LAYER FORMATION AND EVOLUTION IN ICY SATELLITE SUBSURFACE OCEANS BY DOUBLE-DIFFUSIVE CONVECTION. T. Wong\textsuperscript{1}, U. Hansen\textsuperscript{1}, T. Wiesehöfer\textsuperscript{1}, S. Stellmach\textsuperscript{1}, W. B. McKinnon\textsuperscript{2}, \textsuperscript{1}Westfälische Wilhelms-Universität Münster, Münster, Germany (t.wong@uni-muenster.de), \textsuperscript{2}Washington University in St. Louis, St. Louis, MO, USA.

Introduction: Images of colored bands and disrupted terrains on Europa’s surface that are potentially indicative of the composition of the subsurface ocean invoke various hypotheses of how materials are being transported from the seafloor to the surface by hydrothermal plumes, and ultimately through the icy shell, and raise questions on heat transfer. Previous studies assessed the occurrence of double-diffusive convection as a possible mechanism affect heat and material transport by analyzing the stability of the subsurface ocean mainly based on linear stability [1, 2]. However the onset of convection predicted by linear theory has been shown to be inadequate for the non-linear behaviour of the fluid from laboratory and numerical experiments [3, 4]. We perform numerical simulations of double-diffusive convection to study the transport of heat and material through the subsurface ocean.

Double-diffusive convection: Double-diffusive convection is a mixing process driven by the difference in thermal and chemical diffusivities when two chemical constituents are present. The chemical diffusivity is usually orders of magnitude smaller than the thermal diffusivity, which means temperature of the perturbed fluid is adjusted much more rapidly to its surroundings than the concentration, such that the small diffusivity acts to preserve the concentration of the fluid. The different combinations of driving and restoring forces with different diffusive timescales give rise to very different dynamics in the convecting layer.

We model this subsurface water layer in Europa subjected to a destabilizing temperature gradient (warm at the bottom, cold on top) and simultaneously to a stabilizing compositional (salt) distribution. This configuration favours the formation layers, which form in a self-organized manner as they can evolve from a gradient without imposing a prior stratification of material or temperature [5, 6].

Layer formation and evolution in the subsurface ocean: The figure panel on the right presents an example system that is initially cold, compositionally light on top and heavy at the bottom. Top figures show the initial temperature (left) and concentration (right) field (red=high, blue=low). Layers develop in a self-organized manner from a concentration gradient, as shown in the bottom figures. Parameters of the system for this figure panel are buoyancy ratio $R_b=3$, Rayleigh number $Ra = 10^{10}$, Lewis number $Le=100$, Prandtl number $Pr=7$.

The dynamics of layering is known to often exhibit intermittent behaviour. Individual layers can suddenly merge, increasing overall transport substantially. These intermittent changes in the layer pattern can potentially induce sudden large motion in the icy shell. The questions are how long would these layers last? How many layers can it develop? How deep are these layers? Do they depend on the entire depth of the ocean? How do boundary conditions due to ice-water and water-rock interactions affect layering? Basic theoretical models were proposed for the terrestrial ocean [4, 7-9]. We discuss these theories in relation to our numerical simulations. As layers can buffer heat transport through the ocean, in this study we observe the evolution of the ocean and discuss its potential impact on the icy shells of Europa and Enceladus.