Remote Sensing with Noise

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ABSTRACT

Acoustic noise is ubiquitous in the ocean. The noise comes from many sources including ships, marine life, and breaking waves. For sonar systems, this ambient noise has generally been considered a nuisance. However, recent studies have shown that the noise itself contains valuable information about properties of the ocean, Earth and atmosphere. For example, distant storms have been observed using measurements of low frequency (0.1 Hz) noise that has propagated through the Earth's core. Wind speed over the ocean has also been determined from hundreds of kilometers away using noise measurements at coastal observing stations.

An example of this involves tracking a storm in the deep East Pacific ocean (water depth about 5 km) from the noise sensed on an array of land-based geophones in southern California 8000 km away. The storm created ocean waves at a period of about 10 s. These ocean waves attenuate with depth and cannot be sensed at the ocean bottom. However two wave systems can interact and create a standing wave at half the period, 5 s, which will reach the bottom nearly unattenuated. This is the wave that can be sensed 8000 km away.

Another example is the process of using breaking wave noise to image the seabed structure tens of meters below the ocean floor. The breaking waves provide a type of overhead acoustic lighting analogous to the moon and stars providing natural light that allows one to see at night. The basic principle involves correlating noise signals arriving from the sea-surface with the echoes that reflect from the seabed. This echo processing is similar to active sonar systems (such as those used in nature by bats), but the sound source is the background noise. As concerns are raised about the impact of man-made sound on the marine environment, it is not surprising that using naturally occurring noise for remote sensing has become a hot topic in acoustical oceanography. Essential components of noise processing will be described along with examples illustrating applications. A recent application involves extracting the ocean bottom profile from noise.

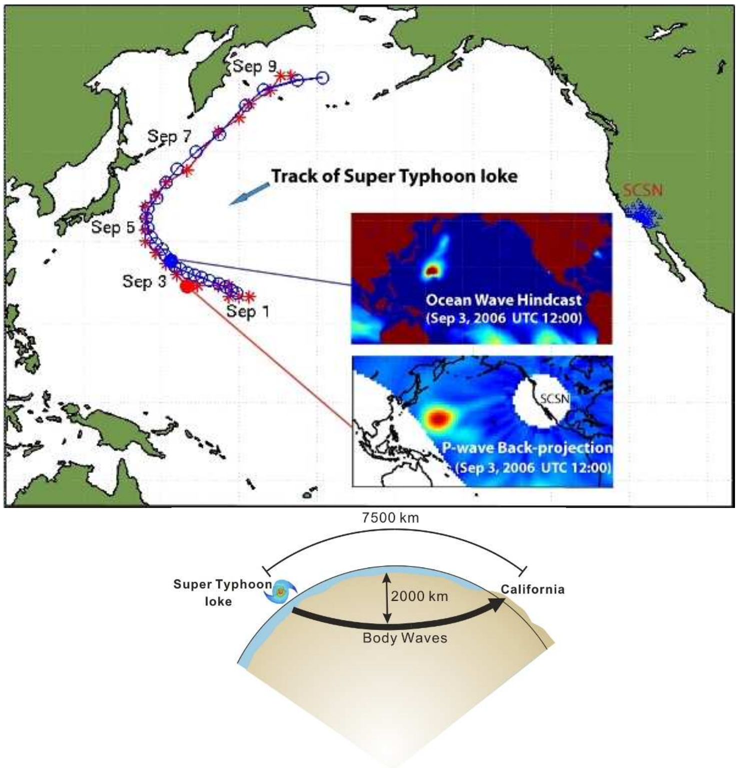

Figure 1. Map showing tracks of the *P*-wave source regions (*) and Super Typhoon Ioke (o). The track of peak energy of source regions is derived from back-projecting the SCSN beamformer outputs as indicated in the insert. The best track of Super Typhoon Ioke is extracted from an ocean wave hindcast, as indicated in the insert. Bottom figure shows sketch of propagation path.

地圖中標示出 P-波頻源(*)及強颱 Ioke 的路徑圖(o)。頻源路徑的最大能量可以從 SCSN 的波束構成器輸出資料(如插圖所示)中反推。而 Ioke 颱風的最可能途徑則從一個海波歷史模擬預報(如插圖所示)摘錄。下圖則為海波的路線。

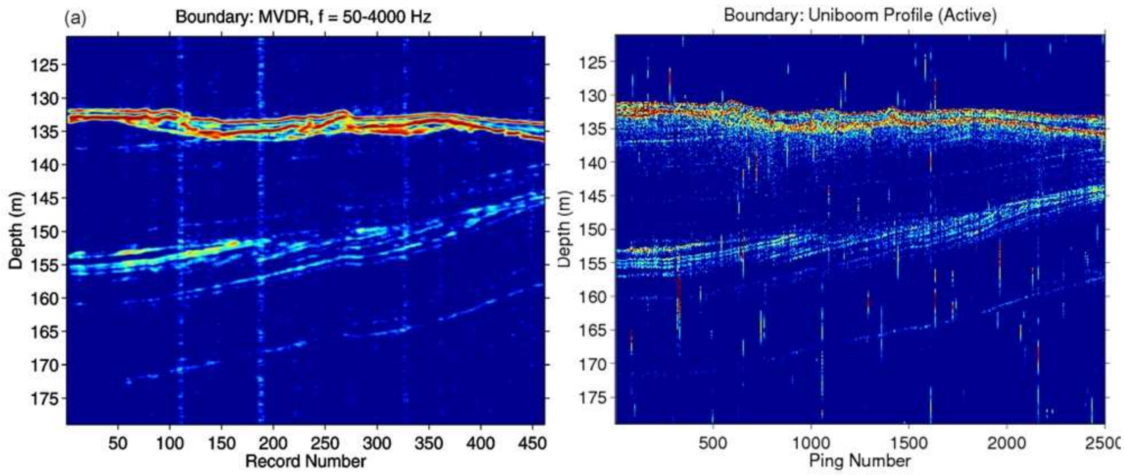

Figure 2. Seismic profile (left) obtained from noise and (right) obtained from active source. As the vertical array drifts over the seabed the reflection time between the down- and up-going noise gives the reflections in (a). In (b) a horizontal array and a source is towed over the same ground. Note the strong resemblance of the two profiles

左邊的震波圖來自噪音，而右邊則來自活動源。當垂直波通過海底，上下噪音的反射時間形成了(a)影像。而(b)影像則顯示平行波和波源被拉向同一地方。請注意到兩個圖片有高度的相似度。

噪音遙測法

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摘 要

海洋中的噪音（acoustic noise）無所不在。噪音的來源很多，包括了船隻、海洋生物、碎波等等。對聲納系統而言，這些環境噪音都是干擾。不過，近來的研究指出這些噪音隱藏著珍貴的資訊，可讓我們了解海洋、陸地、大氣的特性。譬如說，科學家發現風暴的低頻噪音(0.1 Hz)可傳達到地心，所以利用噪音測量法也可觀察到遠處的風暴。近岸觀測站也可以利用噪音測量法觀測數百公里外的海面風速。

南加州外海八千公里遠的陸基地震檢波器利用這個概念追蹤到東太平洋深處的風暴（水深約五公里），風暴每十秒鐘就會激起海浪，而海浪的強度隨深度遞減，所以在海底無法偵測。不過兩個波浪系統（wave systems）會互相影響，造成週期一半的駐波（standing wave），也就是五秒鐘一次，而駐波會在強度幾乎不減的情況下抵達海底。而八千公里外的偵測站就可偵測到這個駐波。

另一個應用實例是利用碎波噪音來繪製海底數十公尺的海床結構圖，碎波會產生一種空中聲光（overhead acoustic lighting），這個原理類似月球和星星的自然光讓我們可以在夜晚看得到星月。基本原則是建立海面噪音信號與海床反射回音之間的相關分析。回音處理就類似主動聲納系統（就像蝙蝠）只不過音源是背景噪音。儘管目前會顧慮到海洋環境裡的人為聲響，但顯然利用自然聲響進行遙測已經是水聲海洋學中的熱門議題。噪音處理的主要元素將會在介紹應用實例時詳加敘述，近來的應用也包括利用噪音瞭解海底地形。