Geophysical Research Abstracts
Vol. 18, EGU2016-2366-1, 2016
EGU General Assembly 2016

The effect of El Niño – Southern Oscillation events on CO_2 and H_2O fluxes in a mountainous tropical rainforest in equatorial Indonesia

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The possible impact of El Niño–Southern Oscillation (ENSO) events on the main components of CO_2 and H_2O fluxes between the tropical rainforest and the atmosphere was investigated. The fluxes were continuously measured in an old-growth mountainous tropical rainforest in Central Sulawesi in Indonesia (1°39.47'S and 120°10.409'E) using the eddy covariance method for the period from January 2004 to June 2008 (Ibrom et al. 2007). During the period of measurements two episodes of El Niño and one episode of La Niña were observed. All these ENSO episodes had moderate intensity and were of the central Pacific type. To quantify the ENSO impacts on meteorological parameters and fluxes and to distinguish them from effects caused by the seasonal migration of the Intertropical Convergence Zone (ITCZ) we analyzed the correlation between the deviations of monthly meteorological parameter and flux values from their monthly averages over the entire measuring period and the Nino4 and Nino3.4 indexes. The typical timescale of the full ENSO cycle is estimated to be about 48–52 months (Setoh et al., 1999), whereas the timescale of the main meteorological parameters (global solar radiation (G), precipitation amount (P), air temperature (T)) is characterized by much higher month-to-month variability even after annual trend filtering. In order to filter the high-frequency oscillation in the time series of atmospheric characteristics and monthly Net Ecosystem Exchange of CO_2 (NEE), Gross Primary Production (GPP), Ecosystem Respiration (RE) and evapotranspiration (ET) anomalies, the simple centered moving average smoothing procedure was applied. The moving averages of variables were calculated over 7 months (centered value $\pm$ 3 months). Statistical analysis included both simple correlation and cross-correlation analysis.

Analysis of the temporal variability of CO_2 and H_2O fluxes showed a high sensitivity of monthly GPP and ET of the mountainous tropical rainforest to ENSO intensity (Olchev et al. 2015). This was mainly governed by the high dependency of incoming solar radiation (G) to Nino4 and Nino3.4 SST changes and the strong sensitivity of GPP and ET to G. Time shifts between the SST anomalies and smoothed GPP anomalies driven by radiation anomalies were observed. The maximal deviations of GPP and G from their mean values occurred 2–3 months before the peak phase of the ENSO events. Such an effect of El Niño episodes on G can be explained by a decrease in the cloud cover in the region of Indonesia, due to the El Niño-associated shift in the Walker circulation cell and the corresponding zone of deep convection from the maritime continent of Indonesia toward the dateline, following SST anomaly displacement. The opposite effect takes place during the La Niña with similar phase shift: simultaneously, with the spreading of a negative SST anomaly over the Pacific, the increasing of deep convection over Indonesia occurs, which results in an increase in cloudiness and precipitation, being more pronounced as it falls into the dry period of the year.

The effect of ENSO intensity on RE was relatively small, mainly due to its weak effect on air temperature. In any case, the small cross correlation between RE and ENSO intensity had a compensatory effect on the respective timing of NEE, which was thus – like evapotranspiration – in synchrony with El Niño culminations. Unlike the observations at other tropical sites, precipitation variations had no influence on the CO_2 and H_2O fluxes at the study site, mainly due to the permanently sufficient soil moisture condition in the study area.

Other climatic anomalies in the western Pacific region, such as the Indian Ocean Dipole (IOD) and the Madden–Julian Oscillation (MJO), did not show any significant effect on either the meteorological conditions or the CO_2 and H_2O fluxes in the investigated rainforest in Central Sulawesi.

The study was supported by the German Research Foundation as part of the projects "Stability of Rainforest

Margins in Indonesia", STORMA (SFB 552), "Ecological and Socioeconomic Functions of Tropical Lowland Rainforest Transformation Systems (Sumatra, Indonesia)" (SFB 990) and KN 582/8-1. The Russian Science Foundation (grant RSCF 14-27-00065) supported A. Olchev during the model development.