SAND2013-5159P

Designing a Continuous Infrasound Resonator Source for Fine Scale Sampling of Atmospheric Properties [LDRD 14-0871]

PI: Kyle R. Jones [5736]

Team:

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National Center for Physical Acoustics, Ole Miss.: Roger Waxler

Introduction

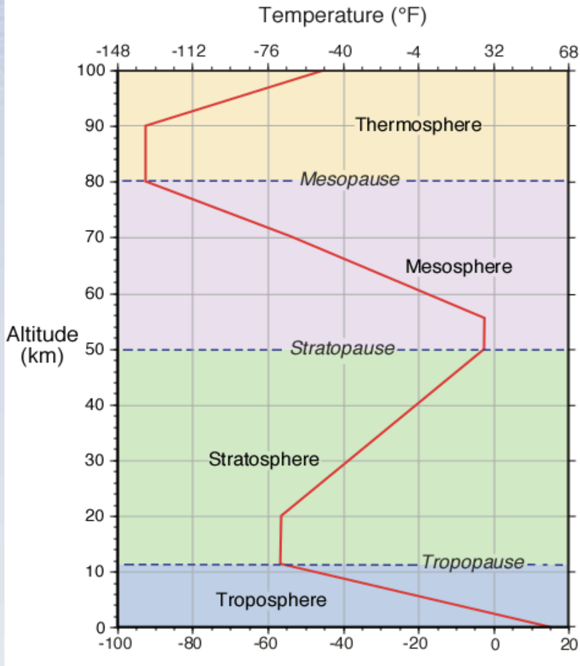
- **Goal: Develop a unique, continuous and controlled infrasound resonator source capable of directly measuring climatological properties of the upper atmosphere**
  - To understand the seasonality and variability of the upper atmosphere
  - To directly measure winds and temperature of the upper atmosphere
  - Improve atmospheric propagation models

- **Implications: 3 areas of interest**
  - Climate Science – direct measurement of upper atmospheric properties relevant to climate/change study
  - Nuclear Detonation Monitoring – accurate atmospheric propagation modeling
  - Natural Hazards – advanced understanding of atmospheric hazard modeling
  - Improved blast noise propagation predictions

- **Why Sandia?**
  - Several Reasons
    - Sandia has access to not only 1, but 2 shock tubes
    - Already work closely with DTRA on many projects
    - Sandia has the space and resources to accomplish both the fabrication as well as the numerical modeling and data collection.
    - **If funded, Sandia will host the worlds only, Large Infrasound Resonator**

Background

- **Infrasound is the study of low frequency sound waves in the atmosphere that can be used to study:**
  - Nuclear conventional detonations
  - Severe Weather [Tornados, Hurricanes]
  - Volcanic Eruptions
  - Effectively measure upper atmospheric temperature, tidal winds and stratospheric winds
- **Infrasound waves travel long distances [hundreds to thousands of km]**
  - Using sound channels in the upper atmosphere
    - Stratopause [50-60 km]
    - Thermosphere [100-120 km]
- **Traditional atmospheric profilers do not directly measure climatological properties of the upper atmosphere**
- **Currently volcanoes and explosions are the only sources that can monitor this region but…**
    - Volcanoes are remote and unpredictable and
    - Explosions are costly and dangerous



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The Plan

- **Modify a DTRA owned shock tube located on the Southeast corner or KAFB to produce a continuous, controlled infrasound source [~ 0.5 Hz] that can be detected up to 200 km away**

- **In conjunction with the fabrication and retro-fit of the tube, we will develop algorithms capable of**
  - Detecting the infrasonic resonator source
  - Extracting climatological data such as wind speed, temperature and tidal winds in the upper atmosphere

- **We will also utilize CSRI and CRADA developed technologies to modify existing codes related to**
  - Source optimization
  - Signal detection and extraction
  - Waveform inversion

DTRA Shock Tube [Location]

DTRA Shock Tube [Infrasound Resonator]

DTRA Owned
820' (0.25 km) Long
20' (6.1 m) Diameter

LDRD
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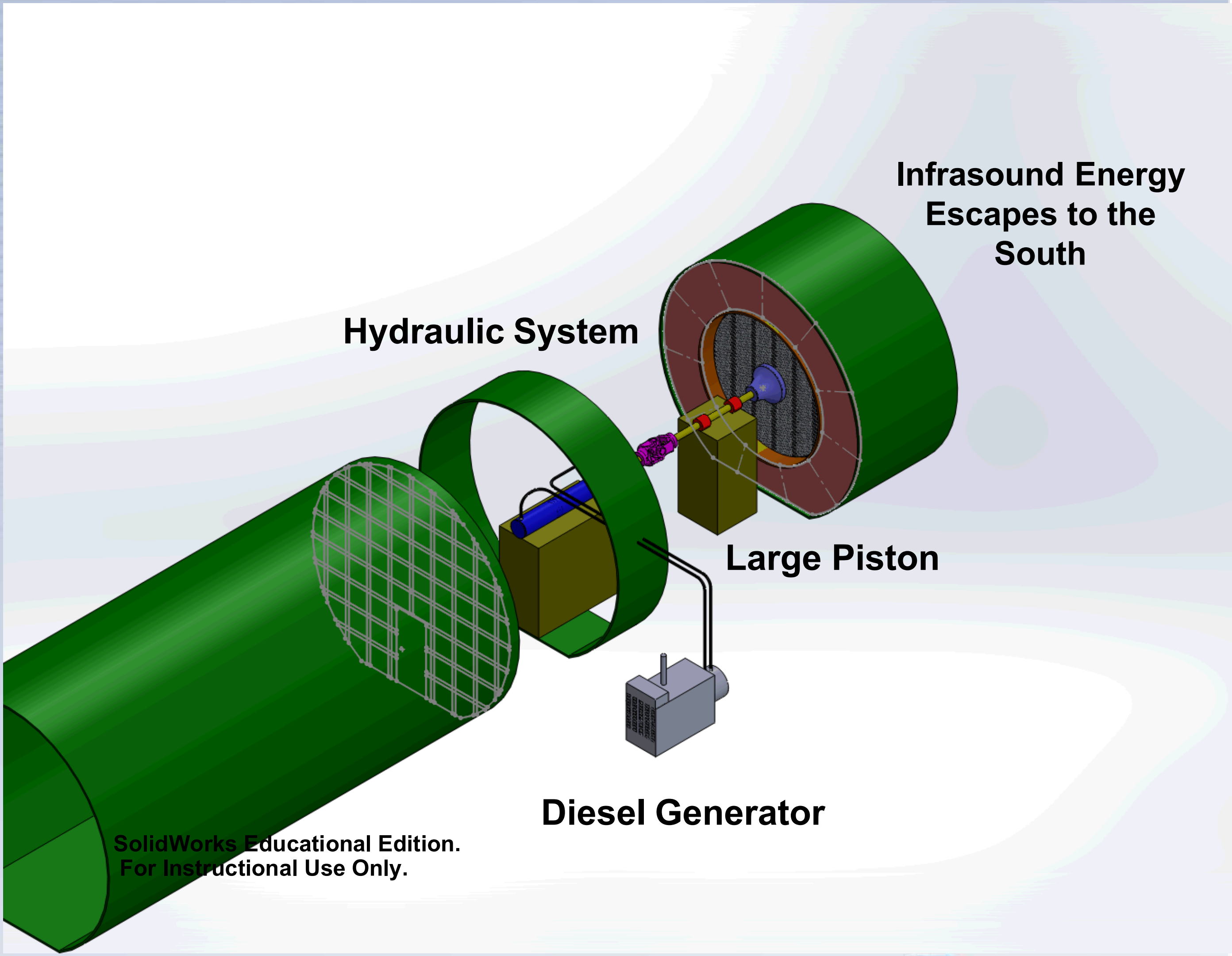
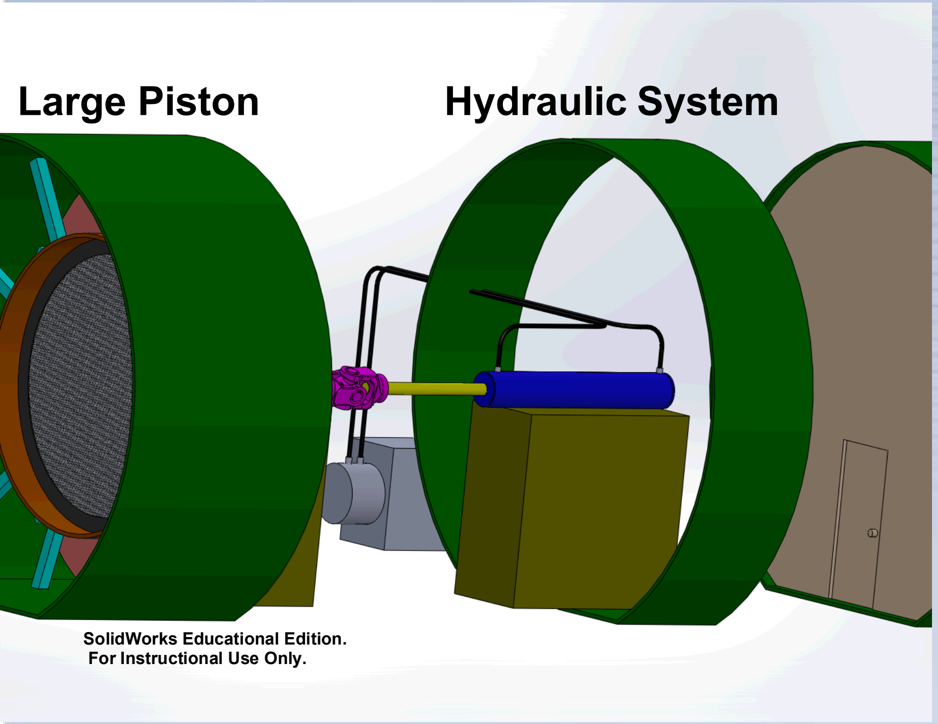
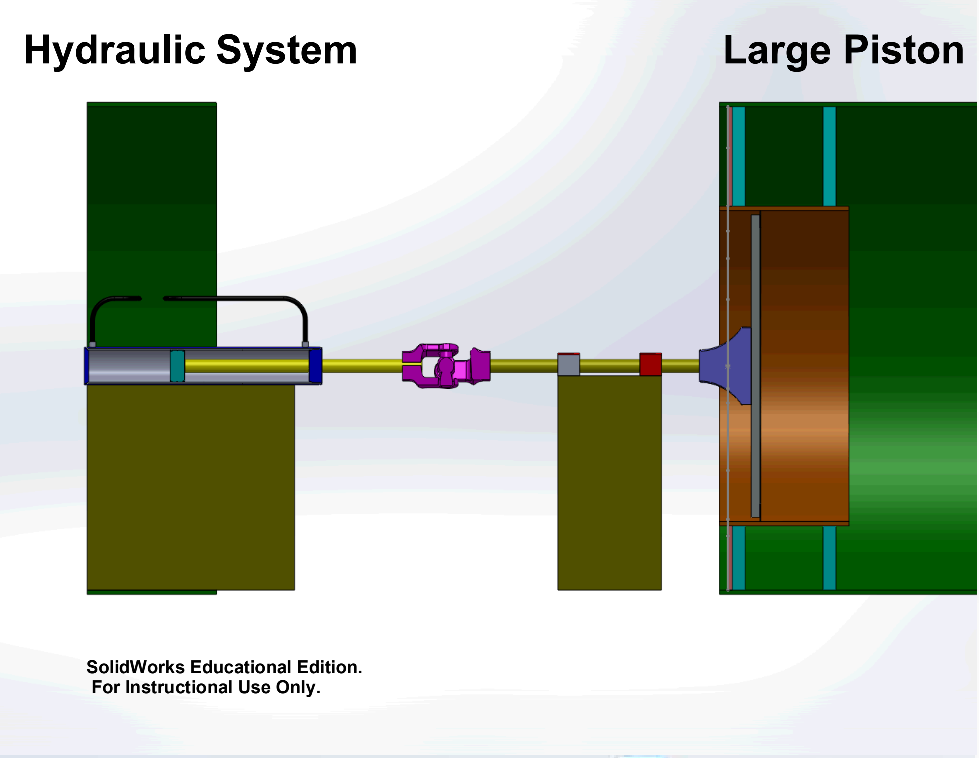
Resonator Fabrication

- Diesel driven hydraulic system
- Large piston supported by struts
- Sealed with heavy rubber
- Lubricated with graphite

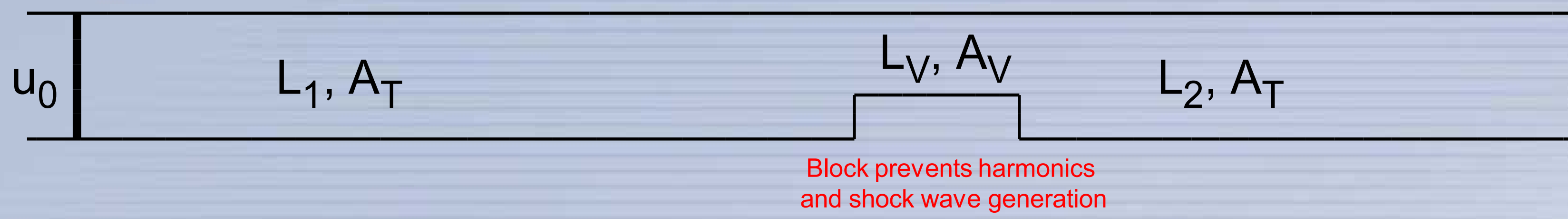


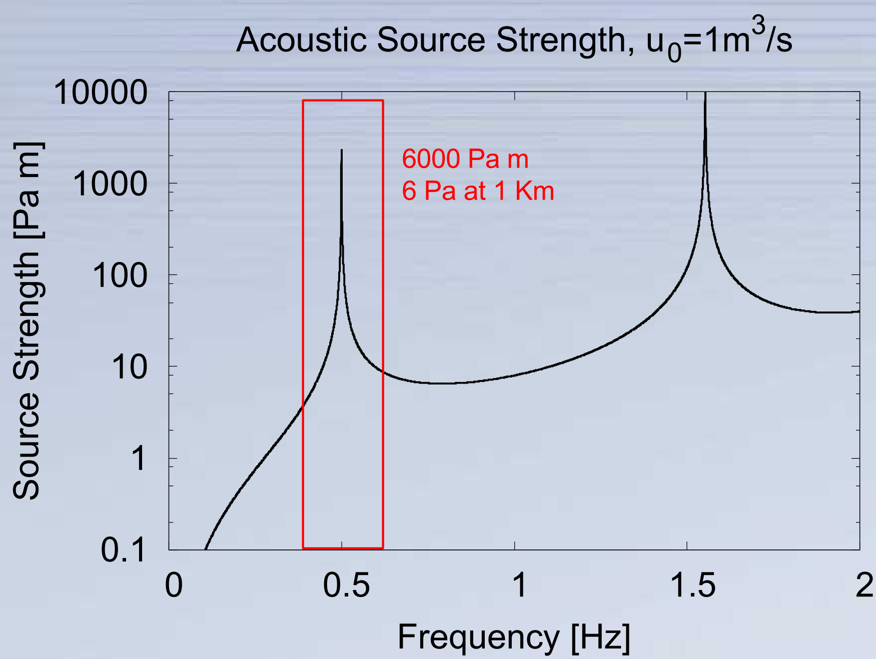
Resonator Fabrication

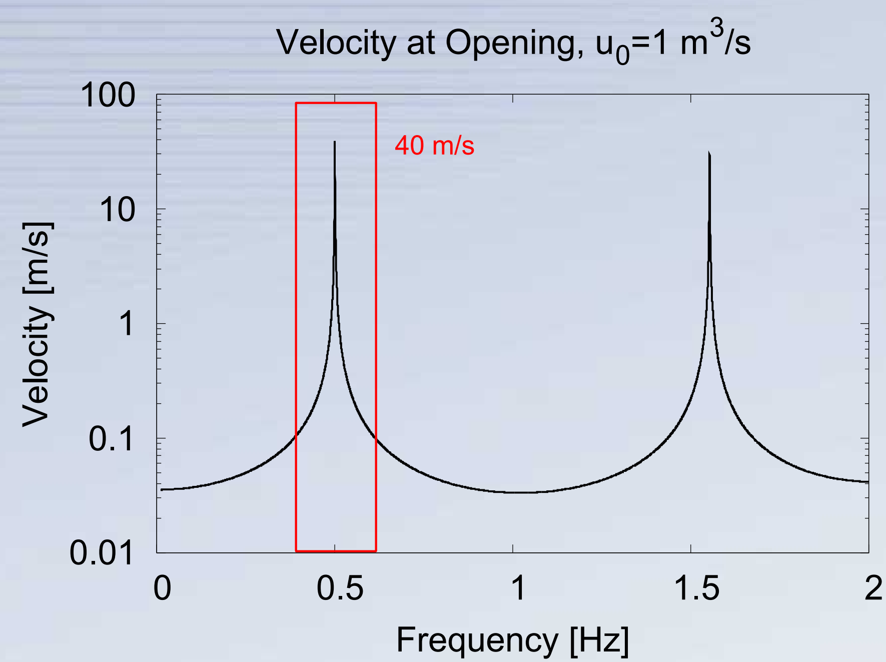




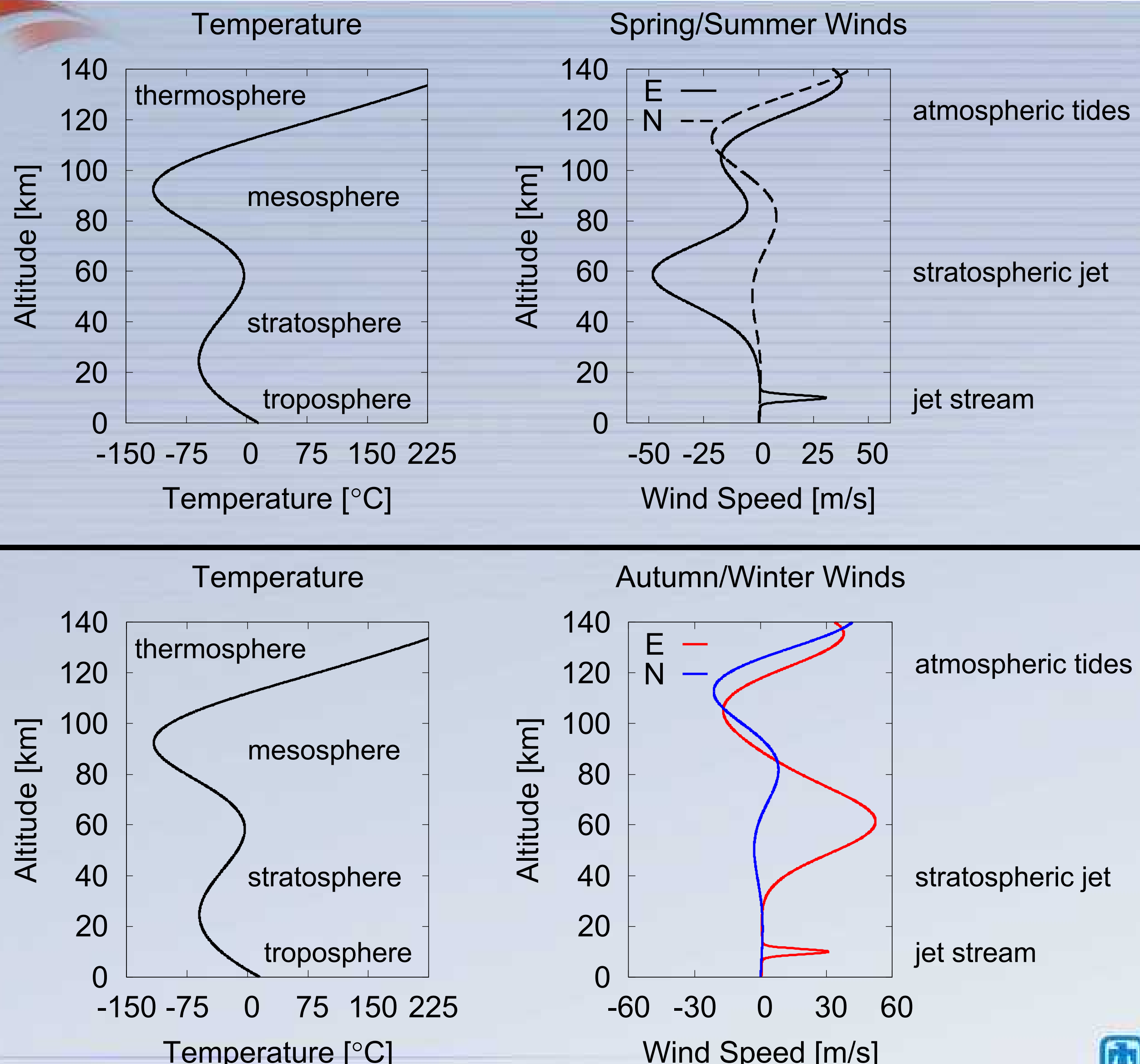
Resonator Theory







Upper Atmospheric Winds



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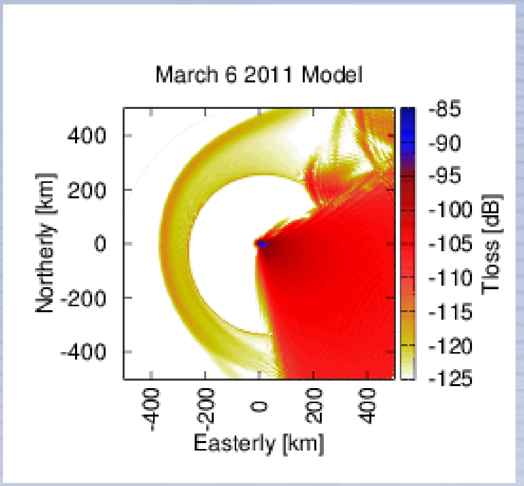
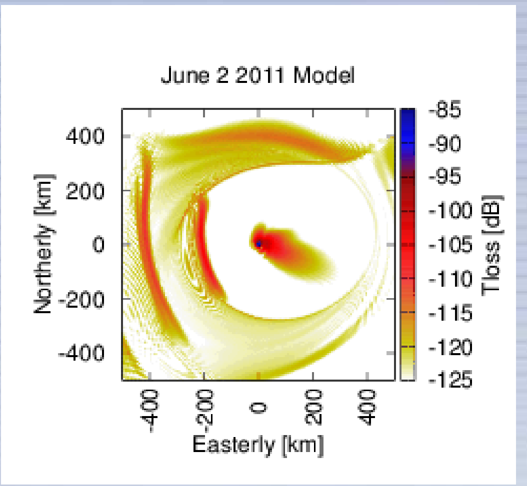
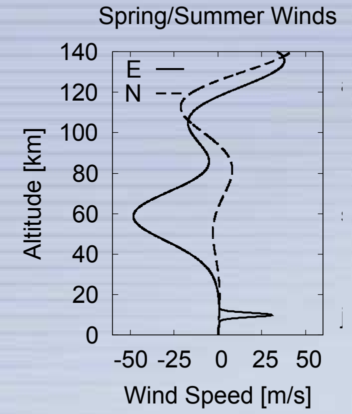
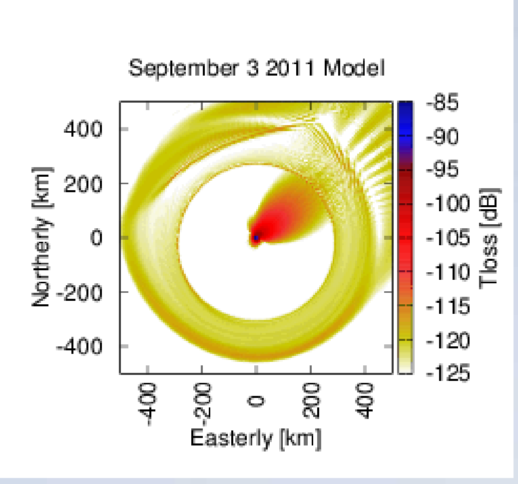
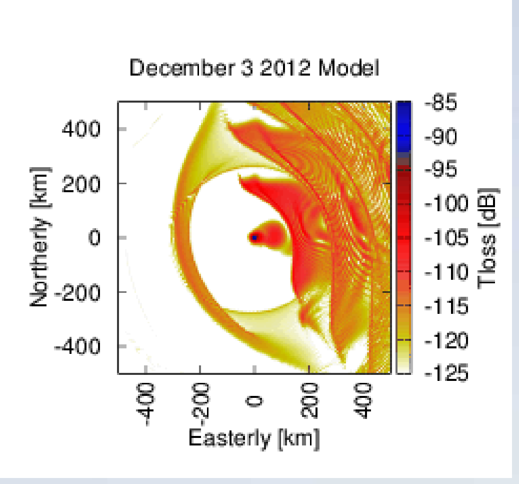
Atmospheric Propagation

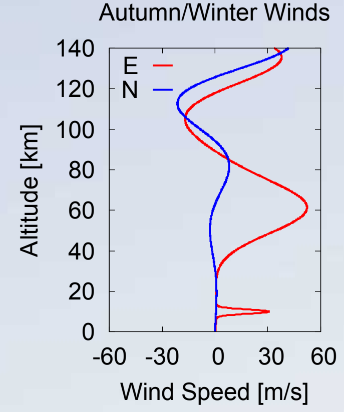












Timeline and Risks

- **Year 1 [FY 14]:**
  - Use fluid dynamics to model the DTRA tube to develop fabrication plan
  - Fabricate, modify and construct piston system in the tube
  - Run small-scale characterization studies on the tube/piston system
    - This is a GO/NO GO Milestone for advancement
  - Concurrently develop and modify existing modeling algorithms and codes
- **Year 2 [FY 15]**
  - Enact operational safety plan for full-scale operation
  - Deploy sensors for continuous data collection for bearing and phase velocity determinations
  - Develop plan to modify tube at the end of the FY to modulate the signal
    - Allows measurements of travel times and relative phase along different pathways
- **Year 3 [FY 16]**
  - Begin coherent signal studies
  - Modify deployment plan for optimized data collection

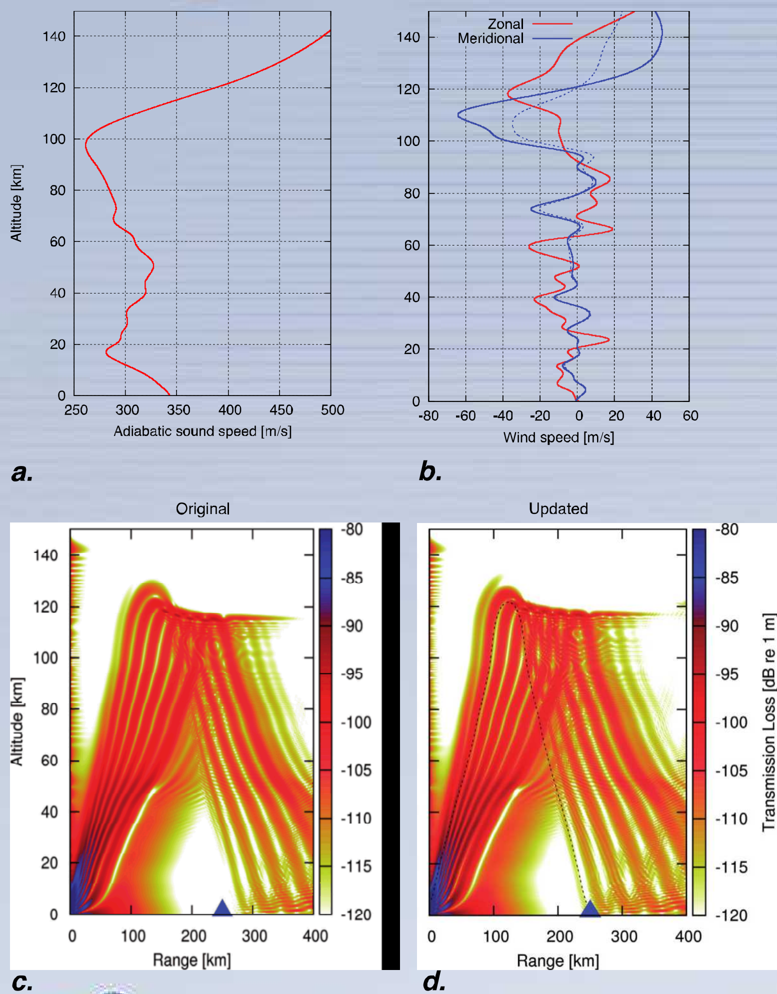
A Dataset Like Never Before!!!

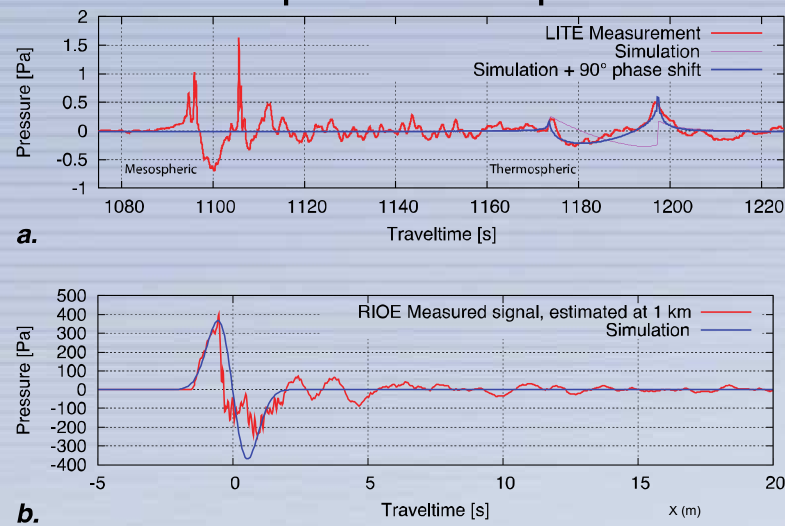
Timeline and Risks

- **Risks [Minimal]**
  - The successful engineering and operation of the resonator to the full propagation extent
  - Separating multi-pathing effects from narrow band data at large distances

Expected Results and Mission Relevance

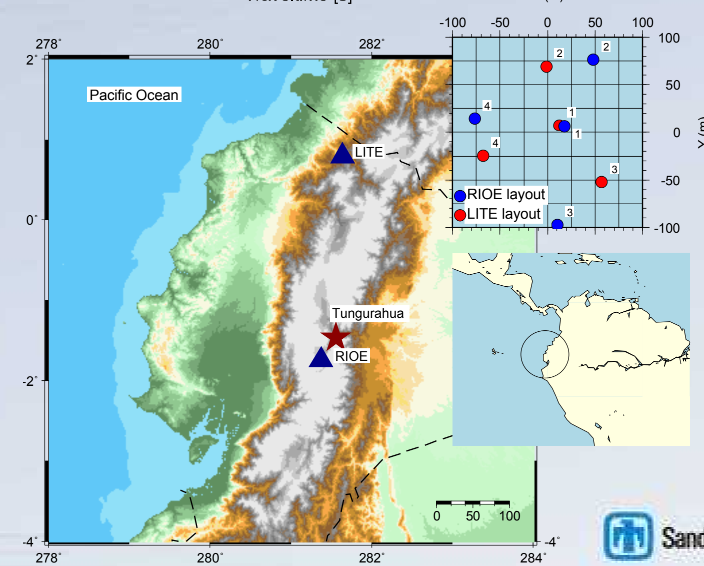
- Using infrasound to update the upper atmospheric wind profile model





250 km North

37 km S. East



LDRD LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

Expected Results and Mission Relevance

- **This project will produce the world's only man-made, continuous, infrasound source capable of measuring climatological properties of the upper atmosphere!!!**
  - Separate multi-pathing effects from narrow band data at large distances from a continuous source
  - Fundamentally change the way that infrasound wave propagation and variations in the atmosphere are understood
  - Characterization of global climate change
  - Provide updates to atmospheric climate models and profiles
  - Natural hazard observation and mitigation

- **With the revolutionary nature of this project we will be significantly advancing the science of infrasound detection of continuous infrasound sources in a complex and extreme environment**

Expected Results and Mission Relevance

- **The work proposed in this LDRD ties-in well to the DOE, DOD, DTRA, NNSA, and Sandia missions**
  - Source uncertainty in coupled climate systems
    - Direct and continuous observations of the upper atmosphere
    - Climate modeling of big data-sets
  - Nuclear security
    - Understanding the propagation pathways in the atmosphere,
    - Advances in accuracy and reliability for determining locations of nuclear events
    - Better characterized source signatures
  - Threat Reduction
    - Compliments current DTRA projects designed to study the upper atmosphere for nuclear detection and forensics
      - Humble/Humming Series
      - Propagation modeling
      - Atmospheric variability
      - Source Characterization
    - Data Sharing
      - DTRA researchers will have access to this unique data set

The Team

Center 5700
Monitoring Systems and Technology
Videre Est Credere

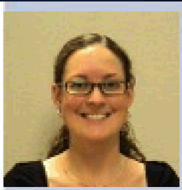
ORG. 5736

Kyle R. Jones [PI]

- Large-scale Infrasound data collection experience
- Infrasound generation and propagation research
- Real-time data integration and processing

CENTER 6900 GEOSCIENCE, CLIMATE, and CONSEQUENCE EFFECTS

ORG. 6913



Hunter Knox

- Significant geophysics modeling and
- field experience
- Project management

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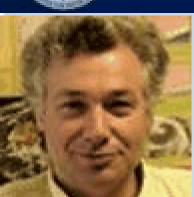
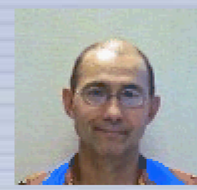


Roger Waxler

- Senior Research Scientist
- Infrasound source and propagation theory and modeling
- Large-scale Infrasound data collection experience

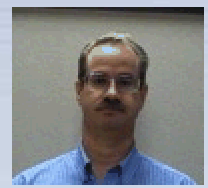
CSRI
Computer Science Research Institute

ORG. 1442



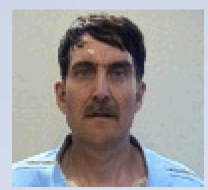
Bart Van Bloemen Waanders

- Advanced modeling and inversion
- Develops optimization and inversion techniques with ExxonMobil [FWI CRADA]



Curtis Ober

- Fluid Dynamics, seismic imaging, and wave propagation
- Team lead for ExxonMobil [FWI CRADA]



Louis Romero

- Applied and classical mathematical modeling

Total FTE: 1.12

Frequently Asked Questions [FAQ]

- **Will there be a mechanical engineer involved in the project?**
  - Yes, both at the fabrication facility (U. Miss) and Tom Gabrielson (Penn State) mech. Engineer and acoustics professor

- **How will we modulate the signal?**
  - One of two ways – 1) turn on/off the piston in a coded sequence or 2) cut mechanical holes in the tube much like a flute

- **By sealing the tube at one end, will the source be directional to the South?**
  - No, the opening is 6 m and at 0.5 Hz, the wavelength of radiated energy is 700 m, making the source omni-directional

- **What are the health and safety concerns associated with this infrasound resonator?**
  - There are little to no safety and health concerns related to this project due to the following reasons:
    - The amplitude of our source is comparable if not less than the natural barometric fluctuations we experience every day
    - There are no conclusive studies indicating that infrasound at 0.5 Hz produces nausea or un-easiness
    - We have consulted with Sandia and DTRA ES&H and they have identified no major issues
    - The general public should not even know that this source is running
  - The resonator will **not** produce "high-intensity" infrasound capable of rattling structures or windows
    - Infrasound at 1 km will be ~6 Pa or less

- **What about using other natural sources of infrasound such as earthquakes, volcanoes, winds or auroras?**
  - All of these sources are unpredictable, uncontrollable and have varying degrees of continuity and amplitude

- **What about using commercial jets to do acoustic tomography of the atmosphere?**
  - This study was done using data from the super-sonic Concorde Jet. Todays jets do not produce enough infrasound during flight, typically only during take off and landing, among other issues

Frequently Asked Questions [FAQ]

- **What about large wind turbines?**
  - No conclusive evidence that wind turbines produce infrasound much less at the amplitudes/frequencies needed for this study

- **Why are we not doing full 3-D waveform inversion to solve for the atmospheric properties?**
  - For the desired research result a full 3-D estimate of the atmosphere is not needed due to the distances at which we are looking at
  - Additionally, it is more important to develop the 1-D approximation first

- **Why are we not using "crossing paths" like traditional seismology tomography and inversion?**
  - We are doing an azimuth dependent approximation, combined with a large-scale infrasound array deployment to reproduce a range-independent approximation for the meridional (North-South) and Zonal (East-West Winds)
  - This is similar to what would be experienced during and underground nuclear test
  - This is also not necessary for a 1-D approximation as opposed to a full 3-D inversion
  - We will also be using at least 10 infrasound arrays spaced at multiple azimuths and distances

- **Will 10 infrasound arrays be enough?**
  - Yes, especially for 1-D models. Previous studies on volcanoes have shown exceptional results using only one or two arrays. With multiple arrays we can resolve the atmospheric model in multiple directions

- **The goal of this research is not to replicate explosion amplitudes, frequencies or data of any kind. In fact, we aim to replace the use of conventional explosion for this type of research, which are dangerous, expensive, temporally inconsistent, and troublesome to the general public and city of Albuquerque**

Additional Questions?