Aust. Met. Mag. 49 (2000) 87-96

Objective classification of Australian climates

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(Manuscript received July 1999; revised December 1999)

Köppen's scheme to classify world climates was devised in 1918 by Dr Wladimir Köppen of the University of Graz in Austria. Over the decades it has achieved wide acceptance amongst climatologists. However, the scheme has also had its share of critics, who have challenged the scheme's validity on a number of grounds. For example, Köppen's rigid boundary criteria often lead to large discrepancies between climatic subdivisions and features of the natural landscape. Furthermore, whilst some of his boundaries have been chosen largely with natural landscape features in mind, other boundaries have been chosen largely with human experience of climatic features in mind. The present paper presents a modification of Köppen's classification that addresses some of the concerns and illustrates this modification with its application to Australia.

Introduction

Köppen's scheme to classify world climates was devised in 1918 by Dr Wladimir Köppen of the University of Graz in Austria (Köppen 1931; Köppen and Geiger 1928, 1930-39). This paper presents a modification of Köppen's scheme.

The Köppen classification is based on the concept that native vegetation is the best expression of climate, climate zone boundaries having been selected with vegetation limits in mind (Trewartha 1943). The classification may be applied to present-day climatic conditions. Alternatively, it also may be used to develop a future climatology that is implied by the output of a numerical climate model (Löhmann et al. 1993) – although the reliability of such a future climatology would be dependent upon the reliability of the numerical climate model output.

Köppen recognises five principal groups of world climates that are intended to correspond with five principal vegetation groups. These five climatic groups may be described as tropical rainy, dry, temperate rainy, cold snowy forest, and polar.

The dry climates are defined on the basis of there being an excess of evaporation over precipitation (which is determined from the mean annual temperature and the mean annual rainfall). The tropical rainy

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climates are climates, as yet unclassified, with a mean temperature of the coolest month of at least 18°C. The polar climates are climates, as yet unclassified, with a mean temperature of the warmest month of below 10°C. The cold snowy forest climates are climates, as yet unclassified, with a mean temperature of the coolest month of below -3°C. Remaining climates are defined as temperate rainy.

Each of these climates is further divided into subdivisions based upon differences in the seasonal distribution of temperature and precipitation. For example, Köppen climates with distinctly dry winters are defined as those temperate rainy climates and cold snowy forest climates with at least ten times as much rain in the wettest summer month as in the driest winter month. Trewartha (1943) presents a full description of all of the subdivisions and provides a detailed map depicting the distribution around the globe of the original Köppen climates.

The purpose of this paper is two-fold. Firstly, a new modification of Köppen's classification of world climates is presented. Secondly, the modification is illustrated with its application to Australia.

Discussion

Trewartha (1943) notes that Köppen's classification has been criticised from 'various points of view' (Thornthwaite 1931; Jones 1932; Ackerman 1941). Rigid boundary criteria often lead to large discrepancies between climatic subdivisions and features of the natural landscape. Some boundaries have been chosen largely with natural landscape features in mind (for example, 'rainforest'), whilst other boundaries have been chosen largely with human experience of climatic features in mind (for example, 'monsoon'). Trewartha (1943) acknowledges the validity of these criticisms when he writes that 'climatic boundaries, as seen on a map, even when precisely defined, are neither better nor worse than the human judgements that selected them, and the wisdom of those selections is always open to debate'. He emphasises, however, that such boundaries are always subject to change 'with revision of boundary conditions ... (and that) ... such revisions have been made by Köppen himself and by other climatologists as well'.

Nevertheless, the telling evidence that the Köppen classification's merits outweigh its deficiencies lies in its wide acceptance. Trewartha (1943) observes that 'its individual climatic formulas are almost a common language among climatologists and geographers throughout the world ... (and that) ... its basic principles have been ... widely copied (even) by those who have insisted upon making their own empirical classifications'. Trewartha's (1943) comments are as relevant today as they were half a century ago (see, for example, Müller (1982); Löhmann et al. (1993)).

For the above reasons, in modifying the Köppen classification (Figs 1 and 2), the authors have chosen to depart only slightly from the original. Nevertheless, the additional division of some of the Köppen climates and some recombining of other Köppen climates may better reflect human experience of significant features. In recognition of this, the following changes, which are also summarised in Table 1, have been adopted in this work:

(1) The former tropical group is now divided into two new groups, an equatorial group and a new tropical group. The equatorial group corresponds to the former tropical group's isothermal subdivision. The new tropical group corresponds to that remaining of the former tropical group. This is done to distinguish strongly between those climates with a significant annual temperature cycle from those climates without one (although this feature is not as marked in the Australian context, as elsewhere in the world). Under this definition some climates, distant from the equator, are classified as equatorial. This is considered acceptable as that characteristic is typical of climates close to the equator. Figure 1 shows that, in Australia, equatorial climates are confined to Queensland's Cape York Peninsula and the far north of the Northern Territory.

(2) The equatorial and tropical group monsoon subdivisions are re-named as rainforest (monsoonal) subdivisions. This is done because, in these subdivisions, the dry season is so short, and the total rainfall is so great, that the ground remains sufficiently wet throughout the year to support rainforest. Figure 2 shows that, in Australia, rainforest subdivisions are found along sections of the northern part of Queensland's east coast.

(3) The former dry group is now divided into two new groups, a desert group and a grassland group. The new groups correspond to the former desert and steppe subdivisions of the dry group. This is believed necessary because of the significant differences between the types of vegetation found in deserts and grasslands. That there is a part of central Australia covered by the grassland group of climates (Fig. 1) is a consequence of the higher rainfall due to the ranges in that region.

(4) The new desert and grassland winter drought (summer drought) subdivisions now require the additional criterion that there is more than 30 mm in the wettest summer month (winter month) to be so classified. This change is carried out because drought conditions may be said to prevail throughout the year in climates without at least a few relatively wet months. It should be noted that the original set of Köppen climates employed the phrases 'winter drought' and 'summer drought' to respectively describe climates that are seasonally dry. Figure 2 shows that the summer drought subdivisions are found in the southern half of the country, whilst the winter drought subdivisions are found in the northern half of the country.

(5) The former temperate group is divided into two new groups, a temperate group and a subtropical group. The new subtropical group corresponds to that part of the former temperate group with a mean annual temperature of at least 18°C. The new temperate group corresponds to that part of the former temperate group remaining. This is done because of the significant differences in the vegetation found in areas characterised by the two new groups, and in order that there is continuity in the boundary between the hot and warm desert and grassland climates where they adjoin rainy climates. Figure 1 shows that a large region, covering much of southeast Queensland and some elevated areas further north, is now characterised as subtropical.

(6) For simplicity, the former Köppen cold snowy forest group of climates is re-named as the cold group. Figure 1 shows that this climate is not found on the Australian mainland or in Tasmania.

(7) For the temperate, subtropical, and the cold groups, the distinctly dry winter subdivision requires the additional criterion of no more than 30 mm in the driest winter month to be so classified. In order that there be consistency between the criteria for the distinctly dry winter and the distinctly dry summer subdivisions, this is thought to be a worthwhile change. Figure 2 shows that, whereas that part of Western Australia characterised as subtropical has a distinctly dry summer, much of subtropical southeast Queensland has no distinctly dry season.

(8) Carved out of the temperate, subtropical, and the cold groups with no distinctly dry season subdivision is the moderately dry winter subdivision. This new subdivision receives at least three times (but less than ten times) the rainfall in the driest winter month. This subdivision has been added in order that there be a match with that part of the distinctly dry summer subdivision that was not matched by the distinctly dry winter subdivision. Figure 2 shows that parts of subtropical southeast Queensland have a moderately dry winter.

(9) The polar group has added to it the subdivision polar maritime, this subdivision reflecting the climate of the sub-antarctic islands, which otherwise would have been classified (inappropriately) as polar tundra. Polar tundra would be an inappropriate description for climates where the average temperature of the coldest month is -3°C or above. This is because, with the temperature not well below freezing, it is difficult for the ground to become frozen (a characteristic of 'polar tundra'). Figure 1 shows that this climate is not found on the Australian mainland or in Tasmania.

(10) The frequent-fog desert and grassland climates are re-named as high-humidity climates. They are also defined in terms of mean annual relative humidity, rather than in terms of fog frequency. This is on account of the dew-fall that results from the high humidity being a significant contributor to plant moisture in regions with such climates. They are also restricted to desert cli-

Table 1. A summary of key differences between Köppen's original scheme and the new scheme.

Köppen's original scheme	*New scheme*
Tropical group	Divided into equatorial & tropical groups
Monsoon subdivision	Becomes rainforest (monsoonal) subdivision
Dry group	Divided into desert & grassland groups
Summer/winter drought subdivisions	Now requires 30+mm in wettest month
Temperate group	Divided into subtropical & temperate groups
Cold-snowy-forest group	Cold group
Dry summer/winter subdivisions	Moderately dry winter subdivision added
Polar group	Maritime subdivision added
Frequent fog subdivision	Applies now only to the desert group
Frequent fog subdivision	Becomes high humidity subdivision
High-sun dry season subdivision	Absorbed into other subdivisions
Autumn rainfall max subdivision	Absorbed into other subdivisions
Other minor subdivisions	Absorbed into other subdivisions

Fig. 1 The key climate groups.

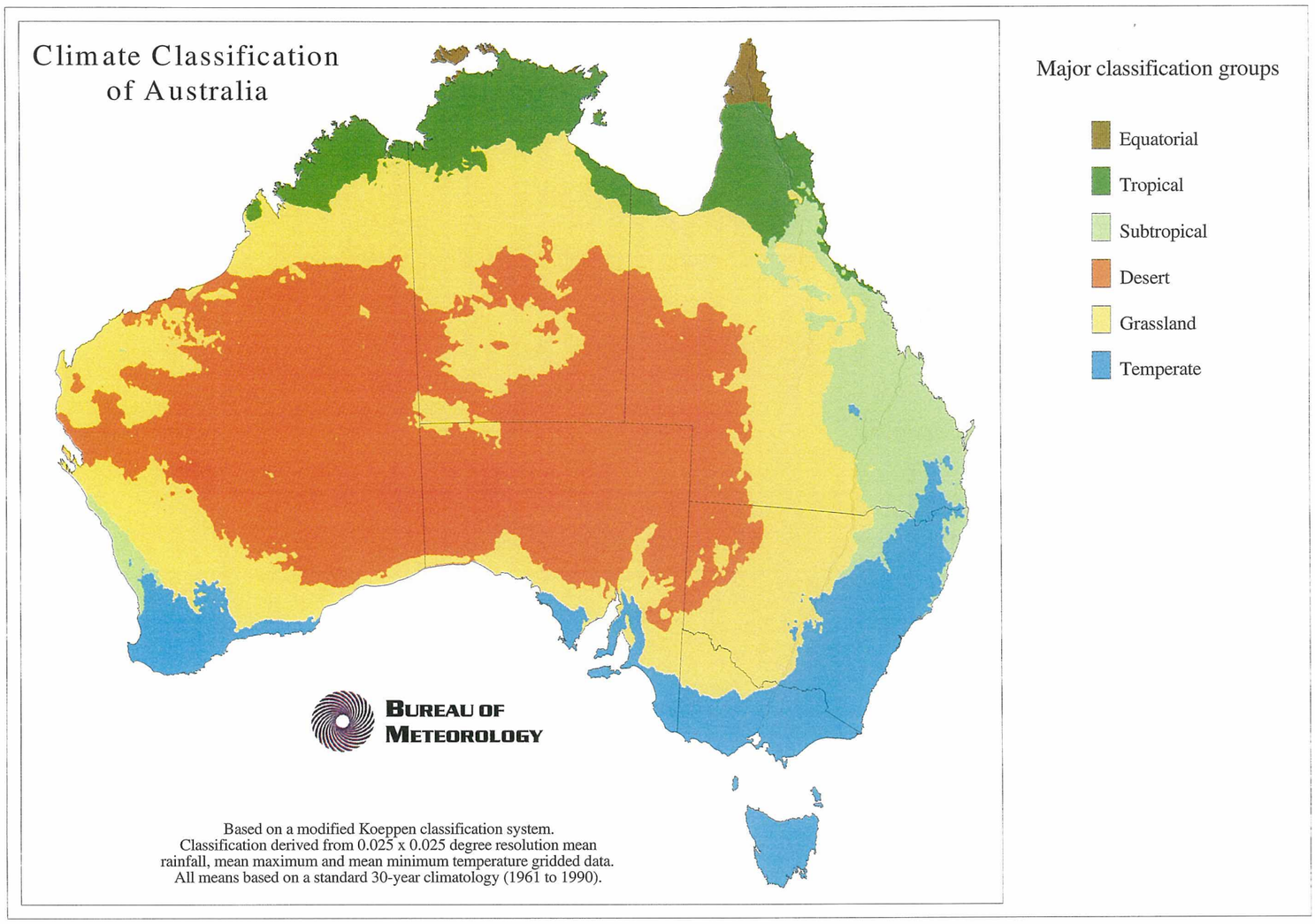

Fig. 2 Subdivisions within the key climate groups.