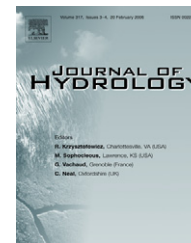




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Characteristics of the water and energy balance in an Amazonian lowland rainforest in Venezuela and the impact of the ENSO-cycle

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Summary From 1996 to 2000 microclimatic conditions (profiles of wind-speed, temperature, humidity and radiation) have been investigated to determine the energy balance within a primary Amazonian rainforest in southern Venezuela (Surumoni crane project), located on the banks of the upper Rio Orinoco. Since 1997 main components of the water balance were examined additionally: gross and net precipitation, stemflow, sapflow and soilwater were measured. The main goal was to determine the water and energy balance for the study site as a contribution to an interdisciplinary ecological research project and to assess consequences of possible land use change. In this study the most important link between energy balance and hydrological cycle, the evapotranspiration, was determined independently by two different approaches.

The results indicate a high interannual variability, which probably was influenced by the strong La Niña-episode in 1996 and the very strong El-Niño-event in 97/98. The impact of the ENSO-cycle is well documented for coastal and marine environments in South America; detailed observations in the Amazon basin however, are very scarce. Beyond the scope of supplying detailed information for a typical pristine tropical lowland forest, this study may also help to improve the understanding of ecosystem impact of ENSO in the Amazon region.

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Introduction

Partial or complete clearance of tropical rainforests affects the hydrologic cycle, at least on a regional scale. Progress in assessing the environmental impact of potential landcover changes is still limited by the current lack of reliable data.

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In part, this deficit is related to the fact that the major interface between the vegetation and the atmosphere, the uppermost forest canopy, remained unexplored for a long time because of the difficulties of access. However, the need for tropical forest research is nowhere greater than for the upper crown area, where natural photosynthetic and consequently radiative transfer rates are highest (Holbrook and Lund, 1995). Canopy-mediated exchanges of energy and mass largely influence the water (Ozanne et al., 2003), carbon and nutrient cycles (Chambers et al., 2000; Richey et al., 2002), as well as the chemical composition of the atmosphere. Understanding the most important exchange surface of this ecosystem can yield insight into changes of the water and energy balance due to alterations of the vegetation structure and species composition.

There is a high demand to improve the understanding of the Amazonian water and energy balance (Bonell and Balek, 1993; Gash et al., 1996) because this region is suffering from deforestation at an advanced pace during the past two decades. Bruijnzeel (1990, 2000) has pointed out the need for more detailed studies to assess possible impacts on local and global scale. Furthermore, parameterization schemes for the soil–vegetation–atmosphere transfer of global climate models rely on datasets that do not cover the high heterogeneity observed in local studies but may well affect the whole planet (Dickinson and Henderson-Sellers, 1988; Henderson-Sellers and Dickinson, 1993; Gedney and Valdes, 2000).

Located in southern Venezuela, in the state Amazonas, a mobile crane system of 42 m height was used for ecosystem studies and since December 1995 microclimatic conditions and the energy balance of the forest have been investigated. Results of the micrometeorological monitoring conducted within the project are published elsewhere (Szczepanski and Anhuf, 2001). In summer 1997 additional measurement systems were installed in order to determine the main components of the water balance.

The aim of this study was to determine a closed energy and water balance for this site, helping to bridge the gap between micro scale climate studies and mesoscale modelling techniques. While point measurements are not capable of describing the spatial differences observed even in small plots, modelling and remote sensing do not regard the actual heterogeneity of the tropical lowland ecosystem. Also it may contribute to the knowledge of the variability of water and energy balance in this seemingly uniform landscape.

Material and methods

The crane plot is located at 3°10'N, 65°40'W, 105 m asl. near the riverbanks of the Rio Surumoni, a small tributary of the upper Rio Orinoco (see Fig. 1). Long-term annual precipitation data are available from La Esmeralda (2700 mm a⁻¹), a small village 15 km upstream the Orinoco and Tama-Tama (3250 mm a⁻¹) which is situated about 20 km downstream from the Surumoni crane (period: 1970–1995; Dirección de Hidrología y Meteorología, Caracas). The average annual temperature in the study area is 26 °C with only slight variations between the coolest (25 °C) and the warmest (26.5 °C) month whereas a daily range of 5 °–10 °C of

maximum temperature frequently occurs (Anhuf and Winkler, 1999).

The structural characteristics of forests directly affect micrometeorological conditions such as energy exchange by turbulent fluxes and radiative transfer, vertical and horizontal temperature gradients within the forest stand and net rainfall. Several variables are available to describe the stand-structure: maximum tree height (33 m at Surumoni), average canopy height (23 m at Surumoni), zero plane displacement height, (21 m at Surumoni) derived as an offset from the logarithmic wind speed measurements above the canopy (see also Szczepanski and Anhuf, 2001), basal area per hectare (here 23 m²/ha), projected crown area (0.78), and LAI (4.24) (Anhuf and Rollenbeck, 2001). Two micrometeorological configurations were employed for simultaneous measurements within and above the forest (Fig. 2). The above-canopy system consists of profile measurements of air temperature, water vapour pressure and wind velocity recorded at 28.5, 31.5, 35 and 41 m height, as well as the determination of wind direction, air pressure and precipitation. Data concerning radiative fluxes were provided by two pyranometers (Kipp and Zonen, The Netherlands) measuring the incoming and the outgoing short-wave radiation, a hemispherical pyrrometer (Schenk, Austria) recording net all-wavelength radiation and a quantum sensor (Sky Instruments, UK) for photosynthetically active radiation (PAR, 400–700 nm). All these instruments were installed on top of the crane above the canopy.

Within the forest, an innovative rope and pulley system was rigged to a 28 m high *Albizia* tree (*Mimosaceae*) (the forest stand station in Fig. 2) to support shielded temperature sensors and relative humidity probes (Vaisala, UK) which were fixed at three heights in accordance with the forest stratification (5–12.5–21 m). Additionally wind speed and PAR were measured in the middle layer (12.5 m) and in the upper canopy (21 m). Soil temperature was registered at five depths (2, 5, 10, 20 and 50 cm) and two heat flux plates and two soil moisture sensors were buried below the surface at 0.8 and 20 cm, respectively. The micrometeorological data were available from December 1995 to December 1999. Results of this micrometeorological monitoring and an analysis of the energy balance are already published elsewhere (Szczepanski, 2000; Szczepanski and Anhuf, 2001).

In 1997 the measurements were completed by the following instruments:

- (1) Precipitation was measured using a tipping-bucket rain gauge (Campbell ARG-00) 10 m above the forest canopy, calibrated by adjacent totalling rain gauges.
- (2) Throughfall was recorded by six half-tubes (3 m long, Ø12.5 cm) each of them connected to a tipping-bucket gauge, thus giving a total collecting area of 3 m².
- (3) Stem flow was determined by plastic collars (Ø50 mm) wrapped around the trunks of 6 trees in the direct vicinity of the throughfall gauges.
- (4) Transpiration was derived from sap flow measurements (Granier-Sensors) of 8 trees consisting of continuously heated temperature probes (slightly northwards of the micro-catchment).

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