Discussion and conclusion

On the basis of this study, the following temporal characteristics of the rainfall over Lagos can be identified. First the CV for the annual rainfall is much smaller than for the individual months which range from 34 per cent (May) to 144 per cent (August), an indication that rainfall variability is greater in the individual months of the year. These variabilities exhibit oscillatory patterns of varying periods. A gradual decrease in annual totals is evident over the period under study. This decrease is much sharper after 1980 in association with the Sahelian drought of the early 1980s. A similar trend is evident in the monthly totals, except January, August and September which have increasing rainfall totals.

The pattern of trend for various sub-periods during this century reveals significant departures from the overall long-term trend. Generally the early part of the century and the recent part were periods of decreasing rainfall, with a reversal of the trend during the middle of the century. This latter period (1931–60) is the standard 'normal' widely used over Nigeria for the planning of water supply and agricultural schemes. Since the rainfall increases of this period are at variance with the trend of the last 30 years, continued usage of this 'normal' for planning purposes is called to question.

The significant rainfall decreases of the recent period, which have averaged over 25mm per year, have been similarly observed in all the regions of Nigeria (Anyadike 1992) and are an indication that the city of Lagos may, with the rest of the country, be entering a drier phase.

Acknowledgement

The author is grateful to the Director-General of the Nigerian Meteorological Service for making the Lagos records available to him.

References

Anyadike, R. N. C. (1992) Regional variations in fluctuations of seasonal rainfall over Nigeria. *Theor. Appl. Climatol.*, **45**, pp. 285–292

Hayward, D. F. and Oguntoyinbo, J. S. (1987) *The climatology of West Africa*. Hutchinson, London, 271 pp.

Ilesanmi, O. O. (1972) Aspects of the precipitation climatology of the July–August rainfall minimum of southern Nigeria. *J. Trop. Geogr.*, **35**, pp. 51–59

Ireland, D. H. (1962) The little dry season of southern Nigeria. *Nigerian Meteorol. Serv. Tech. Note 24*, Lagos

Mitchell, J. M., Dzerdzeenski, B., Flohn, H., Hofmeyer, W. L., Lamb, H. H., Rao, K. N. and Wallen, C. C. (1966) Climatic change. *Tech. Note No. 79*, World Meteorological Organization, Geneva

Ojo, S. O. and Agun, A. (1972) The spatial distribution of rainfall and rainfall variabilities in Metropolitan Lagos. *Nigerian Meteorol. Serv. Q. Meteorol. Mag.*, **2**, pp. 158–177

The cost of climate data – a European experience

Mike Hulme

Climatic Research Unit, University of East Anglia

Recent statements made by major international climate conferences and conventions have called for greater and easier international availability and exchange of national climate data relevant for climate change research. Thus, the Second World Climate Conference held in 1990 concluded, under Conference Statement 1.B.4, that:

> "High priority must be placed on the provision and international exchange of high-quality, long-term data for climate-related

studies. Data should be available at no more than the cost of reproduction and distribution. A full and open exchange of global and other datasets needed for climate-related studies is required." (Jäger and Ferguson 1991, p.499.)

The UN Framework Convention on Climate Change (UNFCCC) states, under Article 4.1 (h), that:

> "All Parties to the Convention shall . . . promote and cooperate in the full, open and prompt exchange of relevant scientific . . . information related to the climate system and climate change . . ."

Similar sentiments have been expressed at a large number of smaller, more specialised international climate workshops and conferences in recent years; for example, the Cairo Climate Conference (1989); the Regional Conference on Global Warming and Sustainable Development (Sào Paulo, 1990); the International Conference on Global Warming and Climatic Change: African perspectives (Nairobi, 1990); the International Conference on Global Warming and Sustainable Development: an agenda for the 90s (Bangkok, 1991); the NATO Advanced Study Institute Workshop on Global Precipitation and Climate Change (La Londe-sur-Maures, 1993). Within the climate research community, and to a large extent amongst negotiators and scientific advisers involved in the UNFCCC and similar processes, the desire for the unrestricted transfer of climate data collected by National Meteorological Agencies (NMAs) into the international research domain is therefore well documented.

Perhaps reflecting this new impetus to the 'freeing' of climate data, the Met. Office have recently attempted to clarify their position with regard to data (Hunt 1993). Thus their data management policy states that: ". . . the widest possible use of data in order to realise their potential value . . ." is to be encouraged; ". . . access [will be given] to non-restricted data on conditions (including financial terms) which will take account of the use to which the data will be put . . ."; but that organisations responsible for funding research should make provision to ensure that ". . . the economic cost of the data, defined as the cost of fulfilling the specific request (media extraction, transmission and data-handling costs) plus a contribution to the cost of generating the data . . ." is met.

These latter two statements do, however, leave much latitude for varying the cost of climate data depending on the nature of the request and the resources available to the applicant!

On the international scale there is a very substantial degree of variation in the pricing and access structures imposed on climate data by different NMAs. This article summarises the recent experience of the author – a research scientist at a leading international climate research centre – in dealing with nearly 40 NMAs in a 'greater European' region regarding access to national climate data. This experience is shared for three reasons: it quantifies the magnitude of the distortions that exist in the international climate data market (to my knowledge this has nowhere before been made public); it highlights the difficulties scientists face when undertaking research which requires new datasets which cross national boundaries; and it provides a vivid illustration of how far short the international climate data market falls of the aspirations quoted at the beginning of this paper. The reader should also note, however, that the prices and responses quoted in the paper cannot be regarded as definitive of each country's position; the information contained here is incidental to the main purpose of my research. To obtain a definitive picture of the cost of European climate data a dedicated survey would need to be undertaken. This may be a very worthwhile activity that some international organisation could initiate.

The project

One of the research projects funded by the Natural Environment Research Council (NERC) under the Terrestrial Initiative in Global Environmental Research (TIGER) IV programme is entitled "Landscape Dynamics and Climate Change". This project is to run from 1993 to 1995 and has as its objective the development of a more detailed understanding

of the processes of ecological change within the framework of intensively managed landscape mosaics, in order to achieve a better prediction of the effects of global change on natural ecosystems in Britain and western Europe. The Climatic Research Unit was subcontracted to provide, for the consortium of research institutes represented on the project, amongst other things, a new 1961–90 baseline climatology for a greater European region (Fig. 1). This climatology was to be gridded at a 0.5° resolution for all land areas within this region. The extent of the region, ranging from Greenland, to the Azores and north Africa, to the Aral Sea and to northern Russia, reflected the extent of the species distribution mapping required in order to adequately model future species dispersal in the UK. This project is a good example of the sort of studies now being undertaken in many different countries and by different disciplines which are assessing the sensitivity of natural or managed ecosystems to climate change and variability. For example, both the Intergovernmental Panel on Climate Change (IPCC, through its Working Group II) and the UNFCCC (through its call for country-based climate change impact assessments) are stimulating these types of research activities and have the support of the international science and policy-making communities. The availability of the necessary observational climate data has therefore a much broader relevance than for the specific project described here.

While numerous climatic normals exist for earlier periods, either time-varying (*e.g.* Müller 1982) or fixed-period normals (*e.g.* 1941–70, 1951–80), no 'off-the-shelf' data yet exist for 1961–90. The World Meteorological Organization (WMO) have sent out repeated calls to all member country NMAs to supply 1961–90 normals and these are currently being collated at the National Climate Data Center, (NCDC), Asheville, USA. As of late-1993, however, data had only been received for about 50 per cent of countries world-wide and these data were still being quality controlled and reformatted (World Meteorological Organization 1989). An approach to NCDC indicated that these normals could not currently be released without permission from respective countries. Furthermore, these normals would not necessarily include all the variables required; for example, frost days and rainday frequencies at fixed thresholds. The Climatic Research Unit therefore decided to approach the European NMAs directly with a request for 1961–90 normals.

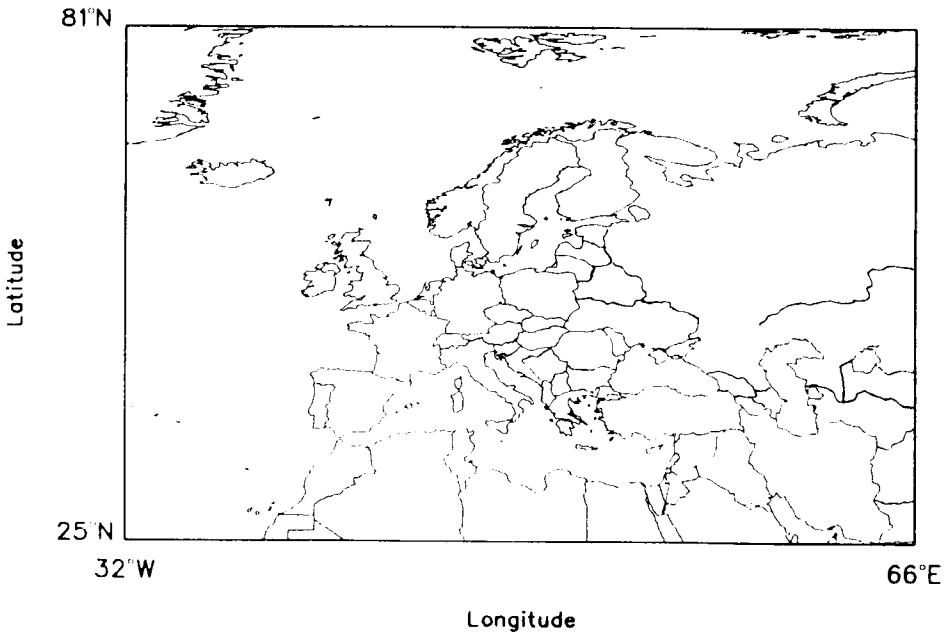


Fig. 1 The 'greater Europe' region for which the gridded climatology was to be constructed

Table 1 The 39 countries approached, together with the response made by each NMA. A station-variable is defined as a set of 12 monthly normals for one station and for one of the requested variables (thus a complete set of data for one station is eight station-variables). The delivery time is defined as the length of time elapsing between the sending of the initial request and the receipt of the required data. The final column indicates whether a Data Agreement Form (DAF) had to be signed. See text for further explanation.

NMA	Station-variables	Total cost (US$)	Format	Delivery (days)	DAF
Albania[1]	48	990	Paper	150	No
Austria	72	500	Disk	80	No
Belgium[&r]	161*	250	Disk	120+	No
Belarus[2]	120+	500	Disk	190	No
Bulgaria[r]	56	Free	Paper	90	No
Croatia[r]	80	Free	Disk	140	No
Czech Republic	1600	60000	Disk	Not ordered	n/a
Cyprus	40	Free	Paper	15	No
Denmark	130	180	Paper	90	No
(+Greenland)	150	Free	Paper	45	No
Estonia[r]	40	190	Disk	150	No
Finland[3]	ca. 200	60	Book	40	No
France	203*	860	Disk	70	No
Germany[r]	105*	80	Paper	180	Yes
Greece	216	600	Disk	40	No
Hungary	56	4400	Disk	Not ordered	n/a
Iceland	250	130	Disk	160	No
Ireland	88+	Free	Disk	30	No
Israel[r]	21	Free	Paper	70	No
Italy[r]	No response				
Jordan	80	Free	Paper	60	No
Lebanon	25*+	Free	Paper	80	No
Lithuania	144	500	Disk	210	No
Luxembourg[r]	8	Free	Paper	150	No
Malta	8	Free	Paper	30	No
Netherlands[4]	120	230	Disk	20	No
Norway[r]	1500	Free	Disk	180	Yes
Poland	80	600	Paper	100	No
Portugal[r]	No response				
Romania[r]	120	35600	Disk	Not ordered	n/a
Russia[&r]	1000*	Free	Disk	140	No
Slovakia	No response				
Slovenia[r]	336	Free	Disk	100	No
Spain	500*	Free	Paper	80	Yes
Sweden	350	1267	Disk	80	No
Switzerland	24*	260	Disk	100	No
Syria[r]	80	605	Paper	80	No
Turkey	2000+	Free	Disk	70	No
UK[5]	15000	2190	Disk	150	Yes
Ukraine[6]	360	ca. 3000	Disk	Not ordered	n/a

Notes:

1 Albania requested max./min. thermometers as payment for data. Equipment of the value of US$990 was duly sent.

2 Belarus originally requested a PC as payment for data. This was subsequently reduced to a charge of US$500.

3 For Finland only an approximate number can be defined since the book contained a large number of station-variables, only a subset of which were extracted.

4 The Netherlands also supplied a book with precipitation normals for several hundred stations which was free, but charged US$840 for the gauge locations!

5 Data for the UK were supplied on special terms under a previously negotiated arrangement under the Climate Impacts LINK Project funded by the UK Department of the Environment.

6 Ukraine originally requested a PC as payment for data. This was non-negotiable and no order for data was placed.
A reminder letter had to be sent in July 1993.

\+ Time-series between 1961 and 1990 of these station-variables were supplied (one could argue therefore that such totals should be multiplied by 30).

* Not all variables were supplied.
Data were eventually supplied via an intermediary.

The request

Thirty-nine NMAs (see Table 1) were written to in May 1993 requesting the following information:

(i) For how many stations had 1961–90 mean monthly normals been calculated for the required variables?
(ii) At what cost could these data be supplied?
(iii) By when?

The requested eight variables were minimum/maximum air temperature, precipitation, hours of sunshine (or cloud cover), relative humidity (or vapour pressure), mean wind speed, and number of raindays (>0.1mm per day) and frost days (grass minimum <0.0°C). It was made clear in the letter that the purpose to which these data would be put was for a scientific research project concerned with climate change impacts, funded by a non-profit making UK research council (NERC) and that the data would not be passed on, unauthorised, to any third parties.

The response

Table 1 summarises the responses of the 39 NMAs approached; 25 NMAs responded to the first request and a further 11 responded to a reminder sent out two months later in July. To date (February 1994) three have not responded. The resulting distribution of stations is illustrated in Fig. 2 which shows the 1318 stations for which 1961–90 mean monthly maximum temperature data were supplied by the responding NMAs (as of February 1994)*. Maximum temperature was one of the variables which was supplied using a uniform definition. This was not the case for some other variables. Thus raindays were supplied using different thresholds, frost days were either ground frosts or air frosts, and usually relative humidity *or* vapour pressure and sunshine hours *or* cloud cover were supplied. This entailed substantial work in standardising these data (described in Hulme *et al.* 1993) using (approximate) conversion methods, and highlights a further difficulty in establishing uniform multinational climate datasets.

The quickest response to the request for normals came from Cyprus who supplied normals, free of charge, for five stations within 15 days. Of the 36 NMAs who responded, 14 supplied normals with no charges attached. The most generous of these countries was Turkey who supplied, on disk, time-series for all the requested variables for over 200 Turkish stations. If the charging rate of the most expensive country was applied to these Turkish data, then the bill would have totalled nearly US$600000. Furthermore, if a 30-year monthly time-series is regarded as containing 30 times the data volume of the normals alone, then at this rate Turkey could have charged US$17.8 million!

Three countries requested payment in equipment and one (Syria) in books. Albania asked for max./min. thermometers to replace obsolete stock; four sets of thermometers were duly supplied to Tirana. Both Ukraine and Belarus requested a PC in return for the climate normals, indicating the great difficulty such NMAs had in obtaining contemporary computer equipment for data analysis. We could not meet these requests and Belarus subsequently agreed to provide a subset of their normals for a fixed fee of US$500.

The 36 country responses were ranked according to the cost per station-variable or, if the data were free, then according to delivery time (Table 2). The three countries that proved most expensive were Romania, Hungary and the Czech Republic; orders for normals from these countries were not placed. At a charge of US$297 per station-variable (*i.e.* US$2376 for a set of normals for the eight variables just for one station) it is difficult to see how Romania will recoup any of their costs since few will agree to pay such a price and this charge is certainly well above the "cost of reproduction and distribution" (Jäger and Ferguson 1991, p. 499).

It is also interesting to note that most of the

* For the work of generating a gridded climatology at 0.5° resolution, this distribution was supplemented with station means derived from other sources, either published normals for earlier or non-standard periods (*e.g.* 1951–80, 1975–84) or extracted from other datasets held by the Climatic Research Unit (see Hulme *et al.* 1993).

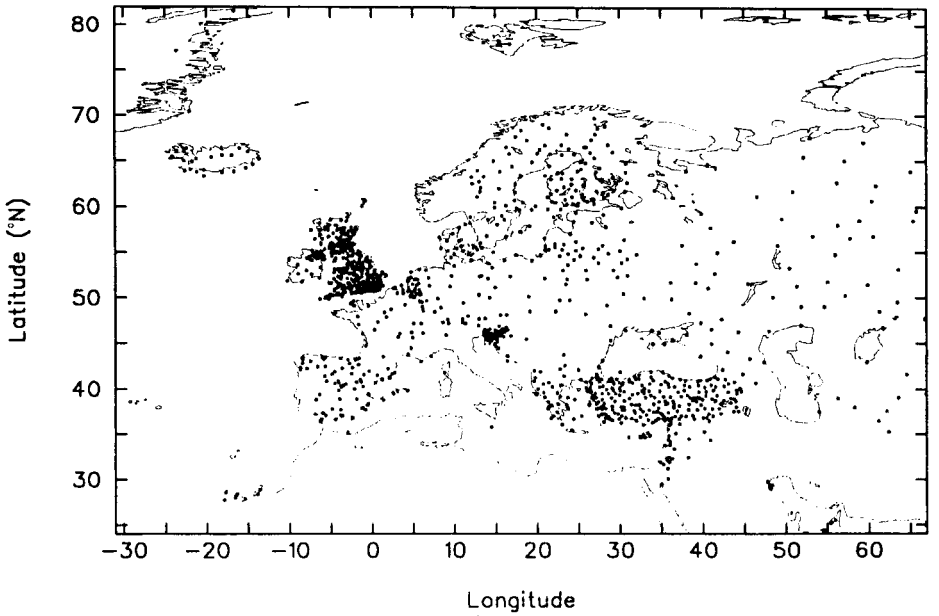


Fig. 2 Distribution of stations for which mean monthly maximum air temperature normals for 1961–90 were supplied by the 39 NMAs approached (as of February 1994)

countries which had clear charging rates were located in the European Union or wealthier regions of greater Europe. Peripheral, less wealthy countries such as Turkey, Jordan, Lebanon and Croatia were considerably more generous in their response. The efficiency of their response as measured either by delivery time or by whether the data arrived (documented) on disk was also often more impressive than that of countries such as Spain and Germany. There was no overall relationship, however, between national wealth (as measured by gross national product (GNP) per capita) and charging rate (Table 2). If one removes the 14 countries which supplied data at no charge, the correlation between GNP/capita and unit cost is very weakly negative, but certainly not significant. The three most expensive countries, for example, have relatively modest GNP/capita of between US$1600 and US$3100.

The conclusion

The cost of climate data indicated by this experience varies enormously from country to country. This is as true within the European Community (*e.g.* Ireland and Spain no charges, France US$4.2 per station-variable) as it is between the wealthier (*e.g.* Switzerland US$10.8 per station-variable) and less wealthy (*e.g.* Jordan no charges) nations. The magnitude of these differences is best illustrated by applying the highest charging rate to the data provided by the most generous country. If this is done then Turkey could have charged between US$600 000 and US$17.8 million for the data they supplied. The relationship between national wealth and unit cost of data is difficult to generalise, however, since some wealthy countries provide data free and some less wealthy countries have high unit costs.

The variations in pricing structures more probably reflect the varying demands placed by national governments on NMAs to raise revenue. Some countries have obviously charged only marginal costs (*i.e.* costs of data extraction and preparation), whereas other countries are passing on (part of) the costs of data collection. The exposure of the NMAs to commercial markets which can inform them about the prices the market will bear also varies from country to country. Some NMAs indicated that they had

Table 2 Country responses ranked by cost per station-variable (derived from Table 1) or, if free, then by delivery time. The 1990 per capita GNP for each country is also shown, if known. The 'R' indicates that, as of 3 February 1994, the country had ratified the UN Framework Convention on Climate Change.

NMA	Cost (US$)	Delivery (days)	1990 GNP/capita (US$1000s)
Cyprus	–	15	
Ireland	–	30	9.6
Malta	–	30	
Jordan (R)	–	60	1.2
Israel	–	70	10.9
Turkey	–	70	1.6
Spain (R)	–	80	11.0
Lebanon	–	80	
Bulgaria	–	90	2.2
Slovenia	–	100	3.1
Croatia	–	140	3.1
Russia	–	140	
Luxembourg	–	150	
Norway (R)	–	180	23.1
UK (R)	0.1		16.1
Finland	<0.3		26.0
Iceland (R)	0.5		
Denmark (R)	0.6		22.1
Germany (R)	0.8		22.3
Belgium	1.6		15.5
Netherlands (R)	1.9		17.3
Greece	2.8		6.0
Lithuania	3.5		
Sweden	3.6		23.7
France	4.2		19.5
Belarus	4.2		
Estonia	4.8		
Austria	6.9		19.1
Poland	7.5		1.7
Syria	7.6		1.0
Ukraine	ca. 8.3		
Switzerland (R)	10.8		32.7
Albania	20.6		
Czech Republic (R)	37.5		3.1
Hungary	78.6		2.8
Romania	297.0		1.6
Italy	No response		16.8
Portugal (R)			4.9
Slovakia			3.1

little experience in pricing climate data. The desire of some countries to receive payment in equipment (Albania, Belarus, Ukraine) or books (Syria) or data exchange (this was suggested by one or two countries) is interesting and perhaps suggests a more constructive way of facilitating the international availability of national climate data. Differences between countries also arise for less systematic reasons; for example, who the individual is who interprets the nature of the request (private company, government agency, individual scientist, etc.) and the more mundane problem of linguistic barriers (*i.e.* translating the request from English). For all these reasons some caution should be applied when comparing the pricing structure of different NMAs.

A number of comments with wider implications, however, seem justified from this analysis. The European Climate Support Network (ECSN) was established by a Memorandum of Understanding in 1992 with, currently, 13 western European nations (including the UK) as signatories through their NMAs. The scientific objective of the ECSN is to: ". . . understand the mechanisms and assess the predictability of the climate system on time scales from 10^{-1} to 10^{2} years". One of the core

projects of this activity is to: ". . . improve the usefulness of existing climate data held in Europe. Key aspects are free availability, easy access, indications of quality and compatibility with international standards" (ECSN 1993).

The recent experience of this author is that with regard to climate data in Europe substantial obstacles are still in place to meeting the above objectives.

Finally, I return to one of the opening quotations contained in the UNFCCC regarding the full, open and prompt exchange of climate data to which parties to the Convention are committed. As of 3 February 1994, only 11 of the 39 countries approached in this project had ratified the Climate Convention (see Table 2). Of these 11 countries, Portugal has failed to respond to our request for data, the Czech Republic charged very high rates, Switzerland supplied a very small number of data at high charges and Germany and Norway took half a year to deliver data.

In the future, if international climate change research is to benefit from the existence of climate data which have been measured and collated by NMAs, then a much more rigorous adherence to the spirit of Article 4.1 (h) of the Climate Convention by NMAs within ratified countries will be necessary. It seems quite clear that the approach adopted here of making bilateral arrangements with numerous NMAs is not the most efficient way to proceed. Regional agreements (such as the ECSN) and global agreements (such as through the WMO), while fine in principle, do not have a good record of delivering the needed climate data, at the right time, to the active scientific institutes. A better way must be found and perhaps the parties to the UNFCCC should consider this as one of their priority activities when they meet for the first time, probably in the spring of 1995.

Acknowledgements

The work described here was funded by the NERC (via a sub-contract from the Environmental Change Unit, Oxford) under the TIGER IV programme. Phil Jones provided valuable advice at various stages of the work and also obtained access to the Russian and Belgian data through personal contacts.

References

European Climate Support Network (1993) *European Climate Support Network: outline.* ECSN BR-1, Madrid, 31pp.

Hulme, M., Jiang, T., Turney, C. and Barrow, E. M. (1993) *A 1961–90 baseline climatology and future climate change scenarios for Great Britain and Europe, Part II: 1961–90 European baseline climatology.* A report prepared for the TIGER IV consortium, "Landscape dynamics and climate change", Climatic Research Unit, Norwich, 55pp.

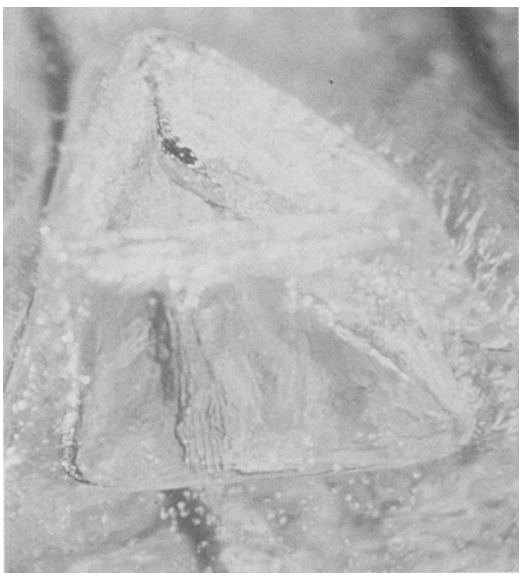
Hunt, J. C. R. (1993) Data management in the Met. Office – a policy statement. *Weather*, **48**, pp. 227–229

Jäger, J. and Ferguson, H. L. (Eds.) (1991) *Climate change: science, impacts and policy.* Proceedings of the Second World Climate Conference, Cambridge University Press, Cambridge, 578pp.

Müller, M. J. (1982) *Selected climate data for a global set of stations for vegetation science.* Dr W. Junk Publishers, The Hague, 306pp.

World Meteorological Organization (1989) *Calculation of monthly and annual 30-year standard normals.* WCDP-No. 10, WMO-TD/No. 341, WMO, Geneva

Triangular ice pinnacle



CP © David Gill

Pinnacle of ice in a bird-bath at Frieth, Henley-on-Thames, on 7 February 1988. The pinnacle, about 50mm high, consisted of an open top, equilateral triangle with curved sides sloping downwards. Is this shape the exception to the rule (see pp. 188–189)?