Laboratoire Eau, Environnement et Systèmes Urbains

TRAINING REPORT

Modelling of Cyanobacteria Dynamics for YuQiao Reservoir in Tianjin, China

1st May 2016

Hong XU[1]

Supervisor:

Brigitte Vinçon-Leite[2], **Yang Luo**[3], **Gui-Feng Tao**[4]

[1]Ludwig-Maximilians-Universität München, Munich, Germany
[2]École des Ponts ParisTech, Marne-la-Vallée, France
[3]Haihe River Water Conservancy Commission, Tianjin, China
[4]Beijing ShengHaiTong Sci. & Tech. Co., Ltd, Beijing, China

Laboratoire Eau, Environnement et Systèmes Urbains (LEESU)

ÉCOLE DES PONTS PARISTECH

École Nationale des Ponts et Chaussées

6 et 8 avenue Blaise-Pascal

F-77455, Marne-la-Vallée

France

Contents

1 Introduction

This chapter is the general introductions to the École des Ponts ParisTech (ENPC), the Haihe River Water Conservancy Commission (HWCC), and also the Yuqiao Reservoir in Tianjin, China.

1.1 École des Ponts ParisTech

École des Ponts ParisTech (ENPC) is the oldest civil engineering institute in the world that trains engineers to a high level of scientific, technical and general competency[1]. Founded in 1747 by Daniel-Charles Trudaine under the name École Royale des Ponts et Chaussées, and it has a rich tradition and is one of the most prestigious and selective French Grandes Écoles.[2]. It is headquartered in Marne-la-Vallée (suburb of Paris), France, and is a founding member of ParisTech (Paris Institute of Technology) and of the Paris School of Economics. Now there are more than 100 researchers and professors worked in 11 research labs and more than 1000 students studied at here.

The school consists of six departments: Civil engineering and construction; Urban planning, environment and transport; Mechanical engineering and materials science; Industrial engineering; Economics, management, finance and Applied mathematics and computer science. My training was taken in the laboratory of Water, Environment and Urban Systems (LEESU), which is a joint laboratory of the École des Ponts ParisTech, the Université Paris-Est Creteil and AgroParisTech (UMR MA 102)[3].

The researches at LEESU are basically focused on the below three points: physical and hydrological cycle of water during thunderstorm: precipitation, runoff and flows; biogeochemical study of the sources and fate of chemical and microbiological contaminants in urban watersheds and their impact on the receiving environment; socio-technical study on the policies, water usage and their evolution in urban environments[3].

1.2 Haihe River Water Conservancy Commission

The Haihe River Water Conservancy Commission of Ministry of Water Resources of P. R. China, which is in charge of the administration affairs in the basin of Haihe River, Luanhe River and etc, is located in 15th Longtan Rd., Hedong Dist., Tianjin City, P. R. China.

The commission is mainly responsible for the following three aspects. The first is the administration and protection of water sources for living, manufacturing and ecological usage. The prevention and control of the drought and floods within the Haihe and Luanhe river basin comes the second. The last one is the development, construction and management of water projects for rivers, lakes, estuaries, coasts and mudflats.[4]

1.3 Yuqiao Reservoir in Tianjin, China

As it is the only reservoir in Tianjin, the third biggest city in China, Yuqiao reservoir (Fig.1-1) served as the main drinking water source for more than four million Tianjin residents (Liu et al., 2008). It was built in 1959 and located 35 m above the sea level in the northeast of Tianjin city (117°32'E, 40°02'N). The storage capacity of Yuqiao reservoir is 1.56×10^9 m^3 with a surface area of 227 km^2 and the maximum depths of 4.6 and 17 m[5].

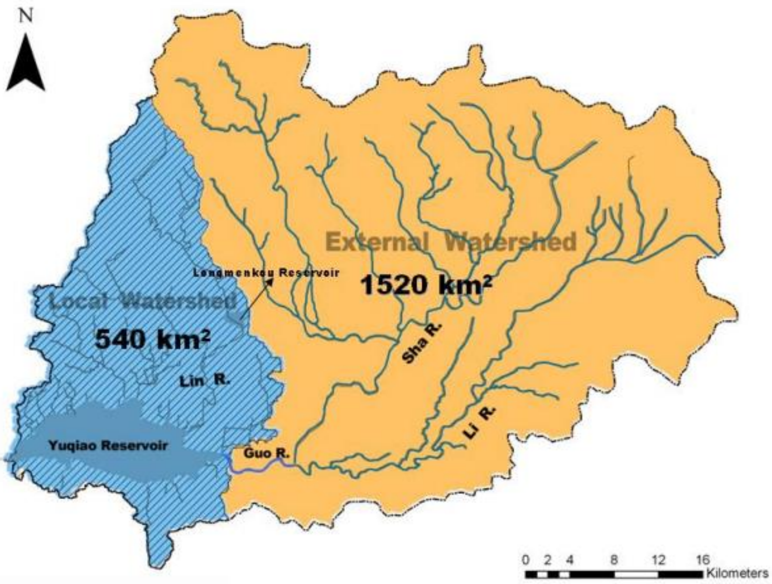

Figure 1-1: The main rivers and watershed of Yuqiao reservoir.
Provided in the Master Thesis of Bishnu Prasad Joshi, University of Oslo, Jan 2014

The area of its total watershed is 2, 080 km^2 of which 540 km^2 lies in local watershed and rest 1520 km^2 constitute external watershed. The external watershed of the reservoir was included as a water source by the construction of a channel diverting 9 water from the Daheiting reservoir and Panjiakou Reservoir (i.e. Luanhe-Tianjin Water Diversion Project[6]).

The historical performed physical-chemical measurements of Chlorophyll-a, temperature, transparency, nitrogen, phosphorous and ratio between total Nitrogen and total phosphorus in the period of 2008 to 2012 are presented in Figure 1-2.

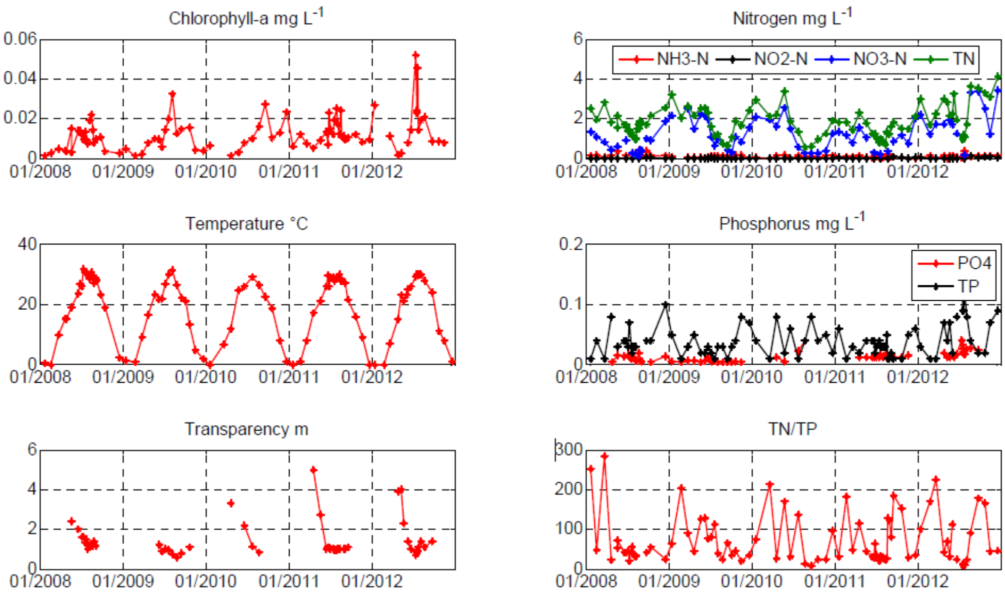

Figure 1-2: Historical physical-chemical data taken at the middle of Yuqiao reservoir between 2008 and 2012.

Provided by Haihe River Water Environmental Monitoring Center (HWEMC)

Anthropic activities attributed mainly industrial wastes and the development of farmland fertilization and fishery increased nutrient concentration in the reservoir. Such eutrophication resulted in massive reproduction of undesirable fungi, waterweeds and cyanobacterial blooms. To avoid health problems due to the increase of toxic cyanobacterial concentration in the Yuqiao reservoir's water, it is necessary to have an early warning system. Predictive ecological models can forecast cyanobacterial blooms and alert reservoir managers. In this report, the performance of a hydrodynamic ecological model was tested to forecast the evolution of cyanobacteria biomass in Yuqiao reservoir.

2 The GLM-FABM-AED Model

The General Lake Model is a one dimensional water balance and vertical stratification model, which is suited to the environmental modelling studies where simulation of lakes or reservoirs is required. It computes vertical profiles of temperature, salinity and density by accounting for the effect of inflows/outflows, mixing and surface heating and cooling, including the effect of ice cover on heating and mixing of the lake.

GLM incorporates a flexible moving layer structure. It allows for layers to change thickness by contracting and expanding in response to inflows, outflows, mixing and surface mass fluxes. When sufficient energy becomes available to overcome density gradients, two layers will merge thus accounting for the process of mixing. Unlike the fixed grid design where mixing algorithms are typically based on vertical velocities, numerical diffusion is limited, making the GLM approach also suited to long-term investigations.

The model has been developed as an initiative of the Global Lake Ecological Observatory Network (GLEON) and in collaboration with the Aquatic Ecosystem Modelling Network (AEMON) that started in 2010[7]. GLM can be coupled with biogeochemical models through a specific interface (Framework for Aquatic Biogeochemical Models, FABM). FABM supports coupling of a diverse array of water quality and ecological models to various physical driver models, ranging from a zero dimensional box model to a suite of 1, 2 or 3-dimensional hydrodynamic models. FABM includes various ecological models, including numerous Aquatic Ecodynamics (AED) component modules suited to lake ecological modelling. Currently these include modules for simulating the dynamics of oxygen, carbon, nutrients, organic matter, phytoplankton, zooplankton and sediment.

2.1 General Lake Mode (GLM)

2.1.1 Energy Budget

In the General Lake Mode, surface exchanges of shortwave radiation flux, net long wave radiation flux, sensible heat and latent heat of evaporative heat fluxes determine the net rate of cooling and heating.

1) Sensible Heat Calculation

The sensible heat loss from the surface of the lake for a time-step Δt is:

$$\Phi_H = -\rho_a c_p C_H U_x (T_a - T_s) \tag{1}$$

Where:

C_H is the sensible heat transfer coefficient (= 1.3×10^{-3});

ρ_a the density of air in $kg{\cdot}m^{-3}$;

C_P the specific heat of air at constant pressure (= 1003 $J{\cdot}kg^{-1}{\cdot}K^{-1}$);

U_x is the wind speed in $m{\cdot}s^{-1}$;

T_a and T_s are air and surface layer temperatures in Celsius.

2) Latent Heat Calculation

For Latent heat calculation:

$$\Phi_E = -\rho_a C_E U_x (e_a[T_a] - e_s[T_s]) \tag{2}$$

Where:

C_E is the bulk aerodynamic coefficient for latent heat transfer;

e_a is the air vapour pressure, which is calculated by this way:

$$e_a[T_a] = \frac{RH}{100} e_s[T_a] \tag{3}$$

e_s is the saturation vapour pressure at the surface layer temperature (hPa).

$$e_s[T_s] = \exp\left[2.303\left(7.5 * \frac{T_s}{T_s+273.15}\right) + 0.7858\right] \tag{4}$$

Or

$$e_s[T_s] = 10^{\left(9.28603523 * \frac{2322.37885 * T_S}{T_S + 273.15}\right)} \tag{5}$$

3) Shortwave Radiation Calculation

Shortwave radiation is able to penetrate according to the Beer-Lambert Law. It is calculated as:

$$\Phi_{SW}(z) = (1 - \alpha_{SW})\widehat{\Phi}_{SW}\exp[-K_W z] \tag{6}$$

$$\alpha_{SW} = \begin{cases} 0.08 + 0.02 sin\left[\frac{2\pi}{365}d - \frac{\pi}{2}\right] & Northern\ hemisphere \\ 0.08 & Equator \\ 0.08 - 0.02 sin\left[\frac{2\pi}{365}d - \frac{\pi}{2}\right] & Southern\ hemisphere \end{cases} \tag{7}$$

Where:

$\Phi_{SW}(z)$ is the shortwave radiation at depth z(m);

α_{SW} is used to account for the effect of albedo on the penetration of Φ_{SW};

d is the day of the year;

K_W is the light extinction coefficient, either set as constant or obtained from a coupled water quality model.

4) Longwave Radiation Calculation

Longwave radiation can either be specified as net flux or incoming flux. The incoming flux may be specified directly or calculated by the model based on the cloud cover fraction and air temperature.

Longwave radiation is calculated as:

$$\Phi_{LW_{in}} = \sigma[T_a + 273.15]^4 \times (1 + c_1 C) \times (1 - c_2 \exp[-c_3 {T_a}^2]) \tag{8}$$

$$\Phi_{LW_{out}} = \varepsilon_W \sigma[T_s + 273.15]^4 \tag{9}$$

$$\Phi_{LW_{net}} = \Phi_{LW_{in}} - \Phi_{LW_{out}} \tag{10}$$

Where:

σ is the Stefan-Boltzman constant;

C is the cloud cover fraction (range from 0 to 1);

Ew is the emissivity of the water surface and constants;

c_1=0.275; c_2=0.261; c_3=0.000777×10^{-4}.

2.1.2 Vertical Mixing

The vertical mixing in General Lake Mode is a simple energy budget approach based on the amount of kinetic energy (E_{TKE}) and potential energy (E_{PE}) available[8].

Kinetic Energy Calculation:

The kinetic energy is consisted of three parts and the formula is shown as below:

1) Convective overturn represents the energy released from the decrease in potential energy resulting from dense water falling to a lover level;
2) Wind Stirring represents the energy from the wind stress applied to the surface layer;
3) Shear production represents the kinetic energy transferred from upper to the lower layers in the water column.

$$E_{TKE} = \underbrace{0.5C_K(w_*^2)\Delta t}_{convective\ overtun} + \underbrace{0.5C_w(\psi^3 u_*^3)\Delta t}_{wind\ stirring} + \underbrace{0.5C_s\left[u_b^2 + \frac{u_b^2}{6}\frac{d\xi}{dh}\right]h_{s-1}}_{\substack{shear\ production \\ K-H\ production}} \tag{11}$$

Where:

C_k is mixing efficiency coefficient in convective overturn;

C_w is mixing efficiency coefficient in wind stirring;

C_s is mixing efficiency coefficient in shear production.

Potential Energy Calculation:

The potential energy is calculated by this way:

$$E_{PE} = \left[\underbrace{0.5C_T(w_*^3 + \psi^3 u_*^3)^{\frac{2}{3}}}_{acceleration} + \underbrace{\frac{\Delta\rho g h_{mix}}{\rho_0}}_{lifting} + \frac{g\xi^2}{24\rho_0}\frac{d(\Delta\rho)}{dh} + \frac{g\xi\Delta\rho}{12\rho_0}\frac{d\xi}{dh}\right]h_{s-1} \tag{12}$$

Where:

u_* and w_* refer to the velocity scales in the horizontal and vertical direction respectively;

The energy required to lift up water at the bottom of the mixed layer, denoted here as layer i-1, with thickness h_{i-1}, and accelerate it to the SML velocity is required for mixing to occur.

This also accounts for energy consumption associated with K-H production and expressed as, E_{PE}.

For the calculation of above mentioned kinetic and potential energy, we need the length scale of the K-H billows, which is summarized as:

$$\xi = KH\frac{\rho_0 u_b^2}{g\Delta\rho} \tag{13}$$

The velocity of the lower layer is approximated from:

$$u_b = \frac{u_*^2 t}{h_{mix}} + u_0 \tag{14}$$

The model first calculates theses energy quantities and then loops through layers from the top to the bottom until there is insufficient energy available to left up the next i th layer. Mixing below the surface mixed layer (SML) is modelled using a characteristic diffusivity, $K=K_\varepsilon+K_m$, based on the formula:

$$K_\varepsilon = \frac{\alpha_{TKE}\varepsilon_{TKE}}{N^2+0.6k_{TKE}^2u_*^2} \tag{15}$$

Where K_m is the fixed molecular diffusivity of scalars. α_{TKE}=0.5 and k_{TKE} is defined as the wavenumber.

For ε_{TKE} :

$$\varepsilon_{TKE}\begin{cases}\varepsilon & z_i > (H_t - h_{mix}) \\ \varepsilon\ exp\left[-\frac{H-h_{mix}-z}{h_{sig}}\right] & z_i < (H_t - h_{mix})\end{cases} \tag{16}$$

Where h_{sig} is the first moment distance of the N^2 distribution below h_{s-1} where N^2 is the buoyancy frequency:

$$N^2 = \frac{g\Delta\rho}{\rho\Delta z} \tag{17}$$

2.2 Framework for Aquatic Biogeochemical Models (FABM)

Framework for Aquatic Biogeochemical Models (FABM) is a joint framework for transferring the calculated data in GLM model to AED model, while further simulation will be done in the AED model. The function of FABM is like a gear between GLM and AED model as showing in the following figure 2-1:

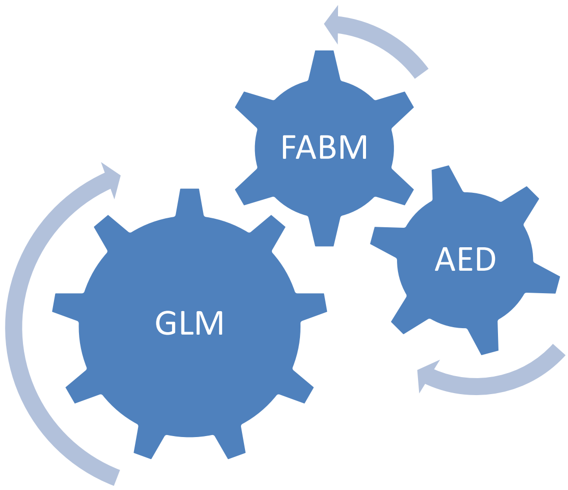

Figure 2-1: Function of FABM model between GLM and AED model.

2.3 Aquatic Eco Dynamics (AED)

The algal biomass of each phytoplankton group (PHY) is simulated in the units of carbon (mmol C/m^3), and the group can be configured to have a constant C:N:P:Si ratio, or has dynamic uptake of N and P sources in response to changing water column condition and cellular physiology. For each phytoplankton group there is a maximum potential growth rate at 20 degree Celsius, while it is multiplied by the minimum value of expressions for limitation of light, phosphorus, nitrogen and silica. Thus, photosynthesis is parameterized as the uptake of carbon, which depends on the temperature, light and nutrient dimensionless functions.

$$f_{uptake}^{PHYC_a} = \underbrace{R_{growth}^{PHYa}}_{\max growth\ rate\ at\ 20\ C} \underbrace{\left(1 - k_{pr}^{PHYa}\right)}_{photorespiratory\ loss} \underbrace{\Phi_{tem}^{PHYa}(T)}_{temperature\ scaling} \underbrace{\Phi_{str}^{PHYa}(T)}_{metabolic\ stress} \ldots$$

$$\ldots min \left\{ \underbrace{\Phi_{light}^{PHYa}(I)}_{light\ limitation}, \underbrace{\Phi_{N}^{PHYa}(NO_3, NH_4, PHY_{Na})}_{N\ limitation}, \underbrace{\Phi_{P}^{PHYa}(PO_4, PHY_{Pa})}_{P\ limitation}, \underbrace{\Phi_{Si}^{PHYa}(RSi)}_{Si\ limitation} \right\} [PHY_{C_a}]$$

3 Model Running Procedure

3.1 Input files Preparation

The GLM-FABM-AED model consists of several “namelist” (nml) text file which decribes the model as outlined in the below figure. All the procedures and namelists are integrated in one software program called “PontYuqiao.exe” in the directory. To run the GLM-FABM-AED model, also the “.csv” files format for boundary conditions of meteorology and inflow/outflows of lakes or rivers. The general flow chart is as follows:

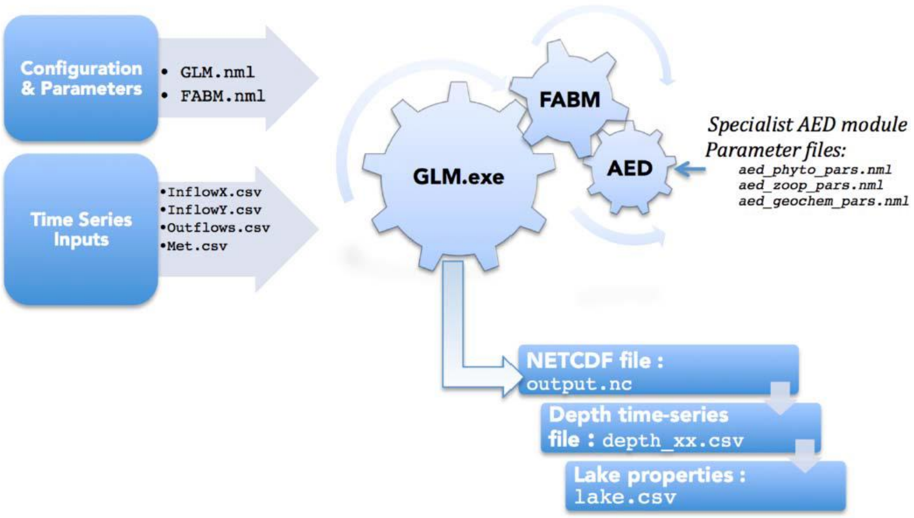

Figure 3-1: Flow chart of the processing of GLM-FABM-AED model.

The results are plotted automatically in the integrated Matlab program with certain format. The details are presented in the following parts.

3.1.1 General Configuration

The main configuration file is the “glm.nml” for the GLM physical model and some descriptions for the FABM coupling. The general simulation information, time control, lake morphometric information, output file details, initial temperature and salinity profiles, information about surface forcing and meteorology data, inflows and outflows are included also.

3.1.2 Meteorological Data

It is presented in the table 3-1 that the meteorological data needed as daily or sub-daily time series. The meteorological file should contain seven compulsory columns and an optional column. The order of variables in these columns should be respected. In the “glm.nml” file, we need to precisely use the name of the “met.csv”.

Met.csv	***Data***	***Unit***	***Descriptions***
Column 1	Time	-	Format YYYY−MM−DD HH:MM:SS
Column 2	Shortwave radiation	W/m^2	Daily average shortwave radiation. Note that the daily value is internally distributed to a sub−daily time step by assuming and idealized diurnal cycle
Column 3	Longwave radiation	W/m^2 if lw_type=LM_IN or LW_NET or 0-1 of lw_type=LW_CC	Longwave radiation input is either direct incident intensity, net longwave flux, or estimated from cloud cover fraction.
Column 4	Air temperature	°C	Daily average air temperature 10m above the water surface
Column 5	Relative humidity	%	Daily average relative humidity (0−100%) 10m above the water surface
Column 6	Wind speed	m/s	Daily average wind speed 10m above the water surface
Column 7	Rainfall	m/day	Daily rainfall depth
Column 8	Snowfall	m/day	Daily snowfall depth (optional)

Table 3-1: Details about meteorological file needed to run GLM

3.1.3 Inflow and Outflow Data

The simulation of inflow is in the GLM model after the configuration of glm.nml, which needs to precise the information of number of river inflows, names of rivers, half angle, streamed slope and streambed drag coefficient, the name of data file of the inflowing streams, the number of columns (excluding data) to be read in the data file and variable names of inflow file columns. Regarding the outflow, similarly we need to precise the number of outflows, their elevation, basin length and width and the name of the outflow data file. The inflow and outflow data are inputted in the file named “inflow.csv” and “outflow_Yuqiao_daily.csv” respectively.

3.2 Forecast Mode Running

To start the program, we need to click the “PontYuqiao.exe” file and it appears the following interface:

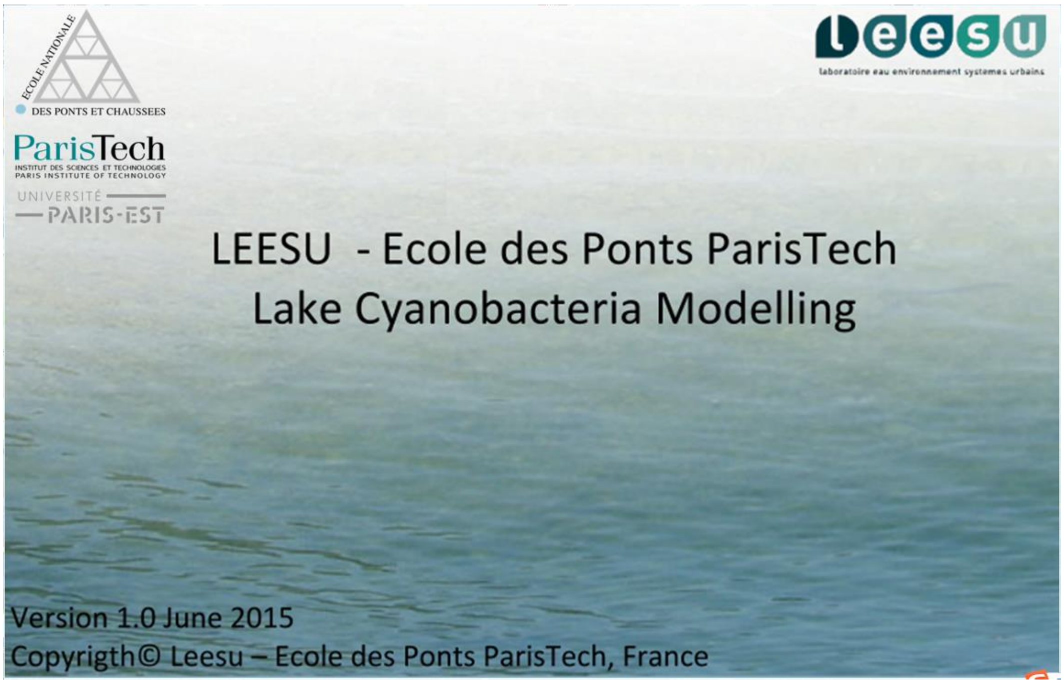

Figure 3-2: Starting Interface of the “PontYuqiao” GLM-FABM-AED model program.
Version 1.0, Copyright © LEESU – École des Ponts ParisTech

Then it will ask “Which mode do you want?”.

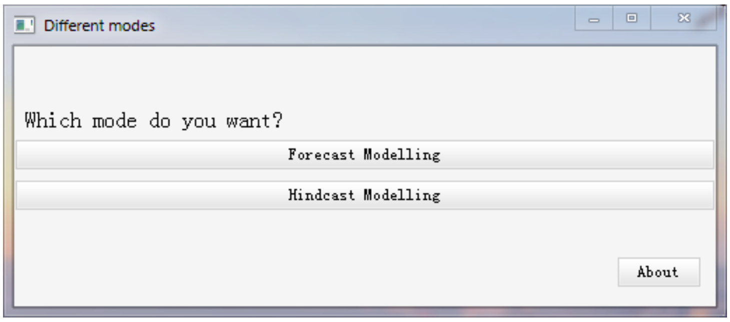

Figure 3-3: Different modes of the “PontYuqiao” GLM-FABM-AED model program.

Here we firstly do the forecast modelling. By clicking the “Forecast Modelling” button, it enters in the forecast modeling setting interface.

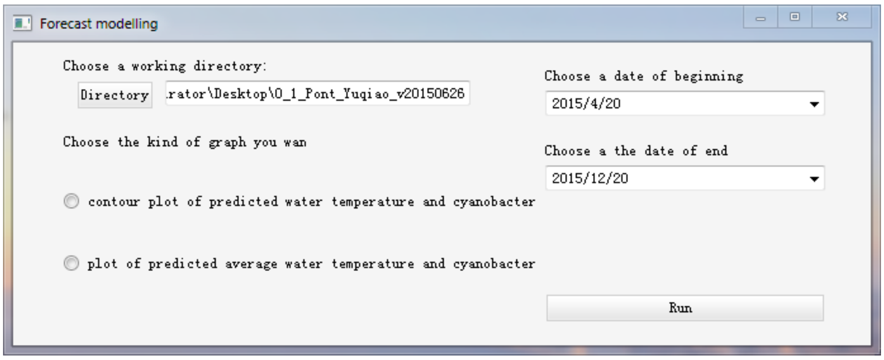

Figure 3-4: Forecast Modelling of the “PontYuqiao” GLM-FABM-AED model program.

Here we need to choose a working directory firstly. Normally the path of the working directory is where you have the PontYuqiao.exe file. The needed inflow, outflow and meteorology data should be already prepared in the right format before running this forecast modelling. And if all the needed files are put in the selected directory, it gives the notice: “All the input files were found”. Then we need to choose the date of beginning and end of the forecast, which is normally efficient for the duration of one or two weeks.

For the plotting of the graph, we have two options: contour plot of predicted water temperature and cyanobacteria and plot of predicted average water temperature and cyanobacteria. The first plot gives the distribution of water temperature and concentration of cyanobacteria in the water body while the second plot gives the average water temperature and cyanobacteria of each layer in the depth of the water body.

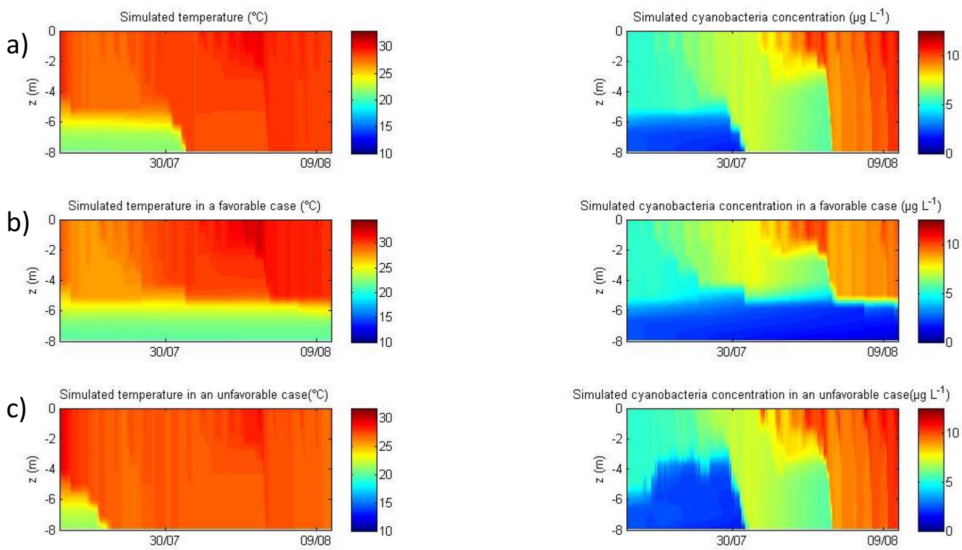

Figure 3-5: Example of contour plot in forecast modelling with a) predicted weather, b) unfavourable and c) favourable conditions.

To plot the average of water temperature and cyanobacteria of each layer, we need to select the needed layer as shown in figure 3-6 in the model. The examples are shown in figure 3-7.

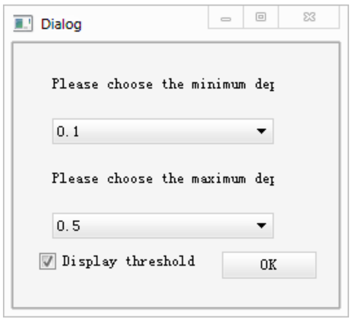

Figure 3-6: Selection interface of minimum and maximum depth in the average plot of forecast modelling.

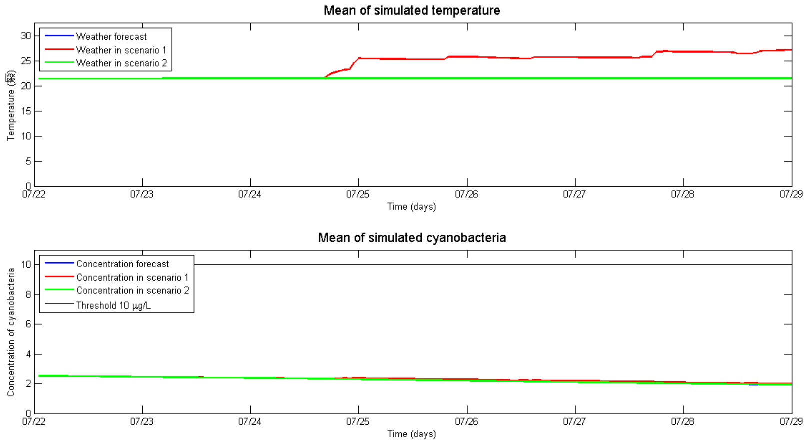

Figure 3-7: Average plot of temperature and cyanobacteria in the depth range of 0.1-0.5 m in the forecast modelling.

3.3 Hindcast Mode Running

For hindcast modelling, the formal preparation and beginning of software is the same as forecast modelling in chapter 3.2. This is mainly used for the checking the difference between forecast results and real collected results.

In figure 3-3, we can choose the hindcast interface for hindcast modelling, which is similar to forecast interface while there the plot choices are different. After choosing of a working directory and the date of begin and end, the first plot is contour plot of water temperature and cyanobacteria biomass with left of measured data and right of simulated data in figure 3-8.

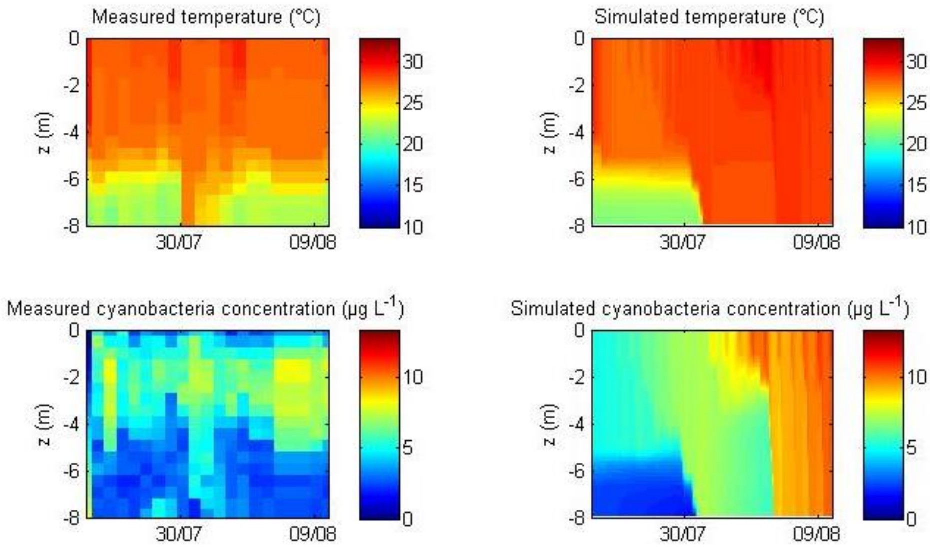

Figure 3-8: Example of contour plot in hindcast modelling biomass with left of measured data and right of simulated data.

It also has the average temperature and biomass in different depth layer, which is shown in figure 3-9.

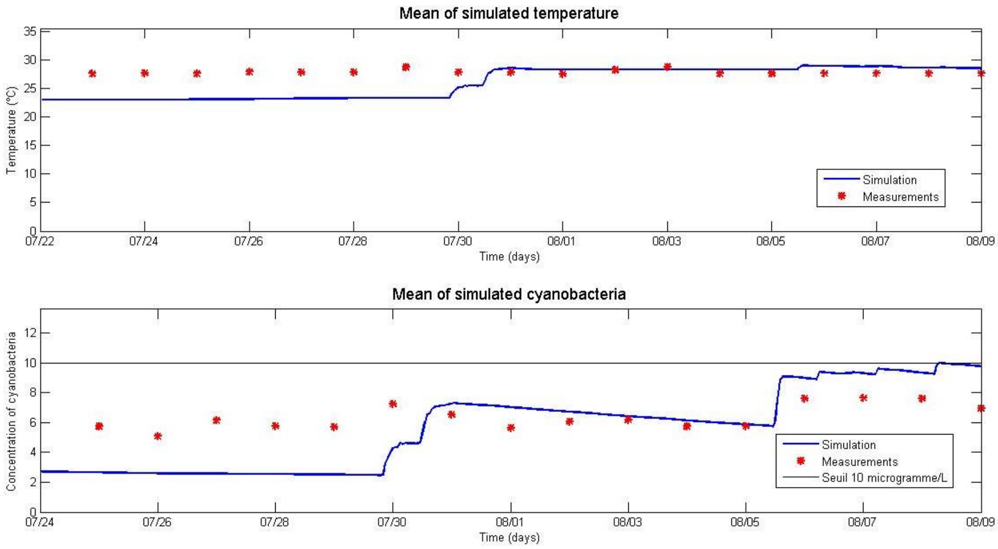

Figure 3-9: Average plot of temperature and cyanobacteria in the depth range of 1-2 m in the hindcast modelling.

The different plot in hindcast modelling is the profile plot of water temperature and cyanobacteria biomass. It can select the specific date (limitation of 6 days) and plot the profile plot for temperature and cyanobacteria biomass.

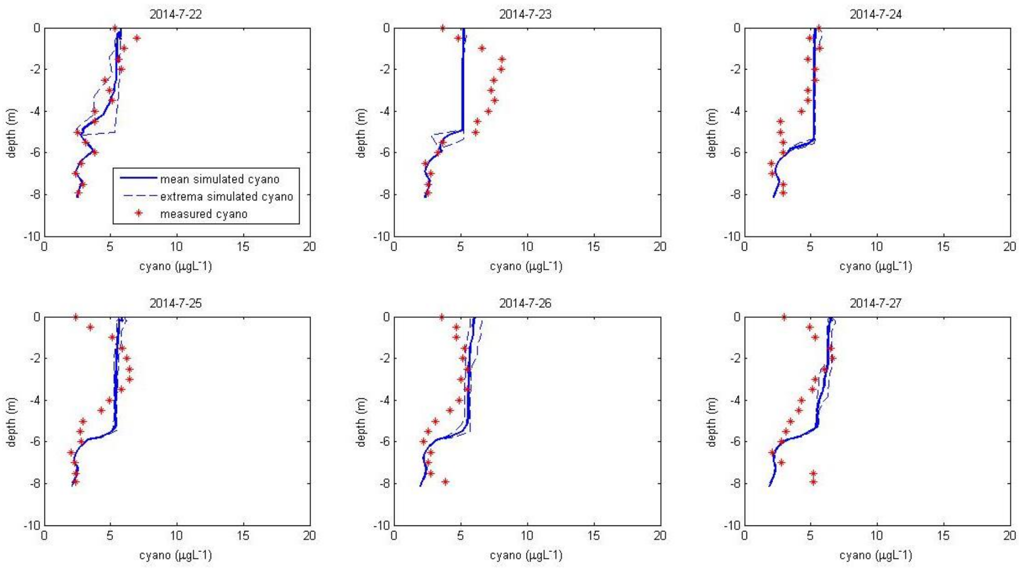

Figure 3-10: Profile plot of cyanobacteria in the depth range of 0-8 m in the hindcast modelling.

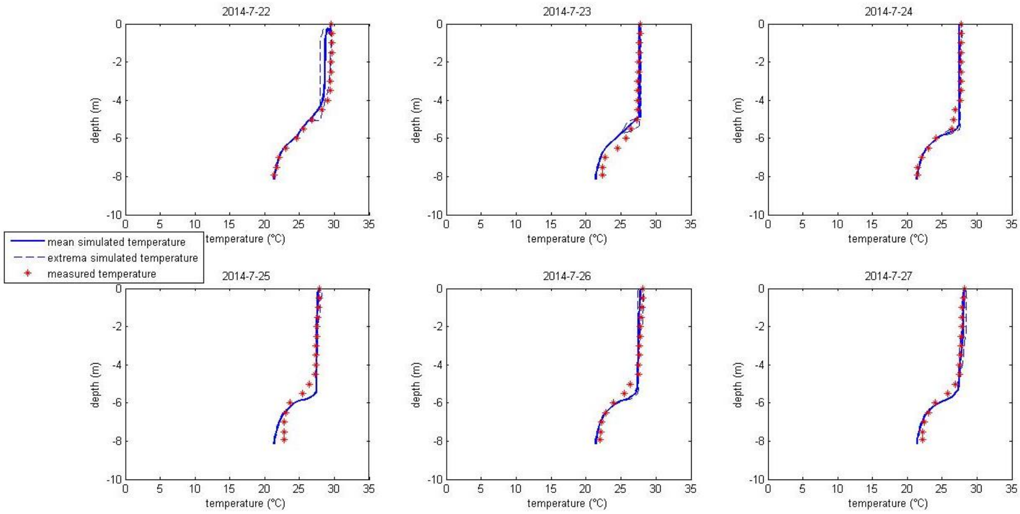

Figure 3-11: Profile plot of temperature in the depth range of 0-8 m in the hindcast modelling.

Through these plots we can compare the simulated and measured results and calibrate our model for more precise modelling in the real case for different lakes.

4 Application in Yuqiao Reservoir

The application of the modelling system has been done for two times in 2014 and 2015 in the summer time when it was the bloom of cyanobacteria. In this report we formatted the provided meteorological and biomass data from HWCC and run them in our model for the period of summer in 2015. The newest results are presented here and analyzed with comparison.

The original meteorological data are collected from Dr. Jun Zhang with cloud cover from Baodi station, while temperature, humidity and wind speed from Jixian station, and solar radiation from Xiqing station. Compared to the data from 2014 in the last report, where the data was collected from Beijing station, the validation this time is more successful but still for better prediction and alarm, more precise meteorological data from Yuqiao station should be collected.

4.1 Simulation in Forecast Mode

4.1.1 Contour Plot of Predicted Water Temperature and Cyanobacteria Biomass

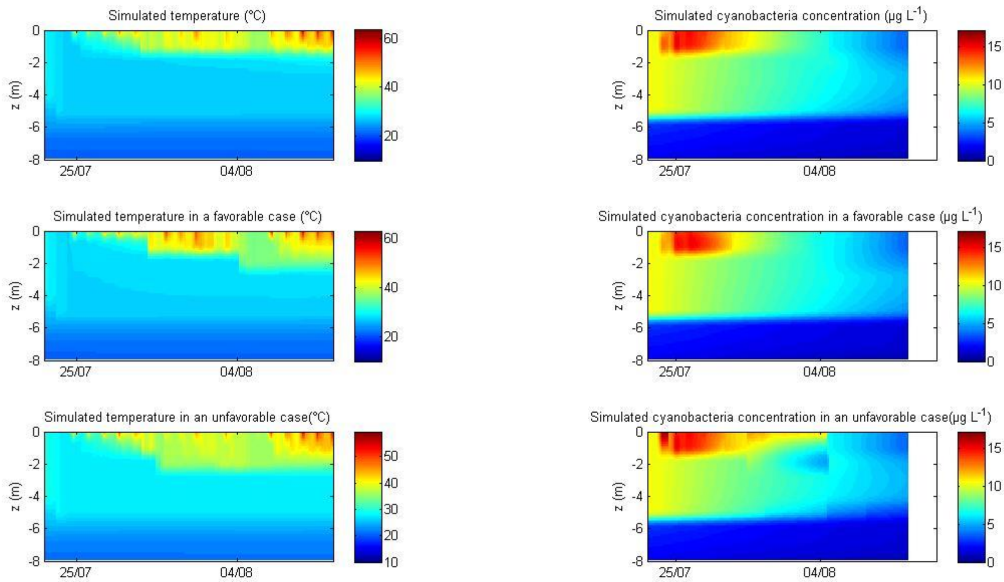

Figure 4-1: Contour plot of predicted water temperature and cyanobacteria biomass with favorable and unfavorable case.

This contour plot gives the estimated water temperature and cyanobacteria biomass with favorable and unfavorable case according to the weather forecast data. This forecast mode is only reliable in a short prediction period, normally within one week. After one week the temperature goes to very high which is not reliable anymore.

4.1.2 Profile Plot of Predicted Water Temperature and Cyanobacteria Biomass on Surface Layer (depth: 0.1-1m)

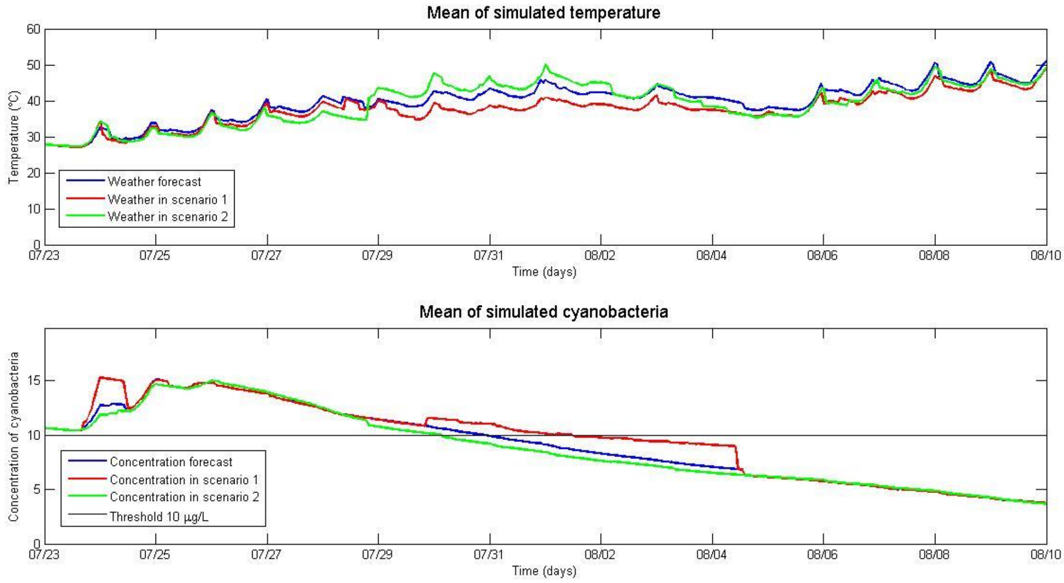

Figure 4-2: Profile plot of predicted water temperature and cyanobacteria biomass on surface layer (depth: 0.1-1m) with favorable and unfavorable case.

This forecast mode is only reliable in a short prediction period, normally within one week. After one week we can see the shifting of the data in simulated temperature to more than 40 degrees, which is not reliable anymore.

4.2 Validation in Hindcast Mode

4.2.1 Contour Plot of Measured and Simulated Water Temperature and Cyanobacteria Biomass

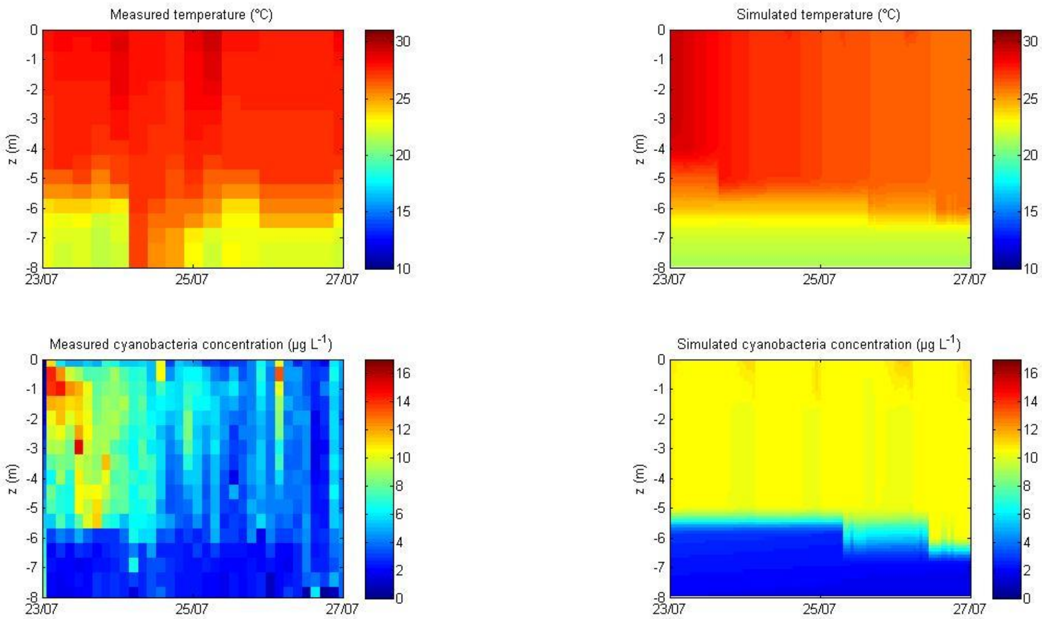

Figure 4-3: Contour plot of measured and simulated water temperature and cyanobacteria biomass from 22.07.2015 to 28.07.2015.

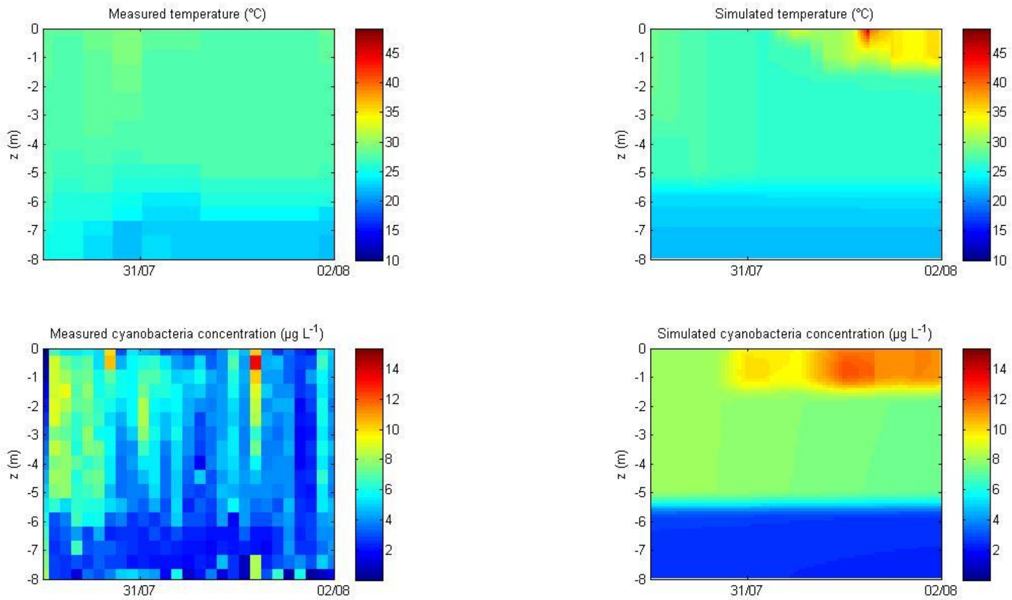

Figure 4-4: Contour plot of measured and simulated water temperature and cyanobacteria biomass from 29.07.2015 to 02.08.2015.

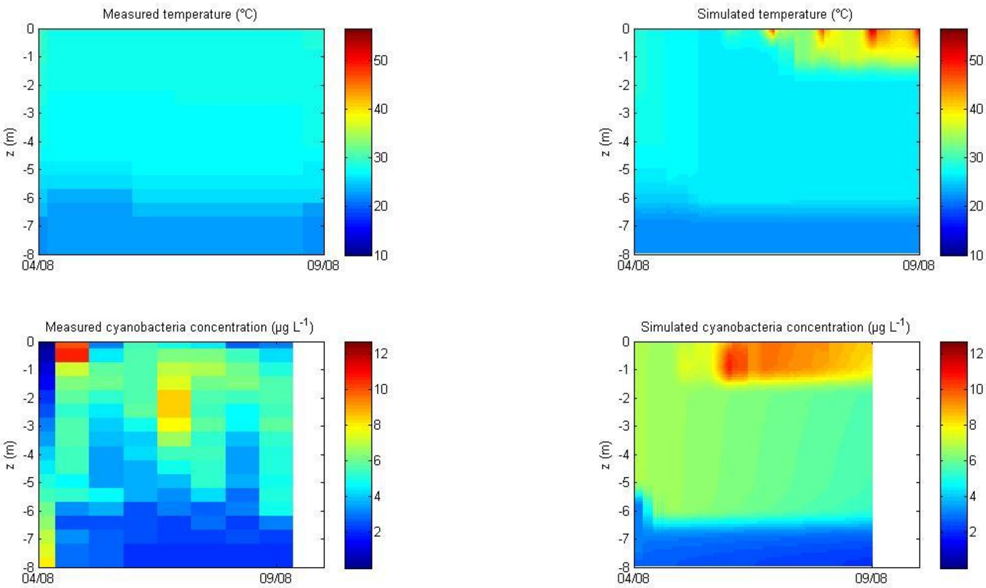

Figure 4-5: Contour plot of measured and simulated water temperature and cyanobacteria biomass from 04.08.2015 to 09.08.2015.

The simulated temperature is mainly depended on the solar radiation data. While out original solar radiation data is lack of unit, thus we compared with the data from 2014 and then divided by 10. The corrected data gives the prediction of reasonable temperature.

4.2.2 Profile Plot of Measured and Simulated Water Temperature

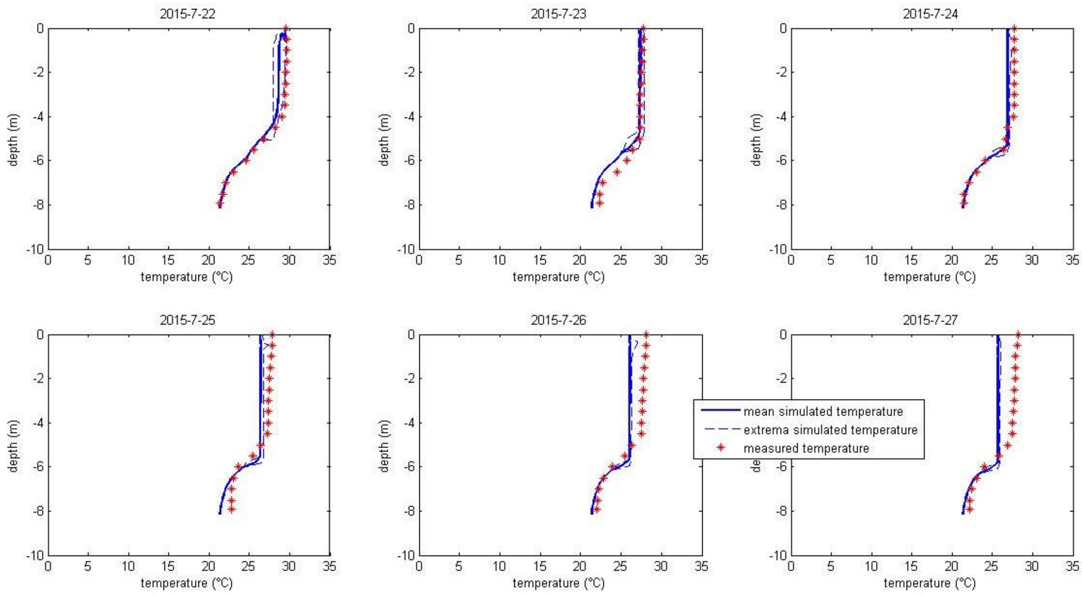

Figure 4-6: Profile plot of measured and simulated water temperature biomass with favorable and unfavorable case from 22.07.2015 to 27.07.2015.

The simulation during this period is quite reasonable and the water temperature column is well profiled.

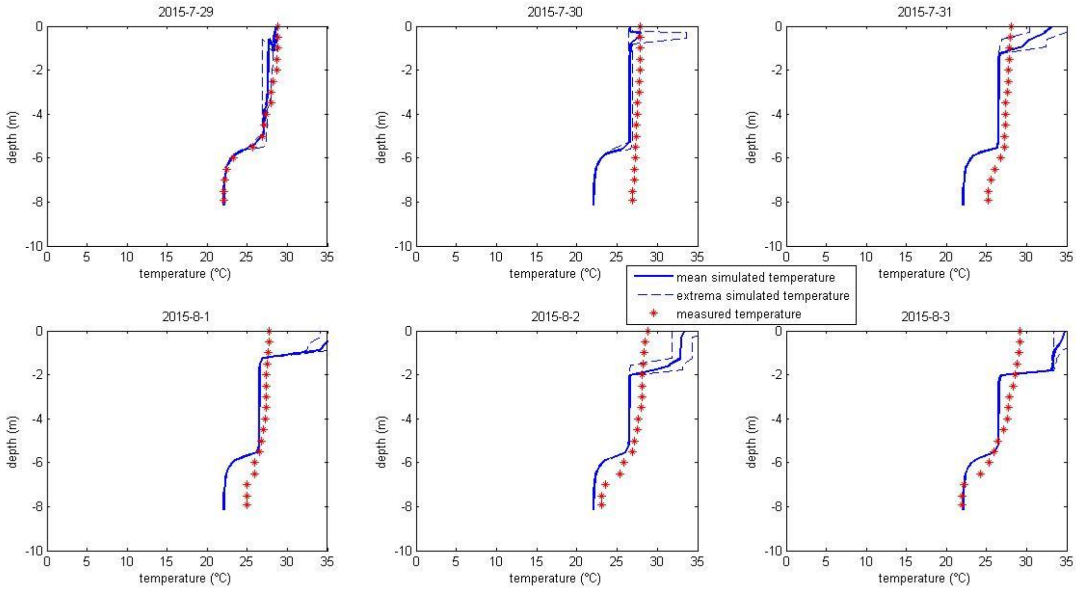

Figure 4-7: Profile plot of measured and simulated water temperature biomass with favorable and unfavorable case from 29.07.2015 to 03.08.2015.

We can clearly see that from the original water temperature column data there was a de-mixing happened on 30th July 2015, which is not explained yet. The reason can be the measurement error, non-natural de-mixing or income flow from another river. Thus the simulation results afterwards are not reliable, but still we can see nearly simulated results one or two days after de-mixing happened.

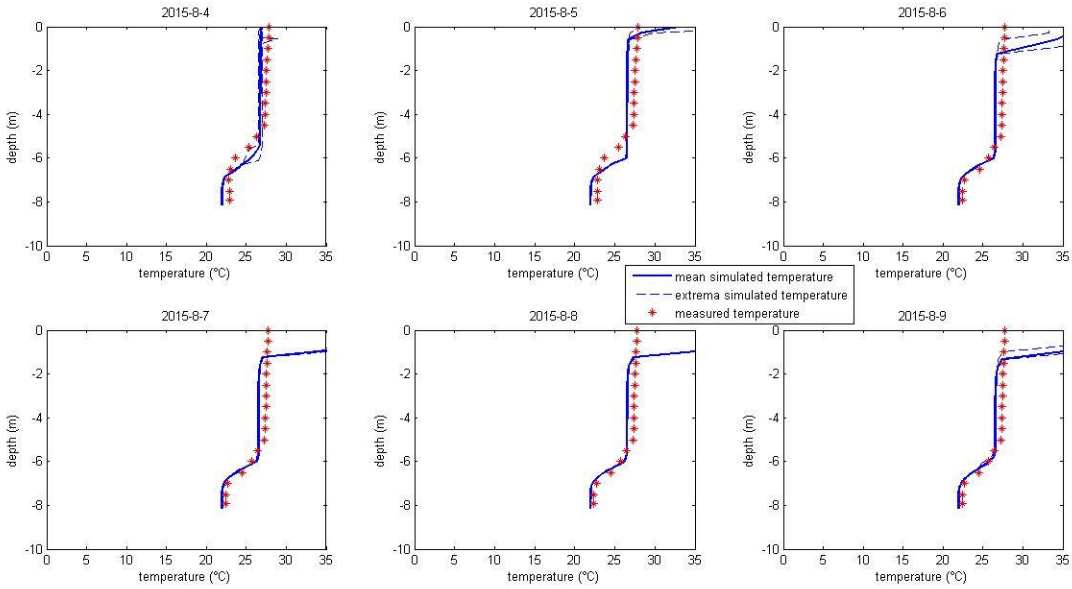

Figure 4-8: Profile plot of measured and simulated water temperature biomass with favorable and unfavorable case from 04.08.2015 to 09.08.2015.

From figure 4-8 we can conclude that in the normal case the simulation for water temperature is quite reliable within one week.

4.2.3 Profile Plot of Measured and Simulated Cyano Biomass

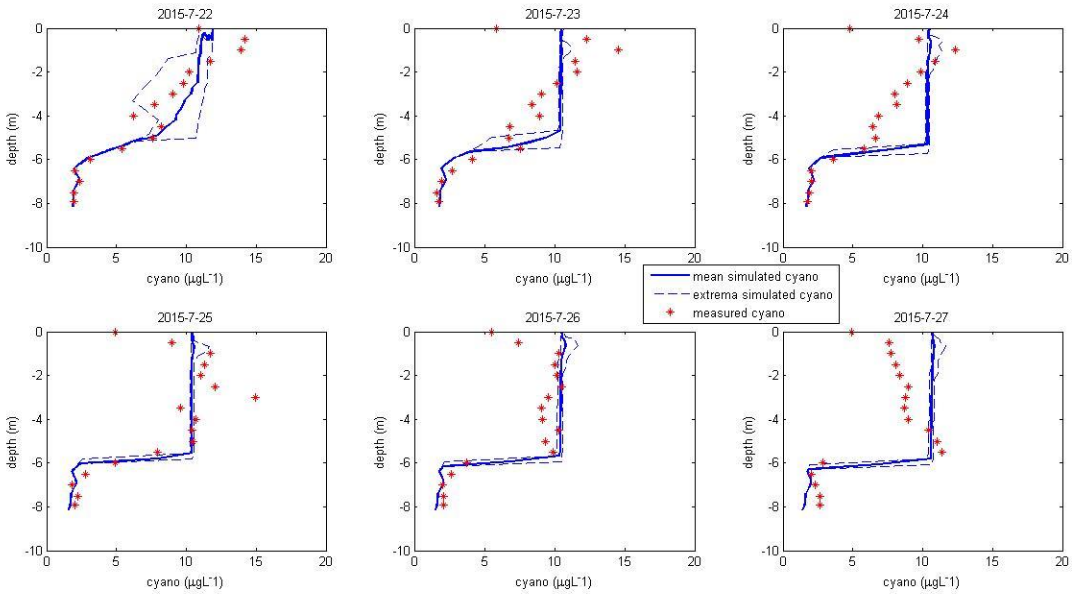

Figure 4-9: Profile plot of measured and simulated cyanobacteria biomass with favorable and unfavorable case from 22.07.2015 to 27.07.2015.

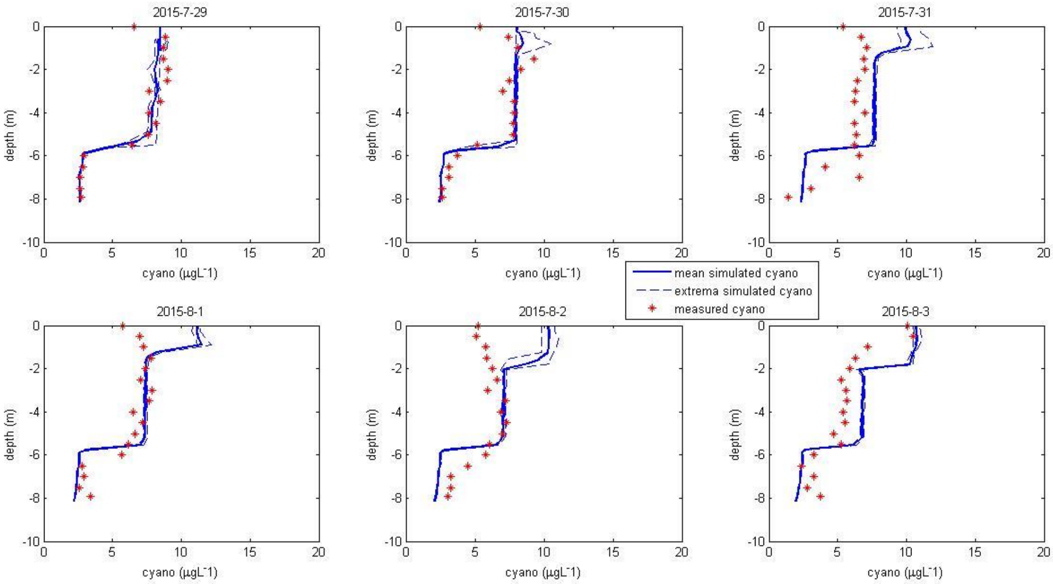

Figure 4-10: Profile plot of measured and simulated cyanobacteria biomass with favorable and unfavorable case from 29.07.2015 to 03.08.2015.

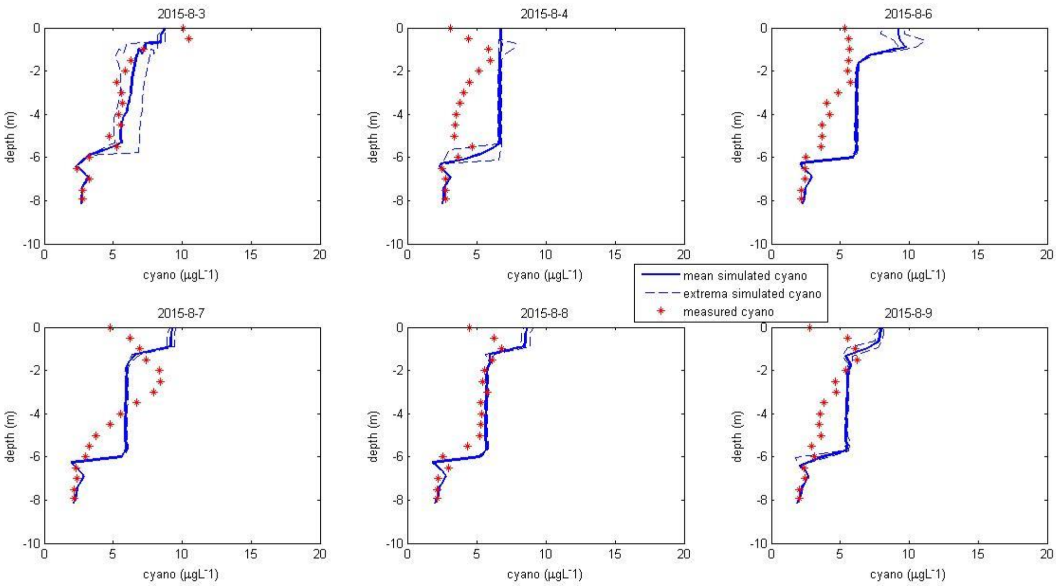

Figure 4-11: Profile plot of measured and simulated cyanobacteria biomass with favorable and unfavorable case from 03.08.2015 to 09.08.2015.

*The original data for 05.08.2015 was missing, please contact Dr. Jun Zhang

From the prediction results above we can evaluate this mode system qualitatively that it works fine for predicting the blooming of cyanobacteria within short period, while for more precisely prediction it needs all the meteorological data from the exact local place and the inflow, outflow and other turbulence should also be indicated clearly.

A Acknowledgements

This training was supported by Haihe River Water Conservancy Commission (HWCC) in Tianjin, China. I would like to thank my supervisor Mme Brigitte Vinçon-Leite from LEESU for her great support and guidance. I also would like to thank Mr. Yang Luo as the project director at HWCC who provided insight and expertise that greatly assisted my training.

I express my warm thanks to Ing. Céline Bonhomme from LEESU, Mr. Guifeng Tao from Beijing ShengHaiTong Sci. & Tech. Co., Ltd, Mr. Gwendal Le Divechen from International Office for Water of French Embassy in China, Dr. Yi Hong and Dr. Neng Jia from LEESU, Dr. Jun Zhang from HWCC for their continuous support, great help and suggestions during my training.

Finally, an honorable mention goes to my family and relatives in Anqing China and my friends Zhang Lijuan in Xiamen; Peng Lan, Li Pujun and Liang Zhiqin in Beijing; Wu Fanglüe in Texas; Togzhan Nurmukanova in Rennes; Apoorva Ambarkar, Marta Mirolo and Asmaa Shaaban in Grenoble; Xiang Xie and Anjani K Mourya in Paris; Shambhavi Pratap in Lausanne; Sujeet Dutta in Hamburg, for their understandings and supports on me during this training.

Thank you all,

1st September 2015
Paris, France

Hong XU

Signature:

徐泓

B Bibliography

[1] Introduction to ENPC (2nd September 2015). Retrieved from http://www.enpc.fr/en/welcome-school

[2] Introduction to ENPC (2nd September 2015). Retrieved from https://en.wikipedia.org/wiki/%C3%89cole_des_ponts_ParisTech

[3] Introduction to LEESU (4th September 2015). Retrieved from http://leesu.univ-paris-est.fr/Presentation-generale-du-LEESU.html?lang=fr

[4] Introduction to HWCC (4th September 2015). Retrieved from http://baike.baidu.com/view/2547712.htm

[5] Introduction to Yuqiao reservoir (4th September 2015). Retrieved from http://baike.baidu.com/subview/33947/8042087.htm

[6] X.Q. Zhou. The water resources protection of the project of water transfer from Luanhe River to Tianjin. The Hydrological Basis for Water Resources Management (Proceedings of the Beijing Symposium, October 1990). IAHS Publ. no. 197,1990.

[7] Hipsey, M.R., Bruce, L.C., Boon, C., Bruggema, J., Bolding, K., Hamilton, D.P., 2012. GLM-FABM Model Overview and User Documentation. The University of Western Australia Technical Manual, Perth, Australia. 44pp.

[8] Spigel, R.H., Imberger, J., Rayner, K.N., 1986. Modeling the diurnal mixed layer. Limol. Oceanogr. 31, 533-556.

C Appendix

Here I attached the indexes I used in this report for reference, together with the training schedule.

C.1 Index of Figures

C.2 Index of Tables

C.3 Training Schedule

Schedule of Training on Cyanobacteria Dynamics Modelling at LEESU				
Day 1: 31st August 2015				
	Training on basic principles of the modelling and general procedures of operation			
1.1	**Visit ENPC and LEESU**	10:00-11:00	√	
1.2	**Introduced to LEESU staffs**	11:00-11:30	√	
1.3	**General introduction to the project**	11:30-12:00	√	
1.4	**Condition of Yuqiao reservoir**	13:30-14:00	√	
1.5	**The GLM-FABM-AED Model**	14:00-15:30	√	
1.6	**PontYuqiao software**	15:30-16:30	√	
1.7	**Installation and demonstration**	16:30-17:30	√	
Day 2: 1st September 2015				
	Practice on modelling and bug fixing			
2.1	**Practice on the modelling software**	10:00-11:00	√	
2.2	**Simulate with data & Find the bugs**	11:00-11:30	√	
Day 3: 2nd September 2015				
	Self-study on the principle and practice parts and start to write the training report			
3.1	**Study the report and slides**	10:00-11:30	√	
3.2	**Start to write the training report**	13:30-18:00	√	
Day 4: 3rd September 2015				
	Write the introduction part of training report and write the training schedule			
4.1	**Write the training schedule**	09:30-12:00	√	
4.2	**Write the training report - Chapter 1**	14:00-18:00	√	
Day 5: 3rd September 2015				
	Discuss questions with Mme Brigitte Vinçon-Leite and write the theoretical parts			
5.1	**Discuss questions**	10:00-11:30	√	
5.2	**Write the training report–Chapter 2&3**	13:00-17:00	√	
Day 6: 14th April 2016				
6.1	**Preparation new data for validation**	10:00-11:30	√	
6.2	**Test new data for validation**	13:00-17:00	√	
Day 7: 15th April 2016				
7.1	**Finish the training report – Chapter 4&5**	10:00- 17:00	√	