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The North Pacific variability during 1981–1991: modeling and comparison with the reanalysis and satellite data

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The development of realistic ocean circulation models may improve our understanding of the ocean processes and enable the prediction of the ocean response to the external forcing. The reanalysis and satellite data may be selected as control data for the simulated variations of the temperature fields on the surface. The 3D finite element North Pacific Circulation Model developed in the ICMMG is used to study the variability of the North Pacific circulation under the varying in time boundary conditions at the sea surface associated with the period of the El-Nino 1982, 1987 and La-Nina 1988 events. The results of the simulation for the period of 1981–1991 with wind-stress and a heat flux at the sea surface, adopted from the reanalysis data of the European Center of the Medium-Range Weather Forecast were analyzed. The anomalies of the circulation, temperature distributions and heat fluxes are discussed in comparison with the reanalysis and satellite measurements for this period.

1. The ocean circulation model

The finite element Pacific Ocean Circulation Model is based on the finite element method. The model grid covers the region between 30 S and 60 N with the spatial resolution of 2° longitude and 1° latitude, with 18 non-uniform levels in depth. The model includes a block of vertical mixing in the upper layer.

2. Data sources

1. The climatic monthly mean temperature and salinity fields from the "World Ocean Atlas" (Levitus, 1994) [1].
2. The climatic monthly mean wind-stress by Hellerman, Rosenstein, 1982 [2].
3. Monthly mean distribution of the satellite-derived SST and wind-stress from "Monthly mean global surface ocean variables", NASA Jet Propulsion Laboratory, Product 001, (Halpern et al., 1994) [3].

4. Wind-stress and heat fluxes from the "European Centre Medium-Range Weather (ECMRWF) Forecast Seasonal Ensemble Simulation", 1987 CD-ROM [4].

The anomalies of the satellite data in comparison with climatic data were used as control values for the anomalies simulated by the model. An analysis of the ECMRWF wind-stress for the 1981–1988 period and Hellerman's wind-stress data has shown a significant structural difference as well as a difference in the maximum and in the mean values. The ECMRWF data have more detailed structural features. It is especially visible in the tropical part of the Pacific. To indicate changes in the structure of the wind-stress in the period of 1981–1989, the wind-stress vorticity was analyzed. In the first half of 1982, there exist changes in the intensity of zonal wind near the equator. The difference of the wind-stress between Februaries of 1983 and 1982 also indicates to essential intra-tropical weakness of the wind atmospheric forcing in 1982. This feature is quite natural for the situation during the pre-EI-Nino period. During the La Nina period 1988 one can mark an increasing of the zonal wind in the tropical zone in comparison with the period of 1983–1986 characterized by near-to-climatic conditions. Heat fluxes, adopted from the ECMRWF data have also some specific features in this period. In the tropical zone, by the fall of 1982 – winter of 1983 a strong decrease of the positive heat fluxes into the ocean is observed in comparison with the climatic heat fluxes by J. Oberhuber, 1992 [5]. In the central part this results in the negative heat fluxes. In the La-Nina 1988 period, the positive heat fluxes to the ocean in the east tropical region became much stronger than the climatic ones.

3. Results of numerical simulation

At the first stage of the numerical experiment the short-range prognostic calculations for the fall season were carried out to make some spin-up for the model with the climatic diagnosis as the initial values [6]. The wind-stress and the surface temperature were chosen for September–October, 1981, from the reanalysis data [4]. At the next stage, the numerical experiments have been carried out with application of the ECMRWF time dependent data on heat fluxes and wind-stress for the period of October, 1981 – August, 1991 to estimate the impact of the wind-stress anomalies and thermohaline factors during the El-Nino and the La-Nina events on the Pacific Ocean circulation and to compare the results of the simulation with the satellite data.

Analysis of the simulated circulation has shown that the general circulation of the Pacific Ocean keeps its main configuration when it is forced by the time-dependent wind-stress and heat flux. The main changes arise in the tropical zone and are connected with the redistribution of temper-

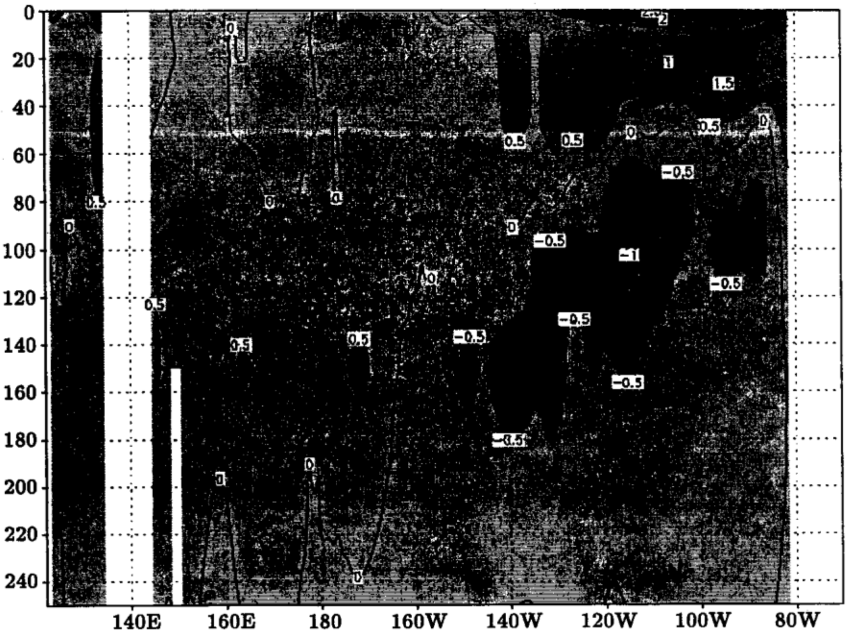

Figure 1. The simulated temperature anomaly cross-section along the equator for December, 1982

ature anomalies west-to-east during the "warm" (El-Nino) and the "cold" (La-Nina) periods. It was interesting to examine the surface and subsurface temperature variations during the simulation period. At the first stage (the fall 1982 – the winter 1983 El-Nino event) under the influence of the surface forcing in the equatorial zone the temperature anomaly in the central part forms. Warm water arises at the thermocline level and propagates to the east. In this period, on the surface there appears a weak enough signal. It is in good agreement with the satellite observational data ([3]).

Propagating to the east the anomaly comes up along the thermocline that becomes shallower to the east. When the temperature anomaly reaches the eastern coast, it comes up to the surface as can be seen in Figure 1, which presents the zonal cross-section of the temperature fields along the equator. The amplitude of the anomaly in the simulation results is about four degrees (Figure 2). This is in agreement with the anomalies (satellite SST-Levitus SST) presented in Figure 3. In the sub-tropical zone, the agreement of the simulated surface temperature and the satellite data are only qualitative. In both cases, there exist negative anomalies in the north-western part of the region, but in the model, the intensive anomaly covers most part of the subtropical gyre, whereas in the satellite data the negative values in the central part are weaker, and only near Japan they reach the the amplitude of four–five degrees.

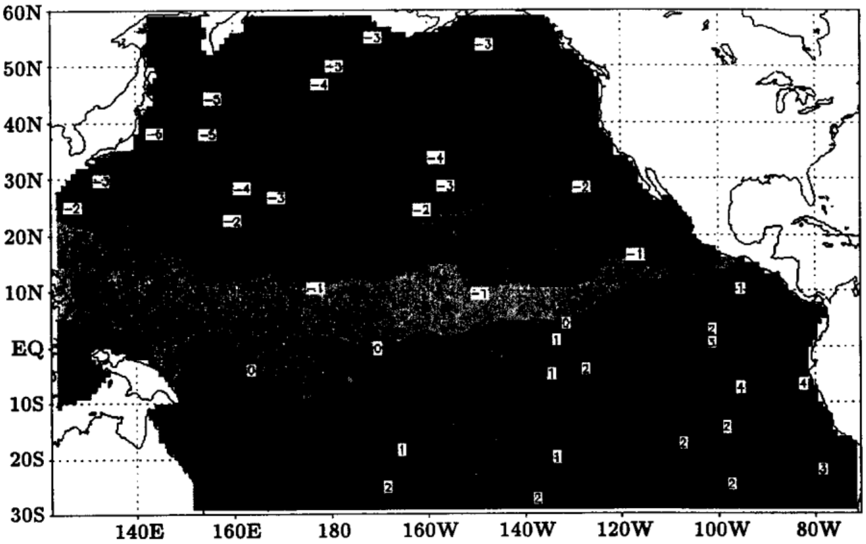

Figure 2. The simulated SST anomalies (Model-Levitus) for December, 1982

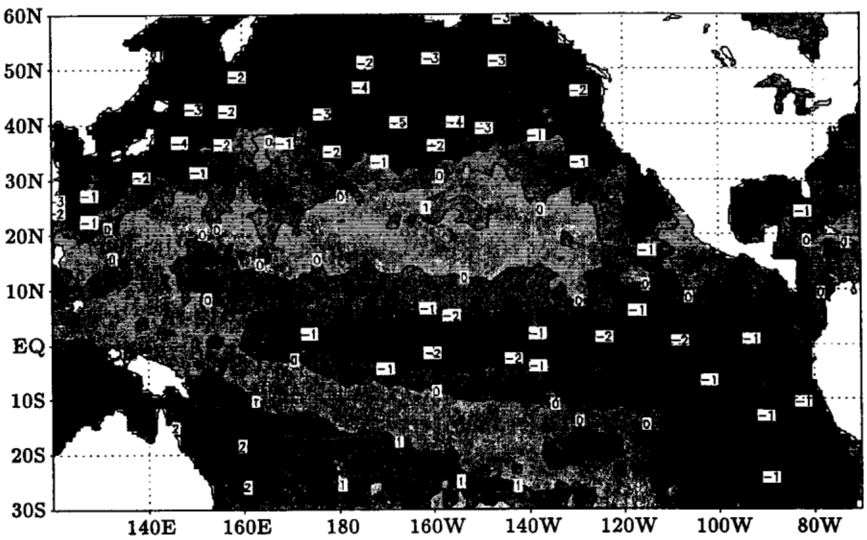

Figure 3. The satellite SST anomalies (Satellite-Levitus) for December, 1982

In the sub-polar zone, as one can see from Figures 2, 3, there is no accordance between the simulated and the satellite data. In the model, the anomaly is mainly negative. In contrast to this, the satellite data give strong, about four degrees, anomalies in the Oyashio region near Kamchatka. The next period (1983–1986) is characterized by not so strong oscillations of the temperature and wind–stress in the tropical, subtropical and sub-polar zones. After this period, as is known, in 1987 there was a weak El-Nino

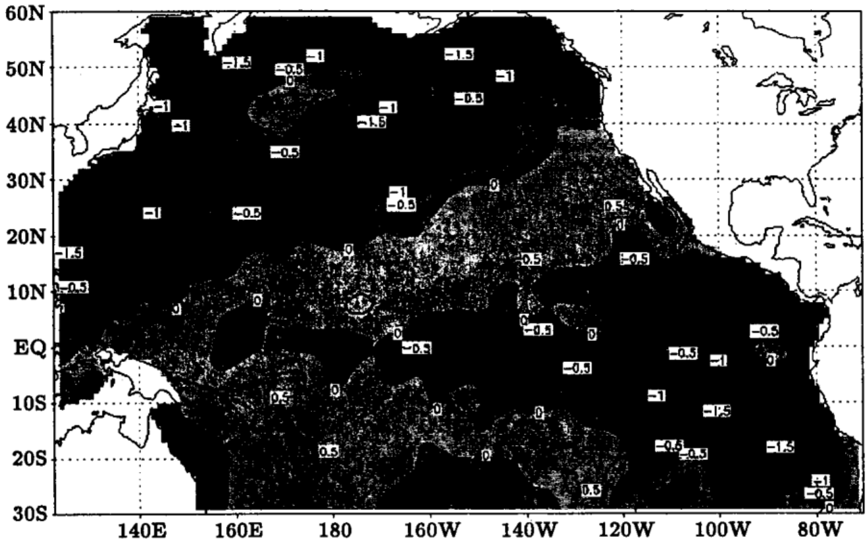

Figure 4. The simulated SST anomalies (Model-Levitus) for October, 1988

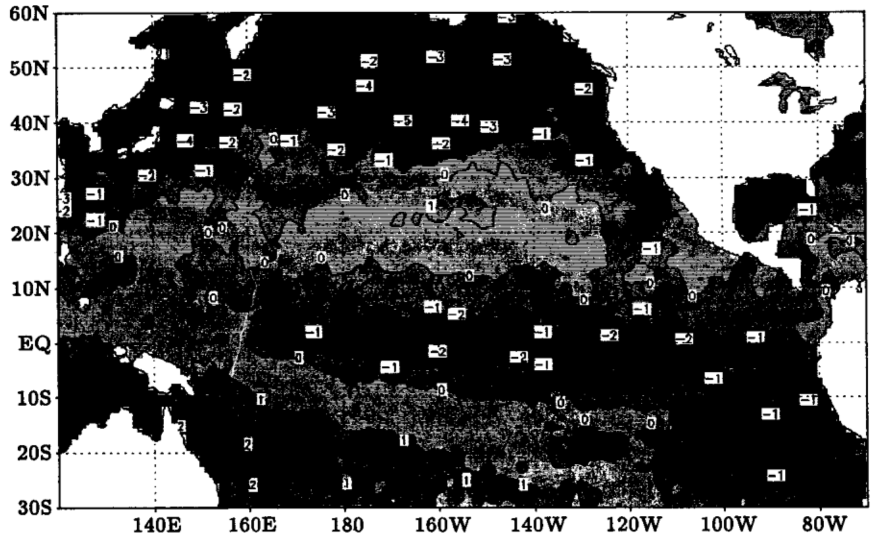

Figure 5. The satellite SST anomalies (Satellite-Levitus) for October, 1988

event. The model successfully simulated it, but with amplitude, which was somewhat weaker than the satellite data. More interesting is the period of 1988, when after El-Nino a well-expressed La-Nino event took place.

In Figures 4 and 5, the model as well as the satellite SST distribution, is presented for October, 1988. One can see a qualitatively good agreement in the configuration of the negative anomaly in the eastern part of the tropical Pacific with the satellite measurements. However, the amplitude of the

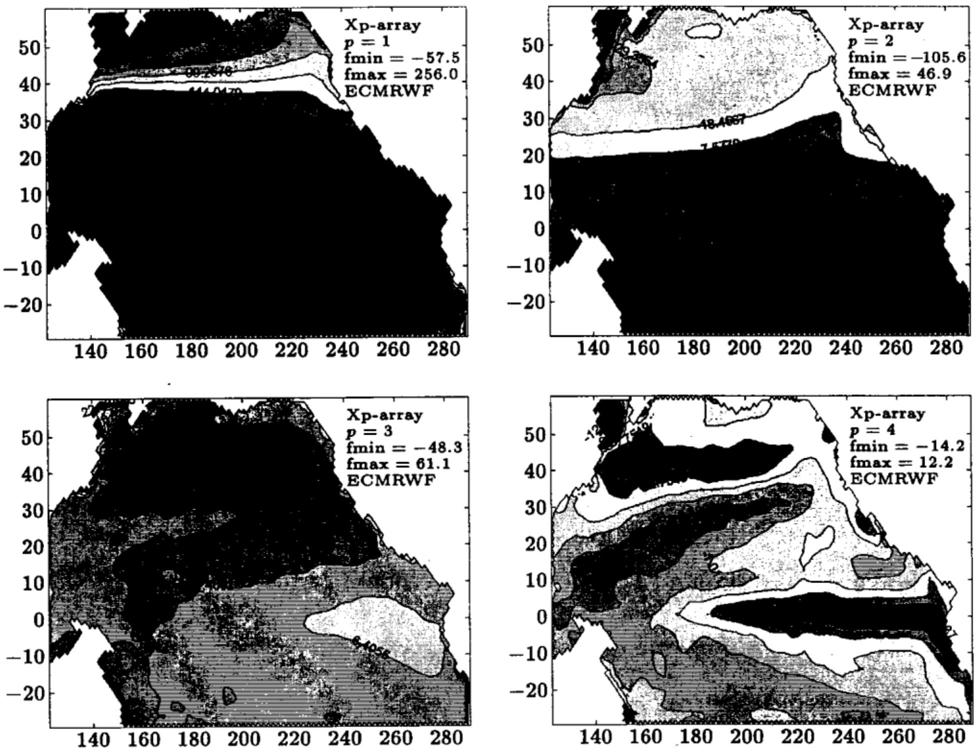

Figure 6. Four Principal Components for the ECMRWF SST

simulated anomaly is 0.5 degrees lower. North to the negative anomaly a positive anomaly is formed. It is also weaker than the satellite SST anomaly. In the sub-polar zone the anomaly is negative especially in the satellite data where the anomaly reaches the value of −0.5 degrees. So, the highest deviations in the SST variability between the model and the satellite data exist in the sub-polar latitudes. Hence, the sub-polar region needs a more accurate further analysis, as for the model results and for the satellite data, based on the independent observational data.

Additional analysis has been done for the model results in comparison with the ECMRWF SST data. The results also give a good agreement in the tropical SST anomalies during the El-Nino and the La-Nina events. Much less accordance exists in the sub-tropical and sub-polar zones. More interesting was the Principal Component (PC) analysis both for the model and the reanalysis data. Figures 6, 7 represent the first four PC for the ECMRWF data and the model, respectively. The first PCs correspond to the climatic state with time varying coefficient weakly oscillating near constant. The second PCs represent the North-South dipole structure in the North Pacific with seasonal time variations. The first and the second PCs are very close in distribution and amplitude for both cases. The third and the

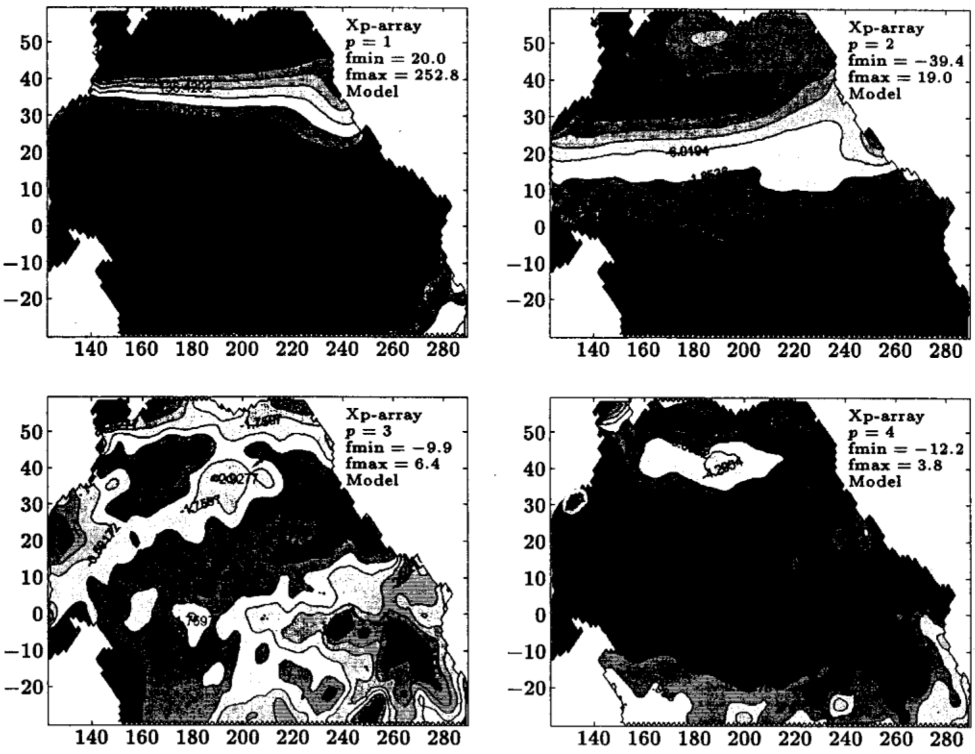

Figure 7. Four Principal Components for the simulated SST

fourth PCs have the qualitative agreement. The third ECMRWF PC has a maximum in the Okhotsk sea zone and the fourth represents the El-Nino-La-Nina events in the tropical zone. The fourth PC of the simulated data has a lower amplitude in the tropical zone.

4. Conclusion

The major features of the general North Pacific SST variability have been revealed in the simulation. A comparison of the results made with the use of the ECMRWF data and the satellite data for the period of 1981–1991 enables us to make the following conclusions:

a) The simulation results obtained by the ECMRWF data have shown keeping the main features of circulation with more detailed peculiarities in some regions, and indicate to the temperature anomalies formation in the tropical, sub-tropical, and sub-polar zones;

b) The modelled SST anomalies are in good agreement with satellite and the ECMRWF data in the tropical region during El-Nino, La-Nina events, whereas the sub-polar zone has a much lesser agreement and needs to be analyzed in more detail;

c) Principal Components analysis for the simulated and the ECMRWF data shows a good quantitative agreement for the first two harmonics and a qualitative agreement for the third and fourth PCs.

References

[1] Levitus S. Climatological Atlas of the World Ocean. – Environmental Res. Lab., Geophys. Fluid Dynamics Lab., Princeton, N.J., Rockville, MD December, 1994.

[2] Hellerman S., Rosenstein M. Normal monthly wind - stress over the World Ocean with error estimates // J. Phys. Oceanogr. – 1983. – Vol. 13.

[3] Halpern D. et al. Monthly Mean Global Surface Ocean Variables 1987–1994. – NASA JPL Product 001, 1994.

[4] ECMRWF Seasonal Simulations CD-ROM, 1987.

[5] Oberhuber J. Climatological Surface Ocean Heat Fluxes. – Hamburg: Max Planck Institute fur Meteorologie, 1992.

[6] Kuzin V.I., Moiseev V.M. Diagnostic and adjustment current calculations in the North Pacific // Izvestia AN. Physics of Atmosphere and Ocean. – 1996. – Vol. 32, № 5. – P. 680–689 (in Russian).