ENSO Teleconnections and Impacts on North America during La Niña summers

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ENSO affects crop yields over North America during summer flowering season

- Summer (Jun-Aug): Flowering season for maize & soybean over NA
- Maize and soybean yields are **positively correlated with flowering season Nino3.4 SST anomalies in the US.** (Anderson et al. 2017)

**Impacts of La Niña on crop yields**

(lizumi et al. 2014)
ENSO affects crop yields over the Midwest during summer flowering season

La Niña life cycle

Life cycle of yield anomalies

1st year La Niña
Peak

Transitioning

Malze

Soybean

Flowering months

Country
United States  Argentina  Brazil

(Anderson et al. 2017)
**ENSO affects crop yields over the Midwest during summer flowering season**

La Niña life cycle

Life cycle of yield anomalies

Maximum temperature

Physical mechanism that causes this warming?

(Alexander et al. 2017)
Objective

1. The physical process behind the warm anomalies over the Midwest during ENSO transition summer.

Session 5: 10:50 ~ 11:10
How relevant is ENSO to global crop production? (Weston Anderson)
La Niña: either transition from El Niño or persistent from La Niña

La Niña life-cycle

Criteria: ERSSTv5 3-month averaged Nino3.4 SSTA < -0.5°C in October-December (OND)

La Niñas during 1950-2016
La Niña: either transition from El Niño or persistent from La Niña

La Niña life-cycle

Oceanic Niño Index (C)

El Niño

1st year La Niña

2nd year La Niña

3rd year La Niña

JJA
SON
DJF
MAM
JJA-

Transition

Persistent
The warm anomalies: only happen during the summer when El Niño transitions to La Niña.
Objective

1. The physical process behind the warm anomalies over the Midwest during ENSO transition summer.

2. The differences between the transition and persistent summers.
Transition summer: shares the characteristics of both the decaying El Niño and the developing La Niña

NCEP-NCAR R1: detrended SSTA & 200hPa height anomalies (zonal mean removed)
Transition summer: shares the characteristics of both the decaying El Niño and the developing La Niña.

NCEP-NCAR R1: detrended SSTA & 200hPa height anomalies (zonal mean removed)
Transition summer: An anomalous ridge over eastern North America

**Transition**

\[ JJA(0)_T \]

Teleconnections propagate toward extratropical North America.

**Persistent**

\[ JJA(0)_P \]

Anomalous circulations are more confined in the tropics.

NCEP-NCAR R1: detrended SSTA & 200hPa height anomalies (zonal mean removed)
Transition summer: An anomalous *ridge* over eastern North America.

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**Transition**

$JJA(0)_T$

**Persistent**

$JJA(0)_P$

Ridge

Anomalous circulations are more confined in the tropics.

NCEP-NCAR R1: detrended SSTA & 200hPa height anomalies (zonal mean removed)
Transition summer:
Rossby waves from both central and western tropical Pacific

western Pacific:
Caused by the delayed Indian Ocean warming due to the previous El Niño.
(Xie et al. 2009)
Transition summer: 
Rossby waves from both central and western tropical Pacific
Transition summer:
Rossby waves from both central and western tropical Pacific

Transition

 Persistent

El Niño  La Niña
Transition summer:
Rossby waves from both central and western tropical Pacific

The suppressed deep convection over the western Pacific due to the previous El Niño also trigger a stationary wave propagate toward NA.
Use **Stationary Wave Model** to examine to the role of tropical forcing during the developing La Niña summer

**Stationary wave model** (Ting and Hoerling 1993; Ting and Yu 1998)

- Linear, primitive equation, steady-state baroclinic model
- Deviations from a prescribed zonally asymmetric basic state
- Interior Rayleigh drag: 15-day
- Forcing: diabatic heating, transient eddies

**Transition**

*JJA(0)*$_{T}$
Use Stationary Wave Model to examine the role of tropical forcing during the developing La Niña summer

Stationary wave model (Ting and Hoerling 1993; Ting and Yu 1998)

- Linear, primitive equation, steady-state baroclinic model
- Deviations from a prescribed zonally asymmetric basic state
- Interior Rayleigh drag: 15-day
- Forcing: diabatic heating, transient eddies

**El Niño winter:**

Contour: stream function
Shaded: diabatic heating (prescribed)
Decompose the diabatic heating/cooling anomalies over the western and central tropical Pacific.

Transition JJA(0) Diabatic heating anomalies @ 400hPa

Western & Central tropical Pacific (WP+CP)

Central tropical Pacific (CP)

Western tropical Pacific (WP)
The contributions from anomalous diabatic cooling over the **WP & CP** dominate the teleconnection patterns.

**Observation**

\[ JJA(0)_T \]

**Model**

**WP+CP**

Shaded: 200hPa streamline function anomalies
The contributions from anomalous diabatic cooling over the WP & CP dominate the teleconnection patterns.
The anomalous diabatic cooling over the WP does modulate the teleconnection patterns during the transition summer.
The anomalous diabatic cooling over the WP does play a role in distinguishing the transition and persistent summers.
The anomalous diabatic cooling over the WP does play a role in distinguishing the transition and persistent summers.
Over North America, the anomalous circulations are alike if only diabatic heating prescribed.

**Observation**

$JJA(0)_T$

$JJA(0)_P$

**Forcing: Q**

Transition $JJA$ Q anomalies

Persistent $JJA$ Q anomalies

Shaded: 200hPa streamline function anomalies
Transient eddies shape the teleconnections pattern over extratropical North America

**Observation**

- **JJA(0)T**

- **Ridge**

- **Transition**

**Forcing: Q**

- **JJA Q anomalies**

**Forcing: Q + Transient eddies**

- **JJA Q + VT anomalies**

Shaded: 200hPa streamline function anomalies
WP diabatic cooling: shift the teleconnections pattern
Transient eddies: shape the teleconnections over the extratropics

Forcing: $Q$

Forcing: $Q + \text{Transient eddies}$

Transition

Persistent

Shaded: 200hPa streamline function anomalies
WP diabatic cooling: shift the teleconnections pattern
Transient eddies: shape the teleconnections over the extratropics

**Forcing: Q**

**Forcing: Q + Transient eddies**

Transition

Persistent

Shaded: 200hPa streamline function anomalies
WP diabatic cooling: shift the teleconnections pattern
Transient eddies: shape the teleconnections over the extratropics

Diabatic heating

Forcing: $Q$

Forcing: $Q + $ Transient eddies

Different tropical forcing $\rightarrow$ Different anomalous circulation $\rightarrow$ Different transient eddies response $\rightarrow$ Different feedback to teleconnections
La Niña summer teleconnections in North America

- Robust warm anomalies over the Midwest during transition summer (El Niño -> La Niña)

- During transition summer, two suppressed deep convections:
  - central tropical Pacific (developing La Niña)
  - western tropical Pacific (decaying El Niño)

  **Rossby waves from both forcings**

- According to SWM experiments,
  - Diabatic cooling over WP: shift the teleconnections
  - Transient eddies: shape the details of teleconnections over the extratropics