



Fast  
**Hazard**

Fastflood  
***Command line tool***

Tutorial book

Project : Fastflood Command line tool  
Date : November 2024  
Contact : [info@fast-hazard.com](mailto:info@fast-hazard.com)  
Versie : 1.0



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Expand if necessary

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## Introduction

So, you have a flood modelling task at hand and you want to model the floods quickly without compromising the quality or accuracy of the modelling. You are at the right place!

Welcome to Fastflood a powerful command-line tool designed for advanced flood modeling and hydrological simulations. Fastflood leverages cutting-edge techniques to provide highly accurate simulations of flood events, catering to researchers, engineers, and disaster management professionals. Its flexibility allows users to simulate various hydrological scenarios with detailed customization, making it a valuable tool for flood risk assessment and planning.

Fastflood offers a wide array of input options, enabling users to configure simulations to meet specific requirements. From downloading elevation and land-use data automatically to applying complex dynamic simulations, the tool is equipped to handle diverse applications. Whether you are modeling design storms, refining channel flow simulations, or working with custom geospatial datasets, Fastflood ensures precision and adaptability.

This manual serves as a comprehensive guide to using Fastflood effectively. It provides detailed explanations of the available input options, their parameters, and practical use cases. By following this guide, users can harness the full potential of Fastflood to simulate flood scenarios, analyze results, and make data-driven decisions to mitigate flood risks. The next section briefly describes the Fastflood method which is at the heart of the Fastflood tool.

## Fastflood method

Fastflood combines industry standard methodologies developed in the LISEM model since 1993 (Bout & Jetten, 2018), with recent innovations in flood modelling (Bout et al., 2023). Fastflood simulates hazard maps directly using the Fastflood method, incorporating a fast, steady-state flow accumulation solver and an adaptive pressure-driven inundation solver, which allows the model to generate detailed flood hazard maps significantly faster than conventional models without sacrificing accuracy. The overview of methodology involved in the working of the Fastflood model is shown in Figure 1.

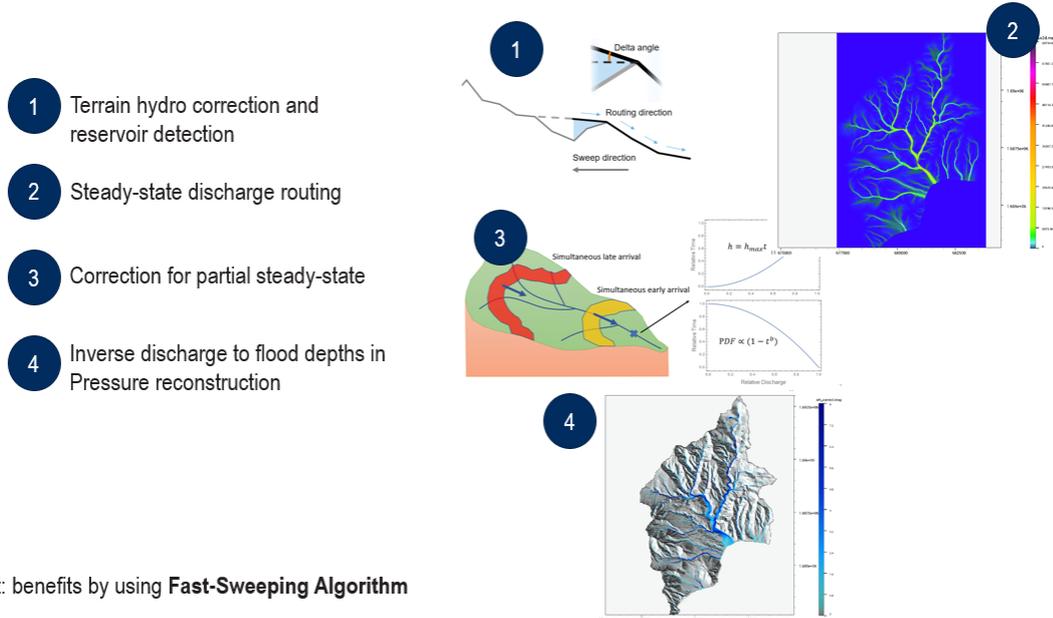


Figure 1: Methodological flow chart presenting an overview of the Fastflood model



## Getting Started with Fastflood

In this section, we'll walk you through the basic setup and usage of Fastflood command line tool, helping you understand how to start simulations and customize input options. By the end of this section, you will be ready to use the tool for both simple and advanced scenarios.

### Downloading the command line tool

The Fastflood command line tool (CLT) can be downloaded from [www.fasthazard.com](http://www.fasthazard.com). Once you have downloaded the executable to the project folder, you can start your simulations right away. The command line tool is a standalone executable and does not require additional installation of libraries.

### Running the command line tool

To run the command line tool, open a command line terminal in the project folder and type the following command.

```
fastflood -help
```

This will show the starting window with version of the Fastflood CLT and the date of release. The help command also shows various input options for the tool and the number of threads available for processing. This window shows that the command line tool is correctly installed and is working.

```
FastFlood command line tool, version 0.1, Nov 26 2024
This software is a commercial property of FastHazard, the Netherlands
Do not share this software without explicit permission of its original owner

Number of threads: 11
Input options for FastFlood
version - Prints the version and compilation date
help - Prints the command line options
helpfull - Prints the command line options, and descriptions of all other parameters
sim - Tasks the app to actually run a simulation using the FastFlood method
designstorm - Auto-sets precipitation intensity from a design storm taken from FastFlood's global datasets
d_dem - Provide an area for which the elevation model is automatically obtained, will also determine the model domain (extent and resolution)
d_lu - Activates an automatic download of land use information, to be used in the flood simulation
luout - Write the lu class file to a geotiff file
channel - Activate 1D-2D coupled channel flow simulation.
```

Figure 2: Fastflood command line tool with the help argument showing various commands and their description.

Now let us go through some commands and arguments that are available in Fastflood command line tool.



## Fastflood commands

There are several commands and input options in the Fastflood CLT. You can see these commands and their arguments using the command `-help`. If you want a detailed description of these then you can use `-helpfull`. Table 1 shows some basic commands in the Fastflood command line tool and their description.

Command	Description
version	Prints the version of the tool
help	Prints the command-line options.
helpfull	Prints detailed descriptions of all parameters.
sim	Runs a flood simulation using the Fastflood method.
rain	Provide rainfall as a value or a GeoTIFF file
dem	Provide an elevation model as a GeoTIFF file.
man	Provide Manning's coefficient as a value or GeoTIFF file.
sm	Provide soil moisture data as a value or GeoTIFF file.

*Table 1: Some of the basic commands in the Fastflood commandline tool.*

## Modelling with Fastflood

In Fastflood you can model the region of your choice with your own datasets or by downloading the ready-to-use global datasets for the region directly through Fastflood. In Fastflood you can specify the bounding box for your region and can download the elevation model, Landuse data and even the design storm for the region. Let's explore how to download these datasets using Fastflood.

### Downloading Elevation data.

Currently Fastflood is hosting the Copernicus DEM, Netherlands National height model and US national elevation map. You can download Copernicus 20 m resolution DEM for an area using the following command. The coordinates can be either in latitude/longitude or Pseudo-Mercator coordinates. Since this global datasets uses the pseudo-mercator projection, the grid-



cell size is approximate and an actual estimate is made based on the location of the downloaded data. Depending on the average latitude of the model domain, the grid-cell size is corrected.

```
fastflood -key xxxxxxxxxxxxxxxx -d_dem cop30 20m minx miny maxx maxy -dout dem_20m.tif
```

The available digital elevation models and their corresponding resolution available in the model are shown in Table 2.

Elevation model	Argument	Resolutions
Copernicus	cop	20m/40m/80m/160m/300m/600m/1.2km
Netherlands National height model	NHA	5m
US national elevation map	usned	10m

Table 2: Available elevation models and their corresponding arguments.

The downloaded DEM can be further noise and hydro corrected using the dfnoise and dfhydro commands respectively. The noise correction uses a bilateral filter.

### Downloading Manning's N values

The frictional force applied by the terrain on the flowing water depends on the type of cover on the terrain. This micro-scale process is captured well by Mannings surface friction coefficient in combination with the Darcy-Weisbach friction law for the Saint-Venant equations. A Mannings coefficient of 0.01 scales the frictional force as it would be on a smooth surface (e.g. concrete, pavement, smooth bare surface). A value of 0.05 would be equivalent more to some types of cropland, while 0.15 would equate to dense forest with undergrowth. As the velocities are determined by the Mannings Coefficient, the discharge response of a catchment is similarly influenced. Typically, higher Mannings values result in lower discharge peaks. On the other hand, locally, water can stagnate and build up higher depths due to a larger surface resistance. You can download the Manning's N value for the modelling domain by using the -manout command. The Manning's N values are based on the Sentinel -2 based WorldCover data.

```
fastflood -key xxxxxxxxxxxxxxxx -dem dem_20m.tif -d_lu -manout Manning_20m.tif
```

Additionally, the landuse classes for the region can also be downloaded using the -lout command.

```
fastflood -key xxxxxxxxxxxxxxxx -dem dem_20m.tif -d_lu -lout landuse_20m.tif
```



## Download design storm

In Fastflood you can also set the precipitation intensity for a region based on 74 years of historic rainfall data from ERA5. For the design storm you can select the return period and the duration of the event in hours. Table 3 shows the arguments and the corresponding values that are available to download a design storm for a region. The design storm can be activated using the command `-designstorm`.

Argument	unit	options
Return period	Years	2,5,10,20,40,50,100,200,500,1000
Duration	Hours	3,6,12,24,48,72,120,240

Table 3: Arguments and corresponding options available for downloading the design storm for a region.

The following command simulates flood for a region with a design storm of 2-year return period and a duration of 120 hours.

```
fastflood -key xxxxxxxxxxxxxxxx -sim -dem dem_20m.tif -man manning.tif -designstorm 2 120 -dur 120 -whout Floodheight.tif
```

## Climate change scenarios

To model the changes in flooding under climate change scenarios you can use the argument `-climate`. You can specify the climate scenario you want to model, the time period you are interested in and the climate model ensemble statistic to consider. Fastflood uses the downscaled climate the NEX-GDDP-CMIP6 dataset by NASA, which has a total of 35 global climate models<sup>1</sup>. Table 4 shows the corresponding arguments and the options available as input to account for the climate change scenarios.

Argument	Type	options
Climate Scenario	String	ssp124, ssp245, ssp460, ssp585
Period	INT	2020,2030,2050,2080
Quantile	INT	15,50,85

Table 4: Arguments and corresponding options available for accounting for the climate change scenarios.

The following command will activate the climate argument which will account for the change in precipitation under different climate scenarios in the future. The code below simulates flood for a region in the period 2080 under the SSP5-8.5 scenario. It considers the 85<sup>th</sup> quantile of the climate ensemble.

```
fastflood -key xxxxxxxxxxxxxxxx -sim -dem dem_20m.tif -man manning.tif -designstorm 2 120 -dur 120 -climate ssp585 2080 85 -whout FloodheightSSP585.tif
```

<sup>1</sup> <https://registry.opendata.aws/nex-gddp-cmip6/>



### Output options

We have seen different options available to modify the flood simulation in the Fastflood, now let us look at different output options available. Fastflood currently outputs only the peak values of flood parameters for every pixel in the modeling region. The Fastflood dynamic model is still in testing. The output flood parameters include maximum flood heights, peak velocity and peak discharge.

Argument	Description	Unit
whout	Provides an output for Maximum Water Height	m
qout	Provides an output for Peak Discharge	m <sup>3</sup> /s
vout	Provides an output for peak velocity	m/s



## Hands on example

Now that we have gone through some basic commands for input, output and downloading global datasets, let us know see how we can run the model using

1. The global datasets in Fastfloods
2. Your own datasets

### **Flood modeling using global datasets.**

Select the region you want to model and determine the bounding box for the region. Make sure that the entire catchment or sub catchment is included to account for all the water flow. Keep in mind that the larger the model domain, the longer simulation will take. Once you have the bounding box coordinates we can start downloading the elevation model, Manning's N and design storm for the region. For this tutorial we will model floods in Nairobi.

1. Downloading elevation model: For this exercise let us download a 20 m resolution Copernicus DEM. This can be downloaded using the following command.

```
fastflood -key xxxxxxxxxxxxxxxx -d_dem cop30 20m 36.4 -4.11 40.14 -0.84 -dout dem_20m.tif
```

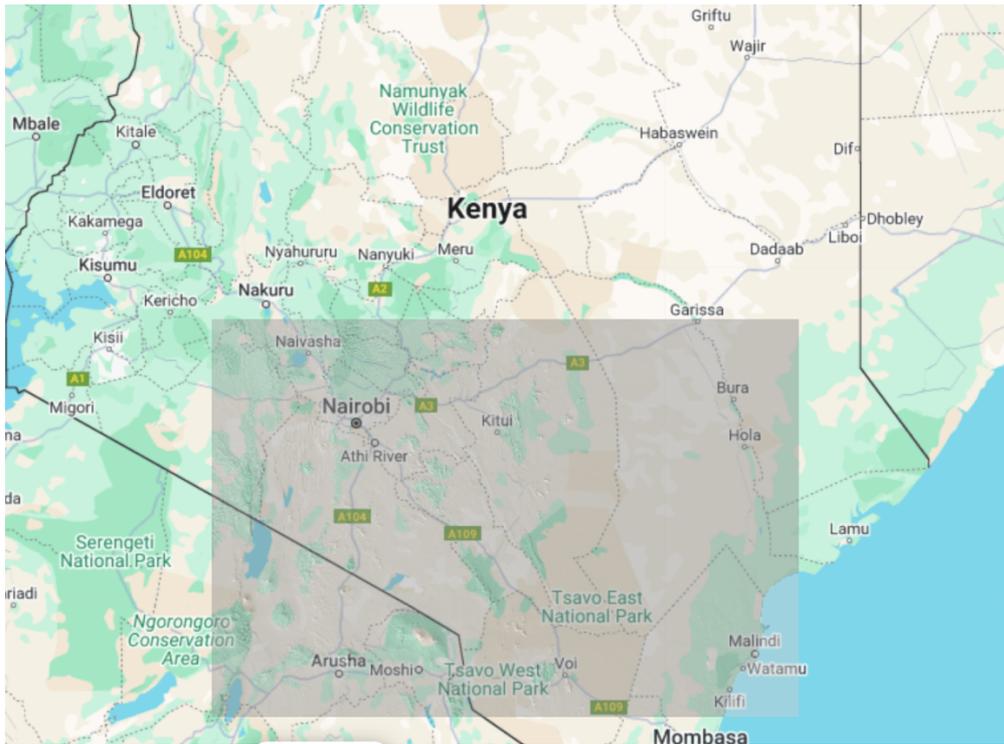


Figure 3: Model domain selected for the tutorial.

The DEM file 'dem\_20m' will be downloaded to your project folder.

2. Now we can proceed to download the Mannings N value for the model domain. This can be done using the following command. Figure 4 shows the Manning's n value downloaded for the model domain.

```
fastflood -key xxxxxxxxxxxxxxxx -dem dem_20m.tif -d_lu -manout Manning_20m.tif
```

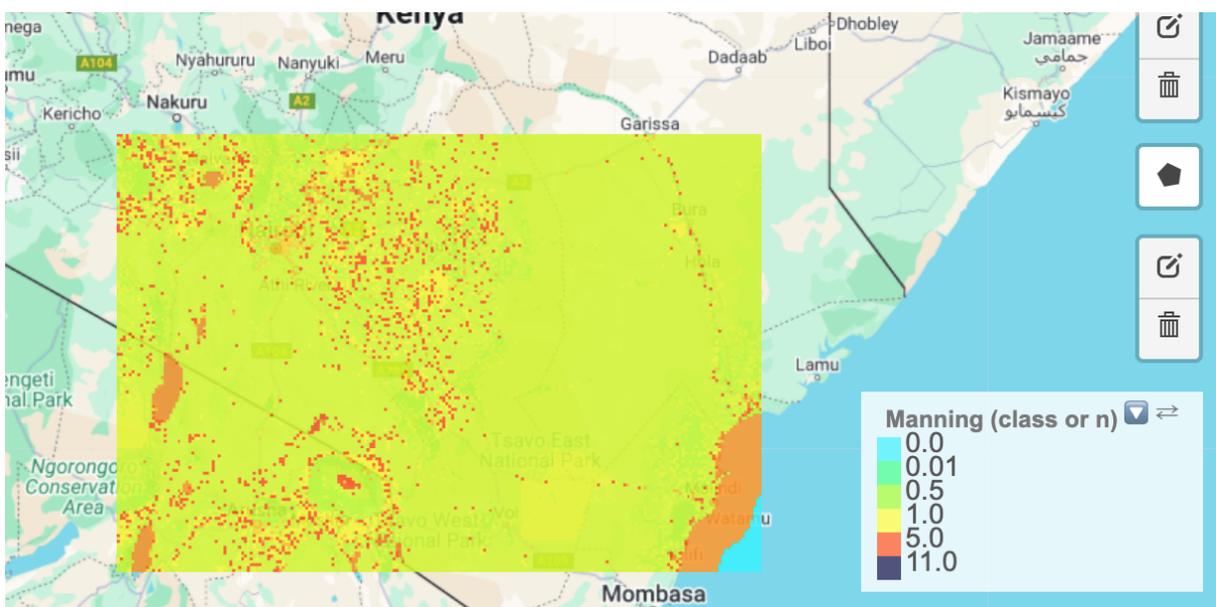


Figure 4: Manning's n value downloaded for the model domain.



3. We can simulate a simple rainfall- fed flooding using the downloaded data in the previous steps and the design storm for the region. It should be noted that the rainfall can be given as a fixed intensity value or a spatial intensity map in .tif format. The command below simulates the flood corresponding to a 20- year return period rainfall for a duration of 120 hours.

```
fastflood -key xxxxxxxxxxxxxxxx -sim -dem dem_20m.tif -man Manning_20m.tif -designstorm 20 120 -dur 120 -whout Flood_height.tif
```

This will give an output file ‘Flood\_height.tif’ with the peak flood heights for each pixel in the model domain. Figure 5 shows the flood map that was created with the above command. Additionally, you can generate peak discharge and peak velocity using the ‘qout’ and ‘vout’ commands respectively.

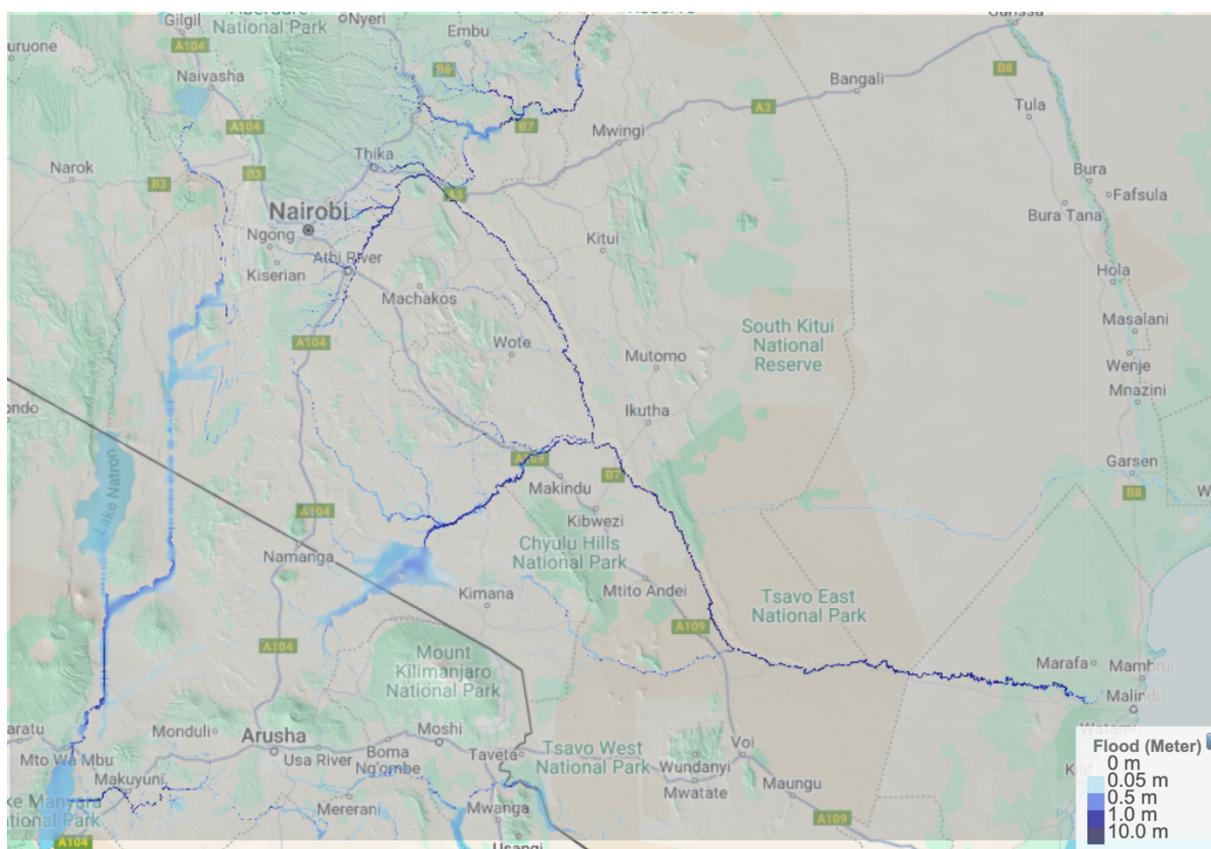


Figure 5: Flood map with flood heights in meters generated.

### **Flood modeling using you own data.**

If you are having higher resolution data for the region you are modelling you can use these datasets directly to model the floods. For example some regions might have Lidar data with a higher resolution (1~5 m), in these cases when higher resolution data is available it is better to use this data to model the region with a greater detail. The table shows example datasets and



how they can be used to model the floods. You can substitute these data names with your file names for the corresponding data to use your own data to model for a region.

Data	Description
my_dem.tif	High resolution DEM for your study area
my_man.tif	Mannings n for the study area
my_inf.tif	Infiltration for the study area
my_rain.tif	Rainfall intensity for the event.

Table 5: Datasets for flood modelling.

The flood can be modeled using the following command for an event duration of 120 hours.

```
fastflood -key xxxxxxxxxxxxxxxx -sim -dem my_dem.tif -man my_man.tif -inf my_inf.tif -rain my_rain.tif -dur 120 -whout Flood_height.tif
```

To get the peak velocities and peak discharges along with maximum flood heights the following command can be used.

```
fastflood -key xxxxxxxxxxxxxxxx -sim -dem my_dem.tif -man my_man.tif -inf my_inf.tif -rain my_rain.tif -dur 120 -whout Flood_height.tif -qout max_discharge.tif -vout peak_velocity.tif
```

### Calibrating the model

The flood model can be fine-tuned and calibrated for the modeling domain by using multipliers for parameters such as Manning's N, infiltration and channel dimensions. These multipliers can be added in the command using the argument 'mult\_' along with the parameter you want to change. For instance the following code uses a multiplier of two for the infiltration, 1.2 for manning's n

```
fastflood -key xxxxxxxxxxxxxxxx -sim -dem my_dem.tif -mult_man 1.2 -man my_man.tif -mult_inf 2.0 -inf my_inf.tif -rain my_rain.tif -dur 120 - whout Flood_height.tif -qout max_discharge.tif -vout peak_velocity.tif
```



All the commands available in Fastflood command line tool and the arguments for these commands are given in the Annexure.



## Annexure

Command	Number of Arguments	Description
version	0	Prints the version and compilation date
help	0	Prints the command line options
helpfull	0	Prints the command line options and descriptions of all parameters
sim	0	Runs a simulation using the Fastflood method
designstorm	2	Sets precipitation intensity using a design storm from Fastflood's global datasets (Return period: INT, Duration: DOUBLE)
d_dem	6	Downloads elevation model for a specified area (Dataset: STRING, Resolution: STRING, ULX: DOUBLE, ULY: DOUBLE, BRX: DOUBLE, BRY: DOUBLE)
d_lu	0	Downloads land use information for flood simulation
luout	1	Writes land use class file to a GeoTIFF file (Output: STRING)
channel	5	Activates 1D-2D coupled channel flow simulation (Width scaling: DOUBLE, Width exponent: DOUBLE, Depth scaling: DOUBLE, Depth exponent: DOUBLE, Min area: DOUBLE)
key	1	API access token (Token: STRING)
use_key_cache	0	Uses cached API access token
token	1	API data access token (Token: STRING)
refine	2	Runs refinement model (High-res DEM: STRING, Low-res water height: STRING)
dynamic	3	Activates dynamic simulation (Duration: DOUBLE, Output moments: DOUBLE, Refinement threshold: DOUBLE)
dyn_nocache	0	Disables super-cell caching
dyn_nosdt	0	Disables spatially dynamic timesteps
cores	1	Specifies CPU core count for the model (Core count: INT)
difc	1	Sets diffusivity coefficient (Coefficient: DOUBLE, Default = 0.001)
delta	1	Sets delta value for hydrocorrection (Delta: DOUBLE, Default = 0.001)
ddepr	0	Accounts for depressions in the elevation model
quality	1	Sets simulation quality level (Low: 1, Medium: 4, High: 7, Very High: 11)
dfhydro	0	Applies hydrocorrection filter on input elevation data
dfnoise	3	Applies noise correction filter (Radius: DOUBLE, Spatial strength: DOUBLE, General strength: DOUBLE)
dfdtm	2	Applies terrain model filter (Sensitivity: DOUBLE, Iterations: DOUBLE)
dem	1	Specifies elevation model as a GeoTIFF file (File path: STRING)
rain	1	Specifies rainfall as a value or GeoTIFF file (Value/File path: DOUBLE STRING)
man	1	Specifies Manning's n as a value or GeoTIFF file (Value/File path: DOUBLE STRING)



inf	1	Specifies infiltration as a value or GeoTIFF file (Value/File path: DOUBLE STRING)
sm	1	Specifies soil moisture as a value or GeoTIFF file (Value/File path: DOUBLE STRING)
mult_inf	1	Specifies infiltration multiplier (Multiplier: DOUBLE)
mult_rain	1	Specifies rainfall multiplier (Multiplier: DOUBLE)
mult_chan	1	Specifies channel dimension multiplier (Multiplier/File path: DOUBLE STRING)
qout_dyn	1	Specifies output filename for discharge timeseries (File path: STRING)
nochanwh	0	Excludes channel water height from output maps
whout	1	Specifies output filename for maximum water height (File path: STRING)
dout	1	Specifies output filename for elevation (File path: STRING)
qout	1	Specifies output filename for peak discharge (File path: STRING)
chwout	1	Specifies output filename for channel width (File path: STRING)
chhout	1	Specifies output filename for channel depth (File path: STRING)
vout	1	Specifies output filename for peak velocity (File path: STRING)
whinitial	1	Specifies initial water height (Height: DOUBLE)
ocean	1	Specifies ocean boundary condition height (Height: DOUBLE)
dur	1	Specifies event duration (Duration: DOUBLE)
qin	3	Specifies input discharge boundary condition (Discharge: DOUBLE, Latitude: DOUBLE, Longitude: DOUBLE)
barriers	1	Specifies barriers as GeoJSON file (File path: STRING)
channelshap es	1	Specifies channel shapes as GeoJSON file (File path: STRING)
adaptation	1	Specifies adaptation polygons or polylines (File path: STRING)
bcond	1	Specifies boundary condition points (File path: STRING)