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Effects of stratospheric ozone depletion, solar UV radiation, and climate change on oceanic CO2 sink and source strengths: Interactions and feedbacks

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Of the ~10 petagrams (Pg) carbon that are annually emitted into the atmosphere via fossil fuel burning and land use change, approximately 30% are taken up by terrestrial ecosystems, 25% by the global ocean, and the rest accumulates in the atmosphere (Canadell et al., 2007). Hence the global ocean is a net CO2 sink. However, coupled climate-carbon models suggest that the oceans, particularly the Southern Ocean will become progressively less efficient at taking up CO2 under global warming (Canadell et al., 2007; Lenton et al., 2009). This paper discusses processes that could decrease the oceanic CO2 sink strength and increase the oceanic CO2 source strength. Decreasing oceanic CO2 sink strengths could be due to (i) the reduction of the CO2 air-sea gradient as a result of enhanced ventilation of carbon-rich deep water through stronger winds thus increasing surface water CO2 (Lenton et al., 2009), and (ii) decreasing efficiency of the biological pump due to negative impacts of solar UV-B radiation and climate change on phytoplankton (Zepp et al., 2011). Increasing oceanic CO2 source strengths, on the other hand, could be a result of enhanced mineralization of organic carbon (OC) due to the combined effects of solar UV radiation and climate change on OC bioavailability (Zepp et al., 2011). Regarding (i), stratospheric polar ozone depletion in conjunction with increasing greenhouse gas concentrations has been shown to lead to an upward trend of the Southern Hemisphere Annular Mode (SAM) and the Northern Hemisphere Annular Mode (NAM) that is coupled with an increasing strength of the westerly polar vortexes and a poleward shift of the westerly wind belts at the Earth's surface (Hartmann et al., 2000; Lenton et al., 2009). As a consequence, enhanced wind-driven ventilation of carbon-rich deepwater occurs in these regions, resulting in reduced air-sea CO2 fluxes (Lenton et al., 2009). Regarding (ii), negative impacts on the biological pump are in part caused by enhanced exposure of phytoplankton to the damaging solar UV-B radiation as a result of UV-induced bleaching of colored dissolved organic matter (CDOM). Climate-change related ocean stratification and acidification enhance CDOM photobleaching and hence this process could represent a UV-mediated positive feedback on climate (Zepp et al., 2011). Regarding increasing oceanic CO2 source strengths, climate-change related amplification of precipitation extremes are likely to increase the input of terrestrial organic carbon (OC) into streams, rivers, estuaries, and coastal waters, where UV-induced transformations may enhance OC bioavailability to heterotrophic bacteria and in turn microbial respiration with production of CO2 and consumption of O2. Hence this process could result in a net loss of organic carbon from terrestrial ecosystems and a UV-mediated positive feedback to CO2 accumulation in the atmosphere (Zepp et al., 2011). References: J. G. Canadell, C. Le QuÈrÈ, M. R. Raupach, C. B. Field, E. T. Buitenhuis, P. Ciais, T. J. Conway, N. P. Gillett, R. A. Houghton, G. Marland, PNAS 104, 18866 (2007); D. L. Hartmann, J. M. Wallace, V. Limpasuvan, D. W. J. Thompson, J. R. Holton, PNAS 97, 1412 (2000); A. Lenton, F. Codron, L. Bopp, N. Metzl, P. Cadule, A. Tagliabue, J. Le Sommer, Geophys. Res. Lett. 36, L12606 (2009); R. G. Zepp, D. J. Erickson III, N. D. Paul, B. Sulzberger, Photochem. Photobiol. Sci. 10, 261 (2011).