EN-ROADS SIMULATOR REFERENCE GUIDE
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https://www.climateinteractive.org/wp-content/uploads/2021/03/En-ROADS_Reference_Guide_030321.pdf

8. Carbon cycle
8.1.1 Introduction

Other models in current use include simple carbon cycle representations. Nordhaus' DICE models, for example, use simple ***first- and third-order linear models*** (Nordhaus, 1994, 2000). The ***first-order model*** is usefully simple, but does not capture nonlinearities (e.g., sink saturation) or explicitly conserve carbon. The ***third-order model*** conserves carbon but is still linear and thus not robust to high emissions scenarios. More importantly for education and decision support, neither model provides a recognizable carbon flow structure, particularly for biomass.

8.1.2 Structure

The Goudriaan and Ketner and IMAGE models (Goudriaan and Ketner, 1984; Rotmans, 1990) have detailed biospheres, partitioned into leaves, branches, stems, roots, litter, humus, and charcoal. To simplify the model, these categories are aggregated into stocks of biomass (leaves, branches, stems, roots) and humus (litter, humus). Aggregate ***first-order time constants*** were calculated for each category on the basis of their equilibrium stock-flow relationships.

8.2 Other greenhouse gases
8.2.1 Other GHGs included in CO2equivalent emissions

En-ROADS explicitly models other well–mixed greenhouses gases, including methane (CH4), nitrous oxide (N2O), and the fluorinated gases (PFCs, SF6, and HFCs). PFCs are represented as CF4-equivalents due to the comparably long lifetimes of the various PFC types. HFCs, on the other hand, are represented as an array of the nine primary HFC types, each with its own parameters. The structure of each GHG's cycle reflects ***first order dynamics,*** such that the gas is emitted at a given rate and is taken up from the atmosphere according to its concentration and its time constant.

9. Climate
9.2 Structure

The model climate is a ***fifth-order,*** linear system, with ***three negative feedback loops.*** Two loops govern the transport of heat from the atmosphere and surface ocean, while the third represents warming of the deep ocean. Deep ocean warming is a slow process, because the ocean has such a large heat capacity. If the deep ocean temperature is held constant, the response of the atmosphere and surface ocean to warming is ***first-order.*** (Page 343)

9.4 pH

Figure 9-5 shows the structure of the pH sector of C-ROADS, which reflects the empirical function presented by Bernie et al. (2010). Variable definitions and equations are presented in Table 9-5. As the atmospheric concentration in the atmosphere increases, the pH of the ocean decreases by a ***third order response.*** Figure 9-6 depicts the historical pH and projected pH for the default RS and the four RCP scenarios.