COMPUTATION OF WATER STORAGE CONTRIBUTIONS TO POLAR MOTION

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ABSTRACT. We have undertaken a computation of water storage fluctuations and their contribution to polar motion excitation for the period 1900-1982. The calculation is based mainly upon monthly mean observations of precipitation at individual stations around the globe. Seasonal average variations are computed for over 500 individual drainage basins, permitting a comparison with observed annual polar motion.

1. INTRODUCTION

Although it has been known for many decades that the seasonal redistribution of water has an observable effect on polar motion, only a few attempts have been made to study the problem in detail. The most recent article on the subject by Van Hylckama (1970) is actually a correction to previous work (Van Hylckama, 1956), and other original studies of the problem, such as that of Jeffreys (1916) date from the earliest years of this century. The additional years of data, the increasing spatial density of stations, the publication of a global water balance atlas (UNESCO, 1977), and the improving accuracy of polar motion data all seem to make a new study of the water storage problem interesting. The scarcity of studies on this subject is certainly due in part to the difficult task of assembling the data. The available data may also be fundamentally inadequate, but at least they ought to be used to make an interim estimate until proper global observations via satellite-based observatories become available.

A. K. Babcock and G. A. Wilkins (eds.), The Earth's Rotation and Reference Frames for Geodesy and Geodynamics, 381–384.

2. DATA

Individual station reports of monthly mean precipitation were obtained from the National Center for Atmospheric Research (NCAR), for approximately 4000 stations which reported for various periods during the 1900-82 time span. Only about 100 of these reported essentially continuously. For each station reporting more than 5 years, the average precipitation Pm for each of the m=1-12 calendar months was computed, along with their sum, Pa, the total annual precipitation. Each of the 566 basins shown in Figure 1 was assigned at least one station. Basins with more than one station were assigned average values, while basins containing no stations were assigned that station nearest the basin centroid.

The precipitation correction map in the UNESCO Atlas was used to adjust the reported precipitation from the NCAR data to account for rain gauge evaporation and other problems. Total annual evapotranspiration,Ea, and the runoff coefficient R, were determined using the basin centroid as the location for reading each contour map. Graphs describing the fraction of runoff and evapotranspiration taking place during each of the twelve calendar months were digitized. Each basin was assigned an evapotranspiration and runoff distribution graph based upon proximity to the basin centroid.

3. COMPUTATIONS

The water balance equation within each basin gives the change in water storage over month m as Sm = Pm - Em - Rm. Pm is determined from the station records as described above. Total annual runoff Ra is the product of R with Pa, and the runoff for each month Rm is the product of Ra with the fraction of runoff for the month m given by the graph of annual distribution of runoff. The remaining quantity, evapotranspiration, is widely known to be the least-well-determined in the equation. Thus, although we could use the contour map value read for each basin, we decided instead to estimate Ea by requiring that over the whole year there is no change in storage, so that Ea = Pa - Ra. Then Em was computed by multiplying Ea by the fraction of evapotranspiration for the month m as determined from the graph of annual distribution of evapotranspiration.

The final aspect of the calculation is to compute the storage for each month, which is the sum of storage changes over the preceding months. For each basin this determines the load in centimeters of water for each month m. Then, integrals over latitude and longitude are taken to calculate the polar motion excitation functions using the appropriate weightings (Lambeck, 1980). Storage variations in the oceans are assumed to be uniformly distributed and the negative of the total variation over all land areas. This conforms to an isostatic ocean model and assumes that water storage in the atmosphere is being accounted for by a separate calculation of air mass redistribution.

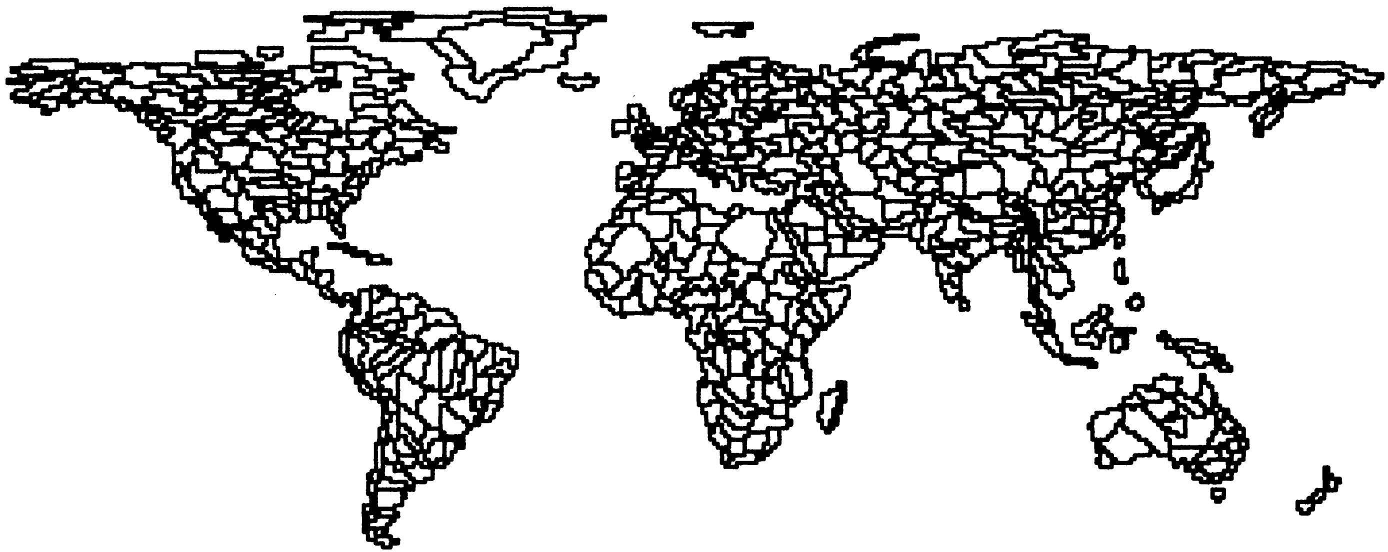

Figure 1. Drainage basin configuration for 566 basins based upon 1 x 1 degree grid resolution.

Future work will be devoted to the computation of a time series which uses linear perturbations of Em and Rm derived from temperature and rainfall anomalies. This will permit comparison with the available polar motion data at other frequencies, especially the Chandler frequency. When combined with previously computed time series of air mass redistibution, this will allow an estimate of the total meteorological contribution to the excitation of polar motion near Chandler and annual frequencies.

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