Energy conversion processes during organization and intensification of Boreal Summer Intraseasonal Oscillation (BSISO)

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Outline

- Background and Motivation
- Significance of the study
- Results and Major Findings
- Proposed Mechanism
- Conclusions

Background and Motivation

❖The Intraseasonal oscillations (ISOs) are the main source of rainfall variability over the Indian Summer Monsoon (ISM) Region (Goswami, 2005; Lau and Waliser, 2005; Zhang, 2005; Wang, 2006)

❖ In boreal winter, the Madden–Julian Oscillation (MJO) [Madden and Julian, 1971, 1994] is the key mode of Intraseasonal variability which propagates east-ward.

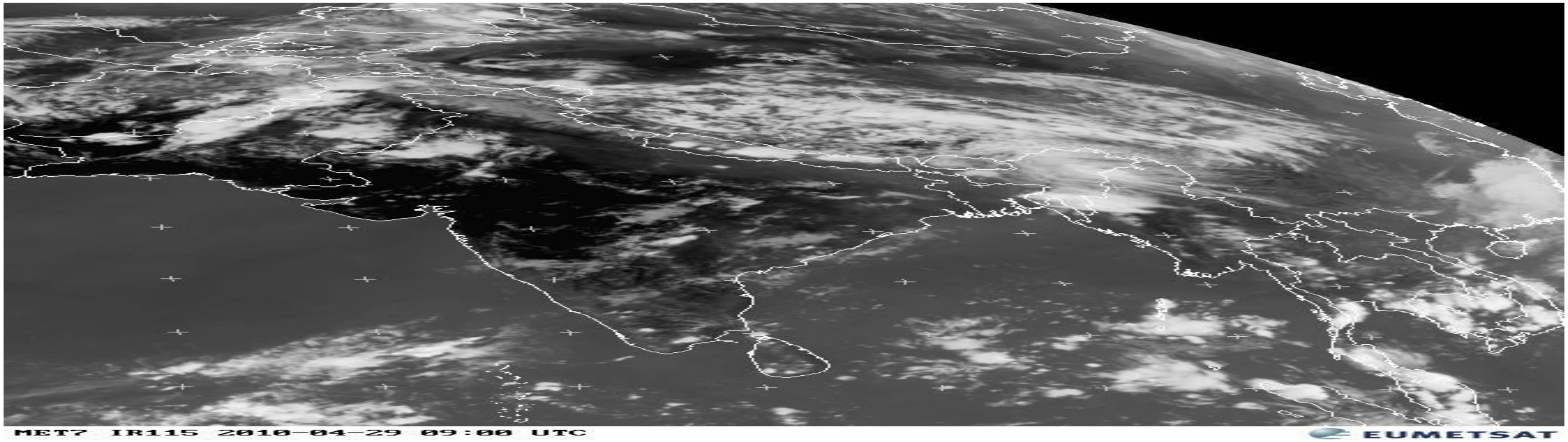
❖In boreal summer, the northward propagating ISO (BSISO) are the significant mode of variability that affects the Indian Summer Monsoon (ISM)

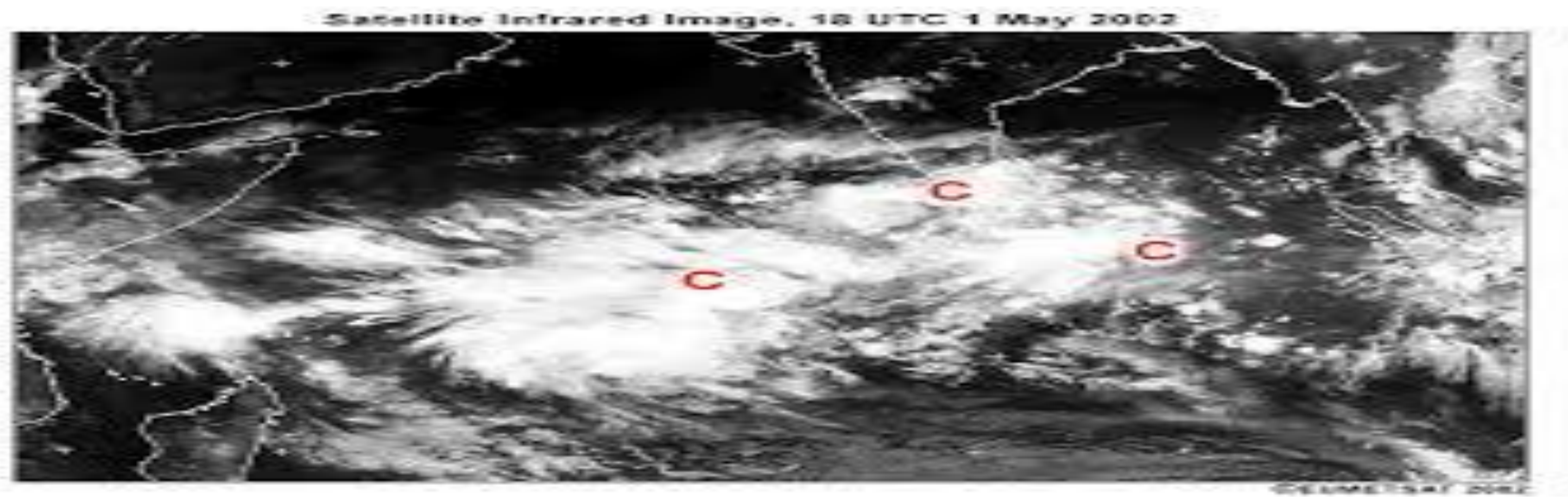
❖Many important contributions have been made in interpreting the northward propagation of the Boreal Summer Intraseasonal Oscillations (Yasunari 1979; Sikka &Gadgil, 1980; Webster 1983; Goswami and Shukla 1984; Fu et al. 2003; Jiang et al. 2004; Yang et al. 2008; Jiang et al. 2011;Abhik et al. 2013).

The organization and intensification of BSISO remains poorly explored. The question remains unrevealed that when do the scattered cloud cluster organize to form an envelope of well organized large scale convection anomaly and propagate northward as BSISO and what are the main source of energy during such organization of BSISO.

Background and Motivation Cont…..

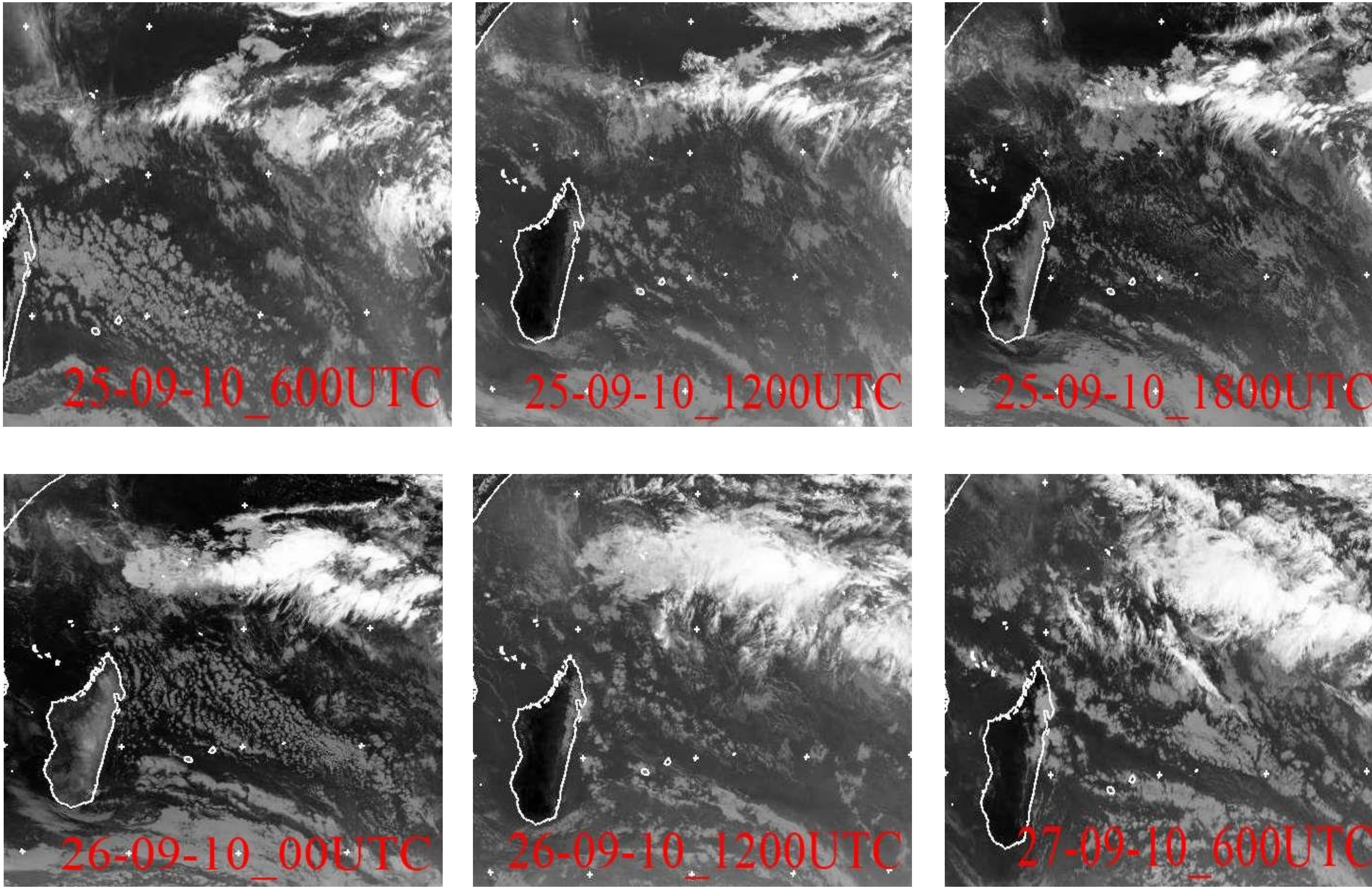
❖One of the important issues from forecaster's point of view would be to know, whether or not a scattered cloud clusters observed on any day would initiate a deep convection and eventually become large scale organized convection in the subsequent days.





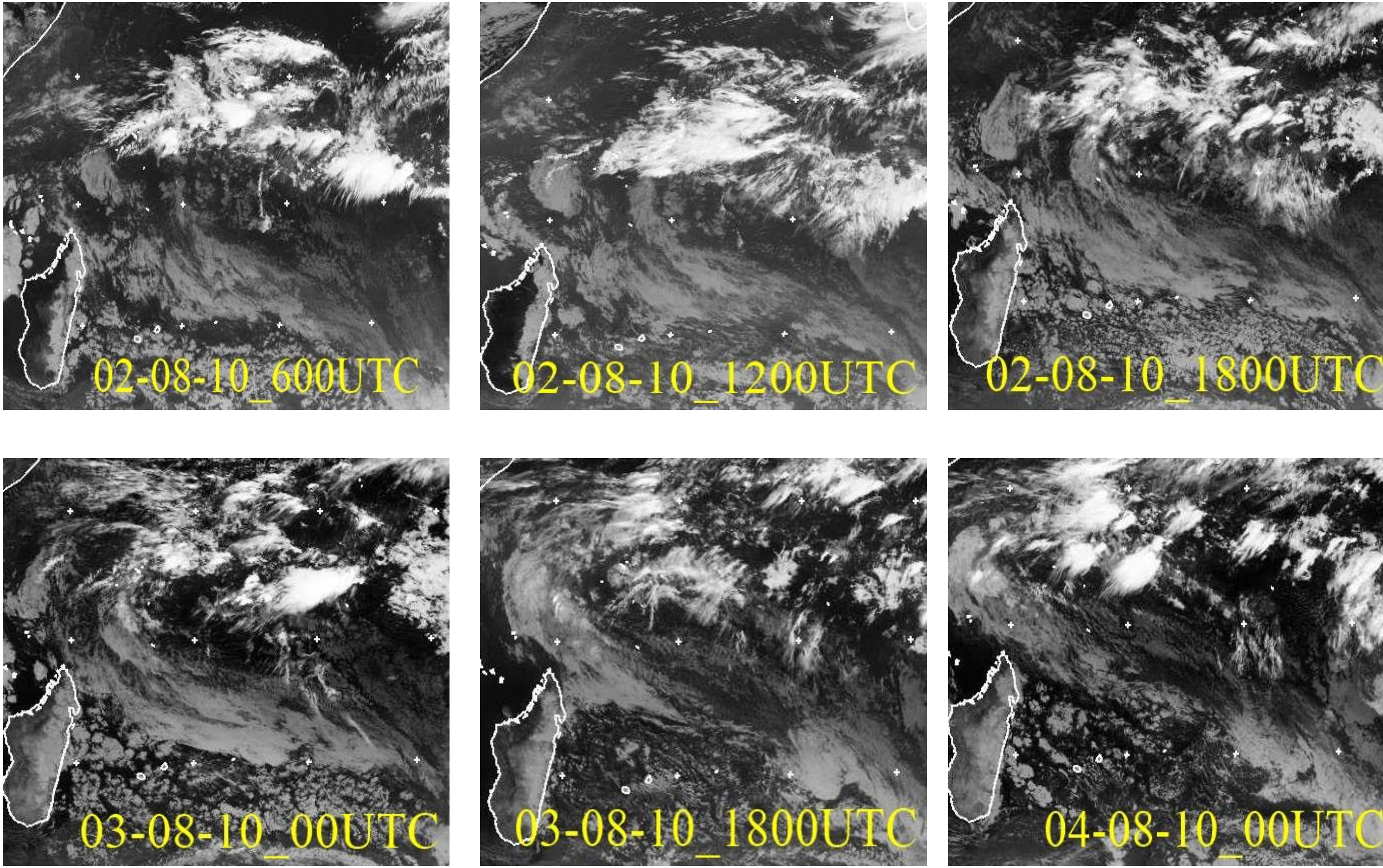
What we are trying to Explore ?

Satellite Image for an organizing events



METEOSAT Image obtained from Dundee Satellite receiving station website

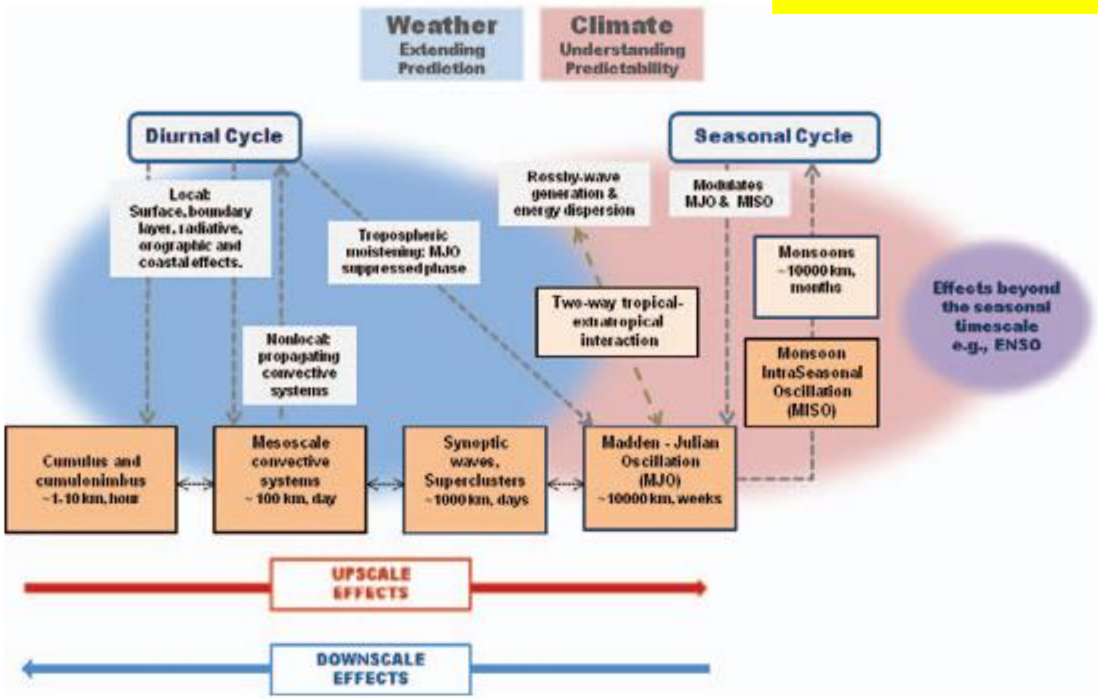
Satellite Image for a non-organizing events

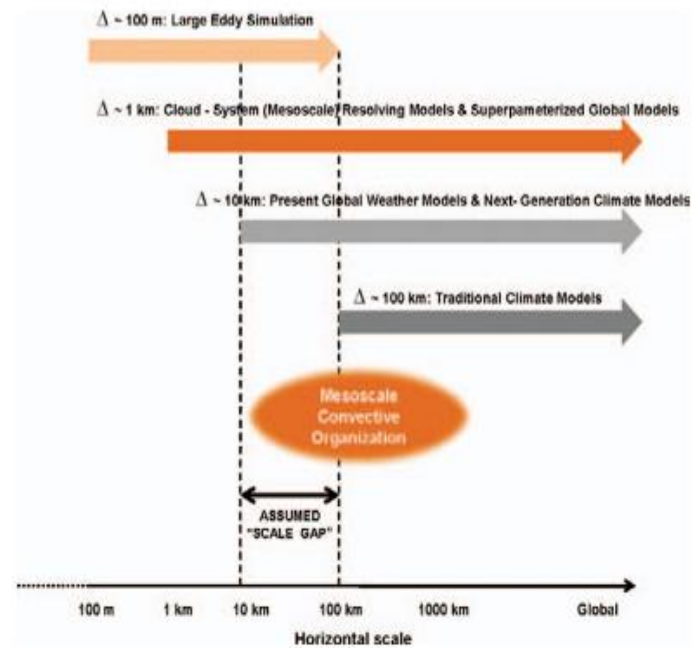


❖**So, there is a need to understand the mechanism through which the small scale scattered cloud clusters organize into a large scale deep convective cloud.**

Moncrieff et al, 2012, BAMS

Scientific Basis of the study





The organized systems exhibit hierarchical coherence: (i) mesoscale systems consist of families of cumulonimbus (ii) cumulonimbus and MCS are embedded in synoptic waves (iii) the MJO/MISO is an envelope of cumulonimbus, MCS, and superclusters.

The upscale effects of convective organization are not represented in traditional climate models.

The mean atmospheric state exerts a strong control (Upscale/Downscale) on convective structure, frequency, and variability. Mesoscale convective organization bridges the scale gap assumed in traditional convective parameterization.

i)SCM/CRM resolves cumulus, cumulonimbus, mesoscale circulations with horizontal resolution (~few m to km) and simulations short (~1 day).

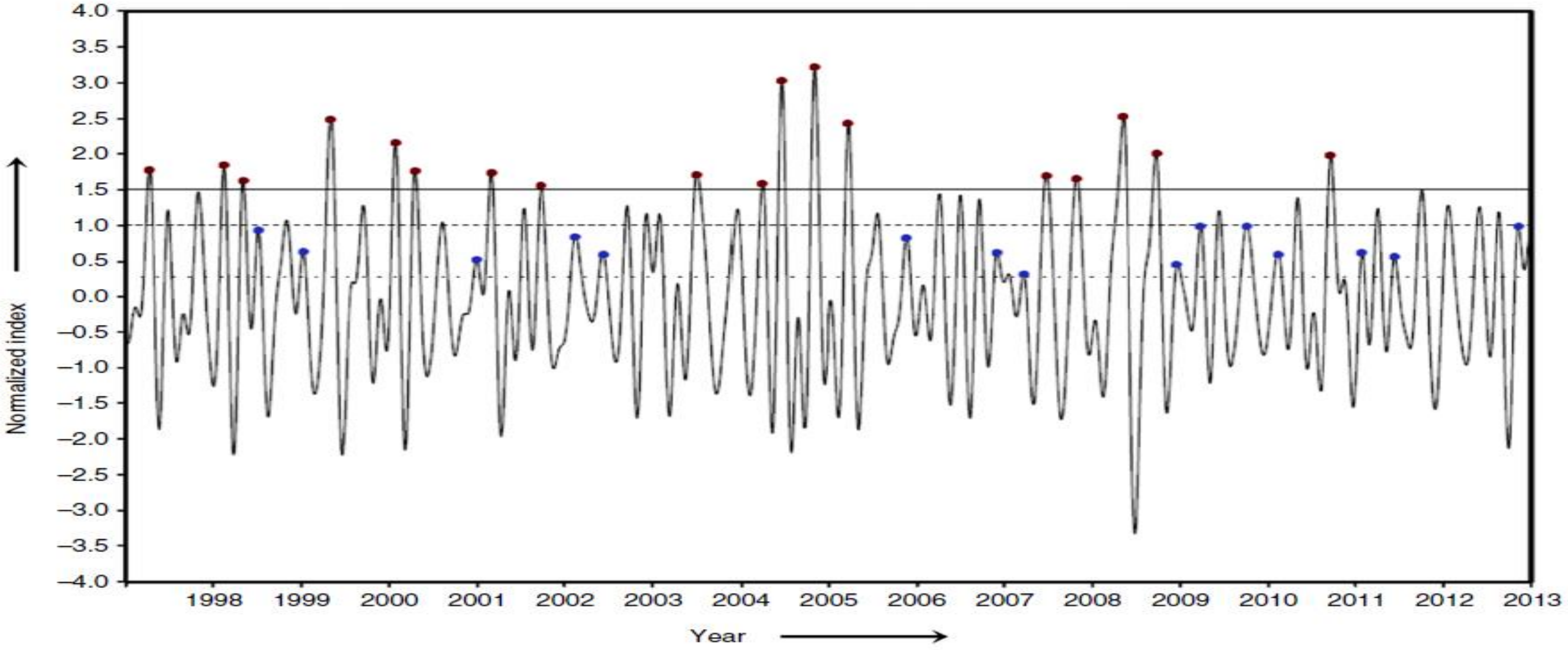
ii)Two-dimensional CSRMs in superparameterized global models permit MCS-type organization and mesoscale dynamics.

iii)High-resolution global numerical prediction models may crudely represent large MCS (superclusters).

(iv) MCS and other mesoscale dynamical systems are absent from traditional climate models—organized convection is not parameterized.

How to identify the BSISO events ?

Identification of the events



Normalized Precipitation Index (PI) (defined as 20-80 day filtered anomaly averaged over 73°E-83°E and 18°N-25°N)

Goswami and Xavier, 2003; Abhik et al. 2013

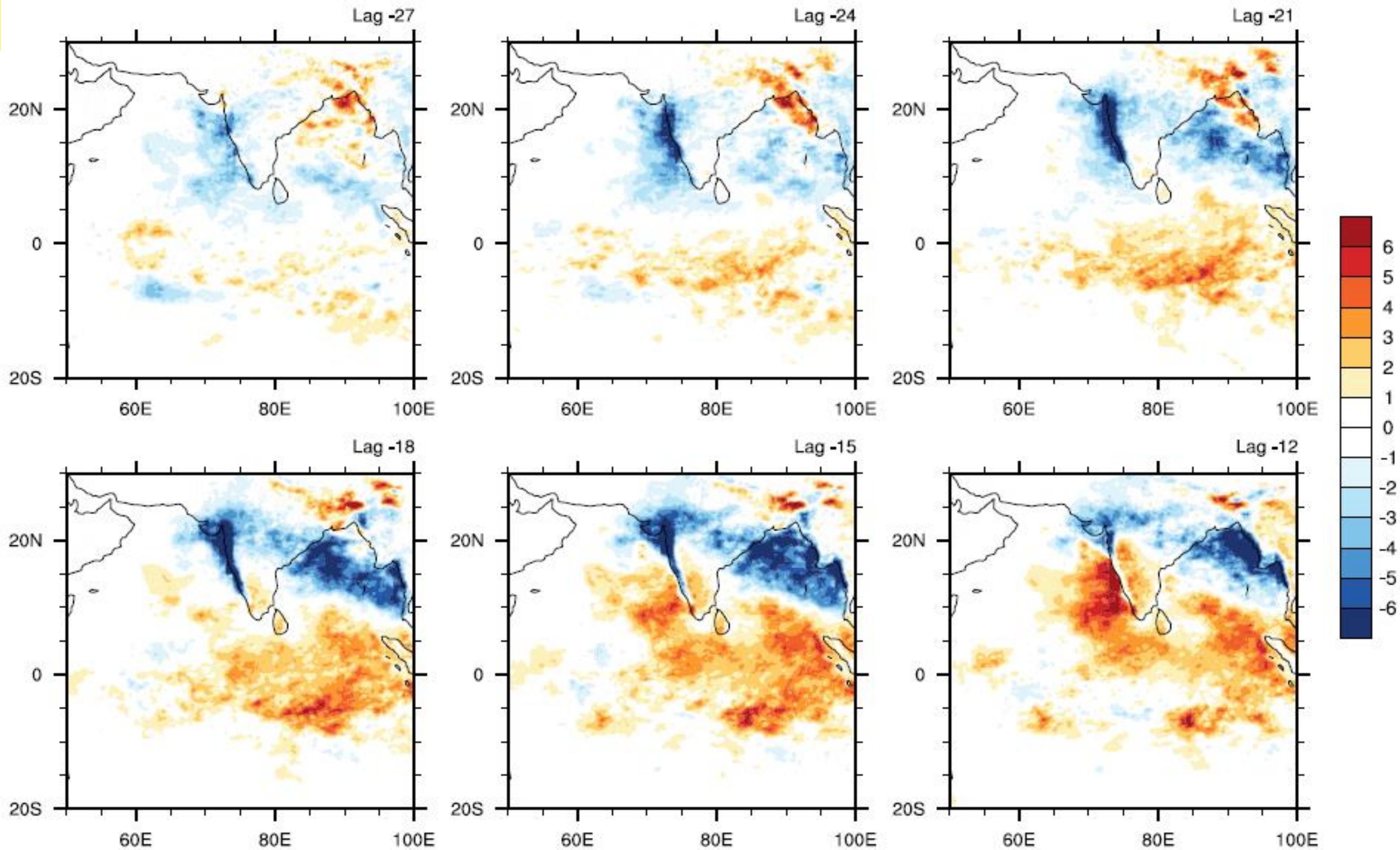
Strong: PI >1.5

Weak: 0.4<PI<1

- ❑ **Relatively high and homogeneous rainfall variability.**
- ❑ **All India Rainfall Index (AIRI) strongly positively correlated with CI.**

Hoyos and Webster, 2007

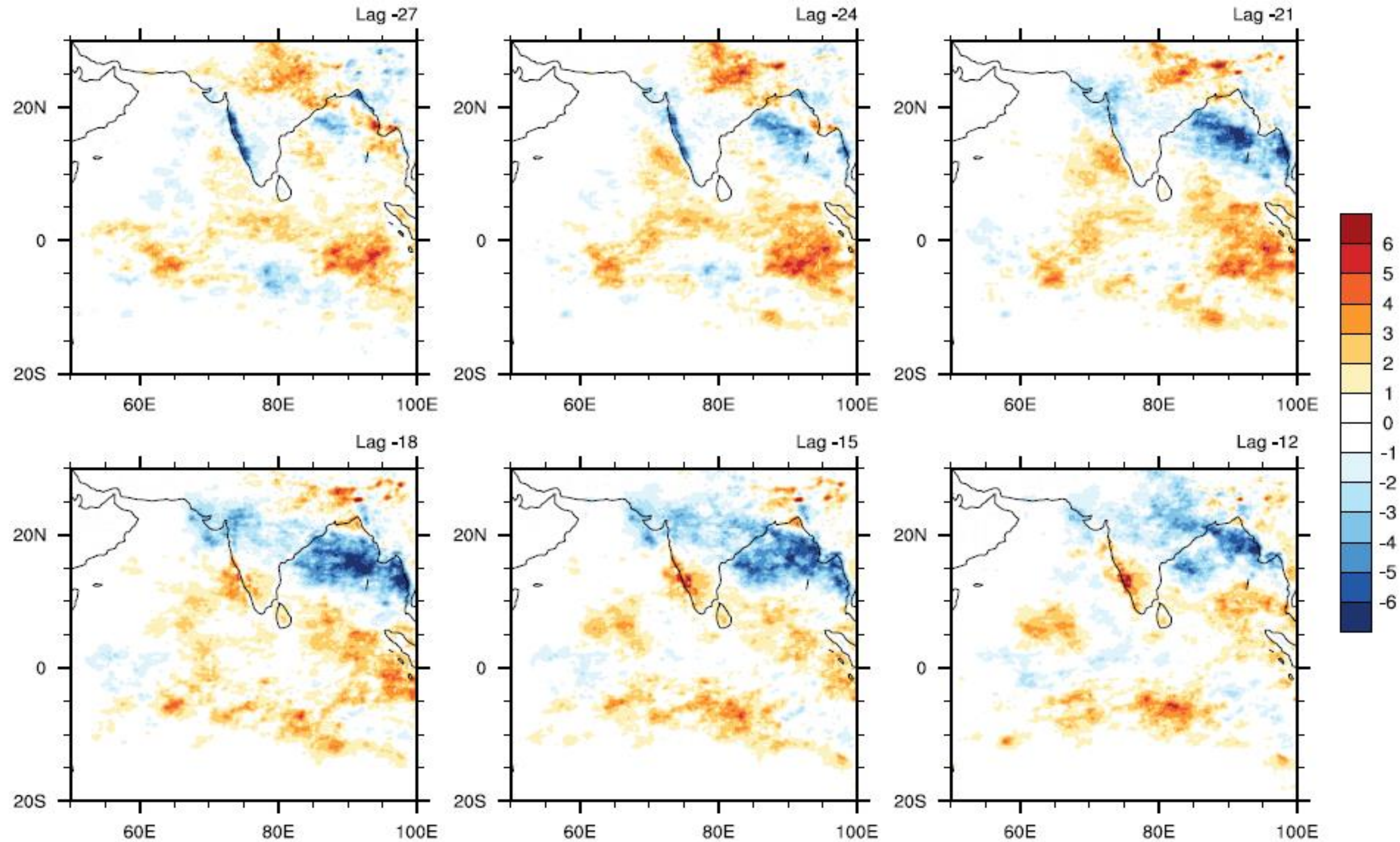
Composite anomalous precipitation (mm/day) structure for strong events



➢**From Composite structure, it is seen that for the strong events before -24 days lag the convection was very weak and from -24 days to -15 days the convection organized over IO region.**

➢ **After -15 days lag the anomaly propagates northward.**

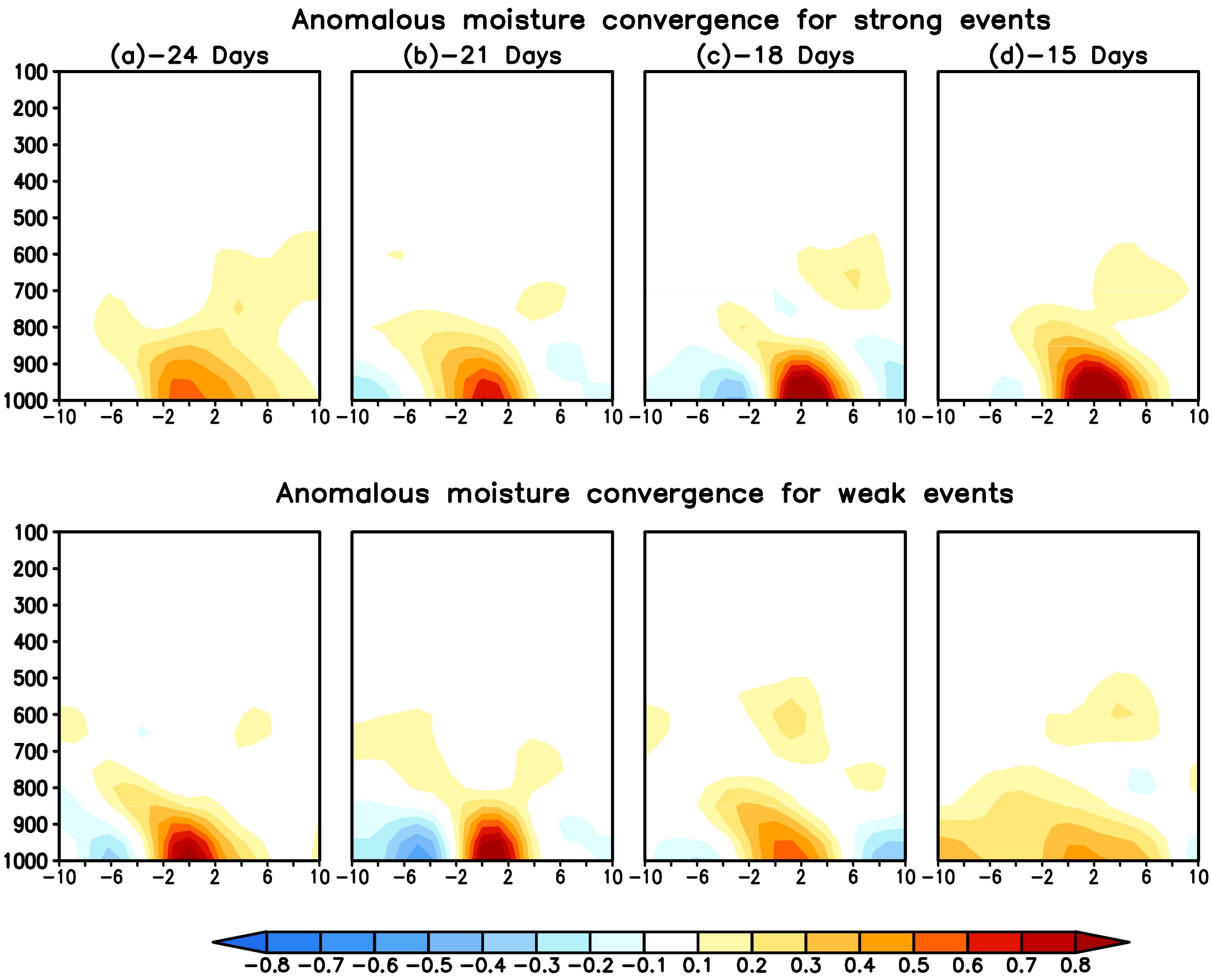
Composite anomalous precipitation (mm/day) structure for weak events



- **From Composite structure, it is seen that the weak events lacks a clear organization as seen for the strong events.**

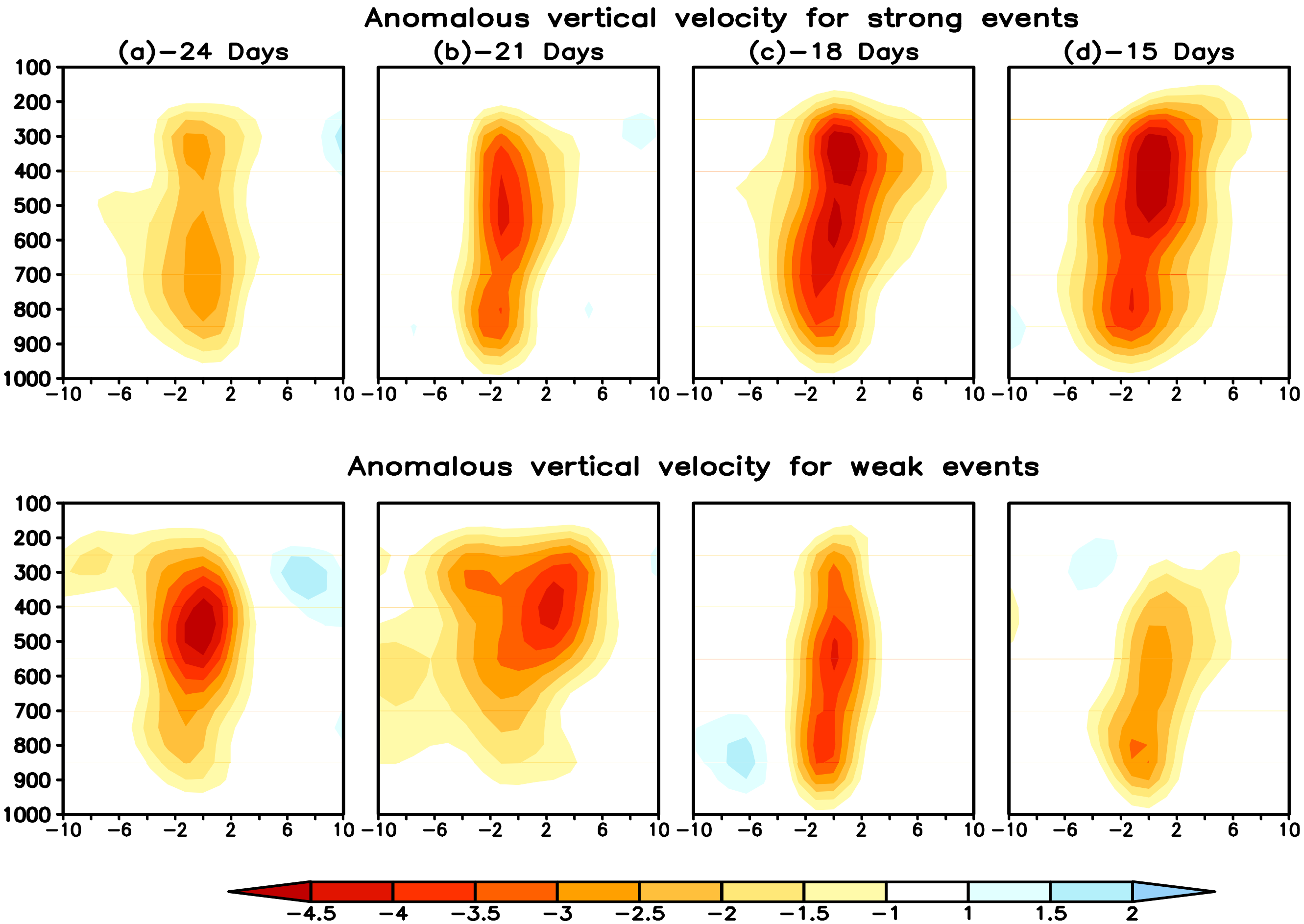
Structure of the dynamical parameters during organization and intensification of BSISOs

Anomalous moisture convergence(×10-7 s-1) based on Strong (Upper Panel) and Weak (Lower Panel) events



- For the **strong events**, the moisture convergence to the north **increases** as BSISO approaches towards the peak.
- It helps the strong events to propagate northward.
- For the **weak events** the strength **decreases** as the event approaches towards -15 days lag.

Anomalous vertical velocity (×10-2 Pa s-1)) based on strong (Upper Panel) and Weak (Lower Panel) events



- **The vertical velocity shows noticeable enhancement from -24 to -15 days for the strong events signifies the strengthening of the convection.**
- **But for the weak events, the strength decreases as BSISOs move in subsequent lags which signifies the lack of deep convection.**

- **Thus the dynamical parameters analysis shows, the stronger vertical velocity along with enhanced moisture convergence play an important role in strengthening the convection from formative to organized phase.**

Sarkar et al, 2017

What are the source and sink of the energy during the organization and intensification of BSISO?

Energetics study is performed following Oort (1967); Hsu et al. (2016)

MKE Equation:

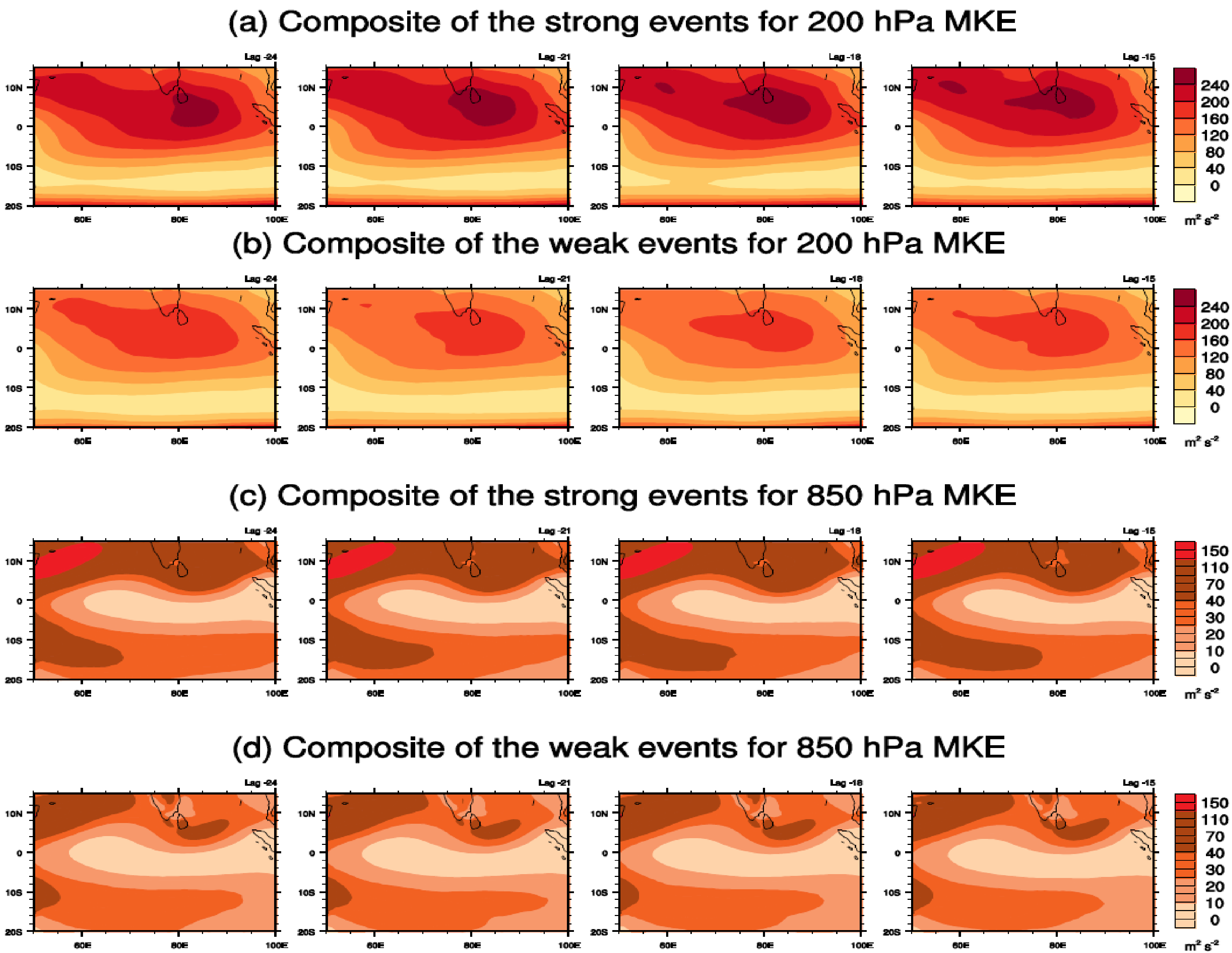
Mean Kinetic Energy $\overline{K} = \left(\overline{u}^2 + \overline{v}^2\right) /2]$

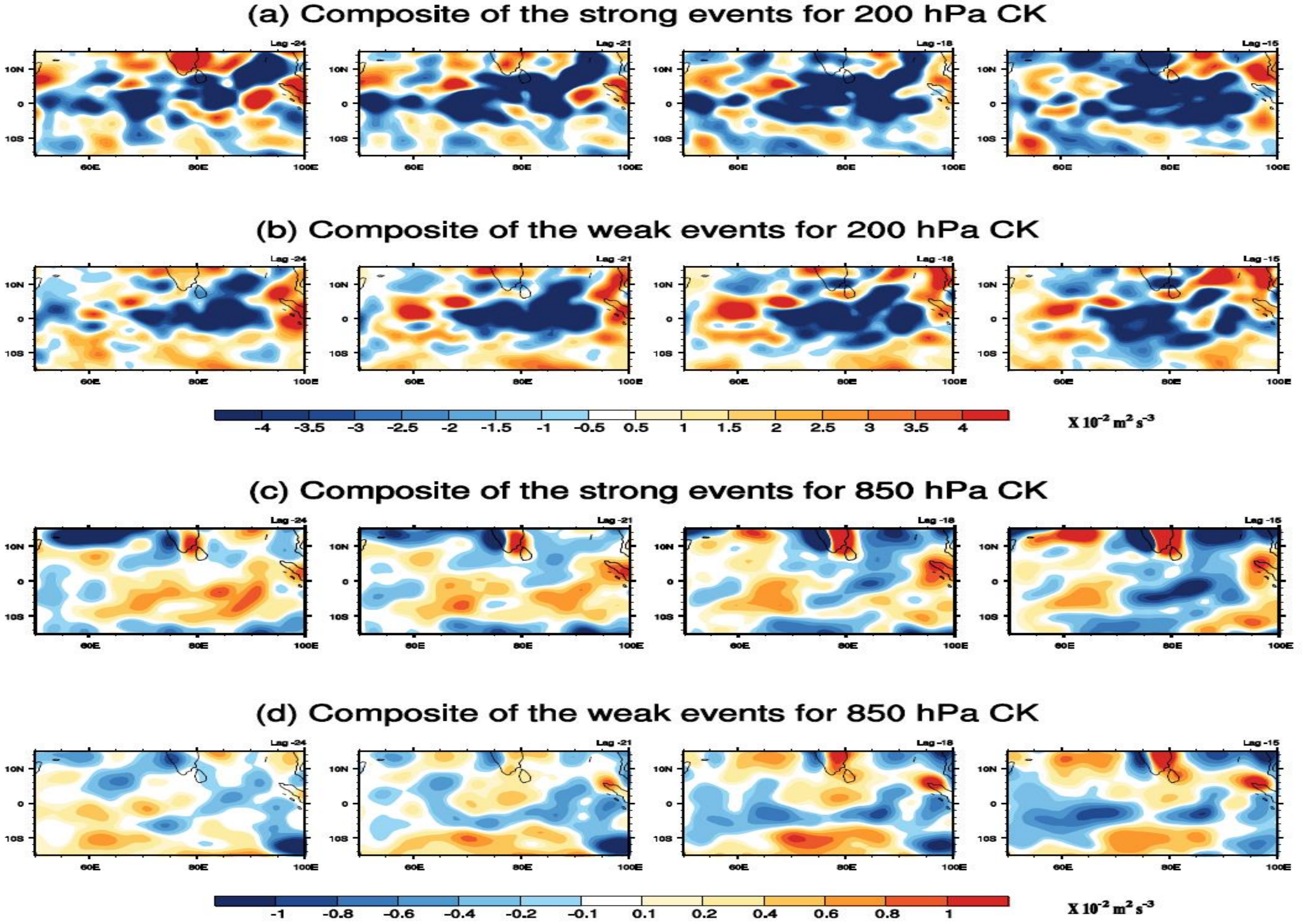
$$\frac{\partial \overline{K}}{\partial t} = \underbrace{\overline{V'.\,(V'.\nabla)\,\overline{V}}}_{\text{CK}} - \underbrace{\frac{R}{P}\,\overline{T\omega}}_{\text{CA}} - \underbrace{\overline{V}\,.\,\nabla\overline{K} - \overline{V'.\nabla K}}_{\text{BK}}$$

$$- \underbrace{\overline{\nabla.\ (V\varnothing)}}_{\text{BG}} + D \qquad (1)$$

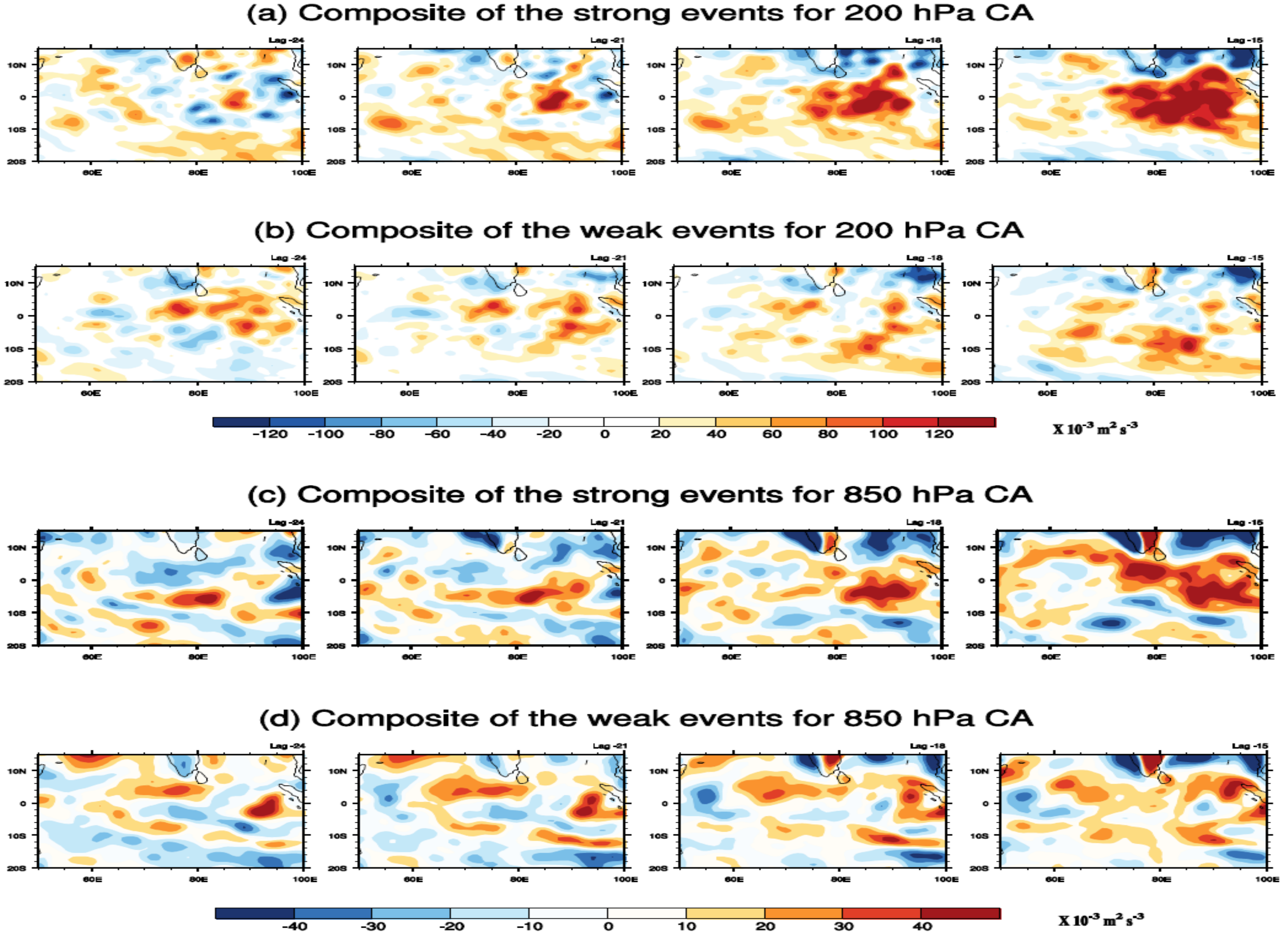
CK-→ Eddy Kinetic Energy (EKE) to Mean Kinetic Energy (MKE) conversion
CA-→ Mean Available Potential Energy (MAPE) to Mean Kinetic Energy (MKE)
BK-→ Mean Kinetic Energy change due to mean and eddy advection
BG→ Boundary Flux
D→ Frictional dissipation

Oort (1967)

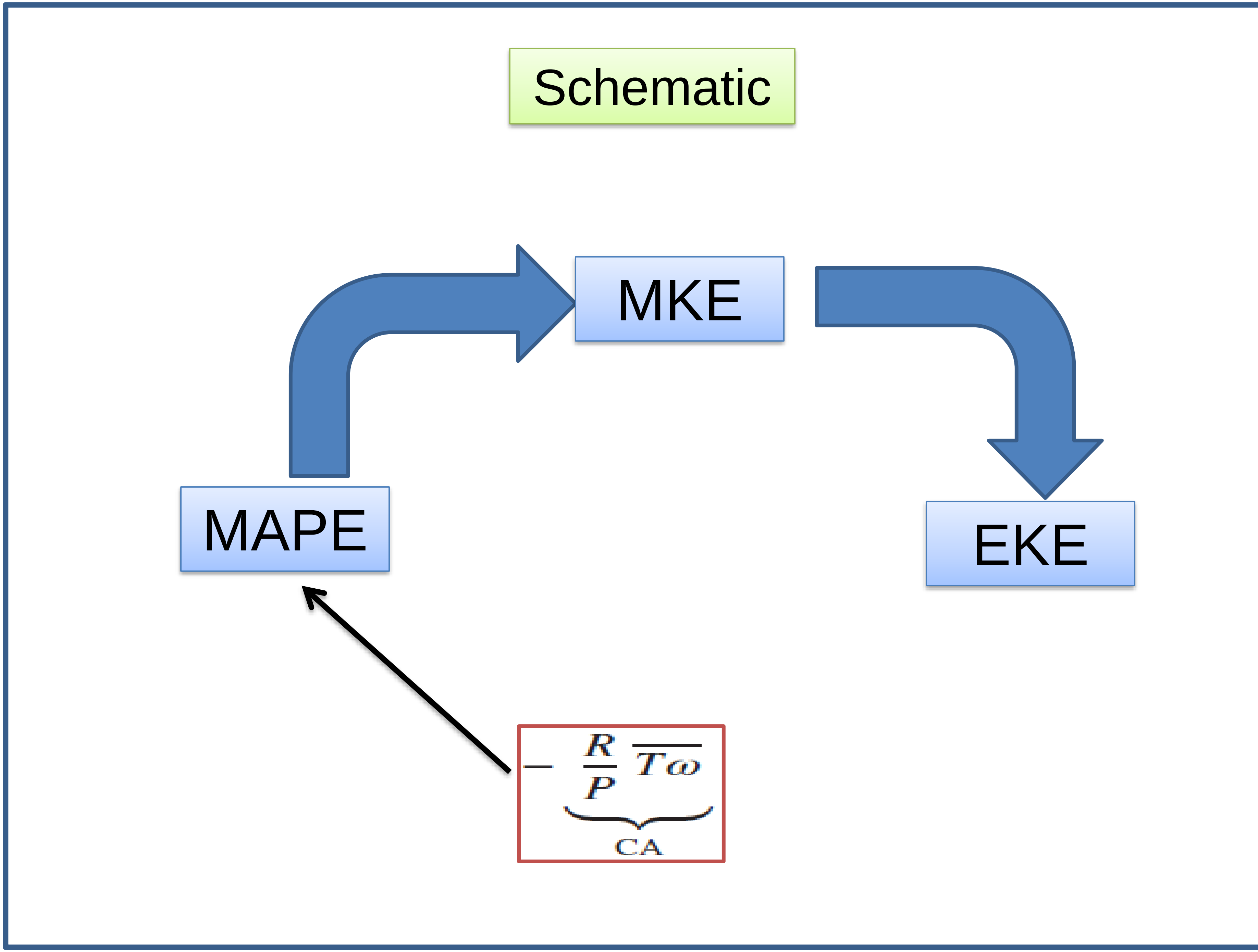

(a) Composite of the strong events for 200 hPa MKE
(b) Composite of the weak events for 200 hPa MKE
(c) Composite of the strong events for 850 hPa MKE
(d) Composite of the weak events for 850 hPa MKE
Lag -24
Lag -21
Lag -18
Lag -15
10N
0
10S
20S
60E
80E
100E
240
200
160
120
80
40
0
150
110
70
40
30
20
10
0
m^2 s^{-2}



Negative means MKE to EKE conversion



Positive means MAPE to MKE conversion

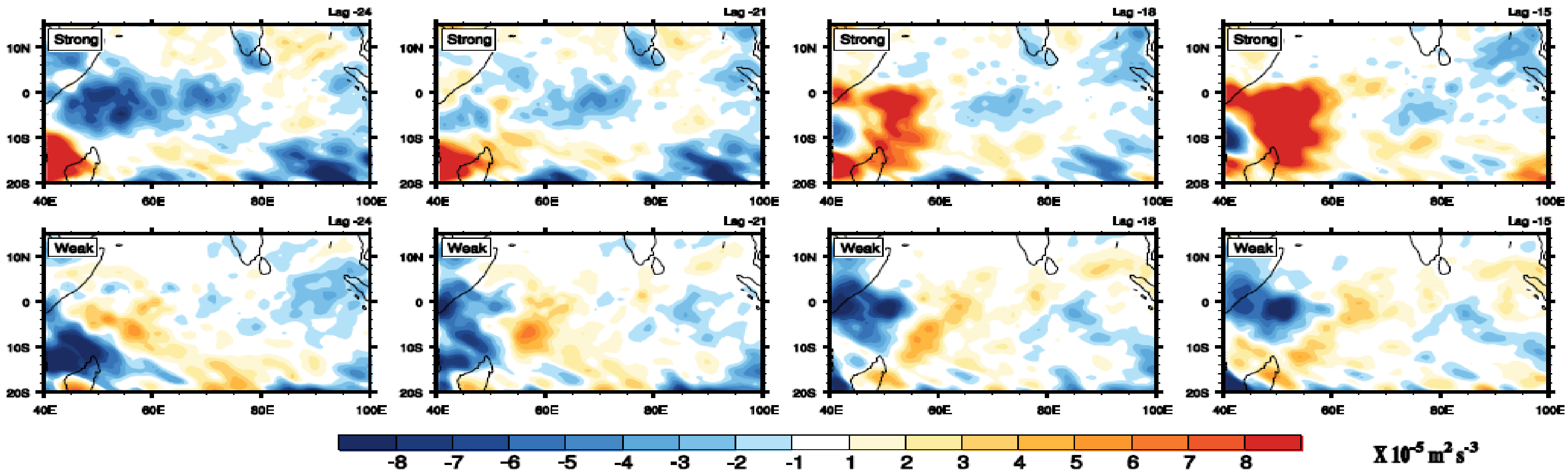

Schematic
MKE
MAPE
EKE
$-\underbrace{\frac{R}{P}\overline{T\omega}}_{\mathrm{CA}}$

Eddy kinetic energy (EKE) to mean kinetic energy (MKE) conversion

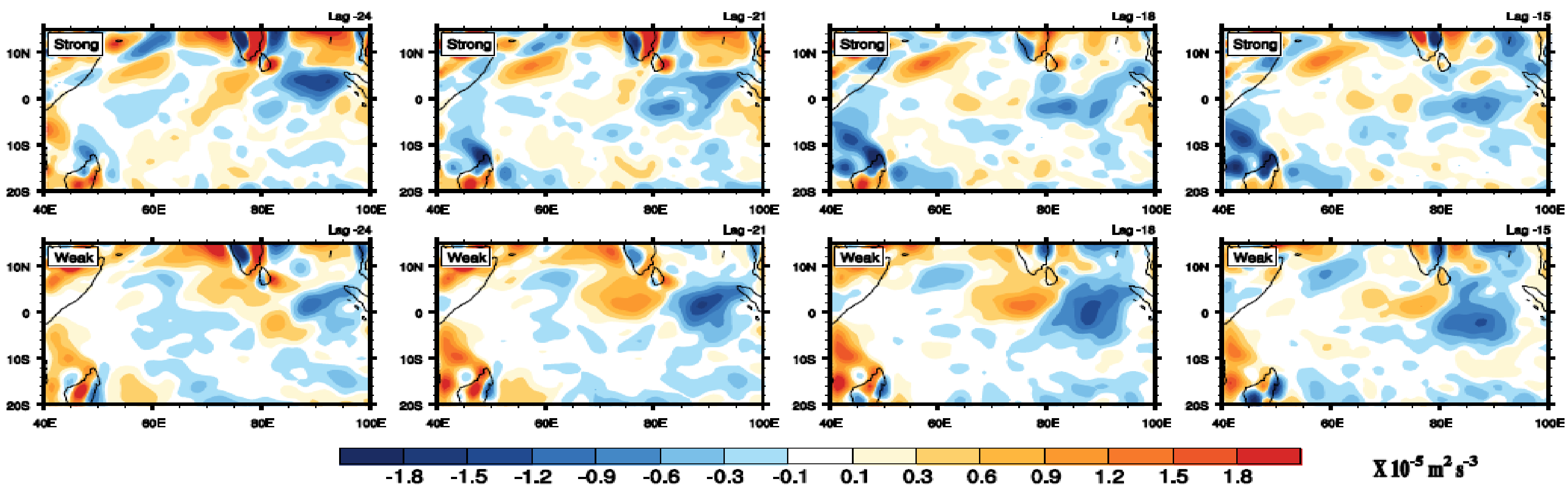
CK1 → Eddy momentum flux and mean flow convergence/divergence interactions.
CK2 → Horizontal eddy momentum and mean vorticity interaction.
CK3 → Vertical eddy momentum and vertical wind shear interaction.

$$\mathrm{CK} = \underbrace{\overline{u'^2\frac{\partial \bar{u}}{\partial x}} + \overline{v'^2\frac{\partial \bar{v}}{\partial y}}}_{CK1} + \underbrace{\overline{u'v'\frac{\partial \bar{u}}{\partial y}} + \overline{v'u'\frac{\partial \bar{v}}{\partial x}}}_{CK2} + \underbrace{\overline{u'\omega'\frac{\partial \bar{u}}{\partial p}} + \overline{v'\omega'\frac{\partial \bar{v}}{\partial p}}}_{CK3}$$

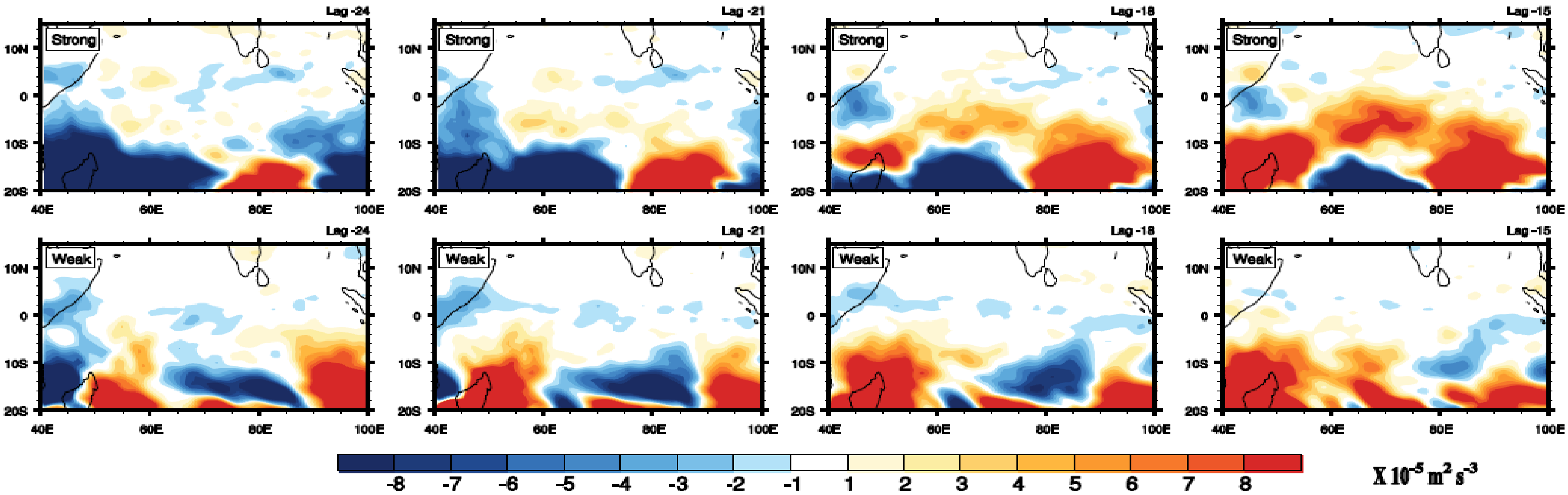
(a) Composite of the strong and weak events for 200 hPa CK_div



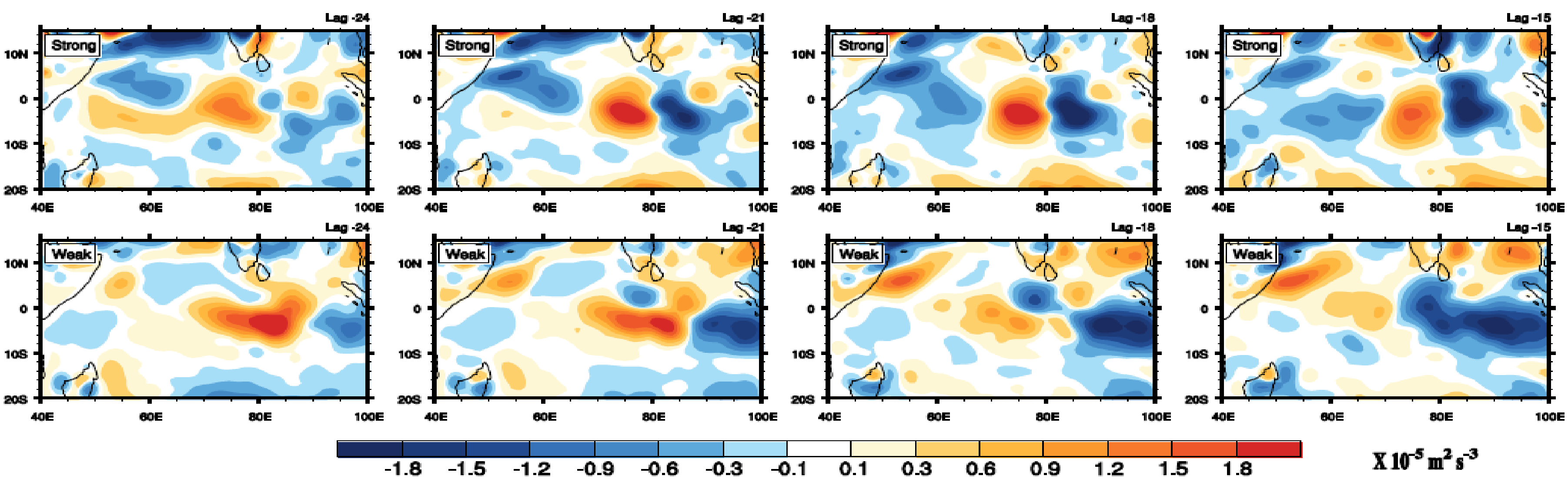
(b) Composite of the strong and weak events for 850 hPa CK_div

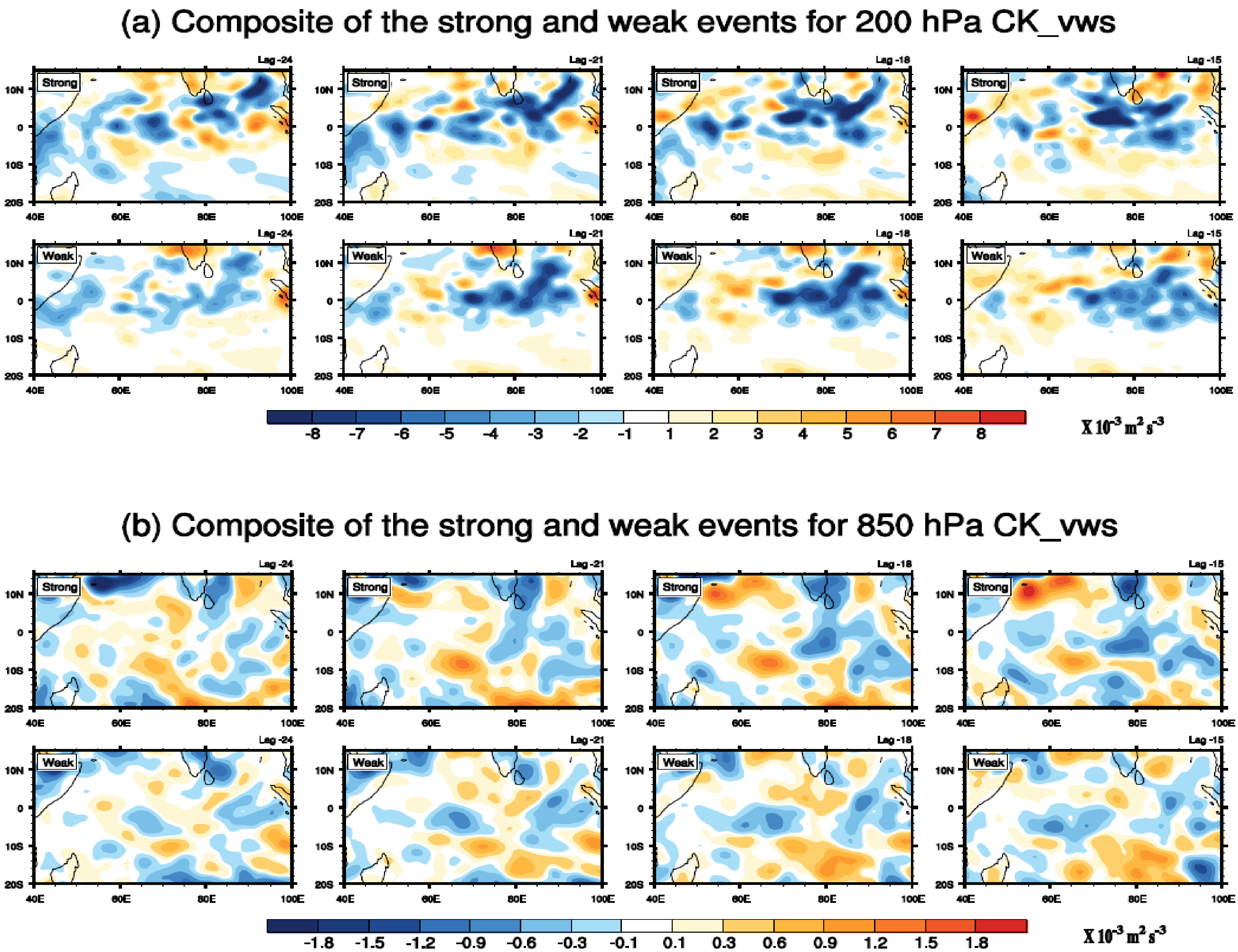


(a) Composite of the strong and weak events for 200 hPa CK_vort



(b) Composite of the strong and weak events for 850 hPa CK_vort




(a) Composite of the strong and weak events for 200 hPa CK_vws
Strong
Weak
Lag -24
Lag -21
Lag -18
Lag -15
10N
0
10S
20S
40E
60E
80E
100E
-8 -7 -6 -5 -4 -3 -2 -1 1 2 3 4 5 6 7 8
X 10^-3 m^2 s^-3
(b) Composite of the strong and weak events for 850 hPa CK_vws
-1.8 -1.5 -1.2 -0.9 -0.6 -0.3 -0.1 0.1 0.3 0.6 0.9 1.2 1.5 1.8
X 10^-3 m^2 s^-3

Conclusions

- ❖ The enhanced moisture convergence and the verical velocity plays important role in organization and intensification of the events.
- ❖ The MKE significantly increases during the intensification of strong BSISO but the strength is significantly weaker during evolution of weak BSISO.
- ❖ There is a conversion from MKE to EKE during the organization and intensification of the events.
- ❖ MAPE to MKE conversion helps the MKE to increase.
- ❖ The vertical eddy momentum and vertical wind shear interaction is the major contributor for MKE to EKE conversion.

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Friends and Family

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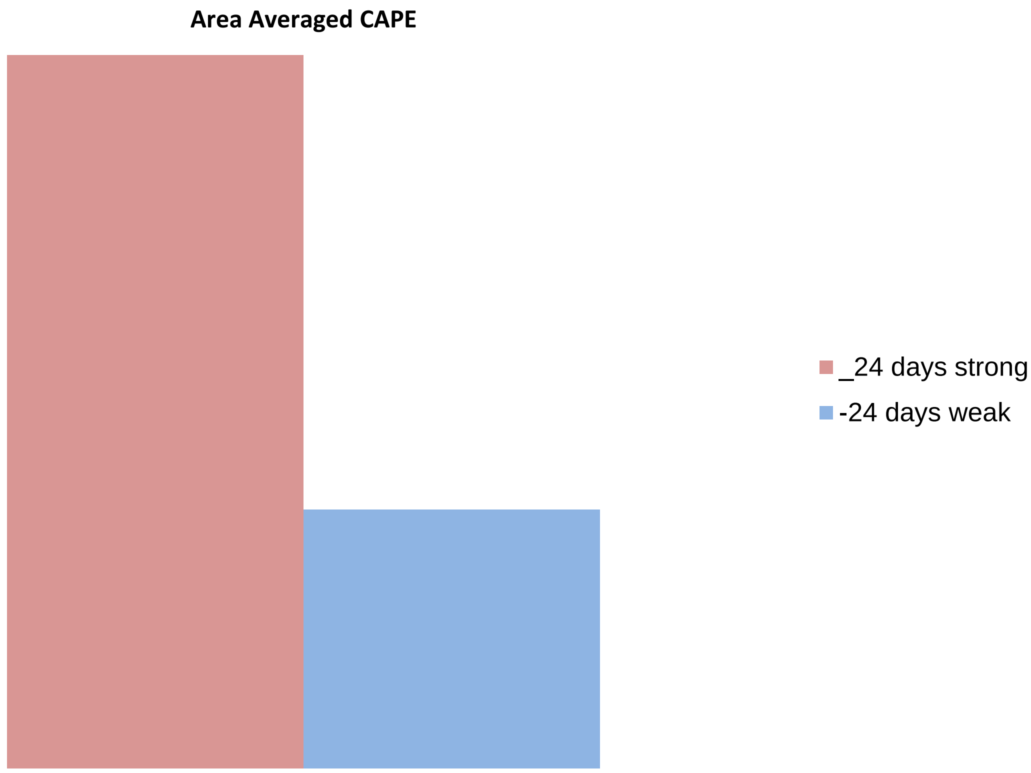
Area Averaged CAPE
_24 days strong
-24 days weak