City University of New York (CUNY)
CUNY Academic Works

International Conference on Hydroinformatics

2014

# Hydrological Ensemble Forecasting And Data Assimilation With An Integrated Hydrological Modelling System

Henrik Madsen

Diana Lucatero

Marc Ridler

Donghua Zhang

Jens Christian Refsgaard

*See next page for additional authors*

How does access to this work benefit you? Let us know!

More information about this work at: https://academicworks.cuny.edu/cc_conf_hic/283
Discover additional works at: https://academicworks.cuny.edu

This work is made publicly available by the City University of New York (CUNY).
Contact: AcademicWorks@cuny.edu

## Authors

Henrik Madsen, Diana Lucatero, Marc Ridler, Donghua Zhang, Jens Christian Refsgaard, and Karsten Høgh Jensen

This presentation is available at CUNY Academic Works: https://academicworks.cuny.edu/cc_conf_hic/283

11th International Conference on Hydroinformatics
HIC 2014, New York City, USA

# HYDROLOGICAL ENSEMBLE FORECASTING AND DATA ASSIMILATION WITH AN INTEGRATED HYDROLOGICAL MODELLING SYSTEM

HENRIK MADSEN (1), DIANA LUCATERO (2), DONGHUA ZHANG (2), DAVID G. JENSEN (4), MARC E. RIDLER (1), JACOB B. KIDMOSE (3), NILS VAN VELZEN (6), M. UMER ALTAF (6), THOMAS BØVITH (5), JENS CHRISTIAN REFSGAARD (3), KARSTEN HØGH JENSEN (2), MICHAEL RASMUSSEN (4), CLAUS PETERSEN (5), RASHPAL GILL (5), HENRIK FEDDERSEN (5), BENT H. SASS (5), ARNOLD HEEMINK (6), MICHAEL QUIST (7), SØREN K. HVID (8), JOHAN LASSEN (9)

*(1): DHI, Agern Allé 5, DK-2970 Hørsholm, Denmark*
*(2): Department of Geosciences and Natural Resource Management, University of Copenhagen, Øster Voldgade 10, DK-1350 Copenhagen K, Denmark*
*(3): Geological Survey of Denmark and Greenland, Øster Voldgade 10, DK-1350 Copenhagen K, Denmark*
*(4): Department of Civil Engineering, Aalborg University, Sohngårdsholmsvej 57, DK-9000 Aalborg, Denmark*
*(5): Danish Meteorological Institute, Lyngbyvej 100, DK-2100 Copenhagen Ø, Denmark*
*(6): Delft Institute of Applied Mathematics, TU Delft, Mekelweg 4, 2628 CD Delft, The Netherlands*
*(7): Danish Road Directorate, Niels Juels Gade 13, DK-1022 Copenhagen K, Denmark*
*(8): Knowledge Centre for Agriculture, Agro Food Park 15, DK-8200 Aarhus N, Denmark*
*(9): Danish Nature Agency, Fejøgade 1, DK -4800 Nykøbing F, Denmark*

## EXTENDED ABSTRACT

Hydrological forecasting is an important instrument for more effective water management, such as warning and protection against water-related hazards, real-time operation of water infrastructure, water allocation, and environmental monitoring. Recent advances within radar rainfall estimation and nowcasting, ensemble-based numerical weather prediction (NWP), in-situ and satellite monitoring, and hydrological data assimilation are opening up new opportunities in real-time hydrological forecasting.

Ensemble based forecast products can be used as input to hydrological forecast models to produce probabilistic forecasts and estimation of forecast uncertainty of the hydrological variables of interest. In this regard, key scientific challenges are understanding, quantification, and propagation of the different uncertainty sources in the forecast modelling chain and updating of the hydrological forecast model using data assimilation. Most studies within hydrological forecasting and data assimilation have used single compartment models and

assimilation of one type of measurements. To fully utilise the information of multiple variables from different sensors, multi-variate data assimilation within integrated hydrological modelling systems is required. This involves development and implementation of robust and computationally efficient data assimilation algorithms that are feasible for real-time applications.

A framework for hydrological ensemble forecasting and data assimilation is being developed as part of the HydroCast project (http://hydrocast.dhigroup.com/) to support water management at different temporal scales, ranging from short- and medium-range, which is relevant for e.g. flood forecasting and warning, to seasonal and long-range forecasting for optimising water allocation. The framework combines different forecast products, including (i) weather radar nowcasts (up to few hours), (ii) high-resolution NWP ensemble prediction system for short-term forecasting (up to 48 hours) from the Danish Meteorological Institute, and (iii) medium-range (up to 15 days) and seasonal ensemble prediction systems from the European Centre for Medium-Range Weather Forecasts (ECMWF). A data assimilation system is being developed for assimilation of weather radar data (including weather radar nowcasts) in the NWP model. The ensemble weather forecast products are used as input to the MIKE SHE hydrological modelling system for producing ensemble hydrological forecasts. The framework allows inclusion of other uncertainty sources such as model parameter uncertainty and uncertainty in the initial state. These uncertainties may be obtained from off-line calibration of the hydrological model or as part of the on-line data assimilation system.

A multi-variate hydrological data assimilation system has been developed for assimilation of in-situ and remote sensing measurements in the MIKE SHE hydrological modelling system. The system integrates the two open source standards OpenMI (www.openmi.org) and OpenDA (www.openda.org). The OpenMI (Open Modelling Interface) standard is used to exchange data at runtime between the model (in this case the MIKE SHE model) and the OpenDA data assimilation toolbox. This toolbox includes a library of different data assimilation algorithms, such as ensemble Kalman filter based algorithms and the particle filter. The data assimilation system is used for testing the value of assimilation of different types of measurements related to hydrological forecasting and environmental monitoring. Particular emphasis is given to the analysis of representation of model and measurement uncertainty in the data assimilation system, including handling of measurement bias.

Three test studies are included in the HydroCast project for development and illustration of the forecasting and data assimilation framework. These include (i) Forecasting of floods for operation of road infrastructure, (ii) Seasonal forecasting of irrigation potentials, and (iii) Integration of on-line measurements and hydrological modelling for environmental monitoring.

## Acknowledgements

This work is carried out with the support of the Danish Council for Strategic Research as part of the project ”HydroCast - Hydrological Forecasting and Data Assimilation”, Contract No. 0603-00466B (http://hydrocast.dhigroup.com/ ).