Seasonal and Interannual Variabilities of the Tropical Indian Ocean Climate

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Introduction

- IOD influences the interannual SST variability in the tropical Indian Ocean significantly.
- IOD is seasonally phase-locked to boreal summer and fall.

⇒ Mechanism?

Purpose of this study

To examine the relationship between the seasonal variabilities (heat content) in the tropical Indian Ocean and IOD

Method

Variable X:

$$X(yr,mon) = X_{annual\ mean} + X_{seasonal\ anomaly}(mon) + X_{interannual\ anomaly}(yr,mon)$$

- Harmonic analysis on $X_{seasonal\ anomaly}$
- Complex EOF on

$$X_{seasonal\ anomaly} + X_{interannual\ anomaly} = X_{whole\ anomaly}$$

Method

Variable X:

$$X = X_{\text{annual mean}} + X_{\text{seasonal anomaly}} + X_{\text{interann. anom.}}$$

$$= X_{\text{annual mean}} + X_{\text{mode1}} + X_{\text{mode2}} + X_{\text{residual}}$$

$$= X_{\text{annual mean}} + (\overline{X_{\text{mode1}}} + X'_{\text{mode1}})$$

$$+ (\overline{X_{\text{mode2}}} + X'_{\text{mode2}})$$

$$+ (\overline{X_{\text{residual}}} + X'_{\text{residual}})$$

Monthly Climatology

Anomaly

DATA

- **heat content in the upper 125m (HC)**

  Simple Ocean Data Assimilation (SODA)

  1981-2000

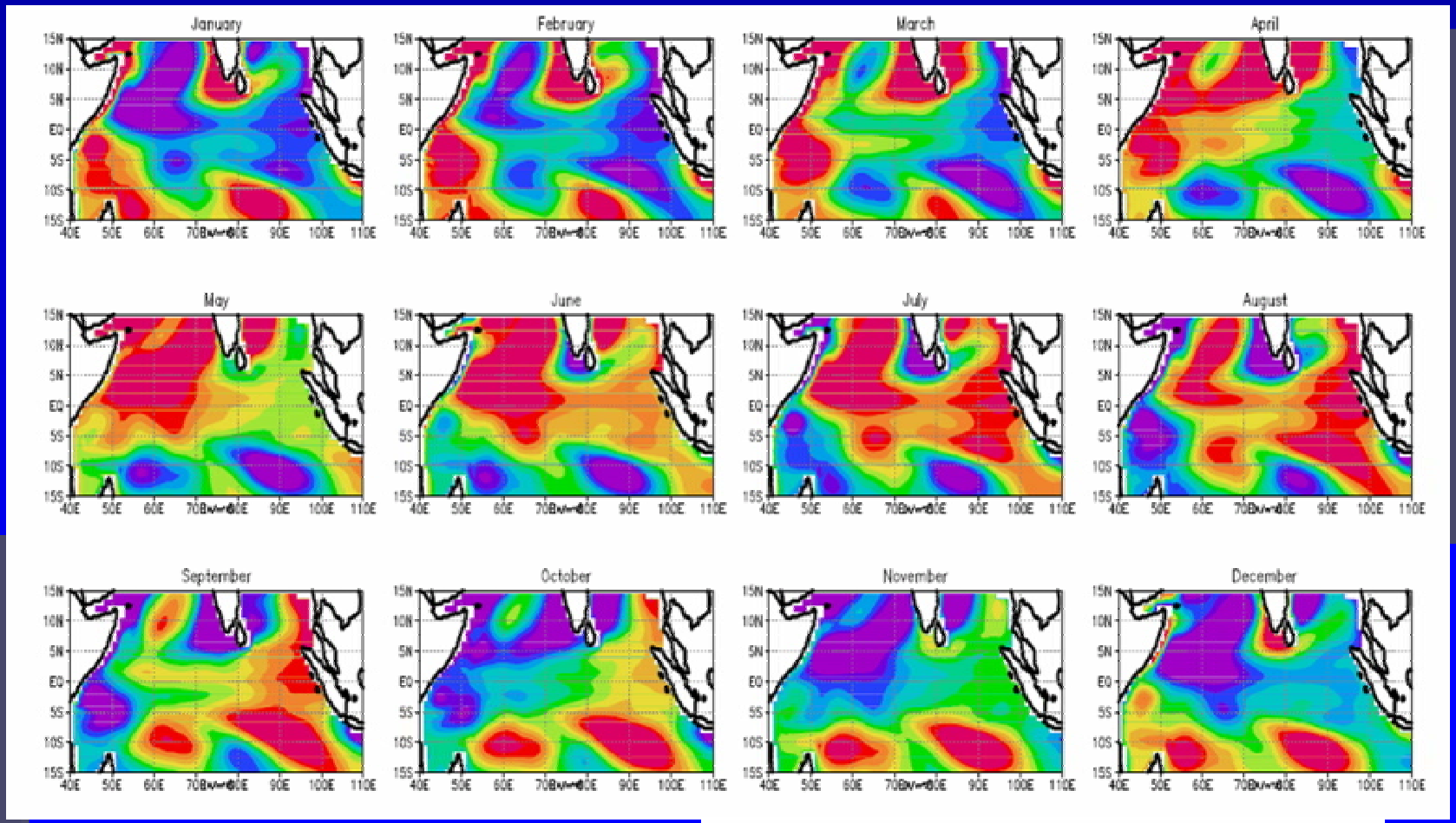
- **SST**

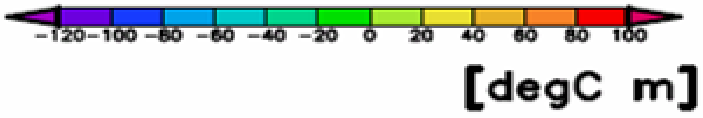
  HADISST 1981-1999

- **wind stress**

  NCEP/NCAR reanalysis data 1981-1998

HC annual component derived by harmonic analysis





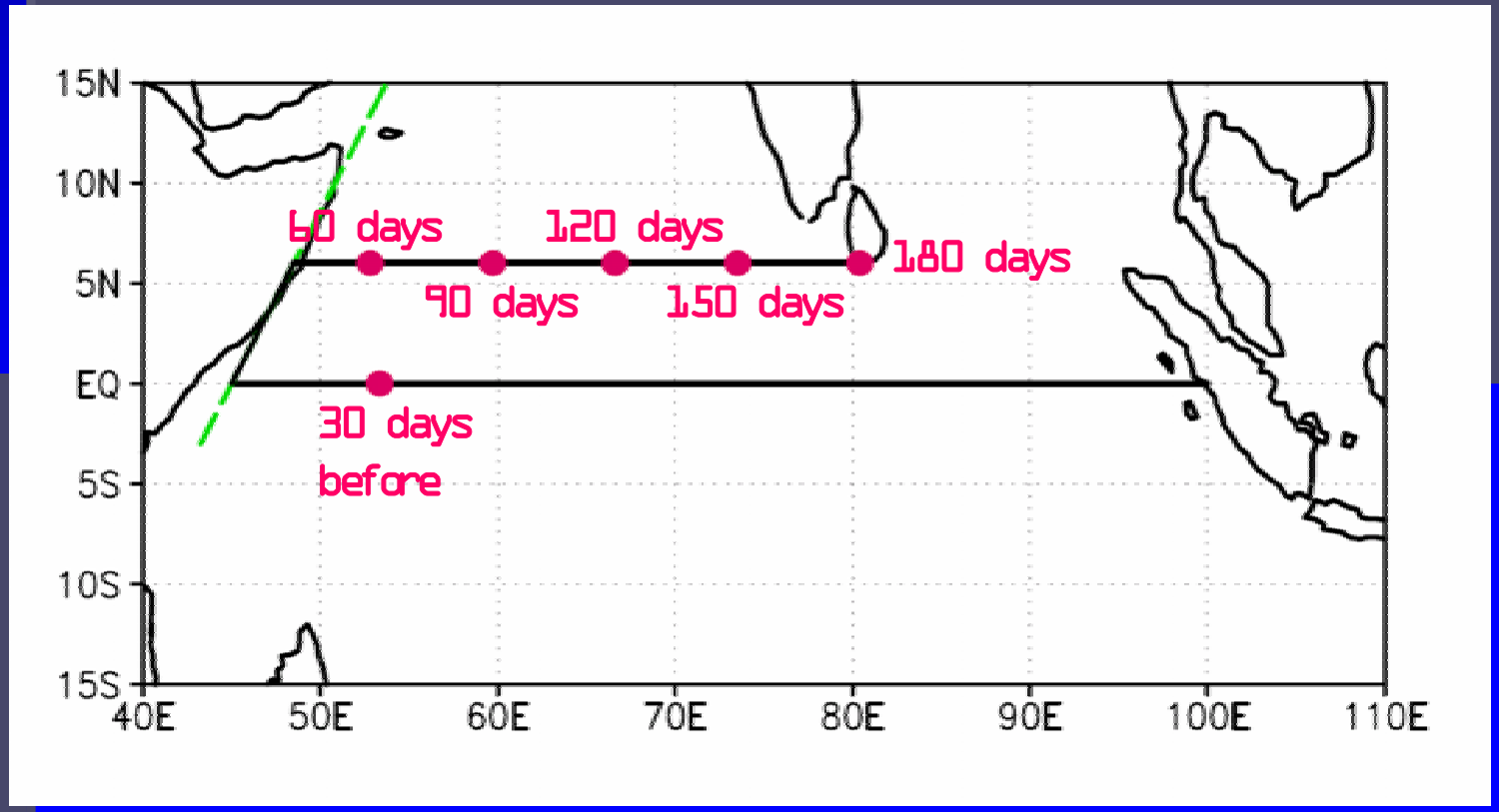
Track of the warm water（simple estimation）

Kelvin wave (on the Equator and along the Somalia coast)

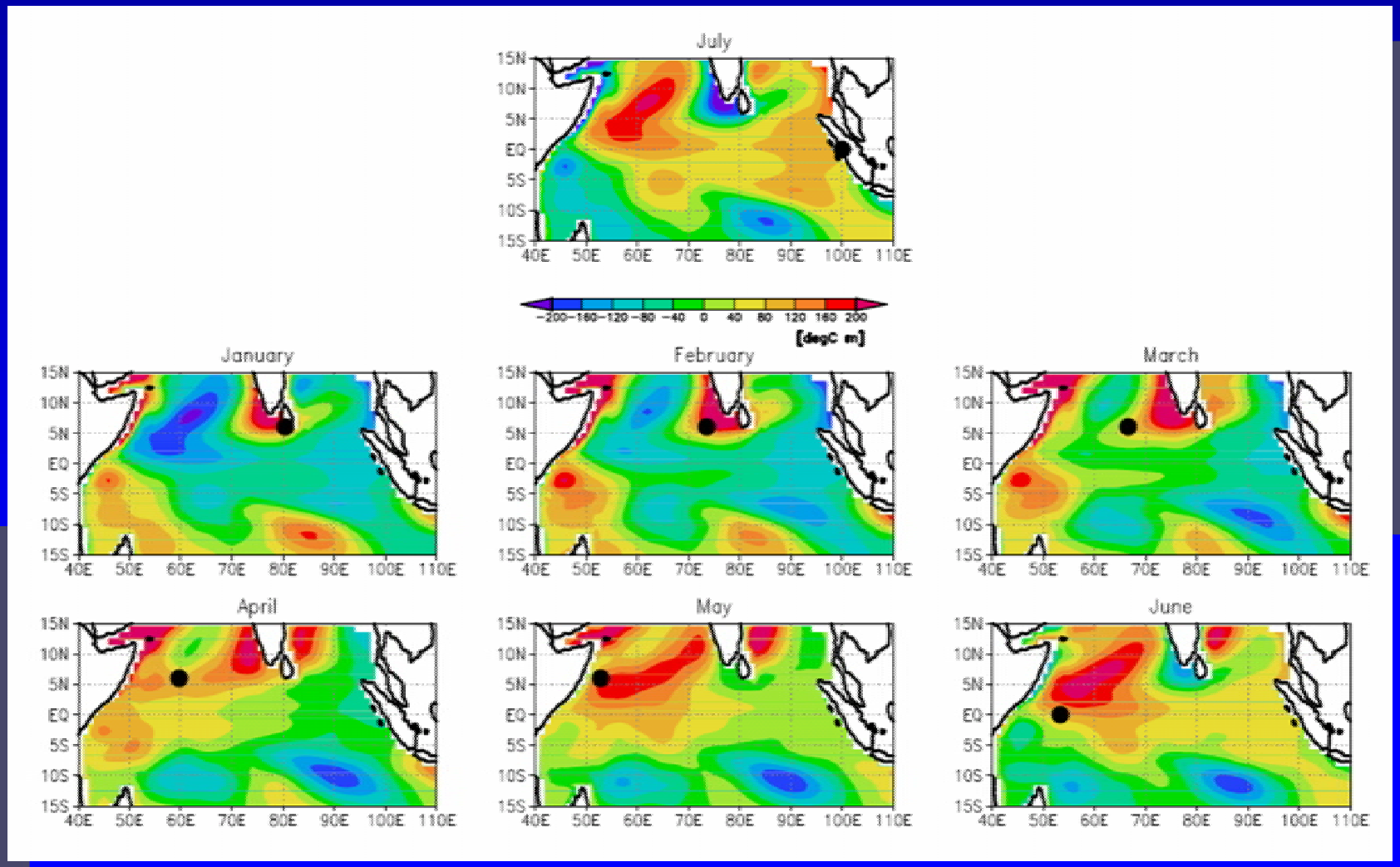
$C_K = \sqrt{g'H}$ $g' = 0.04\,m/s^2$ $H = 100\,m$

Rossby wave

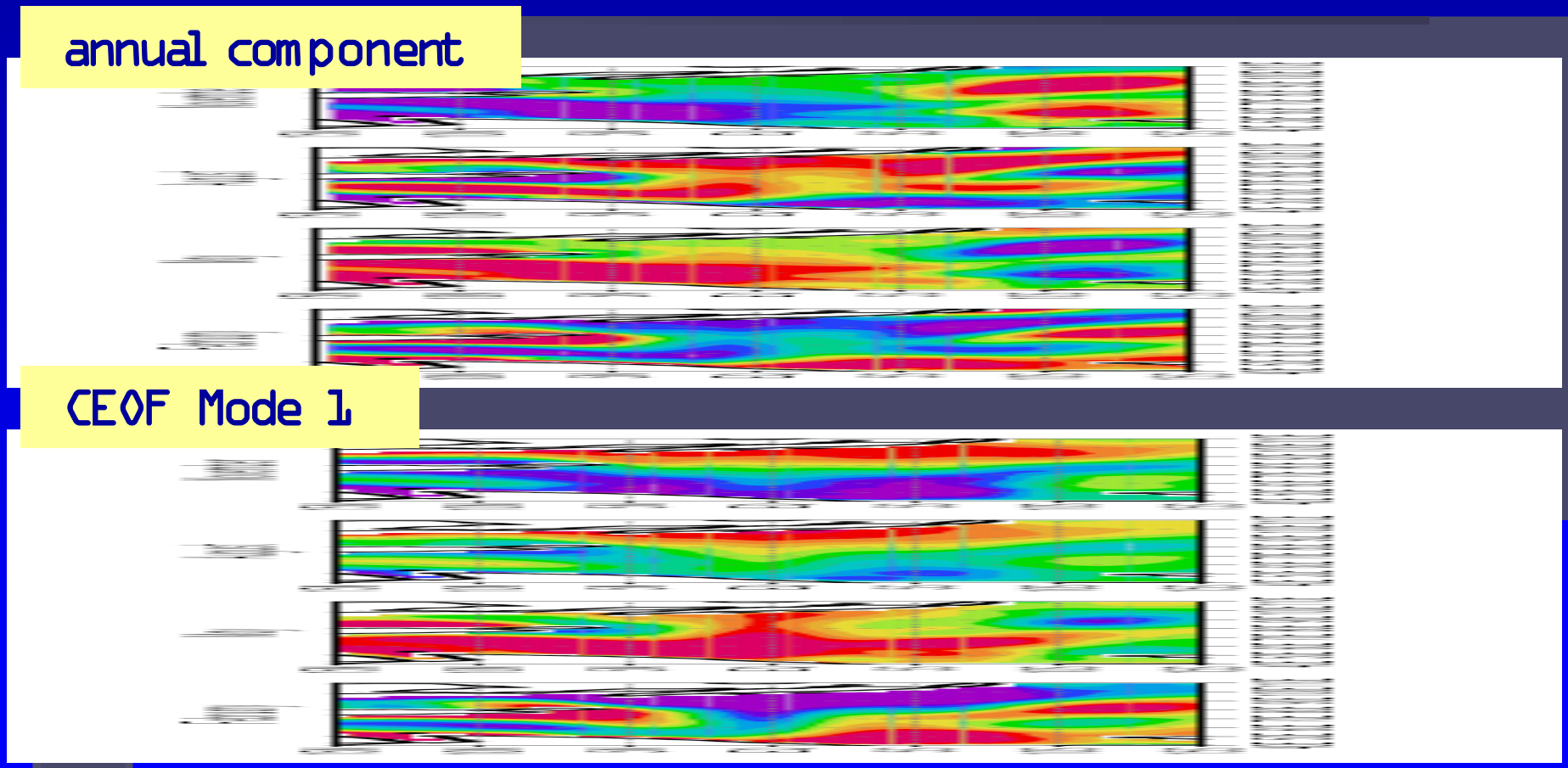
$C_R = g'H\,\beta / f^2$ $g' = 0.03\,m/s^2$ $H = 200\,m$



HC annual component with the track of the warm water

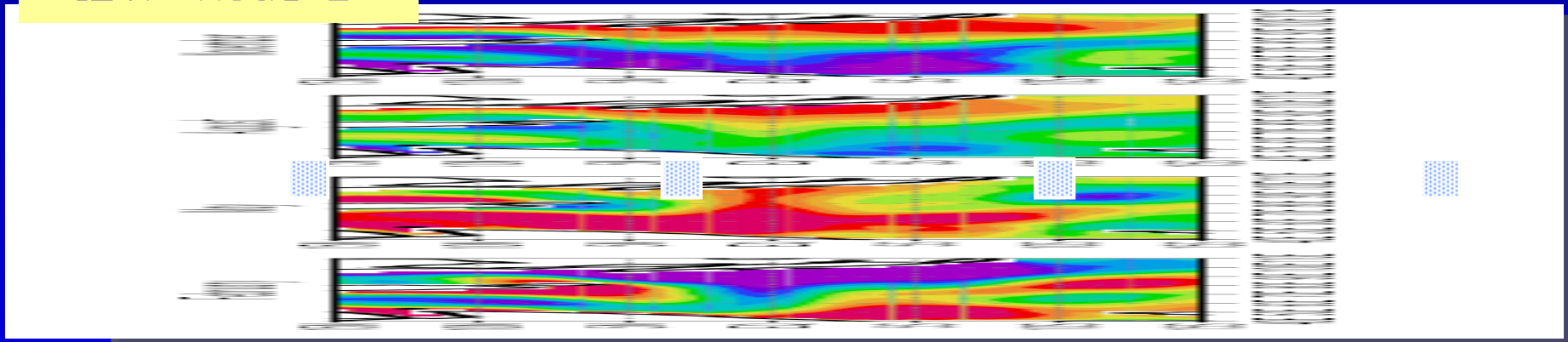


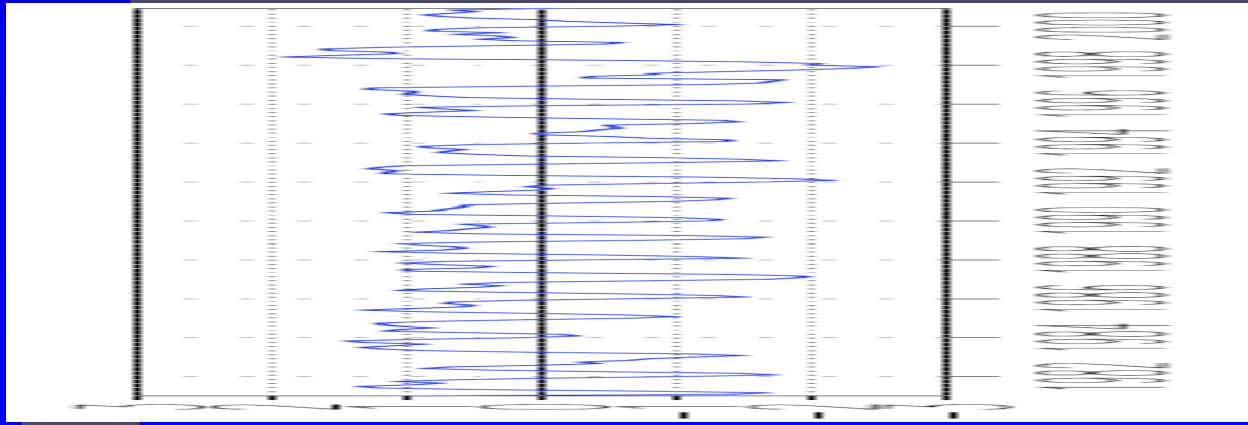
HC annual component & HC CEOF Mode 1 (39%)



HC CEOF Mode 1

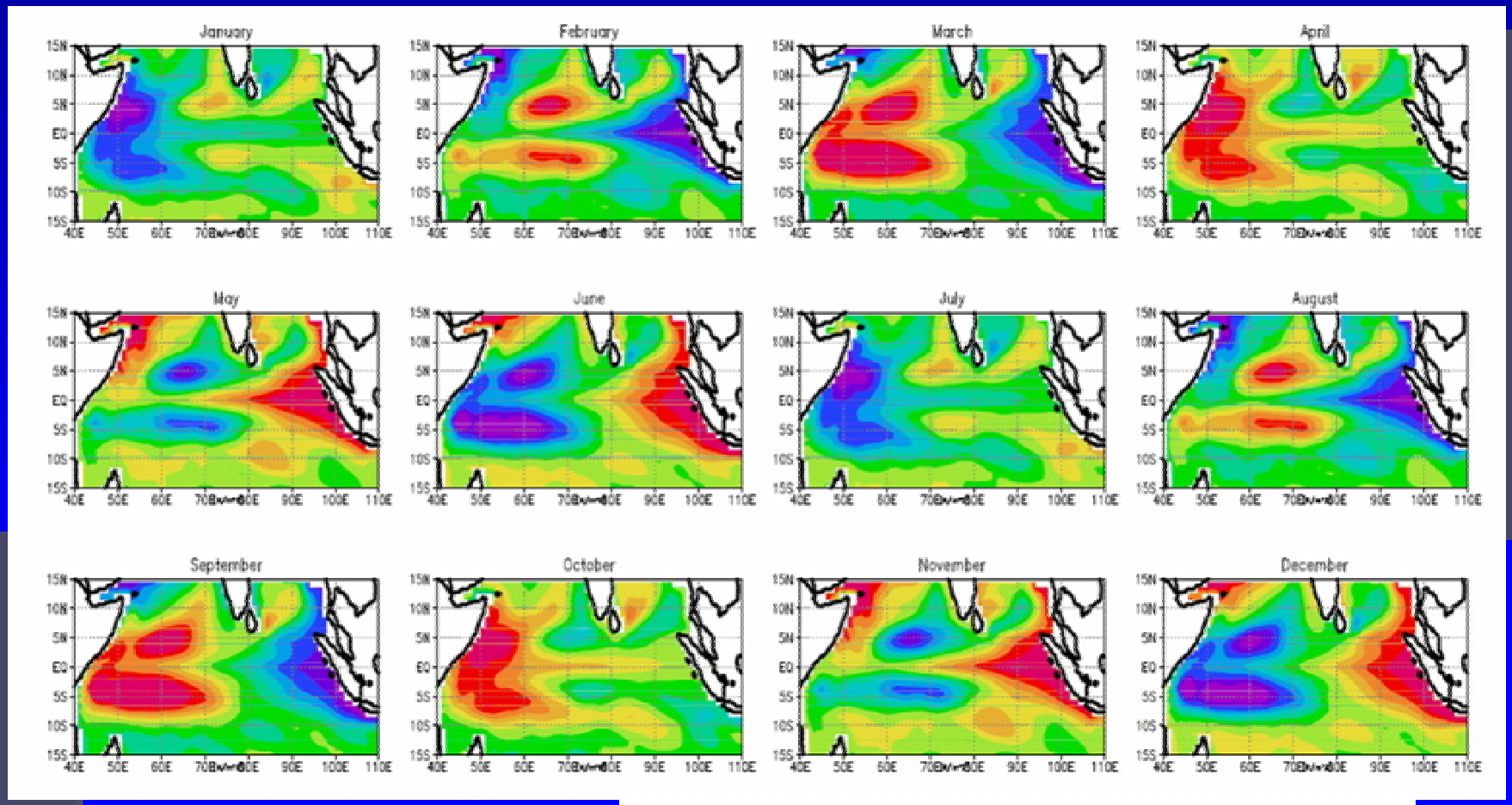
CEOF Mode 1



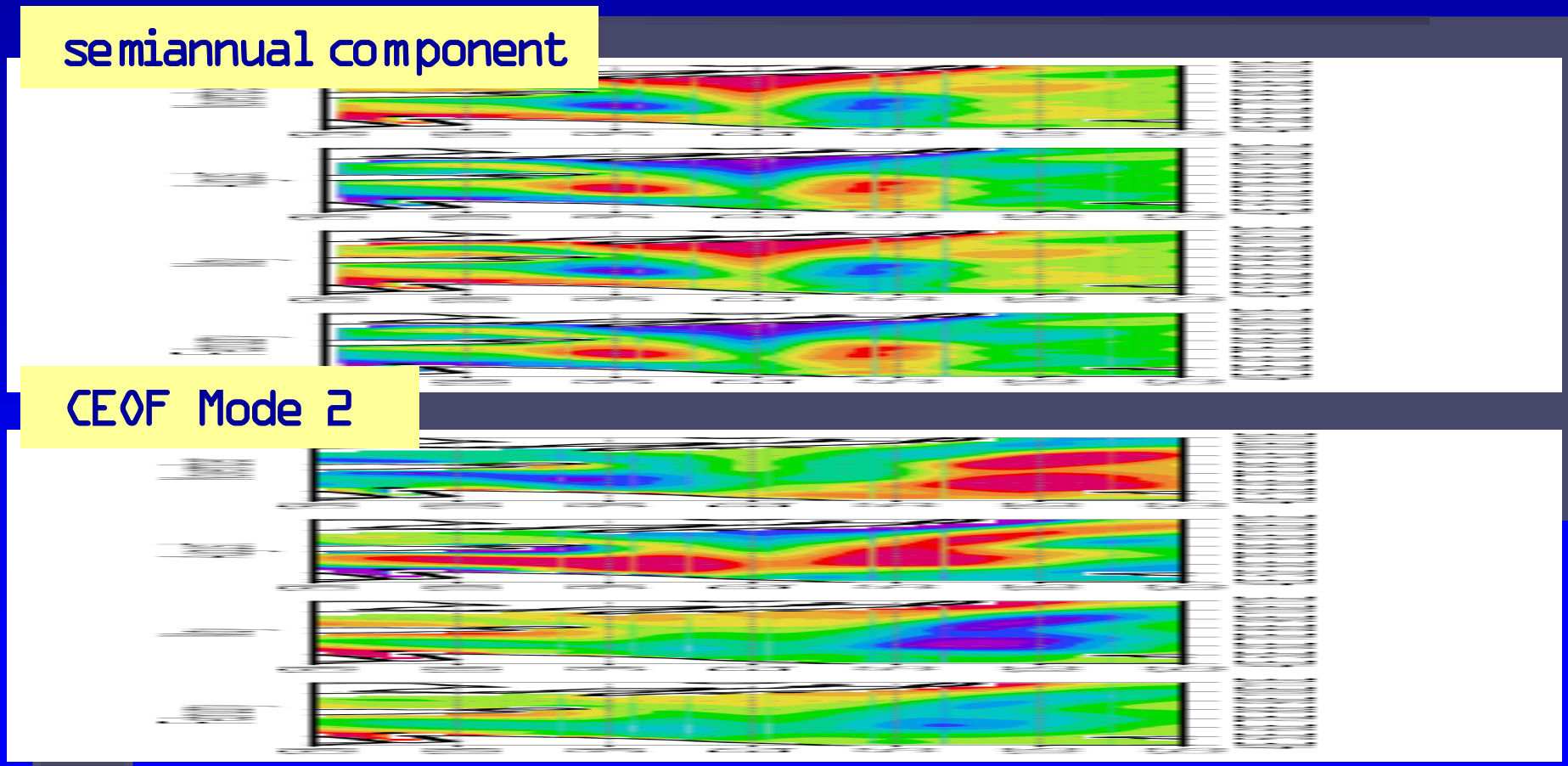


annual + ?

HC semiannual component derived by harmonic analysis

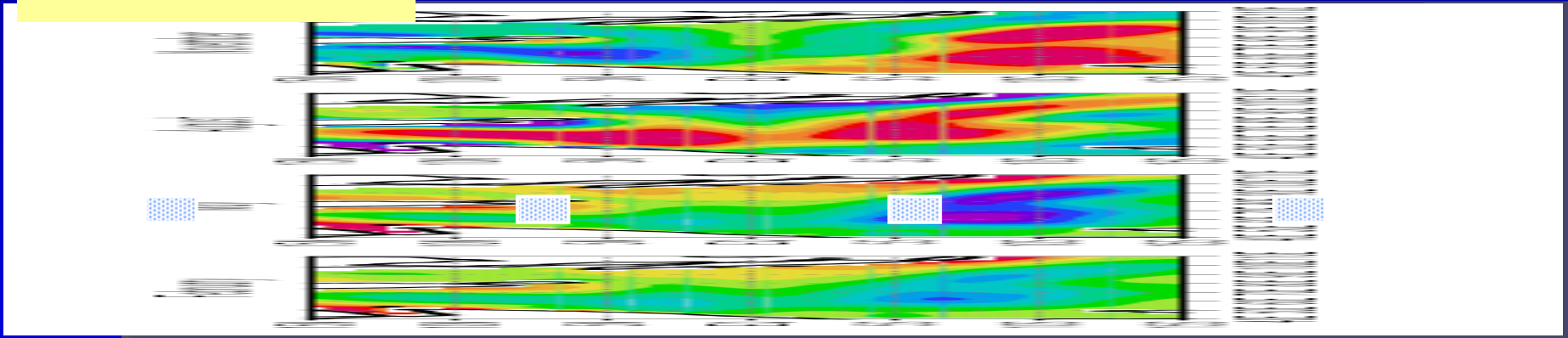


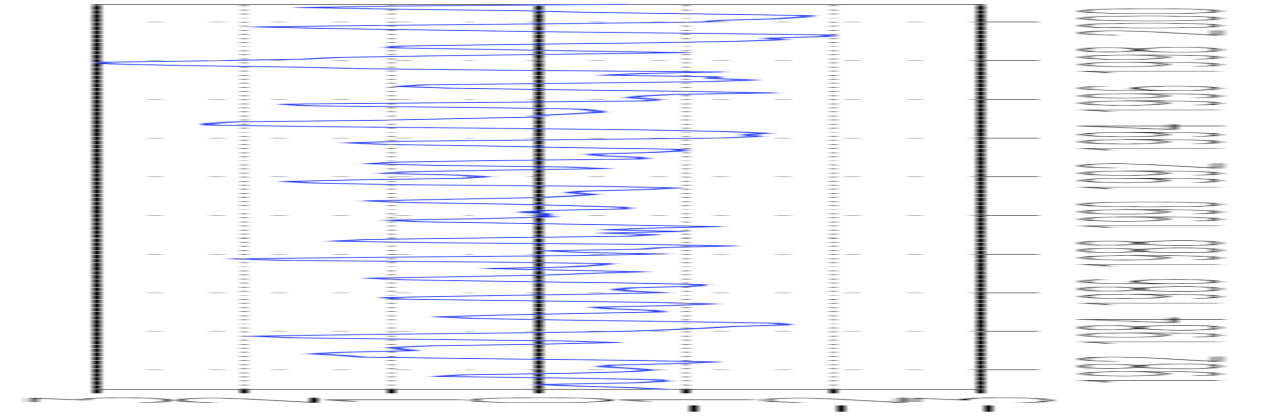
HC semiannual component & HC CEOF Mode 2 (22%)



HC CEOF Mode 2

CEOF Mode 2





semiannual + ?

Method

Variable X:

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$$= X_{\text{annual mean}} + (\overline{X_{\text{mode1}}} + X'_{\text{mode1}}) + (\overline{X_{\text{mode2}}} + X'_{\text{mode2}}) + (\overline{X_{\text{residual}}} + X'_{\text{residual}})$$

DMI

Monthly Climatology

Anomaly

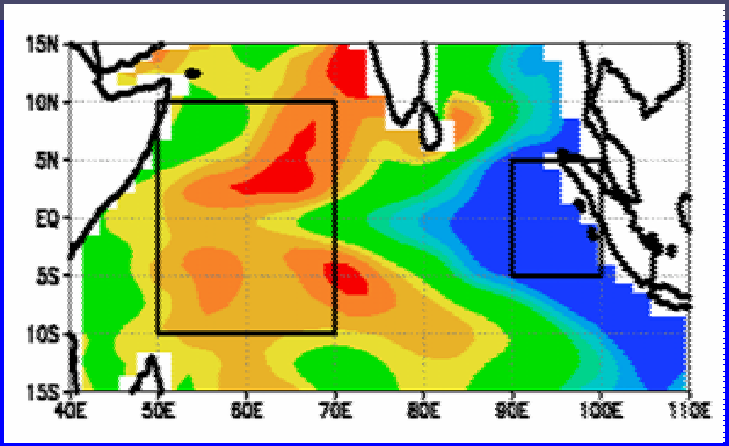
Correlation (Jul.-Dec.) DMI -- HC index

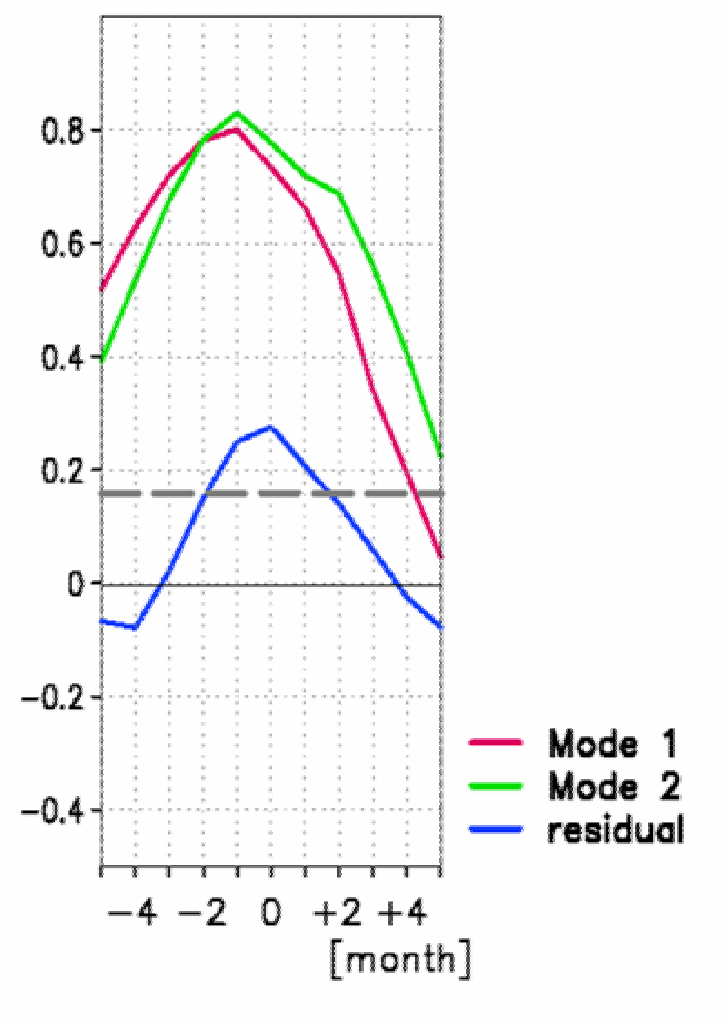
SST, wind stress

Mode 1: annual component

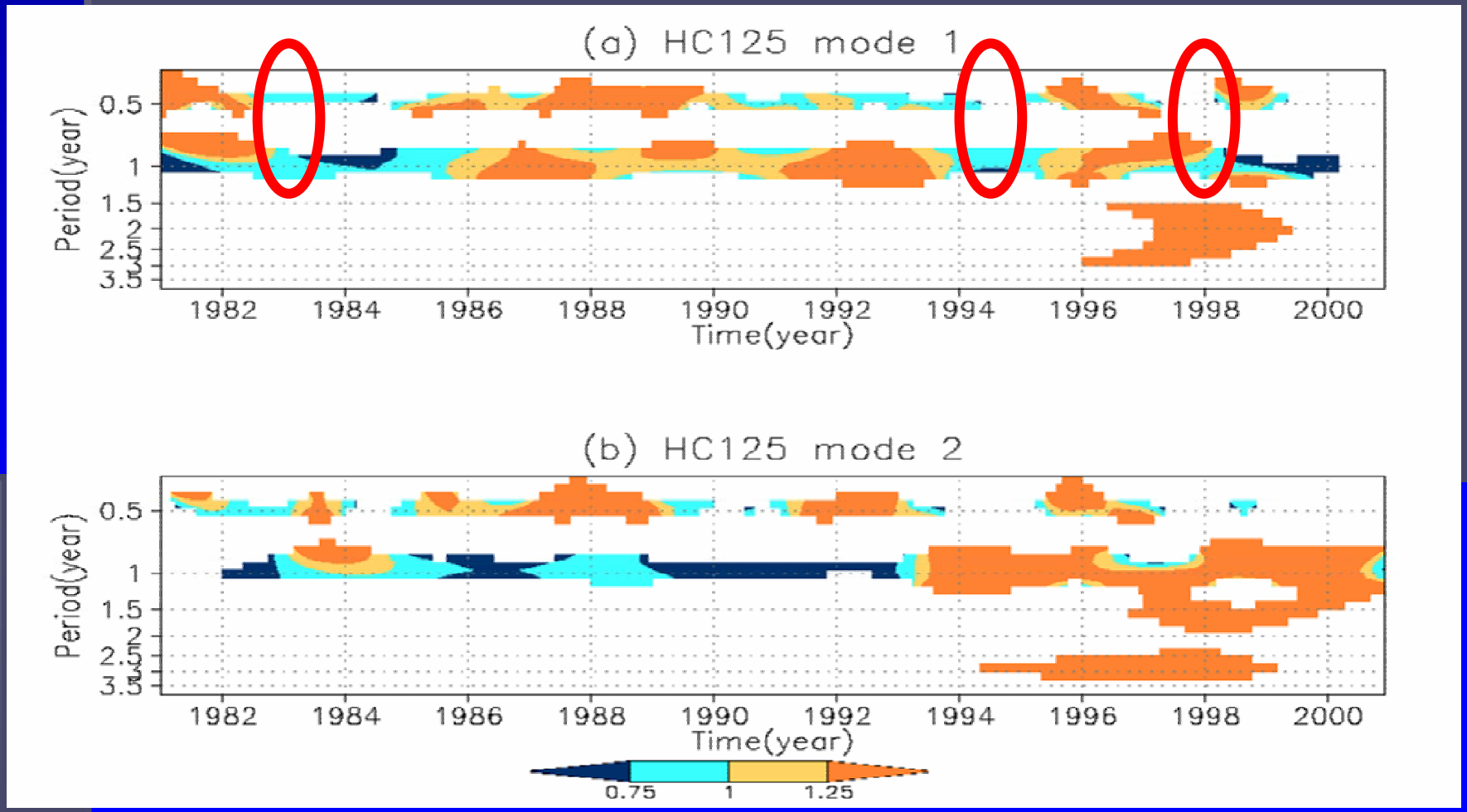
Mode 2: semiannual component

The characteristic features of IOD appears in the residual component anomaly.

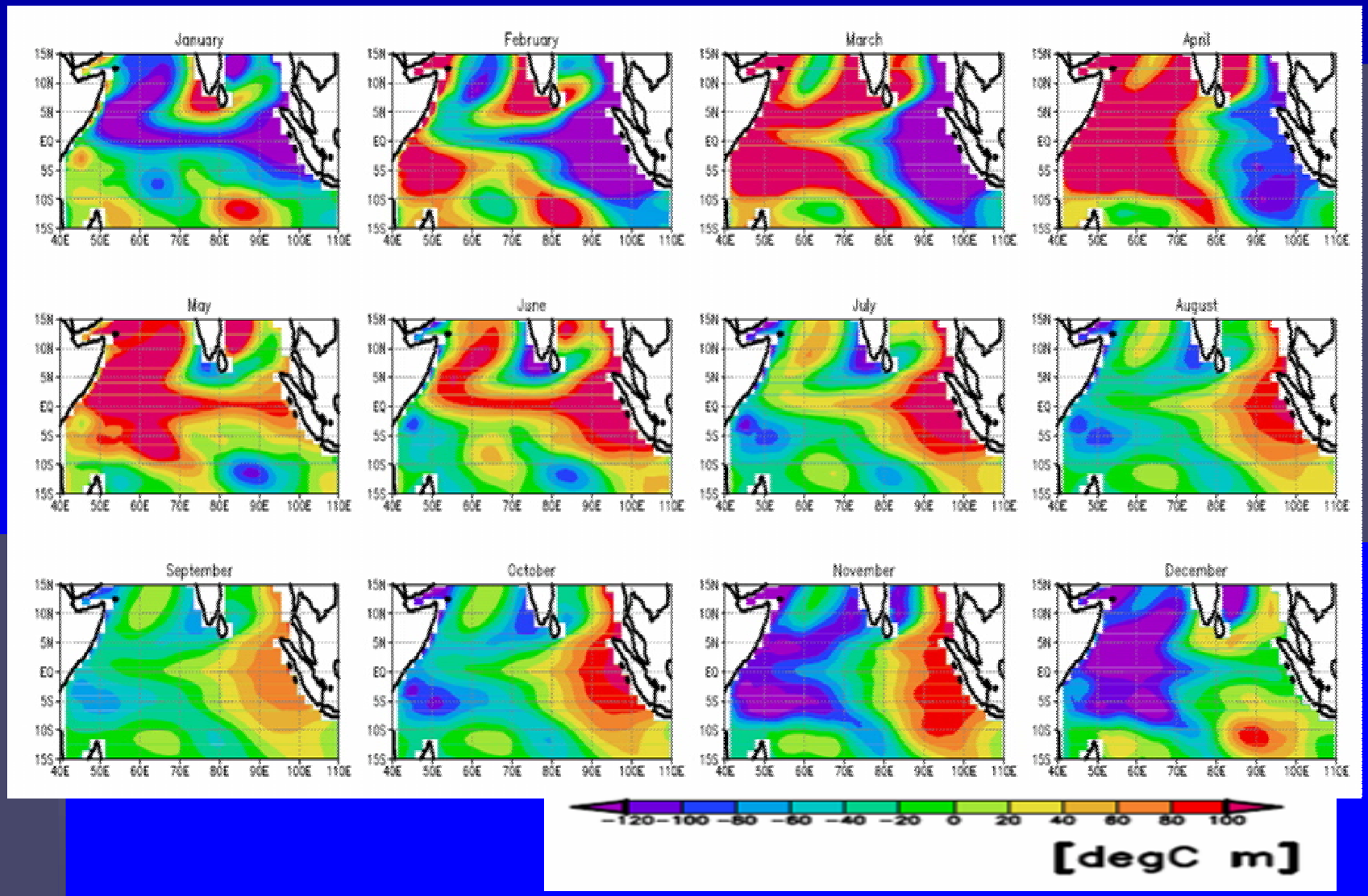




Wavelet spectrum
HC Mode 1, Mode2



HC Mode 1
Monthly Mean



Correlation map with DMI

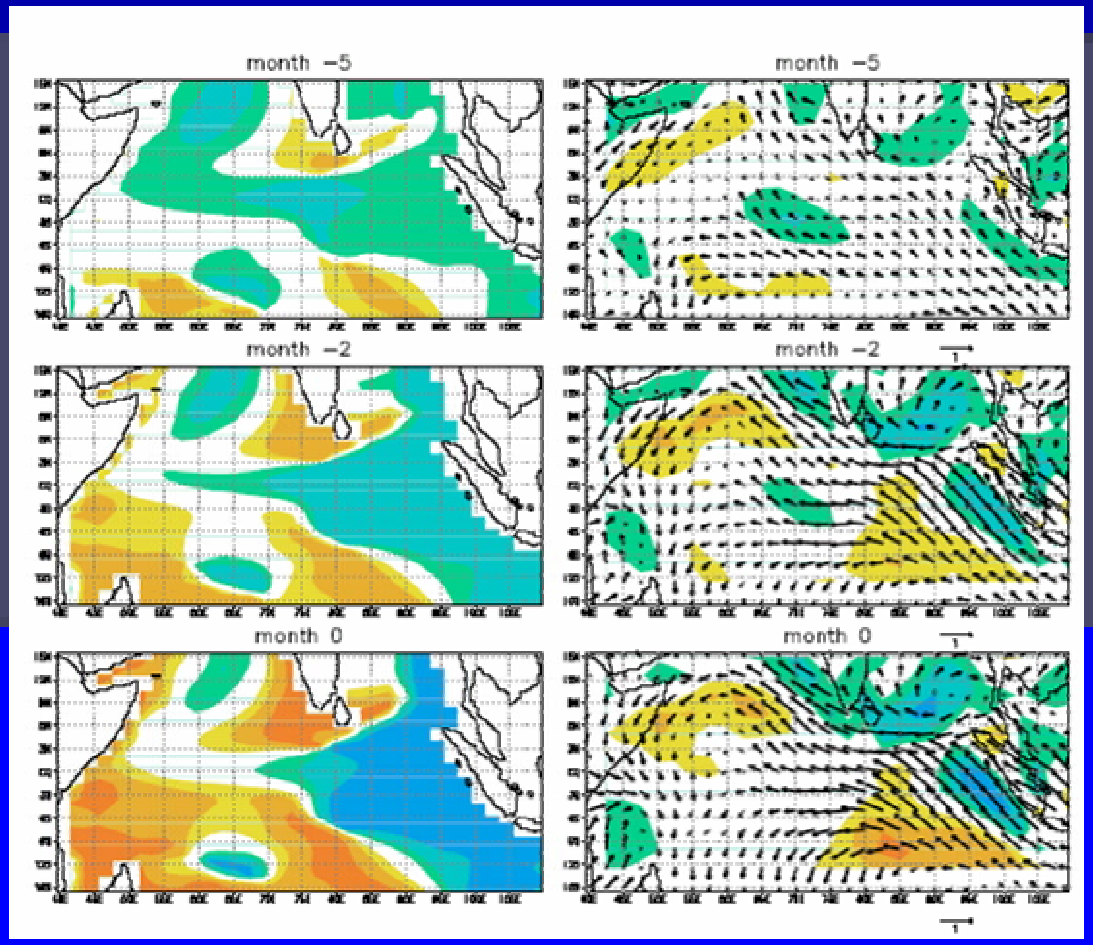
HC Mode 1 anomaly

τ,curl τ residual anomalies

5 months before (May,June)

2 months before (Aug.,Sep.)

No lag (Oct.,Nov.)



Conclusion

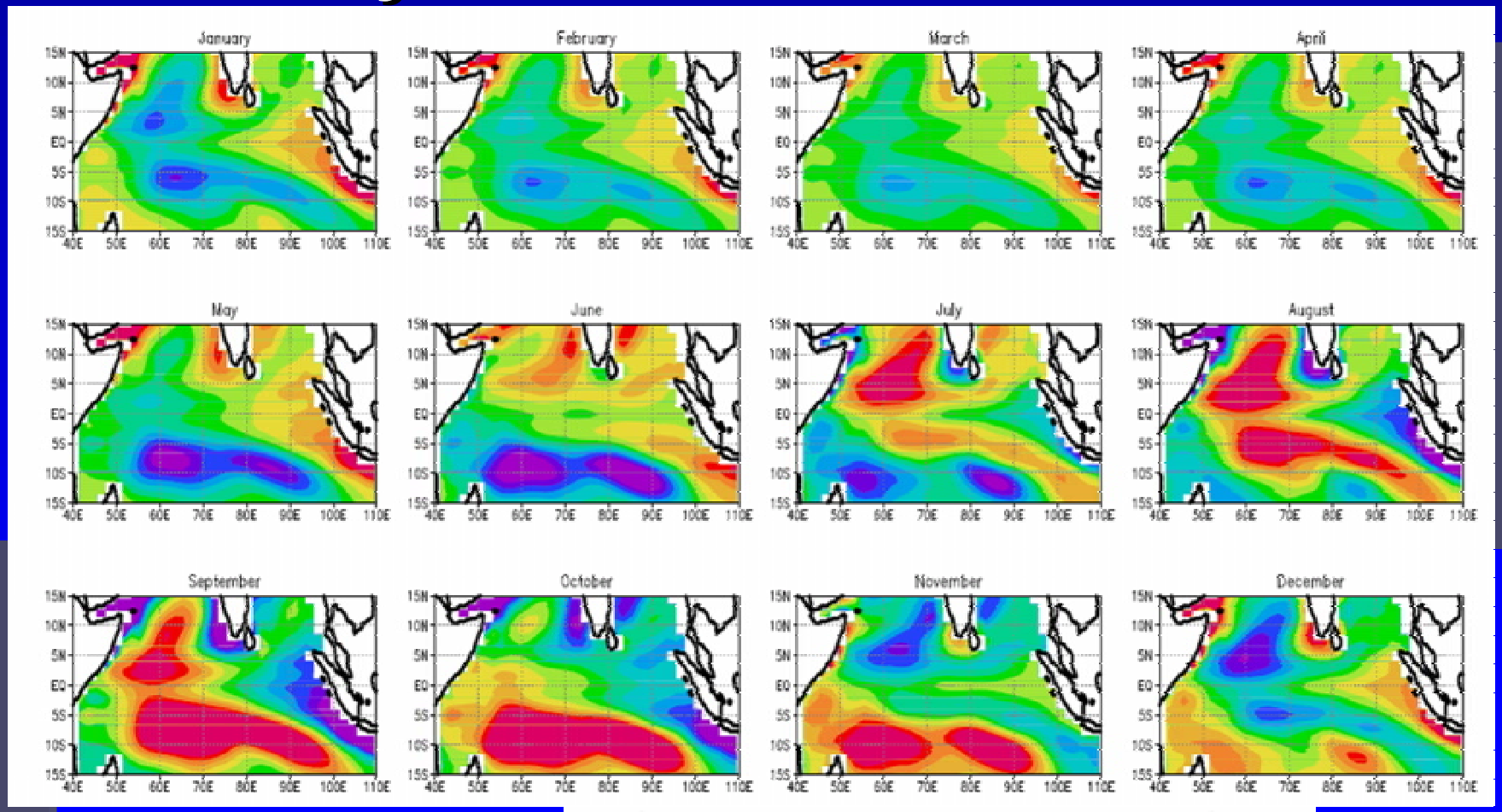
- We found the interesting annual component of the HC for the first time. The warm water mass from the southern tip of India is intensified in the Arabian Sea by the dynamical process of monsoon wind curl around May, propagates as the equatorial Kelvin wave, and reaches Sumatra coast around July.

  This is unfavorable condition for IOD formation.

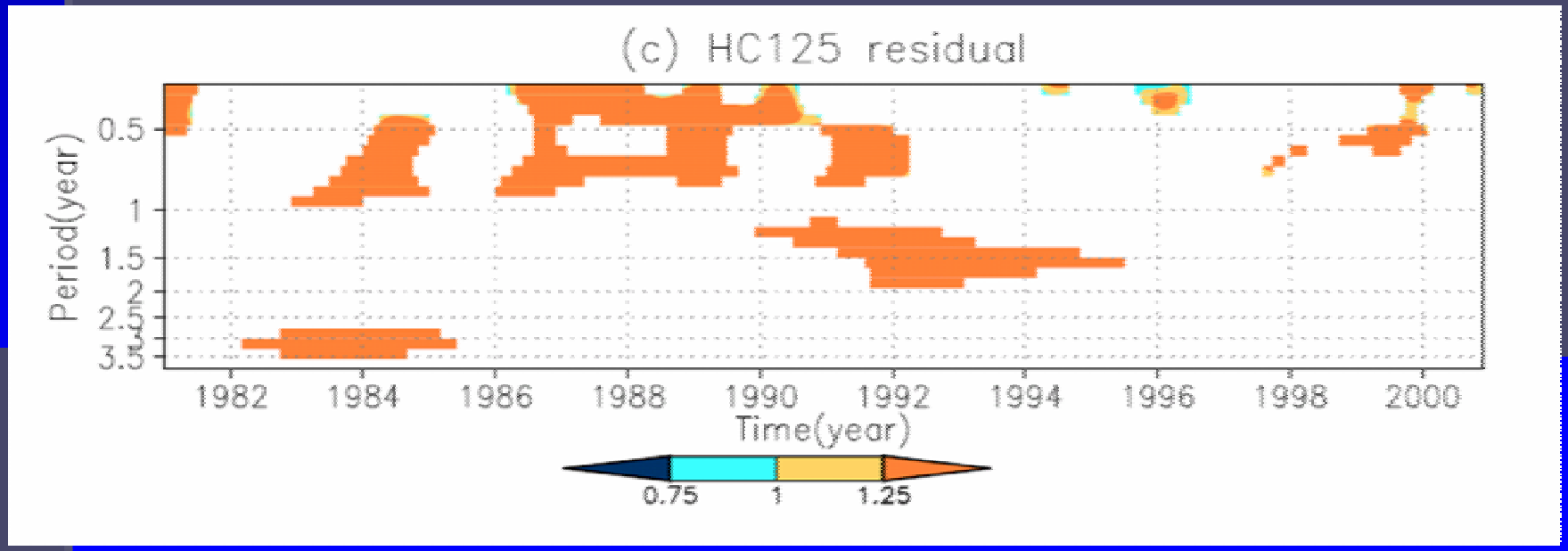
Conclusion

- The magnitude of the annual component of HC weakens in the IOD year.
- This is due to a fact that the anomalous cold water mass is generated in the Arabian Sea by the weakened monsoon winds, and this reaches Sumatra coast around July to provide the favorable condition for IOD.
- This is the key to the predictability of IOD!!

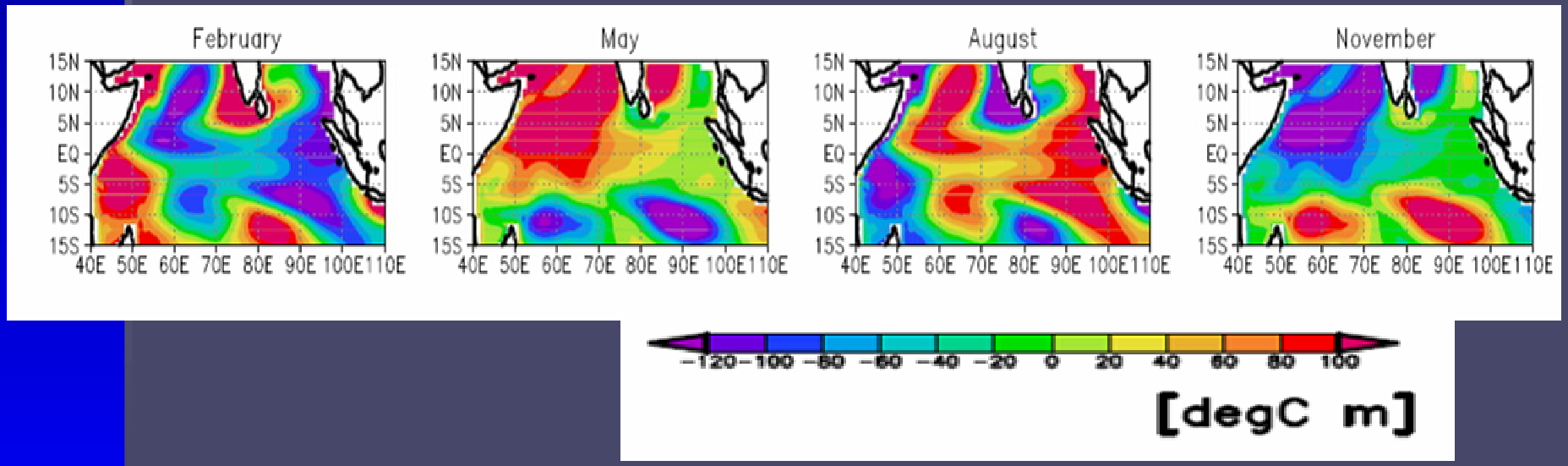
HC Mode 2
Monthly Mean

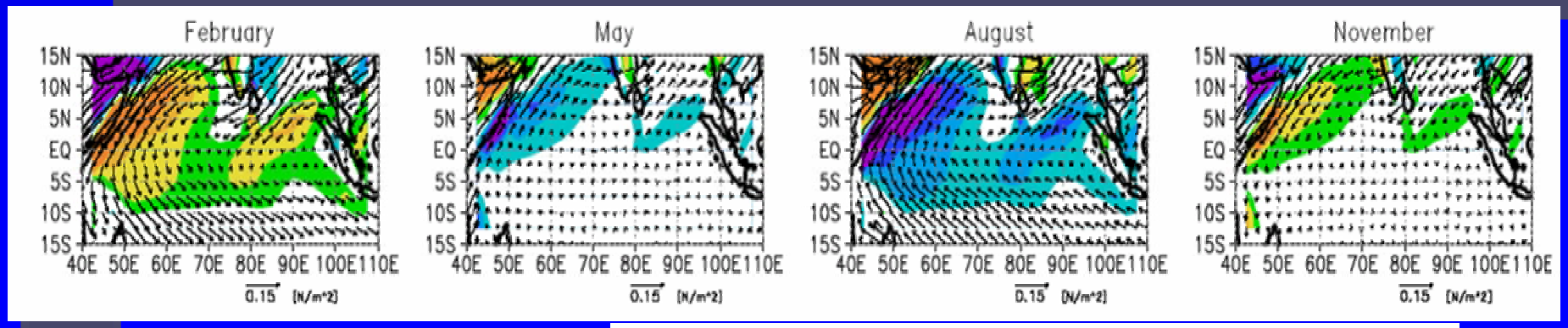


Wavelet spectrum
HC residual (off Sumatra)



HC & wind stress curl annual component





HC & wind stress curl semiannual component