



Localization of water resources management technology to adapt to climate change in the Hong-Thai Binh River basin

Activity 5.1: Development of the technical manual for use of the selected technologies
Request ID# AF-2021000099

Technical Manual



October 2023

Prepared for UNFCCC Climate Technology Centre and Network, CTCN, as part of the Adaptation Fund Climate Innovation Accelerator Programme



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Prepared for: UNFCCC Climate Technology Centre and Network, CTCN, as part of the
Adaptation Fund Climate Innovation Accelerator Programme
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Project No.: 11826891
Revision: Final 1.0
Classification: Open
File name: Act5_1_TechnicalReferenceManual_ENG

Technical Manual

The North Division of the National Center for Water Resources Planning and Investigation (NVWATER), National Center for Water Resources Planning and Investigation (NAWAPI), received technical assistance by the United Nations Climate Technology Centre Network (CTCN), implemented by DHI, to select and customize technology that can provide science-based information on transboundary flows in the Hong-Thai Binh River basin in Viet Nam. This technical manual is a restricted access document intended for the government officials using the delivered technology: a seasonal forecasting system for transboundary inflow estimation in the Hong-Thai Binh River basin. An exemplary in Vietnamese is also available.

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Acronyms and Abbreviations

CEWAFO	Centre for Water Resources Planning and Investigation
CFS	Climate Forecast System
CTCN	Climate Technology Centre Network
DB	Database
DEM	Digital Elevation Model
DFS0	Data File System
DFS2	2D Data File System
DHI-GHM	DHI's Global Hydrological Model
EO	Earth Observation
ERA5	fifth generation ECMWF reanalysis for the global climate and weather
ESP	Extended Streamflow Prediction
FTP	File Transfer Protocol
GFS	Global Forecast System
GIS	Geographical Information System
HTML	HyperText Markup Language
LAV	Level-Area-Volume
MHB	MIKE HYDRO Basin

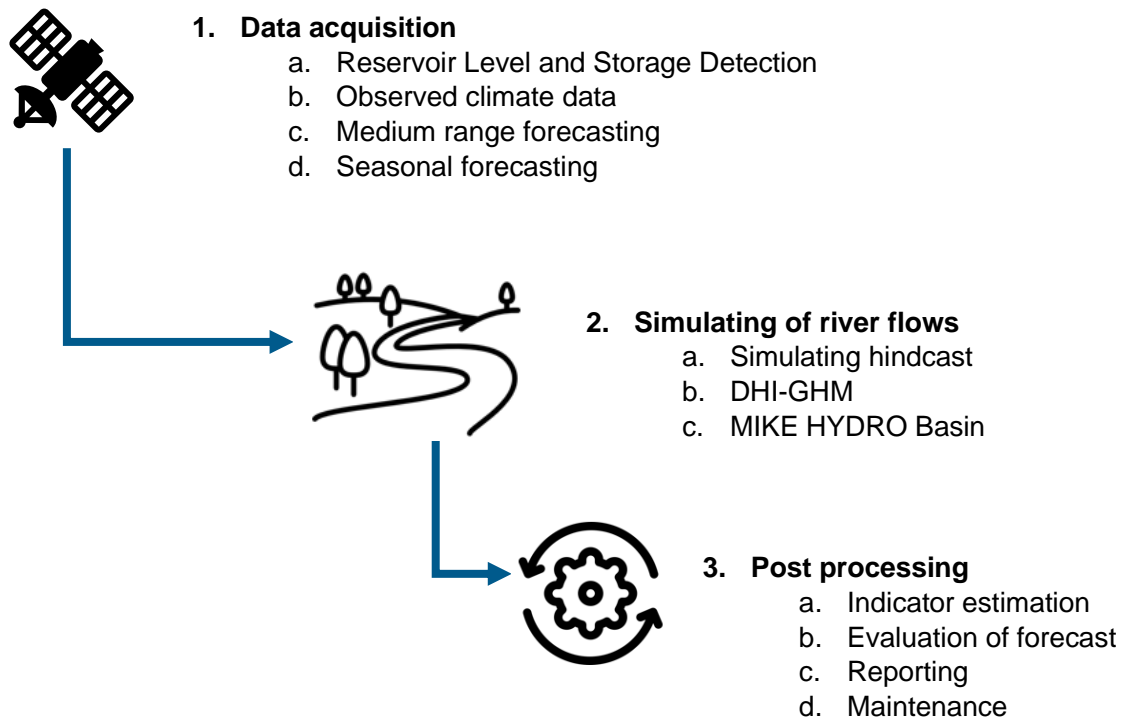
MHB	MIKE H
MW	MIKE Workbench
NAWAPI	National Center for Water Resources Planning and Investigation
NetCDF	Network Common Data Form
NOAA	National Oceanic and Atmospheric Administration
NTFS	New Technology File System
NVWATER	North Division for Water Resources Planning and Investigation
PET	MIKE HYDRO Basin
PFAF ID	Pfafstetter Coding System for Watershed Identification
RAM	Random Access Memory
TOF	Time of forecast
URL	Uniform Resource Locator

1 Introduction

This report describes the **Seasonal forecasting system** (referred as “the system”) that has been developed based on the technology selection made during the technical assistance. The system is described as deployed at CEWAFO.

The Technical reference manual is divided into 3 main chapters:

- **System Components:** lists the main components that compose the System and how they have been configured
- **System Operation:** details the operational workflow that has been set up in the system.



2 System Components

This chapter is divided into several sections:

- **Installation Requirements:** requirement in terms of hardware and software for deploying the system
- **Software:** list of software to be installed on the server to ensure the system is functioning
- **Executables:** list of executable files part of the system that have been deployed in addition to the installed software
- **Installation steps:** details the steps to follow for installing the System using software and executables
- **System Architecture:** location and structure of the files part of the system as deployed in CEWAFO's server
- **Data acquisition:** input data and data pre-processing
- **Modelling Framework:** description of the modelling tools part of the system
- **Postprocessing:**
- **System Performance:** reporting, error logging and database base management procedures
- **Setup operational system:** setup of the jobs that have been configured

This chapter can be consulted to understand how the system has been configured or for example if the system had to be re-deployed on a different server.

2.1 System Requirements

Most recommended minimum system requirements are derived from the MIKE products used. They are, according to MIKE by DHI documentation:

Table 2.1 Recommended minimum system requirements

Component	Requirement
Fully supported operating systems *	Windows 7 Professional, Service Pack 1 (64 bit) Windows 10 Pro, version 1803 (64 bit) Windows Server 2012 R2 Standard (64 bit) Windows Server 2016 Standard (64 bit).
Processor	x64, 2.2 GHz (or higher)
Memory (RAM)	2 GB (or higher)
Hard disk	40 GB (or higher)
Additional disk space	20GB (or higher)
Monitor	SVGA, resolution 1024x768 in 16 bit color
Graphics adapter	64 MB RAM (256 MB RAM or higher recommended), 32 bit true color
File system	NTFS
Software requirements	Microsoft .NET Framework 4.7.2 or later

2.2 Software

By default, all programs are installed on the C:\ drive. Table 2.2 highlights the programs installed. The folder structure delivered is a fundamental part of the operations and should not be altered.

Table 2.2 Location of all installed programs

Component	Component location
PostgreSQL version 10	C:\Program Files\PostgreSQL\10
DHI MIKE Operations 2019	C:\Program Files (x86)\DHI\2019\MIKE OPERATIONS
DHI MIKE Zero 2019 Update 1	C:\Program Files (x86)\DHI\2019\MIKE Zero

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Additionally, Python is required to be installed with the following packages, sourced from PyPI:

- Pandas
- numpy
- mikeio

2.3 Executables

Executables with their dependencies and thus without need of installation are provided by DHI as described in Table 2.3. Their location is given as relative path to “WorkDir”, which is explained in section 2.4.5.

Table 2.3 Executables delivered

Executable	Location	Description
Global Hydro Runner.exe	..\Tools\GlobalHydroRunner_MIKE2022	NAM executable for the DHI-GHM
FastKinRouter.exe	..\Tools\FastKinRouter	Routing executable for the DHI-GHM

2.4 Installation steps

The following steps should be followed to install the system on a server following requirements mentioned in section 2.1 and software mentioned in section 2.2 are installed.

2.4.1 Install MIKE Software

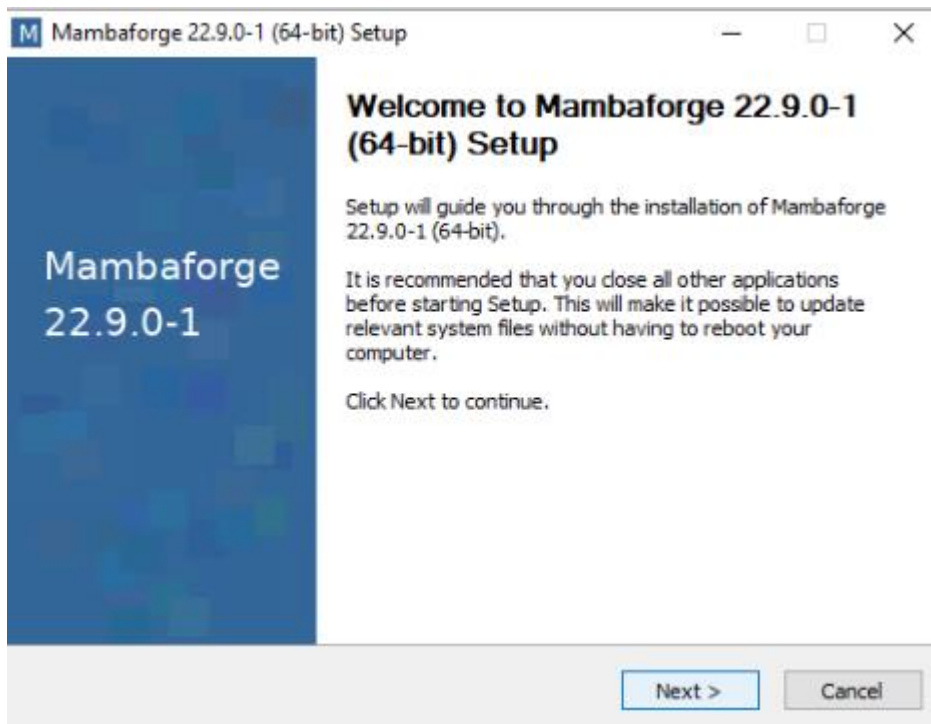
- Install MIKE Operations: Follow guide in pdf
- Install MIKE Zero

2.4.2 Install MicroMamba

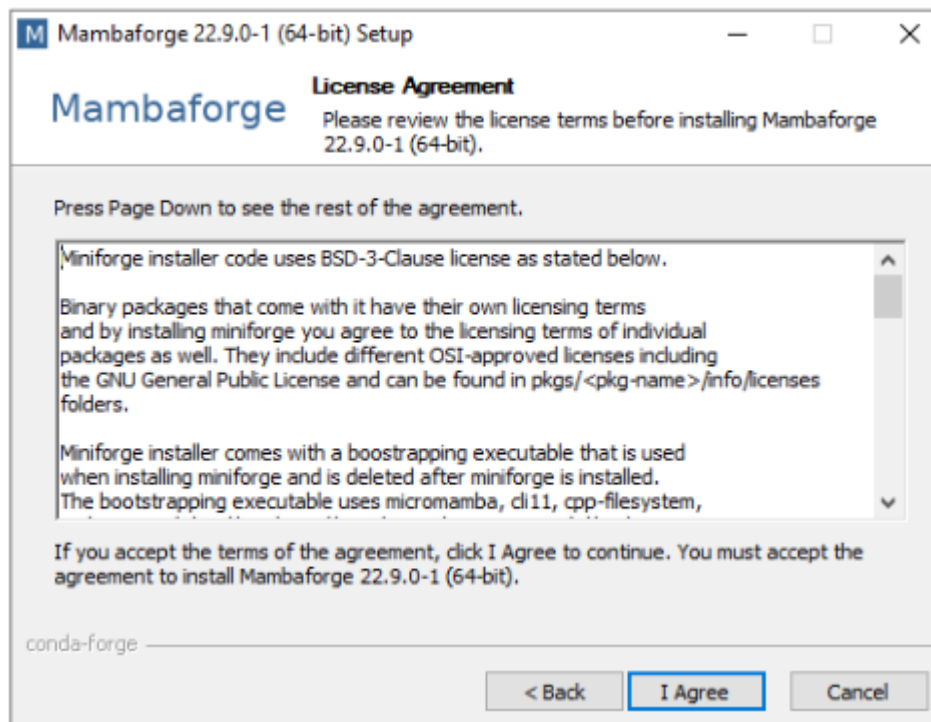
Make a temporary copy of the folder Software\03 MicroMamba on the C: drive if WorkDir is not part of C: drive beforehand. The temporary folder copy can be deleted after successful execution of 2.4.2.1.

Run “Mambaforge-Windows-x86_64.exe” in Software\03 MicroMamba to install mambaforge on the system.

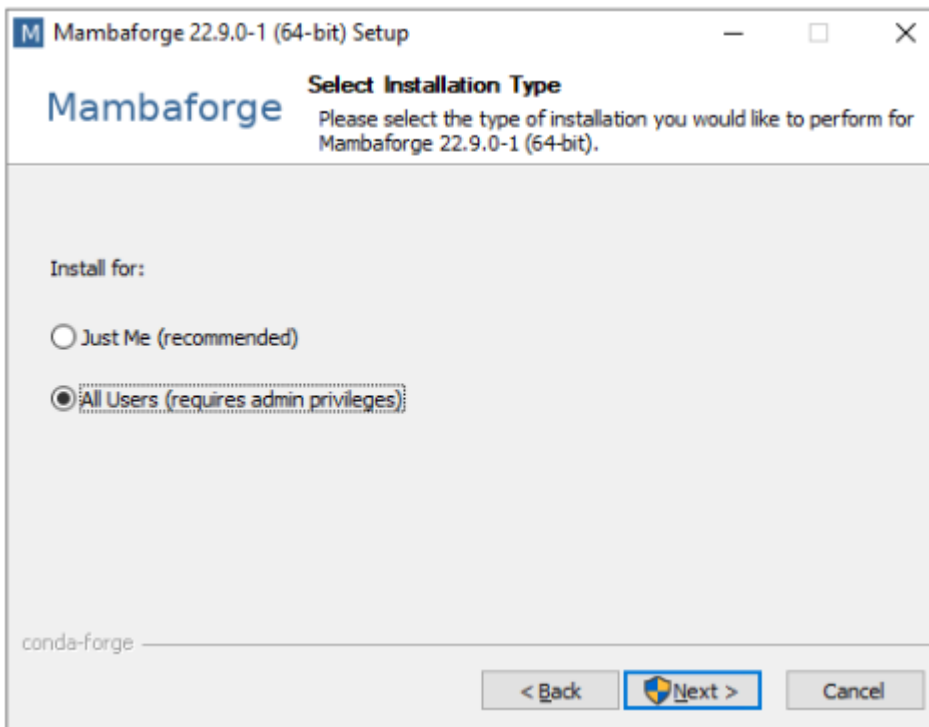
Name	Date modified	Type	Size
environment.yml	3/9/2023 8:00 AM	YML File	1 KB
Mambaforge-Windows-x86_64.exe	11/2/2022 10:36 AM	Application	67,137 KB
SetupEnvironment.bat	3/9/2023 3:25 PM	Windows Batch File	1 KB



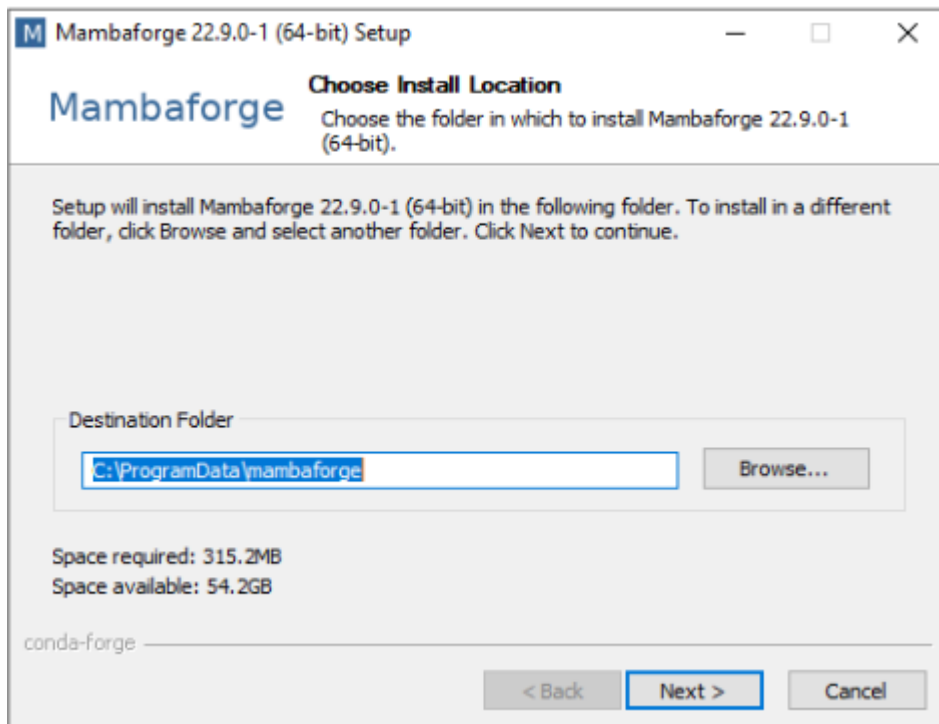
Click "Next".



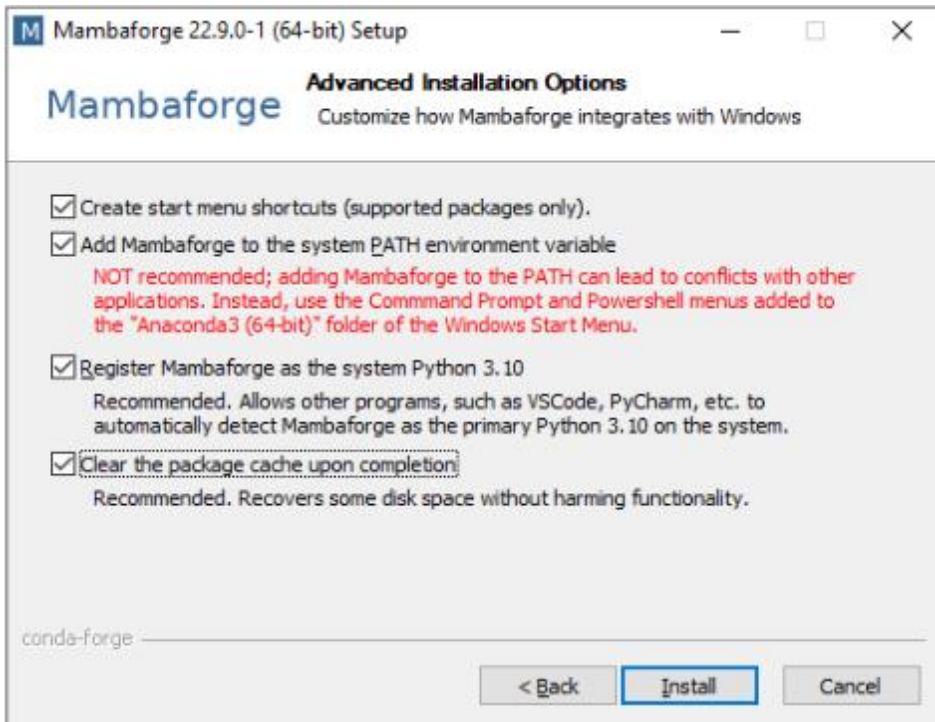
Click "I Agree"



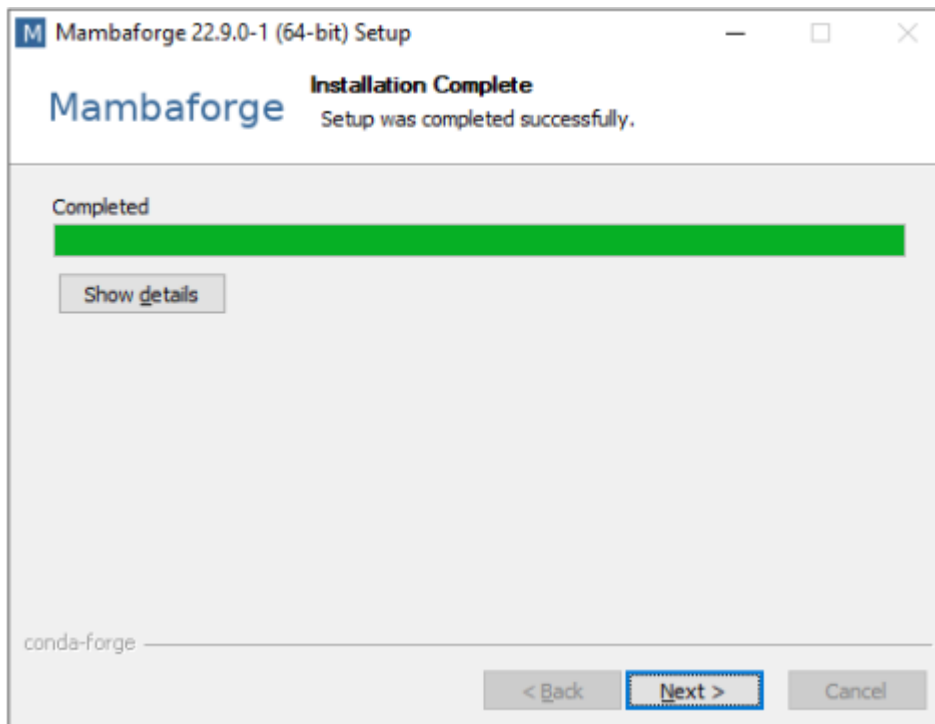
Select "All Users". Click "Next".



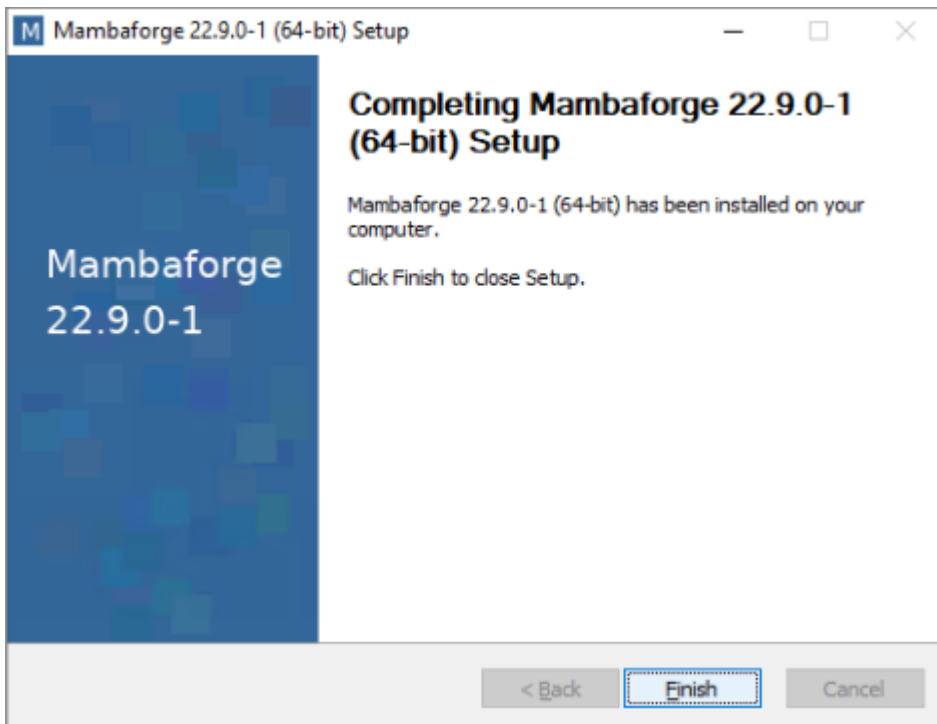
Select the folder to install the software. If there is no reason, keep default. Click "Next".



Check all boxes and click "Install".



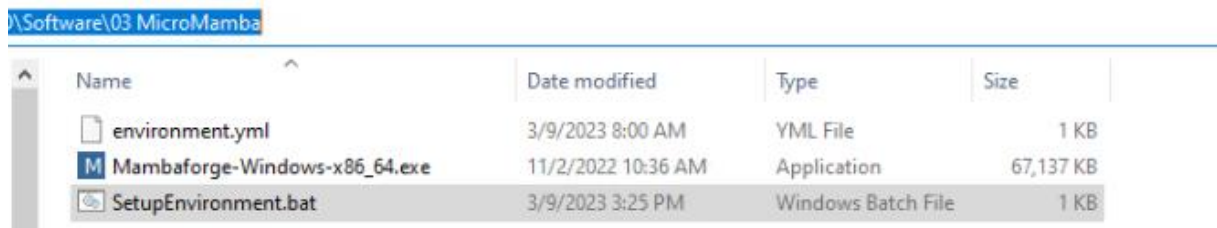
Click "Next".



Click “Finish”.

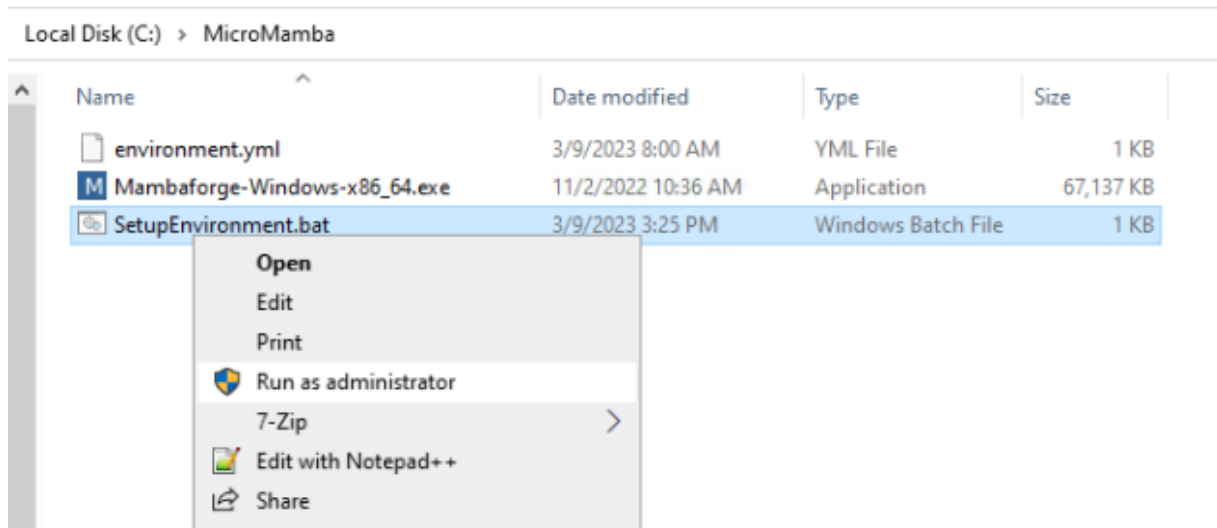
Restart the machine.

2.4.2.1 Set up the “base” environment



Run the batch file SetupEnvironment.bat in Software\03 MicroMamba as administrator to add libraries in the base environment. A command prompt will open to install the packages.

Run the Batch file by right click -> Run as administrator.



Close the command shell, when it looks similar to:

```

C:\Windows\System32\cmd.exe
Collecting PyYAML
  Using cached PyYAML-6.0-cp310-cp310-win_amd64.whl (151 kB)
Collecting xarray
  Downloading xarray-2023.2.0-py3-none-any.whl (975 kB)
----- 975.8/975.8 kB 31.1 MB/s eta 0:00:00
Requirement already satisfied: numpy>=1.15.0 in c:\programdata\mambaforge\lib\site-packages (from mikeio==1.2.4->-r C:\)
Requirement already satisfied: pytz>=2020.1 in c:\programdata\mambaforge\lib\site-packages (from pandas>1.3->mikeio==1.)
Requirement already satisfied: python-dateutil>=2.8.1 in c:\programdata\mambaforge\lib\site-packages (from pandas>1.3->)
Requirement already satisfied: colorama in c:\programdata\mambaforge\lib\site-packages (from tqdm->mikeio==1.2.4->-r C:\)
Collecting packaging>=21.3
  Downloading packaging-23.0-py3-none-any.whl (42 kB)
----- 42.7/42.7 kB ? eta 0:00:00
Requirement already satisfied: six>=1.5 in c:\programdata\mambaforge\lib\site-packages (from python-dateutil>=2.8.1->pa)
Installing collected packages: scipy, PyYAML, packaging, mikecore, xarray, mikeio
Successfully installed PyYAML-6.0 mikecore-0.2.1 mikeio-1.2.4 packaging-23.0 scipy-1.10.1 xarray-2023.2.0

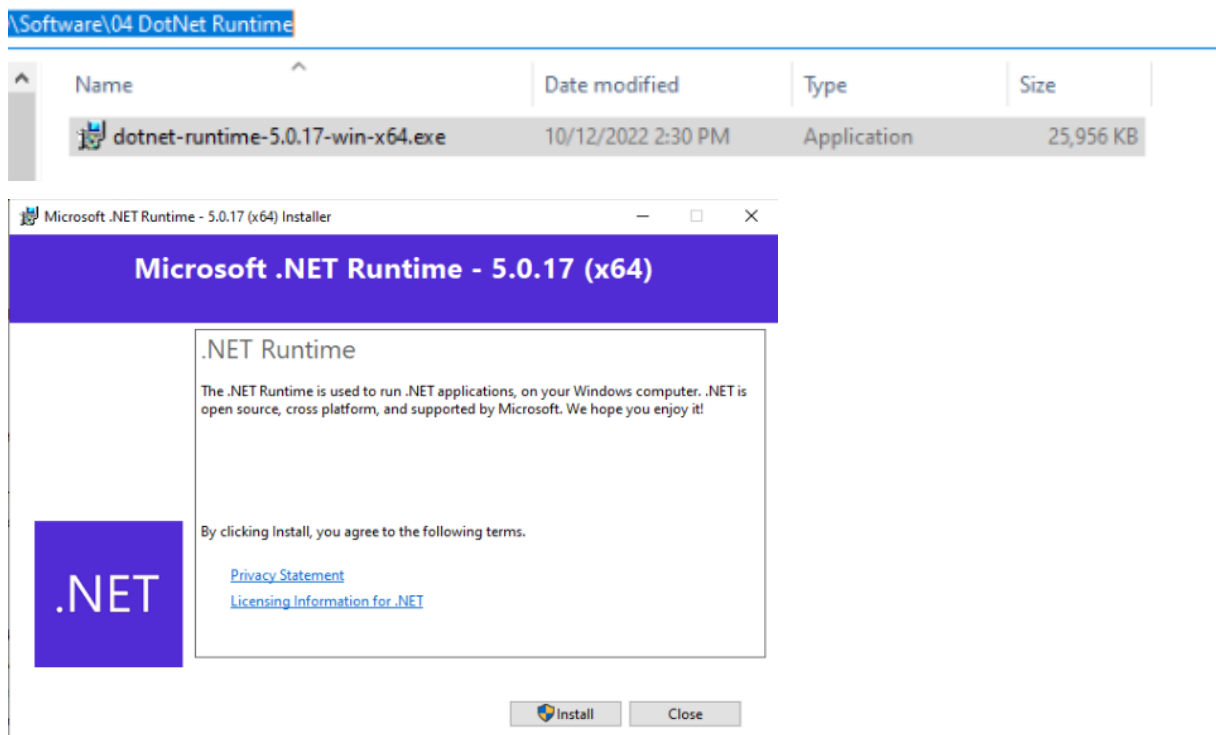
done
#
# To activate this environment, use
#
#   $ conda activate base
#
# To deactivate an active environment, use
#
#   $ conda deactivate

Retrieving notices: ...working... done
C:\MicroMamba>pause
Press any key to continue . . .
  
```

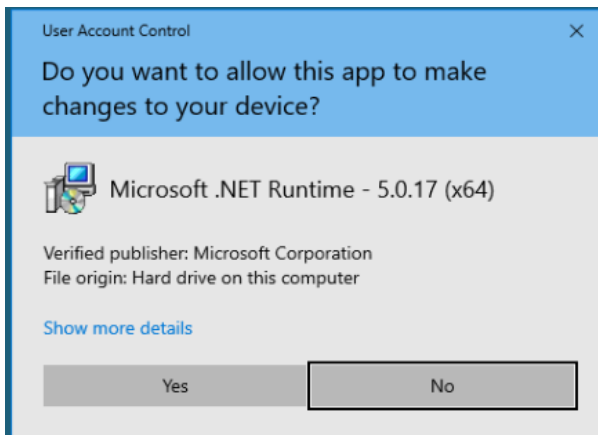
If 2.4.2 required a temporary copy of the Software\03 MicroMamba folder, this can now be removed.

2.4.3 Install DotNet

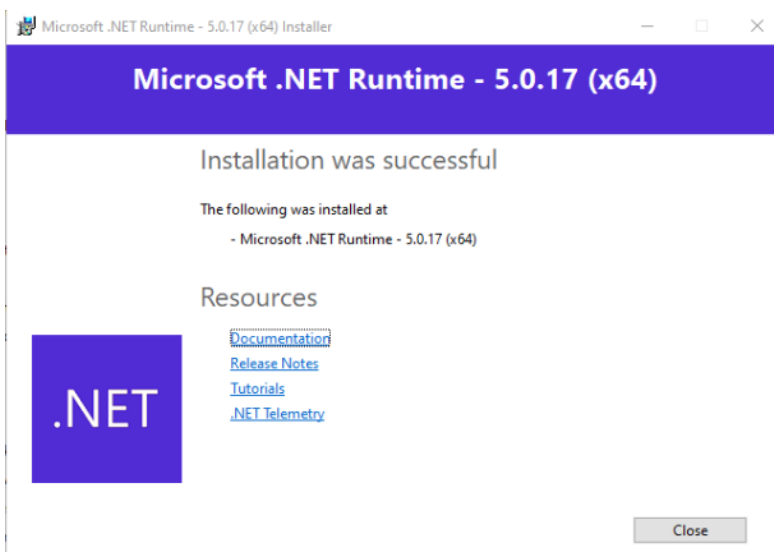
Run “dotnet-runtime-5.0.17-win-x64.exe” in Software\04 DotNet Runtime to install dotnet 5.0.



Click “Install”.



Click “Yes”.



Click “Close”.

2.4.4 Restore database

Restore the database **20231027_CEWAF0.backup** provided by DHI using the Database Manager Utility as described in DHI MIKE Operations help.

2.4.5 Setup DHI-GHM – Define Working Directory

The new WorkingDirectory throughout the whole document is set to be the folder “Configuration” in the created folder.

For example: C:\DHI_GHM\Configuration

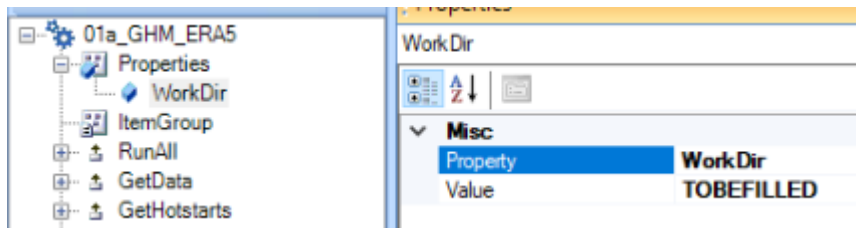
It is called **WorkDir** or “**working directory**” in the following.

2.4.5.1 Database

The working directory of a job needs to be set for the following jobs:

- 01a_GHM_ERA5
- 01b_GHM_GFS
- 01c_GHM_CFS
- 05_MakeDailyReport

The working directory should be set to the same directory as above. To change the working directory, open the job and change the Value under Properties > WorkDir. Replace TOBEFILLED with the working directory.



2.4.5.2 Initial Batch files

These steps will set up the DHI-GHM model. For detailed description of the folder structure see section 2.5.1.

1. Unzip the zipFile **DHI_GHM.zip**, provided by DHI to the location wanted. The containing drive should have a free capacity of at least 20GB.
2. In the folder `..\Batch`, relative to WorkDir, run the batch file **00_GetAllData.bat**. This will take a couple of minutes. Wait, until the batch file has been finished. DHI-GHM data has now been downloaded.

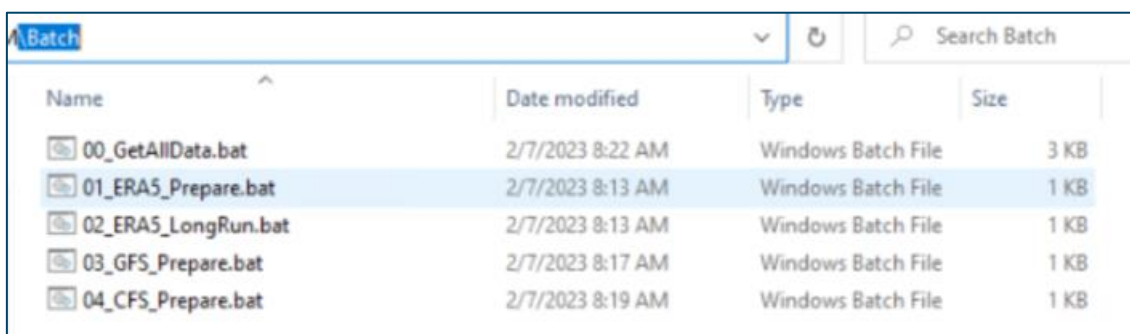


Figure 2.1 Folder with batch files for setting up the System

3. In the folder `..\Batch`, relative to WorkDir, run the batch file **01_ERA5_Prepare.bat**. This will build the hindcast models and simulate the first 3 years as warm up period. This will take a couple of minutes. Wait, until the batch file has been finished.

The warm up hotstarts can be stored by making a copy of the following folders. They will be overwritten in the next step:

- `"..\Hotstart\ERA5\NAM\latest"`
- `"..\Hotstart\ERA5\Routing\latest"`

4. In the folder `..\Batch`, relative to WorkDir, run the batch file **02_ERA5_LongRun.bat**. This will simulate the hindcast long-run from 1997 till now. This will take some time. Wait, until the batch file has been finished.

The long-run hotstart files can be stored by making a copy of the following folders. They will be overwritten by the next hindcast simulation:

- `"..\Hotstart\ERA5\NAM\latest"`
- `"..\Hotstart\ERA5\Routing\latest"`

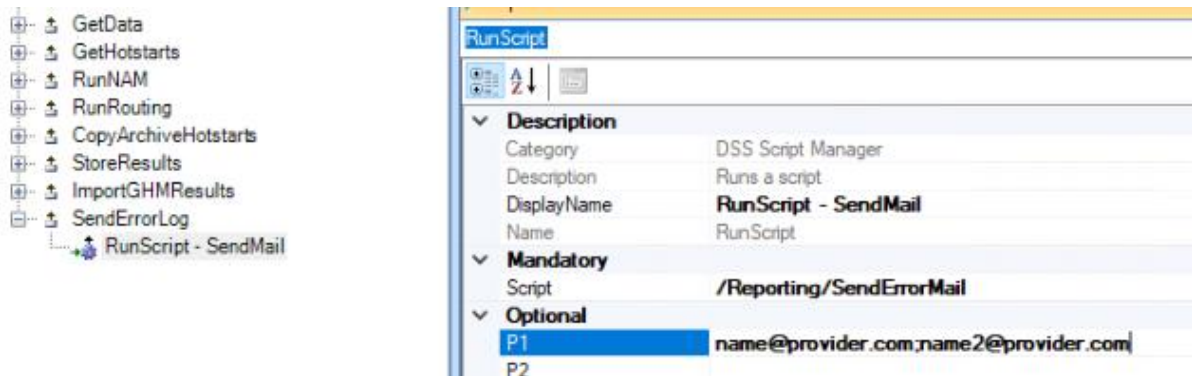
5. In the folder `..\Batch`, relative to WorkDir, run the batch file **03_GFS_Prepare.bat**. This will build the model files for the medium range forecast. This will take some minutes. Wait, until the batch file has been finished.
6. In the folder `..\Batch`, relative to WorkDir, run the batch file **04_CFS_Prepare.bat**. This will build the model files for the seasonal forecast. This will take some minutes. Wait, until the batch file has been finished.

2.4.6 Database – Email Services

If a job is failing, when running it with “RunAll”, see section 3.2.1, an email is sent. Emails can be many, delimited by “;”. The email address must be changed in the following jobs:

- 01a_GHM_ERA5
- 01b_GHM_GFS
- 01c_GHM_CFS
- 02a_MHB_GFS
- 02b_MHB_CFS
- 03_Maintenance
- 04_DatabaseBackup
- 05_MakeDailyReport

To change the email address, open a job and change the entry under “SendErrorLog” > “RunScript – SendMail” for P1.



Please follow sections 3.5.1 and 3.5.2 to set up email services.

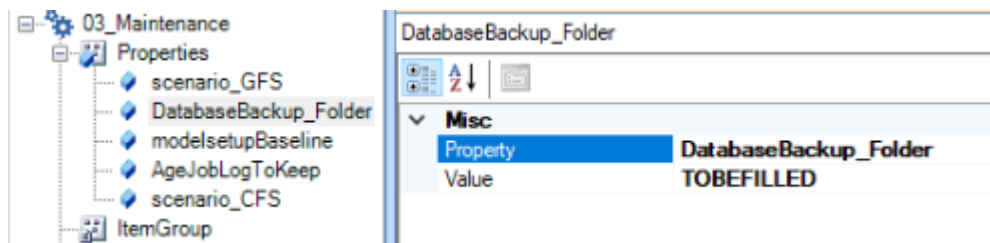
2.4.7 Maintenance

These steps are required to set up the automatic maintenance (backup) of the database.

In the jobs

- 03_Maintenance
- 04_DatabaseBackup

change the Value under Properties > DatabaseBackup_Folder to the folder, where database backups may be written. Both jobs should receive the same value.



Open the batch file **backup.bat**, delivered by DHI with a text editor. Update the first 9 rows using Table 2.4. Save the batch file and import it following section 2.4.8, using the parameters:

- Group = /Maintenance/DatabaseBackup
- Name = backup.bat

```

backup.bat
1 @echo off
2 set backupfolder=D:\H_TB\Backup
3 if "%1" NEQ "" SET backupfolder=%1
4 SET db=H_TB_CTCN
5 if "%2" NEQ "" SET db=%2
6 SET user=postgres
7 if "%3" NEQ "" SET user=%3
8 SET PGPASSWORD=postgres
9 if "%4" NEQ "" SET PGPASSWORD=%4
10 set psql=C:\Program Files\PostgreSQL\10\bin\pg_dump.exe

```

Figure 2.2 Preview of the backup batch file

Open the batch file **vacuum.bat**, delivered by DHI with a text editor. Update the first 10 rows using Table 2.4. Save the batch file and import it following section 2.4.8, using the parameters:

- Group = /Maintenance/Vacuum
- Name = vacuum.bat

```

vacuum.bat
1 SET db=H_TB_CTCN
2 if "%1" NEQ "" SET db=%1
3 SET host=localhost
4 if "%2" NEQ "" SET host=%2
5 SET user=postgres
6 if "%3" NEQ "" SET user=%3
7 SET PGPASSWORD=postgres
8 if "%4" NEQ "" SET PGPASSWORD=%4
9 SET port=5432
10 if "%5" NEQ "" SET port=%5
11 echo %host%

```

Figure 2.3 Preview of the vacuum batch file

Table 2.4 Parameter for the database management – batch files.

Parameter	Description
Backupfolder	Directory path to store the backups in. (can be sent through job by setting DatabaseBackup_Folder)
Psql	Path to pg_dump.exe in the PostgreSQL. MO 2019 uses PostgreSQL 10.
Db	Database name to backup
PGPASSWORD	Postgres password.
Host	Hostname of the postgres database

2.4.8 Import a batch file to MIKE Workbench

This step has to be done for the batch-files **backup.bat** and **vacuum.bat**, which have to be modified, saved and reimported into the database in section 2.4.6.

In MIKE Workbench, open the “Document Manager”.

In the tools Explorer, select the tool Import > Import Document.

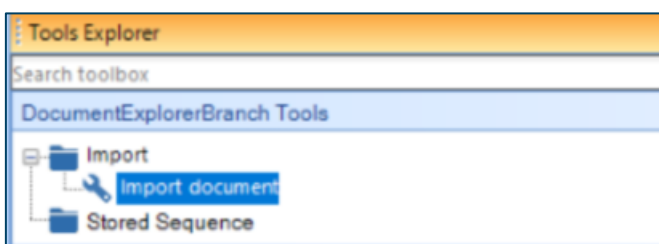


Figure 2.4 Import document tool

Click on in url and navigate to the batch file.

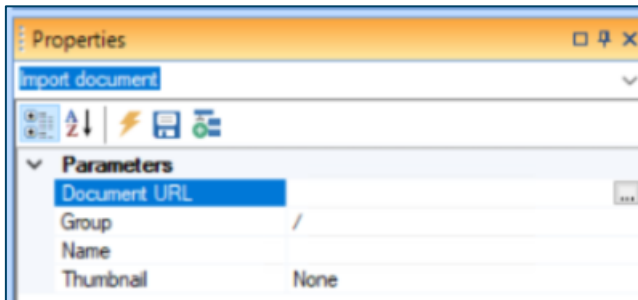


Figure 2.5 Properties (empty) of the import document tool

Add the Group URL and make sure, the name of the imported document is correct.

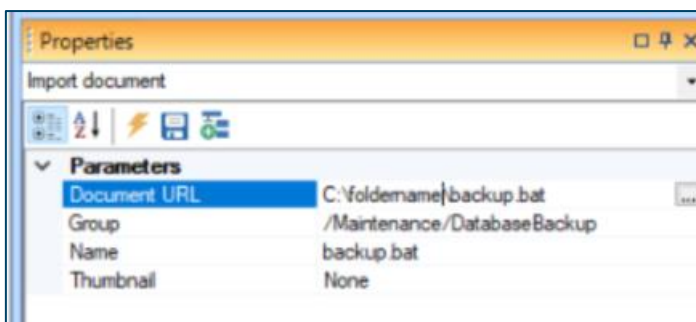


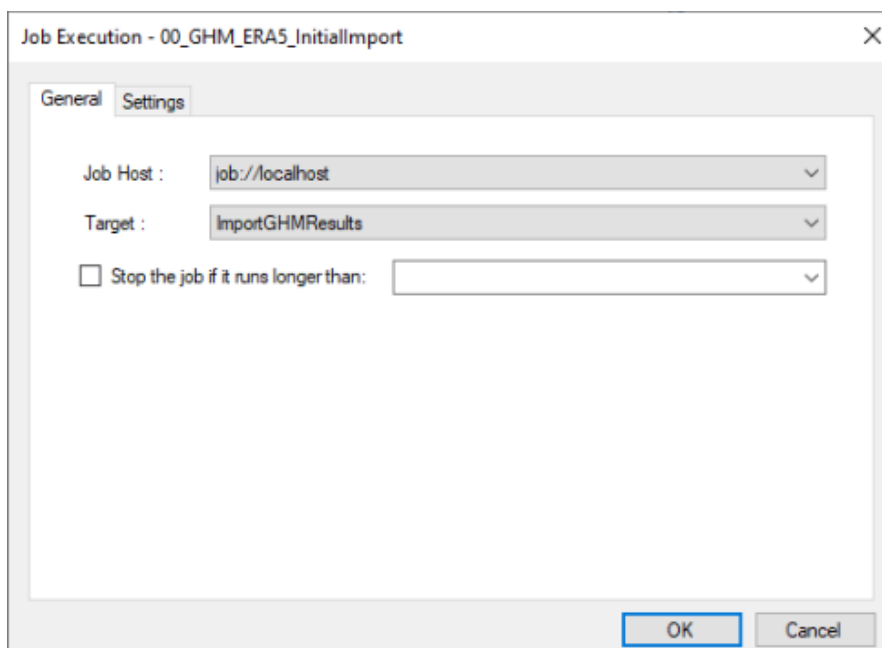
Figure 2.6 Properties (filled) of the import document tool

Click on to execute the tool. The batch file is now imported into the database.

2.4.9 Setup Workbench Simulations

2.4.9.1 Initial Import

In MIKE Workbench, right click on the Job “00_GHM_InitialImport” and click on “Execute”. Run the target “ImportGHMResults” by clicking “OK”.

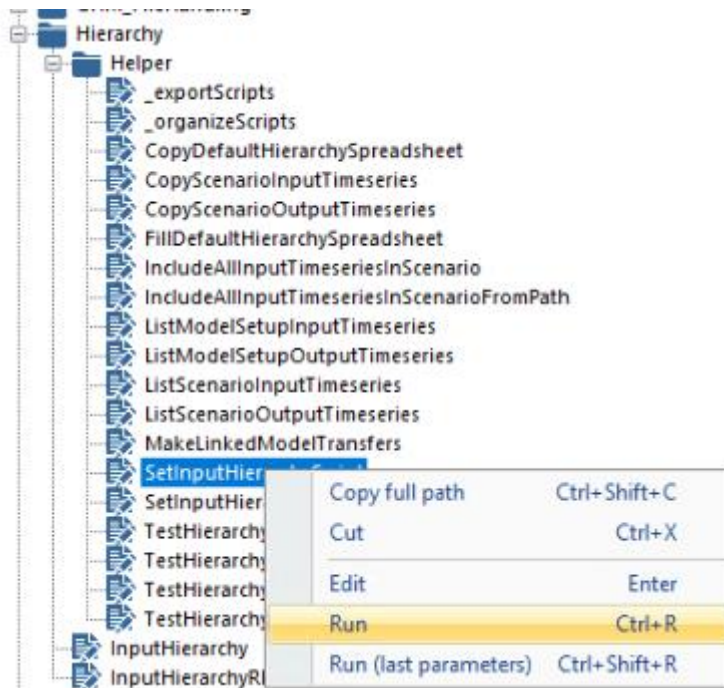


Wait for the job to be finished.

2.4.9.2 Set Hierarchy script as input timeseries

The Hierarchy can be used to modify input timeseries. Instead for the MHB input timeseries to direct to a timeseries, the input can be a script, which generates the input timeseries on the fly and runs a model on them. To do so, the script needs to be set as value for the timeseries definition. The CEWAFO database contains a modified version of the script, which will set the needed timeseries definitions to the script “/Hierarchy/InputHierarchy”.

In the script manager, right click on the script “/Hierarchy/Helper/SetInputHierarchyScript” and click “Run”.



The script needs to be run with the following settings:

Setting 1:

Parameter	Value
Scenario	/Group of Upper_Hong_Thai_binh/Upper_Hong_Thai_binh/Upper_Hong_Thai_binh_With_DA/GFS Upper_Hong_Thai_binh_With_DA
script	/Hierarchy/InputHierarchy

Setting 2:

Parameter	Value
Scenario	/Group of Upper_Hong_Thai_binh/Upper_Hong_Thai_binh/Upper_Hong_Thai_binh_With_DA/CFS Upper_Hong_Thai_binh_With_DA
script	/Hierarchy/InputHierarchy

Setting 3:

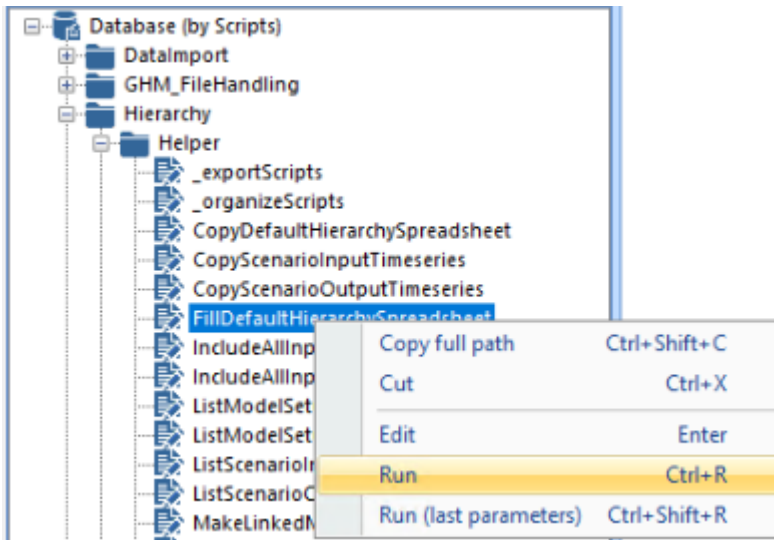
Parameter	Value
Scenario	/Group of Upper_Hong_Thai_binh/Upper_Hong_Thai_binh/Upper_Hong_Thai_binh_No_DA/GFS Upper_Hong_Thai_binh_No_DA
script	/Hierarchy/InputHierarchy

Setting 4:

Parameter	Value
Scenario	/Group of Upper_Hong_Thai_binh/Upper_Hong_Thai_binh/Upper_Hong_Thai_binh_No_DA/CFS Upper_Hong_Thai_binh_No_DA
script	/Hierarchy/InputHierarchy

2.4.9.3 Create the Hierarchy spreadsheet

In the script manager, right click on the script “/Hierarchy/Helper/FillDefaultHierarchySpreadsheet” and click “Run”.



The script needs to be run with the following settings:

Setting 1:

Parameter	Value
Scenario	/Group of Upper_Hong_Thai_binh/Upper_Hong_Thai_binh_With_DA/GFS Upper_Hong_Thai_binh_With_DA
Tsfolder1	/Upper_Hong_Thai_binh/ERA5
Tsfolder2	/Upper_Hong_Thai_binh/GFS
Tsfolder3	/Upper_Hong_Thai_binh/CFS

Setting 2:

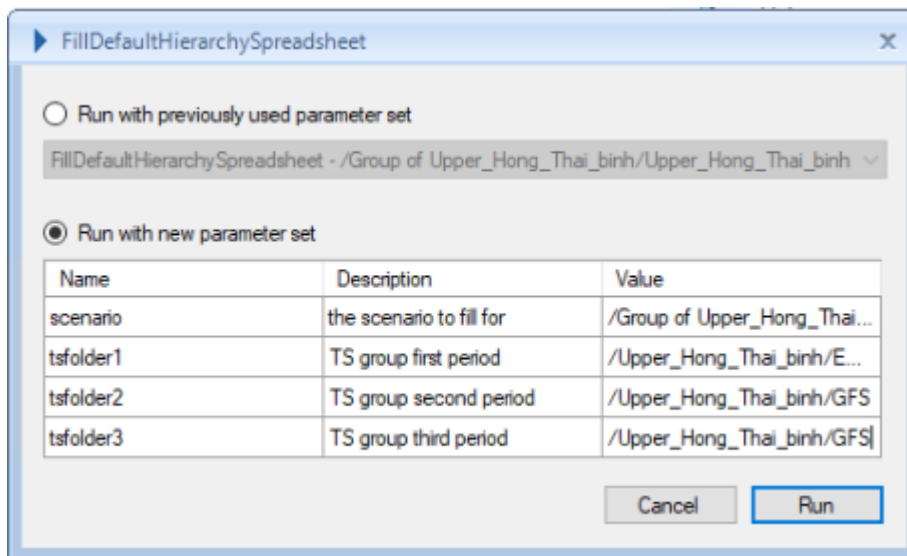
Parameter	Value
Scenario	/Group of Upper_Hong_Thai_binh/Upper_Hong_Thai_binh_With_DA/CFS Upper_Hong_Thai_binh_With_DA
Tsfolder1	/Upper_Hong_Thai_binh/ERA5
Tsfolder2	/Upper_Hong_Thai_binh/GFS
Tsfolder3	/Upper_Hong_Thai_binh/GFS

Setting 3:

Parameter	Value
Scenario	/Group of Upper_Hong_Thai_binh/Upper_Hong_Thai_binh_No_DA/GFS Upper_Hong_Thai_binh_No_DA
Tsfolder1	/Upper_Hong_Thai_binh/ERA5
Tsfolder2	/Upper_Hong_Thai_binh/GFS
Tsfolder3	/Upper_Hong_Thai_binh/CFS

Setting 4:

Parameter	Value
Scenario	/Group of Upper_Hong_Thai_binh/Upper_Hong_Thai_binh_No_DA/CFS Upper_Hong_Thai_binh_No_DA
Tsfolder1	/Upper_Hong_Thai_binh/ERA5
Tsfolder2	/Upper_Hong_Thai_binh/GFS
Tsfolder3	/Upper_Hong_Thai_binh/GFS



Click "Run".

Make sure, a spreadsheet has been created at "/Hierarchy/Upper_Hong_Thai_binh_With_DA", with two sheets

- CFS Upper_Hong_Thai_binh_With_DA
- GFS Upper_Hong_Thai_binh_With_DA

And at "/Hierarchy/Upper_Hong_Thai_binh_No_DA", with two sheets

- CFS Upper_Hong_Thai_binh_No_DA
- GFS Upper_Hong_Thai_binh_No_DA

They should look similar as:

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Realtime:	TRUE											
2	Parent scenario:												
3	Name	ModelSetu AdapterRe	Functions...										
4	Discharge_	/Models an a6bbf283-2	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Discharge_TS_Catchment_C1;TOF;EOS							
5	Discharge_	/Models an 3372053e-4	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Discharge_TS_Catchment_C11;TOF;EOS							
6	Discharge_	/Models an 51547e59-4	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Discharge_TS_Catchment_C12;TOF;EOS							
7	Discharge_	/Models an 19116c21-7	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Discharge_TS_Catchment_C14;TOF;EOS							
8	Discharge_	/Models an e014a581-5	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Discharge_TS_Catchment_C16;TOF;EOS							
9	Discharge_	/Models an ed2f849e-3	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Discharge_TS_Catchment_C17;TOF;EOS							
10	Discharge_	/Models an 698133db-4	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Discharge_TS_Catchment_C18;TOF;EOS							
11	Discharge_	/Models an cfc81ec-0	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Discharge_TS_Catchment_C20;TOF;EOS							
12	Discharge_	/Models an 199513b2-7	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Discharge_TS_Catchment_C21;TOF;EOS							
13	Discharge_	/Models an ec0b0cb0-4	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Discharge_TS_Catchment_C22;TOF;EOS							
14	Discharge_	/Models an 4a972424-4	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Discharge_TS_Catchment_C24;TOF;EOS							
15	Discharge_	/Models an 435e1200-4	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Discharge_TS_Catchment_C26;TOF;EOS							
16	Discharge_	/Models an abbd1155-4	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Discharge_TS_Catchment_C6;TOF;EOS							
17	Discharge_	/Models an 61181f92-a	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Discharge_TS_Catchment_C7;TOF;EOS							
18	Runoff_TS	/Models an fee2c9cf-f2	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Runoff_TS_Catchment_C10;TOF;EOS							
19	Runoff_TS	/Models an 3e262559-4	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Runoff_TS_Catchment_C13;TOF;EOS							
20	Runoff_TS	/Models an 61249055-4	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Runoff_TS_Catchment_C15;TOF;EOS							
21	Runoff_TS	/Models an 49760988-4	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Runoff_TS_Catchment_C19;TOF;EOS							
22	Runoff_TS	/Models an 44a9d1b6-4	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Runoff_TS_Catchment_C2;TOF;EOS							
23	Runoff_TS	/Models an 77736533-3	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Runoff_TS_Catchment_C23;TOF;EOS							
24	Runoff_TS	/Models an 6f37be1b-2	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Runoff_TS_Catchment_C25;TOF;EOS							
25	Runoff_TS	/Models an 06661097-4	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Runoff_TS_Catchment_C27;TOF;EOS							
26	Runoff_TS	/Models an 8992c352-5	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Runoff_TS_Catchment_C28;TOF;EOS							
27	Runoff_TS	/Models an 7a269d8c-2	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Runoff_TS_Catchment_C29;TOF;EOS							
28	Runoff_TS	/Models an 15d7e957-7	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Runoff_TS_Catchment_C3;TOF;EOS							
29	Runoff_TS	/Models an c3a0a70f-1	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Runoff_TS_Catchment_C30;TOF;EOS							
30	Runoff_TS	/Models an d2c3bc55-4	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Runoff_TS_Catchment_C31;TOF;EOS							
31	Runoff_TS	/Models an 993d6f36-f	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Runoff_TS_Catchment_C32;TOF;EOS							
32	Runoff_TS	/Models an 43812b9b-4	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Runoff_TS_Catchment_C4;TOF;EOS							
33	Runoff_TS	/Models an a91faac4-e	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Runoff_TS_Catchment_C5;TOF;EOS							
34	Runoff_TS	/Models an 2865dfe6-a	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Runoff_TS_Catchment_C8;TOF;EOS							
35	Runoff_TS	/Models an f8d33133-3	Raw;/Upp	XRaw;/Upp	XRaw;/Upper	Hong_Thai_binh/CFS/Runoff_TS_Catchment_C9;TOF;EOS							
36													
37													

2.4.9.4 Test other jobs

Execute the following jobs to make sure, all jobs are set up and working:

- 02a_MHB_GFS
- 02b_MHB_CFS
- 03_Maintenance
- 04_DatabaseBackup
- 05_MakeDailyReport

Follow section 2.9.2 to create job schedules, if the system shall run operationally.

2.5 System Architecture

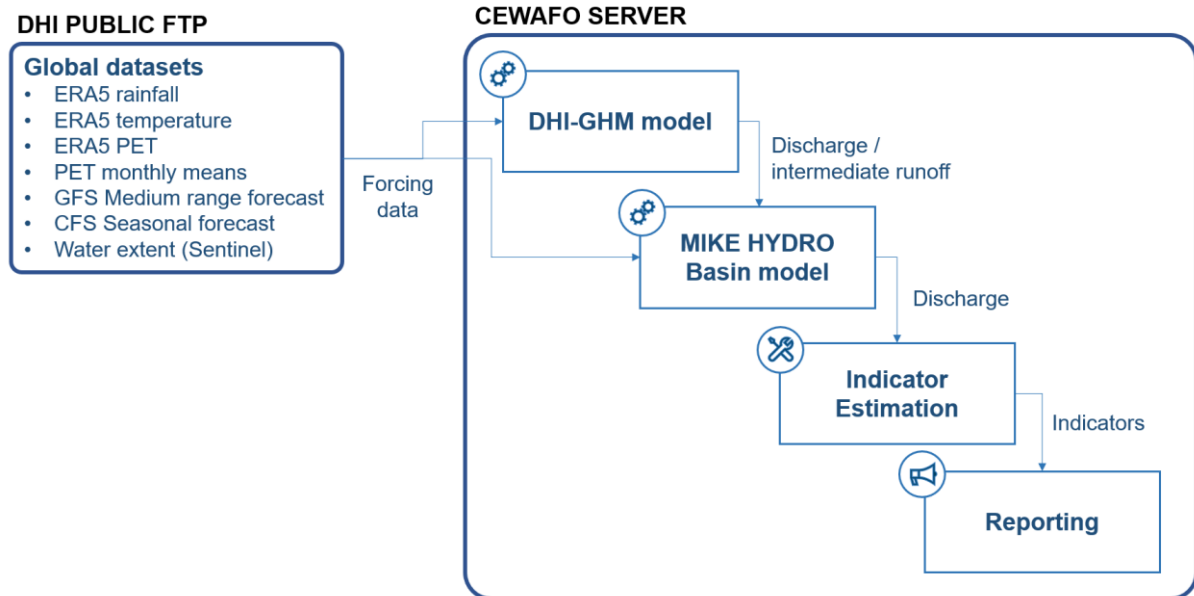


Figure 2.7 Diagram of the System architecture with link between CEWAFO server and DHI FTP server

2.5.1 DHI-GHM folder architecture

The chapter describes the folder structure of the DHI-GHM model. The example is based on ERA5 DHI-GHM simulations, but other setups would have similar structures.

The System is setup on the virtual machine with the following hierarchy of folders on the parent folder for “WorkDir”, which was introduced in section 2.4.5. The content of this folder is depicted in Figure 2.8 and should **not** be modified.

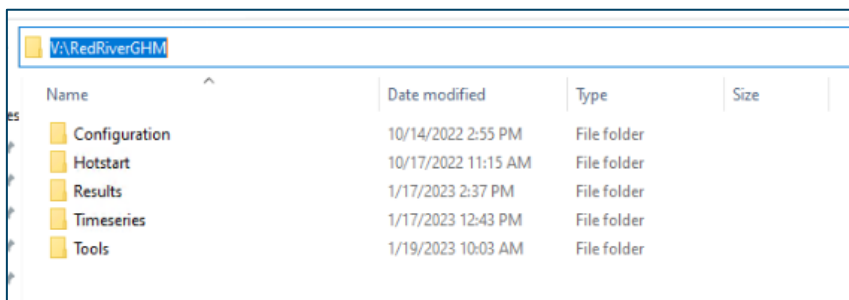


Figure 2.8 Main data folders for the DHI-GHM component

The content of the main data folders for the DHI-GHM component is described in Table 2.5 and more details are given in the following sections.

Table 2.5 Folder structure for the DHI-GHM setup, relative to the working directory used in MIKE Workbench and the DHI-GHM setup

Folder Name	Description
-------------	-------------

..\Configuration\Batch	Contains batch file for the preparation and setup of the DHI-GHM.
..\Configuration	Main folder for Configuration of the DHI-GHM
..\Configuration\ERA5	Example of a DHI-GHM simulation setup. See further details in section 0.
..\Configuration\setup_nam	Setup files for the NAM execution, including: <ul style="list-style-type: none"> - Catchment definitions for each of the runs - Parameter definition, one for all runs
..\Configuration\setup_routing	Setup files for the Routing execution, including: <ul style="list-style-type: none"> - Basin definition - Cell weights - Reference to QObs timeseries - Routing groups
..\Hotstart	Hotstart files for each of the DHI-GHM runs: <ul style="list-style-type: none"> - CFS, received from the GFS run - ERA5, latest hotstarts, including archived - GFS, received from the ERA5 run and latest hotstarts, including archive
..\Results	Main folder of the DHI-GHM Results
..\Results\Catchment_DFS0	Postprocessed DHI-GHM result for each of the DHI-GHM simulations (CFS, ERA5 and GFS) with the subfolders <ul style="list-style-type: none"> - Routed_discharge_to_outlet - Unrouted_runoff_to_outlet
..\Results\HTML	HTML input for reporting
..\Timeseries	Collection of all relevant timeseries inputs for the DHI-GHM simulations (CFS, ERA5 and GFS)
..\Tools\AzCopy	AzCopy executable
..\Tools\FastKinRouter	FastKinRouter executable
..\Tools\GlobalHydroRunner_MIKE2022	GlobalHydroRunner executable
..\Tools\py	Supporting python scripts and their helping setup files

2.5.1.1 Configuration

A configuration and model folder contains configuration files (.conf), which is read by the executables described in Table 2.3 during execution and contains run configurations for the models. The folder furthermore contains a model file (.sim11) and a rainfall-runoff-parameter file (.rr11). While the latter can be regarded as the catchment parameter template file the model file is used when building the hydrological component and saved as MIKE 1D-engine model files (.m1dx). The model files for DHI-GHM's routing component are stored in binary ".fkrx" format. Finally, log files are created during execution of DHI's NAM module. Details of each file is given in Table 2.6.

Each .conf file has various versions:

- Prepare: this is used for the initial prepare run as a warmup period. Here, the model files are built and the model is run for a small number of years as warmup

- Standard version (NAM.conf, Routing.conf): configuration files for the Operational system.

Name	Date modified	Type	Size
NAM.conf	1/19/2023 10:08 AM	CONF File	1 KB
NAM_Prepare.conf	10/12/2022 12:42 PM	CONF File	1 KB
Routing.conf	1/18/2023 9:17 AM	CONF File	1 KB
436-436.Fkrx	12/7/2022 9:05 AM	FKRX File	207 KB
GHM_340.m1dx	1/30/2023 11:30 AM	M1DX File	97,969 KB
default.rr11	9/13/2022 3:27 PM	MIKE Zero RR Parameters	12 KB
GHM.sim11	10/11/2022 11:49 AM	MIKE Zero Simulation	3 KB
GHM.omi	10/11/2022 11:49 AM	OMI File	1 KB
GHM_340.log	12/7/2022 8:54 AM	Text Document	1 KB
GHM_340_diag.log	1/30/2023 11:30 AM	Text Document	1 KB
GHM_340-RRStat.txt	1/27/2023 11:33 AM	Text Document	6,735 KB

Figure 2.9 Preview of “..\Configuration\ERA5” folder

Table 2.6 NAM Configuration for the operational ERA5 simulation

Parameter name	Value	Description
m1dxRunFile	..\Configuration\ERA5\GHM.sim11	<p>Relative path to the sim11 file where specifications can be made:</p> <ul style="list-style-type: none"> - Input: path to the dummy “RR parameter” file - Simulation: “Time step type” with “Time step” and “Unit” - Results: “Filename” as path to result files ending with res11. Here, res1d files will be written. “Storing frequency” together with “Time step” from simulation is used to define the output timestep. <p>The sim11 is only read, when building the model m1dx files, see below.</p>
catchReferenceTable	..\Configuration\setup_nam\CatchDef_ERA5.csv	<p>Path to the catchment reference table, see 2.7.1.2.</p> <p>It is only read, when building updating the model m1dx files using “SkipM1dxConstruction=false” or “UpdateDfs2Boundaries=true”.</p>
ParReferenceTable	..\Configuration\setup_nam\ParDef.csv	<p>Path to the parameter definition file, see 2.7.1.1.</p> <p>It is only read, when updating the model m1dx files, using “UpdateParameters=true”.</p>
HotstartFilePath	..\Hotstart\ERA5\NAM\latest	Path to the folder, where hotstarts files (one for each m1dx-model file) are expected.
SimStart	1997,01,01,00,00,00	Simulation start.

Parameter name	Value	Description
		Can be overwritten by "RuntimeFromDfs2", "RunTimeFromHot" and "HotStartTimeOverwrite". Should be specify as Date format
SimEnd	2022,10,27,00,00,00	Simulation end. Overwritten by "RunTimeFromDfs2" Should be specify as Date format
HotStartTimeOverwrite		Overwrites hotstart time used in simulation else last time step in hotstart is used. Force simulation start. Only used, if "RunTimeFromHot=true". In this case, the latest values of the hotstart-file are used, but the time is adjusted. Should be specify as Date format
RuntimeFromDfs2	true	Simulation times are taken from the rainfall-timeseries files, if not overwritten by a combination of settings in "RunTimeFromHot", "HotStartTimeOverwrite"
RunTimeFromHot	true	Use runtime from Hotstart files. In this case, hotstart files need to be in place at "HotstartFilePath". Can be overwritten using "HotStartTimeOverwrite".
UpdateDfs2Boundaries	false	Update boundaries to use Dfs2
UpdateParameters	false	Update m1dx files with RR parameters from "ParReferenceTable"
SkipM1dxConstruction	true	If false, build m1dx files from scratch using "m1dxRunFile". In this case, it is suggested to set "UpdateDfs2Boundaries=true" and "UpdateParameters=true".
FilterOutput	true	Filter results from elevation zones.
HotExportFromSOSMin	-1	Time in minutes to extract hotstart, before simulation end. A value of "-1" indicates the last timestep.
IsEnsemble	false	Is configuration a model ensemble
WriteDfs2Result	0	Write results as dfs2, additionally. 0 for no, 1 for yes
WriteAddFile	false	Write NAM additional output to write commonly used model states. If false, Total Runoff is the only NAM output.

Table 2.7 Routing configuration for the operational ERA5 simulation

Parameter name	Value	Description
routingGroups	..\Configuration\ setup_routing\ routingGroups.c sv	Relative path to the routing groups definition file.
NAMResultFolder	..\Results\ERA5 \NAM\NAM	Relative location of the NAM results, with the beginning of the filename "NAM". What comes after "NAM" is used to identify the tile number.
RoutingResultFolder	..\Results\ERA5 \Routing	Relative path to the routing results directory.
modelFolder	..\Configuration\ ERA5	Relative path to the model setup directory.
RuntimeFromNAM	true	If true, take the model start and end dates from the NAM results files. If false, take the model start and end dates from SimStart and SimEnd.
SimStart	2001,01,01,00, 00,00	Date to start the simulation, only used if "RuntimeFromNAM = False".
SimEnd	2001,10,01,00, 00,00	Date to end the simulation, only used if "RuntimeFromNam = False".
Hotstart	true	If true, initialize the model using the hotstart file. If false, do not.
SkipFkrxConstruction	true	If true, do not build the fkrx binary files. If false, build the fkrx binary files.
TimestepRouting	10	Internal routing timestep (minutes). Value not to exceed 20.
HotExportFromSO SMin	-1	Indicate the timestep to create a hotstart file.
LakeEvaporation	true	If true, evaporation from lakes is considered in the model.
LakeEvapFactor	1	Scaling factor for lake evaporation.
RealTime	false	If true, operates in realtime mode.
IrrigationTs	..\Timeseries\irr igation\irrigation Tsm3_all.csv	Relative path to irrigation time series file.
saveInflow	true	If true, produce Inflow results file (labelled same as outflow for each catchment, with "_ Inflow" in filename).

2.5.1.2 Hotstart

The hotstart folder contains all the files used as hotstart by DHI-GHM model.

Hotstart\ERA5\NAM

Name	Date modified	Type	Size
latest	1/27/2023 11:33 AM	File folder	
20221010T000000.zip	10/17/2022 11:13 AM	Compressed (zipp...	804 KB
20221011T000000.zip	10/18/2022 3:01 AM	Compressed (zipp...	822 KB
20221012T000000.zip	10/19/2022 3:03 AM	Compressed (zipp...	810 KB
20221013T000000.zip	10/20/2022 3:01 AM	Compressed (zipp...	805 KB
20221014T000000.zip	10/21/2022 3:01 AM	Compressed (zipp...	804 KB
20221015T000000.zip	10/22/2022 3:01 AM	Compressed (zipp...	796 KB
20221016T000000.zip	10/23/2022 3:01 AM	Compressed (zipp...	787 KB
20221017T000000.zip	10/24/2022 3:01 AM	Compressed (zipp...	781 KB
20221018T000000.zip	10/25/2022 3:01 AM	Compressed (zipp...	781 KB
20221019T000000.zip	10/26/2022 11:11 AM	Compressed (zipp...	781 KB
20221020T000000.zip	10/27/2022 3:01 AM	Compressed (zipp...	796 KB
20221025T000000.zip	11/1/2022 3:01 AM	Compressed (zipp...	796 KB
20221026T000000.zip	11/2/2022 3:01 AM	Compressed (zipp...	794 KB
20221027T000000.zip	11/8/2022 10:48 AM	Compressed (zipp...	793 KB
20221120T000000.zip	11/28/2022 10:49 AM	Compressed (zipp...	807 KB
20221121T000000.zip	11/28/2022 11:31 AM	Compressed (zipp...	807 KB
20221122T000000.zip	11/29/2022 11:31 AM	Compressed (zipp...	802 KB

Figure 2.10 Preview of NAM hotstart folder with the latest hotstart and zipped archives

Hotstart\ERA5\NAM\latest

Name	Date modified	Type	Size
GHM_340.20230120T000000.sta1d	1/27/2023 11:33 AM	STA1D File	6,988 KB

Figure 2.11 Latest hotstart file of the NAM

Name	Date modified	Type	Size
latest	1/27/2023 11:33 AM	File folder	
20221017T111324.zip	10/17/2022 11:13 AM	Compressed (zipp...	24 KB
20221018T030111.zip	10/18/2022 3:01 AM	Compressed (zipp...	24 KB
20221019T030324.zip	10/19/2022 3:03 AM	Compressed (zipp...	24 KB
20221020T030111.zip	10/20/2022 3:01 AM	Compressed (zipp...	24 KB
20221021T030115.zip	10/21/2022 3:01 AM	Compressed (zipp...	24 KB
20221022T030117.zip	10/22/2022 3:01 AM	Compressed (zipp...	24 KB
20221023T030115.zip	10/23/2022 3:01 AM	Compressed (zipp...	24 KB
20221024T030124.zip	10/24/2022 3:01 AM	Compressed (zipp...	24 KB
20221025T030118.zip	10/25/2022 3:01 AM	Compressed (zipp...	24 KB
20221026T111123.zip	10/26/2022 11:11 AM	Compressed (zipp...	24 KB
20221027T030110.zip	10/27/2022 3:01 AM	Compressed (zipp...	24 KB
20221101T030106.zip	11/1/2022 3:01 AM	Compressed (zipp...	24 KB

Figure 2.12 Routing hotstart folder with the latest hotstart and zipped archives

Name	Date modified	Type	Size
436-436_hot.csv	1/27/2023 11:33 AM	CSV File	52 KB

Figure 2.13 Latest hotstart of the routing

2.5.1.3 Results

The Results folder contains the result files of the DHI-GHM model.

Name	Date modified	Type	Size
436-436.csv	1/27/2023 11:33 AM	CSV File	27 KB
436-436_hot.csv	1/27/2023 11:33 AM	CSV File	52 KB
436-436_inflow.csv	1/27/2023 11:33 AM	CSV File	28 KB

Figure 2.14 Routing result folder after the last simulation

Date	436890090500	436890090400	436890090300	436890090200	436890090100	436890080200	436890080100
2023-01-19 00:00:00	0.1586	0.3698	0.7076	0.9524	1.305	0.2838	0.6275
2023-01-20 00:00:00	0.1508	0.3531	0.6772	0.9123	1.251	0.2718	0.6017
2023-01-21 00:00:00	0.1430	0.3364	0.6468	0.8724	1.197	0.2601	0.5801

Figure 2.15 Latest routing result file

Catchment DFS0

Timeseries are extracted from DHI-GHM results at locations as listed in Appendix E and using upstream catchments as in table Appendix F.

They are stored at a location as:

- Location: “..\Results\Catchment_DFS0\ERA5”

Name	Date modified	Type	Size
Routed_discharge_to_outlet	11/18/2022 10:13 AM	File folder	
Unrouted_runoff_to_outlet	11/18/2022 10:14 AM	File folder	

Figure 2.16 Main folder for extracted results

After extraction, timeseries from ERA5, GFS and CFS are stored to the MW database, where the model is run.

Bottom nodes are the outlets of a basin (most downstream points). Top nodes are the bottom nodes of catchments discharging to the basin.

All upstream basins of each basin of interest (top or bottom node basins) are stored in “..\Tools\py\SetupFiles\Upstream_PFAF_ID.csv”. The table is depicted in Appendix F.

For each bottom node basin, a full list of top node basins is stored in “..\Tools\py\SetupFiles\NAWAPI_CatchmentNodes.yml”, which’s content is shown in Appendix E.

- The script “..\Tools\py\ExtractTimeseries.py” is used for the result extraction. It produces two kind of outputs: Discharge: extracted values from results-csv
- Runoff: sum runoff of all upstream pfaf-ids and subtract summed runoff from top-nodes pfaf-ids

Routed discharge to outlet

DHI-GHM results at locations as listed in Appendix E and using upstream catchments as in table Appendix F.

M:\Results\Catchment_DFS0\ERA5\Routed_discharge_to_outlet

Name	Date modified	Type	Size
Discharge_TS_Catchment_C1.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Discharge_TS_Catchment_C2.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Discharge_TS_Catchment_C3.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Discharge_TS_Catchment_C4.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Discharge_TS_Catchment_C5.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Discharge_TS_Catchment_C6.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Discharge_TS_Catchment_C7.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Discharge_TS_Catchment_C8.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Discharge_TS_Catchment_C9.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Discharge_TS_Catchment_C10.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Discharge_TS_Catchment_C11.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Discharge_TS_Catchment_C12.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Discharge_TS_Catchment_C13.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Discharge_TS_Catchment_C14.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Discharge_TS_Catchment_C15.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Discharge_TS_Catchment_C16.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB

Figure 2.17 Routed discharge timeseries files from ERA5

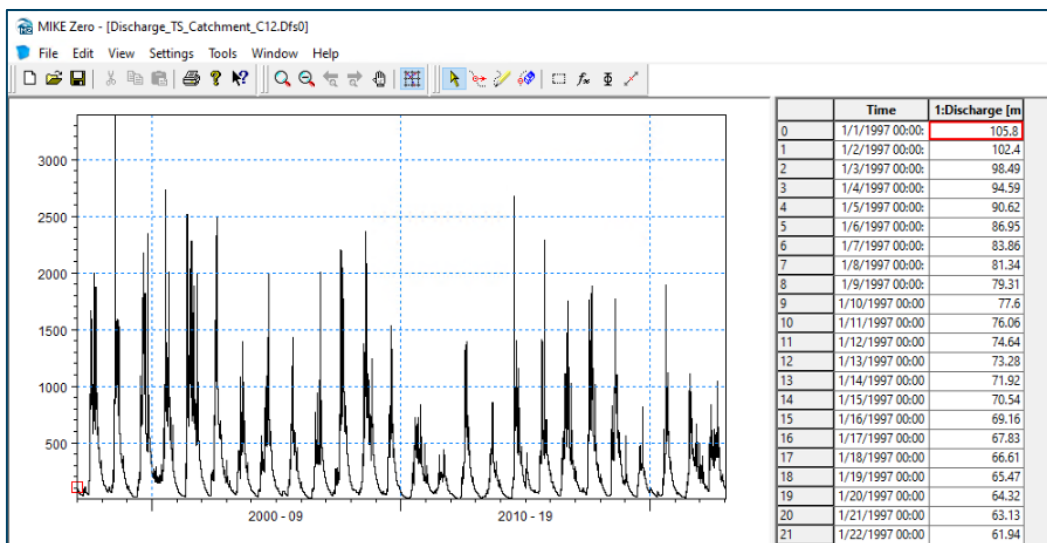


Figure 2.18 Example of a routed discharge timeseries from ERA5

Unrouted runoff to outlet

Intermediate runoff is calculated DHI-GHM results at locations as listed in Appendix E and using upstream catchments as in table Appendix F.

For each station, the runoff is calculated, which has been generated from it's last upstream points, used in the MHB setup, to the point itself.

Results\Catchment_DFS0\ERA5\Unrouted_runoff_to_outlet

Name	Date modified	Type	Size
Runoff_TS_Catchment_C1.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Runoff_TS_Catchment_C10.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Runoff_TS_Catchment_C11.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Runoff_TS_Catchment_C12.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Runoff_TS_Catchment_C13.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Runoff_TS_Catchment_C14.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Runoff_TS_Catchment_C15.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Runoff_TS_Catchment_C16.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Runoff_TS_Catchment_C17.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Runoff_TS_Catchment_C18.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Runoff_TS_Catchment_C19.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Runoff_TS_Catchment_C2.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Runoff_TS_Catchment_C20.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Runoff_TS_Catchment_C21.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Runoff_TS_Catchment_C22.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Runoff_TS_Catchment_C23.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB
Runoff_TS_Catchment_C24.Dfs0	1/27/2023 11:34 AM	MIKE Zero Time S...	243 KB

Figure 2.19 Unrouted runoff timeseries files from ERA5

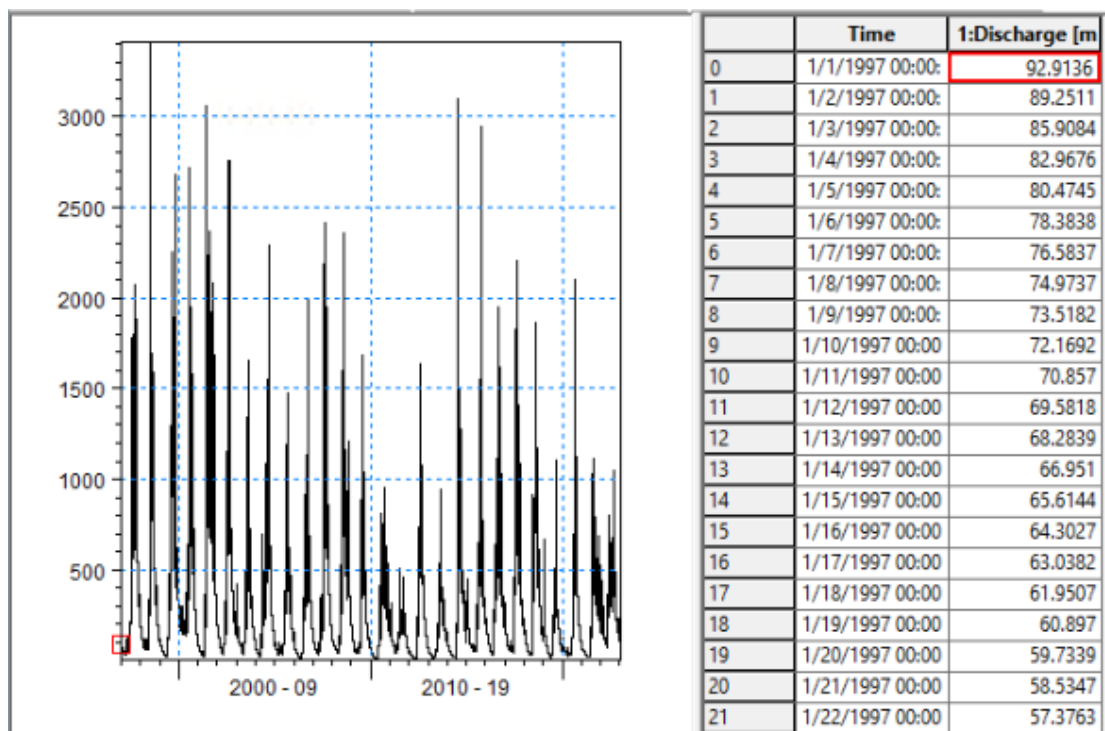


Figure 2.20 Example of an unrouted runoff timeseries from ERA5

2.5.1.4 Timeseries

The timeseries folder includes the forcing data needed for the DHI-GHM to run. The data usually comes in dfs2 format, where the irrigation timeseries comes as .csv file.

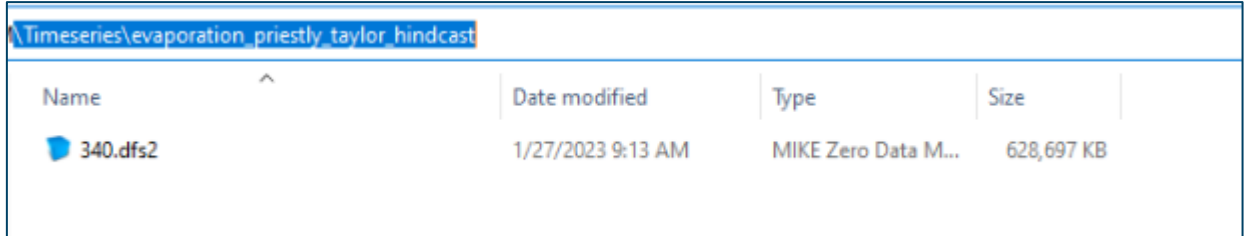


Figure 2.21 Folder with the evaporation dfs2 file for hindcast simulations

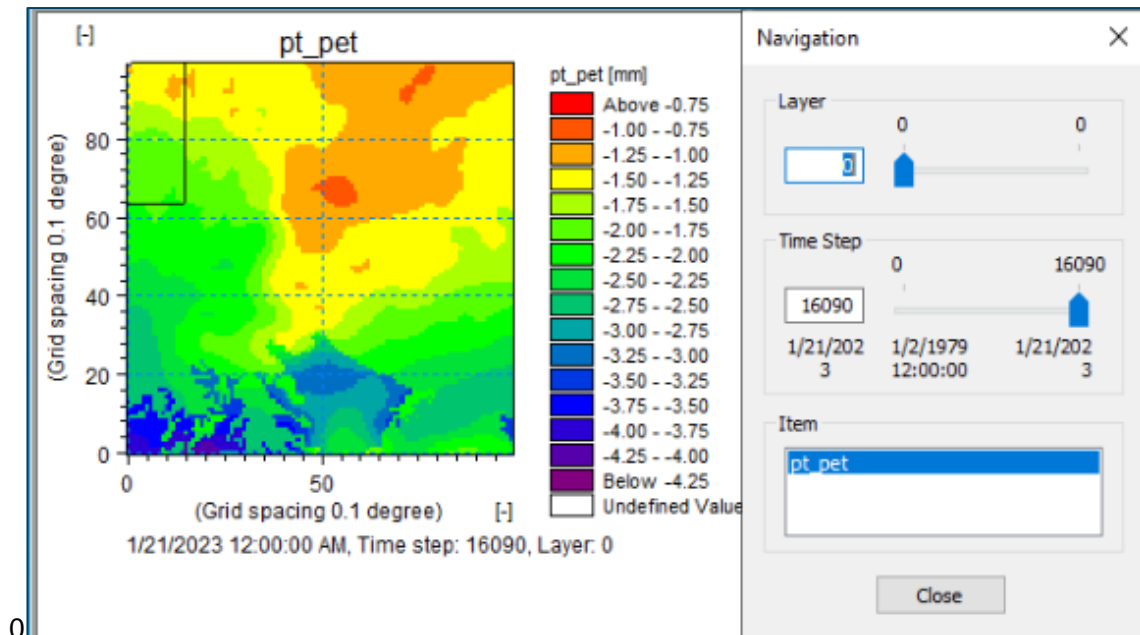


Figure 2.22 Evaporation dfs2 files used for hindcast simulations

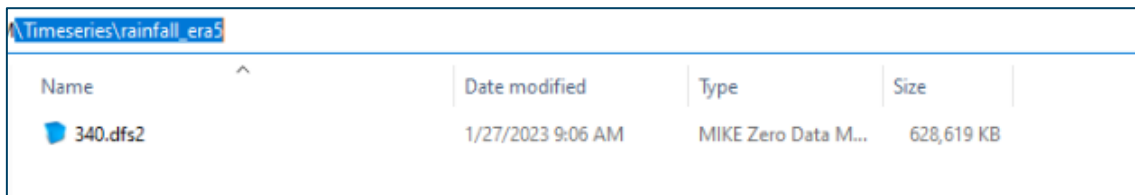


Figure 2.23 Folder with the rainfall dfs2 file for hindcast simulations

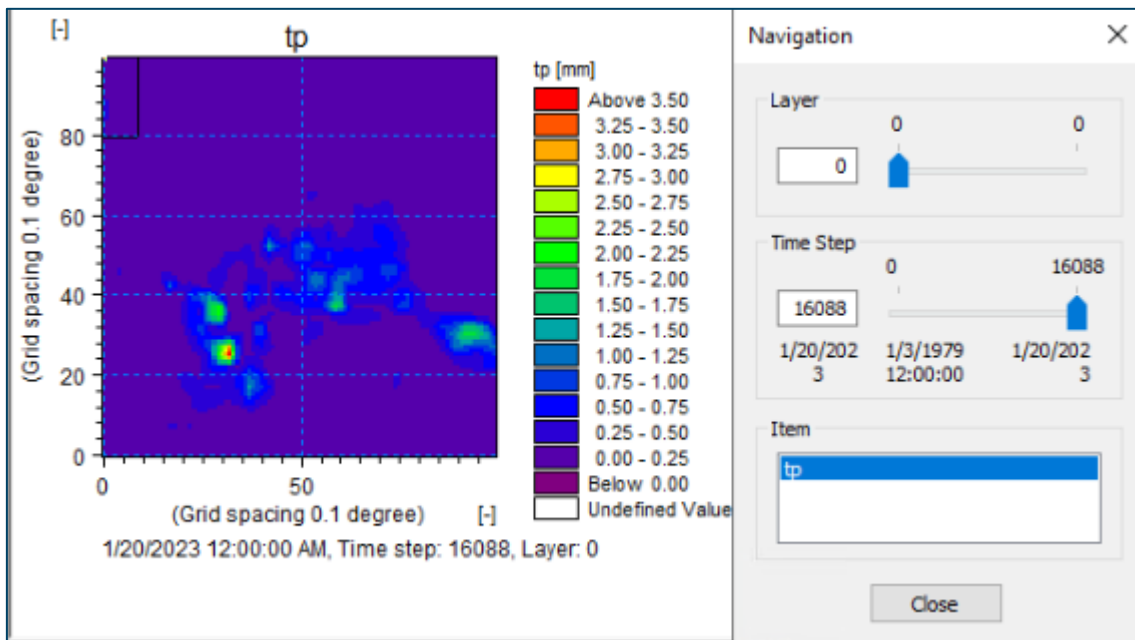


Figure 2.24 Precipitation dfs2 file for hindcast simulations

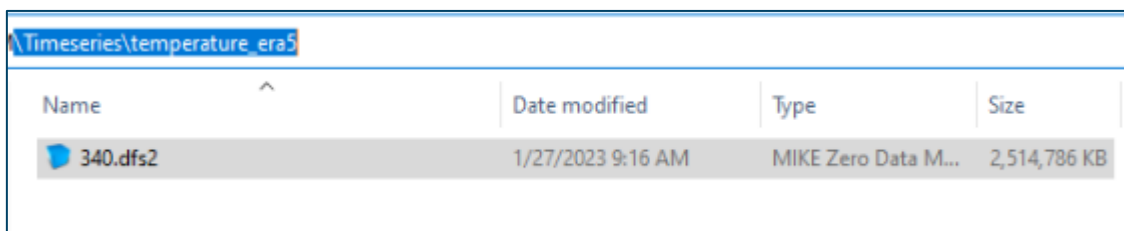


Figure 2.25 Folder with the temperature dfs2 file for hindcast simulations

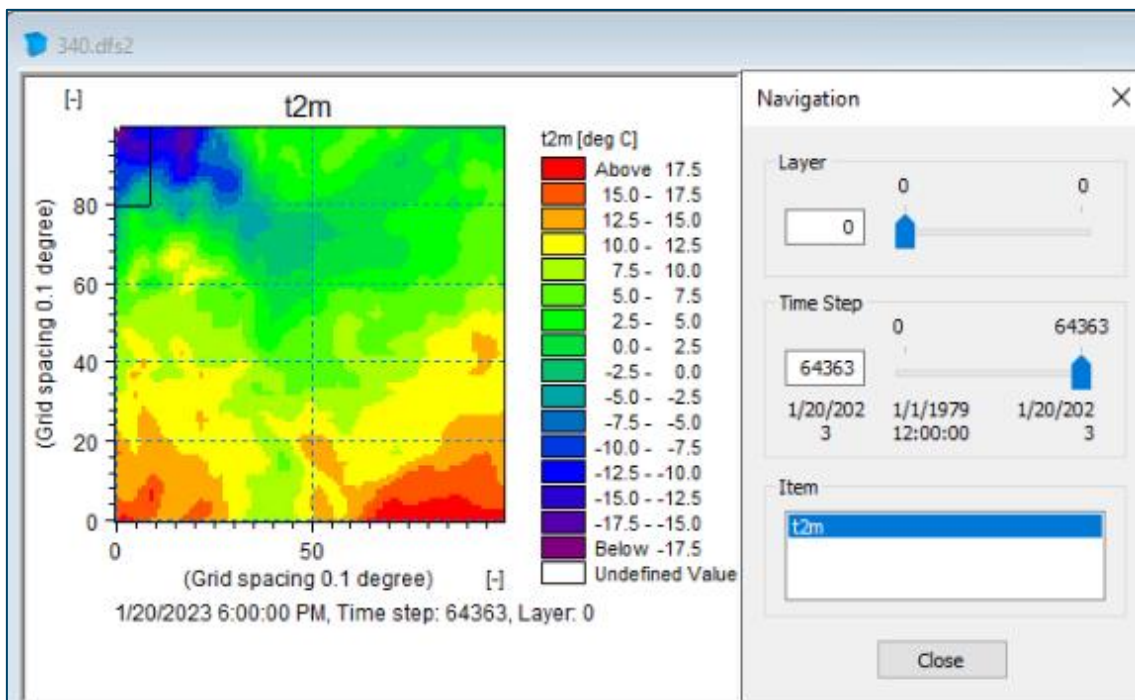


Figure 2.26 Temperature dfs2 file for hindcast simulations

2.5.1.5 Tools

In the Tools folder, the tools for the DHI-GHM can be found:

- FastKinRouter: the routing component of the DHI-GHM
- GlobalHydroRunner_MIKE2022: the NAM component of the DHI-GHM
- Py: pre- and postprocessing scripts and their setup files for the DHI-GHM

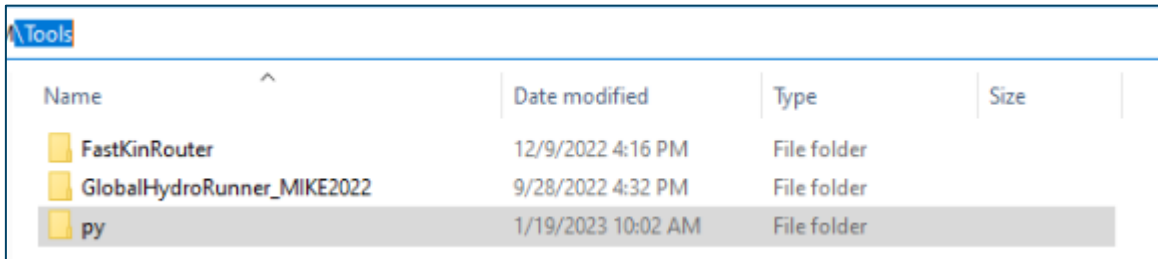


Figure 2.27 Preview of the Tools folder

AzCopy

AzCopy is used to download GHM files from a secure Azure blob-storage, where DHI updates the data daily.

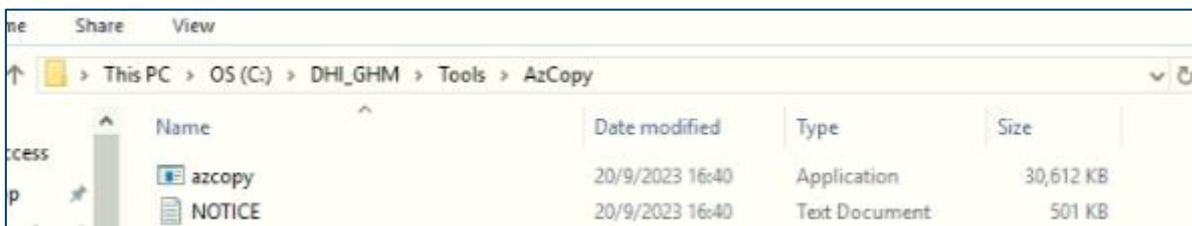


Figure 2.28 Preview of the AzCopy tools folder

FastKinRouter

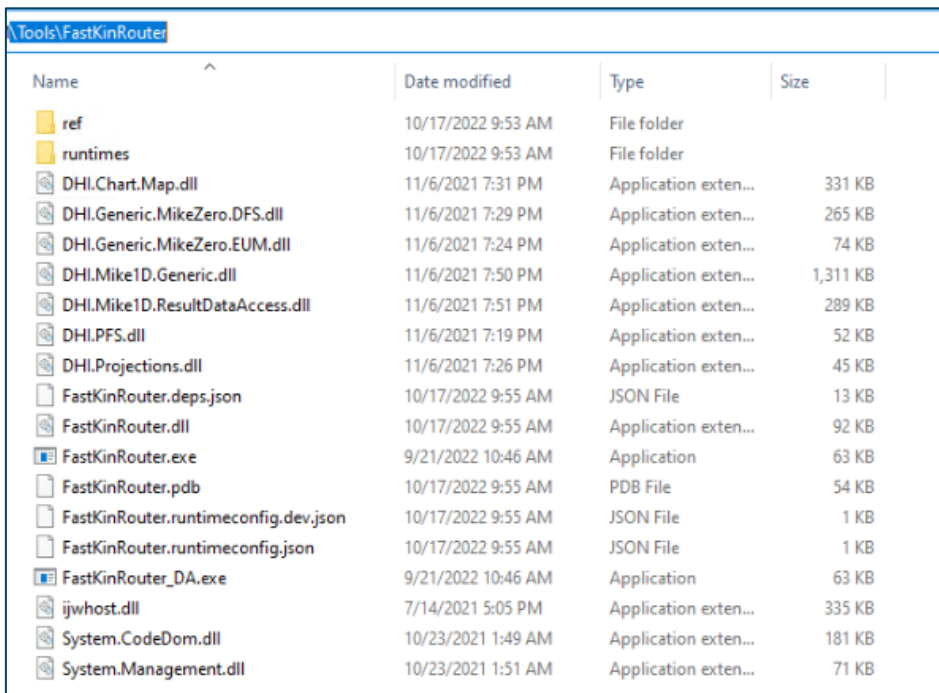


Figure 2.29 Preview of the FastKinRouter tool folder

GlobalHydroRunner_MIKE2022

Name	Date modified	Type	Size
GlobalHydroRunner.exe	10/17/2022 7:57 AM	Application	83 KB
GlobalHydroRunner.exe.config	10/17/2022 7:57 AM	CONFIG File	3 KB
GlobalHydroRunner.pdb	10/17/2022 7:57 AM	PDB File	176 KB
DataAssimilation.dll	10/17/2022 7:57 AM	Application exten...	23 KB
DataAssimilation.pdb	10/17/2022 7:57 AM	PDB File	104 KB
ExtendedSnowModel.exe	10/17/2022 7:57 AM	Application	69 KB
ExtendedSnowModel.pdb	10/17/2022 7:57 AM	PDB File	188 KB
DHI.Mike1D.M11Bridge.dll	9/16/2022 8:39 AM	Application exten...	178 KB
ExtendedSnowModel.exe.config	9/16/2022 8:39 AM	CONFIG File	2 KB
DHI.Mike1D.MzCouplings.dll	5/12/2022 9:41 PM	Application exten...	61 KB
DHI.Mike1D.StructureModule.dll	5/12/2022 7:41 PM	Application exten...	450 KB
DHI.Mike1D.SimLauncher.dll	5/12/2022 7:41 PM	Application exten...	55 KB
DHI.Mike1D.RainfallRunoffModule.dll	5/12/2022 7:40 PM	Application exten...	300 KB
DHI.Mike1D.ResultDataAccess.dll	5/12/2022 7:40 PM	Application exten...	491 KB
DHI.Mike1D.Optimization.dll	5/12/2022 7:40 PM	Application exten...	31 KB
DHI.Mike1D.NetworkDataAccess.dll	5/12/2022 7:40 PM	Application exten...	60 KB
DHI.Mike1D.Mike1DDataAccess.dll	5/12/2022 7:40 PM	Application exten...	379 KB
DHI.Mike1D.HDPParameterDataAccess.dll	5/12/2022 7:40 PM	Application exten...	112 KB
DHI.Mike1D.Generic.dll	5/12/2022 7:39 PM	Application exten...	1,321 KB
DHI.Mike1D.FloodMap.dll	5/12/2022 7:39 PM	Application exten...	29 KB
DHI.Mike1D.Engine.dll	5/12/2022 7:39 PM	Application exten...	1,245 KB
DHI.Mike1D.DataAssimilationModule.dll	5/12/2022 7:39 PM	Application exten...	33 KB

Figure 2.30 Preview of the GlobalHydroRunner_MIKE2022 folder

py

Name	Date modified	Type	Size
SetupFiles	1/3/2023 1:16 PM	File folder	
ExtractTimeseries.py	1/19/2023 8:16 AM	PY File	8 KB
GenerateReportingHTML.py	1/4/2023 10:48 AM	PY File	12 KB
Store1DResults.py	12/7/2022 7:35 AM	PY File	6 KB
UpdateConfig_GFS.py	1/19/2023 7:39 AM	PY File	2 KB
UpdateNAMConfig_CFS.py	10/24/2022 1:26 PM	PY File	2 KB

Figure 2.31 Preview of the py tool folder

Name	Date modified	Type	Size
NAWAPI_CatchmentNodes.yml	1/10/2023 9:57 AM	YML File	3 KB
NAWAPI_Reporting.yml	1/9/2023 7:55 AM	YML File	6 KB
Upstream_PFAF_ID.csv	1/10/2023 10:09 AM	CSV File	42 KB

Figure 2.32 Preview of the py tool setup folder folder

2.5.2 MIKE HYDRO Basin

The MIKE HYDRO Basin model (as described in Section 2.7.2) is registered in the MIKE Workbench database as illustrated in Figure 2.33.

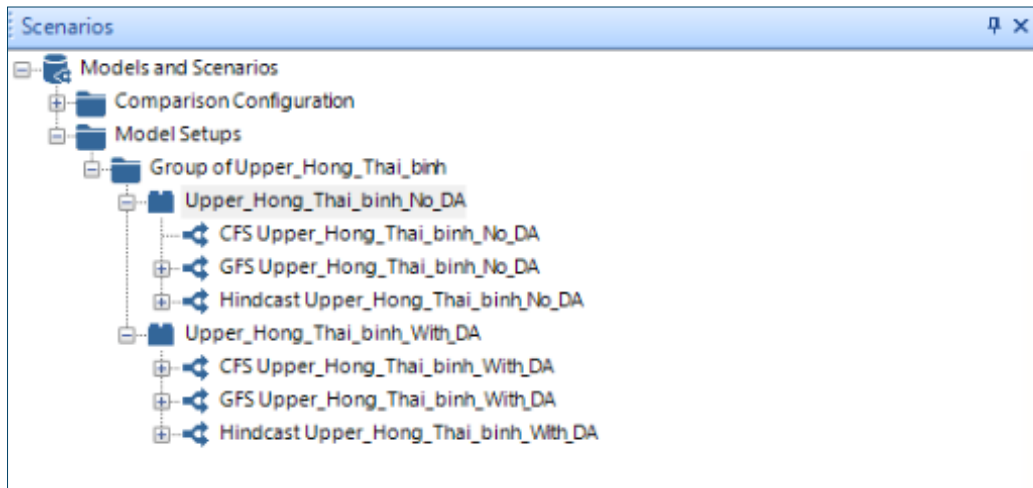


Figure 2.33 Preview of the scenario manager with the MIKE HYDRO Basin model setup.

There are two versions of the model registered:

- Upper_Hong_Thai_binh_No_DA: this model is registered and set up to simulate without data assimilation (DA) at reservoirs
- Upper_Hong_Thai_binh_With_DA: this model is registered and set up to simulate with DA at reservoirs

It should be noted that three scenarios are derived from each model setup:

- GFS – medium range forecasts
- CFS – seasonal forecast
- Hindcast – this scenario is only run once and used to derive long term statistics and for validation. In the operational runs, CFS and GFS will simulate a longer hindcast period.

The scenario configuration for the GFS with DA is shown in Figure 2.34. GFS scenario without DA has the same configuration. CFS with DA scenario has a similar configuration whereas CFS without DA has the same configuration as CFS with DA.

The modelling framework for MHB is described in section 2.7.2.

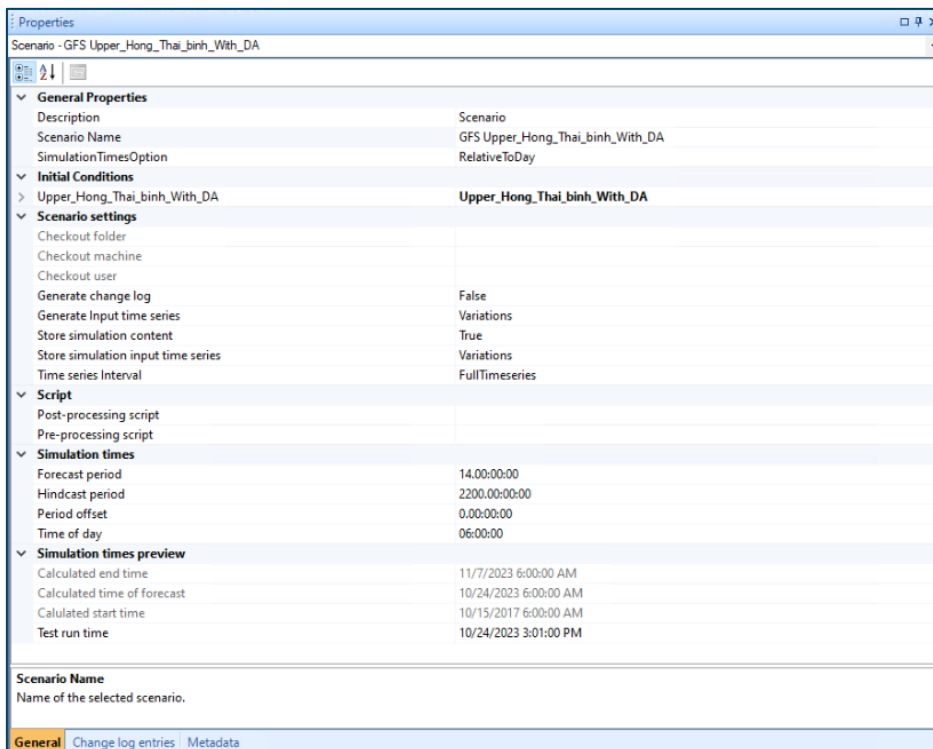


Figure 2.34 Properties of the GFS Scenario (Medium Range Forecast)

The table below gives an overview of the main scenario settings:

- Hindcast period warmup period used for ensuring proper initial conditions
- Forecast period that covers the same period as available in the weather/climate forecast.

Table 2.8 Main properties of the MIKE HYDRO Basin Scenarios

Scenario	Hindcast period	Forecast period
GFS Medium Range Forecast with DA	2200 days (= 6 years)	14 days
CFS Seasonal Forecast with DA	2200 days (= 6 years)	270 days
GFS Medium Range Forecast without DA	2200 days (= 6 years)	14 days
CFS Seasonal Forecast without DA	2200 days (= 6 years)	270 days

2.6 Data Acquisition

2.6.1 DHI-GHM Forcing data

Forcing data for the DHI-GHM is pre-processed in the DHI internal system to a format, that the DHI-GHM can consume (dfs2 file format). Data is then stored on a secure Azure blob-storage, from where it can be downloaded. The tool AzCopy.exe is used from synchronising the blob-storage with a local repository on the server with input files (See section 2.5.1.4).

The data download and process frequencies are:

- Daily for hindcast and seasonal forecast data
- 3hourly for medium range forecast data

```

1 | echo off
2 | setlocal
3 | pushd "%~d0%~p0"
4 |
5 | set workdir=%~1
6 | set tsdir=%workdir%\..\Timeseries
7 | set tool=%workdir%\..\Tools\AzCopy\azcopy.exe
8 |
9 | set sastoken="https://wrddata.blob.core.windows.net/nawapi/rainfall_era5/*?sp=rl&st=2023-09-19T12:48:21Z&se=2073-09-19T12:48:21Z"
10 | "%tool%" copy %sastoken% "%tsdir%\rainfall_era5" --recursive
11 |
12 | set sastoken="https://wrddata.blob.core.windows.net/nawapi/temperature_era5/*?sp=rl&st=2023-09-19T12:48:21Z&se=2073-09-19T12:48:21Z"
13 | "%tool%" copy %sastoken% "%tsdir%\temperature_era5" --recursive
14 |
15 | set sastoken="https://wrddata.blob.core.windows.net/nawapi/evaporation_priestly_taylor_hindcast/*?sp=rl&st=2023-09-19T12:48:21Z&se=2073-09-19T12:48:21Z"
16 | "%tool%" copy %sastoken% "%tsdir%\evaporation_priestly_taylor_hindcast" --recursive
17 |
18 |

```

Figure 2.35 Snippet of the batch file to download ERA5 data from DHI's Azure blob-storage. "workdir" as input parameter is to be set as the "WorkDir" in the calling job in MIKE Workbench.

The following datasets are downloaded:

- ERA5 rainfall
- ERA5 temperature
- Priestly Taylor Potential Evaporation (PT_PET) hindcast
- CFS Medium range forecast
- GFS Seasonal forecast
- PT_PET forecast

2.6.2 Reservoir Level and Storage Detection

A spreadsheet has been prepared in MIKE Workbench (**/Reservoir Curves/Curves**) for handling the surface water extend timeseries data from earth observations.

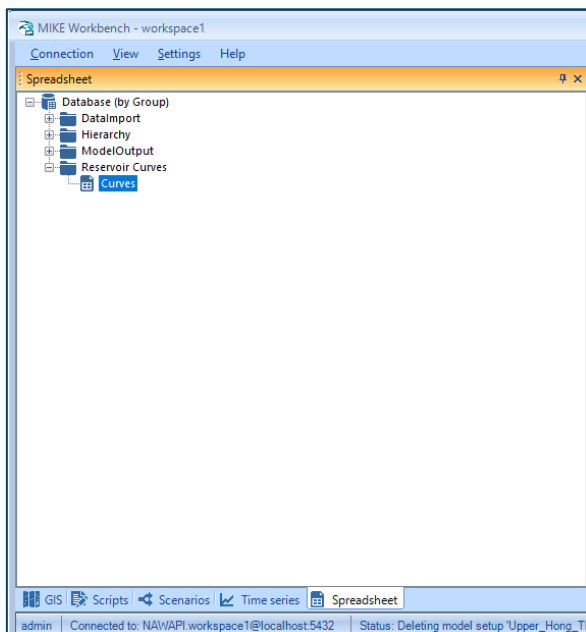


Figure 2.36 Location of surface water extend data handling spreadsheet.

The worksheet for surface water extend contains 12 sheets:

1. Mapping sheet
2. The remaining 11 sheets hold the Level-Area-Volume relations for each reservoir. These sheets are named after each reservoir.

2.6.2.1 Mapping worksheet

The Mapping worksheet, see Figure 2.37 below, is a single sheet containing information about what model object name relates to which reservoir name (sheet name of reservoir with LAV curve) and timeseries path.

	A	B	C	D	E	F
1	ModelObjectName	SheetName	Timeseries_Path			
2	DA_R70.dfs0 - 1 - R70 Water Level	Gelantan	/Observed/Reservoir Surface Area/DA_R70			
3	DA_R68.dfs0 - 1 - R68 Water Level	Jupudu	/Observed/Reservoir Surface Area/DA_R68			
4	DA_R2.dfs0 - 1 - R2 Water Level	Yayangshan	/Observed/Reservoir Surface Area/DA_R2			
5	DA_R60.dfs0 - 1 - R60 Water Level	Shimenkan	/Observed/Reservoir Surface Area/DA_R60			
6	DA_R62.dfs0 - 1 - R62 Water Level	Longma	/Observed/Reservoir Surface Area/DA_R62			
7	DA_R64.dfs0 - 1 - R64 Water Level	Puxiqiao	/Observed/Reservoir Surface Area/DA_R64			
8	DA_R66.dfs0 - 1 - R66 Water Level	Sinanjiang	/Observed/Reservoir Surface Area/DA_R66			
9	DA_R72.dfs0 - 1 - R72 Water Level	Nalan	/Observed/Reservoir Surface Area/DA_R72			
10	DA_R74.dfs0 - 1 - R74 Water Level	Nansha	/Observed/Reservoir Surface Area/DA_R74			
11	DA_R76.dfs0 - 1 - R76 Water Level	Madushan	/Observed/Reservoir Surface Area/DA_R76			
12	DA_R78.dfs0 - 1 - R78 Water Level	Malutang	/Observed/Reservoir Surface Area/DA_R78			
13						
14						
15						
16						
17						
18						
19						
20						
21						

Figure 2.37 Mapping worksheet holding the relation between model object names, reservoir names, and time series path.

The mapping sheet contains the following:

1. **Model Object Name**
Name of the model object containing the output timeseries
2. **Sheet Name**
The name of the sheet where the LAV relations are stored
3. **Timeseries Path**
Path to the observation time series collected and stored

2.6.2.2 Reservoir LAV relation sheets

There are 11 sheets, one per reservoir, holding the LAV curves relations, see example below for Gelantan reservoir. Each reservoir sheet contains the following columns level, area and volume.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Level (m)	Area (km2)	Volume									
2	371	0.0282695	0.068532224									
3	376	0.0985151	0.423186486									
4	381	0.2055967	1.213877025									
5	386	0.3786405	2.689033156									
6	391	0.6176467	5.244428474									
7	396	0.9431747	9.324665786									
8	401	1.295259	15.02140694									
9	406	1.7193022	22.72271566									
10	411	2.1587651	32.64789506									
11	416	2.6787533	44.96056584									
12	421	3.2912601	60.19442267									
13	426	3.8952003	78.42313772									
14	431	4.571956	99.92683644									
15	436	5.3035375	124.9231086									
16	441	6.0788083	153.7400524									
17	446	6.8780654	186.4984556									
18	451	7.7766942	223.5264165									
19	456	8.7481384	265.3559163									
20	461	9.6639003	311.8224778									
21	466	10.541969	362.7110811									
22	471	11.388342	418.0448557									
23	476	12.231289	477.5548128									
24	481	13.014269	541.0687651									
25	486	13.77926	608.4239486									

Figure 2.38 Preview of Level-Area-Volume relation for Gelantan

2.6.2.3 Data download

A custom-made script has been prepared in MIKE Workbench under script (*/DataImport/ImportEOData*) for downloading the processed surface water extend timeseries for 11 reservoirs. The data is retrieved from DHI's public ftp server, see below Figure 2.39. This script reads data in a csv format file, converts it into timeseries objects and stores it on the database.

```

1 import ftplib
2 import System
3 from System import DateTime
4 from System.IO import *
5 from System.Globalization import *
6 import subprocess
7 import clr
8 import os.path
9 import tempfile
10 import shutil
11
12 sprMgr = app.Modules.Get('Spreadsheet Manager')
13 tmgr = app.Modules.Get('Time series Manager')
14
15 def ImportEOData(spreadsheetPath):
16     """
17     <Script>
18     <Author>EEME</Author>
19     <Description>Updates reservoir water extend from satellite data. Observations of reservoir water extend from satellite missions are processed
20     <Parameters>
21     <Parameter name="spreadsheetPath" type="string">EO setup spreadsheet</Parameter>
22     </Parameters>
23     </Script>
24     """
25
26     try:
27         temp_file = tempfile.NamedTemporaryFile(mode='w')
28         temp_file_path = temp_file.name
29         temp_file.close()
30         is_download = _download_from_ftp("ftp.dhigroup.com", "/pub/NAWAPI/reservoir_levels/", "tea42", "with-Milk", temp_file_path)
31         if is_download == True:
32             list_values = _read_csv_eo(temp_file_path)
33             config_paths = _read_reservoir_curves_spreadsheet(spreadsheetPath)
34             for name in config_paths.keys():
35                 ts_path = config_paths[name]
36                 ts_values = []
37                 for pair_value in list_values:
38                     if pair_value["name"] == name:
39                         ts_values.append(pair_value)
40                 sorted(ts_values, cmp=pair_value_compare)
41                 _update_timeseries_db(ts_path, ts_values)

```

Figure 2.39 ImportEOData script for 11 reservoirs from DHI's public FTP server.

/ImportData/ImportEOData script uses the timeseries ids from the mapping sheet in the **/Reservoir Curves/Curves** worksheet for storing the observed water surface extend timeseries in the respective path as shown below in Figure 2.40.

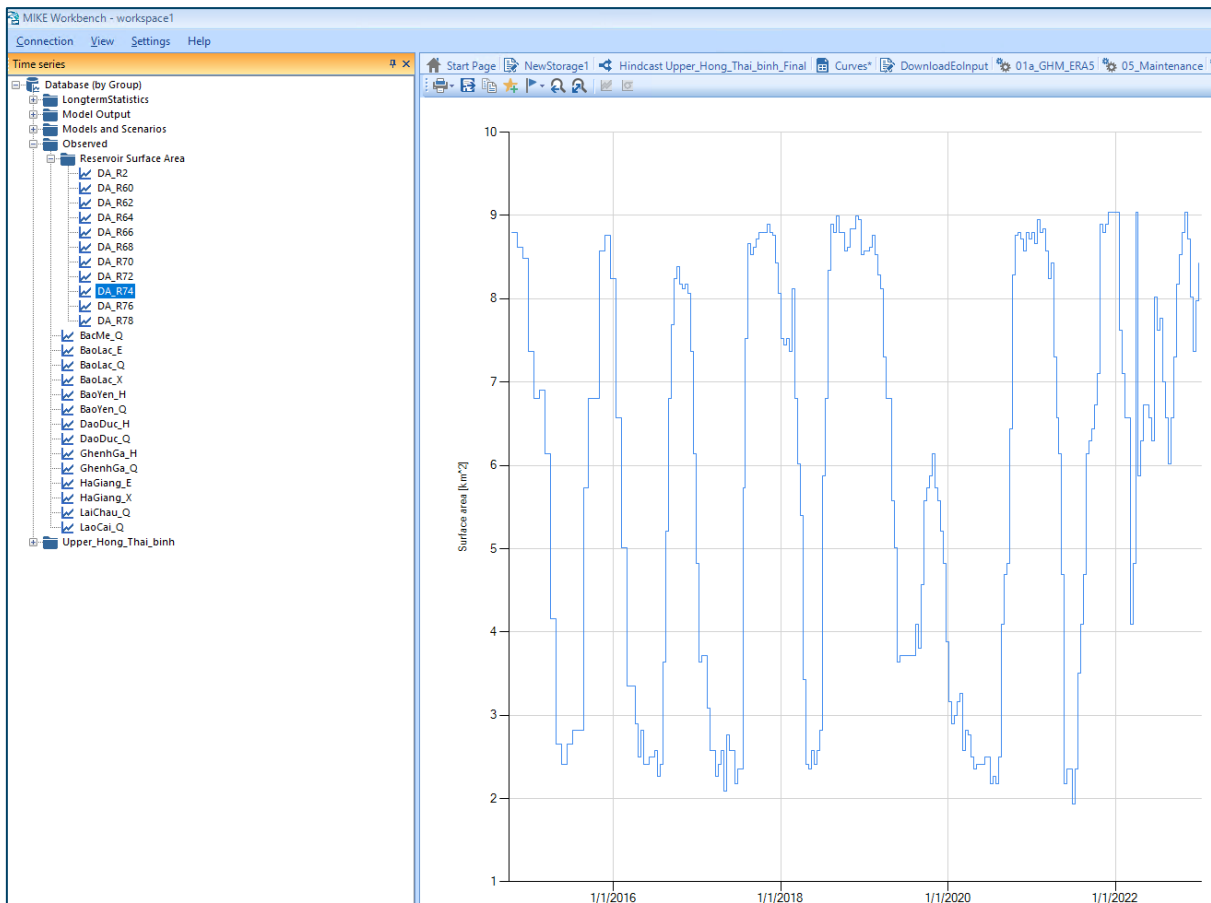


Figure 2.40 Observed surface water extend timeseries for Malutang reservoir.

2.6.2.4 Input timeseries definition for data assimilation

A custom-made script has been prepared in MIKE Workbench (**/LAV_Curves/build_reservoir_wl_ts**) for constructing water level timeseries on the fly using the configuration parameters found on the **/Reservoir Curves/Curves** worksheet as described before. The script is registered in the model input definition as shown below in Figure 2.41

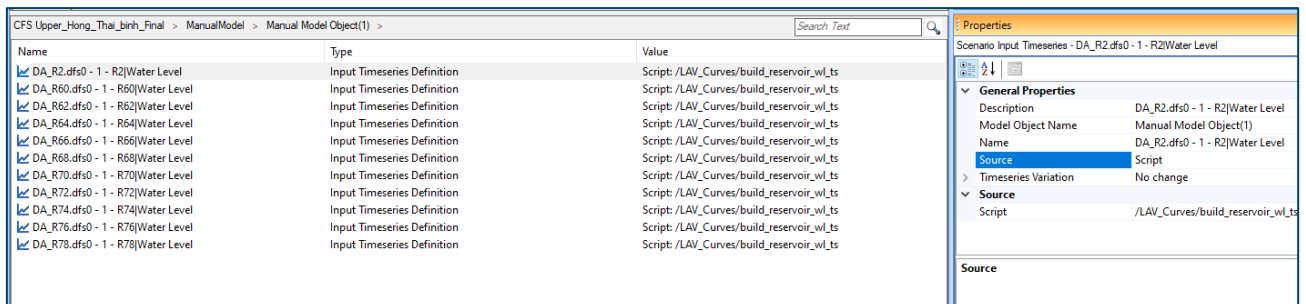


Figure 2.41 Example of script registration used to define the model input time series for the forecast scenario

The timeseries is made available before each model run as estimated water level observed at the reservoir. The estimated water level timeseries input use at each model calculation run can be found under the model simulation outputs in the following path relative **.../Manual Model Object(1)/Input**, relative to the simulation path as shown below in Figure 2.42.

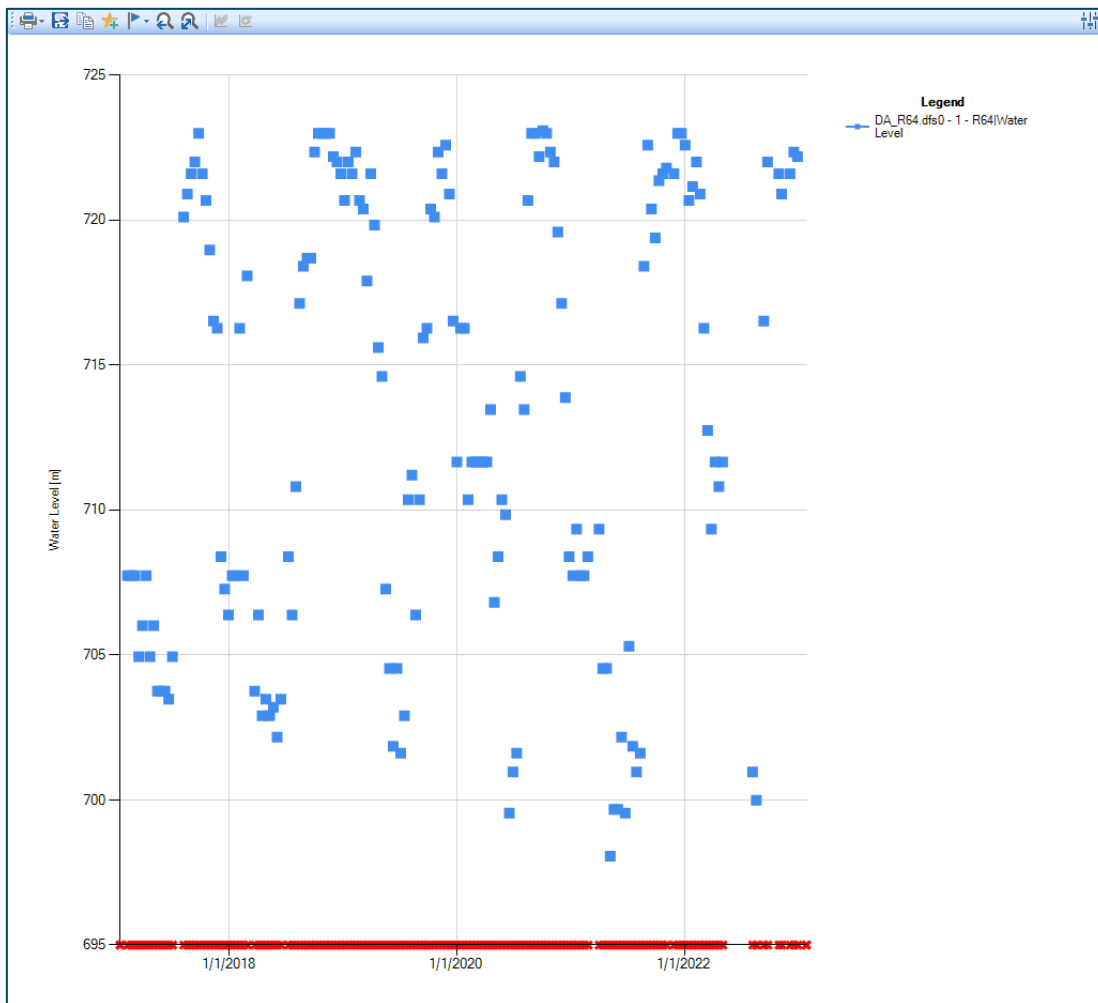


Figure 2.42 Input water level timeseries used during data assimilation for Puxiqiao

2.7 Modelling Framework

The following chapter describes the two main modelling components used in the System:

- DHI-GHM
- MIKE HDYRO Basin

2.7.1 DHI-GHM

2.7.1.1 Parameter values

The NAM parameter values are stored in csv format and at the relative location "`..\Configuration\setup_nam\ParDef.csv`". The table is shown in Appendix A.

Table 2.9 Parameter values, which can be used to calibrate the DHI-GHM

Parameter	Unit	Description
U_{max}	mm	Maximum water content in the surface storage. U_{max} can be interpreted as including the water content in the interception storage, in surface depression storages, and in the uppermost few cm's of the soil
L_{max}	mm	Maximum water content in the lower zone storage. L_{max} can be interpreted as the maximum soil water content in the root zone available for the vegetative transpiration
CQOF	--	Overland flow runoff coefficient. CQOF determines the distribution of excess rainfall into overland flow and infiltration
TOF	--	Threshold value for overland flow. Overland flow is only generated if the relative moisture content in the lower zone storage is larger than TOF
TIF	--	Threshold value for interflow. Interflow is only generated if the relative moisture content in the lower zone storage is larger than TIF
TG	--	Threshold value for recharge. Recharge to the groundwater storage is only generated if the relative moisture content in the lower zone storage is larger than TG
CK_{IF}	hour	Time constant for interflow from the surface storage. It is the dominant routing parameter of the interflow because $CK_{IF} \gg CK_{1,2}$
$CK_{1,2}$	hour	Time constant for overland flow and interflow routing. Overland flow and interflow are routed through two linear reservoirs in series with the same time constant $CK_{1,2}$
CK_{BF}	hour	Baseflow time constant. Baseflow from the groundwater storage is generated using a linear reservoir model with time constant CK_{BF}

2.7.1.2 Catchment definition

The catchment definition for the hindcast simulation using ERA5 data is stored in csv format and at the relative location "..\Configuration\setup_nam\CatchDef_ERA5.csv". The table is shown in Appendix B

Table 2.10 Catchment definition file, used for the NAM

Column name	Description
name	Name of the catchment following the naming convention <ul style="list-style-type: none"> - "{x_coord}_{y_coord}" - for lowest level - "{x_coord}_{y_coord}_{elevation}" – for elevation zones, meters relative to lowest level
isCombined	Catchment is a combined catchment (for elevation zones) (TRUE or FALSE)
combined catchment	If combined, name of the main catchment at elevation 0
parameter template	Reference parameters initially used and must reference a catchment defined in the .RR file which is part of the setup. Parameters can be updated with the parameter file.
areakm2	Area of the catchment in km2
elevation	Elevation relative to lowest level elevation of the combined catchment
max. snow depth	Maximum snow depth modelled in the catchment
max. swe retention	Definition of snow water equivalent volume maximum.

Column name	Description
min. full cover storage	Minimum snow water equivalent needed for full coverage of the area
radiation coeff	Multiplication factor for radiation
precip_corr	Precipitation correction in %. 0 stands for no correction, where 10 stands for adding 10%.
evap_corr_factor	Multiplication factor for potential evaporation.
temp_wet_corr	Temperature correction relevant for elevation zones
temp_dry_corr	Temperature correction relevant for elevation zones
ini_qof	Initial overland flow
ini_qif	Initial interflow
ini_qbf	Initial baseflow
ini_qbflow	Initial lower baseflow. Set to zero
ini_swe	Initial snow water equivalent
ini_u_umax	Initial maximum water content in the surface storage
ini_l_lmax	Initial maximum water content in the lower zone storage
evap file	Filepath to evaporation timeseries, relative to model-file
evap item	Item number in evaporation file to use
temp file	Filepath to temperature timeseries, relative to model-file
temp item	Item number in temperature file to use
precip file	Filepath to precipitation timeseries, relative to model-file
precip item	Item number in precipitation file to use
radiation file	Filepath to radiation timeseries, relative to model-file (obligatory)
radiation item	Item number in radiation file to use
x_dfs2	X coordinate in the internal coordinate system of the Dfs2 file
y_dfs2	Y coordinate in the internal coordinate system of the Dfs2 file
partition	Partition number in DHI-GHM's tiling system
ensemble	Ensemble number (empty if no ensemble)
x	X coordinate, WGS1984
y	Y coordinate, WGS1984

2.7.1.3 Routing groups

The routing groups are stored in csv format and at the relative location "..\Configuration\setup_routing\RoutingGroups.csv". A routing group is a grouping of basins used for parallelization. Grouping is done at PFAF level 3 (using the first three digits of the 12-digit PFAF ID). All PFAF IDs defined in the BasinDef.csv file (described in Section 2.7.1.4) that begin with the first three digits defined in the routing group are executed on one core during model operation. This also means that if a PFAF ID is defined in the basin definition whose first three digits are not in a routing group, it will not be included in the model setup.

Five things are needed to define a routing group:

1. PFAF_DOWN: The lower value of the 3-digit PFAF ID
2. PFAF_UP: The upper value of the 3-digit PFAF ID
3. Area: The area covered in the routing group (for statistics purposes)
4. Basin: The relative path to the BasinDef file
5. Cellweight: The relative path to the CellWeight file

Each routing group requires a BasinDef and CellWeight file to complete its execution, and each line in the routing groups file contains these filepaths. Each of these files are explained below.

Table 2.11 Routing groups used for DHI-GHM's Fast Kinematic Router. Derived from hydrosheds HydroBASINS on level 3.

PFAF_Down	PFAF_Up	Area	Basin	CellWeight
436	436	139350.7	..\Configuration\setup_routing\BasinDef.csv	..\Configuration\setup_routing\CellWeights.csv

2.7.1.4 BasinDef

The basin definitions are stored in csv format and at the relative location "..\Configuration\setup_routing\BasinDef.csv". The table is shown in Appendix C. This file defines the basin network and necessary parameters for the kinematic router.

Table 2.12 Basin definition file for DHI-GHM's Fast Kinematic Router

Parameter	Description
HYBAS_ID	Unique 10-digit identification number for each sub-catchment, to denote the HydroBASINS network.
MAIN_BASIS	The HYBAS_ID of the most downstream sub-catchment for the sub-catchment. Defines the main basin for each catchment.
NEXT_DOWN	The HYBAS_ID of the sub-catchment directly downstream in the network. If NEXT_DOWN=0, then there is no downstream sub-catchment (ocean outlet, endorheic basin)
DIST_MAIN	The distance in km from the sub-catchment to the main basin.
SUB_AREA	The area of the sub-catchment in km ² .
min	Minimum elevation at the sub-catchment outlet.
Q_avg	The average discharge in m ³ /s for the sub-catchment.
manning	The Manning coefficient used during routing in the sub-catchment.
PFAF	The first three digits of the PFAF ID for the catchment, used for routing groups.
UP_AREA	The combined area of the sub-catchment and all sub-catchments upstream of the sub-catchment in km ² .
PFAF_ID	The 12-digit Pfafstetter ID for the sub-catchment.
LakeArea	Area of lakes (greater than 10km ²) in the sub-catchment in km ² .
LakeAreaPlastic	Area of lakes (greater than 0.5km ²) in the sub-catchment in km ² . Only used if routing solid transport.
CK_Lake	Routing constant for linear reservoir model for lakes.

Parameter	Description
CK_LakeCalc	Potential for variance in the lake routing constant, default same as CK_Lake.
factor0	Lower factor for solid transport routing curve. Only used if routing solid transport.
factor100	Upper factor for solid transport routing curve. Only used if routing solid transport.
LakeCollection	Collect solids in lakes boolean. Only used if routing solid transport.
LakeCollectionCapacity	Mass possible to collect in lakes. Only used if routing solid transport.

2.7.1.5 CellWeights

The cell weights are stored in csv format and at the relative location "..\Configuration\setup_routing\CellWeights.csv". The table is shown in Appendix D. The cell weights file is used to define the model transition from grids to basins. Runoff calculated from distributed NAMs in grid cells is distributed to the appropriate basins in the network.

Table 2.13 Cell weights for DHI-GHM's Fast Kinematic Router

Parameter	Description
HYBAS_ID	Unique 10-digit identification number for each sub-catchment, to denote the HydroBASINS network, as defined in the Basin Definition file.
GRID_ID	Name of the catchment following the naming convention, as defined in the Catchment Definition file (“{x_coord}_{y_coord}”)
REDUCTION	Value from 0 to 1, indicating how much of the area of the grid cell is covered by the sub-catchment. This factor is used to direct runoff from each grid cell to the corresponding sub-catchments.
TILE	Partition number in DHI-GHM's tiling system – same as Partition in the Catchment Definition file.
PFAF	The first three digits of the PFAF ID for the catchment, used for routing groups.

2.7.1.6 From distributed runoff to discharge on natural basins

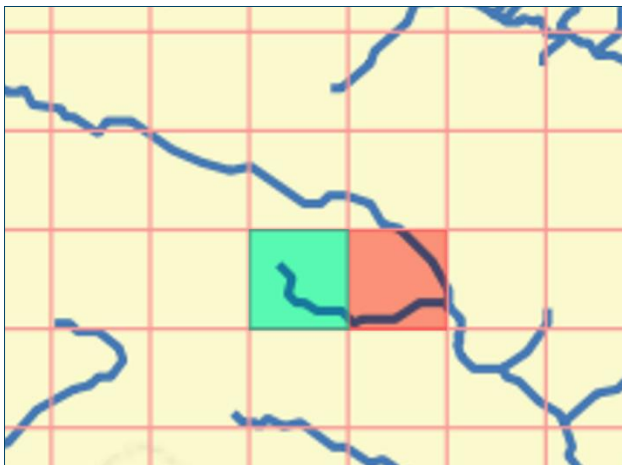
The following images depict the transition of computation from grid cells to natural basins. Grid cells are defined in the Catchment Definition file, and the link to the natural catchments is defined in the Cell Weights file.



Figure 2.43 ERA5 grid: 0.25x0.25 degrees



Figure 2.44 DHI-GHM grid: 0.1x0.1 degrees



```

Name,Umax,Lmax,CQF,CQLow,CRIF,CROF1,CROF2,CRBF,CKLow,TOF,TIF,TG,Csnow,TO,Cwr,K0,SWECoverageMinStorage,Ini_QOF,Ini_QIF,Ini_QBF,Ini_QBFlow,Ini_SWE,Ini_U_Umax,ini_L_Lmax,partition,x,y
102.15_25.25,13.349,133.43,0.7576,0.996476,14.736,14.736,1992.95,1000,0.7585,0.38097,0.5113,2.5,0.5,,25,0,0,0.4,0,0,0.5,0.5,340,102.15,25.25
102.25_25.25,13.416,134.16,0.7657,0.993312,16.401,16.401,1996.62,1000,0.7569,0.38997,0.5129,2.5,0.5,,25,0,0,0.4,0,0,0.5,0.5,340,102.25,25.25
102.35_25.25,13.483,134.83,0.7748,0.990624,18.401,18.401,1996.62,1000,0.7569,0.38997,0.5129,2.5,0.5,,25,0,0,0.4,0,0,0.5,0.5,340,102.35,25.25
102.45_25.25,13.550,135.50,0.7839,0.987936,20.401,20.401,1996.62,1000,0.7569,0.38997,0.5129,2.5,0.5,,25,0,0,0.4,0,0,0.5,0.5,340,102.45,25.25
102.55_25.25,13.617,136.17,0.7930,0.985248,22.401,22.401,1996.62,1000,0.7569,0.38997,0.5129,2.5,0.5,,25,0,0,0.4,0,0,0.5,0.5,340,102.55,25.25
102.65_25.25,13.684,136.84,0.8021,0.982560,24.401,24.401,1996.62,1000,0.7569,0.38997,0.5129,2.5,0.5,,25,0,0,0.4,0,0,0.5,0.5,340,102.65,25.25
102.75_25.25,13.751,137.51,0.8112,0.979872,26.401,26.401,1996.62,1000,0.7569,0.38997,0.5129,2.5,0.5,,25,0,0,0.4,0,0,0.5,0.5,340,102.75,25.25
102.85_25.25,13.818,138.18,0.8203,0.977184,28.401,28.401,1996.62,1000,0.7569,0.38997,0.5129,2.5,0.5,,25,0,0,0.4,0,0,0.5,0.5,340,102.85,25.25
102.95_25.25,13.885,138.85,0.8294,0.974496,30.401,30.401,1996.62,1000,0.7569,0.38997,0.5129,2.5,0.5,,25,0,0,0.4,0,0,0.5,0.5,340,102.95,25.25
103.05_25.25,13.952,139.52,0.8385,0.971808,32.401,32.401,1996.62,1000,0.7569,0.38997,0.5129,2.5,0.5,,25,0,0,0.4,0,0,0.5,0.5,340,103.05,25.25
103.15_25.25,14.019,140.19,0.8476,0.969120,34.401,34.401,1996.62,1000,0.7569,0.38997,0.5129,2.5,0.5,,25,0,0,0.4,0,0,0.5,0.5,340,103.15,25.25
103.25_25.25,14.086,140.86,0.8567,0.966432,36.401,36.401,1996.62,1000,0.7569,0.38997,0.5129,2.5,0.5,,25,0,0,0.4,0,0,0.5,0.5,340,103.25,25.25
103.35_25.25,14.153,141.53,0.8658,0.963744,38.401,38.401,1996.62,1000,0.7569,0.38997,0.5129,2.5,0.5,,25,0,0,0.4,0,0,0.5,0.5,340,103.35,25.25
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103.55_25.25,14.287,142.87,0.8840,0.958368,42.401,42.401,1996.62,1000,0.7569,0.38997,0.5129,2.5,0.5,,25,0,0,0.4,0,0,0.5,0.5,340,103.55,25.25
103.65_25.25,14.354,143.54,0.8931,0.955680,44.401,44.401,1996.62,1000,0.7569,0.38997,0.5129,2.5,0.5,,25,0,0,0.4,0,0,0.5,0.5,340,103.65,25.25
103.75_25.25,14.421,144.21,0.9022,0.952992,46.401,46.401,1996.62,1000,0.7569,0.38997,0.5129,2.5,0.5,,25,0,0,0.4,0,0,0.5,0.5,340,103.75,25.25
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104.05_25.25,14.622,146.22,0.9295,0.944928,52.401,52.401,1996.62,1000,0.7569,0.38997,0.5129,2.5,0.5,,25,0,0,0.4,0,0,0.5,0.5,340,104.05,25.25
104.15_25.25,14.689,146.89,0.9386,0.942240,54.401,54.401,1996.62,1000,0.7569,0.38997,0.5129,2.5,0.5,,25,0,0,0.4,0,0,0.5,0.5,340,104.15,25.25
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104.35_25.25,14.823,148.23,0.9568,0.936864,58.401,58.401,1996.62,1000,0.7569,0.38997,0.5129,2.5,0.5,,25,0,0,0.4,0,0,0.5,0.5,340,104.35,25.25
104.45_25.25,14.890,148.90,0.9659,0.934176,60.401,60.401,1996.62,1000,0.7569,0.38997,0.5129,2.5,0.5,,25,0,0,0.4,0,0,0.5,0.5,340,104.45,25.25
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105.75_25.25,15.761,157.61,1.0842,0.899248,86.401,86.401,1996.62,1000,0.7569,0.38997,0.5129,2.5,0.5,,25,0,0,0.4,0,0,0.5,0.5,340,105.75,25.25
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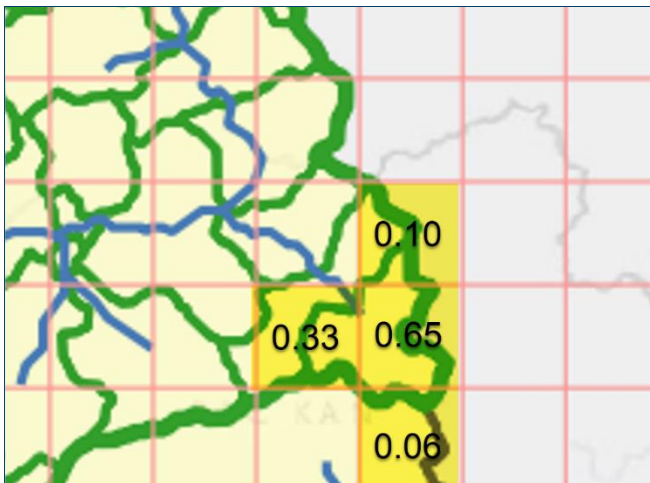


Figure 2.48 Map of the cell weights for transition from grid cells to natural basins for a single sub-catchment

2.7.2 MIKE HYDRO Basin

This section included a description of the MHB model setup used in the system. Figure 2.49 is a schematic representation of the model setup with the river network, schematic catchments, reservoirs and connections. The model is registered in two versions:

- With Data Assimilation (DA) at reservoir water levels
- Without DA

The model consists of:

- 32 catchments
- 11 reservoirs (rule curve reservoirs)

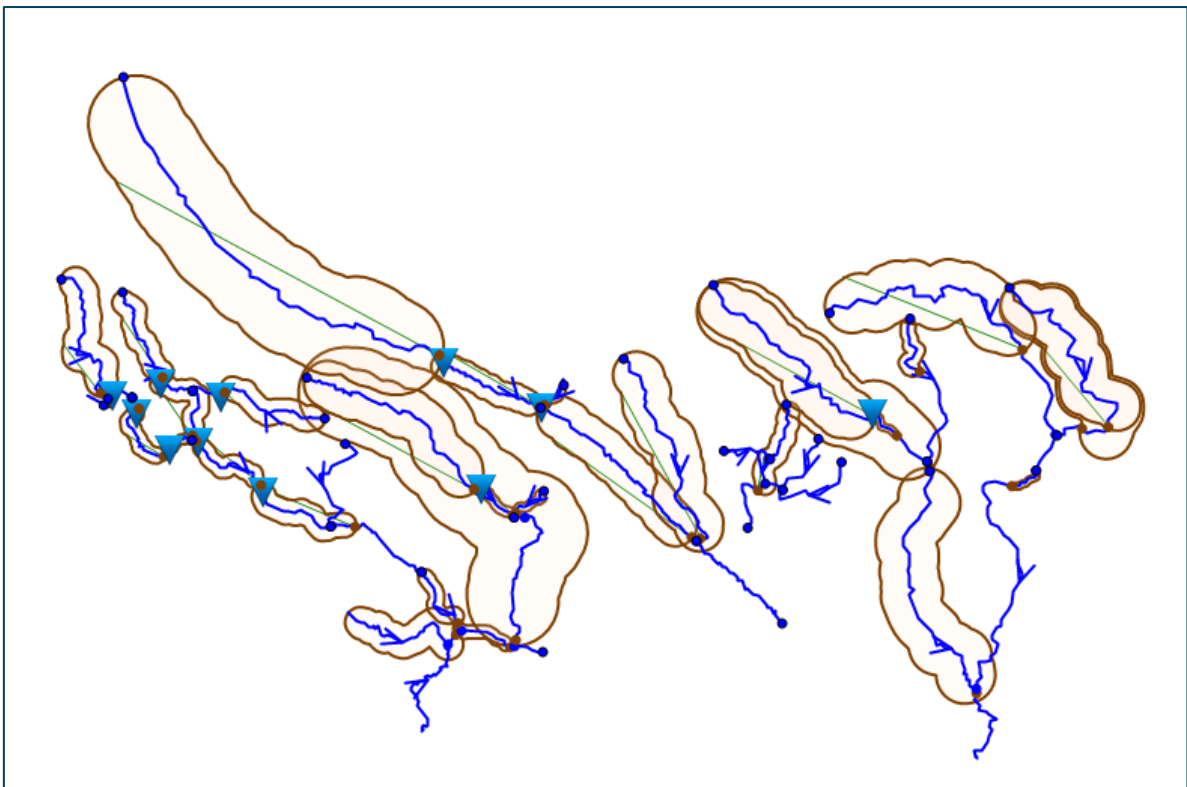


Figure 2.49 Map overview of the MIKE HYDRO Basin model setup

2.7.2.1 Catchments

All the 32 catchments (see Figure 2.52) are set up with the following properties:

- **Area** in km²
- **Runoff time series** with runoff in m³/s

The catchments can be categorised into two types:

- **Head catchments:** runoff time series used as runoff correspond to the DHI-GHM results files located under **Routed_discharge_to_outlet** folder (see section 0) – see example in Figure 2.50
- **Intermediate catchments:** runoff time series used as runoff correspond to the DHI-GHM results files located under **Unrouted_runoff_to_outlet** folder (see section 0) – see example in Figure 2.51.

Figure 2.50 Preview of the catchment definition of a head catchment

Figure 2.51 Preview of the catchment definition of an intermediate catchment

		Name	Area	Branch name	Chainage
8	<input type="checkbox"/>	Da_Lixian_AtJupudu	418.49336	Branch 2	67677.31
9	<input type="checkbox"/>	Da_AtGelatan	1219.4234	Branch 2	112347.54
10	<input type="checkbox"/>	Da_AtBorder	3032.397...	Branch 2	172175.8
11	<input type="checkbox"/>	NamNa_AtNalan	3369.810...	Branch 6	115366.69
12	<input type="checkbox"/>	Thao_AtNansha	34698.37...	Branch 5	234545.86
13	<input type="checkbox"/>	Thao_AtMadustan	2805.417...	Branch 5	296949.83
14	<input type="checkbox"/>	Thao_AtMadushan_trib	131.80403	Branch 19	15286.13
15	<input type="checkbox"/>	Thao_AtBorder	4045.1295	Branch 5	403017.18
▶ 16	<input type="checkbox"/>	Thao_AtBorder_Trib	4485.848...	Branch 7	115194.78
17	<input type="checkbox"/>	Chay_AtBorder	3550.4762	Branch 8	51399.46
18	<input type="checkbox"/>	Lo_AtMalutang	6539.8649	Branch 12	122078.5
19	<input type="checkbox"/>	LO_AtBorderDsMalutang	244.42744	Branch 12	140006.45
20	<input type="checkbox"/>	Mien_AtBorder	1712.375...	Branch 13	36017.96
21	<input type="checkbox"/>	Gam_NhoQue_AtBorder	4044.9617	Branch 14	133429.04
22	<input type="checkbox"/>	Gam_AtBorder	2773.447...	Branch 15	113493
23	<input type="checkbox"/>	Nam_Na_AtBorder	1462.738...	Branch 6	140415.52
24	<input type="checkbox"/>	NamNa_AtBorder_trib	376.49858	Branch 17	21072.53
25	<input type="checkbox"/>	DA_Border2NAM_Nhat	3654.637...	Branch 20	37457.2
26	<input type="checkbox"/>	Da_NamNhat_trib	2866.959...	Branch 21	75675.27
27	<input type="checkbox"/>	NamNhat2Obs	945.63252	Branch 20	69410.74
28	<input type="checkbox"/>	NamNa_Border2Da	2218.566...	Branch 6	223051.96
29	<input type="checkbox"/>	Lo_Mien_Borders2Obs_HaGi...	1530.644...	Branch 12	163475.54
30	<input type="checkbox"/>	Gam_border2Obs1	740.54921	Branch 15	129313.17
31	<input type="checkbox"/>	GamObs1_NhoQue_Border2...	2970.589...	Branch 24	16058.83
32	<input type="checkbox"/>	Lo_HaGiang_Gam2Obs3	11948.19...	Branch 23	140205.84
33	<input type="checkbox"/>	Chau_border2BaoYenObs	1849.563...	Branch 25	76727.58

Figure 2.52 List of the 32 catchments defined in the MHB model setup.

2.7.2.2 Reservoirs

The 11 reservoirs included in the model setup are listed below with their key characteristics:

- Levels
 - Bottom level
 - Dead Zone Level: as known as top of dead storage
 - Dam Crest
 - FCLmax: maximum flood control level
 - FCLmin: minimum flood control level
 - reduct1: reduction level applied below the flood control level.
 - Fraction: reduction fraction
- Hydropower
 - HP Target Demand: hydropower target demand
 - Demand unit: unit of the target demand (m³/s or MW)
 - Installed Cap (MW): installed capacity in MW

- Storage
 - full storage: full storage in MCM
 - dead storage in MCM
 - Live storage in MCM

The main properties of the 11 reservoirs are summarised in Table 2.14.

Table 2.14 Main characteristics of the reservoirs in MHB setup

Name	Res ID	Levels						Reduction fraction	Water Use			Storage (MCM)		
		Bottom	Dead Zone Level	Dam Crest	FCLmax	FCLmin	reduct1		HP Target Demand	Demand unit	Installed Cap (MW)	full storage	dead storage	Live storage
Yayangshan	R2	769	825	857	851	851	846	0	20	m3/s	120	384	137	247
Shimenkan	R60	675	745	791	785	759	758	0	30	m3/s	130	380	183	197
Longma	R62	531	604.8	666	660	660	630	0	45	m3/s	240	750	160	590
Puxiqiao	R64	617	698.4	761	755	755	715	0	30	m3/s	190	656	135	521
Sinanjiang	R66	814	890.5	929	923	923	897	0	20	m3/s	201	424	153	271
Jupudu	R68	458	521	553	547	547	521	0	110	m3/s	285	294	120	174
Gelantan	R70	371	429.6	484	478	478	450	0	120	m3/s	390	503	94	409
Nalan	R72	334	376.5	443	437	433.5	433.5	0	30	MW	150	311	25	286
NanSha	R74	207	263.4	292	286	286	283	0	30	MW	150	362	150	212
Madushan	R76	150	229.5	258	252	252	248	0	0	Flow	300	1,214	663	551
Malutang	R78	494	568.1	648	642	642	580	0	50	Flow	400	643	97	546
Lai Chau	R82	180	270	300	295	295	270	0	280	MW	1200	1,400	450	950

2.7.2.3 Routing of the Hong main river

For the Hong river a significant and slow baseflow component has been observed. Considering the relatively modest reservoir storage on the river this most likely stems for a slow groundwater component. Since the slow lower groundwater component is not available in the DHI-GHM, the base flow in the Hong river has to be further routed upstream of the border.

Consequently, a fictive bifurcation loop (Branch 26) has been introduced taking only the lowest 150 m³/s of the hydrograph. The flow in Branch 26 is routed through an extra linear reservoir with a time constant of 10,000 hours, which has improved the simulated baseflows, see Figure 2.53.

It should be noted, however, that routing storages in MHB is not stored if the normal stage of the model is stored for resetting of the model (hostart). Due to the slow routing, MHB will have to run with large hindcast periods in the order of 6 years to obtain the right state of the linear routing reservoir at TOF.

Another option could have been to describe the linear routing reservoir as a normal reservoir with linear storage and linear spillway formula ($q=x*\text{level}$). Storage in normal reservoirs can be hotstarted or data assimilated.

Alternatively, inactivate the reservoir by changing the diversion from 150 m³/s to 0 m³/s

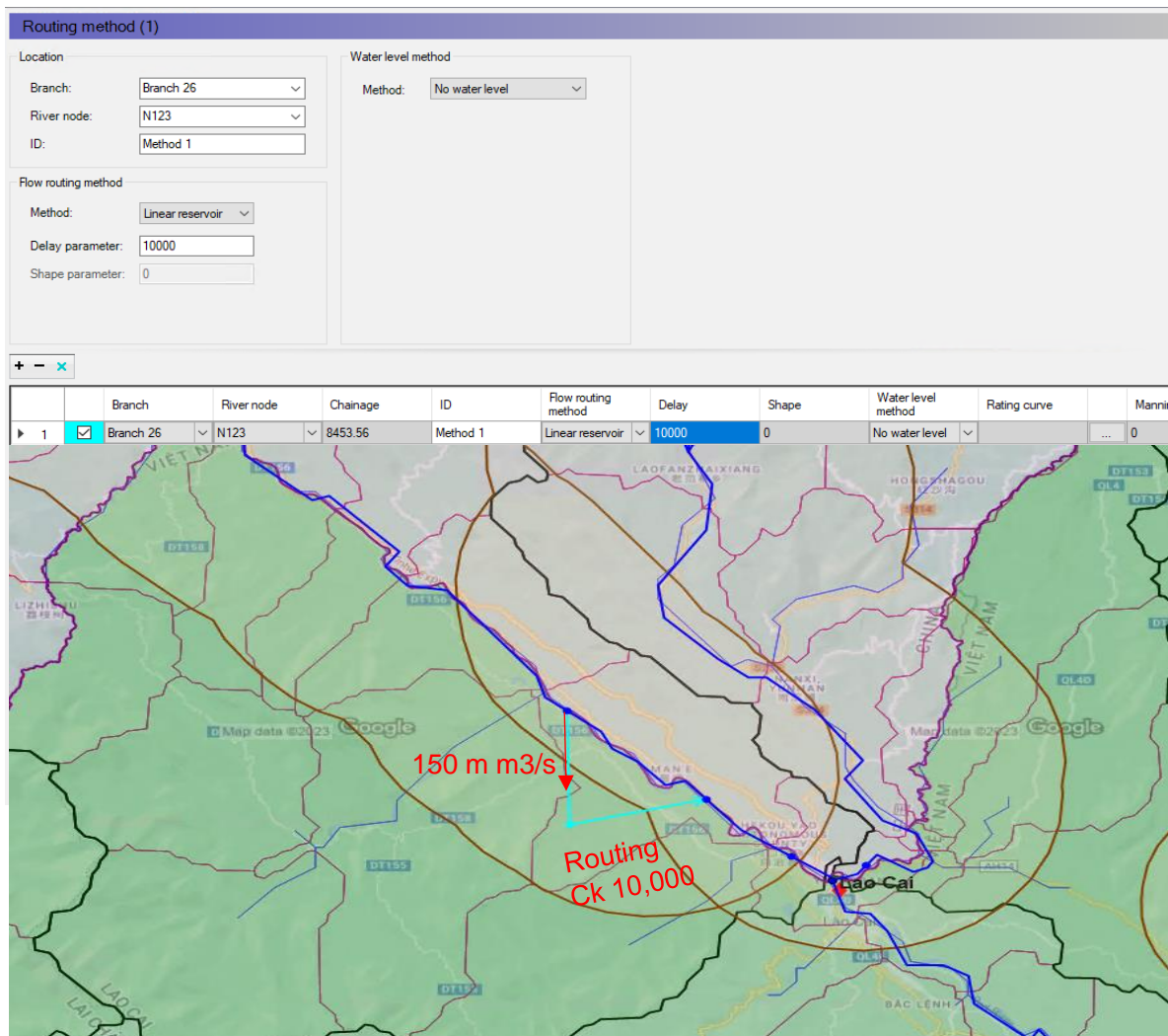


Figure 2.53 Baseflow routing in the Hong River

2.8 Postprocessing

2.8.1 Indicator Estimation

A number of indicators are calculated at the MHB model simulation has been completed. These indicators are computing statistics on the forecasted flow.

2.8.1.1 10-daily statistics

This indicator calculates the mean discharge over the 10-day period. The period covered is from about 1 year before TOF until the end of the time series.

```

def _CalcDailyStats(ts, indiname, nDays, tof, nYears=1):
    def GetDailyStartEnd(tsEnd):
        enddate = tsEnd
        #days between tof - nYears and enddate
        daygap = (tof - tof.AddYears(-nYears)).TotalDays + (enddate - tof).TotalDays
        #bring to 10-daily timestep
        dayrange = (daygap // nDays) * nDays
        startdate = enddate.AddDays(-dayrange)
        return (startdate, enddate)

    ts = ts.Clone()
    ts.Name = "{} {}".format(ts.Name, indiname)

    members = [mem.CreateDataSeries() for mem in ts.Members]

    (resStart, resEnd) = GetDailyStartEnd(ts.End)
    membersProcessed = []
    for m in [mem.CreateDataSeries() for mem in ts.Members]:
        membersProcessed.Add(Resample(m, timeStepDay=nDays, startDate=resStart, endDate=resEnd))

    ts.SetData(membersProcessed[0].GetAll())
    for i in range(1, ts.MembersCount):
        values = map(lambda vp: vp.YValue, membersProcessed[i].GetAll())
        ts.Members[i].SetValues(values)
    return ts

```

Figure 2.54 Code snippet of the methodology to calculate 10-daily statistics of a forecasted timeseries, including the 1 year before time of forecast

2.8.1.2 Monthly statistics

This indicator calculates the monthly mean discharge from about 1 year before TOF until the end of the time series.

```

def _CalcMonthlyStats(ts, indiname, tof, nYears=1):
    def GetMonthlyStartEnd(tsEnd):
        enddate = DateTime(tsEnd.Year, tsEnd.Month, 1)
        startdate = tof.AddYears(-nYears)
        startdate = DateTime(startdate.Year, startdate.Month, 1)
        return (startdate, enddate)

    members = [mem.CreateDataSeries() for mem in ts.Members]

    (resStart, resEnd) = GetMonthlyStartEnd(ts.End)
    membersProcessed = []
    for m in [mem.CreateDataSeries() for mem in ts.Members]:
        membersProcessed.Add(Resample(m, timeStepMonth=1, startDate=resStart, endDate=resEnd))

    ts = createTSCloneEmpty(ts)
    ts.Name = "{} {}".format(ts.Name, indiname)

    ts.SetData(membersProcessed[0].GetAll())
    for i in range(1, ts.MembersCount):
        values = map(lambda vp: vp.YValue, membersProcessed[i].GetAll())
        ts.Members[i].SetValues(values)
    return ts

```

Figure 2.55 Code snippet of the methodology to calculate monthly statistics of a forecasted timeseries, including the 1 year before time of forecast

2.8.1.3 Seasonal statistics

This indicator calculates the seasonal mean discharge from about 1 year before TOF until the end of the time series. The season are defined based on the hydrological year.

```

HYDROLOGICALYEARSTART = 6
def _getSeasonalDate(date, nMonths):
    inMonth = date.Month
    cMonth = HYDROLOGICALYEARSTART
    while cMonth > nMonths:
        cMonth -= nMonths

    while date.Month >= cMonth:
        cMonth += nMonths

    sMonth = cMonth - nMonths
    sYear = date.Year
    if sMonth <= 0:
        sMonth = 12 + sMonth
        sYear -= 1
    return DateTime(sYear, sMonth, 1)

def _CalcSeasonalStats(ts, indiname, nMonths, tof, nYears=1):

    def GetSeasonalStartEnd(tsEndDate):
        enddate = _getSeasonalDate(tsEndDate, nMonths)
        startdate = _getSeasonalDate(tof.AddYears(-nYears), nMonths)
        return (startdate, enddate)

    members = [mem.CreateDataSeries() for mem in ts.Members]

    (resStart, resEnd) = GetSeasonalStartEnd(ts.End)
    membersProcessed = []
    for m in [mem.CreateDataSeries() for mem in ts.Members]:
        membersProcessed.Add(Resample(m, timeStepMonth=nMonths, startDate=resStart, endDate=resEnd))

    ts = createTSCloneEmpty(ts)
    ts.Name = "{} {}".format(ts.Name, indiname)

    ts.SetData(membersProcessed[0].GetAll())
    for i in range(1, ts.MembersCount):
        values = map(lambda vp: vp.YValue, membersProcessed[i].GetAll())
        ts.Members[i].SetValues(values)
    return ts

```

Figure 2.56 Code snippet of the methodology to calculate seasonal statistics of a forecasted timeseries, including the 1 year before time of forecast

2.8.1.4 Historical Means

For each indicator, the indicator is calculated for the period 01.01.2003 – 31.12.2022. Its mean has been stored in the database for each timestep:

- The 10 daily mean contains a timeseries for one year, where every day represents the long-term averaged 10 daily mean.
- The monthly mean has a long-term averaged mean-value for every first day of a month and contains thus 12 values.
- Seasonal contains 4 values at the start of a hydrological season, where each value represents the long-term averaged mean over the season.

After a MHB simulation, statistics are calculated for the forecast period + time of forecast – 1 year. Furthermore, the long term mean statistics are used to extract the timesteps, which are part of the statistics of the forecast. That way, the recently calculated statistics can be plotted against their long-term mean. System performance

2.8.2 Reporting

To inform the operators of the seasonal forecasting system, a reporting framework was set up. This automatically sends the operator(s) an email with a description of the performance of the system. The email starts with a time tag to indicate when the report was generated, followed by the name of the MIKE Workbench database as the amount of free disk space.

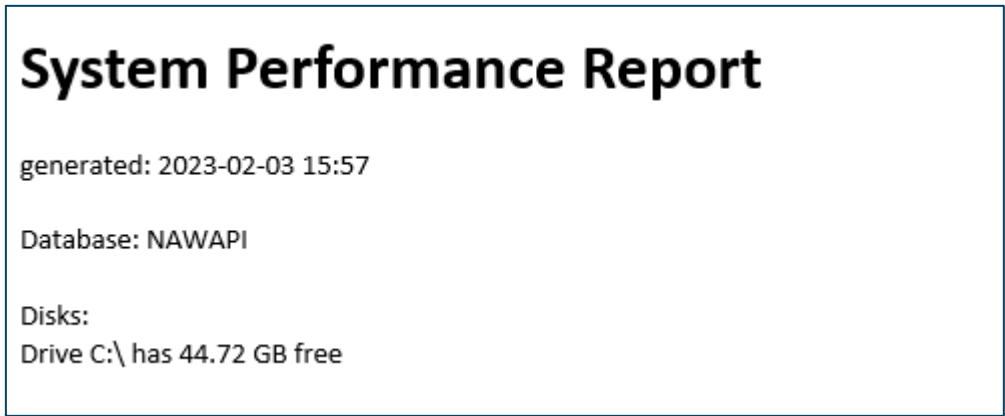


Figure 2.57 System performance report - system specifications

Forcing data

Dataset	Variable	Startdate	Enddate	InvestigationDate	LastModified
Hindcast	Evaporation	1996-01-02 00:00:00	2023-01-28 00:00:00	2023-02-03	2023-02-03 07:38:12
Hindcast	Evaporation	1996-01-02 00:00:00	2023-01-28 00:00:00	2023-02-02	2023-02-03 07:38:12
Hindcast	Rainfall	1979-01-03 00:00:00	2023-01-27 00:00:00	2023-02-03	2023-02-03 03:06:55
Hindcast	Rainfall	1979-01-03 00:00:00	2023-01-27 00:00:00	2023-02-02	2023-02-03 03:06:55
Hindcast	Reservoir water level	2017-02-05 00:00:00	2022-12-29 00:00:00	2023-02-03	
Hindcast	Temperature	1979-01-01 00:00:00	2023-01-27 18:00:00	2023-02-03	2023-02-03 03:09:42
Hindcast	Temperature	1979-01-01 00:00:00	2023-01-27 18:00:00	2023-02-02	2023-02-03 03:09:42
Medium Range Forecast	Evaporation	2021-01-02 00:00:00	2032-01-01 00:00:00	2023-02-03	2021-11-14 05:46:45
Medium Range Forecast	Evaporation	2021-01-02 00:00:00	2032-01-01 00:00:00	2023-02-02	2021-11-14 05:46:45
Medium Range Forecast	Rainfall	2022-10-12 12:00:00	2023-02-18 09:00:00	2023-02-03	2023-02-03 00:29:17
Medium Range Forecast	Rainfall	2022-10-12 12:00:00	2023-02-18 09:00:00	2023-02-02	2023-02-03 00:29:17
Medium Range Forecast	Temperature	2022-10-12 09:00:00	2023-02-18 12:00:00	2023-02-03	2023-02-03 00:30:32
Medium Range Forecast	Temperature	2022-10-12 09:00:00	2023-02-18 12:00:00	2023-02-02	2023-02-03 00:30:32
Seasonal Forecast	Evaporation	2021-01-02 00:00:00	2032-01-01 00:00:00	2023-02-03	2021-11-14 05:46:45
Seasonal Forecast	Evaporation	2021-01-02 00:00:00	2032-01-01 00:00:00	2023-02-02	2021-11-14 05:46:45
Seasonal Forecast	Rainfall	2023-01-12 00:00:00	2023-12-01 00:00:00	2023-02-03	2023-02-03 05:45:57
Seasonal Forecast	Rainfall	2023-01-12 00:00:00	2023-12-01 00:00:00	2023-02-02	2023-02-03 05:45:57
Seasonal Forecast	Temperature	2023-01-11 12:00:00	2023-12-01 00:00:00	2023-02-03	2023-02-03 06:14:29
Seasonal Forecast	Temperature	2023-01-11 12:00:00	2023-12-01 00:00:00	2023-02-02	2023-02-03 06:14:29

Figure 2.58 System Performance Report - Forcing data table

Summary of scenario performance

- Hindcast
 - Forcing data status

Time coverage summary (Evaporation, Rainfall, Temperature): There are possible issues in the time coverage. See below, if simulation is possible. This issue concerns the hindcast simulation and should be resolved soon. Please contact DHI, if the issue is not resolved within the next days. In the meantime, forecast simulations are not dependent on this simulation to work.
 - Evaporation

Update status: File did not receive any update. Check time coverage to assert, whether run can be successful.

Time coverage: Starttime does not match with precipitation. Simulation possible from hotstart. This issue concerns the hindcast simulation and should be resolved soon. Please contact DHI, if the issue is not resolved within the next days. In the meantime, forecast simulations are not dependent on this simulation to work.
 - Rainfall

Update status: File did not receive any update. Check time coverage to assert, whether run can be successful.

Time coverage: OK
 - Temperature

Update status: File did not receive any update. Check time coverage to assert, whether run can be successful.

Time coverage: OK
 - Reservoir water level

Update status: Last timestep available is older than 1 month in at least one reservoir

Time coverage:

Reservoir	Start time	End time	Description
Jupudu	2017-02-05	2023-01-05	
Gelantan	2015-10-31	2022-12-29	Last timestep available is older than 1 month
Nalan	2017-02-05	2023-01-05	
Nansha	2017-02-05	2023-01-05	
Madushan	2017-02-05	2023-01-05	
Yayangshan	2015-10-31	2022-12-29	Last timestep available is older than 1 month
Shimenkan	2015-10-31	2022-12-29	Last timestep available is older than 1 month
Puxiqiao	2015-10-31	2022-12-29	Last timestep available is older than 1 month
Malutang	2014-10-16	2022-12-31	Last timestep available is older than 1 month
Sinanjiang	2017-02-05	2023-01-05	
Longma	2014-10-21	2023-01-07	

Figure 2.59 System Performance Report - Summary of scenario performance

Jobs

last 3 job instances per jobhost in the past 96 hours

job	At
00_RunAll	
01a_GHM_ERA5	NAWAPI @ 2023-02-03 11:30:07 - Finished Success - 00:05:46 NAWAPI @ 2023-02-02 11:30:07 - Execution Error - 00:02:42 NAWAPI @ 2023-02-01 11:30:06 - Execution Error - 00:00:29
01b_GHM_GFS	NAWAPI @ 2023-02-03 11:45:07 - Finished Success - 00:01:41 NAWAPI @ 2023-02-02 11:45:05 - Finished Success - 00:01:39 NAWAPI @ 2023-02-01 11:45:08 - Finished Success - 00:02:31
01c_GHM_CFS	NAWAPI @ 2023-02-03 12:00:06 - Finished Success - 00:35:35 NAWAPI @ 2023-02-02 12:00:05 - Finished Success - 00:35:15 NAWAPI @ 2023-02-01 12:00:06 - Finished Success - 00:33:42
02a_MHB_GFS	NAWAPI @ 2023-02-03 13:00:07 - Finished Success - 00:05:13 NAWAPI @ 2023-02-02 13:00:05 - Finished Success - 00:05:17 NAWAPI @ 2023-02-01 13:00:08 - Finished Success - 00:05:29
02b_MHB_CFS	NAWAPI @ 2023-02-03 13:15:08 - Execution Error - 00:44:49 NAWAPI @ 2023-02-02 13:15:06 - Finished Success - 00:59:27 NAWAPI @ 2023-02-01 13:15:05 - Finished Success - 01:05:27
03_Maintenance	NAWAPI @ 2023-02-03 02:30:07 - Finished Success - 00:00:06 NAWAPI @ 2023-02-02 14:30:10 - Finished Success - 00:00:08 NAWAPI @ 2023-02-01 14:30:10 - Finished Success - 00:00:11
04_DatabaseBackup	NAWAPI @ 2023-02-03 03:30:05 - Finished Success - 00:12:43 NAWAPI @ 2023-02-02 14:45:06 - Finished Success - 00:13:40 NAWAPI @ 2023-02-01 14:45:09 - Finished Success - 00:21:32
05_MakeDailyReport	NAWAPI @ 2023-02-03 15:56:19 - Running - 00:01:38.8191990 NAWAPI @ 2023-02-03 15:30:48 - Finished Success - 00:01:13 NAWAPI @ 2023-02-03 15:28:01 - Finished Success - 00:01:14

Figure 2.60 System Performance Report - Jobs table

Finally, two tables are included with the result of system runs, namely:

- Jobs table: indication of number of jobs executed in the last 48 hours, job name, time of completion of run, whether it was executed successfully or returned an error.
- Simulations table: name of the scenario the run corresponds to (the system runs seasonal and mead), time of completion of run, approval status and time of forecast (TOF).

System basin model status

last 3 simulations in the past 48 hours

Simulation	Execution time	Status	Time of forecast
Upper_Hong_Thai_binh_Final - CFS Upper_Hong_Thai_binh_Final	2023-02-03 13:15:13	APPROVED	2023-02-03 06:00:00
Upper_Hong_Thai_binh_Final - CFS Upper_Hong_Thai_binh_Final	2023-02-02 13:15:09	APPROVED	2023-02-02 06:00:00
Upper_Hong_Thai_binh_Final - CFS Upper_Hong_Thai_binh_Final	2023-02-01 13:15:09	APPROVED	2023-02-01 06:00:00
Upper_Hong_Thai_binh_Final - GFS Upper_Hong_Thai_binh_Final	2023-02-03 13:00:12	APPROVED	2023-02-03 06:00:00
Upper_Hong_Thai_binh_Final - GFS Upper_Hong_Thai_binh_Final	2023-02-02 13:00:09	APPROVED	2023-02-02 06:00:00
Upper_Hong_Thai_binh_Final - GFS Upper_Hong_Thai_binh_Final	2023-02-01 13:00:13	APPROVED	2023-02-01 06:00:00

Figure 2.61 System Performance Report -System basin model status

Table 2.15 Status messages for simulations in MIKE Workbench

Status	Description
UNDEFINED	the initial status message when the simulation definition in the database is created
INITIALIZED	simulation name, simulation dates etc have been given
INPUT_DATA_ERROR	the status set after start generating into for the model
INPUT_DATA_OK	all is created and saved
MODEL_RUN_ERROR	the status set once the model run is started. If the model fails, roll back to this state.
MODEL_RUN_OK	status after successful model run
OUTPUT_DATA_ERROR	outputs are started to be retrieved retrieving,. If something goes wrong, stay at this Status
OUTPUT_DATA_OK	is set when we have successfully saved the outputs in the database and cleaned up the simulation folder
APPROVED	set once we have successfully approved the simulation (including eventual copying of outputs and initial conditions to the database)

2.8.3 Error Logging

When running a job using the target RunAll, and a target errors, thus the job is erroring, the target SendErrorLog is called. Which sends the whole log as html.

```

Target executed at: 3/2/2023 15:11:55. Duration: 1m 48s 83ms

05_MakeDailyReport (1m 47s 989ms)
GenerateHTML_ForcingData (43s 694ms)
python ".\Tools\py\GenerateReportingHTML.py" -htmlfile \\DKCPH1-STOR.DHI.DK\Projects\11826891\RedRiverGHM\Results\HTML\latest\html.txt -repsup ".\Tools\py\SetupFiles\NAWAPI_Reporting.yml"
-htmfile \\DKCPH1-STOR.DHI.DK\Projects\11826891\RedRiverGHM\Results\HTML\latest\html.txt
2023-02-03 15:12:00 - Reading ..\Timeseries\vainfall_eras\340.dfs2
2023-02-03 15:12:06 - Reading ..\Timeseries\temperature_eras\340.dfs2
2023-02-03 15:12:23 - Reading ..\Timeseries\evaporation_priestly_taylor_hindcast\340.dfs2
2023-02-03 15:12:27 - Reading ..\Hotstart\ERAS\NAM\latest\GHM_340.20230127T0000000.sta1d
2023-02-03 15:12:27 - Reading ..\Timeseries\vainfall_gfs\340.dfs2
2023-02-03 15:12:28 - Reading ..\Timeseries\temperature_gfs\340.dfs2
2023-02-03 15:12:29 - Reading ..\Timeseries\evaporation_priestly_taylor_forecast\340.dfs2
2023-02-03 15:12:34 - Reading ..\Hotstart\GFS\latest\ERAS\NAM\GHM_340.20230127T0000000.sta1d
2023-02-03 15:12:34 - Reading ..\Timeseries\vainfall_cfs\340_0.dfs2
2023-02-03 15:12:35 - Reading ..\Timeseries\temperature_cfs\340_0.dfs2
2023-02-03 15:12:37 - Reading ..\Timeseries\evaporation_priestly_taylor_forecast\340.dfs2
2023-02-03 15:12:38 - Reading ..\Hotstart\CFS\latest_gfs\NAM\GHM_340.20230203T0000000.sta1d
2023-02-03 15:12:38 - Setting html for Hindcast
2023-02-03 15:12:38 - Setting html for MediumRange Forecast
2023-02-03 15:12:38 - Setting html for Seasonal Forecast
2023-02-03 15:12:38 - Writing \\DKCPH1-STOR.DHI.DK\Projects\11826891\RedRiverGHM\Results\HTML\latest\table.csv
2023-02-03 15:12:38 - Writing \\DKCPH1-STOR.DHI.DK\Projects\11826891\RedRiverGHM\Results\HTML\latest\html.txt

RunScript - MakeDailyReport (1m 3s 983ms)
InputProperties:Script=/Reporting/MakeDailyDataReport;P1=jaan@dhigroup.com;P2=\\DKCPH1-STOR.DHI.DK\Projects\11826891\RedRiverGHM\Results\HTML\latest\html.txt;P3=;P4=;P5=;P6=;P7=;P8=;P9=
2023-02-03 15:12:46 - 00_RunAll
2023-02-03 15:12:46 - 01a_GHM_FRAS

2023-02-03 15:13:33 / - 2023-02-03 13:15:13
2023-02-03 15:13:37 - 2023-02-02 13:15:09
2023-02-03 15:13:37 - 2023-02-01 13:15:09
2023-02-03 15:13:37 - GFS_Upper_Hong_Thei_binh_Final
: ERROR C:\Users\jaan\AppData\Local\Temp\DHIDSS\PID6464\JOB_0cae7e7f-d8f5-4a54-8319-7ba5eb4d3dc\05_MakeDailyReport.job(1,954,GenericADOException: could not execute query
[ SELECT this_id as id250_0, this_name as name250_0, this_description as descript3_250_0, this_simulation_start_date as simulation4_250_0, this_time_of_forecast as time5_250_0, this_simulation_end_date as
simulation6_250_0, this_content as content250_0, this_status as status250_0, this_out_init_condition_content as out9_250_0, this_out_init_condition_start_date as out10_250_0, this_out_init_condition_end_date as
out11_250_0, this_scenario_id as scenario12_250_0, this_time_of_simulation_run as time13_250_0, this_ensemble_runs as ensemble14_250_0, this_parent_id as parent15_250_0, this_model_setup_id as
model16_250_0, this_job_instance_log as job17_250_0, this_param_spreadsheet_id as param18_250_0, this_total_simulation_time as total19_250_0, this_version as version250_0 FROM workspace1.simulation this_
WHERE this_scenario_id in (:p0)
Name:cp0 - Value:33f32d3-c239-4ddb-e8b6-e8d1c9e1a714
[SQL: SELECT this_id as id250_0, this_name as name250_0, this_description as descript3_250_0, this_simulation_start_date as simulation4_250_0, this_time_of_forecast as time5_250_0, this_simulation_end_date as
simulation6_250_0, this_content as content250_0, this_status as status250_0, this_out_init_condition_content as out9_250_0, this_out_init_condition_start_date as out10_250_0, this_out_init_condition_end_date as
out11_250_0, this_scenario_id as scenario12_250_0, this_time_of_simulation_run as time13_250_0, this_ensemble_runs as ensemble14_250_0, this_parent_id as parent15_250_0, this_model_setup_id as
model16_250_0, this_job_instance_log as job17_250_0, this_param_spreadsheet_id as param18_250_0, this_total_simulation_time as total19_250_0, this_version as version250_0 FROM workspace1.simulation this_
WHERE this_scenario_id in (:p0)]
at NHibernate.Loader.Loader.DoList(ISessionFactory session, QueryParameters queryParameters)
at NHibernate.Loader.Loader.ListIgnoreQueryCache(ISessionFactory session, QueryParameters queryParameters)
at NHibernate.Impl.SessionImpl.List(CriteriaImpl criteria, IList results)
at NHibernate.Impl.CriteriaImpl.List(IList results)
at NHibernate.Impl.CriteriaImpl.List(T[])
at DHI.Solutions.Generic.Data.DAO`1.Query(IQuery query)
at DHI.Solutions.Generic.Business.BaseEntityList`1.Query(IQuery query)
at DHI.Solutions.ScenarioManager.Business.SimulationList.Query(IQuery query)
at DHI.Solutions.Generic.Business.BaseEntityList`1.Fetch(IQuery query)

```

Figure 2.62 Example-email of error logging. Sent to

Common error message:

- Validation Errors: most likely simulation period does not match with forcing data. If it happens, it is usually in the hindcast and when forcing data has not been updated (no new time to simulate)

```

RunNAM
RunNAM
Information
Properties
Log
".\Tools\GlobalHydroRunner_MIKE2022\GlobalHydroRunner.exe" -r ".\Configuration\ERA5\NAM.conf"
Updated 6577 / 7800 catchment from par. file in GHM_340.m1dx
Running partitions with number of threads 1:
Z:\11826891\RedRiverGHM\Configuration\ERA5\GHM_340.m1dx
Created directory Z:\11826891\RedRiverGHM\Results\ERA5\NAM
Cleaning up sta1d files. Found: 0
Hotstart file found: ..\Hotstart\ERA5\NAM\latest\GHM_340.20230120T0000000.sta1d
Running instance : GHM_340
Unhandled Exception: System.Exception: Validation errors, aborting
at GlobalHydroRunner.ModelRunners.RunModel(String simFile, Nullable`1 nInstance, Int32 dfs2OutputMode, Boolean
at GlobalHydroRunner.ModelRunners.RunModelParallel(List`1 mike1dFilePaths, Int32 numberThreads, Boolean
at GlobalHydroRunner.Program.Main(String[] args) in C:\Users\jaan\OneDrive - DHI\repos\GlobalHydrologicalM
: ERROR C:\Users\jaan\AppData\Local\Temp\DHIDSS\PID11328\JOB_bb17d326-63cd-4e5e-b56d-9a5ecc807531

```

Figure 2.63 Log of the job

2.9 Setup operational system

This section described how the operational workflow has been setup via jobs.


2.9.1 Working directory for DHI-GHM jobs

To setup the Working directory, open the jobs by double clicking on them from the Job manager in MW.

A list of existing jobs where the working directory must be setup:

- 01a_GHM_ERA5
- 01b_GHM_GFS
- 01c_GHM_CFS
- 05_MakeDailyReport

Under “Properties”, find the entry WorkDir. Update its “Value” with the working directory, identified in section 2.4.5.

Save the job clicking . The job can now be closed

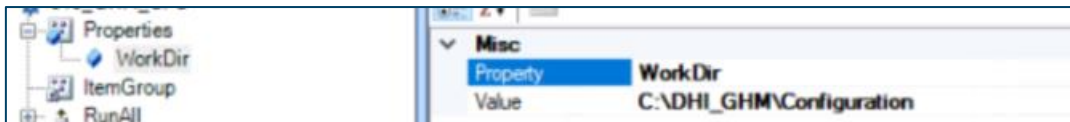


Figure 2.64 Setup WorkDir on a job

2.9.2 Create a job schedule

Jobs in MIKE Workbench can be scheduled and thus ran operationally. For the operational run of the DHI-GHM, a job schedule must be created for the following jobs:

- 01a_GHM_ERA5
- 01b_GHM_GFS
- 01c_GHM_CFS
- 02a_MHB_GFS
- 02b_MHB_CFS
- 03_Maintenance
- 04_DatabaseBackup
- 05_MakeDailyReport

To create a job schedule, right click on the job and select “Create a schedule”:

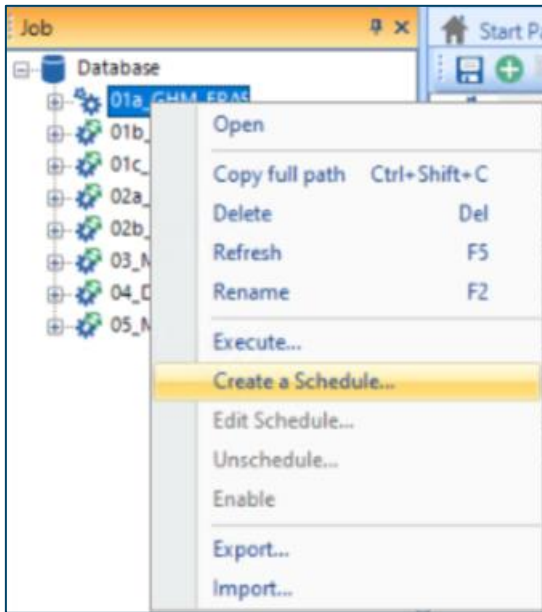


Figure 2.65 Job menu to create a Schedule

Click “Add”

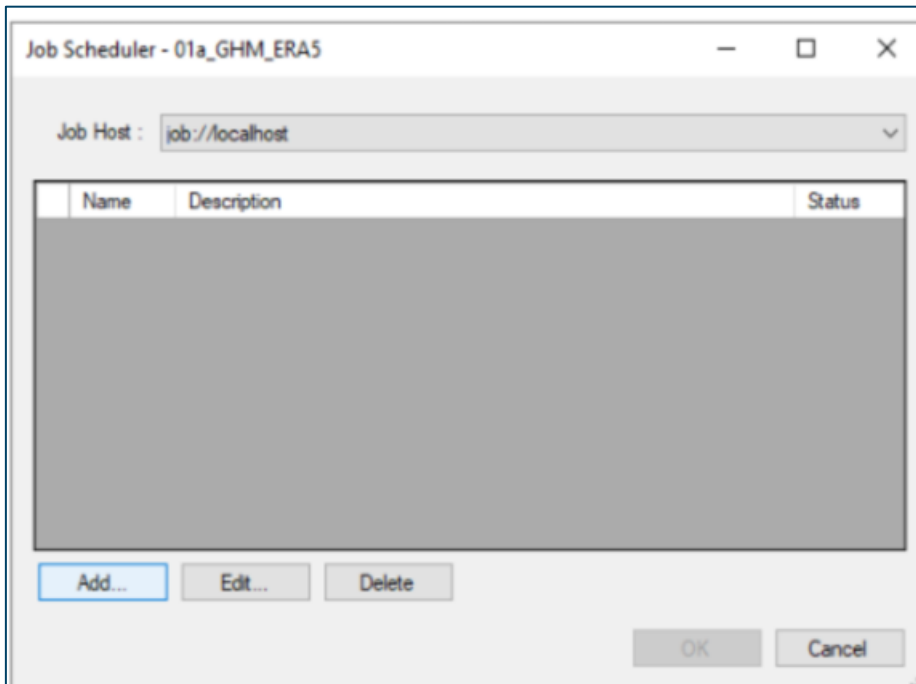


Figure 2.66 Properties of a job scheduler

Under “General”, give the job a name and select the targets, which shall be executed. In this system, only “RunAll” needs to be selected for each job.

Figure 2.67 Properties of the job schedule – General tab

Under the ribbon “Triggers” click “New” to create a new trigger.

Trigger	Details

Figure 2.68 Properties of the job schedule – Triggers tab

Set the schedule wanted and click “OK”.

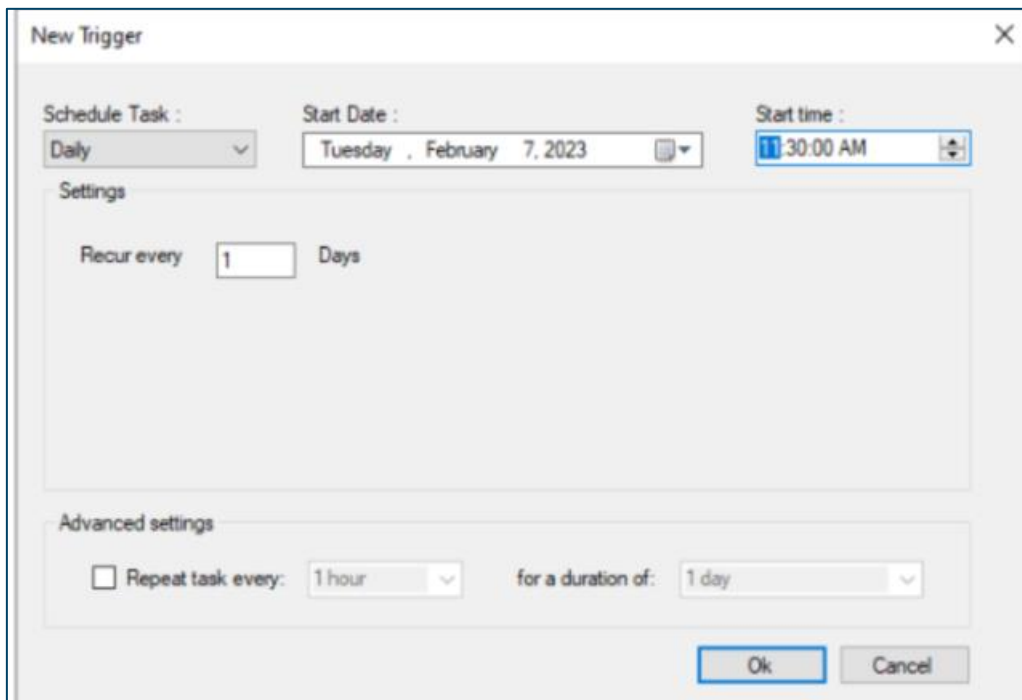



Figure 2.69 Trigger properties for a job scheduler

Close all windows by clicking “OK”. The job has now the scheduler sign attached. 

2.9.3 Edit a job schedule

Job schedules can be an iterative process and schedules may need adjustment.

In this system, the jobs should be executed after each other. The previous job should be finished before the next one is executed.

Simulation jobs are regarded as one group and should be executed in sequence.

1. 01a_GHM_ERA5
2. 01b_GHM_GFS
3. 01c_GHM_CFS
4. 02a_MHB_GFS
5. 02b_MHB_CFS

Where maintenance related jobs can be seen as another group and can be scheduled independently.

1. 03_Maintenance
2. 04_DatabaseBackup
3. 05_MakeDailyReport

To modify a job schedule, right click on the job and select “Edit Schedule”.

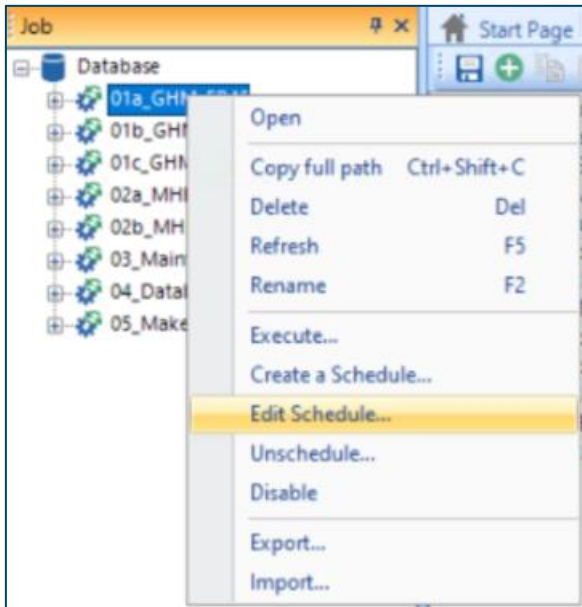


Figure 2.70 Job menu to edit a schedule

Select the schedule and click “Edit”.

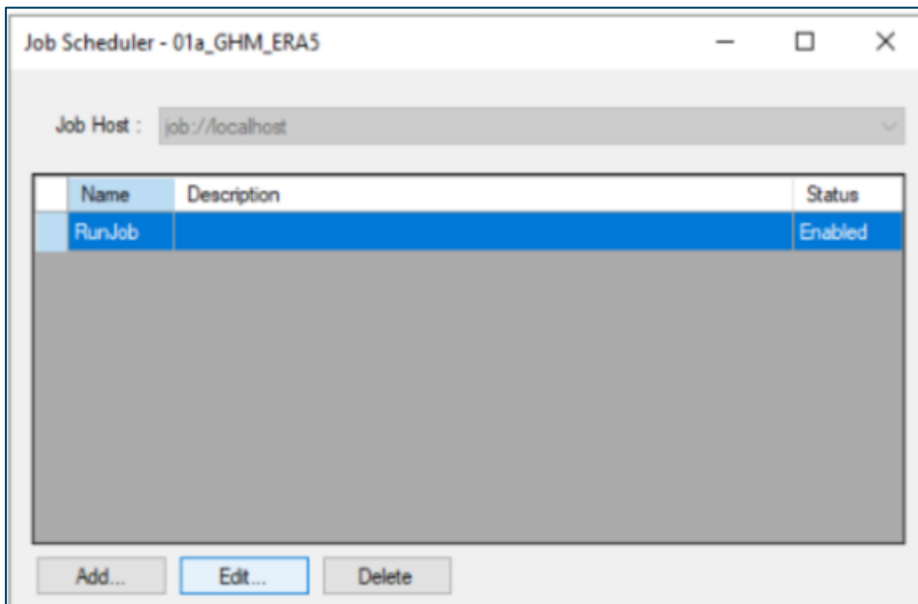


Figure 2.71 Job scheduler properties

Under “Triggers” select the trigger to edit and click “Edit”.

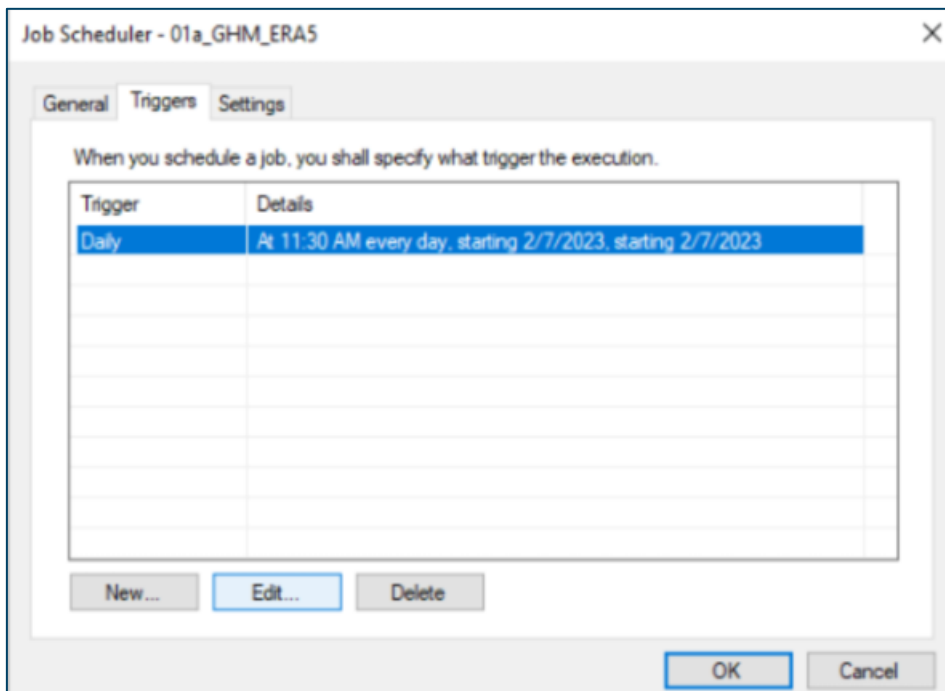


Figure 2.72 Job scheduler – Edit trigger option

Select the new trigger time and close with “OK”.

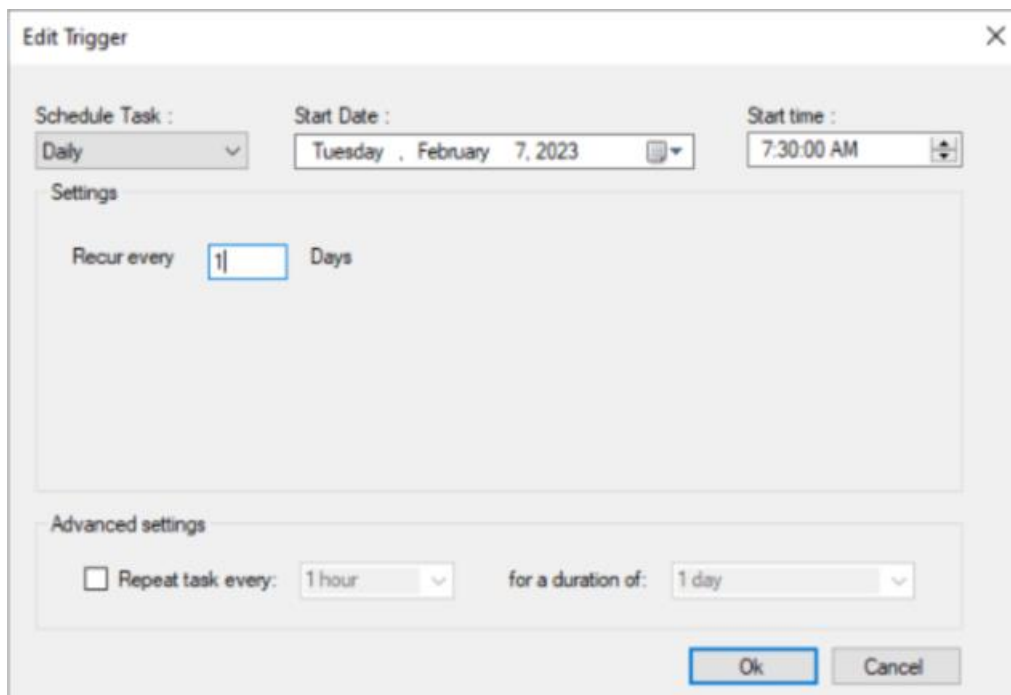


Figure 2.73 Job scheduler – Edit trigger option schedule

Close all windows by clicking “OK”.

3 System Operation

This chapter describes how the jobs are organized and how the operation is scheduled.

3.1 From Satellite data to MHB Simulations

Satellite data is downloaded by DHI and converted to Dfs2-tiles, which is the forcing data to the hydrological model of the Hydrological Forecasting Component of the system. The software and model used in this component is the DHI-GHM (the Global Hydrological Model of DHI). In this component there are three types of simulations: hindcast, medium range- forecast and seasonal forecast simulation. For each of the three, datasets of precipitation, temperature and potential evaporation are prepared. The simulation periods associated with each simulation of the Hydrological Forecasting Component are depicted in Figure 3.1.

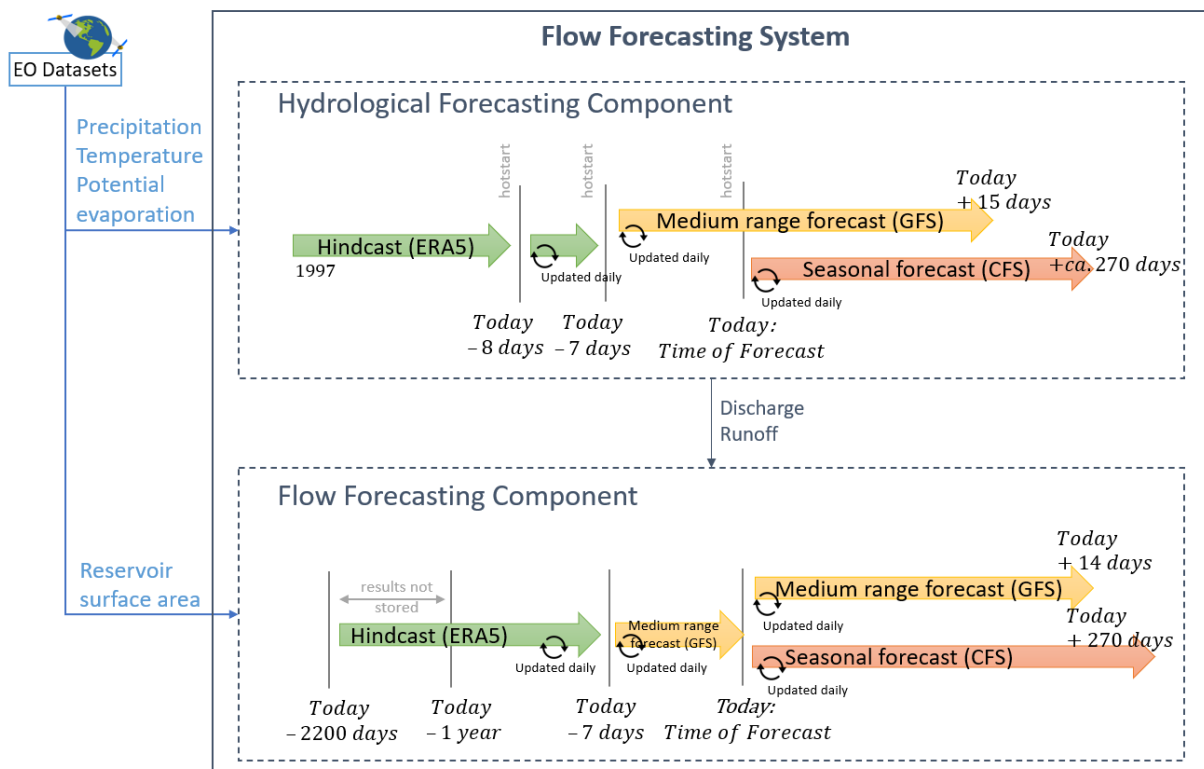


Figure 3.1 Overview of data-input to the simulations of the DHI-GHM and MHB models within their respective system components

The DHI-GHM model hindcast simulation is updated daily, where the latest added data is used to run the simulation, hot started from the previous simulation. This simulation produces another hotstart, which replaces the previous as “latest status”. It will be used to hotstart the Medium Range Forecast, MRF, which at the current days’ time at 00:00 will extract its state as hotstart. However, it will continue simulating until 14 days forecast to simulate MRF GHM results (yellow arrow of the hydrological forecast component). The MRF hotstart will then be used as input to the Seasonal Forecast, SF, (orange arrow of the hydrological forecast component), which will simulate all 20 ensemble members of that dataset (the simulation is run 20 times) and up to about 270 days lead time.

At some locations, discharge and intermediate runoff will be extracted, imported into MIKE Workbench and set as an input to the MHB model of the flow forecasting component of the system.

Moving into the Flow Forecasting Component of the system (bottom half of Figure 3.1), as the model is not hotstarted, a warmup-period of 2200 days was introduced. Until 7 days prior to the current day, the outputs of the hydrological hindcast simulation are used (green arrow of the flood forecasting component) in the simulation, followed by the MRF outputs until the current day, which is also Time of Forecast (ToF). After ToF, the MHB simulations run using its respective forecast products (yellow and orange arrows of the flow forecasting component) up until the end of their respective lead times.

Results are stored within a period of one year before the current day until a set number of days after ToF (MRF: 15, SF: 270).

3.2 DHI-GHM Simulations

The DHI-GHM model is run operationally. Input datasets are used for the distributed NAM models and then the Fast Kinematic Router component. Model results are postprocessed to calculate key indicators. The different components are illustrated below.

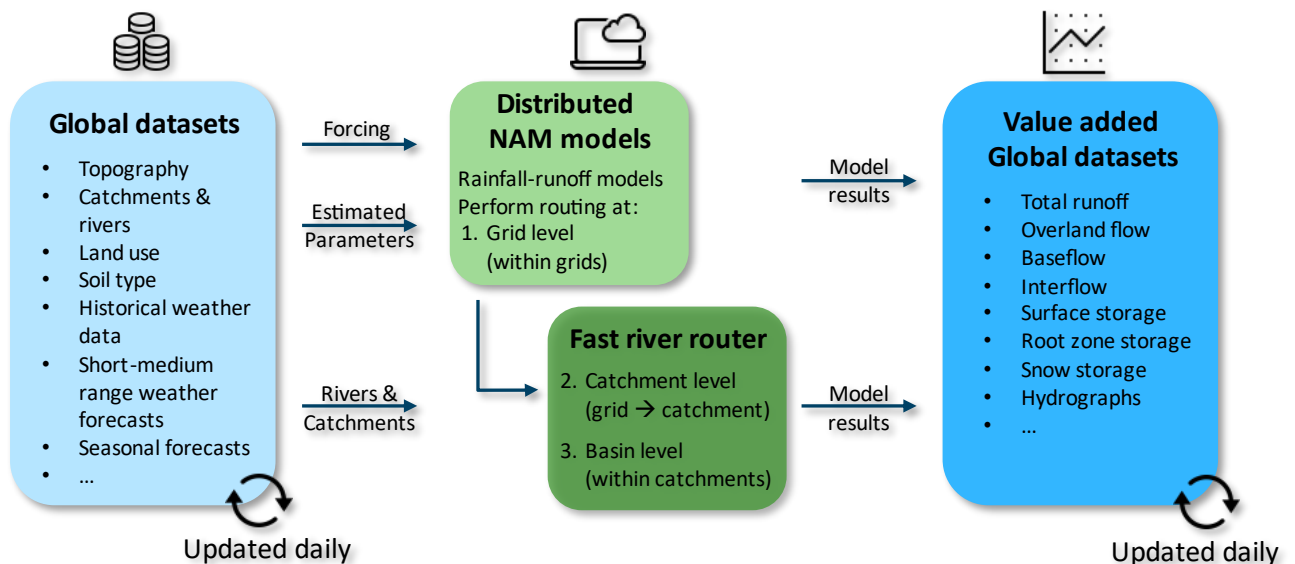


Figure 3.2 Operational workflow of DHI-GHM

3.2.1 General operational workflow

The DHI-GHM is scheduled using MIKE Workbench’s Job Manager. A DHI-GHM job usually has the following targets to execute:

1. Get Forcing Data
2. Hotstart handling – pre simulation
3. Simulate rainfall runoff (NAM)
4. Simulate discharge (Routing)
5. Hotstart handling – post simulation
6. Result postprocessing
7. Result import to MIKE Workbench database

Furthermore, each job has 2 targets, called “RunAll” and “SendErrorLog”. “RunAll”-target can be used to run all the targets needed the target “SendErrorLog” is started, if one of the targets in RunAll is erroring. It sends the job-log as html to the recipients, set in the target.

3.2.2 Simulating hindcast

This section describes the target-workflow of the DHI-GHM hindcast simulation. The job for the hindcast simulation is called 01a_ERA5.

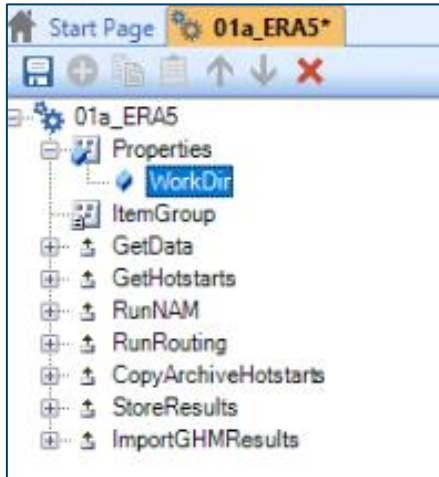


Figure 3.3 Job to run DHI-GHM simulations for the Hindcast period

3.2.2.1 Get Forcing Data

This target downloads DHI-GHM forcing data from DHI's Azure blob-storage.

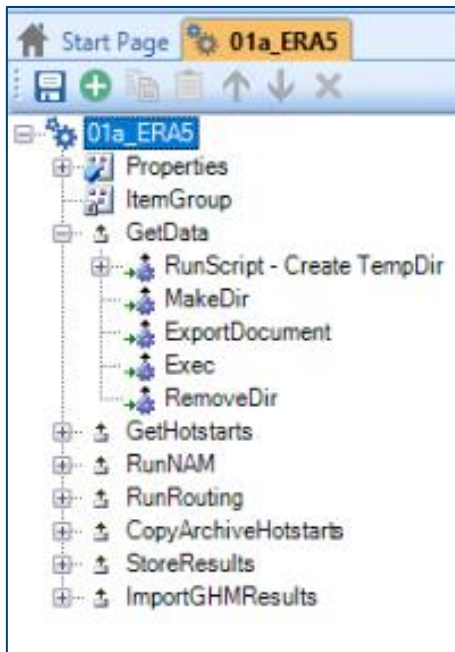


Figure 3.4 Target for getting forcing data.

3.2.2.2 Hotstart handling – pre simulation

This target ensures hotstart files used by the routing model are in the expected location.

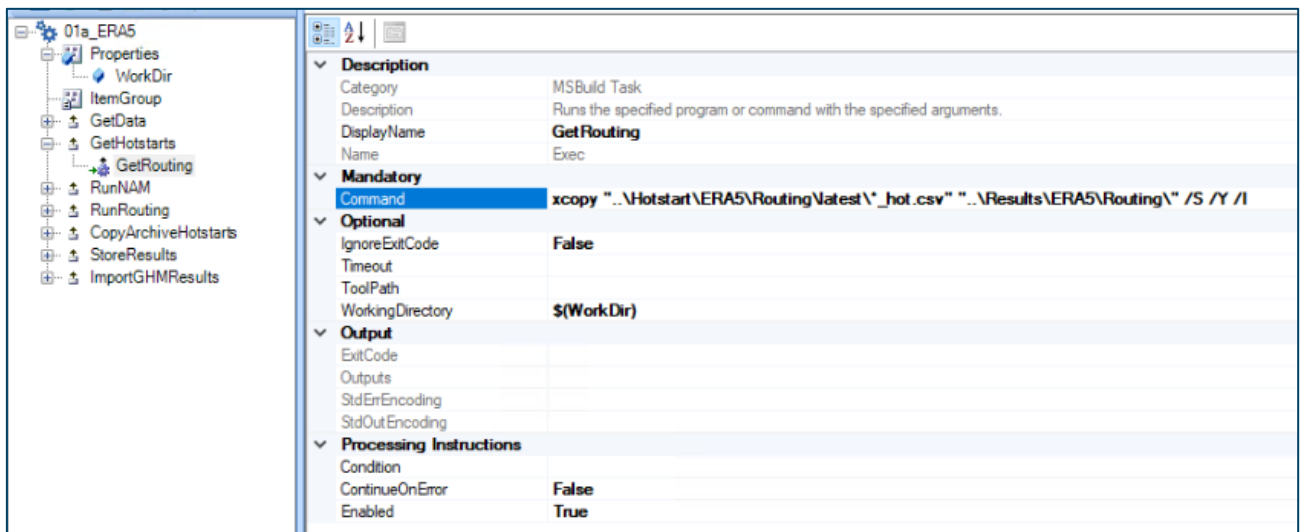


Figure 3.5 Target for Hotstart handling

3.2.2.3 Simulate rainfall runoff (NAM)

This target runs the NAM simulation of the DHI GHM model.

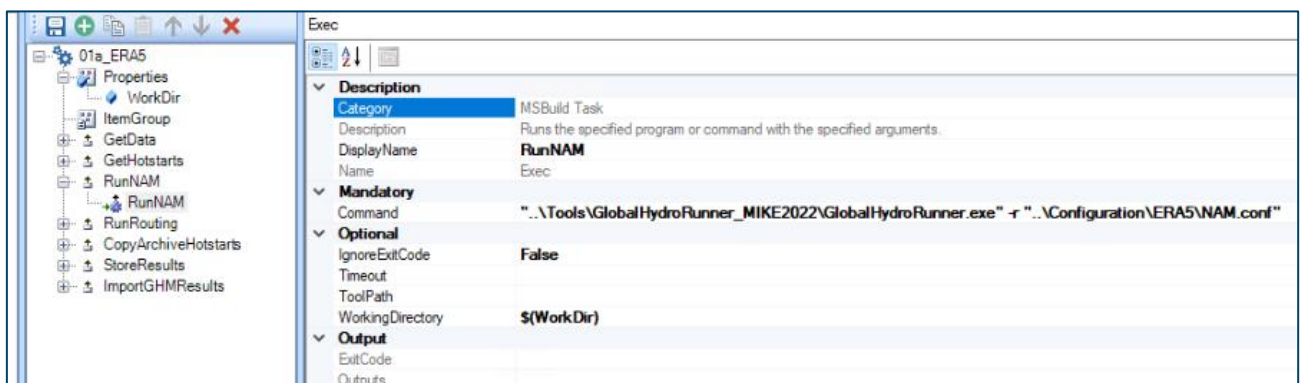


Figure 3.6 Target for Simulating rainfall runoff (NAM)

3.2.2.4 Simulate discharge (Routing)

This target runs the routing component of DHI-GHM model.

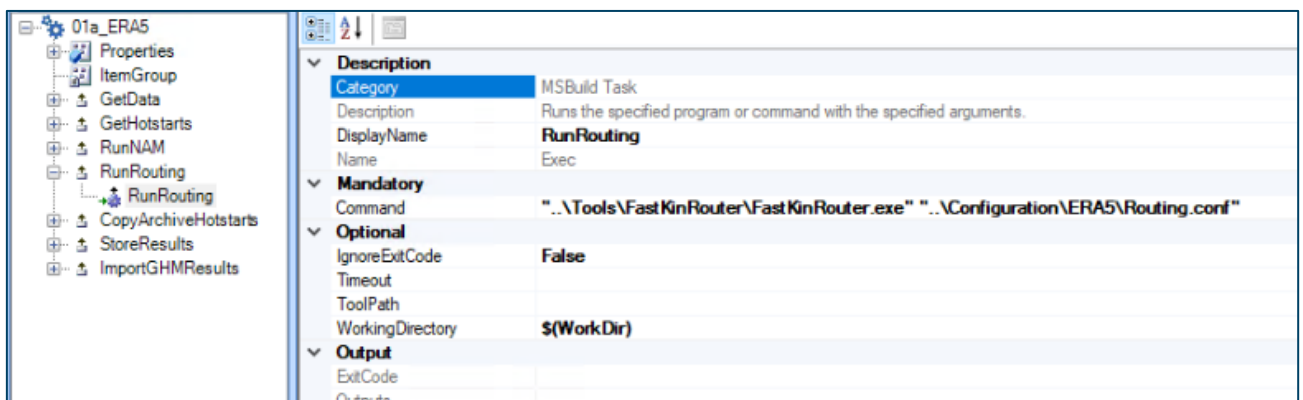


Figure 3.7 Target for running routing

3.2.2.5 Hotstart handling – post simulation

This target has 2 steps:

1. To copy NAM hotstart files to latest folder, so they can be used by the next simulation

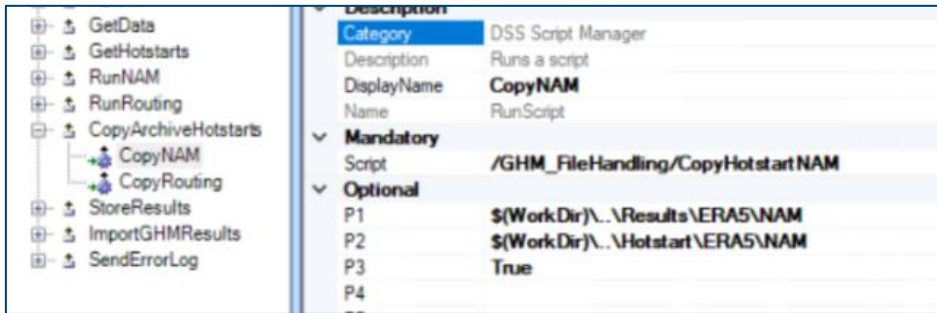


Figure 3.8 Target for Hotstart handling after simulation – step 1

2. Copy Routing hotstart files to latest folder, so they can be used by the next simulation.

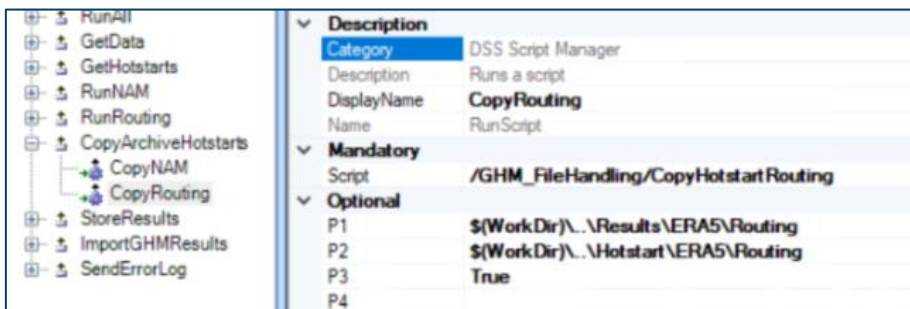


Figure 3.9 Target for Hotstart handling after simulation – step 2

3.2.2.6 Result postprocessing

This target creates a long timeseries into folder “..\Results\ERA5_full\Routing” and then updates the long timeseries with most recent data.

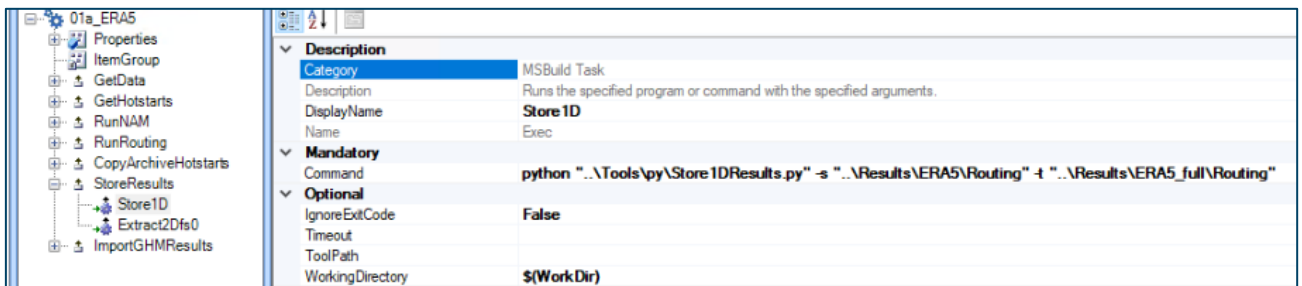


Figure 3.10 Target for Result postprocessing – step 1

Then it extracts the timeseries at given locations and export to Dfs0 files.

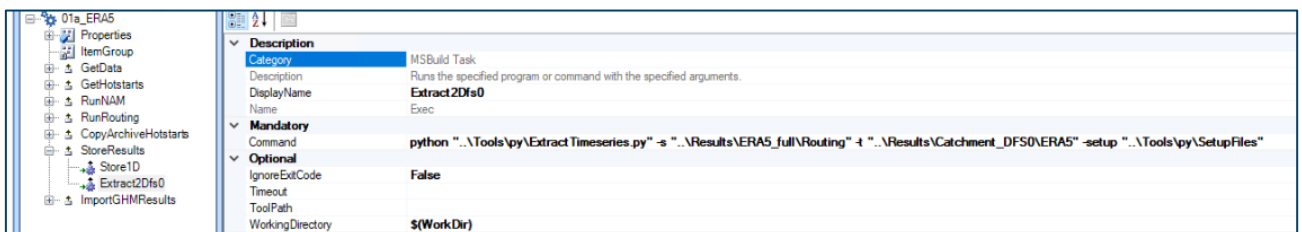


Figure 3.11 Target for Result postprocessing – step 2

3.2.2.7 Result import to MIKE Workbench database

This targets imports Dfs0 files into MIKE Workbench database.

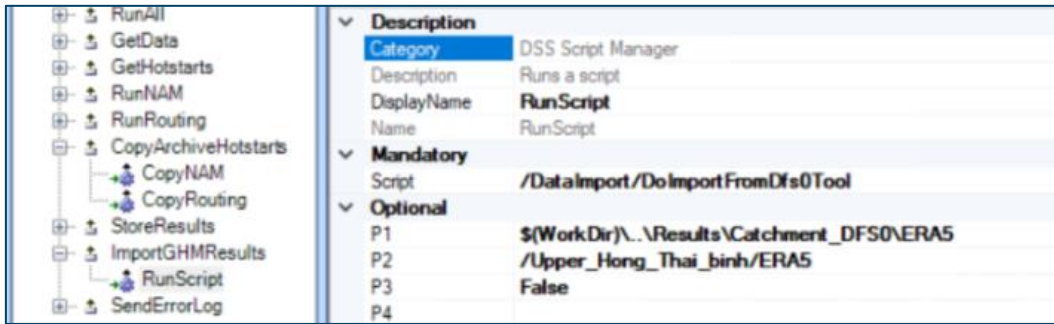


Figure 3.12 Target for importing Results

3.2.3 Medium range forecasting

This section describes the target-workflow of the DHI-GHM Medium range forecasting simulation (GFS).

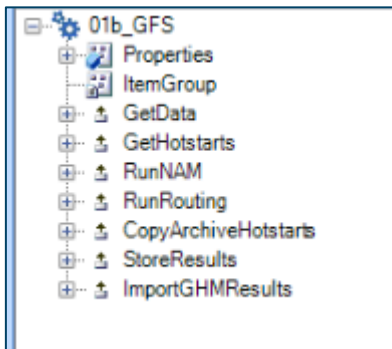


Figure 3.13 Job to run Medium range forecasting

3.2.3.1 Get Forcing Data

This target downloads DHI-GHM forcing data from DHI's Azure blob-storage.

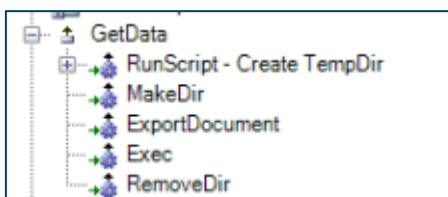
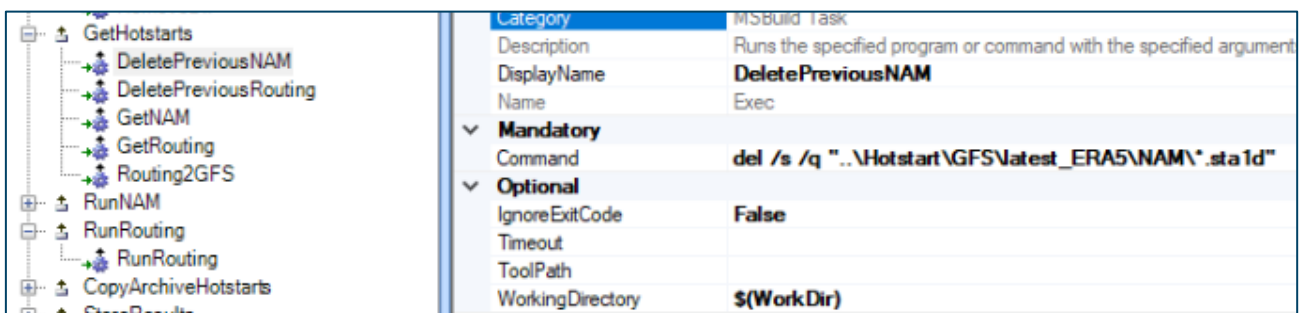


Figure 3.14 Target for getting forcing data

3.2.3.2 Hotstart handling – pre simulation

This target ensures hotstart files used by the routing model are in the expected location.



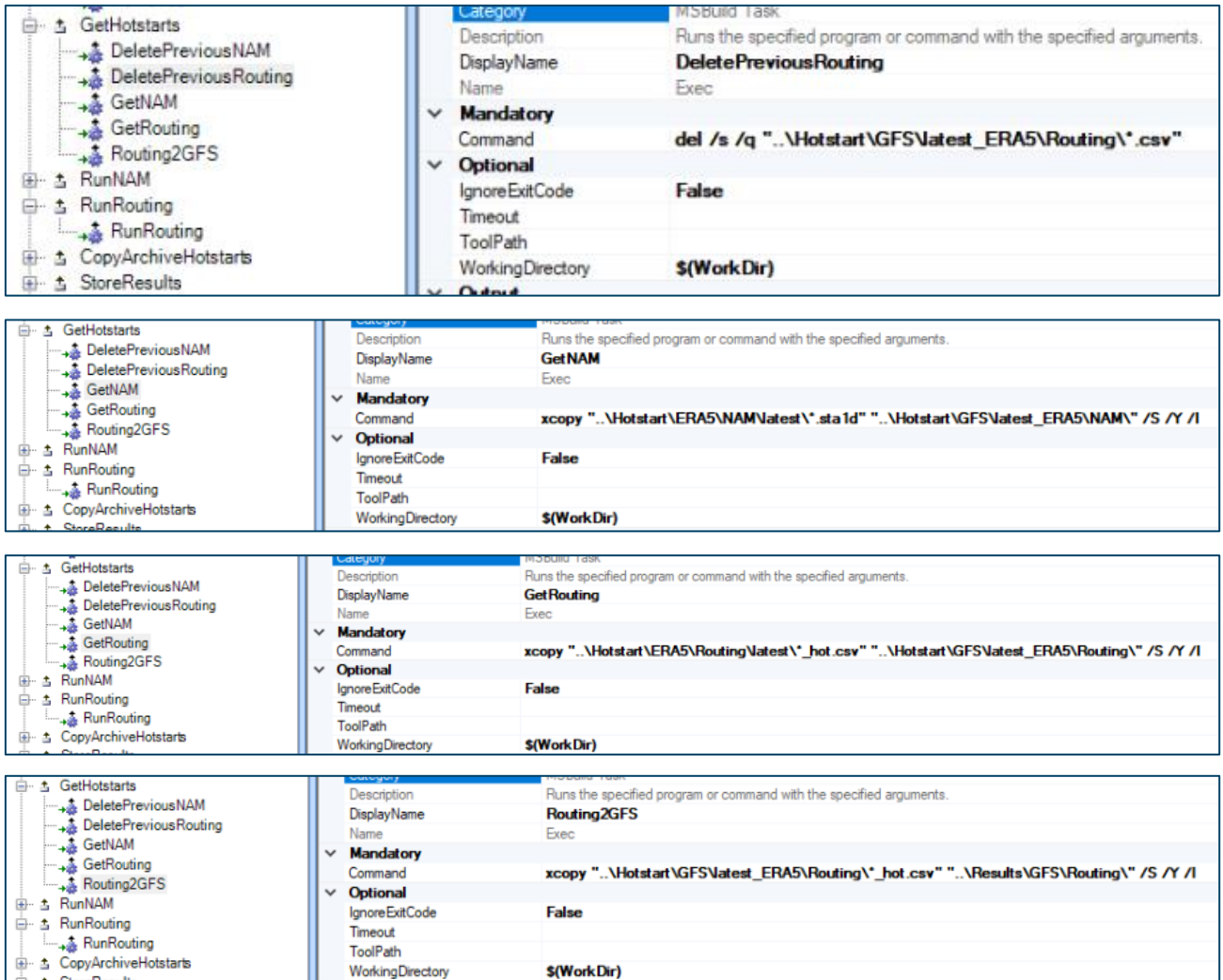


Figure 3.15 Target for Hotstart handling – step 1 to 5

3.2.3.3 Simulate rainfall runoff (NAM)

This target runs the NAM simulation of the DHI GHM model.

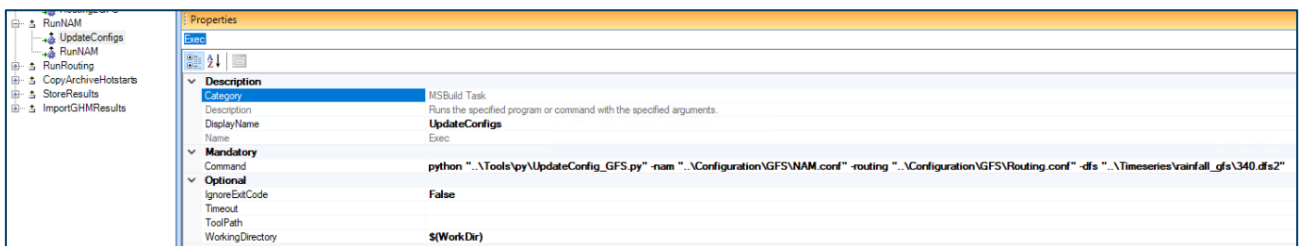


Figure 3.16 Target for Simulating rainfall runoff (NAM)

3.2.3.4 Simulate discharge (Routing)

This target runs the routing component of DHI-GHM model.

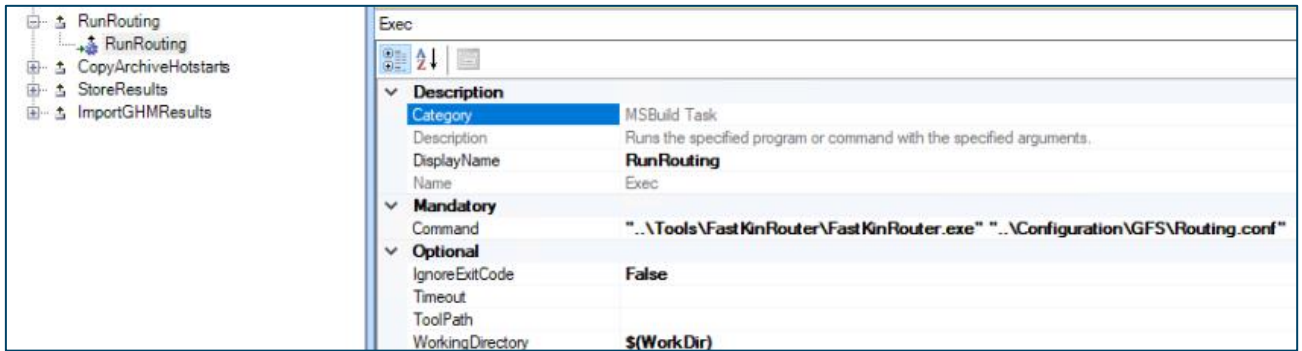


Figure 3.17 Target for running routing

3.2.3.5 Hotstart handling – post simulation

target has 2 steps:

1. To copy NAM hotstart files to latest folder, so they can be used by the next simulation

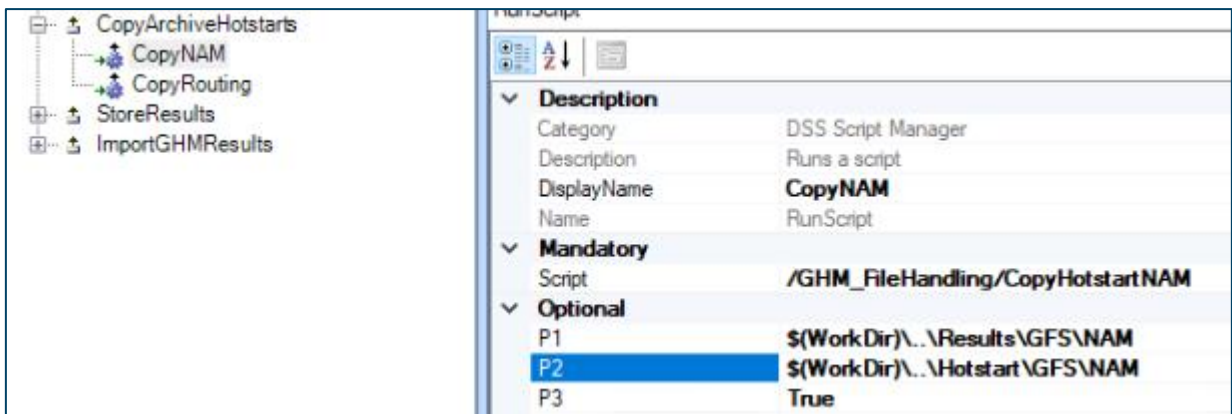


Figure 3.18 Target for Hotstart handling after simulation – step 1

2. Copy Routing hotstart files to latest folder, so they can be used by the next simulation.

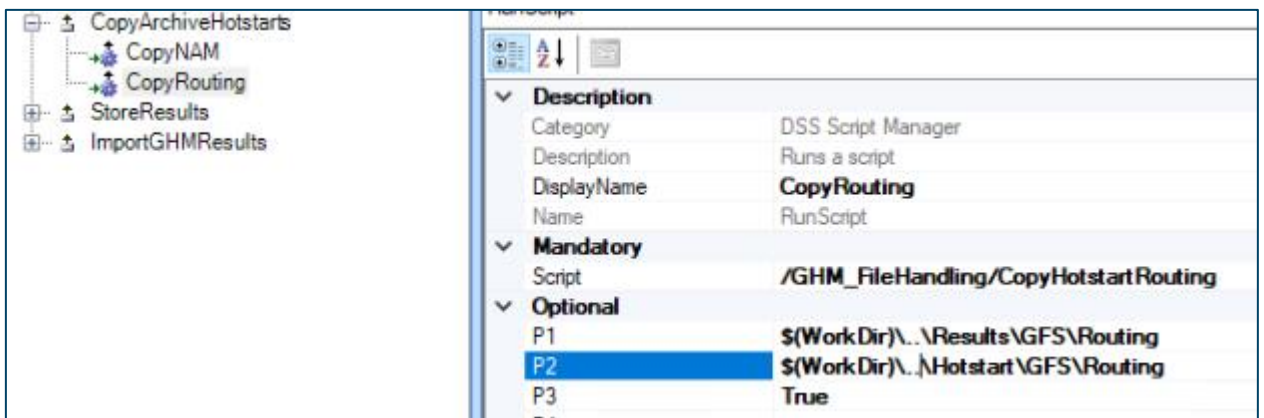


Figure 3.19 Target for Hotstart handling after simulation – step 2

3.2.3.6 Result postprocessing

This target creates a long timeseries into folder “..\Results\GFS\Routing”.

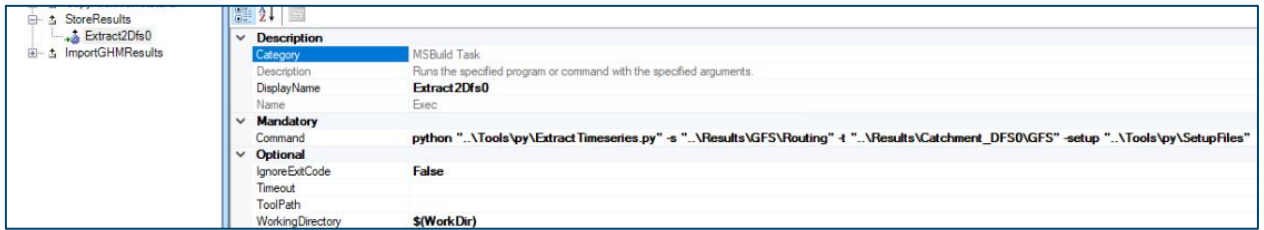


Figure 3.20 Target for Result postprocessing

3.2.3.7 Result import to MIKE Workbench database

This target imports Dfs0 files into MIKE Workbench database.

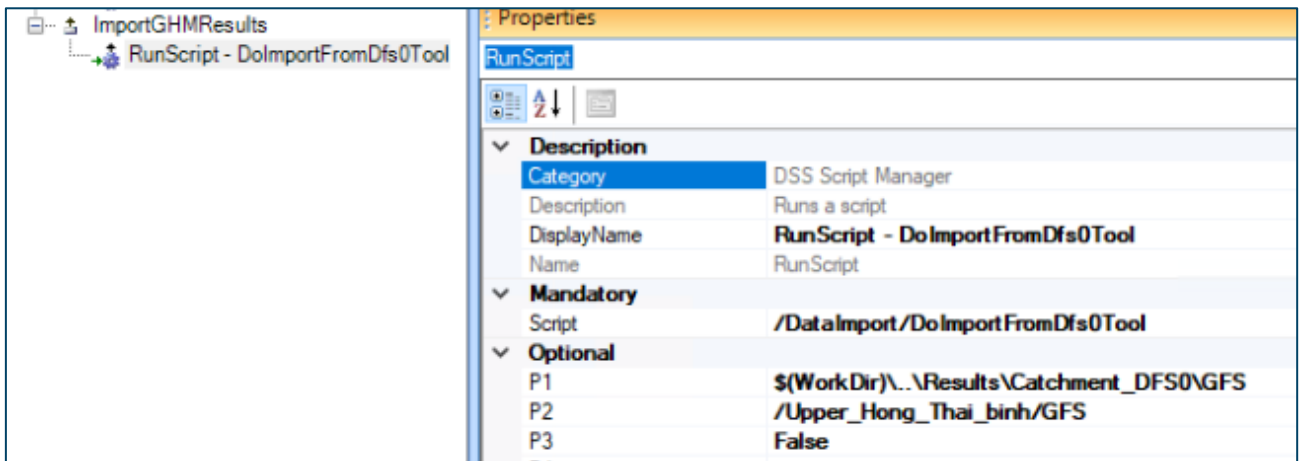


Figure 3.21 Target for importing Results

3.2.4 Seasonal Forecasting

This section describes the target-workflow of the DHI-GHM Seasonal forecasting simulation (CFS).

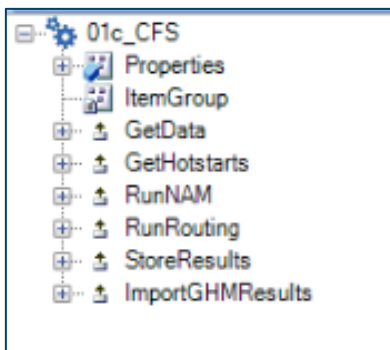


Figure 3.22 Job to run Seasonal Forecasting

3.2.4.1 Get Forcing Data

This target downloads DHI-GHM forcing data from DHI's Azure blob-storage.

<ul style="list-style-type: none"> GetData <ul style="list-style-type: none"> RunScript - Create TempDir MakeDir ExportDocument Exec RemoveDir GetHotstarts RunNAM RunRouting StoreResults ImportGHMResults 	<table border="1"> <tr><td colspan="2">Exec</td></tr> <tr><td colspan="2">Description</td></tr> <tr><td>Category</td><td>MSBuild Task</td></tr> <tr><td>Description</td><td>Runs the specified program or command with the specified arguments.</td></tr> <tr><td>DisplayName</td><td>Exec</td></tr> <tr><td>Name</td><td>Exec</td></tr> <tr><td colspan="2">Mandatory</td></tr> <tr><td>Command</td><td>CopyCFS_from_FTP.bat "\$(WorkDir)"</td></tr> <tr><td colspan="2">Optional</td></tr> <tr><td>IgnoreExitCode</td><td>False</td></tr> <tr><td>Timeout</td><td></td></tr> <tr><td>ToolPath</td><td></td></tr> <tr><td>WorkingDirectory</td><td>\$(TempDir)</td></tr> </table>	Exec		Description		Category	MSBuild Task	Description	Runs the specified program or command with the specified arguments.	DisplayName	Exec	Name	Exec	Mandatory		Command	CopyCFS_from_FTP.bat "\$(WorkDir)"	Optional		IgnoreExitCode	False	Timeout		ToolPath		WorkingDirectory	\$(TempDir)
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Figure 3.23 Target for getting forcing data

3.2.4.2 Hotstart handling – pre simulation

This target ensures hotstart files used by the routing model are in the expected location.

<ul style="list-style-type: none"> GetHotstarts <ul style="list-style-type: none"> DeletePreviousNAM DeletePreviousRouting GetNAM GetRouting Routing2CFS RunNAM RunRouting StoreResults ImportGHMResults 	<table border="1"> <tr><td colspan="2">DeletePreviousNAM</td></tr> <tr><td colspan="2">Description</td></tr> <tr><td>Category</td><td>MSBuild Task</td></tr> <tr><td>Description</td><td>Runs the specified program or command with the specified arguments.</td></tr> <tr><td>DisplayName</td><td>DeletePreviousNAM</td></tr> <tr><td>Name</td><td>Exec</td></tr> <tr><td colspan="2">Mandatory</td></tr> <tr><td>Command</td><td>del /s /q "..\Hotstart\CFS\atest_gfs\NAM*.sta1d"</td></tr> <tr><td colspan="2">Optional</td></tr> <tr><td>IgnoreExitCode</td><td>False</td></tr> <tr><td>Timeout</td><td></td></tr> <tr><td>ToolPath</td><td></td></tr> <tr><td>WorkingDirectory</td><td>\$(WorkDir)</td></tr> </table>	DeletePreviousNAM		Description		Category	MSBuild Task	Description	Runs the specified program or command with the specified arguments.	DisplayName	DeletePreviousNAM	Name	Exec	Mandatory		Command	del /s /q "..\Hotstart\CFS\atest_gfs\NAM*.sta1d"	Optional		IgnoreExitCode	False	Timeout		ToolPath		WorkingDirectory	\$(WorkDir)
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<ul style="list-style-type: none"> GetHotstarts <ul style="list-style-type: none"> DeletePreviousNAM DeletePreviousRouting GetNAM GetRouting Routing2CFS RunNAM RunRouting StoreResults ImportGHMResults 	<table border="1"> <tr><td colspan="2">GetNAM</td></tr> <tr><td colspan="2">Description</td></tr> <tr><td>Category</td><td>MSBuild Task</td></tr> <tr><td>Description</td><td>Runs the specified program or command with the specified arguments.</td></tr> <tr><td>DisplayName</td><td>GetNAM</td></tr> <tr><td>Name</td><td>Exec</td></tr> <tr><td colspan="2">Mandatory</td></tr> <tr><td>Command</td><td>xcopy "..\Hotstart\GFS\NAM\atest*.sta1d" "..\Hotstart\CFS\atest_gfs\NAM" /S /Y /I</td></tr> <tr><td colspan="2">Optional</td></tr> <tr><td>IgnoreExitCode</td><td>False</td></tr> <tr><td>Timeout</td><td></td></tr> <tr><td>ToolPath</td><td></td></tr> <tr><td>WorkingDirectory</td><td>\$(WorkDir)</td></tr> </table>	GetNAM		Description		Category	MSBuild Task	Description	Runs the specified program or command with the specified arguments.	DisplayName	GetNAM	Name	Exec	Mandatory		Command	xcopy "..\Hotstart\GFS\NAM\atest*.sta1d" "..\Hotstart\CFS\atest_gfs\NAM" /S /Y /I	Optional		IgnoreExitCode	False	Timeout		ToolPath		WorkingDirectory	\$(WorkDir)
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Optional																											
IgnoreExitCode	False																										
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ToolPath																											
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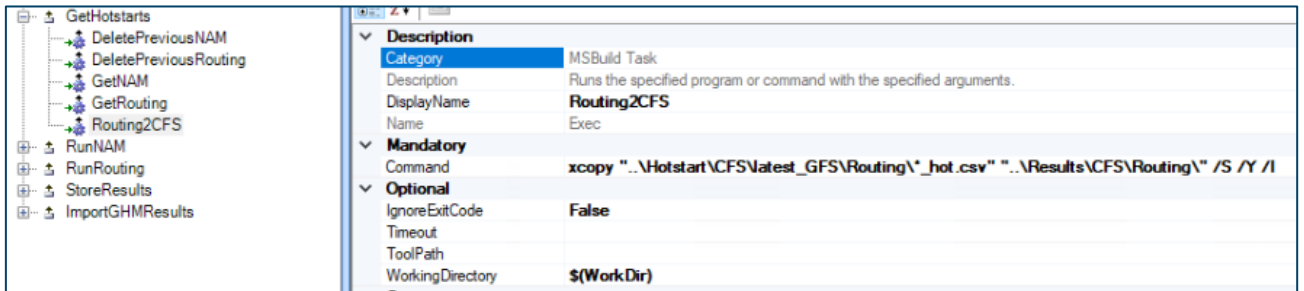
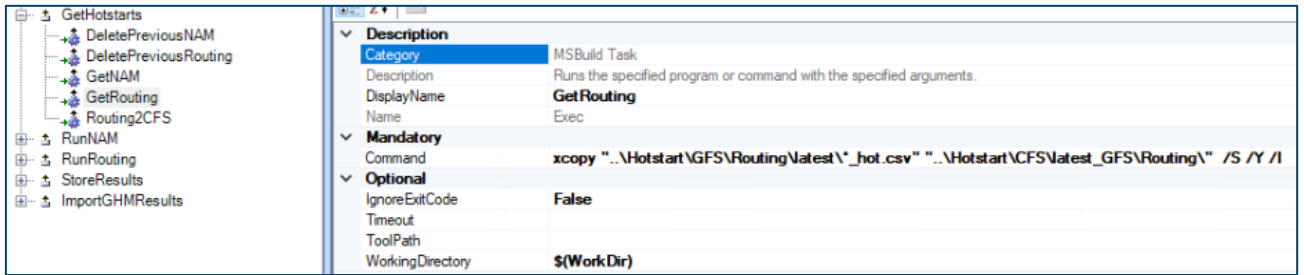


Figure 3.24 Target for Hotstart handling – step 1 to 5

3.2.4.3 Simulate rainfall runoff (NAM)

This target runs the NAM simulation of the DHI GHM model.

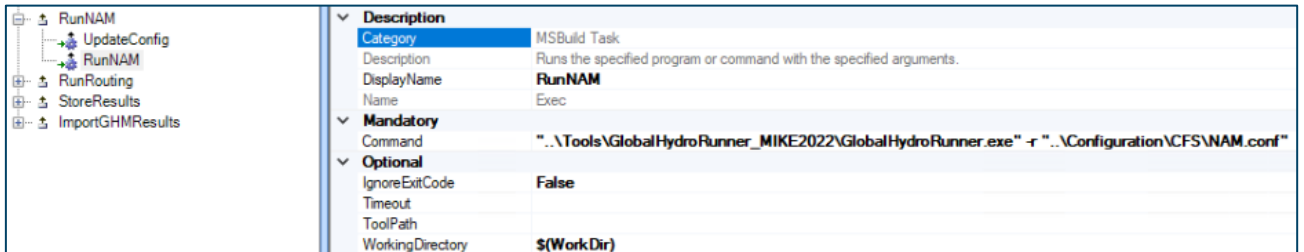
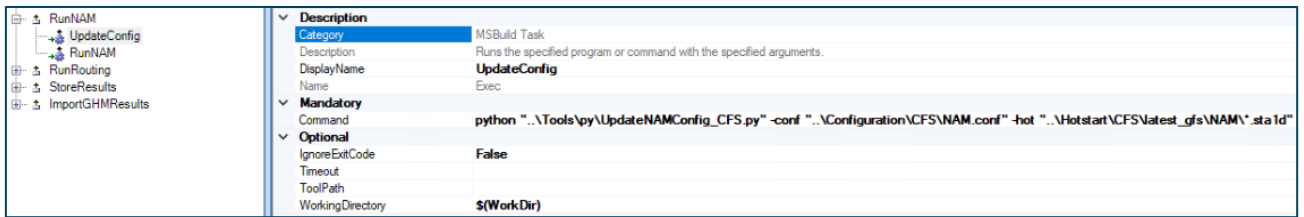


Figure 3.25 Target for Simulating rainfall runoff (NAM) – step 1 and 2

3.2.4.4 Simulate discharge (Routing)

This target runs the routing component of DHI-GHM model.

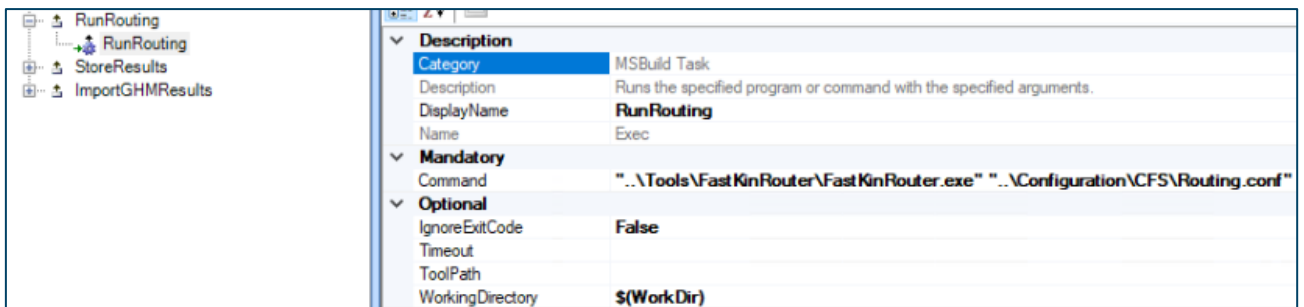


Figure 3.26 Target for running routing

3.2.4.5 Result postprocessing

This target creates a long timeseries into folder “..\Results\GFS\Routing”.

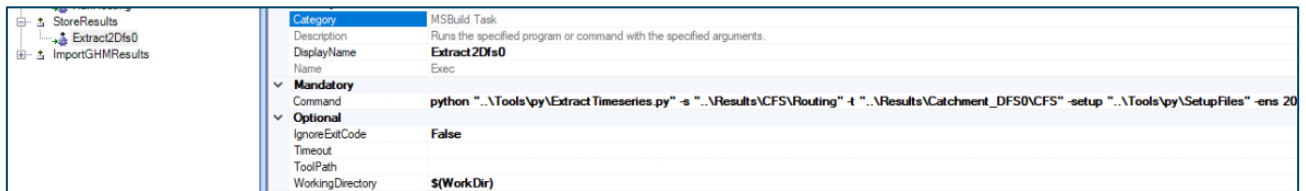


Figure 3.27 Target for Result postprocessing

3.2.4.6 Result import to MIKE Workbench database

This targets imports Dfs0 files into MIKE Workbench database.

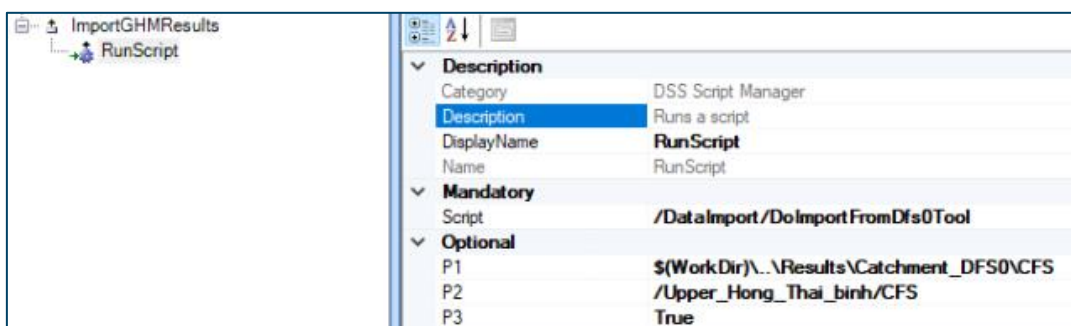


Figure 3.28 Target for importing Results

3.3 MHB Simulations

The MHB simulations are run after the DHI-GHM simulation and are composed of 4 runs:

- Medium range forecasting with data assimilation (DA)
- Seasonal forecasting with DA
- Medium range forecasting without DA
- Seasonal forecasting without DA

Using the hierarchy, MHB simulations use input timeseries from the GHM. The input timeseries are merged timeseries, as in

3.3.1 Medium range forecasting

This job runs the MHB simulation for the Medium range forecast.

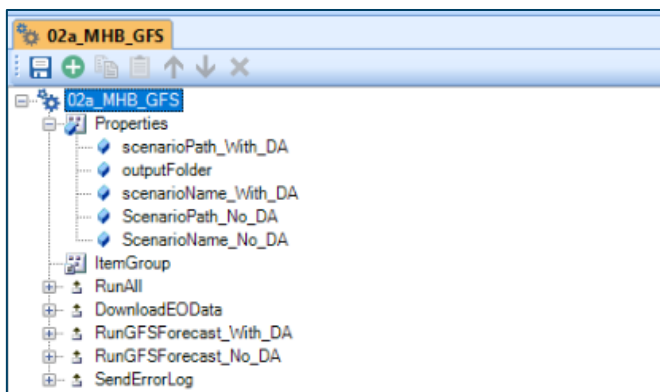


Figure 3.29 Job to run MHB simulation for the Medium range forecast

For the job, the following properties are defined:

Properties	Value
scenarioPath_With_DA	/Group of Upper_Hong_Thai_binh/Upper_Hong_Thai_binh_With_DA/GFS Upper_Hong_Thai_binh_With_DA
outputFolder	Model Output
scenarioName_With_DA	GFS Upper_Hong_Thai_binh_With_DA
scenarioPath_No_DA	/Group of Upper_Hong_Thai_binh/Upper_Hong_Thai_binh_No_DA/GFS Upper_Hong_Thai_binh_No_DA
scenarioName_No_DA	GFS Upper_Hong_Thai_binh_No_DA
EO_Filename	China-RK-reservoir-monitoring.csv

The first step is to download the EO data. Data is downloaded from an azure blob-storage to a temporary directory and then processed using the script “/DataImport/ImportEOData”

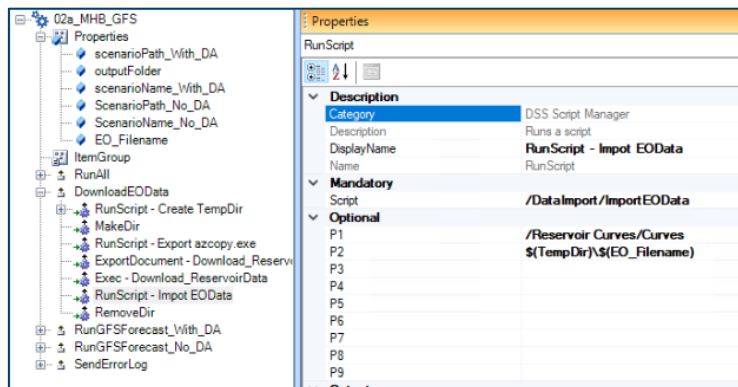


Figure 3.30 Target to download the EO data

Then both scenarios based on GFS data are run: with DA and without DA. This workflow describes the simulation with DA. No DA follows the same procedure with accordingly changed parameters.

It should be noted that the script /Processing/AfterOutputCreatedDelegate is run after the simulation to keep only 1 year before TOF.

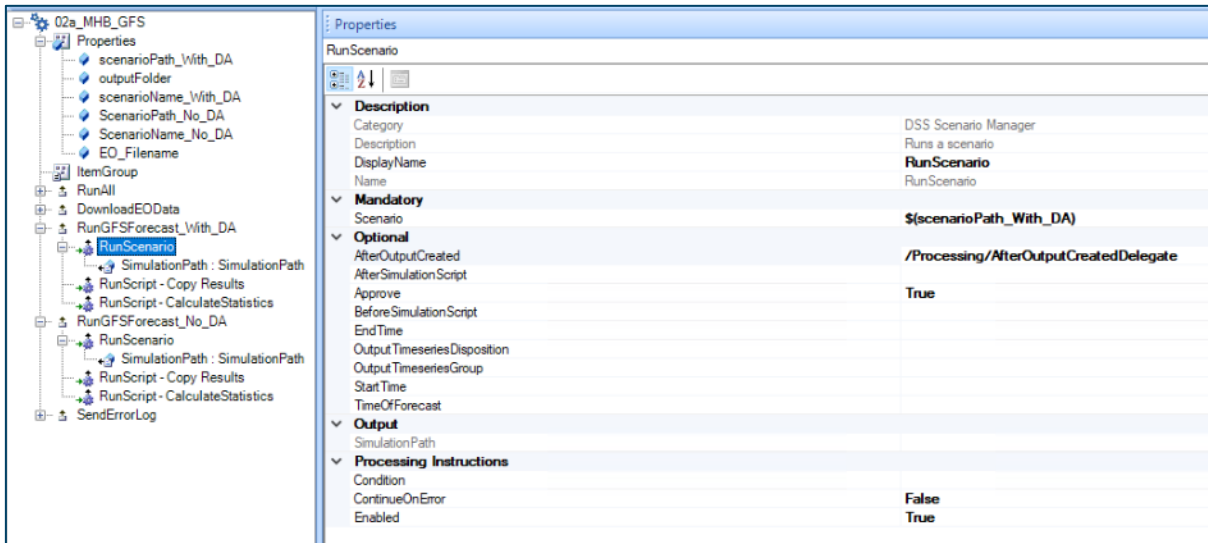


Figure 3.31 Target to run MHB scenario with GFS

Then results of MHB scenario with GFS are copied to an output folder.

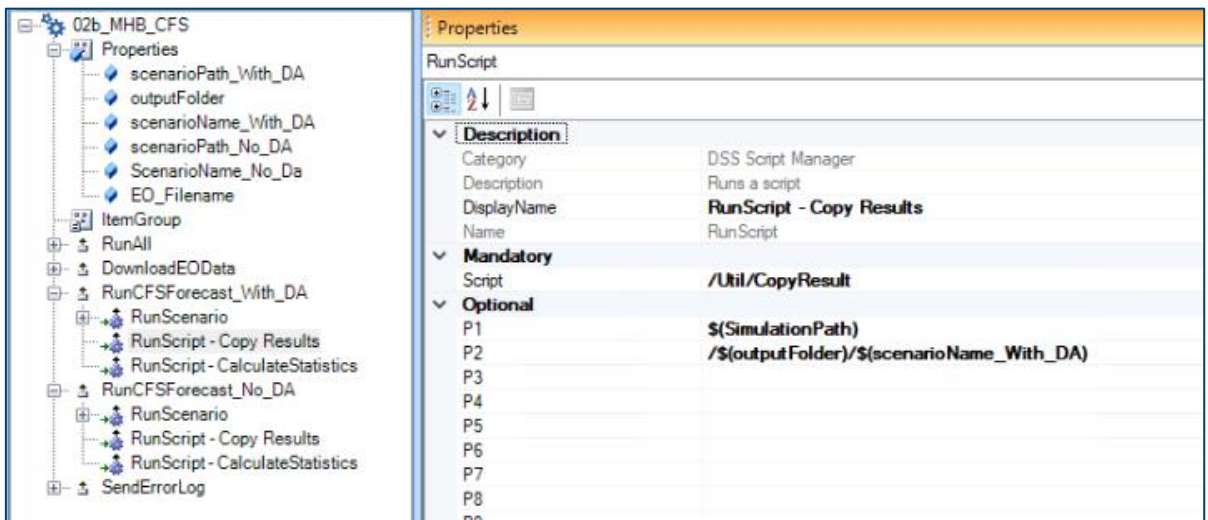


Figure 3.32 Target to copy results of MHB scenario with GFS

Finally, the statistics are calculated based on the output time series.

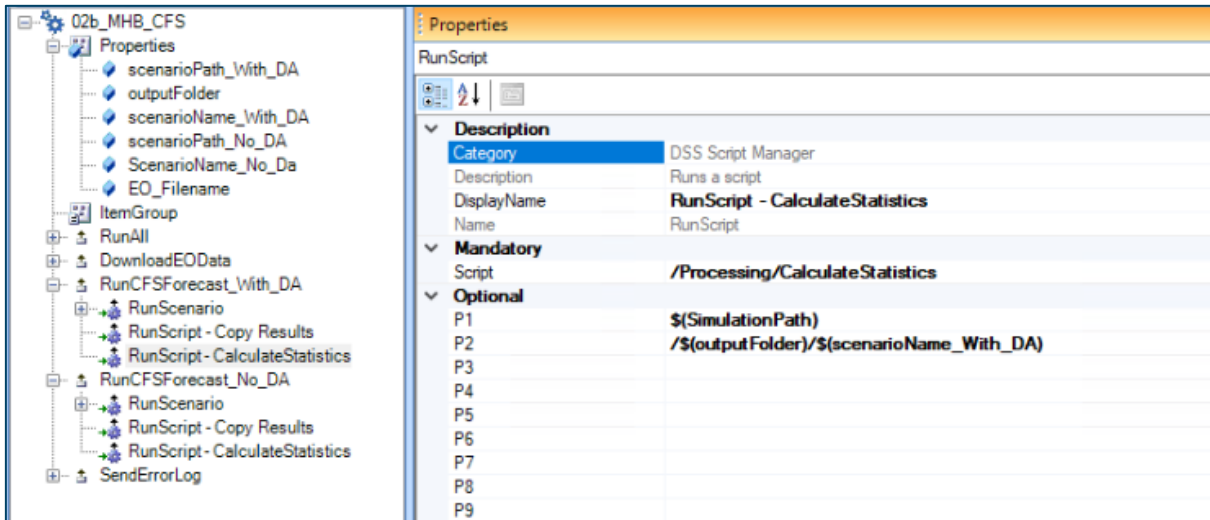


Figure 3.33 Target for calculating statistics

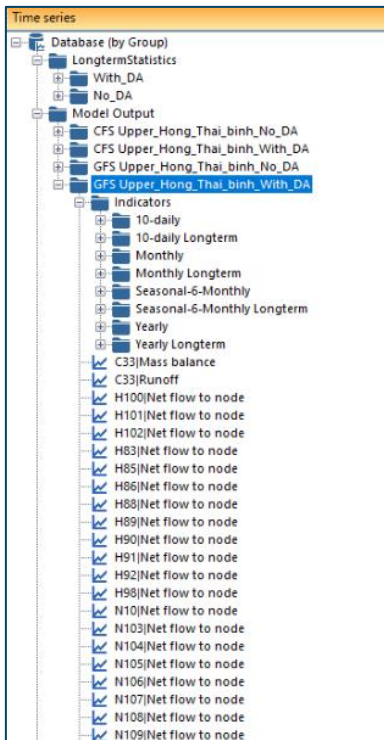


Figure 3.34 Folder structure of the Medium Range Forecast Model Output time series including statistics (indicators)

3.3.2 Seasonal Forecasting

This job runs the MHB simulation for the Seasonal forecast.

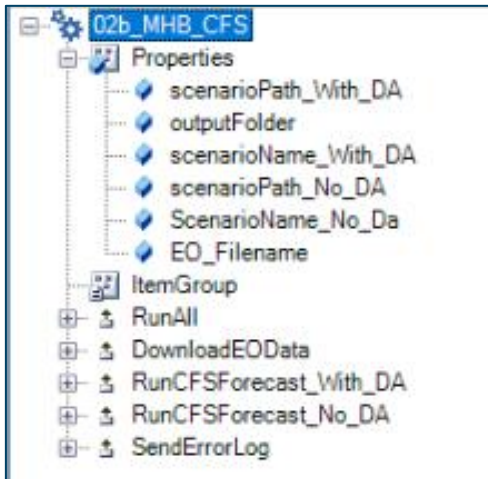


Figure 3.35 Job for running the MHB simulation for the seasonal forecast

For the job, the following properties are defined:

Properties	Value
scenarioPath_With_DA	/Group of Upper_Hong_Thai_binh/Upper_Hong_Thai_binh_With_DA/CFS Upper_Hong_Thai_binh_With_DA
outputFolder	Model Output
scenarioName_With_DA	CFS Upper_Hong_Thai_binh_With_DA
scenarioPath_No_DA	/Group of Upper_Hong_Thai_binh/Upper_Hong_Thai_binh_No_DA/CFS Upper_Hong_Thai_binh_No_DA
scenarioName_No_DA	CFS Upper_Hong_Thai_binh_No_DA
EO_Filename	China-RK-reservoir-monitoring.csv

The first step is to download the EO data. Data is downloaded from an azure blob-storage to a temporary directory and then processed using the script “/DataImport/ImportEOData”.

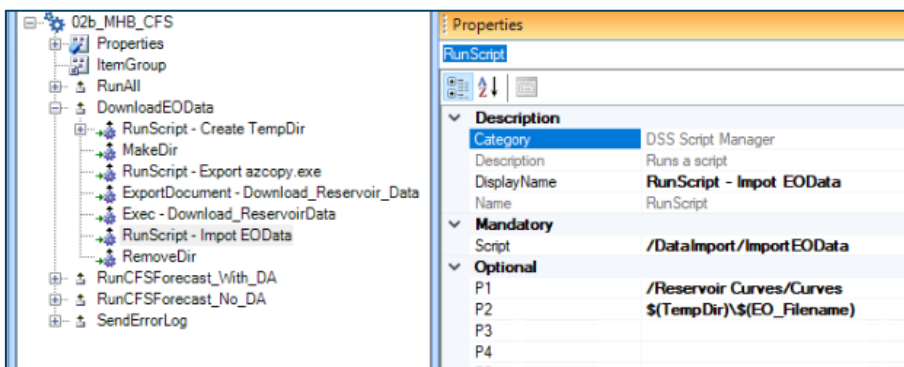


Figure 3.36 Target to download the EO data

Then both scenarios based on CFS data are run: with DA and without DA. This workflow describes the simulation with DA. No DA follows the same procedure with accordingly changed parameters.

It should be noted that the script /Processing/AfterOutputCreatedDelegate is run after the simulation to keep only 1 year before TOF.

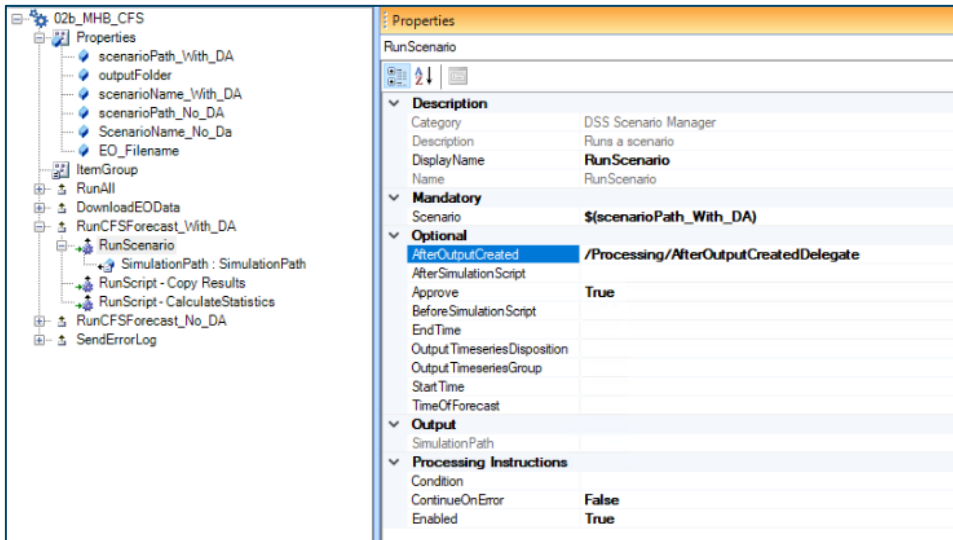


Figure 3.37 Target to run MHB scenario with CFS

Then results of MHB scenario with CFS are copied to an output folder.

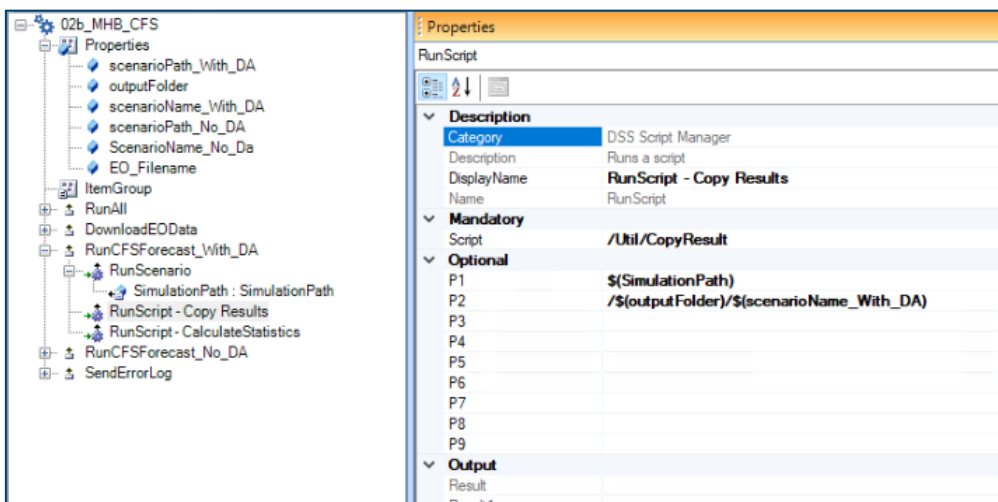


Figure 3.38 Target to copy results of MHB scenario with CFS

Finally, the statistics are calculated based on the output time series.

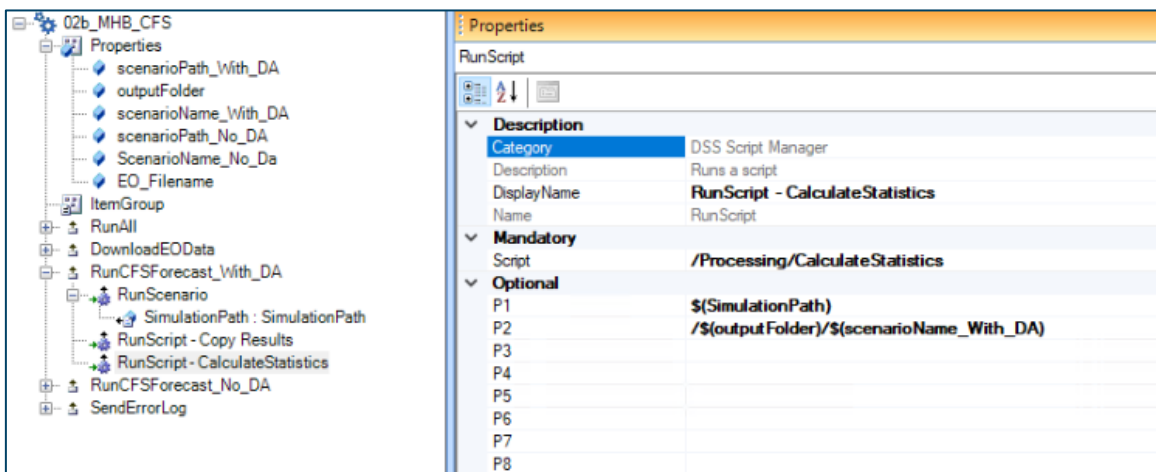


Figure 3.39 Target for calculating statistics

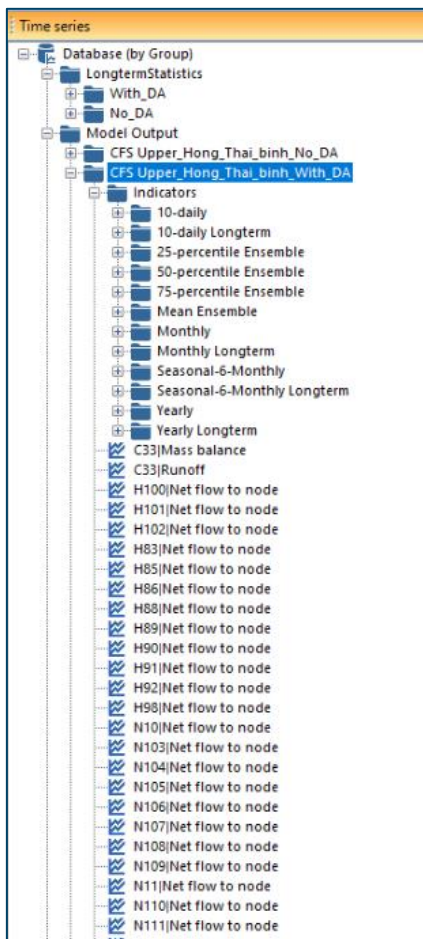


Figure 3.40 Folder structure of the Seasonal Forecast Model Output time series including statistics (indicators)

3.4 Result inspection

The day-to-day operation should include the visual inspection/evaluation and possibly extraction of the key timeseries of trans boundary inflows to Vietnam for further processing or input to downstream models.

This concerns the following output time series:

MIKE HYDRO Basin Results	Type of data	Location
N12 Net flow to node	Simulated transboundary flow	Da at Border
N32 Net flow to node	Simulated transboundary flow	Nam Na + trib at border
N19 Net flow to node	Simulated transboundary flow	Chay at border
N21 Net flow to node	Simulated transboundary flow	Lo at border
N22 Net flow to node	Simulated transboundary flow	Mien at border
N23 Net flow to node	Simulated transboundary flow	Nho Que at border
N24 Net flow to node	Simulated transboundary flow	Gam At border

Other results of relevance could be the results at the Vietnamese calibration stations:

MIKE HYDRO Basin Results	Type of data	Location
N44 Net flow to node	Simulated flow	LaiChau GS
N34 Net flow to node	Simulated flow	Lao Cai GS
N80 Net flow to node	Simulated flow	Bao Yen GS
N47 Net flow to node	Simulated flow	Dao Duc GS
N57 Net flow to node	Simulated flow	Bac Me GS

Also the various modelled output for the reservoirs in China and Lai Chau might be relevant to consult, i.e.:

MHB Results	Type of data	Location
R2	Water Level, Stored Volume, Net flow to node, Outflow to river, Outflow to HP	Yayangchan
R60	Water Level, Stored Volume, Net flow to node, Outflow to river, Outflow to HP	Shimenkan
R62	Water Level, Stored Volume, Net flow to node, Outflow to river, Outflow to HP	Longma
R68	Water Level, Stored Volume, Net flow to node, Outflow to river, Outflow to HP	Jupudu
R70	Water Level, Stored Volume, Net flow to node, Outflow to river, Outflow to HP	Gelantan
R64	Water Level, Stored Volume, Net flow to node, Outflow to river, Outflow to HP	Puxiqiao
R66	Water Level, Stored Volume, Net flow to node, Outflow to river, Outflow to HP	Sinanjiang
R74	Water Level, Stored Volume, Net flow to node, Outflow to river, Outflow to HP	Nansha
R76	Water Level, Stored Volume, Net flow to node, Outflow to river, Outflow to HP	Maduschan
R72	Water Level, Stored Volume, Net flow to node, Outflow to river, Outflow to HP	Nalan
R78	Water Level, Stored Volume, Net flow to node, Outflow to river, Outflow to HP	Malutang
R82	Water Level, Stored Volume, Net flow to node, Outflow to river, Outflow to HP	Lai_Chau

3.5 System Performance

This section describes the operational tasks to monitor and ensure the performance of the System.

3.5.1 Reporting

The reporting task will issue a report by email with a status of the entire system.

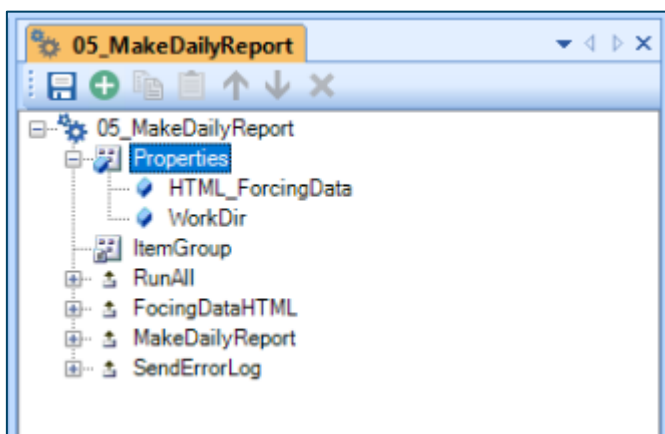


Figure 3.41 Job for daily report

For the job, the following properties are defined:

Properties	Value
HTML_ForcingData	..\Results\HTML\latest\html.txt
WorkDir	Working directory

The first step is to generate an html text with an overview of the forcing data. This html will then be included in the daily report.

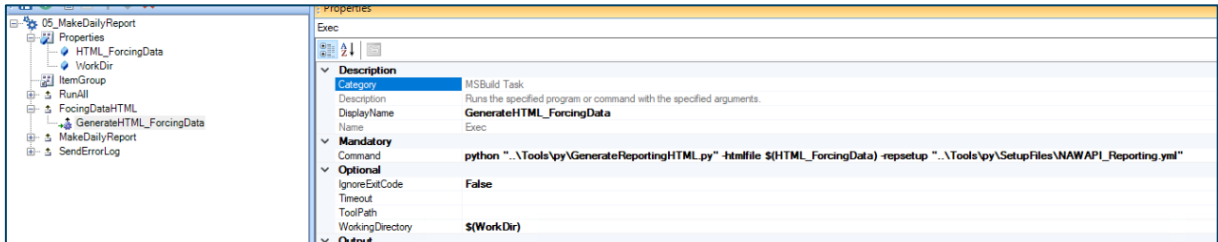


Figure 3.42 Target to generate html for forcing data

The next target generates and sends the daily report.

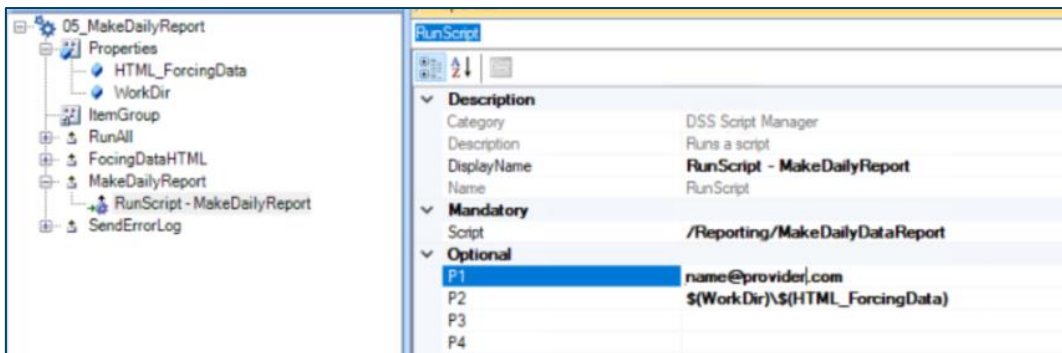


Figure 3.43 Target for preparing and sending the daily report

Email addresses for recipients can be many, delimited with “;”.

The script “/Reporting/MakeDailyDataReport” relies on a Gmail email address. It is required for the SMPT access. The email details are hardcoded in script directly – see screenshot below.

Please note that an authentication is needed in google account with an App password. The following steps can be consulted to ensure the proper security settings of the google account have been defined: <https://support.google.com/accounts/answer/185833?hl=en>

A quick way to add AppPasswords is using url <https://myaccount.google.com/apppasswords>

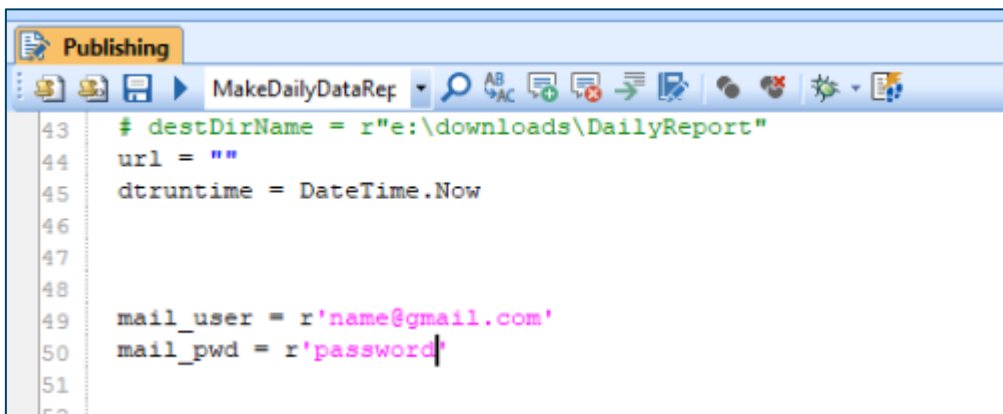


Figure 3.44 Preview of the script for daily report where email account must be set up

3.5.2 Error logging

When an error occurs during a job execution a script is executed to send an email.

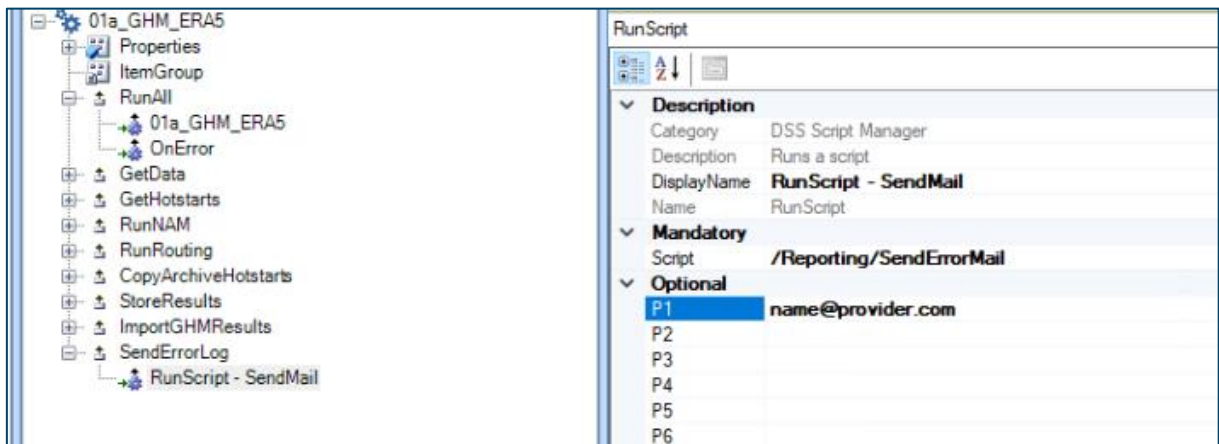


Figure 3.45 Target for sending email on error

Email addresses for recipients can be many, delimited with “;”.

The script “/Reporting/SendErrorMail” relies on a Gmail email address. It is required for the SMTP access. The email details are hardcoded in script directly – see screenshot below.

Please note that an authentication is needed in google account with an App password. The following steps can be consulted to ensure the proper security settings of the google account have been defined: <https://support.google.com/accounts/answer/185833?hl=en>

A quick way to add AppPasswords is using url <https://myaccount.google.com/apppasswords>

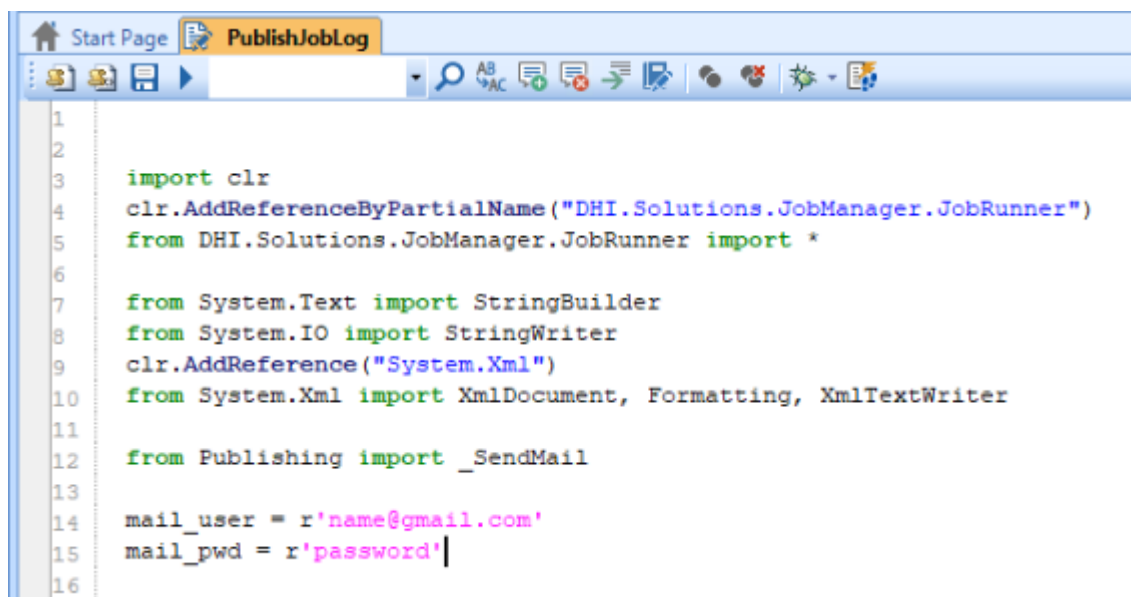


Figure 3.46 Preview of the script for error logging where email account must be set up

3.6 Maintenance

Various maintenance procedures are implemented to ensure the health of the “NAWAPI” system. These include database maintenance and is presented in the subsequent section.

3.6.1 Database Maintenance

This job ensures the database is maintained.

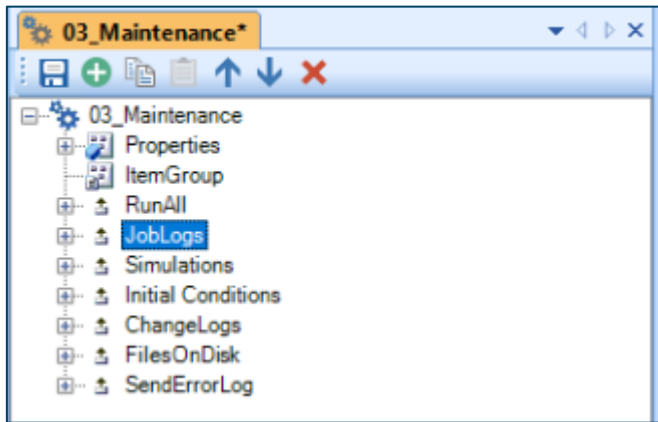


Figure 3.47 Job for database maintenance

The first step will ensure old job logs are cleaned up.

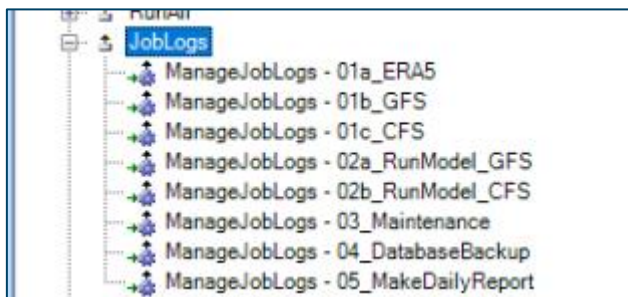


Figure 3.48 Target for managing job logs

The next step will ensure old simulations are cleaned up.

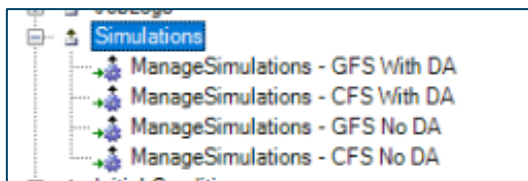


Figure 3.49 Target for managing old simulations

The next step will ensure old initial conditions are cleaned up.

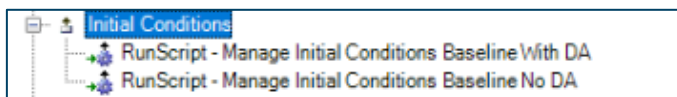


Figure 3.50 Target for managing old initial conditions

The next step will ensure old change logs are cleaned up.



Figure 3.51 Target for managing old change logs

The next step will ensure old database backup files are cleaned up on the disk.

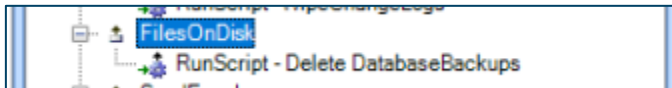


Figure 3.52 Target for managing old database backup

3.6.2 Database Backup

This part of the job will clean up the database (vacuum) and create a backup.

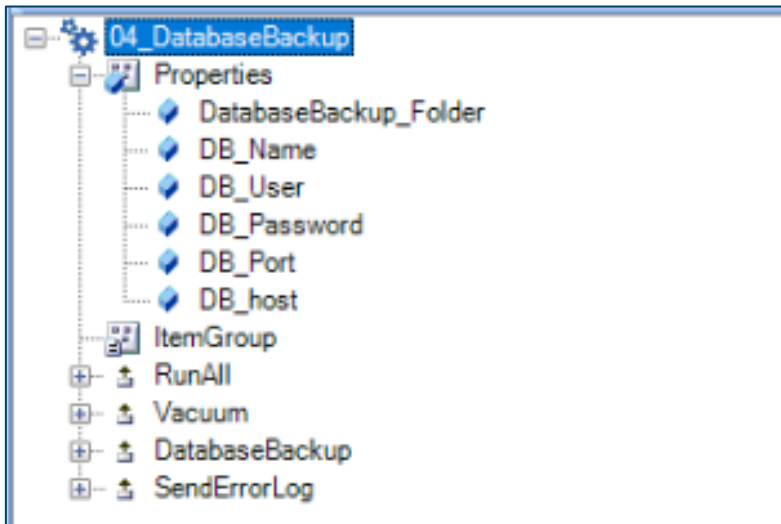


Figure 3.53 Job for database vacuum and backup

The vacuum and backup are done by batch files run on disk. These batch files are stored in the document manager and are exported on a temporary folder before execution.

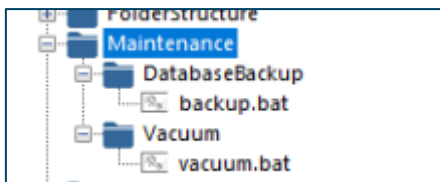


Figure 3.54 Location of DB vacuum and backup in document manager

The batch files are designed to be able to use parameters:

- DatabaseBackup_Folder
- DB_Name
- DB_User
- DB_Password
- DB_Port
- DB_host

If any of the parameters differs from the fallback values (Table 3.1), it needs to be set.

Table 3.1 Fallback values for database backup parameters

Parameter	Fallback value
DatabaseBackup_Folder	D:\H_TB\Backup <i>This should be set to match maintenance, see section 3.6</i>
DB_Name	H_TB_CTCN

DB_User	postgres
DB_Password	postgres
DB_Port	5432
DB_host	localhost

The batch file execution uses all parameters needed (Figure 3.55 and Figure 3.56) , where by default (parameter is empty), the fallback value is used.

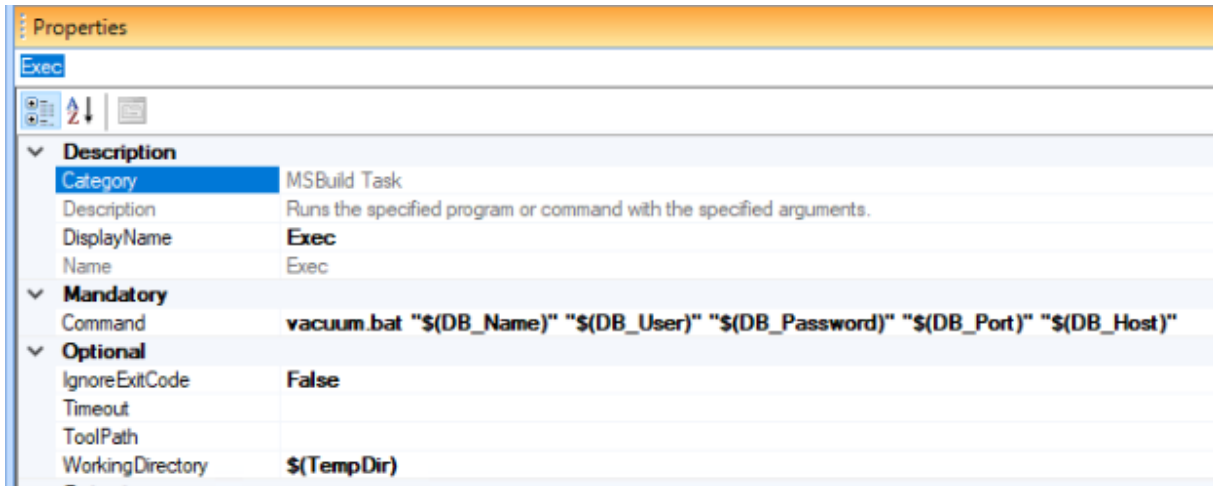


Figure 3.55 Call of the exported vacuum.bat file with parameters

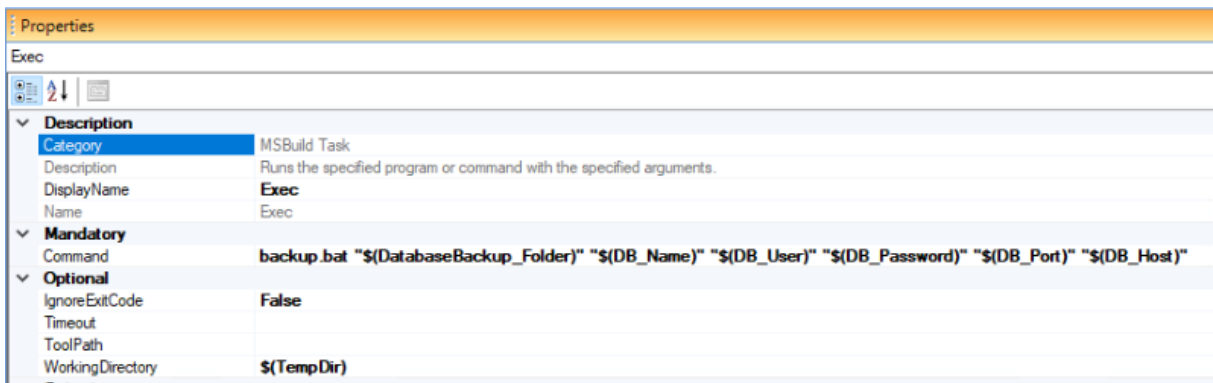


Figure 3.56 Call of the exported backup.bat file with parameters

Appendix A Parameter definition table

Name	Umax	Lmax	CQOF	CQLow	CKIF	CKOF1	CKOF2	CKBF	CKLow	TOF	TIF	TG	Csnow	T0	Cwr	k0	SWECoverage	MinStorage	Ini_QOF	Ini_QIF	Ini_QBF	Ini_QBFlow	Ini_SWE	Ini_U_Umax	ini_L_Lmax	partition	x	y
100.05_25.55_1400	18.6	186	0.45	0	1482	17	17	1186	1000	0.76	0.428	0.372	2.5	0	5	25	0	0	0.4	0	0	0.5	0.5	340	100.05	25.55		
100.05_25.55_1600	18.6	186	0.45	0	1482	17	17	1186	1000	0.76	0.428	0.372	2.5	0	5	25	0	0	0.4	0	0	0.5	0.5	340	100.05	25.55		
100.05_25.55_1800	18.6	186	0.45	0	1482	17	17	1186	1000	0.76	0.428	0.372	2.5	0	5	25	0	0	0.4	0	0	0.5	0.5	340	100.05	25.55		
100.05_25.55_2000	18.6	186	0.45	0	1482	17	17	1186	1000	0.76	0.428	0.372	2.5	0	5	25	0	0	0.4	0	0	0.5	0.5	340	100.05	25.55		
100.05_25.55_2200	18.6	186	0.45	0	1482	17	17	1186	1000	0.76	0.428	0.372	2.5	0	5	25	0	0	0.4	0	0	0.5	0.5	340	100.05	25.55		
100.05_25.55_2400	18.6	186	0.45	0	1482	17	17	1186	1000	0.76	0.428	0.372	2.5	0	5	25	0	0	0.4	0	0	0.5	0.5	340	100.05	25.55		
100.05_25.55_2600	18.6	186	0.45	0	1482	17	17	1186	1000	0.76	0.428	0.372	2.5	0	5	25	0	0	0.4	0	0	0.5	0.5	340	100.05	25.55		
100.15_25.55_1600	19.3	193	0.44	0	1235	17.2	17.2	988	1000	0.764	0.459	0.341	2.5	0	5	25	0	0	0.4	0	0	0.5	0.5	340	100.15	25.55		
100.15_25.55_2000	19.3	193	0.44	0	1235	17.2	17.2	988	1000	0.764	0.459	0.341	2.5	0	5	25	0	0	0.4	0	0	0.5	0.5	340	100.15	25.55		
100.15_25.55_2200	19.3	193	0.44	0	1235	17.2	17.2	988	1000	0.764	0.459	0.341	2.5	0	5	25	0	0	0.4	0	0	0.5	0.5	340	100.15	25.55		
100.15_25.55_2400	19.3	193	0.44	0	1235	17.2	17.2	988	1000	0.764	0.459	0.341	2.5	0	5	25	0	0	0.4	0	0	0.5	0.5	340	100.15	25.55		
100.15_25.55_2600	19.3	193	0.44	0	1235	17.2	17.2	988	1000	0.764	0.459	0.341	2.5	0	5	25	0	0	0.4	0	0	0.5	0.5	340	100.15	25.55		
100.15_25.55_2800	19.3	193	0.44	0	1235	17.2	17.2	988	1000	0.764	0.459	0.341	2.5	0	5	25	0	0	0.4	0	0	0.5	0.5	340	100.15	25.55		
100.25_25.55_2000	19.6	196	0.44	0	879	27	27	703	1000	0.763	0.412	0.388	2.5	0	5	25	0	0	0.4	0	0	0.5	0.5	340	100.25	25.55		
100.25_25.55_2200	19.6	196	0.44	0	879	27	27	703	1000	0.763	0.412	0.388	2.5	0	5	25	0	0	0.4	0	0	0.5	0.5	340	100.25	25.55		
100.25_25.55_2400	19.6	196	0.44	0	879	27	27	703	1000	0.763	0.412	0.388	2.5	0	5	25	0	0	0.4	0	0	0.5	0.5	340	100.25	25.55		
100.25_25.55_2600	19.6	196	0.44	0	879	27	27	703	1000	0.763	0.412	0.388	2.5	0	5	25	0	0	0.4	0	0	0.5	0.5	340	100.25	25.55		
100.45_25.55_2200	19.2	192	0.48	0	1348	19.9	19.9	1079	1000	0.746	0.459	0.341	2.5	0	5	25	0	0	0.4	0	0	0.5	0.5	340	100.45	25.55		
100.45_25.55_2400	19.2	192	0.48	0	1348	19.9	19.9	1079	1000	0.746	0.459	0.341	2.5	0	5	25	0	0	0.4	0	0	0.5	0.5	340	100.45	25.55		
100.45_25.55_2600	19.2	192	0.48	0	1348	19.9	19.9	1079	1000	0.746	0.459	0.341	2.5	0	5	25	0	0	0.4	0	0	0.5	0.5	340	100.45	25.55		
100.45_25.55_2800	19.2	192	0.48	0	1348	19.9	19.9	1079	1000	0.746	0.459	0.341	2.5	0	5	25	0	0	0.4	0	0	0.5	0.5	340	100.45	25.55		
100.45_25.55_3000	19.2	192	0.48	0	1348	19.9	19.9	1079	1000	0.746	0.459	0.341	2.5	0	5	25	0	0	0.4	0	0	0.5	0.5	340	100.45	25.55		
100.55_25.55_1800	18.1	181	0.46	0	1600	20.6	20.6	1335	1000	0.757	0.4	0.4	2.5	0	5	25	0	0	0.4	0	0	0.5	0.5	340	100.55	25.55		

Appendix B Catchment definition ERA5

name	isCombined	combined catchment	parameter template	areakm2	elevation	max. snow depth	max. swe retention	min. full cover storage	radiation coeff	precip_corr	evap_corr_factor	temp_wet_corr	temp_dry_corr	ini_qof	ini_qif	ini_qbf	ini_qbflow	ini_swe	ini_u_umax	ini_l_lmax	evap file	evap item
100.05_25.55	FALSE	DEFAULT		111.1228	1997.8	2000	10	200	1	0	1	0	0	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.05_25.55_1400	TRUE	100.05_25.55	DEFAULT	8.125854452	1400	2000	10	200	1	-17.93	1	2.39	3.59	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.05_25.55_1600	TRUE	100.05_25.55	DEFAULT	18.20407566	1600	2000	10	200	1	-11.93	1	1.59	2.39	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.05_25.55_1800	TRUE	100.05_25.55	DEFAULT	19.7165801	1800	2000	10	200	1	-5.93	1	0.79	1.19	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.05_25.55_2000	TRUE	100.05_25.55	DEFAULT	20.35707952	2000	2000	10	200	1	0.07	1	-0.01	-0.01	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.05_25.55_2200	TRUE	100.05_25.55	DEFAULT	21.11333174	2200	2000	10	200	1	6.07	1	-0.81	-1.21	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.05_25.55_2400	TRUE	100.05_25.55	DEFAULT	14.20674156	2400	2000	10	200	1	12.07	1	-1.61	-2.41	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.05_25.55_2600	TRUE	100.05_25.55	DEFAULT	9.399136951	2600	2000	10	200	1	18.07	1	-2.41	-3.61	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.15_25.55	FALSE	DEFAULT		111.1228	2358.5	2000	10	200	1	0	1	0	0	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.15_25.55_1600	TRUE	100.15_25.55	DEFAULT	6.868006187	1600	2000	10	200	1	-22.75	1	3.03	4.55	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.15_25.55_2000	TRUE	100.15_25.55	DEFAULT	14.62345166	2000	2000	10	200	1	-10.75	1	1.43	2.15	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.15_25.55_2200	TRUE	100.15_25.55	DEFAULT	28.72215837	2200	2000	10	200	1	-4.75	1	0.63	0.95	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.15_25.55_2400	TRUE	100.15_25.55	DEFAULT	25.99810513	2400	2000	10	200	1	1.25	1	-0.17	-0.25	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.15_25.55_2600	TRUE	100.15_25.55	DEFAULT	17.42467288	2600	2000	10	200	1	7.25	1	-0.97	-1.45	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.15_25.55_2800	TRUE	100.15_25.55	DEFAULT	17.48640738	2800	2000	10	200	1	13.25	1	-1.77	-2.65	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.25_25.55	FALSE	DEFAULT		111.1228	2244.8	2000	10	200	1	0	1	0	0	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.25_25.55_2000	TRUE	100.25_25.55	DEFAULT	25.88235232	2000	2000	10	200	1	-7.34	1	0.98	1.47	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.25_25.55_2200	TRUE	100.25_25.55	DEFAULT	44.85811446	2200	2000	10	200	1	-1.34	1	0.18	0.27	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.25_25.55_2400	TRUE	100.25_25.55	DEFAULT	30.72082294	2400	2000	10	200	1	4.66	1	-0.62	-0.93	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.25_25.55_2600	TRUE	100.25_25.55	DEFAULT	9.661510229	2600	2000	10	200	1	10.66	1	-1.42	-2.13	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.45_25.55	FALSE	DEFAULT		111.1228	2533.6	2000	10	200	1	0	1	0	0	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.45_25.55_2200	TRUE	100.45_25.55	DEFAULT	22.91135988	2200	2000	10	200	1	-10.01	1	1.33	2	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.45_25.55_2400	TRUE	100.45_25.55	DEFAULT	29.46297633	2400	2000	10	200	1	-4.01	1	0.53	0.8	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.45_25.55_2600	TRUE	100.45_25.55	DEFAULT	28.32859717	2600	2000	10	200	1	1.99	1	-0.27	-0.4	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.45_25.55_2800	TRUE	100.45_25.55	DEFAULT	22.08565696	2800	2000	10	200	1	7.99	1	-1.07	-1.6	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.45_25.55_3000	TRUE	100.45_25.55	DEFAULT	8.334210376	3000	2000	10	200	1	13.99	1	-1.87	-2.8	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.55_25.55	FALSE	DEFAULT		111.1228	2137	2000	10	200	1	0	1	0	0	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.55_25.55_1800	TRUE	100.55_25.55	DEFAULT	11.6833279	1800	2000	10	200	1	-10.11	1	1.35	2.02	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.55_25.55_2000	TRUE	100.55_25.55	DEFAULT	43.16812184	2000	2000	10	200	1	-4.11	1	0.55	0.82	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.55_25.55_2200	TRUE	100.55_25.55	DEFAULT	32.71949082	2200	2000	10	200	1	1.89	1	-0.25	-0.38	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.55_25.55_2400	TRUE	100.55_25.55	DEFAULT	17.10056502	2400	2000	10	200	1	7.89	1	-1.05	-1.58	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
100.55_25.55_2600	TRUE	100.55_25.55	DEFAULT	6.451296084	2600	2000	10	200	1	13.89	1	-1.85	-2.78	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1
102.25_25.55	FALSE	DEFAULT		111.1228	2199.1	2000	10	200	1	0	1	0	0	0	0	0	0	0	0	0	...//Timeseries//evaporation_priestly_taylor_hindcast//340.dfs2	1

Appendix C Basin definition file for Routing

HYBAS_ID	MAIN_BAS	NEXT_DOWN	DIST_MAIN	SUB_AREA	min	Q_avg	manning	PFAF	UP_AREA	PFAF_ID	LakeArea	LakeAreaPlastic	CK_Lake	CK_LakeCalc	factor0	factor100	LakeCollection	LakeCollectionCapacity
4121505180	4120015000	4121506150	1197.6	148.9	1702.972412	2.062	15	436	148.9	436890090500.0	0	0	0	0	1	100	0	0
4121506150	4120015000	4121506950	1186.1	150.9	1483.457642	4.203	15	436	299.8	436890090400.0	0	0	0	0	1	100	0	0
4121506950	4120015000	4121507590	1176	175.7	1329.067871	6.487	15	436	475.3	436890090300.0	0	0	0	0	1	100	0	0
4121507590	4120015000	4120935620	1167.3	107.2	1277.071655	8.018	15	436	582.6	436890090200.0	0	0	0	0	1	100	0	0
4120935620	4120015000	4120937970	1159.9	137.7	1252.164063	9.749	15	436	720.3	436890090100.0	0	0	0	0	1	100	0	0
4121506160	4120015000	4120935630	1178.6	166.2	1470.986572	2.203	15	436	166.2	436890080200.0	0	0	0	0	1	100	0	0
4120935630	4120015000	4120937970	1159.7	158.1	1252.164063	4.204	15	436	324.1	436890080100.0	0	0	0	0	1	100	0	0
4120937970	4120015000	4121509770	1145.7	150.2	1189.594971	15.959	15	436	1194.8	436890079000.0	0	0	0	0	1	100	0	0
4120935940	4120015000	4120937700	1157.1	123.9	1326.486938	1.576	15	436	123.9	436890078300.0	0	0	0	0	1	100	0	0
4120935930	4120015000	4120937700	1157.2	108.5	1326.486938	1.39	15	436	108.5	436890078200.0	0	0	0	0	1	100	0	0
4120937700	4120015000	4121509770	1145.6	38.4	1189.594971	3.466	15	436	270.8	436890078100.0	0	0	0	0	1	100	0	0
4121509770	4120015000	4121510190	1138.5	174.3	1166.838623	21.762	15	436	1639.8	436890077300.0	0	0	0	0	1	100	0	0
4121510190	4120015000	4120942000	1134.3	148.4	1153.10144	24.211	15	436	1788.3	436890077200.0	0	0	0	0	1	100	0	0
4120942000	4120015000	4121511760	1124.9	98.7	1140.269165	25.118	15	436	1887	436890077100.0	0	0	0	0	1	100	0	0
4120942230	4120015000	4121511760	1125.1	189.5	1137.607666	2.427	15	436	189.5	436890076000.0	0	0	0	0	1	100	0	0
4121511760	4120015000	4121512700	1115.9	153	1121.734009	29.747	15	436	2229.6	436890075700.0	0	0	0	0	1	100	0	0
4121512700	4120015000	4121513250	1104.9	170.2	1114.397827	31.878	15	436	2399.8	436890075600.0	0	0	0	0	1	100	0	0
4121513250	4120015000	4121514070	1099	113.9	1108.160767	33.356	15	436	2513.8	436890075500.0	0	0	0	0	1	100	0	0
4121514070	4120015000	4121514080	1089.3	152.5	1098.971191	35.363	15	436	2666.3	436890075400.0	0	0	0	0	1	100	0	0
4121514080	4120015000	4121514840	1085.1	86.6	1085.626099	36.456	15	436	2752.9	436890075300.0	0	0	0	0	1	100	0	0
4121514840	4120015000	4120954210	1077.3	130.3	1078.595337	38.08	15	436	2883.2	436890075200.0	0	0	0	0	1	100	0	0
4120954210	4120015000	4121517010	1065.6	121.4	1066.632446	39.539	15	436	3004.7	436890075100.0	0	0	0	0	1	100	0	0
4120954320	4120015000	4121517010	1065.6	144.7	1066.632446	1.855	15	436	144.7	436890074000.0	0	0	0	0	1	100	0	0
4121517010	4120015000	4121518100	1054.5	180.3	1058.404419	43.238	15	436	3330	436890073330.0	0	0	0	0	1	100	0	0
4121518100	4120015000	4120961230	1043.9	203.7	1019.849487	45.388	15	436	3533.5	436890073320.0	0	0	0	0	1	100	0	0
4120961230	4120015000	4120965850	1034.3	73.4	1000.264954	45.816	15	436	3607	436890073310.0	0	0	0	0	1	100	0	0
4120961310	4120015000	4120965850	1034.2	133.1	1000.264954	1.73	15	436	133.2	436890073200.0	0	0	0	0	1	100	0	0
4120965850	4120015000	4121521950	1013	221	954.6912842	49.447	15	436	3961.1	436890073100.0	0	0	0	0	1	100	0	0
4120965990	4120015000	4121521950	1012.8	132.5	954.6912842	1.856	15	436	132.5	436890072000.0	0	0	0	0	1	100	0	0
4121521950	4120015000	4120967260	1006.1	127.8	938.4224854	52.634	15	436	4221.4	436890071200.0	0	0	0	0	1	100	0	0
4120967260	4120015000	4121522850	1000.6	125.4	932.1247559	54.125	15	436	4347	436890071100.0	0	0	0	0	1	100	0	0

Appendix D Cell weights for Routing

HYBAS_ID	GRID_ID	REDUCTION	TILE	PFAF
4120064610	104.35_23.65	0.015031528	340	436
4120064610	104.25_23.55	0.317930274	340	436
4120064610	104.35_23.55	0.893709511	340	436
4120064610	104.45_23.55	0.135182951	340	436
4120064610	104.25_23.45	0.062538293	340	436
4120064610	104.35_23.45	0.687921218	340	436
4120066510	104.05_23.75	0.010036479	340	436
4120066510	104.15_23.75	0.411495636	340	436
4120066510	104.25_23.75	0.233348135	340	436

Appendix E Bottom and top node overview of catchment nodes

Catchment	Bottom node	Top nodes
C1	436890033100	
C10	436870700000	436870905320
C11	436860050300	
C12	436843071000	
C13	436843055300	436843071000
C14	436843055200	
C15	436843010100	436843055300,436843055200
C16	436842010000	
C17	436822035500	
C18	436829010500	
C19	436829010300	436829010500
C2	436890032000	
C20	436828003600	
C21	436824910330	
C22	436824630200	
C23	436860033000	436860050300
C24	436860032100	
C25	436870300100	436870700000
C26	436870201000	
C27	436870100100	436870300100,436870201000
C28	436860011100	436860033000,436860032100
C29	436827009000	436829010300,436828003600,436829000100,436829000200, 436829000600,436829000300,436829000500,436829000400
C3	436890031500	436890033100,436890032000
C30	436824610000	436824630200
C31	436824507120	436824910330,436824610000,436824900200,436824900400, 436824900100,436824900300,436824900500,436824900600
C32	436823000300	436827009000,436824507120,436824000000
C33	436822031500	436822035500
C4	436890010300	436890031500
C5	436880010100	436880052000,436880021000
C6	436880021000	
C7	436880052000	
C8	436870909000	436890010300,436880010100
C9	436870905320	436870909000

Appendix F Upstream PFAF_IDs

436890033100	436870700000	436860050300	436843071000	436843055300	436843055200	436843010100	436842010000	436822035500	436829010500	436829010300	436890032000	436828003600	436824980100
436890050300	436890027400	436860060100	436846100100	436846100100	436846100100	436846100100	436842030300	436822035500	436829070000	436829070000	436890032000	436828003600	436824980100
436890073310	436890050300	436860050300	436846901000	436846901000	436846901000	436846901000	436842010000	436822050000	436829050000	436829050000	436890032000	436828005000	436824910330
436890033100	436870700000	436860070100	436846403000	436846403000	436846403000	436846403000	436822030100	436822041000	436829090020	436829090020	436890033300	436828004000	436824920000
436890033200	436870901000	436860070300	436847001100	436847001100	436847001100	436847001100	436842020100	436822070100	436829010500	436829010300	436890033300	436828007000	436824931000
436890033300	436870801000	436860070200	436847005000	436847005000	436847005000	436847005000	436842030200	436822060100	436829031100	436829010400	436890033300	436828006100	436824933100
436890040100	436870902100	436860060200	436843075000	436843075000	436843075000	436843075000	436842020200	436822043100	436829020100	436829010500	436890040100	436828009100	436824932000
436890050100	436870903000	436860070500	436843071000	436843055300	436843055300	436843010100	436842020300	436822042100	436829031200	436829031100	436890050100	436828008000	436824933200
436890050200	436870802000	436860070400	436843073000	436843055500	436843055500	436843010200	436842050100	436822070200	436829020200	436829020100	436890050200	436828006200	436824935000
436890040200	436870803000	436860060300	436843072000	436843055400	436843055400	436843010300	436842040100	436822043200	436829031300	436829031200	436890040200	436828006300	436824934000
436890050400	436870902300	436860060400	436843074000	436843056000	436843056000	436843075000	436842050200	436822060200	436829031400	436829020200	436890050400	436828009200	436824950000
436890071100	436870902200	436860091000	436843076000	436843057100	436843057100	436843030100	436842040200	436822070300	436829020300	436829031300	436890071100	436828009300	436824940000
436890060100	436870905100	436860080100	436843090100	436843057200	436843057200	436843020100	436842070110	436822042200	436829031500	436829031400	436890060100	436828009300	436824960000
436890060200	436870904000	436860092000	436843080100	436843057310	436843057310	436843030200	436842061000	436822042300	436829020400	436829020300	436890060200	436828009300	436824970000
436890060300	436870804100	436860060500	436843080200	436843057331	436843057331	436843030300	436842062000	436822043300	436829033000	436829031500	436890060300	436828009300	436824991000
436890071200	436870805100	436860080200	436843080300	436843057320	436843057320	436843030300	436842070120	436822060300	436829032000	436829020400	436890071200	436828009300	436824980310
436890072000	436870905310	436860093000	436843090300	436843057332	436843057332	436843020200	436842070130	436822090100	436829020500	436829033000	436890072000	436828009300	436824980200
436890073100	436870905200	436860094000	436843090200	436843057500	436843057500	436843051100	436842070140	436822080100	436829035000	436829032000	436890073100	436828009300	436824992000
436890073200	436870804200	436860095000	436844010000	436843057400	436843057400	436843040100	436842063000	436822043400	436829034000	436829020500	436890073200	436828009300	436824993000
436890073320	436870805200	436860096000	436845011000	436843057700	436843057700	436843051200	436842064000	436822080200	436829050100	436829035000	436890073320	436828009300	436824980320
436890073330	436870905320	436860097000	436845013000	436843057600	436843057600	436843051300	436842070200	436822090200	436829040000	436829034000	436890073330	436828009300	436824994000
436890074000	436870905330	436860098000	436845012000	436843057900	436843057900	436843040200	436842070300	436822090300	436829050200	436829050100	436890074000	436828009300	436824995100
436890075100	436870805300	436860099000	436844020100	436843057800	436843057800	436843052100	436842065000	436822090400	436829050300	436829040000	436890075100	436828009300	436824995200
436890075200	436870804300	436860099500	436844031100	436843059000	436843059000	436843053310	436842066000	436822090500	436829060100	436829060100	436890075200	436828009300	436824995300
436890075300	436870805400	436860099500	436845015000	436843058100	436843058100	436843053200	436842090100	436822090600	436829070100	436829050300	436890075300	436828009300	436824995300
436890075400	436870907000	436860099500	436845014000	436843071000	436843071000	436843052200	436842080100	436822090700	436829070200	436829060100	436890075400	436828009300	436824995300
436890075500	436870906100	436860099500	436845016000	436843060100	436843060100	436843053320	436842080200	436822090800	436829070300	436829070100	436890075500	436828009300	436824995300
436890075600	436870909000	436860099500	436845017000	436843060300	436843060300	436843053500	436842080200	436822090900	436829060200	436829070200	436890075600	436828009300	436824995300
436890075700	436870908000	436860099500	436844031200	436843060200	436843060200	436843053400	436842080300	436822091000	436829080110	436829070300	436890075700	436828009300	436824995300
436890077100	436870906200	436860099500	436844020200	436843073000	436843073000	436843055100	436842090200	436822091100	436829091000	436829060200	436890077100	436828009300	436824995300
436890076000	436870906310	436860099500	436844031300	436843072000	436843072000	436843054000	436842090300	436822091200	436829080120	436829080110	436890076000	436828009300	436824995300
436890077200	436870906320	436860099500	436845020100	436843058200	436843058200	436843055300	436842000000	436822091300	436829080130	436829091000	436890077200	436828009300	436824995300