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Towards a global km-scale flood forecasting system

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River discharge has direct influence on the water-food-energy-environment nexus and can have devastating impacts during extreme events with rapid onsets such as floods. Floods often occur after extreme precipitation events, which are challenging to forecast accurately, both in time and space. Unresolved small-scale processes and features, including convection and orography, have a detrimental effect on precipitation and consequently hydrological forecast skill. This calls for a spatial resolution increase in Numerical Weather Prediction (NWP) models, including their land component.

The Destination Earth programme of the European Commission addresses this with globally coupled forecasts at spatial resolutions down to the km-scale with lead times of 5 days: the Digital Twin on Weather-Induced Extremes (EDT). These meteorological forecasts are used to force ECMWF's Land Surface Modelling System (ECLand), the land component of the Integrated Forecasting System (IFS), to generate runoff. Subsequently, the river-routing scheme CaMa-Flood, effectively 1-way coupled to the IFS, is used to route runoff in rivers and to produce hydrological simulations. Essentially, CaMa-Flood will be part of the continuous component of the EDT, which in phase 2 of Destination Earth will provide daily high-resolution forecasts to monitor extreme events, such as floods, in real time. As river discharge acts as a natural integrator of the water cycle, CaMa-Flood can be used as a diagnostic tool to assess the hydrological response to increases in spatial resolution of the forcing and the river-routing network.

In this study, two data products are derived: i) long-term hydrological simulations forced by atmospheric analysis data (e.g. ERA5 or ECMWF operational analysis) and ii) hydrological forecasts (daily forecasts in June - July 2021 and January - February 2022 as well as selected flood cases). To assess their quality, these data are validated with point-observed river-discharge time series. Analysis shows that the long-term hydrological simulations benefit from spatial resolution increases in the meteorological forcing and to a lesser extent from spatial resolution increases in the river-routing network. This is evidenced by higher Kling-Gupta Efficiency (KGE), higher correlations and lower biases across 876 river stations in Europe. Further, hydrological forecasts also benefit from higher spatial resolution meteorological forcing, evidenced both by higher correlations of the continuous summer/winter forecasts against river discharge observations from

798 river stations across Europe and by more pronounced flood peak magnitude for selected flood cases. These results highlight the added value of high resolution for hydrological forecast accuracy.