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Hydrological characterization of mountain slopes via guided GPR waves

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The use of GPR waves for the measurement of soil moisture content has become increasingly popular both in surface and borehole antenna configurations. Advantages of GPR over other more traditional techniques, such as TDR, are: (a) that the scale of measurement is larger (about a cubic metre at 100 MHz, smaller at higher frequencies) and the estimated moisture content is therefore representative of a larger support volume; (b) measurements are fast and totally non invasive; (c) a large area can be covered in a limited time, so that spatial variations of moisture content can be reliably mapped with no need for (uncertain) interpolation of TDR point measurements. Disadvantages emerge as a consequence of the free propagation of electromagnetic waves that are not, unlike in the case of TDR, bounded by a man-made waveguide. Consequently some care must be taken in the data interpretation. In this work we plan to demonstrate that the measurement of moisture content along Alpine mountain slopes is one of the cases that require more sophisticated processing and inversion techniques to yield representative results. The hydrological dynamics along mountain slopes control many important phenomena, such as shallow landslide triggering and flood generation. The governing factors include: soil thickness, slope and bedrock morphology, rainfall pattern and subsurface groundwater conditions, both in vadose zone and under the water table. We present the results of a monitoring project currently undertaken on a large slope plot in the Alpine region of Northern Italy. Both direct (piezometers, tensiometers, etc.) and indirect (geophysical) methods are being used to characterize slope and bedrock morphology and changes in soil moisture content. The site is lo-

cated at an elevation of 1150 m a.s.l. The slope faces WSW, with a dip varying between 30° and 40°. The soil cover, 1-2 m thick, is characterized by extended unconsolidated deposits, with decimetric to metric blocks of different nature (serpentinites, granites, limestones) in a sandy-gravelly matrix, usually interpreted as moraine deposits. The bedrock is made of paragneiss with subvertical foliation and highly friable. The GPR monitoring has been performed using a PulseEkko 100 radar system. Given the small soil thickness and the limited porosity of the underlying bedrock, the soil layer behaves as a low-velocity waveguide sandwiched between air and the high velocity bedrock. This fact gives rise to the propagation of dispersive guide waves (velocity is a function of frequency) that obey a modal equation. We present a methodology to process and interpret the data to yield radar velocity of soil and bedrock, and soil thickness. The amount of additional information that can be derived from GPR data collected in the process is assessed, and we compare the results of GPR monitoring with other information on moisture content dynamics and geological structure of the site.