KKF-Model platform coupling

Application of KKF-pilot system in case studies

KfC/038F/2011 KKF01b

KKF-Model platform coupling

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Content

1 Summary

In this report, the first applications of the FEWS-KKF pilot coupled modelling platform are shown. FEWS-KKF is a modular modelling system, containing hydrological and hydraulic models of the Rhine, Meuse (HBV and SOBEK, based on the FEWS-GRADE system), Northern Delta area (SOBEK), North sea and Wadden sea (Delft continental shelf model, DCSM) and the dutch water system (part of NHI). For the applications, described in this report, a schematization of the IJsselmeer area and HABITAT models of the IJsselmeer and Markermeer have been added to the FEWS-KKF system. The design of the system is described in (Schellekens et al., 2010).

Two case studies were performed, that require a full run of all the models, available in the FEWS-KKF system, using a consistent input dataset. The main goal of the case studies is to provide a prove of concept by executing the model chain from top to bottom.

The case studies are *not* meant to produce meaningful results for climate change scenarios. We have not included any bias correction to the climate model output and did no include a projected sea level rise.

The case studies are:

1 Co-variance of flood situations from the main river branches and from the North Sea
2 Changing habitat conditions in Lake Marker and Lake Ijssel

In the first study, the joint probability distribution of extreme discharges from the main rivers and extreme water levels, coming from the North Sea, has been investigated. The coupled model system can estimate both these variables using a consistent input dataset. In the second study, the impact of natural variability of climate on HABITAT conditions in the IJsselmeer area has been studied. The boundary conditions to determine water levels in the IJsselmeer are delivered by all other models in the FEWS-KKF system and can again be based on the same consistent input dataset, by means of the FEWS-KKF system. The case studies have been performed by running the complete system with a 30-year input dataset from the ESSENCE project.

With the case studies, we have shown that it is possible and feasible to perform large coupled computations over long time series. The case studies in fact require a coupled model system such as FEWS-KKF. The case study results have led to the following conclusions:

- The FEWS-KKF pilot system is capable to run long series of climate data. This requires decomposing the input data into small temporal and

spatial domains and decomposing the computation into small temporal slices due to memory constraints. This step will become easier when FEWS is extended with the capability to directly read components of NetCDF files from an OpenDAP server (further work under the NMDC umbrella is scheduled to deliver this next year).

- The 30-year run resulted in a limited number of issues where models were not producing any output. These issues are being investigated.
- The results of a run with FEWS-KKF can be used to estimate consistent joint probability distributions of events at different locations. This has been tested using a relatively small 30-year run with ESSENCE climate inputs.
- HABITAT models can be implemented within the FEWS-KKF system, but require at the moment of writing, some work-arounds to take care of the classical non-transient character of these models.

The following recommendations are made based on the case study results

- Impose projected sea level rise on the DCSM model results for more realistic scenarios.
- Replace typical profiles for downstream boundary conditions of SOBEK-Rhine and SOBEK-Meuse with astronomical tides for more realistic boundary conditions.
- Perform bias-correction of the ESSENCE input data.
- Perform longer simulation to provide more samples to better estimate joint probability density functions, and in order to observe changes in HABITAT conditions.
- Introduce more complex survival rules in the HABITAT models, (e.g. rate of change of water levels and occurrence of extreme events) and make the species occurrences transient states.

2 Introduction

This report describes the application of the ESSENCE climate scenario's in combination with the coupled models for the Rhine-Meuse system and looks into two case studies:

1. Co-variance of flood situations from the main river branches and from the North Sea.
2. Changing habitat conditions in Lake Marker and Lake Ijssel.

The goal of this project is to show that we can do this kind of studies and demonstrate what the results would look like. The selected case studies need a consistent model run with all the models in the FEWS-KKF system (the setup of the system is decribed in detail in the technical report “Inventory of available and accessible data and models and design and first setup for a pilot system”). The FEWS-KKF system is the first in its kind, able to deliver such consistent model runs. The goal of this project is not to analyze the results in detail. This can be done only when the final climate datasets are available and when bias correction has been applied to the regional climate model output. This has not been done in the present project.

In the first case study, we investigate the joint probability distribution of extreme discharges from the main rivers and extreme water levels at the North Sea coast. To simulate this joint occurrence and the associated joint probability distribution, a long continuous time series of climate data is required, and a model instrument, that jointly computes extremes from the main rivers and from the North sea. We can also compute whether the water levels ‘inside’ the Maeslant barrier may become higher than the water levels ‘outside’ the Maeslant barrier. This is a force that the barrier has not been designed for.

For the second case study we investigate the habitat conditions in Lake IJssel. The Veerman committee suggested to raise the water level of Lake IJssel by 1.5 meters. Although this brings benefits for the supply of fresh water during dry situations, it may have a serious impact on habitat conditions in the lake. In earlier research this effect has been investigated using the HABITAT software imposing a pre-defined water level on all other variables. HABITAT then computes habitat suitability as a steady-state solution. In the KKF pilot system, we are able to generate long transient time series of water levels. This enables us to compute transient habitat suitability indices for different species. We will do this first of all by estimating a decadal averaged water level and compute habitat suitability indices for each 10-years of computations.

3 Setting up of input dataset

For this pilot, a 30-year dataset from the “Ensemble SimulationS of Extreme weather events under Nonlinear Climate change” (ESSENCE) project has been made available by the Royal Netherlands Meteorological Institute (KNMI). The data are based on a long simulation of climate (1950-2100). The model used is the ECHAM5/MPI-OM coupled climate model developed at the Max-Planck-Institute for Meteorology (MPI-Met) in Hamburg. The emission scenario used as boundary condition is the SRES A1B scenario. The model runs are performed on the NEC SX-8 at the Höchstleistungsrechenzentrum Stuttgart (HLRS). As the ESSENCE project is still progressing, at the moment of conducting this experiment, only 30 years of data were made available to this project (2001-2030).

The dataset includes 3-hourly grids of longitudinal and latitudinal wind speed, temperature, dew point temperature, surface pressure and daily grids of large scale precipitation, convective precipitation, net short-wave radiation and net long-wave radiation.

3.1 Bias correction

In order to drive the connected models in the Rhine-Meuse basin (including the North-Sea) a range of forcing variable is needed provided by the climate model output. Although project such as ENSEMBLES have looked at bias correction of climate models (Christensen et al., 2008; Piani et al., 2009) they have not investigated all the parameters (e.g. windspeed and direction) that are required. Previous studies that used climate model output for hydrological applications have focused on precipitation and temperature alone (Hurkmans et al., 2010; Kleinn et al., 2005; Terink et al., 2010, 2009; Van Pelt et al., 2009).

For the purpose of this pilot project we have used the input data as is, without any bias correction of the model output. Bias correction is planned to be included in the KvK Theme 6 project in cooperation between Deltares and KNMI.

3.2 Grid temporal subsetting

The original 3-hourly grids were stored in NetCDF files over periods of 5 years, while the daily grids were stored per period of 75 years. Such large quantities cannot be parsed by FEWS during one import run. Therefore, these global grids have first been subsetted to smaller NetCDF files using an external python script (large2monthly.py for 3-hourly grids and large2annual.py for daily grids). The resulting files have been stored per month for the 3-hourly grids and per year for the daily grids. The respective file naming conventions is as follows:

- ESSENCE_OPER_3hr_yyyymm.nc

- ESSENCE_OPER_Day_yyyy.nc

3.3 Grid spatial subsetting and processing

The 30-year grids demand a too large storage demand of the relational database of FEWS-KKF. Therefore the global grids were first subsetted to a smaller extent, covering the total extent of all models, used in this case study. These subsetted grids have been exported into external NetCDF-CF formatted files for re-use purposes. The windowed NetCDF files have the following naming conventions:

- yyyymmESSENCE.nc for 3-hourly grids
- yyyyESSENCE.nc for daily grids

The NetCDF windows have been imported and processed into gridded variables, needed as primary input for the configured models. The following processing has been performed:

- 3-hourly temperature → Daily temperature
- 3-hourly x-windspeed → Daily x-wind-speed
- 3-hourly y-windspeed → Daily y-wind-speed
- 3-hourly dew-point temperature → Daily temperature
- 3-hourly surface pressure → Daily surface pressure
- Daily advective and convective rainfall → Daily rainfall
- Daily net long-wave and net short-wave radiation → Daily net radiation
- Daily net radiation and temperature → Daily reference evaporation

Potential evaporation has been estimated using the method by Priestley and Taylor (Priestley and Taylor, 1972).

An example of a windowed and processed total daily precipitation field is given in Figure 3.1.

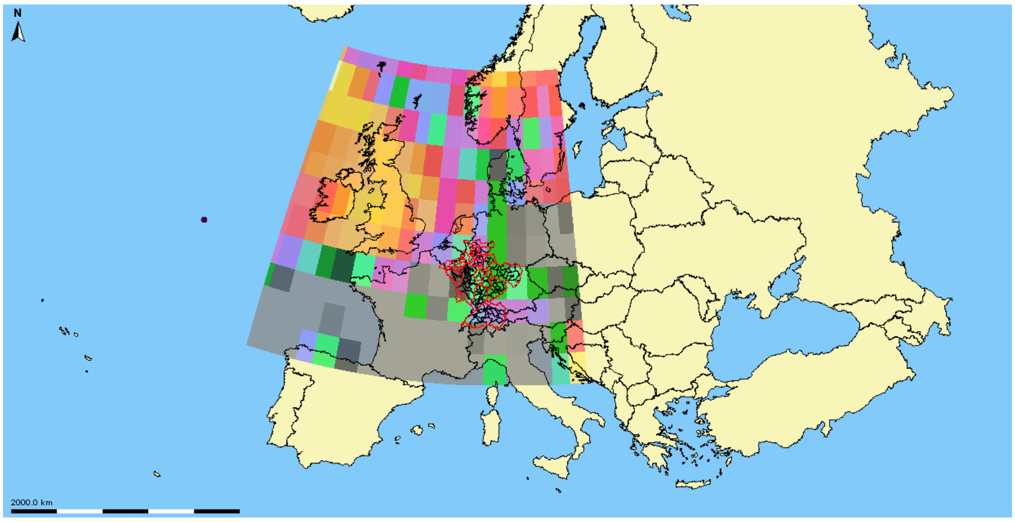


Figure 3.1. Precipitation field on 28-07-2010 according to the essence dataset

3.4 Processing of grids into primary model inputs

The gridded variables have been processed into the following primary model inputs:

FEWS-GRADE (Rhine and Meuse rivers, upstream of the Netherlands):

- Daily precipitation at subcatchment centre points
- Daily temperature at subcatchment centre points
- Daily potential evaporation (computed using the Priestley-Taylor approach) at subcatchment centre points

Noordelijk Deltabekken (Meuse and Rhine delta)

- 10-minute disaggregated wind speed at Hoek van Holland (x,y)

Delft Continental Shelf model (North and Wadden Sea)

- Gridded 3-hourly wind speed (x,y)
- Gridded 3-hourly surface pressure

SOBEK-BEKKEN model (IJssel- and Markermeer)

- Daily precipitation averaged over the total domain
- Daily open water evaporation averaged over the total domain
- Hourly wind speed averaged over the total domain
- Hourly wind direction averaged over the total domain

4 Additional case study models

4.1 Introduction

For the IJsselmeer area case study, a number of additional models were needed. In this chapter a short description of the coupling procedure of these models is given.

4.2 SOBEK-BEKKEN

The SOBEK-BEKKEN model for the IJsselmeer area has been implemented into FEWS-KKF as an additional module. The model runs using the latest SOBEK 2.13 version, which needs to be installed on the hard drive, where FEWS-KKF is located in order to function properly.

The model is run as a standard GeneralAdapter (GA) run under FEWS. This means that Delft-FEWS takes care of the data preparation and visualization while executing the native model if needed (see http://public.deltares.nl/display/FEWSDOC/Home for a description of the General Adapter). A detailld desctiption of the setup in the KKGF system is given in the technical report "Inventory of available and accessible data and models and design and first setup for a pilot system". In brief, the model receives the following inputs:

- Daily rainfall and potential evaporation (derived from ESSENCE, see Section 3.4).
- Hourly wind speed and wind direction (derived from ESSENCE, see Section 3.4).
- 10-minute water levels at the Kornwerderzand and Den Oever sluices in the Waddenzee and at IJmuiden (from DCSM model)
- Daily discharges at Kampbovenhaven (from GRADE, SOBEK model for the Rhine branches)
- Constant daily discharges of 5 m3/s at the Irene sluices and 15 m3/s at the Beatrix sluices in the Amsterdam-Rhine channel.

The model run exports the following data:

- Simulated water levels in the Markermeer and Lake IJssel
- Simulated water levels at structures

4.3 HABITAT IJsselmeer and Markermeer

The Veerman committee suggested to raise the water level of Lake IJssel by 1.5 meters. Although this brings benefits for the supply of fresh water during dry situations, it may have a serious impact on habitat conditions in the lake. Maarse (2009) used the HABITAT software to estimate the effect of raising the water levels in Lake IJssel on its habitat conditions. The effects turned out to be positive (i.e. more species diversity) with a small change in water levels and negative for larger changes.

In the above-mentioned application, a pre-defined water level is imposed on all other variables. HABITAT then computes habitat suitabilities as a steady-state solution. In the KKF pilot system, we are able to generate long transient time series of water levels. This enables us to compute transient habitat suitability indices for different species. Although HABITAT is in principle a steady-state modeling environment, we have estimated a decadal averaged water level and compute habitat suitability indices for each 10-years of computations.

Within this pilot, the HABITAT models for Lake IJssel and Lake Marker have been coupled to the Sobek-Bekken model. No alterations in the HABITAT model have been performed.

4.3.1 Procedure to running of HABITAT under FEWS

Since no specific adapter is available for HABITAT and since HABITAT classically only runs steady-state, some technicalities had to be overcome to run HABITAT in quasi-transient mode under FEWS. The following steps have been undertaken to run HABITAT under FEWS:

Step 1: export case and adapt to run stand-alone

Cases have been generated by exporting the reference case from the HABITAT models into a .folder file. This can be done by opening the case in the HABITAT GUI and select ‘export to PCRaster scripts’. The .folder file is a zip-file containing all the submodels, relations and input maps to compute the HABITAT suitability.

The subfolders of the .folder file each contain one sub-model of the habitat-case. The references to maps within these folders were however found to be incorrect (referring to a hard and incorrect temporary location instead of a relative path).

To correct this, a python script was generated which is included in the module folder of the HABITAT models. *replaceString.py*, replaces in each pcraster sub-model (pcraster.xml) a string ‘sourceText’ with the standard prefix that each mapfile should have. These mapfiles are referred to in the pcraster.xml model files, contained within each sub-model folder. If this script is run in a python console, each pcraster.xml file within the folder structure is opened and the hard path is replaced for a new (relative) path.

Step 2: running a case as part of a general Adapter run in FEWS

Then, instead of running the HABITAT model under the HABITAT GUI, a batch should be run in the correct order. To create this batch, another python script has been made named 'createBatchFile.py' This script generates a .bat-run file based on the earlier mentioned HABITAT sub-model structure. The input to this script is the file 'project.xml' which provides all linkages to models in the correct order. This xml-file is stored in the .folder archive.

This batch-file can in principle be run under FEWS as a generalAdapter run. It requires 4 arguments to be delivered by the generalAdapter, described below in order:

- Location of the pcrcitd bin-file
- Root-location of all sub-models, this is the folder in which the 'project.xml_data' folder is located. All submodels are located inside 'project.xml_data'.
- The time in the following format: yyyyMMddHHmm. The user can here use %TIME0% as argument.
- The time step in minutes. In principle one could here select a time step of 10 year, converted into minutes, however, this is not required. The time step is only used to import the results back into FEWS and map it into a variable. This time step will be allocated to the imported variable. In our case, one day (1440 minutes) was selected.

The following PCRaster libraries and executables must be present in the bin-folder of the generalAdapter run:

PCRaster.Net.dll

pcrcalcl.dll

pcrme.dll

qt-mt334.dll

xerces-c_2_7

pcrcitd.exe

The generalAdapter run works as follows: first a number of outputs from the IJsselmeer model are converted into water depth maps and exported to the correct folders inside the HABITAT submodel structure. Hence the first PCRaster submodel, that converts bathymetry into water depths is skipped, because it is being overruled by an export module within FEWS. The configuration is given in the figure below:

```xml
<?xml version="1.0" encoding="UTF-8"?>

<!-- edited with XMLSpy v2010 (http://www.altova.com) by ICT (Stichting Deltares) -->

<generalAdapterRun xmlns="http://www.wldelft.nl/fews"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.wldelft.nl/fews
http://fews.wldelft.nl/schemas/version1.0/generalAdapterRun.xsd">

	<general>

		<description>Run HABITAT IJsselmeer</description>

		<rootDir>%REGION_HOME%/Modules/HABITAT/IJsselmeer</rootDir>

		<workDir>%ROOT_DIR%/work</workDir>

		<exportDir>%ROOT_DIR%</exportDir>

		<importDir>%ROOT_DIR%</importDir>

		<dumpFileDir>%REGION_HOME%/DumpFiles</dumpFileDir>

		<dumpDir>%ROOT_DIR%/work</dumpDir>

		<diagnosticFile>%ROOT_DIR%/diag_placeholder.xml</diagnosticFile>

		<time0Format>yyyyMMddHHmm</time0Format>

	</general>

	<activities>

		<executeActivities>

			<executeActivity>

				<command>

					<executa-
ble>%ROOT_DIR%/bin/runHabitatIJsselmeer.bat</executable>

				</command>
```

```
<arguments>
<argument>%ROOT_DIR%\bin</argument>
<argument>%ROOT_DIR%</argument>
<argument>%TIME0%</argument>
<argument>1440</argument>
</arguments>
<timeOut>5000000</timeOut>
</executeActivity>
<executeActivity>
<command>
<executable>%ROOT_DIR%/bin/copy_files.bat</executable>
</command>
<arguments>
<argument>%ROOT_DIR%\project.xml_data\321</argument>
<argument>%REGION_HOME%\Import\HABITAT</argument>
<argument>1</argument>
</arguments>
<timeOut>5000000</timeOut>
</executeActivity>
<executeActivity>
<command>
<executa-
```

```
ble>%ROOT_DIR%/bin/copy_files.bat</executable>
                    </command>
                    <arguments>
                         <argument>%WORK_DIR%</argument>
                         <argu-
ment>%REGION_HOME%\Import\HABITAT</argument>
                         <argument>tim</argument>
                    </arguments>
                    <timeOut>5000000</timeOut>
               </executeActivity>
          </executeActivities>
     </activities>
</generalAdapterRun>
```


Figure 4.1. GeneralAdapter run for HABITAT Ijsselmeer

- First the batch-file, in this case 'runHabitatIJsselmeer.bat' is run. This batch-file also generates a .tim file, necessary to be able to import BIL-formatted GIS files (standard output format of HABITAT).
- After the batch file has been run, the output of the model (a HABITAT map) is copied to the Import-folder. 'Copy_files.bat' is a simple command-line script to copy files.
- Finally, the .tim file, generated by the HABITAT-batch file is copied to the same Import folder.

Step 3: Import BIL file into FEWS

The final step is to run a standard timeSeriesImport configuration to import the generated .BIL file back into FEWS (see http://public.deltares.nl/display/FEWSDOC/BIL+Import). This is not shown here.

5 Model runs

Figure 5.1 shows how the different models are coupled in the FEWS-KKF system and in which order they are being run (blue numbers). The upper box defines the chainage of hydrological and hydraulic models. The lower box represents the HABITAT models, that are run based on the results of the hydrological and hydraulic models.

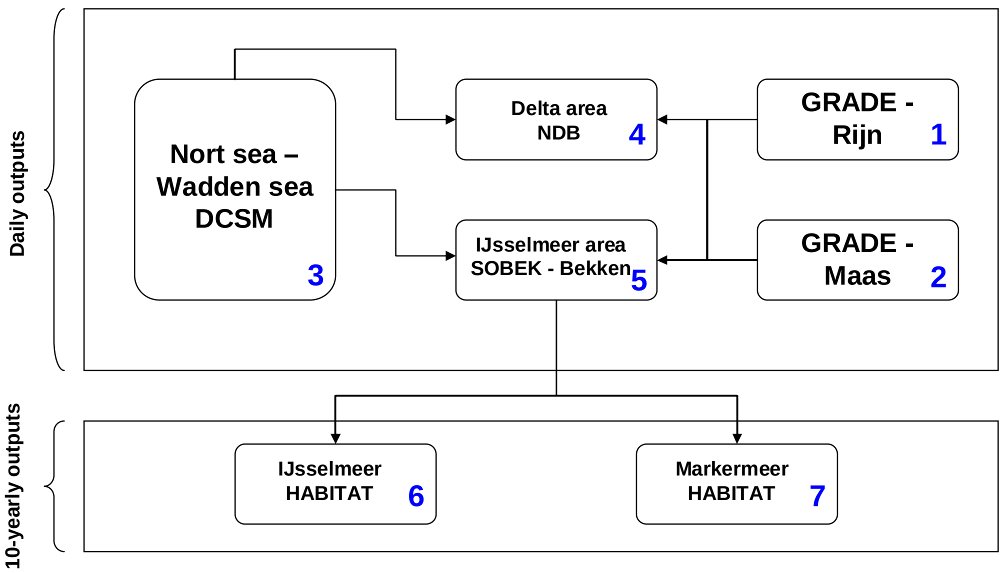


Figure 5.1. Overview of model workflow. The upper block represents models that run on a daily or sub-daily basis and provide output on daily basis. Th elower block represents the HABITAT models, that run on a 10-yearly basis, based on processed outputs of the upper models

5.1 Description of 30-year model runs of hydrological and hydraulic models

Due to memory constraints, the models need to be run over short time slices. This time slice has been set to 20 days. The order in which the models need to run is defined in the workflow "CASE_Bovenrivieren_Noordzee". Figure 5.1 shows a schematic overview of the order. First the models GRADE-Rijn and GRADE-Maas were run that model water levels and discharges for the river basins Rhine and Meuse, respectively. After this step, North Sea and Wadden Sea levels were modeled with DCSM. The Delta area was modeled (SOBEK-NDB) with boundary conditions provided by GRADE and DCSM. Finally, the IJsselmeer area (SOBEK-Bekken) was modeled. The calculation time to run these models for 30 years was 17,5 days The average run time of the workflow "CASE_Bovenrivieren_Noordzee" was about 45 minutes per 20 days (Table 5.1).

Model (Workflow)	Average run time per 20 days
GRADE Maas	3 min 45 sec
GRADE Rijn	7 min 41 sec
DCSM	38 min 56 sec
SOBEK-NDB	1 min 43 sec
SOBEK-Bekken	45 sec
Complete model chain	45 min 29 sec

Table 5.1 Model run times of 30 year running hydrological and hydraulic models

Note that the average run times in Table 5.1 represent the run time in FEWS, which includes besides the running time of the model executables also data pre- and postprocessing and data export to the model and data import from the model.

A check has been made after 3 periods of 20 days (t0 21-01-2001, 10-02-2001 and 02-03-2001), whether the expected outputs are indeed picking up warm states. This has been checked for water levels at Hoek van Holland, discharges at Lobith, discharges at Borgharen, water levels at the IJsselmeer, and discharges at Rotterdam Harbour.

After the complete run (01-01-2001 01:00 – 15-12-2030 01:00) we checked if all the runs over the short time slices were successfull. A total of 39 runs were not successful (Table 4.2). Four runs were not successful mainly due to issues with warm states for Sobek Rhine and HBV models not running. Thirty five runs (between T0 10-05-2007 and 09-04-2009) were not successful because DCSM did not run and subsequently Sobek NDB and Sobek Bekken failed. At the moment we are investigating these issues.

T0 of run	Model	Reason
22-03-2001 1:00	Sobek Rhine did not run for complete period	two warm states at 02-03-2001 01:00 and 02-03-2001 03:00 available for Sobek Rhine
13-09-2002 01:00	HBV Rhine and Meuse did not run	unknown
03-10-2002 01:00	HBV Rhine did not run, HBV Meuse only data afer T0	unknown
10-05-2007 01:00 - 09-04-2009 01:00	DCSM, Sobek NDB and Sobek Bekken did not run	unknown
06-04-2021 01:00	Sobek Rhine did not run for complete period	two warm states at 17-03-2021 01:00 and 25-03-2025 00:00 available for Sobek Rhine

Table 5.2 Runs of of hydrological and hydraulic models that were not successfull

Table 5.2 shows simulated water levels at Rotterdam and simulated discharges at Lobith for the year 2023-2024 as an example of the output from the 30-year model runs of hydrological and hydraulic models. We will discuss the results of this run in more detail later.

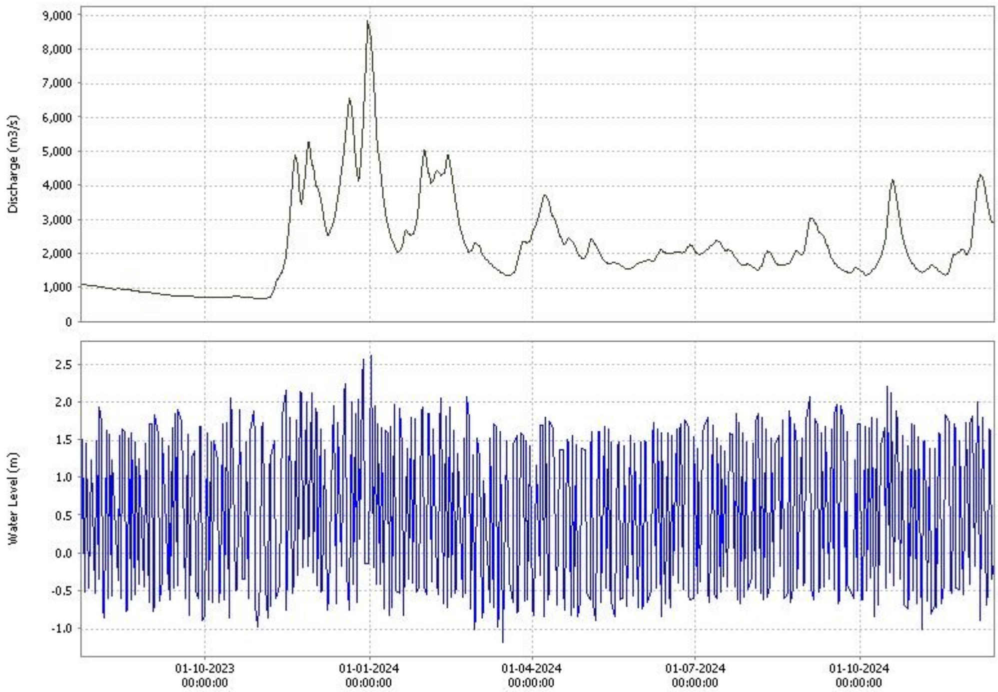


Figure 5.2 A snapshot of simulated water levels at Rotterdam (output from SOBEK-NDB) and simulated discharge at Lobith (output from GRADE-Rhine)

5.1.1 Discussion

The results from the 30 year run of hydrological and hydraulic models show that these models can be run in the FEWS-KKF system. While 39 runs of 20 days did not run completely successfull, they did not affect the total run of 30 years in a significant way. On the other hand, one has to keep in mind that when model runs fail warm states are not written to the FEWS database. A subsequent model run will start with a default state (cold state) that is in most cases different from the warm state and results from the subsequent run are less reliable.

While the 30 year run of hydrological and hydraulic models was generally successful a few improvements can be made. For instance, the projected sea level rise due to climate change for the North Sea and Wadden Sea was not included in this 30 year run. As a consequence the modeled water levels from DCSM and the boundary conditions used by SOBEK-NDB and SOBEK-Bekken were underestimated. A projected sea level rise can be easily included in the FEWS-KKF system by superimposing the projected sea level rise onto the DCSM results. Furthermore, the tidal boundary conditions during the run of the SOBEK Meuse (Keizersveer) and SOBEK Rhine models (Werkendam and Krimpen aan de Lek) were provided by typical profiles that are part of GRADE. These typical profiles represent average conditions and thus these boundaries do not include variability caused by the astronomical tide and by wind and pressure fields. Including astronomical tides based on harmonic components for these locations would result in more realistic boundary conditions.

5.2 Description of decadal HABITAT model runs

The HABITAT models represent a special case because these models cannot be run every 20 days. Instead, the HABITAT models require long-term information about the conditions in the lakes. The original HABITAT models contain a number of sub-models to compute the water depth in different periods in the year. In these models, it is assumed that a fixed winter level is imposed as well as a fixed summer level. In this model experiment, we have replaced these sub-models by a subroutine that computes these water depths based on the results of SOBEK-BEKKEN. Over each 10-year period, the following water depths have been computed for both IJsselmeer and Markermeer in this manner:

- Minimal depth in the past 10 years during summer
- Average depth during summer in the past 10 years
- Average depth during winter (Nov-Feb) in the past 10 years
- Average depth during March in the past 10 years

These depths are used to determine the habitat suitability for several species in the IJsselmeer and Markermeer.

The above-mentioned depths and resulting habitat conditions have been calculated for 3 periods: 2001-2010, 2011-2020, 2021-2030. These periods are too short to represent real climate change. Therefore this analysis has to be considered as establishing the effect of natural variability on the habitat.

We have run the HABITAT models for the IJsselmeer and Markermeer for 3 decadal periods:

- 1-01-2001 until 31-12-2010
- 1-01-2011 until 31-12-2020
- 1-01-2021 until 31-12-2030

The input to both HABITAT models consists of a number of water levels:

- minimal depth in summer
- average depth in summer
- average depth in winter
- average depth in march

These 4 water levels were taken from the SOBEK-Bekken model.

shows the variability of water levels (averaged over the whole lake) as simulated by SOBEK-Bekken over the complete 30-year period. It is obvious that there is not a great deal of variability in the water level (maximum range: 11 cm) within the simulation results. This means that we cannot expect a great deal of variability in the output of HABITAT either. Nu full analysis has been mad of the SSOBEK-Bekken results. Presently it is assumed that a combination of the regulation options of Lake IJssel and that fact that no sea level rise has been taken into account cause this behaviour.

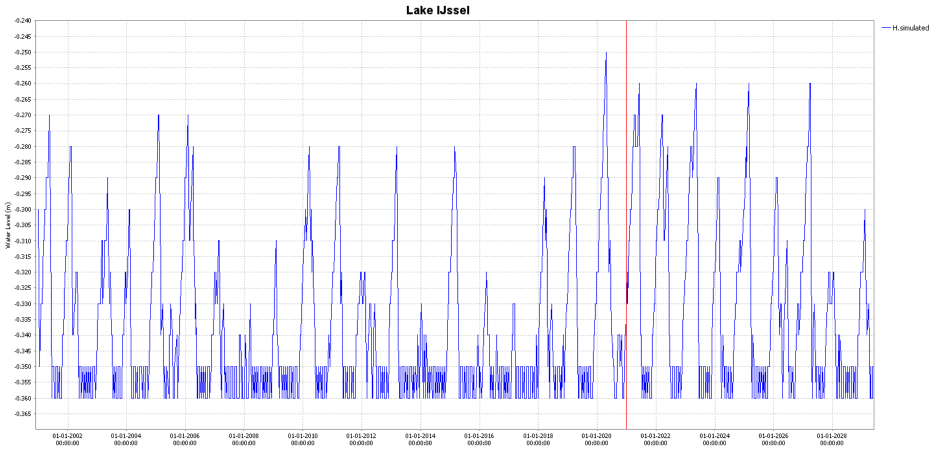


Figure 5.3 30 year time series of simulated water levels in the IJsselmeer

6 Results

6.1 Storm surges and high discharges in the Rotterdam harbour area

For this analysis return periods were calculated for yearly maximum water levels occurring at Hoek van Holland (North Sea) and Dordrecht (Rotterdam harbour area) at the same time during the simulation period. The time series of interest were exported from the FEWS database as .csv files. Further analysis was done using the R software package. Occurrence of yearly maximum water levels of a large storm surge and high river flow were determined by adding the 10 minute time series from DCSM output at Hoek van Holland and SOBEK-NDB output at Dordrecht and searching for the yearly maximum of this time series. A joint probability density function of yearly maximum water levels at Hoek van Holland and Dordrecht was estimated with the two-dimensional kernel density estimation in R. Return periods were derived from a cumulative joint probablity function that was calculated from the joint probability density function.

Figure 6.1 shows contours of return periods (year) for water levels at Hoek van Holland and Dordrecht. The vertical red line in the figure represents the alarm level (2.50 m) for Dordrecht. When the water level is predicted to rise above this level, the Storm Surge Warning Service of Rijkswaterstaat will alarm the dike and dam authorities and recommends that the dikes will be watched. The alarm level for Hoek van Holland lies at 2.80 m (horizontal red line) and the warning level for Hoek van Holland (2.20 m) (horizontal dotted red line) are also illustrated in Figure 6.1. As indicated previously we have not applied any bias correction to the ESSENCE data in this run and no sea level rise has been added to the surge forecast. As such the actual numbers will not be discussed.

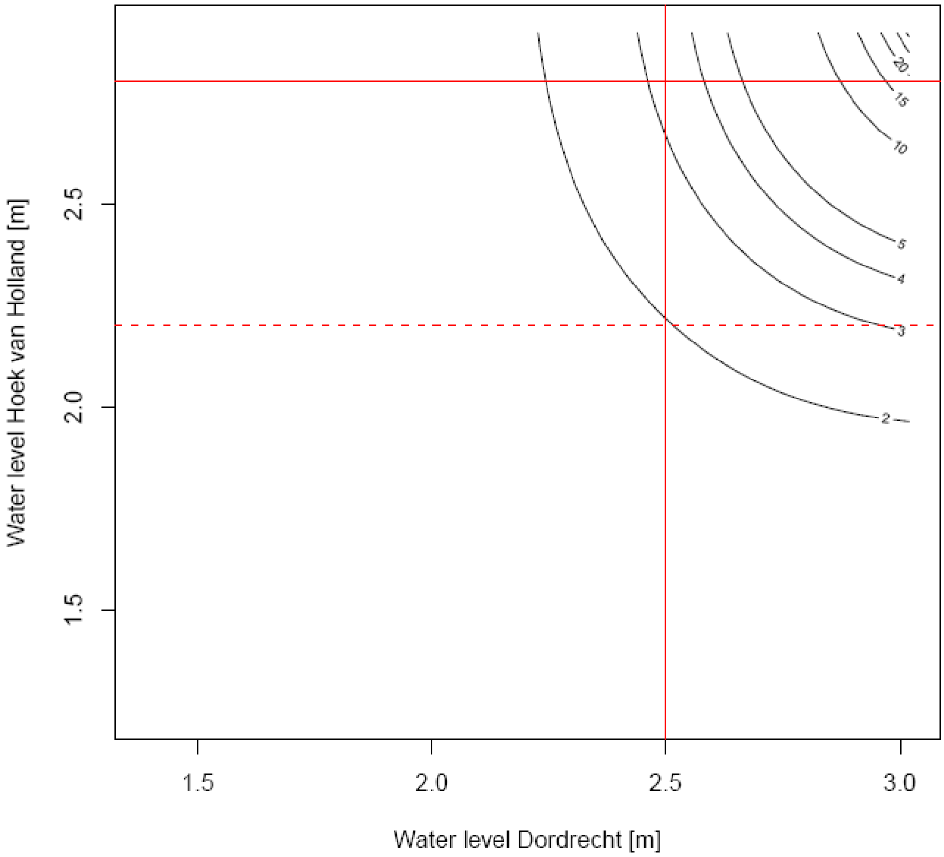


Figure 6.1 Contours of return periods [year] for water levels at Dordrecht and Hoek van Holland

6.2 Effects of natural variability and climate change on IJsselmeer habitats

After running of the HABITAT models, results were imported back into FEWS-KKF for displayed and analysis. Figure 6.2 shows the output for the period 2001-2010 over the IJsselmeer. Results for the other 2 periods fully resemble the 2001-2010 period and are therefore not repeated here. The HABITAT model for the Markermeer shows similar stable results as the HABITAT IJsselmeer (see Figure 6.3).

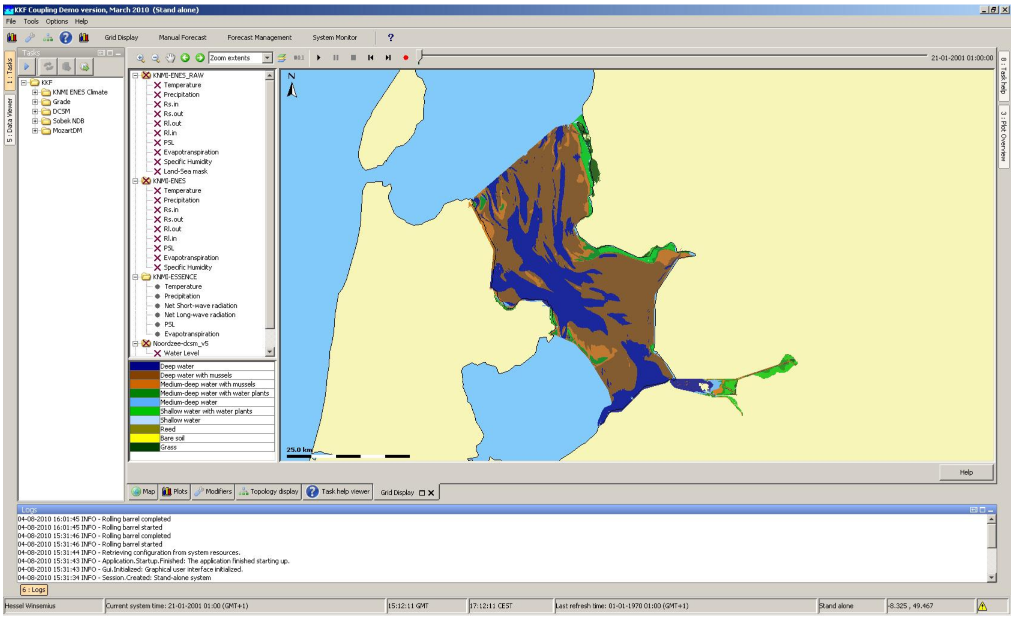


Figure 6.2. Example of HABITAT-IJsselmeer output in KKF-FEWS

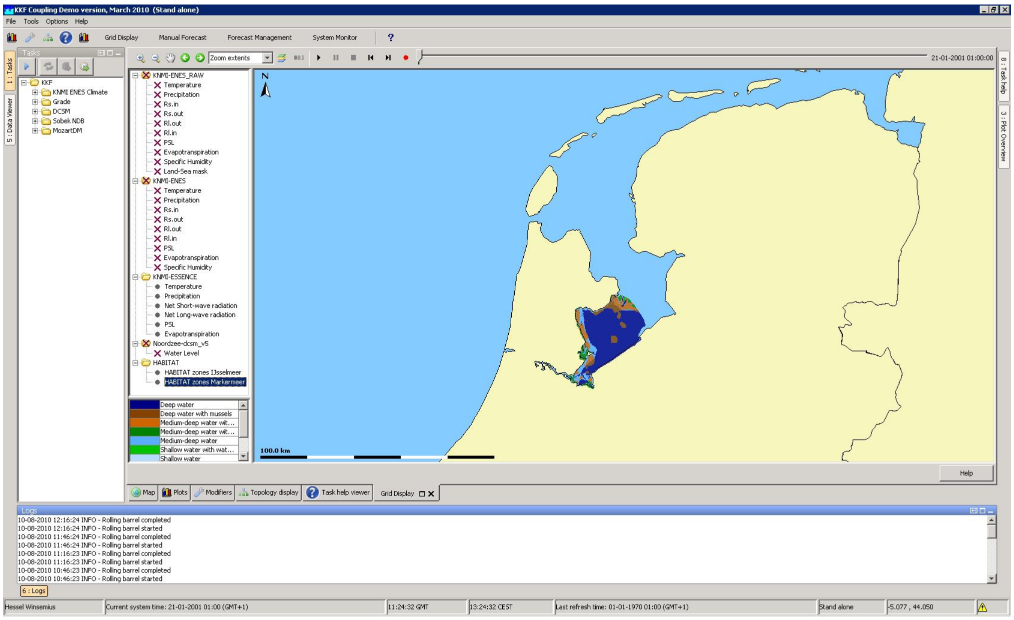


Figure 6.3 Example of HABITAT Markermeer output in KKF-FEWS

The results from the HABITAT IJsselmeer and Markermeer models, show that HABITAT models can be run and forced by the FEWS-KKF system. The current 30-year time series, available for FEWS-KKF are, however, rather short to see a change in HABITAT properties. Figure 5.4 shows that the envisaged winter and summer water levels can be maintained relatively well, which means that the variability in the water level is rather small.

The current versions of HABITAT include certain rules to determine whether a species can occur within a pixel or not. These rules are rather simple, and only allow for dependencies with fixed water levels, such as the average summer water level and winter level. Given the fact that FEWS-KKF computes water levels dynamically, more complex survival rules could be implemented, for instance dependent on the rate of change of water levels. Also, specific events could be taken into account. If for instance some time ago and extreme event (drought or flood) has taken place, certain species may be rather sensitive to this event and may have suddenly disappeared. The currently present species combinations may then become a transient state of this model, on which the HABITAT combinations in the next time step will depend. Such and extension would make the HABITAT models more realistic and more useful for transient simulations. In addition, different nutrient inputs (available from the coupled LOTO-EUROS/RACMO system) may substitute built-in loads.

7 Conclusions and recommendations

In this report, we have described the first applications of the FEWS-KKF pilot coupled modelling system. With the case studies, we have shown that it is possible and feasible to perform large coupled computations over long time series. The case study results have led to the following conclusions:

- The FEWS-KKF pilot system is capable of running long series of climate data. This requires decomposing the input data into small temporal and spatial domains and decomposing the computation into small temporal slices due to memory constraints. To make this step easier, FEWS will be extended with the capability to directly read components of NetCDF files from an OpenDAP server as part of the National Model and Data Centre (NMDC) that is currently being started. In this way, downloading and local storage of large datafiles will not be necessary anymore.
- The 30-year run resulted in a number of issues where models were not producing any output. These issues are being investigated.
- The results of a run with FEWS-KKF can be used to estimate consistent joint probability distributions of events at different locations. This has been tested using a 30-year run with ESSENCE climate inputs. 30 years is too short for accurate estimation of probability distributions, however when the full 150 years is available, this analysis will be more valid.
- HABITAT models can be implemented within the FEWS-KKF system, but require at the moment of writing, some work-arounds to take care of the classical non-transient character of these models.

The following recommendations are made based on the case study results

- Impose projected sea level rise on the DCSM model results for more realistic scenarios.
- Replace typical profiles at downstream boundary conditions of SOBEK-Rhine and SOBEK-Meuse (as part of FEWS-GRADE Rhine and Meuse) with astronomical tides for more realistic boundary conditions.
- Perform bias-correction of the ESSENCE input data.
- Perform longer simulation to provide more samples to better estimate joint probability density functions, and in order to observe changes in HABITAT conditions.
- Introduce more complex survival rules in the HABITAT models, (e.g. rate of change of water levels and occurrence of extreme events) and make the species occurrences transient states.

8 References

Christensen, J. H., Boberg, F., Christensen, O. B. and Lucas-Picher, P.: On the need for bias correction of regional climate change projections of temperature and precipitation, Geophys. Res. Lett., 35, 6 PP., doi:200810.1029/2008GL035694, 2008.

Hurkmans, R., Terink, W., Uijlenhoet, R., Torfs, P., Jacob, D. and Troch, P. A.: Changes in Streamflow Dynamics in the Rhine Basin under Three High-Resolution Regional Climate Scenarios, J. Climate, 23(3), 679-699, doi:10.1175/2009JCLI3066.1, 2010.

Kleinn, J., Frei, C., Gurtz, J., Lüthi, D., Vidale, P. L. and Schär, C.: Hydrologic simulations in the Rhine basin driven by a regional climate model, J. Geophys. Res., 110, 18 PP., doi:200510.1029/2004JD005143, 2005.

Maarse, M. J.: Verkenning Van Effecten Van Peilstijging Op De Natuur in Het IJsselmeer Een HABITAT Analyse, Deltares, Delft., 2009.

Piani, C., Haerter, J. O. and Coppola, E.: Statistical bias correction for daily precipitation in regional climate models over Europe, Theor Appl Climatol, 99(1-2), 187-192, doi:10.1007/s00704-009-0134-9, 2009.

Priestley, C. H. B. and Taylor, R. J.: On the assessment of surface heat flux and evaporation using large-scale parameters, Monthly weather review, 100, 81–92, 1972.

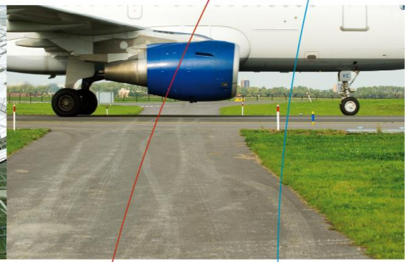
Schellekens, J., Verseveld, W. J. and Winsemius, H. C.: KKF-Model platform coupling: inventory of available and accessible data and models and design and first setup for a pilot system, KKF01b report KfC/038B/2011, Deltares, Delft, The Netherlands., 2011.

Terink, W., Hurkmans, R., Torfs, P. and Uijlenhoet, R.: Evaluation of a bias correction method applied to downscaled precipitation and temperature reanalysis data for the Rhine basin, Hydrology and Earth System Sciences, 14(4), 687–703, 2010.

Terink, W., Hurkmans, R., Uijlenhoet, R., Warmerdam, P. M. M. and Torfs, P.: Bias correction of temperature and precipitation data for regional climate model application to the Rhine basin, Hydrology and Earth System Sciences Discussions, 6, 5377–5413, 2009.

Van Pelt, S. C., Kabat, P., Ter Maat, H. W., Van Den Hurk, B. and Weerts, A. H.: Discharge simulations performed with a hydrological model using bias corrected regional climate model input, Hydrology and Earth System Sciences, 13(12), 2387–2397, 2009.



To develop the scientific and applied knowledge required for Climate-proofing the Netherlands and to create a sustainable Knowledge infrastructure for managing climate change

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