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Large-scale hydro-geological characterization of flow systems in an alpine region (Northern Tyrol, Austria)

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Introduction

One of the precipitation-runoff (P/R-)models in frequent use in Austria is known by the acronym ZEMOKOST (e.g. Kohl et al. 2014, https://bfw.ac.at/cms_stamm/050/PDF/Bedienungsanleitung_ZEMOKOST_V2_0.pdf). It has been developed since the 1990s by WLV (Austrian Federal Service in Torrent and Avalanche Control) and BFW (Federal Research and Training Centre for Forests, Natural Hazards and Landscape), for design flood estimation in alpine catchments. A code of practice for practitioners has been written by Markart et al. (2014). Peak runoff is well predicted by this model, but this is not always true for secondary peaks. It was concluded that subsurface flow was not sufficiently accounted for. Consequently, a method of using geological data in P/R-models was developed, and a pilot study of the Eastern Tyrol conducted, by H. Pirkl (2016). The method is based on a qualitative classification of contributing areas, including type, depth, and relative impact of subsurface flow. In the current project HYGENOT, we extend this approach to the entire Northern Tyrol of Austria, and want to improve on it by considering flow systems and quantifying their contribution.

Methods

Two kinds of information were required: (1) the temporary and perennial stream network; (2) the contributing areas in all catchments, classified according to hydro-geological properties.

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(1) The stream network, for the most part, has first been calculated in SAGA GIS (Flow Accumulation - Channel Network method), then manually modified. Springs are mapped extensively, and used for separating temporary and perennial stream lines.

(2) Runoff type mapping basically distinguishes between the 7 classes of Pirkl (2016); some have subdivisions according to extent, fracturing, karstification, and storage capacity. Types are delineated on top of the DEM (1m terrain model; hillshade and topographic openness overlays for emphasis of bedrock and structural features), while additional information is derived from topographic and geological maps (1:50.000), incl. a special report on the Northern Calcareous Alps (NCA) by the Austrian Geological Survey, ortho-images, digital inventories (landslides, glaciers, rock glaciers, springs, lakes), case studies (e.g. MSc theses), and localized field work.

Given the size and complexity of the area, an efficient workflow had to be set up in order to complete the study in reasonable time. In a first step, all relevant information from maps, inventories, etc., was transformed directly into generalized subsurface flow types (e.g. landslides = predominantly deep-seated). Available geological maps typically differentiate bedrock rather than softrock, so the map from the first step required a major overhaul, which has to be done manually for each catchment.

Groundwater flow in typical slope sections is calculated using SEEP/W (Geoslope), as a plausibility check on subsurface flow routing speeds; and finally the entire workflow is tested in a sub-catchment of the Ötz valley.

Results and discussion

Pilot tests in the Eastern Tyrol have shown that the manually mapped stream network is too sparse. In comparison, our semi-automatic method, despite all the editing, leads to a more consistent network of high density. It is important to include the temporary streams, which appear above the spring lines following extreme precipitation.

All of the Northern Tyrol has been mapped (example Figure 1). Pirkl's (2016) classification turned out to be readily usable in all areas where crystalline rocks predominate, while sub-classes had to be added for the NCA. The descriptive parts were refined by hydro-geological information and mapping criteria. First attempts at implementing subsurface flow in ZEMOKOST indicate a sizable but plausible impact on the results. A detailed description of the workflow is planned to make the method available for other regions and operators.

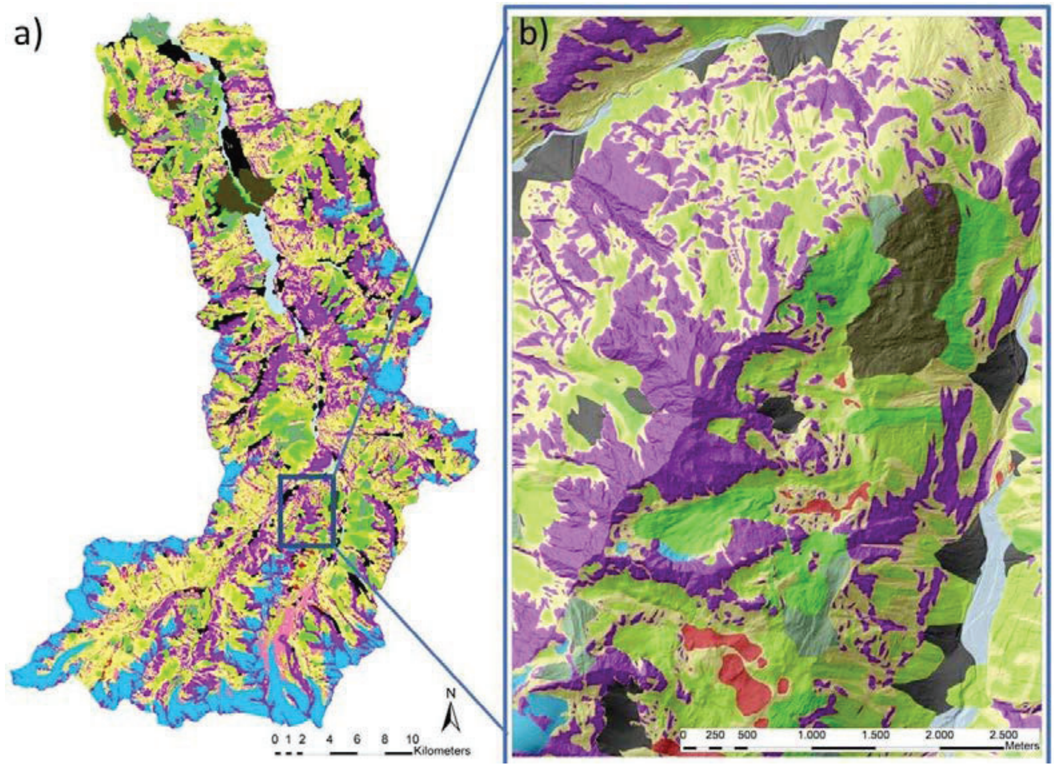

Figure 1: Example of mapped subsurface flow types in the Northern Tyrol. a) Subsurface flow types in the Ötz valley (ca. 900 km²). b) Detail on top of hillshade image. Colors represent different subsurface flow types.

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