PROCLIAS

Process-based models for climate impact attribution across sectors

"Assessing the suitability of streamflow station observations for consistent evaluation of simulated river discharge data of the ISIMIP global water sector"

Report by
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Table of Contents

1 Introduction

Comparing model results to observations is an important step to assess the ability of models to represent historical dynamics and thus can be seen as very relevant in the ISIMIP context regarding model evaluation and impact assessment (see e.g., Krysanova et al., 2020; Schewe et al., 2019). The cumulative nature from upstream to downstream makes streamflow (or river discharge: the amount of water that flows in a river section) one of the key variable of the global water sector and consequently very suitable to compare model output (provided in a cumulated dimension alongside a drainage network (DN)) with observational data (provided as point data). The models use a specific DN for river routing. However, not all models use the same DN and due to the nature of the 0.5° x 0.5° grid cell resolution of a typical DN, the original station data coordinates for a given river basin might not fit to the much coarser DN river basin. Both hinders a fair inter-model evaluation of streamflow performance within the ISIMIP context. This report describes the status of the DNs used in ISIMIP2b as well as a proposal for an assessment of the suitability of station data for consistent streamflow evaluation based on the ISIMIP2b global water models that submitted this variable.

2 Data and methods

2.1 Collecting information about drainage direction maps

Earlier works already indicate that DNs differ among some of the models in the ISIMIP global water sector (Masaki et al., 2017, their Fig 3 and 5). However, a structural assessment and collection of information was not yet done. For the Amazon river basin and the 12 ISIMIP2b GHMs that have been available during that time, the yearly streamflow of GFDL-ESM2M GCM for the year 2000 was plotted jointly with the DDM30 (Döll and Lehner, 2002) which has been defined as a standard DN for predecessor phases of ISIMIP. Please note that usage of DDM30 *is classified as not mandatory* in ISIMIP2 (and 3). Modelling groups have been contacted in case of visible deviations from DDM30 in order to get information which DN is being used.

2.2 Generation of the streamflow dataset

Within the framework of updating the calibration basis for the GHM WaterGAP (Müller Schmied et al., 2021) a streamflow dataset has been collected that bases on data from the Global Runoff Data Centre (GRDC), from GSIM (Do et al., 2018; Gudmundsson et al., 2018) and ADHI (Tramblay et al., 2021). The criteria to consider a station as calibration station was i) an upstream area of at least 9.000 km², ii) a time series of at least 4 complete not necessarily consecutive calendar years (with a maximum of 2 missing days per month) and iii) an interstation catchment area of at least 30.000 km² (Müller Schmied et al., 2021). If available, updates of GRDC stations that have been used in earlier calibration databases have been preferred and additional stations from GSIM and ADHI have been used. The stations have been co-registered to the DDM30 based on the location, the reported upstream area and other attributes such as river and station names, also by using internet resources. The priority was given to assign the location to the correct hydrological position. For example, if the station is located on a tributary, it can happen that the upstream DDM30 grid cell is used instead. The station data have been homogenized and partly merged. A detailed description is available in Müller Schmied et al. (model description of WaterGAP v2.2e in prep). As a result, 1509 stations (thereof 1252 from GRDC, 177 from GSIM and 80 from ADHI) with a total of 38543 years of streamflow data have been selected as basis for calibrating WaterGAP 2.2e as well as for this assessment.

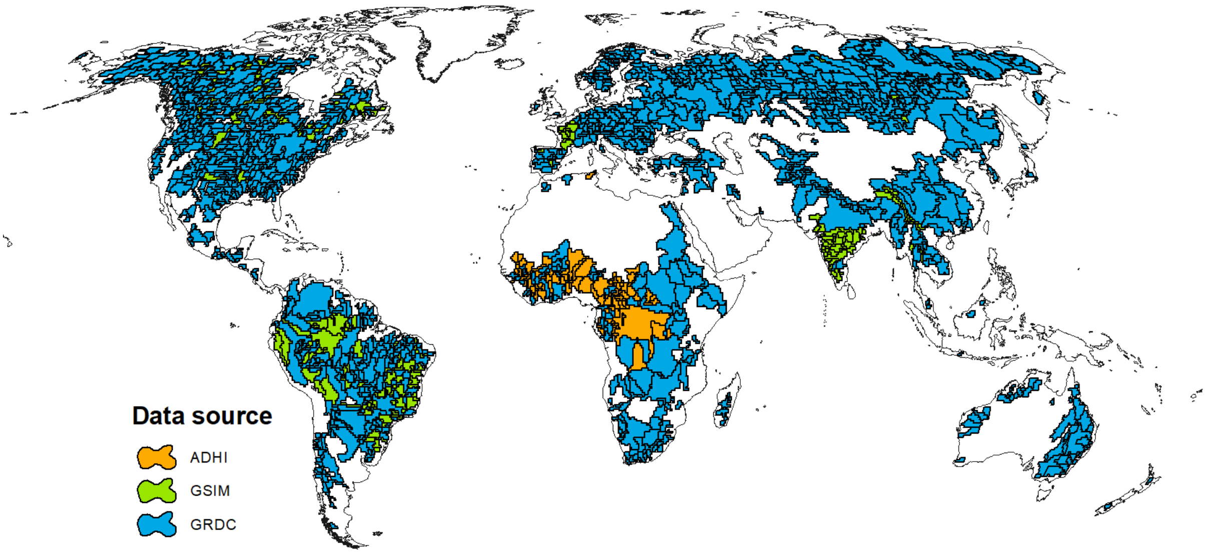

Fig. 1: Basins selected for calibrating WaterGAP 2.2e and this assessment and its data source (see references in Sect. 2.2).

2.3 Outline of the streamflow assessment as such

As not for all GHMs the DNs are available and also a fully automatic check of the location of a station data within the stream network cannot be achieved, we derived a semi-automated method for assessing the compatibility of the streamflow station to the DN of each model (Fig. 2). The 1509 stations form the basis of the assessment. Those stations are forced to be located in the DDM30 stream network at the – to the authors best knowledge – best suitable position from the hydrological perspective. However, as this might still be subjectively biased, a subset of the data basis was generated that contains only those stations where the original station coordinates are within the original 0.5° x 0.5° grid cell. Furthermore, a minimum basin area of 50.000 km² was set to avoid uncertainties that come along with small river basins. This resulted in a subset of 323 stations.

For each of the 323 selected stations, a multi-panel plot has been generated. A 3.5° area with gridded streamflow around the station was plotted together with the DDM30 network for each model. In order to visualize the results, a logarithmic scale for streamflow was chosen allowing the identification of the model's DN in most cases. Through visual inspection the alignment of the observation station and the DN of each individual model was assessed. If a positive alignment could be identified a corresponding "1" was appended to the stations meta data and this model, otherwise a "0". Finally, if all models contain a "1" for a station, this station was selected as suitable for a consistent evaluation of streamflow among all models. There are cases with streamflow values that are smaller as the logarithmic scale of the legend; here a manual modification of the scale was required.

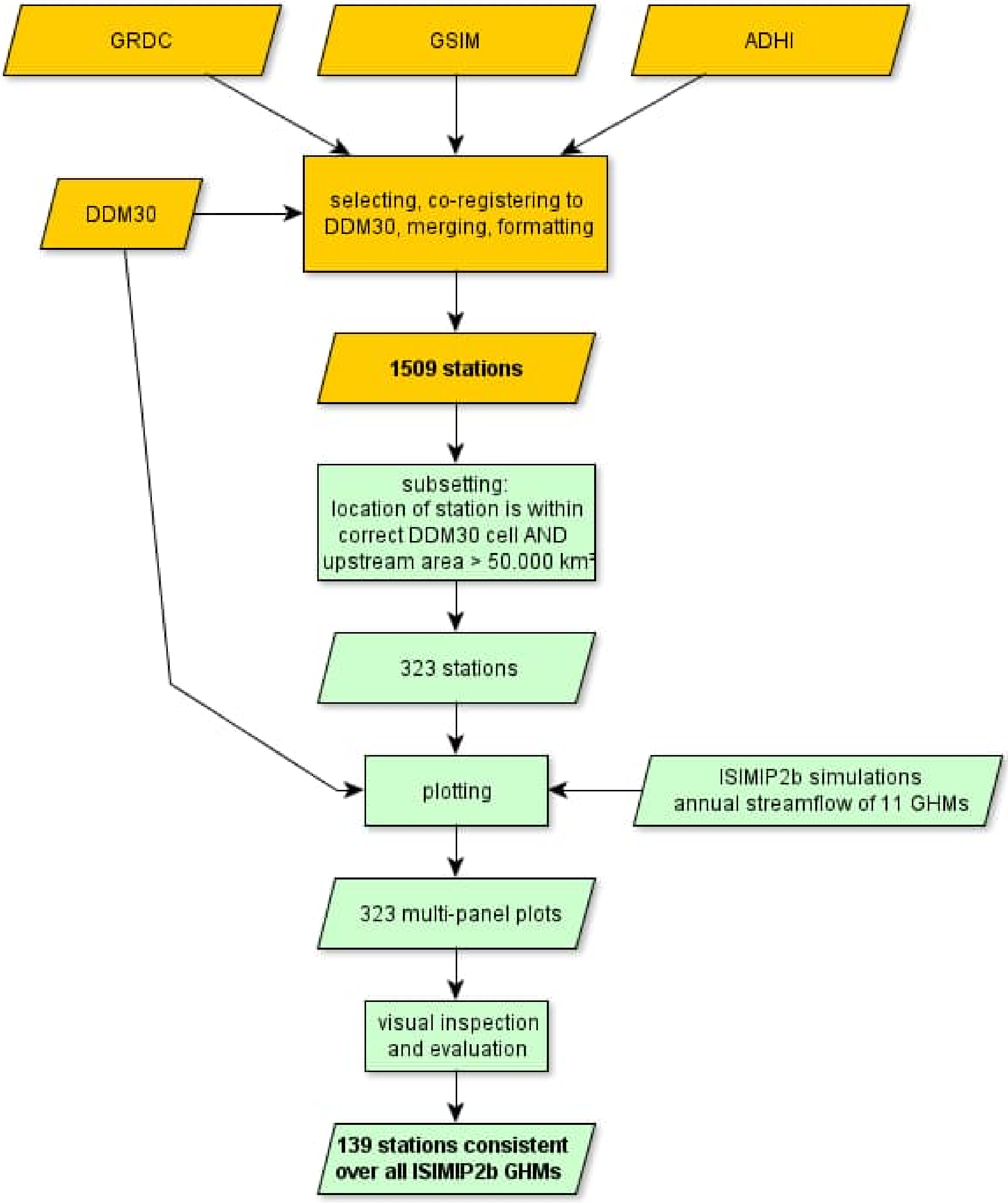

Fig. 2: Schematic of the streamflow assessment methodology. The orange components are done outside of this assessment whereas the green components are conducted within this assessment.

3 Results

3.1 Drainage direction maps used in global water sector of ISIMIP 2b phase

Based on the visual inspection of the Amazon example (Appendix A1) and the follow-up email conversation with the modelling teams, a comprehensive information about the DNs used in the ISIMIP2b global water models are indicated in Tab. 1.

Tab. 1: DNs used by the ISIMIP2b global water models as a result of the Amazon example and a following email conversation with the modelling teams.

Model	DN used	Comment
CLM4.5	MOSART	Description in https://escomp.github.io/ctsm-docs/versions/master/html/tech_note/MOSART/CLM50_Tech_Note_MOSART.html#routing-processes (information from Nans Addor). MOSART scheme will be replaced by the vectorial model miziroute (but too late for isimip3), including reservoirs, sectoral water use and improved irrigation scheme (information from Wim Thiery). Routing files can be downloaded from https://svn-ccsm-inputdata.cgd.ucar.edu/trunk/inputdata/rof/mosart/ (information from Yi Yao)
CWatM	DDM30	Lakes and reservoirs are included in the DN. In case they are bigger than a single grid cell on the main river (e.g. Lake Constance or Lake Victoria but some in the Amazon), inflows are taken from DDM30 but inside the grid cells correct river discharge is unclear. Therefore, the river network stops if the river reaches a lake/ reservoir and the whole lake/ reservoir gets the discharge of the outlet of the lake/reservoir. (information from Peter Burek)
H08	DDM30	
JULES-W1	CaMa-Flood v3.6 (Yamazaki et al., 2011)	The CaMa-Flood v3.6 DN contains a "Flexible Downstream Format" which means that each cell could be a receiving cell, not necessarily the neighbouring cell. Hence, a conversion into the traditional D8 representation is not possible. However, a file with upstream area is provided alongside the ISIMIP2b data. TRIP (Oki and Sud, 1998) will be used for ISIMIP3. Also, recent activities are going on towards the DNs, including the potential use of DDM30. (information from Aristeidis Koutroulis and Manolis Grilliakis)
LPJmL	DDM30	
MATSIRO	DDM30	
MPI-HM	DDM30	
ORCHIDEE	STN-30p (Vörösmarty et al., 2000)	ORCHIDEE/ORCHIDEE-DGVM ISIMIP2b runs were done at 1° resolution due to the limited computation resources, and the outputs were all interpolated to 0.5°. ISIMIP3 will run with 0.5° resolution. DN is available. (information from Jinfeng Chang)
ORCHIDEE-DGVM	See above	See above. It is possible that NaN or filled values exists in ORCHIDEE-DGVM which gives very high streamflow values > 1e10. I would recommend using ORCHIDEE instead of ORCHIDEE-DGVM for all assessment. (information from Jinfeng Chang)
PCR-GLOBWB	internal	DN is available. ISIMIP3 will probably using DDM30. (information from Niko Wanders).
WaterGAP2	DDM30	Deviates at Lake Ladoga which is included in DDM30 but excluded in the WaterGAP2 model. DN is available. (based on conversation between Peter Burek and Hannes Müller Schmied)

3.2 Suitability of streamflow observation data for consistent evaluation of ISIMIP 2b global water models

For 711 stations, the original location of the station aligns with the corresponding DDM30 grid cell. Out of those, 323 stations have an upstream area (based on DDM30) of at least 50.000 km^2 and have been selected for the compatibility assessment (see example in A2). A total of 139 stations are within the DN of all 11 analysed models. Please note that for subsets or for individual models, this number can be higher (Tab. 2).

Tab. 2: Number of stations that are within the DN (as indicated by streamflow accumulation) of the individual ISIMIP2b global water models.

Model	Number of stations within DN
CLM4.5	223
CWatM	323
H08	323
JULES-W1	244
LPJmL	322
MATSIRO	323
MPI-HM	323
ORCHIDEE	275
ORCHIDEE-DGVM	275
PCR-GLOBWB	301
WaterGAP2	323

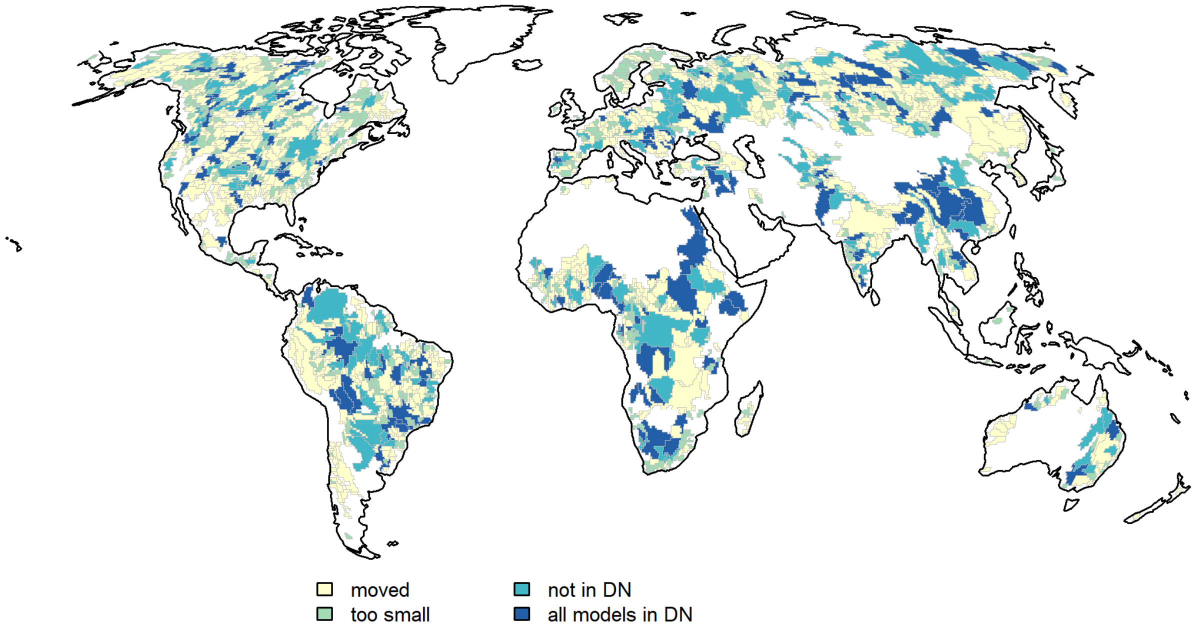

Fig. 3: Global map of basins showing the results of the streamflow assessment. Yellow basins indicate that original station location has been moved to the hydrologically correct corresponding DDM30 grid

cell. Light green basins are not moved but have an upstream basin area of < 50.000 km². Light blue basins are not moved, have an upstream basin area of > 50.000 km² but station is not in DN for all models. Dark blue basins are those where all criteria are met, i.e. those basins can be used consistently for all analyzed ISIMIP2b global water models.

The spatial representation of the assessment result is visualized in Fig. 3. There are suitable basins in each continent but less for Europe. The station information (station and basin metadata) is available jointly with the observed streamflow data (Müller Schmied and Schiebener, 2022c), jointly with the via the scripts and a technical documentation (Müller Schmied and Schiebener, 2022a) and the results of the assessment of this report (Müller Schmied and Schiebener, 2022b). It is planned to publish the DNs for the models alongside the model simulations in the ISIMIP data repository in case they deviate from input DDM30.

4 Summary and outlook

The DNs used within the ISIMIP global water models are not similar through all models. As the DN of some models cannot be easily adapted and the DDM30 is not a mandatory dataset this is understandable. However, differences in DNs can lead to problems when assessing streamflow simulations with station-based observations. Also, spatial explicit impact assessments might be flawed even though in most publications until now a coarser spatial resolution (e.g. country, regional or basin level) has been used which significantly reduces the inconsistency. In order to document this inconsistency, a survey has been done based on DDM30 (the provided DN by ISIMIP) and streamflow data from 11 ISIMIP2b global water models for the area of the Amazon basin. Based on an email-conversation with the modelling teams, information about the DNs have been collected (Tab. 1).

The main purpose was to assess which observed streamflow data can be consistently used over all models. As basis, a collection of 1509 streamflow stations from GRDC, GSIM and ADHI data sources which was created within the update process of the WaterGAP v2.2e calibration procedure has been used. Following some automatic processes and visual inspection, a total of 139 stations are assessed to be located consistently within all analysed models (Fig. 3) and up to 323 stations are within the selected criteria for individual models. However, this does not mean that the remaining stations cannot be used for model evaluation. To be as inclusive as possible, the plotting and assessment could be done for all 1509 station. Also, it would be meaningful to repeat this assessment for ISIMIP2a and ISIMIP3 to find suitable stations for model evaluation.

This assessment might build the basis for developing an automatic quality assessment (one main goal of the PROCLIAS TG1.2) as those 139 stations derived here can be safely used as evaluation basins throughout the ISIMIP2b global water models. The process itself can be adapted and repeated for ISIMIP3 with minor modification efforts. Future ISIMIP phases (starting with ISIMIP3) will most likely have less deviations with respect to the DN used but further discussion is needed towards a fully consistent use of a DN.

Abbreviations

DN	drainage network
DDM30	drainage direction map (Döll and Lehner, 2002)

Acknowledgments

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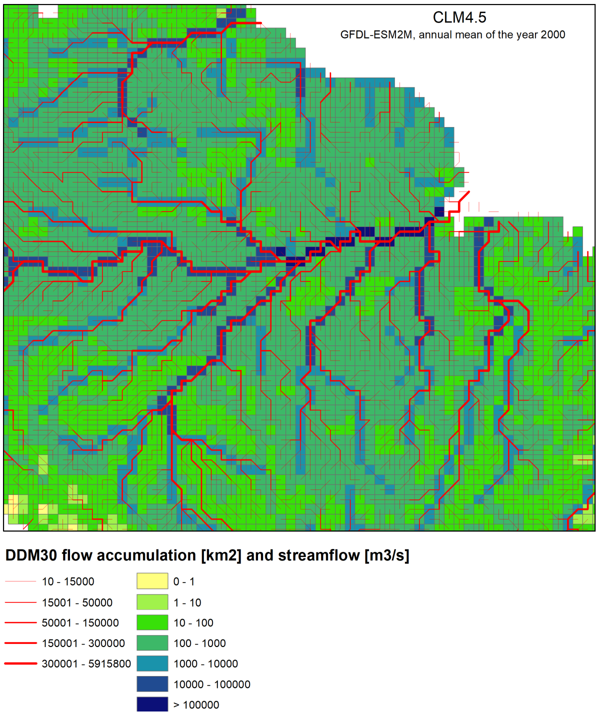
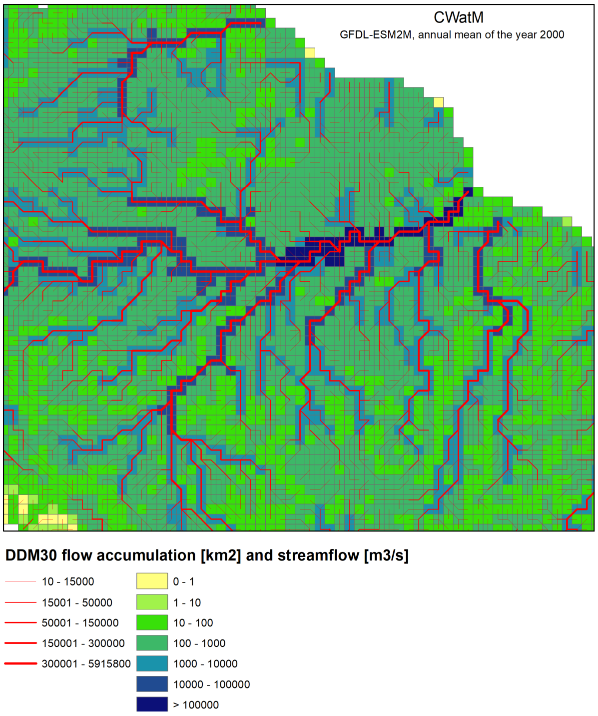
Appendix

A1 DNs of the ISIMIP2b GHMs for the Amazon area


Representation of drainage network in the Amazon river basin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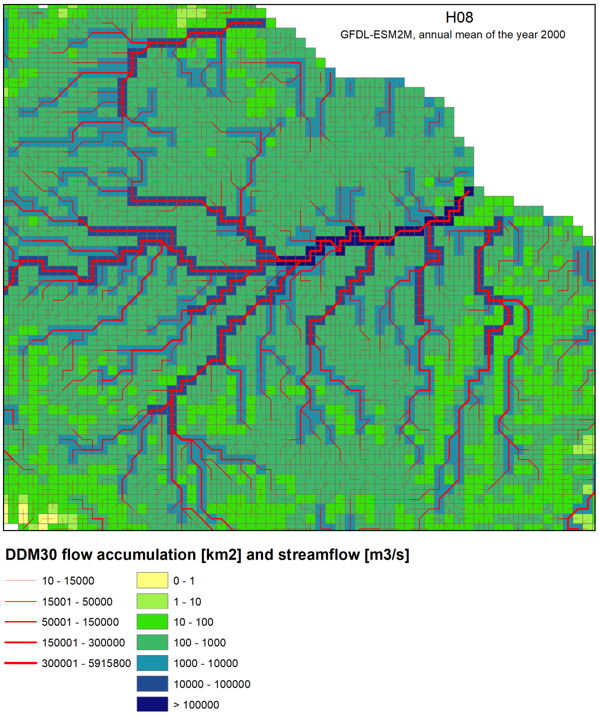
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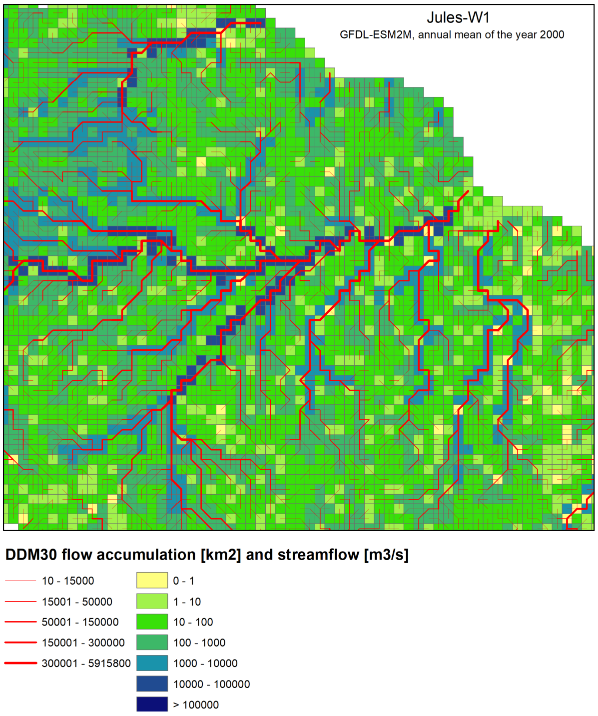
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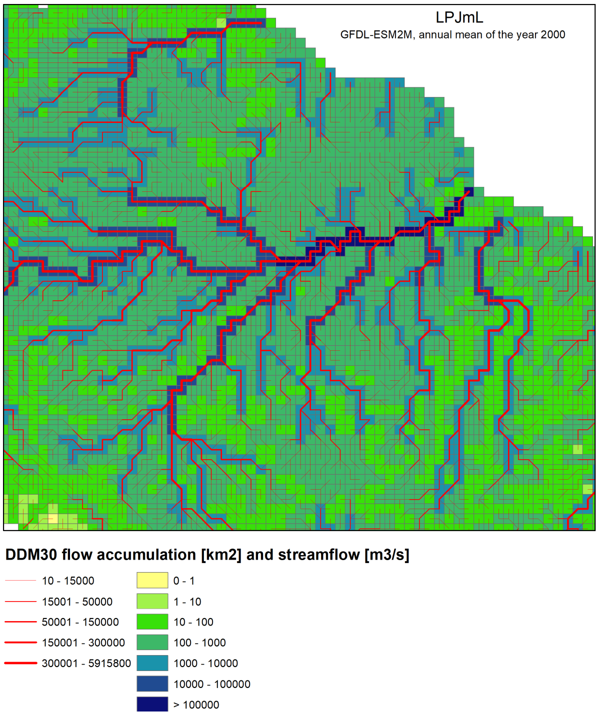

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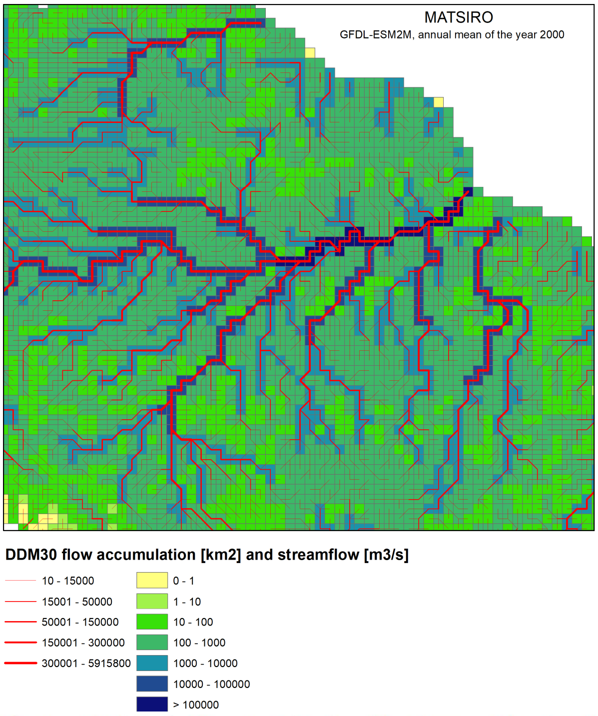

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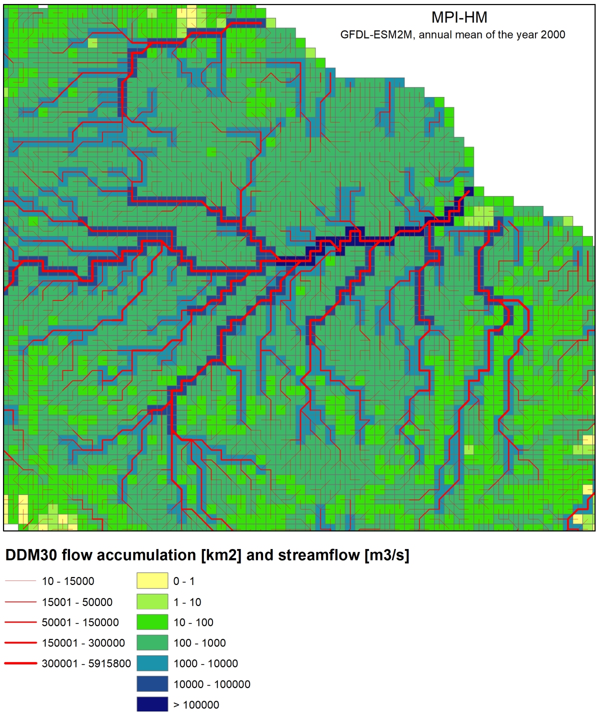

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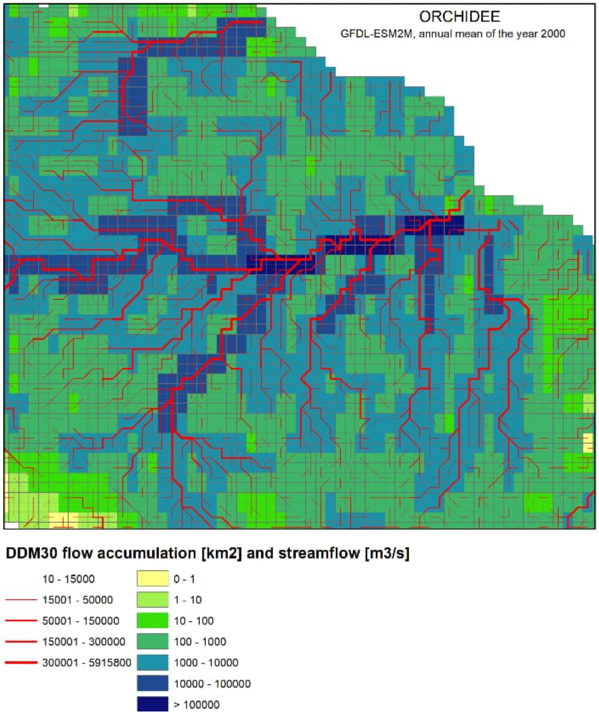

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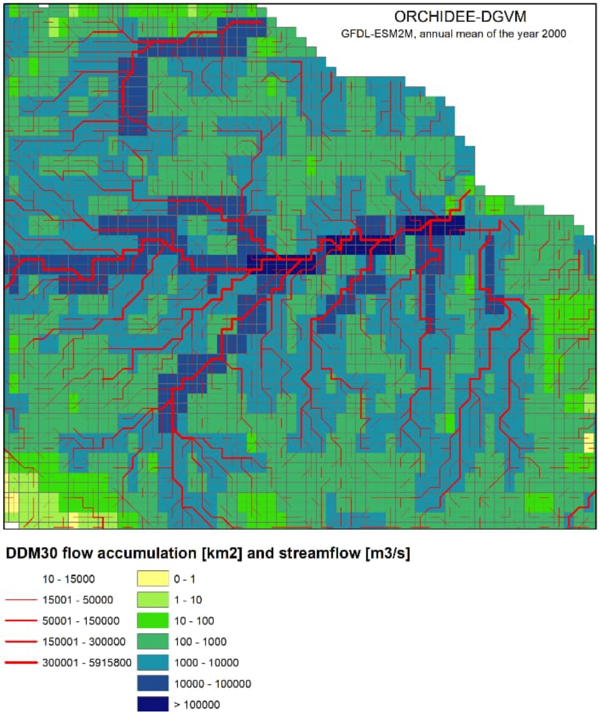

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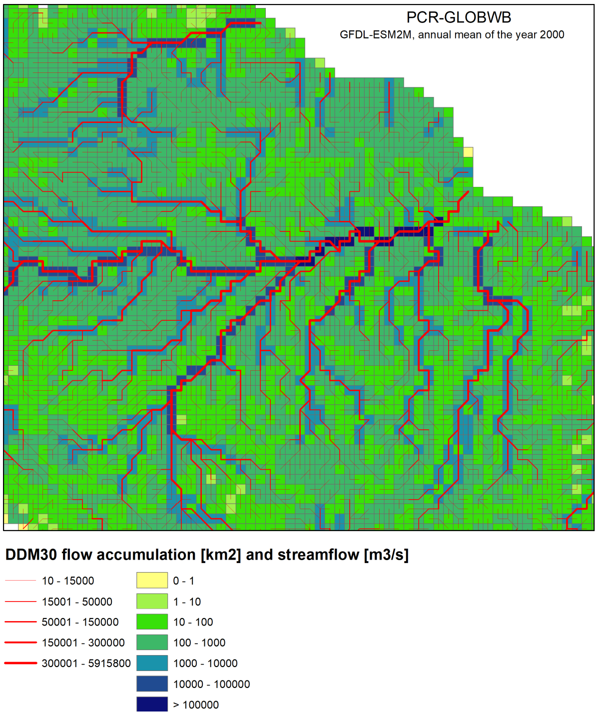

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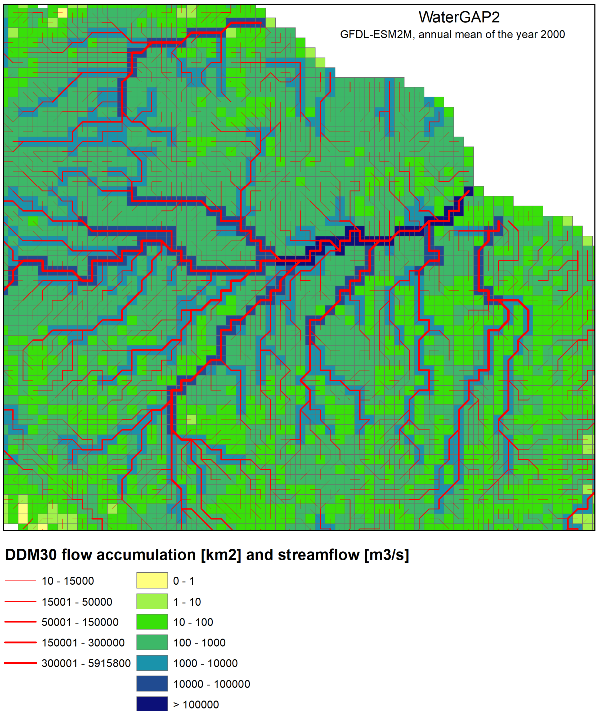

A2 Multi-panel plot for one example streamflow station as basis for visual inspection