

Non-linear controls on the persistence of La Nina events in CCSM4

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CESM Workshop

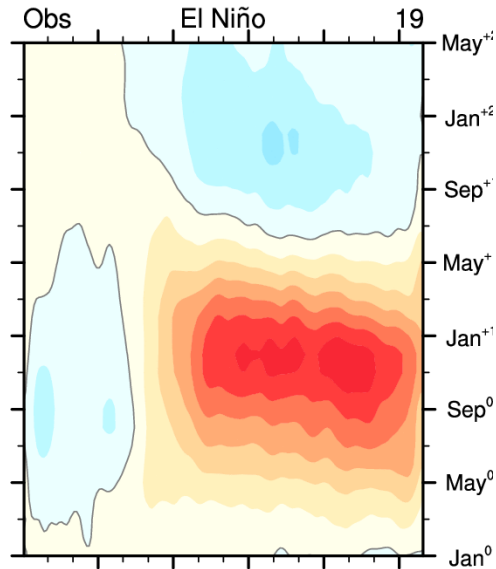
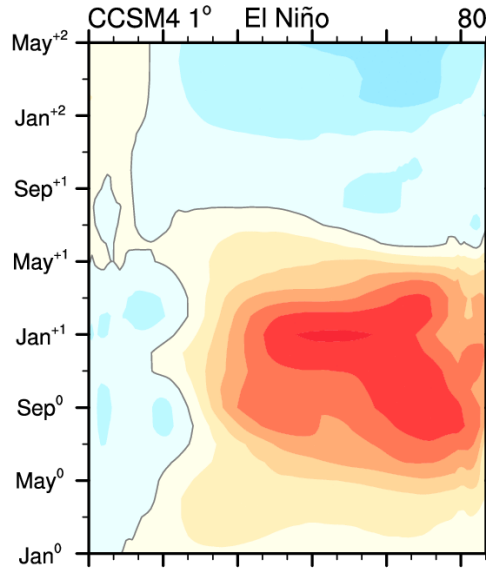
June 17-20, 2013

2 year duration of La Nina

CCSM4
preindustrial run

time ↑

El Niño



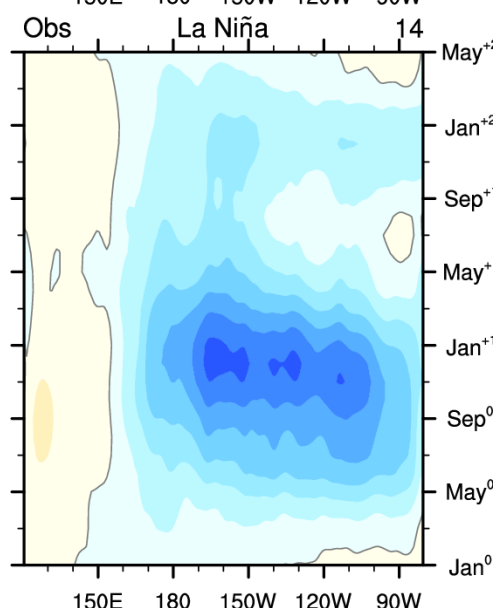
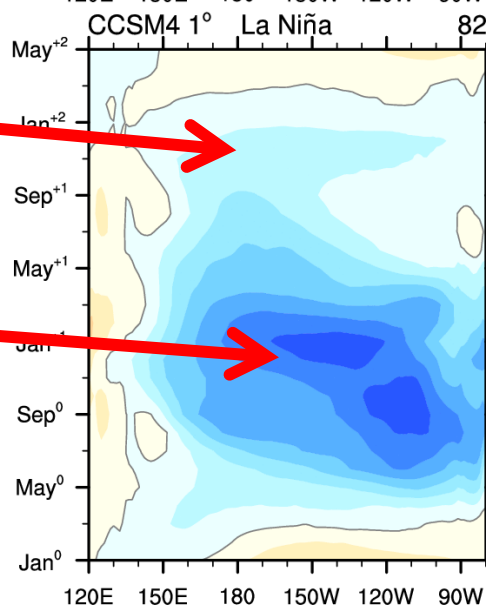
Observations

time ↑

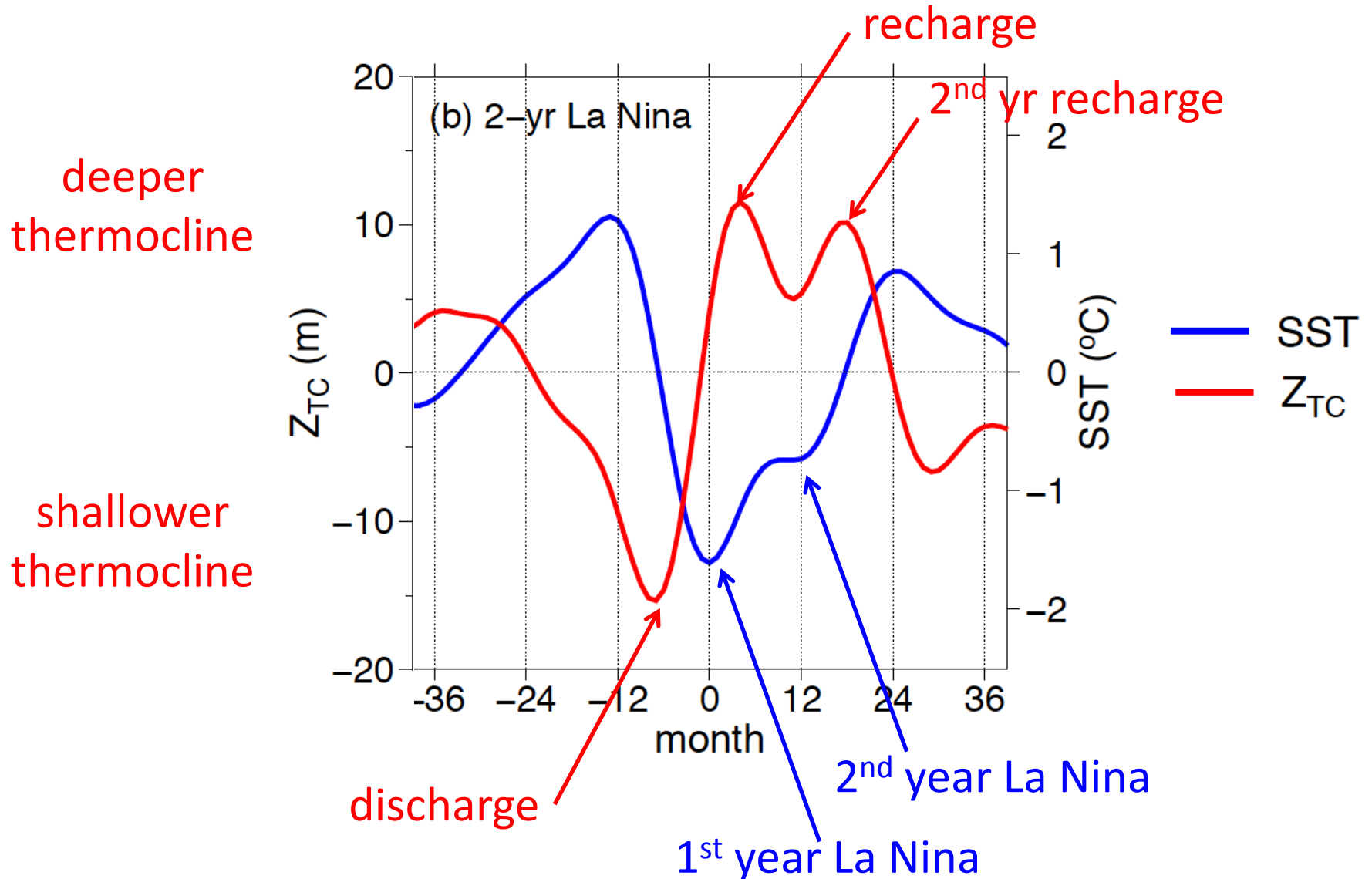
2nd year
La Nina

1st year
La Nina

La Niña



CCSM4's ENSO is not a thermocline-SST oscillation



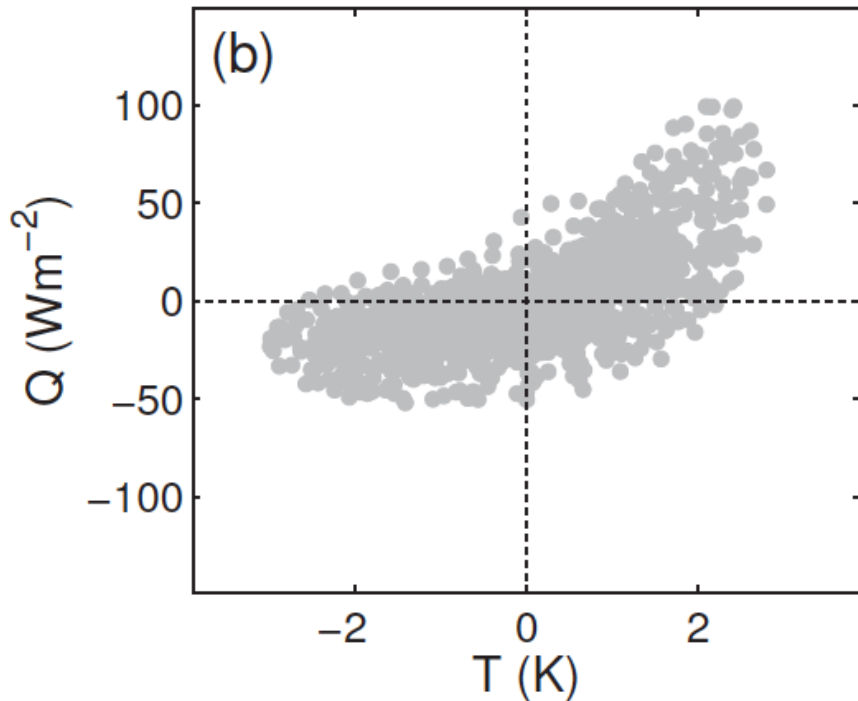
Nonlinearities in the heat budget

$$\frac{\partial T'}{\partial t} = - \left(u' \frac{\partial \bar{T}}{\partial x} + w' \frac{\partial \bar{T}}{\partial z} + \overline{w' \frac{\partial T'}{\partial z}} \right) - \frac{Q_{air-sea}}{\rho_0 c_p H}$$

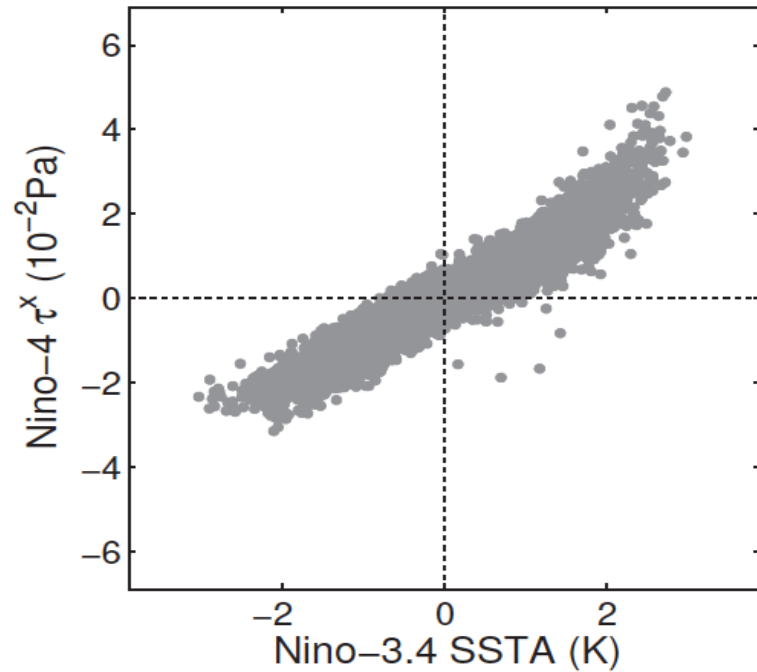
Bjerknes feedback

$$\frac{\partial T'}{\partial t} = - \left(u' \frac{\partial \bar{T}}{\partial x} + w' \frac{\partial \bar{T}}{\partial z} + \overline{w' \frac{\partial T'}{\partial z}} \right) - \frac{Q_{air-sea}}{\rho_0 c_p H}$$

Bjerknes feedback



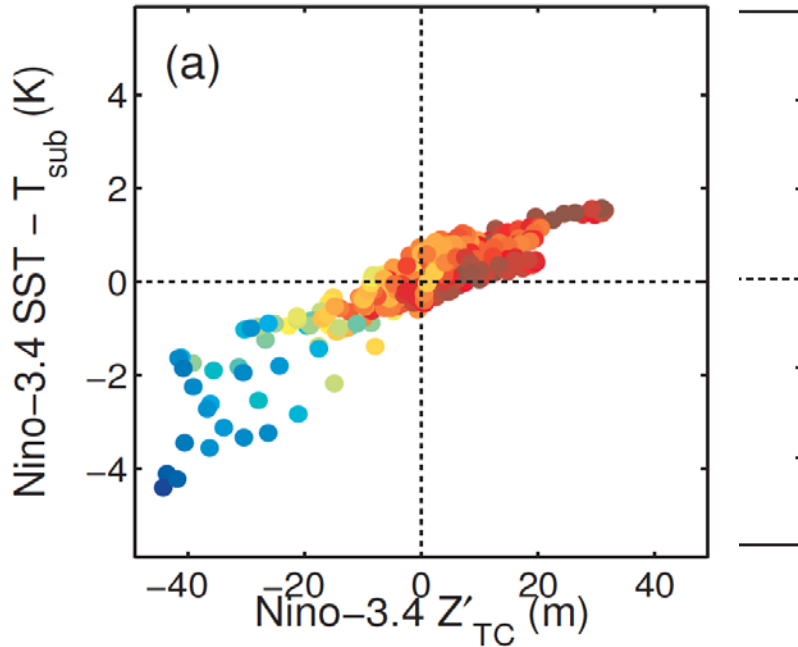
wind – SST coupling



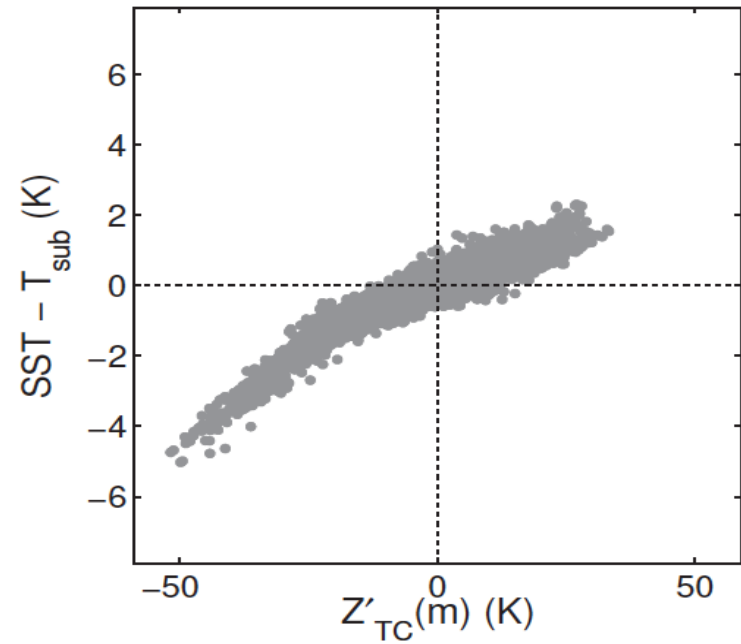
Delayed thermocline feedback

$$\frac{\partial T'}{\partial t} = - \left(u' \frac{\partial \bar{T}}{\partial x} + w' \frac{\partial \bar{T}}{\partial z} + \boxed{w' \frac{\partial T'}{\partial z}} \right) - \frac{Q_{air-sea}}{\rho_0 c_p H}$$

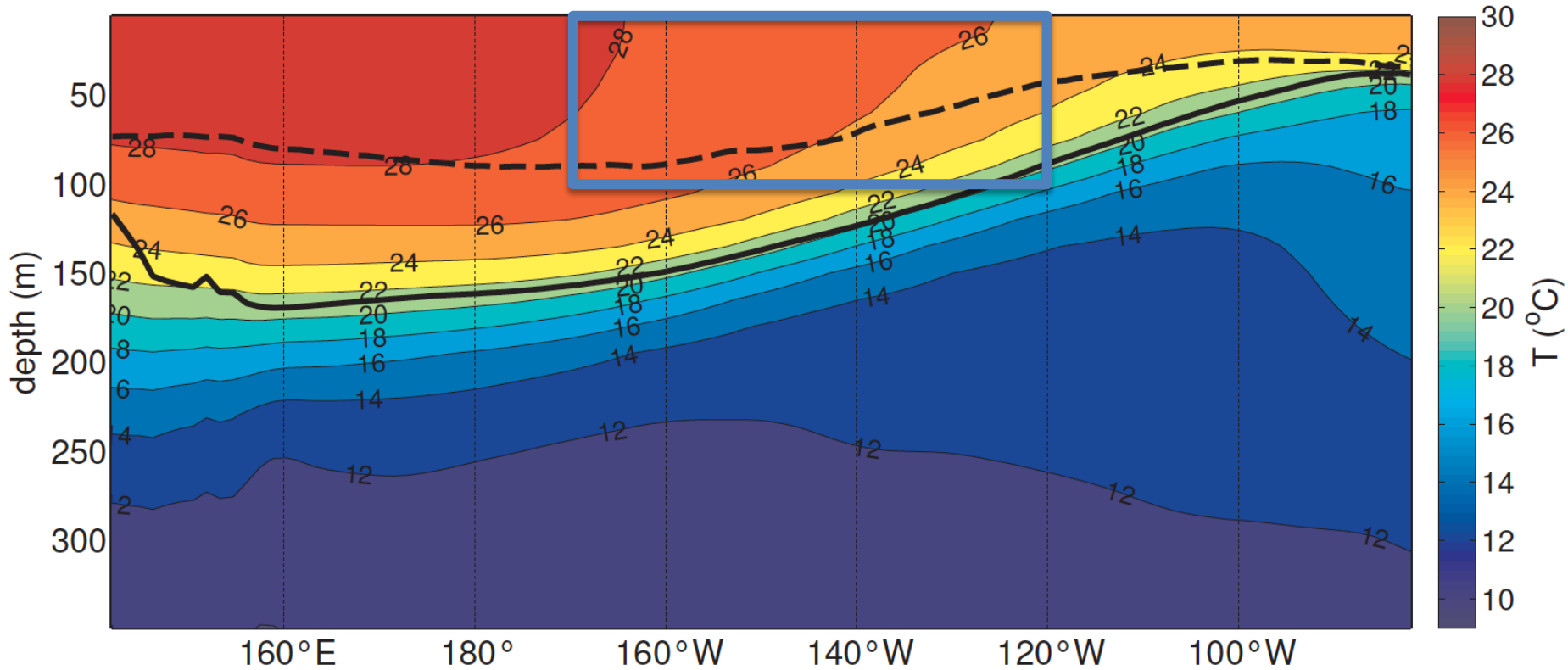
Observed relationship (ORA S3)



thermocline – mixed layer coupling



Thermocline – surface layer coupling



- Mixed layer depth
- Thermocline depth

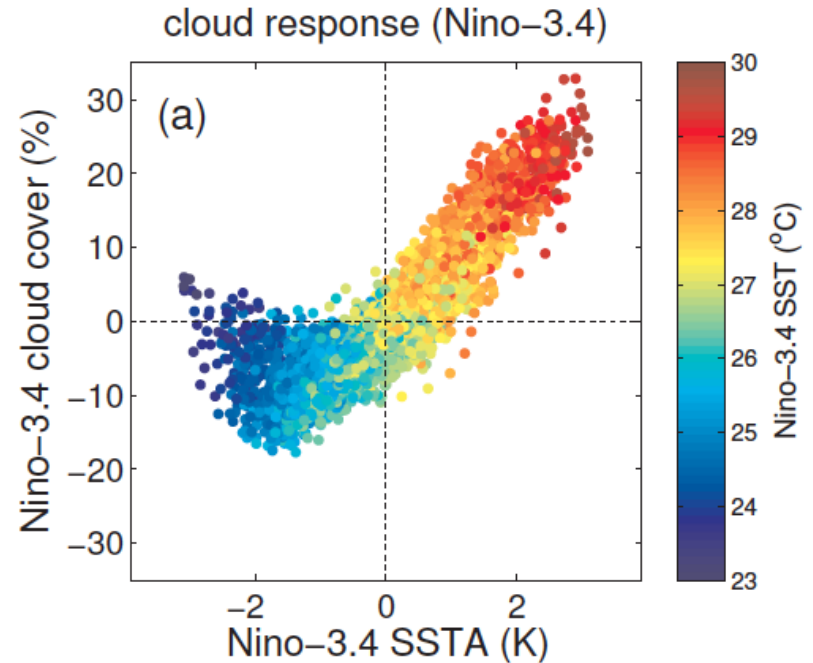
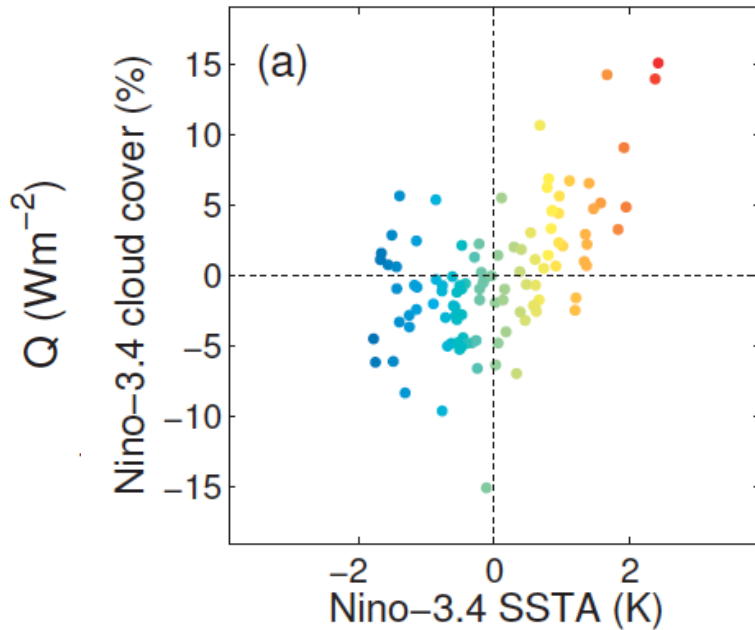
Nino-3.4

Atmospheric damping

$$\frac{\partial T'}{\partial t} = - \left(u' \frac{\partial \bar{T}}{\partial x} + w' \frac{\partial \bar{T}}{\partial z} + \overline{w' \frac{\partial T'}{\partial z}} \right) - \frac{Q_{air-sea}}{\rho_0 c_p H}$$



Observed relationship (COADS)



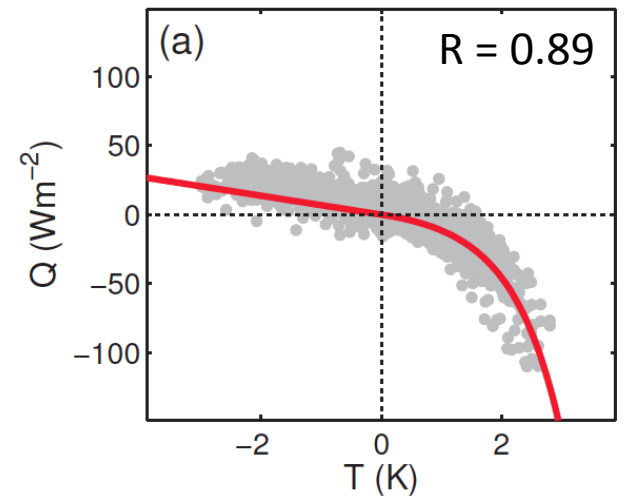
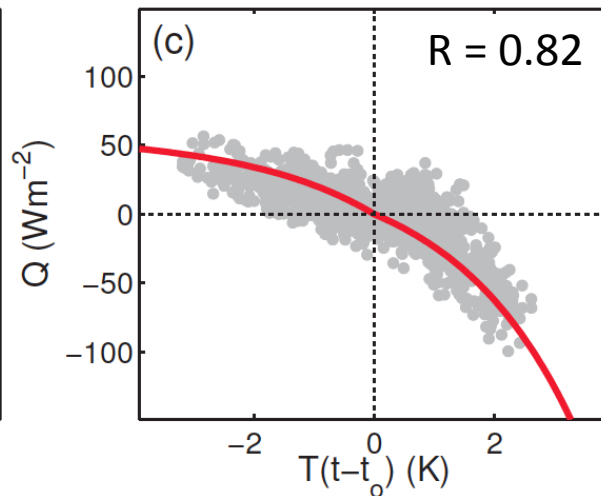
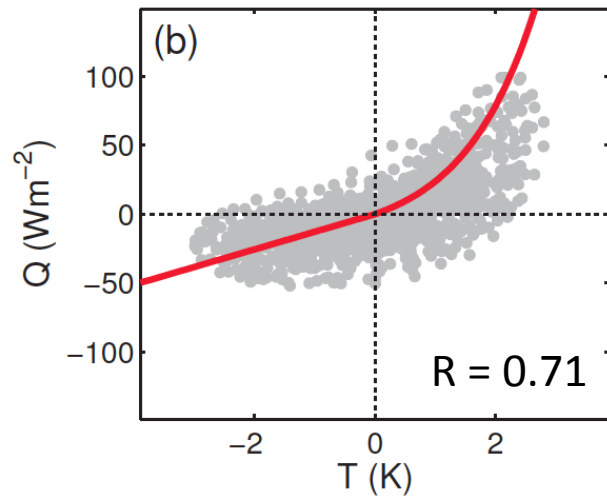
Nonlinear delayed oscillator

$$\frac{\partial T'}{\partial t} = a(T') - b(T'(t-t_0)) - c(T') - \text{noise}$$

Bjerknes feedback

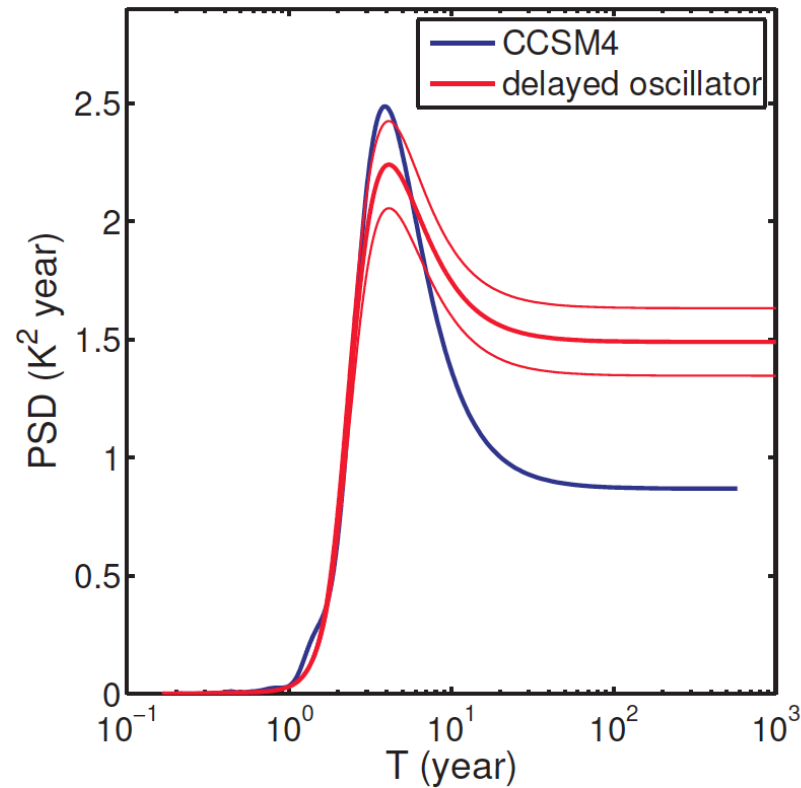
delayed (negative) feedback

atmospheric damping

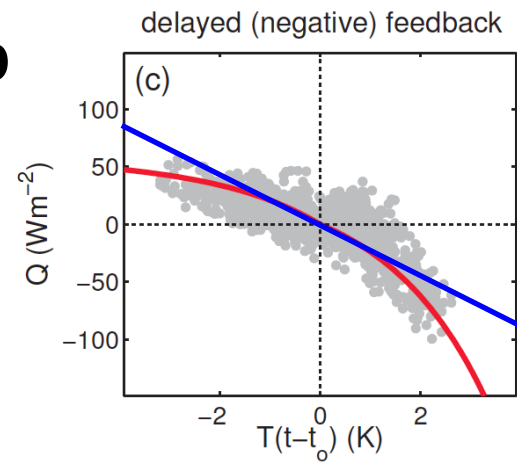
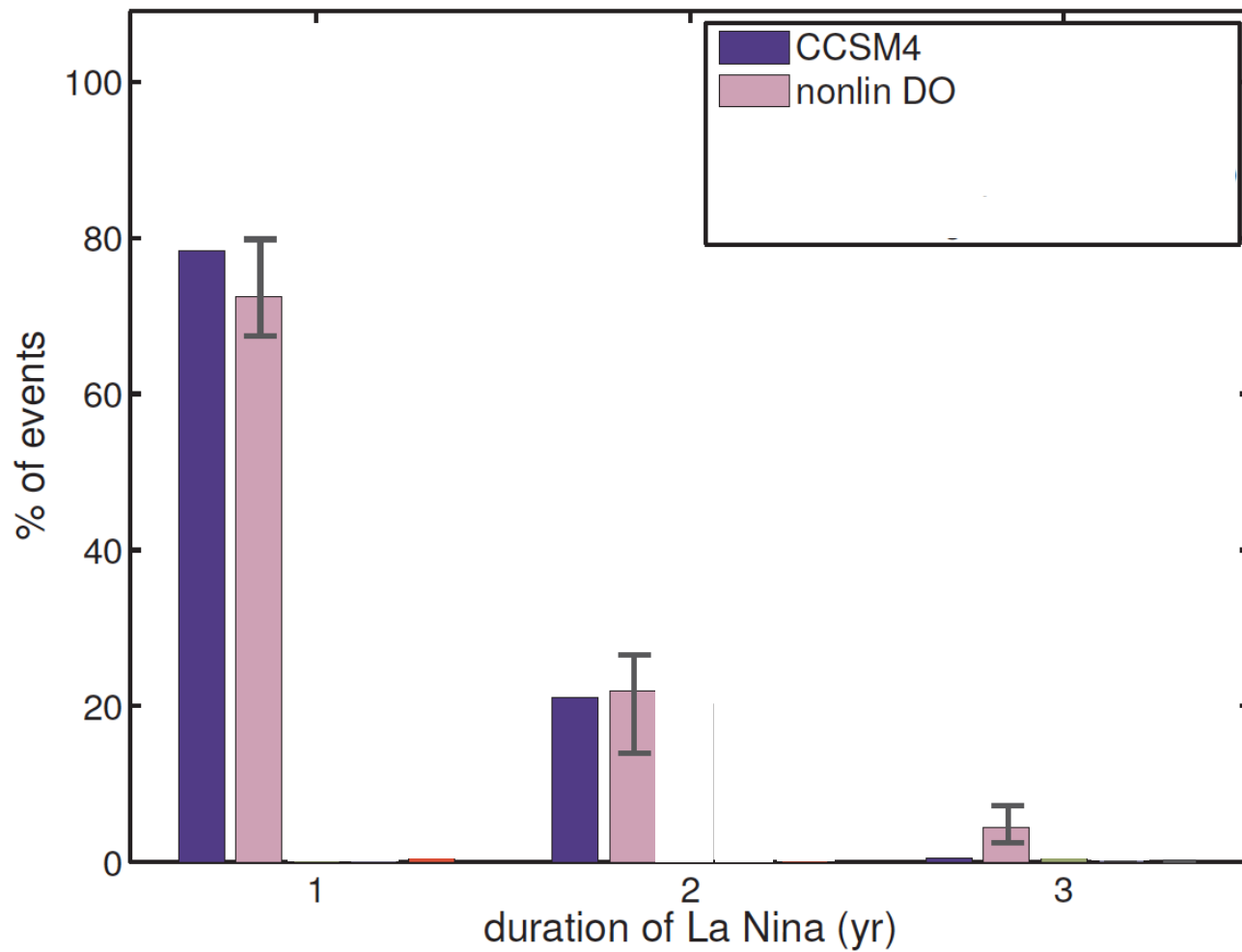


Nonlinear delayed oscillator

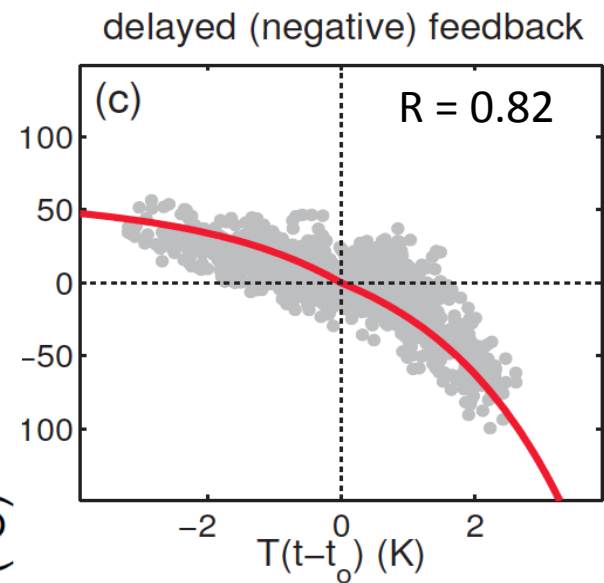
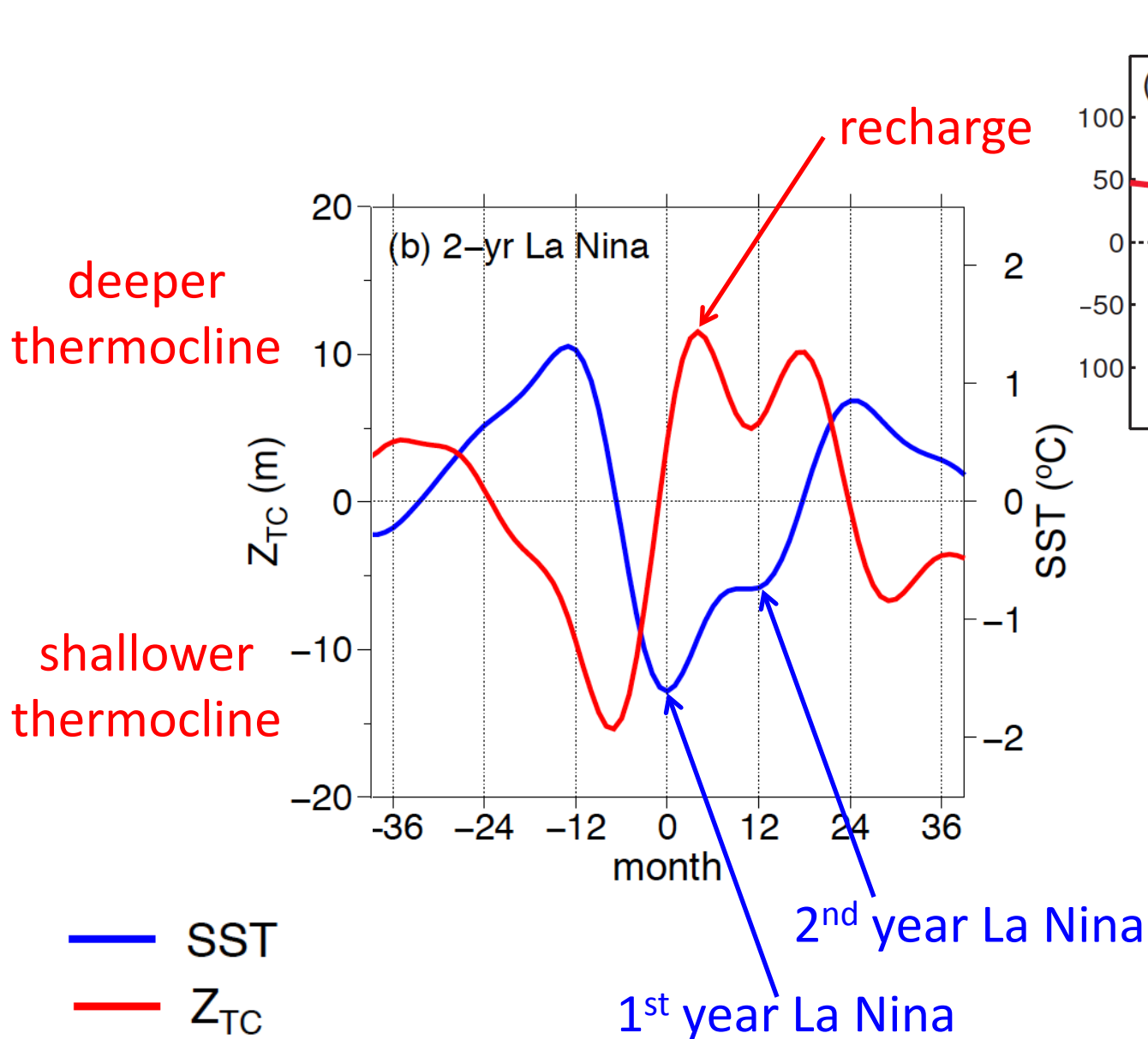
	CCSM4	Delayed oscillator
std. dev.	0.99	1.00 ± 0.03
skewness	0.11	0.06 ± 0.11



Nonlinear delayed oscillato



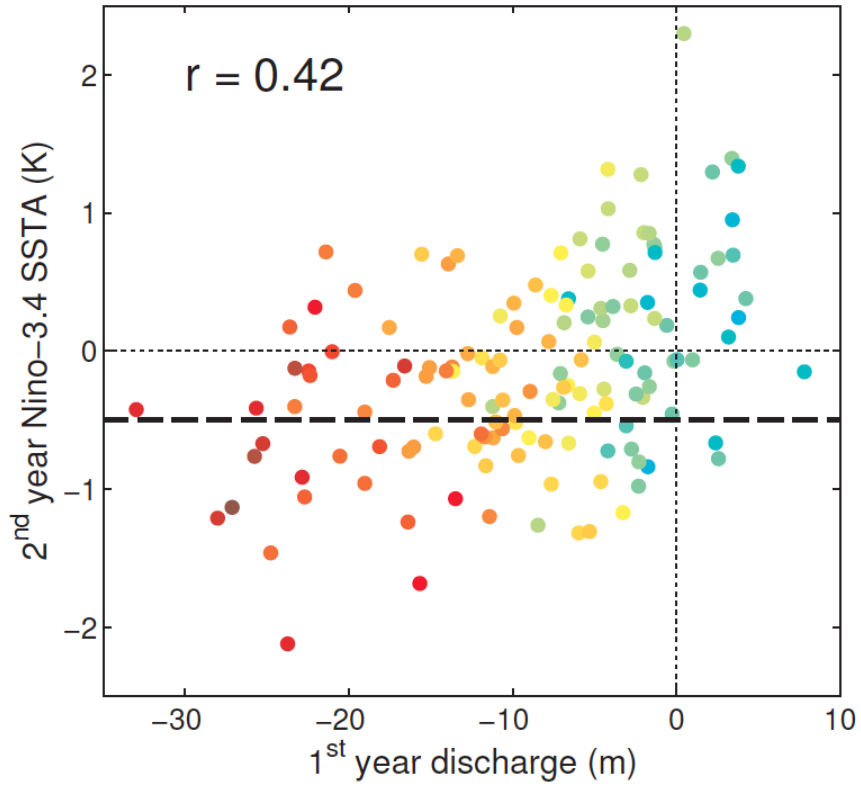
CCSM4's ENSO is not a thermocline-SST oscillation



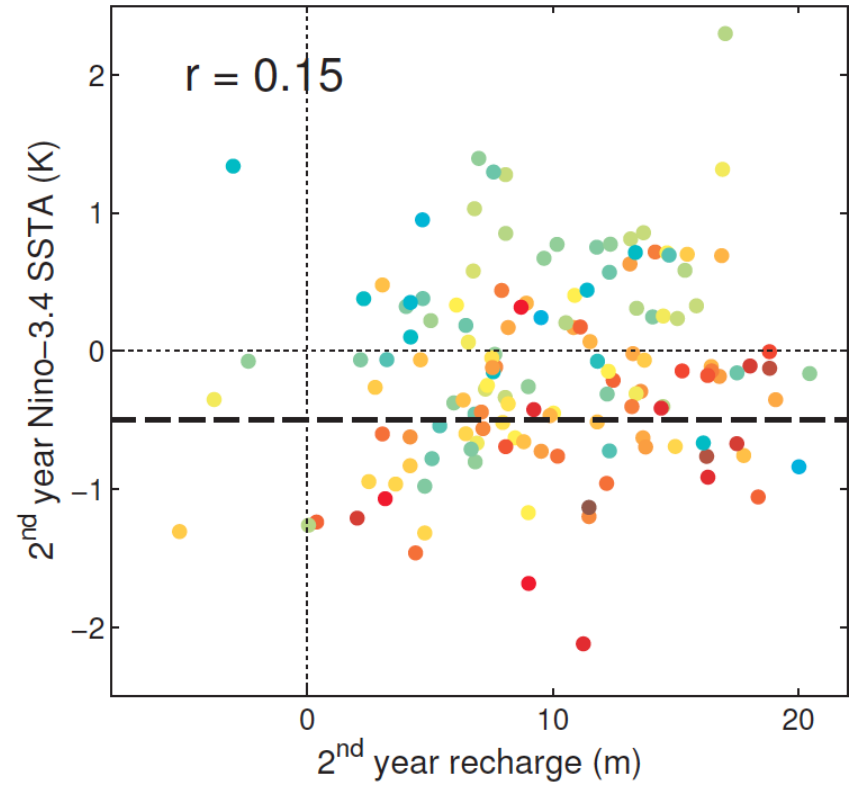
Conclusions

- ENSO dynamics
 - La Nina events persist for more than 2 years due to nonlinear coupling between thermocline and SST anomalies.
- Model Evaluation
 - CCSM4 simulates very realistic atmospheric and ocean nonlinearities that play a key role in ENSO
- Prediction
 - What are the precursors for 2nd year La Nina?

Precursors



18 months lead



6 months lead

Additional slides

We tuned the noise so thatfit to reproduce the std. dev. and skewness of CCSM4's ENSO:

	CCSM4	Delayed oscillator
std. dev.	0.99	1.00 ± 0.03
skewness	0.11	0.06 ± 0.11

But at the same time we get good:

1. Spectrum

1. La Nina duration

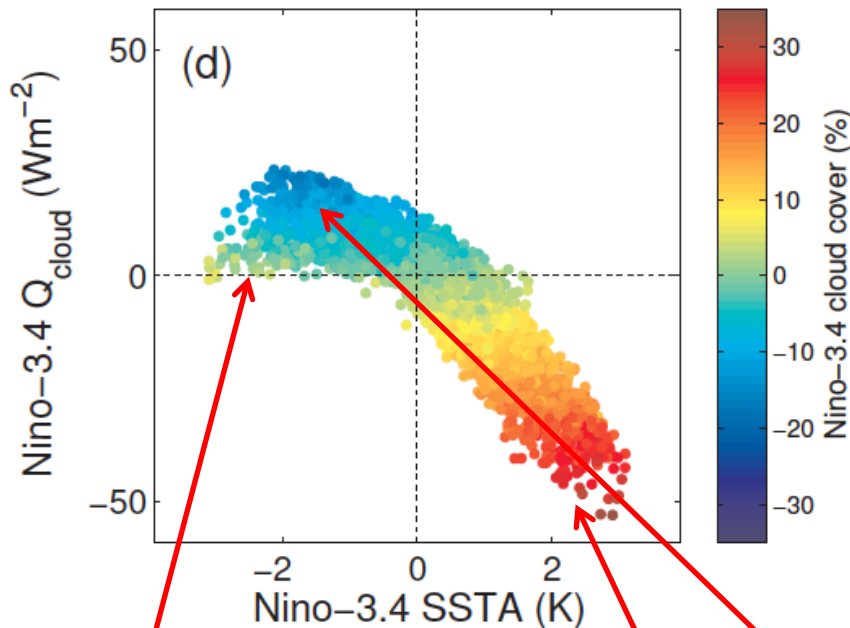
See next slide...

Atmospheric damping (clouds)

CCSM4

OAFflux (1983-2007)

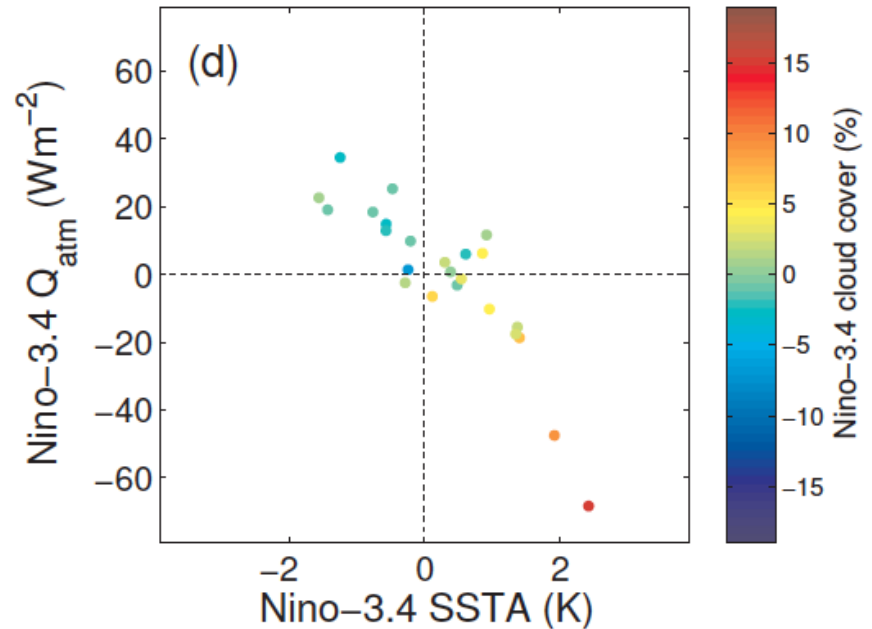
cloud sfc. radiation response (Nino-3.4)



Muted damping due to increased low-cloud cover

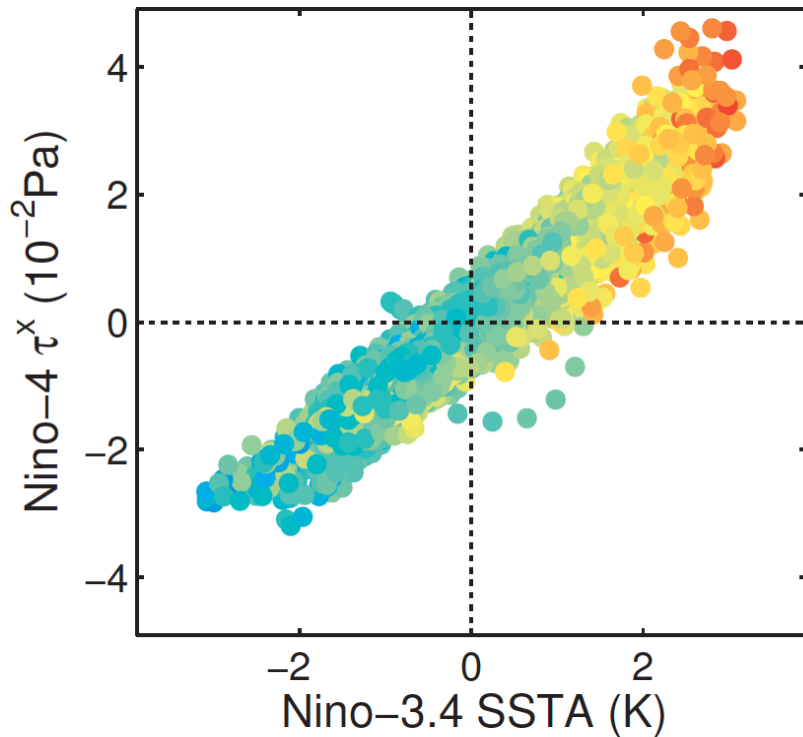
Cooling (heating) due to increased (decreased) cloud cover, i.e. damping of warm (cold) SSTA.

atmospheric damping (Nino-3.4)

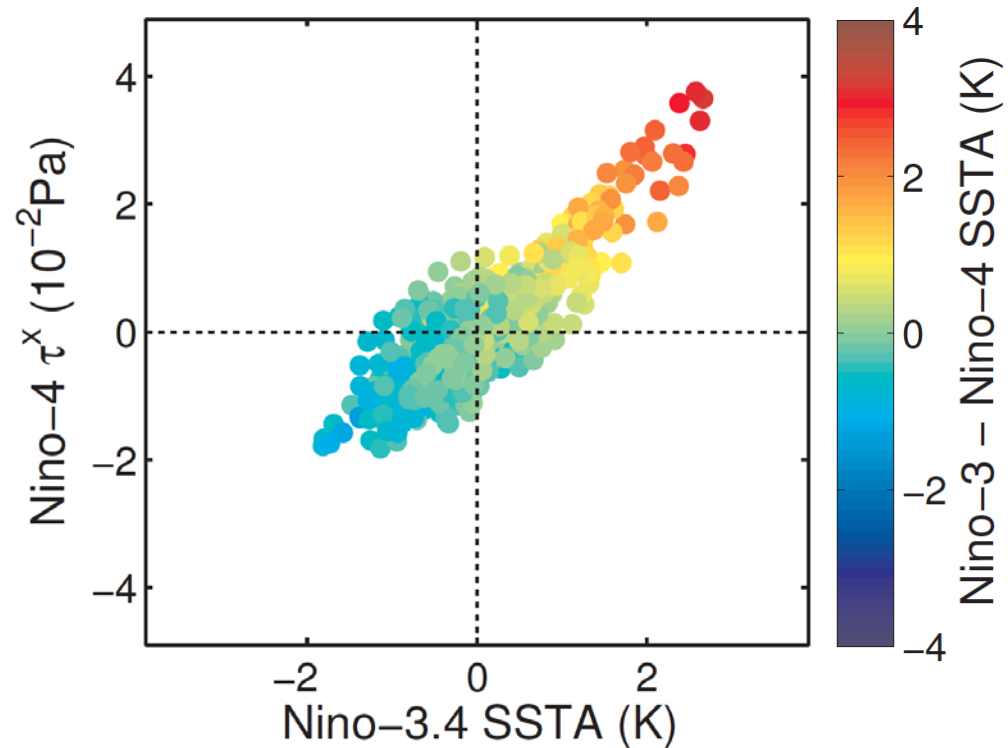


Wind – SST coupling

CCSM4



ERA40 (1959-2009)



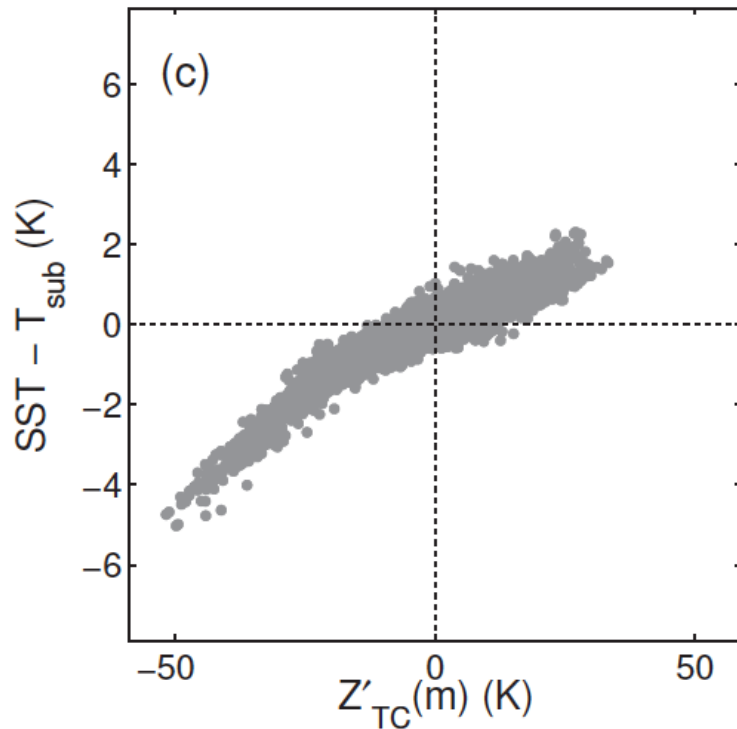
x-axis: SSTA on Nino-3.4

y-axis: zonal wind stress on Nino-4

Thermocline – surface layer coupling

CCSM4

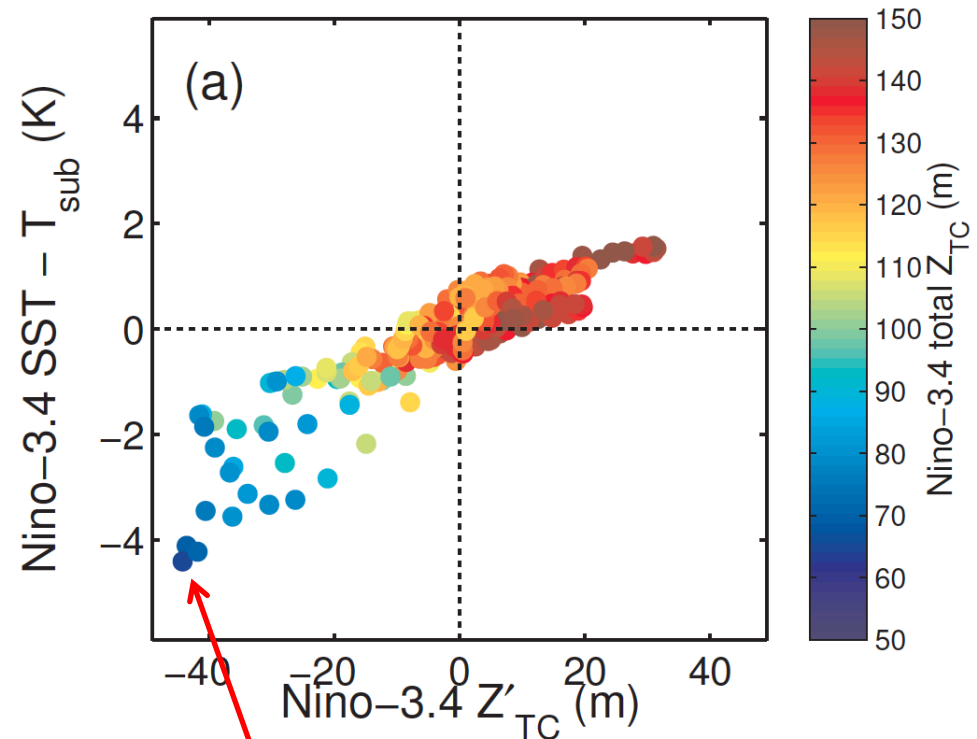
thermocline response



x-axis: depth of max dT/dz
y-axis: SST minus $T(90\text{m})$

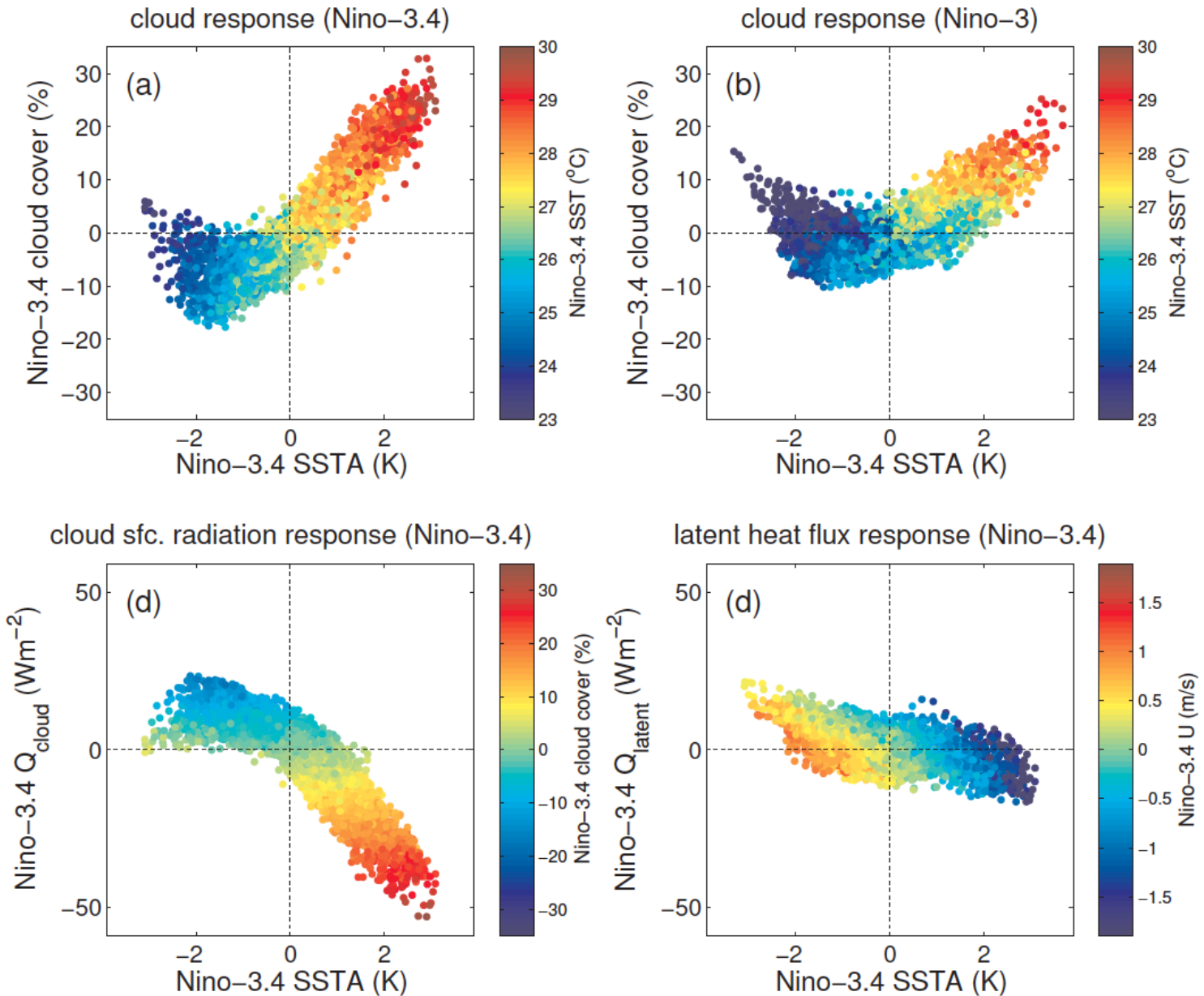
ORAS3 (1959-2009)

thermocline response (Nino-3.4)



1998 La Nina

Atmospheric damping (CCSM4)



Atmospheric damping (obs)

