Weston Anderson
R. Seager, W. Baethgen, M. Cane,
L. You
October 16-18, 2018
Guayaquil, Ecuador

Twitter: @HydroClim
ENSO and global food production

1. Why Does ENSO pose a unique risk to global food security?

2. Which teleconnections pose a risk?

3. How important is ENSO relative to other factors?
ENSO and global food production

1. Why Does ENSO pose a unique risk to global food security?
2. Which teleconnections pose a risk?
3. How important is ENSO relative to other factors?
The global food system

Figure 2. Global population in different food availability (A), food self-sufficiency (B) and food trade (C) categories. Upper figures express the population in absolute numbers and lower figures in relative numbers. DES and DEP refer to dietary energy supply and dietary energy production.

doi:10.1371/journal.pone.0082714.g002

(Porkka et al., 2013)
The global food system

Figure 2. Global population in different food availability (A), food self-sufficiency (B) and food trade (C) categories. Upper figures express the population in absolute numbers and lower figures in relative numbers. DES and DEP refer to dietary energy supply and dietary energy production.

doi:10.1371/journal.pone.0082714.g002

(Porkka et al., 2013)
The global food system

Figure 2. Global population in different food availability (A), food self-sufficiency (B) and food trade (C) categories. Upper figures express the population in absolute numbers and lower figures in relative numbers. DES and DEP refer to dietary energy supply and dietary energy production.

(Porkka et al., 2013)
The global food system

Figure 2. Global population in different food availability (A), food self-sufficiency (B) and food trade (C) categories. Upper figures express the population in absolute numbers and lower figures in relative numbers. DES and DEP refer to dietary energy supply and dietary energy production.

doi:10.1371/journal.pone.0082714.g002

(Porkka et al., 2013)
The global food system

Figure 3. Major crop import flows for caloric trade dependent countries. Countries are colored according to the crop they are importing. The color intensification signifies the import dependency ratio. Each country is linked to its major supplier via an import arrow. The thicker the arrow, the higher the share the exporting country has on the import volume of that country.

(Bren d’Amour et al., 2016)
The El Niño Southern Oscillation (ENSO)
The El Niño Southern Oscillation (ENSO)

Figures 5 from (Horel and Wallace, 1981)
The El Niño Southern Oscillation (ENSO)

Figures 5 and 11 from (Horel and Wallace, 1981)
ENSO and global food production

1. Why Does ENSO pose a unique risk to global food security?

   The global scale of ENSO teleconnections pose a unique risk to our global food production system
ENSO and global food production

1. Why Does ENSO pose a unique risk to global food security?
2. Which teleconnections pose a risk?
3. How important is ENSO relative to other factors?
Agriculturally-relevant ENSO teleconnections

Identify crop growing regions and seasons

Circulation associated with ENSO in observations and AMIP

Compare observed and forced heat and moisture stress anomalies
Agriculturally-relevant ENSO teleconnections

**Killing Degree Days (KDD)**

\[ KDD = \sum_{i=1}^{n} \max(0, T_{\text{max},i} - T_c) \]

- \( n \): days around flowering season
- \( T_c \): critical temperature

**Soil Water Content (SWC)**

\[ \text{SWC anomaly} = \left( \frac{\delta \theta}{\theta_v} \right) \]

\( \frac{d \theta}{dt} = P - \text{ET} - \text{R} \)

Cropping cycle evapotranspiration

- \( \text{ET} = \left( \frac{\theta}{\theta_v} \right) \times K_c \times ET_0 \)
- \( K_c \): FAO Pennman-Monteith
- \( \theta \): Plant available water
Killing Degree Days (KDD)

\[ KDD = \sum_{i=1}^{n} \max(0, T_{\text{max},i} - T_c) \]

n = days around flowering season
T_c = critical temperature

Soil Water Content (SWC)

\[ \text{SWC anomaly} = \left( \frac{\delta \theta}{\theta_v} \right) \]

\[ \frac{d \theta}{d t} = P - ET - R \]

\[ ET = \left( \frac{\theta}{\theta_v} \right) * K_c * ET_0 \]

Plant available water
FAO Pennman-Monteith

Atmospheric Model Intercomparison Project (AMIP)

Agriculturally-relevant ENSO teleconnections
Agriculturally-relevant La Niña teleconnections

(During the three months before local maize harvest)

- Observations
- AMIP Multi-Model Ensemble Mean
- Soil water content
  - (ASO)
  - (JJA)
  - (JFM)
- Killing degree days
- Seasonal precipitation
- Maximum temperature

During the three months before local maize harvest (ASO), (JJA), (JFM)
Trans-Pacific ENSO teleconnections

La Niña

Mid-season (JASO)

Late season (NDJF)
Trans-Pacific ENSO teleconnections

La Niña

Mid-season (JASO)

Late season (NDJF)

See analysis by Bor Ting Jong
Trans-Pacific **ENSO** teleconnections

See analysis by I. Bor-Ting Jong
Trans-Pacific ENSO teleconnections

See analysis by

La Niña

Mid-season (JASO)

Late season (NDJF)

\[ \beta v = f \frac{dw}{dz} \]
Trans-Pacific ENSO teleconnections

La Niña

Mid-season (JASO)

Late season (NDJF)

See analysis by Bor-Ting Jong

$\beta v = f \frac{dw}{dz}$

$\zeta = 0$

$Q = f(\theta_2)/H_2 = f(\theta_1)/H_1$

$Q = f(\theta_1)/H_1$

Latitude $\theta_1$

move northwards

Latitude $\theta_2$

$Iri$
ENSO and global food production

2. Which teleconnections pose a risk?

Trans-Pacific teleconnections pose a correlated risk to global food production
1. Why Does ENSO pose a unique risk to global food security?

2. Which teleconnections pose a risk?

3. How important is ENSO relative to other factors?
How important is ENSO to maize yield variability?

Fields of SST and crop yield anomalies

Maximum Covariance Analysis (MCA)

Separate ENSO-forced anomalies

Variance explained by ENSO

- Observed US maize anomalies
- ENSO-forced maize anomalies

23%
How important is ENSO to maize yield variability?
How important is ENSO to synchronous crop failures

(Figure 2 from Mehrabi and Ramankutty, in press)
How important is ENSO to synchronous crop failures

Observed 1983 yield anomalies

ENSO-forced 1983 yield anomalies

Observed 1983 yield anomalies
China
South Africa
United ... ENSO-forced
Maize anomalies [kg]
-2          1          0          1           2
How important is ENSO to synchronous crop failures?

Tropical SST anomalies

Observed 1983 yield anomalies

ENSO-forced 1983 yield anomalies

Observed 1983 yield anomalies

China
South Africa
United...

Maize anomalies [kg]

-2 1 0 1 2
How important is ENSO to synchronous crop failures?

Tropical SST anomalies

Observed 1983 yield anomalies

ENSO-forced 1983 yield anomalies
How important is ENSO to synchronous crop failures? Tropical SST anomalies

Is this statistical reconstruction consistent with what we know about ENSO teleconnections?
How important is ENSO to synchronous crop failures?
How important is ENSO to synchronous crop failures?

**Climate**

**Crop**


How important is ENSO to synchronous crop failures?


How important is ENSO to synchronous crop failures?


Crop yield anomalies


How important is ENSO to synchronous crop failures

Tropical SST anomalies

Crop yield anomalies

ENSO-forced 1983 yield anomalies

Observed 1983 yield anomalies

China
South Africa
United States

Tropical SST anomalies

Crop yield anomalies
3. How important is ENSO relative to other factors?

ENSO accounts for ~18% of global maize production variance, but may play a particular role in forcing synchronous crop failures.
How important is ENSO to food security?
Conclusions

- ENSO poses a unique **correlated risk** to food production due to its global teleconnections
  (i.e. crop failures are not always independent)

- ENSO can (and has) forced **globally-synchronous** crop failures

- ENSO accounts for ~10-30% of regional maize variance, 18% of global variance

Synchronous crop failures and climate-forced production variability
(submitted) Anderson, W.B., Seager, R., Baethgen, W., Cane, M., and You, L.

Trans-Pacific ENSO teleconnections pose a correlated risk to agriculture

Crop production variability in North and South America forced by life-
cycles of the El Niño Southern Oscillation (2017) Anderson, W.B., Seager, R.,

Weston Anderson westonanderson.cnrd @HydroClim