UNCERTAINTIES AND INTERDISCIPLINARY TRANSFERS THROUGH THE END-TO-END SYSTEM (UNITES)

THE UNITES TEAM YEAR 3 OVERVIEW

Capturing Uncertainty DRI: Final Review

Westfields Marriott, Chantilly, VA

June 15, 2004

Environmental Uncertainty and Its Effect on Sonar Performance -- UNITES Team Year 3 -- Agenda

0845-0900 **UNITES Team Overview**: Abbot

PRIMER Mid Atlantic Bight (MAB) Efforts

0900-0915 Climatological Approaches to Uncertainty in the MAB: Gawarkiewicz

0915-0930 Acoustic Propagation and Uncertainties in MAB Estimated by Coupled Data Assimilation: Lermusiaux

0930-0945 Uncertainty due to 3-D Coastal Oceanography with Practical Implications: Lynch

0945-1000 Coffee Break (15 minutes)

China Seas Efforts

1000-1015 Impulsive Low Frequency Active Sonar Detection Statistics with Environmental Uncertainty: Cable

1015-1030 Estimate of Uncertainty in Acoustic Propagation Adjacent to the Strait of Korea: Fulford

1030-1045 Stochastics of Transmission Loss Measurements in the ASIAEX ECS Experiment: Dyer

South China Sea (SCS) Efforts

1045-1100 SCS Shelfbreak TL and Horizontal Coherence Statistics: Chiu

1100-1115 Fluctuating Pulse Statistics in a SCS Shelfbreak Area, and Issues Regarding Data, Theory, Simulation Comparisons: Duda

1115-1130 Propagation of Randomness in a Model End-to-End System – Miller

1130-Noon Wrap-Up

UNITES Team Summary and Accomplishments

- Refined *Methodology* for Characterizing and Quantifying Uncertainty, Transferring Through the E/E System
  - Probabilistic Sonar Equation with Environmental PDFs
  - Assimilation of Data and Models
- Extensive *Operational* and *Scientific* Results
- Enthusiastic and Useful Inter-Disciplinary Effort and Exchange
- Overall Successes are an Amalgam of Team Member's Efforts

UNITES Team Accomplishments: *Methodology*

- Probabilistic performance prediction for E/E system(s)
  - Mandated by inability to predict acoustics deterministically due to often unknown aspects of the ocean state (including bottom)
  - Controlled by 3 parameters: μ_t, σ_t and n (minimum)
  - PDF of each uncertainty component, when taken in total, gives shape to the PPD tails
- TL μ set primarily by macro state of ocean (w/bottom)
  - Determined by numerous samples of measured TL (or improved estimates of ocean) or from fewer TL samples assimilated with a competent TL model
- TL σ and PDF set by micro state of ocean (temporal/spatial “graniness”)
- 4-D data assimilation for coupled ocean dynamical-acoustical fields for reduction and forecast of TL μ

UNITES Team Accomplishments: *Operational* Results

- ECS passive broad-band E/E sonar system study
- PPD method reasonably represents the sonar/target system and may be relevant to operational Navy needs
- Relevance to Navy is now under study (SOWG)
  - Narrowband Sonar End-to-End System Study using fleet data
- ECS TL Uncertainty Province Map
- Measurements in probabilistic framework that supplement propagation and environmental (ocean and bottom) models (i.e. data assimilation) for SW, rather than models alone, are necessary for competent prediction

UNITES Team Accomplishments: *Scientific* Results

- TL μ, σ, and PDF of some oceanographic and geo-acoustic features (spatial and temporal scales) determined
  - Temporal effects of internal waves, tides (SWARM, PRIMER and ASIAEX/SCS) and other PO "hot spots"
  - Bottom and oceanographic spatial effects (ASIAEX/ECS)
- Statistical dependence/independence of TL studied
  - Partial correlation of signal and noise caused by internal waves
- Ambient noise/reverberation PDFs measured (PRIMER, ECS, ACT)

UNITES Team Accomplishments: *Scientific* Results (Continued)

- Model sensitivity studies
  - Effects of IW scattering on TL μ
  - TL PDF dependence on signal bandwidth (short time scales)
  - TL μ to ocean sound speed estimate resolution (mesoscales) – optimum: 20 m vertical, 4 km horizontal
  - PRIMER mesoscale physics – atmospheric forcing controls summer variability, more than expected
- Ground-truthing of fleet oceanographic models shows improvements needed
  - PRIMER: misses horizontal gradient in coastal fronts
  - SCS: misses energy in currents and eddies
- Seasonal climatology of shelfbreak improved by wind forcing

UNITES Transitions

- PPD Methodology via ASTO (SOWG) and NAVO
  - Evaluation w/APB-98 measured detection data
  - Design experiments for testing PPD methods
  - Distant Thunder performance prediction
- Fleet Rules-of-Thumb/Insights Formulated
  - Briefs to COMSUBDEVRON12, COMSUBPAC, SOWG, NAVOCEANO, NPS Tactical Oceanography Course
- Uncertainty TL Provincing (ECS and Nearby)
- *In situ* TL Measurements, supplementing models, necessary for competent prediction

IEEE Special Issue Publications

- Abbot, Dyer and Emerson, “Stochastics of Transmission Loss in the Shallow East China Sea”
- Abbot, Chiu, Lynch, “Acoustic Signal and Noise Level Variability Measurements From 1996 Summer Shelfbreak PRIMER Tests”
- Chiu, Gawarkiewicz and Lynch, "A note on long-scale transmission-loss uncertainty reduction through ocean data integration“
- Lermusiaux and Gawarkiewicz, "A note on salting the PRIMER summer experiment
- Lermusiaux, Abbot, Chiu and Lynch, “Uncertainty in the End-to-End System”
- Fulford, “Estimate of Uncertainty in Acoustic Propagation adjacent to the Strait of Korea
- Lin, Chen, and Lynch, “An equivalent transform method for evaluating the effect of the water column mismatch on geoacoustic inversion”
- Linder, C., G. Gawarkiewicz, and M. Taylor, 2004: Climatological estimation of environmental uncertainty over the Middle Atlantic Bight shelf and slope.
- Duda, Abbot, Shanahan and Newhall, “Rapid vertical beam power fluctuations in the presence of coastal internal waves: Discrete signals and noise”

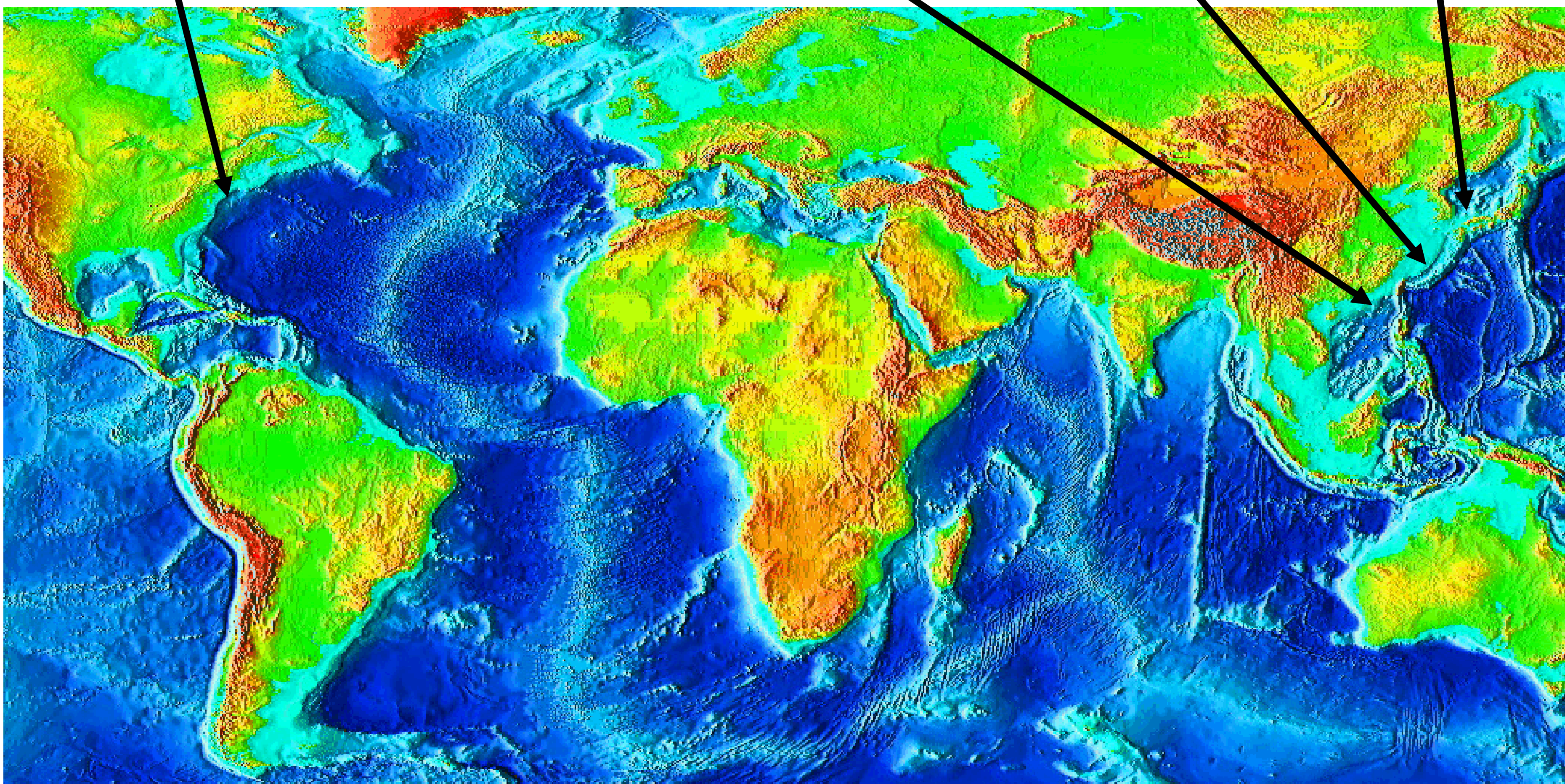
UNITES Team Uncertainty Data Sets

Mid-Atlantic Bight (PRIMER)

South China Sea

East China Sea

Straits of Korea



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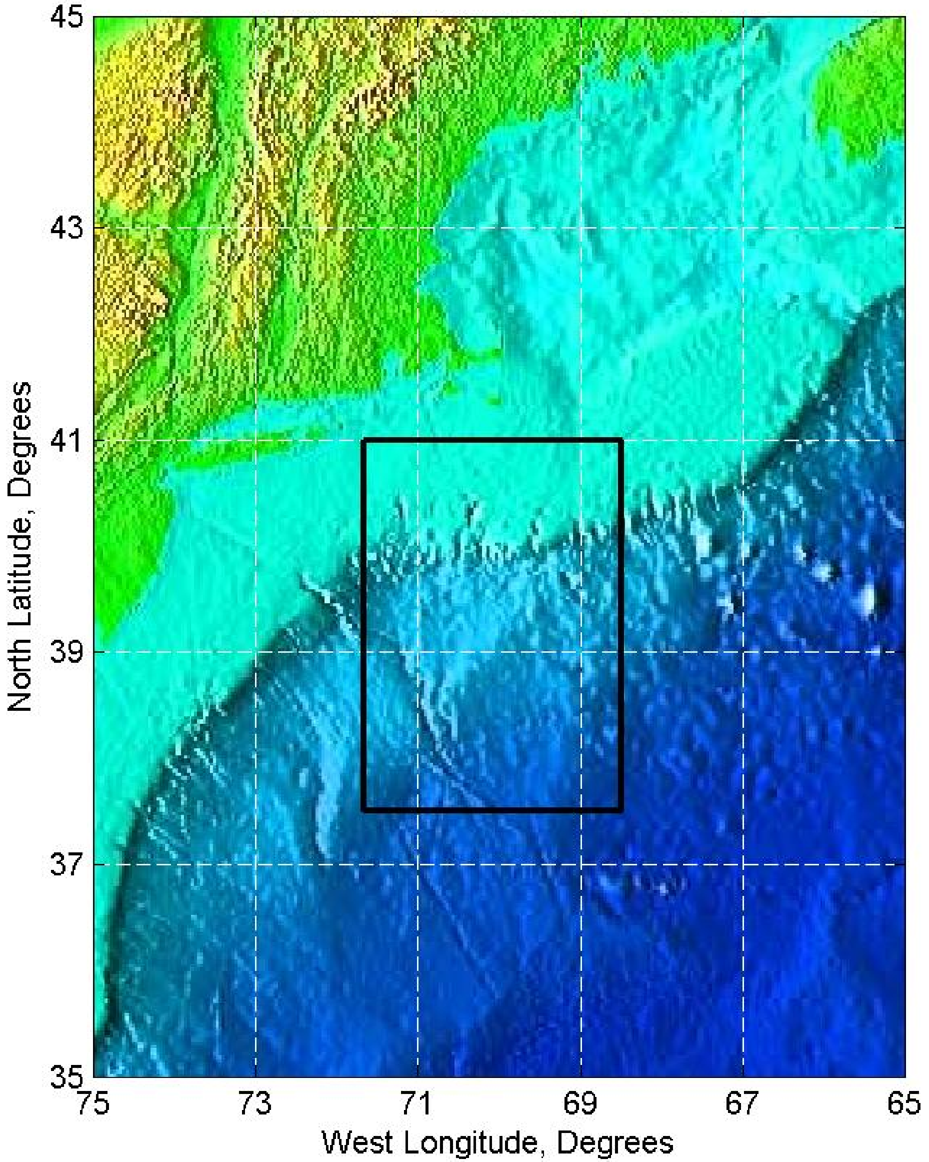
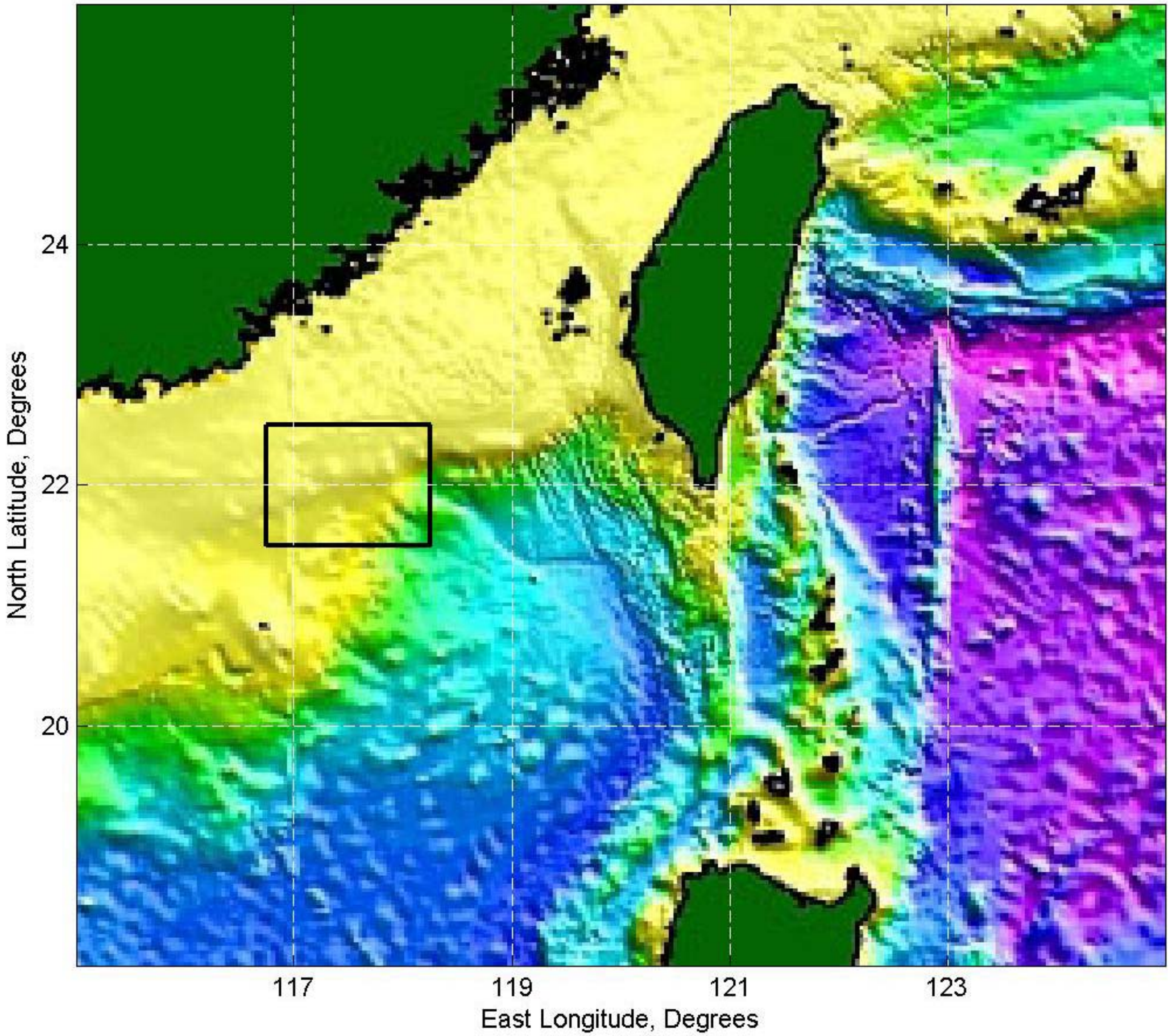
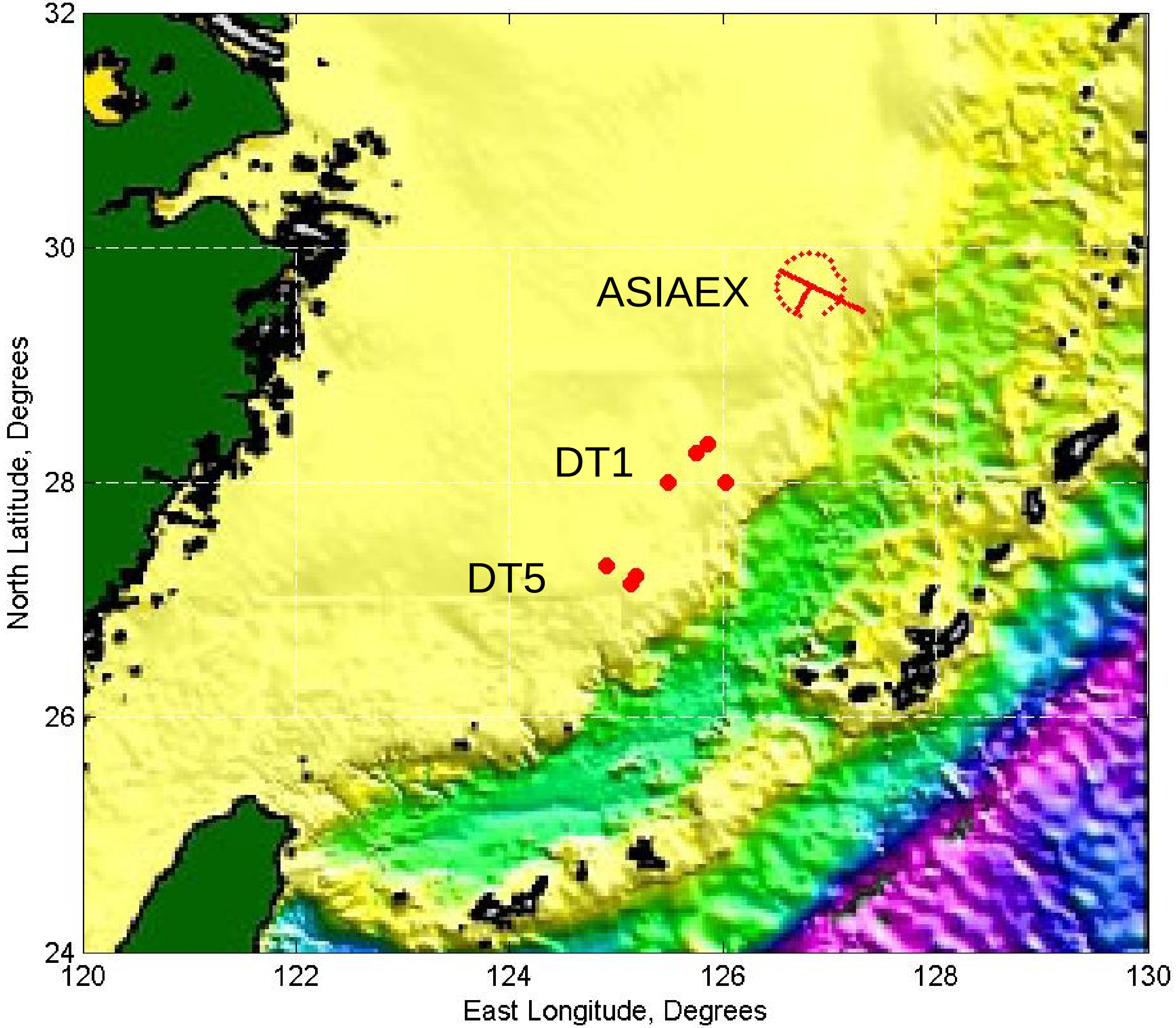
Mid-Atlantic Bight



South China Sea



East China Sea



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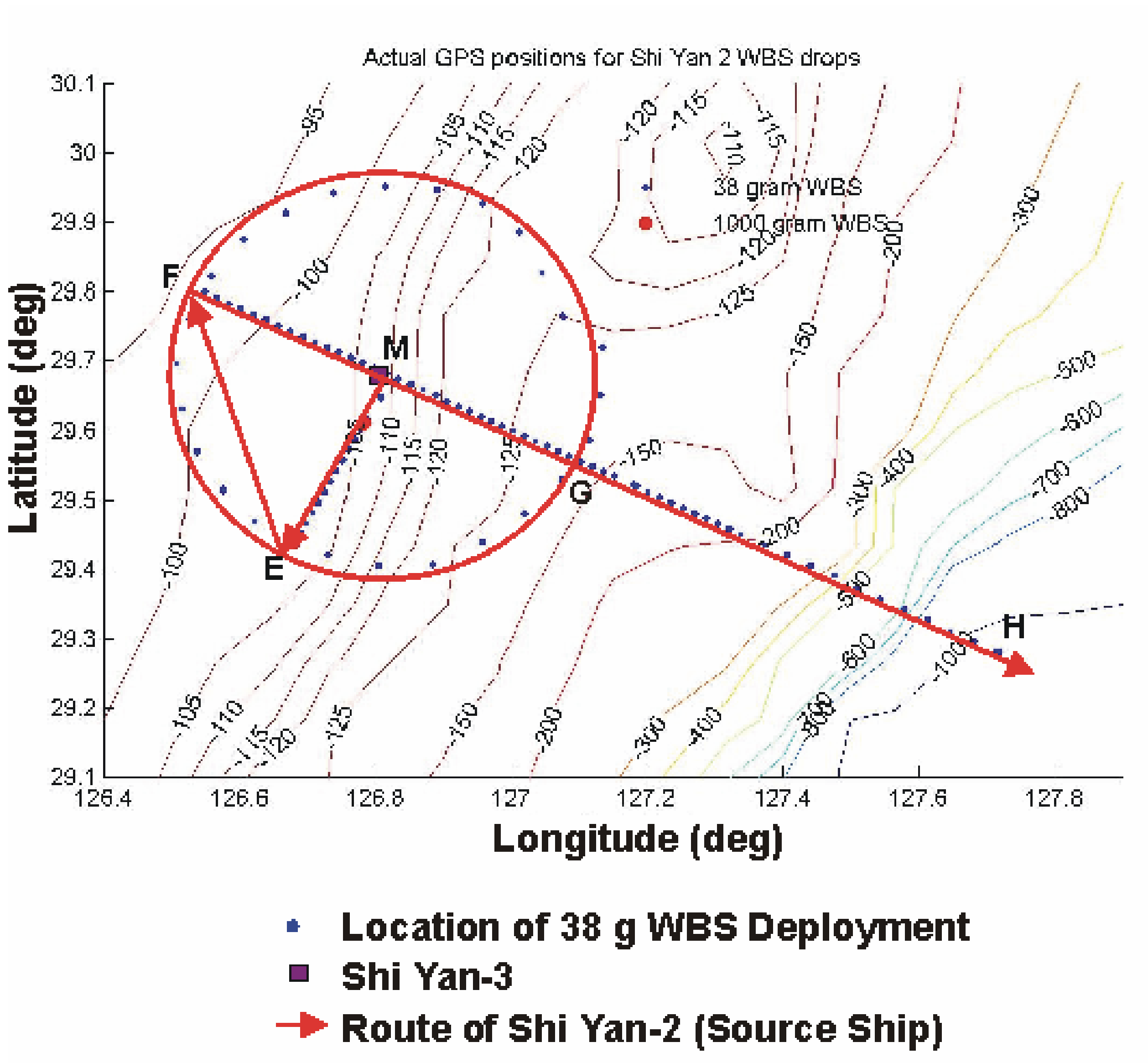
ASIAEX East China Sea



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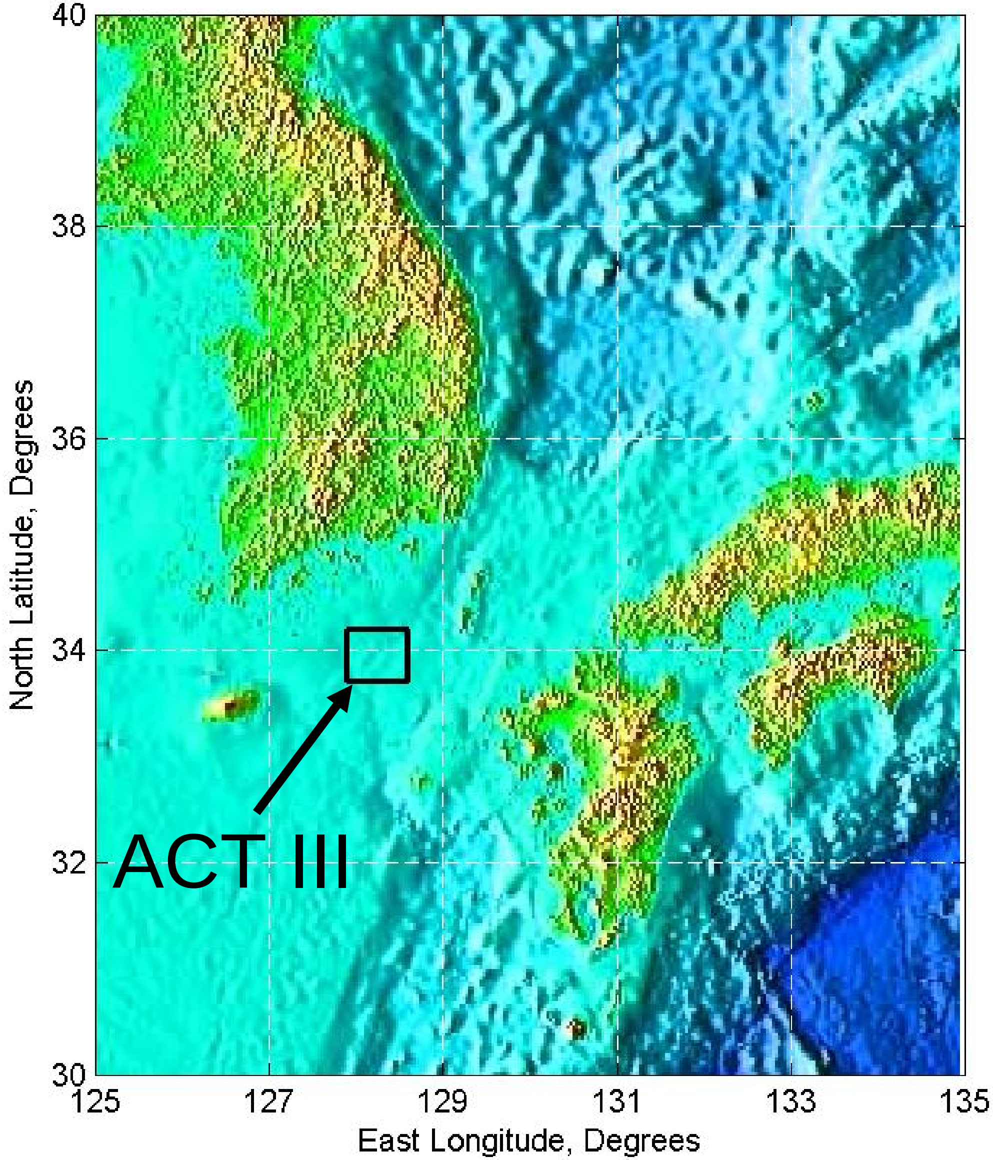
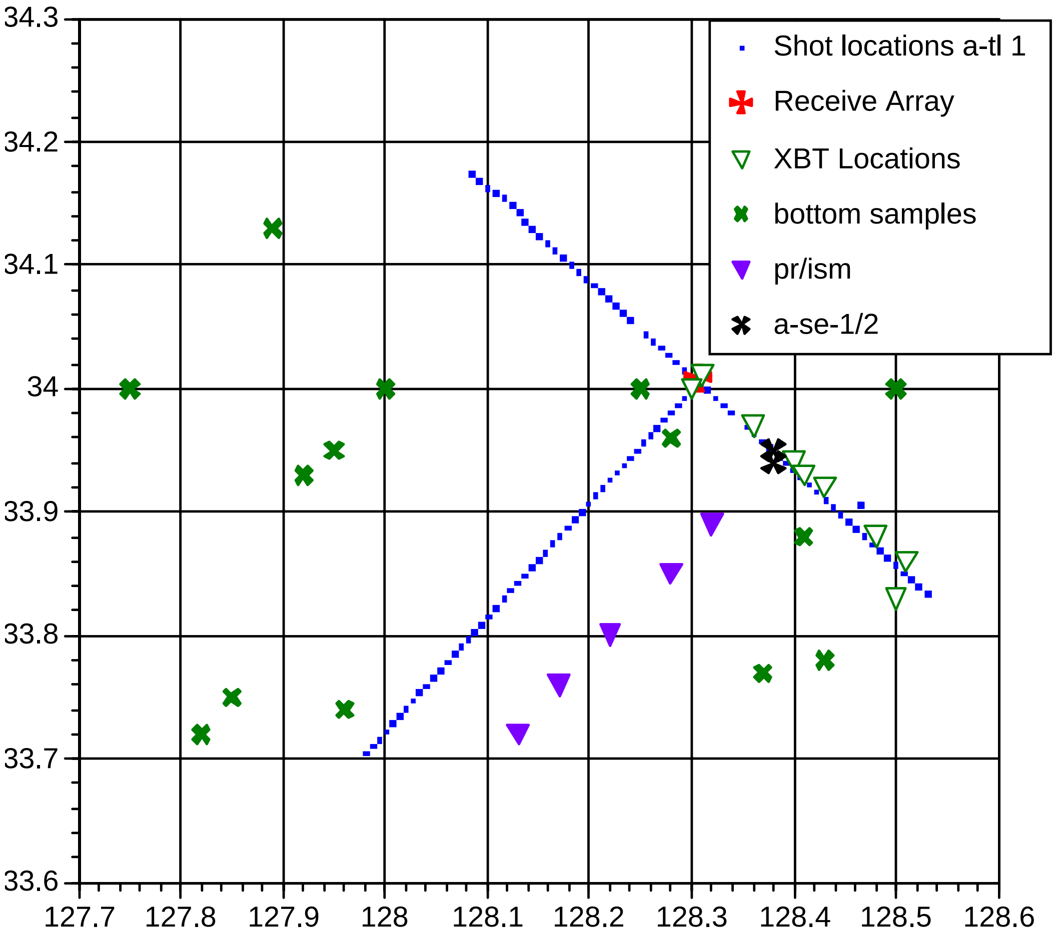
Straits of Korea



ACT III Site 1



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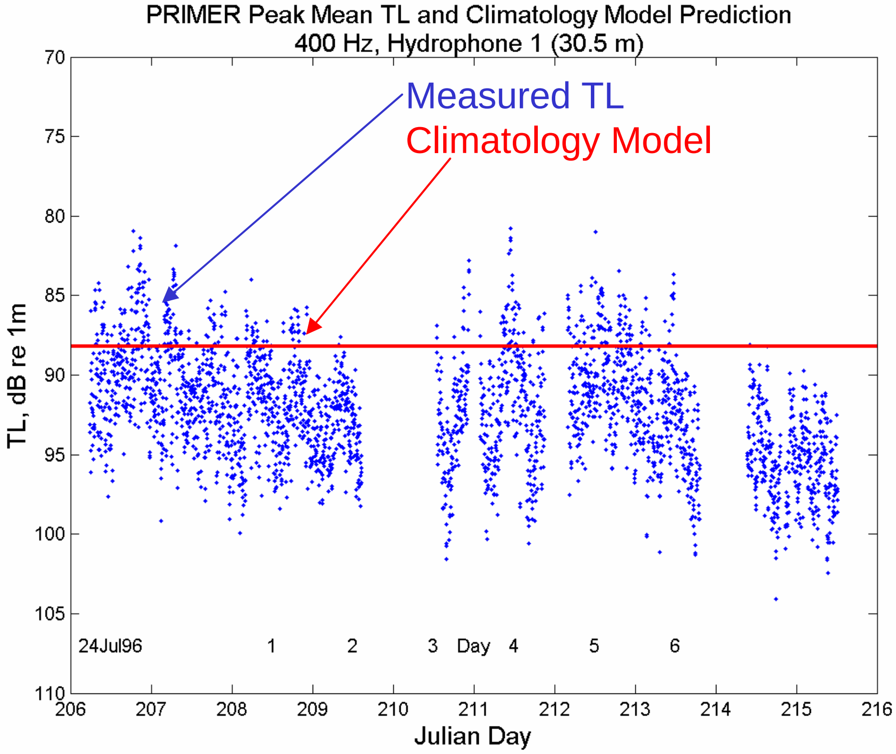
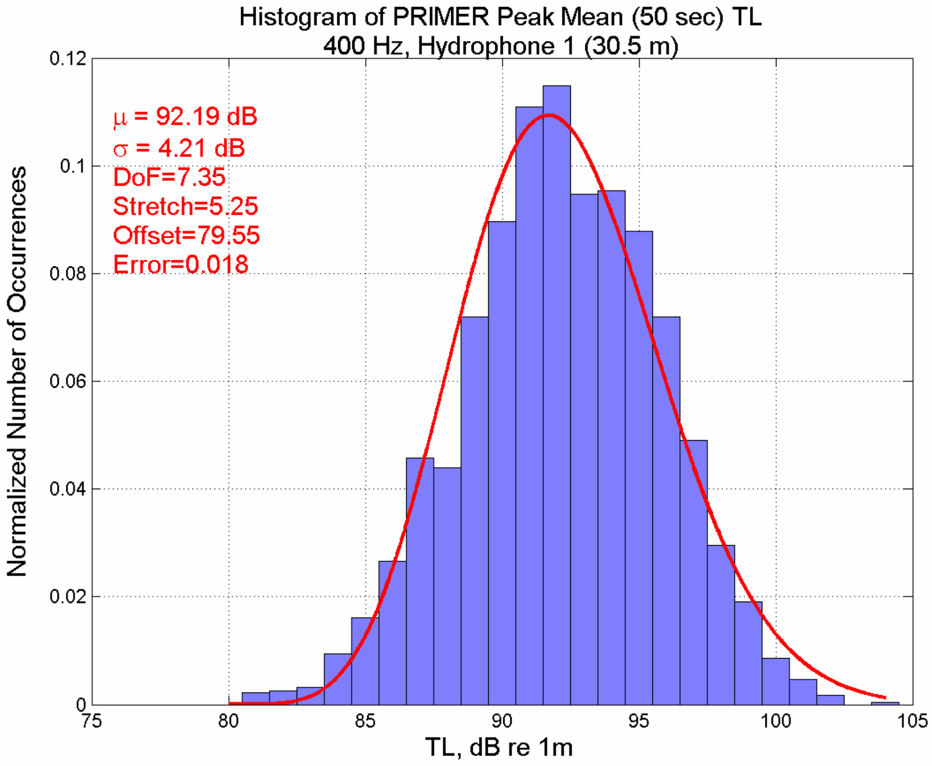
TL Temporal Variability, Shelfbreak PRIMER Data

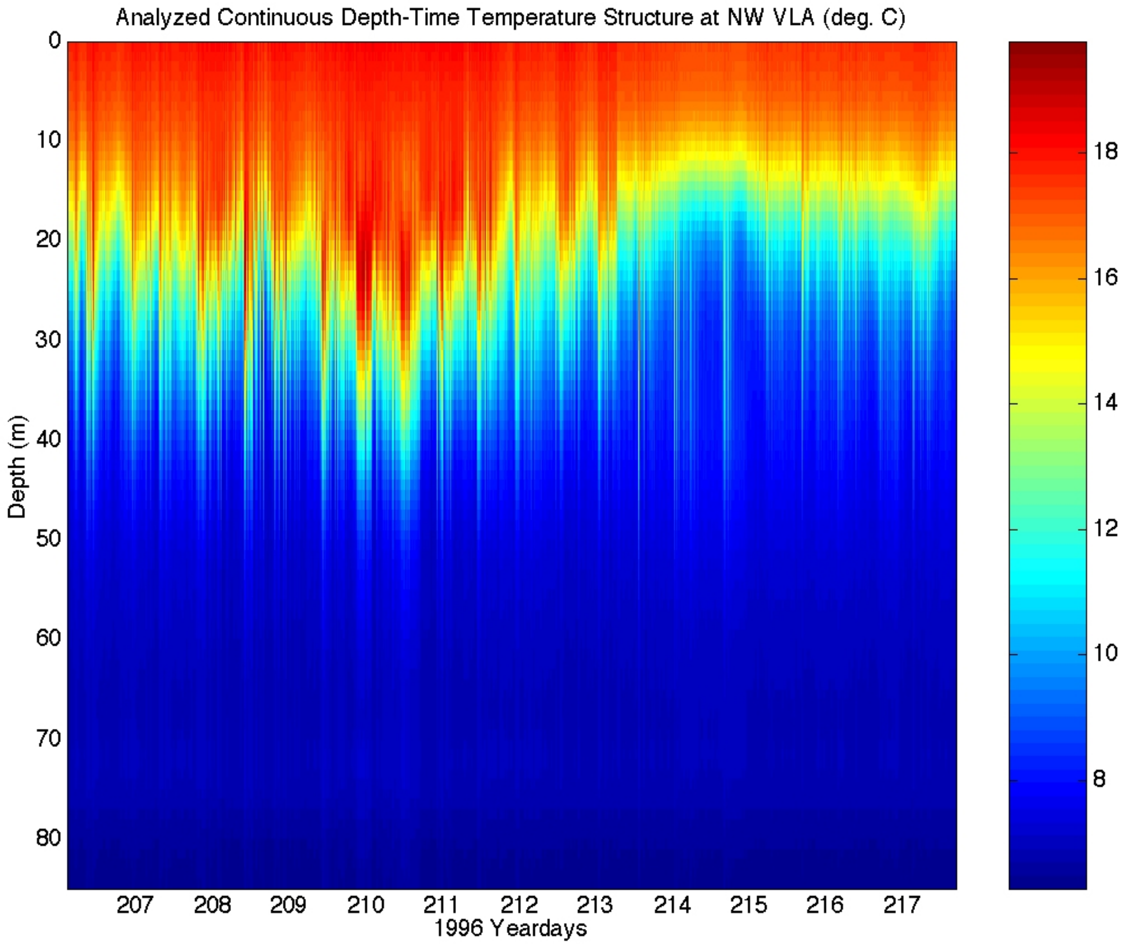
R = 42 km, f_c = 400 Hz, BW = 100 Hz, TBW = 1, D_S = 295 m, D_R = 30.5 m, Water Depths: 300 to 90 m, Upslope



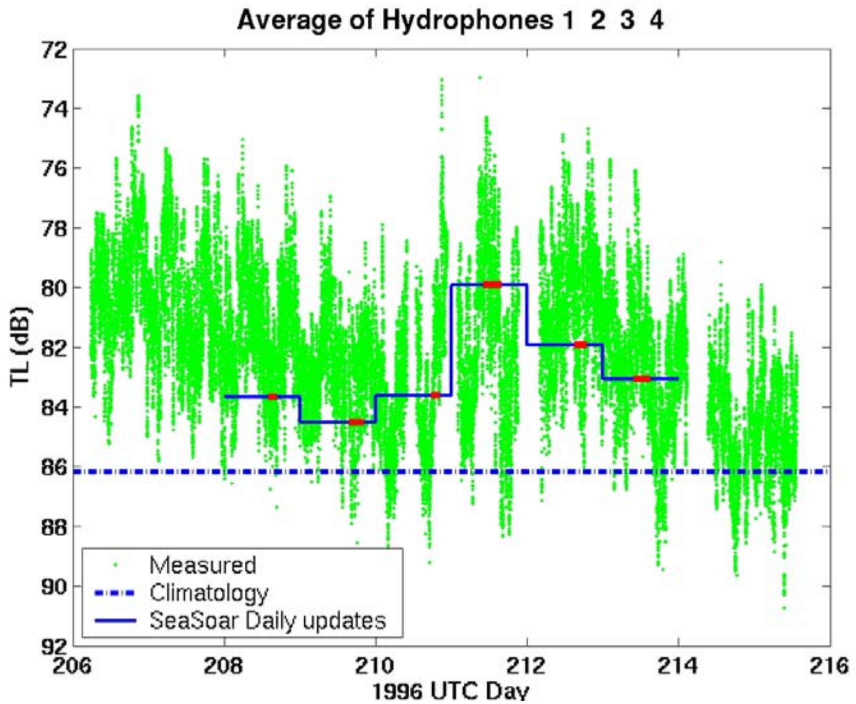


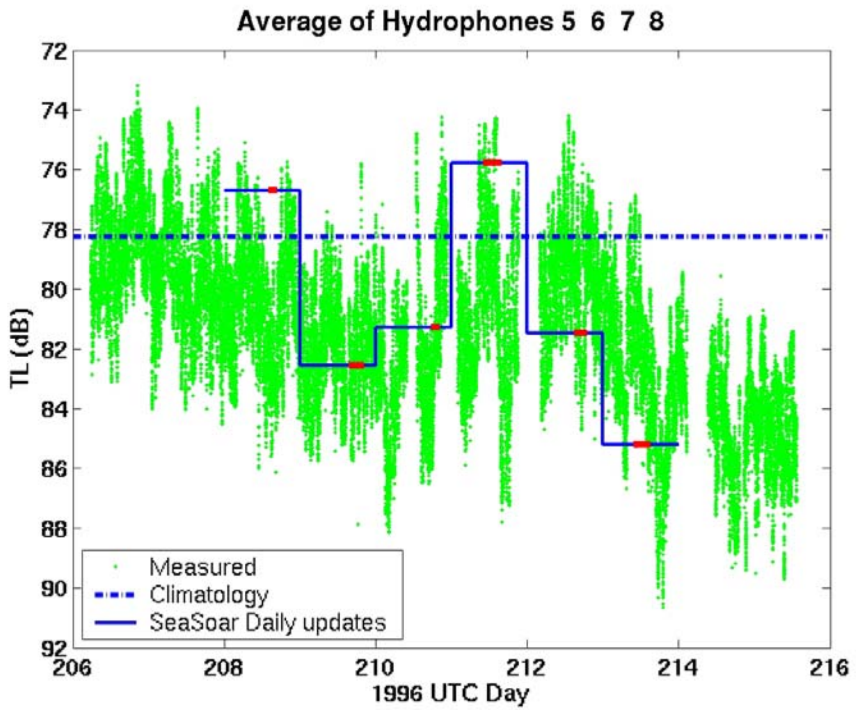
TL Fluctuations Due to Internal Tide and Internal Waves, Used for Extrapolating to Other Systems (Time-Band Product)

Temperature Temporal Variability, Shelfbreak PRIMER at Hydrophone Array Location (Fixed)



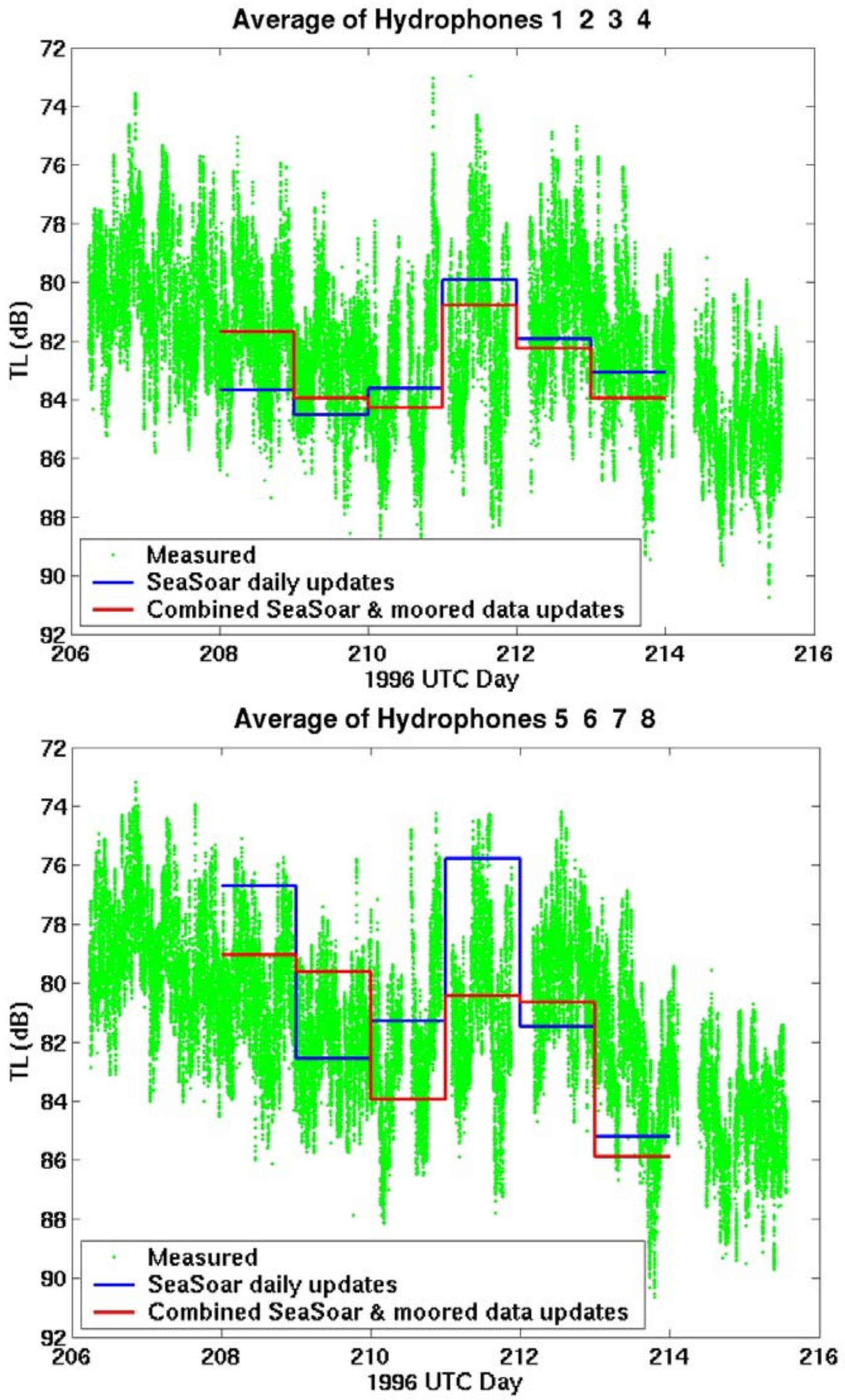
Provided by Prof. CS Chiu, NPS





“Previous Results”

TL predicted using seasonal climatology, updated using daily SeaSoar maps, and measured by the top half of the western VLA.



TL predicted using using SeaSoar-only daily maps, using SeaSoar-plus-moored data daily maps, and measured by the top half of the western VLA.

Publications

- Abbot and Dyer, “Sonar performance predictions based on environmental variability,” *Impact of Littoral Environmental Variability on Acoustic Predictions and Sonar Performance*, Ed. By Pace and Jensen, Kluwer Academic Publishers, 2002
- Robinson, Abbot, Lermusiaux, and Dillman, “Transfer of uncertainties through physical-acoustical-sonar end-to-end systems: a conceptual basis,” *Impact of Littoral Environmental Variability on Acoustic Predictions and Sonar Performance*, Ed. By Pace and Jensen, Kluwer Academic Publishers, 2002
- Lynch, Fredricks, Colosi, Gawarkiewicz, Newhall, Chiu and Orr, “Acoustic effects of environmental variability in the SWARM, PRIMER and ASIAEX experiments,” *Impact of Littoral Environmental Variability on Acoustic Predictions and Sonar Performance*, Ed. By Pace and Jensen, Kluwer Academic Publishers, 2002
- Lermusiaux and Chiu, “Four-dimensional data assimilation for coupled physical-acoustical fields,” *Impact of Littoral Environmental Variability on Acoustic Predictions and Sonar Performance*, Ed. By Pace and Jensen, Kluwer Academic Publishers, 2002
- Duda, “Relative influences of various environmental factors on 50-1000 Hz sound propagation in shelf and slope areas,” *Impact of Littoral Environmental Variability on Acoustic Predictions and Sonar Performance*, Ed. By Pace and Jensen, Kluwer Academic Publishers, 2002
- Abbot, Gedney, Dyer and Chiu, “Ambient noise and signal uncertainties during the Summer shelfbreak Primer Exercise,” *Impact of Littoral Environmental Variability on Acoustic Predictions and Sonar Performance*, Ed. By Pace and Jensen, Kluwer Academic Publishers, 2002

Publications (Continued)

- Abbot, Celuzza, Dyer, Gomes, Fulford and Lynch, “Effects of East China Sea shallow water environment on acoustic propagation,” *IEEE J. Ocean Eng*., April 2003
- Lynch, Newhall, Sperry, Gawarkiewicz, Fredricks, Tyack, Chiu and Abbot, “Spatial and temporal variations in acoustic propagation characteristics at the New England Shelfbreak front,” *IEEE J. Ocean Eng*., Jan. 2003
- Fredericks, Colosi, and Lynch (2003). “Analysis of multipath scintillations observed during the summer 1996 New England shelfbreak PRIMER study,” Submitted to *IEEE J. Ocean Eng*
- Duda, Lynch, Newhall, Wu, and Chiu (2003). “Fluctuation of 400 Hz sound intensity in the 2001 ASIAEX South China Sea Experiment,” Submitted to *IEEE J. Ocean Eng*
- Chiu, Ramp, Miller, Lynch, Duda and Tang (2003). “Acoustic intensity fluctuations induced by South China Sea internal tides and solitons,” Sub. to *IEEE J. Ocean Eng*
- G. Gawarkiewicz, F. Bahr, K. Brink, R. Beardsley, M. Caruso, J. Lynch, C.-S. Chiu, A large amplitude meander of the shelfbreak front in the Middle Atlantic Bight: Observations from the Summer PRIMER Experiment, *J. Geophys. Res.-Oceans,* (2003) [submitted]
- Sperry, B., J. Lynch, G. Gawarkiewicz, C.-S. Chiu, A. Newhall, “Characteristics of acoustic propagation to the eastern vertical line array receiver during the summer 1996 Shelfbreak PRIMER experiment,” *IEEE J. Oceanic Eng.* (2003). [in press, refereed]
- A. Fredricks, J. Colosi, J. Lynch, G. Gawarkiewicz, C.S.Chiu, and P. Abbot, 2003. Analysis of multipath scintillations observed during the summer 1996 New England shelfbreak PRIMER study. *J. Acoust. Soc. Am*.

Publications (Continued)

- Lermusiaux P.F.J., C.-S. Chiu and A.R. Robinson (2002). Modeling Uncertainties in the Prediction of the Acoustic Wavefield in a Shelfbreak Environment. Proceedings of the 5th ICTCA, May 21-25, 2001, in "Theoretical and Computational Acoustics 2001", E.-C. Shang, Q. Li and T.F. Gao (Eds.), World Scientific Publishing Co., 191-200.
- Lermusiaux, P.F.J., A.R. Robinson, P.J. Haley, Jr. and W.G. Leslie (2002) Advanced Interdisciplinary Data Assimilation: Filtering and Smoothing via Error Subspace Statistical Estimation. *Proceedings of Oceans 2002 IEEE/MITS Conference*, 795-802.
- Robinson, A.R., P.F.J. Lermusiaux, P.J. Haley, Jr. and W.G. Leslie (2002). Predictive Skill, Predictive Capability and Predictability in Ocean Forecasting. *Proceedings of Oceans 2002 IEEE/MITS Conference*, 787-794.
- Robinson, A.R. and W.G. Leslie (2003). Advanced Systems for Operational Ocean Forecasting of Interdisciplinary Fields and Uncertainties, in "Proceedings of the MREP2003 Conference", R. Tyce (editor), SACLANTCEN. [In Press]
- Robinson, A.R. and P.F.J. Lermusiaux (2003). Prediction Systems with Data Assimilation for Coupled Ocean Science and Ocean Acoustics, Proceedings of the Sixth International Conference on Theoretical and Computational Acoustics (A. Tolstoy, et al., editors), World Scientific Publishing. [In press].
- Chiu et al., "Bandwidth dependence of shelf-slope TL statistics," to be submitted to IEEE Journal of Ocean Engineering.
- Lermusiaux and Chiu et al., "Four-Dimensional data assimilation for coupled physical-acoustical fields: Methodology and computational aspects," to be submitted to Journal of Computational Acoustics.
- Lermusiaux and Chiu et al., "Four-Dimensional data assimilation for coupled physical-acoustical fields: Application to Shelfbreak PRIMER data," to be submitted to IEEE Journal of Ocean Engineering.

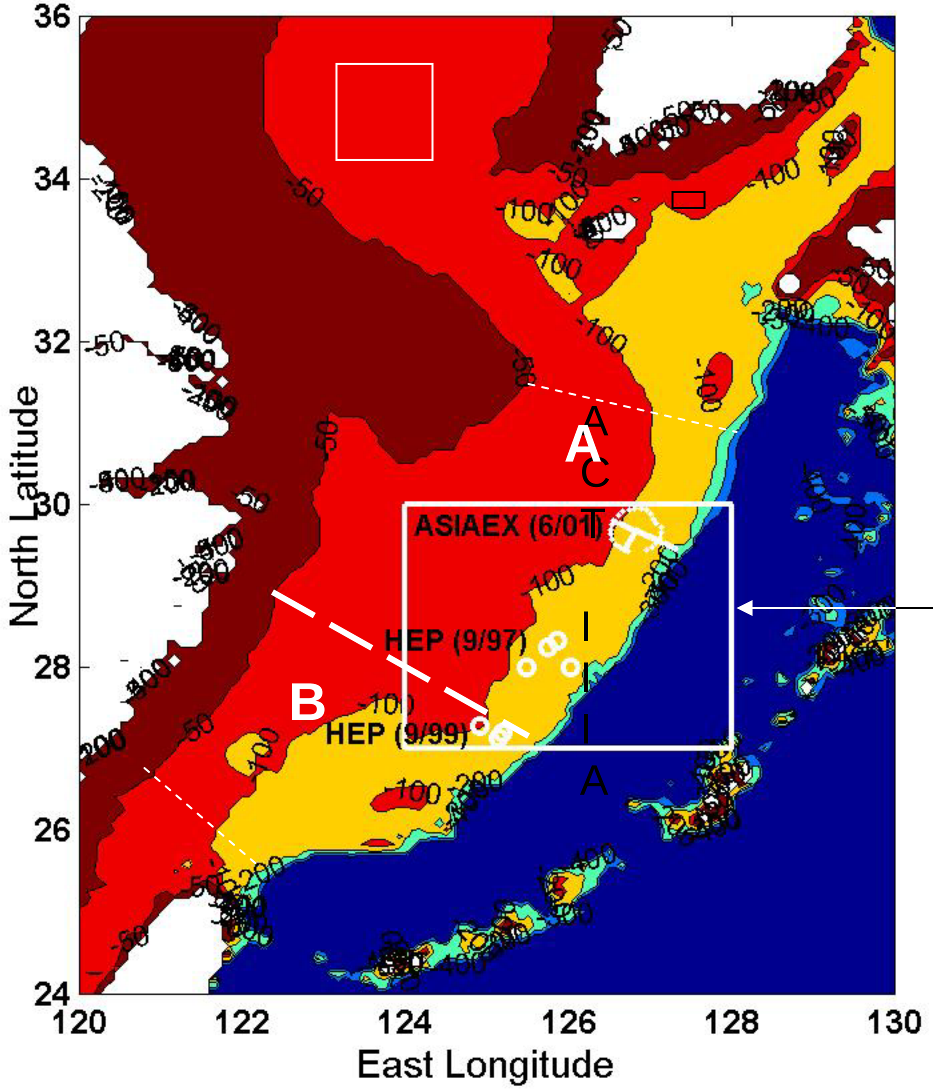
East China Seas TL Provinces for Performance Prediction (Preliminary)

A (Red/Yellow): 50 to 200m

B (Red/Yellow): Outcrops

C (Green): Slopes

D (Blue): Deep



ASIAEX
HEP 97
HEP 99

ECS TL Province Example: Elements of Performance Prediction (Earliest Stages)

Province	Description/ Depth	μ_{TL}	σ_{TL}	Oceanographic Effects	Bottom Effects	TL Data/ Models
A	SW - 50 to 200 m	Horizontally Isotropic	Small	IW effects anomolous[1]	Sedimentary layers of varying thickness[2]	1 X 2D
B	SW - 50 to 200 m	Horizontally Anisotropic	Large (if bearings aggregated)	IW effects anomolous[1]	Large scale ridges, sedimented river beds/ depressions[2]	N X 2D
C	Continental Slopes: 200m to Deep Water	Horizontally Anisotropic	Large (if bearings aggregated)	IW and ocean volume[3] effects anomolous	Large scale ridges, sedimented canyons, other depressions[2]	N X 2D
D	Deep Water	Horizontally Isotropic	Small	Traditional Effects	Traditional Effects	1 X 2D

1 IWs give rise to large anisotropic anomalies in μ_{TL} and σ_{TL} requiring 3D data/models.
2 Based on highly resolved bottom/subbottom profiles.
3 Fronts, jets
Note: fish school effects also give rise to important scattering (ONR NJ Coast data)