Journal of Environmental Science and Engineering B 2 (2013) 723-727
Formerly part of Journal of Environmental Science and Engineering, ISSN 1934-8932

On a Method of Climatological Observations Processing

Shamil Iliasov[1, 2]

1. Faculty of Natural and Technical Sciences, Kyrgyz-Russian Slavic University, Bishkek 720000, Kyrgyz Republic

2. Climate Change Centre of Kyrgyzstan, Bishkek 720033, Kyrgyz Republic

Received: November 17, 2013 / Accepted: November 28, 2013 / Published: December 20, 2013.

Abstract: The task of climate observation data processing is central to the quality of an assessment of future climate change impact. The current state-of-the-art is based on the long-running observation records of the meteorological stations. However, it is common for the developing states to have only relatively short and/or intermittent record histories. The issue becomes even more aggravated under an effort to assess the climatic trends for specific territories with few meteorological stations. The paper offers a simple and effective technique to handle the climate observations; the technique makes the most complete use of an available data set by counting the data provided by all meteorological stations including those with short records and omissions. The method is based on numeric differentiation of source data samples.

Key words: Climate change, meteorological station, observation, data processing, trends.

1. Introduction

A wide range of problems related to adaptation to climate change are based on a preliminary analysis stage of a variety of climatic trends such as ground-level atmospheric temperature, precipitation levels, humidity, wind speed, solar radiation and so on.

Many climate change-related actions are regulated by the guides and recommendations permitting to standardise the employed techniques. Still, the problem of climatological observation processing remains uncovered by any regulations.

On one hand, this motivates novel approaches. On the other hand, variability in data processing method does not ensure straightforward reproduction and comparison of results. This makes difficult the results aggregation and, in particular, detection of the joint regional policies based on the trend estimates. An example of a relevant regional policy might become the adaptation to climate change in maintenance of trans-border water resources. Table 1 illustrates such a case of mismatch. The table presents the comparative estimates of temperature increase trends for the countries in a part of the Central Asia. The geographical closeness proposes that the trends should be similar. The actual trend estimates differ substantially. The underlying reason is not using the available data in full and basing estimates on differing time periods.

For all the countries, except Kyrgyzstan, temperature trends were received by means of the conventional technique. The substantial variance in the trend values mirrored in Table 1 can be explained by the relatively small number of long-running records providing initial data and also differing sampling intervals. Calculations of the observations data for Kyrgyzstan have led to the finding that temperature trends are highly sensitive to the length of observation interval utilized for the trend assessment (Fig. 1).

The smaller an observation interval is, the higher respective trend the assessment becomes. This shows anon-linear nature of an average temperature increase. Significant acceleration of temperature increase for the last decades makes overall trends non-linear. Since conventional trend estimates are based on linear

Corresponding author: Shamil Iliasov, Ph.D., associate professor, main research field: applied mathematics. E-mail: climate.kg@gmail.com.

Table 1 Temperature trend estimates for several Central Asian countries.

Country	Warming trend, ΔT (°C/10 years)	Time period for sample data
Afghanistan [1]	0.12	From 1960
Kazakhstan [2]	0.31	From 1936
Kyrgyzstan [3]	0.078	From 1885
Tajikistan [4]	0.1-0.2	From 1940
Uzbekistan [5]	0.22-0.36	From 1951

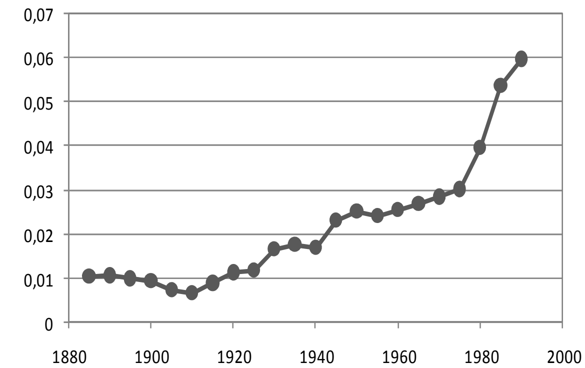

Fig. 1 Estimate of temperature increase rate depending on the length of observation interval (100 × ΔT (°C/years)). The x-coordinate gives the date of starting point of an observation interval.

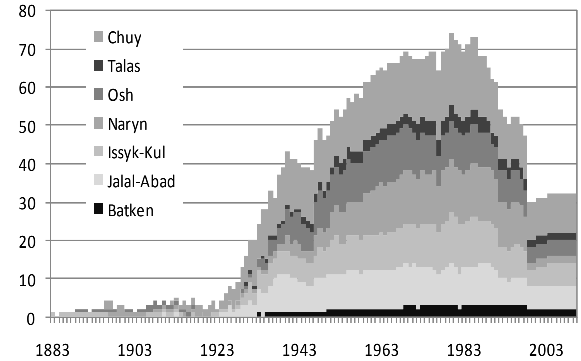

Fig. 2 The number of active meteorological stations in Kyrgyzstan, per each administrative region.

approximation, the increase in observation period leads to a lower growth rate. It is worth noting that the basis temperature increase estimate for Kyrgyzstan for the period from mid of the last century would lead to the figures much closer to those of the neighbouring countries, as given in Table 1.

Normally, the problem of climate observations processing does not pose serious challenges provided the national meteorological monitoring system operates at a satisfactory level. However, for many developing countries, it is not exceptional to have an under par monitoring system. This means a small number of long-running observation histories with frequent omissions. Omissions are often not insignificant, at timed, spanning over years; this complicates a valid correlation. Situation is even more challenging while focusing on the specific areas where the number of meteorological stations is limited and data quality might be low.

As an illustration, Fig. 2 shows how the total number of meteorological stations in Kyrgyzstan has varied over years. Fig. 2 shows that the long observation records start around the 1930s and last till the early 1990s of the last century. Due to the economic encounters, the amount of available observations has reduced dramatically during the last two decades. This means that overall trends estimates for the country on the whole and selected zones cannot be obtained by means of the conventional approach, based on the long-running, omission-free observation histories as a source data.

Fig. 3 represents an illustrative subset of available observations of annualised average atmospheric temperature for a selected zone of Kyrgyzstan; the goal is to produce the temperature trend estimate for the area. The territory takes in only three meteorological stations (Ak-Suu, Alabel, Alplager) with differing record periods.

It is clear that for data illustrated in Fig. 3, it is impossible to obtain essentially relevant assessments of temperature trends with the conventional method demanding the long-running records. In this data set, the conventional approach is limited to the period starting 1979. Moreover, in this case, the conventional

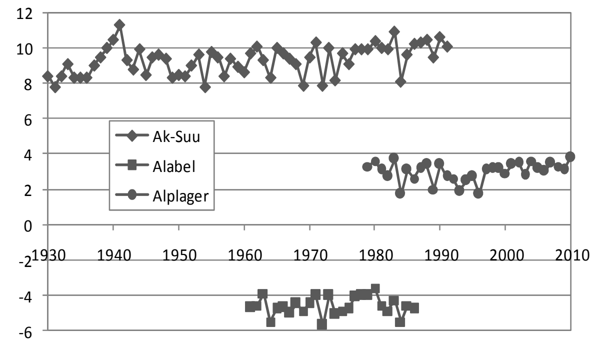

Fig. 3 Changes in annualised average temperature for the considered territory, in °C.

method accounts only the records of a single meteorological station (Alplager), despite the disposal of additional data of the remaining two stations with records starting from 1931. Hence, the majority of available data is excluded from the consideration by the conventional approach. This leads to higher uncertainties in the resultant estimates.

2. Materials and Methods

While standard of meteorological monitoring is not satisfactory, a good quality assessment of climate trends may be achieved through a transformation of source record histories.

The essence of the proposed approach consists in a preparatory numeric differentiation stage applied to source data. This removes a constant factor from a data record thus permitting the assessment of an overall trend, based on the complete record history.

The preparatory stage introduced by the method consists in applying the following numeric transformations to the raw records of climate observations:

- separate differentiation of each record history;
- averaging over the differentiated records;
- integration of the overall record.

Differentiation of record histories:

$$\begin{aligned} &d(i,j) = x(i,j)\ x(i-1,j) \\ &for\ i = n(j)+1 \ldots\ldots k(j)\ and\ j = 1 \ldots\ldots m \end{aligned} \quad (1)$$

where, $x(i, j)$ is the value from a source history record of climate observations for time point i and station j; $d(i, j)$ is the value of differentiated climate observations for time point i and station j; $n(j)$, $k(j)$ is the start and end observation time points for meteorological station j, m represents the overall number of meteorological stations for the considered area.

Averaging over the differentiated records:

$$\begin{aligned} &s(i) = \sum_{j=1}^{m} \frac{d(i,j)}{l(i)} \\ &for\ i = \min_j(n(j)) + 1 \ldots \max_j(k(j)) \end{aligned} \quad (2)$$

where, $\min(n(j))$ is the time of earliest observation for all the considered meteorological stations; $\max(k(j))$ represents the time of latest observation for all the considered meteorological stations; $l(i)$ is the number of records from meteorological stations at time i; $s(i)$ is averaged differentiated records for time point i.

Integration of the averaged record:

$$\begin{aligned} &y(i) = \sum_{j=1}^{i} s(j), \\ &for\ i = \min_j(n(j)) + 1 \ldots \max_j(k(j)) \end{aligned} \quad (3)$$

where, $y(i)$ represents the values of a record with the resultant trend for time i given $y(1) = 0$.

If observation records have omissions, then the solution is in a consideration of individual records as if there were produced by unrelated meteorological stations. This is a very simple technique that often yields a satisfactory result.

Unfortunately, in some situations (very rare), this approach leads to error in the trend estimate. As an example, Fig. 4 shows a fragment of observations with omissions at the Naryn meteorological station. Processing of the source data by treating individual record intervals, as if they were independent monitoring stations, leads to a significantly decreased trend estimate for the overall data fragment. Each individual record interval features a negative trend (-0.2383 and -0.1028) and this is how they will be accounted for in the differentiated record*s* (i). However, on the whole for the considered fragment, the overall positive trend (0.00815) is evident, which

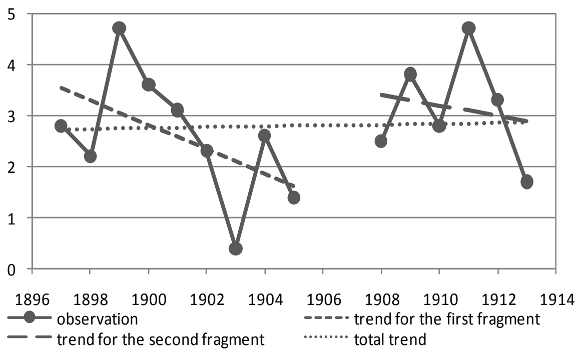

Fig. 4 Fragment of temperature observations at meteorological station Naryn, in °C.

will not be counted in $s(i)$.

For a correct handling of this situation, it is sufficient to redefine one value in the record of differentiated values, specifically

$$d(a, j) = x(a, j) - x(b, j) \tag{4}$$

where, a is the time of the initial observation of the second omission-free record; b is the time of the last observation of the first omission-free record.

In general, the application of Eq. (4) is recommended when the difference between the last value before an omission and the first value after the omission is considerable.

Calculations under Eq. (3) lead to a record of a resultant trend in relative scale since the constant factor is removed by the differentiation process. For assessment of a general trend, this is sufficient. However, sometimes it is necessary to obtain a record in the absolute scale.

In the ideal case, when all the observations are available, the actual value for a considered area is calculated as a weighted average:

$$z(i) = \sum_{j=1}^{m} \frac{x(i, j) \times p(j)}{P} \tag{5}$$

where, $p(j)$ is the area covered by the meteorological station j; and P is the overall area of the considered geographical territory.

When all the meteorological station covers the territory of the same area, that is $p(1) = p(2) = ... = p(m)$, the actual value is obtained as a trivial average:

$$z(i) = \sum_{j=1}^{m} \frac{x(i, j)}{m} \tag{6}$$

where, m represents the overall number of meteorological stations within a given area.

In the case of processing a specific record of associated with monitoring station j, the actual value of climate indicator is calculated as

$$x(i, j) = y(i) + C(j) \tag{7}$$

where, $C(j)$ is the integration constant, invariant for all the values of i, including $i = 2$.

Since $y(n(i)) = 0$, then $C(j) = x(n(i), j)$.

In the proposed method of the climate observations processing, the authors recover the value of considered observations over the complete observation interval, including periods of time when the actual value of $y(i)$ is missing for some meteorological stations.

Replacing the actual value of climate indicator in Eq. (6) with a corresponding expression from Eq. (7), and taking into the account that value $y(i)$ is obtained via series summation over j, the following expression for calculating actual value is arrived at:

$$z(i) = y(i) + \sum_{j=1}^{m} \frac{C(j)}{m} \tag{8}$$

Eq. (8) is derived for the case when the assumptions of Eq. (6) hold. The proposed method of processing climate observations is easy to extend for the case of assumptions of Eq. (5). Unfortunately, actually, the assumptions underlying Eqs. (5) and (6) are not often true. It is common then to apply some conditional estimate for the territory covered by the meteorological stations.

3. Results and Discussion

For the example territory given in Fig. 3, Fig. 5 presents the results of observation processing, obtained by applying the discussed steps of the numeric differentiation, averaging and integration of

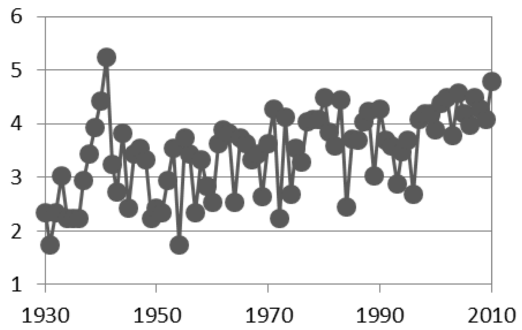

Fig. 5 The final estimate of trend of annualised average temperatures for the example territory, in °C.

time series contained in record history; the result was recalculated to reflect absolute scale.

The obtained result covers time period starting from 1931, while the traditional approach was limited to the period starting 1979. Even for the interval from 1979, the presented method delivers a lower uncertainty due to utilisation of information of extra two meteorological stations—something not possible with the conventional assessment method.

The application of presented method has allowed us to calculate changes trends of climate observations for Kyrgyzstan using records dating from 1885 (the beginning of systematic instrumented observations). Such trends cannot be obtained with the conventional approach. The trends the authors have computed with the method were included in the Climate Change National Communications of Kyrgyzstan and also used for the vulnerability assessment of specific sectors to future climate changes, including the whole country and the trans-border water basins as well.

4. Conclusions

The authors have presented a method of processing climate observation records that

(1) is simple to apply in practice;

(2) enables to take the full advantage of the available information. The method allows considering the data from all meteorological station, including those with shorter than normal and intermittent records. This makes it possible to reduce the uncertainty in the resultant estimates.

Acknowledgments

The author expresses his gratitude to the Climate Change Centre of the Kyrgyz Republic, the Kyrgyz Hydro Met Agency of the Emergency Situations Ministry of the Kyrgyz Republic for their unfailing support in the course of the development of the proposed method and fruitful discussions of the obtained results.

References

[1] Afghanistan Initial National Communication to the United Nations Framework Convention on Climate Change, 2013.

[2] Kazakhstan's Second National Communication to the Conference of the Parties of the United Nations Framework Convention on Climate Change, Astana, 2009.

[3] The Kyrgyz Republic's Second National Communication to the United Nations Framework Convention on Climate Change, Bishkek, 2009.

[4] The Second National Communication of the Republic of Tajikistan under the United Nations Framework Convention on Climate Change, Dushanbe, 2008.

[5] The Second National Communication of the Republic of Uzbekistan under the United Nations Framework Convention on Climate Change, 2008.