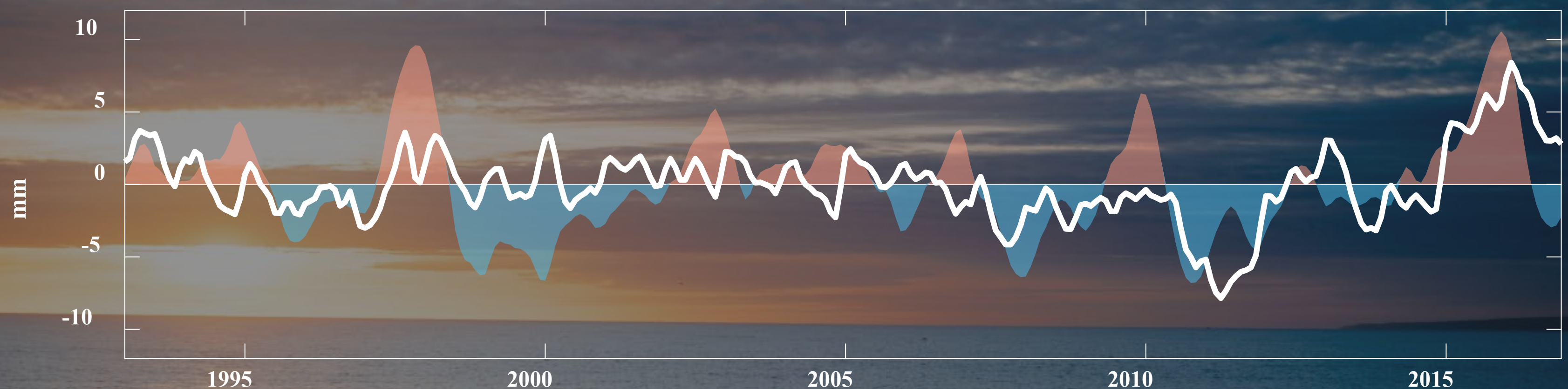
NCAR Climate Variability and Change Working Group

ENSO diversity and its impact on **Terrestrial Water Storage** to Sea-Level



Yan-Ning Kuo
Ph.D. Student in Cornell University

Outline

Part I: Interannual variation of terrestrial water storage from satellites, reanalysis and offline CLM5 simulation

(Coauthors: Dr. Min-Hui Lo, Dr. Yu-Chiao Liang, Dr. Yu-Heng Tseng, Dr. Chia-Wei Hsu)

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RESEARCH LETTER
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Key Points:

- Variations of global mean sea level (GMSL) in two extreme El Niño events during the altimetry era are mainly due to barystatic differences
- Higher terrestrial water storage (TWS) anomalies during typical Eastern Pacific (EP) El Niño cause lower barystatic variations in the 1997–1998 event

Terrestrial Water Storage Anomalies Emphasize Interannual Variations in Global Mean Sea Level During 1997–1998 and 2015–2016 El Niño Events

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Part II: Internal variability and hydroclimate in CESM2

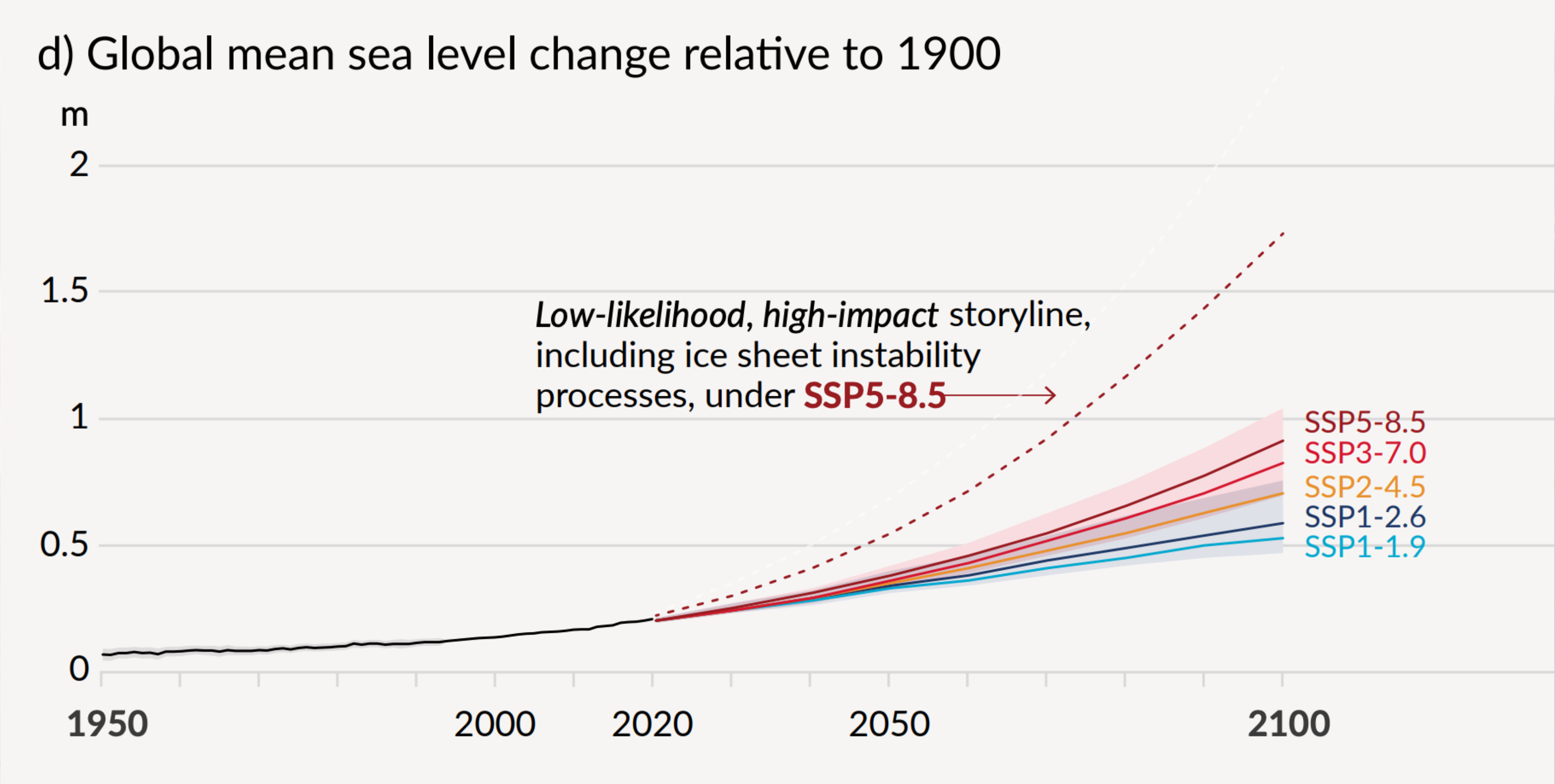
(Ongoing project supervised by Dr. Flavio Lehner, collaborating with Dr. Matt Newman)

國立臺灣大學

National Taiwan University

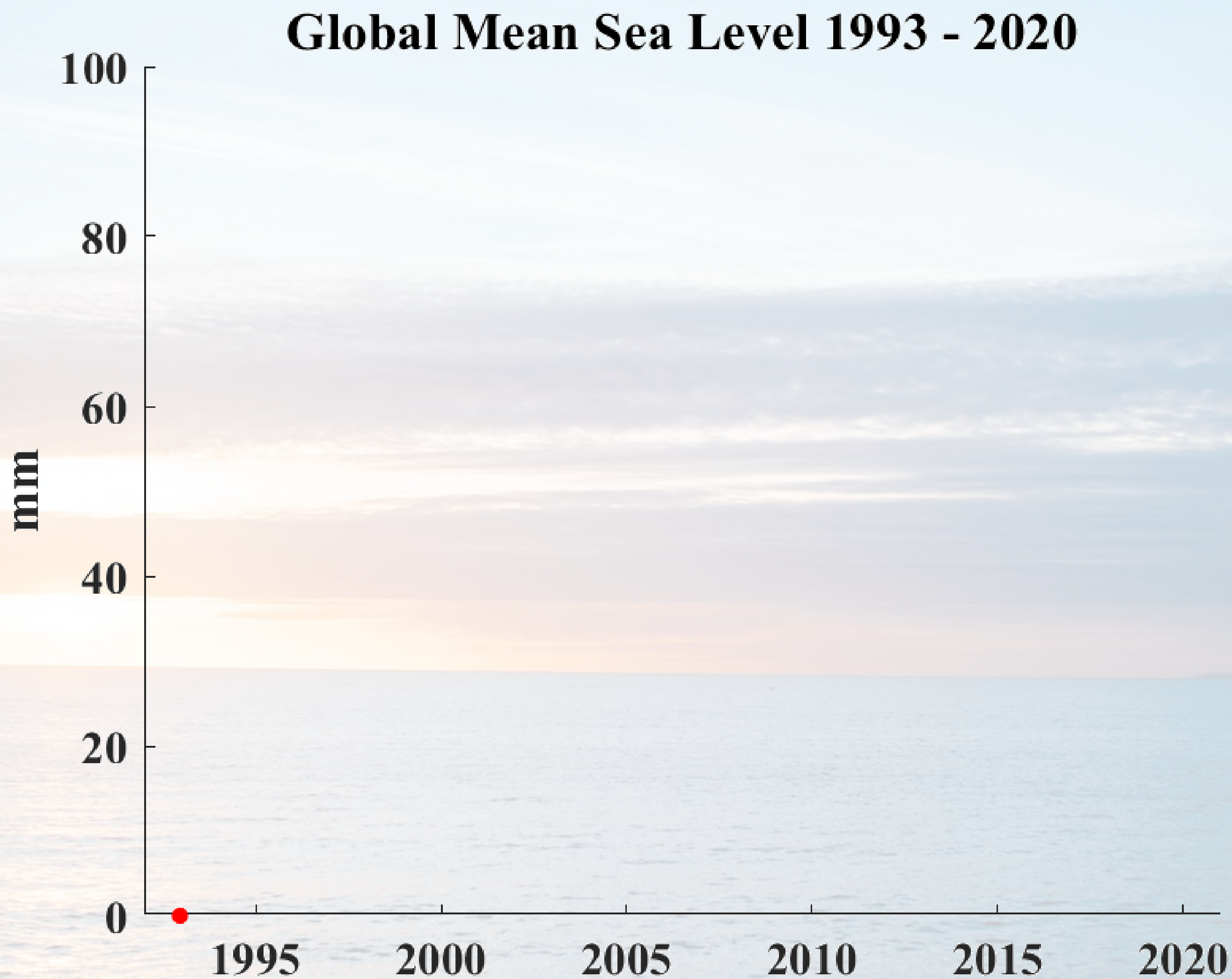
Part I: Interannual variation of terrestrial water storage from satellites, reanalysis and offline CLM5 simulation

The sea level rise is accelerated and this is ***very likely*** *to be related to human activities*



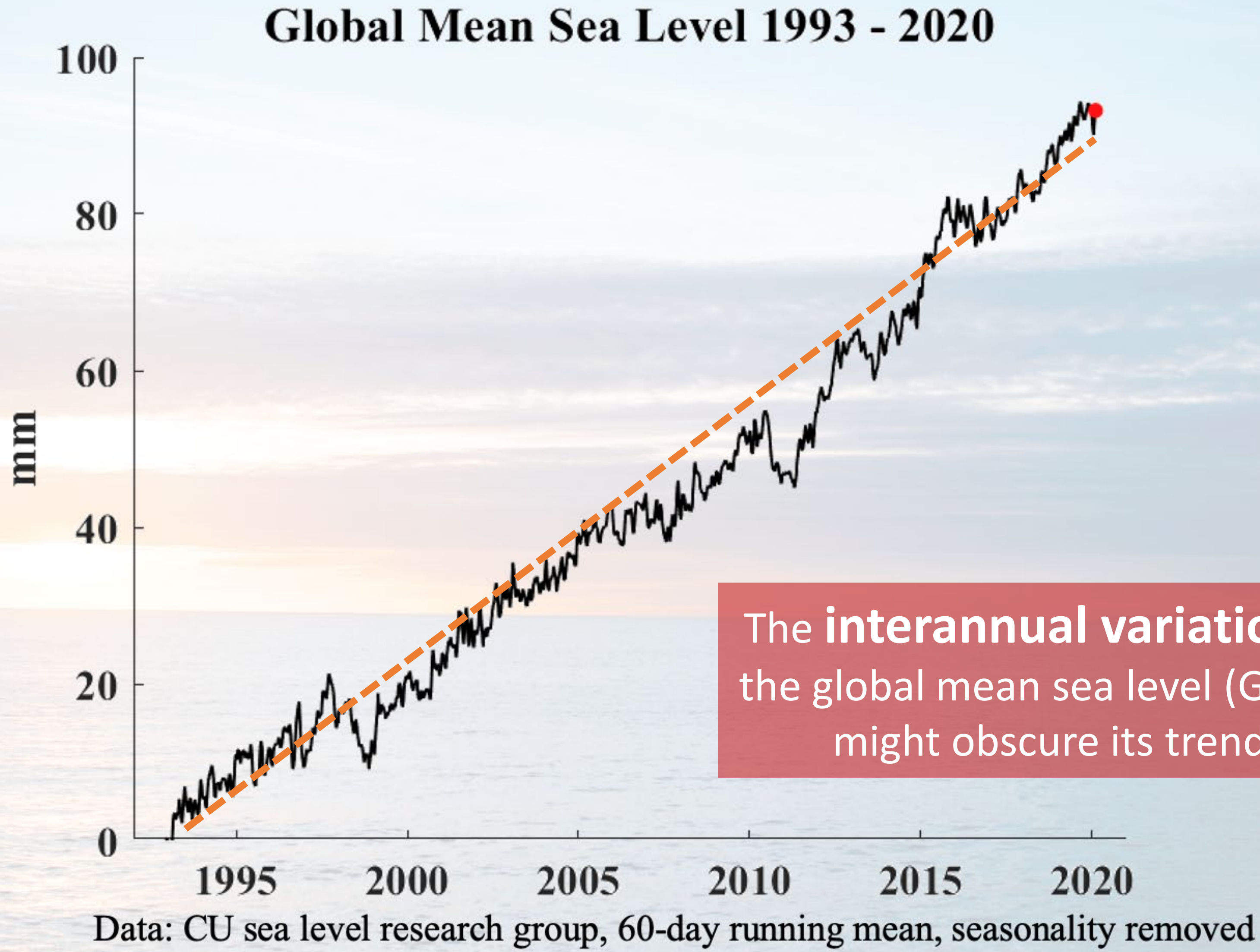
Ref: IPCC AR6

Trend: 3.3mm/year



Data: CU sea level research group, 60-day running mean, seasonality removed

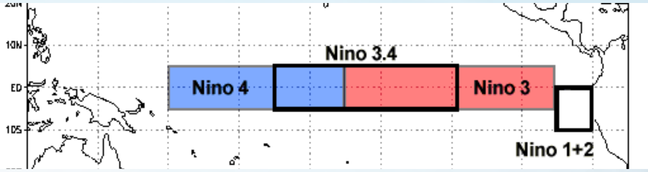
Trend: 3.3mm/year

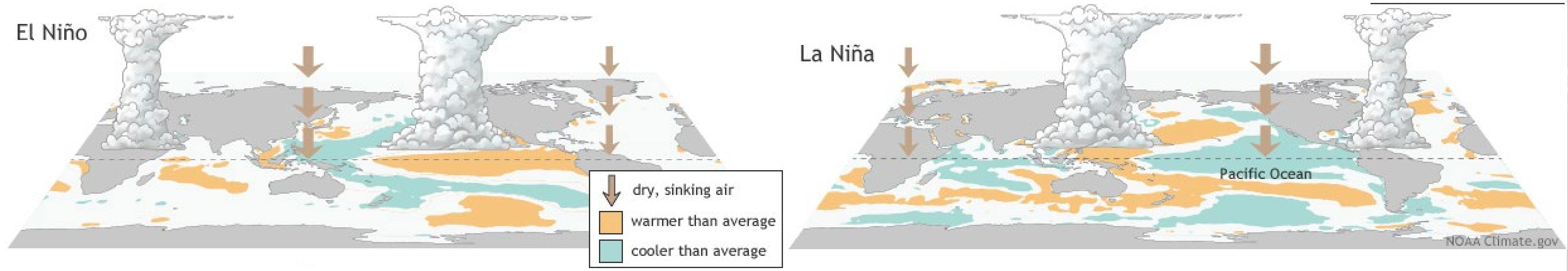


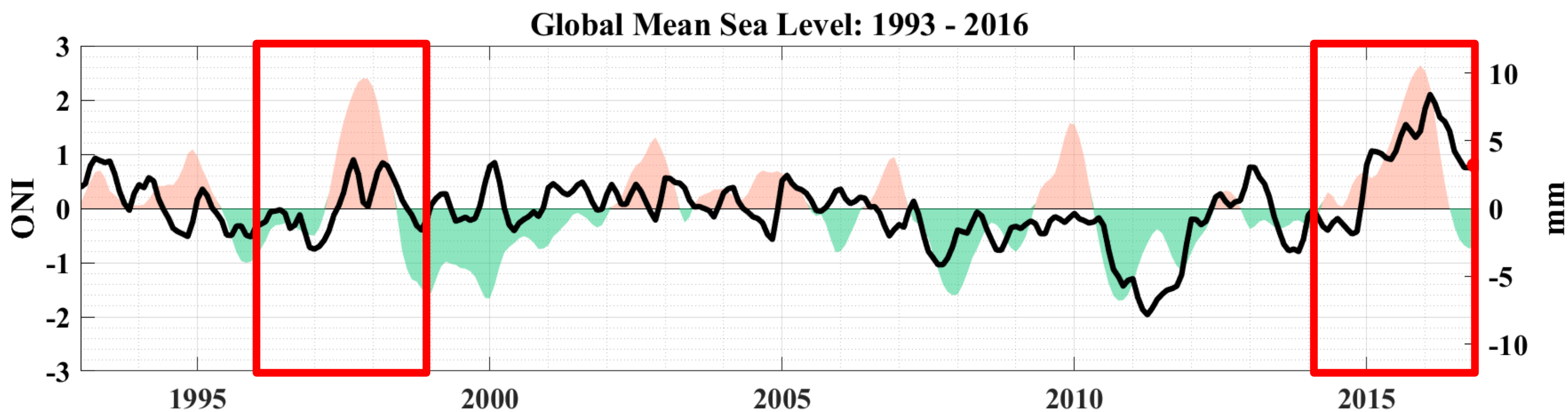
The **interannual variation** of the global mean sea level (GMSL) might obscure its trend

El Niño-Southern Oscillation (ENSO):

- Dominates the interannual variation of GMSL
- The warm (El Niño) and cold (La Niña) phases of Equatorial Pacific sea surface temperature



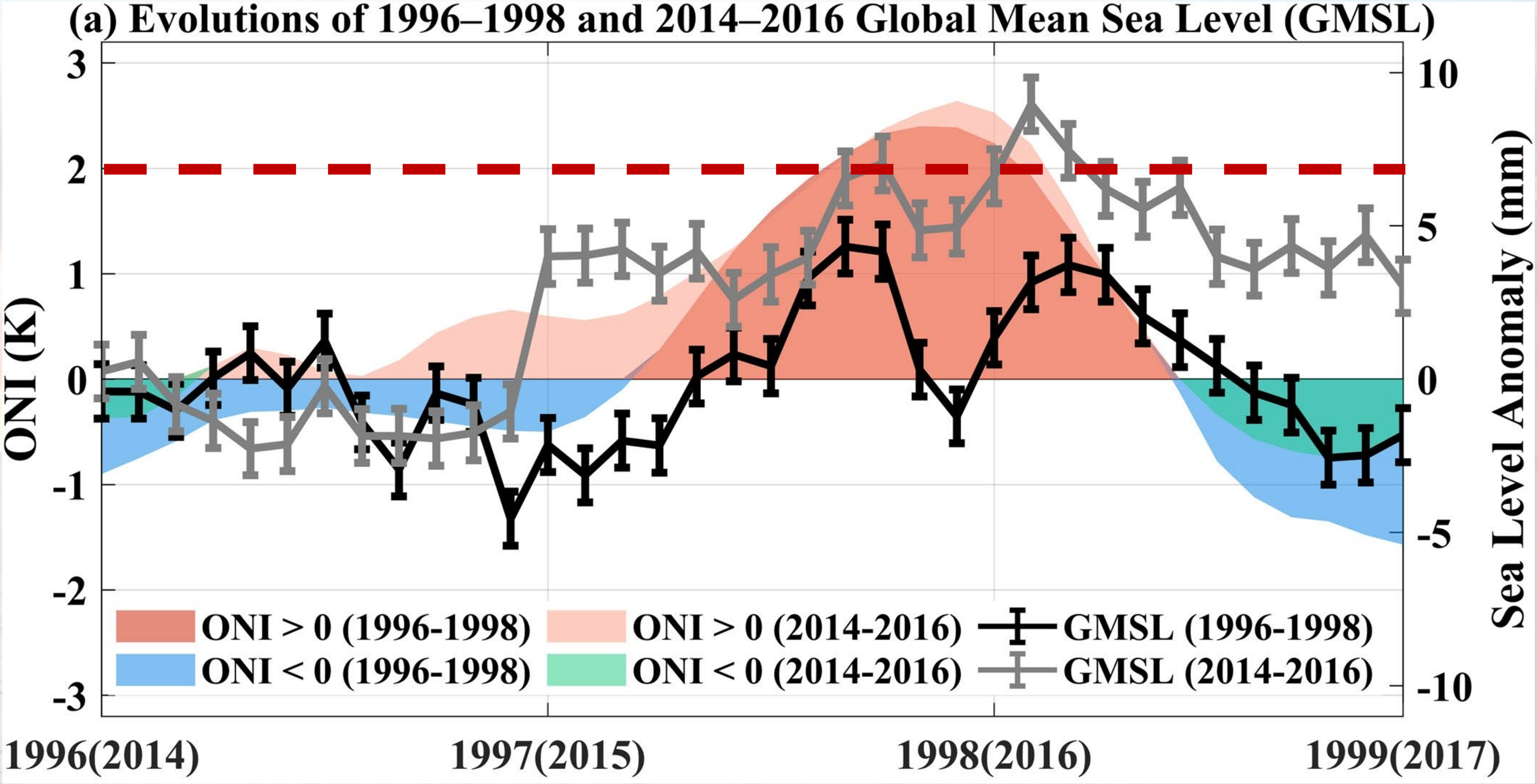




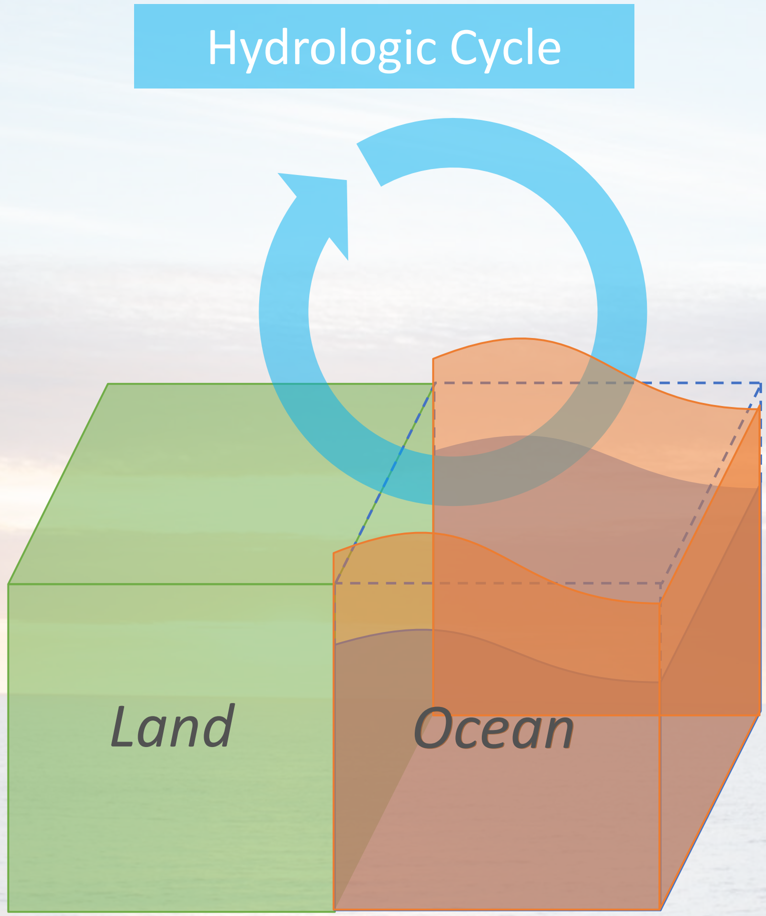
El Niño and La Niña diagrams from NOAA, Satellite altimetry data from AVISO+

The peaks of GMSL of the two extreme El Niños differ for 5.28 ± 0.96 mm

WHY?



Satellite Altimetry Observation from AVISO+



Sea-level variations:

1. Steric sea-level

Density variation, controlled by ocean heat content (OHC; major factor) and salinity (saltiness; minor)

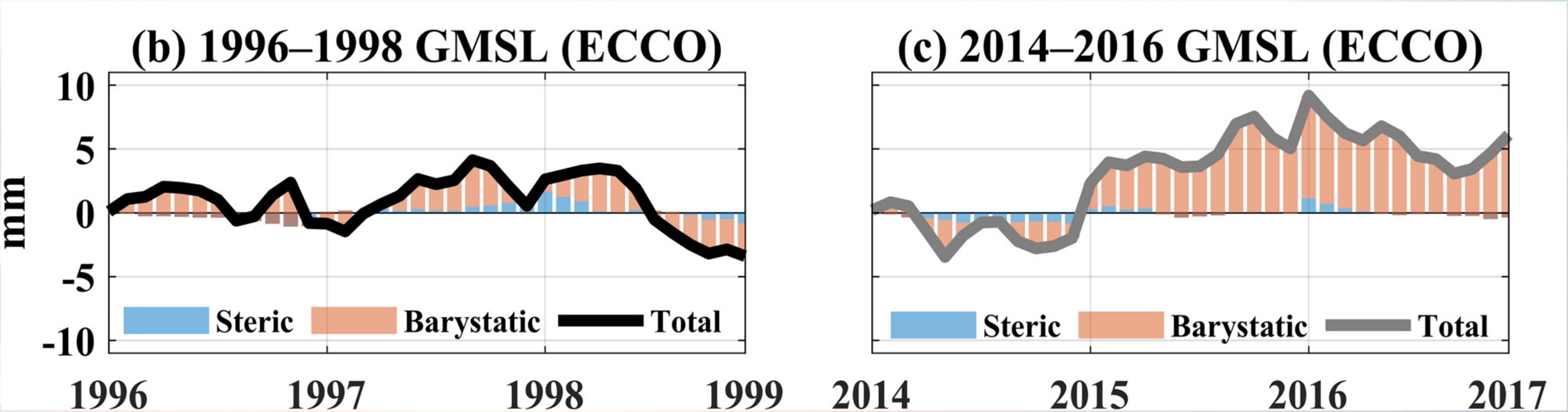
$$steric = \frac{-1}{\rho_0}\int_{-H}^{0}(\rho - \bar{\rho})dz$$

2. Barystatic sea-level

Mass variation, the **extra** water mass into the ocean

$$\Delta M_{ocean} \approx -\Delta M_{land}$$

The interannual sea-level difference of the two events is mainly from barystatic variation



Why the barystatic sea-level (ocean mass) increased more in 2015 El Niño?

ECCO – An Ocean Reanalysis from NASA JPL

Assume the Earth is a closed system:

$$\Delta M_{ocean} \approx -\Delta M_{land} = -\Delta TWS$$

Terrestrial Water Storage Flux

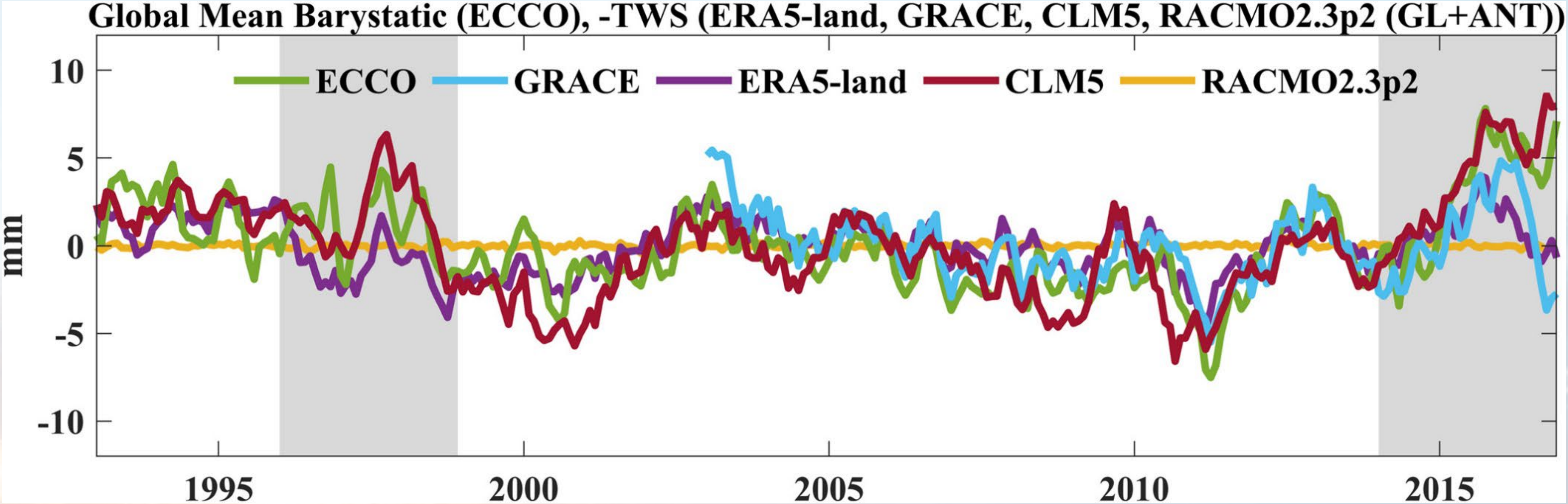
(Llovel et al., 2011; Wada et al., 2016)

$$\Delta TWS = P - E - R$$

- **P: Precipitation**
- **E: Evapotranspiration**
- **R: Runoff**

$$TWS = \int \Delta TWS dt = \int_{1993}^{2016} (P - E - R)dt = -Barystatic$$

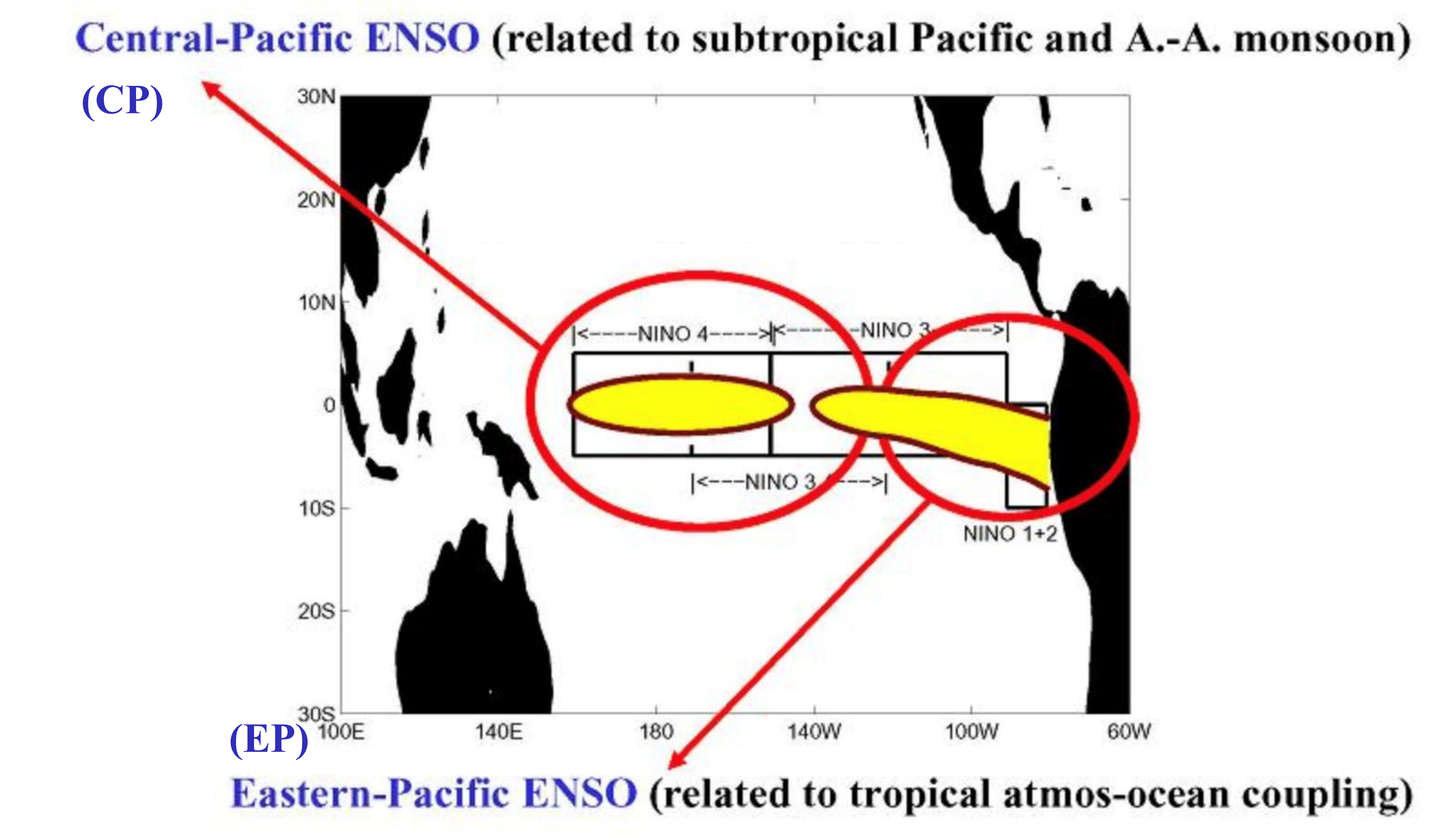
	Data sets	TIME
-TWS	ERA5-land, CLM5 I1850	1993-2016
-TWS from GL+ANT	RACMO2.3p2	1993-2016



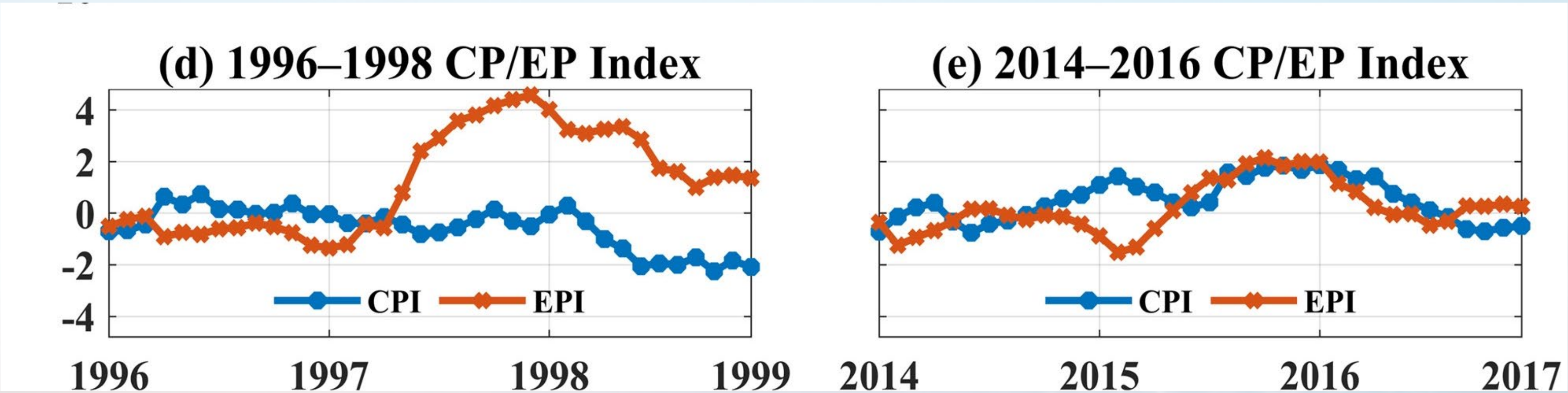
1. The barystatic sea-level varies as **–TWS**
2. Both ERA5-land and CLM5 demonstrate higher –TWS in DJF of 2015-16

Why there was larger anomalous –TWS in 2015 El Niño?

RECALL: El Niño



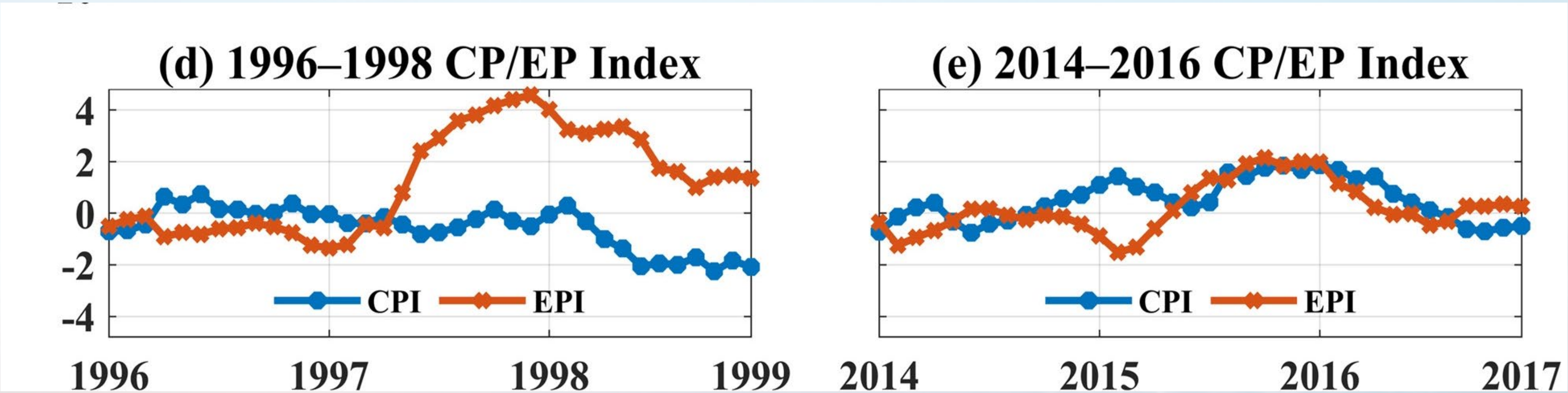
El Niño and La Niña diagrams from NOAA; CP/EP figure from Dr. Yu, Jin-Yi in UC Irvine



1997-98 El Niño is a pure EP El Niño

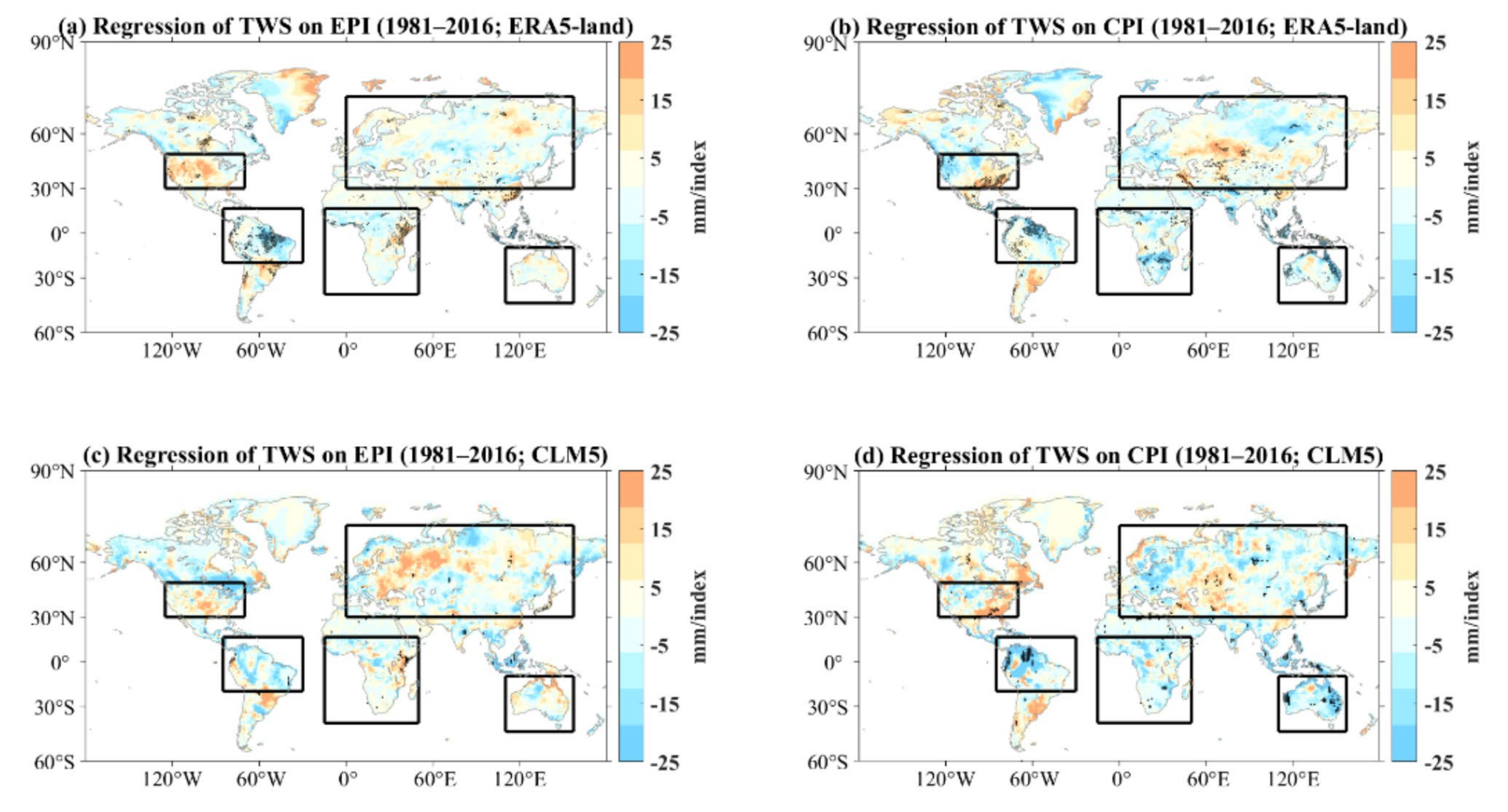
2015-16 El Niño is a mixture of EP and CP El Niño

Calculating the CorrCoef. and regression of barystatic sea-level and –TWS on EPI/CPI



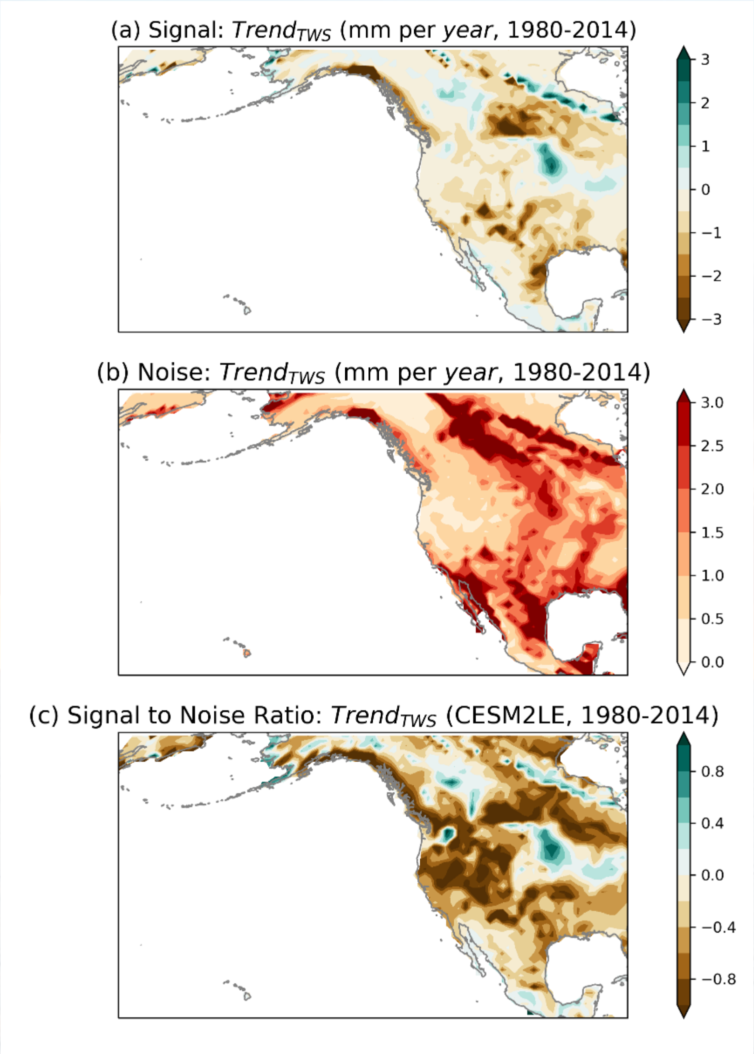
CP ENSO drives more interannual -TWS (barystatic) variation

Italic: p<0.05; **Bold: p<0.01**		ECCOv4r4	ERA5-land	CLM5	GRACE
CPI	CorrCoef	*0.45*	**0.63**	**0.56**	**0.54**
	mm/index	1.04±0.90	0.88±0.33	1.50±1.13	0.99±0.62
EPI	CorrCoef	0.19	-0.12	0.17	-0.01
	mm/index	0.44±1.21	-0.16±0.62	0.44±2.76	-0.02±1.31



"So far, consistent results of the global mean TWS can be seen from the two models. Further studies about model uncertainties of TWS predictability are necessary."
– from Conclusion and Discussion of Kuo et al. (2021)

Part II: Internal variability and hydroclimate in CESM2



TWS trend in CESM2-LE:

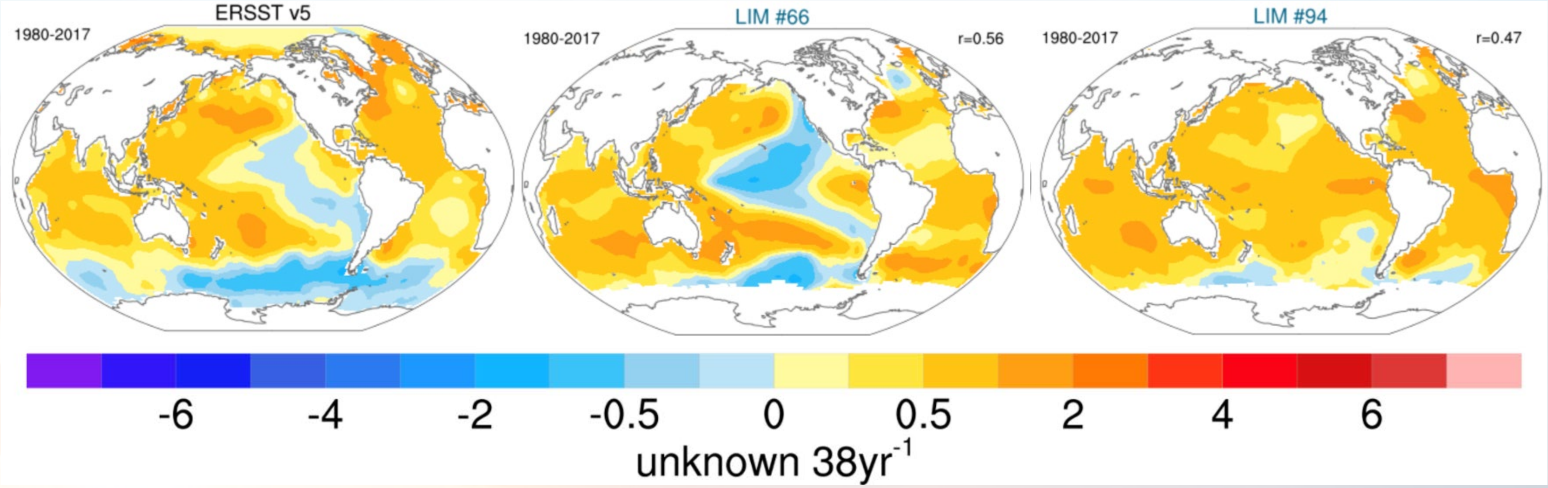
- Signal: ensemble mean trend over 1980 – 2014
- Noise: standard deviation of trend across ensemble members

1. Overall drying in North America with drying in western coast
2. Trends across ensemble members spread in eastern U.S.

What's tropical SST's contribution to such a drying trend in North America?

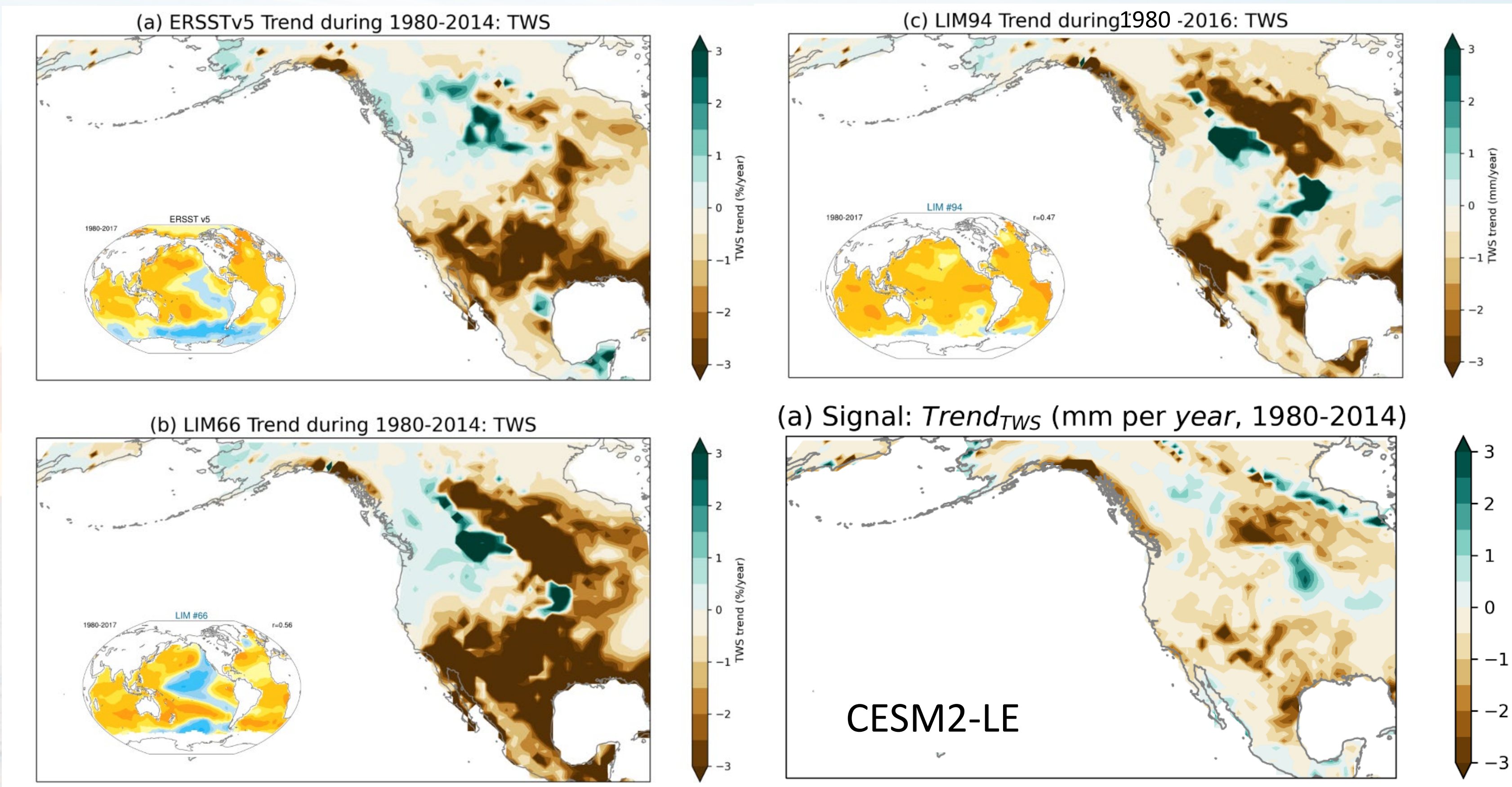
CAM6 Prescribed SST AMIP Ensembles:
Tropical Ocean Global Atmosphere (TOGA) simulations

SST trend maps from Climate Variability Diagnostics Package for Large Ensembles (CVDP-LE)



- Prescribed with historical ERSSTv5 (10 ensemble members), LIM66 (10) and LIM94 (10) SSTs in the tropics
- LIM66 and LIM94 SSTs generated from a cyclostationary linear inverse model (Shin et al., 2021)

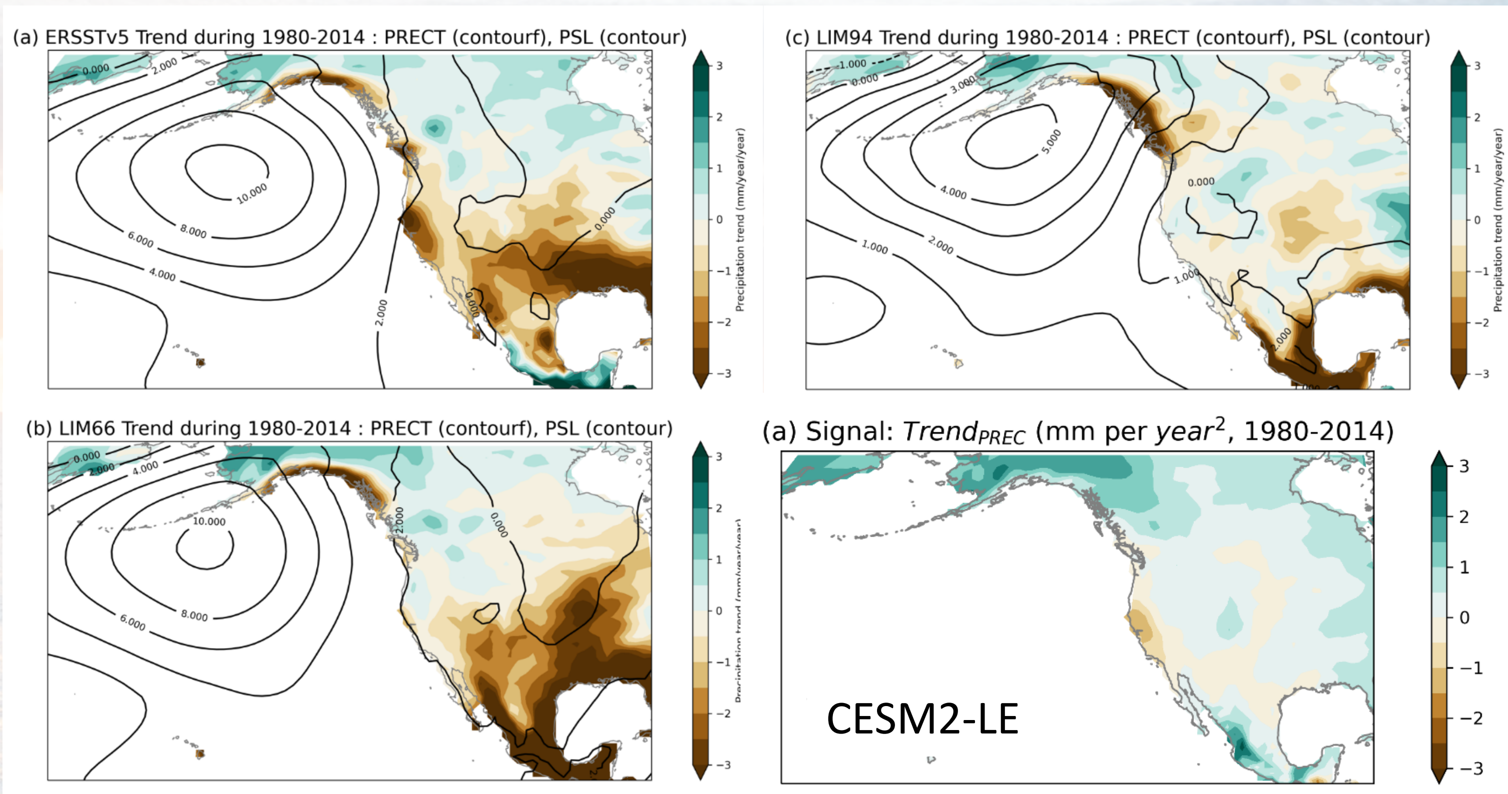
Drying is stronger compared to the fully coupled CESM2-LE



$$\Delta TWS = P - E - R$$

- P: Precipitation
- E: Evapotranspiration
- R: Runoff

ERSSTv5, LIM66, LIM94 all show increasing PSL trend (negative PDO like) and overall decreasing precipitation BUT different from CESM2-LE



CESM Climate Variability and Change Working Group

Thanks for your attentions!

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