

# **Preliminary assessment of LAWR performance in tropical regions with high intensity convective rainfall**

Chris Nielsen: DHI Water and Environment (Malaysia), Fanny Dugelay, Université de Nice Sophia Antipolis, France, Sazali Osman, JPS Malaysia, Niels Einar Jensen, DHI Water and Environment (Denmark)

**Abstract** There is interest in the application of radar as a tool for rainfall detection and measurement which, by accurately measuring rainfall distributions and intensities in realtime, has application to flood forecasting and flood and drainage management. Research is currently being undertaken to assess the potential application of a specific type of radar (LAWR) to rainfall and runoff prediction in Kuala Lumpur, Malaysia. The preliminary findings of the research is presented, which highlights the specific climatic conditions associated with the occurrence of heavy rainfall in tropical zones.

## **Introduction**

In the context of predicting flooding there is a requirement to accurately measure rainfall, both spatially and temporally. This can be achieved by:

1. Using point rain gauge information
2. Using radar (one or many)
3. Combining 1 and 2

Preliminary research has been conducted in Kuala Lumpur, Malaysia to consider Approach 2 and to a lesser extent Approach 3, with specific reference to the application of Local Area Weather Radar (LAWR). Subsequent research will concentrate further on Approach 3.

## **X, C and S Band Radar**

A radar generates a short pulse of high power microwave energy produced by a magnetron in the transmitter system, which is focused by an antenna system into a narrow beam. This pulse of energy travels through the atmosphere at the speed of light. When a target such as a raindrop is encountered, some of the energy is scattered, of which a minute fraction is in the direction back to the antenna system. A sensitive receiver system then processes and amplifies this received signal. From the azimuth and elevation information on the pointing direction of the antenna, the time between transmitting and receiving and the power of the received signal, the target location can be determined as well as its intensity or reflectivity.

The letter defines the wavelength of the radio waves being emitted from the radar. X band uses a wavelength of 3 cm, C band a wavelength of 5 cm and S band a wavelength of 10 cm. The wavelength is a measure of the power of the radar, which translates to its range and ability to “see” through higher density weather patterns such as tropical storms and heavy rain.

The general perception of the application of radar to weather is that X band is not powerful enough to penetrate high intensity rainfall events. This means that the X band cannot measure the maximum rainfall intensity inside the storm, nor can it “see” beyond the rain to determine the extent (or depth) of the storm pattern.

Considering the fundamental properties of radar, this would appear to be a limitation. However, the context in which the radar is applied must also be considered; this is a major focus of the research.

## **LAWR**

LAWR stands for Local Area Weather Radar, which is a short range high intensity weather radar to detect the spatial variation of local rainfalls. This is useful for providing rainfall forecasts with a few hours' warning. For applications such as flood forecasting it has the following advantages:

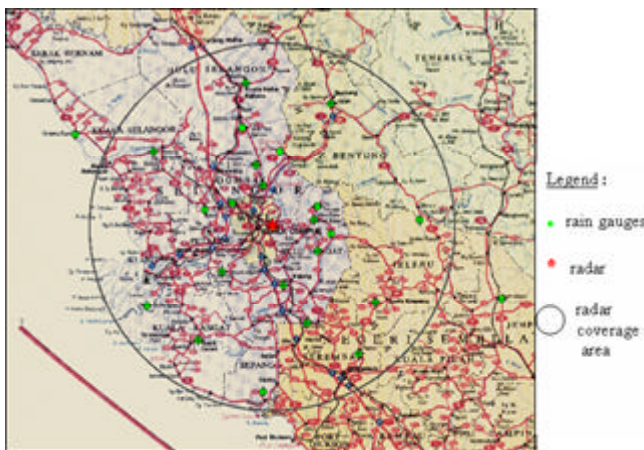
- it is cheap relative to other conventional systems; it is an X band radar that uses cheap, off the shelf Furuno marine radars.

- it has a high spatial resolution; typically, the size of a rain cell on the radar is set at 100 x 100 m, 250 x 250 m or 500 x 500 m - depending on the type of application. The radar provides a high-resolution image of the rainfall pattern, usually every 5 minutes or (optionally) once per minute.

LAWR is installed in many locations around the world, and comprehensive analysis and academic publications have been conducted at many of these installations. LAWR has been shown to give accurate predictions of rainfall. However, most applications are not installed in areas where tropical convective thunderstorms and weather systems comparable to those that cause floods in Kuala Lumpur occur. Those installations in tropical zones are currently being applied for more specific purposes (such as measuring vertical distributions).

### Radar Site

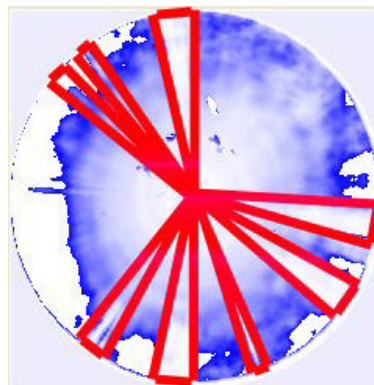
The radar site is located within Kuala Lumpur city area on the roof of a 4 storey building. The existing site of the LAWR is not particularly suitable. A panoramic view from the installation site (Figure) shows buildings in the line of sight of the horizon, which leads to beam blockage which can partially or fully block the LAWR transmitting power. To determine the extent of beam blockage, the signal from the LAWR was integrated over a period from October 15 to November 1, 2005. Using the accumulated signal sectors where beam blockage occurs can be clearly seen and identified. A key recommendation from this phase of the research is to relocate the LAWR to a more suitable site.



**Figure 1** Locality plan, showing coverage of radar image and available rain gauges



**Figure 2** Panoramic view of city from installation site



**Figure 3** identification of sectors affected by beam blockage

## Assessment of LAWR in Kuala Lumpur

A fundamental disadvantage of X band radar (and LAWR) is that it cannot penetrate precipitation above a certain threshold intensity, defined as the saturation limit. Above this limit, all that can be known is that the rainfall intensity is greater than the threshold intensity. This leads to the specific goals of the research:

1. To determine if LAWR alone can be used to measure rainfall in Kuala Lumpur
2. If Goal 1 cannot be achieved, to determine if the saturation threshold is a limitation to providing useful spatial descriptions of rainfall during intense convective thunderstorms that cause flooding in Kuala Lumpur
3. If Goal 1 and/or 2 is achieved, investigate a system by which spatial descriptions of rainfall from LAWR are overlaid with point gauge rainfall data to create an accurate spatial and temporal rainfall description
4. Provide a quantitative assessment of the likely improvements in accuracy and lead time of flood forecasts in Kuala Lumpur as a result of using LAWR

This presentation focuses on goal 2; previous studies indicate that the LAWR alone is not sufficiently accurate to predict intense rainfall events (goal 1); however additional hardware features and adjustments and site relocation may improve this. To do this, a number of storm events were selected from available gauge rainfall data and compared to the LAWR. The events selected recorded 30 minute duration rainfall intensities greater than a 1 year return period design event (see table), based upon design rainfall information (MASMAM, 2000).

**Table 1 Storm events selected for analysis**

ID: Date	Maximum rainfall intensity recorded at any gauge (mm/hr) for Duration:			Estimated return period of 30 minute event (years)
	5 min	15 min	30 min	
1: 15/10/2005 18:00	180	130	83	1
2: 06/11/2005 15:20	144	138	99	2
3: 10/11/2005 18:00	215	177	152	20
4: 01/01/2006 20:30	166	133	131	10
5: 23/03/2006 16:30	187	106	114	5

A comparison of peak gauged rainfall intensities to the corresponding spatial distributions of rainfall predicted by the LAWR for the storm events listed in the table are presented in Figure 4 and Figure 5. Each figure shows:

- Contour shading of reflectivity values predicted from the LAWR; a value of 254 is considered to be the saturation limit.
- Rainfall intensities (mm/hr) at each rain gauge, presented as [5 minute peak] | [15 minute peak] | [30 minute peak]; a value of “n” denotes “no data”
- Sectors where beam blockage is likely; radar images within these sectors may not be accurate
- A circle identifying the 25 km radius from the radar site; radar images of intensity outside this radius may not be particularly accurate (although the spatial extents may be reasonable)

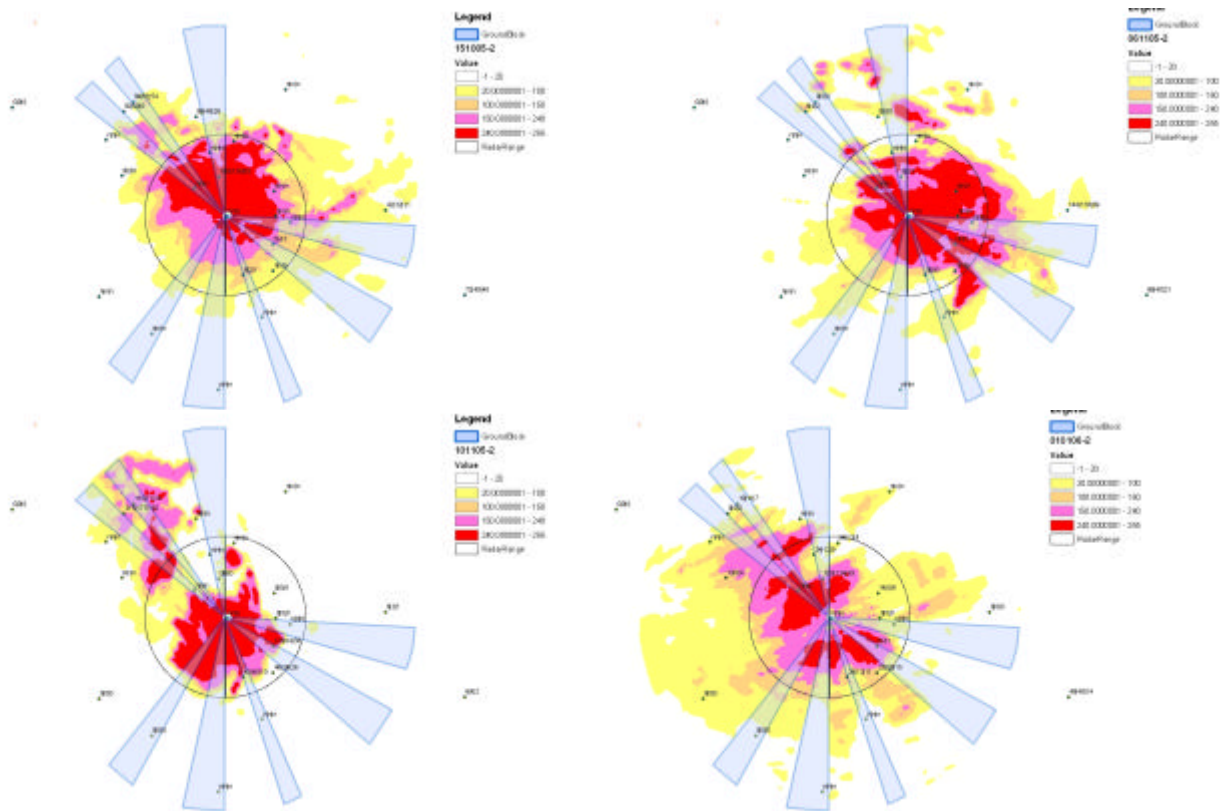


Figure 4 Comparison of gauged rainfall intensity to LAWR predictions of spatial rainfall distributions, storms 1 to 4

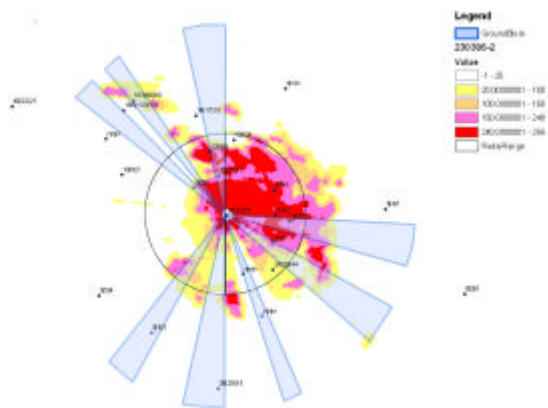


Figure 5 Comparison of gauged rainfall intensity to LAWR predictions of spatial rainfall distributions, storm 5

## Conclusions

In general the LAWR can identify the spatial extent of rainfall generated from intense storms. There does appear to be some inconsistencies in predictions behind the storms, which is likely due to attenuation correction; a function of the backscatter (rain echo) detected between the radar and a given point. Underestimating this leads to under-correction of the signal and hence under-estimation of intensity, which is to be corrected during the next phase of the research.

LAWR operating alone without integration with point source rainfall gauges does not appear to be accurate enough to measure rainfall in Kuala Lumpur, however relocation of the site and additional modifications to compensate for attenuation correction may improve this.

The saturation threshold, above which rainfall intensities cannot be measured, is sufficiently high to enable useful spatial descriptions of rainfall to be made during intense convective thunderstorms that cause flooding in Kuala Lumpur. This relates to the maximum rainfall intensity “seen” by LAWR, and also to the spatial definition behind the thunderstorm centre. Further adjustments to the LAWR signal in the next phase of research will raise this threshold.

## **Recommendations**

LAWR has the potential to improve the accuracy of describing rainfall patterns in Kuala Lumpur, and hence the accuracy of flood prediction. Future research studies are proposed:

- Relocation of the LAWR to a more suitable site
- Comparison of the LAWR predictions with existing S-band radar data
- Optimisation of LAWR parameters and signal processors for better performance
- Comparison of LAWR spatial rainfall distributions with standard Thiessen polygon (or other) calculations from point gauge data
- Integration of LAWR into a flood forecasting model to assess if improvements in accuracy and lead times of flood forecasts can be made.

## **References**

- MSMAM (Manual Saliran Mesra Alam Malaysia, or Urban Stormwater Management Manual for Malaysia), Department of Irrigation and Drainage, Malaysia, 2000.