Rijkswaterstaat
Ministerie van Infrastructuur en Waterstaat

User's Guide KALMAN

General Information

An introduction to the Kalman system

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Maintenance : see www.helpdeskwater.nl/waqua

CONTENTS

1 ABOUT THIS MANUAL

This User's Guide describes the KALMAN system, which is based on SIMONA tools and routines. KALMAN is a linearized, time independent WAQPRO system computing an invariant Kalman filter gain for use by WAQUA. This steady-state filter is able to improve the results of short term WAQUA forecasts using waterlevel observations.

This document is written for those who want to compute time-invariant Kalman filter gains and for users executing short term WAQUA forecasts in combination with the Kalman filter (mostly in operational environment).

This User's Guide consists of five sections. Section one consists of chapters dealing with General Information about the manual, about the KALMAN System and about the WAQUA system combined with the Kalman gain. Section two is a Quick Reference Guide for the available KALMAN subsystems. In section three the KALMAN processor is fully described. Section four describes the observed data pre-processor for WAQUA. Finally, section five deals with the use of the Kalman gain within the WAQUA processor.

2 ABOUT KALMAN

The Kalman filter provides a statistical approach to tidal predictions using on-line measurements. WAQUA predictions are corrected in order to adapt the model to changing physical circumstances using waterlevel measurements.

From a computational point of view it is not (yet) feasible to compute a real Kalman filter based on a two-dimensional non-linear tidal model. Therefore the filter is approximated by a time-invariant one, as developed by A.W.Heemink (re. A.W.Heemink, 'Storm Surge Predictions using Kalman Filtering', Ph-D thesis, Twente University of Technology, 1986). In this case the filter equations are solved only once, off-line, and do not have to be computed each time when new measurements become available.

The system is written in Fortran77, with a minimum of computer dependent code. The procedure running the Kalman filter program is written for UNIX and has been tested on the HP9000 series. But it also runs on Linux and MS-Windows.

2.1 Function of the system

The steady-state Kalman filter provides a combination of a numerical and a statistical approach of the forecast of a tidal model. A WAQUA-with-Kalman run consists of a hindcast and a forecast. During the hindcast the computed model state is adapted using waterlevel measurements at pre-defined locations. The adaptations are correlated in time resulting in a decreasing effect of the filter in the forecast.

The implemented Kalman filter approach requires complete measurement series at each location for which the filter is computed. When measurement values are "missing", the residuals are estimated with the Kalman filter.

2.2 Theoretical basis

2.3 Architecture of the system

The Kalman program computes the filter and writes it on an SDS file created by WAQPRE. This SDS file is only used to contain the Kalman filter and not to run WAQUA. WAQUA-with-Kalman runs on its own SDS file and reads the Kalman filter from the Kalman SDS file. The reasons for maintaining a separate SDS file are:

- The implemented Kalman filter is time-invariant and thus does not belong to certain forecast periods.
- The filter occupies a notable amount of disk storage. Duplication in each WAQUA SDS file seems unnecessary waste of disk space.

Kalman filter computation

The steady state Kalman filter is computed off-line using linearized WAQUA equations.
This off-line computation of the Kalman filter for a given WAQUA model is fed by an SDS file resulting from WAQPRE (re. 'User's Guide WAQUA') and an ascii input file with control data. The resulting filter is appended to this Kalman SDS file.

The Kalman filter must be computed on the same system as where it will be used by WAQUA, while the SDS file is a binary file and thus can not be transported to a different system.

WAQUA-with-Kalman

WAQUA will use the Kalman filter when the name of the Kalman SDS file and the name of the Kalman experiment are given in the WAQUA input file.
The Kalman filter needs observed waterlevels which will be obtained by WAQPRE from DONAR in the near future. To append observations to an SDS-file, use OBS2SDS. This procedure must be executed after WAQPRE and before WAQPRO with Kalman. It reads observed data from an ascii file as described in the User's Guide WAQAD and appends this data to the WAQUA SDS file.

post-processing

With the future SIMONA post-processing the computed Kalman filter can be made visible.

2.4 Possibilities and restrictions

possibilities

- Uncertain parameters can be defined for wind noise and boundary conditions.

restrictions

- KALMAN obtains the model information from the SDS file generated by WAQPRE. Only 2-D spherical models are accepted in the current release.
- Uncertain boundary parameters can only be defined for open waterlevel boundaries.
- The Kalman filter must have been computed on the same system as where WAQUA is to be executed.

2.5 Data Flow

2.5.1 KALMAN program

2.5.1.1 Input

SDS-file

An SDS file generated by WAQPRE is required.

Control Input File

Control input for the Kalman filter computation is given through a control input file. This file is a free-formatted file meeting the SIMONA requirements describing among others the uncertain parameters, the computation length, the waterlevel stations with their standard deviation etc. Refer to User's Guide for more information.

2.5.1.2 Output

Error and warning messages

All messages are redirected to the file kalman-m.{runid}. After each Kalman iteration the actual maximum absolute filter values per station are shown. These values should converge.

2.5.2 WAQUA-with-Kalman

2.5.2.1 Input

SDS-file

An SDS file generated by WAQPRE is required. The simulation input file must contain the name of the Kalman SDS file and the experiment name. At the current release the SDS file must be extended with the observed data, which is done through procedure OBS2SDS.

Observed data input file

The KALMAN program needs time series with observed data. In future, this data will be read from the standard database (DONAR) when SIMONA is able to interface with this database. At the current release a previous lay-out of an observed data file is used. This file can be generated from an OBSFIL file (refer to the User's Guide of WAQUA) by means of the NEWOBS procedure, of which a brief user's guide exists.

2.5.2.2 Output

No special output is generated for the Kalman part in WAQUA. WAQUA's results are adapted with the Kalman filter gain.

2.6 KALMAN programs

pre-processor WAQPRE

The processor KALMAN operates on an SDS file generated by WAQUA's pre-processor WAQPRE. The simulation input file must not contain a reference to the Kalman SDS file.
To run WAQUA-with-Kalman, WAQPRE must be executed with a simulation input file containing a reference to the Kalman SDS file and experiment. The WAQUA SDS file may not have the same name as the Kalman SDS file.

processor KALMAN

The Kalman processor computes the time-invariant filter gain, which is appended to the Kalman SDS file.

program OBS2SDS

In the current release observed data needed to activate the Kalman filter is appended to the WAQUA SDS file by means of the program OBS2SDS.

WAQUA-with-Kalman

When the WAQUA processor is to use the Kalman filter gain, its state is adapted according to changing physical circumstances at the end of each complete time step. The filtering starts with the first observed data and will fade away after the last observed data. Special restart information is saved for the Kalman filter mechanism.

Post-processor

The future SIMONA post-processing will enable to examine the computed filter values by means of plot output.