INTERACTION OF THE DEEP CONVECTION WITH THE LARGE SCALE CIRCULATION IN THE MJO

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INTRODUCTION

Since its discovery by Madden and Julian, Madden-Julian Oscillation formation and its development are not very well understood. Nowadays, a large number of theories attempt to explain MJO mechanism and it is still an on-going research. Actually, this quest could be seen as the Holy Grail of tropical atmospheric dynamics !

The goal of this research work is then to further understand this physical phenomena. In particular, we are interested in the link between tropical convection and the MJO. Is there any interaction or association ?

I. ISCCP CLUSTER ANALYSIS

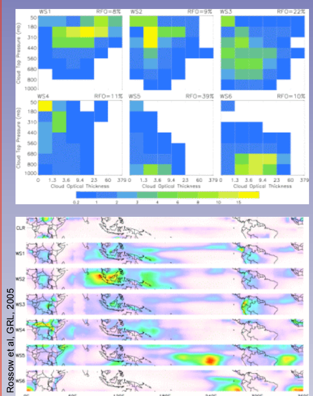

Fig.1. PC - TAU histogram pattern and Map in Tropics over 21.5 years

Rossow et al, GRL, 2005

Cluster Analysis + ISCCP D1 data

- WS1 : Deep cumulus clouds
- WS2 : Anvils clouds
- WS3 : Congestus clouds
- WS4 : Cirrus clouds
- WS5 : Shallow cumulus clouds
- WS6 : Stratocumulus clouds

An interesting approach to study interaction between convection and the MJO is to use the International Satellite Cloud Climatology Project (ISCCP) Cloud-Top-Pressure (PC) - Optical Thickness (TAU) histogram patterns (**Fig.1**, top). Using the K-Means clustering algorithm applied to 3-hourly ISCCP PC-TAU histograms for 2.5 deg latitude-longitude regions covering the whole tropics for the period of 21.5 years, we are able to describe cloud variability via these six patterns :

• We refer to these patterns or clusters as "Weather States" (WS) because these cloud property patterns are associated with distinct states of the tropical atmosphere.

• The states are numbered from "most convectively active" (WS1) to "least convectively active" (WS6) and their relative frequencies of occurrence (RFO) are shown in this upper right corner.

• The corresponding geographic distribution maps of the frequency of occurrence for each weather state are shown on the bottom of **Fig.1**, the first map being for clear sky.

• The four first Weather States correspond to regimes dominated by deep convective clouds (WS1), Cirrostratus Anvil clouds (WS2), mid-level cumulus congestus clouds (WS3) and isolated cirrus (WS4).

• The two others Weather States represent suppressed cloud regimes. WS5 defines shallow trade cumulus over the central/east pacific (as show on the map) and the WS6 characterizes marine stratocumulus off the west coast of South America and Africa.

Using these Weather States, the idea is then to look at their evolution as a function of the MJO phase using a MJO index.

II. MJO INDEX THRESHOLD

To get an MJO Index, Extended Empirical Orthogonal Function (EEOF) analysis is applied to NCEP reanalysis pentad 200-hPa velocity potential (CHI200) anomalies equatorward of 30°N during ENSO-neutral and weak ENSO winters (November-April) in 1979-2000. Negative values of Index represent enhanced convection, while positive values correspond to suppressed convection. This MJO Index is used to estimate the date (in pentads) that the peak of a MJO event passes at 10 different longitudes.

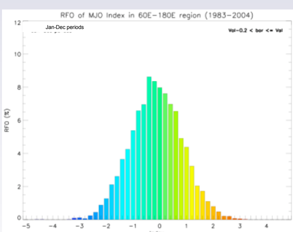

Fig.2. Relative Frequency of Occurrence of MJO Index in 60E-180E region (1983 - 2004)

The annual histogram Composite of Relative Frequency of Occurrence of MJO Index shows (**Fig.2**) :

• Quasi-Symmetric distribution of MJO Index

• Continuum of index values

• MJO signal all over the year

• Arbitrary choice of an index threshold for strong MJO event

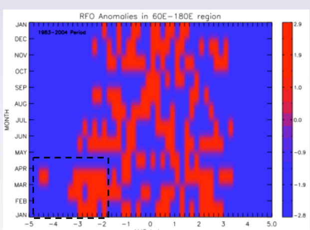

Fig.3. Relative Frequency of Occurrence Anomalies of MJO Index in 60E-180E region (1983 - 2004)

Making the difference between monthly histogram composite and annual histogram composite allow us to obtain composite of RFO anomalies of MJO Index over the year (**Fig.3**) :

• We can note more extreme positive values of RFO anomalies during the Boreal Winter activity (dashed line). This could be the signature of a strong MJO event.

• In terms of positive RFO anomalies, Index distribution becomes more narrow when we look at anomalies going from April to November. This could be the signature of a decreasing MJO activity during the Boreal Summer.

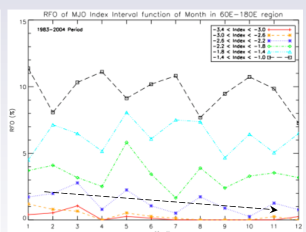

Fig.4. Relative Frequency of Occurrence of MJO Index Interval function of Month in 60E-180E region (1983 - 2004)

RFO of six different MJO index intervals as a function of months allow us to define an MJO index threshold (**Fig.4**) :

• Index threshold inferior to -1 (black dashed line) shows a permanent weak MJO signal all over the year .

• Strong MJO events mainly occur during the Boreal Winter (red and orange lines).

• First signature of a strong MJO could be seen from index threshold equal to -2.2 (blue line), where MJO activity is decreasing (black dash arrow) from January to December.

• Considering the index sampling and in order to get enough MJO events in this study, we then consider that strong MJO events occur during the Boreal Winter once MJO index is inferior to -2.2.

III. TROPICAL CLOUD REGIMES AND MJO PHASE

Weak MJO (index < -1)

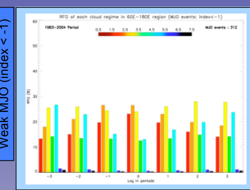

Fig.5. Relative Frequency of Occurrence of each cloud regime in 60E-180E region and 5S-5N latitude band (MJO events in November-April periods from 1983 - 2004) : MJO index < -1

Strong MJO (index < -2.2)

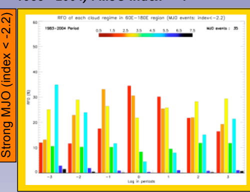

Fig.6. Relative Frequency of Occurrence of each cloud regime in 60E-180E region and 5S-5N latitude band (MJO events in November-April periods from 1983 - 2004) : MJO index < -2.2

Using the Weather State classification and a MJO Index, composite RFO bar-charts of cloud regimes are formed at seven lag time (in pentads) with respect to MJO phase index for both weak (**Fig.5**) and strong (**Fig.6**) MJO cases :

• Each color bar corresponds to a weather state. The first three weather states defined as convective cloud regimes are depicted respectively with red (WS1), orange (WS2) and yellow (WS3) color bars. The green bar (WS4) shows cirrus regime evolution. Finally, bluish bars (WS5 and WS6) represent suppressed cloud regimes while the black one (WS7) is for clear sky.

• Whatever the Index threshold, the RFOs of the deep convection (red bar) and anvil regime (orange bar) increase significantly to the peak of MJO phase. After the peak, the occurrence of these cloud regimes decreases gradually. Besides, in the meantime, the small-scale convection with shallow cumulus regime dominate several weeks before the MJO peak, decreasing before the peak, and increasing after it.

• We can note that the RFO of the cirrus regime is almost constant with MJO phase, suggesting that the presence of isolated cirrus is not associated with convective activity.

• Moreover, the first main difference between these both cases is the RFO value of deep convection at the MJO peak. In the stronger case, RFO of deep convection is 10% more than in the weak case.

• Besides, suppressed cloud regimes decrease more dramatically in the stronger case, in particular for WS5 or shallow cumulus clouds.

• Finally, thanks to the Cluster Analysis and using this MJO index, we are able to characterize organized and disorganized convection as function of the MJO phase. These results then suggest a strong interaction between MJO and deep convection.

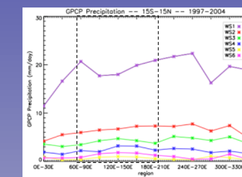

Fig.7. Composite of precipitation in Tropics (1997 - 2004)

Composite of precipitation in Tropics sorted by weather states (**Fig.7**) shows that :

• Rainfall is mainly due to WS1 which corresponds to deep convection or cumulus clouds. Knowing that WS1 and WS2 go always together since WS2 represents anvil clouds which are horizontal extension of cumulus clouds, tropical rainfall are clearly dependent of the RFO of these two weather states in the Tropics.

• Precipitation are nearly constant in Tropics whatever the longitude, except a drop observed over Africa due to less WS1 precipitation. In particular, precipitation is more regular in the Indo-pacific warm "pool" (dashed frame).

Knowing RFO of each cloud regime as a function of MJO phase (**Fig.5** and **Fig.6**), we can sort precipitation as a function of RFO of cloud regimes and MJO phase. Composites of precipitation are then obtained for both weak and strong MJO (**Fig.8**) :

Total precipitation (left figures)

• Total precipitation shows a MJO phase dependence whatever the MJO index threshold.

• A Maximum of total precipitation occurs at the MJO peak in both MJO cases.

• However, in the stronger case, intensity of total precipitation is very well marked while the distribution is almost flat for a weak MJO.

Precipitation and cloud regimes (right figures)

• It is interesting to see that precipitation contribution is mainly due to deep convection (red bar) whatever the lag time.

• Moreover, precipitation increases at the MJO peak because the RFO of these cloud regimes increases strongly.

• Finally, intensity of precipitation is maximum at the MJO peak and is almost twice more in the strong MJO case.

Weak MJO (index < -1)

Strong MJO (index < -2.2)

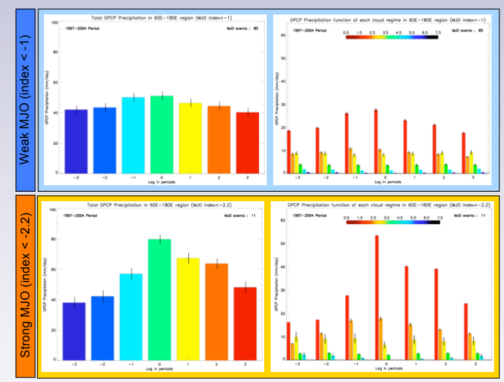

Fig.8. Composite of GPCP precipitation and cloud regimes in 60E-180E region and 5S-5N latitude band (MJO events in November-April periods from 1997-2004)

CONCLUSION

MJO Index

• Continuum of MJO Index values : permanent MJO signal all over the year

• MJO Index thresholds : weak and strong MJOs

Weather State variation with MJO

• Characterization of organized and disorganized convection as a function of MJO phase

• Presence of isolated cirrus clouds is not associated with convective activity

• Most of precipitation come from deep convection

• Intensity of precipitation is almost twice more in strong MJO case

Strong interaction between MJO and deep convection

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