# Numerical model for a population of dunes: big dunes ⇄ small dunes

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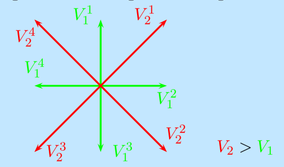
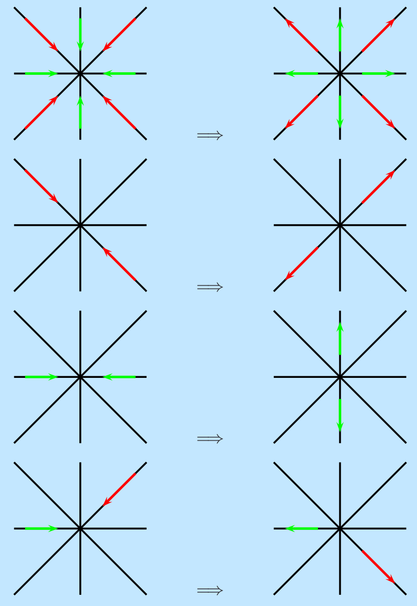
## Lattice gas automata

Lattice gas automata are based on lattices whose nodes can be occupied by *fluid* particles. Thus space is discretised. All particles have the same mass (equal to one unit) and they fly from one lattice node to its neighbour in one unit of time. Two particles cannot sit simultaneously on the same node if their direction are identical. Here, we have implemented a multispeed model taking into account motions of particules between nearest and next nearest neighbours on a regular rectangular lattice.



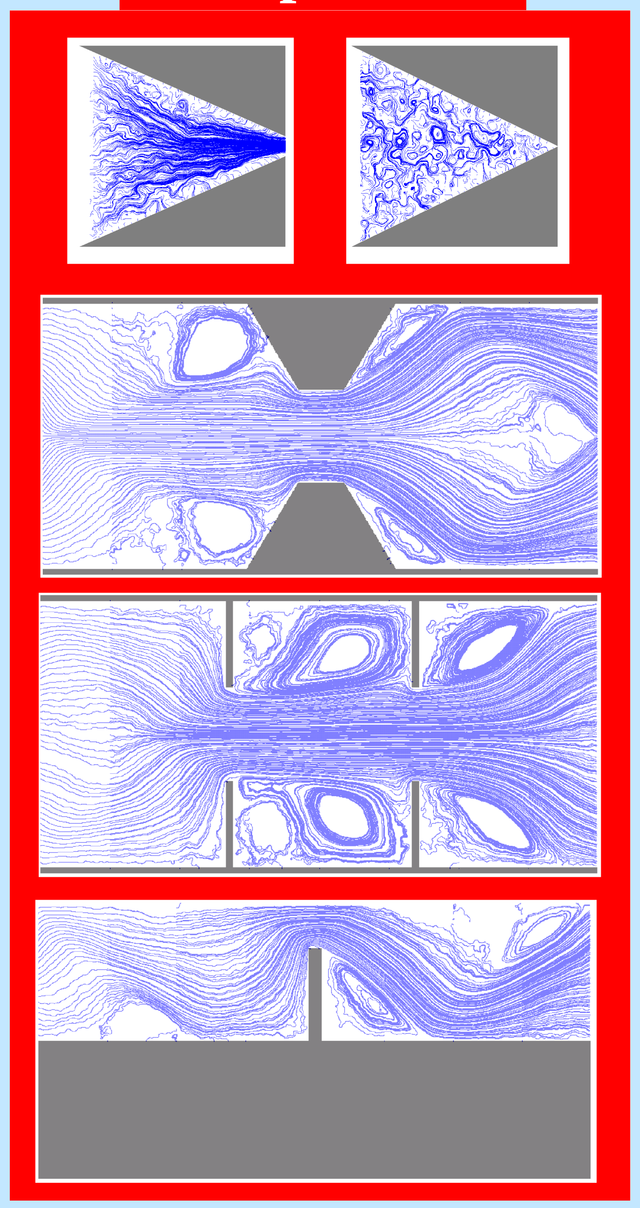

Interactions between particles are simple : they may only take place on nodes with several particles, taking the form of local instantaneous collisions. The collision rules are chosen in order to conserve both mass and momentum. In this model there is no additional conservation law associated to energy since energy is directly proportional to mass; it is thus trivially conserved.



The evolution of the system from one time-step to the next takes place in two successive stages:

1. **Propagation:** the particles move from their node to the nearest neighbour in the direction of their velocity vector.
2. **Collision:** particles on the same node may exchange momentum if it is compatible with the imposed collision rules.

## Flow patterns

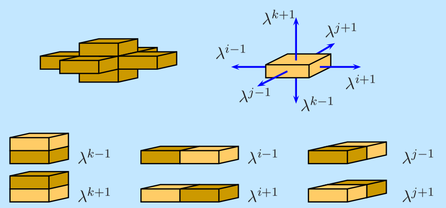


## Generalized Markov process

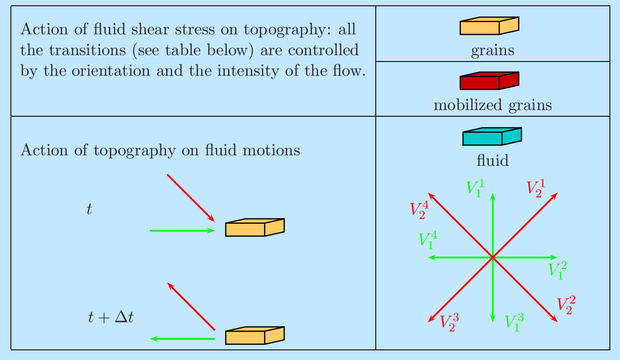
A 3D regular rectangular lattice models an interface between a turbulent fluid and a layer of erodible sediment lying on a solid flat bedrock. This interface is subject to a so-called *fluid action* modeled by a lattice gas automata. $\rho_s$, $\rho_f$ and $d$ are the grain density, the fluid density and the characteristic length scale of a grain. An elementary cell has a slab shape with a square base of length $l$ and a height $h$. The characteristic time scale is determined from an arbitrary sediment sand flux $Q$ :

$$l_d = \frac{\rho_s}{\rho_f} d \qquad h = l_d \qquad l = \frac{h}{\eta} \qquad \tau = \frac{lh}{Q}$$

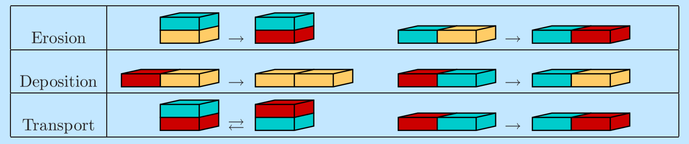
Physical processes such as erosion, deposition and transport are modelled at the elementary scale by different sets of transitions between nearest neighbours. There are six different orientations of doublets:

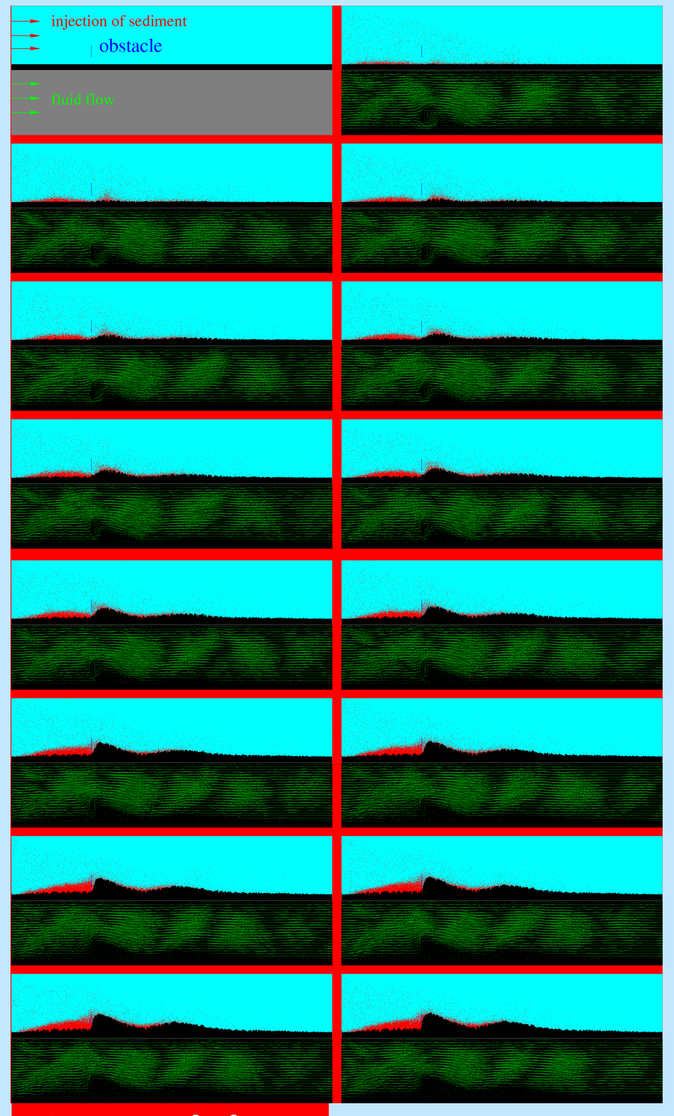



We consider 3 states, 2 solid and 1 fluid. The two solid states, grains and mobilized grains, allow to implement the action of fluid shear velocity on the surface. Boundary conditions of the lattice gas model are determined by the distribution of solid cells. Thus the flow is evoving with respect to an evolving topography. We consider 7 transitions (see below) and gravity: grains falls on the ground and an avalanche rule limits the heigth difference between nearest neighbours to $nh$ (the avalanche angle is $\sim 30°$).

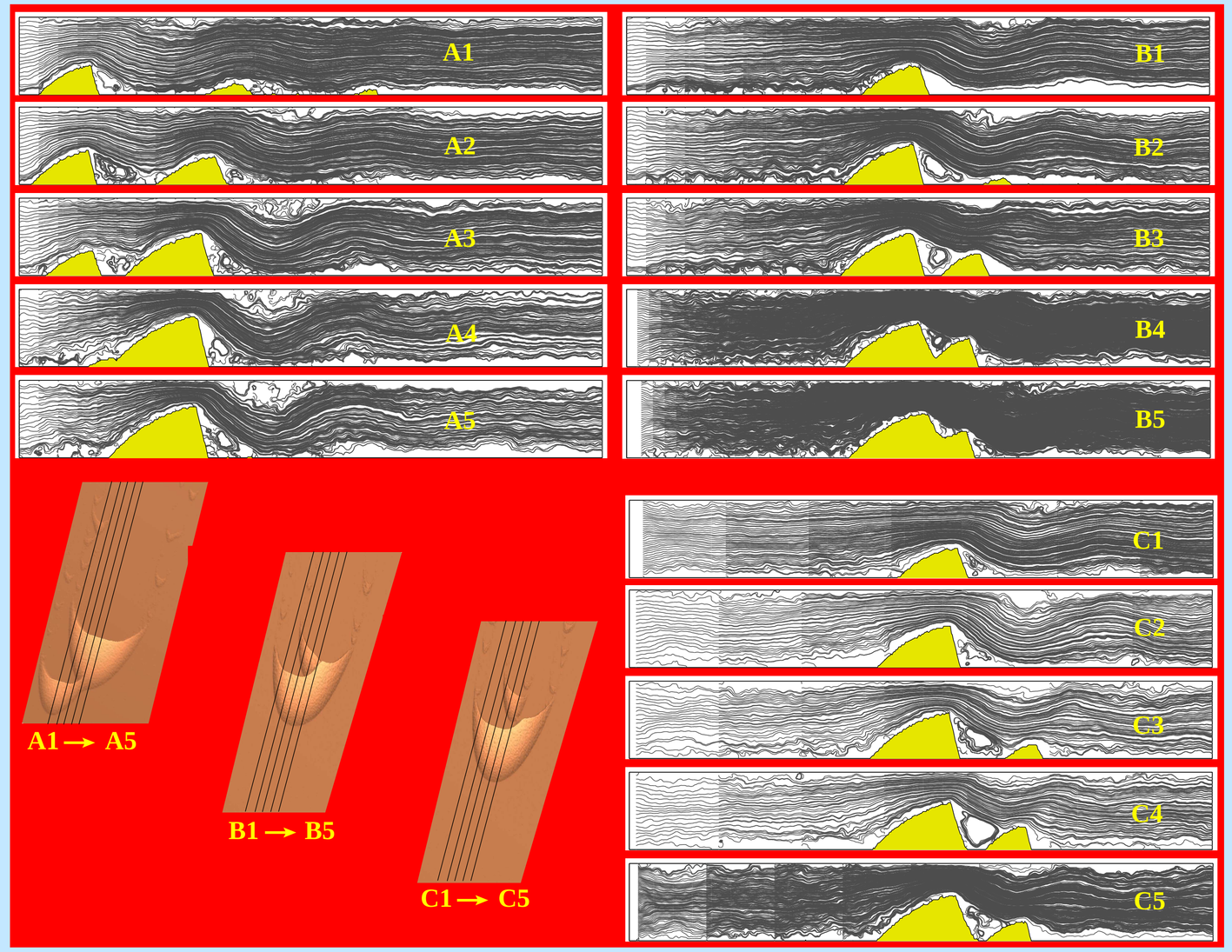



The lattice gas automata ensures the conservation of momentum.
Our set of transition ensures the conservation of mass.

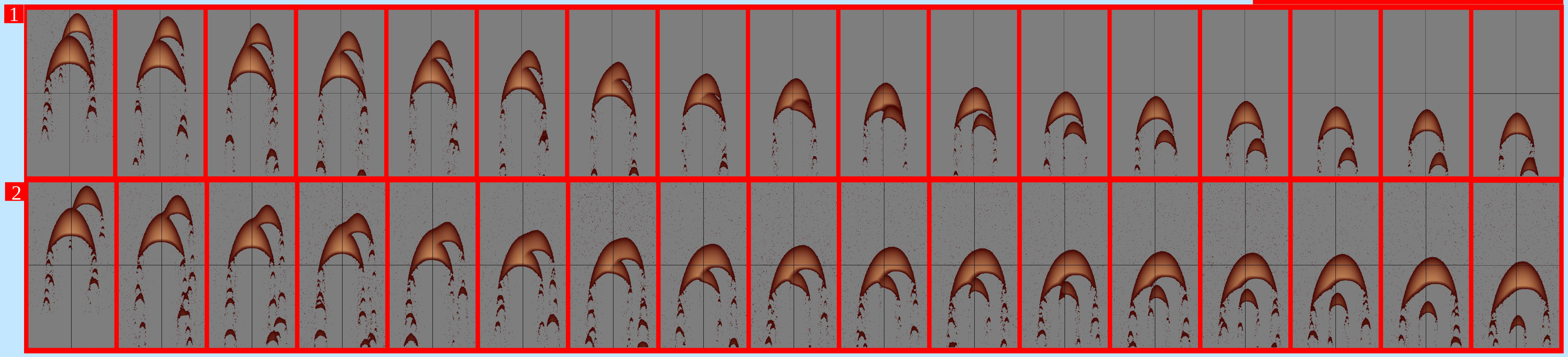



## Deposition




## Collisions between dunes




## Rotating wind conditions