1. Motivation: desertification

Desertification and rising sea levels affect an increasing part of the world’s population. Around 23% of the land surface and 1.5 billion people are affected by desertification at present [1]. Active dunes move several meters per year, the fasts dunes up to 100m per year [2], thereby threatening infrastructure and homes. At the same time, dunes protect us from flooding in the form of dykes along coastlines. How can we control dunes? One widely used option is to erect soil erosion fences.

In this paper we study how effective fences are at reducing wind shear stress near the surface, using a computational fluid dynamic model.

2. Methods: computational fluid dynamics

Model setup:
- software OpenFOAM: C++,, finite volume numerical scheme
- air: incompressible, newtonian fluid
- Reynolds averaged standard k-epsilon turbulence model: steady state solver porousSimpleFoam
- 2D channel, x=40m, y=1m, refinement up to dx=2mm, dy=1mm

Boundary and initial conditions:
- Turbulence caused by friction with the ground leads to logarithmic profile of wind velocity u in lower part of the atmosphere – the Atmospheric Boundary Layer (ABL). We implement the turbulence by using functions of the atmBoundaryLayerClass

\[ u = \frac{u_*}{k} \ln \left( \frac{z}{z_0} \right) \]

These equations are used for:
- inlet conditions for u, k, epsilon
- wall functions for lower wall for turbulent viscosity nut, k, epsilon
- and initial conditions for k, epsilon.

Dimensionless theoretical description: Resulting wind profile:

\[ z^+ = - \frac{u^+}{k} \]

When using wall functions as described, logarithmic profile starts above first cell. Here \( z^+ = 30 \) equals \( z = 1 \) mm.

With this setup we successfully produce the logarithmic wind profile.

Implementation of Fences:
- fence height 0.1m, thickness 0.03m and 30 % porosity
- definition of porous cell zones, acting as momentum sink

3. Results: wind profile & shear stress

2D channel with dimensions: 40mx1m:

Wind shear stress over height

Shear stress varies in first three cells above ground but remains constant for several centimeters above. Velocity and shear stress profile remain approx. constant after >20m downwind channel.

4. Results: flow over porous fences

Flow over single fence

Flow over array of fences

- fence height 0.1m, thickness 0.03m and 30 % porosity
- definition of porous cell zones, acting as momentum sink

Bulletin layer

Logarithmic layer:

\[ \ln \left( \frac{z}{z_0} \right) \]

Velocity along channel at heights z=0.38h and z=1.88h as Santiago et al 2007 [4].

Velocity uw; normed by velocity uw at inlet of channel at same height. Results for single fence as well as array of fences are in good qualitative agreement with earlier results of our group by Lima et al. [3] and results of Fang et al. [5].

Flow over single fence and array of fences can be simulated with the chosen solver, boundary conditions and grid resolution. Velocity decreases significantly in the vicinity of fences at z=0.38h.

5. Conclusions & Outlook

- Grid resolution is important for wall functions of atmospheric boundary layer flow. First cell at the bottom should have a size of \( z^+ = 30 \) to resemble ABL flow over smooth surfaces.
- Wind velocity and wall shear stress decrease substantially up- and downwind of fences. Shear stress inside saltation layer above -1cm height, increases right before and downwind of fence.
- Flow over array of fences leads to recirculation bubble behind the first fence that becomes smaller behind subsequent fences - for given velocities, dimensions and spacing.
- Outer layer stabilizes after second or third fence of array (in good agreement to Lima et al. [3]).

Outlook:
- Couple OpenFOAM simulation of atmospheric wind with sand transport model [2], to simulate dunes with fences and examine the efficiency of fences for aeolian sand erosion.

6. References & Acknowledgements


Outlook: Couple OpenFOAM simulation of atmospheric wind with sand transport model [2], to simulate dunes with fences and examine the efficiency of fences for aeolian sand erosion.