MAPS OF EVAPOTRANSPIRATION

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INTRODUCTION

Evapotranspiration (ET) is a collective term for the transfer of water, as water vapour, to the atmosphere from both vegetated and unvegetated land surfaces. It is affected by climate, availability of water and vegetation.

ET is a large component of the water balance; almost 90 per cent of the precipitation that falls on the Australian continent is returned through ET to the atmosphere. However, despite its importance, ET is almost impossible to measure or observe directly at a meaningful scale in space or time. In the past, surrogate measures, such as evaporation from the US Class A evaporation pan, have been used, with maps of mean monthly and annual pan evaporation published by the Bureau of Meteorology (1988).

This current publication provides derived data on both ET limits and actual ET. Three variables are mapped here: areal actual ET, areal potential ET and point potential ET. For each variable, there is one mean annual map and twelve mean monthly maps. The text below describes the three variables, the methodology and data used to derive them, and the mapping technique. Advice is given on the use of the information for practical applications.

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DEFINITION OF MAP VARIABLES

Areal actual ET is the ET that actually takes place from an area so large that the effects of any upwind boundary transitions are negligible and local variations are integrated to an areal average.

Areal potential ET is the ET that would take place, if there was an unlimited water supply, from an area so large that the effects of any upwind boundary transitions are negligible and local variations are integrated to an areal average.

Point potential ET is the ET that would take place, if there was an unlimited water supply, from an area so small that the local ET effects do not alter local air mass properties. It is assumed that latent and sensible heat transfers within the height of measurement are through convection only.

The above definitions are based on those given by Morton (1983), but we have used the term areal potential ET for Morton's wet-environment ET and the term point potential ET for Morton's potential ET.

APPLICATION

Areal potential ET is the ET from a large area with unlimited water supply. For example, it is conceptually the upper limit to actual ET in most rainfall-runoff modelling studies. It also provides an estimate of ET from a large irrigated area under no water shortage. As a rough guide, an area greater than 1 km2 may be regarded as 'areal'. Point potential ET by definition is the ET from a 'point' with unlimited water supply. An example is a very small irrigated field surrounded by unirrigated land.

By definition, point potential ET is very similar to the Penman-Monteith potential ET. The latter, although defined for a large area, also assumes that the actual ET does not affect the overpassing air. However, the estimates of the two are not quite the same because they are calculated differently.

These ET maps are not intended for use in estimating open-water evaporation. Analysis techniques recommended in well-known hydrological texts dealing with open-water bodies should be used. However, point potential ET may be taken as a rough preliminary estimate of evaporation from small water bodies such as farm dams and shallow water storages.

METHOD OF ESTIMATION

We used Morton's (1983) complementary relationship areal ET model to derive the estimates of areal potential ET, point potential ET and areal actual ET. The complementary relationship states that under normal conditions, the sum of areal actual ET and point potential ET is equal to twice the value of areal potential ET.

Morton's formulation for areal potential ET uses the Priestley-Taylor equation with modification to allow for advection. We re-calibrated the coefficients fZ, b1, b2 (equations 14 and 15, Morton 1983) and set them to 29.2 Wm-2mbar-1, 13.4 Wm-2 and 1.13 respectively to give an overall equivalent of the commonly used 1.26, instead of Morton's 1.32, for the constant in the Priestley-Taylor equation (equation 13, Morton 1983).

Morton's method for point potential ET is based on solving simultaneously energy transfer and balance equations, using a constant energy transfer coefficient, unlike the Penman-Monteith potential ET formulation in which the energy transfer coefficient is a function of wind speed. Once the point potential ET and areal potential ET are estimated, the complementary relationship can be used to give an estimate of the areal actual ET.

In this project, we computed average monthly values of areal potential ET, point potential ET, and areal actual ET by running the complementary relationship areal ET model (Morton 1983) at a monthly interval. We found that Morton's estimates of mean annual areal actual ET gave good spatial trend but were not accurate in absolute values. Consequently, we made adjustments to Morton's estimates to remove bias and extremes. The adjustments were based on annual actual ET estimates derived from the long-term water balance of 77 large catchments grouped into nine climate zones using the Koeppen classification system (Koeppen 1931). The mean monthly actual ET values were then proportionately adjusted according to the adjustments made to the mean annual actual ET values.

The adjusted areal actual ET estimates were interpolated to give gridded values (see Mapping section). The gridded annual areal actual ET values were compared with the latest available rainfall maps (Bureau of Meteorology 2000), and adjusted to ensure that the annual areal actual ET did not exceed rainfall and that the runoff coefficients were reasonable. The rainfall maps, being based on directly measured data from a larger number of stations, are considered to be more accurate. The annual adjustments were proportionately applied to the gridded monthly ET values.

Following the adjustments to the areal actual ET values, checks were made to ensure that there was consistency between areal potential ET and point potential ET for all the monthly and annual maps. Only very minor adjustments were required.

DATA

The required inputs to Morton's (1983) complementary relationship areal ET model are temperature, vapour pressure and solar global exposure (commonly called global radiation). For this project, data from a total of 713 meteorological stations throughout Australia were used; their locations are shown in the figure at the end of this commentary. These stations were selected based on the criterion that at least 5 years of record of temperature and vapour pressure after 1961 were available. The monthly data used to compute the ET terms were derived from daily data. A month was considered to have a valid record only if it had 10 or more days of data. Daily mean temperature was taken as the average of daily maximum and minimum temperatures. Daily mean vapour pressure was taken as the average of vapour pressures, calculated from dry and wet-bulb temperatures, at 0900 and 1500 hours.

Solar global exposure is very sparsely observed in Australia. It may be estimated from sunshine hours or cloudiness but reliable relationships for the Australian region were not considered available. The Bureau of Meteorology has developed reliable relationships between satellite radiance observations and mean monthly total global exposure, and these were used to estimate mean monthly values for each of the 713 locations for the period 1990 to 1994. Satellite-derived data were compared with some ground-measured data and showed good agreement with differences generally under 10 per cent. Furthermore, the period 1990-1994 was found to be reasonably representative of the whole period from 1961 at mean monthly level. Interannual variability in monthly global exposure is relatively low and was not accounted for in our computation of ET. The surface records indicate that the interannual variation for 1990-1994 was not exceptional and the satellite data were shown to represent the standard climatology (Weymouth 1998).

We also used long-term rainfall and runoff data from 77 catchments to obtain, by water balance, reference estimates of areal actual ET. These reference estimates, divided into nine climate zones, were used to adjust the calculated areal actual ET estimates. We also used an annual rainfall map (Bureau of Meteorology 2000) to fine-tune the areal actual ET maps.

It should be noted that this series of ET maps provides the climate means of 30 years from 1961, a relatively wet period for the Australian continent compared with longer term climate means. The maps should be used in conjunction with the rainfall maps for the same period (Bureau of Meteorology 2000).

MAPPING

Hutchinson's (1991,1995) interpolation method of thin plate smoothing splines was used to produce grid data at a 0.1 degree resolution. Elevation as well as latitude and longitude were used as explanatory variables to take into account the variation of precipitation, temperature and vapour pressure with elevation. The interpolated (gridded) data were smoothed using a one-pass 5x5 binomial smoother. The gridded data were then imported into the Arc/Info GIS engine and mapped using the map creation tools within the GIS software suite. A final 'polishing' of the maps was carried out to smooth jagged edges resulting from the automated contouring process and to label the contours. In addition to the printed map set, digital datasets are available for the data in Arc/Info grid export or ASCII formats. The datasets are available from the Bureau of Meteorology.

CAUTION

The ET maps presented here are subject to error from a number of sources. The basic input data used are subject to measurement error. The estimates of ET means are subject to sampling error due to limited record lengths. The mapping of ET estimates is affected by the spatial coverage of the climate stations available, and by the interpolation and mapping techniques used. In addition, there is also the model error in deriving the ET estimates and some degree of professional judgment in adjustments made to the estimates. However, we believe that these maps are the best available at present for Australia at the continental scale and should provide a sound basis for improved resources management.

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