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Optimization of air pumping from underground covered by an impermeable tarp

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A large number of gas species are present in pores and fractures below the ground surface. They bear important information on the transport properties of the media as well as on the underground processes at play. Therefore long-term gas flux measurements at the surface are increasingly needed in various contexts such as safety assessment of geologic carbon sequestration, monitoring of land contaminated by volatile species or verification of the Comprehensive Nuclear Test Ban Treaty. Depending on the target gas species, on the employed analytical techniques and their performances, the volume of air drawn from underground may be large and the depth from which air is collected may not be sufficiently deep to prevent atmospheric air intrusion. This intrusion may contaminate the samples, and dilute the underground air, which could be an issue if the concentration of the target gas species is close to the detection limits of the instruments.

A simple design for surface collection of air from underground consists in an impermeable tarp covering a permeable or perforated pipe. In addition, embedding the pipe in a sand layer brings many advantages; it avoids digging a trench and it protects against free water, gas accumulation in the additional pore volume, and so on. When air is pumped from the surrounding medium into the pipe, at the beginning, it exclusively comes from the embankment and the underground medium, and it is only after some time that some atmospheric air reaches the pipe; a critical proportion eta of underground air can be defined.

The major objective of this work is to numerically quantify the flow of air and to minimize the fraction of atmospheric air by optimizing the system parameters. The air flow is described by a time dependent Laplace equation which is discretized by the classical box integration method and solved by a conjugate gradient technique. The results are processed and yield the total mass of air injected into the pipe, and the proportion which comes from the atmosphere as functions of time. A typical example is presented and discussed in dimensionless terms. It is also shown how the dimensional results can be derived from the dimensionless graphs. The case of a punctual pipe is thoroughly analyzed. The numerical parameters, namely the size of the domain and the discretization, are discussed. Then, the influence of the pipe properties such as its position and the pumping pressure is illustrated. Finally, the influence of the geometrical parameters relative to the tarp and the embankment are discussed as well as the permeability of the

embankment. For each parameter, all the others being fixed, the dimensionless time for which eta is obtained is determined, and the corresponding dimensionless mass M of injected air is calculated. For instance, it is shown that M is maximal for an intermediate permeability of the embankment.

An analogous study devoted to non-punctual pipes is briefly summarized.
Concluding remarks and possible extensions are presented.