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Dynamic and Thermodynamic Coupling: Implications for ecosystem-BGC response to climate change

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Tropical Pacific is well known for the El Niño-Southern Oscillation (ENSO), the dominant coupled climate mode with a global reach. The phase-locking of ENSO to the annual cycle raises issues about the role of subannual and subseasonal modes of variability also and the inherently high-frequency variability of the lower-trophic level ecosystem necessitates that the physical-biological responses be placed in that context. It has been shown that satellite ocean color does show that even the intraseasonal Madden-Julian Oscillations organize the ecosystem response in the ocean while seasonal to interannual and longer time-scale signals are also clearly extractable from various satellite and in situ data for ecosystems and biogeochemistry. The question of what organizes the ecosystem response is critical for understanding the response of the ocean ecosystem to climate variability and change. This study shows that the tropical Pacific is the only region in the tropics where leading modes of physical variability is directly manifest in the dominant modes of response of the ecosystem and biogeochemistry. The Atlantic Ocean is remarkably similar to the Pacific Ocean with an equatorial upwelling and an east-west SST gradient, cross-equatorial wind-forcing with the ITCZ to the north and a trade-wind structure and the oligotrophic subtropical gyres. However, like the Indian Ocean, the narrow zonal extent of the deep tropics results in east-west modes of interannual variability in the smaller oceans that are barely a season-long. This determines the ecosystem response and its relationship with the environmental forcing. The Atlantic Ocean does experience intraseasonal variability driven by the tropical instability waves and seasonal to interannual variability that is characterized by a bi-modal seasonal peak in surface production and short-lived ENSO-like variability but a more prominent meridional mode that involves the subtropical gyres and the asymmetry in iron supply off of African desert to the north. The dominant patterns of variability in the coupled climate system and the ecosystem thus do not correspond to each other and the dynamical response of the ocean in terms of the themocline variability has to be invoked to explain the ecosystem-biogeochemical variability at all scales. The Indian Ocean has no significant equatorial upwelling and the most productive regions are in the Arabian Sea and the Bay of Bengal to the north and in the thermocline ridge in the south. Monsoonal forcing explains the ecosystem variability in the Arabian Sea but eddy-mechanisms are necessary in the Bay of Bengal. Local and remote forcing of the thermocline drive primary production in the southern thermocline ridge. Global tropical primary productivity in the coming years and decades will depend on the resonse of these dynamical relations and their response to climate change.