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Progress and opportunities for monitoring greenhouse gases fluxes in Mexican ecosystems: the MexFlux network

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RESUMEN

Para entender los procesos de los ecosistemas desde un punto de vista funcional es fundamental entender las relaciones entre la variabilidad climática, los ciclos biogeoquímicos y las interacciones superficie-atmósfera. En las últimas décadas se ha aplicado de manera creciente el método de covarianza de flujos turbulentos (EC, por sus siglas en inglés) en ecosistemas terrestres, marinos y urbanos para medir los flujos de gases de invernadero (p. ej., CO_2, H_2O) y energía (p. ej., calor sensible y latente). En diversas regiones se han establecido redes de sistemas EC que han aportado información científica para el diseño de políticas ambientales y de adaptación. En este contexto, el presente trabajo delimita el marco conceptual y técnico para el establecimiento de una red regional de medición de flujos de gases de efecto invernadero en México, denominada MexFlux, cuyo objetivo principal es mejorar nuestra comprensión de la forma en que la variabilidad climática y la transformación ambiental influye en la dinámica de los ecosistemas mexicanos ante los factores de cambio ambiental global. En este documento se analiza primero la importancia del intercambio de CO_2 y vapor de agua entre los ecosistemas terrestres y la atmósfera. Después se describe brevemente la técnica de covarianza de flujos turbulentos para la medición de éstos, y se presentan ejemplos de mediciones en dos ecosistemas terrestres y uno urbano en México. Por último, se describen las bases conceptuales y operativas a corto, mediano y largo plazo para la continuidad de la red MexFlux.

ABSTRACT

Understanding ecosystem processes from a functional point of view is essential to study relationships among climate variability, biogeochemical cycles, and surface-atmosphere interactions. Increasingly during the last decades, the eddy covariance (EC) method has been applied in terrestrial, marine and urban ecosystems to quantify fluxes of greenhouse gases (*e.g.*, CO_2, H_2O) and energy (*e.g.*, sensible and latent heat). Networks of EC systems have been established in different regions and have provided scientific information that has been used for designing environmental and adaptation policies. In this context, this article outlines the conceptual and technical framework for the establishment of an EC regional network (*i.e.*, MexFlux) to measure the surface-atmosphere exchange of heat and greenhouse gases in Mexico. The goal of the network is to improve our understanding of how climate variability and environmental change influence the dynamics of Mexican ecosystems. First, we discuss the relevance of CO_2 and water vapor exchange between terrestrial ecosystems and the atmosphere. Second, we briefly describe the EC basis and present examples of measurements in terrestrial and urban ecosystems of Mexico. Finally, we describe the conceptual and operational goals at short-, medium-, and long-term scales for continuity of the MexFlux network.

Keywords: Environmental networks, eddy covariance, FLUXNET, greenhouse gases, long-term measurements, surface-air exchange.

1. Introduction

Humankind faces new challenges to develop policies for the reduction, adaptation and mitigation of global environmental change. The scientific community has the responsibility of providing information to enable the development of such policies and strategies. This includes the generation of knowledge about the components, processes and mechanisms by which ecosystems respond to: (1) climate variability, and (2) the interaction and effects of greenhouse gases (*e.g.*, CO_2, CH_4, N_2O) on global climate.

From a functional standpoint, the interaction between climate variability, vegetation dynamics (*e.g.*, land use change), and biogeochemical cycles are necessary to understand ecosystem processes within the context of global environmental change (Chapin *et al.*, 2002). From a socio-ecological point of view, the water and carbon cycles are critical for the regulation and supporting of ecosystem services, and therefore represent part of our natural capital (Millennium Ecosystem Assessment, 2005). Thus, it is important to: (1) evaluate the influence of these processes on atmospheric dynamics, (2) estimate the potential ecosystem services provided to human populations, and (3) provide relevant information to define policies for management and conservation.

Through the processes of photosynthesis and respiration, ecosystems play a key role in the capture and emission of CO_2 (Fig. 1). Furthermore, the characteristics of vegetation cover also affect water vapor fluxes into the atmosphere through evapotranspiration (Fig. 1), and therefore the balance between sensible and latent heat fluxes that impact the atmosphere (Fisher *et al.*, 2011). Additionally, the type and extent of vegetation defines the physical properties, such as surface albedo, emissivity and aerodynamic roughness that can affect air temperature, precipitation, and wind speed (Burba and Verma, 2005). In turn, climate is the main factor determining the presence and distribution of ecosystems around the world, and establishes complex feedbacks between the biosphere and global biogeochemical cycles (Bonan, 2008; Heimann and Reichstein, 2008).

Current knowledge on the interactions between climate and carbon and water cycles is still limited. This has been identified by the Intergovernmental Panel on Climate Change (IPCC) as a “key uncertainty” in our understanding of present and future climate (IPCC, 2007). The experimental evaluation of the interaction between weather and these cycles has made significant progress with the development of new methodologies to measure the mass (*e.g.*, water vapor, CO_2) and energy exchange (*e.g.*, sensible heat, solar radiation) at multiple spatial and temporal scales (Canadell *et al.*, 2000). This development has required a multidisciplinary link between earth and atmospheric sciences, functional ecology, biogeochemistry, and mathematics, which has improved the application of model-data fusion (Vargas *et al.*, 2011a). This scientific development, known as the third scientific paradigm, is complemented by the integration of knowledge from computer systems science, which is emerging as the fourth paradigm in scientific research (Hey *et al.*, 2009).