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Using observation to constrain coupled climate-carbon cycle models

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The atmospheric CO2 concentration has increased by 30 % from 280 ppm in 1860 to almost 380 ppm today. This increase has two impacts on the carbon cycle : a direct response to the increase in atmospheric CO2 and an indirect response due to the CO2 induced climate change. Recent climate carbon cycle coupled models have all shown that the indirect effect is negative, i.e. climate change induces a reduction in both land and ocean carbon sinks. Consequently, this climate-carbon cycle interaction results in a positive feedback and an addition of atmospheric CO2 that ranges anywhere between 20 and 200 ppm by 2100 (Friedlingstein et al. 2006). To reduce this large uncertainty, a comprehensive validation is needed. In this study, we use several carbon cycle and climate datasets to investigate the processes responsible for the different modes of variability in continental biosphere fluxes (seasonal, inter-annual and trends). Moreover, we also infer the sensitivity of the modelled carbon cycle to climate on different time-scales. The atmospheric CO2 concentrations simulated by the carbon models were compared to measurements made at the CMDL stations between 1979 and 2003. To this end, the land and ocean carbon fluxes computed by 3 coupled models (IPSL-CM2-C, IPSL_CM4_LOOP, HADCM3LC), along with anthropogenic emissions, have been transported in the atmosphere by the atmospheric transport model LMDZ (forced by observed winds for the 1979-2003 period). The seasonal cycle of atmospheric CO2 at the CMDL stations highlights the response of the terrestrial biosphere to climate. We show that IPSL_CM4_LOOP exhibits the best agreement with observations. In order to understand the differences in the simulated seasonality, we further compare the seasonality of predicted terrestrial NEP, photo-

synthesis and respiration fluxes with FLUXNET towers data and inferred fluxes from atmospheric inversion. The inter-annual variability of the CO2 concentration is essentially controlled by the variability in the land net carbon fluxes. The El Niño Southern Oscillation generates climate anomalies in the tropics that cause anomalies in NEP and atmospheric CO2. It therefore provides a good validation of a model's sensitivity to climate variations. More specifically, we focus on the amplitude of the CO2 growth rate variability and on the lags between the Tropical Pacific temperature perturbation, the tropical land carbon flux response, and the Mauna Loa atmospheric CO2 concentration anomaly. This study allows a better constraint of both the ability of models to reproduce the mean state as well as the climate sensitivity of the key processes that determine the amplitude of the carbon-climate feedback.