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TITLE: Emergent constraints on projections of declining primary production in the tropical oceans

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ABSTRACT:

Emergent constraints on tropical marine primary production increase confidence in a long-term decrease in primary productivity in response to rising sea surface temperatures. The most extreme projected declines in productivity are, however, unlikely. Marine primary production is a fundamental component of the Earth system, providing the main source of food and energy to the marine food web, and influencing the concentration of atmospheric CO<sub>2</sub> (refs 1,2). Earth system model (ESM) projections of global marine primary production are highly uncertain with models projecting both increases<sup>3,4</sup> and declines of up to 20% by 2100<sup>5,6</sup>. This uncertainty is predominantly driven by the sensitivity of tropical ocean primary production to climate change, with the latest ESMs suggesting twenty-first-century tropical declines of between 1 and 30% (refs 5,6). Here we identify an emergent relationship<sup>7,8,9,10,11</sup> between the long-term sensitivity of tropical ocean primary production to rising equatorial zone sea surface temperature (SST) and the interannual sensitivity of primary production to El Niño/Southern Oscillation (ENSO)-driven SST anomalies. Satellite-based observations of the ENSO sensitivity of tropical primary production are then used to constrain projections of the long-term climate impact on primary production. We estimate that tropical primary production will decline by  $3 \pm 1\%$  per kelvin increase in equatorial zone SST. Under a business-as-usual emissions scenario this results in an  $11 \pm 6\%$  decline in tropical marine primary production and a  $6 \pm 3\%$  decline in global marine primary production by 2100.

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