Project Description

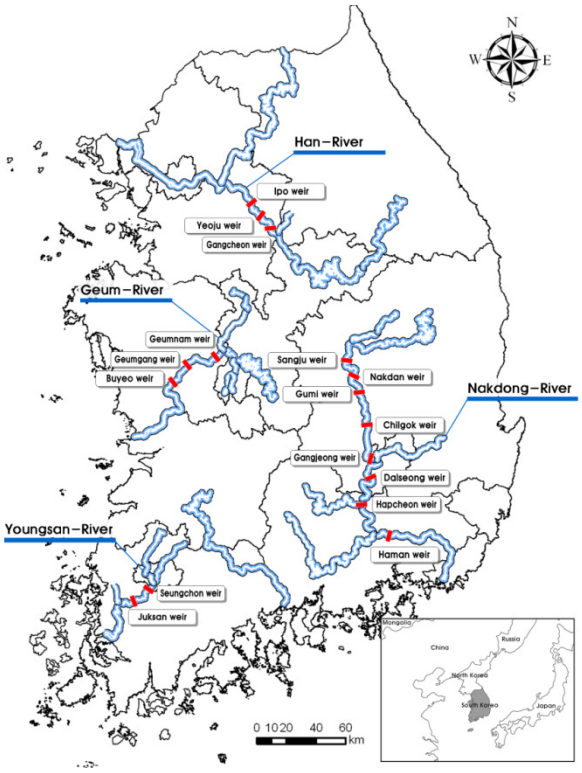
Four Rivers Water Quality Forecasting System (Four Rivers WQFS), South Korea

Introduction

The Korean Government has initiated the "4 Major Rivers Restoration Project" (4MRRP), a massive engineering project to cope with water resources management problems in the Han, Nakdong, Geum and Yeongsan rivers. These river basins cover almost 65% of Korea's main land. The 4MRRP aims to provide water security, flood control and ecosystem vitality by restoring and improving river and eco-environment. The study was conducted during 2012-2013.

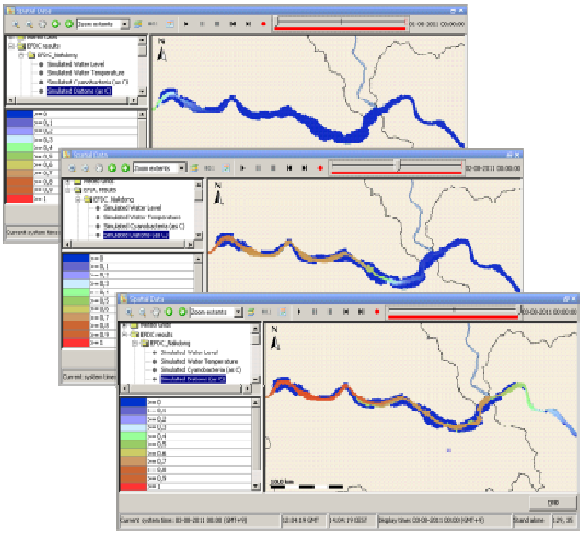
There are serious water quality issues in the water systems of the 4 major rivers. To mitigate their negative effects as much as possible, water quality control needs to be undertaken by carefully controlled flushing with water stored behind weirs and in reservoirs. This improves the water quality improvement especially in case of severe algal blooming events. Weir operators are be able to operate the gates of weirs and flush the river system to prevent these events if accurate forecast of algal blooming is possible. Hence, an operational water quality forecast service for the four major rivers was needed. Deltares has been contracted by the National Institute for Environmental Research (NIER), Republic of Korea (South Korea) to develop a water quality forecasting system – the Four Rivers Water Quality Forecasting System (Four River WQFS). The forecasting system has been developed within the Delft-FEWS open shell forecasting platform [1].

Impression of one of the 16 weirs of the Four River Project



***Keywords**: water quality forecasting, operational water quality management, data assimilation, Delft FEWS, OpenDA*

The development of Four Rivers WQFS commenced as a result of the "4 Major Rivers Restoration Project" (4MRRP), a massive engineering project initiated by the Korean government to cope with water resources management problems. 4MRRP aims to provide water security, flood control and ecosystem vitality by restoring and improving river and eco-environment.



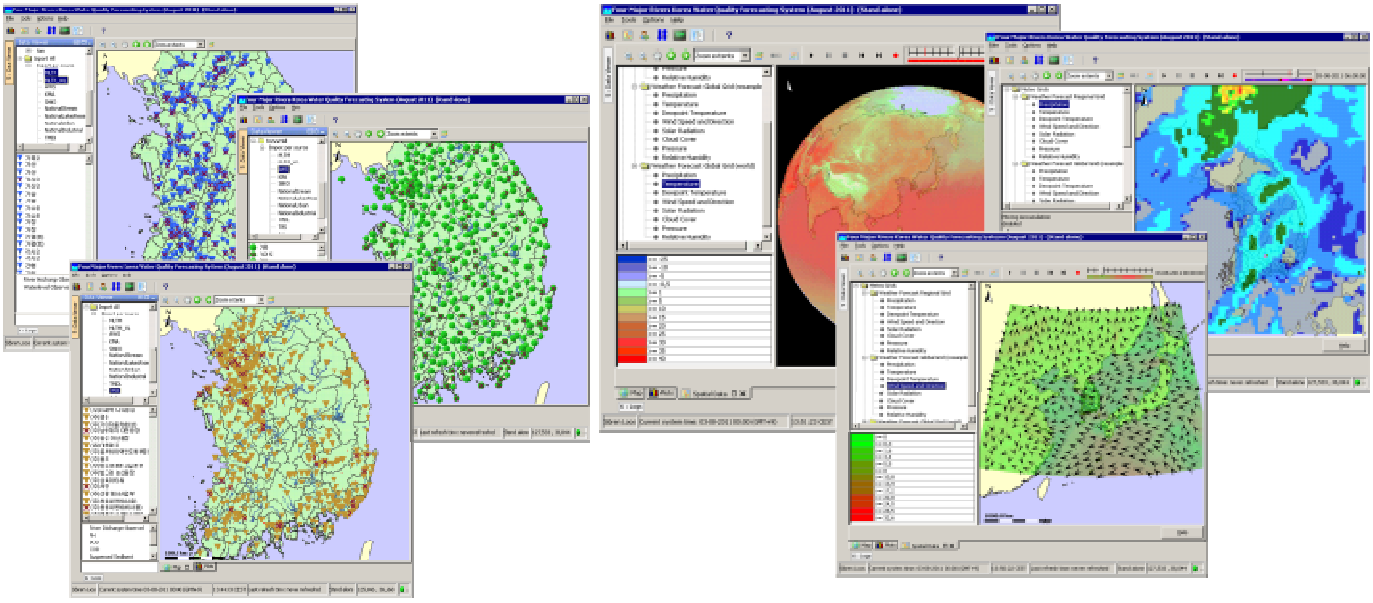
Two models have been used in Four Rivers WQFS for the forecast of various water quality variables: HSPF a hydrological and water quality catchment model for the upstream reaches and watersheds, and EFDC, a 3D hydrodynamic model for the mainstream. The three goals of the Four Rivers WQFS are: 1) Monitoring of the water quality in the river and reservoirs, 2) Informing the public about the water quality with daily forecasts 7 days ahead and 3) provide the operating managers information of optimal operation of each weir for good water quality.

To better predict the water quality, Four Rivers WQFS was set up to facilitate data assimilation using OpenDA [2], an open source initiative for data assimilation in numerical models. In the Han River the water quality forecast system including data assimilation is operative and the benefits can already be appreciated.

Methods

Forecasting system overview

Four Rivers WQFS makes use of observed and forecasted time series to run the HSPF watershed model and the EFDC model for a 7 day forecast for several water quality indicators.



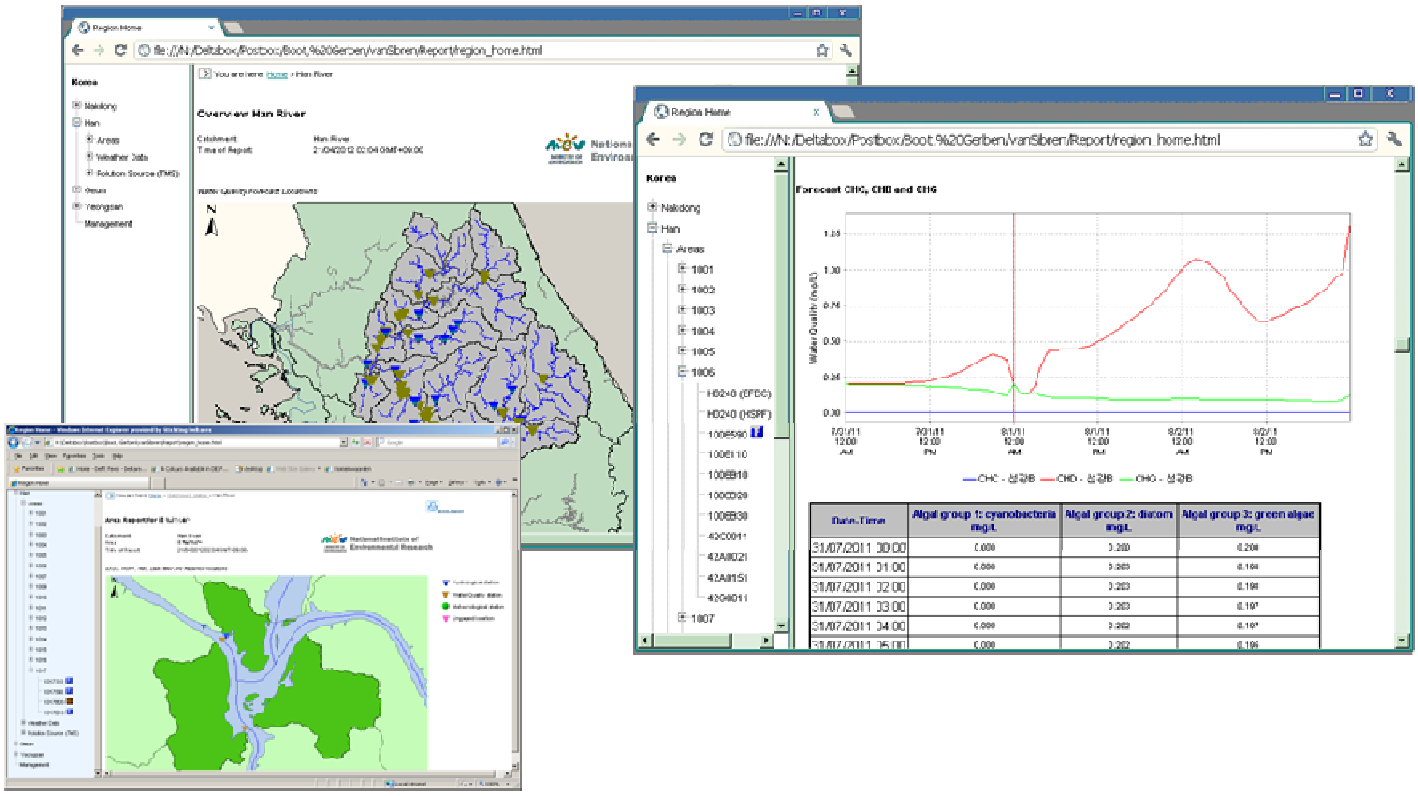
Meteorological data, model results and water quality indicators managed by Four Rivers WQFS

Model input data

The Han River basin is divided into 188 reaches. For each of these reaches the HSPF model calculates 21 water quality indicators at reach outlets and requires meteorological variables (precipitation, temperature, wind speed and direction, dew point temperature, solar radiation, cloud cover, pressure, relative humidity, computed potential evapo-transpiration, using the Jensen and Haise [3] method), hydrological variables (discharge, water levels, lake outflow) and point emission data (Biochemical Oxygen Demand, dissolved oxygen, heat discharge, NO3-N, NH3-N, PO4-P, organic carbon, -nitrogen, and -phosphorus). The results provided by the HSPF model feed the EFDC model boundaries, tributary cells in the EFDC grid. In this way the HSPF model is connected to the EFDC and is therefore run prior to the EFDC model run, that generates 2D (water column average obtained from 3D results) grids of the main channel.

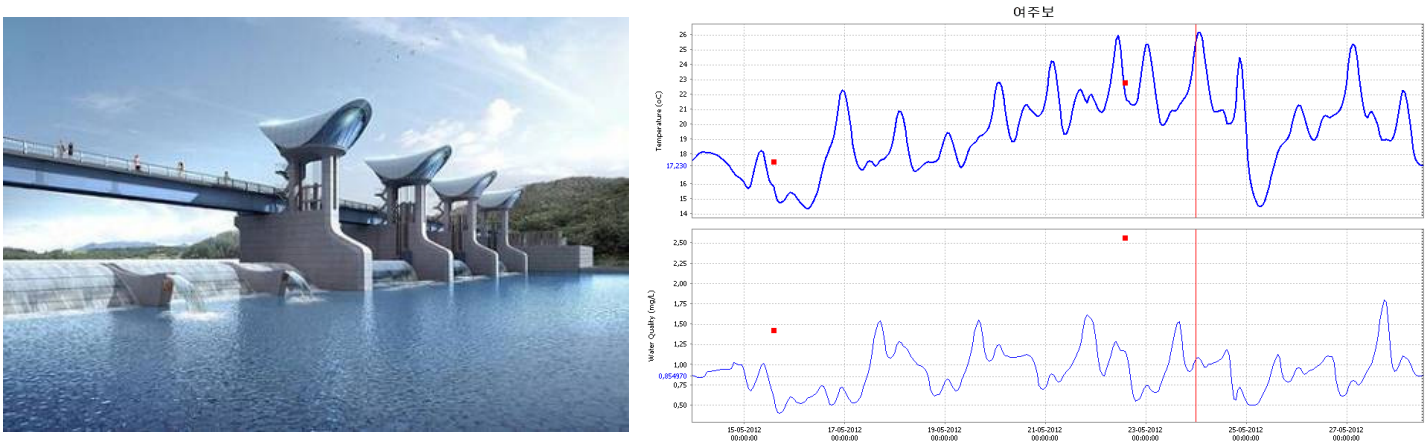
Results and discussion

The Four Rivers WQFS system is producing weekly forecasts on a daily basis and results are communicated to water managers via web-reports.



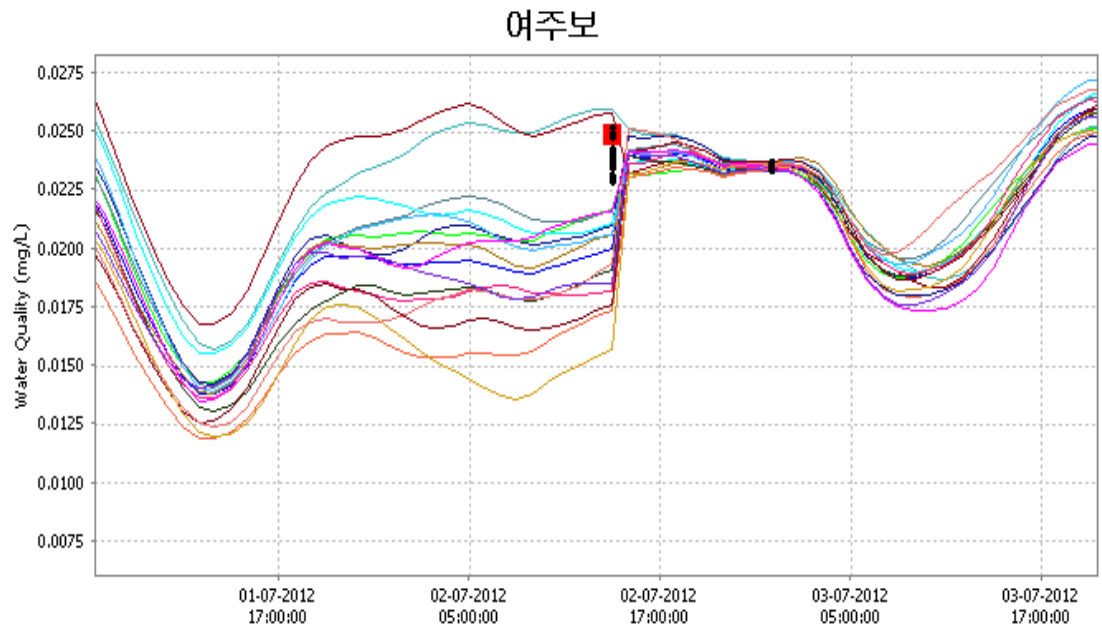
Web-reports provide basin overviews, monitoring stations, time graphs and tabular data

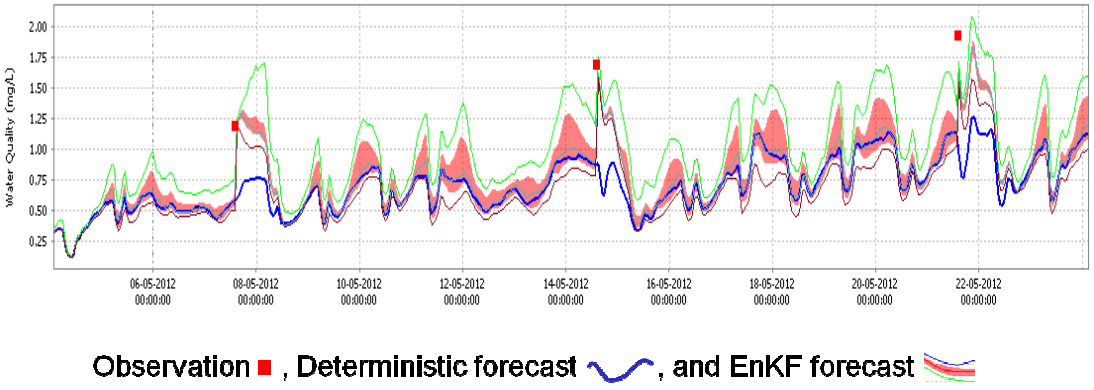
The two main forecast variables, water temperature and algae concentrations at the Ipo weir on Han River are shown below.



Water temperature (up) and algae concentration (down) model forecasts and observations for Ipo Weir

From a rough evaluation on overall forecast performance, it was found that prediction of stream temperature was relative satisfactory but algae prediction still showed much room for improvement. To improve the algae prediction the Four Rivers WQFS forecasting platform recent developments focused on the implementation of Ensemble Kalman Filtering to test different data assimilation setups.





Visualization of algae forecasts updated with Ensemble Kalman Filtering (EnKF)

The application of DA techniques for water quality forecasting is promising, but requires a good understanding of the river system and the datasets that feed the system (i.e. the limiting factors for algae growth, the uncertainty associated to the model forcing and the accuracy of the in-stream water quality observations). After fine tuning the DA setup for all four river basins the live system will be upgraded to include the real-time data assimilation of algae concentration and further improve the forecasts that can help the water manager to take effective and timely measures that reduce the environmental impact.

While water quality forecasting is challenging, this study proves that with a good monitoring network and the use of real-time data assimilation techniques reasonable forecasts can be provided for several days ahead. It also shows that data assimilation can drastically improve forecasts and is therefore essential in water quality prediction. Although the lead time of the forecasts is to a great extent influenced by the variability within the water system, the implementation of data assimilation algorithms into operational systems and additional improvements to the emission input data may result in longer lead times and better forecasts. The operational water quality forecasting system helps water managers to optimize the operation of each weir based on the information provided by the system, which helps them to improve the water quality in these rivers.

1] Werner M.G.F. et al., 2013. The Delft-FEWS flow forecasting system. Environmental Modelling & Software 40 (2013) 65-77, www.elsevier.com/locate/envsoft.
[2] OpenDA, www.openda.org
[3]Jensen M.E., and Haise H.R., “Estimating evapotranspiration from solar radiation.”, Journal of the Irrigation [and Drainage Division, Proceedings of the American Society of Civil Engineers, Vol. 89, (1963), pp 15-41.