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Research paper

Interoperability challenges in river discharge modelling: A cross domain application scenario

Mattia Santoro [a,*], Volker Andres [b], Simon Jirka [c], Toshio Koike [d], Ulrich Looser [b], Stefano Nativi [a], Florian Pappenberger [e], Manuela Schlummer [f], Adrian Strauch [f], Michael Utech [g], Ervin Zsoter [e]

[a] Consiglio Nazionale delle Ricerche, Italy
[b] Global Runoff Data Centre at the Federal Institute of Hydrology (BfG), Germany
[c] 52°North GmbH, Germany
[d] University of Tokyo, Japan
[e] European Centre for Medium-Range Weather Forecasts, UK
[f] University of Bonn, Germany
[g] KISTERs AG, Germany

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ABSTRACT

River discharge is a critical water cycle variable, as it integrates all the processes (e.g. runoff and evapotranspiration) occurring within a river basin and provides a hydrological output variable that can be readily measured. Its prediction is of invaluable help for many water-related tasks including water resources assessment and management, flood protection, and disaster mitigation. Observations of river discharge are important to calibrate and validate hydrological or coupled land, atmosphere and ocean models. This requires using datasets from different scientific domains (Water, Weather, etc.). Typically, such datasets are provided using different technological solutions. This complicates the integration of new hydrological data sources into application systems. Therefore, a considerable effort is often spent on data access issues instead of the actual scientific question.

This paper describes the work performed to address multidisciplinary interoperability challenges related to river discharge modeling and validation. This includes definition and standardization of domain specific interoperability standards for hydrological data sharing and their support in global frameworks such as the Global Earth Observation System of Systems (GEOSS).

The research was developed in the context of the EU FP7-funded project GEOWOW (GEOSS Interoperability for Weather, Ocean and Water), which implemented a "River Discharge" application scenario. This scenario demonstrates the combination of river discharge observations data from the Global Runoff Data Centre (GRDC) database and model outputs produced by the European Centre for Medium-Range Weather Forecasts (ECMWF) predicting river discharge based on weather forecast information in the context of the GEOSS.

1. Introduction

River discharge is a key variable of the global water cycle as it provides an integrated signal of all the hydrological processes occurring within a river basin. Its observation and prediction is an information source for many application areas such as water resources assessment and management, design and operation of technical facilities (dams, reservoirs), aquatic ecosystem management or flood protection and disaster mitigation (Group on Earth Observation, 2014). Additionally, the Global Climate Observing System (GCOS) programme (World Meteorological Organization, 2010) (Bojinski et al., 2014) defined river discharge as an Essential Climate Variable (ECV) because its observation is critical for the characterization, understanding and prediction of the Earth's climate and its changes. In these various application areas, the exchange of river discharge data across disciplinary and institutional boundaries is of high importance (e.g. for the validation and calibration of hydrological

* Corresponding author.
E-mail addresses: mattia.santoro@cnr.it (M. Santoro), volker.andres@mac.com (V. Andres), s.jirka@52north.org (S. Jirka), tkoike@hydra.t.u-tokyo.ac.jp (T. Koike), looser@bafg.de (U. Looser), stefano.nativi@cnr.it (S. Nativi), florian.pappenberger@ecmwf.int (F. Pappenberger), manuela.schlummer@uni-bonn.de (M. Schlummer), astrauch@uni-bonn.de (A. Strauch), michael.utech@kisters.de (M. Utech), ervin.zsoter@ecmwf.int (E. Zsoter).

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prediction models or regional and global analysis of river discharge). Thus, scientists and policy makers would highly benefit from a common interoperability framework that addresses the needs of the Earth science community for improved information sharing among its different domains through an eased access to diverse hydrological data sources and their integration into application systems.

From a technological perspective, the main challenge to achieve this stems from the diversity of the involved components (i.e. geospatial data sharing infrastructures, services, data models, etc.). In fact, when creating a geospatial data-sharing infrastructure for a given scientific domain, a set of discipline-specific needs must be taken into account and addressed. This has an impact on the adopted technological solutions as far as data, metadata, processing models, services protocols and interfaces, semantics, and embedded knowledge are concerned (Craglia et al., 2011). As result, the landscape of existing discipline-specific infrastructures for geospatial data sharing is highly heterogeneous (Laney, 2001). Multidisciplinary interoperability is essential to achieve an effective integration of such information systems and to provide integrated access to a range of advanced information and processing resources for the environment and the policy-makers support (Mazzetti and Nativi, 2012).

This research focuses on the work performed to address multidisciplinary interoperability challenges for river discharge modeling and validation. The research was developed in the context of the EU FP7 project GEOWOW (GEOSS Interoperability for Weather, Ocean and Water) and of the Global Earth Observation System of Systems (GEOSS). A cross-domain application scenario was implemented to combine river discharge observations data from the Global Runoff Data Centre (GRDC) database and model outputs produced by the European Centre for Medium-Range Weather Forecasts (ECMWF) predicting river discharge based on weather forecast information.

This paper is structured as follows. Section 2 introduces the scientific needs for this research. Section 3 describes the main interoperability challenges stemming from the scientific needs. Section 4 describes the adopted multidisciplinary interoperability approach, the resulting system architecture and the developed application scenario and the results. Section 5 provides an example of possible further applications. Finally, Section 5 draws the conclusions and describes possible applicability in a different application scenario.

2. Scientific framework: river discharge and prediction

According to the Emergency Event Data Base (EM-DAT) of the Centre for Research on Epidemiology of Disasters, floods (including general river floods, flash floods, storm surges/coastal floods) accounted for 30% of all recorded natural disasters between 1900 und 2006, while 6,899,095 people were killed and more than 3 billion people affected (Adikari and Yoshitani, 2009). Since, furthermore, flooding is an increasingly frequent thread in many regions of the world (Adikari and Yoshitani, 2009) (Intergovernmental Panel on Climate Change, 2014) flood protection and risk management are a urgent issues for policy-makers and managers to reduce the vulnerability of societies against flood damages. Crucial elements of flood disaster prevention are river discharge forecasting systems based on numerical weather prediction (NWP) models that provide medium range forecasts and early warnings to civil protection authorities, flood forecasting services and the public (Cloke and Pappenberger, 2009). A recent trend in the field of medium term flood forecasting goes to Ensemble Prediction Systems that are used as input for hydrological models to forecast river discharge (Cloke and Pappenberger, 2009). For the calibration and validation of river discharge prediction systems data centers such as the Global Runoff Data Centre (GRDC), that collects river discharge data from more than 9000 stations in 160 countries in various data formats, provide valuable databases. A subset of these river discharge data sets is made freely available as GEOSS Data-CORE[1] and is discoverable in standardized formats (see section 4.2) via the GEOSS Portal.[2]

General issues regarding the collection and combined use of data from different sources (in the case of the GRDC various National Hydrological Services) and different domains (e.g. river discharge observations from national hydrological services and ensemble predictions from meteorologists) are the large variety of interfaces and data formats. This heterogeneity regarding data formats and data exchange mechanisms within the hydrology domain combined with data quality assurance and data policy issues lead to the fact that many datasets are uploaded to global databases such as the Global Runoff Data Centre with a delay of a few years. This is an obstacle to all applications that require near-real-time data access (access to data within one year of the measurement). Scientists and decision makers often suffer from the low interoperability within their specific domain and between different domains and therefore have to spend considerable effort on data access issues besides the actual scientific question and application.

Application areas such as the validation and calibration of river discharge prediction models or regional and global analysis of river discharge would highly benefit from an increased multidisciplinary interoperability that allows a harmonized and timesaving access to different data sources and an eased integration of new hydrological data sources into application systems.

The river discharge forecasting performed within the framework of the GEOWOW project was performed for NWP models available in the THORPEX Interactive Grand Global Ensemble (TIGGE) archive (Bougeault et al., 2010). TIGGE is a major component of the WWRP-THORPEX research program, whose aim is to accelerate improvements in forecasting high-impact weather. TIGGE provides a database of ensemble predictions, collected from leading operational NWP centers for scientific research on various topics since October 2006, and has been instrumental in supporting cooperation between the academic and operational meteorological communities. In turn, it has provided a basis for research on objective evaluation, predictability and dynamical processes. The research undertaken includes studies on multi-model combination, correction for systematic errors, tropical cyclones and the dynamics of extra-tropical storm tracks. Although TIGGE is a research project, it has proved invaluable for the development of several applications in relation to operational forecasting. Examples include the development of multi-model tropical cyclone tracks, severe weather early warning products for heavy rainfall or strong winds, and various applications in flood forecasting using coupled hydrological models.

The modelling work was based on the HTESSEL (Hydrology-Tiled ECMWF Scheme for Surface Exchange over Land) land-surface model used operationally at ECMWF (Balsamo et al., 2009). The offline version of HTESSEL was extended to accommodate ensemble forecast runs from TIGGE with also using ECMWF climate and initial conditions. The HTESSEL runs require atmospheric forcing of temperature, humidity, pressure, wind, radiation and precipitation. The radiation parameters are not archived in TIGGE therefore ERA Interim (ECMWF global atmospheric reanalysis from 1979) was used to provide common radiation forcing replacement. The rest of required forcing parameters were available from four TIGGE models, ECMWF, UKMO (UK Met Office), NCEP (National Centers for Environmental Prediction in the US) and CMA (China Meteorological Administration). The other models had some missing parameters. The land-surface model output is runoff, which is provided in the grid structure of the HTESSEL model. To aggregate the runoff into river discharge we used the CaMa-Flood river routing scheme and produced discharge for about 400 global river catchments (Fig. 1).

The production of the TIGGE based hydrological discharge forecasts covered the period 2008–2013. Within the framework of the GEOWOW

[1] https://www.earthobservations.org/geoss_dsp.shtml.

[2] http://www.geoportal.org/.