Trainings Session to simulate discharge using the Hydrological Discharge (HD) model

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Overview

1. Introduction to HD model
2. Get the Model running
3. Write program to read HD model output at a certain gridbox
4. HD model river flow directions (RDFs)
   How to find river mouth gridboxes?
5. Change HD model setup to use other input data
   Run with REMO data (or RegCM)
6. Restart problem for new simulations
7. How to improve the HD model topography

1. The Hydrological Discharge (HD) model

Some background information

The HD model - References

- **A parameterization of the lateral waterflow for the global scale**

  (Hagemann, S. and L. Dümenil, 1998, Clim. Dyn. 14 (1), p. 17-31)

- **Validation of the hydrological cycle of ECMWF and NCEP reanalyses using the MPI hydrological discharge model**

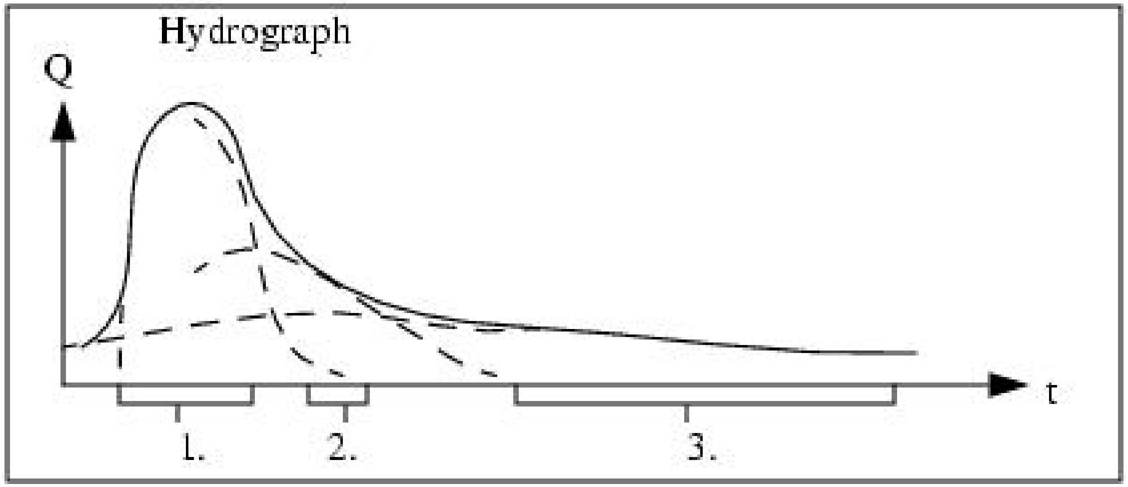
  (Hagemann, S., and L. Dümenil Gates, 2001, J. Geophys. Res., Vol. 106, 1503-1510)

MPI-M models available at (procedure + form):

http://www.mpimet.mpg.de/en/wissenschaft/modelle/model-distribution.html

Flows within a gridbox

- 1. **Overland flow** (sometimes refered to as fast flow)
- (2. *Interflow*, often considered as part of overland flow)
- 3. **Baseflow** (sometimes refered to as slow flow)



- 4. **Riverflow** = Channel Flow = Flow between gridboxes

Scales in hydrology and meteorology

Model approaches used	Grid resolution
Physical based	0.01 - 25 km^2
Conceptual	100 - 5.000 km^2
Mesoscale	> 500 km^2
GCM	> 10.000 km2
empirical	smaller scales
statistical	larger scales

Linear Reservoir (conceptual approach)

- Linear reservoir definition**:**
  Outflow **Q(t)** = Storage **S(t) / k**
  k = Retention time

- Continuity Equation: **dS(t) / dt =** Inflow **I(t) – Q(t)**

- Differential Equation for linear reservoir

  k * dQ(t) / dt = I(t) – Q(t)

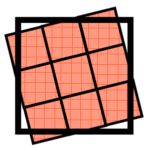
Lateral soil water fluxes

HD Model

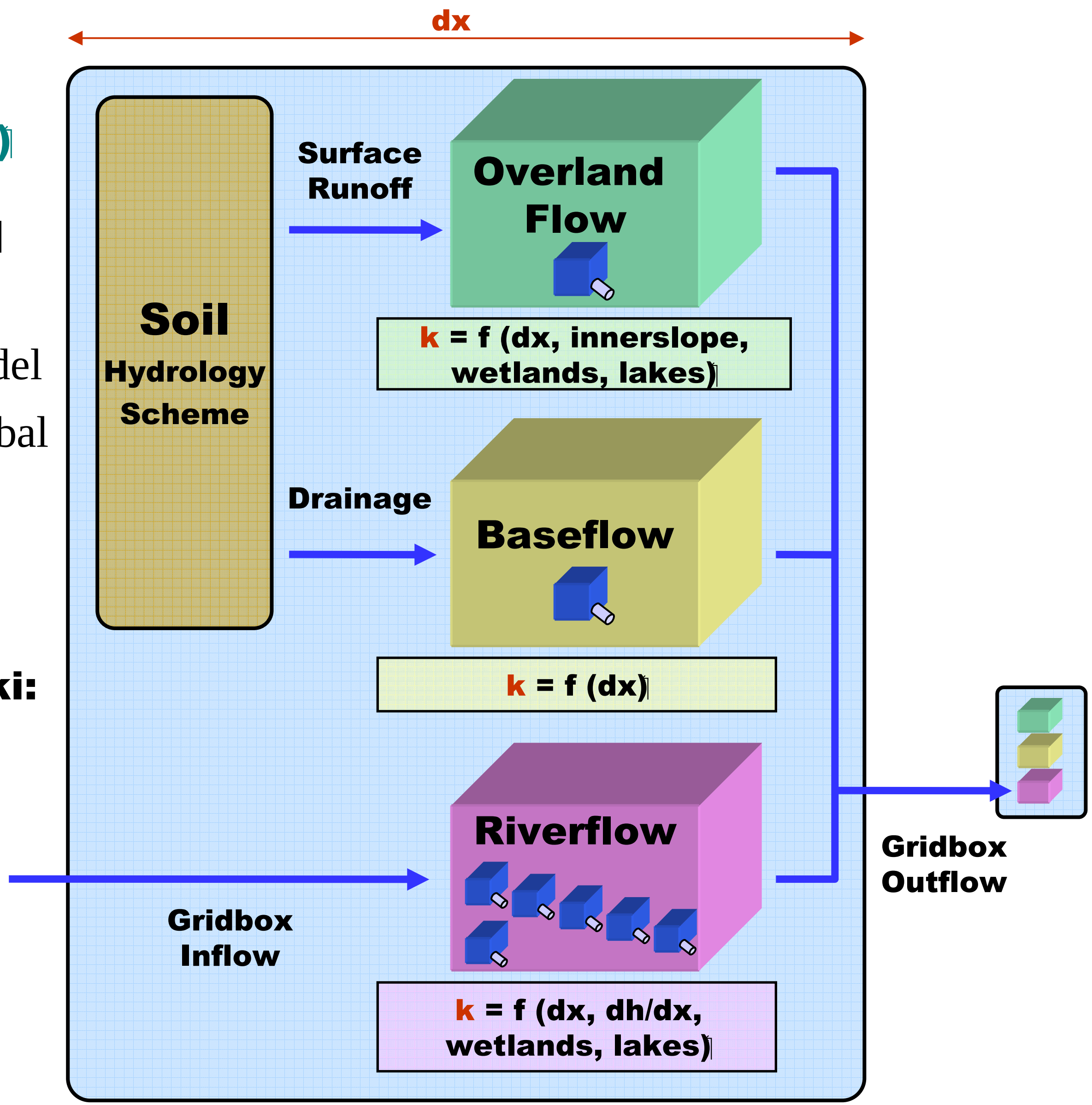
- (Hydrological Discharge)
- **Hagemann & Dumenil (1998)**
  State of the art discharge model
- Applied and validated on global scale at 1/2 deg.
- Part of ECHAM5-MPI-OM

Adjustments by Kotlarski:

1/2 ° → 1/6 °



1 d → 1 h



2. Get the model running

Make directory and copy TAR file

- cd /scratch
- mkdir <choose name> e.g. yourname
- cd <yourname>

Copy only HD-model tar file into this directory

- cp /scratch/smr2029/hdm/hdm_vs1.5.tar .

Unpack tar file

- tar xvf hdm_vs1.5.tar

HD Model: Tar file package

- Tar file content: Program files

```
HDDIR/hdt106.f        # converts atmospheric T106 input into 0.5 degree
HDDIR/hdmain.f
HDDIR/hdmodel.f
HDDIR/hdini.f
HDDIR/hdrest.f
HDDIR/hduse.f
HDDIR/hdtooc.f
HDDIR/pcom05.for
HDDIR/phd_t106.for    # include file with input grid information
HDDIR/pcom.for
HDDIR/pinp.for
HDDIR/hdech.f
HDDIR/hdcorr.f

HDDIR/fhdcomp         # Script to compile the HD model
HDDIR/HDMODEL         # Sun Executable
```

HD Model: Tar file package

❖ Tar file content: In- and Output files

HDDIR/hdini.inp # Model Initialization Input file (similar to a namelist) It has to be in the directory where the HD model is executed.

❖ Input files im SRV-Format

HDDIR/hdpara.srv # HD Parameter file
HDDIR/hdrestart_6951422_881231.dat
Restart file to start at 1.1.1989

❖ Output files for comparison

HDDIR/meanflow_1989.srv.gz # Output 12 months of 1989, SRV file compressed with GZIP

HDDIR/iso7_elbe.dat # Simulated Daily Discharge for river Elbe 1989 (ISOLOG=7)

HD Model: Test input

❖Input time series of surface runoff and drainage

❖Two example input files with 1 year of daily surface runoff and drainage simulated with the SL scheme using ERA40 data for 1989. Array size: 320*160, Resolution T106

runoffbin.dat.gz   # SRV format, compressed with GZIP
drainagebin.dat.gz   # SRV format, compressed with GZIP

Directory: e.g. /scratch/smr2029/hdm

SRV format

- Binary ieee file format. You may read the data with the following FORTRAN statements. (Big Endian = SUN/SGI/NEC binary - **for PC, byte swapping or compiler option is necessary for all binary files**)

```
PARAMETER (NL=720, NB=360)       ! example for 0.5 degree
INTEGER IHEAD(8)
REAL FWERT(NL, NB)
LU=20  ! Logical Unit LU
OPEN(LU, FILE="filename",STATUS='OLD',FORM='UNFORMATTED')
```

- !Loop over all datasets/fields included in the SRV file:

```
DO I=1, <Number of datasets>

  READ(LU) IHEAD
  READ(LU) ((FWERT(JL,JB),JL=1,NL), JB=1,NB)
ENDDO

CLOSE(LU)
```

SRV format

Usual meaning of Header numbers in array IHEAD

- IHEAD(1) = Code number of variable in following real array
- IHEAD(2) = Atmospheric level of variable in following real array
- IHEAD(3), IHEAD(4) contain date informations YYYYMMDD, Format example for 8 June 2006: IHEAD(3)=IHEAD(4) = 20060608
- IHEAD(5) and IHEAD(6) contain the array sizes NL (longitudes) and NB (latitudes), respectively.
- IHEAD(7) and IHEAD(8) are usually not predefined

Other input grids than T106

The current model setup is suitable to read T106 data as input.

❖ For other input resolutions, two files have to be modified:

HDDIR/phd_t106.for Contains input field characteristics
HDDIR/hdt106.f Interpolates T106 resolution to 0.5 degree

❖ For different input resolutions you have to link a file containing the subroutine HDECH(CODE, TOCODE, IQUE) where CODE ist the 2 dimensional input array, TOCODE is the interpolated array on a regular 0.5 degree grid.

❖ Origin: Northpole/date line = North West corner of gridbox [1,1]

❖ IQUE is just a commentary switch (usually set to = 0).

❖ 2 pairs of files for T42 and T63 input grid are included in the tar file.

❖ Files for the RCM grid will be provided.

Example for RCM input

❖ Files for the interpolation from a rotated lat-lon grid, such as used by REMO over Siberia.

hdr_remo.f	Interpolates RCM grid to global 0.5 degree
premo_sibi.for	Contains RCM grid characteristics, file must be named pinp.for in the compilation
fhdcomp_remo	Compile script example

Compile script fhdcomp

HD-Model compilation for T106-Input (with)

- cp -p pcom05.for ./pcom.for
- cp -p phd_t106.for ./pinp.for
- cp -p hdt106.f ./hdech.f

The compile statement must be written in **one** line

- SUN Compiler

f90 -X9 -o HDMODEL
hdmain.f hdmodel.f hdini.f hdrest.f hduse.f hdech.f hdtooc.f hdcorr.f

- NEC –complier

f90 -R2 -o HDMODEL
hdmain.f hdmodel.f hdini.f hdrest.f hduse.f hdech.f hdtooc.f hdcorr.

- NEC Compiler on Linux system

sxf90 -C hopt -P auto -R2 -o HDMODEL
hdmain.f hdmodel.f hdini.f hdrest.f hduse.f hdech.f hdtooc.f hdcorr.f

Compile script fhdcomp

- ICTP Compiler on Linux system

gfortran -fconvert=big-endian -o HDMODEL
hdmain.f hdmodel.f hdini.f hdrest.f hduse.f hdech.f hdtooc.f hdcorr.f

- other examples for compiler on Linux system

ifc -cm -w -w90 -w95 -o HDMODEL …
Alternative Compiler on Linux system that reads Big Endian files
pgf90 -byteswapio -o HDMODEL …

- If you want to run the HD model on a Linux-PC using Big Endian Binary files and the compiler has no option regarding this, instead of using a byteswapping program before, you may also set the following environment variable, so that all binary files will be treated as Big Endian. For example, with intel compiler.

setenv F_UFMTENDIAN big # tcsh: read in/out in Big Endian

Important lines in the file

❖ ISWRIT: time step for writing a restart file (0 = No)
365

❖ NSTEP : Number of days the model should run
365

❖ JAHR1 : First simulation year
1989

❖ ISOLOG: Log file output into ASCII file iso.dat (0=No)
7

❖ UFAKRU: Unit factor applied to input arrays RUNOFF and DRAIN for m^3/s (REMO --> mm/day)
1.

HD model initilization input file: hdini.inp

❖ TDNRUN: File name of SRV file with runoff input time series
../runoffbin.dat

❖ TDNBAS: File name of SRV file with drainage input time series
../drainagebin.dat

❖ TDNPAR: File name of HD model parameter file
hdpara.srv

❖ TDNRES: File name of HD model restart file
hdrestart_6951422_881231.dat

HD model initilization input file: hdini.inp

- IOUT: Switch for averaging interval of HD model output
5
- 1 = 30 days
- 2 = 10 days
- 3 = 7 days
- 4 = Monthly without special years (each year: 365 days)
- 5 = Monthly including special years
- 6 = Daily (requires a lot of disk space)

Current valid ISOLOG numbers

❖ If ISOLOG = 0, no ASCII logfile iso.dat is written. **100** = coordinates are read from hdini.inp. Otherwise the file contains daily discharge [m³/s] for a certain rivers/catchments.

ISOLOG	1. Column	2. Column
❖ 1	Bothnian Bay	Bothnian Sea
❖ 2 or 3	Day number	Torne-/Kalixaelven
❖ 4	St. Lawrence river mouth	Last gauge station
❖ 5	Day number	Paraguay
❖ 6	Odra river mouth	Odra -Hohensaaten/Finow
❖ 7	Elbe at river mouth	Elbe at New Darchau
❖ 8	Orange river	Congo river
❖ 9	Amu-Darya	Syr-Darya
❖ 10	Lena	Ob

ISOLOG = 100

If ISOLOG = 100, coordinates are read from hdini.inp.
Column 1 = outflow box 1, Column 2 = outflow box 2

- FLLOG1: Longitude for outflow box 1 for ISOLOG=100
127.0

- FBLOG1: Latitude for outflow box 1 for ISOLOG=100
71.5

- FLLOG2: Longitude for outflow box 2 for ISOLOG=100
68.5

- FBLOG2: Latitude for outflow box 2 for ISOLOG=100
67.0

HD model parameter file: hdpara.srv

Rec	Date	Code	Level	Size:	Minimum	Mean	Maximum
HD model Land Sea Mask							
1 :	0	172	0	720* 360 :	0.000e+00	3.357e-01	1.000e+00
River Direction File = RDF							
2 :	0	701	0	720* 360 :	-1.000e+00	1.088e+00	9.000e+00
HD model parameter fields							
3 :	0	702	0	720* 360 :	0.000e+00	6.974e+00	2.348e+04
4 :	0	703	0	720* 360 :	0.000e+00	2.496e-01	1.111e+00
5 :	0	704	0	720* 360 :	0.000e+00	1.564e-01	9.098e+01
6 :	0	705	0	720* 360 :	0.000e+00	9.900e-01	5.479e+00
7 :	0	706	0	720* 360 :	0.000e+00	9.084e+01	1.028e+03
Areas at 0.5 degree grid [m^2] = f(latitude)							
8 :	0	707	0	1* 360 :	1.348e+07	1.968e+09	3.091e+09

Run the program on scratch

Run the model in your scratch directory

- **cd /scratch/<yourname>**
- **Compile the model**

Copy the file hdini.inp into this directory

- **cp HDDIR/hdini.inp .**

Edit the file hdini.inp with pathes from here

Run the model with

- **./HDDIR/HDMODEL**

Run the program on scratch

Runscript, assumes edited hdini.inp in Run-directory DIROUT

- echo "Executing HD-Model"
- # Directory with HD-Model Executable
- set DIRHD=/scratch/<yourname>/HDDIR
- # Directory with HD-Model Parameter and restart input
- set DIRINP=/scratch/<yourname>/HDDIR
- # Directory where HD-Model runs
- set DIROUT=/scratch/<yourname>
- cd $DIROUT
- $DIROUT/HDMODEL

A slightly sophisticated script for experience unix user is fhdrun located in /scratch/smr2029/hdm/

Helping programs and files in useful.tar

Extract archive with: **tar xvf useful.tar**

indexcalc.f By entering the North-West corner coordinates of a global 0.5° gridbox the program allocates the index numbe rs of the specified gridbox within the grid.

readoutput.f See next slide

catchnr.txt Allocates certain numbers to several large river catchments on the globe.

tracer.inp Allocates the river mouth coordinates (NW corner of the gridbox) for several large rivers within the HD model topography / RDF. Here, the numbers from file catchnr.txt are used.

example.gnp GNUplot example script that reads data from file **example.txt**

Program to read HD model output

readoutput.f

- Compile the program, eg. with

gfortran -fconvert=big-endian -o READOUT readoutput.f

- Program needs to be in the same directory as the HD model output file meanflowbin.dat

- Run the program with

./READOUT

Program asks for latitude and longitude, then it creates a file „data.txt“ with the data at the specified grid box.

Elbe: Lat: 54.5, Lon: 8.5

Gnuplot

- Open source plotting program
- 2D plots, surface plots and 3D plots
- Interactive use or scripts
- Documentation: http://www.gnuplot.info/documentation.html
- Examples: http://gnuplot.sourceforge.net/demo_4.2/

General Options

```
set terminal postscript color solid enhanced 'Arial' 16
set output 'figure.ps'
```

Postscript instead of screen output

```
set key left
```

Position of legend

```
set xlabel 'X-Axis'
set xrange [0:1]
```

Label and range of X-Axis

```
set title 'Gnuplot figure'
```

Plot title

Time dependent data

set xdata time

set timefmt "%m-%d" Data file time format:

e.g. 2009-04-16 ⇨ %Y-%m-%d

set format x "%b" X-axis time format:

e.g. Jan Feb Mar ... ⇨ %b

Excourse: GNUPLOT

Plotting

```
plot 'data1.txt' using 1:2 with lines lw 2 lc rgb 'red'  title 'data1', \
    'data2.txt' using 1:4 with lines lw 2 lc rgb 'blue' title 'data2'
```

Name of datafile

columns

lines/points etc.

linewidth

linecolor

label

Excourse: GNUPLOT

Example script

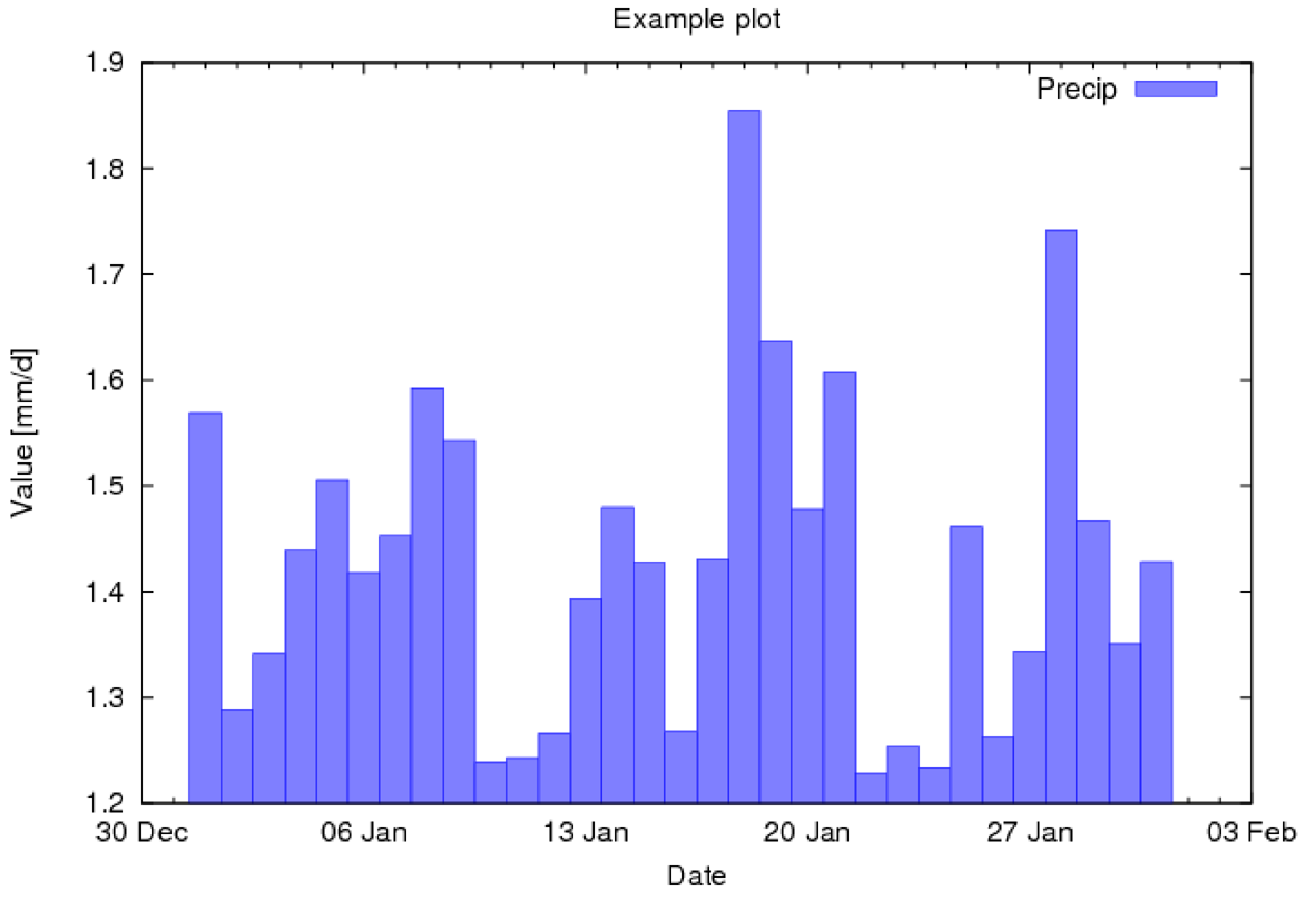
```
set title "Example plot"
set xlabel "Date"
set ylabel "Value [mm/d]"
set xdata time
set timefmt "%Y-%m-%d"
set format x "%d %b"
set terminal postscript color solid enhanced 'Arial' 16
set output 'example.ps'
set style fill solid 0.5 border
plot 'example.txt' using 1:($3 * 86400.) with boxes lc rgb 'blue' title 'Precip'
```

Excourse: GNUPLOT

Example script in HDDIR if you did: tar xvf useful.tar

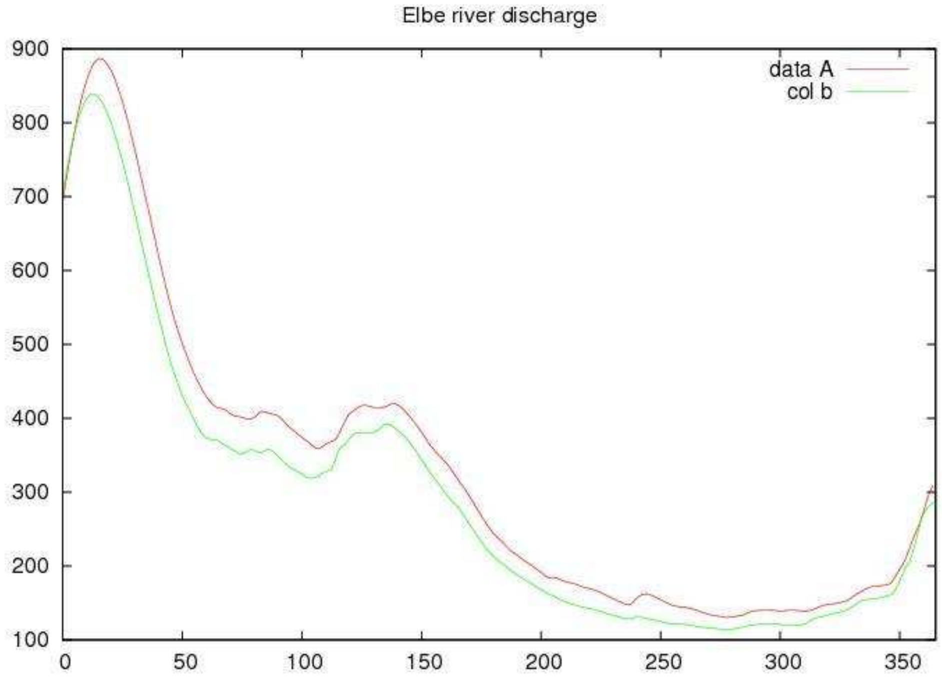
$> gnuplot example.gnp → PS file example.ps is created

Use **gs example.ps** to view it.



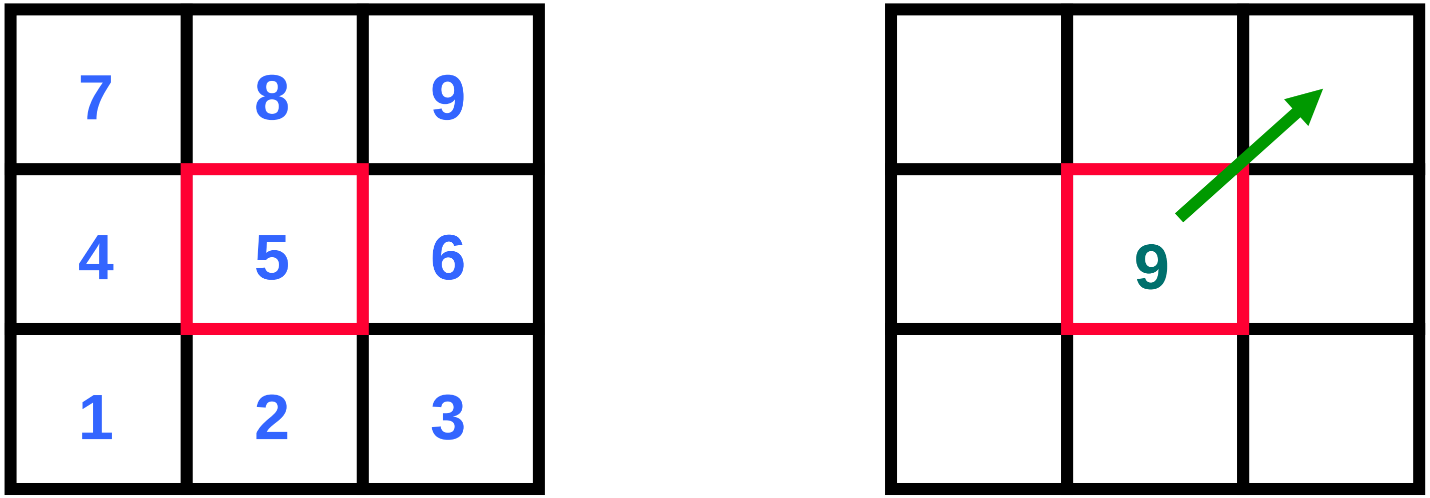
Example for plotting curves from a file with 2 data columns
time column starts at 0 [start gnuplot first]

```
$> clear
$> set xrange [0:365]
$> plot 'iso.dat' using 0:1 title 'data A' with lines, \
$>        'iso.dat' using 0:2 title 'col b' with lines
```



3. Read HD output at certain grid boxes

River Direction File

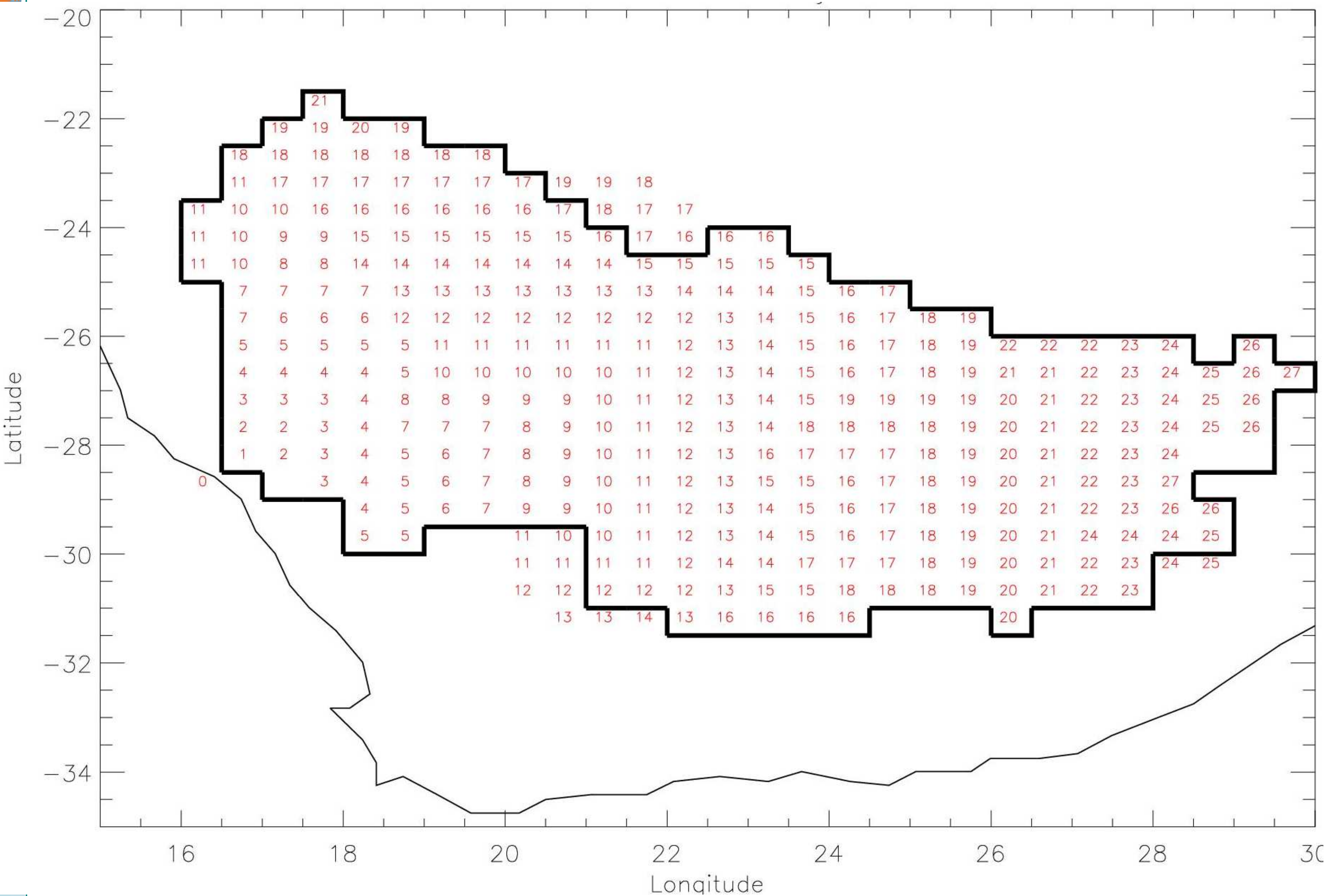


HD African river mouths

Lat	Lon	No.	Catchment
31.5	31.5	60	Nile
17.0 16.0	-16.0 -17.0	62 62	Senegal
4.5	5.5	64	Niger
12.5	14.5	66	Chari
-6.0	12.0	68	Zambezi
-16.0	33.5	70	Limpopo
-25.0	33.5	72	Orange
45.0	29.0	14	Danube

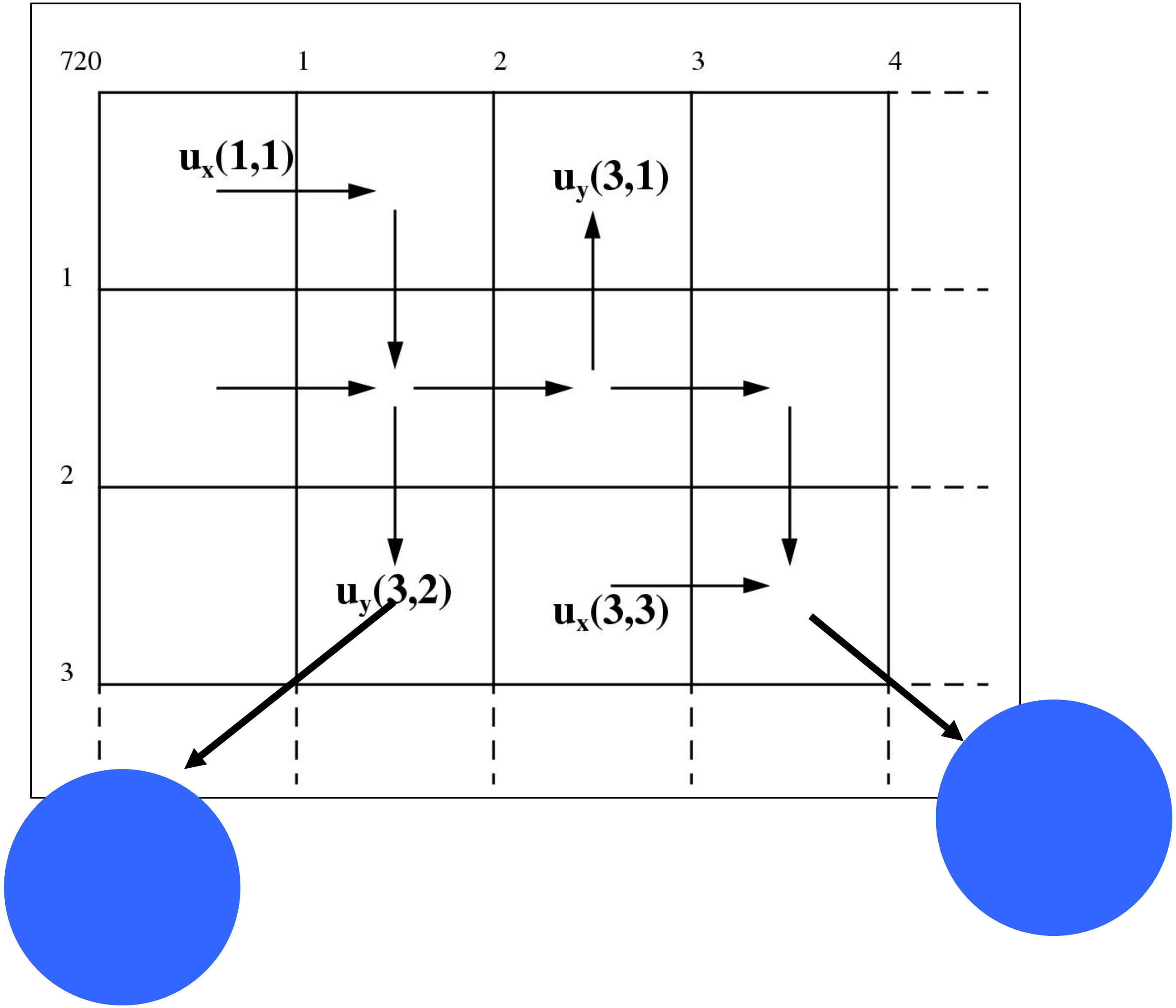
Coordinates indicate the NW corner of a gridbox

Orange River

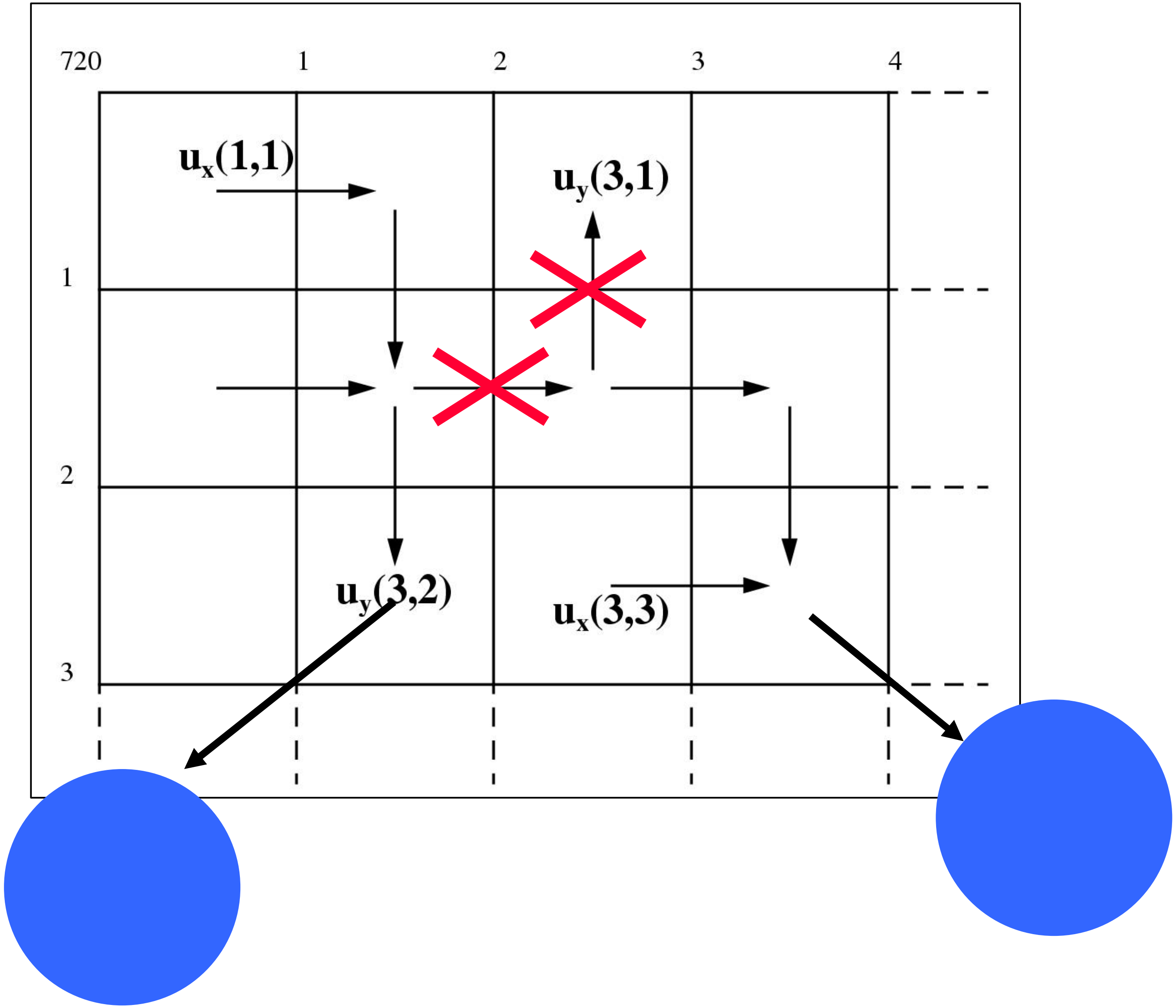


4. HD model topography features and RDF construction

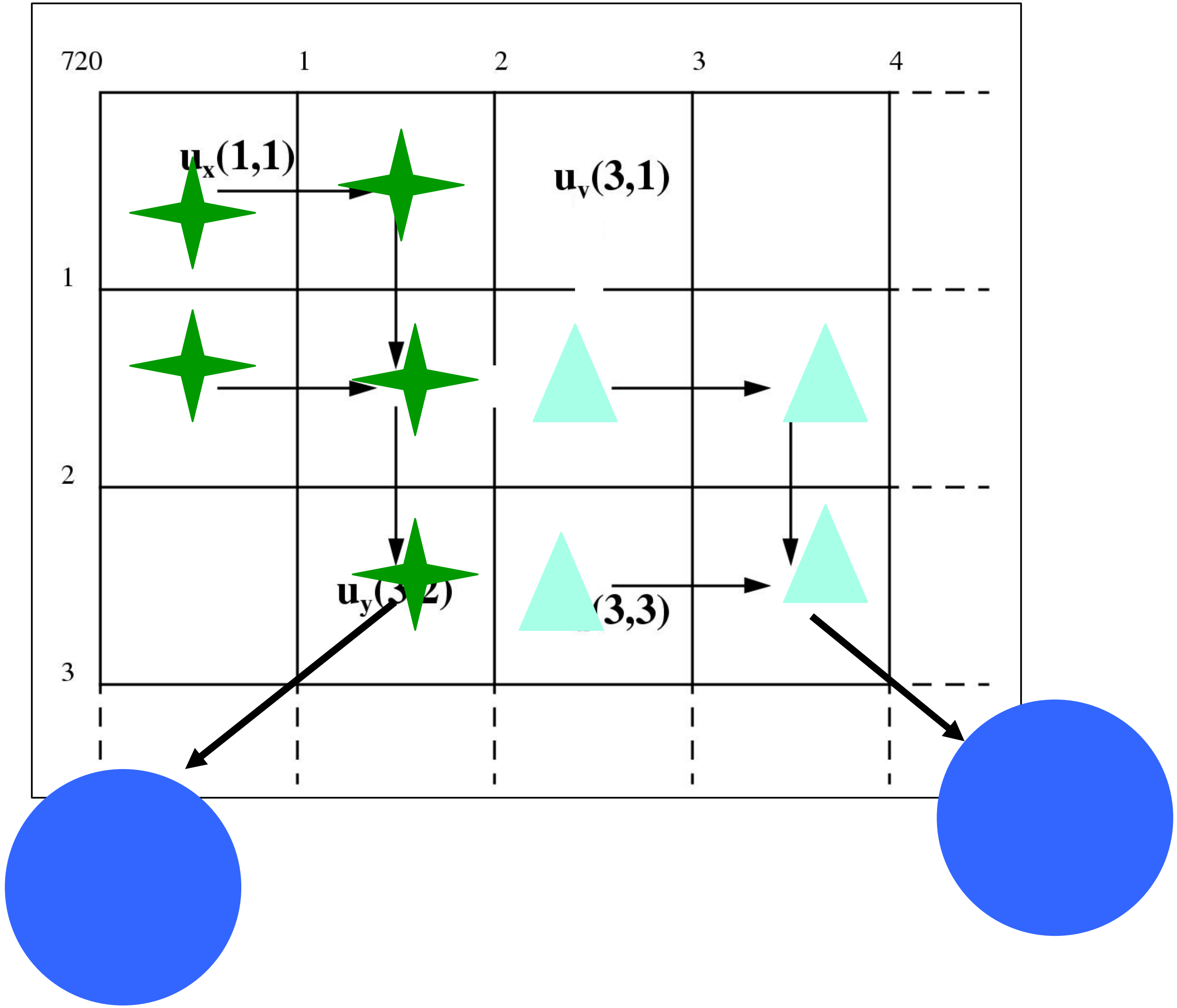
Ambiguous flows vs. unique flows



Ambiguous flows vs. unique flows



Ambiguous flows vs. unique flows



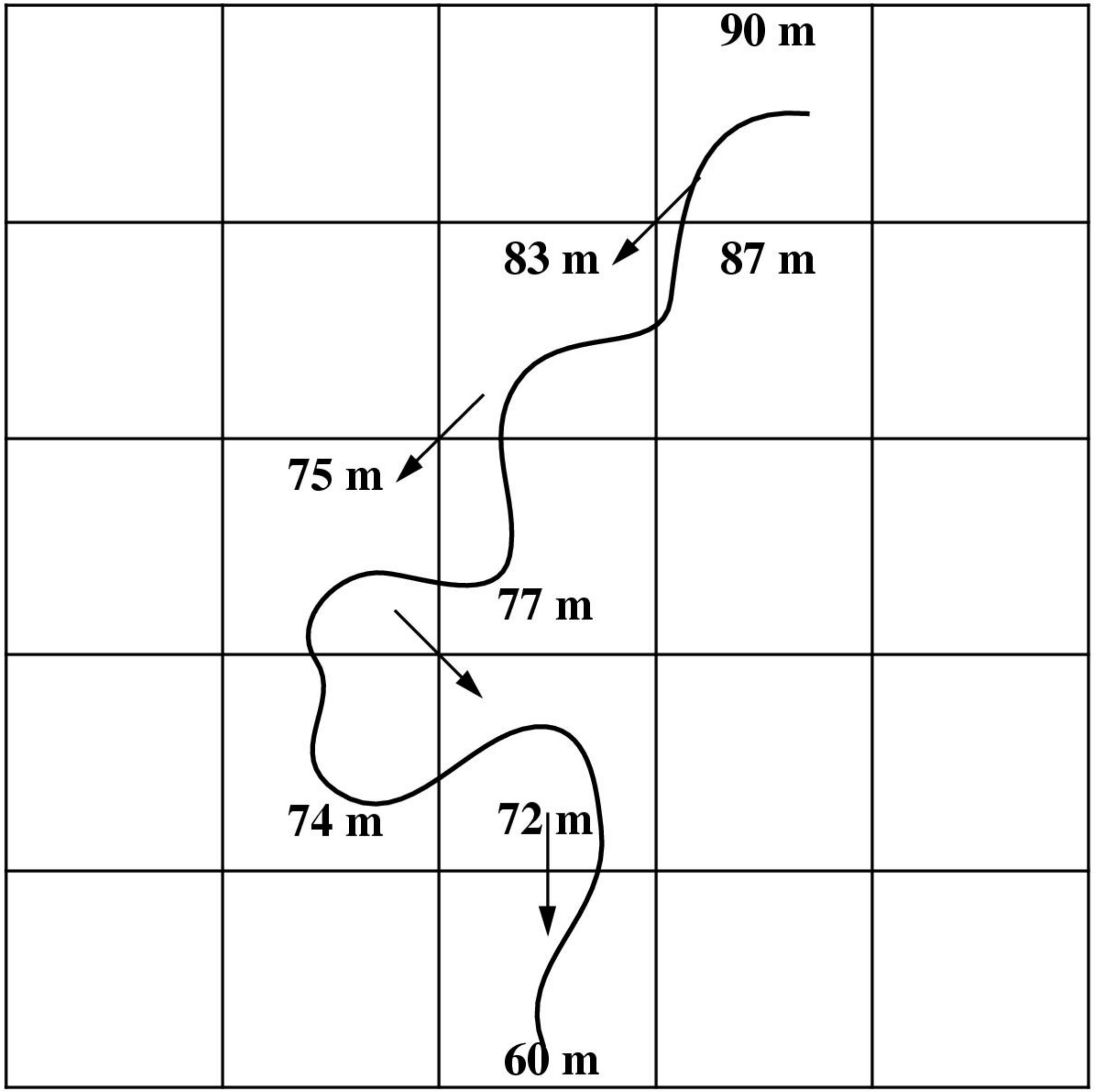
Smoothing of local minimal

43 m	62 m	65 m	61 m	71 m	69 m	76 m
60 m	61 m	62 m	63 m	64 m	65 m	77 m
59 m	72 m	49 m	62 m	42 m a)	66 m	72 m
33 m	58 m b)	65 m	60 m	72 m	77 m	82 m
53 m	62 m	69 m	72 m	72 m	63 m	61 m

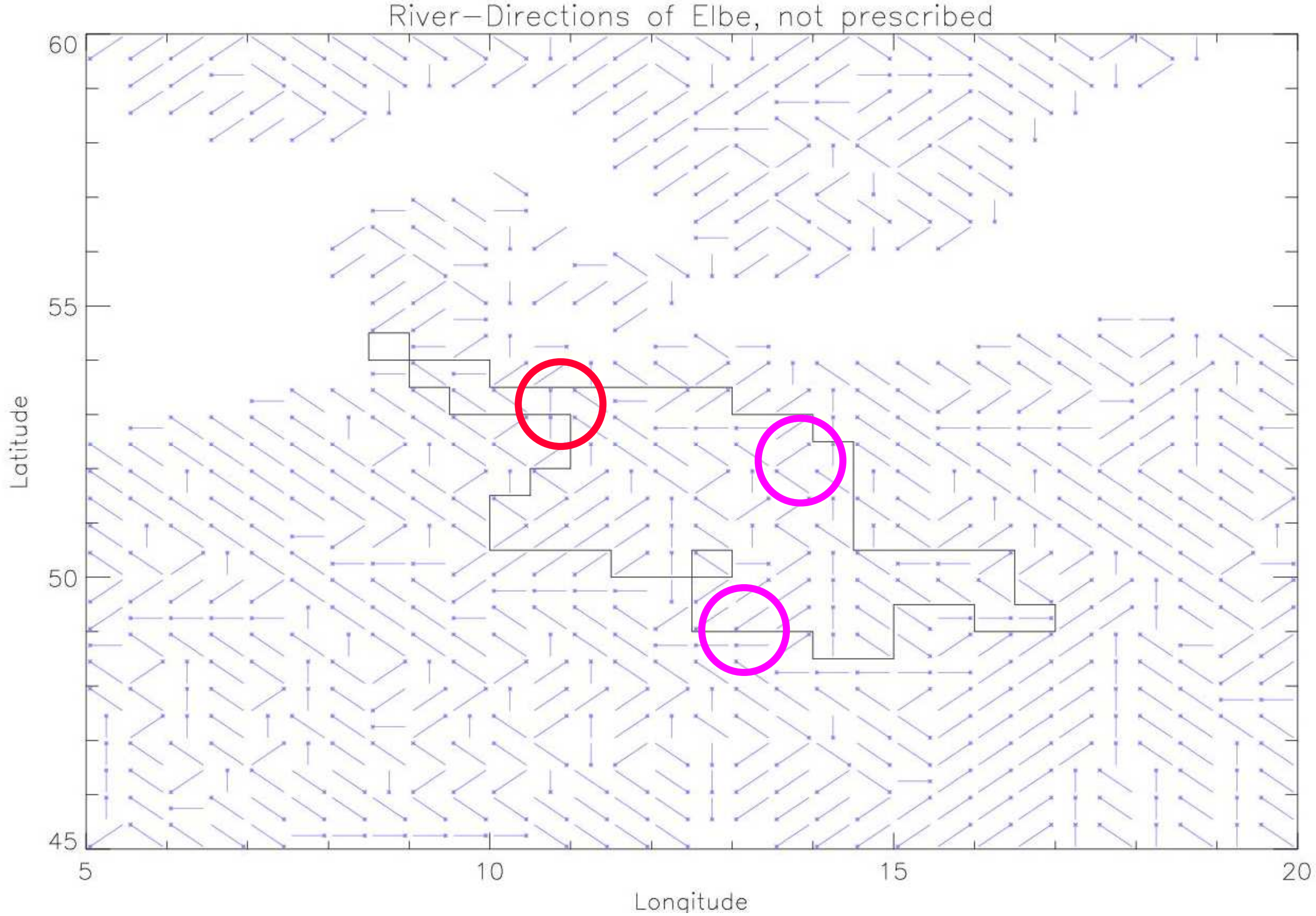
Manual breakdown of barricades

43 m	62 m	65 m	61 m	71 m	69 m	76 m
60 m	61 m	62 m	63 m	64 m	65 m	77 m
59 m	72 m	49 m	62 m	42 m a)	66 m	72 m
33 m	58 m b)	65 m	60 m	72 m	77 m	82 m
53 m	62 m	69 m	72 m	72 m	63 m	61 m

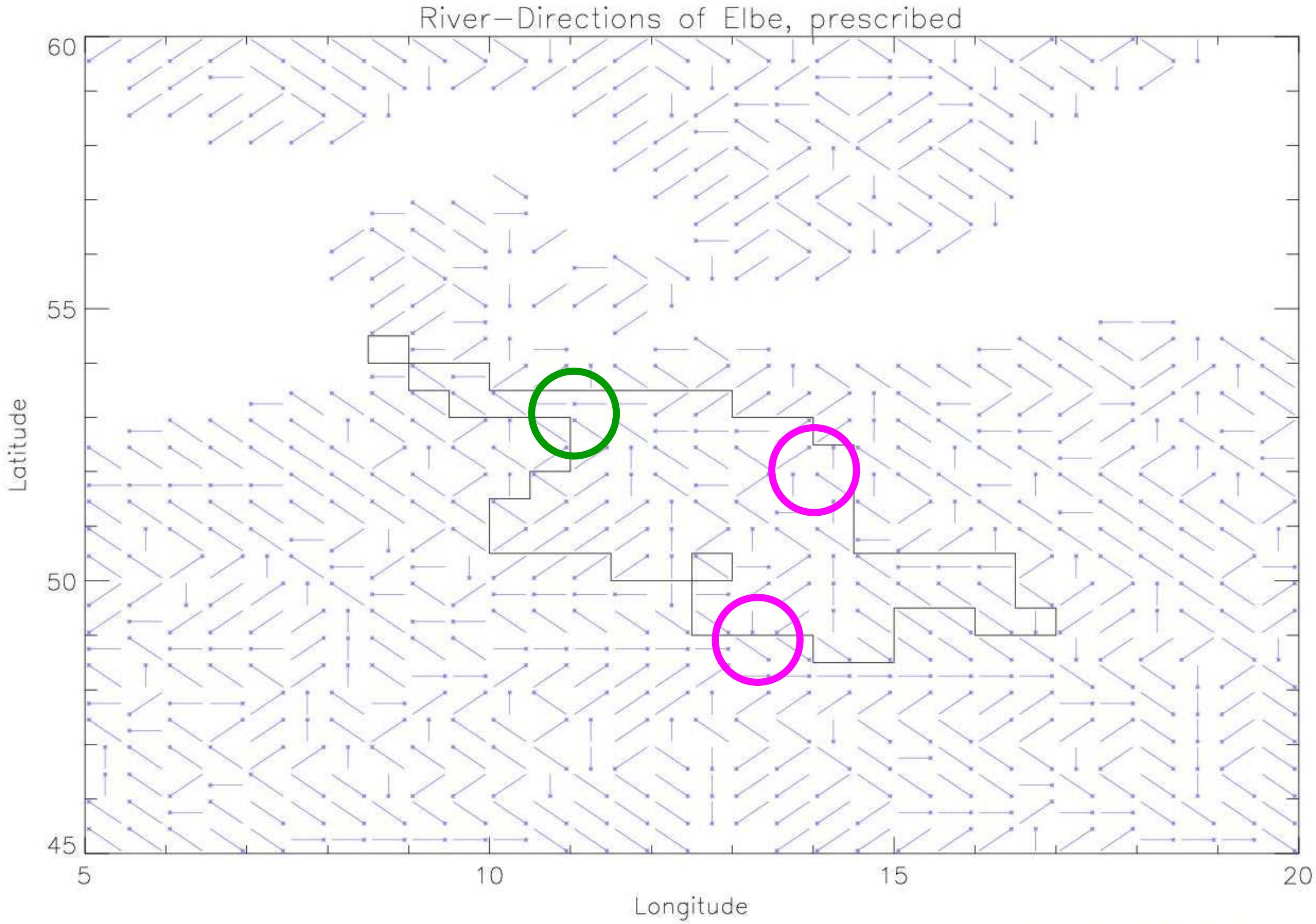
Prescription of main river path into the HD model topography



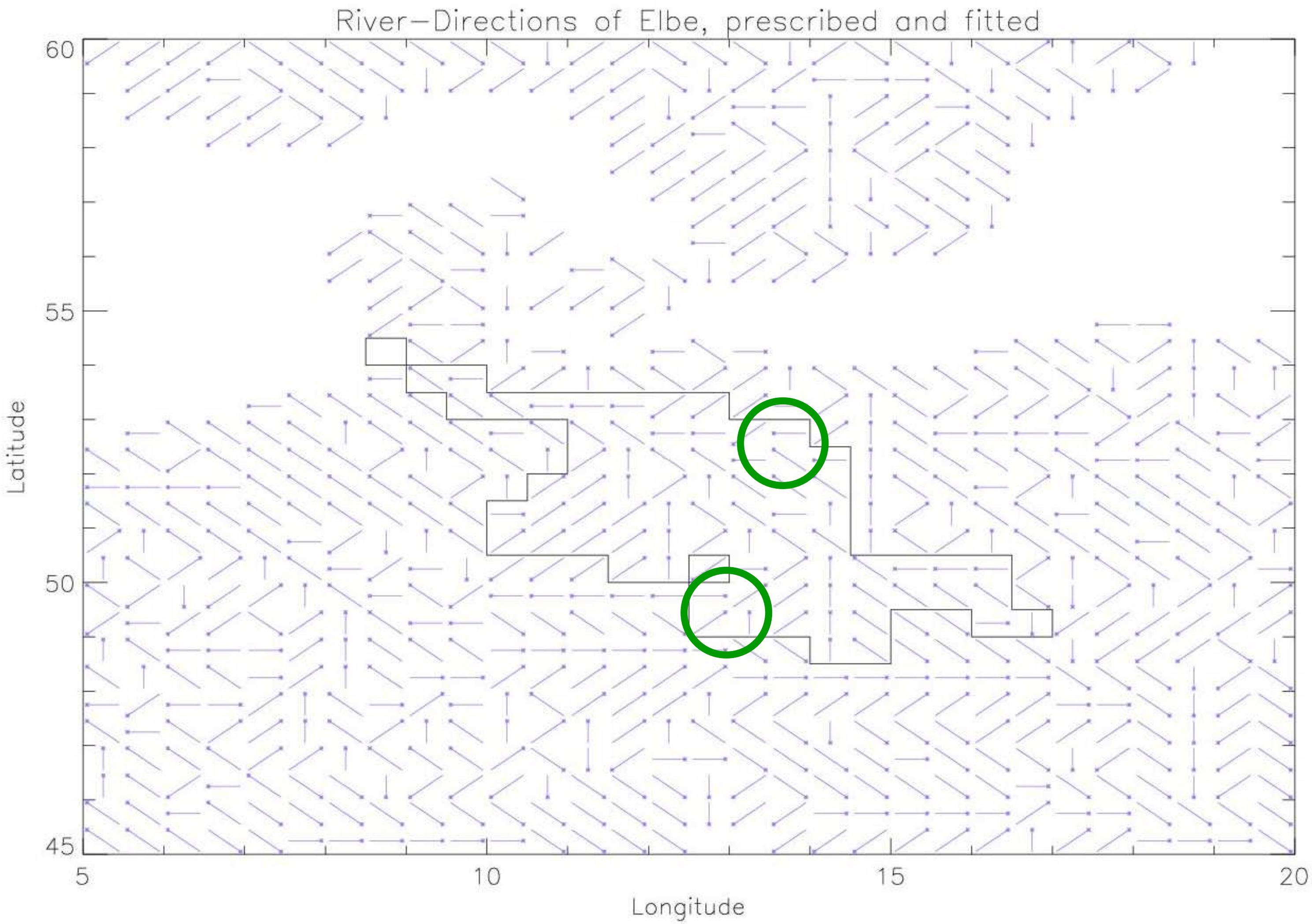
Elbe - river path not prescribed



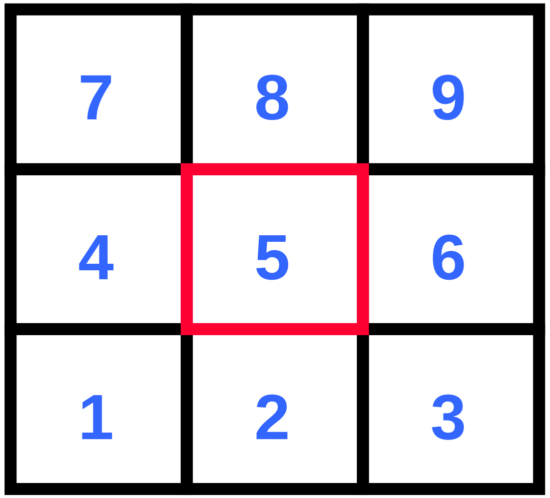
Elbe - river path prescribed

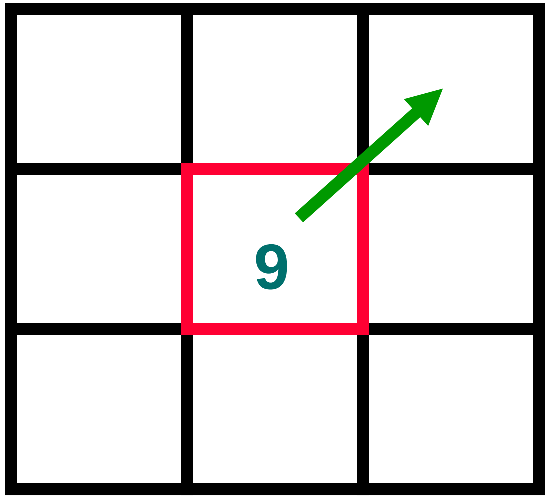


Elbe – flow directions fitted at catchment boundary



River Direction File





Summary

- One outflow per gridbox allows for a reconstruction of spatial discharge behaviour, and thus the allocation of a model catchment
- The extended smoothing method yields better agreement of model and real catchments
- For certain catchments a prescription of the main stream flow path is necessary.
- The used prescription method yield significant better agreements model and real catchments
- For some Interior Drainage Basins the setting of allowed local minima is necessary

5. Change HD model setup to use other input data

Run with REMO data (or RegCM)

Compile script fhdcomp

Example: Changing Input, i.e.HD-Model compilation for T106-Input (with)

- cp -p pcom05.for ./pcom.for
- **cp -p premo_sibi.for ./pinp.for**
- **cp -p hdr_remo.f ./hdech.f**
-

Other input grids than T106

The current model setup is suitable to read T106 data as input.

❖ For other input resolutions, two files have to be modified:

HDDIR/phd_t106.for Contains input field characteristics
HDDIR/hdt106.f Interpolates T106 resolution to 0.5 degree

❖ For different input resolutions you have to link a file containing the subroutine HDECH(CODE, TOCODE, IQUE) where CODE ist the 2 dimensional input array, TOCODE is the interpolated array on a regular 0.5 degree grid.

❖ Origin: Northpole/date line = North West corner of gridbox [1,1]

❖ IQUE is just a commentary switch (usually set to = 0).

❖ 2 pairs of files for T42 and T63 input grid are included in the tar file.

6. Restart problem for new simulations

Model Initialization for new run

❖ Year 1: Usually no restart file available

a. Take restart file from another simulation, e.g. Restart file included in TAR file

b. This usually does not fit to the start year and atmospheric model behaviour.

c. Run HD model for one year, write out restart file and take this restart file to run the first year again.

d. If possible use the first model year as spin-up year and consider results only from year 2 onwards

e. Some regions (especially if they include large wetlands or inland lakes) require more than 1 year of spin-up. Then, repeat Step **c** several times

7. Steps for HD model topography improvements

It might be that you find an inappropriate model catchment in a specific area which has not been considered in more detail up to now. Either the main flow path may be incorrect, or the model catchment area does not agree with the observed one. Here, the automatic procedures to derive the model topography may have failed because of a complex real orography.

At MPIM I have several programs which I can easily use to improve the HD model topography, and thus create an update of the HD model parameter file hdpara.srv. To do this two files are required.

1) A mask on the HD model grid (0.5 degree) in the SRV format, indicating a 1 in gridboxes within the catchment, and a 0 else where.

2) An ASCII file with the main river flow path from the source to the mouth, indicating the centre coordinates of the gridboxes (1. Column: latitude, 2. Column: longitude). Note that diagonal directions are prefered as shown on the next slide.

Prescription of main river path into the HD model topography