IRS '88: CURRENT PROBLEMS IN ATMOSPHERIC RADIATION

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SECULAR VARIATION OF GLOBAL RADIATION IN EUROPE

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ABSTRACT

Long-time series of global radiation in Europe were investigated. In all regions, from the Atlantic coast to the interior of the continent, systematic changes were found. The changes were caused by the varying cloud conditions. The spectral analysis of the 100 years' sunshine duration hours for Zurich shows the periodicity of 12 years overlapped with a generally decreasing trend.

1. INTRODUCTION

Under the World Climate Program-Water Project A7, Global Energy Balance Archive (GEBA), the Department of Geography (ETH, Zurich) has been archiving the following 14 fluxes of the energy balance for the earth's surface, which are instrumentally measured (excluding empirically calculated fluxes) (Ohmura, 1986). They include direct solar radiation, diffuse sky radiation, global radiation, short-wave reflected radiation, albedo, long-wave incoming radiation, long-wave outgoing radiation, long-wave effective radiation, net radiation, sensible heat flux, latent heat flux, subsurface heat flux, heat of fusion and UV-radiation. The aim of Project A7 is to archive the measured fluxes, providing the measurement duration is longer than a month. Some long-time series of global radiation in GEBA are evaluated in WRR.

Contrary to the findings by Budyko (1974) that global radiation is stable in time and 10-yr observations are sufficient for obtaining norms, we found rather systematic secular variations with substantial amplitudes. Because the range of the variation is well beyond the instrumental error and the radiative changes are considered to be an important aspect of climatic changes, the best time-series of global radiation in Europe are analysed and the results are discussed.

2. AVAILABLE DATA

For building the GEBA, data are taken from periodicals, data reports, monographs and unpublished sources. In the case of global radiation, the data for a number of stations for the period after 1963 are published monthly by World Radiation Data Centre at Voeikov Main Geophysical Observatory. The data not forwarded to WRDC or older than 1964 must be sought in various sources. The monthly and annual global radiation data for Potsdam in IPS56 are evaluated from 1937 onward and forwarded to the GEBA where they are stored in WRR. The Stockholm global radiation is available dating back to 1941 in Lindholm (1957). The Trömsö global radiation for the period 1947 to 1965 and the Sodankylä for 1953 to 1965 are published by Marshunova and Chernigovskii (1971). The Hamburg and other West German data are published in WRR by Kasten (1986), dating back to 1950. The Kew Station data for the period 1951-1975 are obtained from British Meteorological Office (1980). The data from the Austrian stations, such as Salzburg since the IGY, are available in Steinhauser (1963, 1964, 1966 and 1968). The Zurich data are available for the period 1959 to 1968 in Schram and Thams (1970), up to 1972 in Ambrosetti and Valko (1980) and thereafter in the Annual Report of the Swiss Meteorological Institute. The above description is intended to show how we collected the data for the GEBA for the period prior to the regular publication by the WRDC in Leningrad. Presently all these data are stored in the VAX 3600 system and available to external users.

3. TREND IN GLOBAL RADIATION

The annual total global radiation for the 13 stations which the authors judge to be of high quality is plotted in Fig. 1. The stations, such as Trömsö, Bergen and Kew, located near the Atlantic coast, show gradual increase after 1950 at a rate of 0.13 to 0.24 % yr^{-1}. The interior stations, such as Potsdam, Salzburg and Zurich decreased their global radiation from the late 1950s to the end of the 1970s. Stockholm, Taarstrup (Copenhagen), Hamburg and Sodankylä, the stations located near the shore of the Baltic Sea, show prominant increase in the early 1970s followed by rapid decrease. Generally speaking, the meridional gradient of global radiation in Europe decreased during the last 30 years.

In the region of Zurich, there are three stations with pyranometers, Zurich International Airport, the Swiss Meteorological Institute and the Federal Institute of Forest Research, located within 10 km of each other, which have many years' overlapping observation periods. The mean annual as well as summer (June, July Aug.) and winter (Dec., Jan., Feb.) global radiation for Zurich was calculated with the data from the

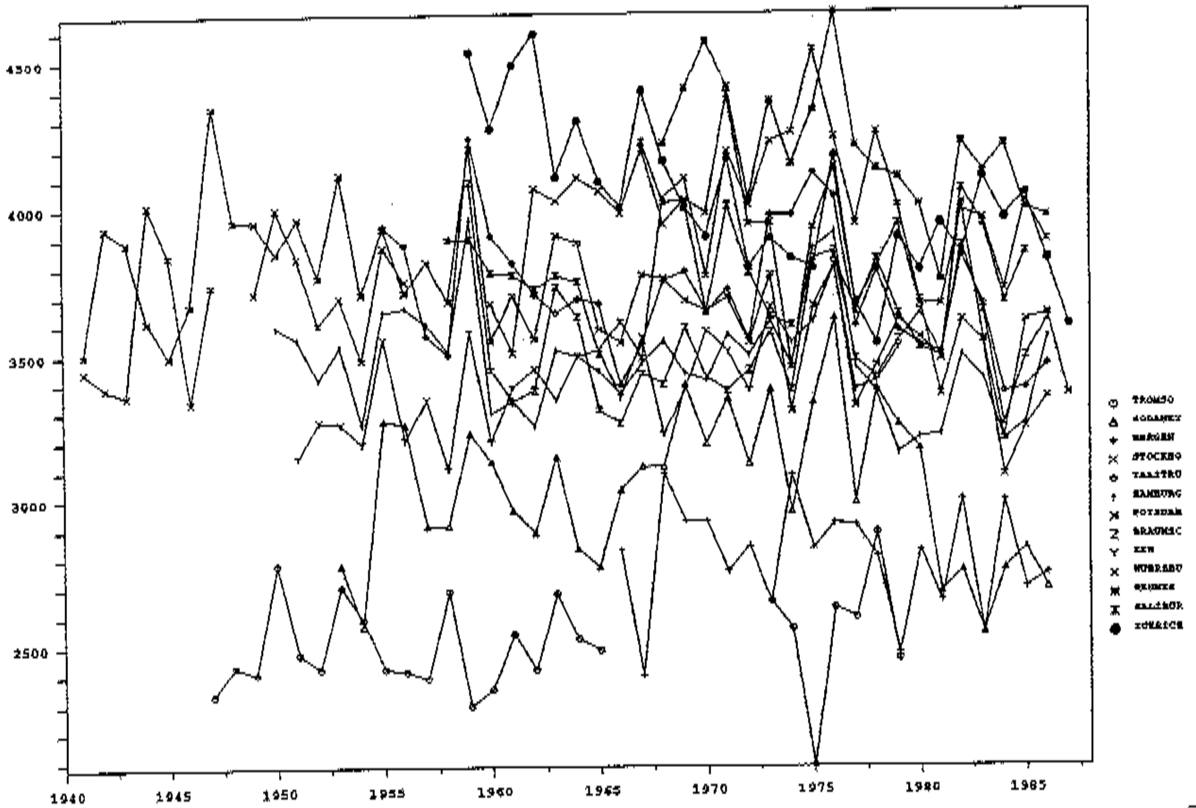

Fig. 1: Annual total global radiation for 13 European stations with long records. Unit in MJ m^{-2} y^{-1} WRR

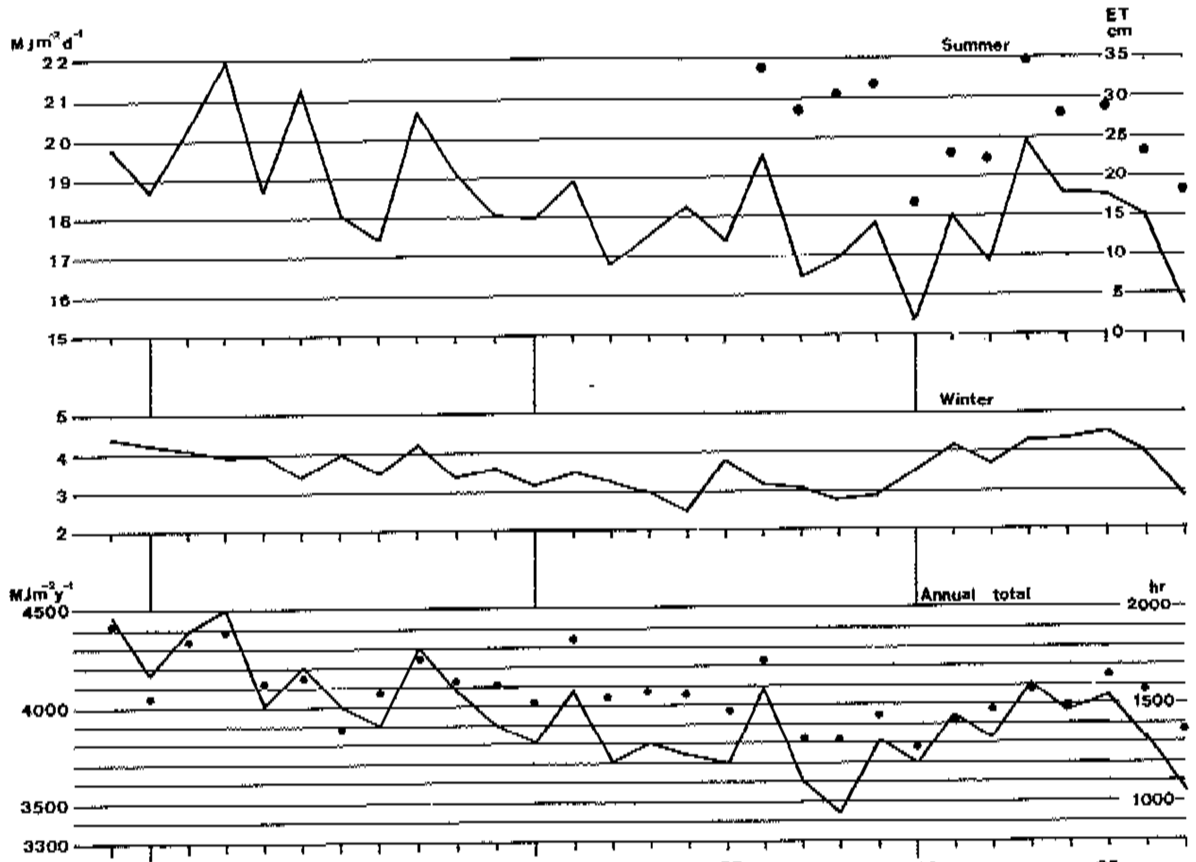

Fig. 2: Annual and seasonal global radiation for Zurich. Summer and winter are periods of June, July, August and December, January and February, respectively. Dots in the upper-right are summer evapotranspiration. Dots in the bottom figure are annual total sunshine duration for Zurich.

three stations and shown in Fig. 2. The RMSE of seasonal values for each station from the regional mean is 0.35 MJ $m^{-2}d^{-1}$. In the region of Zurich global radiation decreased over the twenty years from the end of the 1950s to the end of the 1970s by as much as 20 %, thereafter it tended to recover slightly. This trend was shared in summer and winter as well as in annual total.

4. FEATURES IN SUNSHINE DURATION FOR ZURICH

For time-series analysis, the presently available length of global radiation is too short in comparison with significant periods. As possible causes for the change in global radiation, the changes in the atmospheric transmission and cloud conditions were considered. The possibility of the atmospheric transmission was unlikely as the long trend in the transmission was not found by Hoyt and Fröhlich (1983). Most of these variations were caused by the change in cloud conditions. The monthly global radiation is well correlated with the monthly sunshine duration, as is seen in Fig. 2. The features in the latter time-series were investigated.

An advantage of the Zurich sunshine duration series is the clear documentation of the instruments and their relative sensitivites. Since a Campbell-Stokes type sunshine recorder was adopted for use by the Swiss Meteorological Institute in Zurich the instruments were exchanged in 1927 for a more sensitive recorder of the same type, and in 1978 for a solar cell type sunshine recorder. In 1927 the old and new instruments were in operation simultaneously for a period of ten months. Since 1978 the Campbell-Stokes type and electric sunshine recorders have been in parallel use and both data have been published (Swiss Meteorological Institute, 1978-1985). This circumstance made it possible for the authors to adjust the scale of the oldest instrument wich was used from January 1884 to February 1927 to the present Campbell-Stokes recorder which has been in use since March 1927.

The 102 year's annual total sunshine duration hours are presented in Fig. 3. In this diagram not only the decreasing trend for Zurich after the late 1950s, but also a peak in the mid-1940s for another interior station with the longest record of global radiation at Potsdam are recognizable.

A power spectral analysis of the 102 years'

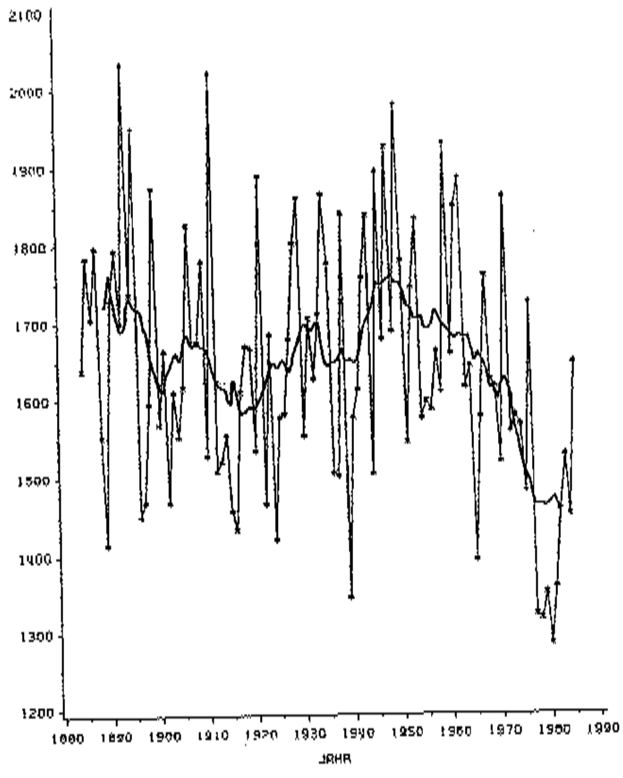

Fig. 3: Annual total sunshineduration hours for the period 1884-1985 with the 11-year running means for Zurich

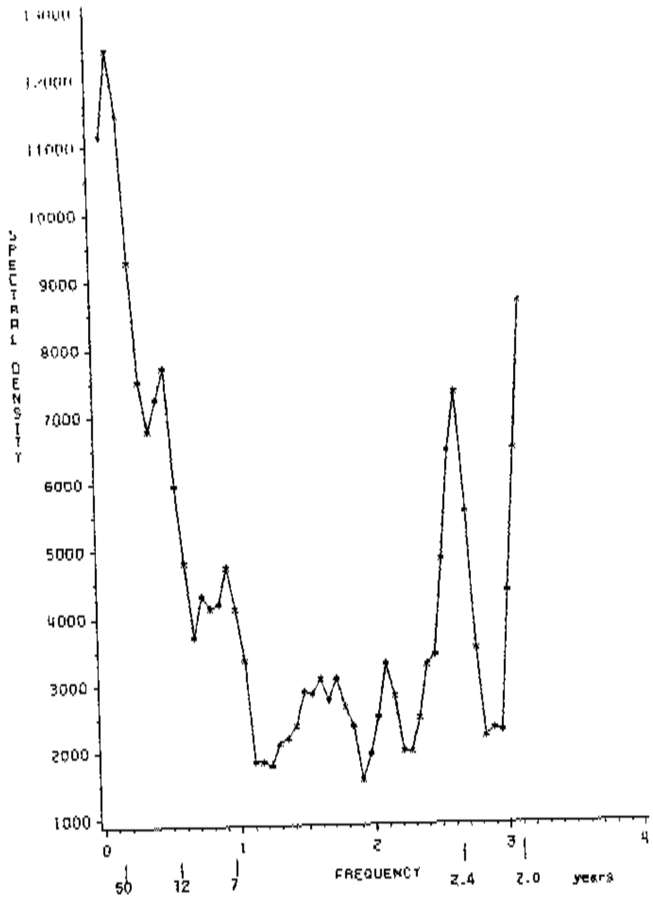

Fig. 4: Powerspectral density distribution of the annual total sunshineduration hours for Zurich

annual values shows the most prominant peak at 12 years' period (Fig. 4), overlapped with the longer trend and short-term fluctuations. The authors must still clarify the causes of these tendencies.

5. CONSEQUENCE OF THE RADIATION CHANGE

The change in global radiation of as much as 20 % over 20 years must have a significant effect on other terrestrial processes. The authors found a similar fluctuation in the 12 yrs. time-series of evapotranspiration which has been measured continuously at an experimental hydrological basin, Rietholzbach, 30 km east of Zurich. The summer total (June, July, Aug.) of evapotranspiration plotted in Fig. 2 changed parallel to the summer global radiation. In most of the region north of the Alps, the surface layer of the soil is almost always at near saturation and this condition causes the evapotranspiration to be very near the potentail evapotranspiration, which is a very distinct function of global radiation. Thus it is possible that latent heat flux of vapourization experienced secular variation of a large amplitude during the last 100 years.

6. CONCLUSIONS

Despite a widely spread belief that heat balance components are stable in time, the present work shows that global radiation, a primary energy source for the earth's surface, shows a clear and relatively large secular change. The change in global radiation is considered to be the primary reason for the change in evapotranspiration. From the estimation of the sunshine duration hours, global radiation for Zurich is considered to have changed during the last 100 years, with periodicity of 12 years overlapped with a generally decreasing trend.

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