Changes of the El Niño quasi-cyclic dynamics from the analysis of phase portraits

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Long-period changes of the El Niño / Southern Oscillation (ENSO) characteristic periods are analyzed with the use of special method of cycles proposed in [1] (see also [2,3]). This method is based on the analysis of phase portraits for quasi-cyclic processes like ENSO. ENSO processes are characterized by the time series of the Southern Oscillation Index (SOI) and sea surface temperature $T(t)$ in the Pacific equatorial basins Niño-3, Niño-3.4 and Niño-4 (https://psl.noaa.gov/gcos_wgsp/). In particular, if there is a statistically significant linear regression of $d^2T(t)/dt^2$ on $T(t)$ with a negative regression coefficient $-\omega^2(t)$, then the process can be fitted by a harmonic oscillator:

$$d^2T/dt^2 + \omega^2 T = 0, \qquad (1)$$

$$T(t) = A(t)sin[\omega(t)t + \varphi(t)]\,. \qquad (2)$$

The variables dT/dt and d^2T/dt^2 can be determined by taking the second-order finite differences of the original time series $T(t)$. The characteristic frequency $\omega(t)$ and corresponding period $P(t)$ are calculated using the least-squares fitting technique at a moving segment of length I_0. To filter out the higher frequency noise, the raw data can be smoothed taking running means at the window I_s.

Figure 1 (a,b) shows phase portraits for ENSO by the data for indices Niño-3 (a) and Niño-4 (b) for the period 1950-2020 (with Is = 12 months). Trajectories for the strongest El Niño events in last decades are highlighted in different colors. Difference between the phase portraits in Fig. 1 indicates a substantial difference in the dynamics of El Niño phenomena of different types, characterized by temperature anomalies in the eastern and central equatorial regions of the Pacific Ocean.

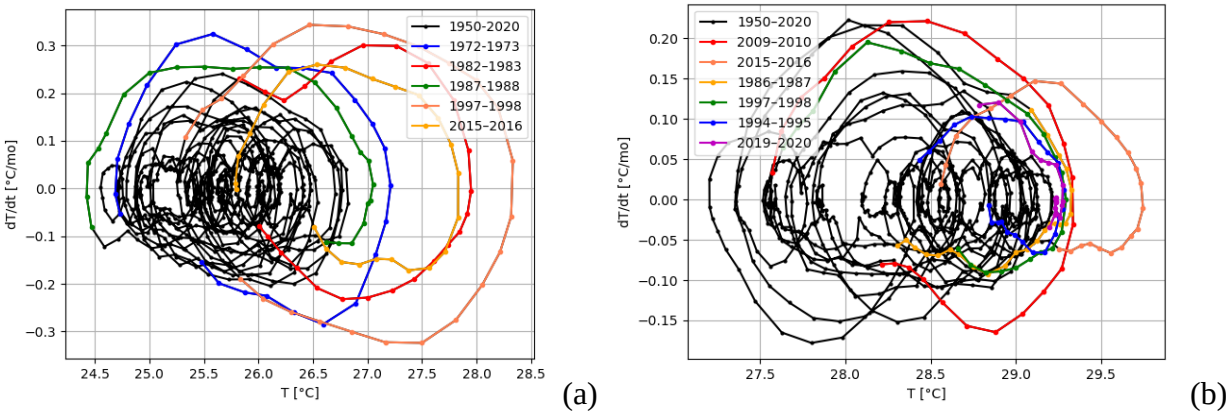

Fig. 1. Phase portraits for ENSO by the data for indices Nino 3 (a) and Nino 4 (b) for the period 1950-2020 (with I_s = 12 months)

Figure 2 (a-d) shows changes of periods of ENSO, characterized by various indices: Niño-3 (a), Niño-4 (b), Niño-3.4 (c), SOI (d) from analysis of data for the period 1870-2020 with I_s = 12 months and I_0 = 120 months. Black curves (corresponding to the 30-years running means)

characterize long-term changes, against the background of which there are significant interdecadal variations.

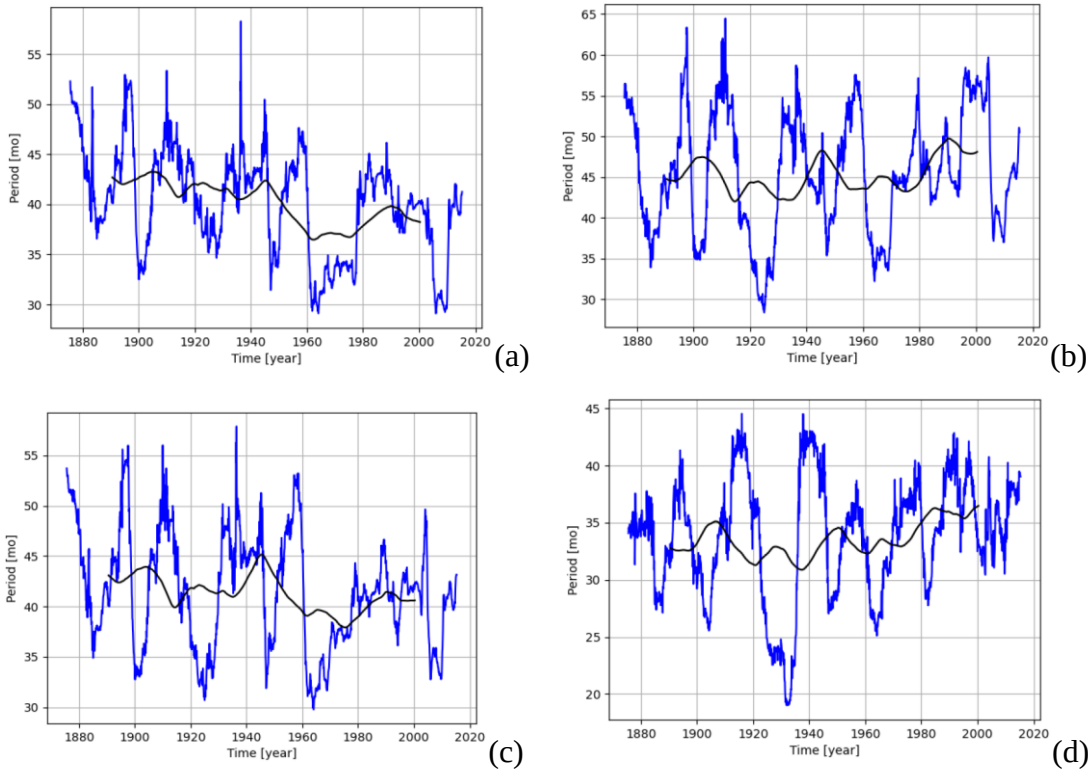

Fig. 2. Changes of periods of ENSO, characterized by various indices: Niño-3 (a), Niño-4 (b), Niño-3.4 (c), SOI (d) from analysis of data for the period 1870-2020 with I_s = 12 months and I_0 = 120 months (black curves correspond to the 30-years running means).

According to the results obtained, changes in the characteristic ENSO periods determined by different indices are very different. In particular, significant differences are associated with changes for Niño-3 and Niño-4 indices, which characterize different manifestations of El Niño in the eastern and central equatorial regions of the Pacific Ocean.

This work was supported by the Russian Science Foundation (project 19-17-00240).

References

[1] Mokhov I.I. (1993) Climate changes: Analyses of global cycles. *Ann. Geophys.* **12** (Suppl. II): C334.

[2] Mokhov I.I., Eliseev A.V., Khvorostyanov D.V. Evolution of the characteristics of interannual climate variability associated with the El Niño and La Niña phenomenon. *Izvestiya Atmos. Ocean. Phys.* **36**: 681–690, 2000

[3] Mokhov I.I., Khvorostyanov D.V., Eliseev A.V. (2004) Decadal and longer term changes in El Nino – Southern Oscillation characteristics. *Intern. J. Climatol.* **24**: 401- 414.