Integrating Climate Change Risks into Water and Flood Management by Vulnerable Mountainous Communities in the Greater Caucasus Region

Deliverable 7 (2016): Hydrometric and Forecasting platform

REPORT TITLE - Deliverable 7 (2016): Hydrometric and Forecasting platform

PROJECT - Integrating Climate Change Risks into Water and Flood Management by Vulnerable Mountainous Communities in the Greater Caucasus Region

Deliverable 7 (2016): Hydrometric and Forecasting platform			Date
Prepared by	Juan Fernandez	Signature	20/12/2016
Checked by	David Milton		10/1/17
Approved by	David Milton		10/1/17

TABLE OF CONTENTS

1. Introduction

The main aim of this document is to present the final design of the flood forecasting platform, its components and recommendations for the success operation of the above-mentioned platform.

2. Background

Within the framework of this project, the implementation of several flood Community-Based Early Warning Systems (CBEWSs) was proposed. As it has been described previously in several deliverables by this consultant, the implementation of a flood CBEWS do require the implementation of a full (National or Central) Flood Forecasting Early Warning System (FFEWS). This is due to the local characteristics of the catchments in the study area, with very short lead times.

The FFEWS requires the implementation of a Flood Forecasting System that would allow the timely warnings to be disseminated to the relevant communities.

3. Flood Forecasting System

The proposed system was described in detail in Deliverable 1 (Terms of Reference for a full FFEWS in the Pilot Catchments, 2014). The flood forecasting framework can be observed in Figure 1. All the different components and its relationship and link will be detailed below.

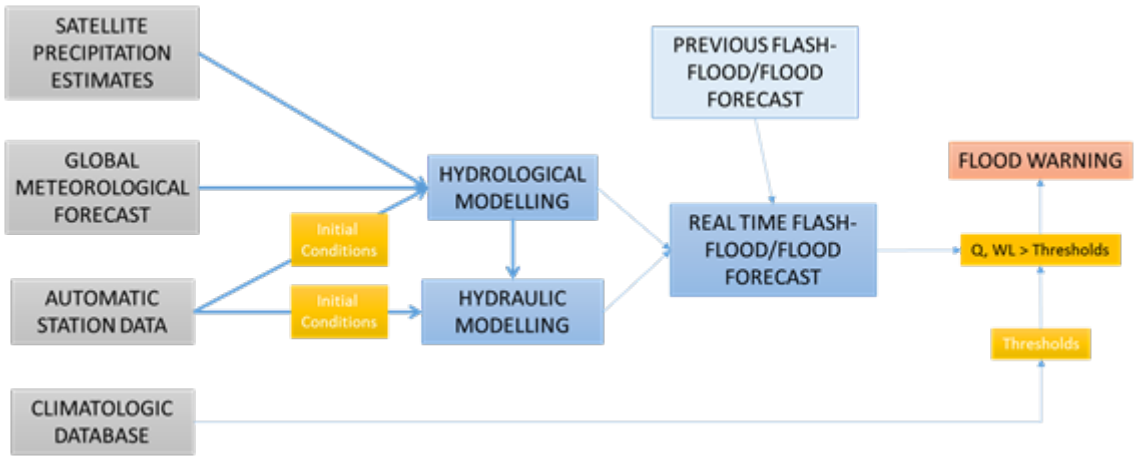

Figure 1 – FEWS Structure

The forecasting platform selected for this implementation is DELFT-FEWS. The structure of this platform will be described below in detail.

3.1 FFEWS components

The different components of the FFEWS are briefly outlined below.

3.1.1. Meteorological Inputs

Several meteorological inputs are considered in the FFEWS.

3.1.1.1. Automatic Stations

Information from weather and hydrological automatic stations and posts is being imported into the system.

3.1.1.2. Meteorological Forecasting (GFS and ACCESS)

At this stage global forecasting models are being used. The Global Forecasting System by NOAA (National Oceanic and Atmospheric Administration of the USA) is the main forecasting input. Also, the global Australian Community Climate and Earth-System Simulator (ACCESS) weather model is also being imported into the platform.

3.1.1.3. Satellite Precipitation Estimates

Satellite precipitation estimates (TRMM/GPM) are available. At this stage TRMM estimates are being imported automatically into the FFEWS.

All the different precipitation and temperature data sources are analysed and combined within the forecasting platform to be used in the hydrological model.

3.1.2. Hydrological Modelling

A hydrological model (HEC-HMS) has been implemented for the FFEWS. This hydrological model is using the precipitation and temperature information from the meteorological inputs in order to calculate flow at pre-specified locations.

3.1.3. Hydraulic Modelling

A hydraulic model (HEC-RAS) has been implemented for the FFEWS. This hydraulic model is routing the flows generated by the hydrological model and providing discharge and water level information.

3.1.2. Forecasting Platform

A forecasting platform (Delft-Fews) has been deployed in order to collect all the data, analyse all the data and provide the necessary means for model launching.

4. Basic Delft-Fews User Guide

As it has been detailed in several Deliverables by this consultant, the forecasting platform selected for the Turyanchay Flood Forecasting System is Delft-Fews. In order to ensure that the reader is familiar with the main features of this platform, a very brief user guide is detailed below.

4.1 Launching Turyanchay River Basin Delft-Fews

Delft-Fews can be started using the application launcher (executable file FEWS-AZE.exe) within the bin directory.

4.2 Explorer and Menus

FEWS Explorer is the principal window of Delft FEWS. The main elements of FEWS Explorer are shown in Figure 2.

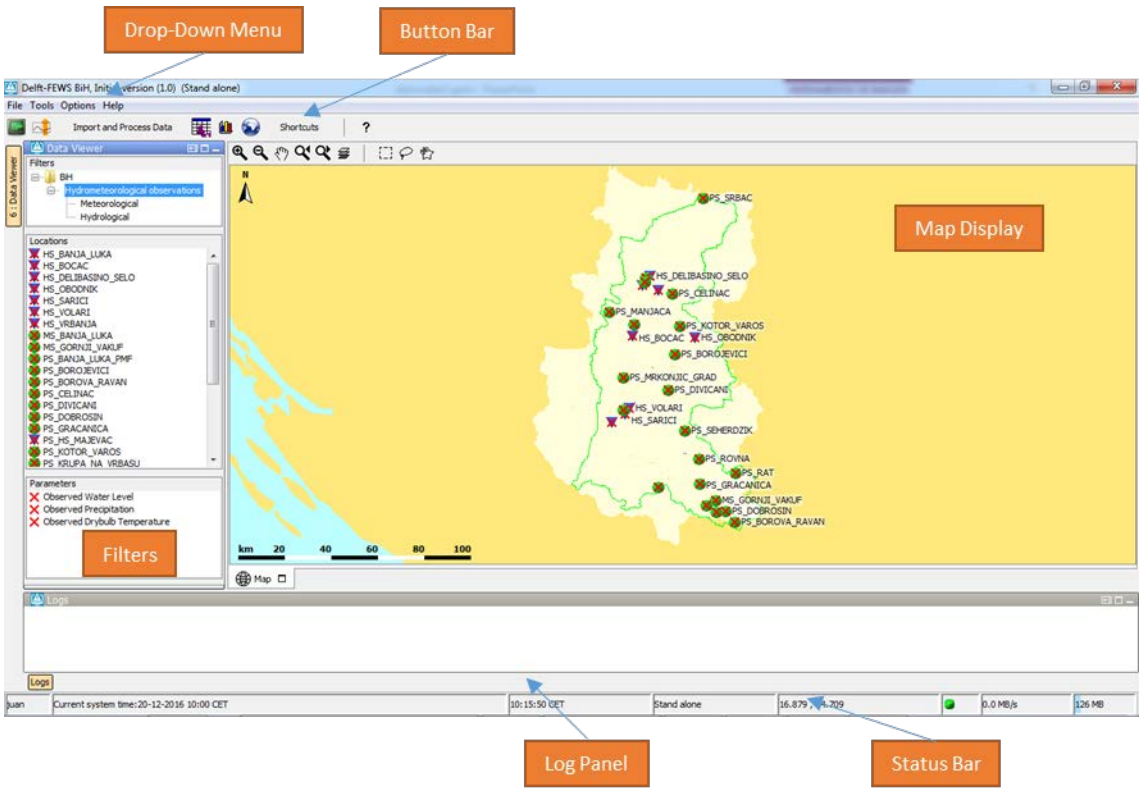

Figure 2 – FFEWS Explorer

Map display

The map display serves a double purpose. The first is to give an overview of the available locations given a combination of filters applied and to allow the user to select or deselect locations by clicking the location icon. The second is to provide a geographical background to the locations involved in the flood forecast.

Filters

The list filters are required to identify the data to be displayed in a graph or table, or the icons on the map. There are four list boxes, from top to bottom:

- Time series groups: Time series sets can be selected in the upper filter. Time series sets are configured groups of locations with similar data types. The locations with the selected time series set will be displayed on the map display and listed in the locations filter, the second list box. The data types associated with the locations are displayed in the data types filter, the third list box.
- Locations: The locations associated with the selected main filter are shown in the locations filter. Selected location will be highlighted on the map by means of a blue square. Locations can also be selected in the map display. Location related icons are displayed on the map as well as in front of the location names. Different icons (*Table 1*) are used to display locations and give information about the availability of data and about the hydrological status of the locations.

	Meteorological Station/Post Location
	Hydrological Station Location
	Catchment Location
	Hydrological Output Location
	Hydraulic Modelling Output Location

Table 1 – Location Icons

- Data types (parameters): The data types associated with the selected main filter are shown in the data type list box. Selecting one or multiple data types causes the location list box to be updated regarding the potential availability of data, as shown by the icon displayed to the left of the location. When depending on the selections made no data is available for a particular location or parameter its name is greyed out. Data availability is shown based on different icons (*Table 2*).

	no data available in view period
	data never written to database
	missing data in view period
	soft validation limit exceeded
	hard validation limit exceeded
	data edited or interpolated

Table 2 – Data Availability Icons

- Forecasts: The forecast list box displays forecasts that have been selected for viewing with help of the Forecast Manager. By highlighting one or more forecasts in this filter you can display them in graphs and tables. The current forecast will also always be shown in the time series display. If any of the pre-defined thresholds are surpassed, different icons will appear (*Table 3*).

	a threshold exceeded in view period
	Level 1 threshold crossing in historic and forecast period
	Level 2 threshold crossing in historic and forecast period
	Level 3 threshold crossing in historic and forecast period

Table 3 – Forecast threshold Icons

Drop down menus

The drop down menu bar provides access to all displays configured.

Button bar

The Tool bar provides quick access to frequently used tools. Tools are plug-ins to the FEWS Explorer.

Log Panel

The Log Viewer relays high level messages generated by active system components (*Table 4*). Additionally, detailed messages are available in the Log Browser.

Log level	**Description**
Fatal	Severe errors that cause premature termination

Error	Other runtime errors or unexpected conditions
Warn	Events that are undesirable or unexpected, but not necessarily wrong
Info	Runtime events (startup/shutdown) that allows tracking of the progress of the system

Table 4 – Log Levels

Status Bar

The Status Bar provides information about the status of the forecasting system.

The following information can be displayed:

Operator name (always displayed)

The name of the operator that has logged in is displayed.

Current system time

The current system time is the time in which the system 'lives'. The current system time moves forward in the so-called "Cardinal Time Step".

FEWS time

This is the time that is configured in FEWS to display information.

Local time

The actual computer time. This is the time the user configures in the regional settings of windows.

Mouse co-ordinates

Mouse co-ordinates displayed in the configured co-ordinate system

System status icon

The System status icon (*Table 5*), in the lower right corner of the display, indicates whether the system operates normally or that severe errors are encountered. The icon has the following display modes:

Icon	**System status**
	System is running normally but warnings have been encountered
	System encountered severe errors in the past 48 hours. This means that at least one system message has been generated with log level ERROR. After all messages with this log level have been acknowledged by the user via the System Monitor, the icon becomes green again.

	System encountered fatal errors in the past 48 hours. This means that at least one system message has been generated with log level FATAL. After all messages with this log level have been acknowledged by the user via the System Monitor, the icon becomes green again.

Table 5 – System Status Icons

F12 Menu

In the FEWS Explorer a number of options are available under the <F12> key (*Table 6*).

F12	**Action**
1	Open most recent current forecast and adjust system time
2	Open most recent forecast and adjust system time
3	Run last created task
4	Ids visible
5	Names visible (default)
6	Descriptions visible
7	Child locations visible
8	Debug feature
9	Verbose location tool tips
A	Tracking sql objects enabled
B	Clear track open sql statements
C	Print open sql statements
D	Load time series info
E	Compact local data store
F	Rolling Barrel local data store
G	Start/resume recording
H	Pause recording
I	Stop recording
J	Copy current map scale to clipboard
K	Copy current map extent to clipboard
L	Copy current map to png file
M	Show database statistics last run
N	Clear time series memory caches
O	Restart

Table 6 – F12 menu options

4.3 Data Editor and Data Display

The Data Display and Data Editor offer graphical displays for presenting and editing of data. Both have nearly the same functionality but only the Data Editor allows data to be edit. In addition, the data editor can only be opened once while multiple instances of the data display can be opened.

This display offers the following features:

- Display of time series in:
  - graphs (scalar/longitudinal profiles)
  - tables (scalar/longitudinal profiles)
- Tabular data editor
- Display of actual data with:
  - Historical events
  - Threshold levels

Data is displayed in a table and a graph simultaneously. The splitter between the table and the graph can be moved to modify the display.

When the display is started through the FEWS Tools menu item Data Editor, data can be edited and the edited data can be stored in the FEWS database. When the display is started through the FEWS Tools menu item Data Display or through the FEWS toolbar, the data can only be viewed.

4.4 Spatial Display

The Spatial Display grid display can be used to display time series of any type: scalar, polygon or grid. The display will depict the data on a map background. The display time is then set using a ruler that can be moved manually or made to move automatically.

The spatial display consists of following components:

- Spatial Display selection filters
- Control Toolbar with following options:
- Manual zoom and zoom previous buttons
- Predefined zoom range selector
- Play, pause, stop, step forward, step backward and record buttons
- Time slider with time slice indicator
- Data availability and maximum value indicator
- Moving average slider

- Legend
- Contours button
- Export time step data in ascii grid-file

Also, scalar time series can be extracted from the grid by double clicking the point of interest. Depending on the type of data, which is displayed, the scalar time series will be relevant to either a point, polygon or grid cell.

5. Configuration Guidelines

In this section the consultant will give some brief guidelines regarding how to the system can be configured. The proposed configuration of the Turyanchay River Basin FFEWS will be outlined too. Also, in following sections some examples of required configuration will be described.

5.1 Archive

The archive folder contain two different folder about import and export datasets.

5.2 Cold States

This folder contains information about the different cold-states files used for the simulations or the linked models.

5.3 Config

The 'config' folder is the main folder within Delft-Fews containing all the different configuration information. Display, module configuration, regional configuration, system configuration, workflows and unit conversion XML files are contained within this folder. These are some of the important files within this folder.

Configuration Item	**Directory on File System**	**Table name in file system**
Definition of regional configuration, including all locations, parameters etc.	RegionConfigFiles	RegionConfigurations
Definition of system configuration items, including the plug-ins available to the system, definition, icons etc.	SystemConfigFiles	SystemConfigurations
Definition of modules for handling data and running forecasting models	ModuleConfigFiles	ModuleInstanceConfigs

Definition of workflows for running sequences of modules	WorkflowFiles	WorkflowFiles
Cold states for modules. Zip file containing model specific data exported by GA usually before running a model	ColdStateFiles	ColdStateFiles
Definition of mapping of ID's and parameters between external sources (e.g. telemetry, modules) and ID's and parameters defined in the Delft-Fews configuration	IdMapFiles	IdMaps
Definition of unit conversions between external sources (e.g. telemetry, modules) and units used in Delft-Fews	UnitConversionFiles	UnitConversions
Definition of flag conversions between external sources (e.g. telemetry, modules) and flags used in Delft-Fews	FlagConversionFiles	FlagConversions
Definition of layout of user displays, including What-if scenarios, Grid Display etc.)	DisplayConfigFiles	DisplayConfigurations
Definition of module parameters stored in Delft-Fews	ModuleParameters	ModuleParameters
Zipped files containing datasets for modules used by the forecasting system.	ModuleDataSetFiles	ModuleInstanceDatasets
Definition of HTML template files used in creating HTML reports for use on the web server.	ReportTemplateFiles	ReportTemplates
Map layers (shape files) used in main map display and spatial interpolation	MapLayerFiles	MapLayerFiles
Images used in reports etc	ReportImageFiles	ReportImageFiles
Icons used in main map display and button bar	IconFiles	IconFiles

Table 7 – Delft-Fews Structure

5.4 Dump-files

In this directory the dump files are written to. These Dump Files are created when one of the execute activities fails. A dump file is a ZIP file which includes all the dumpDir directories defined. The dump file is created immediately on failure, meaning that all data and files are available as they are at the time of failure and can be used for analysis purposes. The ZIP file name is time stamped to indicate when it was created.

5.5 Export

In the Export directory all the different export files are located temporarily.

5.6 Import

Within this folder the directories for all the different data to be imported into Delft-Fews should be located. There should be folders for the two meteorological models, for the telemetry data and for the satellite precipitation data (TRMM/GPM and MPE). In this folder the files to be imported should periodically be placed automatically. It should be noted that a back-up of this files should be kept somewhere prior the import process, because once they are imported to the platform, those files are deleted by the importing process. If the import process fails for some files, those files will be moved to the ImportFailed directory. Otherwise they will be deleted unless it is specified otherwise.

5.7 Map

Within this folder the different GIS files used in the visualisation platform can be found.

5.8 Modules

All the different models connected within Delft-Fews have a folder within this directory. In this case a folder for MIKE 11, MIKE-NAM and the GridReader should exist. Within the respective folders information about the link procedure, operational files (*.bat) and the actual models are located.

6. Configuration Recommendations

Below, some simple examples of procedures to update the system are described. This could be the case if new stations are added, or when adding new meteorological forecasting data and hydrological or hydraulic models. In the sections below, brief examples detailing this process are given.

6.1 Adding Telemetry Stations

In order to add a new telemetry station to the system the following procedure should be undertaken.

- Locations: the forecaster should update the Locations.xml file in the RegionConfigFiles folder and add the new station in the same format used in this file (Figure 3).

```
<location id="95000" name="Gabala">
        <description>Gabala new station</description>
        <shortName>Gabala2</shortName>
        <x>522158.92</x>
        <y>6714970.9</y>
        <z>366.00</z>
</location>
```

Figure 3 – Location information for stations

- LocationSet: the forecaster should also update the LocationSet.xml file in the RegionConfigFiles folder and add the new station to the list of stations, depending on the type of station (Figure 4).

```
<locationSet id="Meteo_P">
        <locationId>95000</locationId>
</locationSet>
```

Figure 4 – LocationSet information for stations

- IdMap Import: finally, the forecaster should update the IdImportTelemtry.xml file in the IdMapFiles folder (Figure 5)

```
<map internalLocation="95000" internalParameter="P.obs" externalLocation="95000" externalParameter="P.obs"/>
```

Figure 5 – IdMap information for stations

It should be noted that if the station is measuring more than one variable, lines should be added to this file in order to account for that.

6.2 Adding Rating Curves

The following procedure should be followed to include new rating curve information into the system.

- RatingCurves: the RatingCurves.xml file in the RegionConfigFiles folder should be update it with the required information (Figure 6). This information is based on the equation type $Q = a(h + b)^c$.

```
<ratingCurve ratingCurveId="Gabala">
        <location>
                <locationId>95001</locationId>
        </location>
        <ratingCurveType>LevelToFlow</ratingCurveType>
        <reversible>true</reversible>
        <ratingCurveEquation>
                <lowerLevel>0.56</lowerLevel>
                <upperLevel>5.00</upperLevel>
                <equation>Power</equation>
                <a>63.423</a>
                <b>-0.560</b>
                <c>1.764</c>
        </ratingCurveEquation>
</ratingCurve>
```

Figure 6 – RatingCurves file.

- LevelToFlow: add the required information in the LevelToFlow.xml file in the ModuleConfigFiles folder. In this case the information should be supplied for the input variables, for the output variables and for the id of the rating curve transformation (Figure 7).

```
<variable>
        <variableId>level</variableId>
        <timeSeriesSet>
                <moduleInstanceId>ImportTelemetry</moduleInstanceId>
                <valueType>scalar</valueType>
                <parameterId>H.obs</parameterId>
                <locationId>Gabala</locationId>
                <timeSeriesType>external historical</timeSeriesType>
                <timeStep unit="minute" multiplier="15"/>
                <relativeViewPeriod unit="hour" start="-96"
                startOverrulable="true" end="0"/>
                <readWriteMode>read only</readWriteMode>
        </timeSeriesSet>
</variable>
<!-- output variable-->
<variable>
```

```
        <variableId>flow</variableId>
        <timeSeriesSet>
            <moduleInstanceId>ImportTelemetry</moduleInstanceId>
            <valueType>scalar</valueType>
            <parameterId>Q.rated</parameterId>
            <locationId>Gabala</locationId>
            <timeSeriesType>external historical</timeSeriesType>
            <timeStep unit="minute" multiplier="15"/>
            <relativeViewPeriod unit="hour" start="-96"
            startOverrulable="true" end="0"/>
            <readWriteMode>add originals</readWriteMode>
            <synchLevel>1</synchLevel>
        </timeSeriesSet>
    </variable>
    <!-- transformations -->
    <transformation id="LevelToFlow">
        <rangeTransformation>
            <range>
                <limitVariableId>level</limitVariableId>
                <lowerLimit>0</lowerLimit>
                <upperLimit>50</upperLimit>
            </range>
            <stageDischarge>
                <power>
                    <stage>
                        <variableId>level</variableId>
                    </stage>
                    <coefficientSetId>Gabala</coefficientSetId>
        <coefficientSetFile>RatingCurves</coefficientSetFile>
                    <discharge>
                        <variableId>flow</variableId>
                    </discharge>
                </power>
            </stageDischarge>
        </rangeTransformation>
    </transformation>
```

Figure 7 – Level to Flow transformation

- ImportTelemetry: the LevelToFLow module should be added to the ImportTelemetry workflow.

6.3 Adding Meteorological Models

In some occasions, new meteorological models become available. In the sections below, the procedures for adding a new model (WRF in this case) would be described. The following activities should be carried out to include the WRF model (or any given model) into the system:

- Location and Grid: the WRF grid should be defined in both the locations.xml and the grid.xml file with the required information.
- Import folder: a new WRF folder should be created in the main Import folder. WRF results should be copied into this folder. It should be noted that the results should be in GRIB format.
- Grid Display: the WRF modelling results should also be included in the GridDisplay.xml file in the DisplayConfigFiles folder.
- IdMap: a new IdImportGribWRF.xml file in the IdMapFiles filder should be created. The GRIB files should be inspected in order to gather the information required for this file (Figure 8), specifically the external parameter ID for the required variables.

```
<map internalParameter="P.forecast" internalLocation="GribWRF"
externalParameter="61" externalLocation="GribWRF"/>
<map internalParameter="T.forecast" internalLocation="GribWRF"
externalParameter="11" externalLocation="GribWRF"/>
```

Figure 8 – IdMap for WRF

- Import Grid Module: the ImportGribWRF.xml file in the ModuleConfigFiles folder should be created with the required information (Figure 9).

```
<import>
  <general>
    <importTypeStandard>grib</importTypeStandard>
    <folder>$IMPORT_FOLDER_WRF$</folder>
    <failedFolder>$IMPORT_FAILED_FOLDER$</failedFolder>
    <idMapId>IdImportGribWRF</idMapId>
    <unitConversionsId>ImportUnitConversions</unitConversionsId>
    <gridStartPoint>SW</gridStartPoint>
    <importTypeConfig>$IMPORT_GRIBREADER$</importTypeConfig>
  </general>
  <timeSeriesSet>
    <moduleInstanceId>ImportGribWRF</moduleInstanceId>
    <valueType>grid</valueType>
    <parameterId>P.forecast</parameterId>
    <locationId>GribWRF</locationId>
    <timeSeriesType>external forecasting</timeSeriesType>
    <timeStep unit="hour" multiplier="1"/>
    <readWriteMode>add originals</readWriteMode>
    <synchLevel>6</synchLevel>
    <expiryTime unit="day" multiplier="2"/>
  </timeSeriesSet>
  <timeSeriesSet>
    <moduleInstanceId>ImportGribWRF</moduleInstanceId>
    <valueType>grid</valueType>
    <parameterId>T.forecast</parameterId>
    <locationId>GribWRF</locationId>
    <timeSeriesType>external forecasting</timeSeriesType>
```

```
    <timeStep unit="hour" multiplier="1"/>
    <readWriteMode>add originals</readWriteMode>
    <synchLevel>6</synchLevel>
    <expiryTime unit="day" multiplier="2"/>
  </timeSeriesSet>
  <externUnit parameterId="P.forecast" cumulativeSum="true" unit="mm"/>
  <externUnit parameterId="T.forecast" unit="K"/>
</import>
```

Figure 9 – Import WRF module

- Import Workflow: a workflow should be created with the required information (Figure 10) in the workFlowFiles folder.

```
<activity>
  <runIndependent>true</runIndependent>
  <moduleInstanceId>ImportGribWRF</moduleInstanceId>
</activity>
```

Figure 10 – Import WRF WorkFlow

7. Maintenance Guidelines

There are several basic recommendations for the proper maintenance of the Delft-Fews platform:

- Optimisation of Config Folder: the Config folder should be properly maintain, optimising the number of files and deleting unnecessary ones.
- Reduce number of configuration files.
- Reduce size of configuration files.
- Make maintenance easier.
- Make use of templates.
- Remove redundant system config files.
- The Delft-Fews database should also be maintained.