

Summary from the group exploring “Non-smooth phenomena in the climate system”, with Chris Budd, Andrew Roberts, Anna Barry, Boualem Khouider, and Jonah Bloch-Johnson.

We discussed examples of nonsmooth dynamics in climate, and collected them into categories. Boualem suggested the model presented in Stechmann and Neelin (2011), "A Stochastic Model for the Transition to Strong Convection," (<http://journals.ametsoc.org/doi/abs/10.1175/JAS-D-11-028.1>). This was used as an example of a "friction" or "threshold" like system, in which convection only occurs after an initial "potential" has been overcome.

Anna suggested her modified energy balance model which includes a basic carbon feedback from changes in land ice cover. Here, the non-smoothness occurs because of the finite nature of the domain (the iceline can only be an angle between  $0^\circ$  and  $90^\circ$ ), leading to a discontinuity in the derivative of this angle at times when the angle reaches one of these extremes. This can lead to phenomena such as sliding bifurcations.

Andrew described the Stommel ocean model, in which two boxes representing a pole and the equator are connected by two pipes; the boxes have their own respective salinity and temperature. Here, the nonsmoothness comes because the dynamics are a function of the absolute value of the circulation, through the pipes, and is symmetric between the two directions. Chris seized upon this example as potentially exhibiting more interesting nonsmooth behavior.

Other examples discussed were convection in the ocean and related "stratified" systems, and systems with delta-functions like volcanos, meteorities, or ice shelf collapses. Chris suggested fronts as a complex example of a non-smooth system. It was agreed that non-smooth dynamics has a lot of unexplored components, with noisy non-smooth systems and non-smooth PDEs being frontiers of knowledge. Discontinuities break many of the assumptions necessary for early warning signs as well, creating a need for additional tests to use these techniques.