Annual and Semiannual Cyclicity of the Upper Ocean Temperature from Model Simulations

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1. Introduction

The most pronounced temporal changes of the thermal state of the upper ocean in middle and high latitudes are determined by the seasonal course of solar insolation and have an annual period. In some areas of the ocean, in addition to the annual cycle, higher harmonics may also be present. Harmonics of this kind having a half-year period were examined, for example, in [1] basing on processing the Argo observations. Here we are trying to trace the geography of such oscillations, their origin and mode structure using the simulations with the NEMO model.

2. Model configuration

For the analysis, the simulations with Version3.6 of the NEMO model [3], coupled with the ice model LIM3, were used. The simulations were performed with a one-degree horizontal resolution and 75 vertical levels (362 × 332 × 75 grid-points). The atmospheric forcing at the ocean surface was prescribed from the DFS5.2 data set [2]. During the model integration, the observational data from profiling Argo buoys were assimilated through the 3Dvar analysis and the computed sea ice concentrations were corrected by satellite observations using the nudging technique. The model output was averaged over 5 day intervals during overall simulation period 01.01.2001–31.12.2010.

3. Geographical features of annual and semiannual cyclicity

Figure 1a shows the frequency spectra of the upper ocean temperature fluctuations, obtained from the 01.01.2001–31.12.2010 simulation, and Figures 1b and 1c are the geographical distributions of the amplitudes of annual and semiannual oscillations. The amplitudes were evaluated as the coefficients of Fourier expansion.

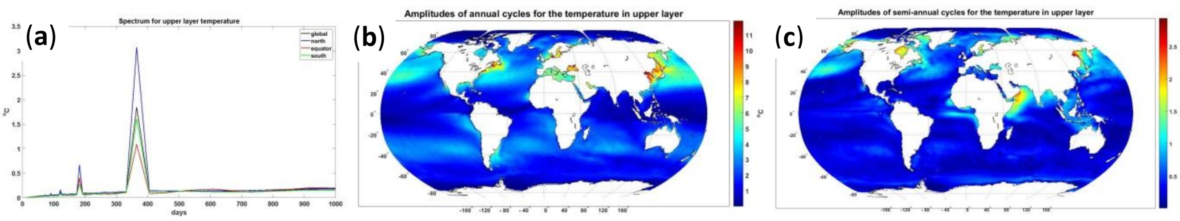

Figure 1. (a) Frequency spectra of the upper ocean temperature fluctuations for the global World Ocean (black), Northern Hemisphere (blue), Southern Hemisphere (green) and equatorial region (red). (b) and (c) The amplitudes of annual and semiannual oscillations correspondingly.

As is seen from the Figure, the annual oscillations are most pronounced in the Northern Hemisphere, especially in the western parts of the oceans. This can be obviously explained by the influence of air masses carried from the continent regions by western winds and characterized by enhanced seasonal variations typical for continental climate conditions. The predominance of land over the ocean area in the Northern Hemisphere also explains the greater amplitude of annual fluctuations as compared with those in the Southern Hemisphere.

In the near equatorial region, annual changes are less pronounced, and proportion of semi-annual fluctuations increases. The both amplitude distributions in Figures 1b and 1c are generally similar to those obtained by Chen and Wang [1] from direct processing of Argo data. This similarity may be considered as a confirmation of consistency of the model results with observations.

The semiannual components of the spectrum are of different origin in different regions. For example, in the Indian Ocean, the semiannual harmonic is generated by monsoonal processes with half year periodicity [4]. As is seen from Figure 2a, in the western part of the Arabian Sea this harmonic corresponds to real oscillations with half year period. In contrast to this, in regions with water temperature remaining for some time near the freezing point during winter season the semiannual harmonic is just an artifact of the annual changes differing in form from sinusoidal (Figure 2b). It can be assumed that the actual semiannual nature of temperature fluctuations occurs in places where the ratio of the amplitudes of the semiannual component to the annual one is comparable to or greater than one. This takes place in the near equatorial belt (Figure 2c).

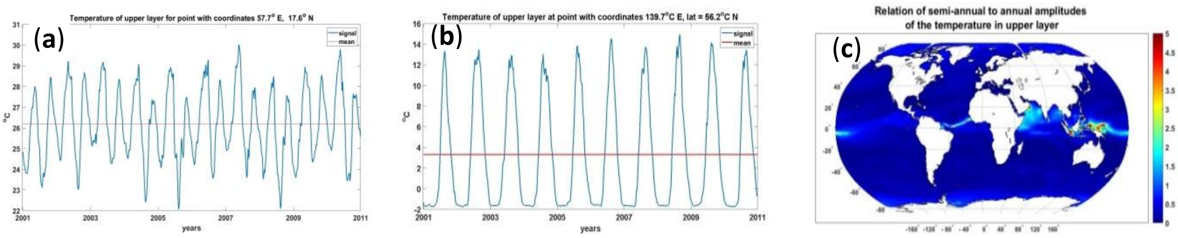

Figure 2. Temporal changes of the upper ocean temperature in the western part of the Arabian Sea (a), in the western part of the Sea of Okhotsk (b) and geographical distribution of the ratio of the amplitudes of semiannual and annual harmonics (c).

4. Modal structure

The semiannual cycle may also be traced in the EOF coefficients (Figure 3). The EOFs (empirical orthogonal functions) and expansion coefficients were computed using as input model time series from which the annual changes were filtered out. Calculated in this way the first EOF mode characterizes to semiannual changes, and the second mode characterizes oscillations with periods of 4–5 years. However, in order to obtain more reliable estimates of such oscillations, longer simulations are required, which are planned to be performed in the near future.

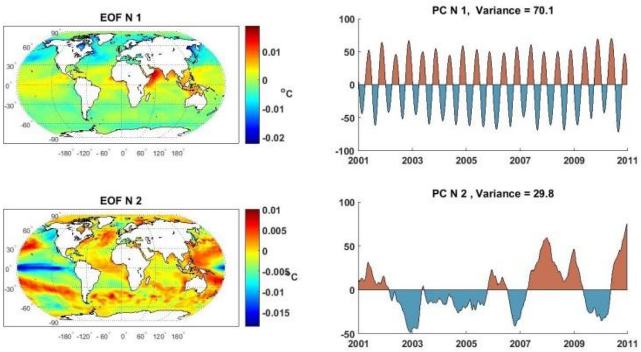

Figure 3. The geography of the first and second EOF modes of the upper ocean temperature with filtered seasonal changes (left panels) and the corresponding expansion coefficients for 01.01.2001–31.12.2010 (right panels).

References:

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