CONTRIBUTION TO UNCONVENTIONAL MONITORING METHODS OF SELECTED ENVIRONMENTAL PARAMETERS: PRECIPITATION AND SNOW

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This contribution is aimed to give a survey of unconventional methods monitoring some environmental parameters in the atmosphere and on the ground. The development of the electronics systems and their miniaturization together with the enormous growth of the numerical micro-controllers computational capacity enable the use of indirect methods of environmental data collection and their fusion for getting the relevant information that are hardly accessible by using standard methods.

The measurements of selected parameters of dense net of mobile phones base receiver stations in 1GHz band were experimentally used to test precipitation occurrence, its dynamics and extreme atmospheric phenomena in the boundary layer. The measurement was based on the correlative character of the transmission channel in the line of horizon transmission and their evaluation by Kalman filter. The detection of hard particles is rather difficult in this case in comparison to the liquid particles. Nevertheless, we work on the formation of the virtual network of crossing lines by using more receivers and their evaluation by SART class algorithms. We expect the resolution within 100m diameter in space and 1 min in time.

Electromagnetic emission caused by piezoelectric effects by mechanic stress of polycrystalline form of snow can be used to monitor snow dynamics and its icy form. These effects were checked by experimental measurements on mechanic stress of granite and related crystalline rocks in 0.5-3MHz band. The aim was to monitor the landslides. Nevertheless, it is confirmed that the same mechanism can be used to monitor the drift of snow and ice. To validate this fact experimentally we work on the construction of the autonomous sonde being placed in avalanche slope. Communicating in the VLF band the sonde brings the data about the electromagnetic emission, temperature, mechanics stresses. These data can be used to estimate the trigger point of the snow drift.

Monitoring the time parameters of the diffusivity of radiation by placing the thermometers above the ground gives the information usable for the estimation of the snow cover height; vertical temperature profile gives us indirect information about the soil water content. As the thermic diffusivity coefficient is not universally usable parameter, monolitic impendance convertor can be used to specify the measurements and to measure the complex permitivity of adjusted space. This srongly depends on the water content in the respective space. It is assumed that the combination of these two methods it can be obtained the information about snow height, its form as well as about its vertical profile. This method was experimentally tested by the measurements of soil temperature profile being focused on the prediction of road icing.

Key words: transmission channel, Kalman filter, electromagnetic emission, thermic diffusivity

INTRODUCTION

People feel, for the whole history of the mankind, the need to get the knowledge, to observe the natural phenomenon and to benefit from them. From simple monitoring of environmental parameters man worked through a sophisticated methods of remote sensing which enable us to get a global view on ecosphere in real time at almost each location on the globe. The extent of cohesion of the phenomenon around us is high and despite of the colossal progress being done in the science and technologies the development of further methods in monitoring and processing of information is desirable. The present development in electronics together with enormous increase of available numerical power enable the use of indirect methods of the collection of the data, which are basically not accessible by the classical methods. Further possibilities come from the development in numerical methods and algorithms and in the processing of big volumes of data, in their interpretation, in the fusion of data coming from different sources and in the creation of process models enabling to predict the development of environmental parameters.

OBSERVING THE DYNAMICS OF THE HEAT DIFFUSIVITY IN THE ENVIRONMENT

Soil temperature is the basic parameter of soil climate characterizing temperature regime of the soil. The changes in soil temperature depend on many environmental elements definining the energetic input and the ability of soil to convert this energy to heat, mainly on intensity of solar radiation and on the character of soil cover. Standard measurements of the soil temperature are done by mercury or active resistance thermometers in vertical profiles placed in standard depths up to 100 cm and to 700 cm [1] at selected stations with the period of measurements from one minute to a few hours. It is possible to get the information about the diffusivity parameters of the environment by using the surface soil temperature as independent variable when monitoring the dynamics of the heat transport. The changes in diffusivity can be caused by the change of water content in the soil or by the change of the structure of snow layer. A system of digital thermic sensors in plastic container with the diameter 15 mm was used to test the possibilities of the assessment of the coefficient of thermic diffusivity. The sensors work with the accuracy +/- 0.1°C with the resolution of 0.0625°C. They are interconnected by two-wire link which eliminates parasite transfer of heat in the container and in parallel it enables the communication as well as supplies the sensors with the power. The system enables independent individual communication with each sensor and also the simultaneous measurement of all sensors. The speed of the data collection from all sensors was 1 measurement in 1 second for the full resolution (13 bits) in the temperature range from -20°C to +70°C. 100 m long communication cable is placed on the soil surface in protective cornice with the diameter 8 mm. The control unit with the galvanic separator and protection against electrostatic charge is in the end of the cable and connects the cable to the PC or to other system of data collection with interface RS485, RS232 or USB. Power supply comes directly from the USB interface by adapter or other external power supply of 12 V/ max. 500mA. During the experiment the vertical thermometer was placed close to the edge of asphalt road in a drill hole fixed by loam to prevent penetration of the water to the container. The primary task was to test the process model for prediction of road surface temperature and the creation of icing. A system of thermometers placed in different layers of the road profile was a part of the experiment. Local micro-controler navigated the measurements, measured data were stored in central server. One dimensional process model of heat diffusivity in laminose environment was used to evaluate the data. Diffuse parameters of the environment were recalculated by Kalaman filter in such way that the difference between measured and modeled values was under known boundary conditions minimal.

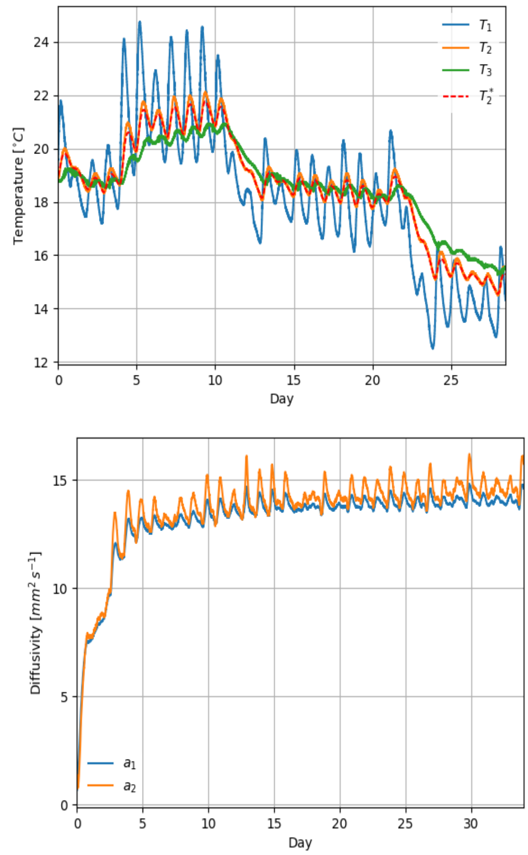

Figure 1. Temperatures in the period of 26.08.-29.09. 2014 and the sample of plotting 3 thermometers (T_1, T_3 – outer thermometers, T_2 inner) by Kalman filter. a_1 and a_2 are coefficients of thermal diffusivity between T_1 and T_2, T_2 a T_3 resp. The process of learning of Kalman filter from initial condition is visible in the beginning of the graph. The oscillations of the variables show the minority defects of the model which most probably does not consider all mechanisms of the heat transport in the environment.

The coefficient of thermal diffusivity is defined like a ratio of thermal conductivity to volume density and thermal capacity of the mass. Under the constant structural composition of the ambient mass we can try to attribute the changes of the coefficients of the diffusivity to the changes of the water conent or soil moisture in the respective environment. The situation is much more complicated under the structural changes of the ambient mass. For example, in snow cover being fragmented into more layers with different consistency the state phase can change. These facts lead to the construction of contactless sensor for the measurement of the parameters of impendance of the environment in combination with the measurements of the vertical profile. The principle of the sensor is based on the creation of sonding electrostatic field and on the measurements of complex conductivity between the electrodes by impendance convertor in the frequency interval 0.1-100 Hz. The data of the sensor will be involved into process model of Kalman filter to specify the results of the measurements of the parameters of thermal diffusivity and the changes of the environment.

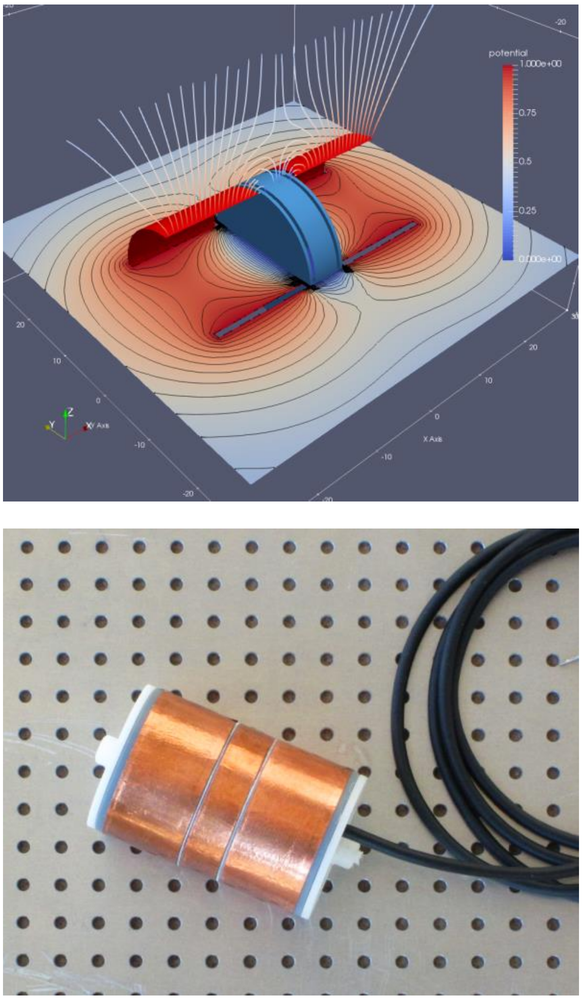

Figure 2. Simulation of electrodes of capacity sensor and electric field with active electrodes and a sensor without the cover prepared for testing

Static data from vertical temperature profile are standardly used in agriculture, forestry and construction. Evaluation of the diffusive parameters of the environment enables us to widen the monitoring of the distribution of heat and water in the soil profile, as well as the monitoring of the height and structure of snow cover, of the degradation of biologically active substances producing the heat (stored plant products, compost, silage, biological dumps, etc.)

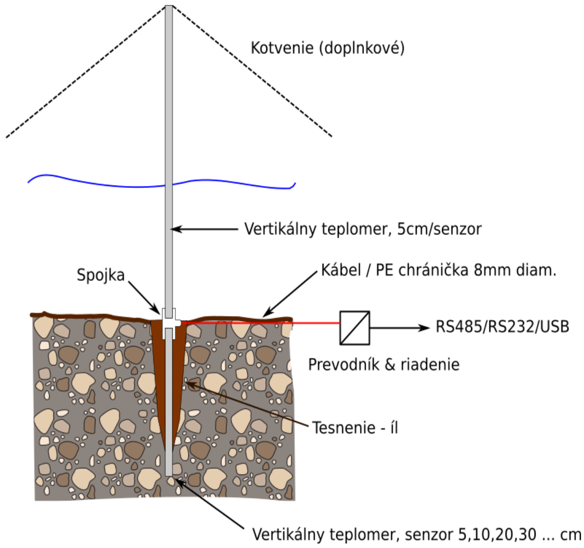

Figure 3. System scheme for complex measurement of vertical profile of temperature in soil and snow layers

EMISIVITY OF ELECTROMAGNETIC RADIATION OF ROCKS AND ICE

Emisivity of electromagnetic radiation from piesoelectric polycrystalic substances is prooved both experimentally and theoretically from different sources [4], [5]. We verified these effects at mechanical stress of granit and similar rocks in the band of 0.5-3 MHz with a perspective to monitor the land slides.

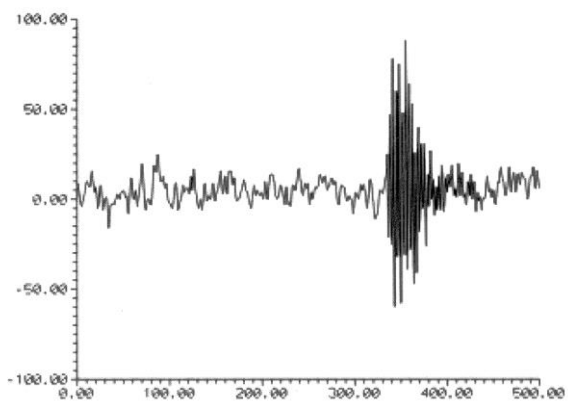

Figure 4. Impuls of electromagneic emisivity [6] recorded at the deformation of granite. Time 2.5 usec is atributed to the value 500 at x-asis.

It was prooved [7], [8] that it is possible to utilize the same mechanism with snow and ice. These substances also have piezoelectric ccharacteristics. Deducted from the experiments when experimenting with different rocks one can assume that spectral composition of emited electromagnetic radiation depends on the speed of sound in the particular environment and on the statistical value of dielectric pole. Based on these facts one can assume that it is possible to utilise the respective effects to monitor the dynamics of the snow movements and its ice parts (firn) in avalanche slopes under mechanical stress of polycristalic forms of snow in compact layers. To verify this fact we suppose to do experimental measurements in climate chamber. Based on it, an autonomous probe will be constructed. This will be placed to the avalanch slope. The information about the intensity and spectral composition of emited electromagnetic energy, temperature and mechanical stress tension will be communicated in VLF band.

THE USE OF LOCAL SOURCES OF ELECTROMAGNETIC ENERGY FOR ATMOSPHERIC PROBING

Both the frequency and magnitude of climate extremes like tornado, derecho, supercells, microbursts and heavy rains increase under climate change. Many of these phenomena were hardly noticed in Central Europe in the past. New instruments as well as new physical-mathematic models are needed to observe and to predict such events. The network of meteorological radars provides useful information from about 1000 m above the ground with the frequency of 5 min. Further important information about the meteorological objects and events comes from meteorological satellites. The satellites orbit the globe in two trajectories. First of them is called LEO (Low Earth Orbit). These meteorological satellites orbit above 850 km above the ground. Second type is GEO (Geostationary Earth Orbit). These satellites are "hanged" 36000 km above the ground in a concrete position above the equator. That is why such satellite scans the area up to about 80 degree of north and south latitude as the earth surface beyond these lines is not directly visible for them and the scan is difficult to interprete.
Despite of the complex processing of radar and satellite information we are not able to measure, with satisfactory accuracy, different hydrometeors, precipitation and mainly heavy rains over a certain area in lower parts of boundary layer. This concerns the layer of about 40-50m above the ground. The required resolution is 100 m with time period of 1 min. These supportive data are necessary for hydrologic prognosis and they can also serve to verify the results of numerical weather prediction. Further to that they can be used in ground transportation, irrigation management but mostly in the warning service giving the warnings about different meteorological phenomenon. To get the information about such phenomenon in the mentioned part of boundary layer we verified experimentally the possibility to use electromagnetic energy transmitted by BTS stations of mobile operators in GSM networks. The density of such stations in Europe is big, only in the territory of Slovakia there are about 15000 of them. The attenuation of the electromagnetic energy by precipitation and water vapor is in the band below 3 GHz quite low [9]. Nevertheless, by using efficient methods of signal processing based on correlated characteristics of transmit channel in the line of visibility distance, due to the influence of the signal by precipitation, we are able to get the information about the precipitation intensity in real time. By using more receivers we can establish a network which would cover a particular area. Based on the knowledge of the character of lines of visibility distance in such network by applying a appropriate algorithms (for example class SART) we can localize the place with a certain intensity of rain in the resolution of 100 m. This information can be obtained in real time with time resolution below 1 min. As the principle of measurement uses correlated changes of the characteristics of transmit channel in first Fresnel zone, which are caused by inhomogenity in the atmosphere, it is possible, beside the precipitation to localise also other selected phenomenon which cause such inhomogenity (derecho, tornado, supercell). Above described method does not require establishing of further broadcasting stations. It uses passive receiving of signals from existing BTS network which parameters (localization of the sources, their position, frequency) is possible to get from the operators of mobile networks

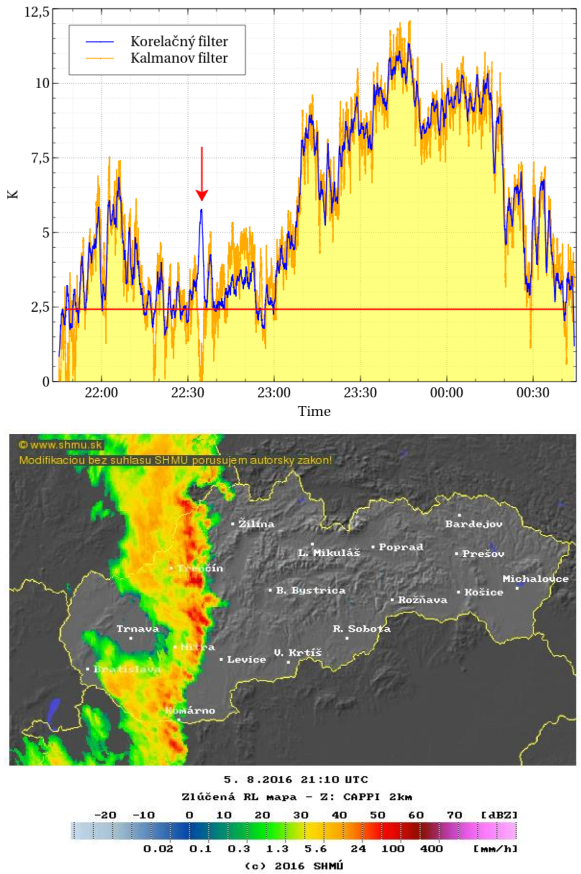

Figure 5. Meteorological situation when a cold front was passing and the data from the measurement of correlated characteristics communication channel in the length of 400 m in Trencin (UTC+2 hours). A method of diverse space receiver of pilot signal of BTS station at 920MHz with two antennas was used. K values are a relative correlation coefficient to compare the parameters of process model of Kalman filter and standard correlation filter. Its value correlate with the rain intensity. Kalman filter is sensitive to the state of matter which is in the line of propagation of the inhomogenity. They are marked by an arrow. Horizontal level points the level of the correlation of noise at input channels of the receiver. It is possible to diminish it statistically by increasing the frequency of sampling and by using more antennas.

CONCLUSION

The paper presents the methods which are under the development and only firts experimental results are available. Their practical application will require thorough and long time verification, the results will have to be compared with standard methods of measurements of these type of phenomenon. Nevertheless, when applying the right interpretation they can strongly contribute to the classical measurements.

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