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Critical Zone in Tropical Montane Cloud Forest of a Volcanic Island: Specific Constraints and Forcings

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Introduction and motivation

La Réunion is a high volcanic island subjected to a humid tropical climate with several world records of rainfall. In this environment, the drainage basin "OSUR/Erorun", part of the OSU-R multiple site platform, is dedicated to the study of water and material flows within the critical zone (the area between the top of the canopy and the base of the soil). Hence, this site constitutes an excellent location for the study of tropical montane cloud forest (TMCF) ecohydrology, similar to that of the Hawaiian climatic and geological situation.

In this project we have taken steps to enhance the investigation of the canopy water balance in the context of a TMCF. This mountain forest presents specific hydrological function linked to its ability to capture fog and affect the water balance specifically due to fog supply, interception and storage in the epiphytes considered as an upper soil compartment. Hence, we have set up an experimental protocol aiming specifically to quantify the increase of infiltration due to the fog and epiphytic contribution.

The canopy water balance approach supported by field measurements will be used to estimate the Cloud Water Interception (CWI). The canopy water balance can be described according to:

$$RF + CWI = TF + SF + Ei + \Delta S$$

where: RF is rainfall, CWI is cloud water interception, TF is throughfall, SF is stemflow, Ei is interception evaporation, and ΔS is the change in the above ground water storage. All terms are in units mm.

Scientific objectives

The purpose of this project was develop a research protocol to investigate the upstream region of the Erorun watershed, in the heart of a preserved tropical forest, including in a National Park, using the field-instrumented site of OSUR/FOREST at "Plaine des Fougères" (1350 m) dedicated to the water balance monitoring. This site is already equipped with a weather station, soil water tension gauges and hydrometric station for runoff flows, the implementation of new sensors will lead to measure TF, and SF directly at the study site. CWI, Ei and ΔS will be calculated using the method of Takahashi et al. (2011).

Methodology and experimental set-up

Fieldwork conducted during the mission on the site was carried out over a period of 13 days was dedicated to the identification of new sensors and alternative sensors for a later evaluation established over a period of 6 months including at least 3 intense precipitation events. Emphasis was given to the enhancement of existing instrumentation with new sensors and protocols suited to the bioclimatic context. Ultimately, the meteorological variables measured at the site will be used to estimate the potential evaporation (PE), a variable used in the estimation of Ei. Also needed are recording TF and SF gauges to allow continuous observation of the precipitation (from rain and fog) reaching the ground. The TF gauges are tipping-bucket devices that capture water falling beneath the canopy in troughs (Ziegler et al., 2009; Takahashi et al., 2011). The tipping mechanism is a scaled up version of the type found in tipping-bucket rain gauges and is equipped with a magnet-sensitive switch to signal tips. The signal is recorded using a Hobo Event Logger (Onset Computers, Inc.). The gauges are set up to tip at a nominal depth of 0.2 mm over the area of the collecting troughs. A dynamic calibration relationship will be determined for each gauge to allow for differences in tip volume over the range of observed tipping rates. Each collection trough is approximately 43 mm wide, with a triangular-shaped channel and 25 mm vertical risers to reduce rain splash loss. Two TF gauges will be installed at each site and positioned to sample a representative range of canopy density; one SF gauge will be used to collect from multiple stems at each site.

A Juvik-type passive fog collector with rain shield was purchased and brought to Reunion for future use under and outside canopy. Water collected by the fog gauge will be funneled into a tipping bucket rain gauge to record the time series of fog water collection. Leaf wetness sensors will also be set up, to record dew and fog events under and outside the canopy.

Another aspect of the project was a conference and field training dedicated to the OSUR masters students and technicians of the OSUR/Erorun and OSUR/FOREST stations.

Preliminary results and conclusions

As a result of the discussions and field visits during the Reunion visit, the follow field protocols are suggested for the study of the hydrology of Tropical Montane Cloud Forests on La Reunion.

Recommended Field Equipment at Each Field Site

Meteorological Observations:

Description	Model	QTY
Enclosure & Accessories		
enclosure - 16x18	ENC 16/18	1
openings, 2 conduit	-DC	1
backplate -SB (std)	-SB	1
mount, MM (mast mount)	-TM	1
ENC RH indicator	CS210	1
desiccant, 4 Unit Bag (20)	6714	1
Datalogger & Storage		
datalogger	CR3000	1
base, no battery	-NB	1
standard temp range	-ST	
standard warranty	-SW	
no calibration cert	-NC	
CFM100	CFM100	0
CF card, 2GB	CFMC2G	0
Sensors		
Rnet	NR01	1
Cable (feet)		20
CM204 1" IPS x 4' w/CM210	CM204	1
CMB200 Crossarm Brace Kit	CMB200	1
Temp/RH - 1	HMP155A	1
Cable (feet)		20

Description	Model	QTY
RM Young 14-plate radiation shield	41005-5	1
Temp/RH - 2	HMP155A	1
Cable (feet)		20
RM Young 14-plate radiation shield	41005-5	1
RM Young Wind Monitor - HD	05108	1
Cable (feet)		20
Nu-Rail - 17953 (1"x1")	17953	1
Tsoil	TCAV	1
Cable (feet)		25
soil heat flux - 1	HFP01	1
Cable (feet)		25
soil heat flux - 2	HFP01	1
Cable (feet)		25
soil moisture - 1	CS616	1
Cable (feet)		25
soil moisture - 2	CS616	1
Cable (feet)		25
soil moisture - 3	CS616	1
Cable (feet)		25
Raingauge	TE525	1
Cable (feet)		25
Nu-Rail - 17953 (1"x1")	17953	1
1" x 12" IPS Al pipe	3659	1
Power		
PVM, 20W, 15 ft cable	SP20	1
PVM mounting bracket	-SM	1
12V power supply w/ 7 Ahr battery	PS150	1
Mast		
UT10 tower	UT10	1
J-Bolt Kit	-J	1
CM204 1" IPS x 4' w/CM210	CM204	1
Software		
LoggerNet 4	LOGGERNET	1

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Fog and cloud water interception observations:

Description	QTY
Fog measurement	
Digital infrared/visible camera system	1
Juvik fog gauge	1
Tipping bucket gauge to monitor fog gauge	1
Leaf wetness sensors	1
Throughfall gauges	≥3
Stemflow gauges	≥3
Event loggers for TF/SF gauges	≥6

The design and calibration of throughfall and stemflow gauges are available upon request (thomas@hawaii.edu).

Network Design, Site selection, and Instrument Placement

To adequately assess the spatial patterns of fog occurrence and cloud water interception, a network of field stations should be established with station locations representing the range of fog frequency, fog density, wind speed, exposure (ground slope and aspect in relation to wind direction), and vegetation characteristics (height, leaf area, structure, and epiphytic abundance). While it might not be possible to establish the number of fully equipped stations necessary to monitor the full range of these site variables, much could be gained to establishing stations across an elevation gradient.

Sites should be selected with certain characteristics in mind. While exceptionally high cloud water interception rates are likely to be found for isolated trees, the windward edges of forest stands, and topographic ridge tops, such sites are not representative of the larger landscape and should be avoided. Chose sites with relatively homogeneous cover extending in the windward direction for at least 100 m if possible.

Most meteorological sensors used to estimate potential evapotranspiration (e.g., net radiation, wind speed, air temperature, and relative humidity) should mounted on a mast at a level at least 2 m above the highest vegetation. The raingauge should be placed so that vegetation does not interfere with windblown rainfall reaching the gauge orifice. Also, the raingauge should not be mounted higher than necessary to avoid excessive wind-related under-catch error. Throughfall gauges should be positioned so that collecting troughs lie as close to the ground as is practical and troughs should lie under representative vegetation, especially with regard to the tree canopy. Stemflow collars should be attached to tree stems of a representative range of species and diameters. Scaling up stem flow measurements will require surveying of sample plots to determine the stem size distribution of tree species sampled by stemflow gauges. Fog gauges (Giambelluca et al., 2011) should be placed slightly above the highest vegetation to obtain fog frequency/density data of the air in direct contact with the highest parts of the vegetation.

Multidisciplinary approach

The study of Tropical Montane Cloud Forests requires a highly multidisciplinary approach involving plant ecology, bryology, hydrology, soil science, and meteorology (Giambelluca et al., 2010; Giambelluca and Gerold, 2011). These special ecosystems are often refugia for rare and endangered endemic plant and animal species and important sources of freshwater supporting downstream ecosystems and supplying water resources for human use. Here, we bring together the expertise of scientists of many disciplines to address questions about the flows of water TMCFs.

Outcome and future studies

We expect this project to instigate new collaborative multidisciplinary research efforts among scientists within OSUR/Erorun and in Hawai'i. These future collaborations will take the form of integrated studies of the ecology, climate, hydrology, and biogeochemical processes occurring in TMCFs in Reunion, Hawai'i and other tropical islands.

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