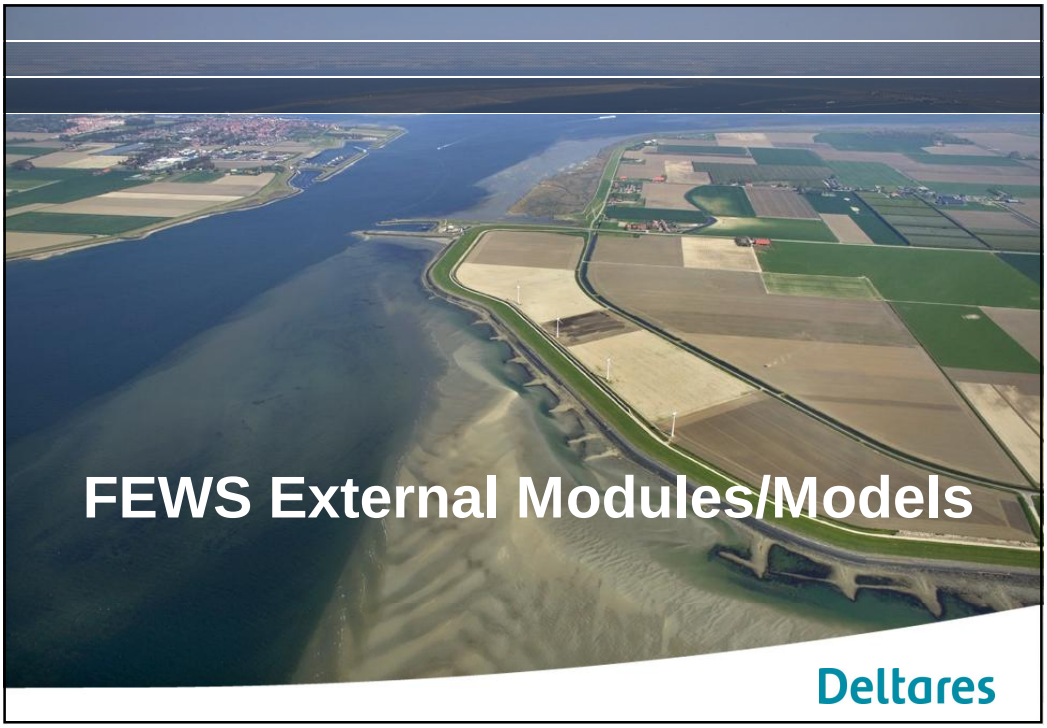
Deltares
Enabling Delta Life

Delft-FEWS

Advanced Configuration Course



FEWS External Modules/Models

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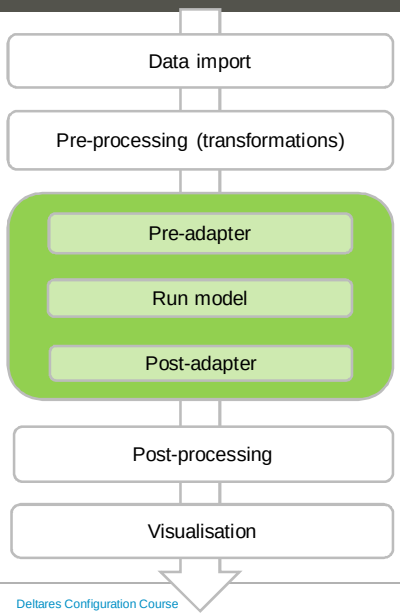
Generic workflow to run a model in FEWS



Running any external module

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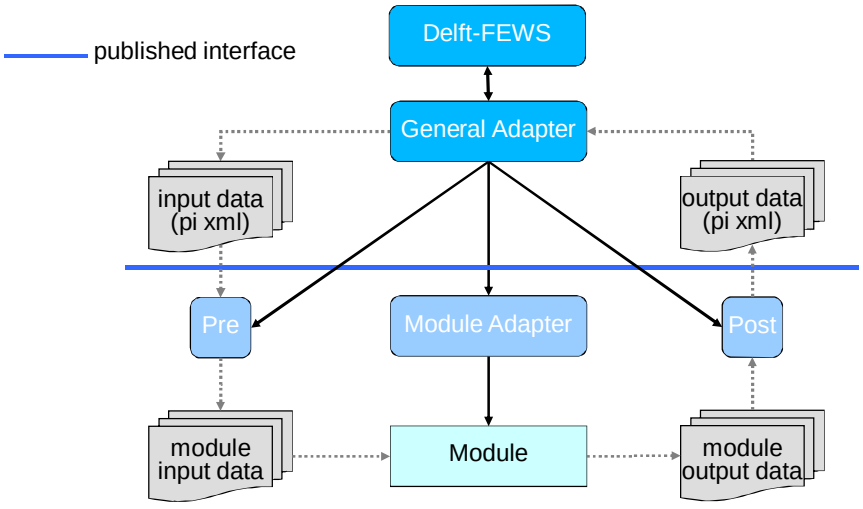
General Adapter -Concepts



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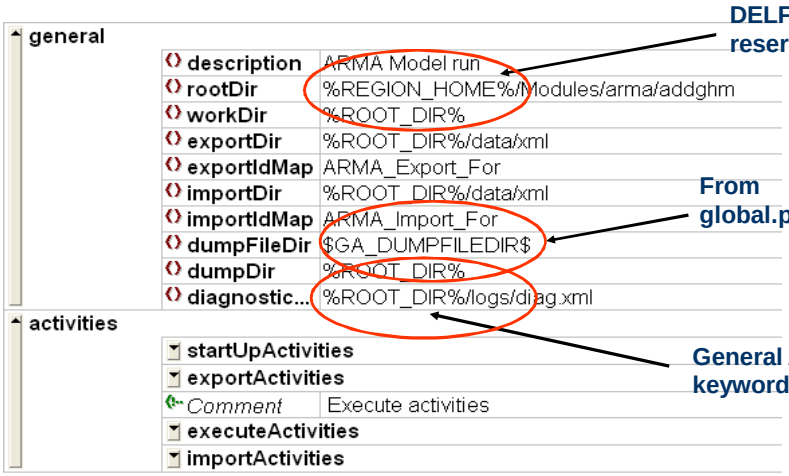
General Adapter – Configuration



DELFT-FEWS reserved keyword

From global.properties

General Adapter keywords

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General Adapter – Export Activities

Export Activities

Time Series – scalar

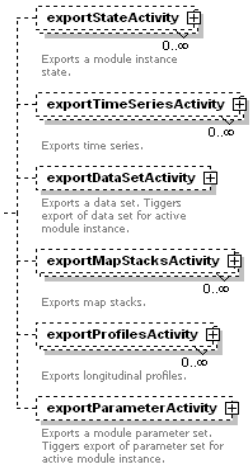
Time Series – grids (map stacks)

Time Series – profile

States

ModuleDataSet

ModuleParameters



Export Activities – Scalar/longitudinal time Series

Exports time series from database to a PI-XML file

Assign File name to export data to

Assign Time Series Sets to export

Written to exportDir

LocationID's & ParameterID's will be translated on export (as indicated in IdMapping)

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Export activities - grid time series

Same principle as exporting scalar time series

Supported grid file formats

ASC: ArcView/ARC-INFO grid interchange file

- Time Series as map stack

PCR: PCRaster file format

- Time Series as map stack

BIL: USGS standard grid format

- Time series in one file

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Export Activities – Module parameters

DELFT-FEWS administers module parameters

Exports to external module as PI-XML file

Held in Config\ModuleParFiles

exportParameterActivity	
description	Module Parameters
fileName	pi_parameters.xml
moduleInstanceId	ISIS_Eden_Forecast

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Export Activities – Module dataset

DELFT-FEWS administers module dataset

- Dataset: native module file
- Held in Config\ModuleDataSets by DELFT-FEWS as a ZIP file

Exports to external module by extracting data in ZIP file

Exported to a “root”directory

exportDataSetActivity	
description	ISIS DAT File
moduleInstanceId	ISIS_Eden_Forecast

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Exporting States

DELFT-FEWS can manage module states

What is a state?

- Module initial conditions
- Handled in “native”module format

Type of state;

- Cold State – default initial conditions
- Warm State – initial conditions from a previous run

For each module requiring management of states;

- ZIP file of cold state MUST be available in ColdStates dir.

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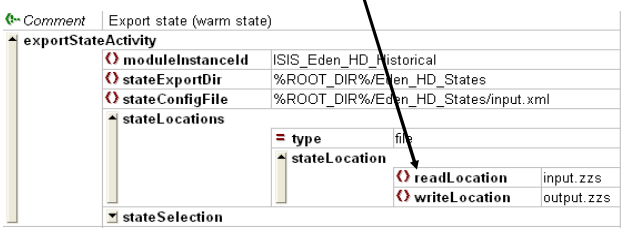
Exporting States

Defining “how” to export state

moduleInstanceId
stateExportDir
stateConfigFile
stateLocations

- read
- write

From the perspective of the model!!



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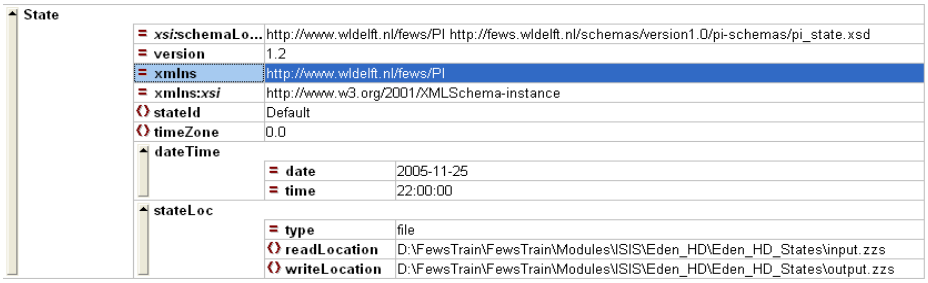
Exporting States

stateConfigFile

For export: Written by DELFT-FEWS ; read by adapter

For import:Written by adapter ; read by DELFT-FEWS



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Exporting States

Defining “what” to state export; stateSelection

State selection determines length of module run!!!!!

Cold State: Always use a cold state to initiate module run

Warm State: Use most suitable/recent state in search period

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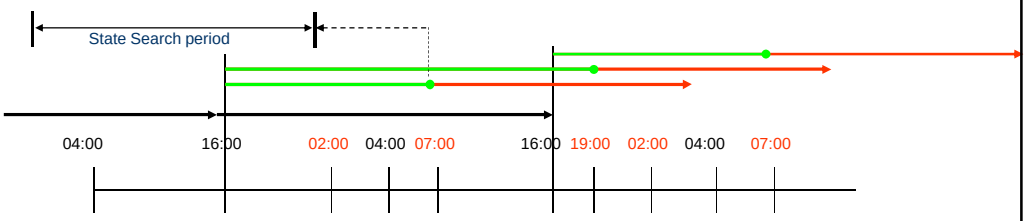

- **Start 02:00 Jan 05. T0 16:00 04 Jan**
- **Start 7:30 and T0 07:00 Jan 05**
- **Start 19:30 and T0 19:00 Jan 05**
- **Start 02:00 Jan 06. T0 16:00 05 Jan**
- **Start 07:30 and T0 07:00 Jan 06**

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General Adapter – Execute Activities

Running modules

Executables or Java classes

Arguments can be passed

Timout is set in case module “hangs”

If Diagnostic file indicates error – or non zero return code

- Executable considered to have failed

```
Comment        Run module post adapter to transform ASCII to XML
executeActivity
  description
  command
    className  nl.wldelft.fews.adapter.common.PostCommonAdapter
  arguments
    argument (2)
              Text
            1 %ROOT_DIR%
            2 Config/TFAdapterConfig.xml
  timeOut      8000
```


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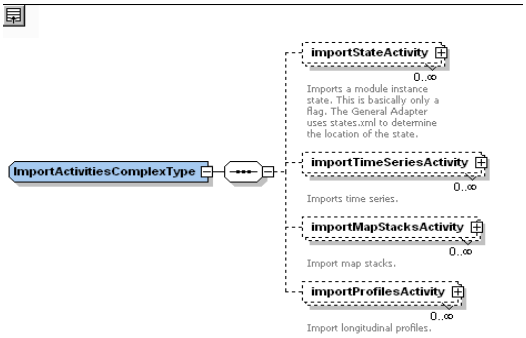
General Adapter – Import Activities

Import Time Series

- Scalar
- Longitudinal
- Grid

Import States



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General Adapter – Import Activities

- Importing time series
- Same principle as exporting
- File name & Time Series Set to save data to
- IdMapping used to translate locationId's and parameterId's
- Grids imported as mapstack + XML file

importActivities

importTimeSeriesActivity (2)

	importFile	timeSeriesSets
1	out_hindcast.xml	timeSeriesSets
2	out_forecast.xml	timeSeriesSets

timeSeriesSet (3)

	moduleInstanceSetId	valueType	parameterId
1	DODO	scalar	Q.simulated.forecast
2	DODO	scalar	Q.updated.forecast
3	DODO	scalar	Floodplain.storage

timeSeriesSet (3)

	moduleInstanceSetId	valueType	parameterId
1	DODO	scalar	Q.simulated.forecast
2	DODO	scalar	Q.updated.forecast
3	DODO	scalar	Floodplain.storage

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General Adapter – Import Activities

- Importing states
- Simple instruction where to find stateConfigFile

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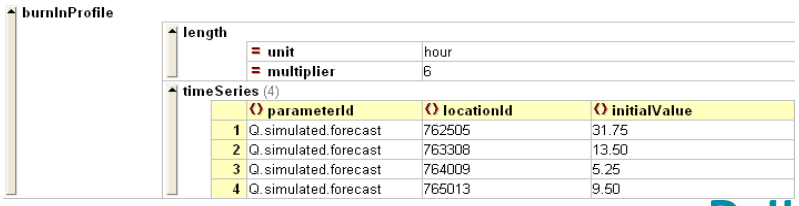
Burn-in profiles

- Avoid “abrupt” shock to model on startup
- Mainly relevant to HD modules (stability)

Only applied when starting from a cold state

- Identify start value in cold state
- Gradual “climb” to actual value



	parameterId	locationId	initialValue
1	Q.simulated.forecast	762505	31.75
2	Q.simulated.forecast	763308	13.50
3	Q.simulated.forecast	764009	5.25
4	Q.simulated.forecast	765013	9.50

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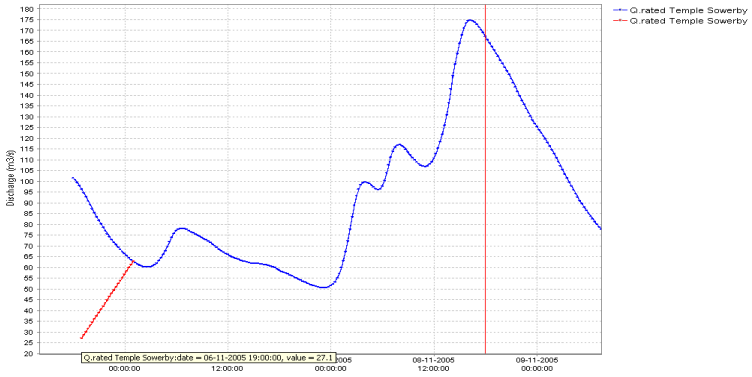
Burn-in profiles

Burn-in at Temple Sowerby



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Startup/Shutdown activities

Clean up files from module

- Startup – before running module
- Shutdown – after completing module

startUpActivities

purgeActivity (3)

	filter
1	%ROOT_DIR%/logs/*.*
2	%ROOT_DIR%/data/xml/*.*
3	%ROOT_DIR%/data/native/*.*

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Module diagnostics/debugging

PI-XML includes module diagnostics exchange

- To be written by module/adapter
- General Adapter Defines where diagnostics file is expected
- Not all logging passed – use native module log files

External module log inserted into FEWS log

- Most messages DEBUG level
- Error/Fatal: System messages

Detecting module failure

- Error in diagnostics log
- non-zero return code

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Using Module Configuration Templates

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Module Configuration Templates

Purpose:

- Allows for multiple instances of the same process for various modules using a single General Adapter configuration
- Reduces configuration effort
- Increases consistency

For example:

You want to run a Delft3D Flow simulation for two models

- Use moduleInstanceID: D3D_flow_1h_hc
- Use workflow: D3D_flow_model1 & D3D_flow_model2

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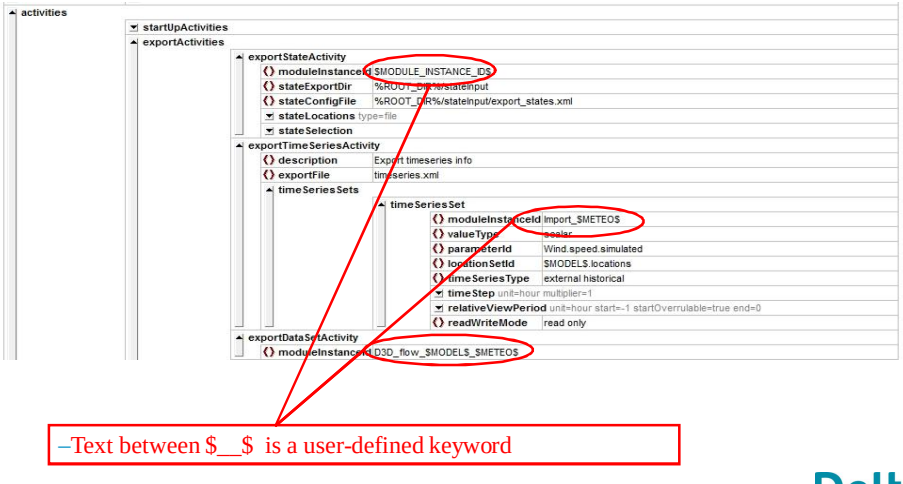
Module General Adapter template

Templates are made unique using keywords defined in the workflow



–Text between $__$ is a user-defined keyword

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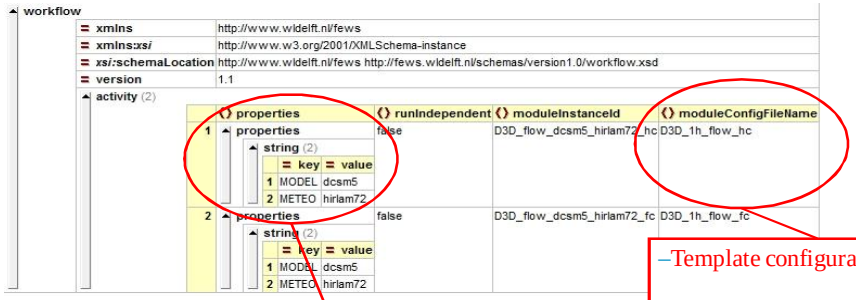
Workflow file

–Keywords are passed to the General Adapter from the Workflow as properties



–Template configuration file!

–$MODEL$ = dcsm5

–$METEO$ = hirlam72

–**D3D_flow_$MODEL$_$METEO$ = D3D_flow_dcsm5_hirlam72**

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Quick guide and wiki for model adapters

https://publicwiki.deltares.nl/display/FEWSDOC/Quick-start+Guide+for+Adding+an+External+Module+in+FEWS

https://publicwiki.deltares.nl/display/FEWSDOC/Model+adapters

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General Adaptor - Exercise

Exercise 12: Add an external module

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Extracting series from Gridded Data

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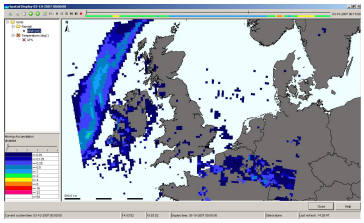
Use NWP series in the rainfall runoff model

- NWP gridded forecasts available



1. Make an Import module
2. Extract NWP cells for Isle of Man
3. Merge NWP forecast with other data sources
4. Use NWP forecast in external model

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Gridded Data – Exercises

The exercise is split into three sections

1. **Import NWP forecasts (Exercise 13)**
2. Extract scalar series from gridded data (Exercise 14)
3. Using the extracted scalar series in the model (Exercise 15)

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Grid Import module

Before importing data, some questions must be answered:

- What is the data format?
  - Does FEWS support this data format?
- What is the coordinate system used in the grid?
  - Check supported coordinate systems in FEWS.
- What are the grid dimensions?
  - Ask data supplier or use a data viewer that supports the format
- What are the parameters and units used?
  - Ask data supplier or check on the internet
- What are the time intervals used in the file?
- How long do I want to store the data in the database?
  - Gridded data can be voluminous

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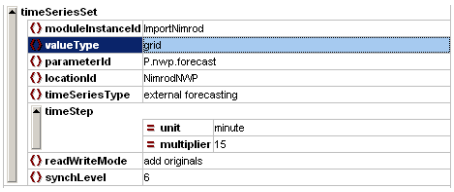
FEWS Time Series Sets: NWP

Properties of time series:

- location Id – or – locationSetId
- parameter Id
- timestep
- relativeViewPeriod



- valueType (scalar, grid, profile, ..)
- timeSeriesType (external historical, external forecast, ..)
- moduleInstanceId (import, PDM, KW, ISIS, ..)
- readWriteMode

- expiryTime (when to delete from database)
- synchLevel

- simple transformations (delay, multiplier, divider, incrementer)
- ensembleId

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Gridded Data – Exercises

The exercise is split into three sections

1. Import NWP forecasts (Exercise 13)
2. **Extract scalar series from gridded data (Exercise 14)**
3. Using the extracted scalar series in the model (Exercise 15)

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Extracting data from a Grid

The FEWS interpolation module can be used to extract series from a grid

For a location

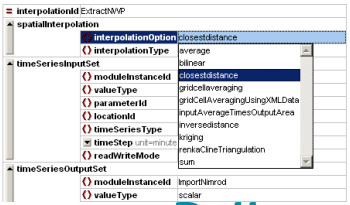
- extract the closest cell center (*closestdistance*)

For a catchment

- extract average of cells within a polygon (average)
- compute average of surrounding cells using bi-linear, kriging or inverse distance functions (*bilinear, kriging*, ..)

For a different grid

- extract the closest cell center (*closestdistance*)



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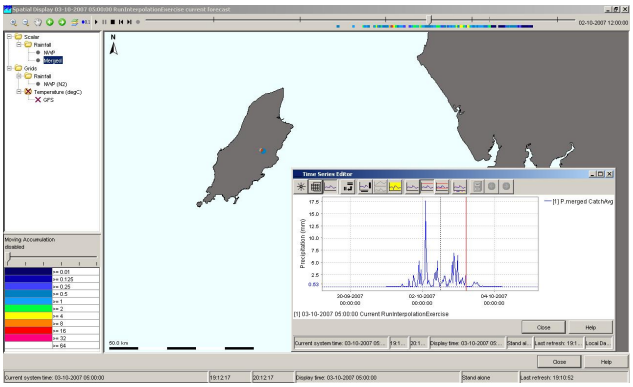
Display scalar time series in Spatial Display

With the FEWS Spatial Display it is possible to display, grids and scalar time series

- Some functionality only works with grid series, other only with scalar series.



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Gridded Data – Exercises

The exercise is split into three sections

1. Import NWP forecasts (Exercise 13)
2. Extract scalar series from gridded data (Exercise 14)
3. **Using the extracted scalar series in the model (Exercise 15)**

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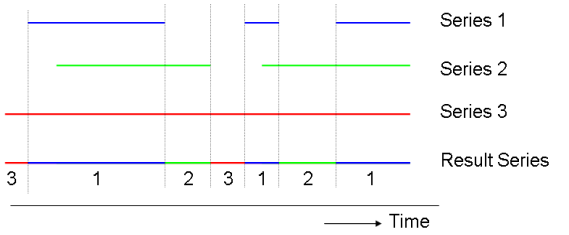
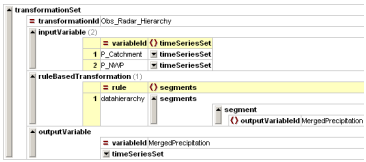
Merge forecast with observed series

The Transformation module is used to merge series into one (*datahierarchy*)

- Merging observed precipitation with nwp forecast





- What is the output series type (external forecast, simulated forecast)?

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Add series to External Model

The *RunInterpolationExercise* Workflow contains 7 module instances

	runIndependent	moduleInstanceId
1	true	InterpolateExample
2	true	LevelToFlow
3	true	IoM_CatchmentAveragePrecipitation
4	true	InterpolateNimrod
5	true	Merge_Precipitation
6	true	Hydro_Train_Interpolate_Forecast
7	true	Hydro_Train_Forecast

- What can we do to use the P.merged series by the model?
  - Update the Hydro_Train_Interpolate_Forecast: use the P.merged series

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Gridded Data – Exercises

The complete Exercise is split into three sections

1. Import NWP forecasts (Exercise 13)
2. Extract scalar series from gridded data (Exercise 14)
3. Using the extracted scalar series in the model (Exercise 15)

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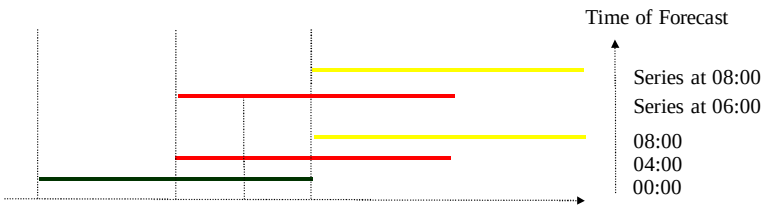
Gridded Data – Exercise 13 - Questions

- What forecast do you see?
- How can you see a forecast for 3-10-2007 00:00:00



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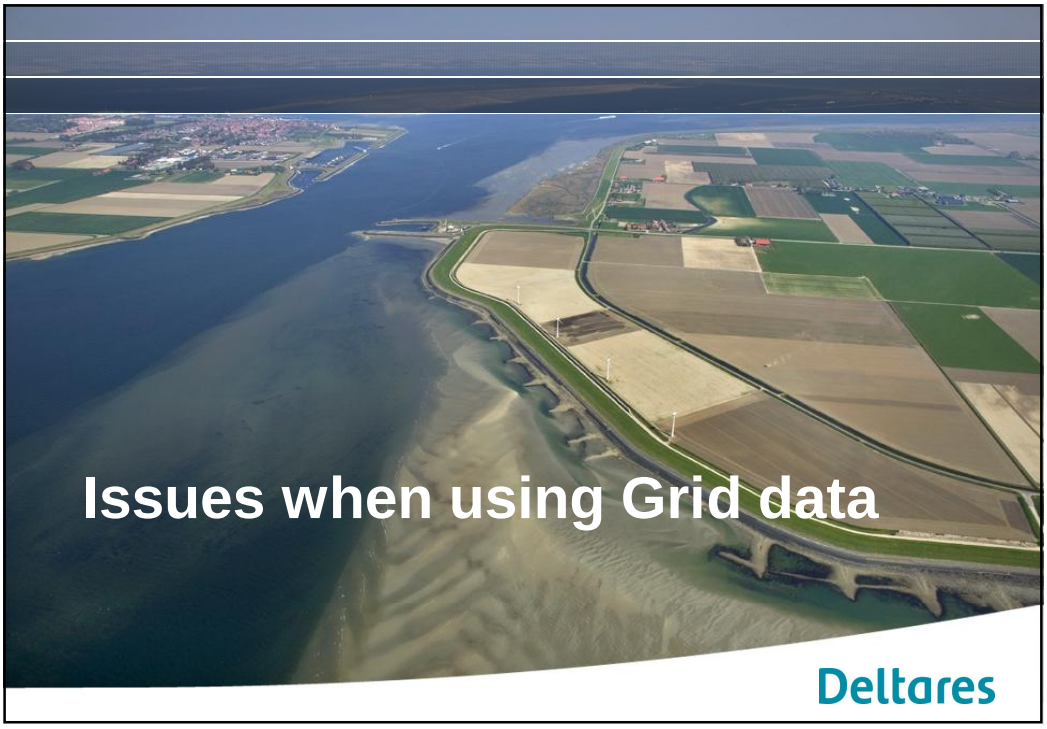
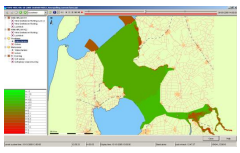


Issues when using grid data (1)

- Is it always required to configure the Grid XML file?
  - **No**: In some cases these grid characteristics are included in the data files (GRIB).
    - Good example are ECMWF Forecasts
    - Bad example are MetOffice local surge models (characteristics only use 2 decimal places)
- For an irregular grid the Cell centres must be included in the Grid xml file
  - **No**: it is also possible to use shape files with cell centres.
    - Since December 2008
    - Example: WAQUA models used in The Netherlands



Issues when using grid data (2)

- In a Client-Server environment all imported grids are only stored in the Central Database
  - **No**:By using synchlevels it is possible to configure the data to be synchronised.
    - Examples of synchlevels will follow later today
- The number of supported geodatums is limited to the enumeration in the config files
  - **Yes**: but
    - New geoDatums can be added by the FEWS Software developers
    - Try to use the polarStereographic or rotatedPoles elements (only regular grids)
    - Example KNMI Radar

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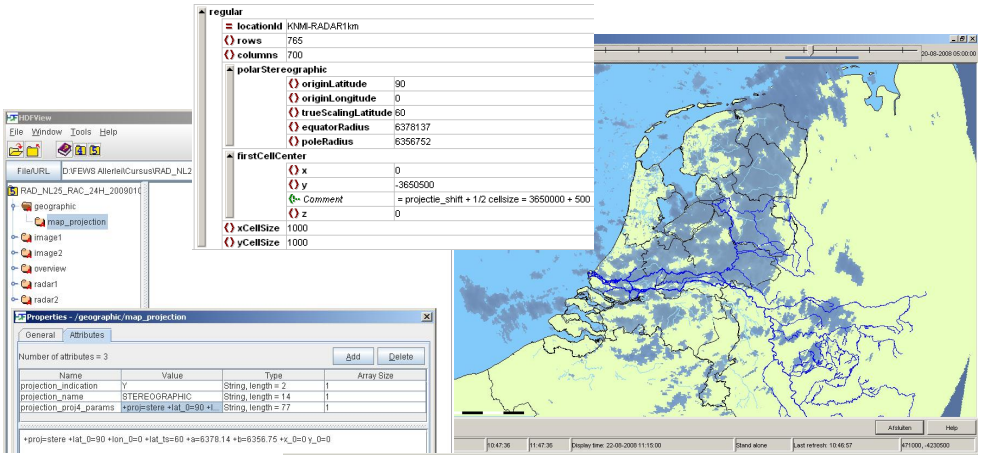
Issues when using grid data (3)

KNMI Radar



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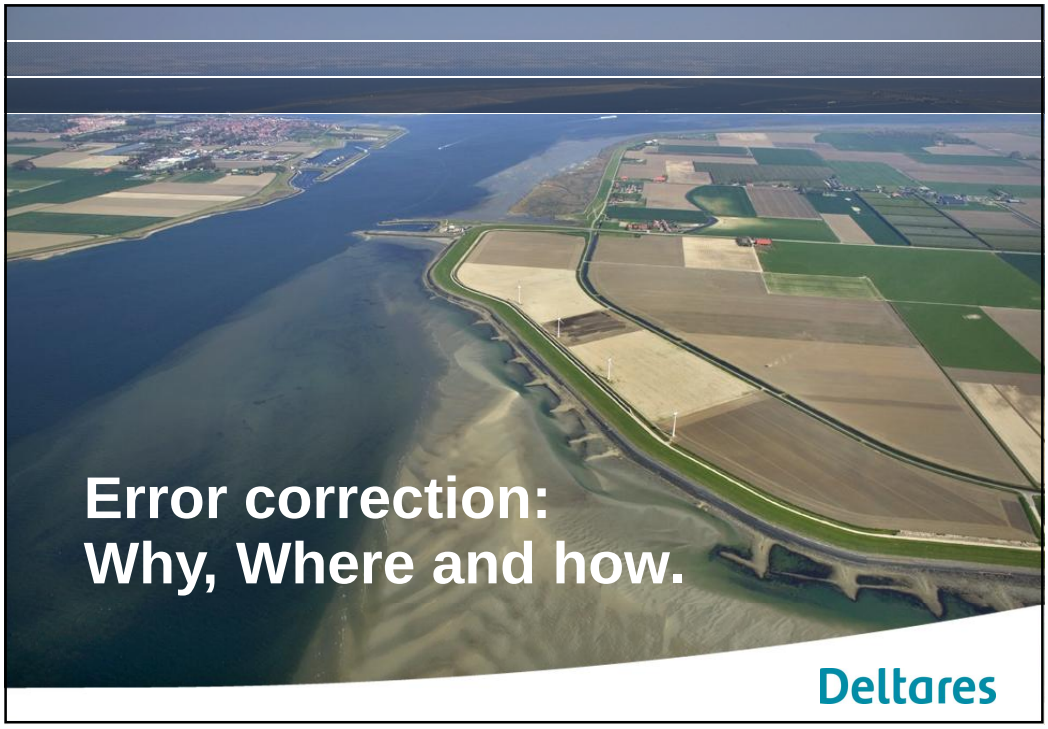
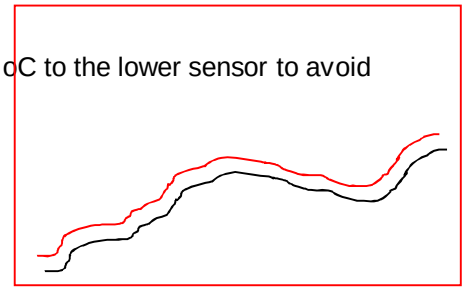


Error correction

1. Why?
2. Let's start simple
3. Two temperature sensors you want to use to measure temperature difference in incoming and outcoming water of a solar heater system.
4. First you monitor both at the same location for some time….
5. You find a difererence of 0.5 oC
6. When using the sensors you add 0.5 oC to the lower sensor to avoid wrong calculations



Data Assimilation/Error correction

Key elements of a forecasting system (Madsen et al, 2000)

- Real time data acquisition for observed meteorological and hydrological conditions
- Hydrologic and hydraulic models for simulation
- Forecast of meteorological conditions
- Updating and data assimilation

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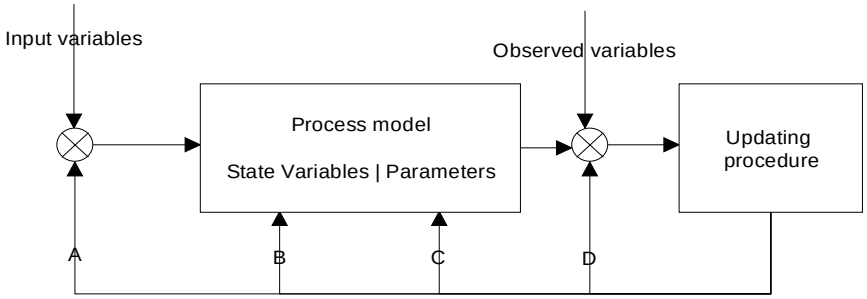
Improving the Forecast



A: Input correction
B: State Updating (data assimilation)
C: Parameter Updating
D: Postprocessing (including Error Correction)

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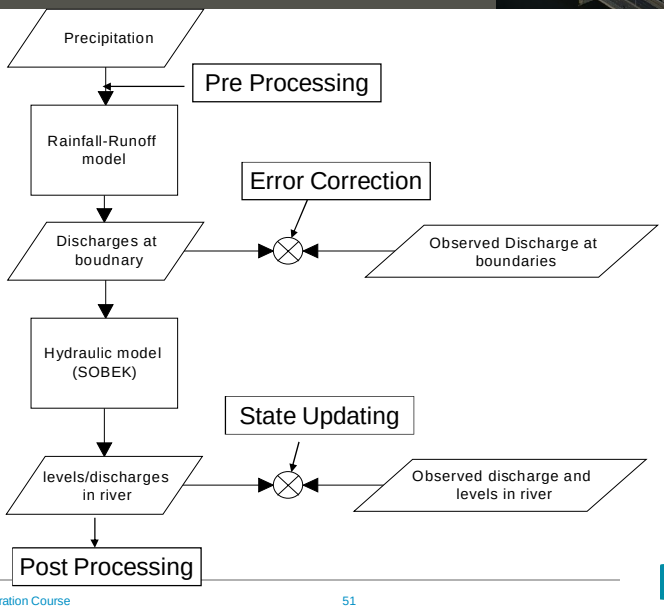
Data-assimilation in flood forecasting



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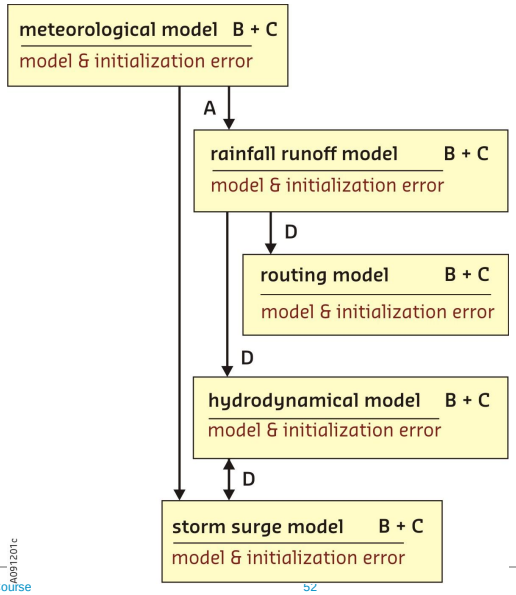
Data-assimilation in flood and storm surge forecasting



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A: Input Correction

An example of this is the rainfall-runoff model HBV-96 (SMHI) where you can specify a time window (before starting a forecast) in which it is tried(through optimization) to reduce the difference between measurement and model by adjusting the input (temperature and/or rainfall).

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B: State Updating

Adjust the model states based on the difference between model and measurement.

This can be done

- manually (for instance by the NWS through MODS)
- automatically (for instance through Ensemble Kalman Filtering)

=> Example EnKF for the Meuse (at Chooz)

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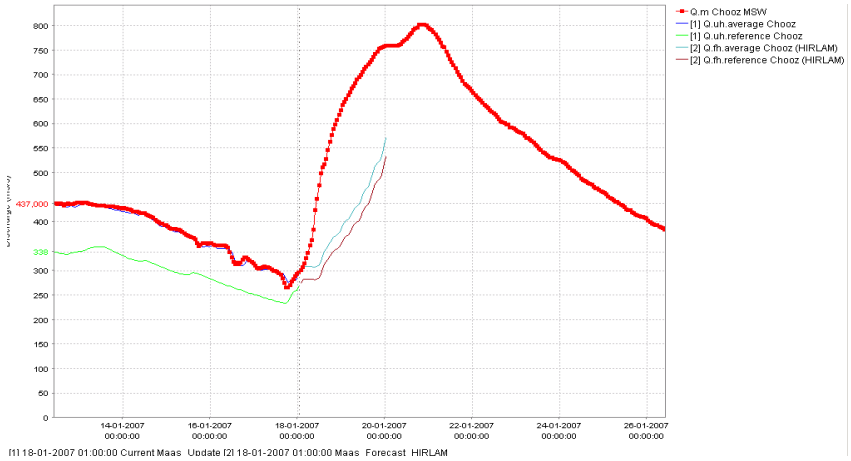
Result of EnKF filtering at Bar etc (Chooz) during the forecast starting at 18-01-2007 01:00.



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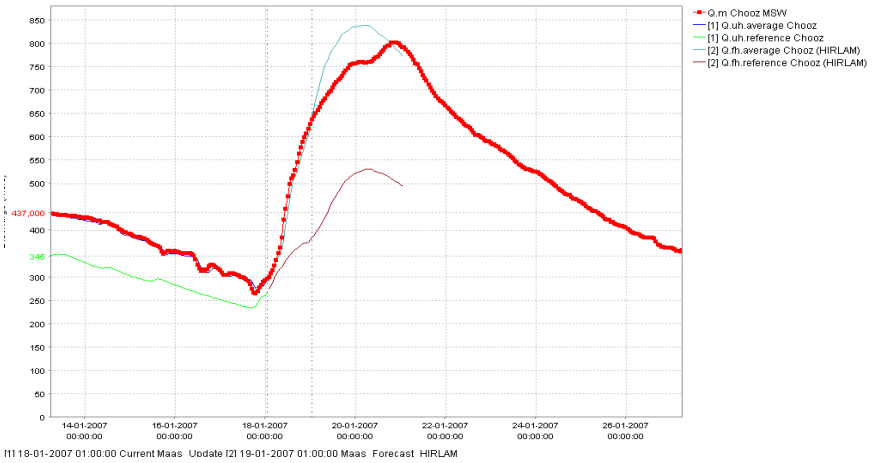
Result of EnKF filtering at Bar etc (Chooz) during the forecast at 19-01-2007 01:00.



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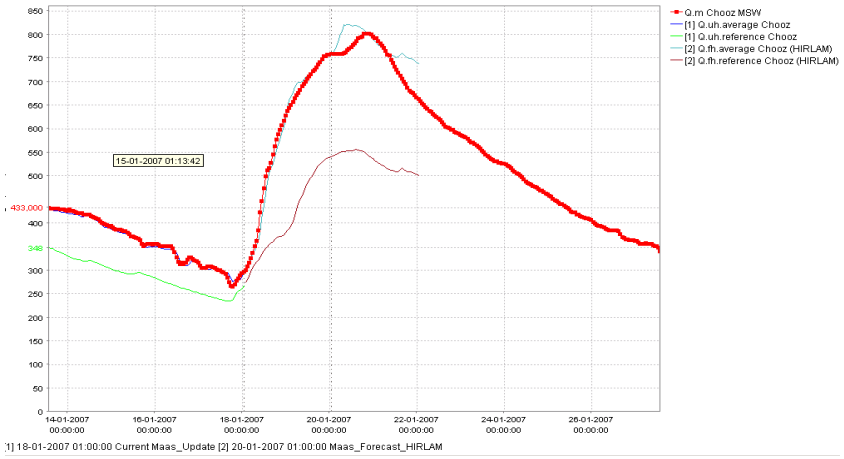
Result of EnKF filtering at Bar etc (Chooz) during the forecast 20-01-2007 01:00



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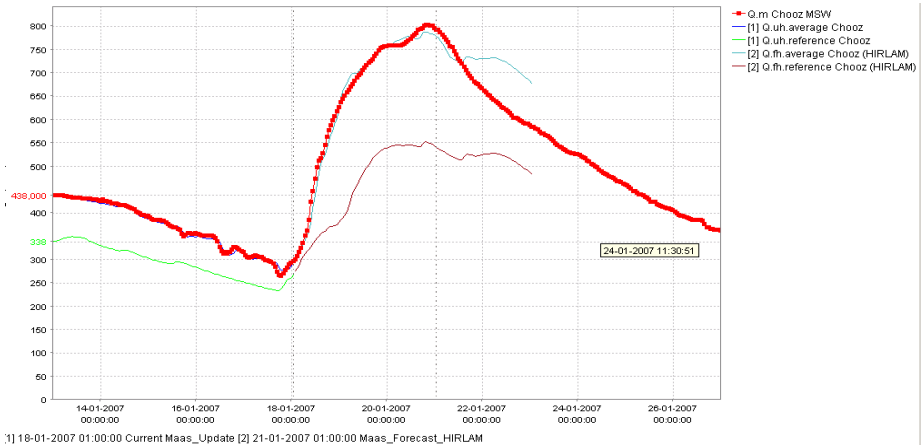
Result of EnKF filtering at Bar etc (Chooz) during the forecast 21-01-2007 01:00.



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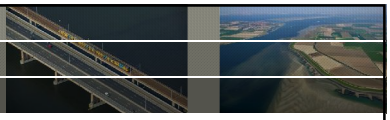
C: Parameter Updating



No example available

By the NWS MODS (manually)

Parameter uncertainty can affect the forecasts

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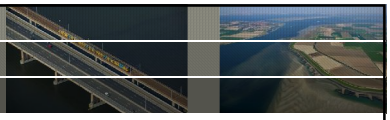
D: Output Processing



This can be done very simple but also complicated (determine uncertainty and all)

simple methods:

-Adjust Q (correction at start forecast)

-AR or ARMA type error correction

Complicated methods:

-Bayesian Model Averaging: Weighing different forecast into a single forecast based on their past performance and derived an 'uncertainty' band

-Bayesian Processor of Output: Condition a deterministic or ensemble forecast on past performance (remove of biases etc) to derive the predictive uncertainty

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AR module Delft-FEWS - 1

Autoregressive Moving Average Models used for forecasting of stationary timeseries

AR: This part of the model describes how each observation is a function of the previous p observations. For example, if p = 1, then each observation is a function of only one previous observation. That is, $Y(t) = c + \varphi_1 Y(t-1) + e(t)$

where Y(t) represents the observed value at time t, Y(t−1) represents the previous observed value at time t − 1, e(t) represents some random error and c and φ_1 are both constants. Other observed values of the series can be included in the right-hand side of the equation if p > 1:

$$Y(t) = c + \varphi_1 Y(t-1) + \varphi_2 Y(t-2) + \cdots + \varphi_p Y(t-p) + e(t).$$

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AR module Delft-FEWS - 2

MA: This part of the model describes how each observation is a function of the previous q errors. For example, if q = 1, then each observation is a function of only one previous error. That is,

$$Yt = c + \theta_1 e(t-1) + e(t).$$

Here e(t) represents the random error at time t and e(t−1) represents the previous random error at time t − 1. Other errors can be included in the right-hand side of the equation if q > 1.

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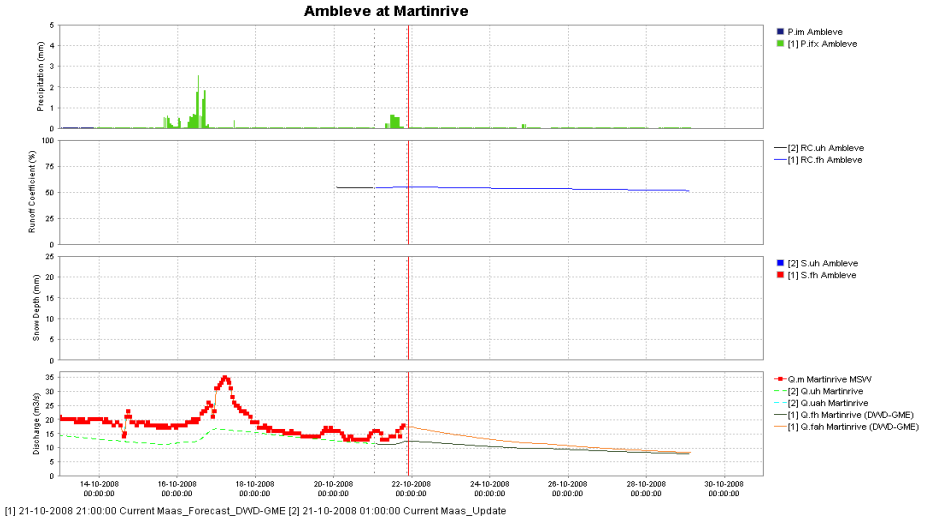
Error Correction



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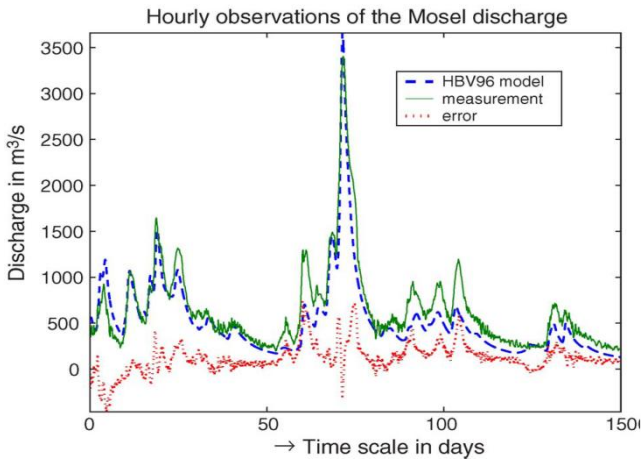
Are the errors stationary?



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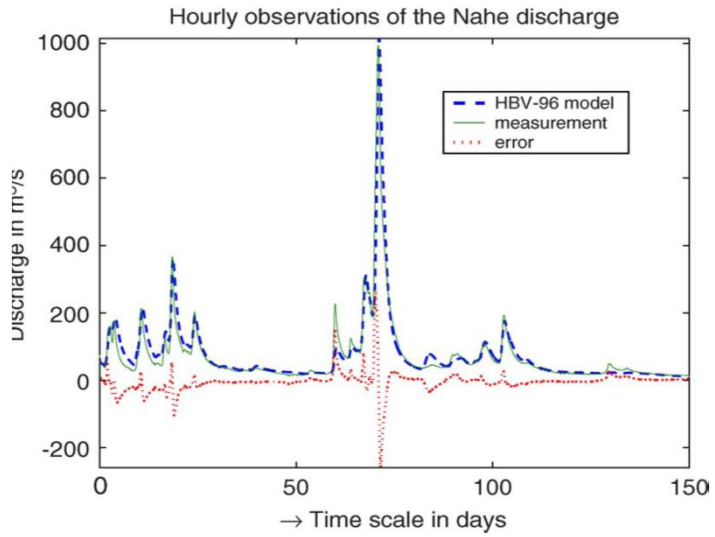
Stationary?



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Stationarity and Configuration of Error Module

mean correction (the mean over the training period is or is not subtracted)

<subtractMean>false</subtractMean>

Box-Cox transformation: $T(y)=(y^{\lambda}-1)/\lambda$ for $\lambda=0$ $T(y)=\log(y)$

can make the data more stationary

<boxcoxTransformation>false</boxcoxTransformation>

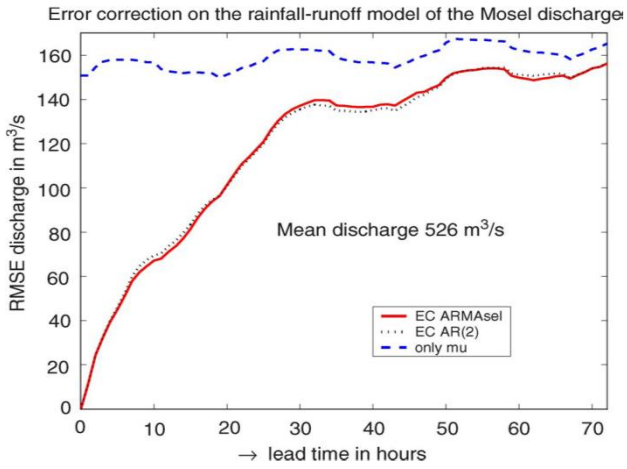
<lambda>0</lambda>

However be careful the transformation can also result in strange results because small changes in transformed space can be large changes in the real space.

Another way (not implemented!!) would be to use AR-I-MA (AR Integrated MA) type where the difference is taken between time steps to make the data more stationary

Deltares

Results large catchment (over 150 days daily steps)



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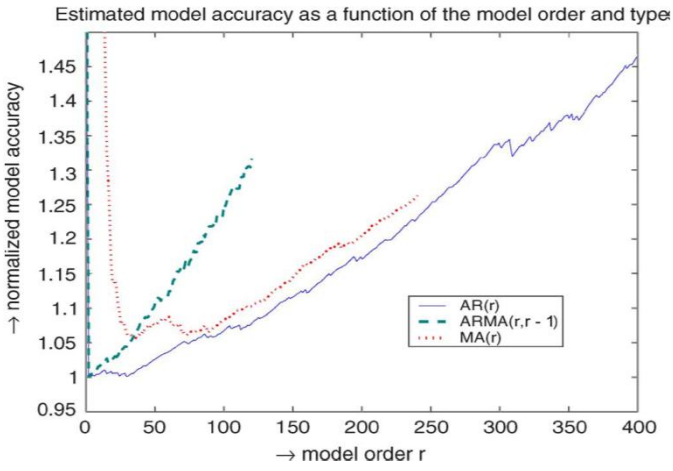
AR, ARMA, MA? Which order?



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Order and Configuration of Error Module

The amount of orders and value of coefficients is automatically calculated by the error module and consider up 1,2, ..,10 orders

<orderSelection>true</orderSelection>

<order_ar>10</order_ar>

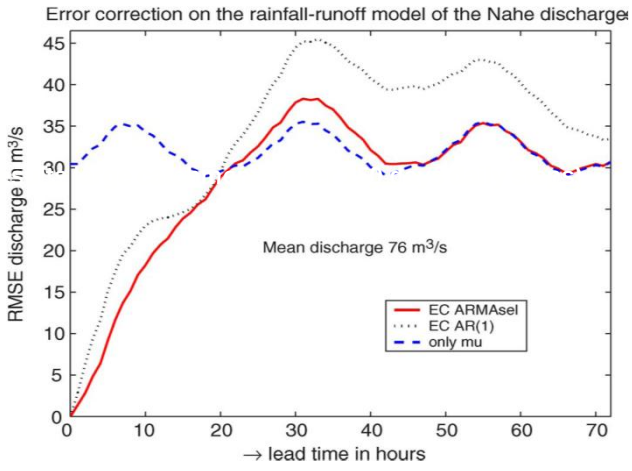
It is possible to put the orderSelection to false and use for instance

2 or 3 orders and calculate the coefficients automatically by the error module on the basis of the training period

It is also possible to put the orderSelection to false and specify your own coefficients (when determined offline over a calibration period)

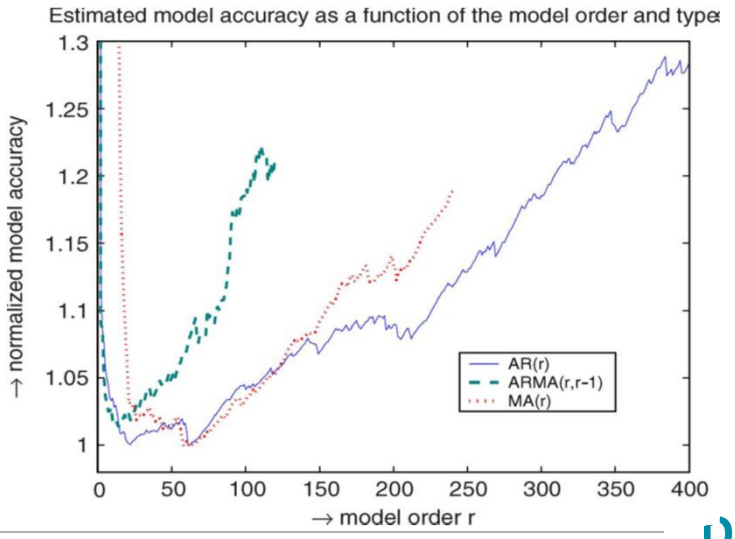
Deltares

Results smaller catchment (over 150 days daily steps)



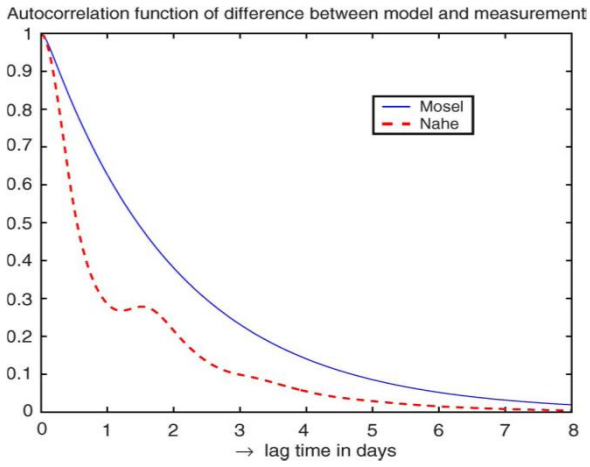
Deltares

AR, ARMA, MA? Which order?



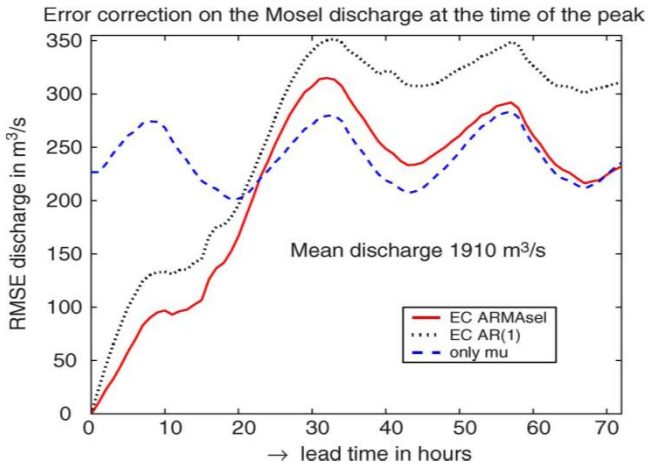
Deltares

Autocorrelation



Deltares

Results large catchment (over peak 10 days daily steps)



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Length Training period

TABLE 1
INFLUENCE OF THE HISTORY LENGTH IN HOURS, USED FOR ESTIMATION WITH ARMAsel, ON THE RMSE ACCURACY OF THE MOSEL DISCHARGE ERROR CORRECTION, WHICH IS AVERAGED OVER THE FIRST 12 h OF THE PREDICTION. PREDICTIONS HAVE BEEN MADE OVER THE 150-DAY PERIOD AND OVER A SHORT PERIOD OF TEN DAYS AROUND THE PEAK DISCHARGE

History length in hours	150 day period	10 days, peak period
10	83.5	216.4
20	79.4	203.5
50	62.8	129.5
100	57.8	108.0
200	53.1	80.4
300	51.5	71.9
400	50.4	67.1
500	49.6	***66.3***
750	***49.3***	72.6
1000	50.8	85.8
2000	50.7	85.6
3500	50.5	80.8

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So why do we do error correction?

- To get the best forecast possible
- The make sure the forecasters 'trust' the system
- To make best use of the avaiable data
- To show the uncertainties in the system

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Where and how?

- Depends on the hydrological and modelling system
- Some good candidates:
  - Outlet of catchment model (gauged) fed into a routing model
  - Link between two routing models
  - Reservoirs (up/downstream)
  - Suggestions?

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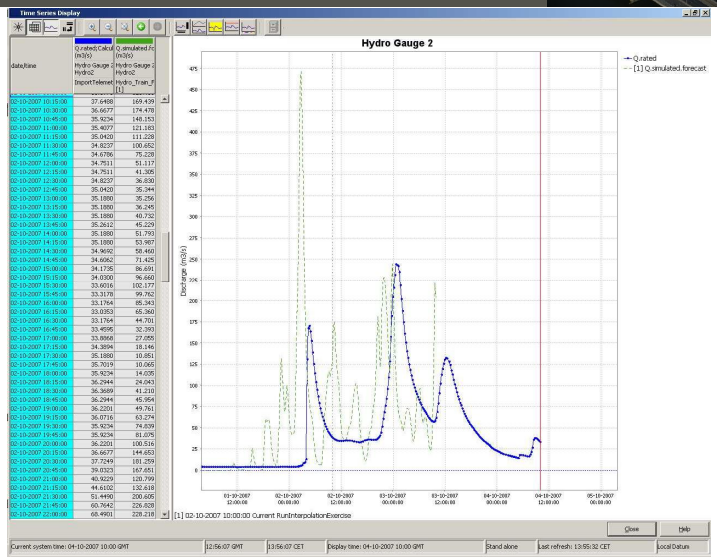
Where and how?



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Using Ensembles

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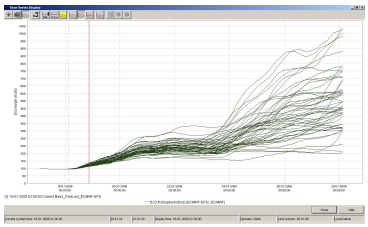
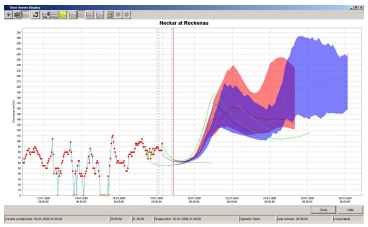
Ensemble Forecasting: What is it?

What is an ensemble forecast?

- An ensemble forecasting system samples the uncertainty inherent in weather prediction to provide more information about possible future weather conditions. Rather than producing a single forecast, multiple forecasts are produced by making small alterations to either the starting conditions or the forecast model, or both. (From: UK Met-Office)





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FEWS Time Series Sets: Ensemble

Properties of time series:

- location Id – or – locationSetId
- parameter Id
- timestep
- relativeViewPeriod

- valueType (scalar, grid, profile, ..)
- timeSeriesType (external historical, external forecast, ..)
- moduleInstanceId (import, PDM, KW, ISIS, ..)
- readWriteMode

- expiryTime (when to delete from database)
- synchLevel

- simple transformations (delay, multiplier, divider, incrementer)
- ensembleId

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Ensemble in Delft FEWS

- Delft FEWS can import ensemble data sets
  - ECMWF EPS
  - COSMO-LEPS
  - SNRWP-PEPS
  - UK-MetOffice MOGREPS
  - …
- Delft FEWS can run module instances in ensemble mode
  - The database knows the number of members
  - If an ensemble contains 50 members, the modules are run 50 times
- Only a limited number of functions/displays know about ensembles
  - Statistics, time series display, ..

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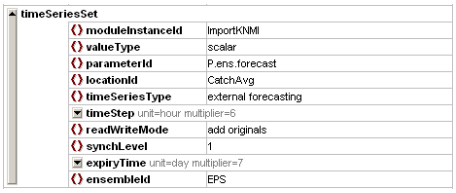
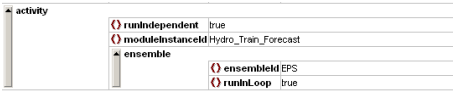
Ensembles and Workflows

- On importing, the Ensemble Id is configured



- Forecast Workflow is using the same Ensemble ID



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Ensembles and Module Instances

- When running ensembles in loop from a workflow, only configure non-ensemble time series: <ensembleId>main</ensembleId>

inputVariable (2)

	= variableId	{} timeSeriesSet		
1	P_Catchment	timeSeriesSet		
			{} moduleInstanceId	ImportTelemetry
			{} valueType	scalar
			{} parameterId	P.catchment
			{} locationId	CatchAvg
			{} timeSeriesType	external historical
			timeStep	unit=minute multiplier=15
			relativeViewPeriod	unit=hour start=-96 end=0 startOverrulable=true
			{} readWriteMode	read only
			{} ensembleId	main
2	P_NWP	timeSeriesSet		
			{} moduleInstanceId	ImportKNMI
			{} valueType	scalar
			{} parameterId	P.ens.forecast
			{} locationId	CatchAvg
			{} timeSeriesType	external forecasting
			timeStep	unit=minute multiplier=15
			relativeViewPeriod	unit=hour start=-24 end=24 endOverrulable=true
			{} readWriteMode	read only

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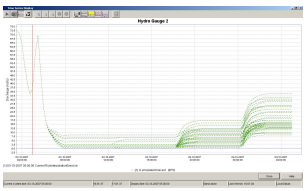
Ensembles – Exercise 16

1. Import ECMWF Ensemble forecasts
   - Import KNMI ECMWF ensemble
   - Store the data at location CatchAvg
   - Add and update import module, ID mapping, import workflow, filters, parameters, global.properties, descriptors
2. Add ensemble element to Forecast workflow and Module instances
   - Update Merge_Precipitation module instance
   - Update the Forecast Workflow
   - What is strange with the simulated discharge?



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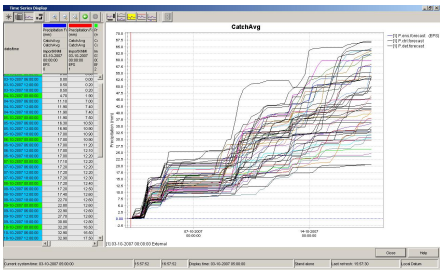
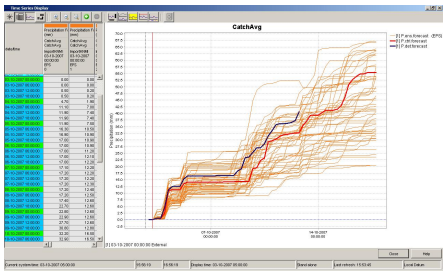
Ensembles – Extra Exercise

- Why are the colours of the rainfall Ensemble members all different and of the simulated discharge all green? Can you give the rainfall members also one colour?
- Give the deterministic and control run different colours and a thicker line.





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More on Ensembles (1)

- The **Transformation** module allows creation of ensembles, create individual members
- When using ensembles where members have different lengths, use module **forecastLengthEstimator** to determine length of each ensemble member
- Presentation of ensembles in **Spatial Display**, require Ensemble Member ID

2	Member 01	timeSeriesSet	
		moduleInstanceId	ImportECMWF-EPS
		valueType	grid
		parameterId	P.fg
		locationId	ECMWF-EPS
		timeSeriesType	external forecasting
		timeStep	unit=hour multiplier=3
		readWriteMode	read complete forecast
		ensembleId	ECMWF
		ensembleMemberIndex	1

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More on Ensembles (2)

- Not all FEWS import functions support ensembles
  - Example: UK MetOffice MOGREPS
  - Each member is stored in a separate 'nimrod' binary file
  - For Importing 24 ensemble members, configure 24 import functions

	general		timeSeriesSet	
1	general		timeSeriesSet	
	importType	nimrod	moduleInstanceId	ImportMOGREPS
	folder	$IMPORT_MOGREPS_FOLDER$/00	valueType	grid
	failedFolder	$IMPORT_FAILED_FOLDER$	parameterId	P.nwp.forecast
	idMapId	IdImportMOGREPS	locationId	MOGREPS
	unitConversionsId	ImportUnitConversions	timeSeriesType	external forecasting
	dataFeedId	MOGREPS	timeStep unit=hour multiplier=3	
			readWriteMode	add originals
			synchLevel	7
			expiryTime unit=day multiplier=2	
			ensembleId	MOGREPS
			ensembleMemberIndex	0
2	general		timeSeriesSet	
3	general		timeSeriesSet	

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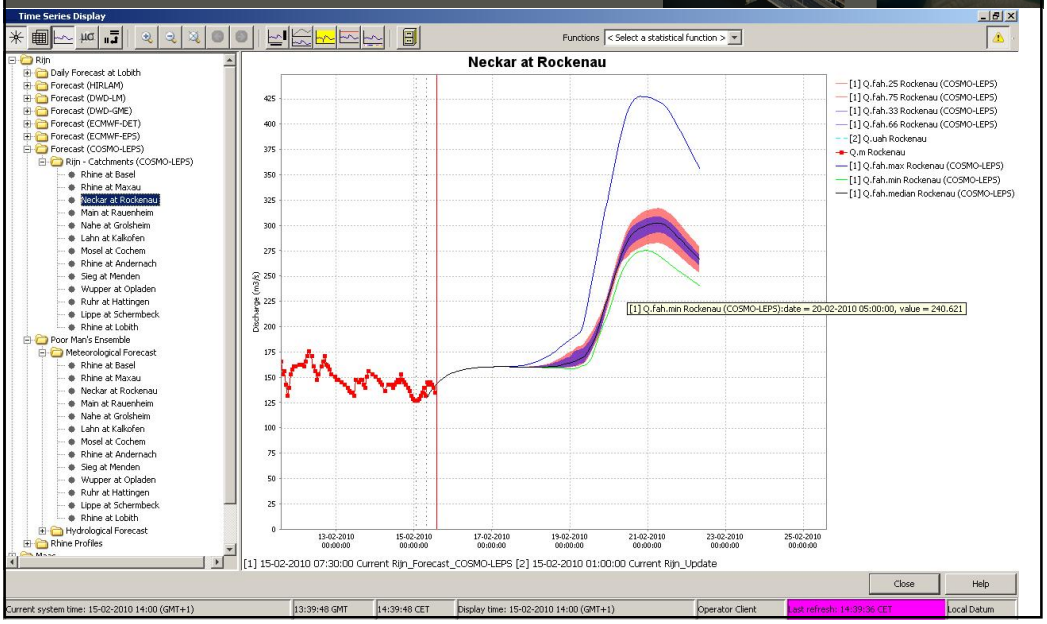
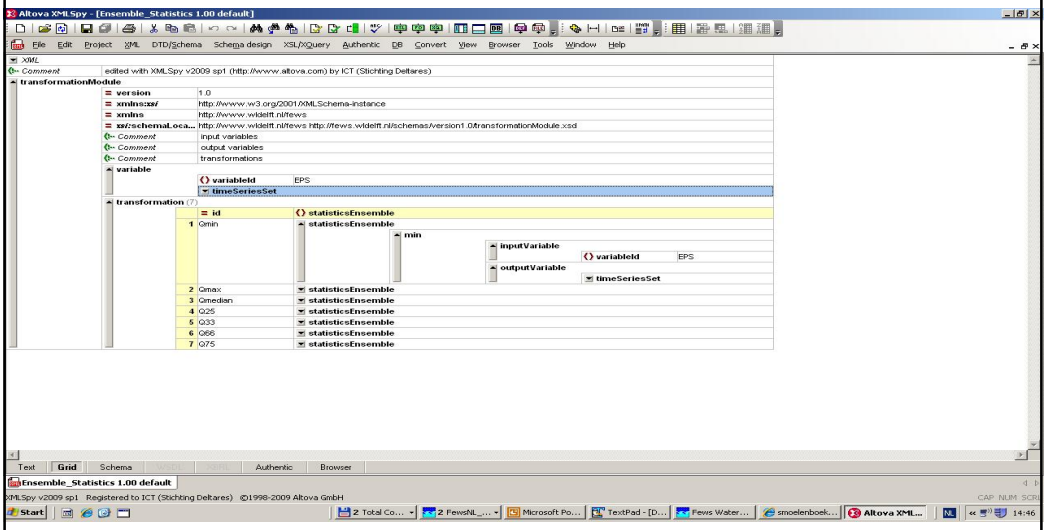
More on Ensembles (3)



More on Ensembles (4)



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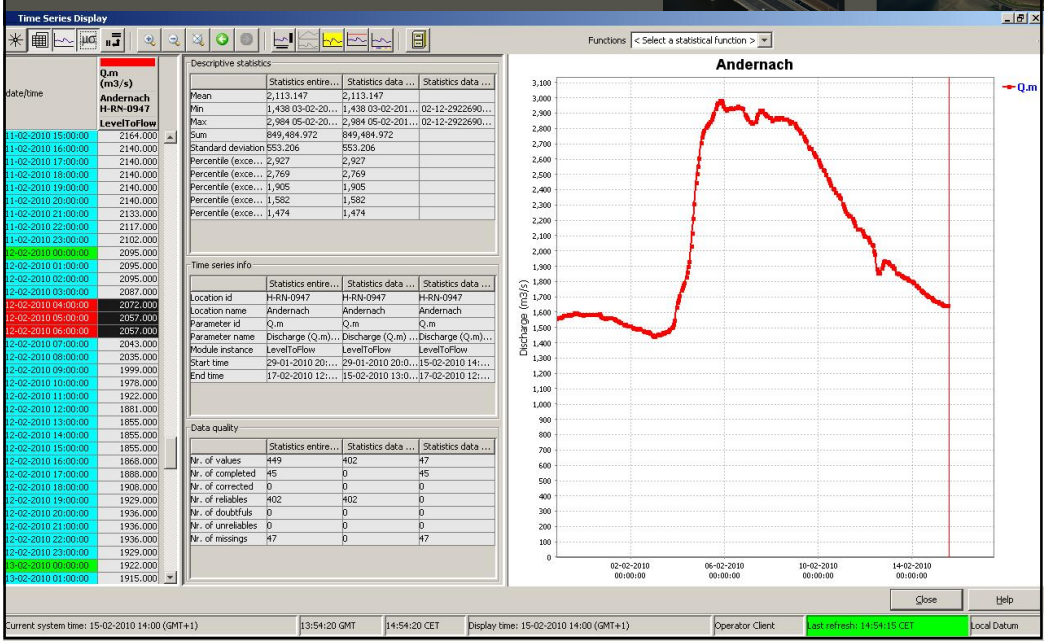
Interactive statistics (1)



Interactive statistics (2)

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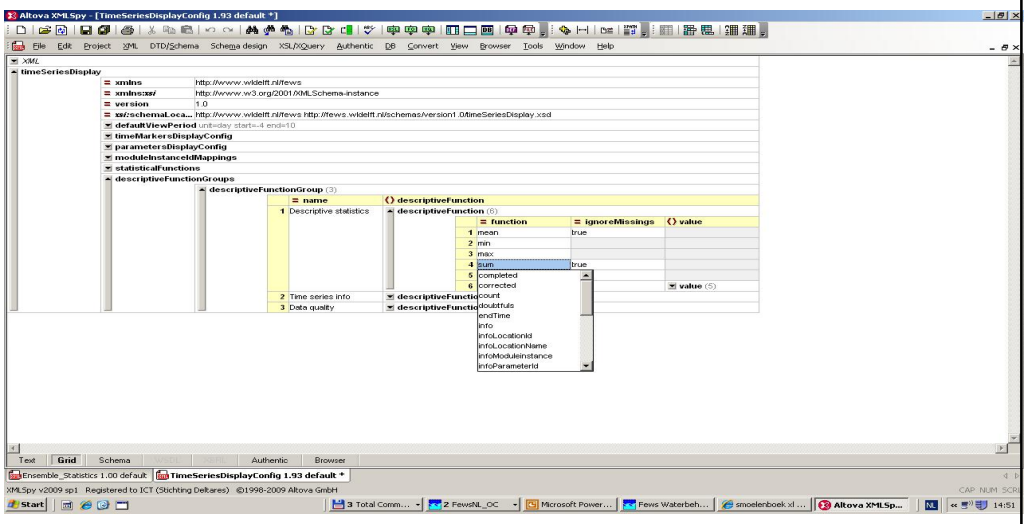
Interactive statistics (3)



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Ensembles – Exercise 17

Run statistics transformation module

- Import KNMI ECMWF ensemble

Adding interactive statistics