Acoustic Detection and Measurement of Intermittent Rainfall At Little-Ryukyu (ADMIRAL)
運用被動音響方式量測小琉球附近海域降雨

Barry B. Ma[1], Yueh-Jiuan G. Hsu[2], Dong-Jiing Doong[3], Hsin-Lung Chin[4], Chau-Chang Wang[5], Pay-Liam Lin[6],

[1] **Department of Marine Science, Naval Academy** 馬炳彬 海軍官校 海洋科學系

[2] **Marine Meteorology Center, Central Weather Bureau** 徐月娟 中央氣象局 海象測報中心

[3] **Costal Monitoring Center, National Cheng-Kung University** 董東璟 成功大學 近海水文中心

[4] **Southern Region Weather Center, Central Weather Bureau** 秦新龍 中央氣象局 南區氣象中心

[5] **Institute of Undersea Technology, National Sun Yat-Sen University** 王兆璋 中山大學 海下技術所

[6] **Institute of Atmospheric Physics, National Central University** 林沛練 中央大學 大氣物理研究所

Abstract

The ocean ambient noise can be divided into two categories, the man-made and the natural generated noise. For the natural generated noises, the main contribution is from the breaking wave caused by the wind blowing over the ocean surface and the rainfall. The impact of the raindrops and subsequently generated bubbles are the major sources of noises. The oceanic rainfall is one of most difficult nature phenomena to measure due to the unstable platform on the ocean surface causing by winds and waves. Thus most of the land base rain measuring instrument are not suitable for the ocean. In order to study the possibility of acoustic rainfall measurement at the continental shelf region, an experiment combined several rainfall measuring instrument is conducted at Little Ryukyu island near the water of Taiwan in the summer 2006. There are several observations conducted simultaneously, including disdrometer, accumulation rain gauge, surface wind speed, air-sea temperature and Passive Acoustic Listener. The Central Weather Bureau of Taiwan precipitation radar at Chi-Ku also covers the experiment site providing reflectivity measurement during the rainfall. The preliminary result shows that the background noise at the Little Ryukyu is about 8 dB higher than the ocean open location. The low frequency band at 0-3 kHz has an unidentified diurnal cycle which is unique to this region. It might cause by the strong diurnal current. Several rainfall events are also detected by the Passive Acoustic Listener. The data shows that it is feasible to detect rainfall acoustically even in a noisy continental shelf region.

1. Introduction

Rainfall is once of most difficult nature phenomena to measure over the ocean since it varies both in temporal and spatial scales. Most of rain measuring instruments are no applicable to the ocean due the unstable ocean surface causing by the waves and tides. An innovated method to measure the rainfall on the ocean is using the ambient noises generated by the rainfall. The ocean ambient noises are the sum of all sources. Some of the sources are location dependent. For example, at some continental shelf regions, biological sounds related to a particular fish could be the dominant ambient noise source. Sites near ocean shipping lanes are much noisier than other open ocean locations in the low frequency spectrum. For the higher frequency (50 kHz plus), thermo noise is a dominant source whereas the other sources are often attenuated. For the frequency range from 1 to 50 kHz, wind generated noise is the major persistent noise source component, characterized by a spectrum with a uniform negative slope. However when the rain present, the rain generated sound often dominates all the other sources in this frequency band. Several studies have been made at the open ocean sites near the equator (Ma and Nystuen, 2005, Nystuen 2001). This time, an experiment designed for the rainfall measurement using the ambient noise at a continental shelf site near the Little Ryukyu is conducted in the summer of 2006. Ancillary measurements are also acquired for the rainfall comparison.

2. The experiment setup

Little Ryukyu (LRK) is an offshore island about 7 miles off the Taiwan. The annual rainfall at LRK is about 1,000 mm. The month of June has most of rain climatologically. The experiment site is selected at about one mile south of the LRK. A surface mooring is deployed at the water depth 82 meters. The ocean ambient sound data are collected using Passive Acoustic Listener (PAL) deployed at 27 meters (Ma and Nystuen, 2005). The experiment is divided into two periods. The first period is from April 19 to May 23, 2006. The second period is from June 12 to August 18, 2006. Several ancillary data are also collected from both surface mooring and land base station simultaneously, including disdrometer, accumulation rain gauge, surface wind speed, air-sea temperature. The Central Weather Bureau (CWB) precipitation radar at Chi-Ku also covers the experiment site providing reflectivity measurement during the rainfall. The schematic of experiment and instruments involved is shown in the figure 1 and table 1.

3. The acoustic data collection

The PAL is designed for rejecting transient noise and records the data depend on a simple preset trigging code

(Ma and Nystuen, 2005). In the first period the triggering code is set at 1 minute for the rain, 2 minutes for the drizzle and 10 minutes for wind. After the PAL was recovered from first period deployment, the data shows that the threshold of the triggering algorithm is too low. Thus it trigged the rain sequence all the time. For the second deployment, the sample sequence is set at 2 minutes for rain, 3 minutes for drizzle, and 10 minutes for wind in order to conserve the battery power. The overall acoustic data is shown in the figure 2. The frequency band from 0-3 kHz is shown in the figure 3. At frequency 1.5 kHz has a strong diurnal. The source of this strong signal is unknown. It might relate to the strong local current which needs a further investigation.

4. Results for the first period (April 19 to May 23)

For the first deployment period, the ancillary data from the Costal Ocean Monitoring Center of Nation Cheng-Kung University (COMC-NCKU) indicates only two significant rainfall events occurred at year day 118 and 137 (Figure 4, panel 1 and 2). The acoustic spectra screening is perform by using

$$SP_{15\,kHz} - SP_{5\,kHz} \geq 3\,dB \;,$$
$$SP_{20\,kHz} - SP_{15\,kHz} \geq 3\,dB \;,$$
$$SP_{15\,kHz} - SP_{5\,kHz} \geq 3\,dB$$
$$, SP_{15\,kHz} \geq 65\;dB$$
$$\text{and}\quad SP_{47\,kHz} \leq 65\;dB \qquad (1)$$

for the drizzle spectrum and the temporal screening is using 30 minutes event interval with at least 5 rainfall detections. The criteria are able to detect rainfall signals at the day 118, but not at day 137. The radar reflectivity confirms that the rainfall was only occurred on the land base station on day 137. The quantification of rainfall amount is using the rainfall conversion algorithm developed for the Tropic Pacific Ocean

$$dBR/10 = (SPL_{5kHz} - 42.4)/15.4 \qquad (2)$$

where $dBR = 10\log_{10}(R)$ and SPL_{5kHz} is the sound pressure level at 5kHz with an offset of 6 dB to compensate the geometry effect of this region. The acoustic spectrogram, the converted rainfall rate and accumulation for the event at day 118 is shown on the figure 5. The accumulation of rainfall calculated acoustically is comparable to the ground station. The small deviation in time might be due to those two stations are physically apart by 2 km.

5. Preliminary results for the second period (June 12 to August 18)

For the second period of deployment, the data from the COMC mooring shows the month of July has 600 mm of rainfall (Figure 6). The acoustic data also indicates drizzle, medium, and large rainfall events are being recorded. With the CWB Chi-Ku radar station proving reflectivity data and ground base disdrometer data (Figure 7). The detail of the rainfall signals will be studied.

6. Conclusion

The preliminary acoustical screening on the first period of data shows that the acoustic detection of rainfall on the continental shelf region is feasible even given the poor acoustic condition with strong diurnal noise at low frequency. The special drizzle signals at 15 kHz is able to be picked up by inspecting the spectrum and temporal consistency. The quantification of rainfall will need more data to construct an empirical algorithm special for this region. The preliminary results from the second period of deployment shows large rainfall events were recorded. The further analysis combining with ancillary data is needed.

References:

Black, P. G., J. R. Proni, J. C. Wilkerson, and C. E. Samsury, 1997: Oceanic rainfall detection and classification in tropical and subtropical mesoscale convective systems using underwater acoustic methods. *Mon. Wea. Rev.* **125**, 2014-2024.

Freitag, H.P., M. O'Haleck, G. C. Thomas, and M. J. McPhaden, 2001: Calibration procedures and instrumental accuracies for ATLAS wind measurements. *NOAA. Tech. Memo. OAR PMEL*-**119,** NOAA/Pacific Marine Environmental Laboratory, Seattle, Washington, 20 pp.

Ma, B. B., J. A. Nystuen, and R. C. Lien 2005: Prediction of underwater sound levels from rain and windThe Journal of the Acoustical Society of America, Vol. **117**, No. 6, pp. 3555–3565, June 2005

________, and J. A. 2005: Passive Acoustic Detection and Measurement of Rainfall at Sea, *Journal of Atmospheric and Oceanic Technology*, Vol. 22, No. 8, pages 1225–1248.

Medwin, J. A. Nystuen, P. W. Jacobus, L. H. Ostwald, and D. E. Synder, 1992: The anatomy of underwater rain noise. *J. Acoust. Soc. Am.* **92**, 1613-1623.

Nystuen, J. A. 1993: An explanation of the sound generated by light rain in the presence of wind. *Natural Physical Sources of Underwater Sound*, B. R. Kerman, Ed., Kluwer Academic Publishers, 659-668.

_________, 1996: Acoustic rainfall analysis: Rainfall drop size distribution using the underwater sound field. *J. Atmos. And Oceanic Tech.*, **13**: 74-84.

_________, M. J. McPhaden, and H. P. Freitag, 2000: Surface measurements of precipitation from an ocean mooring: The Acoustic Log from the South China Sea. *J. Appl. Meteor.* **39**, 2182-2197.

_________, 2001: Listening to raindrops from underwater: An acoustic disdrometer. *J. Atmos. and Oceanic Tech.* **18**, 1640-1657.

Pumphrey, H. C., L. A. Crum, and L. Bjorno, 1989: Underwaer sound produced by individual drop impacts and rainfall. *J. Acoust. Soc. Amer.*, **85**, 1518-1526

Serra, Y., P. A. Hearn, H. P. Freitag, and M. J. McPhaden. 2001: ATLAS Self-siphoning rain gauge error estimates. *J.Atmos.and Oceanic Tech,*.**18**, 1989-2002

Table 1. List of Instrument and data collected

Instrument	Sampling Interval	Data Type	Note
Passive Acoustic Listener	5 sec ~1 min	dB re 1μPa	Acoustic ambient noise
Accumulation Rain Gauge	5 mins	mm	Rainfall accumulation
Precipitation Radar	10 mims	Reflectivity (dBz)	Chi-Ku radar station rang bin 250 x1698 m
Disdrometer	1 mins	mm/m^3	Drop size distribution
Anemometer	1 hour	m/s	Wind speed for ambient noise calibration

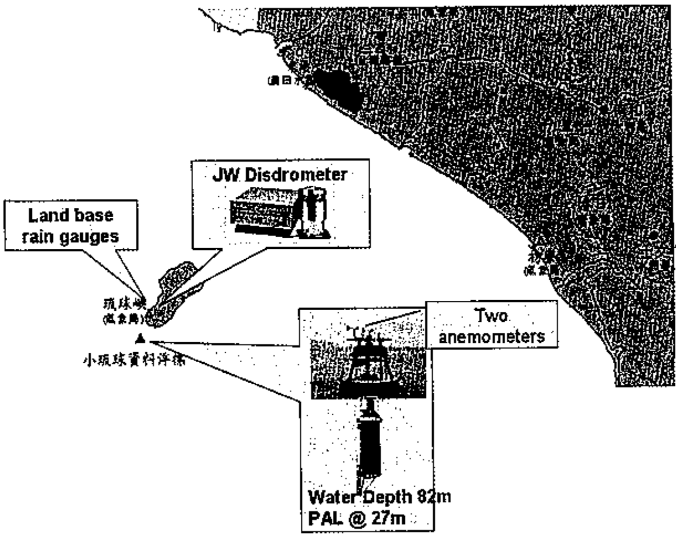

Figure 1. The schematic plot of ADMIRAL.

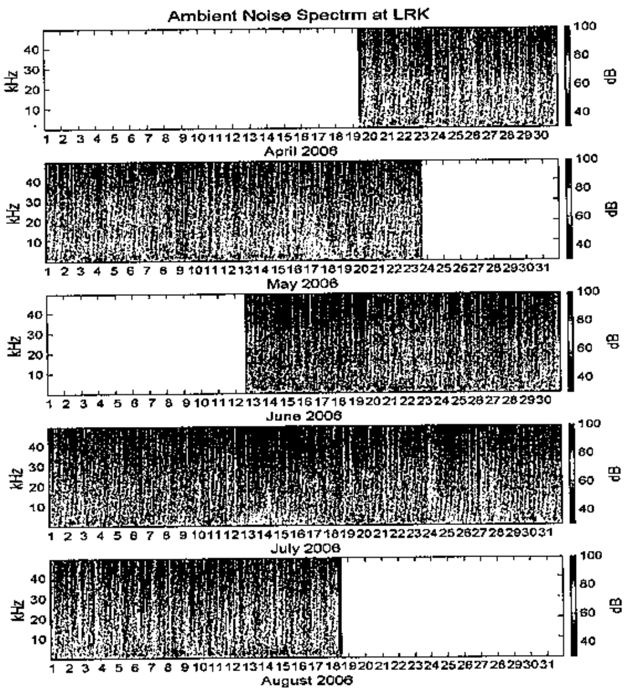

Figure 2. The acoustic ambient noise data form 1-50 kHz.

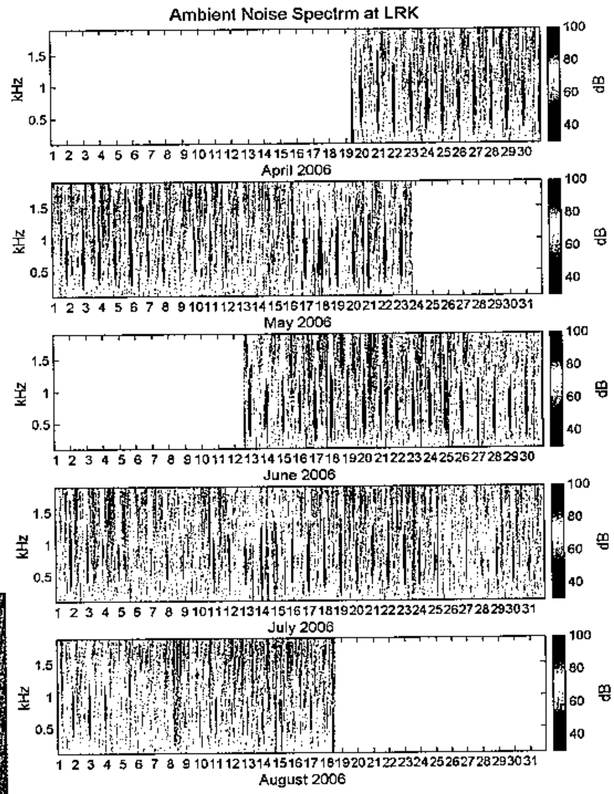

Figure 3. The acoustic data form 0-3 kHz shows strong diurnal cycle.

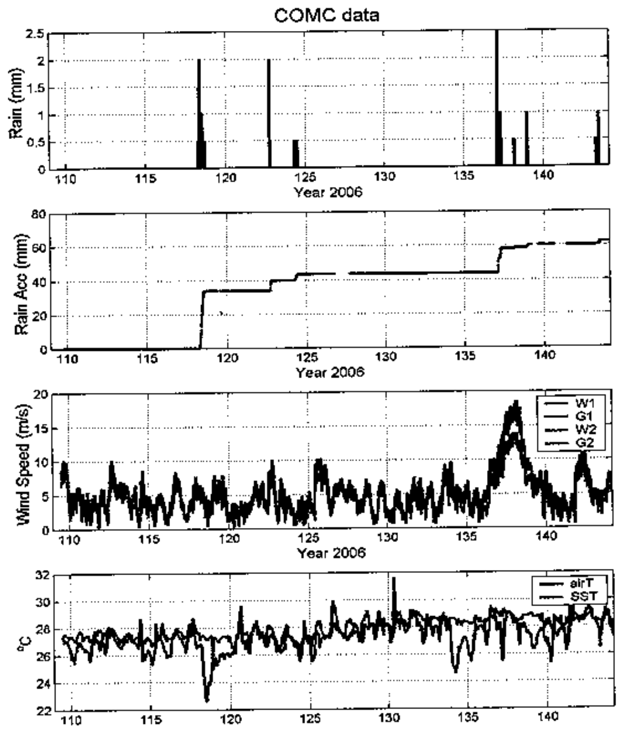

Figure 4. The ancillary data from the COMC mooring and ground station.

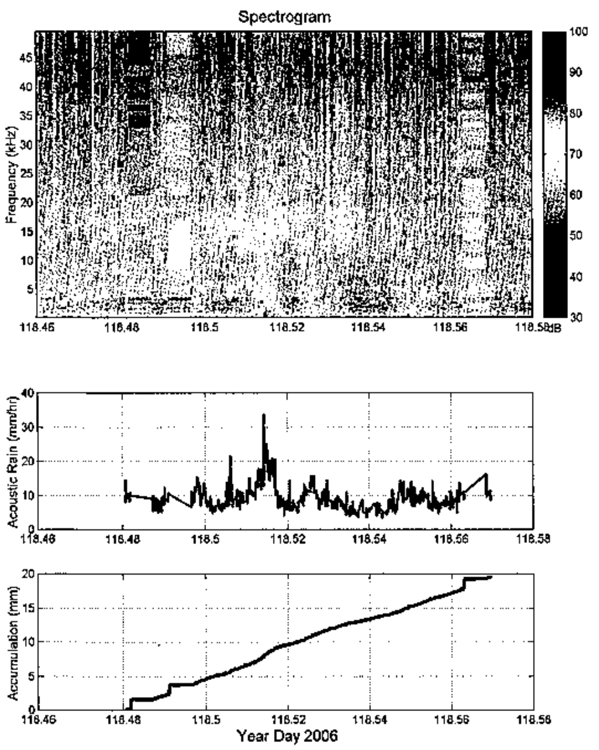

Figure 5. The spectrogram of drizzle occurred at day 118 and acoustic rainfall conversion.

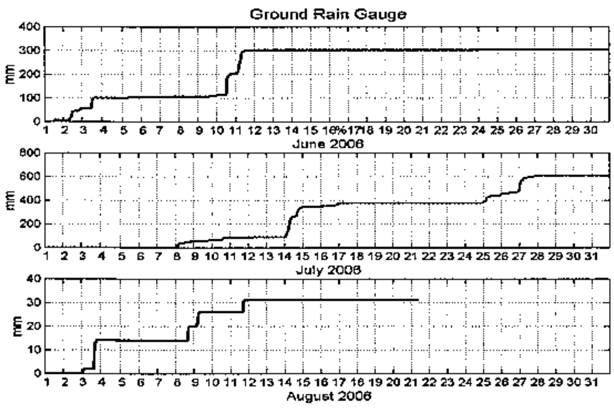

Figure 6. The COMC ground rainfall station data

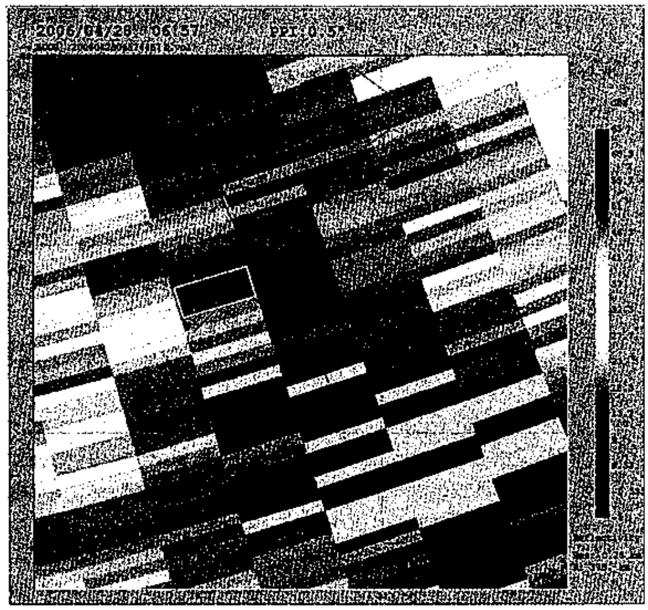

Figure 7. The CWB Chi-Ku radar station covers the LRK site proving reflectivity data during the rainfall.