

Energy Budget Perspective on Monsoon Low Pressure System Growth by Barotropic and Moisture-vortex Instabilities

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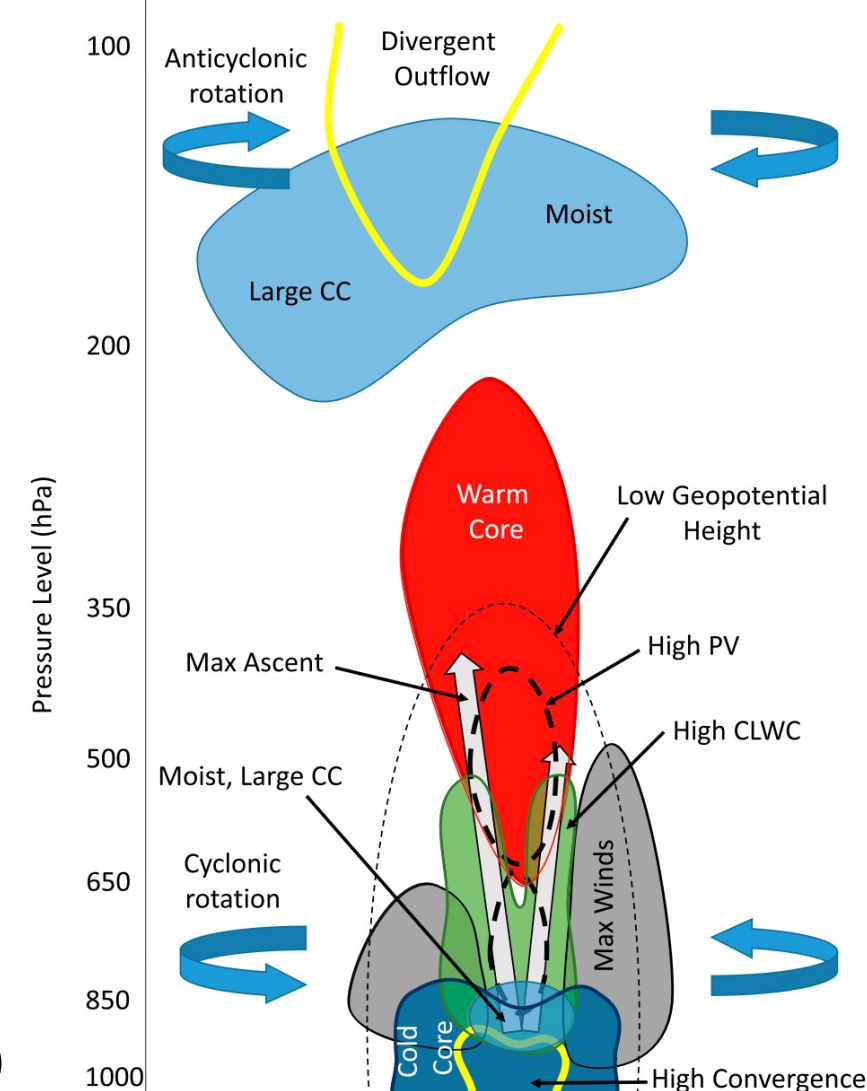
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1. Introduction

- Form near the Bay of Bengal
- Westward-propagating
- Synoptic-scale disturbances
- Surface wind speed:
 - <8.5 m/s: monsoon lows
 - 8.5 – 16.5 m/s: monsoon depressions
- Two per month from June to September
- Each lasts 3 to 5 days
- Phase speed ~7m/s
- Heavy precipitation

(Hunt et al., 2016)

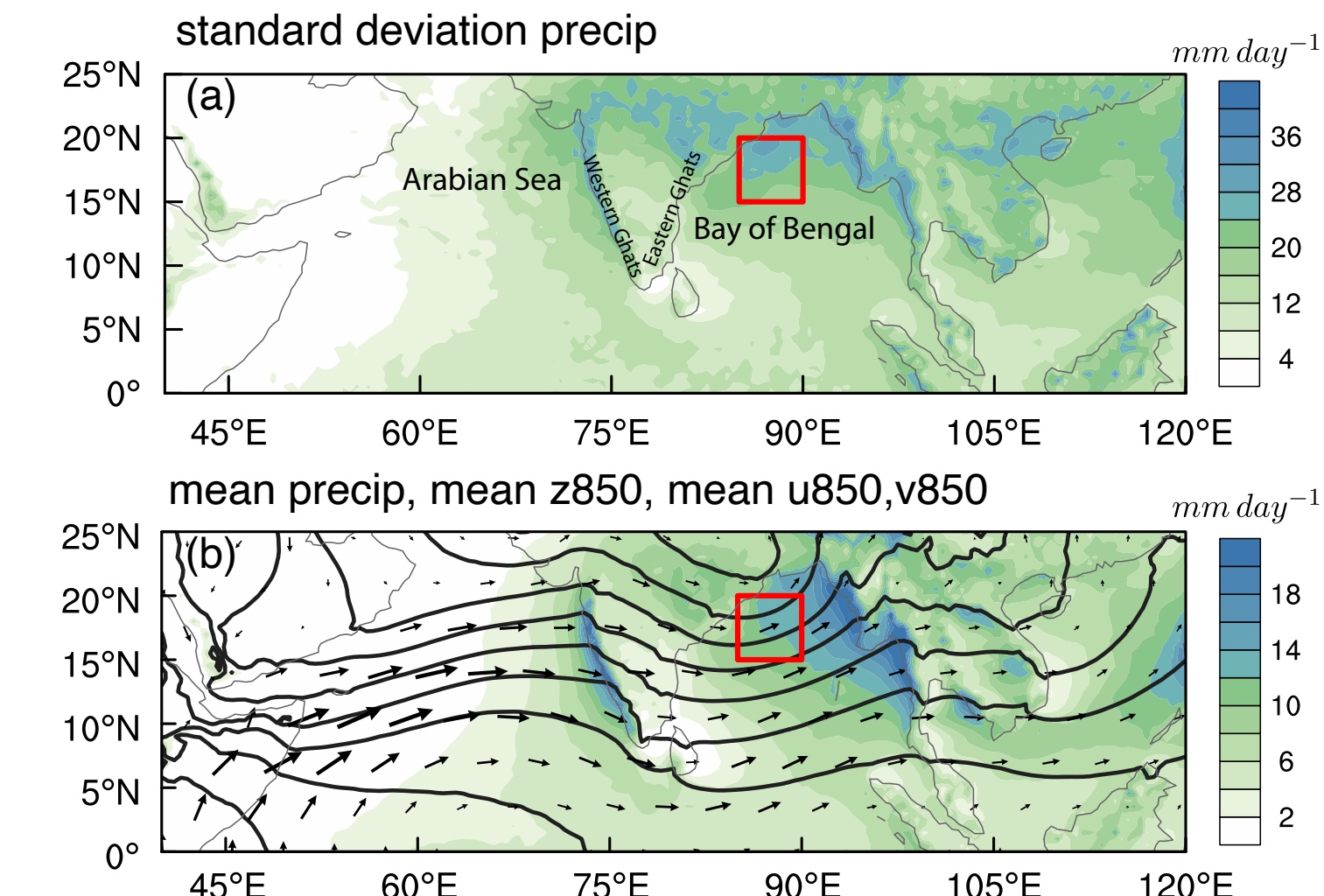


2. Data and Methods

Data: ERA5, 1979-2019, 6-hourly

Methods: Precipitation data were filtered to retain timescale 2 – 15 days⁻¹, zonal wavenumber 3 – 25 westward signal. Zonally-averaged over the head of Bay of Bengal (85-90°E 15-20°N, red box below) to create the index.

Fig.1. (a) Standard deviation of mean total precipitation rate. (b) JJAS mean P , z and u, v at 850 hPa.



3. Horizontal structure

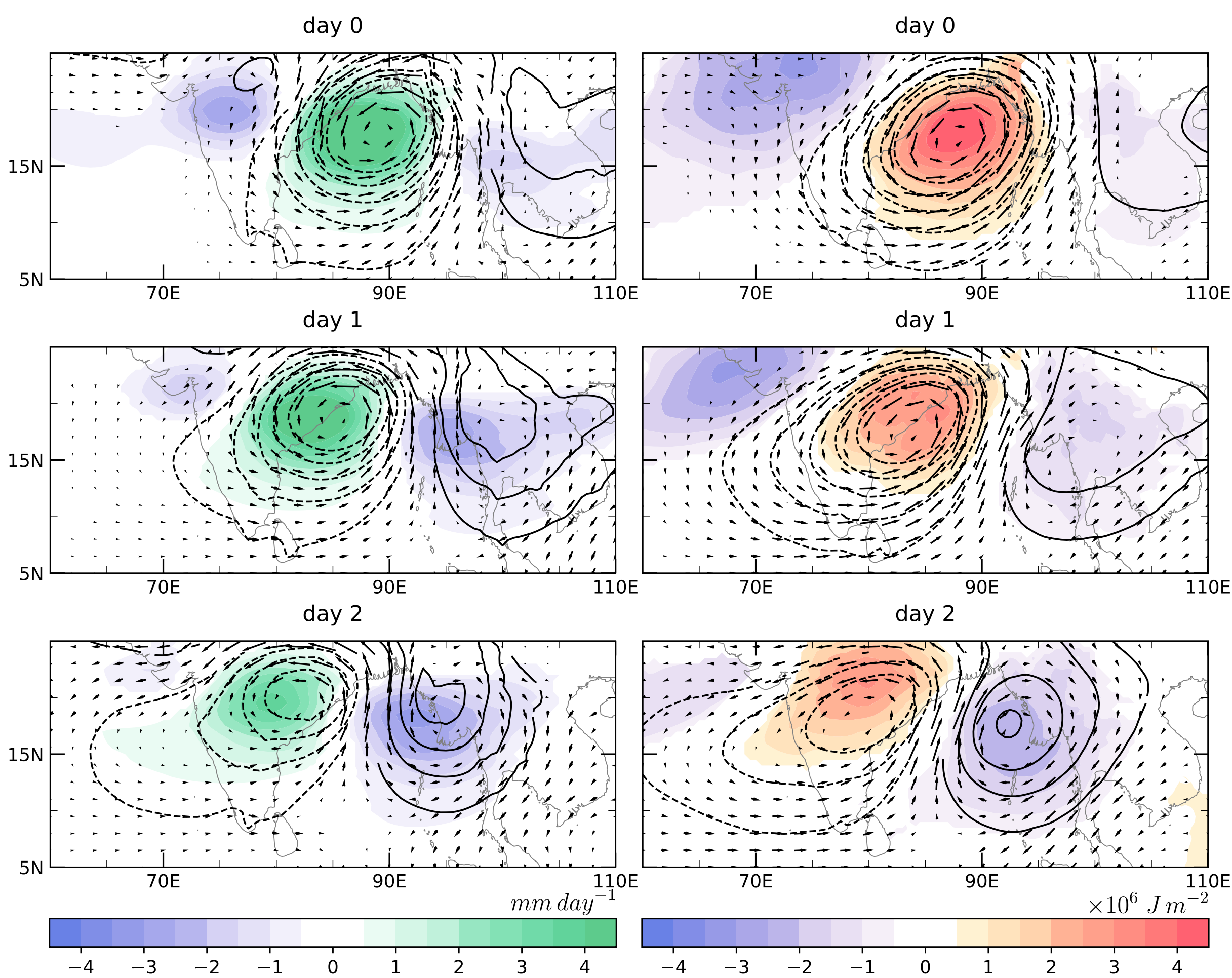


Fig.2. (left) Lag regressions of P , z' and u', v' at 850 hPa onto MLPS index. (right) $\langle MSE' \rangle$, z' and u', v' at 500 hPa

4. Vertical structure

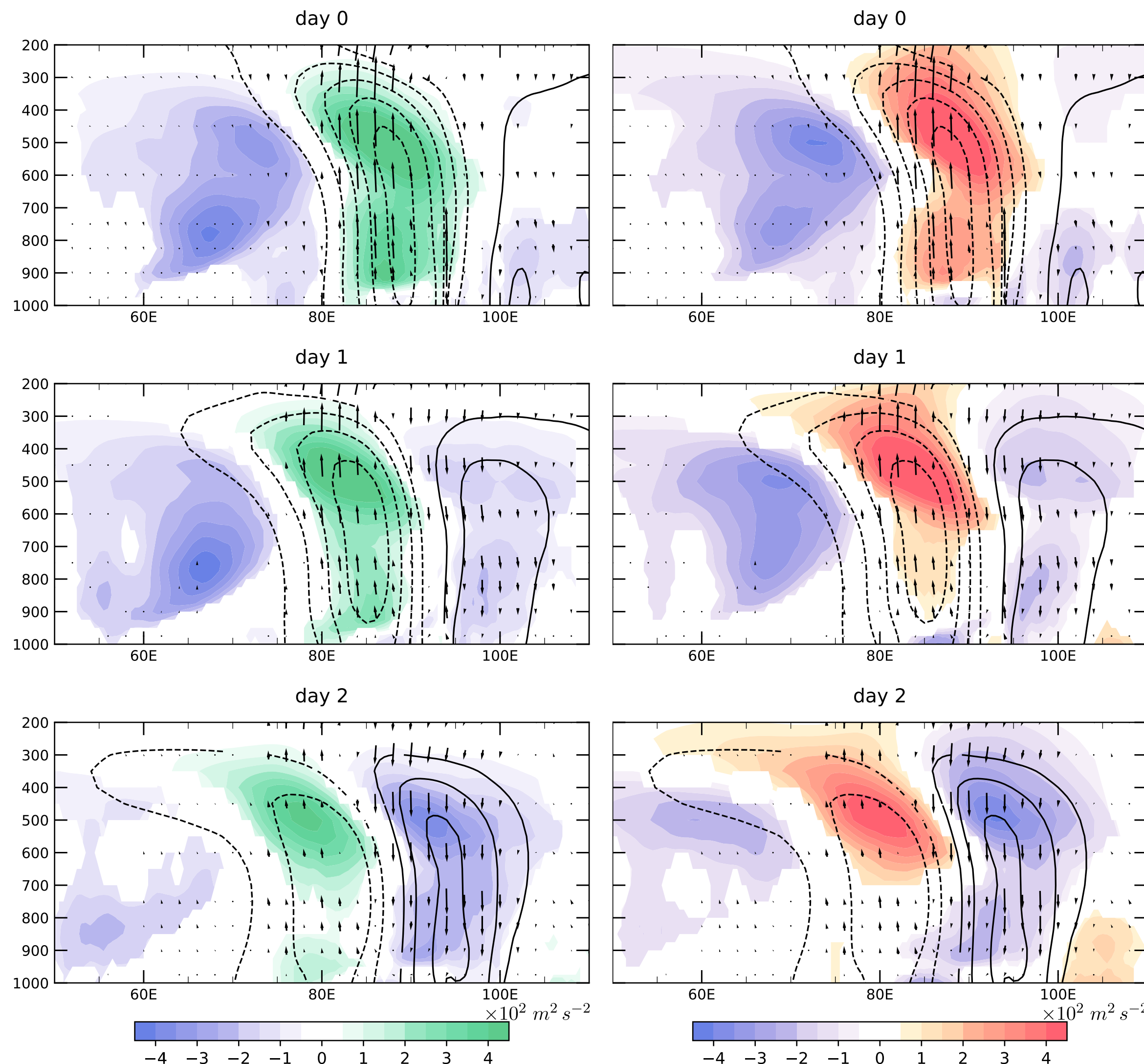


Fig.3. Longitude-height cross-sections of Lvq' (left shadings), MSE' (right shadings), z' (contours) and u', w' regressed onto MLPS index from day 0 to +2.

5. Barotropic instability

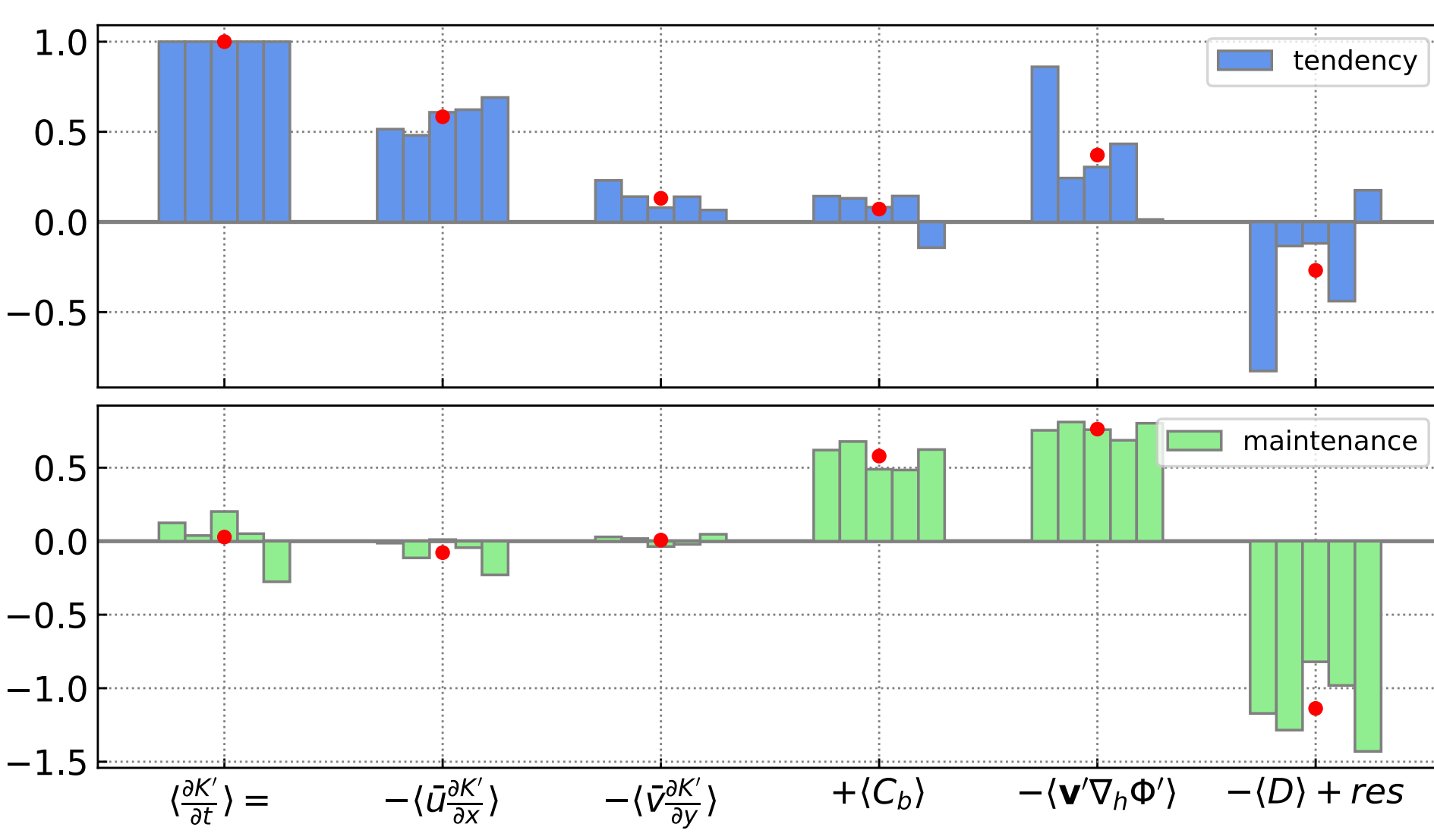


Fig.4. Normalized contributions to PKE tendency (top) and maintenance (bottom). The five bins within each term represent the lag regression from day -2 to +2. The red dots are the averages of the bins.

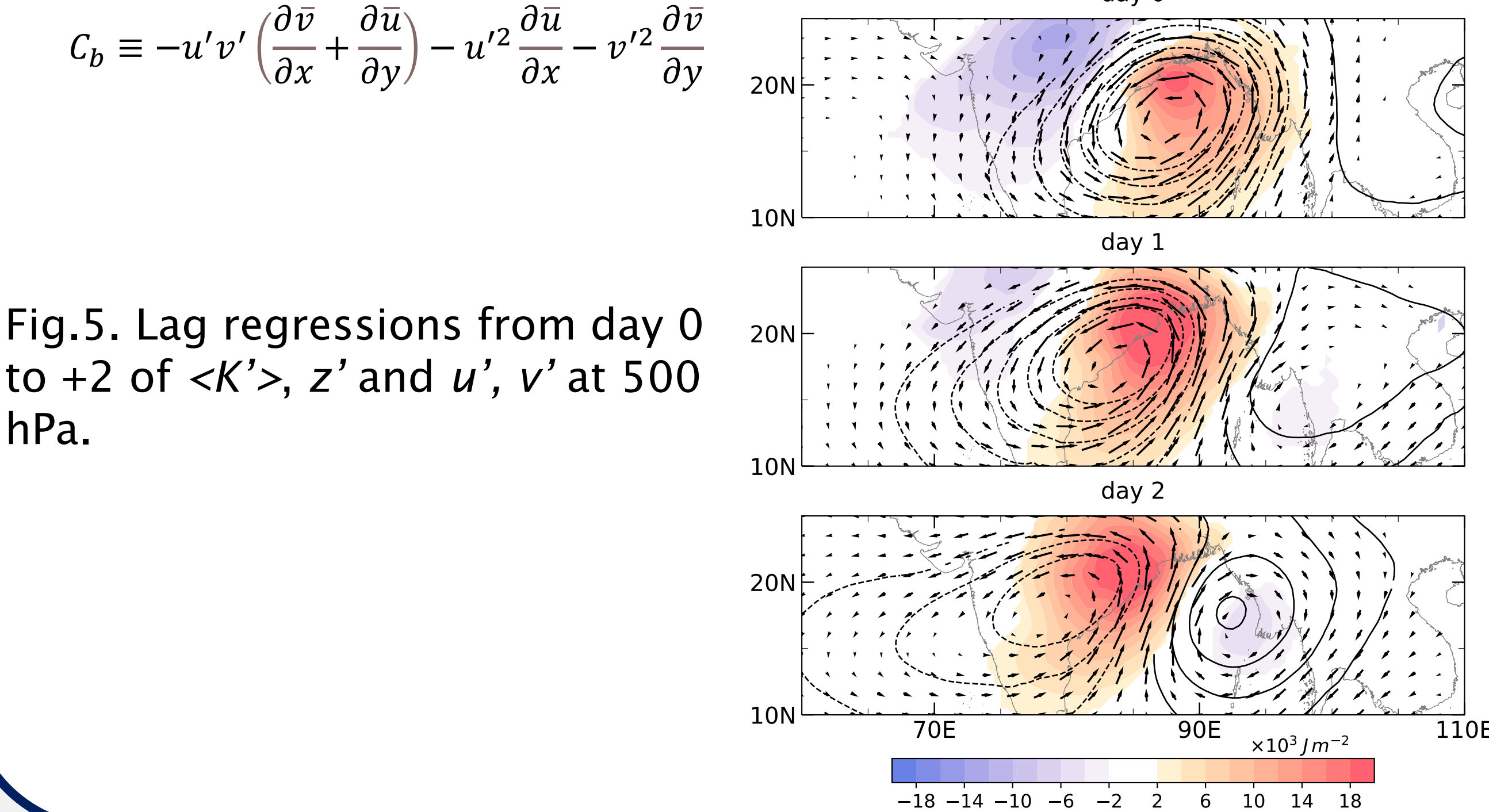


Fig.5. Lag regressions from day 0 to +2 of $\langle K' \rangle$, z' and u', v' at 500 hPa.

6. Moisture-vortex instability

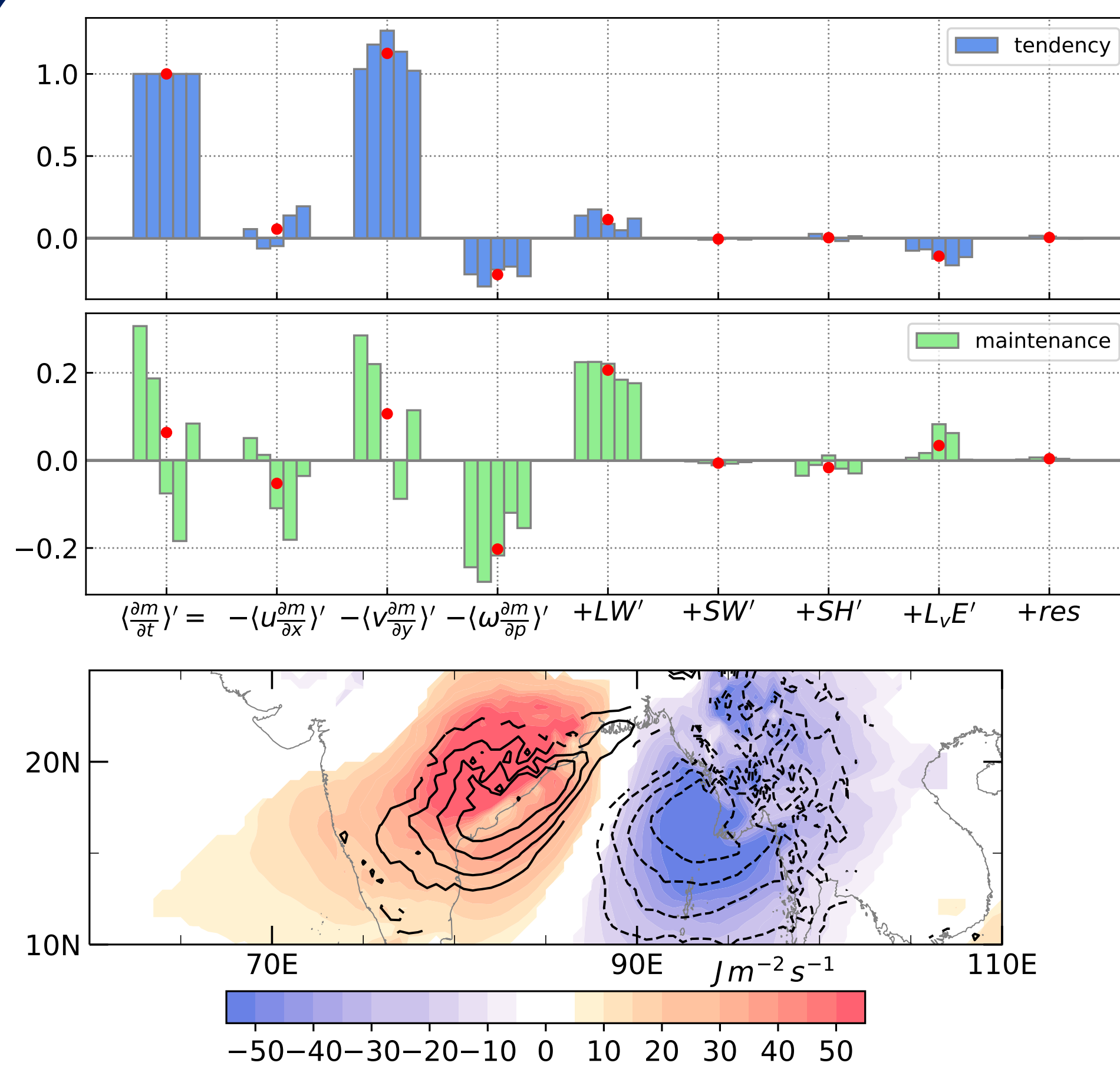


Fig.6. Normalized contributions to MSE tendency and maintenance.

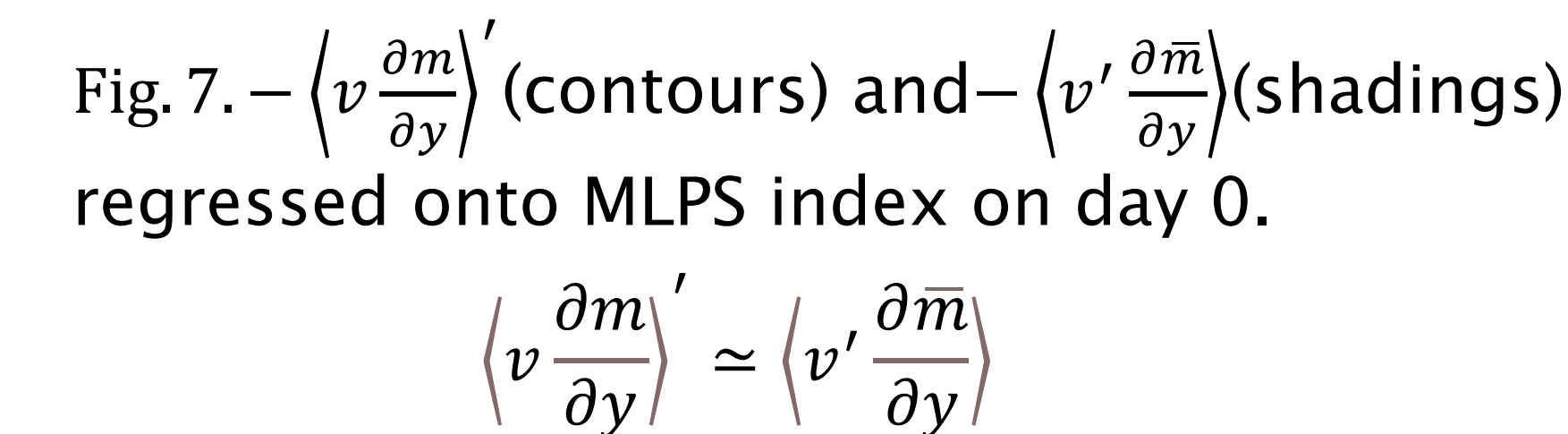


Fig.7. $-(v \frac{\partial m'}{\partial y})$ (contours) and $-(v' \frac{\partial m}{\partial y})$ (shadings) regressed onto MLPS index on day 0.

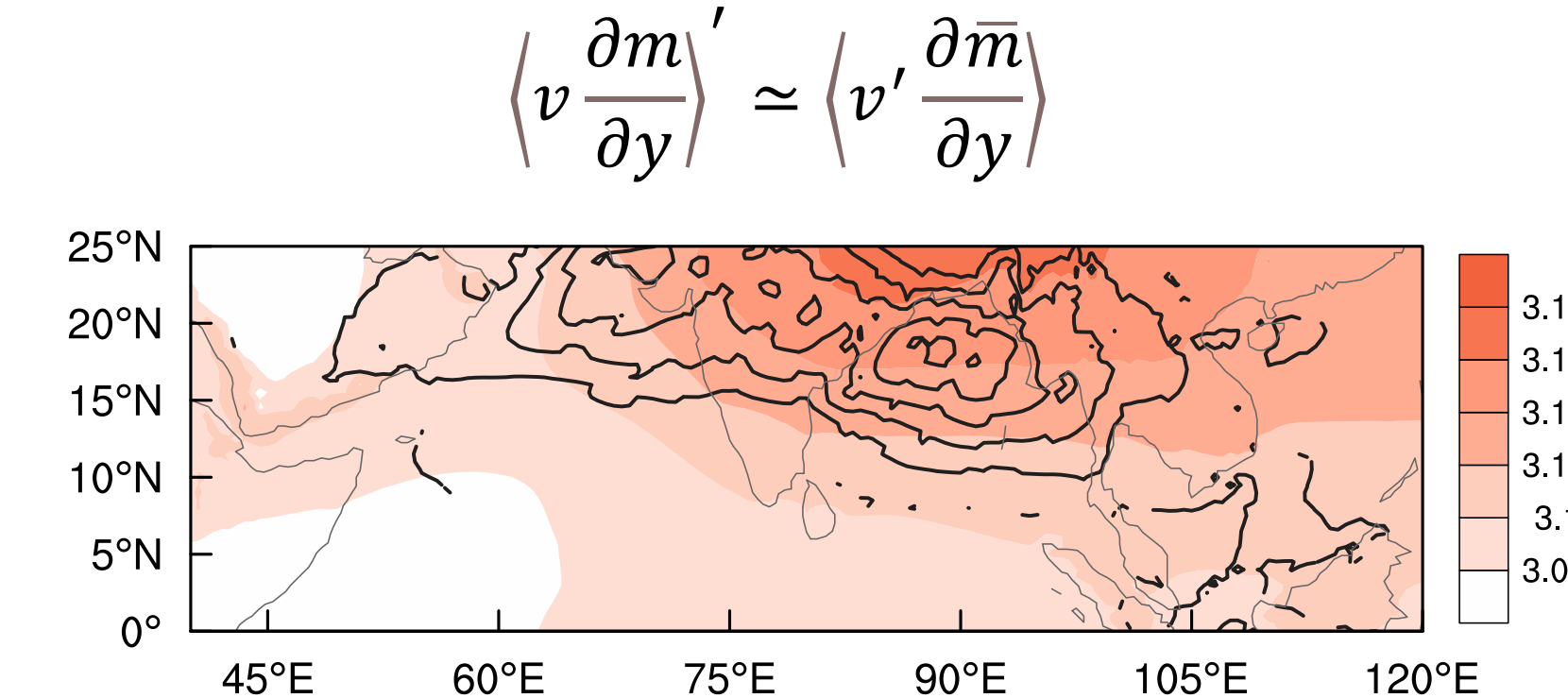


Fig.8. Column-integrated $\langle MSE' \rangle$ (shadings), the root-mean square of $\langle MSE' \rangle$ regressed onto the depression index (contours).

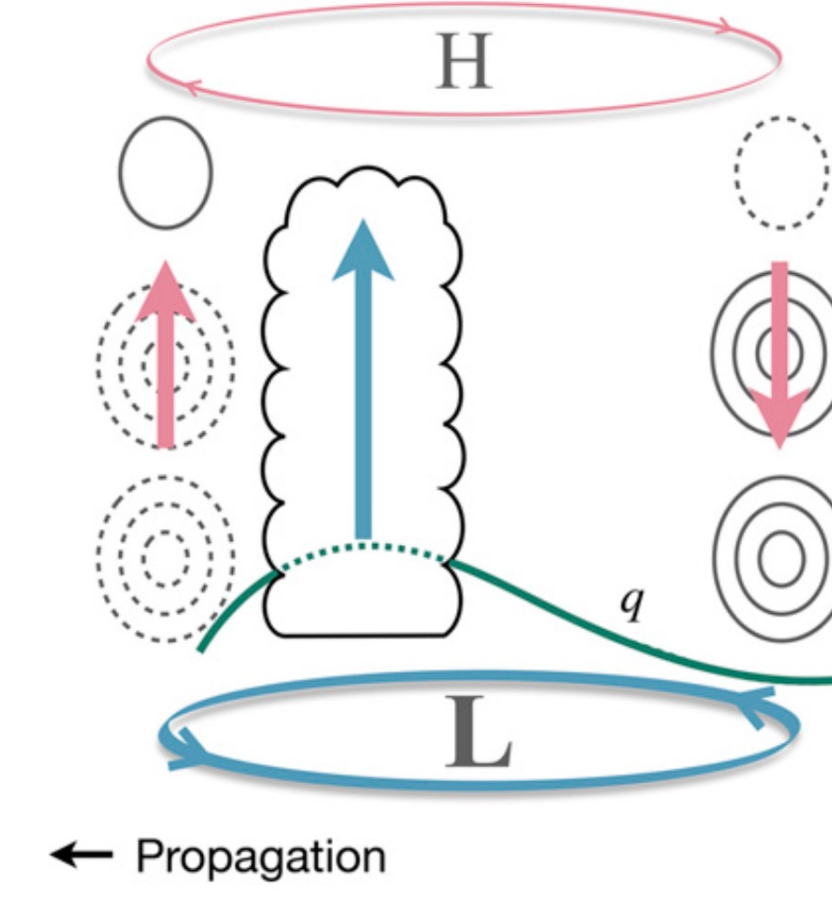


Fig.9. Schematic plot of moisture-vortex instability. Adiabatic lifting is shown as upward-pointing pink arrow. Enhanced convection is shown as upward-pointing teal arrow. Solid contours show the poleward flow. (Adames 2021)

7. Summary

Observed Feature	MVI	Dry Barotropic	Moist Baroclinic
Upright vertical structure	Yes	Yes	No
Tilts against horizontal shear	No	Yes	No
Synoptic horizontal scale of ~1000 km	Yes	Yes	Yes
Moisture, precipitation and vorticity have an in-phase component	Yes	No	No
MSE anomalies follow MSE isopleths	Yes	No	No
Meridional MSE advection important for MSE growth	Yes	No	No
Barotropic energy conversion important for PKE generation	No	Yes	No
PKE generation through downgradient geopotential advection	Yes	No	Yes