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"TECHNIQUE FOR ASSESSING VEGETATION-INDUCED MOISTURE FLUX, WITH IMPLICATIONS FOR GLOBAL CLIMATE MODELING"

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General

The Mission to Planet Earth has as main objective the study of the changes that the planet has and is undergoing. Mission to Planet Earth describes a focused effort in satellite remote sensing and the associated ground-based research from a variety of fields that will characterize the global environment as an interacting system. The Earth Observing System (EOS) is an integral part of Mission to Planet Earth and is dedicated to providing the new observations, data and information necessary to understand the way the Earth works as a natural system.

With the development of EOS, scientists will be able to observe and understand many of the key variables and processes of the global-scale cycles of energy and water. Water plays a global role of enormous variety of Earth system processes. Water is considered to be the most powerful agent of topographic change. Water is also necessary for life on Earth, playing a major role in climate regulation. In addition to its role in ocean circulation and precipitation, water can also affect climate in the continents through transpiration within plant and soil ecosystems. Short term hydrological events, such as droughts or large precipitation activity can cause substantial ecological changes on regional scales.

Large scale hydrologic studies are essential to the NASA/MSFC EOS initiative in order to better understand hydrological flux processes that are a main ingredient in global biosphere interactions. One of the most important questions for modeling the global hydrologic cycle includes the interrelationship between land surface and atmospheric processes for variable spatial and temporal scales. Global climate models have shown that proper modeling of the Earth's surface (which is commonly modeled as a boundary layer) is of great importance to the results obtained in such modeling studies.

Introduction

Recent simulation experiments on the sensitivities of climate to hydrological processes have been conducted by Mintz (1984) and Ye (1989). Hydrological processes have been found to significantly affect terrestrial climate. Yeh et al. (1984) showed that in addition to affecting the planetary boundary layer, ground hydrological processes can be felt through the whole troposphere.

The relationship between vegetation and soil (especially in the rooting zone) is crucial to both the heat and water balance. Only through vegetation can water in the deep soil layers be connected with the atmosphere and take part in the hydrological processes. Hydrologically, the three main factors controlling this are: the time between storms, the duration of storms, and the storm depths, (Eagleson, 1978). This research project attempts to study each of these features, in relation to vegetation controls on the disposition of rainfall. It is proposed that understanding the movement of water between the vegetation and soil (including evapotranspiration and infiltration) will be the gateway for modeling atmospheric flux and improving global climate models.

Despite increasing efforts by hydrologists and atmospheric scientists to measure short-term rainfall intensity, it may not be the important variable for soil water physical interpretation. As indicated above, rain does not fall directly upon the earth surface where soil physical measurements are made. It is funnelled there by the resident vegetation; either throughfall or stemflow. These plants may act as 'lenses' and focus the water, so that the local flux density of water application to the surface may be substantially above the recorded rainfall rate. Therefore, the vegetation plays a critical role in the transmission of rainfall to the surface and deeper soil deposits.

Objective

The overall goal of the proposed research effort is to develop a field/laboratory methodology which will provide a better understanding of vegetation-induced water movement. Water flow initiated from stemflow of wooded slopes feeds soil water pathways, which in turn feed the deeper groundwater system and give rise to stream response. This is balanced by more water inputs via throughfall, where it percolates the soil matrix and allows much greater rates of evapotranspiration and atmospheric/soil moisture flux. Until now, soil physicists and hydrologists have not treated the vegetation-soil interface in any detail. In fact, most studies have disregarded the effect of rainfall 'funnelling' and modeled surface hydrologic flux solely on the basis of evenly applied rainfall. Calculation of soil moisture flux requires frequent measurement of soil suction during a storm. This research study seeks to gain an understanding the effect of vegetation on soil moisture, and the effect of this 'differential' wetting on resulting evapotranspiration and atmospheric flux.

Instrumentation

A small forested research plot on the Redstone Arsenal has been instrumented with an intensive network of electronically multiplexed tensiometers, throughfall and stemflow collectors, rain gauges and soil moisture sampling devices. The overall instrumentation set-up is managed and operated by two Campbell 21X field data-loggers which are programmed to gather and store the appropriate data, a sketch of the apparatus. The research site is located in the immediate proximity of Building 4372. A mobile trailer, located on the high ground (west side) of the site houses the data-loggers and acts as the control room to the research site. The data-loggers are powered by DC current and are kept recharged by means of solar energy. Solar panels were mounted on the north-east corner of the site and are connected to each of the six sets of 12 volt batteries located in the middle of each instrumentation grid.

The research site is discretized into six identical grids. Each grid consists of four sets of tensiometers and one set of soil moisture sampling devices. Each of the grids is connected to a centrally located multiplexer that is excited by one of the two data-loggers (located inside the field laboratory). Each set of both the tensiometers and soil moisture sampling devices, is composed of three instruments which were installed to depths of 1, 2, and 3 feet from the surface elevation. Also, a seventh grid was instrumented located away from base of one of the trees in the site. This last grid is composed of 9 sets of tensiometers and 4 sets of soil moisture sampling devices and will enable the identification of soil zones of high flux density, where vegetation 'funnelling' through the tree roots may occur. The total number devices in the research site is 99 tensiometers and 30 soil moisture sampling devices. In addition, six tipping bucket rain gauges were installed. One of them was installed in the north-east corner of the site (as far away from the trees) in order to measure the total volume of rain during a given event. Another rain gauge is fed by a stemflow receptacle installed on the trunk of one of the down slope trees in order to measure quantities of water that travel to the surface via the tree trunk. The remaining four rain gauges were installed below the tree canopies in order to measure the canopy rain throughfall.

An above ground sprinkling system was installed at the site. Artificial sprinkling experiments will be conducted to enable specific tests of observed phenomena. By controlling water application, vegetation-induced moisture flux can be correlated to pre-storm antecedent wetness condition. This will greatly enhance data collected from natural events, and place results within the context of seasonal and annual conditions.

<u>Soil Conditions</u>

In order to assess the soil conditions at the indicated research site, three soil borings were drilled and soil samples were obtained from each of these borings. The results of the test drilling indicated a topsoil cover at each of the test locations ranging in thickness from approximately 1.0 to 1.5 feet. Below the topsoil cover the test borings encountered an upper stratum of sandy lean clay extending to depths ranging from approximately 6 to 9 feet below the surface elevations. The tests borings were terminated in an underlying stratum of fat clay with variable proportions of leached limestone fragments. The borings were terminated at approximately 10 feet below the surface elevation.

Operation of the Site

The data-loggers have been programmed to excite the multiplexers and hence record data from the pressure transducers (tensiometers) and the rain gauges at given time intervals. These time intervals will depend on the meteorological forecast. During anticipated rain events the sampling intervals will vary between 15 and 20 minutes in order to obtain as much data as possible. During anticipated dry periods the sampling intervals will be expanded to every hour in order to minimize non-usable data. The data obtain during the sampling periods is collected by the data-loggers and then stored into two detachable storage modules. In order to analyze the data the storage modules can be plugged into a personal computer by means of an RS232 connector and specially developed software retrieves and converts the data into ASCII format spreadsheets that can be readily accessed by any spreadsheet software package.

Conclusions

The expected results can be used for improving hydrologic sub-models of global climate change. With information obtained during the experiments outlined above, specific questions regarding the nature of vegetation-induced moisture flows can be addressed.

The experimental and numerical methods developed through this research could be used in future large-scale experiments on hydrologic and atmospheric flux. These efforts involve remote sensing applications, to predict regional-scale processes. Knowledge gained in the proposed study will be used to develop a Vegetation-Soil-Water index for regional atmospheric flux and hydrological models.