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Uncertainty: Confidence & Sensitivity

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June 19, 2002

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Issue

- Fleet has low confidence in performance predictions that are sometimes right, sometimes wrong but never in doubt

- No warnings provided concerning confidence in predictions

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Issues: Confidence and Sensitivity

- What is the confidence in environmental inputs?
- What is the sensitivity of acoustic performance to uncertainty in environmental inputs?

Note: Frequently a small change in an environmental parameter can make a big change in acoustic results.

Sensitivity depends on

- Environment
- Use

$$dP = \sum \frac{\partial P}{\partial \alpha_i} d\alpha_i$$

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Challenge

…to convey environmental uncertainty to fleet users in a **useful, responsible** way.

Note: Statistical descriptions that are ok for experts may not be useful to operators.

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Status

- Modern computers, displays and propagation models give rise to tactical decision aids (TDA's) to help fleet operators
- TDA's
  - Perform propagation and other acoustic calculations
  - Manipulate sonar equation
  - Display results colorfully
- Environmental calculations in TDA's assume environmental inputs are true
  - SVP
  - Bottom geoacoustics
  - Topography
  - Scattering

  without reservation about the quality of these inputs and data bases
- Models are good but outputs are only as good as inputs.

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Sonar Equations

Passive:

+SL	Source level	Intelligence
-TL	Transmission loss	Fleet Needs Input
-AN	Noise	Measurable
+AG	Array gain	Measurable
-RD	Recognition differential	Fleet Experience
SE	**Signal excess**	

Active:

Includes reverberation	Measurable

Uncertainties in all terms but operators depend on us for TL

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Use of Performance Estimates

- System design
  - Frequency dependence
  - Different environments
- Plans and analysis
  - Resource Allocation
  - Search Plans
- Tactics
  - Submarine Safety
  - System Setup
  - Depth, positioning
  - Ranging
  - Fancy Processing

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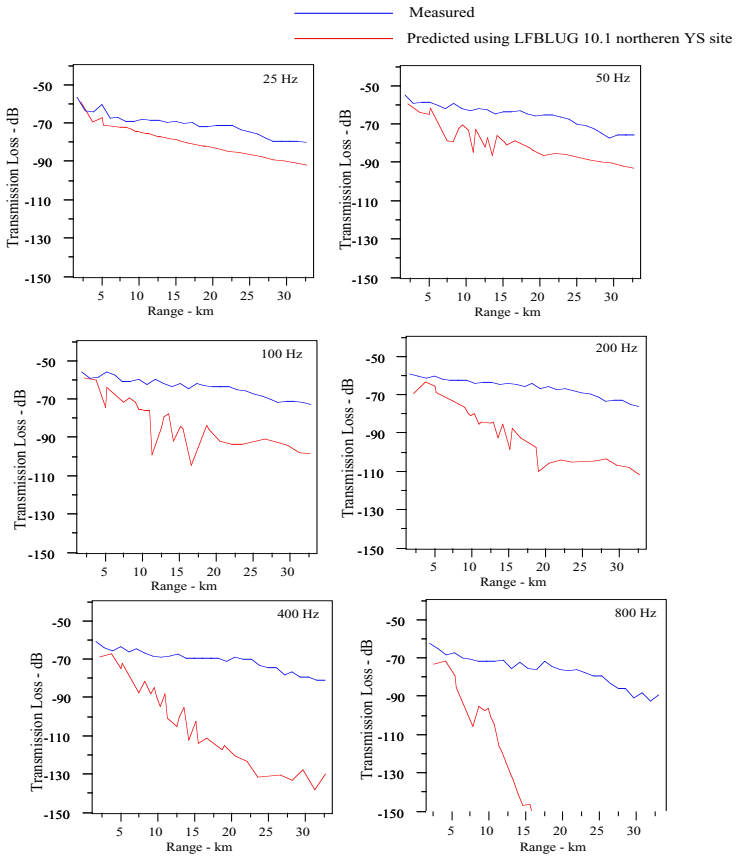
Environments

- Deep water
  - SVP dominates
    - Range to Shadow Zone
    - Convergence Zone Range/Intensity
    - Duct Properties
  - Bottom Bounce Exploitability
- Shallow water
  - Bottom characteristics dominate
    - Multipath propagation
- Slopes
  - Complex :
    - Cross/Up-Downslope differences
    - Strong SVP Variability
    - Strong Bottom Variability
    - Currents
    - Mode stripping/coupling
- Littoral:
  - Shallow
  - Slopes

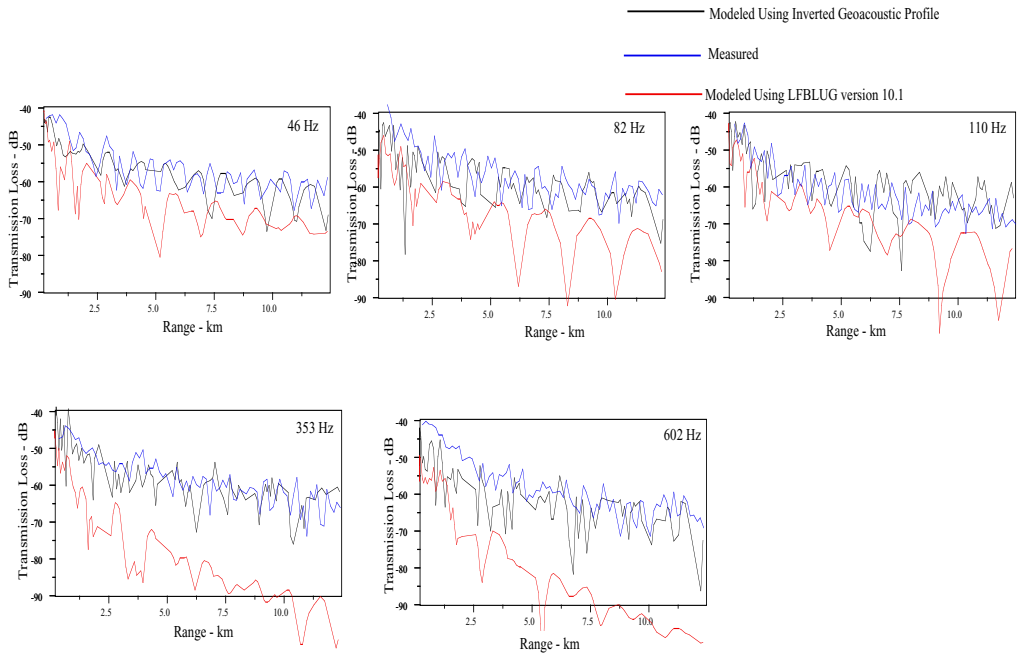
Environmental Inputs

- Sound Speed Fields (MODAS) $c(z: x,y,t_0)$
  - Accuracy?
  - Spatial and Temporal Variability
  - Merging of *in-situ* measurement and MODAS field SVP (if they don't agree)
  - EOF's, Correlations, etc (OK for R&D)
- Bottom Properties – (Frequency Depedence?)
  - "Bottom Loss" BL(θ,f), confidence bounds
  - Critical Angle
  - Backscatter coefficient
  - Geo-acoustic Parameters
  - Low confidence in bottom databases suggests need for in-situ verification/characterization

Environment:Measured TL vs. Modeled (using LFBLUG database parameters)



Yellow Sea



Straits of Korea

Inversion and modeling results provided by ARL/UT

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Submarine Support

- Submarines depend on acoustics
  - Ownship Safety
  - Tactical Operations
- Requirement for covertness
  - Limits use of controlled sources
  - Limits COMMS
- “Should I go to COMMS depth to update SVP information?”
  - Cost/Benefit
- Special forward littoral needs

General: Environment ('01 PSAC Active SUMMARY)

- Littoral regions involve shallow, intermediate and deep water. Performance in all three areas is required.
- In winter, surface duct may be exploited by active SONAR (especially AN/SQS-53C) against shallow/in-duct targets, independent of water depth
- TDAs are required but existing prediction capability is inadequate
  - In shallow and intermediate water depths performance is controlled by bottom properties
  - Standard Navy databases of bottom properties (Loss, scattering and frequency dependence) are inadequate and misleading.
  - In-situ characterization difficult and ambiguous without calibrated echo repeater
  - Many results from experiments and exercises in important littoral regions are not incorporated into standard databases
- Recommendation
  - Area specific measurement program and database building required
  - Development of inexpensive expendable calibrated echo repeater for environmental characterization, performance assessment and training

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PSAC Environmental Recommendation: Multi-function Target Simulator

- Concept (not for submarines)
  - Low cost, expendable, programmable calibrated source with r.f. link and control electronics (like active sonobuoy)
  - Use for:
    - System performance measurement – direct bottom line
    - Environmental characterization and model validation – permits direct unambiguous measurement of all terms in the SONAR equation (TL1, TL2, AN, R, SNR);
    - Training target
  - Features:
    - Active – receives active transmissions
      - Generates echo at known target strength and doppler
      - Returns received signal by r.f.
    - Passive
      - Transmits specified signal at specified level for TL measurement and simulated target.

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Concerns

- Bottom property data bases in many areas are not based on sufficient acoustic measurements
  - No confidence assessment
  - Little comparison of predictions with data
  - Critical in littoral
- Bottom reverberation/scattering strength data is lacking
- Many R&D measurements do not get into NAVO data bases
- Fragmented responsibility for performance prediction

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Area Assessment

For each important area:

- Identify all relevant acoustic data
- Compare data bases and model predictions with measurements
- Identify problems and short fall
- Establish measurement priorities
- Establish near-term confidence intervals
- Summarize oceanographic, features, variability, seasonal dependence
- Summarize shipping activity
- Identify features that could be exploited
- Capture Fleet Experience
- Distilled wisdom
  - Operational guidelines

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Challenge

How to convey environmental uncertainty to fleet users in a **useful, responsible** way

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Caution Message Examples

!!!!!!!WARNING !!!!!!!!!!

Propagation loss calculations in this region may be highly sensitive to local bottom properties. Current databases are deficient. 90% Confidence bounds can be obtained by using the following sets of input parameters:

A: xxxx

B: yyyy

!!!!!!!WARNING !!!!!!!!!!

This is an area of strong ocean dynamics. Sound speed profiles can be expected to change significantly over distances of xxxx nmi and time periods of yyyy hours.

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BACK-UP

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Uncertainty

- Characterization
- Reduction
- Implications

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Variability

- Spatial
- Temporal
- Need for in-situ updates of SVP
  - How often?
  - How far?
- Historic as a guide