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

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**Acknowledgements:**

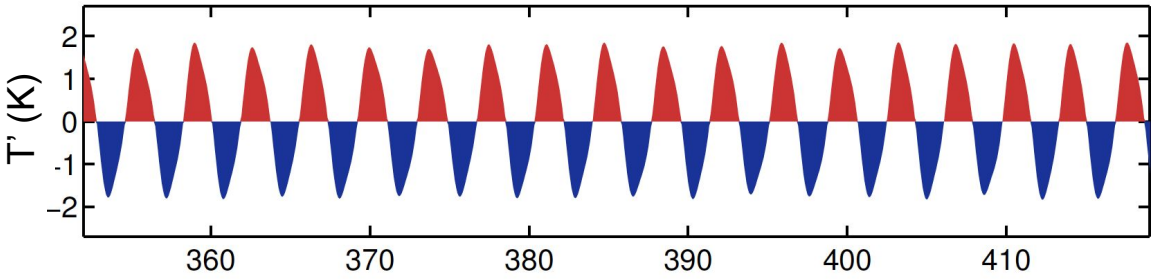
Clara Deser and Yuko Okumura for ideas on asymmetries between of El Niño and La Niña.

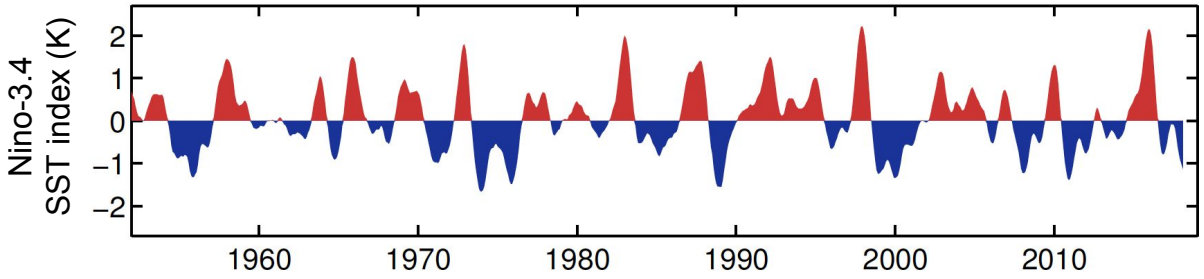
Martin Puy and Alicia Karspeck for insightful discussions about predictability.



MAPP
Modeling, Analysis, Predictions, and Projections

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



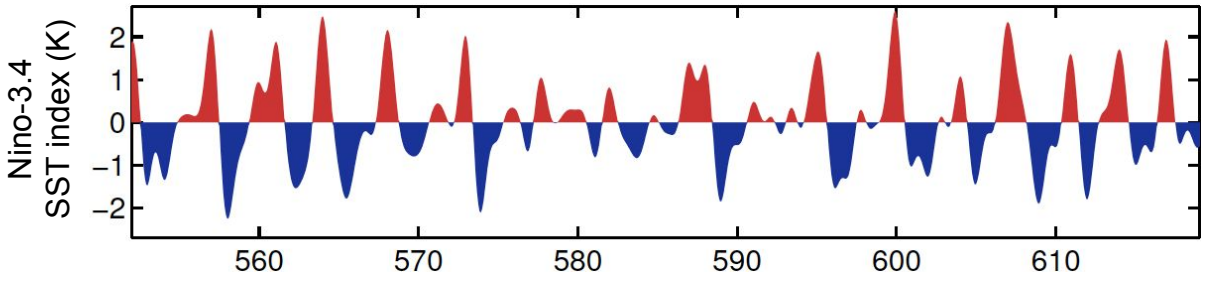




GEOPHYSICAL RESEARCH LETTERS, VOL. 29, NO. 23, 2125, doi:10.1029/2002GL015924, 2002

**Is ENSO a cycle or a series of events?**

William S. Kessler
NOAA/Pacific Marine Environmental Laboratory, Seattle, Washington, USA

Received 19 July 2002; revised 1 October 2002; accepted 2 October 2002; published 12 December 2002.

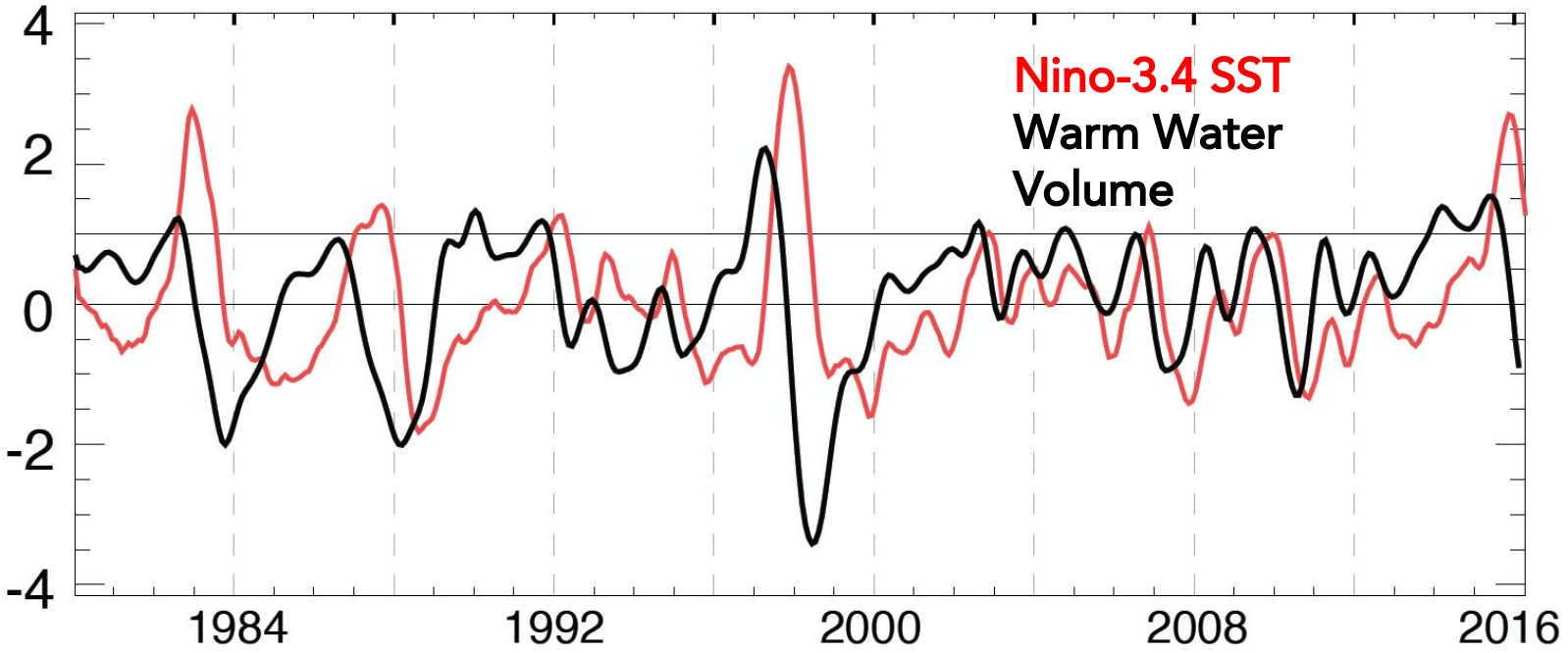



# Asymmetries in the predictability of El Niño and La Niña:

- 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.

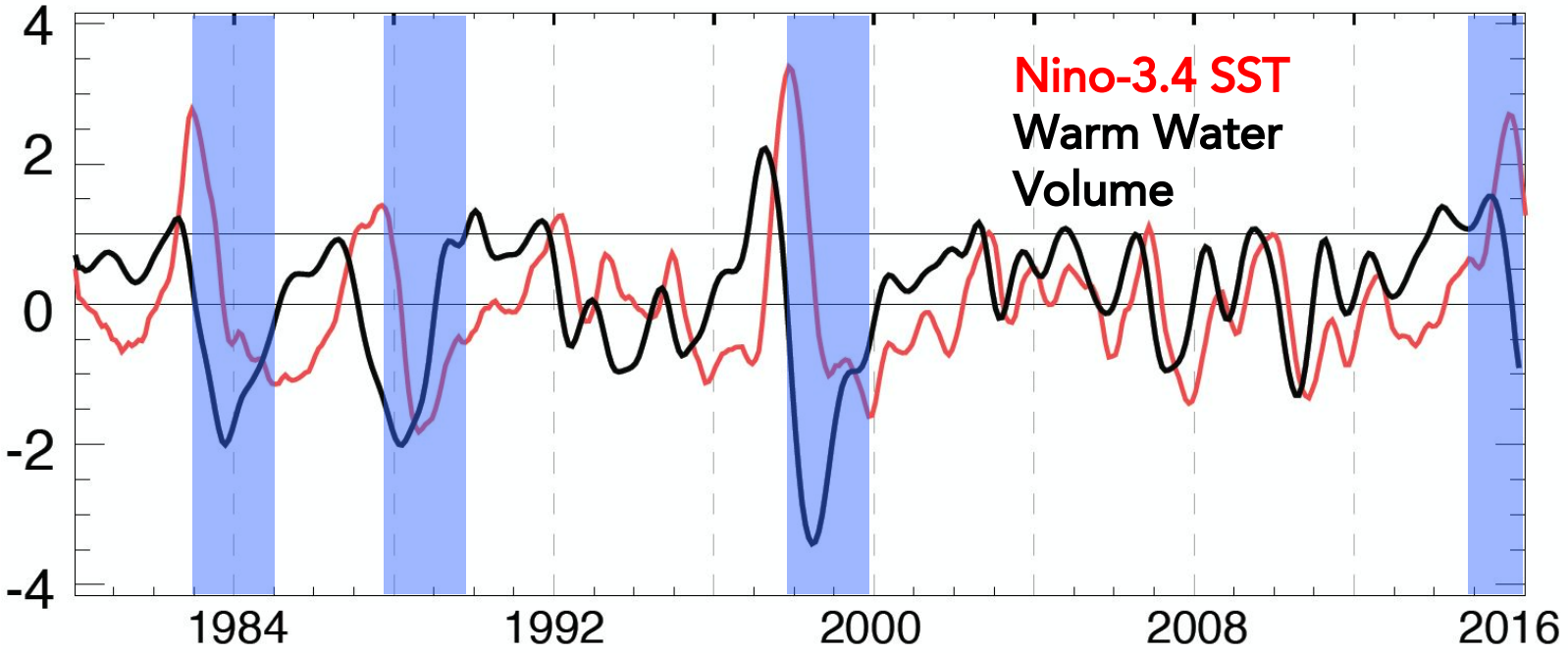
# Subsurface thermal anomalies provide predictability of El Niño and La Niña




- Subsurface warming before El Niño
- Subsurface cooling before La Niña

~ 9 month lag

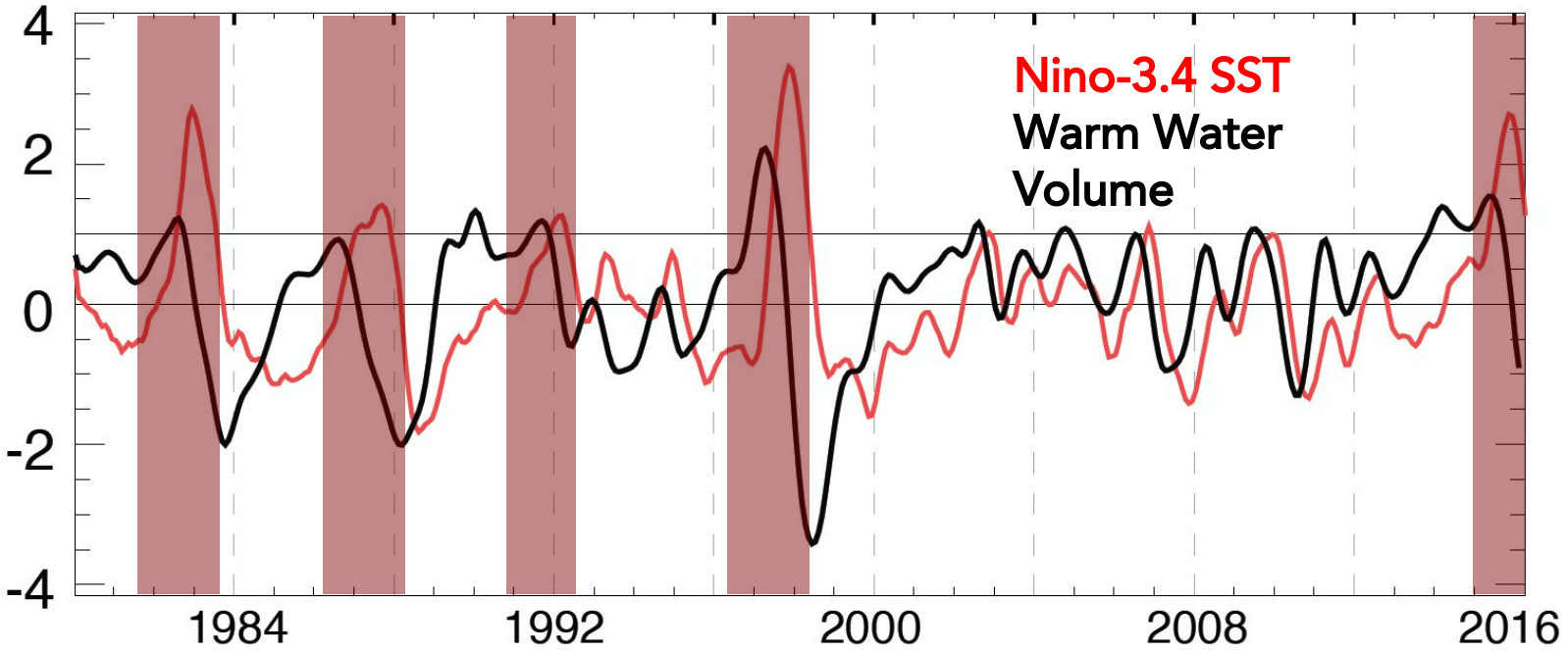
# Subsurface thermal anomalies provide predictability of El Niño and La Niña




**Subsurface cooling <u>always</u> leads to La Niña**

- Well understood
- Facilitates prediction

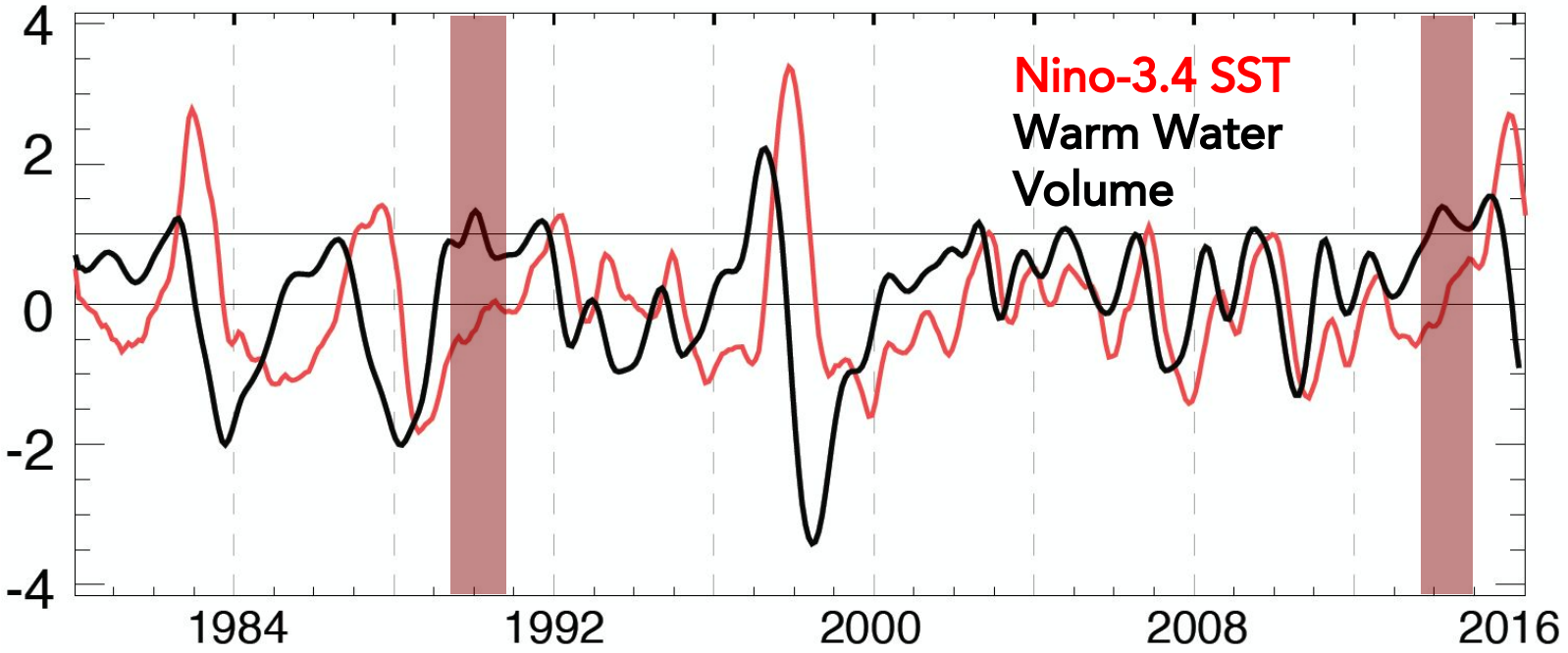
# Two issues:




## 1. Subsurface warming <u>sometimes</u> leads to El Niño

- Well understood
- Facilitates prediction

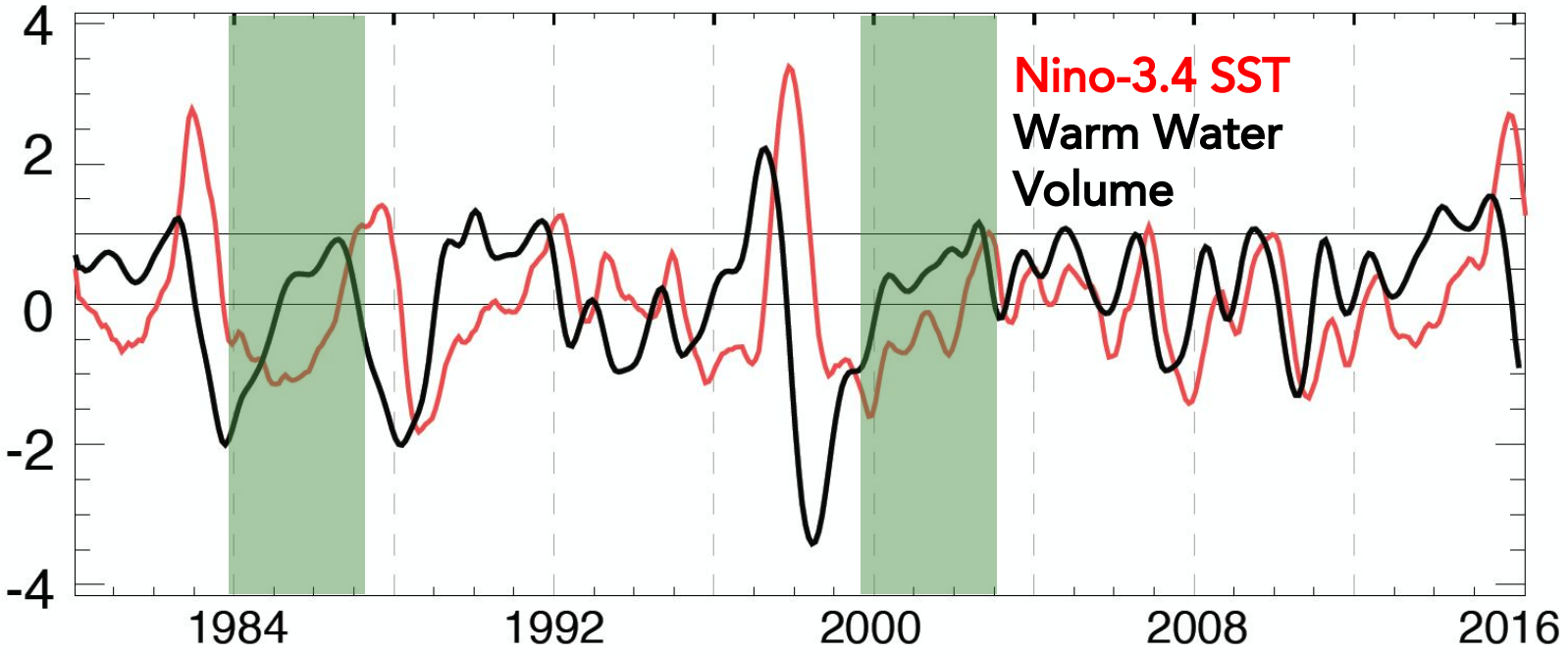
# Two issues:




**1. Subsurface warming <u>sometimes</u> does not lead to El Niño**

- Not appreciated until 2014
- Complicates prediction

# Two issues:

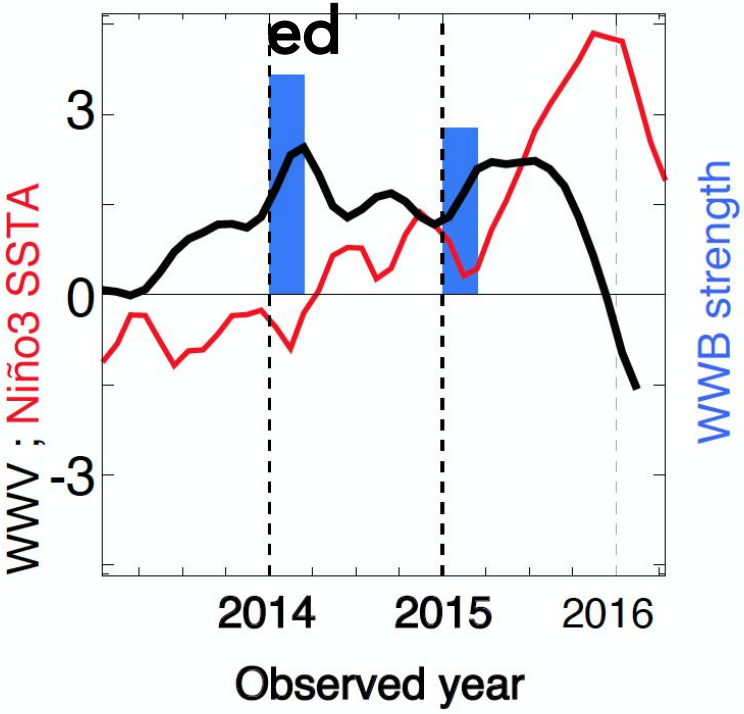



## 2. Subsurface warming is ineffective at terminating La Niña

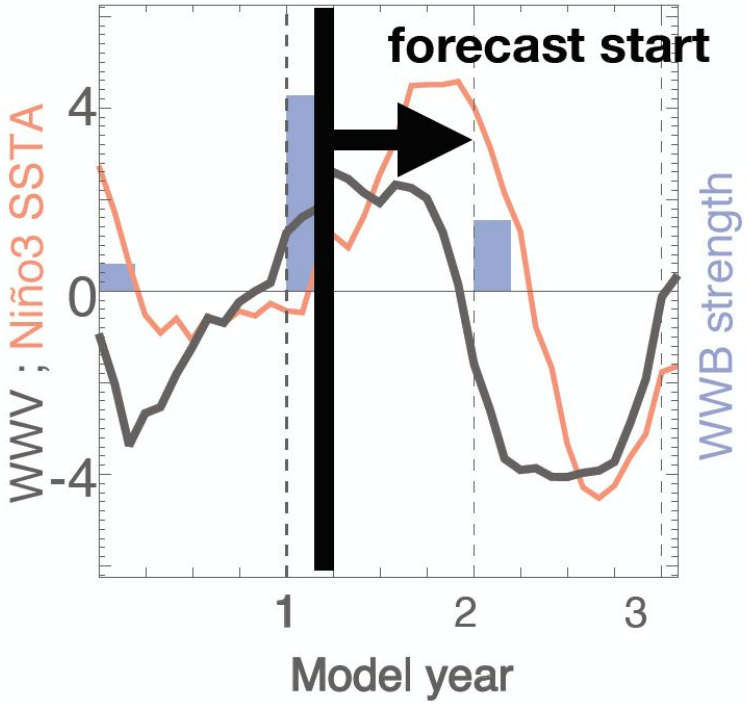
- Not well-understood until recently
- Predictability not studied until recently

# Issue #1: Subsurface warming <u>not always</u> leads to an El Niño

Observed



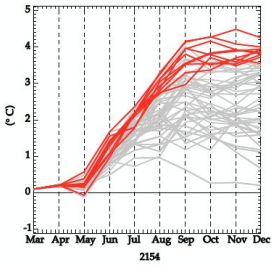

CNRM-C



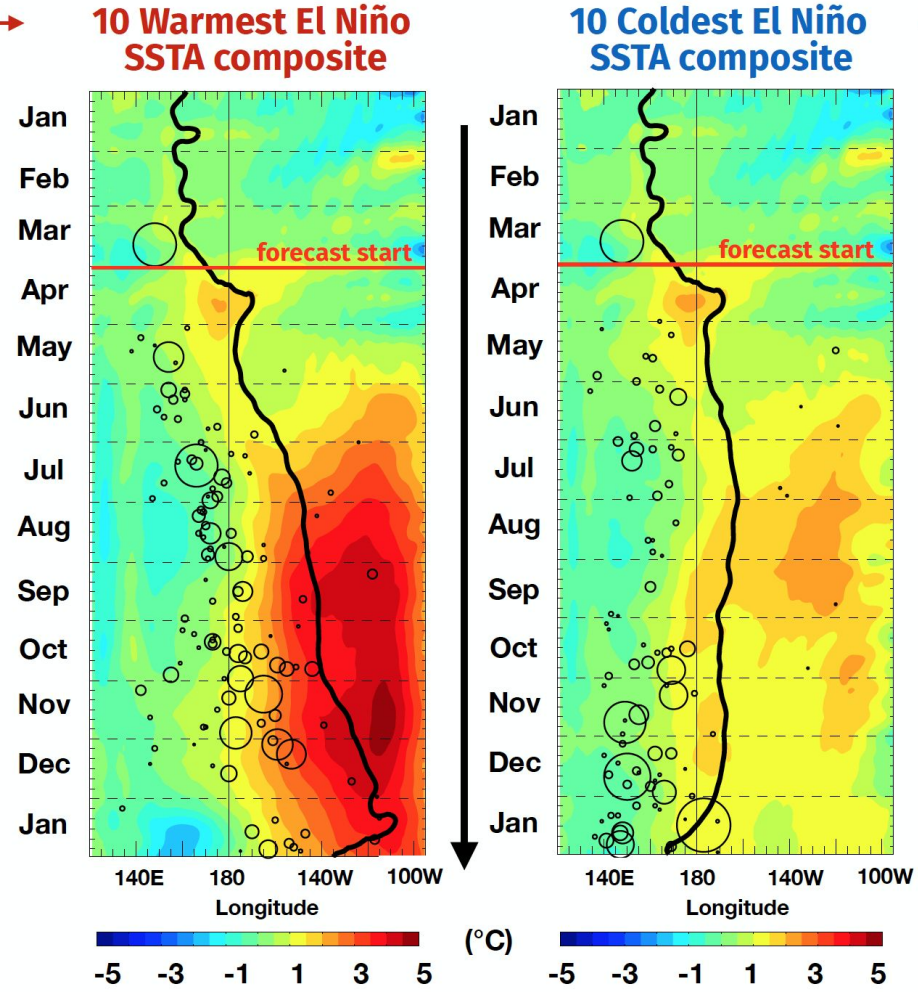

- Warm subsurface temperature anomaly (oceanic precursor)
- Strong WWB in March (atmospheric precurso

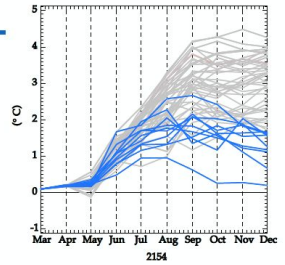
Puy *et al.* 2017

# Forecasts show large spread
## arising from random atmospheric variability




**SSTA evolution**
**Similar to 2015**



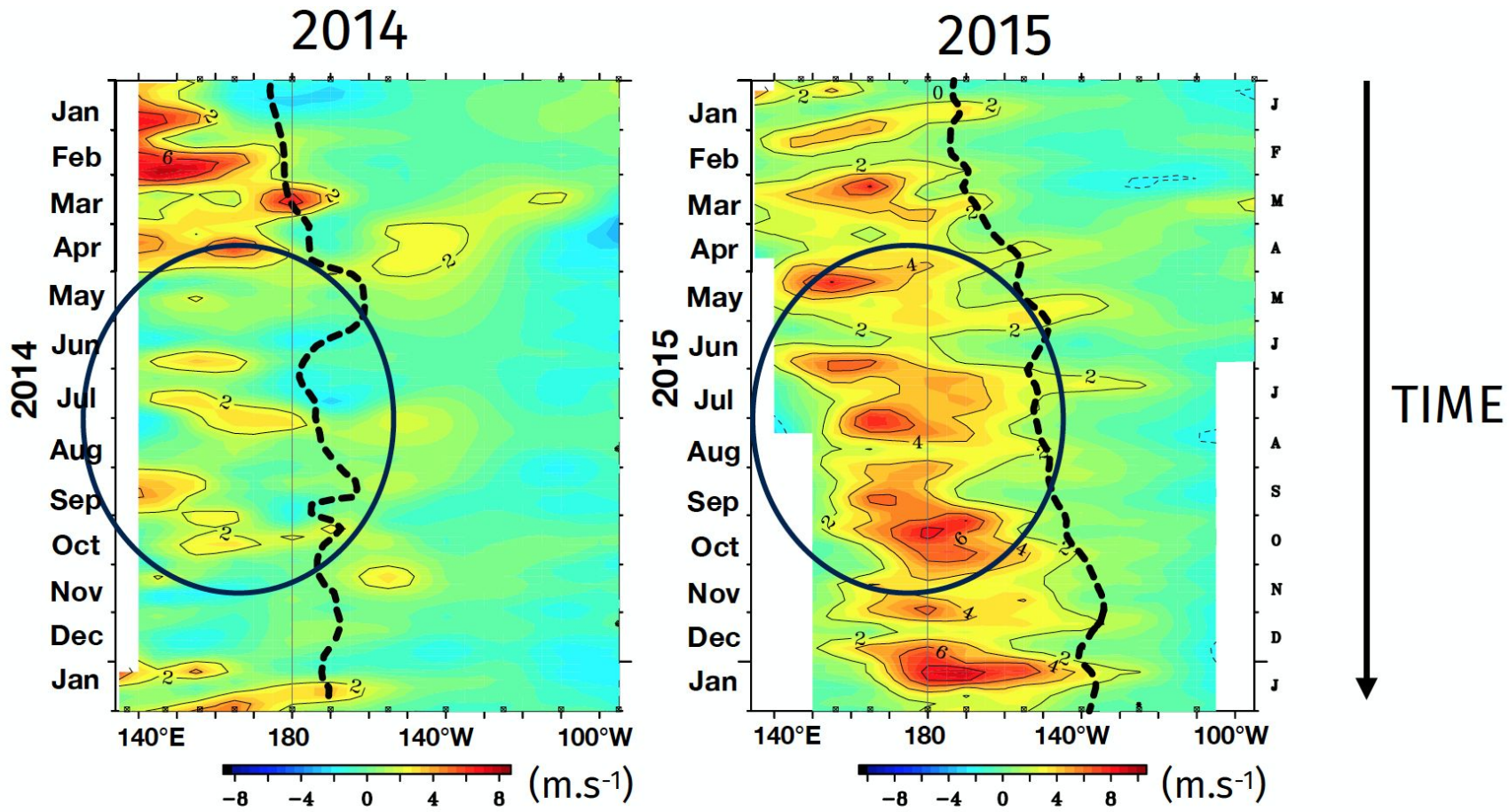




**SSTA evolution**
**Similar to 2014**

Puy et al. 2017

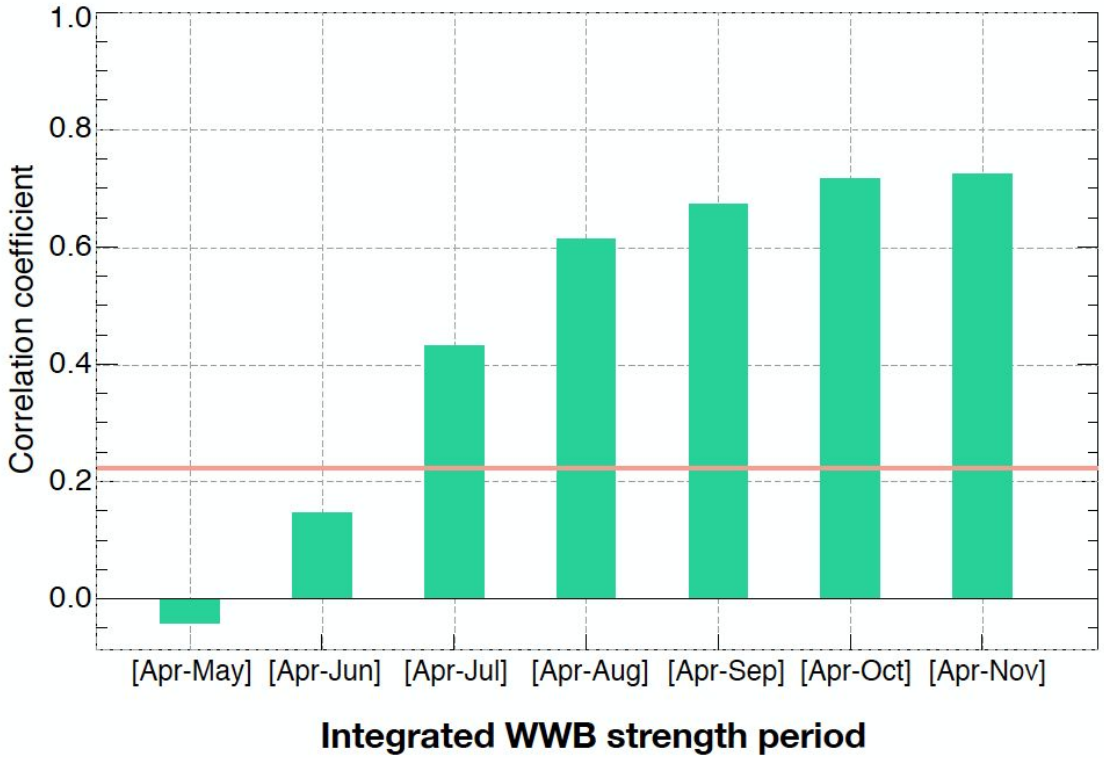
Puy *et al.* 2017

# unpredictable atmospheric variability led to:
# La Nada in 2014 and El Nino in 2015




despite similar ocean initial states

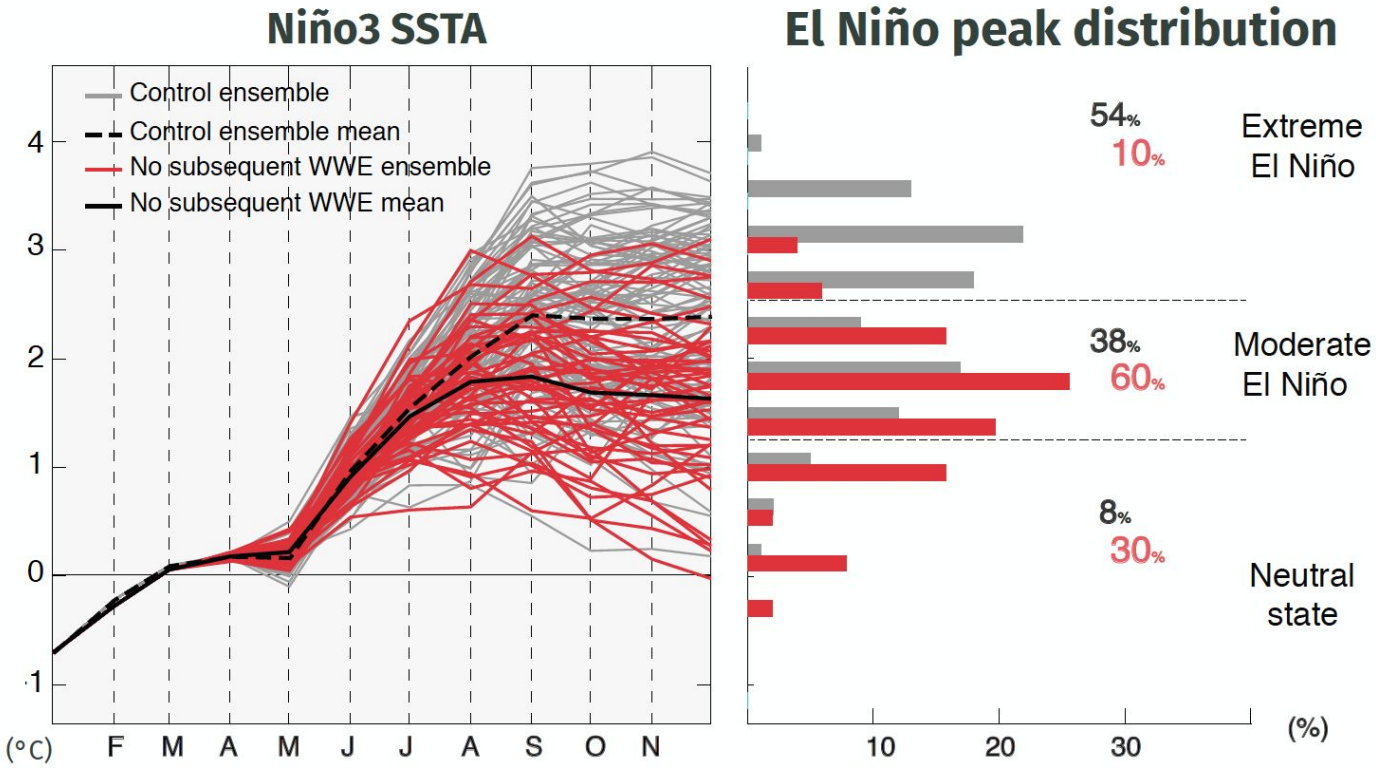
# Summer WWBs critical for El Niño predictability




**June-July-August is when WWBs have the largest impact on El Niño's peak amplitude**

Puy *et al.* 2017

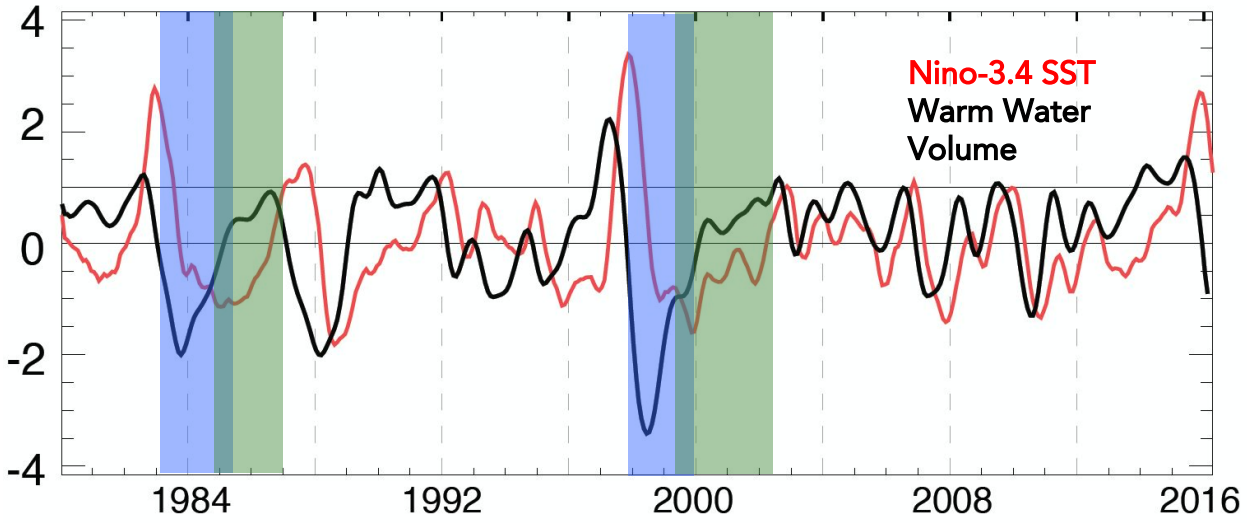
# Subsequent WWBs are key



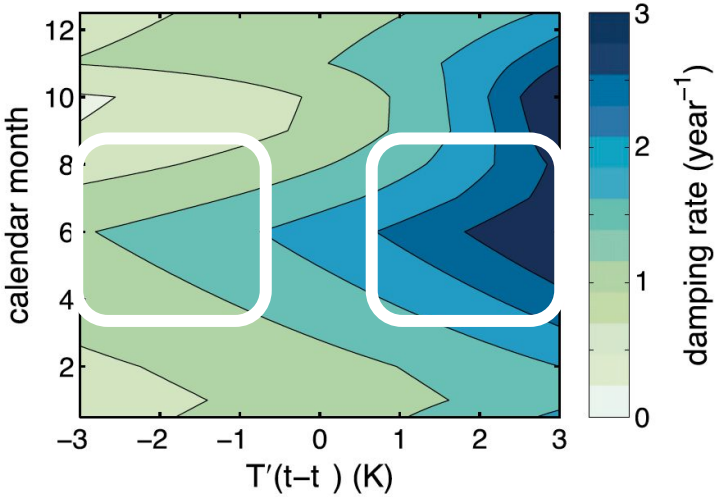

- Ensemble with all WWBs
- **Ensemble with initial WWB, but all subsequent events removed**

Puy *et al.* 2017

# Issue #2: Subsurface warming is ineffective at terminating La Niña

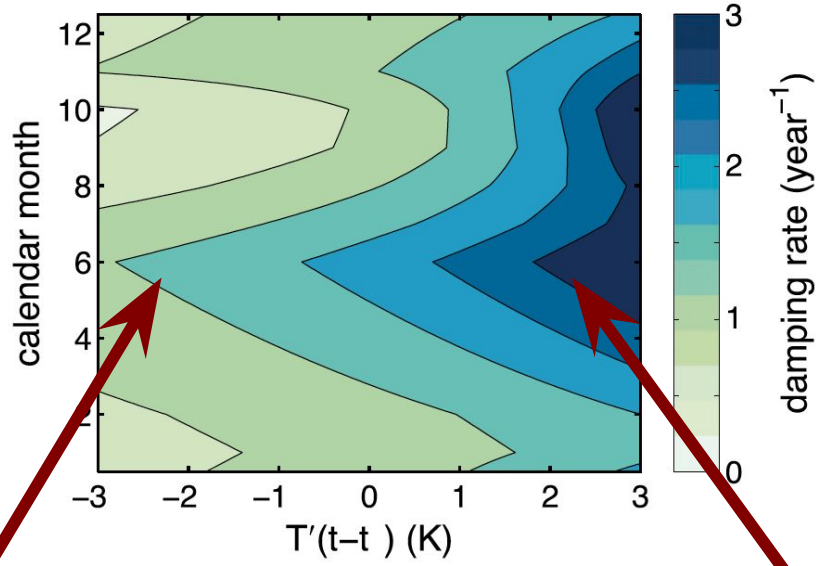


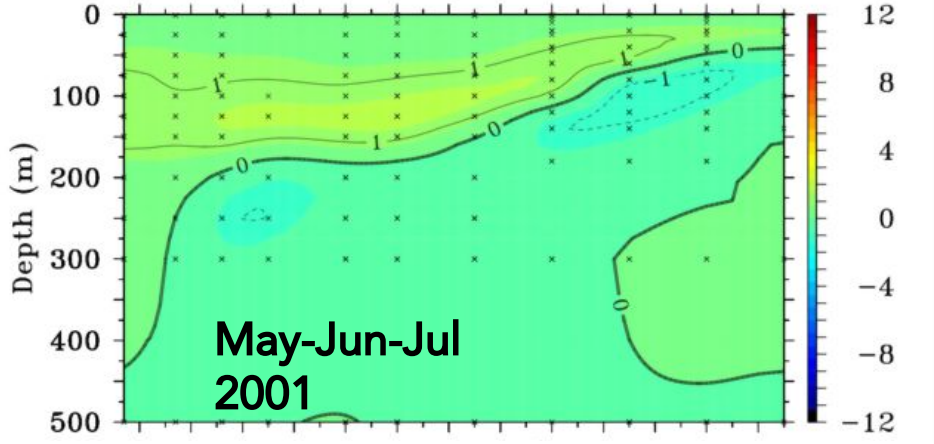

Weak (delayed) damping of La Niña

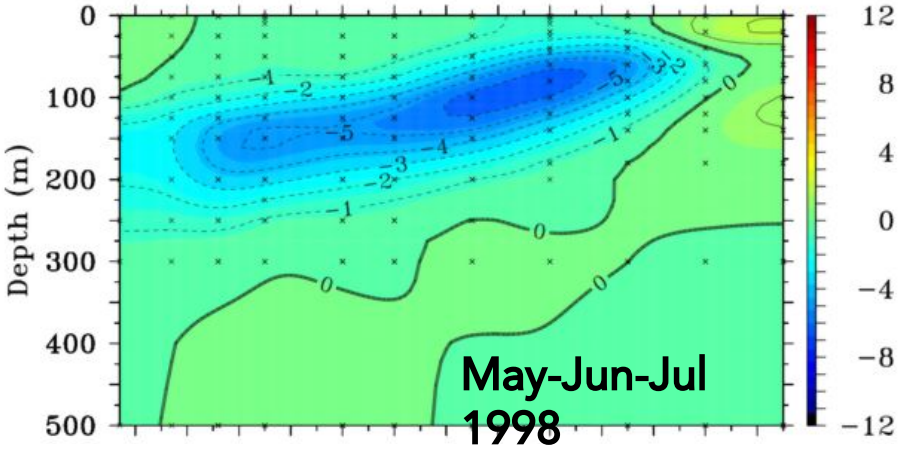



Strong (delayed) damping of El Niño

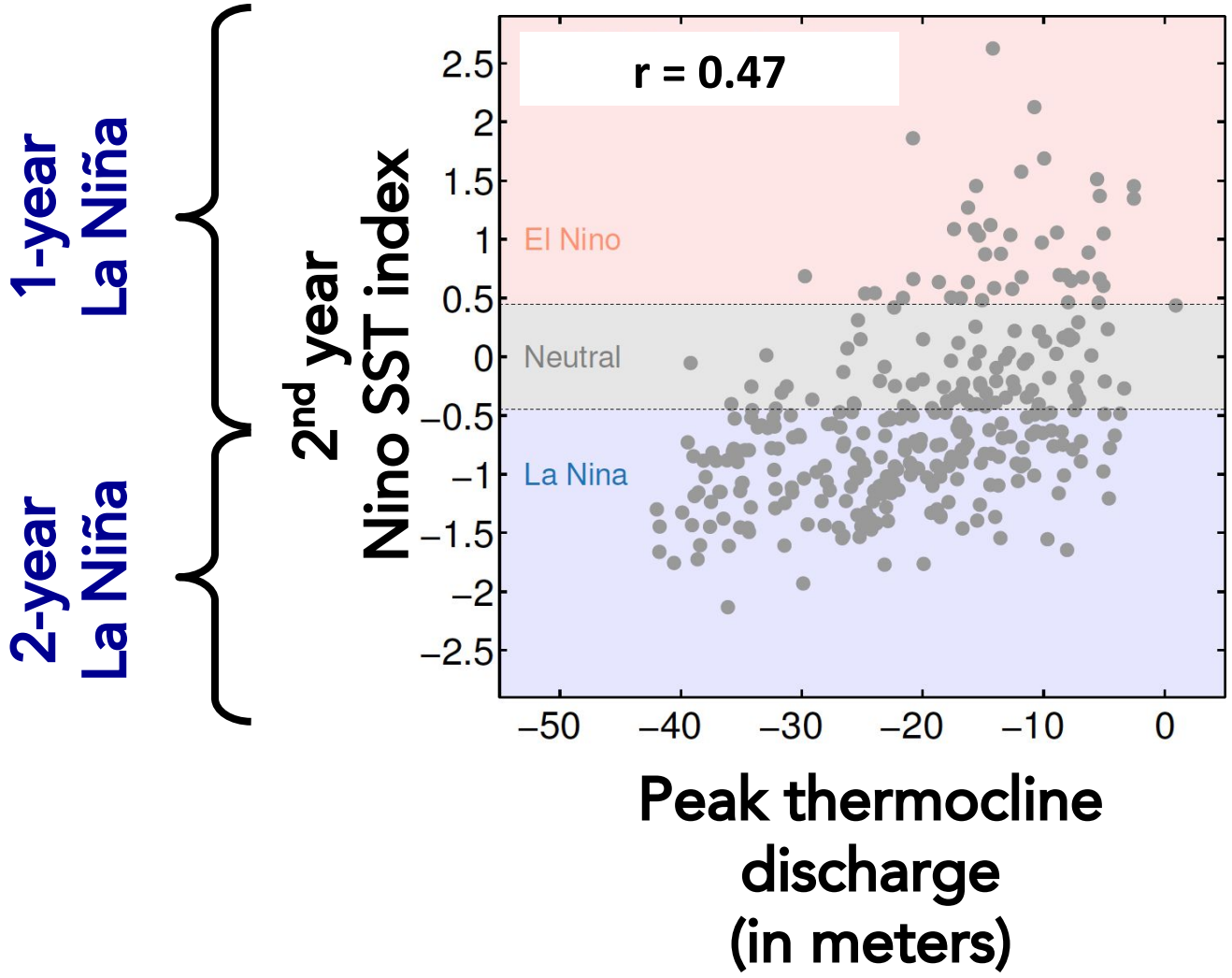
Di Nezio and Deser 2014


calendar month
T′(t–t ) (K)
damping rate (year$^{-1}$)


Depth (m)
May-Jun-Jul
2001

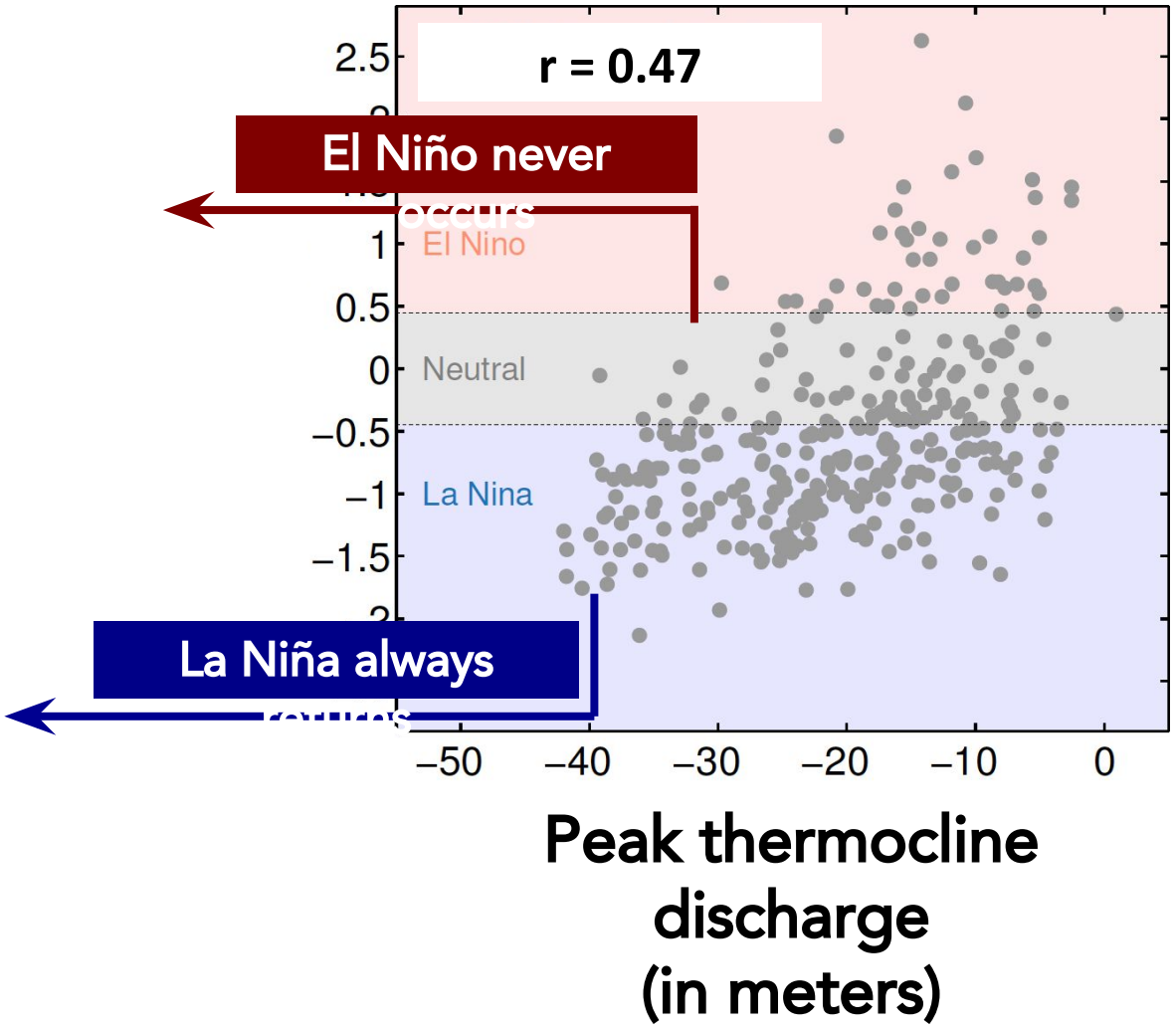

Depth (m)
May-Jun-Jul
1998

# Duration of La Niña correlated with magnitude of initial thermocline discharge




DiNezio *et al.*

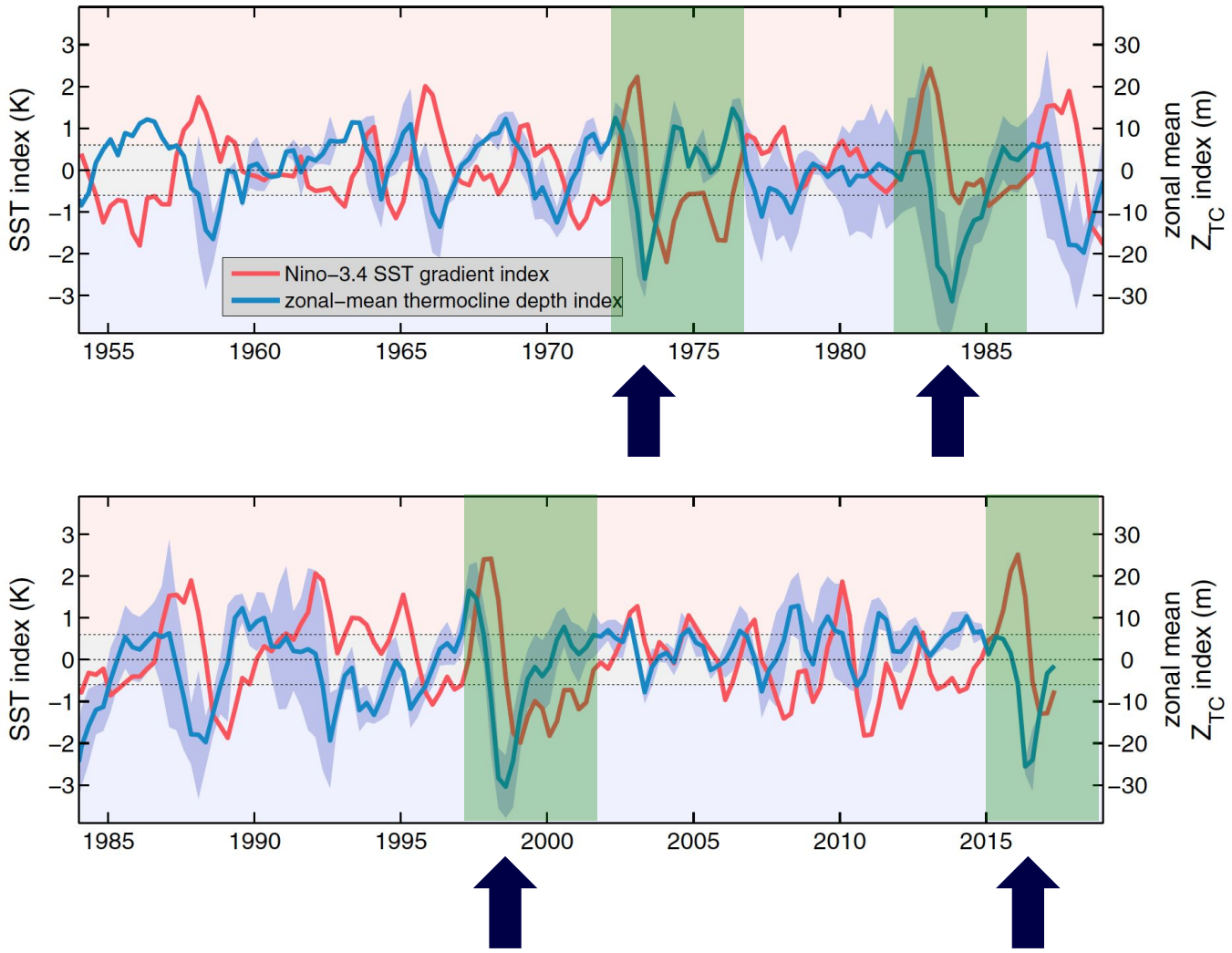
# Duration of La Niña correlated with magnitude of thermocline discharge




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

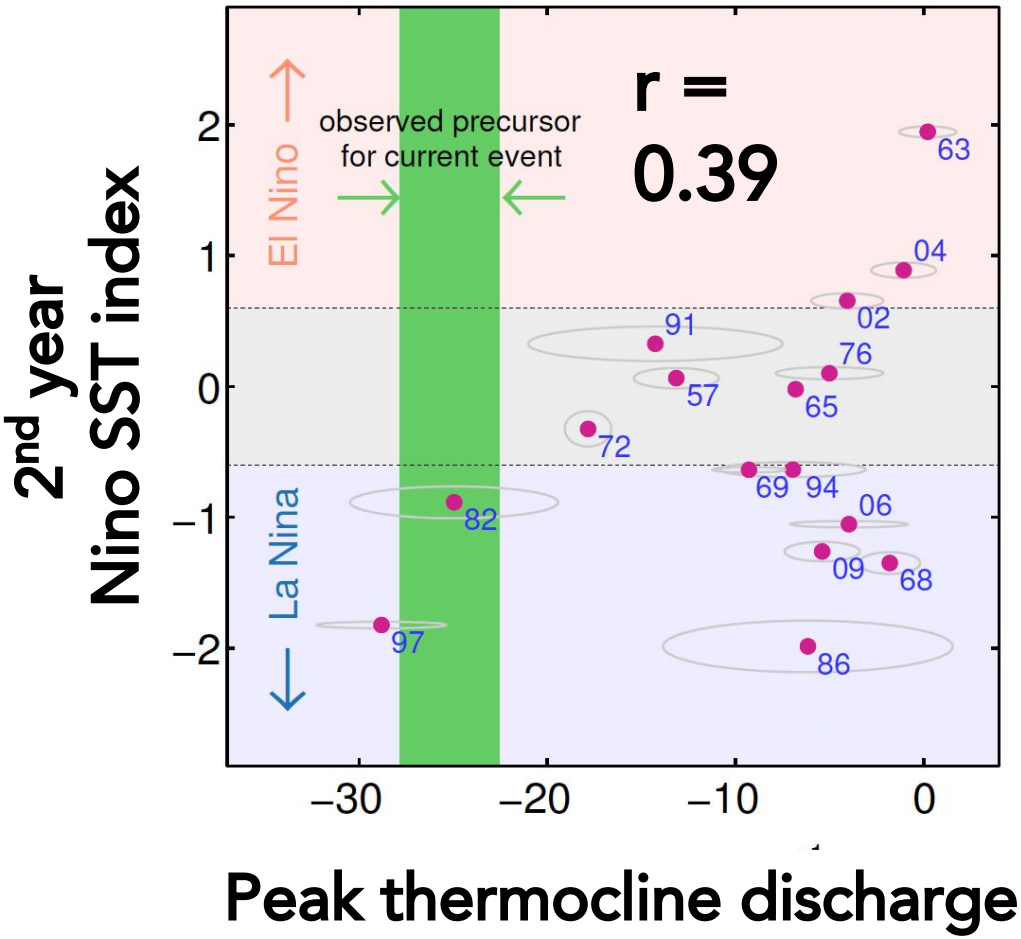
DiNezio *et al.*

# The strongest El Niño on record were followed by strong discharge and 2-year La Niña




DiNezio *et al.*

# Number of observed events is <u>insufficient</u> to develop a statistical model for prediction

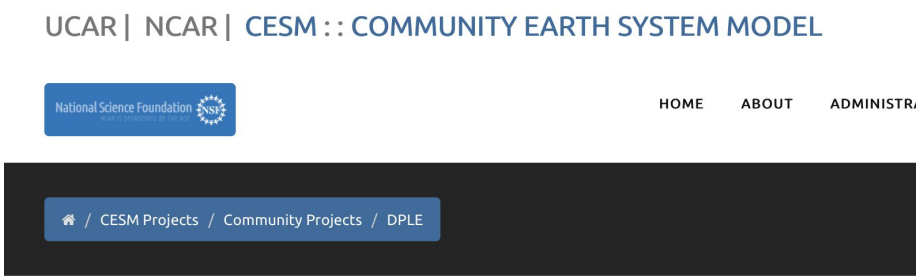



Dots indicate observed ENSO events

Ellipses indicate observational uncertainty

DiNezio *et al.*

# Initialized forecasts

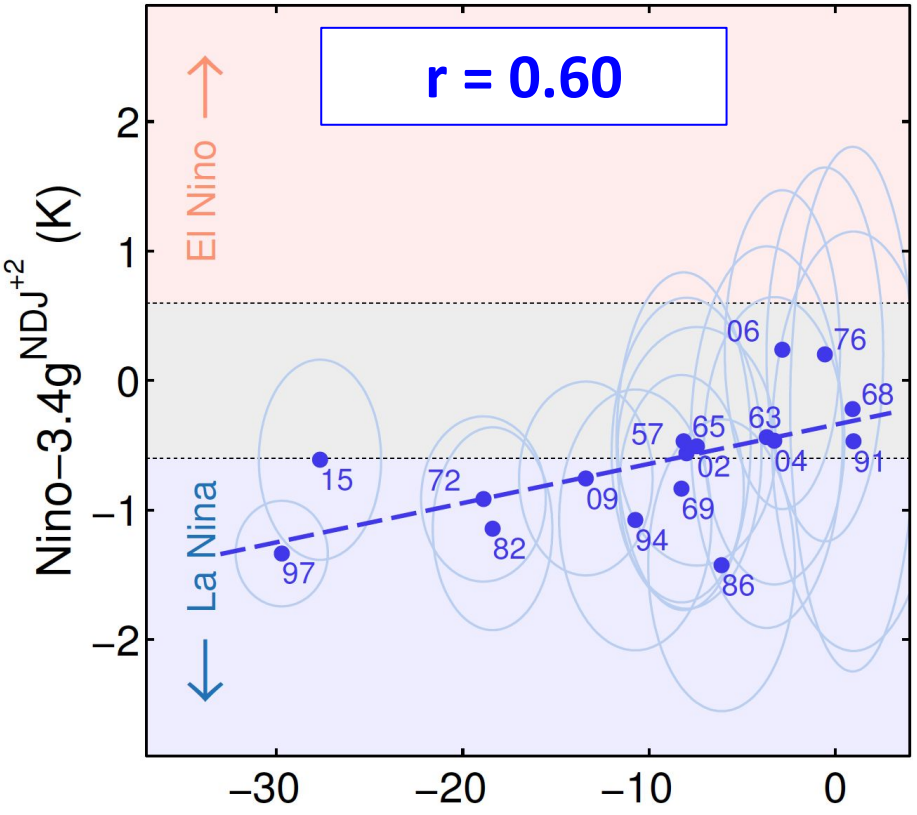



www.cesm.ucar.edu/projects/community-projects/DPLE/

Yeager et al., 2018: Predicting near-term changes in the Earth System: A large ensemble of initialized decadal prediction simulations using the Community Earth System Mode, Bull Amer Meteor Soc, in

- 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

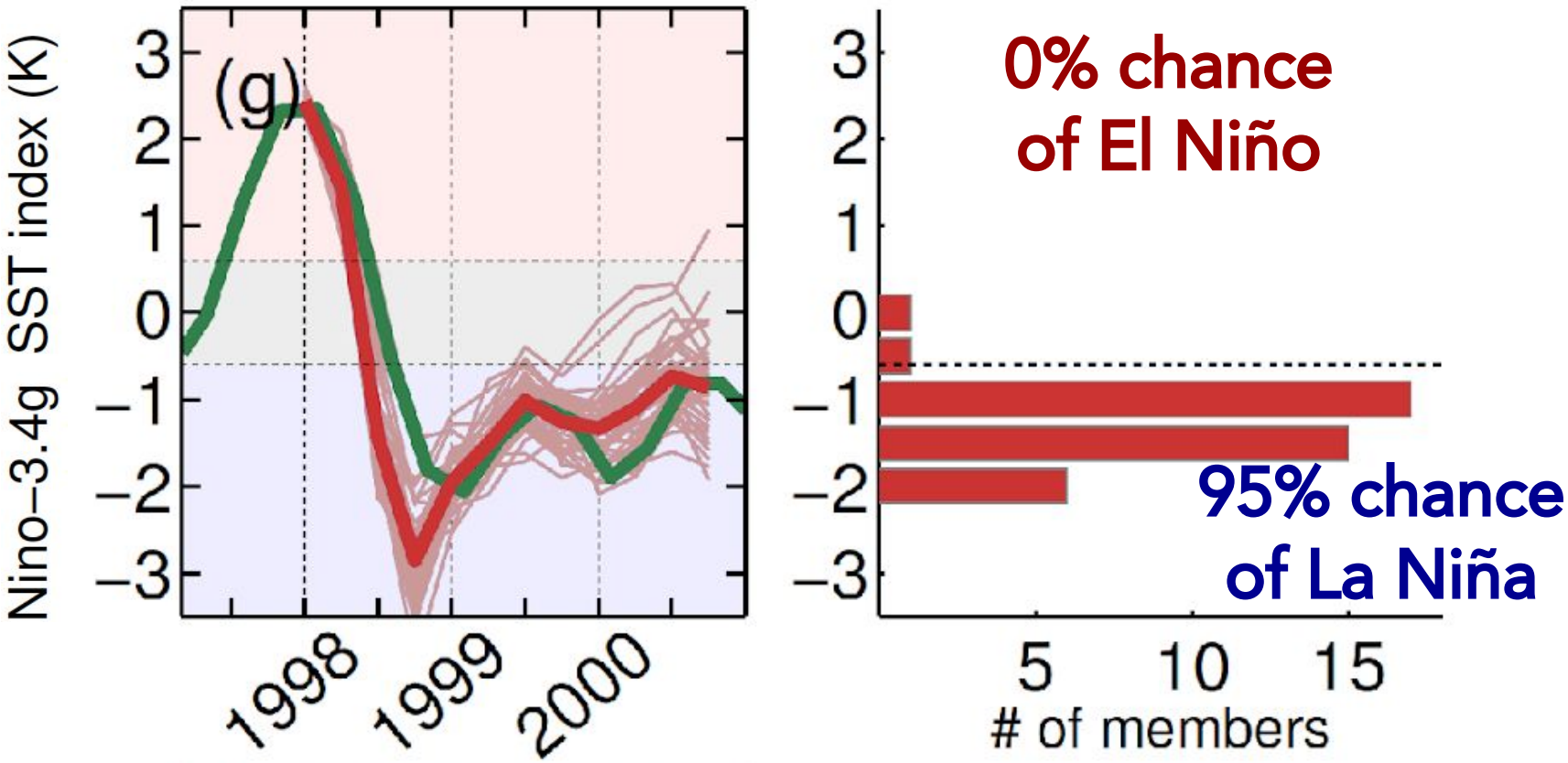



Peak thermocline discharge

Ellipses show ensemble spread

DiNezio *et al.* 2017b

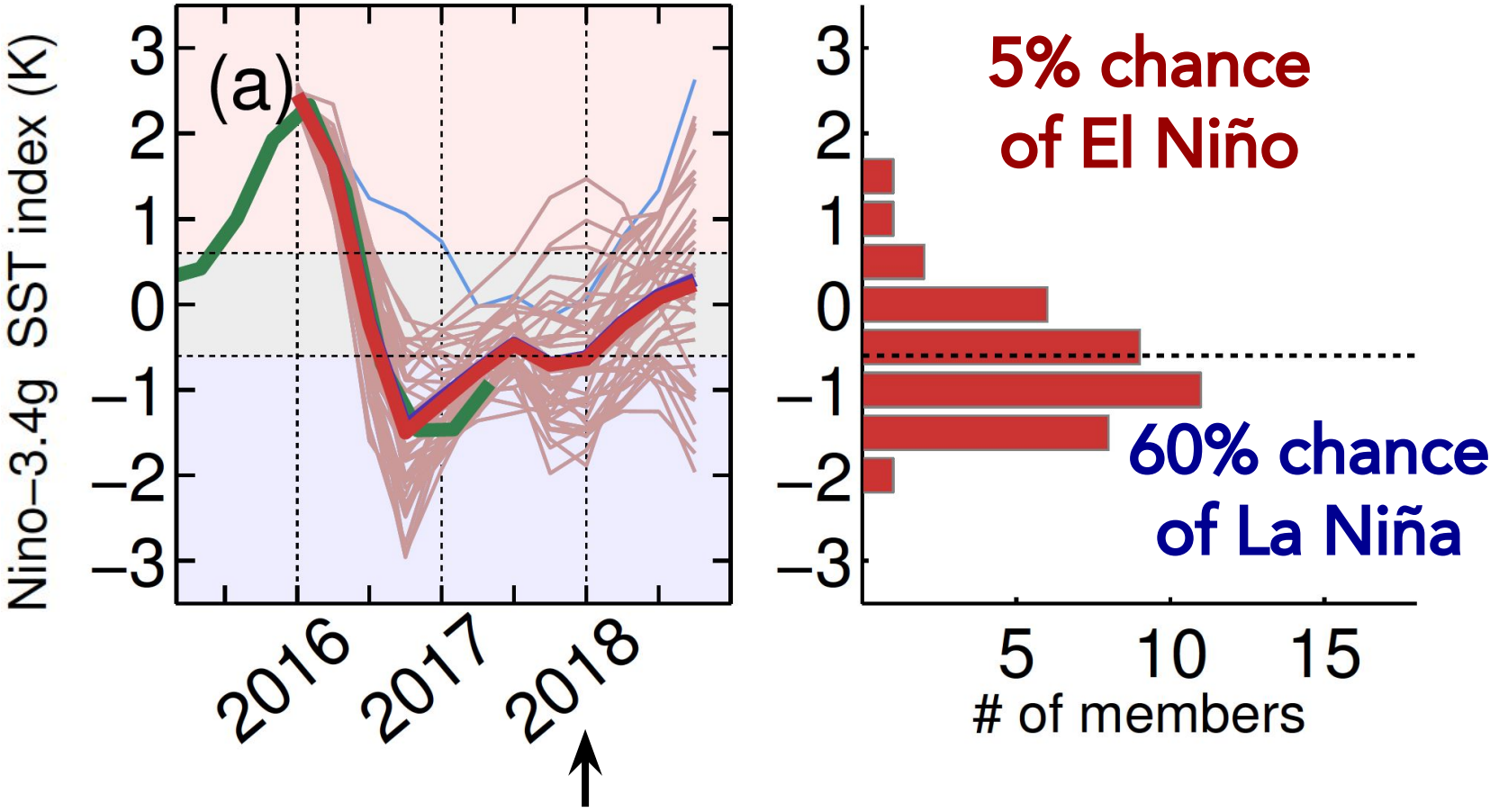
# CESM-DP-LE predicted the 2-year La Niña that followed the El Niño of 1997




Target season:
NDJ

DiNezio *et al.*

# Predictions initialized in November 2015 showed La Niña persisting into this winter




DiNezio *et al.*

# 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

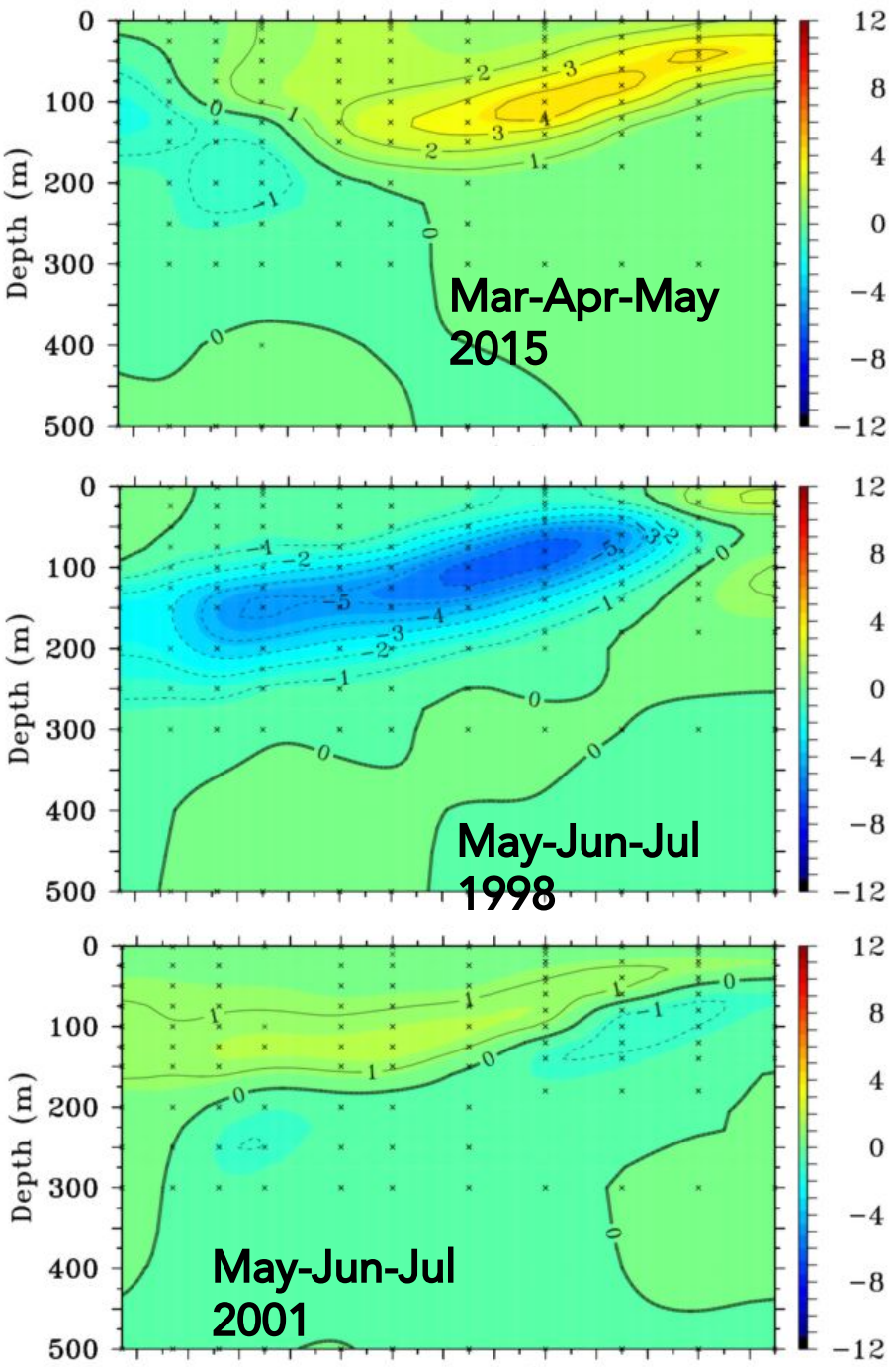
weak SST-thermocline coupling?

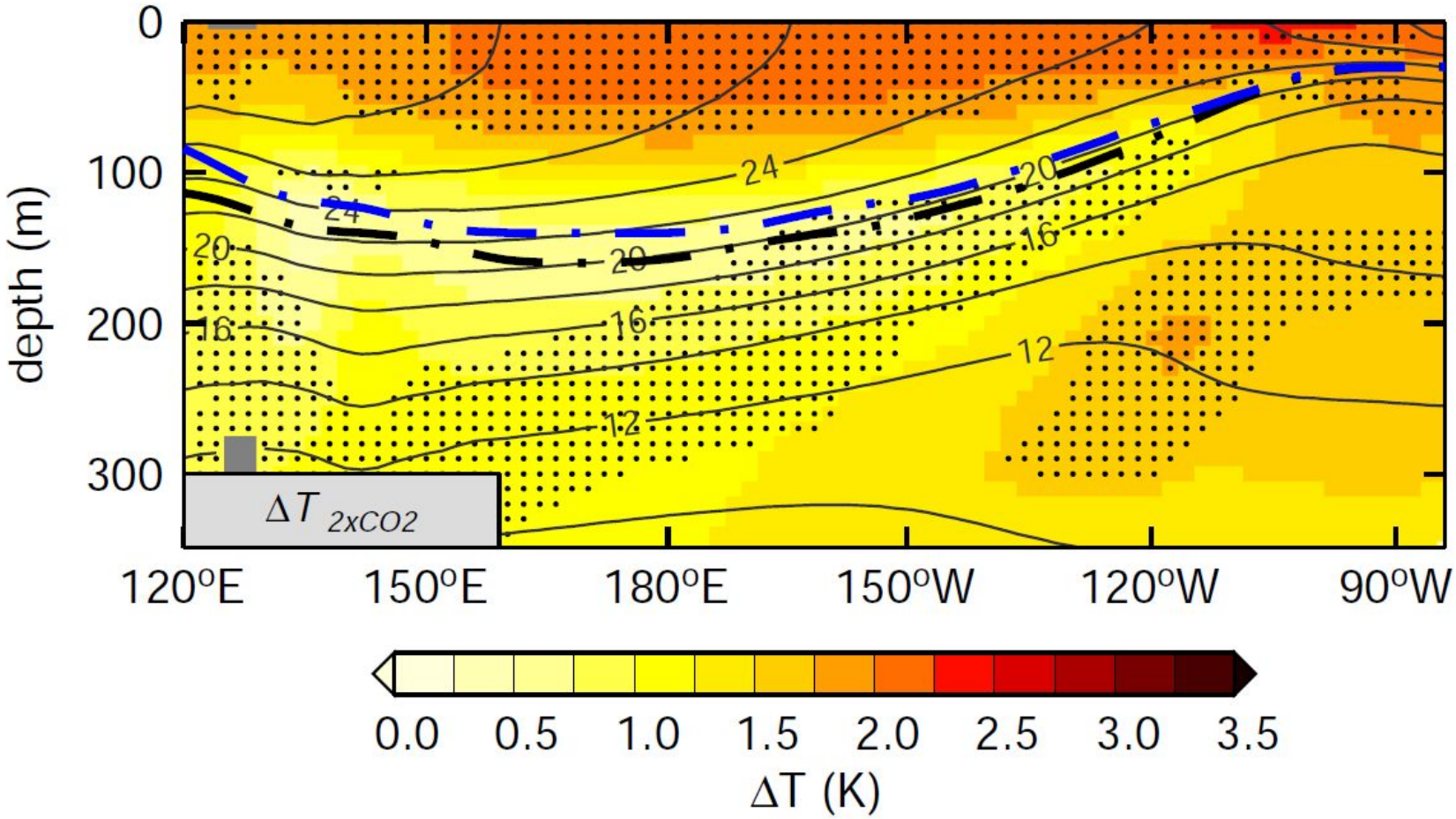
## onset of La Niña

strong SST-thermocline coupling

## termination of La Niña

weak SST-thermocline coupling






DiNezio et al.

# Thank you!

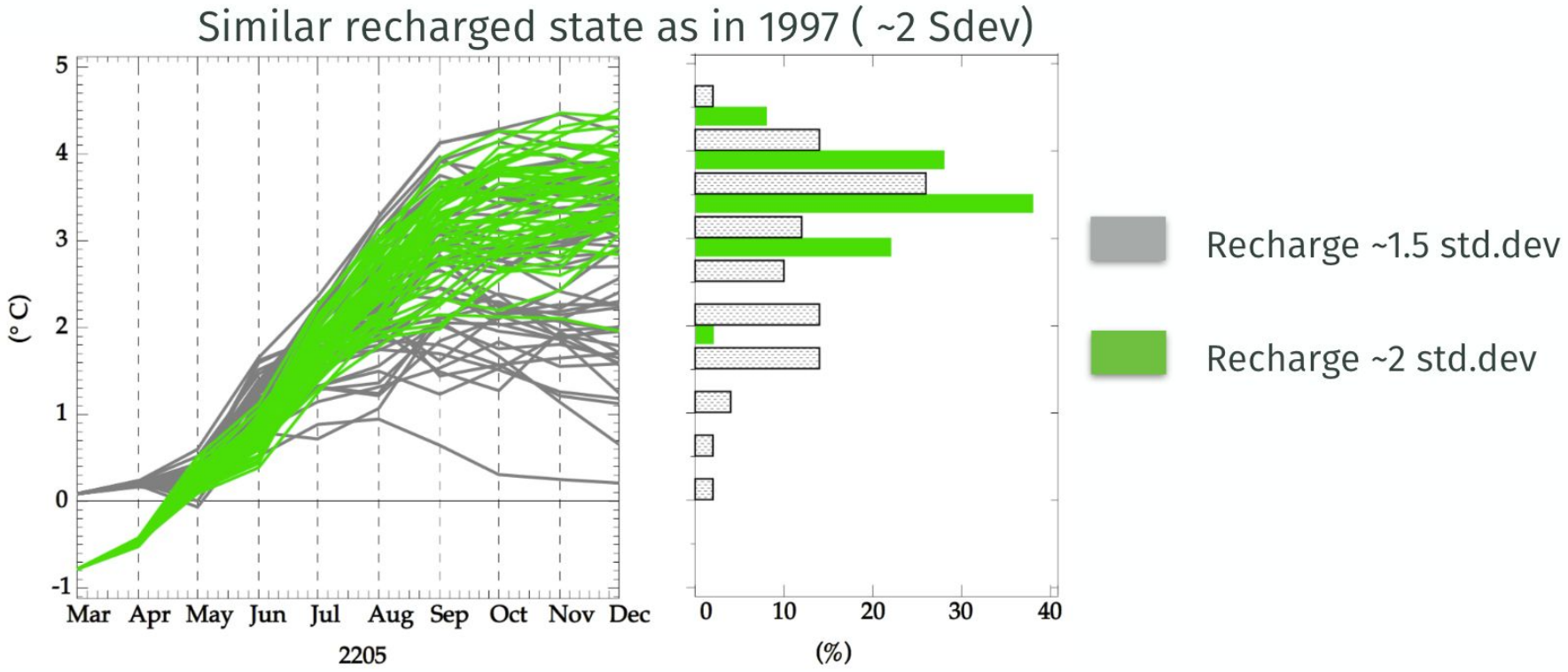
# Pedro – ENSO dynamics & predictability

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:

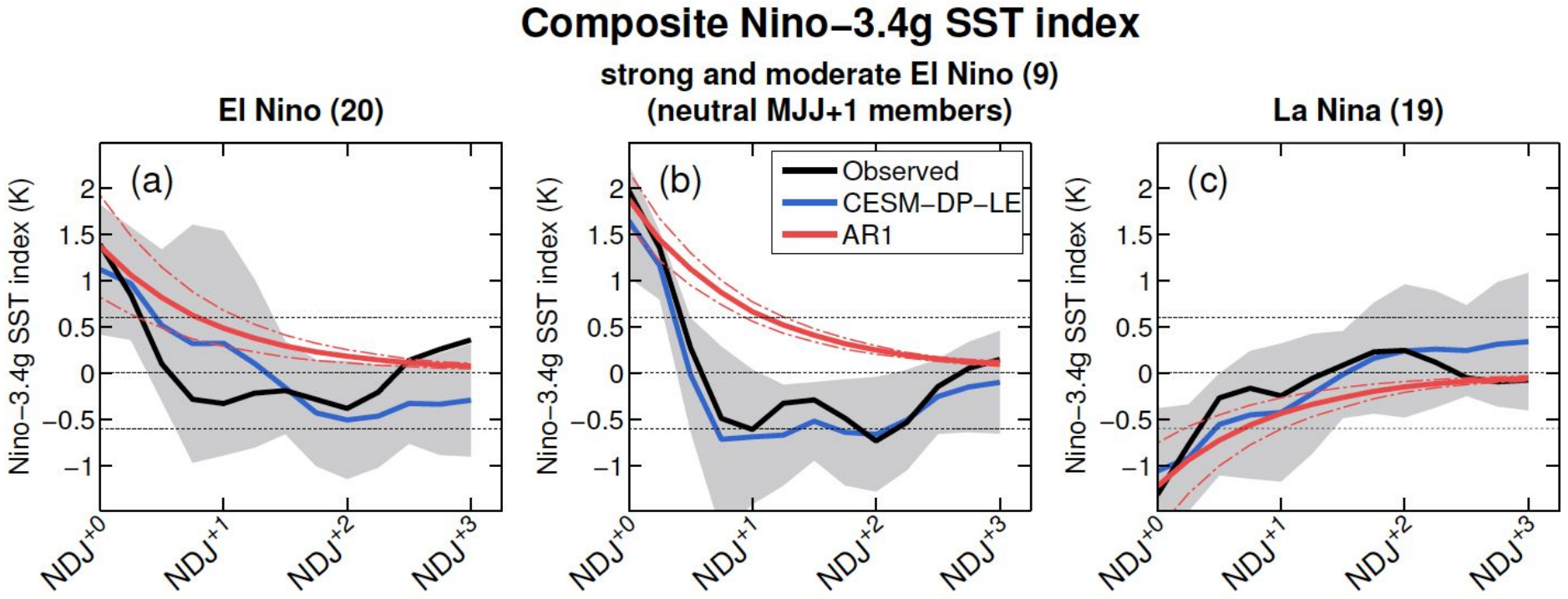
1. Is the current observing system adequate to observe the coupling between the thermocline and the mixed-layer in the central equatorial Pacific on ENSO timescales?
2. How can it be improved to better observe these processes?
3. Do models simulate this coupling realistically?
4. Would model improvements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

- Sensitivity of WWB-ENSO to subsurface initial conditions



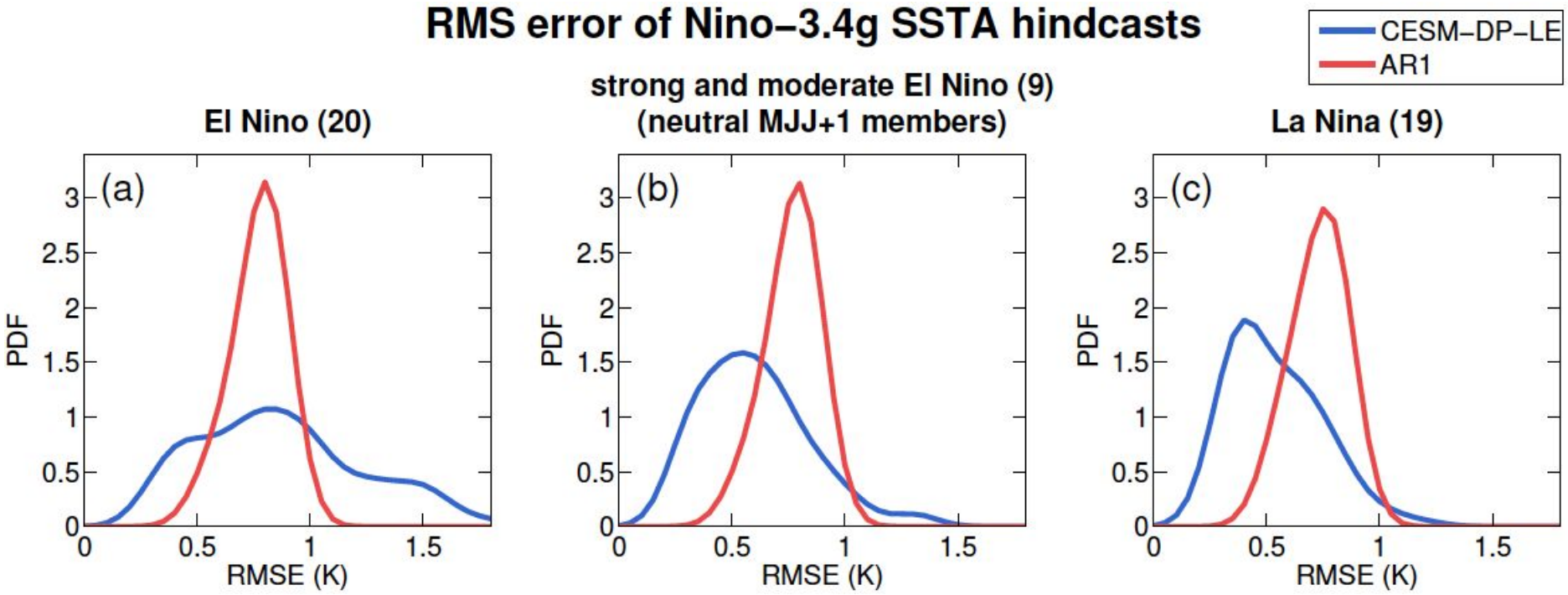

**The modulation of WWEs by El Niño depends on the initial conditions**

# Retrospective predictions show low bias

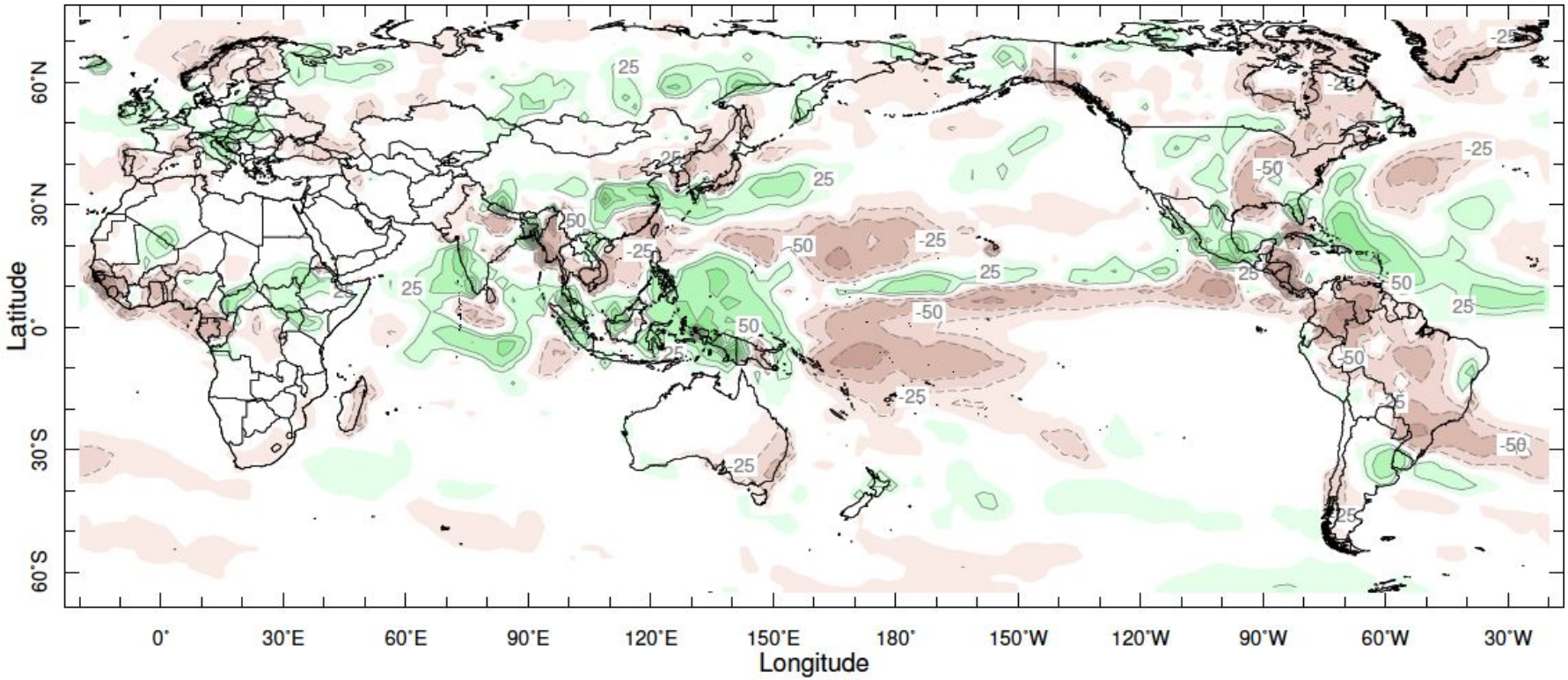



DiNezio *et al.*

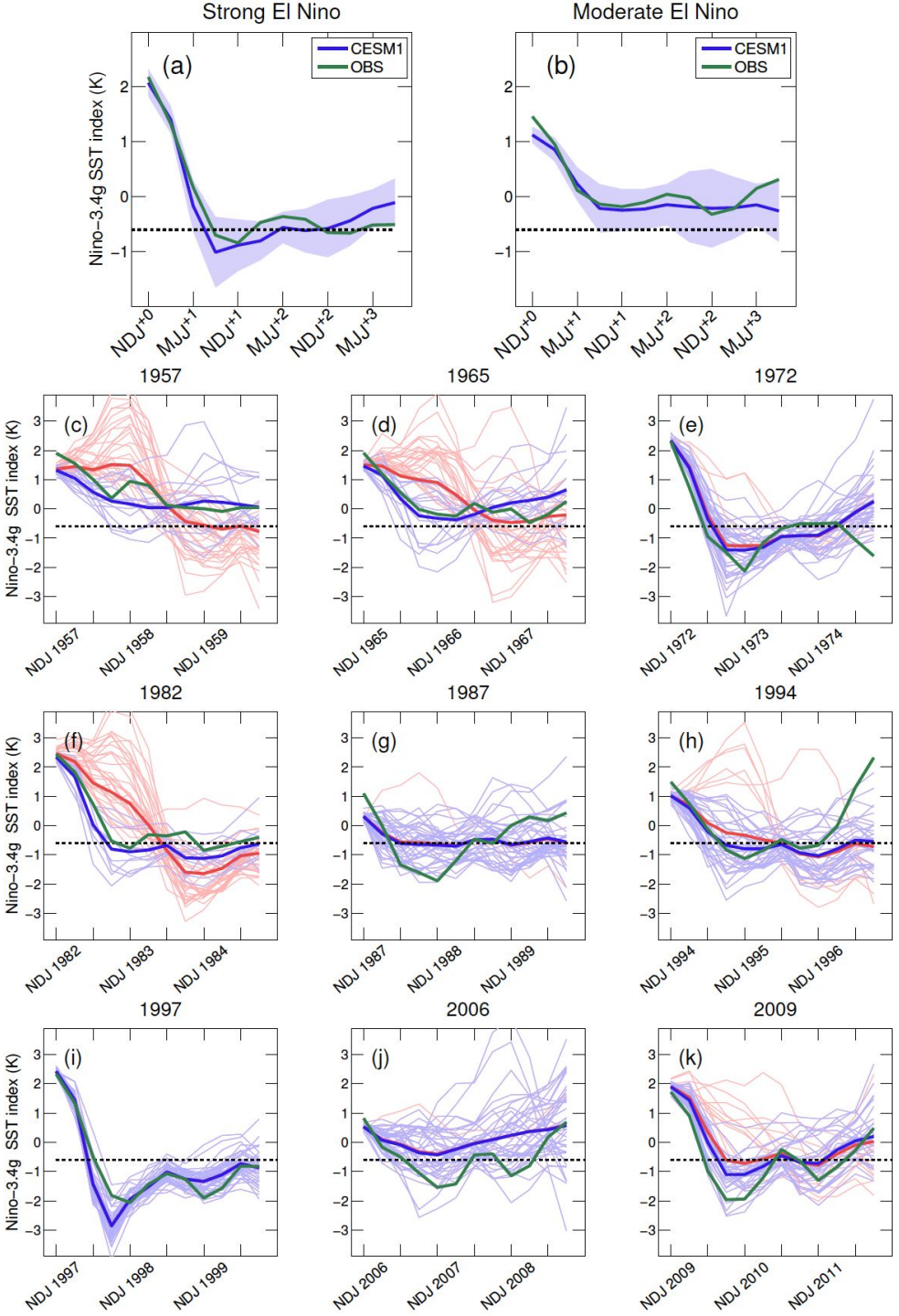
# Retrospective predictions show lower RMS error than forced persistence forecasts




DiNezio *et al.*


Latitude
60°N
30°N
0°
30°S
60°S
0°
30°E
60°E
90°E
120°E
150°E
180°
150°W
120°W
90°W
60°W
30°W
Longitude
25
-25
50
-50

Sep 2017


Strong El Nino
Moderate El Nino
(a)
(b)
CESM1
OBS
Nino−3.4g SST index (K)
NDJ+0
MJJ+1
NDJ+1
MJJ+2
NDJ+2
MJJ+3
1957
1965
1972
(c)
(d)
(e)
NDJ 1957
NDJ 1958
NDJ 1959
NDJ 1965
NDJ 1966
NDJ 1967
NDJ 1972
NDJ 1973
NDJ 1974
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1987
1994
(f)
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1997
2006
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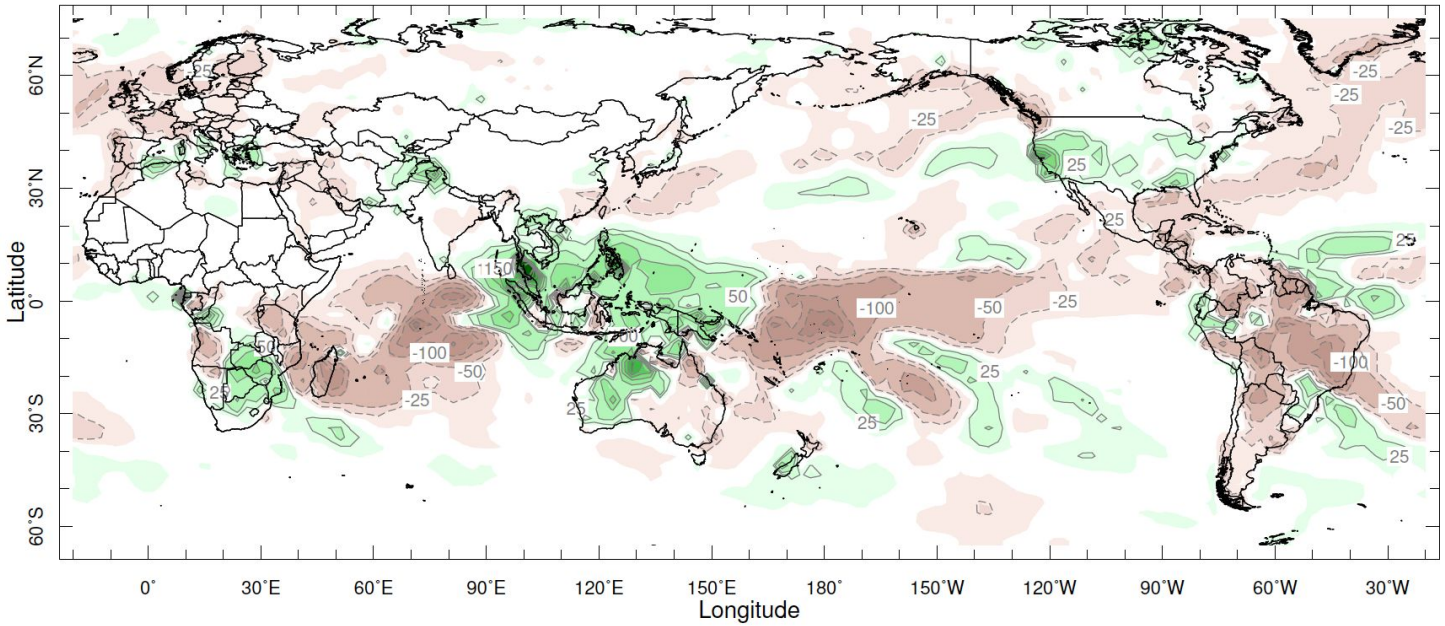
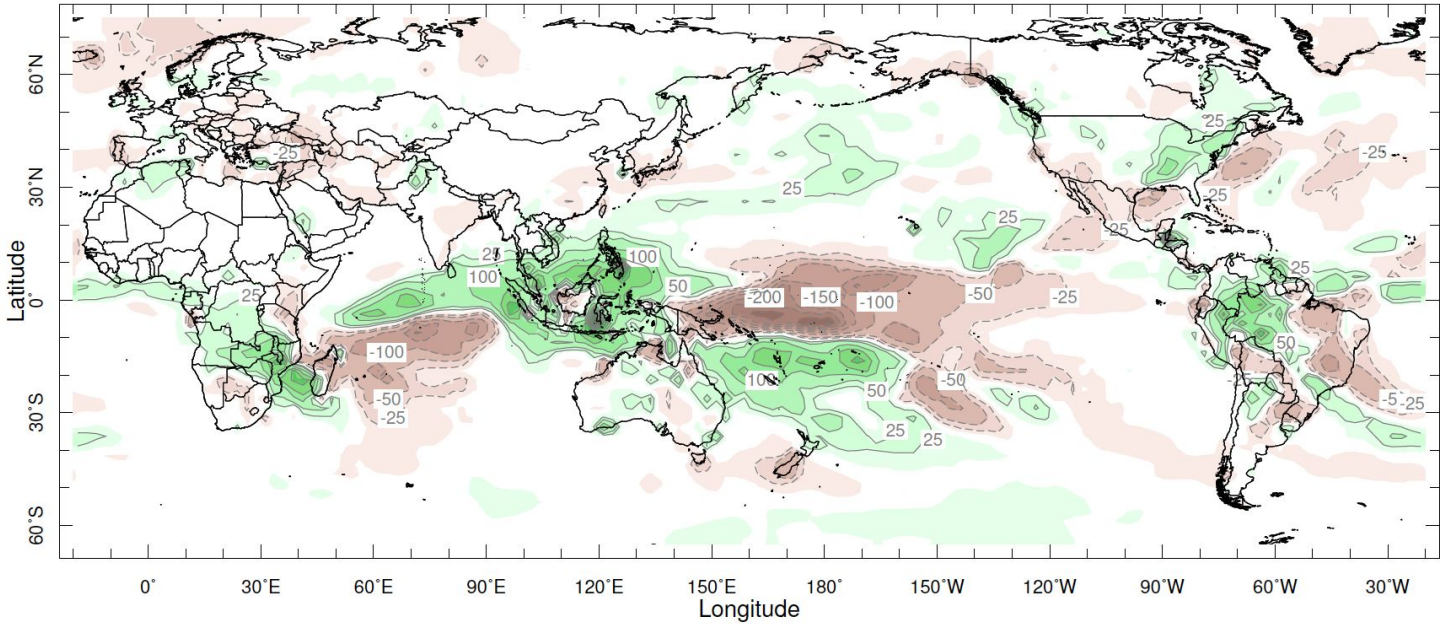
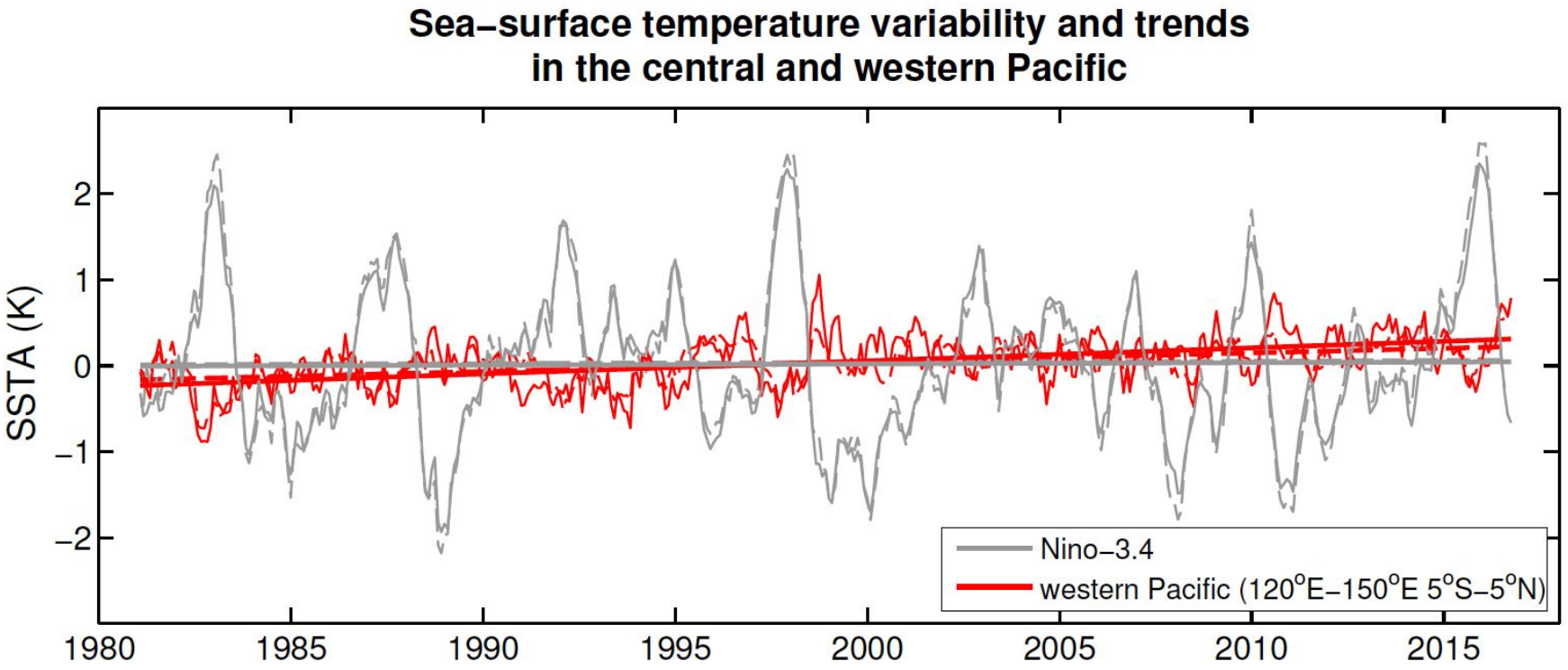
NDJ 2008
NDJ 2009
NDJ 2010
NDJ 2011



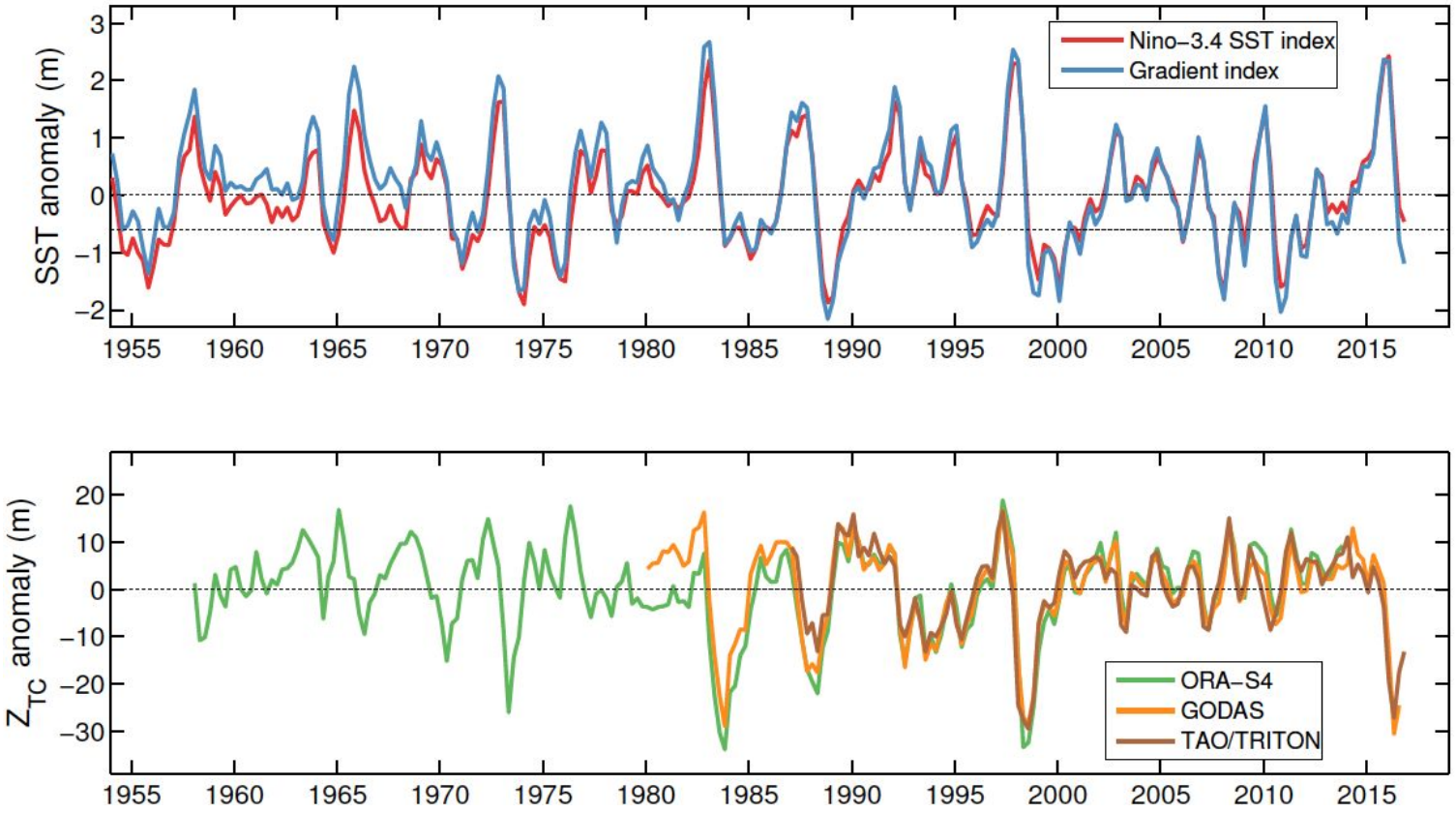

Jan 2017




Jan 1999


Sea–surface temperature variability and trends
in the central and western Pacific
SSTA (K)
2
1
0
−1
−2
1980
1985
1990
1995
2000
2005
2010
2015
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

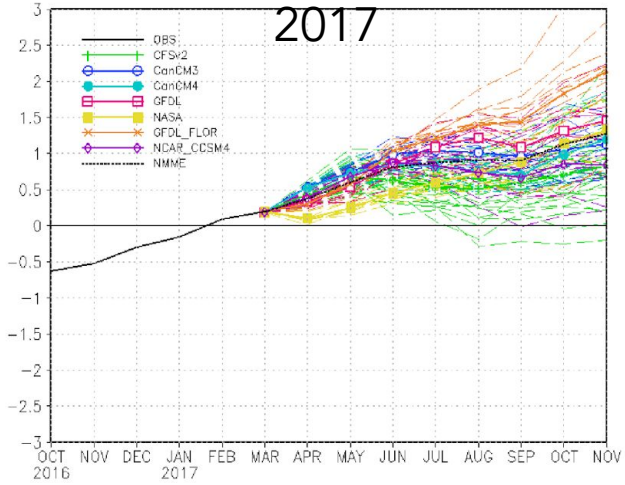



Magnitude of this year's discharge is not much different than during the previous two strongest El Nino events

DiNezio *et al.* in prep.

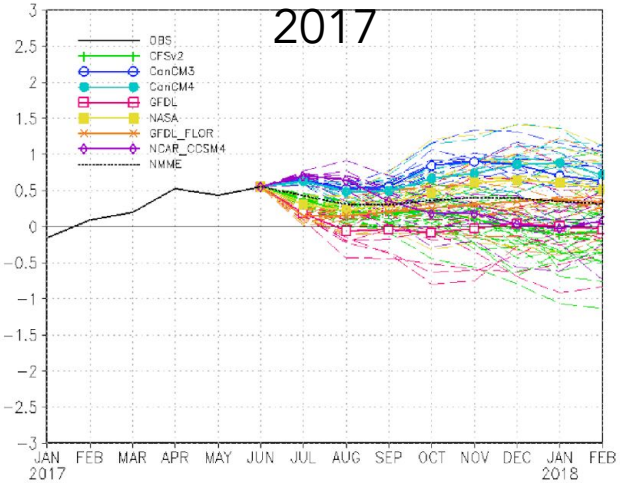
# What happened to operational forecasts this year?

NMME forecasts initialized in April 2017



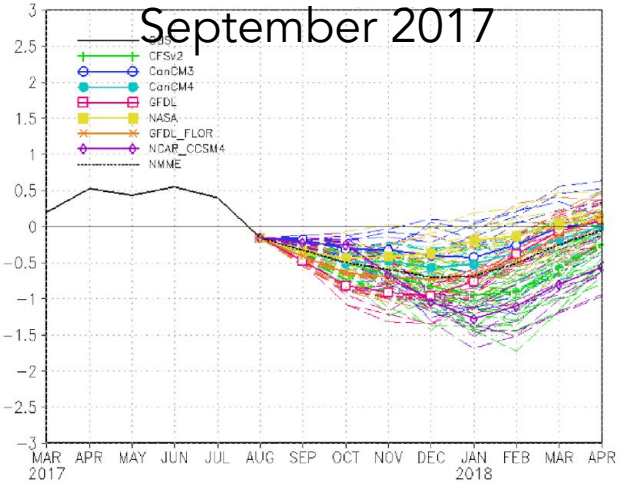

Target season: NDJ 2017/18

NMME forecasts initialized in July 2017




Target season: NDJ 2017/18

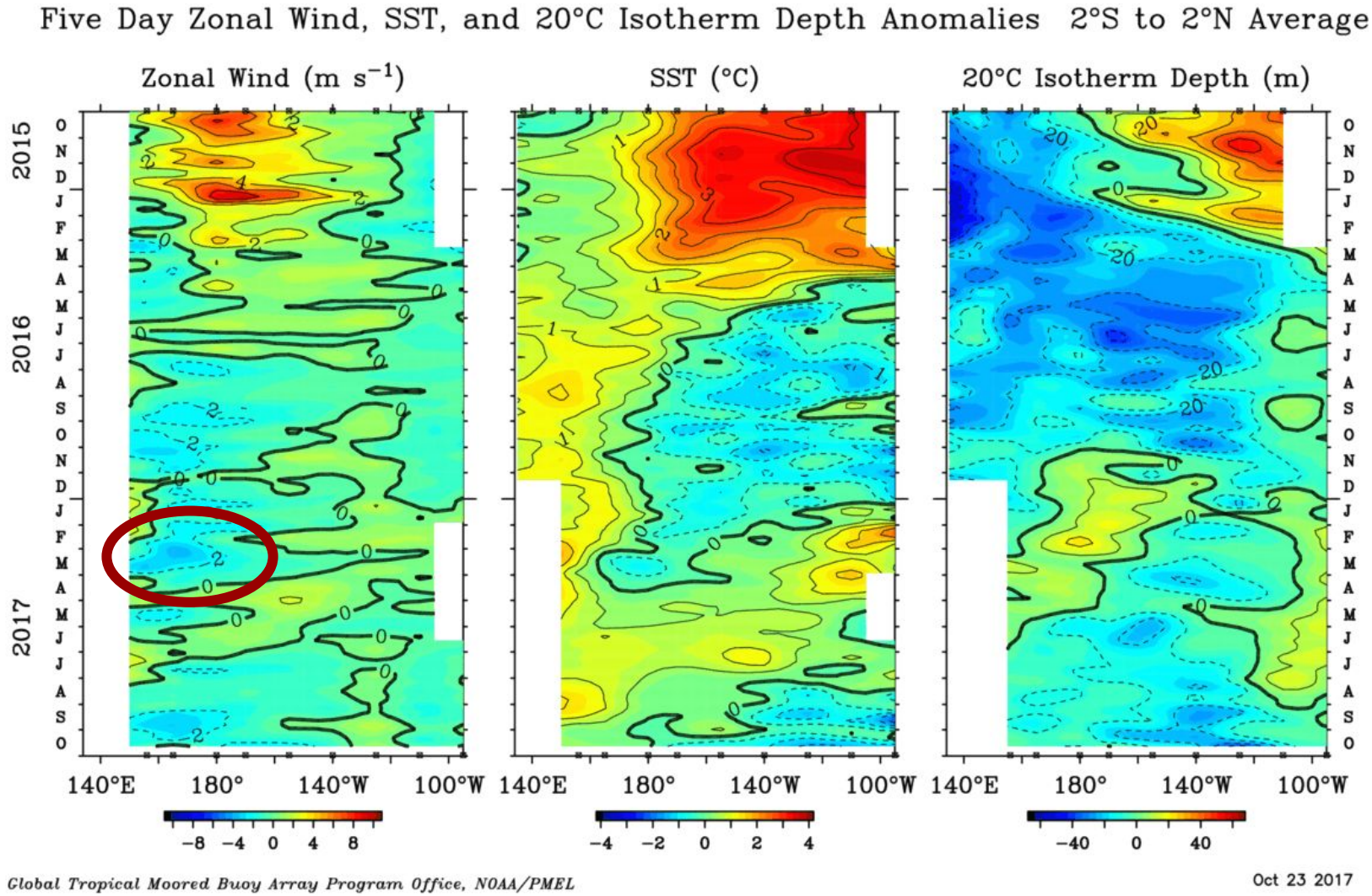
NMME forecasts initialized in September 2017



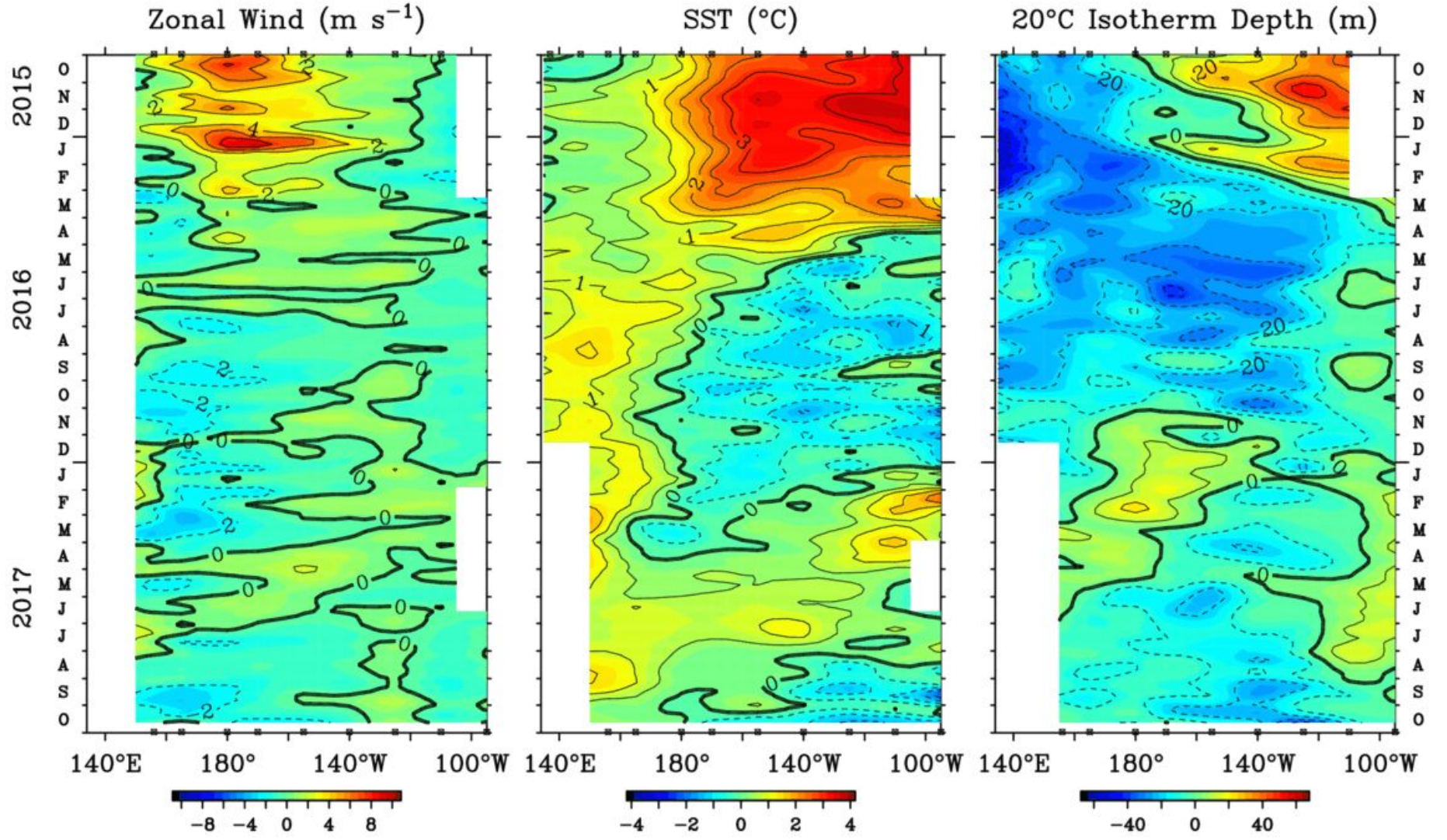

Target season: NDJ 2017/18

**Is this the sign of systematic biases?**

# What's the role of stochastic forcing in the evolution of this year's event?

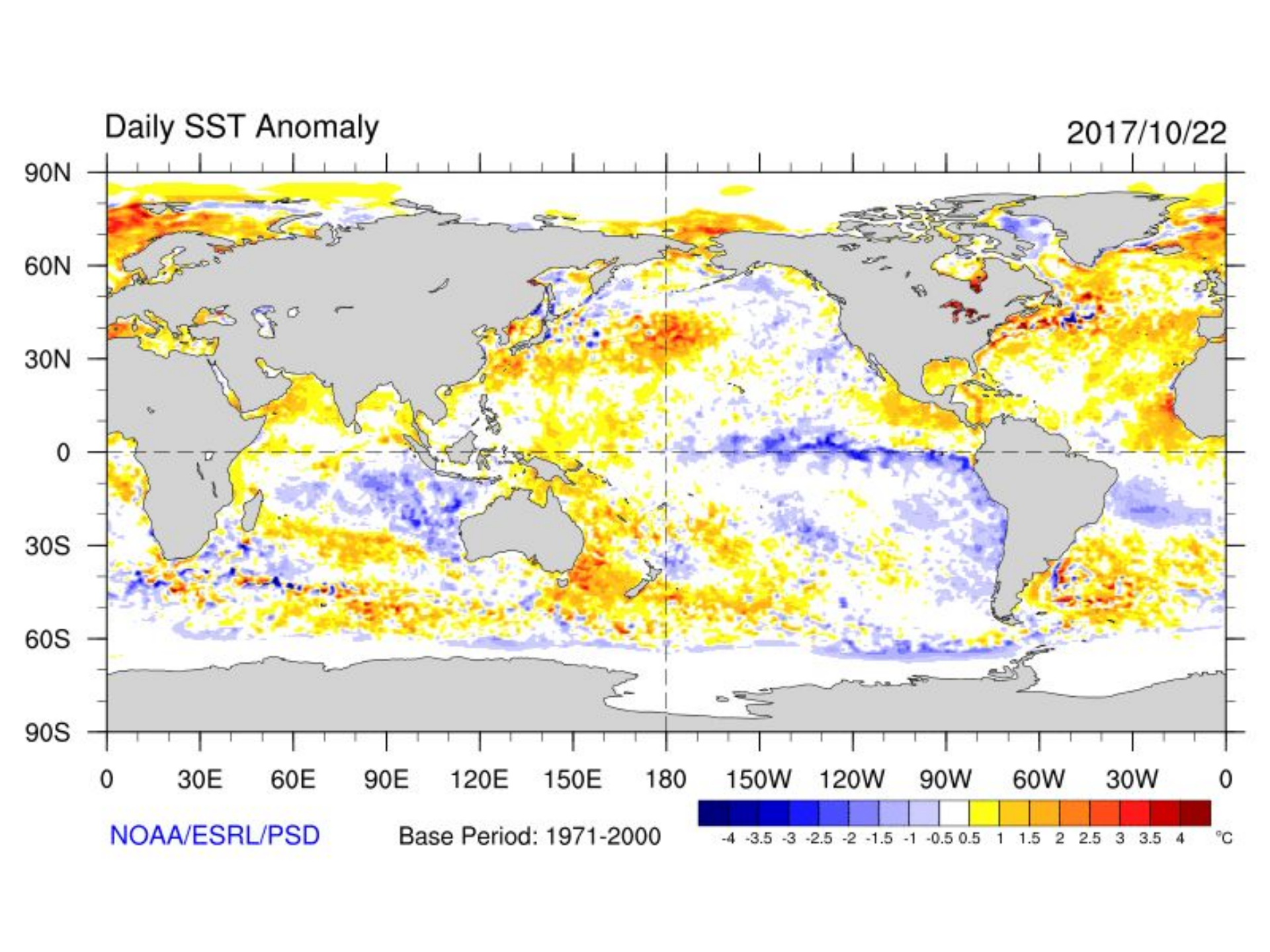


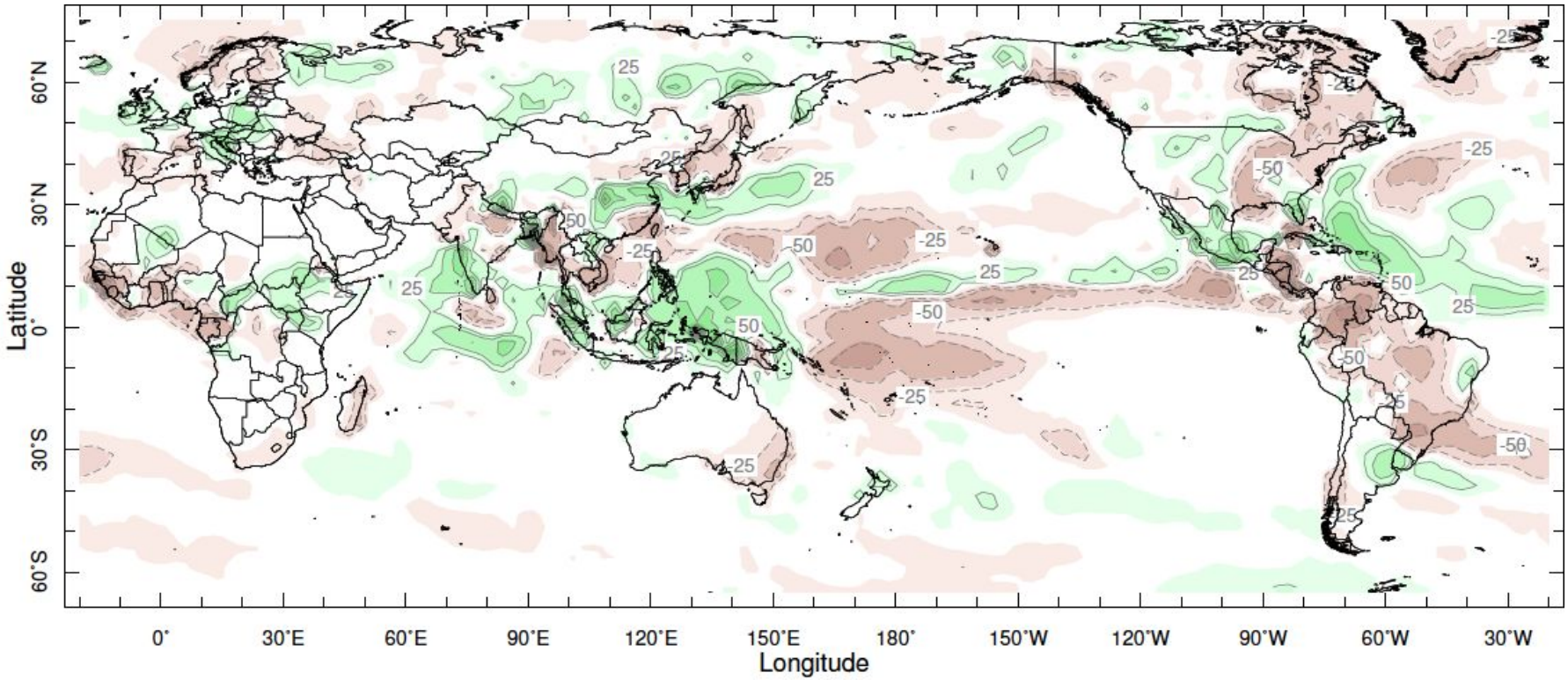
# Five Day Zonal Wind, SST, and 20°C Isotherm Depth Anomalies 2°S to 2°N Average



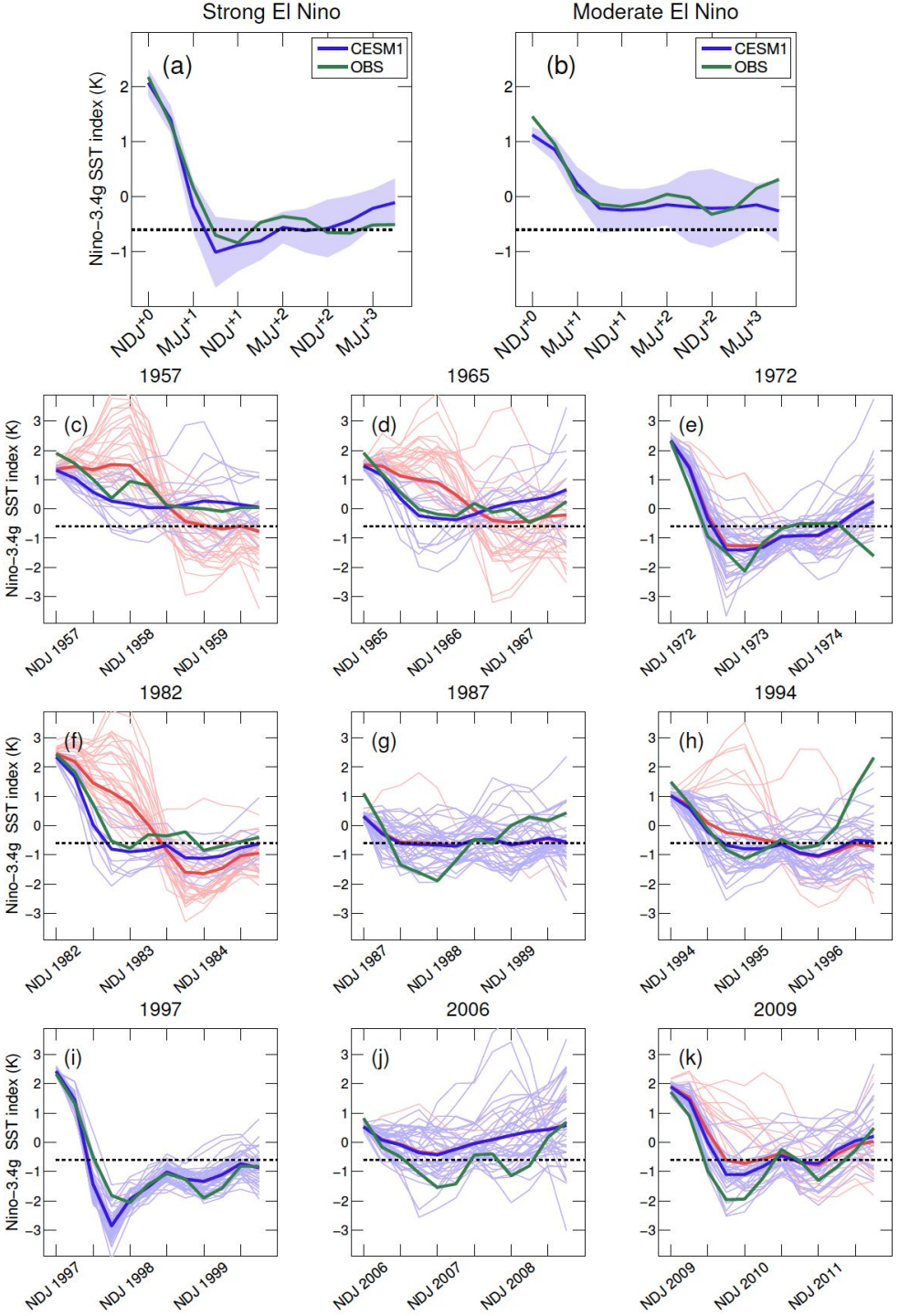

*Global Tropical Moored Buoy Array Program Office, NOAA/PMEL*

Oct 23 2017

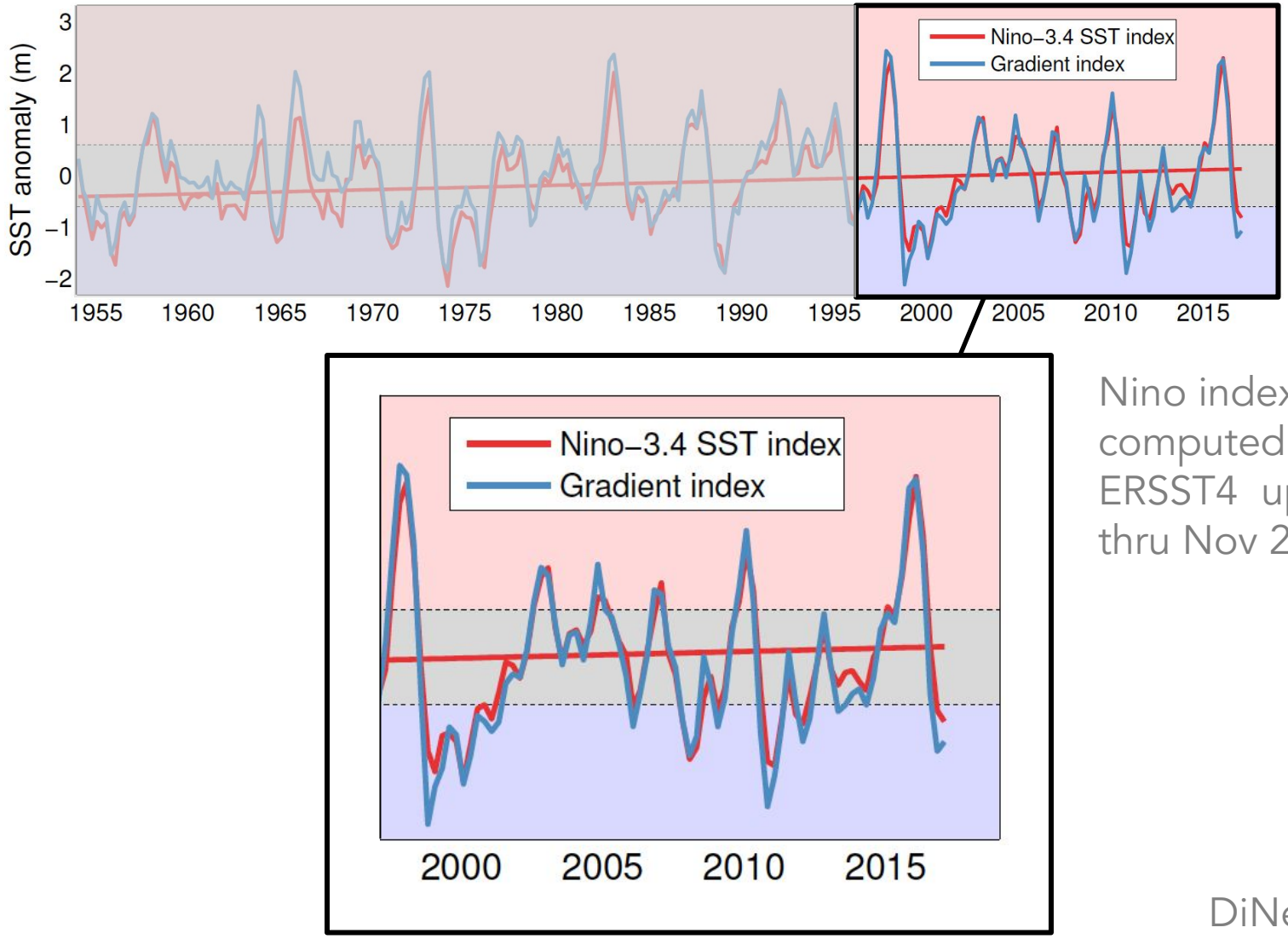

Daily SST Anomaly
2017/10/22
90N
60N
30N
0
30S
60S
90S
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
0
NOAA/ESRL/PSD
Base Period: 1971-2000
-4 -3.5 -3 -2.5 -2 -1.5 -1 -0.5 0.5 1 1.5 2 2.5 3 3.5 4
°C


Latitude
60°N
30°N
0°
30°S
60°S
0°
30°E
60°E
90°E
120°E
150°E
180°
150°W
120°W
90°W
60°W
30°W
Longitude
25
-25
50
-50

Sep 2017

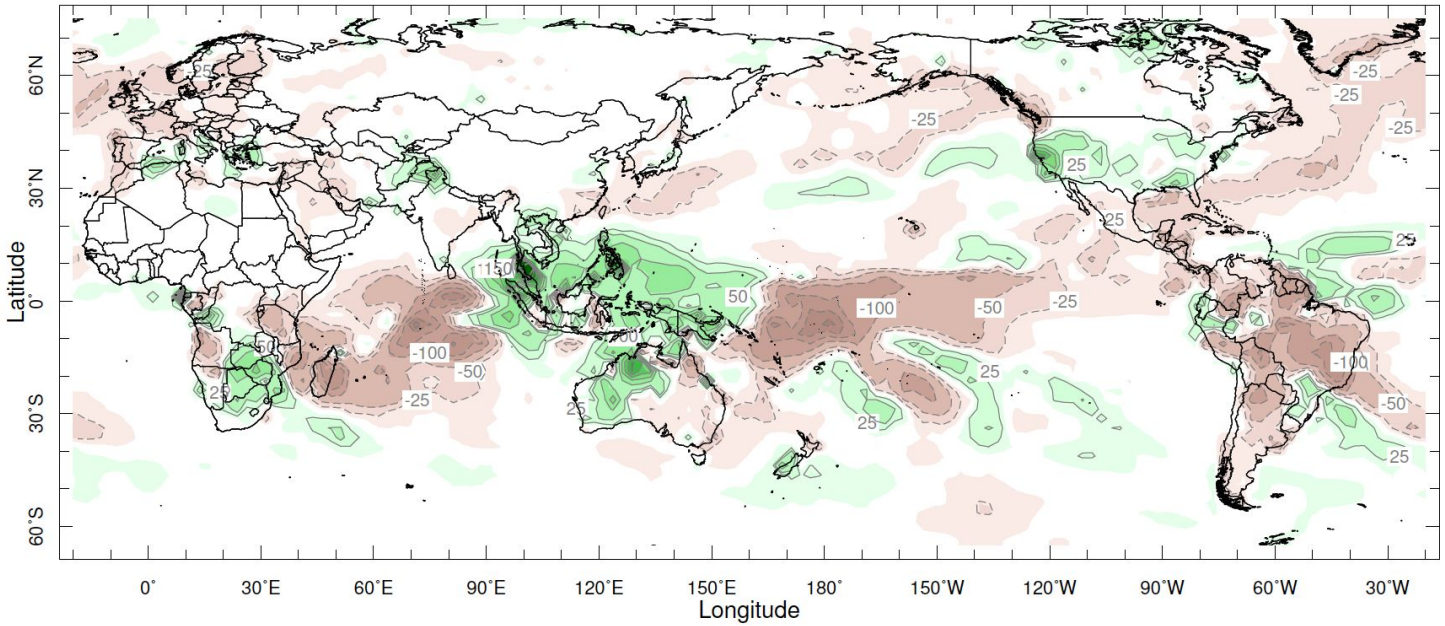

Strong El Nino
Moderate El Nino
(a)
(b)
CESM1
OBS
Nino−3.4g SST index (K)
NDJ+0
MJJ+1
NDJ+1
MJJ+2
NDJ+2
MJJ+3
1957
1965
1972
(c)
(d)
(e)
NDJ 1957
NDJ 1958
NDJ 1959
NDJ 1965
NDJ 1966
NDJ 1967
NDJ 1972
NDJ 1973
NDJ 1974
1982
1987
1994
(f)
(g)
(h)
NDJ 1982
NDJ 1983
NDJ 1984
NDJ 1987
NDJ 1988
NDJ 1989
NDJ 1994
NDJ 1995
NDJ 1996
1997
2006
2009
(i)
(j)
(k)
NDJ 1997
NDJ 1998
NDJ 1999
NDJ 2006
NDJ 2007
NDJ 2008
NDJ 2009
NDJ 2010
NDJ 2011

# Define La Niña based on the SST gradient to avoid biases caused by long-term warming

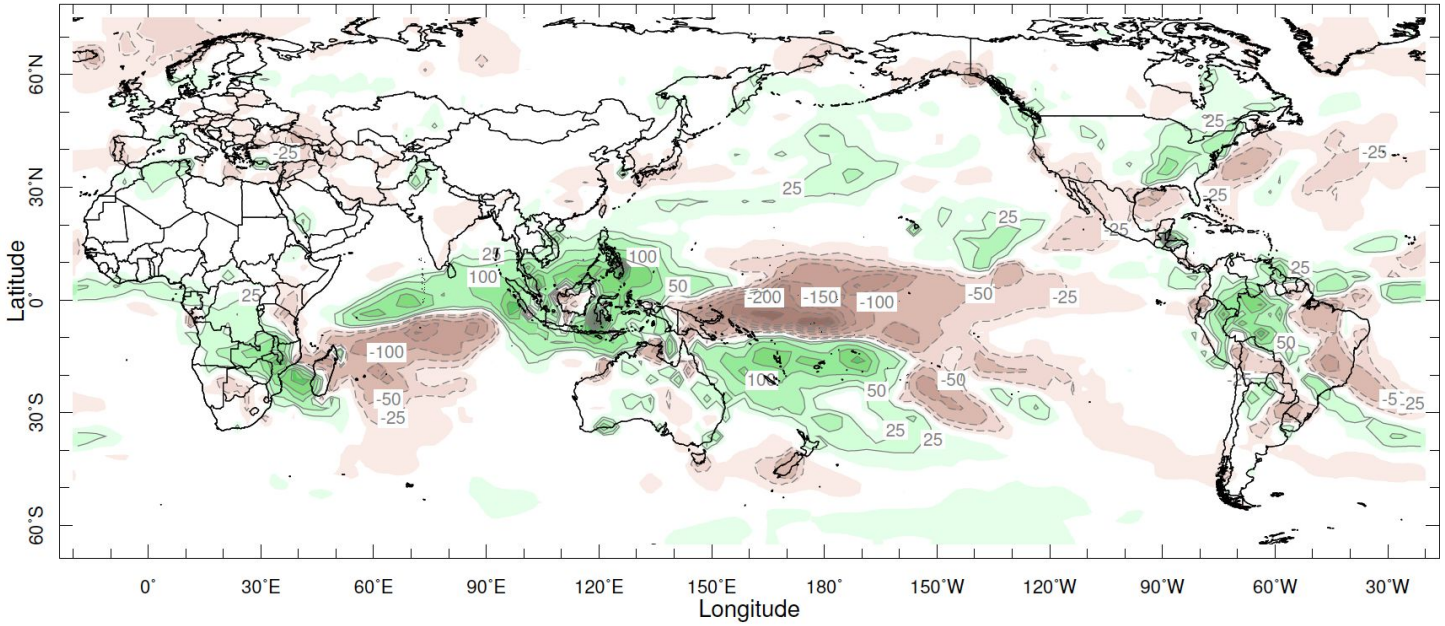



Nino index computed from ERSST4 updated thru Nov 2016.

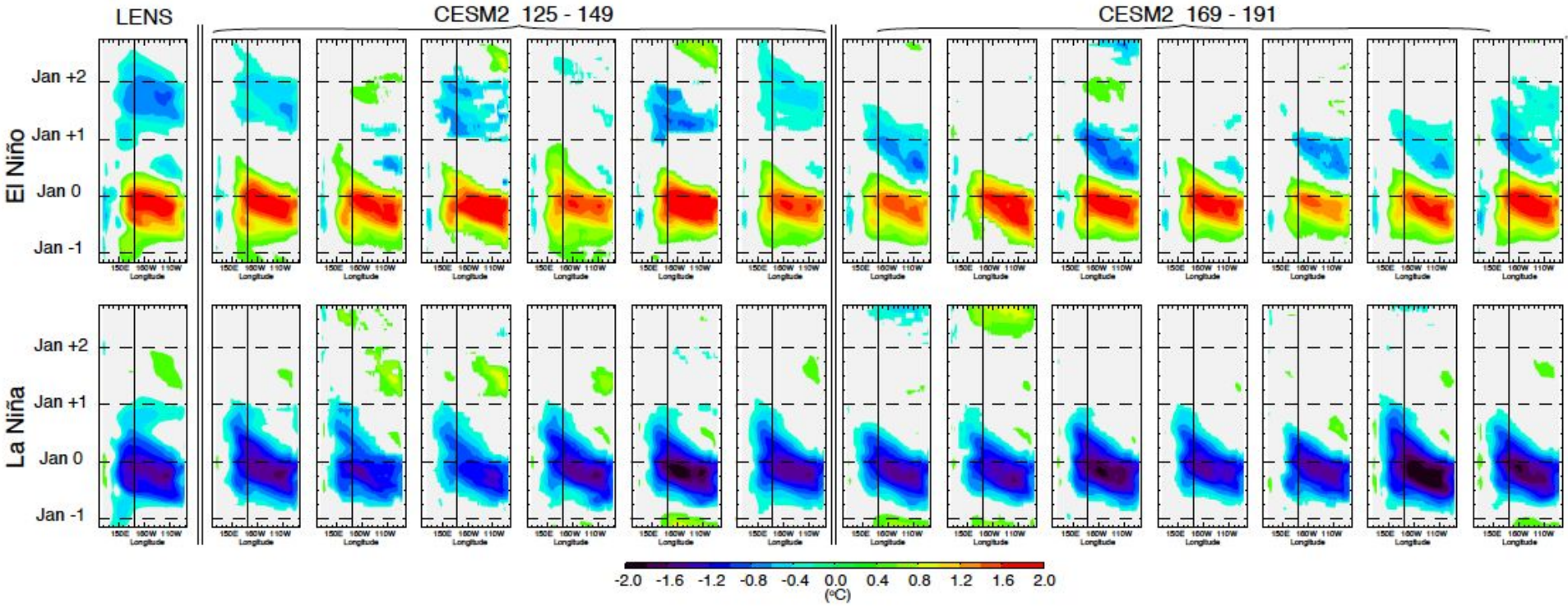
DiNezio *et al.*



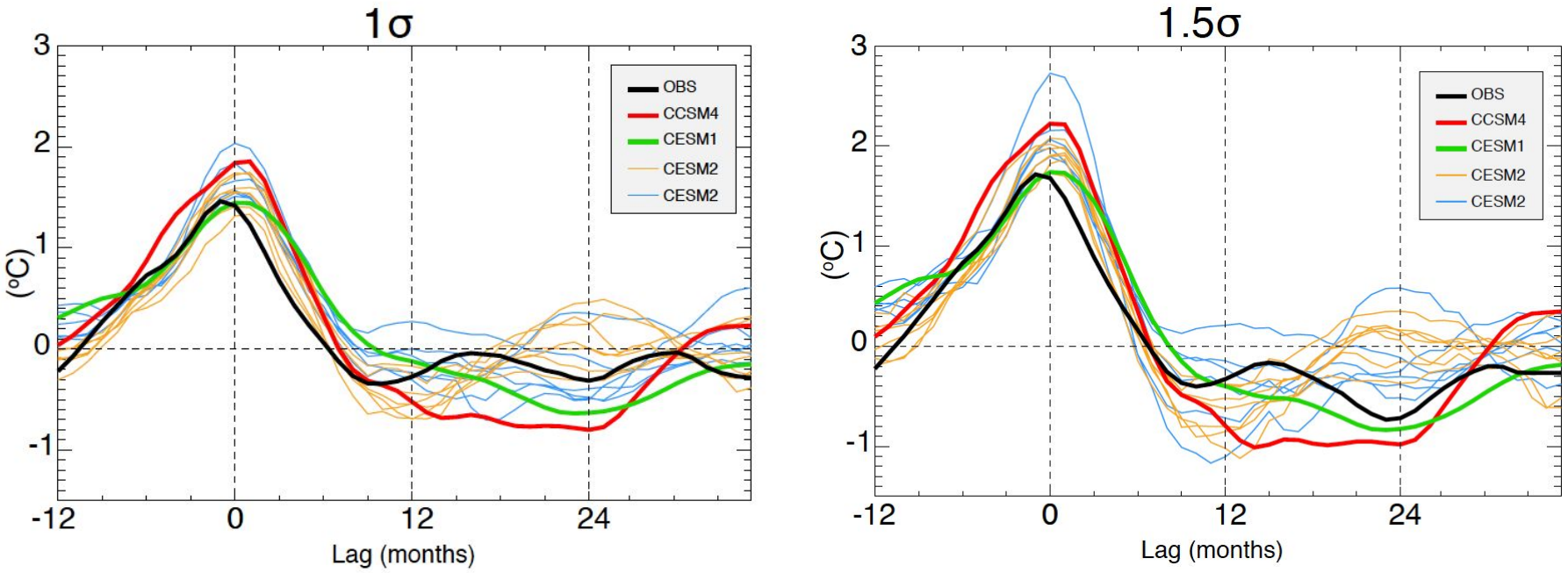

Jan 2017




Jan 1999


LENS
CESM2_125 - 149
CESM2_169 - 191
El Niño
La Niña
Jan +2
Jan +1
Jan 0
Jan -1
150E 160W 110W
Longitude
-2.0 -1.6 -1.2 -0.8 -0.4 0.0 0.4 0.8 1.2 1.6 2.0
(°C)

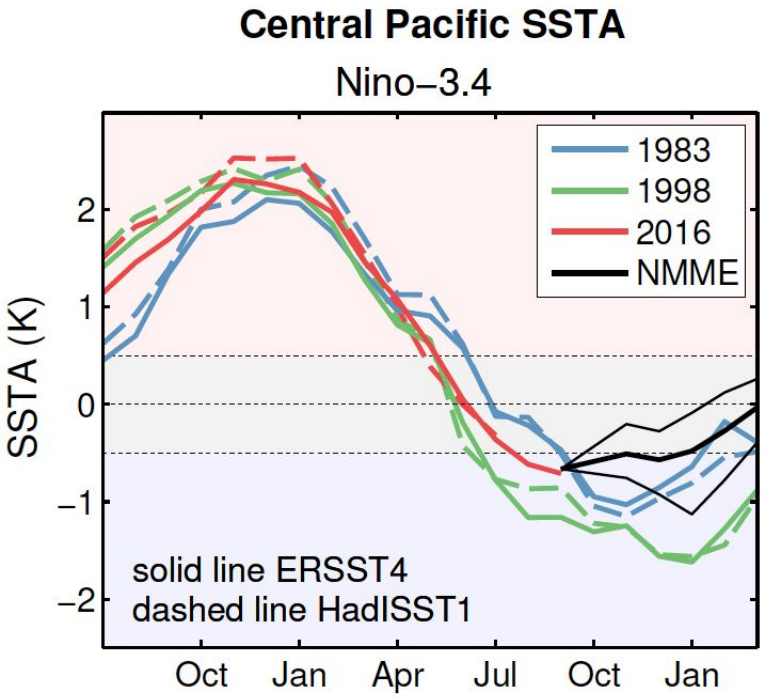
# Composite Nino-3.4




- Blue composites are CESM2 cases 169-191
- Orange composites are CESM2 cases 125-149

**Since case 169 CESM2 simulates less 2-year La Nina than obs, CCSM4, or LENS**

# Very weak La Nina according to observations and prediction models




NMME: North American Multi-Model Ensemble

*Is La Nina here?*

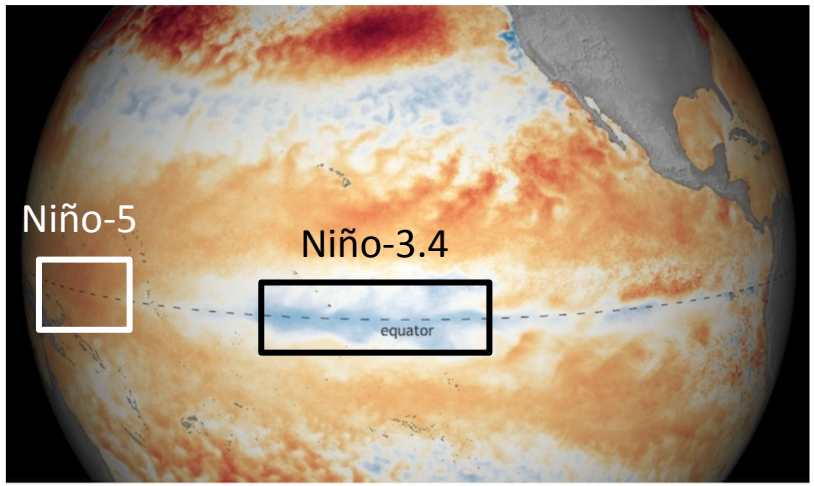
September 2016

# 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.

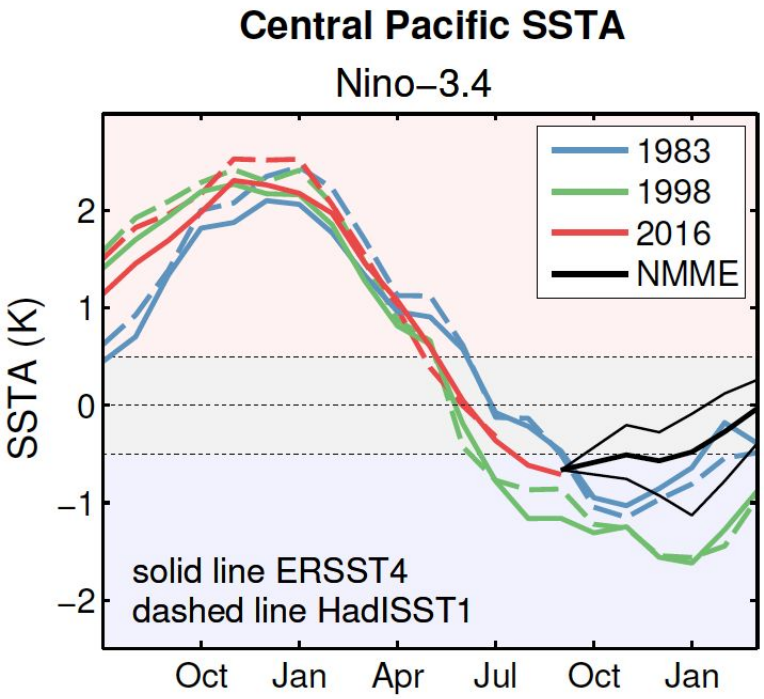
NOAA dropped their La Niña watch in September, indicating that it was **unlikely that a La Niña will form this fall or winter**. However, the La Niña watch was reinstated in October.

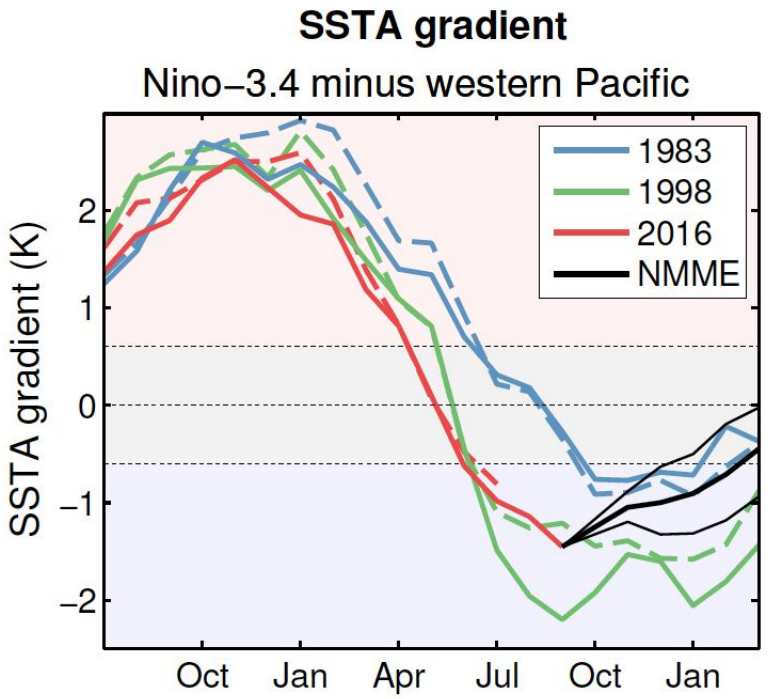



*August monthly sea surface temperature anomalies in the tropical Pacific.*
*Credit: NOAA climate.gov*

CLIMATE CENTRAL

# Observations and models show stronger SST gradient




*Cooling of the Niño-3.4 region not as strong as during 1998, but definitively not neutral*

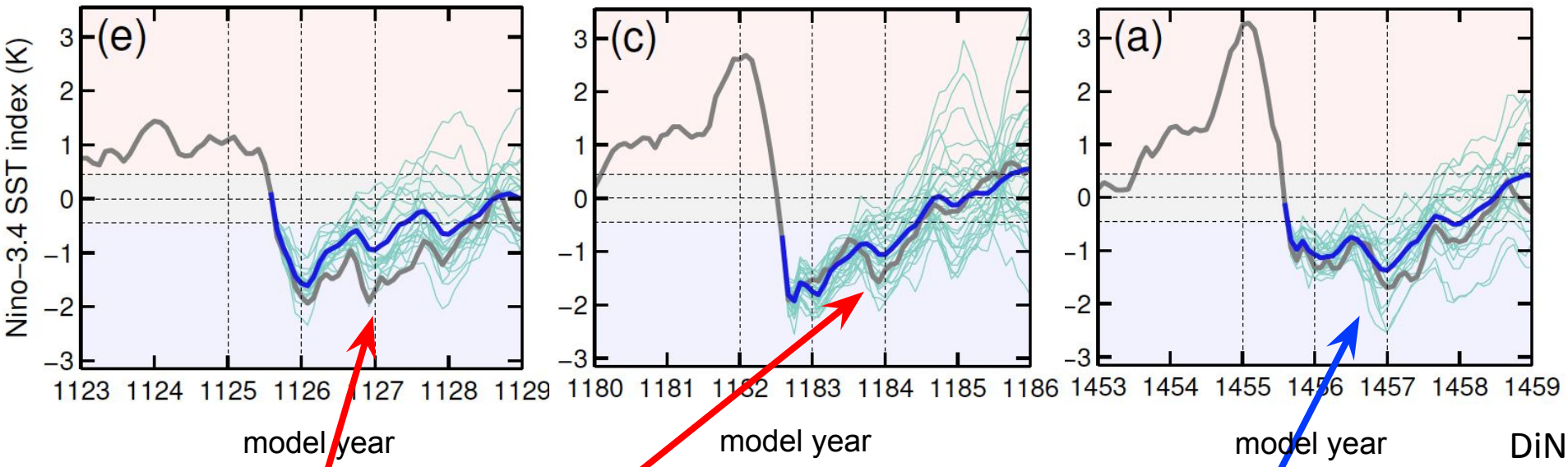
# The predictability of La Niña depends on magnitude of the initial discharge

control
individual forecast
ensemble-mean

**weak predictor**

**moderate predictor**

**strong predictor**

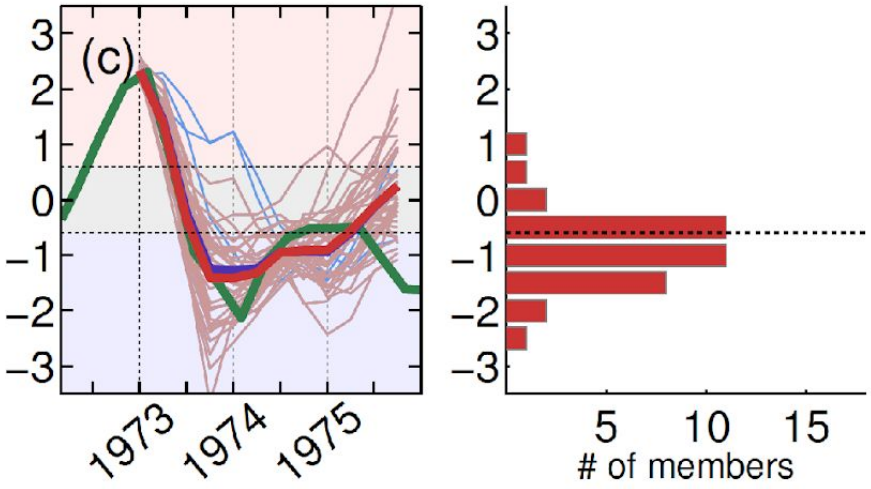



DiN
al. i
revi

control run was an outlier, however within forecast spread

19 out of 20 members predict the return of La Niña

# CESM-DP-LE predicted historical 2-year La Niña preceded by strong El Niño

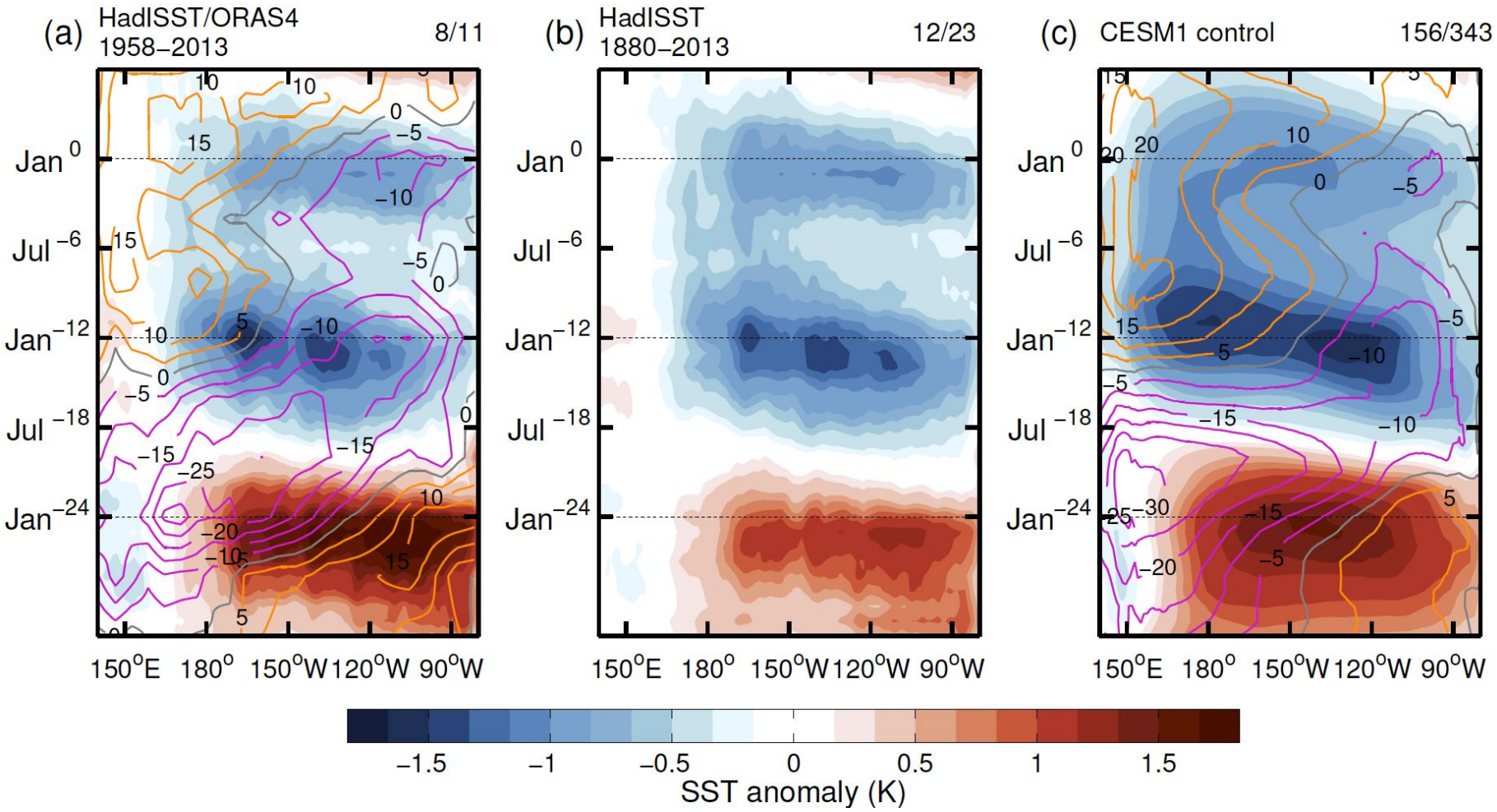



DiNezio *et al.*

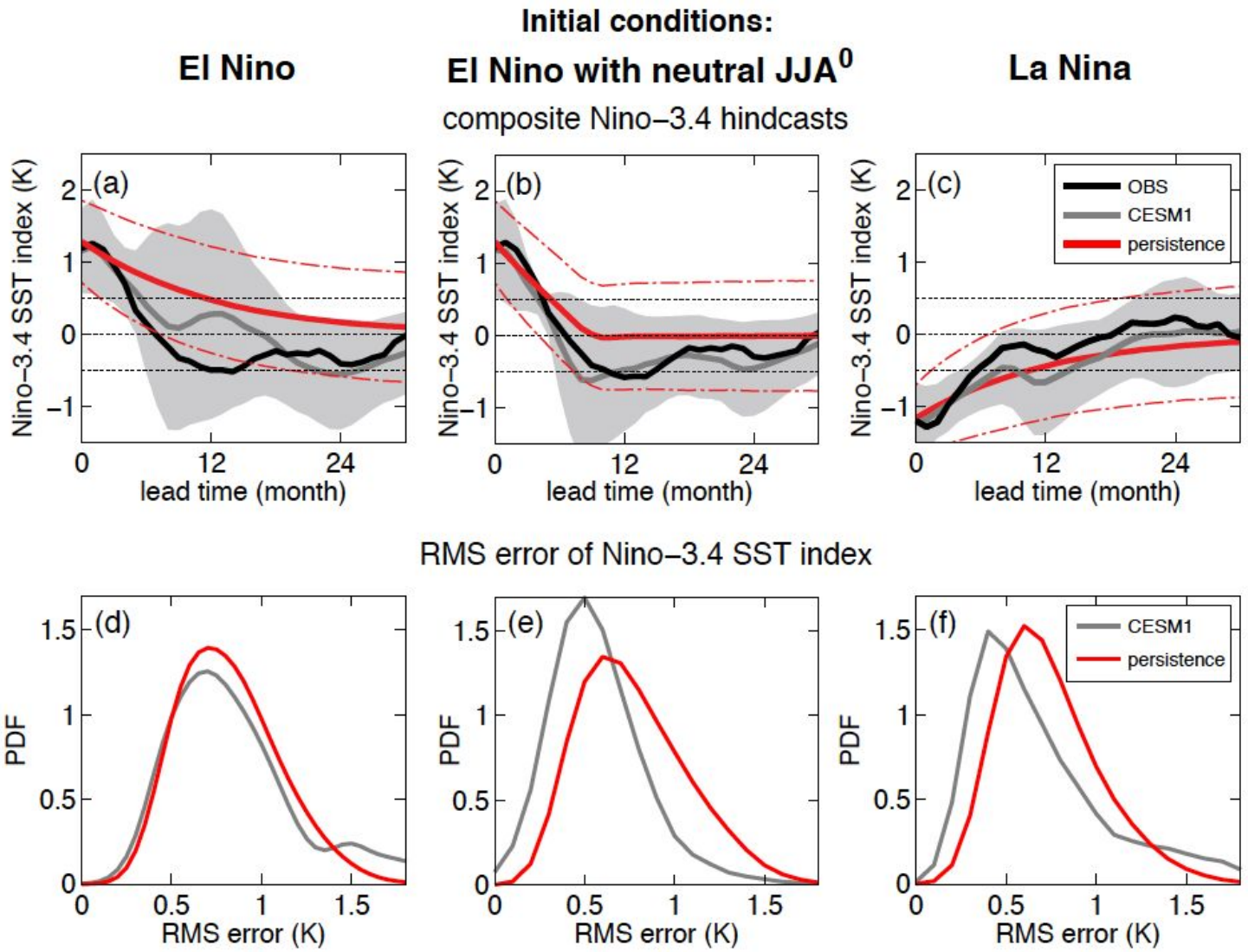
# CESM1 simulates realistic 2-yr La Nina

*observed composites*

*simulated composite*

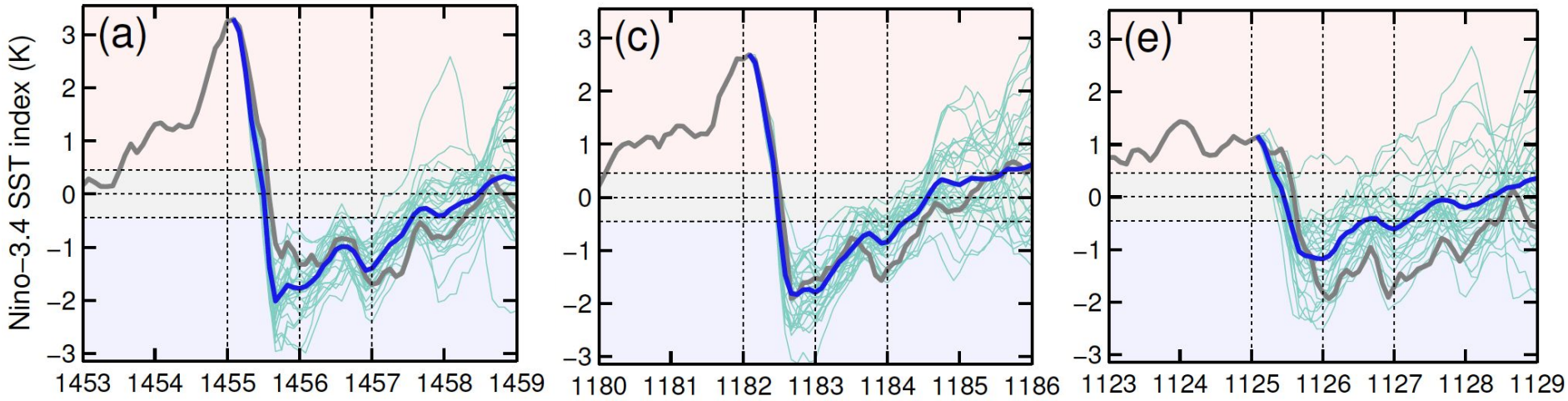


# Verification: CESM1 is better than damped persistence



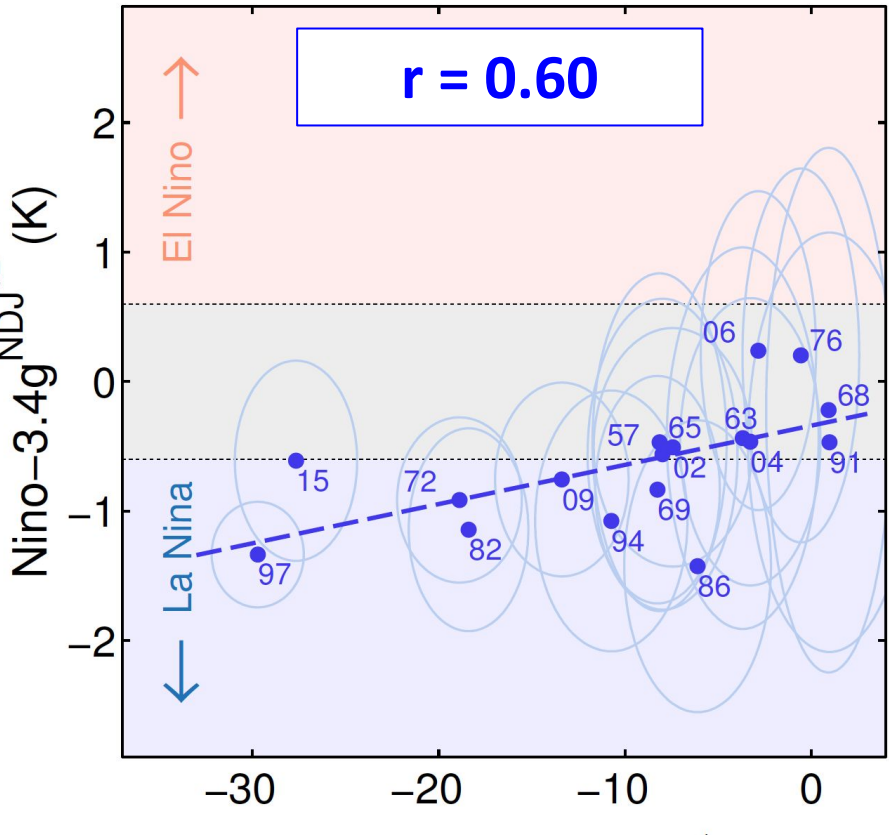
# Three case studies based on magnitude of preceding El Nino:

**strong** **moderate** **weak**

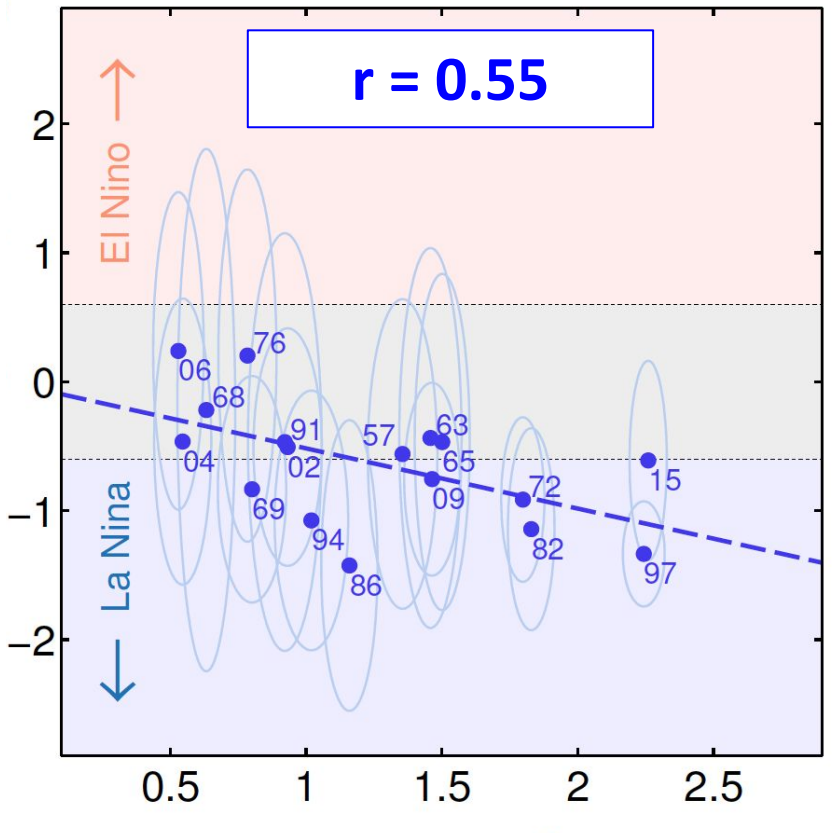



control
individual forecast
ensemble-mean

# More predictable La Niña after strong El Niño and associated discharge




Peak thermocline discharge

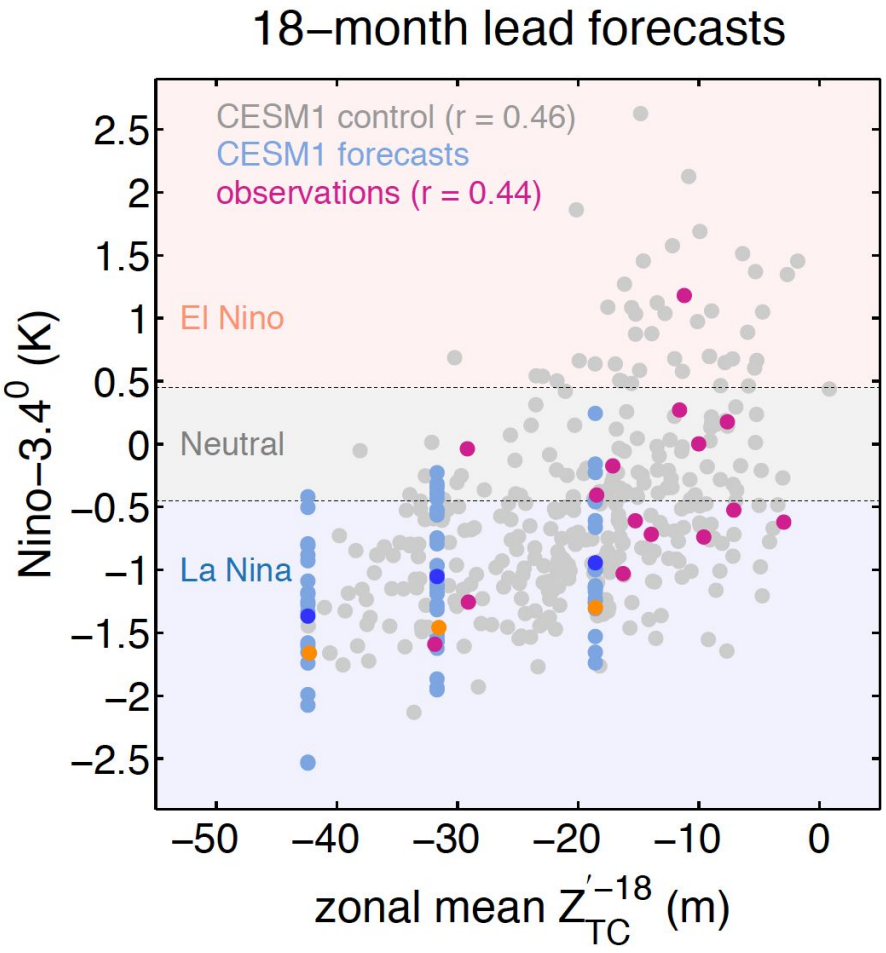



Peak El Niño amplitude

Ellipses show ensemble spread

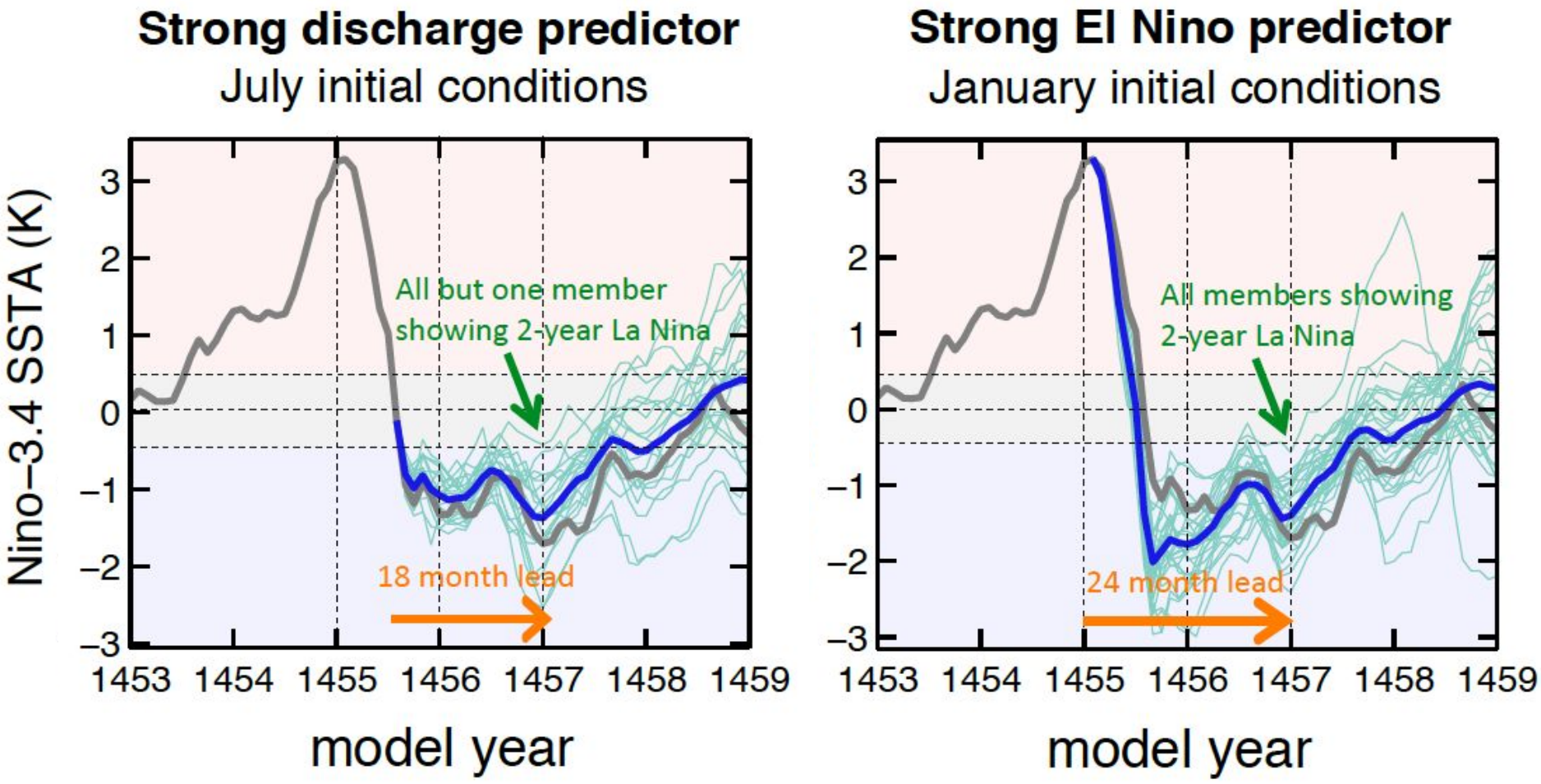
DiNezio *et al.*

# Observed La Niña events are consistent with our hypothesis

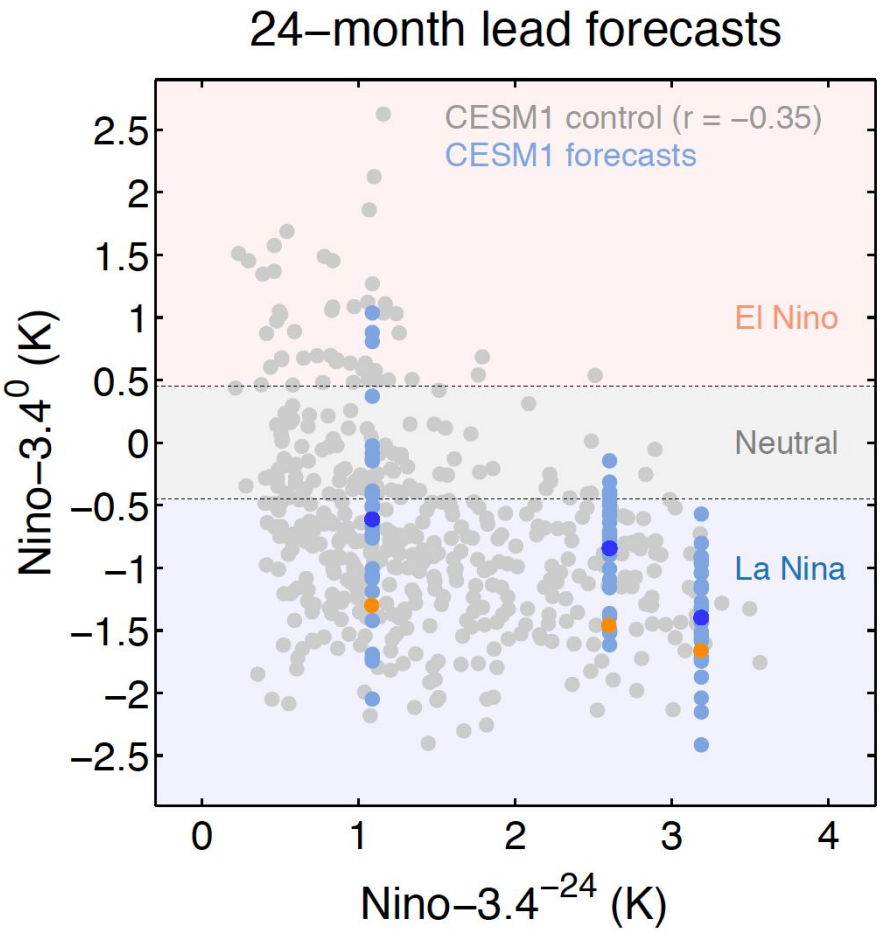



**Magnitude of thermocline shoaling prior to the the onset of La Niña**

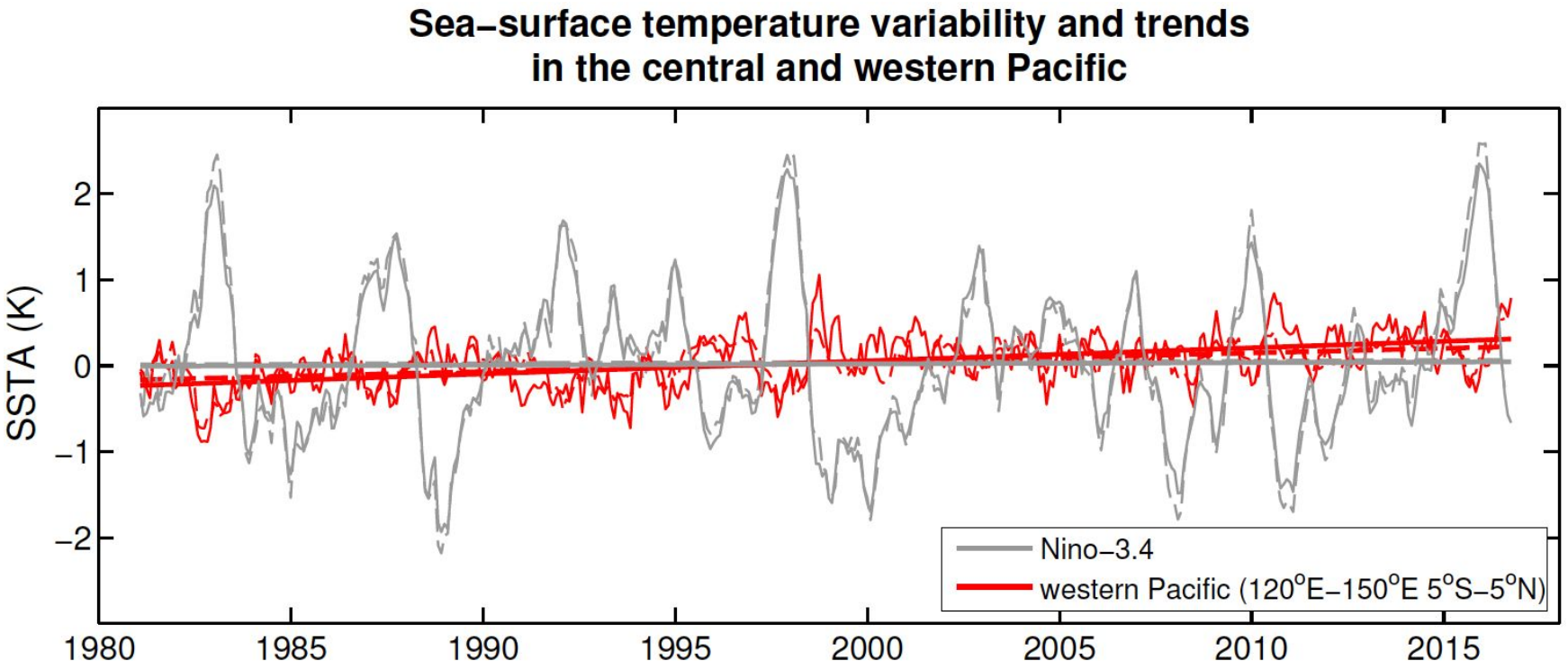
# The forecasts are also skillful when initialized at the peak of El Nino



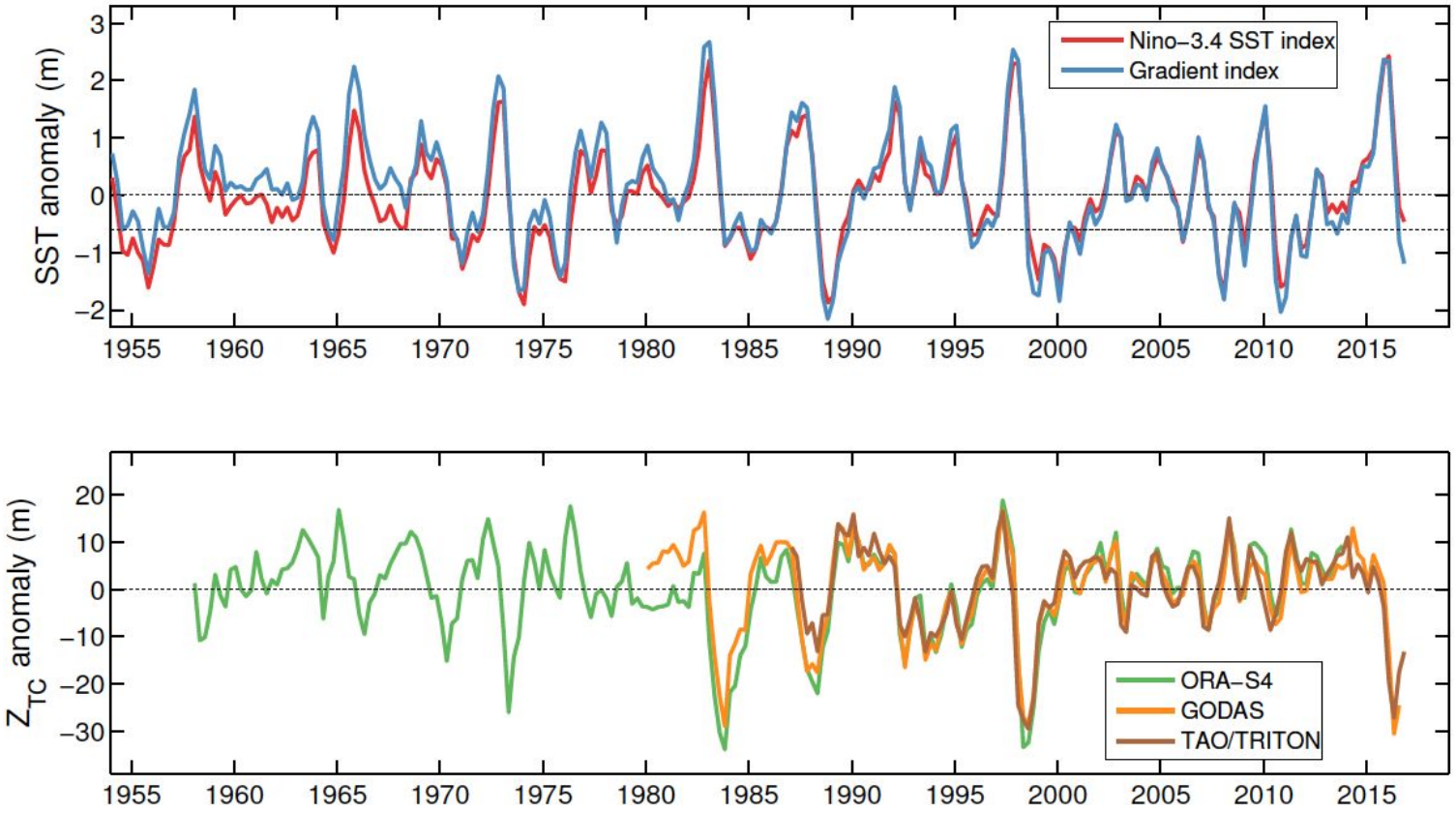
# 2-year La Niña could also be predicted 24 months in advance




**Peak amplitude of preceding El Niño**


Sea–surface temperature variability and trends
in the central and western Pacific
SSTA (K)
2
1
0
−1
−2
1980
1985
1990
1995
2000
2005
2010
2015
Nino–3.4
western Pacific (120°E–150°E 5°S–5°N)

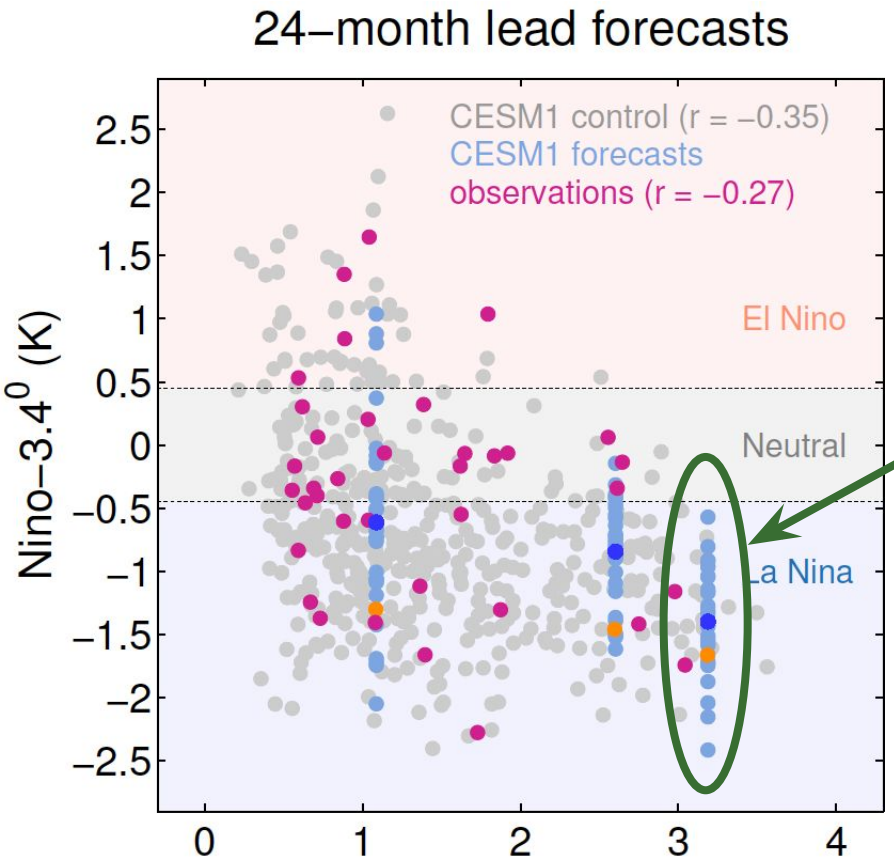
# The strongest El Niño on record were followed by large discharge and 2-year La Niña




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

DiNezio *et al.* in prep.

# Highly predictable 2-year La Niña after strong El Niño events




**20 out 20 members predict**

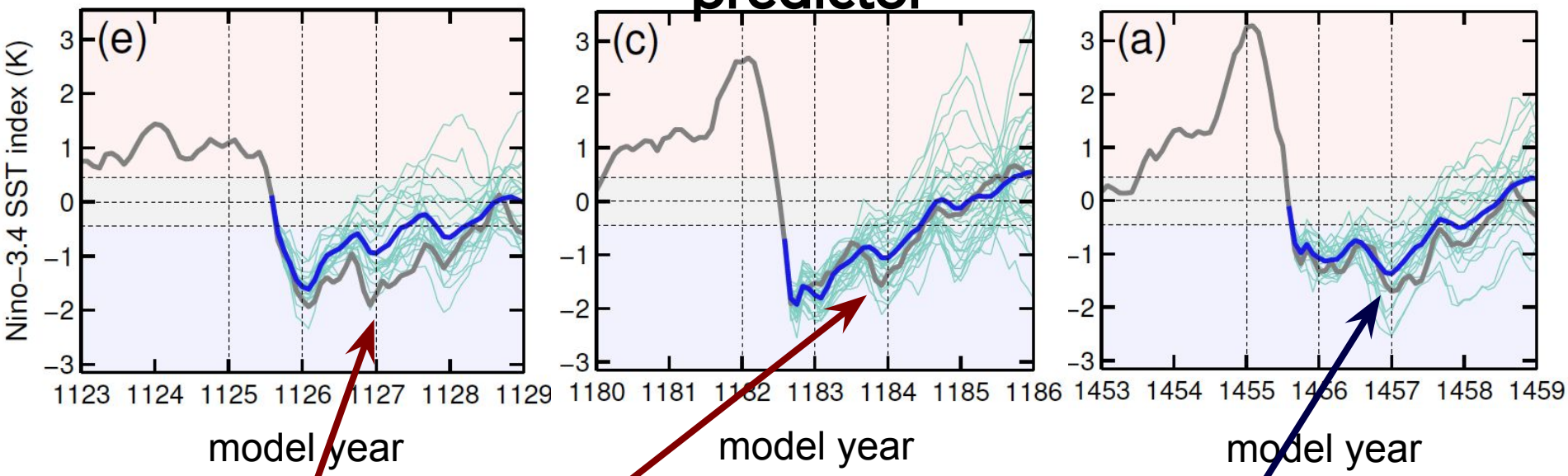
DiNezio *et al.* 2017

# The predictability of La Niña depends on magnitude of the initial discharge

weak predictor

moderate predictor

strong predictor



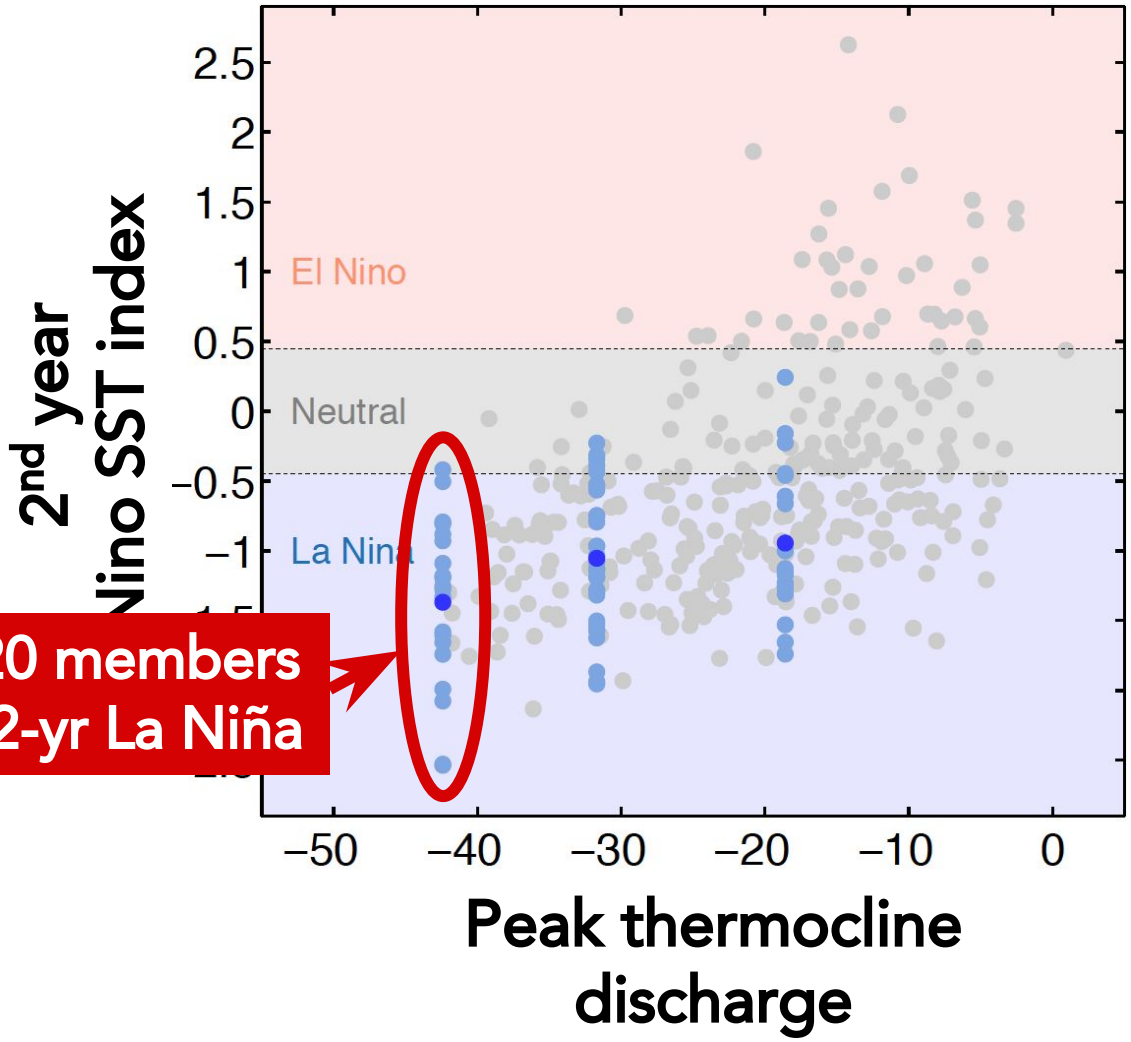

control run was an outlier, however within forecast

19 out of 20 members predict the return of La

n

DiNezio *et al.*

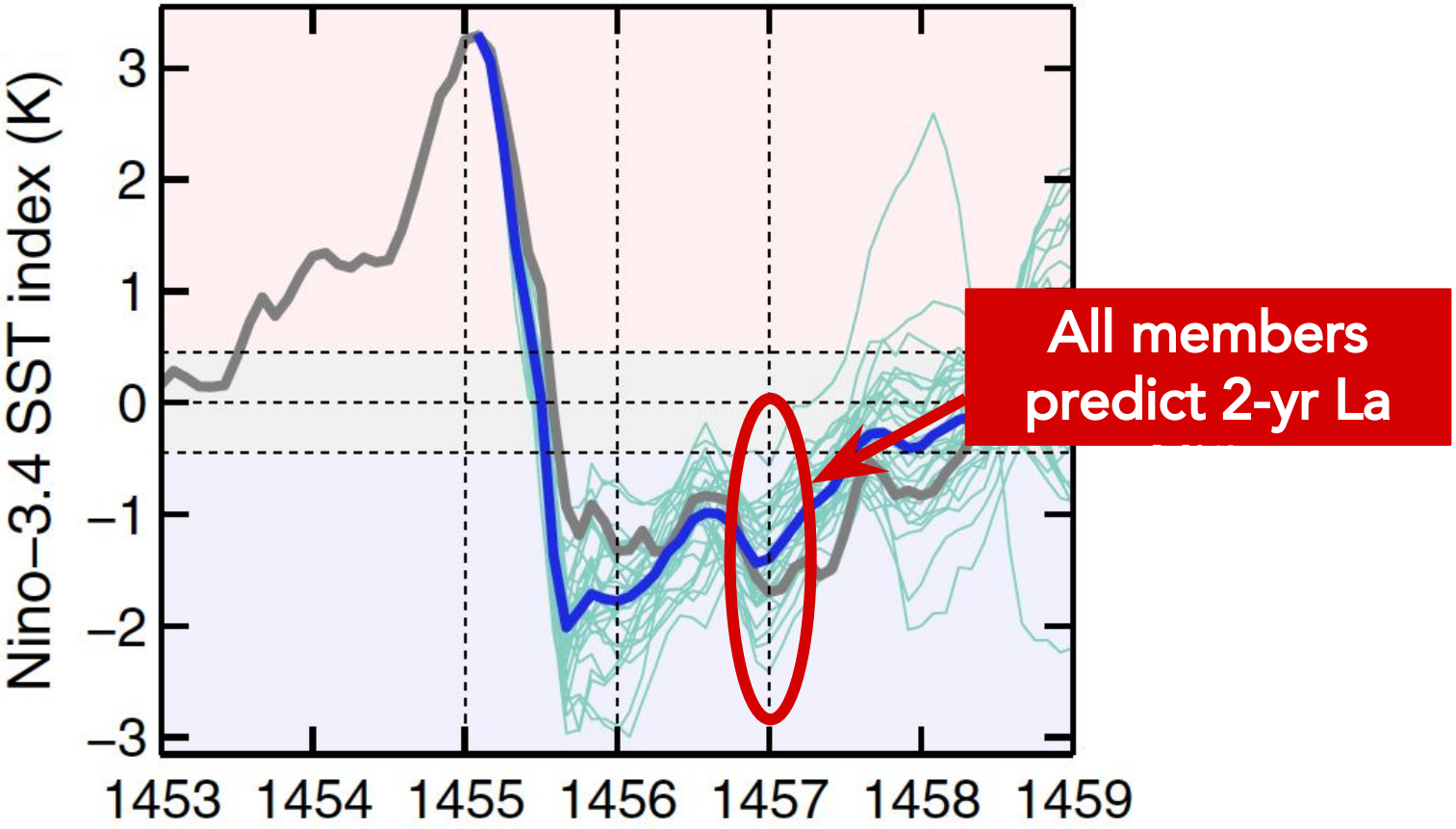
# Strong discharge leads to highly reliable forecasts:




19 out 20 members predict 2-yr La Niña

DiNezio *et al.*

# Skillful 2-year predictions initialized at the peak of a strong El Niño




DiNezio *et al.*