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TRENDS IN NORTH CAROLINA EVAPOTRANSPIRATION AND LINKS WITH WATER AVAILABILITY

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1. INTRODUCTION

Water usage throughout North Carolina is increasing as population and *per capita* consumption increases. Water shortages are also increasing. Recently there was a long-term drought in the west, now much of the east has state-mandated water use limits, a response to rapidly falling water table levels. The relative roles of human activities and climatic variability in such events is unclear.

Precipitation is virtually the only natural water source for the state. No rivers, with one minor exception, flow in. Thus long term water available is the difference between evapotranspiration (ET) and precipitation, provided adjustments are made for changes in underground storage and outflow, and for multiple uses of water.

Estimation of precipitation and ET trends thus provides the first step in assessing the impact of climate, as opposed to population, on the water availability in the state. Area-averaged values of annual totals for most of the 20th century are readily available for precipitation (e.g. NCDC, 2002), but not for evaporation. The development of such estimates is presented here.

2. EVAPORATION ESTIMATION METHODS

Since there are no long-term continuous evaporation or evapotranspiration observations in the state, three estimation methods were developed and their trends compared.

2.1 Rehabilitation of Direct Observations

Since 1948 there have been 10 NWS Class A evaporation pans in the state. None covered the entire period, few measured winter values, and no records appear to have been rigorously quality controlled. A preliminary quality control, to remove outliers and interpolate missing values, was undertaken here. Evaporation was assumed to be negligible in winter. The results were about 10% lower than those of Purvis (2000), but differences were consistent from decade to decade and had a minor impact on trends. Further quality control, based on this initial experience, is currently underway.

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Between 1949 and 1998 there was always at least 4 stations operative. Statewide averages were computed by treating each station as representative of its own and, if needed, a neighboring, Climate Division. Division results were then area-weighted.

2.2 Empirical Techniques

Potential ET was estimated from temperature observations using the Thornthwaite (1948) method. Climate Division data were used for compatibility with the pan approach. No attempt was made to calibrate the coefficients for North Carolina conditions, since in all cases the resultant trends are a direct reflection of the temperature trends.

2.3 Water Balance

On a long-term, state-wide basis the actual ET can be approximated as the difference between precipitation and run-off. This assumes that ground water amounts do not change substantially, the flow directly into the oceans is approximately constant, and that stream flow measurements are accurate. All are debatable and need further refinement. However, run-off measured by gauges near the mouth of all major rivers was converted to the equivalent average basin-wide water depth and the results integrated for the total state area.

3. COMPARISON OF EVAPORATION ESTIMATES

The long term average estimates (Table 1) show the expected relationships between the three methods. The pan evaporation is highest, although when a suitable pan coefficient is applied (Farnsworth and Thompson, 1982), the values are similar to those from the other methods. The empirical method estimates potential ET, whereas the mass balance simulates the actual ET, and the latter gives the lower values. Thus the three methods suggest reasonable agreement for long-term averages.

Table 1
Average statewide annual total evaporation and precipitation estimates (mm)

	1912-1998	**1949-1998**
Mass Balance	837	848
Empirical	924	917
Pan Obs	---	1233
Precipitation	1254	1263

The average values mask major differences in trends (Fig 1). The pan results indicate an evaporation increase by about 15% over the last 50 years, with a rapid rise recently. The empirical method is much more conservative, but indicates a slow recovery from a dip in the 1960's. The water balance suggests a 10% increase in ET in the first half of the century, a 5% decrease in the second half. In this method some changes, especially decreased variability from the 1930's onwards, may reflect increased stream regulation, but the long decline started in the 1950's has recently been reversed.

4. IMPLICATIONS FOR WATER AVAILABILITY

On the long term, using the mass balance ET estimates as a measure of the water leaving the state vertically, the average difference between actual ET and precipitation (Table 1) is about 400 mm, so that approximately 70% of the arriving precipitation leaves the state as evapotranspiration. Further, precipitation is much more variable temporally than ET. The 1980's were a period of low precipitation and near normal ET, suggesting that relatively little water was available for human consumption. During the 20th century there was only a period in the 1950's which had a similar small difference.

Of major concern is the discrepancy between the trends of the three estimates in the last two decades. All show increases, but at much different rates, and starting at different times. Consequently, during this period of increased precipitation it is difficult to suggest whether the amount of water actually made available through atmospheric processes is increasing or not.

More detailed knowledge of ET amounts is clearly required. Two approaches are immediately available: the continued rehabilitation of the historical records, to provide the long-term context for future variations; and use of radiation, humidity and wind observations available from a local network (Agnet, 2002) to develop estimates through a Penman-Monteith approach. The utility of incorporating the newer, highly accurate, values from the single Ameriflux site in the state (Katul *et al.*, 1996) will also be explored. On a longer time scale, model estimates may prove useful. Further, another pertinent data set is being developed, as the current shortages are forcing water companies statewide to monitor not only billable use but also their total water extraction and consumption.

References

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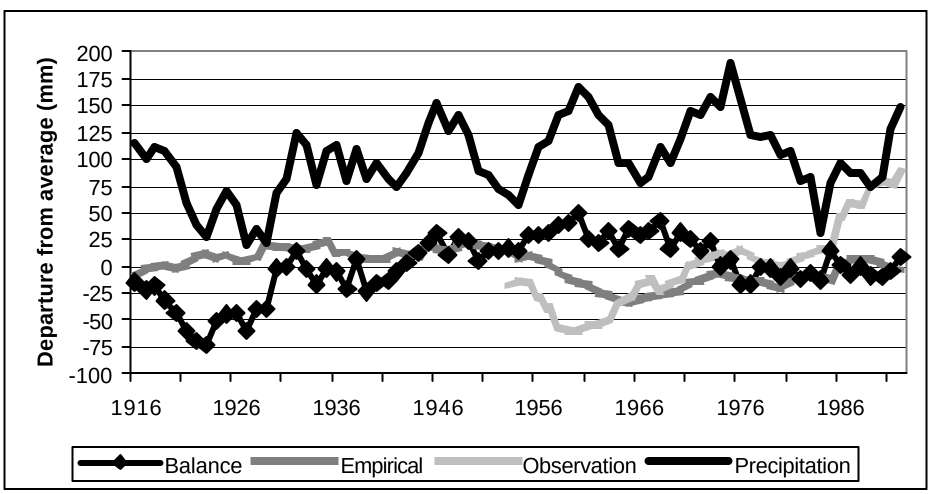

Figure 1: Annual statewide anomaly for precipitation and evaporation. Means were determined using the whole period of record for each method. All data are smoothed with 9-year running means. The precipitation anomaly is offset by 100 mm for clarity.