3D underwater source localization based on parabolic equation model combined with matched-field processing technology

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Underwater source localization based on acoustic modeling has been a subject of intensive research since a long time. Many works have devoted to provide accurate estimates of both source range and depth based on normal-mode or ray tracing models combined with Matched-Field Processing (MFP) techniques. This work discusses the use of parabolic equation models for 3D source localization, including range, depth and azimuth. The accuracy of this approach is tested using data from the stationary source in the SACLANTCEN 1993 Mediterranean Experiment.

In order to avoid environmental mismatch and improve the speed of inversion, the two-dimensional model RAMgeo is used for estimation of the environmental parameters. Since the geometric, sound speed profile and geoacoustic parameters cannot be decoupled, the GA preprocessor in SAGA was first used to jointly estimate these types of parameters[2]. The experimental setup and the baseline environmental model can be found in the literature[1], thus it isn't repeated here. As shown in TABLE I, The optimization was carried out using 16 parameters. It should be noted that the sound speed profiles is described by the Empirical Orthogonal Function (EOF)[3], in which the first 5 items are taken into account. For each parameter the search space was quantized into different increments according to prior knowledge. Analysis of the posteriori probability distribution of the estimated parameters has shown that the mean is the most robust, thus it was used as the parameter estimate.

TABLE I model parameters of inversion

Model parameter		Baseline	Lower bound	Upper bound	Inc	CA mean
geometric	source range (m)	5500	5200	6000	128	5889.9
	source depth (m)	65	60	80	64	78.5
	bathymetry at source (m)	130.0	129	133	64	129.5
sound speed profile	coefficient 1	-12871	-12874	-12868	64	-12870.4
	coefficient 2	0.1	-1.0	1.0	64	-0.9
	coefficient 3	1.9	1.0	1.6	64	1.55
	coefficient 4	-3.9	-4.5	-3.0	64	-3.0
	coefficient 5	1.0	0	2	64	0.03
sediment	sound speed, upper (m/s)	1505	1495	1515	64	1507.7
	sound speed, lower (m/s)	1556	1545	1565	64	1550.7
	density (g/cm^3)	2.0	1.6	2.5	32	2.32
	attenuation (dB/λ)	0.11	0.05	0.21	32	0.057
	depth (m)	3	1.3	5.3	64	5.07
bottom	sound speed (m/s)	1576	1565	1585	64	1568.1
	density (g/cm^3)	1.6	1.2	2.0	32	1.76
	attenuation (dB/λ)	0.18	0.12	0.24	32	0.20

The estimated sound speed profile and geoacoustic parameters are then used by the three-dimensional model FOR3D to accurately predict the 3D replicas, but the geometric parameters are discarded at this stage. Personal archival data with the site bathymetry in geographical coordinates were introduced and converted to UTM coordinates, as well as the VLA and stationary source GPS positions. The search space and it’s discrete step size are shown in Table 2. Assume that the underwater source may exist in any discrete location, a total of 53382 three-dimensional acoustic fields need to be calculated. Considering the large scale, the calculation of the replicas is run on Tianhe-2. Computer resources used include 21 nodes with 24 cores per node. MPI and OPENMP algorithm libraries were used to accelerate the parallel computing speed.

TABLE II model parameters of inversion

Spatial dimension	Lower bound	Upper bound	Step size
range(m)	5280.0	5480.0	5.0
depth(m)	43.0	84.0	1.0
azimuth(deg)	80.0	110.0	1.0

The location result are obtained finally with a standard Bartlett processor. As shown in FIG.1, the source range is 5415m, the depth is 65m, and the azimuth is 90 degrees. From the report of the SACLANT experiment[4], stationary source - VLA range calculated from Cartesian coordinates corresponds to 5836m, source depth is 79m, while source bearing relative to the VLA is 93.3 degrees. Taking into account the errors of GPS positions and wind induced source drifting and tilt, the result in this work should be accepted. So, the proposed approach can provide accurate estimates of source range, depth and azimuth at same time.

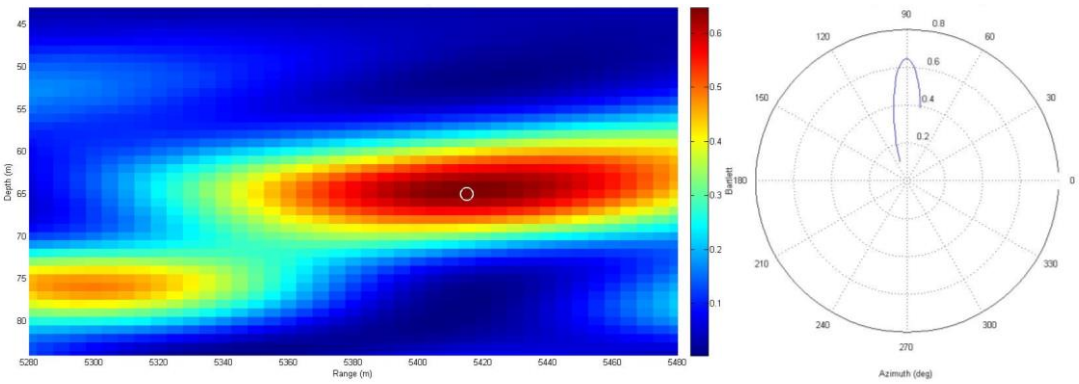

FIG. 1 result of 3D underwater source localization

Reference

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