OA413 : Climate Dynamics Assignment No. 3

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Problem III.1: 2-box model

a) What steady-state solutions are possible in the 2-box model of the thermohaline circulation (THC) discussed in class if the flow field is prescribed as an external parameter (that is, assumed independent of density; it depends neither on temperature nor on salinity)? *Hint:* Plot the salinity difference as a function of freshwater forcing, with q given and constant. [20%]

b) Suppose now that the surface heat and salt fluxes are formulated as restoring laws, as originally done by Stommel, i.e., the equations are

$$\dot{T}_1 = \lambda_T \left(T_1^* - T_1\right) + |q|\left(T_2 - T_1\right), \quad (1)$$

$$\dot{T}_2 = \lambda_T \left(T_2^* - T_2\right) - |q|\left(T_2 - T_1\right), \quad (2)$$

$$\dot{S}_1 = \lambda_S \left(S_1^* - S_1\right) + |q|\left(S_2 - S_1\right), \quad (3)$$

$$\dot{S}_2 = \lambda_S \left(S_2^* - S_2\right) - |q|\left(S_2 - S_1\right), \quad (4)$$

where overdot marks the time-derivative and the starred quantities are the target values. The flow strength, q, is given, as before, as

$$q = k\left[\rho_1 - \rho_2\right] = k\left[\alpha\left(T_2 - T_1\right) - \beta\left(S_2 - S_1\right)\right]. \quad (5)$$

Assume now that $\lambda_T = \lambda_S$ and construct, from (5) and (1) – (4), a single ordinary differential equation for q. What are the physically meaningful steady-state solutions now? Discuss qualitatively what would change if $\lambda_T \neq \lambda_S$. [60%]

c) What do a) and b) tell us about what makes multiple equilibria of the THC possible? [20%]