Mechanisms of Multi-year ENSO predictability

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With:
Lisa Goddard (IRI)
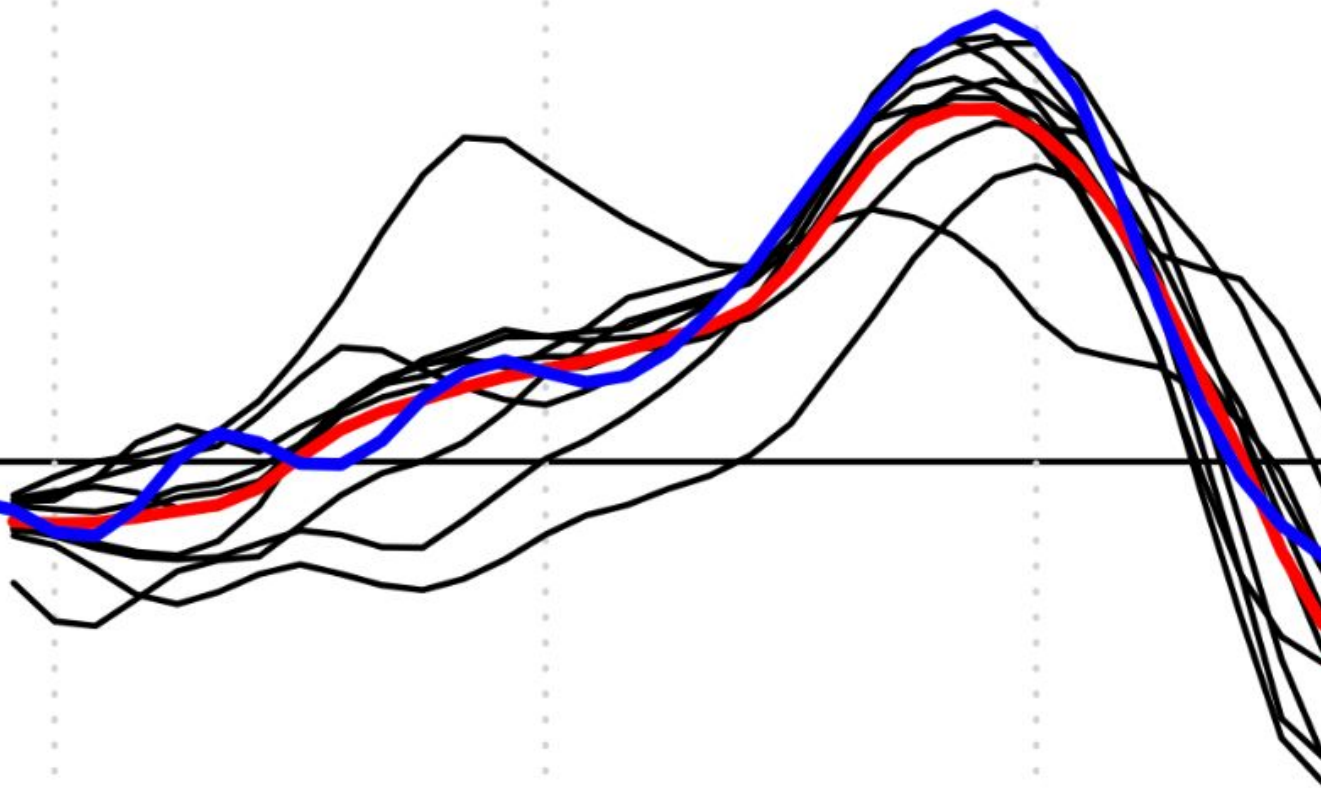*Pedro DiNezio (CU Boulder)*

Yochanan Kushnir (LDEO)
Simon Mason (IRI)
Matt Newman (NOAA)
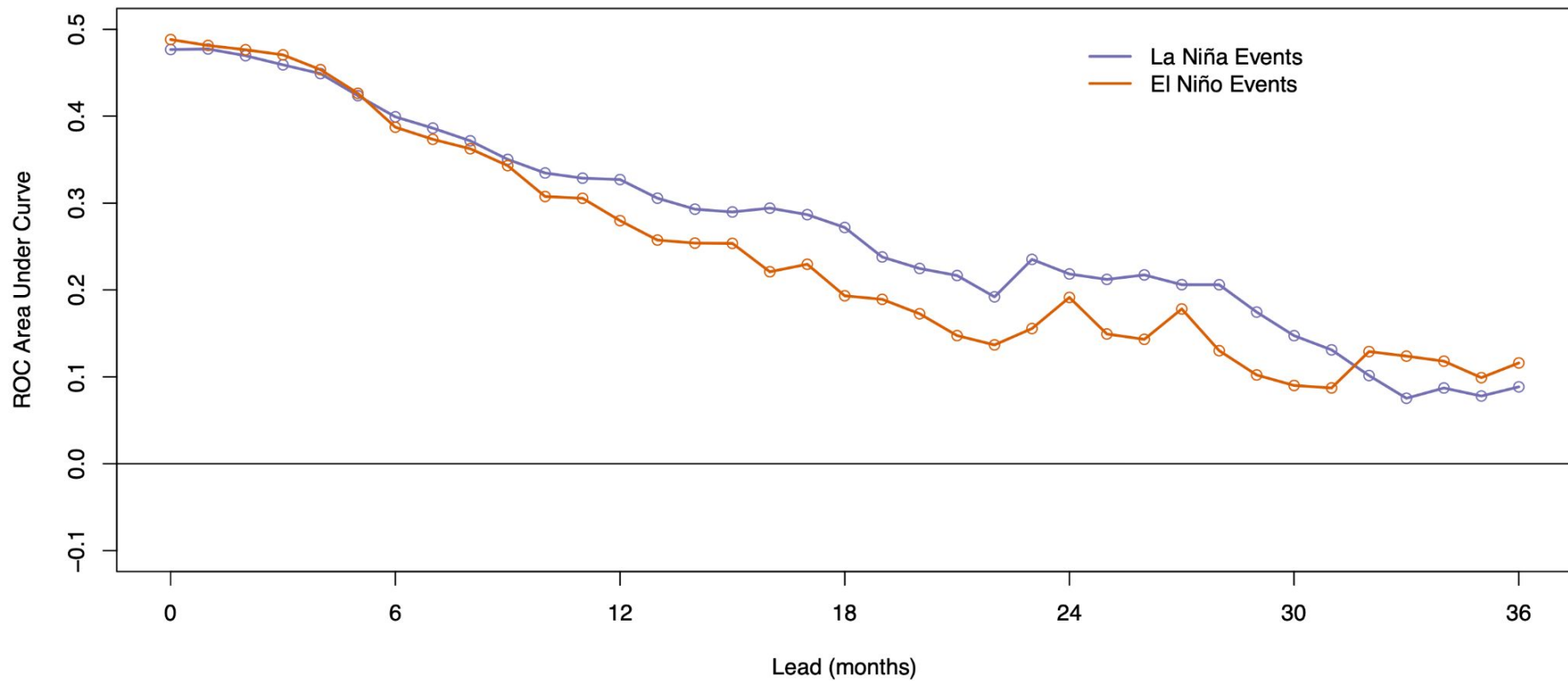Clara Deser (NCAR)
Xian Wu (NCAR)
Yuko Okumura (UT Austin)
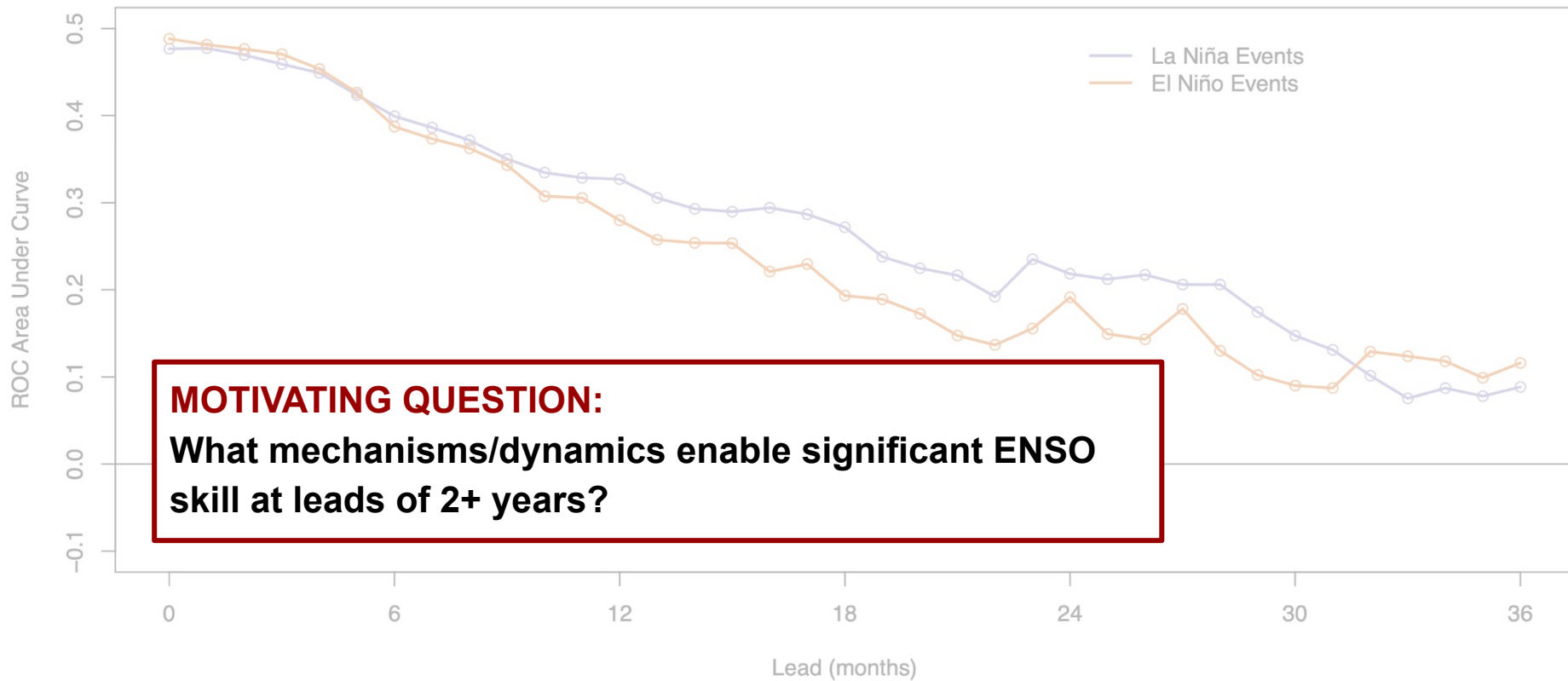
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NSF

DJF Probabilistic ENSO Detection Skill (Perfect Model, CESM1−1−CAM5−CMIP5)

La Niña Events
El Niño Events

ROC Area Under Curve

Lead (months)

DJF Probabilistic ENSO Detection Skill (Perfect Model, CESM1−1−CAM5−CMIP5)

MOTIVATING QUESTION:
What mechanisms/dynamics enable significant ENSO skill at leads of 2+ years?

Potentially Predictable Multi-Year ENSO Events

EN -> **LN**: La Niña usually follows El Niño *(Suarez & Schopf 1988; Many others)*

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# Potentially Predictable Multi-Year ENSO Events

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Large EN -> **LN** -> **LN:** Double La Niña events are most predictable when preceded by large El Niño events *(DiNezio et al. 2017; Wu et al. 2019; Wu et al. 2021b)*
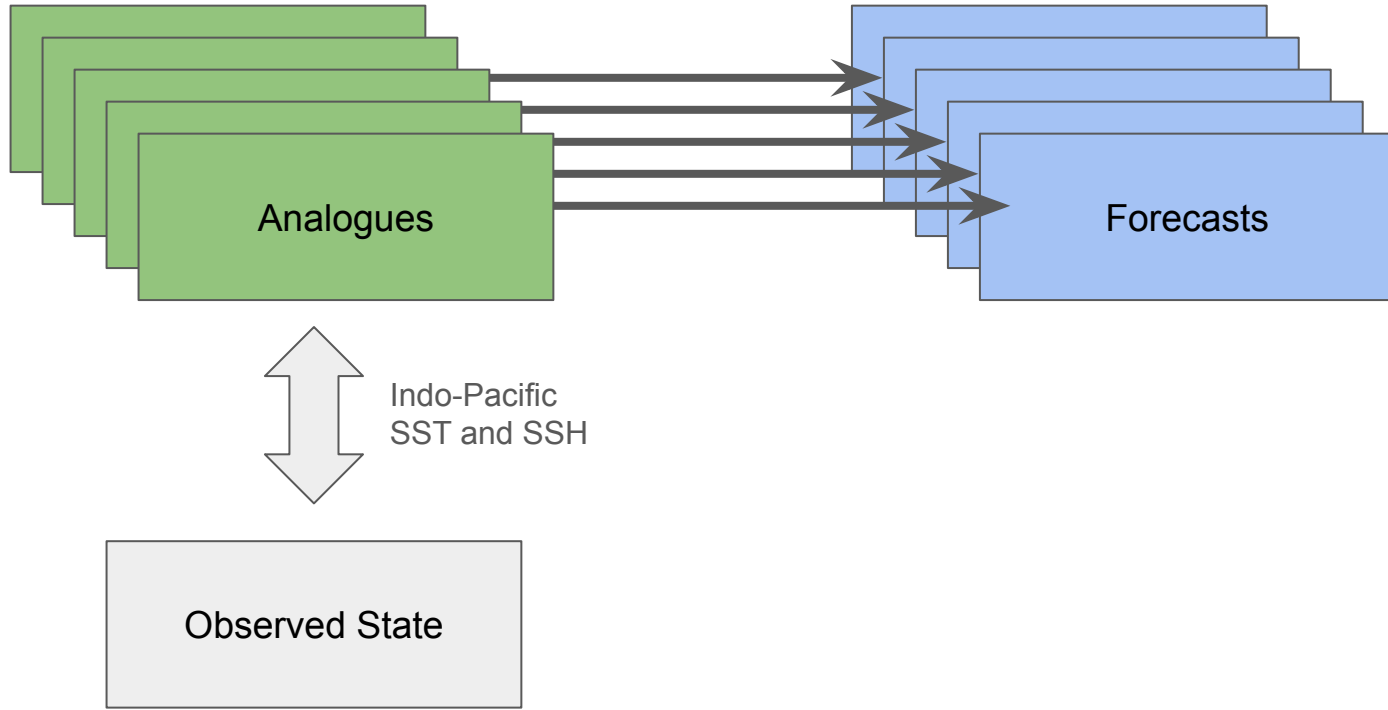
Late Onset EN -> **Second Year EN:** Late onset of El Niño increases the chance of a second El Niño event *(Wu et al. 2019; Wu et al. 2021a; Wu et al. 2021b)*

Method: Model-Analogue Forecasts
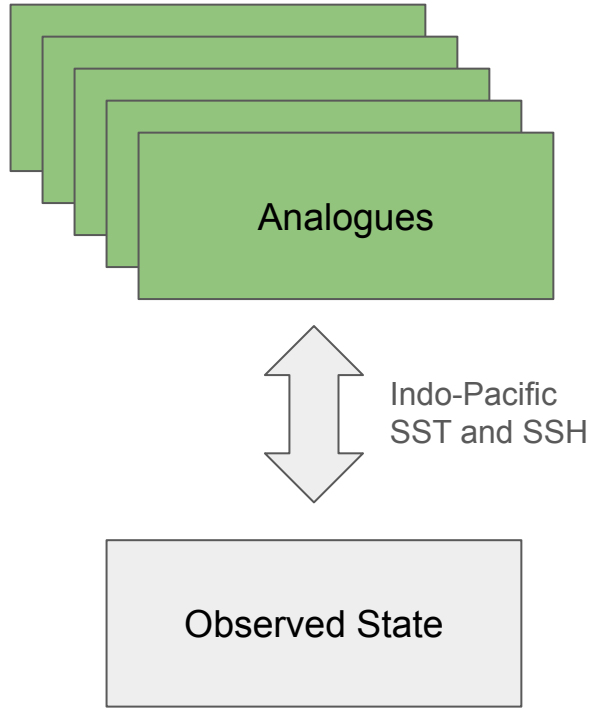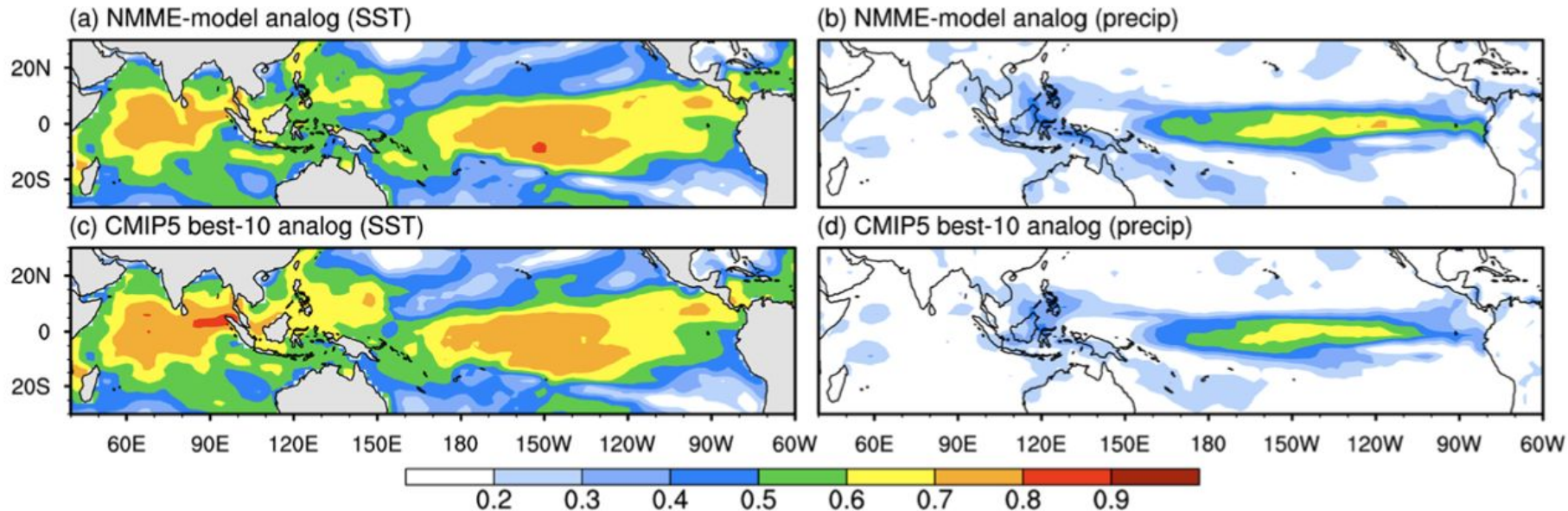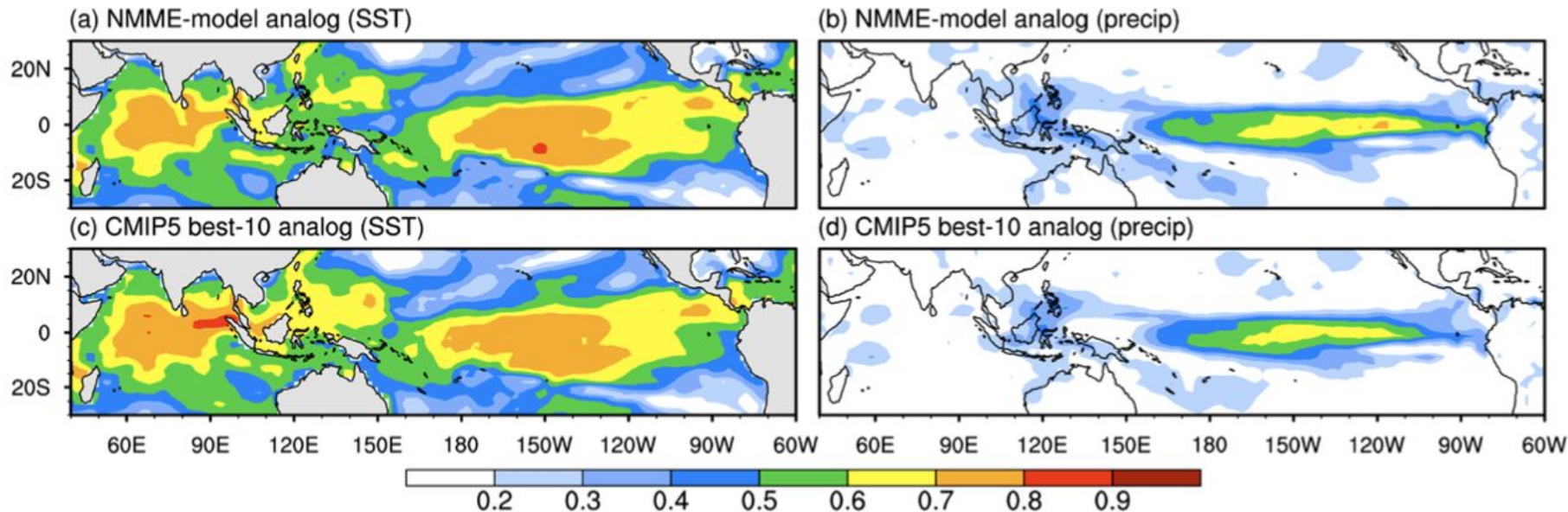
Method: Model-Analogue Forecasts

Analogues

Indo-Pacific
SST and SSH

Observed State

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6-Month Lead Anomaly Correlation

(a) NMME-model analog (SST)

(b) NMME-model analog (precip)

(c) CMIP5 best-10 analog (SST)

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(Ding et al. 2019, GRL)

Method: Model-Analogue Forecasts

6-Month Lead Anomaly Correlation

(a) NMME-model analog (SST)
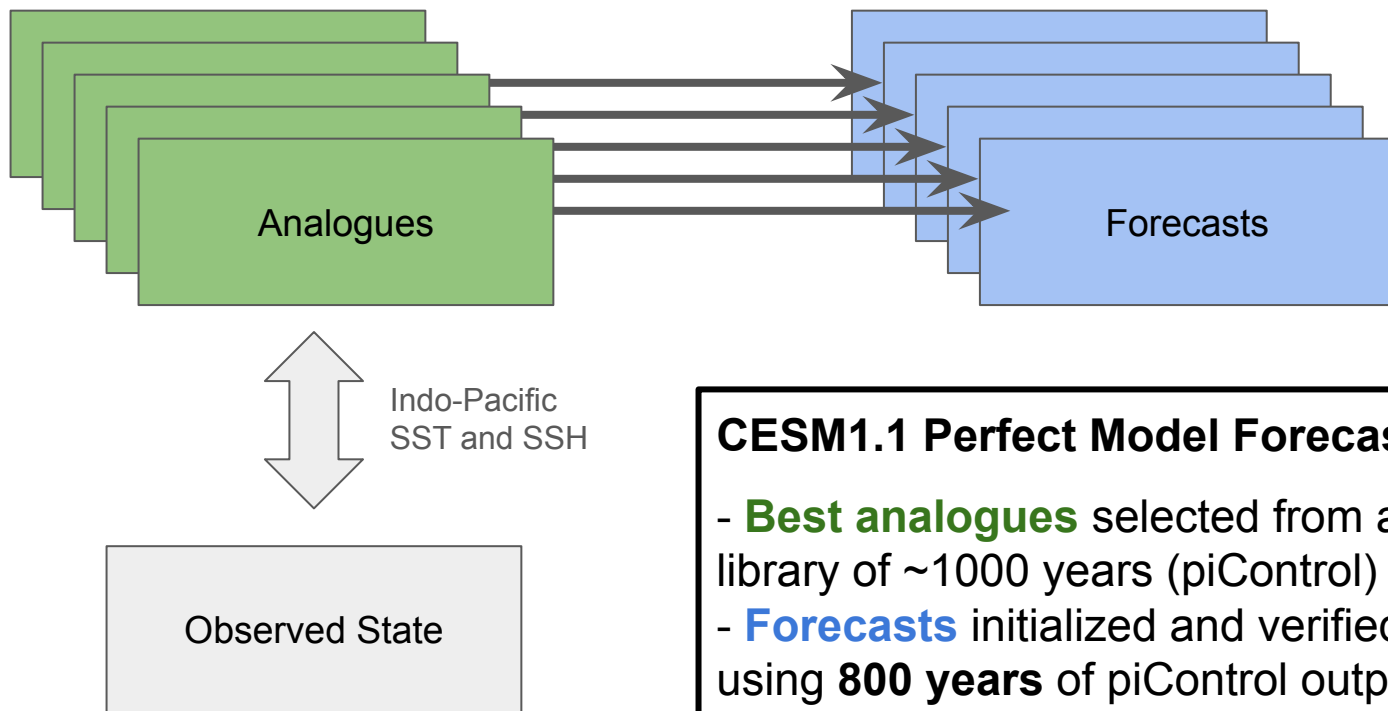(b) NMME-model analog (precip)
(c) CMIP5 best-10 analog (SST)
(d) CMIP5 best-10 analog (precip)

Model-analogue forecasts show comparable hindcast skill to the NMME (Ding et al. 2018, 2019, 2020)

(Ding et al. 2019, GRL)

Method: Perfect Model-Analogue Forecasts

Analogues

Forecasts

Indo-Pacific
SST and SSH

Observed State

CESM1.1 Perfect Model Forecasts:

- **Best analogues** selected from a library of ~1000 years (piControl)
- **Forecasts** initialized and verified using **800 years** of piControl output
- Runs on my laptop in ~1 hour!

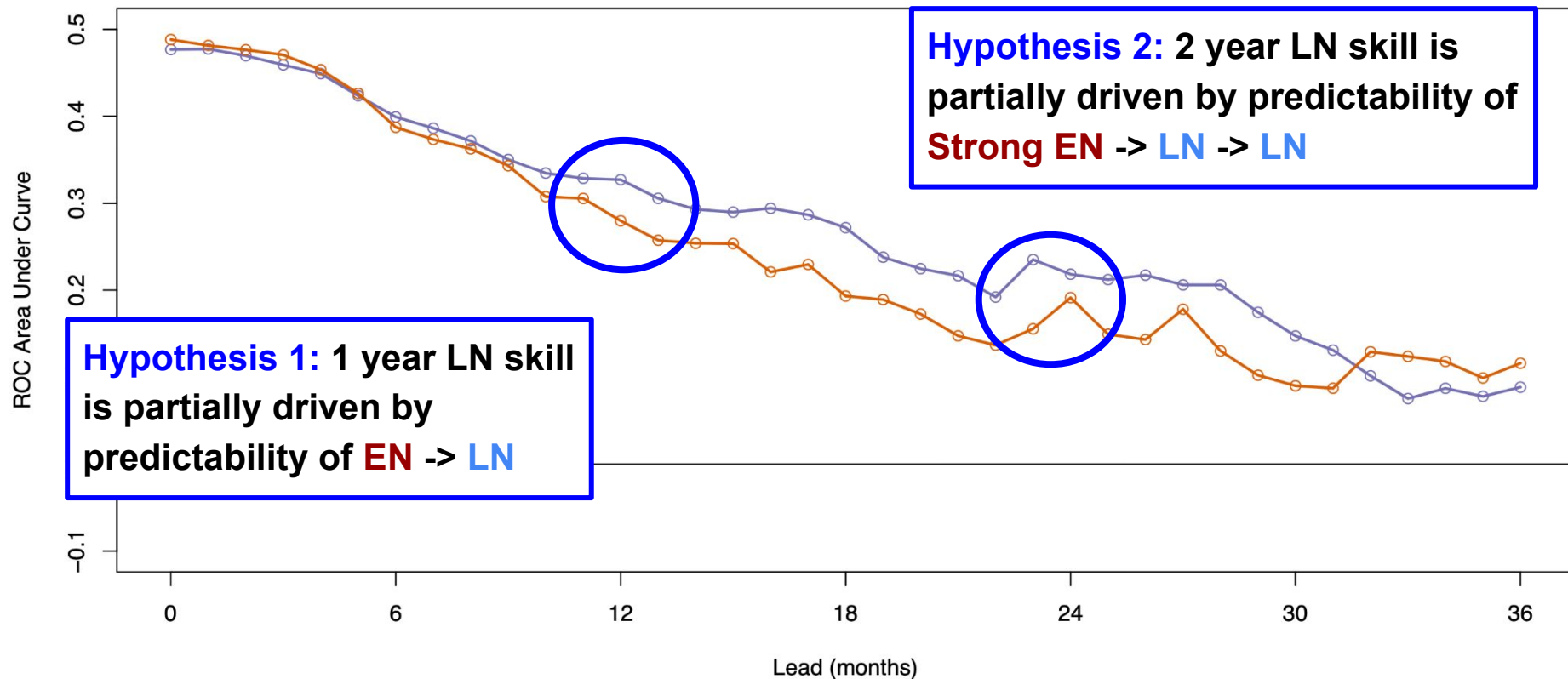DJF Probabilistic ENSO Detection Skill (Perfect Model, CESM1–1–CAM5–CMIP5)
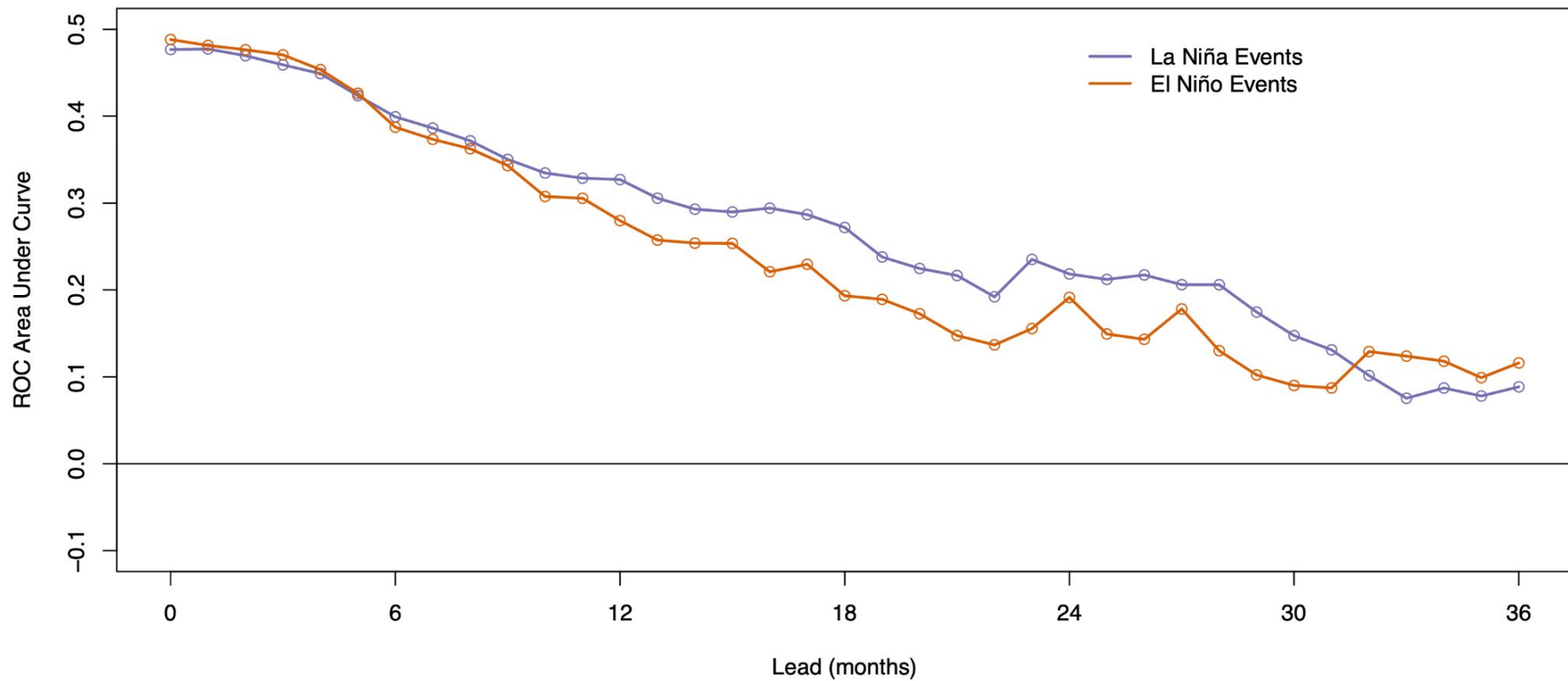
**DJF Probabilistic ENSO Detection Skill (Perfect Model, CESM1−1−CAM5−CMIP5)**
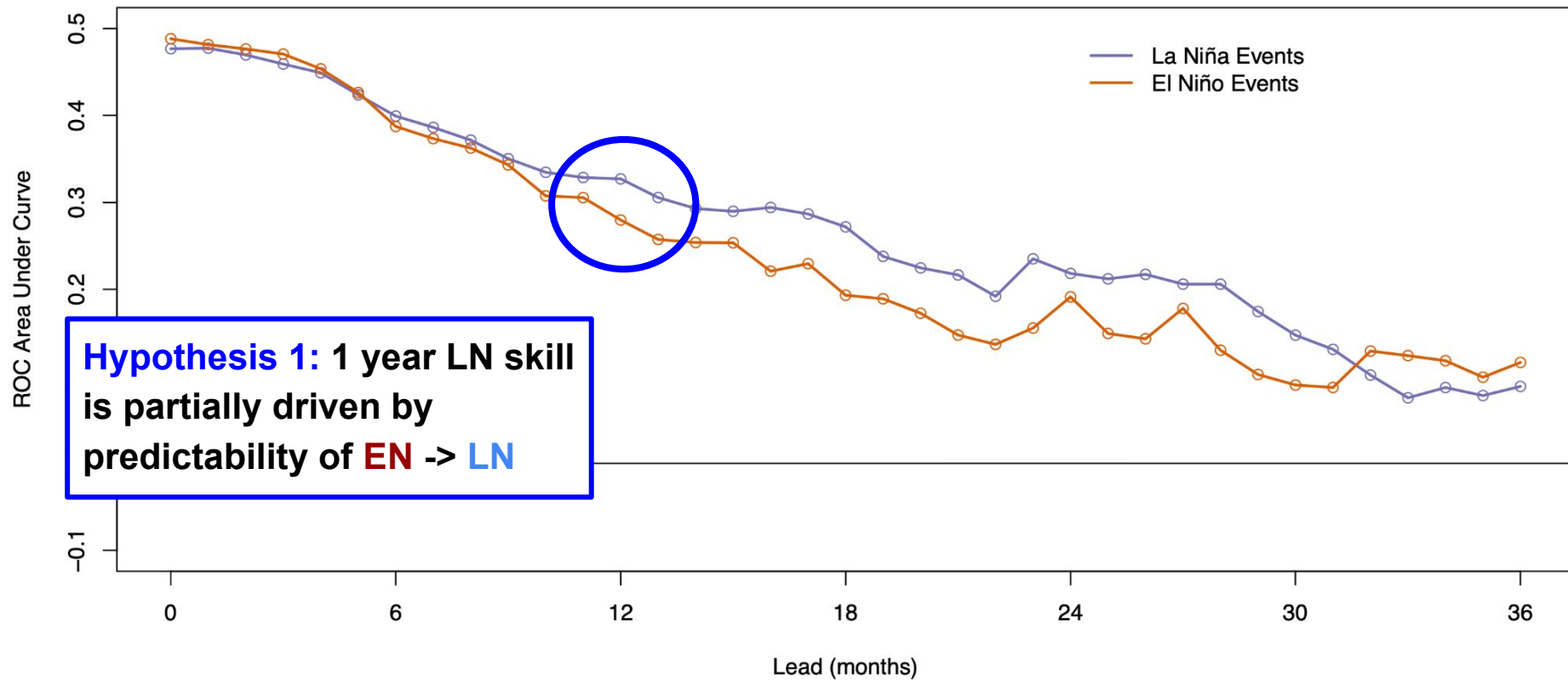
Hypothesis 1: 1 year LN skill is partially driven by predictability of EN -> LN

DJF Probabilistic ENSO Detection Skill (Perfect Model, CESM1–1–CAM5–CMIP5)

Hypothesis 2: 2 year LN skill is partially driven by predictability of Strong EN -> LN -> LN
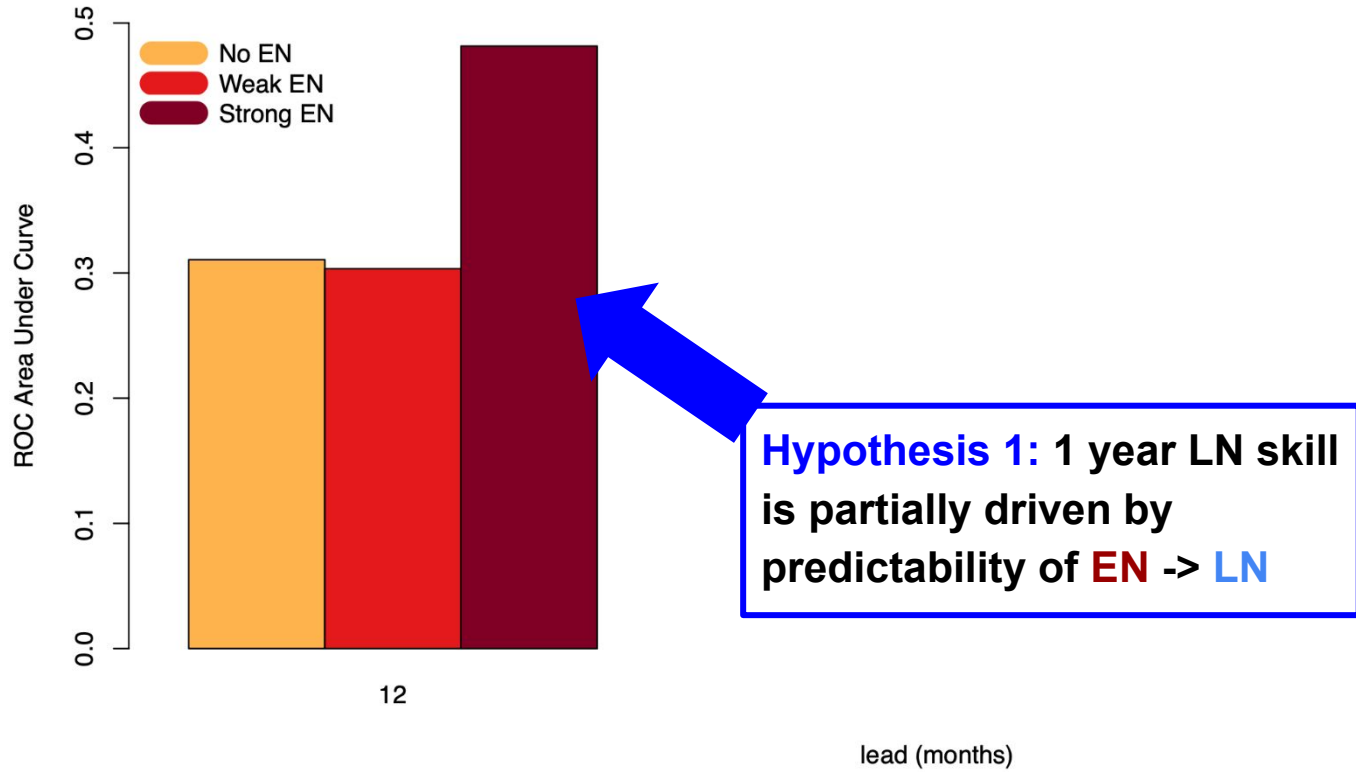
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La Niña skill stratified by El Niño magnitude at initialization
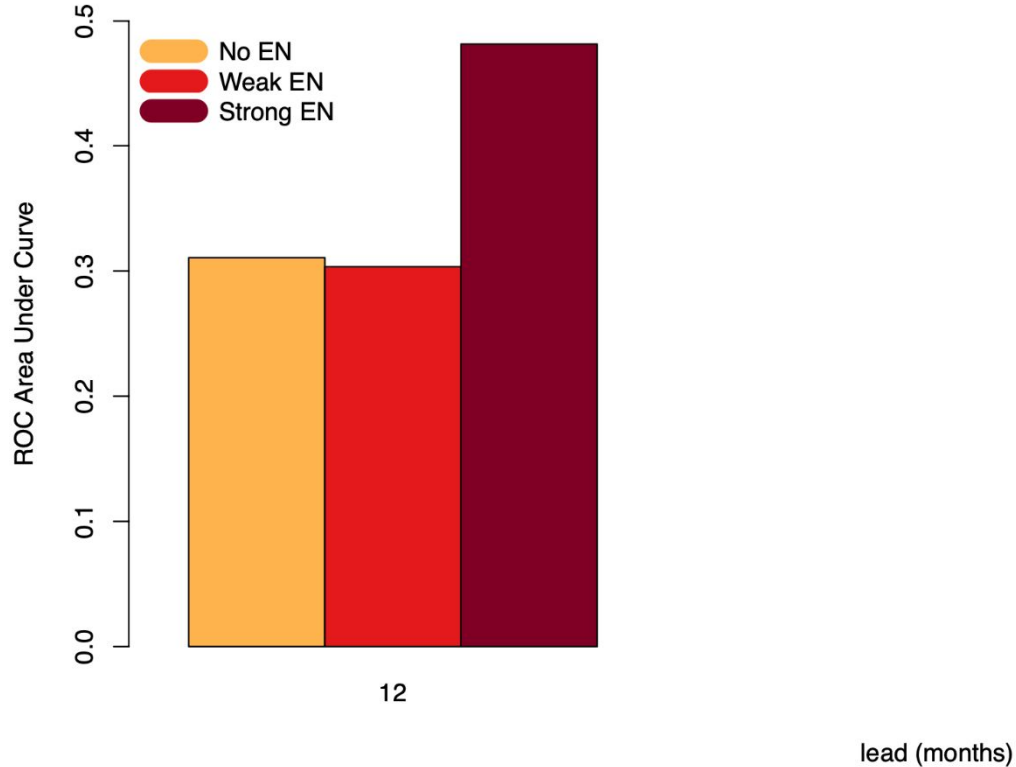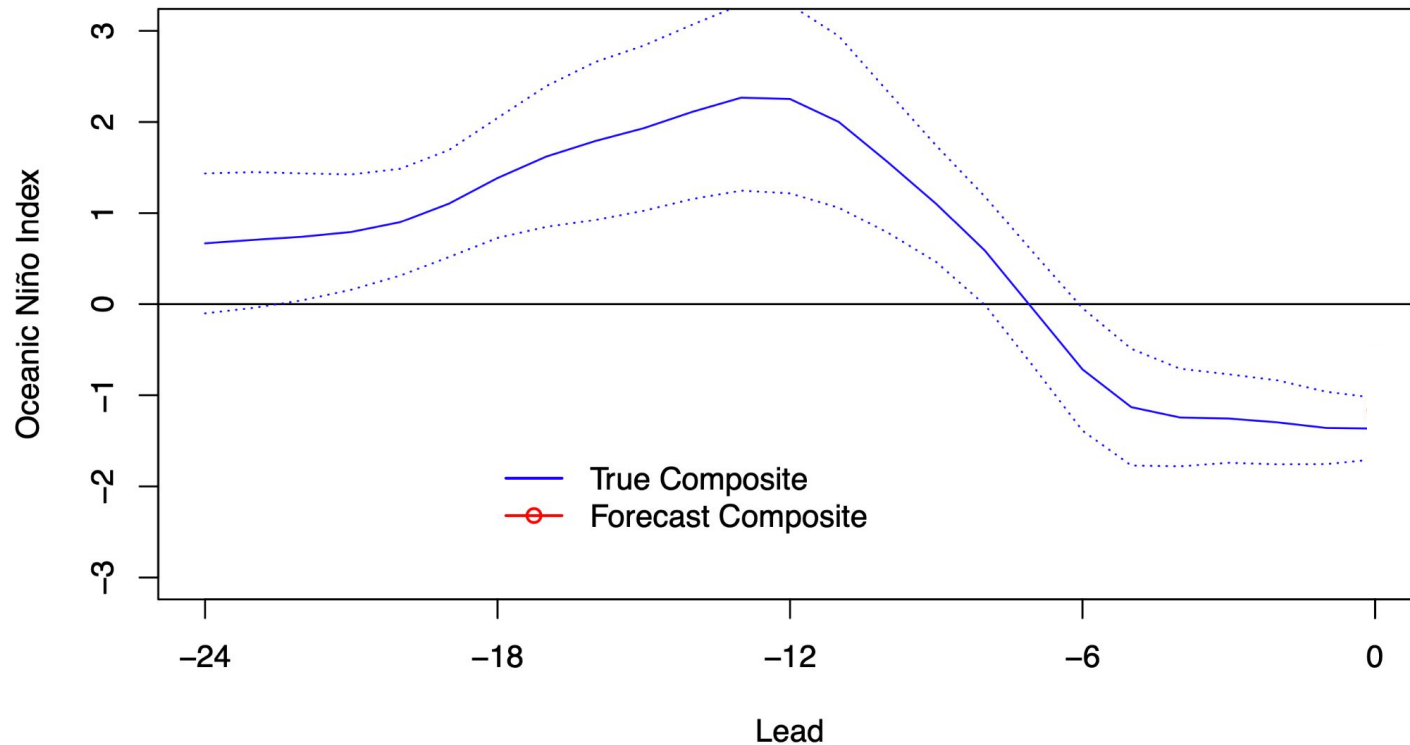
La Niña skill stratified by El Niño magnitude at initialization

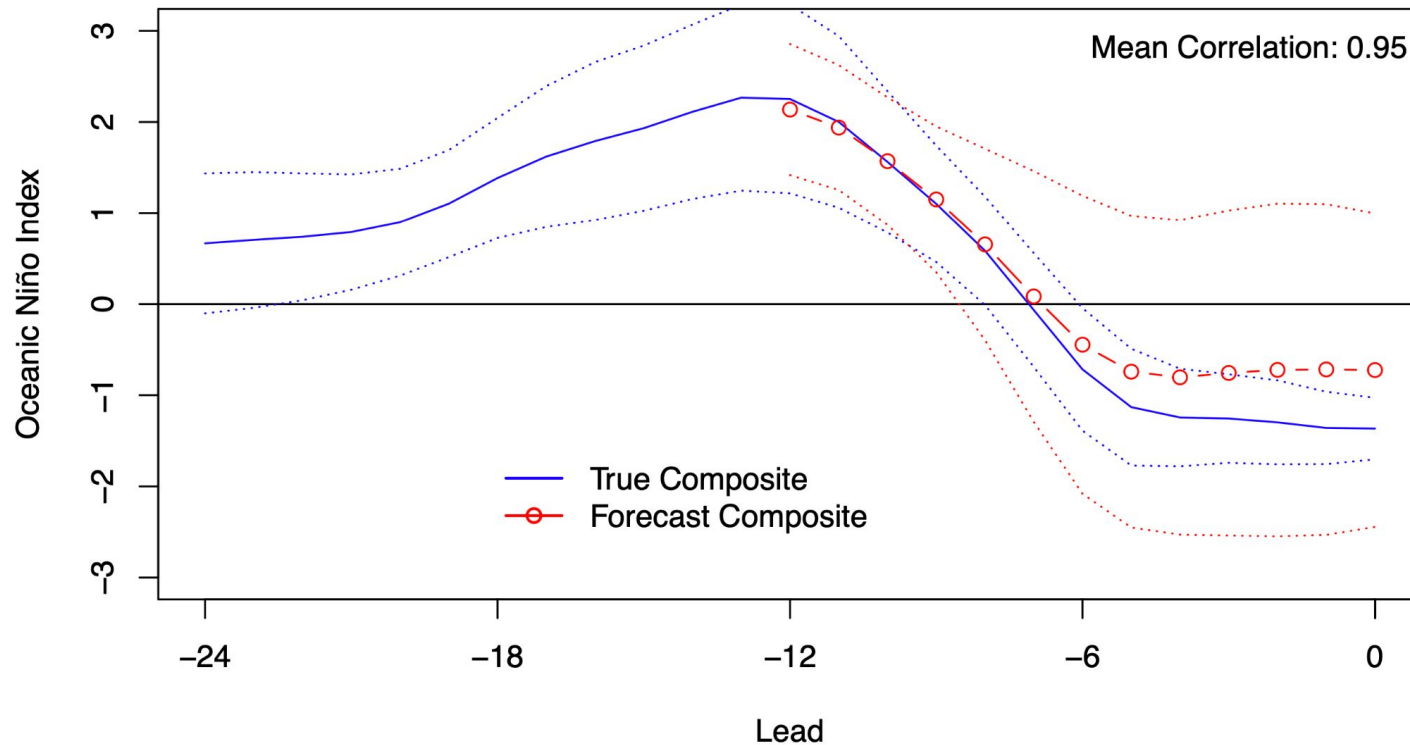# Retrospective Composite Analysis (EN -> LN)

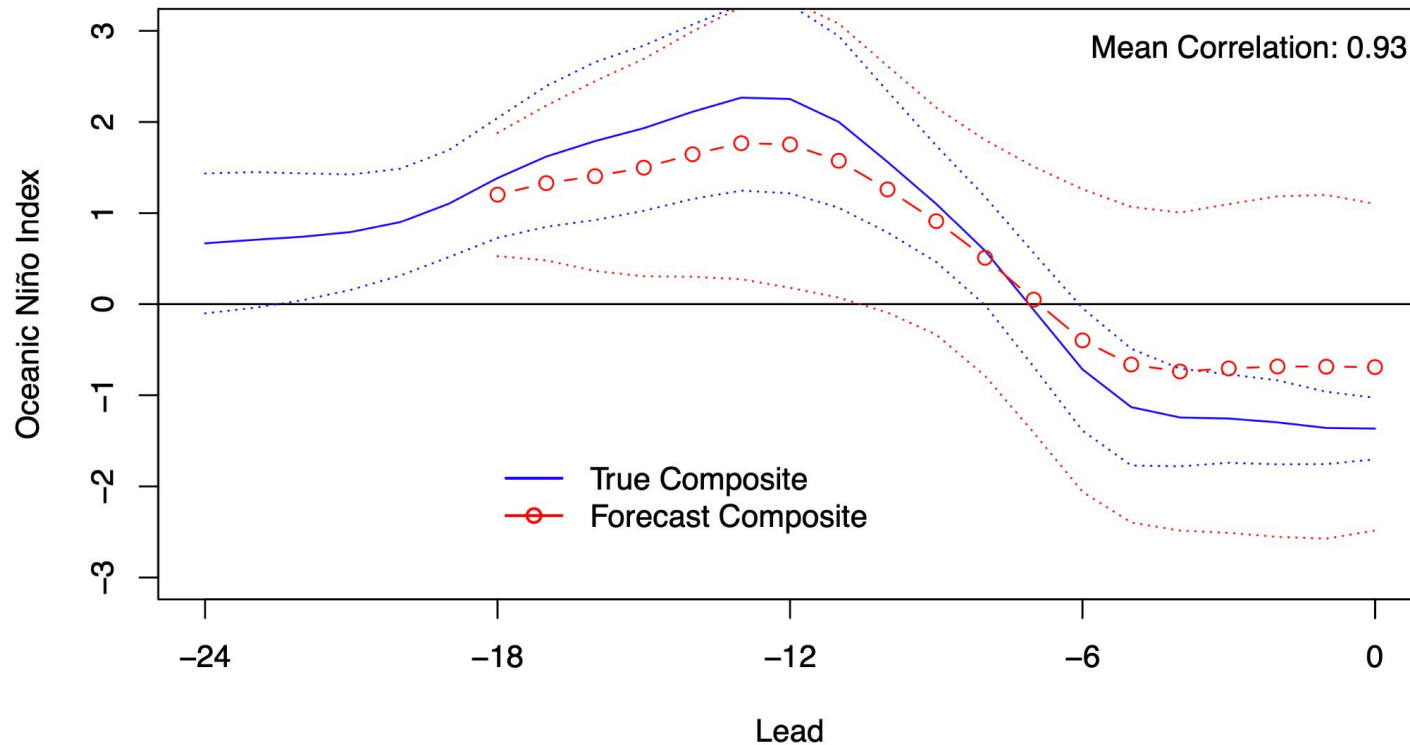El Niño –> La Niña Perfect Model Composite

Legend:
- True Composite
- Forecast Composite

Retrospective Composite Analysis (EN -> LN)

El Niño –> La Niña Perfect Model Composite

Mean Correlation: 0.95

- True Composite
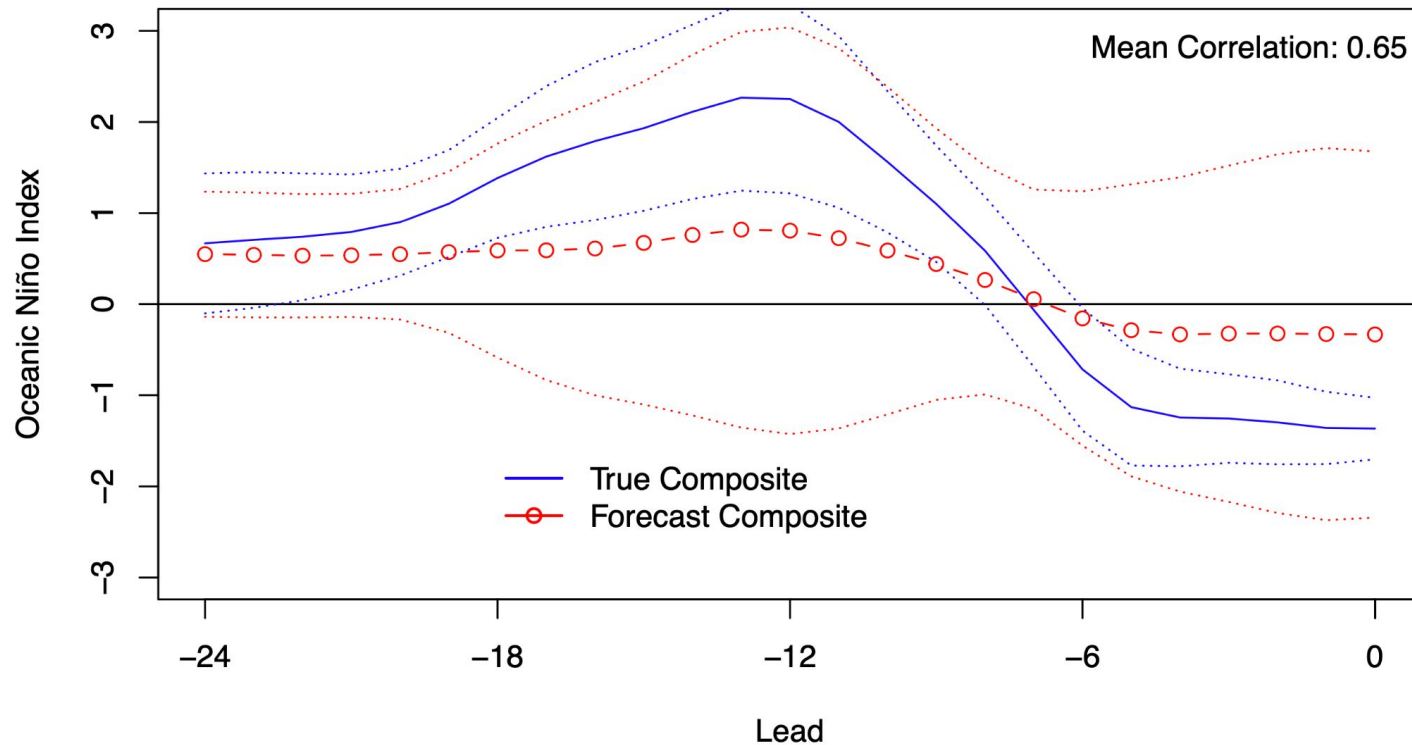- Forecast Composite

Oceanic Niño Index

Lead

Retrospective Composite Analysis (EN -> LN)

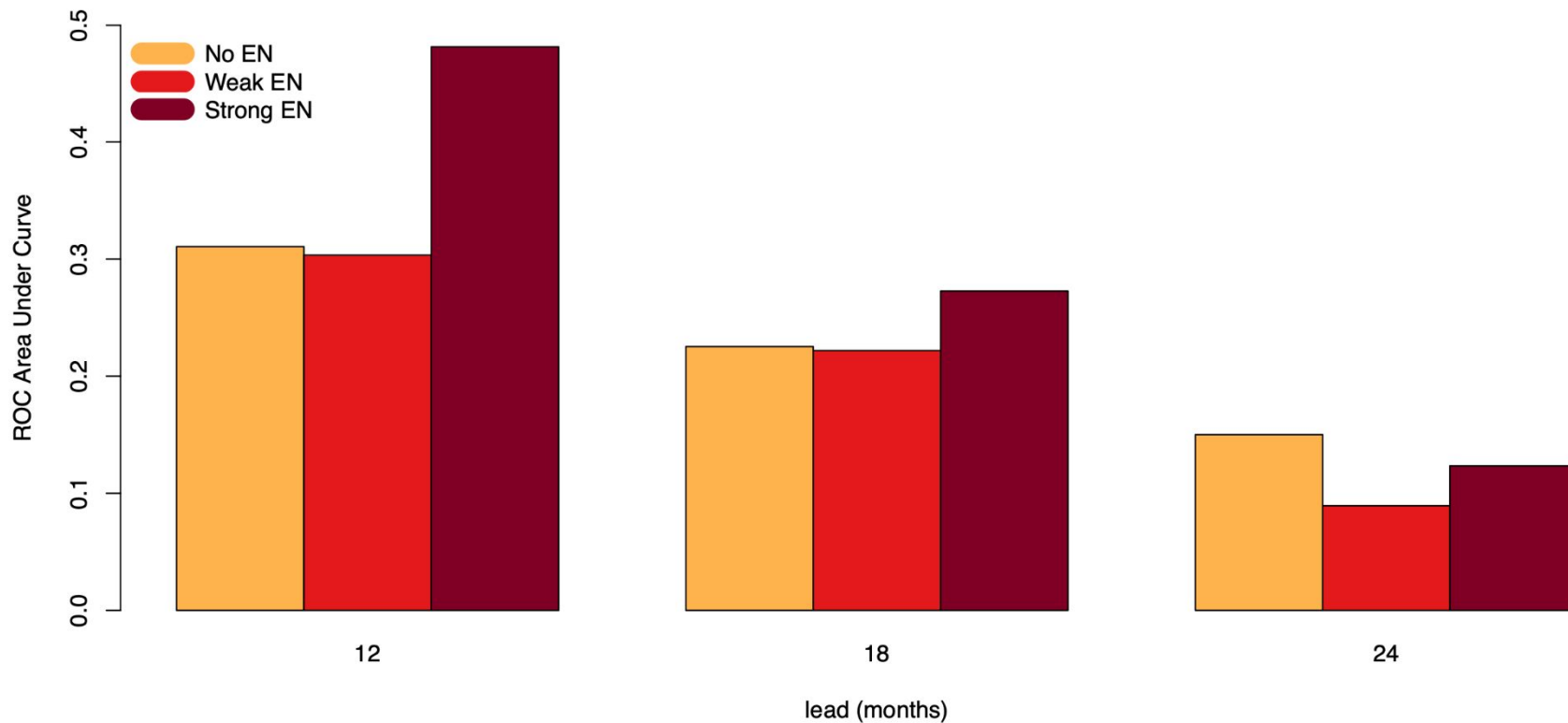El Niño –> La Niña Perfect Model Composite

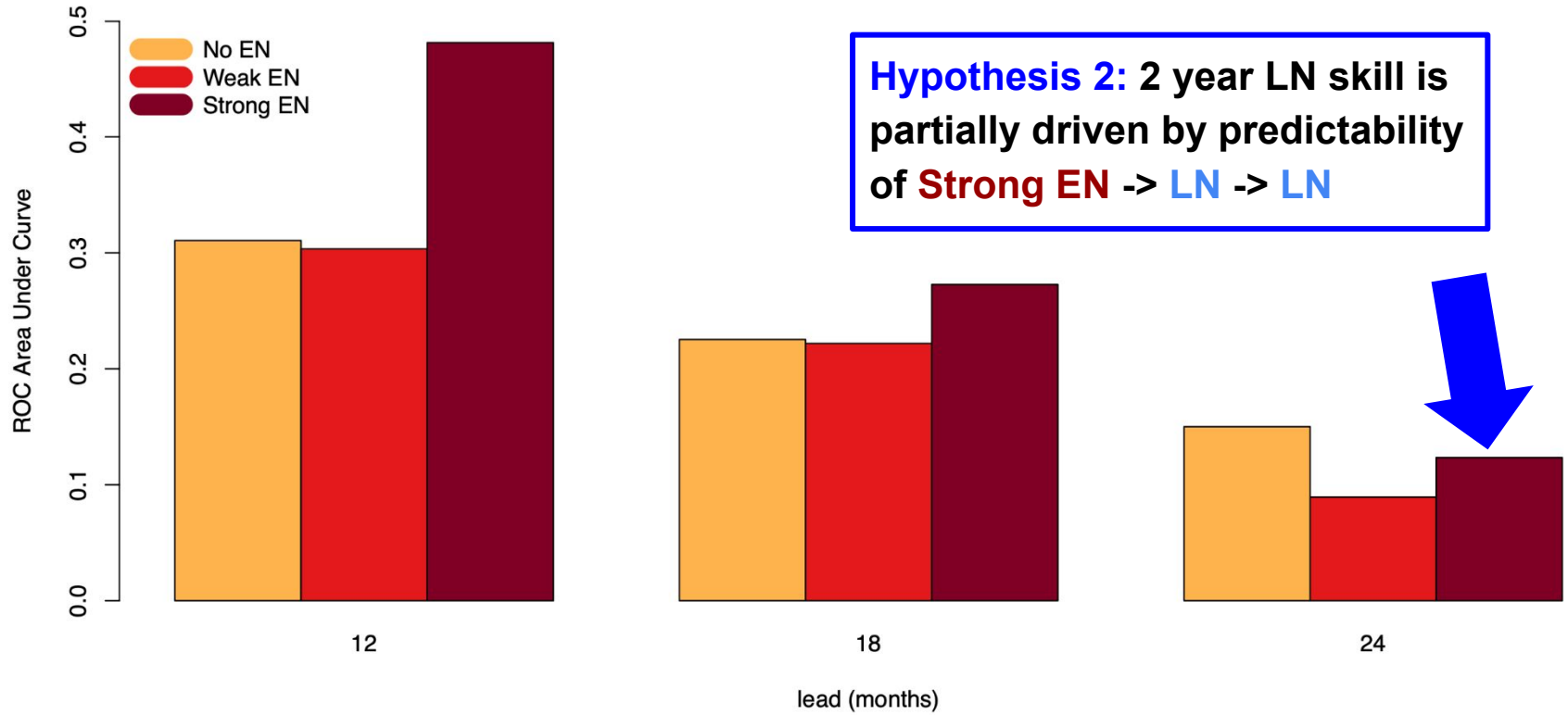# Retrospective Composite Analysis (EN -> LN)

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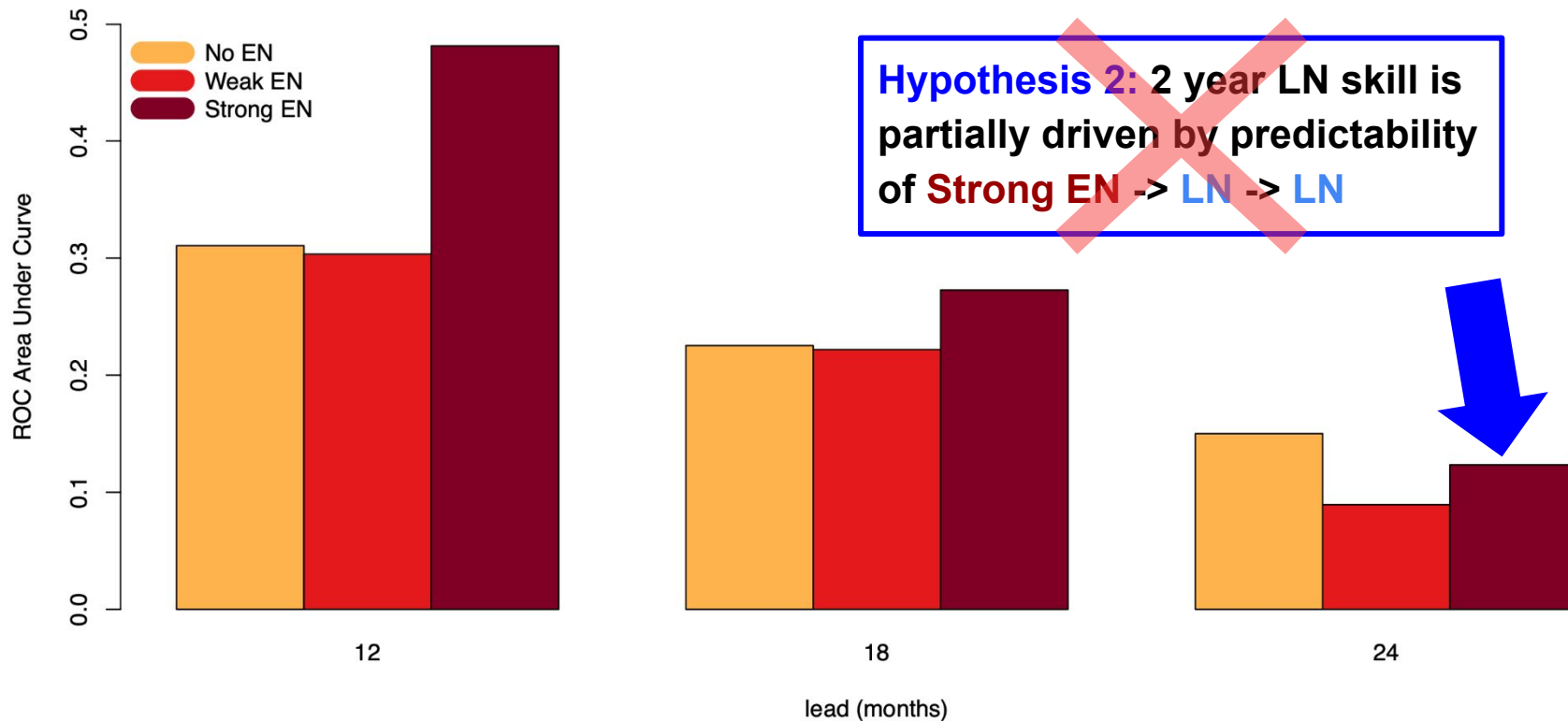
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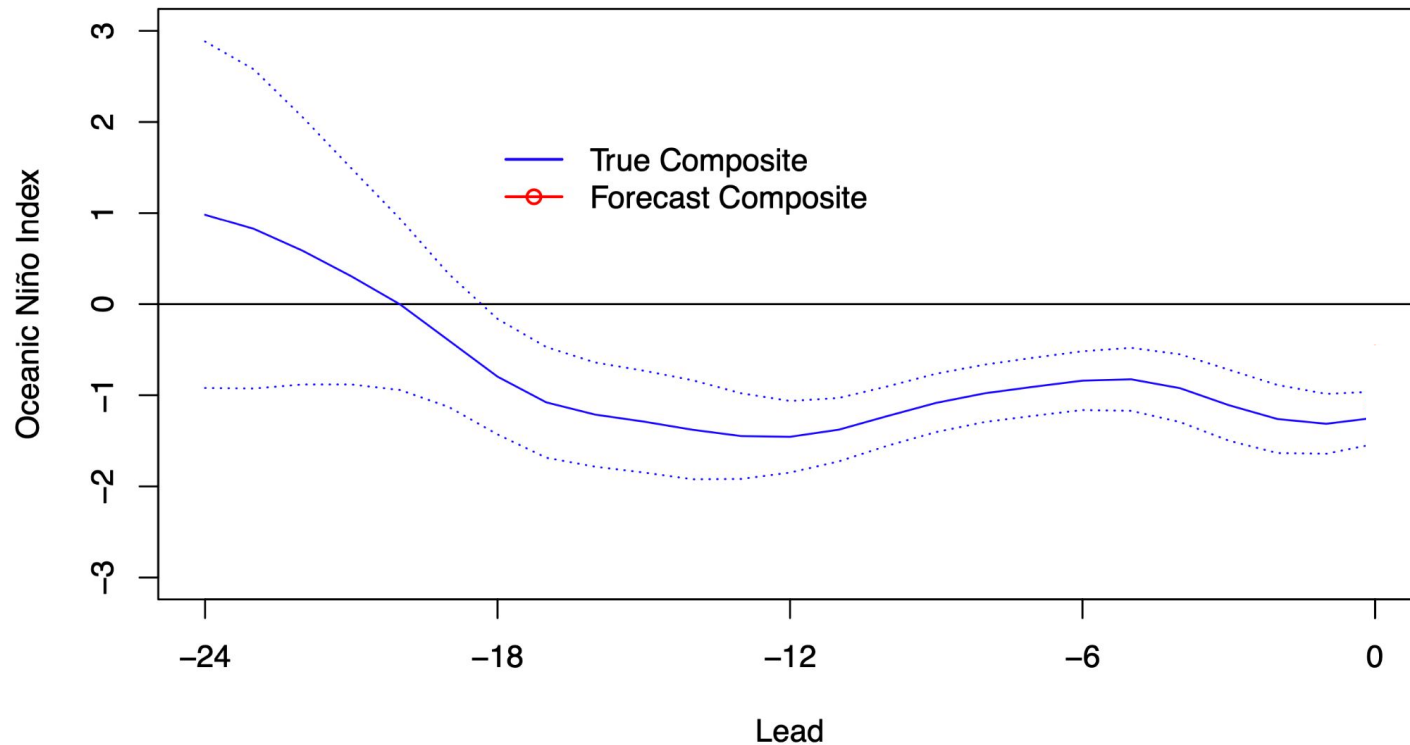Hypothesis 2: 2 year LN skill is partially driven by predictability of Strong EN -> LN -> LN

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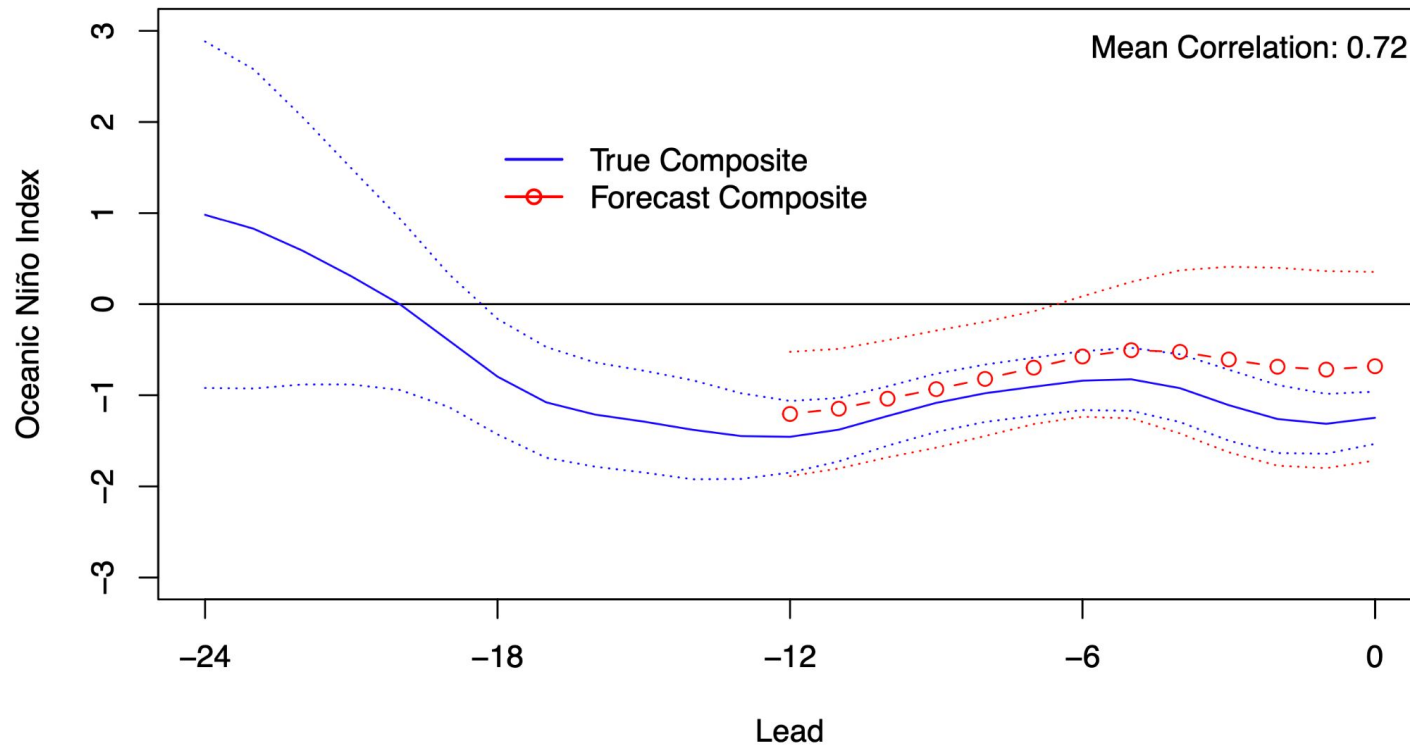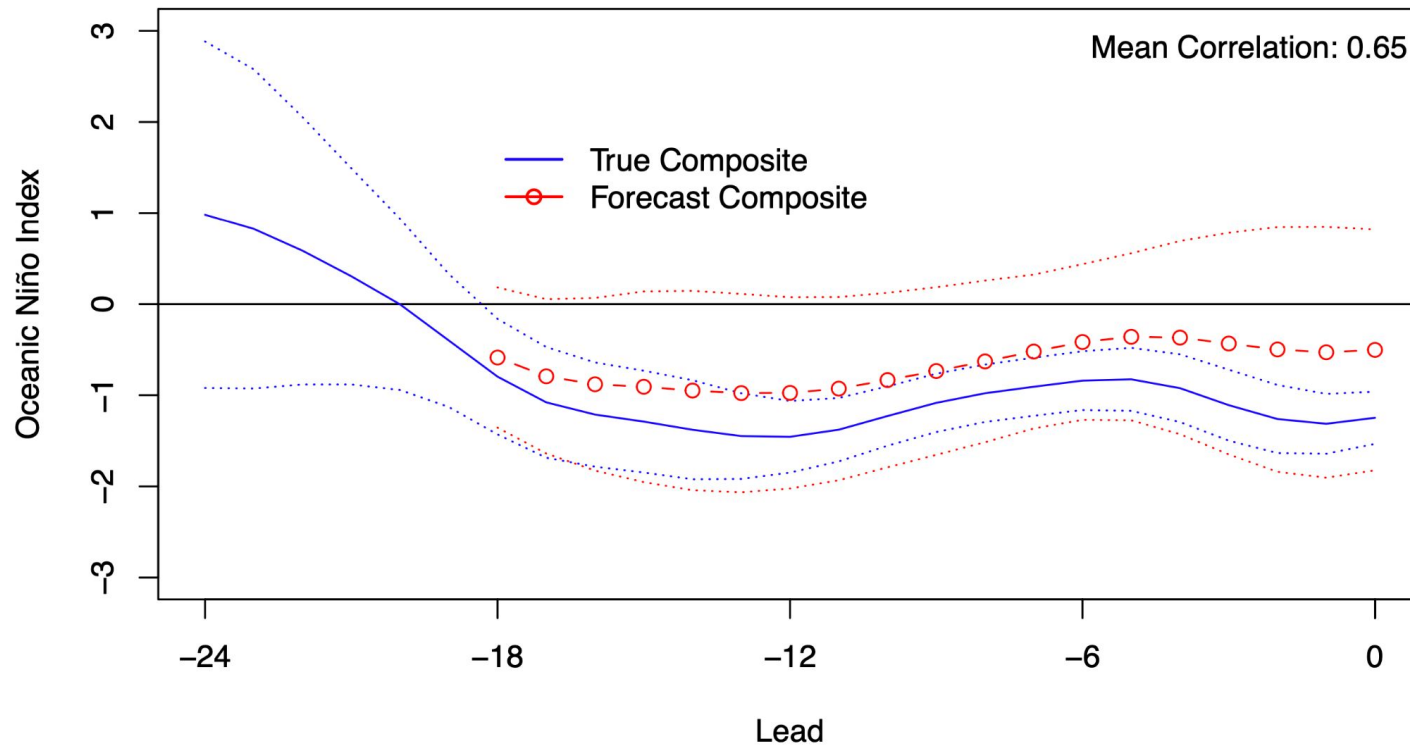
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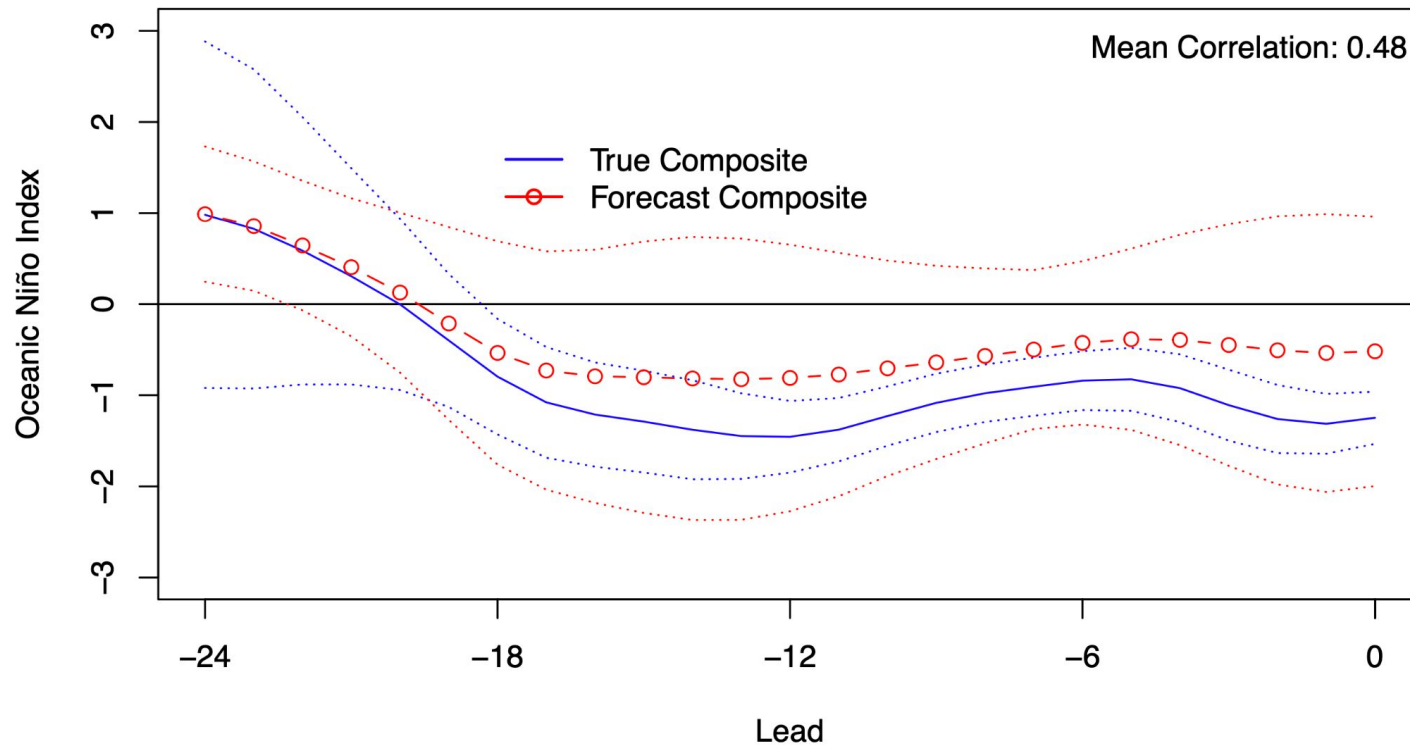
Conclusions

1. There is **3+ year** perfect model ENSO skill in CESM1.1 using model-analogue forecasts

2. Stratification of forecast skill by initial state is possible with 800+ years of hindcasts
    - Strong El Niño events lead to very predictable La Niña events the following year
    - However, strong El Niños don't show the expected double La Niña predictability

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Extensions:
- Compare model analogue and initialized ENSO dynamics and predictability
- Investigate the skill transitioning out of (multiple) La Niña events