Acoustic Mine Detection Using the Navy' CASS/GRAB Model

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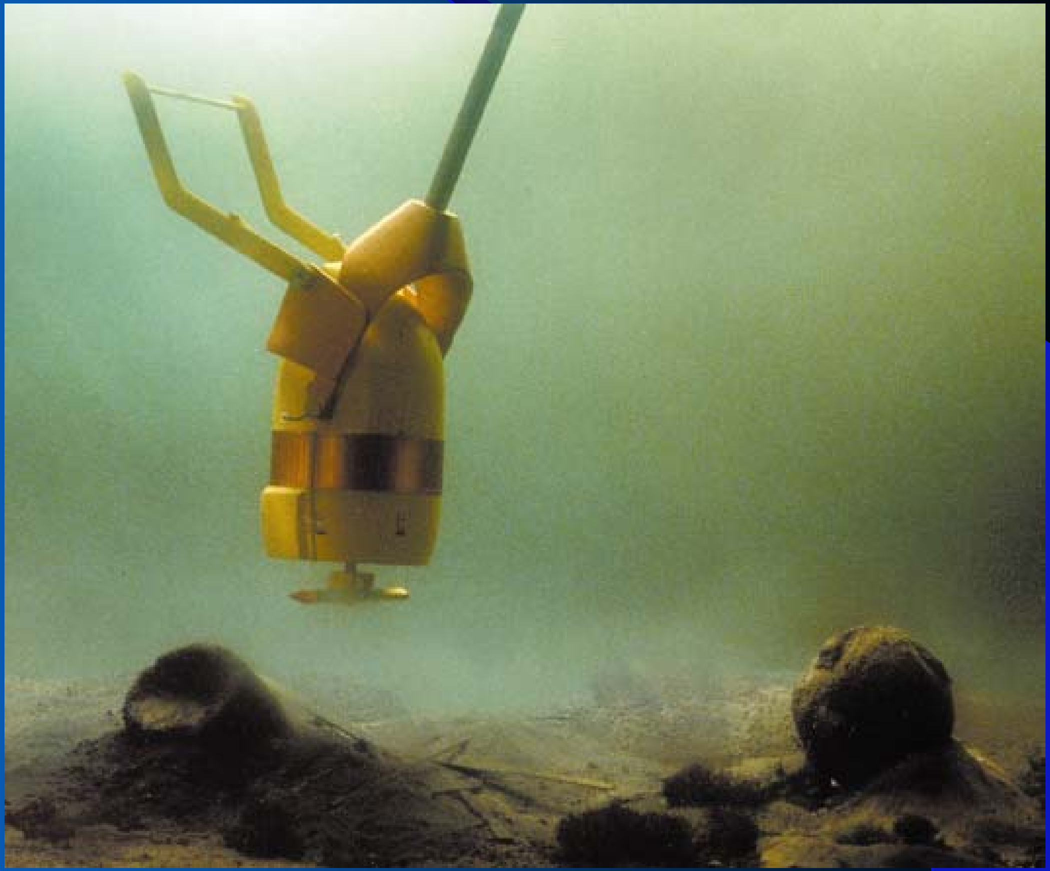
Purposes

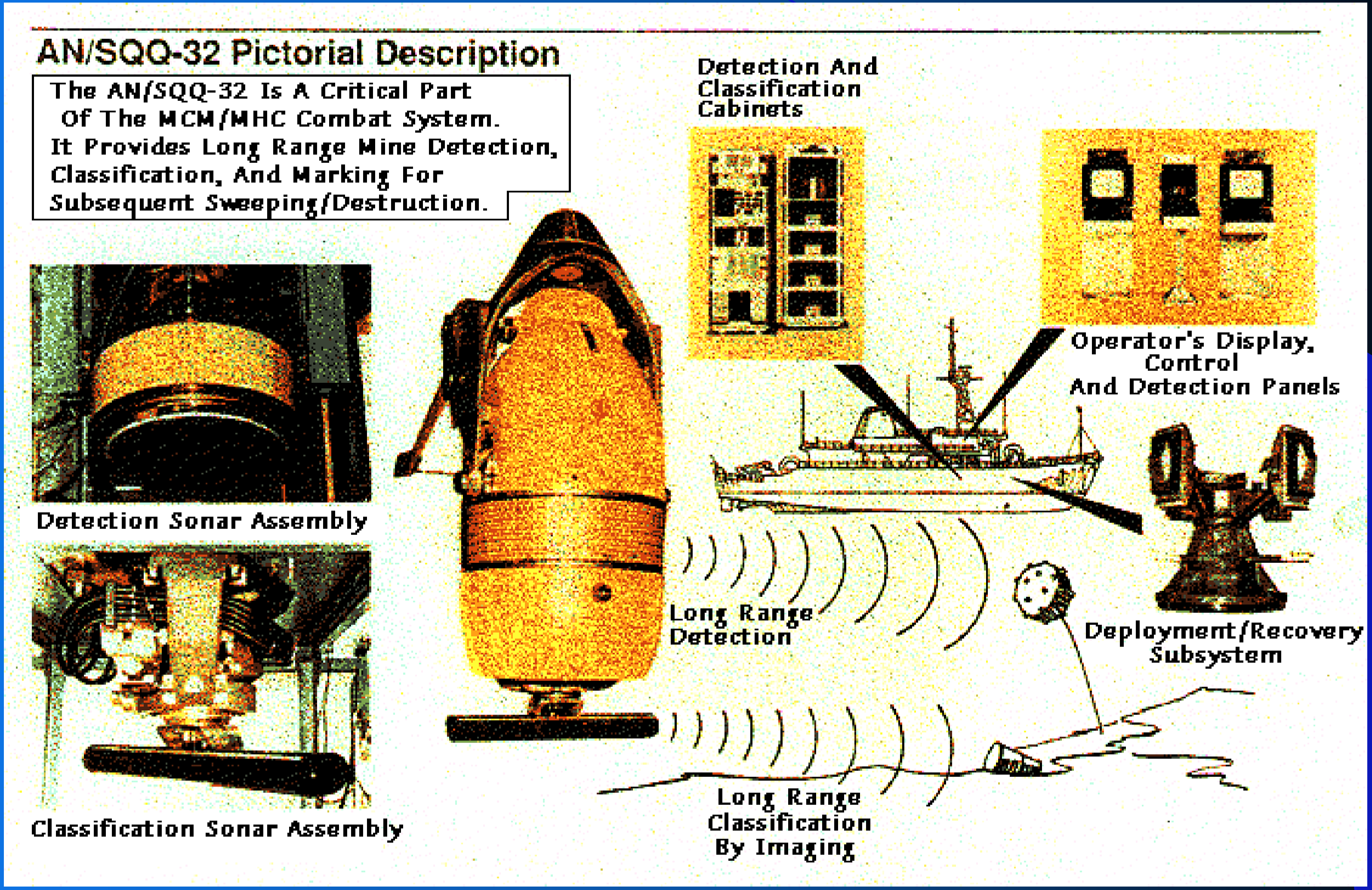
- Determine the necessity of a near real time ocean modeling capability such as MODAS for mine hunting applications in shallow water regions.
- Determine the acoustic uncertainty caused by environmental uncertainty.

AN/SQQ-32 Mine Hunting Sonar System

- The CASS/GRAB acoustic model input file used in this study was designed to simulate the Acoustic Performance of the AN/SQQ-32.
- The AN/SQQ-32 is the key mine hunting component of the U.S. Navy's Mine Hunting and Countermeasure ships.

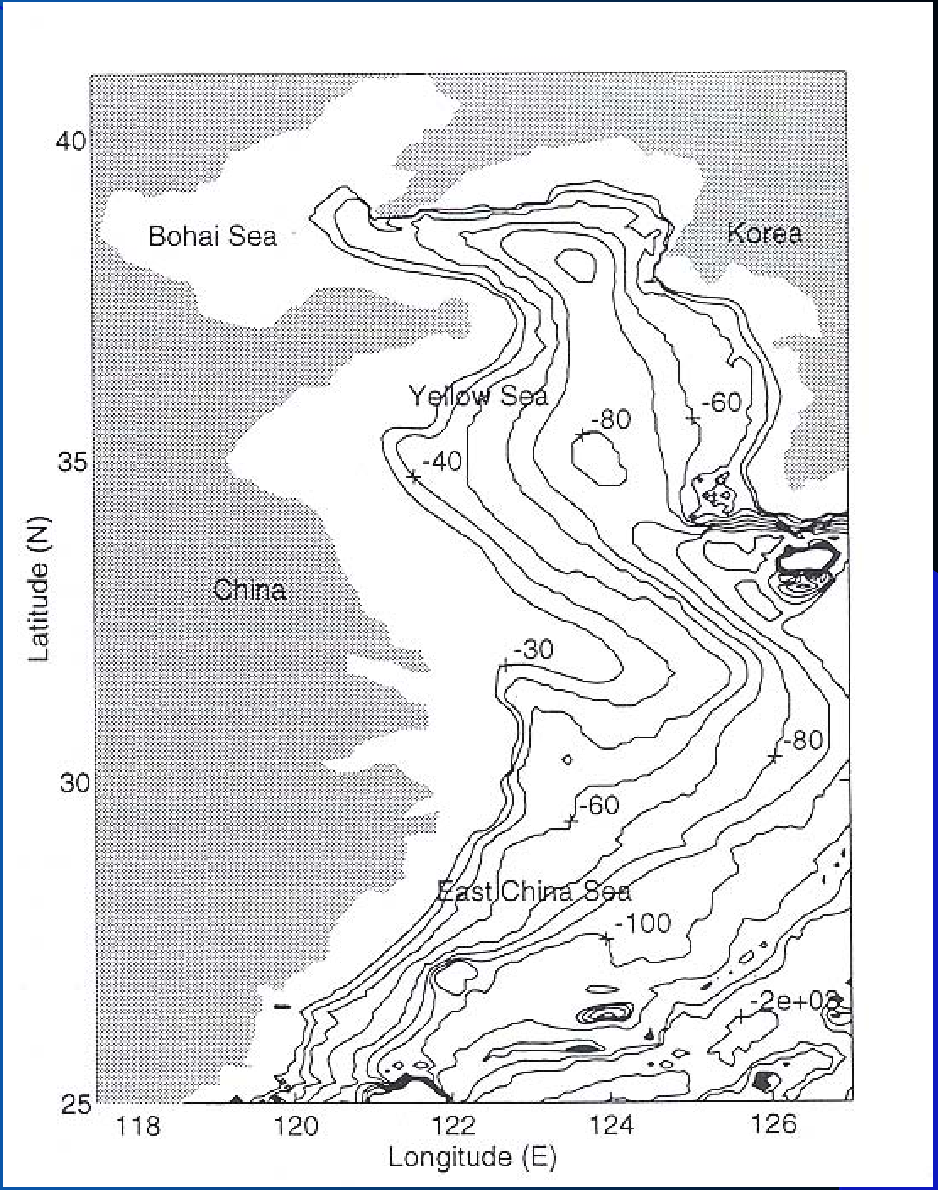


Detection Sonar and Classification Sonar Assembly



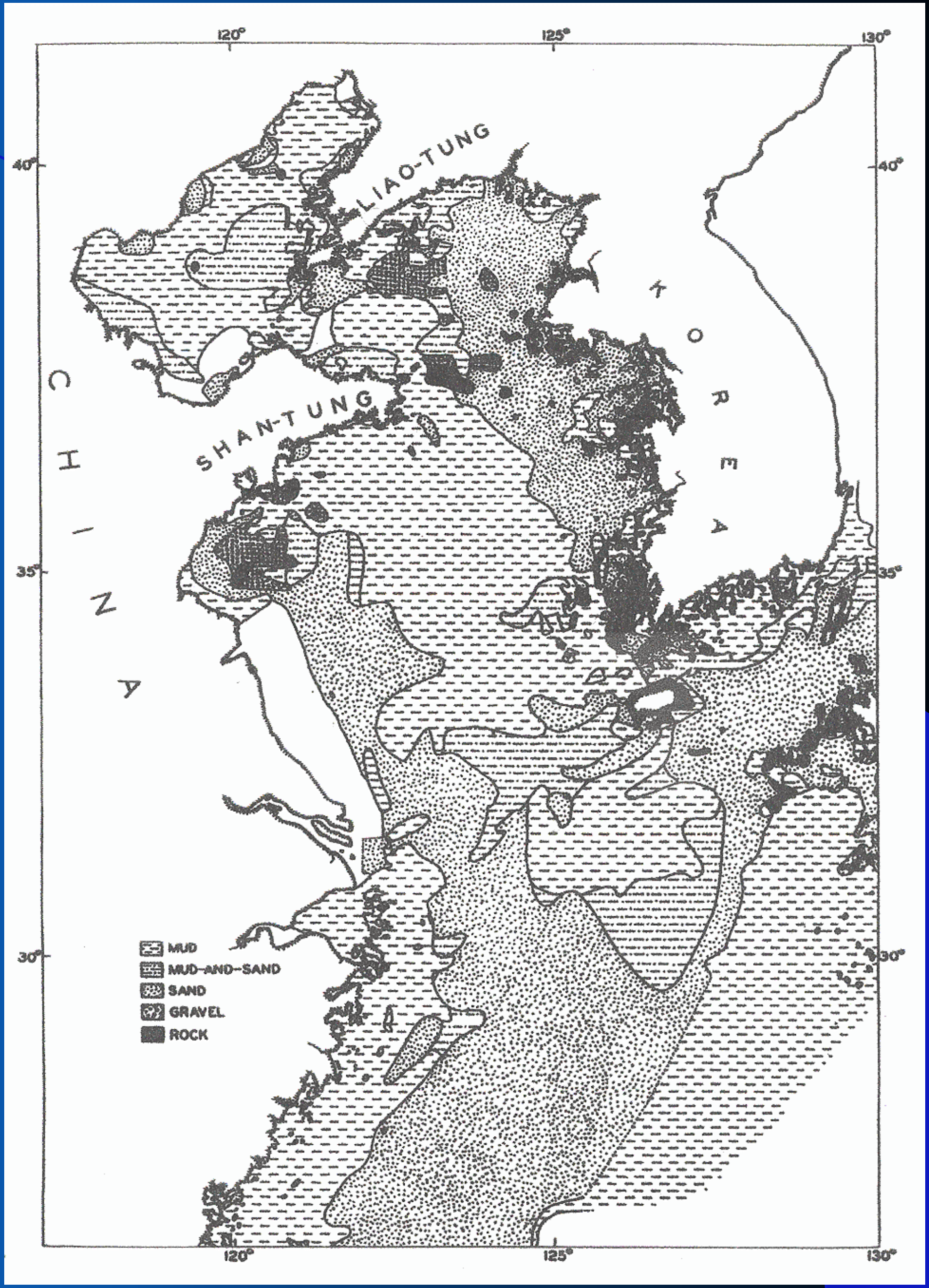
Yellow Sea Bottom Topography

- Water depth in most of the region is less than **50 m**.
- Within 50 km of the Korean coastline the average water depth is **20 m**.



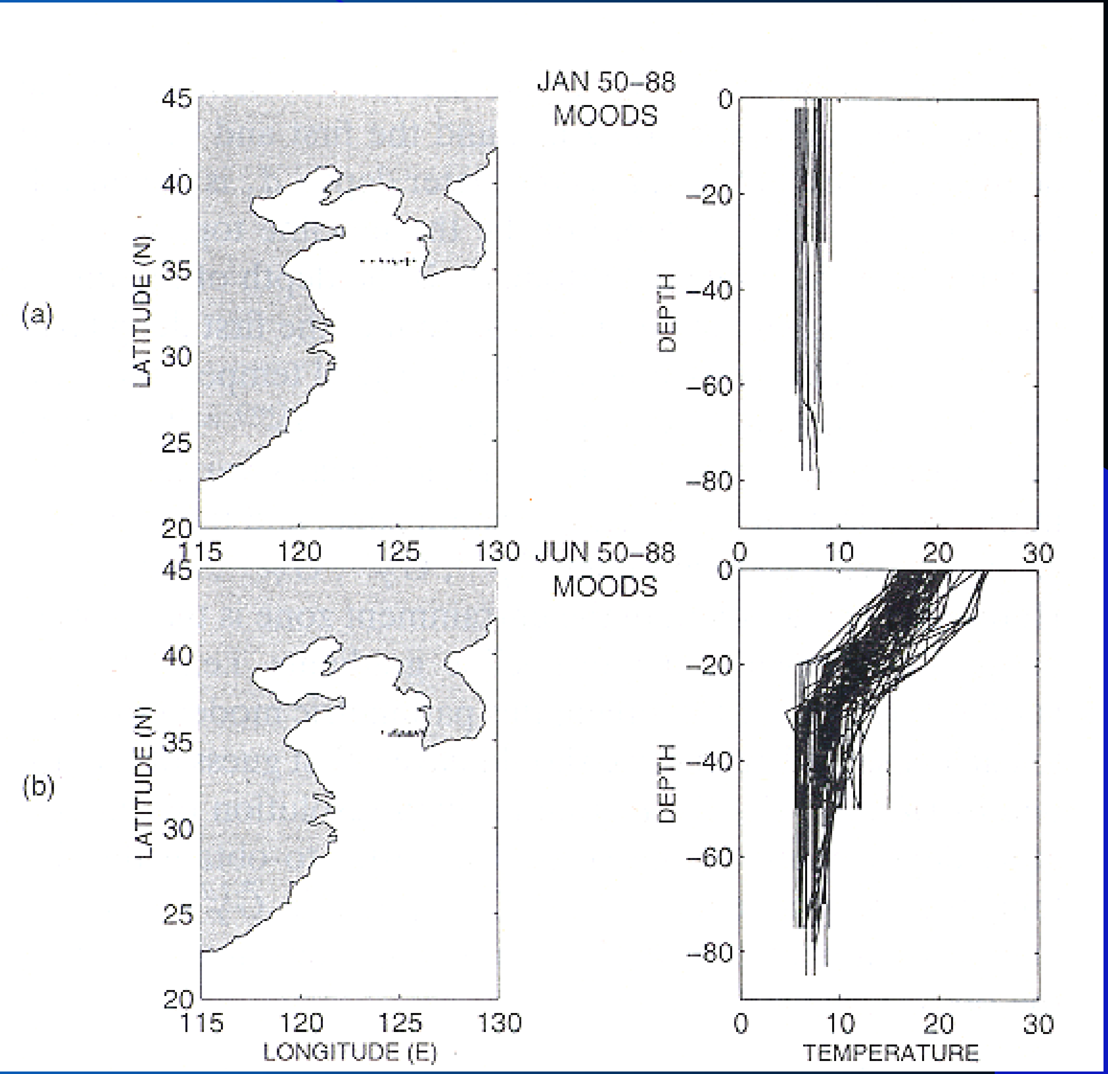
Yellow Sea Bottom Sediment Chart

- Four Bottom Sediment types were chosen for this Study
  1. **Mud**
  2. **Sand**
  3. **Gravel**
  4. **Rock**



Seasonal Temperature Profile Structures

- (a) Winter and Fall Temperature Profile Structure.
  - Isothermal
- (b) Spring and Summer Temperature Profile Structure.
  - Multi-layer
    - Mixed layer
    - Thermocline
    - Deep Layer

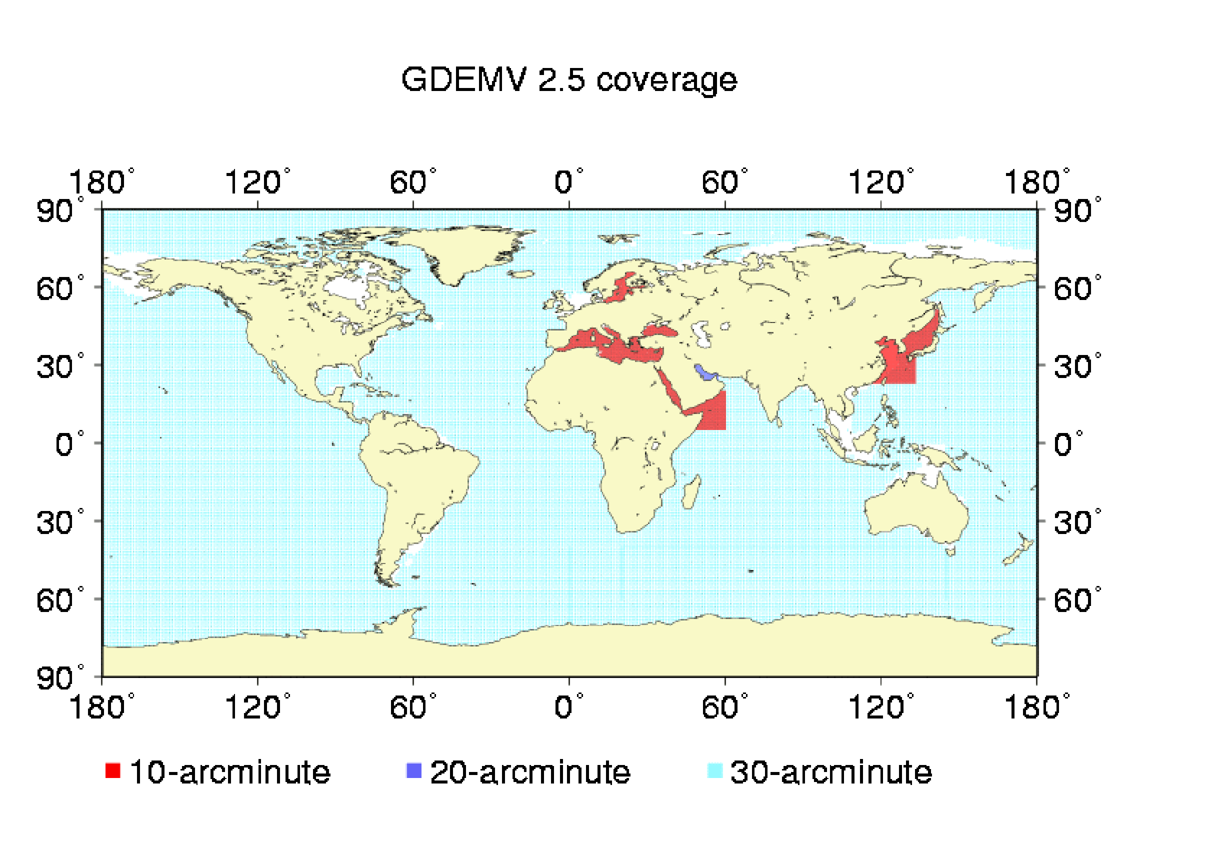


Oceanographic Data Sets

- Master Oceanographic Observational Data Set (MOODS)
- Generalized Digital Environmental Model (GDEM)
- Modular Ocean Data Assimilation System (MODAS)

Generalized Digital Environmental Model (GDEM)

- Gridded Climatological Data derived from MOODS.
- Global GDEM has a 30’ resolution
- U.S. Navy’s Operationally important areas contain resolutions of 20’ and 10’.
- Contains 3, 6, and 12 month data sets.



Modular Ocean Data Assimilation System (MODAS)

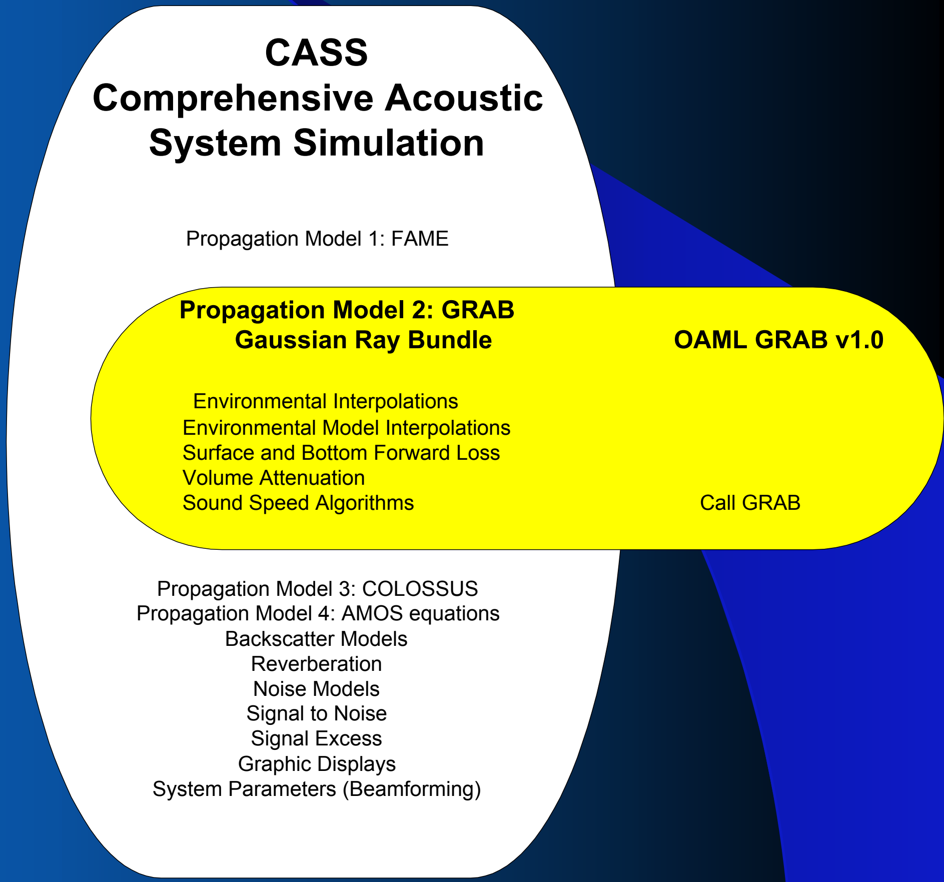
- Climatological MODAS (Static)
  - Gridded Climatological Data derived from MOODS
- Near real time Synthetic MODAS (Dynamic)
  - Inputs Satellite SST and SSH into Climatology via model algorithms to produce synthetic Temperature and Salinity fields which are in turn used to produce 3-Dimensional Sound Speed Fields.
- MIODAS becomes degraded in shallow water regions because SSH is not entered into the model.
    - Altimetry is not entered into the MODAS model in waters less the 150 m due to satellite orbit errors and other model corrections which amplify the error levels near land.

Comprehensive Acoustic Simulation System/Guassian Ray Bundle (CASS/GRAB)

- CASS/GRAB is an active and passive range dependent propagation, reverberation, and signal excess acoustic model that has been accepted as a Navy Standard for the frequency bands of 600 Hz to 100 kHz.

CASS/GRAB Model Description

- The CASS model is the range dependent improvement of the Generic Sonar Model (GSM). CASS performs signal excess calculations.
- The Grab model is a subset of the CASS model and its main function is to compute eigenrays and propagation loss as inputs in the CASS signal excess calculations.

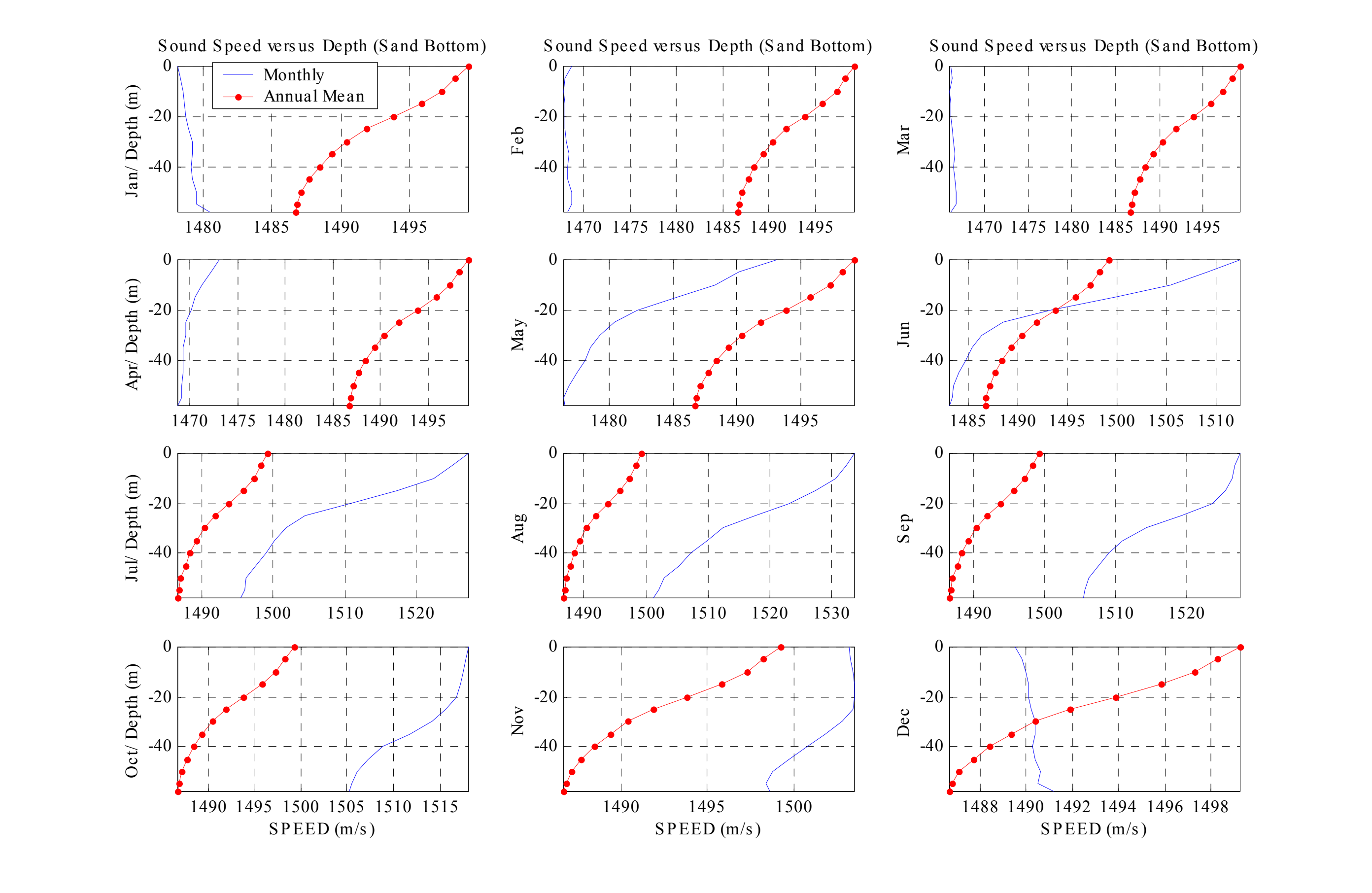


Comprehensive Acoustic Simulation System/Guassian Ray Bundle (CASS/GRAB)

- In the GRAB model, the travel time, source angle, target angle, and phase of the ray bundles are equal to those values for the classic ray path.
- The main difference between the GRAB model and a classic ray path is that the amplitude of the Gaussian ray bundles is global, affecting all depths to some degree whereas classic ray path amplitudes are local. GRAB calculates amplitude globally by distributing the amplitudes according to the Gaussian equation

$$\Psi_\nu = \frac{\beta_{\nu,0}\Gamma_\nu^{\ 2}}{\sqrt{2\pi}\,\sigma_\nu\, p_{r,\nu}\, r}\exp\left\{-0.5\left[(z - z_\nu)/\sigma_\nu\right]^2\right\}$$

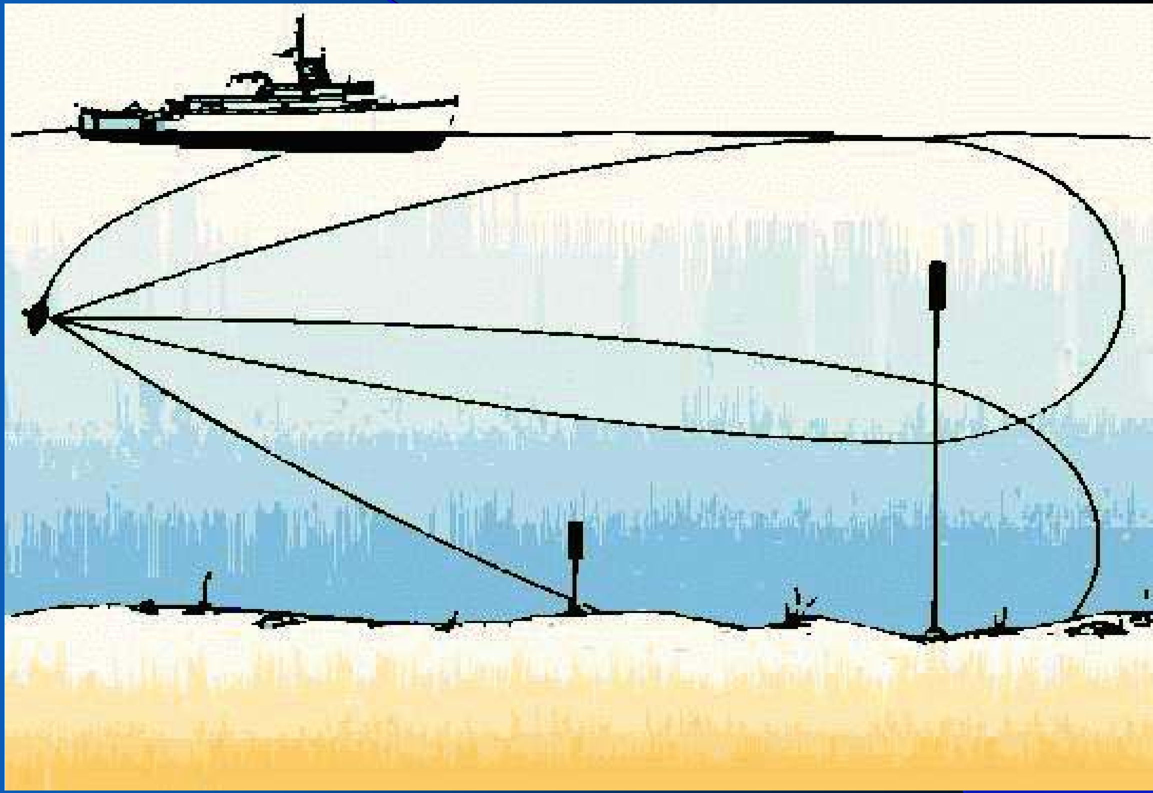
Monthly and Annual Mean Sound Speed (35ºN, 123ºE)



- Sound Speed profiles transition from Isotherm in the winter to Multi-layer in the Summer

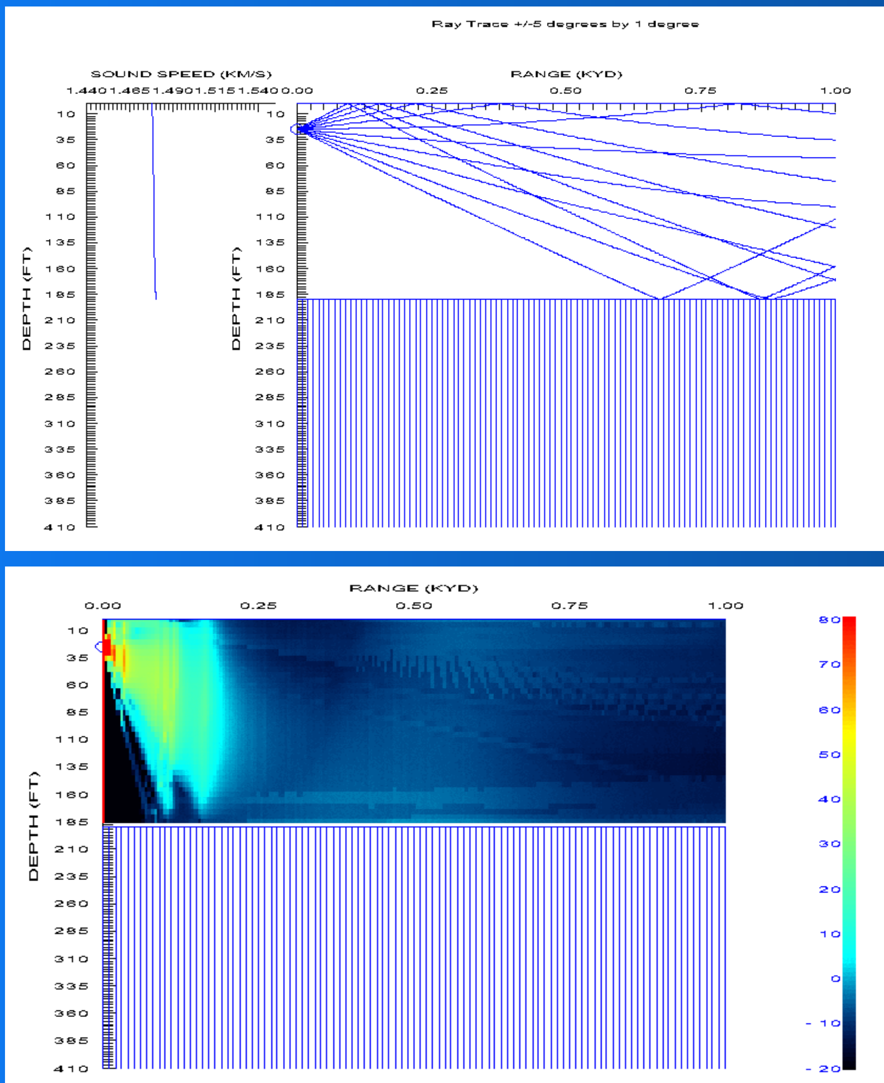
AN/SQQ-32 Concept

- Variable depth high frequency sonar system
  - Sonar can be place at various positions in the water column to optimize the detection of either a moored or bottom mines.
- In complimenting the AN/SQQ-32 mine hunting sonar system concept in this Study
  - Two source depths were chosen.
    - **25 ft** (Above the thermocline if present)
    - **125 ft** (Within or below the thermocline if present)

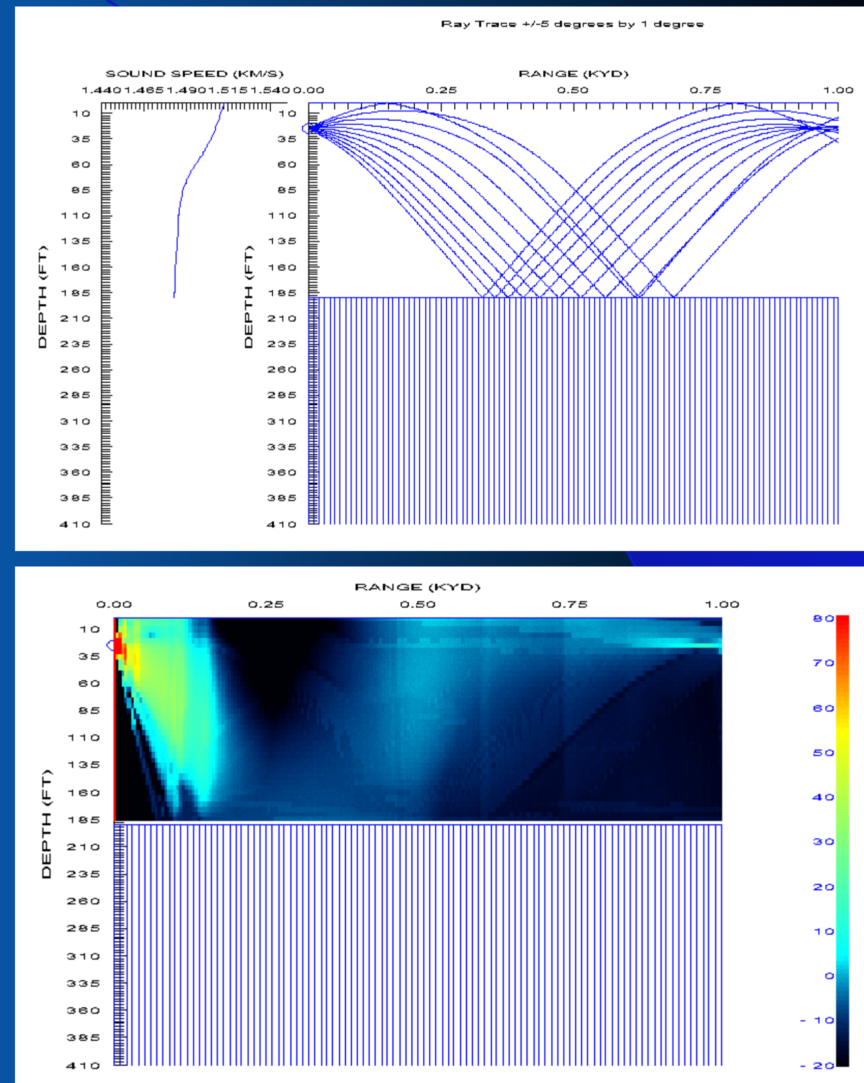


GDEM Seasonal Variability for Signal Excess

GDEM /January/ Sand/ SD = 25 ft

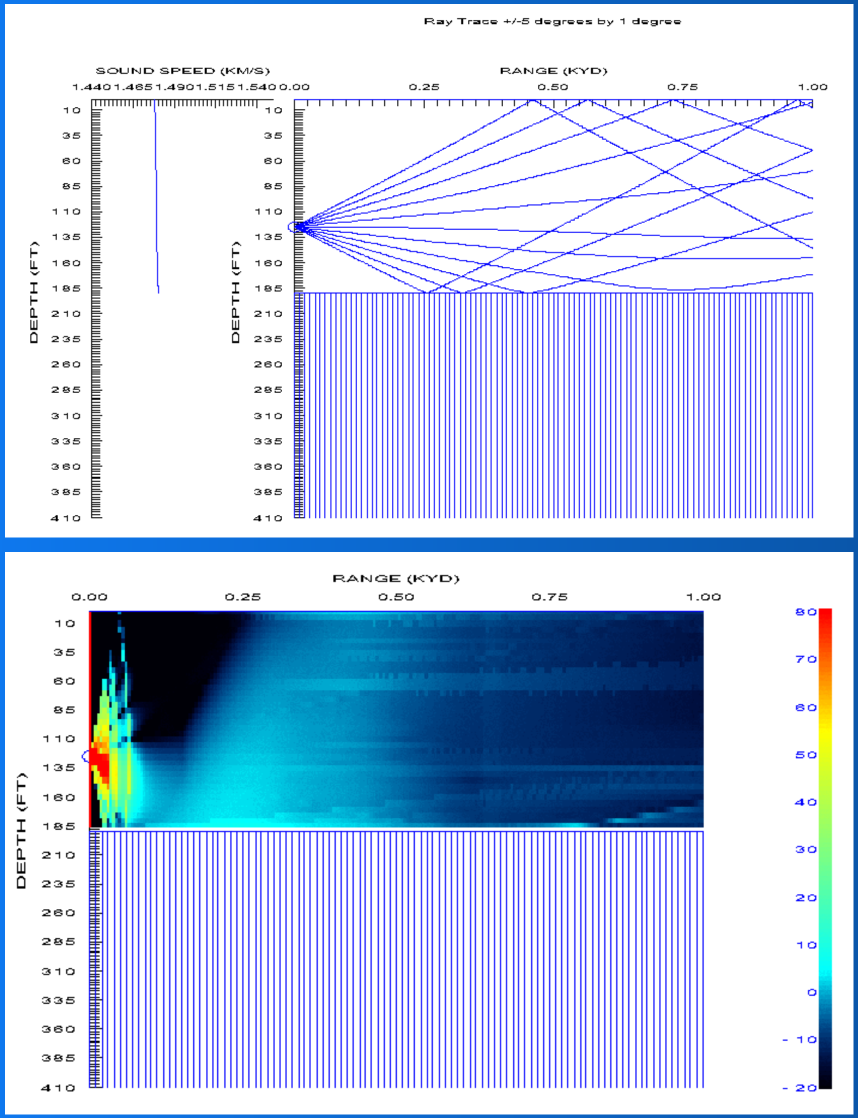


GDEM /June/ Sand/ SD = 25 ft

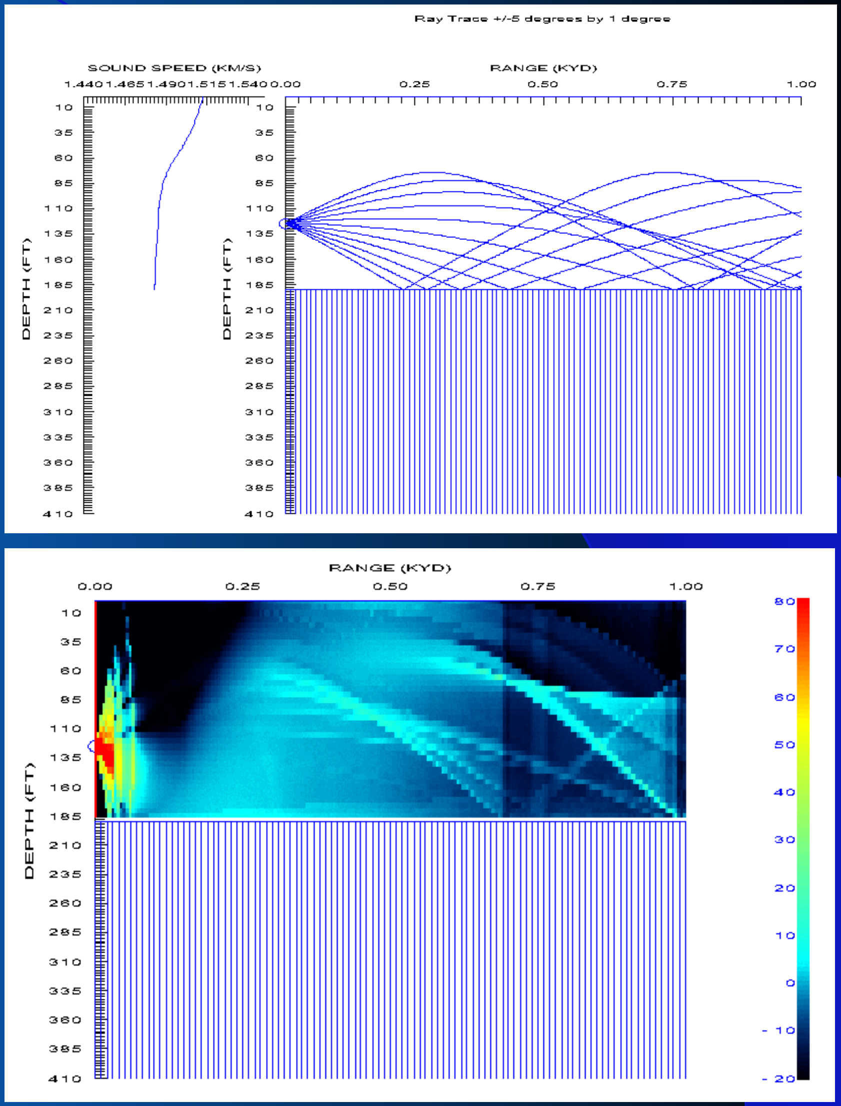


GDEM Seasonal Variability for Signal Excess

GDEM /January/ Sand/ SD = 125 ft

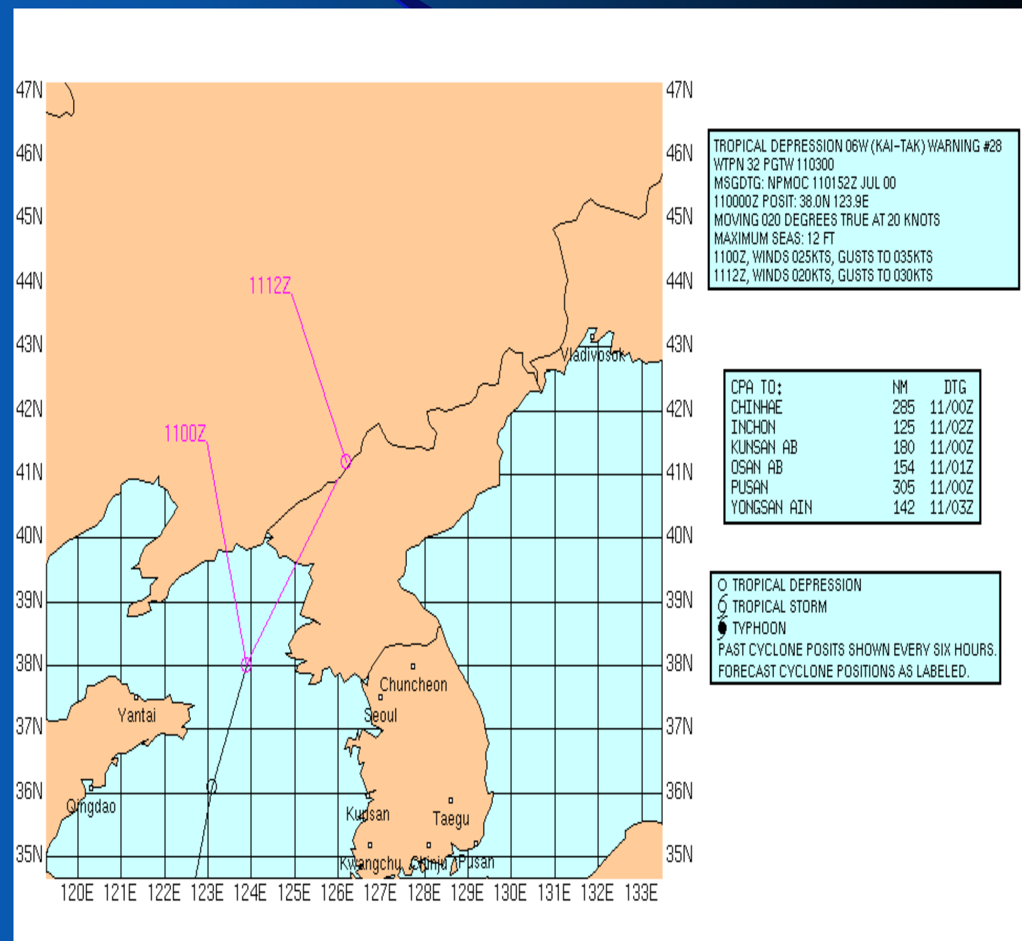


GDEM /June/ Sand/ SD = 125 ft



Acoustic Transmission Under Severe Weather Events

- Track of Tropical Depression Kai-Tak over the Yellow Sea for 7-11 July 2000

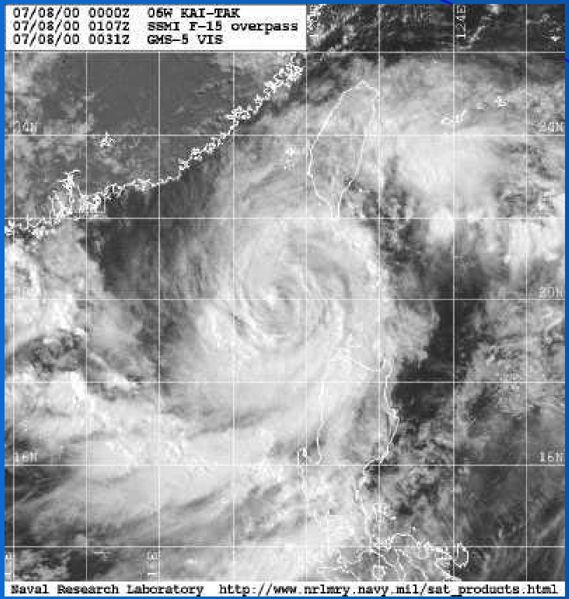


Significant Acoustic Differences in detection ranges as Defined by the Mine Warfare Community

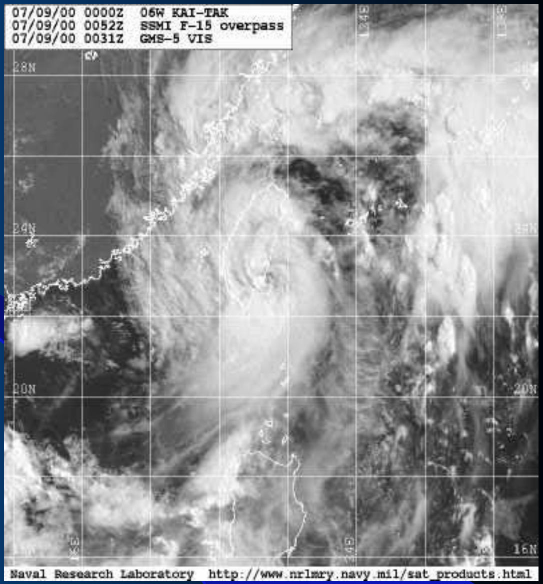
A Significant Acoustic Differences in detection ranges as Defined by the Mine Warfare Community:	
Position of Detection ranges of Mine relative to Source	A significant Acoustic Difference exists if:
If Both Detection Ranges are less than 600 yards	$|\Delta$ Detection Ranges$|$ > 100 Yds
If either of The Detection Ranges are greater than or equal to 600 yards	$|\Delta$ Detection Ranges$|$ > 200 Yds

Satellite Images of Tropical Depression Kai-Tak

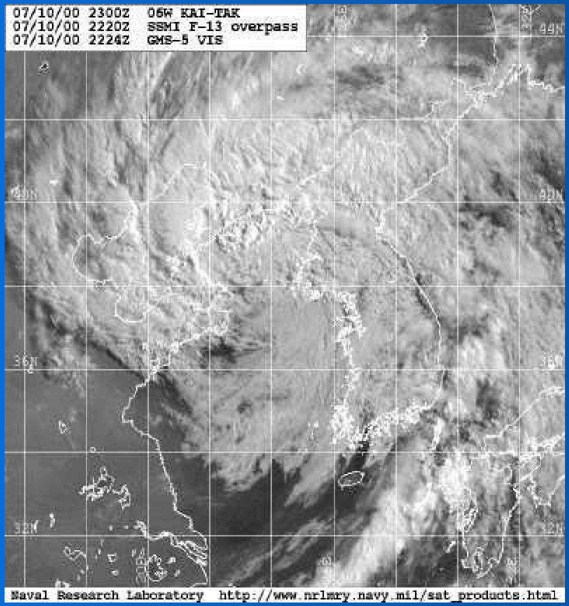
July 8, 2000
Tropical Cyclone over the East China Sea



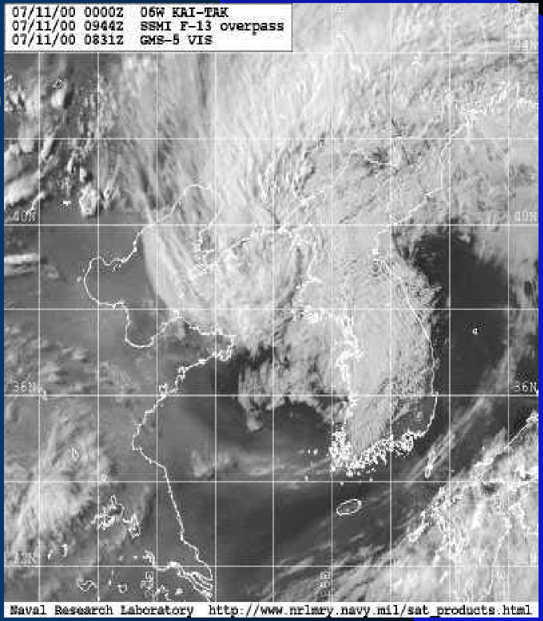
July 9, 2000
Tropical Cyclone over the Northern East China Sea



July 10, 2000
Tropical Depression over the Yellow Sea



July 11, 2000
Tropical Depression over the Northern Yellow Sea

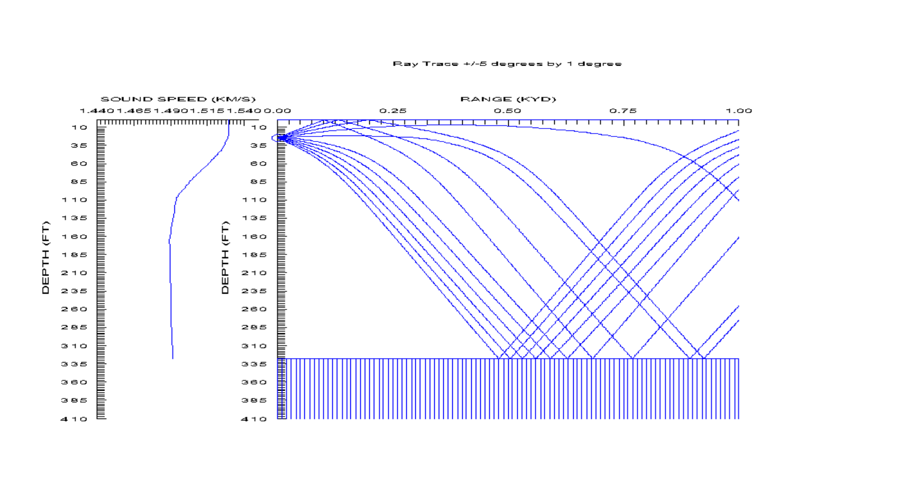


Ray Traces of Profiles with Significant Acoustic Differences

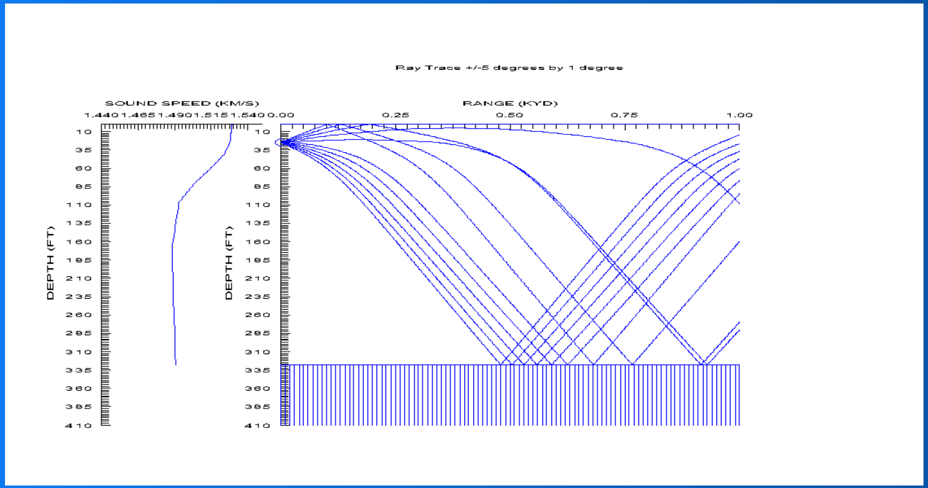
Moored Mine

Source Depth = 25 ft

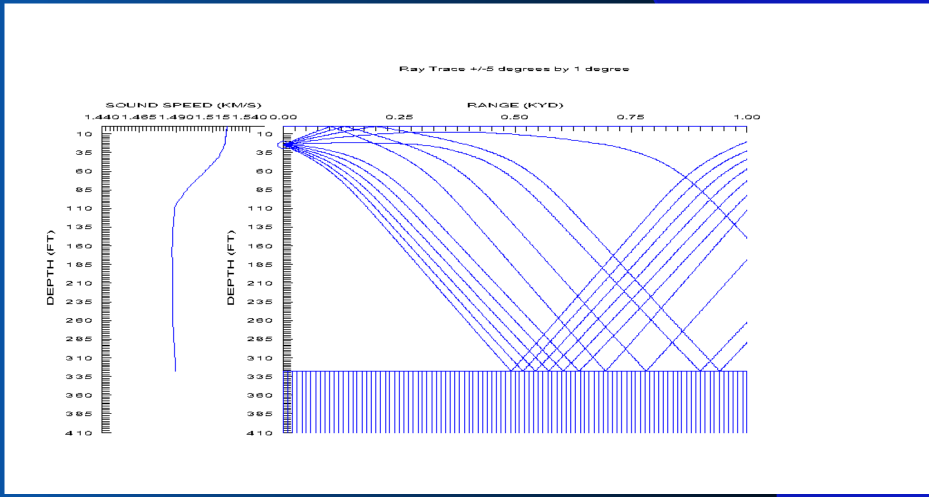
July 7, 2000/ Mud



July 10, 2000/ Mud



July 15, 2000/ Mud

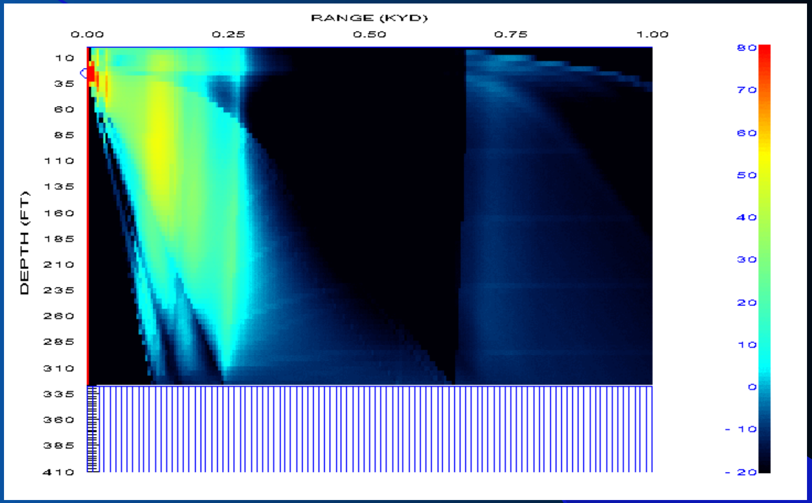


Signal Excess Contours of Profiles with Significant Acoustic Differences

Moored Mine

Source Depth = 25 ft

July 7, 2000/ Mud



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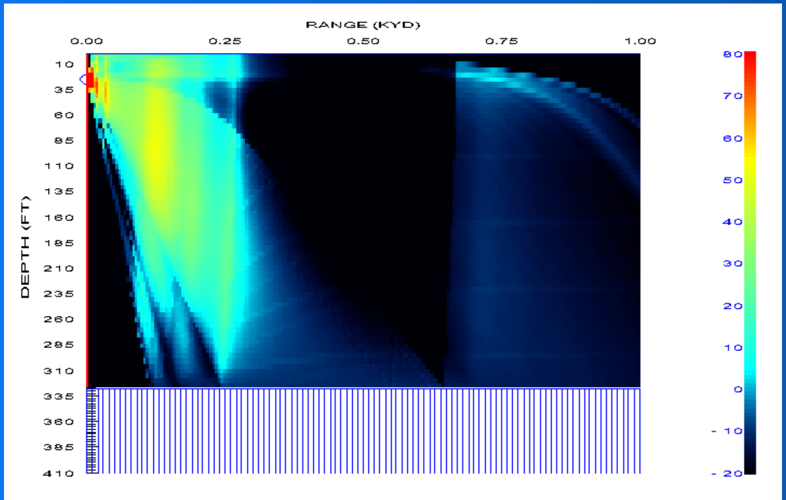
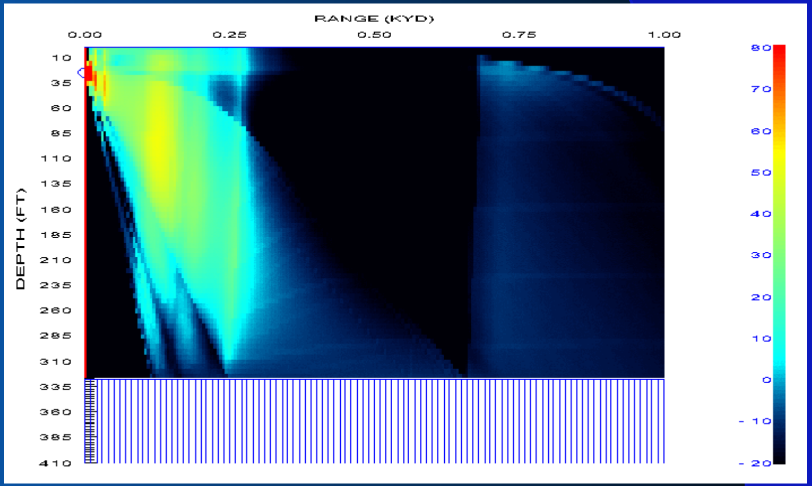


July 15, 2000/Mud



Maximum Significant Acoustic Difference in detection ranges for MODAS before and after the Tropical Depression During July 7-15, 2000 (SD =25ft)

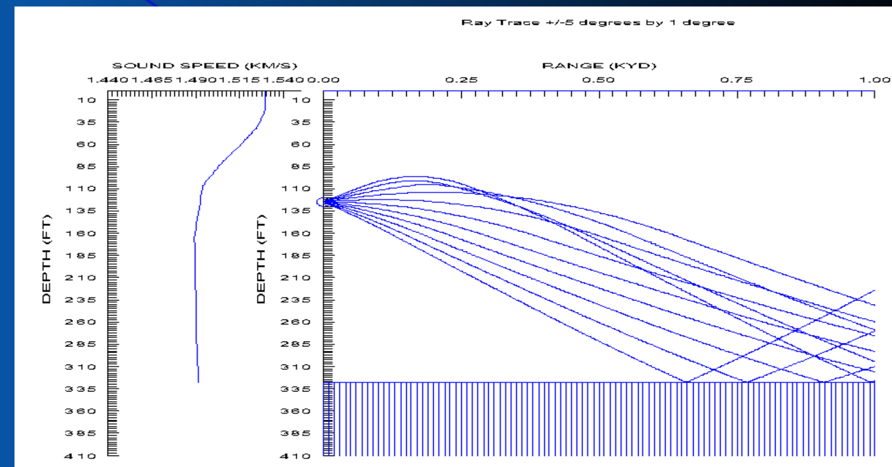
Target Depth	Source Depth = 25 ft			
	Mud		Sand	
	July 10 – July 7	July 15 – July 10	July 10 – July 7	July 15 – July 10
26 ft	Lat 36.5N Lon 124.0E -490 yds	Lat 36.5N Lon 124.0E -490 yds	Not Evident	Not Evident
Bottom	Not Evident	Not Evident	Not Evident	Not Evident

Ray Traces of Profiles with Significant Acoustic Differences

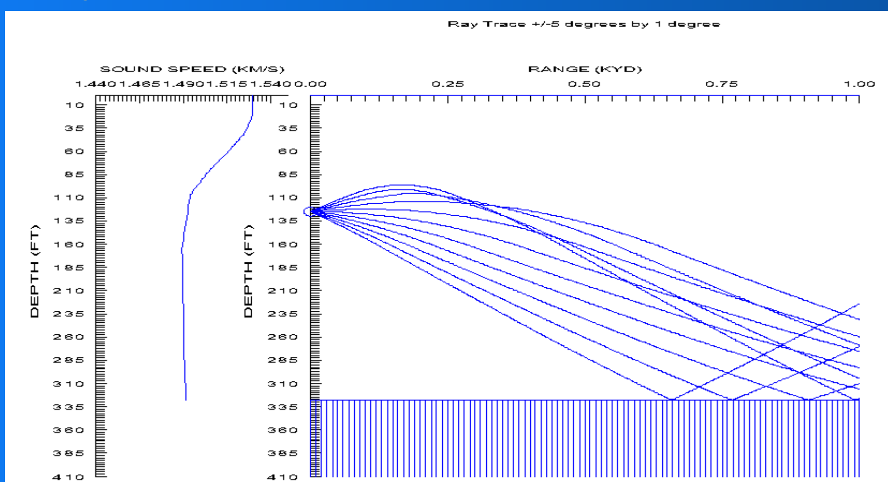
Bottom Mine

Source Depth = 125 ft

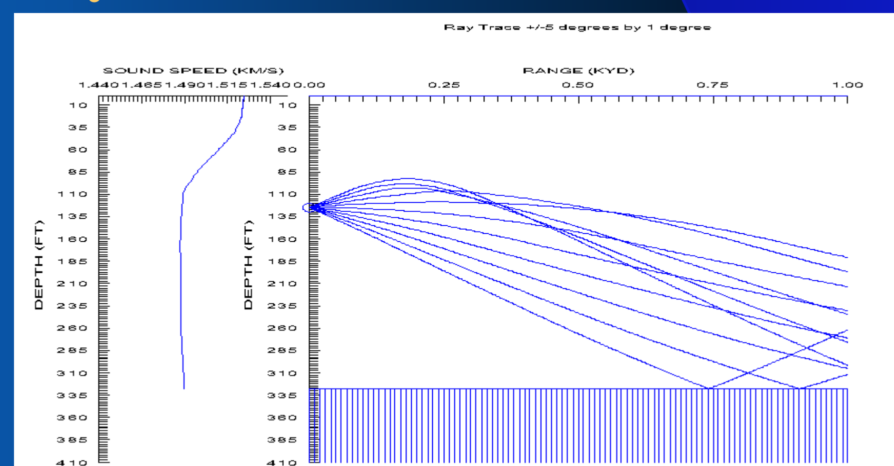
July 7, 2000/Mud



July 10, 2000/ Mud

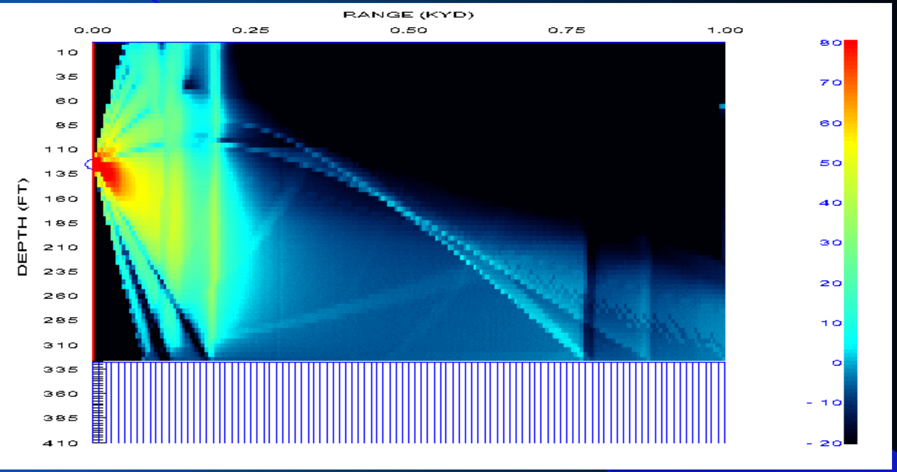


July 15, 2000/Mud



Signal Excess Contours of Profiles with Significant Acoustic Differences

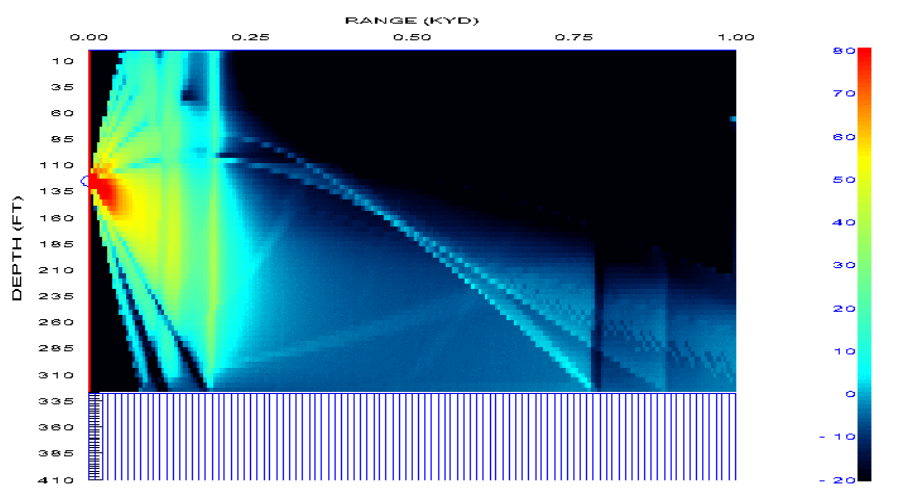
July 7, 2000/Mud/



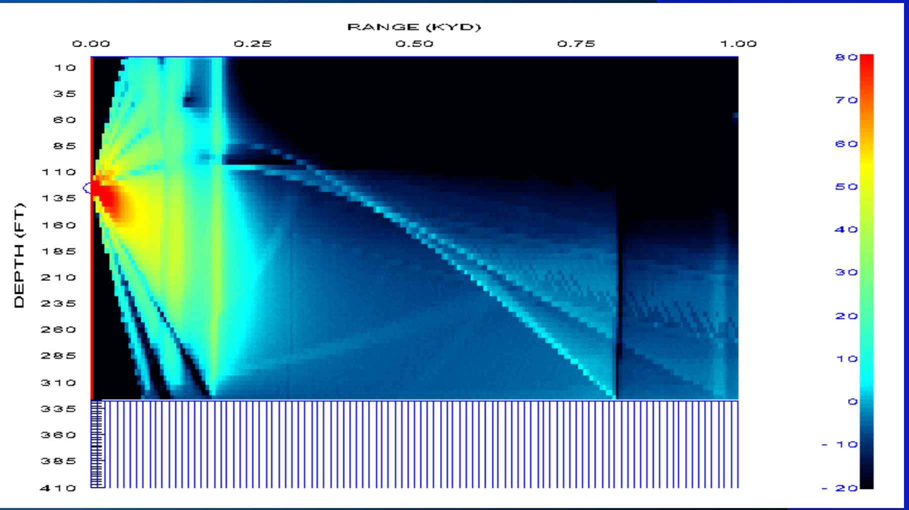
Bottom Mine

Source Depth = 125 ft

July 10, 2000/ Mud/



July 15, 2000/Mud/

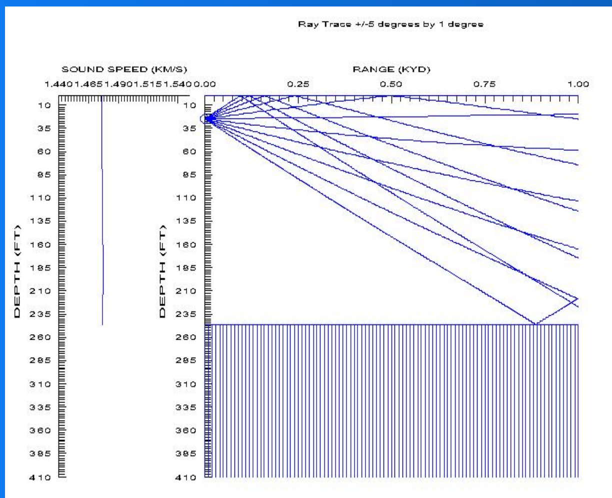


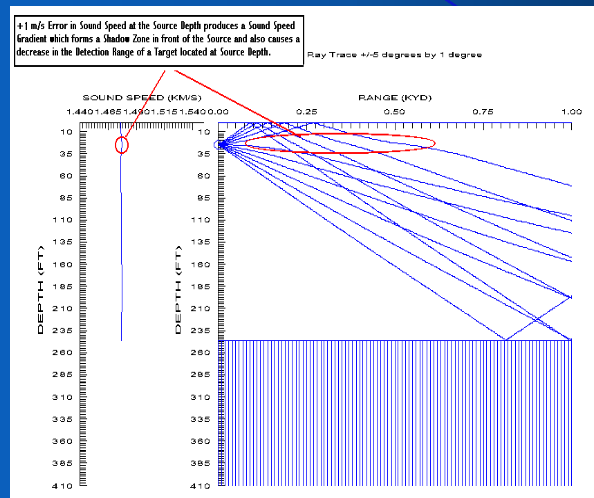
Maximum significant acoustic difference in detection ranges for MODAS before and after the Tropical Depression during July 7-15, 2000 (SD=125ft)

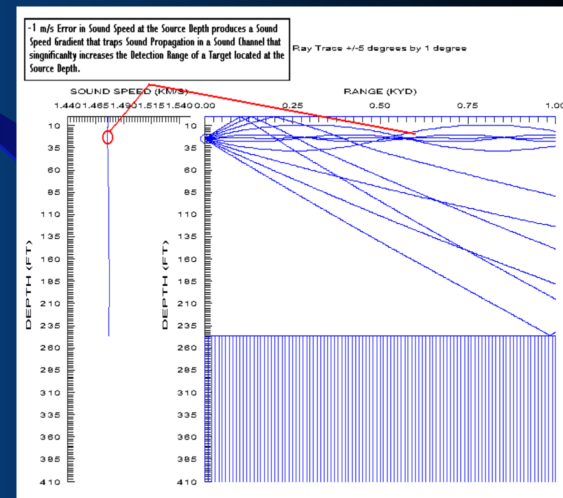
Target Depth	Source Depth = 125 ft			
	Mud		Sand	
	July 10 – July 7 2000	July 15 – July 10 2000	July 10 – July 7 2000	July 15 – July 10 2000
26 ft	None	None	None	None
Bottom	Lat 36.5N Lon 124.0E -790 yds	Lat 36.5N Lon 124.0E -810 yds	None	None

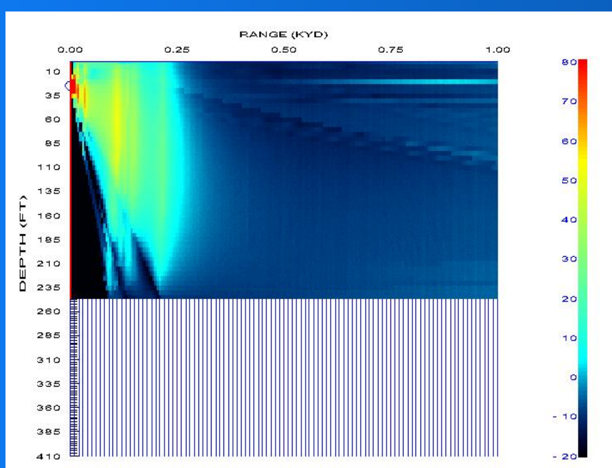
Effect of Sound Speed Error at Source Depth

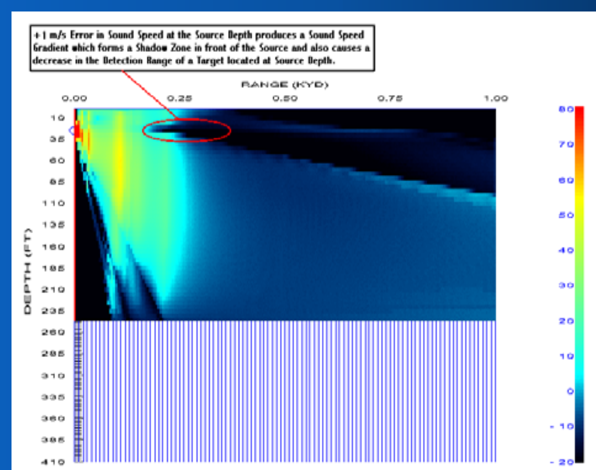
No Error | +1 m/s Error | -1 m/s Error

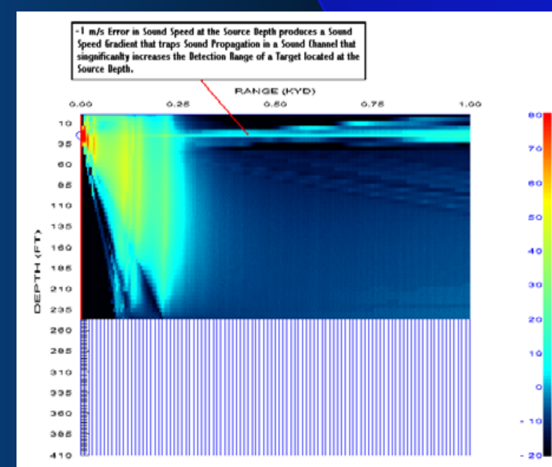












Conclusion

- Capability of CASS/GRAB model
- Strong seasonal variability in acoustic transmission (detection range, signal excess)
- Effect of the tropical cyclone on acoustic transmission
- Acoustic transmission sensitive to ocean environment

Future Work

- There is no synchronized environmental (T, S, SS) and acoustic transmission data set especially for high frequency SONAR (MIW).
- We need develop some experiments analogous to Asian Acoustic Experiment (ASIAEX) using high frequency.