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Marine and Freshwater Research

Supplementary Material

Mapping knowledge structure and research frontiers of underwater acoustic tomography: a scientometric study

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Table S1. Applications of acoustic tomography technique and relevant details, including the frequency used, sound wave propagation distance, study area and researchers.

Underwater Acoustic Tomography

OAT						CAT					FAT				
Year	Hertz	Range (km)	Study Area	Subject	Author	Hertz	Range (km)	Study Area	Subject	Author	Hertz	Range (km)	Study Area	Subject	Author
1992	57	18000	Atlantic, Pacific, and Indian Oceans.	Heard Island Feasibility Test (HIFT)	Baggeroer & Munk [14]										
1979	220	1000	Eleuthera and Bermuda	One-way tomography/ temperature	Munk and Wunsch [2]										
1982	224	300	Bermuda	3-D eddy fields	Behringer *et al.* [34]										
1984	-	300	Gulf Stream	Reciprocal tomography	Whalen [35]										
1986	495.5588	45	Florida Strait	range- and depth-averaged current and temperature	DeFerrari & Nguyen [36]										
1987	400	300	Bermuda	Mesoscale Velocity	Howe *et al.* [37]										
	510	60	Florida Straits	Effects of Bathymetry on acoustic tomography	Nghiem-phu & Deferrari [38]										
1991	250	3000	northeast Pacific	estimate an algorithm for sound speed	Spiesberger & Metzger [39]										
1993	50-600	6	Atlantic	sediment effect on acoustic wave propagation in	Rogers *et al.* [40]										
	250	110	Greenland Se	ocean mixed layer model	Sutton *et al.* [41]										
	250	121	Greenland Se	Effects of sea ice cover on acoustic tomography	Jin *et al.* [42]										
1994	250	110	Greenland Se	Acoustic normal mode extraction from acoustic tomography	Sutton *et al.* [43]										
	110	50	-	Effects of bottom topography irregularitieson acoustic tomography	Taroudakis [44]										
1995	400	60	Gulf of Lions	deep convection regime	Send *et al.* [45]										
	400	250	Mindanao Island	ENSO-related variabilities detection by Acoustic Tomography	Yuan rt al [46]										
	75	3500-5000	Pioneer Seamoun	Instrumentation for the Acoustic Thermometry of Ocean Climate (ATOC) prototype Pacific Ocean network	Howe *et al.* [47]										
1996	224	80	Barents Sea	internal waves and internal tides	Lynch *et al.* [48]										
	224	80	Barents Sea	Polar Front	Parsons *et al.* [49]										
	133	3709	northern California	Validation Acoustic Tomography with Ray Theory	Spiesberger & Tappert [50]										

Underwater Acoustic Tomography

OAT Year	Hertz	Range (km)	Study Area	Subject	Author	CAT Hertz	Range (km)	Study Area	Subject	Author	FAT Hertz	Range (km)	Study Area	Subject	Author
	75	2000	North Pacific	modal group time delays	Brown *et al.* [51]										
	50-70	5000	Pacific Ocean	Performance bounds on acoustic tomography	Krolik & Narasimhan [52]										
	19.6	1000	Lincoln Sea	large-scale thermal variability	Pawlowicz *et al.* [53]										
1997	75	-	Kauai	The effect of Acoustic Tomography on mammals	Whitlow *et al.* [54]	10600	5.7	Seto Inland	velocity measurement	Zheng *et al.* [5]					
			Gulf of Lion	A four-dimensional analysis of the thermal structure	Gaillard & Desaubies [55]										
	459.5588	21.11	Florida Straits	Modulations of detectable pulse	Monjo *et al.* [56]										
1998				Comparison of Acoustic Tomography, Satellite Altimetry, and Modeling	The ATOC Consortium [57]										
1999	19.6	2600	Beaufort Sea	Climate Monitoring in the Arctic	Mikhalevsky *et al.* [59]	150-15000	3	Haro Strait	coastal front	Elisseeff *et al.* [58]					
	75	5000	North Pacific Ocean	Measurement of Ocean Temperature	Dushaw *et al.* [60]										
		270.92	eastern Arabian Sea	2-D temperature anomaly	Kumar *et al.* [61]										
2000	224 & 400	32	Mid-Atlantic Bight	Acoustic normal mode fluctuation	Headrick *et al.* [63]			Sero Inland Sea	Assimilation ocean model	Park & Keneko [62]					
	400	32	New Jersey coast	Modeling mode arrivals	Headrick *et al.* [64]										
	10-500	-	-	matched-field processing	Tolstoy [65]										
	-	-	-	Physical limitations of travel-time tomography	Rodrı´guez & Jesus [66]										
	-	-	-	matched-peak inversion approach	Skarsoulis [67]										
	-	-	-	Numerical Analysis of Acoustical Propagation Characteristics	TSUCHIYA *et al.* [68]										
	-	-	-	Tomographic inversion for geoacoustic parameters	Tolstoy [69]										
	-	-	-	Calculation of eigenray	Takahashi [70]										
	400	-	Gulf of Lion	Assessing the Postconvection Mesoscale Dynamics	GAILLARD *et al.* [71]										
	-	-	-	Determine range dependent geoacoustic propertiES	Corre *et al.* [72]										
2001				Spectral Description of Low-Frequency Oceanic Variability	ZANG & WUNSCH [74]	1500	1.1	Haro Strait	Tomographic inversion of geoacoustic properties	Pignot & Chapmana [73]					
	20.5	2700	Arctic Ocean	Acoustic thermometry	Mikhalevsky & Gavrilov [75]										

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Year	Hertz	Range (km)	Study Area	Subject	Author	Hertz	Range (km)	Study Area	Subject	Author	Hertz	Range (km)	Study Area	Subject	Author
	133	4000	Arctic Ocean	Basin-scale tomography	Spiesberger [76]										
	-	-	-	Vertical-slice matched-field Tomography	Corré & Chapman [77]										
	-	-	Kuroshio	data assimilation Kalman Filter	SHINKE *et al.* [78]										
	60 & 200	-	-	Adiabaticity of Acoustic Propagation	SHANG *et al.* [79]										
	39-244	-	La Jolla	Tomographic Reconstruction of Shallow Water Bubble Fields	Rouseff *et al.* [80]										
2002	-	-	-	Assimilating Acoustic Tomography Data into Numerical Models	YAREMCHUK & KROT [81]										
	200	974	Kuroshio	Estimating frontal positions of the Kuroshio extension	Shinke *et al.* [83]	-	-	Atlantic Ocean	Passive Coastal Tomography	Marinis *et al.* [82]					
2003	250	1000		Ocean-acoustic fluctuations in parabolic-equation simulations	Flatte & Vera [84]										
	-	10	Terra Nova Bay	Monitoring polynyas with Ocean Acoustic Tomography	MARINIS *et al.* [85]										
2004	250-400	220-610	western Mediterranean	heat-content estimates	Skarsoulis *et al.* [87]	2500	3	Sea of Japan	Currents measurement at the Shelf zone	Akulichev *et al.* [86]					
	75	3115	Gulf of Alaska	Acoustic identification of a single transmission	Spiesberger [88]										
2005	28, 75, 84	3000-5000	North Pacific Ocean	Different Low-frequencies Acoustic Transmission	Worcester [90]	8000-11000	1-Oct	Kauai	Assimilation of ocean model	Lewis *et al.* [89]					
	75	-	Kauai	Assessing responses of whales to Acoustic Transmission	Mobley [91]										
	200	2000	Central Equatorial Pacific	El Niño and the Southern Oscillation (ENSO) monitoring	Wang & Hachiya [92]										
2006	20.5	1250-2720	Arctic climate observations using underwater sound (ACOUS)	Franz Josef Land	Gavrilov & Mikhalevsky [94]	250-2500	3	East/Japan Sea	Flow Monitoring of Ocean Shelf Zones	Akulichev *et al.* [93]					
2007						2500	3	East/Japan Sea	Study of the Vector Receivers in Application to Ocean Tomography	Burenin *et al.* [95]					
2008						2500	2	Sea of Japan	A Hardware and Software System for Measuring the	Bezotvetnykh *et al.* [96]					

Underwater Acoustic Tomography

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Year	Hertz	Range (km)	Study Area	Subject	Author	Hertz	Range (km)	Study Area	Subject	Author	Hertz	Range (km)	Study Area	Subject	Author
									Angular Structure of the Acoustic Fields						
2009	133	2000-4000	Kaneohe, Hawaii	acoustic thermometry	Dushaw *et al.* [98]	400	15	southeast of Elba, Italy	Kalman filtering for tracking of time variations of a range-dependent sound-speed	Carrière *et al.* [97]					
	-	-	-	A decade of acoustic thermometry in the North Pacific Ocean	Dushaw *et al.* [98]										
						400	15	southeast of Elba, Italy	Inversion for Time-Evolving Sound-Speed Field by Ensemble Kalman Filtering	Carrière *et al.* [47]					
	75	3200	northeast Pacific Ocean	LOAPEX: The Long-Range Ocean Acoustic Propagation Experiment	Mercer *et al.* [100]	2500	1.5	-	Simulation Double-Beamforming Algorithm	Iturbe *et al.* [99]					
						5500	9	Hiroshima Bay, Japan	Measurement of Multisubtidal Internal Modes	Nguyen *et al.* [101]					
						366-5000	2.9	East/Japan Sea	Water Structure and Dynamics	Akulichev *et al.* [102]					
2010											30000	0.23	Ota River, Japan	Long-term measurement of stream flow and salinity in a tidal river by	Kawanisi *et al.* [9]
											18000-23000	0.0015	Lake Qiezishan, China	2-D temperature distribution around hot springs on floor of Lake	Fan *et al.* [103]
											30000	0.42	Hyakken River, Japan	continuous measurement of river discharge and water temperature	Kawanisi *et al.* [104]
2011	-	650	Bay of Bengal	mapping of observed sub-surface mesoscale cold core eddy	Murty *et al.* [105]										
2012						5000	3	Qiantang River, China	Measuring discharge in a river with tidal bore	Zhu *et al.* [11]	25000	0.3	Gono River, Japan	Continuous measurements of flow rate in a shallow gravel-bed river	
						10000	1	Shelf of the Black Sea	possibility of acoustic tomography in a local region of a shallow water sea	Goncharet *et al.* [106]					

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Year	Hertz	Range (km)	Study Area	Subject	Author	Hertz	Range (km)	Study Area	Subject	Author	Hertz	Range (km)	Study Area	Subject	Author
2013	140-325	700	Philippine Sea	glider position using acoustic tomography sources	Van Uffelen *et al.* [109]	5000	10	Zhitouyang Bay, China	Mapping tidal current structures	Zue *et al.* [108]	20500	0.0015	Lake Qiezishan, China	2-D temperature distribution around hydrothermal vents	Fan *et al.* [107]
	-	-	-	time-mean state of ocean models and	Dushaw *et al.* [112]	18500	-	Sizihwan Bay, Taiwan	Underwater Networking, Communications, and Acoustic Tomography experiment	Huang *et al.* [111]	30000	0.198	Ota Estuary, Japan	continuous velocity monitoring in shallow tidal streams	Razaz *et al.* [110]
	800	48	Taiwan	Measuring the Kuroshio Current	Taniguchi *et al.* [15]						2500	1.5	-	acoustic tomography from angle measurements instead of travel-time measurements	Aulanier *et al.* [113]
	50	8	-	characterization of underwater acoustic signal	Taroudakis & Smaragdakis [115]						30000	0.15	Ota estuary, japan	Variability in salt flux and water circulation	Soltaniasl *et al.* [114]
2014		20000		Antipodal acoustic thermometry: 1960, 2004	Dushaw & Menemenlis [118]	6000	1.1	Korea strait	Hardware and Software design	Morgunov *et al.* [117]	2000	1.3	-	Increases the accuracy of AUV position measuring	Morgunov *et al.* [116]
	50	8000	New Jersey Continental Shelf	statistical signal characterization	Taroudakis *et al.* [119]										
	300	8.7	Yellow Sea in	Acoustic travel-time perturbations due to shallow-water internal waves in t	Li *et al.* [120]										
2015						5000, 7000	3	Qiantang River	Tidal bore measurement	Bahreinimotlagh *et al.* [122]	30000	0.27	Gono River, Japan	reconstruct the horizontal flow velocity field	Razaz *et al.* [121]
2016	-	-	eastern tropical Pacifi	Internal tide oceanic tomography Zhongxiang to monitor ocean warming on a global scale	Zhao[125]	3000-9000	50	coast of Oregon, USA	ocean attenuation tomography using eigenray amplitudes	Tippmann *et al.* [124]	3000	0.3	Gono River, Japan	measure flow direction and river discharge	Bahreinimotlagh *et al.* [123]
	189-290	130	Fram Strait	Time series of temperature (DAMOCLES)	Sagen *et al.* [128]	5000	15	Zhitouyang Bay, China	Coastal tomographic mapping of nonlinear tidal currents and residual currents	Zhu *et al.* [127]	3000	0.3	Gono River, Japan	High-frequency streamflow acquisition and bed level/flow angle estimates	Kawanisi *et al.* [126]
	189-290	130	Fram Strait	effects of small-scale variability on acoustic propagation (DAMOCLES)	Dushaw *et al.* [129]										
	189-290	130	Fram Strait	Sound speed as a proxy variable to temperature (DAMOCLES)	Dushaw *et al.* [130]										
2017	250	301	Fram Strait during	Resolution, identification, and stability of	Sagen *et al.* [133]	-	-	Sanmen Bay, China	Assimilation of coastal acoustic tomography data using an	Zhu *et al.* [132]	30000	0.3	Gono river, Japan	Scaling characteristics of mountainous	Sawaf *et al.* [131]

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Year	Hertz	Range (km)	Study Area	Subject	Author	Hertz	Range (km)	Study Area	Subject	Author	Hertz	Range (km)	Study Area	Subject	Author
				broadband acoustic arrivals					unstructured triangular grid ocean model					river flow fluctuations	
	400	308	Canary Basin	Meddies and Tides measurement (CAMBIOS)	Dushaw *et al.* [134]										
	-	-	-	The role of small-scale ocean variability in acoustic tomography-shadow zone	Dushaw & Sagen [135]										
	20-1000	-	-	Modeling and Forecasting Ocean Acoustic Conditions	Duda [136]										
2018	-	-	-	Raypath Separation With a High-Resolution Algorithm in	Jiang *et al.* [138]						30000	0.3	Gono river, japan	Automated Real-Time Streamflow Acquisition	Kawanisi *et al.* [137]
2019						5000	18	Lombok Strait, Indonesia	Observing Internal Solitary Waves	Syamsdin *et al.* [25]	60000	0.39	southwest coast of the Taiwan Strait	Real-Time Observation of Range-Averaged Temperature	Yu *et al.* [139]
						18000	3	Kaohsiung, Taiwan	moving ship acoustic tomography	Huang *et al.* [141]	50000	0.01	Anechoic tank	Water Temperature Observation in Artificial Upwelling Area	Huang *et al.* [140]
						-	20	Northwestern Pacific Ocean	Sensitivity of sound speed fluctuation on acoustic arrival delay of	Chen *et al.* [143]	53000	0.1	Ota river, Japan	Characteristics of Tidal Discharge and Phase Differenc	Danial *et al.* [142]
											30000	0.05	Zayanderud River, Iran	Error analysis	Bahreinimotlagh *et al.* [13]
2020	255	517	Canada Basin	Temporal and spatial dependence of a yearlong record of sound propagation	Ballard *et al.* [18]	10000	4	Bali Strait, Indonesia	tidal current and associated 3-h oscillation	Hanifa *et al.* [145]	30000	-	-	Influence of Suspended Sediment Concentration and Particle Sizes on the Sound Attenuation	Bahreinimotlagh *et al.* [144]
	250	300	Fram Strait	regional ocean model to understand the structure and variability of acoustic arrivals	Geyer *et al.* [146]										
2021	-	-	-	Global Multi-Purpose Ocean Acoustic Network	Miksis-Olds *et al.* [20]						50000	0.28	Huangcai Reser-voir, China	Water Temperature in a Reservoir	Huang *et al.* [147]
						5000	15	Jiaozhou Bay, China	Dynamics of Tidal and Residual Currents, Assimilated Data	Zhu *et al.* [26]	30000	0.22	Ota river, Japan	Mapping tidal current and salinity at a shallow tidal channel junction	Xiao *et al.* [148]

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Year	Hertz	Range (km)	Study Area	Subject	Author	Hertz	Range (km)	Study Area	Subject	Author	Hertz	Range (km)	Study Area	Subject	Author
						9000	3	Yangtze River, China	River Discharge	Zhu *et al.* [150]	60000	0.027	China	water pool	Yu *et al.* [149]
						10000	0.6	Noryeok Island, Korea	Vertical Temperature Profiles	Park *et al.* [152]	30000	0.3	Ota river, Japan	Acoustic Monitoring of Tidal Flow and Salinity	Nguyen *et al.* [151]
						5000	16	Qiongzhou Strait, China	Observation of Internal Tides in the Strait	Minmo *et al.* [24]	50000	0.3	Huangcai Reservoir, China	Layer-Averaged Water Temperature Sensing in a Lake	Xu *et al.* [153]
											30000	0.3	Gono River, Japan	Flood hydrology	Safaw *et al.* [154]

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