E R D K U N D E

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WORLD THERMAL CLIMATES AND THE CONCEPTS OF SEASONALITY AND CONTINENTALITY IN CLIMATE CLASSIFICATION

With 6 figures (partly as supplements XIII–XIV), 1 table and 4 appendices

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Zusammenfassung: Thermische Klimate der Erde und die Konzepte der Saisonalität und Kontinentalität im Rahmen der Klimaklassifikation

Mit Hilfe eines Computerprogramms wurden für 167 weltweit verteilte Stationen die über Beobachtungsräume von drei bis 40 Jahren gemessenen Monatsmittelwerte von stündlichen, dreistündlichen oder sechsstündlichen Lufttemperaturen in Thermoisoplethen-Diagramme umgesetzt. Für diese und weitere 42 vor allem von CARL TROLL erarbeitete Diagramme wurden aus dem Verlauf und dem Abstand der Isoplethen Maßzahlen der thermischen Saisonalität, der Tagesschwankung sowie der Kontinentalität abgeleitet. Die so ermittelten Daten wurden zu Zeit-Temperatur-Histogrammen (Abb. 6, Beilage XIV) zusammengefaßt, die Aussagen über Wärmesummen und den Grad der Ähnlichkeit zwischen den Klimastationen erlauben. Der praktische Nutzen des Thermoisoplethen-Modells reicht von der Analyse thermischer Klimate zum Zwecke bioklimatischer Vergleiche über die Bestimmung des Energiebedarfs bei der Aufrechterhaltung kontrollierter Umweltverhältnisse bis zur Information für Reisende. Auch andere klimatische Phänomene, die durch einen zyklischen Tages- und Jahresverlauf gekennzeichnet sind, lassen sich in ähnlicher Weise wie die Thermoisoplethen als Oberflächen darstellen, wobei Eigenschaften deutlich werden können, die bei einer rein numerischen Präsentation der Daten verborgen bleiben.

Introduction

The zonation and classification of world climates have been centrally important themes in physical and bio-geography since the early observations of ALEXANDER VON HUMBOLDT, but global schemes of climate typification and analysis have hitherto suffered from a sparsity of data from most of the Southern Hemisphere (KUKLA et al. 1977; JACKA, CHRISTOU a. COOK 1984; JONES et al. 1986). The placing of meteorological stations on many of the remote islands in the Southern Ocean and in the Antartic since the International Geophysical Year (1956–57), has resulted in the accumulation of some 30 years detailed climatic data from these parts of the world whose climates were previously little known. Over the same period, the establishment of military bases and civil airports, has added to climate data worldwide. This study uses long runs of hourly drybulb air temperatures recorded at more than 200 places, mostly in coastal situations. It attempts to refine ideas concerning the comparative nature of thermal climates at the earth's surface, and to demonstrate a range of uses for isopleth data modelled on a temporal basis.

TROLL (1941, 1943, 1961) pointed to the fundamental difference between the diurnal nature of thermal climates in low latitudes, and their seasonal nature in high latitudes. This is clearly expressed in the trend of the isopleths in his "thermoisopleth" diagrams. He thus emphasised an important *qualitative* distinction, which was used in the classification of climates on a world map (TROLL a. PAFFEN 1964). PAFFEN (1966) used 100 such thermoisopleth diagrams to define the relationship between seasonal and diurnal temperature fluctuations, and published another world map displaying the world distribution of this relationship (PAFFEN 1967). His seasonal and diurnal temperature ranges were based on tables of daily or monthly mean and extreme air temperatures for rather short time spans. In drawing up his world maps of "periodic" and "aperiodic" fluctuation in air temperature at different sites, he was obliged to use a nomogram based on extremes in order to estimate his values of seasonality (J_s) and diurnality (J_t). PAFFEN had little data for mid-latitude sites in the Southern Hemisphere, and none from the Antarctic.

Thermoisopleth diagrams are simple graphical displays of the march of air temperatures experienced at any site, modelled as a surface of temperature levels within a framework of diurnal and seasonal time. A very large amount of information is summarized in such diagrams, in the same way that a large amount of topographic information is summarized in a contour map derived from numerous spot heights. The *forms* of the thermoisopleths in the diagrams are therefore useful in the analysis and comparison of thermal climates. The present paper extends TROLL's ideas by the use of simple geometric methods, to quantify the seasonal and diurnal trends of the thermoisopleths, to measure the closeness in their spacing, and to display the time spent between different levels of temperature. It treats the isopleths of temperature levels modelled in time, like the altitudes of surveyed landscape modelled in space as a contour map. It uses some of the methods of the morphometric analysis of landforms (STRAHLER 1952, KING 1966), and suggests that thermoisopleth models have a quantitative value in climate analysis, and a number of practical uses.

Methods

The monthly mean values of six-, three-, or one-hourly, drybulb surface air temperatures, taken over periods of between 3 and 40 years, have been collected for 167 places worldwide. These temperature data have been assembled into diurnal × seasonal matrices for each site, and contoured at 1 °C intervals. Interpolation and smoothing are performed by a cubic method (MCCONALOGUE 1970), using independently written programs developed in two modules on a DEC10 computer. The first module transforms the matrix into 1 °C isopleths, and calculates the area enclosed between each isopleth and its neighbour, and the means, medians and standard deviations of the input data. The second module plots the axes, the headings and the isopleths themselves.

The relative dimensions of each thermoisopleth diagram are similar to those employed by TROLL (1943), with mid-summer and midday at the centre of each plot, and the seasonal (X) axis 1.35 times the length of the diurnal (Y) axis. This arrangement has the advantage of allowing direct comparisons to be made between plots from sites in the Northern and Southern Hemispheres, and between the older hand-drawn and the new computer-generated plots, by optical enlargement or reduction and subsequent overlay. For this reason, the adoption of this seasonal/diurnal ratio, and summer/noon centered plots is urged as standard practice on future compilers of thermoisopleth diagrams.

Forty-two published thermoisopleth diagrams have been included in the data set, making a total of 209 stations worldwide. The numerical data from which most of these printed diagrams were compiled remain unpublished, and the trend and spacing of the isopleths have therefore been counted directly from the printed diagrams. Many of them cover only short periods of time, and their temperature-sampling intervals are unstated. Their accuracy and reliability are therefore less easy to evaluate than the 167 diagrams generated by computer. Since the published plots include some covering periods of observation which stretch back more than a century, they may have an interest in the analysis of changes in thermal climates which may be influenced locally or globally by human activities.

Two kinds of quantitative data concerning their thermal climates have been derived from each of these 209 thermoisopleth diagrams:

a) measures of seasonal (S) and diurnal (D) isopleth trends, registering the pattern of air temperature fluctuations;

b) indices of continentality (C), reflecting the overall spacing of the thermoisopleths.

The derivation of these values is described below. They are tabulated, together with geographical information, and the data sources for each site, in Appendices 1 a. 2. For the 167 computer-generated diagrams, mean and median temperatures, and the percentage of annual time spent between different levels of temperature, have also been calculated.

Seasonal and diurnal values

Thermoisopleth diagrams for 30 sites compiled from data covering periods of five or more years since 1942, mostly sampled at 3-hourly intervals or less, are shown in Fig. 1 (Supplement XIII). The seasonal (vertical) trend of the isopleths in high latitudes, compared to their diurnal (horizontal) trend in low latitudes is obvious. Temperature peaks and troughs

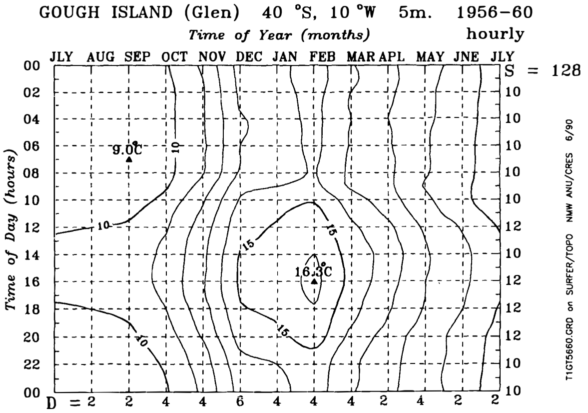

Fig. 2: Thermoisopleth diagram for Gough Island (The Glen), South Atlantic, based on hourly data from 1956–1960. A 12 × 12 grid has been superimposed, showing counts of the diurnal (D) and seasonal (S) intersections with the isopleths. S/D = 128/40 = 3.20

Thermoisoplethen-Diagramm für Gough Island, Südatlantik, mit Gitternetz zur Bestimmung der Maßzahlen der Tages- (D) und Jahresschwankung (S)

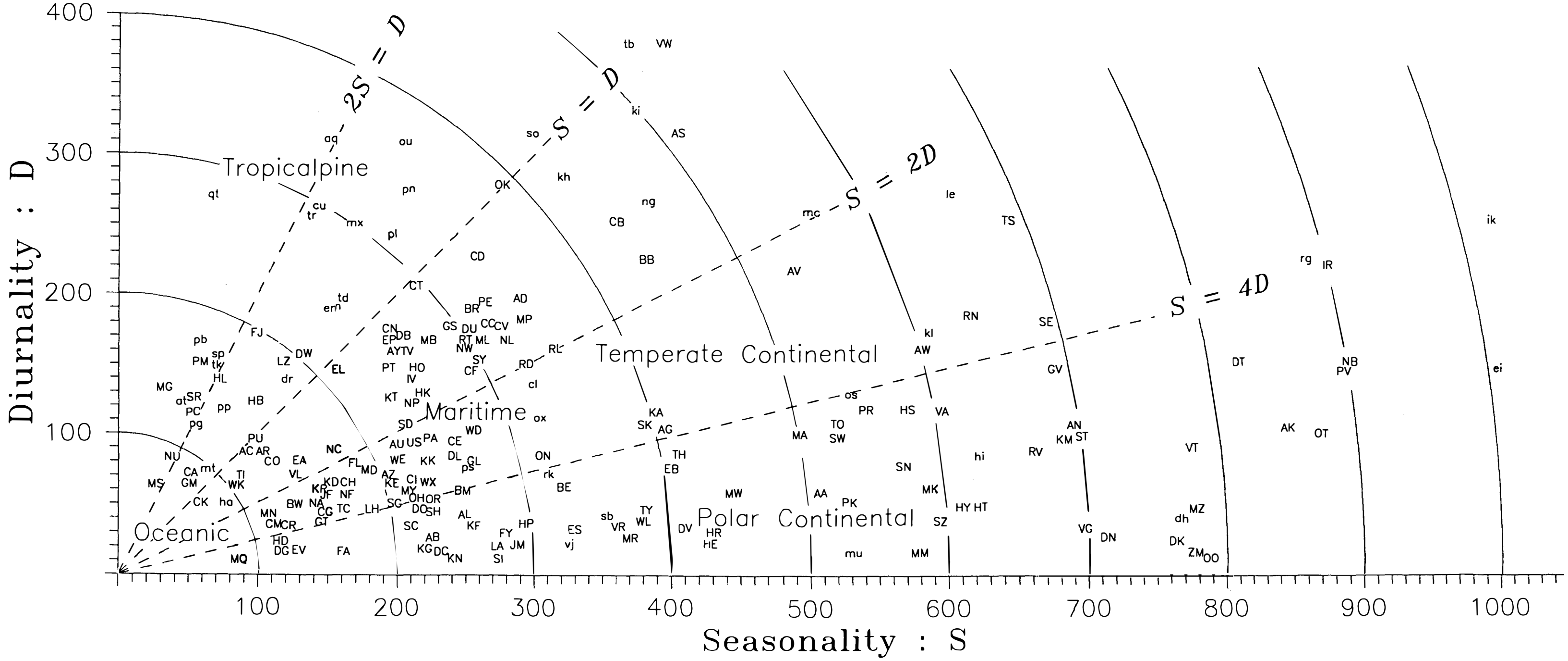

Fig. 3: Ordination of world thermal climates by seasonal (S) and diurnal (D) trends in mean air temperatures, taken from thermoisopleth diagrams. Upper case codes refer to computer-generated diagrams (Appendix 1), lower case codes to older published diagrams (Appendix 2). Some site codes have been omitted or moved slightly, to prevent overlapping. For alphabetical key to all codes, see Appendix 3

Anordnung der thermischen Klimate der Erde nach den aus den Thermoisoplethen-Diagrammen abgeleiteten Trends der Jahres- (S) und Tagesschwankungen (D) der mittleren Lufttemperatur

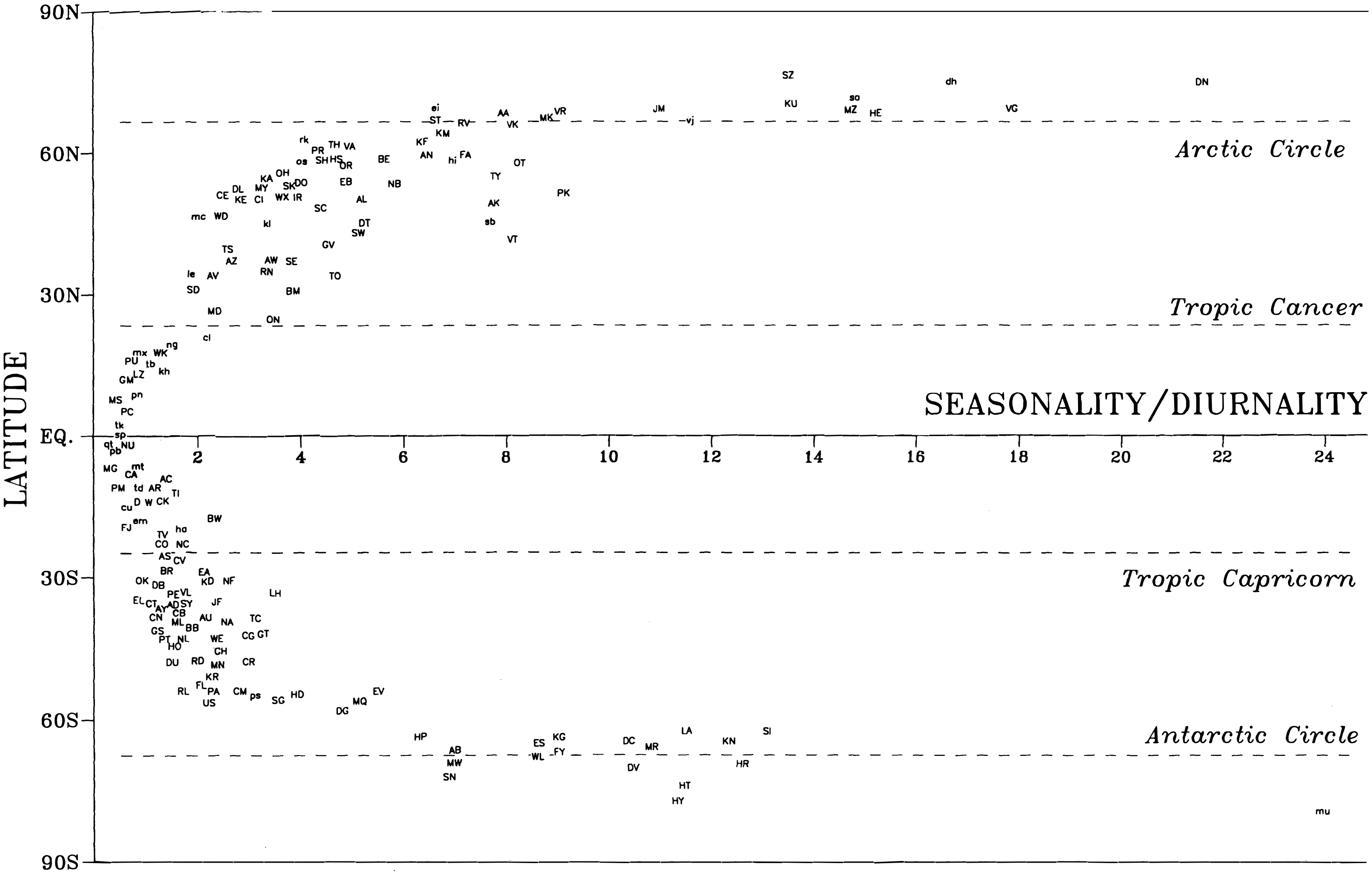

Fig. 4: S/D values derived from thermoisopleth intercepts (X-axis) plotted against latitudes of sites (Y-axis). Some site codes have been omitted or moved slightly, to avoid overlapping. For alphabetical key to codes, see Appendix 3

Quotienten aus Jahres- und Tagesschwankung (S/D) in Relation zur geographischen Breite der Stationen

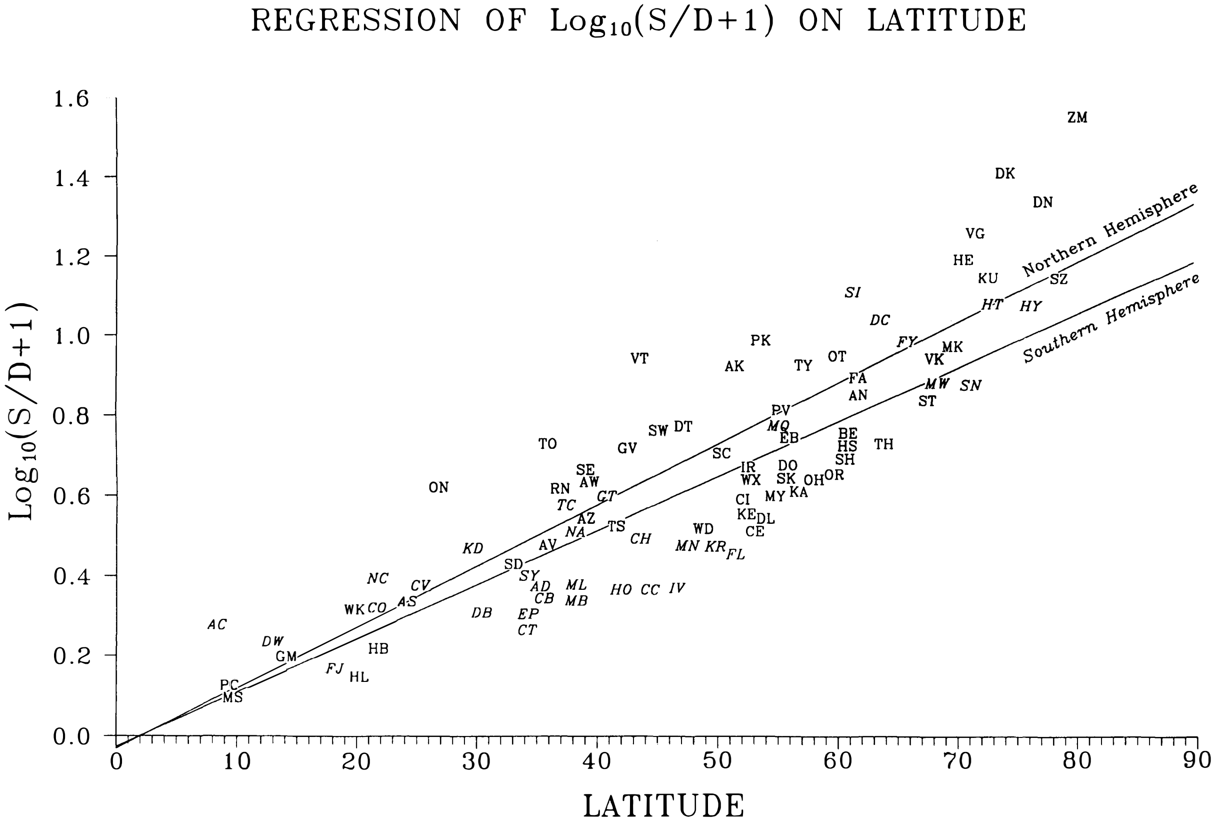

Fig. 5: S/D values transformed to $\text{Log}_{10}(S/D+1)$ regressed on latitude for 60 northern (upright code lettering) and 40 southern hemisphere (italic code) sites in which temperatures were sampled 3-hourly or less, over continuous periods of 4 years or more. Some codes omitted or moved slightly to avoid overlapping, but regression lines and equations calculated on correct values of all 100 sites. For alphabetical key to codes see Appendix 3

Regression der logarithmisch transformierten Quotienten aus Jahres- und Tagesschwankung (S/D) auf die geographische Breite der Stationen

generally occur in August or February (depending on hemisphere), but irregularity in the seasonal timing of the warmest and coldest periods of the year are greater in low than in high altitudes. Apparent anomalies in the diurnal timing of temperature peaks and troughs can not be inferred from these diagrams because of unrecorded differences between sun times and local clock times at some sites, and the seasonal adoption of "daylight saving" time in higher latitudes.

To measure the trends in temperature fluctuation, a standard 12 × 12 grid is imposed on each thermoisopleth diagram (Fig. 2). The number of intersections between the thermoisopleths themselves and the 12 horizontal gridlines was used as a measure of the vertical trend or *seasonality* (S) of a site. Similarly, the number of intersections between the thermoisopleths and the 12 vertical (monthly) gridlines is used as a measure of their horizontal trend, or *diurnality* (D). In this way, S and D values were taken from each of the 209 diagrams in the data set.

The paired values of S and D are plotted for all sites in Fig. 3. This ordination suggests that broad categories of thermal climates may be recognized worldwide, based solely on the measured seasonal and diurnal trends in their air temperature regimes, irrespective of the recorded levels of temperature. Any attempt at a formal classification of thermal climates based on S:D relationships can not be drawn from these data, because of their uneven geographical cover – particularly the inadequate representation of inland and high altitude sites. The data from which the computer-generated diagrams were compiled are not homogeneous. They have been collected over different spans of years, and the air temperatures themselves been sampled at different time intervals (hourly, 3-hourly, 6-hourly) within these different time-spans. With the exception of some older Scandinavian data (BIRKELAND 1935: sites AA, BE, HE, TH, KR, SZ), and two sites with very short time spans (AR, VR), all computer-made diagrams cover periods of between 3 and 40 years since the 1940's.

If this method of measuring thermal seasonality and diurnality from thermoisopleth trends has any validity, S/D values might be expected to show some consistent relationship to latitude. Fig. 4 displays this relationship for all sites: their clustering suggests that Northern sites show more marked deviations from the S/D values which might be expected from their latitudes than those in the Southern Hemisphere. But these data as a whole are not homogeneous. Log-transformed values of S/D regressed on latitude for 100 sites whose thermoisopleth diagrams are based on 4 or more years of temperature readings sampled at 3-hourly intervals or less, gave similar values for both hemispheres (Fig. 5):

NH: $\mathrm{Log10}\,(S/D + 1) = 0.0152\mathrm{Lat} - 0.0306$, $r^2 = 0.72$, $n = 60$;

SH: $\mathrm{Log10}\,(S/D + 1) = 0.0135\mathrm{Lat} - 0.0261$, $r^2 = 0.75$, $n = 40$.

Continentality and oceanity

A surface factor of climate that has long been a favourite of climatologists is continentality, which STRINGER (1972) defined as: "the degree to which a given climate is controlled by the physical nature of an extensive land surface, rather than by the physical nature of an extensive sea surface". He added that "continentality is usually measured as a function of the sea surface temperature of a location" - but thus defined, places remote from the sea can hardly be assigned a value. TUKHANEN (1980) considered that oceanity ("maritimity") was the reciprocal of continentality, so that values for the two concepts form a continuum, and asserted: "there is no simple unit in which the degree of continentality may be measured in any unambiguous way ... continentality and maritimity can not be expressed absolutely, although one may well attempt to set up some relative determination". He summarized attempts by European authors to establish indices of continentality. The purely thermal components of such indices use various measures of temperature range, with seasonal and diurnal phase lags, and anomalies from latitudinal mean values at the sites considered. Constants are usually assigned to provide a range of decimalized index values up to 10 or 100 for the most extreme continental sites. Many such indices incorporate the latitude of the site in question in the divisor, so as to exclude purely latitudinal effects from the index itself (CONRAD 1946).

Since thermoisopleth diagrams incorporate much data on the timing and amplitude of air temperatures experienced at different places, they should also provide a good vehicle for measurement of the thermal component of the continentality/oceanity continuum. Qualitatively, places with continental climates have close-spaced thermoisopleths, their diagrams resembling contour maps of steep mountainous country. In contrast, places with oceanic climates have widely spaced thermoisopleths, with diagrams resembling a contour map of an undulating landscape.

To quantify this concept relating "steepness" of the thermal climate to continentality, counts of the intercepts between the thermoisopleths and the standard 12 x 12 gridlines used to measure S and D values, are combined. The index of continentality (C) is expressed as the hypotenuse of triangle in which S and D are the other two sides:

$$\text{i.e. } C = \sqrt{S^2 + D^2}\ .$$

In the ordination of S and D values (Fig. 3), the value of the continentality index, C, of any site is thus equal to the distance from the origin of the plot to the plotted position of the site itself. Extreme oceanic climates, with values of C = <100 cluster near the origin:

No	Code	Island and Ocean	Latitude	C
88	MS	Kwajalein, Marshall Is., Pacific	9.25°N	72
98	CK	Cocos Keeling Is., Indian Ocean	12.20°S	77
24	MQ	Macquarie Is., Southern Ocean	54.50°S	82
94	GM	Guam, Mariana Is., Pacific	13.58°N	82
100	CA	Diego Garcia, Chagos, Indian Oc.	6.57°S	90
210	ha	Hao Atoll, Tuamotu Is., Pacific	18.10°S	91
95	NU	Nauru, Western Pacific	0.57°S	94

Continental climates spread out to the most extreme values, with C = >1000, for the Siberian sites (off the plot in Fig. 3):

No	Code	Site	Latitude	C
141	KU	Khatanga, North Siberia, USSR	71.98°N	1103
234	sa	Sagastyr, North Siberia, USSR	73.40°N	1133
212	ik	Irkutsk, South Siberia, USSR	52.30°N	1203
150	VK	Verkhoyansk, Yakutskaya, USSR	67.55°N	1510

Table 1: Selected sites outside the tropics
Ausgewählte Klimastationen außerhalb der Tropen

No.	Code	Island or coastal site	Latitude	C	C/1510%
25°–30°					
87	MD	Midway Island	28.20°N	190	13
92	ON	Okinawa, Ryukyu Islands	26.53°N	313	21
91	EA	Easter Island	27.08°S	151	10
82	NF	Norfolk Island	29.07°S	170	11
89	KD	Raoul Island, Kermadecs	29.25°S	162	11
30°–35°					
104	BM	Bermuda	32.40°N	306	20
83	LH	Lord Howe Island	31.53°S	184	12
33	JF	Rob. Crusoe, Jn. Fernandez	33.62°S	158	10
35°–40°					
105	AZ	Terciera, Azores	38.75°N	202	13
32	TC	Tristan da Cunha	37.02°S	164	11
31	NA	Amsterdam Island	37.80°S	147	10
c. 50°–55°					
106	SC	St. Marys, Scilly Islands	49.93°N	210	14
155	AL	Adak Island, Aleutians	51.83°N	249	16
27	FL	Pt. Stanley, Falklands	51.10°S	184	12
28	CM	Campbell Island	52.30°S	117	8
36	EV	Evangelistas, Chile	52.40°S	126	8
20	HD	Heard Island	53.00°S	114	8
c. 55°–60°					
115	OH	Benbecula, Hebrides, Scotld.	57.47°N	219	15
116	OR	Kirkwall, Orkney, Scotland	58.95°N	224	15
117	SH	Lerwick, Shetland, Scotland	60.13°N	220	15
118	FA	Akraberg, Faeroe Islands	61.24°N	158	10
26	DG	Diego Ramirez, Drake Passage	56.53°S	115	8
19	SI	Signy Island, S. Orkney	60.90°S	271	18
18	LA	Laurie Island, S. Orkney	60.75°S	275	18
65°–70°					
120	JM	Jan Mayen, Arctic Ocean	70.98°N	282	19
152	VG	Vrangela Is, Arctic Ocean	70.97°N	693	46
9	HR	Horseshoe Is, Antarctic Pen.	67.82°S	425	28
5	SN	SANAE Base, Antarctica	70.50°S	567	38

If these C-values based on thermoisopleth intercepts are scaled to 100% over a range from zero to 1510 (Verkhoyansk, the most continental), no site in the Southern Hemisphere considered here exceeds 50% continentality, except for the South Pole (where C = 774:51%). Outside the tropics, the greater oceanicity of almost all Southern Hemisphere islands and coastal sites is obvious, when compared to those of corresponding latitudes in Northern Hemisphere. Of the 30 sites with S > D and C < 200, only Faeroe and Midway Islands, are situated in the Northern Hemisphere.

Twenty-eight islands and coastal sites outside the tropics are grouped in six latitudinal belts (Table 1), within each of which the C values for the northern exceed those for the southern sites, except Faeroe and Jan Mayen in the North Atlantic/Arctic Ocean.

The greater oceanity of remote mid-ocean islands in the Southern Hemisphere is most marked in middle and higher latitudes which are subjected to the full influence of the Antarctic Circumpolar Current. Away from the northern continents, the low C values for Faeroe and Jan Mayen illustrate the more limited moderating influence of the North Atlantic Drift.

Only the islands near the Antarctic Peninsula in the South Atlantic (Signy, Laurie) have more continental thermal climates than their latitudinal equivalents in the North Atlantic. Vrangela Island, in the ice-choked Arctic Ocean, has a more continental thermal climate than the coast of the Antarctic continent at SANAE in the corresponding south latitude. Within the tropics, continentality as measured by thermoisopleth spacing, is more similar in northern and southern hemispheres. Tropical sites where D > S and C < 200 are found in both hemispheres.

This greater oceanity of thermal climates in the middle and higher latitudes in the Southern Hemisphere, compared to their latitudinal counterparts in the Northern Hemisphere has been little emphasised in previous attempts to measure continentality on a global basis. IVANOV (1959) developed a measure of continentality based on seasonal and diurnal air temperature fluctuations and humidity, but his plot of the global distribution of continentality ("K") puts Central Australia in the same category as Eastern Siberia and the Sahara. IVANOV's K values and my C values derived from thermoisopleth diagrams for the same places, are compared below, with scaling up to 100% for Verkhoyansk.

	K: IVANOV		C: WACE	
Alice Springs	229	97%	511	34%
Timbuktu	250	105%	529	35%
Irkutsk	191	81%	1203	80%
Verkhoyansk	237	100%	1510	100%

CONRAD (1946) derived empirical formulae for calculating coefficients of continentality, based only on latitude and average annual ranges of temperature at different Eurasian sites, and selecting constants to give a range of percentage values from 0% at Thorshavn, Norway (62°N; near Trondheim: TH, 63.40°N), to 100% at Verkhoyansk (VK). Many Southern Hemisphere sites would yield negative continentality coefficients, using CONRAD's formula.

An index expressing the *relationship* between seasonal and diurnal temperature fluctuations (as suggested here), rather than the *ranges* of recorded temperature levels, in which the seasonal and diurnal inputs are mixed up, is more likely to yield measures of continentality which are useful globally. Hemispheric differences in continentality, which are fundamentally due to the global distribution of land and sea, have important bioclimatic correlates (e.g. distribution of evergreen and deciduous forests). World-wide measurement of continentality may also help to explain the ability of temperate species introduced from one hemisphere to adapt to the thermal regimes of the other.

Time/temperature relationships

The above analyses of air temperature regimes have used the form of the thermoisopleths (without regard to the actual levels of temperature measured), as expressions of the thermal seasonality and diurnality, and hence the continentality-oceanity of the different sites. Used thus, thermoisopleth diagrams have nothing to say about the apportionment of time spent above or below particular levels of temperature. Because a thermoisopleth diagram models the overall experience of air temperature levels (as reduced to mean values) in a time framework, direct measurement of the *areas* lying between the isopleths enables the relative *times* spent between specified levels of mean temperature to be discovered. These areas lying between the 1 °C thermoisopleths, have been plotted as frequency histograms, which show the percentage of the year spent between different temperature levels (Fig. 6, Supplement XIV). The different form of these time/temperature histograms, especially as between the extreme oceanic and extreme continental sites, is obvious. The narrow steep-sided histograms of the bland invariable thermal climates in oceanic islands, are quite different to the extended (and potentially more stressful) thermal climates on the continents.

Visual display of the extent to which different sites overlap in their experience of ambient air temperature (irrespective of seasonal or diurnal apportionment) can be made by comparing these histograms when arranged in register (Fig. 6, Supplement XIV). The degree of time/temperature overlap between the histograms can be used to measure similarities between thermal climates. Times spent above or below critical temperatures are important in controlling the rates of many physical and biological processes, and therefore of many human activities at the surface of the earth.

The data used to compile these time/temperature histograms, which are based on frequent sampling of the air temperatures experienced at different sites, provides better comparisons between those sites than the "heat sums" of agriculturalists and engineers, who use mean temperature levels based on daily maxima and minima. Their "day-degrees" are calculated by subtracting a base temperature (for crop growth, or the heating/cooling of buildings) from daily mean temperatures, and accumulating the positive or negative values. Monteith (1981) observed that "day-degrees" are less useful in oceanic climates where air temperatures stay close to base temperatures for crop growth (as in Britain), than in continental climates. Time/temperature histograms derived from thermoisopleth diagrams may thus have an important practical use in predicting crop growth, especially in oceanic climates.

Summary: uses of thermoisopleth models

The integration of time and temperature experience in the form of descriptive isopleth models, has a number of theoretical and practical applications:

a) Contributing to the understanding of the nature of temperature flux at the earth's surface

Analyses of thermoisopleth diagrams, as described here, can lead to the quantification of climatic concepts such as thermal seasonality, diurnality, and the continentality-oceanity continuum. In diagrams covering the temperature experience of a number of years, these are of use in comparative climatology and climate classification. Their most important value in the study of thermal climates may be to quantify the characteristics of thermal climate such as seasonality and continentality, independently of the levels of temperature actually recorded.

When compiled on a year-by-year basis, as a continuous strip-chart, thermoisopleth diagrams can display changes in the structure of thermal climates over short periods of time, which are difficult to demonstrate or display digitally. For the periods over which continuous hourly or three-hourly data are now becoming available, the display of these changes can be demonstrated as local "heat island" effects with the growth of industrial cities; or more widely as regional or global changes which are probably related to the effects of "greenhouse gases" in the atmosphere. Most studies of changing global temperatures concentrate on trends in measured temperature levels: but analyses of serial thermoisopleth diagrams reveal changes in the seasonal and diurnal structure whithin which temperature levels fluctuate.

b) Bioclimatology

The thermoisopleth diagrams displayed here are based on *mean* temperatures, over varying periods of time. There are limits to which the data derived from any analyses of *mean* temperatures, can be used to explain the temperature requirements of sedentary species, because "A plant does not . . . experience a mean temperature; it experiences the continually changing temperatures from which the mean is computed" (Carter a. Prince 1985). Nor can these methods of portraying mean temperatures be applied to the thermal regimes which such organisms actually experience at ground level (rather than the standard conditions within a Stevenson screen). Nevertheless, thermoisopleth data are useful in comparing the climatic experiences of similarly-adapted groups of organisms or vegetation, and in comparing the thermal component of the climatic ranges of economic plants and animals and their pests in different parts of the world.

A particular use of thermoisopleth data is in the more accurate measurement of thermal time, as *'day degrees'* (Monteith 1981). Estimates of "thermal time" spent above or below any particular temperature will be more reliable if based on the hourly or three-hourly recording of surface temperatures (such as are incorporated into a thermoisopleth diagram), than those based only on mean temperatures derived as mid-points between extreme values.

c) Controlled environments

Space heating in buildings occupied by humans has been considered by a leading authority to be: "a necessity, where average daily temperatures fall for appreciable periods of time below 18 °C" (Landsberg 1976), and cooling is thought to be desirable when temperatures rise above such a threshold, in some types of buildings (at least in prosperous societies addicted to a profligate use of energy).

At present, energy demands for such heating and cooling are assessed by the summation of heating or cooling degree days, which lie respectively below or above the threshold levels adopted. Thermoisopleth diagrams should provide a better estimate of the heating and cooling requirements for buildings whose thermal inertia is understood. In more closely-controlled environments (such as a phytotron) the data recorded in thermoisopleth diagrams could be used to drive heating and cooling systems, and thus to mimic the thermal conditions for any chosen location from which long runs of hourly temperatures are available.

d) Display of thermal climates for travellers

Anybody who can understand a contour map can read a thermoisopleth diagram. Especially when colour-coded, they can give an idea of the ambient temperatures to expect at any part of the earth's surface, at any time of year, and at any time of day or night. They give better, and easily comprehended, expectations of the thermal conditions at their destinations, than figures of mean and extreme temperatures which are generally quoted to travellers. Coloured thermoisopleth diagrams could be provided to intending air-travellers, or even used as informative decoration to adorn the walls of airports, and thus find a place in the travel industry.

e) Further developments

This paper has been concerned only with the two-dimensional display of mean dry-bulb air temperatures, and the abstractions derived from those displays. Other climatic data which vary both diurnally and seasonally, may be portrayed in this way, and such portrayals will have applications which are not apparent in digital presentation of the same data. Time-based isopleth models of different percentile experiences of dry-bulb or wet-bulb temperatures, relative humidity, sultriness (TILLEY 1988), or the various spectral components of solar radiation, will all have different applications. Dry-bulb temperatures are easy to measure, and such data have been accumulated for a long time, but with modern methods of environmental sensing, and the automatic recording and handling of data by computer, two-dimensional isopleth displays of a range of data are now easier to assemble and analyse than hitherto.

Using a range of climate data, LECHOWICZ a. ADAMS (1978) stated: "... graphical analysis ... effectively condenses and displays information on the temporal structures of climate ... More traditional methods, such as synthetic indices, climate diagrams, tables, or simple bivariate graphs, are useful in biological analyses of climate patterns, *but only the contour plot can illustrate changes in a variable through the day and across the seasons simultaneously* ... Contour graphs of means and standard deviations can illustrate the temporal structure of a climate. Such graphs provide a detailed basis for comparing climatic regimes, and the analysis of adaptive strategies."

The thermoisopleth diagrams presented here, are one such species of diurnal/seasonal "contour plot". Computerized extension of this method of data presentation and analysis, and its employment for both theoretical and practical purposes, is now much easier than it was when CARL TROLL described its bioclimatic uses. Isopleth modelling in a time framework could be more widely employed to analyse any climatic phenomena which fluctuate simultaneously on a diurnal and a seasonal basis.

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Appendix 1: Details of sites and data base for computer-plotted thermoisopleth diagrams

Indices tabulated are those for seasonality (S), diurnality (D), S/D, and continentality (C).

Two-letter codes to sites (as used in Fig. 3) are listed alphabetically in Appendix 3. For codes to sources of data, see Appendix 4.

Merkmale der Meßstationen und Datengrundlagen für die computer-erzeugten Thermoisoplethen-Diagramme

No.	Situation	Code	Lat.	Alt. (m.)	Hrs	Years no.	Years dates	Mean (°C)	Median (°C)	S	D	S/D	C	Source
Antarctic Continental Shield														
1	Amundsen Scott Base SOUTH POLE	OO	90.00°S	2800	6	23	1957-79	-49.21	-55.67	780	20	39.00	780	J
2	American Base McMURDO SOUND Ross Sea Coast	MM	77.70°S	8	6	5	1973-77	-17.26	-21.31	572	22	26.00	572	J
3	American Base HALLETT Ross Sea Coast	HT	72.32°S	5	3	16	1957-72	-15.26	-17.92	614	54	11.37	616	J
4	British Base HALLEY BAY Weddel Sea Coast	HY	75.52°S	31	3	10	1972-81	-18.03	-18.98	607	54	11.24	609	A

No.	Situation	Code	Lat.	Alt. (m.)	Hrs	Years no.	Years dates	Mean (°C)	Median (°C)	S	D	S/D	C	Source
5	South African Base SANAE Atlantic Coast	SN	70.50°S	62	1	10	1971–80	−16.73	−18.23	561	83	6.76	567	M
6	Australian Base DAVIS Indian Ocean Coast	DV	68.58°S	12	3	6	1958–63	−10.47	−12.84	404	39	10.36	406	C
7	Australian Base MAWSON Indian Ocean Coast	MW	67.60°S	8	3	12	1956–67	−11.10	−14.37	438	64	6.84	442	C
8	Australian Base WILKES Indian Ocean Coast	WL	66.25°S	12	3	7	1961–67	−9.53	−12.70	374	44	8.50	377	C
Antarctic Peninsula and Islands														
9	British Base HORSESHOE ISLAND Antarctic Peninsula	HR	67.82°S	9	3	4	1956–59	−6.85	−6.69	424	34	12.47	425	A
10	British Base FARADAY Antarctic Peninsula	FY	65.25°S	10	3	10	1972–81	−4.19	−3.73	277	31	8.94	279	A
11	Argentine Base ALMIRANTE BROWN Antarctic Peninsula	AB	64.88°S	18	6	5	1973–76 1978	−2.40	−2.13	220	32	6.88	222	F
12	Argentine Base MARAMBIO Antarctic Peninsula	MR	64.23°S	6	6	5	1973–76 1978	−7.72	−7.54	364	34	10.71	366	F
13	Argentine Base ESPERANZA Antarctic Peninsula	ES	63.40°S	10	6	5	1973–76 1978	−5.82	−5.88	324	38	8.53	362	F
14	British Base HOPE BAY Antarctic Peninsula	HP	63.40°S	53	3	7	1953–59	−6.02	−5.89	288	42	6.86	291	A
15	British Base DECEPTION ISLAND South Shetland	DC	62.98°S	8	3	11	1951–61	−2.86	−2.30	226	22	10.27	227	A
16	Eduardo Frei Base KING GEORGE ISLAND South Shetland	KN	62.20°S	9	6	10	1971–80	−2.55	−1.78	232	19	12.21	233	D
17	British Base KING GEORGE ISLAND South Shetland	KG	62.08°S	9	3	9	1951–56 1958–60	−2.75	−2.07	214	24	8.92	215	A
18	Argentine Base LAURIE ISLAND South Orkney	LA	60.75°S	3	6	5	1972–74 1976–78	−3.97	−2.30	274	24	11.42	275	F
19	British Base SIGNY ISLAND South Orkney	SI	60.90°S	22	3	10	1951–60	−3.45	−1.97	270	22	12.27	271	A
Southern Ocean Islands														
20	Atlas Cove HEARD ISLAND S. Indian Ocean	HD	53.00°S	5	3	7	1948–54	1.12	1.20	110	29	3.79	114	C
21	Grytviken SOUTH GEORGIA South Atlantic	SG	54.28°S	2	3	10	1972–81	2.05	2.20	192	56	3.43	200	A
22	Port aux Francais KERGUELEN S. Indian Ocean	KR	49.33°S	14	3	17	1951–67	4.08	3.66	141	66	2.14	156	E
23	Isle de la Possession CROZET ISLANDS S. Indian Ocean	CR	46.43°S	142	3	9	1973–81	4.84	4.50	114	40	2.85	121	E
24	Buckles Bay MACQUARIE ISLAND S.W. Pacific	MQ	54.50°S	6	3	12	1957–68	4.71	4.20	80	16	5.00	82	C

No.	Situation	Code	Lat.	Alt. (m.)	Hrs	Years no.	Years dates	Mean (°C)	Median (°C)	S	D	S/D	C	Source
25	South African Base MARION ISLAND S. Indian Ocean	MN	46.90°S	23	2	12	1949–60	5.09	4.85	101	48	2.10	112	M
26	Drake Passage DIEGO RAMIREZ IS. S.E. Pacific	DG	56.53°S	42	6	5	1976–80	5.06	5.01	112	24	4.67	115	D
27	Port Stanley FALKLAND ISLANDS South Atlantic	FL	51.10°S	53	3	10	1951–60	5.50	5.28	164	84	1.95	184	A
28	Perserverance Harbour CAMPBELL ISLAND S.W. Pacific	CM	52.30°S	15	1	11	1971–81	7.10	6.70	110	41	2.68	117	K
29	Waitangi CHATHAM ISLAND S.W. Pacific	CH	43.15°S	48	1	10	1970–80	11.22	11.15	158	71	2.23	173	K
30	Transvaal Bay GOUGH ISLAND South Atlantic	GT	40.35°S	54	1	10	1966–75	11.46	11.27	140	45	3.11	147	M
31	French Base NEW AMSTERDAM S. Indian Ocean	NA	37.80°S	27	3	17	1951–67	13.25	12.94	136	56	2.43	147	E
32	Settlement TRISTAN DA CUNHA South Atlantic	TC	37.02°S	23	1	10	1943–47 1956–60	14.36	13.88	156	52	3.00	164	M
33	Isla Robinson Crusoe JUAN FERNANDEZ S.E. Pacific	JF	33.62°S	30	6	10	1971–80	15.46	15.35	144	64	2.25	158	D
Southern South America														
34	Beagle Channel USHUAIA Argentina	US	54.80°S	14	6	5	1971–75	5.61	5.99	206	99	2.08	229	F
35	Magellan Straits PUNTA ARENAS Chile	PA	53.00°S	37	6	10	1971–80	5.88	5.84	218	102	2.14	241	D
36	Magellan Straits EVANGELISTAS Chile	EV	52.40°S	52	6	5	1976–80	6.80	6.70	124	23	5.39	126	D
37	Airport RIO GALLEGOS Argentina	RL	51.62°S	17	6	5	1971–75	7.25	7.20	310	166	1.87	352	F
38	Airport COMODORO RIVADAVIA Argentina	RD	45.78°S	61	6	5	1971–75	12.51	12.97	288	155	1.86	327	F
39	Llanquihue Province PUERTO MONTT Chile	PT	41.43°S	83	6	10	1971–80	10.06	9.63	188	152	1.24	242	D
40	Airport BAHIA BLANCA Argentina	BB	38.73°S	83	6	5	1971–75	14.86	14.48	376	230	1.63	441	F
41	Airport MAR DEL PLATA Argentina	MP	37.93°S	24	6	5	1971–75	14.02	13.78	286	187	1.53	342	F
42	CONCEPCION Chile	CN	36.77°S	13	6	10	1971–80	12.40	12.19	188	178	1.06	259	D
43	VALPARAISO Chile	VL	33.02°S	41	6	10	1971–80	13.83	13.55	122	76	1.61	144	D
New Zealand														
44	INVERCARGILL South Island	IV	46.40°S	1	1	10	1960–69	9.57	9.70	206	144	1.43	251	K
45	DUNEDIN South Island	DU	45.90°S	1	1	7	1963–69	9.95	9.90	246	180	1.37	305	K

No.	Situation	Code	Lat.	Alt.	Hrs	Years		Mean	Median	S	D	S/D	C	Source
				(m.)		no.	dates	(°C)	(°C)					
46	HOKITIKA South Island	HK	42.70°S	37	1	5	1965–69	11.24	11.60	212	134	1.58	251	K
47	CHRISTCHURCH South Island	CC	43.55°S	30	1	10	1960–69	11.34	11.50	260	184	1.41	319	K
48	KAIKOURA South Island	KK	42.40°S	99	1	4	1964–69	11.69	11.40	216	86	2.51	232	K
49	NELSON South Island	NL	41.30°S	2	1	8	1962–69	12.05	12.60	274	172	1.59	324	K
50	WELLINGTON North Island	WE	41.30°S	126	1	8	1962–69	12.27	11.96	194	87	2.23	213	K
51	NEW PLYMOUTH North Island	NP	39.05°S	27	1	8	1962–69	13.19	12.96	204	130	1.57	242	K
52	GISBORNE North Island	GS	38.70°S	4	1	8	1962–69	13.85	13.65	232	182	1.27	295	K
53	ROTORUA North Island	RT	38.10°S	287	1	5	1964–69	12.20	12.15	246	172	1.43	300	K
54	AUCKLAND North Island	AU	36.90°S	45	1	8	1962–69	15.11	14.85	198	98	2.02	221	K
55	KAITAIA North Island	KT	35.10°S	80	1	8	1962–69	15.04	14.75	190	131	1.45	231	K
Southern Africa														
56	Malan Airport CAPETOWN South Africa	CT	33.80°S	44	1	24	1957–80	16.12	16.30	208	211	0.99	296	M
57	EAST LONDON South Africa	EL	33.03°S	125	1	40	1941–80	18.05	18.55	152	151	1.01	214	M
58	Central Cape VICTORIA WEST South Africa	VW	31.40°S	1257	1	5	1933–36 1950–52	14.55	14.50	388	385	1.01	547	M
59	Louis Botha Airport DURBAN South Africa	DB	29.97°S	8	1	24	1957–80	20.37	21.10	194	175	1.11	261	M
60	N.W. Cape Province O'OKIEP South Africa	OK	29.60°S	930	1	5	1932–36	17.19	16.90	270	283	0.98	397	M
Australia a. Papua New Guinea														
61	HOBART Southern Tasmania	HO	42.83°S	4	3	13	1959–71	12.19	12.35	208	148	1.41	255	C
62	Atmospheric Baseline Monitoring Station CAPE GRIM N.W. Tasmania	CG	40.68°S	21	1	5	1978–80	12.28	12.32	142	50	2.84	151	C
63	MELBOURNE Southern Australia	ML	37.82°S	35	3	17	1955–71	14.87	14.56	254	172	1.48	307	C
64	MT. GAMBIER Southern Australia	MB	37.75°S	65	3	10	1971–80	13.24	12.56	216	172	1.26	276	C
65	Airport CANBERRA Eastern Australia	CB	35.20°S	571	3	19	1952–70	12.57	12.35	354	257	1.38	437	C
66	ALBANY Western Australia	AY	34.95°S	71	3	10	1971–80	14.84	14.48	194	164	1.18	254	C
67	RAN Air Station NOWRA Eastern Australia	NW	34.95°S	109	3	10	1971–80	16.00	16.19	246	174	1.41	301	C
68	ADELAIDE Southern Australia	AD	34.94°S		1	20	unstated	16.43	15.89	284	203	1.40	349	U
69	SYDNEY Eastern Australia	SY	33.93°S	6	3	20	1952–71	17.21	18.06	254	158	1.61	299	C
70	ESPERANCE Southern Australia	EP	33.82°S	25	3	10	1971–80	16.01	16.04	188	172	1.09	255	C
71	CEDUNA Southern Australia	CD	32.13°S	23	3	5	1946–50	16.54	16.54	252	232	1.09	343	C

No.	Situation	Code	Lat.	Alt. (m.)	Hrs	Years		Mean (°C)	Median (°C)	S	D	S/D	C	Source
						no.	dates							
72	PERTH Western Australia	PE	31.90°S		1	5	unstated	17.85	17.56	254	198	1.28	322	U
73	COFF'S HARBOUR Eastern Australia	CF	30.32°S	5	3	8	1973–80	18.49	19.07	248	152	1.63	291	C
74	BRISBANE Eastern Australia	BR	27.05°S	10	1	5	unstated	20.04	20.60	250	197	1.27	318	U
75	CARNARVON Western Australia	CV	24.88°S	4	3	10	1971–80	21.89	21.99	268	182	1.47	324	C
76	ALICE SPRINGS Central Australia	AS	23.82°S	545	3	10	1970–79	20.51	20.60	399	320	1.25	522	C
77	TOWNSVILLE Eastern Australia	TV	19.25°S	5	3	10	1971–80	23.91	24.57	198	164	1.21	257	C
78	Airport DARWIN Northern Australia	DW	12.42°S	31	3	10	1970–79	27.24	27.38	126	162	0.78	205	C
79	THURSDAY ISLAND Torres Strait	TI	10.58°S	58	3	6	1971–76	26.12	26.20	84	72	1.17	111	C
80	MADANG Papua New Guinea	MG	5.22°S	4	3	6	1968–73	26.48	26.34	26	138	0.19	140	C
81	PORT MORESBY Papua New Guinea	PM	9.45°S	35	3	6	1968–73	26.29	25.98	52	156	0.34	164	C
82	NORFOLK ISLAND S.W. Pacific	NF	29.07°S	113	3	5	1977–81	18.68	18.55	158	64	2.47	170	C
83	LORD HOWE ISLAND S.W. Pacific	LH	31.53°S	5	3	5	1977–81	19.31	18.99	176	52	3.38	184	C
	Pacific Ocean: Tropical a. Subtropical Islands													
84	Hilo HAWAII North Pacific	HL	19.72°N	11	3	19	1949–67	22.44	22.22	67	144	0.46	159	J
85	Barbers Point OAHU North Pacific	HB	21.30°N	10	3	22	1949–70	23.84	23.58	92	128	0.72	158	J
86	Airport WAKE ISLAND North Pacific	WK	19.30°N	3	3	19	1946–47 1949–65	26.55	26.64	78	68	1.15	103	J
87	MIDWAY ISLAND North Pacific	MD	28.20°N	4	3	5	1973–77	22.50	22.33	173	79	2.19	190	J
88	Kwajalein Atoll MARSHALL ISLANDS North Pacific	MS	9.25°N	8	3	29	1944–72	27.66	27.19	20	69	0.29	72	J
89	Raoul Island KERMADEC GROUP S.W. Pacific	KD	29.25°S	40	1	11	1971–81	19.10	19.10	146	71	2.06	162	K
90	Rarotonga Airport COOK ISLANDS South Pacific	CO	21.25°S	7	1	11	1970–80	24.26	24.30	104	89	1.17	137	K
91	Mataveri Airport EASTER ISLAND S.E. Pacific	EA	27.08°S	40	6	17	1963–79	20.64	20.41	124	86	1.44	151	D
92	Kadena Airbase OKINAWA Ryukyu Islands	ON	26.35°N	42	3	10	1968–78	22.11	22.58	300	90	3.33	313	J
93	Bataan LUZON Philippine Islands	LZ	14.78°N	17	3	5	1973–77	27.58	27.08	113	157	0.72	193	J
94	Andersen Airport GUAM Mariana Islands	GM	13.58°N	192	3	10	1968–78	26.36	26.17	44	69	0.64	82	J
95	NAURU Western Pacific	NU	0.57°S	26	3	6	1968–73	27.88	27.77	32	88	0.36	94	C

No.	Situation	Code	Lat.	Alt. (m.)	Hrs	Years no.	Years dates	Mean (°C)	Median (°C)	S	D	S/D	C	Source
96	Nandi FIJI South Pacific	FJ	17.78°S	19	1	10	1960-69	24.95	24.70	94	177	0.53	200	K
97	Noumea NEW CALEDONIA S.W. Pacific	NC	21.27°S	70	3	30	1951-80	22.69	22.55	148	94	1.57	175	L

Indian a. Atlantic Oceans: Tropical and Subtropical Islands

No.	Situation	Code	Lat.	Alt. (m.)	Hrs	Years no.	Years dates	Mean (°C)	Median (°C)	S	D	S/D	C	Source
98	West Island Airport COCOS KEELING Eastern Indian Ocean	CK	12.20°S	3	3	5	1977-81	26.40	26.36	53	56	0.95	77	C
99	Ile Picard, Seychelles ALDABRA Western Indian Ocean	AR	9.40°S	4	1	2	1973-75	25.87	25.70	98	92	1.06	134	V
100	Diego Garcia CHAGOS ARCHIPELAGO Central Indian Ocean	CA	6.57°S	3	3	5	1973-77	26.70	26.31	46	77	0.60	90	J
101	Bottom Wood St. HELENA South Atlantic	BW	15.93°S	435	3	4	1976-80	17.50	17.30	120	55	2.18	132	B
102	Airport ASCENSION ISLAND South Atlantic	AC	7.97°S	86	3	17	1942-47 1957-67	24.66	24.58	89	92	0.97	128	J
103	Roosevelt Roads PUERTO RICO Caribbean	PU	18.25°N	12	3	5	1973-77	26.30	26.22	92	101	0.91	137	J
104	St. George BERMUDA North Atlantic	BM	32.40°N	54	3	5	1973-77	22.45	21.50	241	65	3.71	306	J
105	Lajes, Terciera AZORES North Atlantic	AZ	38.75°N	55	3	11	1971-81	17.26	16.89	188	74	2.54	202	J

Western Europe a. Northeast Atlantic Islands

No.	Situation	Code	Lat.	Alt. (m.)	Hrs	Years no.	Years dates	Mean (°C)	Median (°C)	S	D	S/D	C	Source
106	St. Marys SCILLY ISLES N.E. Atlantic	SC	49.93°N	51	3	10	1968-77	11.30	10.15	204	40	4.25	210	B
107	Roche Point CORK Ireland	CI	51.80°N	40	1	24	1958-81	10.17	9.70	206	68	3.03	217	G
108	Valentia KERRY Ireland	KE	51.93°N	9	1	24	1958-81	10.65	10.30	190	70	2.71	202	G
109	Rosslare WEXFORD Ireland	WX	52.25°N	23	1	24	1958-81	10.10	9.55	214	61	3.51	223	G
110	Shannon Airport CLARE Ireland	CE	52.68°N	3	1	24	1958-81	10.04	9.70	236	100	2.36	256	G
111	Galway Town GALWAY Ireland	GL	53.28°N	18	1	3	1978-81	9.41	8.65	250	86	2.91	264	G
112	Airport DUBLIN Ireland	DL	53.43°N	68	1	24	1958-81	9.48	9.15	236	90	2.62	253	G
113	Belmullet MAYO Ireland	MY	54.23°N	9	1	24	1958-81	9.81	9.45	202	65	3.11	212	G
114	Malin Head DONEGAL Ireland	DO	55.37°N	20	1	24	1958-81	9.38	8.80	212	56	3.79	219	G
115	Benbecula OUTER HEBRIDES N.E. Atlantic	OH	57.47°N	6	3	10	1968-77	8.74	8.11	211	60	3.52	219	B

No.	Situation	Code	Lat.	Alt. (m.)	Hrs	Years no.	Years dates	Mean (°C)	Median (°C)	S	D	S/D	C	Source
116	Kirkwall ORKNEY ISLANDS N.E. Atlantic	OR	58.95°N	26	3	10	1968–77	7.72	7.00	216	59	3.66	224	B
117	Lerwick SHETLAND ISLANDS N.E. Atlantic	SH	60.13°N	82	1	10	1968–77	6.94	6.20	214	50	4.28	220	B
118	Akraberg FAEROE ISLANDS N.E. Atlantic	FA	61.24°N	95	3	18	1962–79	6.38	5.70	156	22	7.09	158	I
119	Keflavik ICELAND	KF	63.97°N	51	3	5	1973–77	4.40	4.53	250	40	6.25	253	J
120	JAN MAYEN Arctic Ocean	JM	70.98°N	23	1	9	1882–83 1921–27	1.15	2.34	282	26	10.85	282	Y
Mainland Scandinavia														
121	ALBORG Denmark	AG	57.10°N	3	3	10	1970–79	7.69	7.11	390	109	3.58	405	I
122	ALTA Norway	AA	69.97°N	7	1	3	1882–83 1924–25	0.61	−0.04	502	64	7.84	506	Y
123	BERGEN Norway	BE	60.40°N	43	1	35	1896– 1931	7.00	6.74	316	68	4.65	323	Y
124	ESBJERG Denmark	EB	55.50°N	11	3	10	1970–79	8.33	8.05	394	83	4.75	402	I
125	HALDDE Norway	HE	69.93°N	893	1	13	1913–25	3.72	5.29	422	28	15.07	423	Y
126	HELSINKI Finland	HS	60.32°N	53	1	10	1956–65	4.33	4.70	564	123	4.59	577	Z
127	KARUP, JUTLAND Denmark	KA	56.28°N	52	3	10	1970–79	7.59	6.70	383	119	3.22	401	I
128	KEMI Finland	KM	65.78°N	10	1	5	1956–59	0.81	0.10	676	102	6.63	684	Z
129	MAARIANHAMINA Finland	MA	60.12°N	2	1	10	1956–65	4.96	4.45	486	105	4.63	497	Z
130	PORI Finland	PR	61.47°N	13	1	10	1956–65	4.19	4.55	534	123	4.34	548	Z
131	ROVANIEMI Finland	RV	66.57°N	195	1	5	1956–60	0.18	−1.20	656	93	7.05	663	Z
132	SKRYDSTRUP Denmark	SK	55.23°N	1	3	10	1970–79	7.52	6.65	375	112	3.35	391	I
133	THYBORON Denmark	TY	56.70°N	3	3	10	1970–79	8.47	8.00	377	49	7.69	380	I
134	TRONDHEIM Norway	TH	63.40°N	58	1	35	1896– 1935	4.75	4.17	400	88	4.54	410	Y
135	VAASA Finland	VA	63.05°N	4	1	5	1956–60	3.21	2.80	590	122	4.84	602	Z
136	VARDO Norway	VR	70.37°N	10	1	2	1929–31	0.73	0.11	356	40	8.90	358	Z
137	SPITZBERGEN Arctic Ocean	SZ	78.03°N	11	1	19	1912–30	−7.50	−9.36	588	44	13.36	590	Y
U.S.S.R. a. Japan														
138	ALEKSANDROVSK Sakhalin, USSR	AK	50.92°N	0	1	18	1934–35, 38 + 41–53, 59–60	0.31	2.35	840	110	7.64	847	O
139	DIKSON OST. Arctic Coast, USSR	DK	73.52°N	0	1	28	1933–60	−11.49	−12.05	758	30	25.27	759	O
140	IRKUTSK Irkutskaya, USSR	IR	52.27°N	485	3	10	1959–68	−0.75	−0.30	870	226	3.85	899	J
141	KHATANGA N. Siberia, USSR	KU	71.98°N	24	1	11	1950–60	−13.39	−14.10	1100	82	13.41	1103	O
142	MEDVEZH'I OSTROVA Arctic Ocean, USSR	MZ	70.63°N	6	3	10	1959–68	−13.73	−13.89	772	53	14.57	774	J

No.	Situation	Code	Lat.	Alt. (m.)	Hrs	Years		Mean (°C)	Median (°C)	S	D	S/D	C	Source
						no.	dates							
143	MURMANSK Arctic Coast, USSR	MK	68.97°N	46	3	10	1959-68	0.04	0.08	580	67	8.66	584	J
144	NOVOSIBIRSK SW. Siberia, USSR	NB	55.03°N	162	3	10	1959-68	1.00	1.14	882	155	5.69	896	J
145	OKHOTSK Eastern Coast, USSR	OT	59.48°N	6	1	23	1935, 37-40 + 1942-60	-4.96	-3.75	864	106	8.15	870	O
146	Majak (Lighthouse) PETROPAVLOVSK Kamchatka, USSR	PK	53.05°N	0	1	23	1936-40 1943-60	0.72	0.30	522	58	9.00	525	O
147	PETROPAVLOVSK N. Kazakhastan, USSR	PV	54.83°N	136	3	10	1959-68	1.41	1.86	880	154	5.71	893	J
148	RANG-KUL Tadzhikskaya, USSR	RN	36.47°N	3809	3	10	1959-68	-3.58	-3.42	610	190	3.21	639	J
149	TASHKENT Uzbekistan, USSR	TS	41.27°N	428	3	10	1959-68	14.18	13.82	638	258	2.47	688	J
150	VERKHOYANSK Yakutskaya, USSR	VK	67.55°N	137	3	10	1959-68	-15.69	-15.41	1498	187	8.01	1510	J
151	VLADIVOSTOK Eastern Coast, USSR	VT	43.12°N	138	3	10	1959-68	4.13	6.31	770	96	8.02	776	J
152	VRANGELYA OST. Arctic Ocean, USSR	VG	70.97°N	3	3	10	1959-68	-11.26	-10.86	692	39	17.74	693	J
153	SEVERNAYA ZEMLYA Arctic Ocean, USSR	ZM	79.55°N	3	3	10	1959-68	-15.51	-16.91	775	22	35.23	775	J
154	Haneda Airport TOKYO Japan	TO	35.55°N	5	3	20	1946-60 1967-72	15.24	15.44	514	113	4.55	526	J
North America, Greenland, Panama														
155	ADAK, ALEUTIAN IS. Alaska, U.S.A.	AL	51.83°N	5	3	5	1973-77	4.13	3.19	244	48	5.08	249	J
156	Elmendorf Airbase ANCHORAGE Alaska, U.S.A.	AN	61.23°N	65	3	11	1966-76	1.52	1.33	684	108	6.33	692	J
157	Andrews Air Base WASHINGTON Maryland, U.S.A.	AW	38.92°N	0	3	11	1969-70 1973-81	13.36	13.36	575	166	3.46	598	J
158	ASHVILLE N. Carolina, U.S.A.	AV	35.58°N	658	3	16	1965-80	12.45	12.83	483	222	2.18	532	J
159	DULUTH Minnesota, U.S.A.	DT	46.75°N	0	3	10	1973-82	3.68	4.89	804	157	5.12	819	J
160	GLENVIEW Illinois, U.S.A.	GV	42.08°N	201	3	28	1945-72	9.60	10.25	670	152	4.41	687	J
161	SAN DIEGO California, U.S.A.	SD	32.70°N	6	3	28	1945-72	16.51	16.58	200	112	1.79	229	J
162	Scott Airbase ST. LOUIS Illinois, U.S.A.	SE	38.67°N	138	3	11	1971-81	12.88	13.03	664	186	3.57	690	J
163	WHIDBEY ISLAND Washington, U.S.A.	WD	48.33°N	0	3	10	1973-82	9.47	9.17	249	108	2.31	271	J
164	Shearwater Air Base HALIFAX Nova Scotia, Canada	SW	44.63°N	0	3	13	1954-66	6.47	6.17	513	103	4.98	523	J
165	Thule Air Base DUNDAS Greenland	DN	76.58°N	60	3	11	1968-70 1973-81	-11.77	-13.08	708	33	21.45	709	J
166	Sondestrom Air Base STROMFJORD Greenland	ST	67.08°N	53	3	27	1941-67	-4.87	-5.50	690	106	6.51	698	J
167	Howard Airbase PANAMA CANAL Central America	PC	8.92°N	16	3	10	1968-70 1973-80	26.51	25.75	47	120	0.39	129	J

Appendix 2: Published thermoisopleth diagrams

Thermoisopleth diagrams for the following sites have been published, or obtained as completed plots. The sampling intervals (hourly, 3-hourly) are unstated. Many are based on old data covering short periods, and may not be of comparable quality to the computer-generated diagrams (nos. 1–167).

Publizierte Thermoisoplethen-Diagramme

No.	Situation	Code	Lat.	Alt. (m.)	Years no. = dates	S	D	S/D	C	Source of data
201	AREQUIPA Peruvian Andes	AQ	16.37°S	2360	1 unstated	146	316	0.46	348	Troll 1959, 1966
202	ATUONA Marquesas Is., E. Pacific	AT	9.80°S	51	20 = 1962–81	40	124	0.32	130	N
203	CALCUTTA India	CL	22.54°N	21	13 unstated	295	141	2.09	327	Troll 1958
204	CUZCO Peruvian Andes	CU	13.45°S	3380	1 = 1894–95	138	266	0.52	300	Troll a. Paffen 1964
205	DANMARKS-HAVN Greenland	DH	76.77°N	2	2 = 1906–08	762	46	16.57	763	Troll 1953
206	DAR ES SALAAM Tanzania	DR	6.80°S	14	4 = 1895–99	116	144	0.81	185	Troll 1969
207	EISMITTE Greenland	EI	71.20°N	3000	3 = 1930–33	994	152	6.54	1005	Troll a. Paffen 1964
208	EL MISTI Peruvian Andes	EM	16.30°S	4760	2 = 1894–95	148	197	0.75	246	Troll 1953, 1959, 1961, 1966
209	FRAMDRIFT Arctic Ocean	FR	82.67°N (mean position)	0	3 = 1893–96 (incomplete)				800 +	Troll a. Paffen 1964 (Nansen voyage)
210	HAO ATOLL Tuamotu, S. Pacific	HA	18.10°S	3	17 = 1965–81	72	56	1.29	91	N
211	HELSINKI Finland	HI	60.04°N	10	12 = 1844–63	618	90	6.87	624	Troll a. Paffen 1964
212	IRKUTSK Southern Siberia	IK	52.30°N	491	11 = 1887–97	990	258	3.84	1203	Troll 1958
213	KHARTOUM Sudan	KH	15.60°N	390	5 = 1908–12	316	289	1.09	428	Troll a. Paffen 1964
214	KIMBERLEY South Africa	KI	28.70°S	1230	4 = 1898–02	370	336	1.10	500	Troll a. Paffen 1964
215	KLAGENFURT Austria	KL	46.60°N		? unstated	582	178	3.27	609	Trewartha 1968
216	LEH, LADAKH Kashmir, India	LE	34.20°N	3506	2 unstated	598	277	2.16	659	Paffen 1967
217	McMURDO SOUND Antarctica	MU	77.70°S	8	5 = 1902–04 1908, 1911–12	524	22	23.82	524	Troll, 1953, 1958, 1966
218	MEXICO CITY Mexico	MX	19.40°N	2278	20 = 1877–96	162	256	0.63	303	Troll 1959, 1966
219	MT. WILHELM Papua New Guinea	MT	6.00°S	3480	1 = 1970	58	80	0.72	99	Hnatiuk et al. 1976
220	MUNICH Germany	MC	48.15°N	545	33 = 1948–80	494	264	1.87	560	Troll a. Paffen 1964
221	NAGPUR India	NG	21.15°N		? unstated	378	272	1.39	466	Trewartha 1968
222	ORURO Bolivia	OU	17.97°S	3703	2 = 1917–19	200	314	0.64	372	Troll 1959
223	OSLO Norway	OS	59.93°N		? unstated	524	134	3.91	541	Birkeland 1935
224	OXFORD England	OX	51.80°N	63	5 = 1911–15	299	117	2.56	321	Troll 1958
225	PANGERANGO West Java	PG	6.80°S	3022	? unstated	50	112	0.45	123	Troll 1953, 1959
226	PAPEETE, TAHITI South Pacific	PP	17.50°S	1	24 = 1958–81	70	124	0.56	142	N
227	PARA Brazil	PB	1.45°S	10	3 = 1901–03	53	172	0.31	180	Troll a. Paffen 1964
228	POONA India	PN	10.50°N	561	10 = 1879–88	202	280	0.72	345	Troll 1958

No.	Situation	Code	Lat.	Alt. (m.)	Years no. = dates	S	D	S/D	C	Source of data
229	PUEBLA Mexico	PL	19.03°N	2150	1 = 1968	192	248	0.77	314	Lauer 1973
230	PUNTA ARENAS Chile	PS	53.17°S	10	10 = 1931-40	248	84	2.95	262	Troll a. Lauer 1978
231	QUITO Ecuador	QT	0.23°S	2850	2 = 1906-07	63	276	0.23	283	Troll 1958, 1959, 1961, 1966
232	REGINA Saskatchewan, Canada	RG	50.40°N	575	9 = 1899 1902-08	854	231	3.70	885	Troll a. Paffen 1964
233	REYKJAVIK Iceland	RK	64.50°N		2 = 1882-83	306	77	3.97	315	Troll a. Paffen 1964
234	SAGASTYR Northern Siberia	SA	73.40°N		2 = 1882-83	1130	77	14.68	1133	Troll 1953
235	SANTIAGO Chile	SO	33.40°S	519	4 = 1911-14	293	320	0.92	434	Troll a. Paffen 1964
236	SINGAPORE	SP	1.30°N		2 = 1844-45	66	159	0.41	172	Paffen 1967
237	SONNBLICK Austria	SB	47.05°N	3106	14 = 1886-99	348	46	7.57	351	Troll 1953, 1972
238	TABORA Tanzania	TR	5.05°S	1214	1 = 1911	134	264	0.51	296	Troll 1969
239	TANDALA Tanzania	TD	9.40°S	2040	1 = 1911-12	154	199	0.77	252	Troll 1969
240	TIKO Cameroon Republic	TK	4.02°N	15	7 = 1933-39	63	154	0.41	166	Troll 1969
241	TIMBUKTU, MALI Saharan Africa	TB	16.80°N		? unstated	364	384	0.95	529	Trewartha 1968
242	VASSITJAKKO Swedish Lapland	VJ	68.40°N	1372	6 = 1907-12	322	28	11.50	323	Troll 1953, 1972

Appendix 3: Alphabetical list of station codes for thermoisopleth diagrams and derived statistics

Two letter codes as used in Figs. 3, 4, a. 5. Numbers refer to sequential entries in Appendix 1 (computer-plotted diagrams, upright script), and Appendix 2 (published diagrams, italic script).

Liste der Kodierungen der Meßstationen für die Thermoisoplethen-Diagramme und die daraus abgeleiteten statistischen Kennziffern

Code	No.	Station	Location
AA	122	ALTA	Norway
AB	11	ALMIRANTE BROWN	Antartic Peninsula
AC	102	ASCENCION ISLAND	South Atlantic
AD	68	ADELAIDE	Southern Australia
AG	121	ALBORG	Denmark
AK	138	ALEKSANDROVSK	Sakhalin, USSR
AL	155	ADAK, ALEUTIAN IS.	Alaska, USA
AN	156	ANCHORAGE	Alaska, USA
AQ	*201*	*AREQUIPA*	*Peru*
AR	99	ALDABRA ISLAND	Western Indian Ocean
AS	76	ALICE SPRINGS	Central Australia
AT	*202*	*ATUONA, MARQUESAS IS.*	*Eastern Pacific*
AU	54	AUCKLAND	New Zealand
AV	158	ASHVILLE	North Carolina, USA
AW	157	ANDREWS AIR BASE	Washington DC, USA
AY	66	ALBANY	South-western Australia
AZ	105	TERCIERA IS., AZORES	North Atlantic
BB	40	BAHIA BLANCA	Argentina
BE	123	BERGEN	Norway
BM	104	BERMUDA	North Atlantic
BR	74	BRISBANE	Eastern Australia
BW	101	ST. HELENA ISLAND	South Atlantic
CA	100	DIEGO GARCIA, CHAGOS	Central Indian Ocean
CB	65	CANBERRA	Eastern Australia
CC	47	CHRISTCHURCH	New Zealand
CD	71	CEDUNA	Southern Australia

Code	No.	Station	Location
CE	110	CLARE	Ireland
CF	73	COFF'S HARBOUR	Eastern Australia
CG	62	CAPE GRIM	Northwest Tasmania
CH	29	CHATHAM ISLAND	Southwest Pacific
CI	107	CORK	Ireland
CK	98	COCOS-KEELING ISLAND	Eastern Indian Ocean
CL	*203*	*CALCUTTA*	*India*
CM	28	CAMPBELL ISLAND	Southwest Pacific
CN	42	CONCEPCION	Chile
CO	90	RAROTONGA, COOK IS.	South Pacific
CR	23	CROZET ISLANDS	Southern Indian Ocean
CT	56	CAPE TOWN	South Africa
CU	*204*	*CUZCO*	*Peru*
CV	75	CARNARVON	Western Australia
DB	59	DURBAN	South Africa
DC	15	DECEPTION ISLAND	Antarctic Peninsula Is.
DG	26	DIEGO RAMIREZ ISLAND	Southeast Pacific
DH	*205*	*DANMARKS-HAVN*	*Greenland*
DK	139	DIKSON OSTROVA	Arctic coast, USSR
DL	112	DUBLIN	Ireland
DN	165	THULE BASE, DUNDAS	Greenland
DO	114	DONEGAL	Ireland
DR	*206*	*DAR ES SALAAM*	*Tanzania, East Africa*
DT	159	DULUTH	Minnesota, USA
DU	45	DUNEDIN	New Zealand
DV	6	DAVIS	Antarctic Shield
DU	78	DARWIN	Northern Australia
EA	91	EASTER ISLAND	Southeast Pacific
EB	124	ESBJERG	Denmark
EI	*207*	*EISMITTE*	*Greenland*
EL	57	EAST LONDON	South Africa
EM	*208*	*EL MISTI*	*Peru*
EP	70	ESPERANCE	Southern Australia
ES	13	ESPERANZA	Antarctic Peninsula
EV	36	EVANGELISTAS	Southwest Chile
FA	118	FAEROE ISLANDS	Northeast Atlantic
FJ	96	NANDI, FIJI ISLANDS	Southwest Pacific
FL	27	FALKLAND/MALVINAS IS.	Southwest Atlantic
FR	*209*	*FRAMDRIFT VOYAGE*	*Arctic Ocean drift*
FY	10	FARADAY	Antarctic Peninsula
GL	111	GALWAY	Ireland
GM	94	GUAM, MARIANA IS.	Western Pacific
GS	52	GISBORNE	New Zealand
GI	30	GOUGH ISLAND	South Atlantic
GV	160	GLENVIEW	Illinois, USA
HA	*210*	*HAO ATOLL, TUAMOTU IS.*	*Southeast Pacific*
HB	85	OAHU, HAWAIIAN IS.	North Pacific
HD	20	HEARD ISLAND	South Indian Ocean
HE	125	HALDDE	Norway
HI	*211*	*HELSINKI (1844–63)*	*Finland*
HK	46	HOKITIKA	New Zealand
HL	84	HILO, HAWAIIAN IS.	North Pacific
HO	61	HOBART	Southern Tasmania
HP	14	HOPE BAY	Antarctic Peninsula
HR	9	HORSESHOE ISLAND	Antarctic Peninsula
HS	126	HELSINKI	Finland
HT	3	HALLETT	Antarctic Shield
HY	4	HALLEY BAY	Antarctic Shield
IK	*212*	*IRKUTSK (1887–97)*	*Irkutskaya, USSR*
IR	140	IRKUTSK	Irkutskaya, USSR
IV	44	INVERCARGILL	New Zealand
JF	33	JUAN FERNANDEZ IS.	Southeast Pacific
JM	120	JAN MAYEN ISLAND	Arctic Ocean
KA	127	KARUP	Denmark
KD	89	RAOUL, KERMADEC IS.	Southwest Pacific
KE	108	KERRY	Ireland
KF	119	KEFLAVIK, ICELAND	North Atlantic
KG	17	KING GEORGE ISLAND	Antarctic Peninsula
KH	*213*	*KHARTOUM*	*Sudan, Northeast Africa*
KI	*214*	*KIMBERLEY*	*South Africa*

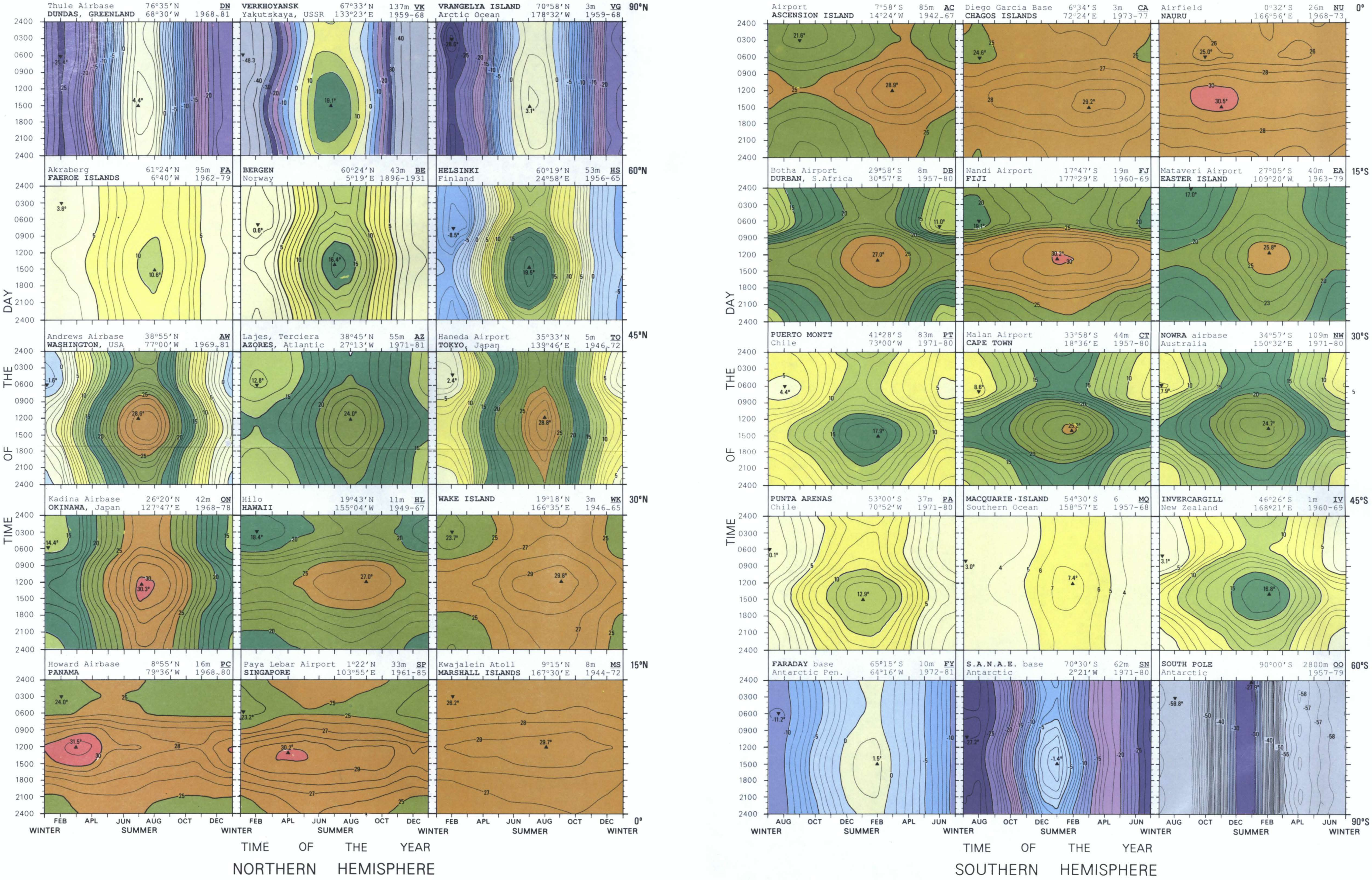
Code	No.	Station	Location
KK	48	KAIKOURA	New Zealand
KL	*215*	*KLAGENFURT*	*Austria*
KM	128	KEMI	Finland
KN	16	KING GEORGE ISLAND	Antarctic Peninsula
KR	22	KERGUELEN	Southern Indian Ocean
KT	55	KAITAIA	New Zealand
KU	141	KHATANGA	Northern Siberia, USSR
LA	18	LAURIE ISLAND	Antarctic Peninsula
LE	*216*	*LEH, LADAKH*	*Kashmir, Himalayas*
LH	83	LORD HOWE ISLAND	Southwest Pacific
LZ	93	BATAAN, PHILIPPINES	Eastern Pacific
MA	129	MAARIANHAMINA	Finland
MB	64	MT. GAMBIER	Southern Australia
MC	*220*	*MUNICH*	*Germany*
MD	87	MIDWAY ISLAND	North Pacific
MG	80	MADANG	Papua New Guinea
MK	143	MURMANSK	Arctic coast, USSR
ML	63	MELBOURNE	Southern Australia
MM	2	MCMURDO SOUND	Antarctic Shield
MN	25	MARION ISLAND	Southern Indian Ocean
MP	41	MAR DEL PLATA	Argentina
MQ	24	MACQUARIE ISLAND	Southwest Pacific
MR	12	MARAMBIO	Antarctic Peninsula
MS	88	KWAJALEIN, MARSHALL IS.	North Pacific
MT	*219*	*MT. WILHELM*	*Papua New Guinea*
MU	*217*	*MCMURDO SOUND (1902-)*	*Antarctic Shield*
MW	7	MAWSON	Antarctic Shield
MX	*218*	*MEXICO CITY*	*Mexico*
MY	113	BELMULLET, MAYO	Ireland
MZ	142	MEDVEZH'I OSTROVA	Arctic Ocean, USSR
NA	31	NEW AMSTERDAM ISLAND	South Indian Ocean
NB	144	NOVOSIBIRSK	Southwest Siberia, USSR
NC	97	NOUMEA, NEW CALEDONIA	Southwest Pacific
NF	82	NORFOLK ISLAND	Southwest Pacific
NG	*221*	*NAGPUR*	*India*
NL	49	NELSON	New Zealand
NP	51	NEW PLYMOUTH	New Zealand
NU	95	NAURU	Western Pacific
NW	67	NOWRA	Eastern Australia
OH	115	BENBECULA, HEBRIDES	Northeast Atlantic
OK	60	O'KIEP, NW CAPE	South Africa
ON	92	OKINAWA, RYUKYU IS.	Northwest Pacific
OO	1	SOUTH POLE	Antarctic Shield
OR	116	KIRKWALL, ORKNEYS	Northeast Atlantic
OS	*223*	*OSLO*	*Norway*
OT	145	OKHOTSK	Pacific coast, USSR
OU	*222*	*ORURO*	*Bolivia*
OX	*224*	*OXFORD (1911-15)*	*England*
PA	35	PUNTA ARENAS	Chile
PB	*227*	*PARA/BELEM*	*Brazil*
PC	167	HOWARD BASE, PANAMA	Central America
PE	72	PERTH	Western Australia
PG	*225*	*PANGERANGO, WEST JAVA*	*Indonesia*
PK	146	PETROPAVLOVSK	Kamchatka, USSR
PL	*229*	*PUEBLA (1968)*	*Mexico*
PM	81	PORT MORESBY	Papua New Guinea
PN	*228*	*POONA*	*India*
PP	*226*	*PAPEETE, TAHITI*	*South Pacific*
PR	130	PORI	Finland
PS	*230*	*PUNTA ARENAS (1931-40)*	*Chile*
PT	39	PUERTO MONTT	Chile
PU	103	PUERTO RICO	Caribbean
PV	147	PETROPAVLOVSK	Kasakhastan, USSR
QT	*231*	*QUITO (1906-07)*	*Ecuador*
RD	38	COMODORO RIVIDAVIA	Argentina
RG	*232*	*REGINA (1902-08)*	*Saskatchewan, Canada*
RK	*233*	*REYKJAVIK, (1882-83)*	*Iceland, North Atlantic*
RL	37	RIO GALLEGOS	Argentina
RN	148	RANG-KUL, PAMIR MTS.	Tadzhikskaya, USSR
RT	53	ROTORUA	New Zealand

Code	No.	Station	Location
RV	131	ROVANIEMI	Finland
SA	*234*	*SAGASTYR (1882–83)*	*Arctic coast, USSR*
SB	*237*	*SONNBLICK (1886–99)*	*Austria*
SC	106	SCILLY ISLES	Northeast Atlantic
SD	161	SAN DIEGO	California, USA
SE	162	SCOTT BASE, ST. LOUIS	Illinois, USA
SG	21	GRYTVIKEN, S. GEORGIA	South Atlantic
SH	117	LERWICK, SHETLAND IS.	Northeast Atlantic
SI	19	SIGNY ISLAND	Antarctic Peninsula Is.
SK	132	SKRYDSTRUP	Denmark
SN	5	SANAE	Antarctic Shield
SO	*235*	*SANTIAGO (1911–14)*	*Chile*
SP	*236*	*SINGAPORE (1844–45)*	
SR		*SINGAPORE (1961–85)*	
ST	166	STROMFJORD	Greenland
SW	164	HALIFAX	Nova Scotia
SY	69	SYDNEY	Eastern Australia
SZ	137	SPITZBERGEN	Arctic Ocean
TB	*241*	*TIMBUKTU, MALI*	*Saharan Africa*
TC	32	TRISTAN DA CUNHA	South Atlantic
TD	*239*	*TANDALA, TANZANIA*	*East Africa*
TH	134	TRONDHEIM	Norway
TI	79	THURSDAY IS. TORRES ST.	Northern Australia
TK	*240*	*TIKO, CAMEROON*	*West Africa*
TO	154	HANEDA AIRPORT TOKYO	Japan
TR	*238*	*TABORA, TANZANIA*	*East Africa*
TS	149	TASHKENT	Uzbekistan, USSR
TV	77	TOWNSVILLE	Eastern Australia
TY	133	THYBORON	Denmark
US	34	USHUAIA	Argentina
VA	135	VAASA	Finland
VG	152	VRANGELYA OSTROVA	Arctic Ocean, USSR
VJ	*242*	*VASSITJAKKO*	*Sweden*
VK	150	VERKHOYANSK	Yakutskaya, USSR
VL	43	VALPARAISO	Chile
VR	136	VARDO	Norway
VT	151	VLADIVOSTOK	Pacific coast, USSR
VW	58	VICTORIA WEST, CAPE	South Africa
WD	163	WHIDBEY ISLAND	Washington State, USA
WE	50	WELLINGTON	New Zealand
WK	86	WAKE ISLAND	North Pacific
WL	8	WILKES	Antarctic Shield
WX	109	ROSSLARE, WEXFORD	Ireland
ZM	153	SEVERNAYA ZEMLYA	Arctic Ocean, USSR

Appendix 4: Sources of data for thermoisopleth diagrams
Datenquellen für die Thermoisoplethen-Diagramme

A	British Antarctic Survey, Cambridge, U.K.
B	British Meteorological Office, Bracknell, U.K.
C	Bureau of Meteorology, Melbourne, Australia
D	Direccion Meteorologica de Chile, Santiago, Chile
E	Direction de la Météorologie, Ministère des Transports, Paris, France
F	Fuerza Aerea Argentina, Servicio Meteorologico Nacional, Buenos Aires, Argentina
G	Irish Meteorological Service, Glasnevin, Dublin
I	Meteorologie Institute, Copenhagen, Denmark
J	National Climate Center (N.O.A.A.), Ashville, North Carolina, U.S.A.
K	New Zealand Meteorological Service, Wellington
L	Service de la Météorologie, Direction de L'Aviation Civile, Nouméa, Novelle Calédonie
M	Weather Bureau, Pretoria, South Africa
N	Director, Civil Aviation, Tahiti
O	Research Institute of Hydrometeorological Information, Kaluga, U.S.S.R.
U	WARREN 1945 (see references)
V	R.J. HNATIUK – personal communication (Leader, Royal Society Expedition to Aldabra, 1973–75)
Y	BIRKELAND 1935 (see references)
Z	HEINO 1973 (see references)

Fig. 1: Thermoisopleth Diagrams Thermoisoplethen - Diagramme



Thermoisopleth diagrams of screened, drybulb, mean air temperatures in °C for 15 sites in each hemisphere;
arranged in latitudinal belts, with midsummer and noon at the centre of each diagram.
Mean maximum and mean minimum values are indicated by triangles. Two-letter codes for sites as in Fig. 3, 4, 5.
For details of diurnal temperature sampling frequency and data sources, see Appendix 1

Cartography: University of Sydney

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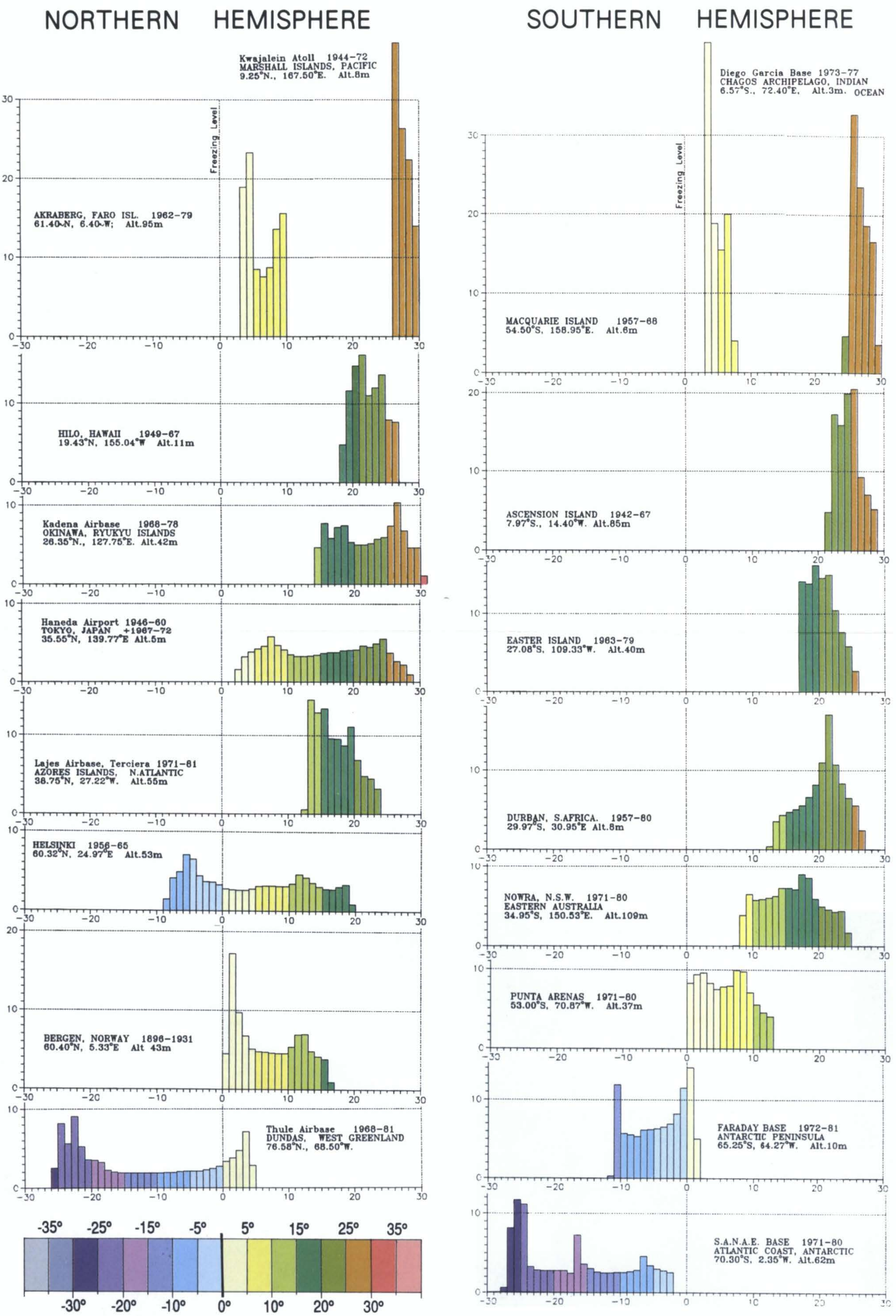
Fig. 6: Time-Temperature Histograms

Zeit-Temperatur-Histogramme



Time-temperature histograms for 18 coastal and island sites whose thermoisopleth diagrams are shown in Fig. 1. The percentage of yearly time spent between 1° C mean temperatures (Y-axis), plotted against temperature levels (X-axis). Histograms are arranged in register for each hemisphere. Colour layering as in Fig. 1