Comprehensive Monitoring of CO_2 Sequestration in Subalpine Forest Ecosystems and Its Relation to Global Warming

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ABSTRACT

Global warming is an increasing concern worldwide. Assessing the contribution of CO_2 to this phenomenon is an important issue. This project's goal is to improve understanding of CO_2 and H_2O transport in a mountainous terrain that confound current efforts to resolve CO_2 budgets at regional and global scales.

Categories and Subject Descriptors

J.J.2 [**Computer Applications**]: PHYSICAL SCIENCES AND ENGINEERING – Earth and atmospheric sciences.

General Terms

Design, Experimentation, Measurement, Performance, Reliability

Keywords: biogeochemistry, carbon sequestration, ecosystem, multi-tier, multi-modal, multi-scale, self organized, sensor array, trigger, wireless

1. INTRODUCTION

Researchers in the discipline of biogeochemistry face an enormous challenge as they attempt to quantify energy and element flows through the earth system, couple these flows to the dynamic climate system and devise modeled scenarios about how the flows might change in the future – i.e. Carbon cycle studies related to Global Climate Change. In facing this challenge, researchers must accommodate spatial and temporal heterogeneity at unprecedented scales and confront non-linearity's and intermittency of gas transport that renders many earth system processes intractable for existing approaches. This paper describes the design and implementation of a multi-scale, multi-modal wireless sensor network to comprehensively monitor ecosystem carbon sequestration. The network consists of CO_2, Weather (pressure, temperature, wind, humidity, rain and light), Soil temperature and moisture, Sap Flow, water temperature and PAR sensors that can be deployed in a forest to more accurately detect the movement of CO_2 within the forest, and thus improve the accuracy of our estimates of forest-atmosphere CO_2 exchange. Individual components of the multi-tiered system have been implemented, tested, and deployed separately, and the first phase of the *integrated* system deployment is currently underway at Niwot Ridge, CO., this July 2006.

SenSys'06, November 1–3, 2006, Boulder, Colorado, USA.
ACM 1-59593-343-3/06/0011.

2. DESIGN AND DEPLOYMENT

To achieve comprehensive ecosystem monitoring using independent but inter-linked measurements at a variety of scales, our multi-tiered network combines meteorological and environmental sensing modalities. As shown in Figure 1, our system integrates wireless arrays, which focus on microscale (<1m), macroscale (10s of meters), and mesoscale/network nodes (100 meters to 10 km) variations. The latter allow bi-directional within-tier and cross-tier communications to connect local and remote networks.

Microscale Network Our microscale sensing system is the most mature of the three tiers. A key component is the Transact Measurement System (TRAM). The TRAM system consists of two sensor heads for high frequency (10 Hz) measurements of wind speed, CO_2 concentration, and air temperature that travels on cables through the canopy. The TRAM package is capable of traveling 5 m/s at various heights (1-6m) above ground. This system has been tested successfully outdoors on the grounds of the NCAR (National Center for Atmospheric Research) campus in Boulder, Colorado. The TRAM instrument package allows us to capture fine-spatial and time variations of the CO_2 and wind fields along the track.

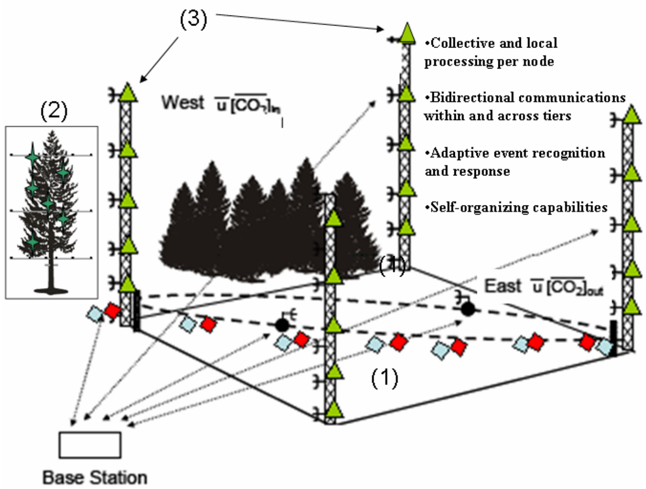

Fig. 1 CO_2 Flux Measurements from 3 scales: (1) *Microscale* data of soil, air and MET measurements from TRAM (2) *Macroscale* – Photosynthetic data from tree canopy. (3) *Mesoscale* - CO2 data co-located with MET.

Beneath the TRAM lies a network of sensor motes that measure soil temperature, moisture and air temperature. Our initial mote deployments on Niwot Ridge are shown in the poster figures and [5]. Seventy two LM20 soil temperature sensors were deployed using six probes on twelve Crossbow Mica2 motes. Four motes each were deployed in a Willow, Pine and an Aspen ecosystem. Each mote utilized alkaline rechargeable batteries and a solar panel. Before deployment, the soil temperature sensors were calibrated in an oil bath. The calibration coefficients were added to the mote software which used a second order fit equation to convert the A/D count to the appropriate temperature reading. Due to the imprecision of the A/D, over sampling and averaging of the data were found to be necessary to achieve the needed accuracy of +/- 0.25C [5].

A unique feature of the current microscale WSN deployment is the *integration* of the TRAM and mote subsystems into one integrated system, unlike [4] and [6]. In particular, the TRAM system *triggers* the data collection of the motes when the TRAM travels over the mote. Building an integrated *event-based* WSN that triggers the *closest* mote to the overhead tram in a mesh network configuration represents an exciting and non-trivial research challenge. Triggering mechanisms will be employed in future developments to intelligently monitor and measure system and sensed events across network scales.

Macroscale Nodes The macroscale WSN is in its initial design. The goal of this array is to gather fine-grained spatial and temporal data on the solar photon flux within the complex structure of a coniferous forest canopy, and couple this to the transpiration water flux of individual trees [2][3].Twelve trees will contain PAR, Temperature, Humidity and Sap Flow sensors.

Mesoscale Nodes We are currently deploying the mesoscale WSN, which sequentially measures the CO_2 concentration at five vertical levels on each of the towers, requiring 90 sec for each measurement. By measuring atmospheric CO_2 concentration at two opposite edges of the box, and multiplying by the mean horizontal wind speed moving through the box, we are able to calculate the horizontal advective CO_2 flux for the footprint within the box.

The nested format of the microscale, macroscale and mesoscale arrays permits us to measure the CO_2 transport at three different scales; the scale of tens of centimeters, the scale of tens of meters and the scale of 100's of meters respectively.

3. SUMMARY

Our integrated system of three sensing tiers, microscale, macroscale, and mesoscale, provides comprehensive monitoring of an entire ecosystem, enabling scientists to better monitor the processes of CO_2 sequestration and its relation to global warming. We have built and tested various subsystems both in the lab (TRAM) and in the field (mote soil sensors). Our summer 2006 deployment, which is currently underway, combines the TRAM System, CO_2 sensors, MET sensors, Soil Moisture and Temperature Sensors in a cross wind configuration to examine where CO_2 collects and flows.

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