The magnitude of sea surface temperature variability in the NINO3.4 region of the equatorial Pacific on decadal and longer timescales is assessed in observational data, state-of-the art (CMIP5) climate model simulations, and a new ensemble of paleoclimate reconstructions. On decadal to multidecadal timescales, variability in these records is consistent with the null hypothesis that it arises from multivariate red noise generated from a linear inverse model of tropical ocean-atmosphere dynamics. On centennial and longer timescales, variability in both a last millennium simulation performed using the Community Climate System Model 4 (CCSM4) and in the paleoclimate reconstructions is inconsistent with the null hypothesis. However, the model and the reconstruction do not agree. In the model, variability reflects transient boundary conditions used to force it, whereas in the reconstruction, variability arises from either internal climate processes, forced responses that differ from those in CCSM4, or non-climatic processes that are not yet understood. These findings imply that the response of the tropical Pacific to future forcings may be even more uncertain than portrayed by state-of-the-art models because there are potentially important sources of century-scale variability that these models do not simulate.