# CMIP5における亜表層非線形力学加熱とENSO非対称性：人為的熱帯温暖化の不確実性に対する示唆
# Subsurface nonlinear dynamical heating and ENSO asymmetry in CMIP5: Implications for anthropogenic tropical-warming uncertainties

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El Niño-Southern Oscillation (ENSO) is a dominant interannual tropical variability, playing a key role in worldwide climate. Most climate models participating in CMIP5 (Coupled Model Intercomparison Project phase 5) can produce ENSO amplitude close to observations, but the asymmetry between its warm and cold phases is still poorly simulated in general. Here, using 25 CMIP5 historical simulations and multiple ocean reanalysis datasets, it is shown that the model-to-model diversity of ENSO asymmetry is mostly explained by the representation of nonlinear dynamical heating (NDH) in the subsurface ocean along the equatorial Pacific thermocline. The skewness of sea-surface temperature (SST) anomalies in the Niño-3 region linearly increases with respect to the variability of the subsurface NDH among the CMIP5 models (correlation of 0.8). The NDH variability in most CMIP5 models is under-simulated due to weak Equatorial Undercurrent variability.

Using a small subset of the models having the NDH variability greater than the CMIP5 average, the influence of ENSO amplitude change in CMIP5 anthropogenic warming scenarios is further assessed. The future change in ENSO amplitude still shows a large spread even within this subset. Nevertheless, the long-term change in climatological NDH mean follows the ENSO amplitude change, which is absent in the rest of the CMIP5 models having weak NDH variability. Hence, increasing the rectification effect of the subsurface NDH that deepens the mean-state thermocline to warm the SST can enhance the so-called "El Niño-like" global-warming pattern that exhibits the faster eastern-Pacific surface warming. In contrast, suppressing the subsurface rectification effect can cause a more "La Niña-like" warming pattern. These results suggest that properly simulating ENSO asymmetry and subsurface NDH in climate models is critical on projecting future climate.