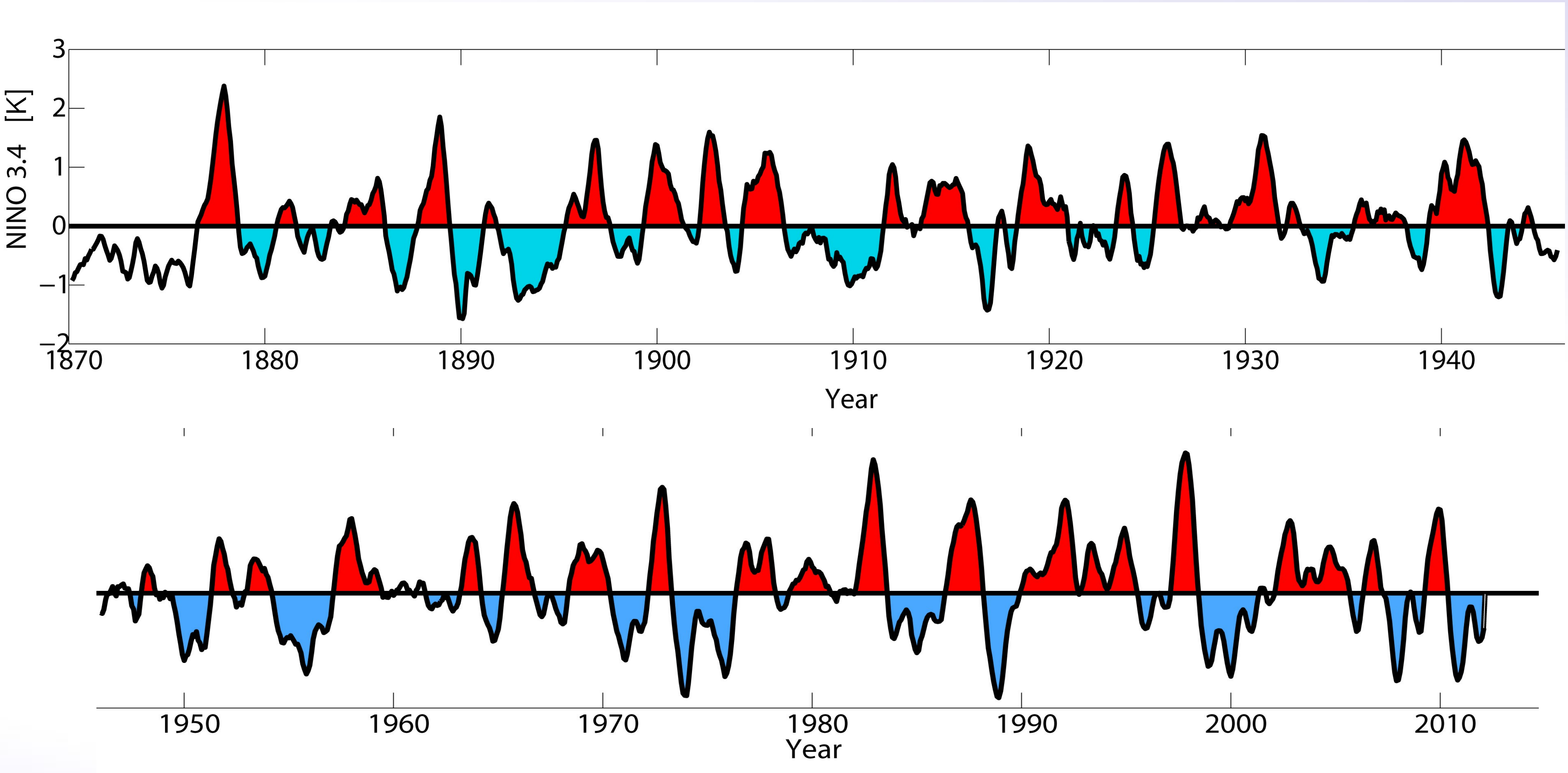
AGU Fall Meeting (Dec 7, 2012)

A proposed mechanism for ENSO asymmetries in Transition, Duration and Amplitude

Kit Yan Choi (Princeton University)
Gabriel A. Vecchi (GFDL)

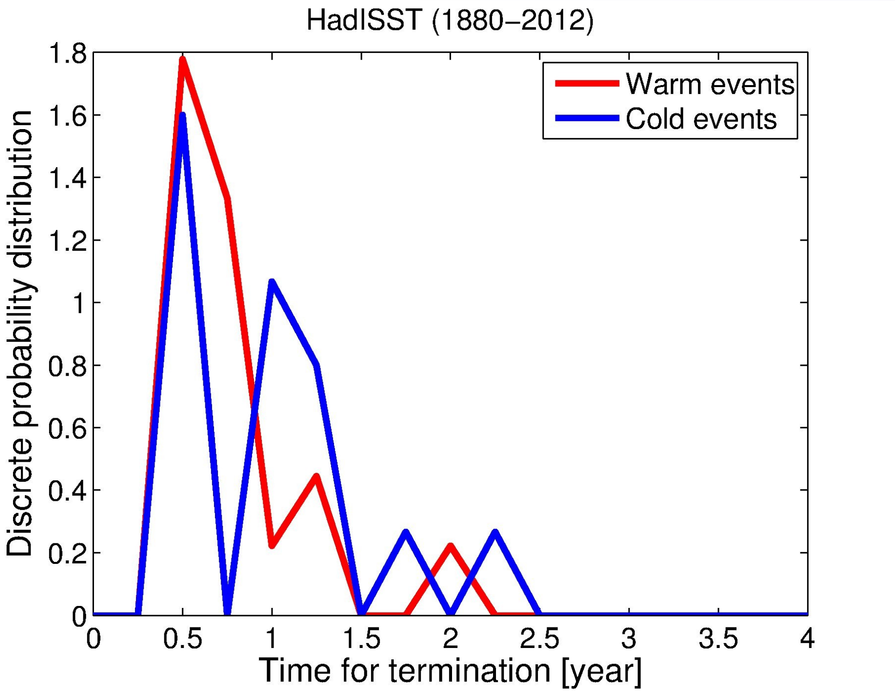
El Niño – Southern Oscillation



Asymmetries:

- Amplitude: El Niño tends to be stronger than La Niña
- Duration: La Niña persists longer
- Sequencing: El Niño tends to be followed by La Niña

Asymmetry in duration: Cold events last longer



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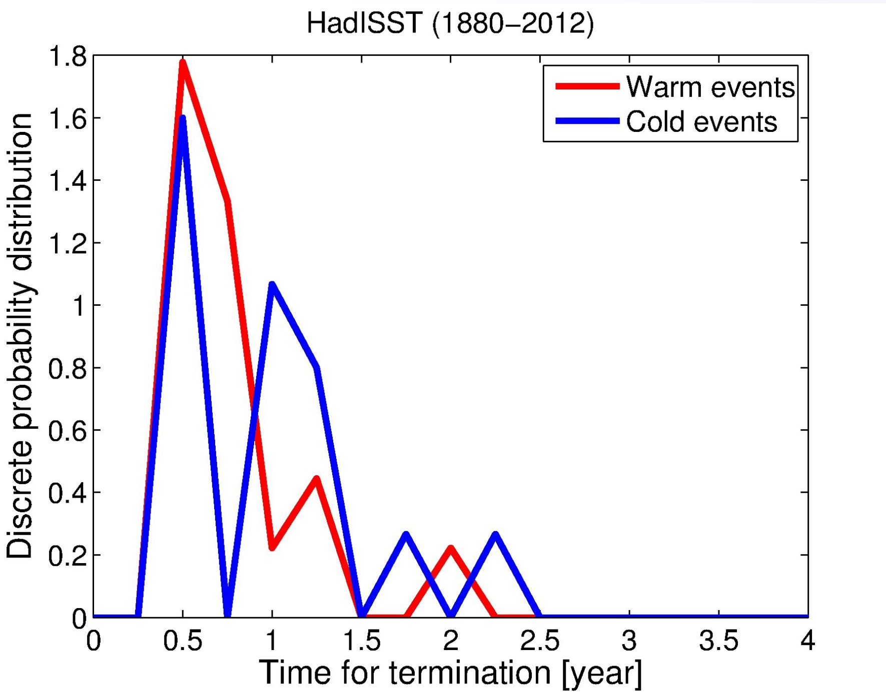

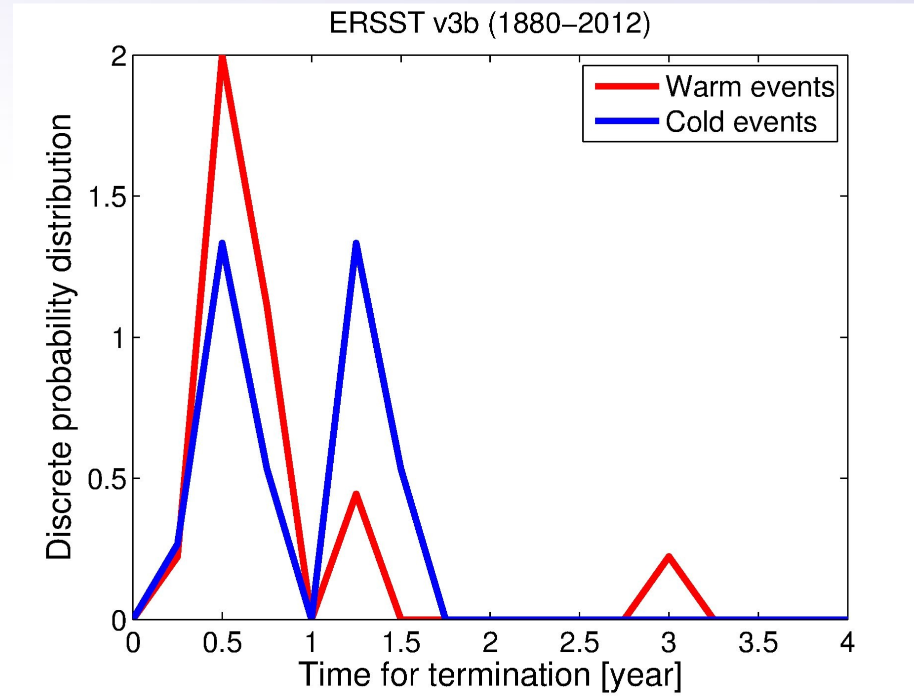

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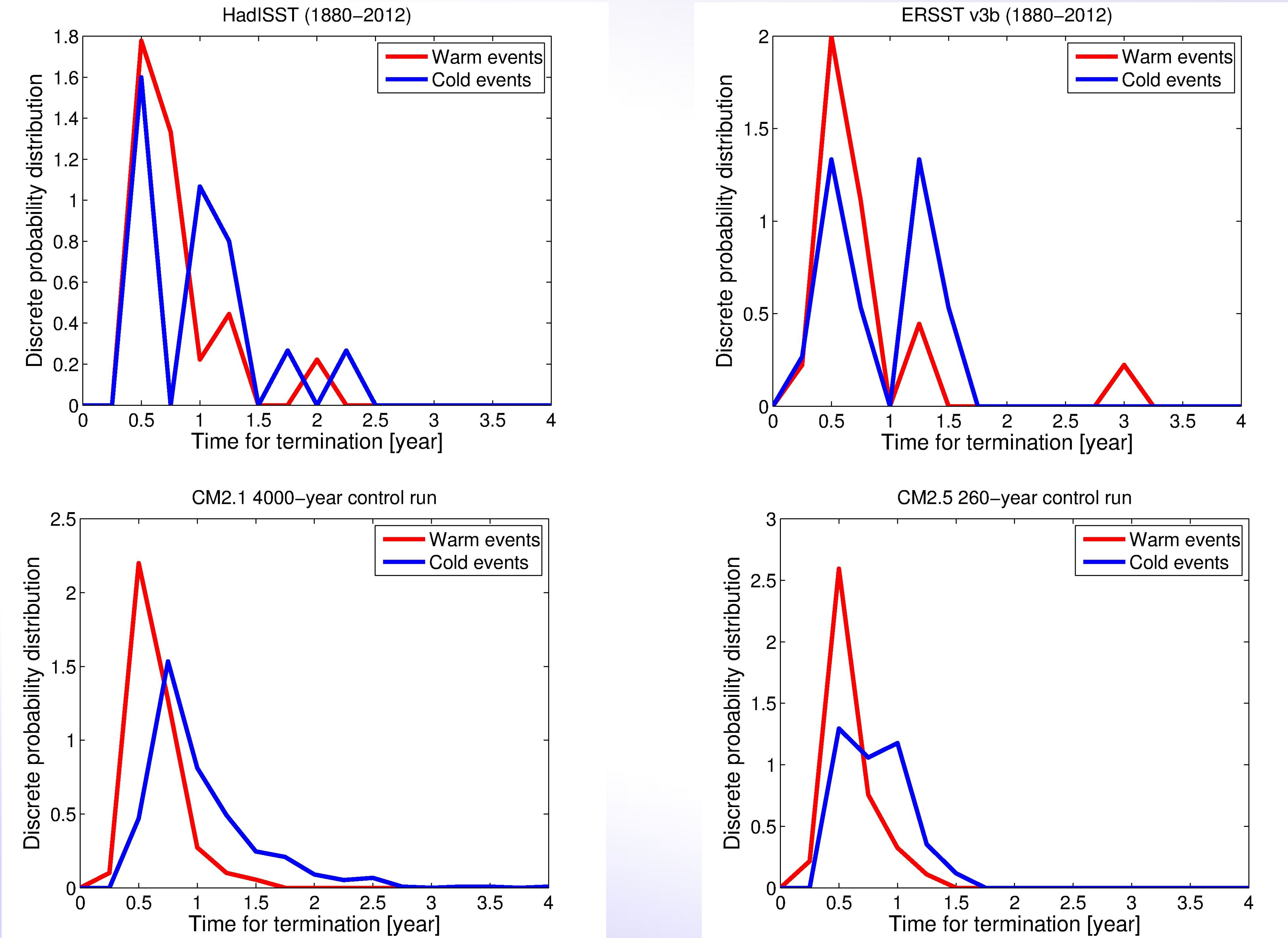
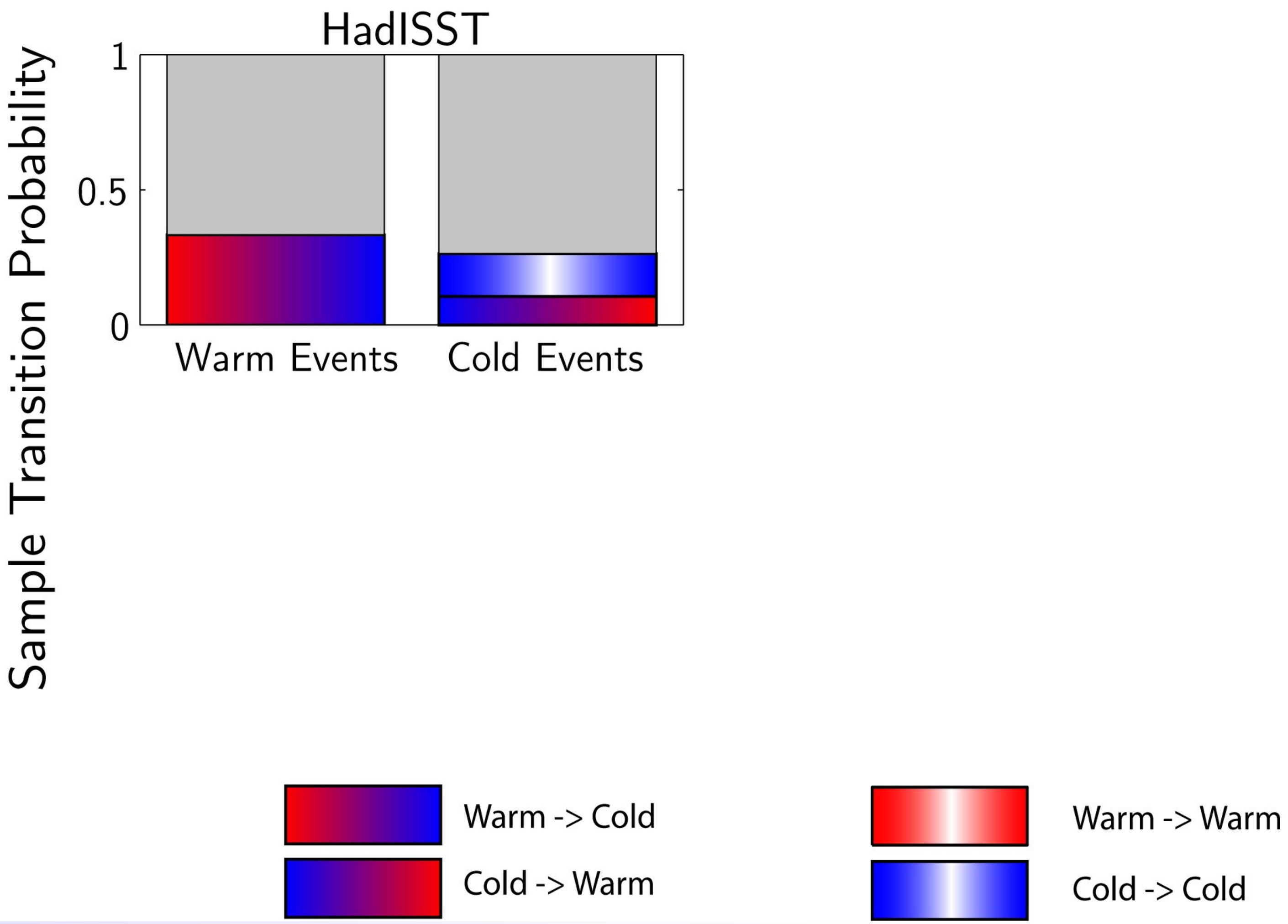


Asymmetry in sequencing:
Warm-to-Cold is more likely than Cold-to-Warm



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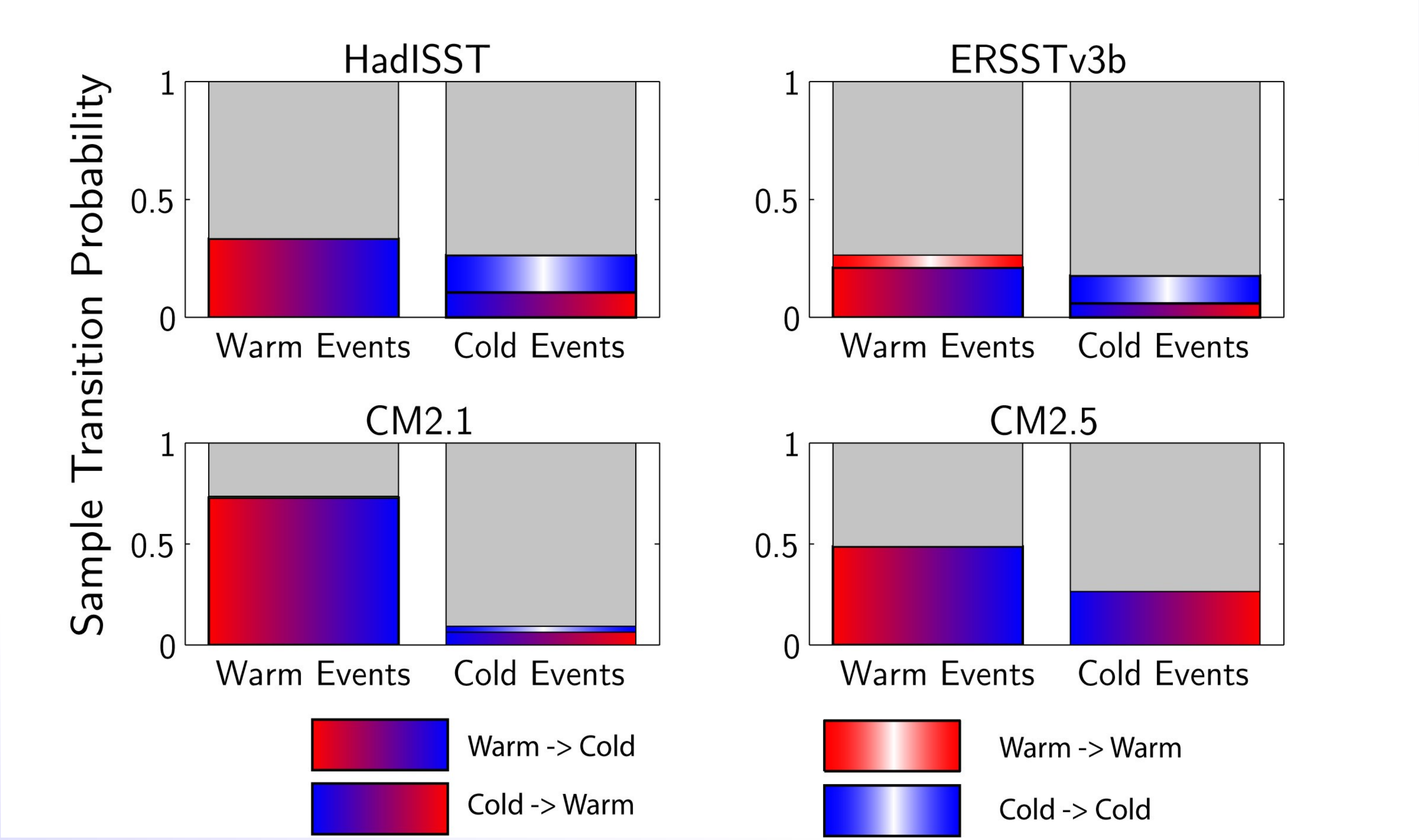


What causes the asymmetries of ENSO in
(1) Amplitude (2) Duration and (3) Sequencing?

Proposed mechanism

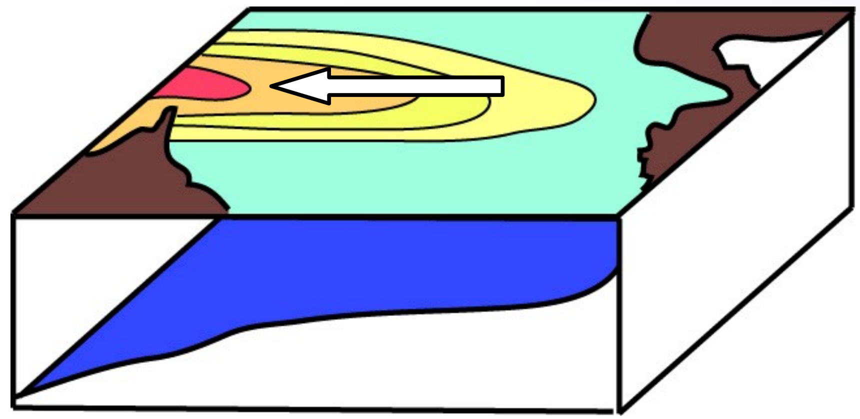
Air-Sea coupling efficiency is **higher** during **warm** conditions, **lower** during **cold** conditions, at the Pacific Ocean.

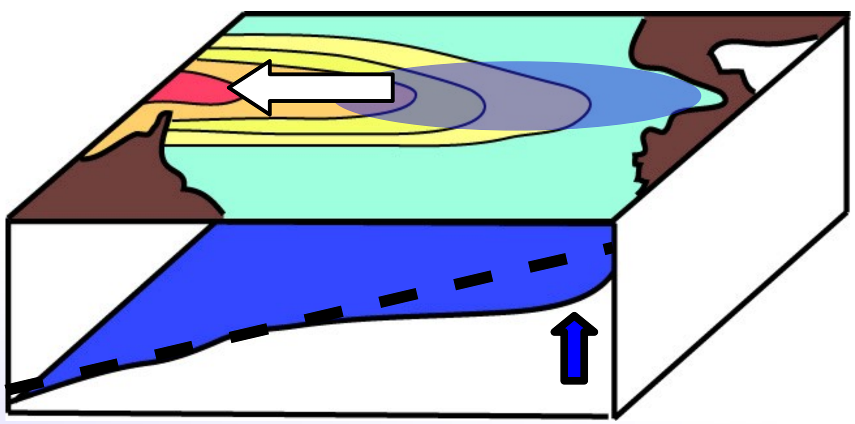
This can result in the above asymmetries in a consistent way.

Air-Sea coupling for ENSO

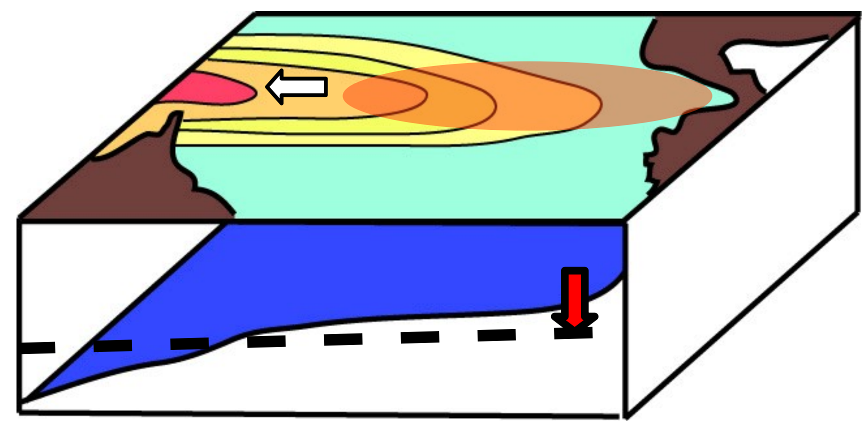
Efficiency: how strong surface wind stress responds to changes in SST

Climatology



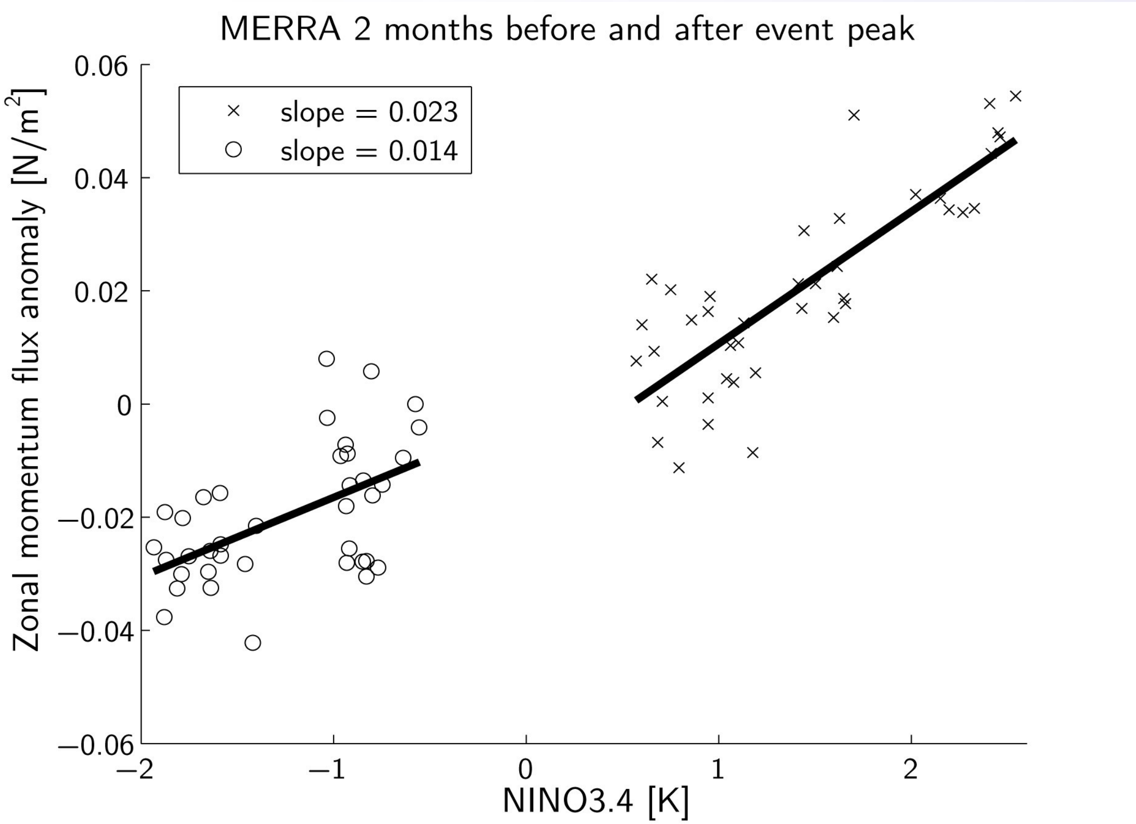


La Nina



El Nino

Wind responds more strongly to warm conditions



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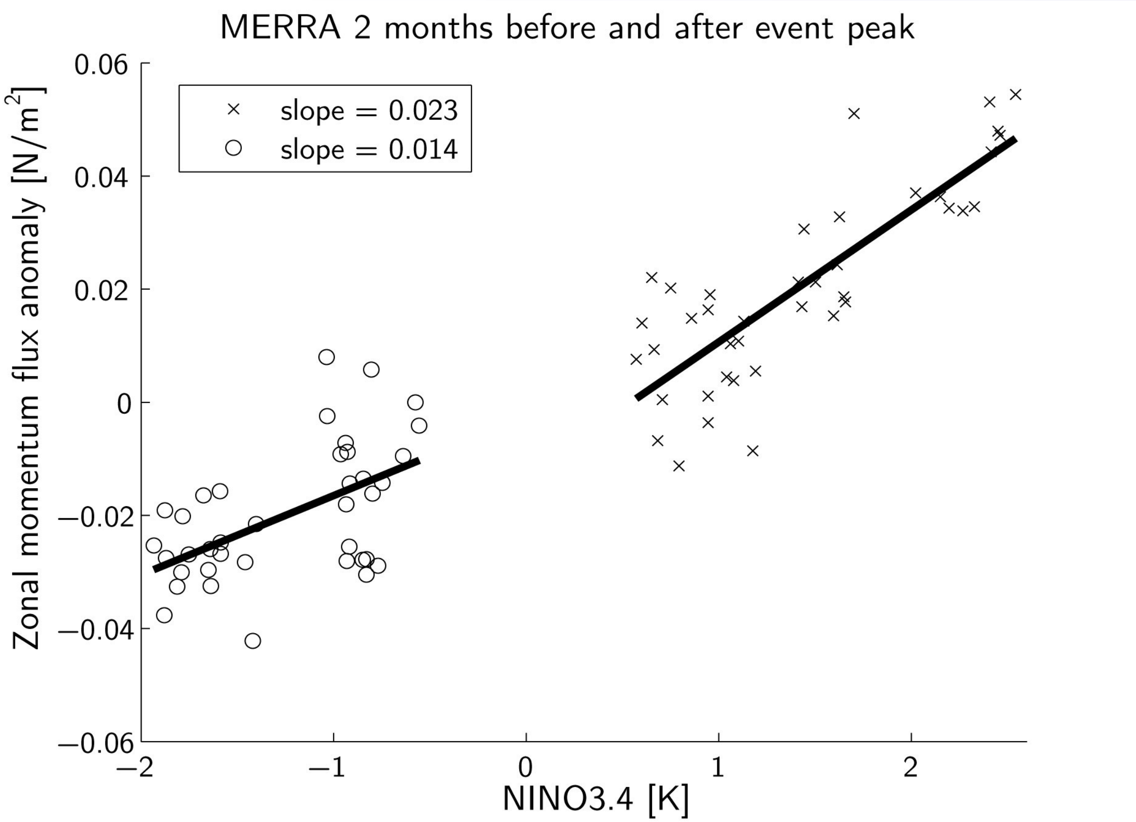

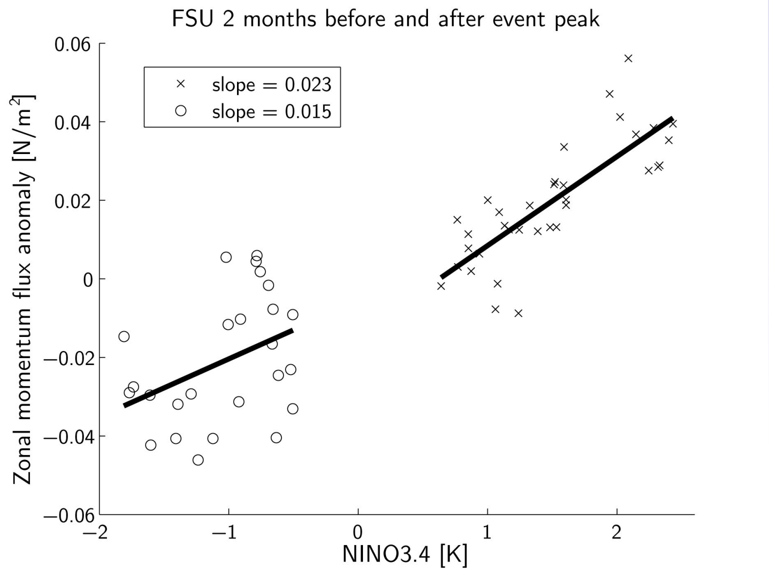

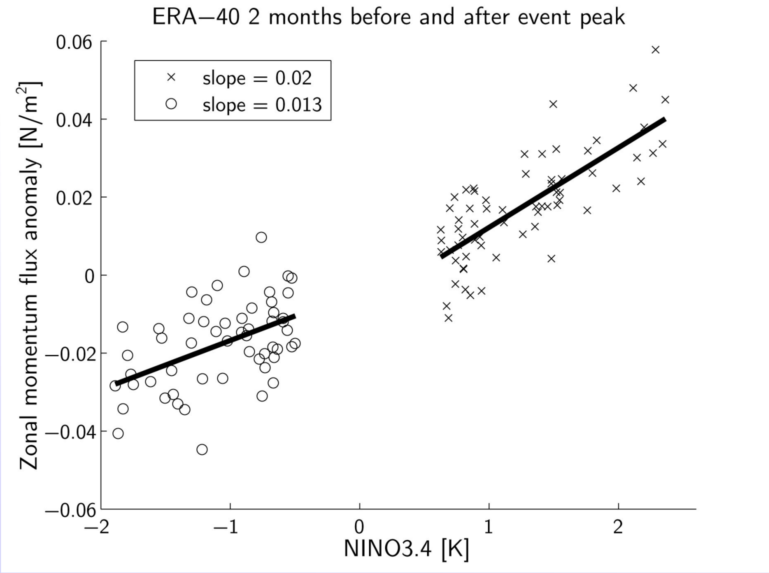

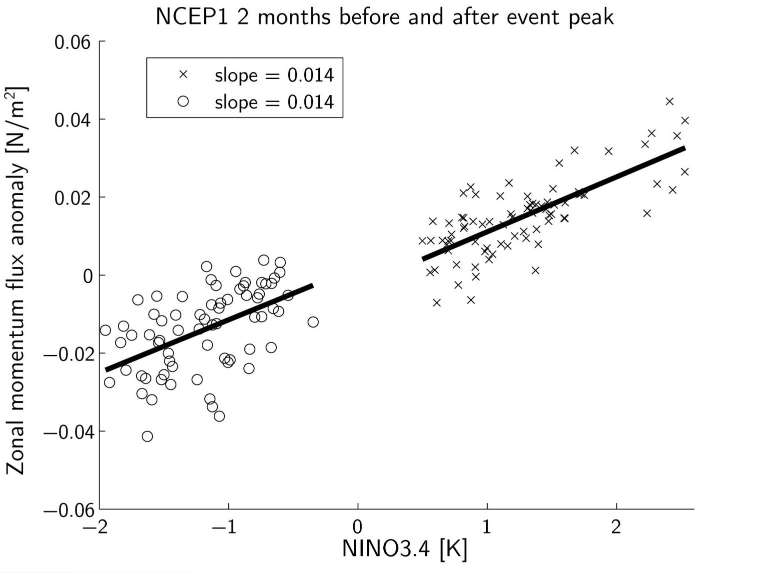

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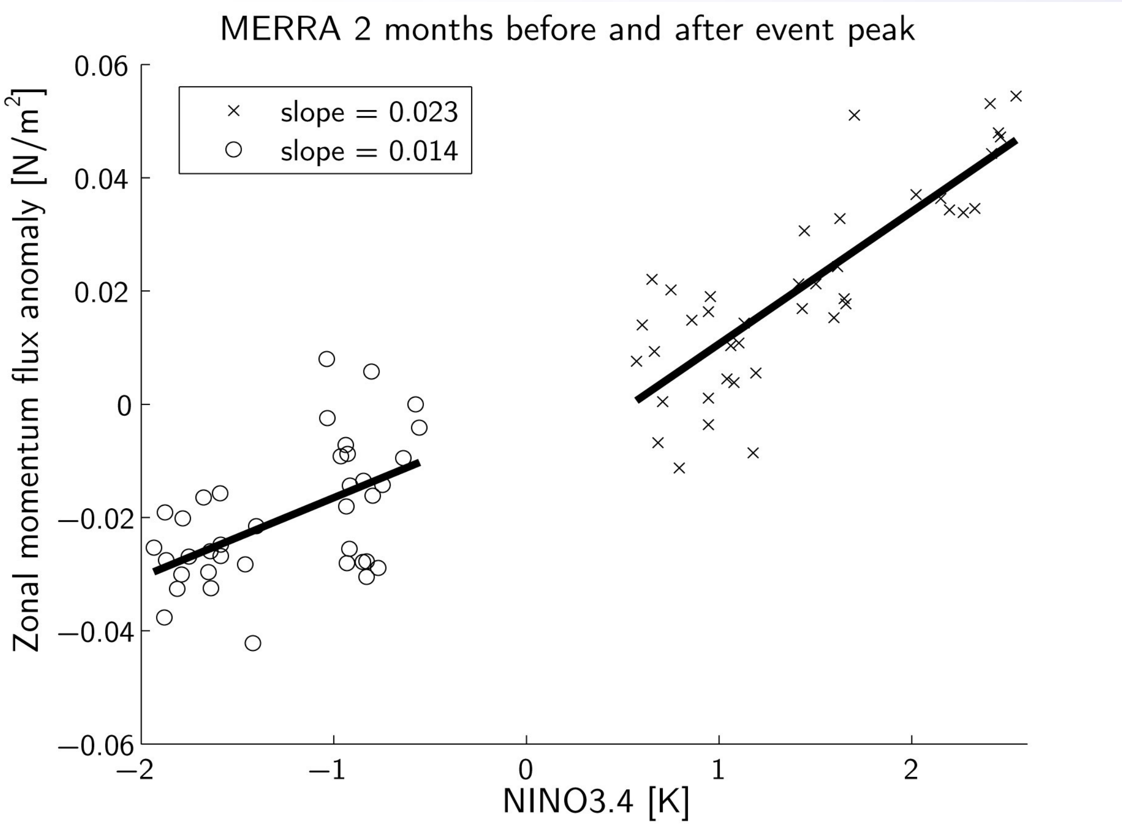
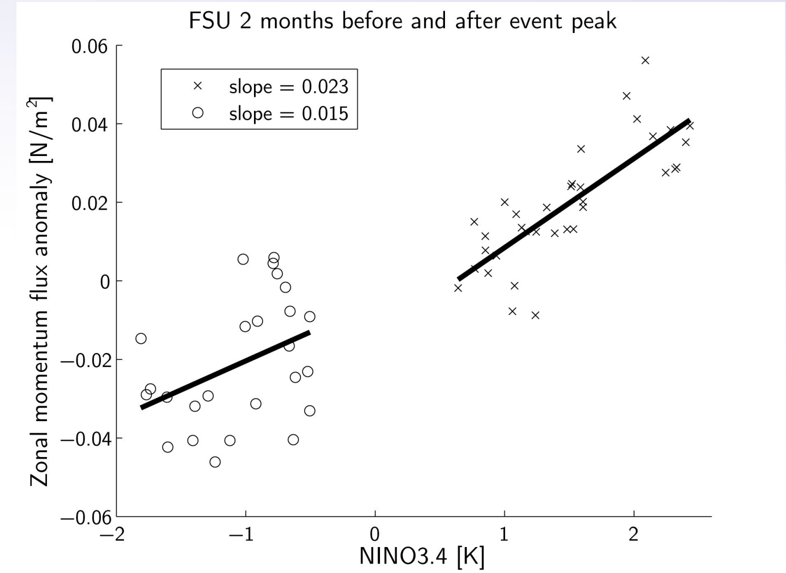
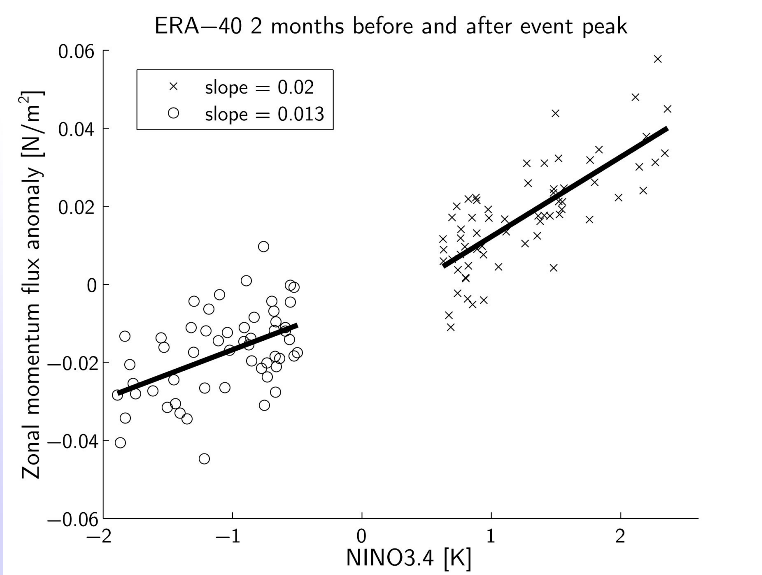
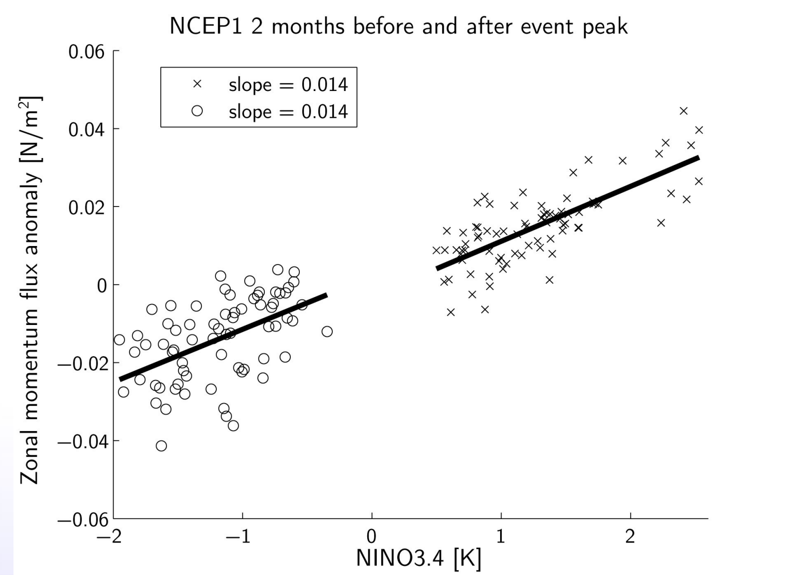


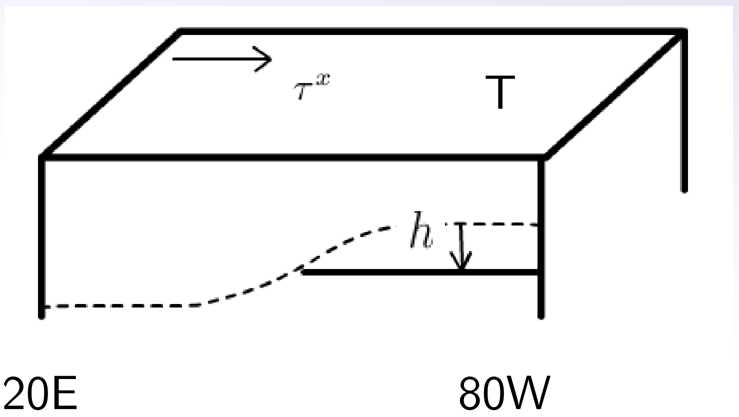


$$\tau^x = \gamma(T + r\,|T|)$$





Modified delayed Oscillator



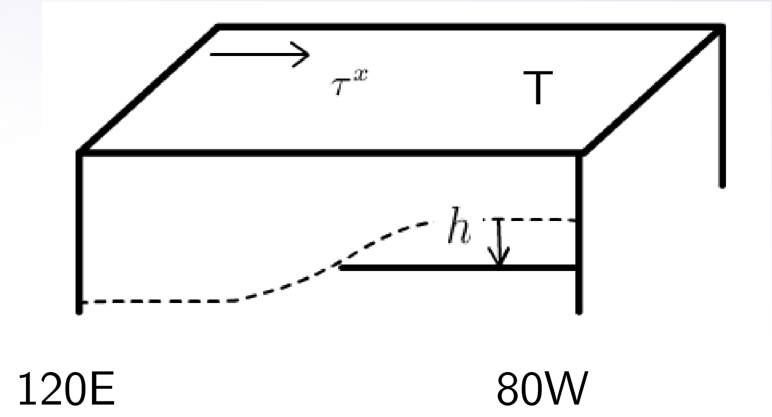
$$\frac{\partial T}{\partial t} = -bT + c\tau^x(t-t_1) - d\tau^x(t-t_2)$$

Damping

Positive feedback

Delayed Negative feedback

Modified delayed Oscillator



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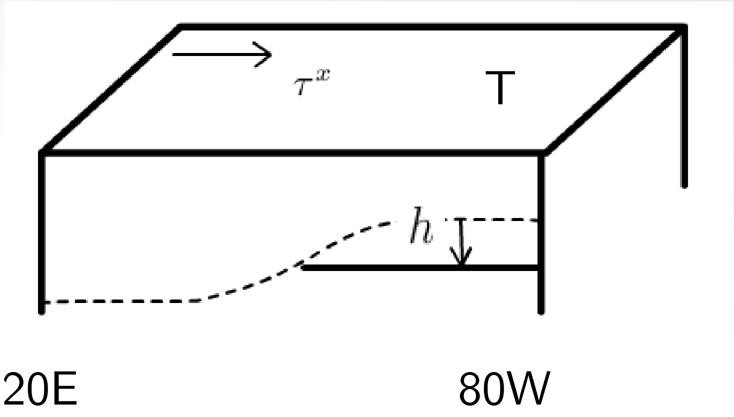

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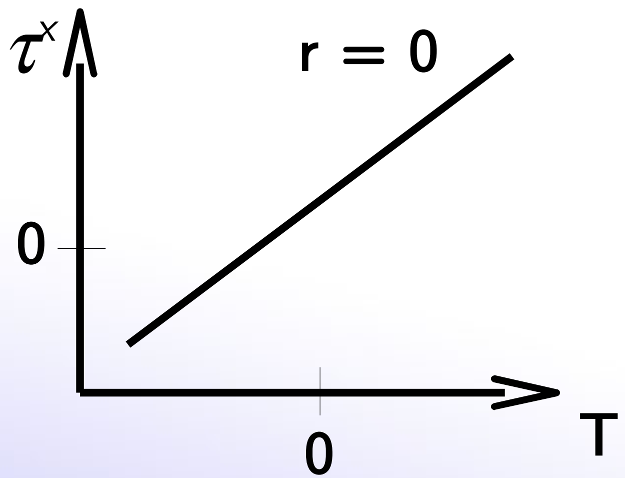

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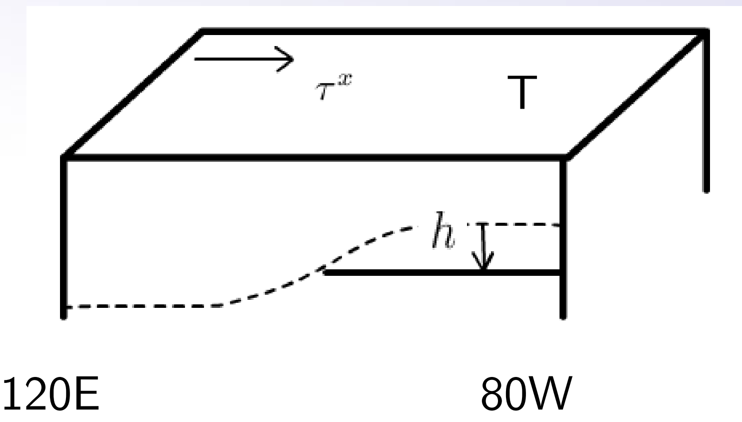

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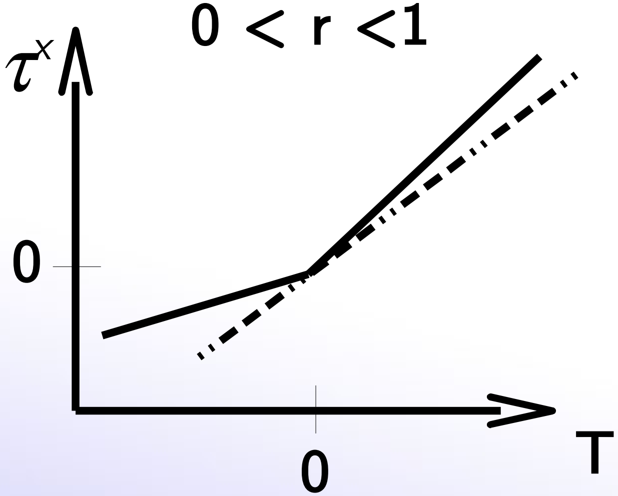
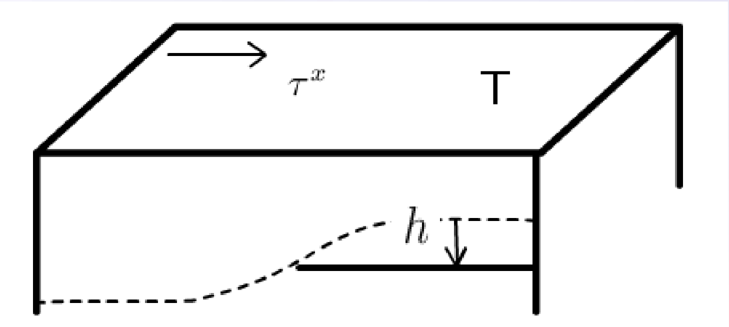


0 < r <1

$$\tau^x = \gamma T + r\gamma |T|$$

Modified delayed Oscillator



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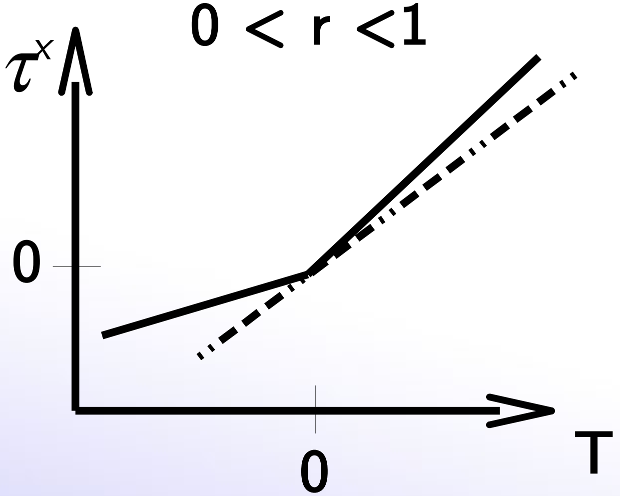
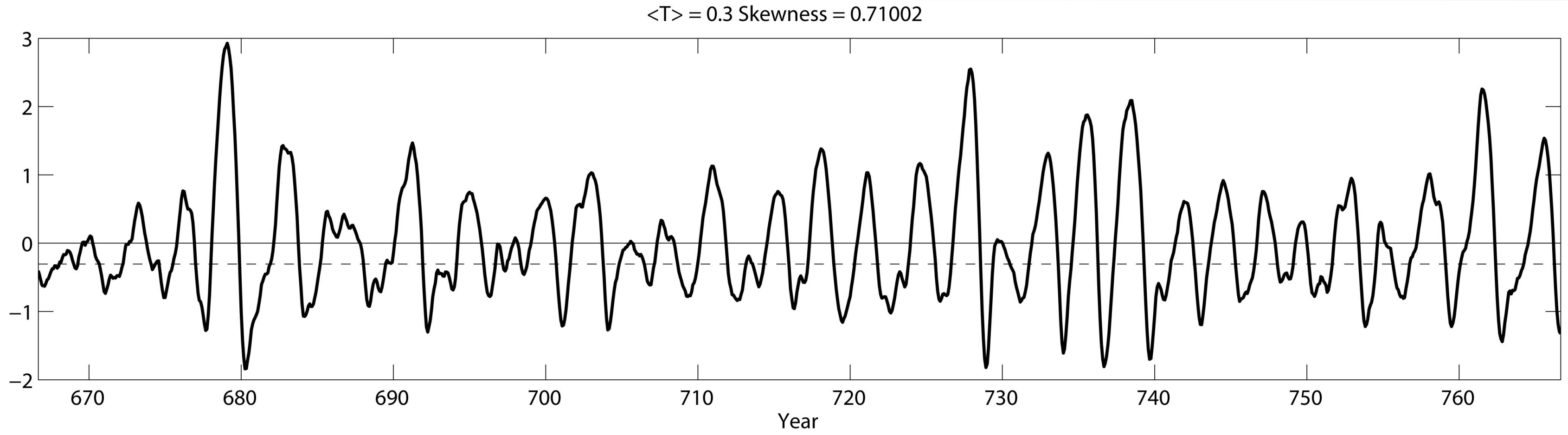


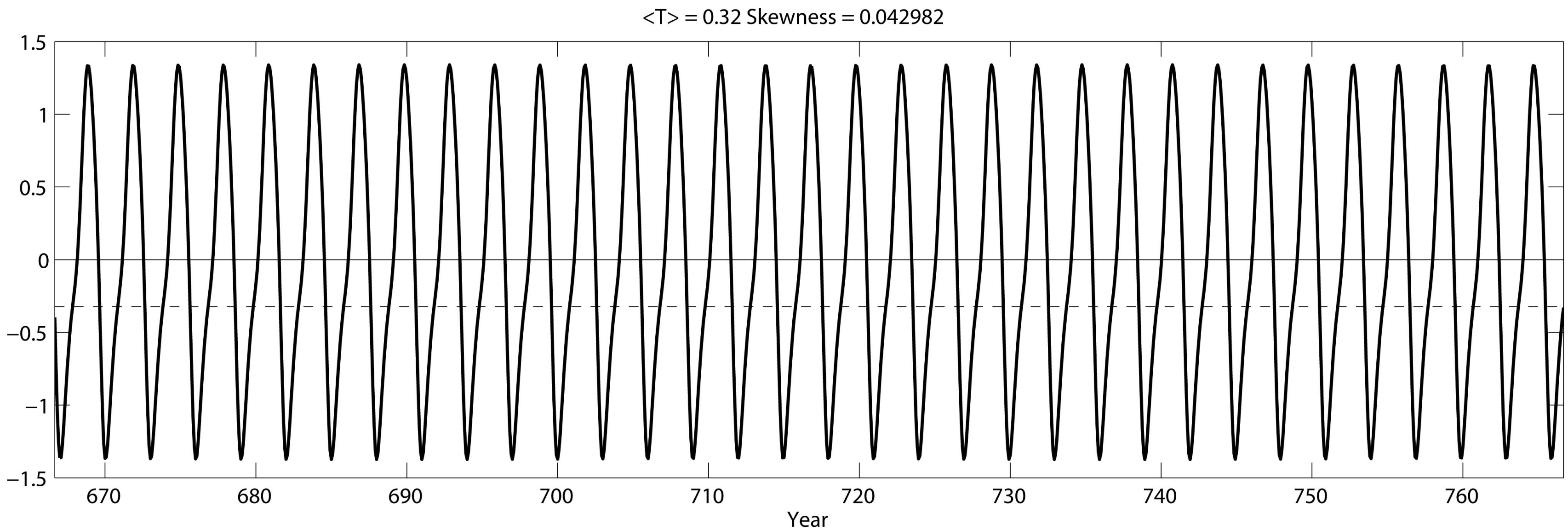
NCEP1 : r ~ 0%
FSU : r ~ 26-38%
ERA40 : r ~ 21-27%
MERRA: r ~ 19%
CM2.1 : r ~ 46%
CM2.5 : r ~ 15%
AM2.1 : r ~ 46%

Two scenarios:

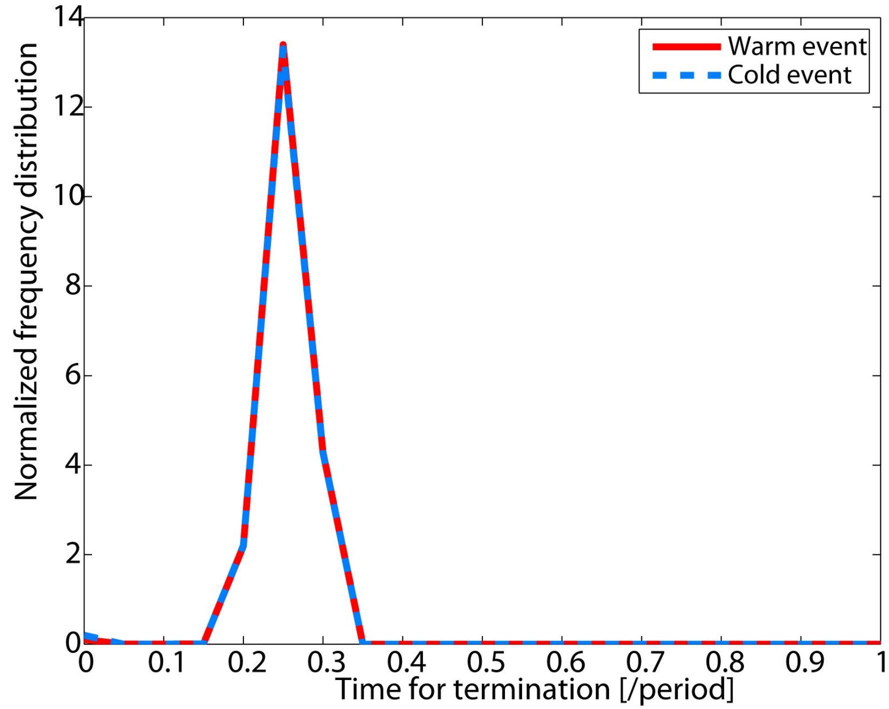
1) Oscillations of a stable system triggered by stochastic noise



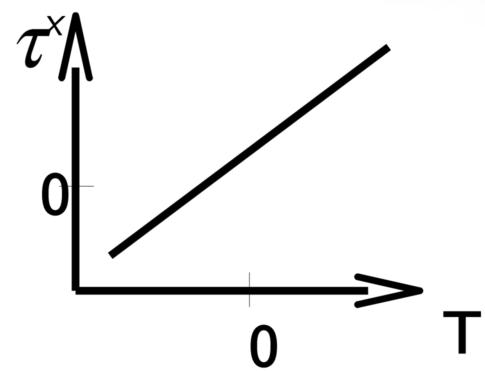
2) Self-sustained oscillation

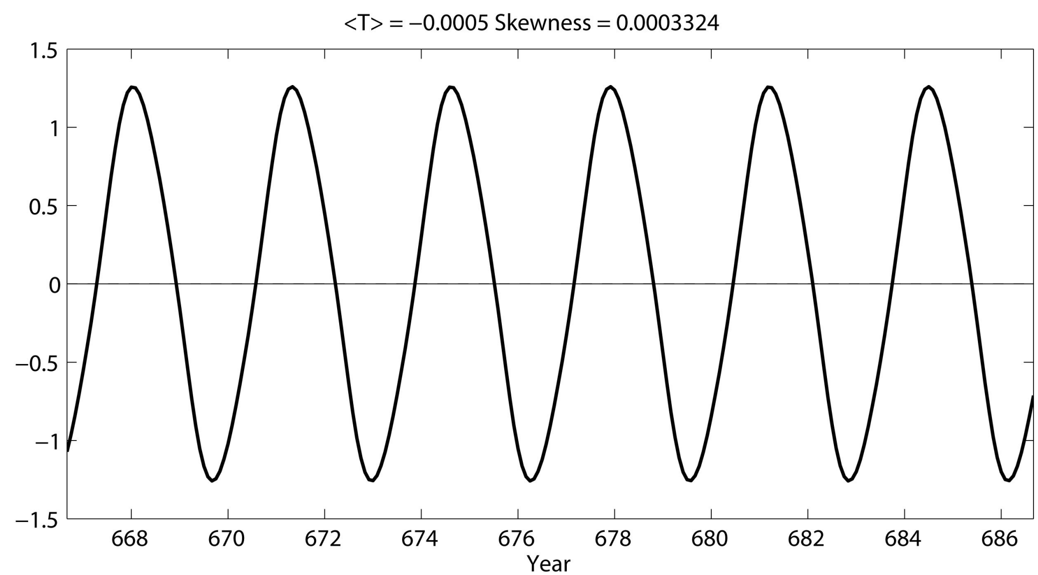


Asymmetry in duration: Cold events last longer



r = 0 %





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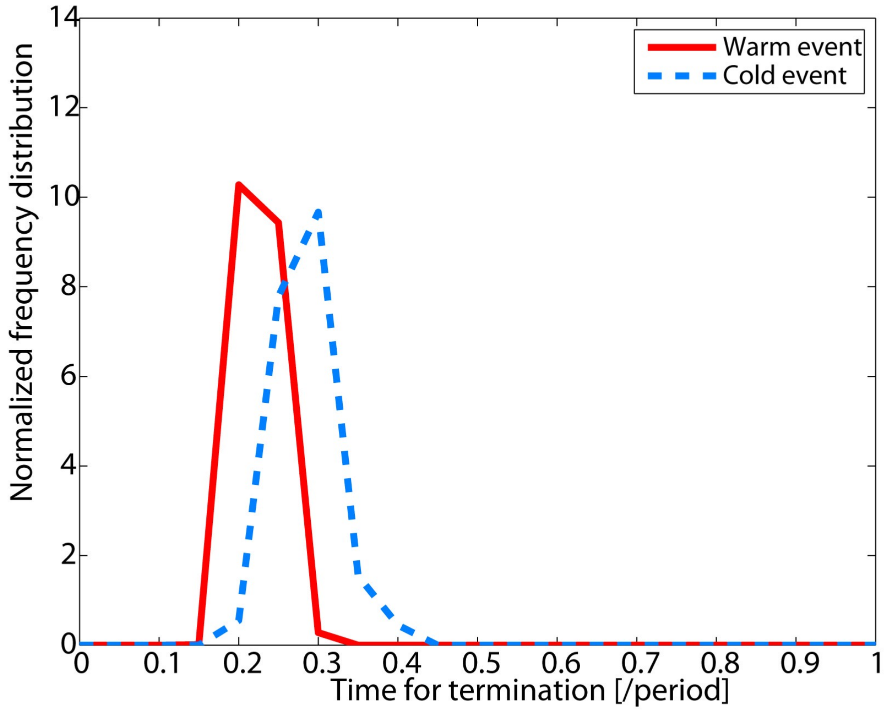
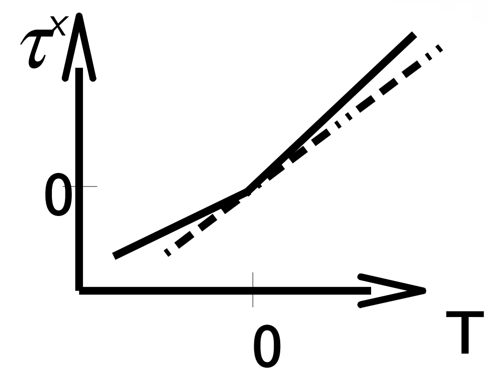
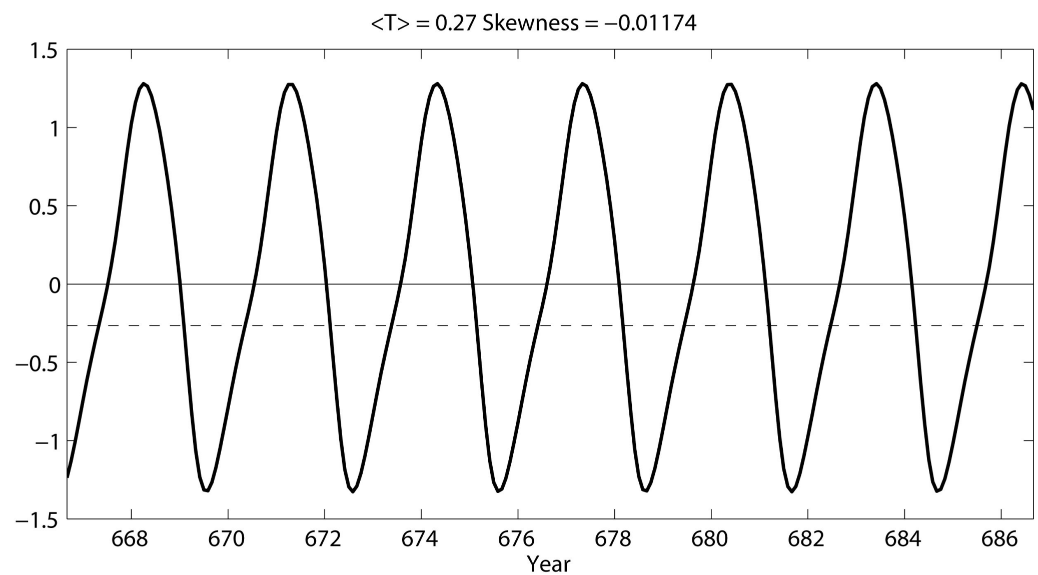


r = 40 %





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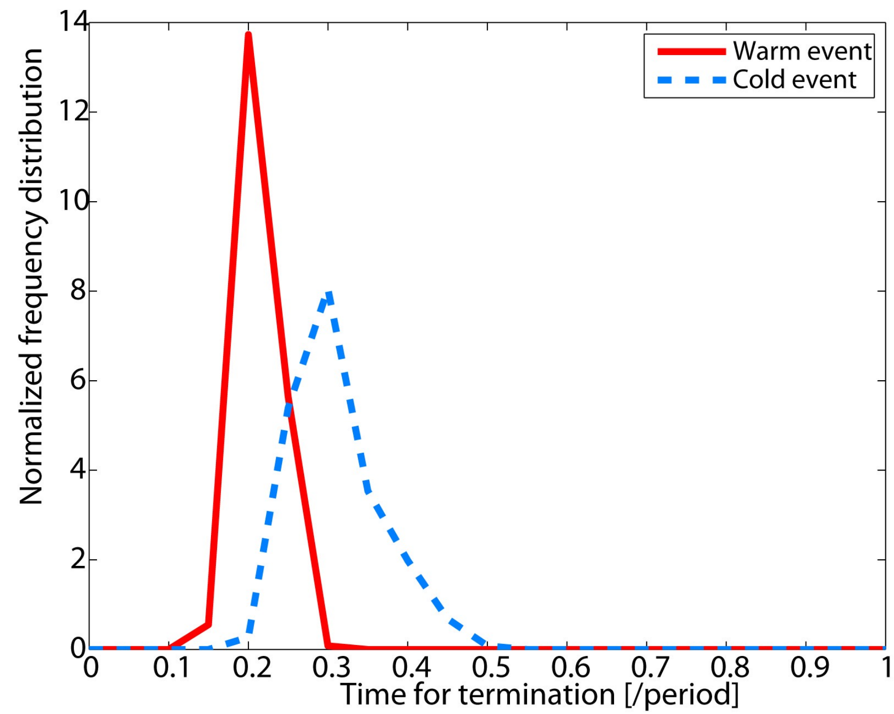

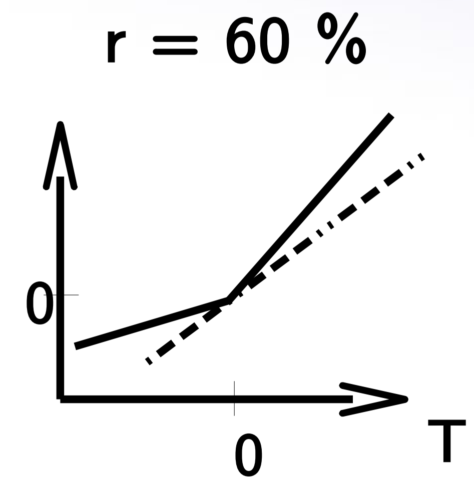

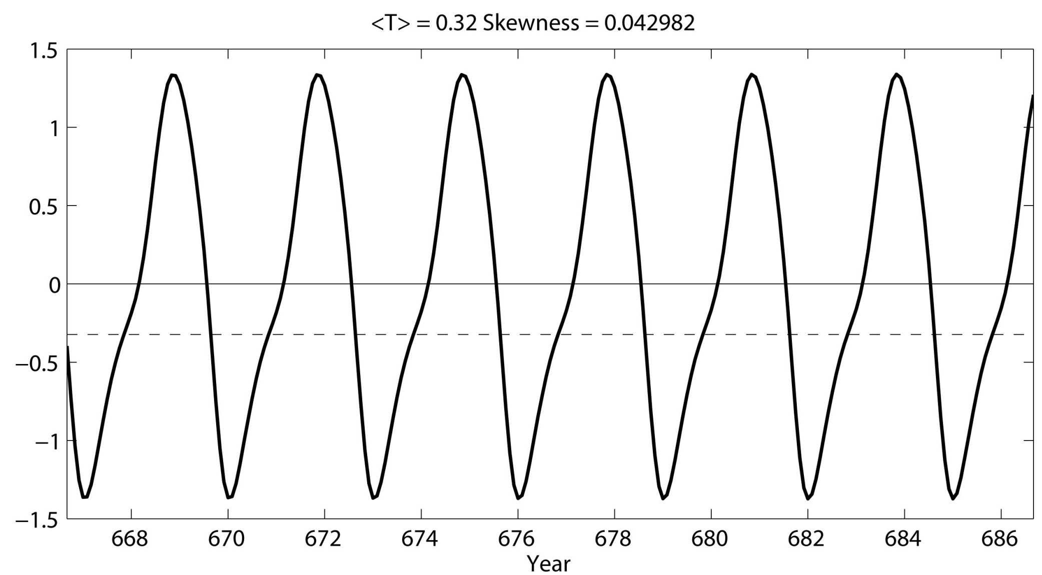

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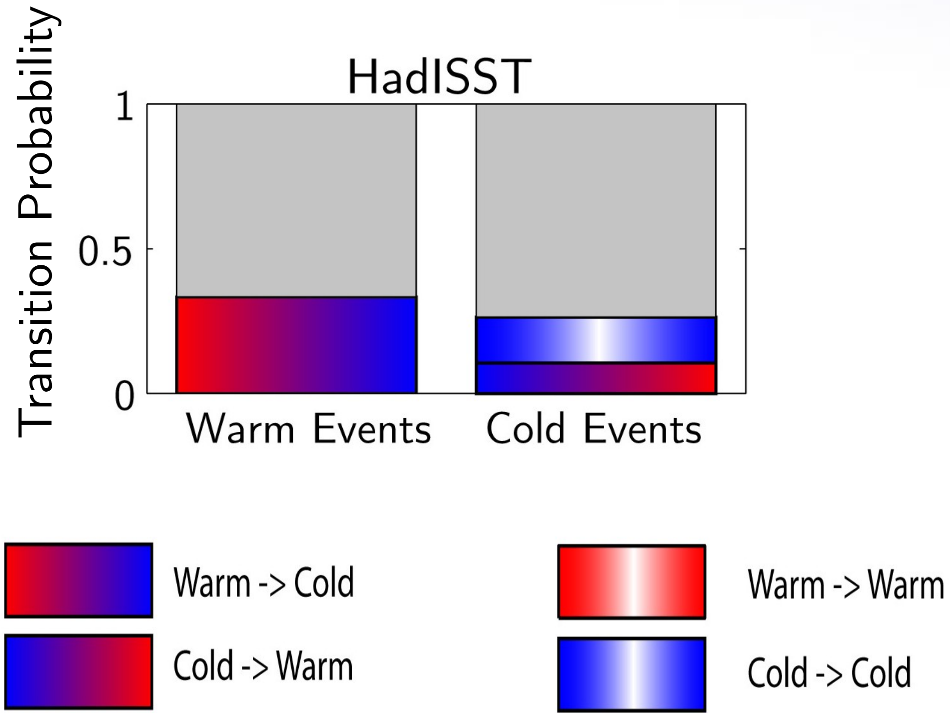

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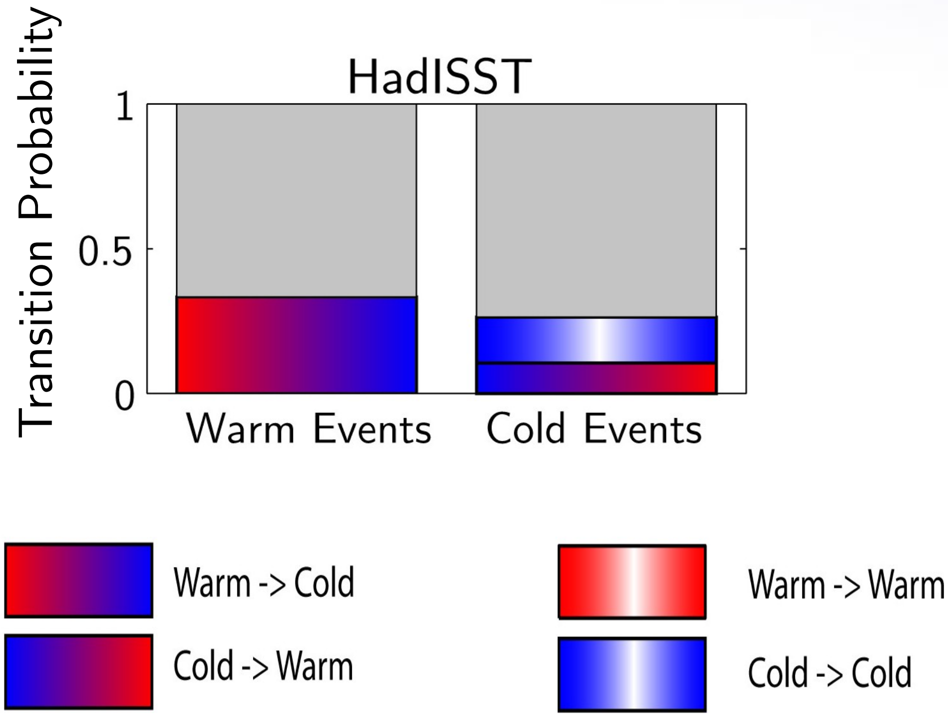
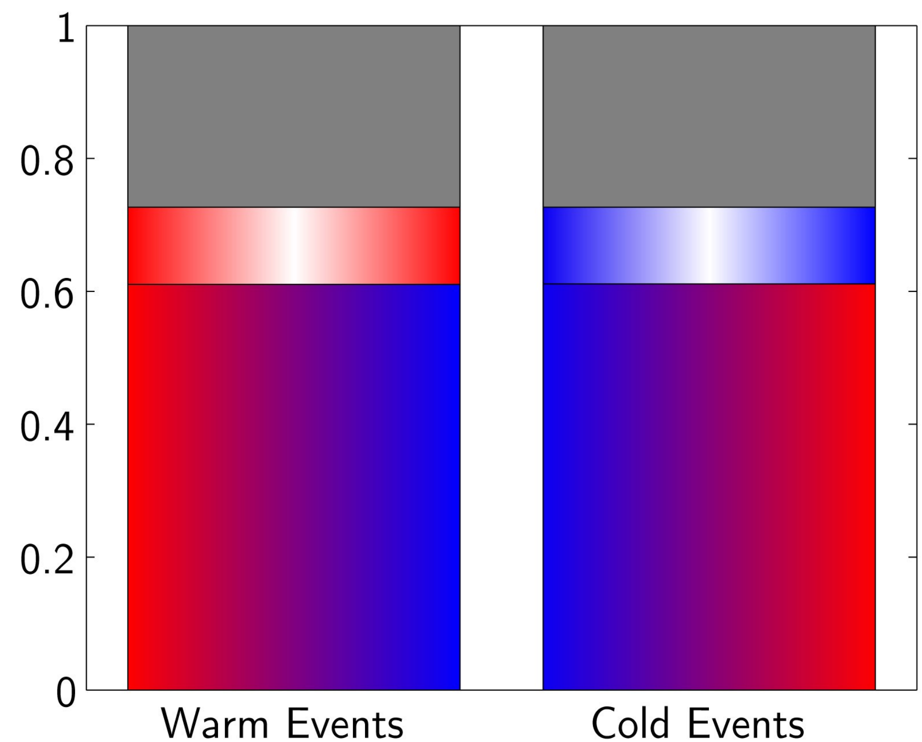
r = 0 %





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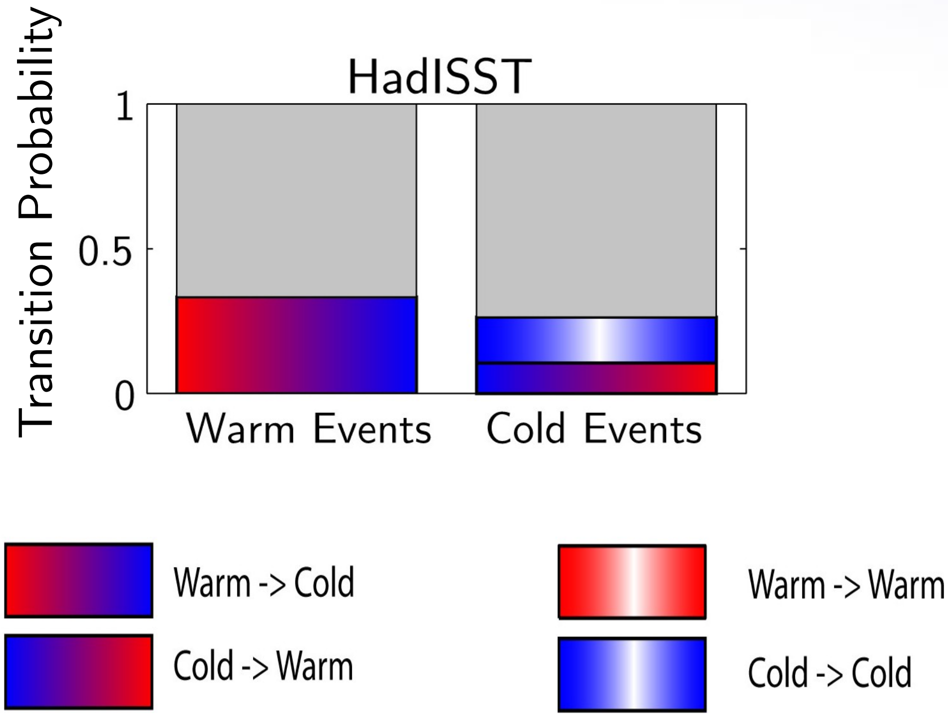

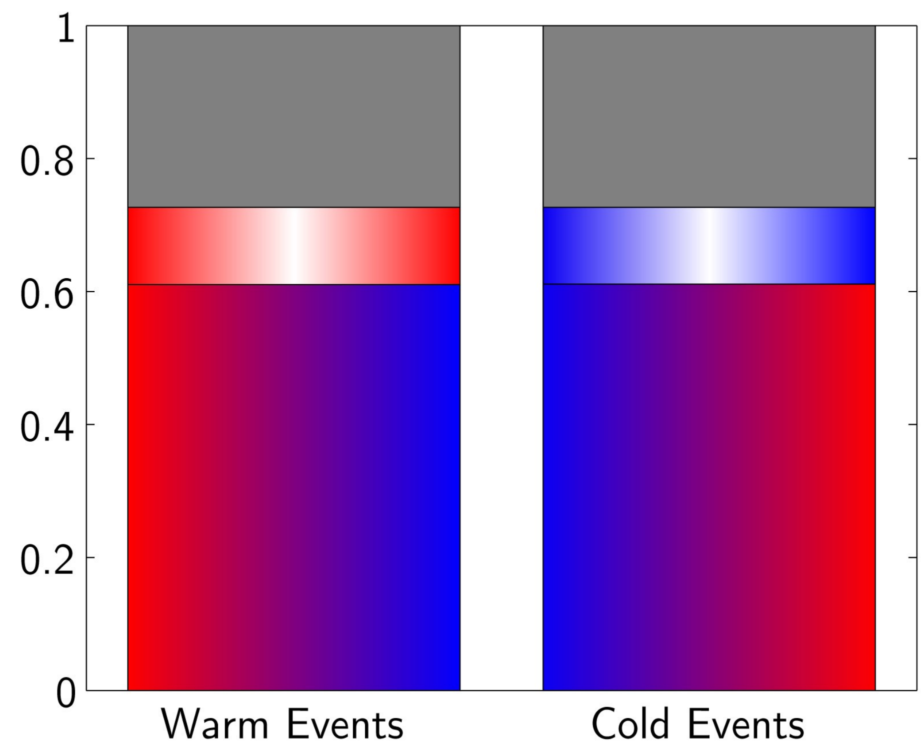

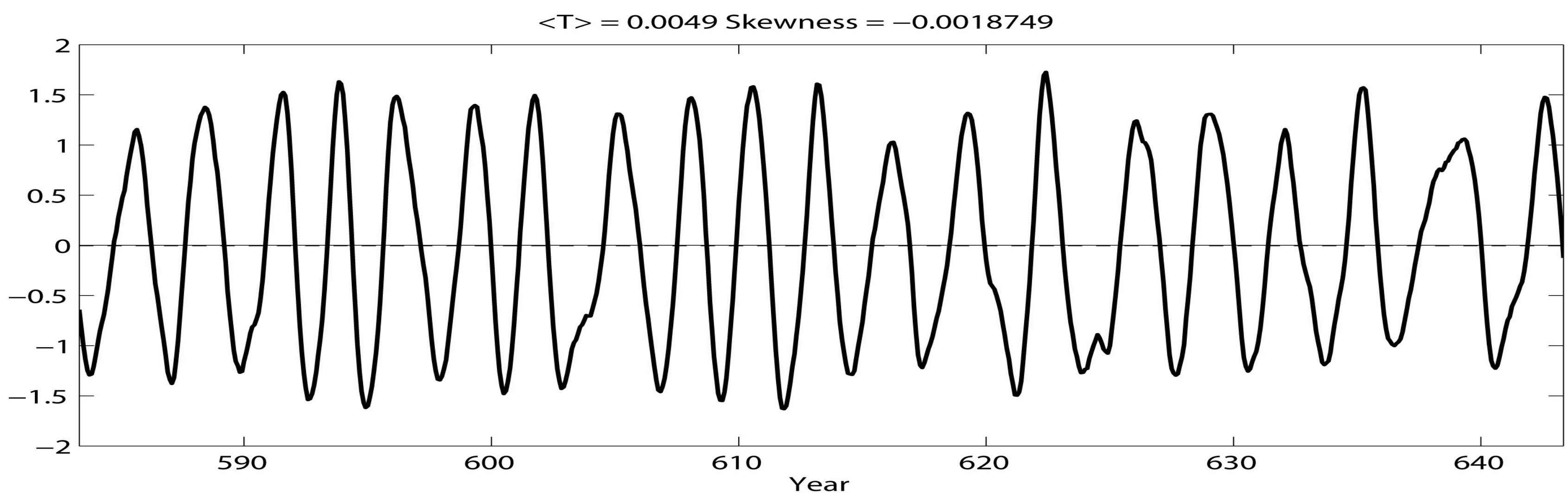

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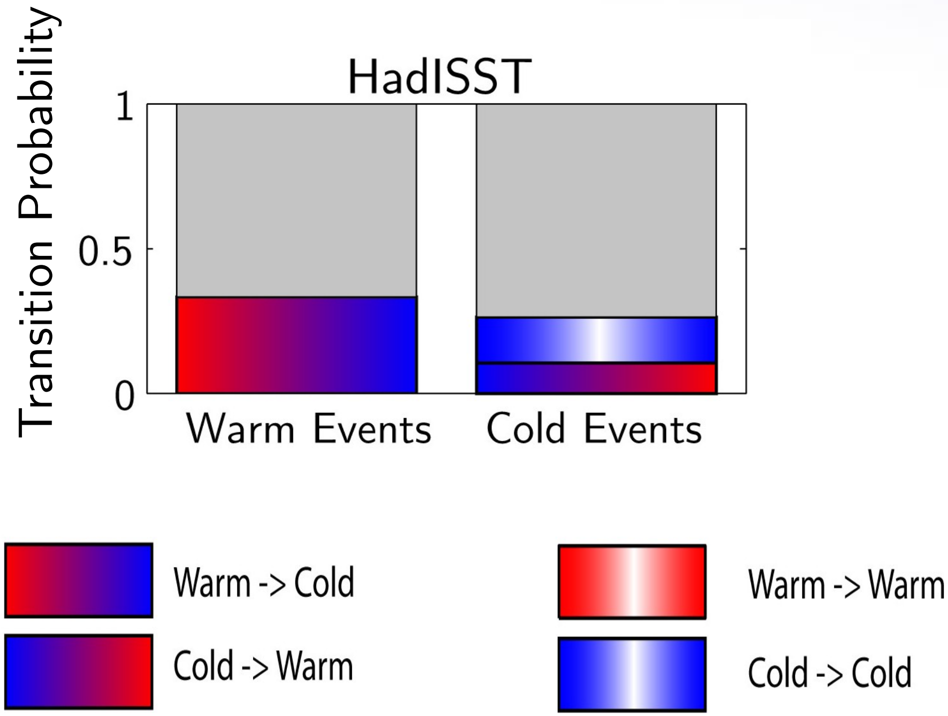

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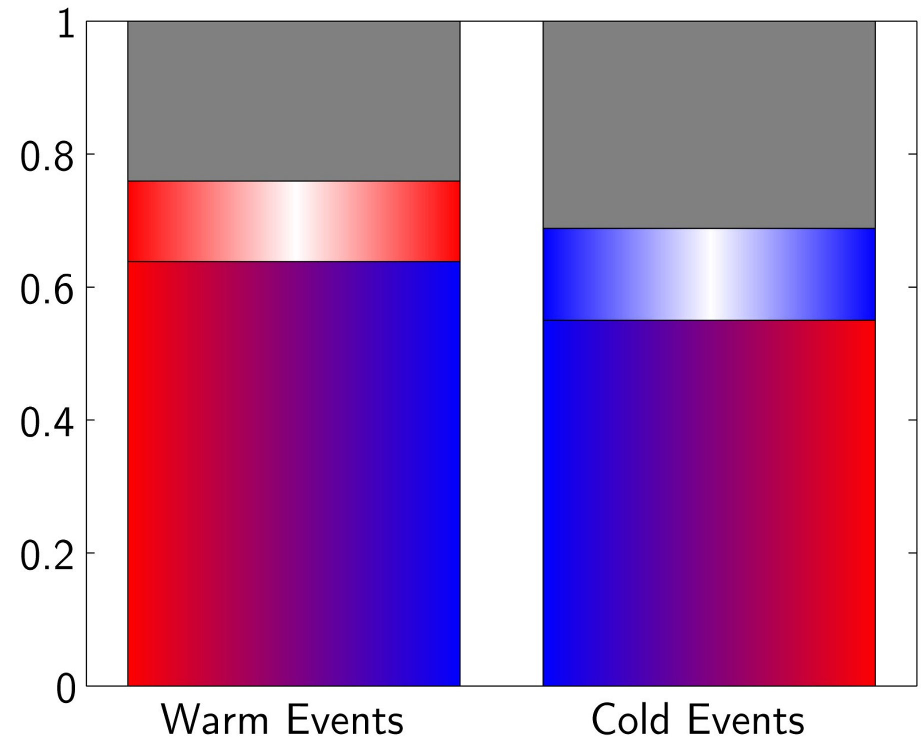

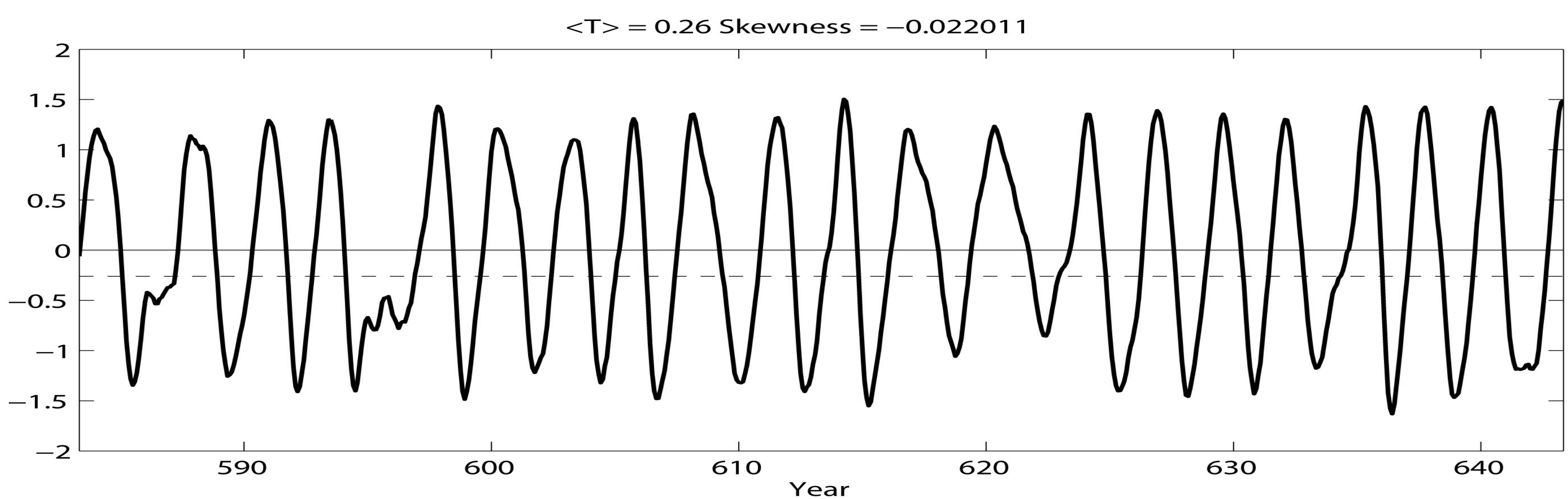

Asymmetry in sequencing:

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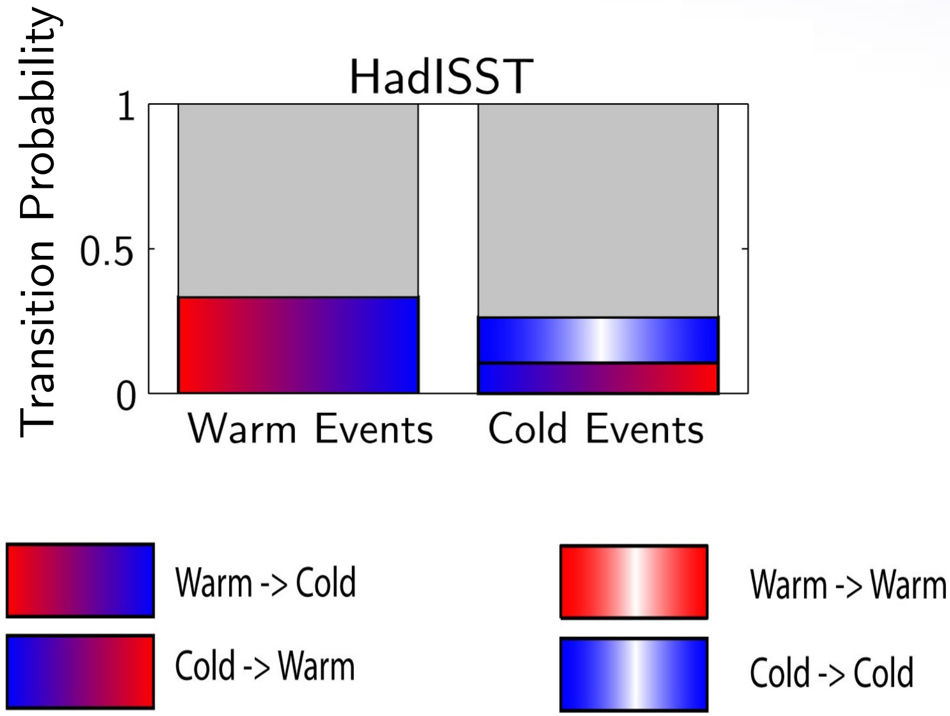
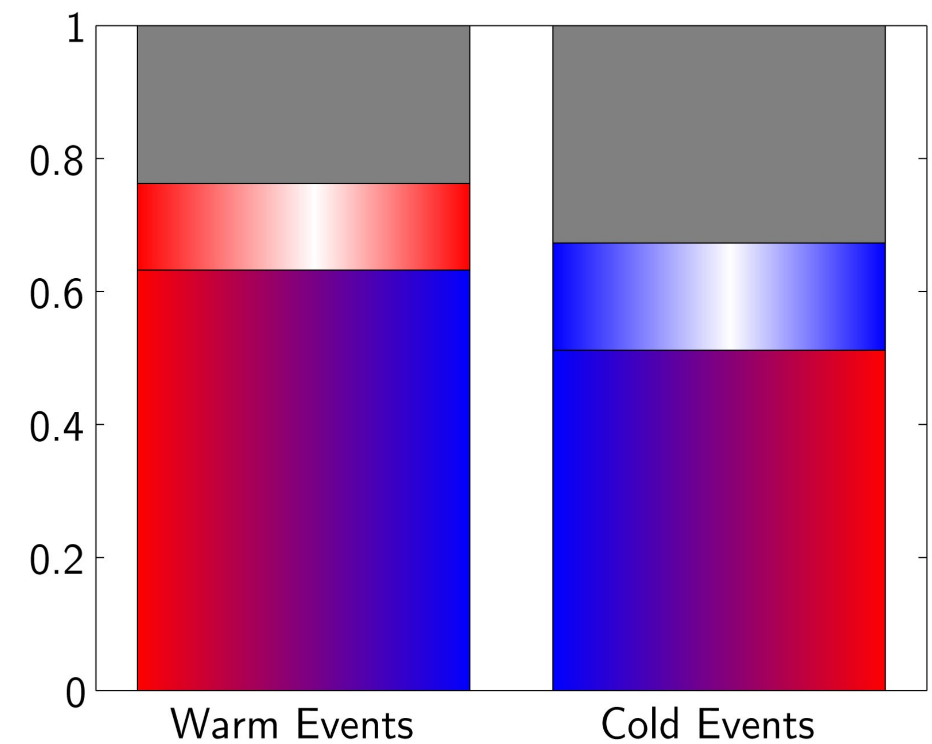
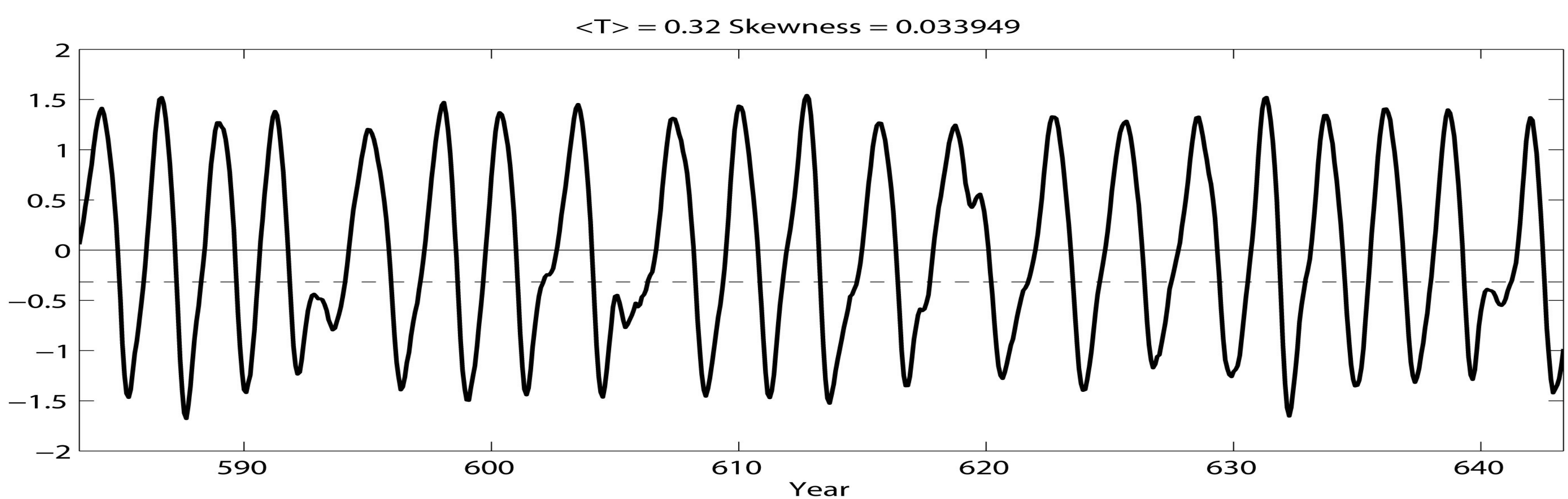
r = 60 %



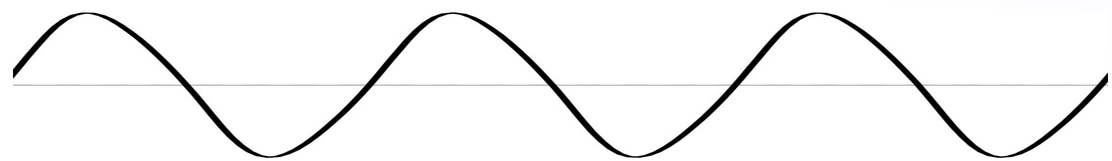




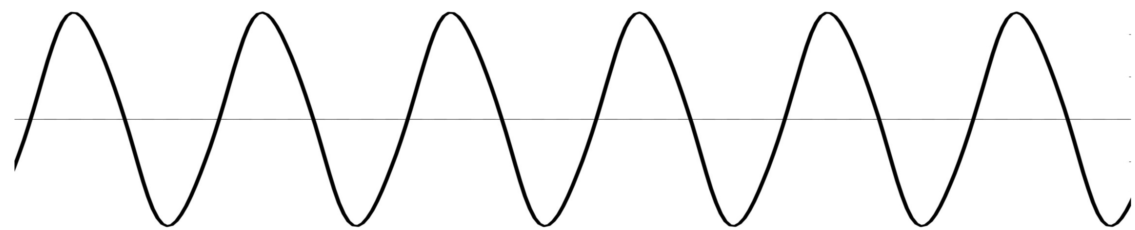
Why does the polarity dependence in the coupling efficiency result in the asymmetries?

Coupling efficiency = 0, no oscillation

Coupling efficiency is small



Coupling efficiency is larger



Larger coupling efficiency for El Nino → El Nino terminates faster and overshoots

Smaller coupling efficiency for La Nina → La Nina terminates slower
and is more susceptible to noise

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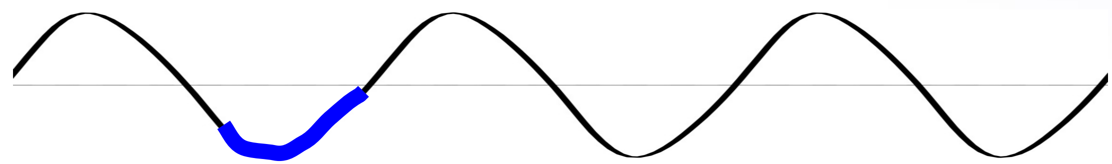

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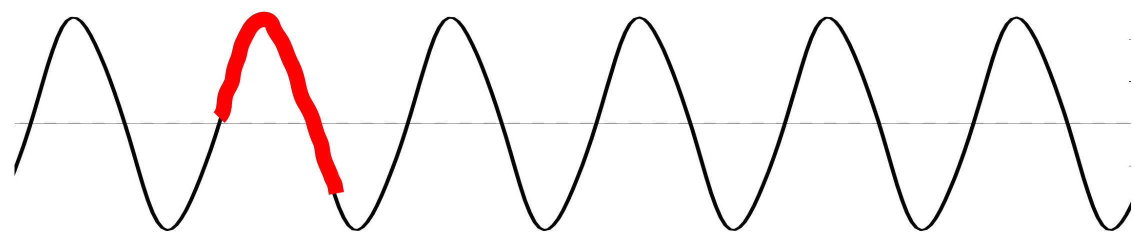

Larger coupling efficiency for El Nino $\rightarrow$ El Nino terminates faster and overshoots

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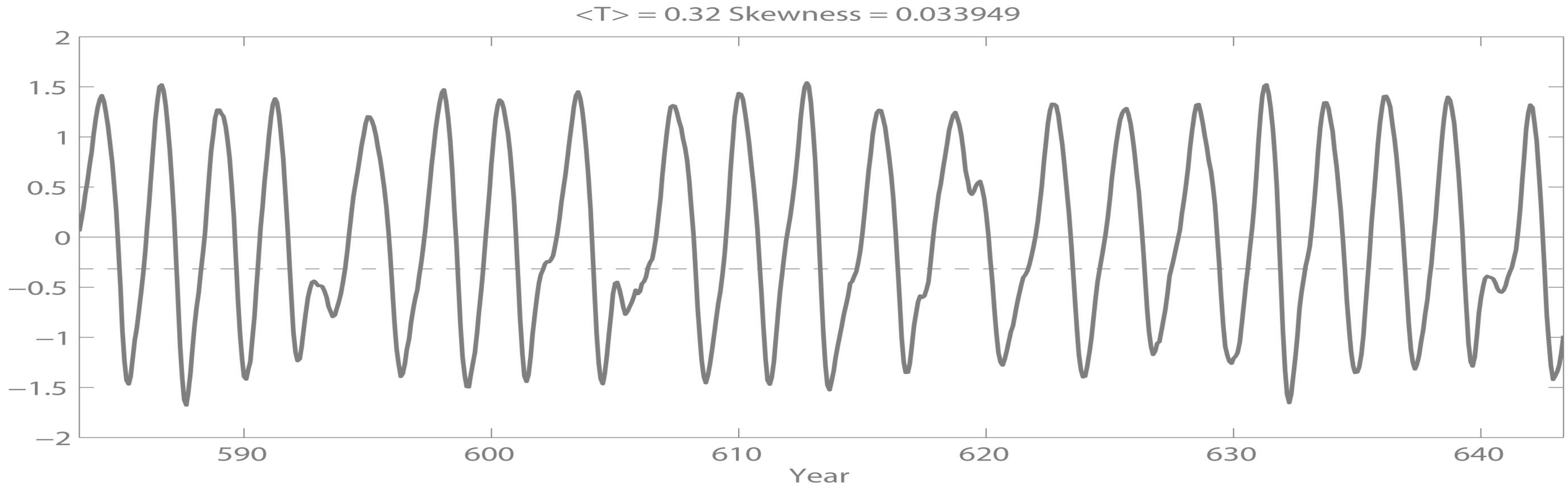
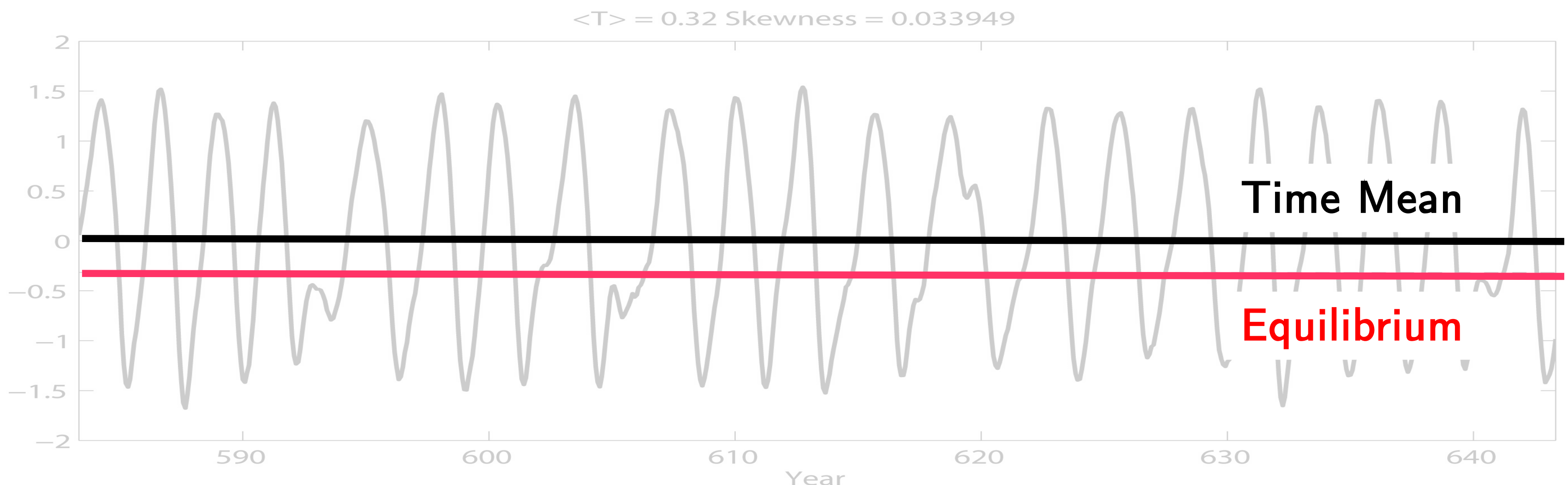
The time mean state is, in fact, a warm state



The time mean state is, in fact, a warm state



That accounts for a fraction of the duration asymmetry.

Summary

- Within the framework of a delayed-oscillator, if the wind response is more sensitive to warm SST anomalies, or more generally,

if the coupling efficiency is higher during warm events:

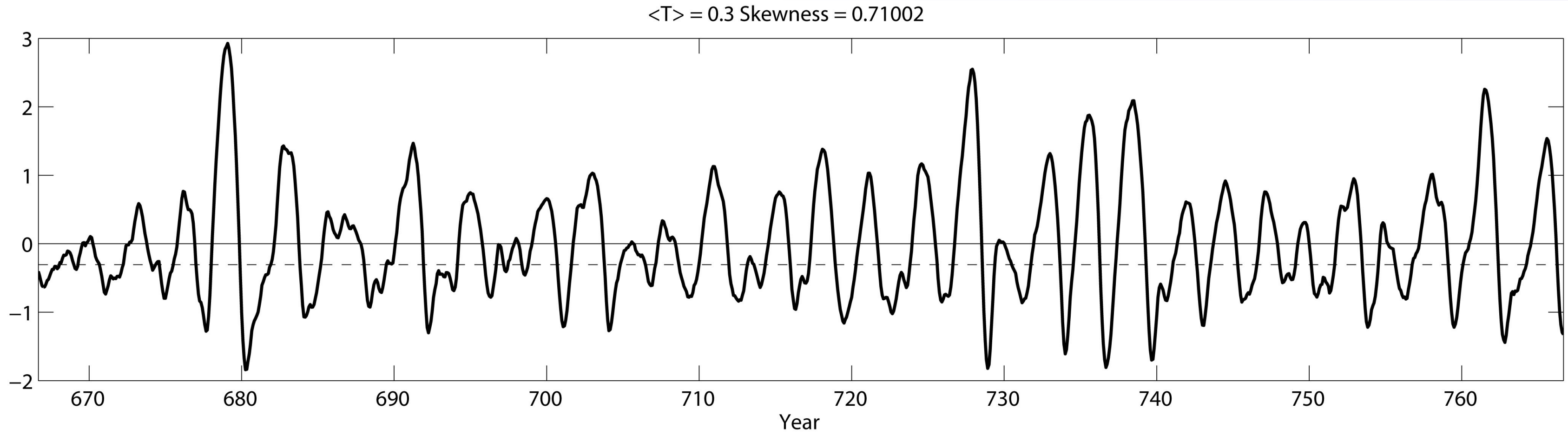
- Higher likelihood of warm $\rightarrow$ cold than cold $\rightarrow$ warm
- Cold events last longer and are more susceptible to noise
- The time mean state is a warm state

These results hold for
the stochastically-forced stable mode and **self-sustained oscillatory mode.**

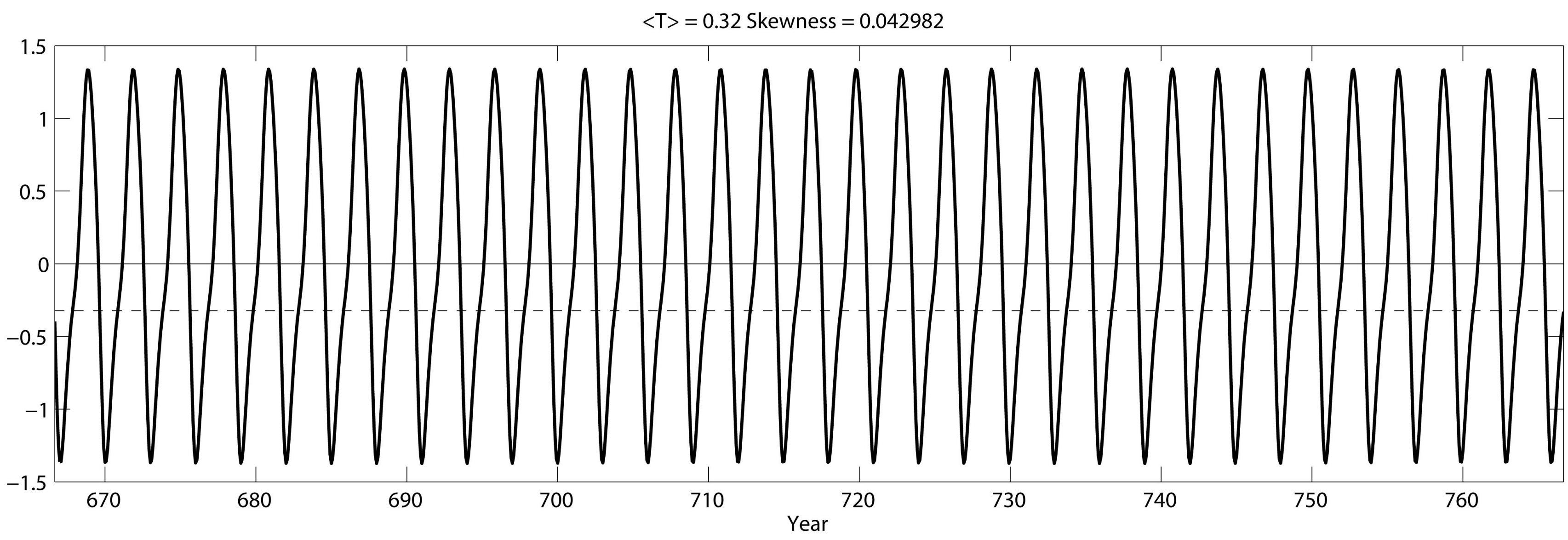
Thank You!

Two scenarios:

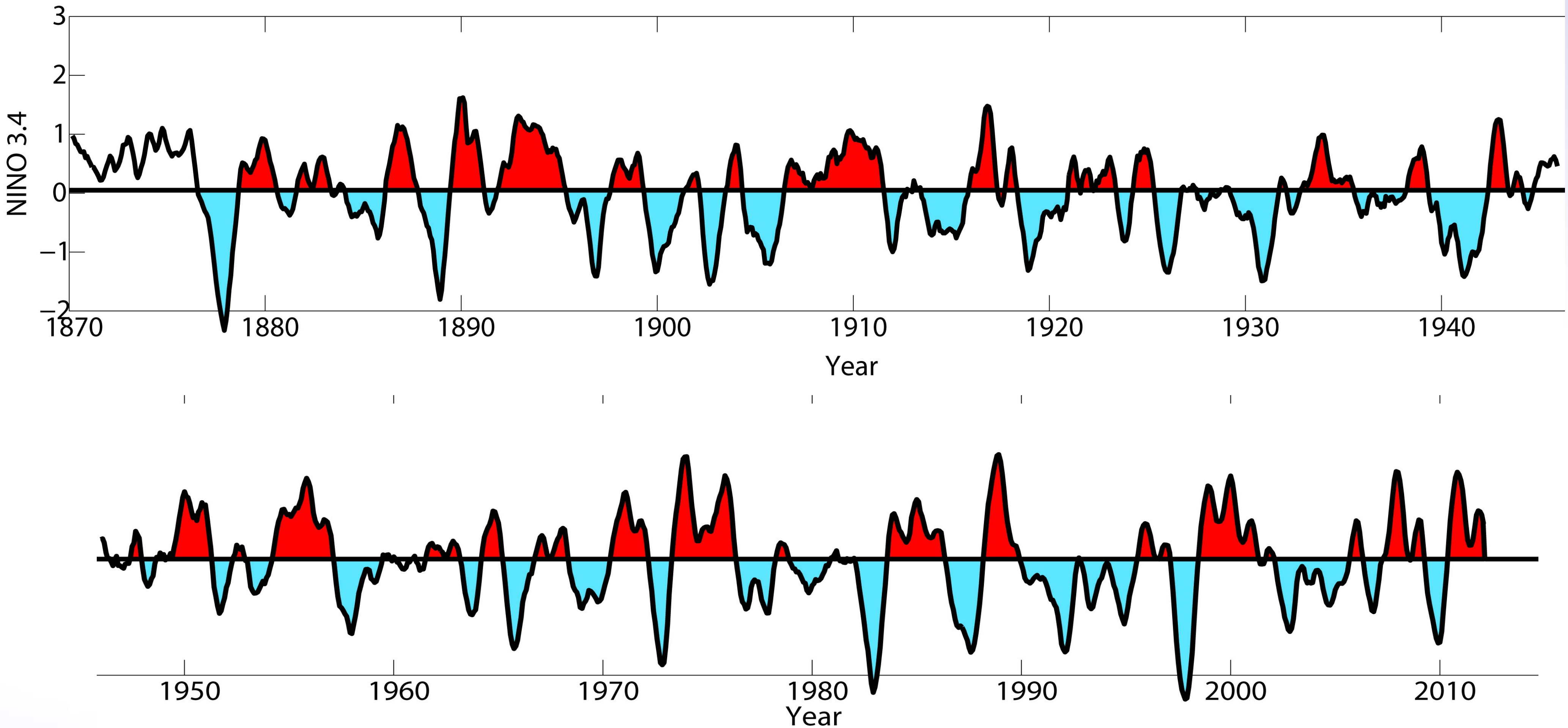
1) Oscillations of a stable system triggered by stochastic noise



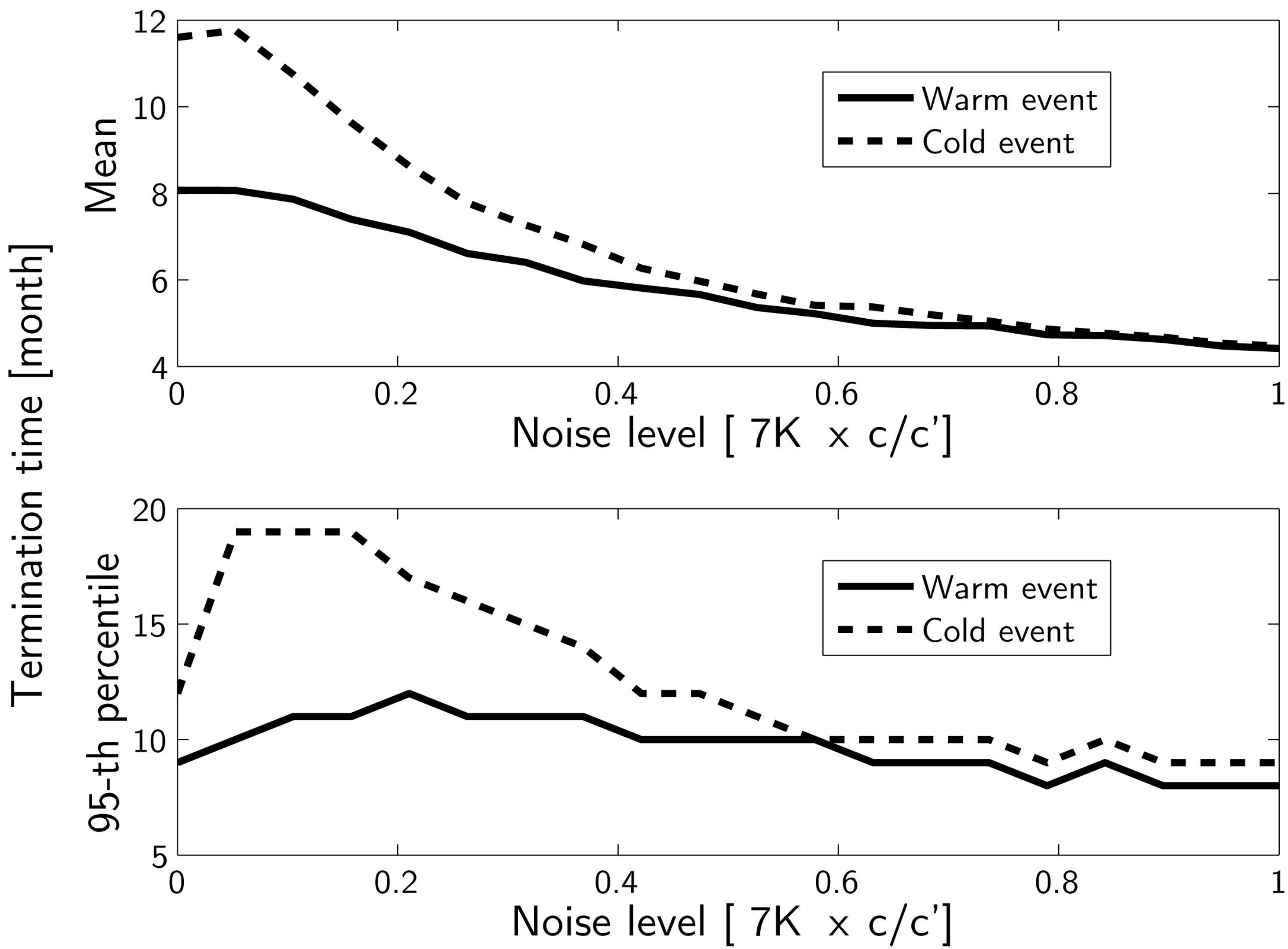
2) Self-sustained oscillation



El Niño – Southern Oscillation

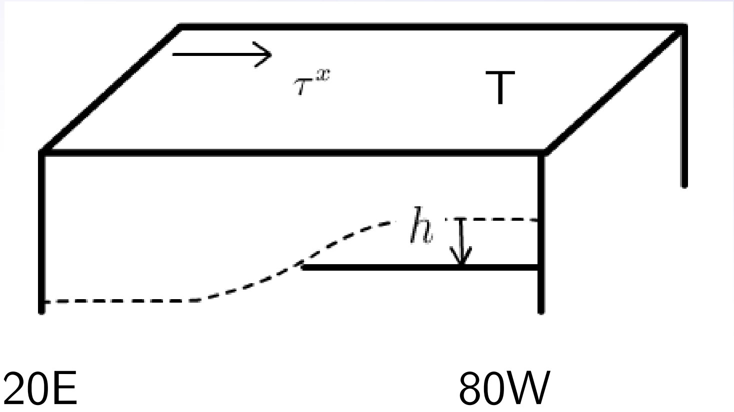


Flipped upside down



Termination time [month]
Mean
12
10
8
6
4
Warm event
Cold event
0
0.2
0.4
0.6
0.8
1
Noise level [7K x c/c']
95-th percentile
20
15
10
5
Warm event
Cold event
0
0.2
0.4
0.6
0.8
1
Noise level [7K x c/c']

Modified delayed Oscillator



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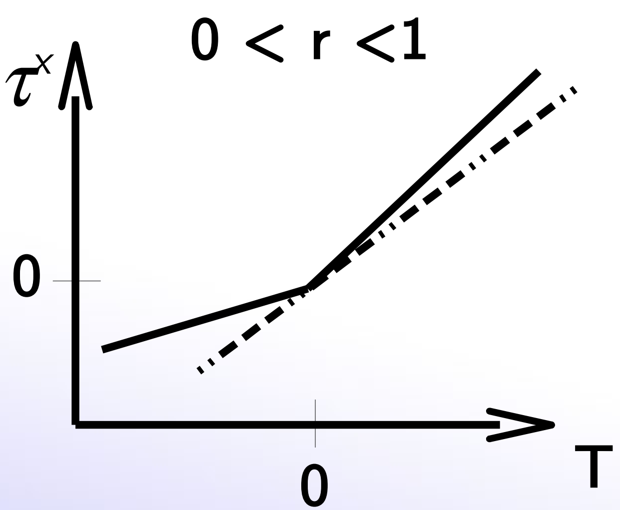
$$\tau^x = \gamma T + r\gamma\,|T| + N(0, \sigma)$$



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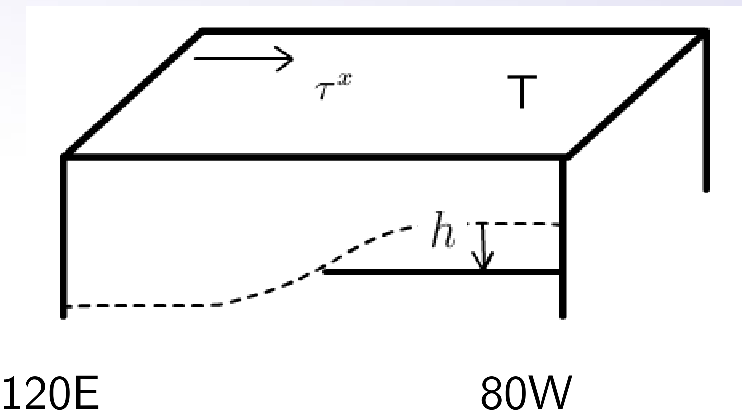
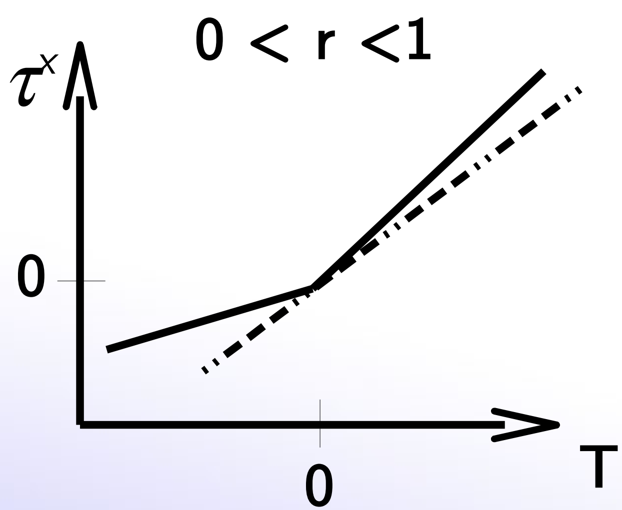
AM2.1 : r ~ 46%

Modified delayed Oscillator



$$\frac{\partial T}{\partial t} = -bT + c\tau^x(t - t_1) - d\tau^x(t - t_2) - \epsilon T^3$$

$$\tau^x = \gamma T + r\gamma\,|T| + N(0, \sigma)$$



NCEP1 : r ~ 0%
FSU : r ~ 26-38%
ERA40 : r ~ 21-27%
MERRA: r ~ 19%
CM2.1 : r ~ 46%
CM2.5 : r ~ 15%
AM2.1 : r ~ 46%