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BuPuSA Flood and Drought Monitoring and Forecasting System (BuPuSa-FDM)

User Guide

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Introduction

This practical guide provides an overview of the main features of the pilot version of the web-interface of the Buzi-Pungwe-Save Flood and Drought Monitoring and Forecasting System (BUPUSA-FDM). The BUPUSA-FDM comprises a database of climate and hydrological information from ground observations, satellite remote sensing and models, which can be accessed via the web interface for use in near real-time monitoring and forecasting of hydrological variability in support of early warning of flood and drought hazards. The interface allows access to the data and derived flood/drought information as maps, time series and summary statistics, including alert information on current and potential future hazard conditions. This is a practical, self-guided exercise on accessing and navigating the system, including the various menus and data access/download. This guide will take about 45-60 minutes to complete.

NOTE: this guide is based on a pilot version of the system that is intended to showcase the potential to provide early warning of floods and droughts for the BUPUSA basin. The functionality and data have undergone initial testing, but there may be some lingering bugs and inconsistencies in the data.

Accessing the system

⇒ Open your web browser (preferably Google Chrome or Firefox) with the system URL: **https://hydrology.soton.ac.uk/apps/bupusa_app**
⇒ The system is fully open, so there is no need to register.
⇒ When you first access the system, there may be a delay of a few seconds for the system to initialize, and for the interface to be rendered. If you are presented with the interface but no information (e.g. no maps) then continue to wait a few seconds more.

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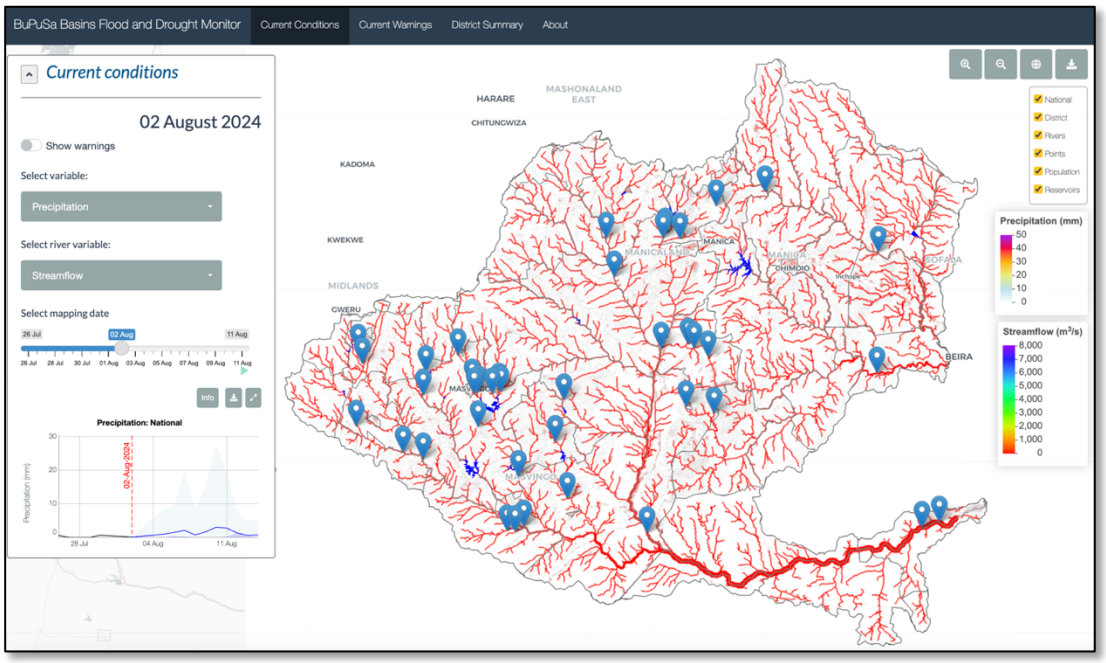
1. The Main Interface



On opening the system web page, you will see the main interface which provides visualization and access to the main data and information of the BUPUSA-FDM.

The top bar shows the name of the system and a menu with a series of tabs. The tabs provide access to the different parts of the BUPUSA-FDM.

- Current Conditions – This is the default tab and shows a summary of current conditions (for the past 7 days) and the latest forecast (for the next 9 days) for a range of meteorological and hydrological variables and indices.
- Current Warnings - This tab shows specific warnings for a set of hydrometeorological hazards based on extreme wet or dry values of some of the meteorological and hydrological variables for the current day and the forecast out to 9 days.
- District Summary - The current conditions and forecasts are also summarized in table form for the districts and river points.
- About – This tab provides information on the latest update of the system, background information on the system, and some help information on the functionality and navigating the system.

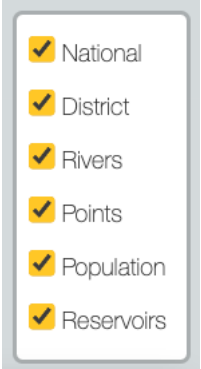
For the remainder of this guide, you will learn how to explore the interface, starting with the main tab and then each other tab in turn.

2. The "Current Conditions" tab

This tab allows you to view current conditions and forecasts of a set of meteorological, hydrological, flood and drought variables in an interactive way, as spatial data layers, and area/point time series. The map display provides functionality to pan and zoom in on the map layers to see regional and local detail, and select summaries of the data for different areas or points.

The Main Map

The main map shows current conditions for different hydrological variables and flood/drought indices. The background to the map is provided by Open Street Maps which gives the geographical context of political boundaries and landscape features such as lakes and coastlines. By default, precipitation is shown, overlain by the river network showing streamflow. Other meteorological and hydrological variables can be selected and displayed using the left menu panel (see later). A set of other overlay maps are also shown by default (see Table 1). These overlays are used to provide visual context (e.g. district boundaries, population exposed to flood) but can also be clicked to access subsets of the data (see later). Below the list of overlays are scale bar legends for the displayed maps.



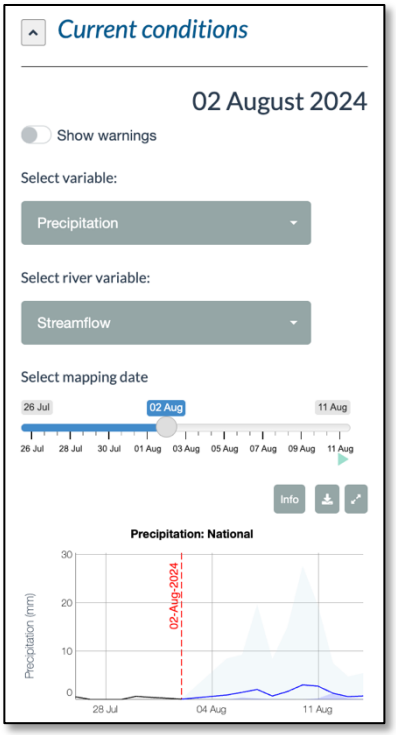
⇒ Toggle different overlay maps on or off by clicking their check boxes on the list on the right.
⇒ Click and drag the map to move the view of the map. Once you have chosen an area of interest use the zoom buttons (+ and –) to zoom in or out.
⇒ Click on the globe button to return to the original map view of the whole basin.
⇒ Download the maps using the download button, which will save the map layers for all variables for the selected date to your Desktop or Downloads folder in Tiff format. These Tiff files can be imported into GIS software for further display and analysis.

Table 1. The various overlay maps:

Layer Name	Description	Type
Basin	BUPUSA basins	Vector Map
District	Districts of Zimbabwe and Mozambique within the BUPUSA basin	Vector Map
Rivers	River network derived from the MERIT Hydro dataset	Vector Map
Points	Selected river gauging points from the GRDC database	Points
Population	Population density derived from the WorldPop datasets for Zimbabwe and Mozambique	Raster Map
Reservoirs	Reservoir maps derived from GRanD database	Vector Map

Menu Panel

On the left of the tab window is a menu panel where you can select different variables, change the map display date and show time series of the evolution of the displayed variable the historic and forecast periods. Currently available variables that can be shown as raster maps are precipitation, evaporation, runoff, soil moisture, water table depth, flood inundation, SPI, and soil moisture index. Streamflow and streamflow index are listed in a separate drop-down list as these are displayed as vector maps on top of the displayed raster map, and so can be selected separately. A table of variables and their attributes is given in Table 2.



Selecting Different Variables and Dates

⇒ Select a different variable from the dropdown list, e.g. "*Runoff*". This will update the map, legend and timeseries below.

⇒ Change the date of the displayed map, by clicking a different data on the selector bar, or drag the selector button to the left or right. The red highlighted date on the time series chart below will be updated.

⇒ You can also select the date by clicking on the time series chart.

⇒ Run through the dates of the historic and forecast periods automatically by clicking on the "*play*" button at the bottom-right of the date selector. This will animate the maps one day at a time. Stop the animation by clicking on the "*pause*" button.

Note: the current selected date is displayed at the top of the menu panel. If the date is within the forecast period, then the date will be appended by "*Forecast:*". When in the forecast period, the map shown is the forecast ensemble mean.

Table 2. List of variables currently available in the system.

Variable Name	Description	Units
Precipitation	Daily total precipitation	mm/day
Evaporation	Daily total evapotranspiration	mm/day
Runoff	Daily total surface runoff and subsurface drainage	mm/day
Soil Moisture	Daily average soil moisture	mm
Water Table Depth (WTD)	Daily average water table depth	m
Streamflow	Daily average streamflow	m^3/sec
Streamflow Index	Daily average streamflow percentile	%
Inundation	Daily inundation	No/Yes
SPI-1	Standardized precipitation index (1-month time scale)	-
Soil Moisture Index	Daily average soil moisture based on standardized anomalies	-

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Showing Warnings

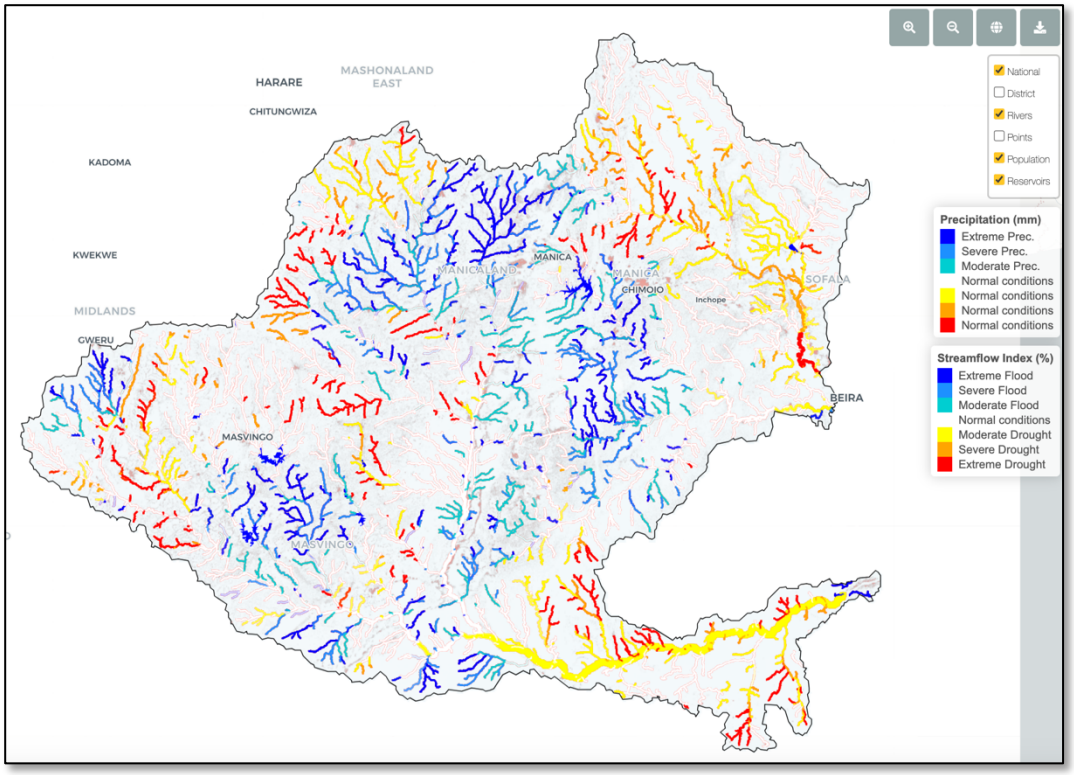
Warnings can be shown in two ways in the system. On the "*Current Conditions*" tab, warnings can be shown for variables that have extreme values associated with impacts (e.g. flood or drought conditions). Warnings are available based on high percentiles of precipitation (extreme precipitation), high (pluvial) and low (drought) values of SPI, high (flood) and low (drought) percentiles of streamflow, and high (water-logging) and low (drought) anomalies of soil moisture. The warnings are provided for the selected date. The "*Current Warnings*" tab (see later) provides more targeted warning information.

A switch button above the variable drop-down list toggles the map between showing the original variable or a categorized version indicating warnings.

⇒ Select "*Precipitation*" from the variable dropdown list. The map will be updated for the selected date.

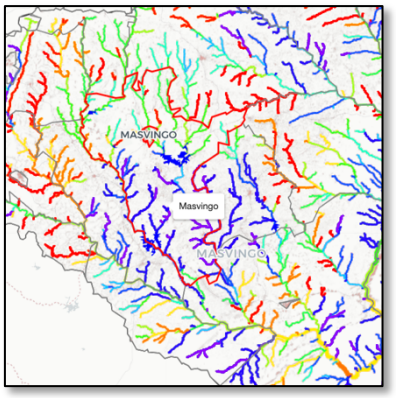
⇒ Click on the "*Show warnings*" switch to display any warnings for precipitation (i.e. if any values are over the warning thresholds for the selected date). The legend will be updated to show warning categories, such as "*Extreme*", "*Severe*", etc.

⇒ Select the "*Streamflow Percentile*" variable from the streamflow variable dropdown list. This will update the map and legend, with warning categories for flood or drought conditions. In the map below, there are no warnings for precipitation, but various parts of the river network are in drought (yellow/red colors) or flood conditions (blue colors).



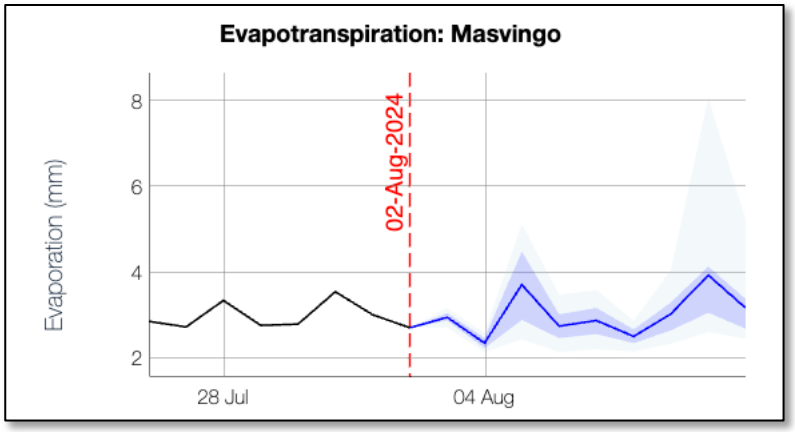
Showing Data as Time Series

At the bottom of the left menu panel is a time series chart. This shows the currently selected variable for a selected area or point. By default, this is the variable averaged over the whole basin. You can select other areas and points by clicking a feature on the map (e.g basin, district, river point – see Table 1). This will update the time series chart to show a time series of the selected variable averaged over the selected area feature or point.



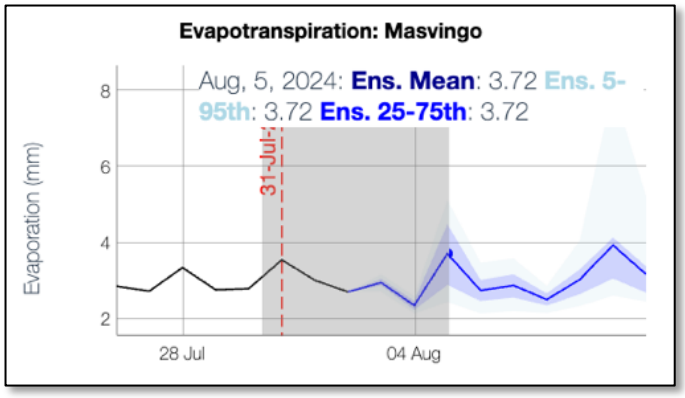
⇒ Select one of the layers (e.g. "*District*"), and then hover the mouse over the vector features on the map and these will be highlighted in red.

⇒ Click on one of the districts on the map, and the time series will be updated with data for the current variable averaged over the selected district. For example, the time series below shows evaporation averaged over the Masvingo district.



The chart shows the evolution of the currently selected variable for the past 7 days of historic data and the future 9 days of the forecast. The historic data are shown as a single estimate (black line); the forecast is shown as the ensemble mean (dark blue line), 25-75th (blue shading) and 5-95th (light blue shading) percentile ranges to represent the most likely forecast (mean) and its uncertainty (percentile ranges).

- ⇒ Hover the mouse over the chart to show the values of the data.
- ⇒ Click on the chart to change the display date and update the map.
- ⇒ Drag on a section the chart to zoom in on a selected part of the time series. The chart will be shaded grey as you drag to indicate the selected time period
- ⇒ Double click on the chart to revert to showing the full time series period.



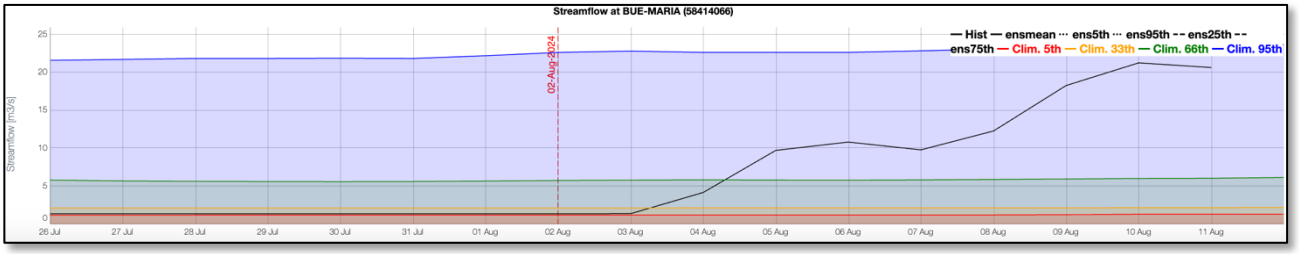
Above the chart are three buttons:

- ⇒ Toggle the "*info*" button to show a small panel on the right of the map below the legend. This shows information on the displayed variable (this can be useful when taking a screenshot of the map for later use)
- ⇒ Click the "*download*" button to download the currently displayed time series data as a csv file, which can be used to carry out further analysis in Excel or other software.
- ⇒ Click the "*expand*" button to expand the times series to a larger chart at the bottom of the window that allows for more detailed examination of the data. Drag and click on the chart to zoom in or update the map to see how the time series and map data relate to each other.
- ⇒ Select other variables from the menu and areas/points on the map to update the time series chart.
- ⇒ Click the "*expand*" button again to revert to the small time series on the menu panel.

If the selected layer is "*Points*", the time series shows past and current conditions for streamflow for the selected river point. These river points are listed in the appendix (Table A1).

- ⇒ Click the "*Points*" overlay on the top-right of the map to show the river gauging points, if they are not shown already.
- ⇒ Click on one of the points on the map to update the chart with the time series of streamflow at the point. In the example right and below, the location at Bue-Maria has been chosen. The time series chart shows the evolution of streamflow at the location.
- ⇒ Click the "*expand*" button to show the larger version of the chart. Now the climatology of streamflow at this point is also shown for context. The climatology is provided as the 5th, 33rd, 66th and 95th percentiles calculated from the long-term historic simulation, and shown as different colored shading.

⇒ Hover the mouse over the time series chart to see the values at each date. Click and drag the time series to show more detail and change the map date.



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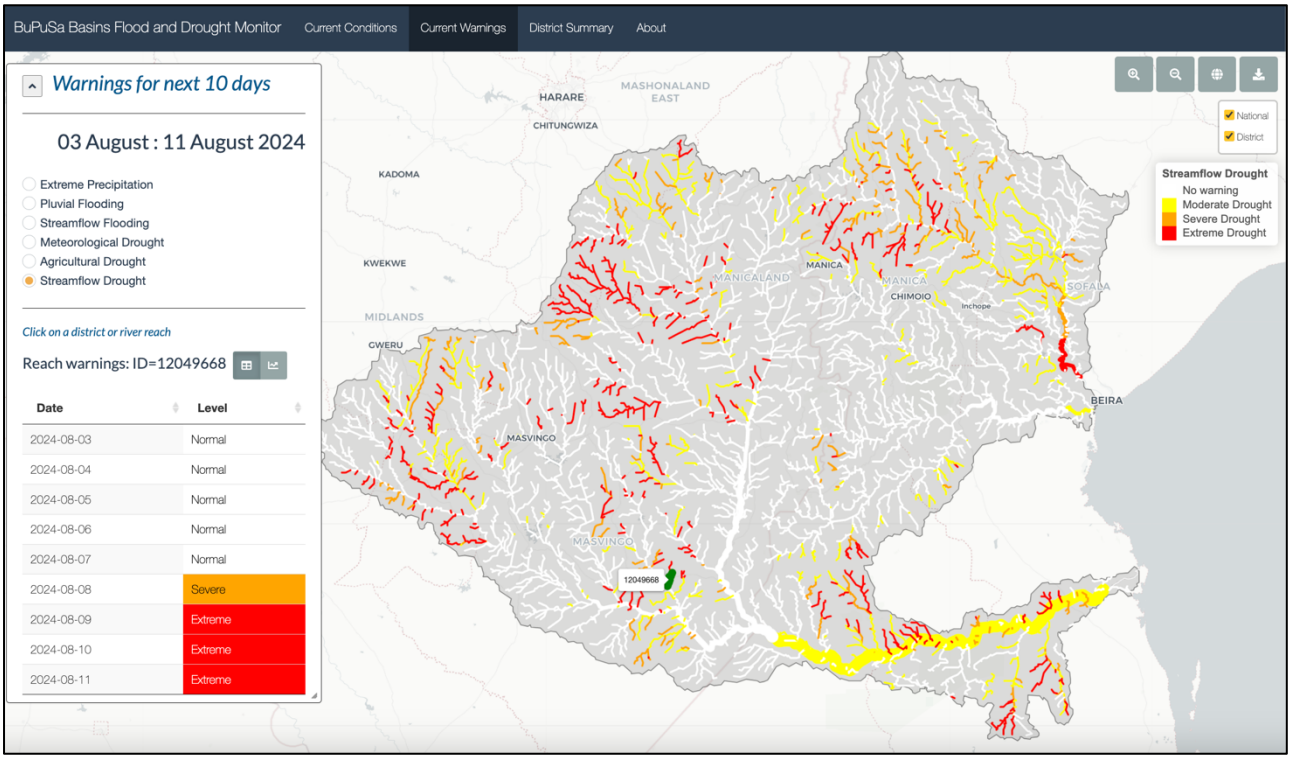
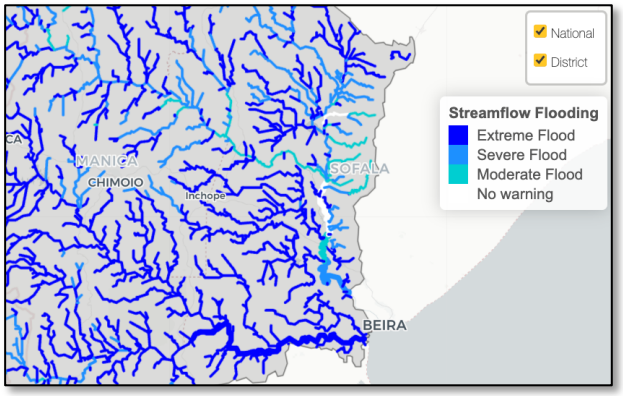
3. The "Current Warnings" tab

This tab provides warnings based on extreme wet or dry values of a specific set of meteorological and hydrological variables that are relevant for early warning of flood and drought hazards (see figure below). It is similar to the "*Current Conditions*" tab in terms of the layout but is solely focused on warnings shown as maps of the maximum warning category over the forecast period and as charts of the evolution of warning categories for user-selected areas or river points over the forecast period.



⇒ Click on one of the variables in the menu to update the map to show the current warnings for that variable. For example, clicking on "Streamflow Flooding" will show the maximum warning category for fluvial flooding over the forecast period based on the ensemble mean (most likely forecast). The legend shows the warning categories. The example on the right shows streamflow flood warnings based on percentile thresholds for "*Extreme – 99th percentile*", "*Severe – 95th percentile*" and "*Moderate – 90th percentile*" daily streamflow values.

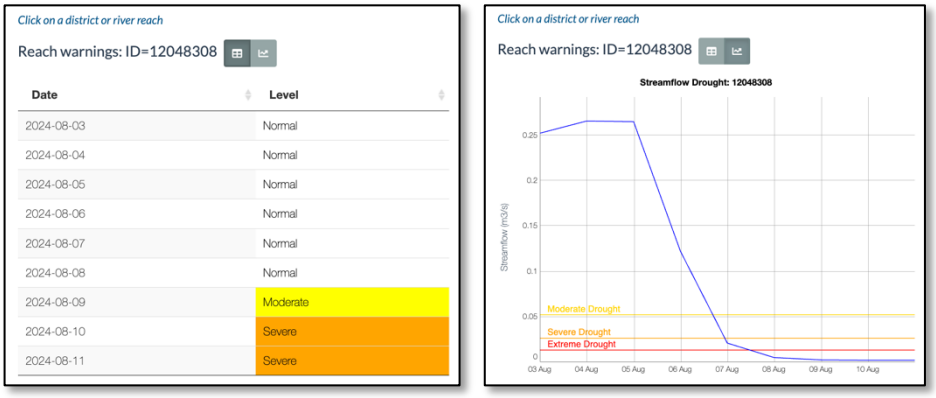


⇒ To see the evolution of warnings over the forecast period, click on a district for raster warning maps (e.g. "*Extreme Precipitation*" or "*Agricultural Drought*"), or a river reach for

vector warning maps (i.e. "*Streamflow Flood*" or "*Streamflow Drought*"). This will update the chart at the bottom of the left panel to show the evolution of warnings.

⇒ The chart can be shown in two ways: 1) a table of warning categories calculated from the average of the variable over the basin, selected district or selected river reach, and converted to a warning category; or 2) a time series of the underlying variable with categorical warning thresholds shown as horizontal lines for context.

⇒ Click on the time series or table buttons to switch between the two views of the data. Below is an example for "*Streamflow Drought*" showing (left) the evolution of warning categories over the forecast period, and (right) the time series of streamflow with warning thresholds shown for context. In the example, streamflow descends into moderate and then severe drought over the forecast period.



Types of hazards and warning threshold

Warnings are provided for high and low values of the following variables (with specific details in Table 3):

- Extreme rainfall (storms) based on frequencies (e.g. 99th percentile).
- Flooding (fluvial) based on streamflow percentiles (return period).
- Flooding (inundation) based on presence of inundation.
- Drought of various types: meteorological (precipitation), agricultural (soil moisture), hydrological (streamflow). Thresholds are based on frequencies (percentiles) estimated from a normalized index of the variable.

Table 3. Hazards represented in the system, including the variable representing the hazard, the threshold type, threshold and warning levels/categories.

Hazard type	Variable	Threshold type	Thresholds and warning levels/categories
Extreme rainfall	Daily precipitation (mm/day)	Percentile / daily. Constant over time.	
			99th, Extreme rainfall
			95th, Severe rainfall
			90th, Moderate rainfall
Flooding (fluvial)	Daily streamflow (m^3/s)	Percentile / daily. Constant over time	
			99th, Extreme flood
			95th, Severe flood
			90th, Moderate flood
Flood (inundation)	Daily inundation (-)	Binary (presence)	Inundation present

Drought (meteorological)	Daily precipitation (mm/day)	SPI value / daily. Constant over time.	Thresholds are approximately equivalent to the 1st, 5th and 10th percentiles of the SPI distribution
			-2.33, Extreme drought
			-1.65, Severe drought
			-1.28, Moderate drought
Drought (agricultural)	Daily top 1m soil moisture (mm)	Standardized anomaly / daily. Constant over time.	Thresholds are approximately equivalent to the 1st, 5th and 10th percentiles of the SM anomaly distribution
			-2.33, Extreme drought
			-1.65, Severe drought
			-1.28, Moderate drought
Drought (hydrological)	Daily streamflow (m^3/s)	Percentile / daily. Constant over time.	
			1st, Extreme drought
			5th, Severe drought
			10th, Moderate drought

Representation of uncertainty

Uncertainty in the forecasts is inherent and an important aspect of early warning. The system represents uncertainty in the forecasts based on ensemble meteorological forecasts that are used to drive the hydrological model to provide an ensemble of forecasts of hydrological variables and derived flood and drought indices. Uncertainty is represented by the ensemble spread (5-95th and 25-75th percentile ranges) in the time series in the "*Current Conditions*" tab. For the information in the "*Current Warnings*", uncertainty information is not yet provided but will be integrated in a next system update.

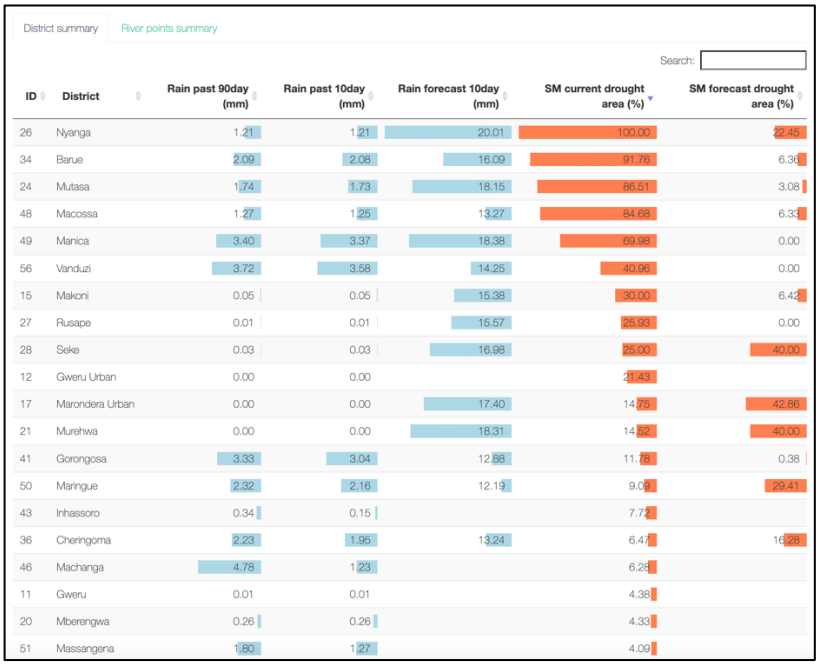
4. The "District Summary" tab

The current conditions and forecasts are also summarized in table form for the districts and river points. This provides information that can be used to quickly identify locations that are in, or are expected to transition to, hazard conditions.

The District Summary

⇒ Click on the "*District Summary*" sub-tab. The table shows a set of metrics averaged or accumulated over each district (see Table 4). The historic rainfall for the past 10 and 90 days is calculated from the historic data averaged over each district. The forecast rainfall for the next 9-days is calculated from the forecast ensemble mean and averaged over each district. The current area in drought is calculated from the most recent historic data as the area of each district for which the soil moisture index is below the 20th percentile. The 9-day forecast area in drought is represented by the ensemble mean and calculated for each district.

⇒ Click on the "*SM current drought area*" column title to sort the districts and highlight the districts with highest drought areas. The statistics are coded by color bars which give a quick visual indication of locations with higher or lower values.



⇒ Click on other column titles to sort other variables. For example, you can show the districts that have had the most rain over the past 90 or 10 days, or which are expected to receive the most rain in the next 9 days.

⇒ Start typing a district name in the "*Search*" box in the top right corner to filter the districts to just those of interest.

Table 4: The statistics provided in the "*District Summary*" sub-tab

Statistic	Description	Units
Rain past 90-day	Area average total rainfall over the past 90 days	mm

Rain past 10-day	Area average total rainfall over the past 10 days	mm
Rain fcst 9-day	Area average total rainfall forecast over the next 9 days	mm
SM current drought area	Area in drought for the current day as indicated by the soil moisture index being below the 20th percentile	%
SM fcst drought area	Area in drought for the forecast period (maximum value of the ensemble mean) as indicated by the soil moisture index being below the 20th percentiles.	%

⇒ Now click on the "*River points summary*" sub-tab. The river point table shows the current streamflow for each river gauging point and its equivalent percentile, as well as the 9-day forecast, again as represented by the ensemble mean (Table 5).

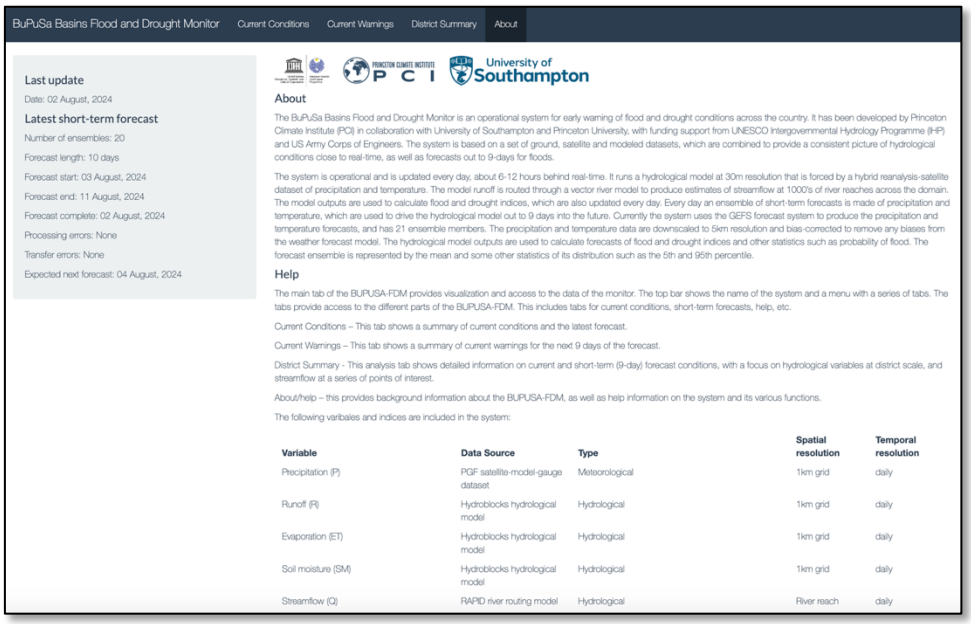
⇒ Click on the table column titles to sort, and identify locations where flows are currently higher or lower than normal or expected to be over the forecast period.

Table 5: Streamflow statistics provided in the "*River Points Summary*" sub-tab

Statistic	Description	Units
Current flow	Current streamflow	m^3/sec
Current pctl	Percentile of the current streamflow, relative to the long-term climatology	%
Fcst 7-day max flow	Forecast streamflow. This is based on the maximum of the forecast ensemble mean.	m^3/sec
Fcst 7-day max pctl	Percentile of the forecast streamflow, relative to the long-term climatology. This is based on the maximum of the forecast ensemble mean.	%

5. The “About” Tab

The “About” tab gives an overview of the system and its background, including the methods and datasets, and some detail on how it is run operationally. Some details of the operational monitoring and forecasts are given, including of the latest update, forecast statistics, and forecast status, and when the next update and forecast is expected. The “Help” section gives an overview of the functionality and how to navigate the system, and a list of variables, indices and their attributes.



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Congratulations!

You have now completed the BUPUSA-FDM user-guide. We hope that this has given you a useful overview of the wide range of features for data exploration, visualization, and download that the BUPUSA-FDM has to offer. If you have any questions or comments that you would like to give about the contents of this guide or the BUPUSA-FDM interface and its data, please use the email address on the front page, and we will try to address any questions or concerns that you may have. Thanks!

About PCI

PCI is a non-profit organization that carries out fundamental research to understand how the water cycle is changing with climate and how these changes manifest in water risks such as floods and droughts. We translate this research into applications to understand how these changes impact on water resources, agriculture, power generation, land use and the environment. Please visit http://www.princetonclimateinstitute.org/ for more information and how to get involved.

Appendix

Table A1: Locations of the 46 selected river points in the BuPuSa basin, which are also river gauging points in the GRDC river discharge database.

	Station	GRDC ID	Latitude	Longitude	River
1	ESTAQUINHA (58415088)	1894200	-19.958	34.167	BUZI RIO
2	BUE-MARIA (58414066)	1894400	-19.025	34.180	PUNGWE
3	E.N.102 (58414065)	1894401	-18.558	33.250	PUNGWE
4	VILLAFRANCA DO SAVE	1895500	-21.100	34.680	SAVE RIO
5	JUNGULO (58421047)	1895501	-21.142	34.533	SAVE RIO
6	NYARUWA FLUME + G/W (63415007)	1494100	-19.850	32.800	NYAHODI
7	HOBOKEN G/W (63415010)	1494110	-19.833	32.783	ZONUE
8	NYANYADZI DAM U/S (63422320)	1494120	-19.767	32.667	NYANYADZI
9	SHINJA NYANYADZI G/W (63422326)	1494130	-19.733	32.617	SHINJA
10	STAPLEFORD G/W (63414001)	1494200	-18.667	32.850	MAPOPO
11	SOUTHDOWN L/F NOTCH (63415016)	1494300	-20.267	32.833	CHIPUDZANA
12	YPRES (63415018)	1494310	-20.267	32.667	BUZI RIO
13	BANGAZAAN G/W (63415015)	1494311	-20.217	32.600	BUZI RIO
14	PUNGWE CAUSEWAY G/W (63414014)	1494400	-18.400	32.783	PUNGWE
15	SAVE GORGE C/S (63422143)	1495100	-21.183	32.283	SAVE RIO
16	BELINGWE ROAD	1495150	-20.370	30.900	NGEZI
17	INGESI FLUMES	1495160	-20.620	30.450	RUNDE
18	RUNDE U/S INGESI FLUMES (63423133)	1495165	-20.617	30.450	RUNDE
19	AUSTRAL DAM SPILLWAY	1495170	-20.130	30.450	TOKWE
20	MUSHWE FLUMES	1495180	-19.950	30.470	SHASHE
21	RIETFONTEIN G/W (63423142)	1495190	-19.883	29.950	UMTEBEKWA
22	IMPALULI G/W (63423193)	1495195	-19.783	29.917	IMPALI
23	TOKWE CONFLUENCE U/S C/S	1495200	-21.170	31.200	RUNDE
24	LUNDI CONFLUENCE U/S C/S	1495220	-21.130	31.270	TOKWE
25	KYLE DAM U/S G/W (63423344)	1495230	-21.167	31.133	BEVUMI
26	TOKWE CONFLUENCE D/S C/S	1495240	-21.130	31.270	RUNDE
27	BANGALA DAM D/S FLUMES	1495280	-20.750	31.230	MUTIRIKWI
28	WATERWORKS WEIR	1495290	-20.050	30.850	SHAGASHI
29	KYLE DAM U/S G/W (63423369)	1495291	-20.117	30.867	SHAGASHI
30	MAKAHOLI DAM U/S FLUME (63423353)	1495292	-19.817	30.733	SHAGASHI
31	KYLE DAM U/S G/W (63423354)	1495295	-20.100	30.900	UMPOPINYANI
32	KYLE DAM U/S FLUME	1495300	-20.080	31.070	MUTIRIKWI
33	KYLE DAM U/S G/W (63423348)	1495310	-20.100	31.083	MSALI
34	KYLE DAM U/S G/W (63423349)	1495320	-20.117	31.017	POPOTEKE

35	KYLE DAM U/S G/W (63423345)	1495330	-20.083	31.067	MUTIRIKWI
36	R/B CANAL PICK UP WEIR	1495350	-20.920	31.630	CHIREDZI
37	MANJIRENJI DAM U/S (63423208)	1495351	-20.483	31.533	CHIREDZI
38	ROSWA TURGWE FLUME (63422114)	1495360	-20.167	31.600	ROSWA
39	SIVUMBA FLUME (63423551)	1495370	-20.567	30.283	NGEZI
40	MBERENGWA ROAD BRIDGE (63423528)	1495371	-20.367	29.900	NGEZI
41	CONDO D/S G/W (63422121)	1495700	-19.217	32.017	SAVE RIO
42	CONDO U/S G/W (63422219)	1495720	-18.917	31.950	MACHEKE
43	ODZI BRIDGE CONTROL SECTION (63422361)	1495800	-18.917	32.417	ODZI
44	ODZI GORGE G/W (63422330)	1495801	-19.767	32.400	ODZI
45	ODZI FALLS FLUME (63422362)	1495802	-18.883	32.433	ODZI
46	PREMIER ESTATE	1495830	-18.920	32.550	UMTALI