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2009 IOP Conf. Ser.: Earth Environ. Sci. 6 042006

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S04.06

The role of climate variability and extremes for global terrestrial carbon dynamics: lessons learnt from multiple observations and experiments

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Recent research has suggested that not only gradual changes in climate but also the climate variability and extreme events needs to be considered when analyzing the vulnerability of the terrestrial carbon sinks [Ciais et al., 2005; Arnone et al., 2008; Fay et al., 2008; Gu et al., 2008]. We here analyse and review a multitude of results from globally distributed observations, such as whole-ecosystem carbon exchange within the FLUXNET eddy covariance network, ecosystem manipulations experiments, longer-term tree ring, forest inventory and remote sensing data and biogeochemical modeling. Major generalized findings of this work include: 1) The response of the ecosystem carbon balance to climate variability is highly skewed, i.e. large carbon losses are much more likely than large carbon gains during periods with climatic conditions deviating from normal, 2) climate variability and extremes contribute to a “slow-in fast-out” effect, where several years of slow carbon uptake induced by gradual climate change can be undone by single extreme events, 3) the vulnerability of carbon pools on a per-area basis generally correlates with general pool size, but there are important ecosystem dependent exceptions, 4) there are strong interactions between different climate drivers, 5) legacy effects have to be considered for full accounting of the effects of climate variability on long-term carbon balance. We conclude with the finding that carbon-water-cycle interactions under both wet and dry conditions, but also shifts in timing of phenological events, have the potential to drive strongly non-linear reactions of the terrestrial carbon balance to climate variability via direct and lagged effects. Hence, the interaction of the carbon and water cycles needs to be more strongly addressed in future research. We briefly present a respective analytical model-data integration framework to be followed within the EU project CARBO-Extreme.

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