Summer Precipitation Variability over the SE U.S. Analyzed from Atmospheric Moisture Budget

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Oct. 25, 2012

SE U.S. summer precipitation

Mableton, GA

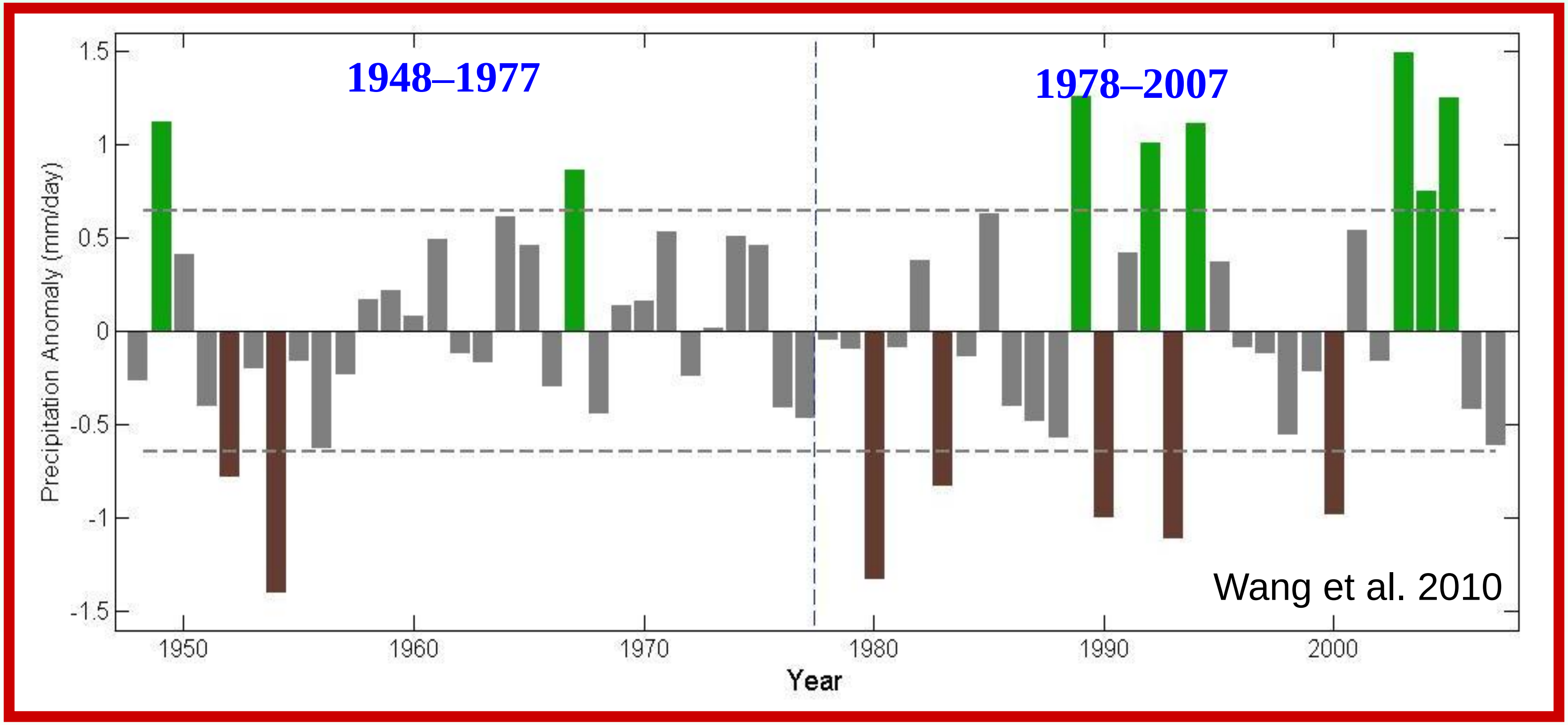
2009 Flood

2007 Drought

– Worst in 100 years

Lake Lanier

Intensified variability of the summer rainfall



	1st 30 years 1948–1977	2nd 30 years 1978–2007
Wet (> 1 Std)	2	6
Dry (< -1 Std)	2	5

χ^2 test:
Intensified precipitation variability is significant

What factors affect the SE US summer precipitation?

Meso-scale and Synoptic-scale systems *(Ba*
ght and Davi
et al. 2007; B

2012)

NASH circ
(Henderson
Katz et al. 20
2011; 2012; L.

All the factors can interact with each other at various spatial & temporal scales. Thus, identifying which factors drive the intensified rainfall variability is complex and difficult.

One possible simplification is to categorize these factors using certain criteria.

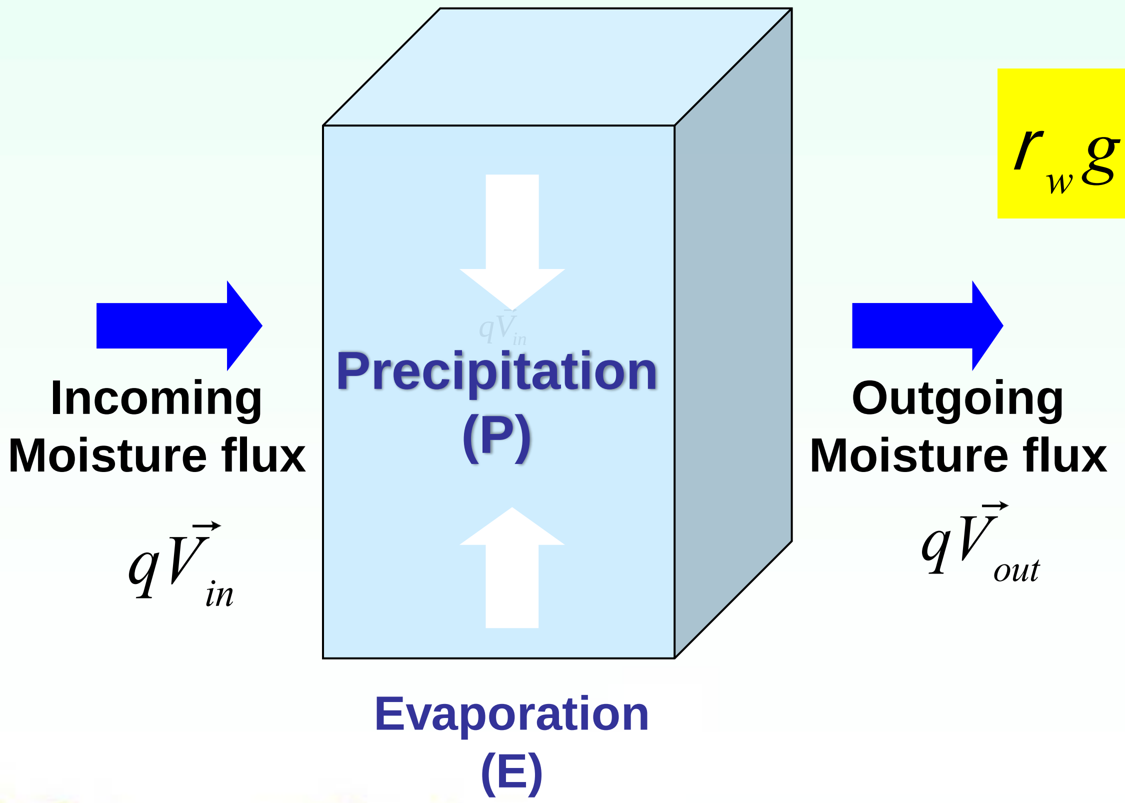
ENSO
(Mo et al. 2008)

Atmo. Internal variability *(Seager et al. 2009)*
Anthropogenic forcing *(Chen et al. 2003; Mearns et al. 2003; Liang et al. 2006; Christensen et al. 2007; W. Li et al.,2011)*

Research Approach:
Atmospheric Moisture Balance

Seasonal Mean: $F_{in} = F_{out}$

(Brubaker et al., 1993)



$$r_w g(P - E) = -\nabla \cdot \int_0^{p_s} q\vec{V}\,dp$$

Trenberth and Guillemot 1995
Seager et al., 2010

Research Approach:
Atmospheric Moisture Balance

Precipitation = Evaporation + Moisture Transport

- SE U.S. Summer Precipitation (P)
  - Moisture Transport
    $$-\nabla \cdot \int_0^{p_s} q\vec{V}\,dp$$
    - Synoptic-Scale Eddy
      - Thermo-dynamic (q)
      - *VS*
      - Dynamic (V)
    - *VS*
    - Large-scale Circulation
      - Thermo-dynamic (q)
      - *VS*
      - Dynamic (V)
  - *VS*
  - Evaporation (E)
    - Thermo-dynamic (q_s-q_a)
    - *VS*
    - Dynamic (surface wind speed)

Data and Methods

- ***Data:***
  - **Precipitation**
    - CPC U.S. Unified Precipitation and PRec/L
  - **Atmospheric Reanalysis Datasets**
    - NCEP/NCAR; ERA-40; JRA-25 and NARR
    - Averaged over June-July-August (JJA) season

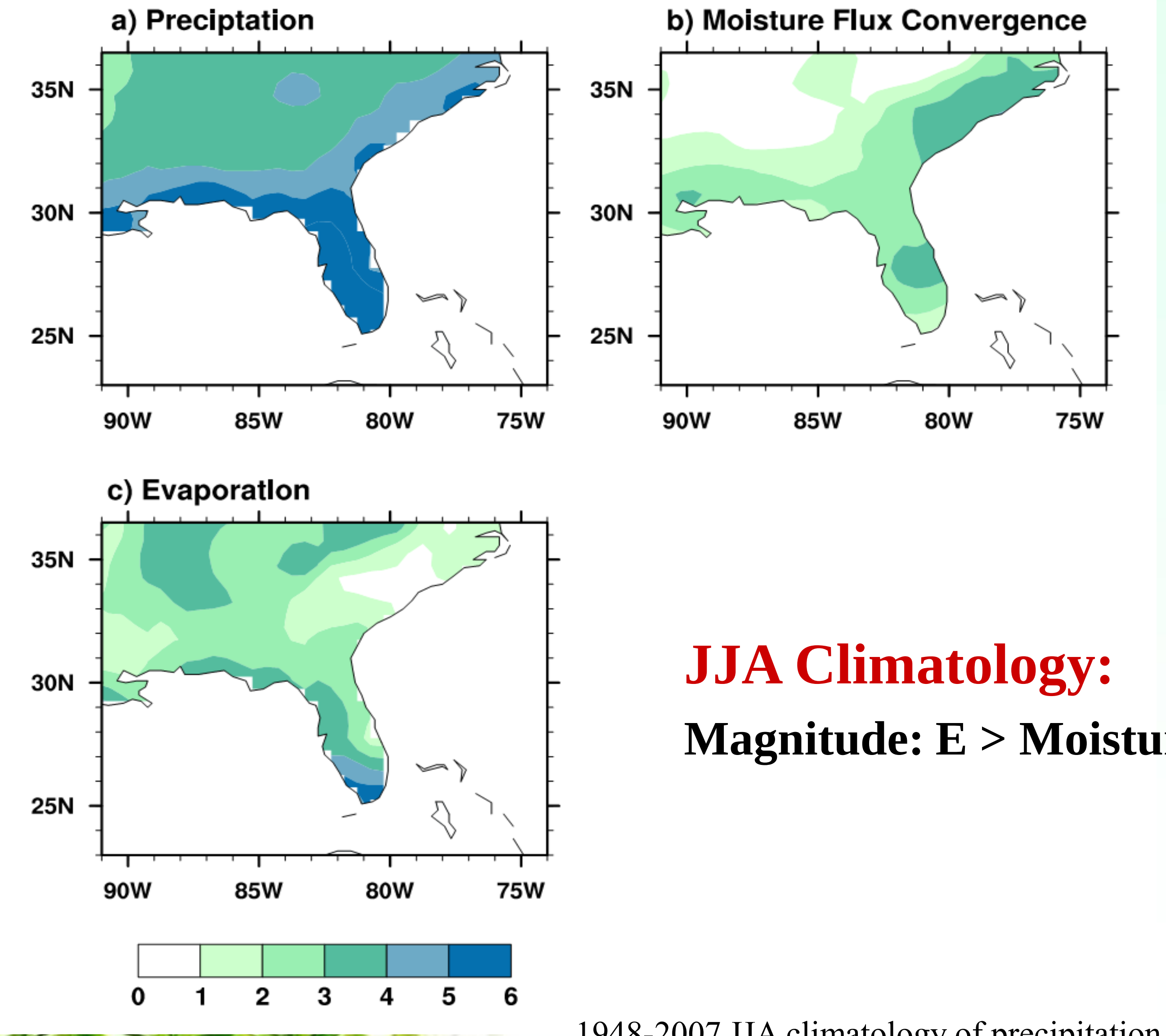
- ***Methods:*** $r_w g(P - E) = -\nabla \cdot \int_0^{p_s} q\vec{V}\, dp$
  - **Analysis of atmospheric moisture balance**
    - Partition of seasonal mean field and synoptic scale eddy

$q = \bar{q} + q'$ $\quad \vec{V} = \overline{\vec{V}} + \vec{V}'$ *(bar is seasonal mean; prime is 6-hr deviation)*

$$-\int_0^{p_s} \nabla \cdot \overline{\left(q\vec{V}\right)} dp = -\underbrace{\int_0^{p_s} \nabla \cdot \left(\bar{q}\overline{\vec{V}}\right) dp}_{\text{Mean flow}} - \underbrace{\int_0^{p_s} \nabla \cdot \overline{\left(q'\vec{V}'\right)} dp}_{\text{Eddy}} - q_s \vec{V}_s \nabla p_s$$

  - **Wavelet analysis (temporal evolution of periodicity)**

SE U.S. Moisture Budget (Climatology)

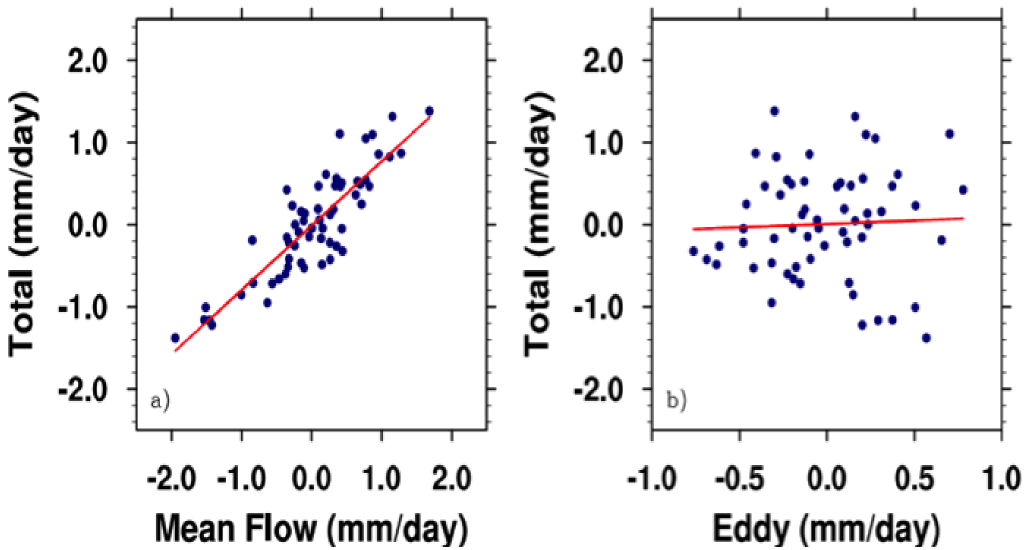


JJA Climatology:

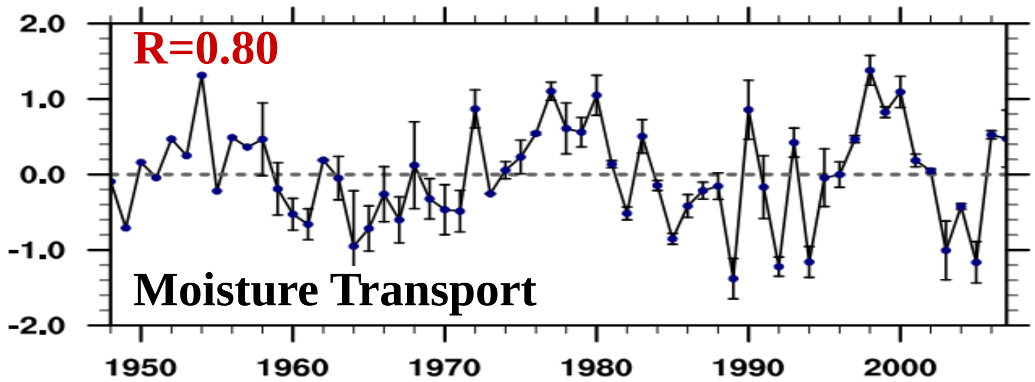
Magnitude: E > Moisture Transport

1948-2007 JJA climatology of precipitation, moisture flux convergence and evaporation (mm/day)

Moisture Budget (Interannual variation)



Total moisture transport vs that associated with JJA mean flow and synoptic eddies. The red lines are the least square fitting lines



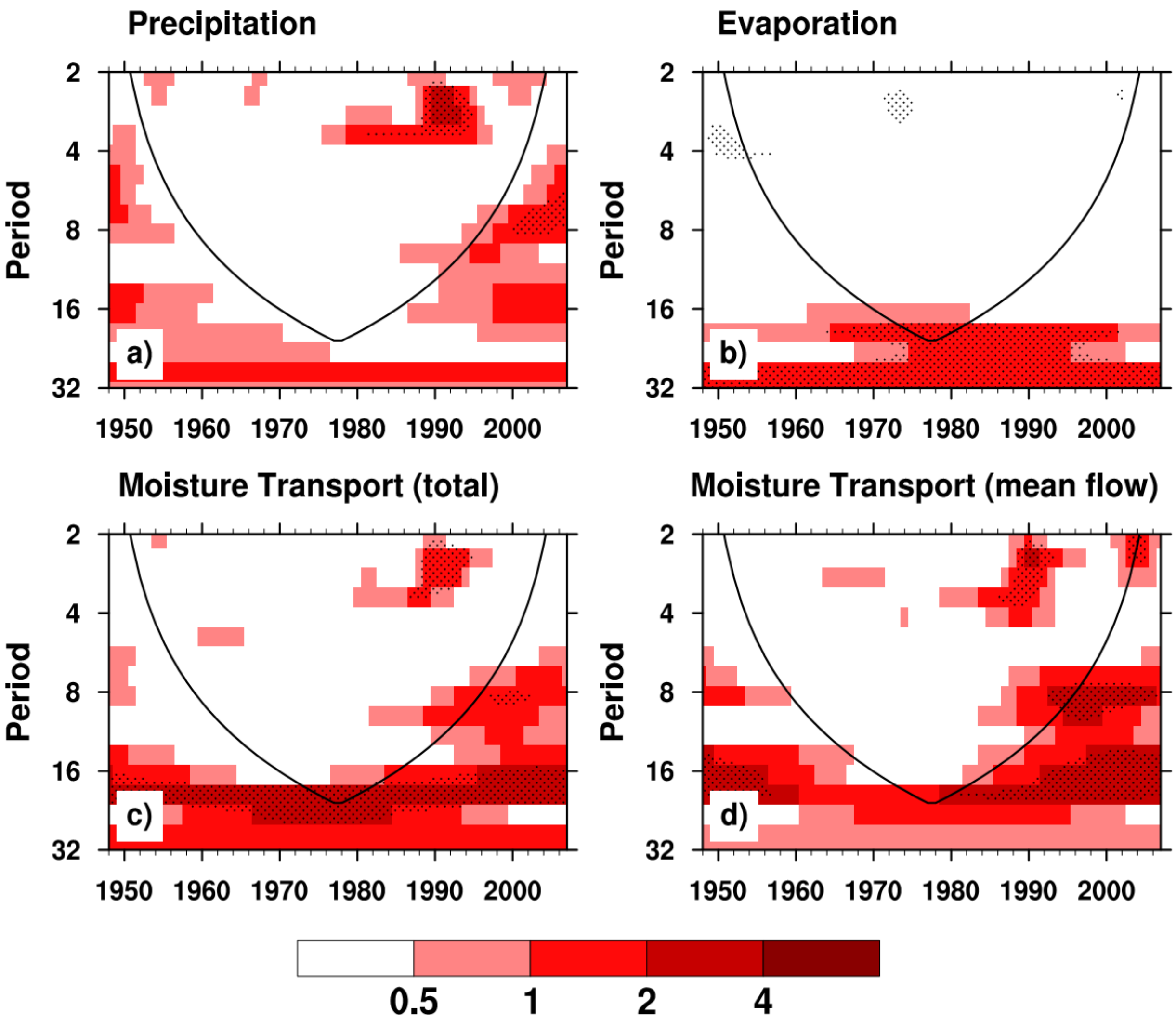
Interannual Variation

- **Mean Flow > Eddy**
- **Moisture Transport > E**

std dev 0.73mm/d > 0.41 mm/d

Time series of JJA mean precipitation, moisture transport and evaporation anomaly over the SE U.S. *(Error bar represents one standard error among reanalysis datasets)*

Moisture Budget → Interannual Variability



Local wavelet power spectrum of a) precipitation, b) evaporation, c) moisture transport and d) JJA mean component of moisture transport in 1948-2007

2-4 yr Variability:

- **Moisture Transport > E**
- **JJA Mean-flow is the main contributor**

"Morlet" wavelet

Thermodynamic (q) *vs* Dynamic (V)

$$\bar{q} = \bar{q}_c + \bar{q}_a \quad \vec{\bar{V}} = \vec{\bar{V}}_c + \vec{\bar{V}}_a$$

$$\bar{q}\vec{\bar{V}} = \left(\bar{q}_c + \bar{q}_a\right)\left(\vec{\bar{V}}_c + \vec{\bar{V}}_a\right)$$

(q_c and V_c: 60-yr climatology; q_a and V_a: deviation from the climatology)

$$\int_0^{p_s} \nabla \cdot \left(\bar{q}\vec{\bar{V}}\right) dp$$

$$= \int_0^{p_s} \nabla \cdot \left(\bar{q}_a \overline{\vec{V}_c}\right) dp$$

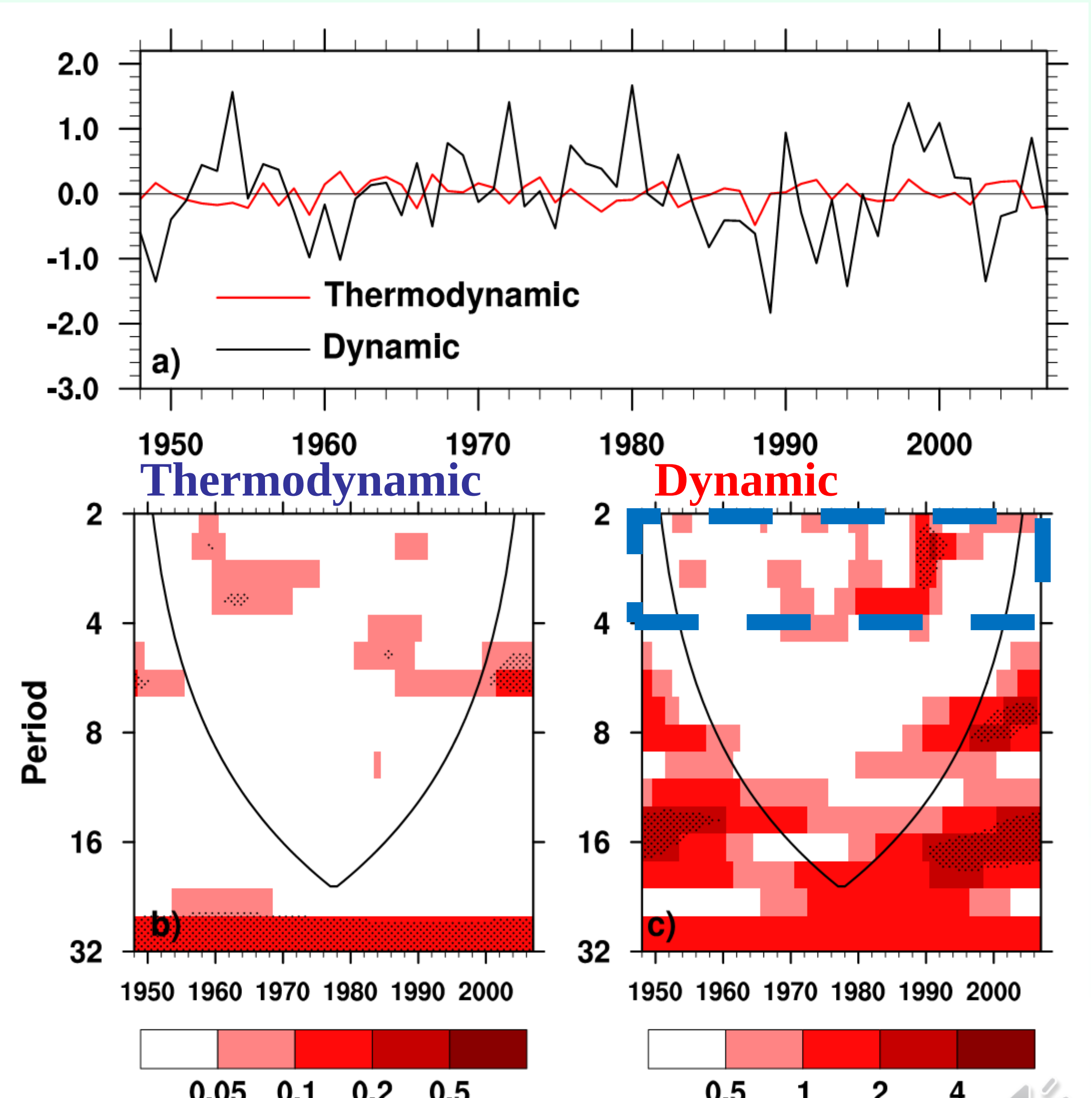
Thermodynamic

$$+ \int_0^{p_s} \nabla \cdot \left(\bar{q}_a \overline{\vec{V}_a}\right) dp$$

$$+ \int_0^{p_s} \nabla \cdot \left(\bar{q}_c \overline{\vec{V}_a}\right) dp$$

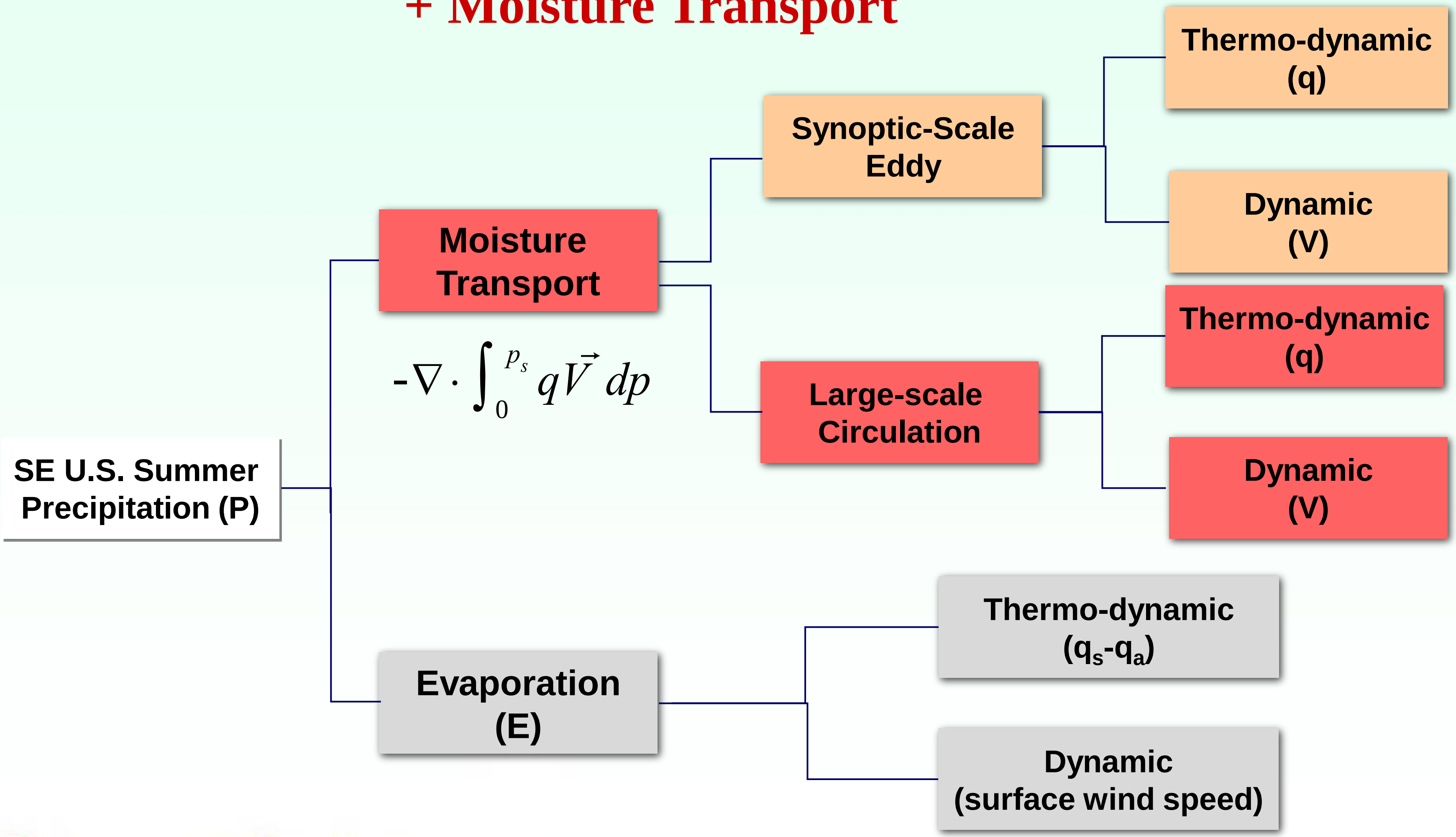
Dynamic

$$+ \int_0^{p_s} \nabla \cdot \left(\bar{q}_c \overline{\vec{V}_c}\right) dp$$

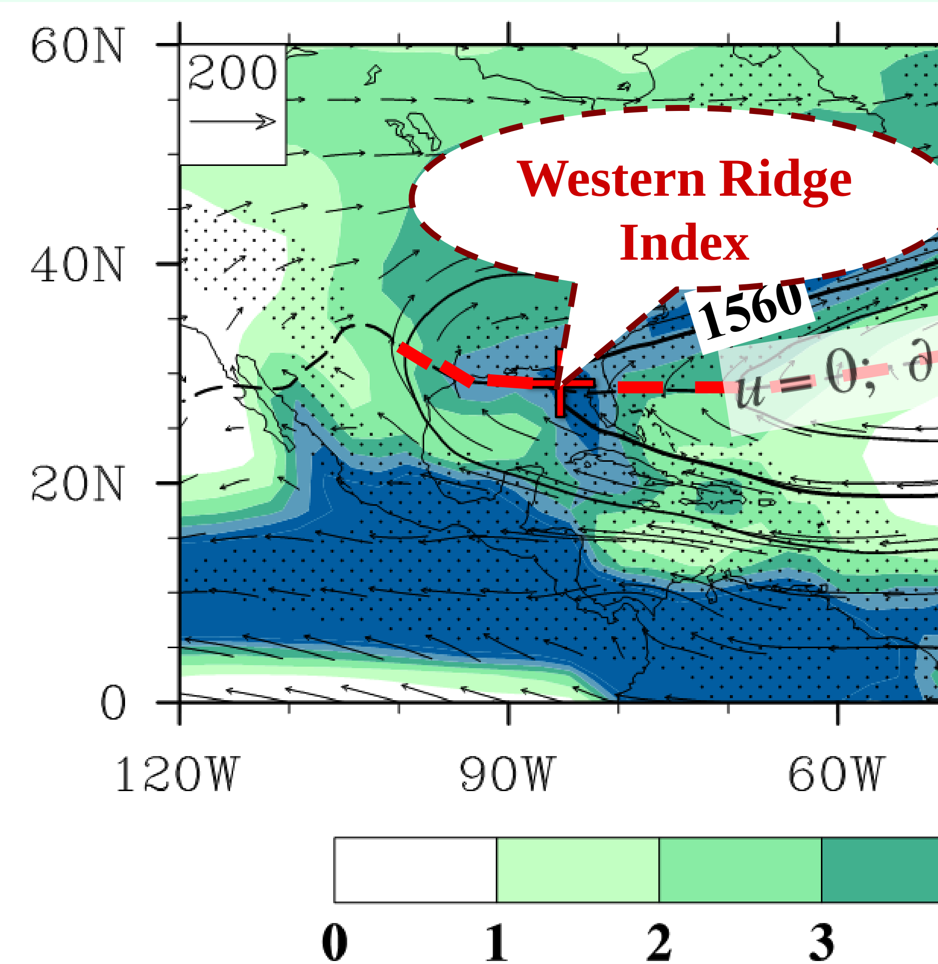


Controlling Process

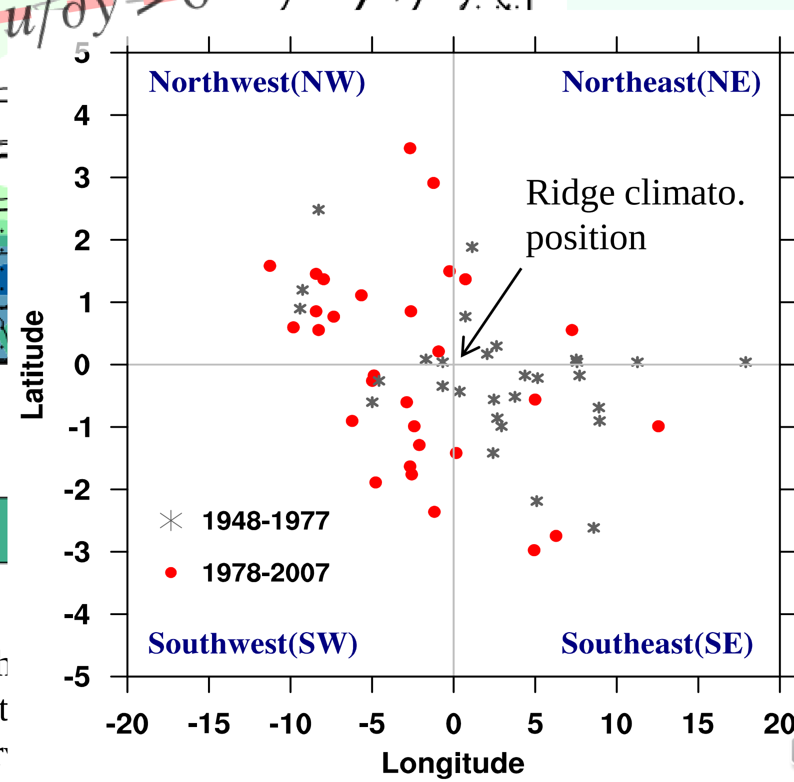
Precipitation = Evaporation
+ Moisture Transport



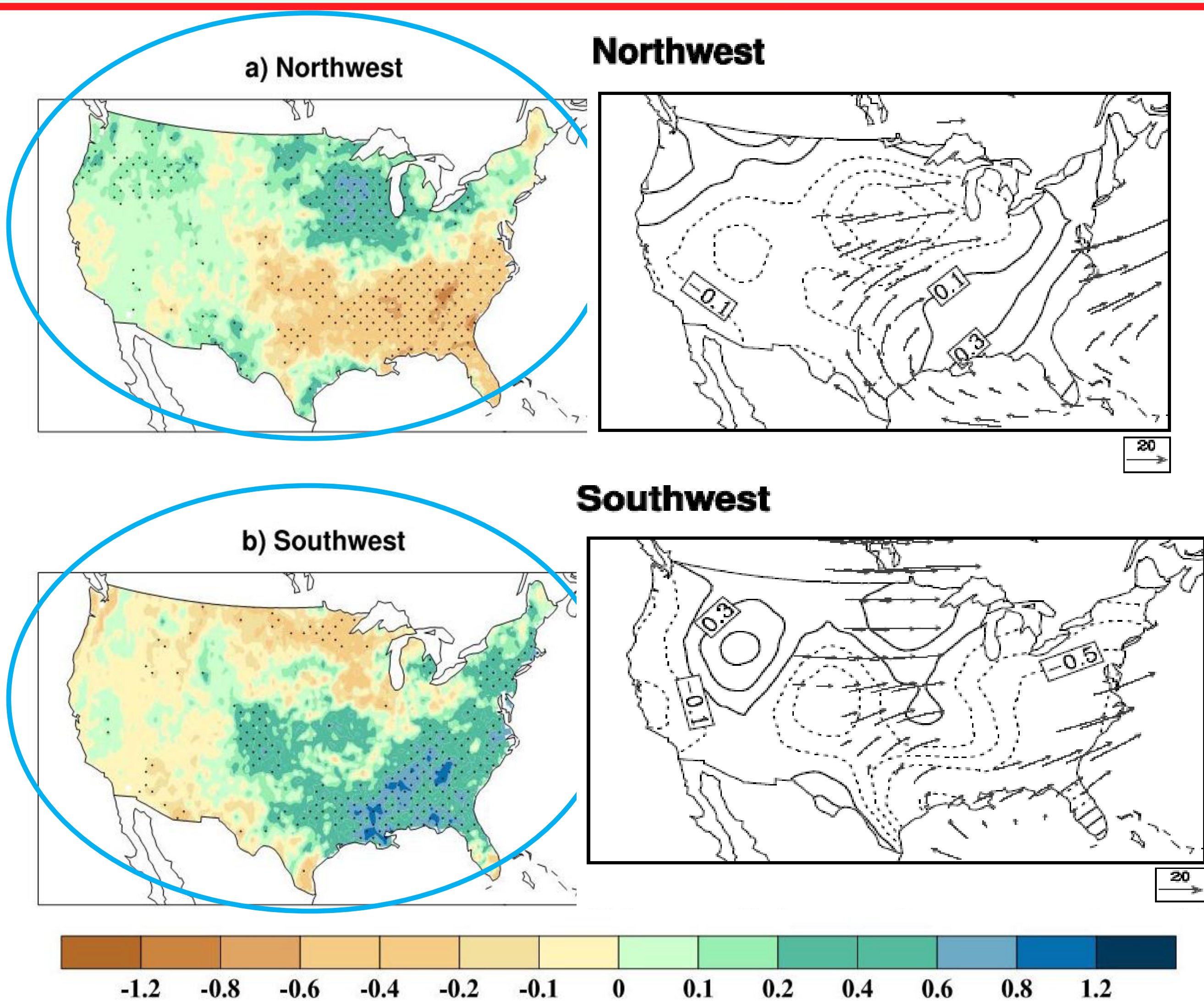
NASH Western Ridge and its Implication to the SE U.S. Summer Precipitation



JJA mean precipitation rate (shaded, unit: mm day^{-1}), 850h
hPa subtropical high ridge line (dashed contour) and moist
of 850hPa geopotential height is 20-gpm, and the bold cur
velocity less than -0.01Pa s^{-1} is stippled.



Ridge position vs precipitation



Composite US summertime precipitation anomaly (left), moisture flux anomaly (vector, right) and 500mb vertical velocity anomaly (contour, right)

NW ridge:
dry summer
Downward motion
Moisture divergence

SW ridge:
wet summer
upward motion
Moisture convergence

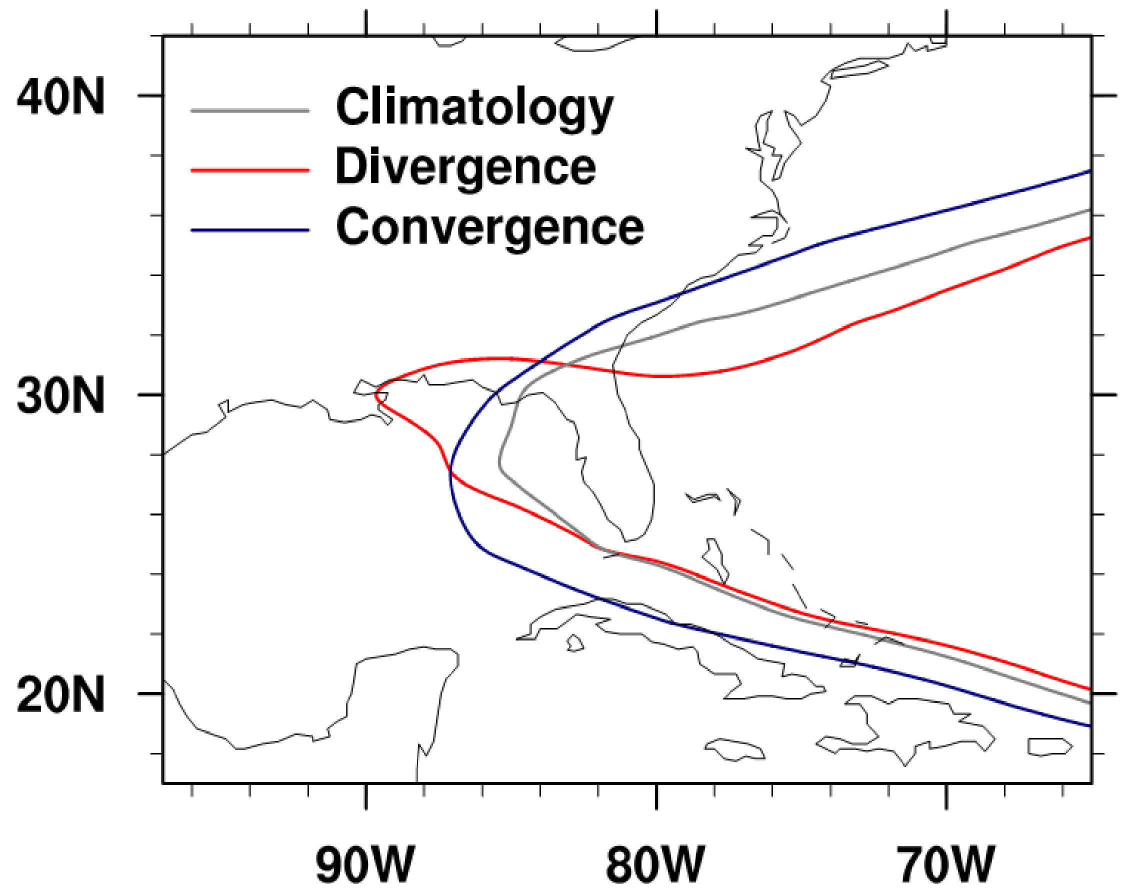
L. Li, W Li, and Y. Kushnir, 2012

Moisture Transport & Western Ridge

Increases in NW and SW types of western ridge during recent 30 years (*L. Li et al. 2012*)

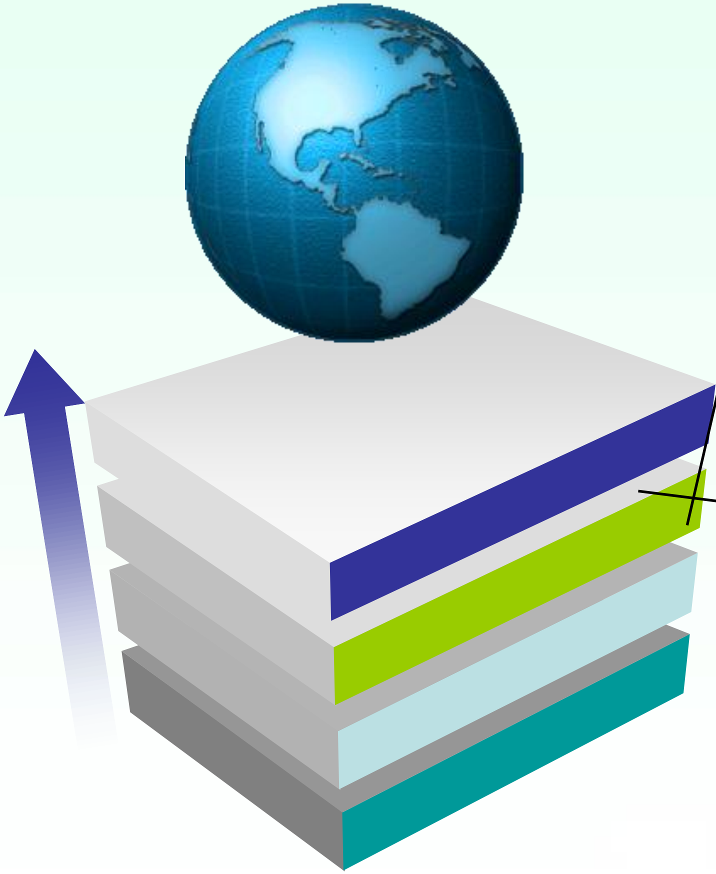
→Intensifies variability in moisture divergence/convergence over the SE US

→Intensifies precipitation variability



Composite 850hPa 1560 geopotential height isoline upon the dynamic component of moisture divergence

Conclusions



- The SE US summer precipitation variability is mainly controlled by atmospheric dynamics

- NASH western ridge position has a close relationship with the summer precipitation of its variability.

Thank you

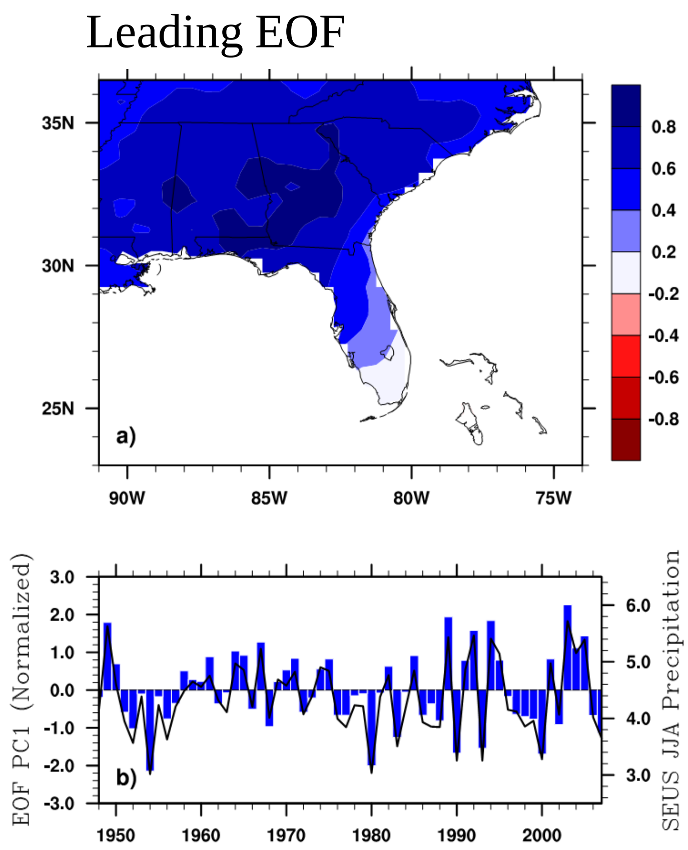


Fig. 1 a) spatial patterns of the first EOF of JJA mean precipitation over SE U.S. (91°W-76°W, 25°N-36.5°N) based on Prec/L data during the 1948-2007 ; b) the normalized PC1 time series corresponding to the spatial pattern (bar, values are shown in the left axis), and areal-averaged SE U.S. summer precip itation (black curve, units: mm day^{-1}, values are shown in the right axis).

ENSO & SE U.S. summer precipitation