Practical application of Quantitative Precipitation Forecasts in flood warnings

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Introduction

The Bureau of Meteorology's flood warning role had its origin in the early 1900s, when warnings were based upon weather forecasts and the dissemination of rain and river level observations. Over time, local organisations in some areas also provided limited flood forecasting based on upstream river levels. Following the devastating floods of 1949 and the 1950s, the Commonwealth Government decided that a more sophisticated hydro-meteorologically based flood warning service was necessary. It was decided that this responsibility should rest with the Bureau as it was best placed to efficiently combine meteorological (rainfall) and hydrological forecasts to provide the maximum possible warning times (McKay 2002). The first quantitative flood warnings were issued by the Bureau in 1962 for the Macleay Valley in NSW.

The Bureau's national hydro-meteorologically based flood warning service is for catchments where the response time between heavy rainfall and flooding is longer than 6 hours. The smaller, or flash flood catchments, are provided with meteorologically based warning services, such as Severe Weather Warnings and Severe Thunderstorm Warnings. The Bureau also provides warnings of flooding from the ocean due to tsunami and, in some States, tidal flooding from storm surges.

In the late 1960's a Confidential Flood Advice (CFA) service was also introduced in NSW, then later in the other States, although the naming of the product varied. The CFA was based upon an assessment of catchment wetness and forecasts of heavy rainfall and was only distributed to the State Emergency Service (SES) as well as some other state and local government authorities. The CFA was the forerunner to the present publicly available Flood Watch product which aims to provide the community and emergency services with additional time to prepare an effective response to potential flooding.

Flooding is Australia's costliest natural disaster and this paper aims to demonstrate the importance of rainfall forecasts to achieve enhanced community safety and well being, which is a key strategic outcome for the Bureau (Bureau of Meteorology,2005), and to encourage meteorological researchers to focus on further improvements in this vital area.

Application of Quantitative Precipitation Forecasts (QPF) in flood warning services

The qualitative, or generalised, use of rainfall forecasts in flood warnings has occurred since the service started in the early 1900s. However, the use of QPF values in quantitative flood forecasting is a relatively high risk approach as the scale of most meteorological models is relatively large to the scale of catchments that are being hydrologically modelled. Even slight differences in the location of rainfall maximums on a synoptic scale can have a profound effect on the amount of rainfall and flooding that is experienced in even medium sized catchments of 5,000 to 10,000 square kilometres. The difficulties are more profound for smaller catchments, including flash flood ones, where the resolution of the present meso-scale model of 0.125^{o} is not fine enough to accurately capture most rainfall events for a specific catchment area. Therefore, QPF values from models are not taken literally as experience has shown that it is rare for the precise amount, location and timing of heavy rainfall to all be simultaneously captured by the models. Instead, the models are used to provide guidance as to which areas are likely to receive heavy rain recognising that there will be variations from the predicted rainfall scenario.

Flood Watch

Flood Watches are usually issued 24 to 48 hours ahead of flood producing rainfall and rely upon reasonably accurate QPF over a broader (generally larger than catchment scale) area. Depending upon the confidence the meteorologist has in QPF estimates, their values may be quoted in Flood Watches. For example, “50 to 100 millimetres” or “up to 150 millimetres”, along with the degree of flooding that can be expected, such as “minor”, “moderate” or “major”, or a range, are routinely quoted in Flood Watches in a number of States. Unless significant localised flooding is possible, Flood Watches are generally not issued for the very large catchments where several days, or longer, warning is available.

In NSW the Flood Watch is increasingly being used by the SES for its strategic planning and community flood education. In particular, Flood Watches are seen as being vitally important for the smaller catchments, including flash flood catchments, as well as for very flood vulnerable areas, such as caravan parks, where the available warning time is a critical limiting factor for a successful community response to flooding. In NSW, the SES aim to disseminate Flood Watches to the community, along with locally based flood advice and education material, within 1 hour of their issue by the Bureau.

The improvement of QPF over time is reflected in the performance of Flood Watches for NSW shown in Fig. 1. Since 1984 over twice as many floods are now preceded by Flood Watches and their accuracy has improved more than threefold. Importantly, during the last 10 years, over 90% of major floods have been preceded by a Flood Watch.

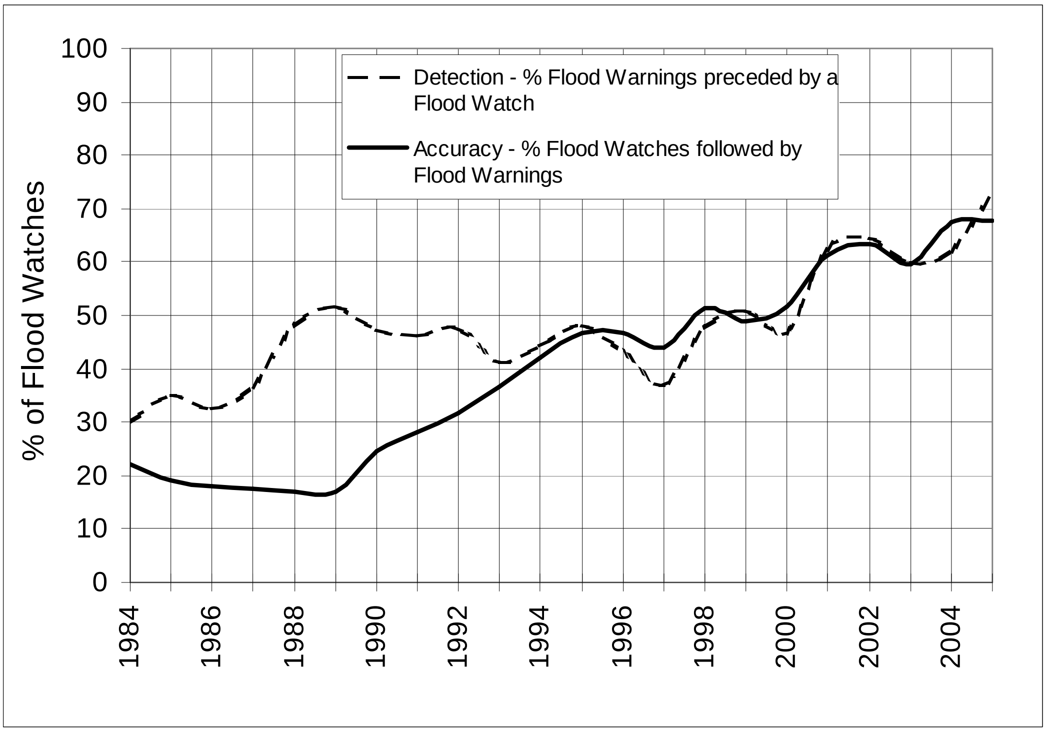

Fig.1: NSW Flood Watches – 5 year weighted average data.

In NSW the “Poor Man’s Ensemble” (PME) is seen as the most valuable guidance for determining the area to be targeted in a Flood Watch. Experience has shown that the PME is consistently more reliable than any individual model, although each of the models are still considered for their rainfall maximums. Naturally, the professional opinion of the Senior Meteorologist is still an over-riding input, as the Flood Watch must be consistent with the overall rainfall outlook contained in other weather forecast and warning products.

Flood Warning

QPF needs to be used in hydrological modelling for Flood Warnings when warning lead time requirements cannot be adequately met using recorded rainfalls alone. The extra warning time could be required to facilitate large scale evacuations during major floods, when the time between rainfall and flooding is less than for smaller events. QPF has also been used to help communities be better prepared for deteriorating conditions by flagging potentially higher flood levels during daylight hours when further heavy overnight rain is forecast.

Despite its limitations, QPF from the Bureau's MesoLapsPT125 model has been used with some success (and caution!) for a number of critical evacuation floods in NSW. In these cases the MesoLapsPT125 model results were only used after comparison with other models and discussion with the senior meteorologist. The use of model output is based more on a visual interpretation of graphical products rather than direct use of modelled grid data points across the catchment. It has also been the experience in NSW that the output of the MesoLapsPT125 model based upon the (larger) 00Z data set is often more accurate than the model run based on the 12Z data set.

Case studies of QPF application in NSW

Flood Watch

An excellent example of the Flood Watch's value in allowing the SES to respond early was the Tamworth, January 2004 flood, where up to 3500 campers attending the annual Tamworth Country Music Festival were evacuated from low-lying floodplains adjacent to the Peel River. In this instance a Flood Watch was issued approximately 60 hours before the onset of minor flooding, enabling the SES to deliver prior warning and advice to campers about the possibility of flooding and what precautions they should take to ensure an efficient evacuation if one was required. Education through Flood Watch messages allowed the SES to educate campers about the risk posed by flooding to their campsites (Opper and Gissing 2005). The local SES also used the extra time to secure resources from outside the region to help them manage the flood.

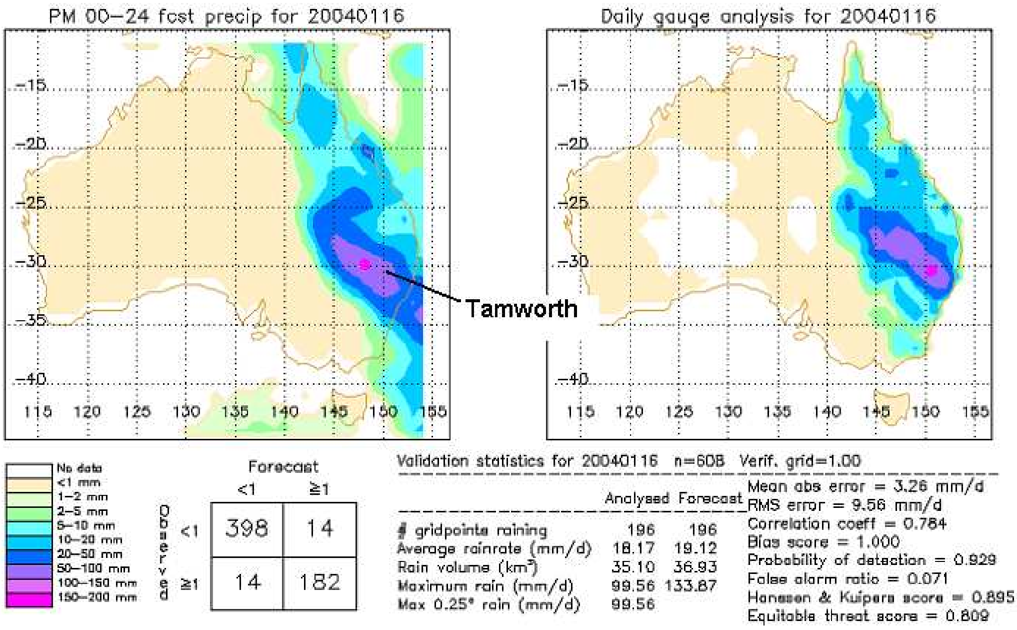

Fig. 2: Poor Man's Ensemble prediction for 16 January 2004.

Although the models had the maximum rainfall well to the west of the Tamworth catchment, as shown in Fig. 2, the overall average rainfall value from the model was a reasonably reliable indicator of the flood threat for the Peel River as well as adjoining areas, for which Flood Watches were also issued.

Flood Warning

QPF was used to predict a near-record (6.8 metre) major flood at Bathurst in August 1998. Figure 3 shows how key major flood predictions were made well ahead of the heaviest rain that fell from 9pm 7/8/98 till 3am 8/8/98. Although this rain fell later than predicted by the MesoLaps model, the forecast totals were fairly accurate. As a result the SES was provided with over 15 hours warning time of major flooding during which they successfully evacuated some 721 people from 600 houses. Barely 6 hours warning time would have been available for this flood using recorded rainfall only.

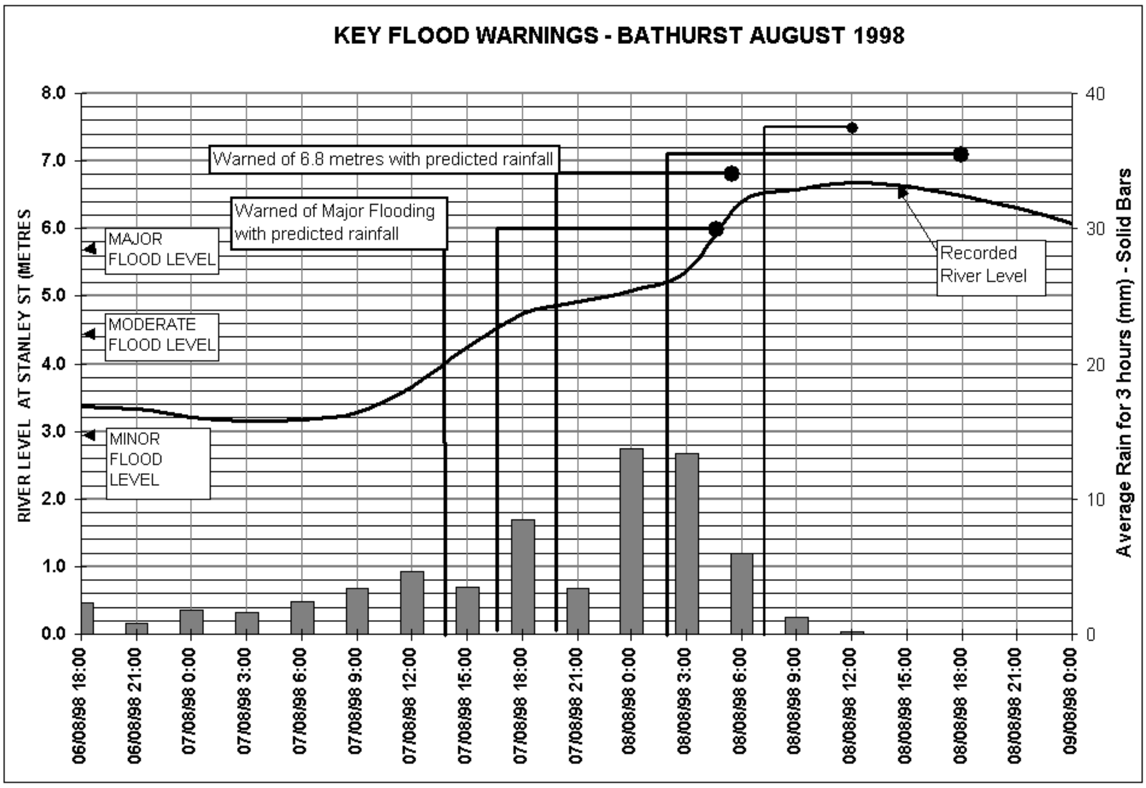

Fig. 3: QPF based flood predictions – Bathurst August 1998.

The Bureau has also successfully used QPF for the major floods of February 2001 and the June 2005 at Lismore, NSW, when warnings issued during daylight hours were based on expected heavy overnight rainfall. These warnings gave flood affected businesses and residents more effective lead times than would have been the case had these warnings been based on recorded rain and issued during night-time.

By comparison, there was some criticism of the Bureau for being “late” in identifying major flooding at Kempsey after the March 2001 flood, for which hydrological modelling was based upon recorded rainfall. Although 18 hours warning was given of overtopping of the CBD levee, peak river level predictions were only made when the heavy rainfall rates eased, which was about 6 hours before the levee was overtopped.

Future directions

The improved performance of Flood Watches in NSW as well as the confidence to apply QPF in quantitative flood warnings is a reflection of the improved accuracy of the numerical models. For the NSW hydrologists some key highlights over the past decade have been the improved resolution of the meso scale models and the introduction of the PME. As well, the availability of graphical displays for the numerous forecasting products and field data, especially radar, on the Bureau's intranet and public internet sites has been very useful operationally and our thanks goes to the various people in the Bureau who helped develop these products.

A "wish list" of future developments includes the following:

- Improved statistical guidance for rainfall higher than the 50 millimetres over 24 hours presently provided with the PME. There is a special need to better understand the probability for high/extreme rainfall that could cause severe flooding.
- Presentation of modelled rainfall data on a GIS platform that can be compared in real time with overlapping recorded rainfall as well as radar images. The work by Alan Seed, described in other sections of this conference, is also seen as crucial to maximise the outcomes achieved from the Bureau's radar upgrade project.
- The PME products should be operationally supported to ensure their availability on a more robust basis.
- A graphically based Flood Watch product, similar to the thunderstorm guidance, showing the likelihood of flooding for internal and external users.
- Higher resolution modelling to more accurately predict extreme rainfall as well as rainfall over the smaller catchments, including the flash flood areas in the major cities and regional centres.
- Assimilation of all available data into numerical models such as radar and satellite derived data. For example, Speer et al. (2005) have shown that by assimilating operationally available quickscat satellite data, vastly improved QPF forecasts for the NSW north coast were achieved for the March 2001 subtropical cyclone. This technique will soon become routine in a new version of the Bureau's GASP model.
- Incorporation of rainfall values from the flood warning networks into the QPF verification process.

Conclusion

The improved performance of Flood Watches in NSW as well as the confidence to apply QPF in quantitative flood warnings has already yielded some positive measurable outcomes for a number of events. There is, however, the need to improve the reliability of QPF across a greater range of catchments, including flash flood areas.

The Bureau's Vision for 2005-2010 is "The safety, security and general well being of Australians enhanced by world standard meteorological services" (Bureau of Meteorology,2005). Improved QPF for flood warning services provides an ideal opportunity for the Bureau to enhance its reputation in this area.

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