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# A Proposal to Measure Diurnal and Seasonal Energetics Above and Within a Lowland Tropical Rain Forest Canopy in Northeastern Australia

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ABSTRACT. Over the past two decades there has been considerable interest in the role of tropical rainforest in local, regional and global atmospheric processes and climate change. Research has tended to focus on forest-atmosphere interactions within the equatorial tropics in regions, such as Amazonia, where seasonal variations in rainfall and temperature are generally small. The main aim of our research project is to quantify diurnal and seasonal energetics (energy balances) for a lowland rainforest canopy located in the seasonally-wet tropics of northeastern Australia (ca. 16°S). A research tower, serviced by a canopy crane, will allow for analysis of diurnal and seasonal variations in canopy energy balances above the forest and microclimate at six heights within the forest.

*Key words:* canopy, tropical rain forest, energetics, microclimate, Australia

## INTRODUCTION

While investigations of energy balances have been thoroughly investigated within equatorial lowland rainforests (e.g., Aoki et al. 1975, Shuttleworth et al. 1984, Shuttleworth 1988, 1989), and temperate deciduous and coniferous forests (e.g., Rauner 1976, Mayer 1981, Black & Kelliher 1989), there have been no energy balance studies within northeastern Australian lowland rainforests. From a forest-atmosphere perspective, there are two fundamental differences between equatorial rainforests, such as those in Amazonia, and seasonally-wet rainforests such as those in northeastern Australia. First, because of the relatively high latitude of northeastern Australia (15–19°S), the region experiences marked changes in sun-earth geometry between the summer and winter solstices compared with rainforests closer to the equator (Turton 1991a, 1993). Such changes have been shown to exert a significant seasonal influence on the amount of solar radiation arriving at the rainforest canopy surface with strong implications for physical and biological processes within the forest (Turton 1993). Second, rainforests in northeastern Australia experience distinct wet and dry rainfall regimes (Turton 1991a) and annual range of temperature greater than 5°C (Turton 1987, 1991b). As a consequence of these broad-scale climatic factors, one would expect marked seasonal differences in forest energy balance regimes within rainforest located in this part of the world.

The main objective of our study is to quantify canopy energetics (energy balances) and microclimate for a lowland rainforest located in the seasonally-wet tropics of northeastern Australia (ca. 16°S) over a three year period. Specific aims of our research project are:

- To quantify diurnal and seasonal variations in canopy energy balances.
- To quantify vertical changes in temperature, humidity, light and wind at six heights within the forest.
- To provide quantitative data for the development and validation of techniques designed to examine rainforest-atmosphere interactions based on remotely sensed data.
- To analyze the response of water and heat fluxes from the rainforest to external climatic factors in order to assist regional scale modeling designed to predict impacts of global environmental change on rainforest ecosystem function.

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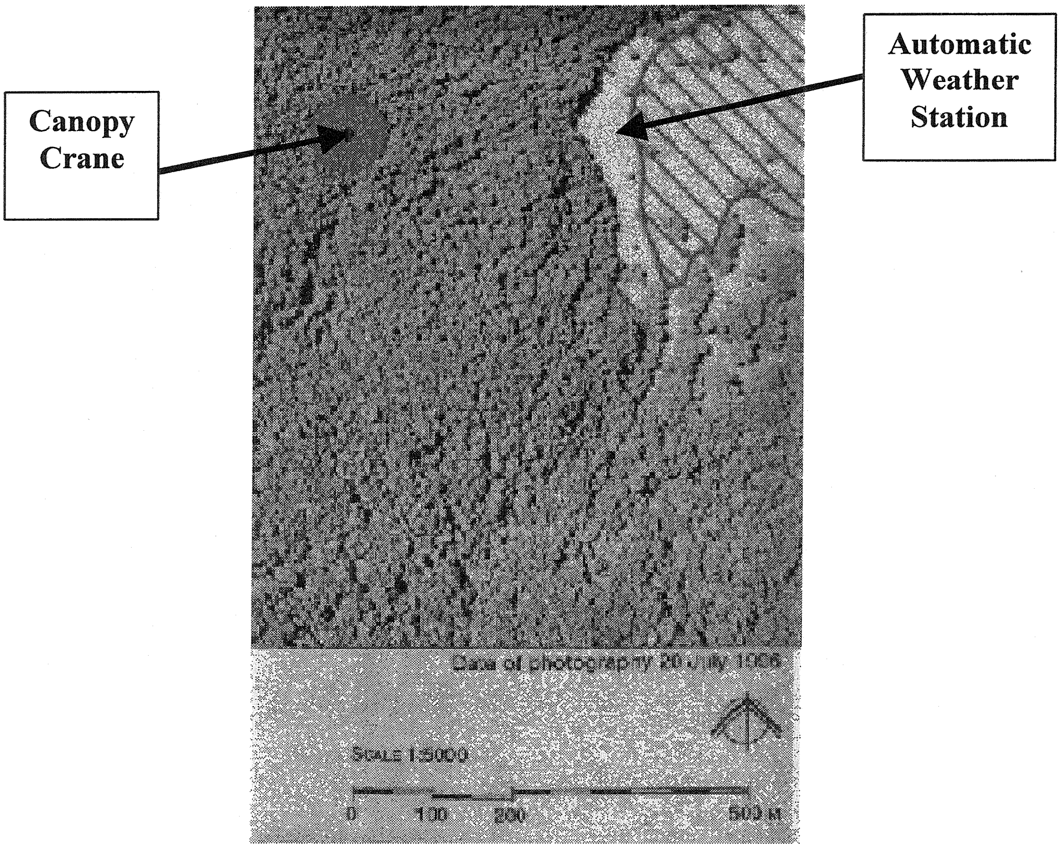


FIGURE 1. Aerial view of the research site in the Daintree lowlands, showing the location of the canopy crane (circular area), the proposed research tower, and the automatic weather station (AWS) in the clearing.

- To provide baseline data for the validation of forest models, related to growth, partitioning of primary production, water and nutrient cycling and forest hydrology.

## STUDY AREA

The Australian Canopy Crane Facility is located in Complex Mesophyll Vine Forest (Tracey 1982) in very wet lowlands near Coconut Beach in Far North Queensland, Australia (16°07′S, 145°27′E, 80 m asl). The canopy crane stands 48.5 m tall with a jib length of 55 m, thereby providing access by means of the gondola (lift box) to about 9500 m² of forest or the equivalent of about 900 trees (FIGURE 1). The crane is located in a fairly extensive area of primary rainforest (average canopy height is 25 m) on relatively flat terrain. Annual average rainfall is about 3500 mm (Tracey 1982) and is strongly seasonal with about 60% falling between December and March. Mean daily temperature ranges from 28°C in January to 22°C in July. Prevailing winds are from the southeast, which provides a fetch distance of about 500 m between the clearing and the canopy crane tower. This distance is within the recommended limits of 325–550 m for forest-atmosphere measurements above a 25 m tall forest (Veen et al. 1996).

## METHODS

### Micrometeorological Measurements

The surface energy balance above the rainforest canopy may be expressed as (Oke, 1987):

$$K{\downarrow} - K{\uparrow} + L{\downarrow} - L{\uparrow} = Q^* = Q_H + Q_E + Q_S + Q_G. \quad (1)$$

Where $K{\downarrow}$ and $K{\uparrow}$ are the incoming global and reflected short-wave radiation fluxes (0.3–3.0 μm), respectively; $L{\downarrow}$ and $L{\uparrow}$ are the atmospheric and terrestrial long-wave radiation fluxes (3.0–100 μm), respectively; $Q^*$ is the flux of net

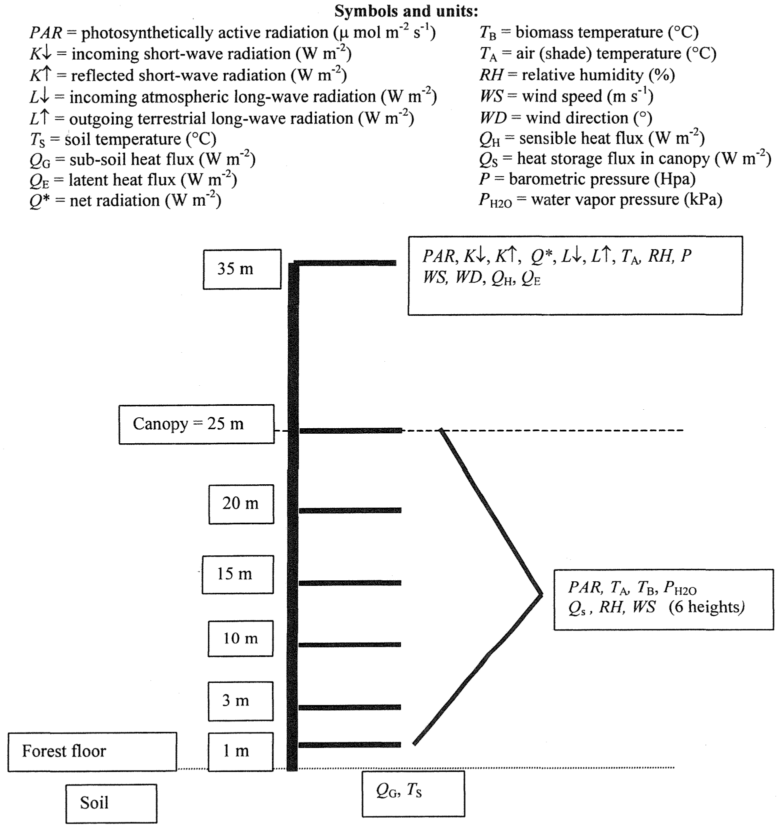


FIGURE 2. Schematic diagram illustrating the meteorological instrumentation layout for the study of energy exchange and microclimate regimes above and within the lowland tropical rainforest.

all-wave radiation (0.3–100 μm); $Q_H$ and $Q_E$ are the convective fluxes of sensible and latent (evaporative) heat, respectively; $Q_S$ is heat storage in the canopy itself, and $Q_G$ is the sub-surface (soil) heat flux.

FIGURE 2 shows the instrumentation layout for the proposed 35 m tall research tower. The tower will be located 50 m to the northwest of the crane tower on the edge of the circular area that may be reached by the 55 m jib (FIGURE 1). It was not possible to mount instrumentation on the crane tower because the canopy is open near the base of the crane to allow for access. Instrumentation on the research tower will be assembled and serviced by means of the crane gondola. The vertical separation of sensors has been designed to maximize the usefulness of the data from a modeling perspective. The above forest eddy covariance system and other micrometeorological sensors will be positioned 10 m above the canopy to best represent the canopy surface in the vicinity of the crane. Sensors within the forest will be positioned near the ground (1 and 3 m), within the sub-canopy (10 and 15 m), and within the main canopy layer (20 and 25 m). Power supply for the instruments and data loggers will be provided by a bank of solar panels, mounted at the top of the tower. A lightning conductor will also be positioned at the top of the tower.

### Above-canopy Radiation Budget

Upward facing and inverted pyranometers (Kipp and Zonen, Holland) will be mounted at height of 10 m above the 25 m tall rainforest to measure the fluxes of short-wave radiation (FIGURE 2). A similar configuration of pyrgeometers (Eppley Laboratory, model PIR, silicon domes, temperature compensated) will mounted at the same height to determine the long-wave fluxes. Net all-wave radiation ($Q^*$) will be measured with a single domed radiometer (Radiation Energy Balance Systems, model 88057) mounted adjacent to the other radiometric sensors. Photosynthetically active radiation (PAR) will be measured with a quantum sensor (Licor, Nebraska) mounted at the same height as the other sensors. Measurements will be continuously recorded on a data logger (Campbell Scientific, model CR23X) operating with a scanning interval of one minute over an integration period of 30 minutes.

### Above-canopy Energy Balance and Canopy and Soil Heat Storage

The convective fluxes of sensible and latent heat will be measured using eddy covariance (EC) Bowen Ratio (BR) systems (both Campbell Scientific). Concurrent measurements of fluxes using EC and BR methods will be useful for validation and comparison of methods. The EC system includes a 3D sonic, and temperature and moisture measurement systems (Licor, Nebraska). The EC system will be mounted 10 m above the forest into the prevailing easterly trade winds. The top arm of the BR system will also be mounted 10 m above the forest, with a 5 m separation with the lower arm. Such a separation is recommended due to the large surface roughness of rainforest canopies and the small vertical gradients of temperature and humidity that typically occur above rainforests (Gash 1986).

Two heat flux plates (Hukseflux Instruments) will be buried in the soil 110 mm apart, and will measure sub-surface heat flux at a standard depth of 60 mm at an undisturbed site beneath the tower. Two probes, buried at a depth of 20 mm, and two buried at a standard depth of 40 mm, will provide a spatially integrated measure of the soil temperature above the soil heat flux plates (FIGURE 2). The two measurements of soil heat flux at 60 mm and the measures of soil temperature ($T_S$) will then be used to derive a measure of soil heat flux ($Q_G$) at the surface using the method described in Oke (1987). Air temperature ($T_A$) and relative humidity (*RH*) will be measured at a height of 10 m above the forest using a Vaisala RH and air temperature sensor, with a Gill radiation shield. Air ($T_A$) and biomass ($T_B$) temperatures and *RH* will be measured at six heights within the rainforest. The $T_A$ and $T_B$ measures will be used to estimate $Q_S$ values for the forest; a parameter often neglected in other studies (e.g., Shuttleworth 1988). Wind speed and direction will be measured 10 m above the forest using Met One precision anemometers, and wind speed and PAR will be measured at six heights within the forest. Barometric pressure (*P*) will be measured on the top of the tower.

Calculations of $Q_H$, $Q_E$, $Q_S$ and $Q_G$ and measurements of $K\downarrow$, $K\uparrow$, $Q^*$, $L\downarrow$, $L\uparrow$, $T_S$, $T_A$, $T_B$, $P$, PAR, *WS* and *WD* will be made with a 30 minute averaging period. These data will provide details of diurnal and seasonal changes in rainforest-atmosphere energy exchanges.

### Meteorological Measurements

An automatic weather station (Environdata, Australia) is located in the large clearing to the east of the crane (FIGURE 1) and currently records half-hourly values for air and soil temperatures, relative humidity, wind speed, solar radiation, soil moisture and leaf wetness. Rainfall is measured with a 0.2 mm resolution tipping bucket rain gage and is stored at 10 minute intervals. The climate data will be correlated with the canopy energy exchange and vertical microclimate values to investigate the response of the forest to climate perturbations over diurnal and seasonal time scales.

## RESEARCH OUTCOMES

The results of our research project will provide, for the first time, a detailed analysis of the interaction between the atmosphere and a lowland rainforest, located in the seasonally-wet tropics of the world. Expected outcomes are:

- A detailed knowledge of how lowland rainforest, located in a seasonally-wet tropical environment, partitions the available energy (net radiation) into sensible and latent heat fluxes at different times of the day and year, thereby improving our understanding of surface-atmosphere dynamics for this part of the world.
- Direct measurements of canopy evapotranspiration, derived from the Bowen ratio and eddy covariance methods, to be compared with estimates derived from other techniques (e.g., remote sensing, Penman-Montieth and Priestly-Taylor methods).
- A more detailed understanding of energy balance storage values for rainforest, particularly those associated with the biomass (leaves, branches and stems), the soil and the air space in the canopy.
- A detailed understanding of natural forest-atmosphere interactions, with direct applications for reforestation and rainforest rehabilitation at other sites in northeastern Australia and elsewhere in the world's seasonally wet tropics.

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