In pure Academic interest, I have made a simple coupled model for ENSO purely relying on delayed oscillator theory and Bjerknes feedback. The ocean model is a linear one-layer thermocline with baroclinic speed set to 3m/sec. It produces the first baroclinic mode Kelvin-Rossby waves in response to the wind forcing. The atmospheric model contains one layer of dry atmosphere with wind represented as wind stress. The wind stress contains two parts: a mean wind stress and an anomalous wind stress. The anomalous part evolves in time, coupling with the thermocline gradients calculated apart at a length scale which exceeds the characteristic scale of motion of the Equatorial beta plane. The zonal and meridional wind stress anomalies are modelled within ±10 degrees on either side of the equator. Elsewhere, it is zero.

To generate the non-linearity, the wind stress anomaly is allowed to fully evolve wherever the thermocline anomalies are positive, mimicking sst-induced wind convergence leading to atmospheric heating. Wherever the thermocline shoals below a threshold, the wind stress anomalies are linearly damped, mimicking a diverging wind is not generating heating in the atmosphere. This heuristic argument is okay and not a serious violation.

The ocean model is initially forced with a mean and constant zonal wind stress within +/-5 degrees with respect to the equator for one month and then switched off. Thereafter the wind stress anomalies grow on its own via coupling with the ocean thermocline gradient and the Bjerknes feedback.

When the model is continued for 100 years run with suitable coupling parameters, the model generates non-linear evolution of El Nino and La Nina. An attached figure indicates composite El Nino and La Nina thermocline anomalies generated by the model and the corresponding model wind stress anomalies. The typical features mimic the observed ENSO features. The location of Nino-3 anomalies is well simulated in the model.

Its a nice learning tool for students on fundamentals of coupling in Tropical Ocean-Atmosphere dynamics. The model code is just one program and runs in desktop computers. It can run 100 years in just two-three minutes.

The ENSO coupled model

Atmosphere.

$$\tau_x = \tau_{xM} + C_x A_x\, e^{-\left\{\frac{\left(y-\frac{LAT}{2}\right)^2}{L_Y}\right\}} \left(h\left(x+\frac{LON}{B}\right) - h\left(x-\frac{LON}{B}\right)\right) \quad (1a)$$

$$\tau_y = \tau_{yM} + C_y A_y\, e^{-\left\{\frac{\left(y-\frac{LAT}{2}\right)^2}{L_Y}\right\}} \left(h\left(y+\frac{LAT}{B}\right) - h\left(y-\frac{LAT}{B}\right)\right) \quad (1b)$$

Ocean.

$$u_t - \beta y v = -\frac{g'}{\rho_0} h_x + A_M\left(u_{xx} + u_{yy}\right) + \tau_x \quad (2a)$$

$$v_t + \beta y u = -\frac{g'}{\rho_0} h_y + A_M\left(v_{xx} + v_{yy}\right) + \tau_y \quad (2b)$$

$$h_t = -H\left(u_x + v_y\right) + A_H\left(h_{xx} + h_{yy}\right) \quad (2c)$$

Coupling and model Parameters.

$$\sqrt{g'H} = 3\, ms^{-1}; LON = 180^0\ ;\ LAT = 120^0; \quad (3a)$$

$$\Delta x = 1^0\ ; \Delta y = 0.5^0\ ;\ H = 100m \quad (3b)$$

$$A_x = 1 \times 10^{-3}\ \frac{kg}{ms^2};\ A_y = 0.5 \times 10^{-4}\frac{kg}{ms^2}; \quad (3c)$$

$$L_Y = 50^0;\ B = 8\ ; A_M = 10^3\frac{m^2}{s};\ A_H = 10^3\frac{m^2}{s} \quad (3d)$$

$$-5 < h - H \leq +\alpha\ ; C_x = 1.0;\ C_y = 1.0 \quad (3e)$$

$$-10 < h - H \leq -5\ ; C_x = 0.5;\ C_y = 0.3 \quad (3f)$$

$$-30 < h - H \leq -10\ ; C_x = 0.2;\ C_y = 0.0 \quad (3g)$$

$$-\alpha < h - H \leq -30\ ; C_x = 0.0;\ C_y = 0.0 \quad (3h)$$

Initial Forcing.

$$0 \leq t \leq 30\ days;\ -5^0 < y < 5^0\ ;\ \tau_{xM} = 0.025\frac{N}{m}\ ;\ \tau_{yM} = 0 \quad (4a)$$

$$30\ days < t \leq \alpha;\quad \tau_{xM} = 0\ ;\ \tau_{yM} = 0 \quad (4b)$$

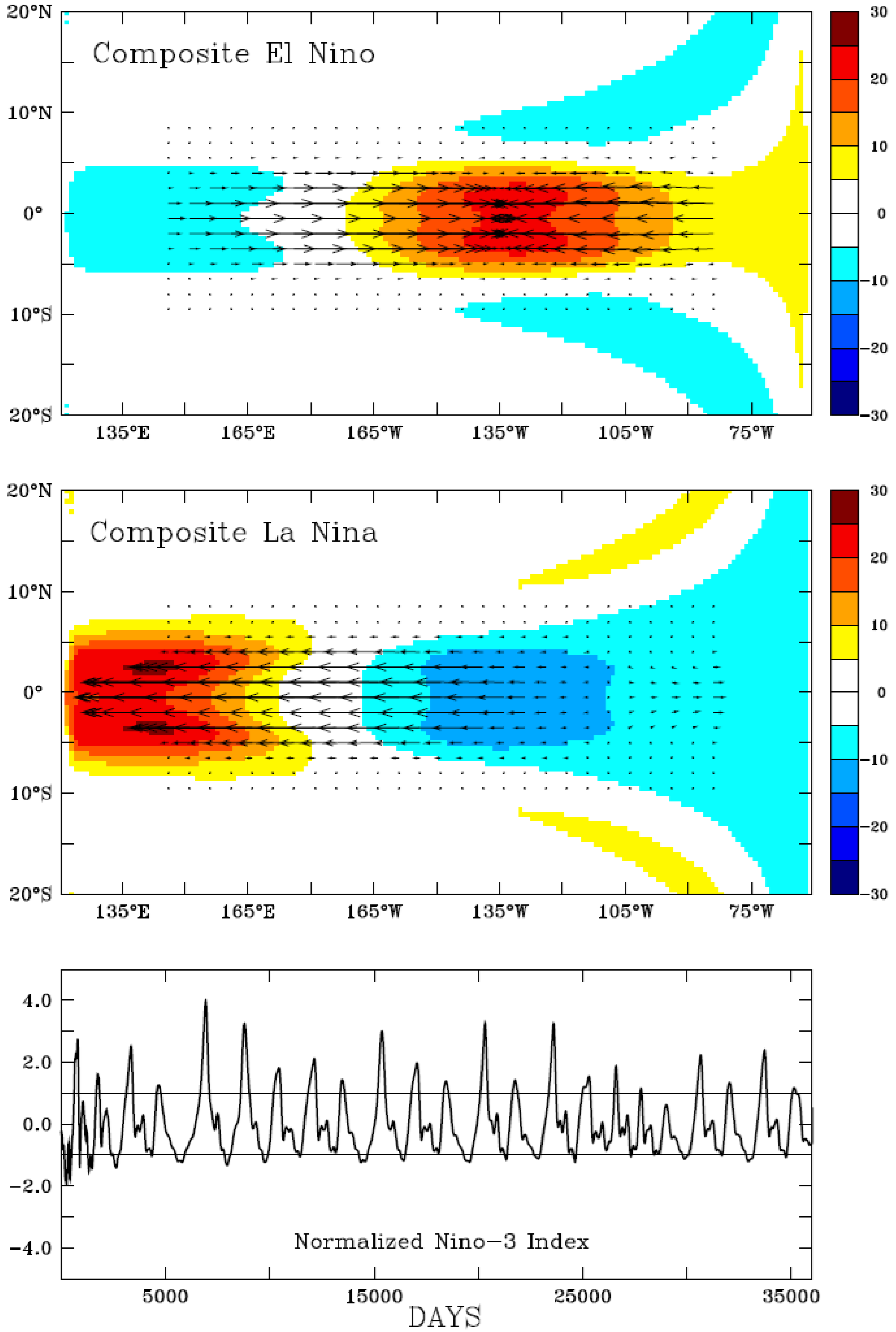

Figure 1: 100-year output of the model. (top panel) Model thickness anomaly and wind-stress anomalies of composite El Nino. (middle) Same as top-panel but for La Nina. (bottom) Normalized Nino-3 index of thickness anomalies.