

Tropical Pacific modulations of global climate

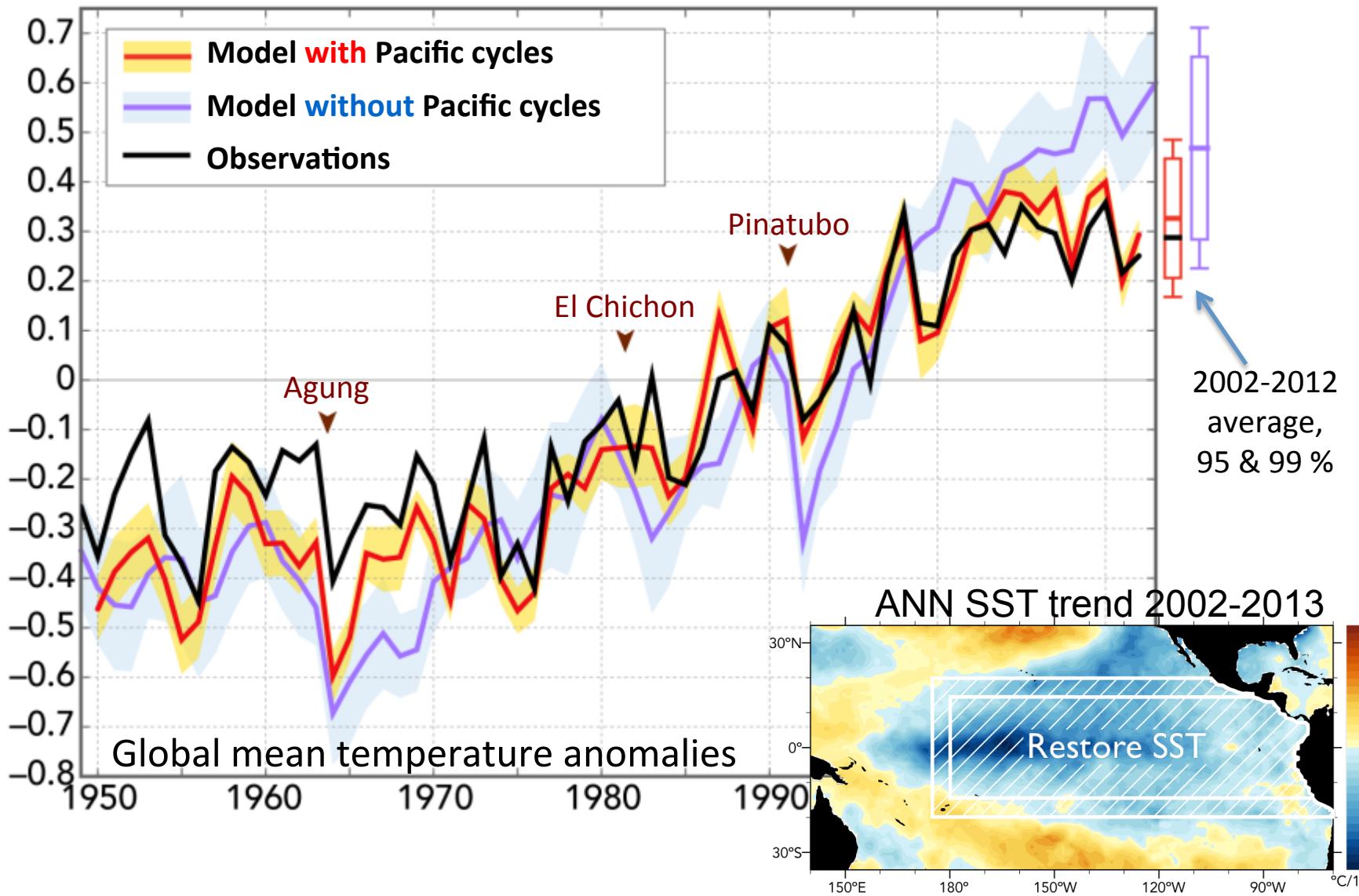
Shang-Ping Xie¹ & Yu Kosaka²

¹Scripps Inst of Oceanogr, UCSD; ²Univ of Tokyo

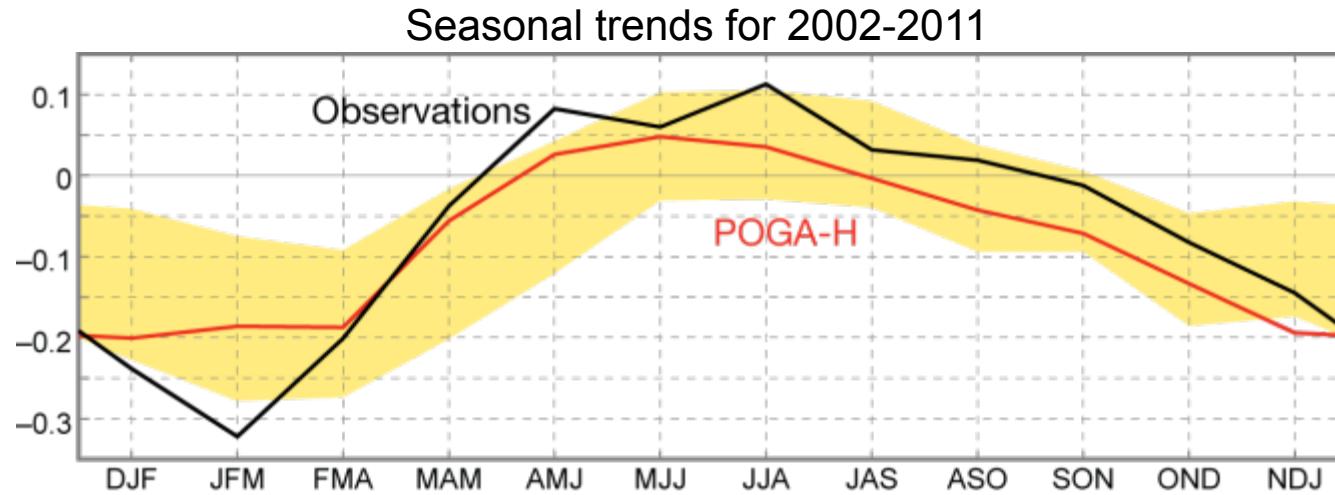
Develop seasonal and spatial fingerprints
beyond global means

POGA (Pacific Ocean-Global Atmosphere) pacemaker run

Kosaka & Xie (2013, Nature)

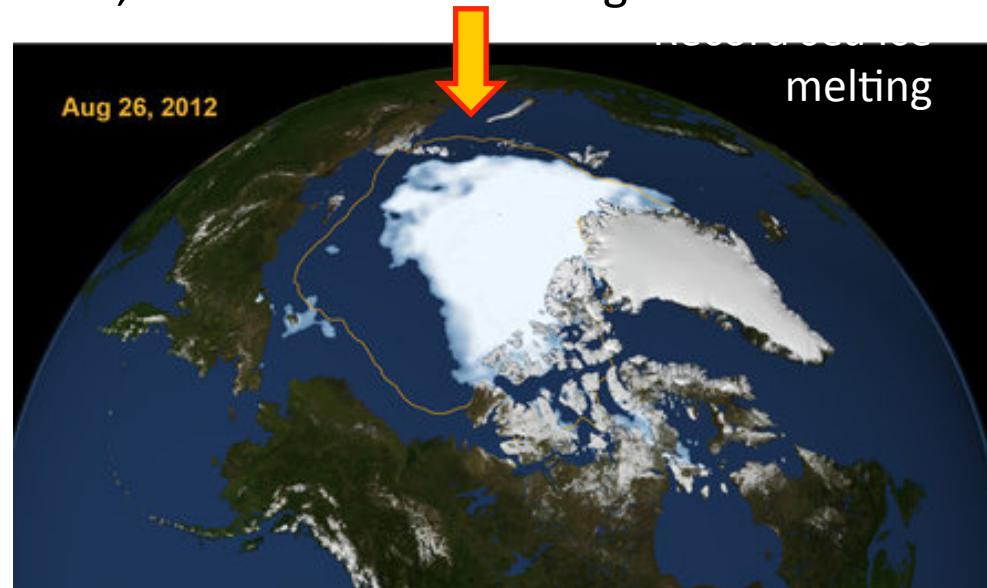
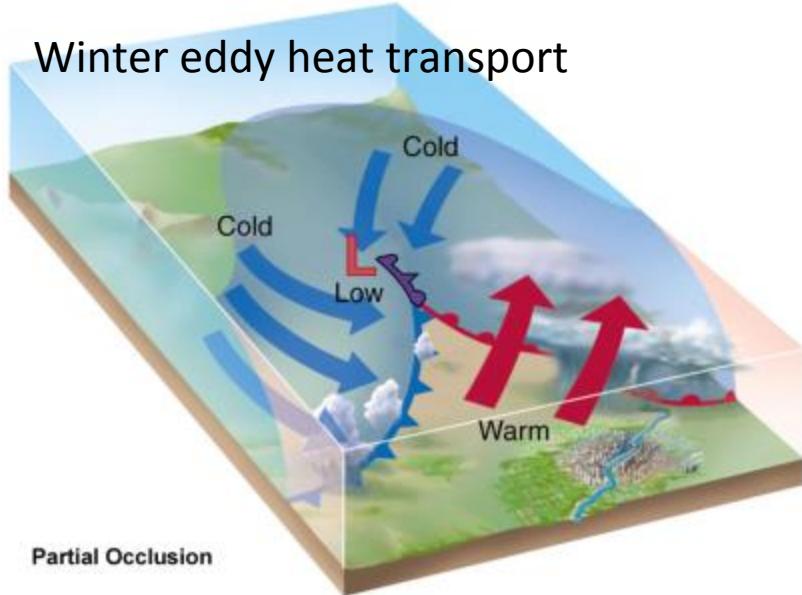


Seasonal fingerprint of the Pacific effect

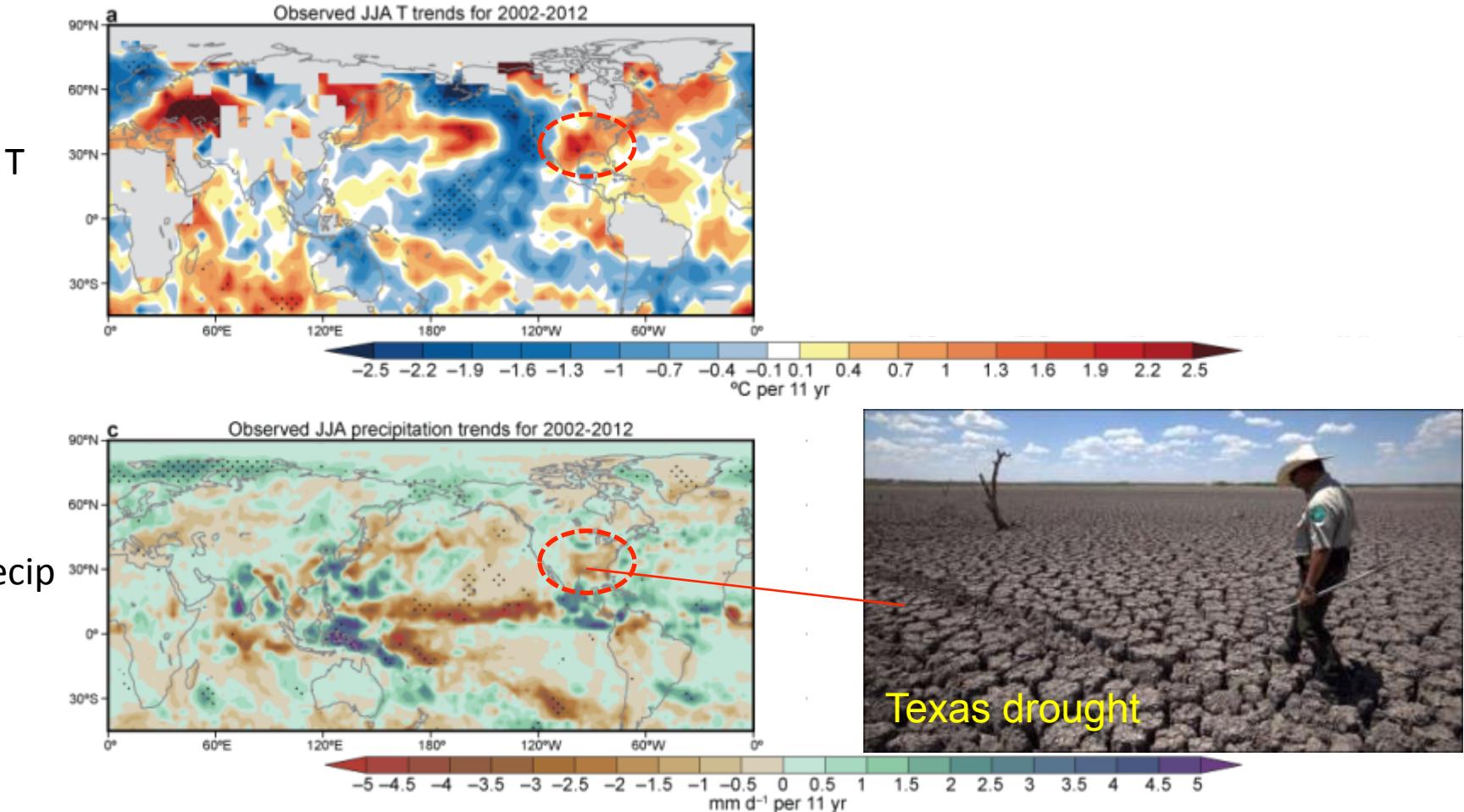


In summer, tropical effect on northern extratropics
is weak, and radiative warming dominates

Winter eddy heat transport



JJA trend pattern for the current hiatus



- Most NH land warmed, a radiative effect.
- Warming and drought over the southern US because of the hiatus.

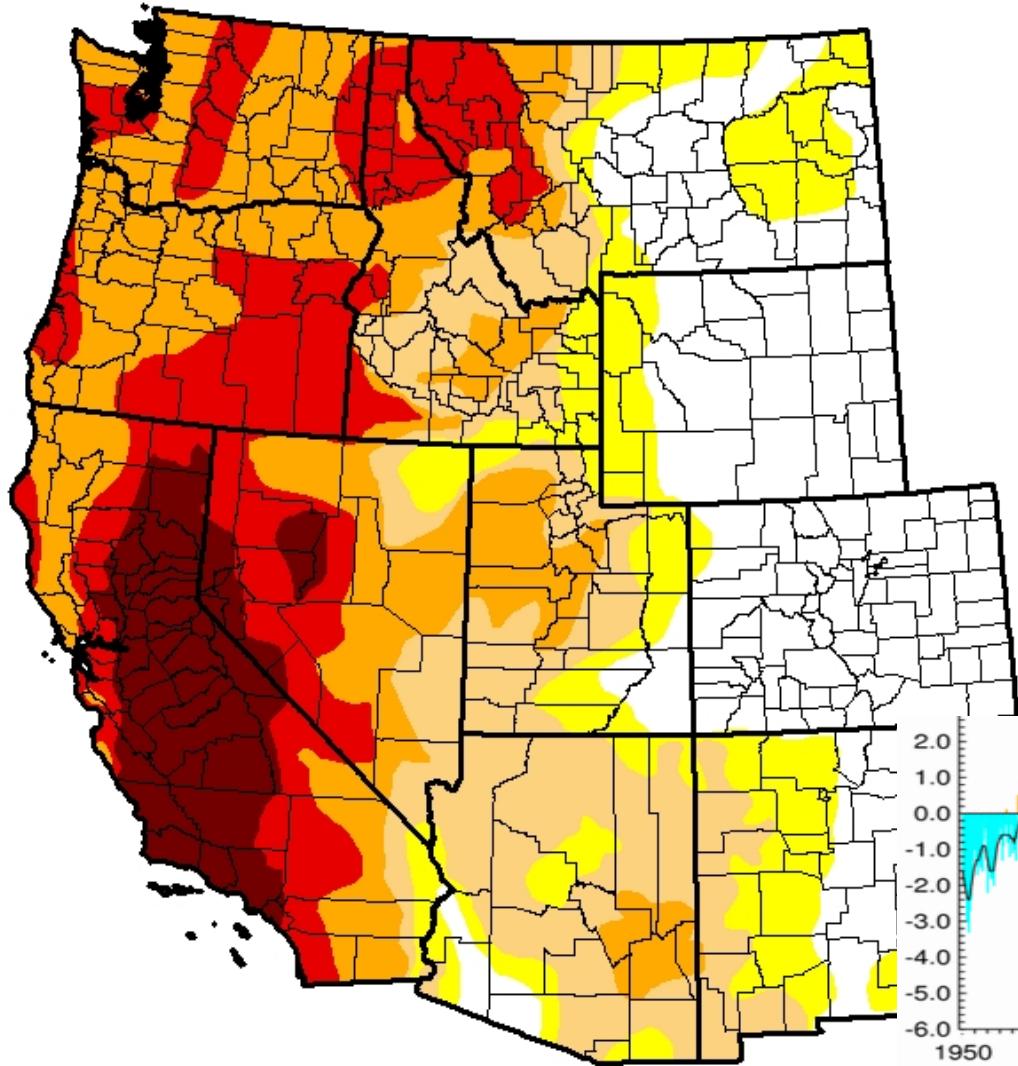
U.S. Drought Monitor

West

July 28, 2015

(Released Thursday, Jul. 30, 2015)

Valid 8 a.m. EDT



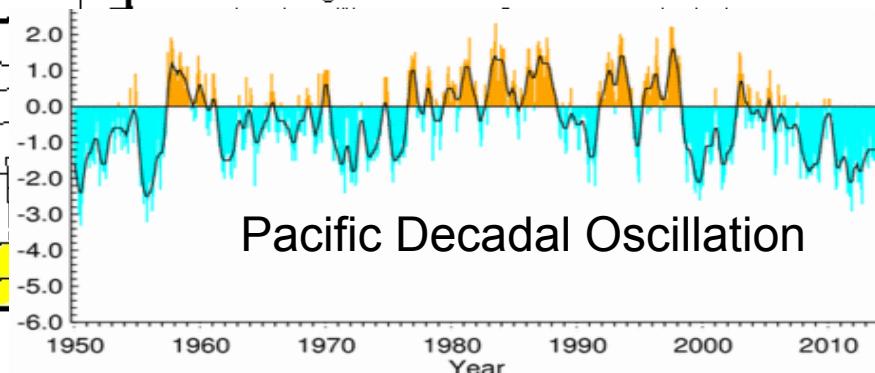
Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	26.53	73.47	60.09	42.99	22.24	7.17
Last Week 7/21/2015	25.49	74.51	61.04	41.92	18.87	7.17
3 Months Ago 4/28/2015	26.14	73.86	62.12	39.33	17.64	7.95
Start of Calendar Year 12/31/2014	34.76	65.24	54.48	33.50	18.68	5.40
Start of Water Year 9/30/2014	31.48	68.52	55.57	35.65	19.95	8.90
One Year Ago 7/29/2014	27.73	72.27	60.93	44.49	21.68	8.98

Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

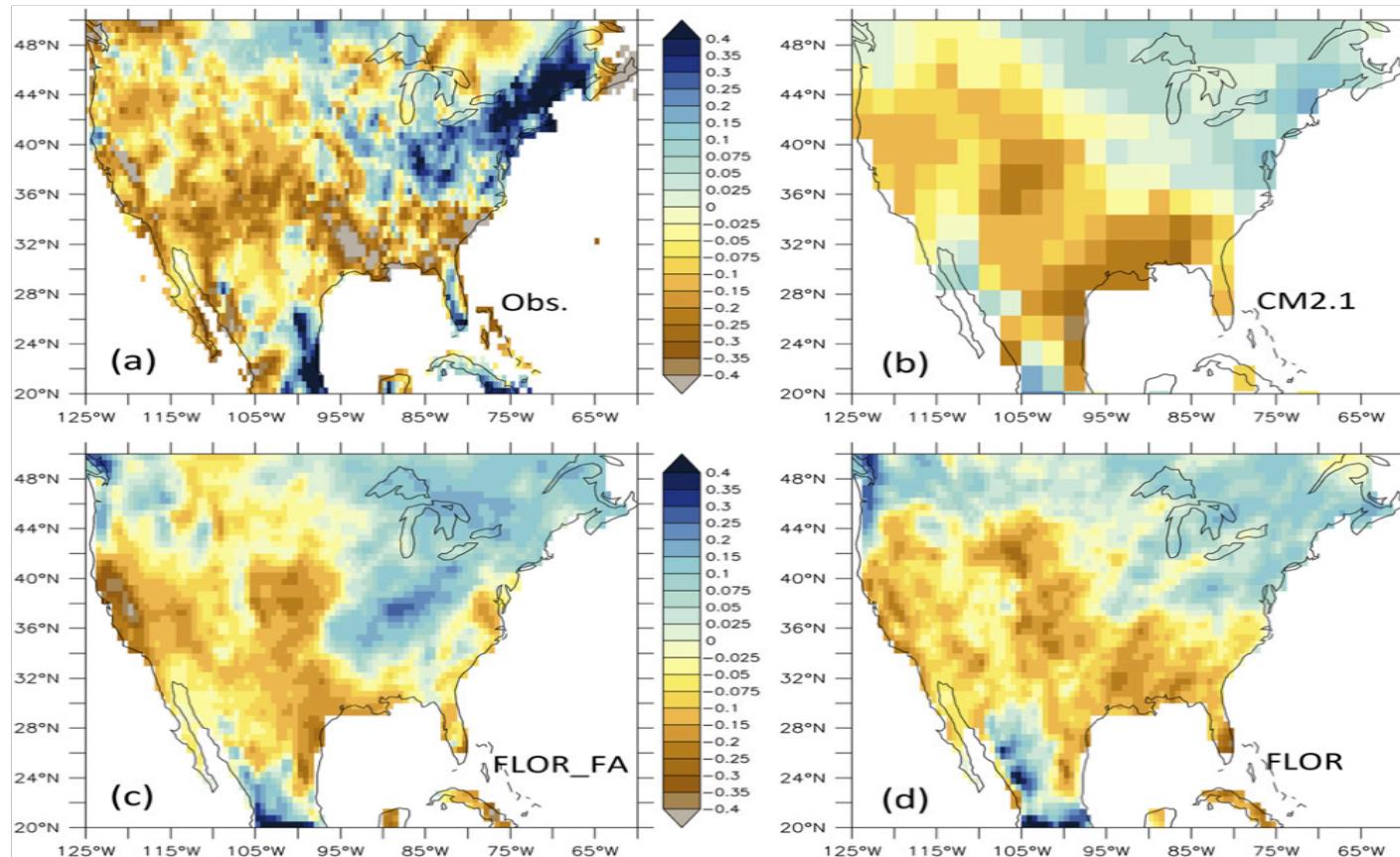
The Drought Monitor focuses on broad-scale conditions.



Pacific Decadal Oscillation

Pacific pacemaker experiments reproduce California drought

Delworth et al. (2015, JC)

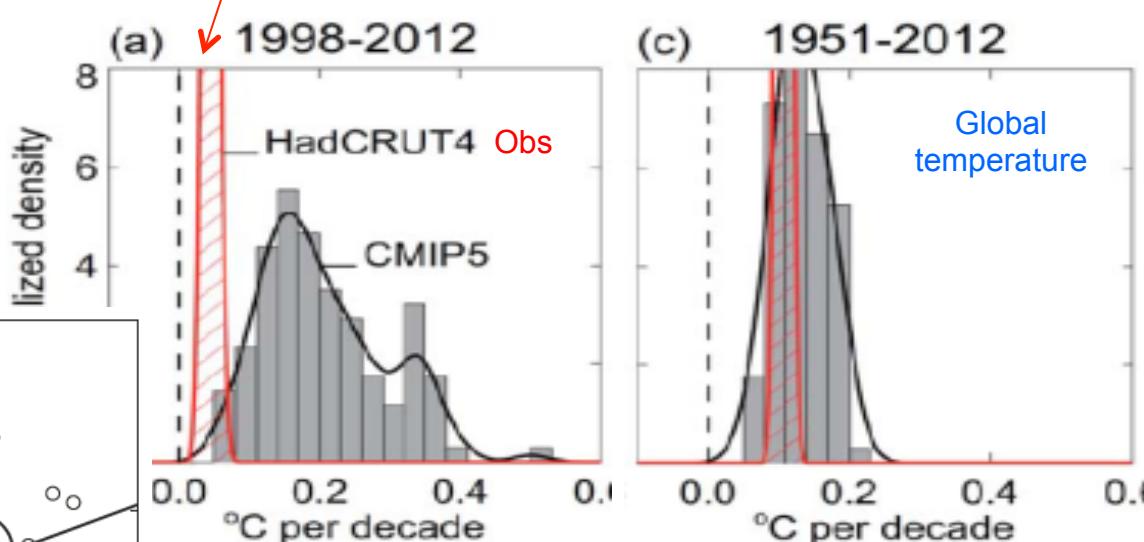
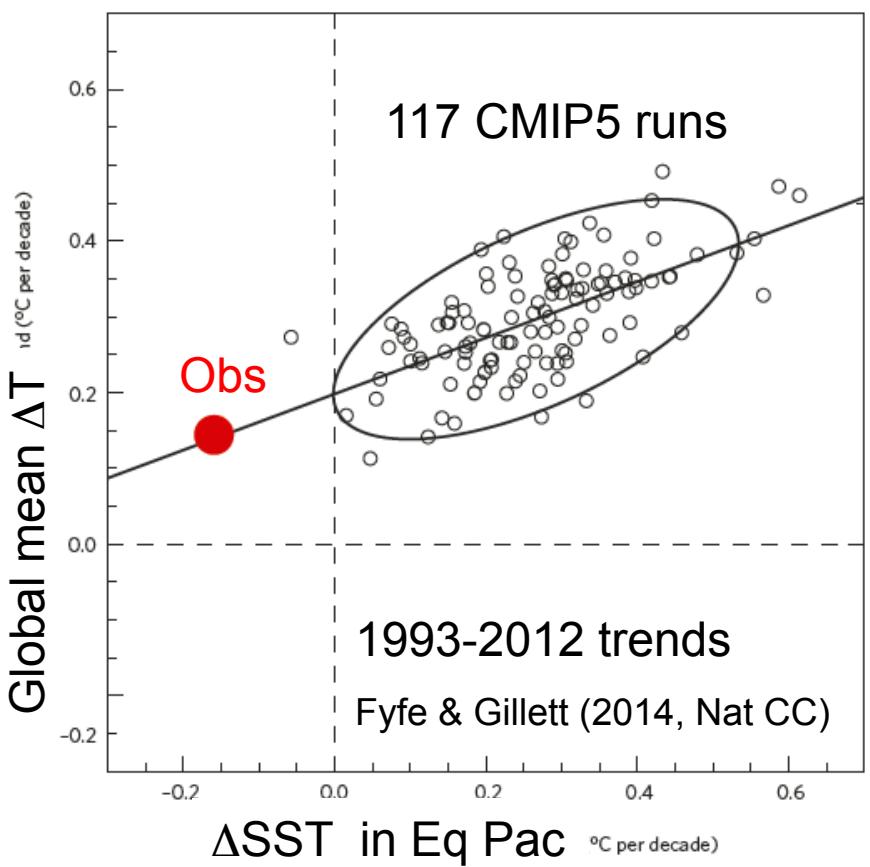


2002-2012 minus 1979-2000 annual mean precipitation (mm/day)

GFDL CM2.5 forecast-oriented low ocean resolution (FLOR) w/ &
w/o flux adjustment (FA)

Flato et al. (2013, IPCC AR5 Ch 9)

Few of the 114 CMIP5 runs
reproduce the hiatus



Much of GMT spread is caused by
tropical Pacific SST

POGA Pacemaker Experimental

- GFDL CM2.1 (CMIP5 generation)

- **HIST** Radiative forcing only

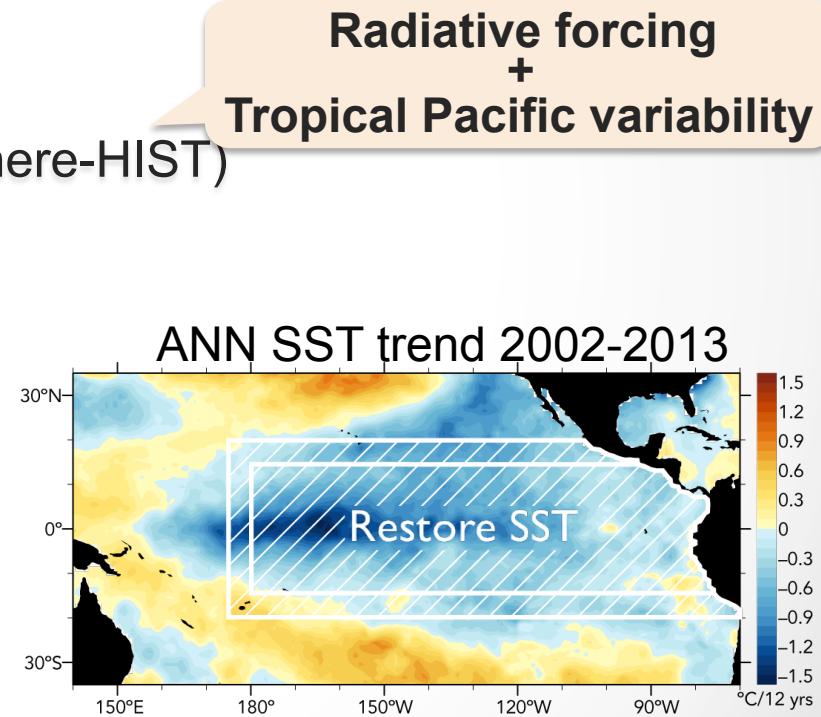
- Historical (~2005) and RCP4.5 (2006~) radiative forcing
 - 20 members

- **POGA-H** (Pacific Ocean-Global Atmosphere-HIST)

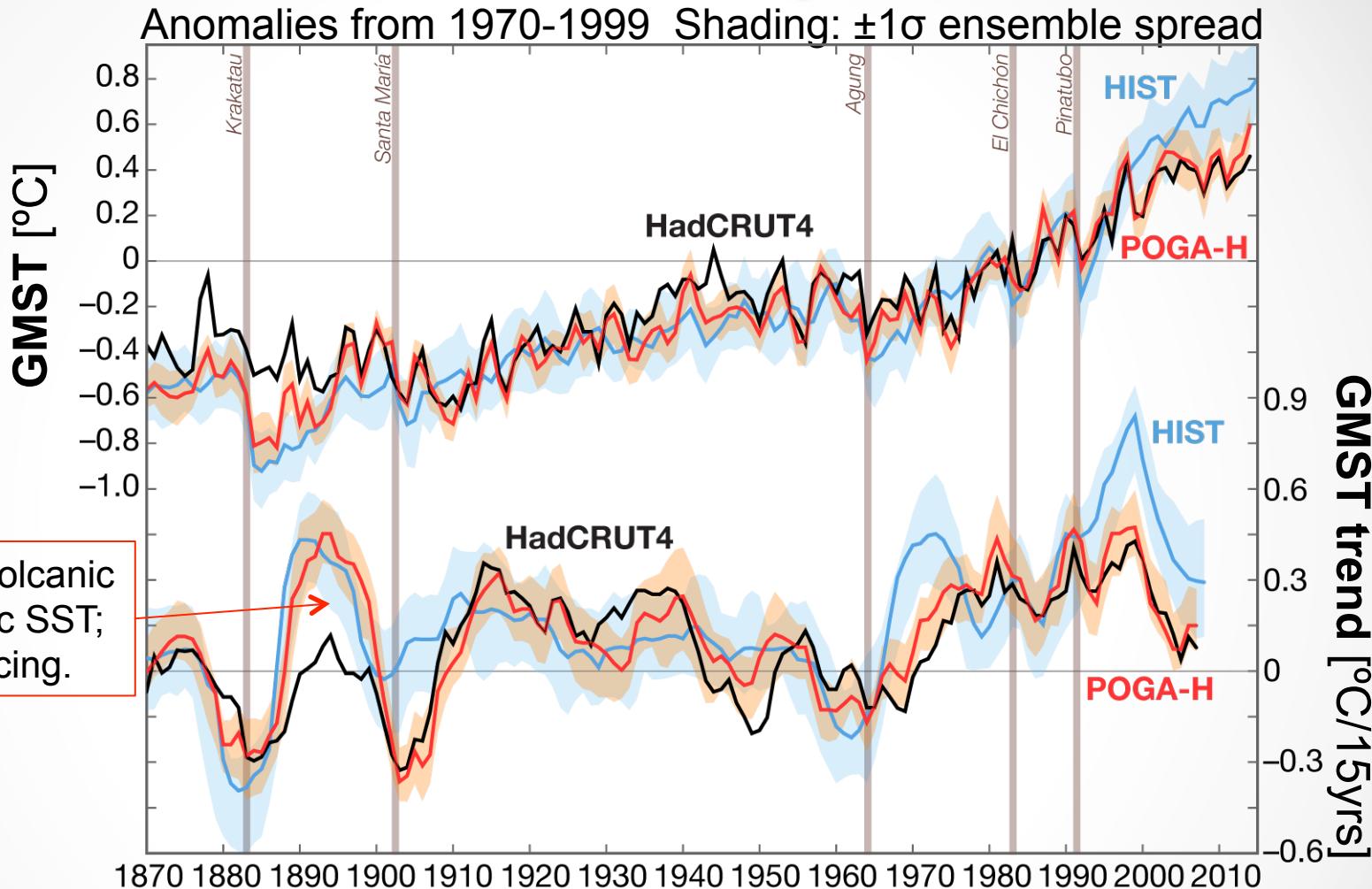
- Tropical Pacific SST is restored toward observed anom (ERSSTv3b)
 - Rest of the ocean is fully coupled with the atmosphere
 - Radiative forcing: same as HIST
 - 10 members
 - **1871-2014**

- **POGA-H minus HIST**

Tropical Pacific effect

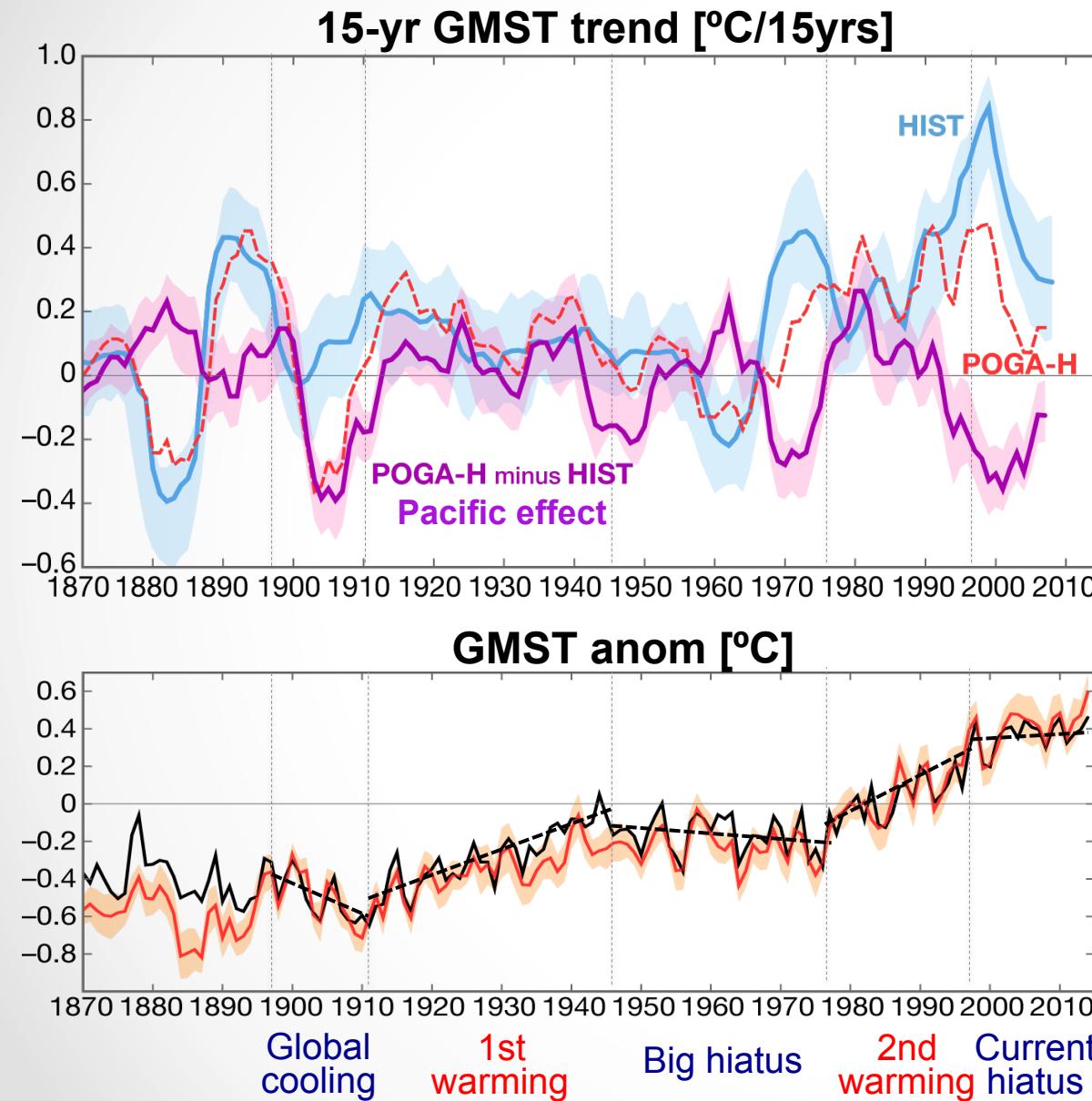


GMST and its 15-year trend



	GMST R	GMST RMSE [$^{\circ}\text{C}$]	trend R	trend RMSE [$^{\circ}\text{C}/15\text{yrs}$]
POGA-H	0.96	0.13	0.80	0.13
HIST	0.91	0.19	0.57	0.21

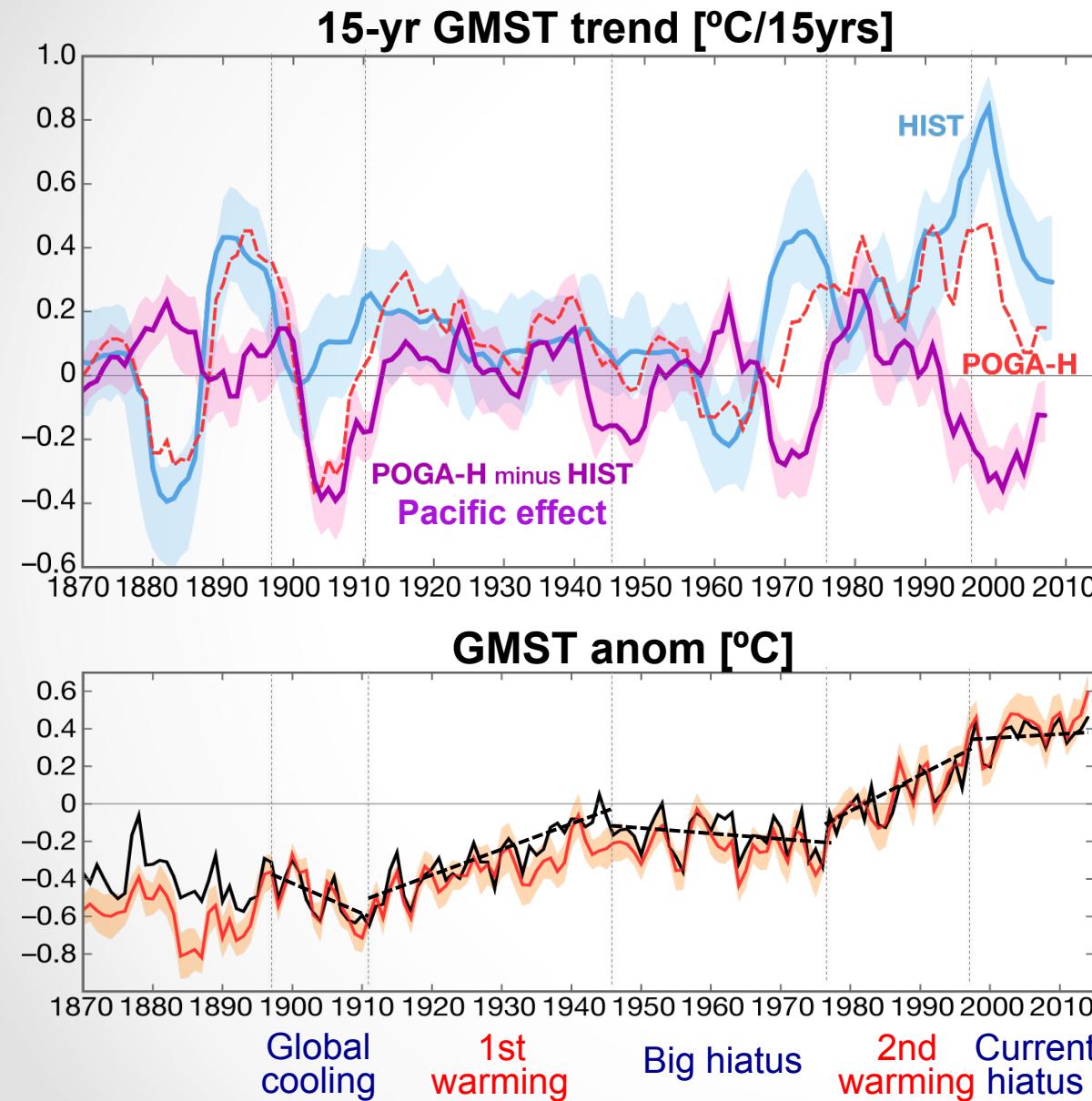
Attribution of past hiatus and warming events



Decompose
POGA-H GMST trend
into
radiative forced (HIST)
+
tropical Pacific effect
(POGA-H minus HIST)

- For 15-yr trend, tropical Pacific effect is comparable with radiative forcing

Attribution of past hiatus and warming events



Tropical Pacific SST contributes to

- Rapid cooling in the beginning of 20c
- Slight acceleration of the 1st warming
- Earlier start and delayed ending of the big hiatus
- Accelerate the 2nd warming in first decade
- The current hiatus

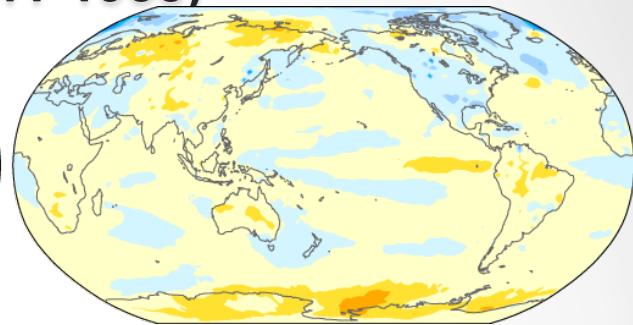
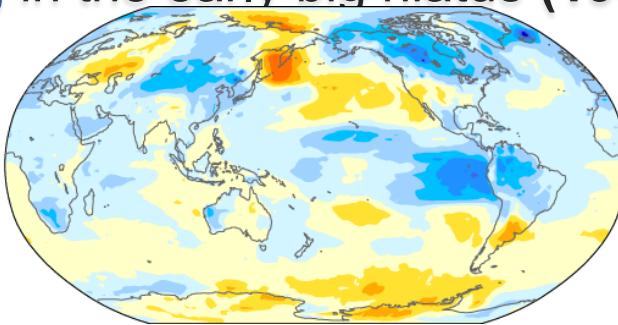
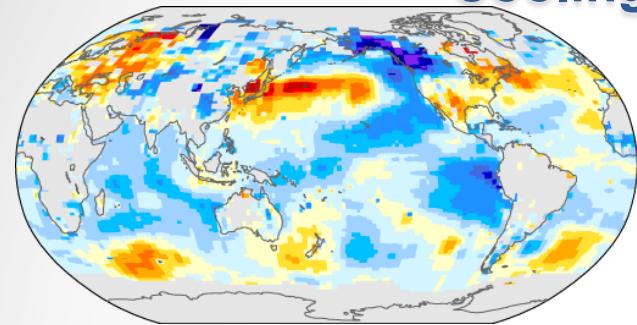
Trend pattern: the big hiatus

Obs (GISTEMP)

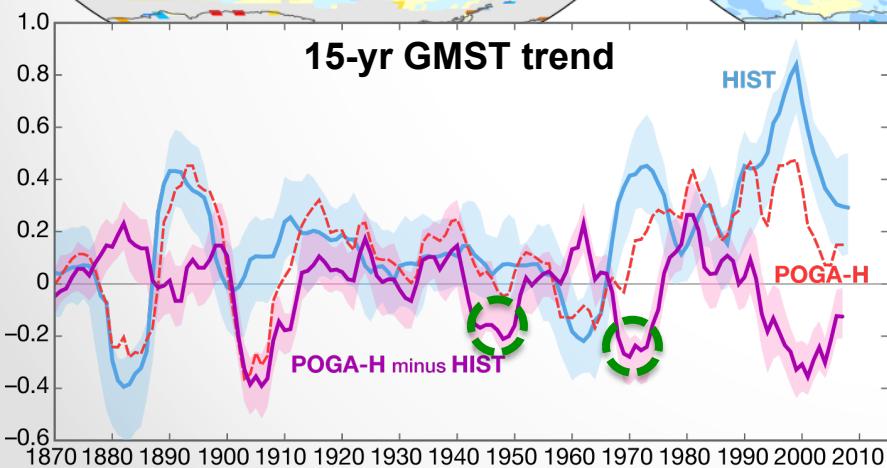
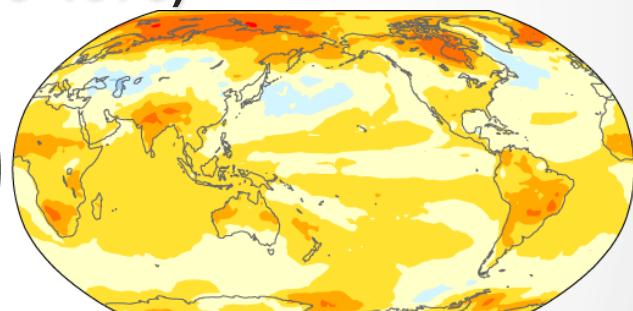
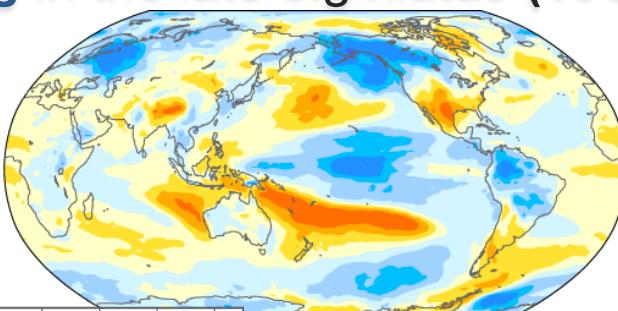
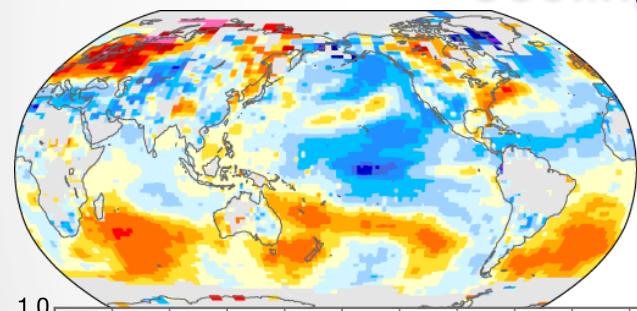
POGA-H

HIST

Cooling in the early big hiatus (1941-1955)



Cooling in the late big hiatus (1963-1976)



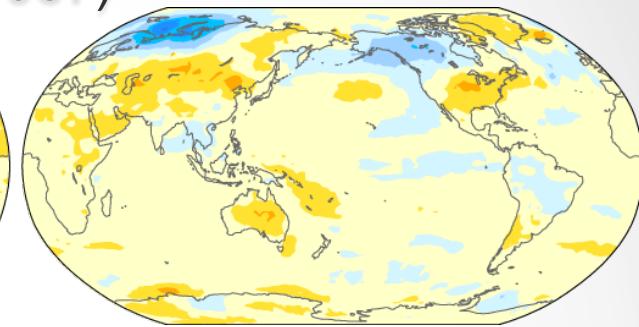
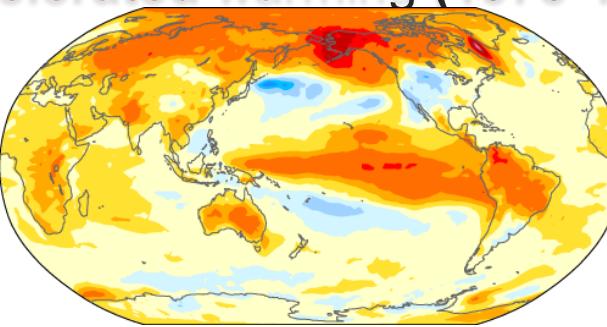
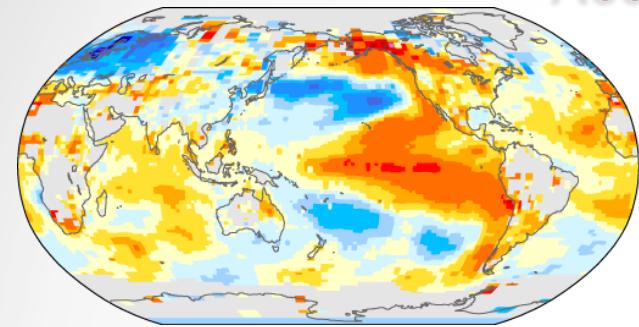
Trend pattern: recent acceleration and hiatus

Obs (GISTEMP)

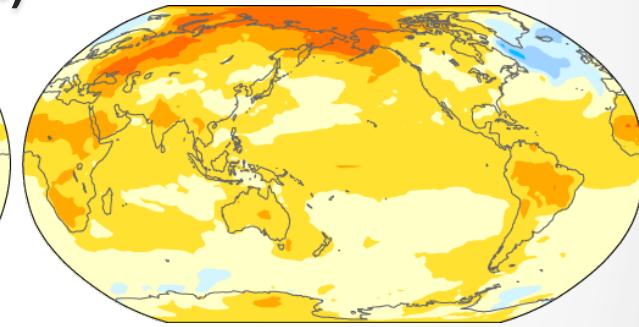
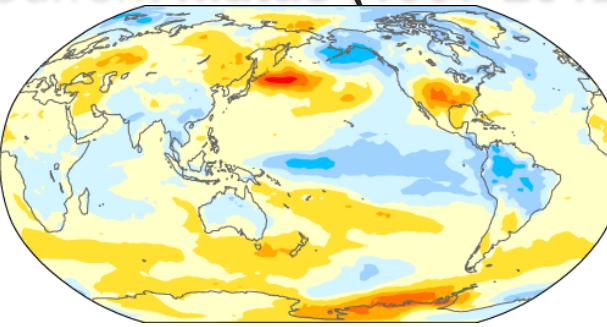
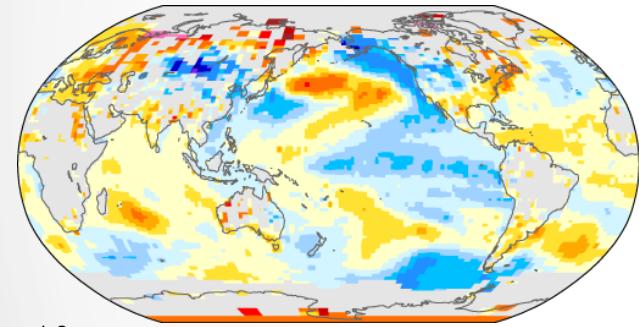
POGA-H

HIST

Accelerated warming (1973-1987)



Current hiatus (1997-2012)

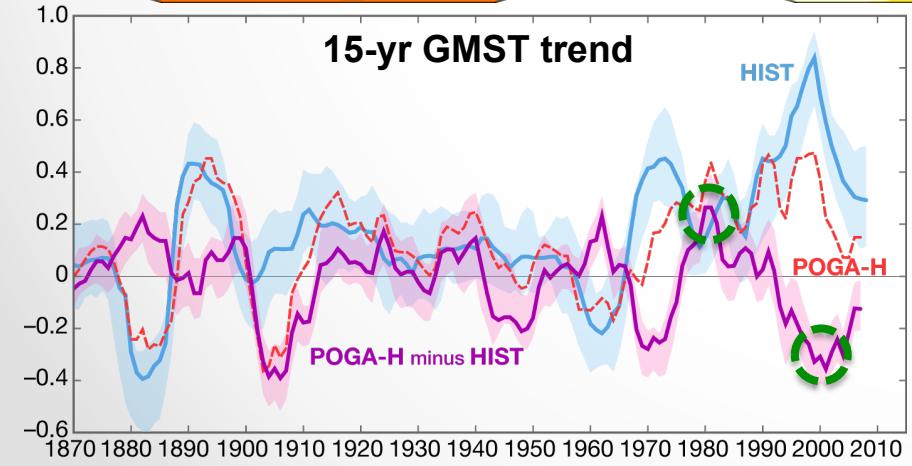


15-yr GMST trend

HIST

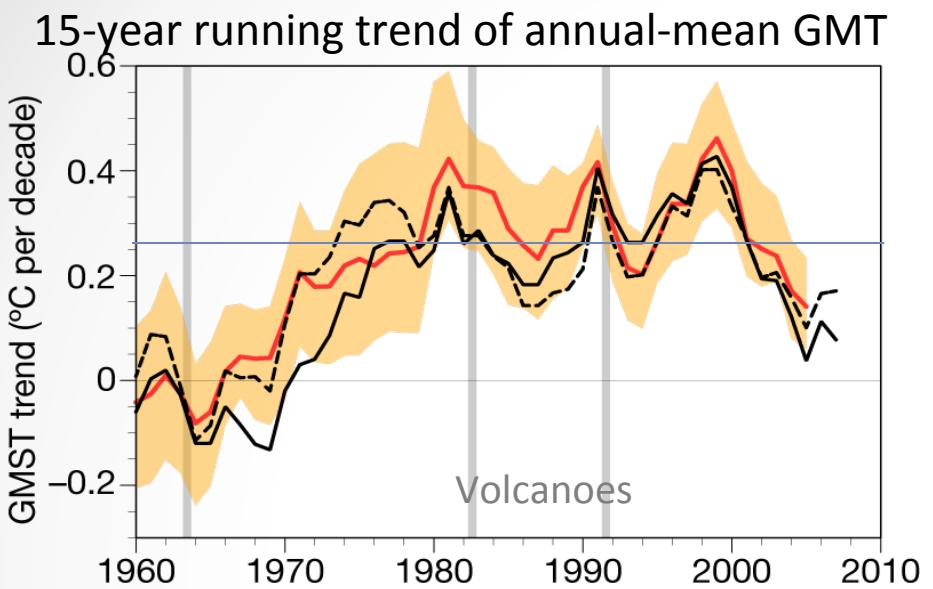
POGA-H

POGA-H minus HIST



- Skills in tropical IO, India, North and South Pacific and North America

-1.6 -1.4 -1.2 -1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 [°C/10yrs]



- 15-yr trends slow down in 21st century compared to 1970s-90s.
- The Karl et al. data show a clear **fingerprint of tropical Pacific effect**.

Summary

- IPO dominates internal GMST variability, with distinctive seasonal and spatial fingerprints.
- Radiative forcing is the major cause of the 20c warming and the big hiatus.
- Tropical Pacific SST affects timing and magnitude of the warming acceleration and slowdown, including the current hiatus.

Outlook

- The hiatus gives a new impetus for decadal variability research.
- Inter-basin interactions: possibility that tropical Atlantic warming contributes to Pacific trade wind intensification.
- Anthropogenic change and decadal variability are distinct energetically, a point studies of TOA energy imbalance and ocean heat uptake need to consider.

Is the La Niña cooling natural or forced?

Three mechanisms for forced SST pattern in Eq. Pacific

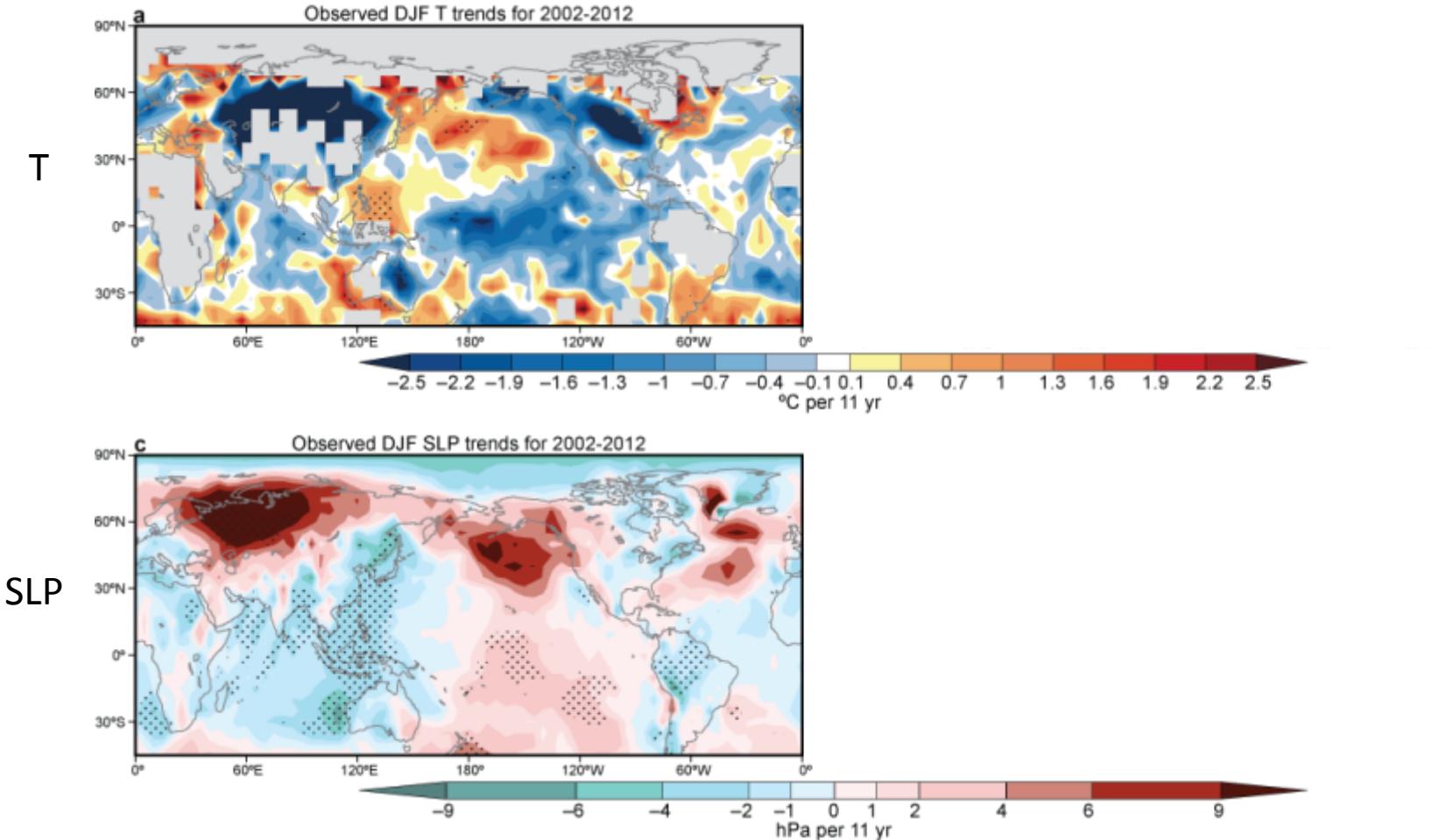
- Ocean dynamic thermostat → reduced warming in the east
(visible in CMIP models in seasonality of the warming.)
- Weakened Walker circulation → enhanced warming in the east.
- Evaporative damping → enhanced warming on the equator and in the east.

In CMIP models

- The equatorial peak in surface warming is common.
- More models favor enhanced warming in the east.

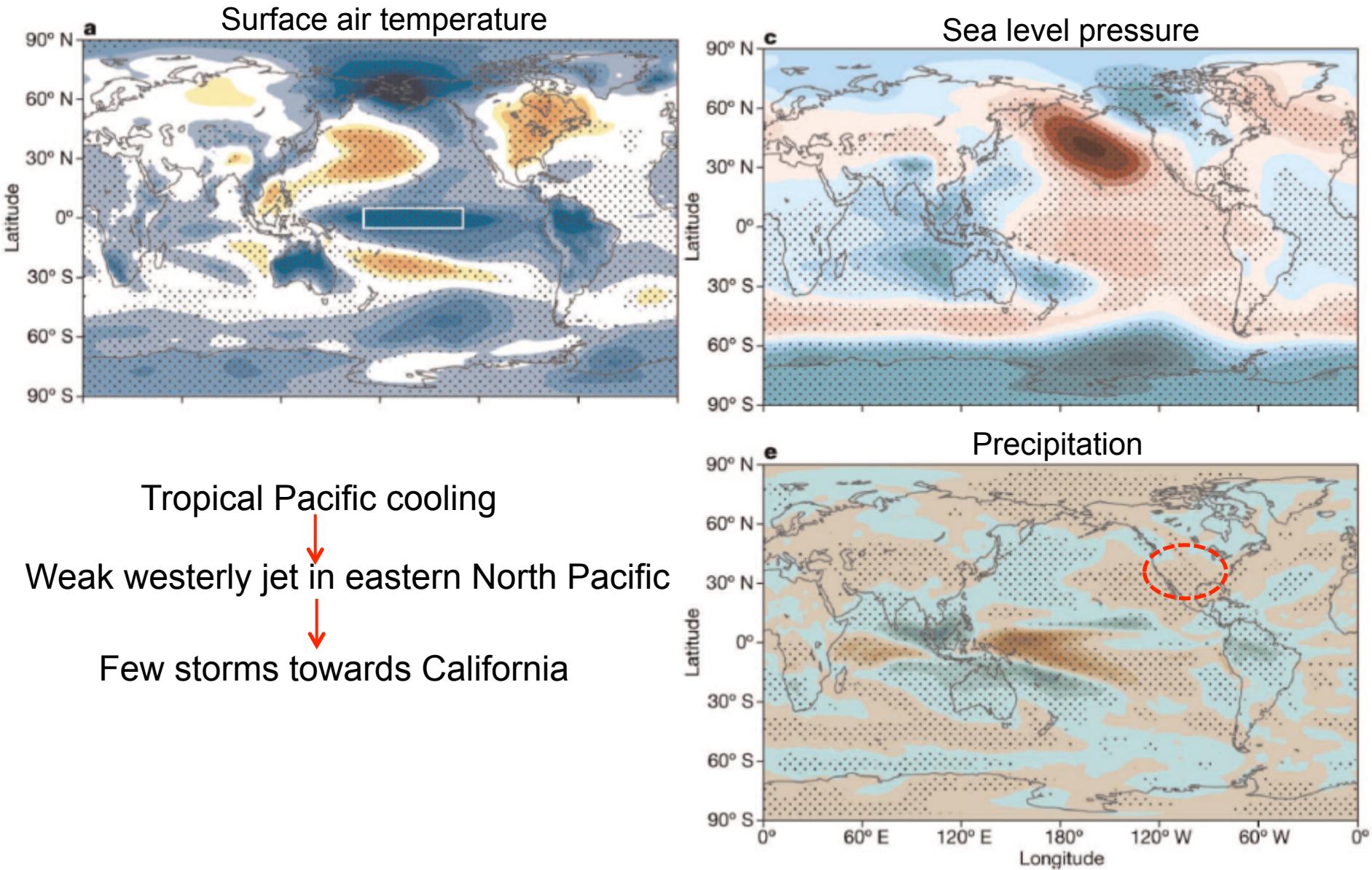
Need to develop observational constraints on relative importance of these mechanisms, e.g., by studying the hiatus.

DJF trend pattern for the current hiatus



- Strengthening of Walker circulation (cf. projected weakening by GW)
- Weakening of Aleutian low and cooling over northwest N. America
- Eurasian trends are unrelated to tropical variability

Winter (DJF) anomalies of tropical Pacific Decadal Oscillation in CM2.1 model

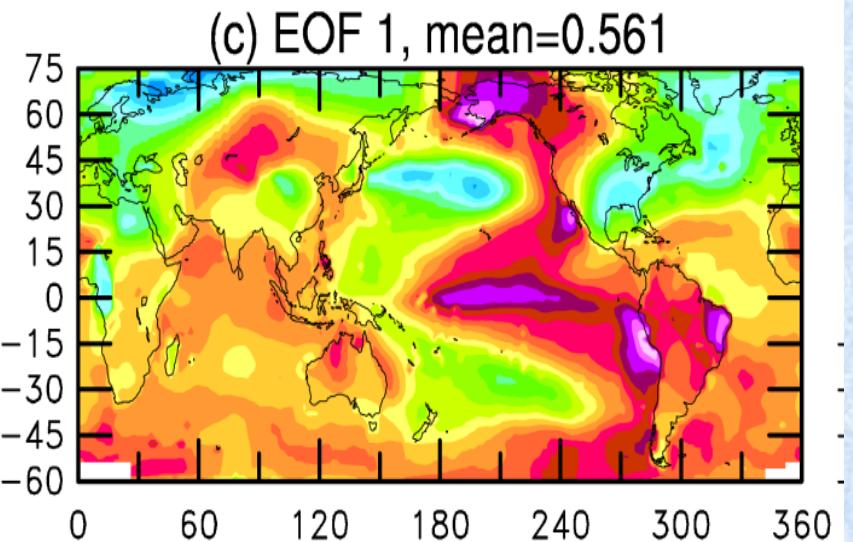
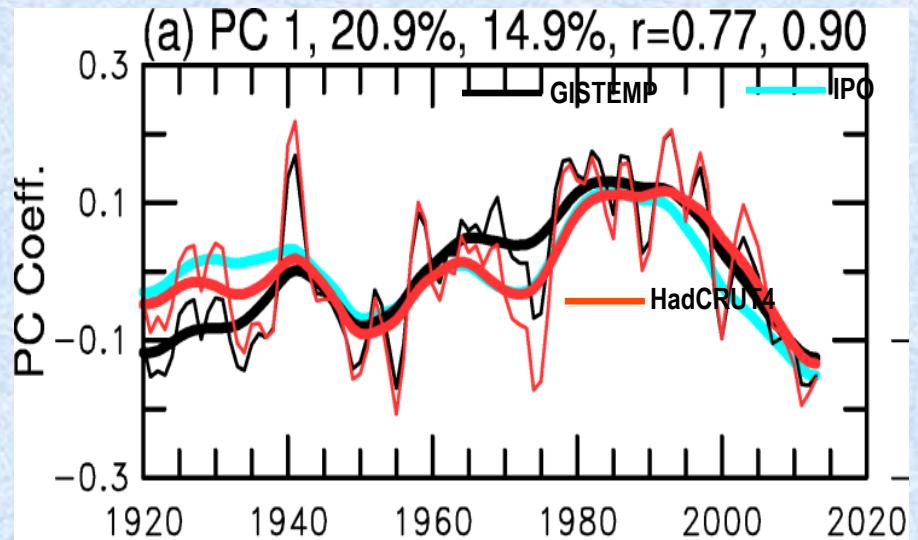


Internal modes with GMST projection

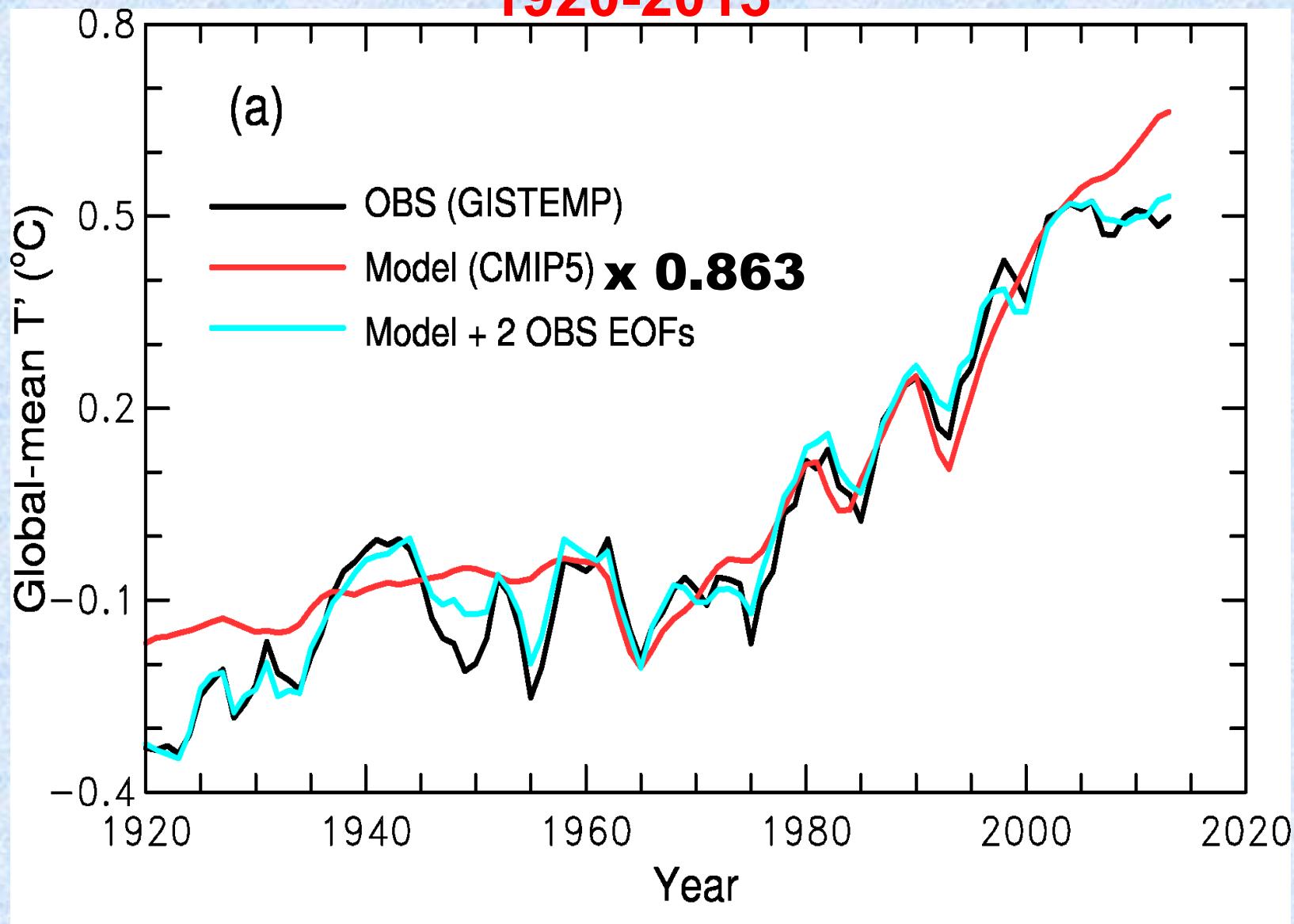
Dai et al. (2015, Nature Climate Change)

- Use CMIP5 multi-model GMST to regress out the forced signal at each grid point
- Residual dT contains mostly unforced internal climate variability
- EOF analysis of detrended dT
- Contribution of the leading EOFs to global-mean dT

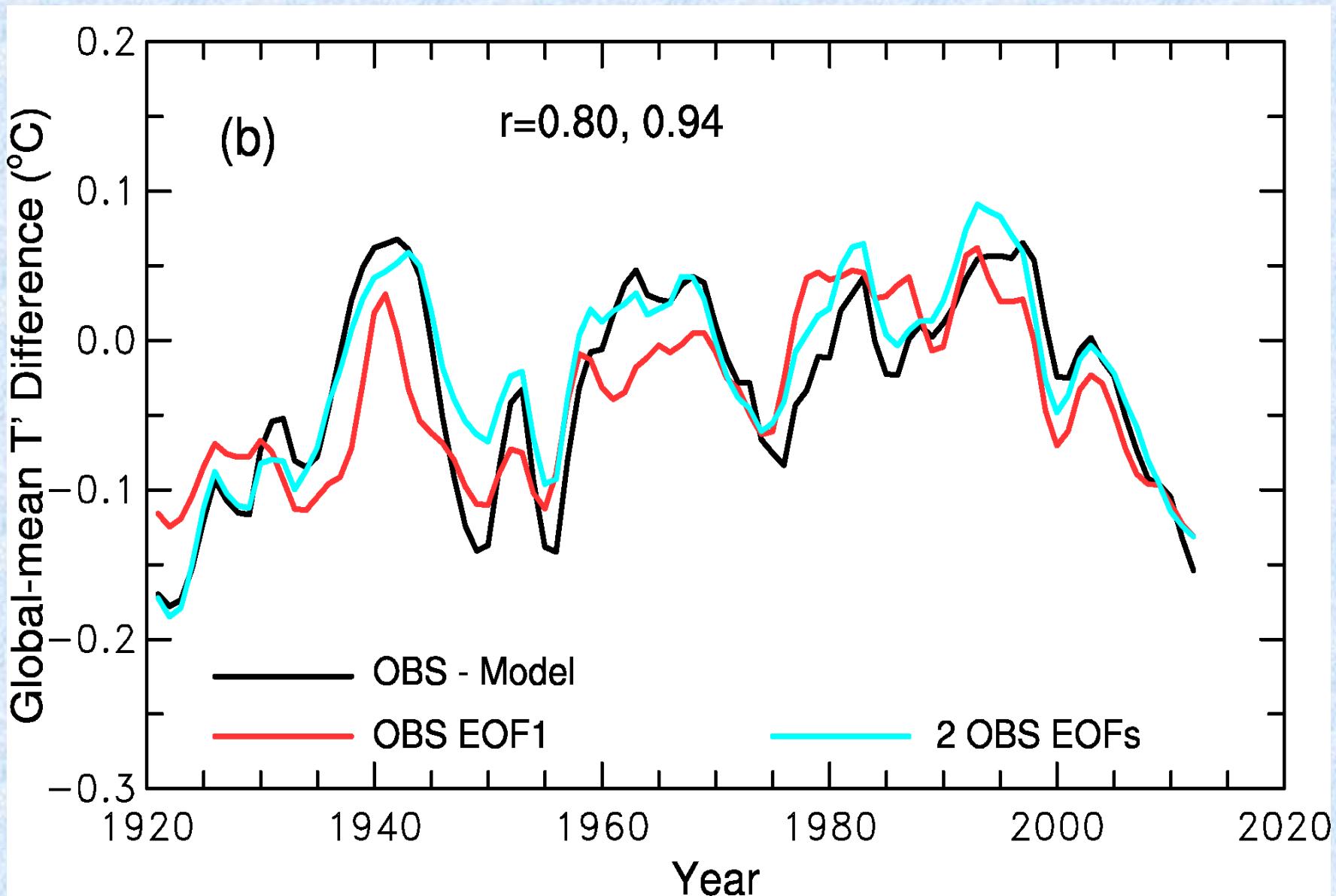
EOF1: IPO Mode



Contribution to Global-mean Temperature 1920-2013

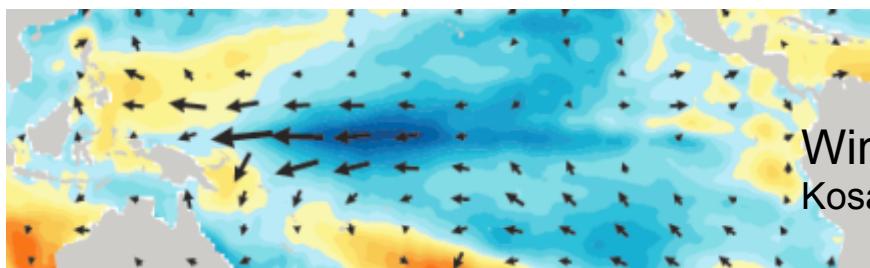
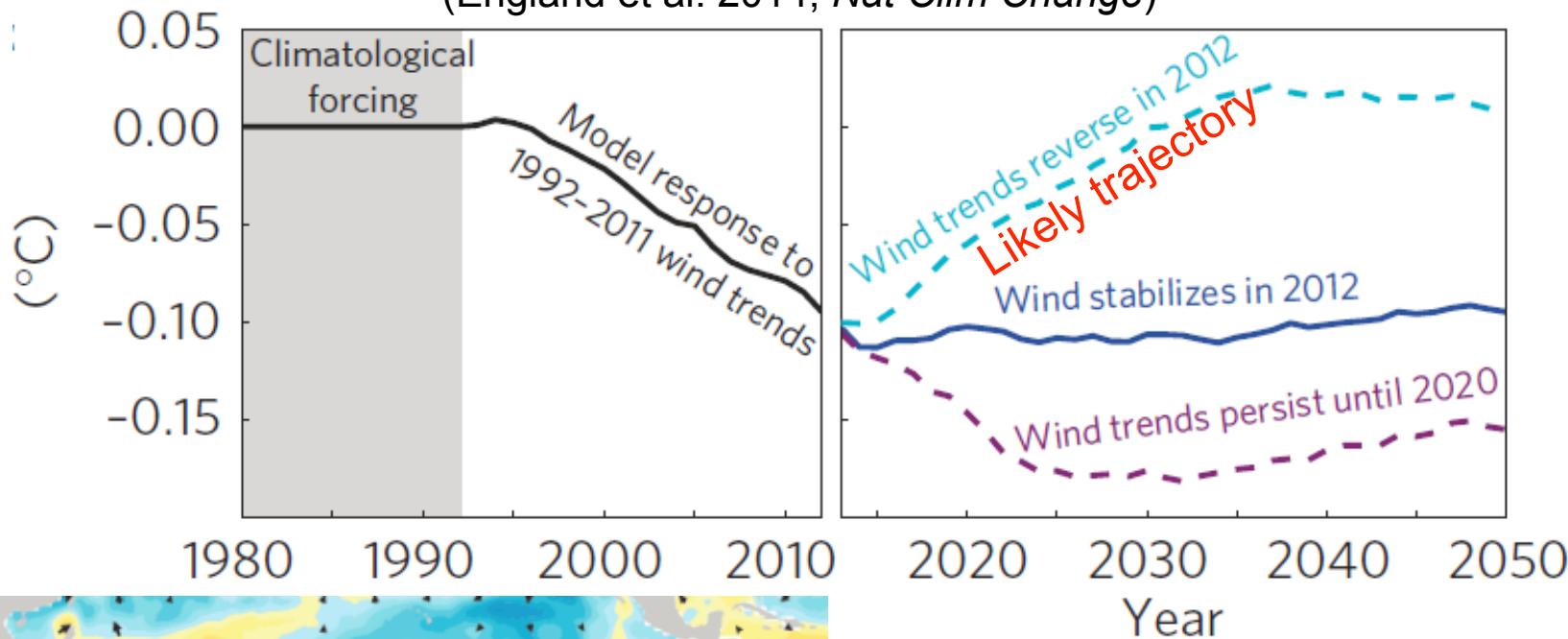


T Difference: OBS — Model



Wind-induced global temperature change

(England et al. 2014, *Nat Clim Change*)



Wind & SST trends for 2001-13
Kosaka (2014, NCC)

- When PDO shifts to positive phase (likely), climate warming will return with accelerated rate.
- Decadal trends are subject to natural variability but centennial trend is mostly anthropogenically forced