Interannual variability and resent increase of summertime significant wave heights in the western North Pacific

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Background

- Understanding changes in the wave climate is important in the design and operation of offshore industries, the selection of ship routing, and the risk assessment of future vulnerability to possible coastal disasters.
- Understanding the past wave climate may help us to predict future wave climate, and contribute to long-term maritime safety.
- Changes in wave climate have been investigated mainly in the North Atlantic Ocean (WASA 1998, etc.).
- However, interannual variability of significant wave heights in the western North Pacific has not been fully investigated.

Purpose

- We investigate the relationship between summertime significant wave heights in the western North Pacific, climate variability, and tropical cyclone activity based on the altimeter wave measurements, reanalysis and observed data.

Methodology

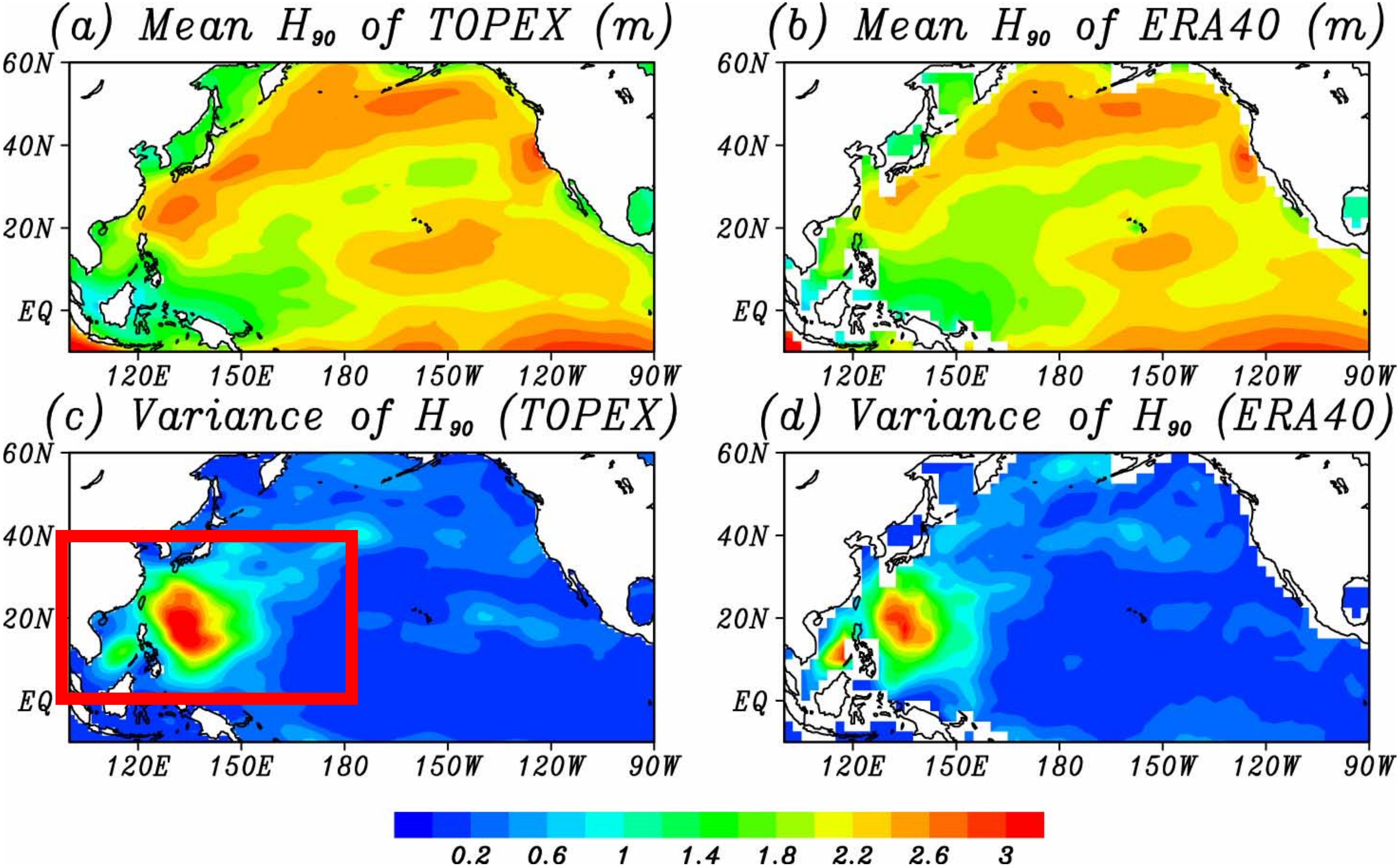
- An EOF analysis is applied to significant wave heights in the western North Pacific to identify the most prevailing interannual variability.
- Regression analysis is applied to the 1st principal component of significant wave heights, and atmospheric and oceanic fields.

Data

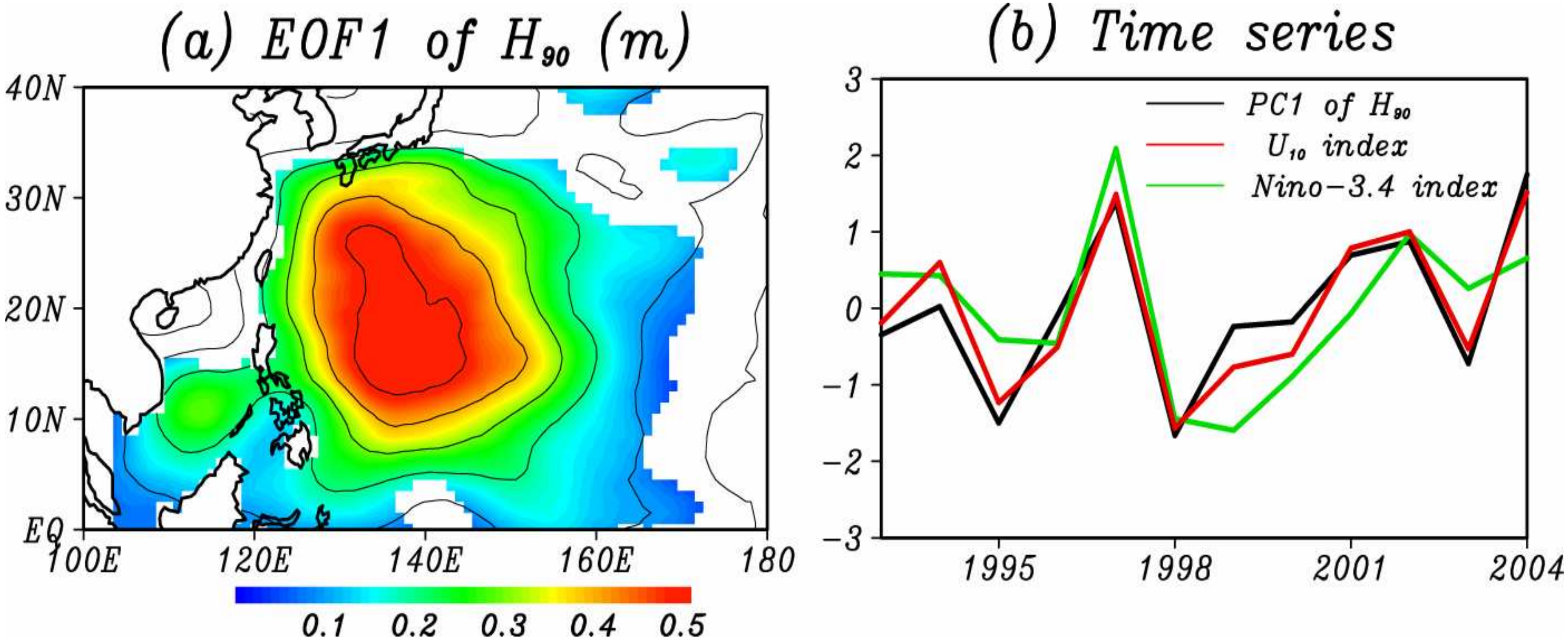
- **TOPEX monthly 90th percentile of significant wave heights (1993-2004)**
- **ERA-40 reanalysis (1958-2002)**
- **NCEP/NCAR reanalysis**
- **Enhanced Reconstructed Sea surface temperature**
- **RSMC tropical cyclone best track data**

- **H90: June-August mean of the monthly 90th percentile of significant wave heights**

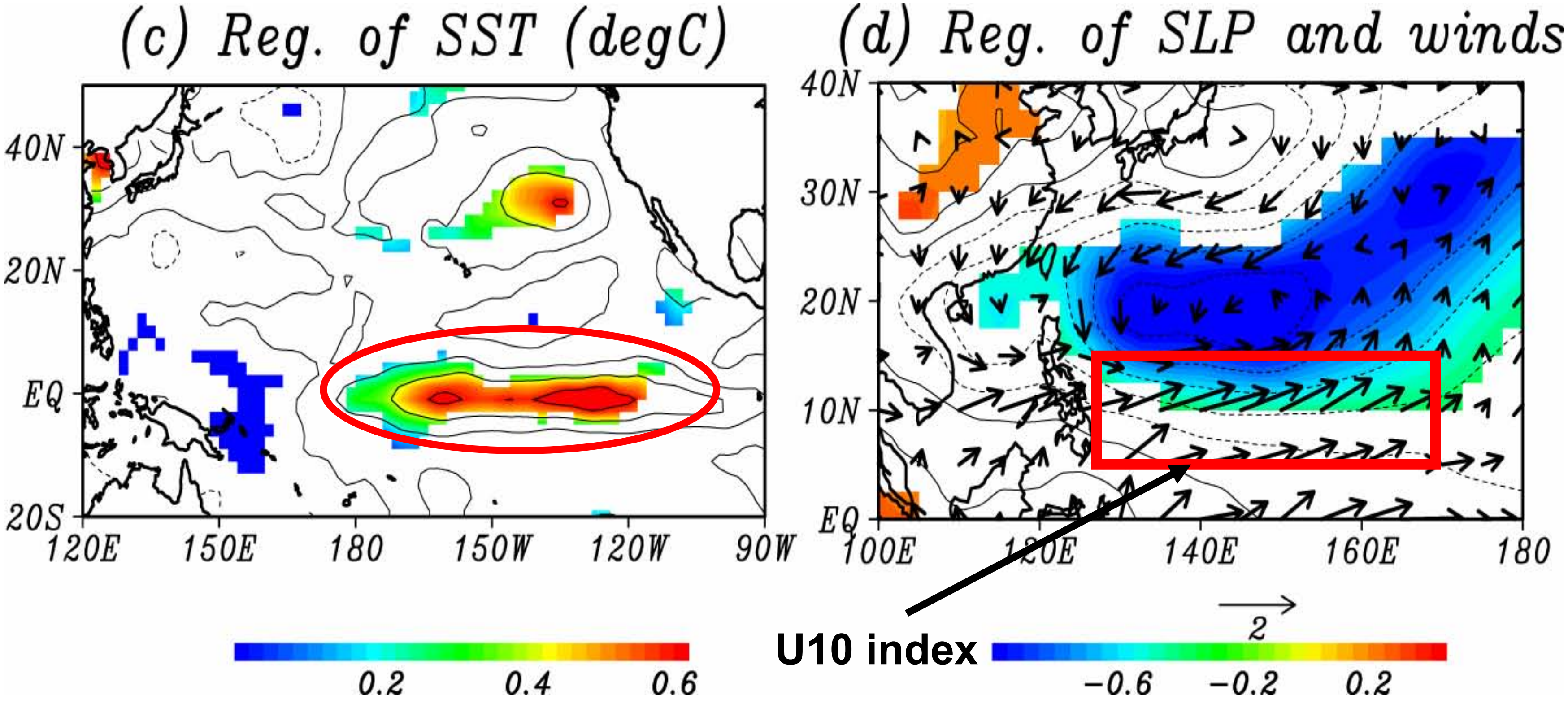
Climatological mean and variance of H_{90}



The 1st EOF of H_{90} (TOPEX) 66.9%



- The spatial pattern of the first EOF mode is characterized by a monopole structure with the maximum amplitude located to the south of Japan.
- Positive anomalies of the PC1 of H_{90} occur during ENSO developing years.

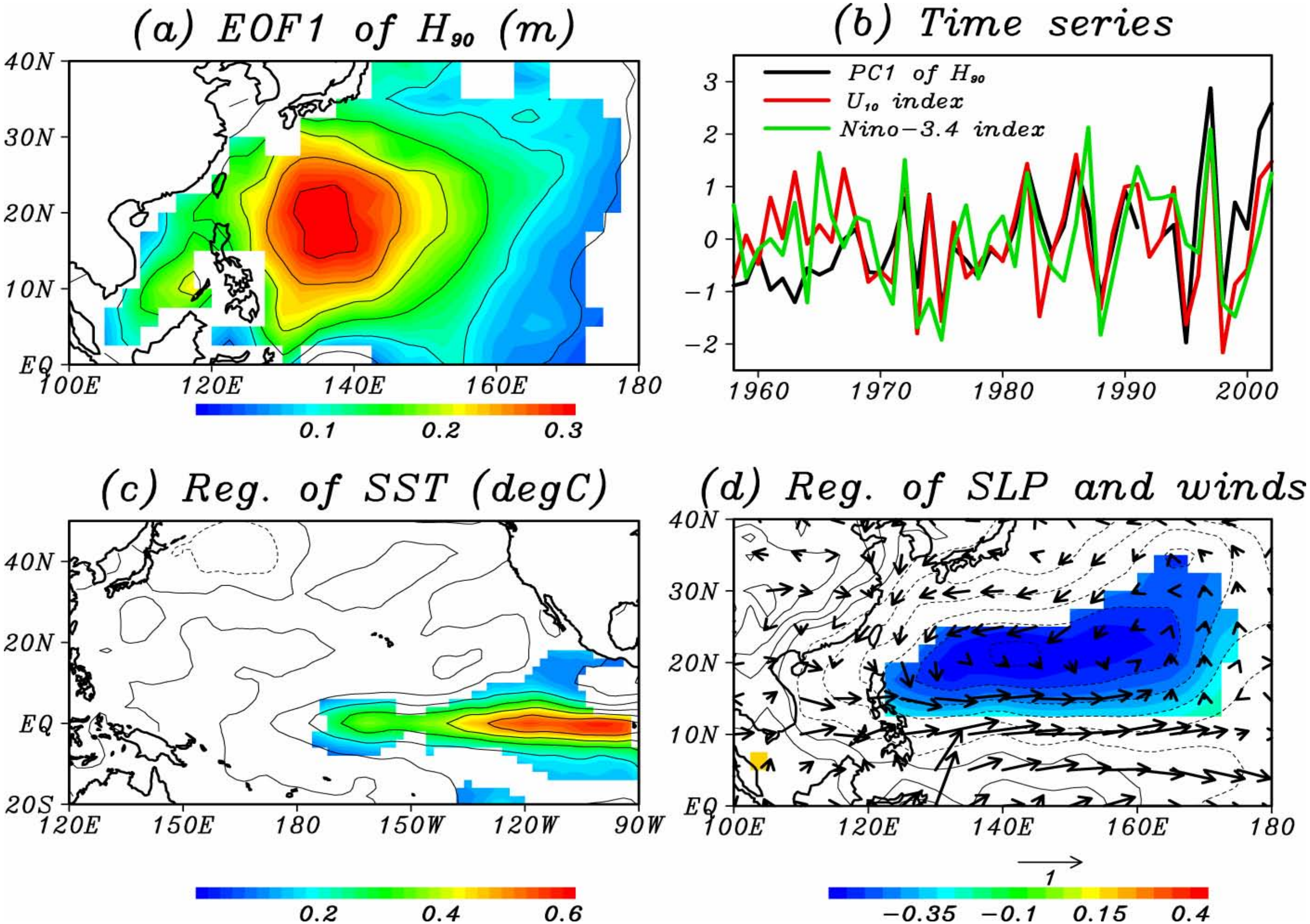


●The PC1 of H_{90} is positively correlated with SST within the Nino-3.4 region.

●Typical atmospheric anomalies are characterized by the counter-clockwise surface wind anomalies and negative sea level pressure anomalies.

●Anomalous westerly winds at latitude of 10N (U10 index).

The 1st EOF of H_{90} (ERA-40) 51%



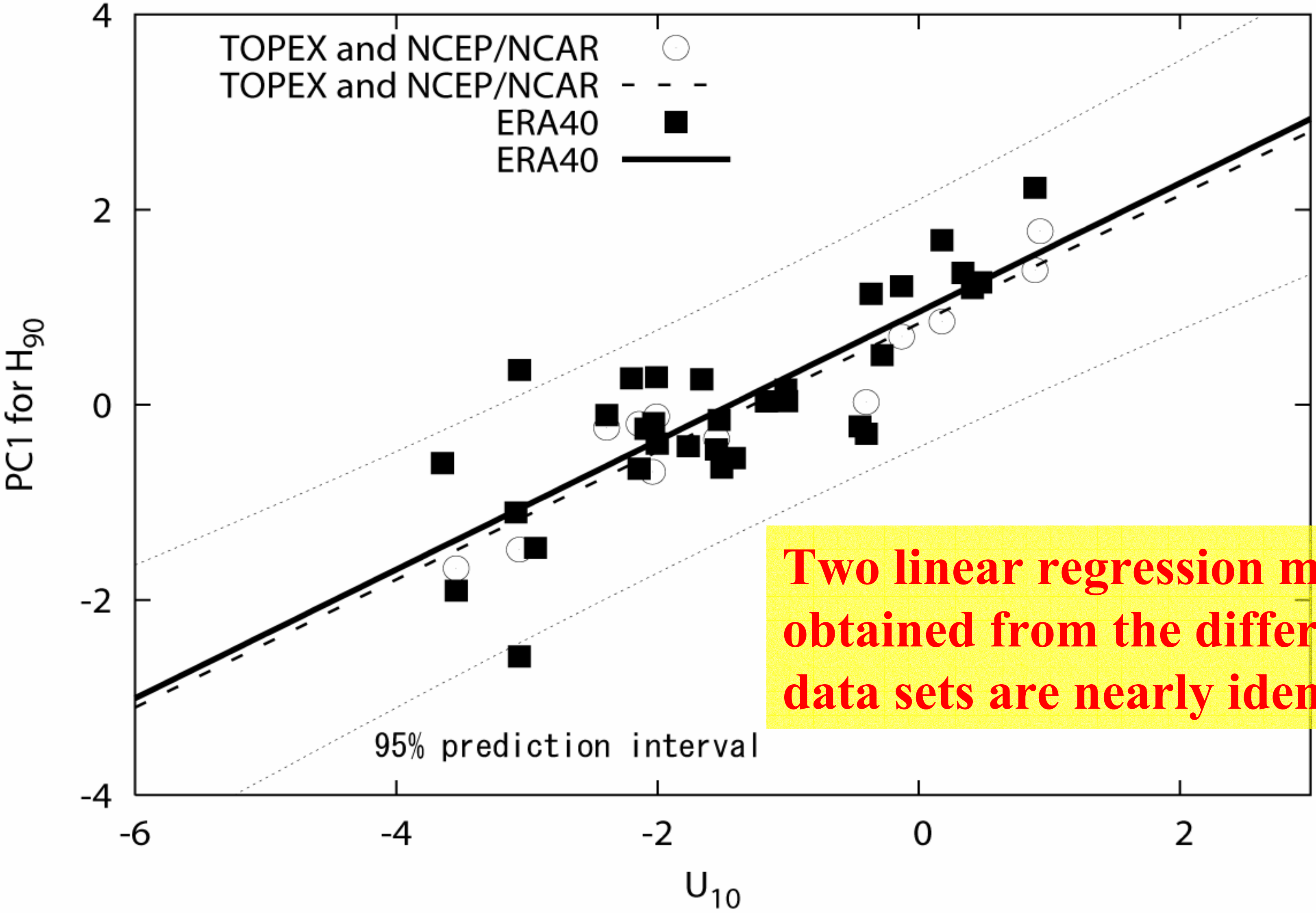
Decadal correlations between the PC1 of H_{90} and the Nino-3.4 index and U_{10} index

	1960-69	1970-79	1980-89	1990-2002	1960-2002
PC1 vs. NINO-3.4	-0.16	0.60	0.67	0.56	0.49
PC1 vs. U_{10}	-0.00	0.88	0.77	0.83	0.66

U_{10} index: Zonal winds averaged over the region 5N-15N, 130E-160E.

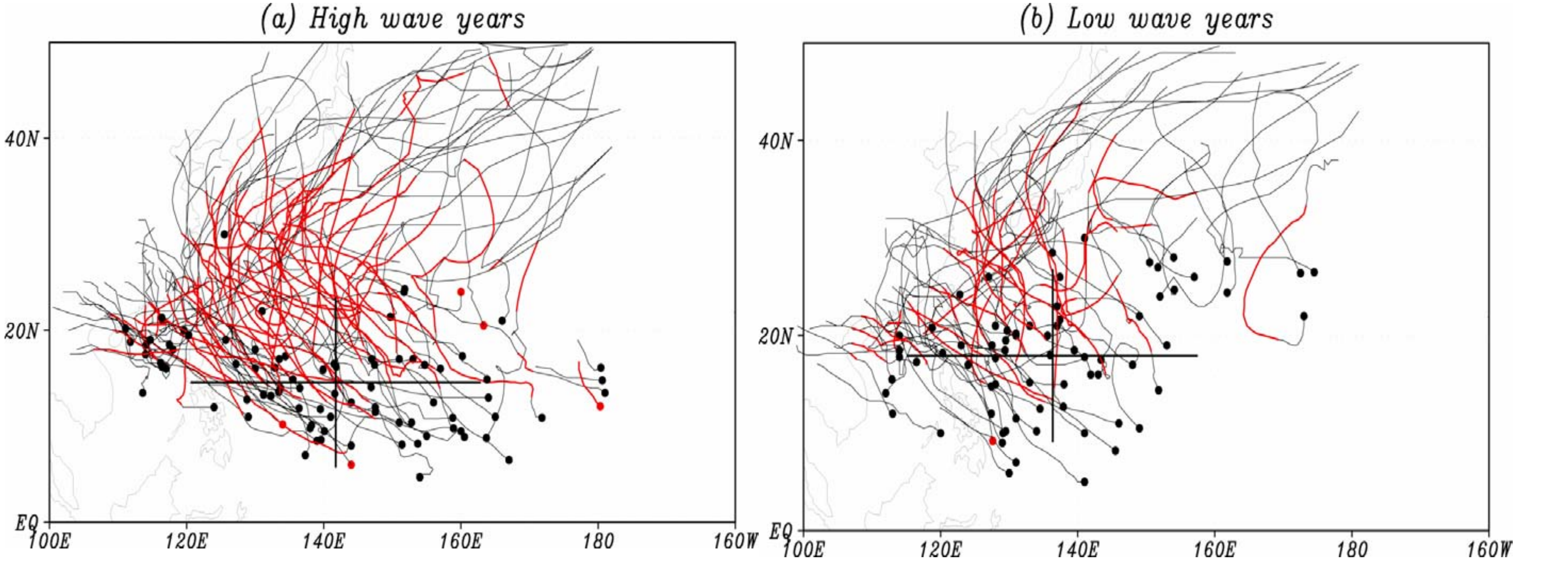
- ***The PC1 of H90 is correlated with the NINO-3.4 index and U_{10} index.***
- ***U_{10} index is closely correlated with the PC1 of H_{90} since 1970.***
- ***The reason of poor correlations during 1960-1969 may be attributable to climate variability (U_{10} index is correlated with PC3).***

Relationship between the PC1 of H_{90} and U_{10} index



Two linear regression models obtained from the different data sets are nearly identical

Comparison of TC occurrence and development



●The mean position of TC occurrence shifts about 3° southward and 5° eastward during the high wave years relative to those during the low wave years.

●The difference between the frequency of intense TC during the high wave years and that during the low wave years is obvious.

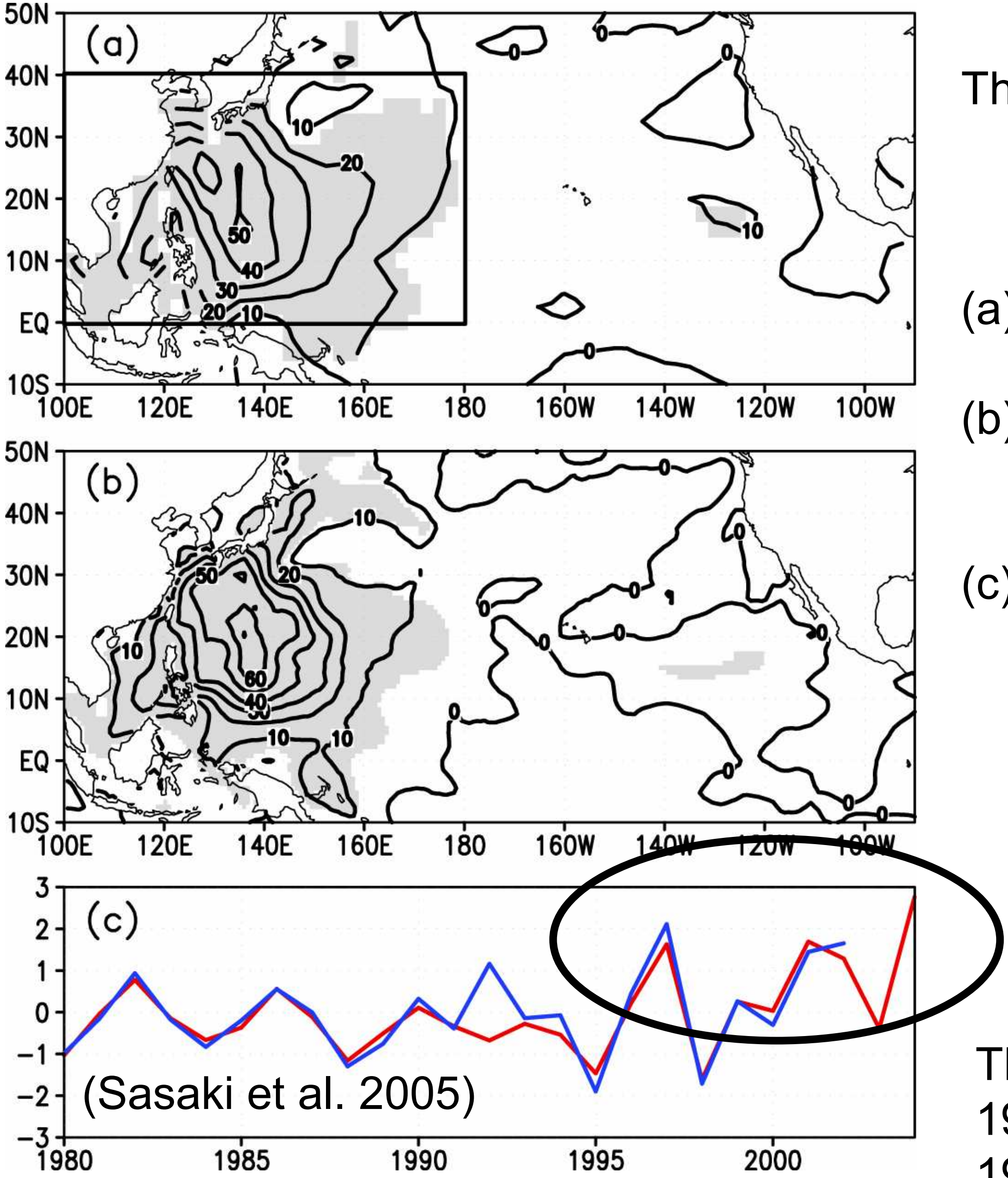
Decadal correlations between the PC1 of H_{90} and TC activity

	1960-69	1970-79	1980-89	1990-2002	1960-2002
PC1 vs. Total duration of intense TC	0.22	0.68	0.81	0.81	0.63
PC1 vs. Frequency of TC occurrence	0.21	0.44	-0.14	0.38	0.02

- **Total duration of intense TC: Sum of the duration of each TC in which the surface pressure under 980 hPa**

High positive correlation since 1970

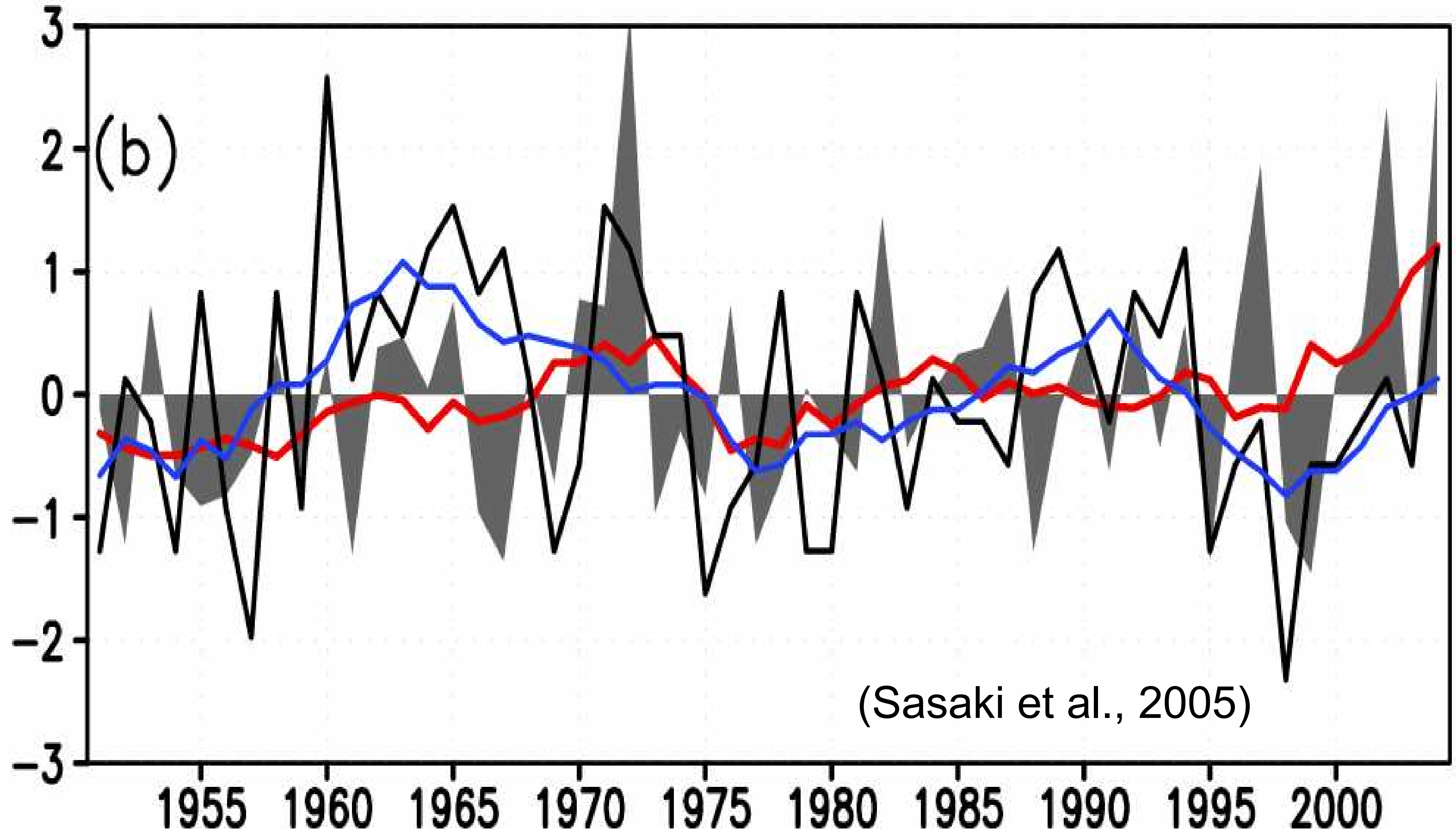
- **Frequency of TC passage: Sum of the frequency of TC passage within the region 10N-30N, 120E-160E.**



The spatial pattern of the 1st EOF of summertime significant wave heights in the western North Pacific

(a) ERA-40 wave reanalysis during 1980-2002
(b) WW3 with surface winds of the NCEP reanalysis during 1980-2004
(c) The first principal component

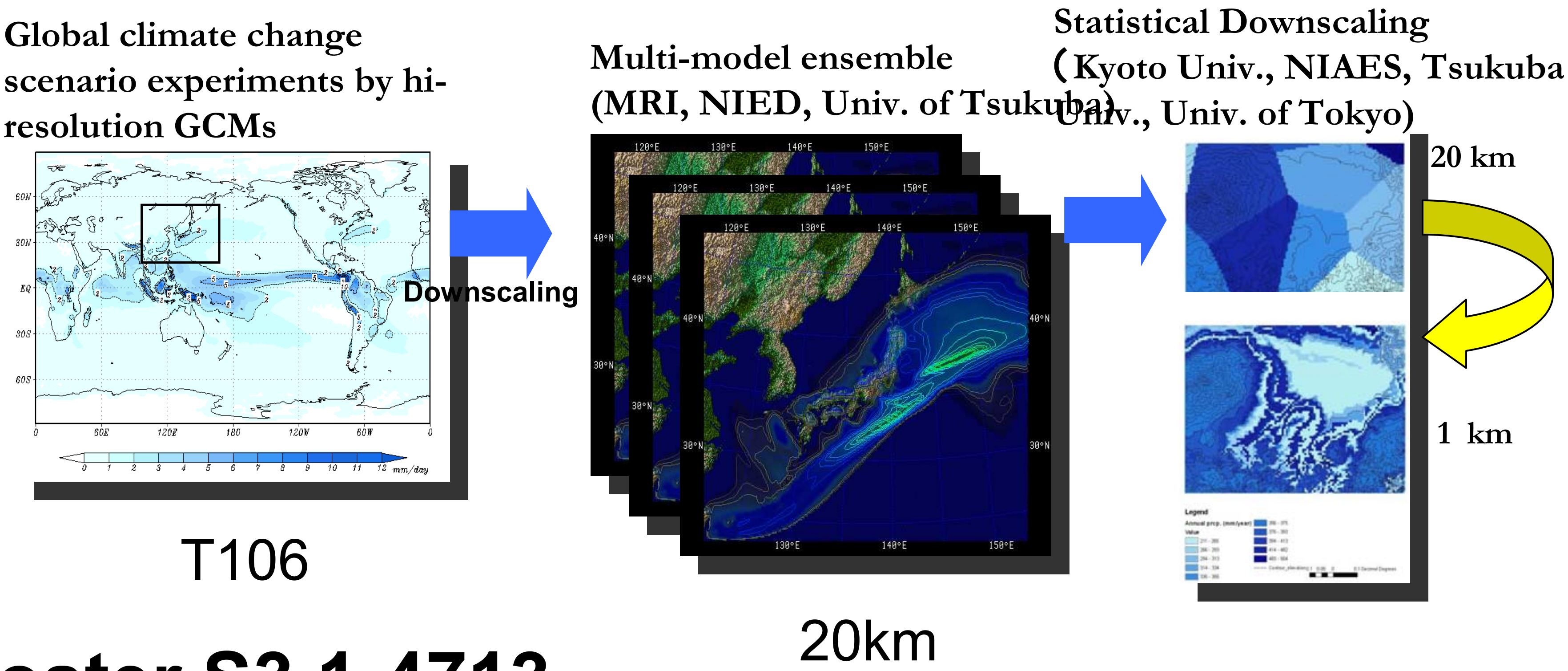
The PC1 of H90 since the late 1990s is larger than that during 1980-1996.



Red: Normalized time series of duration of tropical cyclone in the western North Pacific.
Blue: Normalized time series of the frequency of tropical cyclone passage in the western North Pacific.

- Total duration of intense TC (central pressure<980hPa) in the western North Pacific show positive anomalies since the late 1990s.
- The frequency of TC passage in the western North Pacific shows negative anomalies since the late 1990s.

Future projection using regional climate models



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- As a next step, we will investigate future regional wave climate around Japanese coast.
- Three RCMs are used to downscale global climate change scenario experiments.
- Outputs of RCMs are used to project future wave climate around Japanese coast.
- Uncertainty due to different RCMs

Summary

1. During ENSO developing years, the strengthening of westerly winds at a latitude of 10N causes an eastward shift of tropical cyclone occurrences. This leads to an increase in the duration of tropical cyclones in the western North Pacific
2. The increase in duration of tropical cyclones may cause an increase in significant wave heights in the western North Pacific in summer.
3. Zonal wind anomalies at a latitude of 10N (U_{10} index) are useful to index approximately the interannual variability of significant wave heights in the western North Pacific.

■Sasaki and Hibiya, 2007, J. Oceanogr.

■Sasaki et al. , 2005, Geophys. Res. Lett.

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