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REQUIREMENTS FOR WEATHER RADAR DATA

Review of the current and likely future hydrological requirements for Weather Radar data

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SUMMARY AND PURPOSE OF DOCUMENT

This document provides an overview of the current status and future requirements pertaining to the use of weather radar data in hydrological applications. The current status represents best weather radar data use for hydrologic applications in countries with advanced operational hydrologic forecasting systems. The requirements advanced herein are believed to be applicable to the needs of Hydrologic and Meteorological Services worldwide.

ACTION PROPOSED

Review document for discussion at the workshop on weather radar data exchange in April 2013.

WORKSHOP ON RADAR DATA EXCHANGE – REQUIREMENTS FOR WEATHER RADAR DATA (EXETER, UK, 26-28 APRIL 2013)

1. Introduction

Which application area is being reflected in this report?

This report focuses on the use of weather radar data by operational hydrological modelling and forecasting in countries with advanced operational hydrologic forecast systems. The requirements advanced are believed to be relevant to the needs of Hydrological and Meteorological Services worldwide.

Apart from the author, were others consulted in the generation of this report?

The following individuals contributed substantially in this report with information and comments: Mr. David Kitzmiller, US National Weather Service; Dr. Alan Seed, Australian Bureau of Meteorology; Prof. Witold F. Krajewski, The University of Iowa, USA; Prof. Marco Borga, University of Padova, Italy.

2. Current requirements and use of the data

This section addresses the current requirements for weather radar data in hydrologic forecasting with the knowledge this data exists rather than from a technology free perspective.

What is the data being used for by the application area? Both directly (eg assimilation of Doppler winds by regional NWP) and indirectly (eg contributes to the forecast skill in severe weather forecasting)?

In Meteorological and Hydrological Services with advanced hydrologic prediction systems, the data is used to develop precipitation estimates that are then used to provide input to hydrologic streamflow prediction models and flash flood guidance models for flood and flash flood prediction. The weather data is also used for developing nowcasts for flash flood prediction systems, and to improve rainfall forecasts through their assimilation into mesoscale numerical weather prediction models. In some cases when there are substantial historical archives of quality-controlled weather radar data, the data is used for estimating the characteristics of design storms.

What level of pre-processing of the data is preferred by the application area? Is this currently either insufficient or too much?

Extensive automated pre-processing of radar moments, to mitigate clutter ad non precipitation echoes, is typically carried out prior to their application in precipitation estimation. Operational hydrologic applications require the best precipitation estimates available and this is typically obtained for operational hydrologic prediction on national scales using a combination of data from various sensors: radar, rain gauge, satellite sensors. In most cases, this is not currently sufficient to produce reliable precipitation estimates, and real-time adjustments are enforced by hydrologic forecasters.

What is the use of quality indicators in the processing of the data from weather radars?

Because the radar data are used in conjunction with rain gauges to produce best estimates of precipitation, error statistics are routinely obtained. When a real time bias adjustment method (based on Kalman Filtering) is used to adjust for radar bias (e.g., U.S.A.), the variance of the error residuals over a given time period and over a given region is obtained in real time and it is used to correct the radar bias. In other cases (e.g., Australia), the mean and standard deviation of $10\log_{10}$(30-min gauge/radar ratio) is used for each radar, updated monthly, and the determination coefficient of the correspondence of daily accumulations between the rain gauge and the radar data. These quality indicators are used to monitor the accuracy of the precipitation observations, expose situations during which the available quality control procedures failed, and to demonstrate improvements in precipitation estimates due to new algorithms. Hydrologic model simulations and available corresponding flow observations are also used to identify the effectiveness of the precipitation products for operational hydrologic prediction.

What are the major constraints in the use of the data by the application area?

Inadequate quality control of radar data and mainly biases in the radar data degrade operational hydrologic predictions and simulations, and require forecaster adjustments. The latter in turn require good forecaster experience with the behaviour of the precipitation product for the region of interest and with the hydroclimatology of the region. Other constraints exist on a case by case basis. For example: (a) hydrologic models are calibrated with gauge data but used with radar data yielding degraded performance, generating forecaster bias against radar data; (b) catchments of interest have no radar coverage or are at far ranges from the radar; and (c) the nature of the existing hydrologic models that are not designed for use with raster radar data. In this latter respect, the design of appropriate hydrologic models would be done in conjunction with the design of the appropriate space time resolution of the available radar data to be commensurate with hillslope hydrologic processes. Mountainous terrain degrades the applicability of radar data, due to beam blockages when the unit is sited at a low elevation, and a tendency to overshoot precipitation when the unit is sited on a peak. Radar has limited utility in cold weather, when the beam detects only snow, which complicates the assessment of liquid content.

Is consistency of availability of the data important for the application area?

Consistency of data availability is very important together with the availability of reliable error statistics of the resultant rainfall fields. In the US, radar precipitation is seldom used in hydrologic operations over mountainous regions because of spatially fragmentary coverage.

Is it understood where these data have the biggest impact on the application area?

Current understanding is that the most immediate impact of the radar data is for real time flash flood prediction and associated nowcasting of rainfall fields.

Is the relative value of weather radar data to other sources of data well understood in the application area?

When the focus is on operational hydrologic prediction with existing operational-quality hydrologic models for large basins, the relative value of the radar data for catchments that are reasonably well instrumented with gauge data or snow sensors is relatively low. When the focus is on flash flood prediction in small catchments under tropical or other convective regimes, the value of the radar data is relatively high (assuming they are reasonably well calibrated).

Is there a strong or critical dependency on other observational data to support the use of weather radar data in your application area?

There is critical dependence on real-time rain gauge data for operational hydrologic applications.

3. Known future requirements for use of the data

The use of known within the title of this section is to enable of focus of agreed future uses of the data rather than more speculative uses of the data, which is covered in section 4.

Is there any general trend in these requirements (eg more demanding in terms of availability or spatial coverage)?

The requirements generally vary between regions, National Meteorological and Hydrological Services, and specific purpose of data use. For the main focus of this document (operational hydrologic applications) the precipitation field is of interest. In the US, improved precipitation fields for operational hydrologic applications (better data – more demanding requirements) are the target of planned future activities with the requirement to reduce biases using (a) enhanced quality control to filter non precipitation echoes and (b) data from multiple radars to estimate better the reflectivity versus rainrate relationship. Deployment of dual polarization capability in the US national radar network aims to further improve the precipitation rate estimation, requiring the development of new algorithms. In Australia a large increase in the number of requests for historical data is observed for use in climatology studies. This creates the requirement to re-analyse old data using current algorithms to get a consistent dataset covering 10-20 years. In Italy a significant known future requirement pertains to the integration of the various data sites to form a consistent composite, maintaining consistency in data availability.

Have these future requirements been published or communicated widely with the weather radar operator community?
Communication of such requirements is made routinely through the national hydrological or hydrometeorological services and through the development of academy reports and communications for the operator community.

Of the parameters currently measured by weather radars which are likely to be the most important or more greatly used in the future?
Precipitation rate is the most significant parameter for hydrologic applications of weather radar data.

4. Possible future requirements for use of the data

This section should reflect the possible direction of the application area and the consequential impact this may have on the requirement for weather radar data.

Will the temporal and spatial requirement for data change significantly in the future?
Whether higher temporal and spatial requirements for weather data (say beyond hourly 4kmx4km) resolutions) will improve the reliability of hydrologic applications (especially operational hydrologic applications) is not clearly proven or disproven at this point. In any case, higher data resolutions should also require different hydrologic models that are designed to work with raster data and with sound physical principles on hillslope scales. Existing studies using operational-quality models show that the influence of radar uncertainty on the quality of flow simulations is higher for smaller spatial scales, increasing flow forecast uncertainty. Data quality at higher rainfall rates must be maintained if higher resolution data is produced to be profitably utilized by existing operational hydrologic models for flood and flash flood prediction. From an operational flow prediction perspective, resolution of 1km or so implies the observation of precipitation features with lifetimes that are less than the time it would take to issue and to respond effectively to a warning.

Is it likely there will be a reduction in the requirement for weather radar platform based observational data?
Expansion of weather radar data usage is expected in an operational environment, especially as regards flood and flash flood prediction.

Will new forms of quality data be required, especially to better exploit the data?
New forms of data quality would be required to improve quality as discussed in previous sections, and to maintain consistency in regions with multiple radar coverage. In addition, quantitative estimates of radar precipitation uncertainty (quantitative quality control indicators) should make a standard feature of future data availability.

Will less or more pre-processing of the data be required (the raw data or refined products question)?
More processing would be required because the main requirement for a reliable operational hydrologic application is a reliable precipitation field. Thus, in Australia the next generation radar quality control system would provide the user with QC indices to allow choice of QC level data for a particular application; in Italy new pre-processing of data should consider more properly the network geometry and multiple radar coverage; in the US dual polarization capability will lead to advanced quality control algorithms.

5. Further points to consider

It is considered important to develop guidelines for radar network design based on hydrologic forecast requirements. Typically hydrology has not provided quantitative requirements for radar network design. This would address issues of type of radars most appropriate for hydrologic applications by the nature of the terrain and hydroclimatology of a region. For example, it may be most profitable from a hydrologic perspective to have several radars of lower wavelength with dual polarization capability to effectively cover mountainous catchments of interest than a single S-band radar that would most likely suffer from significant ground clutter effects. Issues of radar data integration from multiple radars of various type arise in this context and require study.
It is also considered important to enhance hydrologic forecaster training in radar hydrology for effective real time adjustment of radar-based precipitation data to improve hydrologic predictions of flow. Such training would cover the basics of precipitation estimation using radar data; random errors and biases of weather radar data, and potential causes of such errors; comparison of radar precipitation fields with raingauge observations in various hydroclimatic regimes and geomorphic regions; influence of weather radar precipitation errors to flow simulations of operational-quality hydrologic models; strategies for adjusting radar precipitation estimates for improved real time flood and flash flood prediction. Training should also be supported with data and information that among other issues document well climatic characteristics of precipitation for comparison with climatologies derived from specific radars.

6. Summary

The key points discussed are as follow:

(a) Significant use of weather radar is made in operational hydrologic forecasting of floods and flash floods worldwide. The radar parameter used in these applications is precipitation rate.
(b) Operational hydrologic applications require significant quality control of radar precipitation fields for removal of biases (local and mean field bias) and other detrimental errors. Such quality control has a critical dependence on real time rain gauge data.
(c) Requirements are advanced for: (i) quality control indicators to become an integral part of the available radar precipitation data; (ii) hydrologic input to radar network design for improved precipitation fields in regions of varying terrain and climate; (iii) development of consistent radar precipitation databases for use in hydroclimatological studies; and (iv) hydrologic forecaster training in radar hydrology.
(d) An issue that remains to be addressed as better quality data become available, concerns the development of a new generation of hydrologic models that represent adequately hillslope scales and that are commensurate with radar precipitation data possessing higher-than-present resolution.