Sounding out the future:
Towards a global acoustic prediction scheme

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Abstract – Most of the key environmental sources of sound — wind, rain and sea-ice and waves — are readily monitored in near real-time via satellites. Thus with the aid of a suitable assimilating model one should be able to predict the presence of these sources and infer their likely contributions to the underwater sound field. This paper discusses the ability of current satellite sensors and models, highlighting the causes of the greatest uncertainties.

1 – Introduction

There is continuing interest in the understanding and prediction of the underwater sound levels due to environmental contributions. These provide a background noise level limiting the ability to monitor cetaceans, detect man-made vessels or exchange sub-sea information via acoustic telemetry. To design systems for these afore-mentioned purposes one needs to know the likely acoustic spectrum due to all the natural features; this can be gained from a knowledge of all the source terms and the propagation conditions. Some of these aspects are constant or slowly-changing, and so the relevant terms are readily supplied from a climatic database; some change fairly frequently and so need regular updates from satellites or other monitoring systems, whilst others change significantly on such short time scales that assimilating models are required to provide the most appropriate estimates. Section 2 provides a summary of the natural acoustic sources in the open ocean and the sound levels generated, whilst section 3 provides an overview of the current monitoring/modelling capabilities.

2 – Summary of sources and spectra

Wind is almost omni-present, and its acoustic signature is discernible most of the time. Wind generates sub-surface sound via the production of small bubbles. Although visibly the production of bubbles ('whitecapping') appears to commence once the wind speed exceeds ~5 ms^{-1}, bubbles are present in small amounts in even the slightest winds [1]. The typical spectra generated by wind increase with wind speed and falls off with frequency (see Fig. 1a). Rain generates sound in a variety of ways, involving both the direct impact on the surface and the creation of sub-surface bubbles [2]. The small raindrops in a drizzle produce a characteristic peak around 14 kHz, whilst the acoustic signature of heavy rain differs from wind in both the spectral slope and the acoustic intensities achieved. (Fig. 1b). Different spectra again are ascribed to hail and snow. In polar climes sea-ice can be an important contributor to the sound field through a number of mechanisms. For example, there is the daily cycle of warming and cooling which leads to "microfracturing", as well as the jostling of neighbouring ice parcels which is dependent upon the magnitude and direction of the wave field. On the other hand, sea-ice reduces the direct generation of sound by wind. Whales, dolphins and porpoises create a wide range of sounds, covering frequencies between 20 Hz and 20 kHz. A number of other creatures, such as croaker fish and snapping shrimp generate significant volumes of sound in certain frequency ranges. The snapping shrimp are common in many shallow warm (tropical) waters.

As well as the source terms, it is necessary to know the local propagation conditions, which depend upon the depth of interest, the sea bottom type and the sound speed profile. The nature of the ocean floor is important in that it may increase acoustic intensity at some frequencies via the reflection of sound. The stratification of the water column may have a marked effect on the refraction of sound rays from distant sources. And finally, the recent meteorological history may have an effect, as both strong winds and heavy rain produce a sub-surface bubble layer that attenuates the higher frequencies generated by any subsequent surface sources [3].

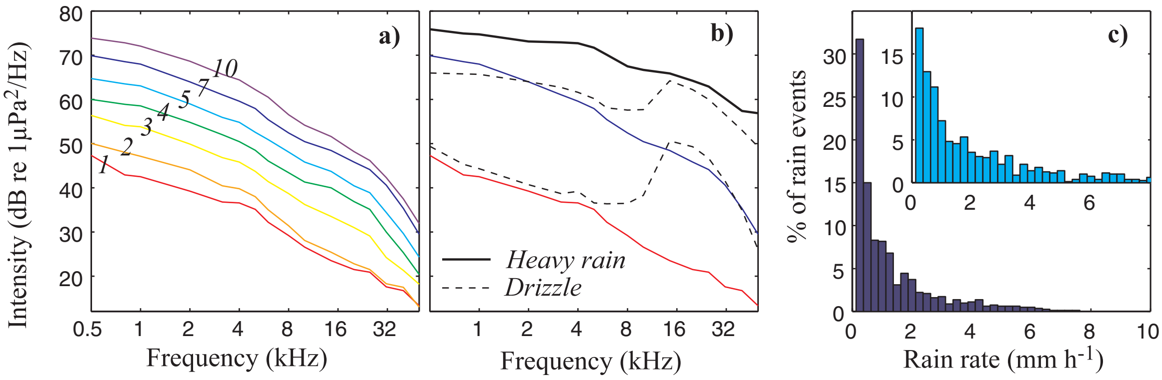

FIG. 1 : a) Underwater acoustic spectra due to wind (speeds given in m s^{-1}); b) underwater acoustic spectra due to rain; c) Probability distribution function of rain rates when raining (upper panel: November-December 1999; lower panel: May-June 2000). [All data collected in Loch Etive, Scotland.]

3 – Monitoring the sources

Much effort has been expended on global monitoring of wind speed by satellites, with algorithms existing for data from altimeters, scatterometers and passive microwave radiometers. Numerical weather prediction models can assimilate past observations to give an accurate estimate of current wind speed, and also forecast several days ahead. Whilst rain can be detected by a number of spaceborne sensors (altimeters, passive microwave radiometers and infra-red sensors), there are large errors in their accuracy. The assimilation and prediction of rain in models is presently an active area of research. Also rain changes on short spatial and temporal scales and bulk averages of the rain rate are not very useful in this context. In many locations, a large fraction of the observations of rain indicate rain rates of 1 mm h^{-1} or less (Fig. 1c). Such low rain rates are poorly detected by many satellite sensors, yet are important because their acoustic contributions can be loud and very distinct from that of heavy rain (see Fig. 1b). At the other extreme, the extent of sea-ice changes slowly (over periods of weeks). The thermal microfracturing is controlled by latent heat loss; monitoring of cloud cover acts as a proxy for this. At present the biological sources are best determined from climatologies of observations; however, monitoring of temperature coupled with knowledge of bathymetry could provide an improvement in the seasonal changes in snapping shrimp. Observations of chlorophyll by ocean colour sensors may be used to indicate the likely feeding zones in the complex marine food web.

4 – The way forward

Many of the building blocks for a global acoustic prediction scheme are present. The typical spectra of the environmental sources are fairly well known (although still an area of investigation), and models have been developed to assimilate the frequent wind observations from a number of sensors. The effect of different bottom types is a factor yet to be fully assessed. For many locations wind information might be sufficient for acoustic predictions for, say 90%, of the time. However, to be useful for defence purposes, much improvement is needed for locations/occasions when rain, sea-ice or various noisy lifeforms are present. There is still much work required to model all these processes sufficiently accurately.

Acknowledgements

The rain radar data were provided by Simon Keogh of the Met Office.

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