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Variability of the Pacific off Central America and its relevance to climatic changes

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Abstract

Correlated climatic variations between the tropical Pacific and the Atlantic were examined. Atlantic SST fields with multi-decadal lags express characteristic high correlation to the tropical Pacific. The Atlantic climatic variations are suggested to come back to the Pacific. Central America, where the two oceans locate nearby each other like as an isthmus, has been proposed as one of the probable candidates connecting with the processes. The Pacific off Central America is affected by atmospheric forcing, such as wind stresses, from the Atlantic side. The variation of atmospheric conditions might considerably reflect that of oceanic conditions. The decadal time scale analysis gives indications of the processes to be influenced by Atmospheric Hand of Atlantic (AHA), the atmospheric forcing of which variation relates to the Atlantic climatic variations. Central America plays a conjunctive role, not only in geomorphology but also as a link for decadal variability between the Pacific and the Atlantic.

Key words: Pacific, Atlantic, Central America, Decadal climate change

1. Introduction

The tropical Pacific is considered as one of the most significant areas of which variabilities are related with global climate changes. In particular, El Niño and Southern Oscillation (ENSO) has been reported to be associated with various climate changes around the world. Meanwhile, the thermohaline circulation (THC) through both hemispheres across the Atlantic are thought to be closely associated with global climate change as well. It is not easy to define an indicator of THC from the direct observations, but the SST is a candidate of the indirect indicator such as the relationship between the two hemispheres over the Atlantic Ocean dipole (Manabe and Stouffer, 1999)[1].

Climatic effects from the Pacific to the Atlantic have been well reported. Latif (2001)[2] suggests that sea surface temperature (SST) variations of the tropical Pacific affect the activities of THC with delay of a few decades time spans. He also reports that North Atlantic Oscillation (NAO) is related with ENSO. Then climate changes around the world should be related together and link each other, it is interesting to investigate the way of the Atlantic to the Pacific.

Here we explored the possibility of affecting the Atlantic to the Pacific through the Central America, bordering the two oceans across a narrow isthmus of Central America. The distribution of the Atlantic SST affects the distribution of the Atlantic atmospheric pressure, and then the pressure gradients across the isthmus of Central America bring up blowing winds over the Pacific off Central America. We introduce a scenario in which those changes affect SST in the Pacific and find the indications of long term impacts of the Atlantic to the Pacific, like as an atmospheric hand of the Atlantic (AHA).

Central America has also been said to be the area of particularly active atmospheric transports of freshwater from the Atlantic to the Pacific, and then the area is thought to be important in considering the relationship of both the ocean. The Pacific off Central America is also known as the interactive area of major currents of the Pacific[3], e.g. North Equatorial Counter Current, North Equatorial Current, South Equatorial Current. They influence the tropical Pacific conditions and some of them develop a massive upwelling area, the Costa Rica Dome[3), 4)], which is also influenced by the wind fields and its variability related to the atmospheric condition mentioned above.

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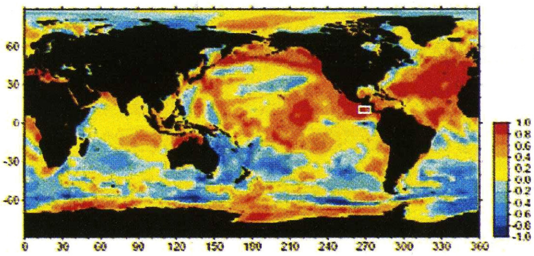

Fig.1 Spatial distribution of correlation coefficients between monthly SST anomaly time series on the Pacific off Central America (95W-85W, 5N-10N) and the global SST anomalies with no lag. The data were low-pass filtered prior to the correlation analyses with an 11-year running mean.

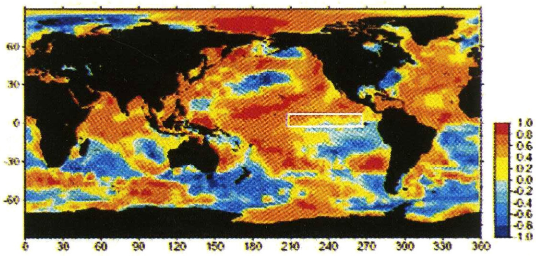

Fig.2 Same as Fig.1 except for between the Nino-3 (150W-90W, 5S-5N) SST anomaly time series and the global SST anomalies with lag 30 years.

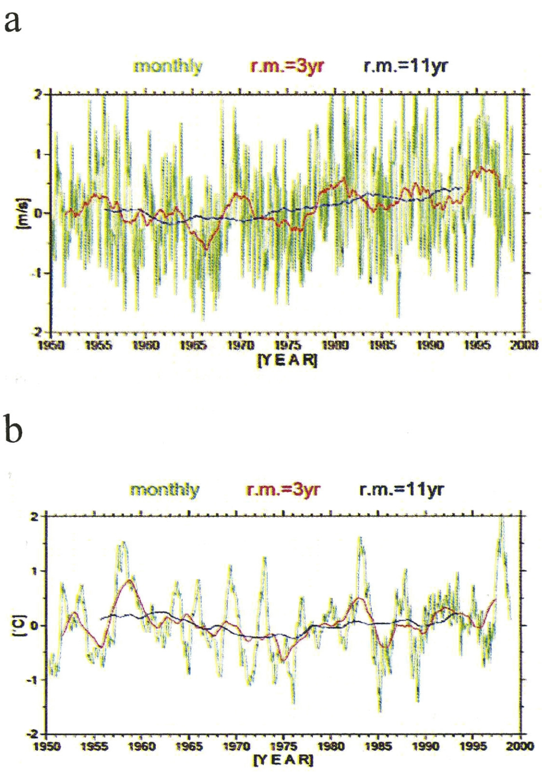

Fig.3 Time series of easterly wind anomalies (a) on the isthmus of Central America, and those of SST anomaly (b) in the Pacific off Central America. Green, red and blue lines denote monthly mean, 3-year and 11-year running mean, respectively.

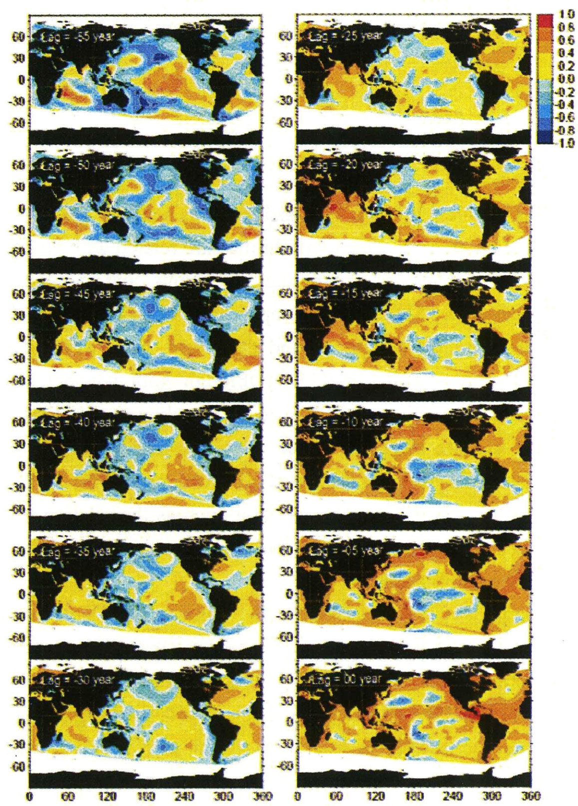

Fig.4 Same as Fig.1 except for time lags of minus 55 years to 0. Kaplan's dataset is adopted here.

2. Data and Analyses

Analyzed data is National Centers for Environmental Prediction (NCEP) reanalysis[5] dataset. Sea surface temperature (SST), sea level pressure (SLP), and 800 dbar wind data are analyzed. In this study, time intervals are one month and the spatial resolutions are about 1.85 × 1.85 deg (Gaussian grid). Time series of their anomalies created from periods 1950 to 1998 are analyzed. Kaplan's dataset[6] of SST anomalies (SSTA) is analyzed to find longer coherences over the global ocean. The data period is from 1856 to 1998 and the time interval is one month. The spatial resolutions are 5 × 5 deg. Temporally averaged time series with 3-year and 11-year are also analyzed. They are corresponding to ENSO resolvable and decadal periods, respectively.

We analyze areas of Nino-3 (150W-90W, 5S-5N; NN3) known as an equatorial El Niño monitoring area, the Pacific off Central America (95W-85W, 5N-10N; PCA) and Caribbean Sea (85W-75W, 10N-15N; CRB). The SSTA correlations of global ocean to NN3 and PCA are compared with several time lags. Time series of SLP anomaly (SLPA) differences between PCA and CRB are compared to those of wind speed on the isthmus of Central America. Kaplan's SSTA data used to find the long term effects of the global ocean to PCA. Lagged correlations from -55 years to 0 are obtained for every 5 years.

3. Results and Summary

The spatial distribution of monthly SSTA correlation coefficients between the Pacific off Central America (PCA) and the global ocean without time lag are shown in Fig.1. The SSTA data is low-pass filtered prior to the correlation analyses with an 11-year running mean. A remarkable dipole like structure is found in north and south Atlantic. The North Atlantic is occupied by positive values, in contrast the South Atlantic is mainly negative. The similar contrast is reported by Latif (2001)[2] on a different time-lag correlation analysis. Figure 2 shows the distribution between Nino-3 (NN3) and the global ocean with lag 30 years. This is as same as his result. Those results suggest that PCA is affected from the Atlantic conditions, which might be caused by the Atlantic SST structure related to that of NN3 at 30 years ago. Interesting similarities are found in other area, e.g. the north Pacific, Indian Ocean, but we do not discuss in details here.

The wind blowing over the isthmus of Central America is almost easterly through the year. The anomaly of the wind is well corresponding to the difference of SLPA between PCA and CRB which induces geostrophic wind fields (no figures shown here). Figure 3a shows the time series of the westerly wind speed anomaly with monthly, 3-year and 11-year averages. The 3-year line denotes the effects of ENSO events. The 11-year line should be meaning multi-decadal variations. Figure 3b shows the time series of SSTA on PCA area. Comparing the 11-year in Fig. 3a with that in Fig. 3b, we find the former is prior to the latter at 6-9 years. Wind variations usually related to SST changes through the atmosphere-ocean heat exchange at the sea surface. It is well known that the phase difference of 90 degree is normally observed between heat flux and heat content changes. The results suggest that even the multi-decadal variations occurring in PCA are affected by the Atlantic side variations through the atmospheric conditions. The detected multi-decadal variation might have about 25 to 35 years periods.

Figure 4 shows that the spatial distributions of monthly SSTA correlation coefficients between PCA and the global ocean with lags of -55 to 0 years every 5 years. Negative coefficients mean that PCA delays to the global. Kaplan's dataset is adopted in this analysis. The dipole-like structures similar to Fig.1 exist in the Atlantic in the results of lags 0 and 5 years. The reversed ones are found in those of -40 and -45 years. This suggests that the expected period of multi-decadal variation is 70-90 years. The period is about twice of the previous estimate. The multi-decadal periodic variation related to PCA and the Atlantic connections is suggested but the exact estimation of its period is unclear yet. The lack of temporal length of datasets, in particular, the NCEP dataset of which data period is about 50 years length might be responsible to the vagueness of the results.

Correlated climatic variations between the tropical Pacific and the Atlantic were examined. Atlantic SST fields with multi-decadal lags express characteristic high correlation to the tropical Pacific. This is considered to be related to air-sea interactions and the thermohaline circulation of the Atlantic. The Atlantic climatic variations should come back to the Pacific. The Pacific off Central America is affected by atmospheric forcing, such as wind stresses, from the Atlantic side. The variation of atmospheric conditions, such as sea level pressure fields, might considerably reflect that of oceanic conditions. The decadal time scale analysis gives us indications of the processes that PCA is influenced by Atmospheric Hand of Atlantic (AHA). The atmospheric forcing of which variation relates to the Atlantic climatic variations and Central America plays a conjunctive role, not only in geomorphology but also as a link for decadal variability between the Pacific and the Atlantic. However, correlation does not indicate causal relationships between observed variables, therefore the analyses must be examined by more physical discussions.

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