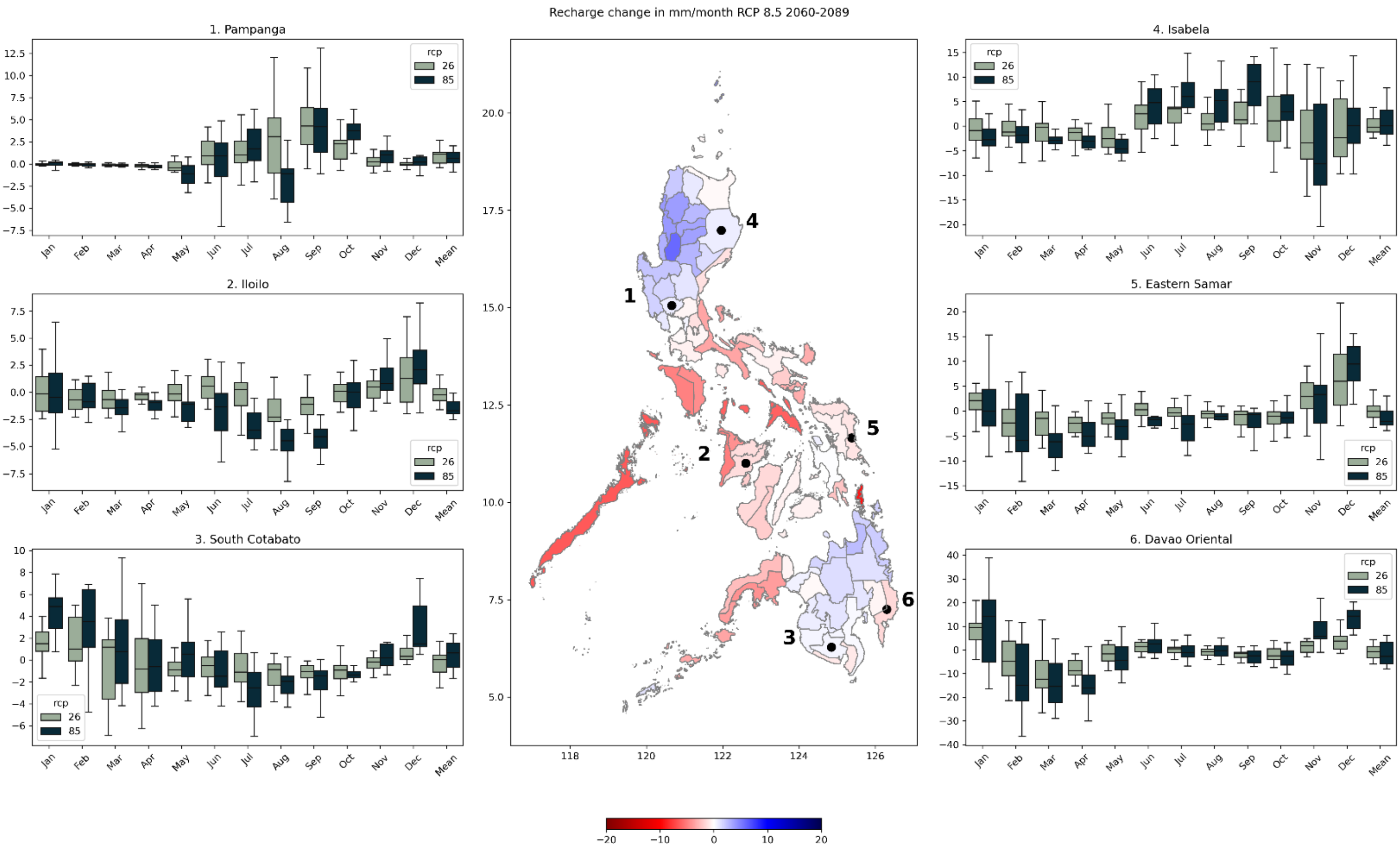


BGS Environmental Change, Adaptation & Resilience

# Future projections of the hydrology of the Philippines: dataset summary

Open report OR/25/010

British Geological Survey

BRITISH GEOLOGICAL SURVEY

ENVIRONMENTAL CHANGE, ADAPTATION & RESILIENCE

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# Future projections of the hydrology of the Philippines: dataset summary

Johanna Scheidegger



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# Acknowledgments

The Philippine National Hydrological Model has been developed under the British Geological Survey's International Geoscience Research and Development programme (IGRD) and its idea originated under the NERC-funded Philippine Groundwater Outlook (PhiGO) project.

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# Summary

The ‘Future Projections of the Hydrology of the Philippines’ dataset consists of ensemble model outputs from the Philippine National Hydrological Model driven by UKCP18 climate change projections considering two relative greenhouse gas concentration pathways RCP2.6 and 8.5. Outputs from the model include: evapotranspiration, soil moisture, groundwater recharge, surface runoff, river baseflow and groundwater levels.

The dataset is available in two formats: gridded data as NetCDF files with a spatial resolution at 2 km, and a spreadsheet in which variables are aggregated to provincial level.

The period for which the data are available is from 1980–2089 at a monthly time interval.

The Philippine National Hydrological model uses a version of the macro-scale hydrological modelling software Variable Infiltration Capacity (VIC), into which a gridded groundwater model has been added so that it simulates the integrated surface water and groundwater system. The model has been constructed using openly available global datasets and calibrated against local observations, principally of river flows when driven by ERA5 historical climatology. To assess potential future change in the water resources of the Philippines, the Philippine National Hydrological Model was driven by two 15-member ensembles of the UKCP18 climate projections considering two relative concentration pathways RCP 2.6 and RCP 8.5.

This dataset provides a means to assess potential climate change impacts for different regions in the Philippines considering two contrasting future relative concentration pathways. The dataset provides an indication of the mean change in the hydrological cycle at a regional spatial scale.

This user guide provides the information required to enable the reader to understand and use the dataset.

# 1 Introduction

Climate change and urban population growth are putting increasing stress on water resources in the Philippines. There is a need for an assessment how climate change will affect the country regionally over the 21st century for decision makers to implement suitable adaptation strategies.

The 'Future Projections of the Hydrology of the Philippines' dataset (Scheidegger 2025) provides projections of hydrological change for the period 1980–2089 generated using the UKCP18 climate change projections based on two greenhouse gas 'representative concentration pathways' (RCP): RCP2.6 and RCP 8.5 (Met Office Hadley Centre 2018). RCP2.6 represents a mitigation scenario aiming to limit the increase of mean global mean temperature to around 1.6C° by 2100 above preindustrial level for mid-range climate sensitivity. In contrast, RCP8.5 is a pathway where greenhouse gas emissions continue to grow unmitigated and lead to an estimated global average temperature rise of 4.3°C above preindustrial level by 2100. It is to note that the estimated ranges for future climate are conditioned on a set of modelling, statistical, and dataset choice assumption with expert judgement in methodological and data choices by the producers of the UKCP18 dataset. The probabilities of the projection are interpreted as an indication of a particular future climate outcome for a given representative concentration pathway and there is more evidence for outcomes near the centre of the distribution than in the tails (Fung et al. 2018). Each of the two climate projections is composed of a 15-member ensemble, representing the uncertainty in the simulations of future climate.

Both ensemble members are used to drive the Philippine National Hydrological model (Scheidegger et al. 2023). Consequently, we present results from 30 model simulations for the period 1980–2089. The model simulates evapotranspiration, soil moisture, groundwater recharge, surface runoff, river baseflow and groundwater level. Aggregated variables at a monthly time interval are provided in in NetCDF format for each RCP and ensemble member and as values aggregated to the provincial level in csv (or 'comma separate value') format. The provincial levels are based on the first level subdivisions from GADM (https://gadm.org/maps/PHL_1.html). The dataset is available from https://webapps.bgs.ac.uk/services/ngdc/accessions/index.html#item187559.

This dataset provides information on the extent to which projected climate change is likely to impact the water resources of the Philippines regionally, and how uncertain these projected changes are. As an example, **Figure 1** represents the mean change in groundwater recharge between 2060–2089 and 1990–2019 aggregated to provincial levels for RCP 8.5 and boxplots of monthly change for six provinces.

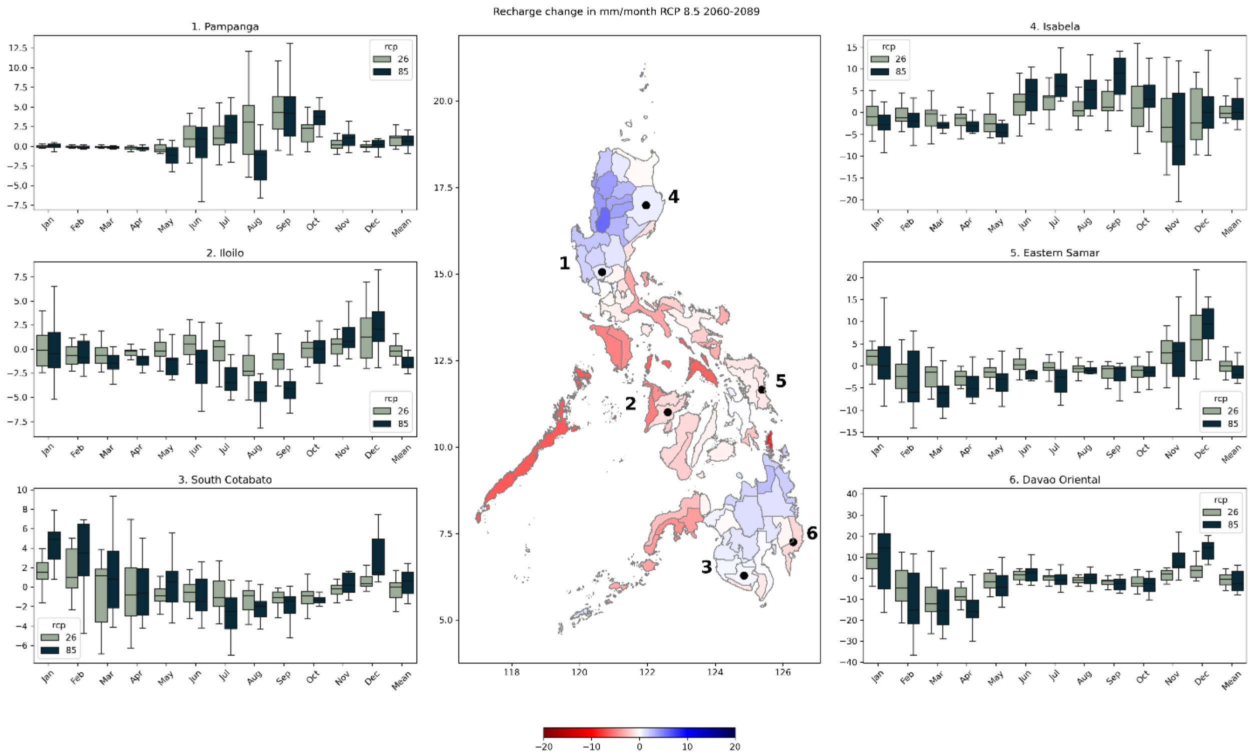



**Figure 1** Change in mean annual groundwater recharge in mm/month between 2060–2089 and 1990–2019 aggregated to provincial levels for RCP 8.5 and boxplots of monthly change for six regions.

# 2 Example use of the dataset for provincial or national level

How climate change will affect the water resources of a country over the 21st century is uncertain. Climate change projections, such as UKCP18, provide an ensemble of models that project different climatic variables over the 21st century at a global scale.

These climate projections have been used to drive the Philippine National Hydrological Model to assess how future climate change could impact the hydrological cycle and water resources in the Philippines. These outputs enable assessments at a provincial or regional level, for example if a region becomes wetter or dryer or if extreme events become more frequent.

A detailed description of the hydrological model and datasets used is provided in section 3.

In this section an example of the dataset is presented using scripts written in the R programming language, which are also provided.

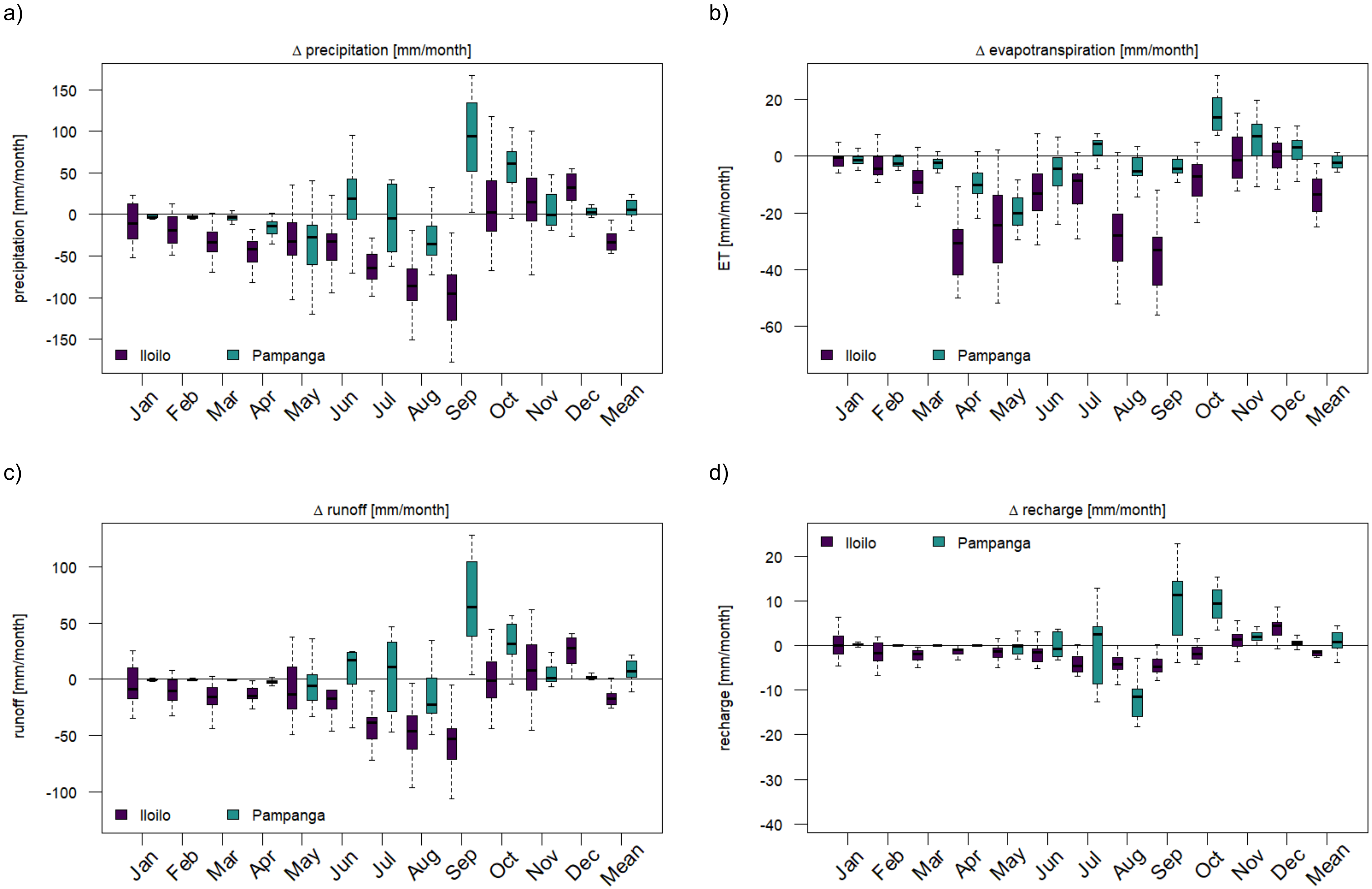
## 2.1 ANALYSIS OF THE HYDROLOGICAL PROJECTIONS FOR TWO REGIONS: ILIOILO AND PAMPANGA

This section provides examples of how the csv files in the dataset can be used to assess the effect of projected climate change on different hydrological state variables aggregated to provincial levels for two different periods in the future, 2030–2059 and 2060–2089, relative to the historical period 1990–2019 for one to four regions of interest. The results can be represented both as differences between a historical and future period, and as absolute values. Here, an example of the provinces of Iloilo and Pampanga are given for the period of 2060–2089. The example script (Notebook-Future_projections_of_the_hydrology_of_the_Philippines.Rmd) that was used to produce these graphs is provided with the dataset. This is written in the R programming language and was run in the open RStudio environment (https://posit.co/products/open-source/rstudio/). The notebook in html format can be opened in a web browser.

The boxplots in **Figure 2** give the change for the future period, 2060–2089, relative to 1990–2018. The boxplots show the spread of the ensemble members for each month of the year. The discussion below refers to the mean annual values and the median of the different ensemble members.

The two regions show a different shift in the driving precipitation (**Figure 2**). In Iloilo, the projections represent a decrease in annual precipitation of 33 mm/month, whereas in Pampanga, there is a slight increase in precipitation of 5.6 mm/month. The evapotranspiration decreases by 13.3 mm/month in Iloilo and by 2.3 mm/month in Pampanga. The decrease in precipitation results in a decrease in runoff in Iloilo of 17.2 mm/month, whereas the increase in precipitation in Pampanga produces an increase in runoff of 7.5 mm. Groundwater recharge shows little change, with a slight increase in Iloilo in groundwater recharge (0.4 mm/month) and a slight decrease in groundwater recharge (-0.76 mm/month) in Pampanga.

The absolute value of each hydrological flux is presented for the three time periods in **Figure 3**. It is evident that there are large uncertainties because of the spread of the results from the ensemble members over both the historical and future periods. Therefore, we suggest using differences between the time periods for the different hydrological state variables as presented in **Figure 2** rather than absolute values as in **Figure 3**. For example, considering RCP8.5 in Iloilo for the period of 1990–2019, the mean annual precipitation ranges from 224 mm/month to 230 mm/month, which is equal to a percentage difference of 2.7%. This spread in values between the different ensemble members increases in the near future (2030–2059) to 15.8% and decreases again to 28.6% in the far future (2060–2089). The mean monthly values show much larger uncertainty between the different model ensemble members. For example, in March, the percentage difference is 80.4 % for historical period, and 112.5% and 111.5% for the near and far future respectively. Therefore, the uncertainty in the annual average values is much smaller than for monthly or seasonal metrics.


a)
Δ precipitation [mm/month]
precipitation [mm/month]
150
100
50
0
-50
-100
-150
Iloilo
Pampanga
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Mean
b)
Δ evapotranspiration [mm/month]
ET [mm/month]
20
0
-20
-40
-60
Iloilo
Pampanga
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Mean
c)
Δ runoff [mm/month]
runoff [mm/month]
100
50
0
-50
-100
Iloilo
Pampanga
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Mean
d)
Δ recharge [mm/month]
recharge [mm/month]
20
10
0
-10
-20
-30
-40
Iloilo
Pampanga
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Mean

d)

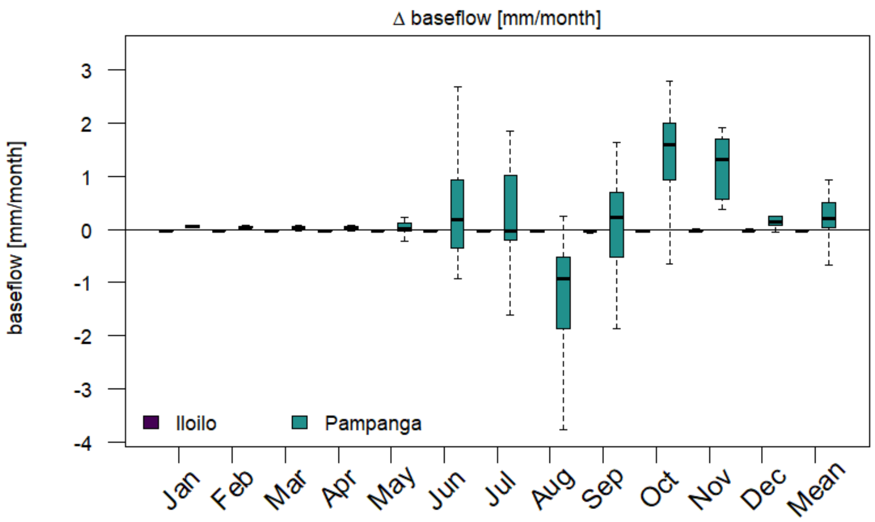
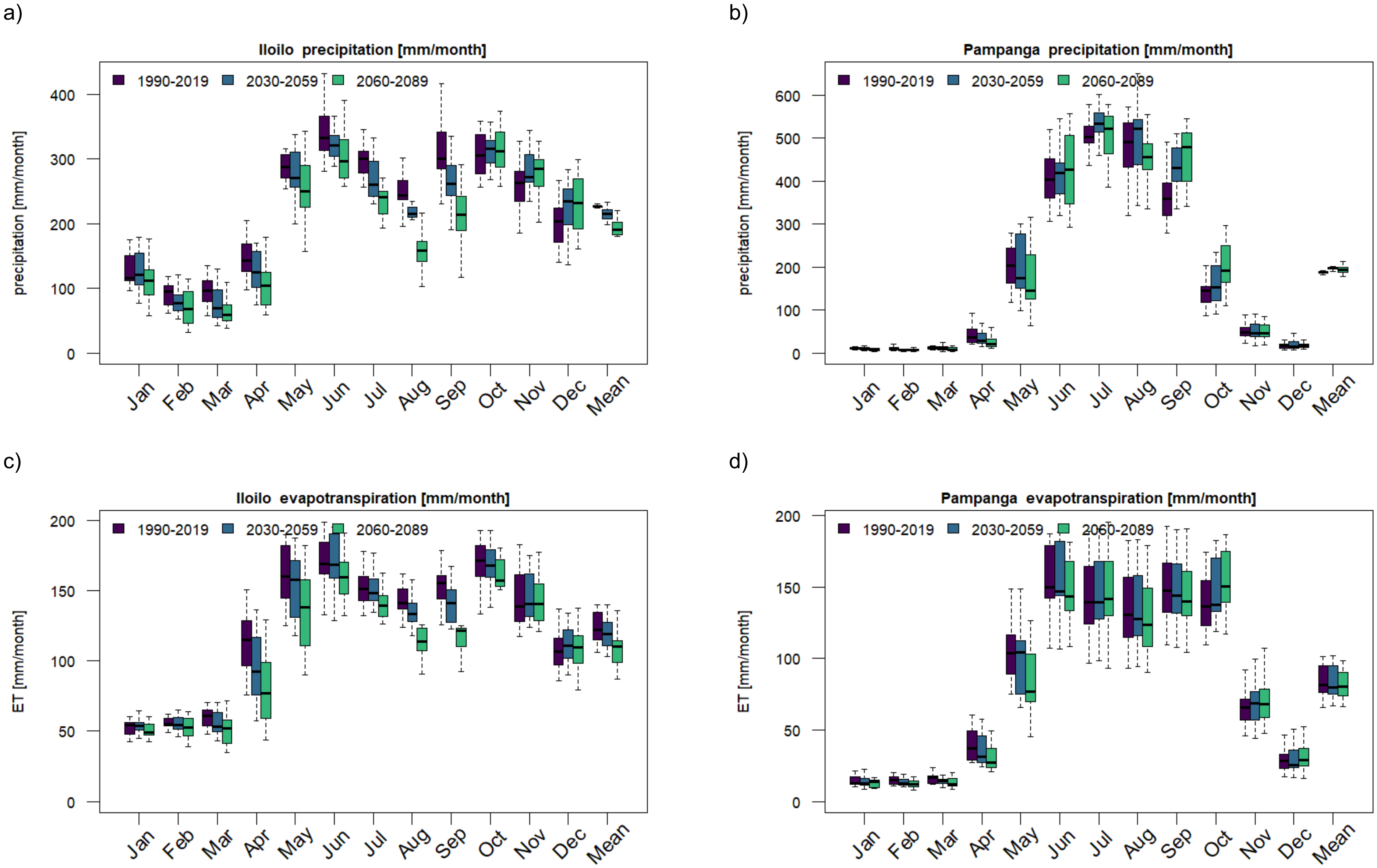
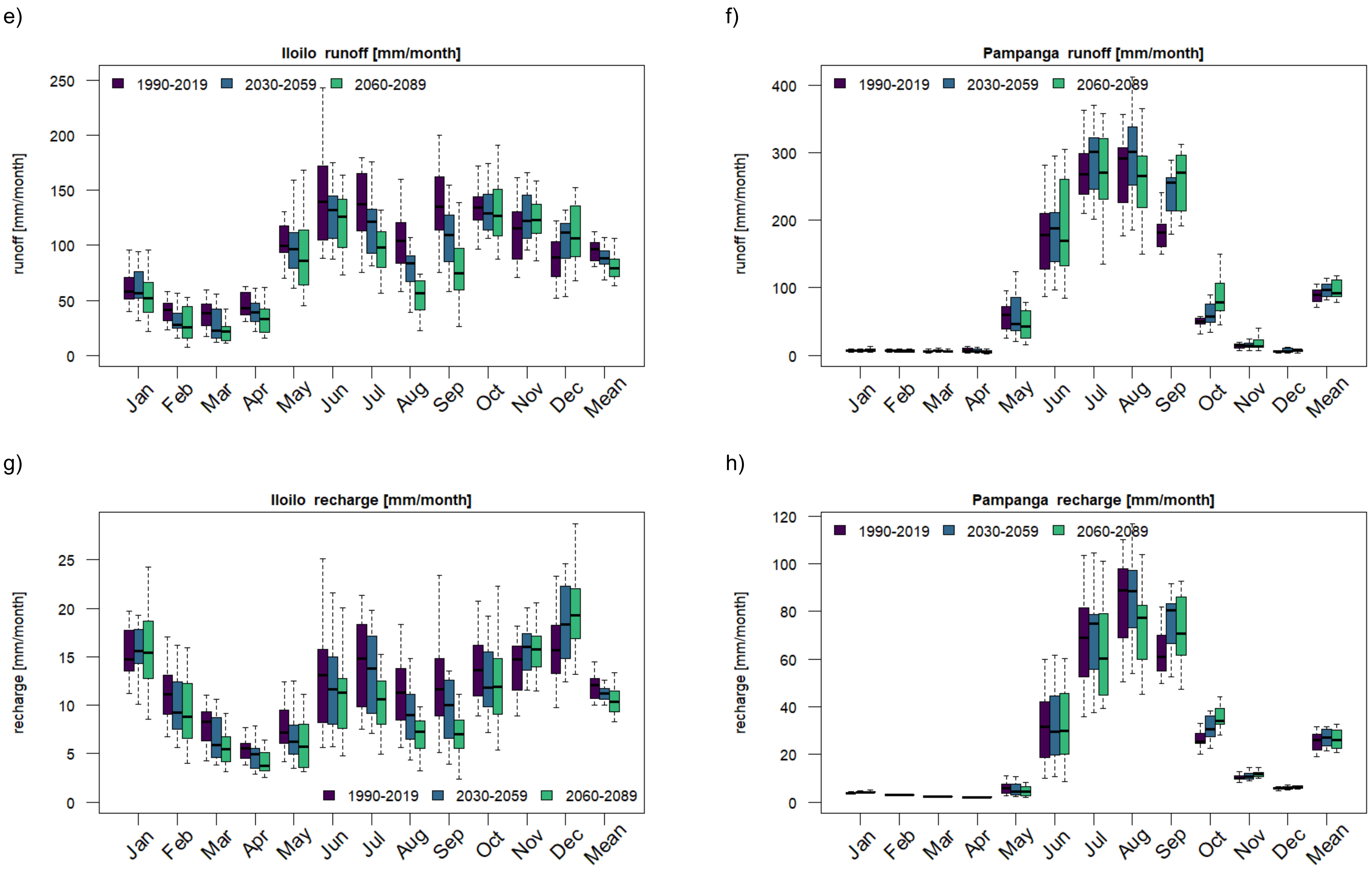
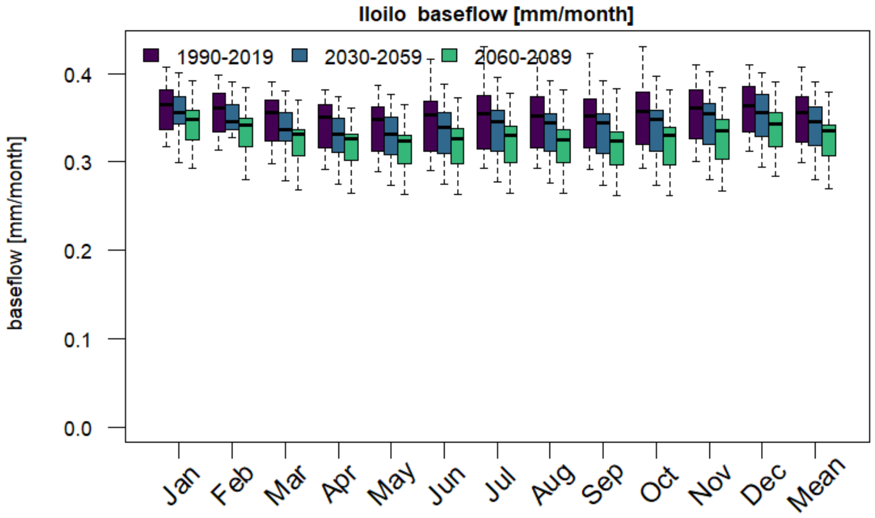



**Figure 2** Change in monthly water fluxes (mm/month) for the period of 2060–2089 and RCP8.5 relative to 1990–2019 for Iloilo and Pampanga. Contains data from Met Office Hadley Centre (2018): UKCP18 Global Climate Model Projections for the entire globe. Centre for Environmental Data Analysis, [2018] available here, released CC BY.


a)
Iloilo precipitation [mm/month]
1990-2019
2030-2059
2060-2089
precipitation [mm/month]
0
100
200
300
400
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Mean
b)
Pampanga precipitation [mm/month]
1990-2019
2030-2059
2060-2089
precipitation [mm/month]
0
100
200
300
400
500
600
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Mean
c)
Iloilo evapotranspiration [mm/month]
1990-2019
2030-2059
2060-2089
ET [mm/month]
0
50
100
150
200
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Mean
d)
Pampanga evapotranspiration [mm/month]
1990-2019
2030-2059
2060-2089
ET [mm/month]
0
50
100
150
200
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Mean


e)
Iloilo runoff [mm/month]
runoff [mm/month]
1990-2019
2030-2059
2060-2089
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Mean
f)
Pampanga runoff [mm/month]
runoff [mm/month]
1990-2019
2030-2059
2060-2089
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Mean
g)
Iloilo recharge [mm/month]
recharge [mm/month]
1990-2019
2030-2059
2060-2089
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Mean
h)
Pampanga recharge [mm/month]
recharge [mm/month]
1990-2019
2030-2059
2060-2089
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Mean

i)




j)

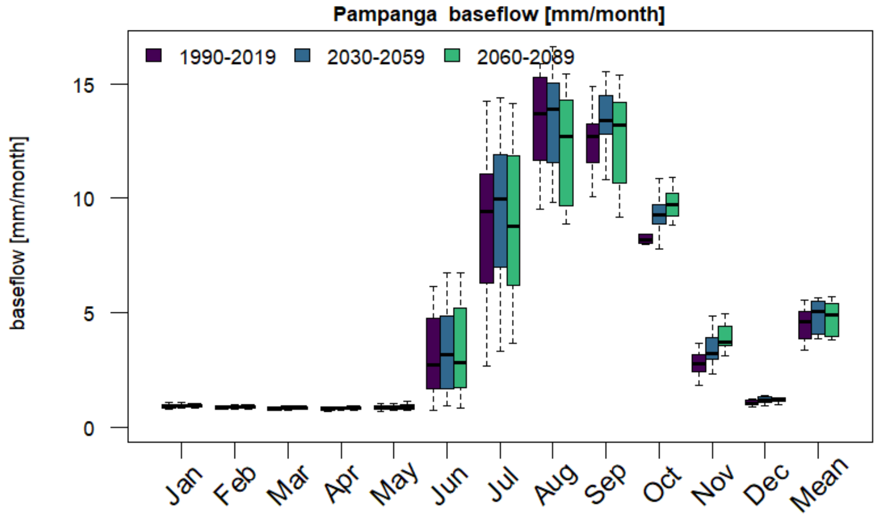
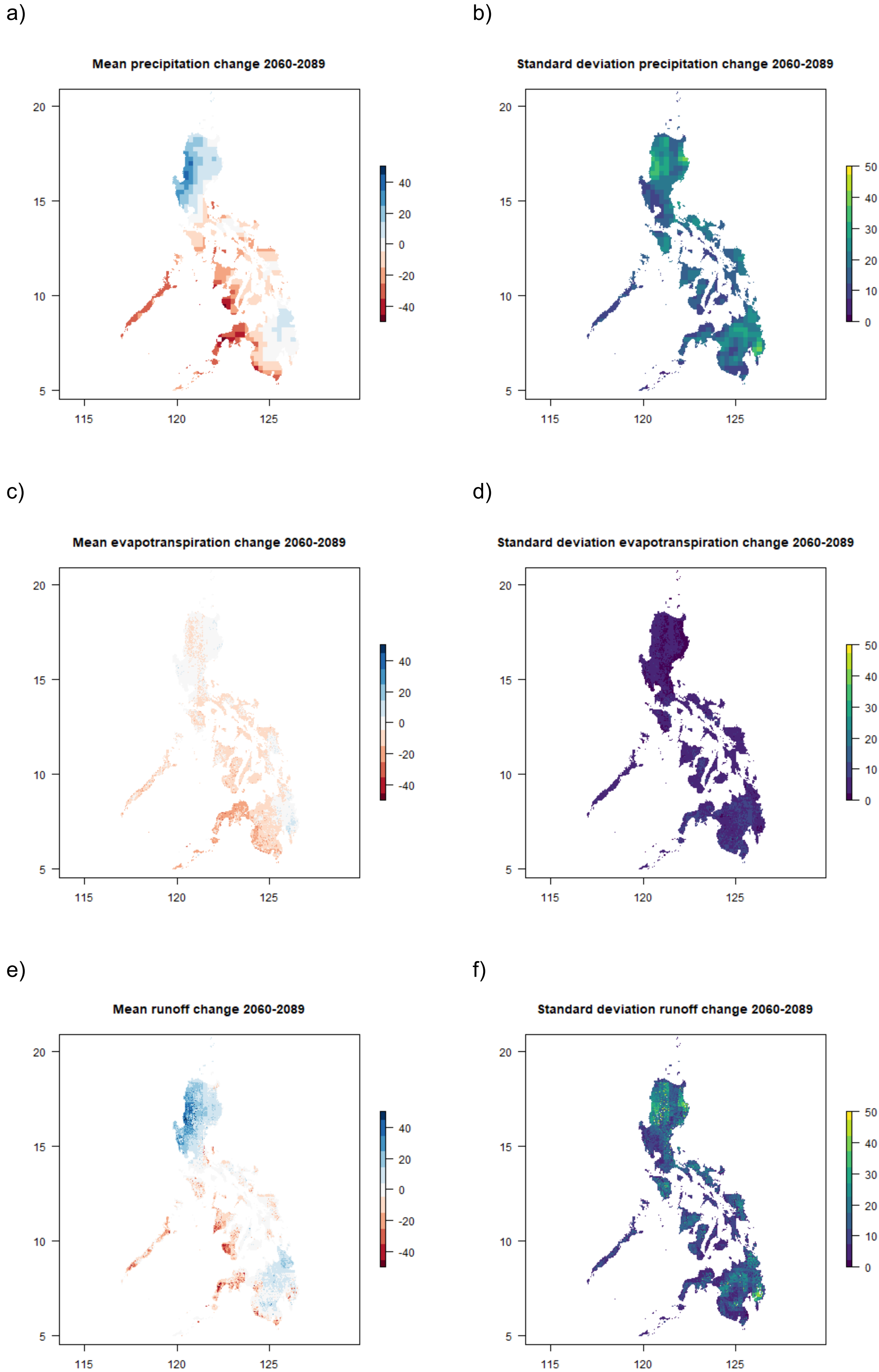



**Figure 3.** . Distributions of simulated monthly fluxes for the time periods 1990–2019, 2030–2059 and 2060–2089 averaged across Iloilo and Pampanga. Contains data from Met Office Hadley Centre (2018): UKCP18 Global Climate Model Projections for the entire globe. Centre for Environmental Data Analysis, [2018] available here, released CC BY.

## 2.2 ASSESSMENT OF GRIDDED UKCP18 CLIMATE CHANGE SCENARIOS BASED ON THE NETCDF FILES

The gridded model outputs from the hydrological model can also be used to explore the effect of climate change on water cycle flux components. For example, produce gridded maps can be produced using the NetCDF model outputs of changes in precipitation, evapotranspiration, surface runoff, groundwater recharge or baseflow for selected time periods (**Figure 4**). The R script (Notebook-Future_projections_of_the_hydrology_of_the_Philippines.Rmd) provided with dataset enables the user to specify which two time periods to compare and which RCP to use. The resulting maps show the mean and standard deviation of the values from the 15 ensemble members.

There are strong regional differences in the projected changes in precipitation. For example, there is a positive change over northern (Luzon) and south-western (Davao) regions of the country, and a decrease in precipitation across central (Visayas) and south-eastern regions. A similar pattern is seen in runoff and groundwater recharge and baseflow. In contrast, mean evapotranspiration was simulated to predominantly decrease.


a)
Mean precipitation change 2060-2089
b)
Standard deviation precipitation change 2060-2089
c)
Mean evapotranspiration change 2060-2089
d)
Standard deviation evapotranspiration change 2060-2089
e)
Mean runoff change 2060-2089
f)
Standard deviation runoff change 2060-2089
5
10
15
20
115
120
125
40
20
0
-20
-40
50
40
30
20
10
0

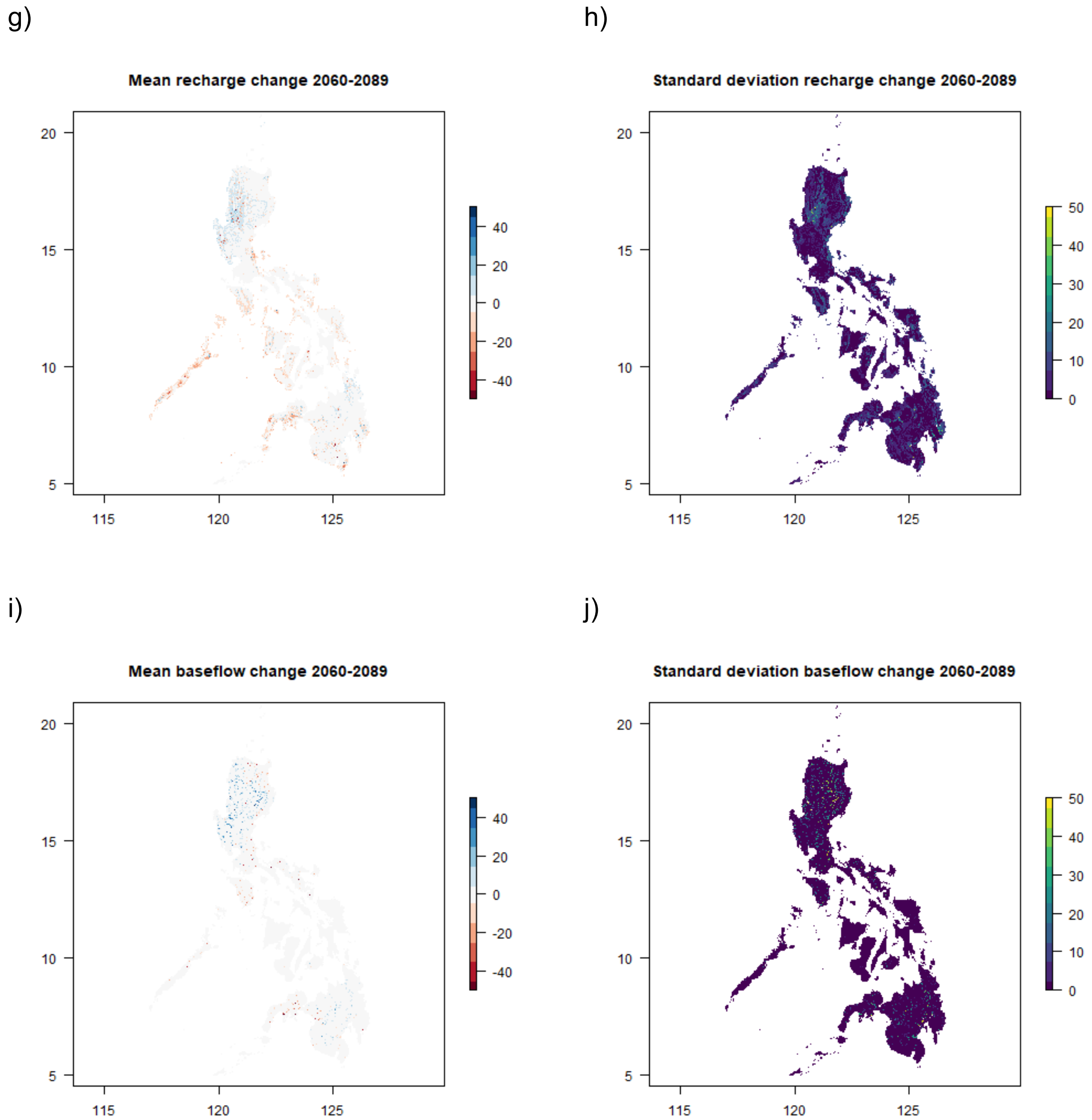



**Figure 4** Gridded changes in hydrological fluxes (mm/month) between the time periods 1990–2019 and 2060–2089 for RCP8.5, expressed as the mean and standard deviation of the 15-member ensemble. Contains data from Met Office Hadley Centre (2018): UKCP18 Global Climate Model Projections for the entire globe. Centre for Environmental Data Analysis, [2018] available here, released CC BY.

# 3 Methodology

For a more detailed description of the methodology, the reader is referred to Scheidegger et al. (2021, 2022, and 2023), but a summary is outlined below.

## 3.1 OVERVIEW

To simulate the hydrology of the Philippines, we use the integrated VIC-AMBHAS hydrological model coupled to a lateral groundwater flow model (**Figure 5**), as developed by Scheidegger et al. (2021). VIC is a macro-scale hydrological model, which has been applied widely for water and energy balance studies (Hamman et al. 2018). The model describes full water and energy transport over a grid cell. When precipitation reaches the land surface, it is partitioned into runoff and infiltration. To accumulate flows at river gauging stations, routing of runoff and baseflow is performed by post-processing model output (Lohmann et al. 1996).

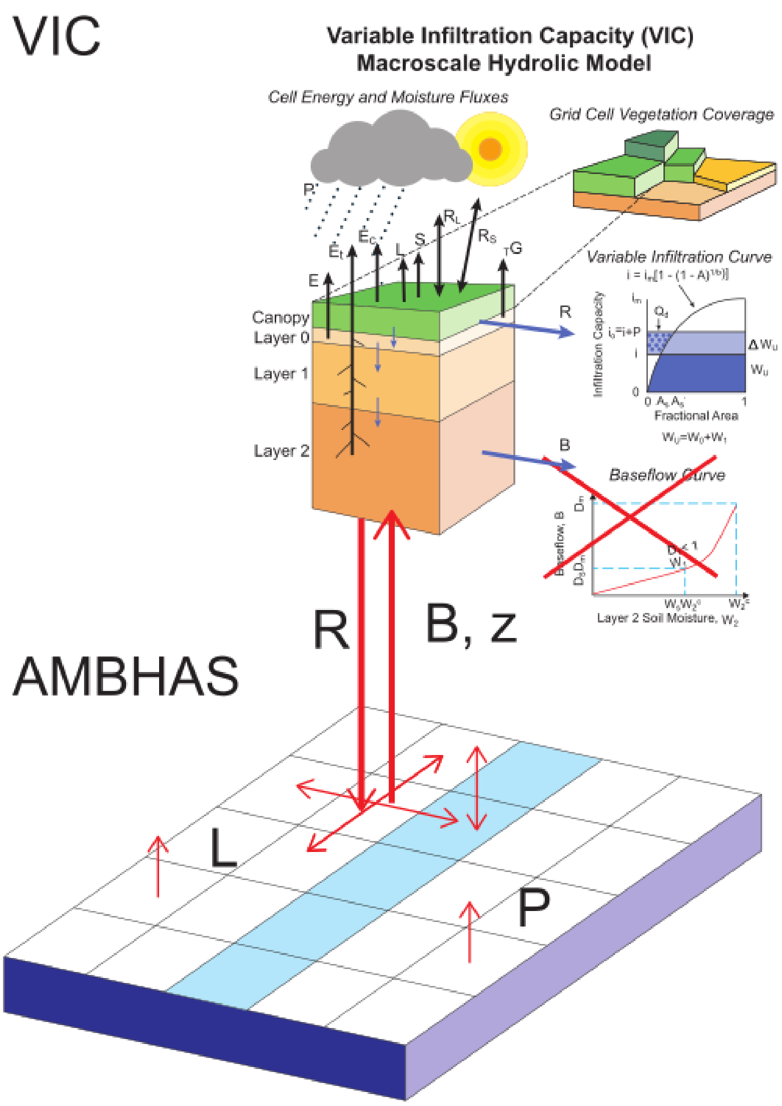



**Figure 5** VIC-AMBHAS model framework. The soil column in VIC is coupled using bi-directional exchange of water between the soil and the aquifer. The aquifer allows for river baseflow, abstraction and leakage BGS © UKRI.

The lateral groundwater model incorporated into VIC is a distributed, one-layer, two-dimensional groundwater model driven by groundwater recharge and groundwater pumping. Groundwater recharge is derived from interaction of the groundwater model with the VIC soil column by allowing bi-directional exchange of water between the aquifer and the soil. A full description of the lateral groundwater model and coupling to VIC is given by Scheidegger et al. (2021).

## 3.2 SOURCE DATASETS

The model is run on a 1/60° (~2 km) grid across the country and is driven with openly available global datasets. The model is parameterised with spatially distributed parameters from a range of sources that describe the land surface, including soil properties and vegetation properties. The soil properties such as field capacity, plant available water, wilting point, saturated hydraulic conductivity, and residual saturation for the VIC model are taken from a global high-resolution map of soil hydraulic properties (Zhang and Marcel 2018). Quartz fraction and bulk density values are from SoilGrid1km (Hengl et al. 2014). Landcover vegetation parameters are taken from Modis (Friedl and Sulla-Menashe 2015), leaf area index and albedo from Copernicus (Smets et al. 2019), and vegetation height from LiDAR-derived Global Estimates of Forest Canopy Height (Healey et al. 2015). The groundwater part of the model requires values for hydraulic conductivity and specific yield, which are classified based on the groundwater availability map of the Philippines (Bureau of Mines and Geosciences and Ministry of Natural Resources 1986). A full description of the model input is given in Appendix 1.

The VIC model is driven by meteorological forcing data using a gridded, sub-daily time-series of meteorological variables as input. Average air temperature, total precipitation, atmospheric pressure, incoming shortwave radiation, incoming longwave radiation, vapor pressure, and wind speed are required. Scenarios of climate for the period 1980–2089 are derived from the UKCP18 climate projections for RCP2.6 and RCP8.5. UKCP18 provides a 15-member ensemble of time-series of daily climate variables (Met Office Hadley Centre 2018). The UKCP18 has a spatial resolution of 0.8333° x 0.5556°.The code has been modified so that each model grid cell is matched to a grid cell of the forcing files without the need for resampling and with the option of reading in daily forcing data rather than needing to resample the forcing data to sub-daily time steps as in the previous versions of the code.

# 4 Technical Information

Two datasets generated by the Philippine National Hydrological model are available:

i. the raw model outputs on a 2km grid;
ii. model outputs aggregated to provincial levels using the first level subdivision from GADM (https://gadm.org/maps/PHL_1.html).

## 4.1 DATA FORMATS

Two data formats are used:

i. The gridded monthly raw model outputs for the period January 1980 to December 2089 are provided as NetCDF files. NetCDF (network Common Data Form) is a self-describing, portable, scalable, appendable, shareable, and archivable data format.
ii. csv (comma separated values) files containing monthly time-series of hydrological fluxes aggregated at the provincial level.

## 4.2 SCALE

The Philippine National Hydrological model has been developed at 1/60° (~2 km) grid resolution and is driven by coarser resolution climate data at 0.8333° x 0.5556° resolution. Therefore, the model output is not appropriate for interpretation at higher resolutions. The datasets used are predominantly datasets at global spatial extent, and therefore the output should be used for regional comparison, rather than a point scale evaluation.

## 4.3 COVERAGE

The extent of the datasets covers the Philippines, as shown in **Figure 1**. The geographic projection used is WGS84.

The raster model output is divided into four files for each RCP *XX* and ensemble member *YY*. Values for *XX* are '26' and '85' for RCPs 2.6 and 8.5. Values for *YY* are for the 15 ensemble members ranging from 01 to 15.

- `North_rcpXX_enYY.1980-01.nc`

  xmin: 119.6417

  xmax: 124.5083

  ymin: 12.1083

  ymax: 20.9250

- `Center_rcpXX_enYY.1980-01.nc`

  xmin: 120.9083

  xmax: 126.0583

  ymin: 8.9417

  ymax: 12.7750

- `South_rcpXX_enYY.1980-01.nc`

  xmin: 121.3583

  xmax: 126.6917

  ymin: 5.2583

  ymax: 10.5583

- `West_rcpXX_enYY.1980-01.nc`

  xmin: 116.8250

  xmax: 122.0250

  ymin: 4.5417

  ymax: 12.4083

## 4.4 OUTPUT VARIABLES

### 4.4.1 Output variables in NetCDF files

Table 1 lists the output variables contained in the NetCDF files. The output is provided on a monthly time-step between January 1980 and December 2089.

**Table 1** List of output variables of the Net CDF files.

| Field name | Field description |
|---|---|
| OUT_PREC | Incoming precipitation [mm/month]. |
| OUT_INFLOW | Moisture that reaches top of soil column [mm/month] |
| OUT_EVAP | Total net evaporation [mm/month] |
| OUT_RUNOFF | Surface runoff [mm/month] |
| OUT_RECHARGE | Groundwater recharge [mm/month]. Bi-directional flux between the soil and the aquifer. Positive values are groundwater recharge and negative values are groundwater discharge. |
| OUT_SOIL_MOIST | Total soil moisture content for each soil layer [mm] |
| OUT_DELSOILMOIST | Change in soil water content [mm/month] |
| OUT_BASEFLOW_AQ | Baseflow from aquifer to river [mm/month] |
| OUT_Z | Depth to groundwater below DEM [mm] |

### 4.4.2 Output variables in CSV files

The output aggregated to the provincial level is the same as presented in the Philippine National Hydrological Model web-tool (https://mapapps.bgs.ac.uk/philippines-national-hydrological-model/). It is based on the 2 km model output. A csv for the following variables is available where XX are '26' and '85' for RCPs 2.6 and 8.5 and YY are for the 15 ensemble members ranging from 01 to 15.

- Precipitation [mm/month]: Precipitation_FutureScenario_XX_YY.csv
- Evapotranspiration [mm/month]: Evapotranspiration_FutureScenario_XX_YY.csv
- Surface runoff [mm/month]: Runoff_FutureScenario_XX_YY.csv
- Groundwater recharge [mm/month]: Recharge_pos_FutureScenario_XX_YY.csv
- Groundwater discharge [mm/month]: Recharge_neg_FutureScenario_XX_YY.csv
- Baseflow [mm/month]: Baseflow_FutureScenario_XX_YY.csv

For each variable, the following model output is given:

- Column 1: row counter
- Column 2: month
- Column 3: year
- Columns 4 to 84: mean monthly model output for each province

# 5 Licencing the data

## 5.1 BGS LICENCE TERMS

Please use the following acknowledgements when using 'Future Projections of the Hydrology of the Philippines' dataset:

- Scheidegger, J. (2025). Future projections of the hydrology of the Philippines dataset. NERC EDS National Geoscience Data Centre. (Dataset). https://doi.org/10.5285/a4b89222-9350-429b-9ed7-8dc45d02aac5

- Future projections of the hydrology of the Philippines dataset: 'Contains British Geological Survey materials © UKRI [2025]'

## 5.2 OPEN DATA

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## 5.3 CONTACT INFORMATION

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# 6 Limitations

## 6.1 DATA CONTENT

The 'Future Projections of the Hydrology of the Philippines' dataset has been generated using openly available global datasets for soil and vegetation properties, land cover, and aquifer properties (Section 3.2). Consequently, the values within this dataset are limited by the components on which they are based.

## 6.2 SCALE

The model was run at a 2 km grid cell resolution and the data have been aggregated to province levels. However, given the uncertainty of the model inputs and driving data, the output should only be used for regional scale assessment and not for point based analysis.

## 6.3 ACCURACY AND UNCERTAINTY

The Philippine National Hydrological Model has only been calibrated to observed streamflow data available from the National Hydrologic Data Collection Program (Department of Public Works and Highways 2016). All other variables apart from runoff and baseflow are uncalibrated and their uncertainty is unknown. The calibration has only been undertaken for the Philippine National Hydrological model driven by ERA5. For the assessment of the accuracy and uncertainty of the Philippine National Hydrological Model, the reader is referred to (Scheidegger 2024).

The uncertainty arising from the different climate projections is represented by the standard deviation (e.g. **Figure 4**) or the spread between the different ensemble members (e.g. as represented by the box plots in **Figure 3**).

The features of the box plots are:

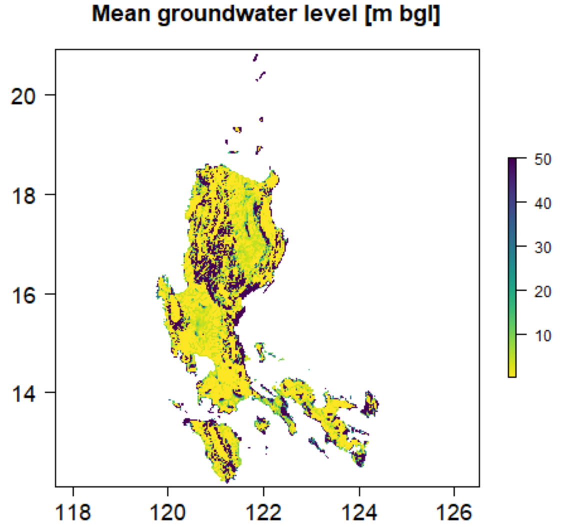
- Median (Q2) – the horizontal line inside the box represents the median (50th percentile) of the data.
- Interquartile Range (IQR) – the box itself extends from the first quartile (Q1, 25th percentile) to the third quartile (Q3, 75th percentile), representing the middle 50% of the data.
- Whiskers – lines extending from the box, covering data points within 1.5 × IQR from Q1 and Q3. They indicate the range of most of the data.

The spread between the ensemble members of the monthly values is large and much smaller for mean annual values, and therefore there is more uncertainty in the projection of monthly changes than in the projected changes in the mean annual hydrological variables.

## 6.4 ARTEFACTS

The Philippine National Hydrological Model simulates recharge from the land surface to groundwater and discharge of groundwater to rivers and the coast and upwards through the soil where the groundwater level is near the land surface. Only major rivers are represented in the model because of the coarse resolution of the model grid (2 km). Consequently, the depth to groundwater can be low (**Figure 6a**) where groundwater discharge up through the soil is simulated to occur. Because the variable OUT_RECHARGE represents the bi-directional flux between the soil and the aquifer, OUT_RECHARGE can be negative where groundwater is discharging to the surface. In **Figure 6b**, only the positive groundwater recharge values are shown; negative values are plotted in white. The user can filter these values out, by setting the values of OUT_RECHARGE that are smaller than 0 to NA and taking a regional average.

a)




b)

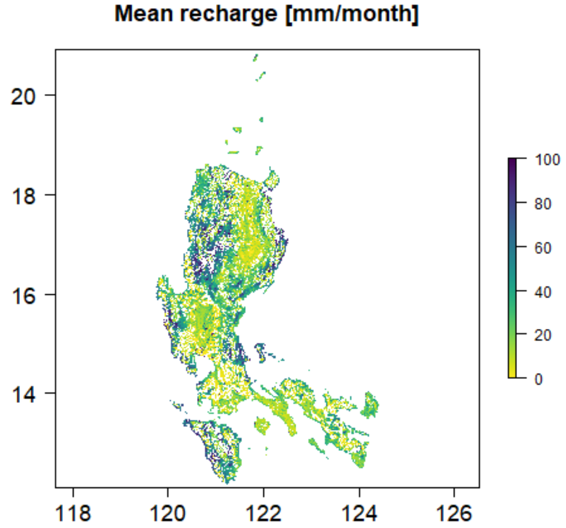



**Figure 6** a) Groundwater level (metres below ground level, m bgl, displayed to 50 m bgl), and b) groundwater recharge; For b) only positive values of groundwater recharge are shown, white pixels represent areas of groundwater discharge.

## 6.5 DISCLAIMER

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# 7 Frequently asked questions

These questions and answers have been provided to address any potential issues relating to how the product can be used or how it can be interpreted. If you have any additional questions, please contact digitaldata@bgs.ac.uk

**Q:** What does the 'Future Projections of the Hydrology of the Philippines' dataset contain?
**A:** The dataset contains projections of various hydrological fluxes simulated by the Philippine National Hydrological Model for the period 1980-2089 in two formats: (i) monthly values on a 2 km grid; and (ii) monthly time-series aggregated to province levels.

**Q**: What areas does the 'Future Projections of the Hydrology of the Philippines' dataset cover?
**A:** This dataset covers the Philippines.

**Q:** In what format is the 'Future Projections of the Hydrology of the Philippines' dataset provided?
**A:** The dataset is provided as NetCDF format. Aggregated output to province level is also provided as CSV files.

**Q:** At what map scale is the 'Future Projections of the Hydrology of the Philippines' dataset provided?
**A:** The Philippine National Hydrological Model used to generate the dataset was run at a 2 km grid cell resolution. Given the uncertainty of the model inputs and driving data, the output should only be used for regional scale assessment and not for point based analysis.

**Q:** How often will the 'Future Projections of the Hydrology of the Philippines' dataset be updated?
**A:** At the time of first publication there are no updates planned for this dataset.

**Q:** Can I use the 'Future Projections of the Hydrology of the Philippines' dataset as part of a commercial application?
**A:** This dataset is licenced from BGS, please refer to the terms of your licence or contact iprdigital@bgs.ac.uk for further information.

# References

BUREAU OF MINES AND GEOSCIENCES AND MINISTRY OF NATURAL RESOURCES 1986. Groundwater availability map of the Philippines, Bureau of Mines and Geo-Sciences, Metro Manila, Philippines.
DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS 2016. National Hydrologic Data Collection Program (NHDCP).
FRIEDL, M AND SULLA-MENASHE, D 2015. MCD12C1 MODIS/Terra+Aqua Land Cover Type Yearly L3 Global 0.05Deg CMG V006. 2015, distributed by NASA EOSDIS Land Processes DAAC https://doi.org/10.5067/MODIS/MCD12C1.006.
FUNG, F, LOWE, J, MITCHELL, J, MURPHY, J, BERNIE, D, GOHAR, L, HARRIS, G, HOWARD, T, KENDON, E, MAISEY, P, PALMER, M AND SEXTON, D 2018. UKCP18 Guidance: Caveats and Limitations. *Met Office Hadley Centre, Exeter*.
HAMMAN, J J, NIJSSEN, B, BOHN, T J, GERGEL, D R AND MAO, Y X 2018. The Variable Infiltration Capacity model version 5 (VIC-5): infrastructure improvements for new applications and reproducibility. *Geoscientific Model Development* 11(8), 3481-3496, https://doi.org/10.5194/gmd-11-3481-2018.
HEALEY, S P, M.W. HERNANDEZ, D.P. EDWARDS, M.A. LEFSKY, E. FREEMAN, P.L. PATTERSON, E.J. LINDQUIST AND LISTER., A J 2015. CMS: GLAS LiDAR-derived Global Estimates of Forest Canopy Height, 2004-2008 https://doi.org/10.3334/ORNLDAAC/1271.
HENGL, T, DE JESUS, J M, MACMILLAN, R A, BATJES, N H, HEUVELINK, G B, RIBEIRO, E, SAMUEL-ROSA, A, KEMPEN, B, LEENAARS, J G, WALSH, M G AND GONZALEZ, M R 2014. SoilGrids1km--global soil information based on automated mapping. *PLOS ONE* 9(8), e105992, https://doi.org/10.1371/journal.pone.0105992.
LOHMANN, D, NOLTE-HOLUBE, R AND RASCHKE, E 1996. A large-scale horizontal routing model to be coupled to land surface parametrization schemes. *Tellus, Series A: Dynamic Meteorology and Oceanography* 48(5), 708-721, https://doi.org/10.3402/tellusa.v48i5.12200.
MET OFFICE HADLEY CENTRE 2018. UKCP18 Global Climate Model Projections for the entire globe. CENTRE FOR ENVIRONMENTAL DATA ANALYSIS, http://catalogue.ceda.ac.uk/uuid/f1a2fc3c120f400396a92f5de84d596a.
SCHEIDEGGER, J 2024. User guide: BGS Philippine National Hydrological Model dataset. OR/24/023.
SCHEIDEGGER, J 2025. Future projections of the hydrology of the Philippines dataset. NERC EDS National Geoscience Data Centre. (Dataset). https://doi.org/10.5285/a4b89222-9350-429b-9ed7-8dc45d02aac5.
SCHEIDEGGER, J, BARKWITH, A, JACKSON, C, MANSOUR, M AND GUZMAN, A 2023. Philippine National Hydrological Model. OR/23/053.
SCHEIDEGGER, J M, JACKSON, C R, MUDDU, S, TOMER, S K AND FILGUEIRA, R 2021. Integration of 2D Lateral Groundwater Flow into the Variable Infiltration Capacity (VIC) Model and Effects on Simulated Fluxes for Different Grid Resolutions and Aquifer Diffusivities. *Water* 13(5), 663, https://doi.org/10.3390/w13050663.
SMETS, B, VERGER, A, CAMACHO, F, VAN DER GOTEN, R AND JACOBS, T 2019. Copernicus Global Land Operations "Vegetation and Energy" https://land.copernicus.eu/global/products/lai.
ZHANG, Y AND MARCEL, G S 2018. A High-Resolution Global Map of Soil Hydraulic Properties Produced by a Hierarchical Parameterization of a Physically-Based Water Retention Model. YONGGEN, Z AND MARCEL, G S, https://doi.org/10.1002/joc.443610.7910/DVN/UI5LCE.