A Planetary-scale Land-sea Breeze Circulation in East Asia and the Western North Pacific

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Reference:

Huang WR, Chan JCL, Wang SY. 2010. A Planetary-scale Land-sea Breeze Circulation in East Asia and the Western North Pacific. *Q. J. R. Meteorol. Soc.* (in press).

Outline

1. Introduction

2. Data

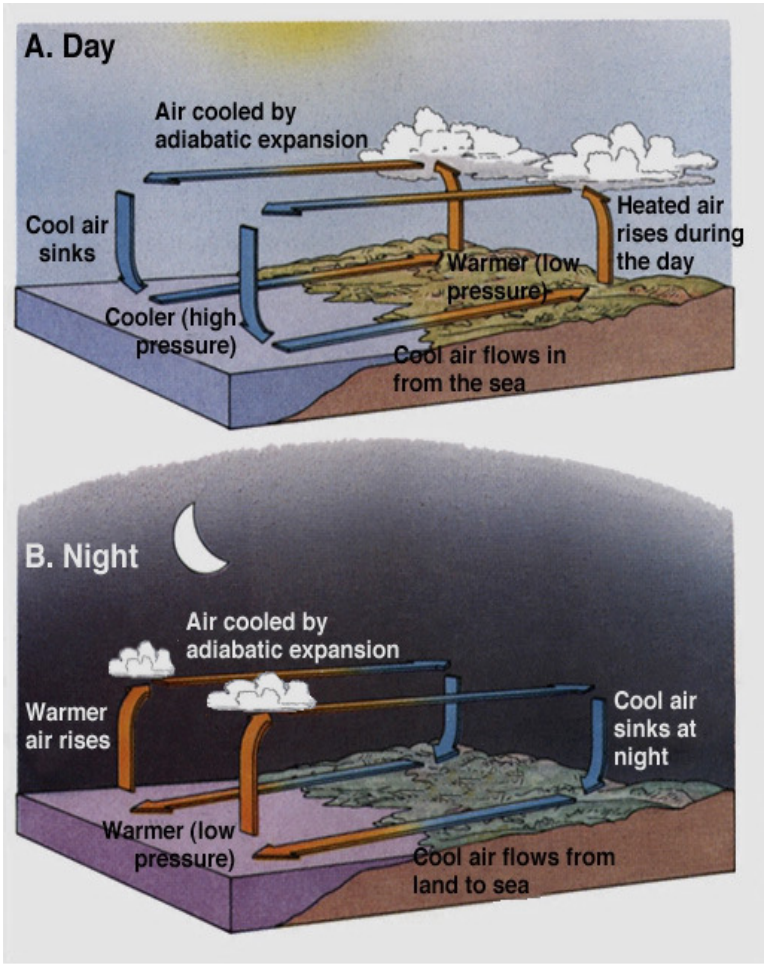
3. Results

Large-scale land-sea breeze (LSB) like circulation and its impact on the diurnal rainfall variation in East Asia

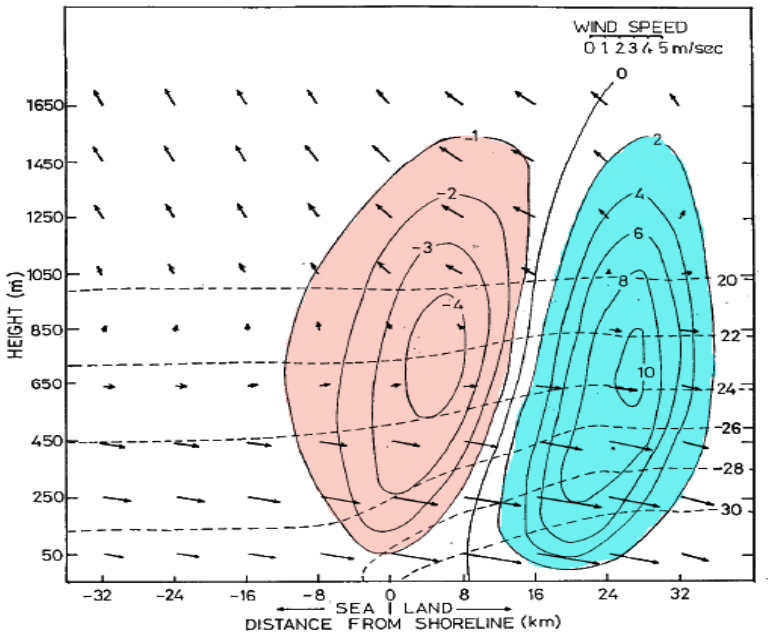
4. Summary

1. Introduction: land-sea breeze (LSB)

- The land-sea breeze circulation is induced by land-sea differential heating

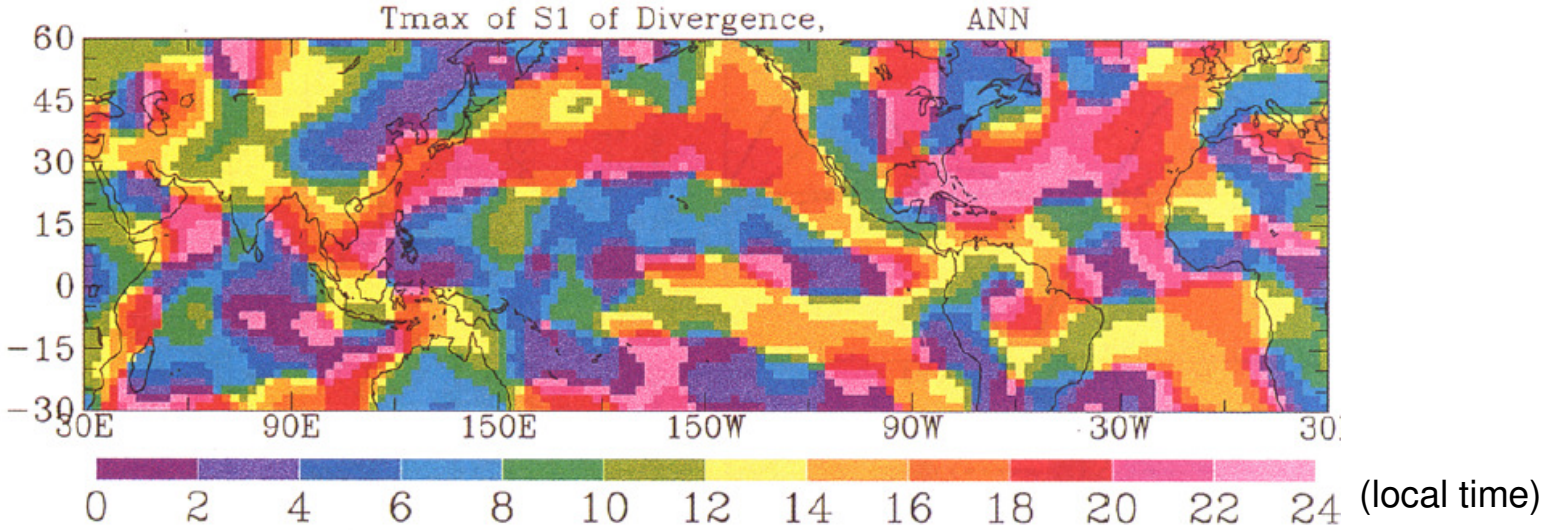


- The local land-sea breeze (LSB) along the coastline typically spans < 100 km



Neumann and Mahrer 1971

In the late 90s, a concept of planetary-scale diurnal surface wind variation was proposed based on observations of the surface wind divergence (Dai and Deser 1999).



➔ This concept implies a large-scale LSB-like circulation that has not been verified. An extra force different to the land-sea differential heating must exist in order to form a circulation in such a large scale.

Motivation

As the low-level circulation is important on representing the physical processes acting above the surface and on controlling timing of the precipitation, diagnostic works of this large-scale LSB-like issue are needed before applying this concept to the adjustment of weather and climate model's simulations.

Objective

We try to find out evidences and explanations for the existence of large-scale LSB-like circulation over the East Asia-Western Pacific region and discuss its impact on the diurnal rainfall variation.

2. Data

- Seven global gridded reanalysis datasets, including NCEP-NCAR Reanalysis-1, NCEP-DOE AMIP-II, ECWMF ERA-40, ECWMF ERA-interim, JRA-25, GEOS5, and GFS

- Wind observations from several WMO surface stations and atmospheric soundings

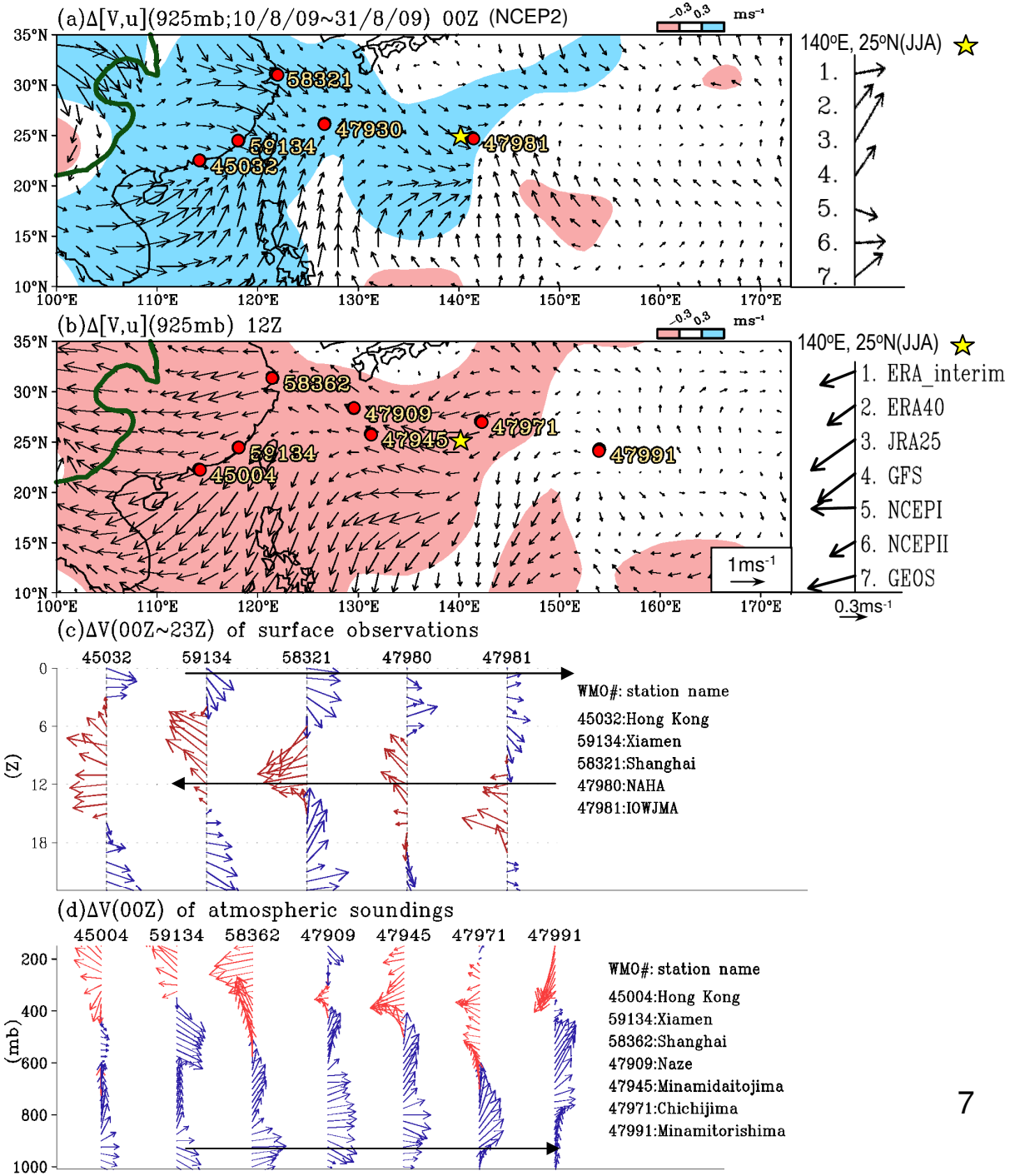
- Rainfall data { TRMM / Station

- Δ : anomalies = (specific individual time step) – daily mean of available time steps

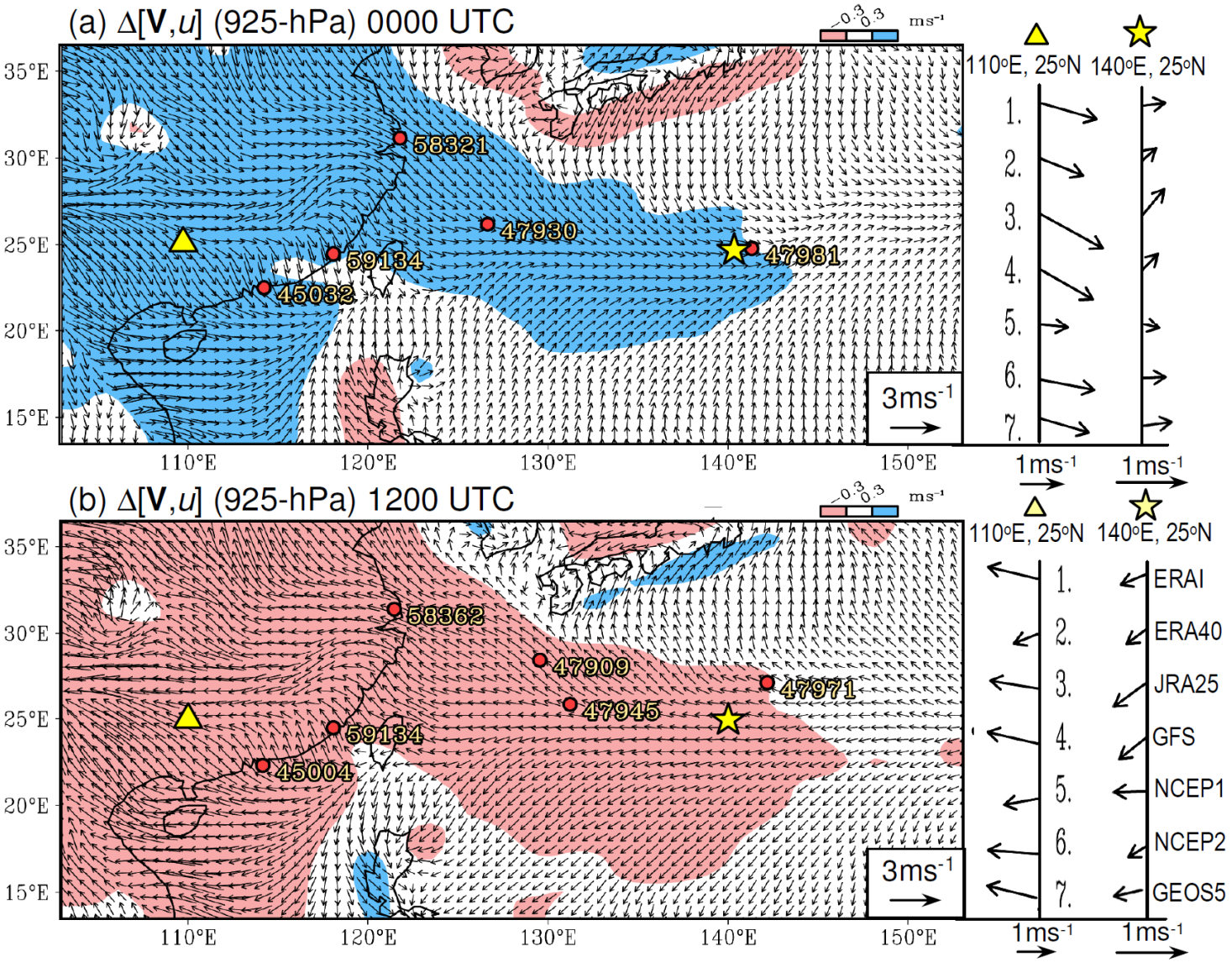
  S1: diurnal harmonic
  S2: semi-diurnal harmonic
  } From the Fourier analysis

3. Results

A seemingly giant land-sea breeze covers a few thousand kilometers over the Western Pacific

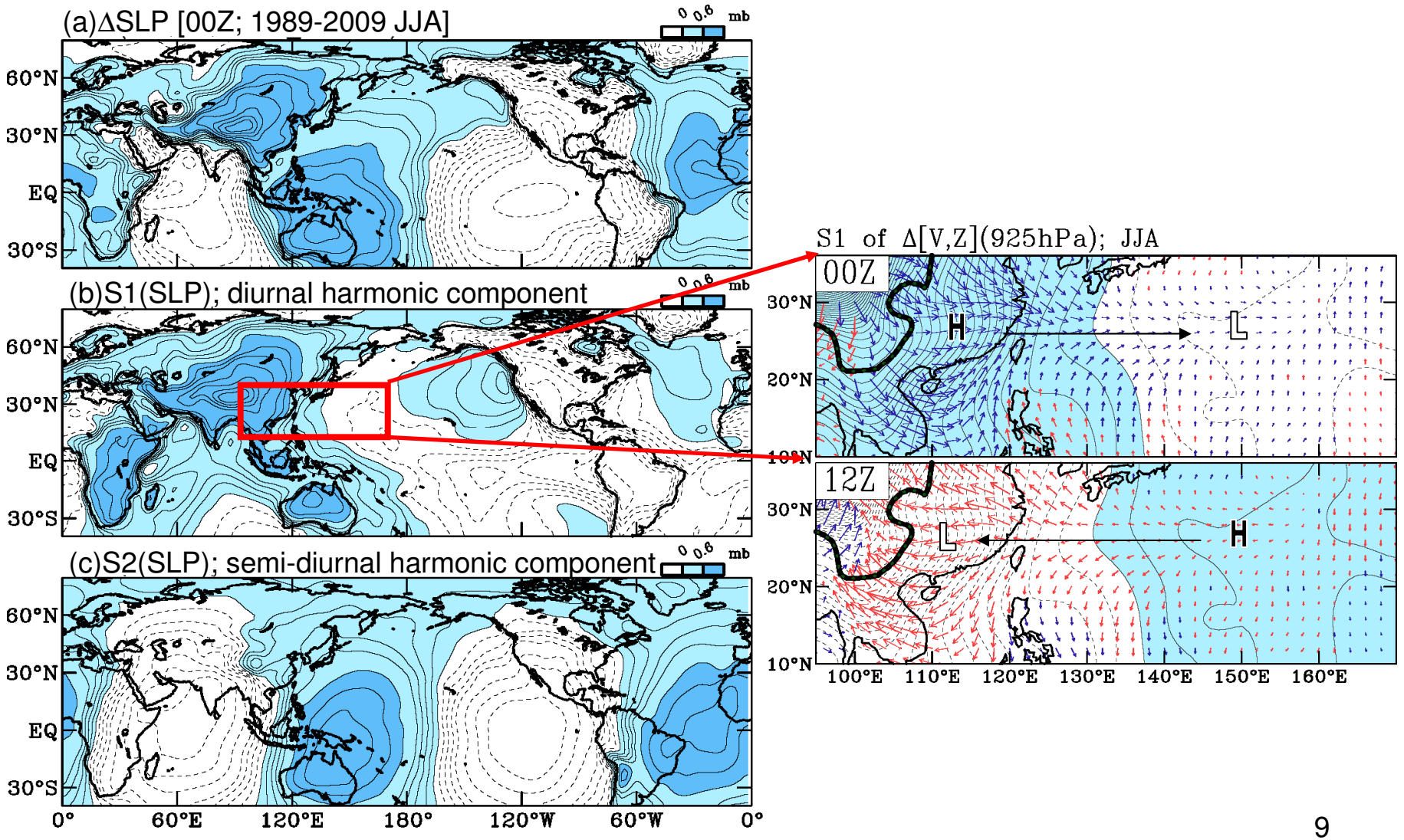


Similar feature is also observed in the higher spatial-temporal resolution of GEOS5 data



Possible cause of large-scale LSB-like circulation:

Pressure gradient force of global pressure tidal wave



TWO questions are raised:

Q1: Does the S1(PGF) contribute most to the large-scale LSB-like circulation?

- A momentum budget equation with standard notations is examined

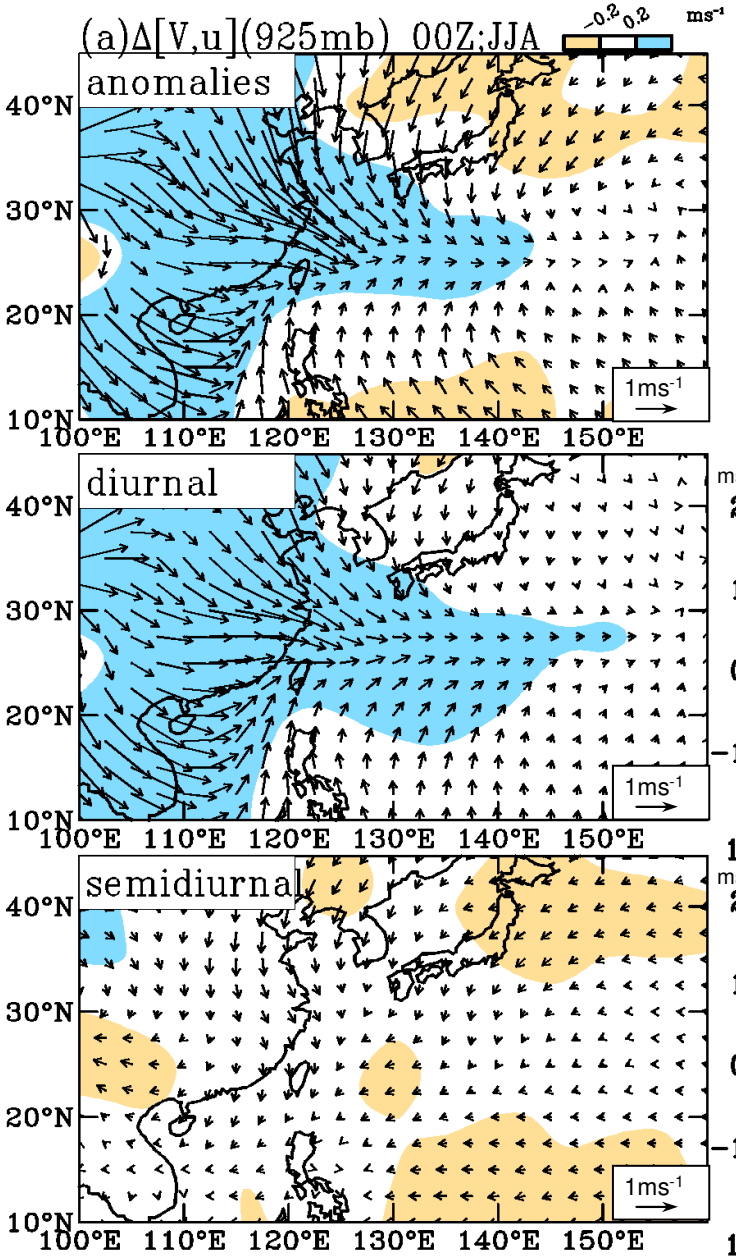
$$\frac{\partial \mathbf{V}}{\partial t} = \underbrace{-f \cdot \mathbf{k} \times \mathbf{V}}_{\text{(CF)}} \underbrace{-\frac{1}{\rho}\nabla p}_{\text{(PGF)}} + \underbrace{\frac{\partial}{\partial z}\left(K_d \frac{\partial \mathbf{V}}{\partial z}\right) + \text{residual}}_{\text{(VDIF+RES)}}$$

Q2: What is the implication of large-scale LSB-like in diurnal rainfall change?

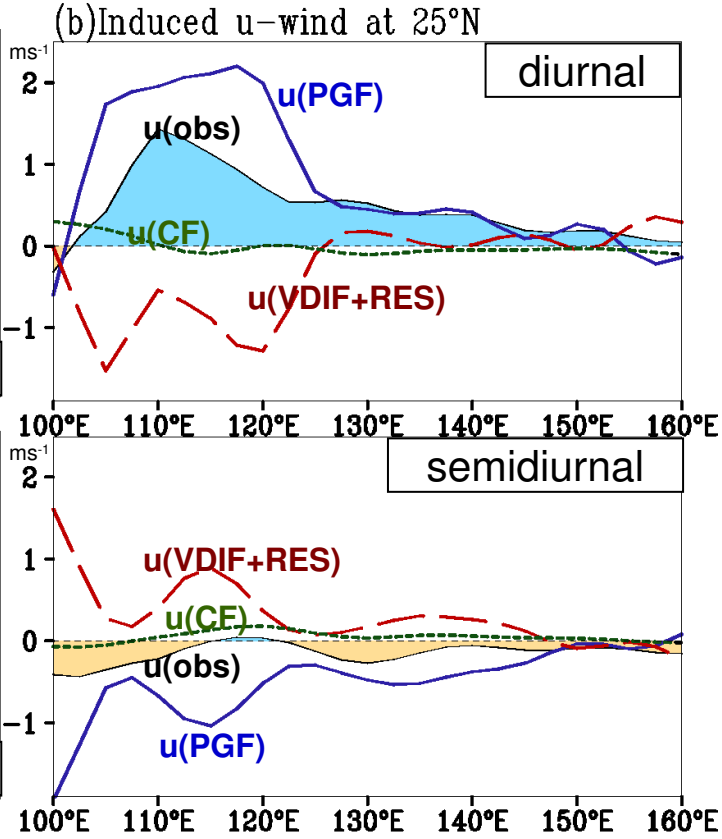
- The equivalent potential temperature is examined.

$$\theta_e = T_e \left(\frac{p_0}{p}\right)^{\frac{R_d}{c_p}} \approx \left(T + \frac{L_v}{c_p} r\right) \left(\frac{p_0}{p}\right)^{\frac{R_d}{c_p}}$$

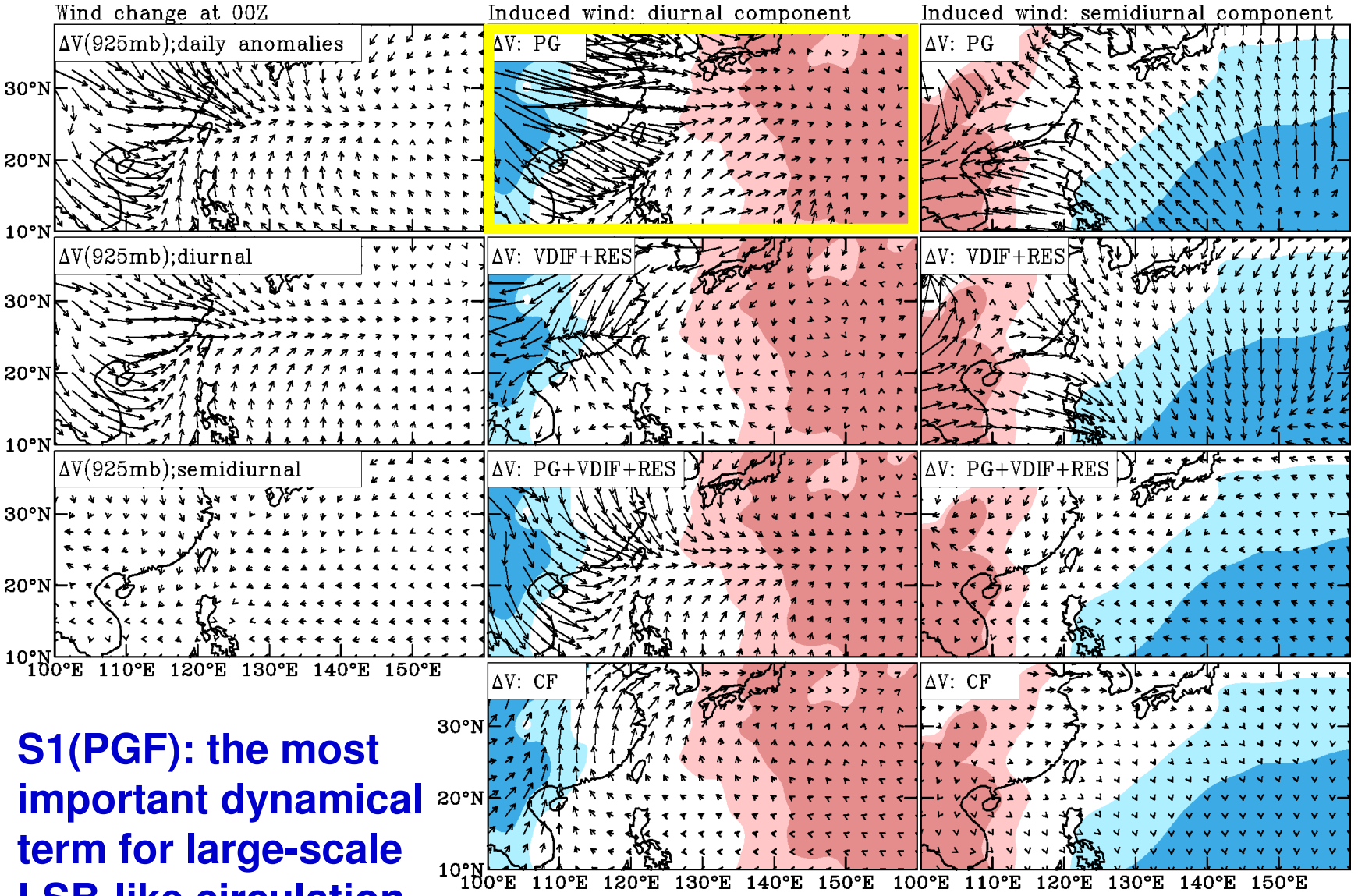
Diagnosis of momentum budget



$$\frac{\partial \mathbf{V}}{\partial t} = \underbrace{-f \cdot \mathbf{k} \times \mathbf{V}}_{\text{(CF)}} \underbrace{-\frac{1}{\rho}\nabla p}_{\text{(PGF)}} + \underbrace{\frac{\partial}{\partial z}\left(K_d \frac{\partial \mathbf{V}}{\partial z}\right) + \text{residual}}_{\text{(VDIF+RES)}}$$



Diagnosis of momentum budget



S1(PGF): the most important dynamical term for large-scale LSB-like circulation

What is the extra force different to land-sea differential heating for forming large-scale LSB-like circulation?

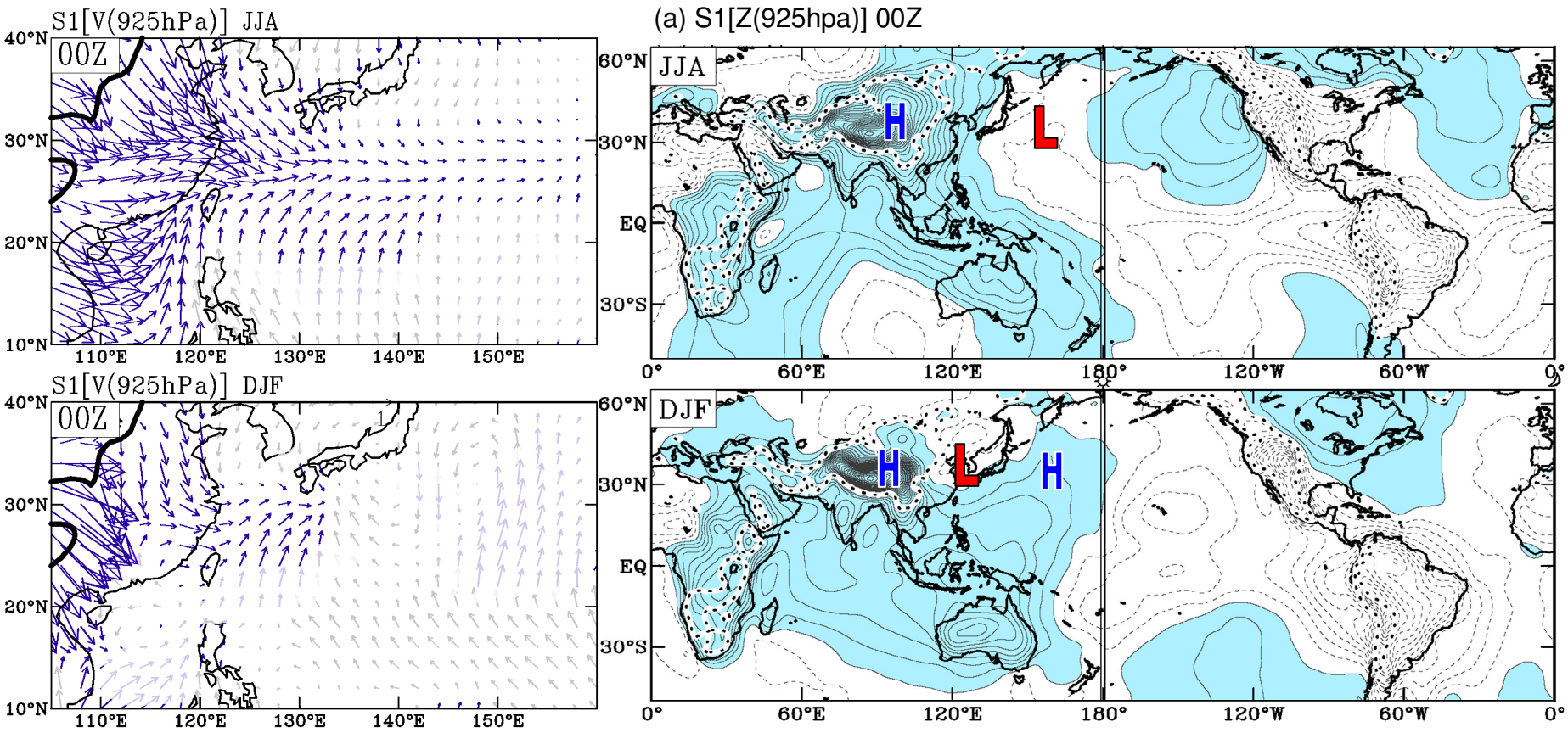
S1(SLP)

Migrating component:
forced by water vapor and ozone heatings
(Lindzen 1967; Groves and Wilson 1982)

Non-migrating component:
forced by latent heat released and sensible heat due to land–sea differences and topography
(Forbes and Groves 1987; Tsuda and Kato 1989)

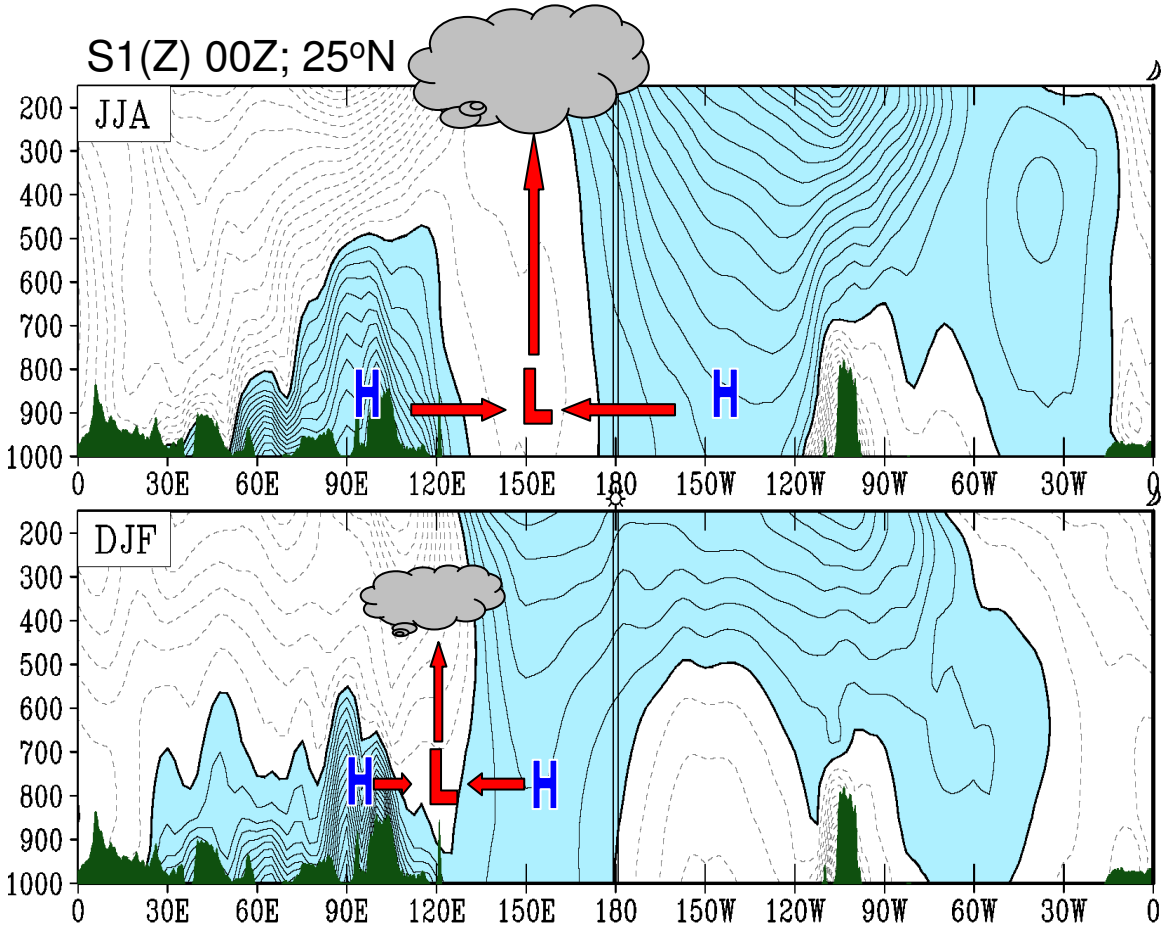
➡ Likely, the forces that generate the global migrating tidal component of S1(SLP) are the extra forces for explaining the large-scale LSB-like circulation

Seasonal variation of LSB-like circulation



Seasonal variation of S1(Z) at 25°N

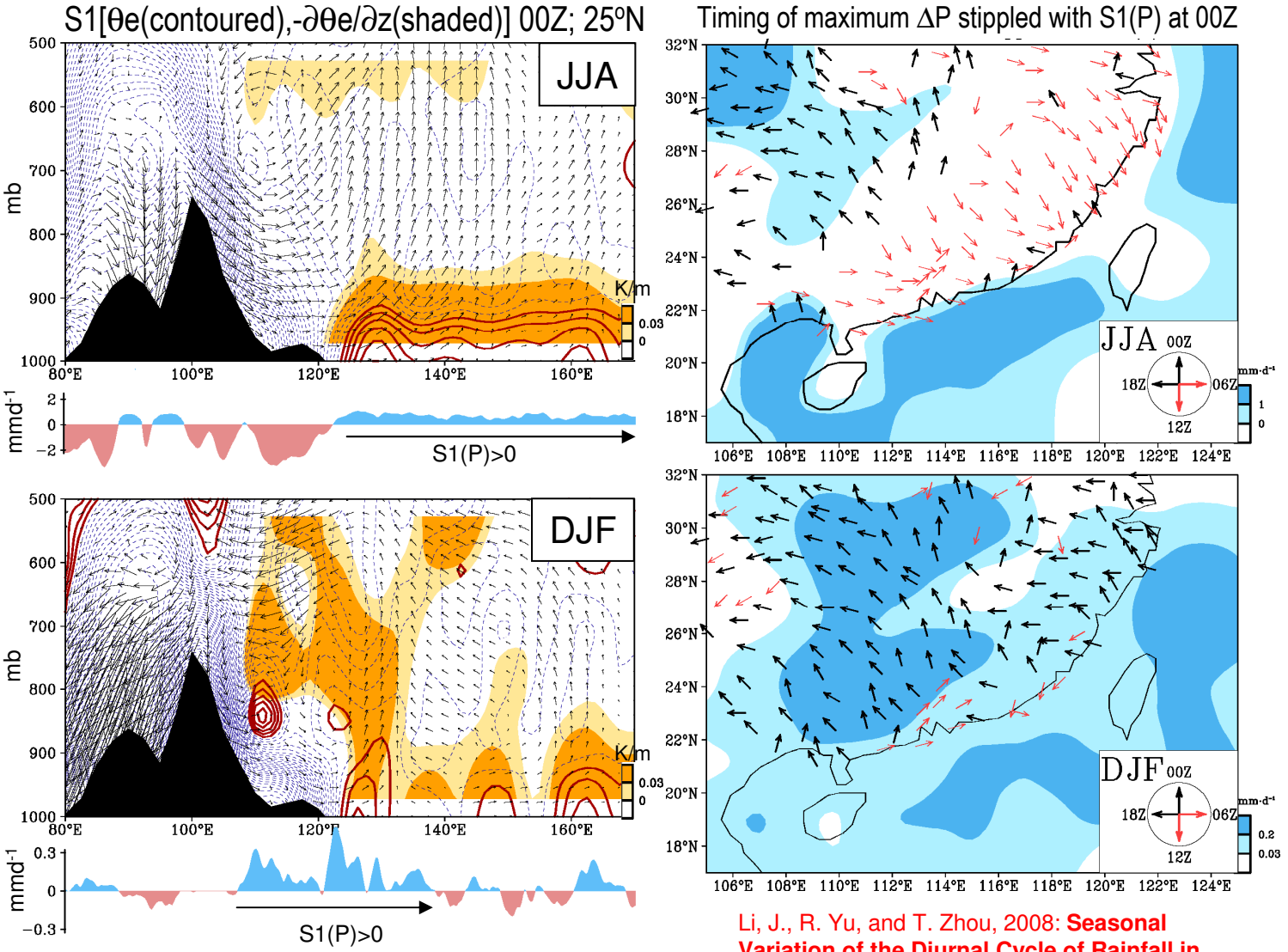
- Because the thermally driven global migrating tide follows the movement of the sun, seasonal variation in this migrating tidal wave occur as the tilt of Earth changes.



The seasonally varying downward propagating global migrating tidal wave combining with the non-migrating tidal wave results in the dimension change of giant land-sea breeze.

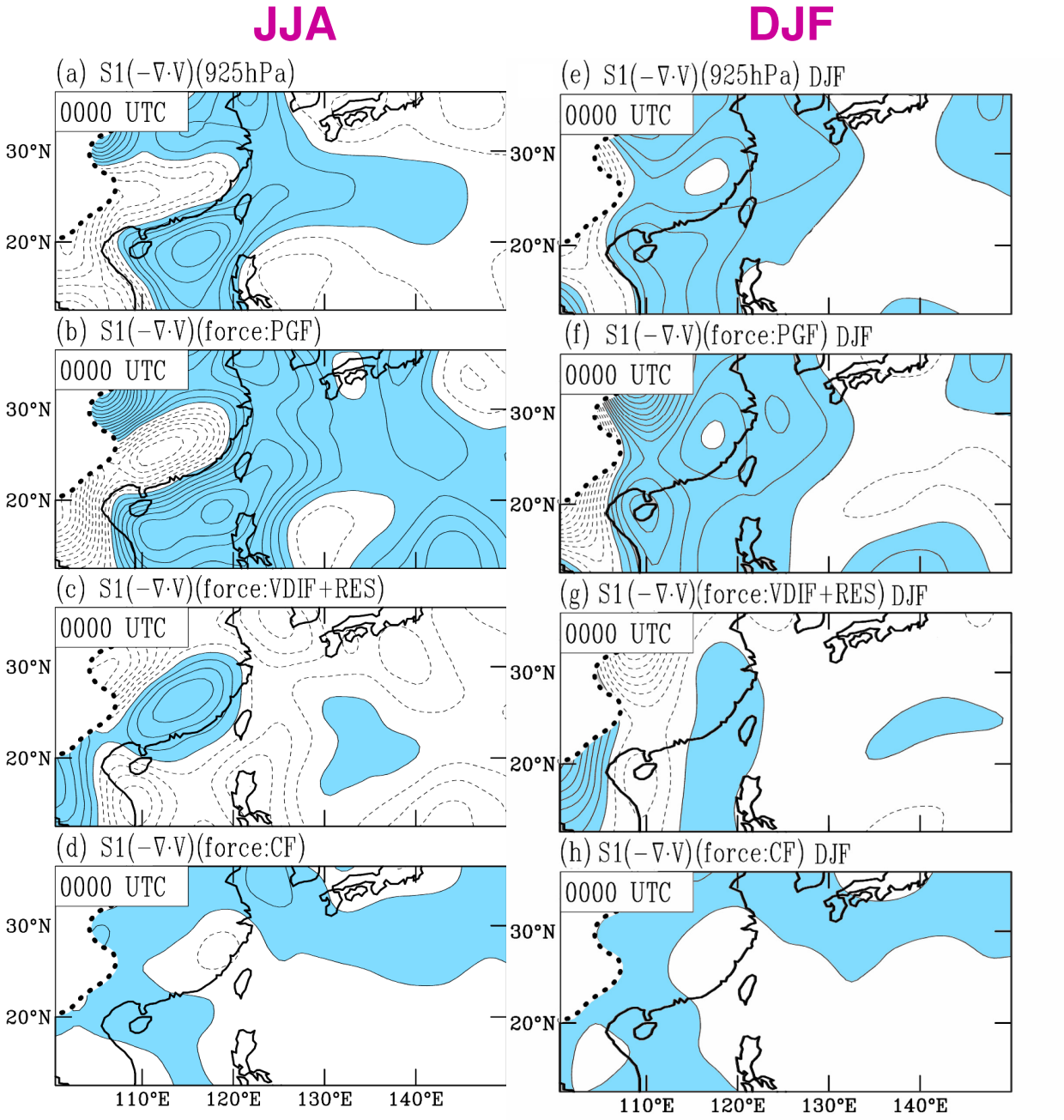
Q: What is the implication of seasonal LSB change in diurnal precipitation change?

Seasonal variation of θ_e vs. ΔP



Li, J., R. Yu, and T. Zhou, 2008: **Seasonal Variation of the Diurnal Cycle of Rainfall in Southern Contiguous China.** *J. Climate*, **21**, 6036–6043.

Seasonal variation of diurnally-varying wind convergence/divergence



Force: PGF

Force: VDIF+RES

Force: CF

$$S1(-\nabla \cdot \mathbf{V})$$

⇩

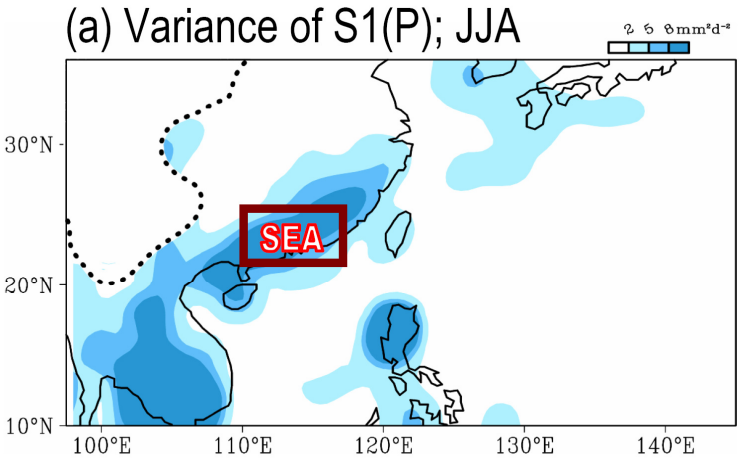
S1(P)

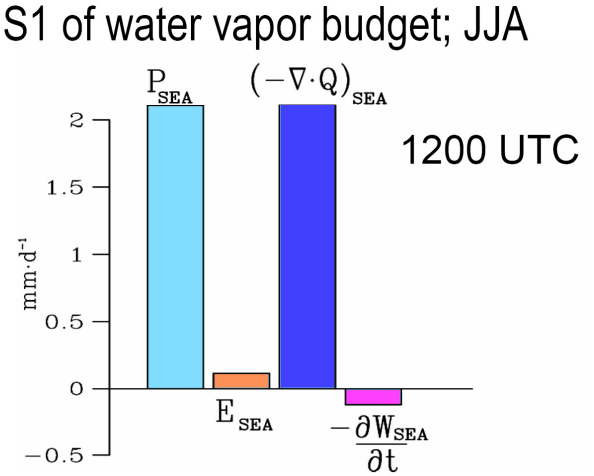
Water Vapor Budget Analyses

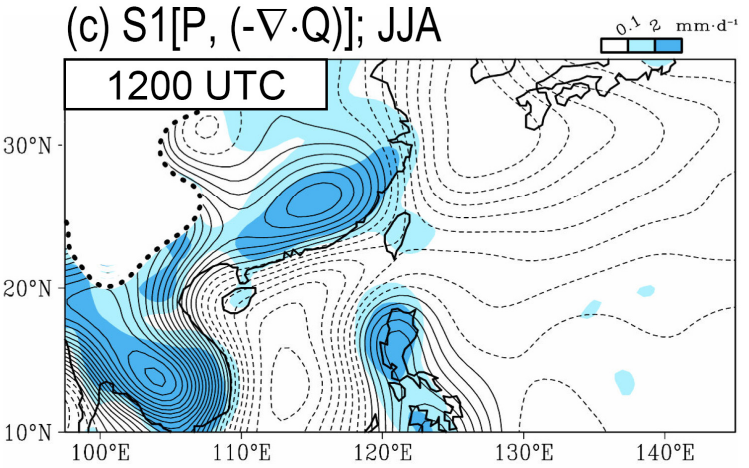
$$P = E + (-\nabla \cdot \mathbf{Q}) + (-\frac{\partial W}{\partial t})$$

W: total precipitable water
∇•*Q*: convergence or divergence of vertical-integrated water vapor flux
P : precipitation
E : evaporation.

$$S1(P) \sim S1(-\nabla \cdot \mathbf{Q})$$







Summary

- The local land-sea breeze along the coastline typically spans less than a hundred kilometers into the ocean. Here we found that the land-sea breeze circulation is coupled with the global-scale diurnal tide. The coupling forms a seemingly giant land-sea breeze that covers a thousand kilometers over the Western Pacific.

- Examination of the momentum budget indicates that the atmospheric diurnal tidal wave contributes the most to this circulation feature.

- The seasonal variations of the diurnal tidal wave and the continental heat content combined result in the dimension change of this giant land-sea breeze. Such seasonal contrast leads to the timing difference of diurnal rainfall in East Asia between summer and winter.

Thank You !