Spatial variability of summer precipitation related to the dynamics of the Great Plains low-level jet

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Great Plains low-level jet

- Long identified as a cause of Great Plains precipitation and its variability
- Generated climatologically by westward pressure decrease from near-surface horizontal increase of temperature
- Diurnal cycle – speeds up at night
- Can be perturbed by various meteorological disturbances (frontal or upper level)

Great Plains low-level jet

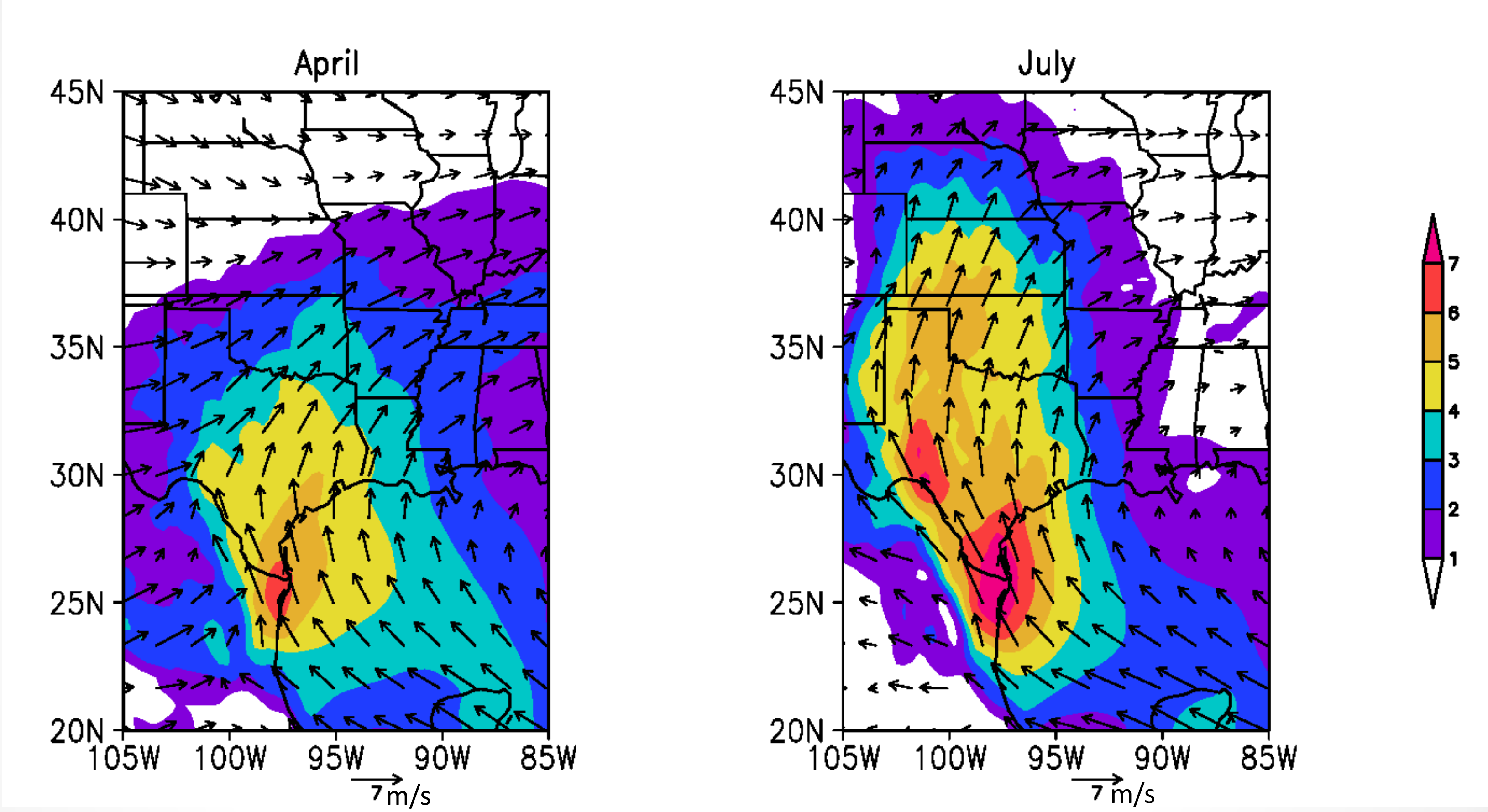
How does the jet relate to summer precipitation dynamically?

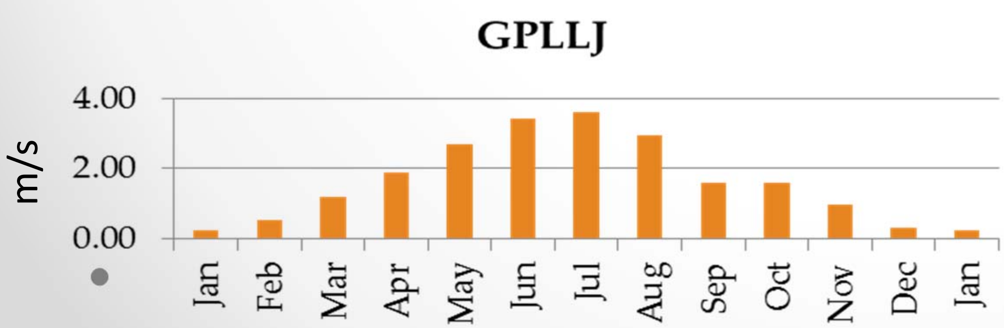
- Large-scale upward motion and associated moisture advection precondition nocturnal convection (Lee et al. 2007, 2008, 2010)

- Try to provide an explanation for the patterns of upward and downward motion indicated by various authors as related to the observed diurnal patterns of precipitation over the central U.S.

- Great Plains low-level jet (GPLLJ)

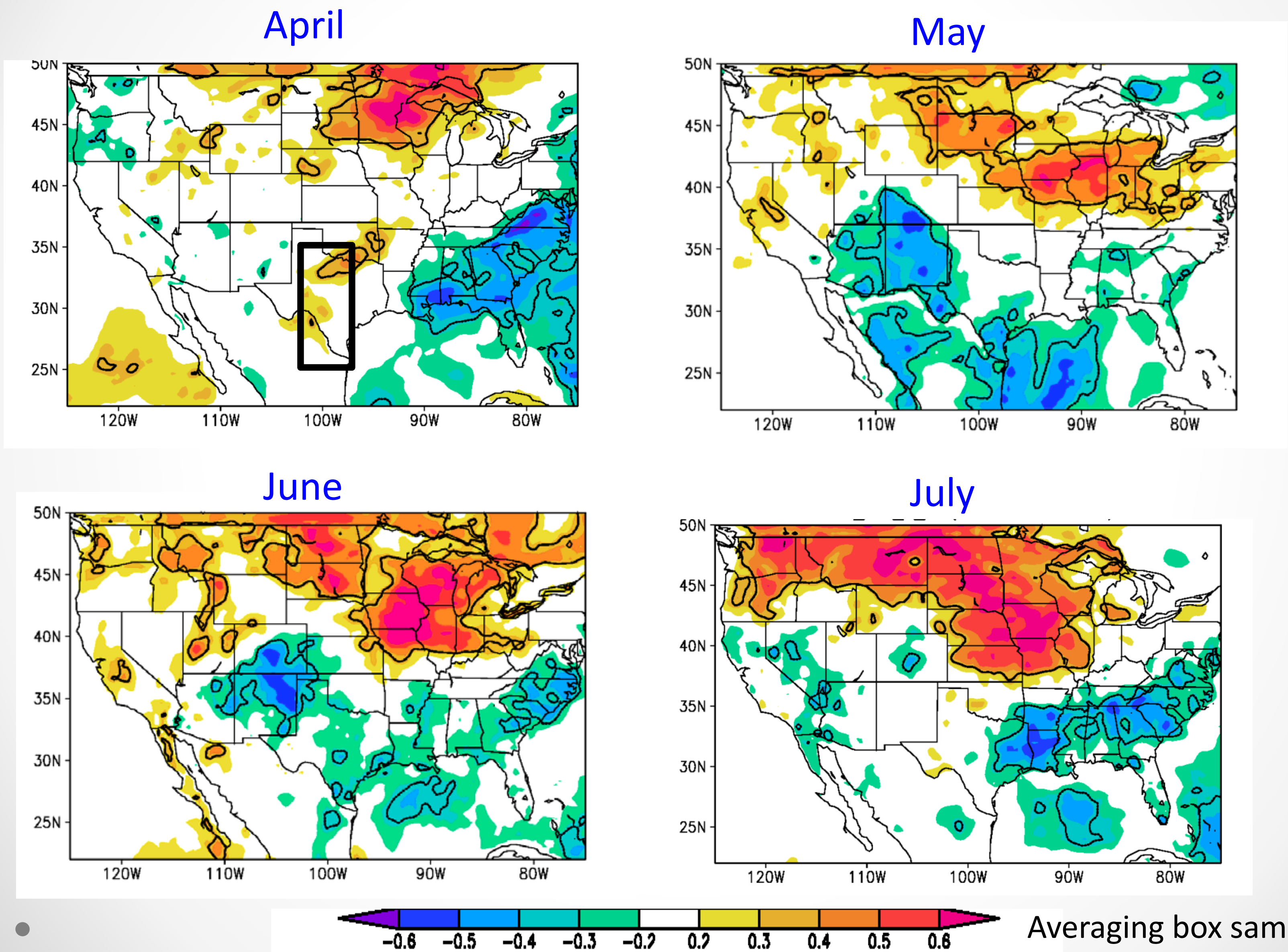
1km above the surface





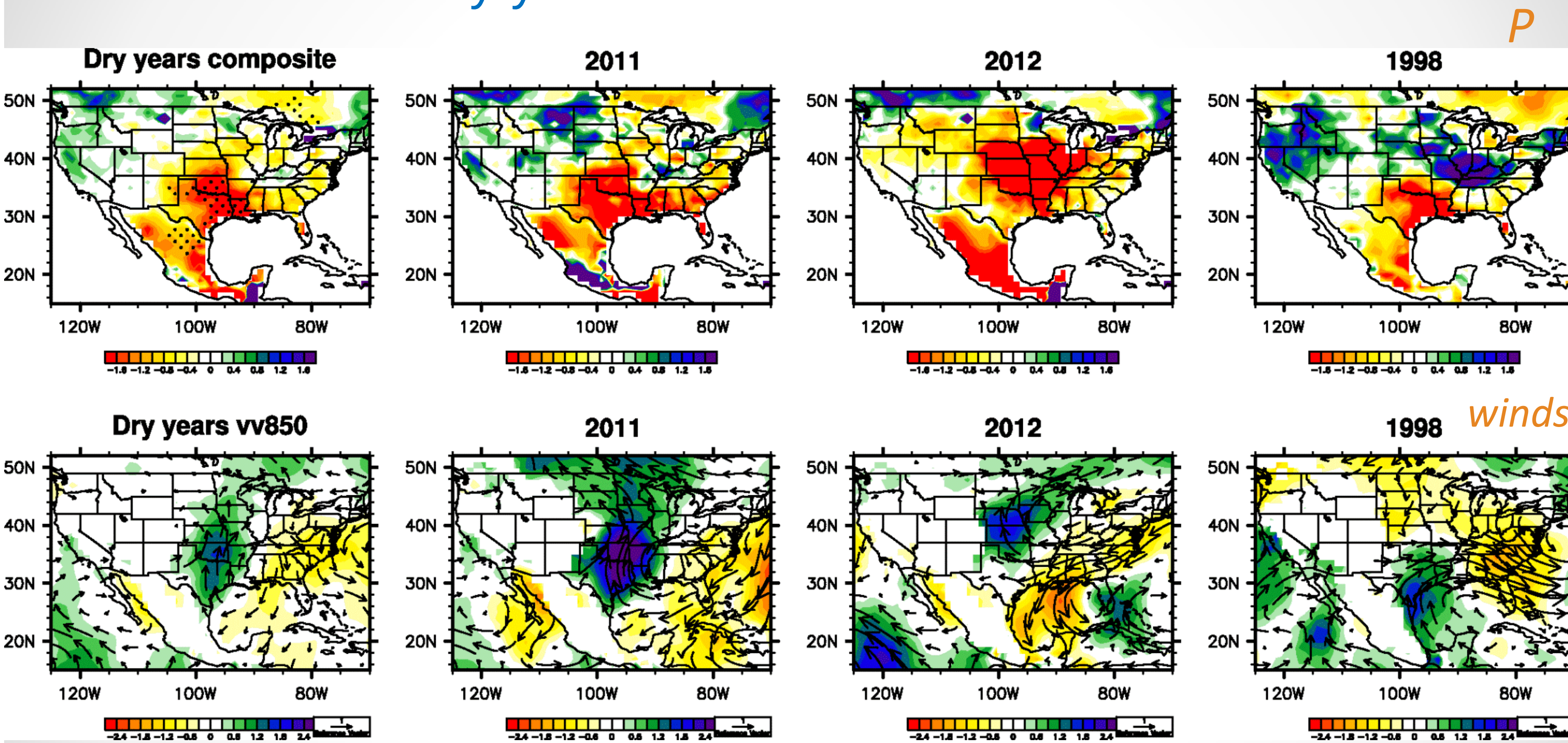
Shading – meridional wind speed

- Correlation between the GPLLJ index (1 km) and precipitation (NARR 1979-2012)



Averaging box same as *Weaver and Nigam (2008)*

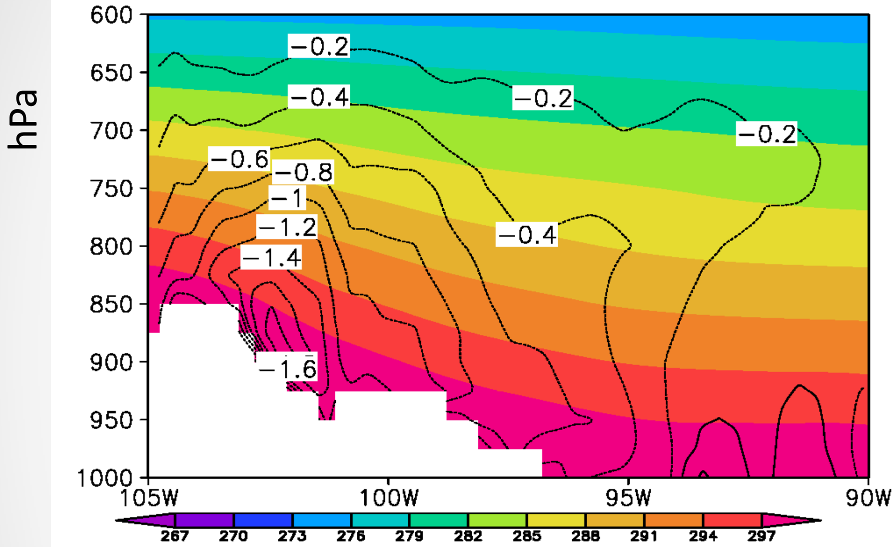
- Precipitation (mm day^{-1}) and wind anomalies (m s^{-1}) at 850 hPa for a few dry years



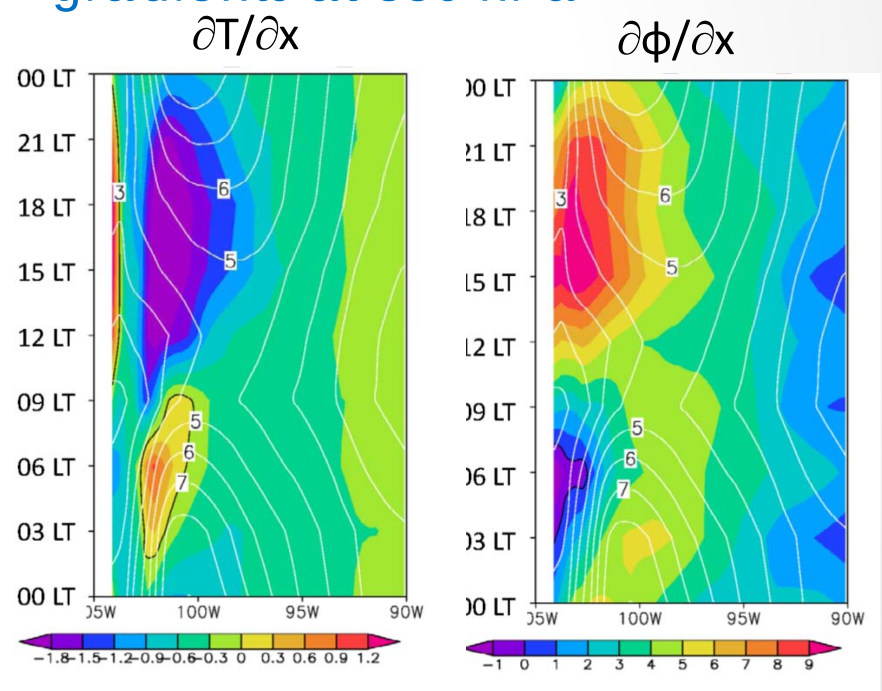
(Shading denotes meridional wind speed)

- Air temperature (shading; K) and zonal temperature gradient (contours; 10^{-2} K km^{-1})

June 30N



- Diurnal cycles of the GPLLJ (contours; m s^{-1}) and geopotential height and temperature zonal gradients at 850 hPa



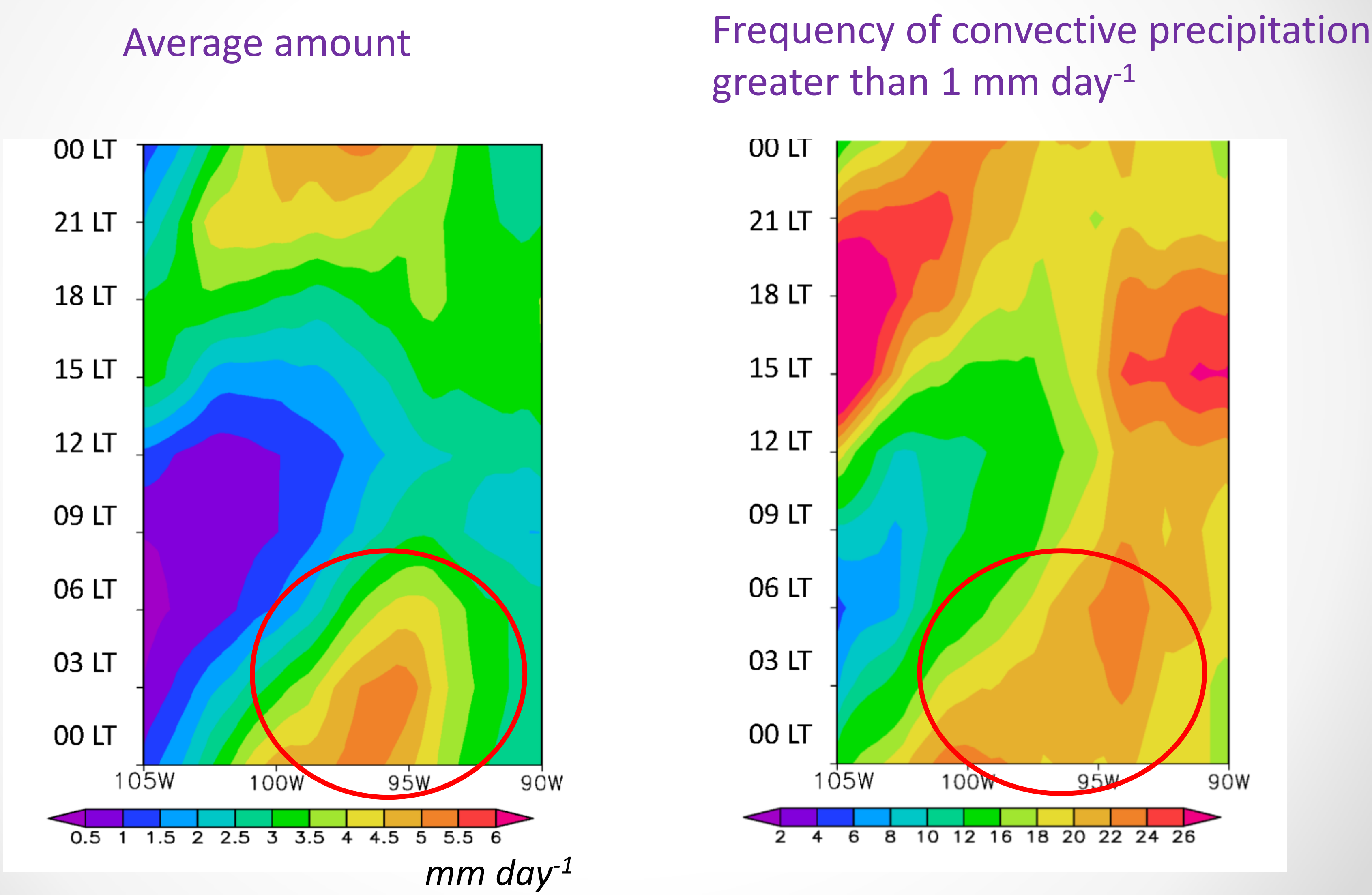
Units: 10^{-2} K km^{-1}

Units: 10^{-2} gpm km^{-1}

Topography induced uneven heating

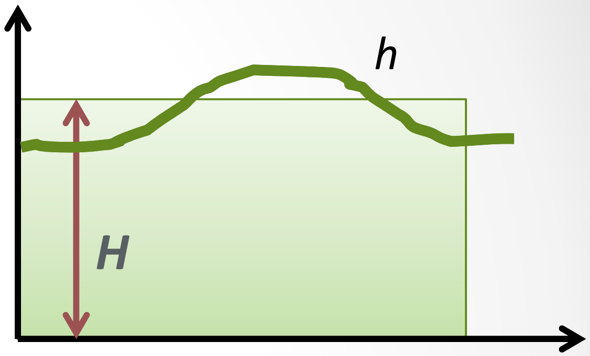
- Diurnal cycle of precipitation from NARR climatology (June-July)

35-40N



1-Layer linear model

- Equations



$$\begin{cases} \dfrac{\partial u}{\partial t} = fv - g\dfrac{\partial h}{\partial x} - \varepsilon u - \phi_x \\ \dfrac{\partial v}{\partial t} = -fu - g\dfrac{\partial h}{\partial y} - \varepsilon v - \phi_y \\ h = -\tau H\left(\dfrac{\partial u}{\partial x} + \dfrac{\partial v}{\partial y}\right) \end{cases}$$

$$H = 1000 \quad m$$

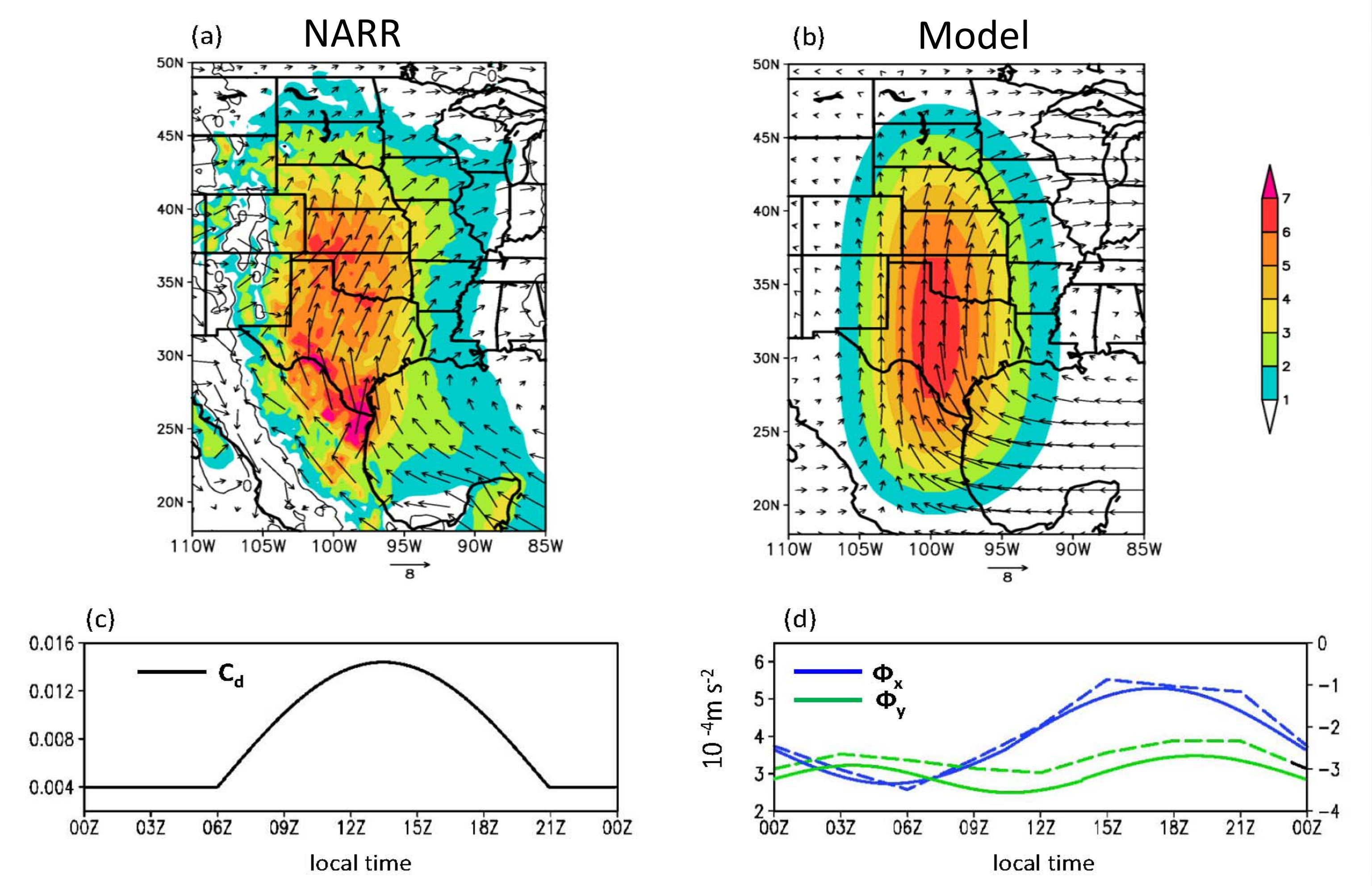
$$\varepsilon = C_d \times \left|\vec{V}\right| / H$$

Lindzen and Nigam (1987)

- Assume convergence is taken up by the upper layer in a very short time τ (3 sec)

*- Forcing terms are : **surface friction (ε)** and **geopotential gradient (Φ_x, Φ_y)***

- Prescribed geopotential gradient and surface drag



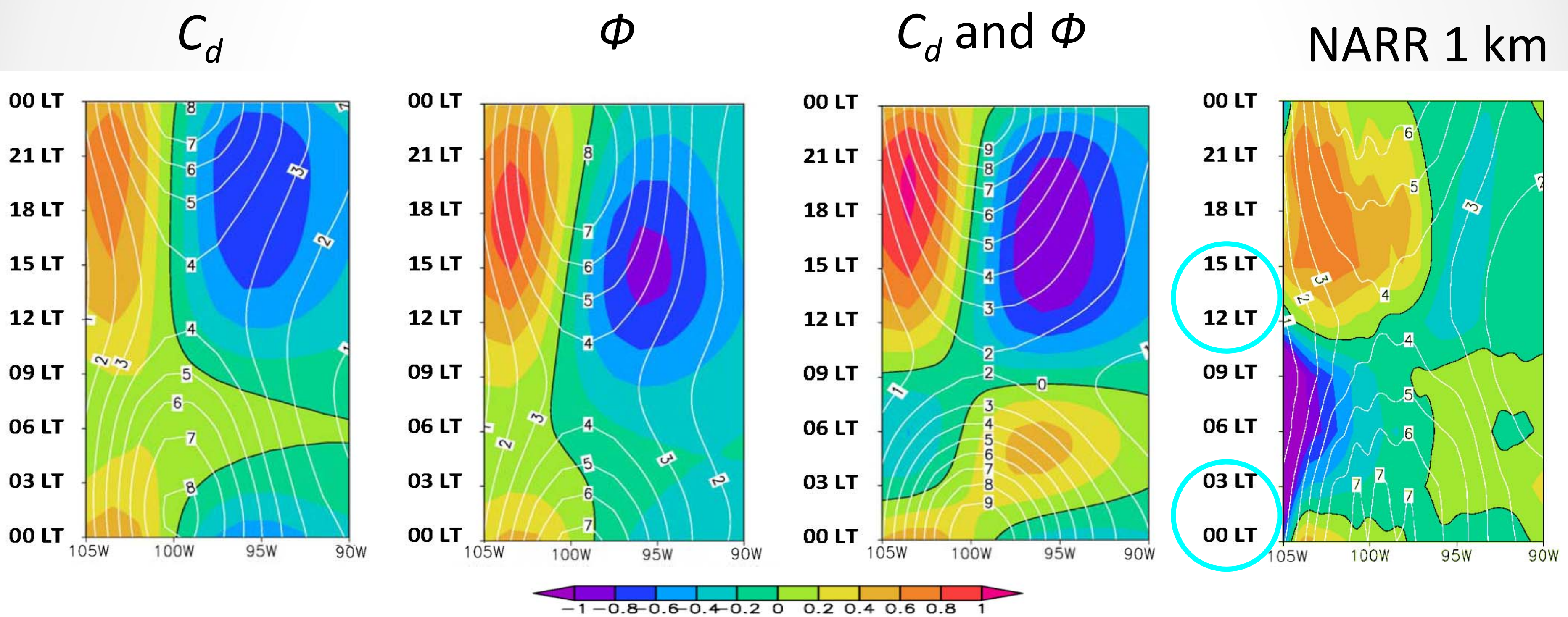
- 3 simulations

Simulation	Forcing	
VDFG (C_d)	Diurnal cycles of C_d	Fixed ϕ_x, ϕ_y
FDVG (ϕ)	Fixed C_d	Diurnal cycles of ϕ_x, ϕ_y
VDVG (C_d and ϕ)	Diurnal cycles of C_d	Diurnal cycles of ϕ_x, ϕ_y

Model results

- Meridional (contours; ms^{-1}) and vertical winds (shading; cms^{-1})

35-40N average



- The diurnal phases of the GPLLJ are captured only when both forcing are included

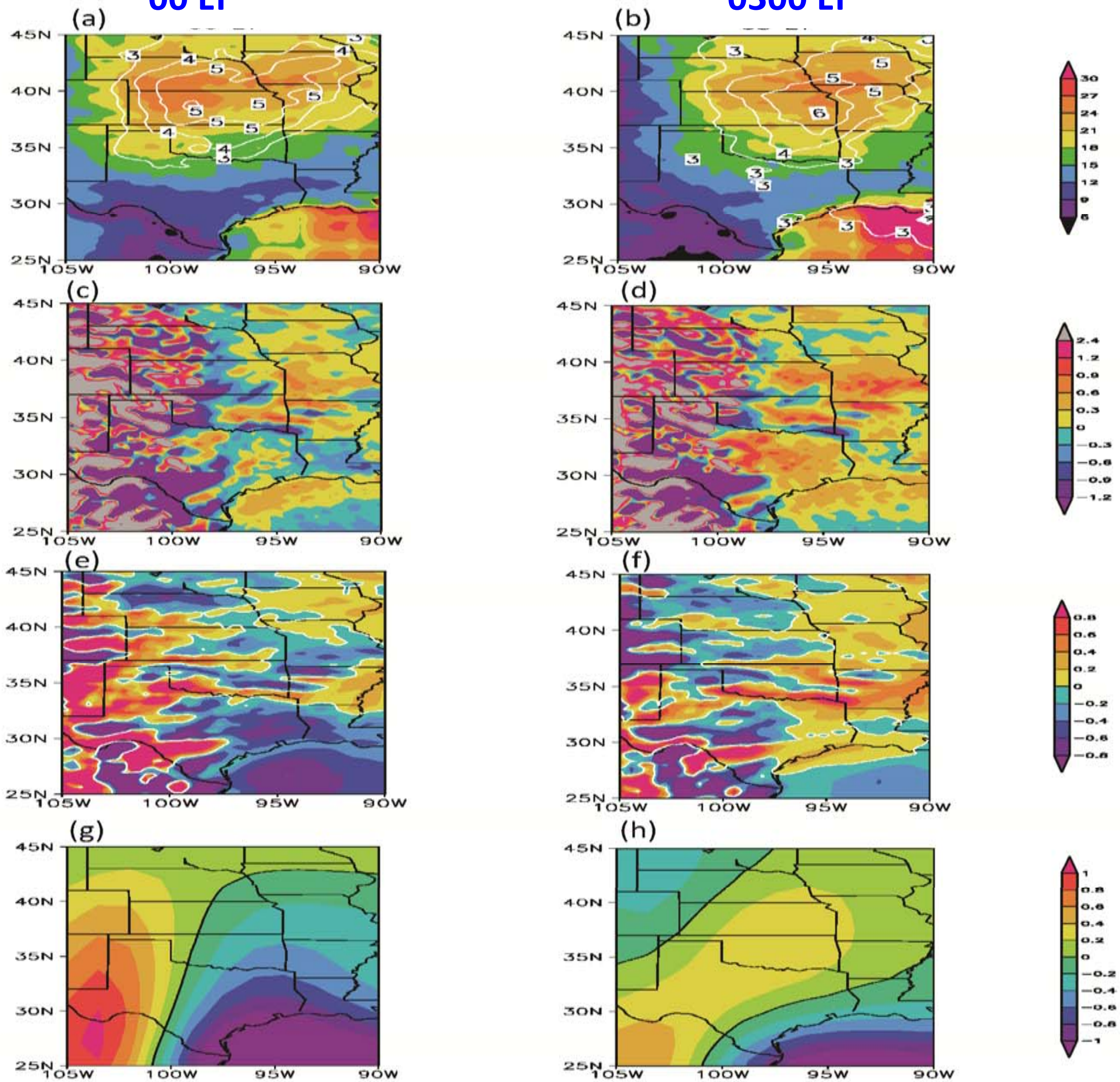
00 LT | 0300 LT

Convective P frequency

Moisture convergence at 850 hPa

Vertical wind

Vertical wind in the model

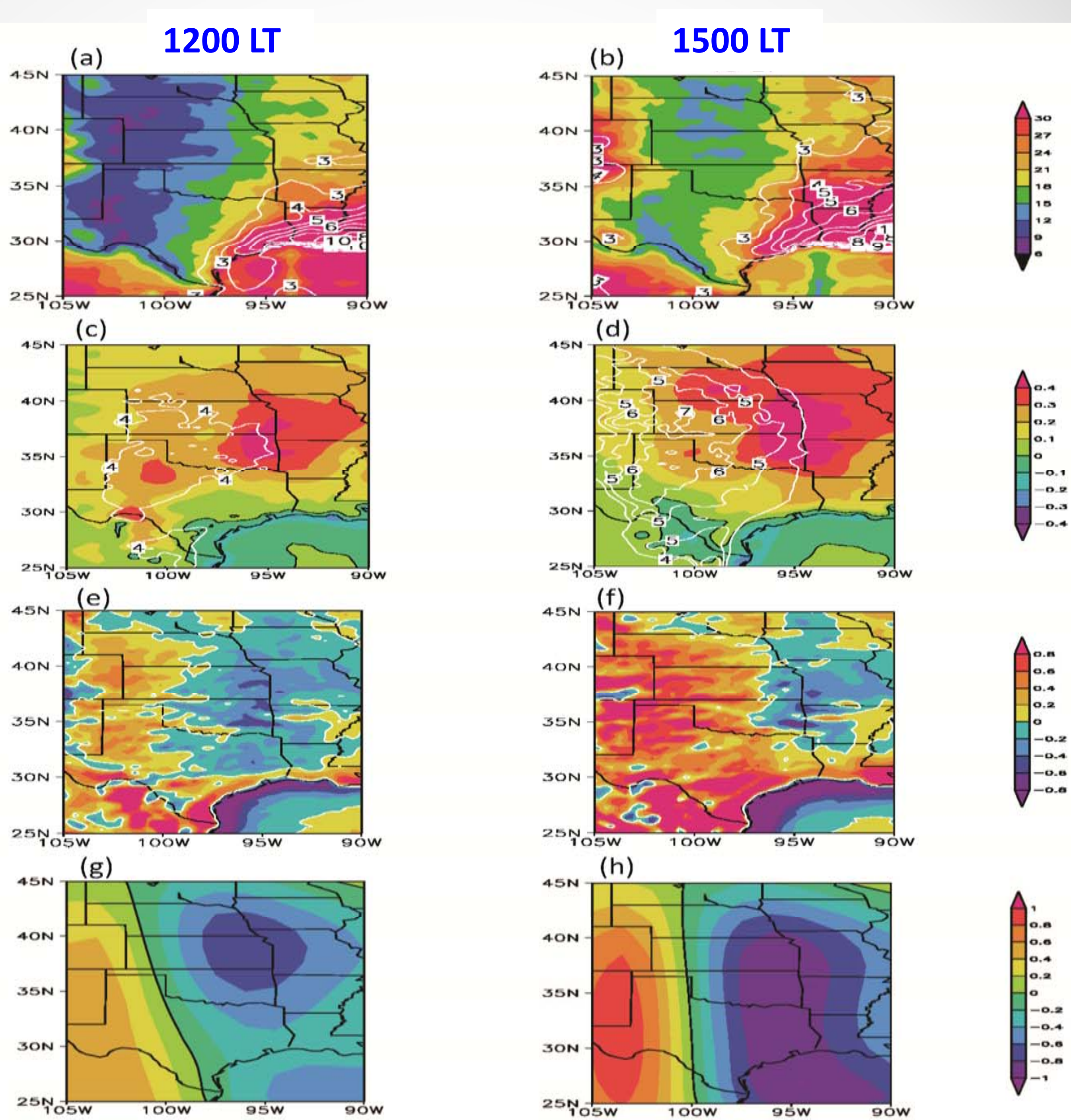


Convective P frequency

CIN and CAPE peaking in late afternoon

Vertical wind

Vertical wind in the model

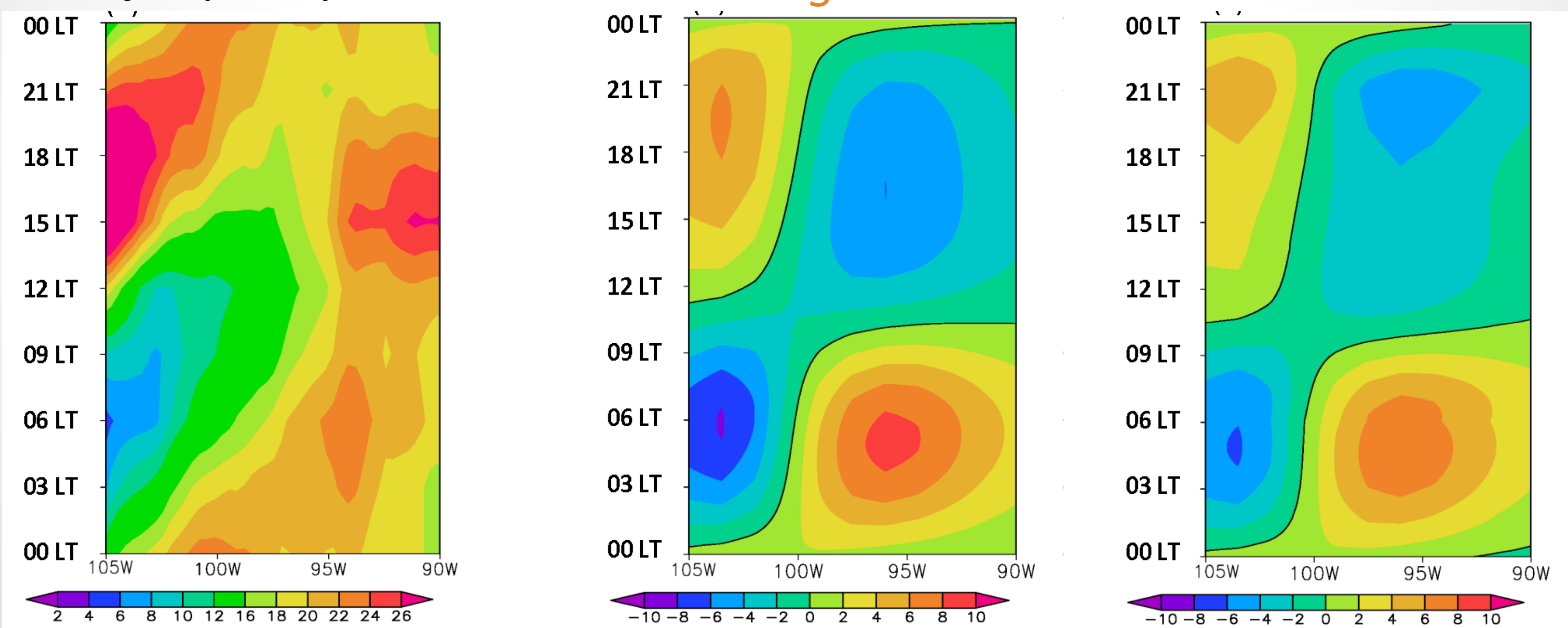


$$-\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right)=\frac{1}{f}\left[\frac{\partial \zeta}{\partial t}+\beta v+\varepsilon\zeta\right]$$

Precipitation frequency

Diurnal cycle of convergence

Vorticity tendency

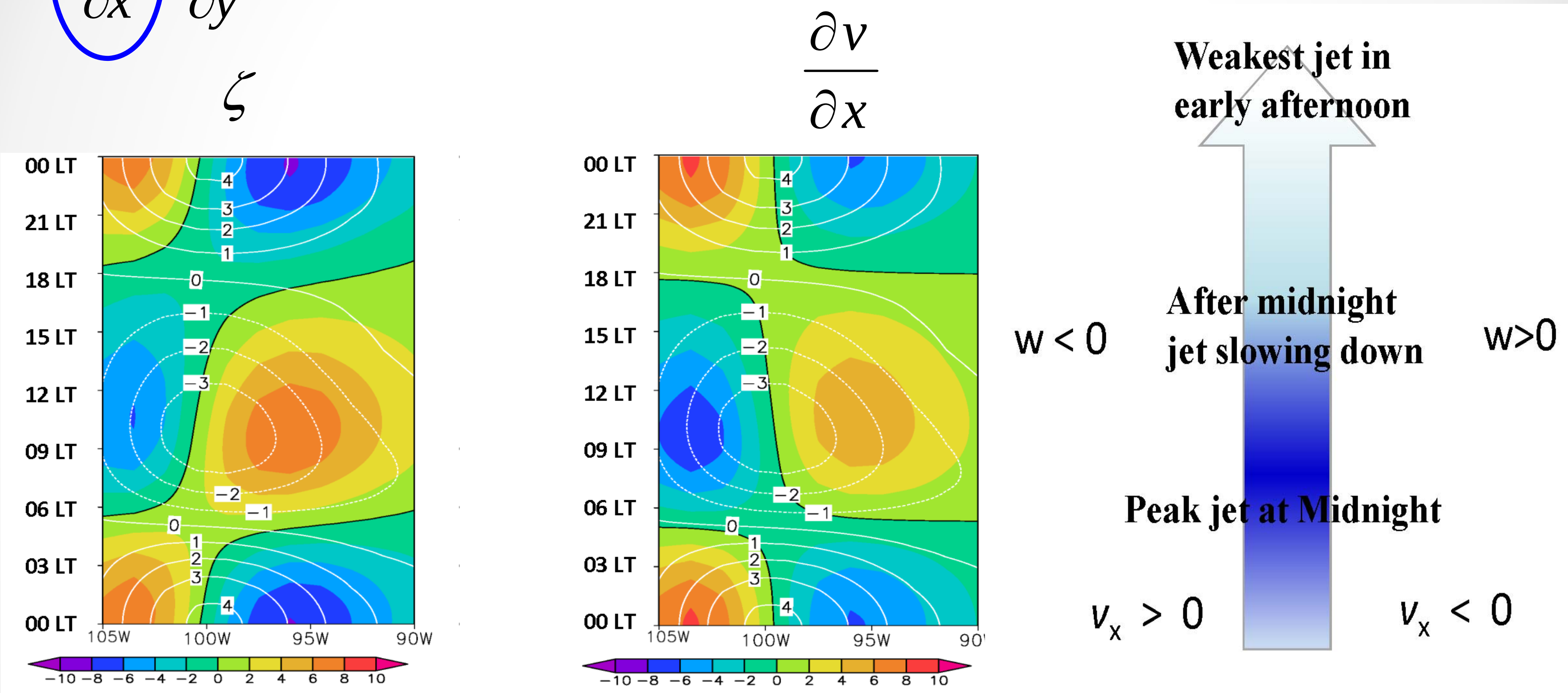


Units: $10^{-6}\ s^{-1}$

- *Diurnal cycle of precipitation occurrence is consistent with boundary layer convergence and is mainly contributed by local vorticity tendency*

$$-\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right)=\frac{1}{f}\left[\frac{\partial \zeta}{\partial t}+\beta v+\varepsilon\zeta\right]$$

$$\zeta=\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}$$



-Changes of vorticity are mainly due to changes of zonal gradient of meridional winds

How does the GPLLJ relate to summer precipitation?

- Moisture transport
- Jet induced low-level convergence

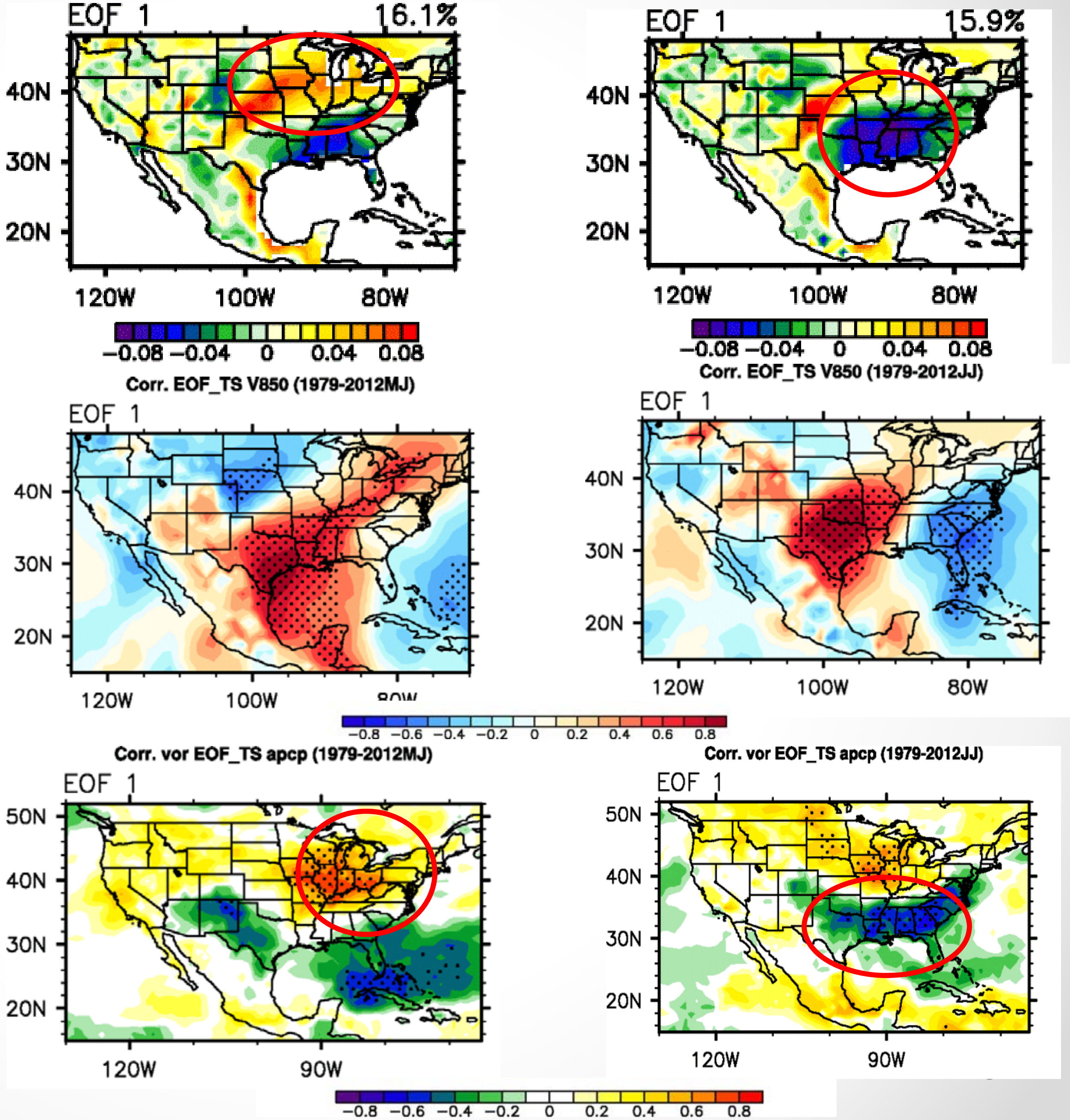
Can this lead to idea about precipitation prediction?

- Negative vorticity over the south coast corresponds to a stronger jet to the west

- Positive vorticity over the Mid-West is related to the jet in the east

- Correlations between the time series of low-level vorticity EOFs and precipitation are very similar to the pattern of correlations between the jet and precipitation

Vor850_MJ Vor850_JJ



May-June-July

corr P and vor850=0.67

corr P and vor500=0.53

corr P and div850=-0.50

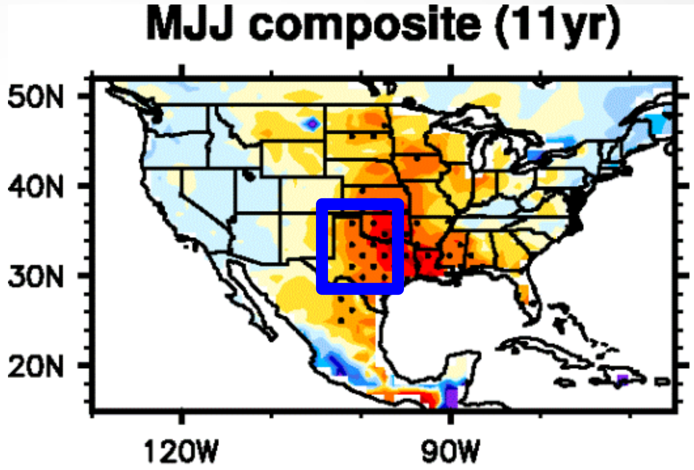
corr P and div500=-0.37

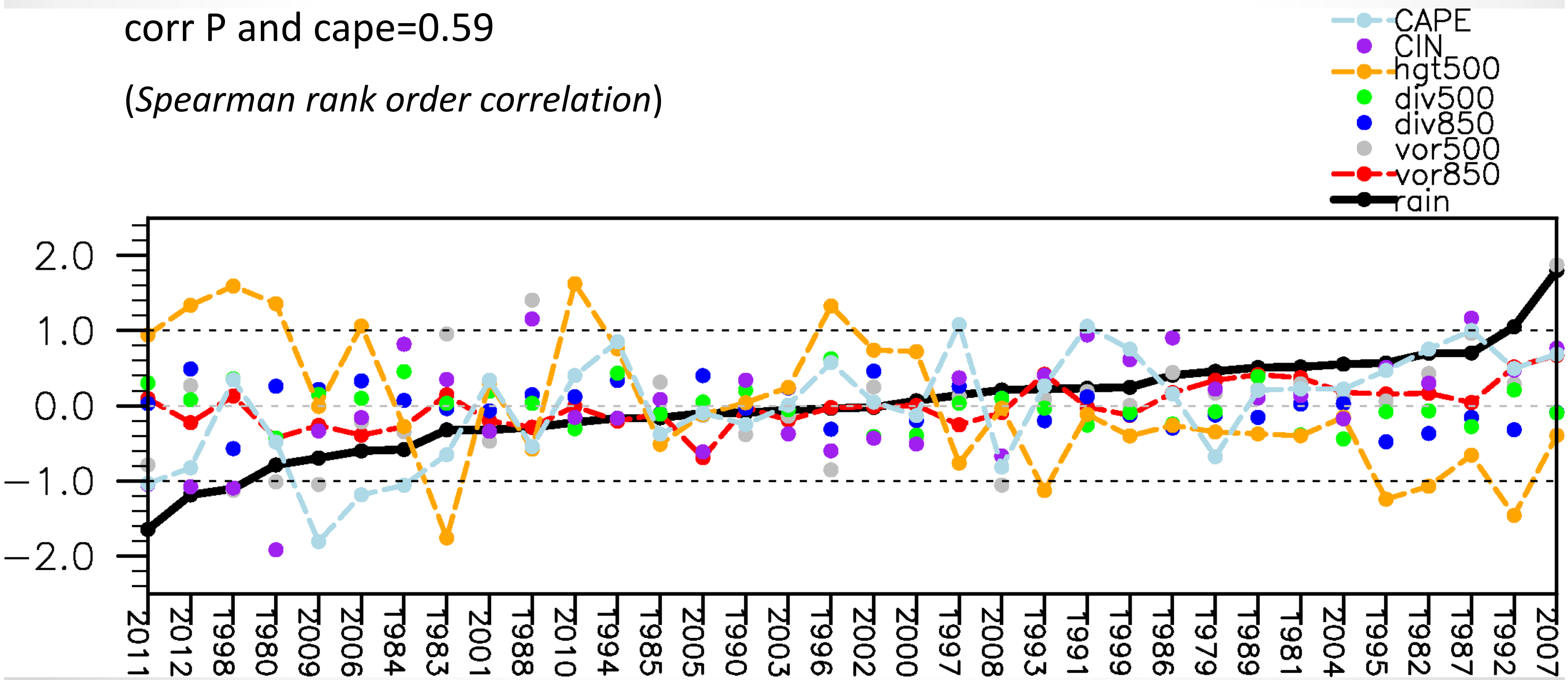
corr P and hgt500=-0.62

corr P and cin=0.54

corr P and cape=0.59

(*Spearman rank order correlation*)





Summary

- Simple slab model forced by representation of observed near surface geopotential reproduces the GPLLJ and a vertical motion pattern consistent with diurnal variation of central US precipitation
- Diurnal phasing of this vertical motion depends on both that of geopotential and surface drag coefficient
- Results can be interpreted in terms of vorticity balance
- The GPLLJ also affects summer precipitation via its modification of local vorticity on the interannual time scale

Thank you all!