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A vision for improving global flood forecasting

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Abstract

Global hydrological forecasts are now produced operationally on a daily basis. However, the lack of global river discharge observations precludes routine flood forecast evaluation, an essential step in providing more skilful and reliable forecasts. A vision is expounded for greater and more timely exchange of global river discharge observations, which would result in improved flood awareness and socioeconomic benefits in some of the World's most vulnerable countries.

1. Introduction

Africa was struck by tropical cyclones Idai and Kenneth in the first half of 2019 and their impacts were catastrophic. In the worst affected countries of Madagascar, Malawi, Mozambique, and Zimbabwe, there was widespread flooding and strong winds, over 1000 fatalities, at least $1 billion of economic damages including the loss of infrastructure and homes, and cholera outbreaks. Furthermore, these countries are some of the most vulnerable and least resilient to such natural hazards, which magnifies the consequences. These two episodes are the latest in the recurring nature of hazardous flooding, and it is pertinent at this time to reflect on the fact that anthropogenic climate change is projected to intensify the global hydrological cycle, thus potentially exacerbating any future flood events [1].

Early warning of extreme weather, such as tropical cyclones, can be provided by using global weather forecasts. This is achieved via a process called numerical weather prediction (NWP) and in recent decades NWP has undergone a revolution owing to increasing computing power, better understanding of earth system processes, and wider observation coverage of the Earth system state, for example, via satellites [2]. The result has been a steady improvement in forecast skill enabling warnings of severe weather to be afforded up to one week in advance [3, 4]. One effect of extreme weather and, in particular heavy precipitation, is flooding, and its magnitude and extent are dependent on the precipitation totals, antecedent land conditions, land surface characteristics, water management (e.g. dams and reservoirs), and the ability of society to respond. In Europe, the effects of flooding were brought to the fore with the disastrous Elbe and Danube flooding in 2002 and in response the European Flood Awareness System (EFAS [5, 6]) was initiated to forewarn of riverine flooding. Since 2012, EFAS has been operational as part of the European Commission Copernicus Emergency Management Service (CEMS) and it has used NWP precipitation forecasts to drive a hydrological model to issue flood alerts across Europe, with the advanced warnings being disseminated to the relevant hydro-meteorological agencies. A fundamental factor in the success of EFAS has been the sharing of hydrologically-relevant observations, particularly temperature, precipitation, and river discharge in real-time. For example, EFAS forecasts are improved by post-processing using these real-time observations to minimise errors in flood timing, volume, and magnitude [7] for 681 catchments across Europe [6].

In April 2018, thanks to access to the requisite computing power and weather forecasts at the European Centre for Medium-Range Weather Forecasts (ECMWF), a global hydrological model became operational and run on a daily basis, with its forecasts provided free of charge as part of CEMS; this system is called the Global Flood Awareness System (GloFAS [8, 9]). The rationale behind running global hydrological models is that their consistent and worldwide view can provide probabilistic forecasts for basins and regions where the spatial scale of flood events can

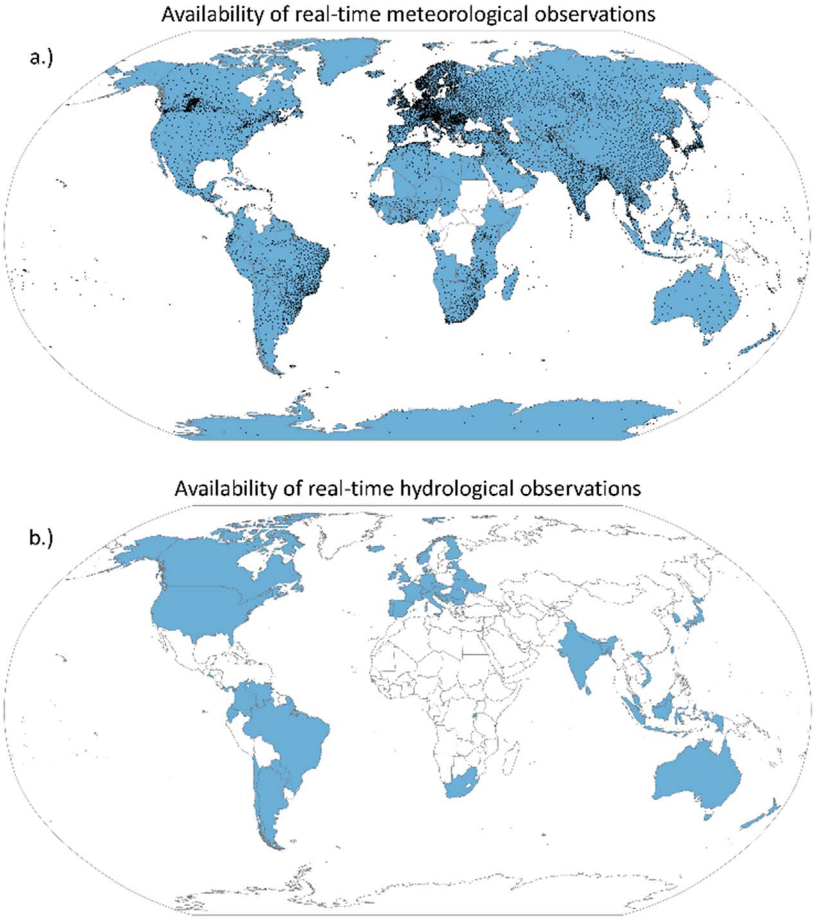

Figure 1. Global availability of real-time weather and hydrology data in June 2019. (a) Locations (black dots) and the countries (blue) with surface-based meteorological observations in the WMO Integrated Observing System (WIGOS) on the OSCAR/Surface repository. (b) Countries (blue) that publish their real-time river discharge data on their individual repositories without restrictions or cost according to the WMO Hydrological Observing System (WHOS); but are yet to disseminate them centrally under a common data sharing protocol. The atmospheric data plotted in (a) are available on https://oscar.wmo.int/surface/#/ and the data in (b) are available on https://public.wmo.int/en/our-mandate/water/whos.

exceed far beyond natural or political borders [10] and when no alternative forecast systems are available [11]. As these regions are some of the most vulnerable, the forecasts can help inform government bodies, international humanitarian aid agencies, (re)insurance companies, and affected populations of possible flood or drought risks. National or local-scale flood forecasting can also benefit from continental and global-scale systems by obtaining additional flood guidance at larger spatial scales and often longer lead times. The GloFAS forecasts for tropical cyclone Idai showed a flood signal up to five days in advance [12]. However, it is unknown how well river discharge and flood extent were predicted for this event and others because there is a paucity of accessible global real-time river discharge observations, which is a major barrier precluding the further development and improvement of such forecasts. Availability of timely observations globally, ranging from hours to even several months delay, would allow for the routine evaluation of flood forecasts for major events, the diagnosis of forecast problems, and the subsequent initialization, calibration, and post-processing of hydrological models. The need for global hydrological observations has long been recognised and remains a challenge [13]. It is argued here that encouraging more countries to modify their data policies to enable open sharing of river discharge data in real-time through an international data dissemination system would drive the development of global hydrological forecasting, which would in turn protect lives and property and realize socioeconomic benefits in some of the most vulnerable communities.

2. Current observation exchange systems and hydrological barriers

A cornerstone of NWP is accurate knowledge of the atmospheric state from which the forecasts are initialized and run, and fundamentally this relies on the global two-way exchange of (i) weather-related observations to NWP centres, such as ECMWF, and (ii) the dissemination of NWP forecasts back to the user community. The observation sharing is achieved under the framework of the World Meteorological Organization (WMO) through the WMO Integrated

Global Observing System and the WMO Information System. Figure 1(a) shows the global availability of surface-based meteorological observations for atmospheric forecasting in June 2019. The sharing of global data has been essential for developing data assimilation systems to ingest observations into the NWP models, in turn, contributing to the continued improvement in NWP.

The WMO mandate lists facilitating cooperation in making hydrological observations and operational hydrology as two of its key purposes [14]. However, in contrast to the broad availability of surface-based meteorological observations, the corresponding global network of hydrological observations is less developed and contains much less data. Figure 1(b) shows which countries have a network of real-time river discharge observations available in principle without restrictions or financial cost. This network is supported through the WMO Hydrological Observing System (WHOS [15]), which is in development. However, as many countries have yet to adopt any international data sharing standards, these data are currently only accessible via the websites or portals of the 54 countries; and the plethora of non-standard data and metadata formats leaves these observations unusable for ingestion into operational continental and global-scale hydrological forecasting systems. Additionally, the main archive facility for global long-term historical hydrological data is the Global Runoff Data Centre (GRDC; http://grdc.bafg.de) at the German Federal Institute of Hydrology in Koblenz which also operates under the auspices of the WMO. The GRDC data upload process relies on voluntary contributions from countries which results in irregular submissions, and hence, severe information gaps in space and time. This is confirmed by an analysis undertaken by the authors in July 2019: 50% of the 7600 GRDC archived stations have no data covering the past decade.

There are multiple reasons why hitherto there has been inadequate sharing of hydrological data [16] and these include: (i) no perceived benefit to the provider for making their real-time observations available and/or loss of commercial revenue; (ii) water rights and policy related to transnational river basins, for example, in the Himalayas region; (iii) poorly gauged river basins; (iv) failure to adopt a single international standard for data and metadata sharing (e.g. standardized data format, WaterML 2.0 [17]) and licensing agreements; and (v) lack of financial and technical (e.g. for data transmission) capacity. We argue that scientific and operational advances, namely global hydrological forecasting and its potential socioeconomic benefits, could be the facilitator necessary to make progress in this matter of global data sharing. This would bring benefits to individual countries on upcoming flood impacts, and it may allow global NWP and hydrology centres to use these extra observations to aid the closing of the water balance within global NWP models, an outstanding grand challenge.

3. A call for action

We therefore call for an impetus on national and international science and policy to support greater and more timely exchange of global real-time and historic hydrological data, an effort potentially made under the WMO through the WHOS and GRDC, respectively. This exchange of data is fundamental for advancing global flood forecasting as it would provide the opportunity to routinely evaluate flood forecasts, diagnose forecast problems, and allow the forecasting community to develop novel initialization, calibration, and post-processing procedures to deliver more skilful and reliable forecasts at longer lead times globally. Increased data exchange is mutually beneficial as countries that provide data would in return receive improved warnings of water-related hazards, thus resulting in positive socioeconomic impacts. This global network could have further longer-term potential in developing new technologies to broaden the global river gauging network especially in poorly monitored regions. For example, these extra observations could be essential as a ground truth for the Surface Water and Ocean Topography satellite mission due to launch in 2021 [18], thus realizing the full value of remote sensing data.

Global hydrological forecast models and the requisite computing power are now available, but the major remaining barrier to advancing global flood forecasting is the ready availability of hydrological observations to complete the forecasting system. By overcoming this challenge, such global hydrological forecasts could become more skilful and provide a consistent, cross-border, and apolitical hydrological forecasting system supporting visions such as the WMO Global Hydrological Status and Outlook System (HydroSOS). This would have socioeconomic benefits by presenting a worldwide perspective and giving earlier warnings of flood hazards especially to the most at-risk or vulnerable countries.

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Data availability statement

Data sharing is not applicable to this article as no new data were created or analysed in this study.

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