15B.1 RADAR RAINFALL ESTIMATES AND NOWCASTS:

THE CHALLENGING ROAD FROM RESEARCH TO WARNINGS

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1. Introduction

Warnings are a big part of the value of weather and climate information because they build the ability of people to use the information to make decisions and take actions that will help them to minimise loss of life and assets and disruption to lifestyle activities.

The Australian Bureau of Meteorology delivers a heavy rainfall warning service based on weather radar rainfall estimates and nowcasts. The heavy rainfall warning is a part of the warning service for severe thunderstorms and is mentioned as “heavy rain which may lead to flash flooding”.

The range of the Australian climate, from tropical in the north to oceanic in the south, and the concentration of densely populated areas along the east coast, are some of challenges of this service. The paper describes the process of designing, planning, implementing, and improving this service and the way that the challenges were addressed. The rainfall estimates are based on data provided by the Australian radar network that provides good quality radar reflectivity observations in the major cities; these data undergo a strict quality control process and are calibrated with a dense network of real-time rain gauges. Different rainfall intensities and distribution over the Australian territory make the use of a homogenous and nationally consistent “intensity or amount threshold based” warning system difficult .

It is necessary to provide forecasters and specialized users with data that expresses the “impact” of the rainfall, not only the amount. The design standard for minor hydraulic works in most Australian cities is the storm with an average recurrence interval (ARI) of 1 in 10 years.

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The Bureau provides a warning to the public when the rainfall accumulation at a point has a 10% probability of being exceeded in a year over a given duration (1 hour by definition). This is referred to as rainfall with a 10-year Average Recurrence Interval (ARI). This rainfall will have approximately the same impact on a city independent of the climate.

2. Radar rainfall estimation

The Australian Bureau of Meteorology operates a heterogeneous network of weather radars. The radars that serve the major cities are S-Band Doppler radars with a 1 degree beam width.

The radars that serve the regional areas are C or S band depending on the climatology of the area and mostly have a beam width of 2 degrees. The radars that are used for quantitative precipitation estimation run a standard volume coverage pattern with 14 elevation angles over a 6 or 10 minute period. The quantitative precipitation estimates (QPE) are provided by a suite of algorithms named Rainfields [1]. Rainfields includes corrections for *reflectivity measurements* and *converts the reflectivities into rainfall*. Corrections applied are: partial beam blocking, variations in the vertical profile [2, 3], clutter identification through clutter masks and vertical profile gradients, and the use of separate Z-R relationships for convective and stratiform rain [4]. Rainfileds also performs the *rain gauge adjustment* every 30 minutes, and a *real-time mean field bias adjustment* [5]. The rainfall accumulations for the previous 0.5, 1, 2, 3, and 6 hours are updated with each new volume scan. This corresponds to the first stage in Rainfields processing of data and ensures a high quality of the quantitative estimate of past rainfall.

3. Rainfall nowcasting

The next step moves the rainfall estimates into the nowcasting time frame domain, which is up to 90 minutes. The quantitative precipitation forecasts are provided by the Short Term Ensemble

Prediction System (STEPS) [6,7] which is used in two configurations:

- the first configuration is the “radar” nowcast, for a lead time up to 90-180 minutes; STEPS uses stochastic space-time models of radar observation error [8] and rainfall to generate a 40-member ensemble that is updated every 6 or 10 minutes; this configuration is known among forecasters as quantitative precipitation nowcast (QPN), or STEPS-RADAR.
- the second configuration is the blending of radar into/with NWP to generate a 40 member time-lagged ensemble of rainfall nowcasts out to 12 hours; this configuration is named by the forecasters as QPF or STEPS-NWP or STEPS-VSR (very short range).

The ensemble is used to calculate the probability that the rainfall accumulation in the next hour will exceed 1 in 10 year ARI and to calculate the ensemble mean which is used as the expected rainfall.

4. Generating the guidance products

The Bureau of Meteorology publishes maps of rainfall ARI for a range of durations ranging from 6 minutes to three days. The ARI frequency for the 0.5, 1, 2, 3, 6 hour rainfall accumulations at each pixel is calculated by linear interpolation between the 1, 2, 5, 10, 20, 50, 100 year ARI for that location. Previously, the forecasters used maps (Fig.1) and compared the rain gauge estimates with these thresholds. There are too many combinations for rainfall durations and forecast lead times for the forecasters to inspect each image separately so a set of summary products was constructed. The designed product (Fig. 2) expresses the rainfall directly as ARI.

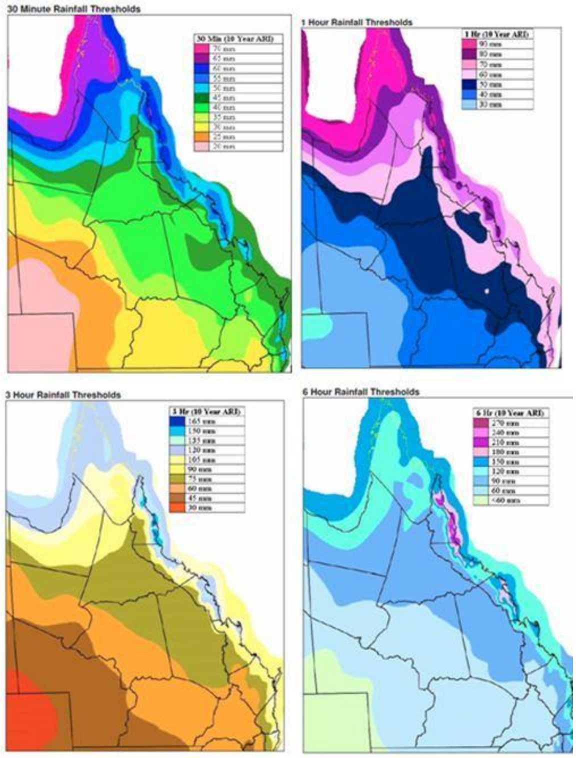

Fig. 1 Example of ARI maps for 30-minute, 1 h, 3h, 6 h rainfall thresholds used in Queensland before Rainfields.

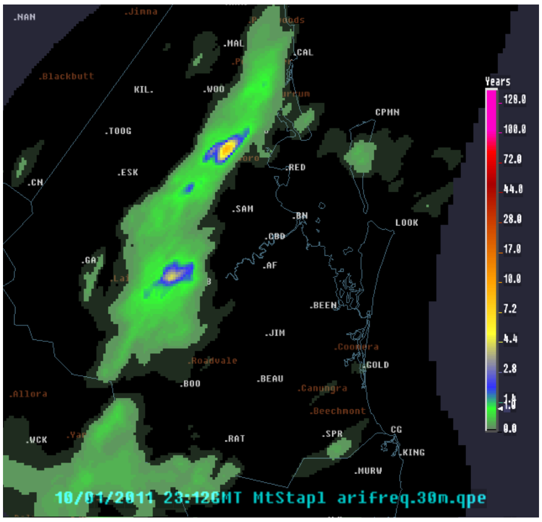

Fig. 2 Example of a 30-minute radar rainfall estimate expressed as ARI.

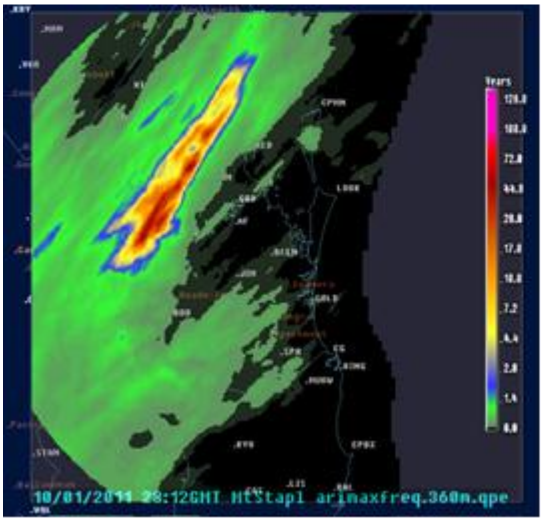

Fig. 3 Example of a maximum ARI within the past 6 hours for radar rainfall estimates.

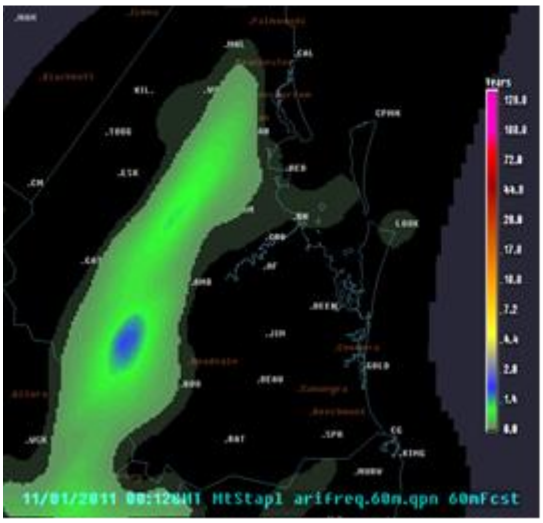

Fig. 4 Example of a 60-minute ensemble mean forecast expressed as ARI.

The first product designed as a base for warnings was the maximum ARI for a rainfall estimate over all five durations, Fig. 3. This product provides a warning that the rainfall accumulation at a point has crossed the warning threshold and a warning should be considered for that location. It provides a clear *diagnostic* tool of the *risk* associated with the rain accumulations. This is one of the big changes made in the heavy rainfall estimation.

The second summary product (Fig.4) integrates the radar rainfall estimates with the nowcasts and calculates the probability that a 60-minute accumulation will exceed an ARI threshold. The first step is to use the 40-member ensemble to calculate the probability that a combination of the radar rainfall for the past and the nowcast will exceed the 1 in 10 year ARI. This is repeated for each combination of radar QPE and QPN, see Fig. 5.

Fig. 5 The calculation of the maximum probability for a combination of QPE and QPN.

5. Developing the operational service

Rainfields, despite the advanced science behind it, could not be implemented directly in operations without further development because:

- Rainfields generates a total of 7000 radar rainfall products an hour; and this was/is overwhelming for the actual decision makers in the forecasting room.
- The forecast process is not yet designed to use the new products and it is difficult to convert nowcasts into warnings.

As a result scientists and IT experts modified the visualisation software to show new fields and generated properly geo-referenced netCDF files for all products.

A new forecast process was needed so that the new products could be used in the service. A draft forecast process has been developed and then refined during workshops where senior forecasters were taken through case studies.

As the forecasters were not trained to interpret the new products, the trainers and scientists generated case studies for each Regional Forecast Office and developed a simulator so case studies could be run as if in real time. They prepared training material and published it on a number of platforms that were accessible for distance-learning.

A real-time trial is planned to test the impact of the new products on a larger pool of stakeholders. This is scheduled for the 2014-2015 Australian summer in the Regional Forecasting Centre in Sydney, known as The Sydney Forecast Demonstration Project.

6. **Forecasters role**

For Rainfields to be adopted by forecasters, new approaches had to be taken. It is not enough to simply generate the quantitative precipitation forecasts and estimates and expect them be used operationally.

In building Rainfields the scientists integrated the forecasters expertise and knowledge in the process of designing the products. Rainfields implementation required high levels of user involvement and management support. Users' participation in the design and development of the products had several positive results. First, users had opportunities to mould the system according to their priorities and requirements, and even more opportunities to control the outcome. Second, they reacted positively to the change process.

Currently the forecasters subjectively adjust the estimates and the forecasts (Figure 7) but this is likely to diminish as the quality of the estimates and forecasts improves and the decision support system matures (Figure 8)

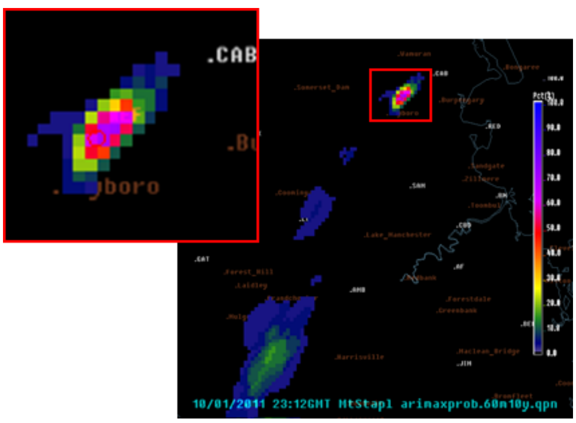

Fig. 6 An example of the maximum probability summary product for a 1-hour accumulation and 1 in 10 year ARI.

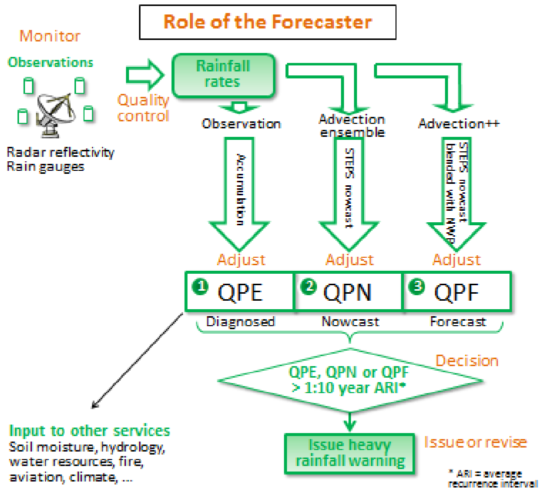

Fig. 7 Forecasters adding value to Rainfields products in the forecasting process.

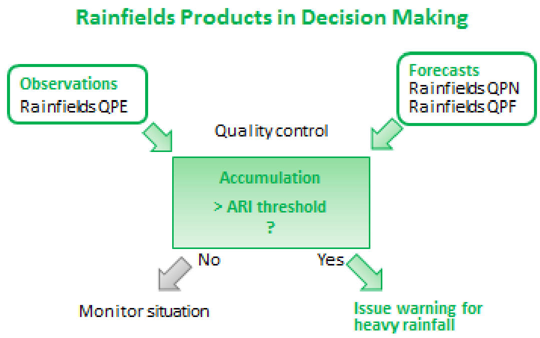

Fig. 8 Rainfields products in a decision making support system.

7. Conclusion on implementing the change

Innovative science disrupts the operational process because it brings about a change. An effective meteorological service has to embrace these disruptions, to give them the supportive infrastructure and to facilitate the implementation of the change. The approach used incorporated service requirements in product specification,involving senior foreacsters and trainers summarising the large volume of products, and trailing of new products is a series of workshops using case studies Senior forecasters and trainers summarised the large number of products efficiently. Senior forecasters trialled new products in a series of workshops using case studies. The implementation plan included *phases* (first QPE products, later QPN, last QPF) giving time to the forecasters to familiarize with the new approach.

The use of ARI approach ensures that warnings are based on a process that begins with the production of information about weather and climate and ends with effective loss minimising activity. They must be customized and consistent with experience. They must apply to severe events over a range of durations (0-6h), very dependent on collective and individual perception of risk, underscore the importance of community hazard and risk awareness.

References

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