LINKS BETWEEN GLOBAL CO_2 VARIABILITY AND CLIMATE ANOMALIES OF BIOMES

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ABSTRACT

The global rate of fossil fuel combustion continues to rise, but the amount of CO_2 accumulating in the atmosphere has not increased accordingly (*Tans et al*., 1990; *Conway et al*., 1994; *Wofsy*, 2001). The causes for this discrepancy are widely debated (*Houghton*, 2003). In particular, the location and drivers for the interannual variability of atmospheric CO_2 are highly uncertain. Here we examine links between global atmospheric CO_2 growth rate (CGR) and the climate anomalies of biomes based on ten years (1986-1995) of global climate data and accompanying satellite data sets. Our results show that four biomes, the tropical rainforest, tropical savanna, C_4 grassland and boreal forest, and their responses to climate anomalies, are the major climate-sensitive CO_2 sinks/sources that control the CGR. The nature and magnitude by which these biomes respond to climate anomalies are generally not the same. However, one common influence did emerge from our analysis; the extremely high CGR that was observed for the one extreme El Niño year was caused by the response of the tropical biomes (rainforest, savanna and C_4 grassland) to temperature.

METHODS

We used the NDVI-derived land cover (*DeFries and Townshend*, 1994) with one degree by one degree resolution as a base for defining the distribution of global biomes. We calculated the ten-year-average (1986-1995) of climate variables, precipitation (P), air temperature (T), photosynthetically active radiation (PAR), net radiation (R_n), and dryness index for each biome based on available global climate data sets. Our analysis is based on a simple premise: world biomes are controlled by climate primarily through influences on the ability of the biome to exchange CO_2 and H_2O with the atmosphere. We assume current equilibrium between biome distribution and the existence of a compatible climate, such that climate characteristics at the centroid probability for biome distribution reflect the optimum. Accordingly, the observed climate values listed in Table 1 represent the optimal climate conditions for each respective biome. The most important two carbon exchange processes between terrestrial ecosystems and atmosphere are photosynthesis (the removal of carbon from atmosphere) and respiration (the emission of carbon to the atmosphere). These two processes are limited to a specific climate regime for each biome. The climate envelopes for each biome represent conditions under which they currently exist. Deviations from these optimal values will likely cause anomalies in the balance between ecosystem photosynthesis and respiration and hence affect the CGR.

IMPLICATIONS

Our results have two important and clear implications. First, our results indicate that the largest atmospheric CO_2 anomaly, during the El Niño year of 1987 (*Elliott and Angell*, 1987) was caused by tropical biomes (tropical rainforest, wooded C4 grassland, and C4 grassland) as they responded to temperature. Second, the tropical rain forest, boreal forest, tropical savanna and C4 grassland are the major climate-sensitive sources/sinks for the interannual variability of atmospheric CO_2. These four

biomes occupy of the total global 39 % land surface area (Table 1) and account for approximately 57% of the total land carbon storage (*Houghton et al*., 2001). Each of these biomes, however, influences the CGR through unique responses to climate perturbations. Our correlation analysis indicates that the boreal forest influences the CGR through responses to anomalies in PAR and temperature; the tropical rainforest influences the CGR through responses to anomalies in drought; all of the tropical biomes influence the CGR through responses to anomalies involving temperature.

Table 1. Climate characteristics of biomes (ten-year average, 1986-1995). The numbers in parentheses are standard deviations**.**

Code	Biome	P mm yr^{-1}	T (^oC)	PAR (MJ m^{-2} yr^{-1})	R_n (MJ m^{-2} yr^{-1})	Dryness	Area (10^6 km^2)
1	Broadleaf evergreen forest	1922 (629)	25.1 (2.4)	2916 (167)	4664 (387)	0.97 (0.07)	13.4
2	Broadleaf deciduous forest and woodland	872 (458)	15.3 (9.2)	2675 (517)	3658 (902)	1.68 (0.05)	3.3
3	Mixed coniferous and broadleaf deciduous forest and woodland	830 (347)	8.6 (5.6)	2109 (387)	2698 (774)	1.30 (0.06)	6.6
4	Coniferous forest and woodland	494 (265)	-2.5 (5.3)	1755 (276)	1948 (529)	1.58 (0.07)	13.0
5	High latitude deciduous forest and woodland	434 (184)	-5.6 (4.2)	1707 (210)	1889 (411)	1.74 (0.09)	5.8
6	Wooded C4 grassland	1248 (528)	23.0 (3.4)	2999 (285)	4413 (482)	1.42 (0.06)	17.1
7	C4 grassland	569 (328)	23.4 (5.2)	3245 (301)	4066 (518)	2.87 (0.16)	8.9
8	C3 wooded grassland	990 (538)	14.0 (2.4)	2523 (515)	3440 (933)	1.39 (0.04)	4.6
9	C3 grassland	396 (378)	7.0 (2.4)	2525 (435)	2936 (705)	2.97 (0.18)	11.5
10	Tundra	312 (176)	-10.8 (4.7)	1475 (132)	1283 (274)	1.65 (0.11)	7.1
11	Shrubs and bare ground	255 (147)	17.0 (8.2)	3106 (390)	3490 (524)	5.50 (0.42)	11.0
12	Cultivation	755 (443)	13.6 (8.2)	2508 (518)	3260 (850)	1.73 (0.06)	13.3

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