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14. ABSTRACT

The 16th Symposium on Long Range Sound Propagation was conducted at the University of Mississippi on 20-21 September 2016. Dr. Roger Waxler, the Principal Investigator for this project, served a moderator for the Symposium. Attendees included academic, government, industry, and international participants.

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Report Title

Final Report: Support for the 16th International Symposia on Long Range Sound Propagation(LRSP)

ABSTRACT

The 16th Symposium on Long Range Sound Propagation was conducted at the University of Mississippi on 20-21 September 2016. Dr. Roger Waxler, the Principal Investigator for this project, served a moderator for the Symposium. Attendees included academic, government, industry, and international participants.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 17.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received Paper

TOTAL:

Number of Manuscripts:

Books

Received Book

TOTAL:

Received Book Chapter

TOTAL:

Patents Submitted

Patents Awarded

Awards

Graduate Students

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Roger Waxler	0.00	
FTE Equivalent:	**0.00**	
Total Number:	**1**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period:	0.00
The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:......	0.00
The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:......	0.00
Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):......	0.00
Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:......	0.00
The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense	0.00
The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:......	0.00

Names of Personnel receiving masters degrees

NAME

Total Number:

Names of personnel receiving PHDs

NAME

Total Number:

Names of other research staff

NAME	PERCENT_SUPPORTED
Tiffany Wilson	0.00
FTE Equivalent:	**0.00**
Total Number:	**1**

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

The 16th Symposium on Long Range Sound Propagation was conducted at the University of Mississippi on 20-21 September 2016. Dr. Roger Waxler, the Principal Investigator for this project, served a moderator for the Symposium. See Attachment for listing of attendees and presentation abstracts.

Technology Transfer

This effort supported a conference involving academic, government, industry, and international participants. Conference presentations constitute a form of technology transfer.

SUPPORT FOR THE 16TH INTERNATIONAL SYMPOSIUM ON LONG RANGE SOUND PROPAGATION (LRSP)

W911NF-16-1-0080

FINAL REPORT

5 JANUARY 2017

SUBMITTED TO:

ARMY RESEARCH OFFICE

BY:

ROGER WAXLER, PH.D.
NATIONAL CENTER FOR PHYSICAL ACOUSTICS (NCPA)
UNIVERSITY OF MISSISSIPPI
UNIVERSITY, MISSISSIPPI 38677

PERIOD: 1 APRIL 2016 – 31 MARCH 2017

Final Report

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1. Meeting Information

The 16th Symposium on Long Range Sound Propagation was conducted at the University of Mississippi on 20-21 September 2016. Dr. Roger Waxler, the Principal Investigator for this project, served a moderator for the Symposium.

2. Attendees

Last Name	First Name	Institution/Organization	Type
Abbott	JohnPaul	University of Mississippi	Academic
Alberts	William	US Army Research Lab	Government
Assink	Jelle	Royal Netherlands Meteorological Institute	Foreign
Attenborough	Keith	The Open University	Foreign
Barlett	Marti	University of Texas, Applied Research Lab	Academic
Blanc-Benon	Philippe	Ecole Centrale de Lyon	Foreign
Blom	Philip	Los Alamos National Laboratory	Government
Chunchuzov	Igor	Obukhov Institute of Atmospheric Physics	Foreign
Collier	Sandra	US Army Research Lab	Government
Cosnefroy	Matthias	French-German Research Institute of Saint-Louis (ISL)	Academic
Costley	Richard	US Army ERDC - GSL	Government
Dragna	Didier	Ecole Centrale de Lyon	Academic
Frazier	William	Hyperion Technology Group Inc.	Small Business
Freimark	Eric	University of Mississippi	Academic
Gilbert	Kenneth	University of Mississippi	Academic
Gladden	Joseph	University of Mississippi	Academic
Gray	Tiffany	University of Mississippi	Academic
Hart	Carl	US Army ERDC-CRREL	Government
Lyons	Gregory	US Army ERDC - CERL	Government
Murray	Nathan	University of Mississippi	Academic
Noble	John	US Army Research Lab	Government
Ostashev	Vladimir	US Army ERDC	Government
Prather	Wayne	University of Mississippi	Academic
Raspet	Richard	University of Mississippi	Academic
Sabatini	Roberto	Ecole Centrale de Lyon	Foreign
Swearingen	Michelle	US Army ERDC - CERL	Government
Talmadge	Carrick	University of Mississippi	Academic
Velea	Doru	Leidos, Inc.	Large Business
Waxler	Roger	University of Mississippi	Academic
Webster	Jeremy	Collie Home Health	Small Business
Williams	Chad	Hyperion Technology Group Inc.	Small Business
Woolworth	David	Oxford Acoustics	Small Business
Zhang	Likun	University of Mississippi	Academic

3. Agenda

16th Long Range Sound Propagation (LRSP) Symposium
The University of Mississippi

20 September 2016

0830 Coffee and pastries

0900 Welcome
- Roger Waxler

0910 Sound propagation through forests
- Keith Attenborough, Imran Bashir, and Shahram Taherzadeh

0930 Acoustic propagation above a spatially-varying impedance plane
- Didier Dragna and Philippe Blanc-Benon

0950 A wide-angle non-coordinate-transforming method for incorporating topography within the PE
- Michelle E. Swearingen, Michael J. White and Mihan McKenna

1010 Break

1025 Machine-learning models for predicting long-range sound propagation
- Carl R. Hart, D. Keith Wilson, Chris L. Pettit and Edward T. Nykaza

1045 Green's function retrieval for outdoor sound propagation
- Sandra L. Collier, David A. Ligon, Jericho E. Cain, John M. Noble, W. C. Kirkpatrick Alberts III, Leng K. Sim, and Deryck James

1105 Development and use of propagation-based, stochastic models for infrasound - association, localization, and characterization
- Philip Blom, Omar Marcillo, Garrett Euler, Rod Whitaker

1125 Break

1140 On the Infrasound Detected From the 2013 and 2016 DPRK's Underground Nuclear Tests
- Jelle Assink, Gil Averbuch, Pieter Smets and Läslo Evers

1200 Impulsive events recorded via an aerostat-mounted infrasonic sensor
- W. C. Kirkpatrick Alberts III, Christian Reiff, Leng Sim, Roger Waxler

1220 Preliminary Results of a Propagation Study Using a Series of Rocket Launches
- John M. Noble, W. C. Kirkpatrick Alberts III, and Stephen M. Tenney

1240 Lunch

1430 The interaction between infrasonic waves and internal gravity wave perturbations in the atmosphere

- Igor Chunchuzov, Sergey Kulichkov, Oleg Popov, Vitaly Perepelkin and Aram Vardanyan

1450 Space-time correlations in the near-ground atmosphere and their influence on acoustic signals

- V. E. Ostashev, D. K. Wilson, S. L. Collier, and S. Cheinet

1530 Break

1545 Properties and Limitations of a Monin-Obukhov-Similar Model of Surface Wind Noise

- Gregory W. Lyons

1605 Cut-off wavenumber criterion for wind noise contributions for wind noise reduction enclosures

- JohnPaul R. Abbott, Richard Raspet, John Noble, W. C. Kirkpatrick Alberts III, and Sandra Collier

1625 Portable Pneumatic Infrasound Source

- Martin Bartlett, Todd Hay, Charles Slack III, Thomas G. Muir, Mihan McKenna, R. Daniel Costley, and Christopher Simpson

1625 Adjourn

1830 Dinner at Snack Bar

21 September 2016

0830 Coffee and pastries

0900 Direct numerical simulation of infrasound propagation in the Earth's atmosphere

- Roberto Sabatini, Olivier Marsden, Christophe Bailly and Olaf Gainville

0920 Experimental analysis and numerical simulations of the irregular reflection of weak shock waves on a plane surface

- Philippe Blanc-Benon, Didier Dragna, Sébastien Ollivier, Cyril Desjouy and Maria Karzova

0945 Multi-Objective Source Scaling Experiment

- R. Daniel Costley, Luis A. De Jesus Diaz, Sarah L. McComas, Christopher P. Simpson, James W. Johnson, Mihan H. McKenna, Chris Hayward

1005 Discussion

1100 Adjourn

4. Abstracts of Presentations

Presentation slides may be accessed at http://ncpa.olemiss.edu/long-range-sound-propagation-lrsp/.

a. Sound propagation through forests

Keith Attenborough, Imran Bashir, and Shahram Taherzadeh

Engineering and Innovation, The Open University

Propagation of sound through forests and tree belts is influenced by 'soft' ground effect due to decaying leaf litter, reverberant scattering out of the direct source-receiver path by trunks and branches (including edge effects), loss of coherence due to the interaction between scattering and ground effect, visco-thermal scattering by foliage and the vertical sound speed profile resulting from modifications of local meteorology. Numerical schemes have been used to predict the 3D results of many of these effects. Semi-empirical schemes such as that in NORD 2000 have been proposed. The accuracy of a model for propagation through forests and tree belts at relatively short range that simply adds ground effect (modified by scattering treated as enhance turbulence) and foliage attenuation is demonstrated through comparisons with data obtained using loudspeaker sources. The effects of periodicity in tree spacing are considered also. As a result of the relatively sparse distributions of scatterers in realistic tree planting schemes, the main band gap due to periodicity is missing. The pass band and the next order band gap may be observed but can be reduced and enhanced respectively if the tree locations are perturbed from periodic spacing.

b. Acoustic propagation above a spatially-varying impedance plane

Didier Dragna and Philippe Blanc-Benon

Laboratoire de Mécanique des Fluides et d'Acoustique , Ecole Centrale de Lyon, Lyon, France

In the current prediction schemes for outdoor sound propagation, ground is usually assumed to be homogeneous or piecewise homogeneous. Recent measurements performed by Guillaume et al. [*App. Acous.*, 2015] have however shown that acoustic properties of natural grounds have large spatial variations. In this talk, the influence of the spatial variations of the ground admittance on the acoustic field is investigated. First, an analytical solution for the average pressure is obtained using the diagram technique. In particular, it is shown that randomness tends to decrease the amplitude of the reflected wave. Then, numerical simulations using a solver of the linearized Euler equations are performed to compute the average pressure and intensity. The average pressure determined from 200 realizations of the admittance spatial profile is in a good agreement with the analytical solution. The average intensity is found to be close to the intensity obtained for a homogeneous ground of average admittance. Finally, uncertainties due to the ground randomness are studied.

c. A wide-angle non-coordinate-transforming method for incorporating topography within the PE

Michelle E. Swearingen, Michael J. White, Mihan H. McKenna

U. S. Army Engineer Research. & Development Center

Low-frequency (< 50 Hz) acoustic propagation for long ranges (10 -100 km) is of significant military interest, particularly for the purposes of persistent surveillance of denied areas and infrastructure/activity sensing. A deep understanding of the myriad of ways that the natural environment influences the signal is critical for accurate interpretation of received signals at monitoring stations. Taking cues from the underwater acoustics community (ex. Huang, Lee and McDaniel), a flexible, wide-angle, finite-element PE model has been developed. This model handles discontinuities as well as gradual variations in density and wavenumber, allowing terrain/topography to be represented as range-dependent density and wavenumber profiles. Using this method, the coupled influences of topography, meteorology, and forests can be explored. Traditional coordinate-transforming methods for propagation over topography require interpolations and/or extrapolations near the top of the computational boundary when transformed back into the original coordinate system, introducing potentially significant errors. These coordinate-transforming methods, such as the Polar PE (Parakkal *et al.*) and the rotated PE (Collins), work well for shorter distances, where the potential for overlap or required interpolations are smaller, and bounded systems, such as propagation in certain ocean conditions, but begin to produce questionable results as the propagation distances, and influences from the upper domain, increase. While not as computationally efficient as these methods, the method presented here does not require a coordinate transformation, eliminating this potential problem. An overview of the mathematical development, comparisons to benchmark cases, and a discussion of the pros and cons of this method are presented.

d. Machine-learning models for predicting long-range sound propagation

Carl R. Hart[1], D. Keith Wilson[1], Chris L. Pettit[2], and Edward T. Nykaza[1]

[1] U. S. Army Engineer Research and Development Center
[2] U. S. Naval Academy

Numerical methods for accurately predicting weather and terrain impacts on long-range sound propagation are computationally intensive, especially when random scattering by atmospheric turbulence is included. A complementary approach is to use machine-learning models for the purpose of learning the nonlinear relationships between the outdoor environment and sound propagation. Our strategy for utilizing machine-learning models is partly based on Monte Carlo sampling parameters of the outdoor environment, propagation geometry, and source frequency. Each multidimensional sample was input into a narrow-angle Crank-Nicholson parabolic equation (CNPE) model to predict the excess attenuation in a modeled turbulent atmosphere. The predictions of the CNPE model, 5 000 in total, together with the sampled input and parameters derived from the input, form a synthetic dataset for the machine-learning models in this study. Three types of supervised learning models are explored: random forest

regression, ensemble neural networks, and cluster-weighted models. Relative to the CNPE output the machine-learning models have a root-mean-square error of five to six dB. These machine-learning models are seven to eight dB better in prediction accuracy relative to an engineering noise model.

e. Green's function retrieval for outdoor sound propagation

Sandra L. Collier, David A. Ligon, Jericho E. Cain, John M. Noble, W. C. Kirkpatrick Alberts III, Leng K. Sim, and Deryck James

U. S. Army Research Laboratory

There is extensive classical utilization of the Green's function for wave propagation in many different media. By extracting the Green's function, or medium impulse response, one may obtain information about the medium channel. This information may be used to overcome the medium effects, as is done in time-reversed acoustic localization or acoustic communications; alternatively, it may be used to deduce information about the medium using inversion theories. The use of time reversal methods has been established for interferometry, phase conjugation, and time reverse mirrors and cavities. Inherent in the assumptions used in many time-reverse methods is that the medium is stationary. For moving media, a flow-reversal theorem may be used in conjunction with time reversal. The objectives of this multi-year research project are to determine the feasibility of using time reversal in conjunction with flow reversal and/or other similar methods to extract a Green's function for outdoor sound propagation utilizing sources in the audible frequency ranges.

f. Development and use of propagation-based, stochastic models for infrasound - association, localization, and characterization

Philip Blom, Omar Marcillo, Garrett Euler, Rod Whitaker

Los Alamos National Laboratory

Propagation-based, stochastic methods for predicting infrasound propagation effects were recently introduced in the context of event localization and have been shown to improve estimates of source location by a significant amount. An overview of stochastic propagation models for infrasound will be given including a discussion of areas of applicability and limitations when compared with alternate methods of accounting for sub-grid scale variability in the atmosphere model. Specifically, applications to network level analysis for association and localization using stochastic path geometry models will be summarized with recent results and source characterization methods utilizing stochastic models for transmission loss will be detailed to demonstrate applications to estimating yield of explosive sources at regional distances.

g. On the infrasound detected from The 2013 and 2016 DPRK's underground nuclear tests

Jelle D Assink[1], Gil Averbuch[2], Pieter Steven Maarten Smets[1,2], and Läslo G Evers[1,2]

[1]Royal Netherlands Meteorological Institute, R&D Seismology and Acoustics, De Bilt, Netherlands,

[2]Delft University of Technology, Geosciences, Delft, Netherlands

The underground nuclear tests by the Democratic People's Republic of Korea (DPRK) generated atmospheric infrasound both in 2013 and 2016. Clear detections were made in the Russian Federation (I45RU) and Japan (I30JP) in 2013 at stations from the International Monitoring System. Both tropospheric and stratospheric refractions arrived at the stations. In 2016, only a weak return was potentially observed at I45RU. Data analysis and propagation modeling show that the noise level at the stations and the stratospheric circumpolar vortex were different in 2016 compared to 2013. A seismo-acoustic analysis of the 2013 and 2016 DPRK tests, in combination with atmospheric propagation modeling, motivates the hypothesis that the 2016 test was at a greater depth than the 2013 test. In such a case, less seismic energy would couple through the lithosphere-atmosphere interface, leading to less observable infrasound. A preliminary analysis suggests that the 2016 test occurred at least 1.5 times deeper. Since explosion depth is difficult to estimate from seismic data alone, this motivates a synergy between seismics and infrasonics.

h. Impulsive events recorded via an aerostat-mounted infrasonic sensor

W. C. Kirkpatrick Alberts III[1], Christian Reiff[1], Leng Sim[1], Roger Waxler[2]

[1] U.S. Army Research Laboratory
[2] University of Mississippi

As part of a large series of low-frequency sound propagation experiments, the US Army Research Laboratory collected signatures of explosive events of varying charge weight using both ground- and aerostat-based infrasound sensors. Given that wind-induced noise increases with higher wind speeds and with decreasing frequency, it might seem counterintuitive to place a low-frequency sensor aboard an aerostat at heights where the wind speeds can be significantly greater than those on the ground. Further, because of their limited payload, aerostats cannot carry the substantial mechanical wind-noise reduction that is often added to infrasound sensors, e.g. porous hose or spherical caps. Despite such limitations, the wind noise aboard the aerostat was not severe enough to impact the ability to measure explosive events at ranges of approximately 1-5 km during the experiment. Power spectra of ground- and aerostat-based wind noise exhibit a 6-8 dB/Hz difference between 1 and 10 Hz when wind speeds aloft are roughly double those on the ground. Both ground- and aerostat-based wind noise and successful measurements of explosion signatures will be discussed.

i. Preliminary results of a propagation study using a series of rocket launches

John M. Noble, W.C. Kirkpatrick Alberts, II, and Stephen M. Tenney

U.S. Army Research Laboratory

NASA’s Wallops Flight Facility launched medium lift rockets for experimental and space station resupply missions during 2013 and 2014. These launches have been a great opportunity to use the rocket-generated infrasound as a repeatable source to study long range propagation. Data from the US Array was used to compare the received amplitude from the rocket launches to a propagation model prediction using realistic atmospheric profiles for ranges out to 500 km from the launch point. The US Array was a distribution of infrasound and seismic sensors which range in a north/south strip across the US and would periodically relocate further east over time. For some of the launches during this period, two, 20-meter arrays were deployed along different directions from the launch site. The preliminary results of this comparison will show how well the modeling was able to track the behavior in the measurements.

j. The interaction between infrasonic waves and internal gravity wave perturbations in the atmosphere

Igor Chunchuzov[1], Sergey Kulichkov[1], Oleg Popov[1], Vitaly Perepelkin[1] and Aram Vardanyan[2]

[1]Obukhov Institute of Atmospheric Physics, Moscow, Russia
[2]Barva Innovation Center, Talin, Armenia

Internal gravity waves (IGWs) play an important role in establishing of the atmospheric circulation that in turn affects a long-range infrasound propagation in the atmosphere. The IGWs also are responsible for the shaping of the vertical fine-scale structure of the wind velocity and temperature both in the lower and upper atmosphere. The statistical characteristics of the fluctuations in the parameters of infrasonic signals (such as variances and temporal spectra of the fluctuations in travel time and angle of arrival, amplitude and time duration) caused by gravity wave perturbations are studied based on the model of 3-D spectrum of the perturbations. The results of theory and numerical modeling of infrasound scattering from gravity wave perturbations are presented. The vertical profiles of the wind velocity fluctuations in the stratosphere and lower thermosphere up to heights of 130 km are retrieved from the scattered signals generated by volcanoes and surface explosions. The results of acoustic probing of the stably stratified atmospheric boundary layer using acoustic detonation source are discussed.

k. Space-time correlations in the near-ground atmosphere and their influence on acoustic signals

V. E. Ostashev[1], D. K. Wilson[1], S. L. Collier[2], and S. Cheinet[3].

U. S. Army Engineer Research and Development Center

U. S. Army Research Laboratory

French-German Research Institute of St. Louis, France

Studies of sound propagation through a turbulent atmosphere are important in several applications such as source detection, ranging, and recognition, advancements in acoustic sounding of the atmosphere with SODARs and tomography techniques, and development of new remote sensing techniques. Most existing treatments of sound propagation through a turbulent atmosphere describe narrowband (harmonic) signals in relation to the spatial structure of the turbulence (such as correlation functions and their spectra). In this paper, propagation of broadband acoustic signals through spatial-temporal fluctuations in temperature and wind velocity is considered. These spatial-temporal fluctuations are modeled by locally

frozen turbulence with the von Karman spectra and height-dependent variances and outer length scales. A general theory is developed for the spatial-temporal correlation function of a broadband acoustic signal propagating above an impedance ground in a turbulent, refracting atmosphere. The theory is used to analyze various statistical characteristics of acoustic signals such as temporal coherence, cross-frequency coherence, coherence bandwidth, and pulse wander and broadening. The results obtained are compared with available experimental data.

l. Properties and limitations of a Monin-Obukhov-similar model of surface wind noise

Gregory W. Lyons

U. S. Army Engineer Research and Development Center

Low-frequency wind noise produced by turbulence in the atmospheric boundary layer is a persistent issue in measurement and detection of sound outdoors. At the ground surface, previous work has found the dominant source of intrinsic wind noise to be the shear-turbulence mechanism. In modeling the wind noise spectrum, the mean shear rate of the near-surface wind is often represented by Monin-Obukhov similarity, a theory that loses validity with increasing elevation. Consequently, wind noise is not uniformly Monin-Obukhov-similar at all horizontal wavenumbers, due to the form of the surface pressure solution in terms of the flow field. Two turbulence models, mirror flow and rapid-distortion, are introduced to model the atmospheric turbulence. Model spectra of the wind noise are computed to illustrate that stability-dependent shear rate principally affects the low-wavenumbers. By estimating the Monin-Obukhov and turbulence parameters from velocity field measurements, model spectra predictions are compared with experimental wind noise. The expected modifications and limitations due to a similarity formulation of the mean wind are generally found to agree with the observations.

m. Cut-off wavenumber criterion for wind noise contributions for wind noise reduction enclosures

JohnPaul R. Abbott[1], Richard Raspet[1], John Noble[2], W. C. Kirkpatrick Alberts III[2], and Sandra Collier[2]

[1] University of Mississippi
[2] US Army Research Laboratory

A physical cut off wavenumber criterion is proposed and tested for contributions for the wind noise generated from the undisturbed and surface regions for a wind noise reduction device, such as wind fence enclosures and semi-porous fabric domes. The calculations of the measured wind noise inside an enclosure assume that contributions from the undisturbed region and the surface region dominate and are physically restricted to turbulence wavelengths that are larger than the enclosure and the same size or smaller than the enclosure, respectively. The cut-off frequency criterion defines the wavelength where the dominant source of wind noise transitions from interactions in the undisturbed region to the surface region. The transition

point is determined by considering when a volume enclosed by a wavelength, V_λ, is equal to 100 times the volume enclosed by the reduction device, V_E. Wind noise calculations following this criterion are presented for a set of semi-porous fabric domes that are 4 m wide and 2.1 m tall, and three cylindrical wind fences that are 5 m wide and 2.9 m tall, 5 m wide and 5.8 m tall, and 10 m wide and 2.9 m tall.

n. Portable Pneumatic Infrasound Source

Martin Bartlett[1], Todd Hay[1], Charles Slack III[1], Thomas G. Muir[1], Mihan McKenna[2], R. Daniel Costley[2], and Christopher Simpson[2]

[1] Applied Research Laboratory, University of Texas at Austin
[2] U. S. Army Engineer Research and Development Center

In this paper, we describe a prototype portable pneumatic infrasound source based on the release of a modulated stream of compressed gas into the atmosphere. The source produces a narrowband fundamental and harmonics from 0.5 to 20 Hz which can be used for a variety of infrasound applications including sensor calibrations, studies of wind suppression methods, and infrasound array operability. Characteristics of the prototype source and a simple aero-acoustic model for sound generation will be described. Examples of infrasound measurements made using the source will also be presented.

o. A numerical study of infrasound scattering from inhomogeneities and diffraction at caustics

Roberto Sabatini,[1,2] Olivier Marsden,[1,3] Christophe Bailly[1] & Olaf Gainville[2]

[1]Centre Acoustique, ´Ecole Centrale de Lyon, Lyon, France
[2]CEA, DAM, DIF, F-91297 Arpajon, France
[3]European Centre for Medium-Range Weather Forecasts, Reading, UK

Direct numerical simulations of the compressible unsteady Navier-Stokes equations are performed to investigate the 3-D acoustic field generated by a high-amplitude infrasonic source placed at ground level in a realistic atmosphere. High-order finite differences and a Runge-Kutta time integration scheme originally developed for aeroacoustic applications are employed. The atmosphere is parametrized as a stationary and vertically stratified medium, constructed by specifying a speed of sound and a mean wind profiles which mimic the main trends observed during the Misty-Picture experiment. The present talk focuses on two specific phenomena. The scattering from stratospheric inhomogeneities is first considered. The spectrum of the scattered signal recorded at ground level and its dependence on the spectrum of the inhomogeneities is in particular discussed. The diffraction at a thermospheric caustic is then analyzed and the influence of non-linearities on the penetration of the acoustic field in the acoustic shadow zone is finally examined.

p. Experimental analysis and numerical simulations of the irregular reflection of weak shock waves on a plane surface

Philippe Blanc-Benon, Didier Dragna, Sébastien Ollivier, Cyril Desjouy and Maria Karzova

Laboratoire de Mécanique des Fluides et d'Acoustique , Ecole Centrale de Lyon, Lyon, France

Reflection of weak shock waves can depart from the Snell-Descartes regular regime, depending on the angle of incidence and on the overpressure. Recently, propagation of spark-generated N-waves above a smooth plane have been investigated by Desjouy et al. [Phys. Fluids, 2016]. An irregular reflection regime, with the presence of a Mach stem, has been observed on Schlieren visualizations for a grazing incidence. These experimental results have been successfully compared to numerical results obtained by solving the full Navier-Stokes equations. This talk presents preliminary numerical results for the reflection of weak shock waves on rough surfaces. The influence of roughness on the reflection pattern is first investigated. For moderate roughness, an irregular reflection regime is observed but the Mach stem height is reduced with reference to a smooth surface. As the roughness increases, the Mach stem is reduced and for strong roughness, it is not observed anymore. The waveforms of the acoustic pressure are finally studied, showing that the roughness leads to a decrease of the maximal overpressure and to an increase of the signal duration and the rise time.

q. Multi-objective source scaling experiment

R. Daniel Costley[1], Luis A. De Jesus Diaz[1], Sarah L. McComas[1], Christopher P. Simpson[1], James Johnson[1], Mihan H. McKenna[1], and Chris Hayward[2]

[1]Geothechnical and Structures Laboratory, U.S. Army Engineer Research and Development Center
[2]Department of Geophysics, Southern Methodist University

An experiment was performed near the U.S. Army Engineer Research and Development Center (ERDC) site near Vicksburg MS on May 2014. Explosive charges were detonated and the shock and acoustic waves were detected with pressure and infrasound sensors stationed at various distances from the source, from 3 m to 15 km. One objective of the experiment was to investigate the evolution of the shock wave produced by the explosion to the acoustic wavefront detected several kilometers from the detonation site. Another objective was to compare the effectiveness of different wind filter strategies. Toward this end, several sensors were deployed near each other, approximately 8 km from the site of the explosion. These sensors used different types of wind filters, including different length of porous hoses, a bag of rocks, a foam pillow, and no filter. Signal-to-noise estimates made from signals recorded with these different sensors will be used to evaluate the effectiveness of the different strategies. Preliminary results from this experiment will be presented. In addition, the different types of local terrain were documented and the local meteorological conditions were recorded. The effects of theses local conditions on long-range propagation will be discussed.

5. Statistical Data

a. Graduate Students - One.

b. Postdoctoral Research Associates – Two.

Note: the graduate student and postdoctoral research associates were participants in the conference. No salaries or stipends were paid from these funds.

c. Publications - None.

d. Conference Presentations – 17.

THE UNIVERSITY of MISSISSIPPI

January 5, 2017

U.S. Army Contracting Command-Aberdeen Proving Ground
Research Triangle Park Division
ATTN: CCAP-SCR-RT (CLOSEOUTS)
P. O. Box 12211
Research Triangle Park, NC 27708-2211

I certify that funds provided by the Army Research Office under Grant W911NF-16-1-0080 were expended in accordance with the provisions of the grant and that required conference proceedings have been delivered to the Army Research Office.

Sincerely,

Renita L. Gray
Manager of Sponsored Programs Accounting