Response to Anonymous Referee #2

The paper entitled "GloFAS-ERA5 operational global river discharge reanalysis 1979- present" presented by Harrigan et al., describes re-analysis driven global river discharge simulations that are updated in near real time and distributed through the Copernicus Climate Change Service Climate Data Store. Overall, the paper is well written and provides the reader with an overview on the methods used for data production, file formats and the performance of the data set.

Thank you for your positive comments and constructive feedback. Your clarifications have improved the manuscript and made it clearer for the reader. Our responses to your comments are provided below in blue together with your original review in black.

Given, that this paper is a data-descriptor and neither a model documentation nor a research article there is little to criticize. Nonetheless, some aspects of the paper would benefit from additional information. My main points are summarized below:

1. Terminology: The data product presented is referred to as "reanalysis". Although the runoff data used to drive lisflood stem from a reanalysis, the presented data product is not an integral part of ERA5. In addition, observational discharge data are only used for calibrating lisflood, but are (to my understanding) not assimilated through a state-updating procedure. Given that the term reanalysis is often associated with state updating, I would find a clarification of the chosen terminology helpful in order to avoid confusion about the nature of the presented data set.

We use the term reanalysis to mean the optimal combining of in situ and satellite earth system observations together with models to provide consistent spatio-temporal "maps without gaps" of land, ocean and atmospheric variables of interest as per Hersbach et al. (2020) and is now common in Earth System Modelling.

2. Transparency of the data production process: Although the paper does a good job in summarizing the workflow resulting in the presented data set, the amount of information presented is not sufficient to replicate the data. While I acknowledge that a description of ERA5 or Lisflood are beyond the scope of the paper, there are a number of essential technical steps that are not described. Open questions include, but are not limited to, (i) how was ERA5 output disaggregated to the finer resolution, (ii) how was lisflood calibrated (are the data used for validation independent of the data used for calibration), (iii) what does it mean that reservoirs are included (e.g. is management also simulated), etc. I realize that some of these questions are also treated in other publications but for a user of the data set a comprehensive overview with more details would be essential to fully understand the capabilities (and limitations) of the data.

Your overall point on the need for additional clarity, especially in regards to the hydrological modelling detail, was also raised Anonymous Referee #1. It is indeed a balance within this data paper to focus on the description of the GloFAS-ERA5 dataset and its evaluation, while providing sufficient detail on the modelling methodology to allow users to gain an understanding of the capabilities and limitations. Our intention is to provide only a summary of the modelling methodology that is already described in full detail in the published literature. Given your queries, we propose to include the new Table A (below) to accompany Fig. 1 in the resubmitted manuscript that summarises the published scientific papers and model documentation for each of the key GloFAS-ERA5 components. All these publications are open access.

Responses to your individual queries are given below:

i.) This question was also asked by Anonymous Referee #1. In order to be consistent with the operational GloFAS procedure, the runoff fields from ERA5 were downscaled using the simple nearest neighbour method from the native resolution to the 0.1° LISFLOOD grid. The task was done using the open source 'pyg2p' module with interpolation 'grib_nearest' option in Python (https://pypi.org/project/pyg2p/). No weights were applied to runoff values and terrain effects within the ERA5 cell were not considered. We will add the additional detail on how the downscaling was done in the resubmitted manuscript.

ii.) The LISFLOOD version used here for GloFAS-ERA5 v2.1 was calibrated by Hirpa et al. (2018) using an evolutionary optimisation algorithm against daily river discharge from 1287 stations worldwide. For each station, the record was split in two for calibration and validation. If the record was shorter than eight years, four years were used for calibration and the remainder for validation. If the record was equal to or longer than eight years, half was used for calibration and half for validation, with the most recent period used for calibration.

iii.) Reservoir outflow is calculated with a set of simplified rules depending on their filling level, and balances water recharge if storage is below normal or release if above normal. There is a minimum outflow to ensure the downstream river does not dry up, and a non-damaging release so the reservoir does not reach full capacity. Simplified reservoir operating parameters were used based on expert opinion (outlined in Zajac et al., 2017) given lack of availability of global operational release records.

Table A: Scientific papers and model documentation for the key components in the production of GloFAS-ERA5 v2.1 river discharge reanalysis dataset.

GloFAS-ERA5 component	Description	Reference
ERA5	Global reanalysis dataset using ECMWF Integrated Forecast System (IFS) model cycle 41r2 from 1979 to present	Hersbach et al. (2020)
ERA5 runoff	Surface and sub-surface runoff within ERA5 generated using the HTESSEL land surface model	Balsamo et al. (2009)
LISFLOOD river discharge	River discharge generated using LISFLOOD hydrological and channel routing model to route runoff into and through the river network and provide groundwater storage. LISFLOOD includes lake, reservoir and human water use routines	Burek et al. (2013)
Lakes and reservoirs used in GloFAS	Incorporated 463 lakes and 667 reservoirs into the GloFAS river network	Zajac et al. (2017)
Calibration of LISFLOOD used in GloFAS	LISFLOOD was calibrated against daily river discharge from 1287 observation stations worldwide	Hirpa et al. (2018)

3. The output variable (discharge) is "Volume rate of water flow, including sediments, . . .". While I acknowledge that this is likely the variable of interest for flood forecasting, I would appreciate if the volume (or mass) of pure H2O could also be made available (if this does not differ significantly, then a statement explaining this might be useful).

The definition given in Table 2 is the generic definition of discharge from rivers and streams by the World Meteorological Organisation (WMO) for hydrological products (https://www.wmo.int/pages/prog/www/WMOCodes/WMO306_vI2/LatestVERSION/WMO306_vI2_GRIB2_CodeFlag_en.pdf). It is used across all river discharge products at ECMWF and on the Copernicus Climate Change Service (C3S) Climate Data Store (https://apps.ecmwf.int/codes/grib/param-db?id=240013). Virtually all hydrological models, including GloFAS-ERA5, simulate the volume rate of water only due to inherent simplifications of reality.

4. What is the time resolution of the observations used for validation? I assume daily, but this was not stated explicitly.

Yes, the observations are daily, and the evaluation carried out at the daily scale. Both will be clarified in the resubmitted manuscript.

5. Stations used for evaluation come "predominantly" from the GRDC. This is not transparent at all and hinders reproducibility of the study. I assume that some of the data cannot be re-distributed, but an overview (e.g. supplementary table) on the considered stations including some key properties (geolocation, river and station names, data-provider, catchment area, . . .) foster reproducibility of the results.

Observations cannot be redistributed by the authors due to licencing agreements but to foster reproducibility of the results we will include a Supplementary Table S1 in the resubmitted manuscript including the following metadata for each of the 1801 stations: *GloFAS_ID, Provider, Provider_ID, Station_Name, River_Name, River_Basin, Country_Name, Catchment_Area_Provider_km2, Catchment_Area_GloFAS_km2, Latitude_Provider, Longitude_Provider, Latitude_GloFAS, Longitude_GloFAS.*

In addition, we will include in the Supplementary Table the corresponding performance metrics for each station to allow users to explore the results in more detail: *KGE', KGESS, correlation, bias_ratio, variability_ratio, MAE_mm_per_day.*

6. If there is more than one station per grid-cell only one station is selected. This is OK. However, what is the criterion to select a particular station (random, expert judgment, catchment size,. . .)?

When multiple observation stations were matched to the same GloFAS river cell, the station with the longest record was retained. This criterion removed 27 stations from the initial list. This will be qualified in the resubmitted text.

7. I personally would find extended global summaries (in addition to medians and IQRs) of the performance metrics useful (e.g. tables with percentiles, or empirical cumulative distribution functions).

We have taken your suggestion on board and will also present the performance metrics for all 1801 stations as a cumulative distribution function in the resubmitted manuscript (Fig. A). We will also include the performance metrics for each station along with the metadata in a Supplementary Table S1 you suggested in your point number 5.

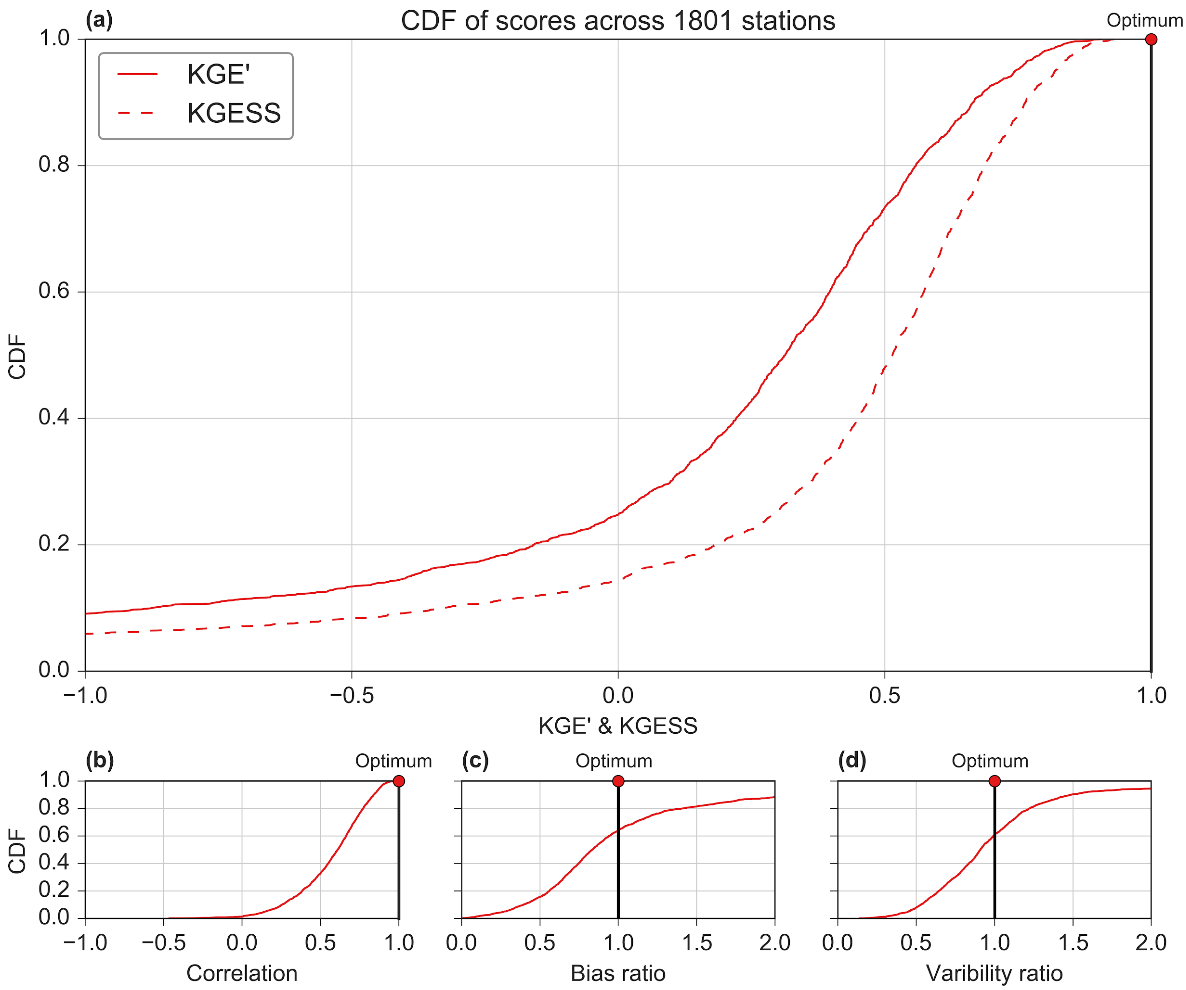

Figure A. Cumulative distribution function of performance metrics across all 1801 stations. Modified Kling-Gupta Efficiency (KGE') and Skill Score (KGESS) (a) with decomposition of KGE' into Pearson correlation (b), bias ratio (c), and variability ratio (d). The red dot marks the optimum value for each metric.

8. The performance assessment focuses predominantly on the skill of the full time series at daily resolution. For some users information focussing on different modes of variability (e.g. seasonal cycle, anomalies of the seasonal cycle, year-to-year fluctuations) would be also of great interest.

Thank you for your suggestion. We agree that there are many other exciting potential applications of GloFAS-ERA5 that would be interested in an aggregation of the dataset. But here, focusing on the daily time-step will provide the performance of the dataset at the highest temporal resolution that is of most interest for the vast majority of hydrological applications. We expect and encourage users to undertake their own local evaluation for their specific application as the use of the dataset grows.

9. Accessibility of the data product. I am aware of and support the effort of the Copernicus Climate Change Service but I don't have an account for this at the time being. I am also reluctant to create "random" accounts that I need to keep track of if not really needed. Given the fact that the data are produced by one of the world leading institutions for global weather data (ECMWF) and hare hosted on the Copernicus platform, I assume that the data format will be state of the art.

Thank you for your positive comment. A requirement for the GloFAS-ERA5 data to be hosted by the C3S Climate Data Store (CDS) is that state-of-the-art cataloguing, data format (i.e. NetCDF), and standardised metadata and documentation are adhered to: https://cds.climate.copernicus.eu/cdsapp#!/dataset/cems-glofas-historical?tab=overview. This allows GloFAS-ERA5 data to be found through the CDS search catalogue, work with the CDS "Toolbox", and follows the protocol that provides programmatic access to the data via the CDS Application Programming Interface (API). These are valuable tools to allow users to work more easily with large global datasets. More general information on the CDS and how data are delivered can be found here: https://climate.copernicus.eu/climate-data-store.

We really appreciate your time and insight in reviewing our manuscript,

Kind regards,
Shaun (on behalf of all co-authors)

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