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A data-driven generative model for sea surface temperature fields in the tropical Pacific

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The most dominant mode of oceanic climate variability on an interannual scale is the El Niño-Southern Oscillation (ENSO), which is characterized by anomalous sea surface temperatures (SSTs) in the equatorial Pacific. The SST fields associated with ENSO show strong variability between different events, also known as ENSO diversity. While the diversity of SST patterns have a strong impact on local climate, ecosystem and society, the spatial differences between ENSO events are not yet fully understood.

In this work, we present a data-driven approach to model SST anomaly patterns in the Pacific using a deep generative model. In particular, we use a variational autoencoder (VAE) to nonlinearly decompose the monthly SST anomalies into a low dimensional 'latent' space. VAEs are probabilistic models with neural network transition functions which allow us to model nonlinear features, quantify uncertainty, and include prior knowledge. In our approach, we use mutual information to favor a disentangled latent space with respect to a ground truth derived from correlation-based spatial SST clustering. The VAE-based approach improves upon earlier non-linear dimensionality reduction methods like kernel PCA which only optimize for statistical properties.

Our results indicate that the anomalous SST field diversity can be explained primarily by 1) an eastern equatorial Pacific component, 2) a central equatorial Pacific component and 3) a transequatorial component. The components capture underlying spatial correlations to regions in the Northern Pacific and to the basin wide horseshoe pattern. We also observe an asymmetry between the warm and cool phases of the components.