Modelling of Advective Transport and Biogeochemistry at a Shallow Hydrothermal Vent System

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In this work we present the first in a series of model results aimed at elucidating the complex couplings between fluid flow, heat transport, advective transport of solutes, and microbial mat growth at a shallow hydrothermal vent. We are primarily interested in the vent systems of Milos, Greece, where biofilm communities are spatially segregated into distinct domains, each with a very different species composition [1]. The locations of these domains vary strongly with the sandbed topography. In particular, there are sharp species composition differences between the windward side and the leeward side of the seafloor ripples.

The delivery of nutrients and removal of waste products is clearly a fundamental constraint on the location of the various niches for these microorganisms. This transport of dissolved chemical species is controlled by the physical properties of the seawater and the flow of fluid over the ripples at the seafloor. Since this is a hydrothermal region, the fluid flow near the seafloor can be strongly influenced by rising warm fluid percolating through the sand from below (combined with the tidal and wind-driven mean flows above). This hydrothermal fluid carries its own unique set of dissolved chemical species.

To try to uncover the relationships between the growth of the various microorganisms and the physicochemical dynamics of these systems, we embarked on a numerical modelling effort, making use of the Lattice Boltzmann Method to simulate fluid flow and the advection and diffusion of heat and passive scalars. In this work, we present the initial results of our simulations, showing how different fluid dynamical boundary conditions control the steady state distribution of chemical species and temperatures throughout the vent system.

[1] Mustafa Yücel et al., Chemical Geology, Volume 356, 2013

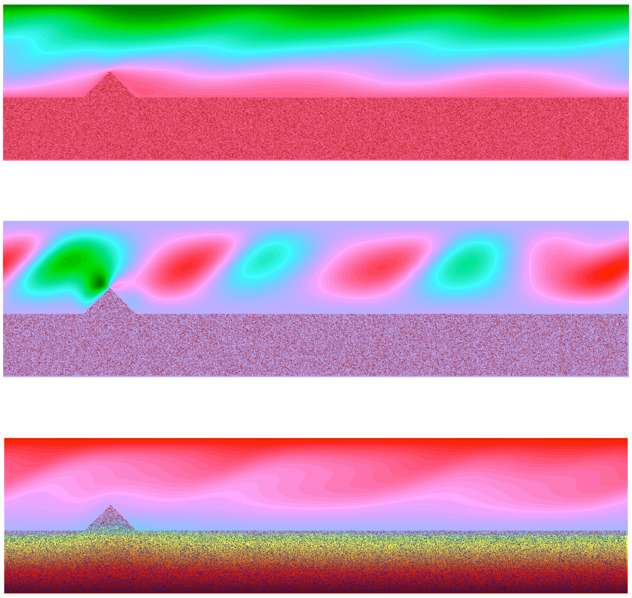

Figure 1: Example flow fields from the shallow hydrothermal vent simulation. The upper panel shows horizontal momentum, the middle panel shows vertical momentum and the lower panel displays temperature. There is a vortex shedding effect from the interaction between the imposed shear flow and the presence of the triangular sand ripple. There is also a vertical convective flow driven by the vertical temperature gradient.