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Towards a Digital Twin for the Alps to simulate water-related processes and geohazards for climate change adaptation strategies.

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The Alps are the most densely populated mountain range in Europe and water resources play a central role in the socio-economic developments of the area (agriculture, tourism, hydropower production...). Furthermore, the Alps are particularly sensitive to the impacts of climate change and thus to hydro-meteorological hazards such as landslides, floods, droughts and glacier related processes, which are expected to increase in the near future, constitute a major threat to human activity. Indeed, over the last century, temperatures have risen twice as fast as the northern-hemisphere average, whereas precipitation has increased non-linearly and has become more discontinuous.

Because of the increasing pressure on human settlements and infrastructure, there is a strong priority for policy-makers to implement climate change adaptation strategies from the local to the regional scale. To support and improve the decision-making process, numerical decision support systems may provide valuable information derived from multi-parametric (in-situ sensors, satellite data) observations and models, linked to computing environments, in order to better manage increasing threats and weaknesses.

The main objective of the Digital Twin of Alps (eg. DTA) platform is to provide a roadmap for the implementation of future Digital Twin Components, with a focus on the Alpine chain. In this context, a demonstrator has been developed that enables a holistic representation of some of the major physical processes specific to the Alpine context, powered by a unique combination of Earth Observation data analytics, machine learning algorithms, and state-of-the-art hydrology and

geohazard process-based models. Advanced visualization tools have been specifically implemented to favor easy exploration of the products for several categories of stakeholders.

The resulting Digital Twin Earth precursor will provide an advanced decision support system for actors involved in the observation and mitigation of natural hazards and environmental risks including their impacts in the Alps, as well as the management of water resources. For instance, through the demonstrator users can investigate the availability of water resources in terms of snow, soil moisture, river discharge and precipitation. Furthermore, it is possible to stress the system with scenario based options to see the impacts on the various hydrological drivers in terms of drought and flood probability. Finally, the user can assess flood hazard, forecast (with a daily leading time) the occurrence of shallow landslides (slope failure probability and material propagation) and predict the activity (e.g. velocity) of large deep-seated and continuously active landslides from extreme rain events through the use of a combination of physics- and AI-based simulation tools. Use cases in Northern Italy, South Swiss and South France are provided.

Finally, the user can visualise maps and time series of terrain motion products over several Alpine regions generated with advanced Earth Observation processing chains and services (GDM-OPT, Snapping) available on the Geohazards Exploitation Platform and the eo4alps-landslides App, providing a consistent description of Earth surface deformation (unstable slopes, large deep-seated landslides, ice glacier) for the period 2016-2022. The data, services and technologies used and developed for the platform will be presented.