10th International Conference on Theoretical and Computational Acoustics

ICTCA 2011
Taipei, Taiwan
April 24-28, 2011

Program
and
Book of Abstracts

Sponsors

National Science Council, Taiwan

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Chinese Society of Sound and Vibration

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Technical Assitance

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Winner Chang
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Welcome

Dear Colleagues,

A very warm welcome to the 10th International Conference on Theoretical and Computational Acoustics (ICTCA 2011), being held on April 24-29, 2011, in the GISNTU Convention Center, National Taiwan University, Taipei. There are about 80 presentations and 100 participants from 18 countries.
The conference seeks to provide a forum for researchers to discuss state-of-the-art developments in theoretical and computational acoustics and related topics, as well as experimental results and comparison with numerical simulations. The program covers a broad range of topics in acoustics and should serve as an excellent platform for intellectual discussion and networking.
The ICTCA has been held in many countries, which started in Mystic, USA (1993), in Honolulu, Hawaii, USA (1995, 2003), in Newark, New Jersey, USA (1997), in Trieste, Italy (1999), in Beijing (2001) and Hangzhou (2005), China, in Crete, Greece (2007), and in Dresden, Germany (2009). The ICTCA 2011 is the tenth conference in this series and we are greatly appreciative to those that organized and participated in the previous conferences.
The conference committee would like to express our whole-hearted appreciation to Dr. Ding Lee for his effort in starting the ICTCA, and continuous support for the subsequent conferences as well as serving as the Honorary Chair of the conference. Acknowledgement is also due to our kind co-sponsors: National Science Council of Taiwan, the U.S. Office of Naval Research Global, the International Atmospheric and Oceanographic R&D Foundation, and the National Taiwan University.
I also trust that you will take some time off and enjoy all that Taipei has to offer. You might well be pleasantly surprised!

On behalf of the Organizing Committee

Chi-Fang Chen
Professor
National Taiwan University, Taiwan
Chairman

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Agenda

Time/Date	4/24 (Sun)	4/25 (Mon)		4/26 (Tue)		4/27 (Wed)		4/28 (Thu)	
08:00-09:00	X	Registration		Registration		08:30	Assembly	Registration	
09:00-09:45	X	**Opening**		**Keynote 3**		09:00-09:50	Transit	**Keynote 6**	
09:45-10:30	X	**Keynote 1**		09:45-10:15	Coffee Break	10:00-11:00	Chung-San Hall Tour	09:45-10:15	Coffee Break
10:30-11:00	X	Coffee Break		10:15-11:00	**Keynote 4**			10:15-11:00	**Keynote 7**
11:00-12:30	X	11:00-11:45	**Keynote 2**	Session III	**AD-3**	11:15-12:00	**Keynote 5**	Session VI	OA-4
					WC-1				PA-1
	X				NT-3	12:00-12:05	Group Photo		IS-1
12:30-14:00	X	Lunch		Lunch		Lunch		Lunch	
14:00-15:30	X	Session I	OA-1	Session IV	**AD-4**	Tour		Session VII	**3D-1**
			AD-1		**WC-2**				PA-2
			NT-1		**RG-1**				UA-1
15:30-16:00	X	Coffee Break		Coffee Break				Coffee Break	
16:00-17:30	X	Session II	OA-2	Session V	OA-3			Session VIII	**3D-2**
			AD-2		**WC-3**				IS-2
			NT-2& RB		**RG-2**				
17:30-18:00	Registration					(16:30) Transit		Closing	
18:00-21:00	Ice Breaking (Leader Hotel)			Session Chairs Dinner		Banquet (The Grand Hotel)			

Special session：**3D :**3D modeling and observation；**AD:**Acoustic Daylight；**WC:**Wave and Computation；**RG:** Reservoir Geophysics；

Technical session：**OA:**Ocean Acoustics；**RB:**Room & Building Acoustics, Structural Acoustics；**NT:** Numerical Technique；

UA: Underwater Acoustics；**IS:** Inversion & Seismic；**PA:** Physical Acoustics

General information

HONORARY CHAIRMAN

Ding Lee – U.S.A.
Yih-Hsin Pao – Taiwan

ORGANIZING COMMITTEE

Chi-Fang Chen, Chairman – National Taiwan University, Taiwan
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Yu-Chiung Teng, Co-Chair – Femarco Inc., U.S.A.
Sean Wu, Co-Chair –Wayne State University, U.S.A
Chia-Chi Sung, Co-Chair – National Taiwan University, Taiwan
Alex Tolstoy – Atolstoy Sciences, U.S.A.

ADVISORY COMMITTEE

Leif Bjorno– Technical University of Denmark, Denmark
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Michael J. Buckingham – University of California, San Diego, U.S.A.
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Elen Livingston–U.S. Office of Naval Research (ONR Global), U.S.A
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Oleg Godin –CIRES, University of Colorado, U.S.A.
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Wei-Shien Hwang –National Taiwan University, Taiwan
Steffen Marburg –Universität der Bundeswehr München, Germany
Tony Wen-Han Sheu –National Taiwan University, Taiwan
Yue-feng Sun –Texas A&M University, U.S.A.
Gee-Pin James Too –National Cheng-Kung University, Taiwan
Chuan-Cheung Tse –National Taiwan University, Taiwan
Chao-Nan Wang –National Taiwan University, Taiwan

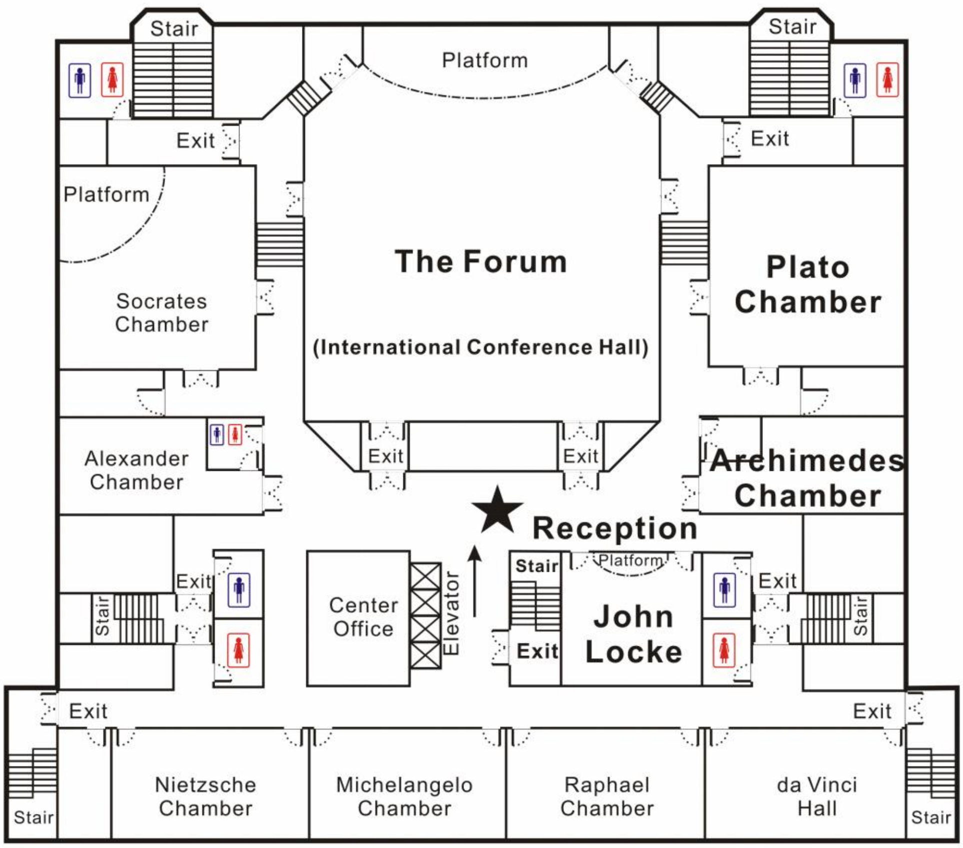
SPECIAL SESSIONS

Topic	**Orgainzer**
3D Modeling and Observation..........	Ching-Sang Chiu
Acoustic Daylight............................	Oleg A. Godin and Francisco J. Sánchez-Sesma
Wave and Computation.....................	GézaSeriani and Dan Givoli
Reservoir Geophysics........................	Yu-Chiung Teng and Yuefeng Sun

Orientation plan

集思台大會議中心
gisNTU convention center

B1 Floor



7 Floor

Hospitality Room

You may take the elevator to the 7 floor and turn right to room 704 and 705. We prepare the hospitality room for you to rest and also provide simple snacks, coffee and tea.

Conference Program

Sunday, April 24 2011

17:30-18:00	**Registration**	**Leader Hotel**
18:00-21:00	**Ice Breaking**	**Leader Hotel**

Monday, April 25 2011

08:00-09:00	**Registration**	**gisNTU convention center**

09:00-09:45	**Opening**	**International Conference Hall**
A New Procedure to Achieve Required Accuracy in Computational Ocean Acoustics: A Summary *Ding Lee*		
Host : Chi-Fang Chen		

09:45-10:30	**Keynote 1**	**International Conference Hall**
Low- to mid-frequency scattering from elastic objects on a sand sea floor, simulation of structural echoes and synthetic aperture sonar images *Mario Zampolli*		
Host : Chia-Chi Sung		

10:30-11:00	**Coffee Break**

11:00-11:45	**Keynote 2**	**International Conference Hall**
Acoustic Daylight Imaging in the Ocean *Michael J. Buckingham*		
Host : Ching-Sang Chiu		

11:45-14:00 **Lunch**

14:00-15:30 **Session I**

Ocean Acoustics I	**Plato Chamber**
Session Chair : Ruey-Chang Wei	

14:00-14:30 **Comparison of noise-enhanced intensity between depression internal wave and elevation internal wave in the ocean**
Hsiang-Chih Chan, Chi-Fang Chen, Ruey-Chang Wei, Yiing-Jang Yang. Andrey N. Serebryany, and James F. Lynch

14:30-15:00 **Effects of Internal Waves on Ambient Noise Vertical Directionality in Shallow Water**
Jianheng Lin, Pengfei Jiang, Xuejuan Yi, Junping Su and Jialiang Li

15:00-15:30 **Evaluation the Capability of Geoacoustic Invertion using Ocean Ambient Noise received by VLA in Shallow Water**
Xinyi Guo, Li Ma, Fan Li and Yaoming Chen

Special Session: Acoustic Daylight I	**John Locke**
Organizer : Oleg A. Godin and Francisco J. Sánchez-Sesma	
Session Chair : Oleg A. Godin	

14:00-14:30 **Information content of two-point cross-correlation functions of diffuse wave fields**
Oleg A. Godin

14:30-15:00 **Passive ocean tomography with mode selections**
Valentin A. Burov, Sergei S. Sergeev, Andrey S. Shurup and Alisa V. Prudnikova

15:00-15:30 **The effects of ambient field directionality on the cross covariance function and implications for passive correlation processing**
Shane Walker

Numerical Technique & Simulation I	Archimedes
Session Chair : Xiaobing Cui	

14:00-14:30 **Study of the coupling of seismic waves in the lithospere and acoustic waves in the atmosphere based on numerical simulation**
Boris G. Mikhailenko and Galina V. Reshetova

14:30-15:00 **Substructure FMBEM for Hybrid Silencer Acoustic Analysis**
Xiaobing Cui and Zhenlin Ji

15:30-16:00 Coffee Break
16:00-17:30 Session II

Ocean Acoustics II	Plato Chamber
Session Chair : T. C. Yang	

16:00-16:30 **Acoustic propagation simulation in a coastal wedge using generalized-ray method**
Piotr Borejko

16:30-17:00 **Temporal Variation of Coherency of Low-Frequency Sound Observed in the OBS Measurement off the East Coast of Taiwan**
Chen-Fen Huang, Jin-Yuan Liu and Peter Gerstoft

17:00-17:30 **Path integral derivation of temporal coherence of acoustic rays and normal modes**
T. C. Yang

Special Session:Acoustic Daylight II	**John Locke**
Organizer : Oleg A. Godin and Francisco J. Sánchez-Sesma	
Session Chair : Francisco J. Sánchez-Sesma	

16:00-16:30 **Ambient Noise Imaging: Experiments with ROMANIS**
Venugopalan Pallayil, Mandar A Chitre, Subash Kuselan, Amogh Raichur, Manu Ignatius, Unnikrishnan K Chandrika, Soo Pieng Tan and Naveen R Chandavarkar

16:30-17:00 **Ocean thermometry and tomography with acoustic daylight**
Oleg A. Godin and Nikolay A. Zabotin

17:00-17:30 **Bayesian Inversion of Ambient Seismic Noise for Earthquake Site Response**
Stan E. Dosso, Sheri Molnar, John F. Cassidy

Numerical Technique & Simulation II And Room & Building Acoustics, Structural Acoustics	**Archimedes Chamber**
Session Chair : Xiaobing Cui	

16:00-16:30 **Efficient finite-difference multi-scheme approach for simulation of seismic waves in anisotropic media**
Vladimir Tcheverda, Dmitry Vishnevsky, Vadim Lisitsa

16:30-17:00 **Study on single-mode excitation in time-variant shallow water environment**
Peng Dayong, Gao Tianfu and Zeng Juan

17:00-17:30 **Sound field rendering bythe holographically designed source array and resource optimization**
Wan-Ho Cho, Jeong-Guon Ih, Takeshi Toi

Tuesday, April 26 2011

08:00-09:00 **Registration**

09:00-09:45	**Keynote 3**	**Plato Chamber**
Subsurface and Biomedical Sensing and Imaging: Application of Computational Acoustics and Electromagnetics *Qing Huo Liu*		
Host : Tony Wen-Hann Sheu		

09:45-10:15 **Coffee Break**

10:15-11:00	**Keynote 4**	**Plato Chamber**
Reverberation modeling inshallow-water waveguide *E. C. Shang*		
Host : Yu-ChiungTeng		

11:00-12:30 **Session III**

Special Session:Acoustic Daylight III	**Plato Chamber**
Organizer : Oleg A. Godin and Francisco J. Sánchez-Sesma	
Session Chair : Francisco J. Sánchez-Sesma	

11:00-11:30 **Wind measurement from acoustic noise interferometry**
V. G. Irisov, O. A. Godin, and M. I. Charnotskii

11:30-12:00 **Mapping of the ocean wind by ocean acoustic interferometers**
Penland Cécile and Alexander Voronovich

12:00-12:30 **Quantifying the emergence rate of the stochastic mean cross covariance for finite duration experimental cross correlation processing**
Shane Walker

Special Session: Wave and Computation I	**John Locke**
Organizer : Géza Seriani and Dan Givoli	
Session Chair : Géza Seriani	

11:00-11:30 **Wave propagation modeling in highly heterogeneous media by a double-grid Chebyshev spectral element method**
Géza Seriani and Chang Su

11:30-12:00 **Multiple Acoustic Scattering from Complexly Shaped Obstacles in the Half-Plane**
Vianey Villamizar and Sebastian Acosta

12:00-12:30 **High-Order Algorithms and Optimal Radiation Boundary Conditions for Acoustics**
Thomas Hagstrom

Numerical Technique & Simulation III	**Archimedes**
Session Chair : Steffen Marburg	

11:00-11:30 **Testing different element types for mixed FE formulation for solution of Galbrun's equation**
Steffen Marburg

11:30-12:00 **The ultra weak variational formulation using evanescent basis functions**
Teemu Luostari, Tomi Huttunen, Peter Monk

12:30-14:00 **Lunch**
14:00-15:30 **Session IV**

Special Session:Acoustic Daylight IV	**Plato Chamber**
Organizer : Oleg A. Godin and Francisco J. Sánchez-Sesma	
Session Chair : Oleg A. Godin	

14:00-14:30 **Diffuse Fields in Layered Elastic Media**
Francisco J. Sánchez-Sesma, Hiroshi Kawase and Shinichi Matsushima

14:30-15:00 **Passive Acoustic Interferometry For Sediment Characterization In Shallow Water**
Q.Y. Ren, J.-P. Hermand and S.C. Piao

15:00-15:30 **Sound Speed profile and array position reconstruction using the ambient noise field**
Goncharov V.V. and Chepurin Yu.A

Special Session: Wave and Computation II	**John Locke**
Organizer : Géza Seriani and Dan Givoli	
Session Chair : Géza Seriani	

14:00-14:30 **Computational Methods for Analyzing Aircraft Noise above Ground with General Topography and Impedance**
Ido Gur, Roman Reitbort and Dan Givoli

14:30-15:00 **Computating acoustic source locations in urban environments**
Lanbo Liu, Donald G. Albert, Paul R. Eller, Jing-Ru C. Cheng, and Hao Xie

15:00-15:30 **Spectral Finite Elements for Computational Aeroacoustics based on Acoustic Perturbation Equations**
Andreas Hüppe and Manfred Kaltenbacher

Special Session: Reservoir Geophysics I	Archimedes
Organizer : Yu-Chiung Teng and Yuefeng Sun	
Session Chair : Yu-Chiung Teng	

14:00-14:30 **Method of Integrating Neural Network Inversion with Finite Element Forward Modeling**
Dongyu Fei and Yu-Chiung Teng

14:30-15:00 **Scattering of Transient Waves by Finite Cracks in a Plane Strain Elastic Solid**
Yu-Chiung Teng

15:00-15:30 **Observation of Scholte waves from multi-component ocean bottom seismic data in the shallowwater environment of the Persian Gulf**
Yuefeng Sun and Karl Berteussen

15:30-16:00 Coffee Break
16:00-17:30 Session V

Ocean Acoustics III	Plato Chamber
Session Chair : James F. Lynch	

16:00-16:30 **Transformation of acoustic-gravity waves (AGW) at the air-water interface**
Iosif Fuks and Oleg A. Godin

16:30-17:00 **A new energy-flux model of multi-layer bottom reverberation in shallow water**
J.R.Wu, E.C.Shang and T.F.Gao

17:00-17:30 **Simulating acoustic pressure and intensity in a strong internal wave field**
Georges A. Dossot, James H. Miller, Gopu R. Potty, Kevin B. Smith, James F. Lynch, Ying-Tsong Lin and Mohsen Badiey

Special Session: Wave and Computation III	**John Locke**
Organizer : Géza Seriani and Dan Givoli	
Session Chair : Lanbo Liu	

16:00-16:30	**Energy partition between elastic waves for dynamic surface loads in a semi-infinite solid** *Francisco J. Sánchez-Sesma, Richard L. Weaver, Hiroshi Kawase, Shinichi Matsushima, Francisco Luzón, Michel Campillo, and Juan J. Pérez-Gavilán*
16:30-17:00	**Cuspidal borehole modes and dual arrivals in TI-formations** *Canyun Wang*
17:00-17:30	**3D finite-difference modeling of sonic logs in tilted-layered porous formations** *Xiao He, Xiuming Wang*

Special Session: Reservoir Geophysics II	**Archimedes**
Organizer : Yu-Chiung Teng and Yuefeng Sun	
Session Chair : Yuefeng Sun	

16:00-16:30	**Physical model experiment for wide angle reflection of seismic waves** *Yang Zhenghua, Huang Yijian and Yu-Chiung Teng*
16:30-17:00	**Application of High Resolution Zero VSP and Walkaway VSP in Fine Delineation of Reservoir** *Guangming Zhu, Vianey Villamizar and Sebastian Acosta*
17:00-17:30	**Bayesian Seismic Inversion Based on Stochastic Modeling under Control of Sedimentary Facies** *Zhu Peimin, Wang Jun*

Wednesday, April 27 2011

08:30-09:00	**Assembly**	**Leader Hotel**
09:00-10:00	**Transit**	
10:00-11:00	**Chung-San Hall Tour**	

11:15-12:00	Keynote 5	Chung-San Hall
Observation and modeling of sound propagation on the continental shelf of the northeastern South China Sea *Ching-Sang Chiu*		
Host : James F. Lynch		

12:00-12:05	**Group Photo**	**Chung-San Hall**
12:05-14:00	**Lunch**	
14:00-18:00	**Tour**	
18:00-21:00	**Banquet**	**The Grand Hotel**

Thursday, April 28 2011

08:00-09:00 Registration

09:00-09:45	Keynote 6	Plato Chamber
Array Signal Processing For Audio Signal Separation And Sound Field Reconstruction *Gee-PinnJames Too*		
Host : Mao-Kuen Kuo		

09:45-10:15 Coffee Break

10:15-11:00	Keynote 7	Plato Chamber
A model based approach to locate multiple incoherent sources in 3D space in real time *Sean F. Wu*		
Host : Chia-Chi Sung		

11:00-12:30 Session VI

Ocean Acoustics IV	Plato Chamber
Session Chair : Ruey-Chang Wei	

11:00-11:30 **Application Of Acoustic Contrast Control Method For Sound Focusing In Shallow Water Environment**
Yi-Wei Lin andGee-Pinn James Too

11:30-12:00 **Current Measurement of Kuroshio Southeast of Taiwan Using Acoustic Tomography**
Chen-Fen Huang, Yen-Hsiang Chen, Cho-Teng Liu, Jin-Yuan Liu, Noakazu Taniguchi, Arata Kaneko, and Noriaki Gohda

12:00-12:30 **Study on the Validity of the Broadband Matching for High Power Low Frequency Narrowband Transducers**
Haijun Liu, Juan Zeng, Tianfu Gao, Haifeng Li,Dayong Peng, Wengyao Zhao and Jianlan Zhang

Physical Acoustics I	Archimedes
Session Chair : Tony W. H. Sheu	

11:00-11:30 **Aeroacoustics Of Merging Flows At Duct Junction**
Tang S.K.

11:30-12:00 **Effect of acoustic streaming in large blood vessels during a high-intensity focused ultrasound thermal ablation.**
Maxim Solovchuk, Tony W. H. Sheu, Marc Thiriet

12:00-12:30 **Vibroacoustic Response of A Underwater Single Cylinder Shell Excited By A Turbulent External Flow**
Meixia Chen, Jianhui Wei

Inversion & Seismic I	John Locke
Session Chair : Jean-Pierre Hermand	

11:00-11:30 **Estimation of shear-wave velocity in marine sediment using Love waves**
Hefeng Dong, Zhengliang Cao and Kenneth Duffaut

11:30-12:00 **Finite-Element Adjoint For A Fully Range-Dependent Parabolic Equation**
Mark Asch, Jean-Pierre Hermand and Mohamed Berrada

12:00-12:30 **Interaction Of Seismic Waves With Cavernous Fractured Reservoirs: Numerical Simulation And Field Study**
Vadim V. Lisitsa, Galina V. Reshetova and Vladimir A. Tcheverda

12:30-14:00 Lunch
14:00-15:30 Session VII

Special Session: 3D Modeling and Observations I	**Plato Chamber**
Organizer : Ching-Sang Chiu	
Session Chair : Ching-Sang Chiu	

14:00-14:30 **Computational Approaches to 3D Propagation on the Continental Shelf**
Kevin D. Heaney

14:30-15:00 **Computational studies of threedimensionalocean sound fields inareas of complex seafloortopography and active ocean dynamics**
Timothy F. Duda, YingTsongLin, Weifeng Gordon Zhang, Bruce D. Cornuelle and Pierre F. J. Lermusiaux

14:00-15:30 **Acoustic field, performance of underwater communication, and passive phase conjugation in an environment of 3D horizontal refraction induced by internal waves in NLIWI07 Experiment**
Linus Y.S. Chiu, Andrea Chang And Chi-Fang Chen and D. Benjamin Reeder and Mei-ChunYuan

Physical Acoustics II	**Archimedes**
Session Chair : Chuan-Cheung Tse	

14:00-14:30 **Highly directivity acoustic beams in two-dimensional phononiccrystal bynegative refraction and by resonant cavity**
C.C Sung

14:30-15:00 **The Sound Radiation of a Conical Shell under a Force Excitation**
Zhang Cong

14:00-15:30 **Physical mechanism on the affecting combustion through sound**
Genshan Jiang, Yingchao Zheng, Jie Pan and Jing Tian

Underwater Acoustics I	**John Locke**
Session Chair : Kevin B. Smith	

14:00-14:30 **A Characterization of Scattered Acoustic Intensity Fields in the Resonance Region**
Robert J. Barton IIIand Kevin B. Smith

14:30-15:00 **Numerical solution of a boundary integral formulation of the Helmholtz equation**
Elena Sundkvist

14:00-15:30 **The improving measurement method on piezoelectric ceramic emission transducer**
Haifeng Li, Juan Zeng, Tianfu Gao, Haijun Liu, Dayong Pengand Wenyao Zhao

15:30-16:00 **Acoustic Image Generation Based on Highlight Model**
Sheng Liu, Xucheng Chang and Bing Li

15:30-16:00 Coffee Break
16:00-17:30 Session VIII

Special Session: 3D Modeling and Observations II	**Plato Chamber**
Organizer : Ching-Sang Chiu	
Session Chair : Ching-Sang Chiu	

16:00-16:30 **Numerical considerations for three-dimensional sound propagation modeling: coordinate systems and grid sizes**
Ying-Tsong Lin, Arthur E. Newhall, Timothy F. Duda and Chi-Fang Chen

16:30-17:00 **A theoretical and computational look at the physics of acoustic propagation through crossing ocean waves**
Alexey Shmelev, James Lynch, Ying-Tsong Lin, and Arthur Newhall

Inversion & Seismic II	John Locke
Session Chair : Jean-Pierre Hermand	

16:00-16:30 **Cross Dipole Anisotropy Inversion By Using Hybrid Simulated Annealing Method**
Hao Chen, Xiuming Wang, Xuebing Yang

16:30-17:00 **Fast Acoustic Imaging For A 3d Penetrable Object Immersed In A Shallow Water Waveguide**
Pan Wen-Feng, Zong Zhi-Xiong, You Yun-Xiang and Miao Guo-Ping

17:30-18:00 Closing Plato Chamber

Opening

Monday, April 25		
09:00-10:45	**Opening**	**International Conference Hall**

A New Procedure to Achieve Required Accuracy in Computational Ocean Acoustics: A Summary

Chi-fang Chen[1] and Ding Lee[2]

[1]*Dept. of Engineering Science and Ocean Engineering, National Taiwan University*
[2]*2603 Ayala Way, The Villages, FL 32162, USA*

Ocean acoustic wave propagation can be predicted by applying numerical methods to solve representative wave equations computationally. For this purpose, numerical methods have been introduced. A latest introduction was the Predictor-Corrector Method. An important concern is whether or not these numerical methods can produce required satisfactory accurate results. This paper introduces a new Predict-Correct Procedure to check whether or not the results, produced by the Predictor-Corrector Method, are within the required accuracy. If not, this new Predict-Correct Procedure will improve the results continuously until the accuracy requirement is met. A section is presented to discuss the Accuracy Issue. A summary is given to describe the Prictor-Corrector Method. Then, the new Predict-Correct Procedure is introduced for the purpose to achieve the required goal. Most importantly, numerical analysis is given to show how the Predict-Correct Procedure can achieve the required accuracy goal.

Keynote Speeches

Monday, April 25		
09:45-10:30	Keynote 1	International Conference Hall

Low- To Mid-Frequency Scattering From Elastic Objects On A Sand Sea Floor: Simulation Of Frequency And Aspect Dependent Structural Echoes

Mario Zampolli

TNO Defense, Security and Safety

A.L. Espana[1], K.L. Williams[1], S.G. Kargl[1], E.I. Thorsos[1], J.L. Lopes[2], J.L. Kennedy[2], P.L. Marston[3]

[1]Applied Physics Laboratory, College of Ocean and Fishery Sciences, University of Washington, Seattle, Washington 98105 (USA)
[2]Naval Surface Warfare Center, Panama City Division, Panama City, Florida 32407 (USA)
[3]Physics and Astronomy Department, Washington State University, Pullman, Washington 99164 (USA)

The scattering from roughly meter-sized cylindrical targets, such as pipes, cylinders and unexploded ordnance (UXO) shells in the 1 – 30 kHz frequency band is studied by numerical simulations and compared to experimental results obtained under controlled conditions using rail mounted sources and receivers staged in a large test pond. At these frequencies, generally referred to as the low- to mid-frequency regime, elastic features associated to specific structural resonances are visible in images of target strength as a function of aspect angle and frequency. The numerical tool used to compute the target strength, is a hybrid model: a finite-element (FE) approach for the vicinity of the target, based on the decomposition of the three-dimensional scattering problem for axially symmetric objects into a series of independent two-dimensional problems, is coupled to a propagation model based on the wavenumber spectral integral representation of the Green's functions for layered media. The approach makes it possibile to obtain solutions for realistic scenarios on standard desktop workstations.

Monday, April 25		
11:00-11:45	**Keynote 2**	**International Conference Hall**

Acoustic Daylight Imaging in the Ocean

Michael J. Buckingham

Marine Physical Laboratory, Scripps Institution of Oceanography University of California, San Diego

Ambient acoustic noise in the ocean is a diffuse radiation field, which, in some respects, resembles the ambient optical field (daylight) in the atmosphere. As a source of illumination, daylight may be used for creating photographic images of objects in the atmosphere, leading to the conjecture that "acoustic" images of objects in the ocean could perhaps be created using the illumination provided by "acoustic daylight", that is, ambient noise. An acoustic lens would be required, in order to focus the noise scattered from the object onto an image plane, where an array of acoustic sensors would record the spatial variations of the acoustic intensity. The output from each sensor would be displayed as a pixel on a computer monitor, and the assemblage of pixels would be in effect a digital image of the object in the ocean. Such incoherent acoustic imaging neglects all phase information (as does its photographic analog) but has the appeal of relative simplicity. Several years ago, incoherent acoustic daylight imaging was in fact realized in the form of ADONIS (Acoustic Daylight Ocean Noise Imaging System), which consists of a spherical reflector acting as the acoustic lens with an elliptical array of 132 hydrophones in the focal plane. Each hydrophone channel has about a decade of bandwidth, from 8 to 80 kHz, which, in one implementation, was mapped to the optical spectrum in each pixel on the screen, thus creating color images. In addition, the screen was refreshed 25 times per second, much like television, the net effect being fluid movement and synthetic color. ADONIS will be described in the talk and examples of the images obtained with the system will be presented. (Research supported by ONR.)

Tuesday, April 26		
09:00-09:45	**Keynote 3**	**Plato Chamber**

Subsurface and Biomedical Sensing and Imaging: Application of Computational Acoustics and Electromagnetics

Qing Huo Liu

Department of Electrical and Computer Engineering, Duke University

Acoustic and electromagnetic waves have widespread applications in geophysical subsurface sensing and in biomedical imaging. In this presentation, we will focus on subsurface sensing in oil exploration and biomedical imaging with microwaves and microwave-induced ultrasound. In such applications, often the problems of understanding the underlying phenomena, designing the measurement systems, and performing data processing and image reconstruction require large-scale computation in acoustics and electromagnetics. Accelerating such large-scale computation is the main objective of our work.After an introduction of our previous work on the perfectly matched layers for the absorbing boundary condition, we will present our recent research on multiscale computation with wave equations in both time domain and frequency domain. We have developed a domain decomposition technique that combines the spectral element method and finite-element method together with the perfectly matched layer; we have also developed fast integral equation solvers in the frequency domain. In the presentation, we will illustrate our applications in microwave-induced thermoacoustic tomography and microwave imaging, and other applications in oil exploration.

Tuesday, April 26		
10:15-11:00	**Keynote 4**	**Plato Chamber**

Reverberation modeling in shallow-water waveguide

E. C. Shang

Institute of Acoustics, Chinese Academy of Science

A number of shallow-water reverberation models have been developed in recent years.However, most of the models are phenomenological model because the key component of the bottom backscattering kernel has been treated with help either by using an empirical Lambert's law or by using an assumed scattering model with parameters to be determined through data fitting. Recently, an explicit analytical expression of the bottom backscattering kernel has been developed base on Bass perturbation theory. The new full-wave scattering kernel matrix is:

$$M_b^W(\theta_i,\theta_o) = \mu(f)\ \sin^2(\theta_i P/2)\ \sin^2(\theta_o P/2)$$

Where P is a parameter related with bottom reflection phase shift, parameter P plays an important role on the angular behavior.The angular behavior and the frequency dependency of the new scattering kernel is discussed with some data comparison.

Wednesday, April 27		
11:15-12:00	**Keynote 5**	**Chung-San Hall**

Observation and modeling of sound propagation on the continental shelf of the northeastern South China Sea

Ching-Sang Chiu

Department of Oceanography, Naval Postgraduate School

In April 2005, a three-day acoustic transmission experiment was carried out on the shelf of the northeastern South China Sea. A 400-Hz signal was transmitted every five min from a moored source to a moored vertical hydrophone array 17-km away. Additionally, a series of oceanographic moorings were deployed along the transmission path to sample the water-column variability that was dominated by the evolution of nonlinear internal tides and high-frequency nonlinear internal waves. Applying time-series filtering, principal component analysis and a feature tracking technique to the oceanographic data, a continuous space-time empirical model for the sound-speed field was developed. Using a coupled-mode sound propagation model, interfacing with the sound-speed model, the temporal variations of the vertical distribution of signal intensity at the hydrophone array were computed. Analyzing the model results and comparing them to the measured signal intensities have allowed for quantification and comparison of the effects of the nonlinear internal tides, depression waves, and elevation waves on the sound transmission. The modeled sound-speed and sound-intensity fields and their comparisons to the measured data are discussed in this presentation. This research is sponsored by the US Office of Naval Research and carried out collaboratively with scientists from the National Taiwan University and the National Sun Yat-Sen University.

Thursday, April 28		
09:00-09:45	Keynote 6	Plato Chamber

Array Signal Processing For Audio Signal Separation And Sound Field Reconstruction

Gee-Pinn James Too and Bo-Hsien Wu

Department of Systems and Naval Mechatronic Engineering, National Cheng Kung University, Tainan, Taiwan

In this paper, two innovation algorithms, which are the audio signal separation algorithm and the sound field reconstruction algorithm, are presented. The audio signal separation algorithm is based on the time-reversal method (TRM). The first step in this procedure is to calculate the impulse response function (IRF) between each source and field points by using deconvolution process. The second step in this procedure is to compute the passive time-reversal process on the signals of field points. Then, the signal of specific source can be separated via the self-adaptive focusing of time-reversal. The performance of TRM can be enhanced by increasing the number of sensors, the spacing of array sensor or the length of array and decreasing the measuring distance. The sound field reconstruction algorithm is based on the similar source method (SSM). The first step in this procedure is to search the source location by using beamforming approach. The second step in this procedure is to solve the source strength of virtual sources by using SSM. Finally, the sound pressure distribution of sound field can be reconstructed via the virtual sources, which have replaced the source. The results for simulation and experiment indicate following conclusions, the algorithm is not confined to a condition in which the measuring spacing must be smaller than wavelength of source. This algorithm can also reconstruct a sound field within measuring distance. Furthermore, the Tikhonov regularization process is used to avoid the singularity effect from noise in deconvolution process and inverse calculation which are included in the two algorithms, respectively. Finally, several simulations and experimentations are shown to verify two innovation algorithms in the present study.(supported by NSC and NCKU-ITRI jointed project)

Thursday, April 28		
10:15-11:00	**Keynote 7**	**Plato Chamber**

A model based approach to locate multiple incoherent sources in 3D space in real time

Sean Wu and Na Zhu

Department of Mechanical Engineering, Wayne State University

This paper presents a model based approach to track and trace multiple incoherent sound sources in 3D space in real time. The underlying principle of this approach consists of modeling acoustic radiation from a point source in a free field, iterative triangulations, and de-noising techniques to enhance the signal to noise ratio of the target signals. This technology is suitable for all types of signals, including harmonic, random, continuous, transient, impulsive, narrow- and broad-band sounds over a wide frequency range (20 − 20,000 Hz). Current technologies for locating sound sources are mainly based on triangulation, beamforming, time reversal, and near-field acoustical holography, which are of limited usages in practice. For example, triangulation alone is suitable for locating sources producing impulsive signals, not arbitrary signals; the beamforming system now available in the market needs to be oriented toward the target it is supposed to locate; time reversal requires sensors to surround the target and its computation is usually very intensive, and nearfield acoustical holography is only valid when measurement microphones are very close to a source. Because of these shortcomings, applications of these technologies are mainly found in a laboratory setting. The present technology has no restrictions whatsoever on the signal types, can cover 3D space simultaneously, allows microphone potions to be reconfigurable so as to fit a test environment, needs much fewer sensors and costs much less than any existing technology does. Experimental validations of this new technology are demonstrated. Experiments are conducted in various nonideal environments such as inside a machine shop, crowded room and large hall way, where there are non-negligible background noise and reverberation effects. Both stationary and non-stationary sources are used in the experiments to produce arbitrarily time-dependent acoustic signals. Practical limitations of this technology are examined and discussed.

Special Sessions

Thursday, April 28 14:00-15:30	
Special Session: 3D Modeling and Observation I	**Plato Chamber**
Organizer : Ching-Sang Chiu	

Comparison Of Adiabatic Mode Parabolic Equation 3d Model With Measurements On The Continental Shelf

Kevin D. Heaney, Richard L. Campbell, James J. Murray

OASIS Inc.

During the CALOPS 2007 experiment, off the coast of Fort Lauderdale, Florida, 3-dimensional multipath was observed using a bottom mounted horizontal line array during source-tows along the 200m isobath (Heaney and Murray, JASA 125 (4), 1394-1402 (2008)). In this paper we present a hybrid modeling approach to model the 3-dimensional sound on the Florida shelf, nearly shaped like the canonical wedge. The approach uses vertical adiabatic modes and horizontal split-step Pade Parabolic Equation. Modal phase speeds, vs. position are used as the input to the PE computation with dimensions of easting (km) and northing (km). Vertical adiabatic modes and horizontal rays are also computed to illustrate the 3D multipath arrival. The AMPE field is computed for all the modes for each element of the horizontal array. Beamforming vs. source range is then conducted and excellent agreement withdata is achieved.

Computational studies of threedimensional ocean sound fields in areas of complex seafloor topography and active ocean dynamics

Timothy F. Duda[1], Ying-Tsong Lin[1], Weifeng Gordon Zhang[1], Bruce D. Cornuelle[2], Pierre F. J. Lermusiaux[3]

[1]*Woods Hole Oceanographic Institution*
[2]*Scripps Institution of Oceanography, University of California, San Diego*
[3]*Massachusetts Institute of Technology*

The geometrical factors responsible for intricately structured fluctuating underwater sound propagation have been recognized for some time. Among these are steep bathymetric slopes and motions of sound speed structures defining the waterborne acoustic waveguide. There are endless possibilities for propagation effects from the wide varieties of seafloor shapes and ocean dynamic phenomena. Much insight has been acquired by studying effects in idealized scenarios like bathymetric wedges, rectilinear internal waves, and simple fronts. Many of the effects are three dimensional, for example curving acoustic normal mode propagation over a slope or inside internal waves. The further step we are taking now is to simulate propagation through environments generated by regional ocean flow models. Regional ocean models are now ubiquitous. They have been developed to the point of being adjustable toward reality by assimilating the information in data, by including tide effects, by including detailed bathymetry and surface forcing, and by having sufficient resolution to include a large fraction of salient processes. We have expectations that propagation simulation through ocean model fields may yield valuable information. The applicability of knowledge derived from the idealized propagation studies to propagation in complex environments is an important question. The four dimensional sound field information within the study volume is quite valuable, with potential to verify the causes of effects discoverable but not verifiable with field data. Here we study the time dependence of sound echoing within two ocean canyons featuring water column internal tide oscillations. One finding is that the scintillation index of narrowband sound is inversely proportional to mean intensity and can greatly exceed the saturation value of unity, suggesting that sound beams move around and can create areas intermittently filled with sound. We also study four dimensional sound field structure in a sloped seafloor area with strong tidal and subtidal frequency water column variability, searching for limits of applicability of two dimensional propagation approximations.

Acoustic field, performance of underwater communication, and passive phase conjugation in an environment of 3D horizontal refraction induced by internal waves in NLIWI07 Experiment

Linus Y.S. Chiu[1], Andrea Chang[1], Chi-Fang Chen[1], D. Benjamin Reeder[2], Yuan, Mei-Chun[3]

[1]*Department of Engineering Science and Ocean Engineering, National Taiwan University*
[2]*Department of Oceanography, Naval Postgraduate School*
[3]*MeiHo University*

Passive Phase Conjugation (PPC) and Time Reversal Mirror (TRM), based on acoustic mode orthogonality as well as mode closure relation, could produce time-domain focusing for a distorted signal by using a densely-sampling vertical receiving array or source-receiver array which entirely cover water column. PPC is the passive version of TRM, which is the result of cross-correlation of impulse response and the impulse response immediately after, can be utilized as the adaptively self-channel equalizer to enhance the communication performance. The performance of PPC equalizer depends upon acoustic mode field and has been published previously. However, performance of PPC in an environment of 3D strong horizontal-refraction has not been mentioned. Experimental data collected in the South China Sea (SCS), entitled the South China Sea Oceanic Processes Experiment (Taiwan) / Non-Linear Internal Waves Initiative (US) (SCOPE / NLIWI) provide the contribution of internal wave induced horizontal refraction to the received acoustic field and performance of communication and PPC. Numerical modeling implemented by fully wide-angle FOR3D are also done to interpret what is observed in acoustic data. BPSK(binary-phase-shift-keying) signals transmitted by Tomo-source is processed with quadrature-demodulation receiver then output of multi-channel equalization performed by PPC is obtained to see how symbols and PPC will hold in a 3D-effect propagation. This paper is aimed to study and highlight acoustic field, the performance of communication system, and PPC in 3D horizontal refraction so that it can provide an idea of optimum combination of least receivers with the knowledge of 3D acoustic field.

Thursday, April 28 16:00-17:30	
Special Session: 3D Modeling and Observation II	**Plato Chamber**
Organizer : Ching-Sang Chiu	

Numerical Considerations For Three-Dimensional Sound Propagation Modeling: Coordinate Systems And Grid Sizes

Ying-Tsong Lin[1], Arthur E. Newhall[1], Timothy F. Duda[1],Chi-Fang Chen[2]

[1]*Woods Hole Oceanographic Institution*
[2]*National Taiwan University*
Department of Engineering Science and Ocean Engineering

Three-dimensional sound propagation models with a parabolic approximate wave equation (PE) solved in either Cartesian (x,y,z) or cylindrical (r,θ,z) coordinate systems are compared. The Split-step Fourier marching algorithm is employed. The solutions can be made arbitrarily more accurate by increasing grid resolution. Both models have limited valid area in horizontal azimuth with respect to the marching direction, which is radial for the cylindrical model and is along the x axis for the Cartesian model. Selection between these two models for a given problem depends on the type of sound wave field. For a cylindrical wave-like field the cylindrical model is more suitable; on the other hand, for a plane wave-like field the Cartesian model is advantageous. In terms of numerical implementation, the cylindrical model requires entry or calculation of the free-space propagator at each step, while this numerical item is spatially uniform for the Cartesian method thus reducing computation time. Conventional implementation of three-dimensional PE models in a cylindrical coordinate system with fixed azimuth grids suffers from loss of resolution in far field, and a method of re-sampling azimuth grids is proposed in this paper to overcome this defect. Further analysis of errors for specific frequencies and grid sizes applicable to ocean acoustics problems will be given in the presentation.

A Theoretical And Computational Look At The Physics Of Acoustic Propagation Through Crossing Ocean Waves

Alexey A. Shmelev[1], James F. Lynch[2],Ying-Tsong Lin, and Arthur Newhall

[1]*Massachusetts Institute of Technology / Woods Hole Oceanographic Institution Joint Program*

[2]*Woods Hole Oceanographic Institution*

Internal waves, bottom sand waves, and ocean surface waves are known to have an impact on low-frequency 3-D acoustic propagation in shallow water. It has been observed both experimentally and numerically that in presence of internal waves in shallow water, acoustic energy propagates further and with less geometrical spreading in a preferred direction centered at the direction of the wave crests. In coastal areas, internal waves are often seen as packets. Different internal wave packets sometimes propagate through each other, creating crossing structures. This work is focused on fully 3-D acoustic propagation through crossing waves that are the result of either internal wave packets crossing or combinations of internal waves, bottom sand waves, and surface waves crossing at various angles. An idealized shallow water column model with infinitely long straight internal waves (bottom waves or surface waves) is used for understanding the physics of normal mode coupling and horizontal refraction at all possible propagation directions. 3-D parabolic equation numerical modeling of acoustic propagation through a more realistic environment with crossing waves is then performed for quantitative analysis of the effects of modal refraction and mode coupling.

Monday, April 25 14:00-15:30	
Special Session: Acoustic Daylight I	**John Locke**
Organizer : Oleg A. Godin and Francisco J. Sánchez-Sesma	

Information content of two-point cross-correlation functions of diffuse wave fields

Oleg A. Godin

CIRES, University of Colorado and NOAA/Earth System Research Laboratory, Physical Sciences Division

In this paper, cross-correlation functions of imperfectly diffuse noise fields are viewed as a source of information about the propagation medium and the noise sources. Random wave sources are distributed in a volume and/or on surfaces and curves and can be also located in discrete points. Cross-correlations of the acoustic noise are studied theoretically within the ray approximation in inhomogeneous, absorbing, moving or motionless media. Neither isotropy of the noise field nor delta-correlation of noise sources is assumed. The goal is to determine the most general conditions under which deterministic ray travel times can be retrieved from noise cross-correlations. Asymptotic techniques are employed to evaluate cross- and auto-correlation functions of noise for generic distributions of the random sources. Effect of non-uniformity of the source spatial distribution on the accuracy of the deterministic travel time retrieval is quantified. In the underwater acoustics context, the environment characterization with diffuse noise is compared to the environment characterization using discrete noise sources. Feasibility of passive acoustic measurements of ocean current and atmospheric wind velocities is discussed.

Passive ocean tomography with mode selections

Valentin A. Burov, Sergei S. Sergeev, Andrey S. Shurup, Alisa V. Prudnikova

Moscow State University, Faculty of Physics, Department of Acoustics

The passive ocean tomography scheme based on modes selection is developed. The purpose is to reconstruct in common approach different ocean waveguide parameters, such as refractive inhomogeneities, currents, eddies and geoacoustical parameters of the bottom. For this purpose the special so called stripe basis was developed. The

initial data are ambient noise signals that are received by short (non-overlapping the whole waveguide) curved by underwater currents antennas, exact positions of antennas are unknown. Reconstruction is based on formalism that uses angle of viewing perturbations and "curved" modes selection. Analytical relationship between space correlation function and Green's function for every mode was obtained. The usage of mode-to-mode correlation instead of point-to-point correlation is an advantage of the developed scheme because mode propagation in the ocean waveguide is 2-D process with cylindrical divergence. It results to the accumulation time decreasing to the comprehensible values (the accumulation time for used procedure was estimated as approximately one or few hours in case of using combined vector-scalar receivers). In the case of point-to-point correlation the 3-D model has to be considered that leads to a dramatically increasing of the noise signal accumulation time that is needed to recover the full field Green's function. Numerical simulation was conducted and combined (refractive, current and geoacoustical) inhomogeneity was reconstructed.

The effects of ambient field directionality on the cross covariance function and implications for passive correlation processing

Shane Walker

Experimental passive correlation processing generally fits into two paradigms. One area of interest is propagation tomography, where information about propagation between distant sensors is extracted from the measured correlation function. Another area of interest involves the determination of directional features of the ambient field. Here we discuss the influence of ambient field directionality on the cross covariance function. In this context, the cross covariance function is a stochastic quantity defined to be the expectation value of the ensemble average of finite duration realizations of the sample cross correlation function. We find that for propagation tomography applications the covariance function is robust to even extremely directional features of the ambient field distribution. In contrast, only under restrictive conditions of the spatial structure of the ambient noise is it possible to determine its directional features. The underlying physics of these results are presented. Implications for ocean acoustics, seismics, and helioseismology are considered.

Monday, April 25 16:00-17:30	
Special Session: Acoustic Daylight II	**John Locke**
Organizer : Oleg A. Godin and Francisco J. Sánchez-Sesma	

Ambient Noise Imaging: Experiments With Romanis, An Arl Built Underwater Ani Camera

Pallayil Venugopalan, Mandar Chitre, Subash Kuselan, Amogh Raichur, Manu Ignatius, Unnikrishan Kutta Chandrika, Naveen R Chandhavarkarand Tan Soo Pieng

Acoustic Research Laboratory, Tropical Marine Science Institute, National University of Singapore

The idea of using ambient noise for imaging underwater objects has been studied by many researchers, though not widely. The first Ambient Noise Imaging (ANI) camera namely ADONIS (Acoustic Daylight Ocean Noise Imaging System) was built in the Scripps Institute of Oceanography, USA and was tested out in the sea during 1994-96. The results obtained from field deployments demonstrated that ANI was indeed feasible by forming images of static underwater objects at a range of about 40m. Since then, DSTO Australia and ARL Singapore have been the only other two institutions that are known to have built their own ANI cameras and tested in the field. ARL deployed its ANI camera, Remotely Operated Mobile Ambient Noise Imaging System (ROMANIS), in 2003 and successfully produced images of static underwater reflecting targets placed at about 70m range from the camera; this is about twice the range reported from the ADONIS system. In 2009, ROMANIS and associated receiver systems were rebuilt for reliable field operations and fast processing so that near real-time images could be created. In May 2010, a month long experiment was conducted in Singapore waters using the new version of ROMANIS. Near real-time images of both static and mobile targets were obtained at ranges close to 100m from the camera during this deployment. In this paper we present the ROMANIS system architecture, beamforming techniques and processing approaches along with the results obtained from field trials conducted in 2010.

Ocean thermometry and tomography with acoustic daylight

Oleg A. Godin[1, 2] and Nikolay A. Zabotin[1, 3]

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In the ocean, acoustic daylight, that is, diffuse acoustic illumination provided by ambient, biological, and shipping noise, can be used as a probing signal to characterize the environment in a cost-effective and non-invasive manner. This paper demonstrates the feasibility and discusses prospects of ocean remote sensing through retrieval of deterministic ray travel times from two-point cross-correlation functions of acoustic daylight. We focus on passive acoustic characterization of the water column, including water temperature variations with time and depth. Compared to highly successful seismic noise interferometry, underwater noise interferometry faces a number of unique challenges. In particular, useful noise averaging times are severely limited by the oceanic environment changing in time orders of magnitude faster than the Earth crust as well as by motion of hydrophones due to oceanic currents. Requirements to the precision of sound speed inversions are extremely high in underwater acoustics. To be oceanographically relevant, sound speed measurements and, hence, passive measurements of the travel time should have accuracy better than 0.1%. We present a theoretical analysis underlying retrieval of precise travel times from noise cross-correlations and an example of passive acoustic tomography and thermometry with ambient noise recordings of opportunity, which were obtained as a by-product of a long-range sound propagation experiment in the Pacific Ocean.

Bayesian Inversion of Ambient Seismic Noise for Earthquake Site Response

Stan E. Dosso[1], Sheri Molnar[1,2] and John F. Cassidy[2,1]

1 *University of Victoria, Victoria, British Columbia, Canada*
2 *Natural Resources Canada, Sidney, British Columbia, Canada*

This paper applies Bayesian inversion to Rayleigh-wave dispersion data derived from array measurements of ambient seismic noise to estimate the near-surface shear-wave velocity profile, an important property for characterizing earthquake site response as required for seismic microzonation. The Bayesian inversion algorithm, based on an

efficient implementation of Metropolis-Hastings sampling of the posterior probability density (PPD), provides the most-probable shear-wave velocity profile together with a quantitative uncertainty analysis. Nonparametric estimation of the data error covariance matrix from residual analysis is applied, with rigorous *a posteriori* statistical tests to validate this covariance estimate and the underlying assumption of a Gaussian error distribution. The most appropriate model parameterization is determined using the Bayesian information criterion, which provides the simplest model consistent with the resolving power of the data. Parameterizations considered vary in the number of layers, and include layers with uniform, linear, and power-law gradients. Seismic noise data were collected at two sites in southwestern British Columbia, the area of highest seismic risk in Canada, to study the ability to recover the shear-wave velocity profile in different geologic settings. One site, on the Fraser River delta near Vancouver, is characterized by unconsolidated sediments several hundred metres thick, while the other site, in Victoria, has thin sediments over bedrock. Invasive measurements from seismic cone penetration and surface-to-downhole methods are used to assess the reliability of the noise inversion results, with excellent agreement at both sites. To extend the uncertainty analysis from shear-wave velocities to microzonation, the PPD sample obtained via Bayesian noise inversion is mapped into probability distributions for a variety of properties used to characterize site response, including building code site class, peak ground velocity/acceleration, and amplification and resonance spectra.

Tuesday, April 26 11:00-12:30	
Special Session: Acoustic Daylight III	**Plato Chamber**
Organizer : Oleg A. Godin and Francisco J. Sánchez-Sesma	

Wind measurement from acoustic noise interferometry

V. G. Irisov,[1, 2] O. A. Godin,[3, 2] and M. I. Charnotskii[1, 2]

[1] *Zel Technologies LLC*
[2] *NOAA/Earth System Research Laboratory*
[3] *CIRES, University of Colorado*

Green’s functions, which describe acoustic signal propagation between two points, can be retrieved from cross-correlation of diffuse acoustic noise measured at these points. In case of moving media, the correlation function appears to be asymmetric with respect to receivers interchange. O. A. Godin [*Phys. Rev. Lett.* **97**, 054301 (2006)] showed that the two-point correlation function provides information about the travel times and phases of waves propagating in opposite directions and, thus, can be used for assessment of the media motion. An experiment on measurement of cross-correlation of acoustic noise produced by road traffic was conducted. A set of four measurement microphones was installed in a vicinity of a busy highway. Sound signals were digitized and recorded by a computer with subsequent processing of cross-correlation functions. Meteorological station provided supporting measurements of air temperature, pressure, humidity, and wind speed and direction. According to the theory, the travel time of acoustic signals between two microphones corresponds to zero of the cross-correlation function located between strongest minimum and maximum. The difference between positions of such two zeros corresponding to sound propagation in opposite directions is related to corresponding projection of the wind vector. An array of 3-4 microphones was used for retrieval of all components of wind vector. The results proved to be in good agreement with supporting wind measurements. Our observations provide a basis for passive acoustic technique for measurements of fluid flow velocity.

Mapping of the ocean wind by ocean acoustic interferometers

Cécile Penland and AlexanderVoronovich

NOAA/ESRL/PSD3

Air-sea interaction is driven mainly by the wind blowing over ocean surface and its monitoring is an important task. Currently, wind is measured from satellites, which provide global coverage. However, such measurements encounter difficulties at high winds and are also expensive. Since wind is well known to be one of the major sources of ambient noise in the ocean, it was suggested long ago to use ambient noise for the wind speed retrieval. Application of this technique to hurricanes tracking has also been considered. Current approaches are based on essentially local measurements with bottom-mounted hydrophones located near the area of interest. Here we present another approach based on measurements of directivity of the ambient noise in the horizontal plane at low frequencies of the order of a few tens of Hertz. Such measurements would be done with the help of long vertical line arrays (VLA) spanning a significant portion of the ocean waveguide. Two VLA separated by a distance of the order of a few tens of kilometers and coherently measuring acoustic pressure due to the ambient noise form an ocean interferometer. A single interferometer allows sharp resolution; however, wind mapping requires at least two significantly separated interferometers so that the area of interest is exposed from

different perspectives. In contrast to the methods of wind measurement based on local measurements, our approach relies on measurements of distant noise sources. The method principally allows mapping ocean wind over areas of the order of 1000 km in horizontal scale with resolution of the order of 10 km. An averaging time required to overcome statistical variability of the noise field was estimated to be of the order of 3 hours. The results will be presented for propagation conditions typical for North Atlantic.

Quantifying the emergence rate of the stochastic mean cross covariance for finite duration experimental cross correlation processing

Shane Walker

Spatio-temporal correlations of the ambient wave field convey information about the ambient wave distribution and the propagation properties of the medium. Correlation processing is applied in many areas of wave physics to passively passively measure these correlations. An issue of practical experimental importance is how much data must be accumulated to generate a useful estimate of the mean value of the spatio-temporal correlations of the environment. The cross covariance function is a stochastic quantity defined to be the expectation value of the ensemble average of finite duration realizations of the sample cross correlation function. Stochastic methods are applied to derive the uncertainty associated with a finite duration realization of the sample cross correlation function. Based on this result, we introduce a method for modeling the emergence rate of the cross covariance function for arbitrary environments. As an example, the special cases of free space and the ocean waveguide are considered. Implications for ocean acoustics, seismics, and helioseismology are considered.

Tuesday, April 26 14:00-15:30	
Special Session: Acoustic Daylight IV	**Plato Chamber**
Organizer : Oleg A. Godin and Francisco J. Sánchez-Sesma	

Diffuse Fields in Layered Elastic Media

Francisco J. Sánchez-Sesma[1], Hiroshi Kawase[2] and Shinichi Matsushima[2]

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[2]*DisasterPrevention Research Institute, Kyoto University*

Multiple wave scattering in the Earth´s crust give rise to both coda of earthquakes and microtremors, also called seismic noise. These motions are frequently referred to as diffuse wave fields because its intensities are governed by diffusion-like equations. For an inhomogeneous, anisotropic elastic medium under diffuse seismic illumination (or, equivalently, with an uncorrelated uniform set of random forces) the average cross correlation of motions at pairs of receivers, in frequency domain, is proportional to the imaginary part of Green function. The imaginary part of Green function at the loading point is proportional to the power injected into the medium by a unit harmonic load. Such power will vary if the motions change by waves reflected back to the source location. Therefore, it represents reflection events. This property of diffuse fields can be used to characterize the mechanical and geometrical characteristics of an elastic domain. Consider a horizontally layered medium overlying a half space. Microtremors are generated close to the free surface and we assume they constitute a diffuse seismic field. Thus, we may link energy densities with Green function, an intrinsic property of the medium. This allows the medium inversion from the surface *H/V* spectral ratio, the well known Nakamura's ratio. On the other hand, relatively deep earthquakes illuminate the site structure from below with predominance of body waves. Extending diffuse field concepts we assume that the autocorrelations, averaged for several earthquakes, represent directional energy densities associated to the site. These densities are proportional to the imaginary part of 1D Green function at the free surface which is proportional to the square of the absolute value of the corresponding transfer function for a plane,vertically incident wave with unit amplitude.

Passive Acoustic Interferometry For Sediment Characterization In Shallow Water

Q.Y. Ren[1,2], J.-P. Hermand[1], S.C. Piao[2]

1Environmental Hydroacoustics lab, Universite libre de Bruxelles (U.L.B.)
2National Key Laboratory of Underwater Acoustic Technology, Harbin Engineering

The underwater broadband sound pressure field generated by a moving source often ex-hibit an interference structure, which is determined by the waveguide properties. It has been used for underwater inverse problems, including geoacoustic inversion and source localization. In this paper, a novel passive acoustic interferometry is proposed for sed-iment characterization by exploring the interference structure of the broadband sound pressure field. Salient features of the interference pattern, i.e., the slope and position of the striations, are extracted by image processing technique. Then the sensitivities of these features to environmental parameters, e.g., the striation position shift with respect to geoacoustic parameters in different frequency bands and ranges, are numerically studied. The coupled effects of geoacoustic parameters on the sensitivity are also discussed. Finally, a simple numerical study based on the Yellow Shark environmental model is used to demonstrate preliminary inversion results.

Sound Speed profile and array position reconstruction using the ambient noise field.

Goncharov V.V. and Chepurin Yu.A.

IORAS

In this paper we discussed the possibility of reconstruction of sound speed profile and array position under the different types of background sound speed profile (SSP). The input data for such reconstruction are the set of arrival times between the different receivers of two vertical arrays that were measured using the ambient acoustic noise. The different types of parameterizations of array shape and SSP were considered.

Tuesday, April 26 11:00-12:30	
Special Session: Wave and Computation I	**John Locke**
Organizer : Géza Seriani and Dan Givoli	

Wave propagation modeling in highly heterogeneous media by a double-grid Chebyshev spectral element method

Géza Serian[1]and Chang Su[2]

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Numerical modeling of wave propagation phenomena in realistic media requires highly accurate algorithms in order to correctly represent the wave field. Among various computational techniques, the spectral element methods, either based on a Chebyshev or a Legendre polynomial basis, have shown their excellent properties in solving wave propagation problems. They outperform other more classical techniques with respect to both accuracy and flexibility in describing complex models. In contrast with standard grid methods, which use dense spatial meshes, spectral element methods may discretize the computational domain with a very coarse mesh. But constant-property elements may in some cases seriously reduce the computational efficiency. For instance, if the medium is finely heterogeneous, we may need to describe it in a much finer way than the acoustic wave field. The double-grid approach presented in this work is a viable way for maintaining the efficiency of the spectral element method and for handling problems where the medium changes continuously or even sharply on the small scale. The variation in the properties is taken into account by using an independent set of shape functions defined on a temporary local grid in such a way that the small scale fluctuations are accurately handled, without the need of a global finer grid. This is formally expressed by a coupling operator and the related transfer matrix. The main advantage of this approach is that the medium variability/heterogeneity can be represented numerically by the most appropriate shape functions, independently of the polynomial basis used to represent the wave field solution. Moreover, the wave field propagation is solved with no loss of computational efficiency. Numerical results for 2D acoustic wave propagation will be shown that assess the present approach.

Multiple Dirichlet-To-Neumann Boundary Condition Adapted To Scattering In The Half-Plane

Sebastian Acostaand Vianey Villamizar

Department of Mathematics, Brigham Young University

The multiple-Dirichlet-to-Neumann (multiple-DtN) nonreflecting boundary condition is adapted to scattering from obstacles of arbitrary shape embedded in the half-plane. For acoustically soft and hard surfaces, the multiple-DtN map is coupled with the well-known method of images. As opposed to the current practice of enclosing the scattering region with a large semicircular artificial boundary, a recent multiple Dirichlet-to-Neumann method devised by Grote and Kirsch is extended to half-plane problems. The proposed technique renders the possibility of using a small circular nonreflecting boundary to enclose the immediate vicinity of the obstacle in the half-plane. A computationally advantageous boundary value problem is numerically solved with a finite difference method supported on appropriate boundary-fitted grids following [S. Acosta and V. Villamizar, J. Comput. Phys. 229 (2010) 5498-5517]. The proposed numerical method is validated by comparing the approximate and exact far-field patterns for the scattering from a circular obstacle in the half-plane.

High-Order Algorithms and Optimal Radiation Boundary Conditions for Acoustics

Thomas Hagstrom

Southern Methodist University

Efficient time-domain solvers for acoustic wave equations must include two crucial components: i. Radiation boundary conditions which provide arbitrary accuracy at small cost (spectral convergence, weak dependence on the simulation time and wavelength) ii. Reliable high-resolution volume discretizations applicable in complex geometry (i.e. on grids that can be generated efficiently) - we believe that high-resolution methods enabling accurate simulations with minimal dofs-per-wavelength are necessary to solve difficult 3+1-dimensional problems with the possibility of error control. In this talk we will discuss our recent results in both areas. In particular we will explain the construction and implementation of complete radiation boundary conditions (CRBCs), which are optimal local radiation conditions, and demonstrate hybrid high-order space-time discretization schemes. The latter involve the coupling of discontinuous Galerkin methods, which can be used on

unstructured grids fitting geometric features, with novel spectral elements based on Hermite interpolation. The advantage of the use of the structured grid method throughout much of the domain is the efficiency of tensor-product operations and the possibility to take significantly larger time steps. We also mention alternative methods based on grid-stabilized difference formulas which can be applied on mapped or composite grids.

Tuesday, April 26 14:00-15:30	
Special Session: Wave and Computation II	**John Locke**
Organizer : Géza Seriani and Dan Givoli	

Computational Methods for Analyzing Aircraft Noise above Ground with General Topography and Impedance

Ido Gur, Roman Reitbort and Dan Givoli

Dept. of Aerospace Engineering Technion – Israel Institute of Technology

The measurement and calculation of aircraft noise in the far field is an important subject in environmental engineering, since such noise has an acute effect on the community. Most of the work that was done in this context has been empirical in nature. Mathematically, the problem may be posed, in the frequency domain, as that of determining the Sound Pressure Level (SPL) distribution near the ground due to a point source of a given acoustic spectrum. The ground is assumed to have general topography and impedance distribution. The process of calculating the SPL distribution involves the repeated solution, for many different wave numbers, of the Helmholtz equation in the upper half space. All these solutions are then combined in a special manner to yield the SPL distribution. Due to this reason, efficient techniques are needed for the fast solution of the Hemlholtz equation in the unbounded domain above ground with general topography and impedance. Three computational methods are presented and compared for this task: . A method of fictitious sources, specially developed for this configuration. . A space-enriched finite-element method (FEM), based on Partition of Unity (PUM) or Generalized FEM (GFEM). . A special range-marching scheme for general topography, based on the parabolic approximation of the Helmholtz equation and spatial transformation. The regimes where each of these methods has an advantage over others are discussed. The performance of each of these schemes is demonstrated using numerical examples.

Computating acoustic source locations in urban environments

Lanbo Liu[1,2], Donald G. Albert[2], Paul R. Eller[3], Jing-Ru C. Cheng[3], and Hao Xie[1]

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Because sounds from vehicles, explosions, and other sources can be heard when a listener is behind one or more buildings, acoustic sensors have the potential to locate sound sources even when situated in a non-line-of-sight (NLOS) position. However, standard acoustic processing algorithms fail in NLOS situations and often perform poorly in LOS conditions in urban areas because of multiple reflections and diffractions from buildings. The sounds can be easily detected, but it is difficult to correctly determine where they came from. Traditional source location methods, including various beam-forming or triangulation algorithms, rely on an accurate determination of the direction of arrival of the acoustic waves. These methods give erroneous results if the direction of the wave arrival is different from the source direction, a situation that often occurs in both LOS and NLOS situations in reverberant urban environment. We report on a systematic study of the time-reversal (TR) processing technique using a time domain finite difference (FDTD) computational code for acoustic wave propagation through an artificial village composed of 15 buildings. Converting the original Matlab code to run on a specialized graphic processor unit (GPU) has increased the speed of the time-reversal calculations by a factor of 200. Solutions for problems requiring 58M grid points and 50k time steps can now be obtained in under a few minutes, for example, compared to more than 12 hours needed for the original code. We examine the performance tradeoffs and the number and location of NLOS sensors needed to obtain accurate sound source locations in this realistic computational model and report them in this presentation. [Research funded by the US Army Corps of Engineers.]

Spectral Finite Elements for Computational Aeroacoustics based on Acoustic Perturbation Equations

Andreas Hüppe, Manfred Kaltenbacher

Alps Adriatic University Klagenfurt

In many problems of computational acoustics, the impact of a present flow field on the wave propagation cannot be neglected. For every finite element (FE) approximation of these cases, stability, accuracy and efficiency are of great importance. In our contribution we present a time-domain spectral finite element formulation for the acoustic perturbation equations (APE). This system of partial differential equations can be seen as a subset of the linearized Euler equations which include convective terms for the incorporation of flow effects on the acoustic field computation. As basis functions for the FE ansatz we use higher order Lagrange polynomials in combination with a Gauss-Lobatto quadrature. This approximation is known as the spectral element method in which the accuracy is increased by choosing a higher polynomial degree instead of a mesh refinement. Furthermore, we choose a continuous H^1 approximation for pressure and velocity unknowns to decrease the memory consumption of the scheme with respect to discontinuous Galerkin methods.
One of the remaining problems within this approach are the instabilities which arise due to the convective terms. Therefore, a streamline upwind Petrov-Galerkin (SUPG) scheme is utilized to stabilize the scheme.With the proposed method it is possible to compute acoustic wave propagation in the presence of a flow field obtained from a previous fluid simulation. In the talk we will present the theoretical fundamentals of the computational scheme and present its performance with respect to CPU time and memory consumption when applied aeroacoustic computation.

Tuesday, April 26 16:00-17:30	
Special Session: Wave and Computation III	**John Locke**
Organizer : Géza Seriani and Dan Givoli	

Energy partition between elastic waves for dynamic surfaceloads in a semi-infinite solid

Francisco J. Sánchez-Sesma[1], Richard L. Weaver[2], Hiroshi Kawase[3], Shinichi Matsushima[3], Francisco Luzón[4], Michel Campillo[5], and Juan J. Pérez-Gavilán[1]

[1]*Instituto de Ingeniería, Universidad Nacional Autónoma de México*
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[5]*Université Joseph Fourier*

While the energy partitions among elastic waves for a dynamic normal load on the surface of an elastic half-space with Poisson ratio of 1/4 is a well known result by Miller and Pursey (1955), the corresponding partitions for a dynamic tangential load are less well known. The partitions for the normal and tangential loads were computed independently by Weaver (1985) against Poisson ratio ($0 \leq \nu \leq 1/2$) using diffuse field concepts and within the context of ultrasonic measurements. This partially explains why the results did not reach the seismological and engineering literature. This communication is aimed to present the partition factors in connection to the Green function retrieval from averaging cross correlations. Therefore, the energies injected into the elastic half space by concentrated normal and tangential harmonic surface loads are proportional to the imaginary part of the corresponding components of the Green's tensor when both source and receiver coincide. The character of the radiation of these two cases is quite different; for a normal load about 2/3 of energy leave the loaded point as Rayleigh surface waves, on the other hand the tangential load induces a similar amount in the form of body shear waves. We use Miller and Pursey (1955) and Weaver (1985) results to calibrate a numerical integration scheme in frequency domain. These deterministic results have significant implications for the explanation of the energy densities at the surface of a layered half-space. They allow obtaining a plausible physical explanation in terms of elastic wave propagation and average response under stochastic, diffuse excitation.

Cuspidal borehole modes and dual arrivals in TI-formations

C.-Y. Wang, R. Burridge, J. Pabon, and M. Schoenberg

Schlumberger-Doll Research, Old Quarry RD, Ridgefield

New expressions for waves in a homogeneous linearly elastic transversely isotropic (TI-) solid are presented in terms of three simple potential wave functions. These expressions are used to study “cuspidal modes”, a new type of acoustic borehole modes which exist in certain anisotropic formations. These cuspidal modes do not have cutoffs in their frequency spectrum, and thus can be exited at all frequencies. Their asymptotes at low and high frequencies coincide with the cuspidal and Scholte waves, respectively. Cuspidal modes may exist in both monopole and dipole forms. When that happens, they are the primary borehole modes, and the Stoneley and flexural modes become leaky and attenuative. The coexistence of a cuspidal mode with the Stoneley mode, or with the flexural mode create \dual arrivals", an interesting phenomenon that has been observed in sonic logs.

3D finite-difference modeling of sonic logs in tilted-layered porous formations

Xiao He, Xiuming Wang

State Key Laboratory of Acoustics, Institute of Acoustics, Chinese Academy of Sciences

Layered structures are frequently encountered in geophysical prospecting. To simulate the monopole and dipole acoustic logs in a stratified fluid-saturated porous formation, a finite-difference (FD) algorithm is developed in the 3D cylindrical coordinate system. In this paper the nonsplitting perfectly matched layer is applied as the absorbing boundary condition to truncate the computational region. To validate the FD algorithm, we compare the FD and the analytical solutions for the case with a homogeneous porous medium surrounding the borehole. The modeling results from those two methods are in good agreement. The synthetic waveforms are calculated for acoustic logs in a tilted-layered formation which is composed of two poroelastic media with different permeabilities and elastic properties. A 3D staircase approximation is used when the tilted interface is not parallel to the grid-cell surfaces. On that interface, we adopt the parameter averaging scheme to guarantee the boundary condition satisfied. The simulation results show that both Stoneley and flexural modes along the borehole have evident attenuation in a highly permeable

layer. When the source is located beneath the layer interface and the receivers are distributed at the upper layer, it is revealed that the amplitudes and the arrival times of the compressional wave, the shear wave, and the flexural modes excited by the horizontally- and vertically- polarized dipole sources, are influenced by the borehole inclination. The Stoneley mode from the monopole source, however, displays little sensitivity to the angle between the borehole axis and the layer interface, since the propagation characteristic of such a guided wave mainly depends on the borehole fluid property.

Tuesday, April 26 14:00-15:30	
Special Session: Reservoir Geophysics I	**Archimedes**
Organizer : Yu-Chiung Teng and Yuefeng Sun	

Method of Integrating Neural Network Inversion with Finite Element Forward Modeling

Dongyu Feii[1] and Yu-Chiung Teng[2]

[1]*New York Computer Institute*
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We summarize our research work by using a combined methodology of neural network inversion and finite element forward modeling. The principle of the neural network is developed. The investigation process consists of the following three parts: (1) Generating a series of synthetic shot records with known physical parameters by finite element modeling to simulate the field survey. A fast computation algorithm of the finite element method is used to generate the synthetic seismic data; (2) Using these synthetic data to train a neural net; and (3) To determine the unknown quantities, such as the physical parameters, by the finite neural network system. We applied the technology to the following problems: (1) To estimate the migration velocity and pollution level for the contamination ground water by electric method; (2) To detect an object of steel or concrete structure in shallow water environment by acoustic wave propagation.

Scattering of Transient Waves by Finite Cracks in a Plane Strain Elastic Solid

Yu-Chiung Teng

Femarco, inc, New York

The transient problem of finite cracks with vanishing thickness in a plane strain elastic solid is investigated by the finite element method. The infinitesimally thin crack with traction free on both faces of the crack is simulated by the energy-sharing-node technique. To simulate transient waves in an elastic whole space embedded with one or more cracks, the following cases are considered:(1) a single horizontal crack with a directional force; (2) a single horizontal crack with a point source; (3) a single vertical crack with a directional force; (4) a single vertical

crack with a point source; and (5) two horizontal cracks with a point source. The synthetic seismograms for displacement components along the cracks are presented. Snapshots of the scattered displacement components for each case are displayed so that the generations of the scatterings and the processes of the wave propagations can be clearly visualized.

Observation of Scholte waves from multi-component ocean bottom seismic data in the shallowwater environment of the Persian Gulf

Yuefeng Sun[1] and Karl Berteussen[2]

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[2]*The Petroleum Institute, Abu Dhabi, United Arab Emirates*

The Persian Gulf where some of the world's most important oil and gas fields reside has an average water depth about 5-15m. Such shallow water environment typical of the Persian Gulf presents unique challenges and opportunities to multi-component ocean bottom cable (OBC) seismic data acquisition, processing and analysis. Besides strong multiples, conversion of acoustic energy in the water column to shear wave energy in the seabed is substantially enhanced when the sea bottom is hard as in the coral reef area. Analysis of a 2D 4-Component (4C) OBC data set acquired in the Persian Gulf reveals presence of Scholte waves with strong dispersions and other P-wave related interface waves. Both field data analysis and modeling results show that the velocity of Scholte wave decreases from about 1950 m/s to about 1500 m/s as frequency increases from zero to about 100 Hz. Because the shot spacing interval and the receiver spacing interval are large, about 20 m and 25 m, respectively, the observed Scholte and other surface waves are severely aliased. Lateral variation of Scholte wave characteristics in the studied area agrees with the variation of the elastic properties of seabed as obtained by sonar data and direct diver observations.

Tuesday, April 26 16:00-17:30	
Special Session: Reservoir Geophysics II	**Archimedes**
Organizer : Yu-Chiung Teng and Yuefeng Sun	

Physical model experiment for wide angle reflectionof seismic waves

Yang Zhenghua[1], Huang Yijian[1], Yu-Chiung Teng[2]

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[2]*Femarco, New York*

Recently, wide-angle acquisition has been considered as one of the most significant field methods to obtain high quality seismic data. In this paper we report results of wide-angle reflection through physical modeling experiment. From the experimental observations, we have the following conclusions:1)The amplitude energy of the wide-angle reflection observed is approximately 1-2 times stronger than that of non-wide-angle reflection. However, the amplitude energy of the wide-angle reflection is 30 times stronger in theoretical calculations. Besides, the observed reflection energy increases gradually rather than increases abruptly as theoretically calculated. 2)The hyperbolic shape of the reflection event is still preserved when the offset is very large. 3) The frequency of wide-angle reflection is lower than that of the non-wide-angle reflection with a 20-30% decrease. Frequency decreases as offset increases. 4) There is neither change in wave shape nor change in polarity when the incident angle is great than the critical angle. 5) There is no change in the characteristics of the reflected waves, no matter the incident angle is greater or smaller than the critical angle.

Application of High Resolution Zero VSP and Walkaway VSP in Fine Delineation of Reservoir

Guangming Zhu

Geophysics department, Changan University

In this paper, we first analyze the main factors influencing the resolution of VSP data, such as bandwidth and dominant frequency of source waveforms, repeatability and consistency of source waveforms with different excitations, different stratum absorption for different frequency components during wave propagation, and spectral narrowing caused by non-uniform waveform summation in data processing, etc.

Subsequently, we present methods to improve the resolution of VSP data. The methods include consistent data acquisition, data consistency processing, stratum absorbing and attenuation estimation (Q-value estimation) and compensation for absorption and attenuation. These methods are then tested by using both model and field data. Test results show that for conventional processing of conventional VSP data, at a depth of 2000m and a time of 1.0s, the dominant frequency is approximately 60Hz, the bandwidth is 10~100Hz, the wave length is about 40m, and the identifiable layer thickness of VSP data is approximately 10m by making use of an estimation limit of 1/4 wavelength. Whereas, for the high-resolution acquisition and processing of VSP data for the same geologic model and source-geophone configuration at the depth of 2000m and the time of 1.0s, the dominant frequency can be enhanced to be approximately 100Hz, the bandwidth is 10~200Hz, the wave length is about 20m, and reservoir layers thinner than 5m can be identified. Test results demonstrate the effectiveness of the proposed methods.

Bayesian Seismic Inversion Based on Stochastic Modeling under Control of Sedimentary Facies

Zhu Peimin and Wang Jun

Institute of Geophysics & Geomatics, China University of Geosciences

During early stage of oil production in an oil field, reservoir characterization using stochastic modeling is very difficult due to few well. But we know both of seismic data of low resolution and its geological interpretation, such as structure and sedimentary facies, can make up the deficiency of few well. Sedimentary facies and geological structure explained by geologists is very useful information. We believe that integrating the sedimentary facies information, well data, and seismic data can make the model characterizing subsurface reservoir fit the actual geological and geophysical truth better. In this paper, a method is suggested to predict the reservoir parameters using wells and seismic data under control of sedimentary facies by Bayesian statistic method that combines the traditional stochastic modeling and seismic inversion. Under the frame of probability, Bayesian seismic inversion based on model can make use of a variety of geophysical and geological priori information to inverse process, and then it could provide related inverse results and uncertainty evaluation of results. But an obvious problem is that the result of inversion is strongly dependent on the initial model and priori information. So the control of sedimentary facies as a new constraint to Bayesian inversion is necessary. In order to reach our

expectation, a new workflow of inversion is presented. First, the information of structure and sedimentary facies are obtained by geological interpretation of seismic data. Next, a set of geophysical models are built through Sequential Gaussian co-simulation with all available information under control of sedimentary facies. Finally, those models as the initial models are used for Bayesian inversion. A numerical experiment was carried out for reservoir prediction of delta facies in Tertiary system located in Qikou Depression, the Bohaiwan basin of east China. And it proved that facies-control Bayesian seismic inversion is very feasible.

Technical Sessions

Monday, April 25 14:00-15:30	
Ocean Acoustics I	**Plato Chamber**

Comparison of noise-enhanced intensity between depression internal wave and elevation internal wave in the ocean

Hsiang-Chih Chan[1], Chi-Fang Chen[1], Ruey-Chang Wei[2], Yiing-Jang Yang[3], Andrey N. Serebryany[4], James F. Lynch[5]

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Depression internal waves (DIW) and elevation internal waves (EIW) are the two general types of nonlinear internal waves (NLIWs) in the sea. DIW were occurred while the depth of top water volume was larger than lower water volume. Thus, DIW were usually observed in the deep sea, such as in ocean continental slope and ocean basin, and EIW in continental shelf. Breaking waves of rips in the convergent region generated by NLIWs that could enhance noise in the sea surface. This study used a numerical modeling to simulate the variations of the noise-enhanced intensities from the NLIWs. The modeling is based on an ocean-waveguide, which included Nx2D noise sources, sound speeds of water, flat sea bottom, and acoustic bottom properties (sound speeds, attenuation, and densities for compression waves.) The calculation of noise fields were considered as transmission loss between each of noise sources and receivers, which was simulated by the adiabatic normal mode in KRAKEN program. The key parameter in this study is NLIWs impact on water temperatures, i.e. sound speeds of water. Thus, the replica waveforms of NLIWs in modeling were produced using the KdV formula. In the presentation of results, the sound speeds of water interfered by NLIWs influenced some changes of noise intensities in a study case with

the same noise source strength. This meant the sound speeds in DIW and EIW had significant effects. The simulated results showed the changes of noise intensities with the passage of NLIWs in time series. Moreover, the breaking waves in the convergent region could be observed from the radar image data, and the simulated results were compared with the noise data collected by the hydrophones in the experiment.

Effects of Internal Waves on Ambient Noise Vertical Directionality in Shallow Water

Jianheng Lin, Pengfei Jiang, Xuejuan Yi, Junping Sun, Jialiang Li

Qingdao Lab of Institute of Acoustics, Chinese Academy of Sciences

In this paper, a three-dimensional sound speed profile model with internal waves and modified ambient noise model are combined, effects of internal waves on ambient noise vertical directionality in shallow water are studied. The numerical simulation results show that each mode makes different contribution to vertical directionality, the low-order modes can fill the horizontal notch in the vertical directionality. For downward sound speed profile, the low-order modes are weakly excited by sea surface noise sources, the noise directionality notch is deep. Internal waves cause the conversion between different modes, low-order modes are strengthened and higher-order modes are weaken, the notch becomes shallower. Besides, the relation between the notch fill-in and the intensity of internal wave is obtained, the notch becomes shallower with the increase of internal wave intensity. The noise notch is gradually filled in when the internal waves propagate to the array.

Evaluation the Capability of Geoacoustic Invertion using Ocean Ambient Noise received by VLA in Shallow Water

Xinyi Guo, Li Ma, Fan Li, Yaoming Chen

Key Laboratory of Underwater Acoustics Environment, Institute of Acoustics, Chinese Academy of Science

Coherence of ocean ambient noise is affected by ocean waveguide, especially in shallow ocean, the geoacoustic parameters of sediment in the seafloor are mostly factors that influence for the coherence characteristics of ocean ambient noise, wherefore, geoacoustic parameters can be inversed using ocean ambient signals. However, the mechanisms of ocean ambient noise sources are not studied intensively at present, and the simulation results which calculated by existent ocean ambient models contain a lot of uncertainties. Thus, the methods using ocean ambient

coherence inversed geoacoustic parameters are less stability and accurate than using broadband explosive signal and the other artificial sources inversion. In the same vertical line array (VLA), there are considerable differences of the geoacoustic parameters inversion results using vertical coherence of ocean ambient noise, when the noise signals are select by different elements in VLA. For the sake of discussed the capability of inversion for geoacoustic parameters using ocean ambient noise, this paper founds a benchmark of geoacoustic parameter by artificial source data inversion, and compared the differences of ocean ambient noise vertical coherence characteristics between model calculations and VLA's survey data. At last, we can obtain several sets of different geoacoustic parameters using ambient noise signals received by different elements in VLA, and then evaluated the best scheme for inversion geoacoustic parameters using vertical coherence of ocean ambient noise which received by VLA in the experiment shallow ocean.

Monday, April 25 16:00-17:30	
Ocean Acoustics II	**Plato Chamber**

Acoustic propagation simulation in a coastal wedge using generalized-ray method

Piotr Borejko

Vienna University of Technology

The generalized-ray method is applied to simulate three-dimensional (3D) acoustic propagation from a point source in a wedge of fluid over an elastic bottom modeling a coastal wedge. One attractive feature of this method is that the acoustic field can be sorted out into parts identifiable in the received time series as pressure pulses arriving along ray paths, so the relative intensities of the received pulses indicate which propagation paths are significant and which are not. This feature is used to show that the cross-slope propagation in a coastal wedge may indeed be 3D and thus significantly affected by horizontal refraction. The calculated time series received at a cross-slope location is split up into two parts: the first composed of pulses propagating along paths with "small" azimuthal arrival angles (signal arrival direction vs. source-to-receiver direction); and the second composed of pulses propagating along paths with "large" azimuthal arrival angles. A pressure response due to the later is significantly stronger than that due to the former. Since in cross-slope propagation

the arrival angle increases with the increasing number of bottom reflections, these results demonstrate that the dominant part of the received field comes in along a group of paths involving multiple bottom interactions (thus traveling up the slope and back to the receiver) and not along a group of paths involving only a few bottom interactions (thus traveling near the straight source-to-receiver path). These theoretical findings are consistent with the recent quantitative measurements of cross-slope acoustic transmission in a coastal wedge, which clearly indicate separation of the received acoustic field into two distinct parts: one of low intensity coming in near the straight source-to-receiver path; and the other of high intensity coming in later along a path having propagated up the slope and back to the receiver.

Temporal Variation of Coherency of Low-Frequency Sound Observed in the OBS Measurement off the East Coast of Taiwan

Chen-Fen Huang[1], Jin-Yuan Liu[2], and Peter Gerstoft[3]

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[2]*National Sun Yat-sen University*
[3]*University of California at San Diego*

The ambient noise recorded by the OBS system deployed off the east coast of Taiwan in the TAIGER (TAiwan Integrated GEodynamics Research) project was employed to calculate the Cross-Correlation Function (CCF) of the noise field. The data recorded between the stations located at Yaeyama Ridge (water depth about 4000 m), starting from May of 2008 for a period of more one year, have been processed using the one-bit noise cross correlation technique. The results of CCF have shown that there exists strong microseism energy in the frequency band between 0.16 Hz and 0.35 Hz all year around, and has also demonstrated a large temporal variations as much as 5 seconds. Since it has been generally accepted that the microseism is attributable to the mechanisms resulted from the nonlinear surface wave-wave interactions (e.g., Longuet-Higgins, 1950; Bromirski, et. al., 2005), therefore, the temporal variations of CCF should be due to the variations of noise sources and/or waveguide propagation. Numerical simulation has indicated that there exist eigenrays between the OBS stations, as a result, the observed CCF variations should be strongly affected by the waveguide variations, in particular, the sound speed profiles. The study has aimed at the investigation of how significantly that the sound speed variation may render the temporal variation of CCF; a quantitative analysis that may potentially pave the way of applying passive acoustic tomography for the monitoring of ocean climate.

Path integral derivation of temporal coherence of acoustic rays and normal modes

T. C. Yang

Naval Research Laboratory

Acoustic propagation in a deep ocean sound channel can be described by refractive rays. Applying the path integral to the 3-dimensional rays, one can calculate the temporal coherence function of the acoustic field (R. Dashen, S. Flatté, and S. Reynolds, J. Acoust. Soc. Am. 77, 1716–1722, 1985). For shallow water where sound interacts with boundaries, the acoustic field can be described by vertical modes and horizontal rays - the ray amplitude is also the mode amplitude. (The vertical mode and horizontal ray approach is also valid for trapped modes in deep water.) Applying the path integral to the 2-dimensional (horizontal) rays, one derives the temporal coherence function of the horizontal rays or the temporal coherence of the normal modes. The derivation of the temporal coherence of the modes and also that of the acoustic field are present in this paper using internal waves as an example The effect of mode coupling due to internal waves is explicitly illustrated. Numerical examples are given to illustrate the effect of mode coupling on temporal coherence loss. (Work supported by the US Office of Naval Research.)

Tuesday, April 26 16:00-17:30	
Ocean Acoustics III	**Plato Chamber**

Transformation of acoustic-gravity waves (AGW) at the air-water interface

Iosif Fuks[1,2] and Oleg A. Godin[2,3]

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At extremely low frequencies (frequencies f of order of several mHz, or the wave periods T of order of several minutes), both gravity and medium's compressibility play essential roles in propagation of fluid perturbations in the water as well as in the air. These perturbations propagate as acoustic-gravity waves (AGW) with specific dispersion laws and a frequency gap between two branches of the dispersion curves –

the gravity branch and the acoustic branch. In this paper, we investigate AGW fields in air and in water generated by a compact underwater source, such as an underwater explosion or an underwater landslide. Air and water are modeled as two semi-infinite fluids separated by a plane interface. Such a medium supports body waves (or the continuous spectrum of the field due to a point source) as well as surface waves (or the discrete spectrum of the field), which are localized in the vicinity of the water-air interface. While water half-space with a free boundary supports surface gravity waves and air half-space with a rigid boundary supports the Lamb wave, two kinds of surface waves exist in the water-air environment, namely, modified surface gravity (mG) and modified Lamb (mL) wave. Each modified surface wave is present in both air and water. The mG wave is slower (faster) than the mL wave above (below) certain “hybridization” frequency. The discrete spectrum of the wave field undergoes a rapid transformation in the vicinity of the “hybridization” frequency. It is found that, at frequencies close to cut-off frequencies of the surface waves, the water-air interface becomes anomalously transparent for sufficiently shallow compact sources of AGWs. Depending on the source type, the increase of wave power flux into air due to diffraction effects can reach several orders of magnitude.

A new energy-flux model of multi-layer bottom reverberation in shallow water

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The modal shallow water bottom reverberation theory and the energy-flux shallow water bottom reverberation theory have already been combined to get a new energy-flux model of waveguide reverberation based on Perturbation theory in case of half-space bottom. In this paper, the new energy-flux bottom reverberation model was extended to the case of multi-layer bottom on the base of study of multi-layer bottom reflection parameters P and Q. There are only three environmental parameters (P, Q, μ) in the new multi-layer bottom reverberation model. The difference with half-space case is that parameter P and Q are no longer a constant but frequency dependent – P(f) and Q(f). It has clear physical picture and it is satisfied the waveguide constraint without any adjustable parameters. The new energy-flux reverberation model was compared with the modal reverberation model (full-wave reverberation model). The results show that the new model can explain the shallow water multi-layer bottom reverberation in most cases.

Simulating acoustic pressure and intensity in a strong internal wave field

Georges A. Dossot[1], James H. Miller[1], Gopu R. Potty[1], Kevin B. Smith[2], James F. Lynch[3], Ying-Tsong Lin[3], Mohsen Badiey[4]

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[3]*Department of Applied Ocean Physics and Engineering, Woods Hole Oceanographic Institution*
[4]*College of Marine and Earth Studies, University of Delaware*

During the Shallow Water 2006 (SW06) experiment, a J-15 acoustic source deployed from the Research Vessel Sharp transmitted broadband (100-500 Hz) chirp signals 15 km away from a vertical line array. The array was intentionally positioned near the shelf-break front and in an area where internal waves are known to occur. During the same time an internal wave, "Event 44," passed through the sound field such that the internal wave front was nearly parallel to the acoustic transmission path. Measured data shows substantial intensity fluctuations that vary over time and space due to complex multimode and multipath (both two and three dimensional) interference patterns. This presentation compares three-dimensional modeling results using the experimental geometry, acoustic signal parameters, and a simulated oceanographic environment based on environmental moorings and ship-born sensors to mimic the measured internal wave event. A modified version of the three-dimensional Monterey-Miami Parabolic Equation (MMPE) code which incorporates a user-defined sound speed field is used. Measured and modeled intensity fluctuations are compared during dominating horizontal regimes such as refraction, ducting, and "anti-ducting." Repeated model runs simulate time progression of the internal wave field. Modal decomposition of the PE field further explains the intensity fluctuations that are shown in both the modeled and measured data. [Work sponsored by the Office of Naval Research.]

Thursday, April 28 11:00-12:30	
Ocean Acoustics IV	**Plato Chamber**

Application Of Acoustic Contrast Control Method For Sound Focusing In Shallow Water Environment

Yi-Wei Lin andGee-Pinn James Too

Department of Systems and Naval Mechatronic Engineering, National Cheng Kung University,

In this study, acoustic contrast control method is applied for sound focusing in shallow water environment. This method provides an optimal sound contrast to increase or decrease the specific area sound potential energy. The simulation was performed in shallow-water environment. First, Green's function between source point and field point is calculated via Acoustic Toolbox User-interface & Post-processor (AcTUP). And then, the effects of this process on environment parameters such as: control sources number, transmitting frequency and controlling zone of geometric location, are discussed. A comparison of the results is made and acoustic contrast control is shown to be an effective approach for sound focusing in shallow water environment.Index Terms—sound focusing, acoustically bright zone, acoustic contrast control.

Current Measurement of Kuroshio Southeast of Taiwan Using Acoustic Tomography

Chen-Fen Huang[1], Yen-Hsiang Chen[1], and Cho-Teng Liu[1], Jin-Yuan Liu[2], Noakazu Taniguchi[3], Arata Kaneko[3], and Noriaki Gohda[3]

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[2]*national Sun Yat-Sen University,Taiwan*
[3]*graduate School Of Engineering, Hiroshima University, Japan*

Ocean acoustic tomography (OAT) measurement was carried out during August–September 2009 in the Lan-Yu areas to obtain the spatial and temporal variations of the sub-branch of the Kuroshio. The reciprocal transmission between the stations T1 and T3 was successfully executed for one month. During the observation, the drift of internal clock occurred caused by both the less accurate quartz crystal

clock equipped in the OAT system and the bad programming of system operation software. The clock drift is corrected through the procedure that the differential travel times for the first arrival rays passing the lowest layer and the measured bottom current velocity by the current meter. The corrected acoustic travel times are used to estimate the variations of average current speed and their vertical profiles along the ray path. The inverted current speed by tomographic measurement is compared with the shipboard ADCP survey.

Study on the Validity of the Broadband Matching for High Power Low Frequency Narrowband Transducers

Haijun Liu, Juan Zeng, Tianfu Gao, Haifeng Li,Dayong Peng, Wengyao Zhao, Jianlan Zhang

Key Laboratory of Underwater Acoustic Environment, Institute of Acoustics, Chinese Academy of Sciences

With a thriving demand for low frequency underwater transducers, we desire transducers can operate in the available wide range of frequency with high power, however low frequency underwater transducers have a very narrow bandwidth, nothing more than tens of Hz, such as a transducer for 200 Hz resonant frequency. It is essential for the electrical broadband matching of transducers. Even though we obtain any bandwidth by some methods of electrical broadband matching, transducers can operate invalidly in the bandwidth range of matching when activating transducers with high power, and whereas operate validly when activating transducers with low power. This Paper describes the equivalent circuit of a piezoelectric transducer for frequency around a simple resonance, the elements parameters of the electrical equivalent circuit is determined by the admittance of the transducer from the electrical measurements. The broadband matching of a low frequency transducer is chosen reasonably by means of inserting a matching network between a driver amplifier and a transducer, With the goal of increasing transmitting bandwidth improving power factor, and providing a good performance. The experiments show that desirous bandwidth is got by matching in the states of small signals. Nevertheless with the activating of high power, the measurements differ from the one with the activating of low power. It is necessary to study the validity of broadband matching for high power narrowband transducers more profoundly, in order to make better use of transducer and activating it more sufficiently. However, for as much as the complexity of the issue, in terms of experimentation the paper mainly states the validity of the broadband matching for high power low frequency narrowband transducers, looking

forward to providing the availability and a applicable value for expanding the bandwidth of transducers in reason.

Thursday, April 28 14:00-16:00	
Underwater Acoustics I	**John Locke**

A Characterization of Scattered Acoustic Intensity Fields in the Resonance Region

Robert J. Barton III[1], Kevin B. Smith[2]

[1]*NUWC Code 1522, Sensors Sonar department*
[2]*Dept. of Physics, Naval Postgraduate School*

In this study, we investigate the properties of the scattered acoustic vector fields generated by simple rigid, fluid-filled, and thin-walled vacuous spheres and finite cylinders. Analytical solutions are derived from acoustic target strength scattering models in the near field region. Of particular interest is the understanding of the characteristics of energy flow of the scattered acoustic vector field in the near to far-field transition region. We utilize the separable active and reactive acoustic intensity fields to investigate the structural features of the scattered field components. Numerical and in-air measured results are presented for the near and transition region scattered acoustic vector field of simple spheres, and results of finite element analysis are shown.

Numerical solution of a boundary integral formulation of the Helmholtz equation

Elena Sundkvist

Uppsala University

The numerical solution of the Helmholtz equation with nonlocal radiation boundary conditions is considered. We model sound wave propagation in a multilayered piecewise homogeneous medium. A fourth-order accurate boundary integral (collocation) method is used, where the solution inside the domain is computed through a representation integral. The method is corroborated by comparison with a fourth-order accurate finite difference discretization of the partial differential equation.

The improving measurement method on piezoelectric ceramic emission transducer

Haifeng Li,Juan Zeng,Tianfu Gao,Haijun LiuDayong Peng,Wengyao Zhao

Institute of Acoustics, The Chinese Academy of Sciences

An improving measurement technique on piezoelectric ceramic transducer was developed in order to meet the need of field measurement. With time passing or transducer aging itself, the impedance of emission transducer is changing. If the impedance was unknowingly changed, the existing match or equalization network was mismatched. The mismatching transducer array will hugely affect the quality of underwater single-mode open-loop excitation or even severely cause its failure. Normally, the impedance or admittance of emission transducer was measured, on the one hand, by the higher precision impedance analyzer in laboratory environment through the electrical bridge method, on the other hand, by the volt meter measuring three voltages of series connection global voltage, series connection resistance voltage and emission transducer voltage in tough environment though the tri-voltage method. The former method has the most excellent accuracy, but its instrument is expensive and delicate, and then the latter method has rough accuracy and asynchronies, but its instrument is easy to acquire. The improving measurement method using the tri-voltage method circuit structure synchronously measures the transfer function of resistance and transducer series connection system. The results show that the precision of measured impedance can completely reach to the higher precision impedance analyzer's if the proper series connection resistance is choose, and that, its device in need is easy to come to practice and can be used in field environment conveniently. The transfer function method has the advantages of both the electrical bridge method and the tri-voltage method; easily it's used for the tough environment on the sea. The advice of choosing proper series connection resistance is given according to the error of analog to digital converter and measurement.

Acoustic Image Generation Based on Highlight Model

Sheng Liu, Xucheng Chang, Bing Li

College of automation, Harbin Engineering University, Harbin,

Image generation is an effective method for underwater target exploration. The three-dimensional image generation technique based on point scattering model is not suitable for the sonar system mounted on the autonomous underwater vehicle (AUV) because of the computational complexity of model. An acoustic image generation method based on highlight model is presented in this paper. Firstly, an echo data model based on the highlight's characteristics of the underwater targets is built, that including three parameters, the reflectance of amplitude, temporal delay and phasic jump. Secondly, the highlight structure of a class of elliptic spherical underwater targets is analyzed, and the computational expressions of three parameters are presented. Also the characteristic information as well as the acoustic image of highlight structure is obtained using beamforming technology. Results show that the highlight structure of underwater targets can be effectively denoted on acoustic image using this method, and the computational complexity of highlight model reduce about 90 percent compared to point scattering model. The image generating algorithm presented in this paper can be easily realized for the sonar system mounted on AUV.

Monday, April 25 14:00-15:30	
Numerical Technique & Simulation I	**Archimedes**

Study of the coupling of seismic waves in the lithospere and acoustic waves in the atmosphere based on numerical simulation

Boris G. Mikhailenko and Galina V. Reshetova

nst. of Comp. Math. and Math. Geoph.

The problem of the propagation of acoustic-gravitational waves in a heterogeneous atmosphere has long been known. The first publications concerning the impact of the gravitational field on the wave processes in the atmosphere and the ocean appeared at the middle of the last century and indicated to an important role of acoustic-gravitational waves for understanding and interpretation of numerous physical processes in the atmosphere. Starting in the 50-s, an increasing interest to studying the generation and propagation of the acoustic-gravitational waves in the real atmosphere is associated with the development of the infrasonic method of monitoring the nuclear explosions in the atmosphere. Recently, the methods of observations of the state of the atmosphere have been improved, the models of media in theoretical calculations becoming more and more complicated. The methods and algorithms for the simulation of the acoustic-gravitational waves' propagation in the atmosphere are being upgraded. Theoretical and experimental studies in the course of the recent decades have shown a tough coupling between lithospheric and atmospheric wave motions. Our approach is an analogue to the frequency-domain forward modeling, but instead of the temporal frequency we have number p - the degree of the Laguerre polynomials. We apply this numerical-analytical method to study the wave propagation in a heterogeneous Earth-Atmosphere model. The algorithm combines the Bessel integral transform along the radial coordinate and the integral Laguerre transform with respect to time with the FD solution along the vertical coordinate. Numerical results for some realistic statements are presented and discussed.

Substructure FMBEM for Hybrid Silencer Acoustic Analysis

Xiaobing Cui and Zhenlin Ji

College of Power and Energy Engineering, Harbin Engineering University

FMBEM has been applied in various fields due to its reduced computational complexity and time spending. For acoustic problem, lots of interests are focused on the sound propagation in single domain with air and the sound radiation in unlimited or half space. However, as to the analysis of sound field in practical hybrid silencers in engineering, which contains perforated tubes, thin bafflers and sound absorbing materials, the FMBEM will fail to be used. So to solve the problem, in the present paper, the substructure approach is combined with FMBEM, and the forming process of substructure FMBEM with perforated interfaces is investigated. Because the parameters of sound in absorbing materials can be equivalent to complex format, their influence to the accuracy of FMBEM must be studied. In addition, the transmission loss of dissipative silencers with perforated tubes is calculated for examples, and the substructure FMBEM is validated compared with experimental data. According to the comparison with BEM, FMBEM shows good advantage on computational efficiency.

Monday, April 25 16:00-17:30	
Numerical Technique & Simulation II	**Archimedes**

Efficient finite-difference multi-scheme approach for simulation of seismic waves in anisotropic media

Vadim Lisitsa, Vladimir Tcheverda, Dmitry Vishnevsky

Institute of Petroleum Geology and Geophysics SB RAS.

Nowadays, anisotropy of the Earth's interior plays a key role in seismic processing and interpretation as it provides the information about fractured reservoirs, finely layered structures, features of core and mantle structure etc. Thus, efficient and accurate algorithms for simulation of seismic wave propagation in such media are required. One of the most common approaches used nowadays is staggered grid finite-difference schemes (fds). Among all it is worth mentioning standard staggered

fds (Virieux-like) for isotropic media and Lebedev scheme for anisotropy. However, fds designed to deal with anisotropy (Lebedev scheme) consume at least four times more RAM and execute about six times more floating points operations than standard staggered fds (Virieux-like) used for isotropic problems. On the other hand, anisotropic formations typically take less than 10% of a model and there is no need to use Lebedev scheme everywhere but only at the anisotropic formations while standard staggered grid scheme can be applied elsewhere. This research was done to design a hybrid scheme based on the idea described above. In order to couple two different schemes we construct a conjugation conditions so that the interface do not cause significant artificial reflections. The approach is nearly as efficient as standard staggered grid scheme but catches all the features of wave propagation in anisotropic formations.This research was done together with Schlumberger Moscow Research and partially supported by RFBR, projects 10-05-00233, 11-05-00238 and 11-05-00947.

Study on single-mode excitation in time-variant shallow water environment

Peng Dayong, Gao Tianfu, Zeng Juan

Key Laboratory of Underwater Acoustic Environment, Institute of Acoustics, Chinese Academy of Sciences

Single-mode excitation is a powerful tool for studying many oceanographic processes. Meanwhile, the complex time-variant ocean environment poses a great challenge for single-mode excitation because Green's function matrix of sound field changes quickly. Previous work by the authors has built a system to excite single-mode in relative simple environment. The purpose of this paper is to study the feasibility of single-mode excitation in rapidly time-variant ocean environment. An improved algorithm is presented to adapt for time-variant environment and single-mode can be excited within very short time by this algorithm. A typical time-variant shallow water environment with internal waves is simulated, and results of the single-mode excitation in this environment are presented.

Tuesday, April 26 11:00-12:30	
Numerical Technique & Simulation III	**Archimedes**

Testing different element types for mixed FE formulation for solution of Galbrun's equation

Steffen Marburg

Universität der Bundeswehr München

Sound propagation in stationary flow can be described by Galbrun's equation. The displacement formulation contains spurious modes whereas, according to the literature, a mixed formulation using Taylor-Hood elements seems to be free of these spurious modes. This contribution investigates the appearance of spurious modes by using different types of elements. It turns out that, in particular, for Mach numbers greater than 0.5, all tested formulations contain these unwanted artefacts. Even for low Mach numbers (greater than zero), spurious modes are found but, for the formulations which were tested, the they may not have a substantial effect. However, it is not clear by now whether these spurious modes affect the solution if absorbing walls are considered. Also, time domain solutions based on a mixed FE formulation must be questioned.

The ultra weak variational formulation using evanescent basis functions

Teemu Luostari[1], Tomi Huttunen[1] and Peter Monk[2]

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[2]*Department of Mathematical Sciences, University of Delaware*

Modeling methods can be generally characterized to polynomial and non-polynomial methods by their use of basis functions. The choice of basis function has a clear impact on the accuracy, complexity and efficiency. The non-polynomial method that is studied herein is called the ultra weak variational formulation (UWVF). This method uses physical basis functions such as plane wave or Bessel basis functions. To date the UWVF has been applied to time-harmonic problems, for example, in acoustics, electromagnetism and 2D elasticity. The UWVF is a volume based method and it uses finite elements (triangles or tetrahedra). In addition, the UWVF is shown to be an upwind discontinuous Galerkin method (DGM). Thus it shares same

properties than the DGM, for instance, the basis is discontinuous and the number of basis functions can vary from element to element. The evanescent waves occurs in many wave modeling problems such as in acoustic fluid/fluid or fluid/solid interface problems. Usually, the evanescent waves are challenging to model and they may hamper the accuracy. In practice, the mesh size can be refined and/or the number of basis functions can be increased to obtain better accuracy. Another attractive choice is to use evanescent basis functions as in the discontinuous enrichment method (DEM), see.Therefore, we shall investigate the UWVF using the evanescent wave basis functions in 2D acoustic model problems. The use of evanescent basis functions is motivated from. We shall show numerical results using the UWVF with different basis functions in 2D.

Thursday, April 28 11:00-12:30	
Inversion & Seismic I	**John Locke**

Estimation of shear-wave velocity in marine sediment using Love waves

Hefeng Dong[1], Zhengliang Cao[1] and Kenneth Duffaut[2]

[1]*Department of Electronics and Telecommunications, Norwegian University of Science and Technology*
[2]*Statoil ASA*

Estimation of shear wave velocity in shallow-water marine sediments is of importance for geotechnical applications, sediment characterization, and seismic exploration studies. Interface waves can be used to estimate the shear wave velocity in the sea bottom. Love wave is much used in land seismic exploration and earthquakes for imaging the shallow targets and earthquake locations. Numerical study shows that Love wave sensitivity and inversion stability in linearized inversion is higher than that of the Rayleigh wave and the inversion of Love wave dispersion curve provides a more accurate result, because the Love wave dispersion is independent of the Poisson's ratio. Moreover, using both Love wave and Scholte wave to estimate shear wave velocities the difference between the estimated SH- and SV-wave velocities may tell transverse isotropy. In conventional underwater experiments only Scholte wave can be generated since sources are located in the water column. In order to generate Love wave a shear wave source located on the sea bottom must be used. In a testing experiment in the North Sea a shear wave source was used to generate shear waves. A 4-C ocean bottom cable (OBC) was used for recording and both Scholte wave and Love wave were recorded. In this study the Love waves were analyzed using different time-frequency analysis methods for studying dispersion behavior. The dispersion curves of the Love waves were extracted. Linearized inversion algorithm was used to invert the dispersion curves for estimating the shear wave velocity as function of depth. The inversion results were compared with the results estimated using Scholte waves (Statoil is acknowledged for providing the data and the work is supported by NFR under grant No. 186923/I30).

Finite-element adjoint for a fully range-dependent parabolic equation

Mark Asch[1,2], Jean-Pierre Hermand[1], Mohamed Berrada[1,3]

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[3]*LOCEAN-CNRS UMR 7159, Université Pierre et Marie Curie*

Adjoint-based methods have been successfully applied by us to a number of inverse problems in shallow-water geoacoustics and acoustic tomography. These inversions were all performed in a range-independent context, using a finite-difference formulation of the wide-angle parabolic equation. In this study we consider realistic, fully range-dependent cases, where the bathymetry is variable and, more importantly, the medium properties (sound speed, density, attenuation) are variable in depth and range and can exhibit discontinuities. We adopt a finiteelement formulation, recently proposed in, and adapt it to our purposes. The finite-element method permits a geometrization and discretization that are consistent with site-specific boundaries and discontinuities. Finally, a modular graph approach is applied for generating, in a semi-automatic manner, the tangent-linear model and the back propagation needed for the gradient-based minimization of a mismatch cost function. This approach overcomes the two major difficulties of the inversion: the adjoint code is easily obtained (when compared to other automatic differentiation tools) and the subsequent minimization is rapid and robust. Various test cases will be presented that show the versatility of this new approach.

Interaction of seismic waves with cavernous fractured reservoirs: numerical simulation and field study.

Vadim V. Lisitsa, Galina V. Reshetova, Vladimir A. Tcheverda

Institute of Petroleum Geology and Geophysics

A major challenge in carbonates environments is to map microheterogeneities which have a positive impact on oil and gas production. Really, in many carbonate reservoirs, matrix porosity contains the oil in place but the permeability is mainly provided by fracture corridors. Therefore the ability to precisely locate these microstructures and to characterize their properties is of a high importance. The first step in the development of any inversion/imaging procedures is an accurate numerical simulation of the wave field being scattered by fractures and caves. The numerical and computer

constraints even on the very large clusters limit the resolution at which a model can be described. One needs to upscale heterogeneities associated with fracturing on a smaller scale (0.01 – 1 meter) and to distribute them in an equivalent/effective medium. This effective medium will properly reproduce variations of travel-times and an average change of reflection coefficients but will absolutely cancel the scattered waves that are a subject of the recently developed methods for characterizing fracture distributions. The main issue with the full scale simulation of cracked (carbonate) reservoirs in a realistic environment (deepened at 2000 – 3000 meters within 3D heterogeneous background) is that one should take into account both macro- and microstructures, which means that large models should be described with extremely fine details. From a computational point of view this contradiction leads to models which cannot be handled even with huge modern clusters. Our solution to this issue is to use different mesh sizes to describe different parts of the model: a coarse grid for the background model, and a fine grid for describing the micro-scale heterogeneities. Numerical experiments are presented and discussed. Their comparison with field data is analysed. This research is done under partial support of RFBR, projects 10-05-00233, 11-05-00238 and 11-05-00947.

Thursday, April 28 16:00-17:30	
Inversion & Seismic II	**John Locke**

Cross dipole anisotropy inversion by using hybrid simulated annealing methods

Hao Chen[1], Xiuming Wang[1], Xuebing Yang[2]

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[2] *Interpretation Centre Daqing Well Logging Company*

Cross-dipole borehole acoustic logging has been used for identifying vertical or deviated fractures, evaluating formation stresses, and monitoring hydraulic fracturing effects. It also can be used for predicting horizontal transverse isotropy of a formation that apparently generates shear wave separation. This characteristic is used for identifying formation anisotropy distributions near the borehole, so that formation stress and fracture in a real formation can be evaluated. Waveform inversion method for anisotropy from cross-dipole logging data is more stable than Alford rotation method. Which optimization used is the key factor that affects propriety of the

waveform inversion method. In this work, we test two simulated annealing (SA) methods. The numerical result shows that one is very fast but the precision decrease drastically when the variable interval. The other, however, is more stable even if the parameter space is very large but may have a slow speed. In one word, both SA can give the good optimization of nonlinear functions. However, they have different proprieties. Combination of two methods to process the four component data of cross dipole logging can give a good and stable estimation of anisotropy magnitude and fast wave angle in an appropriate time. Using hybrid SA, we developed new anisotropy inversion software and had processed a larger amount of oilfield well logging data. The results show the fast angle inverted by the hybrid SA is more stable than the one gotten by very fast SA only.

Fast acoustic imaging for a 3D penetrable object immersed in a shallow water waveguide

Pan Wen-Feng[1] ,Zong Zhi-Xiong[1], You Yun-Xiang[2], Miao Guo-Ping[2]

1School of Science, Wuhan University of Technology
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The paper is concerned with the inverse problem for reconstructing a 3D penetrable object in a shallow water waveguide from the far-field data of the scattered fields with many acoustic point source incidences. An indicator sampling method is analyzed and presented for fast imaging the size, shape and location of such a penetrable object. The method has the advantages that a priori knowledge is avoided for the geometrical and material properties of the penetrable obstacle and the much complicated iterative techniques are avoided during the inversion. Numerical examples are given of successful shape reconstructions for several 3D penetrable obstacles having a variety of shapes. In particular, numerical results show that the proposed method is able to produce a good reconstruction of the size, shape and location of the penetrable target even for the case where the incident and observation points are restricted to some limited apertures.

Thursday, April 28 11:00-12:30	
Physical Acoustics I	**Archimedes**

Aeroacoustics Of Merging Flows At Duct Junction

G.C.Y. Lam[1], S.K. Tang[1], R.C.K. Leung[2]

[1]*Department of Building Services Engineering, The Hong Kong Polytechnic University*
[2]*Department of Mechanical Engineering, The Hong Kong Polytechnic University*

This paper aims to report a numerical investigation of the aeroacoustics of merging flows at a duct junction and this is done by directly solving Navier-Stokes equations with the conservation element and solution element scheme. This method has already been demonstrated as a successful tool in investigating various aeroacoustics problems. The first part of this paper presents a study of wave propagation at 90° junction, which illustrates the capability of CE/SE method in capturing the acoustics accurately. The second part shows the investigation of merging angle effect at the duct junction on the noise generation. Duct junction with merging angles of 30°, 60° and 90° were studied. It is found that the noise is originated at the wake region of the duct junction while the shear layer created between the two merging flows at the upstream corner of the junction is not important in this process.

Effect Of Acoustic Streaming In Large Blood Vessels During A High-Intensity Focused Ultrasound Thermal Ablation

Maxim A. Solovchuk[1], Tony W. H. Sheu[1,2,3], Marc Thiriet[4]

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[3]*Taida Institute of Mathematical Science (TIMS), National Taiwan University*
[4]*LJLL, University of Paris # 6*

This study investigates the significance of blood vessels in the temperature distribution during high-intensity focused ultrasound (HIFU) thermal ablation in liver tumor. Three-dimensional acoustics-thermal-fluid coupling model is presented for simulation of temperature in the treated tumor region. The model is based on the linear Westervelt equation and bioheat equations in liver and blood vessel. The

nonlinear hemodynamic equation is taken into account in the simulation domain. The effect of acoustic streaming is also considered in the current HIFU simulation study. Convective cooling in large blood vessel and acoustic streaming were shown to be able to change the temperature near blood vessel.

Vibroacoustic Response of A Underwater Single Cylinder Shell Excited By A Turbulent External Flow

Meixia Chen, Jianhui Wei

Institute of Naval Architecture and Ocean Engineering, Huazhong University of Science and Technology

This paper presents a method of calculating vibration statistics from a single simple-supported cylinder shell excited underwater by a turbulent external flow. The vibration statistics is expressed by the single cylinder shell's velocity cross-spectral density. First, different mathematic models about turbulent pressure are reviewed and the corcos model which gives the turbulent pressure cross-spectral density is used in this paper as the exciting source. Second, the coupling vibration equation of the single cylinder shell under the turbulent pressure is founded on the *Flügge* thin shell theory, *Helmholtz* wave equation and fluid-structure boundary condition. In order to solve the equation, according to random theory, this paper gives the expression of complex frequency response of the cylinder shell considering the fluid loading effects. Third, the single cylinder shell's velocity cross-spectra density is related to turbulent pressure cross-spectra density and the complex response of the cylinder shell. According to the above two steps, this paper gives the final expression of the single cylinder shell's velocity cross-spectra under the turbulent excitation. Finally, by integrating the final integration equation through numeric methods, this paper gives the cylinder shell's velocity cross-spectra density.

Thursday, April 28 14:00-15:30	
Physical Acoustics II	**Archimedes**

Highly directivity acoustic beams in two-dimensional phononic crystal by negative refraction and by resonant cavity

C.C. Sumg

National Taiwan University

We compare the way which directs acoustic source based on the resonant cavity

of two-dimensional phononic crystals with the other way which performs acoustic collimating beams by negative refraction in two-dimensional phononic crystal. In these two ways , both of each can collimate acoustical beams and the radiation far field of a point source through the phononic crystal with a small divergence angle is obtained. We also discuss the differences between the measurement of transmission ratio and divergence angle on these two ways The measured intensity field distribution in experiment further substantiates the acoustic collimating property.

The Sound Radiation of a Conical Shell under a Force Excitatin

Zhang Cong

Huazhong University of Science and Technology, School of Naval Architecture and Ocean Engineering, Wuhan

An analytical model is presented to describe the vibration of a fluid loaded truncated conical shell and the characteristic of sound radiation under a harmonic force excitation. The displacements of the conical sections are solved by a power series solution. The vibration of the conical and the far-field radiated sound pressure are calculated using Flügge theory and Helmholtz integral. Conical shells with various radius and semi-vertex are compared. And the influence of the fluid is discussed. At last, results from FEM/BEM method are compared with the analytical method to testify its accuracy.

Physical mechanism on the affecting combustion through sound

Genshan Jiang[1], Yingchao Zheng[1], Jie Pan[2] ，Jing Tian[3]

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[2] *School of Mechanical Engineering, The University of Western Australia*
[3] *Institute of Acoustics, Chinese Academy of Sciences, Beijing*

Using the mechanism of acoustic support on combustion to improve the combustion efficiency, is a new way to save energy，reduce energy waste and ease pressure, which is important to solve energy problems, protect resources and the environment, improve economic efficiency of energy enterprises and realize the sustainable development of society.We studied the tangential and radial velocity of surface material of a spherical particles in spherical coordinates, and get their connection to polar angle，sound frequency and sound pressure level. And through the analysis of combustion of fuel particles, investigate the promotion of the surface material that is moving in the radius direction and polar direction. On the spherical particle to the combustion. The relationship between this promotion sound frequency and sound pressure level is studied simultaneously. In addition, an acoustic burner with cylindrical shape is designed. Through experimental method, the combustion status of candles in the acoustic field with varietying frequency and sound pressure level is observed, the embers shape and size of Cotton balls burnout in a sound wave and no sound existed. Both theoretical and experimental aspects of acoustic support on combustion mechanism was studied.

Monday, April 25 16:00-17:30	
Room & Building Acoustics, Structural Acoustics	**Archimedes**

Sound field rendering by the holographically designed source array and resource optimization on the procedure

Jeong-Guon Ih[1], Wan-Ho Cho[2], Takeshi Toi[2]

[1] *KAIST, Daejeon, Korea*
[2] *Chuo University, Tokyo, Japan*

For the sound field rendering,it is important to obtain the source condition in the array system by inversely estimate the transfer matrix between source and field from the given target field condition.In this regard, the acoustical holography based on the inverse boundary element method would be useful in the formulation of the transfer matrix. One of the main concerning points in this inverse method is the applicability of solution among many other technical challenges. For the modeling accuracy in the forward problem, the number of boundary elementsshould be usually greater than the controllable degree of freedom per asound source. Contribution from each source element to the field is described by the inner product of the vector describing the relative complex magnitude in the source nodes and a column of the transfer matrix corresponding to that source.Another main concern is the robustness against input noise which should be essentially guaranteed. To this end, the regularization technique can be applied for the reduction of condition number of the transfer matrix.This is also effective in the optimization of the input power applied to the source system. In the source positioning among many candidate positions, the effective independence (EfI) method can be employed to find the optimal distribution of source set by removing the redundant positions. In this paper, the foregoing procedure of the realization of the desired sound fieldby the array speakers using the holography principle was described with examples of the multiple zone or wave front control.

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