An example of mosquito evolution in Africa

Andy Wilkins

November 9, 2019

1 Introduction

I describe a simple simulation, mainly as an example of the type of simulation that the code can perform.

2 The spatial domain

The spatial domain is defined by a $5\,\mathrm{km}\times 5\,\mathrm{km}$ grid with lower-left corner at $(x, y) = (-4614, -3967)$ (km) and $n_x = 1517$ and $n_y = 1667$, that is

```
Grid(-4614.0, -3967.0, 5.0, 1517, 1667, False)
```

The inactive cells are defined to be those in the ocean, while everything else is active. This results in 1.4×10^6 cells, as shown in Figure 1.

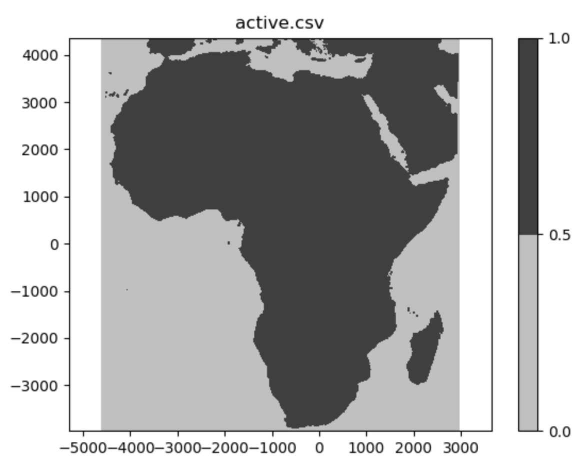

Figure 1: The spatial domain. Active cells are dark-coloured.

3 Cell dynamics

The `CellDynamicsLogistic1_1` class is used. This solves the logistic equation

$$\frac{\mathrm{d}P}{\mathrm{d}t} = rP\left(1 - \frac{P}{K}\right) \ , \tag{1}$$

for population $P(t)$. Here K is the carrying capacity, which varies spatially, and r is a growth rate, defined to be $r = 0.1.\mathrm{day}^{-1}$ for all cells and all times. This means there is just one population and one parameter (carrying capacity) per cell. The population, P, is assumed to diffuse and advect.

The logistic growth only occurs for 0.5 days out of each day.

4 Carrying capacity

This is spatially varying, but is assumed to be constant in time. It is shown in Figure 2

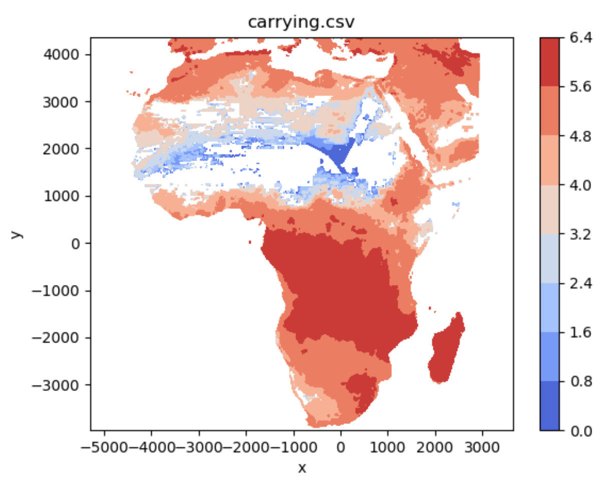

Figure 2: $\log_{10}$(carrying capacity) (mosquitoes per grid cell).

5 Diffusion

Diffusion is assumed to have a constant, uniform diffusion coefficient of $0.1\,\mathrm{km}^2.\mathrm{day}^{-1}$.

6 Advection by wind

Just one wind file is used, so wind is spatially-varying but temporally constant throughout the simulation. It is assumed that 1% of the population, P, of each cell enters the wind steam every day.

The probability distribution for mosquitoes to “drop out” of the wind stream is assumed to be exponential:

$$p(t) \propto \begin{cases} e^{-6t} & \text{for } t \le 0.5 \\ 0 & \text{for } t > 0.5 \end{cases} \tag{2}$$

where t is measured in days. This gives $p(0) \approx 15\%$ and $p(0.5) \approx 0.7\%$. Hence, regardless of the time-step size, mosquitoes advect for up to 0.5 days every time step.

7 Initial conditions

It is assumed that initially there are zero mosquitoes everywhere, except for at cell $(x, y) = (-2000, 700)$, which is in the south of Nigera. At this cell 10,000 mosquitoes are introduced. The carrying capacity of the cell is 150,000. This is shown in Figure 3.

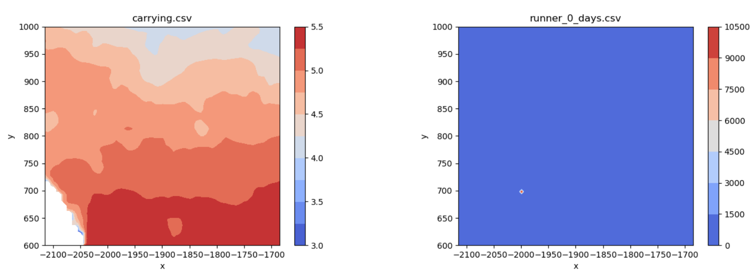

Figure 3: Zoomed views into the region of interest. Left: $\log_{10}$(carrying capacity). Right: the initial population.

8 Simulation results

Simulations of 500 days were performed. No seasonality was included (all parameters are uniform in time). Two simulations were run: one with wind, and one without wind. The simulation with wind took 110 s on my macbook air, and without wind 60 s.

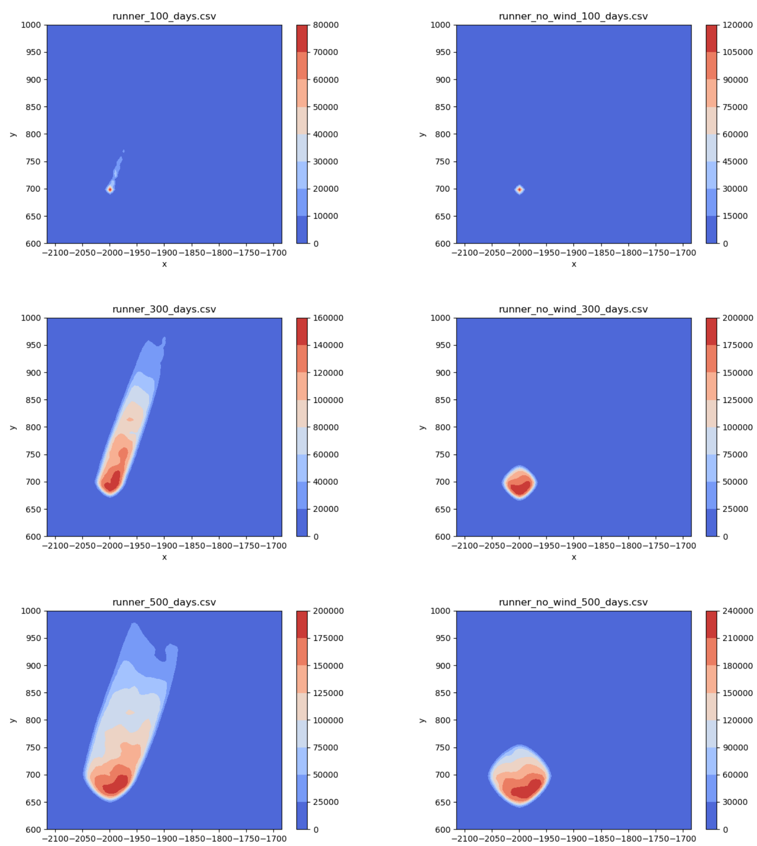

Figure 4: Population results from the simulations. Left column: with wind. Right column: without wind. Notice the colour scales are slightly different in each figure.