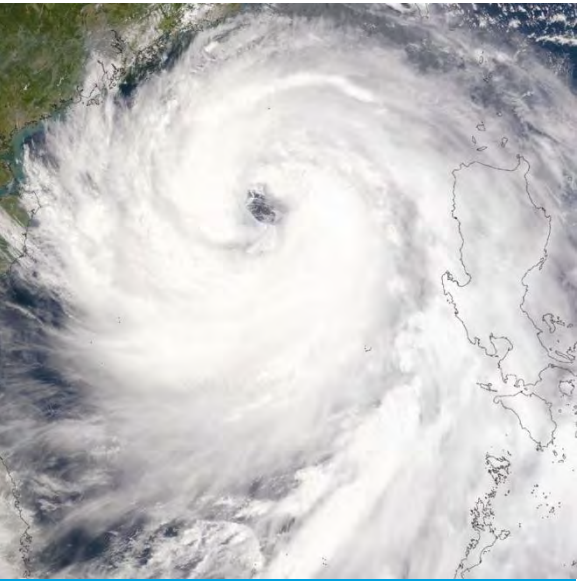
能源及環境學院
SCHOOL OF ENERGY AND ENVIRONMENT

香港城市大學
City University of Hong Kong



Variations of Western North Pacific Tropical Cyclone Activity on Decadal Time Scales and Longer

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Guy Carpenter Asia-Pacific Climate Impact Centre
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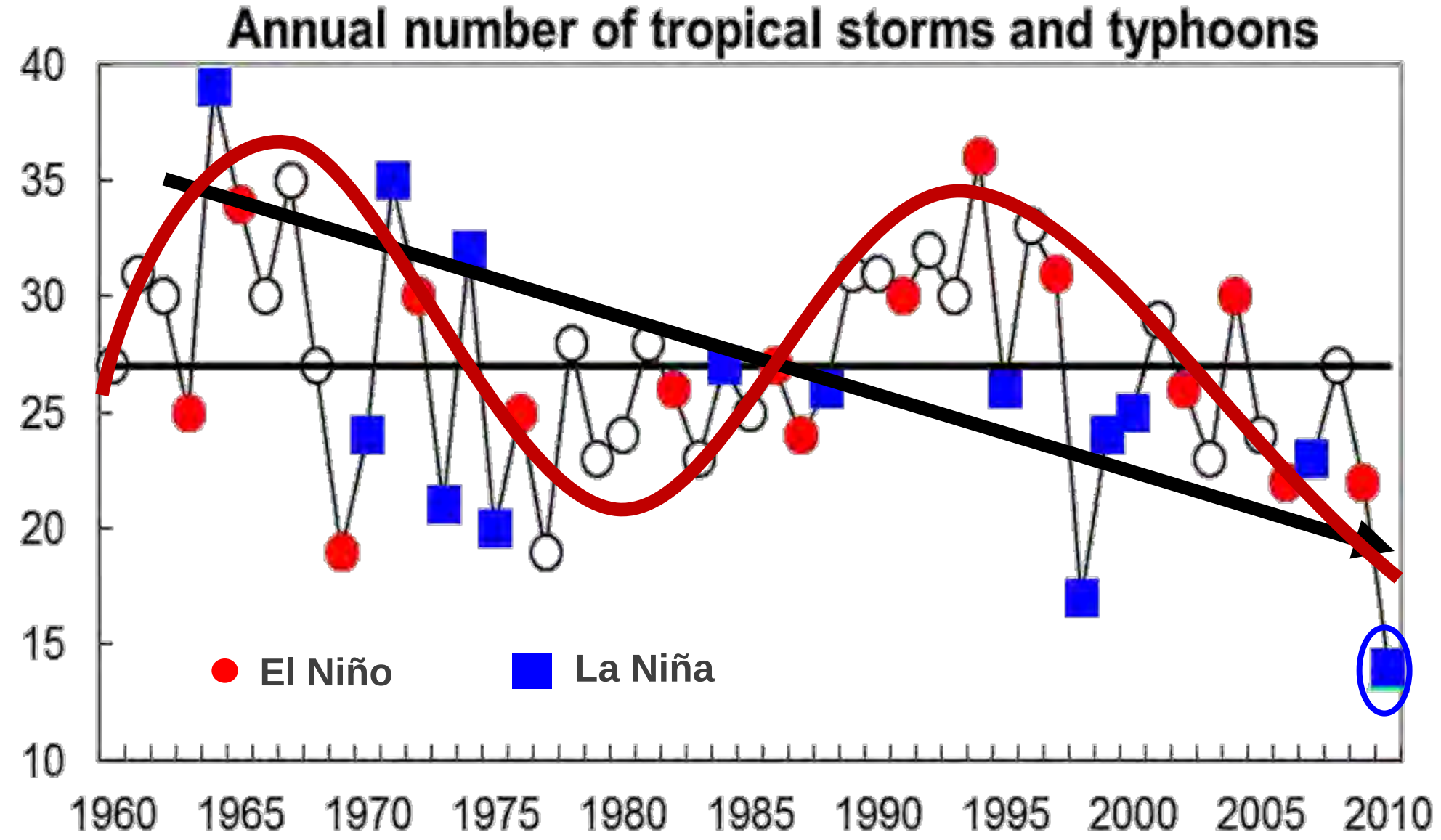
School of Energy and Environment
City University of Hong Kong

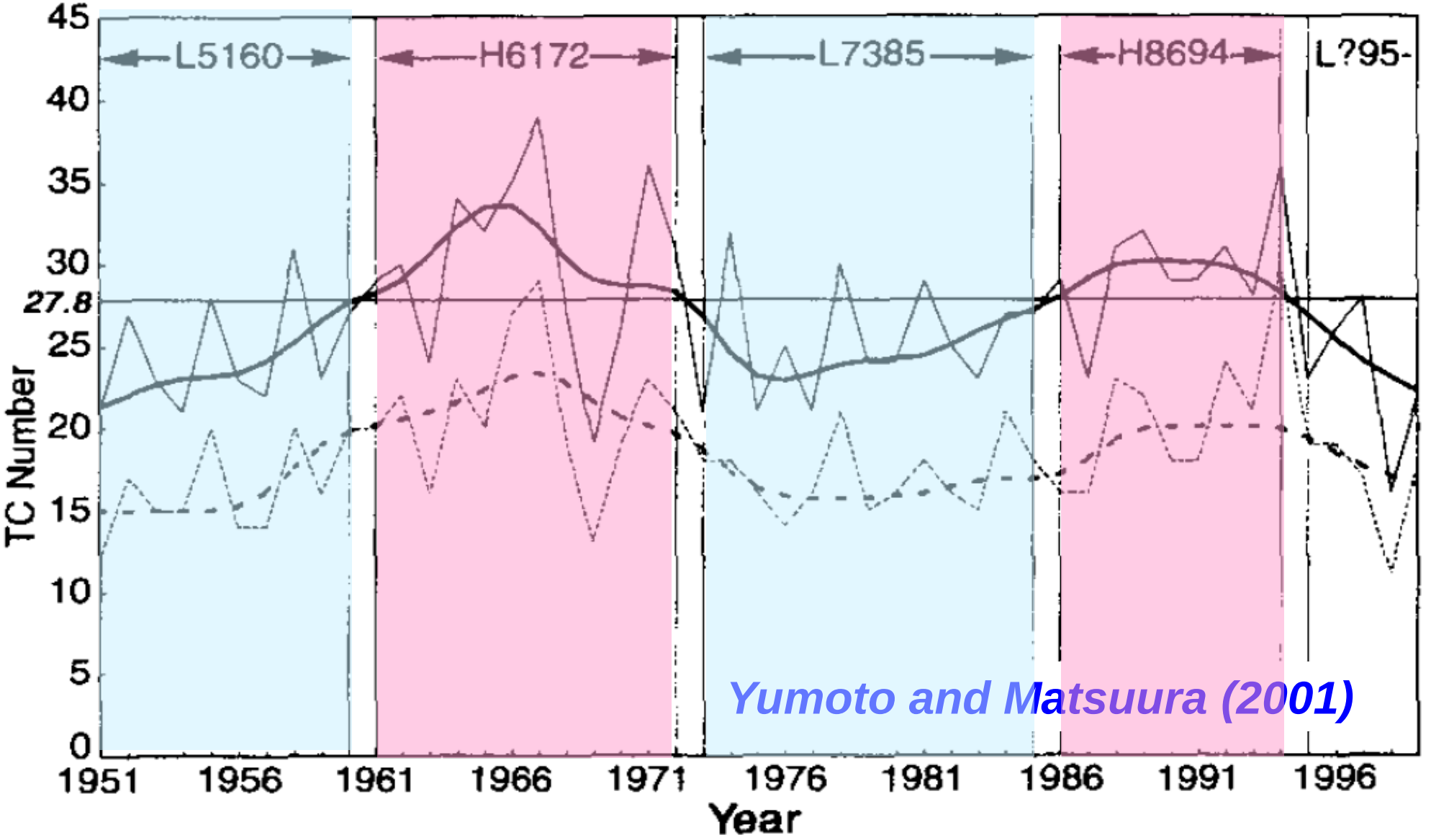
Outline

- Number variations
- Intensity variations
- Track variations
- Landfall variations
- Summary

Annual No. of TS & TY in the western North Pacific

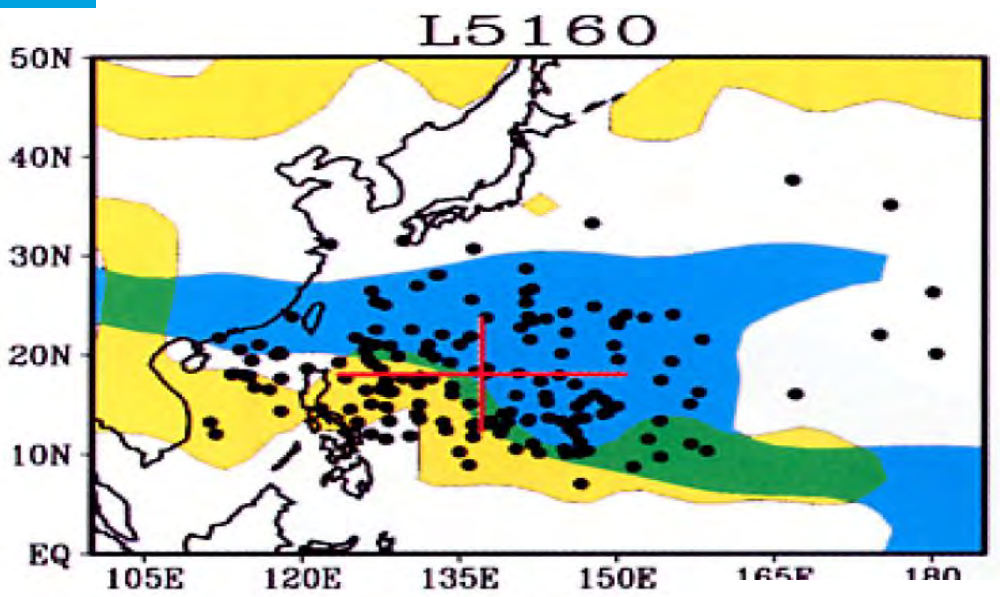


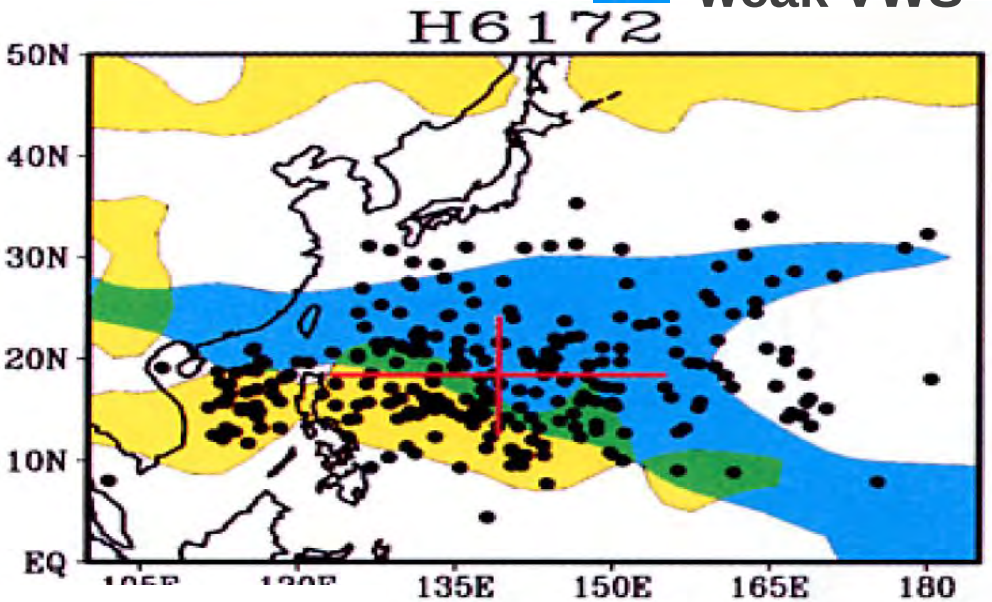
Annual No. of TC & TY in the western North Pacific



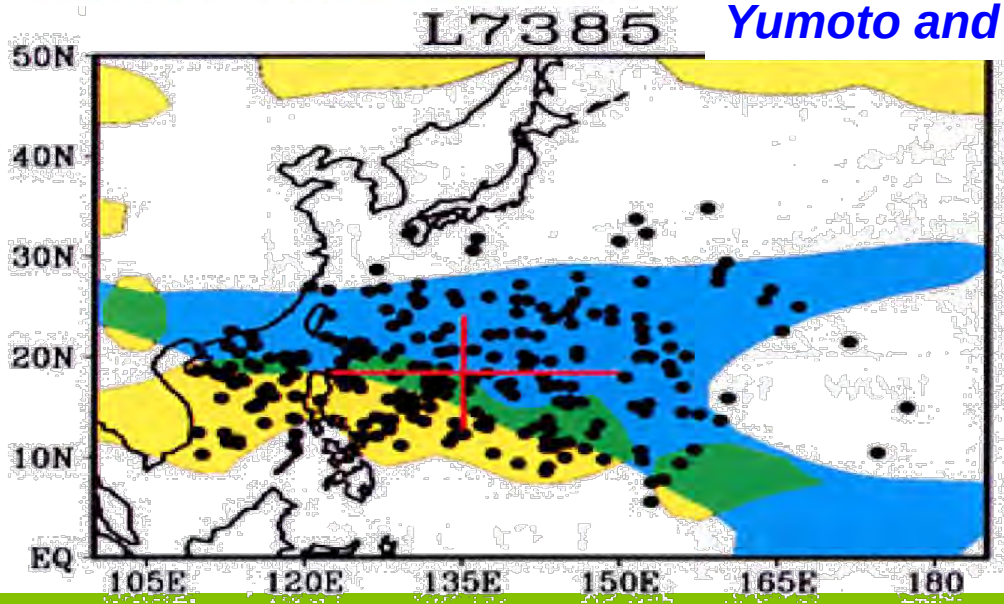
Relative vorticity and vertical wind shear

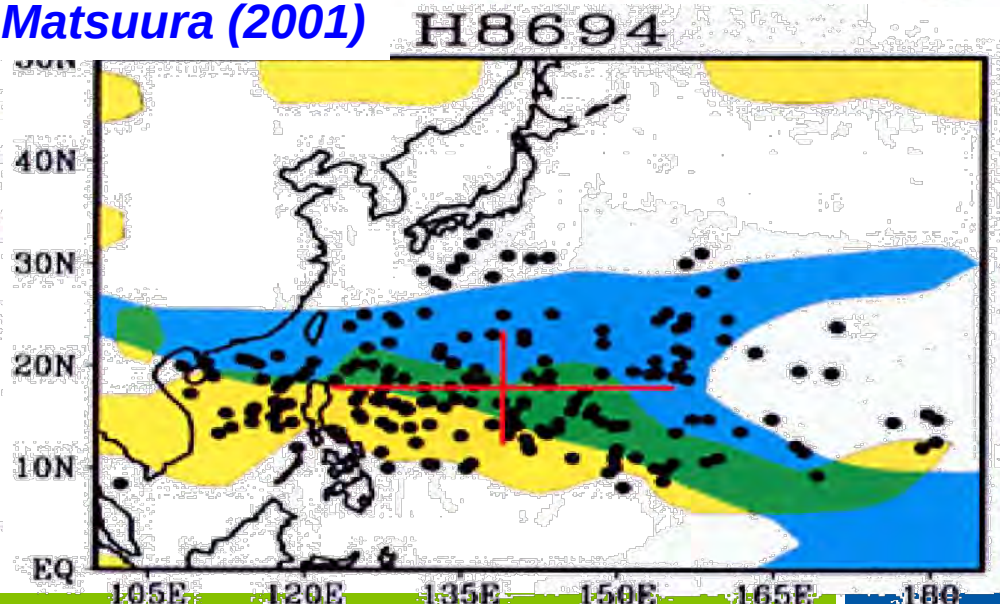
rel. vort.
weak VWS



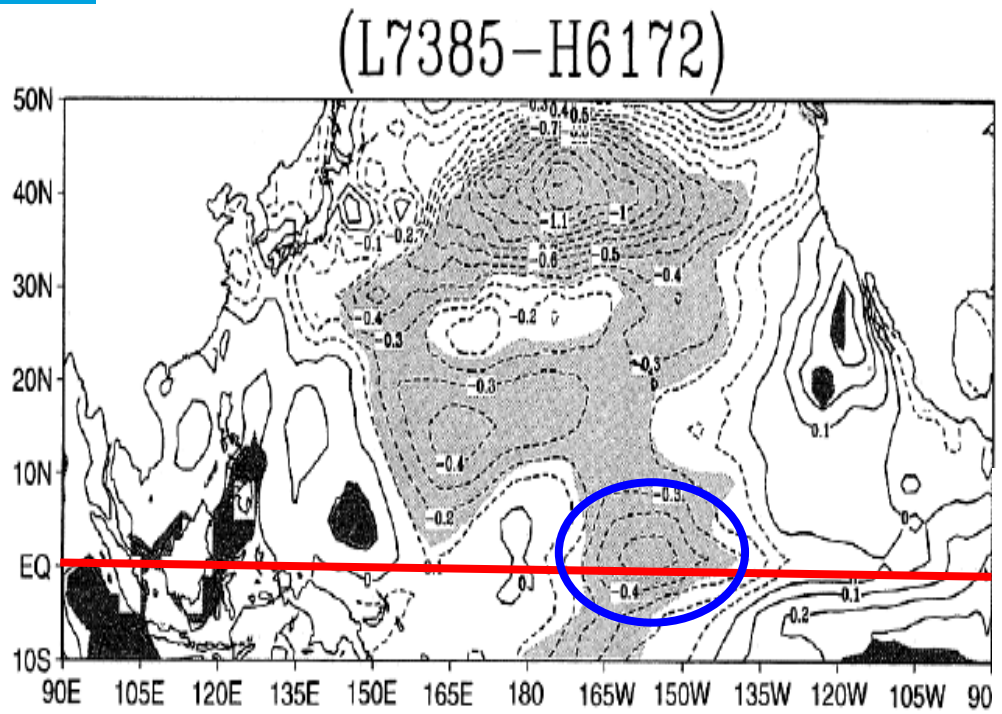


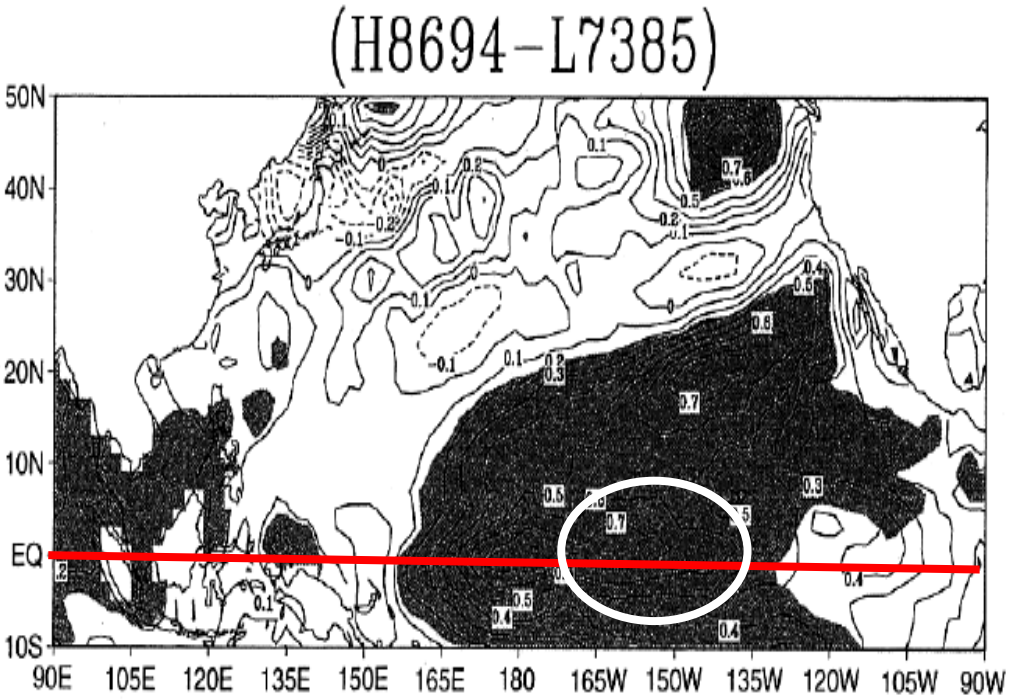
Yumoto and Matsuura (2001)





SST Difference

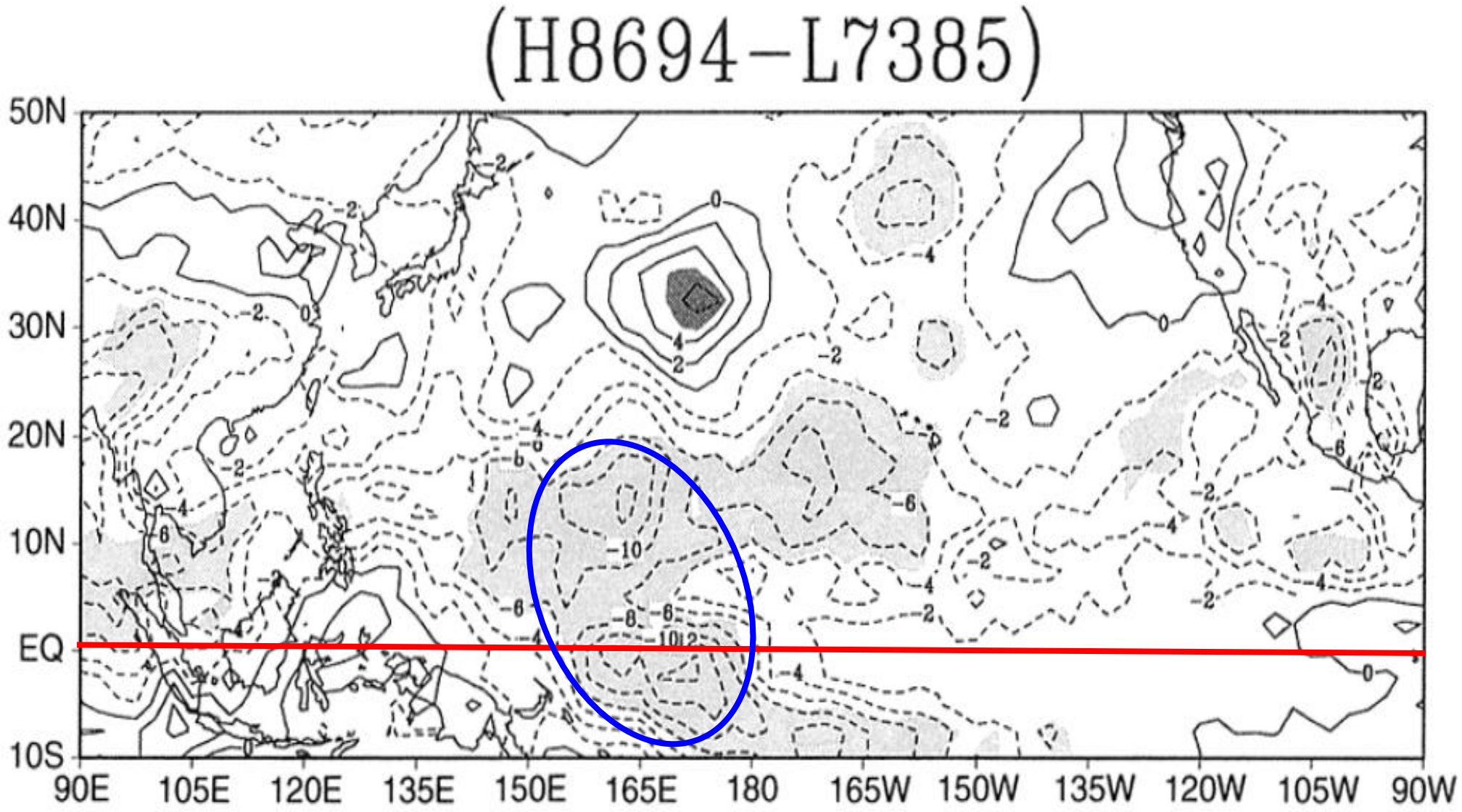




Yumoto and Matsuura (2001)

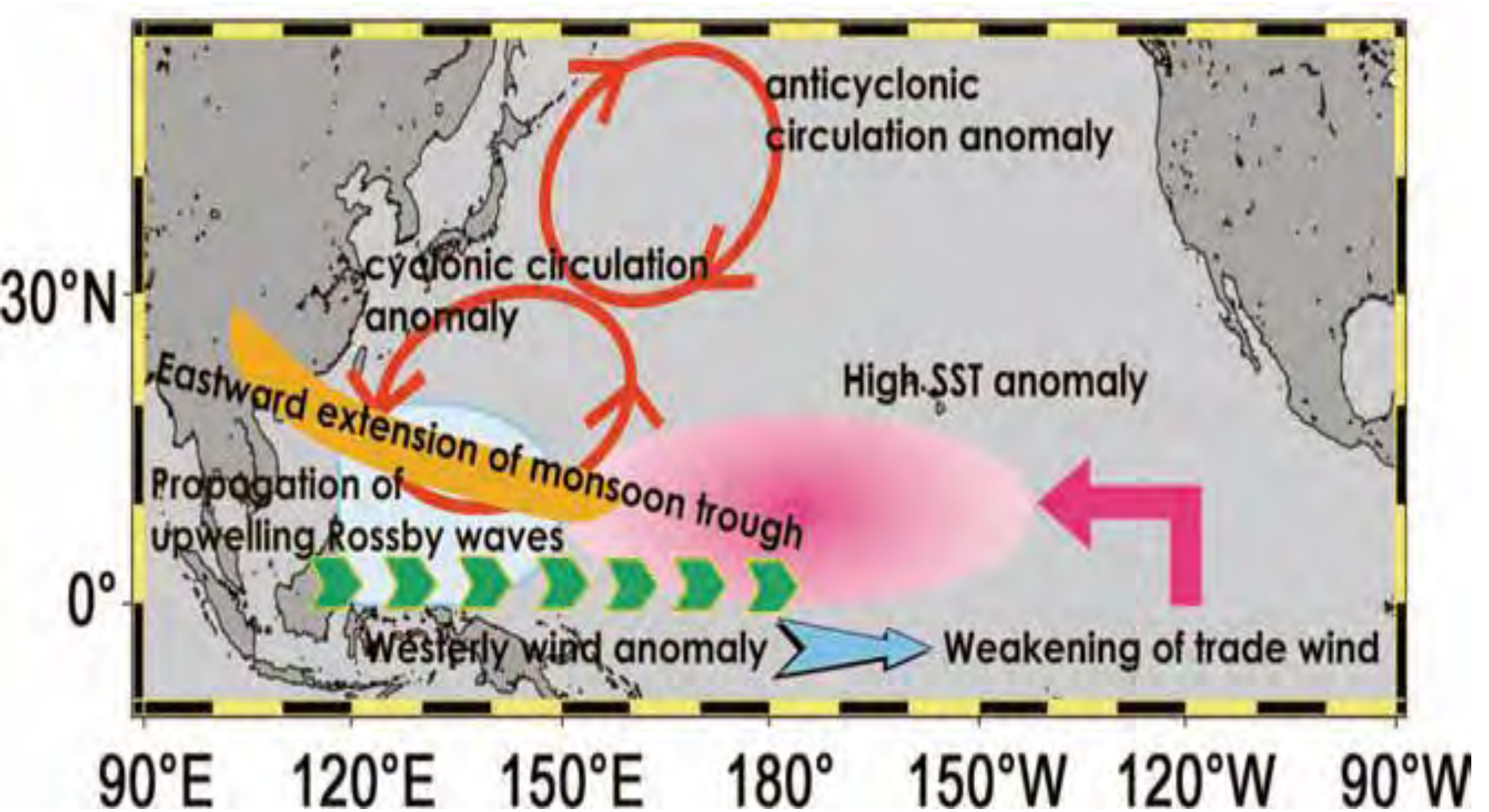
OLR Difference

Yumoto and Matsuura (2001)

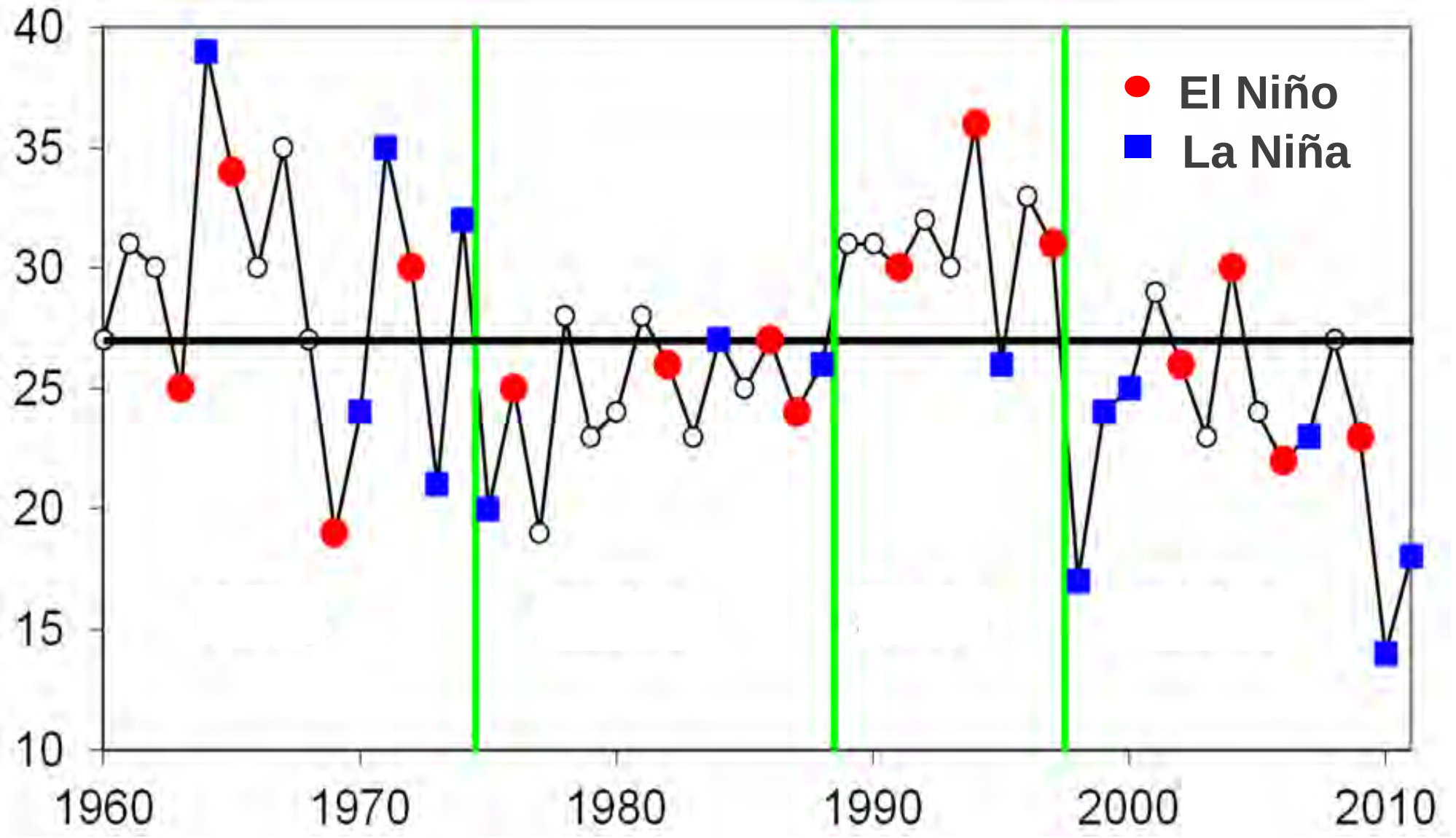


Possible mechanism

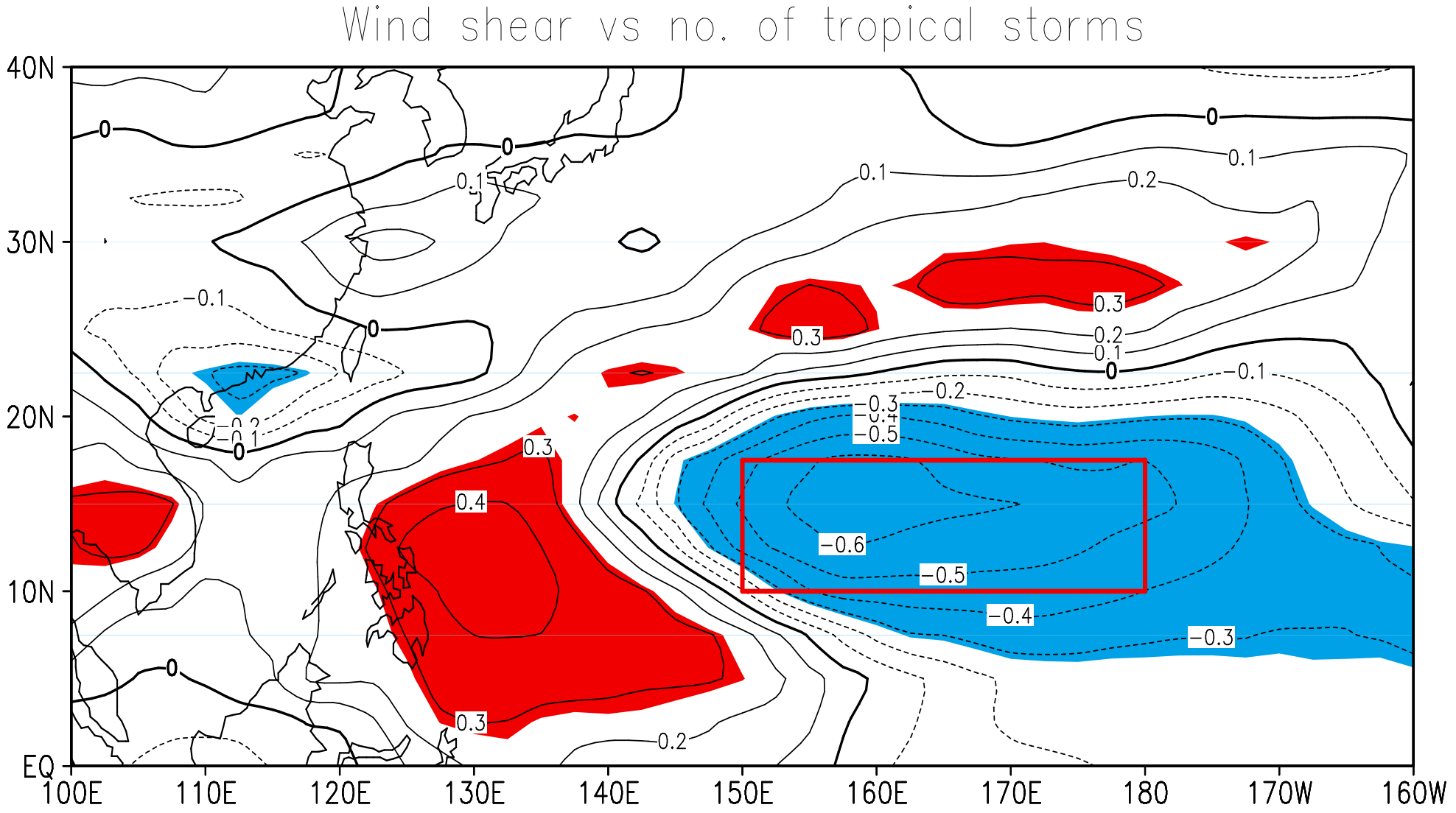
Matsuura et al. (2003)



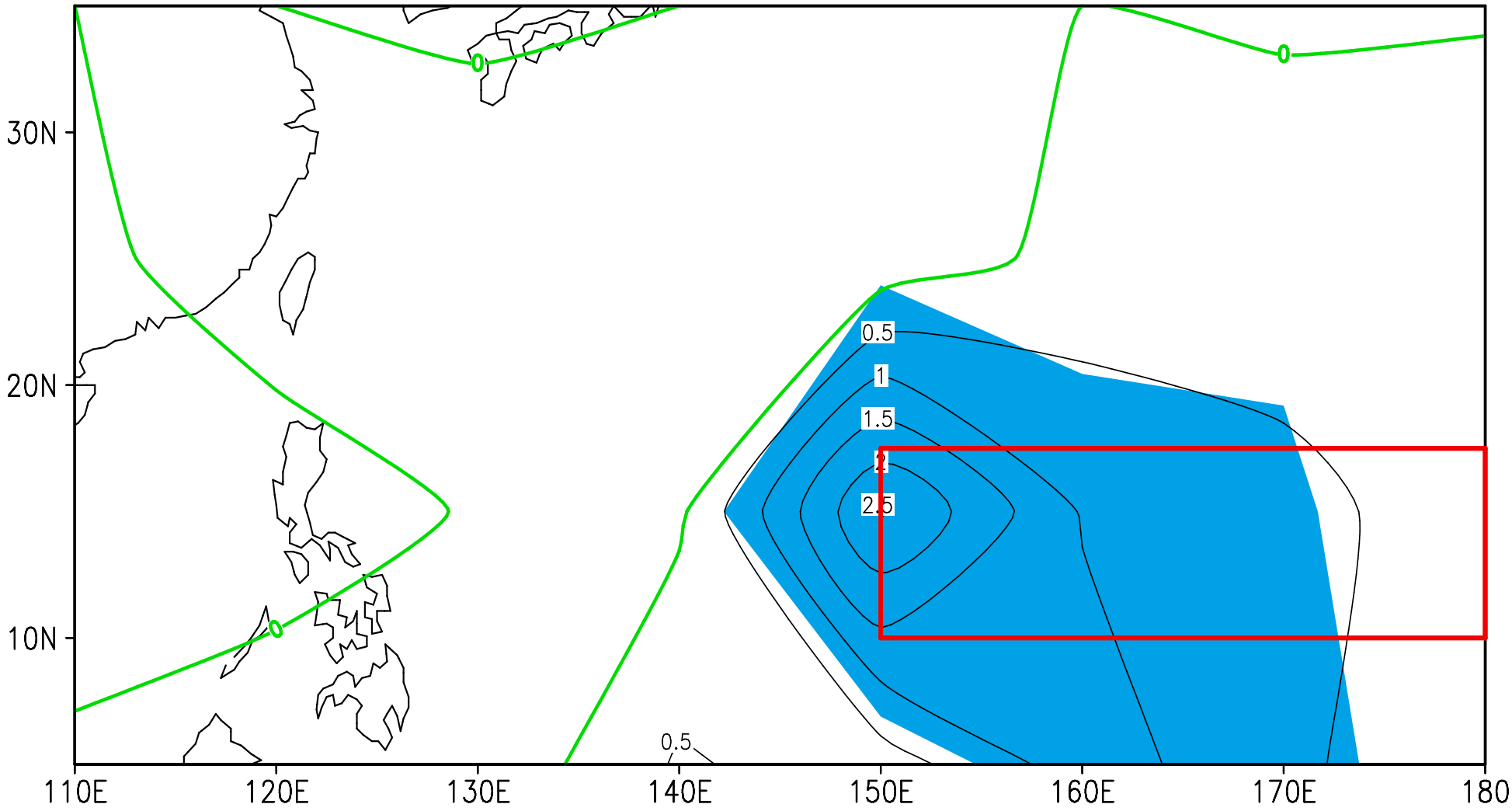
Annual no. of tropical storms and typhoons in the western North Pacific



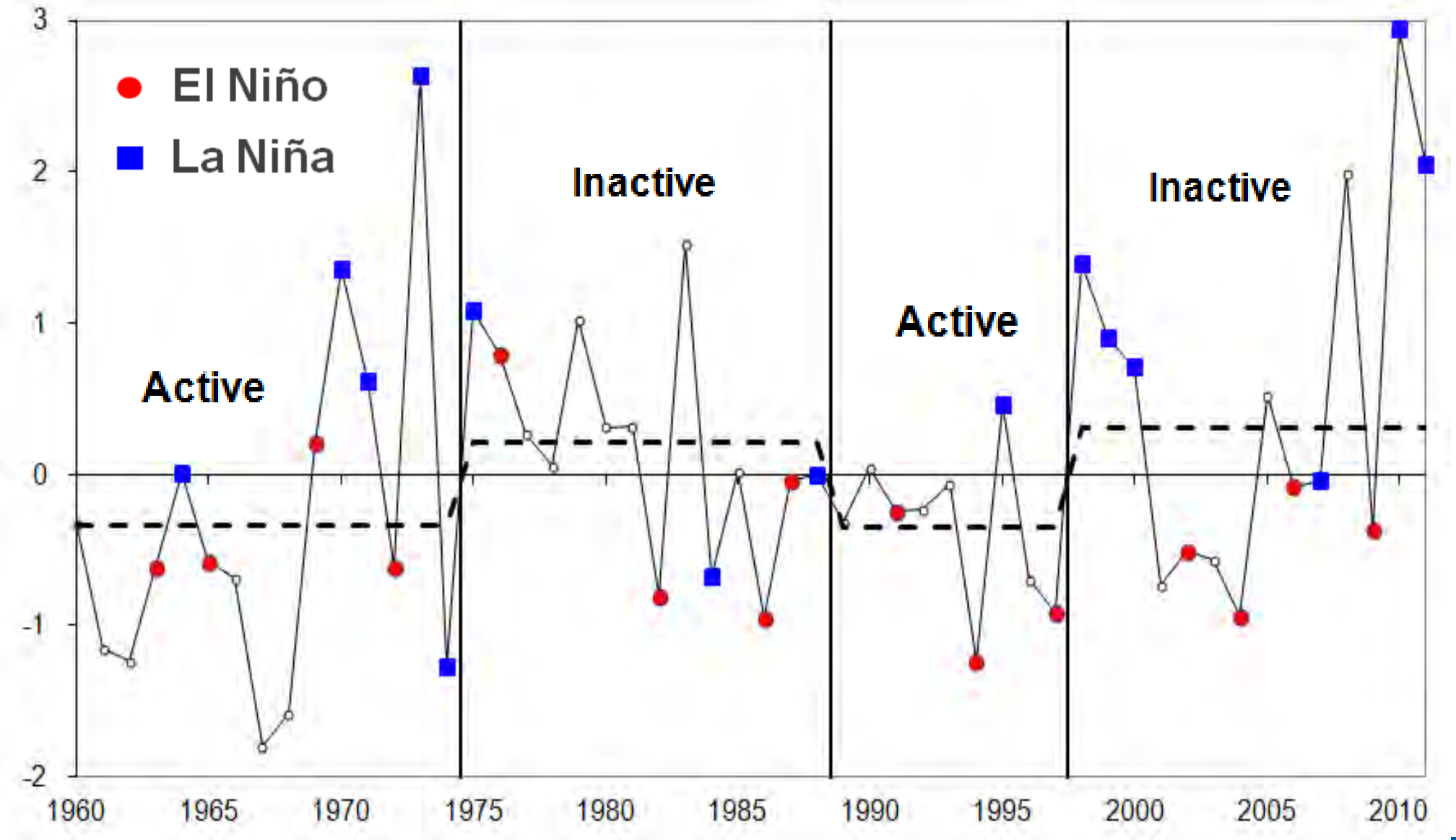
Correlation between TC number and the 850-200-hPa vertical shear of zonal wind



Difference in TC number between weak and strong vertical wind shear years

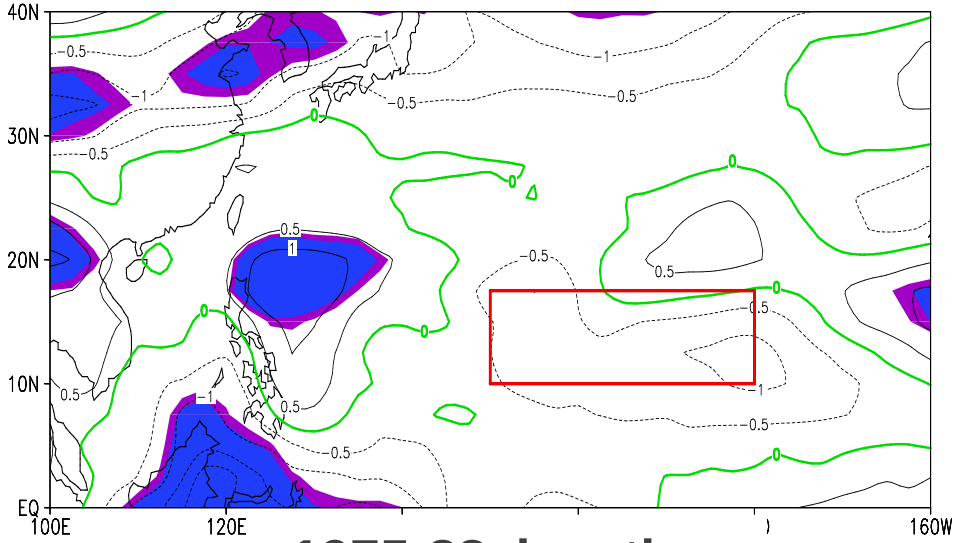


Time series of the vertical wind shear index

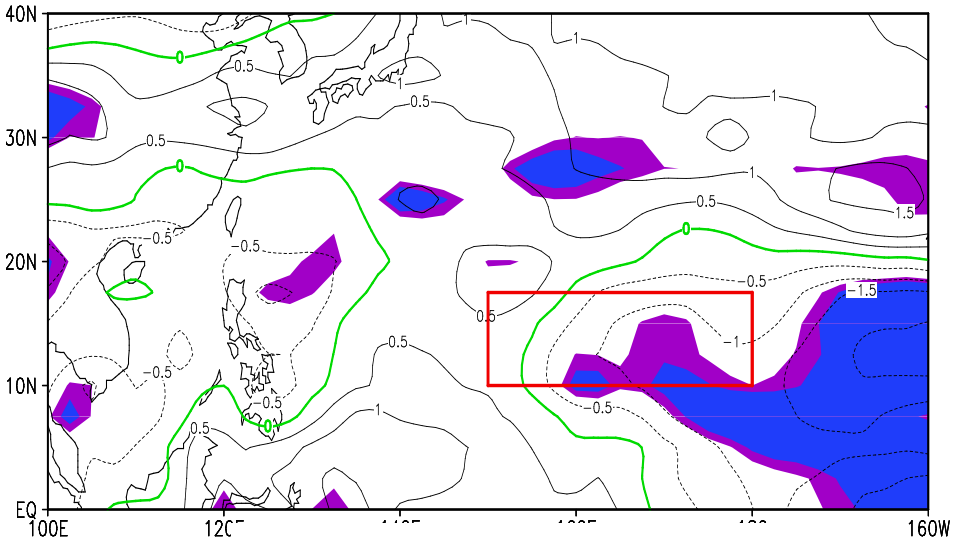


Mean Jun-Oct vertical shear of zonal wind

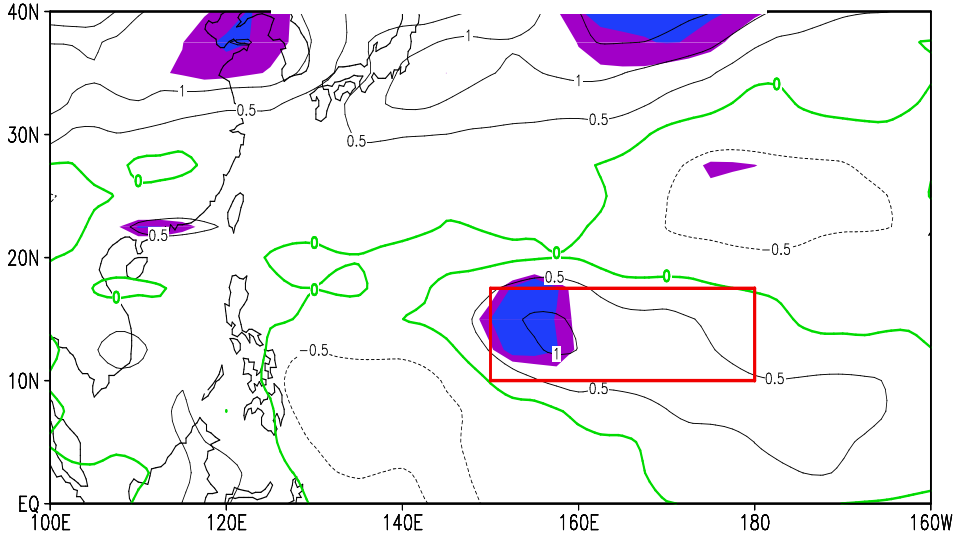
1960-74, active



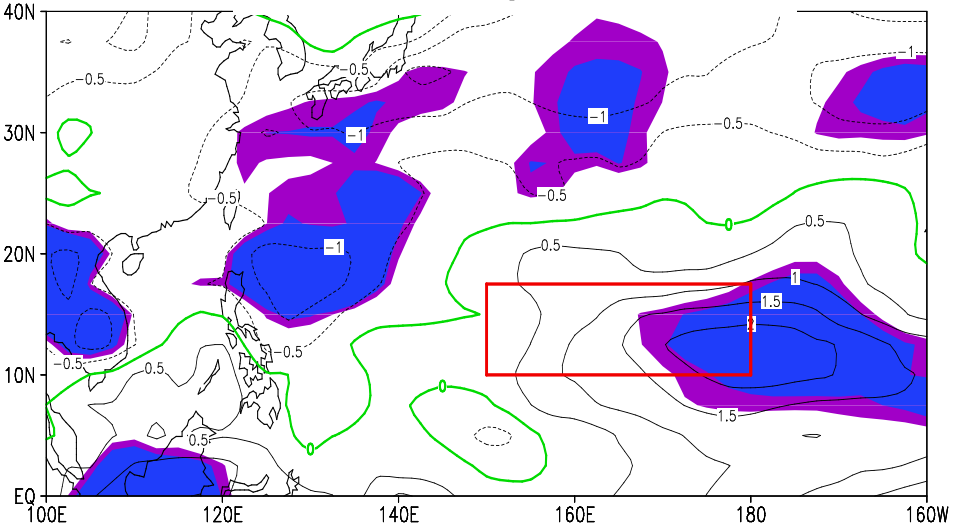
1998-97, active



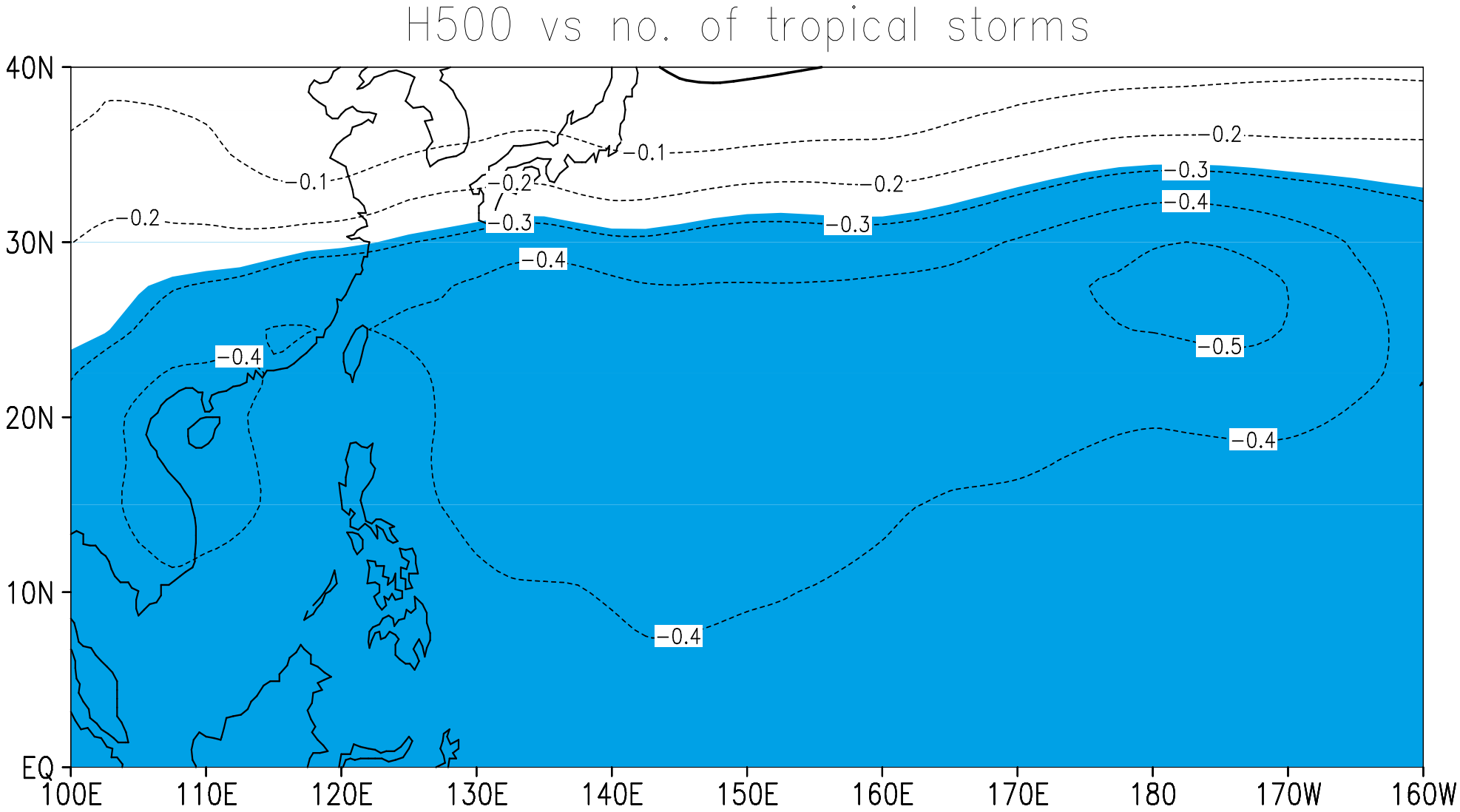
1975-88, inactive



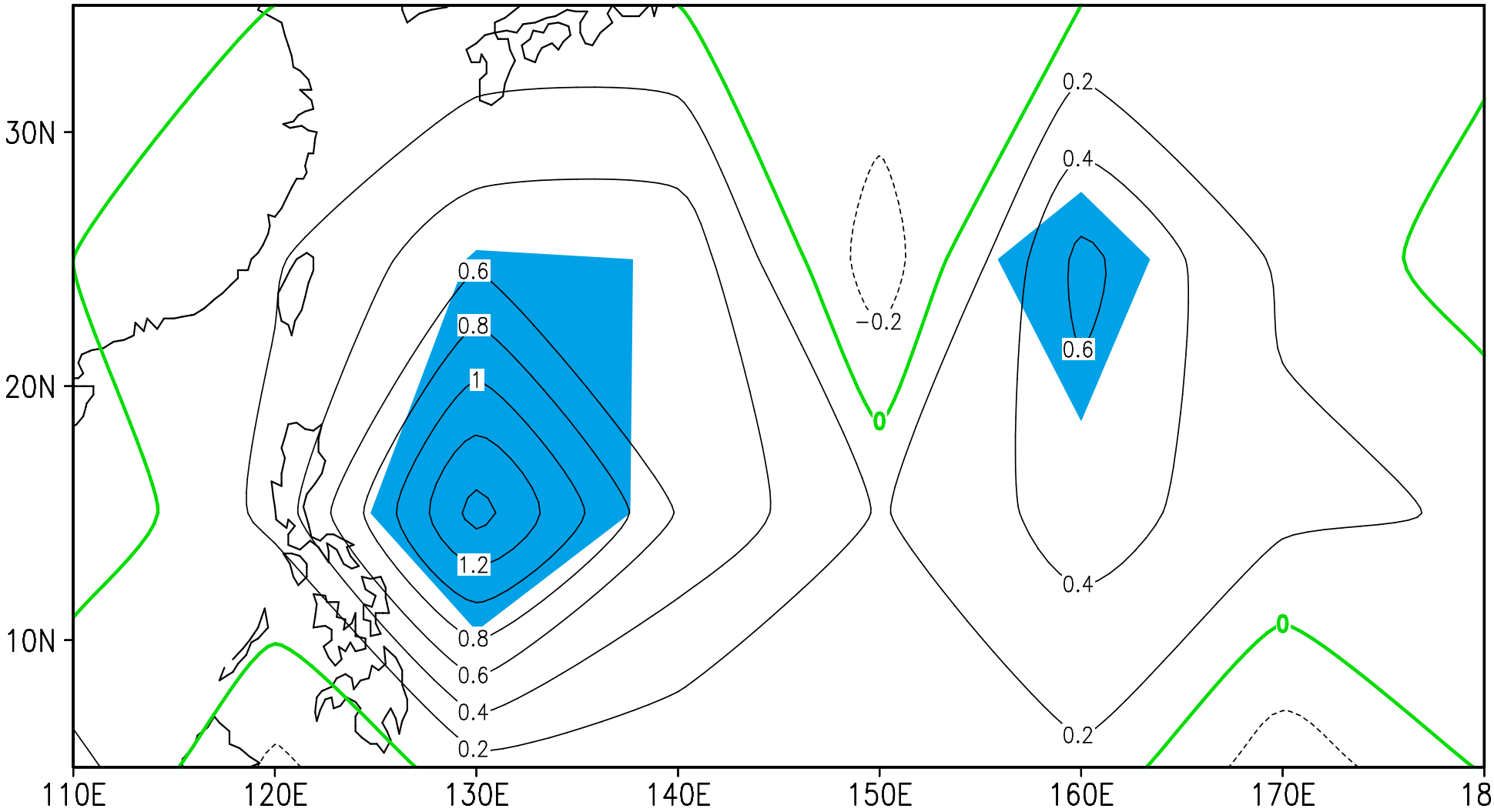
1998-2011, inactive



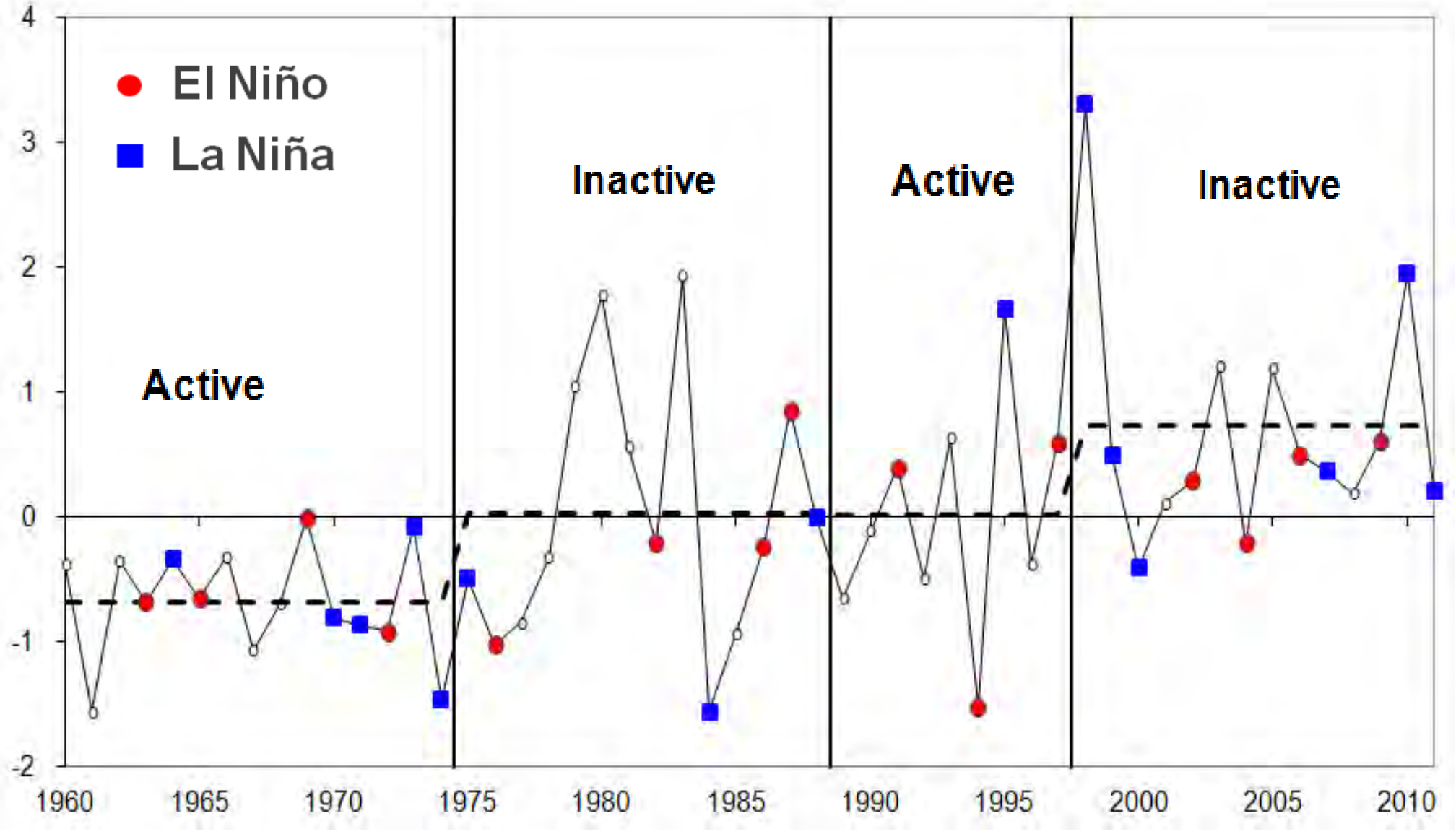
Correlation map between TC number and 500-hPa geopotential height



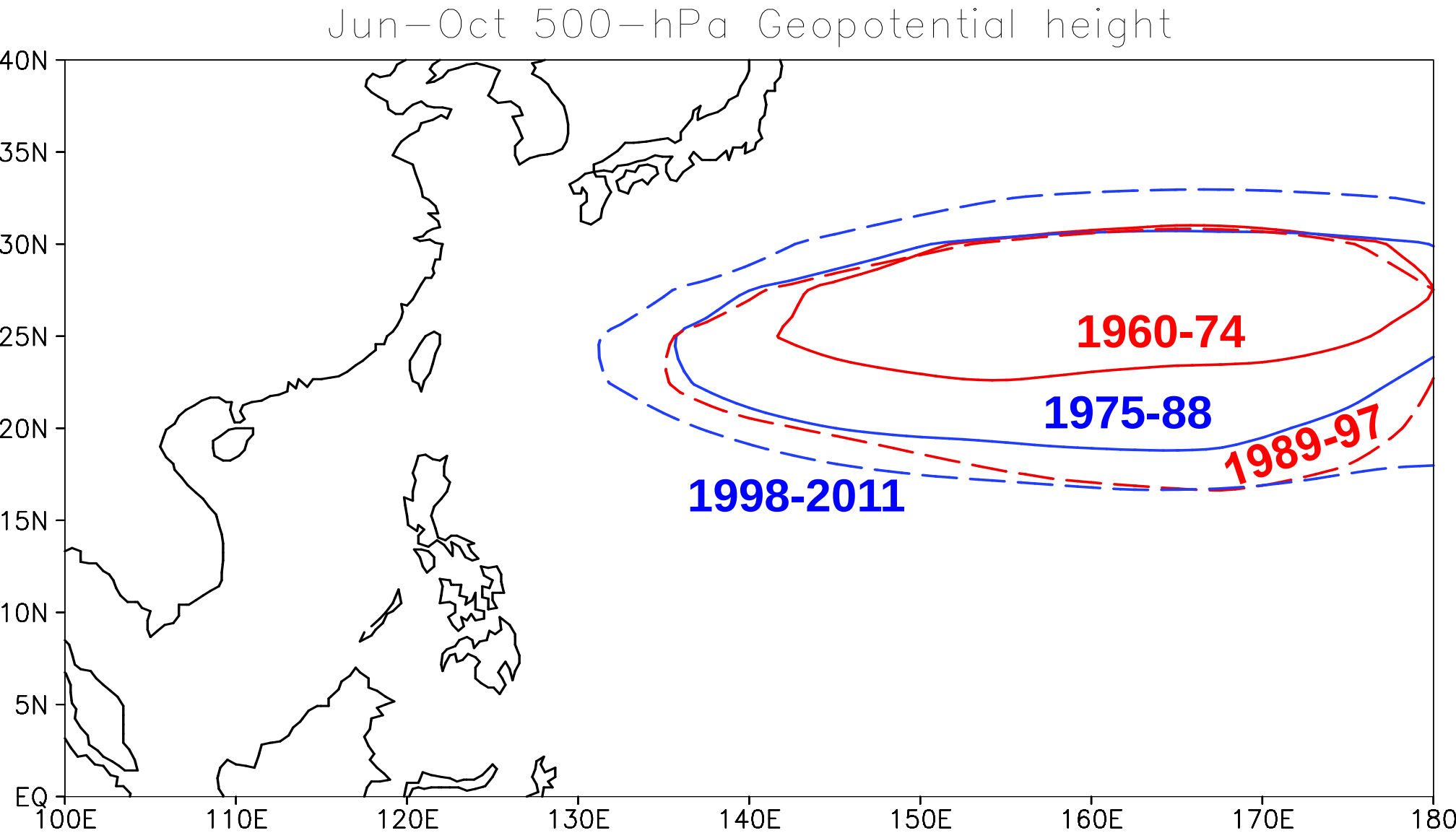
Difference in number of TC formations between the weak and strong subtropical high years



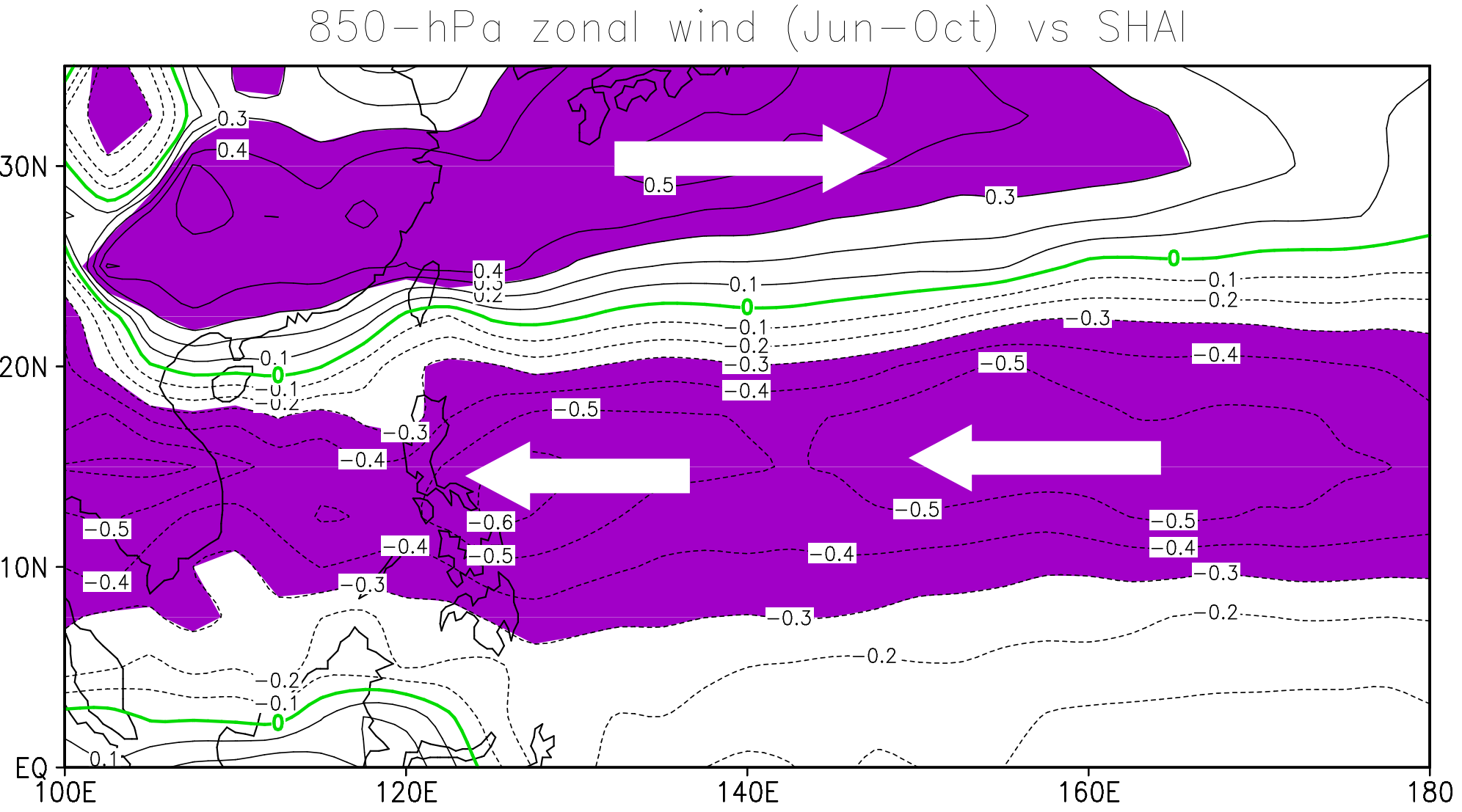
Time series of the subtropical high area index



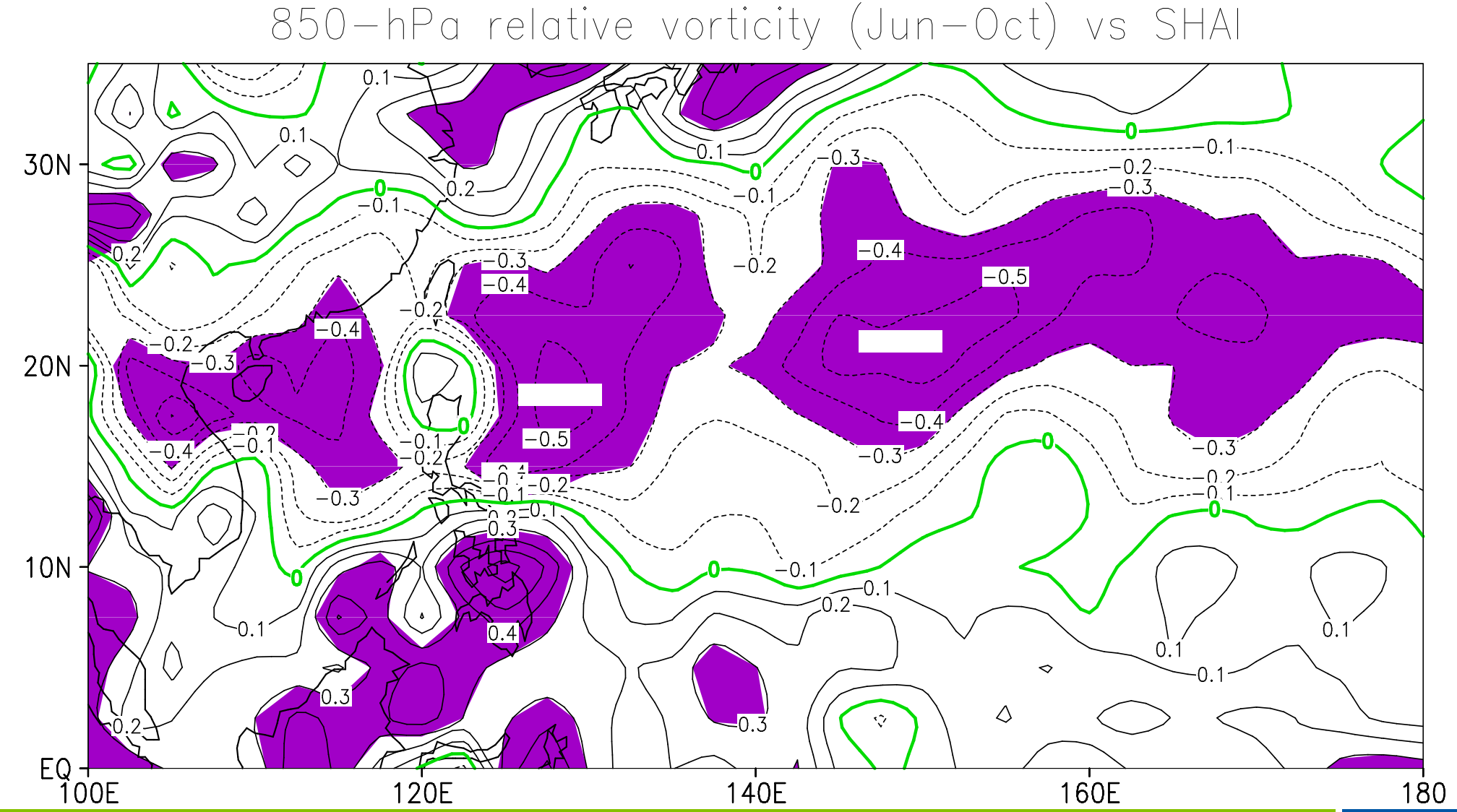
Mean Jun-Oct 5880 gpm lines at 500 hPa



Correlation between 850-hPa zonal wind and subtropical high index

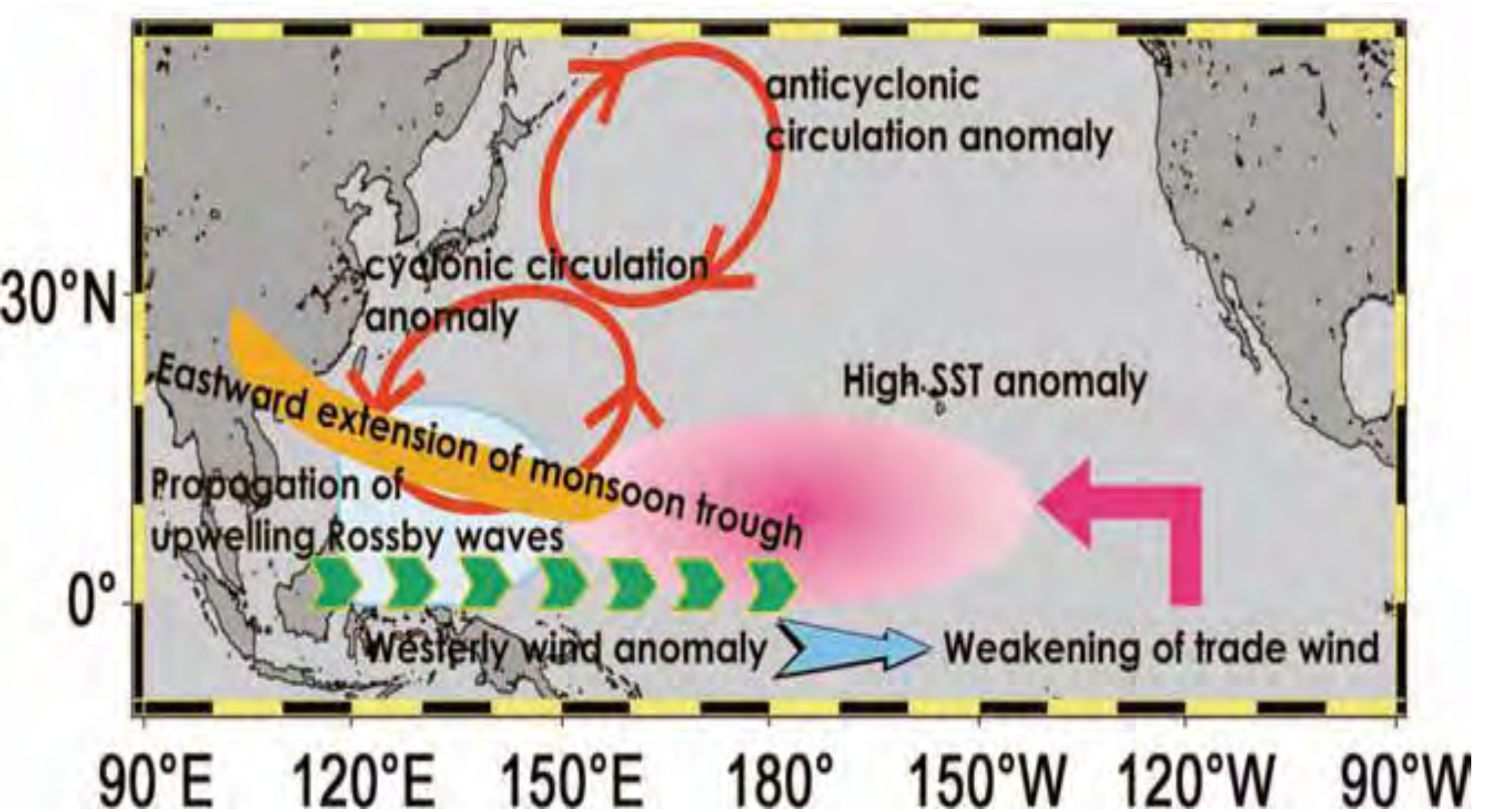


Correlation between 850-hPa relative vorticity and subtropical high index

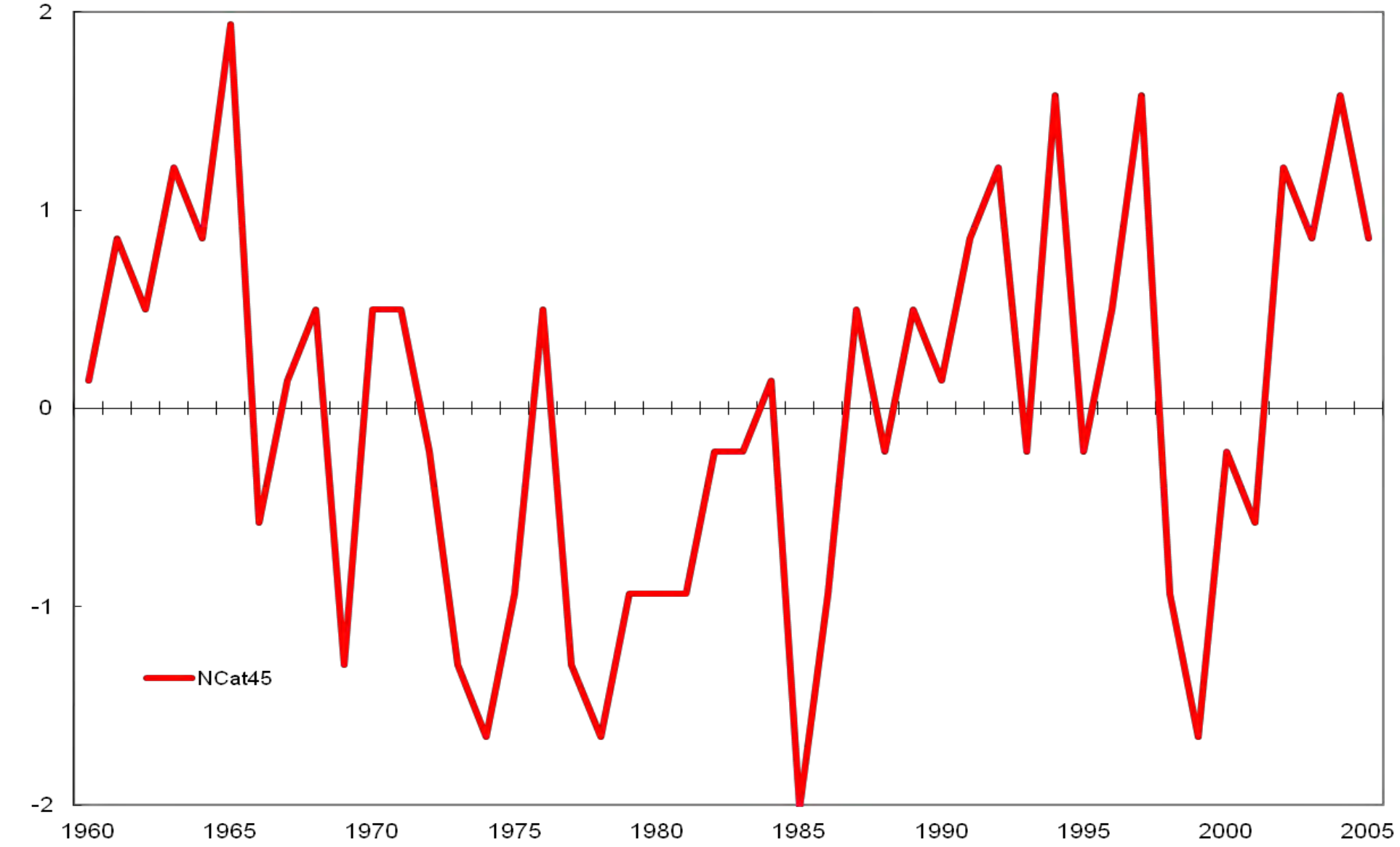


Possible mechanism

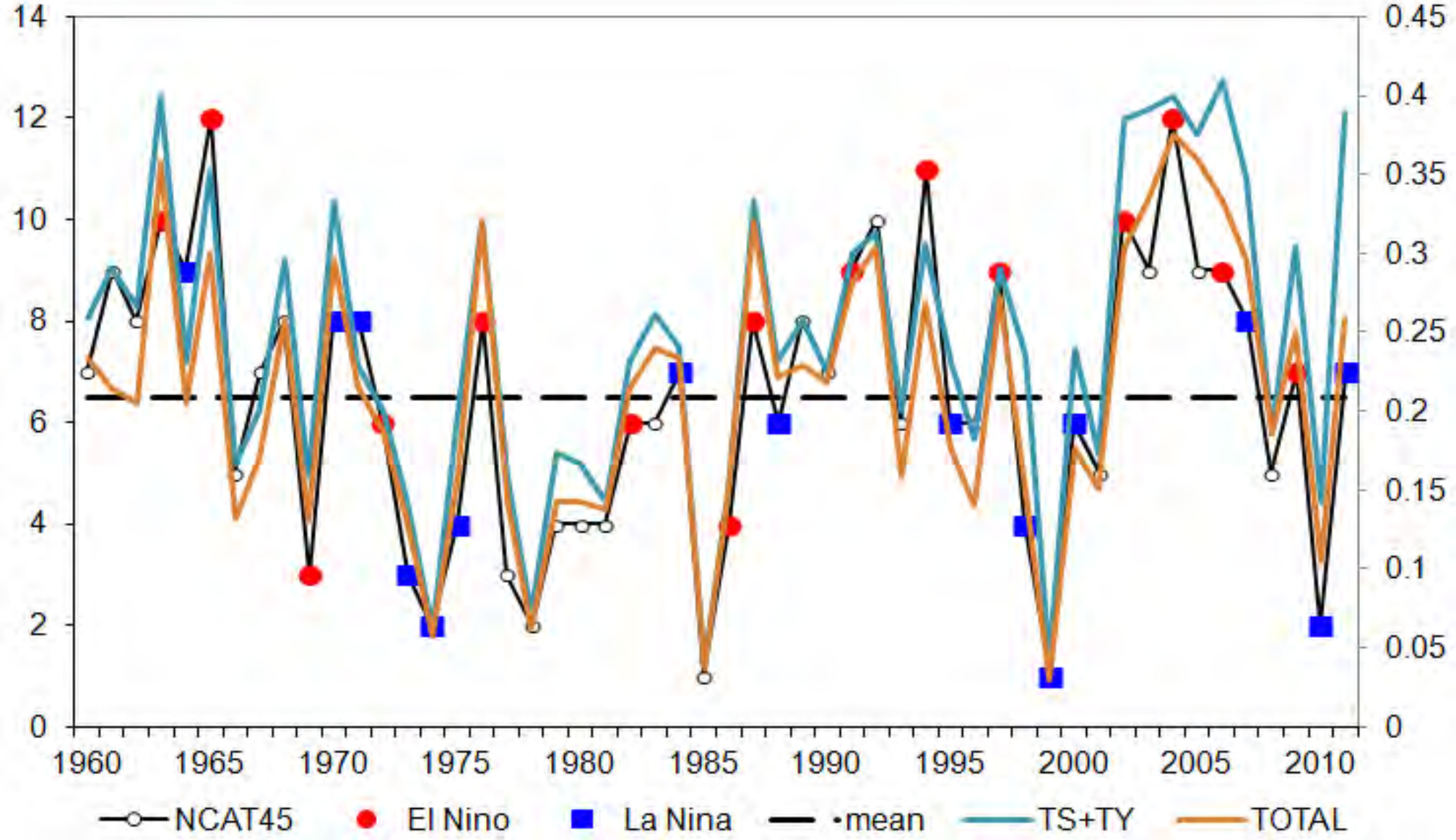
Matsuura et al. (2003)



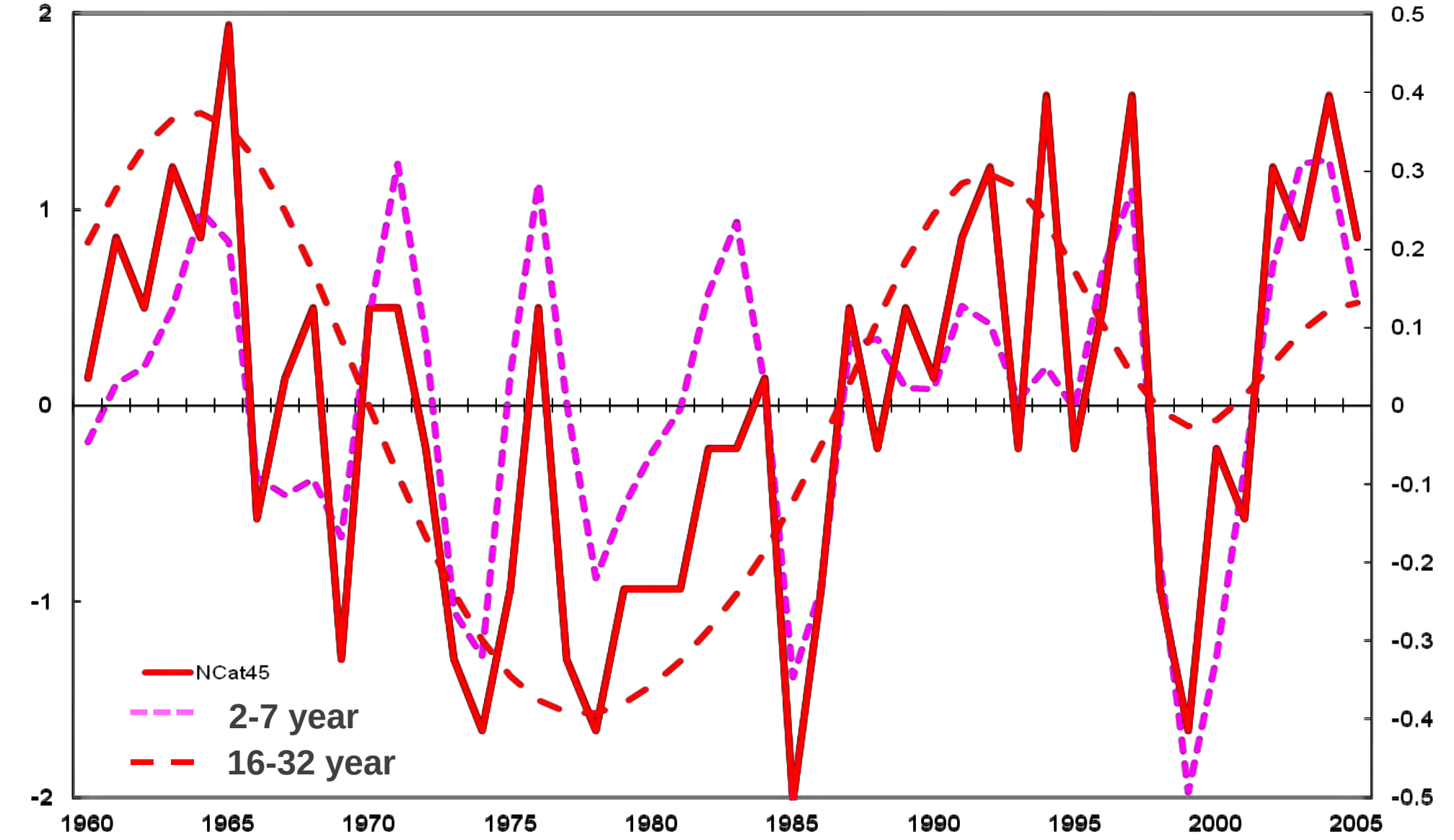
Annual No. of Cat45 in the western North Pacific



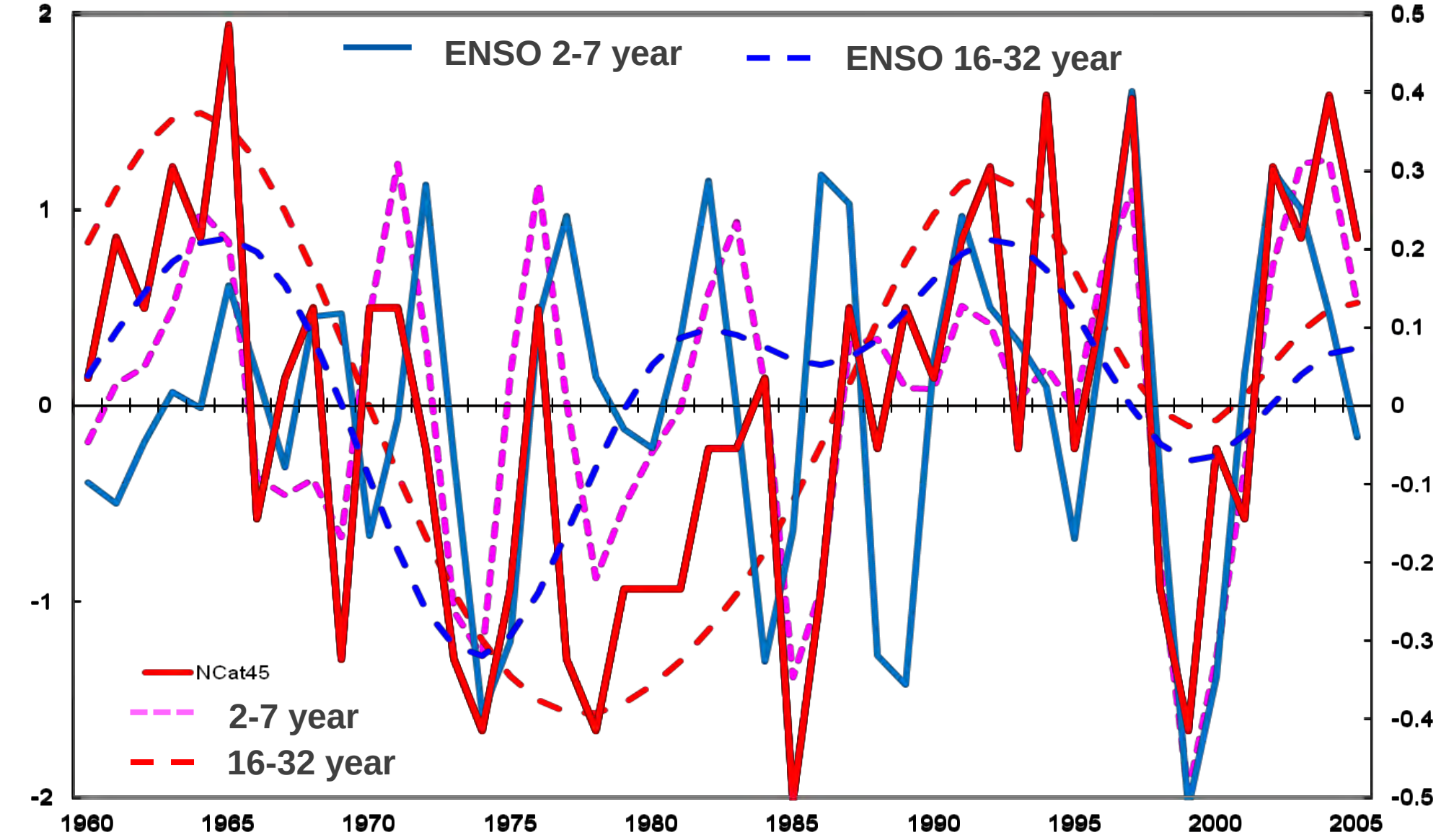
Annual No. of Cat45 in the western North Pacific



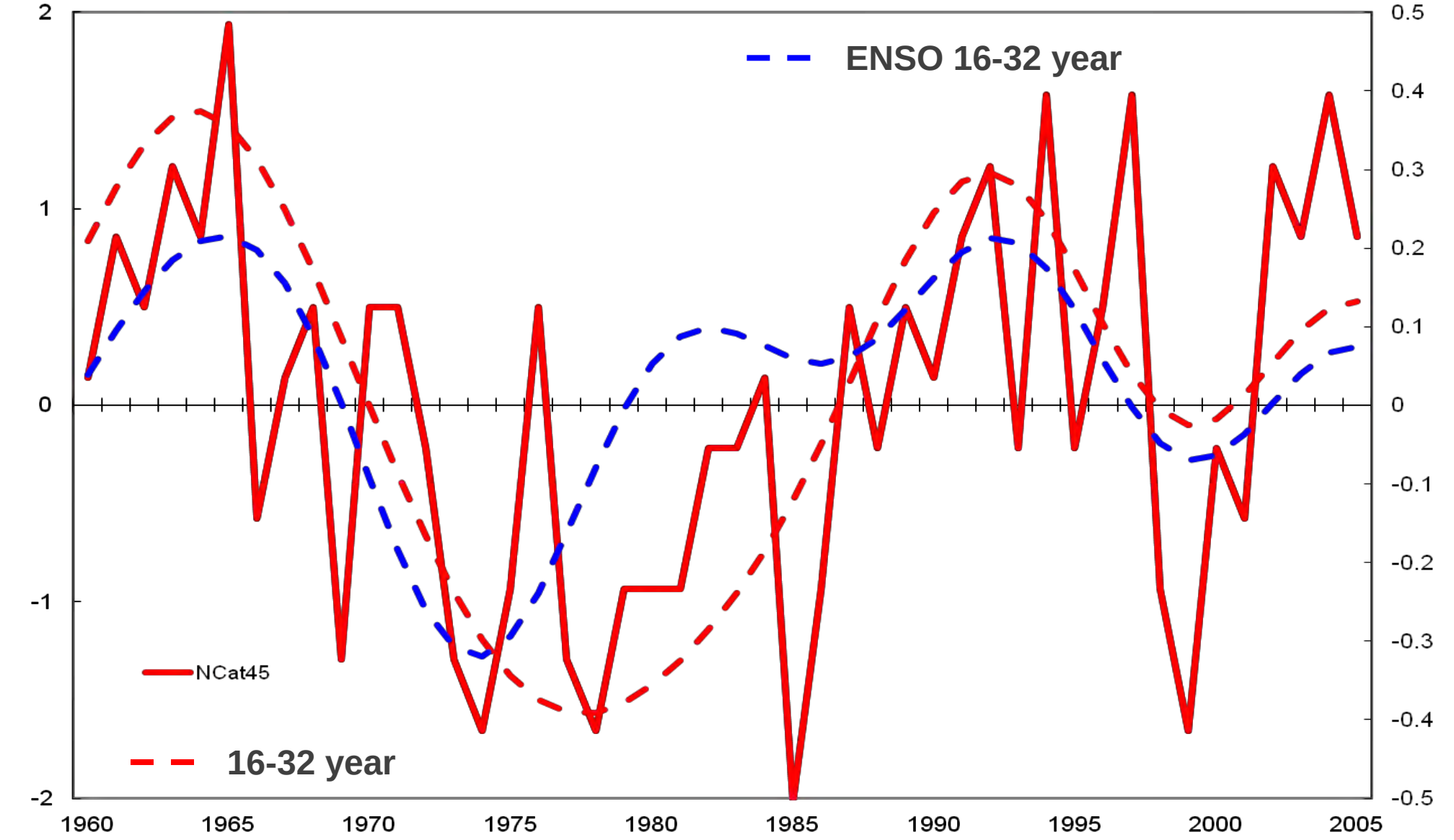
Annual No. of Cat45 in the western North Pacific



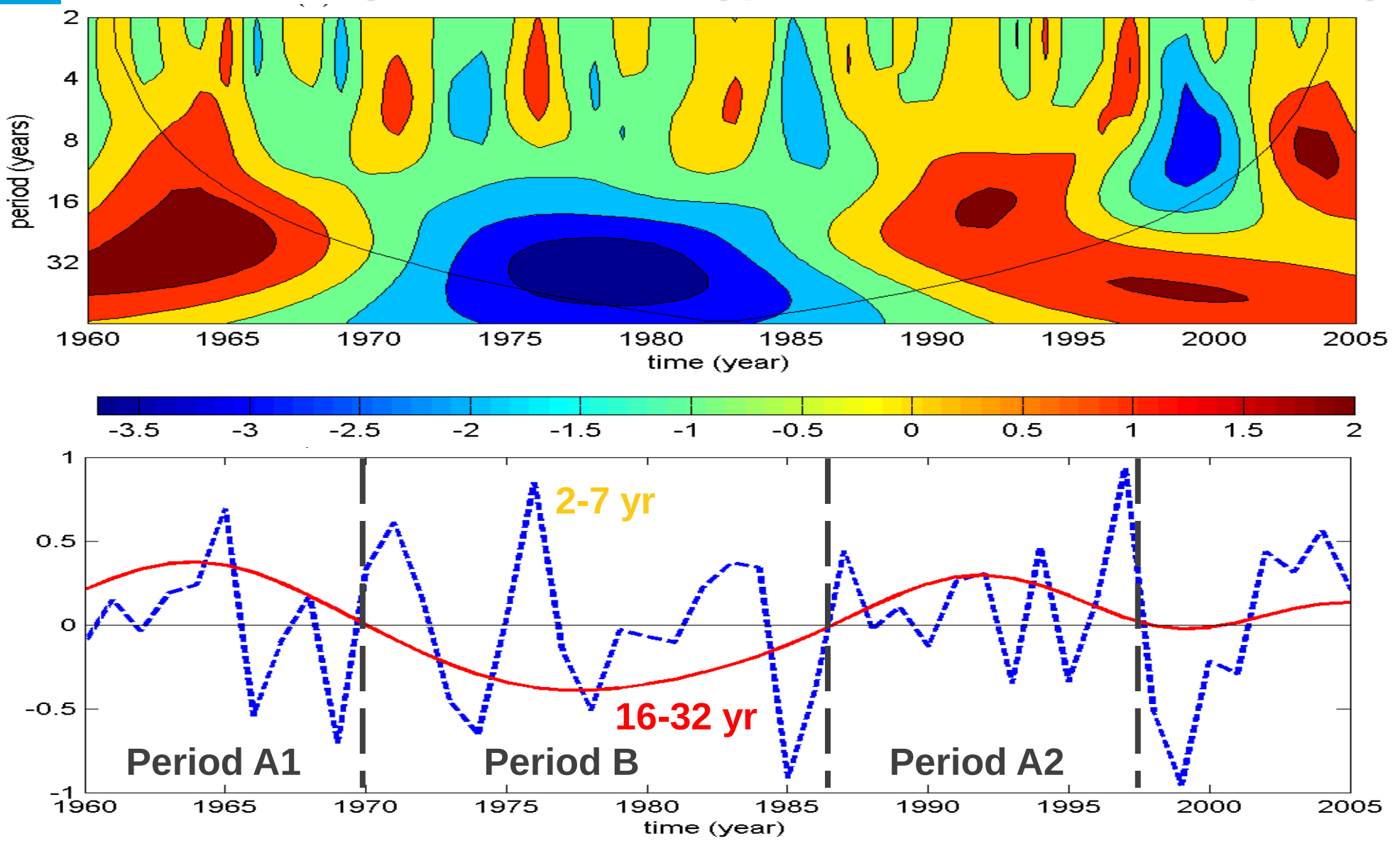
Annual No. of Cat45 in the western North Pacific

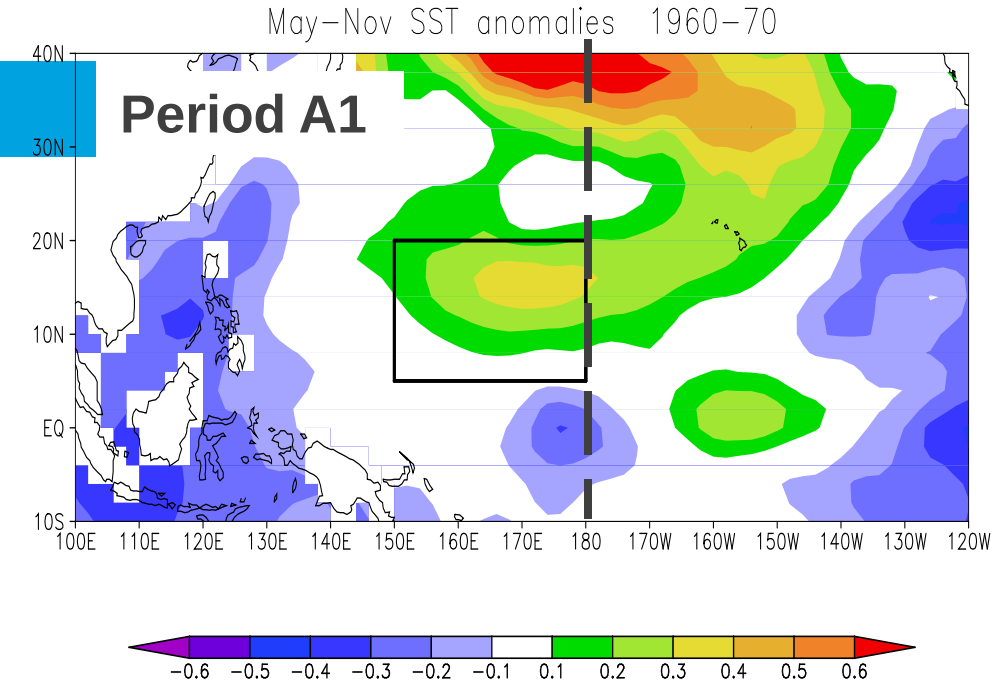


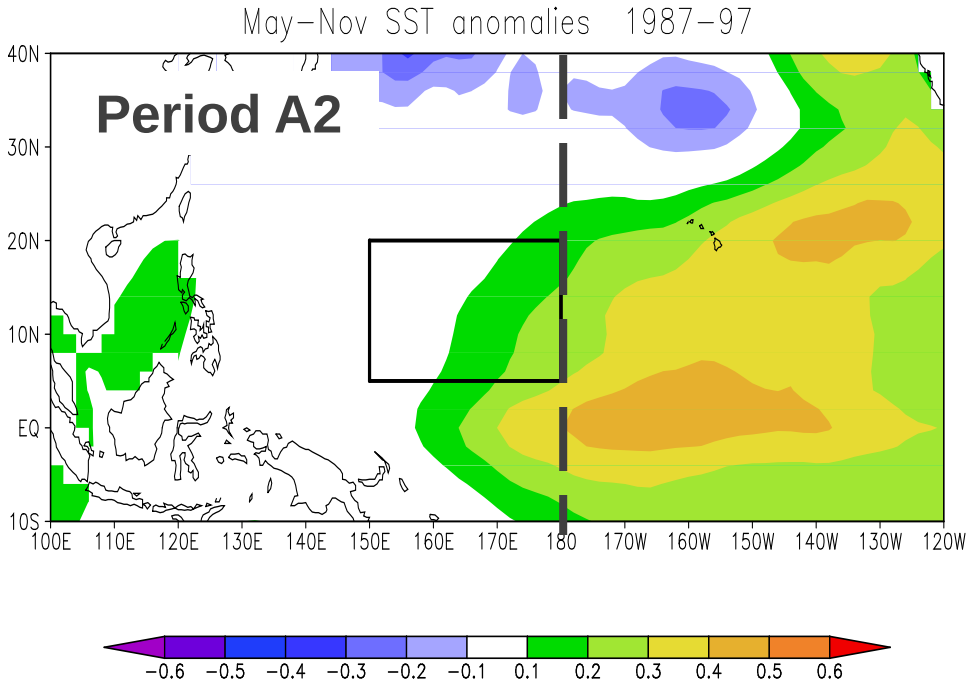
Annual No. of Cat45 in the western North Pacific

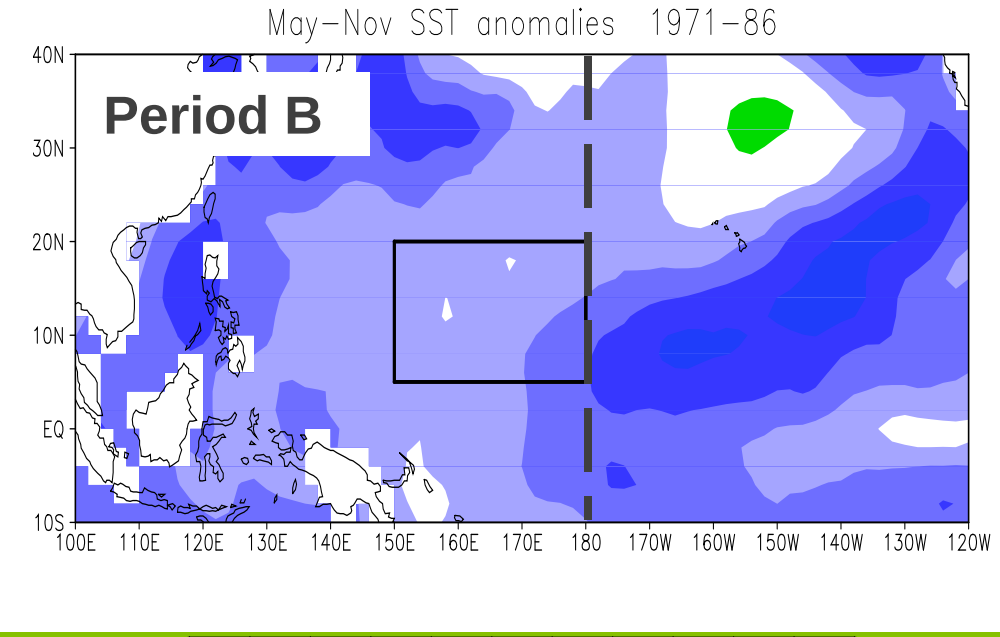


Wavelet Analysis of Intense Typhoon Occurrence Frequency

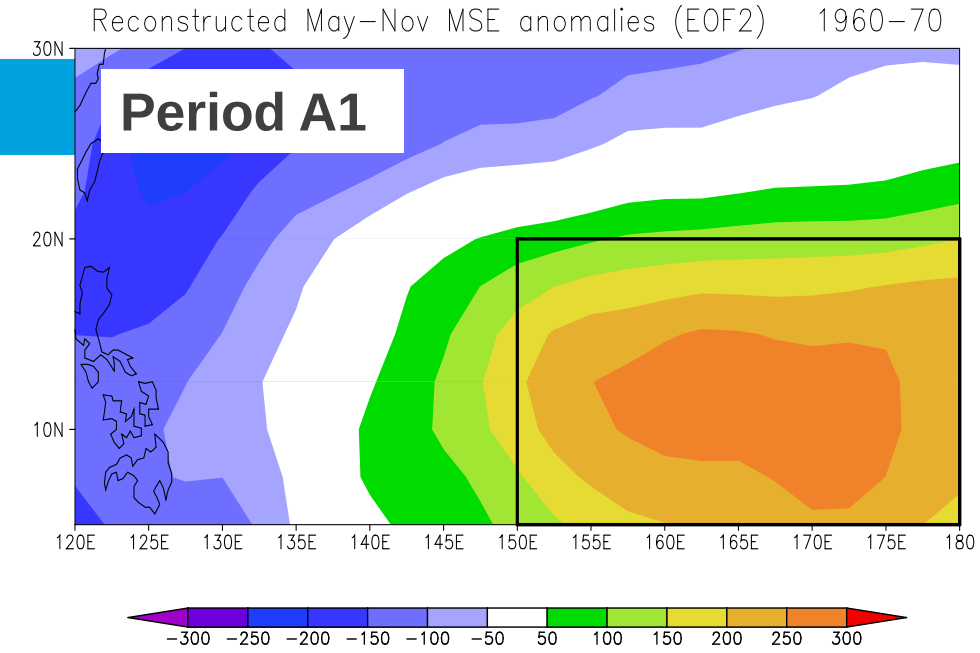


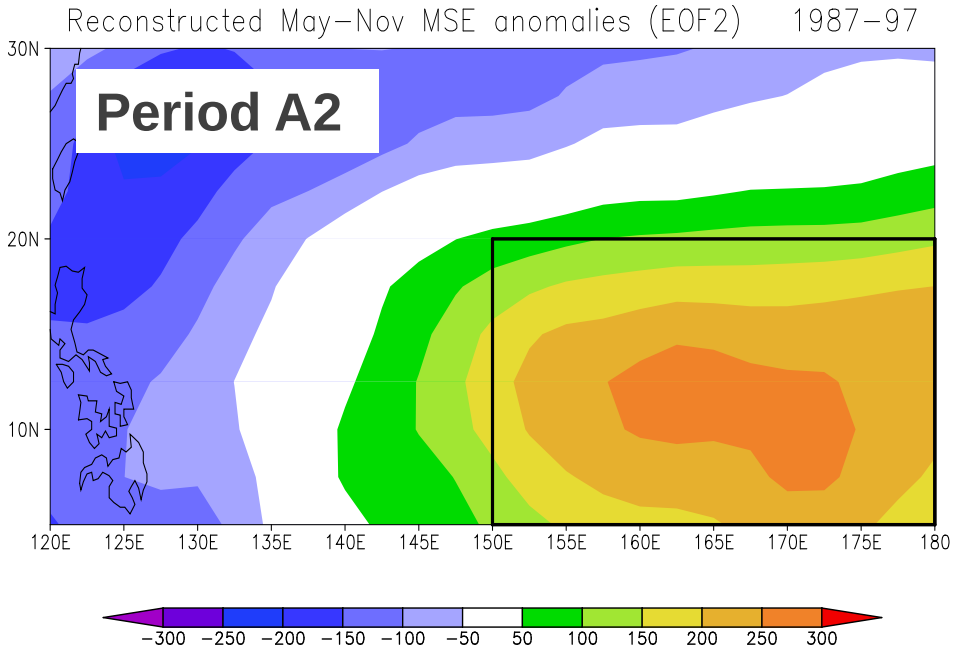


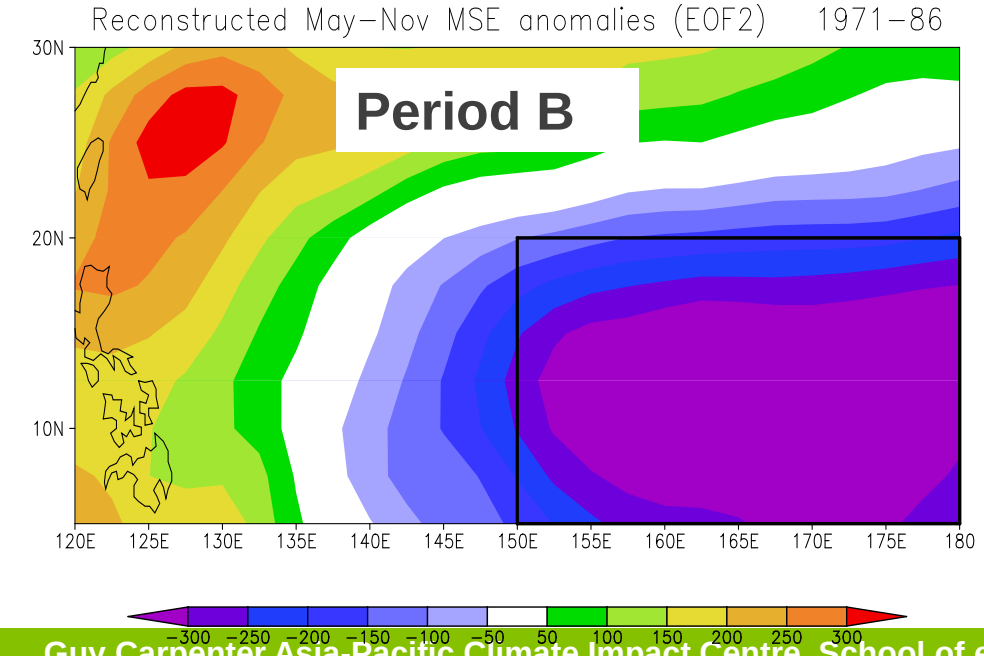




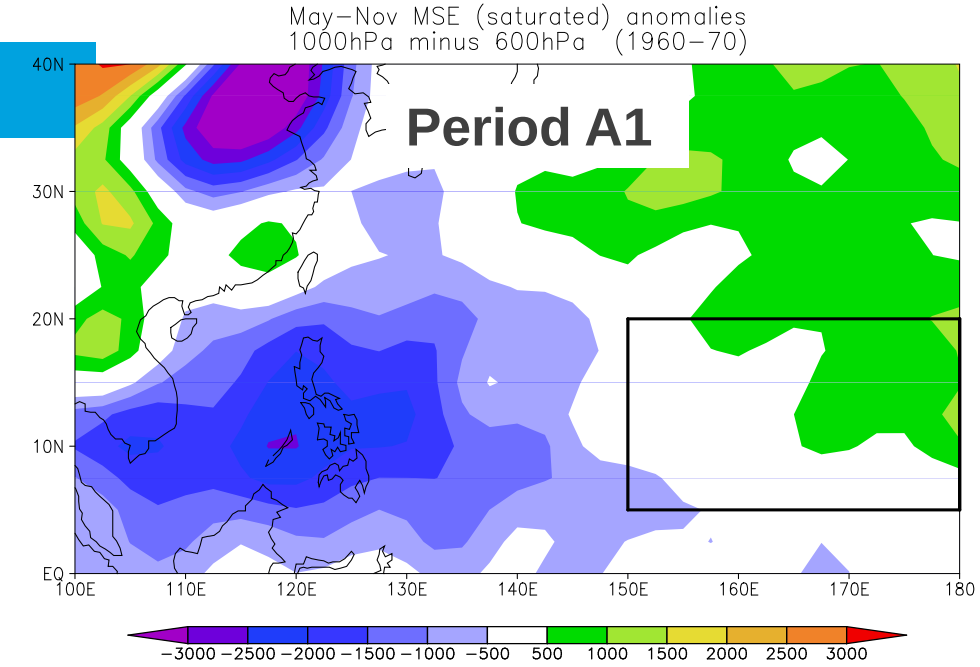
Sea-surface Temperature Anomalies

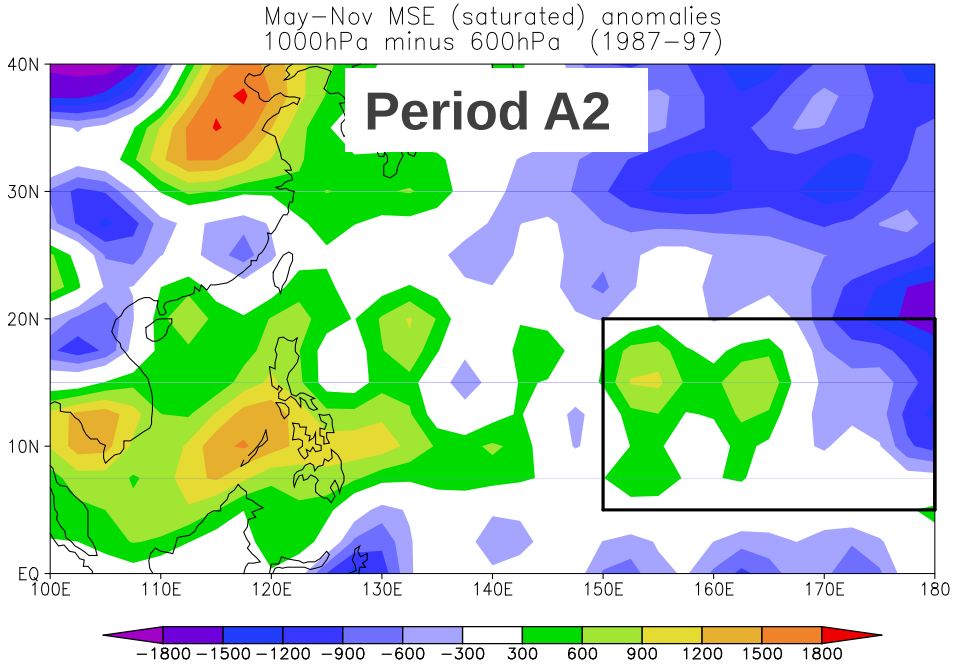


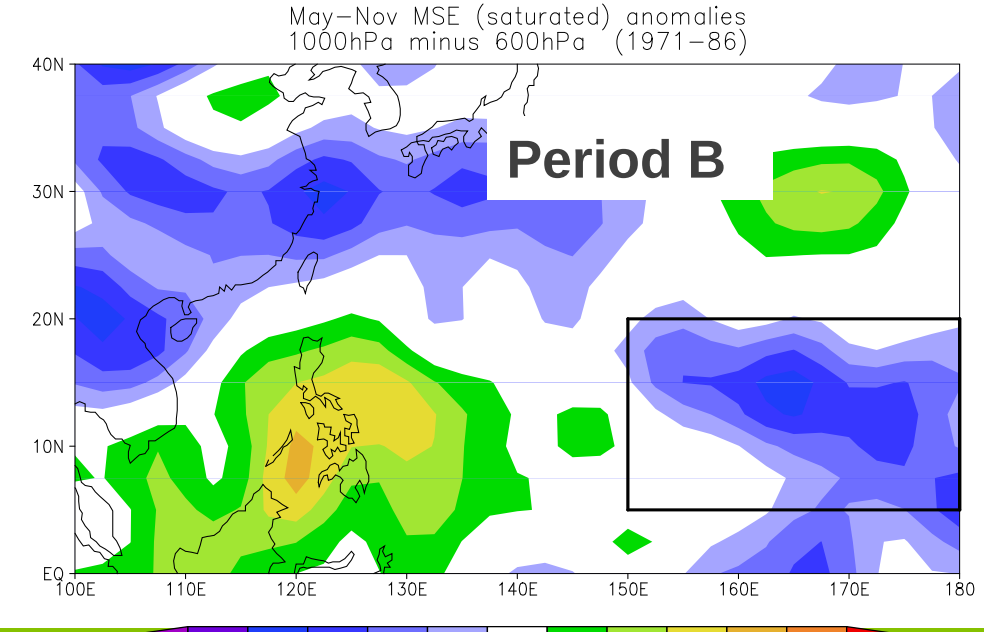




Reconstructed Moist Static Energy (EOF2)

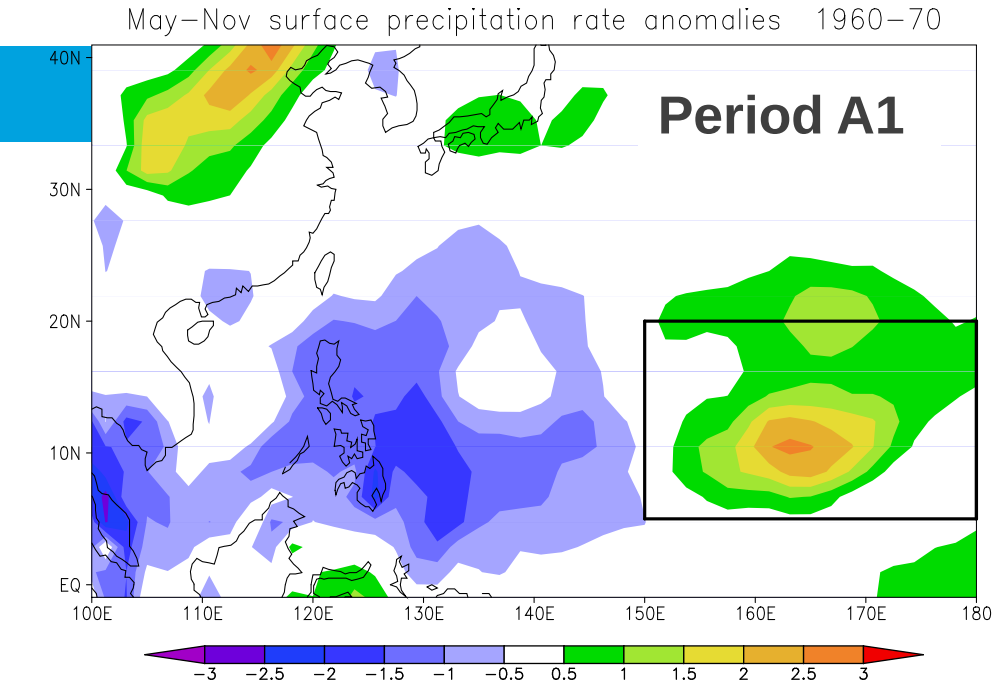


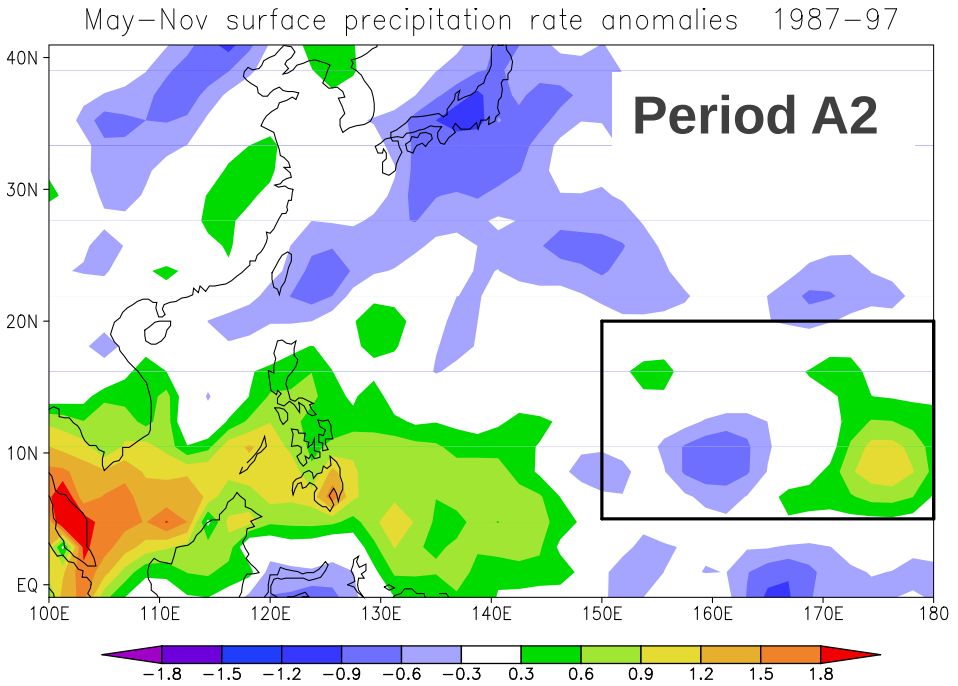


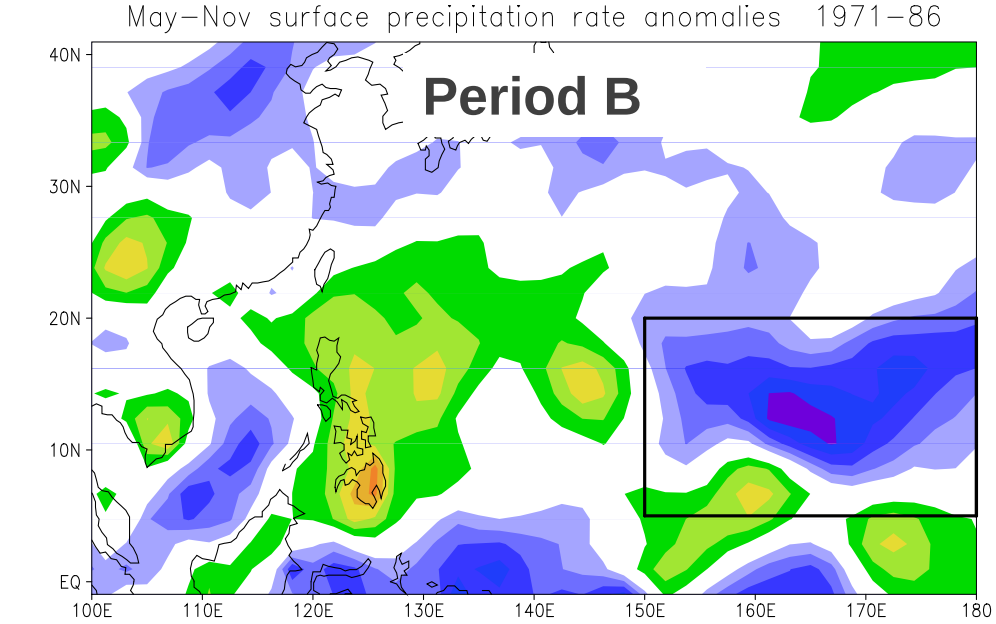


Vertical Gradient of Saturated Moist Static Energy

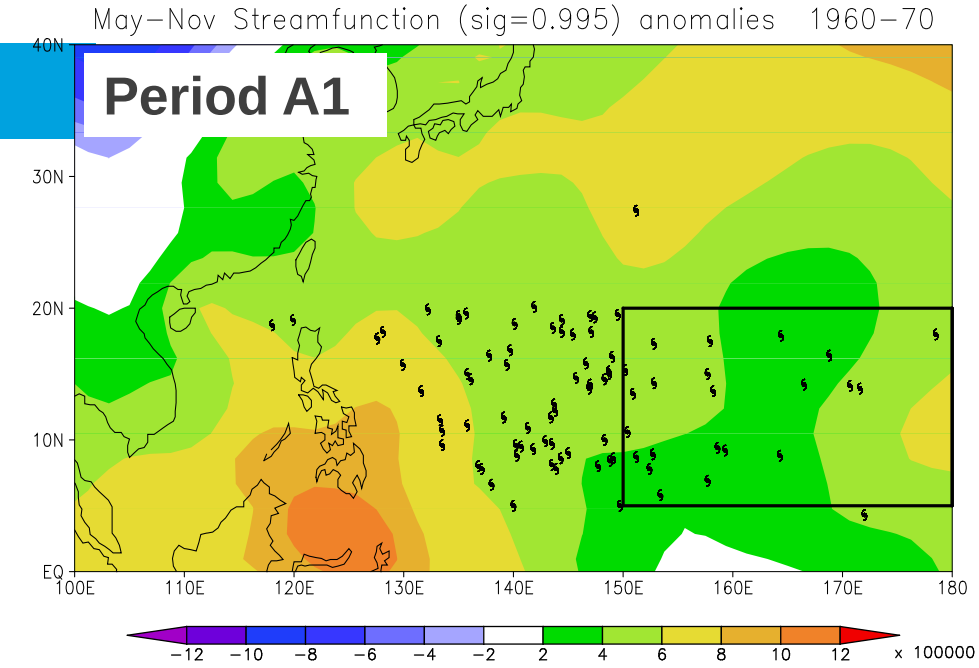
(1000 minus 600 hPa)

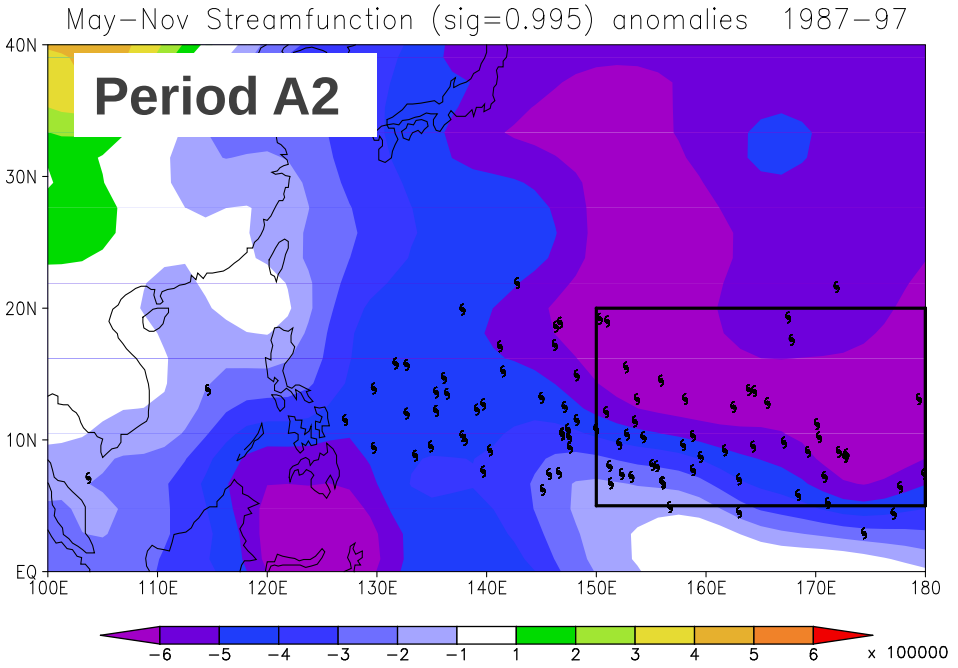


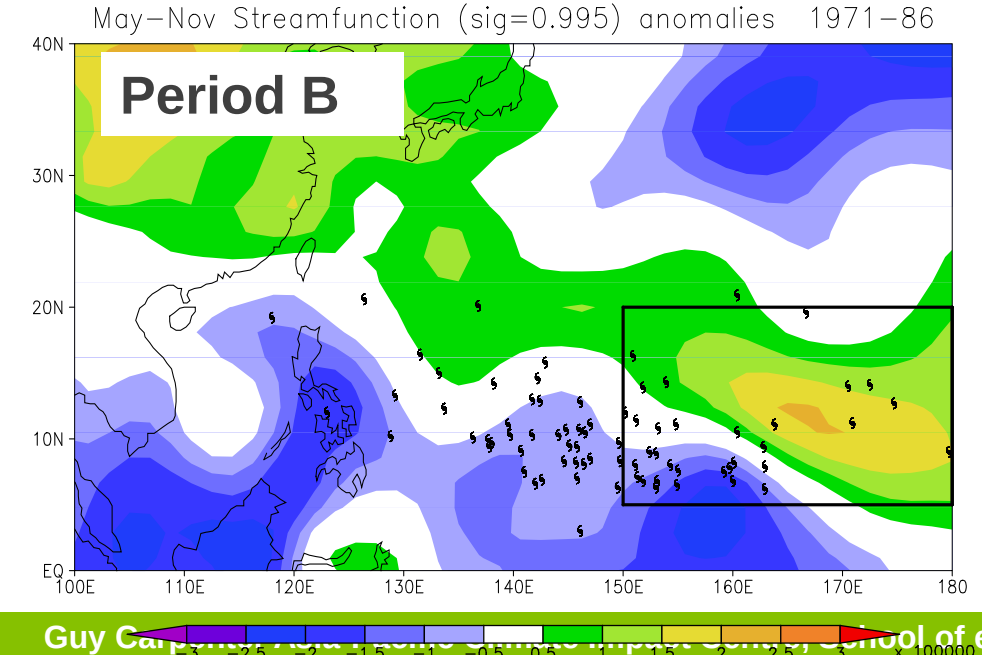




Precipitation Rate Anomalies



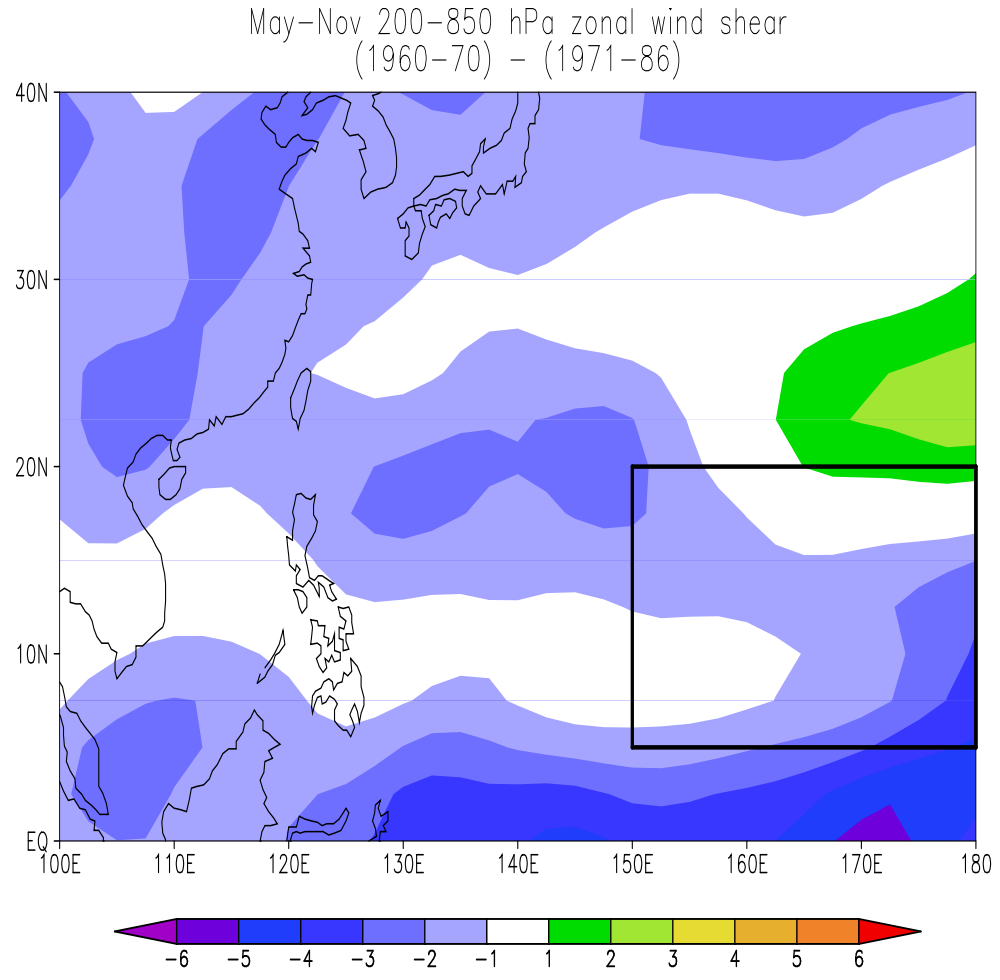




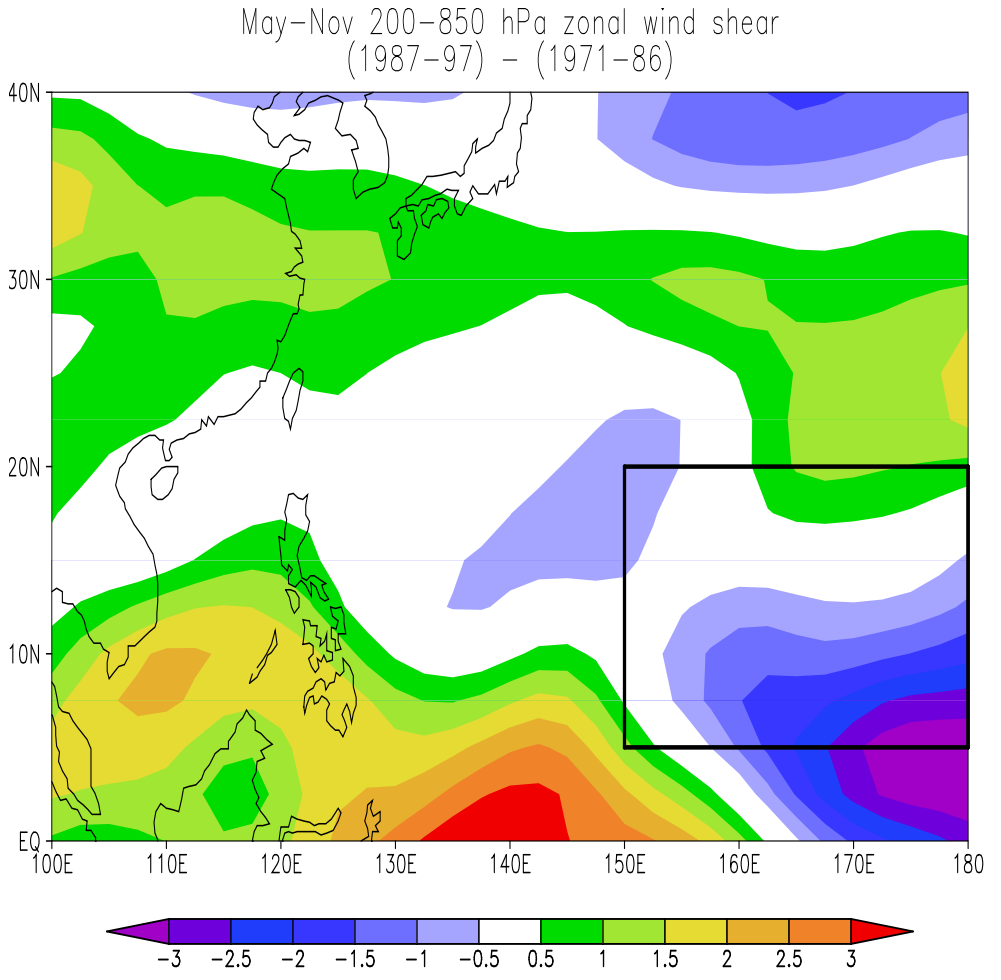
Lower Tropospheric Streamfunction Anomalies

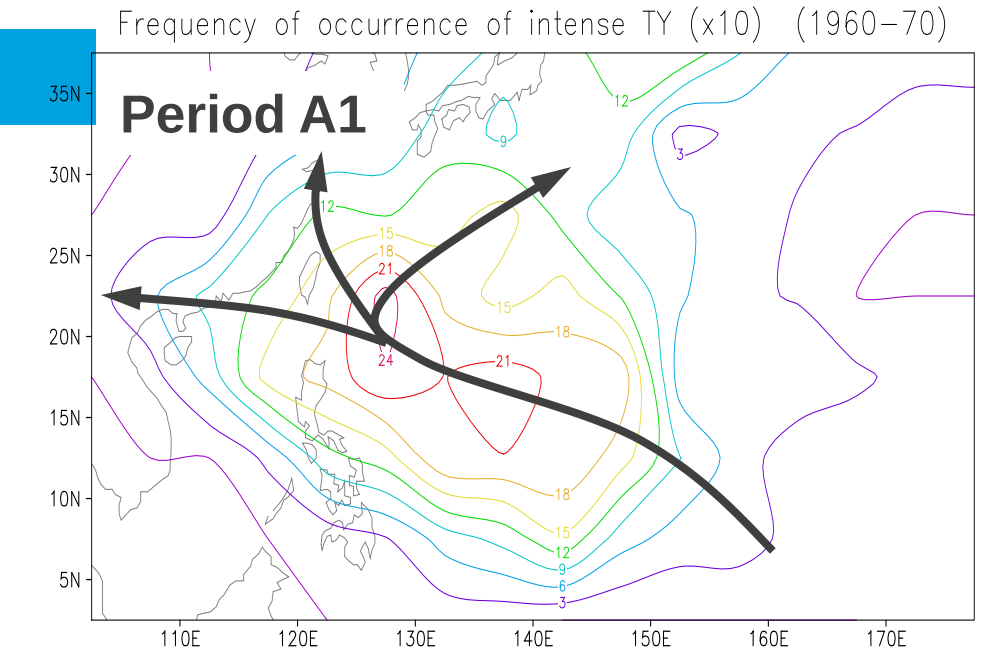
200-hPa minus 850-hPa Zonal Wind Shear

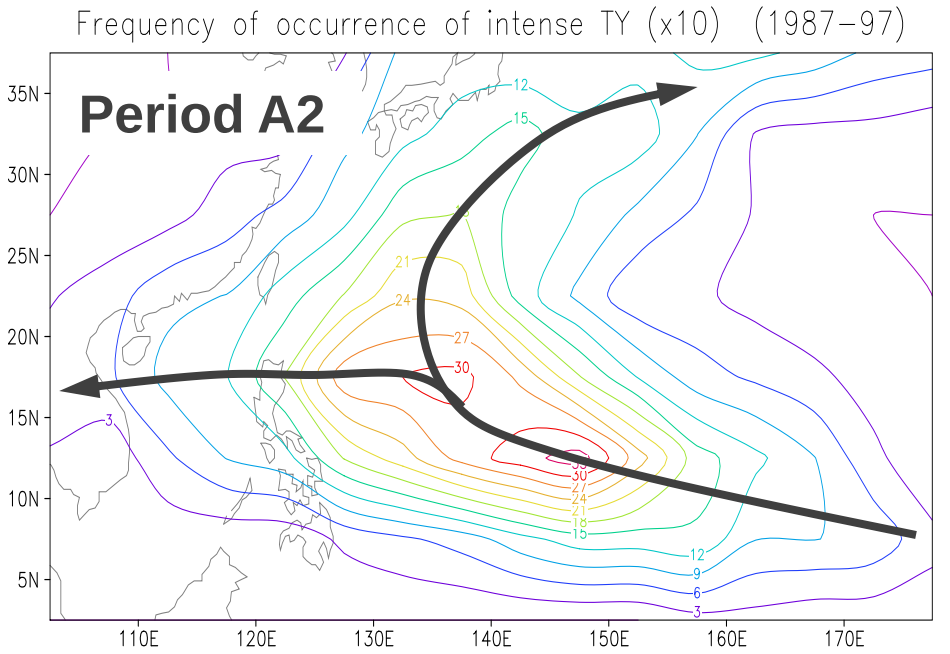
Period A1 minus Period B

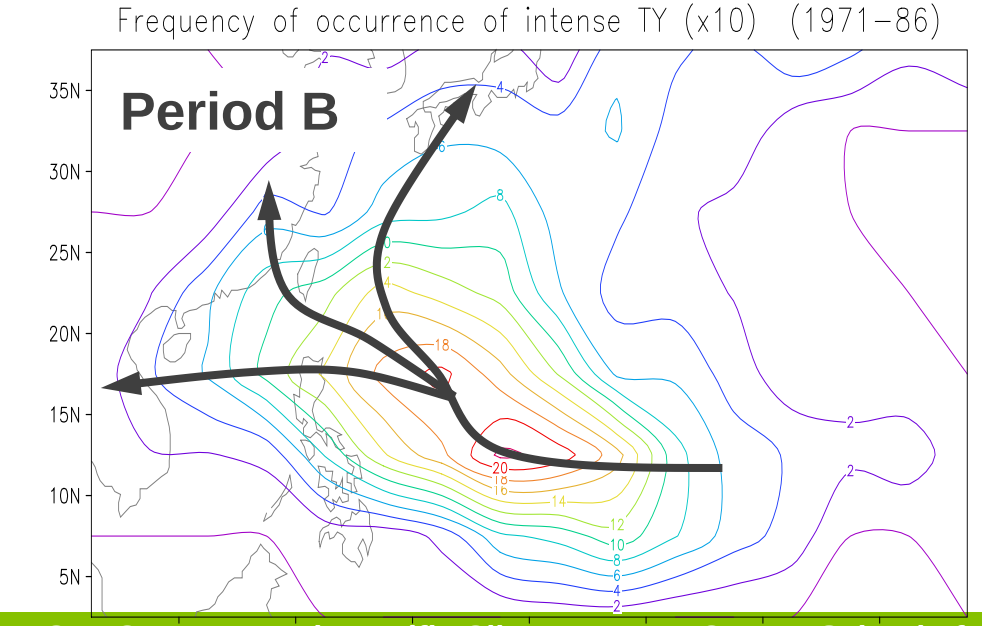


Period A2 minus Period B





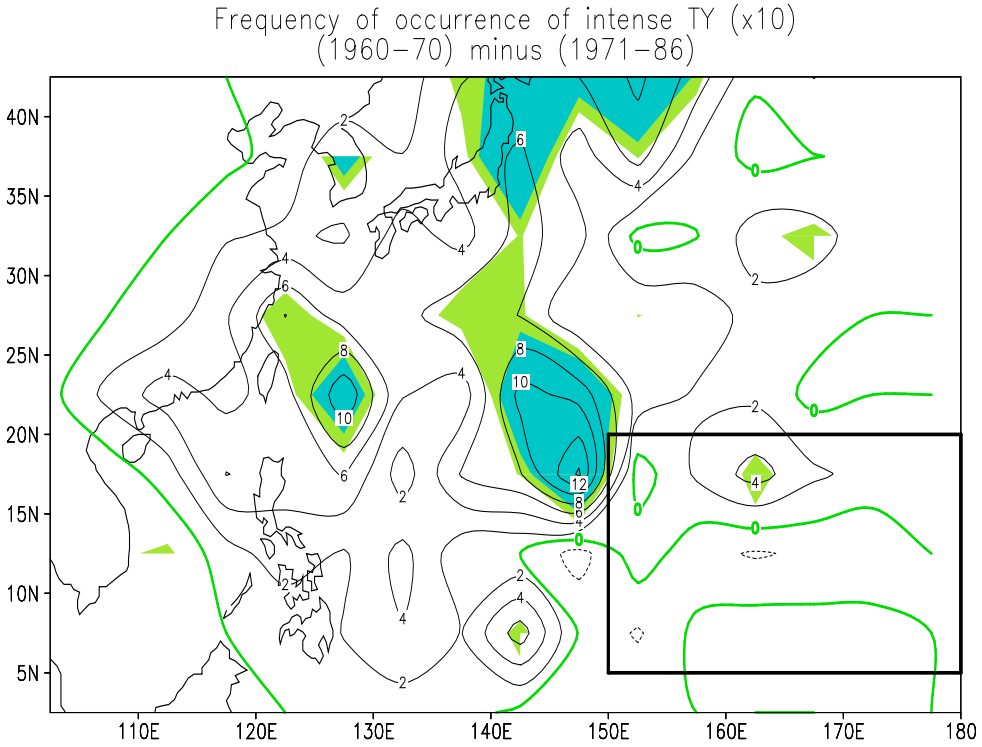




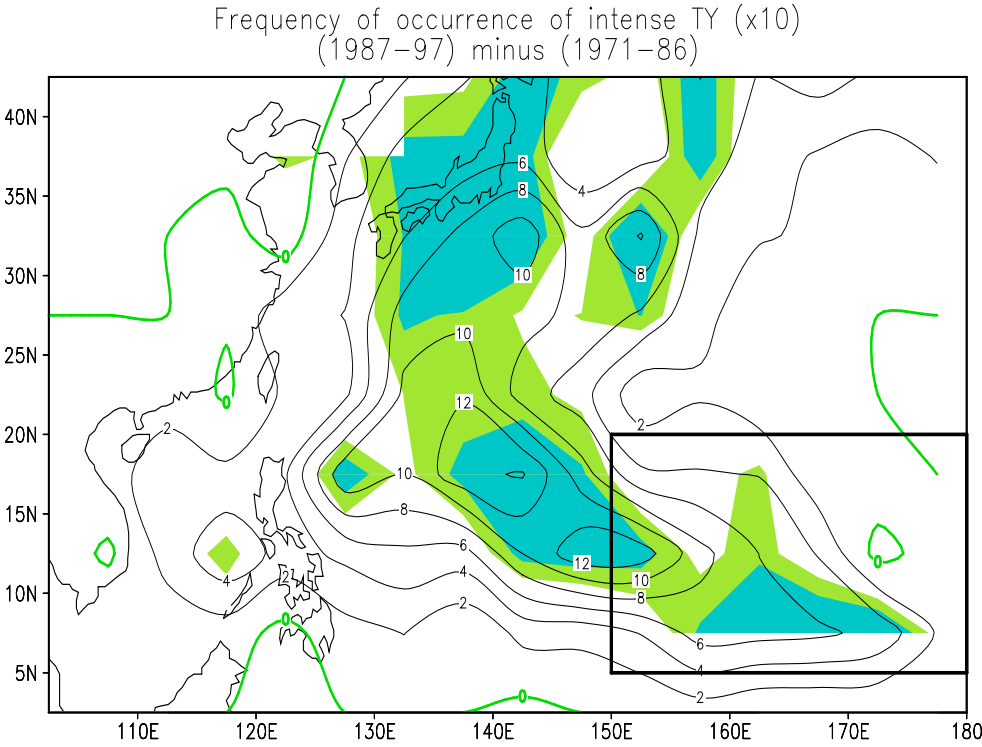
Frequency of Occurrence of Intense Typhoons

Difference in the Frequency of Occurrence of Intense Typhoons

Period A1 minus Period B

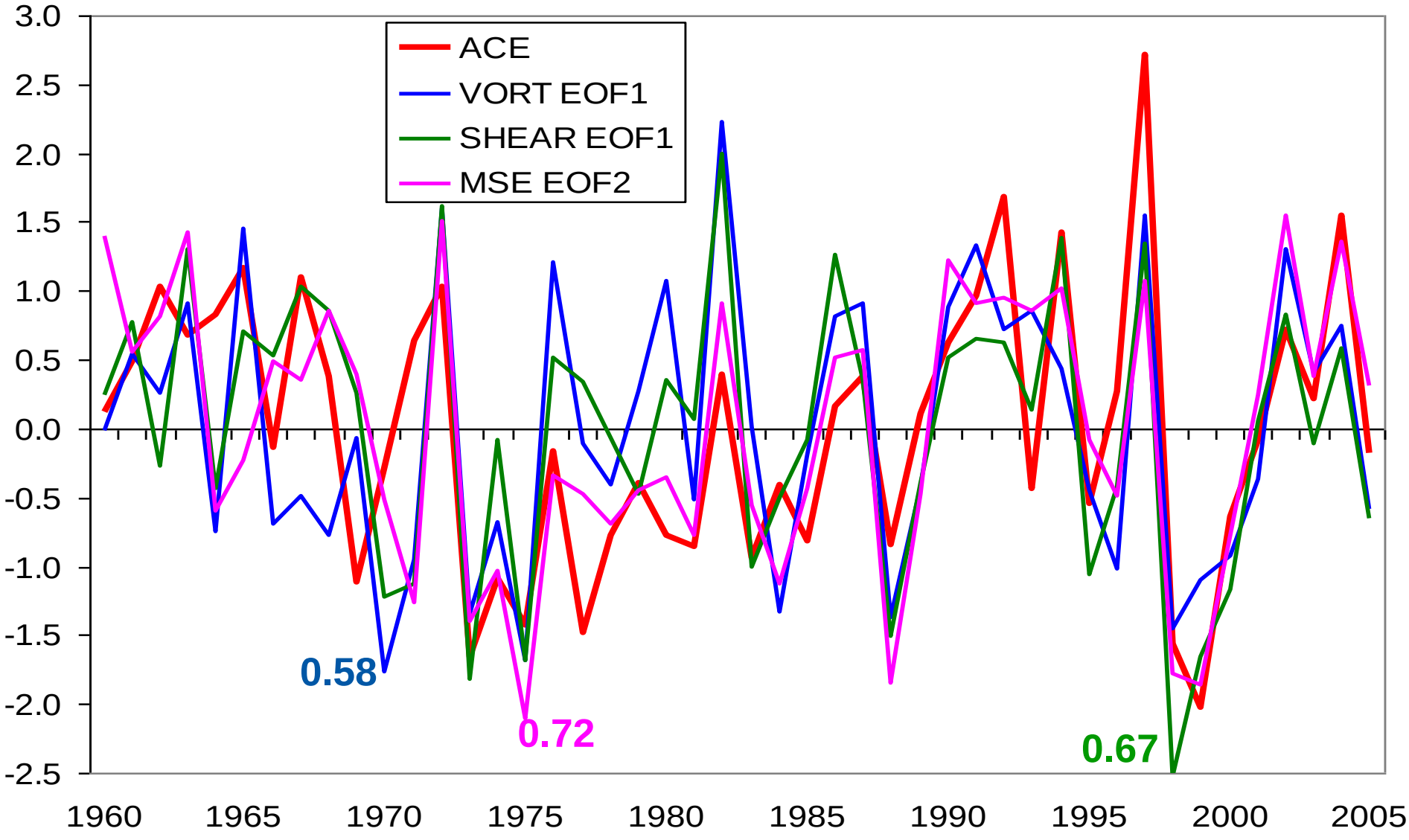


Period A2 minus Period B

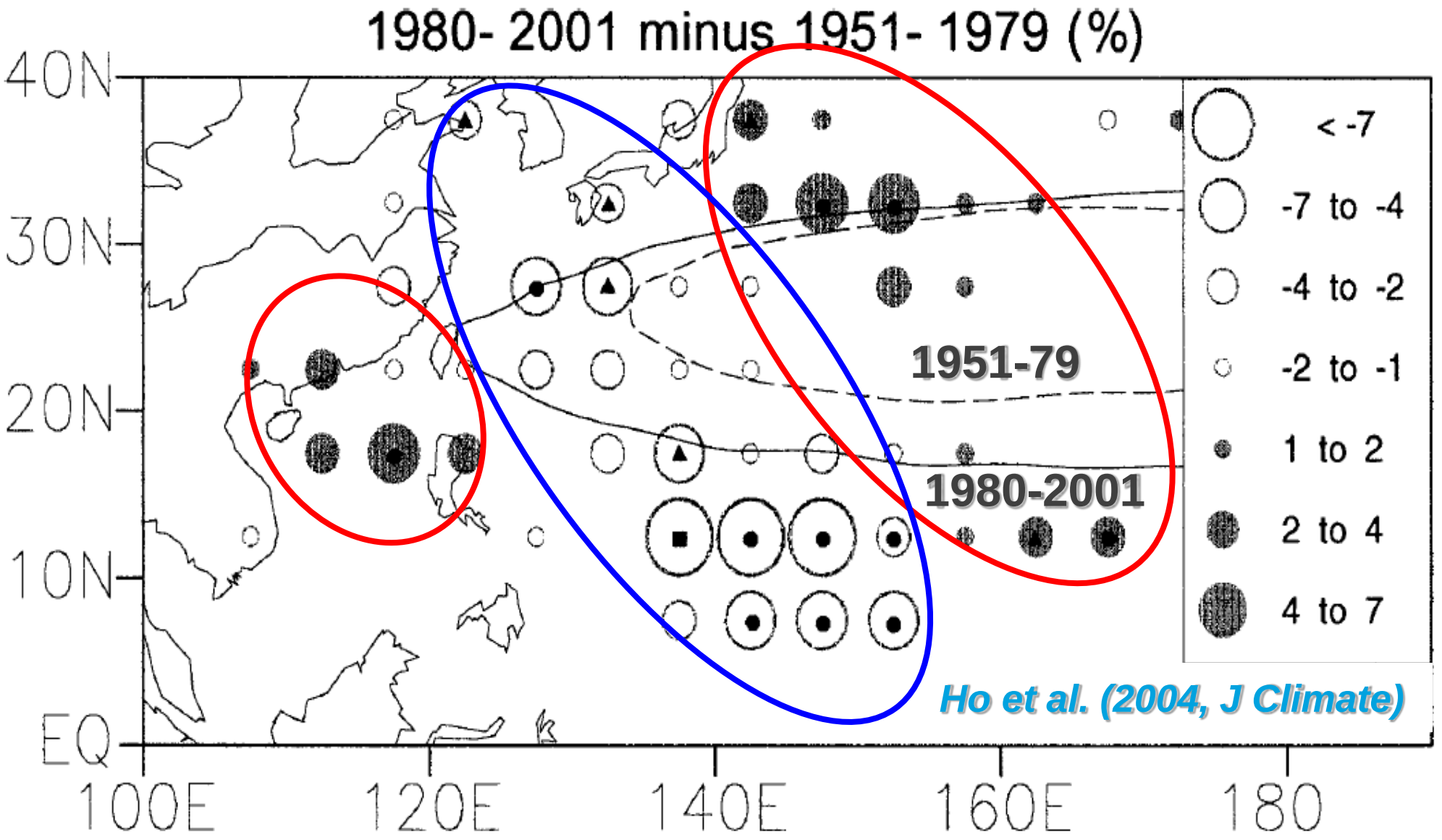


Blue shading: 95% Green shading: 90%

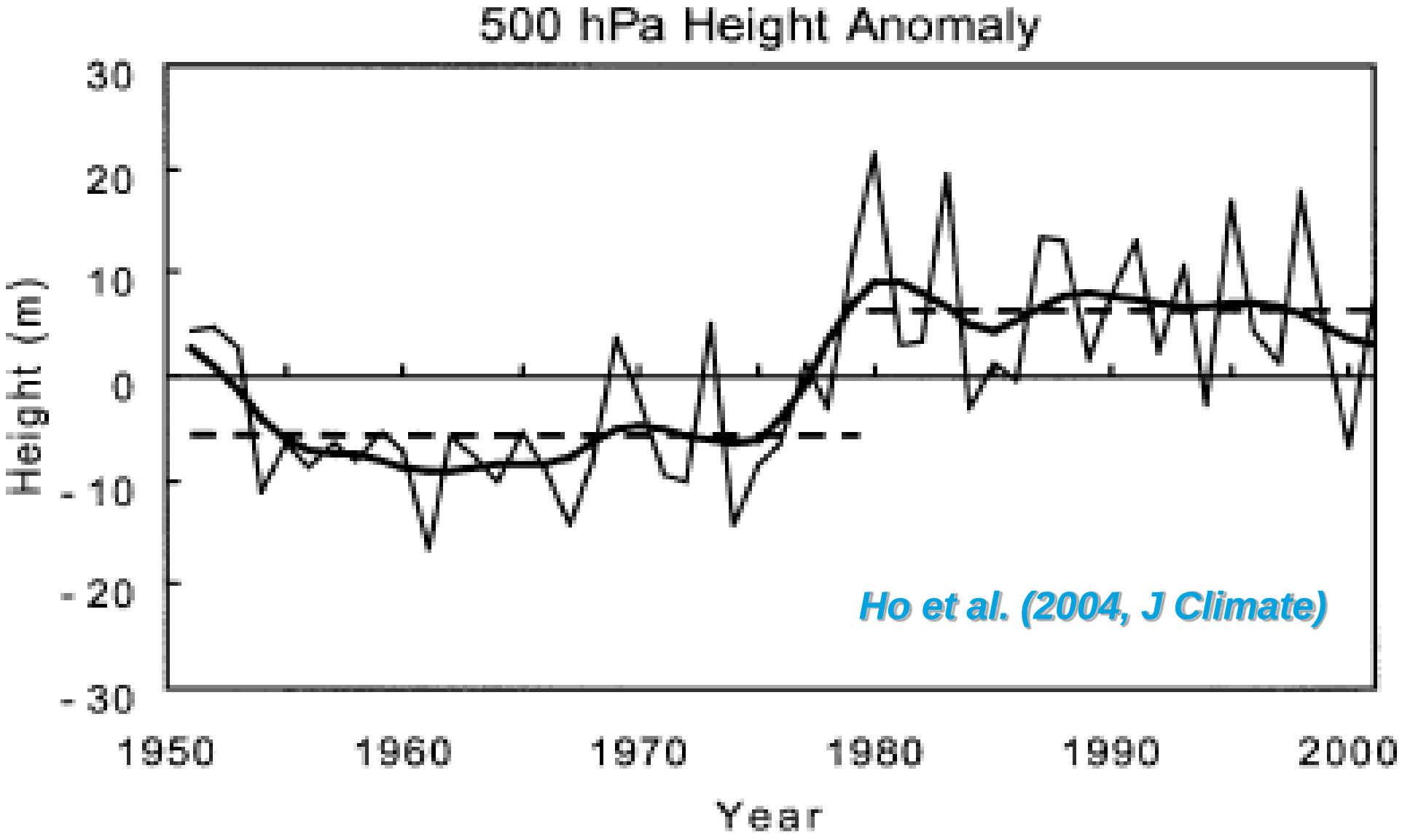
ACE vs. VORT, SHEAR and MSE



Difference in Typhoon Passage Frequency (JJAS)

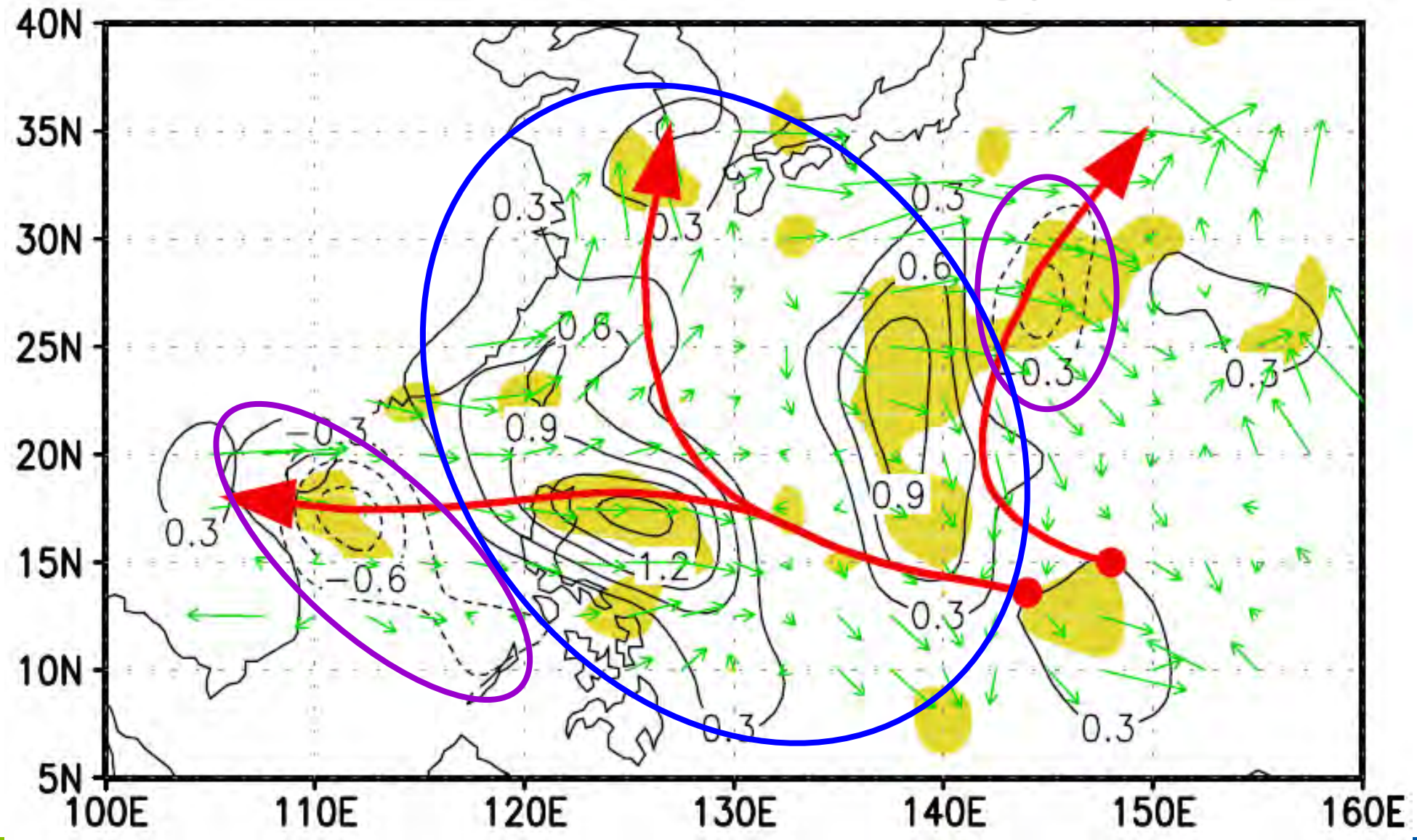


JJAS 500-hPa Height Anomaly (20-25ºN, 125-140ºE)



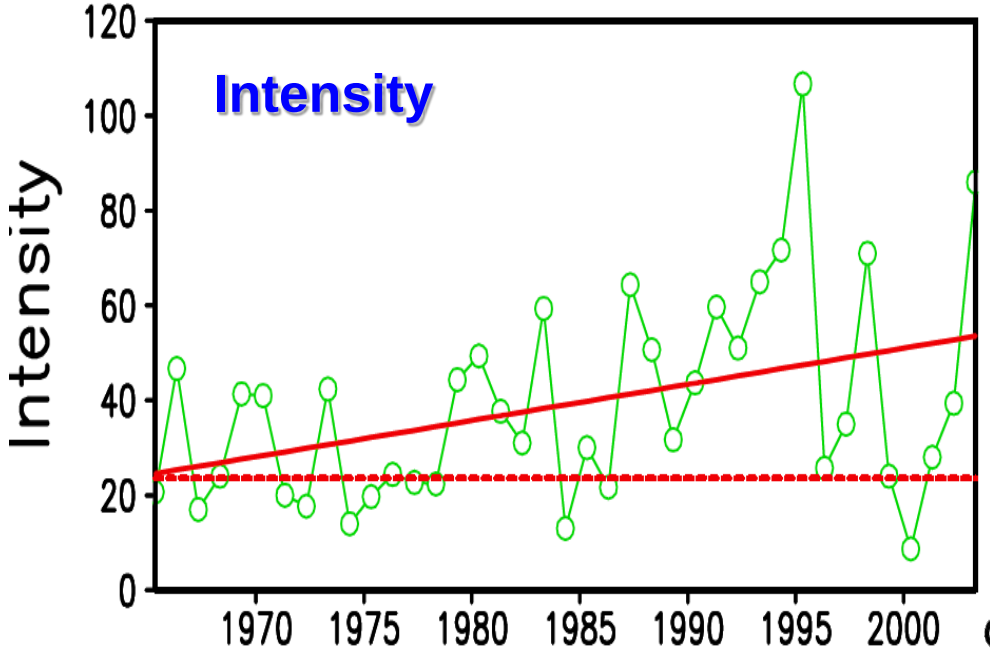
Difference in Typhoon Passage Frequency (JJASO) 1965-83 minus 1984-2003

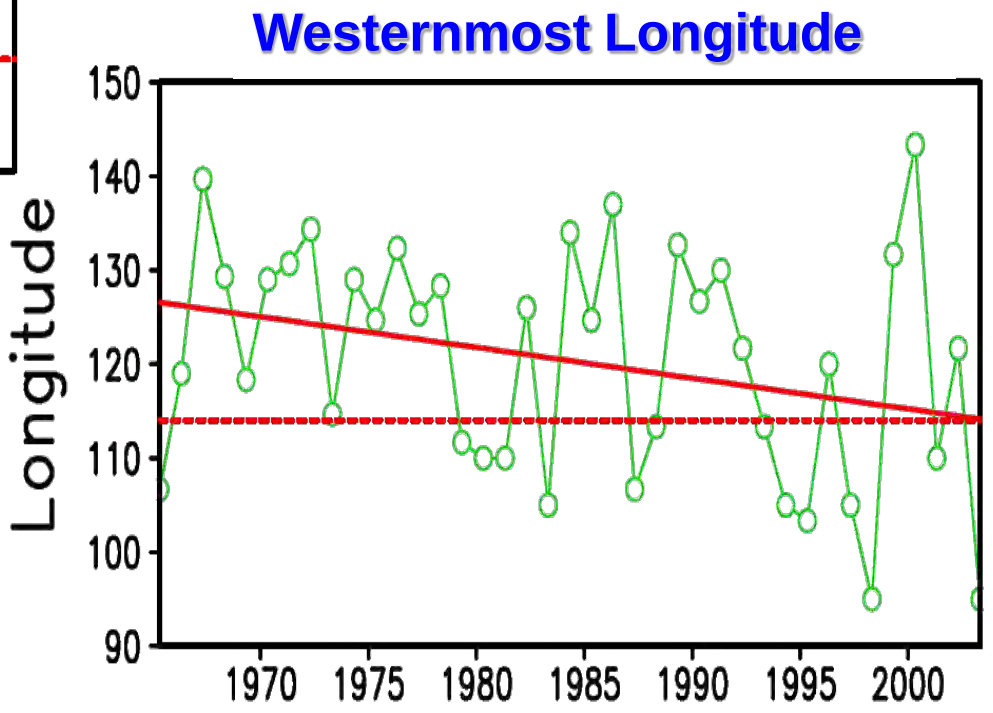
Wu and Wang (2005, GRL)



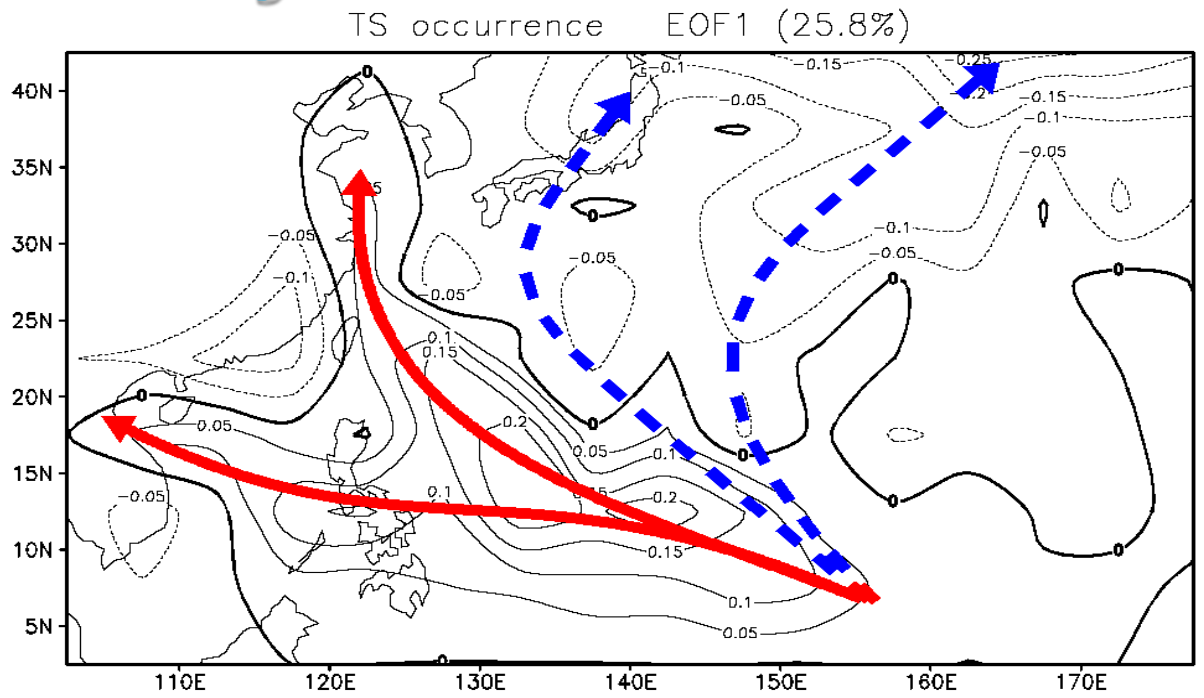
JJAS Subtropical High Intensity and Westernmost Longitude

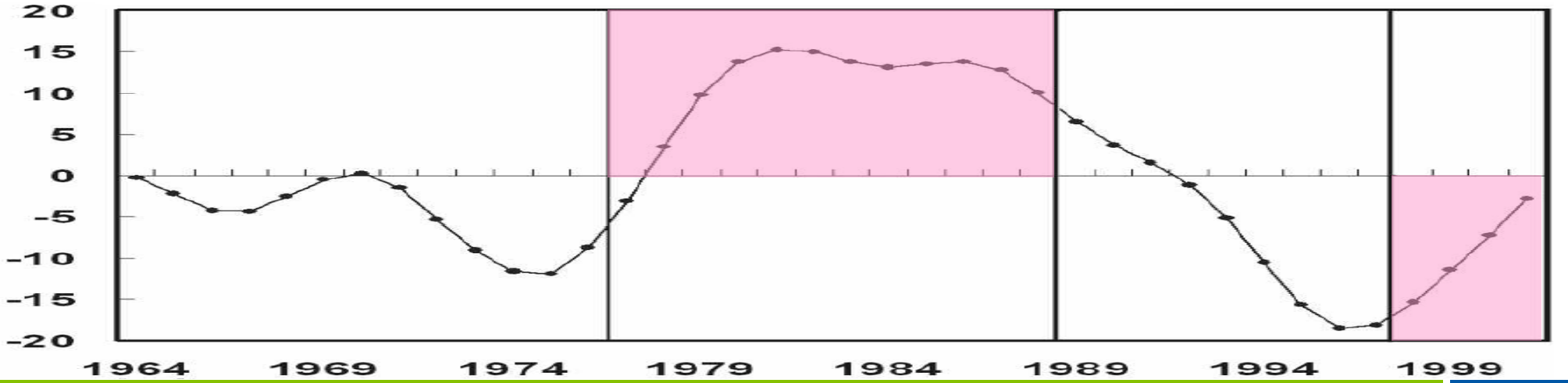
Wu and Wang (2005, GRL)



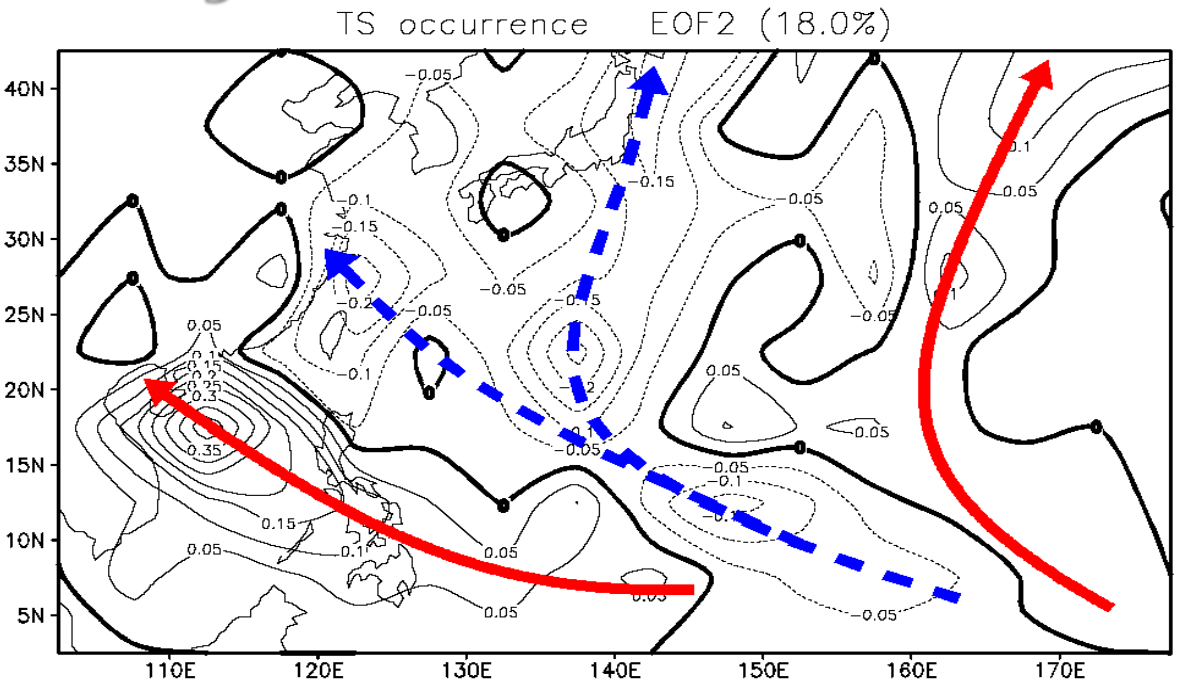


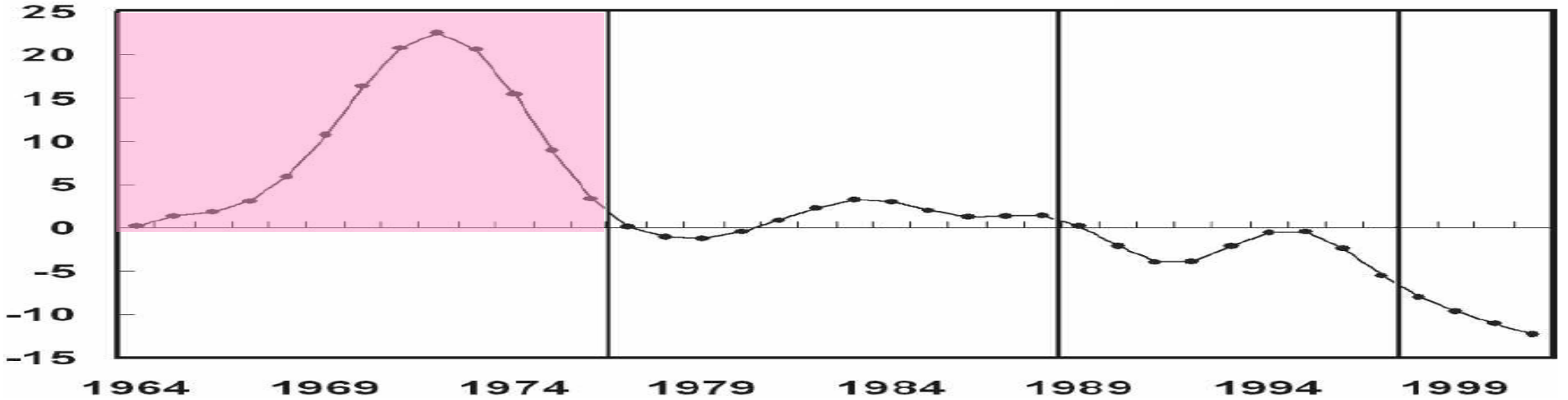
EOF1 of 10-year-filtered TC occurrence



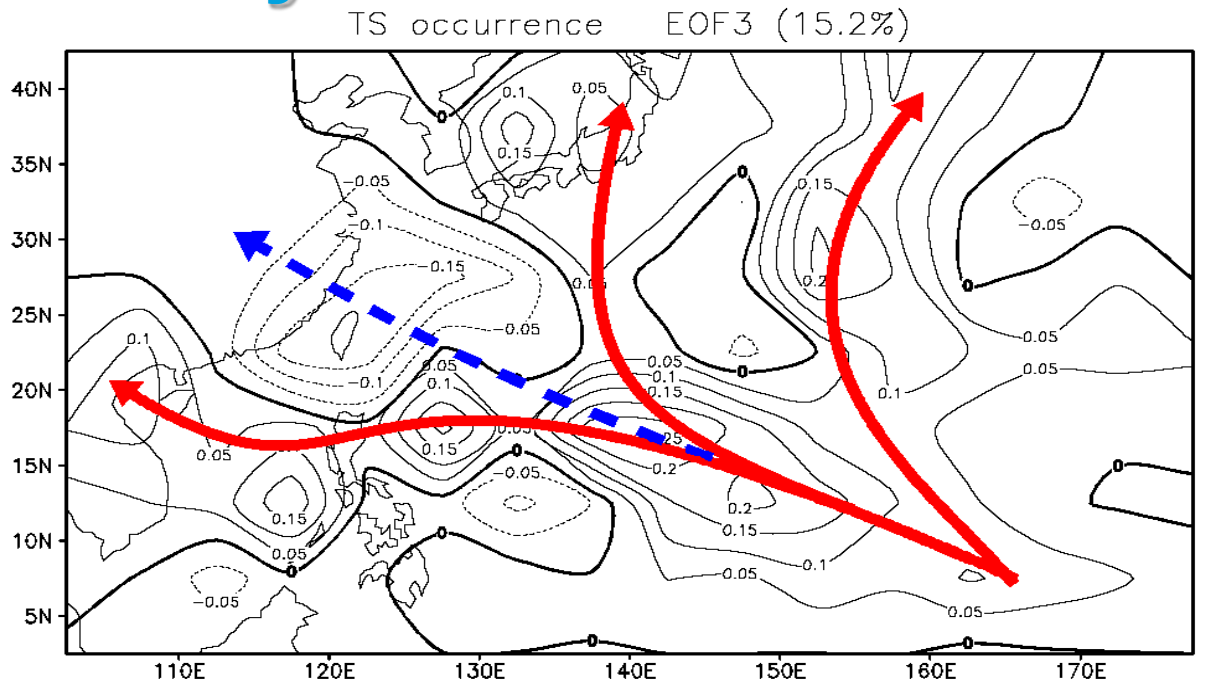


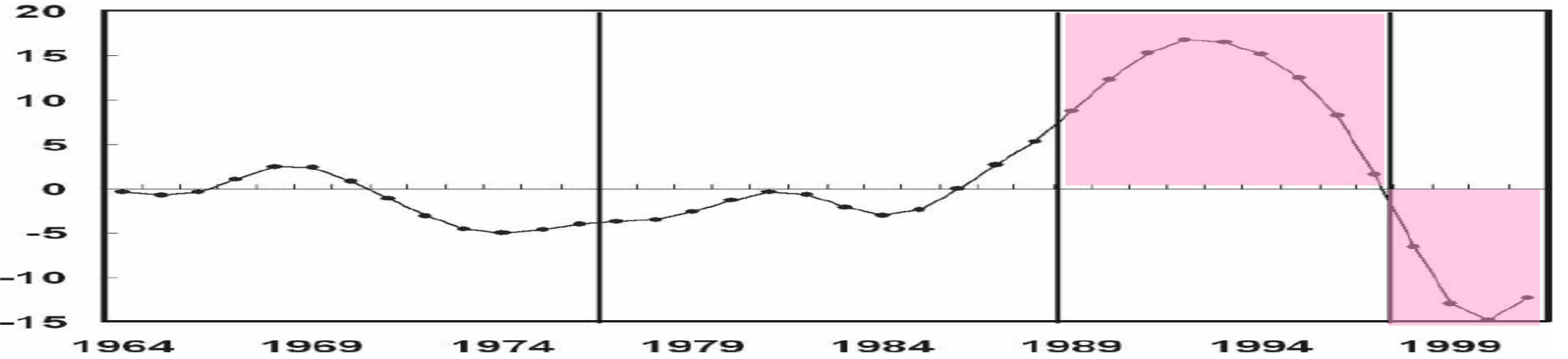
EOF2 of 10-year-filtered TC occurrence



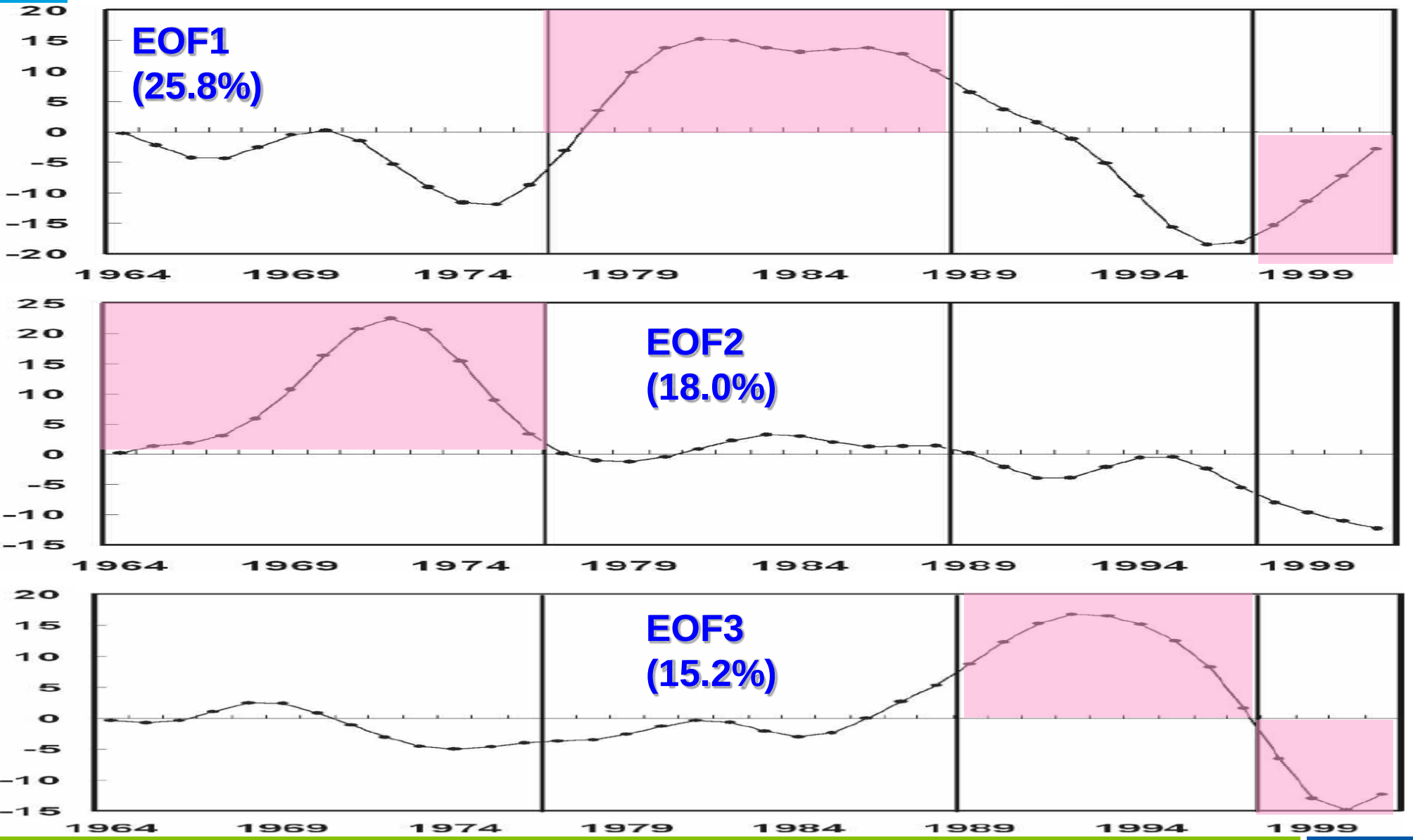


EOF3 of 10-year-filtered TC occurrence

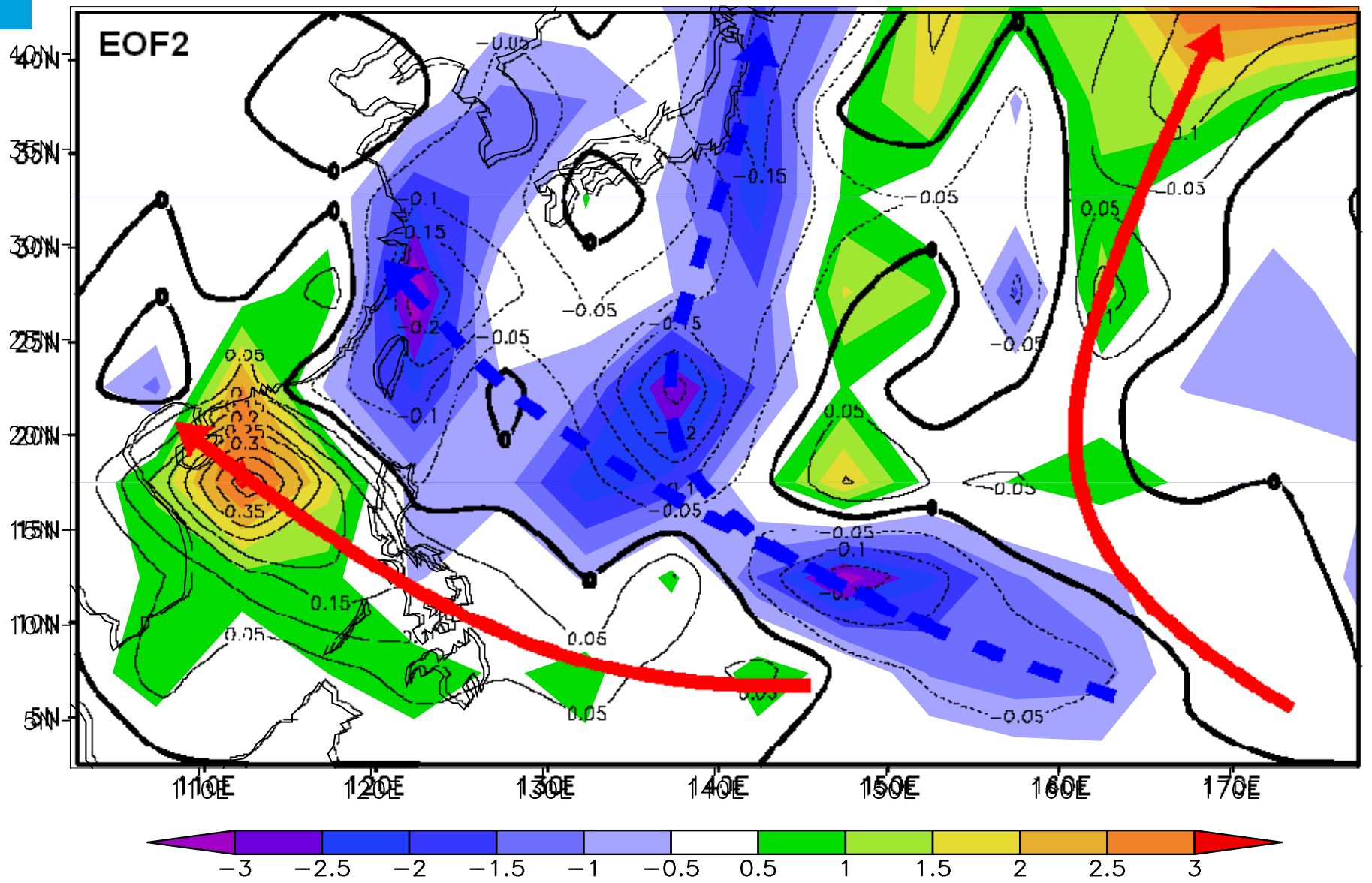




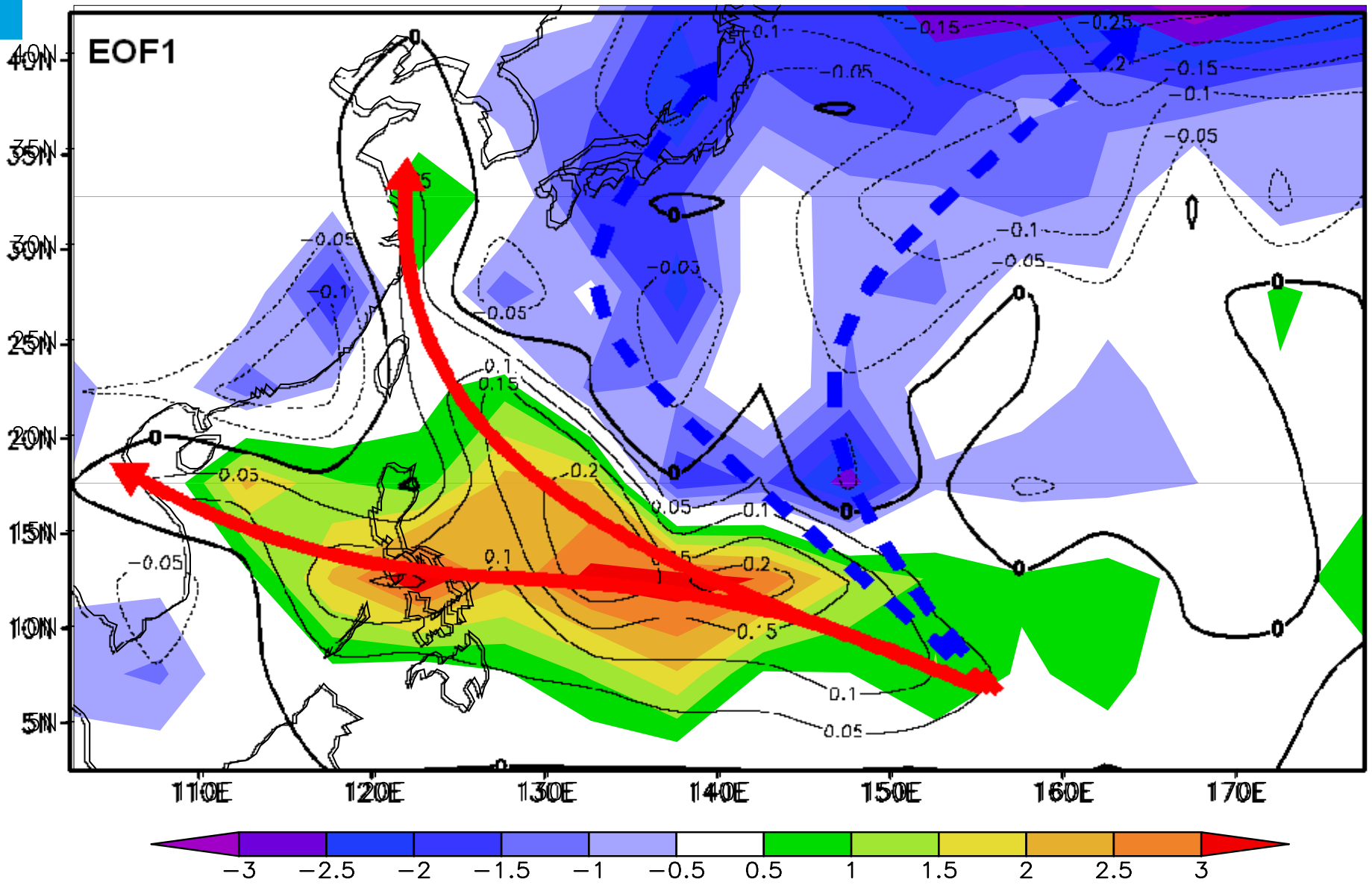
Time series of EOFs of 10-year-filtered TC occurrence



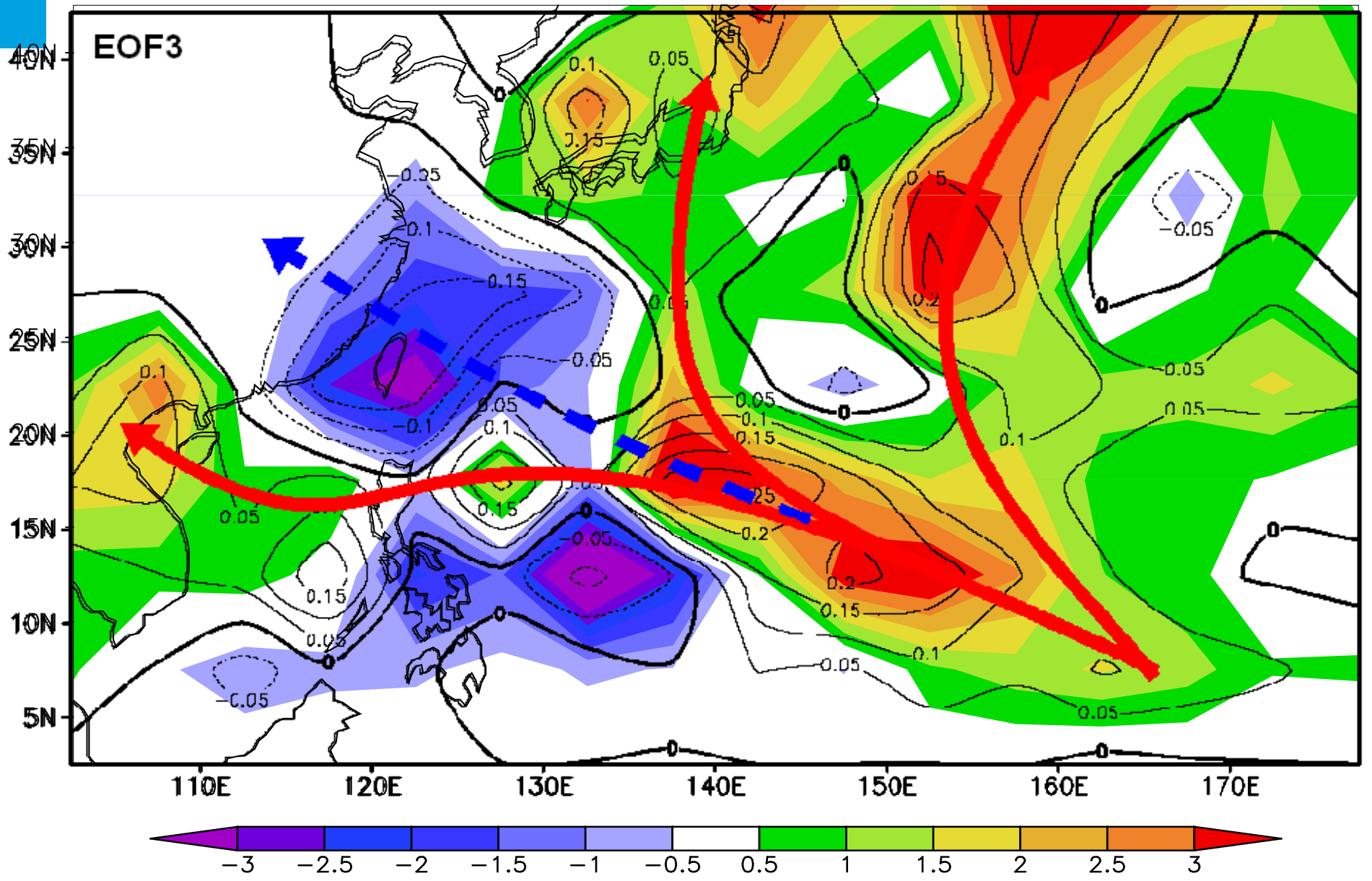
Anomalous TS occurrence (1964–76)

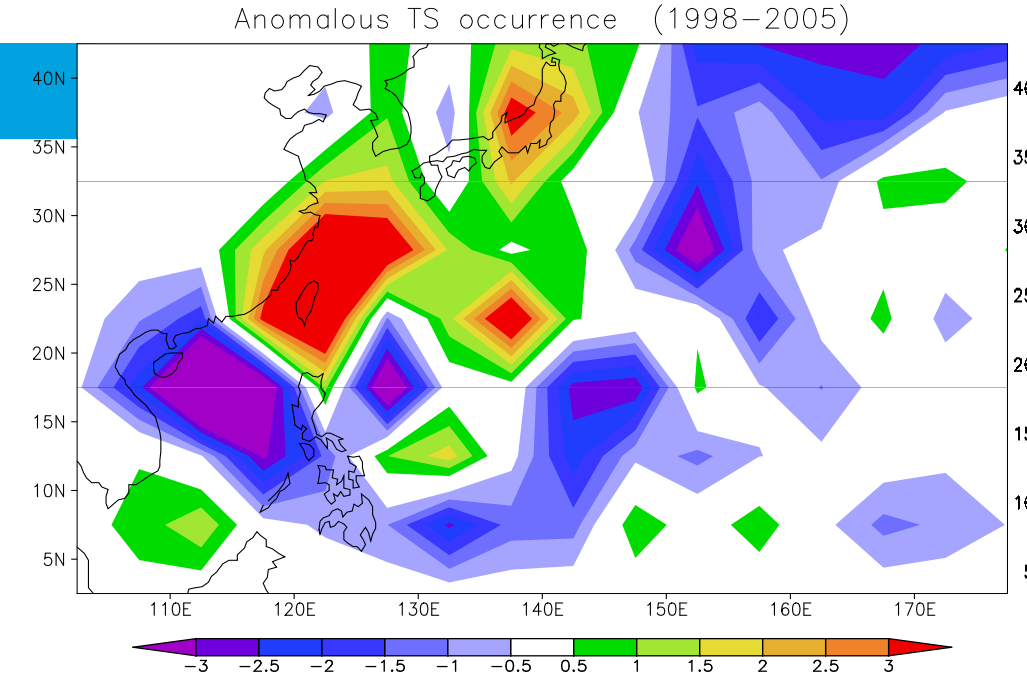


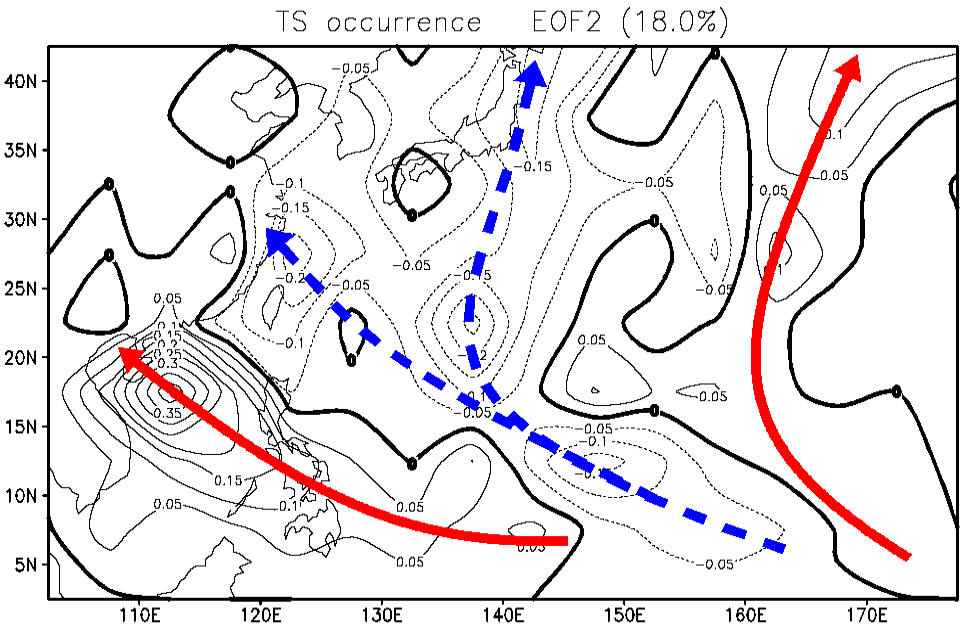
Anomalous TS occurrence (1977–88)

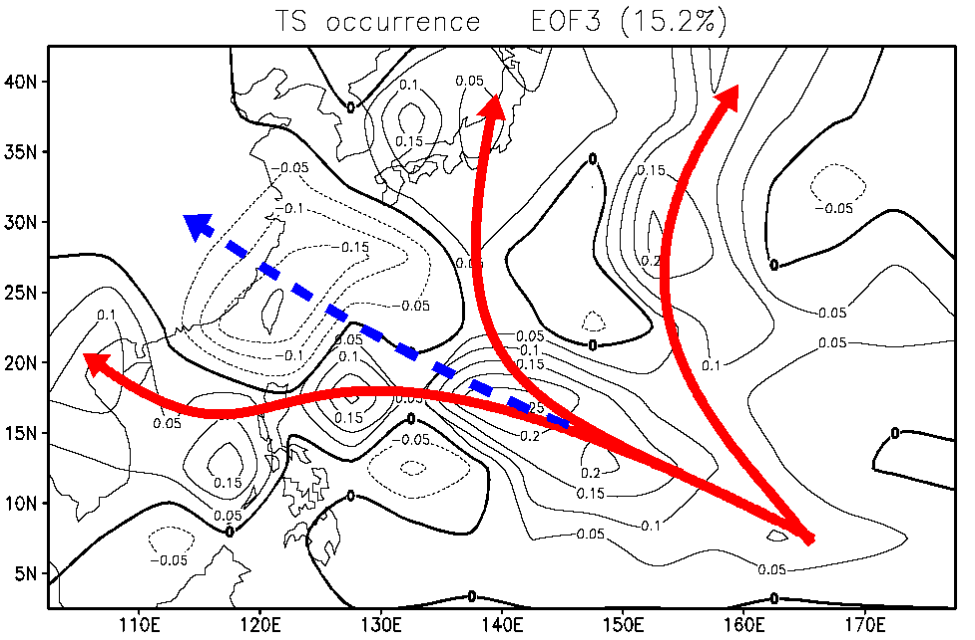


Anomalous TS occurrence (1989–97)

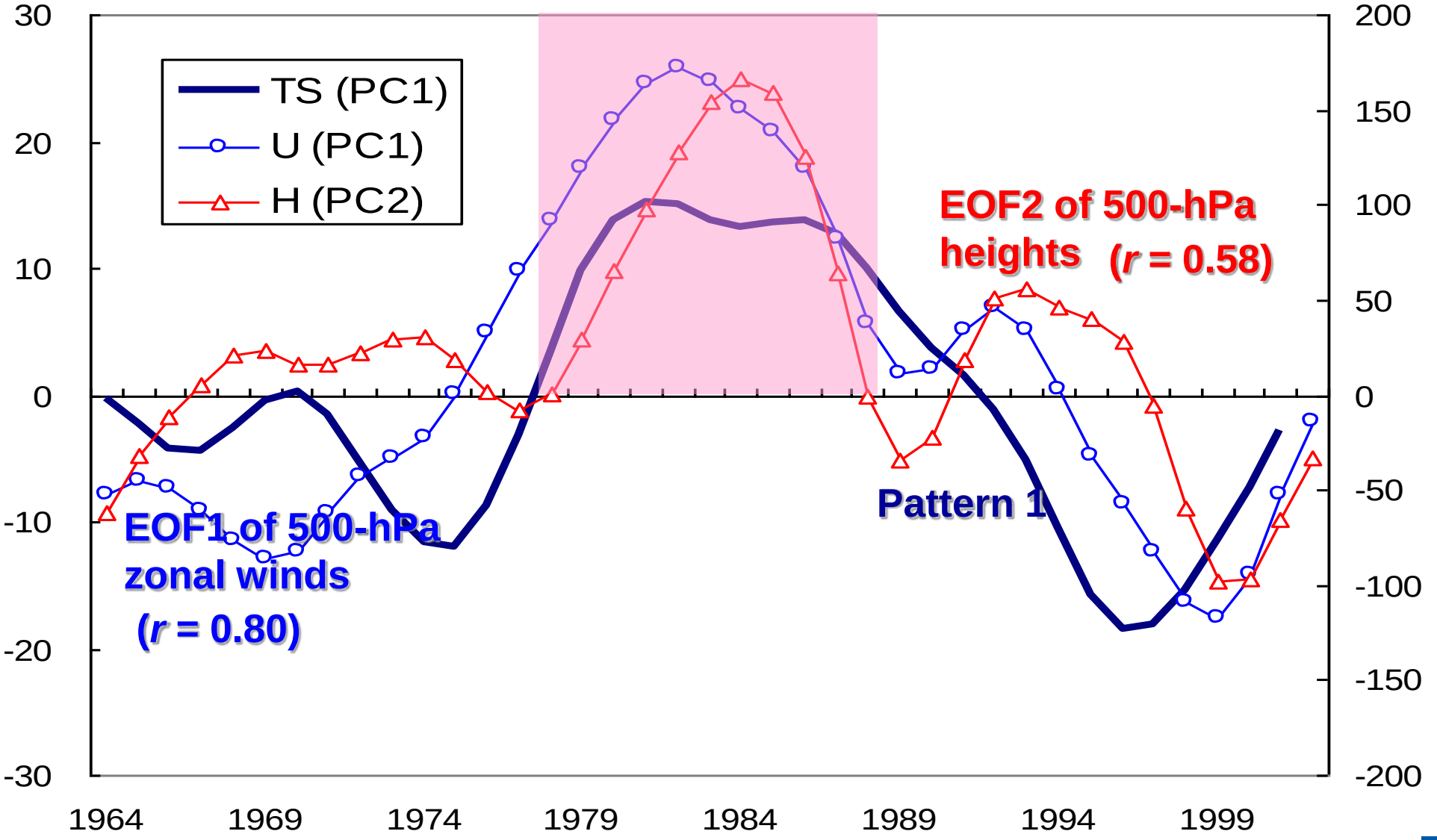



Anomalous TS occurrence (1998–2005)
40N
35N
30N
25N
20N
15N
10N
5N
110E
120E
130E
140E
150E
160E
170E
−3 −2.5 −2 −1.5 −1 −0.5 0.5 1 1.5 2 2.5 3

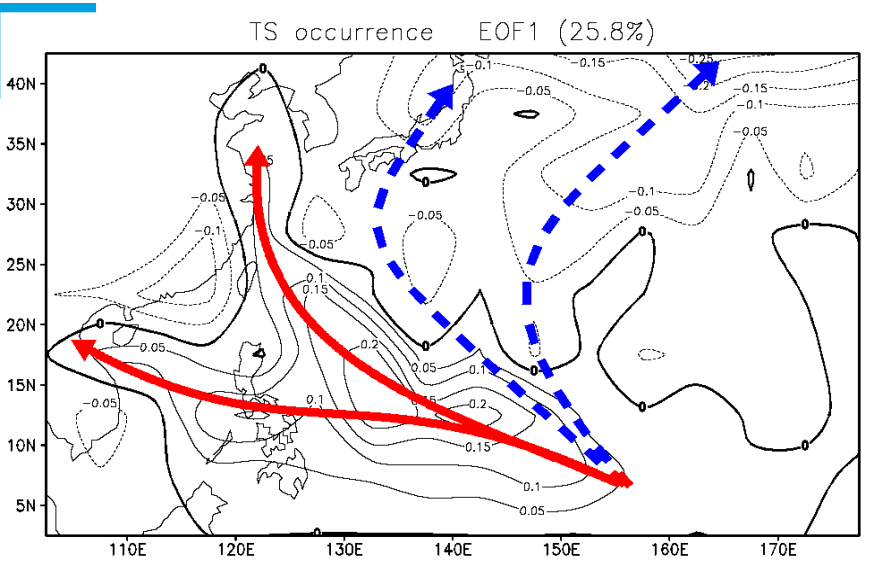

TS occurrence EOF2 (18.0%)
40N
35N
30N
25N
20N
15N
10N
5N
110E
120E
130E
140E
150E
160E
170E

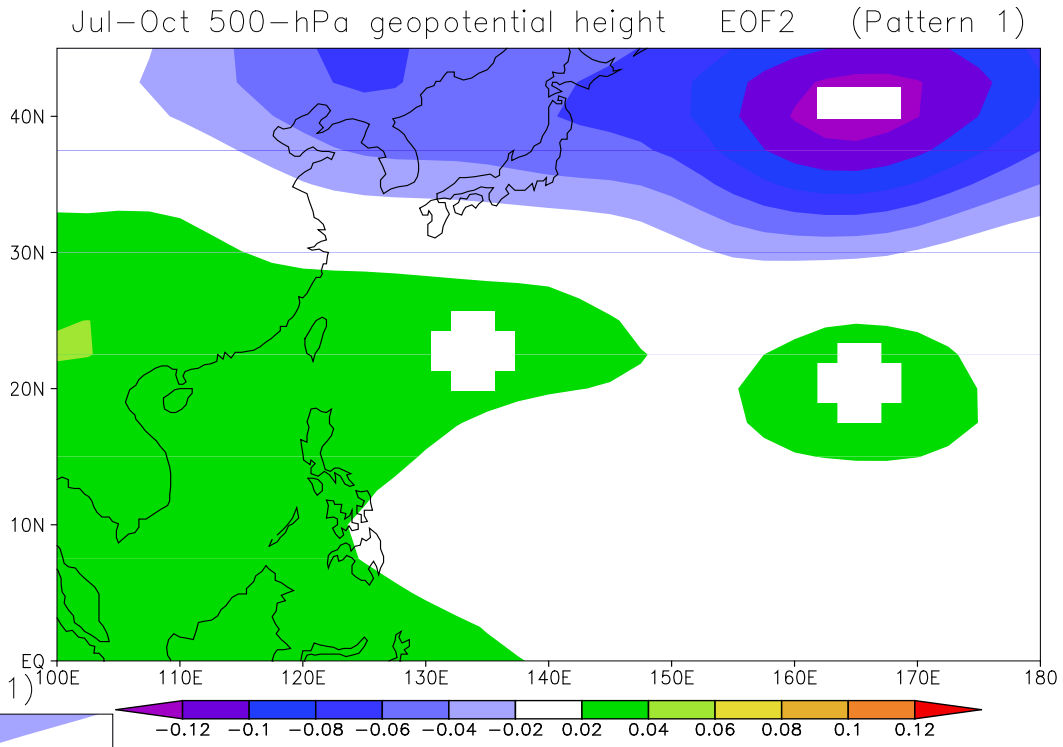

TS occurrence EOF3 (15.2%)
40N
35N
30N
25N
20N
15N
10N
5N
110E
120E
130E
140E
150E
160E
170E

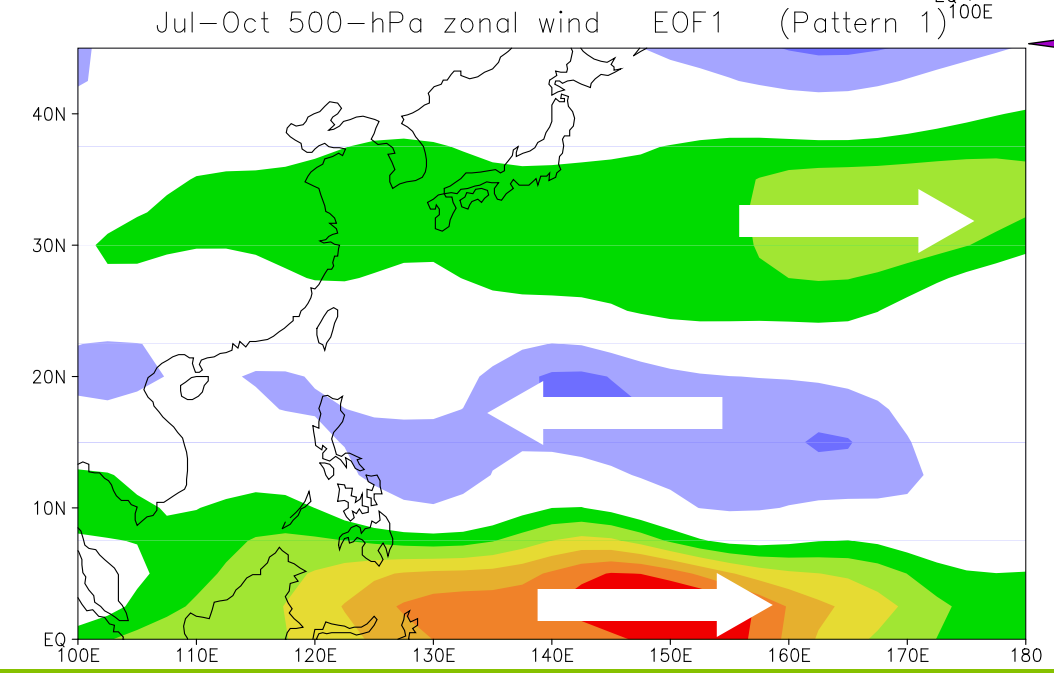
Time series of EOFs of 10-year-filtered 500-hPa Heights and Zonal Winds



1977-88 Pattern 1



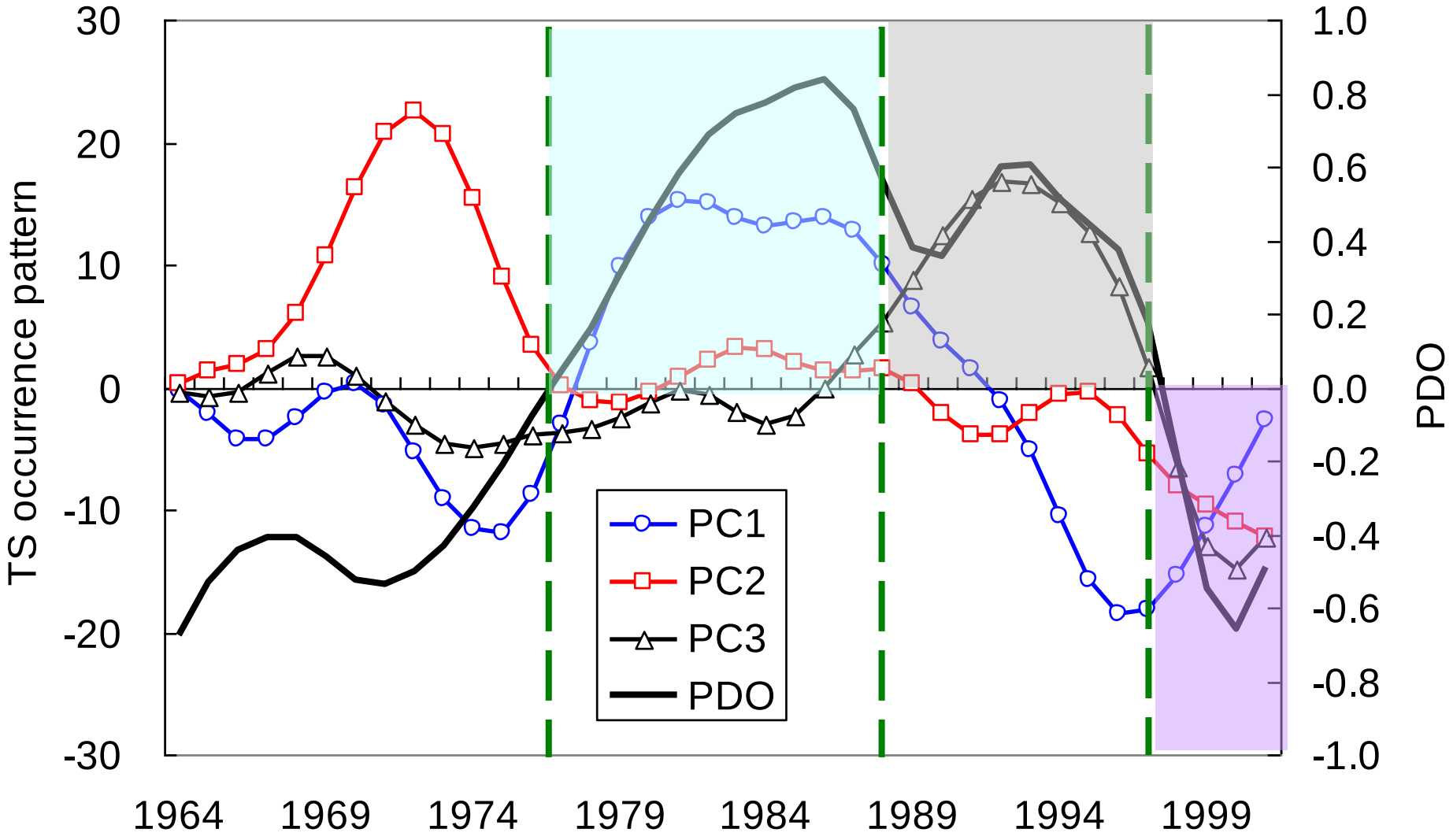




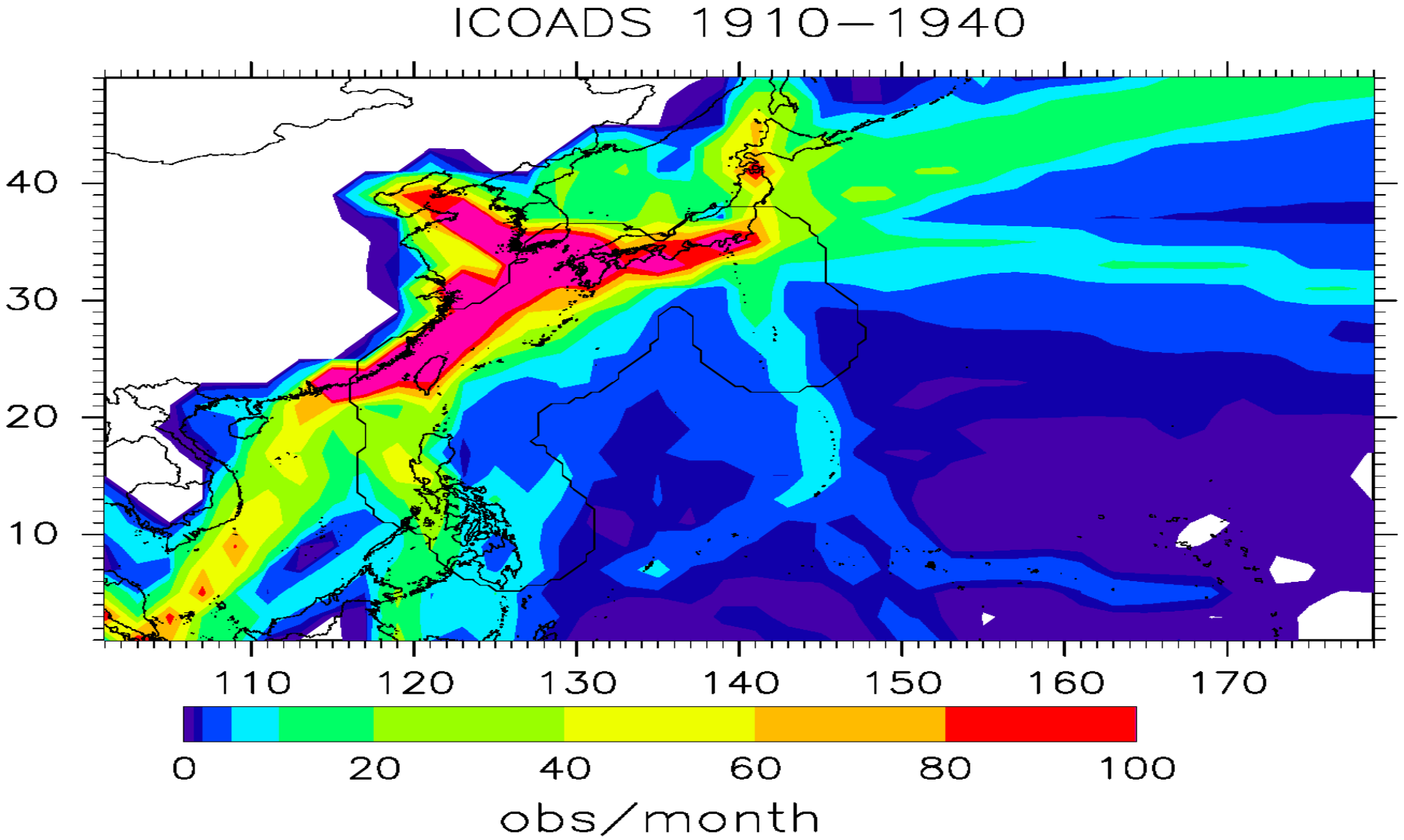
EOF2 of 500-hPa Heights

EOF1 of 500-hPa zonal winds

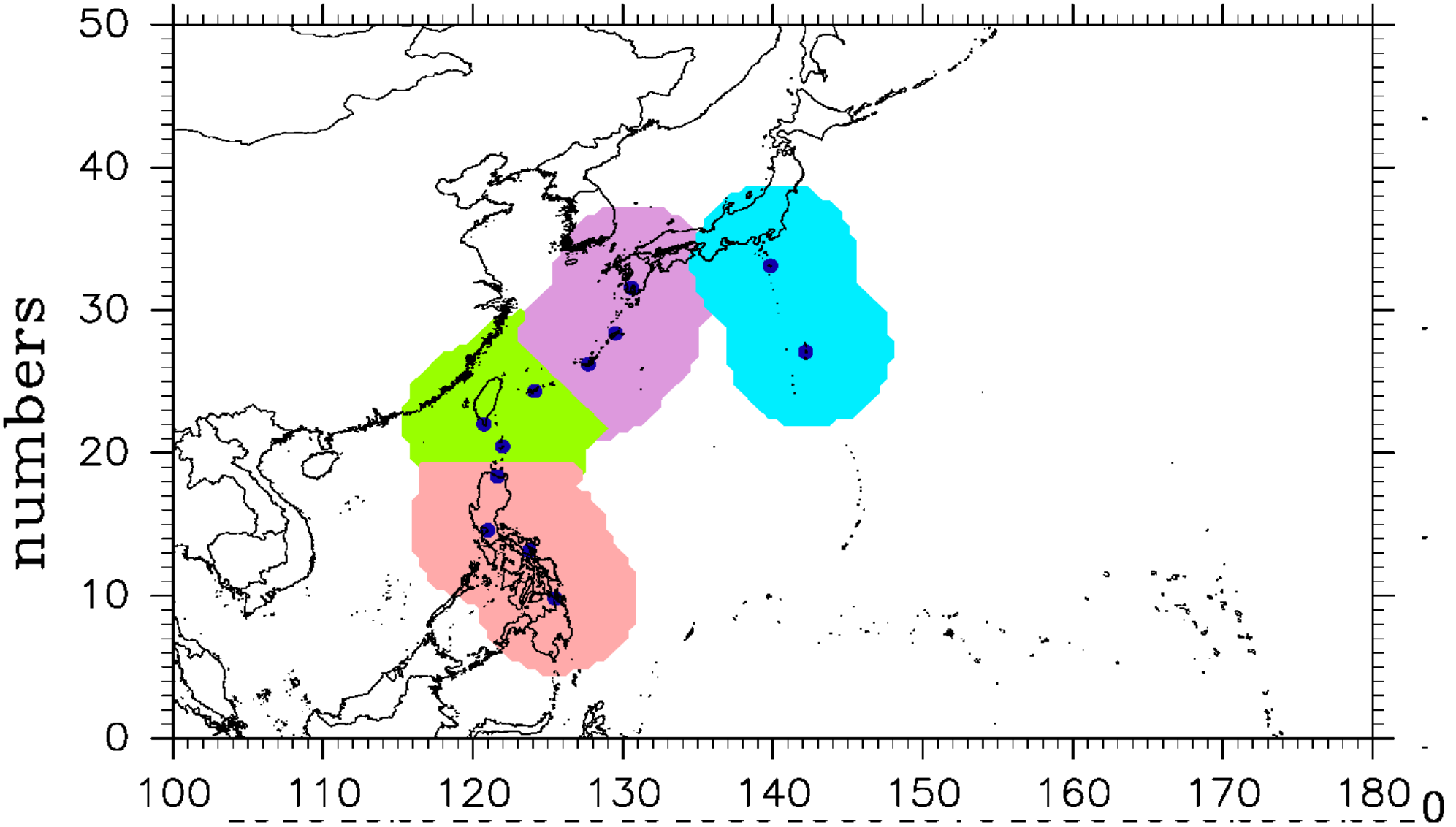
Time Series of EOFs of Track Patterns & PDO



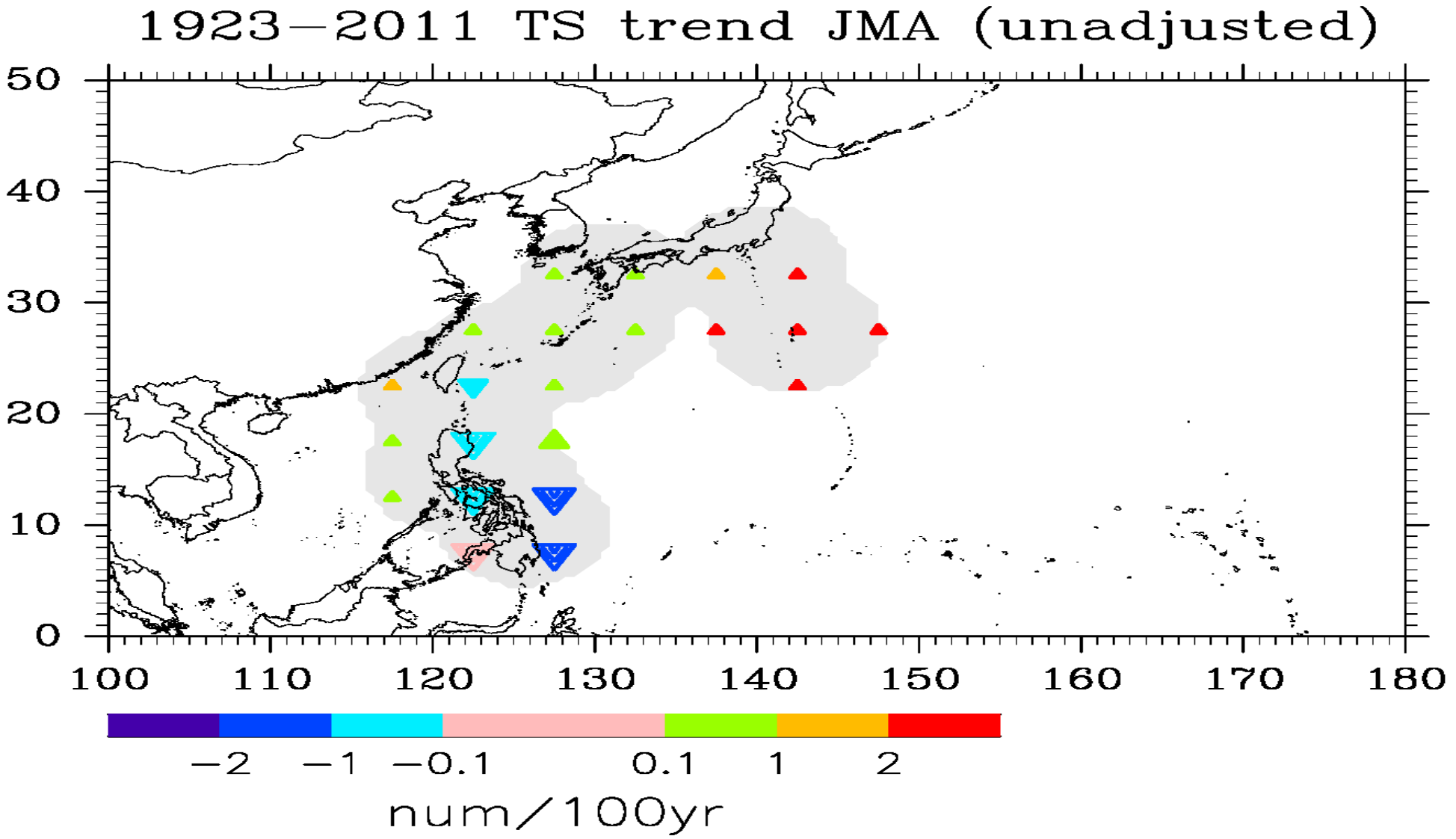
No. of surface pressure observations/month



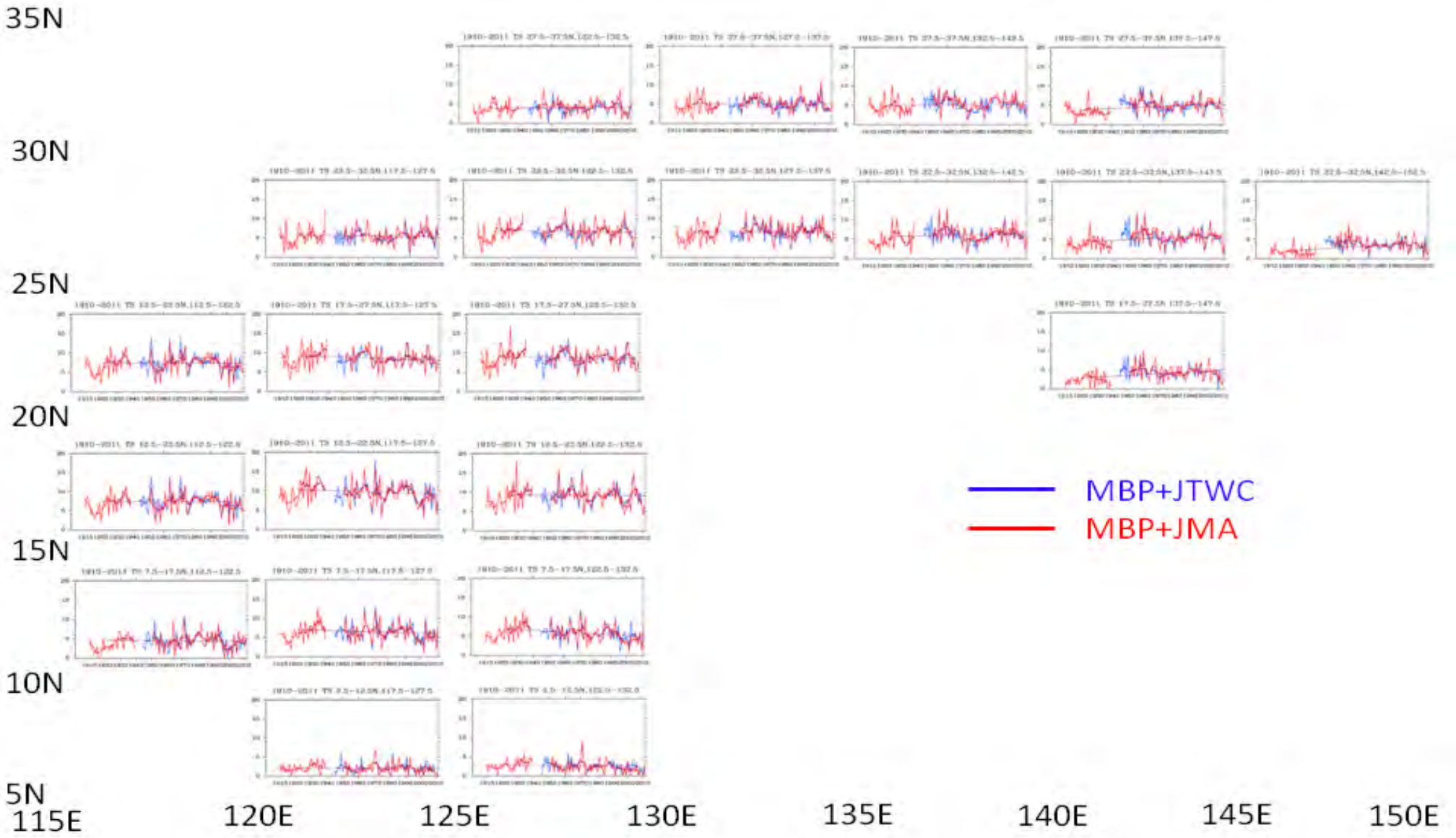
Typhoon numbers of the target area over the Western North Pacific



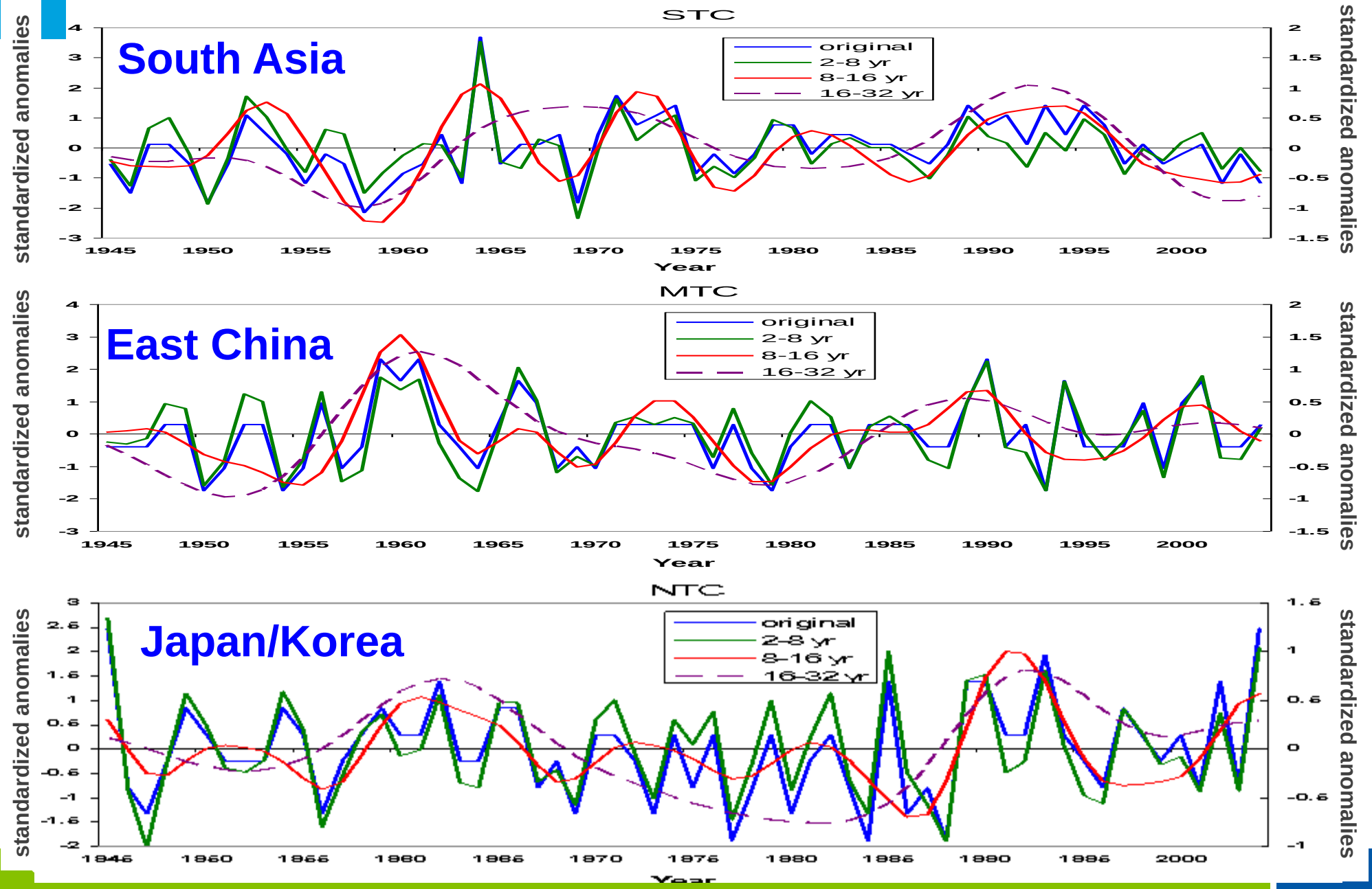
Tropical Cyclone Trends



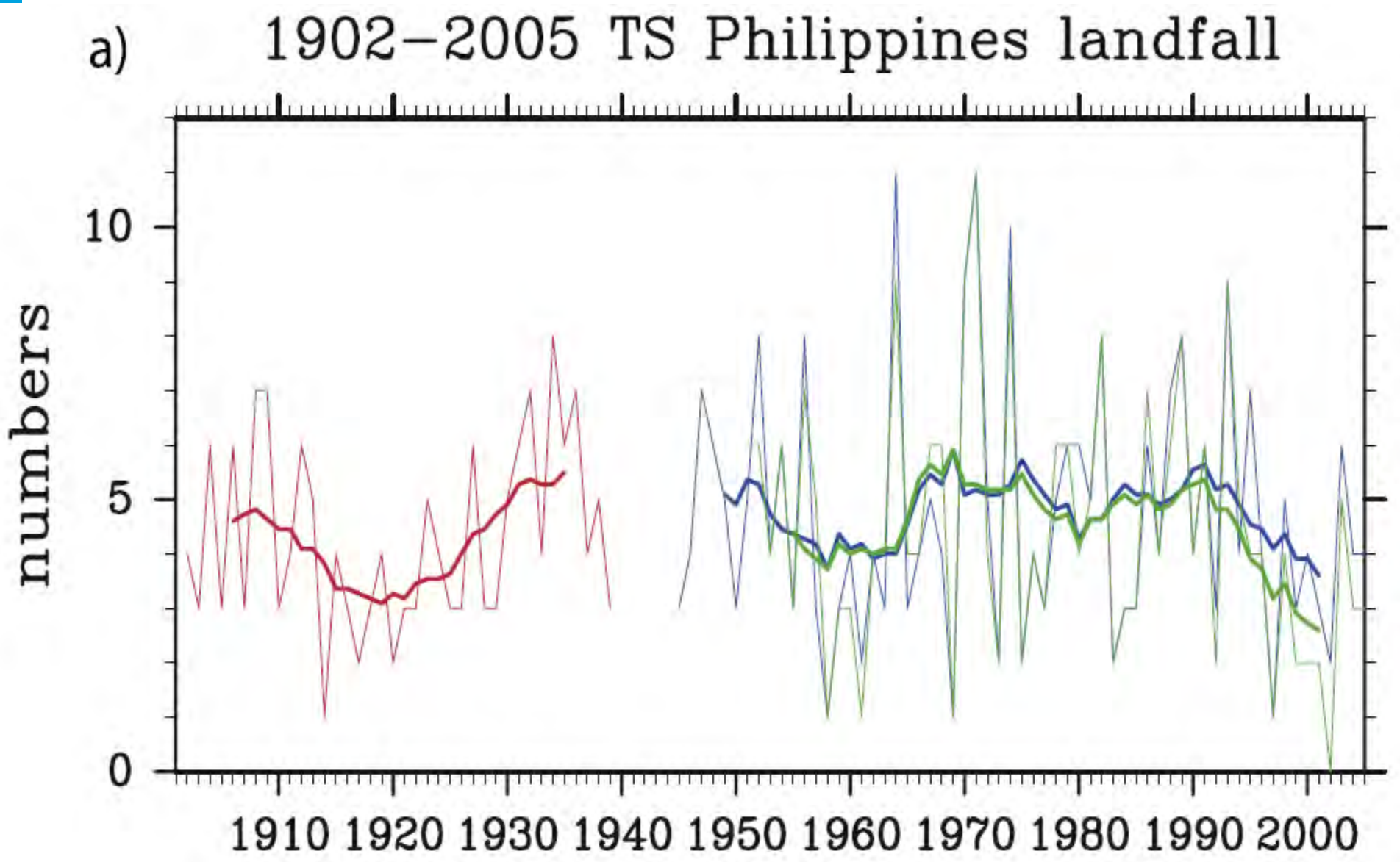
Tropical Cyclone Variations and Trends



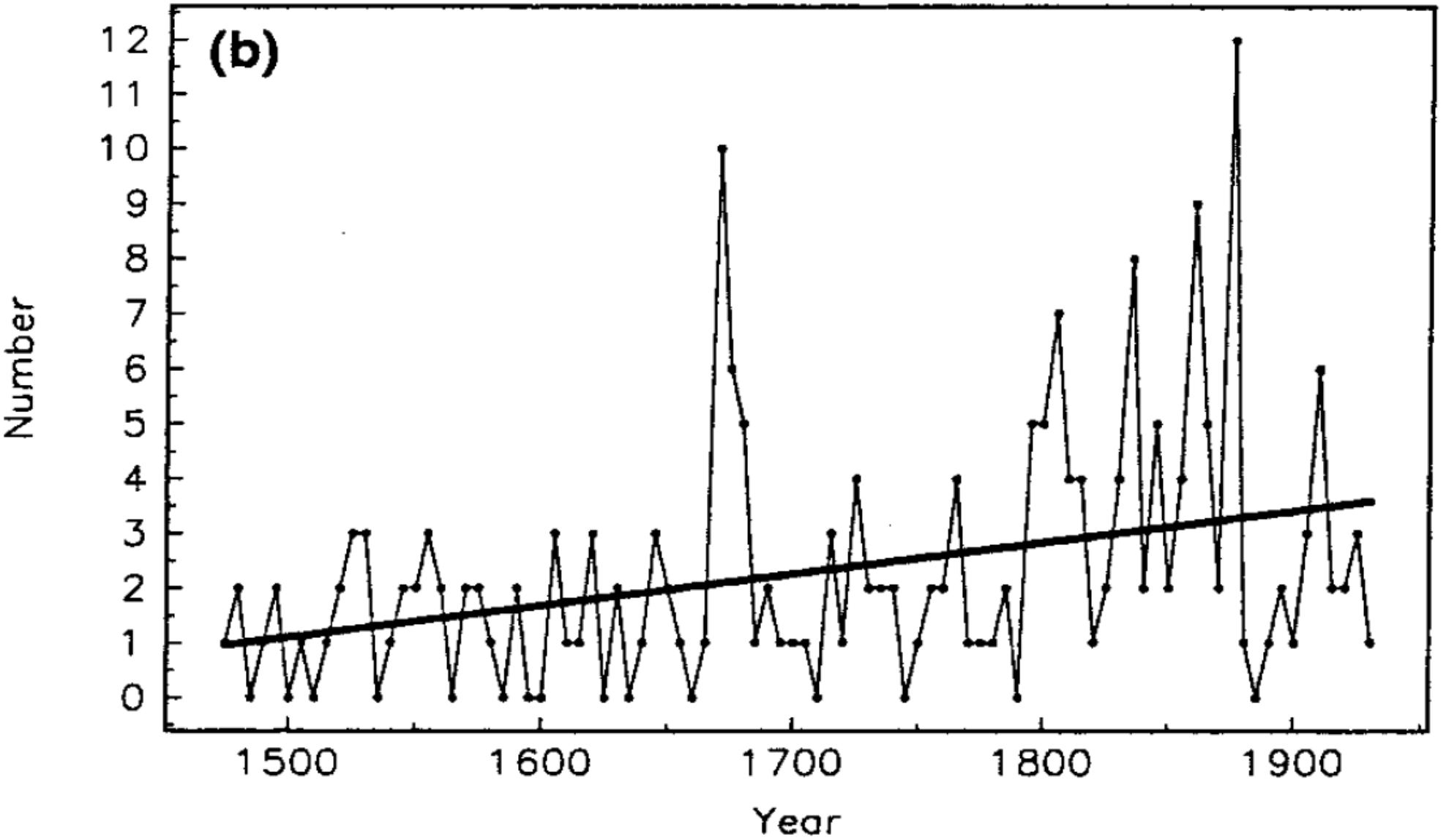
Variations of Landfall in Each Area at Various Oscillation Periods



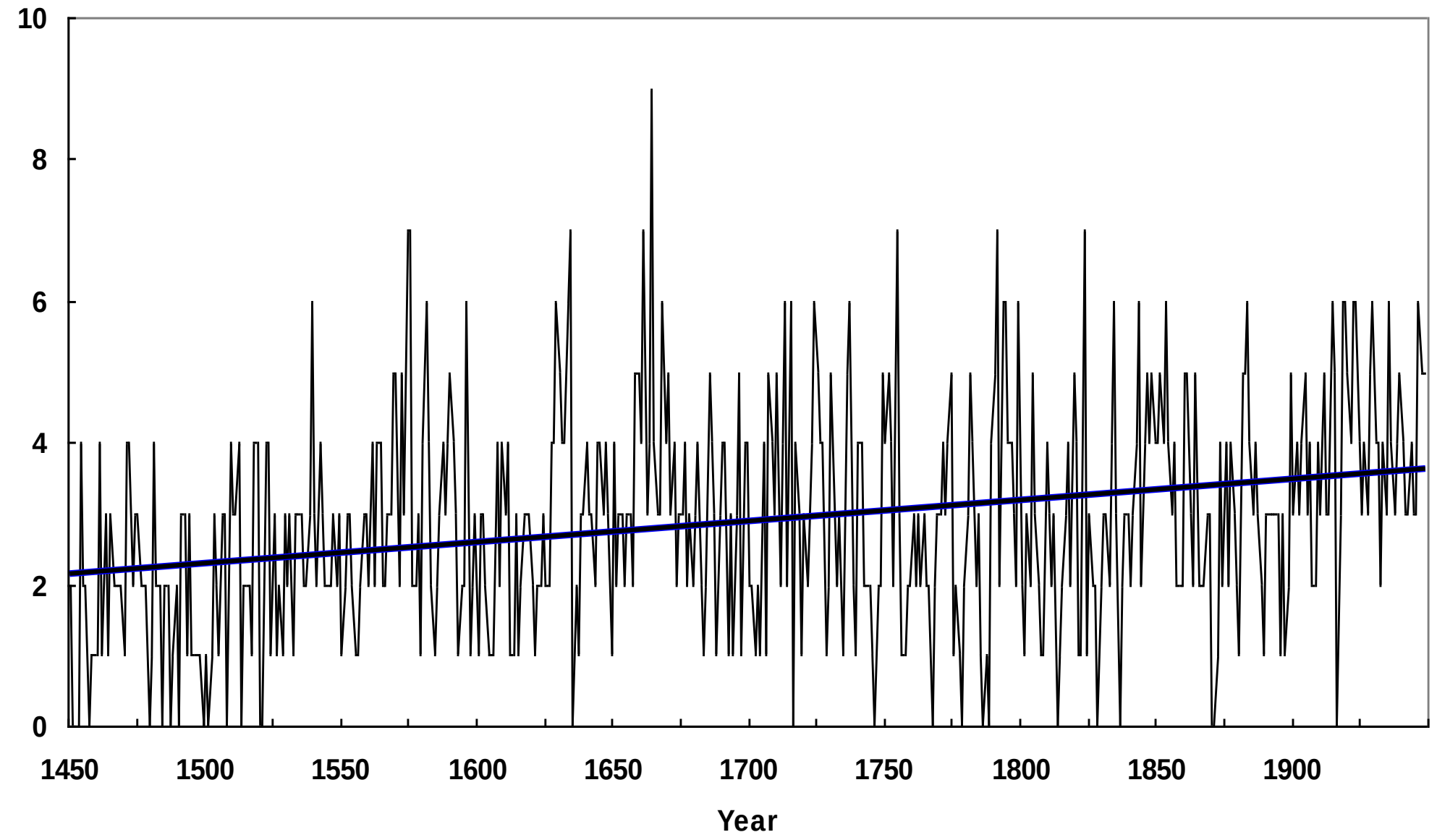
No. of Landfalling TCs in the Philippines



No. of Landfalling TCs in South China



No. of Landfalling TCs in East China



No. of Landfalling TCs in East China

PDO status	Number of years	Mean number of typhoons	Standard deviation
EN			
PDO+	34	3.41	1.62
PDO−	55	3.18	1.47
$t = 0.68$ (not significant)			
LN			
PDO+	16	2.38	1.46
PDO−	31	3.36	1.02
$t = 2.41$ (significant at 99%)			

Summary

- **Variations of TC activity on decadal time scales or longer in the western North Pacific are large.**
- **Dynamic factors (horizontal and vertical shear), which can be forced by *remote* SST variations, such as ENSO and PDO, are mainly responsible for the observed TC variability in these regions.**