Climate Change Content in Math 225: Introduction to Ordinary Diferential Equations

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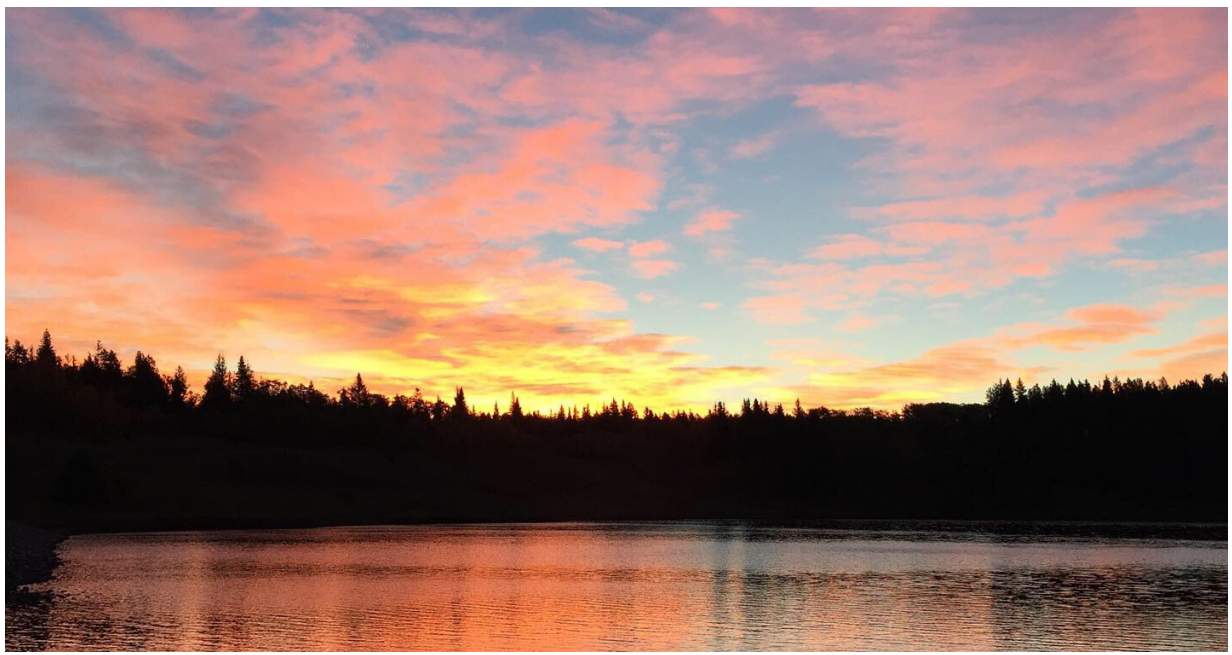
UBC Okanagan

Thanks

- UBC Sustainability Climate Education Grant
  "Mathematical Models of Climate Change: How do they work?"
- CMPS Department TA support
- Syilx Okanagan Nation



Goal

- Address the aphorism "all models are wrong, but some are useful" (Box, 1979)
  - **Main Goal**: That students are able to defend the validity and importance of mathematical climate models
  - **Method**: Make climate change modelling an important focus of the course

Format

- Main components (all marked):
  - reflection quiz
  - several in-person group work projects done in tutorial
  - closing quiz
- New this year:
  - invited speaker: Climate science (UBC scholar - Balsher Singh Sadhu)
  - invited speaker: Climate adaptation (City of Kelowna)
  - two reflection assignments (one for each speaker)

Compost Bomb: Introduction

Climate Change Group Work #3: Second Order ODEs
Soil carbon and climate change: from the Jenkinson effect to the compost-bomb instability

From Luke (2010) and Wieczorek (2010):

$$\overbrace{\mu \frac{dT_S}{dt}}^{\text{soil temperature}} = \overbrace{A \cdot R_S}^{\text{heat gain from soil respiration}} - \overbrace{\lambda(T_S - T_a)}^{\text{soil-to-air heat transfer}} , \qquad (1a)$$

$$\underbrace{\frac{dC_S}{dt}}_{\text{soil carbon}} = \underbrace{\Pi}_{\text{carbon production}} - \underbrace{C_S r_S \exp[\alpha(T_S - T_{ref})]}_{\text{soil respiration}} . \qquad (1b)$$

Compost Bomb: Code

1. Check to make sure that the model equations are properly coded in the file "CompostBombEqs.m". Correct any errors you find. Write down the lines where you found errors in the space below.

$$\mu \frac{dT_S}{dt} = A \cdot R_S - \lambda(T_S - T_a), \tag{2a}$$

$$\frac{dC_S}{dt} = \Pi - C_S r_S \exp[\alpha(T_S - T_{ref})] \tag{2b}$$

Compost Bomb: Results

2. Under warming, we expect the system to be subject to increased temperatures. We also know that some soils have more carbon in them than others. We'll investigate several different initial conditions. Provide a plot or sketch of the solution in each case.

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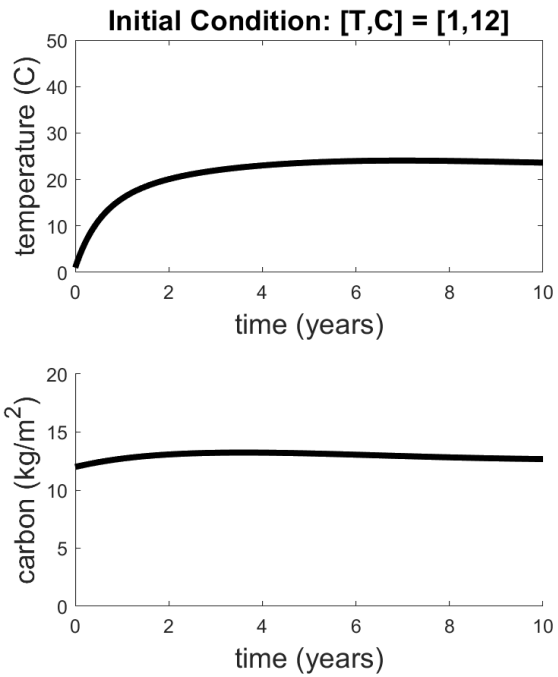

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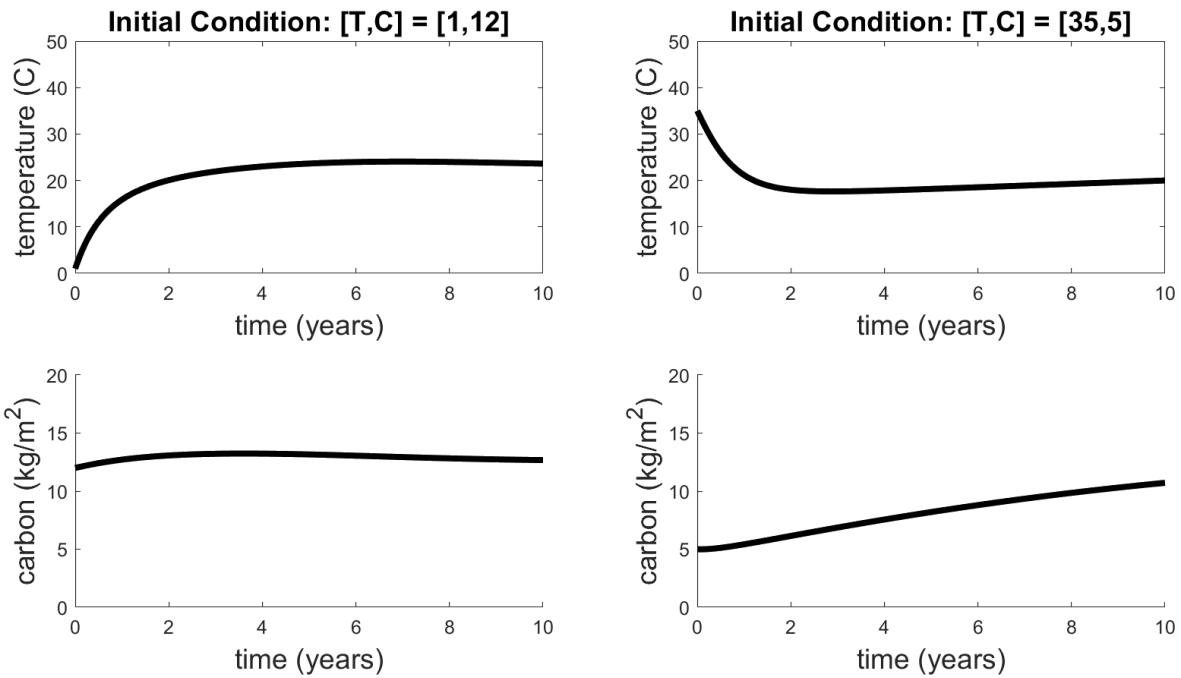

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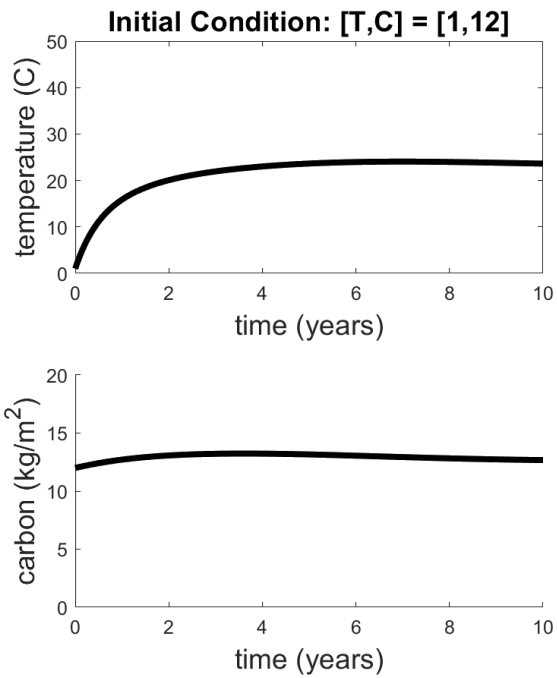
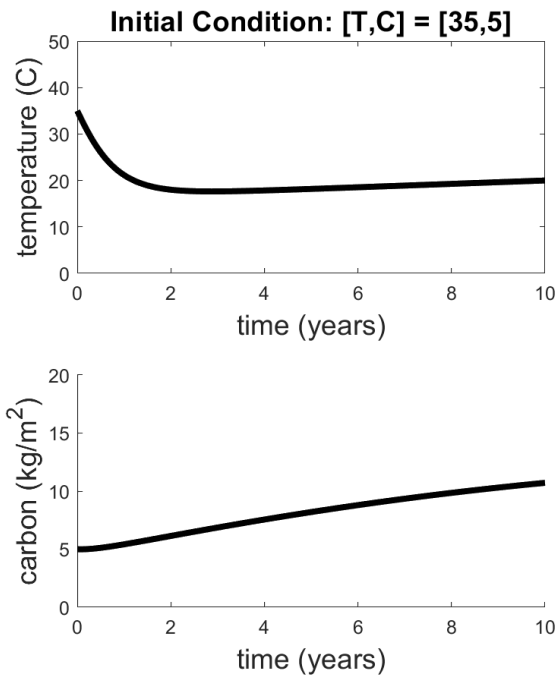
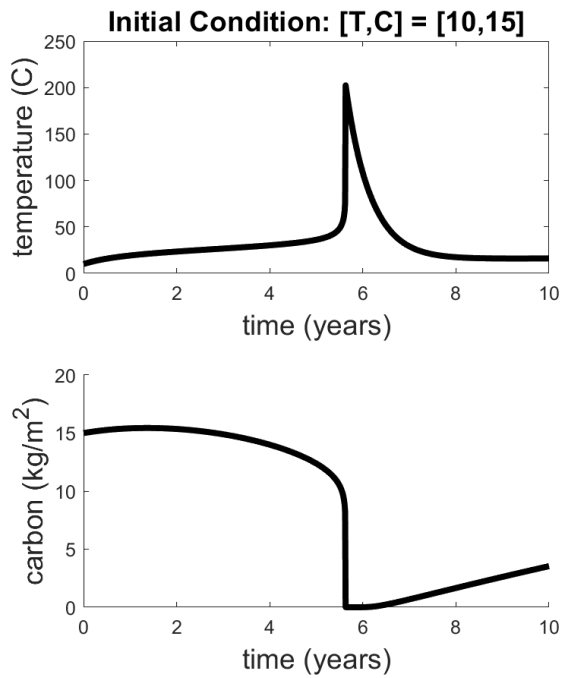




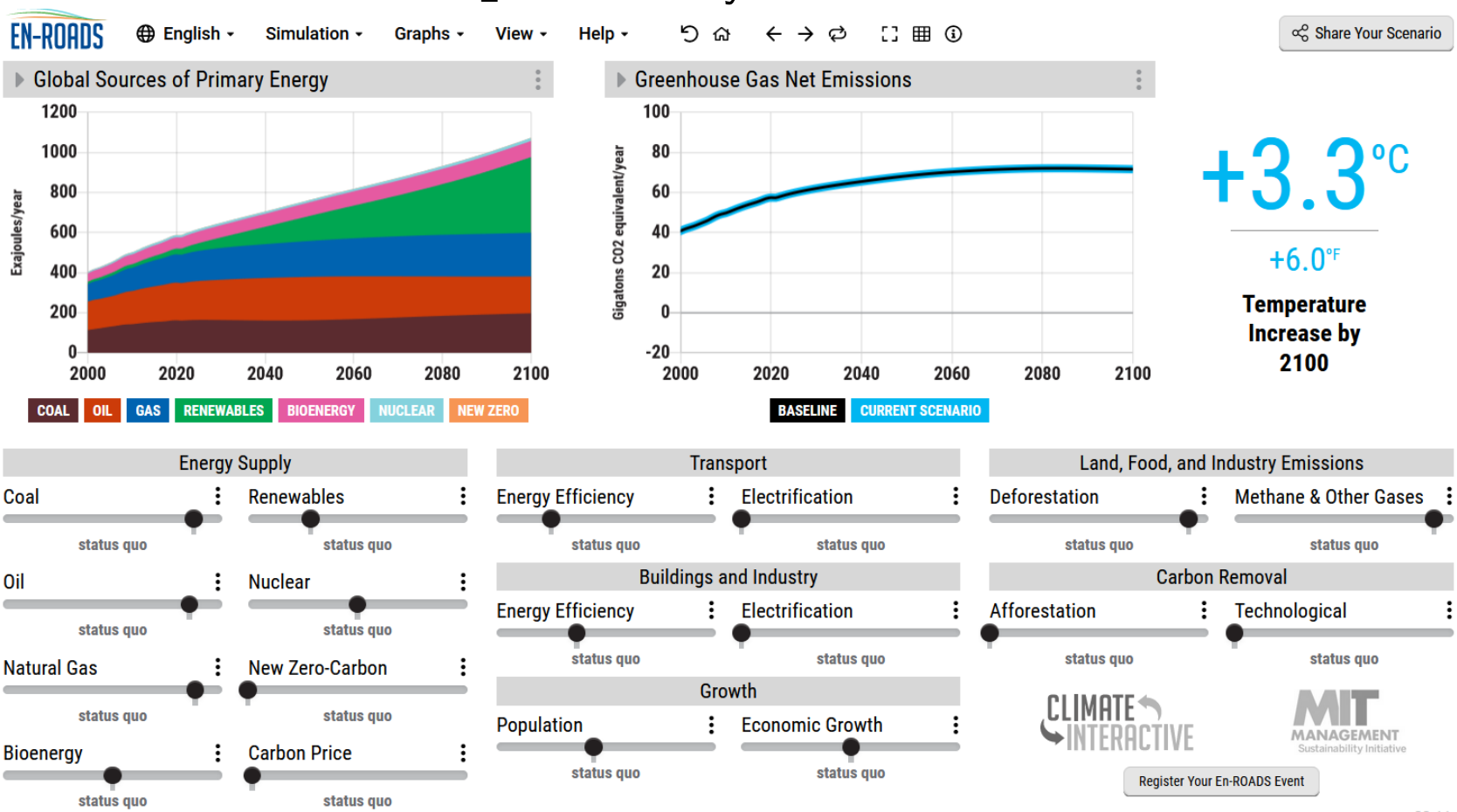


Compost Bomb: Further Investigation

3. What effect did the initial conditions have on your solutions? In which case do you see the compost "bomb"? Discuss why you think this effect occurred. Run additional simulations to check your hypothesis. Summarize your findings.

En-ROADS: Introduction

Climate Change Group Work #6:
Global CO_2 and Policy Model: En-ROADS

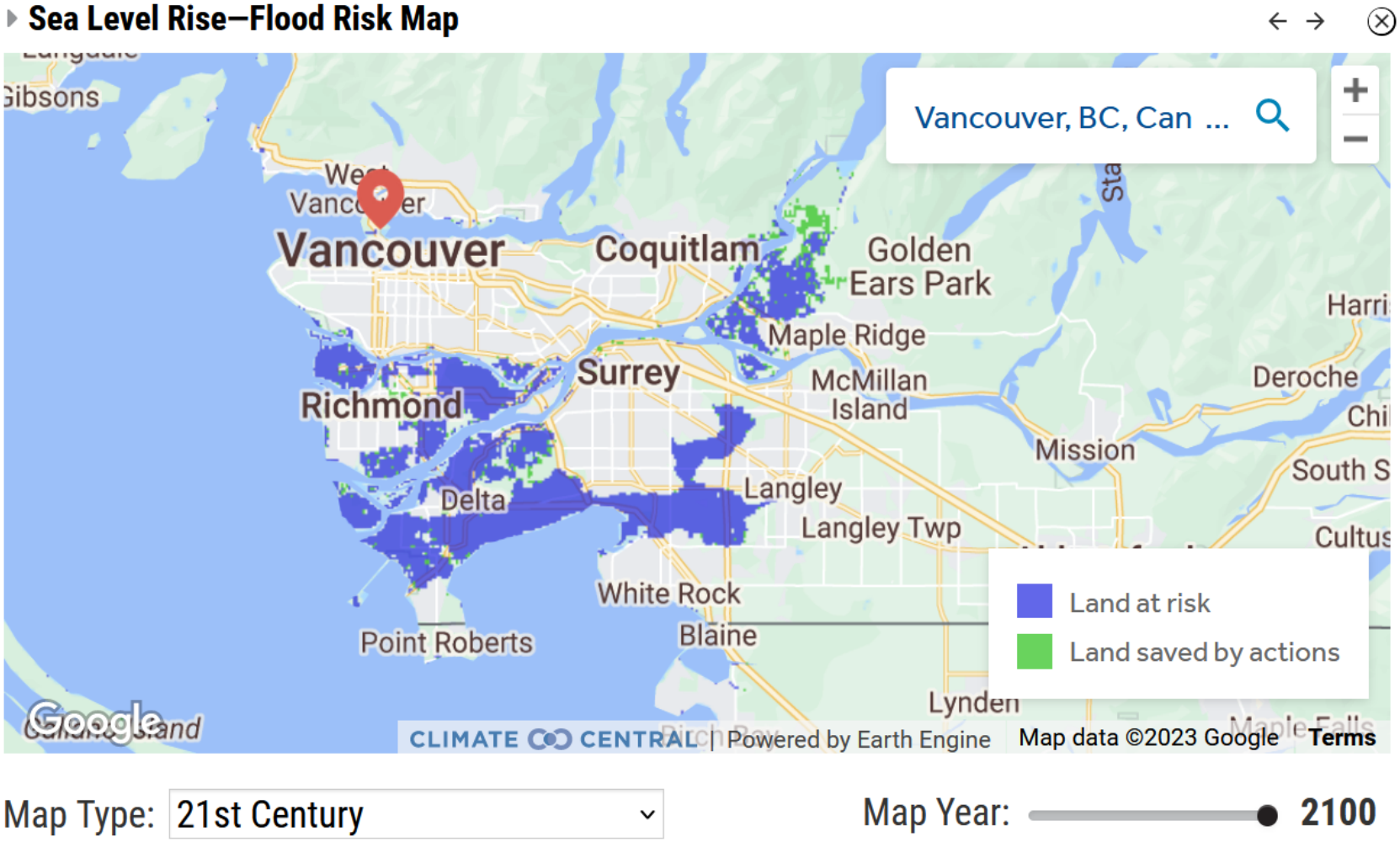


En-ROADS: Sample Questions

1. What combination keeps the temperature change below 1.5°C (Paris agreement)? What temperature change is predicted by the settings you chose?

En-ROADS: Sample Questions

4. Choose two graphs from the "Miniature Graphs" page or from under the "Graphs" tab to investigate more.



What worked

- Group Work
  - Students working together to investigate applications
  - Introduction to mathematical modeling and research
- Course
  - Climate reflection assignment $\longrightarrow$ Response in following lecture
  - Student thanks for climate change content

Issues that arose

- Group Work
  - Little prior coding experience
  - Not enough time for students to think about applications of models
- Course
  - Climate anxiety
  - Invited speakers: framing and connection to students/course

Plans moving forward

- Refining the current projects
- More integration of climate change group work content into lecture
- Math and Earth, Ocean, and Atmospheric Sciences Collaborate to Improve Climate Education at UBC

Climate reflection #1

1. List at least 5 examples of the impact of climate change in either the Okanagan or some other place where you have lived.
2. Has climate change been discussed in relation to the course content in any of your university classes? If yes, how was it discussed?
3. Climate change has been called the biggest problem facing humanity. Do you agree? Why or why not?
4. Do you have any other thoughts to share with regard to climate change issues? Please use this space to tell your story!

List of Group Work Projects

1. One-layer atmosphere energy balance model (phase planes) - The Climate Laboratory by Brian Rose
2. Compost bomb (numerical methods)
3. Abrupt change in an oscillating world (forcing and resonance) - Bathiany et al (2018) Sci Rep
4. Global CO_2 Model (compartmental modelling) - McHugh, Griffiths, & Schiesser (2015) World Scientific
5. EnRoads climate simulator (compartmental modelling; modelling) - `https://www.climateinteractive.org/tools/en-roads/`