Application 1: Stochastic Dynamical Modeling
University of Trento, February 2023

In this project, you will practice with the analysis of observations and a conceptual stochastic climate model to explain certain aspects of these data. Make a Python notebook for the computations below.

(i) Read in the two time series of the corresponding data file for this Project. The data consists of sea surface height (SSH) and sea surface temperature (SST) at the location (153°E, 33°N) in the Pacific Ocean between 1993 – 2018. Plot both the SSH and SST anomalies (w.r.t. to the time mean) and discuss qualitative differences between the time series.

(ii) Determine the probability density function (PDF) of the time series, calculate the Fourier spectra and determine the power law coefficient of the spectral power decay at high frequency. Do this for both SST and SSH. Remove the seasonal cycle and long-term trend before determining the PDF and Fourier Spectra.

Consider the following stochastic differential equation

$$dX_t = -\gamma X_t dt + \sigma dW_t$$

with X_0 given and real parameters γ and σ.

(iii) Provide a method to estimate the parameters γ and σ for both SSH and SST and determine their 'best' values.

(iv) For these best estimates, compute a realisation of the stochastic model and determine the equilibrium PDF. Compare this PDF for the estimated parameters with the PDF of SSH and SST (as in (ii)).

(v) Give a physical argument why this stochastic model is a better model for SST variability than for SSH variability.