A Dynamics-Based MJO Index

David H. Marsico[1,2] , Maria Gehne[1,2] , John Albers[2] , Juliana Dias[2] , Matthew Newman[2]
George Kiladis[2] , Prashant Sardeshmukh[1,2] , and Emerson LaJoie[3]

[1]CIRES University of Colorado-Boulder, [2]NOAA Physical Sciences Laboratory, [3]NOAA NWS/NCEP/CPC

Introduction

The tropics contain phenomena that vary on many different timescales. On intra-seasonal scales, tropical variability is dominated by the MJO, and indices used to identify it contain other processes with different limits of predictability and downstream impacts. In this work, we introduce a way of dynamically filtering tropical variability that is based on a linear inverse model (LIM). Observational fields are decomposed into sub-spaces consisting of LIM eigenvectors, and an MJO index is derived by projecting data onto the adjoint of a specific eigenvector associated with intra-seasonal variability.

Linear Inverse Model (LIM)

Stochastic forcing

$$\frac{d\vec{x}}{dt} = L\vec{x} + \vec{\xi}$$

τ_0: time lag
$\langle * \rangle$: expectation operator
$\ln$: matrix natural logarithm

Linear operator   State vector

$$L = \tau_0^{-1} \ln\left[\langle \vec{x}(t+\tau_0)\vec{x}(t)^T \rangle (\langle \vec{x}(t)\vec{x}(t)^T \rangle)^{-1}\right]$$

Eigenvectors/eigenvalues yield space-time structure of deterministic dynamics:

1) Eigenvectors correspond to spatial patterns
2) Real component of eigenvalue: e-folding time
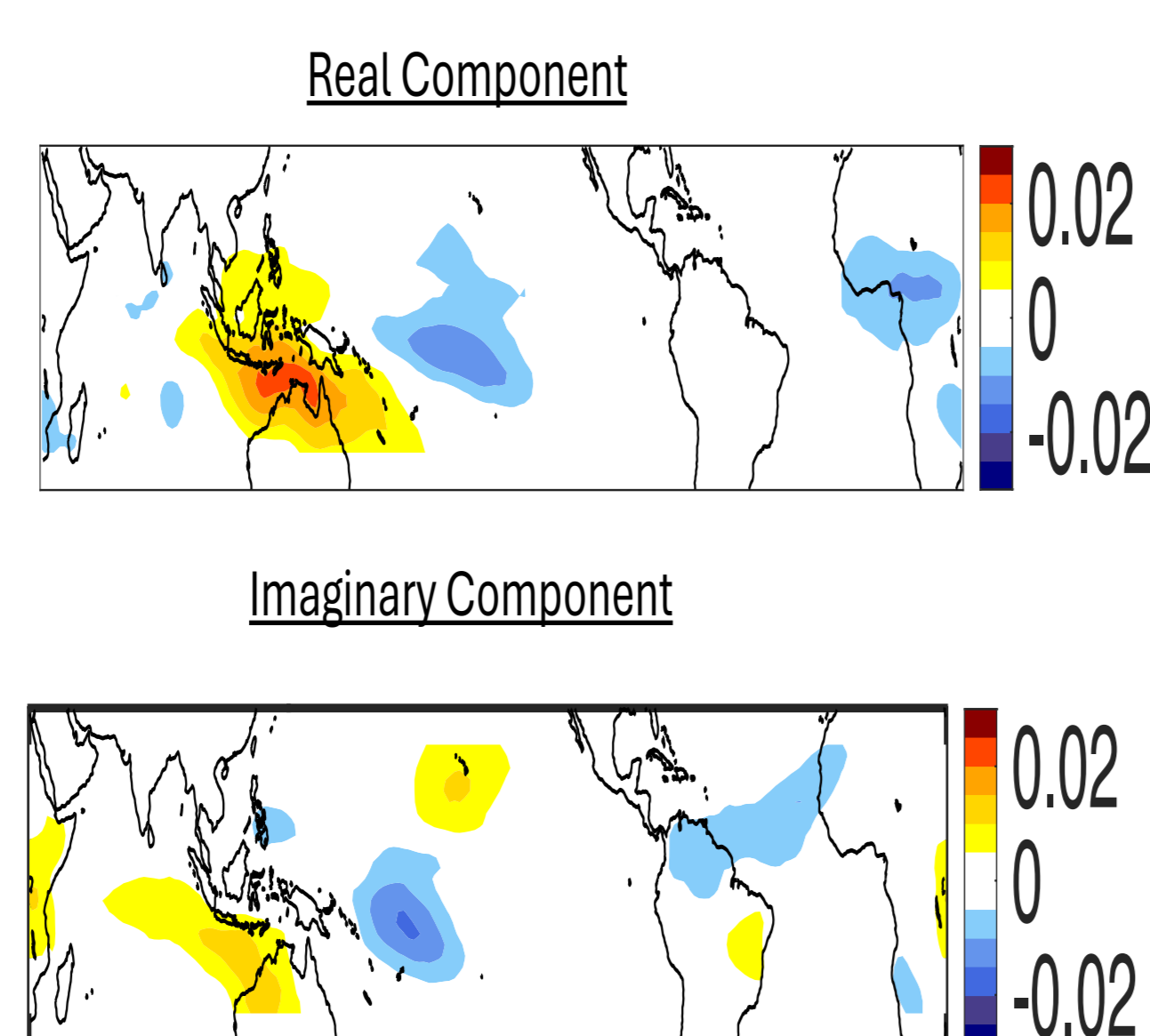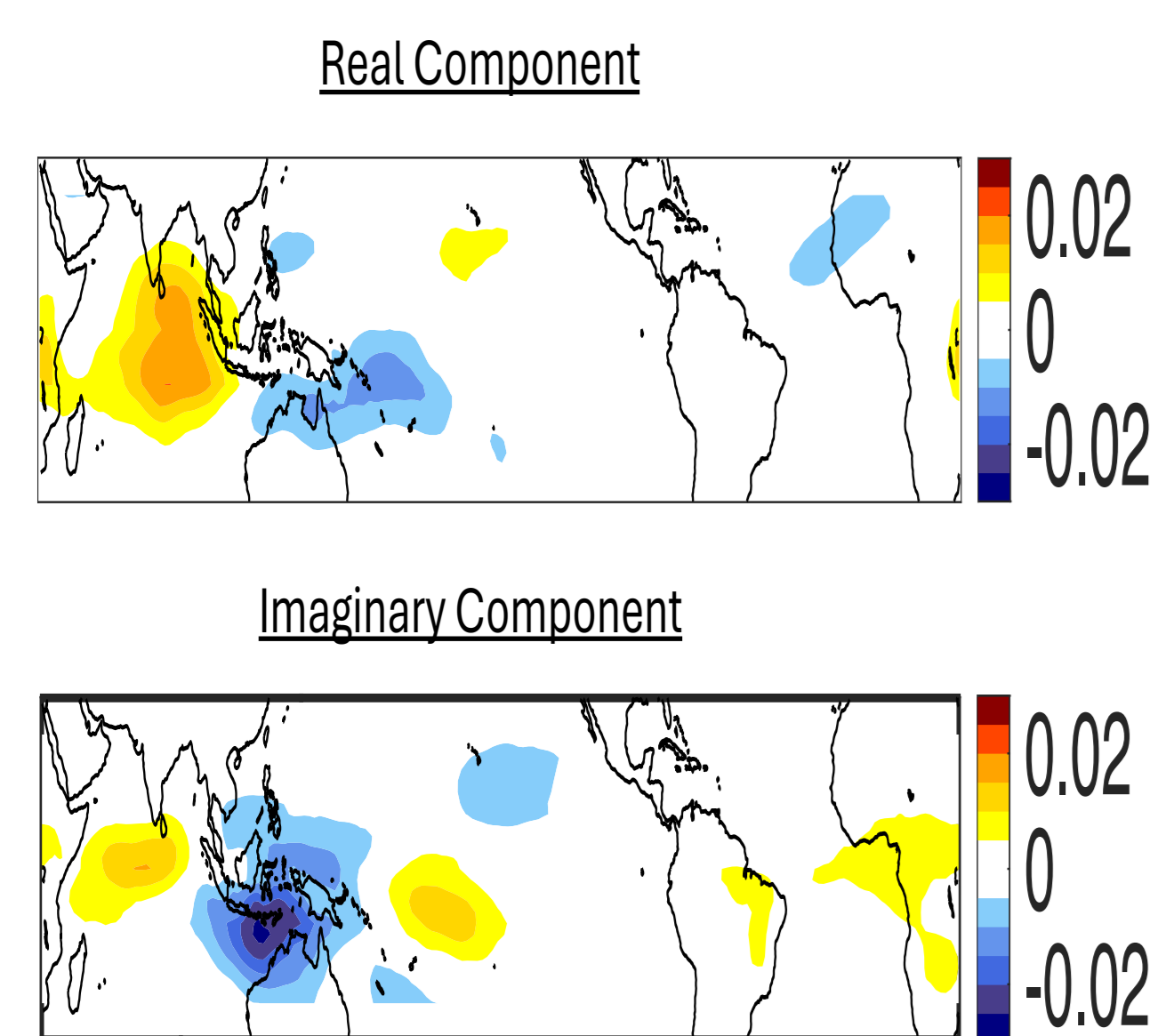3) Complex component of eigenvalue: frequency

Data and LIM Construction

- LIM trained on 5-day lag covariances of 5-day running mean anomalies of winter (Nov 1st – May 1st, 1979-2021) ERA5 data on a 2-degree grid
- Variables are 200-hPa and 850-hPa zonal and meridional winds, SST, and OLR ($24°$ S-$24°$ N)
- Anomalies are projected onto leading EOFs (82 in total):
  1. Combined wind ($u_{200}, v_{200}, u_{850}, v_{850}$) (28 EOFs, 48% of total variance)
  2. SST (14 EOFs, 66% of total variance)
  3. OLR (40 EOFs 62% of total variance)

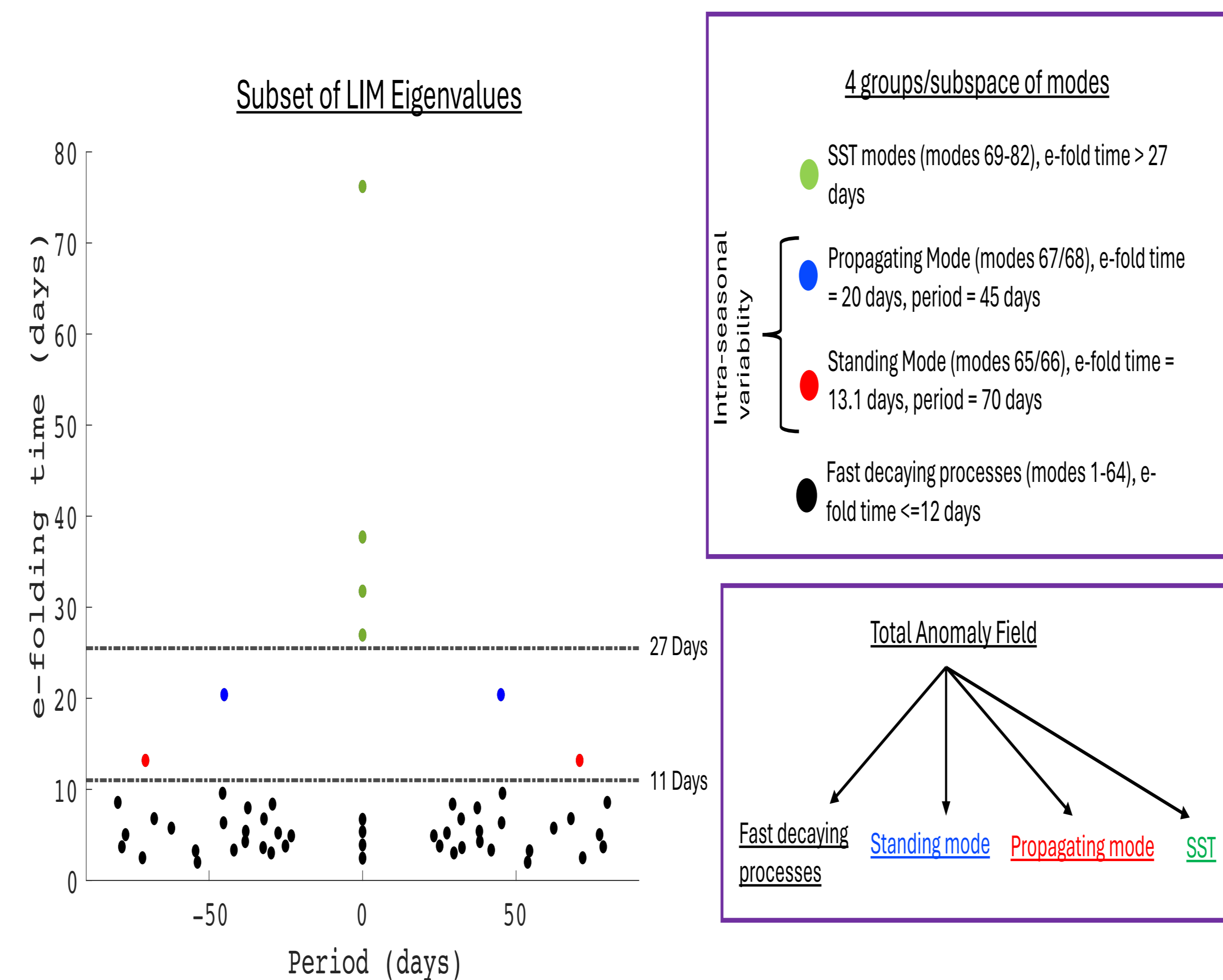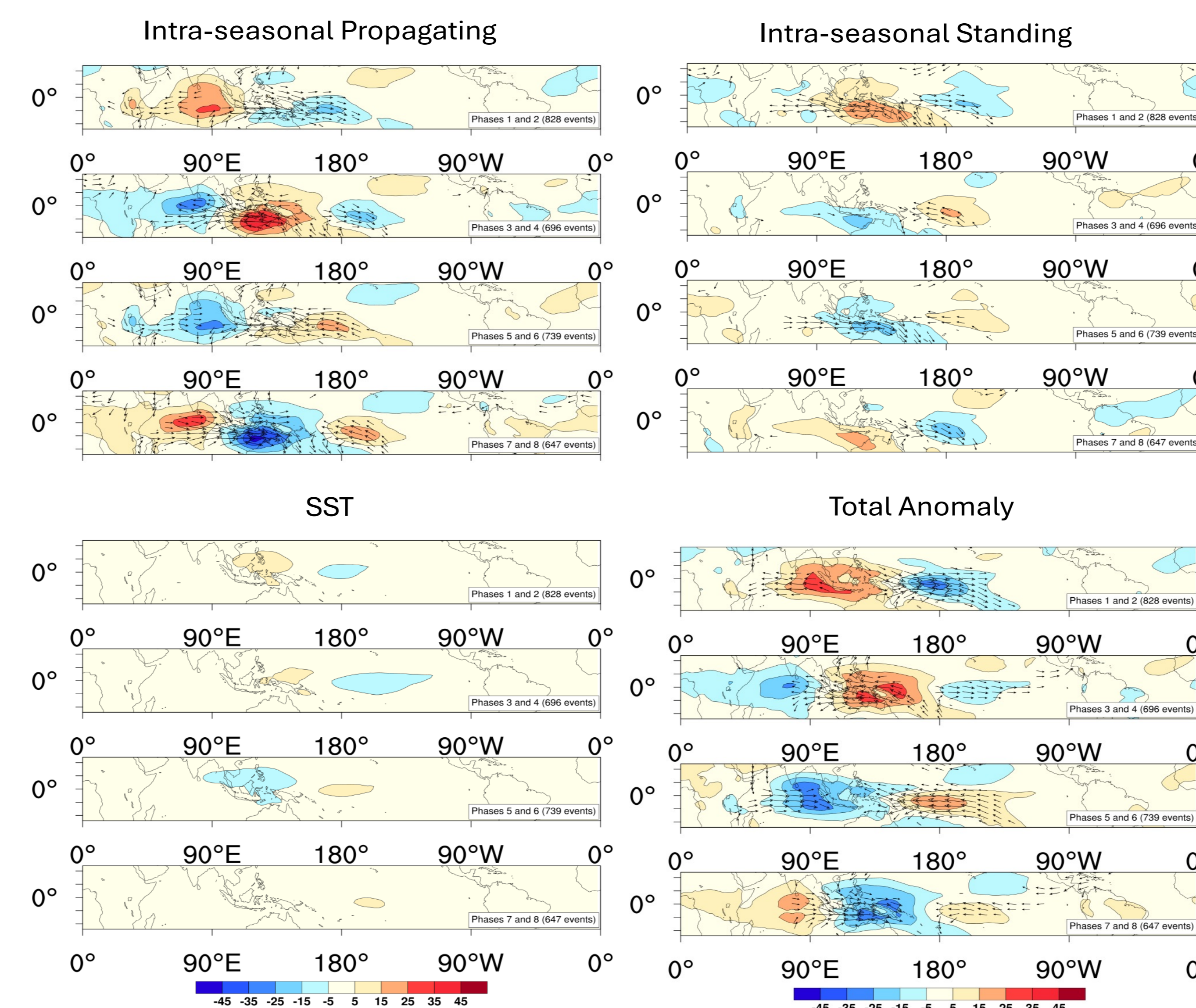## Intraseasonal Modes

Propagating Eigenmode (olr)

Real Component

Imaginary Component

Period: 45 days
e-fold time: 20 days

Standing Eigenmode (olr)

Real Component

Imaginary Component

Period: 70 days
e-fold time: 13.1 days

LIM Filter

Subset of LIM Eigenvalues

4 groups/subspace of modes

- SST modes (modes 69-82), e-fold time > 27 days
- Intra-seasonal variability
  - Propagating Mode (modes 67/68), e-fold time = 20 days, period = 45 days
  - Standing Mode (modes 65/66), e-fold time = 13.1 days, period = 70 days
- Fast decaying processes (modes 1-64), e-fold time <=12 days

Total Anomaly Field

Fast decaying processes   Standing mode   Propagating mode   SST

RMM Composites with LIM Filter

Intra-seasonal Propagating

Intra-seasonal Standing

SST

Total Anomaly

Phase 1 Lagged Hovmoellers (OLR)

Propagating Mode

Standing Mode

SST

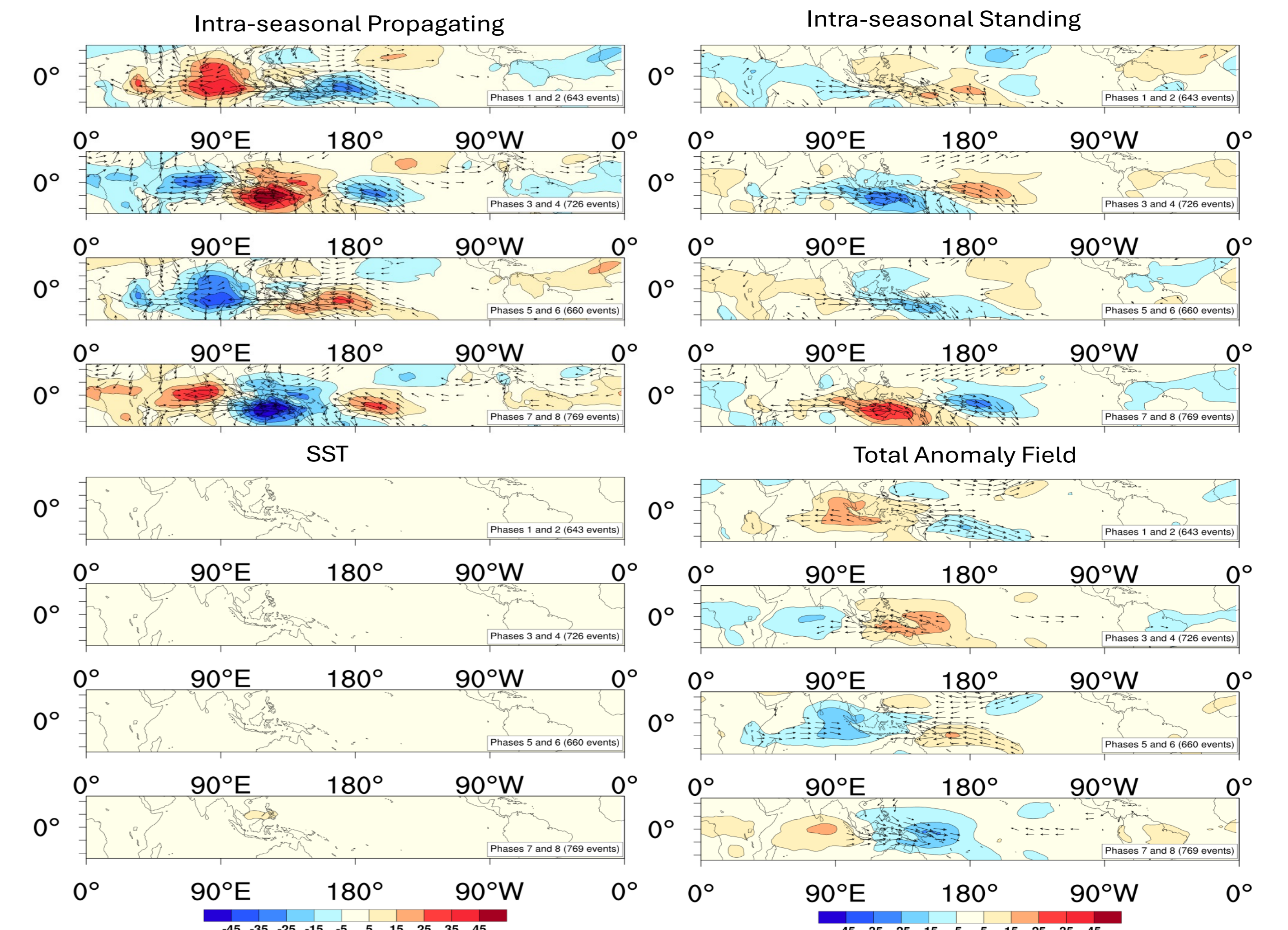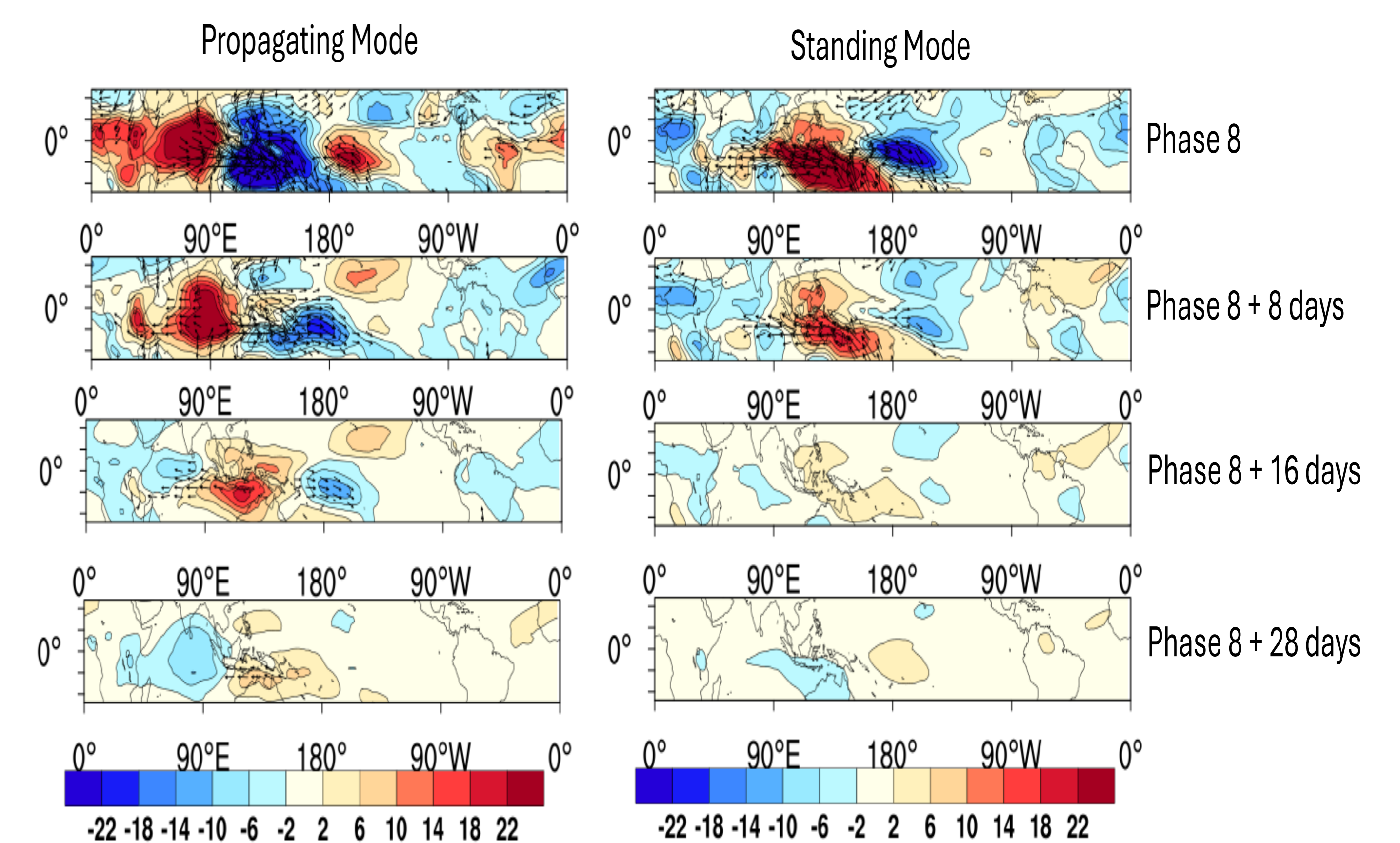Total Anomaly (RMM)
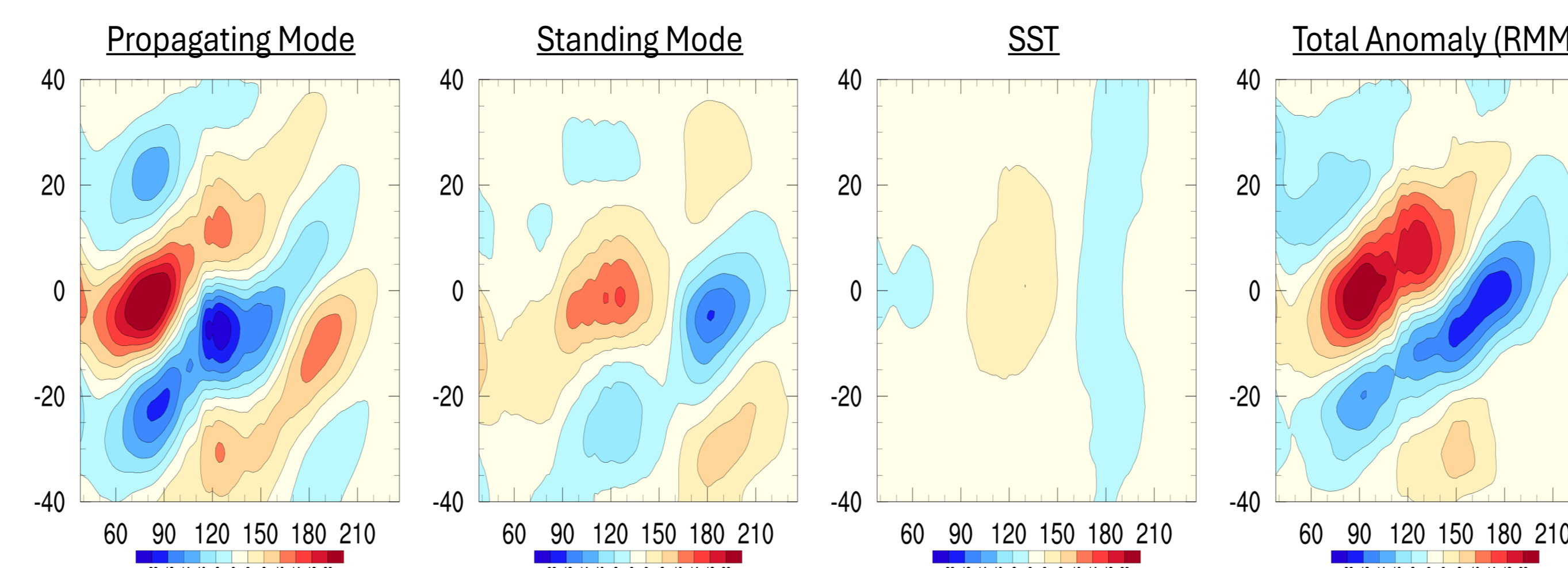
LIM-based MJO Index

- An index based on the LIM is determined by projecting the data onto the adoint of the intraseasonal propagating mode.

LIM Index Composites

Intra-seasonal Propagating

Intra-seasonal Standing

SST

Total Anomaly Field

Phase 8 Lagged Composites

Propagating Mode

Standing Mode

Phase 8
Phase 8 + 8 days
Phase 8 + 16 days
Phase 8 + 28 days

Conclusion

We have presented a method for filtering tropical variability using the eigenmodes of a linear inverse model. We have also introduced an MJO index that is obtained by projecting data onto the adjoint of one of the modes of intraseasonal variability of the LIM linear operator. This index can effectively filter out ENSO and other forms of tropical variability from the MJO.