Oceland: A conceptual model for ocean-land-atmosphere interactions based on water balance equations

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ABSTRACT: Enter the text of your abstract here.

1. Introduction

2. Model description

a. Design goals

Conceptual models do not try to explain natural processes in an exact, quantitative manner. Rather, they aim at helping us understand the dominant physical relationships that give rise to a certain natural phenomenon. These dominant factors often get modulated and thereby obscured by a plethora of complex processes acting simultaneously in the real world and are therefore difficult to disentangle in observations or output of sophisticated climate models. Conceptual models can provide clarity at the expense of realism and with the danger of missing out on relevant physical processes. The successful development of a conceptual model is therefore an iterative process that begins with the most basic assumptions and ends when the "model is only as elaborate as it needs to be to capture the essence of a particular source of complexity, but is no more elaborate than this", as Held (2005) puts it. It is our hope that the proposed model of this study meets this balance and that the assumptions and choices we made in the model development process become clear.

- simplicity over realism (–> for versatile application and easier understanding)
- BUT: based on fundamental conservation laws
- where more complexity is needed: parametrizations based on established empirical relationships

b. Closed model setup

We propose a 2D box model as sketched in Figure [*****], which consists of an ocean and a land domain. Each domain contains a ground box at the bottom and an atmospheric box aloft. However, this spatial arrangement is only reflected in so far as we are interested in the water fluxes crossing the boundaries between boxes. Model output will not be computed for each

- box model, no spatial dimension resolved (?)
- type of fluxes, land fraction, domain size, pseudo-wind
- closed vs open

c. *Water balance equations*

To a good approximation, the total amount of water is conserved within the tropical band. If we further assume that the mean water holding capacity of the atmosphere does not vary significantly over time, we can apply these properties of the tropics to our model and formulate a set of coupled differential equations that describe the rate of change of the water content in each of our model boxes. As we assume the water content in the ocean to be constant in time, the number of equations reduces by one and we are left with the following expressions for the changes in soil moisture saturation and land and ocean mean water vapour passes:

$$\frac{ds}{dt} = \frac{1}{nz_\mathrm{r}}\left[P(w_\mathrm{l}) - R(s, w_\mathrm{l}) - E(s)\right] \tag{1}$$

$$\frac{dw_\mathrm{l}}{dt} = E(s) - P(w_\mathrm{l}) + A_\mathrm{l}(w_\mathrm{l}, w_\mathrm{o}) \tag{2}$$

$$\frac{dw_\mathrm{o}}{dt} = e_\mathrm{o} - P(w_\mathrm{o}) + A_\mathrm{o}(w_\mathrm{l}, w_\mathrm{o}). \tag{3}$$

Precipitation P, runoff R, evapotranspiration E and advection terms A_l and A_o are the four dominant types of water exchange between ocean, land and atmophseric boxes and are expressed as mean water flux rates in mm/day. The flux rates are functions of the state variables as explained in more detail in the next section. Ocean evaporation rate w_o [mm/day], dimensionless soil porosity n and hydrologically active soil depth z_r [mm] are constant parameters of the system.

d. *Parametrizations*

While the conservation of water is a rather fundamental condition, there are no simple, fundamental laws governing the water fluxes between the model boxes. Instead, we need to draw inspiration from existing literature that provides empirical relationships between the flux quantities and our model state variables.

Bretherton et al. (2004)

- mathematical expressions

- table with values that define the parameter space *e. Assumptions*

- same function for precipitation over land and ocean
- fluxes between boxes are characterized by mean moisture contents
- uniform (mean) soil type
- uniform drainage of runoff across land box
- uniform pseudo-wind

3. Evaluation methods

- equilibrium solution
- Monte Carlo sampling
- scatter plot analysis

4. Closed model behavior/results

- general features of the model behaviour (introduce the reader to how the model behaves, e.g. with state plot or fluxes as function of certain parameters)

a. PR < 1

- runoff as a characteristic property of the land
- compensation of runoff through advection (together with our way to parametrise precipitation) demands a moister atmosphere over ocean than over land –> PR <1

b. Parameter sensitivity

- land fraction - the smile
- spatial scaling u/L - how advection makes the equilibrium states scale-dependent
- permanent wilting point - the soil type matters

5. Open model formulation

a. Open model equations

b. Open model results

- How the open model relaxes the condition that PR<1 (PR>1 only under certain conditions)
- The role of synoptic moisture conditions in the atmosphere
- Transforming the open model into the closed model

6. Discussion and summary

- Which conditions need to be met to end up with a precipitation ratio larger one?
- What are possible use cases for the models?
- What can the model(s) tell us and what not and why? (e.g. land distribution not representative for the Tropics)

Acknowledgments.

Data availability statement.

References

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