Rijkswaterstaat
Ministerie van Infrastructuur en Waterstaat

User's Guide KALMAN

KALMAN Processor

The computation of a time invariant Kalman filter for WAQUA models

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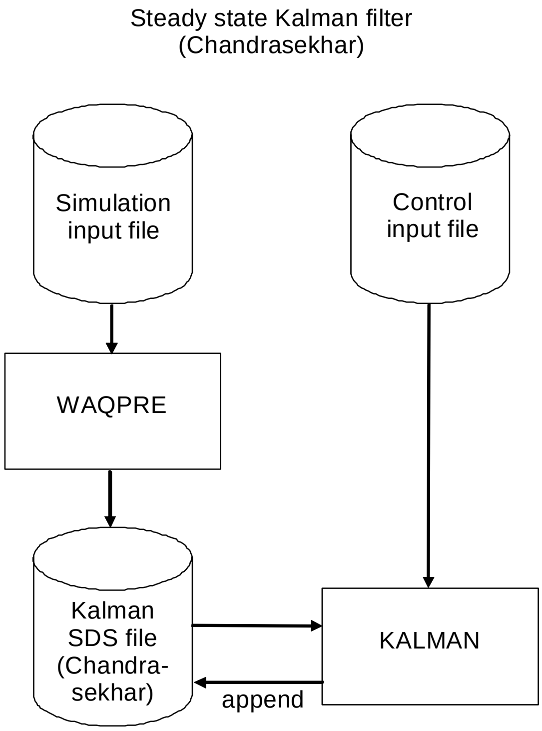
1 ABOUT THE USER'S GUIDE KALMAN PROCESSOR

This User's Guide describes the KALMAN processor with all its ins and outs. With this document a model builder should be able to compute a time invariant Kalman filter for a given WAQUA model.

Chapter 2 describes the general processor flow. In- and output files are described in chapter 3. Chapter 4 deals with more details about the Kalman processor.

2 FLOW CHART



Notes WAQPRE is part of the WAQUA system

3 INPUT AND OUTPUT FILES

This chapter describes the in- and output files of the KALMAN procedure. Files common to SIMONA applications, like the error message file, are not discussed. Refer to the User's Guide SIMONA for a description of these files.

3.1 Input files

The next input files are needed by procedure KALMAN:

- An SDS file created by WAQPRE.
- A control input file
- An SDS documentation file

3.1.1 SDS file

The input SDS file is to be created by WAQPRE. The simulation input file for WAQPRE may not contain the KALMAN keyword. The model must be 2-D in spherical co-ordinates.
Refer to the User's Guide WAQUA for detailed information about the SDS file.

The next compound arrays of problem field FLOW are read by the Kalman system:

- MESH
- CONTROL_FLOW
- COEFF_GENERAL
- CHECKPOINTS_FLOW
- KALMAN

3.1.2 Control input file

The control input file for Kalman is a free-formatted ascii file with control data. The lay-out meets the SIMONA requirements, which implies among others:

- spaces, comma's, "(", ")", ";", ":", etc. are implemented as seperation characters
- a key is a serie of alfanumeric characters
- text is a serie of characters surrounded by quotes
- input can be given across several lines
- an empty line is skipped
- a line starting with a "#" is treated as comment

Refer for a more extensive general description of a SIMONA input file to the "User's Guide WAQUA".

For the input definition the following conventions are used:

[val]	real value
[ival]	integer value
[text]	text string
< ... >	repetition group
| A < | B	either A or B

In this document a part of the key-word is underlined. Only the underlined characters are significant. Extra characters are ignored.

KEY-WORD

O key-word is optional.
M key-word is mandatory.
D key-word has a default value. When this key-word is omitted, a default value will be used for the variable specified.
R key-word may occur more than once.

3.1.2.1 Main key-words

The start of the input of main key-words is identified by the key-word GENERAL (mandatory). In this section general control input is specified together with default values to be used.

GENERAL
  COMPUTATION_TIME=*[val]*
  BOTTOM_FRICTION=*[ival]*
  CHAR_DIST=*[val]*

Explanation:

COMPUTATION_TIME =*[val]*	**M**	Number of iterations * WAQUA integration step in minutes.
BOTTOM_FRICTION =*[val]*	**D**	Linear bottom friction coefficient, valid at each computational grid point. Default = 0.0024
CHAR_DIST=*[val]*	**D**	Characteristic distance in fractions of gridpoints. Default = 0.1 * {length of the diagonal of the computational area}

3.1.2.2 Waterlevel station key-words

The start of the waterlevel stations definition section is identified by the key-word

WATERLEVEL_STATIONS (mandatory)

The waterlevel stations are identified by their name, which must have been specified in the simulation input file for WAQPRE. The match of the names must be exact, for instance HOEKVHOLLAND is not the same as HOEK V HOLLAND. The location of a waterlevel station within the concerning grid is defined in the simulation input file.

S:NAME=*[text]*, STANDARD_DEV=*[val]*

S	**R**	Each station specification must start with key-word S.
NAME=*[text]*	**M**	The station name which must also be specified in the simulation input file for WAQPRE.
STANDARD_DEV=*[val]*	**D**	Standard deviation of the waterlevels in meters. Default: 0.05 m.

3.1.2.3 Wind noise key word

The wind noise parameter definition section is identified by the key-word

WIND_NOISE (optional)

At least one of the sections WIND_NOISE or BOUNDARIES must appear in the input. The section name is mandatory when the concerning parameters are defined.

```
WIND_NOISE
   STATISTICS
      STANDARD_DEV=[val]
      TIME_CORRELATION=[val]
      CHAR_DIST=[val]
   GRID
      M_INCREMENT=[ival]
      N_INCREMENT=[ival]
      M_START=[ival]
      N_START=[ival]
```

STATISTICS	**M**	In this sub-section the statistic values to be used can be set.
STANDARD_DEV=*[val]*	**D**	The standard deviation for the wind. Default=0.003
TIME_CORRELATION=*[val]*	**D**	Correlation in time. Default=0.9
CHAR_DIST=*[val]*	**D**	The characteristic distance. Default: CHAR_DIST as specified in the GENERAL section.
GRID	**M**	Start of the definition of the wind grid.
M_INCREMENT=*[ival]*	**M**	Size in WAQUA grid points between two successive wind grid points in M direction. The wind filter values at WAQUA grid points is linear interpolated.
N_INCREMENT=*[ival]*	**M**	Size in WAQUA grid points between two successive wind grid points in N direction.
M_START=*[ival]*	**D**	A M coordinate in the WAQUA grid which must be part of the wind grid. This enables the transposition of the wind grid on the WAQUA grid. The resulting wind grid will always overlap the complete WAQUA grid. Default=1
N_START=*[ival]*	**D**	A N coordinate in the WAQUA grid which must be part of the wind grid. Default=1

3.1.2.4 Boundaries key word

```
BOUNDARIES
    STATISTICS
        STANDARD_DEV=[val]
        TIME_CORRELATION=[val]
    LINE_SECTIONS
        S: SECTION=[ival1],[ival2]
```

BOUNDARIES	**O**	With the BOUNDARIES key-word uncertain parameters for boundary conditions can be defined.
STATISTICS	**M**	This key-word identifies the sub-section in which statistical values can be set.
STANDARD_DEV= ***[val]***	**D**	The standard deviation for the boundary condition parameters. Default: 0.003
TIME_CORRELATION= ***[val]***	**D**	Correlation in time. Default=0.9
LINE_SECTIONS	**M**	This key-word identifies the input of the line section pairs.
S	**R**	Start of a single line section definition.
SECTION= ***[ival1]*,*[ival2]***	**M**	The starting and ending line section number of which at the outer ends uncertain parameters are defined. All points between the two parameters following the boundary line must concern open boundary points (no gaps allowed). Overlap is not allowed either. Boundary condition filter values are linear interpolated between the two parameter points.

3.1.3 SDS documentation file

The SDS documentation file is an ascii file describing an LDS. The file is opened and read by DIRSYS at initialization. Refer to the User Documentation of DIRSYS for more information.

3.2 Output files

The next output files are created or updated by the KALMAN procedure.

- The SDS file
- Message file

3.2.1 SDS-file

An SDS file created by WAQPRE is input to KALMAN, which appends compound array KALMAN to it.

/KALMAN/INT

contains integer time independent data:

nopnt	number of filter values per waterlevel station. A filter value is computed at each computational grid point for waterlevels and u- and v-velocities, and for each uncertain parameter: nopnt = 3*mnmaxk + nbnd + 2*nwnd
nowl	number of waterlevel stations
mbound	maximum number of uncertain boundary points = 2*(mmax+nmax)
nwnd	number of uncertain wind points.
nbnd	number of uncertain boundary points.
ibroco (4,noroco)	pointer table: - (1,i) gainb index for irogeo(jsta,i) - (2,i) gainb index for irogeo(jend,i) - (3,i) lgrid index for irogeo(jsta,i) - (4,i) lgrid index for irogeo(jend,i) The entries (1,i) and (2,i) are only filled in case of waterlevel openings, (3,i) and (4,i) in case of velocity openings.
ilgrwl(nowl)	lgrid indices of the waterlevel stations.

/KALMAN/REAL

contains real time independent data:

cortiw	correlation in time for the uncertain wind parameters.
cortib	correlation in time for the uncertain boundary condition parameters.

/KALMAN/GAIN

contains real time independent data:

gainsp(mnmaxk,nowl)	waterlevel filter gain
gainu(mnmaxk,nowl)	u-velocity filter gain
gainv(mnmaxk,nowl)	v-velocity filter gain
gainwu(mnmaxk,nowl)	filter gain for the wind effects on the u-velocities
gainwv(mnmaxk,nowl)	filter gain for the wind effects on the v-velocities
gainb(0:nowl,mbound)	filter gain for open boundary conditions

3.2.2 Message file

The message file of procedure KALMAN is kalman-m.<runid>. If any error occurred, the message is given in this file.

After each KALMAN iteration the maximum absolute filter values per waterlevel station per waterlevel, u-/v-velocity and uncertain parameter is printed in this message file. These values should converge.

4 THE KALMAN PROCESSOR

4.1 General

The actual release of the Kalman processor only accepts a spherical 2 dimensional model. The model may contain computational points which can fall dry during the WAQUA forecast. Computational grid points with a depth value < 0.0 (above mean sea level) do not take part in the Kalman filter computation.

A Kalman filter can be computed for wind noise and/or boundary condition parameters. The latter parameters can only be defined for open waterlevel boundaries.

The covariance matrix P for the wind noise is initially filled with:

$$P_{i,j} = \sigma_w^2 e^{-\frac{d_{i,j}}{D}}$$

where:

σ_w standard deviation of the wind
$d_{i,j}$ distance between the points i and j
D characteristic distance for the wind

In the current release a (characteristic) distance is expressed in grid co-ordinates.

The covariance matrix for the uncertain boundary points is initiated with:

$$P = \sigma_b^2 I$$

where:

σ_b standard deviation of the boundary conditions
I unity matrix

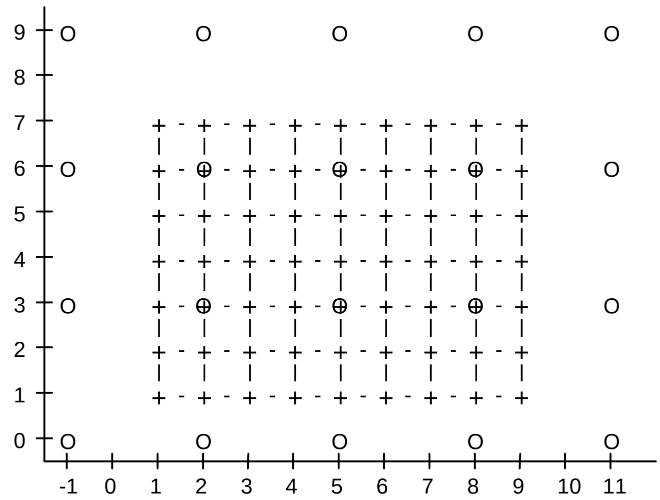
4.2 The interpretation of the parameters

The more parameters the greater the Kalman filter and the greater the amount of CPU time needed to compute the filter. The number of uncertain parameters can be reduced by identifying a subset of the total. Unidentified grid points obtain their stochastic value through linear interpolation.

4.2.1 Wind noise parameters

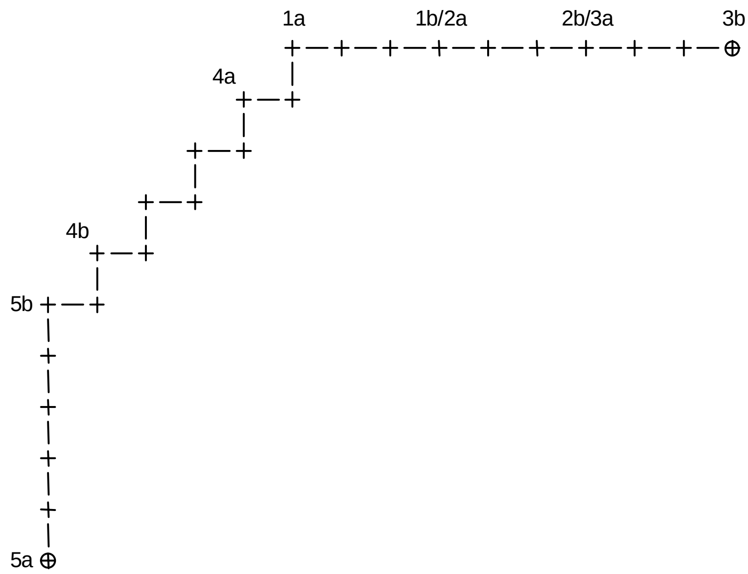
Wind noise parameters are defined at given wind grid points. This wind grid has a grid distance expressed in a multiple of WAQUA grid points. A WAQUA reference point can be given to move the grid to the wanted position. The resulting wind grid will be extended outside the WAQUA grid to ensure a complete overlap.

Example:
Suppose the WAQUA grid is defined as m=1,9 and n=1,7, and the wind grid is defined with an m-increment of 3 WAQUA grid points and an n-increment of 3 WAQUA grid points. The reference point is set at WAQUA grid point (m,n)=(2,3). The resulting wind grid is depicted in the next figure, where 'O' represent the wind noise parameters.



4.2.2 Boundary condition parameters

Open waterlevel boundaries are defined in WAQUA through boundary line sections with an 'a' end and a 'b' end:



Uncertain boundary parameters can be defined at each 'a' or 'b' end. Two neighbour points, for instance the 'a' end of a section and the 'b' end of a following section, are considered to represent one parameter. The points are neighbours when their (m,n) coordinates differ at most one grid point.

Boundary points representing a parameter are defined through line section pairs. To the outer ends of an input line pair two parameters are assigned.

The stochastic waterlevel values at each open waterlevel boundary point is obtained through linear interpolation.