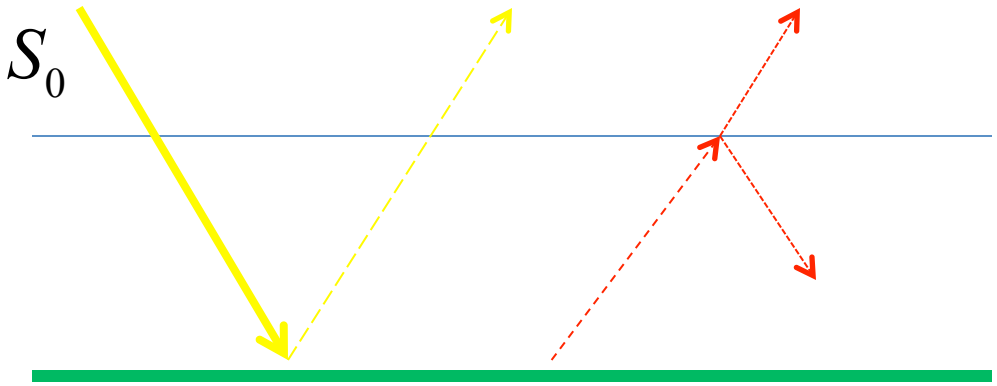
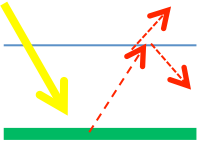
EBM BM RMA PM ICM GCM CM ESM

Energy Balance Model

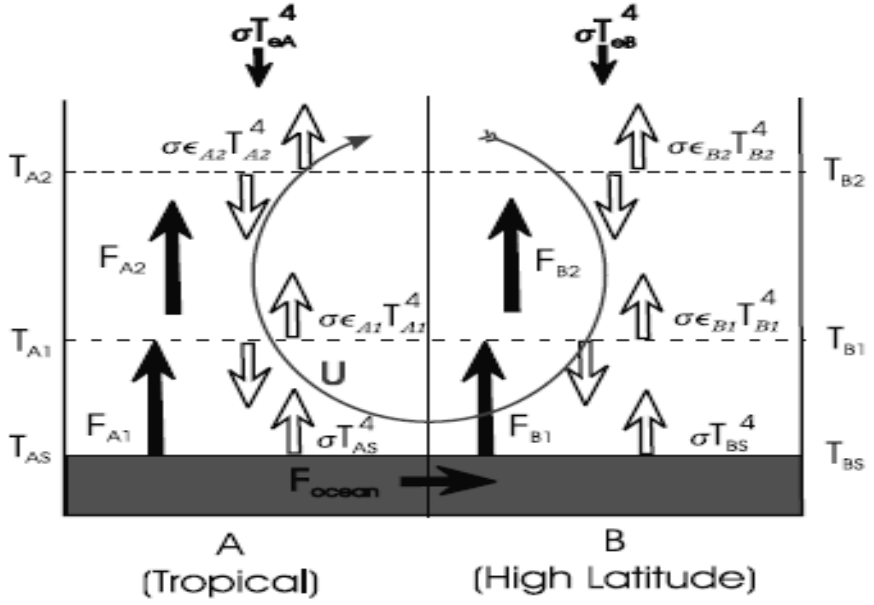


$$cT_t = \left(1 - \alpha(T)\right)\frac{S_0}{4} - \varepsilon\sigma T^4$$

EBM BM RMA PM ICM GCM CM ESM



Box Model



Emmanuel (2002) JGR

$$\frac{\partial T_{A2}}{\partial t} = -2\varepsilon_{A2}T_{A2}^4 + \varepsilon_{A2}\varepsilon_{A1}T_{A1}^4 + \varepsilon_{A2}(1-\varepsilon_{A1})T_{AS}^4 + F_{A2} \quad \text{(A1)}$$

$$\frac{\partial T_{A1}}{\partial t} = -2\varepsilon_{A1}T_{A1}^4 + \varepsilon_{A2}\varepsilon_{A1}T_{A2}^4 + \varepsilon_{A1}T_{AS}^4 + F_{A1} - F_{A2} - U(T_{A2} - T_{B1} + \Gamma) \quad \text{(A2)}$$

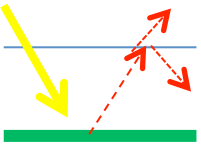
$$\chi\frac{\partial T_{AS}}{\partial t} = 1 + \varepsilon_{A1}T_{A1}^4 + \varepsilon_{A2}(1-\varepsilon_{A1})T_{A2}^4 - T_{AS}^4 - F_{A1} - F_O \quad \text{(A3)}$$

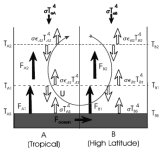
$$\frac{\partial T_{B2}}{\partial t} = -2\varepsilon_{B2}T_{B2}^4 + \varepsilon_{B2}\varepsilon_{B1}T_{B1}^4 + \varepsilon_{B2}(1-\varepsilon_{B1})T_{BS}^4 + F_{B2} + U(T_{A2} - T_{B2}) \quad \text{(A4)}$$

$$\frac{\partial T_{B1}}{\partial t} = -2\varepsilon_{B1}T_{B1}^4 + \varepsilon_{B2}\varepsilon_{B1}T_{B2}^4 + \varepsilon_{B1}T_{BS}^4 + F_{B1} - F_{B2} + U(T_{B2} - T_{B1} + \Gamma) \quad \text{(A5)}$$

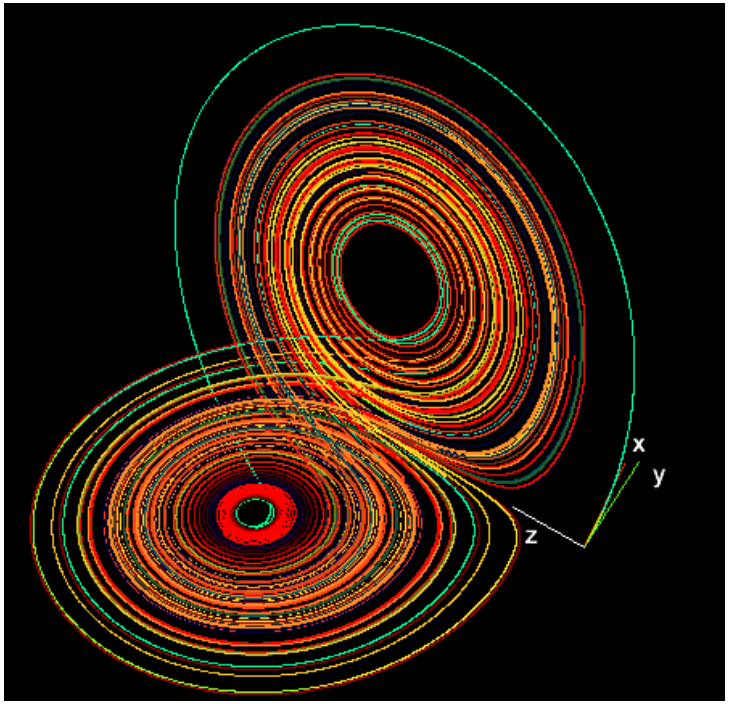
$$\chi\frac{\partial T_{BS}}{\partial t} = T_{eB}^4 + \varepsilon_{B1}T_{B1}^4 + \varepsilon_{B2}(1-\varepsilon_{B1})T_{B2}^4 - T_{BS}^4 - F_{B1} - F_O. \quad \text{(A6)}$$

EBM BM RMA PM ICM GCM CM ESM





Reduced Mode Approximation



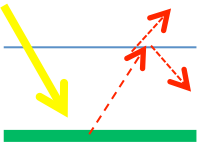
$$\dot{x} = \sigma(y - x)$$

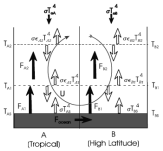
$$\dot{y} = x(\rho - z) - y$$

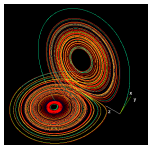
$$\dot{z} = xy - \beta z$$

Lorenz 63

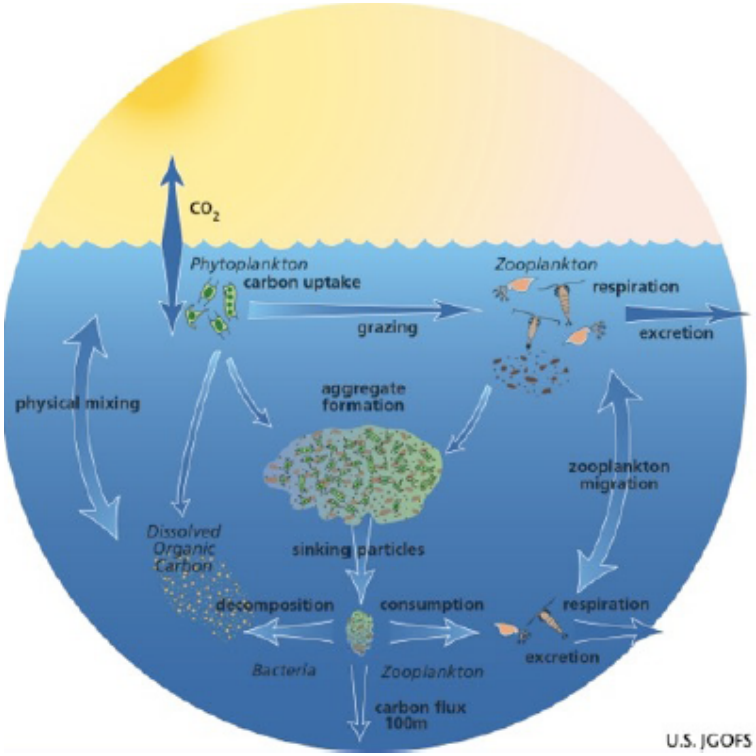
EBM BM RMA PM ICM GCM CM ESM







Process Model



$$DN/Dt = -P_{growth}(light, N, P) + R_{\text{remineralization}}$$

$$DP/Dt = +P_{growth}(light, N, P)$$

$$-Z_{growt}(P, Z) - sinking - mortality$$

$$DZ/Dt = Z_{growth}(P, Z)$$

$$-detritus formation - mortality$$

$$DD/Dt = detritus formation - R_{\text{remineralization}}$$

A. Mahadevan (NCAR talk, 2010)

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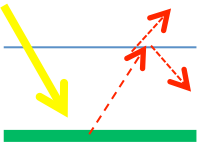
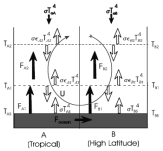
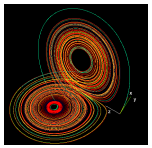
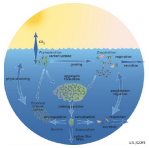
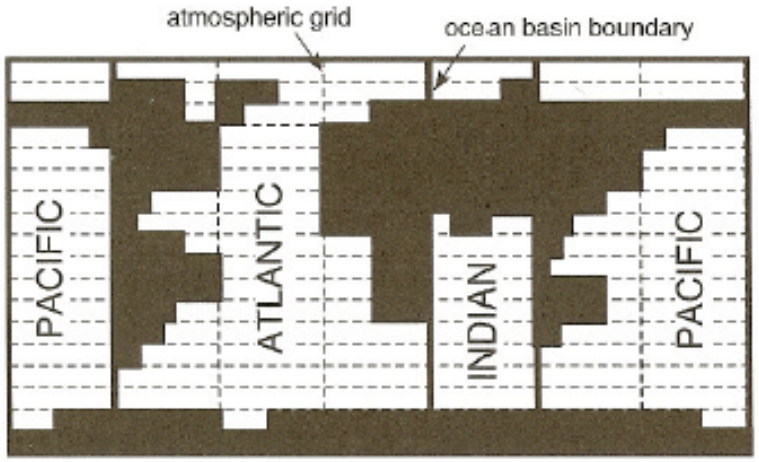
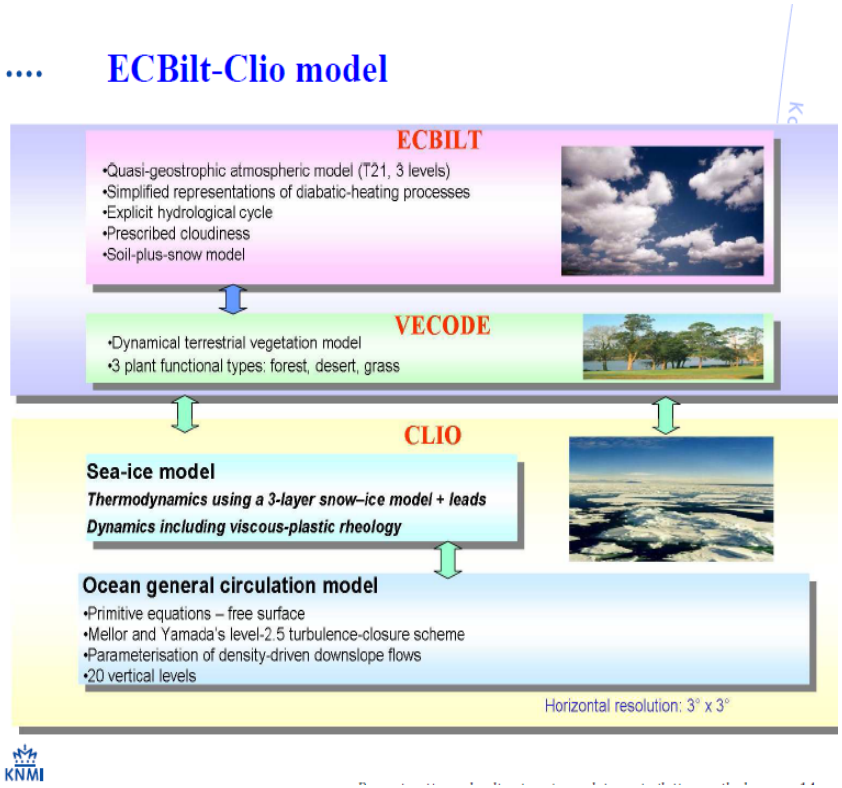





Intermediate Complexity Model

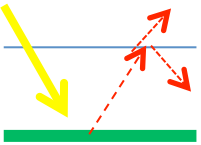


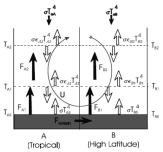
Climber-2 (PIK)

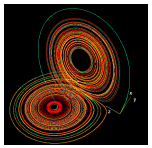


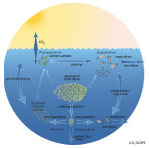
KNMI (The Netherlands)

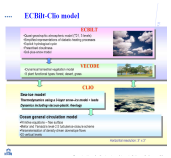
EBM BM RMA PM ICM GCM CM ESM



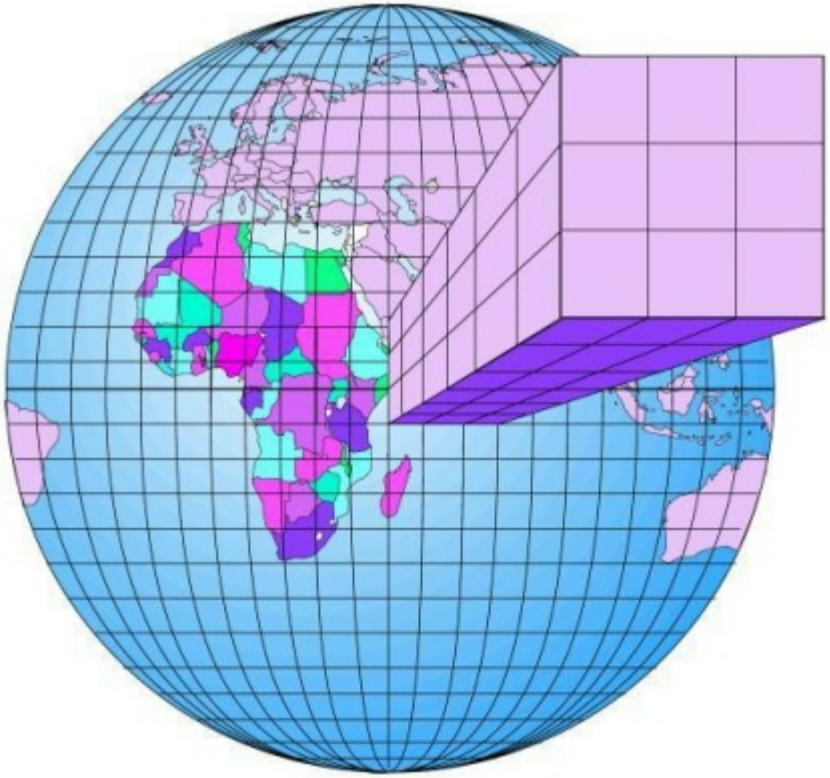




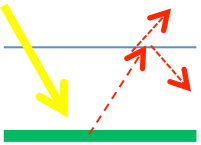


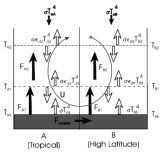


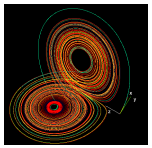
General Circulation Model

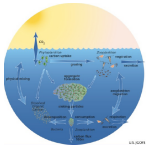


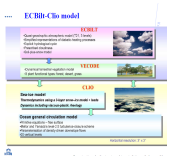
EBM BM RMA PM ICM GCM CM ESM

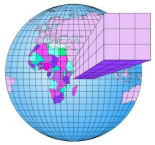




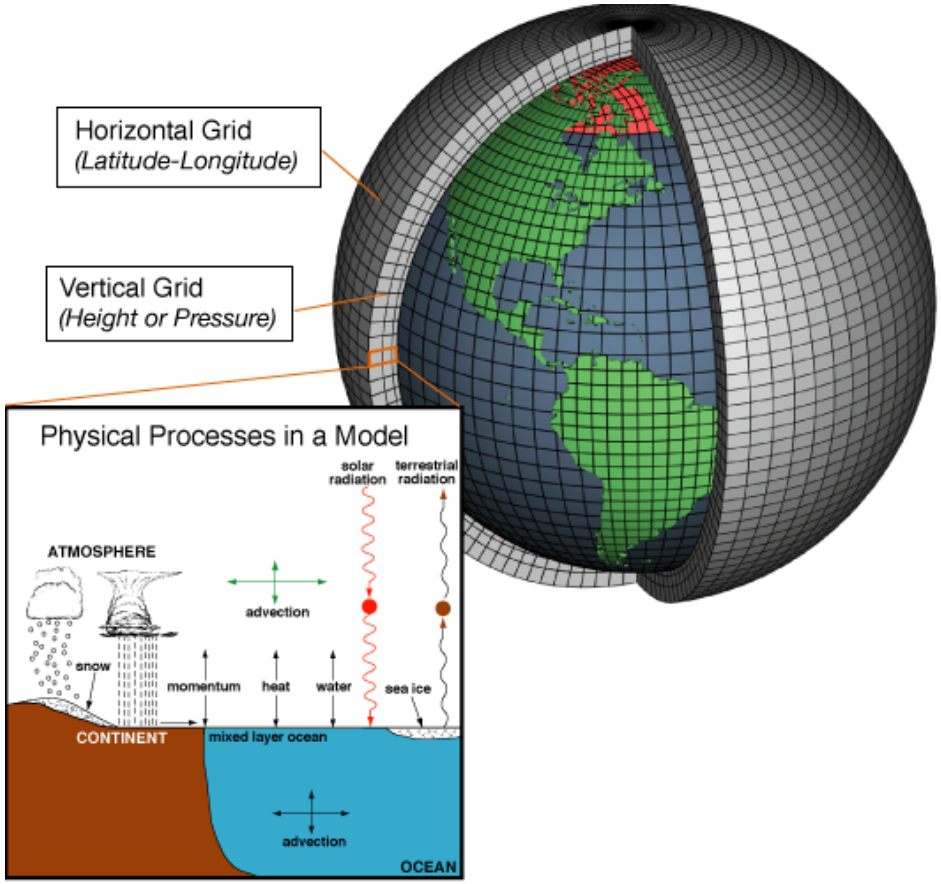




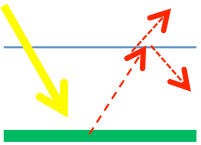


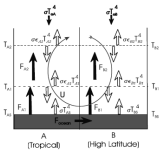


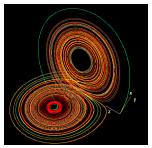
Climate Model

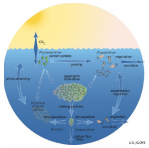


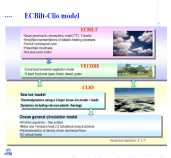
EBM BM RMA PM ICM GCM CM ESM

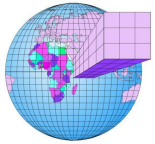


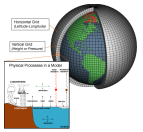




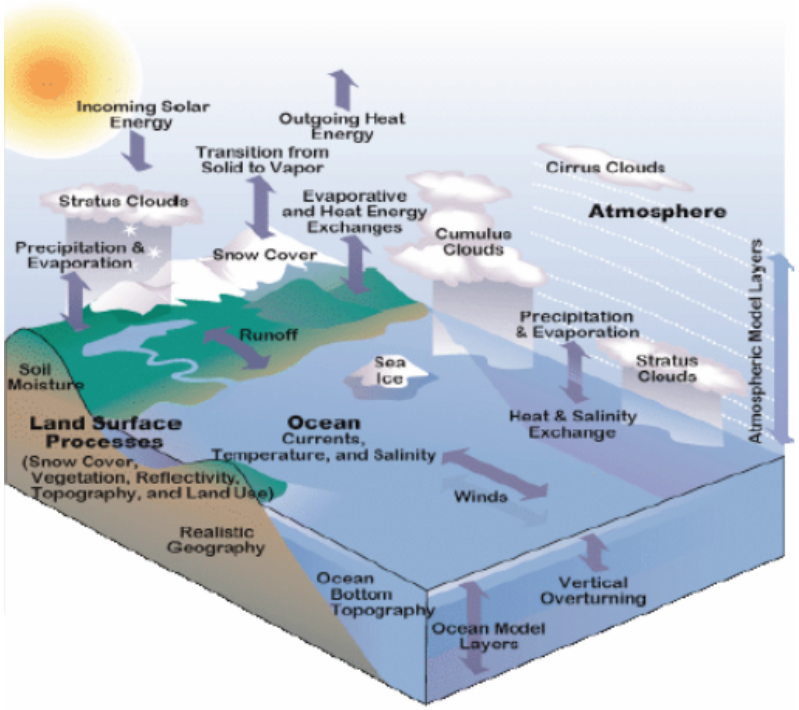




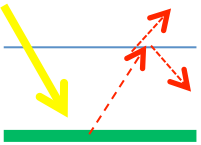
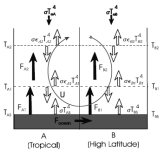


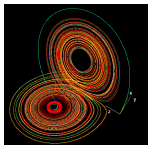
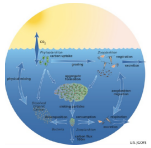
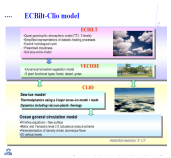


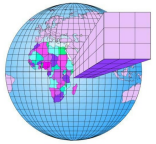
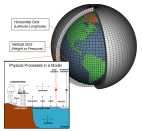
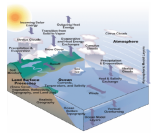
Earth System Model



EBM BM RMA PM ICM GCM CM ESM

General Circulation Model/Climate Model/Earth System Model