The water level variation of a gate-restricted estuary (Ringkøbing fjord)

Background

Ringkøbing fjord is a shallow estuary located at the Danish west-coast, where it experiences mainly easterly and westerly winds. Wind forcing causes large short-term variation of the water level (h) measured at a gate between the estuary and the North Sea. Westerly winds increase the water level at eastern part of the estuary, while the water level simultaneously is lowered at the western part of the estuary. The water level response to the wind forcing is dependent on both wind speed (W_{vel}) and direction (W_{dir}).

Otherwise, the water level variation is dominated by the fresh water supply (Q_f) and the water exchange (Q_s) between the estuary and the North Sea. The water exchange passes through a gate consisting of 14 parts, and the gate can be partly open. The gate is established in order to prevent high water levels, which might otherwise be frequent during high tides in connection to more extreme meteorological forcing of the North Sea.

During periods when the gate is closed, fresh water is accumulated in the estuary causing a water level rise of $\frac{Q_f}{A}$, where A is the surface area of the estuary. During periods of a open gate the stored fresh water is emptied to the North Sea. The gate is also opened in order to allow salt North Sea water to enter the estuary, as flora and fauna need a sufficiently high salinity to maintain their diversity.

The water exchange through the gate is characterised as a salt-water flow (Q_s) driven by the difference between the water level in the open sea (h_{sea}) and the level (h) at the estuary next to the gate. The flow is restricted by the friction of the flow ($f(a)$), which is a function of the number of parts of the gate being open (a). At maximum 14 parts of the gate may be open. The water exchange changes the water level by $\frac{Q_s}{A}$.

A further description of Ringkøbing Fjord can be found at *www.xxx.xxx*.

A model for the variation of the water level

A model for the temporal variation of the water level (h) is:

$$\frac{dh}{dt} = \frac{f(a)}{A} \frac{(h_{sea} - h + h_0)^2}{h_{sea} - h + h_0} + \frac{Q_f}{A} + g(W_{Vel}, W_{Dir}) \tag{1}$$

where h_0 is an unknown constant error in the levelling of the equipment to measure the water level on each side of the gate. The function g describes the effect of the wind.

Data

The available data is

- Time series of h, h_{sea}, Q_f, a, W_{Vel} and W_{Dir}
- A table of A as a function of h

The data are found in the files: *timeser.asc* and *sur.asc*. No data are missing, and the names of the variable are found in the first lines of the files.

Problems

In the model above some of the functions are unknown, and the main purpose is to describe those functions – or to establish a better background for a parameterization of the functions.

You may solve both or either of the tasks:

- Identify the temporal variation of $f(a)$ and compare the results to the gate opening (a).
- Identify the relation between wind forcing and local water level variation.

As a first approach you may assume that the surface area is independent of water level. However, we anticipate your results to be improved if you estimate A as function of the water level in order to use the expression in the equation for the water level variation. Alternatively, you may need to identify the temporal variation of A. The latter has the benefit that you can evaluate your result against the listed values of A. Discuss the outcome of all of your different approaches.