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How might Australian rainforest cloud interception respond to climate change?

Jim Wallace [a,b,*], Dave McJannet [c]

[a] Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER), James Cook University, Townsville, QLD 4811, Australia
[b] CSIRO Land and Water, Australian Tropical Science and Innovation Precinct, Townsville, QLD 4814, Australia
[c] CSIRO Land and Water, EcoSciences Precinct, Dutton Park, QLD 4120, Australia

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SUMMARY

The lower and upper montane rainforests in northern Queensland receive significant amounts of cloud interception that affect both *in situ* canopy wetness and downstream runoff. Cloud interception contributes 5–30% of the annual water input to the canopy and this increases to 40–70% of the monthly water input during the dry season. This occult water is therefore an important input to the canopy, sustaining the epiphytes, mosses and other species that depend on wet canopy conditions. The potential effect of climate change on cloud interception was examined using the relationship between cloud interception and cloud frequency derived from measurements made at four different rainforest locations. Any given change in cloud frequency produces a greater change in cloud interception and this 'amplification' increases from 1.1 to 1.7 as cloud frequency increases from 5% to 70%. This means that any changes in cloud frequency will have the greatest relative effects at the higher altitude sites where cloud interception is greatest. As cloud frequency is also a major factor affecting canopy wetness, any given change in cloud frequency will therefore have a greater impact on canopy wetness at the higher altitude sites. These changes in wetness duration will augment those due to changes in rainfall and may have important implications for the fauna and flora that depend on wet canopy conditions. We also found that the Australian rainforests may be more efficient (by ~50% on average) in intercepting cloud water than American coniferous forests, which may be due to differences in canopy structure and exposure at the different sites.

1. Introduction

Australia contains some unique tropical rainforests in the Wet Tropics region of northern Queensland. These forests vary in structure and composition as the soils and climate change with increasing distance from the coast (Tracey, 1982; McJannet et al., 2007d,b). There is also a marked effect of altitude as the terrain rises rapidly from the coastal plain (~50–100 m ASL) to the 'Tablelands' plateau (~1000 m ASL) and further to the mountains of the Great Dividing Range (up to ~1600 m ASL). On the seaward side of these mountains, rainfall increases with altitude and this has a major effect on the forest water balance and the duration of wet conditions in the canopy (McJannet et al., 2007a,b; Wallace and McJannet, 2012). However, the rainforests above ~1000 m also receive significant inputs of water as cloud interception (McJannet et al., 2007c), which constitutes between 4% and 29% of the annual water input. More importantly, the above studies have also shown that the contribution of cloud interception during dry season months can be as high as 65%, when it becomes the major water input sustaining *in situ* canopy wetness and downstream runoff. If climate change alters the frequency and amount of cloud interception there could therefore be important hydrological and ecological consequences.

The potential impacts of climate change on the water balance of these forests have been reported by Wallace and McJannet (2012). A range of climate simulations for north Queensland predict future (2050) rainfall and temperature changes of ±20% and 1–3 K respectively (see Section 2.5), and using these figures they found that the water balance was primarily affected by rainfall changes rather than temperature. Runoff downstream of the forests changed by a greater amount than rainfall, especially in the dry season, where there were important effects on the onset and duration of the period when there is no runoff. They also found potential *in situ* impacts of climate change that affect how long the rainforest canopy is wet, which may have important implications for the epiphytes, mosses and other species that depend on these wet canopy conditions (Hölscher et al., 2004; Köhler et al., 2006). However, the climate impacts on canopy wetness analysis presented by Wallace and McJannet (2012) only dealt with possible changes in rainfall and no account was taken of how climate change might influence cloud interception. As this is an important input to the higher alti-

* Corresponding author at: Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER), James Cook University, Townsville, QLD 4811, Australia. Tel.: +44 1635 770 634.
E-mail address: jim.wallace@mail.com (J. Wallace).

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tude rainforests in Australia, this paper presents an analysis of how cloud interception might change under future climate scenarios and in turn how this might affect the seasonality of canopy wetness and downstream runoff.

2. Methods

2.1. Locations and weather

The cloud interception and climate impact analyses were performed for four rainforest locations where significant cloud interception has been recorded by McJannet et al. (2007a,b), Fig. 1. Detailed descriptions of the forest sites and methods used to measure rainfall and cloud interception are given by McJannet et al. (2007a,b), so only brief site descriptions are given below.

The first site, Upper Barron (UB), is a lower montane rainforest on the Atherton Tablelands (1050 m ASL). The two sites at Mt Lewis are located in the Mt Lewis Forest Reserve and are also classified as lower montane rainforest. The lower site (ML1; 1100 m ASL) is in a shallow valley while the second site (ML2; 1160 m ASL) is located on a more exposed hill slope. The forest at ML2 is much more stunted because of this exposure, with a canopy height of 12 m, compared to 32 m at ML1. The fourth site is located in upper montane cloud forest near the summit of Bellenden Ker (BK) (1560 m ASL), which is the second highest mountain in Queensland. The rainforests types vary from complex notophyll vine forest on the Tablelands to simple microphyll vine fern thicket at the top of the mountains (Tracey, 1982), Table 1. The rainforests generally form closed canopies and are up to 30 m tall. The upper montane cloud forest at the top of Bellenden Ker is much more stunted (8 m) and has the lowest leaf area index (3.3). Further details the forest types are given by McJannet et al. (2007b,c).

The Australian Wet Tropics region has high annual rainfall, but with distinct wet and dry seasons. The dry season (six driest months) runs from June to November with an average of ~20% of the annual rainfall, while the wet season (six wettest months) generally occurs from December to May with ~80% of annual rainfall. The rainforest furthest from the coast (UB) has the highest radiation and warmest air and all sites have very high humidity (Table 1). The upper montane forest (BK) grows in a much cloudier and cooler climate and is exposed to the highest wind speeds.

Long term weather records for the four sites were obtained from the Australian SILO meteorological database (Jeffrey et al., 2001). Locations within a few kilometres of the rainforest sites were chosen and daily rainfall, temperature, solar radiation and vapour pressure extracted for the period 1950–2008. For the periods where weather data (618–1113 days) were also measured at the rainforest sites by McJannet et al. (2007a) correlations were established between the actual site and the SILO weather data (see Wallace and McJannet, 2012). Site rainfalls, solar radiation and temperature were significantly different from those in SILO, so in subsequent calculations of canopy wetness duration and downstream runoff using SILO long term data we therefore applied the regressions given by Wallace and McJannet (2012) for rainfall, temperature, solar radiation and vapour pressure.

2.2. Rainforest water balance

The water balance of a rainforest has been described by McJannet et al. (2007c) as:

$$(P_g + P_c) = I + E_t + E_s + R + D + \delta\theta, \quad (1)$$

where $(P_g + P_c)$ represents total precipitation input to the forest as rainfall, P_g and cloud interception, P_c. Water losses from the canopy are given by the sum of the canopy interception I, and transpiration, E_t. Direct evaporation from the forest floor, E_s, is usually small and R and D represent the processes of runoff (i.e. lateral flows whether overland or subsurface) and drainage, respectively. Over short time periods (days to months) changes in soil moisture storage ($\delta\theta$) can be a significant part of the water balance. The difference between the rainfall, P_g and the total evaporation $(I + E_t + E_s)$ is referred to as 'excess water' by Wallace and McJannet (2012), and is given by $(R + D + \delta\theta)$. When the change in $\delta\theta$ is small compared to the other water balance components (e.g. high rainfall months and/or annual periods) the excess water gives a good measure of $(R + D)$.

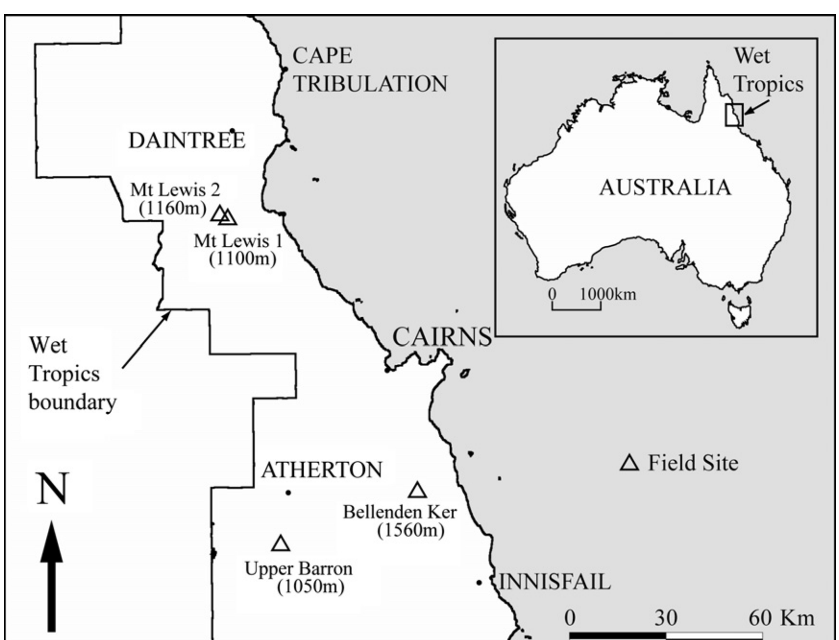

Fig. 1. Location map showing Wet Tropics region and location of the four rainforest sites that have significant cloud interception (Δ). Altitudes of field sites are given in brackets. Reproduced from McJannet et al. (2007c).