Modelling the interaction of atmospheric flow and snow: Are snow dunes and sastrugi an example of a self organized system?

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The Project
A great deal of research has been performed on the physical processes which form structures in granular material. The models used range in complexity from Large Eddy Simulation models of the atmospheric flow and the interaction of the flow with the terrain and the interaction of individual particles to very simple parameterisations of the interaction of the wind flow with grains. Some recent research has shown that these features can be simulated surprisingly well with very simple model frameworks. These model frameworks rely on ideas related to cellular automata and coupled map lattices and fundamentally revolve around the interaction of a few dominant physical processes. For the case of sand the wind blown movement of grains, often called saltation, a gravitational creep and an avalanche mechanism can be very simply modelled in this framework. However, while the actual system is considerably more complicated these processes can produce a system which will self-organize to form the correct hierarchical structure and fractal character of these landforms. Effectively nonlinear interactions between very simple model components form extremely complex landforms, often with fractal structures. The figure below shows an initial height field and the result of saltation, gravitational creep and an avalanche mechanism after some time. The resultant elevation diagrams produce relatively realistic ripple patterns while only really modelling a few of the processes involved. This type of modelling provides an alternative to the often used strategy of simulating every part of the system in detail. These models effectively assume that all the components of the system are complex but the interactions between key components are often the most important part in modelling the system!

The aim of this project is to examine whether snow dunes and sastrugi can be modelled and understood in a similar manner and also to determine the simplest way to include any other physical processes which might be necessary. For example, unlike sand grains which do not physically change their characteristics snow particles can break-up under the action of saltation and will also agglomerate. Thus, at least some variations to the parameterisations will be required. The most interesting result of this research will be whether snow dunes and sastrugi are also self-organising. In layman’s terms “Can we produce complexity from simplicity?”
**Figure** The initial height of a granular field (left figure) and the form of the height field after 100 time steps (right figure).

**Skills Acquired:**
This work uses very simple ideas from cellular automata and will allow the student to gain a fundamental understanding of the ideas associated with ‘complexity science’. In particular, the student will gain some understanding of cellular automata and coupled map lattice models and experience of simple mathematical modelling. It should be noted that the model is largely developed and most of the work will be experimenting to improve the model. The student will also gain some programming experience with a scientific programming language.