Impact of Interactive Westerly Wind Bursts in CCSM3

World Climate Research Programme

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Motivation

- How does state-independent and state-dependent stochastic forcing affects ENSO variability in a sophisticated coupled model?
- Westerly Wind Burst (WWB) do occurs, but are not well represented in Coupled General Circulation Models (CGCM) due to major bias in the mean state.
- WWBs are observed during the onset and development of major El Niño events (Kerr 1999).
- WWBs are known to have a deterministic component, modulated by the Sea Surface Temperature (SST).
- Proper representation of WWBs could improve ENSO prediction.
- Eventually reach a better understanding on ENSO prediction and predictability.

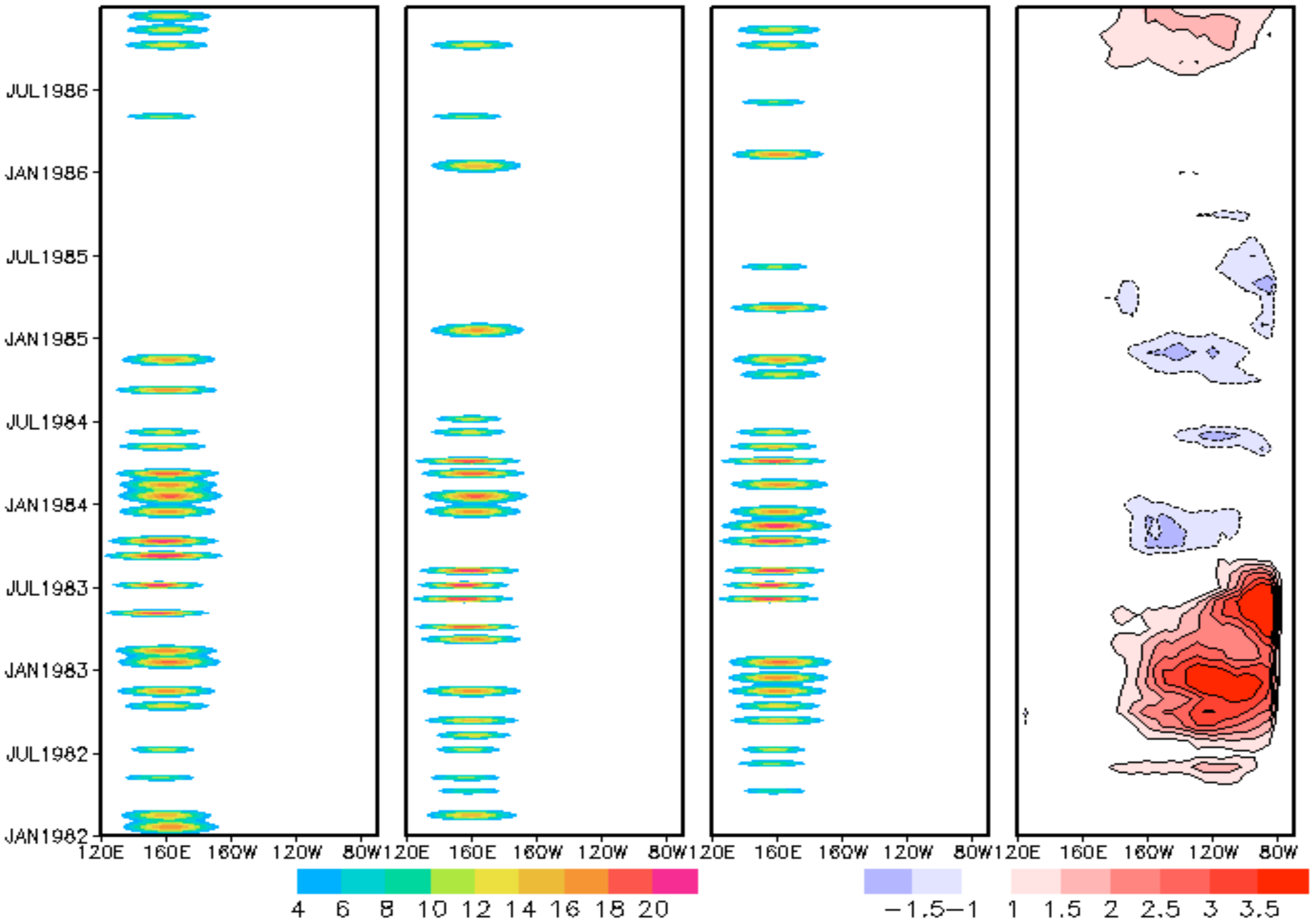
Background

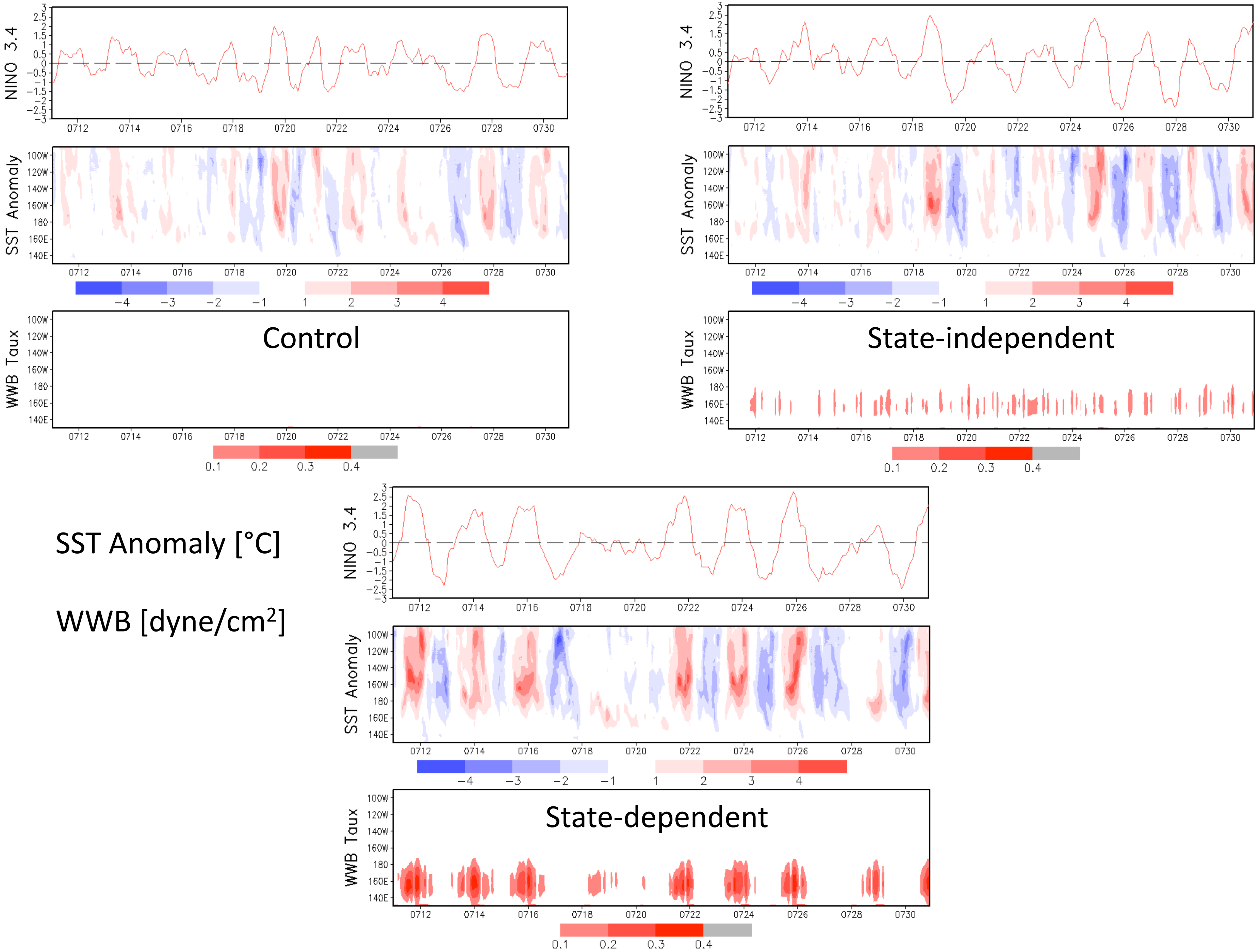
- Westerly wind bursts (WWBs) events are commonly viewed as completely stochastic processes, independent of any oceanic forcing.
- Recent work and observations have suggested that these events also contain a deterministic component, modulated by the SST.
- These events seem to result from various mechanisms:
  - The Madden-Julian oscillation (MJO; Chen et al. 1996).
  - Cold surges from mid latitudes (Chu 1988).
  - Tropical cyclones (Keen 1982).
  - A combination of the three (Yu and Rienecker 1988).

Numerical Experiment

- The Community Climate System Model version 3.0 (CCSM3), is integrated for several hundred years with three different initial conditions:
    - No Westerly Wind Burst (WWB) event. This is our control run.
    - The state-independent run, here the WWB are added to the model as additive noise and are parameterized based on 50 years atmospheric reanalysis data and observed estimates of tropical Pacific SST.
    - The state-dependent run, here the WWB are introduced as multiplicative noise modulated by the SST, the probability of occurrence is different from the stochastic case in that it depends on the large-scale SST anomalies.
- The wind anomalies are always positive (eastward) with not westward counterpart.

Three WWBs realizations [m/s] with observed SSTA [°C], showing cross-section along the equatorial Pacific Ocean



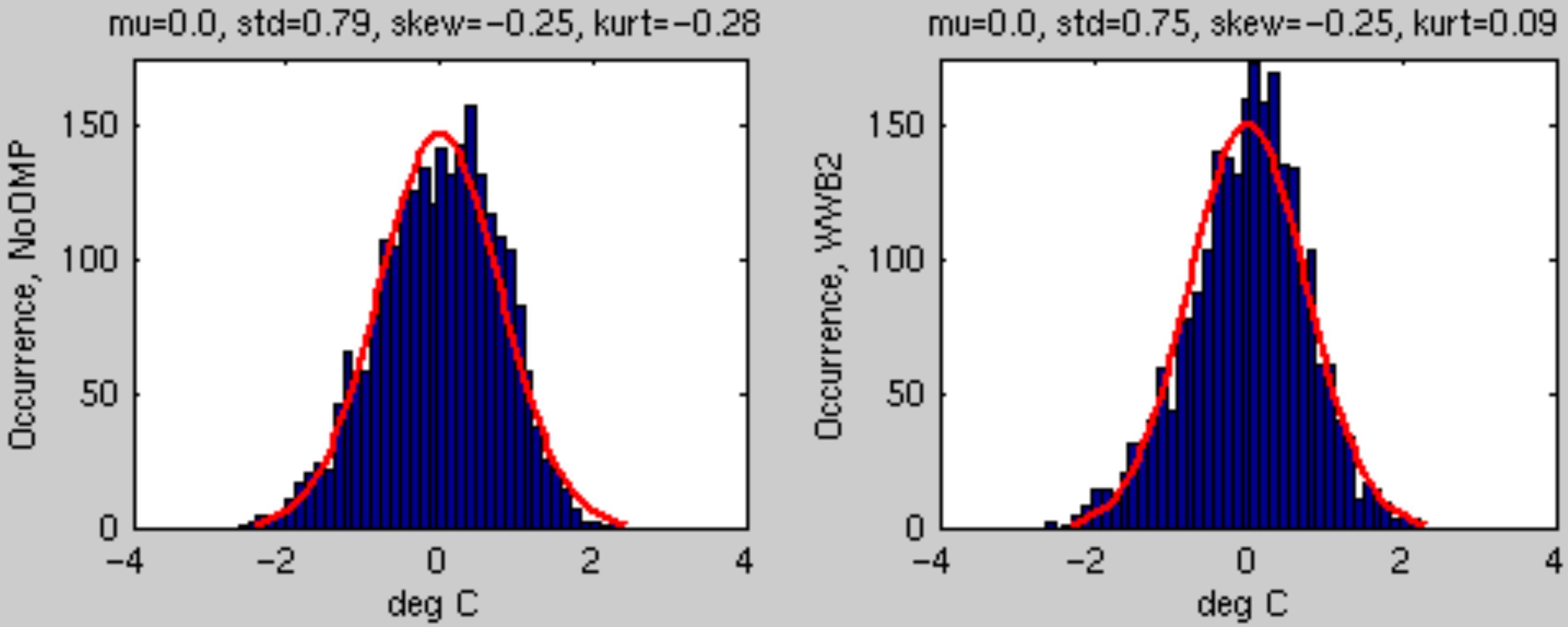


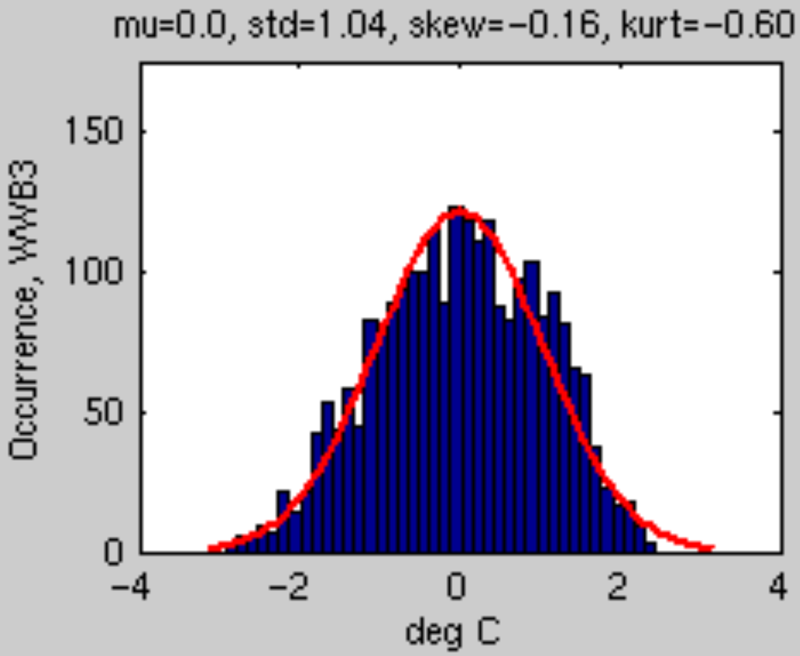
Control
State-independent
State-dependent
NINO 3.4
SST Anomaly
WWB Taux
SST Anomaly [°C]
WWB [dyne/cm2]

Cold Events Bias

°C	Control	State ind.	State dep.
<-1.00	40	30	61
<-1.25	32	23	52
<-1.50	22	15	40
<-1.75	13	8	34
<-2.00	7	7	21
°C			
> 1.00	41	31	73
> 1.25	22	16	61
> 1.50	9	6	48
> 1.75	2	3	22
> 2.00	1	1	4

- DJF extreme events (in deg C) for 201 model years
  - The state-dependent case produces more ENSO events in both extremes.
  - The bias toward cold events is also reduced in that case, except for the very extremes.
  - The state-independent case produces less ENSO events overall.
  - Hint of a shift from an event type to a oscillatory behavior in the state-dependent case.

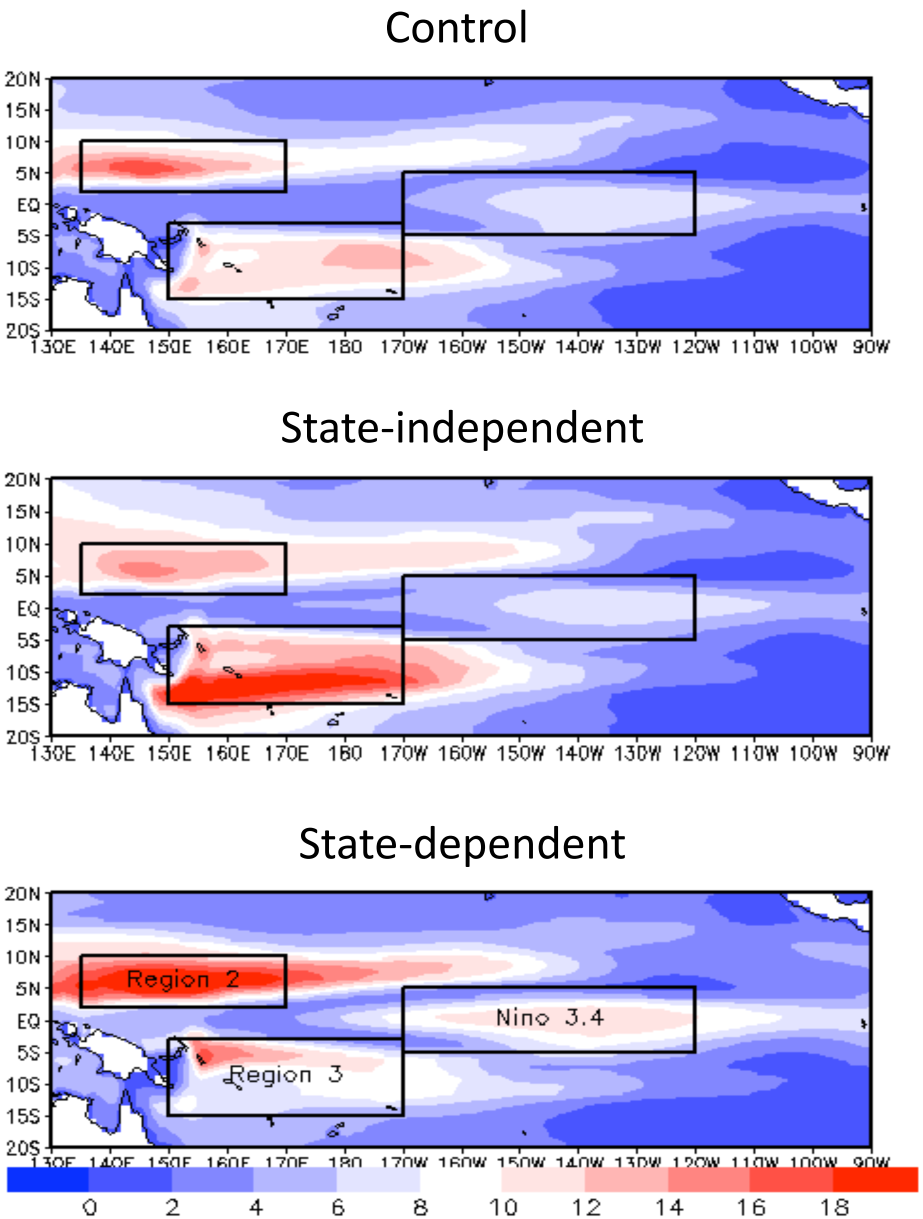




- Niño 3.4 SST anomaly histogram
  - mu = mean
  - std = standard deviation
  - skew = skewness coef.
  - kurt = kurtosis coef.

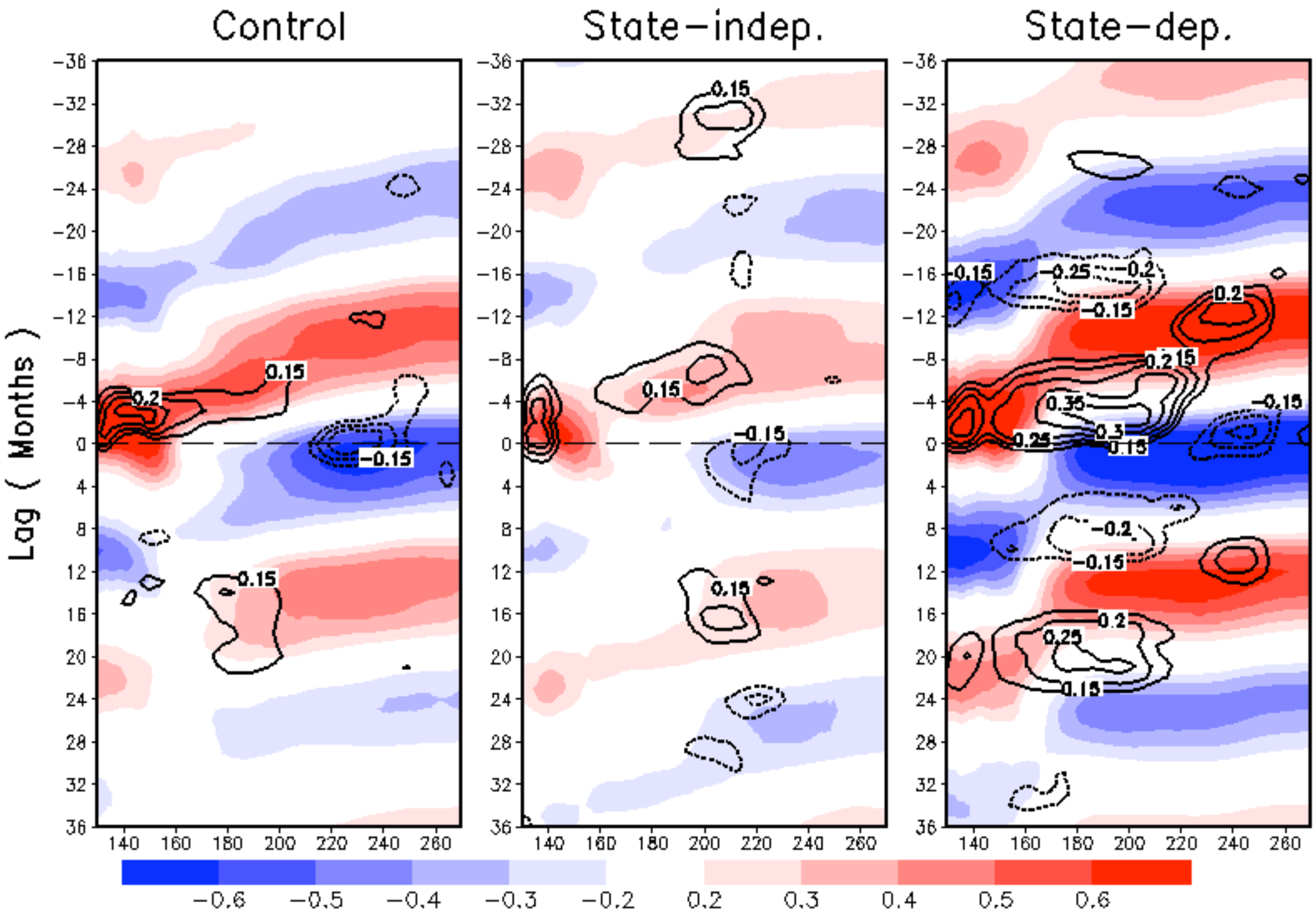
- Normal distribution fitted

WWB and equatorial wave dynamics

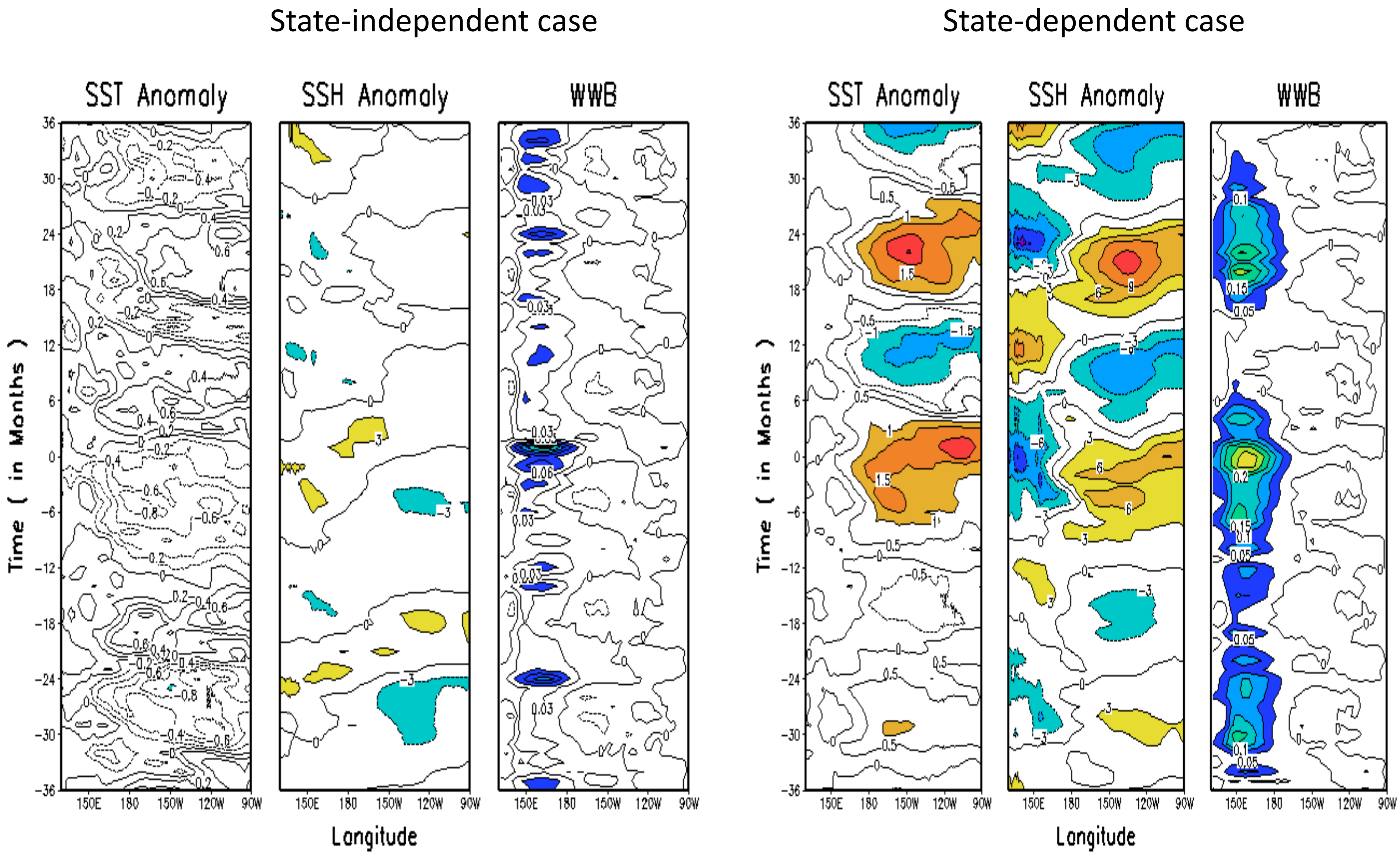


- SSH variance shows three common regions of action for the three experiments.
- These coincide with the equatorial waveguide.
- Niño 3.4 variance is related to upwelling-downwelling Kelvin waves.
- Region 2 variance is associated with north-equatorial Rossby waves.
- Region 3 variance do not appear to be linked to the ENSO cycle.

Lag-lead correlation along the Equator, SST (shaded), zonal wind stress (contour)



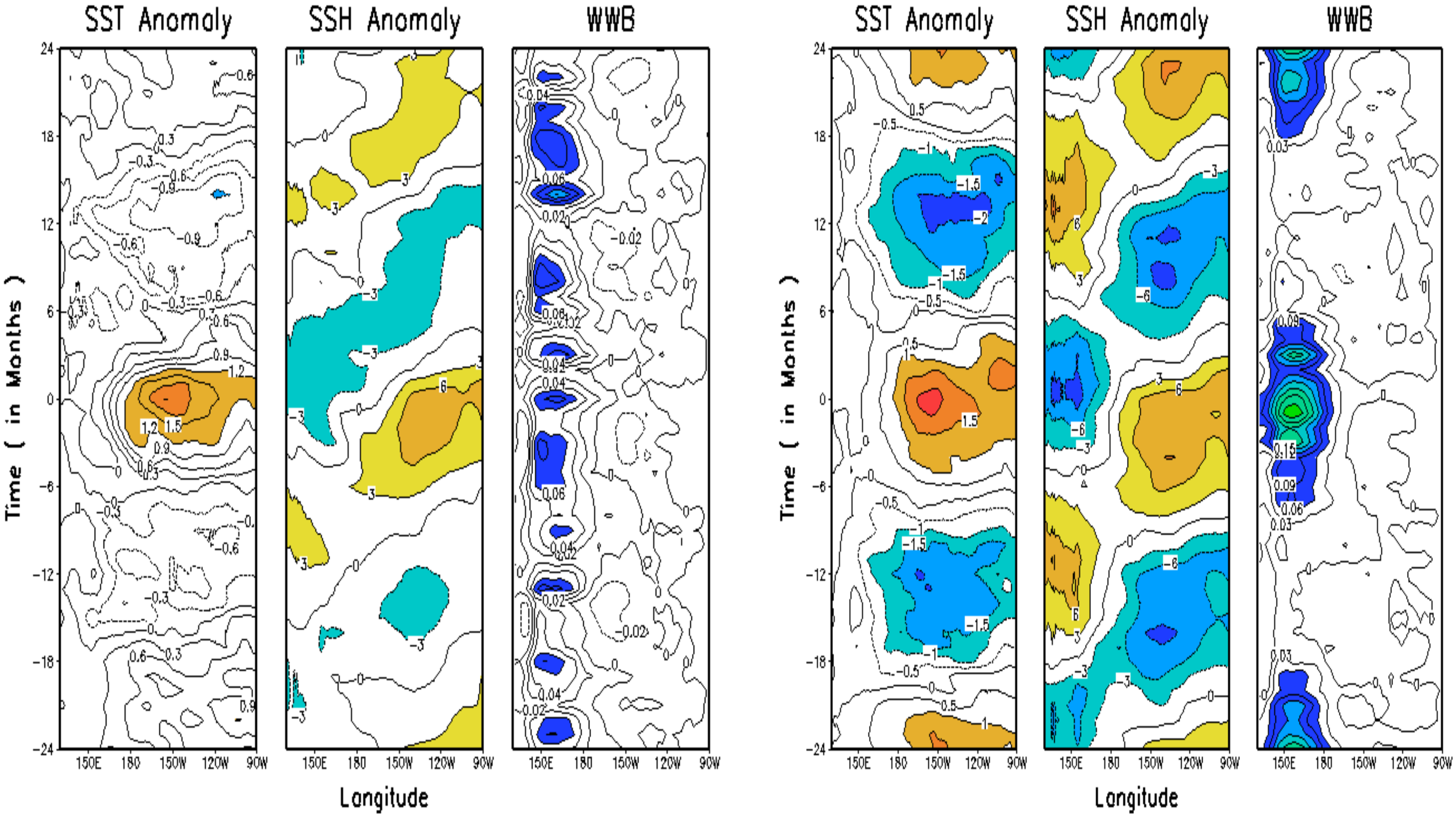
Composite of top 5 WWB events (Ensemble Mean)



Composite of 5 modest warm events (Ensemble Mean)

State-independent case

State-dependent case



Summary and conclusions:

- WWBs were introduced in CCSM3 as state-independent and dependent forcing.
- Basic statistics cannot detect the differences between the control and the state-independent case.
- The state-dependent case produces more ENSO events in both extremes, and the bias towards the cold phase is reduced.
- Lag coherence is degraded (enhanced) in the state-independent (state-dependent) case.
- ENSO characteristics have hifted from an event type to an oscillator type as the experiment progress from the state-independent to the state-dependent case.

Future Work:

- The amplitude, persistence, and spatial extent of the WWB appear to be enhanced by the coupling with the SST, it is not clear yet how this may affect these results.
- Study the impact of each individual components (i.e. amplitude, persistence, central latitude and longitude, and western and eastern extent), on the large scale fields.
- A new version of this model was recently released, CCSM4 , it has a more reasonable ENSO period. One future problem is to extend the study to this model.
- With this, we would be able to compare the effects of different parameter and different models as well.
- Analyze in more detail the ENSO predictability and prediction.

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