Conceptual model for the Atlantic meridional mode and its connection with the equatorial mode

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Plan

I. Brief introduction of meridional mode

II. Objectives

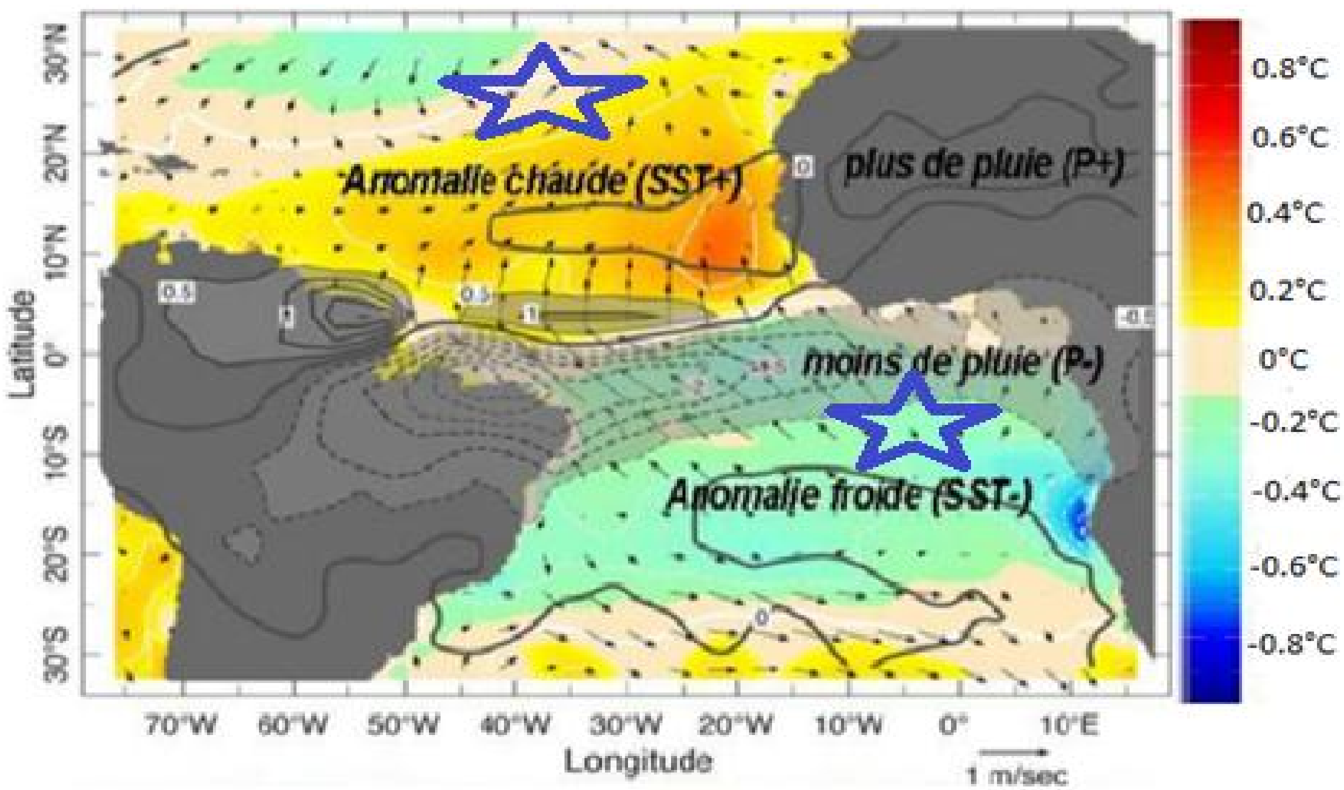
III. Results

IV. Conclusion and Perspectives

Overview of the meridional mode

❖ Characterized by an interhemispheric SST gradient (**Warm SST in NTA** and **Cold SST in STA**).

❖ Could affect the SST in cold tongue region (Lubbecke *et al.*, 2012; Richter *et al.*, 2012) and then influence the west african monsoon.



Objectives

Improve and build models of oscillatory dynamics of the tropical Atlantic.

1. Highlight the key processes responsible for the meridional mode oscillation.

2. Build a conceptual model for the meridional mode oscillation.

3. Clarify the connection processes with the equatorial mode and include this connection in a conceptual model.

Why are we interested by a conceptual model?

Conceptual models allow:

1. to isolate the keys processes giving rise to the interannual modes without interfering with others processes included in the coupled ocean-atmosphere general circulation models.

2. to avoid the need for large-scale computing resources (limited in Africa countries) normally associated with the sophisticated models.

Delayed/ Recharged oscillator models improved our understanding of ENSO in the Pacific.

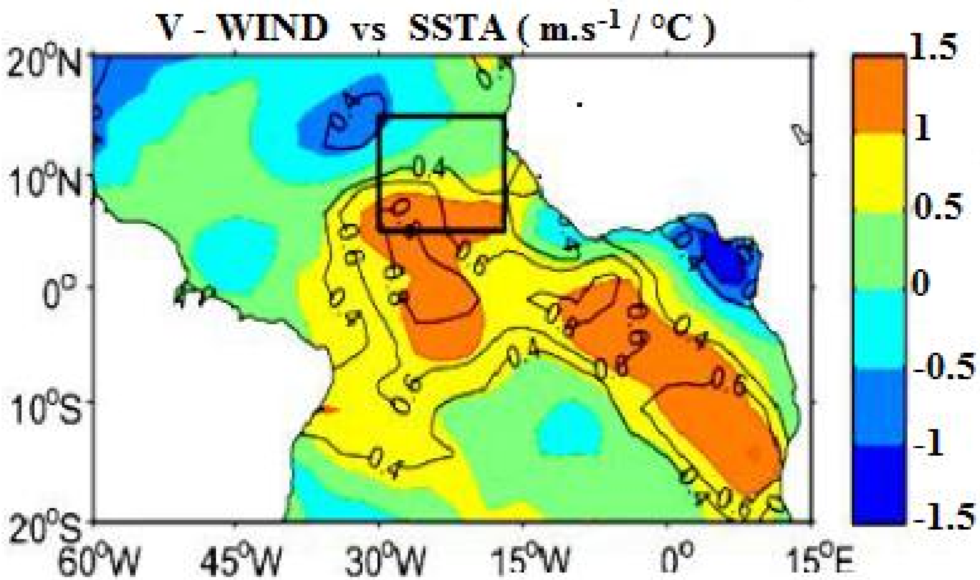
Results 1

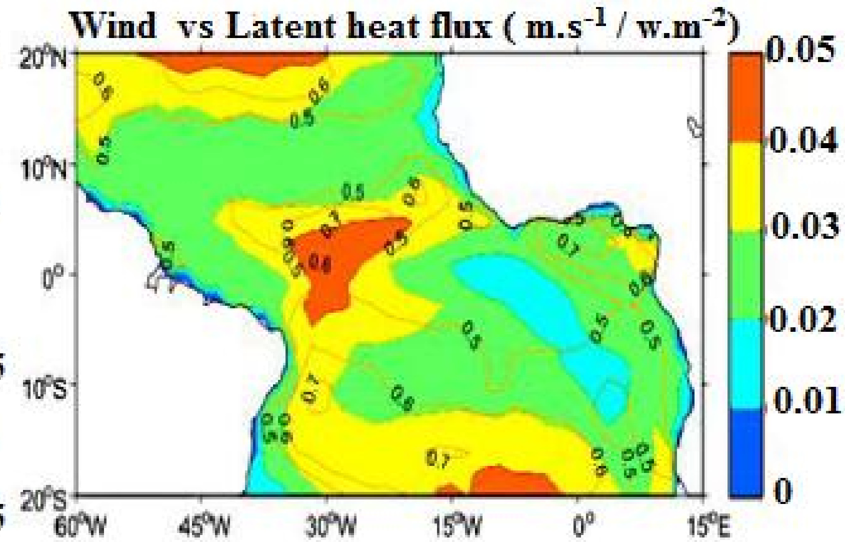
1. Key processes responsible for the oscillations of the meridional mode.

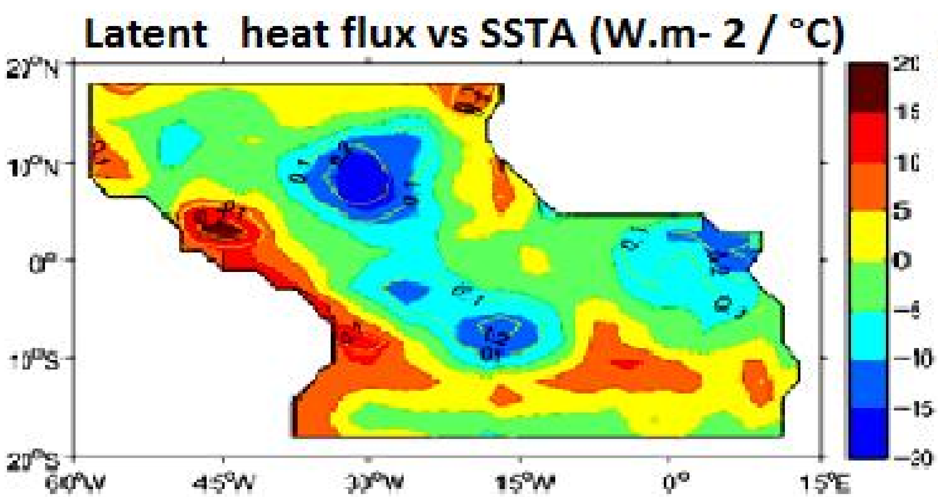
Meridional mode as a self-sustaining mode

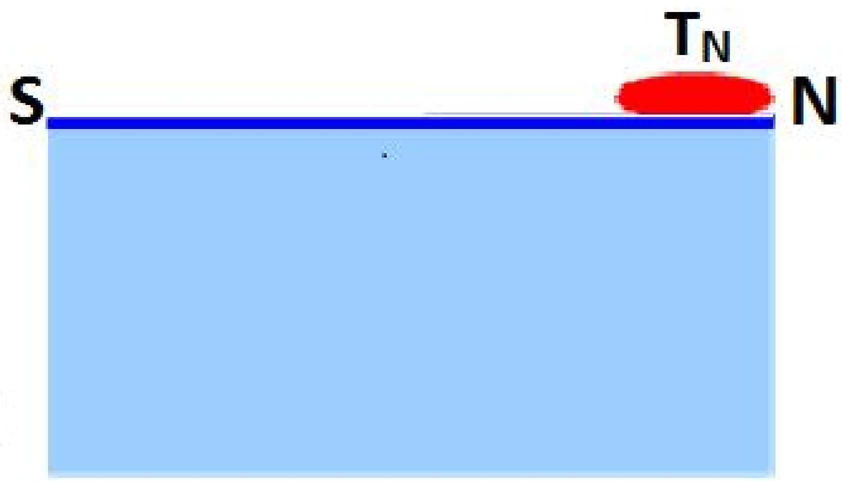
- ❖ Ocean-atmosphere coupling between: SST, V-Wind and Latent heat flux
- ❖ Local convection & WES positive feedback

(NCEP–NCAR reanalysis)









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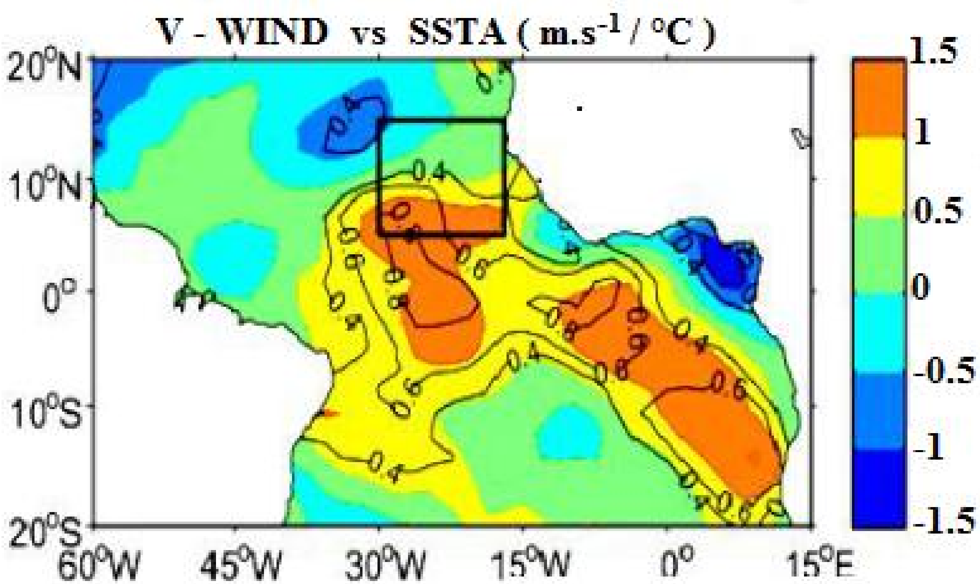

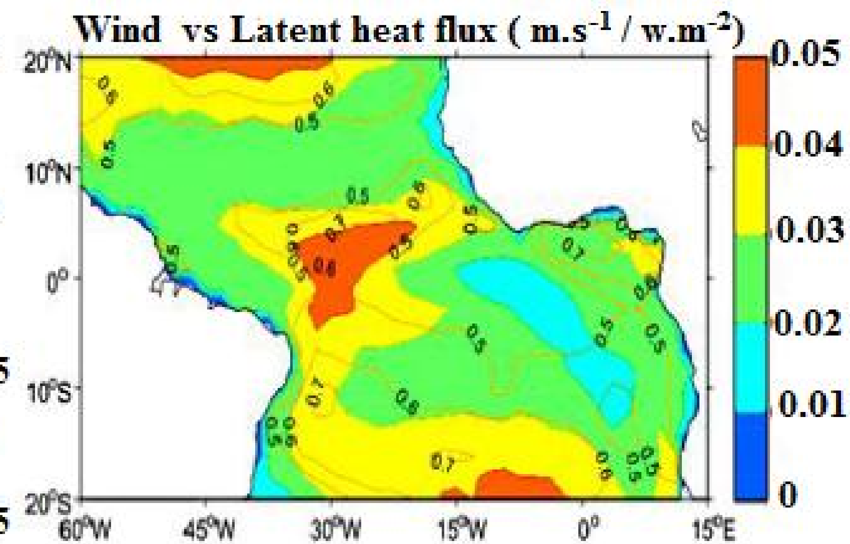

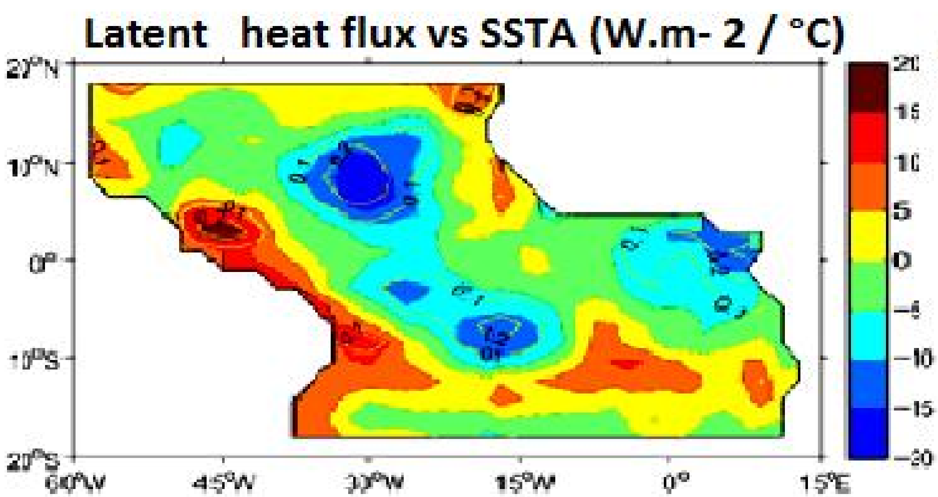

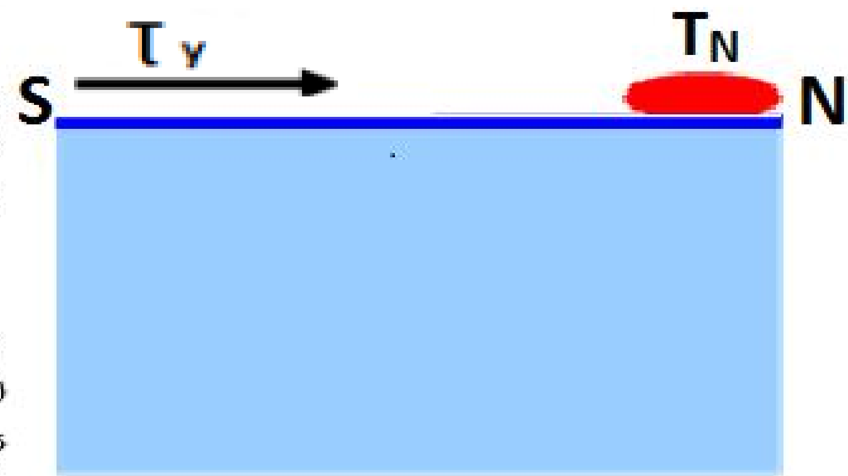

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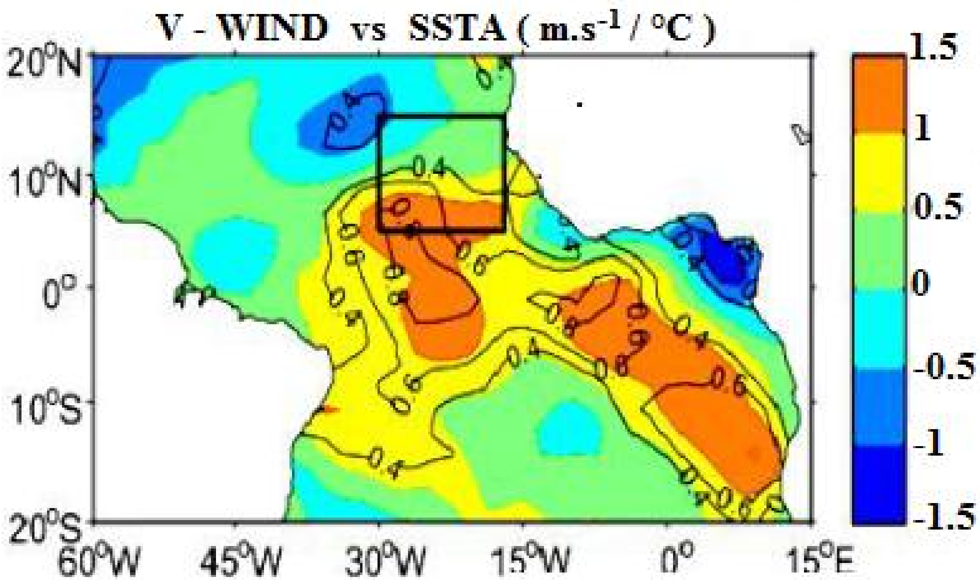

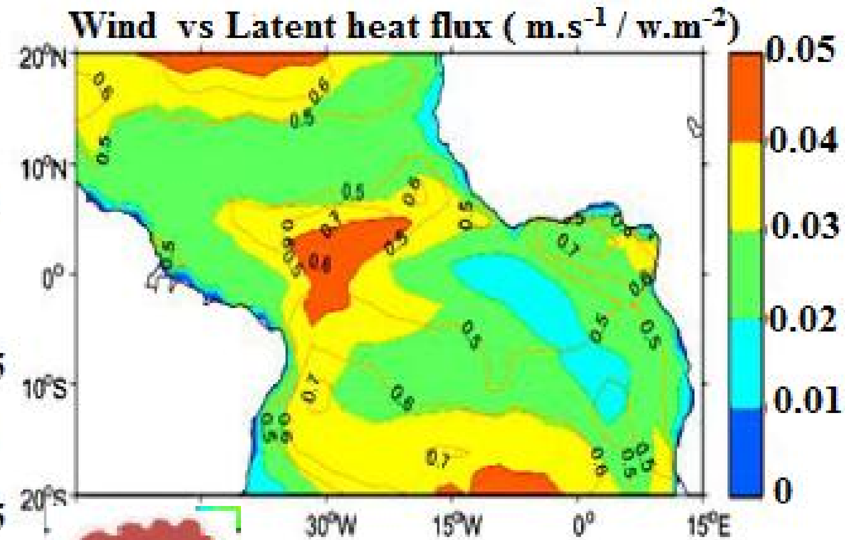

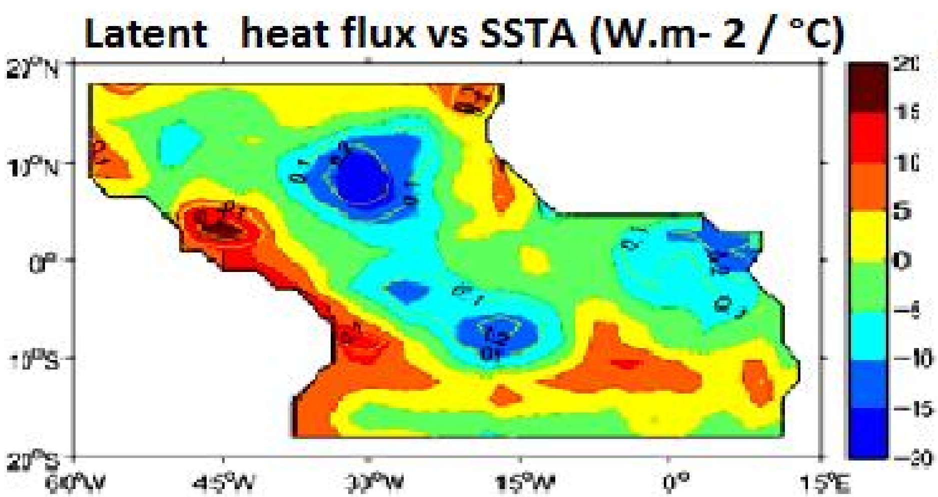

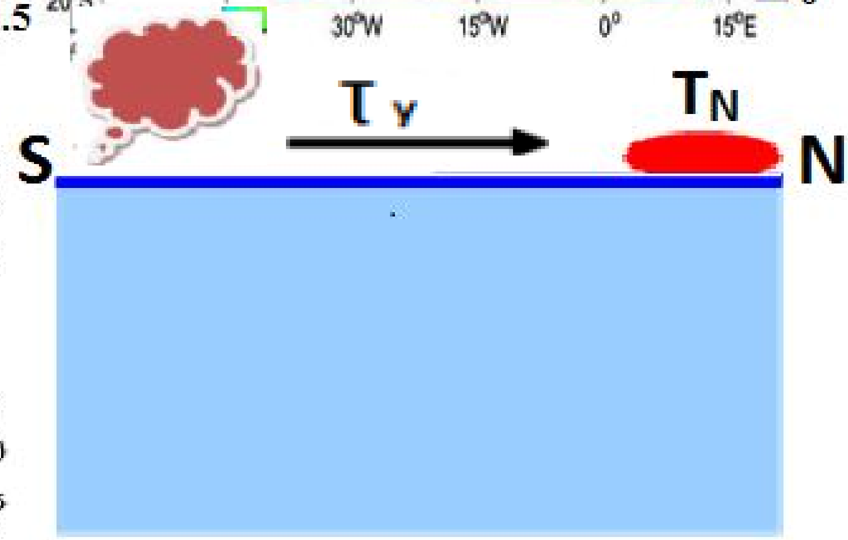

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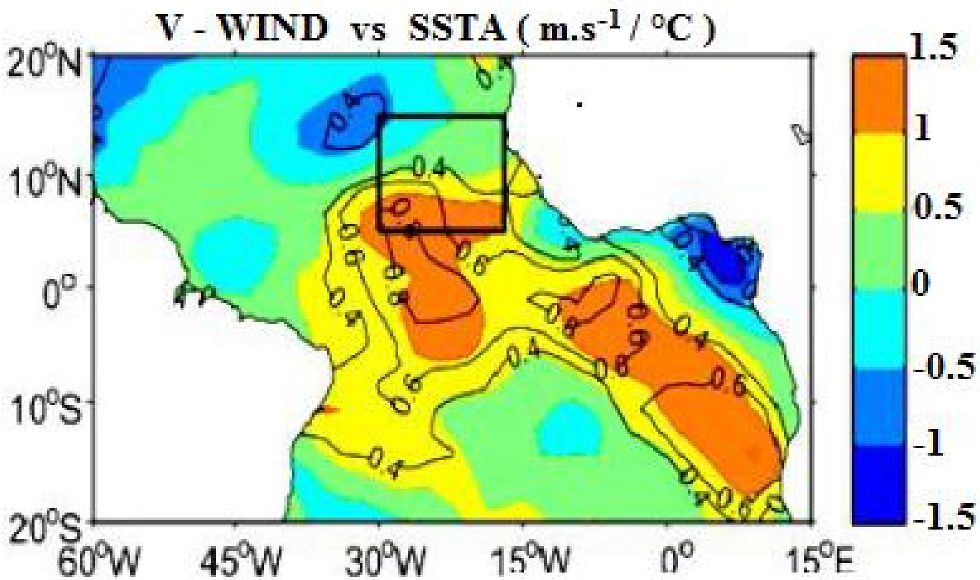

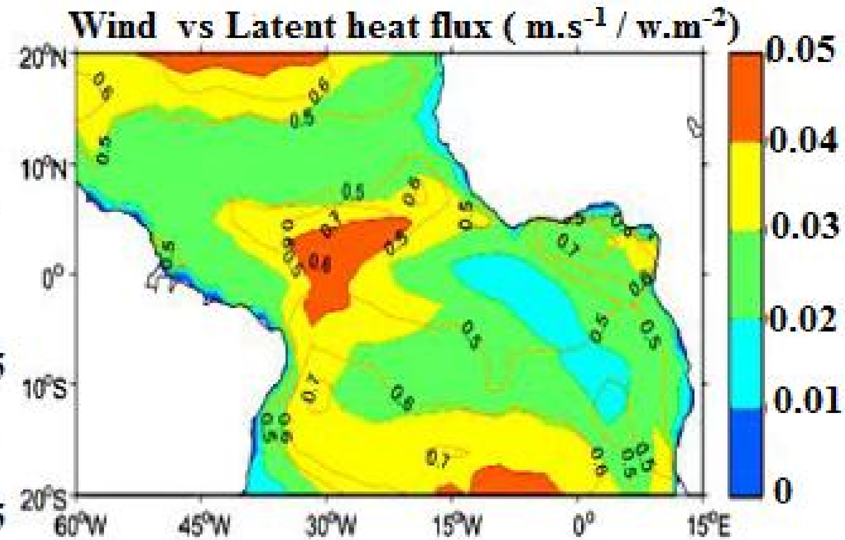

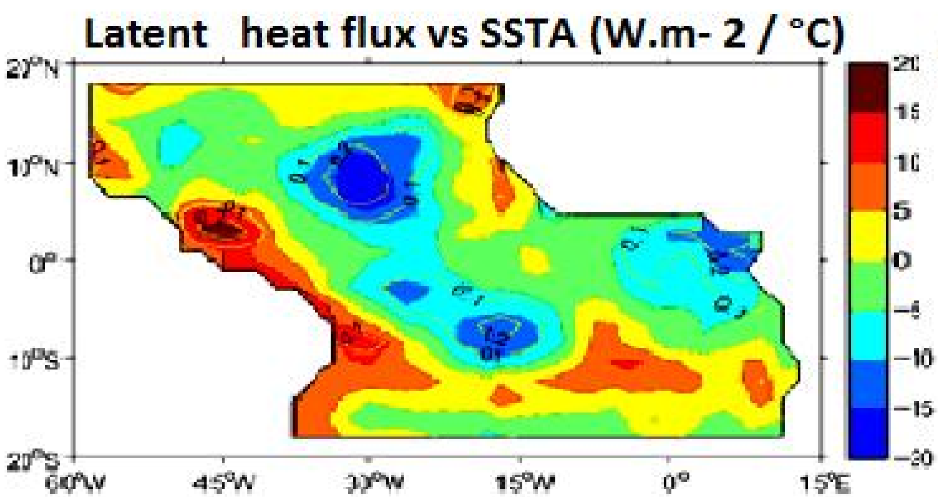

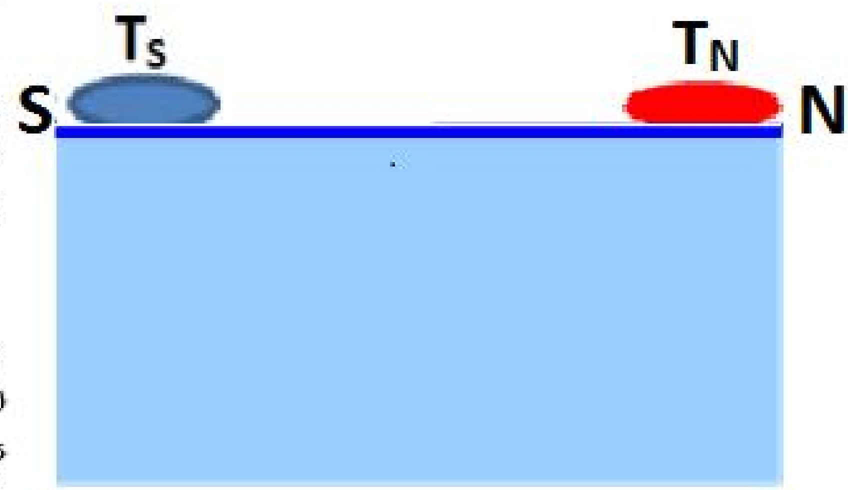

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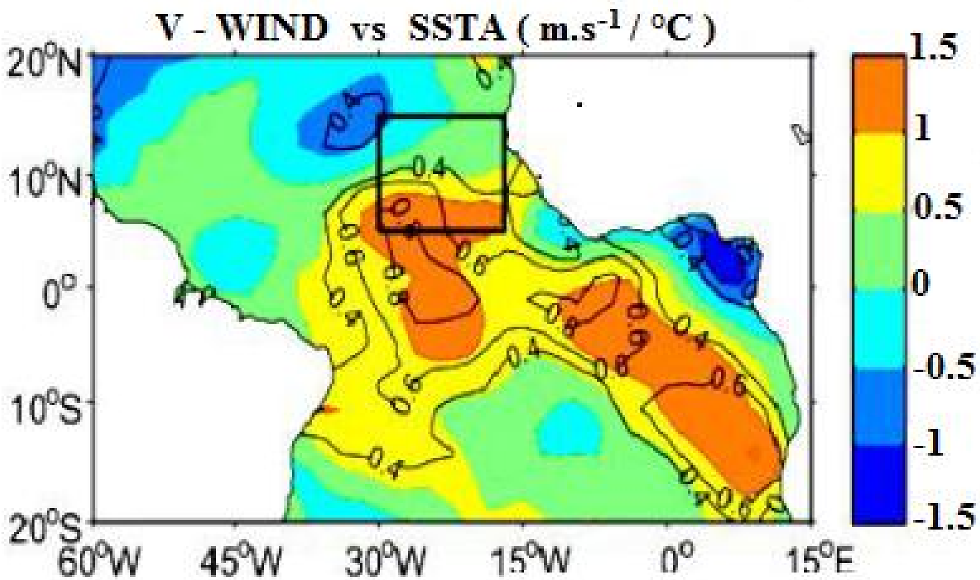
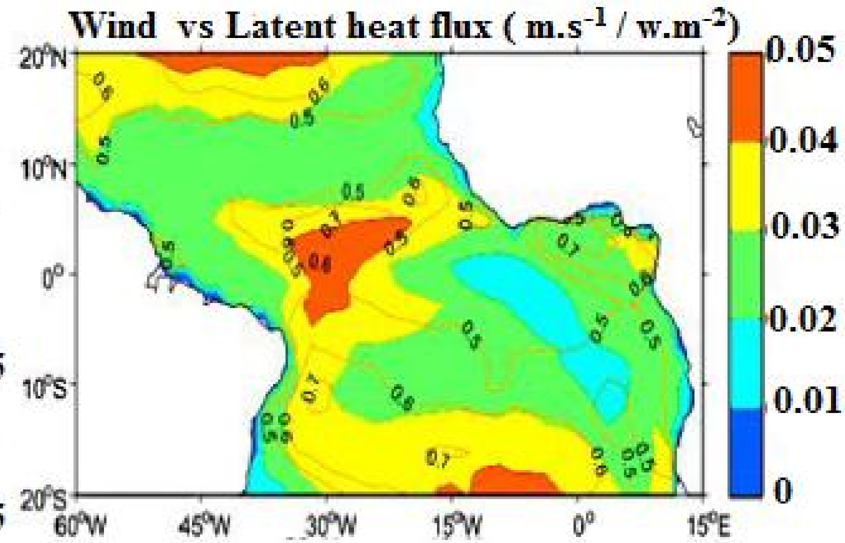
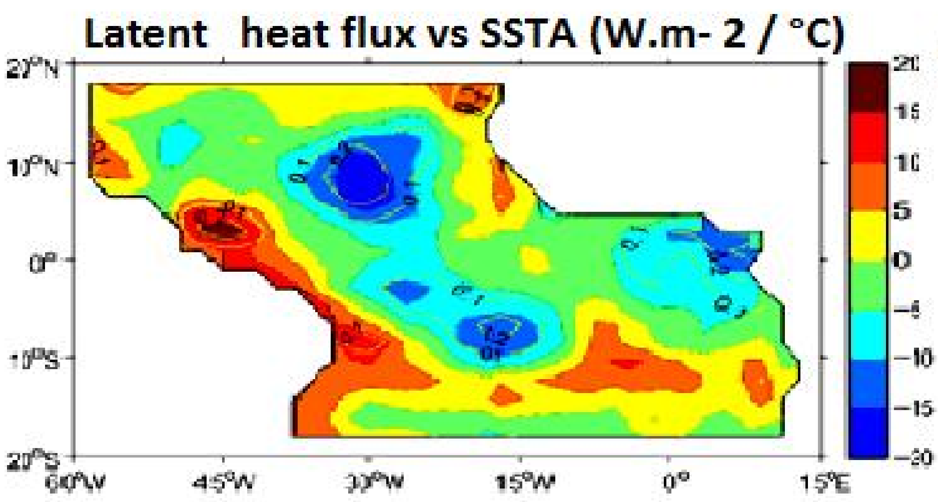
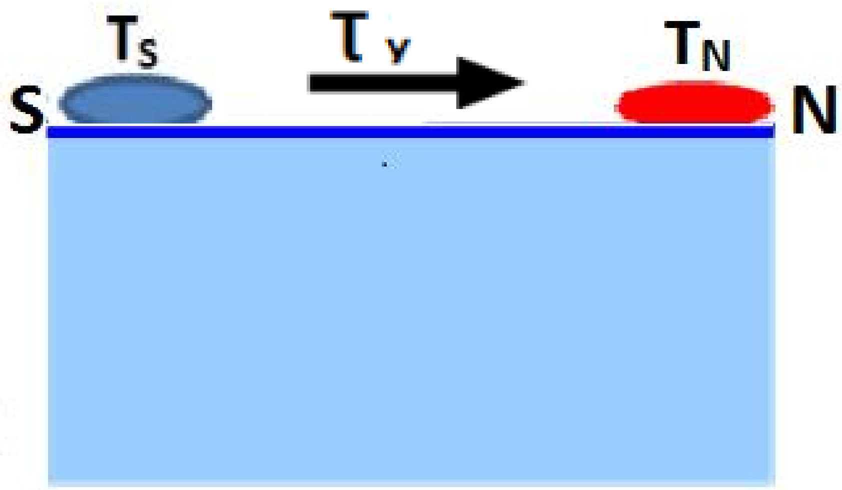








Results 2

2. Modelling of the meridional mode oscillation in conceptual framework.

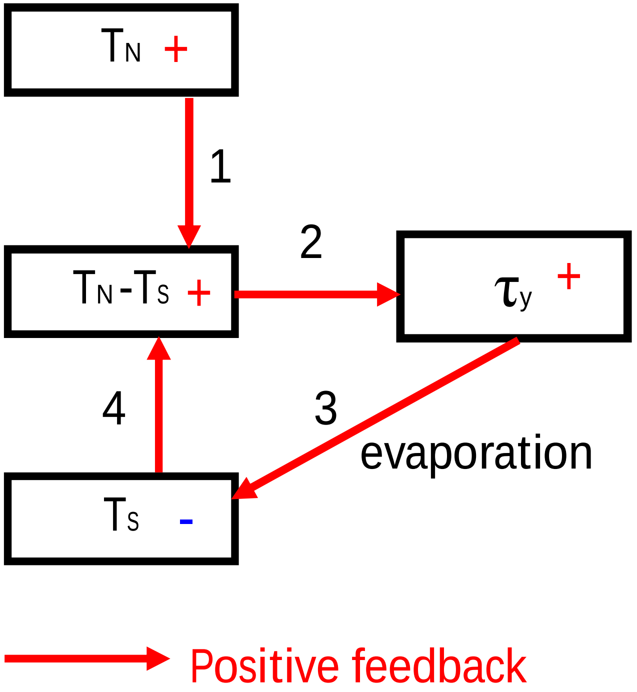
Model schematics and its formulation

Let's consider that: **T(t) = T_N(t) - T_S(t)** is the meridional mode index.

Positive WES feedback

$$\frac{dT}{dt}(t) = \alpha T(t)$$

❖ **T(t)** exponentially grows!



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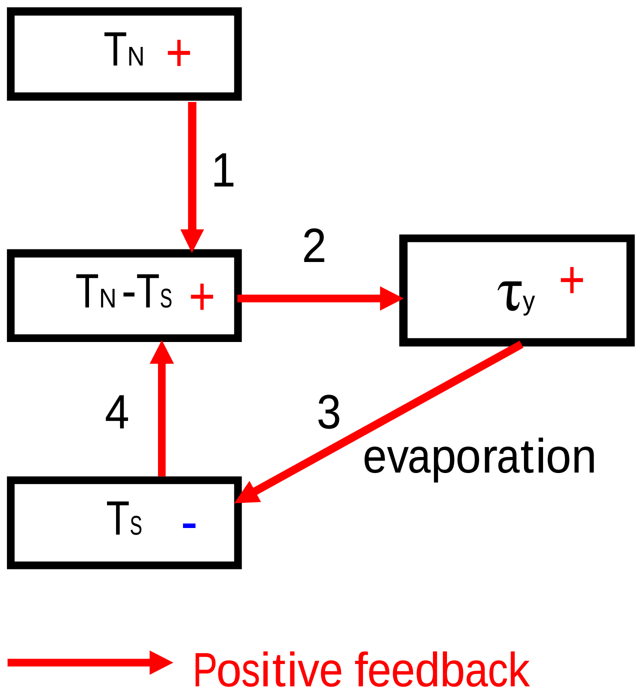
Let's consider that: $\mathbf{T(t) = T_N(t) - T_S(t)}$ is the meridional mode index.

Positive WES feedback

$$\frac{dT}{dt}(t) = \alpha T(t) - \beta T^3(t)$$

- **T(t)** exponentially grows!
- $\beta T^3(t)$ limits the grow rate. (due to the convection associated with the ITCZ)



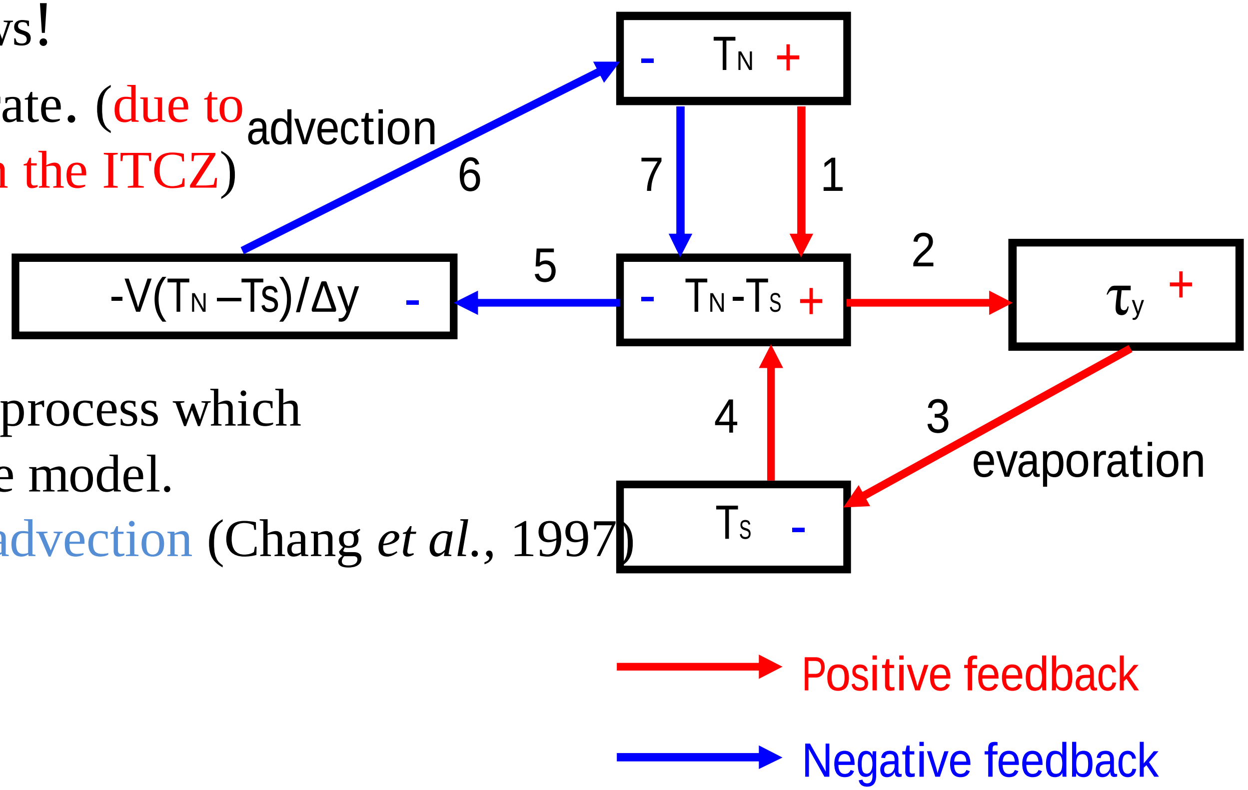
Model schematics and its formulation

Let's consider that: **T(t) = T_N(t) - T_S(t)** is the meridional mode index.

Positive WES feedback | **Negative feedback**

$$\frac{dT}{dt}(t) = \alpha T(t) - \beta T^3(t) - \nu T(t-\tau)$$

- **T(t)** exponentially grows!
- $\beta T^3(t)$ limits the grow rate. (due to the convection associated with the ITCZ)
- **$\nu T(t-\tau)$:** is the delayed process which provides the oscillations in the model. Generated by the meridional advection (Chang *et al.*, 1997)



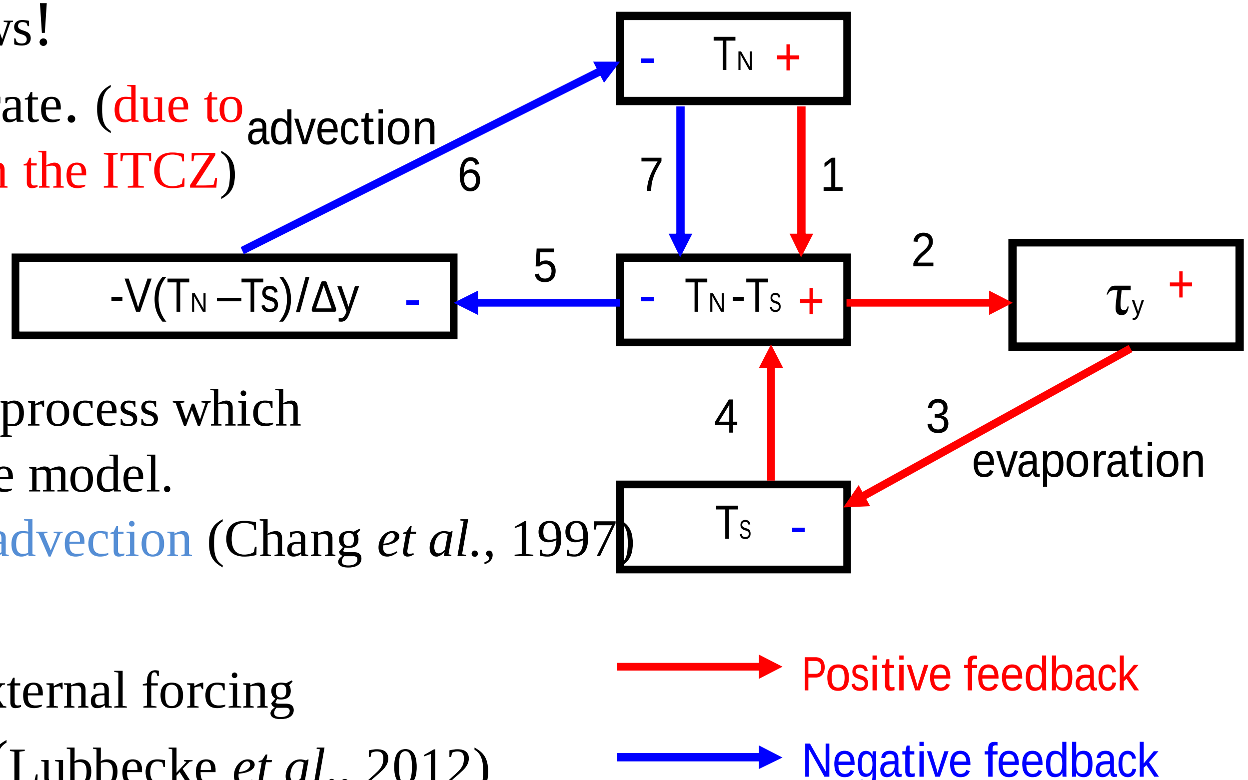
Model schematics and its formulation

Let's consider that: $\mathbf{T(t)} = \mathbf{T_N(t) - T_S(t)}$ is the meridional mode index.

Positive WES feedback | **Negative feedback** | **External forcing**

$$\frac{dT}{dt}(t) = \alpha T(t) - \beta T^3(t) - \nu T(t-\tau) + \lambda Nino(t-\sigma)$$

- **T(t)** exponentially grows!
- $\beta T^3(t)$ limits the grow rate. (due to the convection associated with the ITCZ)

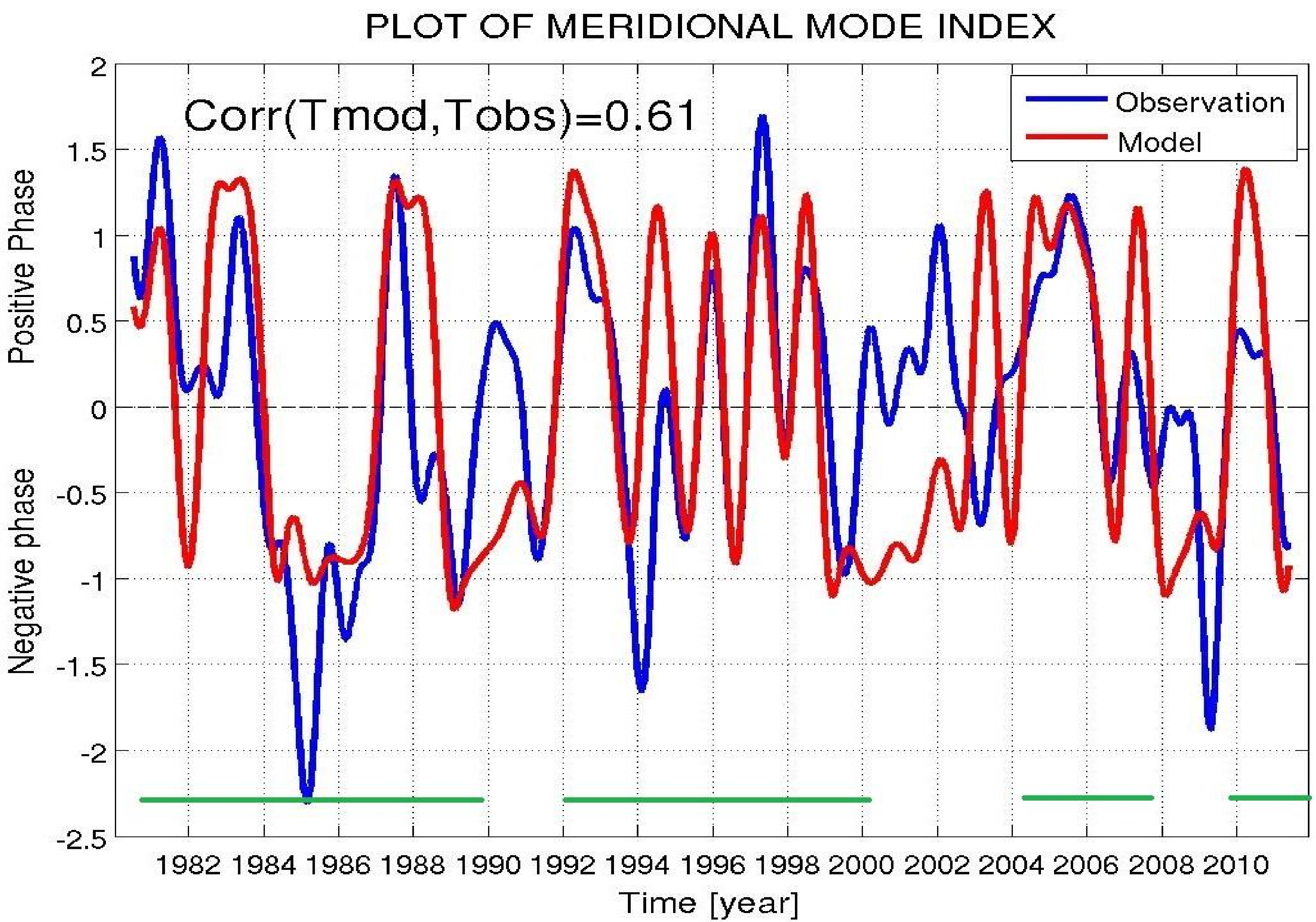


- **$\nu T(t-\tau)$:** is the delayed process which provides the oscillations in the model. Generated by the meridional advection (Chang *et al.*, 1997)

- **λNino (t-σ):** is the external forcing generated by Pacific ENSO. (Lubbecke *et al.*, 2012)

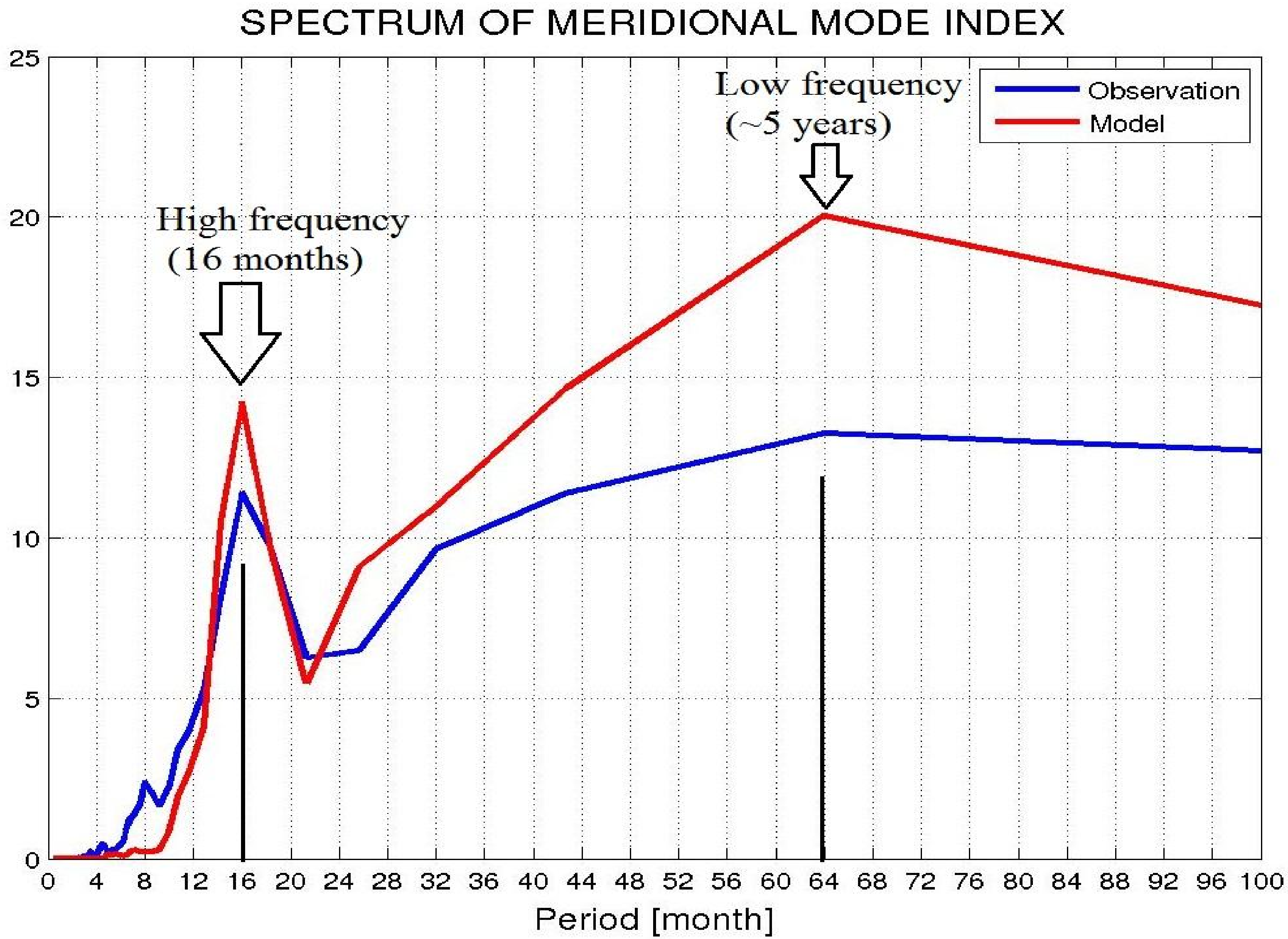
Validation of the model

Comparison between the model and observation: Correlation test of time series



Validation of the model

Comparison between the model and observation: Spectrum analysis



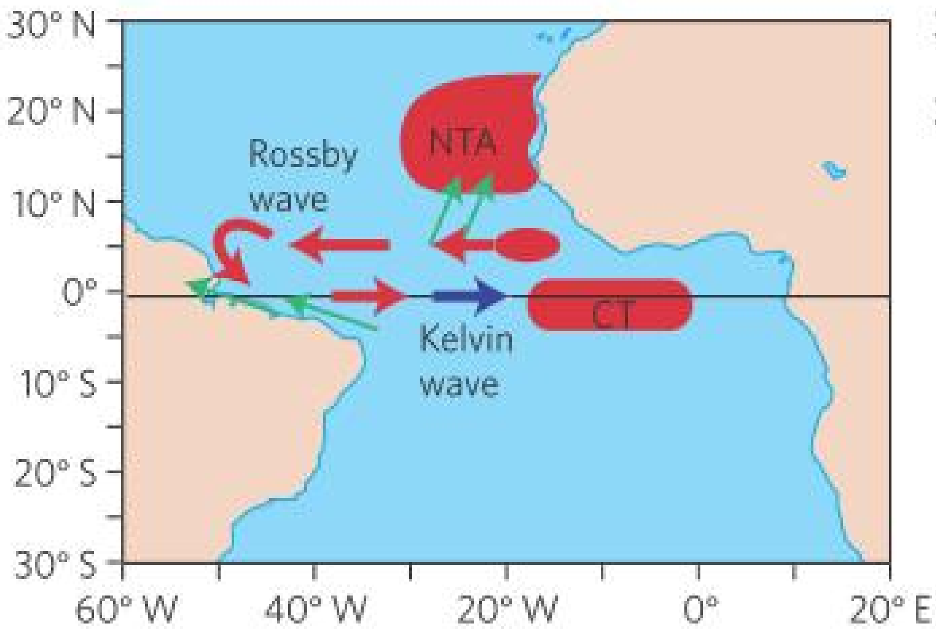
Results 3

3. Connection processes of the meridional mode with the equatorial mode

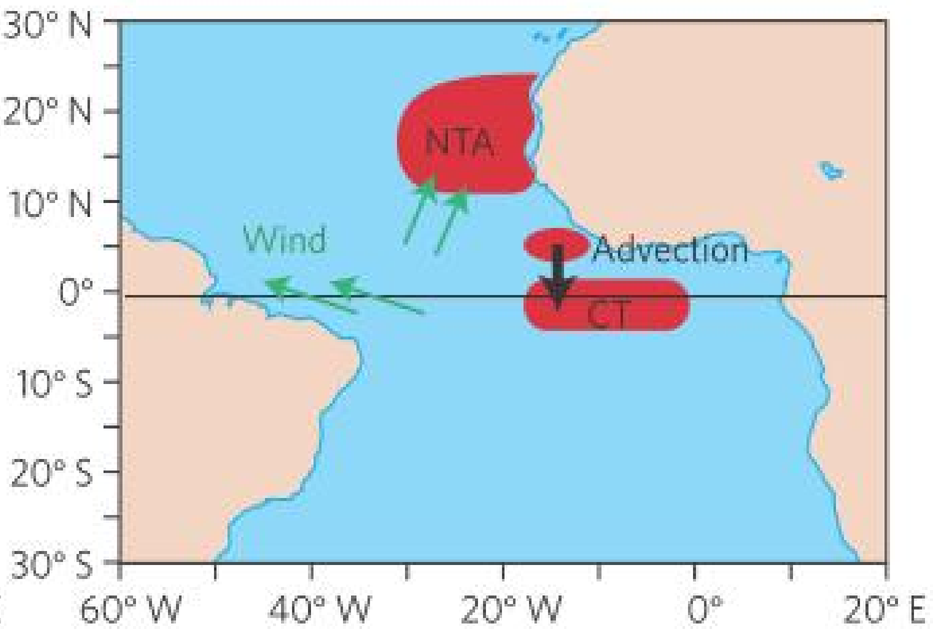
Connection processes

Some warm events in cold tongue region cannot be explained by Bjerknes feedback!
(Foltz *et al.*, 2010; Richter *et al.*, 2012; Lübbecke *et al.*, 2012)

Wave propagation



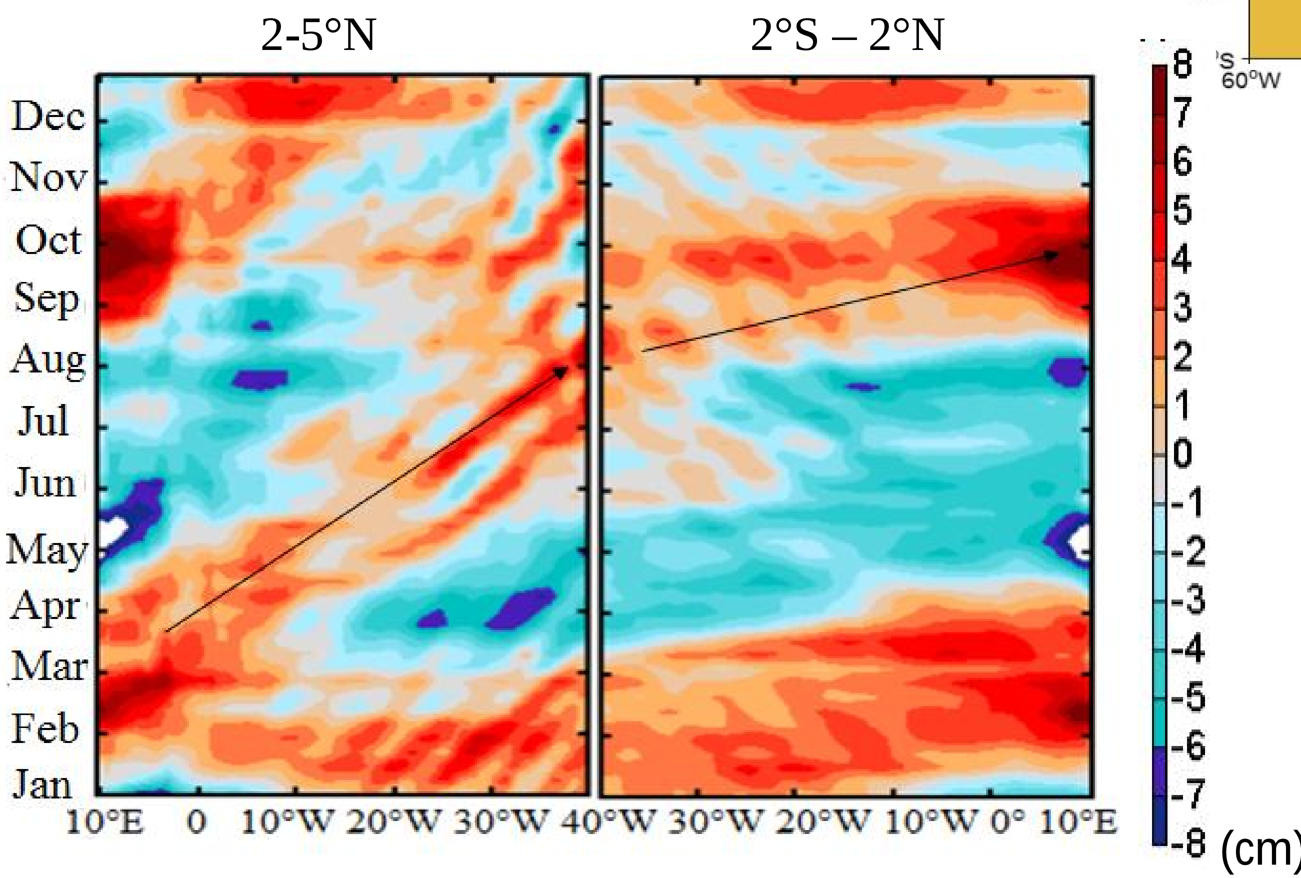
Meridional advection



Connection processes

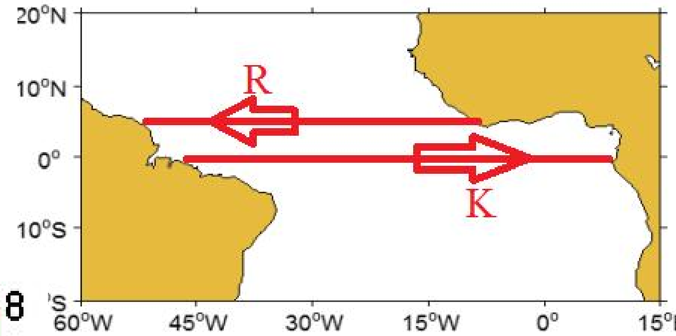
✓ Wave propagation

SLA from NEMO simulation during the positive phase of meridional mode in 1987 (also in 1979, 1998)



Westward Rossby wave (MAM)

Eastward Kelvin wave (JAS)

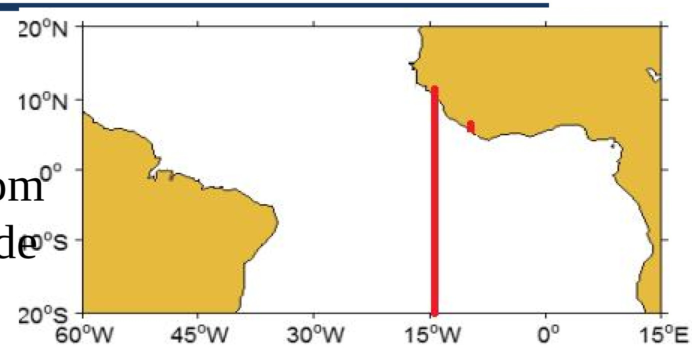


zonal sections location

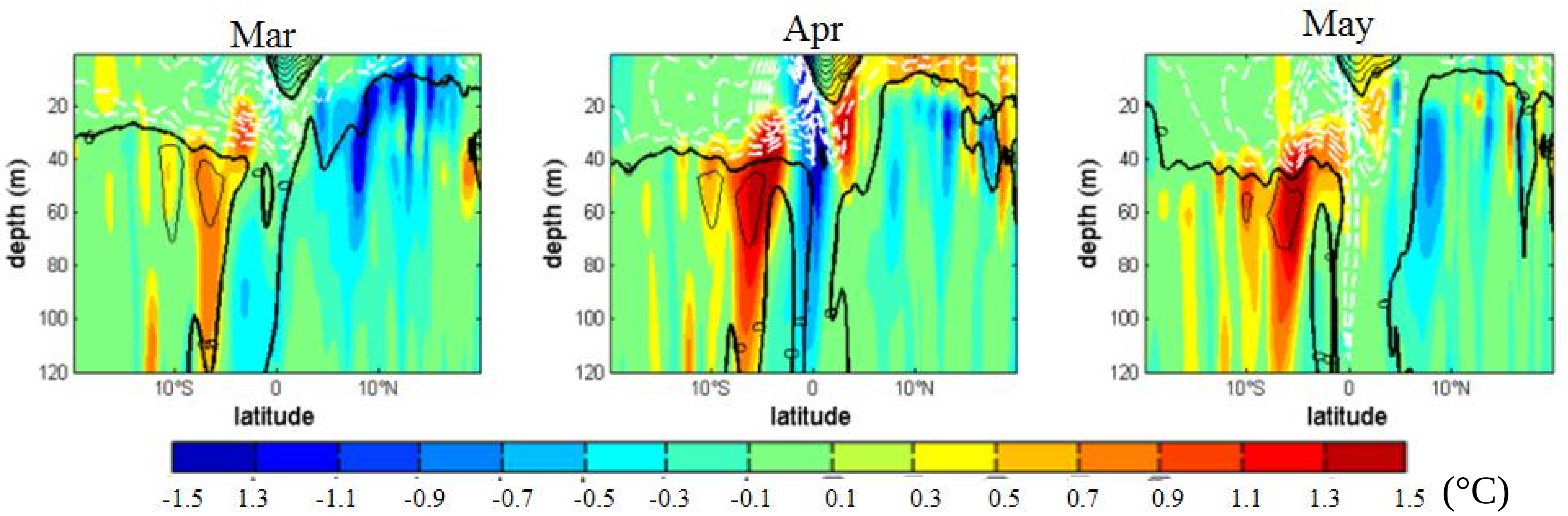
Connection processes

✓ Meridional advection

Meridional section of the temperature and the mean current from NEMO simulation during the positive phase of meridional mode in 2006 (also in 1979, 1987)



vertical section location



Meridional advection processes could be active during the positive phase of meridional mode.

Conclusion and Perspectives

1. Two main frequency peaks characterize the meridional mode oscillation:
   i. The high frequency (16 months), well reproduced by the model, can be explained by the self-sustaining processes.

   ii. The low frequency (~5 years), also well reproduced by the model, can be explained by external ENSO forcing.

2. The propagation processes (seen in 1987) and the advection processes (seen in 2006) could both connect the meridional to the equatorial mode.

We plan to test the connection between the meridional mode and the equatorial mode in a conceptual model framework, to see how it can improve our understanding of the cold tongue interannual variability.

Thank you very much!!!