Hydrological Models for Flood Forecast
Overview

This presentation deals with "flood forecasting" and "hydrological modelling" with a specific angle

Hydrological modelling for flood forecasting: state of art, locks and challenges, regarding the whole forecasting system. Which gain for the whole system is expected from (hydrological) modelling? Who is in charge of the global picture?
THE FLOOD FORECASTING SYSTEM

- Météorological forecasting
- Rainfall forecasting, nowcasting
- Quantification and spatialization of rainfalls
- Discharges/water stages forecasting
- Flood plains forecasting
- Message and delivery service/system
- Evaluation of the system
FLOOD FORECASTING/WARNING SYSTEMS ARE NOT GIVEN RESEARCH OBJECTS

It probably makes no sense to study any hydrological or meteorological components (for real time purposes) out of the framework of the global organization of the forecasting/warning system itself,

How to go beyond the limits of hydrological and meteorological products recycling?

It’s not about usual “academic/applied sciences” discussion, but about systemic approach.
The MINI MAX MODEL (1)

There is a real danger in only minimizing the “maximum” (extreme floods) without really improving the global system and the medium or moderate floods. However, and because of the media coverage, this is the actual trend,

To find a good compromise between Prevention and Prevision is a real challenge,

Flood forecasting and warning have to be incorporated within the global flood management scheme.
MINI MAX MODEL (2)
FLOOD/WARNING SYSTEMS ARE USERS ORIENTED (1)

The USERS are both:

For the scientists, the users are technical Services and institutional bodies: They operate the networks, our models, ... (all technical systems), and design and deliver appropriate messages to End users (ie individuals, citizens, ..., nothing to do with technical people) who are the recipients of the messages (dissemination response) and whose comfort, quality of life, and sometime just life, depend of them.
FLOOD/ WARNING SYSTEMS ARE USERS ORIENTED (2)

If the research and technical object to consider is the global warning system, who is in charge of the this global picture?

If we consider only the hydrological/ meteorological part of the system, what is the maximum possible benefit for the global system, due to improvements of these “hydromet” components, and who is in charge of the global evaluation, to draw future priorities for research and transfer?

Hydromet components: Robustness or accuracy?
flood forecasts, lead time and time to peak

Forecasts at downstream site derived from:

Observations/measurements of water stages at downstream and upstream sites

Measurements of (catchments) and upstream reach flows

Observation of rainfall (snow melting)

Forecasts of rainfall

Nowcasting and forecasts from other basins
TENTATIVE S/T LOCKS AND CRITICAL COMPONENTS IDENTIFICATION

For the headwater catchments, the nowcasting, the rainfall observations and forecasts, the snow melting modelling are, at least, critical components,

For the downstream forecasting sites, flow routing in main channels (including upstream reaches) are critical components,

At basin scale, the improvement of runoff production (robust across scale) and water transfers controlled by topography and soil is important. All spatialized relevant information (geology, terrain, land use and land cover - DOT) is also important, and the incorporation of embedded meteorological information at different scales as well.
RAI NFALL OBSERVATION AND MEASUREMENTS
RAINFALL OBSERVATION AND MEASUREMENTS

It's now obvious that hydrological radar will be soon the most appropriate device in rainfall measurements, in cooperation with the ground systems,

The capability to feed hydrological models with quantified spatially consistent rainfall is critical, even for global rainfall-runoff models, and not only for distributed physically based models (robustness and uncertainty ?)

That doesn’t mean that only distributed physically based models are relevant modelling components
WITH AND WITHOUT RAINFALL FORECASTS ON A SMALL BASIN

J. Lavabre and AI
Pluie en 48 heures le 09/09/2002,
données Météo-France, traitement HYDRAM
Hydrological Model Choice?

“I told you - my model is better than yours.”

Thanks to Bob Moore for the picture
P. Givone, Cemagref - Direction Scientifique  PREVISION DES CRUES

**LE MODELE HYDROLOGIQUE GR3H**

\[ P_S = (1-k^2)P \]

\[ Pr = k^2P \]

\[ S = kA \]

\[ Q = Qe + Qp \]

\[ QR = R_{DEB} - R_{FIN} \]

\[ PR = k^2P \]

\[ Q = \frac{1}{R_{FIN}} - \frac{1}{R_{DEB}} \]

\[ C = \frac{3}{C} \]

\[ HU1 \]

\[ HU2 \]

\[ R = 3/2C \]

\[ Qp \]

\[ ln(A) = 5.3 \text{ fixé} : ln(B) = 5.43 ; ln(C) = -1.15 ; Nash = 94 \]

\[ ln(A) = 5.3 \text{ et } ln(B) = 4.4 \text{ fixés} : ln(C) = 1.01 ; Nash = 83 \]

*figure 4 – Modèle GR3H*

*figure 5 – Perte en calage (crue juin 2000).*
New (X-band) Radars are now available, with doppler and multi-polarization facilities.
HYDROMET COUPLING ACROSS SCALE

24 hours precipitation forecast computed by ALADIN model
PACK Snowmelt Model

Thanks to Bob Moore

Elevation zones

Hypsometric curve

Model simulation
ROUTING AND INUNDATION MODELLING
Routing and Inundation Modelling

In main rivers, the channel flow routing is critical to improve the forecasts. One robust possibility is to use Kinematic wave based models (with lateral flows) as the CEH KW model for example:

\[
\frac{\partial q}{\partial t} + c \frac{\partial q}{\partial x} = cu
\]

The difficulty is in using the results of these models to draw the flood plains according to the inundation modelling needs. The hydrodynamics based models are more efficient, but less robust and, to a certain extend, data driven.
The 1D hydrodynamics models are robust enough to be used as a component incorporated in operational systems. The main questions are about the needs in geometric data to feed the models, and the operational staff skills in operating them,

The flood plains mapping is much more easy from these models if, and only if, only one geometric database is used,

The geometric characteristics of the basins are more and more needed in hydrological modelling, generally speaking, the use of DOT is one way of improvements.
1D HYDRAULICS/GEOMATICS MODELLING
Flood simulation maps

300 m³/s

500 m³/s

Flooded area

900 m³/s
P. Givone, Cemagref - Direction Scientifique  PREVISION DES CRUES
P. Givone, Cemagref - Direction Scientifique  PREVISION DES CRUES
DI SCHARGE MEASUREMENT IS STILL A CHALLENGE

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RUNOFF PRODUCTION
RUNOFF PRODUCTI ON MODELLING IMPROVEMENTS
vs ROUTING IMPROVEMENTS

Improved process representation relevant to scales beyond the point: hillslope, grid, catchment, ..., using with a better “yield” the available DTM and DEM,

Water tracking on slopes, runoff-production is dominated by sub-horizontal water transfers controlled by topography and soil,

Better use of spatial dataset support: terrain, soil, geology, land use, land cover, weather variables, ...

- Improved model transfer to ungauged catchments across scales
- Whole catchment models, linking rainfall-runoff and hydrodynamic river models
- Atmospheric/ hydrological model coupling
Many relevant parameters are derived from spatially consistent information.
Soil moisture (API index) on August 6\textsuperscript{th}

Soil moisture (API index) on August 11\textsuperscript{th}
SPACE AVERAGE of DAILY PRECIPITATION on BASIN and FLOW PEAK DOWNSTREAM
THE GROUND NETWORKS ARE CRITICAL COMPONENTS, and the RESEARCH BASINS, DEVOTED TO FLOOD FORECASTING AS WELL

Real-Collobrier research basin

J. Lavabre
RISK ASSESSMENT

All the technical components have the unique purpose to provide the Service in charge of public warning with relevant information. Messages design and dissemination, and dissemination response, are the most important tasks of a flood forecasting system which must be **first a flood warning system**

The answer is not in hydrological modelling
ARE YOU TALKIN’ TO ME?