Striving Sufficient Lead Time of Flood Forecasts via Integrated Hydro-meteorological Intelligence

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Outlines

- Introductions

- Integrated hydro-meteorological simulations
  - Ensemble Quantitative Precipitation Forecasts Experiment,
  - Unified Regional Circulation Rainfall and Hydrological Watershed Model,
  - Modeling Test-bed with Integrating Simulations/Observations/Assimilations in Demo Site,
  - To improve our understandings from individual ensemble flood forecasts.

- Summary
Introductions
Introduction (Rainfalls)

- Taiwan, located in the subtropical zone of the west Pacific Ocean, often experiences typhoons accompanied by frequent flooding.

- During the summer season, an average of 3 to 4 typhoons make landfall, usually producing massive amounts of precipitation island-wide.

- The total amount of annual rainfall is more than 2,500 millimeters.

The total amount of rainfall is almost 2.6 times the world’s average.
Motive (Floods)

- During the rainy season, excessive *torrential rain* tends to cause *flash floods*, sometimes with devastating effects on people’s lives and property.

- In recent decades, Taiwan has particularly suffered from severe attacks of torrential rain.

- Almost 73 percent of the population of the island are under threats from more than three of major natural disasters.

Typhoon induced flood is the major natural threat to the island.
The topography of Taiwan is steep and as a consequence its rivers are *short* and *fast-moving*, so are prone to frequent flooding following extreme precipitation.

This is particularly the case in Taiwan which is covered by *varied terrain* with most watersheds being located in *mountainous regions*.

Due to such steep landforms, we could only gain *3-5 hours* of hydraulic response time when flash floods occur.

**It is necessary to establish a flood warning system to alert the population for possible evacuations.**
It is unquestionable that **accurate rainfall prediction** is the most crucial factor driving the hydrological response.

It is also important to have very dense observations to provide the **initial conditions** via assimilation for hydrological modeling.

How to integrate **useful early information** and condense the **forecasting process** is of great concern.

This study aims at **understanding the distinctive features of flood** forecasts that are based on integrated rainfall-runoff simulations.
Integrated Hydro-meteorological Simulations
Hydro-meteorological System

- A **quantitative precipitation experiment** has been examined in Taiwan since 2010.
- Over **20 members** of ensemble rainfall forecasts are generated by Weather Research Forecasting (WRF) Model.

- A **hydrology model**, WASH123D, was sequentially employed to flood routing.
- **Field observations** are real-time received, and put into model simulations with feedback control.

- All procedures were scheduled and triggered in **sequence** with controlled by computer program.
- Simulation results are **automatically extracted** from modeling outputs and exhibited on the proposed platform.
The Experiment of Ensemble Quantitative Precipitation Forecasts
Hydrological Routing

- Model **configurations**.
- Combining instantaneous field **observations** to provide initial accurate modeling.
- Estimating **infiltration** for determining effective rainfall.
- Hydro-meteorological **simulations**.
- Improving our **understanding** of Flood Forecasting.
Display

http://140.110.147.168/wims/
Operational Warning System

- am00:00, Start operational process
- am04:00, Get NCEP-gfs data, and start rainfalls generation
- am06:00, QPF-process done, and start hydrological routing
- am08:00, hydro-meteorological simulation done
Study Site

Study site

The Langyang creek basin, situated in Northeastern Taiwan, covering an area of 978 km$^2$. 
Model Configurations

We discretized the computational domain with finite element meshes using **line elements** for rivers and **triangular elements** for land surface.

**Table.** Land use and Manning’s roughness for the study site.

<table>
<thead>
<tr>
<th></th>
<th>Agricultural</th>
<th>Forestry</th>
<th>Traffic</th>
<th>Water</th>
<th>Buildings</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land use</td>
<td>43.94%</td>
<td>19.08%</td>
<td>8.04%</td>
<td>4.65%</td>
<td>15.81%</td>
<td>8.48%</td>
</tr>
<tr>
<td>Manning’s N</td>
<td>0.200</td>
<td>0.350</td>
<td>0.100</td>
<td>0.050</td>
<td>0.150</td>
<td>0.250</td>
</tr>
</tbody>
</table>

- **Four** sorts of Manning’s roughness are assigned in studied river area based on the official reports, varying from 0.030 to 0.038.

- Land-use is classified into **six** types, as shown above, where the sets of Manning’s value are calibrated in coupled 1-D/2-D systems.
Model Calibrations

- Model calibrations using Typhoon Sinluku and Jangmi.

<table>
<thead>
<tr>
<th>Event</th>
<th>RMSE</th>
<th>CE</th>
<th>VER</th>
<th>EQp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typhoon Sinluku</td>
<td>0.27</td>
<td>0.89</td>
<td>0.01</td>
<td>0.08</td>
</tr>
<tr>
<td>Typhoon Jangmi</td>
<td>0.35</td>
<td>0.88</td>
<td>0.03</td>
<td>-0.04</td>
</tr>
</tbody>
</table>
These two cases both show very **small errors** in total volume during this simulation period and captured the peak time exactly.

In general, both cases reveal very good results for the **coefficient** of **efficiency**.

It is noted that there is great improvement in the rising period of simulated hydrograph when the mechanism of infiltration is included.

The simulated hydrograph tuned by artificial adjustments could precisely capture measured flow patterns.
Typhoon Megi (2010)
Figure. Hydro-meteorological simulations from the run that began at 18:00, Oct. 19\textsuperscript{th} of 2010.
Figure. Hydro-meteorological simulations from the run that began at 00:00, Oct. 20th of 2010.
Figure. Hydro-meteorological simulations from the run that began at 12:00, Oct. 20th of 2010.

They warned the approach of a considerable flood, but could not reach an agreement on the peak time and related quantity.
Simulation using rain-gauge

- Model calibrations for Typhoon Magi.

- It seems *easy to obtain* a reasonable response using the measured rainfall to drive the watershed simulation.

- A perfect guess in terms of the quantity as well as distribution of precipitation is not easy to obtain.

- Although precipitation estimates produced by the WRF can capture the total amount of rainfall, its related distributions are sometimes inadequate for numerical hydrological modeling.
- We should *shift our expectations* to the outcome of ensemble quantitative rainfall predictions.

- It is impossible to obtain a perfect guess in advance due to limitations in our understanding of the aspects of atmosphere and hydrology.

- The key is how to *understand* these types of information, and how to *integrate* earlier useful intelligence into the watershed model.
Typhoon Nalgae (2011)
Figure. Hydro-meteorological simulations from the run that began at 00:00, Oct. 02nd of 2011.
Each rainfall participants has been chosen because of their *individual representatives*.

The key to a flood warning system is not to expect too much of *highly accurate quantitative precipitation forecasts*, but to improve our understandings from individual ensemble flood forecasts.

Therefore all participants are necessary to this QPF project with their own specific representatives conducting *individual analysis*. 
This member captures the shapes of the predicted hydrograph *poorly* in the first few runs.

They implied that a considerable flow peak would occur, but missed the time, which was behind the actual occurrence.

They *did not provide* sufficient lead time for flood forecasts here. This actually provided very slight help.
The basically reveal that a flood is going to pass, but the precise time and peak are constantly being adjusted.

They indeed provided some useful information for flood mitigation, because of being able to send out an early warning of the event.

We can obtain some warning from early operational hydro-meteorological runs. To issue advance warnings of possible danger is better than doing nothing.
The water stage for this event was incredibly high from the first to fourth operational predictions.

The advantage in this case was that they always issued warning messages.

This is helpful for mitigation of flash flood danger.
Summary
Concluding Remarks

- A system integrating *rainfall-runoff calculations, field observations* and *instant data assimilations*, is presented.

- Simulation results indicate that well calibrated coefficients of the hydrological model *were not satisfied* for sequential flood predictions. This is because these two types of precipitation data are *systematically different* because of the aspect of their generation.
Concluding Remarks

- Each QPF participants has been chosen because of their *individual representatives*.

- We must further understand that the key for such a warning system is not to have *greatly expectations* of highly accurate rainfall predictions, but to *improve our understanding* from the point of view of individual ensemble flood forecasts.
Thank You.