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IMPROVING FLOOD FORECAST SKILL USING REMOTE SENSING DATA

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Floods are among the most important natural disasters in Australia. Over the last 40 years, the average annual cost of floods was approximately $377 million per year. The 2010-2011 floods in Brisbane and South-East Queensland alone resulted in 35 confirmed deaths and $2.38 billion damage. In order to limit the personal and economic damage caused by floods, operational water managers heavily rely on flood forecasting systems. These systems consist of a hydrologic and a hydraulic model to predict the extent and level of floods, using rainfall predictions. The hydrologic model calculates the amount of water that is flowing through the river network, while the hydraulic model converts this flow volume into river water levels/velocities and floodplain extents. During the last decade, the accuracy and reliability of these flood forecasting systems has significantly improved. However, it remains difficult to provide accurate flood warnings. This is because of errors and/or uncertainties in the model structure, the model parameters, and/or the meteorological forcings (mainly the rainfall). The hypothesis of this project is that remote sensing data can be used to improve modeled flood forecasts. More specifically, in this project we are constraining the hydrologic model using remotely sensed soil moisture values, as this variable determines the partitioning of rainfall into surface runoff and infiltration. Further, we are constraining the hydraulic model using remotely sensed water levels and/or flood extents. Thus every time a remote sensing image becomes available, we correct the model predictions, which should lead to improved model forecasts of flow depth, extent and velocity for a number of days in the future.

1. Introduction

Floods are very important natural disasters in Australia, costing an average $377 million per year. One tool that is being used by operational water managers to mitigate the impact of floods is flood forecasting systems, which use rainfall data to predict the extent and level of floods. Even though these systems have improved during the last decades, further research is needed to make the forecasts more accurate.

The hypothesis of this project is that remote sensing can be a very helpful tool for operational flood forecasting. For this purpose, remote sensing data are being used in two different ways. First, estimated soil moisture profiles from hydrologic models are improved through the merging of these model predictions with remotely sensed surface soil moisture values. This is expected to have a beneficial impact on modelled hydrographs. Second, estimated flood inundations and water levels from hydraulic models are improved through merging these model results with remotely sensed observations of flood inundations or water levels. This is expected to improve the predictive capability of the hydraulic model. Overall, using remote sensing data in flood forecasting is expected to lead to better early warning systems, management of floods, and post-processing of flood damages (for example for insurance companies).

In this project, the best methods to assimilate remote sensing data into operational hydrologic and hydraulic models will be determined. After selecting the models, the data assimilation techniques will be implemented and tested using a data base that will be developed as part of this project. A list of recommendations on how to best use remote sensing data for operational water management will be developed.

2. The project

The project is expected to answer the following science questions:

1. How can terrestrial remote sensing data be best used to improve flood forecasting systems? In other words, is it more important to update the state variables of the hydrologic model or the hydraulic model? How frequent do we need acquisitions; do we need remote sensing data during the flood, or can remote sensing data from before the flood already provide sufficient information?
2. To what extent can we reduce the uncertainty in the flood predictions?

A first step in the project is the identification of two test sites, and the acquisition of required data to meet the project objectives. Criteria used include:

- Representation of the diversity of Australian hydrologic regimes; The occurrence of floods in the recent past;

- The significance of the flood impact on communities;

- The availability of data to apply both hydrologic and hydraulic models;

- The availability of highly accurate digital elevation models at fine spatial resolution.

A second step is the selection and calibration of the hydrologic and hydraulic models to be used in the study. The models will be selected from those typically used in Australia. Criteria will be:

- Availability of the source code; Modularity of the model;
- Data requirements;
- Feasibility to incorporate remote sensing data; Ease to make operational;
- Documented model performance.

The selected hydrologic model will then be calibrated using observed discharge records and remotely sensed soil moisture data. Furthermore, the hydraulic model will be calibrated using a combination of anecdotal flood height information, aerial photographs and radar-based remotely sensed flood extents. Existing imagery of soil moisture and inundation will be used for this purpose.

A very important issue is the estimation of the uncertainty of the flood forecasts, which is the third part of the project. Precipitation forecasts will be used in an ensemble mode, meaning that not one single value is used for a specific time and location, but a number of values. The spread in these ensemble members is a measure of the uncertainty in the predictions. The calibrated hydrologic model will be applied to each member of the precipitation ensemble, leading to an ensemble of hydrologic model discharge values. This will then be used by the hydraulic model, resulting in an ensemble of river water levels and flood extents. Similarly as for the precipitation, the spread in the ensemble will be a measure of the uncertainty in the modelled water levels and flood extends.

The uncertainty in the hydrologic model results will be reduced through the merging with remotely sensed soil water content data and in-situ streamflow observations. More specifically, at each time step where an observation is available, a weighted average between the hydrologically modelled state variables and the observations will be made. The weight of the model results and the observations will be dependent on their level of uncertainty. Additionally, the uncertainty in the flood extent forecasts will be reduced through the merging of the model forecasts with remotely sensed flood extent data and real-time gauge-based water levels.

A fourth and final part of the project is the optimal application of the coupled models in a data assimilation framework. The overall objective of the project is to aid operational flood forecasts through the use of remote sensing data. A remaining question in this context is the adequate spatial and temporal resolution of these data. In order to answer this question, a series of synthetic experiments will be performed. This will allow recommendations to be made on how to optimally use the methodology that has been developed as part of this project.

3. Activities in the project

Ashley Wright has taken up his PhD. scholarship on March 17. He is currently defining the topic of his research for the next 2.5 years.

Yuan Li and Dr. Stefania Grimaldi have commenced working on the project on May 5 and July 1, respectively. Yuan Li has begun assembling a data base for the project, and is also making an overview of the hydrologic models that potentially could be used in the project. Dr. Grimaldi is currently making an overview of the possible hydraulic models that can be used in the project.

On July 21 a workshop with the end-users and researchers has been organized. During this workshop, the following items will be discussed:

- Model selection; Test site selection;
- Source of the remote sensing data; Manner of interaction with the end users.

4. The Project Team:

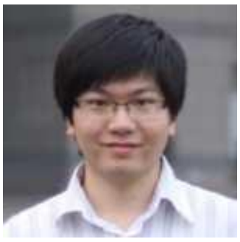
Project Leaders:

Valentijn Pauwels

Jeffrey Walker

Research Fellows:

Yuan Li



Stefania Grimaldi

PhD. student:

Ashley Wright