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Experimental Location Specific Probabilistic Rainfall Nowcast

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定點概率臨近降雨預報試驗

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摘要

香港天文台現時業務運行「小渦旋」臨近預報系統，並通過網站和手機應用程式提供定點降雨預報，這類確定性預報簡單直接和易於理解，適合一般公衆人士使用。然而，對個別人士或機構而言，因其業務運作受降雨的影響各有不同，概率預報或可提供更爲適切的信息。天文台遂通過調控用於追踪雷達回波的光流變分運算法所採用的參數，產生包含 36 個成員的集合預報，並在這個基礎上試驗製作定點概率臨近降雨預報。按 2014 年春季的一小時降雨預報數據來作驗證，相應預報概率爲 50%、並以閾值 0.5 毫米、5 毫米和 30 毫米計算的觀測概率分別爲 55%、50%和 23%；而以閾值 0.5 毫米計算，考慮預報概率超過 50%爲降雨情況，相對操作特徵曲綫 (relative operating characteristic (ROC) curve)顯示檢測概率接近 70%，虛報概率則僅爲 1%。驗證結果顯示，概率臨近預報能提供頗爲可靠的降雨指引。

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Abstract

The Hong Kong Observatory (HKO) currently operates a nowcasting system called the “Short-range Warning of Intense Rainstorms in Localized Systems (SWIRLS)” to provide location-specific rainfall nowcasts through the Internet website and mobile apps. These deterministic products are simple to use and easily comprehensible, thus most suitable for the general public. However, probabilistic quantitative precipitation nowcast (PQPN) can potentially provide more useful and relevant information for decision making, particularly of individuals and organisations bearing various tolerance levels under specific environments. HKO has in recent years developed a “SWIRLS Ensemble Rainfall Nowcast (SERN)” system that makes use of 36 members with various parameters in the variational optical flow tracking of echo motion. In this experiment, PQPN products are generated based on SERN outputs to demonstrate its potential uses. A systematic verification has also been conducted with data collected in the spring of 2014. The observed frequencies corresponding to the 50% forecast probability with hourly intensity thresholds of 0.5 mm, 5 mm and 30 mm are 55%, 50% and 23% respectively. Relative operating characteristic curve further depicts that at hourly intensity threshold of 0.5 mm and probability of exceedance at 50%, the probability of detection achieves about 70% whereas the probability of false detection is only 1%. The results signify the capabilities to provide reasonably reliable PQPN and to discriminate between rain and no-rain scenarios.

1. Introduction

The Hong Kong Observatory (HKO) started developing the "Short-range Warning of Intense Rainstorms in Localized Systems (SWIRLS)" (Yeung, 2012) back in 1999 to support its 3-tier colour-coded rainstorm warning system. In recent years, SWIRLS has been extended to provide location-specific rainfall nowcasts through the Internet website and mobile apps directly to the public (Woo, 2013a & 2013b).

These products, deterministic in nature, are simple to use and easily comprehensible. Hence they are very suitable for public consumption. Nevertheless, certain individuals and organisations may have different tolerance levels under specific environments. For example, a kindergarten graduation ceremony would have to be moved indoors even if there is the slightest chance of rain, while a competitive race for trained athletes may go ahead even though showers are likely. Probabilistic quantitative precipitation nowcast (PQPN) could contribute more useful and relevant information towards users' decision making processes.

2. Methodology

SWIRLS adopts a variational optical flow algorithm, namely "ROVER", to track radar echoes (Cheung & Yeung (2012) and Woo, Cheng & Wong (2014)). There are 6 tunable parameters in ROVER to control the tracking of radar echoes. By perturbing these parameters, various motion vector fields and QPF could be generated. In turn, PQPN based on multiple QPF could be prepared.

The "SWIRLS Ensemble Rainfall Nowcast" (SERN) system has since been constructed. It comprises 36 members and is updated every 6 minutes, in line with the radar scanning cycle. Products are visualized with several tools. Figure 1 depicts a sample meteogram of box plots that shows the observed rainfall amount in the past hour and the probabilistic forecast rainfall amounts in the next 6 hours, based at 18:00 on 15 Sept 2014 (HKT) during the passage of Typhoon Kalmaegi (2014). The meteogram delineates the spread of rainfall depth for designated spatial coverage and is useful in supporting the operation of rainstorm warnings.

3. New Products

Experimental trials using SERN outputs to generate probabilistic rainfall nowcast products have been conducted. Two kinds of products, rain intensity maps and rainfall probability contour maps, have been attempted and are described below:

3.1 Rainfall Intensity Map at Specified Percentile

Figure 2 and Figure 3 show the forecast hourly rainfall intensity maps at the third quantile and the extreme respectively. To generate these maps, for each grid point the QPF from the ensemble of members are ordered by rainfall amount and then extracted based on a specified percentile. The rainfall intensity map is then generated by aggregating the associated QPF at all grid points.

The specific percentile would affect the probability of detection (POD) and false alarm ratio (FAR). For circumstances that demand higher safety margin, higher POD may be favoured at the cost of slightly higher FAR. The third quantile, or equivalently 25% exceedance probability, adopted in Figure 2 would better serve the purpose than the deterministic rainfall nowcast in such a case. The rainfall intensity map at Figure 3, which takes the extreme QPF for all grid points, alerts on the worst case scenario.

3.2 Rainfall Probability Contour Map at Specified Rainfall Intensity

Another way to visualize PQPN is to use a probability contour map as illustrated in Figure 4. To generate this map, the rainfall intensity threshold is fixed and the probability of exceedance at each grid point is determined by counting the number of ensemble members that have QPF exceeding the intensity threshold. In Figure 4 for example, the rainfall intensity of 0.5 mm/hour is chosen and the probability contour indicates that it is likely to rain over the western and northeastern parts of the Pearl River Delta Estuary, including Hong Kong. Figure 5, which shows the observed rainfall map corresponding to the same intensity threshold during the same period, depicts general agreement with the probabilistic rainfall nowcast in this case.

4. Verifications

4.1 Data Set

To gauge the performance of the PQPN, data in the spring, i.e. 1 Mar to 31 May, of 2014 from SWIRLS are collected. They are verified with reliability diagram and relative operating characteristic (ROC) curve, as described below:

4.2 Reliability Diagram

Reliability diagrams (Hartmann *et al.* 2002) are constructed by plotting the observed frequency against the forecast probability. It effectively shows how often a forecast probability actually occurs. A perfect forecast system would have actual percentage of events same as the forecast probability for the whole range of forecast probabilities, thus all points would lie on the diagonal line.

The reliability diagram of SERN is plotted in Figure 6. As shown, the observed frequencies corresponding to the 50% forecast probability with hourly intensity thresholds of 0.5 mm, 5 mm and 30 mm are 55%, 50% and 23% respectively. It signifies that the PQPN is fairly reliable for light to moderate rainfall, though somewhat over-confident for heavy precipitation.

4.3 Relative Operating Curve

ROC curve, also known as receiver operating curve, is a plot of POD against the probability of false detection (POFD), defined as the number of false alarms divided by the total of false alarms and correct negatives, for the whole range of observed frequencies. The diagonal line indicates no skill at all while an ideal forecast system would occupy the upper left triangle entirely. Generally speaking, a forecast system with higher discriminating capability would have larger area between the ROC curve and the diagonal line.

The computed ROC curve at Figure 7 depicts that at hourly intensity threshold of 0.5 mm and probability of exceedance at 50%, the probability of detection (POD) achieves nearly 70% whereas POFD is only 1%. This signifies that SERN has a capability to discriminate between rain and no-rain scenarios.

5. Conclusion and Discussion

By perturbing parameters adopted in the variational optical flow algorithm for radar echo tracking in the SWIRLS nowcasting system, multiple QPF based on the same set of observations were produced and from which PQPN were generated. Verification using data in the spring of 2014 indicates generally reliable probabilistic forecast for light to moderate rainfall, as well as an overall ability to discriminate between rain and no-rain scenarios.

In the future, the verification would be extended to cover all seasons in 2014 or longer for a more holistic view of the performance of PQPN. It would also be interesting to inspect the performance of PQPN under different weather types. Alternative perturbation methods, such as perturbing the deterministic motion field by historical error vectors, may also be experimented.

It is envisaged that, upon completion of more detailed analyses and experiments, PQPN products may be routinely generated to support forecast operation and for reference by trained users.

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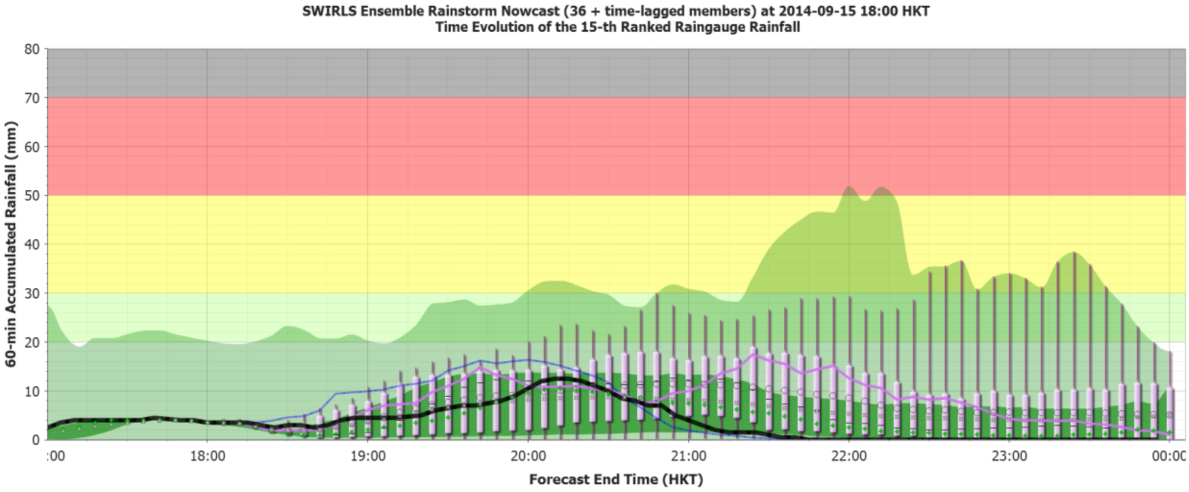

Figure 1. A SERN meteogram available minutes after 18:00 on 15 Sept 2014 (HKT). The box plots represent the ensemble forecast based on 18:00. The pink and blue lines show deterministic results from two selected members, whereas the shadow area depicts time-lagged ensemble. The thick black line indicates the actual amount eventually recorded.

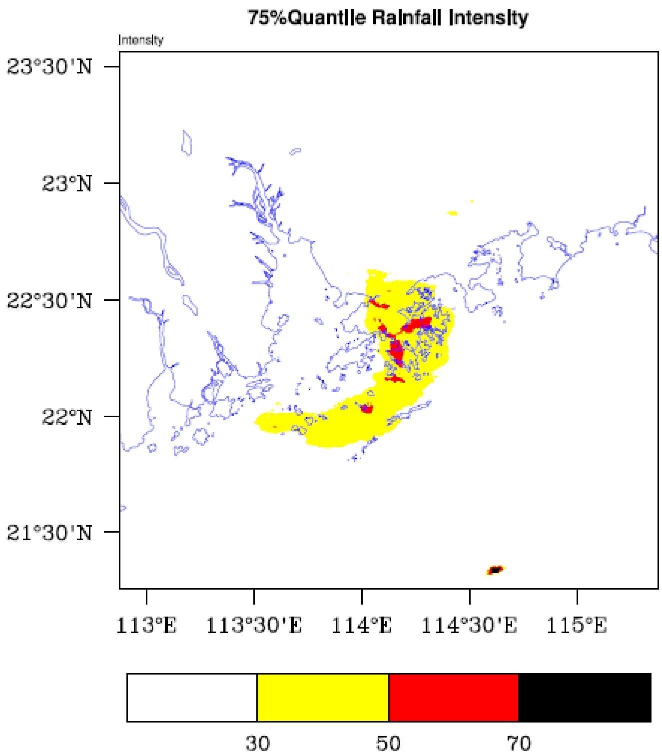

Figure 2. A forecast hourly rainfall intensity map at the third quantile, i.e. 25% exceedance probability, based at 23:00 on 8 May 2014 (HKT).

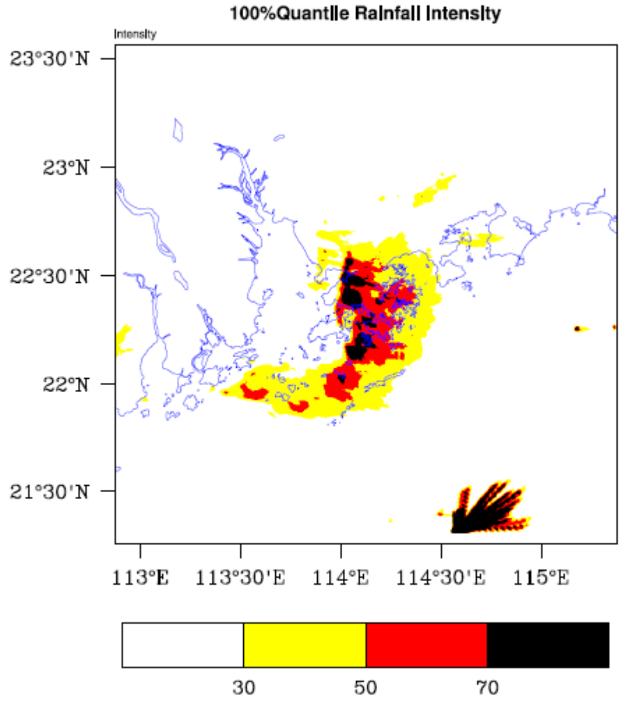

Figure 3. A forecast hourly rainfall intensity map based at 23:00 on 8 May 2014 (HKT), depicting the worst-case scenario by plotting the highest rainfall intensity prediction amongst the 36 members.

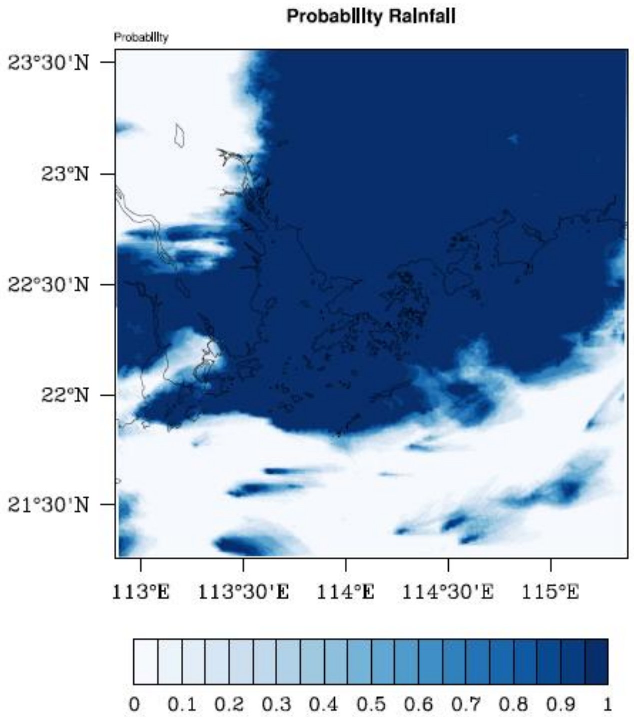

Figure 4. A forecast hourly probability rainfall nowcast contour map with 0.5 mm/hour as rainfall intensity threshold, based at 23:00 on 8 May 2014 (HKT).

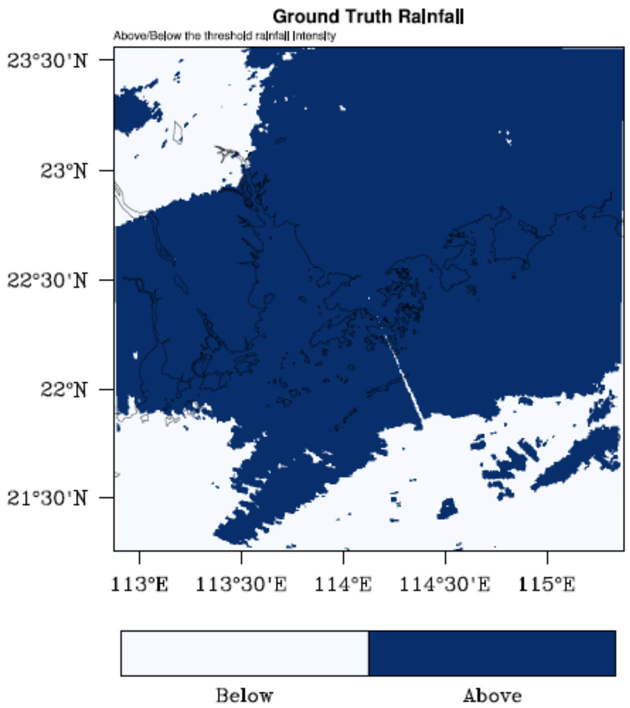

Figure 5. The observed hourly rainfall intensity map during 23:00 – 24:00 on 8 May 2014 (HKT).

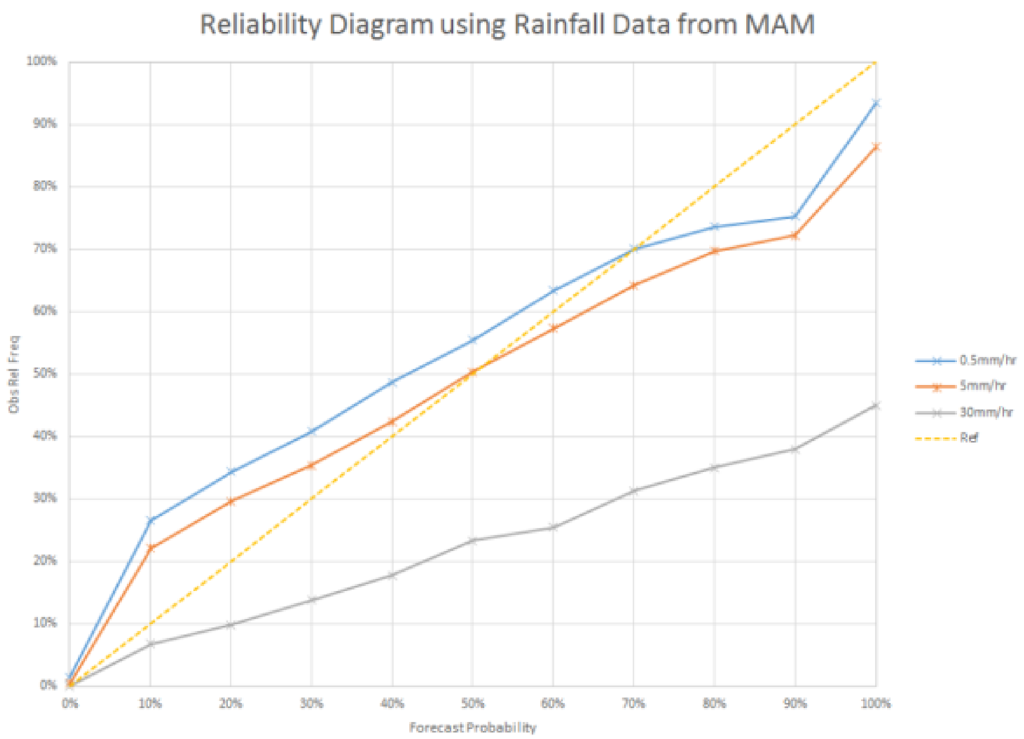

Figure 6. A reliability diagram constructed with probabilistic rainfall nowcast in the spring of 2014.

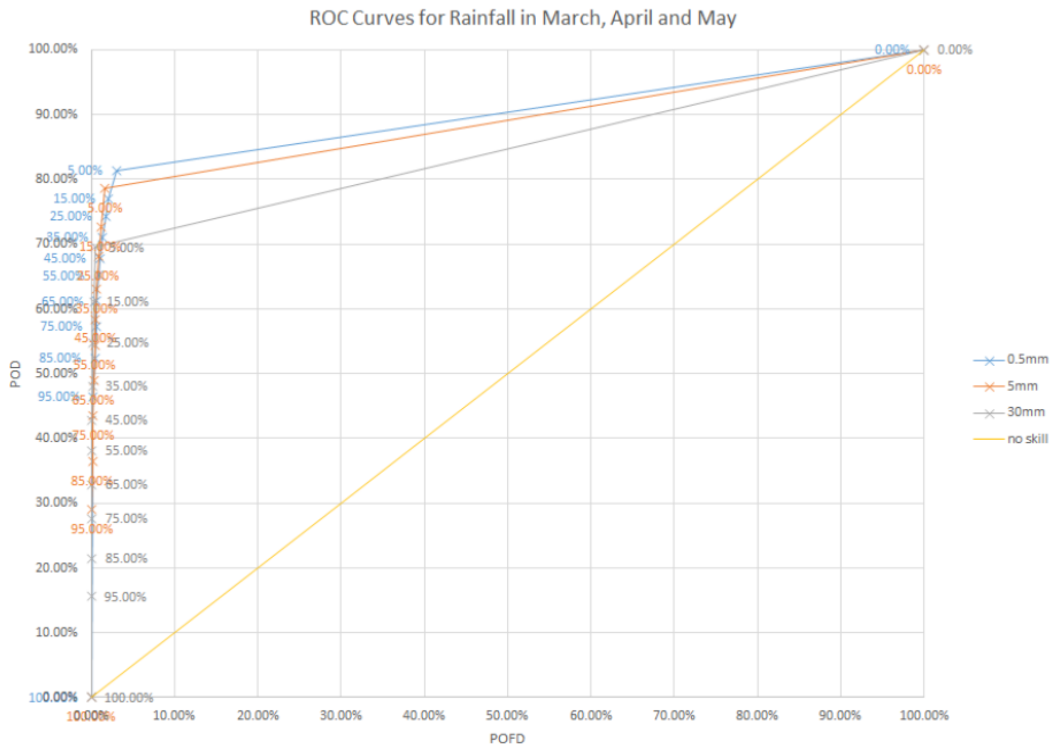

Figure 7. The ROC curve of the probabilistic rainfall nowcast in the spring of 2014.