Influence of air density on dust emission from sandy soil using the PI-SWERL

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1. Project description

The emission of dust as a result of wind erosion is of great interest in the Environmental Sciences due to its on- and off-site effects. The emission of dust from land surface can play a major part in land degradation, especially in semi-arid and arid environments. However, possibly even more important is the effect that suspended particles can have on both regional and global climates, and on public health. On the contrary, it is known that erosion, transport, and depositions of dust can have positive effects e.g. on ocean fertilization and other (bio) chemical cycles (Middleton, 2017).

Many studies have been dedicated to determining the threshold friction velocity of dust emission and the correlation between wind speed and dust emission flux of different sand and soil surfaces. Most of the factors that have been studied are surface characteristics, such as the grainsize distribution, the cohesion of the soil, or the roughness of a surface. Only a few studies addressed the influence of the wind characteristics on the correlation between wind speed and surface characteristic, whereby the most relevant factor is the air density.

The density of air is determined by the temperature, the composition of the air, and the pressure. Since the air pressure at 3.4 km height can be less than 70% of the pressure at sea level, an equivalent density can be expected, assuming the other conditions do not change. This would be equal to a temperature change from approximately -30 ˚C to 74 ˚C. The change in air pressure can therefore be regarded as very important for air density.

There are several consequences to be expected with a decrease in air density. A low density would decrease the shear stress exerted by the air, and could therefore increase the speed necessary for particle entrainment. Even though windtunnel experiments also showed an increase in wind speed with a decrease in density, it still led to a lower total sediment transport (Han et al, 2015).

Insight in the exact influence of air pressure, and therefore air density, on the erodibility of a soil will contribute to improve the quality of dust emission models and enable corrections on present dust measurement approaches. The influence and change in air pressure can be especially important for wind erosion research that aims to extrapolate methods and results from earth to Mars or other planetary conditions.

This study focusses on assessing and measuring the influence of air density on dust emission. In order to accomplish this task, dust emission experiments at four different altitudes were done in the year 2018; namely at our Experimental Soil Surface Processes and Rainfall Laboratory in Witterswil (345 m), at the Brünig Pass (967 m), the Eigergletscher railway station (2319 m), and the Jungfraujoch (3410 m). At three of the four locations the experiments were done indoors, but at the Brünig Pass they had to be done outdoors.

The measurements at the High Altitude Research Station at Jungfraujoch were done between the 14th and the 16th of November 2018. During that period in total 20 experiments with the Portable In-Situ Wind Erosion Lab (PI-SWERL) (Etyemezian et al., 2007) were accomplished (see Figure 1). The PI-SWERL is a device that is capable of creating highly controlled shear stresses on the underlying surface and simultaneously measures the produced sediment flux from the surface. In the experiments, the friction velocity had been slowly increased up to 0.56 m s^{-1} (after Etyemezian et al., 2011) and was kept constant afterwards for five minutes until the end of the experiment. Since the boundary conditions were constant over that period of time, both the threshold friction velocity and the PM_{10} emission flux from the surface could be measured.

It was expected, that the threshold friction velocity at the Jungfraujoch would be higher than at the other altitudes, which consequently should result in lower PM_{10} emission values due to lower air pressure and thus air density.

Following steps were executed to generate the required data at the Jungfraujoch:

1. Measuring of environmental parameters, such as air pressure, air humidity, and air temperature in order to determine the boundary conditions at Jungfraujoch.
2. Assembly and setup of the PI-SWERL experiment in the laboratory at Jungfraujoch.
3. Carrying out of PI-SWERL experiments on two different materials on a flat surface. One substrate was a loamy

sand soil from Central Jutland, Denmark, and the other one was a slightly coarser and better sorted sand from a sand mine in Limburg, the Netherlands. After each experiment the substrate was refreshed to have identical surface conditions.

Figure 1. The Portable In-Situ Wind Erosion Lab (PI-SWERL) that can be placed on a surface to determine the PM10 emitted at a certain friction velocity.

A clear difference in emission flux and threshold friction velocity was found for the different altitudes. A clear increase in threshold friction velocity and a decrease in emission flux of PM_{10} with an increase in altitude can be observed in Figure 2. As expected, the lowest emission values and highest threshold friction values were observed for the experiments at the Jungfraujoch. Further data analyses should result in a correlation between the air density, the threshold velocity, and dust flux.

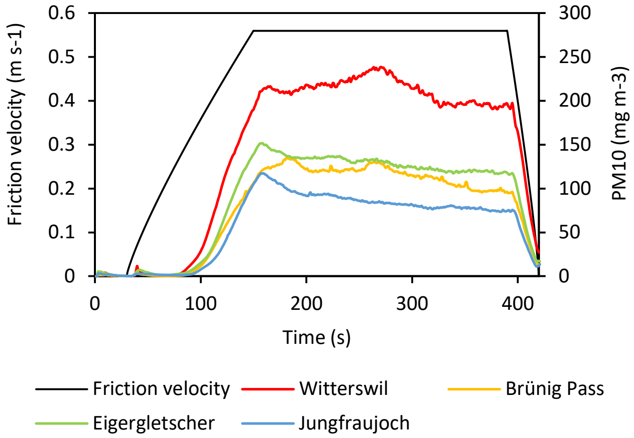

Figure 2. The average friction velocities and PM10 values of ten PI-SWERL tests at the different altitudes for the Denmark soil. A clear decrease in dust emission with altitude is visible. The low value at the Brünig Pass is likely caused by the high air humidity during this outdoor measurement.

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