Use of event vs continuous models for flood forecasting: dogma or context?

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Overview

• Some context
• Current arrangements
• Continuous simulation
• Event-based simulation
• Some considerations
Flooding Mechanisms

Australian Emergency Management Institute (2014)

Flash flooding
- <6hrs between rainfall and flood response (thunderstorms)
- Can occur anywhere
- Evacuation route: very short
- Duration: hours
Responsibilities for flood forecasting in Oz

• Bureau of Meteorology:
  – *Flood watch*: early advice that a significant risk of flooding is expected to affect specific communities (emergency services)
  – *Flood warning*: expected severity levels for floods in a particular region/catchment/location

• Local councils/agencies:
  – *Flash flooding*: a variety of generalised warning systems in place (flooding < 6hrs of rainfall)

• Dam owners
  – *Gated operations*: develop community warning systems as needed, and provide info on planned/unplanned releases
Some relevant dams

• Ross River Dam
• Warragamba Dam
• Wivenhoe and Somerset Dams
• Hume Dam
• Burrendong Dam
• Jindabyne Dam
• Portfolio of HydroTas dams
Some flash flood monitoring systems

<table>
<thead>
<tr>
<th></th>
<th>Melbourne Water**</th>
<th>Moreton Bay City Council</th>
<th>Adelaide - Current</th>
<th>Adelaide - Future</th>
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<tbody>
<tr>
<td>Approximate Area covered (sq km)</td>
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<td>2000</td>
<td>1000</td>
<td>1000</td>
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<tr>
<td>Number of catchments (currently)</td>
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<td>14</td>
<td>0</td>
<td>30</td>
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<tr>
<td>Rainfall sites (Real time telemetry)</td>
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<td>90</td>
<td>102</td>
<td>150</td>
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<td>Water Level/Flow monitoring sites</td>
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<td>30</td>
<td>40</td>
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<td>Forecast Locations (estimated)</td>
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<td>60</td>
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<tr>
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<td>Forecast Rain assessed?</td>
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<td>Flash Flood Warning service available</td>
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<td>Alerting of Response Agencies</td>
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<tr>
<td>Alerting of the Targeted people at risk</td>
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<td>Warnings via the media*</td>
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</table>

 Pagano et al (2016): Flood forecasting at the Australian Bureau of Meteorology

Event-based methods

- URBS, RORB
- HEC-HMS
- SCS-CN
- …

Continuous simulation methods

- GR4H/J
- PDM
- AWBM
- ...

BoM Forecasts

SWIFT: 7-day streamflow forecasts

- BoM/WIRADA
- Continuous simulation
- GR4H/NWP & BJP post-processing
- “… a burgeoning area of research” (Perraud et al, 2015)
- “Scientific hydrology”

HyFS: Hydrological Forecasting System

- BoM
- Event-based modelling
- URBS with rainfall forecasts in FEWS
- “… a system integration challenge” (me, pers comm)
- “Engineering hydrology”
“Despite all the good reasons advanced by hydrologists for using continuous approaches, practitioners often continue using event-based models and see them as the only solution”


“The demand for longer lead times and more accurate forecasts has driven the Bureau’s recent investment in continuous models”

Efficacy of event vs continuous models

• Comparison of event & continuous models in 178 catchments across France
• Lumped model (derived from GR4J) that includes soil moisture and routing
• Updating based on assimilating previous $Q_{obs}$ and $\Delta_{err}$
• Identical models except for initialisation of soil moisture:
  – “Poor Man’s” estimate
  – “Average” estimate
  – Based on API
  – Continuous accounting (1 year warm up period) Continuous
Efficacy of event vs continuous models

PE
Net PE / Net rainfall

P
Interception

AE
Direct runoff

Fixed capacity
Percolation

x θ
Volume adjustment factor
Effective rainfall

Unit Hydrograph (θ₂)

θ₂

Routing function
Q
Efficacy of event vs continuous models

“The main conclusion is that the best results were obtained when the model was run in a continuous mode… we believe that these results are not catchment-dependent (in particular we found no relation to catchment size or reactivity)”
Probabilistic flood risk

- Comparison of event and continuous models:
  - AWBM, SIMHYD, GR4H
  - storage routing model (simple and PDM-style losses)
- Continuous simulation:
  - Whole record
  - Subset of record
  - Large events
  - Flood frequency curve
- Event modelling:
  - Ensemble event
  - Monte Carlo

Calibrated to whole record

Probabilistic flood risk

Calibrated to flood frequency curve

Monte Carlo: annual losses

Savages Crossing

Annual Exceedance Probability (1 in Y)

Peak Flow (m$^3$/s)

- + + Annual loss maxima

Nathan et al (2016): Impact of natural variability on design flood flows and levels. HWR, NZ.
Monte Carlo: seasonal losses

Savages Crossing

Nathan et al (2016): Impact of natural variability on design flood flows and levels. HWR, NZ.
Monte Carlo: seasonal losses & spatio-temporal patterns

Savages Crossing

Nathan et al (2016): Impact of natural variability on design flood flows and levels. HWR, NZ.
Monte Carlo: Losses & Temporal Pats

Savages Crossing

1:100 AEP rainfalls:
8000 → 26000 m³/s

Nathan et al (2016): Impact of natural variability on design flood flows and levels. HWR, NZ.
10000 m$^3$/s result from 1:5 → 1:100 AEP rainfalls

Nathan et al (2016): Impact of natural variability on design flood flows and levels. HWR, NZ.
Influence of aleatory uncertainty reduces when floods -> levels

Nathan et al (2016): Impact of natural variability on design flood flows and levels. HWR, NZ.
Factors affecting applicability

Operational factors

Automated

Manual

Event-based

Continuous

Exogenous factors

Dynamic

Stationary
Factors affecting flood events

- **Operational factors**
  - Automated
  - Manual

- **Exogenous factors**
  - Dynamic
  - Stationary

**Continuous**

- Probability distributions of:
  - Areal rainfall depth
  - Temporal characteristics
  - Spatial characteristics
  - ... at multiple locations (not just catchment average)
  - Antecedent initial soil moisture soon computed
Some useful forecast outputs

Time to peak = \( \text{fn (rainfall forecast, hydrological model, operational factors, hydraulic modelling)} \)

Flood depth
Conclusions

• Tremendous advances made in science of forecasting using continuous simulation models
• In contrast, attention given to event-based models has largely tackled engineering and system integration issues
• There is a clear requirement for both approaches:
  – “automated” routine forecasts for large regions
  – “manual” operational forecasts during flood events in specific catchments
• Relative accuracy of either approach under forecast uncertainty depend on operational and exogenous factors
Thank you!