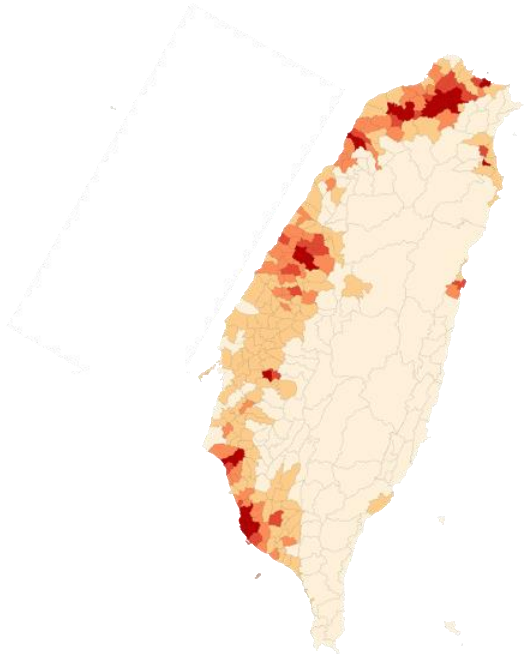
十年一乾，五年一旱

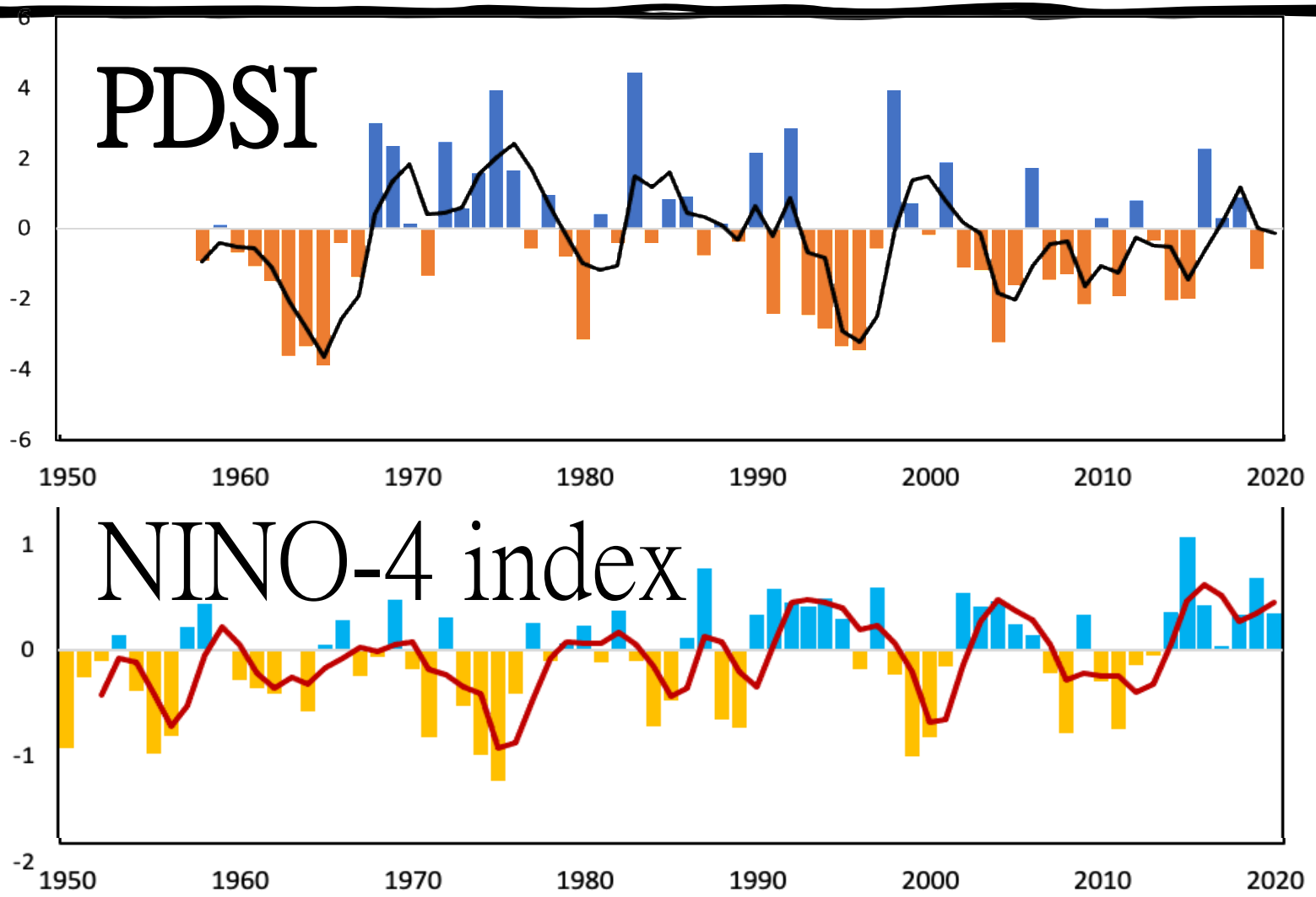
Simon 世宇 Wang, Utah State University

台灣降雨的準十年規律，知道了有用嗎？

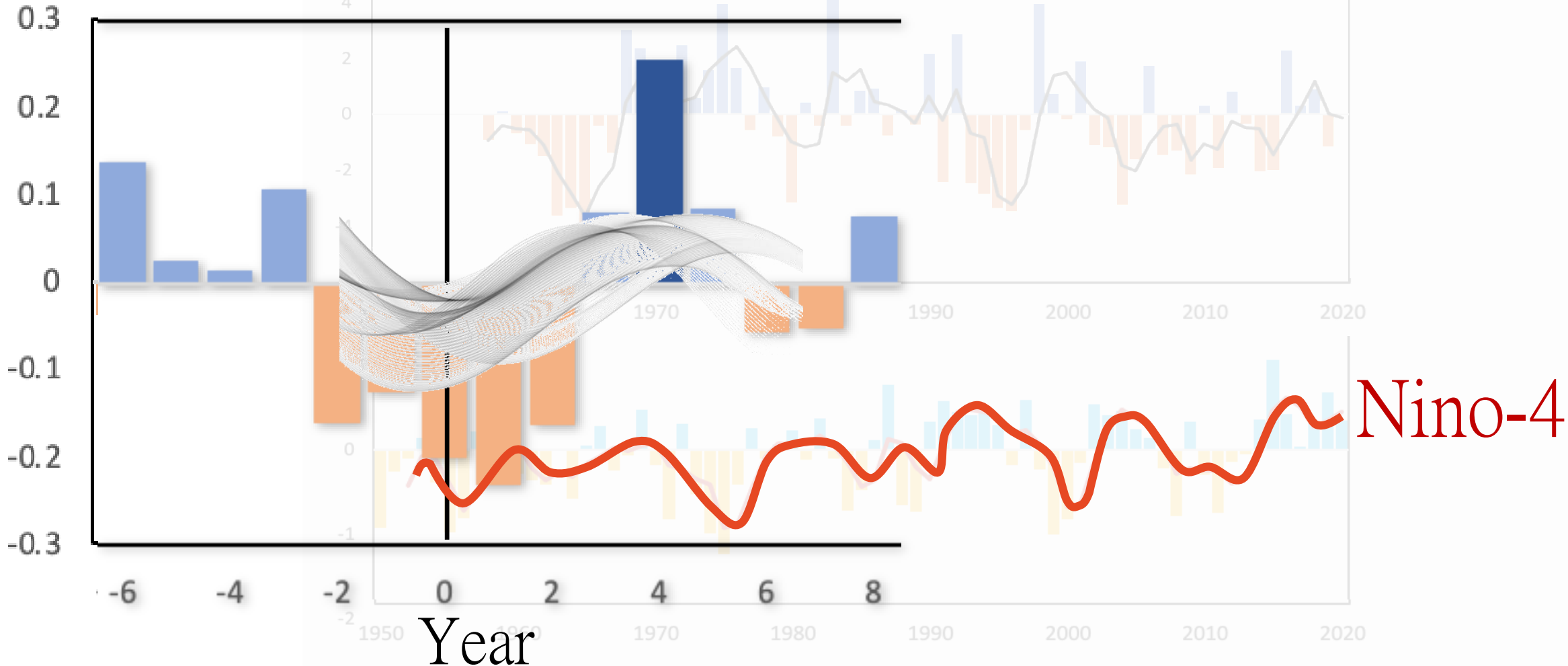
Taiwan annual rainfall

準十年規律?

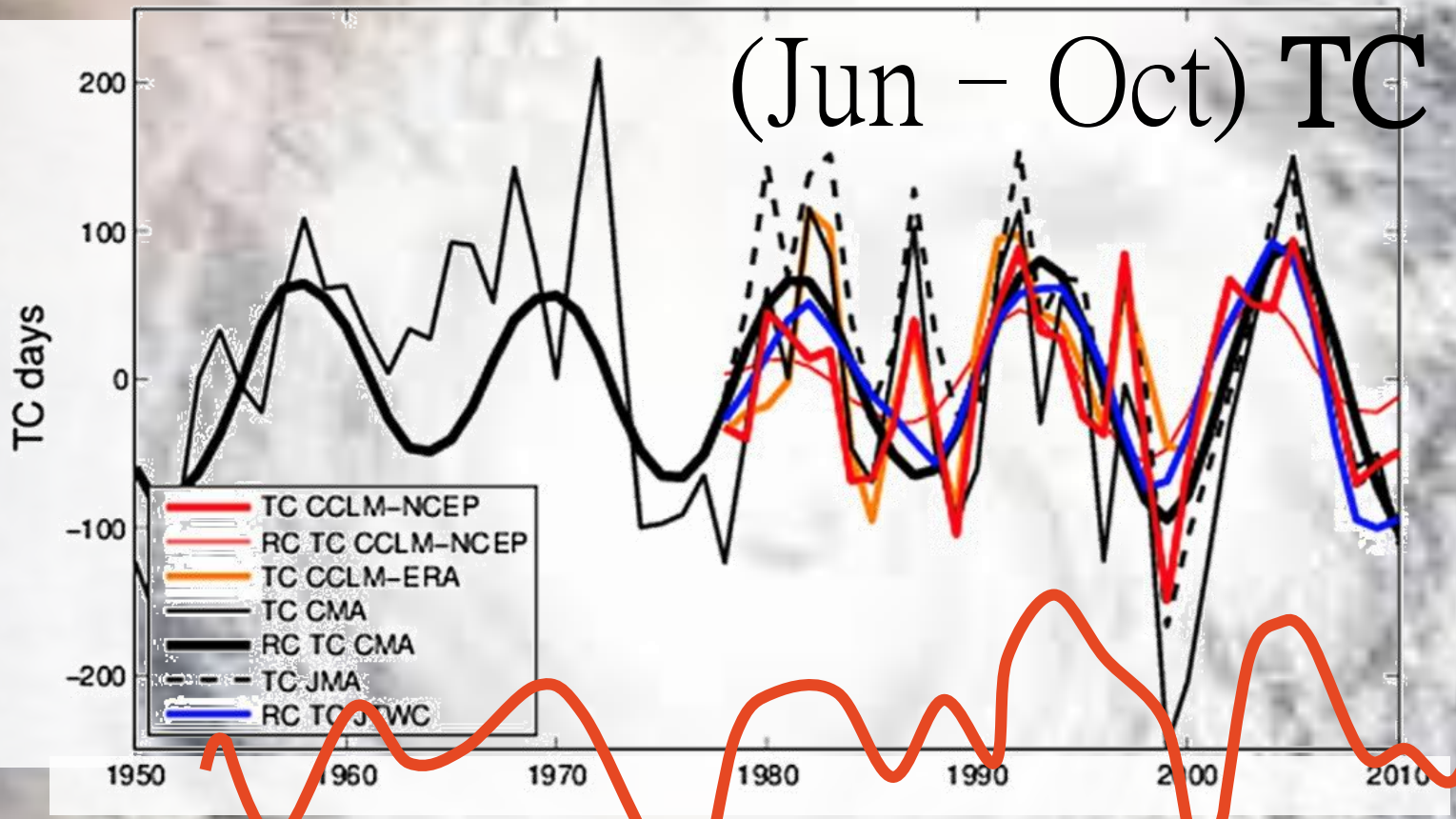



PDSI
6
4
2
0
-2
-4
-6
1950
1960
1970
1980
1990
2000
2010
2020
NINO-4 index
1
0
-1
-2
1950
1960
1970
1980
1990
2000
2010
2020

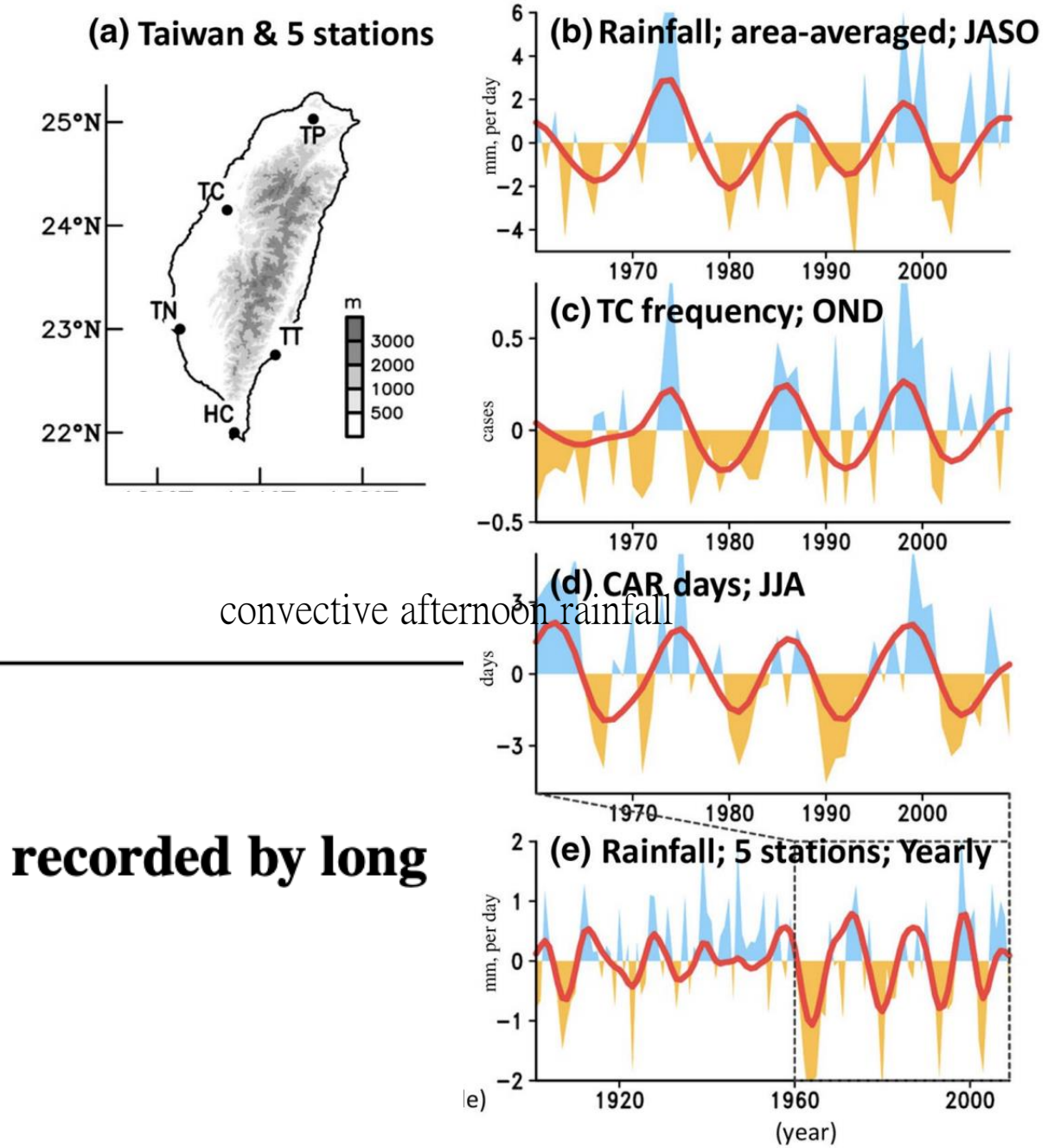
Cross-correlation function



(Jun – Oct) TC days



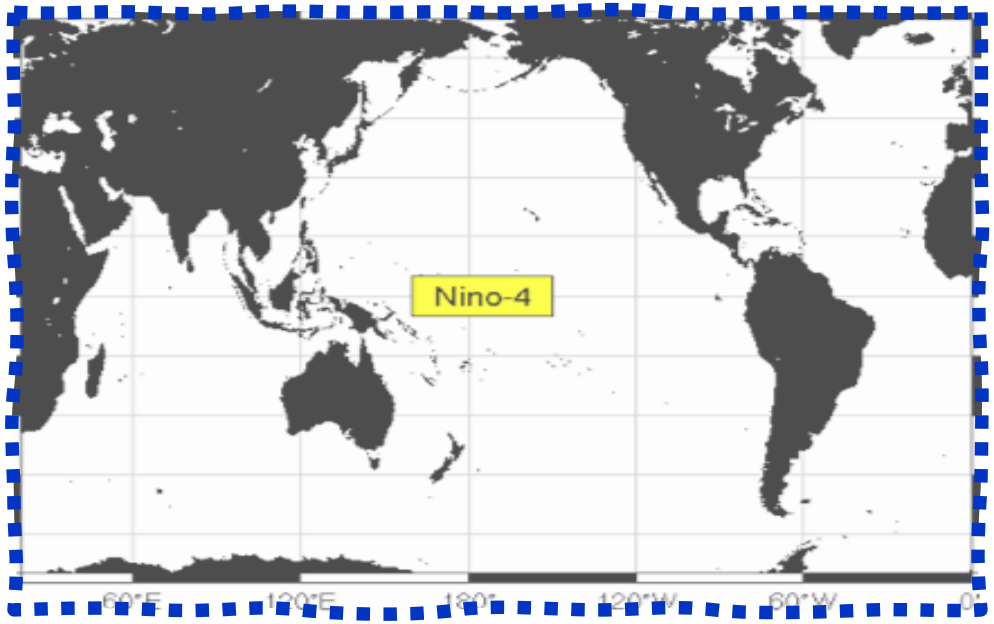
Barcikowska et al. (2017 CliDy)

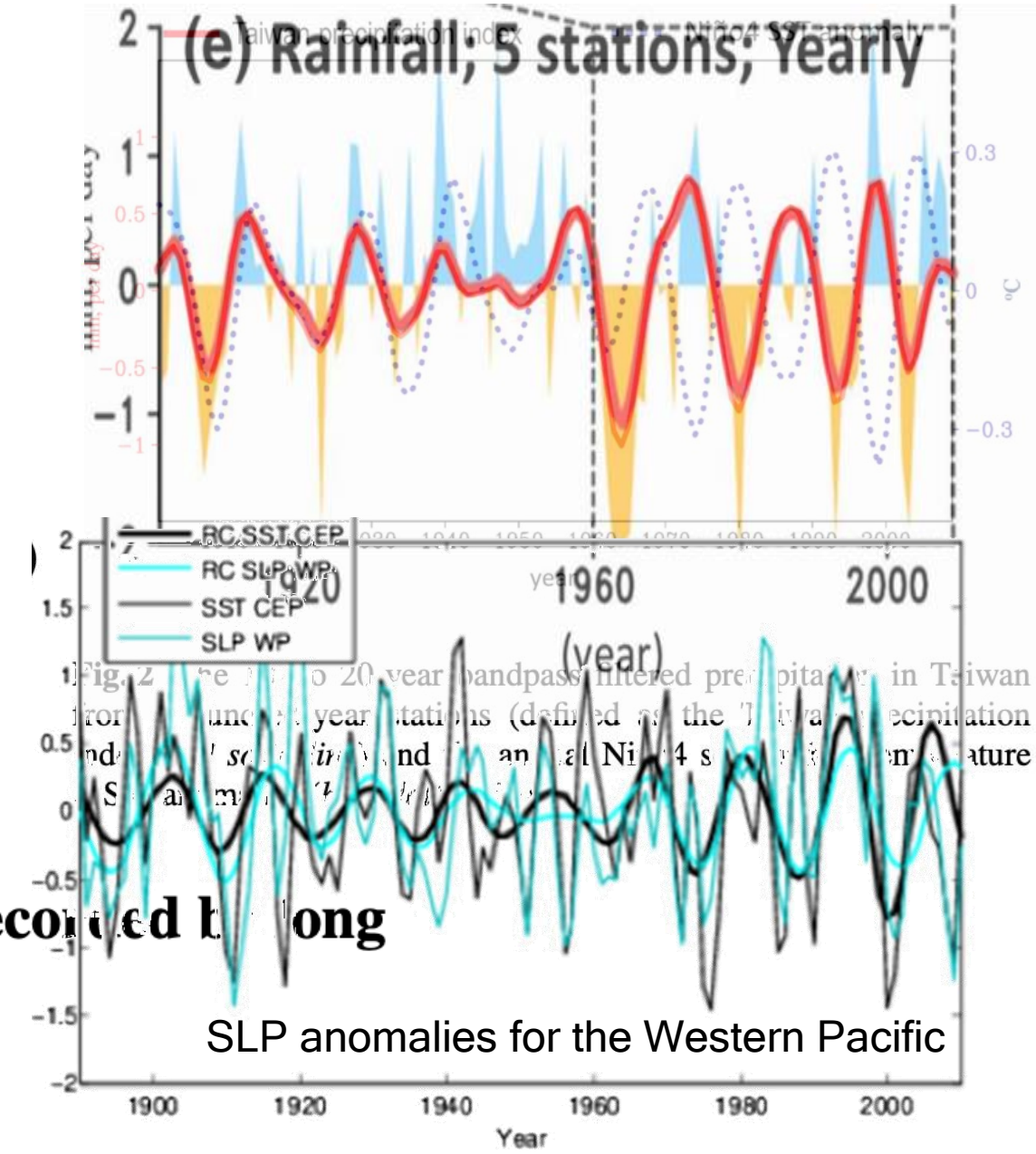


Clim Dyn (2018) 50:1597–1608
DOI 10.1007/s00382-017-3707-9

Decadal fluctuations in the western Pacific recorded by long precipitation records in Taiwan

Wan-Ru Huang[1] · S.-Y. Simon Wang[2,3] · Biing T. Guan[4]



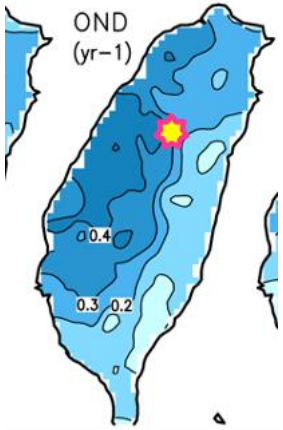


SLP anomalies for the Western Pacific

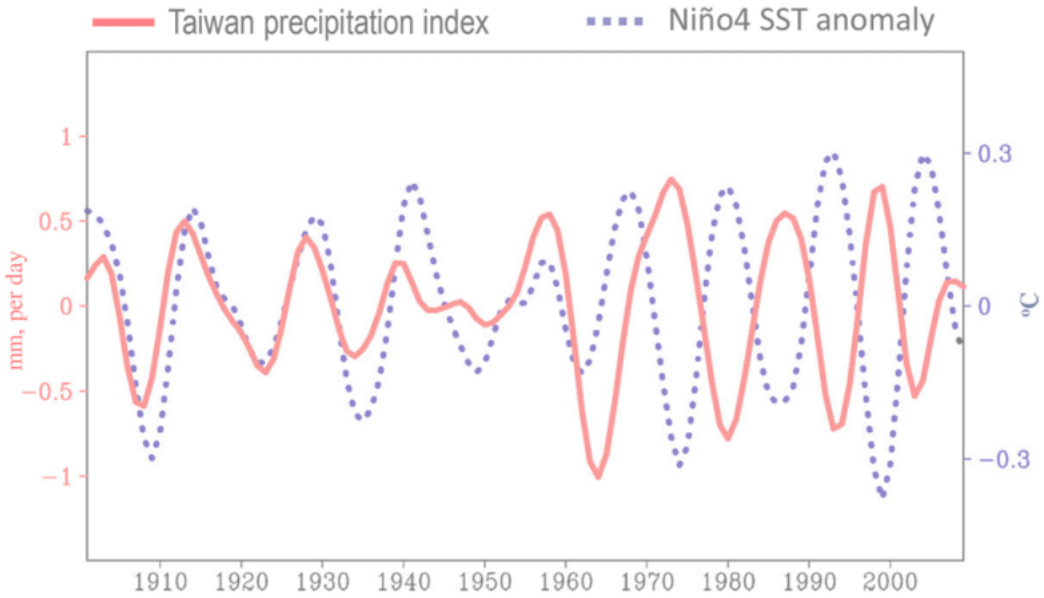
Barcikowska et al. (2017 CliDy)

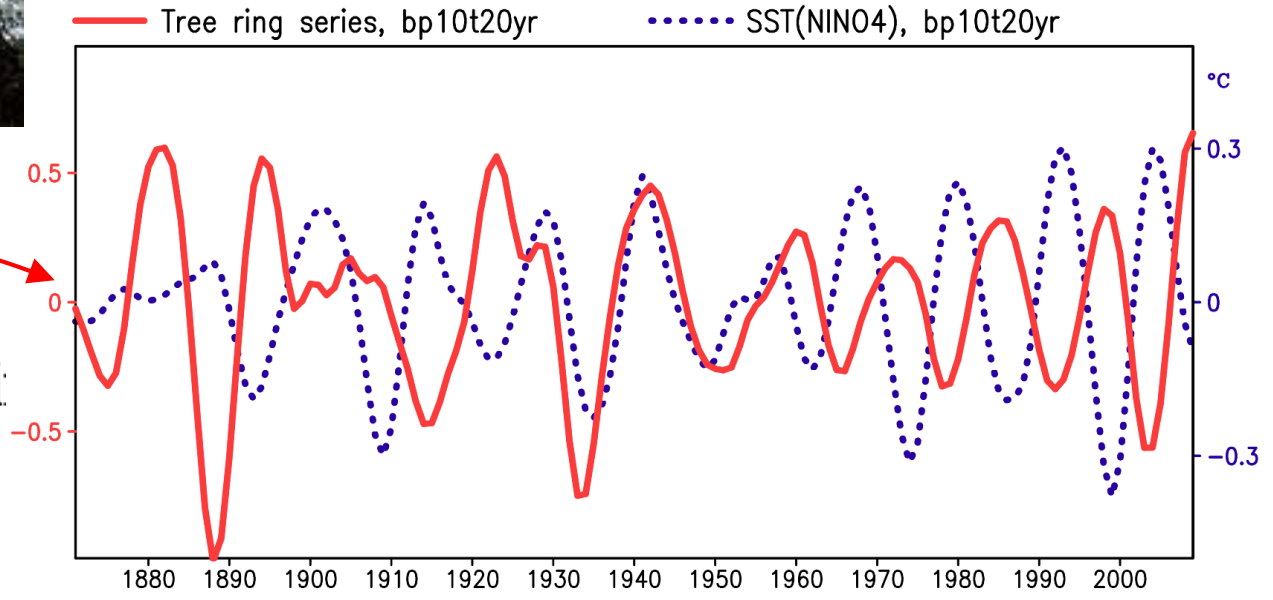
Decadal fluctuations in the western Pacific recorded by long precipitation records in Taiwan

Wan-Ru Huang[1] · S.-Y. Simon Wang[2,3] · Biing T. Guan[4]



台灣黃杉/ 威氏帝杉





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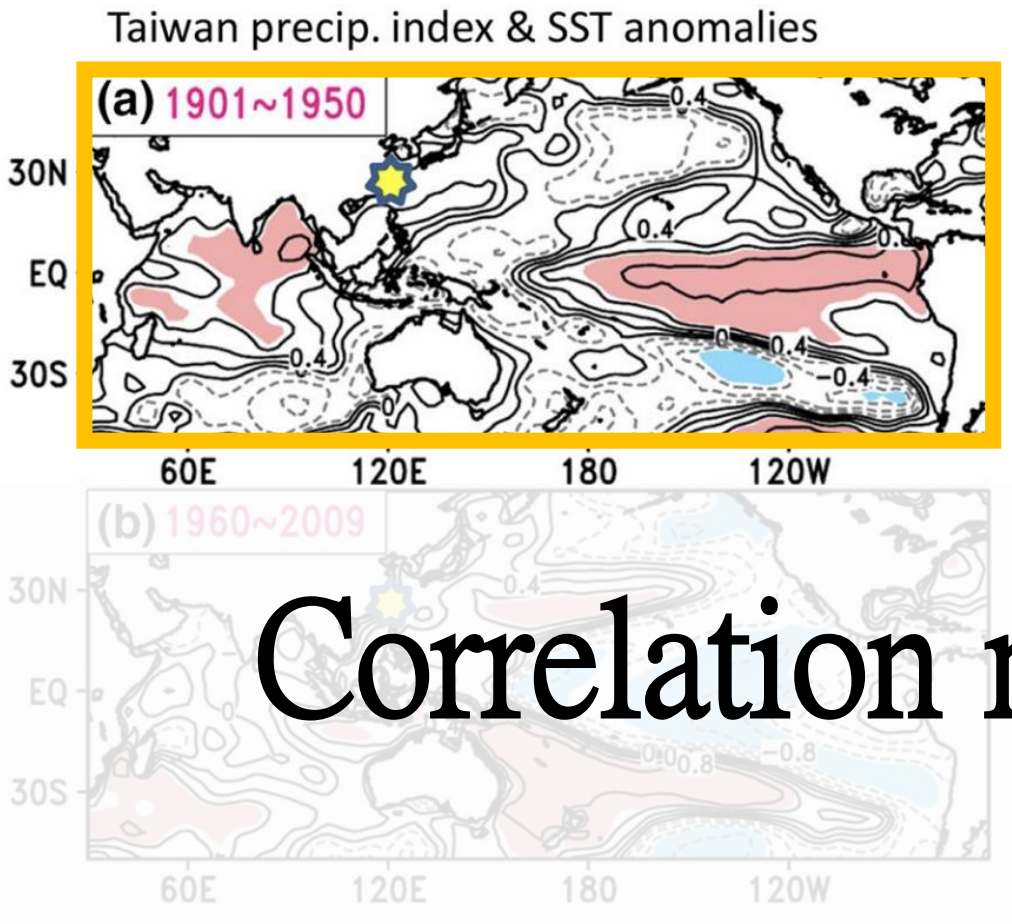
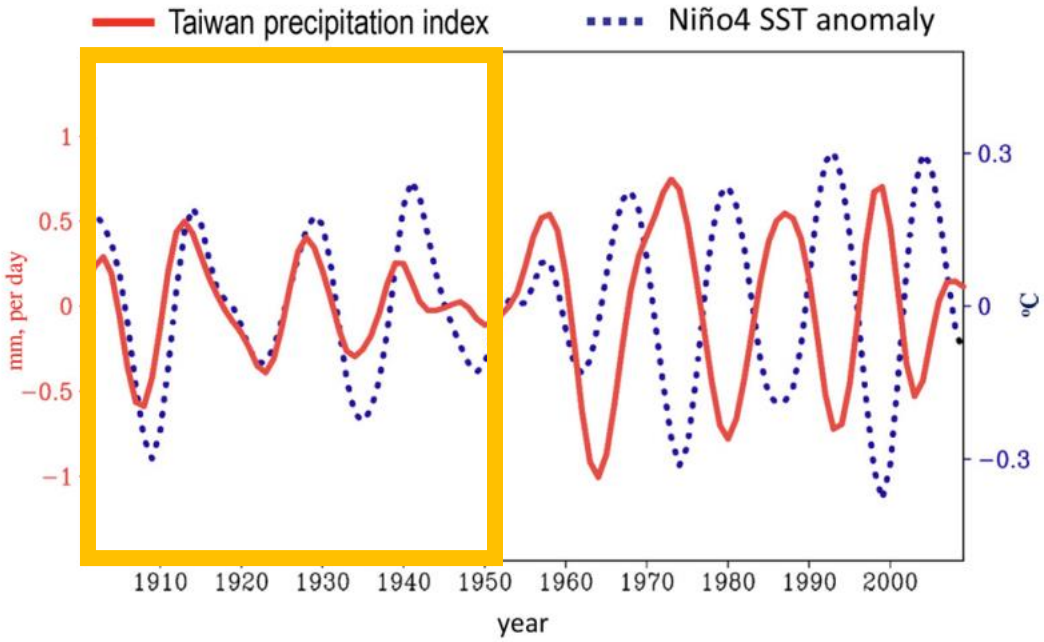
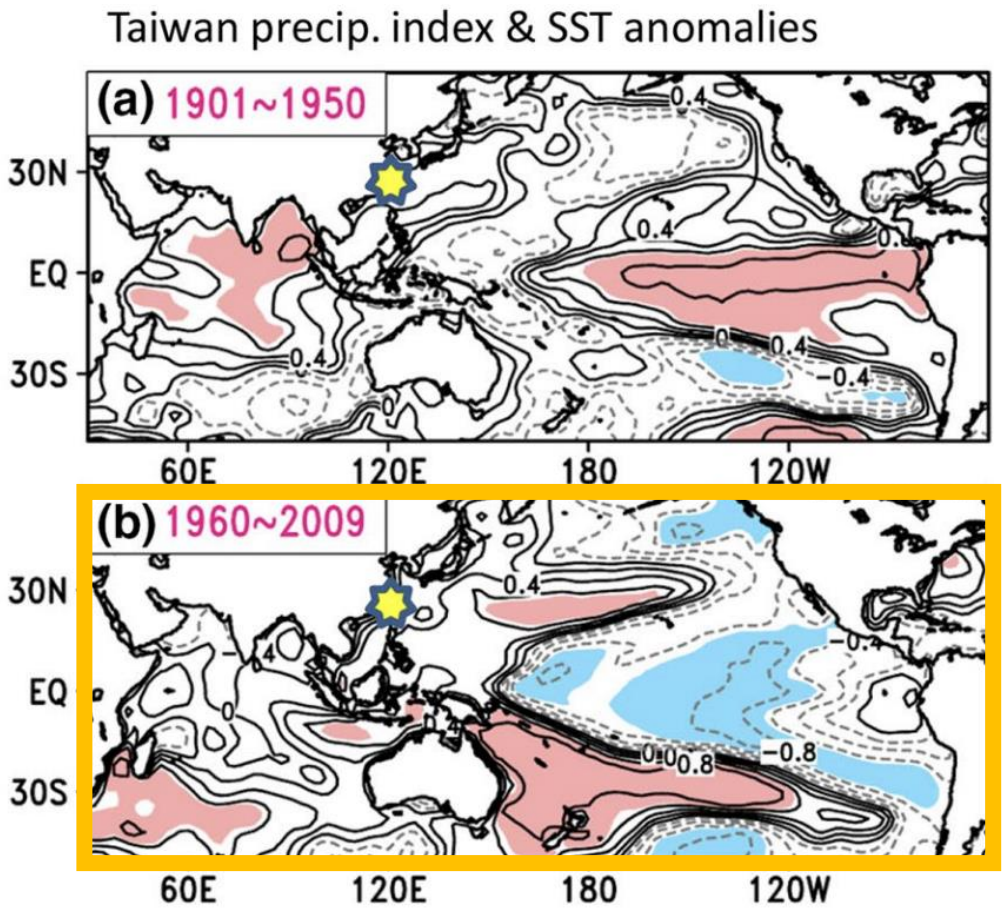


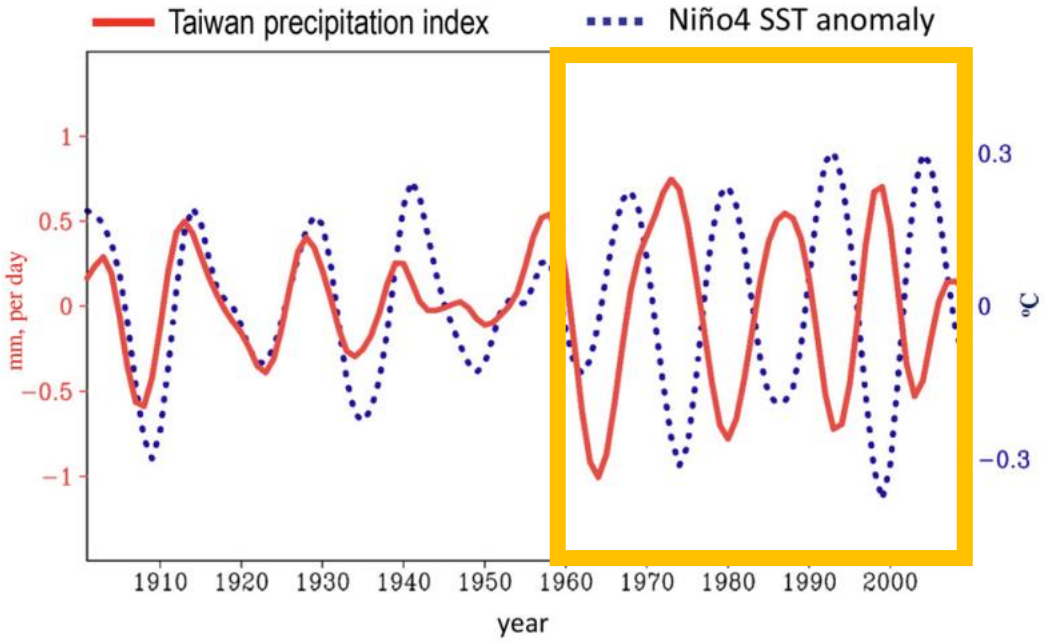


Correlation map

Decadal fluctuations in the western Pacific recorded by long precipitation records in Taiwan

Wan-Ru Huang[1] · S.-Y. Simon Wang[2,3] · Biing T. Guan[4]





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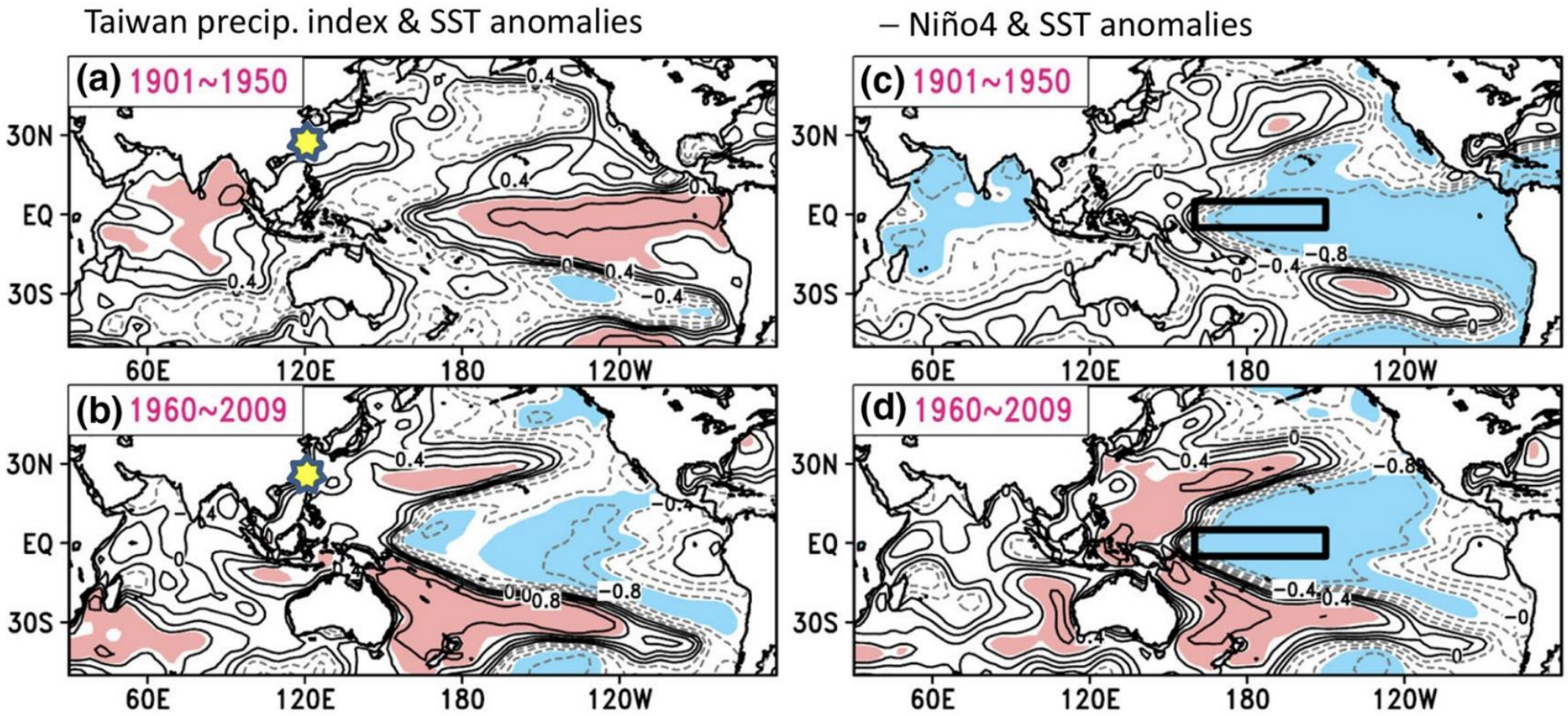

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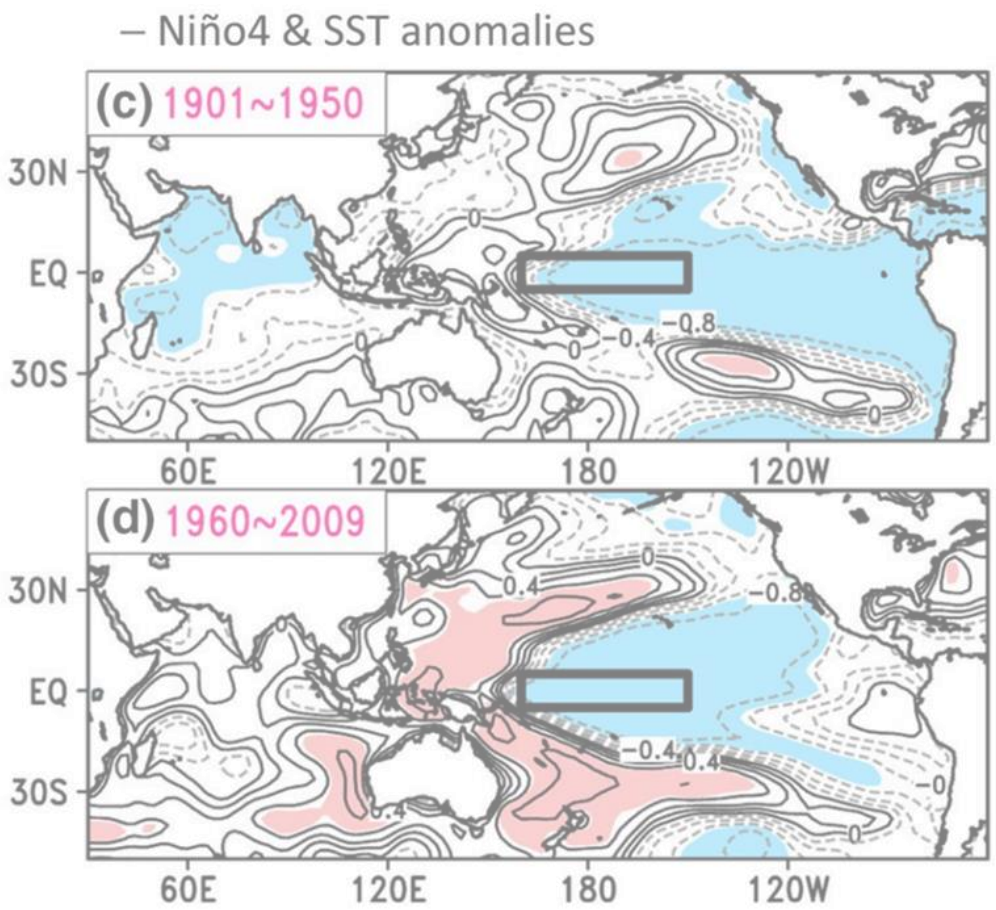
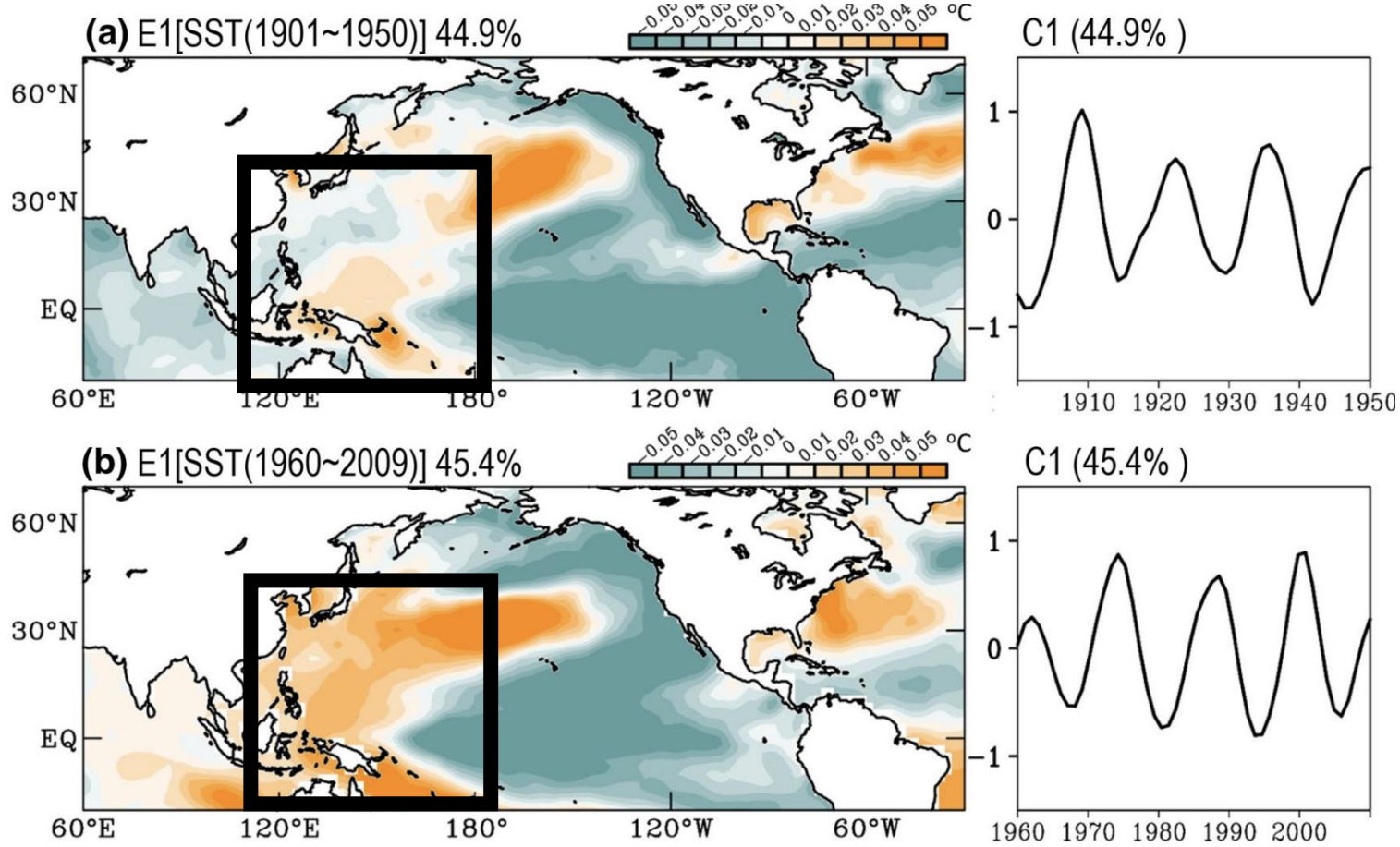
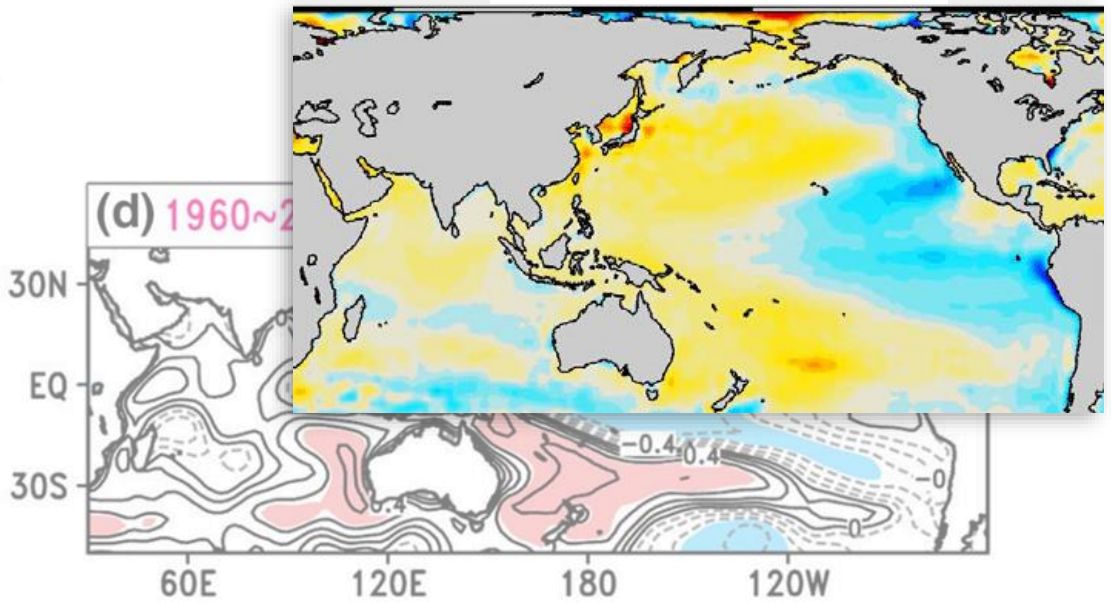




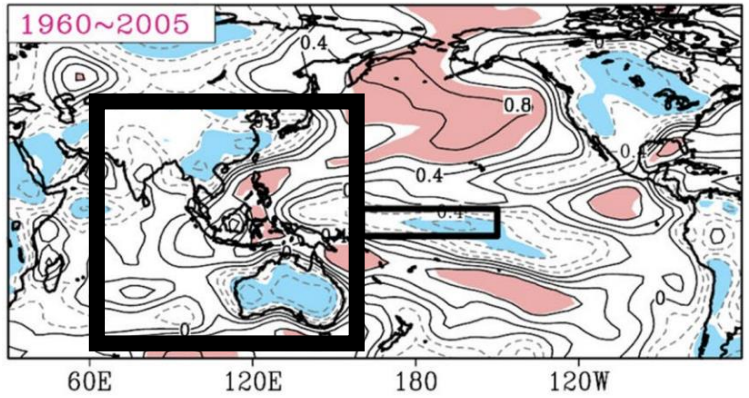
Decadal fluctuations in the western Pacific recorded by long precipitation records in Taiwan

Wan-Ru Huang[1] · S.-Y. Simon Wang[2,3] · Biing T. Guan[4]

Obs SST trend

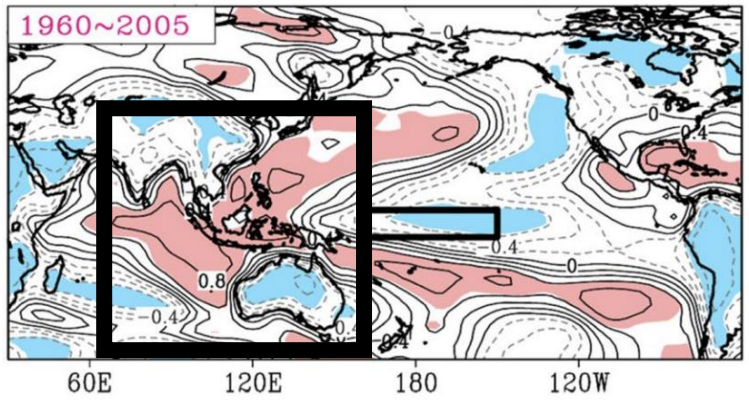


from HistoricalNAT experiment



CMIP5: Na

rom HistoricalGHG experiment



CMIP5: Gl

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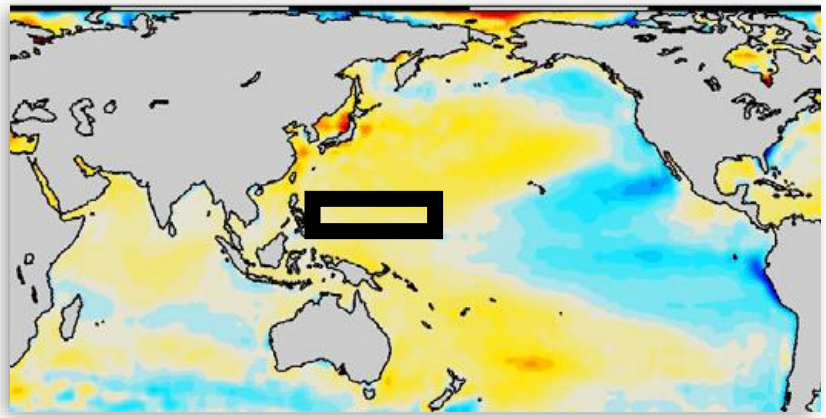
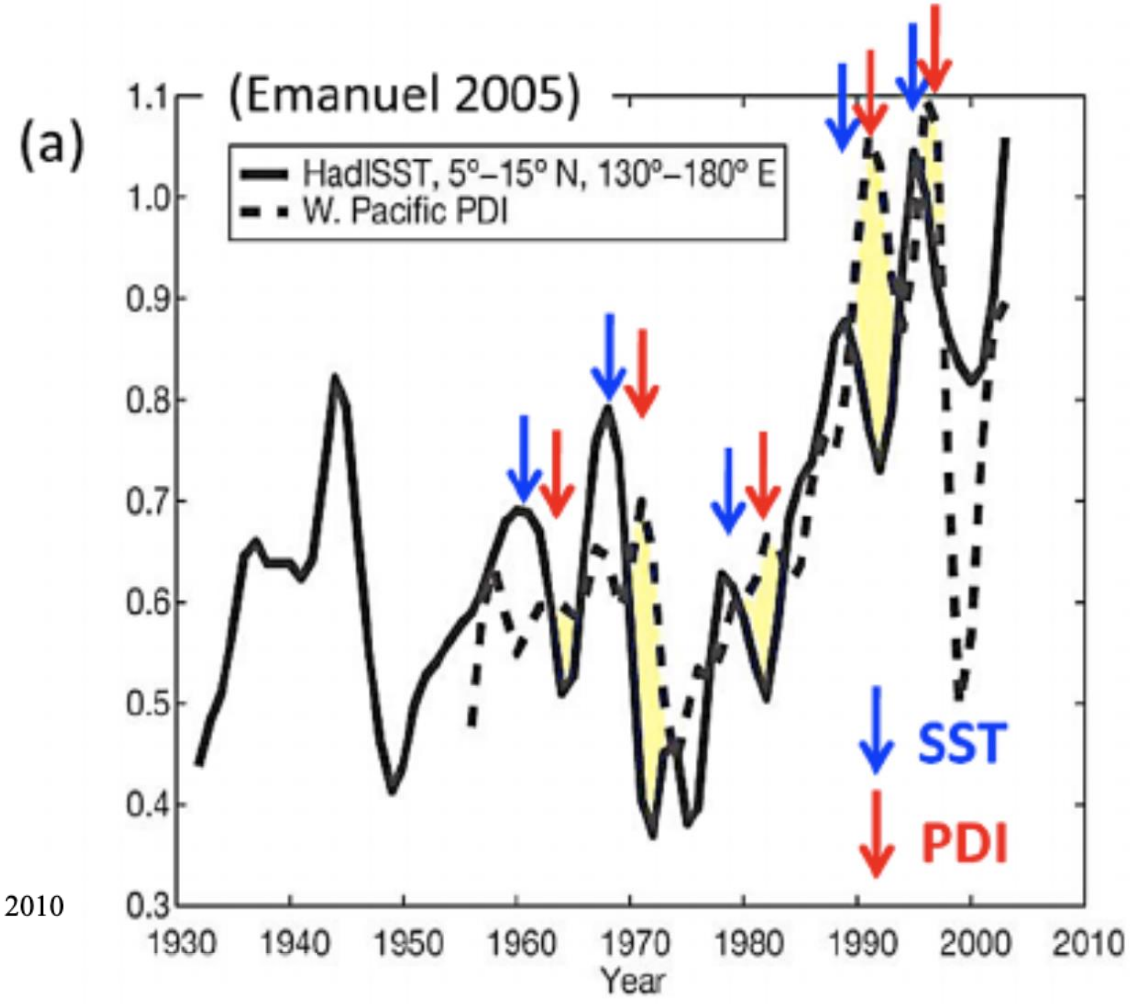




GEOPHYSICAL RESEARCH LETTERS, VOL. 37, L21810, doi:10.1029/2010GL044709, 2010

Geophysical Research Letters

Quasi-decadal spectral peaks of tropical western Pacific SSTs as a precursor for tropical cyclone threat

Shih-Yu Wang[1] and Adam J. Clark[2]

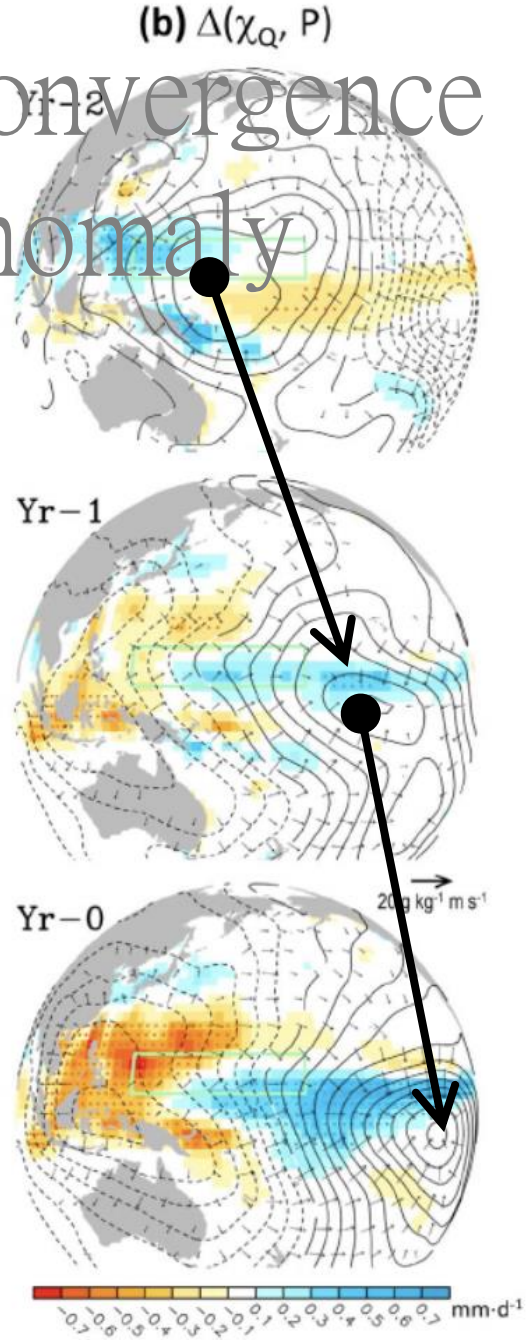
Received 16 July 2010; revised 8 September 2010; accepted 21 September 2010; published 9 November 2010.

the power dissipation index (PDI), defined as

$$\mathrm{PDI} \equiv \int_0^{\tau} V_{max}^3 dt$$

where V_{max} is the maximum sustained wind speed

Water vapor flux convergence and precipitation anomaly



Local SST peak

PDI peak years (Yr-0)

Quasi-decadal spectral peaks of tropical western Pacific SSTs as a precursor for tropical cyclone threat

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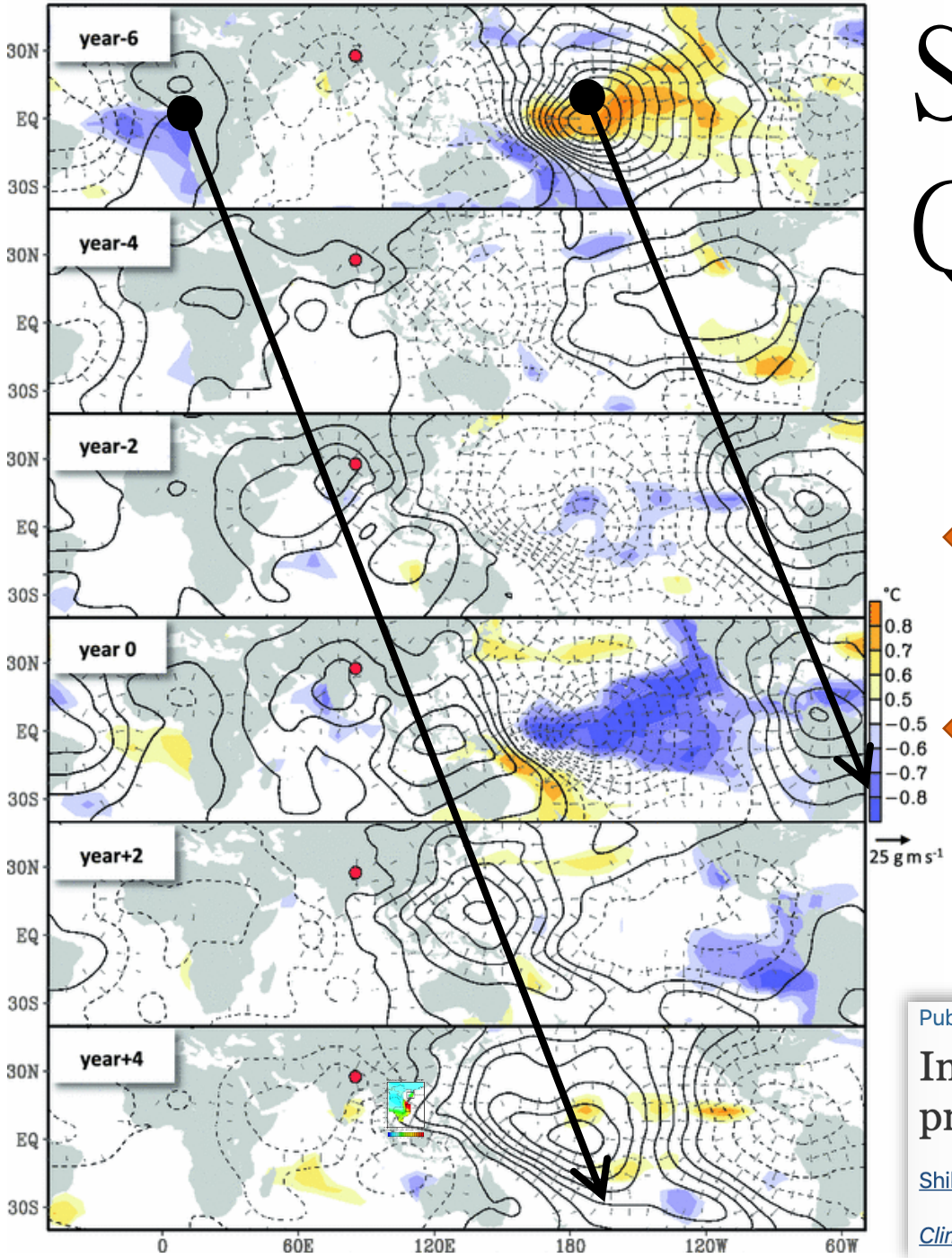


SSTA+$_{Y-6}$

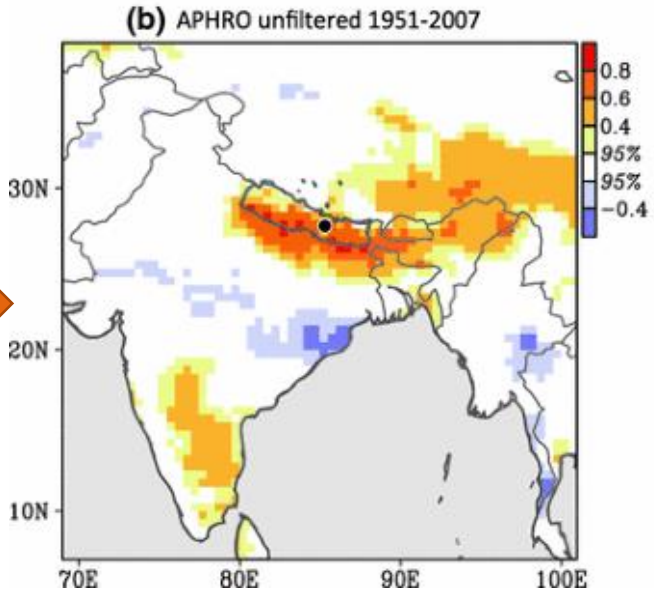
Q.conv $_{Y-4}$

Y-2

Y-0

Y+2

Nepal's monso

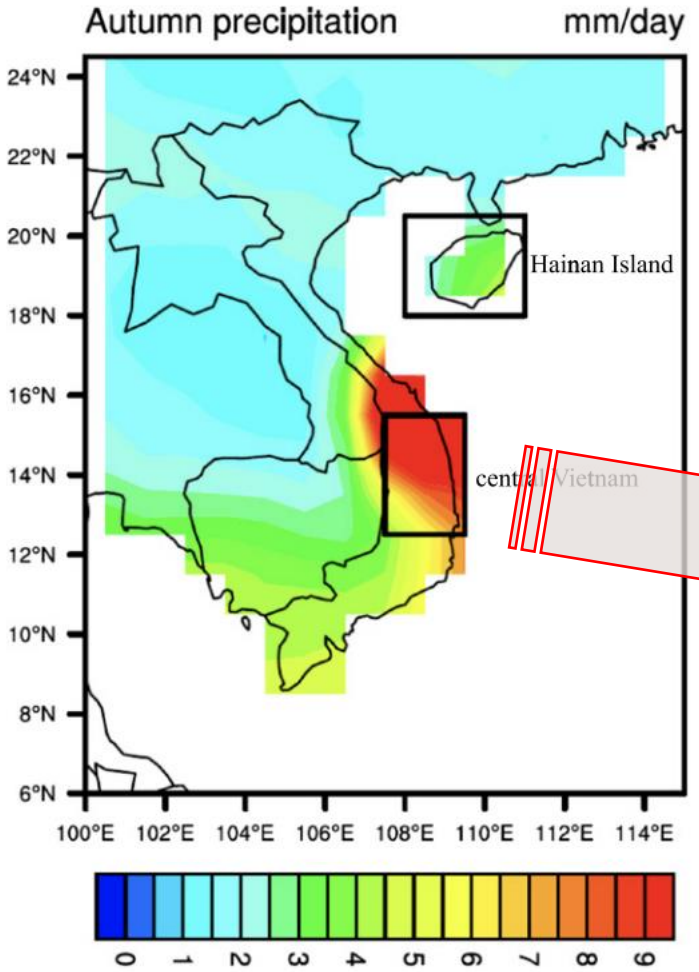


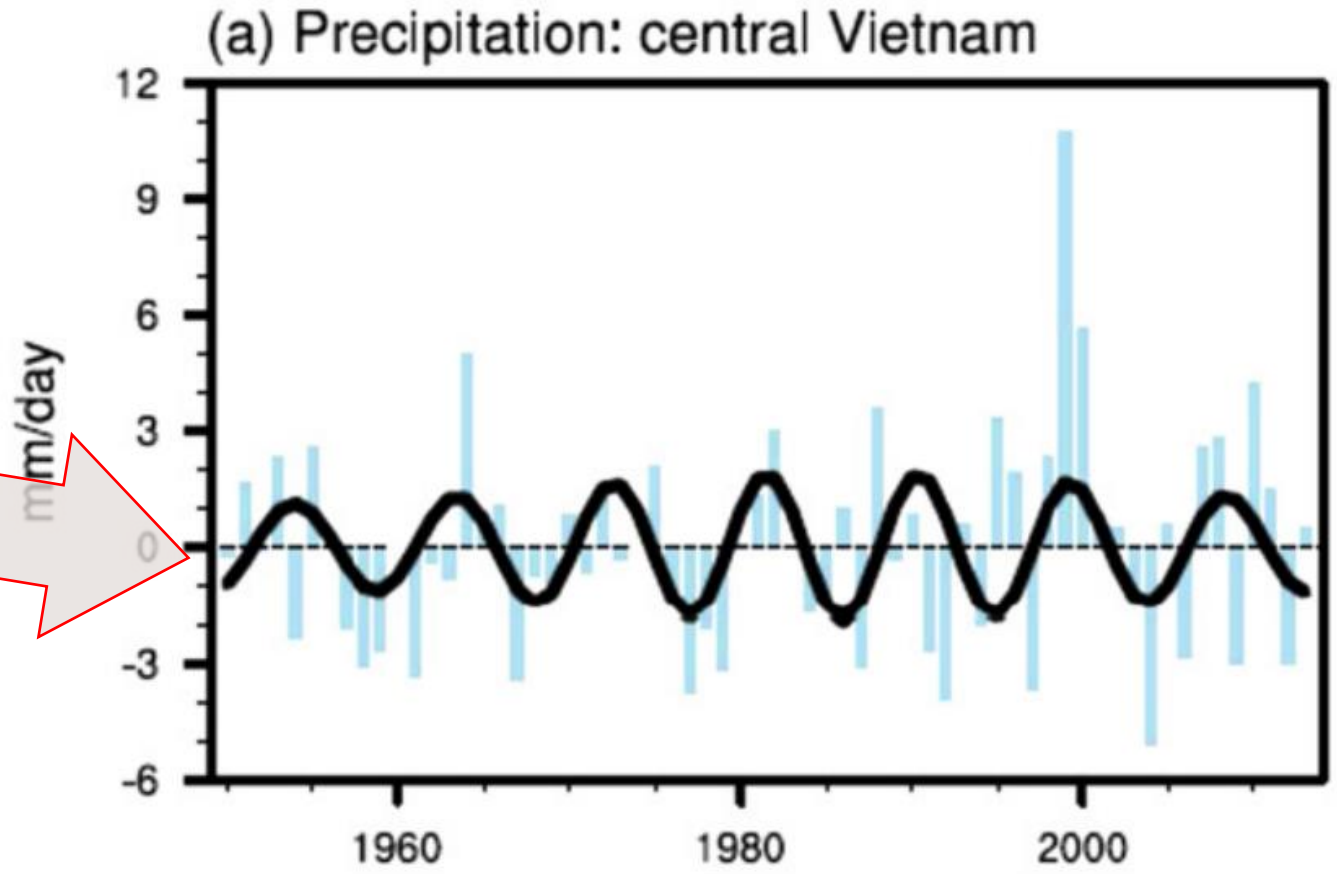
Published: 10 May 2012

Influence of the Pacific quasi-decadal oscillation on the monsoon precipitation in Nepal

Shih-Yu Wang ✉ & Robert R. Gillies

Climate Dynamics **40**, 95–107(2013) | Cite this article





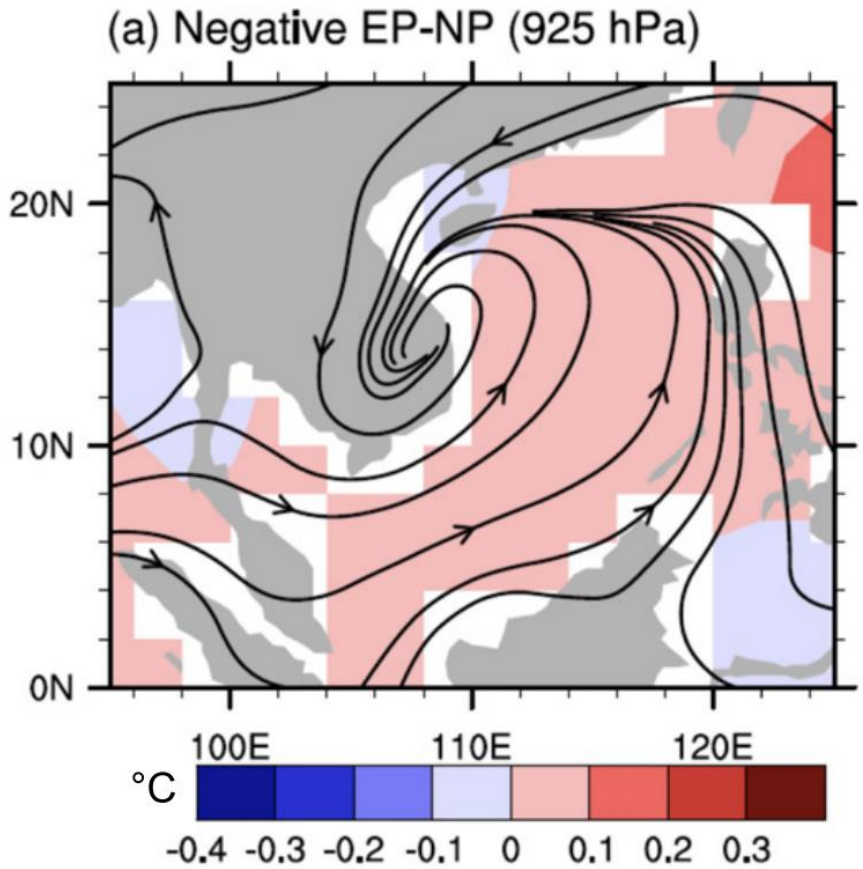
Environmental Research Letters

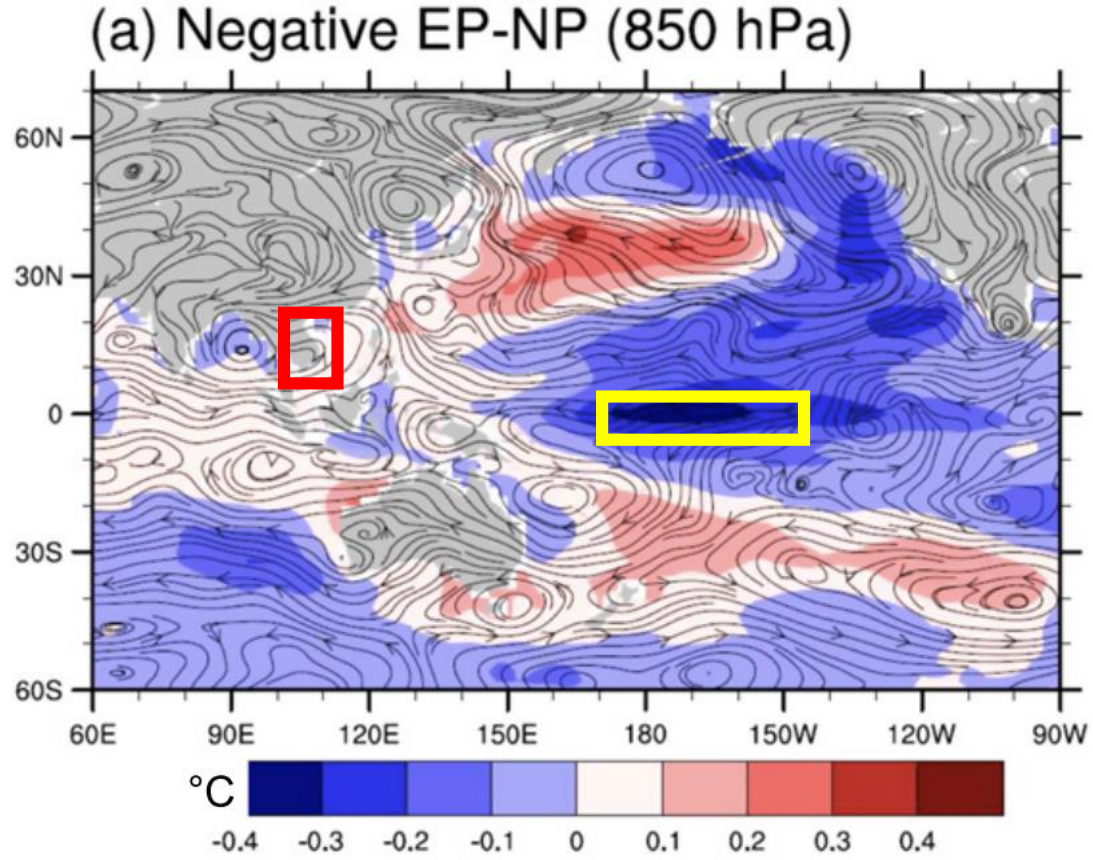
LETTER

Decadal oscillation of autumn precipitation in Central Vietnam modulated by the East Pacific–North Pacific (EP–NP) teleconnection

R Li[1,2], S-Y Wang[1,2], R R Gillies[1,2], B M Buckley[3], L H Truong[4] and C Cho[1,2]

[1] Utah Climate Center, Utah State University, Logan, UT, USA





Environmental Research Letters

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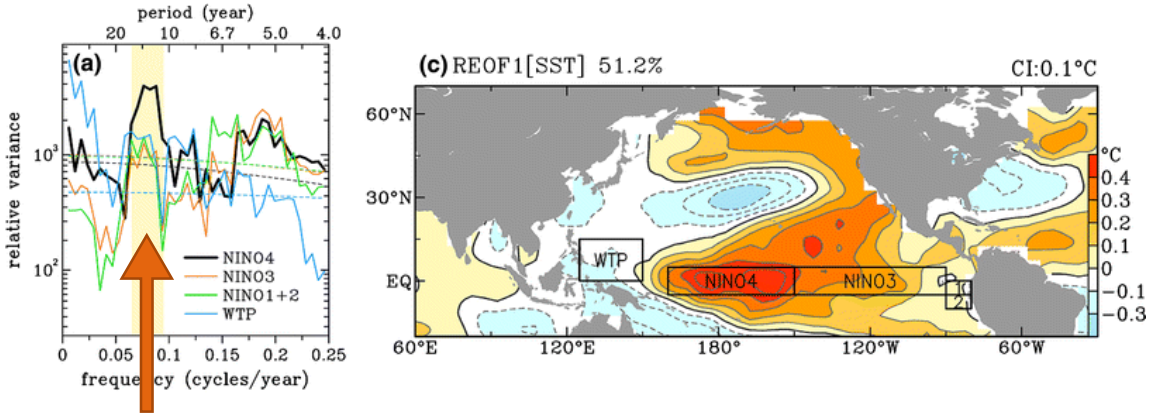
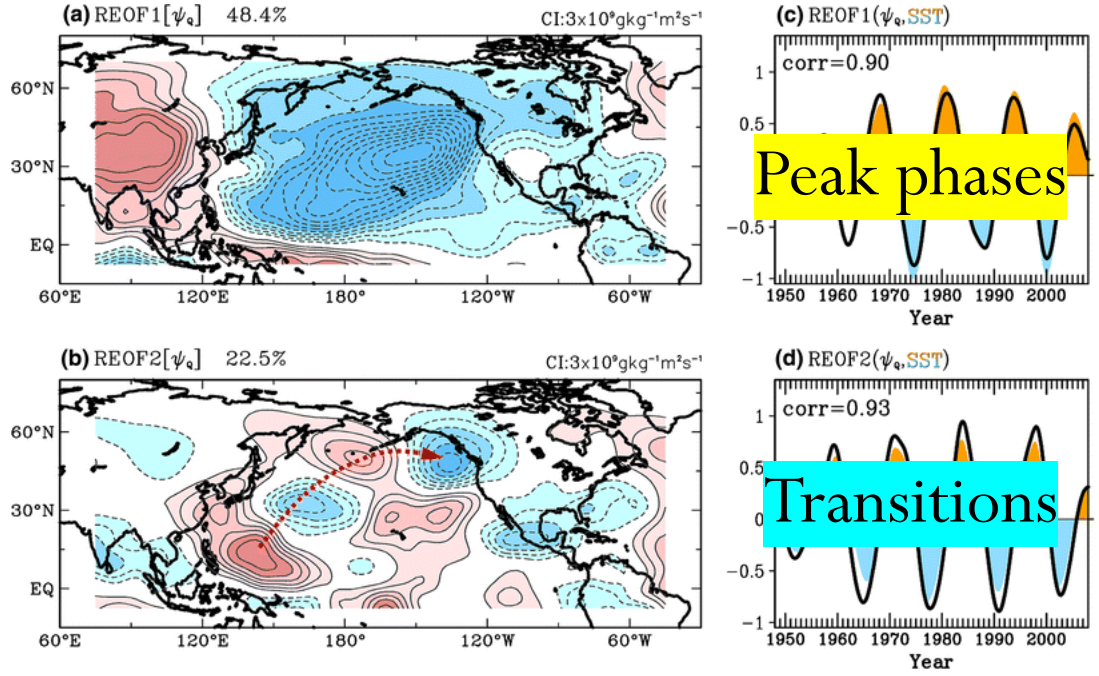
準十年震盪，怎麼來的？



Wang et al. (2011; Cli



準十年震盪，怎麼來的？

- The quasi-decadal sea level modes in the Pacific is an expression of the ENSO-like low-frequency variability
- …but the ENSO-like low-frequency

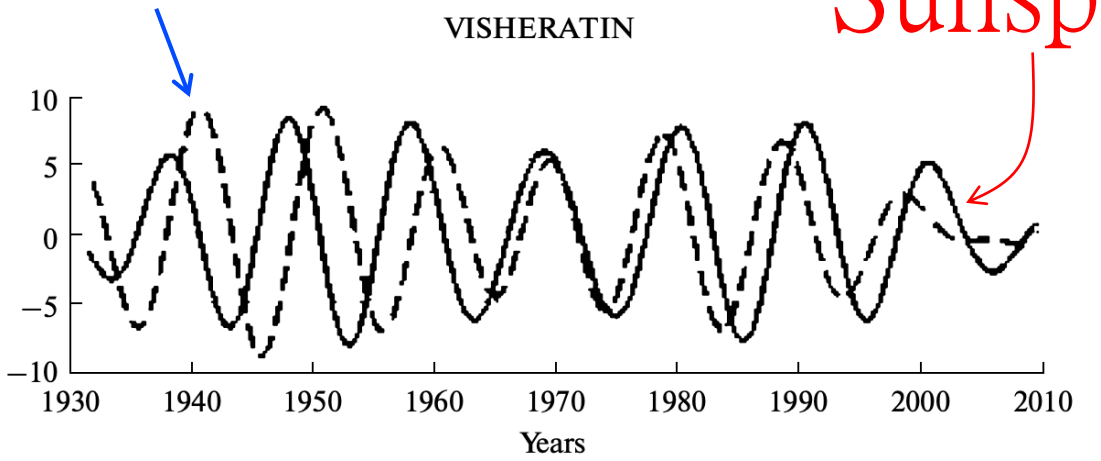
(Lyu et al. 2017 J. Climate)

準十年震盪
不是太陽黑
子造成的

對不起來

Climate cycle

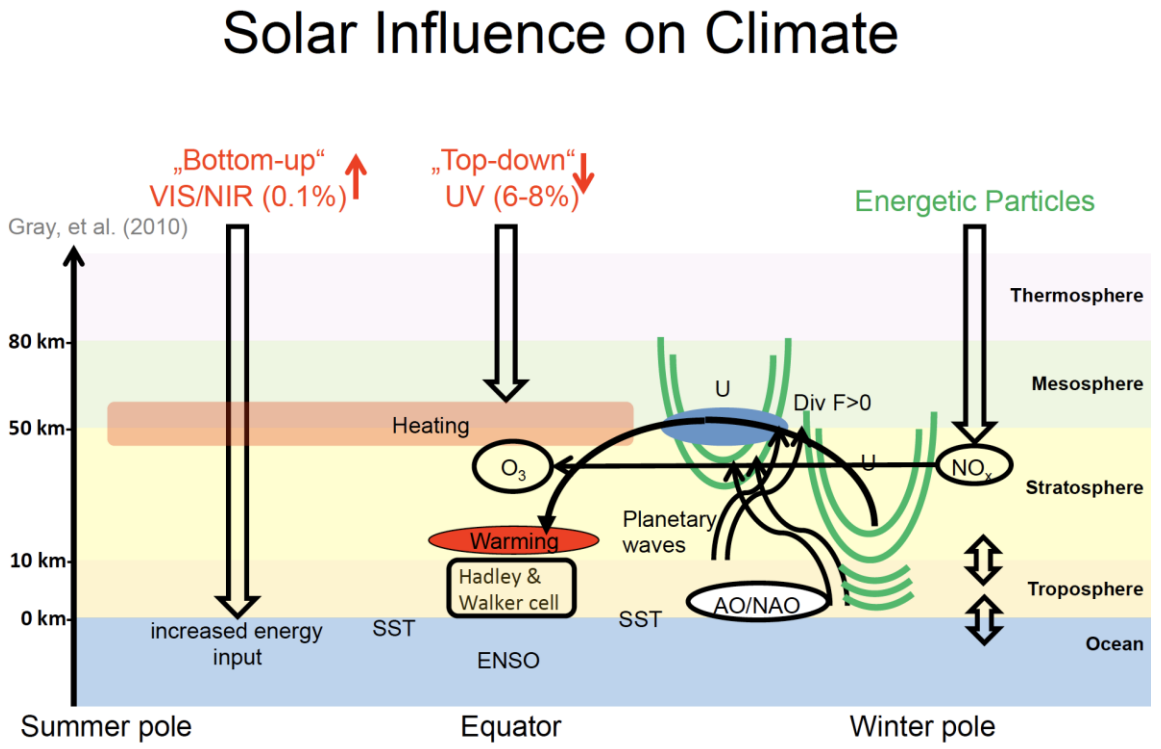
Sunspot c



Composite series (sum of oscillations with periods of 8 – 13 years) of the Ri sunspot index (solid curve) and TO in Arosa (dashed curve). The amplitudes are in relative units.

(Visheratin 2012)

…但也有人說是😂



(Matthes et al. 2016)

- Solar signal projects onto NAO-like pattern, which amplifies through ocean-atmosphere feedback.

Example in the U.K.

CIWEM Chartered Institution of Water and Environmental Management

~4 minutes

十年一乾，五年一旱

Simon 世宇 Wang, Utah State University

台灣降雨的準十年規律，知道了有用嗎？

forecasting

climate

MDPI

Article

Feasibility of Predicting Vietnam's Autumn Rainfall Regime Based on the Tree-Ring Record and Decadal Variability

Yan Sun [1,*], S. -Y. Simon Wang [2,3], Rong Li [3], Brendan M. Buckley [4], Robert Gillies [2,3] and Kyle G. Hansen [4]

[1] Department of Mathematics and Statistics, Utah State University, Logan, UT 84322, USA
[2] Department of Plants, Soils, and Climate, Utah State University, Logan, UT 84322, USA; simon.wang@usu.edu (S.-Y.S.W.); Robert.Gillies@usu.edu (R.G.)

	1-Step-Ahead		2-Step-Ahead		5-Step-Ahead		10-Step-Ahead	
	RMSE	MSTE	RMSE	MSTE	RMSE	MSTE	RMSE	MSTE
ARMA (1,2)	0.94291	0.91012	0.97659	0.96582	0.97619	1.00022	0.98199	1.00556
SpsAR (15)	0.92504	0.87843	0.89998	0.91994	0.92794	0.94119	0.97126	**0.96686**
ARMAX (1,0,6)	0.98752	0.87852	1.03347	0.95508	1.02754	0.97091	1.03543	0.96946
SpsARX (15,6)	**0.84880**	**0.87290**	**0.88449**	**0.91330**	**0.87881**	**0.94081**	**0.93695**	0.97237

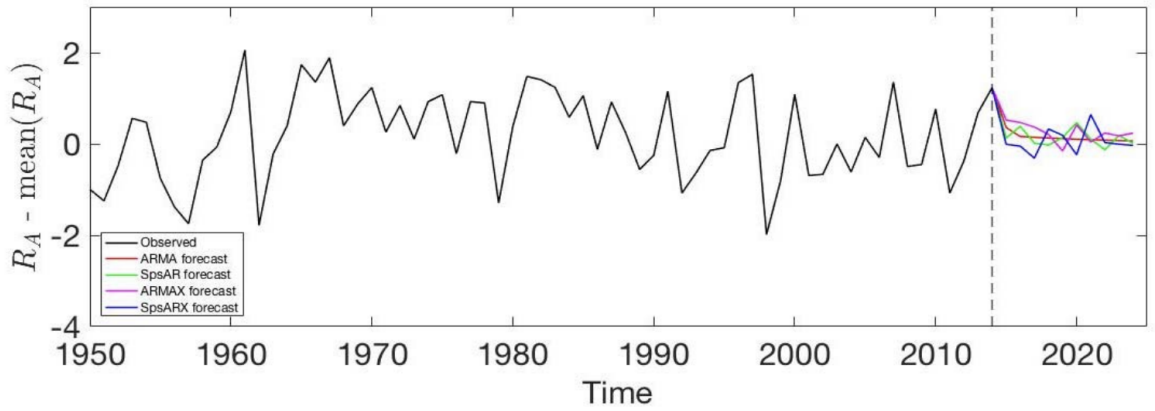
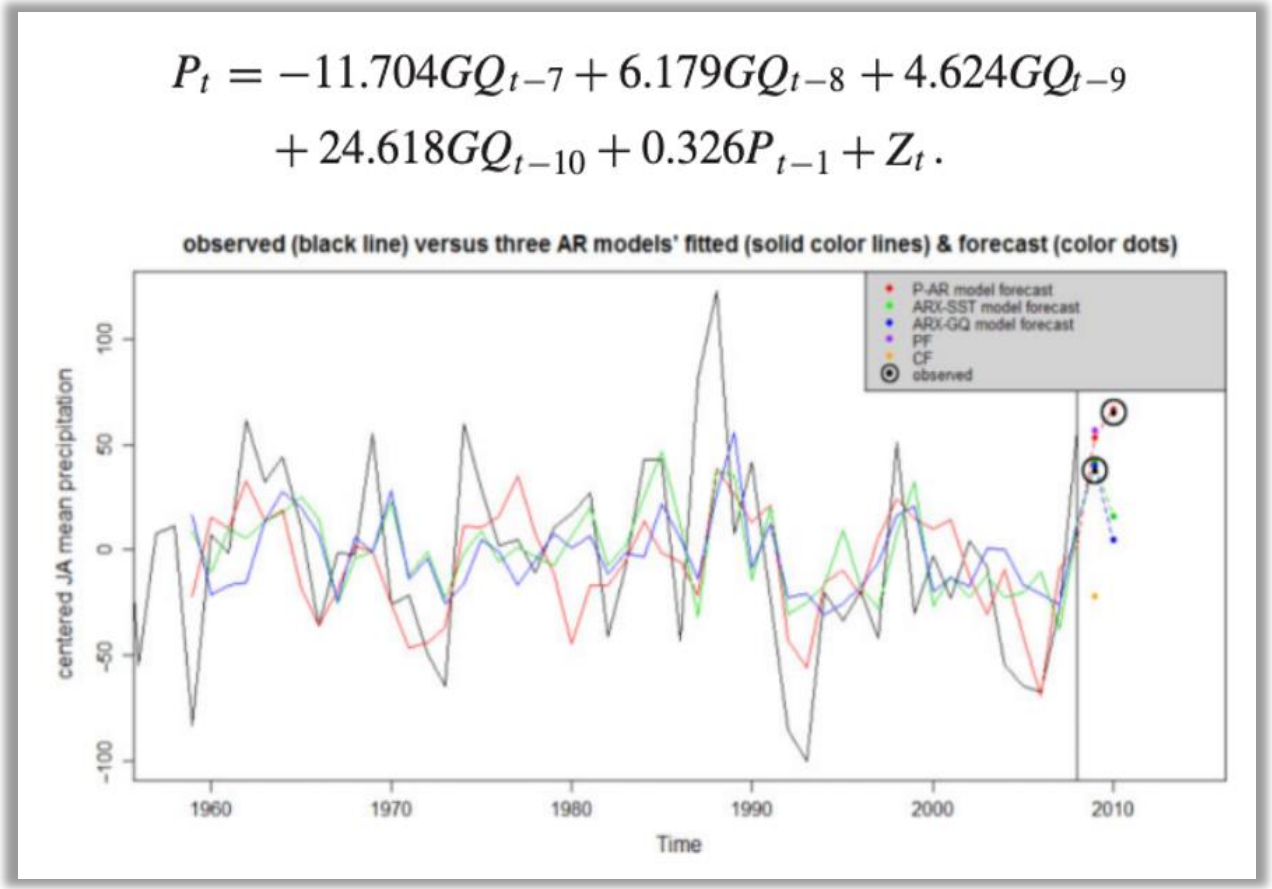


Figure 12. Plot of the 10-year forecasts (2015–2024) by the four models, together with the observed values (1950–2014).

forecasting

$$P_t = -11.704GQ_{t-7} + 6.179GQ_{t-8} + 4.624GQ_{t-9} + 24.618GQ_{t-10} + 0.326P_{t-1} + Z_t\,.$$



International Journal of Climatology

RMetS

RESEARCH ARTICLE

Supportive empirical modelling for the forecast of monsoon precipitation in Nepal

Robert R. Gillies ✉, Shih-Yu Wang, Yan Sun, Oi-Yu Chung

First published: 06 February 2013 | https://doi.org/10.1002/joc.3649 | Citations: 3

forecasting

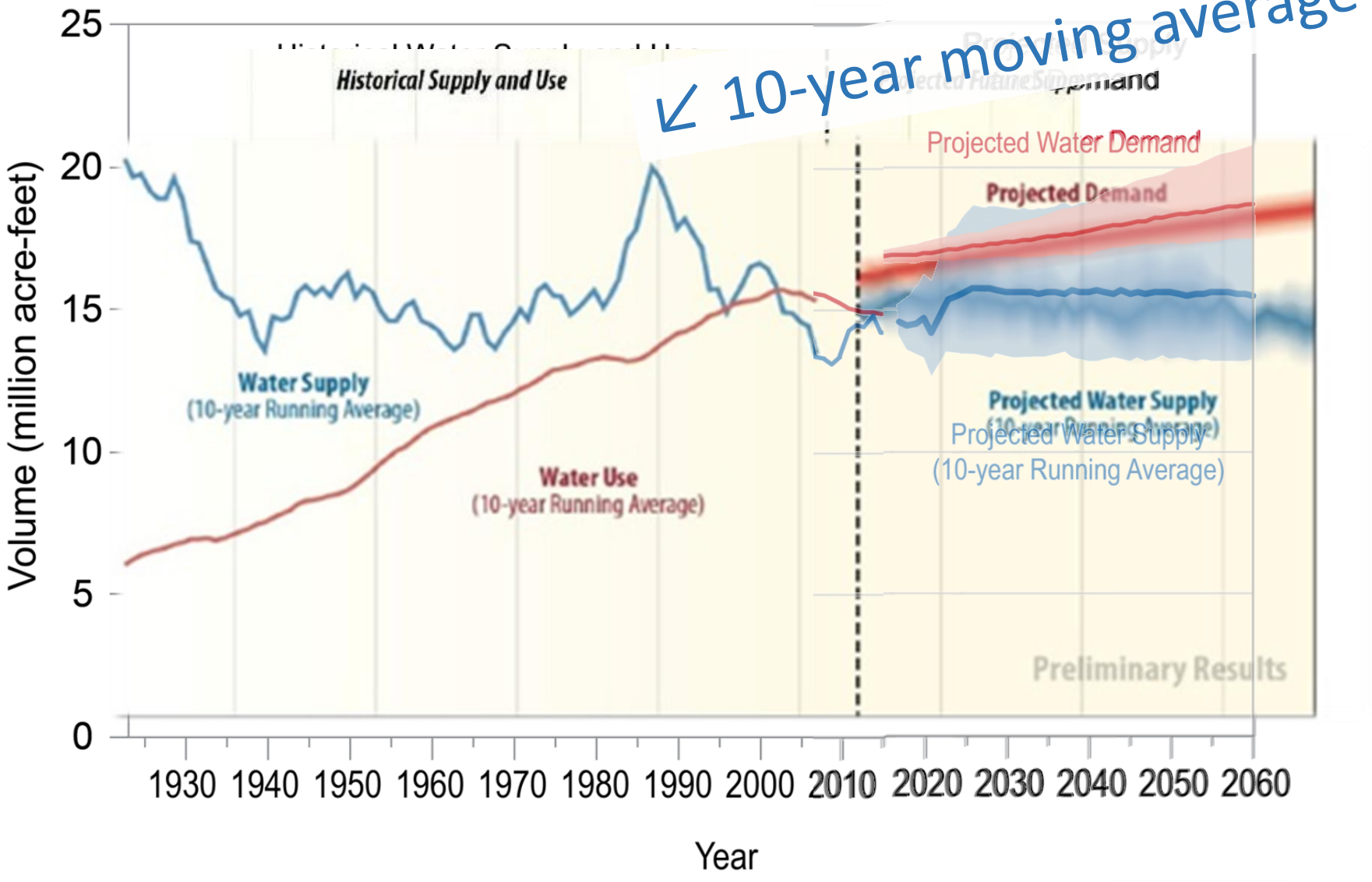
Cross-Basin Climate Connecting

Colorado River Water Supply and the Great Salt Lake

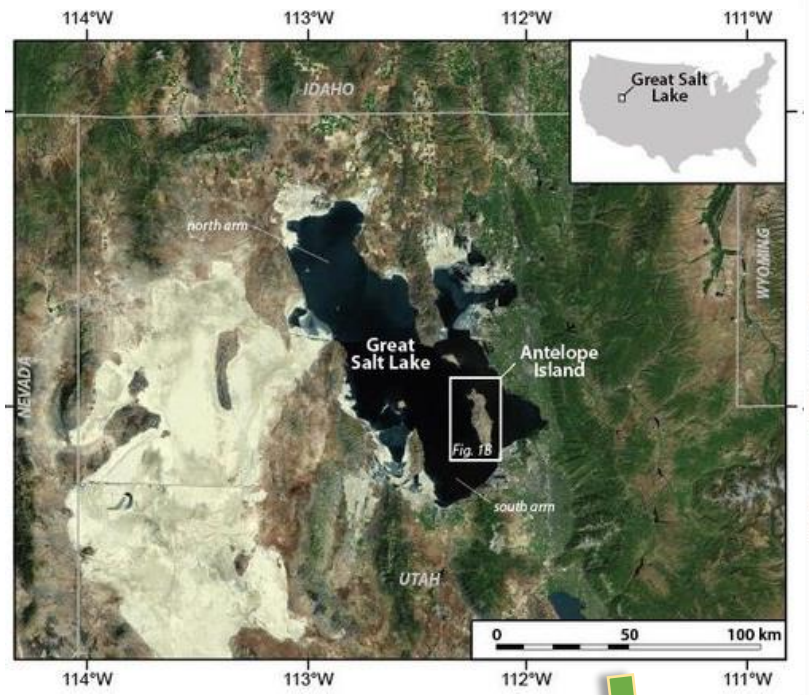
Simon Wang, Utah State University, Logan, UT

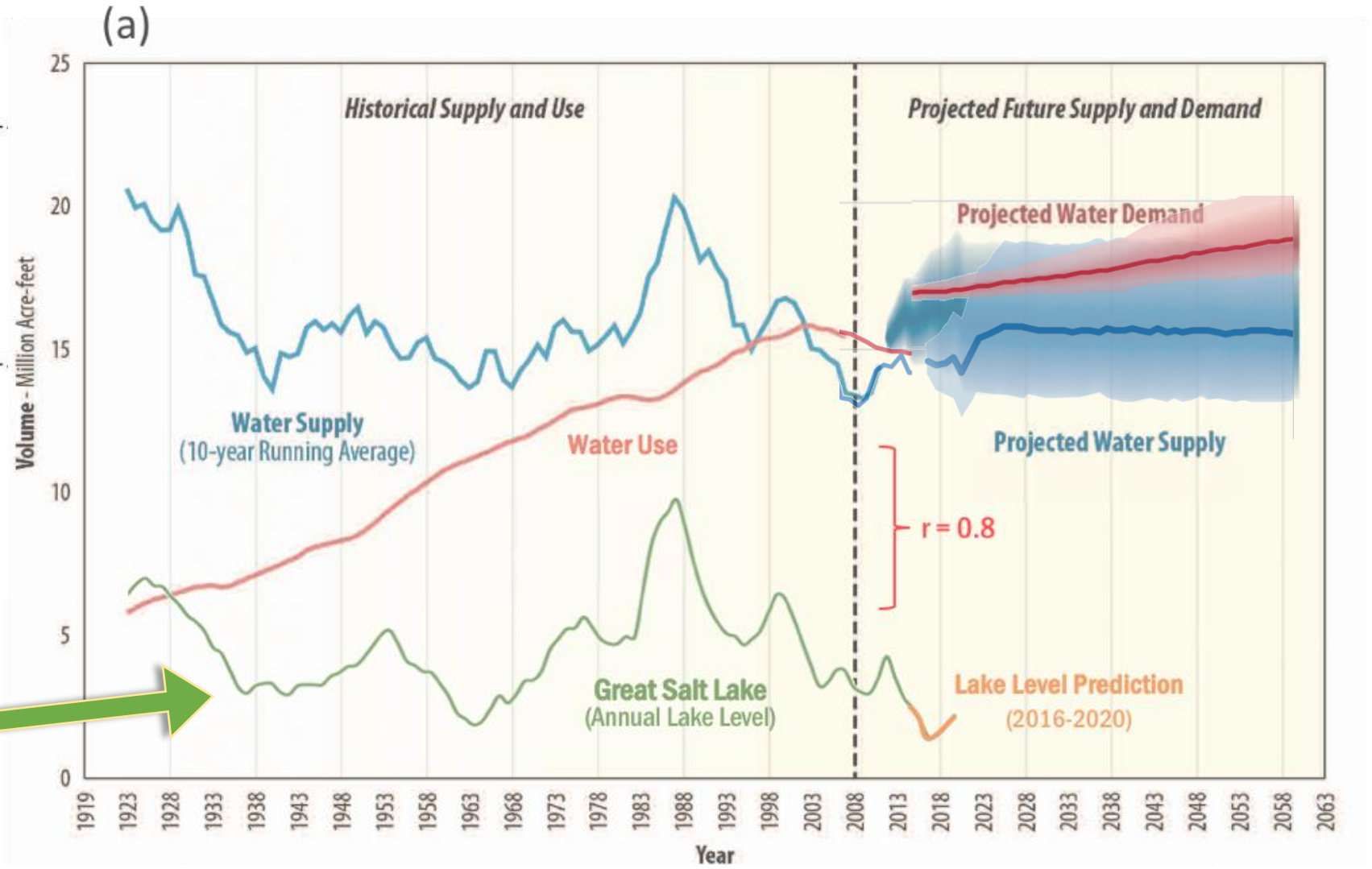
Rob Gillies, Yoshi Chikamoto

& Chaopeng Shen (PennState)



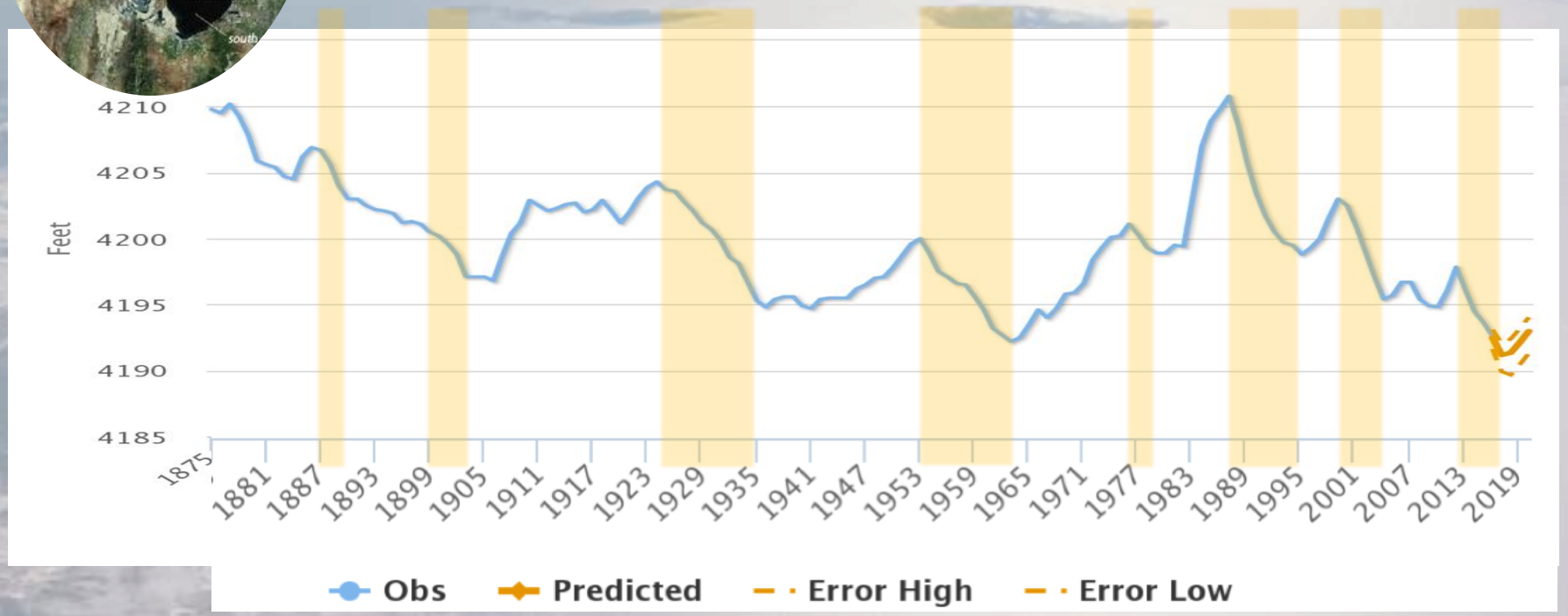
↙ 10-year moving average





Wang, S.-Y., R. R. Gillies, O.-Y. Chung, and C. Shen
(2018) *Journal of Hydrometeorology*

Climate driven
multi-year drought periods



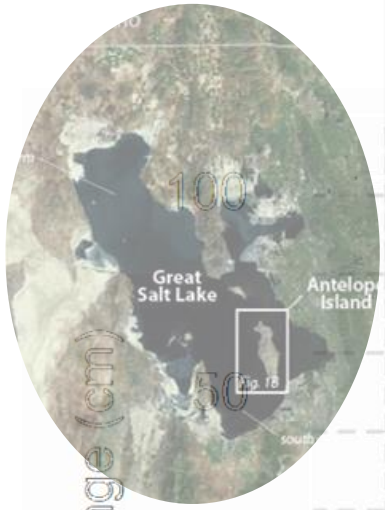
Research paper

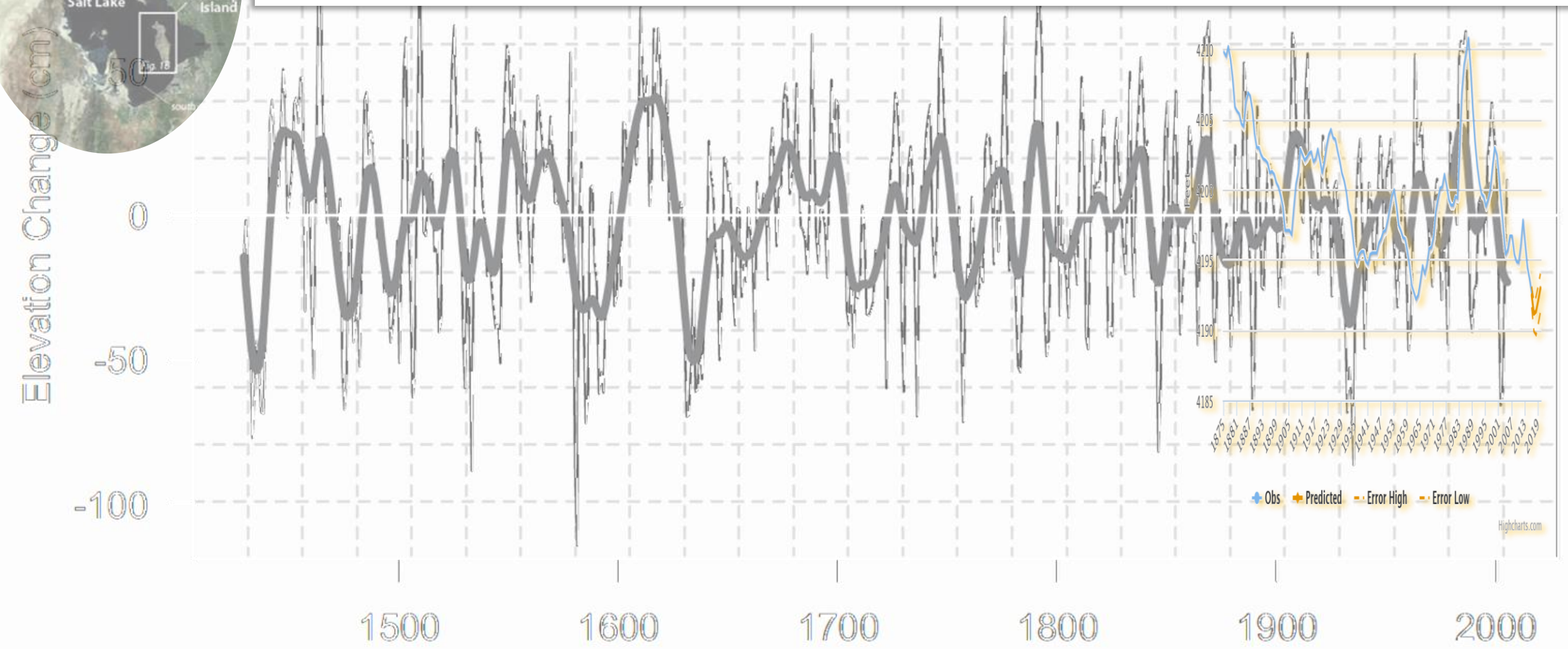
Tree-ring reconstruction of the level of Great Salt Lake 1429 to 2005

The Holocene
1–9

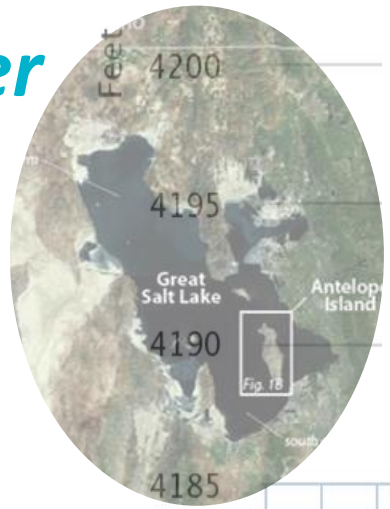
DOI: 10.1177/0959683614530441
hol.sagepub.com
SAGE

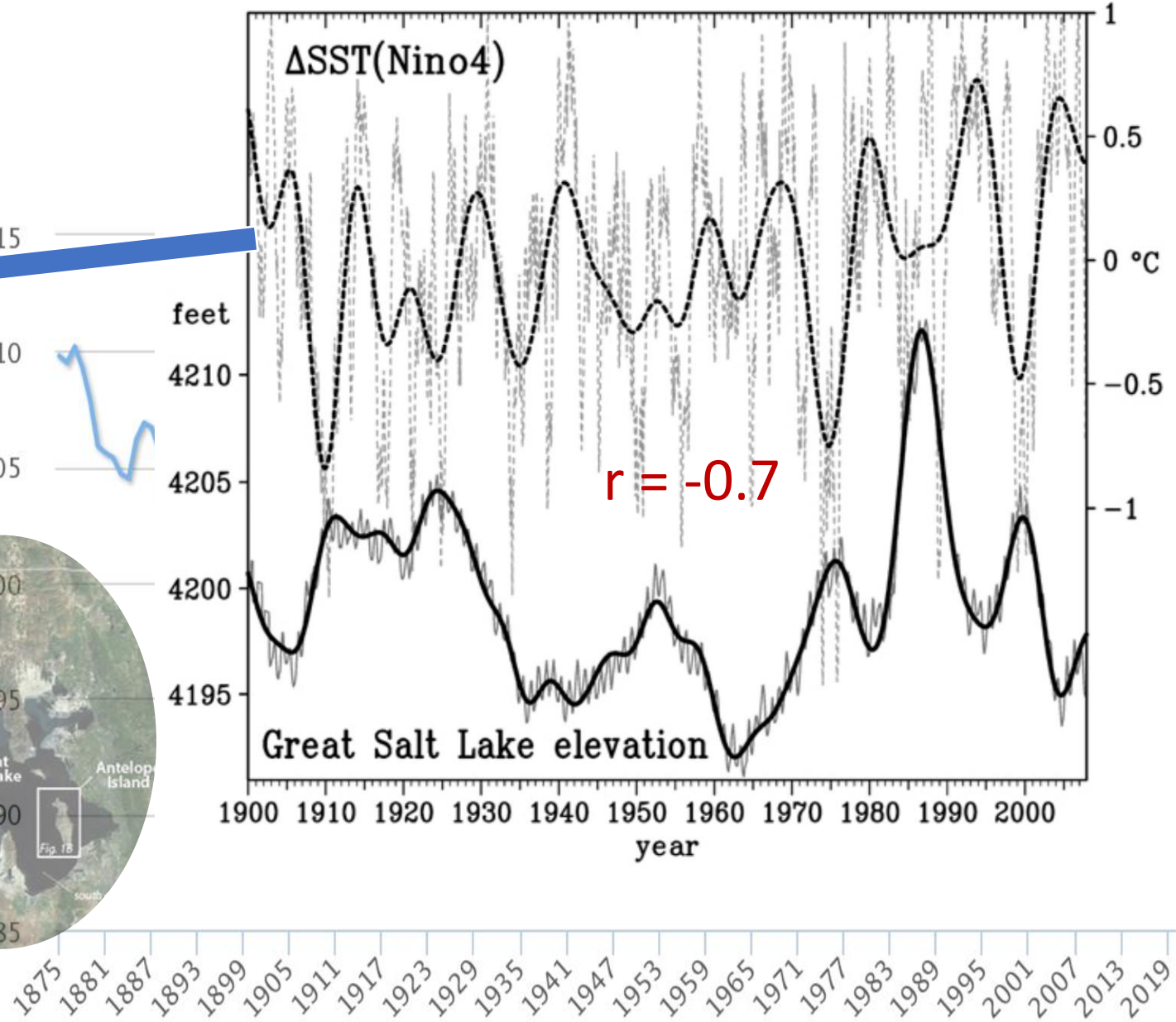
R Justin DeRose,[1] Shih-Yu Wang,[2] Brendan M Buckley[3] and Matthew F Bekker[4]

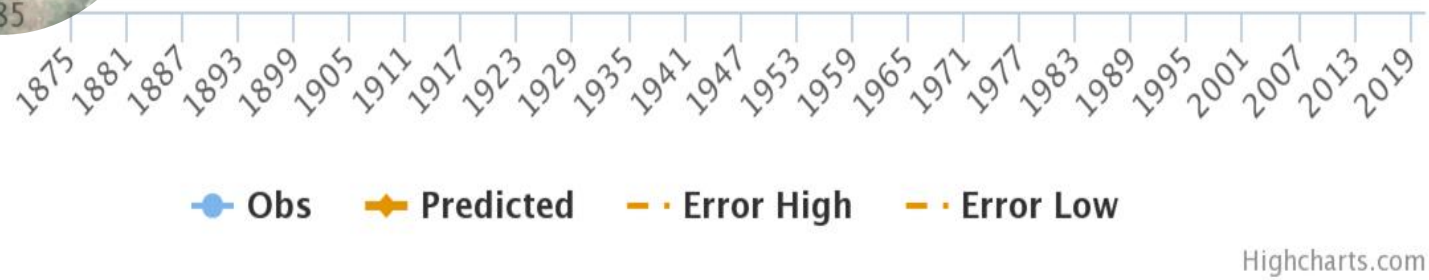




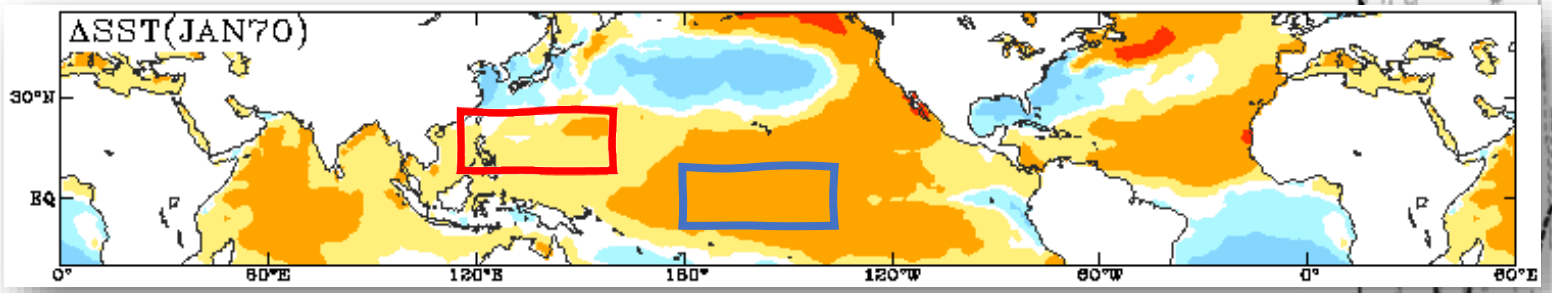
Finding the climate driver



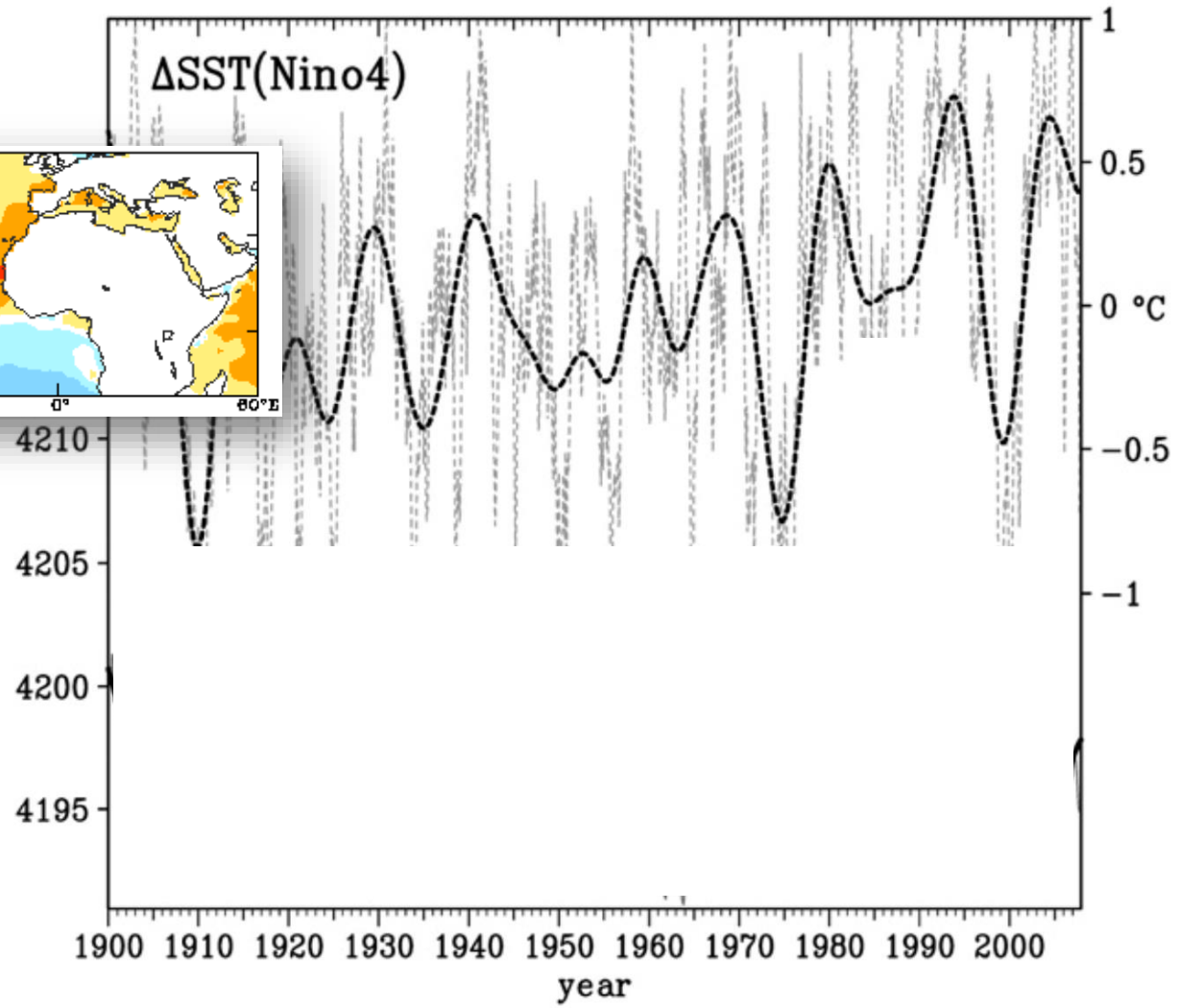


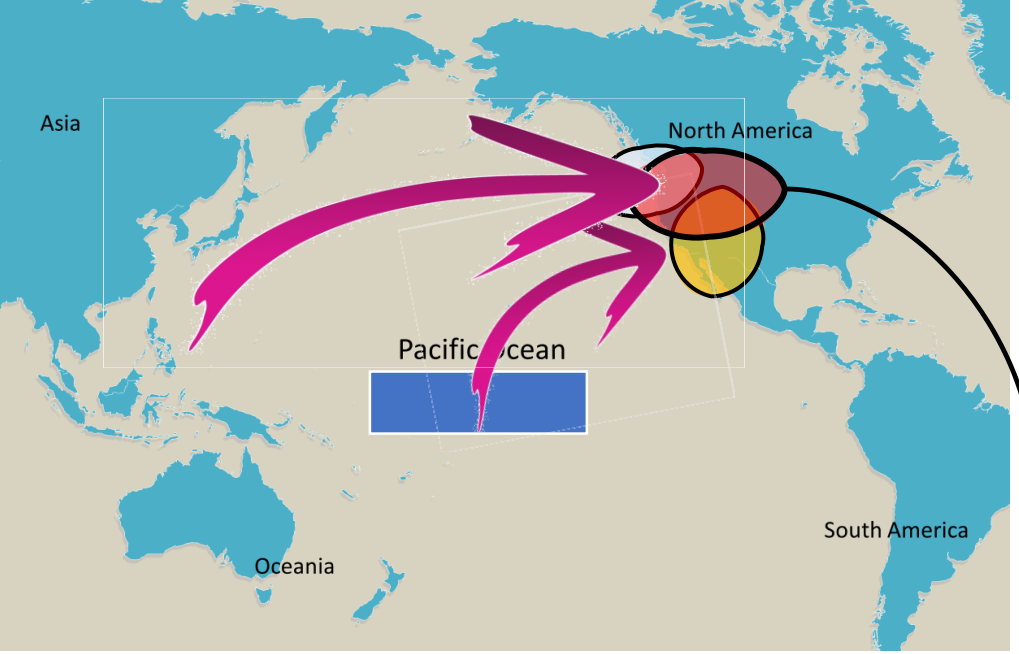


Sea surface temperature anomalies

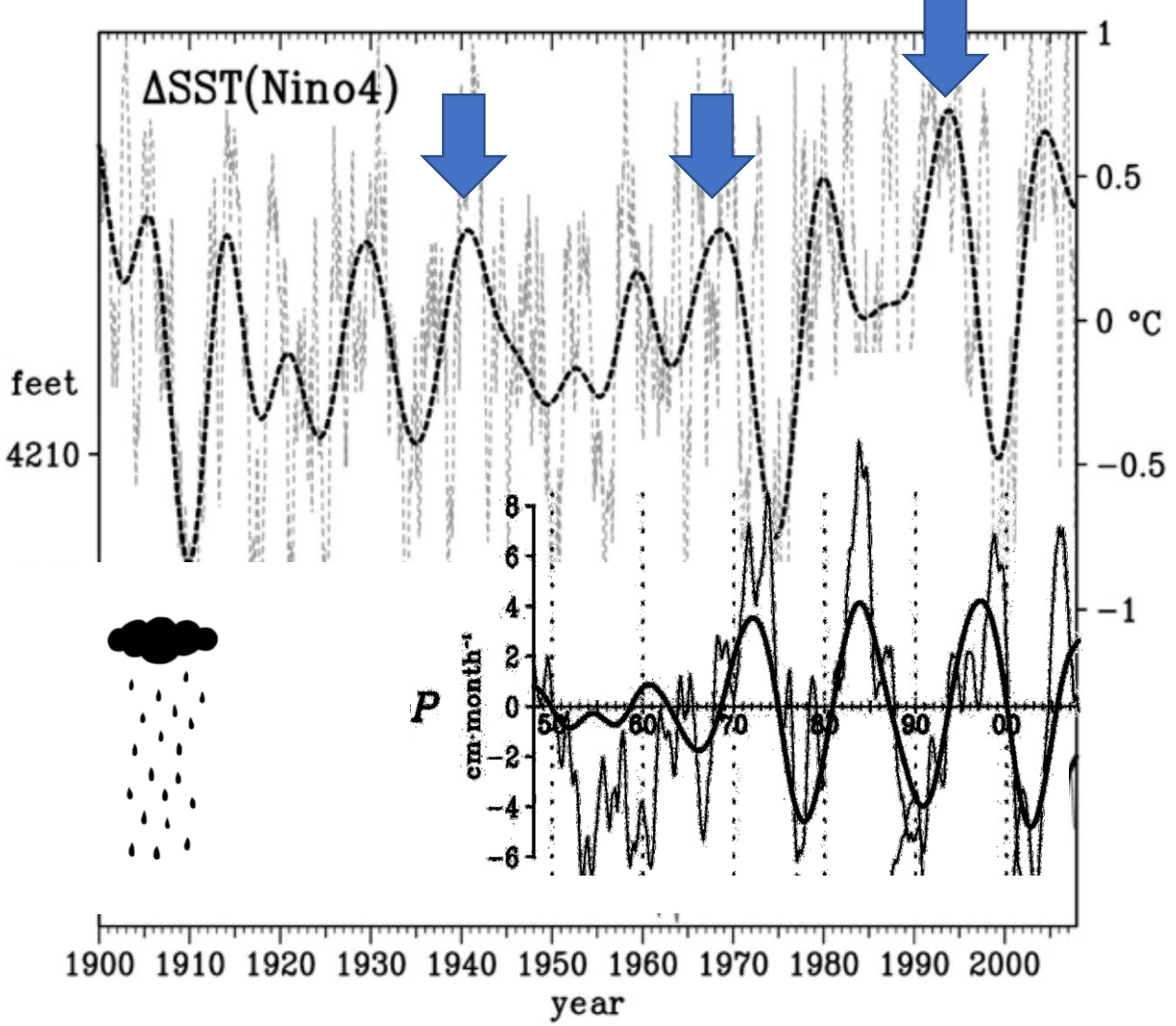


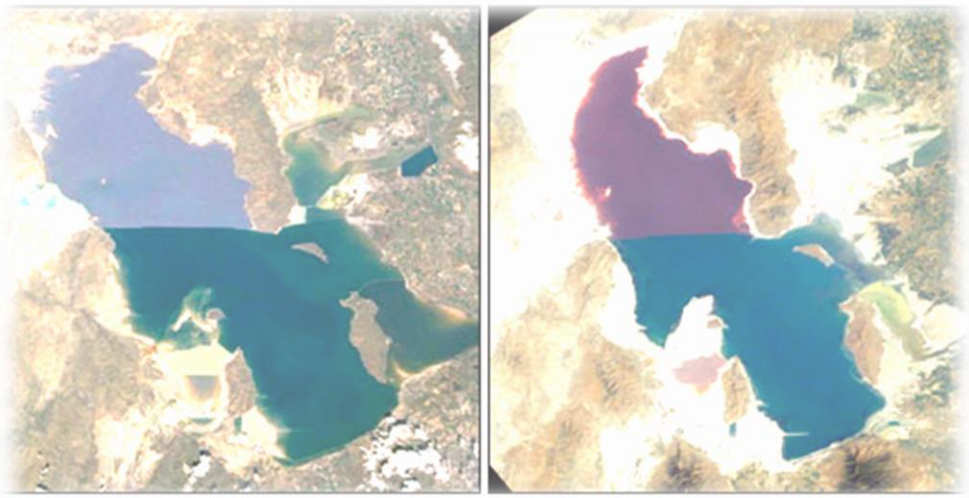
SST evolution | 18-month bandpass filtered

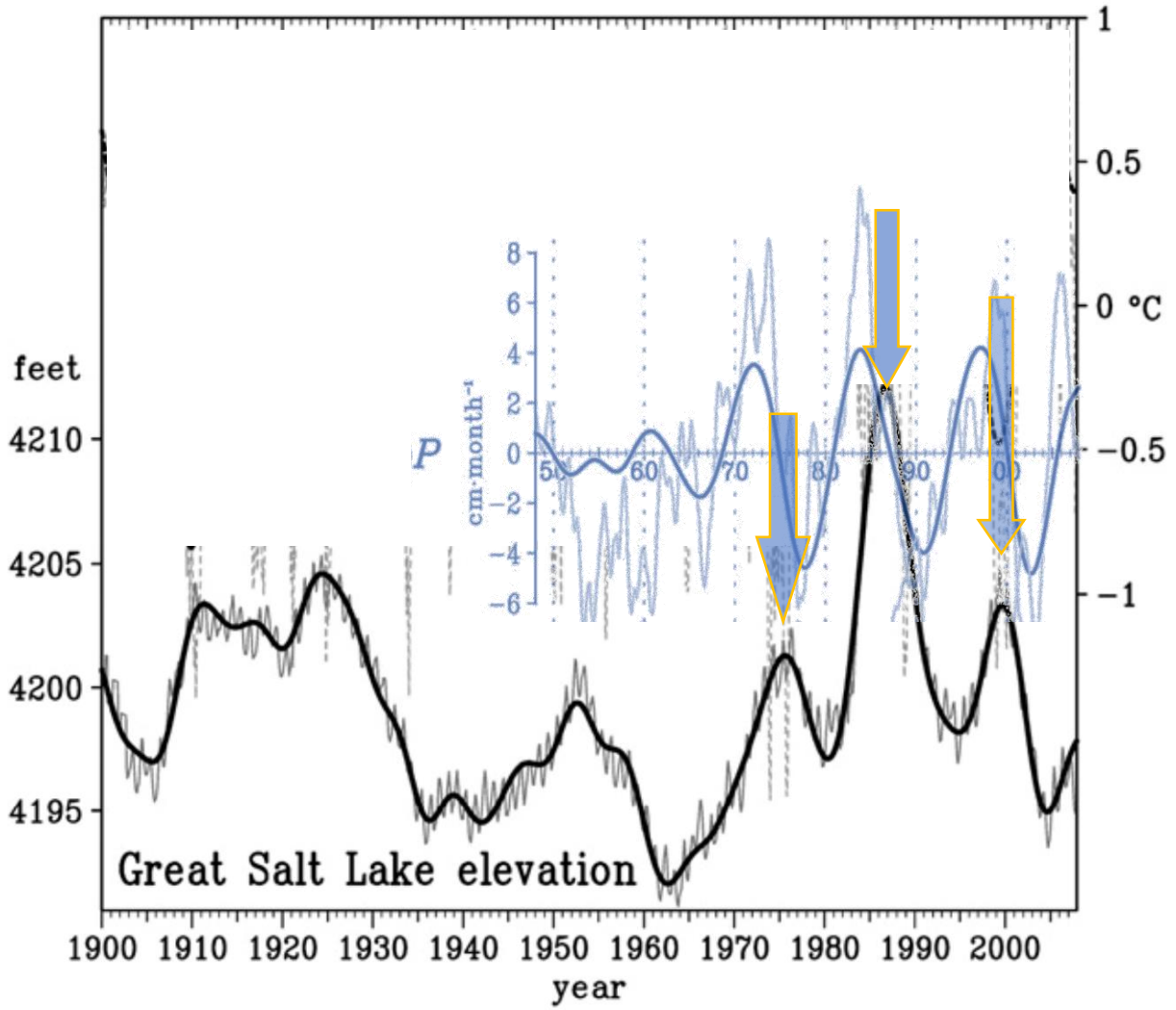




“quasi-decadal oscillation”



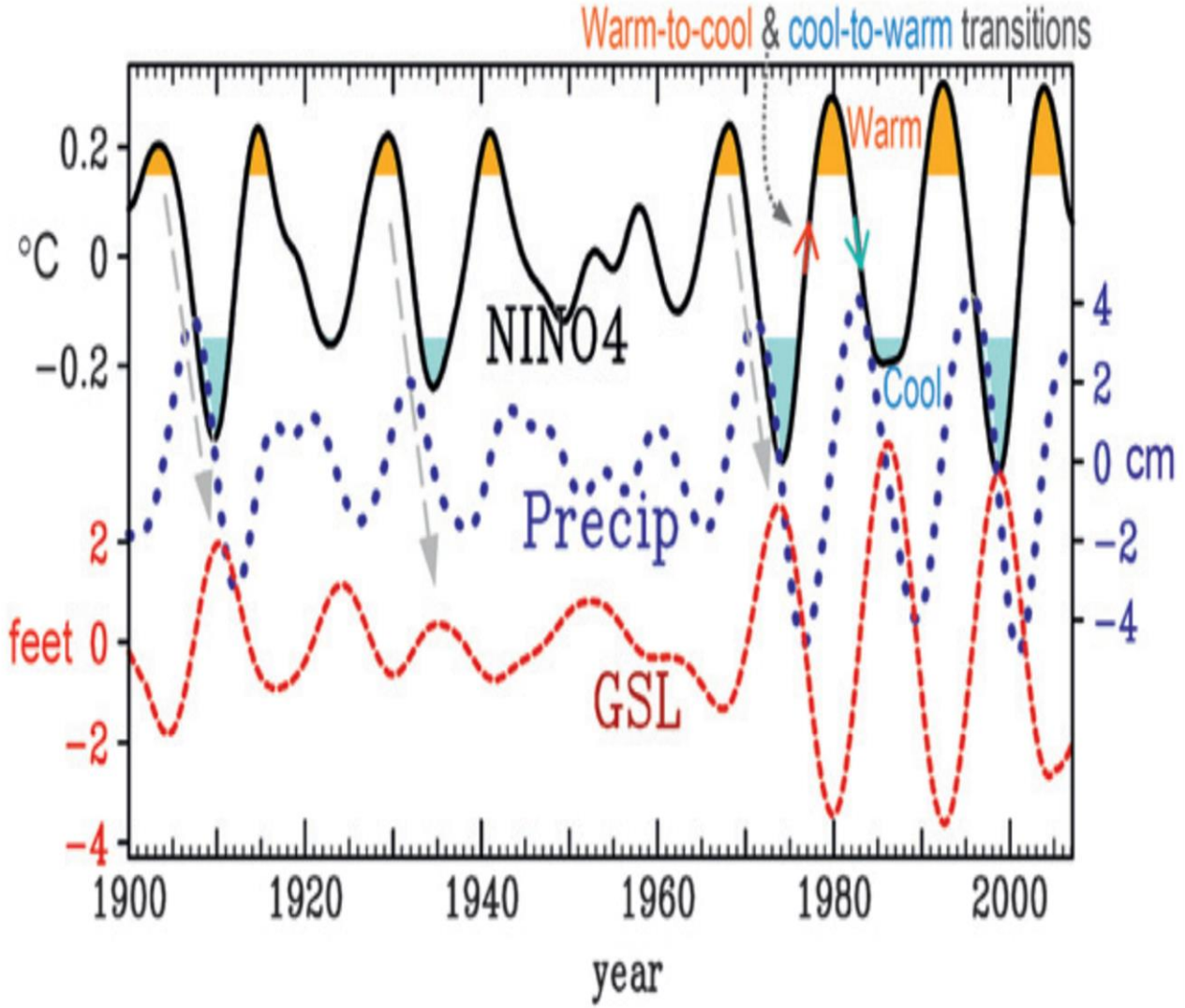



feet
4210
4205
4200
4195
1
0.5
0 °C
−0.5
−1
P
cm·month⁻¹
8
6
4
2
0
−2
−4
−6
50
60
70
80
90
00
Great Salt Lake elevation
1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000
year


Journal
of
Climate
2010


Climate
Dynamics
2011


Journal
of
Climate
2012


Warm-to-cool & cool-to-warm transitions
Warm
Cool
NINO4
Precip
GSL
°C
feet
0.2
0
−0.2
2
−2
−4
4
0 cm
1900
1920
1940
1960
1980
2000
year

UtahStateUniversity

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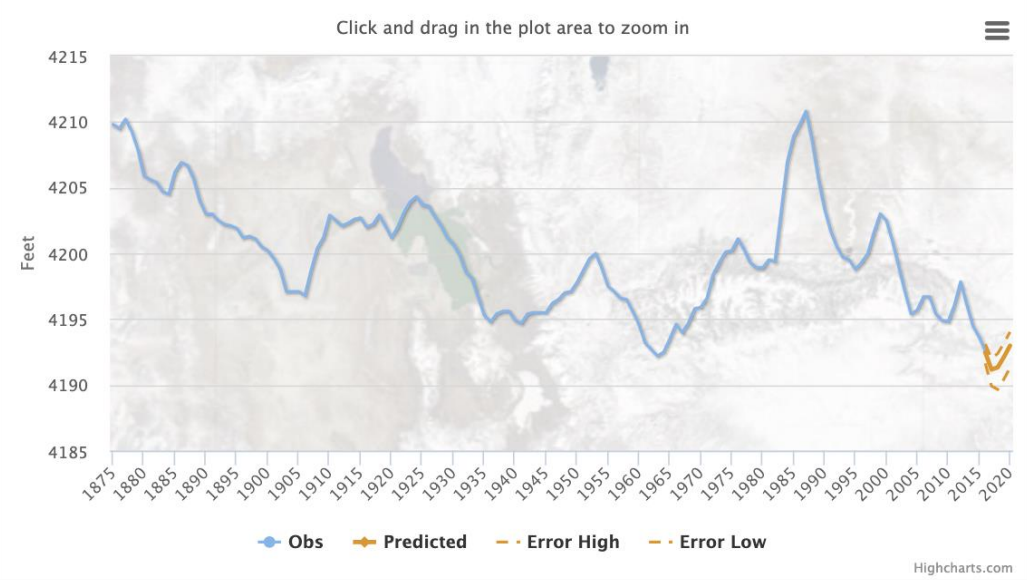
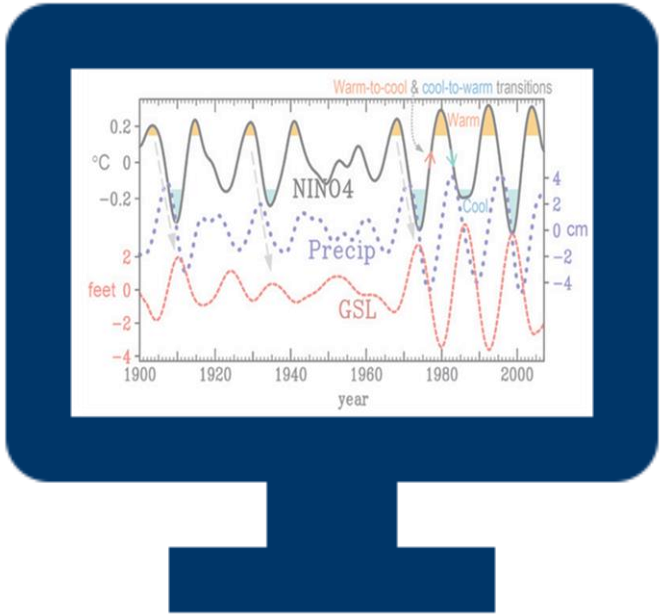
Great Salt Lake Annual Level Prediction

The Great Salt Lake (GSL) contributes an estimated $1.3 billion annually to Utah's economy. The GSL is fed by three major rivers from the Uinta Mountain range in northeastern Utah. Due to its shallowness, the water level can rise dramatically in wet years and fall during dry years, hence reflecting prolonged drought and wet periods. The lake level change is strongly modulated by the Pacific Ocean through atmospheric circulations that fluctuate at low frequency

The following graph shows the observed annual lake level (blue) and predicted lake level (orange).



Toggle Years: 60 Years 30 Years 10 Years All Data



http://climate.usu.edu

UtahStateUniversity

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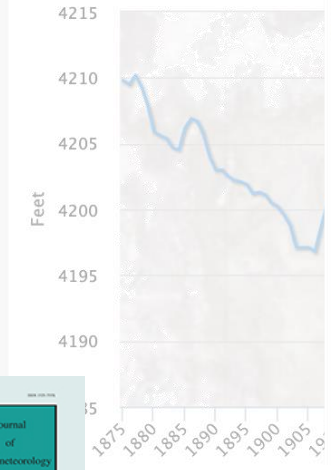
UTAH CLIMATE CENTER

Home Climate Data Research

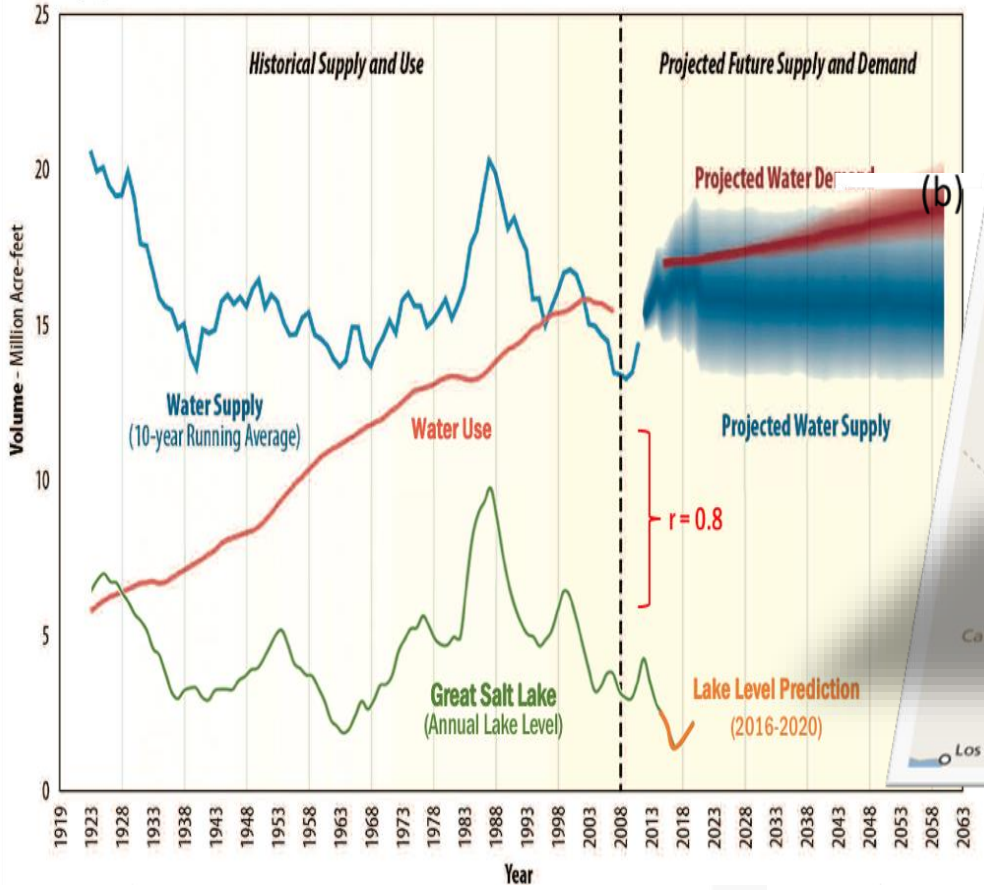
Great Salt Lake Annual

The Great Salt Lake (GSL) c
GSL is fed by three major ri
shallowness, the water level
reflecting prolonged drought
Pacific Ocean through atmos

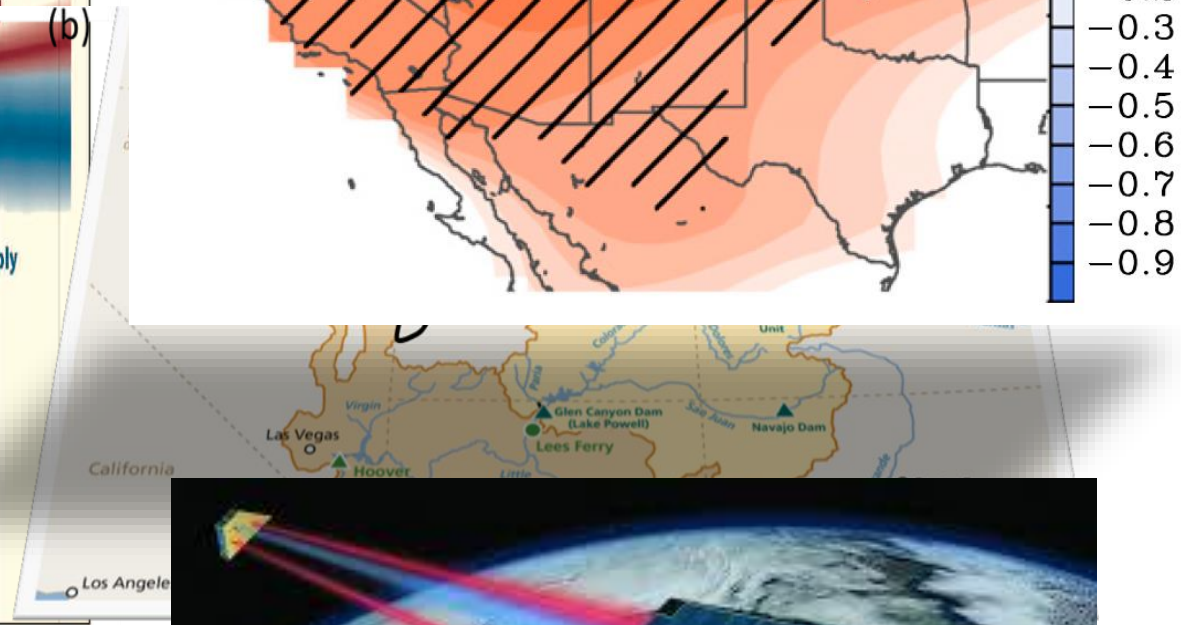
The following graph



(a)



(b)

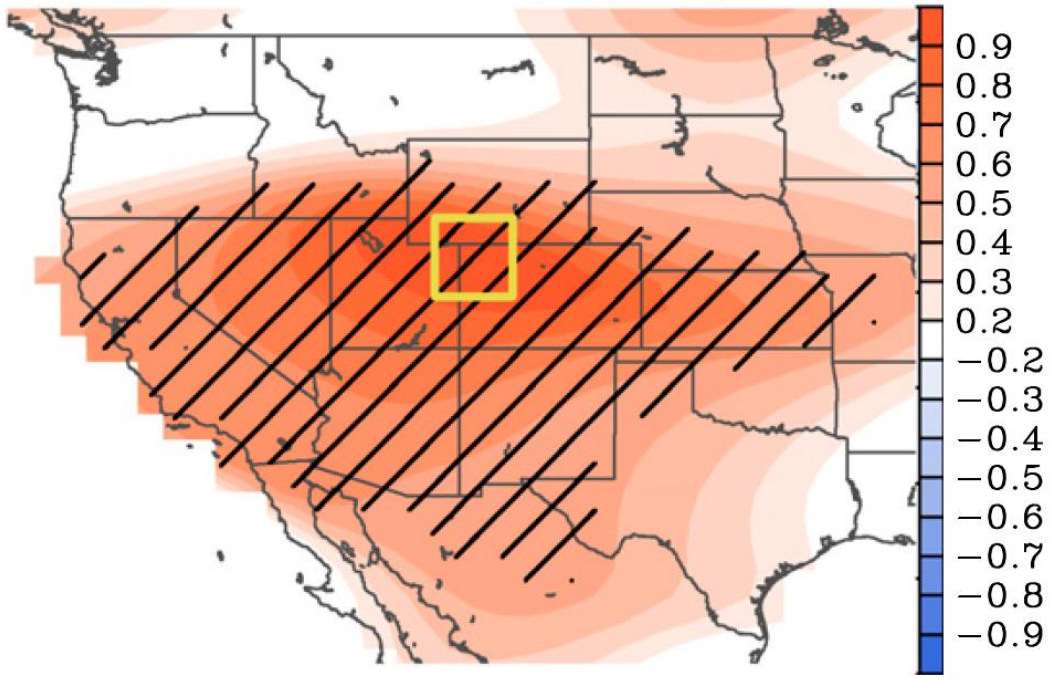


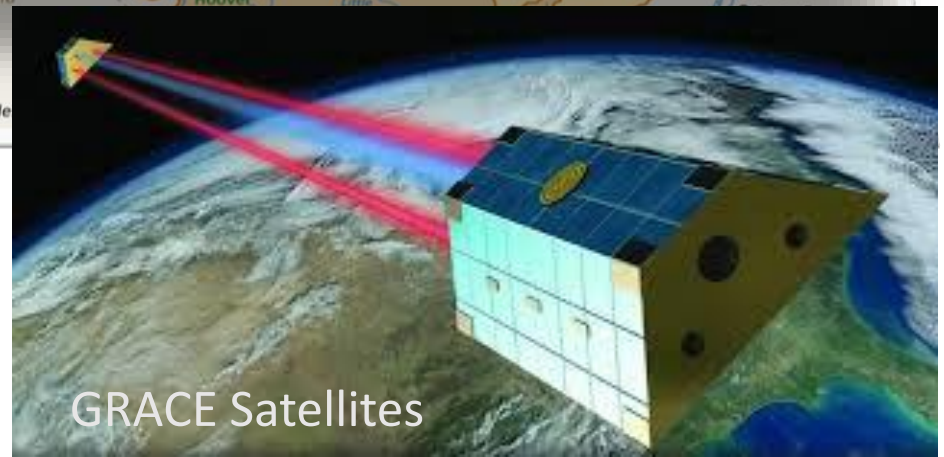
Obs Predicted Error High Error Low

Highcharts.com

e Years 100 Years 30 Years 10 Years Data

(b) TWSA correlation (GRACE)

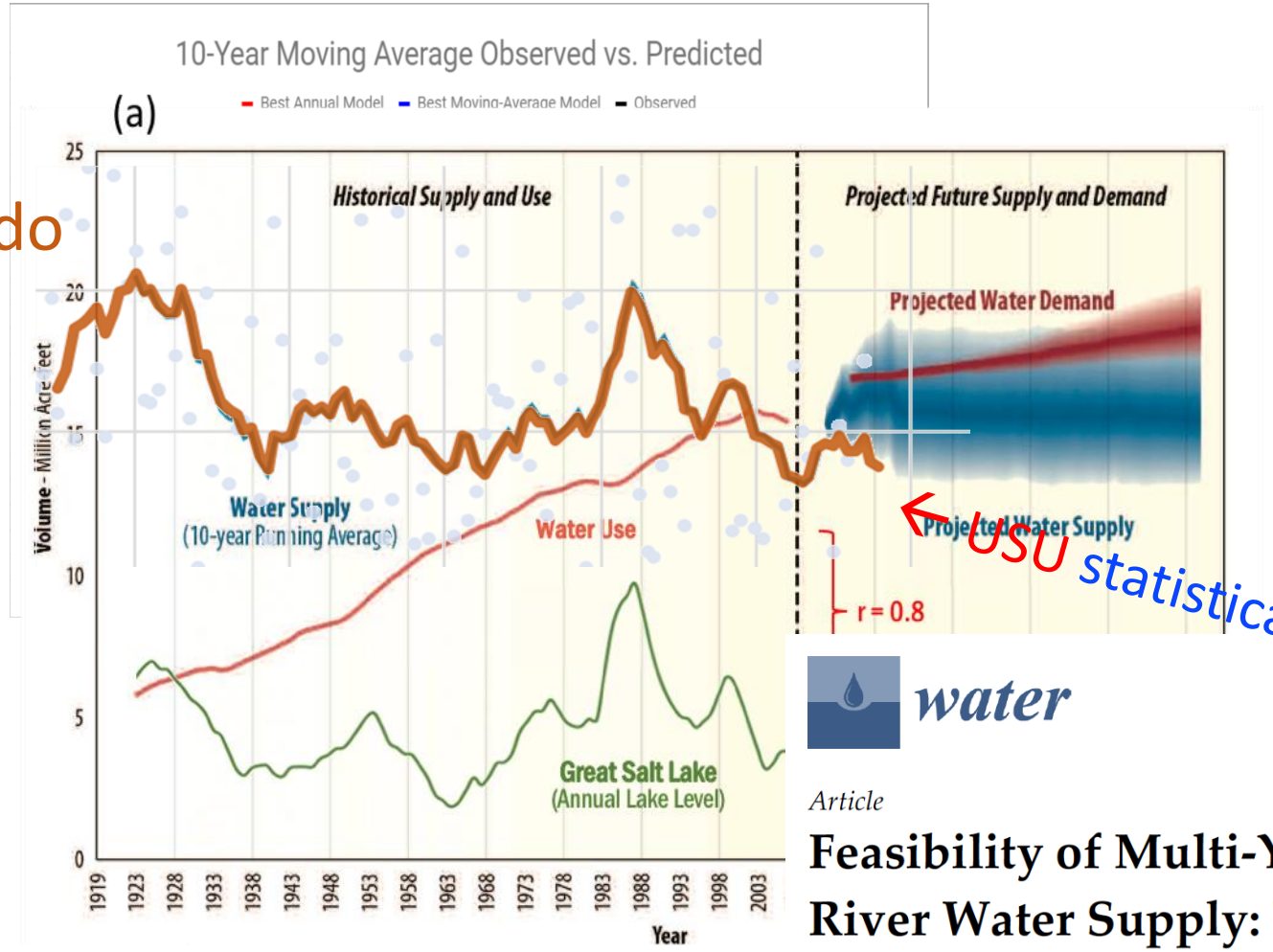




April 2018

Wang, S.-Y., R. R. Gillies, O.-Y. Chung, and C. Shen (2018) *Journal of Hydrometeorology*

Colorado River Water Supply



USU statistical models

water

MDPI

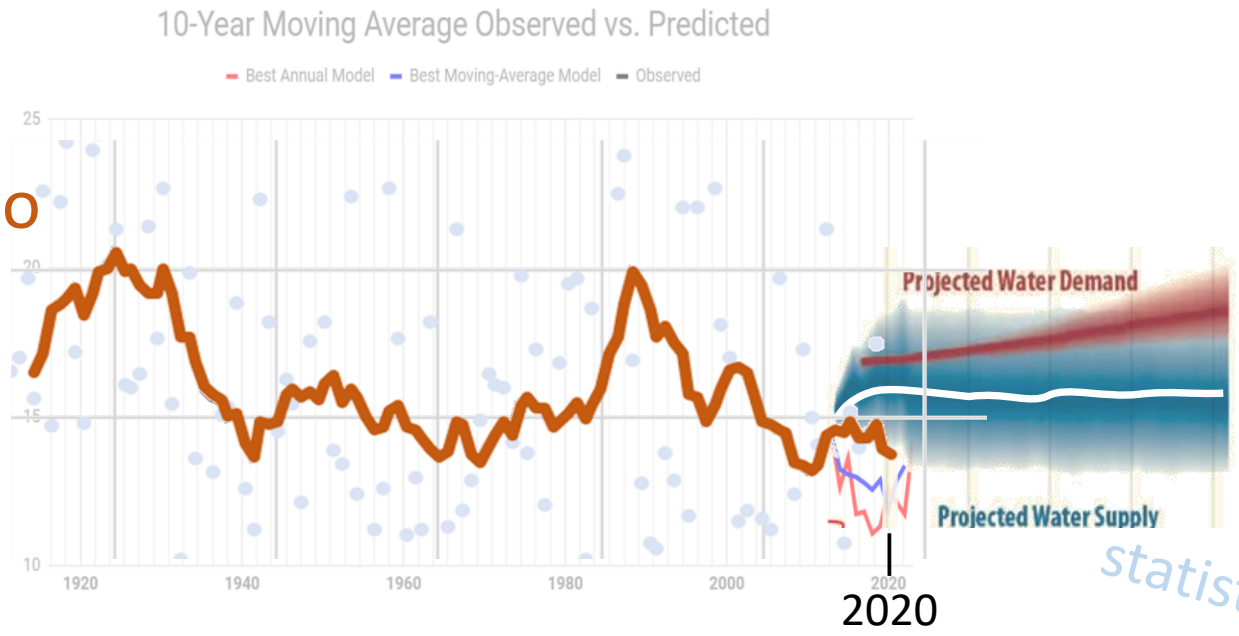
Article

Feasibility of Multi-Year Forecast for the Colorado River Water Supply: Time Series Modeling

Brian Plucinski [1], Yan Sun [1], S.-Y. Simon Wang [2,*], Robert R. Gillies [2], James Eklund [3] and C.-C. Wang [4]

[1] Department of Mathematics and Statistics, Utah State University, Logan, UT
[2] Department of Plants, Soils & Climate, Utah State University/Utah Climate Center, Logan, UT

Colorado River Water Supply

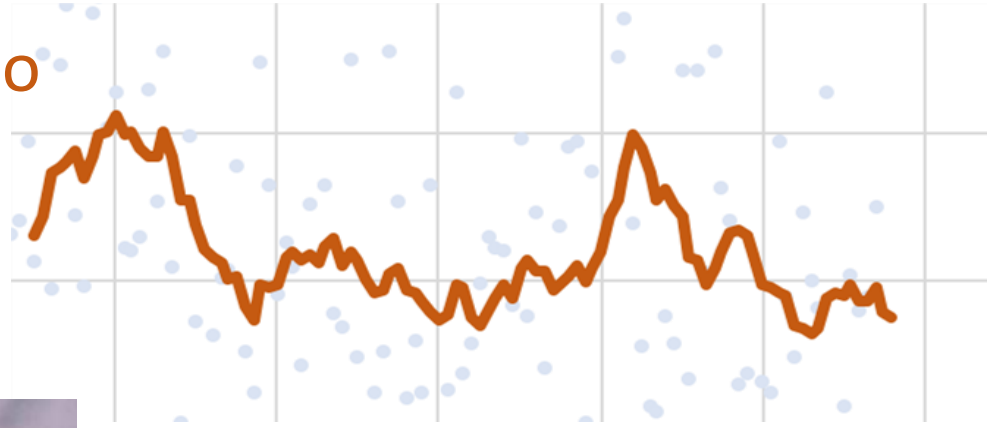


Climate downscaling

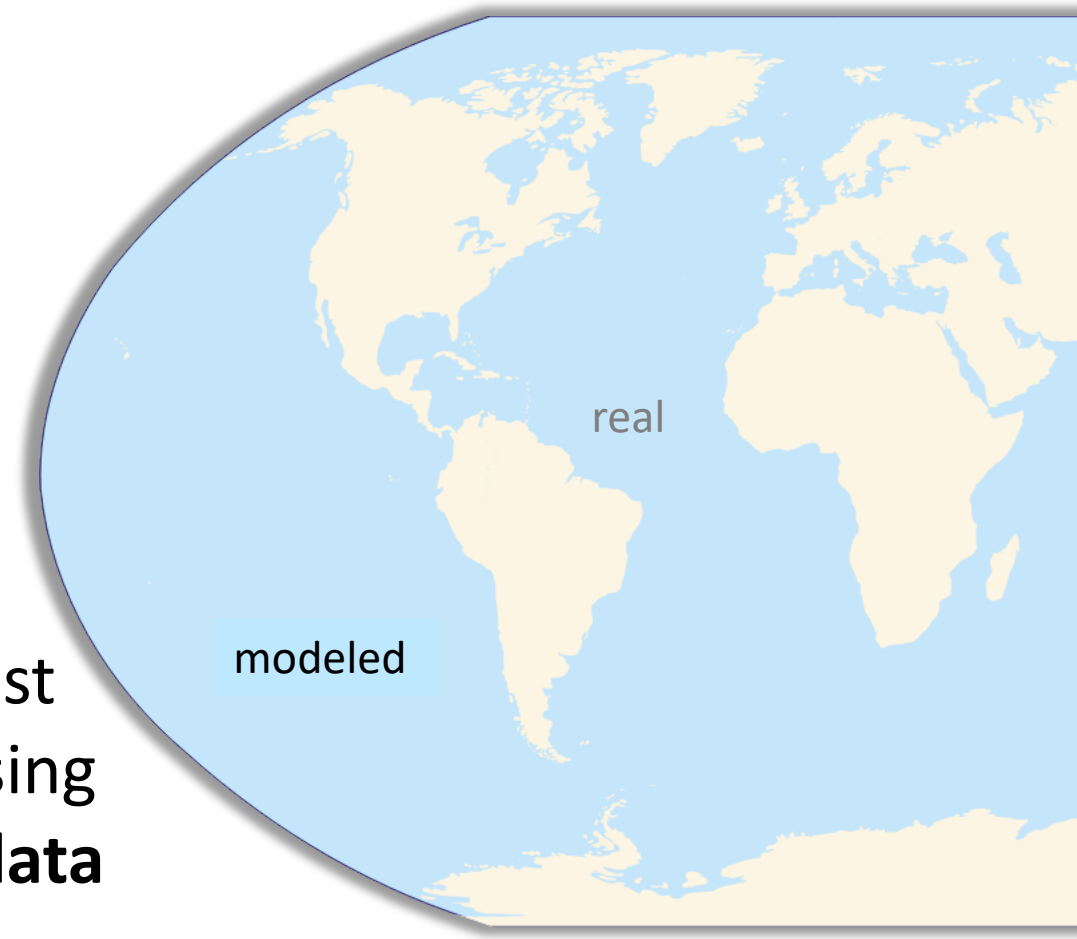
statistical models

NEXT STEP:

Colorado River Water Supply



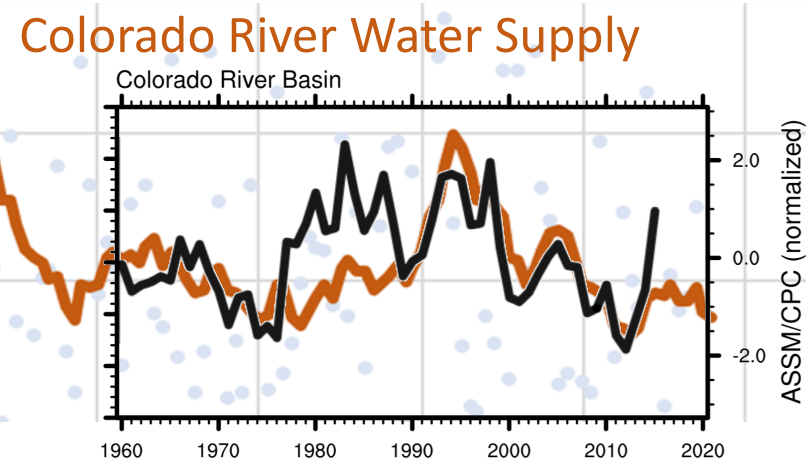
←Soil moisture's low-pass filtering



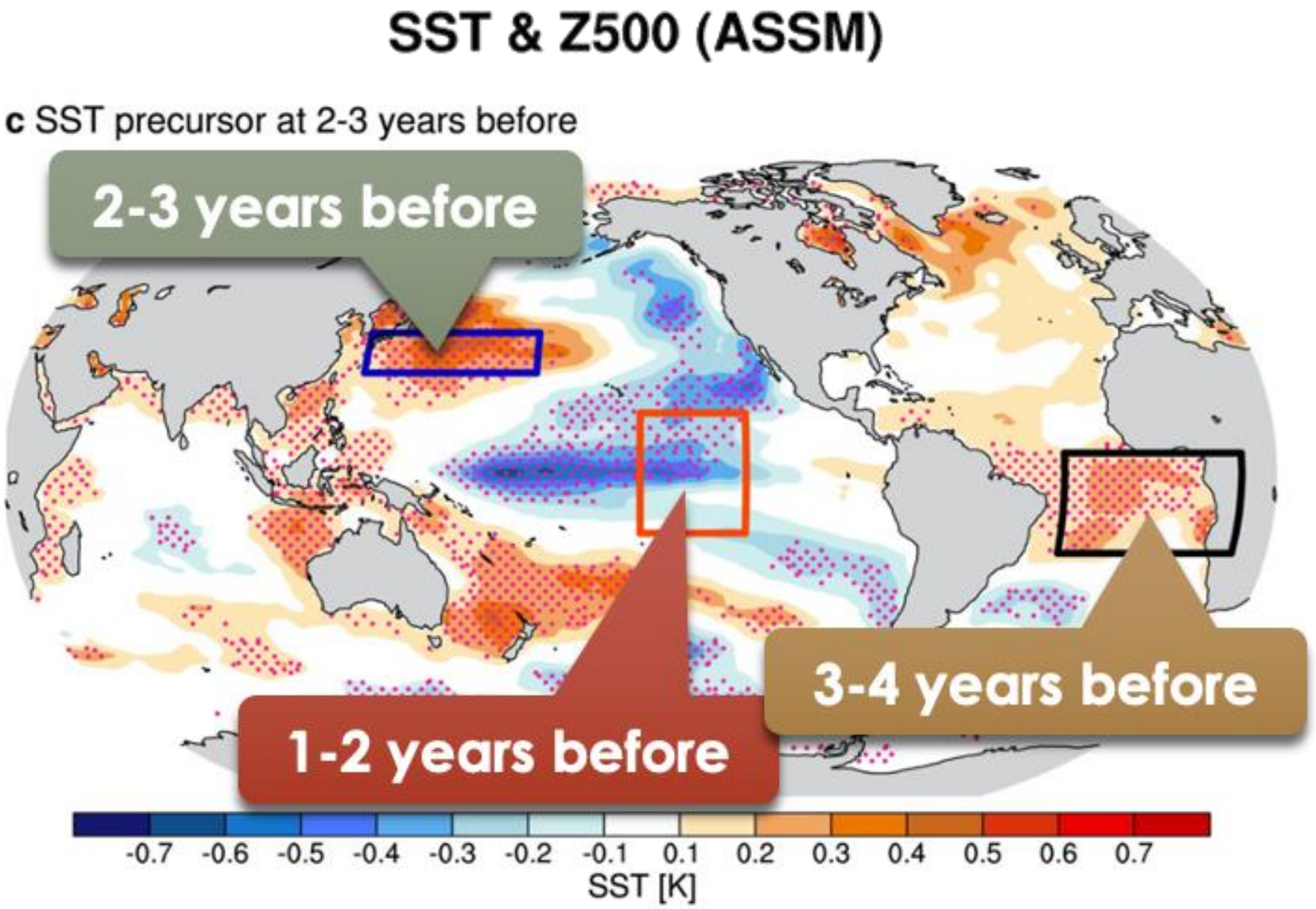
Decadal hindcast experiments using **partial ocean data assimilation**

NEXT STEP:

Colorado River Water Supply

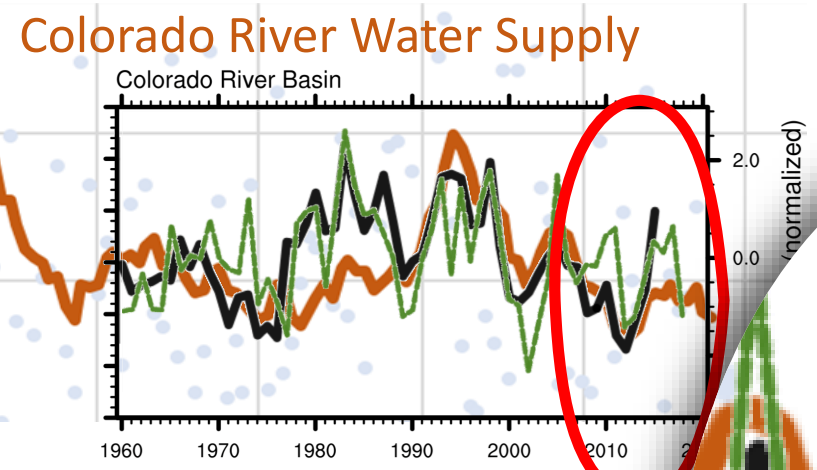


Soil moisture

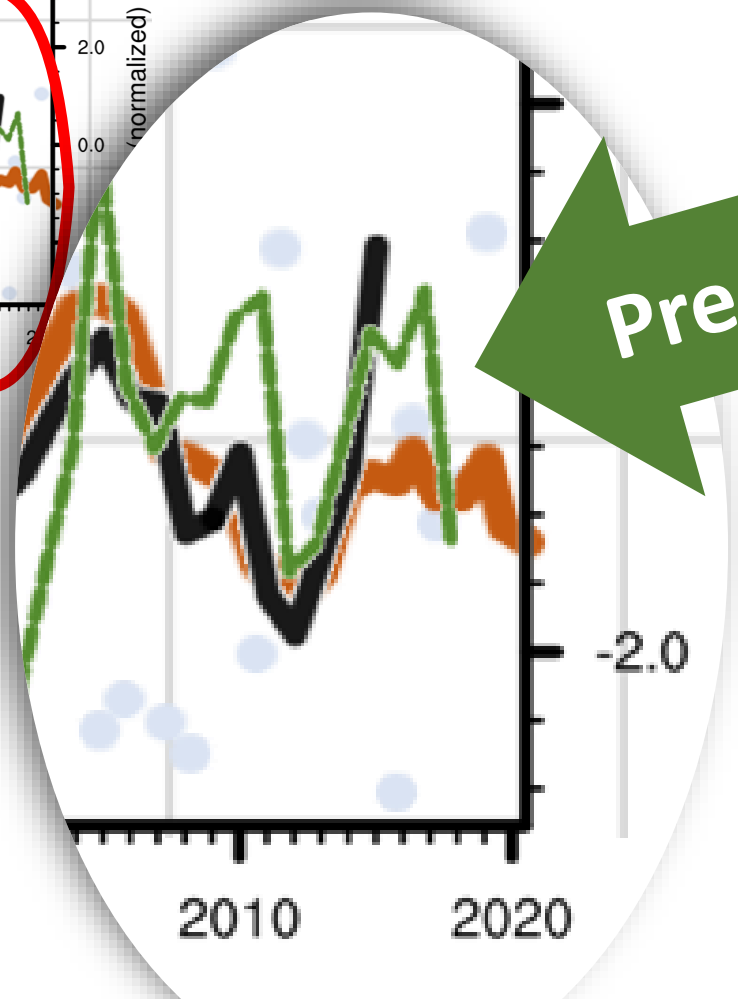


NEXT STEP: Multi-year prediction!

Colorado River Water Supply

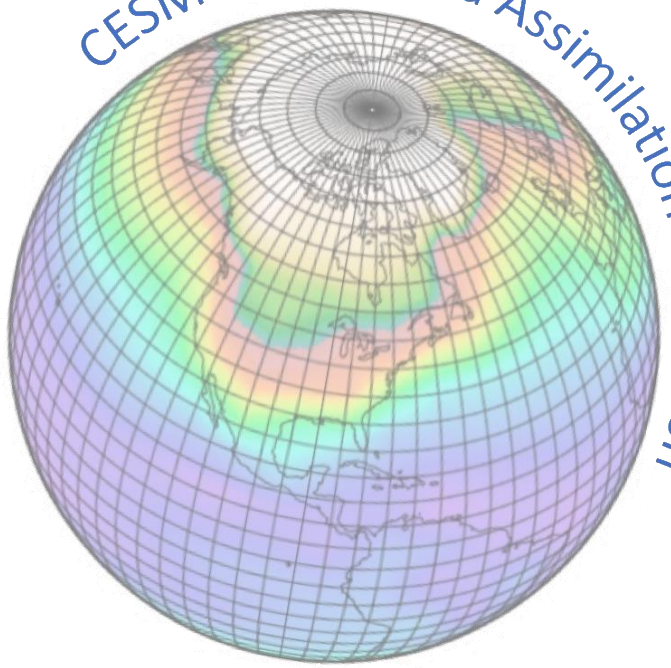


Soil moisture



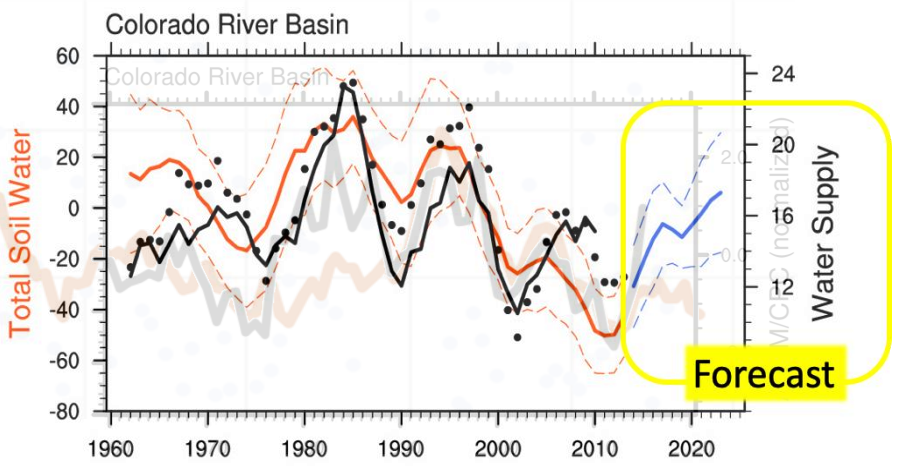
Prediction

CESM Ocean Data Assimilation Prediction



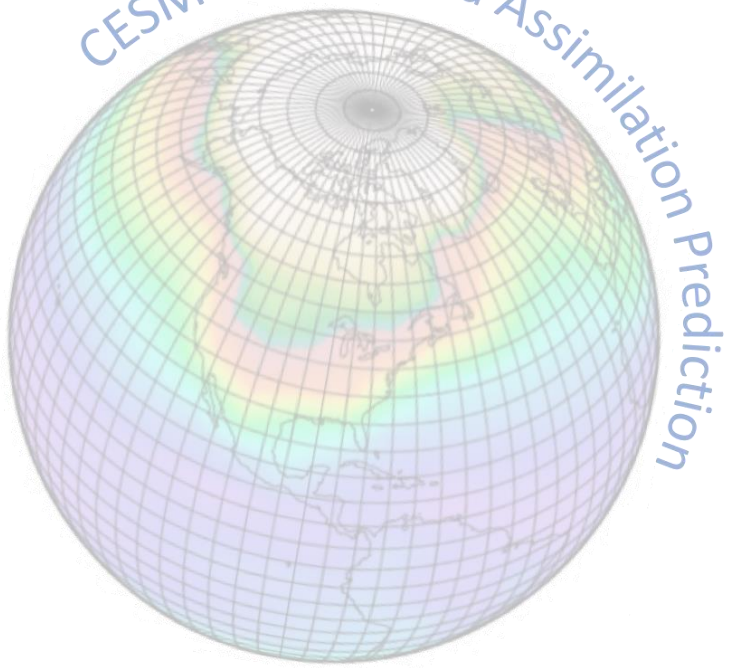
Chikamoto et al. (2020 / Nature)

NEXT STEP: Multi-year prediction!



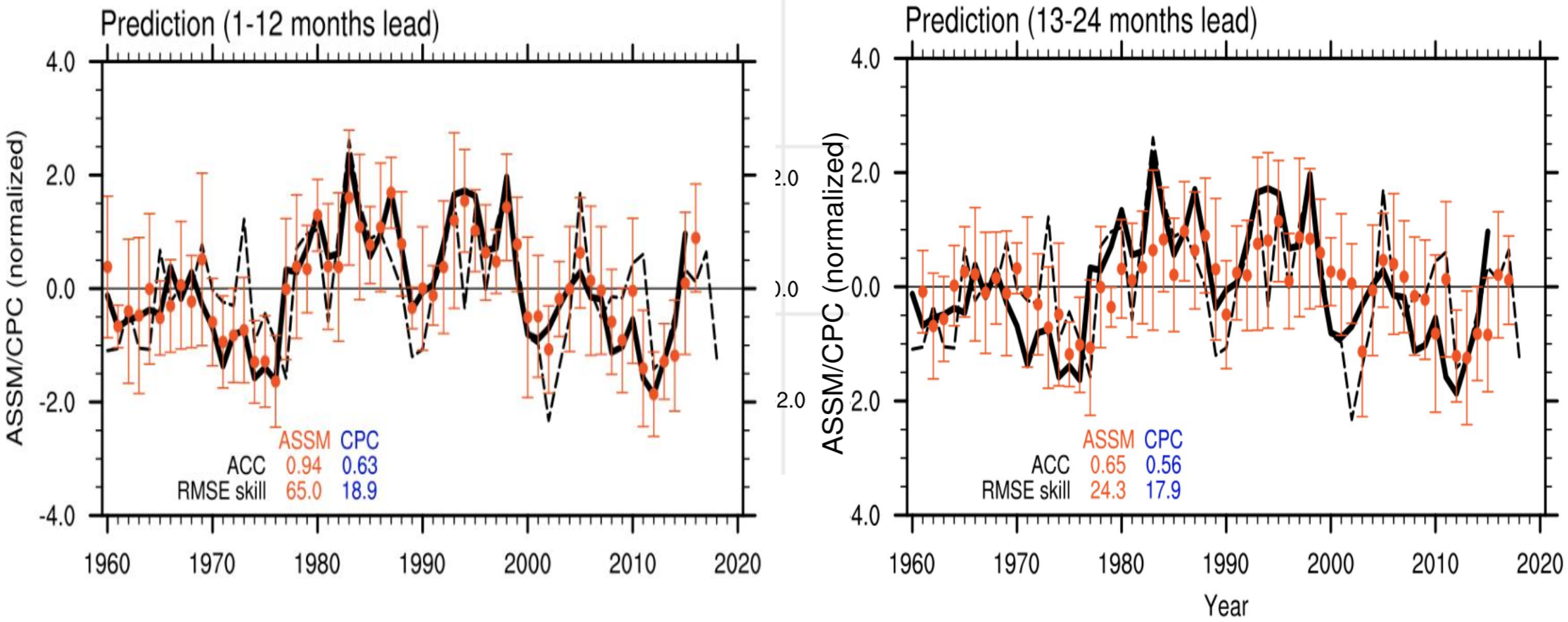
Total water storage

Prediction



Chikamoto et al. (2020 / Nature)

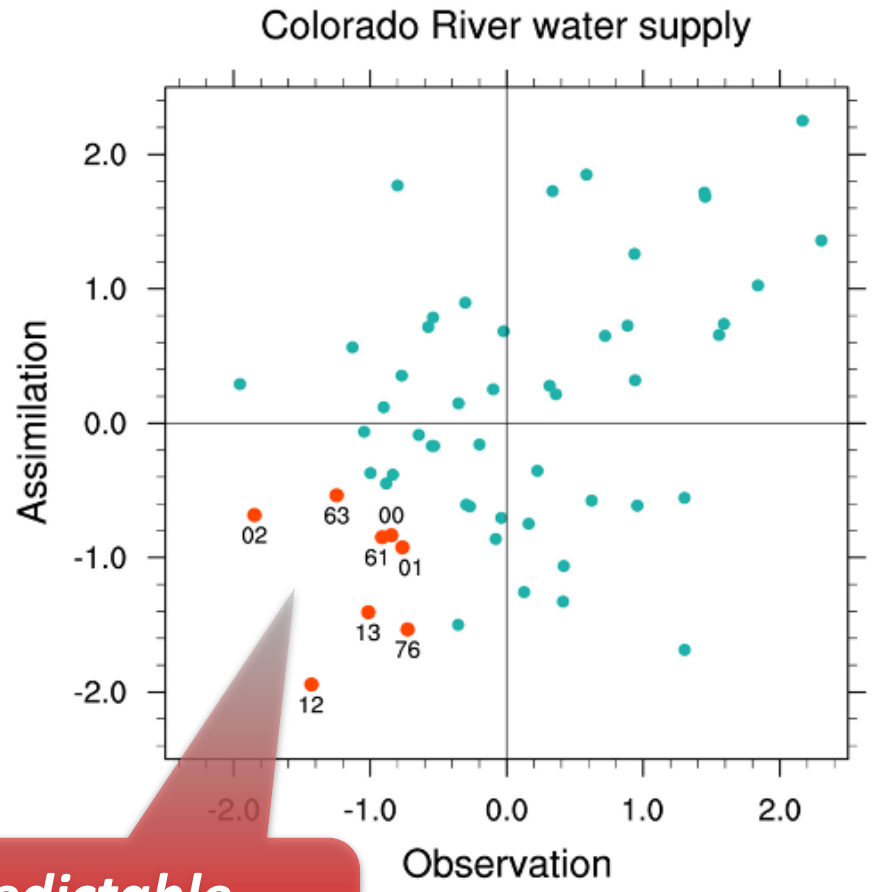
Prediction evaluation:



Soil moisture

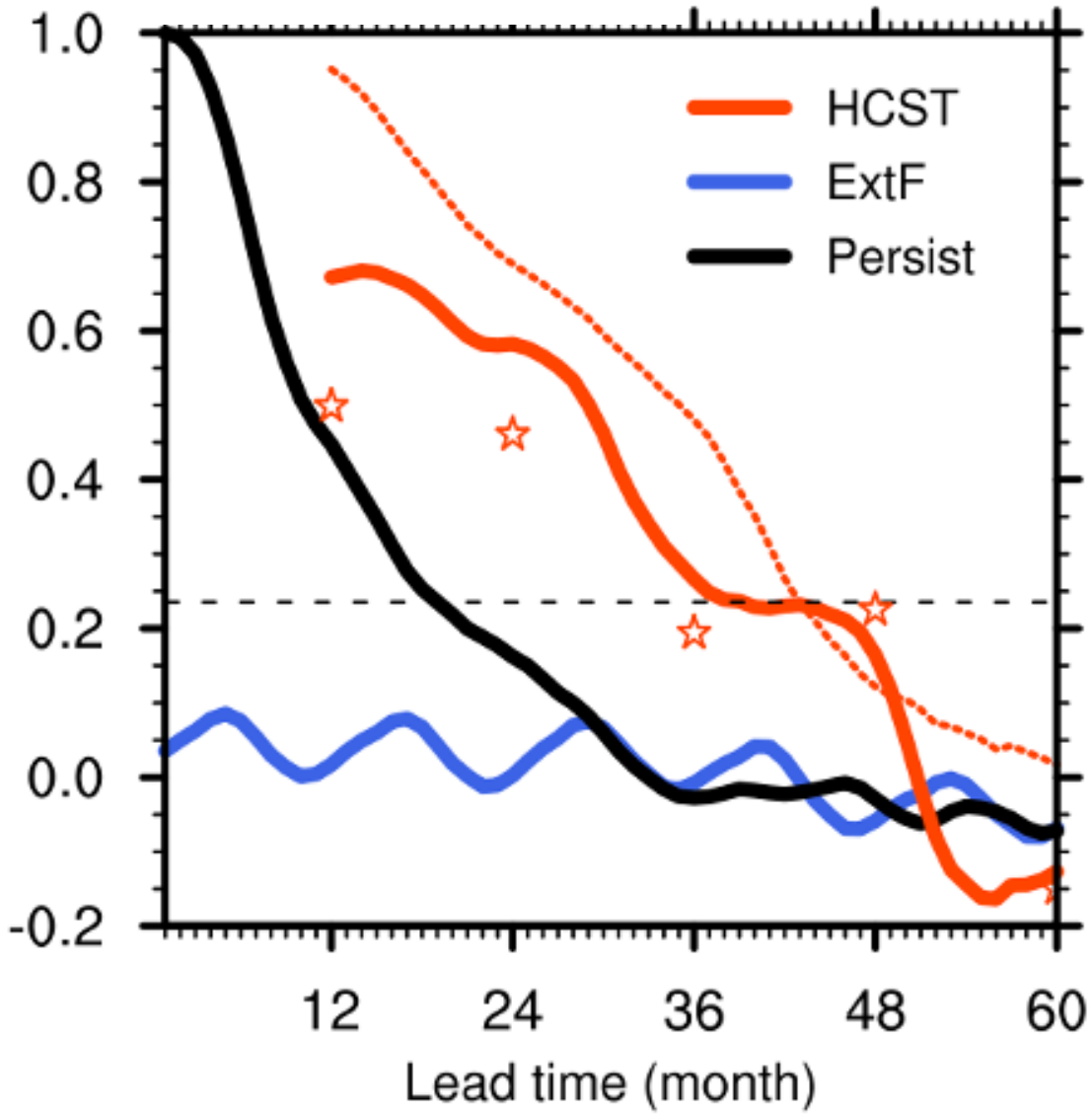
Chikamoto et al. (2020 / Nature)

Prediction evaluation:

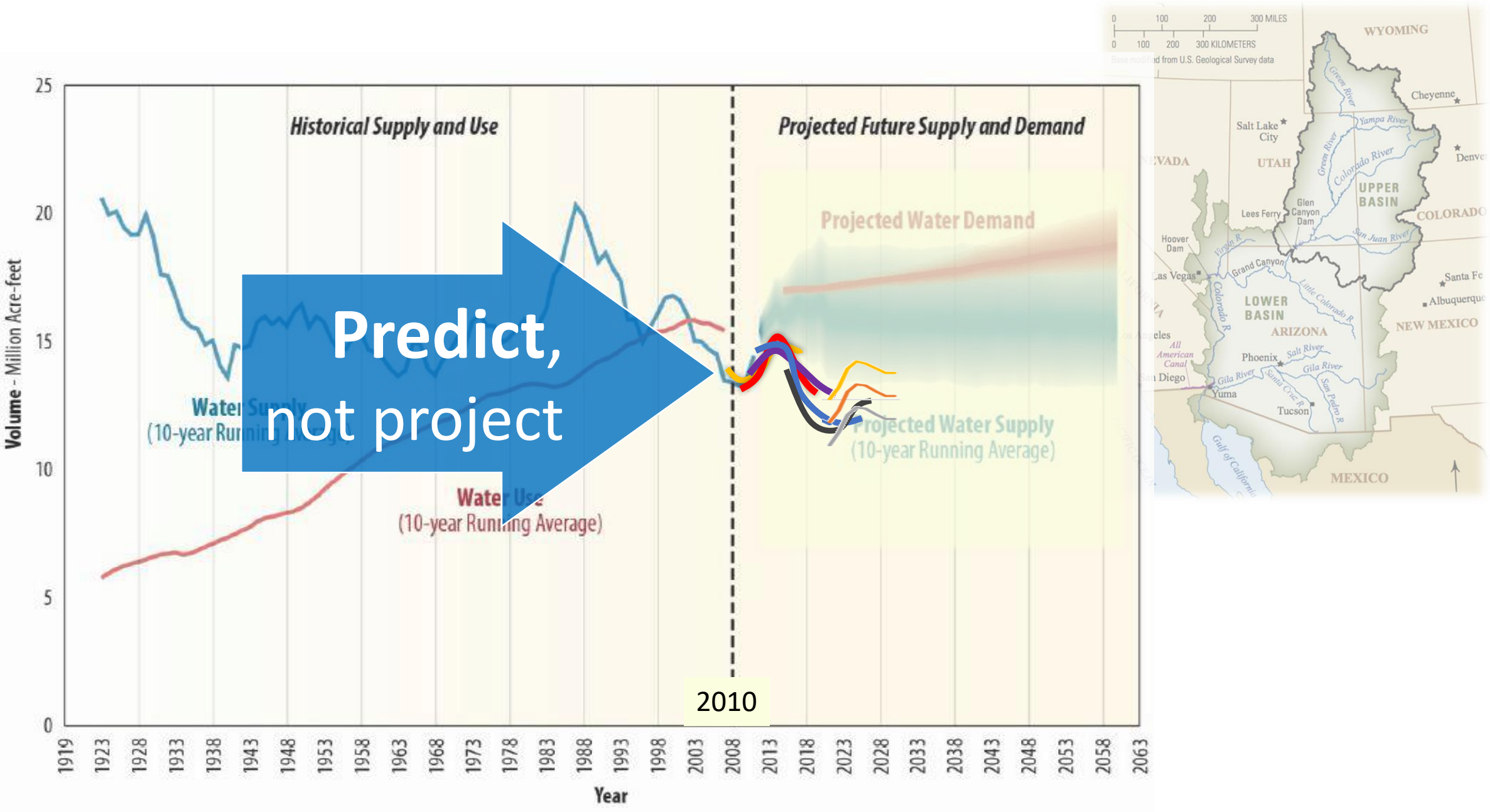


Predictable shortage years

Predictive skill



Chikamoto et al. (2020 / Nature)


Historical Supply and Use
Projected Future Supply and Demand
Projected Water Demand
Projected Water Supply
(10-year Running Average)
Water Use
(10-year Running Average)
Predict,
not project
2010
Volume - Million Acre-feet
Year
0
5
10
15
20
25
1919
1923
1928
1933
1938
1943
1948
1953
1958
1963
1968
1973
1978
1983
1988
1993
1998
2003
2008
2013
2018
2023
2028
2033
2038
2043
2048
2053
2058
2063

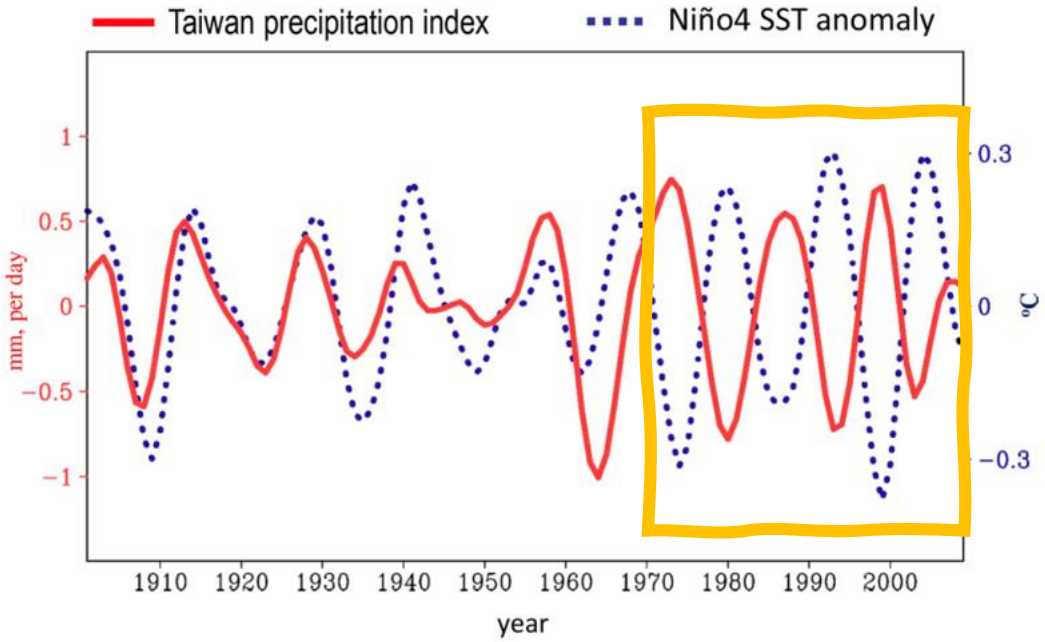
0 100 200 300 MILES
0 100 200 300 KILOMETERS
WYOMING
Cheyenne
Salt Lake City
UTAH
Denver
Green River
Yampa River
Colorado River
UPPER BASIN
COLORADO
Glen Canyon Dam
Lees Ferry
San Juan River
Hoover Dam
Grand Canyon
Las Vegas
Santa Fe
Albuquerque
LOWER BASIN
ARIZONA
NEW MEXICO
Little Colorado R
Phoenix
Salt River
Gila River
Yuma
Tucson
San Pedro R
MEXICO

Scientists think they have found ways to better forecast droughts on the Colorado River, a vital source of water in the arid southwestern United States.
HERDIEPHOTO/FLICKR (CC BY 2.0)

Distant seas might predict Colorado River droughts

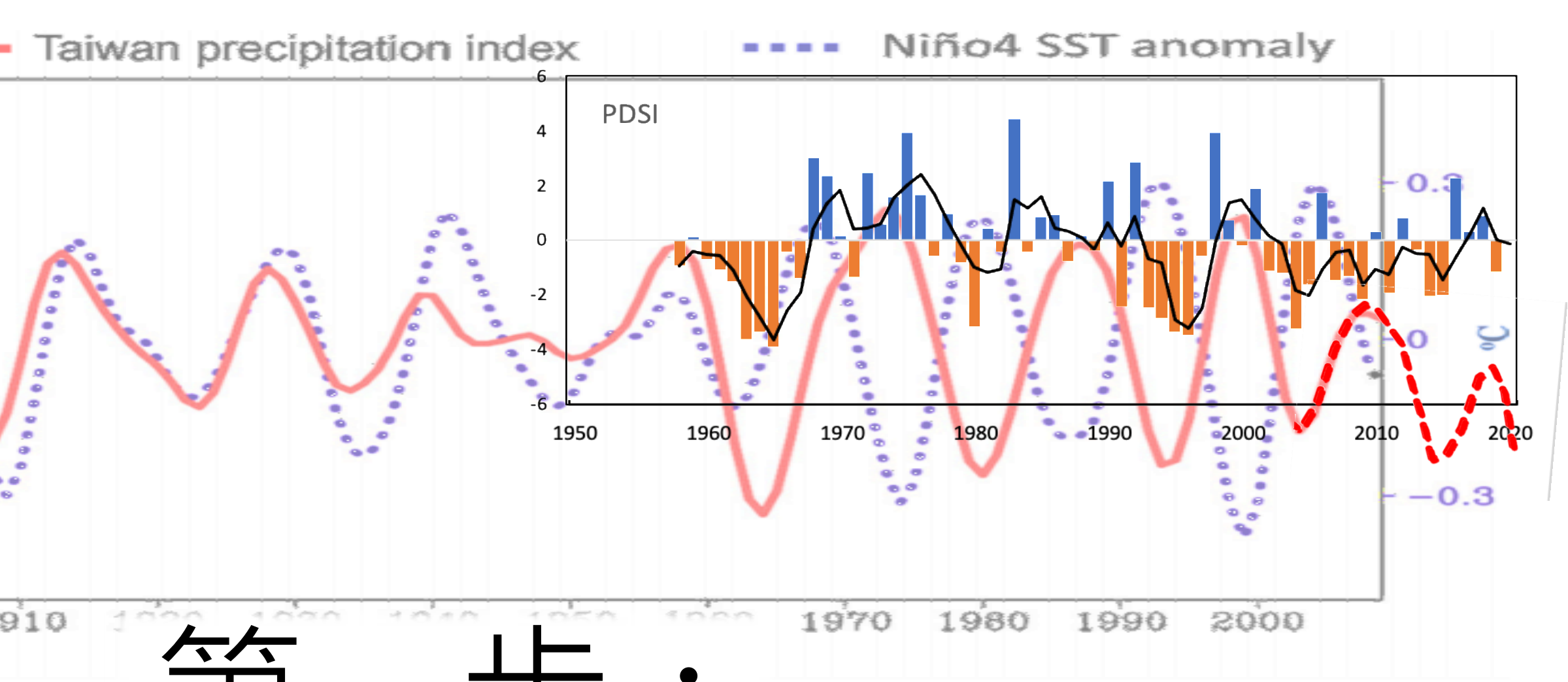
By Warren Cornwall | Oct. 16, 2020 , 6:00 PM

氣候暖化可能幫了我們一把



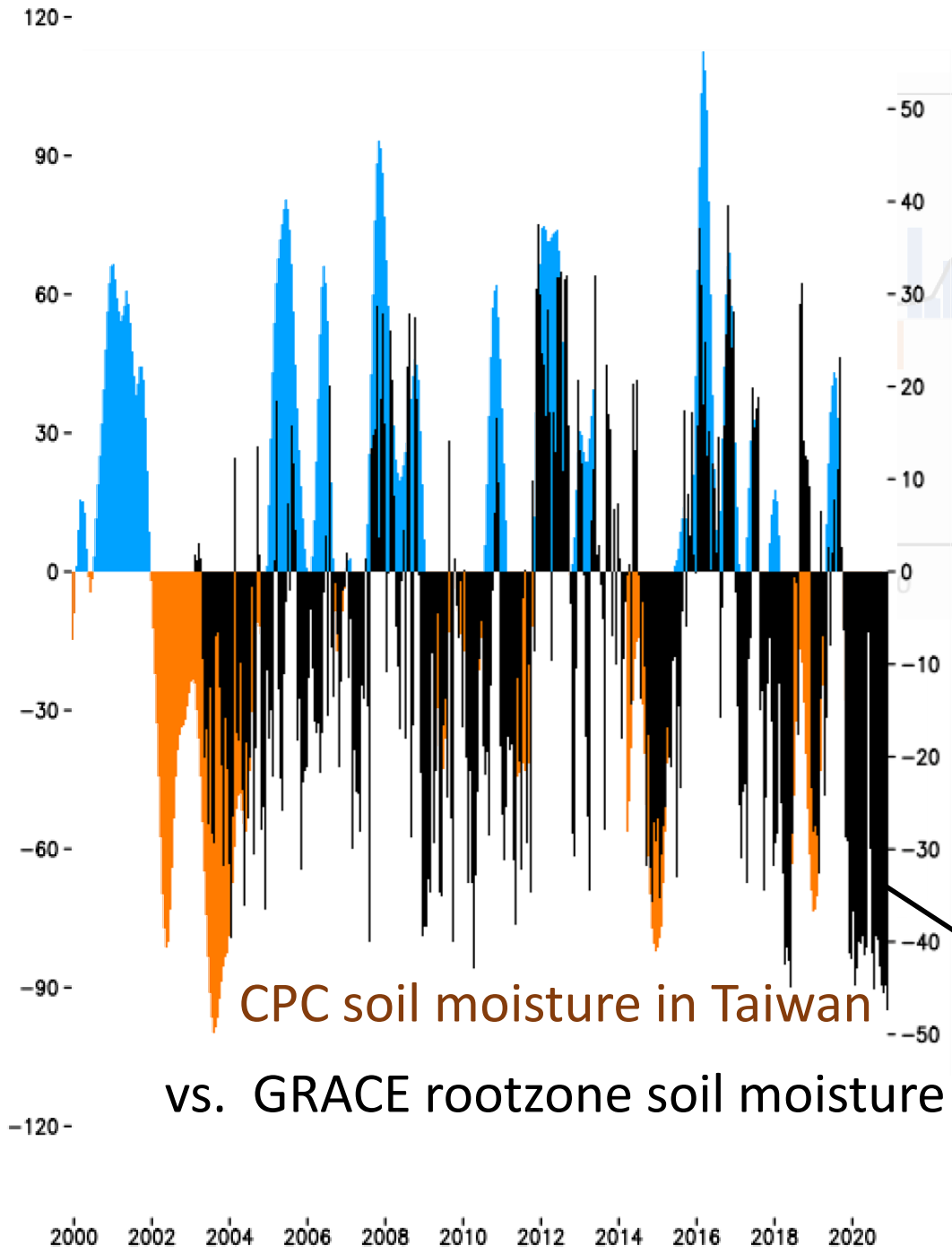
Decadal fluctuations in the western Pacific recorded by long precipitation records in Taiwan

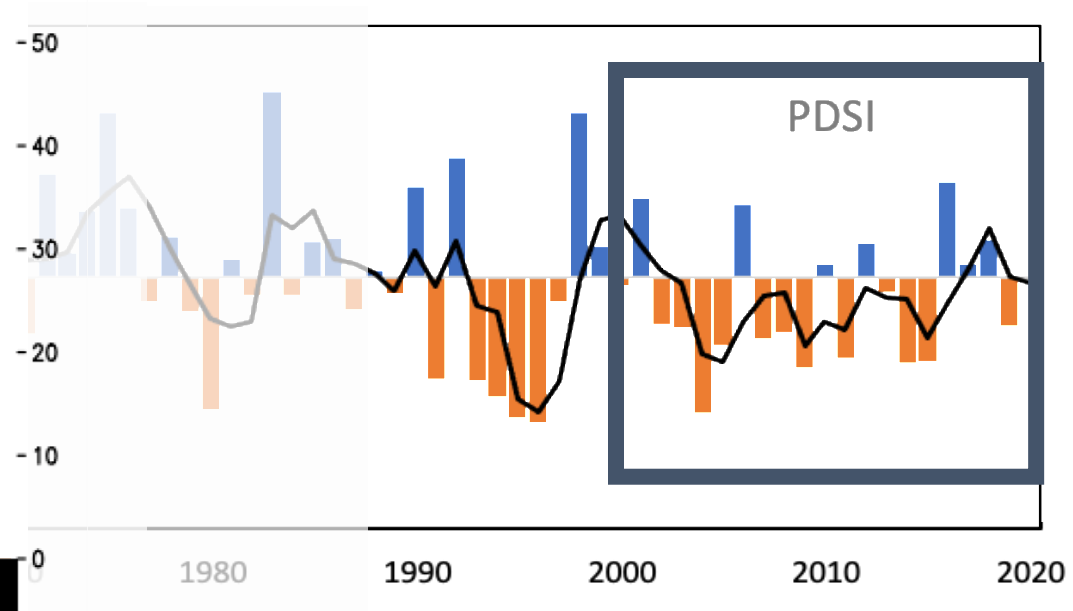
Wan-Ru Huang[1] · S.-Y. Simon Wang[2,3] · Biing T. Guan[4]



第一步：

e 10 tered precipitation in Taiwan
undred-year stations (defined as the Taiwan precipitation
solid line) and the annual Niño4 sea surface temperature
malies (*blue dotted line*)





Drought discrepancy

CPC soil moisture in Taiwan

vs. GRACE rootzone soil moisture

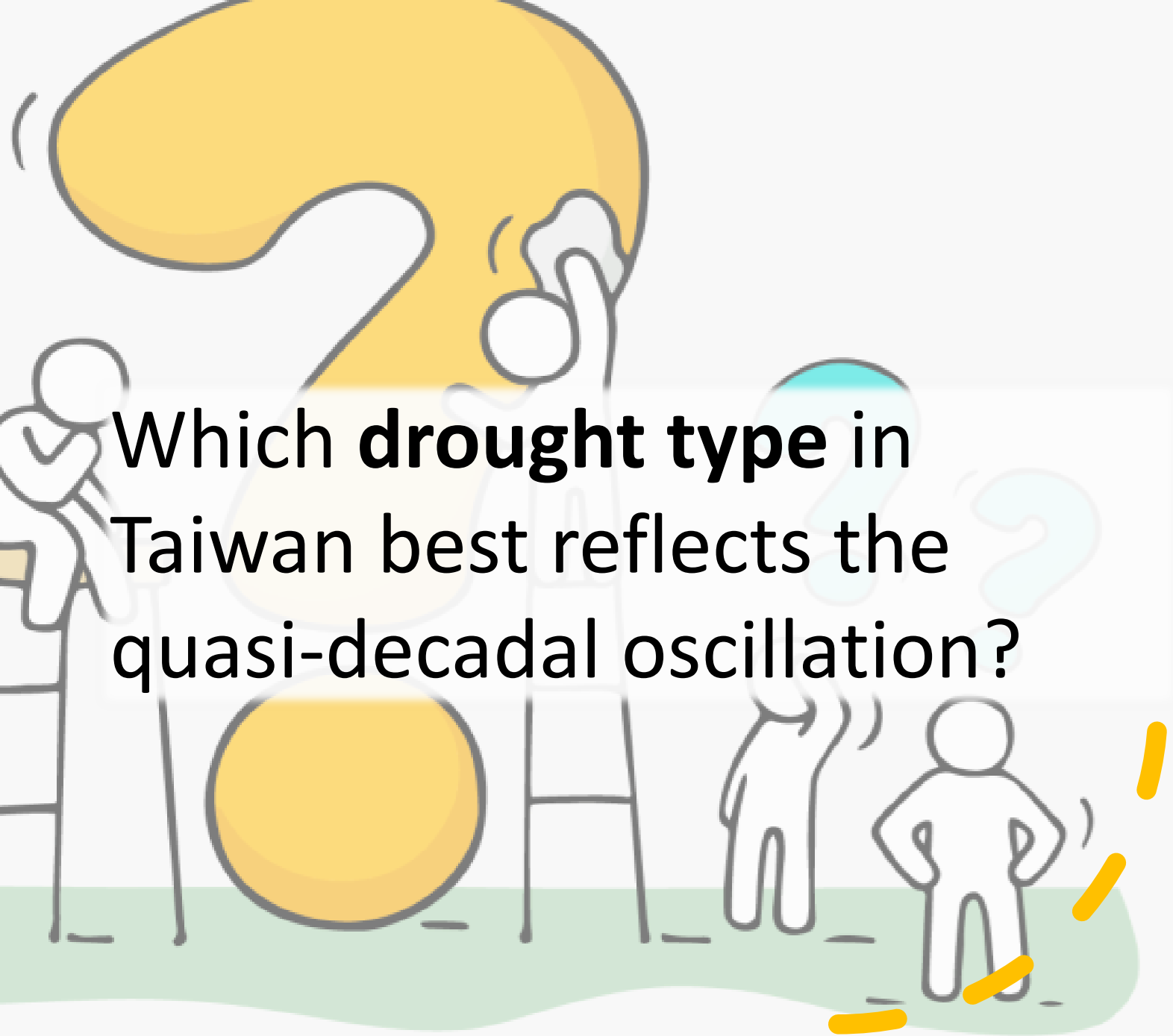
Much worse drought ?

in 2020

Drought discrepancy: Which drought does 2020 belong?

- Water-deficit-based drought
  - drought hazard index, drought exposure index, drought vulnerability index, drought risk index…
  - Shallow groundwater deficit
- Quantile regression-based drought
  - SPI: standardized precipitation index
  - HDI: hydrological drought index
- Meteorological & agricultural drought
  - PDSI 🤦‍♂
  - Vapor deficit index, SPEI, VHI…

Drought cycle



Which **drought type** in Taiwan best reflects the quasi-decadal oscillation?