# Characterizing 3D Structure of Convective Momentum Transport Associated with the MJO Based on Reanalyses

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Acknowledgements
This research was supported via NSF/Climate & Large-scale Dynamics

# Convective Momentum Transport

- **Momentum equation**

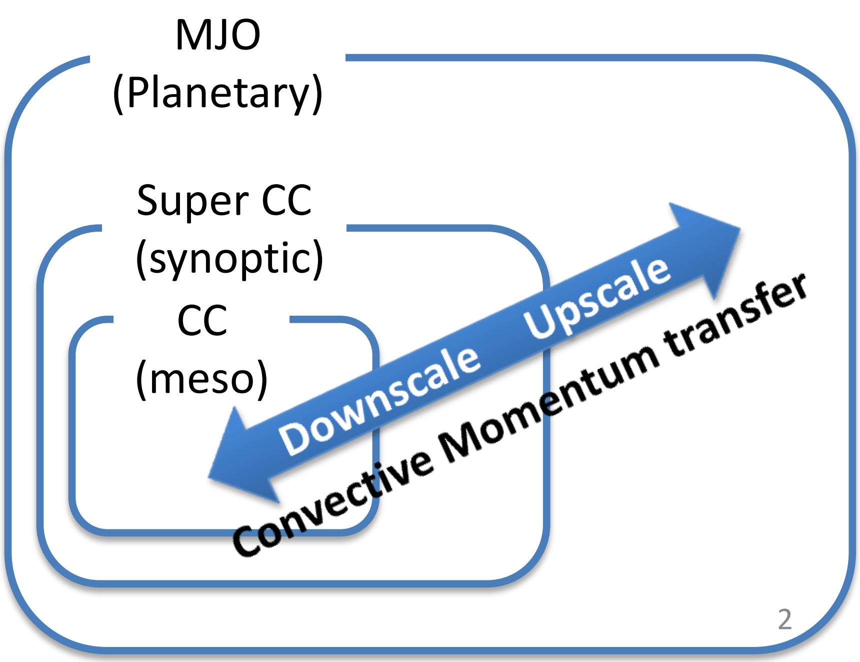
$$\frac{\partial \overline{\mathbf{v}}}{\partial t} = adv + PGF + f + \boxed{X}$$

**Acceleration due to all residual processes i.e. CMT (Process of conversion of convective available PE to horizontal KE in the flow field)**

- **Eddy momentum flux convergence due to convection**

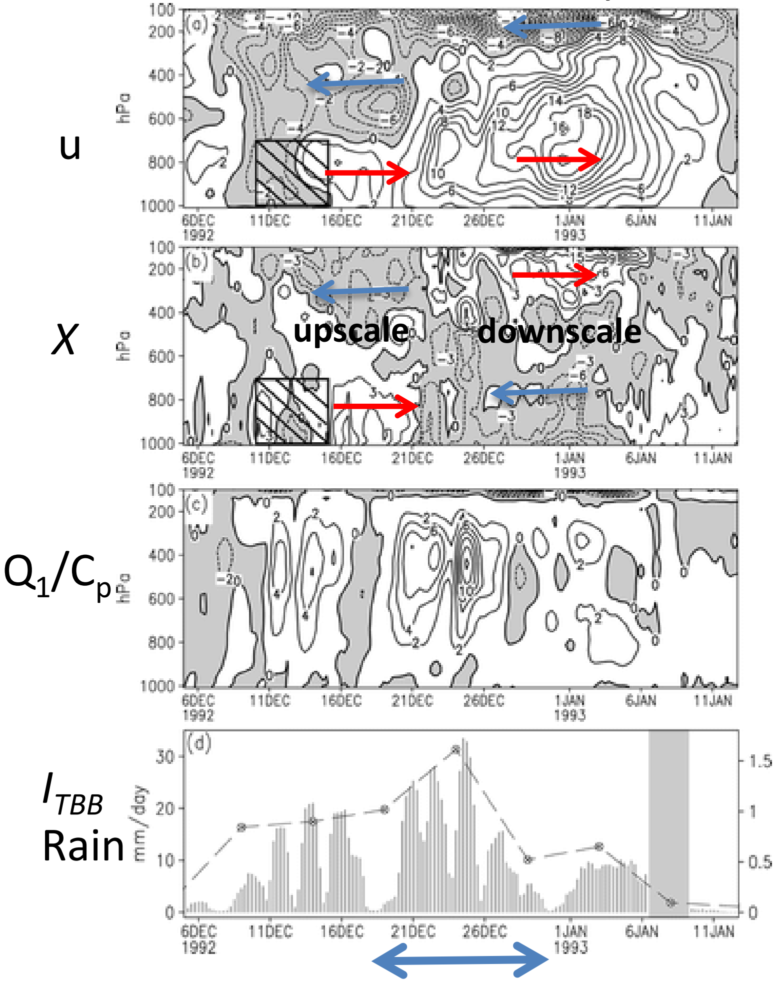
$$X = -\nabla \cdot \overline{\mathbf{v}'\mathbf{v}'} - \frac{\partial}{\partial p}\overline{\mathbf{v}'\omega'}$$

$$\boxed{\approx -\frac{\partial}{\partial p}\overline{\mathbf{v}'\omega'}}$$



# CMT: Roles for the MJO in observation

MJO1: late Dec-early Jan

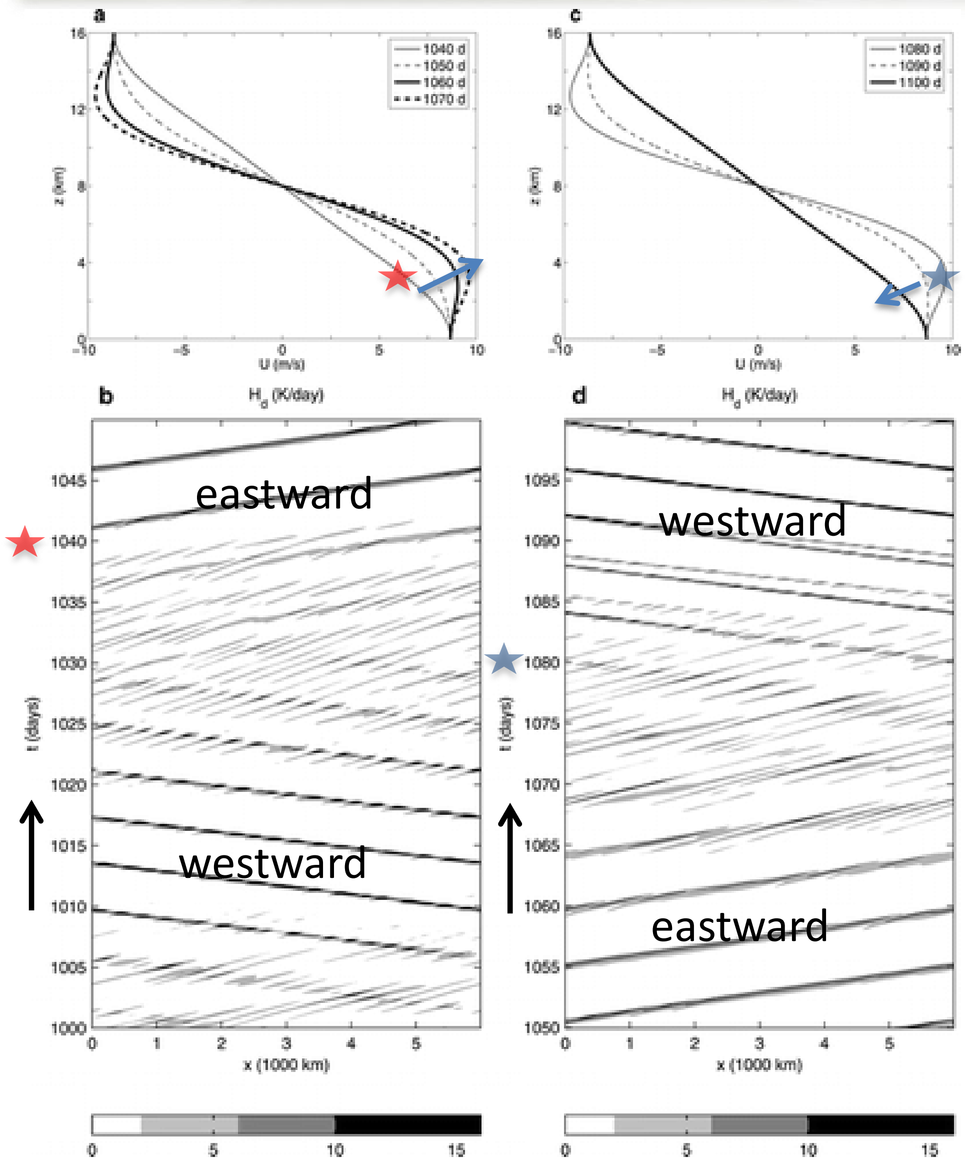



Tung and Yanai (2002a,b) - TOGA-COARE

- *X* and local time change of u have the same order
- of magnitude of 3-6 m/sec/day.
- Upscale: help large scale maintain vertical shear
- Downscale: decelerate the large scale-flow and
- Reduce wind shear by vertical mixing of momentum

# A simple Dynamical model with CMT

Majda and Stechmann (2009)




Two-way interaction between the MJO and synoptic-scale CCWs

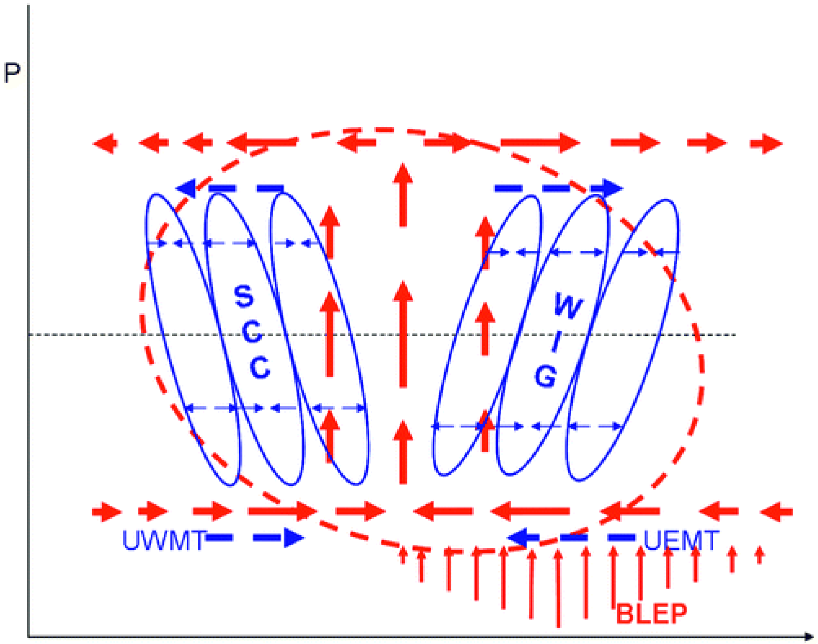
$$\frac{\partial \bar{U}}{\partial T} + \frac{\partial}{\partial z}\langle \overline{w'u'} \rangle = 0$$

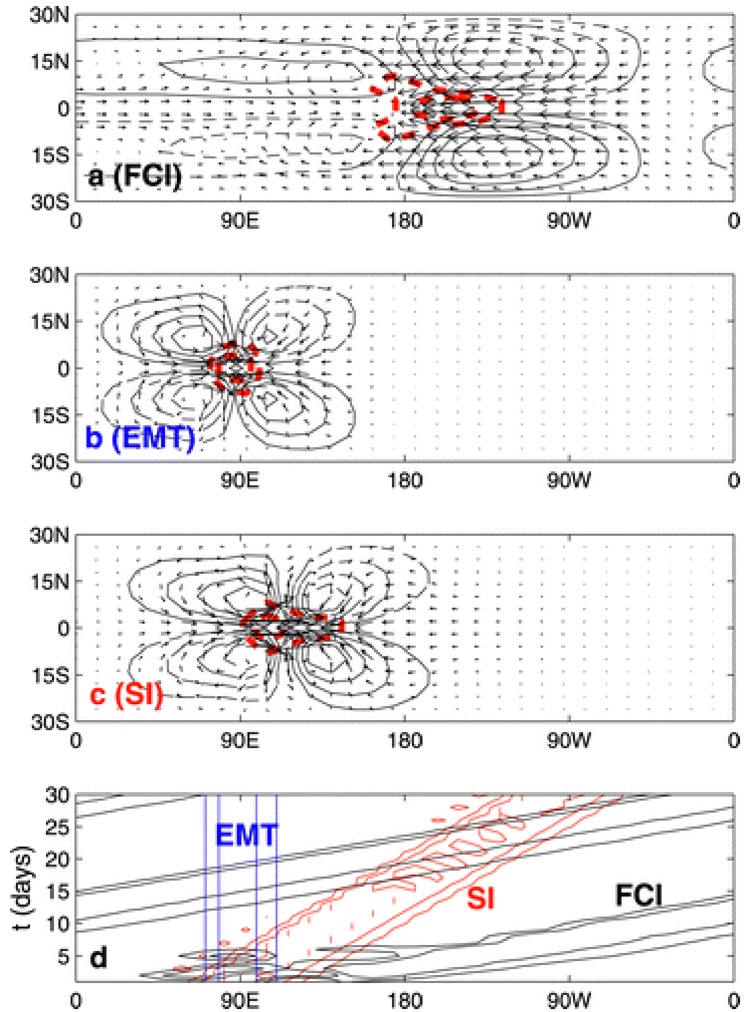
$$\frac{\partial u'}{\partial t} + \bar{U}\frac{\partial u'}{\partial x} + w'\frac{\partial \bar{U}}{\partial z} + \frac{\partial p'}{\partial x} = S'_{u,1}$$

# Theoretical model with scale interaction

Wang and Liu (2010)

Combined effect of frictional CISK (or boundary layer frictional convergence instability, FCI) and Eddy momentum transport (EMT)

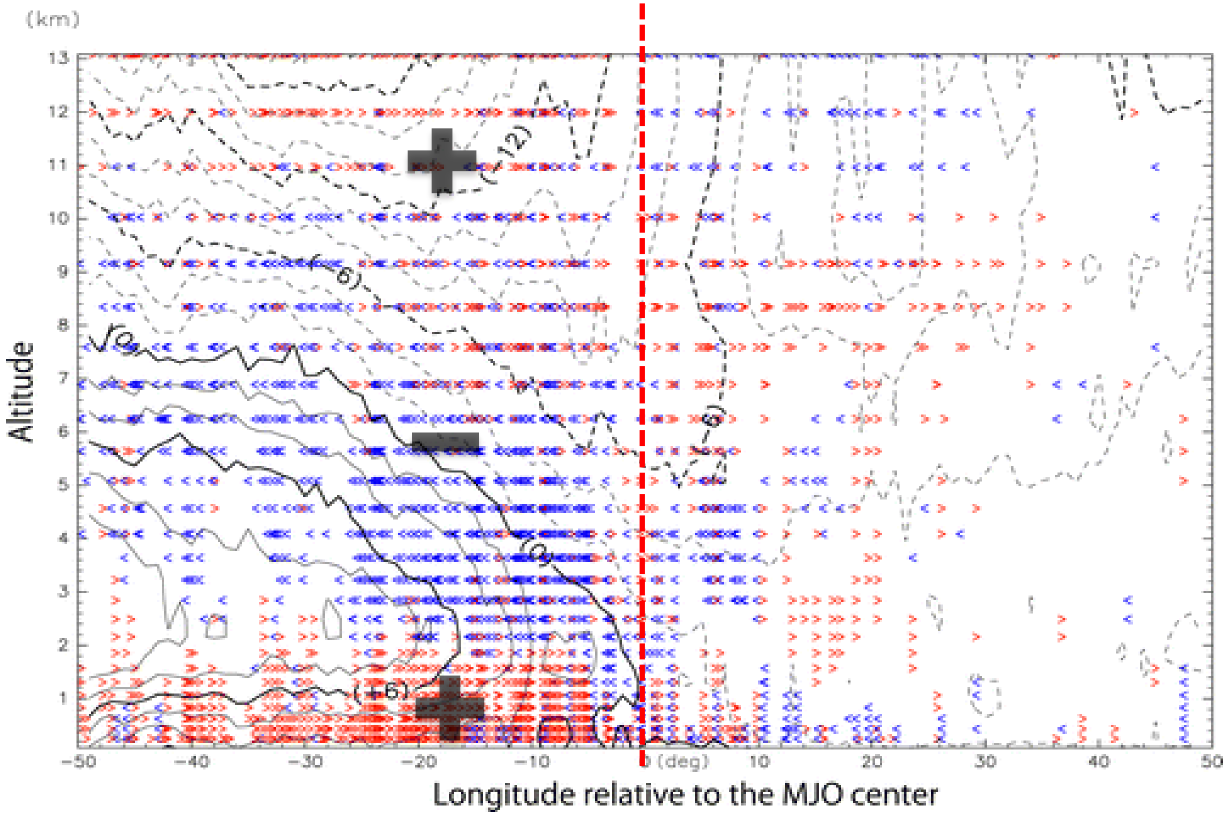



Red ~MJO, blue ~ CCWs

# Cloud Resolving Model: NICAM

Miyakawa et al (2012) – 7 km mesh NICAM output / 32 days starting from 15 Dec 2006



# Scientific approaches to the interaction between CMT and the MJO

| Observation: TOGA COARE -> **limited case over WP** | |
|---|---|
| Tung and Yanai (2002,a,b) | Upgradient effect of zonal components of CMT associated with Rainbands near the leading edge of the lower-tropospheric westerly winds |

| Idealized model -> **Need observational evidence** | |
|---|---|
| Majda and Stechmann (2009): Multicloud model+CMT | Wang and Liu (2010): PBL friction convergence instability + CMT |

| Cloud resolving Model -> **limited case due to expensive computing cost** | |
|---|---|
| Miyakawa et al. (2012) | 3-layered structure |

# Objectives

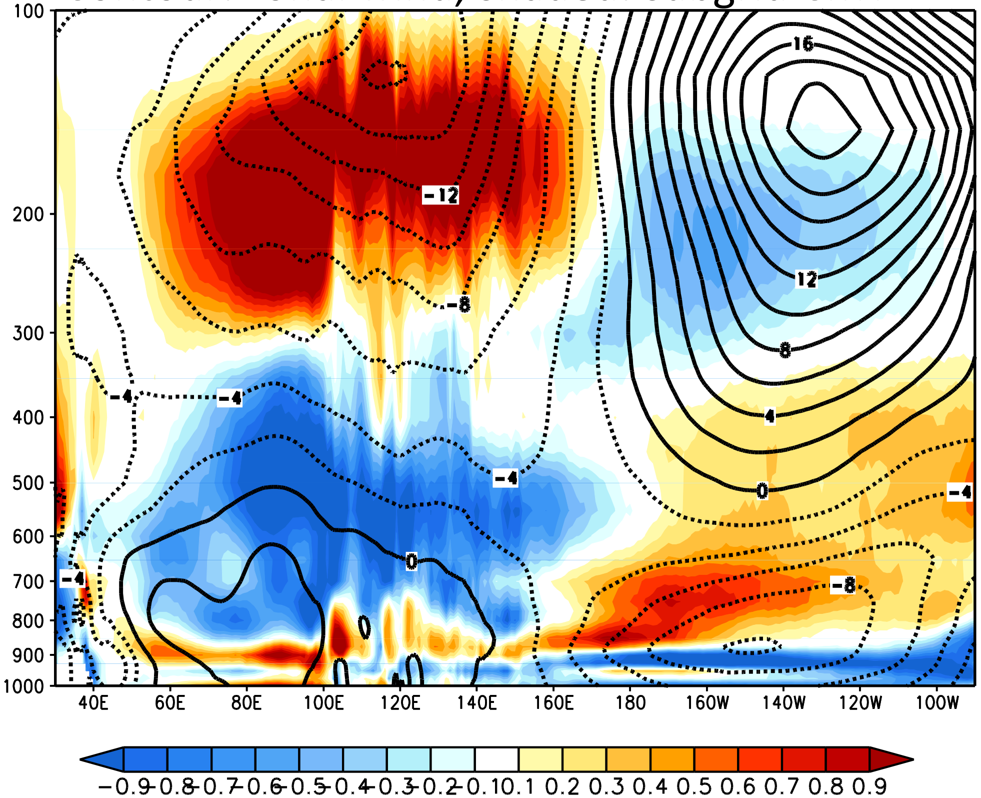
Characterize 3D CMT structure and assess the potential role of CMT for MJO

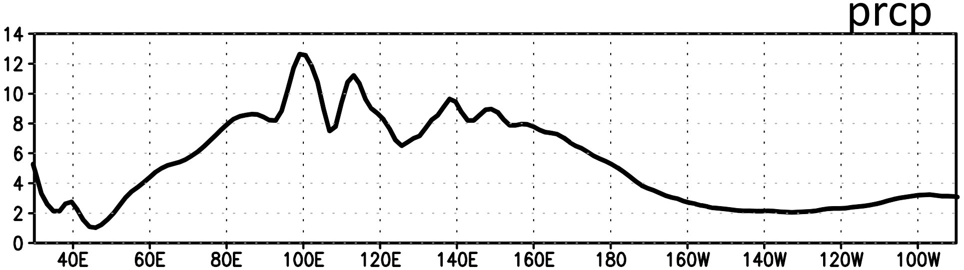
- Generalize characteristics of CMT structure and its relationship with the MJO by using long term period of analysis (13 years)
- Comparison between IO and WP

| | Resolution | Analysis period | CMT parameterization* |
|---|---|---|---|
| NOAA's Climate Forecast System Reanalysis (CFSR) | 0.5 degree, 6hr | 1998-2010 | O |
| ECMWF-the Year of Tropical Convection (ECMWF) | 0.5 degree, 6hr | 05/01/2008-04/30/2010 | O |

# Winter mean state

Contour: zonal wind, shaded: subgrid CMT



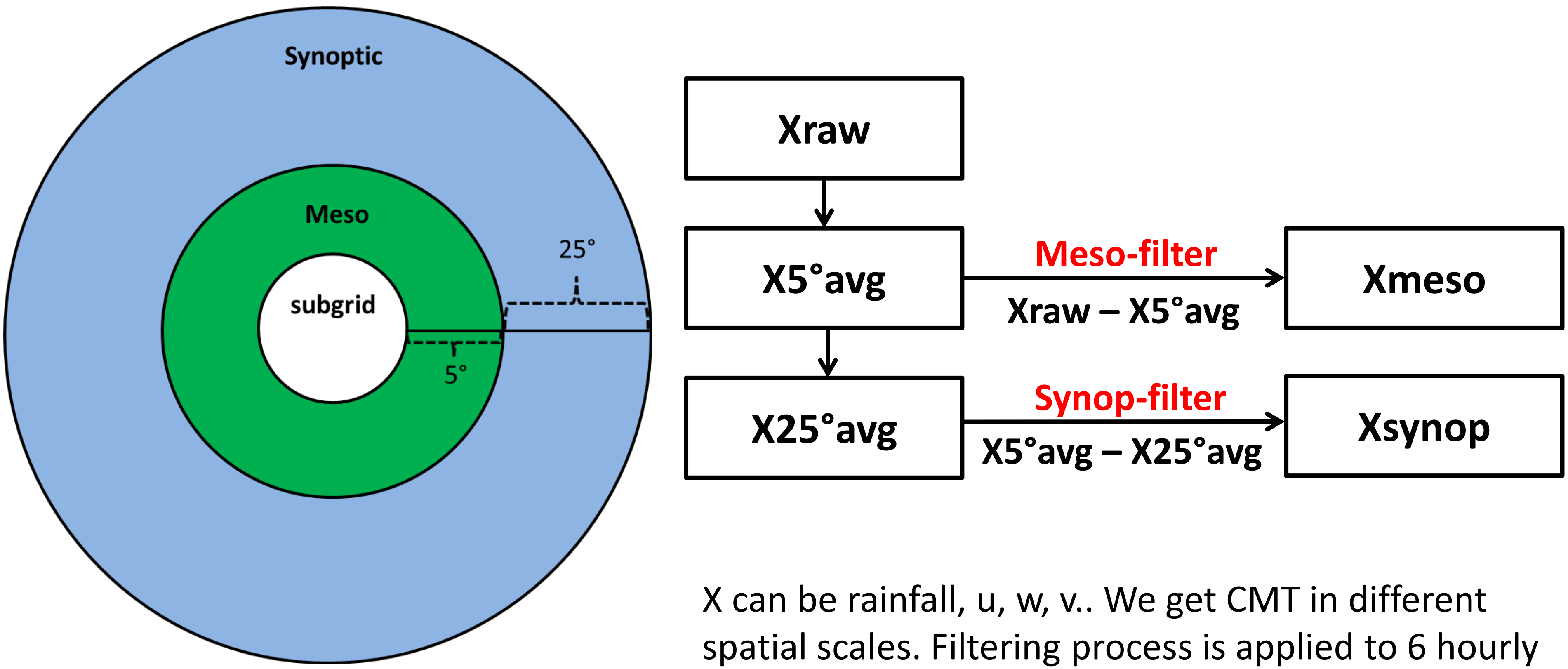

**CMT parameterization**

$$\mathbf{X}_c = -M_c \frac{\partial \overline{\mathbf{v}}}{\partial p} + \delta(\mathbf{v}_D - \overline{\mathbf{v}}) + \sigma\left(\frac{1}{\rho}\nabla p^*\right)$$

Wind shear

# Scale separation

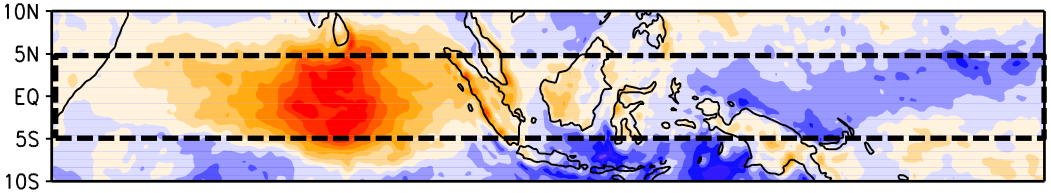
- “Spatial” filtering method



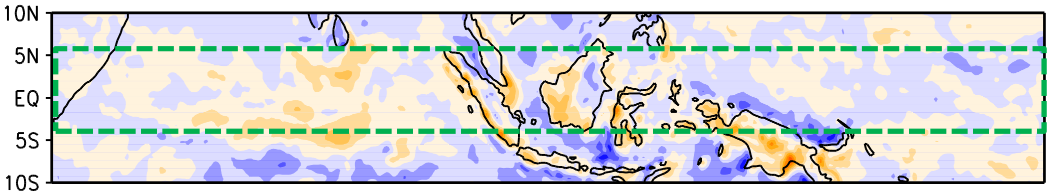

X can be rainfall, u, w, v.. We get CMT in different spatial scales. Filtering process is applied to 6 hourly data and obtained results are daily averaged.

# Regressed multi-scale precipitation against IO MJO index

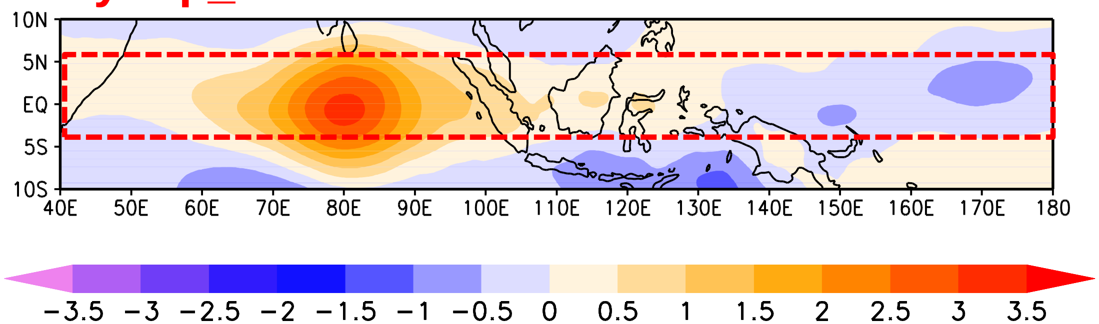
## Total rain

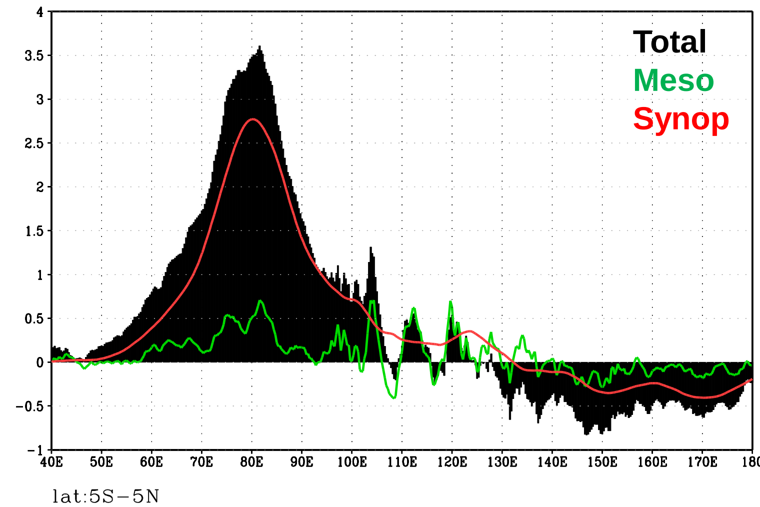



## Meso_filtered rain




## Synop_filtered rain

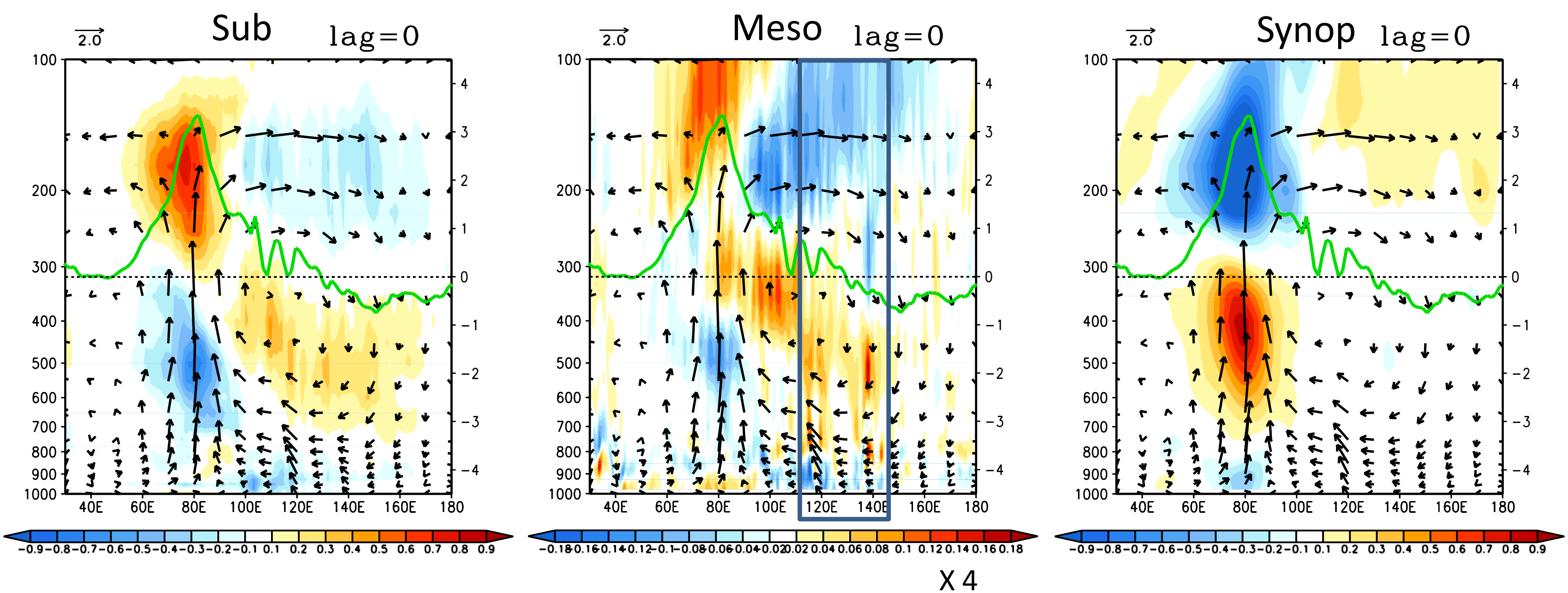


# CMT vertical structure (IO) -CFSR

$$\frac{\partial u}{\partial t} \sim -\frac{\partial}{\partial p}\overline{u'\omega'}$$

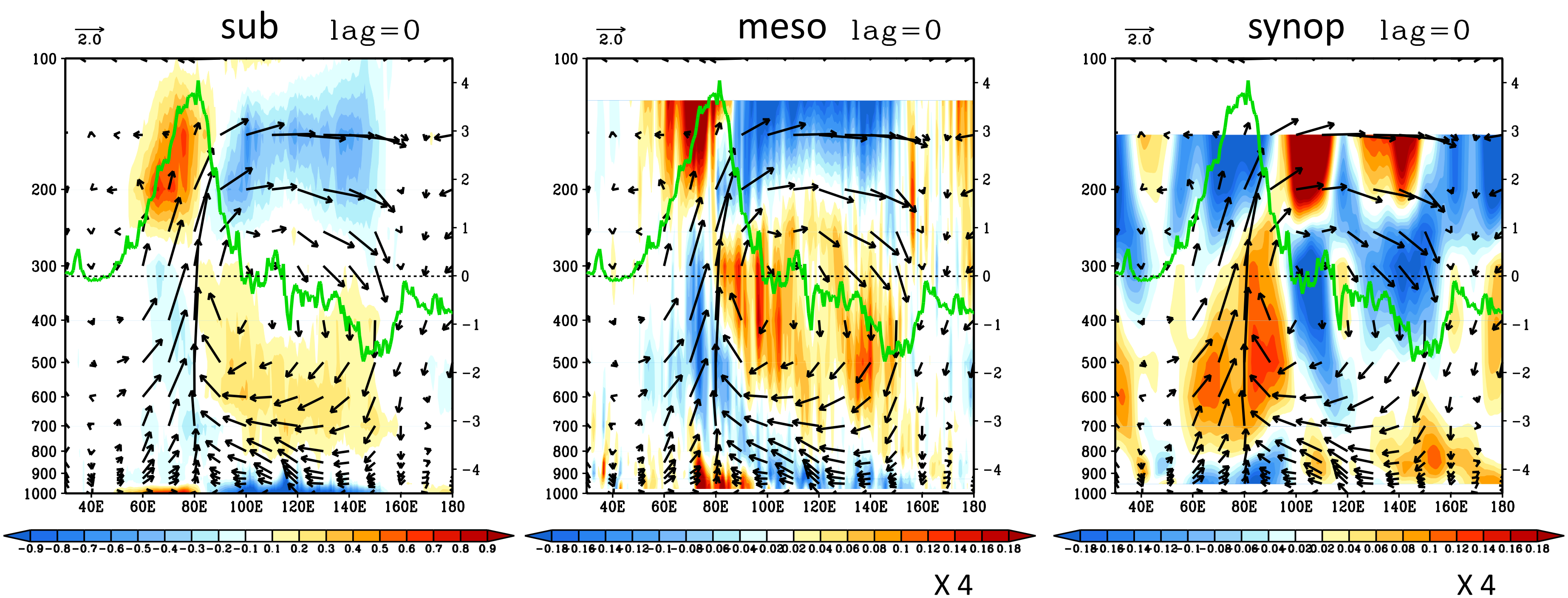
- **Regression of multi-scales of CMT on IO MJO index**




* Green line : MJO precipitation, u;v: MJO circulation

# CMT vertical structure (IO)- ECMWF

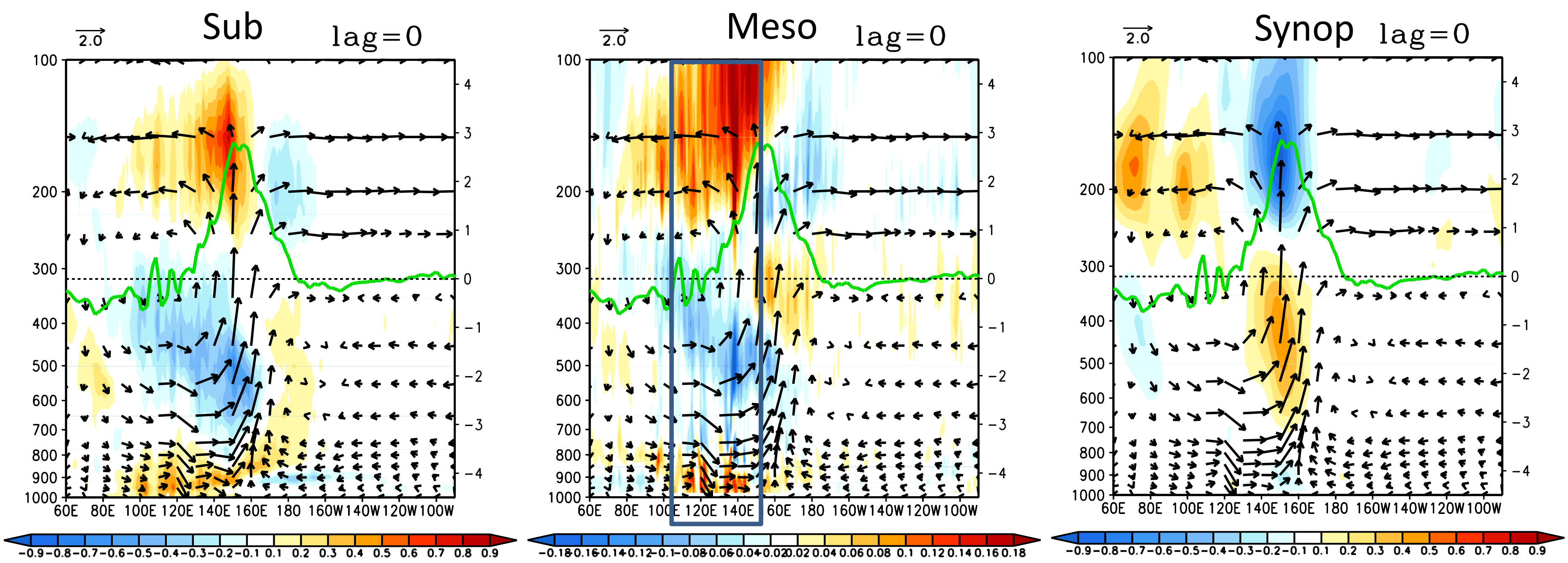
- **Regression of multi-scales of CMT on IO MJO index**




* Green line : MJO precipitation, u;v: MJO circulation

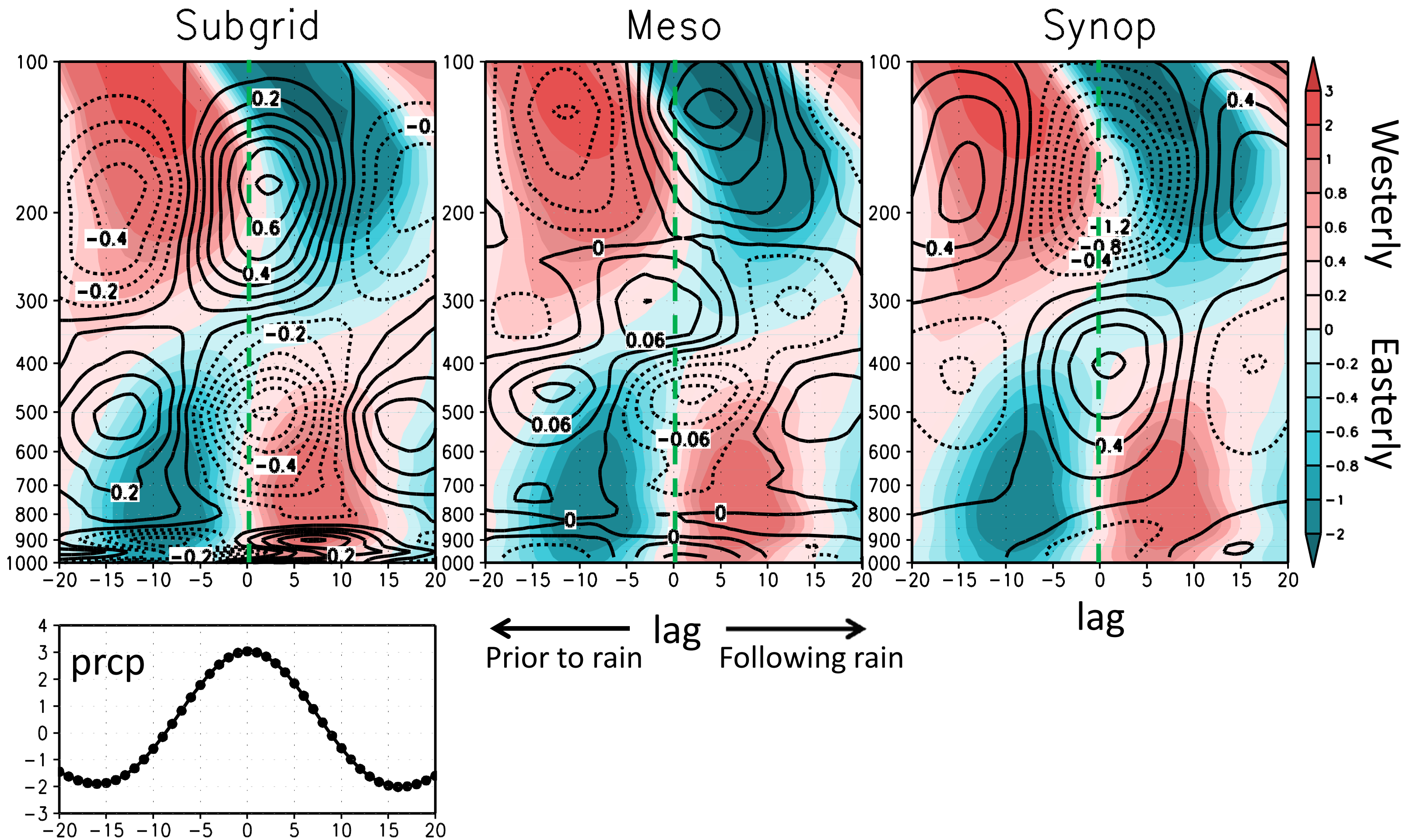
# CMT vertical structure (WP)

- **Regression of multi-scales of CMT on WP MJO index**



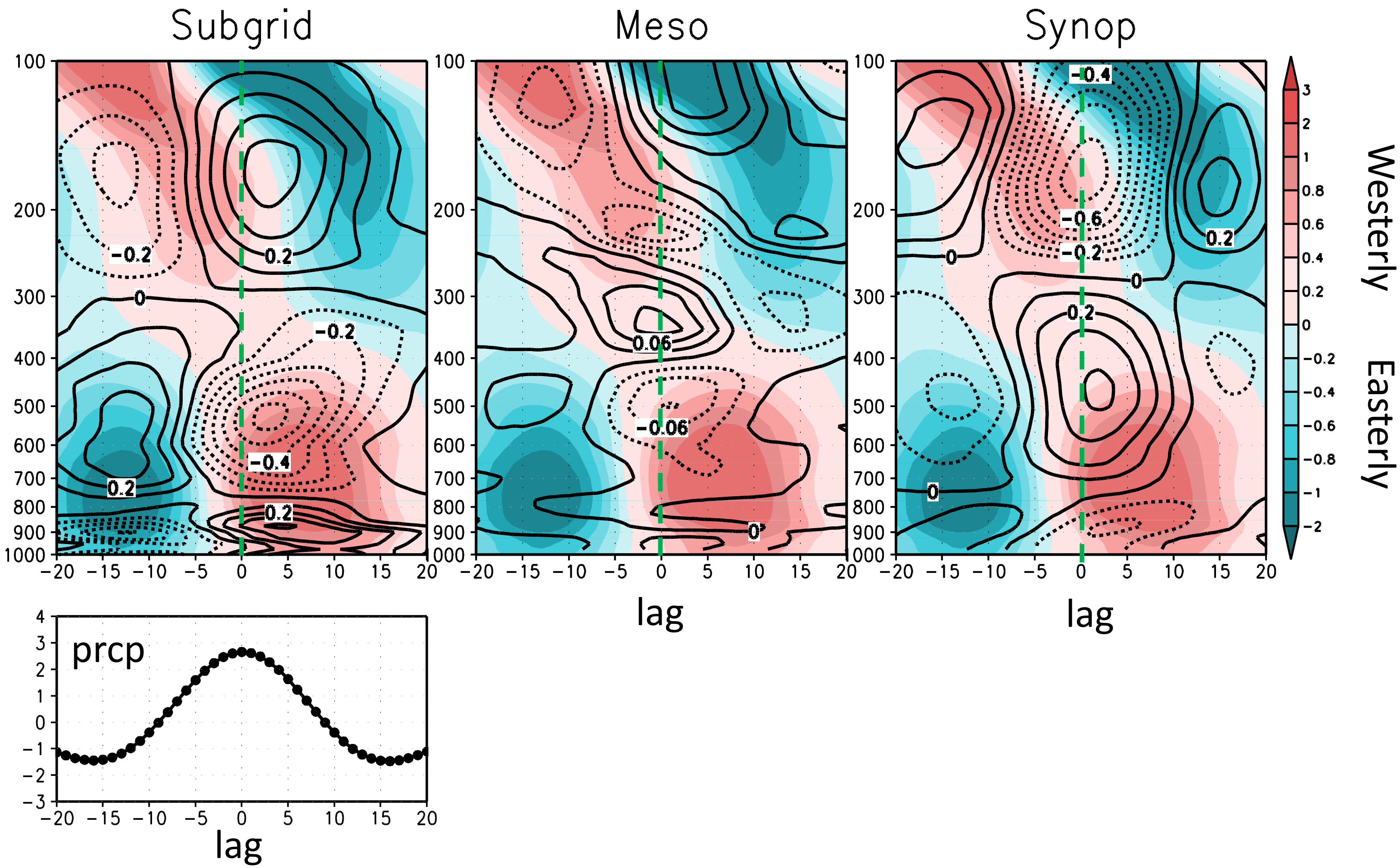
# Lag-height regression of zonal wind and CMT against MJO index

Shaded MJO zonal wind and spatial filtered CMT in contour
Averaged over **IO**: 75-85E, 5S-5N



# Lead-lag regression of zonal wind and CMT against MJO index

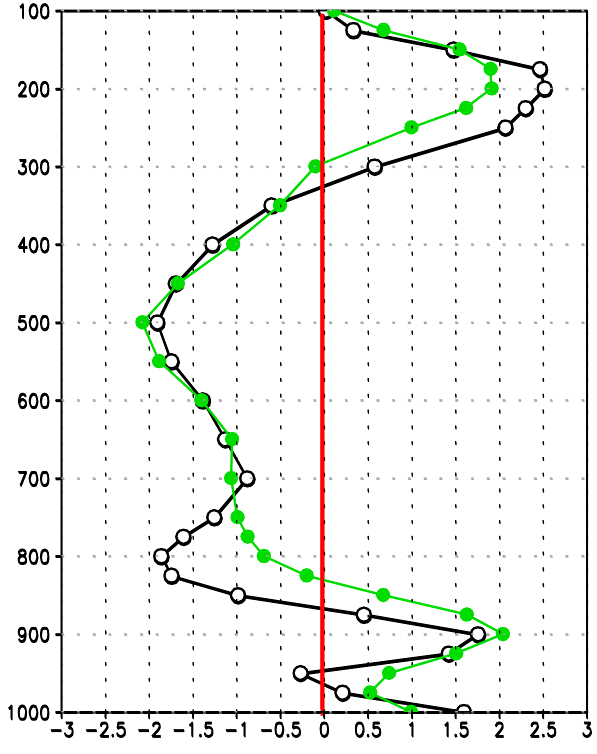
Shaded MJO zonal wind and spatial filtered CMT in contour
Averaged over **WP**: 150-160E, 5S-5N



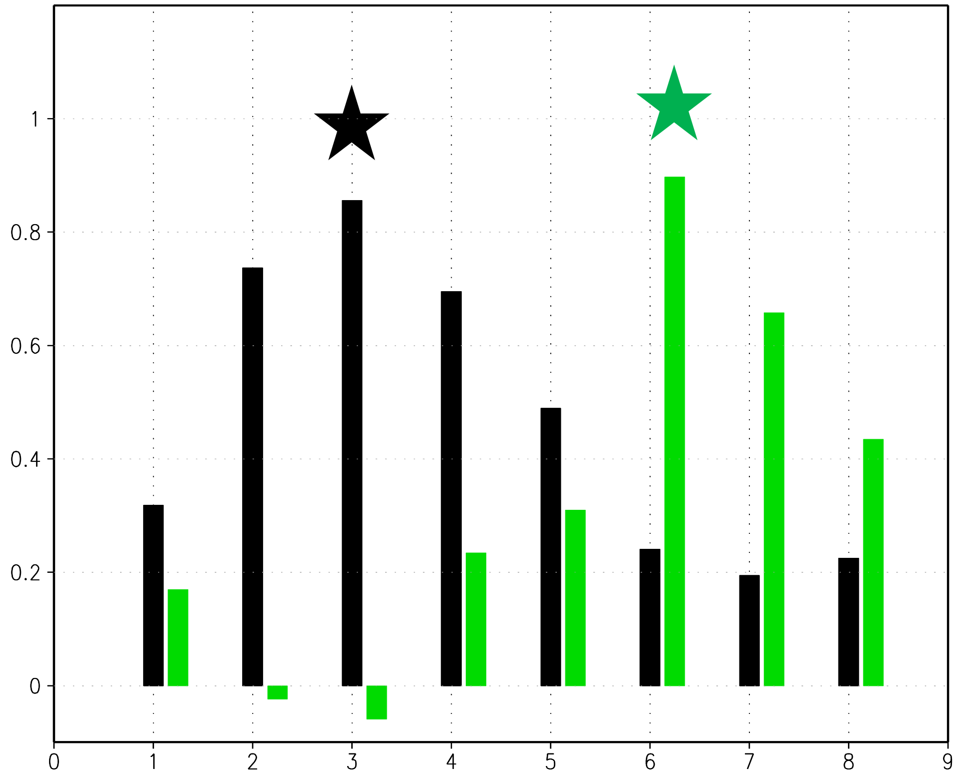
# EOF CMT vertical structure

CMT averaged over 3 points average centered from 80E, IO (black) 155E, WP. (green)

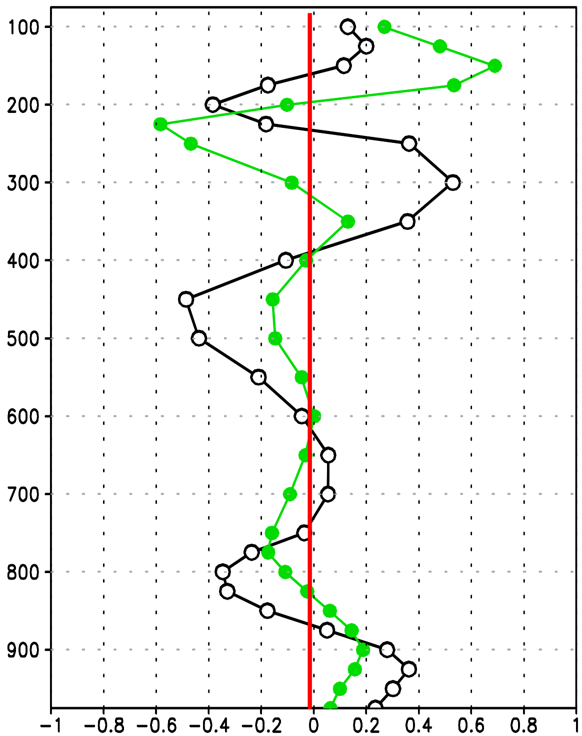
Sub CMT EOF 1st mode

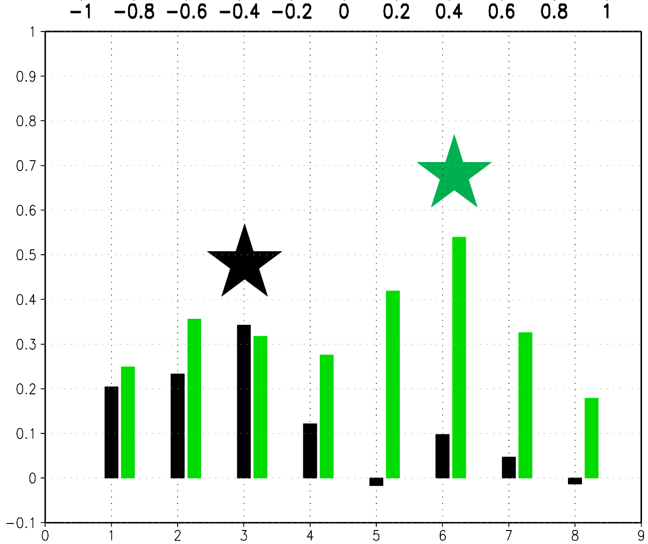



1st mode PC composite

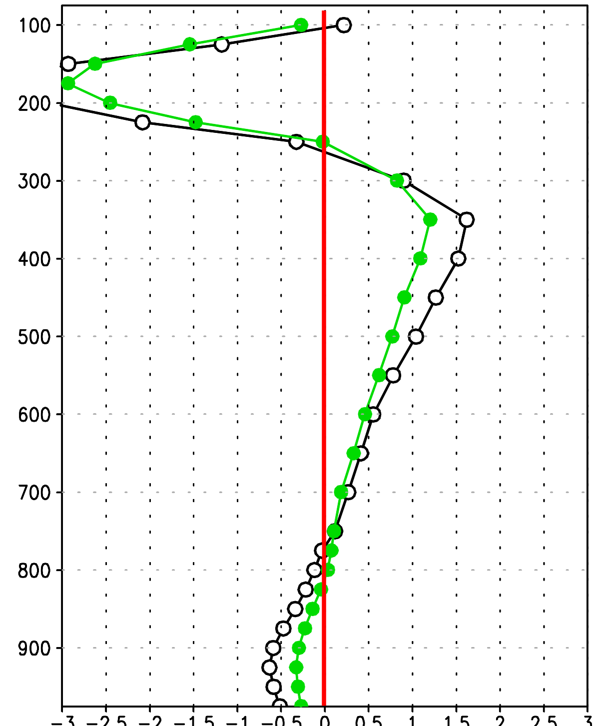


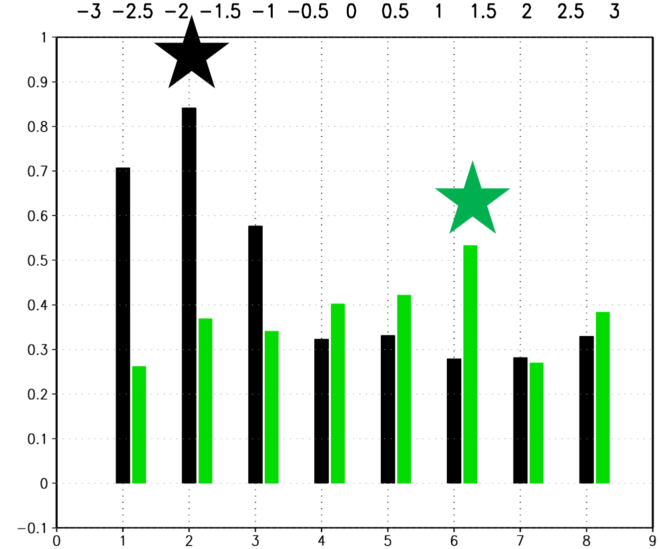
## Meso CMT EOF 1$^{st}$ mode



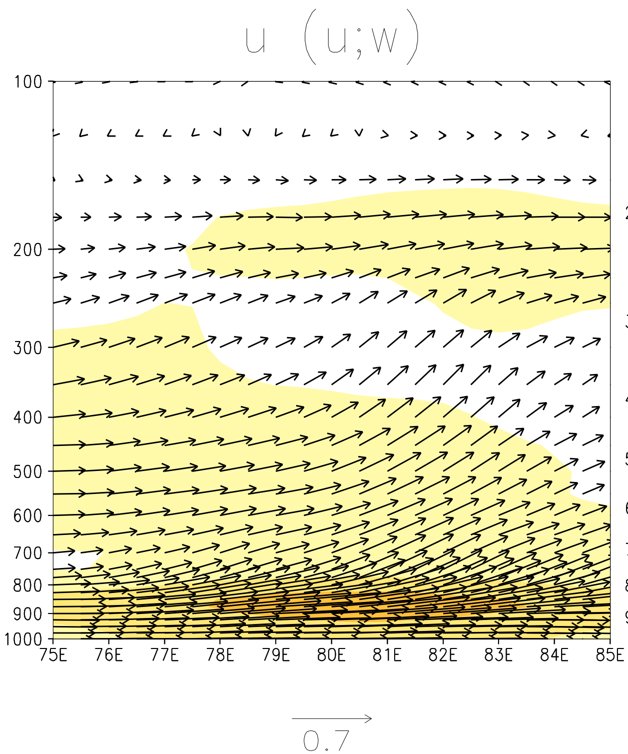
## Synop CMT EOF 1$^{st}$ mode



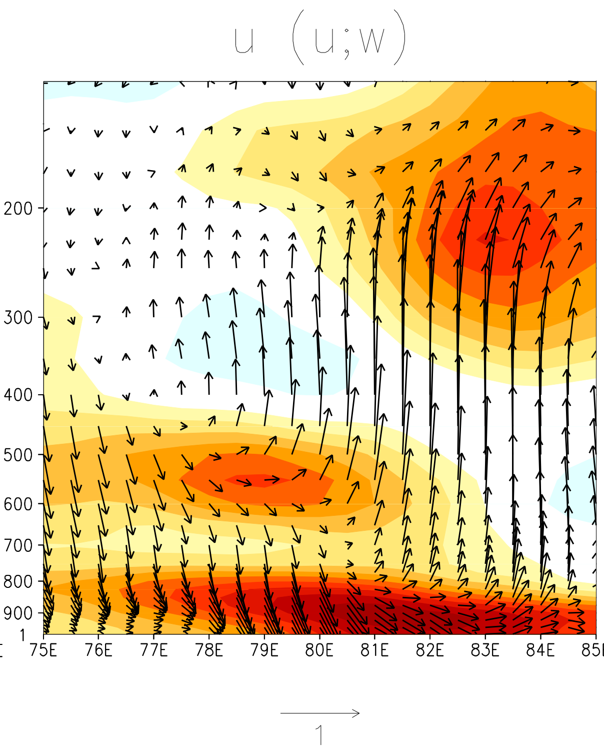



# Regression of wind on the 1st PC (IO)

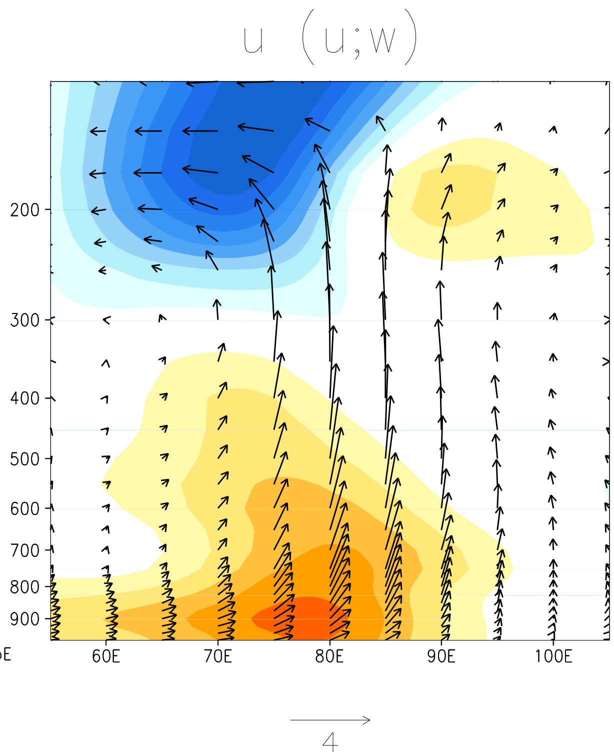
Subgrid




Meso




Synop



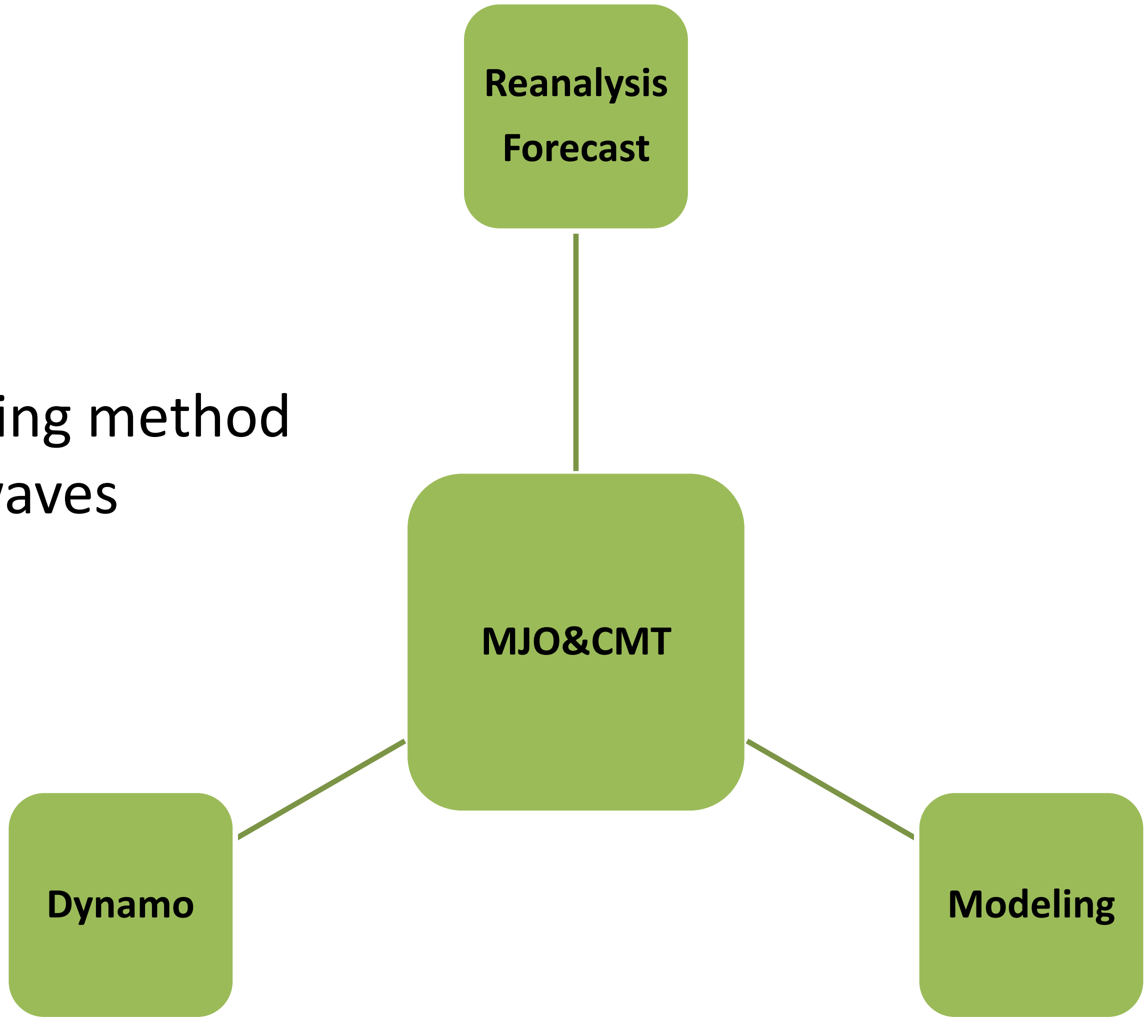

Moncrieff (2004), Mapes et al. (2006)

# Summary

- 3-layer vertical structure is found in CMT patterns associated with the MJO due to the convection on three different spatial scales, i.e., subgrid, meso-, and synoptic-scale. The subgrid and meso-scale CMT show the same sign in general, while an opposite sign is found in the synoptic CMT.
- The amplitude of the CMT is dependent on location: while the strongest CMT due to the mesoscale convection is found over the Maritime Continent, the synoptic scale CMT tends to be stronger over the ocean.
- The subgrid, meso-, and synoptic convective system can feedback to the MJO momentum field through their strong modulation by the MJO envelop.

# Future works

- Spatio-temporal filtering method
- Identifying synoptic waves



# Thank you ☺