Non-linear, long-term evolution of sea surface temperature across the World Ocean

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Sea surface temperature (SST) is the only oceanic parameter on which depend heat fluxes between ocean and atmosphere and, therefore, SST is one of the key factors that influence climate and its variability. Over the twentieth century, SSTs have significantly increased around the global ocean, warming that has been attributed to anthropogenic climate change, although it is not yet clear how much of it is related to natural causes and how much is due to human activities. A considerable part of available literature regarding climate change has been built based on the global or hemispheric analysis of surface temperature trends. There are, however, some key open questions that need to be answered and for this task estimates of long-term SST trend patterns represent a source of valuable information. Unfortunately, long-term SST trend patterns have large uncertainties and although SST constitutes one of the most-measured ocean variables of our historic records, their poor spatial and temporal sampling, as well as inhomogeneous measurements technics, hinder an accurate determination of long-term SST trends, which increases their uncertainty and, therefore, limit their physical interpretation as well as their use in the verification of climate simulations.

Most of the long-term SST trend patterns have been built using linear techniques, which are very useful when they are used to extract information of measurements satisfying two key assumptions: linearity and stationarity. The global warming resulting of our economic activities, however, affect the state of the World Ocean and the atmosphere inducing changes in the climate that may result in oscillatory modes of variability of different frequencies, which may undergo non-stationary and non-linear evolutions. In this work, we construct long-term SST trend patterns by using non-linear techniques to extract non-linear, long-term trends in each grid-point of two available global SST datasets: the National Oceanic and Atmospheric Administration Extended Reconstructed SST (ERSST) and from the Hadley Centre sea ice and SST (HadISST). The used non-linear technique makes a good job even if the SST data are non-linear and non-stationary. Additionally, the non-linearity of the extracted trends allows the use of the first and second derivative to get more information about the global, long-term evolution of the SST fields, favoring thus a deeper understanding and interpretation of the observed changes in SST. Particularly, our results clearly show, in both ERSST and HadISST datasets, the non-uniform warming observed in the tropical Pacific, which seems to be related to the enhanced vertical heat flux in the eastern equatorial Pacific and the strengthening of the warm pool in the western Pacific. By using the second derivative of the nonlinear SST trends, emerges an interesting pattern delimiting several zones in the Pacific Ocean which have been responded in a different way to the impose warming
...of the last century.