexes as well as the details on the QC and homogeneity assessments. Many countries in the region have restricted access to their daily data. In fact, no participants were able to release their daily data, although the Iranian participant followed up the workshop by facilitating the release of her GCOS Surface Network stations' daily data. However, all participants agreed to allow Zhang

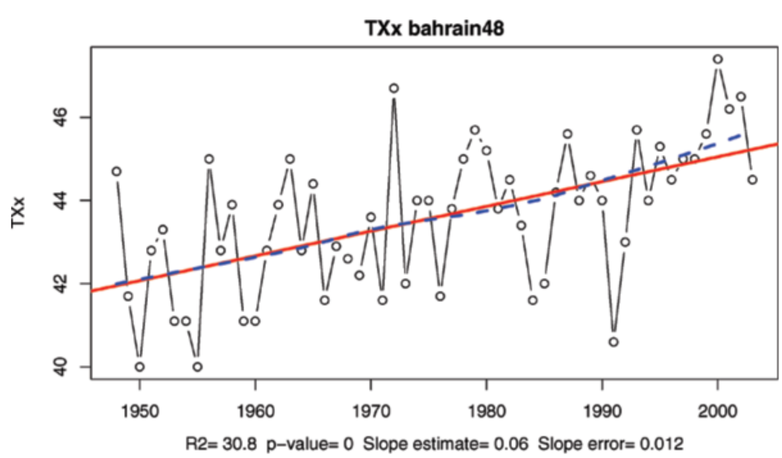

Fig. 2. Example of an index calculated at the workshop and an annual figure generated by the workshop software. This is for the station in Bahrain and the index, TXx, is the highest maximum temperature during the year. The straight line is a linear least squares fit to the data while the dashed line represents the trend using locally weighted regression.

TABLE 2. List of the 27 indices calculated at the workshop.

ID	Indicator name	Definitions	Units
FD0	Frost days	Annual count when TN(daily min) < 0°C	days
SU25	Summer days	Annual count when TX(daily max) > 25°C	days
ID0	Ice days	Annual count when TX(daily max) < 0°C	days
TR20	Tropical nights	Annual count when TN(daily min) > 20°C	days
GSL	Growing season length	Annual (1 Jan to 31 Dec in NH, 1 Jul to 30 Jun in SH) count between first span of at least 6 days with TG > 5°C and first span after 1 Jul (1 Jan in SH) of 6 days with TG < 5°C	days
TXx	Max Tmax	Monthly max value of daily max temperature	°C
TNx	Max Tmin	Monthly max value of daily min temperature	°C
TXn	Min Tmax	Monthly min value of daily max temperature	°C
TNn	Min Tmin	Monthly min value of daily min temperature	°C
TN10p	Cool nights	Percentage of days when TN < 10th percentile	days
TX10p	Cool days	Percentage of days when TX < 10th percentile	days
TN90p	Warm nights	Pecentage of days when TN > 90th percentile	days
TX90p	Warm days	Percentage of days when TX > 90th percentile	days
WSDI	Warm spell duration indicator	Annual count of days with at least 6 consecutive days when TX > 90th percentile	days
CSDI	Cold spell duration indicator	Annual count of days with at least 6 consecutive days when TN < 10th percentile	days
DTR	Diurnal temperature range	Monthly mean difference between TX and TN	°C
RX1day	Max 1-day precipitation	Monthly max 1-day precipitation	mm
Rx5day	Max 5-day precipitation	Monthly max consecutive 5-day precipitation	mm
SDII	Simple daily intensity index	Annual total precipitation divided by the number of wet days (defined as PR > = 1.0 mm)	mm day^{-1}
R10	No. of heavy precipitation days	Annual count of days when PR > = 10 mm	days
R20	No. of very heavy precipitation days	Annual count of days when PR > = 20 mm	days
Rnn	No. of days above nn mm	Annual count of days when PR > = nn mm, nn is user defined threshold	days
CDD	Consecutive dry days	Max number of consecutive days with RR < 1mm	days
CWD	Consecutive wet days	Max number of consecutive days with RR > = 1 mm	days
R95p	Very wet days	Annual total PRCP when PR > 95th percentile	mm
R99p	Extremely wet days	Annual total PRCP when PR > 99th percentile	mm
PRCPTOT	Annual total wet-day precipitation	Annual total PRCP in wet days (PR > = 1 mm)	mm

to keep copies of their data so he could do further evaluations while working on the paper.

After Zhang carefully recalculated the indexes, the participants agreed that he could not only provide the indices for a global extremes paper being lead authored by Lisa Alexander (Alexander et al. 2006), but he also could put all their station indices on the Web. This is a significant development in the sharing of climate change information. Many climate change studies do not need to reveal the exact temperature at a location (i.e., the data), but rather just how the temperature observations are changing (e.g., an index of change). Making the suite of indexes available to researchers will facilitate a wide variety of analyses in a region where the exchange of actual data is rare. Without being able to go back to the source data, the indices lack full reproducibility by others (without holding another workshop); however, evaluation of the QC log files can help a researcher accurately know how the source data were validated.

In summary, the workshop is making a direct contribution to climate change research by initiating a peer-review paper on how extremes are changing in a region never before analyzed and where data ex-

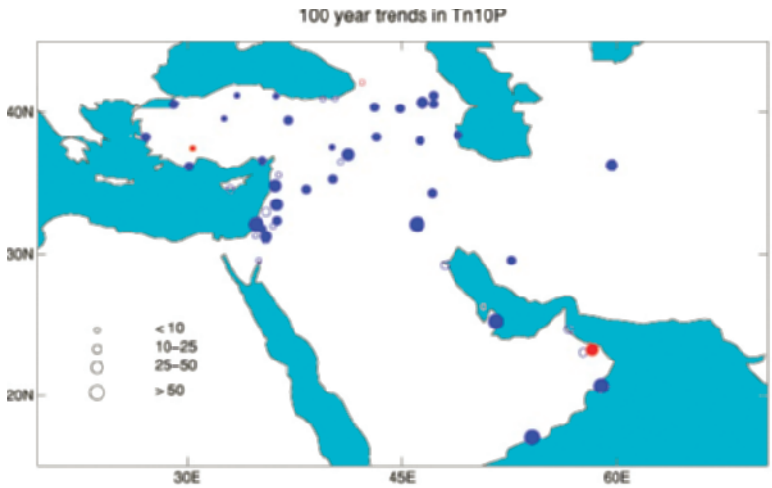

Fig. 3. Linear least squares trends per century of the index for cool nights, the percentage of days when the minimum temperature was less than the 10th percentile of the 1971–2000 base period (Tn10p). Red represents increases, and blue represents decreases. Filled circles represent trends that are significant at the 5% level. The blue dots indicate widespread warming of extreme minimum temperatures.

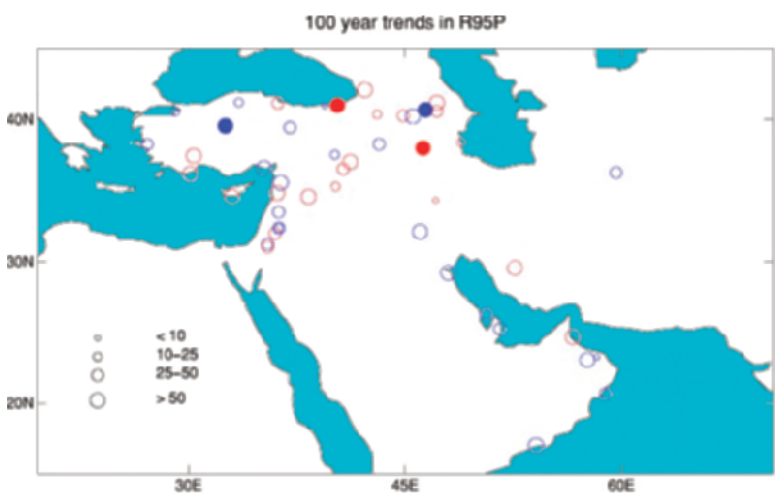

Fig. 4. Linear least squares trends of the index of annual total precipitation [mm (100 yr^{-1})] from days when the daily precipitation was greater than the 95th percentile (R95P), indicative of very wet days. Red represents increases (in the excessive amount of precipitation), and blue represents decreases. Filled circles represent trends that are significant. Unlike in Fig. 3 this index, which shows changes in excessive precipitation events, does not have a clear regional signal.

change is rare. This paper has been submitted in time to contribute to the IPCC Fourth Assessment Report. But more than that, as Mansour Al-Shabibi from Oman summed up, "It was a wonderful chance . . . to gain knowledge and friendships." It increased the data processing and analyzing capacity in the region. Other workshops have found that as the participants gain a greater appreciation for the information contained in their daily data, additional efforts are made to digitize their historical records, and this will likely be true for this region as well. Therefore, this workshop may not be the end of the process, particularly since all the participants realized the value in being able to compare their analyses with results from neighboring countries. As Hamlet Melkonyan from Armenia wrote, "It is a very good beginning for regional cooperation."

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