Climate Change – the near future

Roger Stern

Statistical Services Centre, University of Reading, UK

Abstract

Climate change is considered with a 10 to 20-year time horizon. This includes the time-scale for the Millennium Development Goals and is in our own lifetimes.

On this time-scale the climate modellers and donors agree that the study of climate change must proceed largely through an analysis of the existing climate variability. Hence it is important is to analyse the existing historical records fully and understand how users could cope better with the existing vagaries and extremes.

Every country has a National Met Service and they are the main custodians of the historical climatic data. They need some support to process their data for the wide range of activities that depend on climate variability. Often the just simple statistics is needed, but there is also ample scope for modern statistical modelling.

Introduction

Historical climatic data are available in almost all African countries, often largely unanalysed. Many application areas could benefit from more analyses of these data. Examples are largely drawn from agriculture, though climatic variability and change is also important in health, building construction and many other areas.

Three agricultural examples are provided to motivate the changes proposed in this paper. We then consider climate variability and climate change, to assess how both can be studied. Some tools and methods for the analysis are summarised as is the statistician's potential role in future work. Data analysis often requires statistical support; hence statisticians could play a key role.

Examples

Climate change and cotton growing in West Africa

Farmers from a cotton-growing association demanded support from the agricultural researcher responsible for cotton. They claimed that they now planted the cotton earlier than before, because of the differences in the pattern of rainfall due to climate change. However, their perceived change was a fickle thing, and sometimes the earlier planting had resulted in too much rain when the crop was ready for harvest. This was not what they wanted, and hence they demanded research to inform them on the optimal planting date for their cotton.

The researcher was not clear on how to proceed, but reasoned that their demands required some sort of risk analysis using the historical climatic records. He therefore contacted the National Met Service and they supplied the data. However the researcher's training had been on experimental design, rather than on the processing of the climatic data. He therefore ignored the climatic data and designed a planting date trial on cotton. This was conducted for three years. When analysed, the results confirmed that the “optimal” planting date differed from year-to-year. On reflection he knew this already, as did the farmers. An analysis of the climatic data would have been cheaper, quicker and better.

Farmers in Southern Zambia

Farmers in Southern Zambia were migrating north, citing climate change as the main reason that they could no longer grow the crops as they used to. A local NGO was of the view that poor farming practices were the main reasons that they could no longer farm as previously. The NGO accepted that there were changes in temperatures, but rainfall was the main climatic determinant of the cropping system, and changes in the rainfall pattern were not so obvious.

They therefore requested an analysis of the rainfall data in Southern Zambia, and this was done in collaboration with the Zambia Met service. The conclusions were that cropping in Southern Zambia is risky, because of the year-to-year variability of the rainfall, but there was no evidence of any change in the risk due to any change in the pattern of rainfall. There was evidence that the conservation practices, that included an element of rainwater harvesting, could have an effect in reducing the risks.

Repeating experimental trials

Many agricultural experiments are repeated for two or three years. If asked for the reasons the two usually stated by researchers are that journals demand the repeats, and that they are needed because of changes in the rainfall pattern, that could affect the results.

The climatic reason is interesting, because it implies that a sample of two years is considered adequate, whereas one year is not. Climatic data are usually collected at agricultural institutes and hence the reporting of the results often includes information on the pattern of rainfall for the years when the trial was conducted.

More could be done. For example, if climatic records are available for 50 years they could put the two years of the trial into a historical perspective. This could require statistical support, assuming statisticians have the necessary expertise. We return to this point later in the paper.

Climate variability and climate change.

We differentiate between climate variability and climate change. Different time scales can be used, but the day and the year are natural units, particularly for many agricultural applications. On either time scale, the climatic data are a time series.

Taking the year first, where measures might be:

- Total annual rainfall
- Number of rain days in January to March
- Maximum temperature ever recorded in the year

There are then as many observations as there are years of data. There is usually no discernable serial correlation between successive values, hence unless there is a trend, the data is often analysed as though it is a random sample from some conceptual population of years. Then climate variability is the variability in these values, from year to year, while the trend is the climatic change.

When daily data are considered, it is usually appropriate to consider the analysis at two levels, namely day within year and then year. There are serial correlations on a daily basis, and the data are essentially repeated measures – at least in the absence of a trend. As with other repeated-measures analyses the data may be processed simply i.e. as a two-stage process where the first stage is to summarise the data to a yearly basis and then process the yearly summaries. Or a more complex analysis may consider the two levels together.

So climate variability is considered as the variability, from one year to another, in the climatic elements measured. Climate change is the trend in the (annual) data.

Climate variability has always been important, but the more recent interest in the subject has been because of climate change. There are broadly two ways that climate change can be studied. The first is to analyse the historical records, and the second is to use the global climate models, that are the basis for modern weather forecasting. Using the historical data is largely a statistical problem, while the use of the global climate models is largely for physicists.

In this paper we consider the near-future, say 10, or 20, perhaps 50 years ahead. This is within the lifetime of most people in this audience. A consensus has emerged on the methods to be used on this relatively short time-scale. Some examples are given.

- *African Climate Report*. This was commissioned by DFID. The authors are all modellers, but their main conclusion, also repeated more forcefully in Washington et al (2006) was as follows

  > "We make the case that a plausible route to addressing the challenges of climate change in Africa rests with embracing climate variability. In essence we are arguing that addressing climate on one time scale may be the best way to approach the informational and institutional gaps which limit progress at another, longer, time scale.
  >
  > We spell out exactly why we believe **the optimal management of activities directly influenced by interannual climate variability has the potential to serve as a forerunner to engagement in the wider issue of climate change.** We show this both from the perspective of the climate system and the institutions that engage with climate issues."

- *Look before you leap,* World Bank report, Burton and van Aaist (2004), include the following in their executive summary.

  > A new international consensus has emerged on the need for adaptation to climate change.
  >
  > While priority attention for adaptation is indeed needed, we argue that it is wise

> to *look before you leap.*
>
> Adaptation is likely to be more successful to the extent that it is incorporated into the sustainable development process, and recognizes that **response to current climate variability and extremes is a necessary, if not sufficient, part of an effective adaptation strategy.**

- *Climate Proofing Africa*, DFID (2005). Key points from this report are as follows:

> Climate change will hit developing countries hardest.
>
> Africa has an extreme and unpredictable climate. This already obstructs its development. Climate change will increase vulnerability levels in Africa.
>
> **Developing capacity to deal with today's climate variability is the best way to equip Africa to deal with tomorrow's climate change.**

- These reports are more general than agriculture. Figure 1 is from a report by an international agricultural research institute, Cooper et al (2006), which makes the same key point in the title itself.

Figure 1 ICRISAT report on climate variability and change

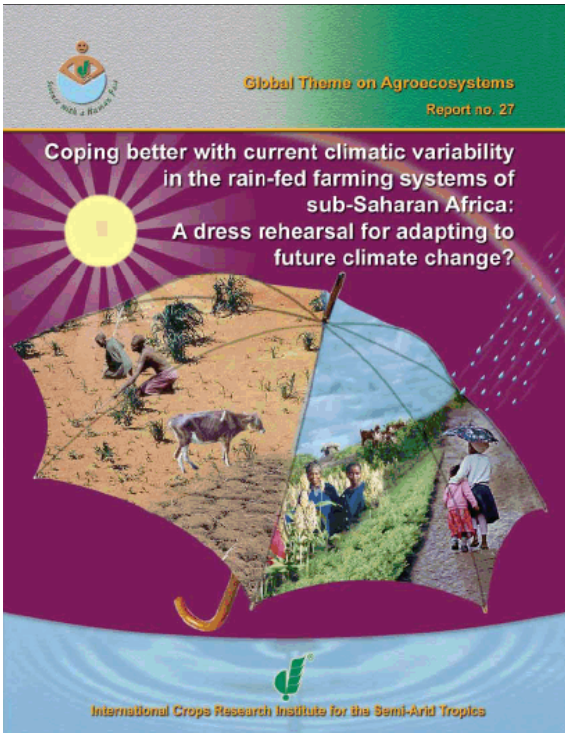
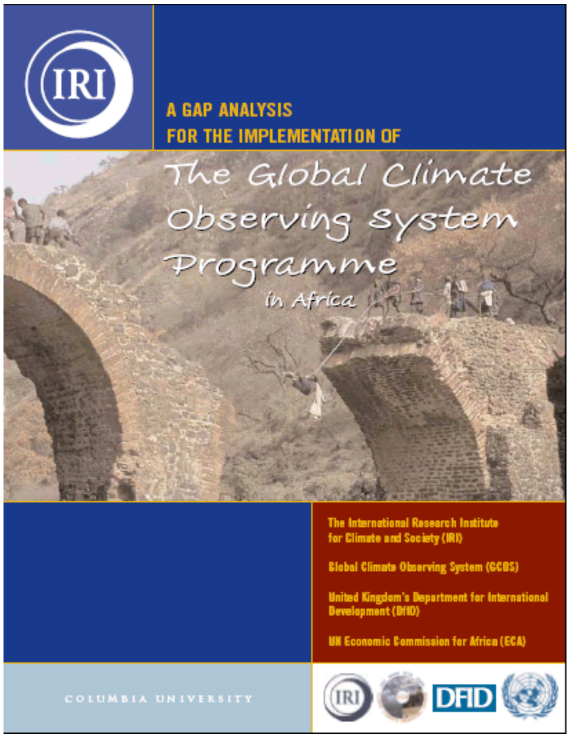


Figure 2 IRI Gap analysis report



These and other reports led DFID to commission a "gap analysis" in 2006, coordinated by IRI, Figure 2, to decide on further actions, in Africa and elsewhere.

They identified a series of gaps, and proposed actions to build bridges. In the section on climate services some of these gaps are shown in Figure 3.

Figure 3 Some gaps identified in the IRI study

The key gap identified is that in too many countries, the Met Office is insufficiently engaged with the national development agenda and that services for rural poor populations are negligible.

Few National Met services in the LDCs have realized that their prime function has moved away from "creating information" towards providing services, and especially to meet development needs.

Lack of knowledge and understanding of "user needs" and how development decisions are made, so there is little capacity to tailor information appropriately.

There is a gap between what is currently provided (24 hour weather forecasting) and what is needed for achieving the MDGs (climate and hydrology services).

Thus, a major challenge for the broad stakeholder community is to assist the national Met Offices to engage their considerable talents in assisting with delivery of national development targets and achieving the MDGs. Without this fundamental reorientation, the gulf between service (potential) user and service provider will remain.

In most African countries the National Meteorological Service (NMS) is the main custodians of the historical climatic data. Important issues of climate variability and change need to be addressed, and this is primarily through analysis of the historical data. Perhaps statisticians could work with the NMS to address these gaps. Currently both groups are on the sidelines.

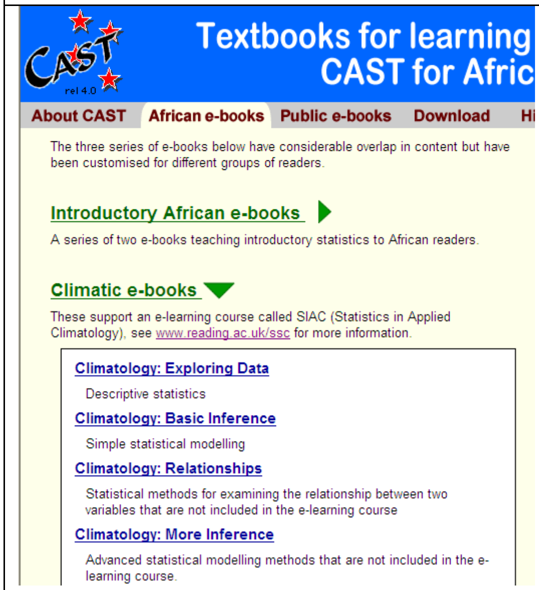
Filling the gaps

There are gaps in both capacity development and in data analysis. There are also important moves to decentralise user services in many countries, and hence training needs to be for staff in district offices, as well as in headquarters. Potentially universities can provide much of what is needed, because they are being established throughout most countries. However, the teaching of statistics needs to be modernised considerably, if users are to be supported to be able to analyse data effectively.

Statisticians have an important role to play, both as trainers, and in becoming involved in the analyses themselves. However, they have typically demanded initial training for themselves, and this has become difficult to justify, given their poor record of training others in the past.

Fortunately, resources are available to support improved training. These include e-learning courses in statistics for climatology and CAST, a series of electronic statistics textbook, that is also discussed elsewhere at this conference, Stern et al. (2009). CAST has been adapted, both for use in Africa, and specifically for some of the techniques needed in climatic analyses, Figures 4 and 5.

Figure 4 CAST for climatic analyses



The three series of e-books below have considerable overlap in content but have been customised for different groups of readers.

Introductory African e-books

A series of two e-books teaching introductory statistics to African readers.

Climatic e-books

These support an e-learning course called SIAC (Statistics in Applied Climatology), see www.reading.ac.uk/ssc for more information.

Climatology: Exploring Data

Descriptive statistics

Climatology: Basic Inference

Simple statistical modelling

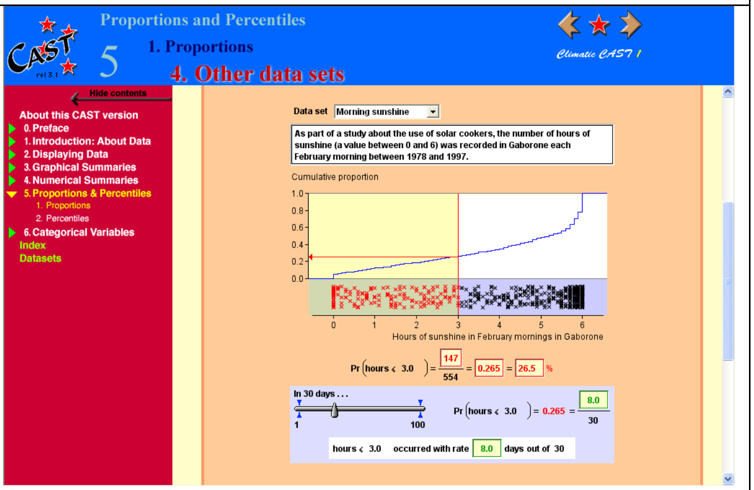
Climatology: Relationships

Statistical methods for examining the relationship between two variables that are not included in the e-learning course

Climatology: More Inference

Advanced statistical modelling methods that are not included in the e-learning course.

Figure 5 One page showing a dynamic element to calculate risks



Data set: Morning sunshine

As part of a study about the use of solar cookers, the number of hours of sunshine (a value between 0 and 6) was recorded in Gaborone each February morning between 1978 and 1997.

$\Pr(\text{hours} \leqslant 3.0) = \frac{147}{554} = 0.265 = 26.5\ \%$

$\Pr(\text{hours} \leqslant 3.0) = 0.265 = \frac{8.0}{30}$

hours ⩽ 3.0 occurred with rate 8.0 days out of 30

Examples of how climatic analyses have been incorporated into the service teaching of statistics are given by Kurji and Stern (2005).

On analysis we can differentiate between two “levels”. There is much that can be done at a “simple” level. This is to do a two stage analysis, where the first stage is to summarise the data as supplied to a yearly basis. The second stage is to process these summaries. This processing is largely descriptive statistics, though simple inferential ideas can be added. The way the data are summarised to a yearly basis is tailored to the needs of the user. Often rainfall is the key element, and many of the needs require a summary that starts with the daily data.

In agriculture, an important characteristic is the start of the season, with the definition depending on the crop being grown. An example is in Figure 6. This shows the data after the first stage, ready for further summary if needed, to calculate, for example, the risk of late planting. Figure 6 also provides a visual inspection of the data for each year, to assess whether there is an obvious trend. Here there is not.

Figure 6. Starting date of the rainy season, for Moorings (Zambia) 1922-2003 (First day with 20mm in 3 days from 15 November and no dry spell exceeding 12 days in next 30 days)

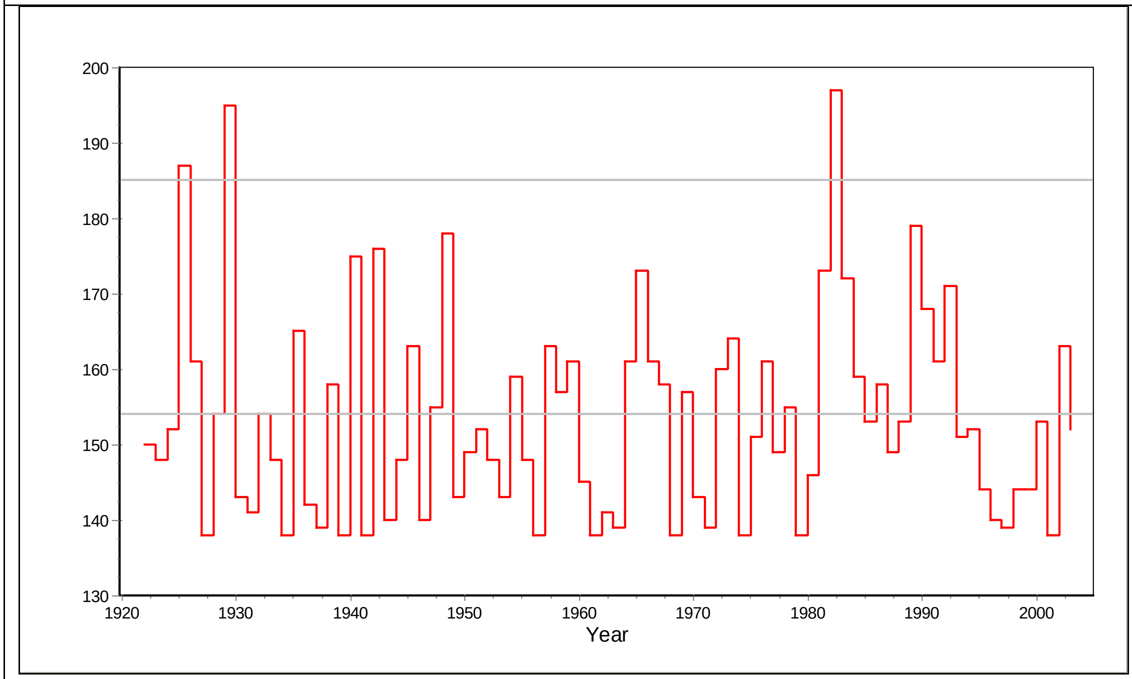
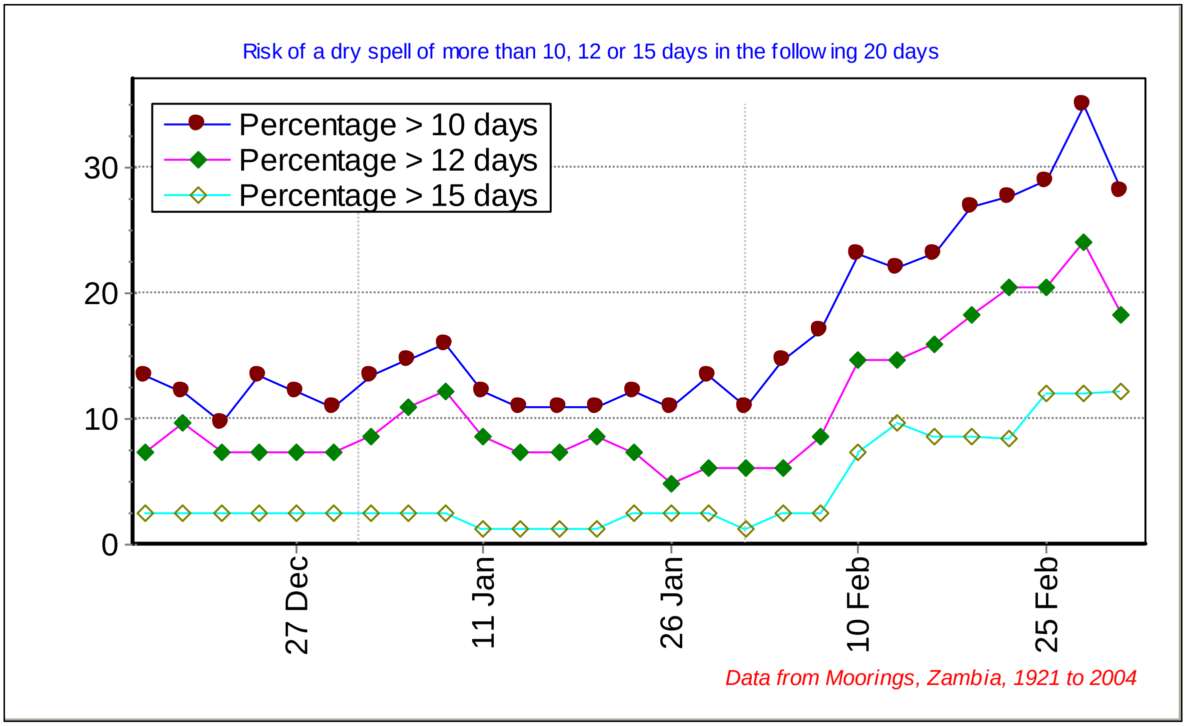


Figure 7 provides a second example, where both stages have been done. Many crops are particularly sensitive to drought during flowering, and hence Figure 7 shows the risk of a long dry spell during alternative flowering periods. The conclusion from examining this figure, is that is always a risk, but it is roughly constant (at just over 1 year in 10 for a 10-day dry spell within the 20-day period), as long as flowering starts before 1st February.

Figure 7. Percentage of years at Moorings with a long dry spell during flowering



There is much that can be done using these simple methods of analysis for both rainfall and other climatic elements. The software is also available, Stern et al (2003). For statisticians these methods do not pose many technical challenges. However, few statisticians have taken up this challenge, so there are many opportunities.

Extending the work

Three types of tool are described, that provide obvious or hidden challenges for statisticians in climatic data processing. The first is a crop simulation model, within which two that are popular are DSSAT and ApSim, see Table 1.

These are each deterministic crop growth models that require daily climatic data, plus soil, crop and management information. They include growth and yield models for many crops that simulate most of the agronomic factors that are factors in real field experiments. Hence running these models for many years is an obvious way to put field experiments into a long-term perspective, see the “Repeating experimental trials” item earlier in this paper.

The daily climatic data needed for these models is rainfall, maximum and minimum temperatures and radiation. If there are missing data, they must be estimated, to provide a complete record, before being used as an input to the models. Jeffrey et al (2001) used spatial interpolation to provide a data archive to provide data for these models, for Australia. In Africa the provision of the data in the correct form, for the required locations is far from simple. This is because the data network is relatively sparse, particularly for stations with temperatures as well as rainfall. There is a formidable challenge for statisticians here.

One solution to the above problem is provided by software called Marksim, Table 1. This uses historical data, much of it monthly, to provide an easy-to-use to simulate up to 99 years of daily data, ready for input to the crop models, or for a wide range of other applications. However, Marksim is based on 1980s' statistical methods and data. It needs testing before use in any country, and perhaps could usefully be updated, another task for statisticians.

Finally, in our short list of tools, statisticians undertaking climatic analyses will make routine uses of statistical software. One possible package is Genstat for which a special climatic guide is available, Stern and Gallagher (2004). Resources in Genstat include facilities for the analysis of extremes, that compete with the Extremes package in R. Those who discuss climate change often state that the extremes are getting "worse". As usual this is often stated without examining the data. Both Genstat and R allow extreme value distributions to be fitted, that can allow for a trend in the extremes. And these types of analysis would, as do many others, benefit from the interest and involvement of statisticians.

Conclusion

Climate change is perhaps the most serious problem affecting us. This problem is not going to go away.

Quantifying the evidence for the extent of climate change involves analyses of the historical data. This is largely a statistical task. Statisticians are often slow to enter new fields. They wait to be invited, and then are surprised to be excluded, particularly when there is funding.

This time they have a partner. The National Met Services are similarly waiting for the invitations that rarely come. Both groups must get bolder. They must also show that they have the necessary expertise to contribute to the work. Just being a statistician, of being a custodian of the data is not enough to expect an invitation.

Table 1: Web sites for software mentioned in the text

Name	**Application**	**Web site**
APSIM	Crop simulation	www.apsim.info/apsim
CAST	Electronic statistics textbook	www.cast.massey.ac.nz
DSSAT	Crop simulation	www.icasa.net/dssat
GenStat	Statistical package	www.vsni.co.uk/genstat
Marksim	Climate simulation	gisweb.ciat.cgiar.org/marksim
Instat	Statistical package	www.reading.ac.uk/ssc

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