# *SHANGHAI URBAN ARRAY WEATHER RADAR NETWORK EXPERIMENT*

**12A-01**

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## 1. STRUCTURE OF ARRAY WEATHER RADAR (AWR)

The Shanghai urban X-band array weather radar observation network consists of a control data processing center and three phased array and transceiver subarrays (Figure 1). It is called the array weather radar because it is distributed and scanned by several transceiver sub-arrays according to the set rules.

Each transceiver sub-array serves as a network point for the array weather radar and has no separate control and data processing sections. The transceiver sub-array uses phased array technology and consists of an antenna array, a transceiver (T/R) module array, a signal processor array, a servo system, a synchronization and a communication module (Figure 2). The main task of the transceiver sub-array is to obtain the echo intensity, Doppler radial velocity and radial velocity spectral width information and send it to the control and data processing center through the communication network.

The control and data processing center is mainly composed of a control server, a data processing server, and a data storage server (Figure 2). The control server controls the synchronous detection of the transceiver sub-array, scans and monitors the running status of the transceiver sub-array. The data processing server synthesizes the velocity vector field V(x, y, z) from the radial velocity data got from three sub-arrays, and combines the three sets of intensity data into one echo intensity field Z(x, y, z) to form a high Time-space-resolved 3D flow field and intensity grid data.

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## 2. THE LAYOUT & DETECTION AREA OF AWR

The basic layout of the array weather radar is an equilateral triangle layout, as shown in Figure 3. It is a schematic diagram of three transceiver sub-array layouts and detection ranges. The middle orange triangle area composed of three transceiver sub-arrays is a three-radar detection area, the yellow area is a dual radar detection area, and the blue is a single radar detection area. There are three sets of intensity data and three sets of radial velocity data for each spatial point in the orange zone. Since each transceiver sub-array is scanned in azimuth 360° and 0° to 90° in elevation, all the detection areas are scanned stereoscopically, and the orange area can directly calculate the actual flow field information. Shanghai AWR Network Experiment Layout is shown in Figure 4.

## 3. AWR DETECTION MODE & COLLABORATIVE SCANING

The array weather radar transceiver sub-array uses a one-dimensional phased array scanning technology, that is, electrical scanning is used in the vertical direction and mechanical scanning is performed in the horizontal direction. There are 64 transmit channels in the vertical direction, using digital beam forming techniques. Up to 16 beams can be formed simultaneously. There are three main types of scanning sub-array scanning modes of Shanghai AWR as shown in Table 1 below.

The S3 detection mode using 64 beams in elevation to cover 0° to 90°, and it is completed in 4 scans, covering 0°~22.5°, 22.5°~45°, 45°~67.5°, and 67.5°~90°. Each time it transmit a wide beam (beamwidth: 22.5°), and receive the echo signal divide into 16 beams (beamwidth: 1.6°) by using digital beam

forming tech. The horizontal direction adopts mechanical scanning mode, the antenna rotation speed is 30°/s, and it takes 2s to complete the 60° azimuth scanning, that is, it takes only 2s to complete the orange area detection, thus ensuring the effectiveness of speed synthesis. The S1 mode uses one by one beam scanning, and the antenna rotates at a relatively slow speed, mainly for searching and early warning.

The number of transceiver sub-arrays can be continuously expanded. As shown in Figure 5, when the subarrays is extended to 7 nodes, there are 6 orange detection areas. As long as the relative scan start time of each radar is defined, the S3-1 mode can still be completed within 12S, and each orange area can also achieve a time error of less than 2s.

## 4. AWR DETECTION CASES

Figure 6 gives a comparison of the combined echo reflectivity observed in the same area of the Shanghai X-band AWR (right) and Shanghai S-band WSR-88D weather radar (left). It shows that two radars have almost same shape and intensity distribution. AWR could see more details.

Figure 7 shows that the AWR radar can directly synthesis three-dimensional wind field product using the radial velocity information detected by the three transceiver sub-arrays.

Figure 8 shows a 3D image of the precipitation echoes acquired by AWR during No.9 typhoon “Lekima” peripheral spiral rainband on August 10, 2019 in Shanghai. The fine structure, echo value and height information of the spiral rain belt precipitation can be seen clearly.

Figure 9 shows a 3D product of a strong local convection process detected by AWR on August 13, 2019. This is a process was a relatively local precipitation with high intensity rainfall. Due to the small size of the echo, it was not easy to be found by S-band radar during the initial period, but AWR can detect it and issue early warning due to its high spatial-temporal resolution observation data.

## 5. SUMMARY

The Shanghai Urban Array Weather Radar Observation Network is built for the fine-detection requirements of urban small-scale weather. It mainly solves the three-dimensional velocity field detection of precipitation echo and the full coverage detection in elevation 0°~90°.

(1) Shanghai Urban AWR Network uses a distributed phased array technology system to make each space point have three radial velocities through a coordinated scan of every three adjacent transceiver subarrays. The time difference is less than 2s, ensuring the effectiveness of speed synthesis.

(2) Each subarray of the Shanghai Urban AWR Network uses advanced digital beam forming technology, wide beam transmission and narrow beam reception, the full coverage detection time of the elevation angle is about 48 milliseconds. The fastest volume sweep time is only 12 seconds. The network observation of X-band phased array radar can make up for the disadvantages of single radar observation, such as X-band precipitation attenuation and detection distance and etc.

(3) Preliminary observations were made in Shanghai. The system can obtain three-dimensional velocity and intensity (reflectance factor) data, reflecting the structural and dynamic processes of precipitation in more detail than any other radar system.

There are still many problems to be explored in the array weather radar technology. Further analysis and research will be carried out through the Shanghai Experiment network to continuously accumulate various weather observation examples and data.

*Table 1 Shanghai AWR Network Detection Mode*

| Mode Type | | S1 | S3-1 | S3-2 |
|---|---|---|---|---|
| Mode Name | | Alert Detection Mode | 3D Detection Mode 1 | 3D Detection Mode 2 |
| Detection Distance | | 40km | 20km | 40km |
| Beam Forming | Transmit | Narrow Beam | Wide Beam | Wide Beam |
| | Receive | Narrow Beam | Narrow Beam | Narrow Beam |
| | Transmit | 1.6° | 22.5° | 22.5° |
| | Receive | 1.6° | 1.6° | 1.6° |
| Coverage | Elevation | 0-22.5° | 0-90° | 0-90° |
| | Azmith | 0-360° | 0-360° | 0-360° |
| Volume time | | 3min | 12s | 30s |

*Figure 1 Shanghai AWR Transceiver Subarray Antenna*

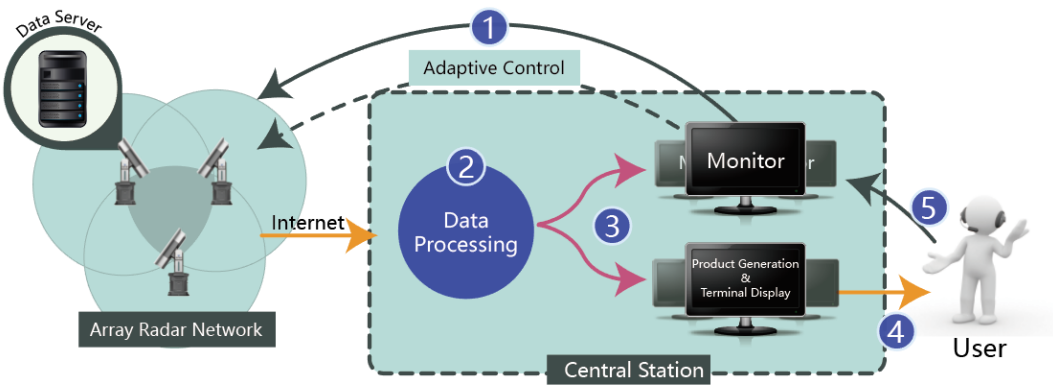


*Figure 2 Data Structure Diagram of Shanghai AWR Observation Network*

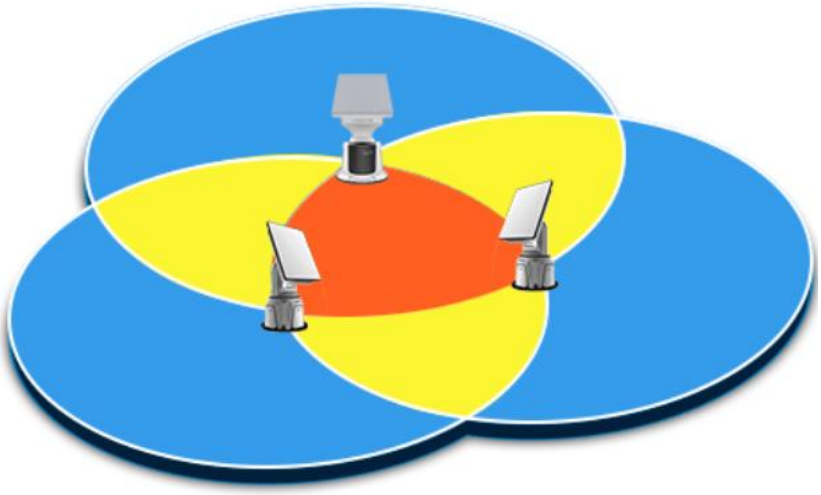

*Figure 3　Schematic Diagram of The Detection Range of AWR Observation Network*

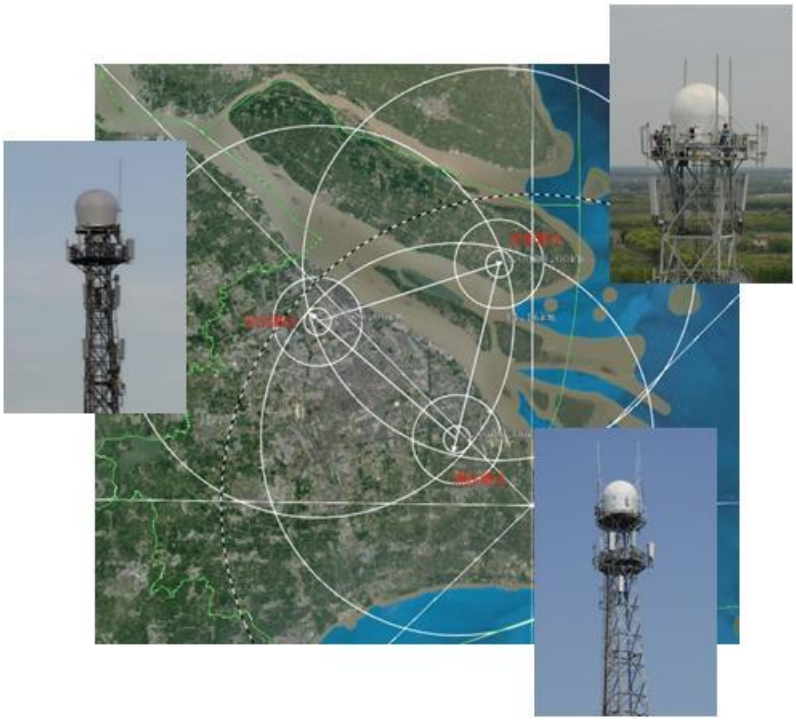

*Figure 4　Shanghai AWR Network Experiment Layout*

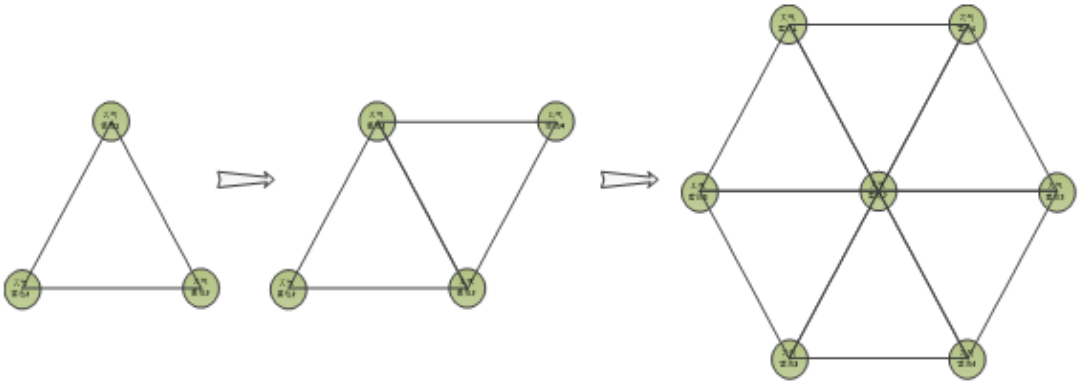

*Figure 5　AWR Subarray Expansion Diagram*

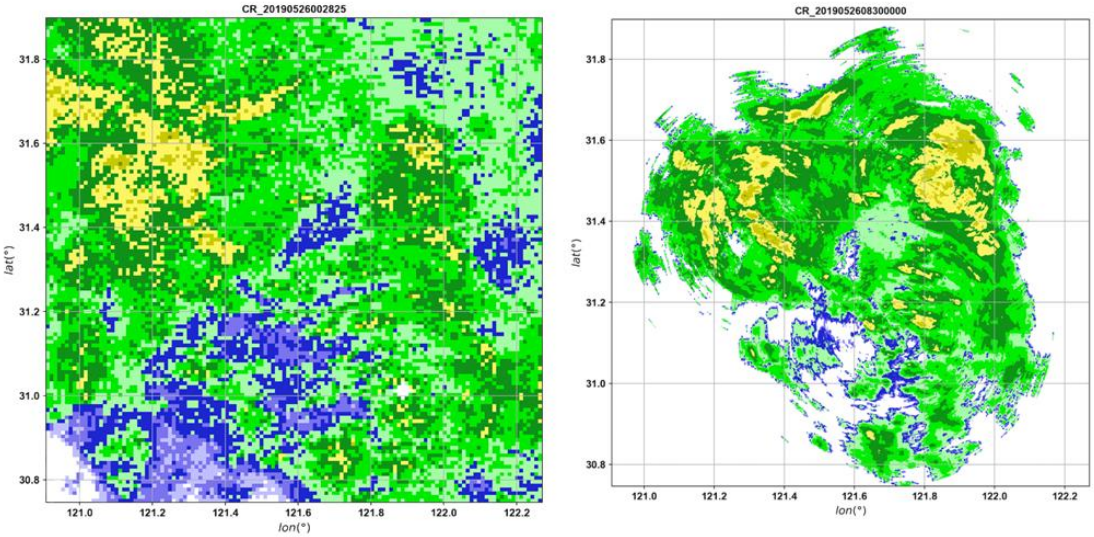


Figure 6　Comparison of Reflectivity Between AWR and Shanghai WSR-88D Radar

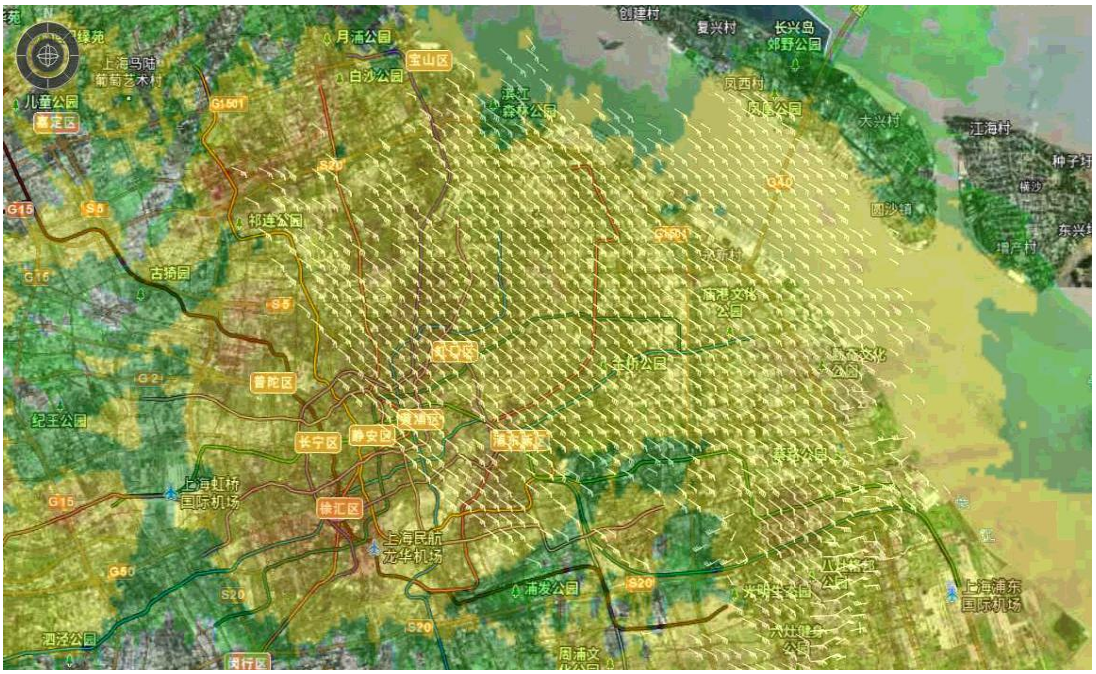


Figure 7　Shanghai AWR Wind Field Synthesis Product

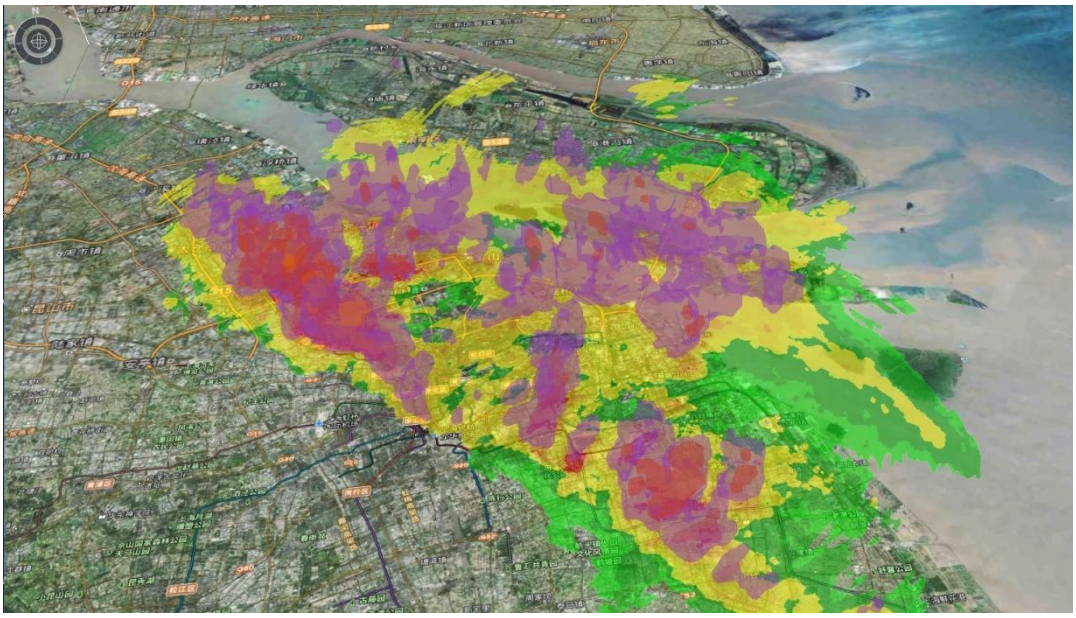

Figure 8　3D Image of The Typhoon “Lekima” Outside Rainband Precipitation Echoes Acquired by AWR on August 10, 2019 in Shanghai

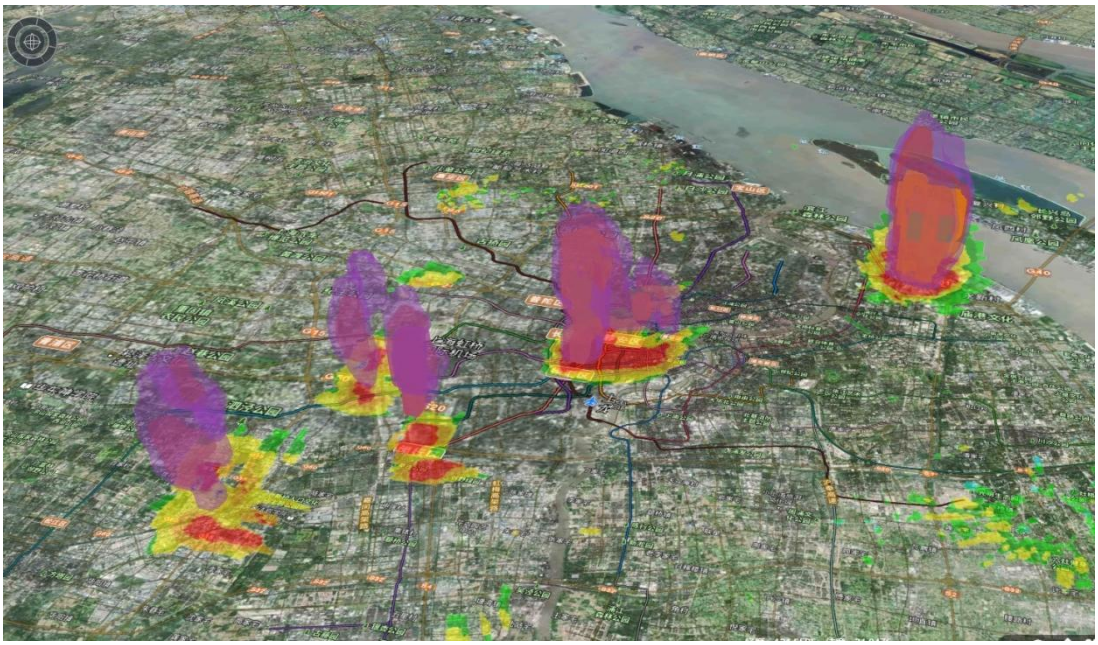

Figure 9　3D Image of A Strong Local Convection Process Detected by AWR on August 13, 2019 in Shanghai