Asymmetries in the predictability of El Niño and La Niña: Implications for TPOS2020

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\[ \frac{\partial T'}{\partial t} = aT' - bT'(t - t_0) - cT' \]


Is ENSO a cycle or a series of events?

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Received 19 July 2002; revised 1 October 2002; accepted 2 October 2002; published 12 December 2002.
Asymmetries in the predictability of El Niño and La Niña:

• It is extremely easy to predict the onset of La Niña,

• It is difficult to predict the onset of El Niño,

• Under specific conditions, it is easy to predict the termination of La Niña.
Subsurface thermal anomalies provide predictability of El Niño and La Niña

- Subsurface warming before El Niño ~ 9 month
- Subsurface cooling before La Niña
Subsurface thermal anomalies provide predictability of El Niño and La Niña

Subsurface cooling **always** leads to La Niña

- Well understood
- Facilitates prediction
Two issues:

1. Subsurface warming sometimes leads to El Niño
   - Well understood
   - Facilitates prediction
Two issues:

1. Subsurface warming sometimes does not lead to El Niño
   - Not appreciated until 2014
   - Complicates prediction
Two issues:

2. Subsurface warming is ineffective at terminating La Niña
   - Not well-understood until recently
   - Predictability not studied until recently
Issue #1: Subsurface warming not always leads to an El Niño

- Warm subsurface temperature anomaly (oceanic precursor)
- Strong WWB in March (atmospheric precursor)
Forecasts show large spread arising from random atmospheric variability.
unpredictable atmospheric variability led to:
La Nada in 2014 and El Nino in 2015
despite similar ocean initial states
Summer WWBs critical for El Niño predictability

June-July-August is when WWBs have the largest impact on El Niño’s peak amplitude
Subsequent WWBs are key

- Ensemble with all WWBs
- Ensemble with initial WWB, but all subsequent events removed

Puy et al. 2017
Issue #2: Subsurface warming is ineffective at terminating La Niña

Weak (delayed) damping of La Niña

Strong (delayed) damping of El Niño
Duration of La Niña correlated with magnitude of initial thermocline discharge

DiNezio et al. 2017a
Duration of La Niña correlated with magnitude of thermocline discharge

Dots indicate simulated ENSO events (~300 of them) in a 1800 year long run performed with CESM1

DiNezio et al. 2017a
The strongest El Niño on record were followed by strong discharge and 2-year La Niña
Number of observed events is **insufficient** to develop a statistical model for prediction.

![Graph showing correlation between Nino SST index and peak thermocline discharge. Dots indicate observed ENSO events, and ellipses indicate observational uncertainty.](image)

- $r = 0.39$
- DiNezio et al. 2017b
Initialized forecasts

- 40-member ensembles
- Initialized on November of each year since 1954
- Initial conditions from CORE-forced POP run
- Historical / RCP8.5 external forcings
- Each member run for 10 years
- Includes forecast initialized on Nov 2015 used to predict current event
- Drift correction (following CLIVAR 2011)
- Verified against forced persistence forecasts (in DiNezio et al. 2017b).

More predictable La Niña after strong El Niño and associated discharge

Ellipses show ensemble spread

DiNezio et al. 2017b
CESM-DP-LE predicted the 2-year La Niña that followed the El Niño of 1997.

Target season: NDJ 1999/2000

0% chance of El Niño
95% chance of La Niña

DiNezio et al. 2017b
Predictions initialized in November 2015 showed La Niña persisting into this winter with a 60% chance of La Niña and a 5% chance of El Niño.
Asymmetries in the predictability of El Niño and La Niña:

- Summertime WWBs are paramount to predict El Niño
  - Unpredictable beyond one or two weeks
- Ocean precursors control the onset of La Niña
  - Controlled by well-known ocean dynamics
  - Highly predictable
- Ocean precursors control the termination of La Niña
  - Persistence of subsurface anomalies due to weak recharge
onset of El Niño
weak SST-thermocline coupling?

onset of La Niña
strong SST-thermocline coupling

termination of La Niña
weak SST-thermocline coupling
Thank you!
Coupling between the thermocline and the mixed-layer appears to vary throughout the life cycle of El Niño and La Niña events affecting our ability to predict them.

Questions that TPOS2020 could help answer:

1. Is the current observing system adequate to observe the coupling between the thermocline and the mixed-layer in the central equatorial Pacific on ENSO timescales?
2. How can it be improved to better observe these processes?
3. Do models simulate this coupling realistically?
4. Would model improvements in the simulation of this coupling lead to improved predictive skill?
• Sensitivity of WWB-ENSO to subsurface initial conditions

Similar recharged state as in 1997 (~2 Sdev)

The modulation of WWEs by El Niño depends on the initial conditions
Retrospective predictions show low bias
Retrospective predictions show lower RMS error than forced persistence forecasts.
Sea–surface temperature variability and trends in the central and western Pacific
The strongest El Niño on record were followed by large discharge and 2-year La Niña

Magnitude of this year’s discharge is not much different than during the previous two strongest El Niño events

DiNezio et al. in prep.
What happened to operational forecasts this year?

NMME forecasts initialized in April 2017

NMME forecasts initialized in July 2017

NMME forecasts initialized in September 2017

Is this the sign of systematic biases?
What’s the role of stochastic forcing in the evolution of this year’s event?

Five Day Zonal Wind, SST, and 20°C Isotherm Depth Anomalies 2°S to 2°N Average
Five Day Zonal Wind, SST, and 20°C Isotherm Depth Anomalies 2°S to 2°N Average
Define La Niña based on the SST gradient to avoid biases caused by long-term warming.
Since case 169 CESM2 simulates less 2-year La Nina than obs, CCSM4, or LENS

- Blue composites are CESM2 cases 169-191
- Orange composites are CESM2 cases 125-149
Very weak La Nina according to observations and prediction models

Is La Nina here?

NMME: North American Multi-Model Ensemble
September 2016

Is La Niña here? Depends who you asked:

Japanese Meteorological Agency (JMA): La Niña has arrived.

The Australian Bureau of Meteorology: La Niña watch, waiting for its “official” arrival.

NOAA dropped their La Niña watch in September, indicating that it was unlikely that a La Niña will form this fall or winter. However, the La Niña watch was reinstated in October.
Observations and models show stronger SST gradient

Cooling of the Niño-3.4 region not as strong as during 1998, but definitively not neutral.
The predictability of La Niña depends on magnitude of the initial discharge.

- **Weak predictor**: 19 out of 20 members predict the return of La Niña.
- **Moderate predictor**: The control run was an outlier, however within forecast spread.
- **Strong predictor**: DiNezio et al. in review.

![Graph showing the predictability of La Niña](image)
CESM-DP-LE predicted historical 2-year La Niña preceded by strong El Niño
CESM1 simulates realistic 2-yr La Nina

observed composites

simulated composite
Verification: CESM1 is better than damped persistence
Three case studies based on magnitude of preceding El Nino:

strong

moderate

weak

control

individual forecast

ensemble-mean
More predictable La Niña after strong El Niño and associated discharge.
Observed La Niña events are consistent with our hypothesis.

Magnitude of thermocline shoaling prior to the onset of La Niña.
The forecasts are also skillful when initialized at the peak of El Nino.
2-year La Niña could also be predicted 24 months in advance

24-month lead forecasts

Peak amplitude of preceding El Niño
Sea-surface temperature variability and trends in the central and western Pacific

SSTA (K)


Nino-3.4
western Pacific (120°E–150°E 5°S–5°N)
The strongest El Niño on record were followed by large discharge and 2-year La Niña.

Magnitude of this year’s discharge is not much different than during the previous two strongest El Niño events.
Highly predictable 2-year La Niña after strong El Niño events

DiNezio et al. 2017a
The predictability of La Niña depends on magnitude of the initial discharge.

Weak predictor: 19 out of 20 members predict the return of La Niña.

Moderate predictor: 19 out of 20 members predict the return of La Niña.

Strong predictor: 19 out of 20 members predict the return of La Niña.

Control run was an outlier, however within forecast.
Strong discharge leads to highly reliable forecasts:

19 out 20 members predict 2-yr La Niña
Skillful 2-year predictions initialized at the peak of a strong El Niño

All members predict 2-yr La Niña