

# Research on the Establishment of the Early Warning Monitoring Model for Slope Collapse of Suhua Highway

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**Abstract** - When Typhoon Meiji made landfall in Taiwan in 2010, sudden and heavy rainfall caused disasters in Yilan, Hualien, and other places quickly. The Suhua Highway on the 9th line of Taiwan was the most serious. It caused a large landslide of 50,000 cubic meters at 115K and lost 500 meters of subgrade and 30 meters of subgrade at 116K, causing severe disasters in the local area. Therefore, it was built on Suhua Highway 115.9K. There is an urgent need for monitoring instruments for the large-scale collapse of slopes.

To provide real-time automatic rainfall monitoring information and GPS satellite positioning monitoring displacement information, a real-time information system was established to receive the coordinates of points measured by GPS instruments and automatically calculate displacement and movement velocity. At the same time, the radar rainfall forecast data of the "Severe Weather Monitoring System (QPESUMS)" of the Central Meteorological Administration was introduced, and the ground rainfall was used to observe the rainfall correction influence factors to improve the estimation accuracy of the radar rainfall forecast. Through the local automatic rain gauge information, it displays information such as hourly rainfall and accumulated rainfall, develops warning reference values, integrates with the "Disaster Warning Data Exchange" for an automatic notification system, and builds functional modules in the "Highway Disaster Prevention and Relief Decision Support System". (TRENDS)". Integrate the front-end and back-end software and hardware interfaces to establish a complete information system to provide real-time slope information for road management units in the face of disasters as an auxiliary tool for decision-making.

**Keywords:** Global satellite positioning system, severe weather monitoring system, highway disaster prevention, relief decision support system.

## I. INTRODUCTION

When Typhoon Meiji landed in Taiwan in 2010, sudden and heavy rainfall brought amazing rain in Yilan, Hualien and

other places in a short period of time. The cumulative rainfall in a single day is 935.5mm in Suao Township in Yilan County and 709.5mm in Nanao Township. The Suhua Highway on the 9th line of Taiwan is the most serious. The 115K landslide was 50,000 cubic meters and the subgrade was lost by 500 meters, and the 116K subgrade was lost by 30 meters, causing serious disasters in the local area. According to the NCDR survey results, the disaster potential areas were found and described As follows: 1. Slope subsidence crack area - 115.9K upper slope top, 2. Slope collapse area - 115.9K earth-rock flow and stream, 3. Dakeng Bridge and valley undercut area - 115.9K below road, 4.116.1K road side slope District -116.1K is adjacent to the slope, so it is an urgent need to build a large-scale collapse monitoring instrument for this road section (Suhua Highway 115.9K) as Figure 1 (Huang Anbin et al., 2008, Zhou Ruizheng et, al., 2010).

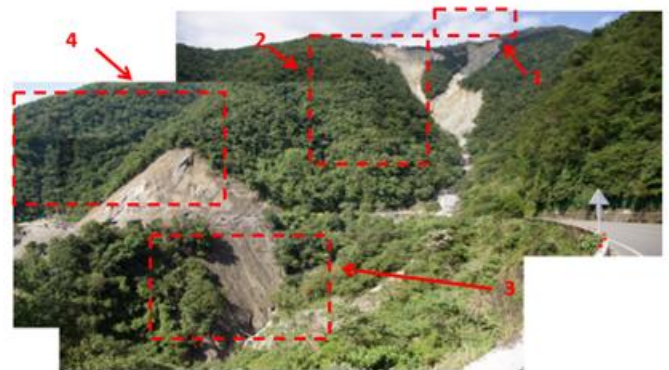


Figure 1: Disaster potential distinction map (preliminary survey by NCDR on November 10, 2010)

## II. SUHUA HIGHWAY SLOPE COLLAPSE MONITORING AND EARLY WARNING SYSTEM

This study integrates the "Highway Slope Monitoring System" to display various instrument information, provides the revised radar rainfall information of the Central Meteorological Administration's "Severe Weather Monitoring System (QPESUMS)" (Liu Bin-liang et, al, 2009), and combines the "Highway Disaster Prevention and Relief Decision Support System (TRENDS)" to conduct roadside monitoring (Lin Jia-nian 2005, Zheng Ming-yuan 2005). Slope

various instruments early warning, forecasting and other actions. The following is a detailed description of each system and its operation mechanism.

### 2.1 Suhua Highway Slope Monitoring

The main task of the Suhua Highway Slope Collapse Monitoring System is to collect real-time information (Liao Hong-jun et al., 2007; Zheng Ming-yuan, et al., 2008). This system acts as the data provider of the "Highway Disaster Prevention and Relief Decision Support System (TRENDS)" (Zheng Ming-yuan, et al., 2008). It corrects the local rain gauge through the correction of the QPESUMS radar rainfall forecast. Provide the most real-time and accurate rainfall forecast (Lin Jia-nian 2005, Zheng Ming-yuan 2006, 2011). The monitoring instrument data of this system include: global satellite positioning system, rain gauge, seismograph, camera and so on. In addition, it interfaces with the meteorological data of the Central Meteorological Administration, including satellite cloud images and typhoon information.

This study collects and builds various system information to establish a real-time notification and early warning mechanism and a display platform. The overall monitoring system planning structure is shown in Figure 2.

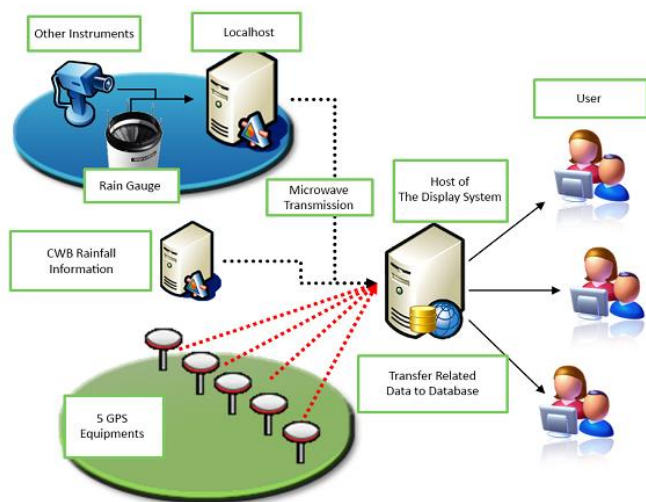


Figure 2: Monitoring system integration architecture

The display system planned by this institute allows users to view various monitoring information through a browser, and combines AJAX technology to allow users to no longer browse electronic maps as before, and build a navigation method similar to Google Earth, allowing users to easily Can inquire about GPS variation, CCD image, earthquake information, rain gauge information, to achieve a truly integrated website. This monitoring and early warning system is constructed, and the development modules and projects are shown in Figure 3. The early warning system is divided into

two categories: display platform and instrument receiving module.

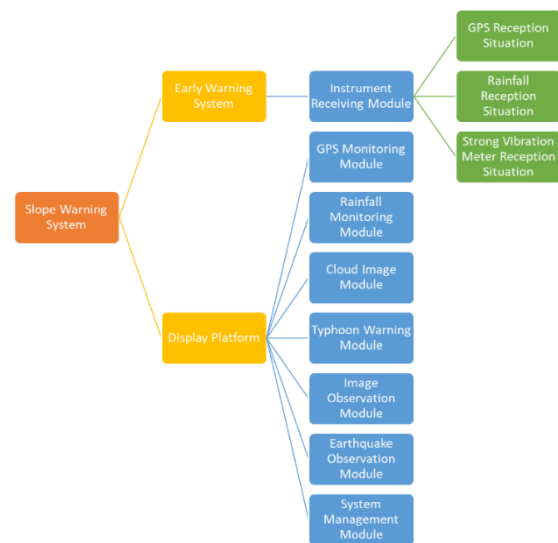


Figure 3: System Functional Architecture Diagram

To fully display the monitoring results and early warning situation of various equipments, this research develops a map display system based on Google Earth map. The coordinates of each device are marked on Google Earth, and users only click on the map through the map platform. You can know the latest instrument and equipment information by displaying the system screen as shown in Figure 4.

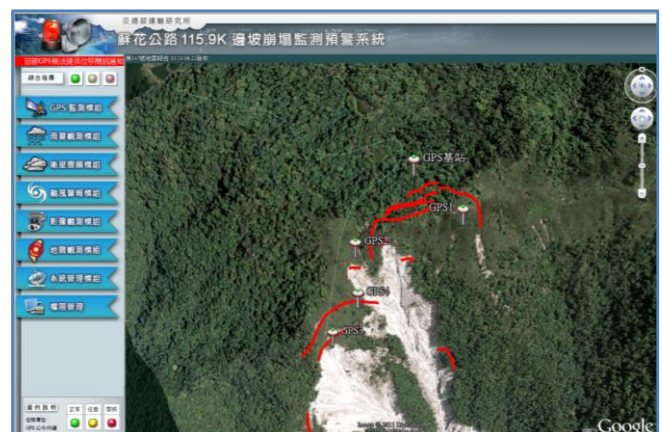


Figure 4: Instrument and equipment information

### 2.2 QPESUMS Radar Rain Forecast

This study uses the QPESUMS radar rainfall forecast data of the Central Meteorological Administration (Zhang Bao-liang et.al.). Since the radar rainfall is not accurate enough in the corresponding point rainfall observation, the ground rainfall is collected to observe the rainfall, and the important factors affecting the radar wave rainfall are considered as the correction factor, in order to improve the

estimation accuracy of radar rainfall forecast (Joss J, et al., 1995).

This study uses the Support Vector regression (SVR) method to correct the estimated rainfall of QPESUMS radar, (Zhang Bao-liang et. al.,) hoping to solve the problem of radar rainfall underestimation, and to maintain the advantages of radar rainfall with high resolution and covering a complete area. Among them, the factor for correcting the radar rainfall is based on the research proposal of Liu Bin-liang (2009), the estimated rainfall of the radar grid, the X coordinate and Y coordinate of the second-degree band of the position of the ground rainfall station as the input factors, the elevation of the ground rainfall station and the ground rainfall. The correction for the straight-line distance from the station to the radar station performed best. The correction process of radar rainfall in this study is shown in Figure 5. First, some forecast data, correction factor combinations, and second: ground rainfall observations (Joss J. et al., (1995) are used to establish a rainfall correction model by support vector regression (SVR), and then the remaining data are used for verification operations. To ensure the accuracy of the revised model, the revised model will be used to modify the 1-3 hour rainfall forecast provided by QPESUMS.

Among them, the correction factor selects the single-point rainfall corresponding to the nine radar grids above as the model's input. Because when dealing with areas without ground stations, the positions of the stations are not necessarily located in the correspondence of single-point radar echoes, so Difficult to handle in a weighted manner. Therefore, in the radar rainfall input part of the model, referring to the method of Liu et al. (2001), the nine radar estimated rainfall above the ground rainfall stations are used as the model's input, as shown in Figure 6. The second degree zonal X coordinate and Y coordinate of the location of the ground rainfall station are selected as the input factors. The purpose is to consider the rainfall intensity and rainfall in different regions, which will have other characteristics at different locations to increase the spatial distribution characteristics of rainfall information. The elevation is because it is found that the radar echo factor is affected by the terrain barrier, which makes the radar estimated rainfall underestimated with the increase of the terrain elevation. It is hoped that the correlation of the radar estimated rainfall in the vertical direction could be increased. In addition, the radar beam will attenuate as the distance increases during the propagation process, so the estimated rainfall of the radar will also be underestimated with the rise in the distance. The rainfall error will be more significant; Morin et al. (2007) pointed out in the paper that the radar estimated rainfall within 100 km from the radar station is well estimated, and beyond 100 km is underestimated. Therefore, the location of the

rainfall station and the radar station will be added. The purpose is to increase the correlation of the radar estimated rainfall in the horizontal direction.

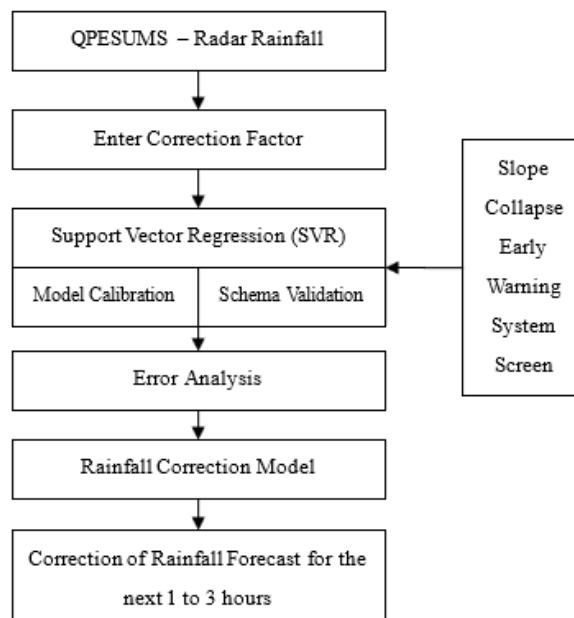


Figure 5: QPESUMS radar rainfall correction process

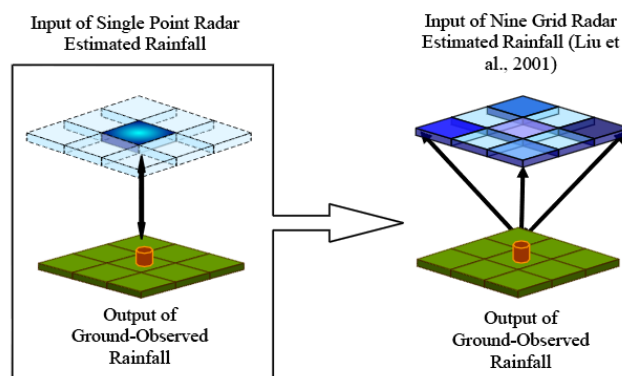


Figure 6: Input Method of Radar Estimated Rainfall

The correction results of radar forecast rainfall are displayed in two parts. Before the establishment of the 115.9K rainfall station, the forecast correction results of typhoon Meiji in October 2010 were used at Dongao Station. After the establishment of the rainfall station, the 115.9K station was displayed in October 2011. The forecast correction results of the rainstorm event on the 3rd are shown in Figure 7 and Figure 8. In the figure, QPESUMS Estimated Rainfall (Liu H. et al., 2001; Trafalis, T.B. et al., 2005, Umehara, S. et al., 2006) represents the forecast rainfall before the correction, and C\_QPF represents the forecast rainfall after correction. After comparing with the actual rainfall, it can be explained that this correction method can effectively correct the error of forecast rainfall and improve the grasp of rainfall data at 115.9K in this study.

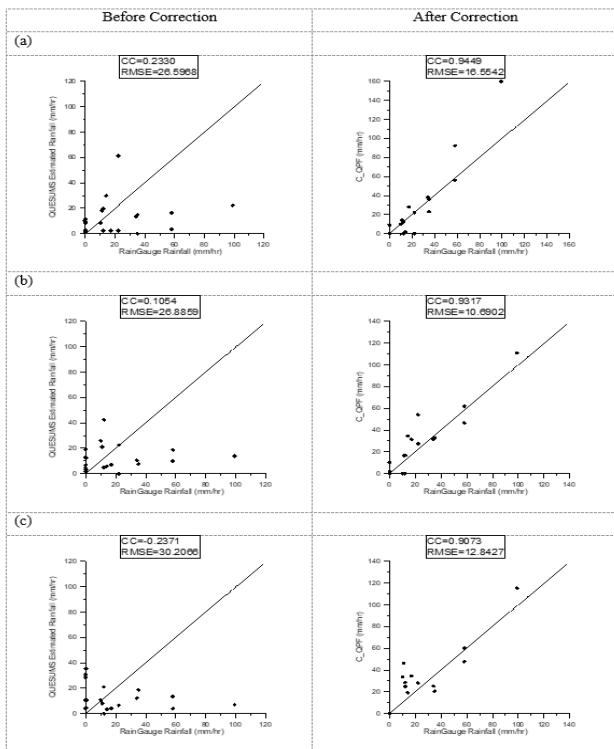


Figure 7: Comparison of the Correction Results of Rainfall Forecast for the Rainstorm Event on October 3, 2011 (115.9k): (a) After 1 hour of the forecast; (b) After 2 hours of the forecast; (c) After 3 hours of the forecast

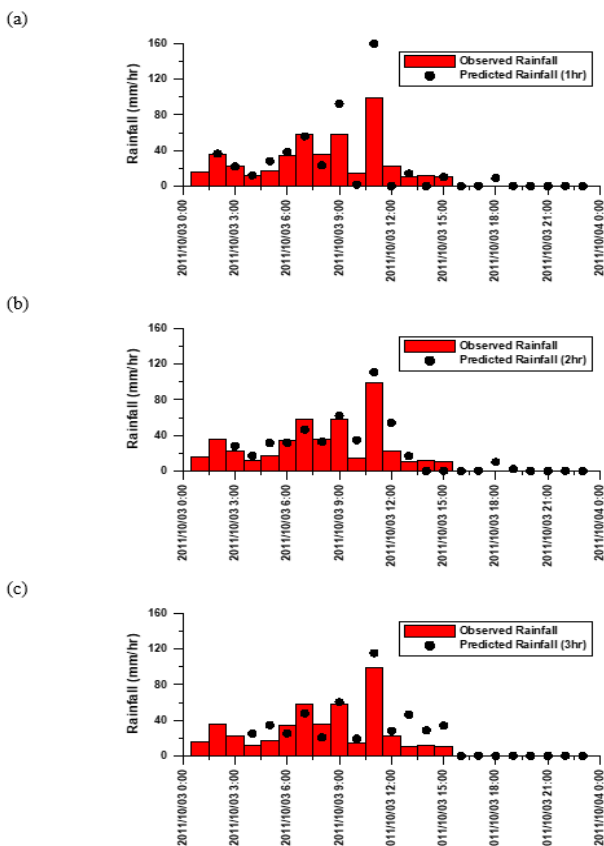


Figure 8: Correction results of rainfall forecast for the rainstorm event on October 3, 2011 (115.9K) (a) after 1 hour of forecast (b) after 2 hours of forecast (c) after 3 hours of forecast

### 2.3 Highway disaster prevention and relief decision support system

The early warning model of this research is based on the concept of Software Agents, and a set of "disaster early warning data exchange" is established. The disaster pre-exchange switch can collect disaster information and on-site instrument monitoring information in real time for data compilation. Once the disaster information and instrument monitoring information reach the set safety warning value, the disaster early warning switch will activate an automatic notification mechanism to immediately notify the relevant responsible engineering personnel for road control or closed measures. At present, the disaster information set by this disaster warning data exchange is "Radar Rainfall Forecast issued by the Central Meteorological Administration" and "Rain Gauge Station Information" (Hong Benshan, et al., 2009); the instrument monitoring information is "GPS Monitoring Information" and "On-site Automatic Rain Gauge Information". The content, the system structure diagram of the 115.9K slope collapse monitoring and early warning mode of Suhua Highway, as shown in Figure 9, and the disaster notification process as shown in Figure 10.

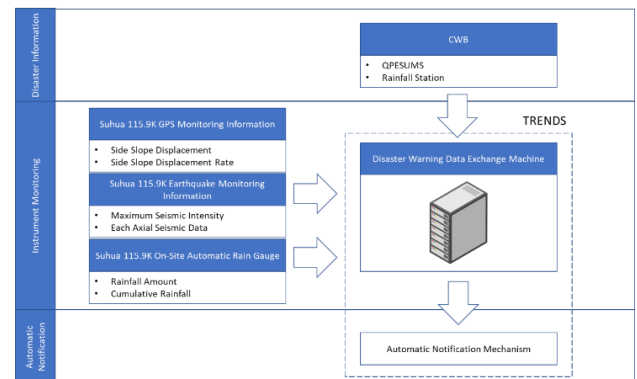


Figure 9: System architecture of the 115.9K slope collapse monitoring and early warning mode system on Suhua Highway

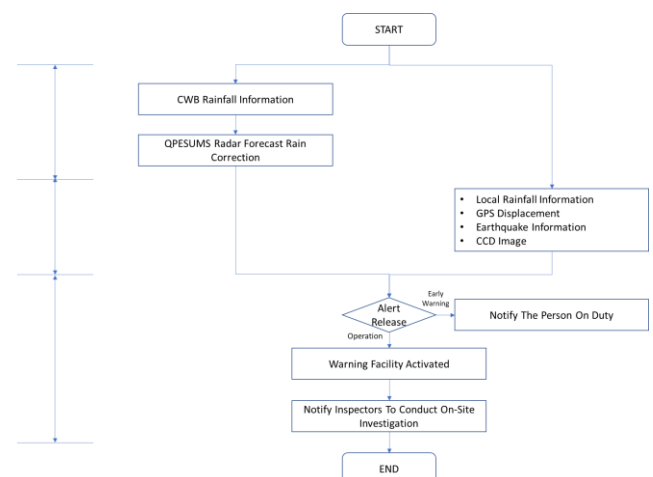


Figure 10: Disaster notification process

The stand-alone version can be divided into real-time monitoring and the forecast data (rainfall, slope sliding, earthquake) displays and warning release, notification personnel list setting, local CCD monitoring image link, slope sliding warning emergency short message release and manual activation of alarms, and other functions, as shown in Figure 11.

### III. RESULTS AND DISCUSSIONS

In 2011, this study detected a total of 2 more significant anomalous events, 1. The military plane crashed into the mountain on September 13, 2011, and 2. The heavy rain event on October 2, 2011. The following will analyze the data of the two events.

#### 1. 0913 Collision event

The system detected an abnormal vibration at 7:46 pm on September 13, 2011. According to the record, the vibration is equivalent to a magnitude 2 earthquake as shown in Figure 13. However, the seismic data of the Central Meteorological Administration was checked, but no relevant earthquake was found. At the same time, by comparing the camera image data, it was found that there was obvious light in the night image, and the time was close to the time of the crash of the military plane, so it was more certain that the shock was caused by the collision of the military plane.



Figure 11: Suhua Highway 115.9K early warning system (stand-alone version)

The web version mainly uploads the data displayed in the stand-alone version to the web page, and the administrator can view the monitoring data where there is a network, and set the same police emergency message function as the stand-alone version, for the administrator to respond to the police emergency. state, as shown in Figure 12.



Figure 12: Suhua Highway 115.9K Early Warning System (Web Version)

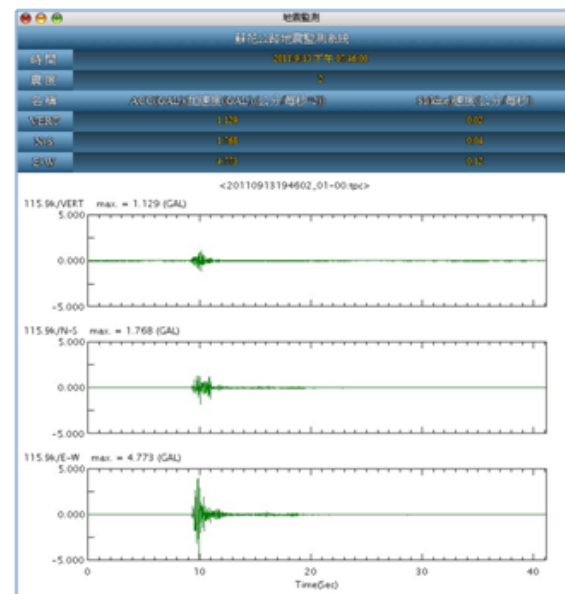


Figure 13: 2011/09/13 19:46 Seismic instruments detected abnormal events

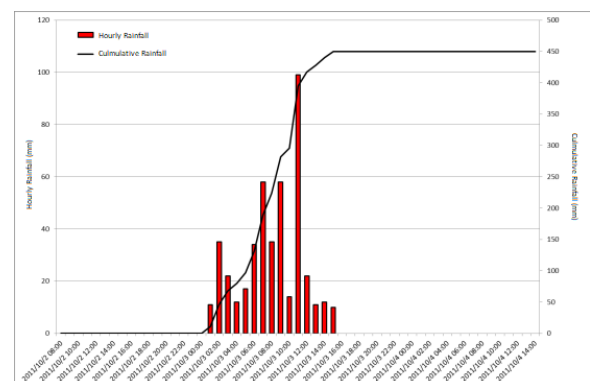


Figure 14: 2011/10/02-2011/10/04 Rainfall Group Diagram

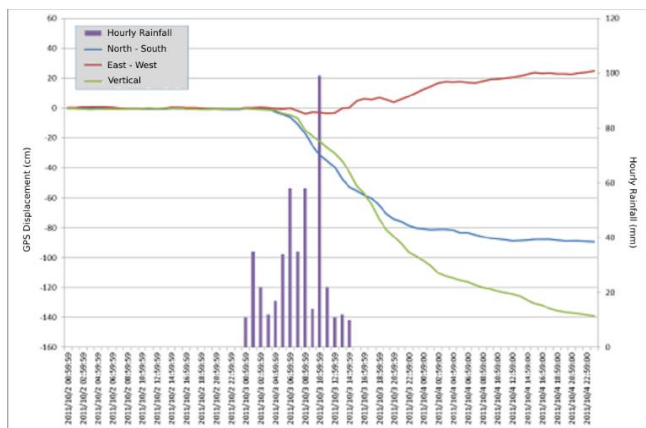


Figure 15: Comparative Analysis of GPS Displacement and Hourly Rainfall

#### IV. CONCLUSION

Suhua Highway Slope Collapse Monitoring System, through the integration of front-end instruments such as GPS, rain gauges, cameras and seismometers, through wired and wireless communication solutions, and with the display and presentation of the back-end system, it provides complete slope observations. Data, and use the setting and establishment of each warning value to achieve the functions of real-time early warning and disaster prevention notification.

QPESUMS radar rainfall forecast, using the data exchange mechanism between the various system platforms, cooperates with the QPESUMS radar rainfall observation data correction method provided by the Central Meteorological Administration, and at the same time, according to this correction method, the forecast rainfall data in the next 1~3 hours is corrected, greatly improving QPESUMS Reliability of radar rain applications.

The decision-making support system for highway disaster prevention and relief, combined with the information provided by the Suhua Highway Slope Collapse Monitoring System, establishes a short message personnel list, reports and publishes warning values and action values, and makes the personnel of the highway management unit familiar with the present through education and training and example exercises. The system provides managers with tools to assist decision-making in the face of heavy rain, slope and earthquake disasters.

The instruments and equipment built in this institute can be transferred to other dangerous slope sections for monitoring after the completion of the slope related works, so as to extend the life cycle of the instruments and equipment and make the best use of everything. And through the implementation experience of the monitoring system in this study, it can provide reference applications for the competent authorities of

landslide prevention and monitoring at home and abroad, such as the Water Conservation Bureau, the General Administration of Highways, the Highway Bureau and other planning references.

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