ENSO in the GFDL-FLOR CGCM: Impacts of Ocean/Atmosphere Formulation & Resolution

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1. Introduction

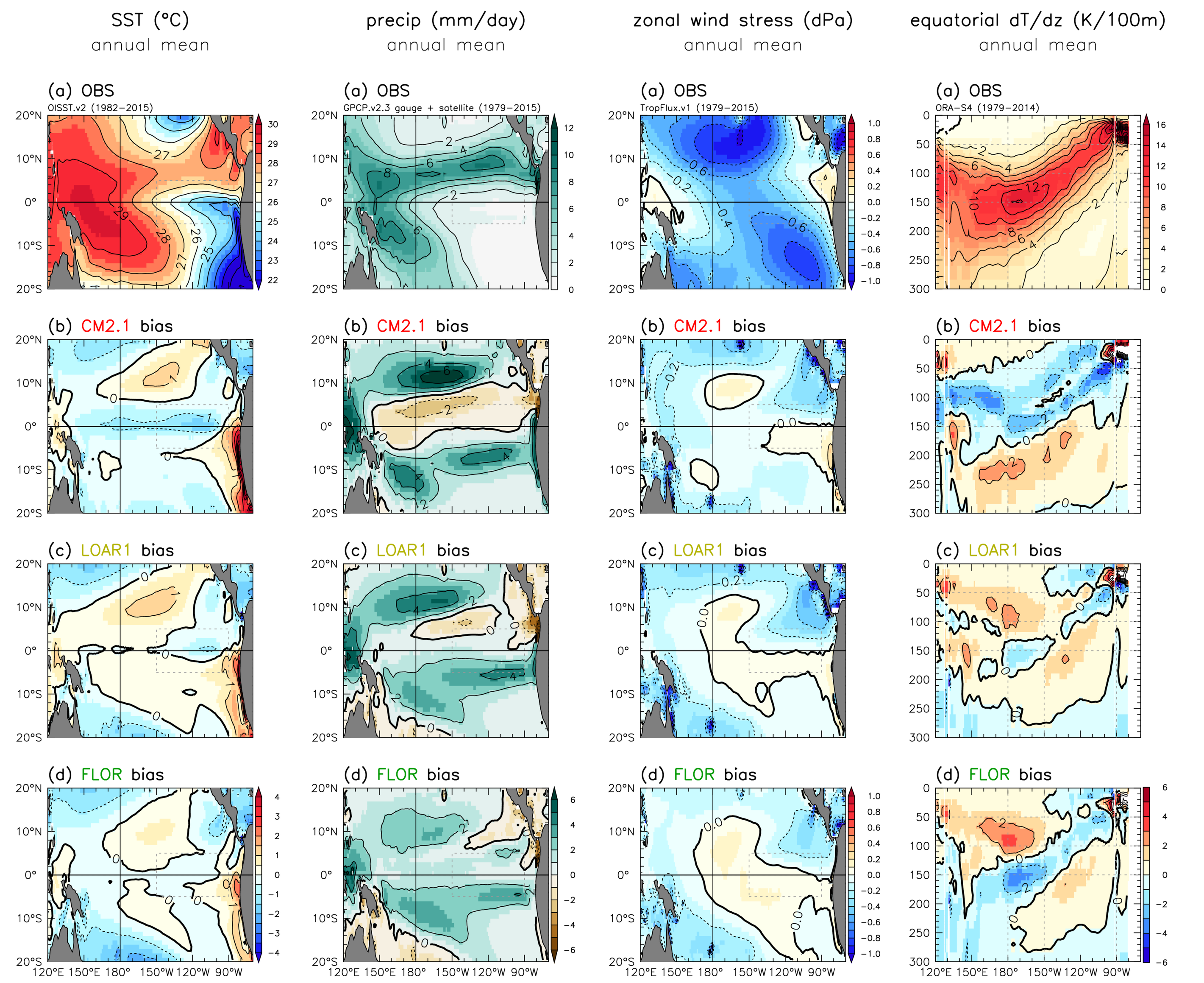
Using 1990-control runs from three of GFDL's global coupled GCMs, we explore sensitivities of the El Niño / Southern Oscillation (ENSO) to refined ocean/atmosphere physics and atmospheric horizontal resolution.

Coupled Model	Grid spacing (km): Δx × Δy	
	Atmosphere	Ocean 111 × (111-37)*
CM2.1	278 × 222	MOM4p0d
LOAR1	208 × 208	MOM5
FLOR	55 × 55	MOM5

*Ocean Δy telescopes from 111 km at 30°N/S, to 37 km at the equator.

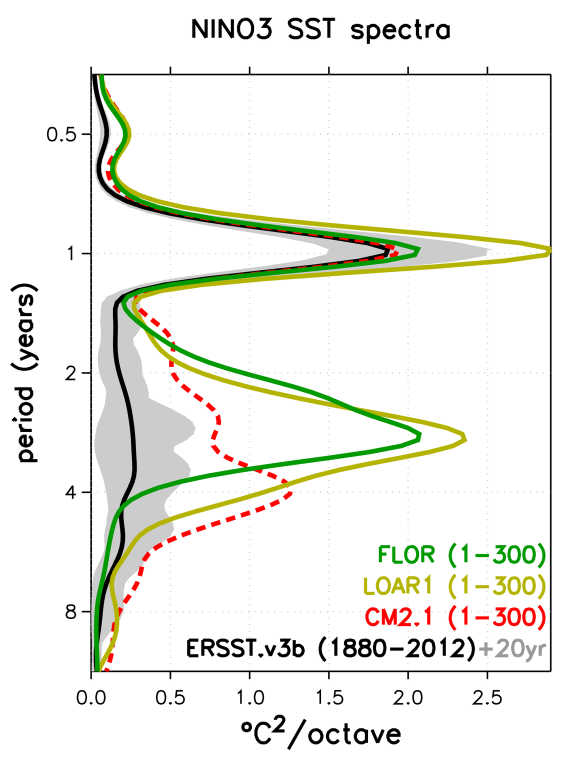
2. Climatological Context

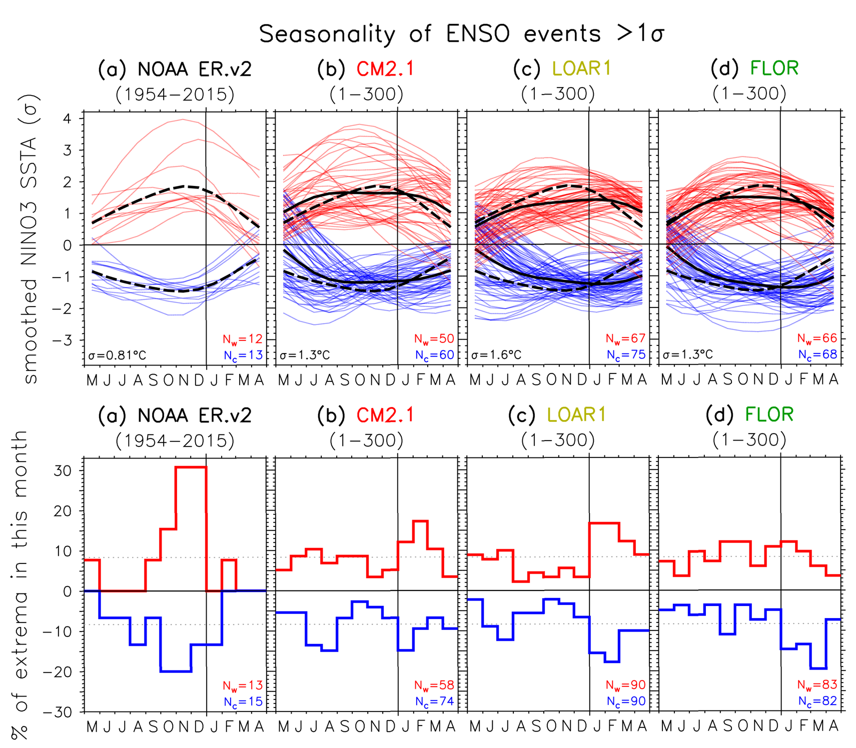
Both the refined ocean/atmosphere physics (CM2.1→LOAR1) and the refined atmospheric grid (LOAR1→FLOR) improve the annual-mean tropical Pacific climatology, greatly reducing the equatorial cold/dry bias, Peru coastal warm bias, double-ITCZ bias, and the overly strong equatorial trade winds in the west – and also boosting the upper-ocean thermal stratification in the central equatorial Pacific.



3. ENSO Spectrum, Seasonality, and Skewness

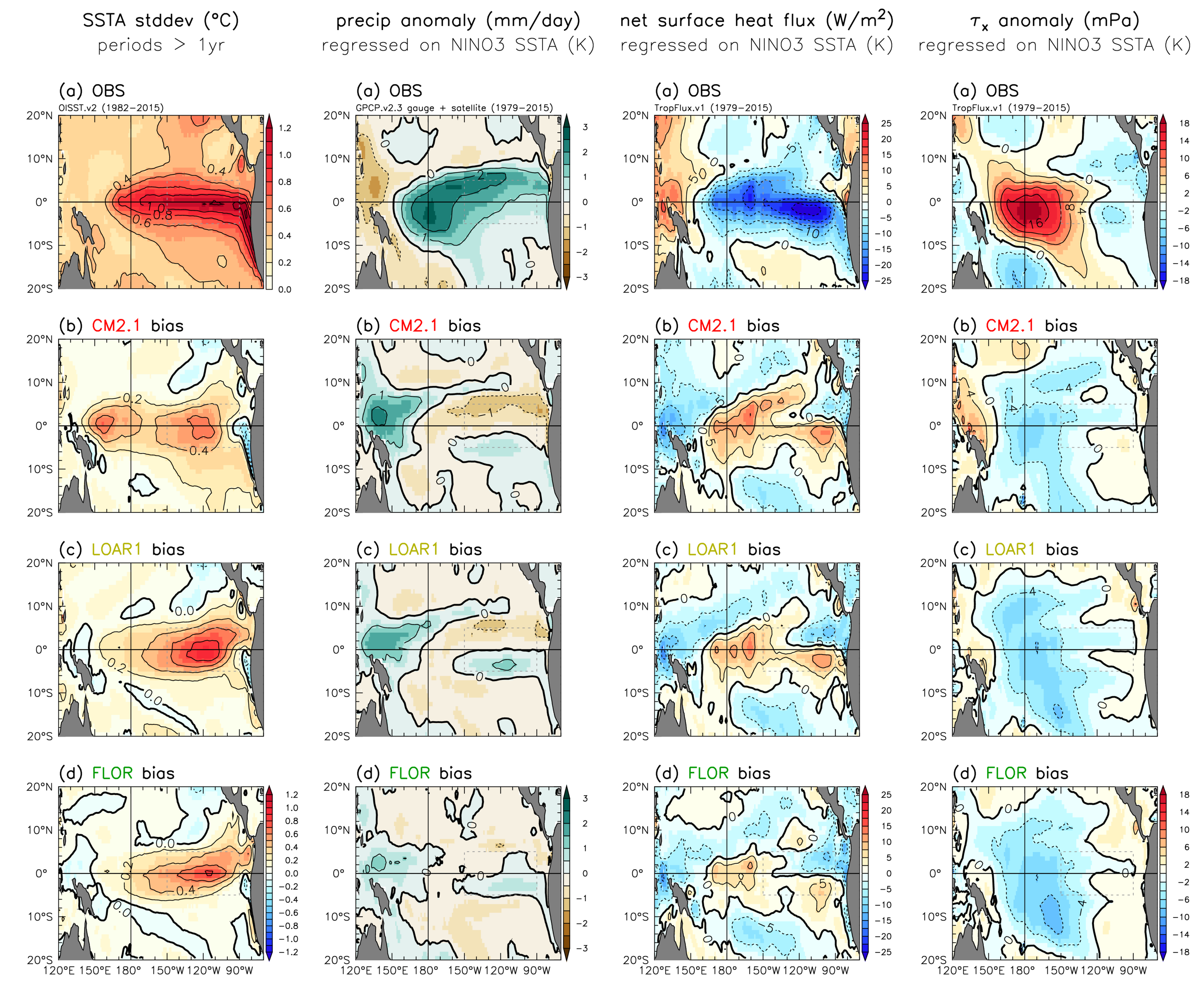
CM2.1's NINO3 (150°W-90°W, 5°S-5°N) SST anomalies (SSTAs) are too strong, but their spectrum and skewness are otherwise fairly realistic. LOAR1 & FLOR retain the excessive NINO3 SSTA variance, and also have a sharper spectral peak, shorter ENSO period, less skewness, and less diversity of amplitudes than observed. ENSO in all three models shows too little synchronization to the end of the calendar year, although FLOR improves slightly due to its reduced double-ITCZ bias.





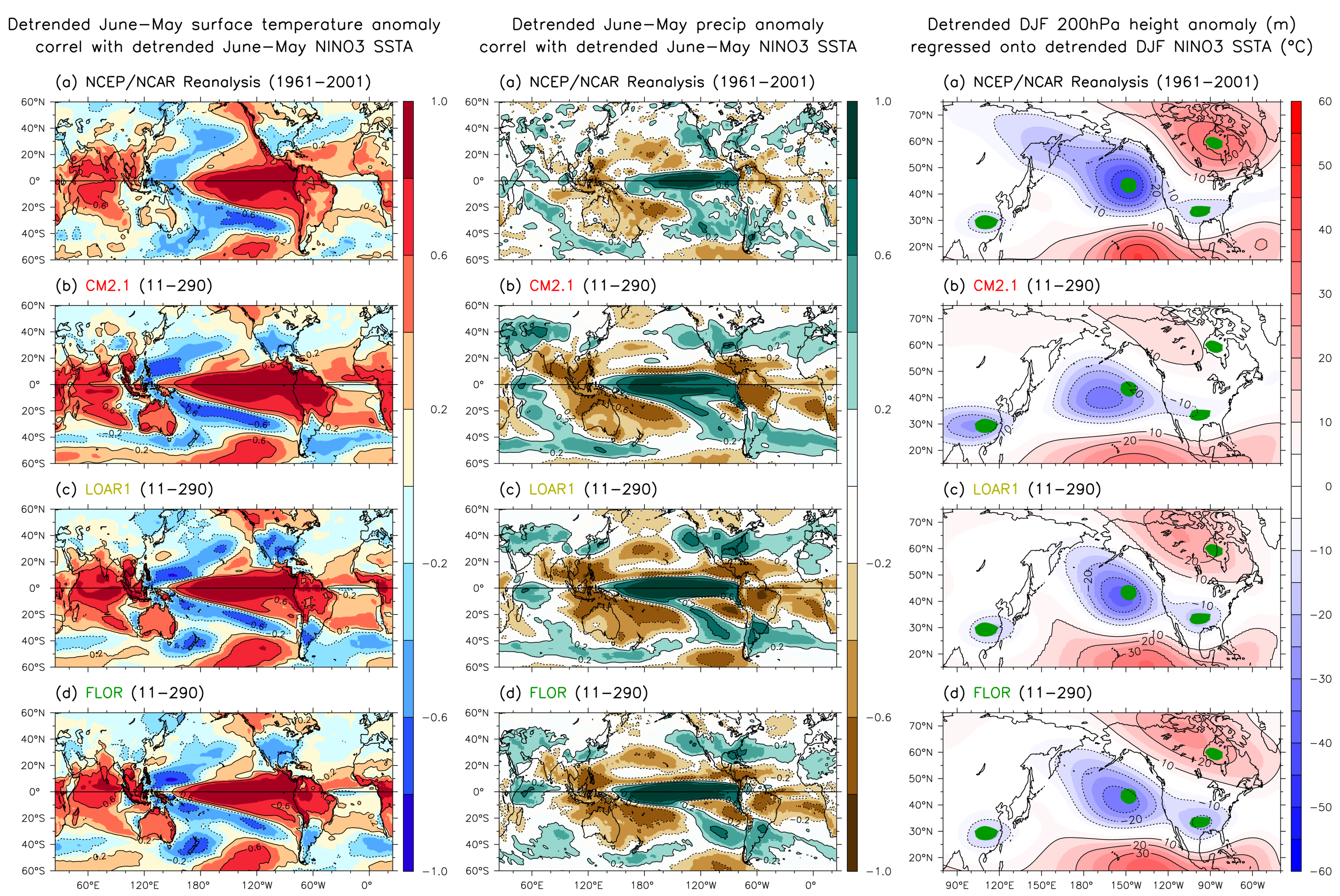
4. Tropical Pacific Patterns of ENSO

CM2.1's ENSO SST, rainfall, and wind stress anomaly patterns are displaced west of observations. LOAR1 & FLOR shift the SSTAs eastward, and also improve the rainfall response pattern and the net heat flux damping of SSTAs. Compared to obs or CM2.1, LOAR1 & FLOR show a westerly wind response to El Niño that is weaker and meridionally-narrower (especially on the southern flank) – which weakens their poleward discharge of equatorial ocean heat content during El Niño, and may help explain their shorter ENSO period.



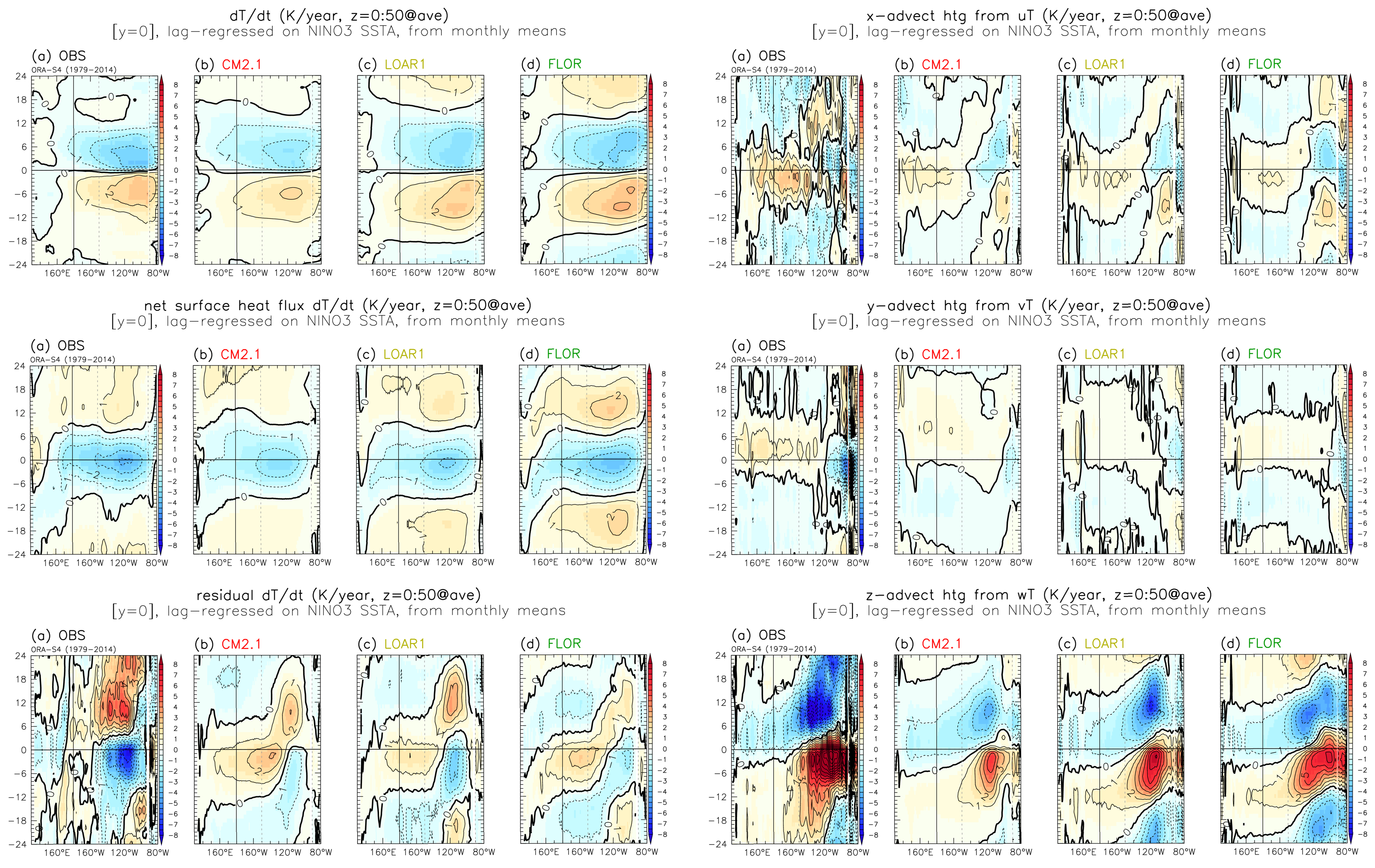
5. ENSO's Global Teleconnections

ENSO's global teleconnections improve in LOAR1 & FLOR – in particular the responses of **surface temperature** over the tropical continents, northeast Asia, Indian Ocean, and tropical South Atlantic; **rainfall** over Brazil, Indonesia, southern Africa, and the Middle East; and **200hPa geopotential heights** over North America, East Asia, and the North Pacific. These signals benefit from the greater eastward shift of the ENSO rain response in LOAR1 & FLOR, and from FLOR's improved storm tracks & global topography.

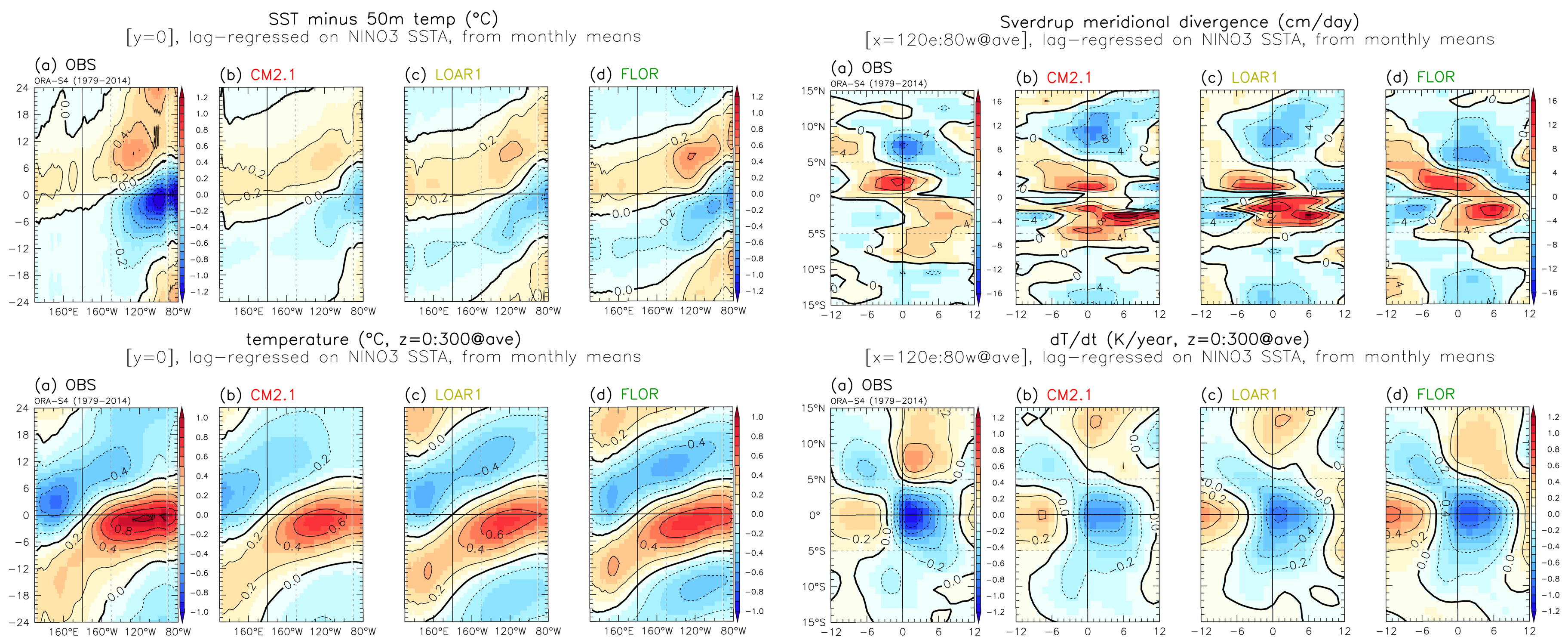


6. ENSO Mechanisms

Compared to obs and CM2.1, the ENSO events in LOAR1 & FLOR are more tightly linked in time, leading to a shorter period and sharper spectrum. While LOAR1 & FLOR both have stronger surface heat flux damping than CM2.1, this is trumped by stronger subsurface vertical advective feedbacks that amplify ENSO and pull its SSTAs eastward. Surprisingly, all three models actually show too *little* SSTA amplification from vertical & zonal advection on monthly and longer time scales. However, the residual effects of diffusion and submonthly eddy advection are also too weak – presumably due to the coarse ocean grid in these models, which inhibits the simulation of strong tropical instability waves (TIWs). The obs indicate that this residual is an important damping term, both during El Niño (when the TIWs and their equatorward heat transport weaken), and at La Niña onset (when strong TIWs slow the warm-to-cold transition, via enhanced equatorward heat transport that compensates much of the cooling from monthly vertical advection). The underestimate of these high-frequency residual effects likely contributes the excessive amplitude, short period, and weak SSTA skewness of ENSO in the models.



Compared to CM2.1, the thermocline feedback in LOAR1 & FLOR is enhanced by stronger subsurface temperature fluctuations – which are driven by both stronger east Pacific thermocline depth anomalies (h) and increased sensitivity of the SSTAs to h via an intensified thermocline. The stronger h is caused not by the *equatorial* wind anomalies (which are very similar among the simulations), but by enhanced *off-equatorial* surface wind stress curl – which generates a stronger delayed meridional Sverdrup recharge & discharge of equatorial heat content, leading to greater overshoot from the previous event. An enhanced Ekman upwelling feedback further amplifies ENSO in FLOR, due to stronger upwelling fluctuations and stronger upper-ocean thermal stratification.



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