MAPPING OCEAN WINDS BY BROADBAND ACOUSTIC INTERFEROMETRY

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1. Introduction

Mapping the wind over vast ocean areas is a very important practical problem, especially at high winds. Satellite measurements using scattering of electromagnetic waves from the rough ocean surface are extremely useful; however, the cross section for this scattering saturates at high winds, when wind speed measurements are most valuable. On the other hand, the same mechanism that precludes use of satellites for the purpose of measuring ocean surface winds may allow measurements via underwater acoustic techniques. Surface wind is one of the most significant contributors to the ocean ambient noise field, and level of the wind-generated noise strongly depends on the wind speed. Using measurements of the ocean ambient noise for wind retrieval was suggested long ago (work [1] was, probably, one of the first where this approach was systematically considered.) Recently this idea was revisited in conjunction with the necessity to accurately estimate wind speed in the hurricanes [2]. Work [2] provides also rational for using acoustical means for solution of this important problem.

2. Approach

All extant studies known to us including [1,2] rely on local measurements, when ambient noise level is related to the local wind speed. This does not allow mapping the ocean wind over vast areas, unless one covers the ocean floor by a sufficiently dense network of hydrophones. This is prohibitively expensive. In this talk we consider another approach, which relies on measurements of directivity of the ocean noise in the horizontal plane by a pair of broadband ocean interferometers. Each interferometer consists in turn of a pair of hydrophones separated horizontally by a few tens of kilometers. The ambient noise is coherently measured at both hydrophones, and the correlation function of the acoustic signals is evaluated as a function of time delay. Only the noise sources located within a narrow interval of angles in the direction dependent on the time delay contributes to the correlation function. The broadband character of the measurements is crucial at this point, since it leads to cancellation of all side lobes except for the central one (correlation dipole.)

In contrast to the local approach, we are using the component of the ambient noise coming from far away, and local noise in our case is rather a hindrance. If the ocean is deep enough, and sound speed at the bottom exceeds the sound speed at the surface, there exists a sector of vertical angles within which the surface-generated noise does not interact with the bottom. In this case the noise propagates over large distances of the order of thousands kilometers. To avoid decorrelation due to scattering by internal waves and the ocean surface ,we suggest using low-frequency sound within frequency range of a few tens of Hertz.

The crucial issue for the feasibility of the approach is how long an integration time is necessary to filter out correlation due to local sources. Since this noise propagates at shallow angles with respect to the sound channel axis (corresponding to low-order acoustic modes), using vertical line arrays of the type described in [3] should help to significantly reduce integration time.

A single interferometer can produce sharp angular resolution; however, in practice, it does not provide radial resolution. For this reason, we suggest using a second interferometer located sufficiently far away from the first one, thus exposing the area of interest to another perspective. Retrieval of the 2D map of the strength of the surface sources (and thus the wind) is a standard linear tomography problem; there exist numerous approaches to its effective solution.

3. Results

We demonstrate theoretically that mapping of the ocean winds with resolution of the order of a few kilometers over vast areas with the size of the order of thousand kilometers by measuring directivity of the broadband ambient acoustic noise with acoustic interferometers is achievable in principle.

References

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