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Integration of paleoclimatic and model scenarios for the Holocene onset of modern El Niño - Southern Oscillation variability

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The El Niño - Southern Oscillation (ENSO) is the most potent source of inter-annual climate variability. As a result of its widespread climatological and economical impact, ENSO is presently one of the best-studied climate systems. Much effort is directed at improving prediction of El Niño events, as well as modeling the behavior of ENSO dynamics in a greenhouse world under increased radiative forcing. The past ENSO record provides important test cases for model simulations, and can contribute to the understanding the forcing mechanisms by providing spatial and temporal patterns of past climate in regions influenced by ENSO. An integrated overview of a variety of marine and terrestrial paleoclimatic data relevant to the detection of ENSO variability is presented, focusing on two time-windows, 6-5 ky BP and 4.5-3.5 ky BP. Analysis of proxy climatic data indicate that, after a state-change around 5 ky BP towards active ENSO cyclicity in the equatorial Pacific, ENSO-teleconnected regions are characterized by an increased amplitude of ENSO events around 3 ky BP. Comparison with climate model scenarios shows that the generally accepted view that ENSO intensification results from summer Pacific trade wind reduction cannot completely explain the observed Holocene changes. However, insolation can provide further explanation for the increased ENSO amplitude after 3 ky BP. Modern observations indicate that westerly wind burst can initiate ENSO events only if enough heat has built up in the Indo-Pacific Warm Pool (IPWP), and larger events require a longer recharge time than small events. Since warm water build-up leads ENSO events by 6 months, boreal winter insolation is an important control for IPWP heat content. Boreal winter exceeded summer insolation since 6 ky BP, and reached maximum levels around 3 ky BP. Most probably, pronounced El Niño events were more likely to develop due to

the enhanced IPWP heat build up, and since such El Niño's cause greater wave reflection, terminating the warm events and inducing strong La Niña conditions, the entire ENSO cycle intensified to maximum variability around 3 ky BP. Thus, reconstruction of specific time-intervals provides an important test case for climate models, needed to accurately predict future climate changes under greenhouse conditions. Further data-model comparisons are essential since radiative forcing changes have a large influence on ENSO dynamics, affecting global moisture distribution and oceanographic conditions. The role of the IPWP in triggering ENSO events under increased greenhouse conditions should be the main focus of model studies, while further high-resolution paleoclimatic data is needed to increase spatial and temporal resolution to resolve recent research issues like decadal modulation and volcanic forcing of ENSO intensity