Assignment 1, CIE4365-16 Coupled Processes
(Deadline Friday April 30, 2021)

14th April 2021

1 Matlab or Python

This course assumes you have some basic knowledge of programming in Matlab or Python. If you have no experience I encourage you to run through several tutorials on the web. With your netid you are entitled to a licensed version of Matlab on your own PC. Python is open source and freely downloadable from the internet and I suggest that you use the Anaconda distribution and in Anaconda setup a specific environment for this course.

On Brightspace you can find links to a number of relevant tutorials and websites in order to get more information under the header *Relevant Resources*

2 Examples given: Programming the Lotka-Volterra Equations

The Lotka-Volterra Equations are a well known system of equations which is also known as the predator prey model. The equations are a set of coupled differential equations given by:

$$
\begin{aligned}
\frac{dx}{dt} &= \alpha x - \beta xy \\
\frac{dy}{dt} &= -\gamma y + \delta xy
\end{aligned}
$$

where x and y are the amounts of prey (rabbits) and predator (foxes) in the system, we assume that the prey grow exponentially with a growth rate of α. This assumption means that we assume that the resources available for the prey are unlimited. The predators live of the prey and therefore prey will decrease due to predation (β). The growth rate of the predators is dependent on the amount of prey available (δ). the predators have an exponential death rate ($-\gamma$).

I have uploaded examples how I solved the Lotka Volterra model, both in Matlab and Python. I suggest you use these example codes as a starting template for all codes you need to develop in this course. The main reason for this is that we will be using a similar approach to solve all problems in this course and using previously developed code increases efficiency! Consequently you need to fully understand these implementations of the Lotka-Volterra problem.

3 Implement a conceptual model for the water balance of a landfill

Read the Water Resources Research paper by Bennetin en al. (2015). The aim is that you implement the model described in paragraph 4 and summarized in figures 4 and 5. Data files containing the measured data relevant for the Wieringermeer landfill near Medemblik in the Netherlands can be found on Brightspace. The model is driven by the rainfall, temperature and evapotranspiration data for which we have a data series from the automatic KNMI weather station in Medemblik, 10 km from the landfill. The landfill produces leachate, and the measured amounts of leachate pumped from landfill 6 are also available. The units for the meteorological data are m/day for rain fall and evapotranspiration and ^oC for temperature. The unit for leachate discharge is m^3/day.

The model requires a number of parameters for which you need to estimate values, other information on the waste body of Cell VP-06 of the Wieringermeer landfill is given in the following table:

Table 1: Some characteristics of Cell VP-06 of the Wieringermeer landfill

	Cell VP-06
base area [m^2]	28355
top area [m^2]	9100
slope width [m]	38
waste body height [m]	12
cover layer height [m]	1.5
waste (wet weight [kg])	281083000
in operation	1992-1998

Please note that you in order to have physical consistency you need to adapt some of the equations from the paper. You should realize that the total storage in a layer can never exceed the volume of the pore space. Water can only flow when the amount of water present in the system is above a minimum amount. The evaporation model in the paper is rather simple. The Wieringermeer landfill is covered with plants which evaporate water. Therefore I suggest you use the following evaporation model:

$$E(t) = pEv(t) * f_{crop} * f_{S_{CL}}$$

with

$$f_{S_{CL}} = \begin{cases} 0 & S_{CL} < S_{Ev_{min}} \\ \frac{S_{CL} - S_{Ev_{min}}}{S_{Ev_{max}} - S_{Ev_{min}}} & S_{Ev_{min}} \leq S_{CL} \leq S_{Ev_{max}} \\ 1 & S_{CL} > S_{Ev_{max}} \end{cases}$$

Please think carefully about the parameter you use. Try to find parameters which are as plausible as possible. You can try to fit parameters to the measured cumulative leachate production from the data available on Brightspace.

4 Submission

You need to write a report describing your results. You report should give a clear description of the model, the equations you used and the values you used for the parameters in the model. Your report has the default layout: Abstract, Introduction, Methods, Results & Discussion, and Conclusions. Please use graphs to show your results.

You need to submit your report as a pdf document to Brightspace as a group. In addition please upload your source codes as well packed in to a single zip file.

5 References

Benettin, P., J. W. Kirchner, A. Rinaldo, and G. Botter (2015), Modeling chloride transport using travel time distributions at Plynlimon, Wales, Water Resour. Res., 51, 3259–3276, doi:10.1002/2014WR016600.