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2013

Dostupný z <http://www.nusl.cz/ntk/nusl-156472>

Dílo je chráněno podle autorského zákona č. 121/2000 Sb.

Tento dokument byl stažen z Národního úložiště šedé literatury (NUŠL).

Datum stažení: 19.04.2024

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A 19m deep well – a downward thermal diffusion cloud chamber?

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Keywords: heterogeneous nucleation, thermal gradient, droplets formation, composition of CN.

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An unusual phenomenon, first observed on a clear summer day after several rainy days, were droplets constantly hitting the water surface in a 19 m deep and 2.4 m diameter water well. This droplet formation was occurring during the night as well. Since the droplet formation was near continuous, we called it “the eternal rain”. The water well is about 230 years old and located in the Benedictine monastery in Broumov, Czech Republic.

A series of measurements, listed below, starting at the top opening of the well, all the way down in steps of 0.5 m, were made. The ambient temperature at the top of the well varied between (in the second half of August) 15 to 30°C. The temperature at the bottom of the well was constant at about 8°C. The decrease in temperature was gradual, except the last few meters, when it was practically constant. The wall surface temperature basically followed the observed air temperatures.

CO₂ varied between around 450 ppm at the top to 2600 ppm at the bottom. The change in concentration occurred between 6 to 10 m depth. O₃ varied between 90 ug/m³ at the top and about 12 ug/m³ at the bottom. The sudden change occurred within the first 3 m of the depth.

The CN concentration, measured by UCPC 3025A, and by P-trak (both of TSI, Inc.) showed a depth dependence similar to ozone. At the top, the concentration was about 16000/cm³, while at 8 m about 3000/cm³. The difference between UCPC and P-trak gives concentration of 3-20 nm. The concentration of 3-20 nm at the bottom several meters is constant, around 1000/cm³.

In an attempt to describe the mechanism causing the observed flux of droplets falling to the bottom of the well, we expected that the well behaves as a natural Thermal Diffusion Cloud Chamber in a downward regime (e.g. Katz and Ostermier, 1967). In that case, we neglect any convective fluxes in the well and the main mechanism of water vapour transport is molecular diffusion driven by concentration gradient between the upper boundary of the well and almost isothermal water surface at the bottom. At the same time, the heat transport between the warmer top of the well and its colder bottom is driven by heat conduction in the water vapour – air mixture. These coupled transport processes lead to almost linear vertical profiles of both temperature and partial vapour pressure of water. Because the equilibrium vapour pressure of water is an exponential function of temperature, water vapour in the well may

become supersaturated with maximum supersaturation located in the lowest third of the well.

Taking into account the temperatures at the well opening and at its bottom, preliminary calculations showed that the supersaturation at its maximum would not be sufficient for homogeneous nucleation of water. In the most extreme case with highest outside temperatures, the supersaturation might have reached a limit for an observable nucleation on air ions. However, at the presence of almost any heterogeneous particle moving downward the well space, this particle would easily serve as a condensation nuclei providing surface for water condensation. Due to a long condensation path and taking into account fast condensational growth in supersaturated water vapour, the grown droplets might have easily grown to sizes of hundreds of micrometers or larger and be observed as macroscopic droplets hitting the water surface at the well bottom.

The question remains concerning the nature of particles serving as CN. It is not clear whether these nuclei enter the well from above as the ambient aerosol particles, or there is some inherent source of particles inside the well. As was shown in measurements in isolated caves and a mine (Holub et al., 1999, and Holub et al., 2001), aerosol particles in the size range 3-200 nm have been observed there without coming from outdoors. These aerosols have been also measured routinely by earth scientists as a prospecting tool for locating hidden deposits (Cao et al., 2009). Similarly, Kristiansson et al. (1990) used entails digging a hole about 1 m³ volume in the ground, placing a collector inside (for instance, a Transmission Electron Microscopy grid), and then measuring, after 45 days of exposure, the size and composition of the nanoparticles collected on the grid. The compositions reflected minerals deep below the collectors, and not of the outdoor aerosols.

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