Predictability of the duration of La Niña

Pedro DiNezio

University of Texas Institute for Geophysics (UTIG)

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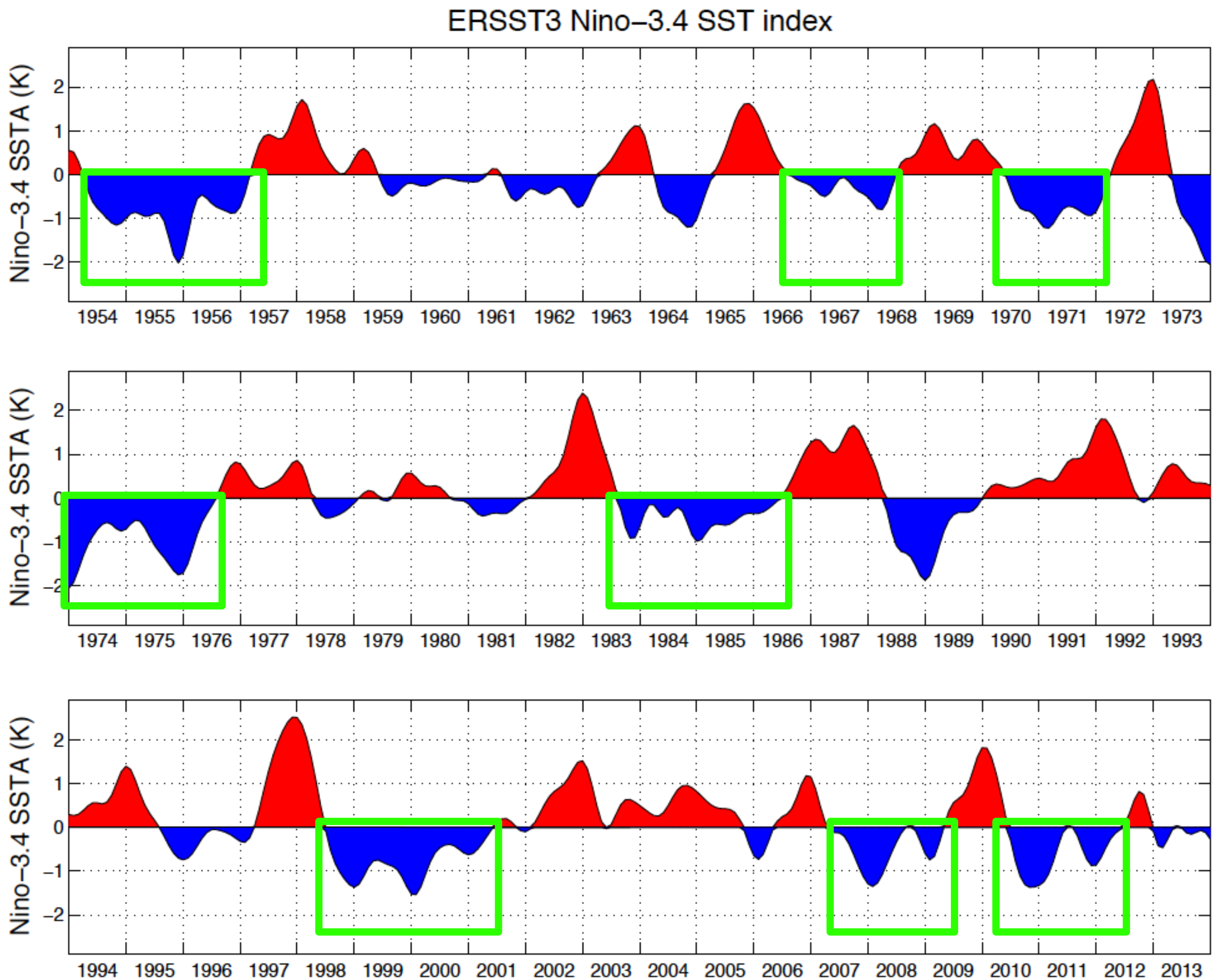
Collaborators: C. Deser[1] and Y. Okumura[2]

[1]NCAR, [2]UTIG

Multi-year La Niña events are very common



Adapted from Okumura and Deser 2011

Can we predict their duration?

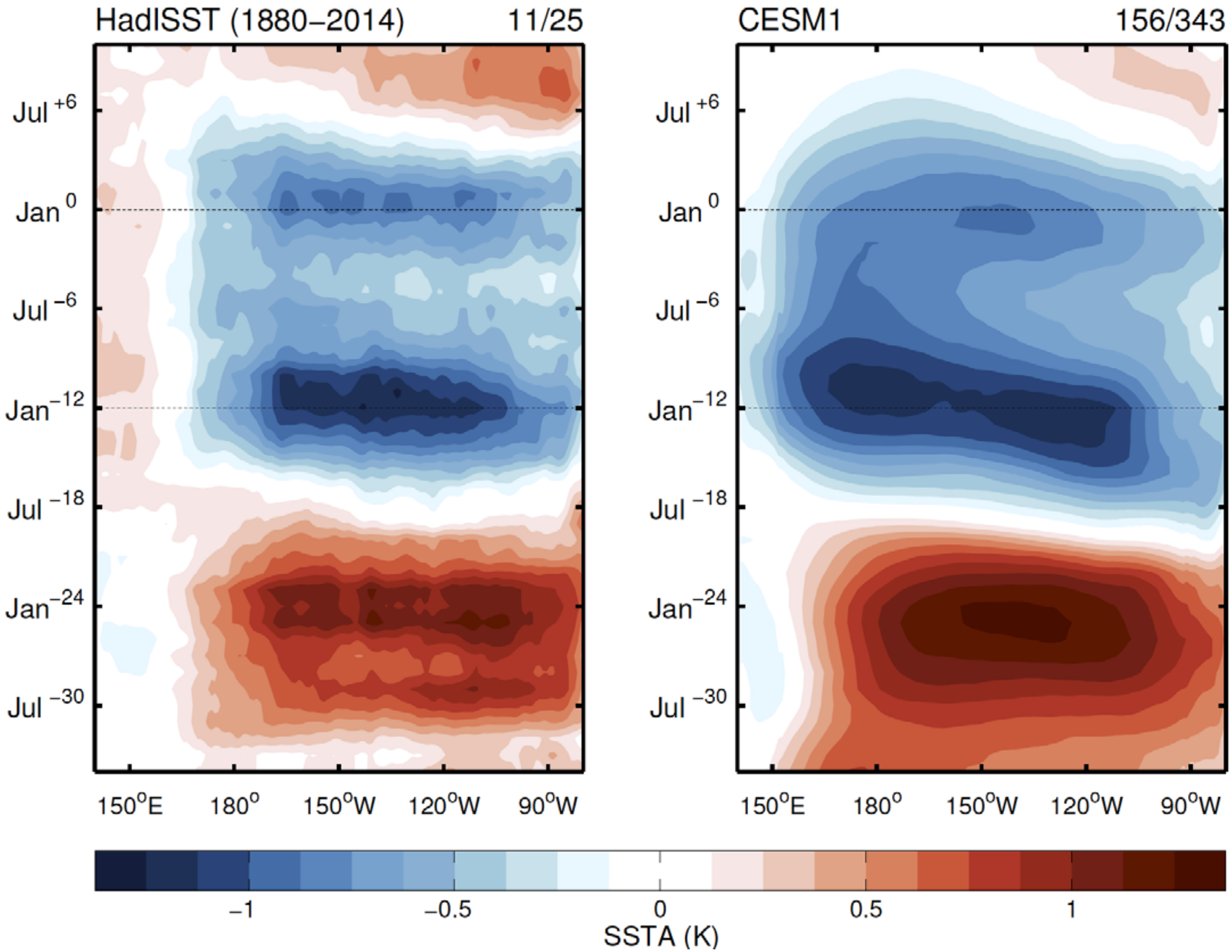
- Previous research has focused on El Niño
- Predicting the **onset** of La Niña is **trivial**:
  - They virtually always occur the year after El Niño.
- Predicting the **termination** of La Niña is very **challenging**:
  - Why some events last 2 years?
  - Is their duration predictable?

Data and Methodology

- **Long control** simulation performed with CESM1
  - 1800 years long
  - Constant pre-industrial forcing
  - 1° atmosphere, 1° ocean (⅓° latitude on the equator)
  - Simulates realistic 2-yr La Nina

- **Perfect-model** prediction experiments with CESM1
  - 3 case studies
  - 20 members for each forecast ensemble
    - Initialized during:
      - Transition from El Nino to La Nina (18 month lead time)
      - Peak of the preceding El Nino (24 month lead time)
    - Each forecast run forward for 3.5 years.

CESM1 simulates realistic 2-year La Nina

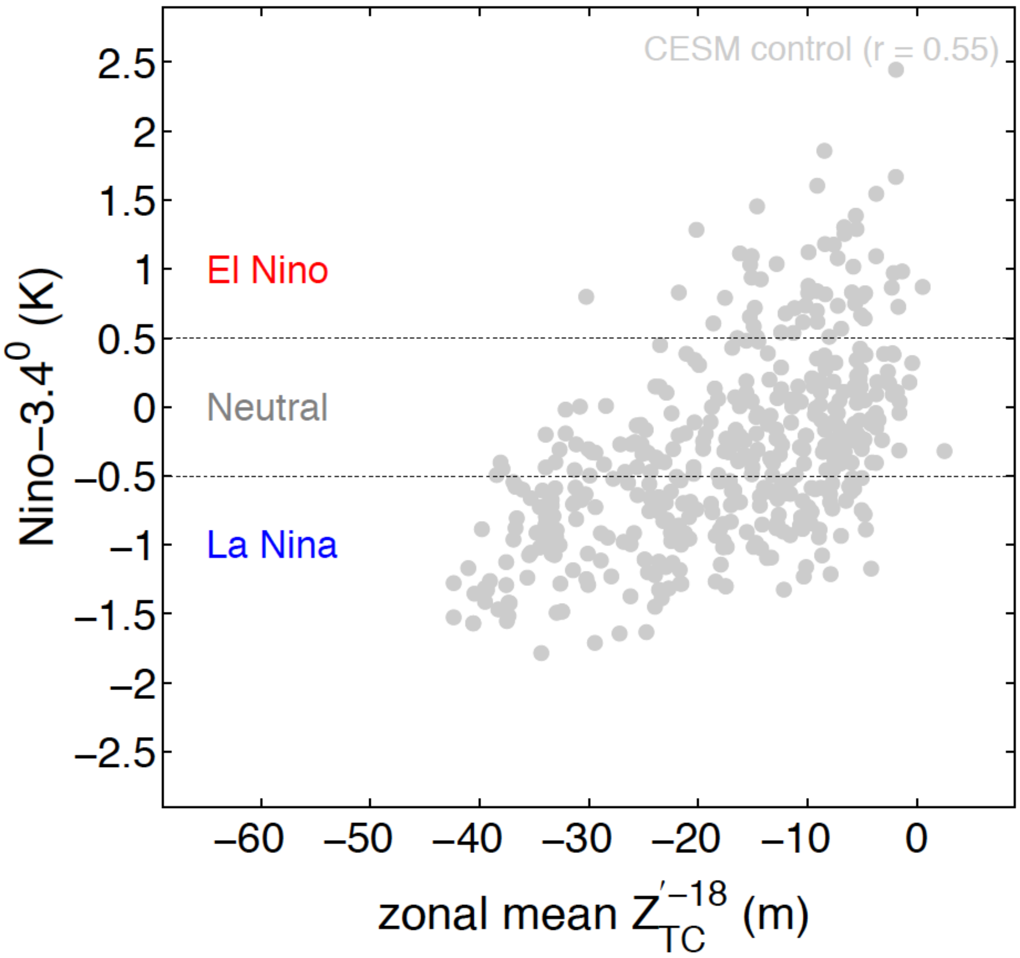


Looking for predictors…

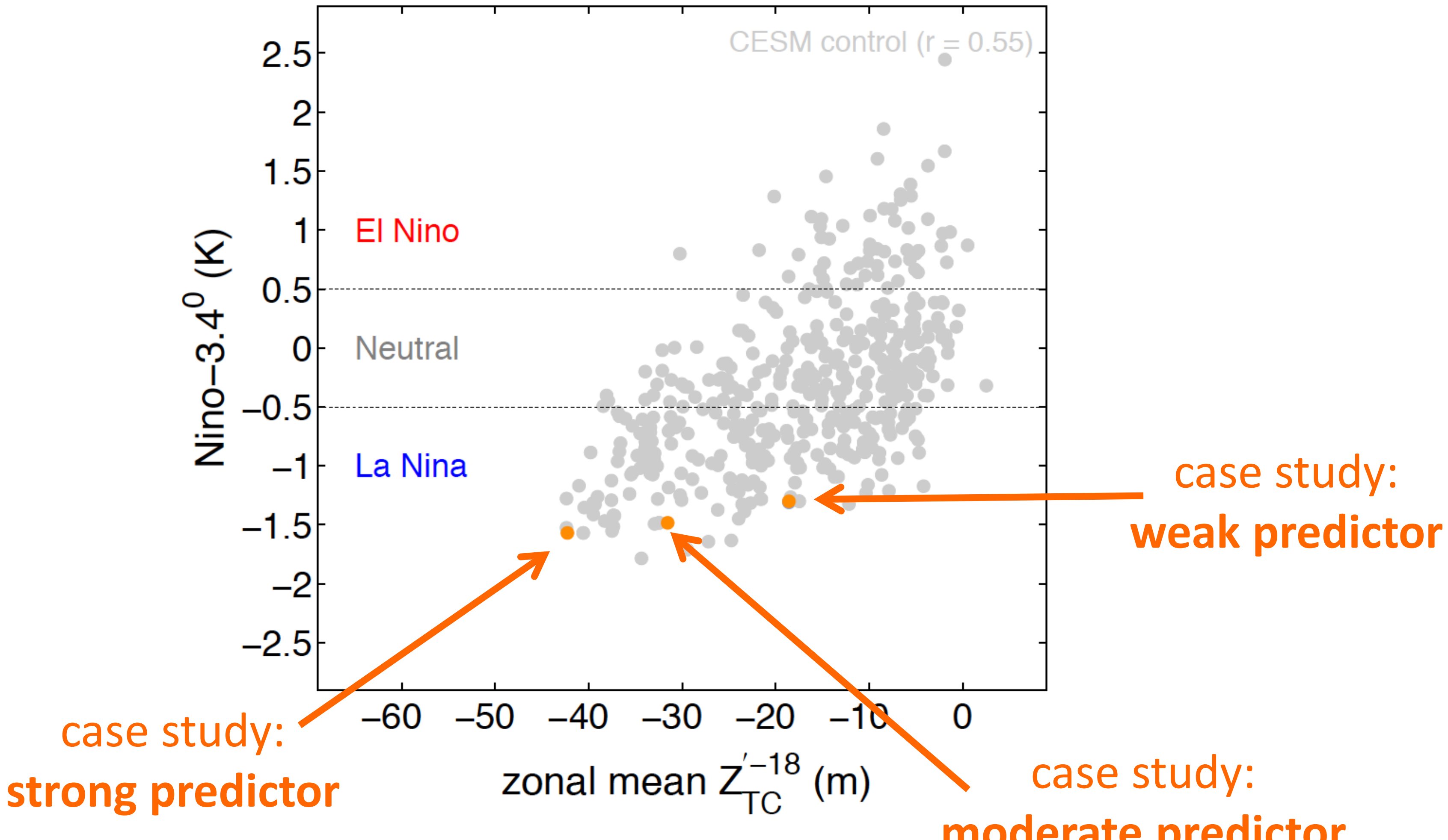
- Two main theories for the duration of ENSO events:
  - Delayed oscillator (Suarez and Schopf 1988; Battisti and Hirst 1989).
  - Recharge oscillator (Jin 1997).

- Both are based on the following idea:
  - Variations in the depth of equatorial thermocline contribute to:
    - The growth of ENSO events (Bjerknes feedback).
    - **The decay of ENSO events, i.e. their duration (delayed thermocline feedback).**

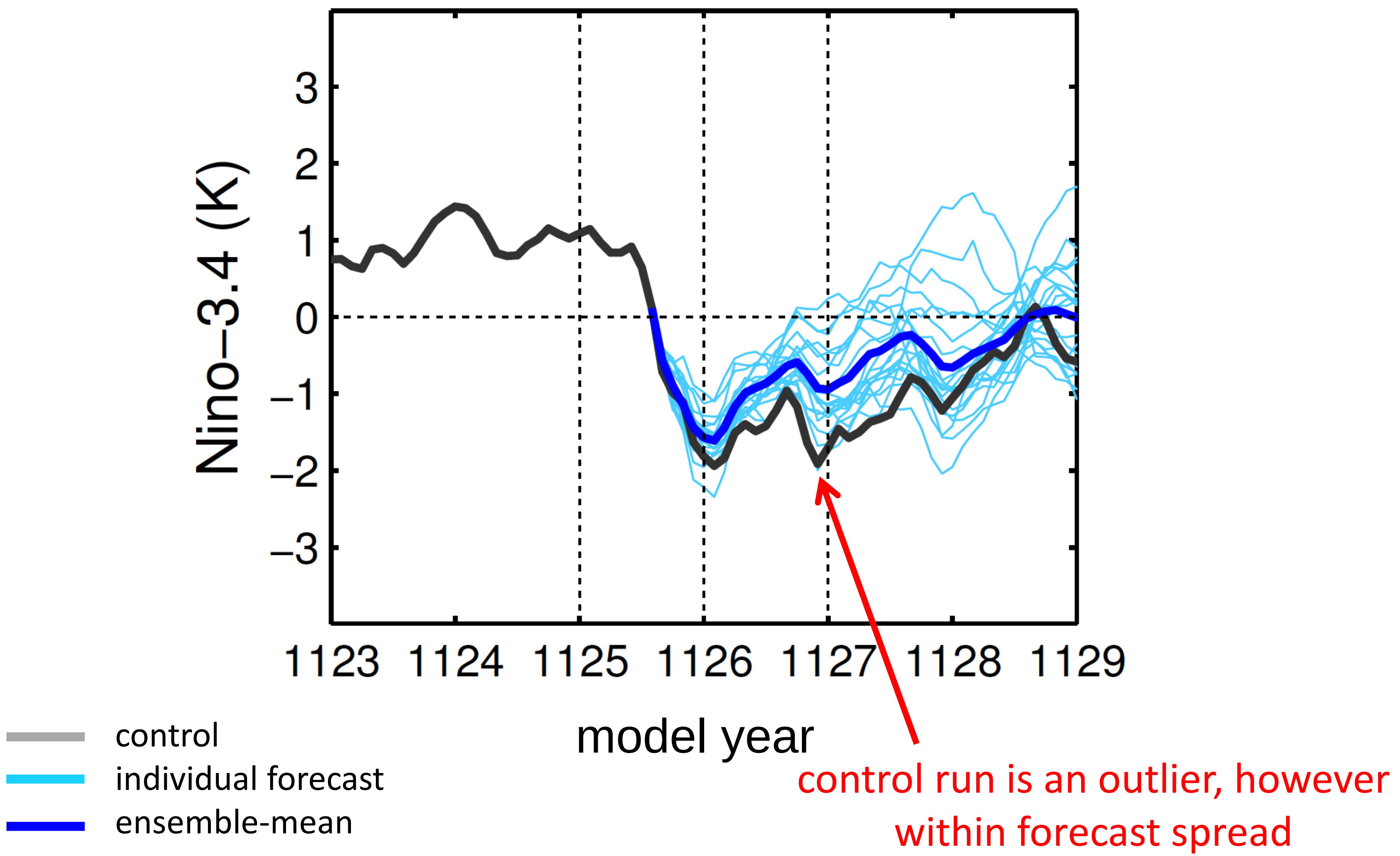
Hypothesis: thermocline depth anomalies before the onset of La Niña determine its duration



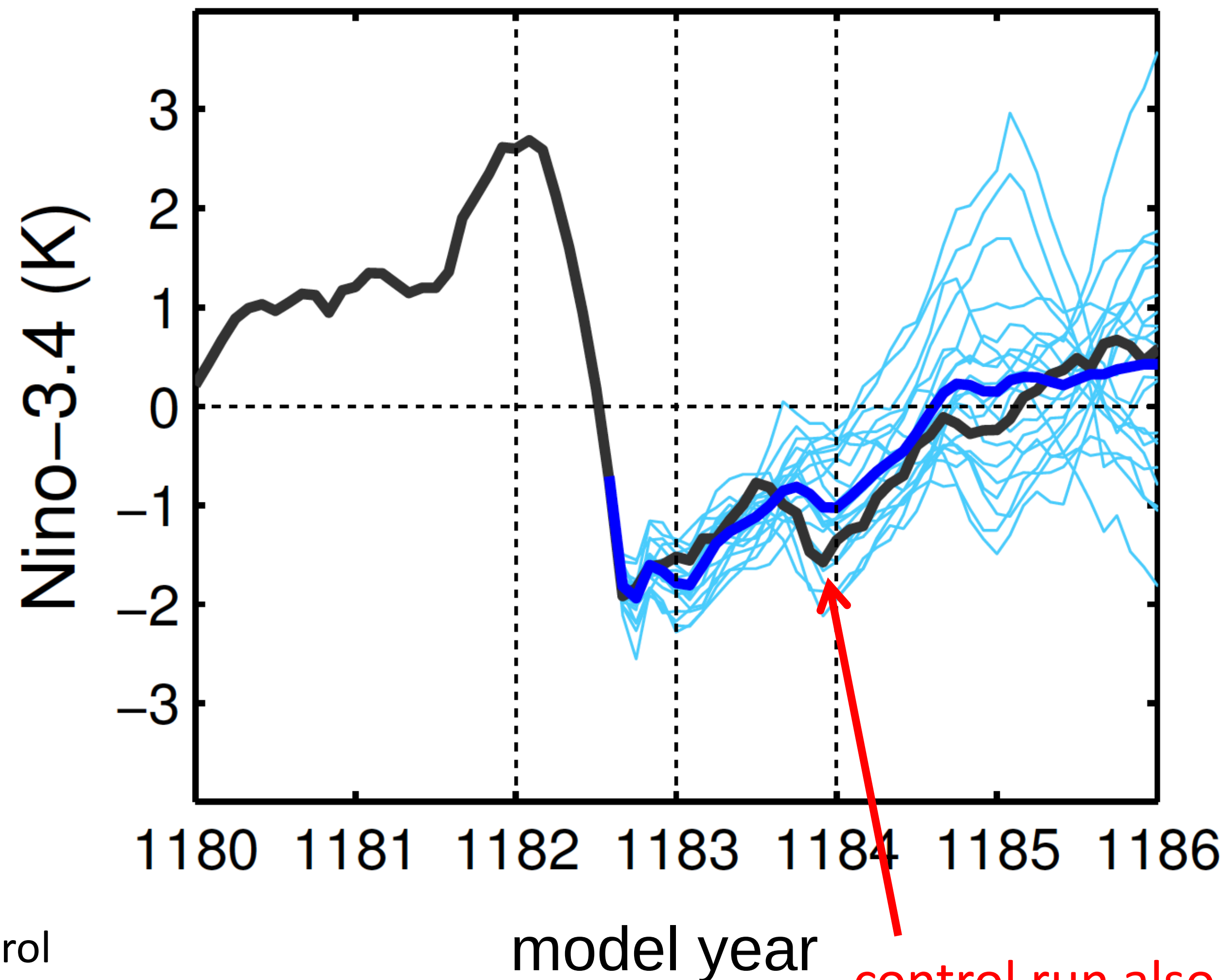
Hypothesis: thermocline depth anomalies **before the onset of La Niña** determine its duration



Case 1: weak predictor



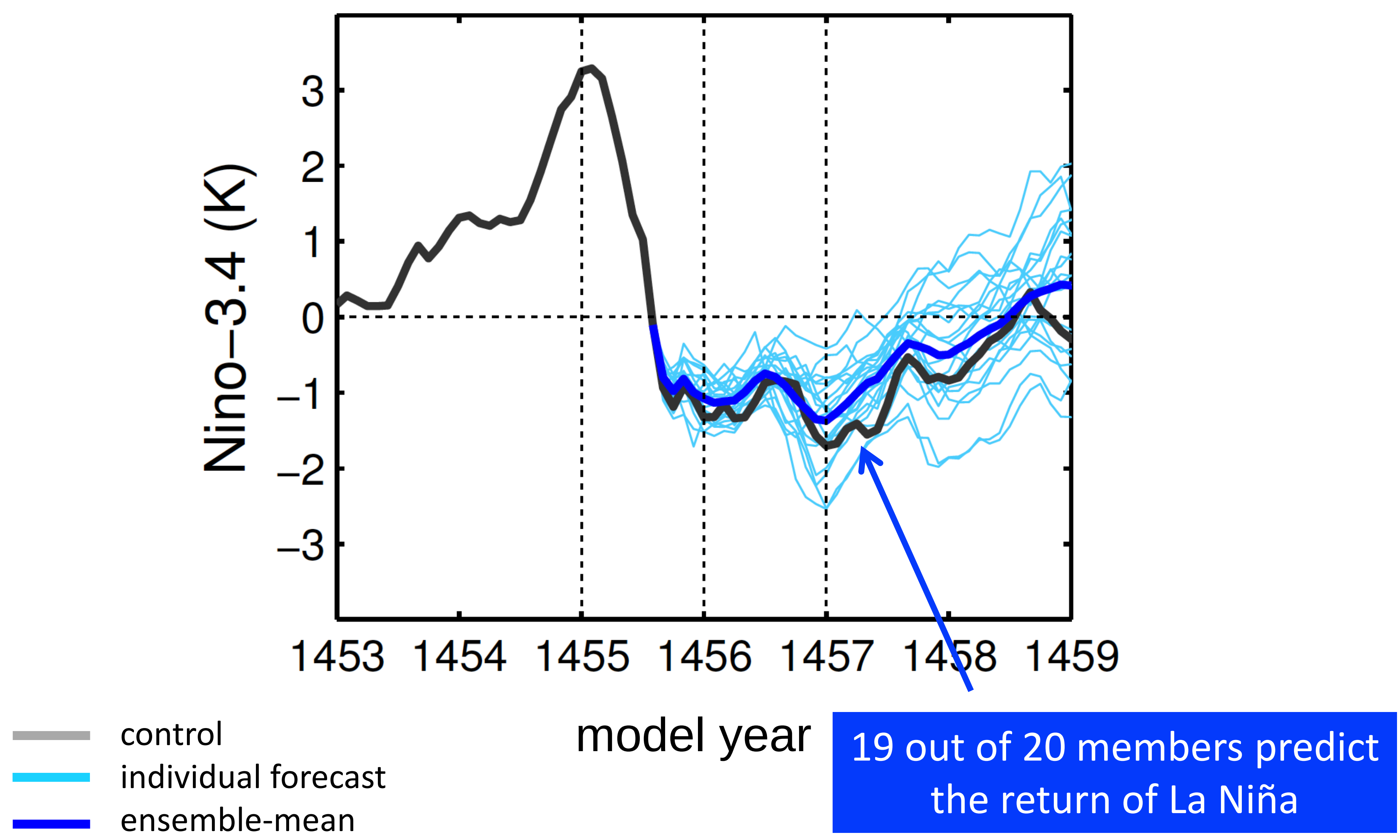
Case 2: moderate predictor



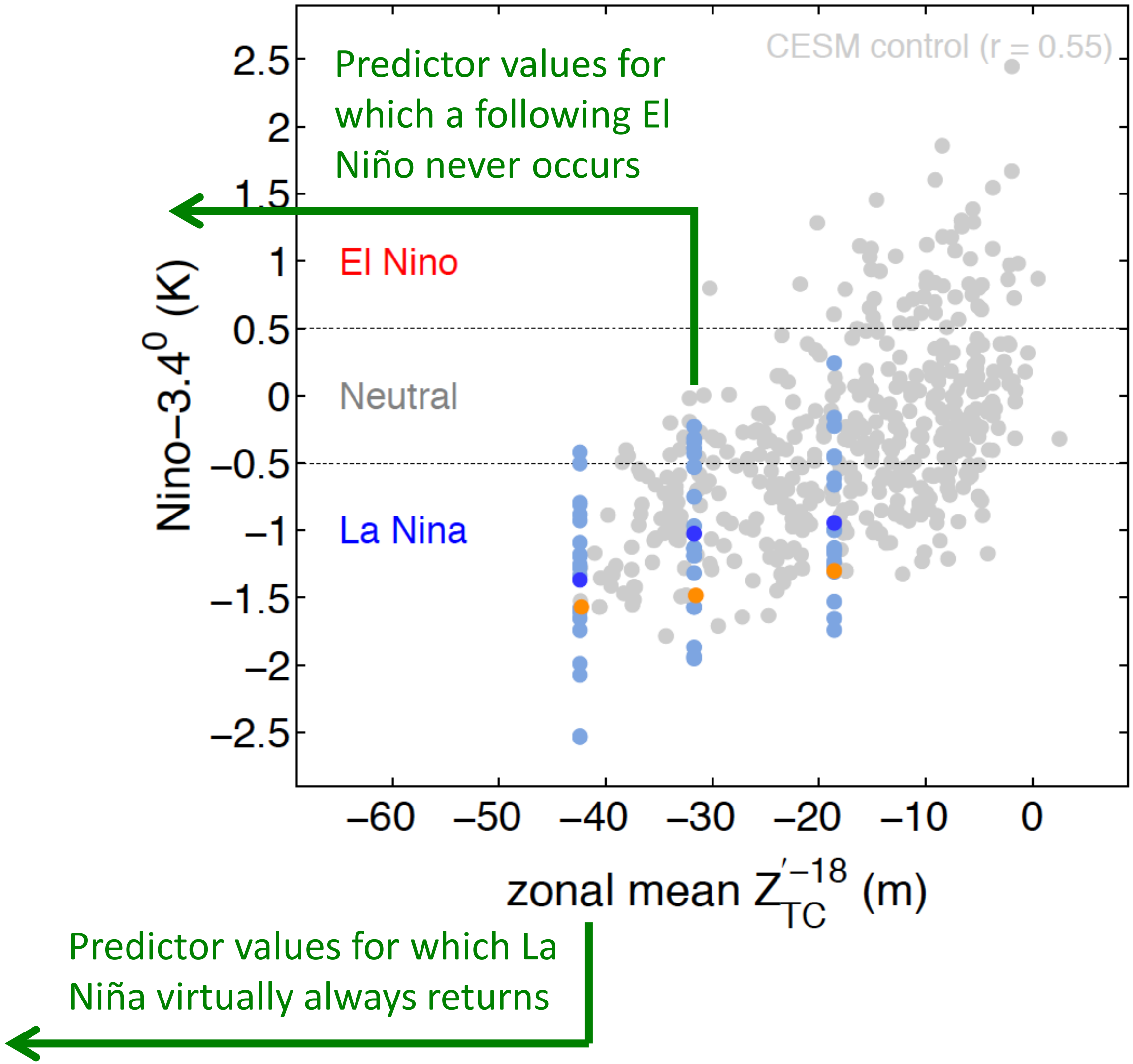
control
individual forecast
ensemble-mean

control run also an outlier,
however within forecast spread

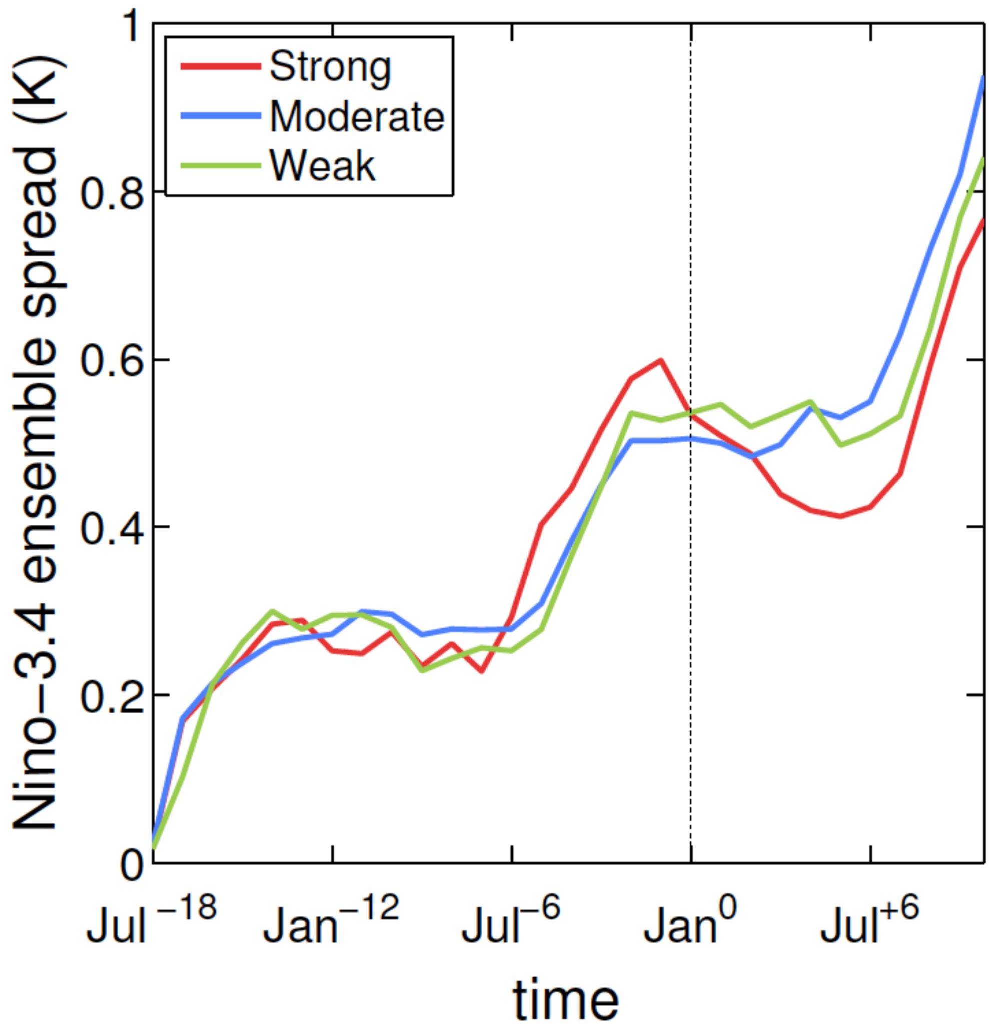
Case 3: strong predictor



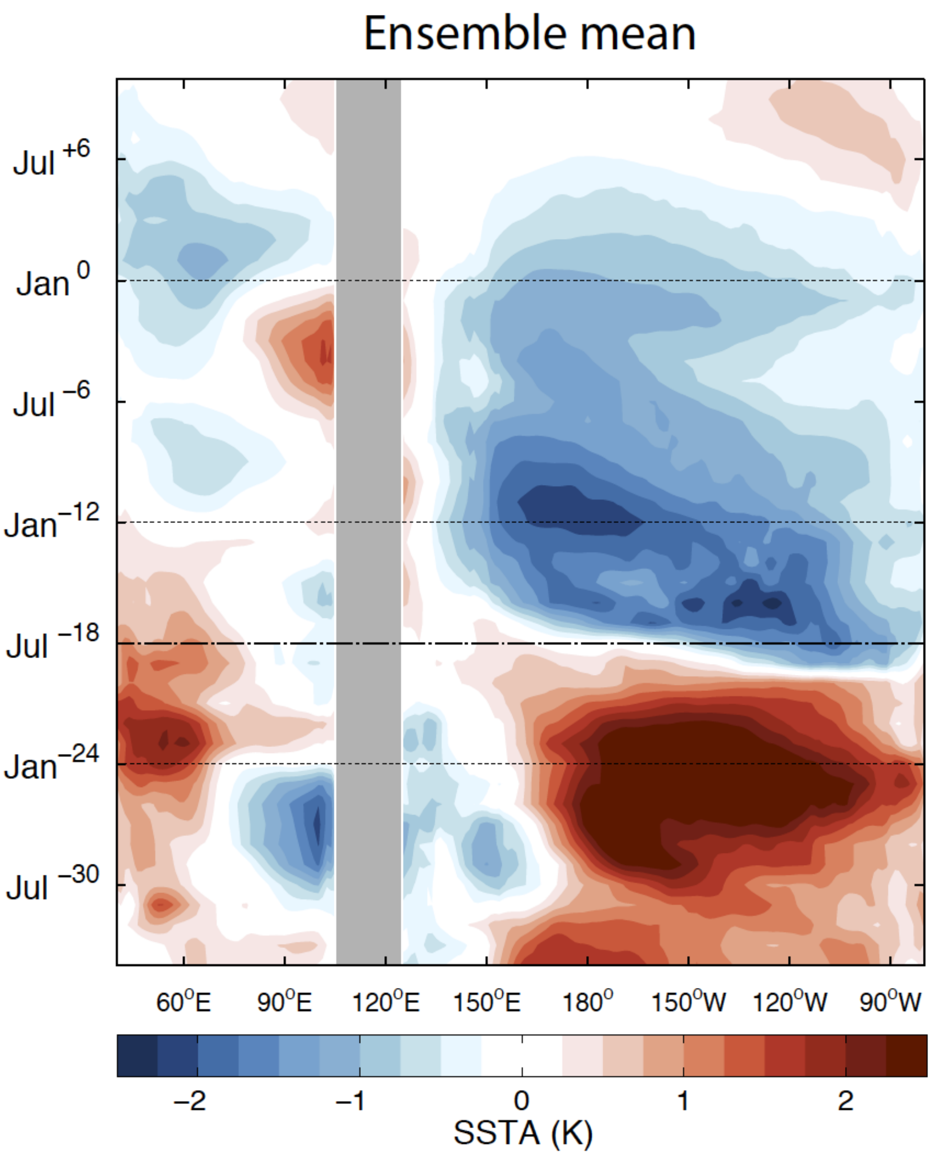
The return of La Nina is highly predictable 18 months in advance



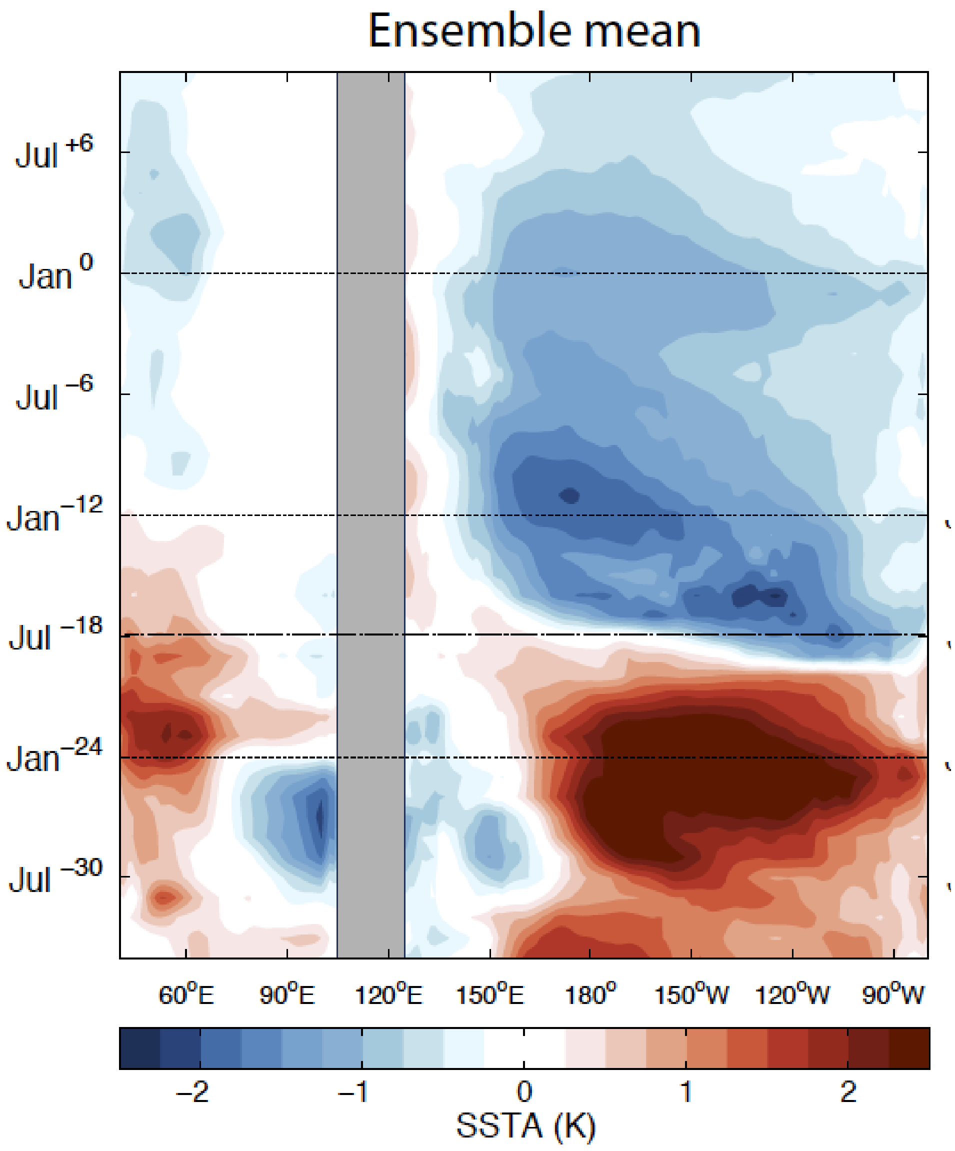
The spread of the forecasts is not sensitive to the initial conditions



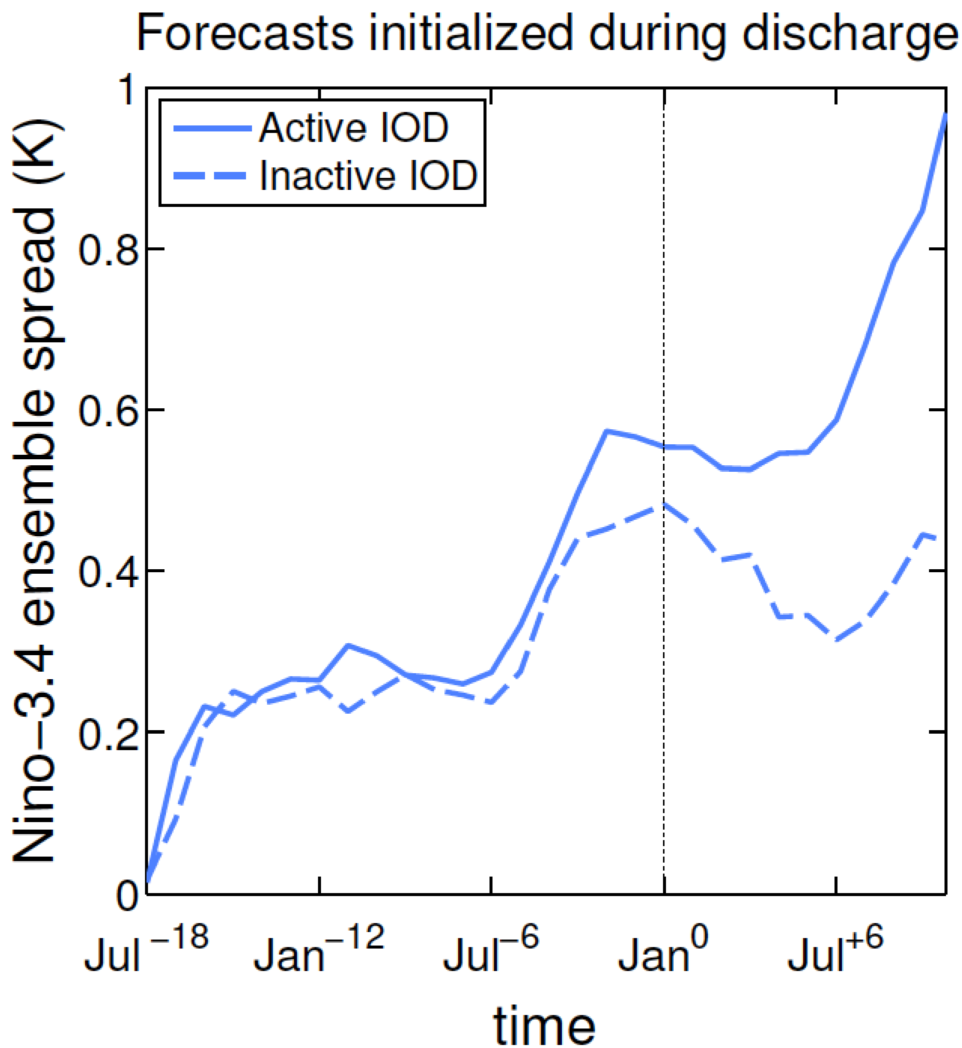
Forecast initialized during discharge phase: moderate case



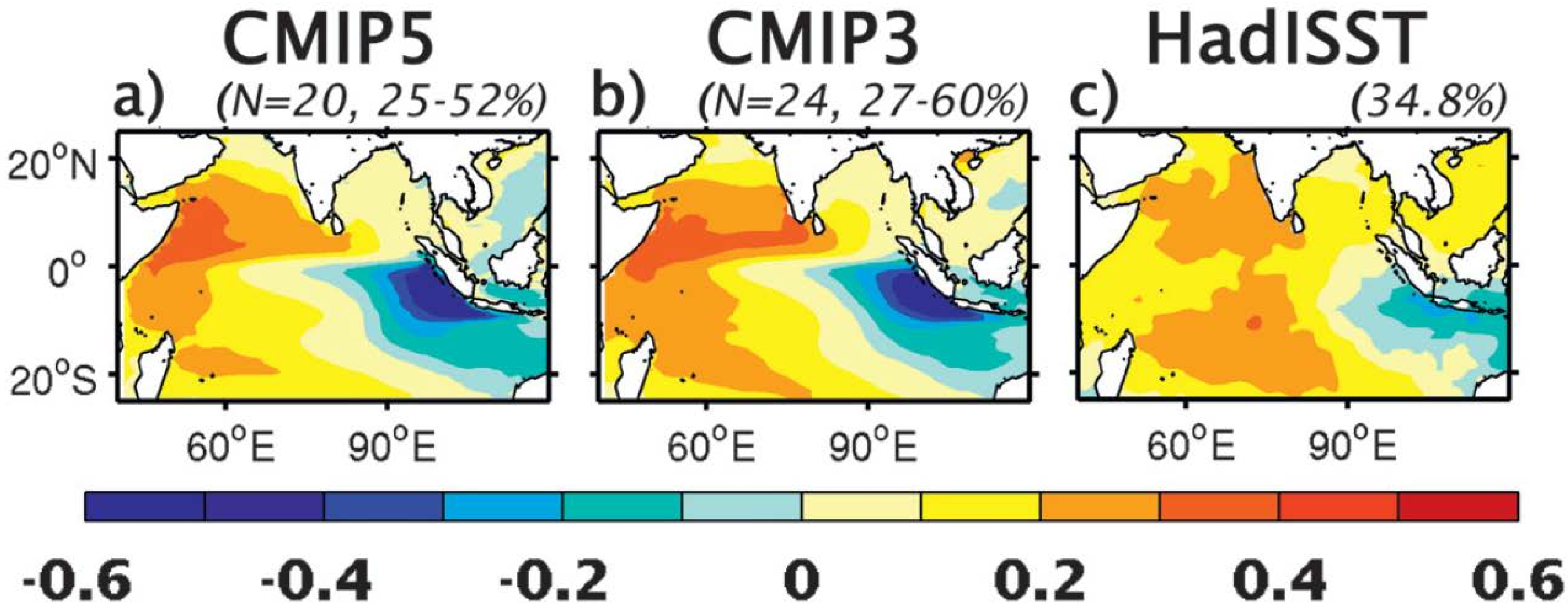
Forecast initialized during discharge phase: moderate case + inactive IOD



The spread of the forecasts is sensitive to variability in the eastern Indian Ocean

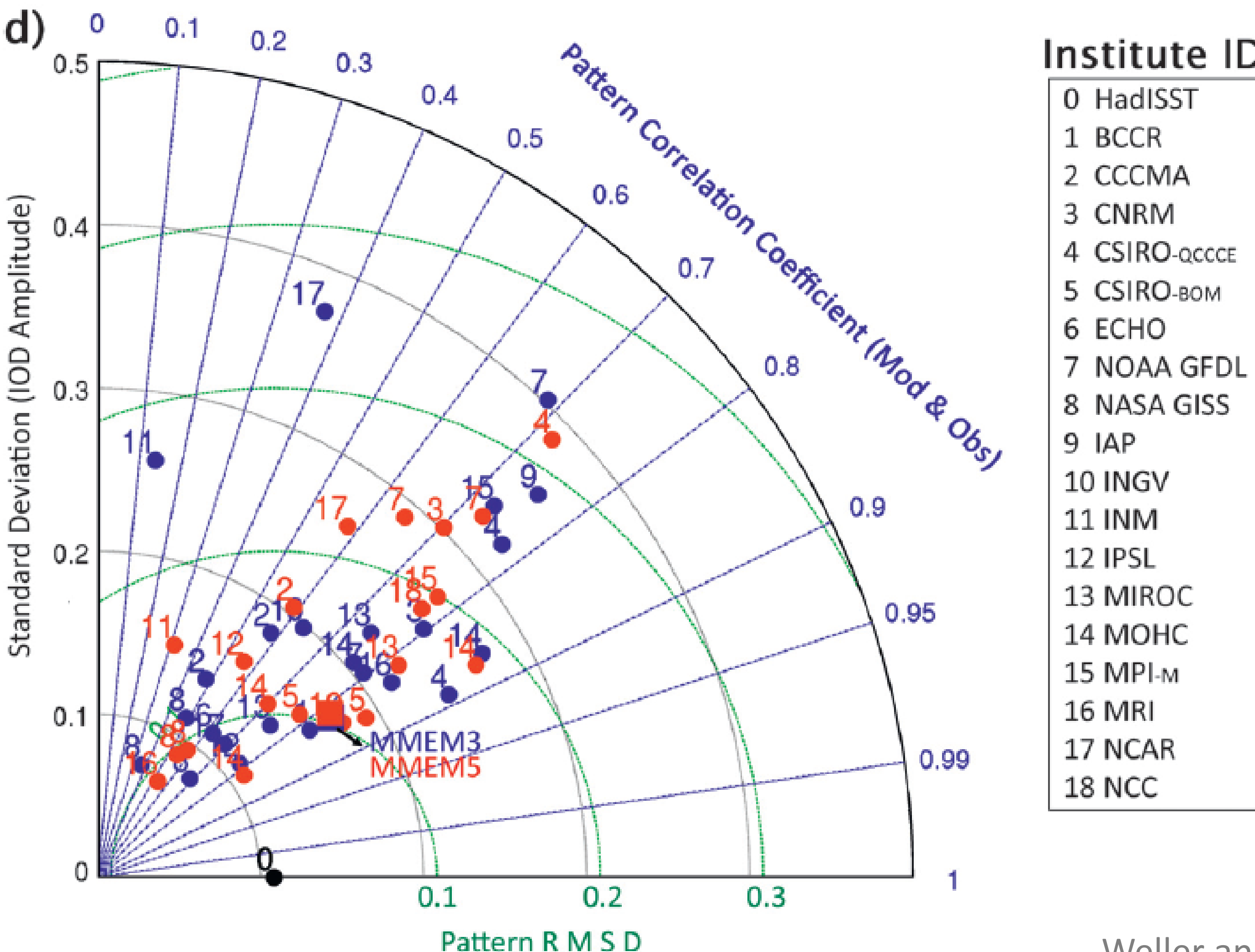


Models simulate too active IOD



Weller and Cai 2013

NCAR models are not the exception



Weller and Cai 2013

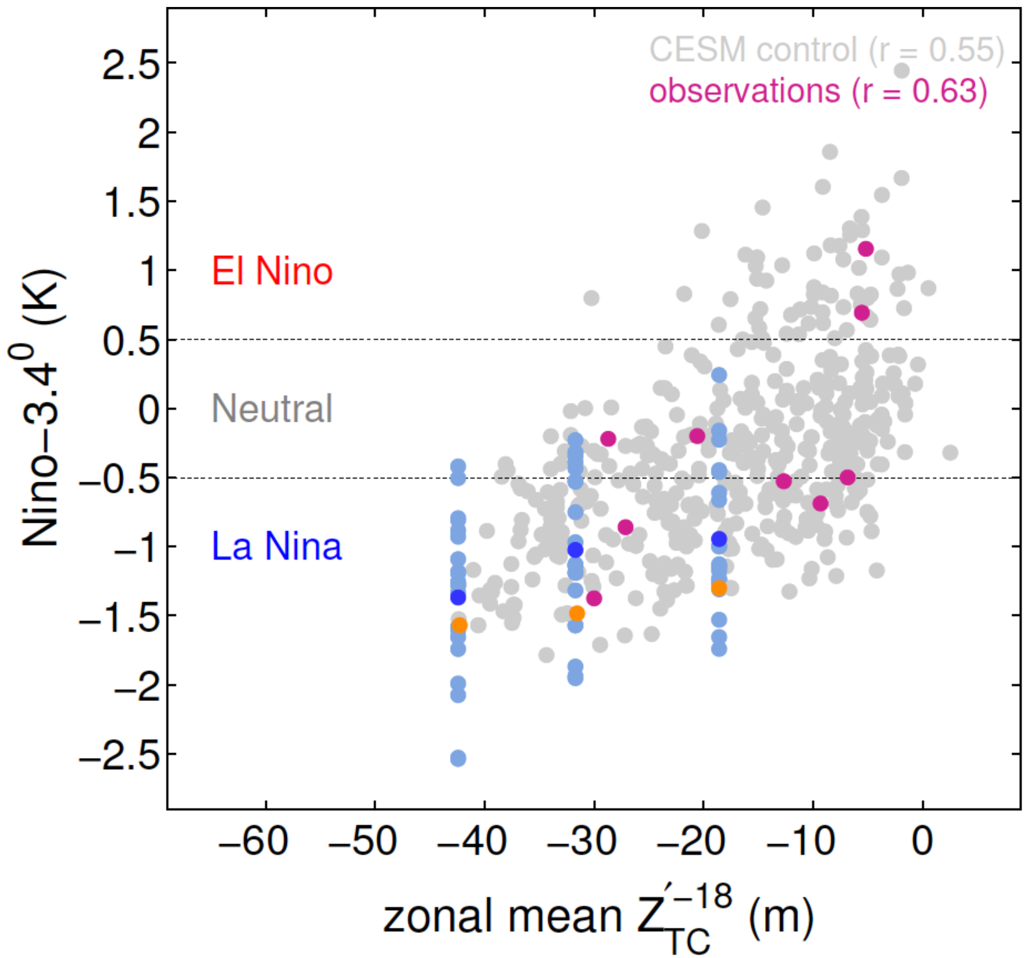
Conclusions

- The return of La Niña is highly predictable in CESM1:
  - Controlled by the depth of thermocline before onset of La Nina.
  - Up to 18 month skillful prediction.

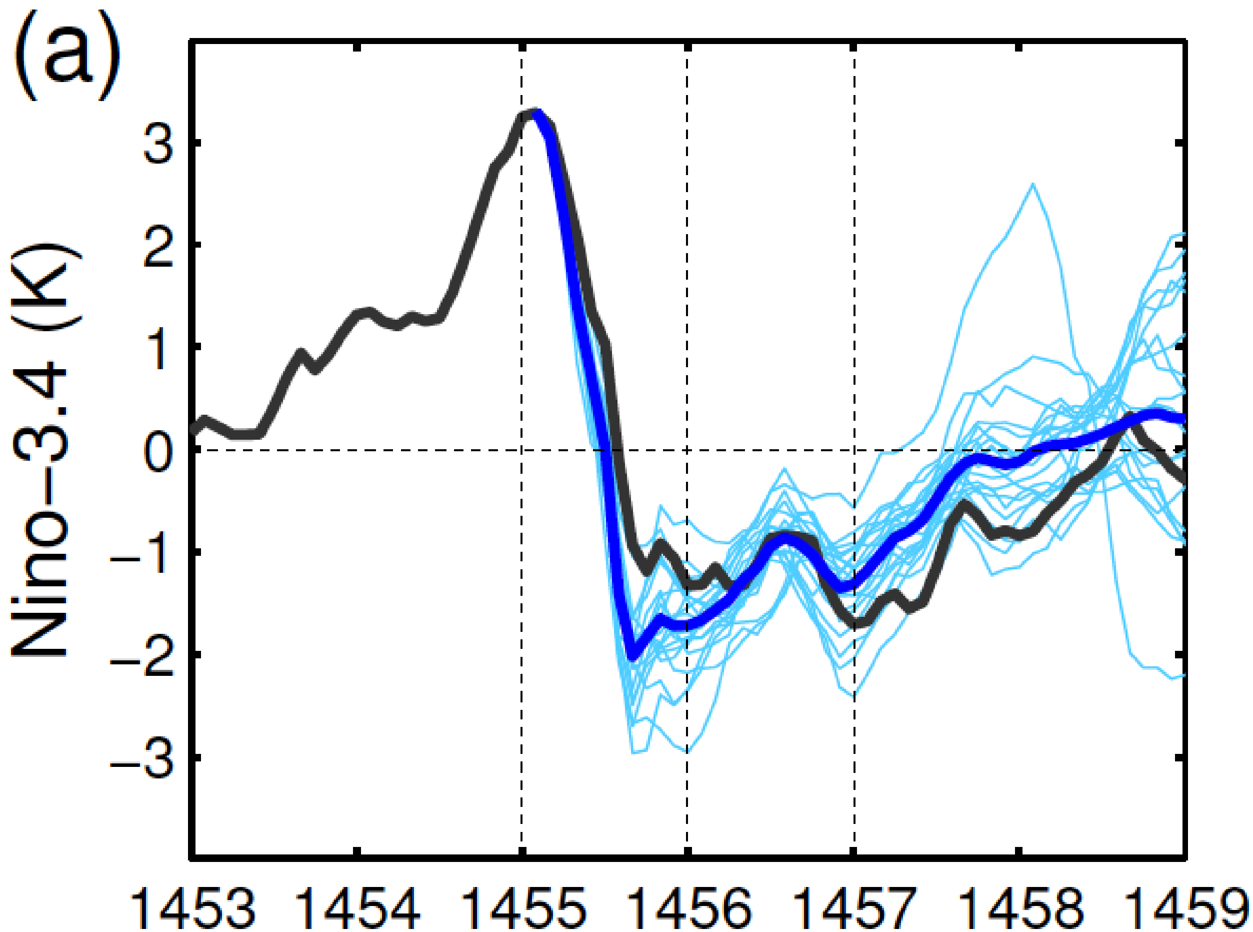
- Too active IOD may lead to unrealistically large spread in forecast
  - Disabling coupled variability over the eastern Indian Ocean reduces the forecast spread by 15%.

Open questions

- Can CESM1's **perfect model** skill be realized in an actual forecast system?
- If a La Nina follows the current El Nino, could we predict its duration?

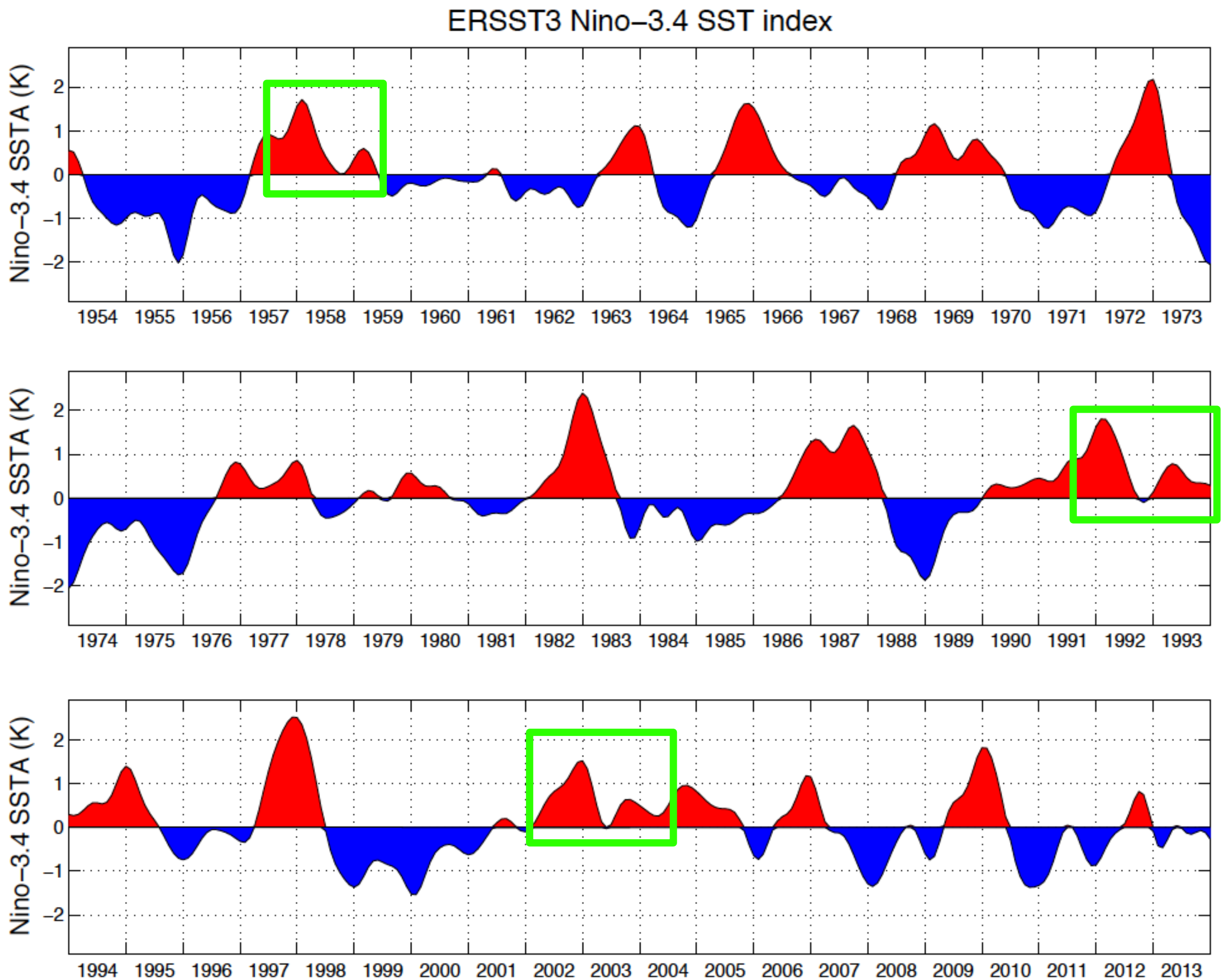


CESM control (r = 0.55)
observations (r = 0.63)
El Nino
Neutral
La Nina
Nino–3.4^0 (K)
zonal mean $Z_{TC}^{\prime -18}$ (m)
2.5
2
1.5
1
0.5
0
–0.5
–1
–1.5
–2
–2.5
–60
–50
–40
–30
–20
–10
0

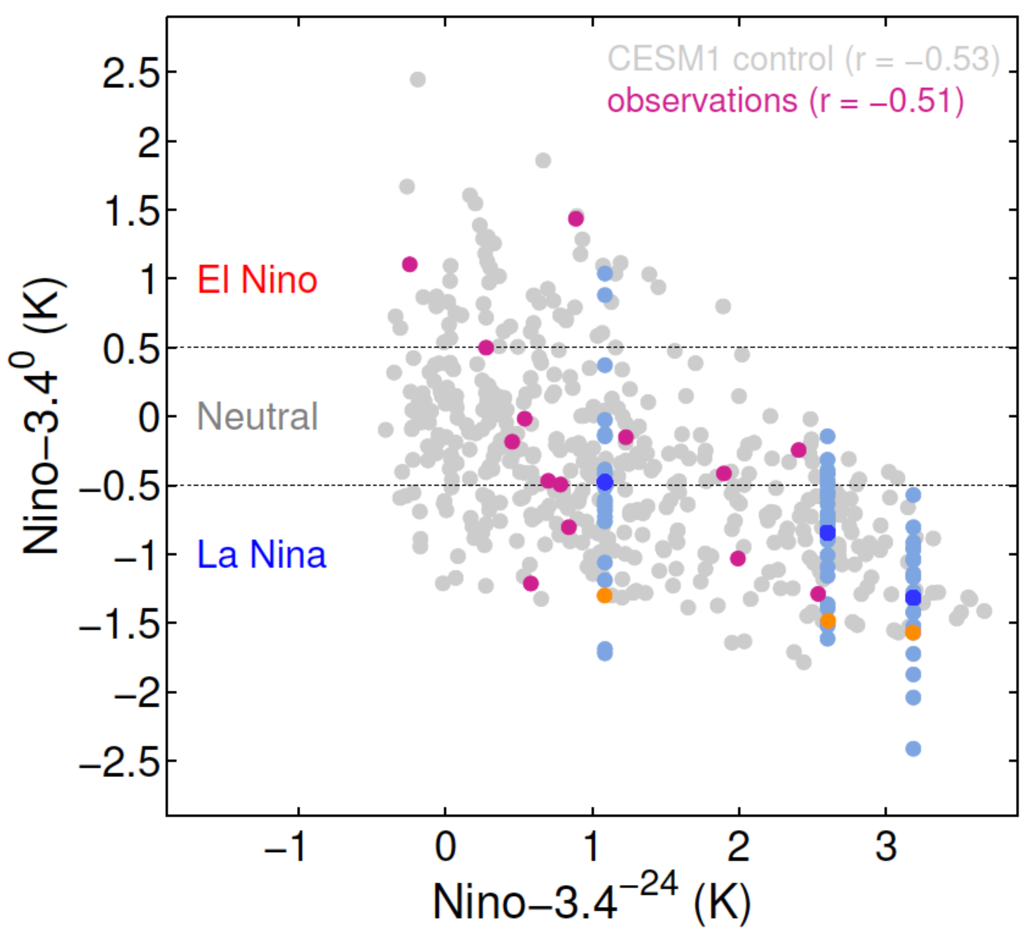


(a)
Nino–3.4 (K)
3
2
1
0
−1
−2
−3
1453
1454
1455
1456
1457
1458
1459

Multi-year La Niña events are very common



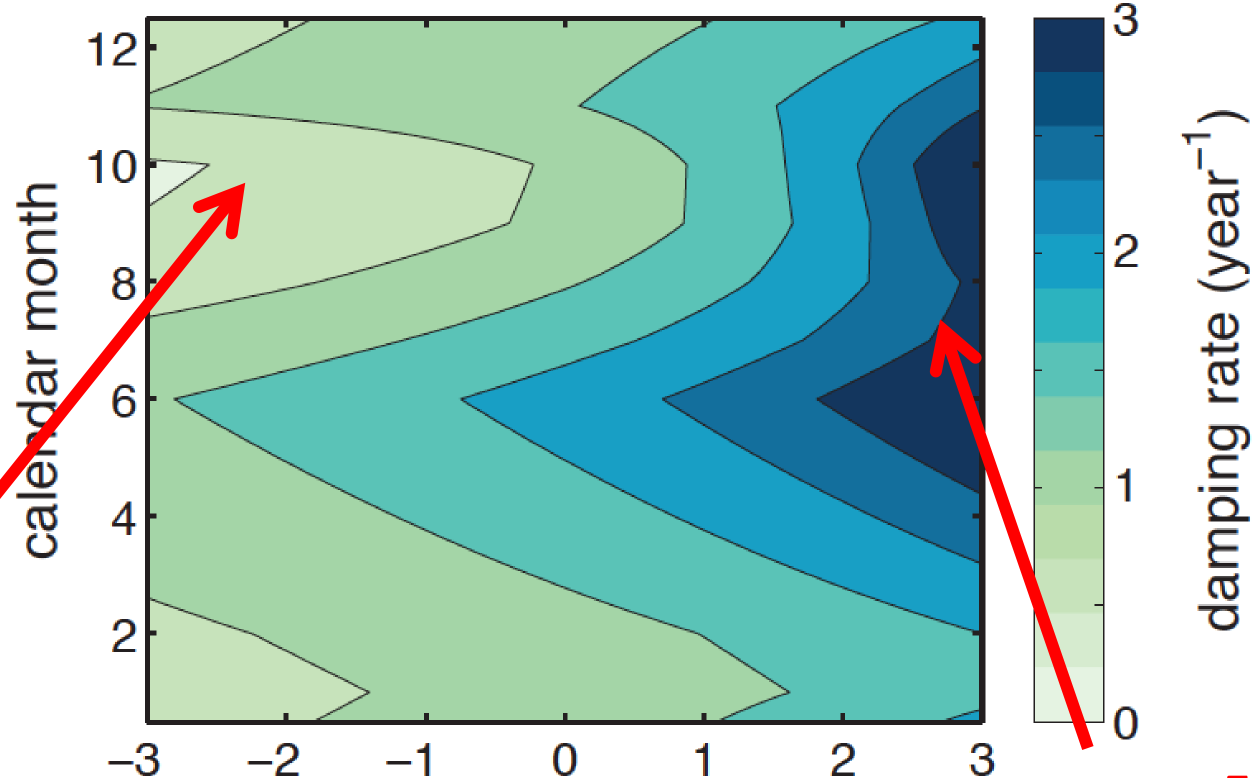
Adapted from Okumura and Deser 2011



CESM1 control (r = –0.53)
observations (r = –0.51)
El Nino
Neutral
La Nina
2.5
2
1.5
1
0.5
0
–0.5
–1
–1.5
–2
–2.5
–1
0
1
2
3
Nino–3.4^0 (K)
Nino–3.4^–24 (K)

Delayed thermocline feedback controls the termination of La Nina

Nonlinear and seasonally-dependent delayed thermocline feedback derived from CCSM4



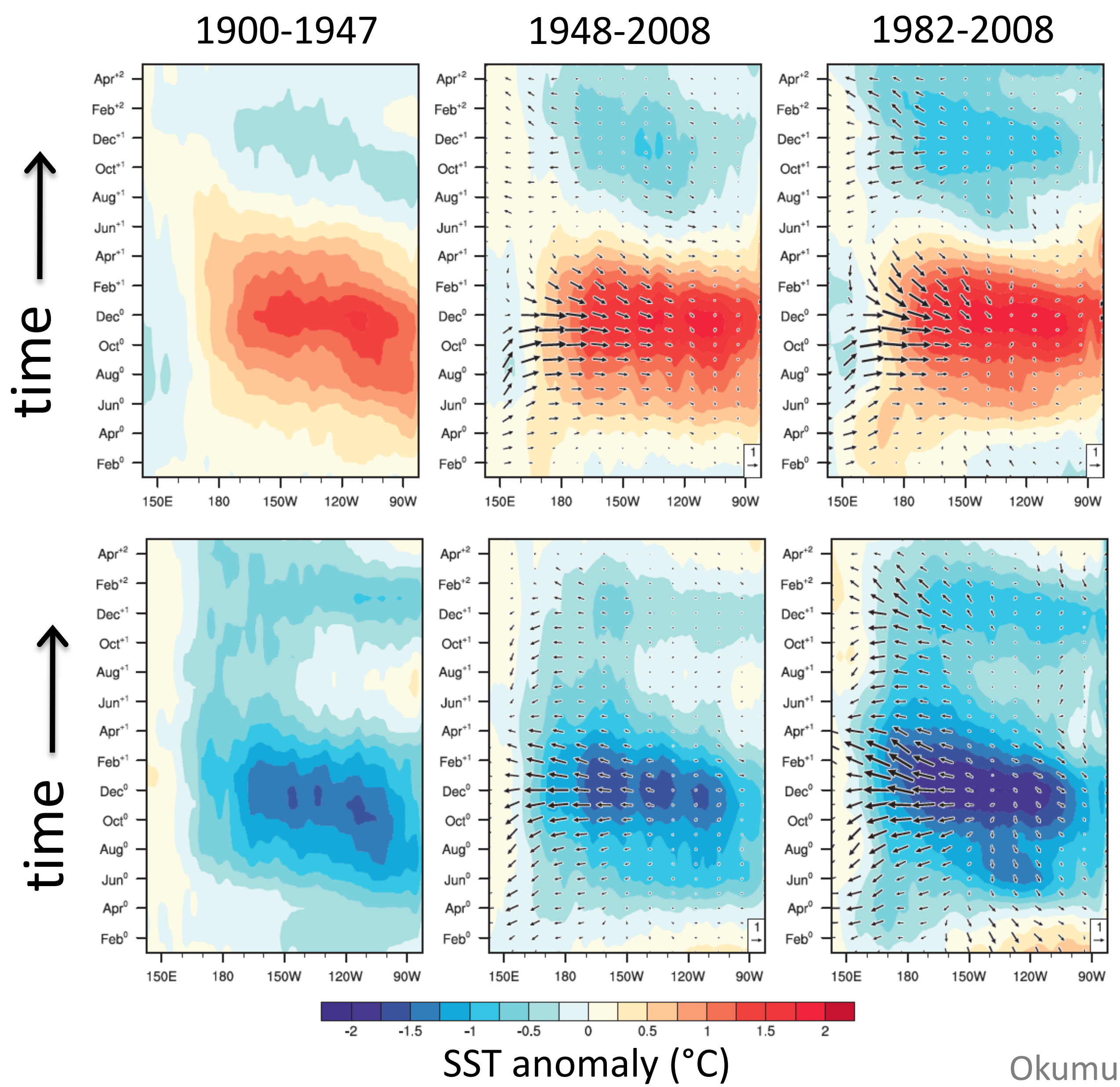
strong La Nina events have weaker damping rates

La Nina

El Nino

strong El Nino events have strong damping rates

Asymmetry in the duration of El Niño and La Niña



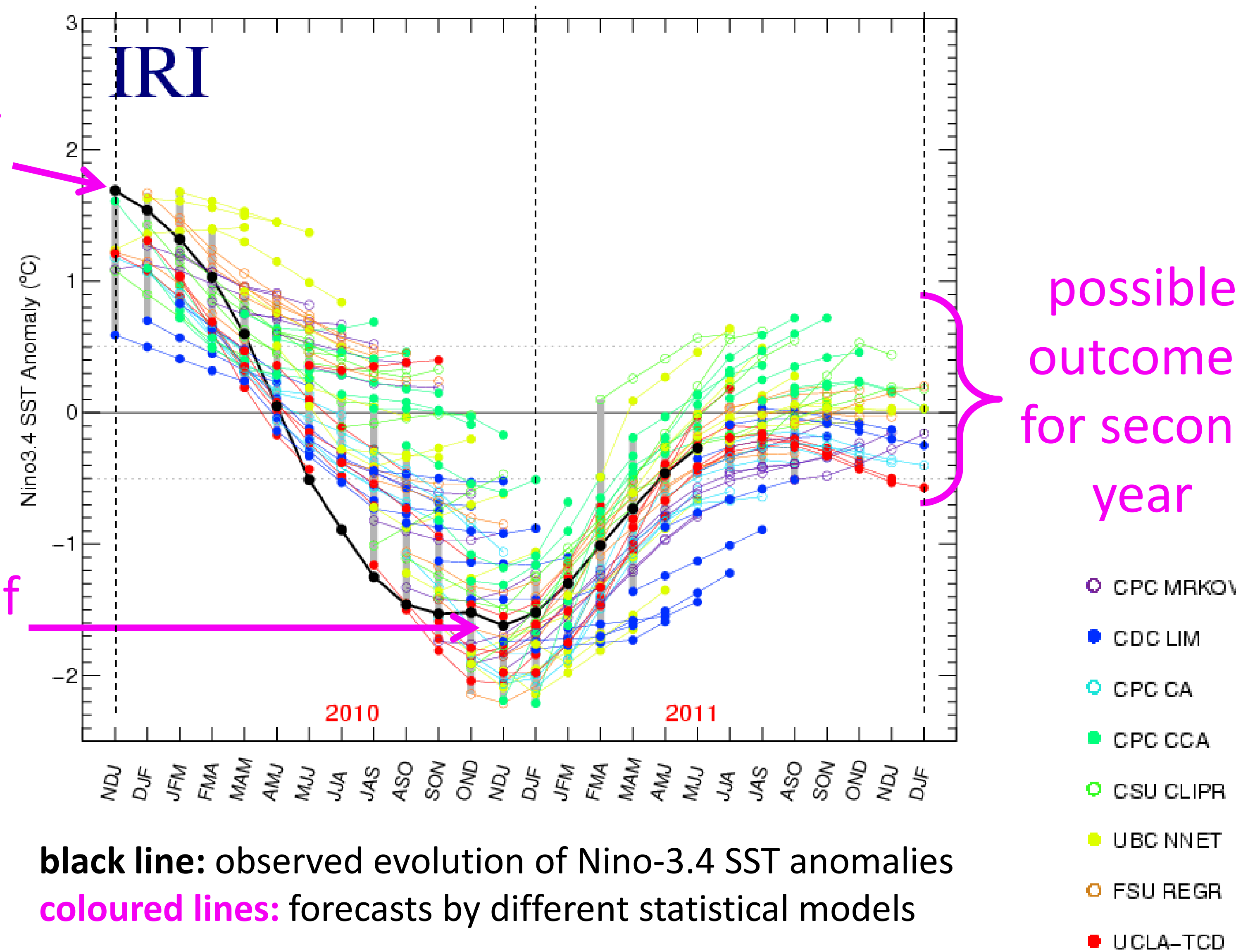
Okumura and Deser 2010

Predicting the return of La Niña is very challenging

ENSO predictions for statistical models, JJA 2011

El Niño of 2009-10

La Niña of 2010-11

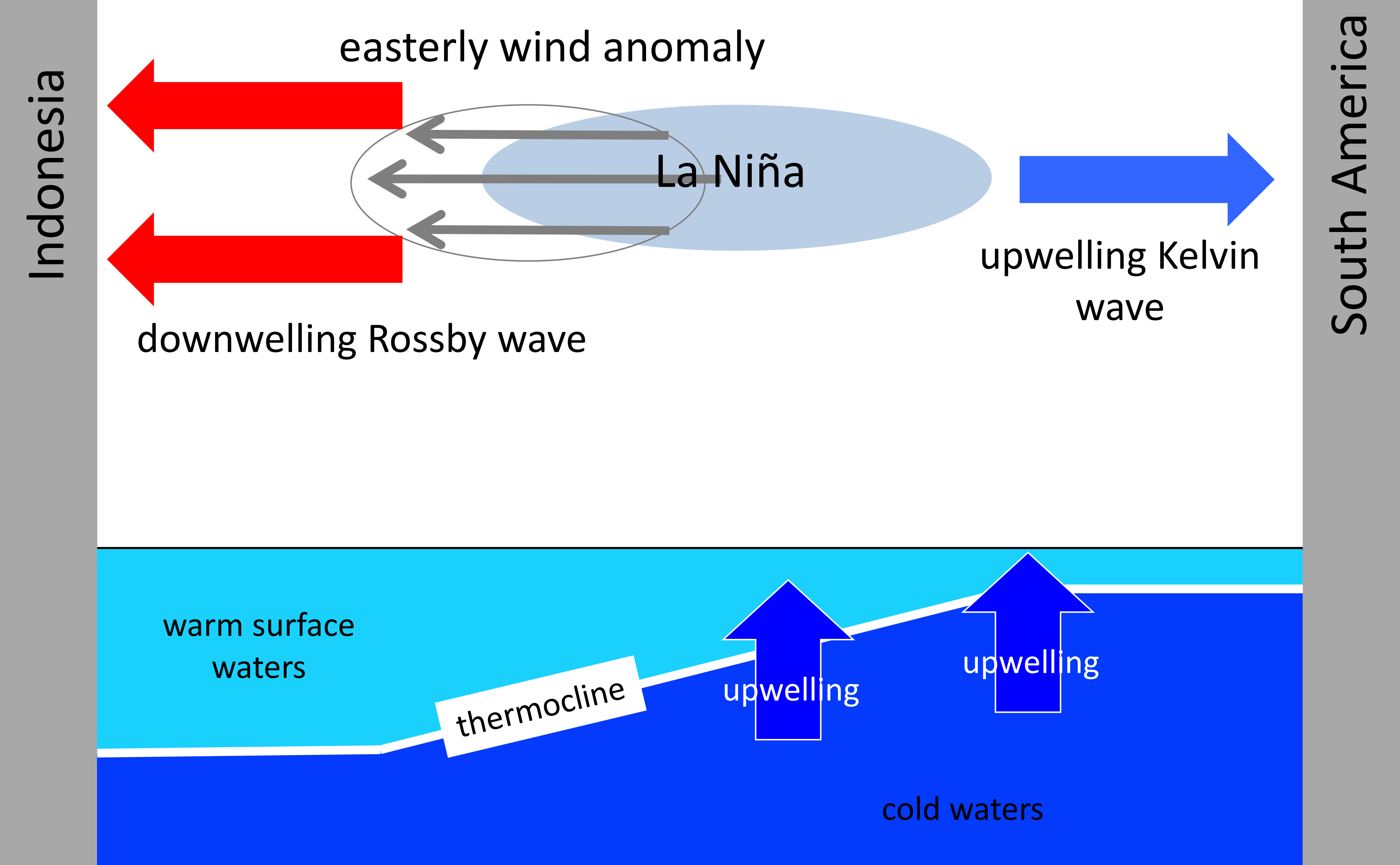


possible outcomes for second year

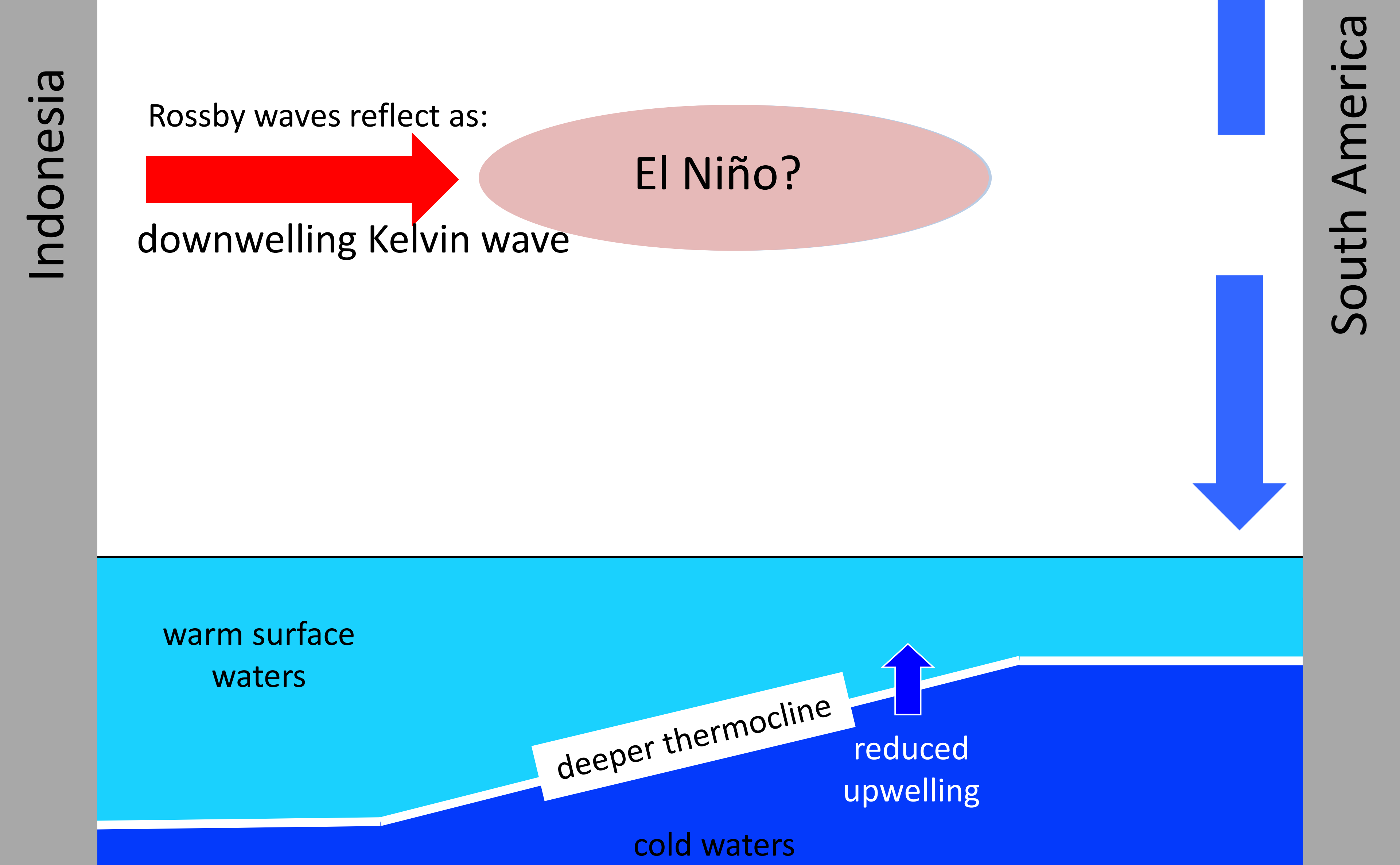
black line: observed evolution of Nino-3.4 SST anomalies

coloured lines: forecasts by different statistical models

Growth phase (Bjerknes feedback)



Decay phase
(delayed thermocline feedback)



Decay phase
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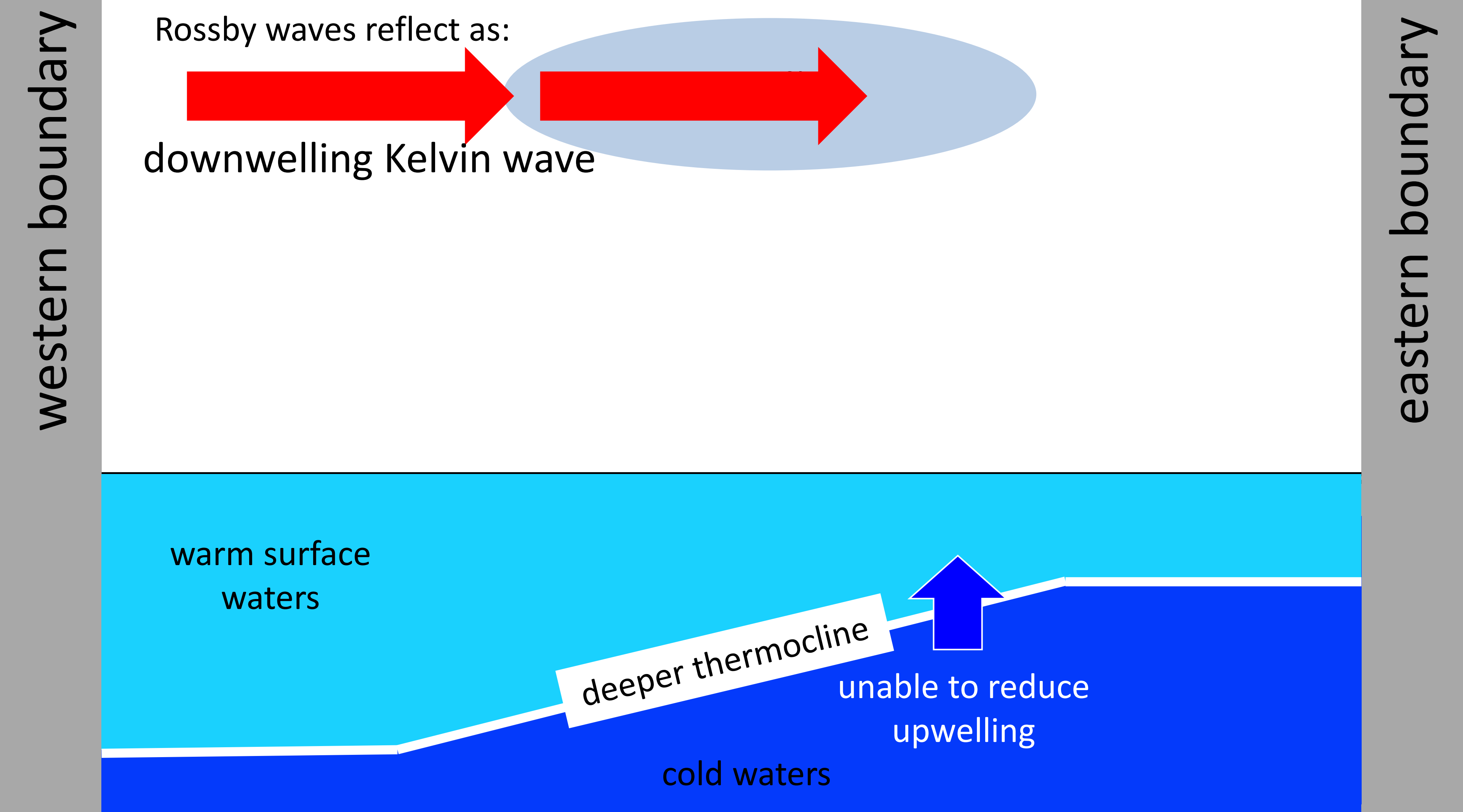
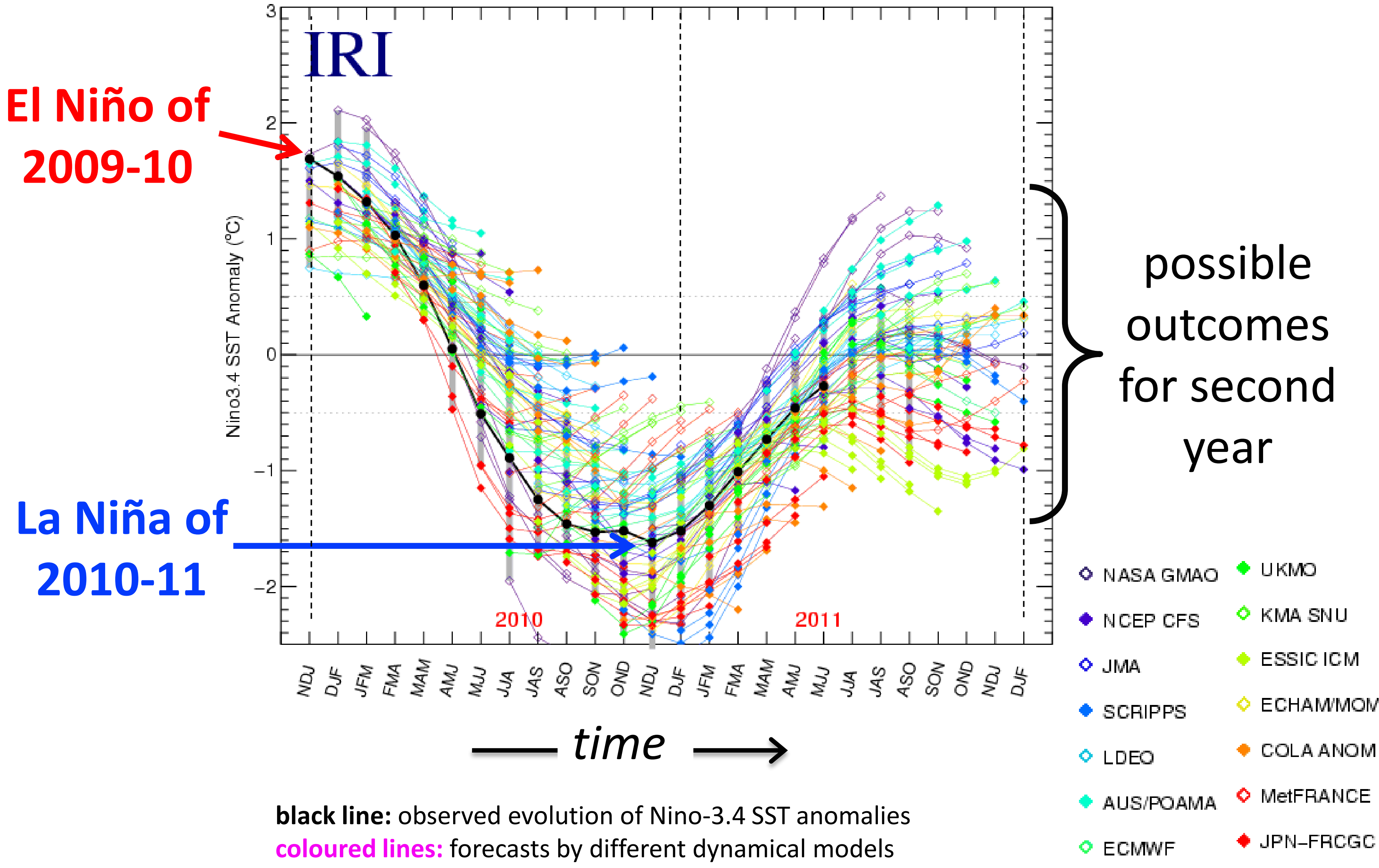


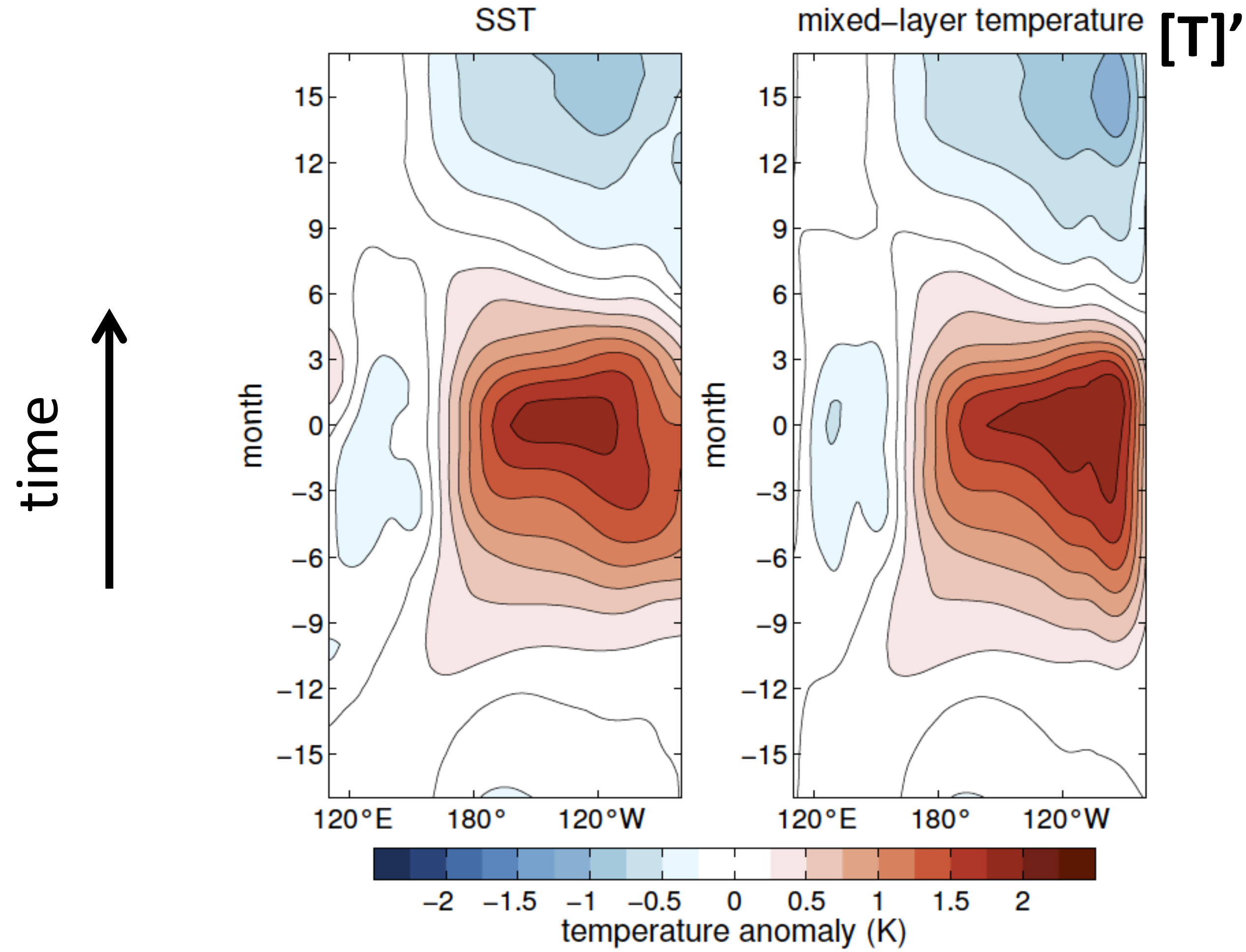
For instance, the return of the 2011-2012 La Niña

ENSO predictions initialized during summer of 2011



black line: observed evolution of Nino-3.4 SST anomalies
coloured lines: forecasts by different dynamical models

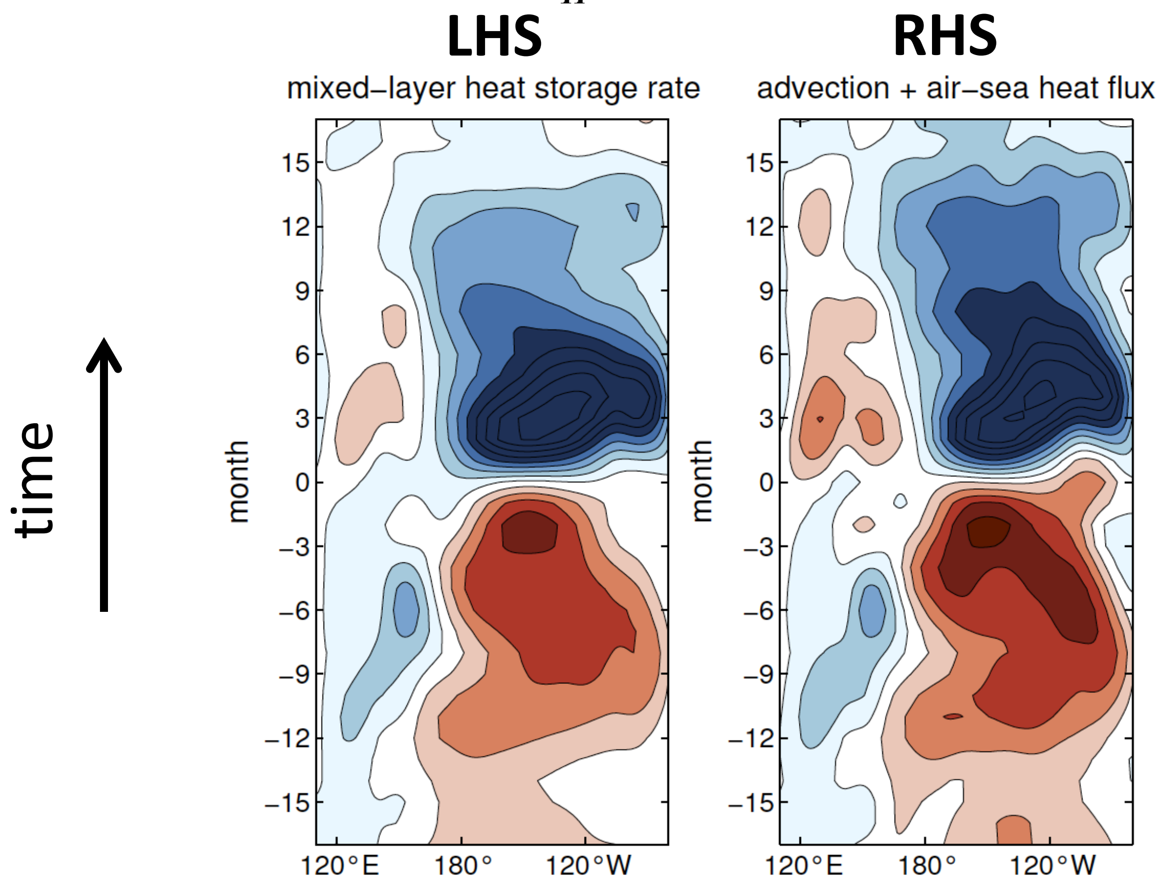
[*T*]' approximates *SST* anomalies very well



Allows us to use the heat budget to diagnose processes driving ENSO SST anomalies

Step 1: ENSO heat budget

$$\rho_0 c_p H \frac{\partial [T']}{\partial t} \cong -\rho_0 c_p \int_{-H}^{0} \left(\mathbf{u}' \cdot \nabla \overline{T} + \overline{\mathbf{u}} \cdot \nabla T' + \mathbf{u}' \cdot \nabla T' \right) dz + Q'_{atm}$$



Negative tendencies during transition to La Nina

← El Nino peak

Positive tendencies during EN growth

Balanced heat budget on ENSO timescales