

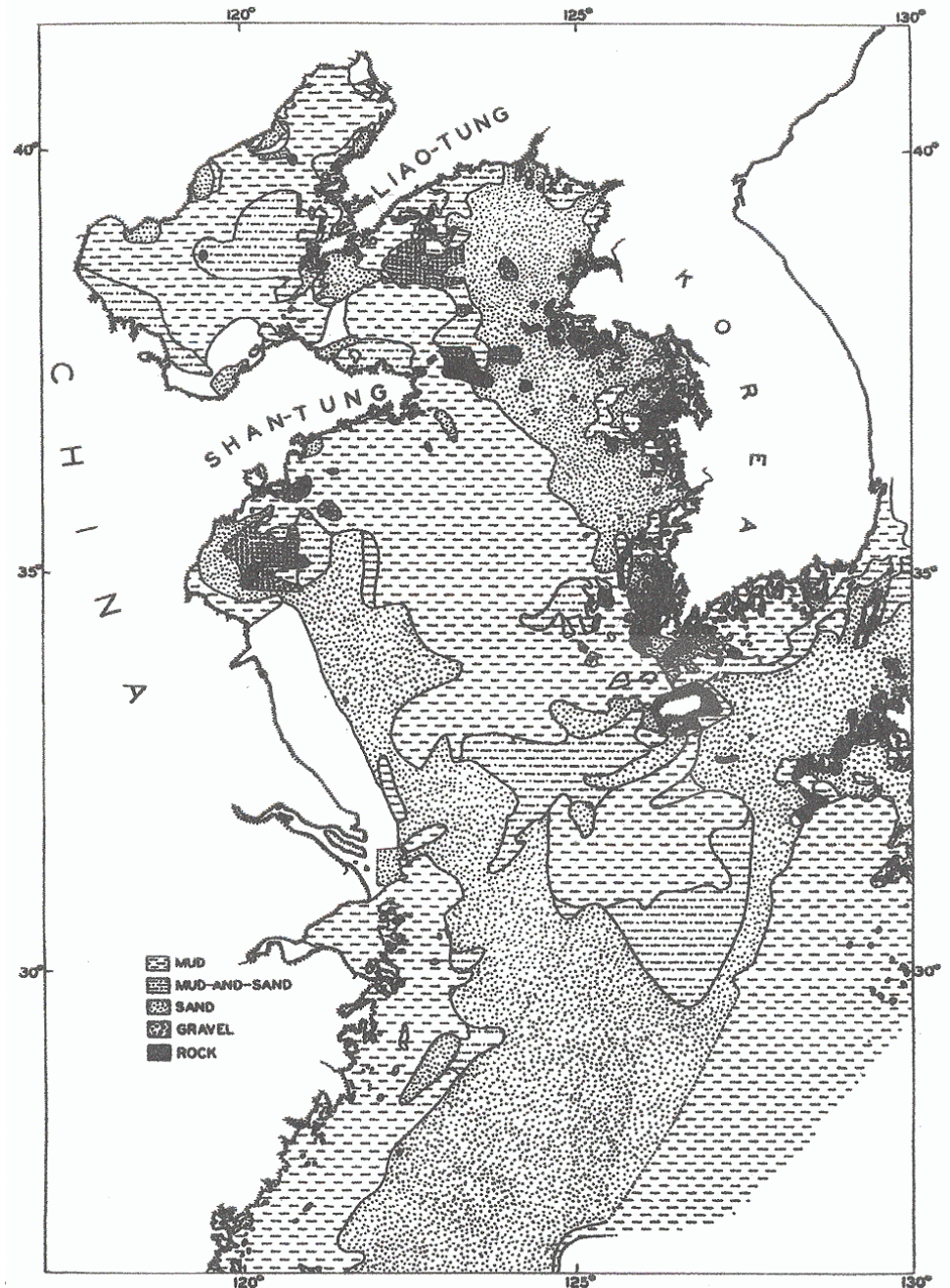
# Yellow Sea Thermohaline and Acoustic Variability

**Peter C Chu, Carlos J. Cintron**  
**Naval Postgraduate School, USA**  
**Steve Haeger**  
**Naval Oceanographic Office, USA**

# Yellow Sea Bottom Sediment Chart

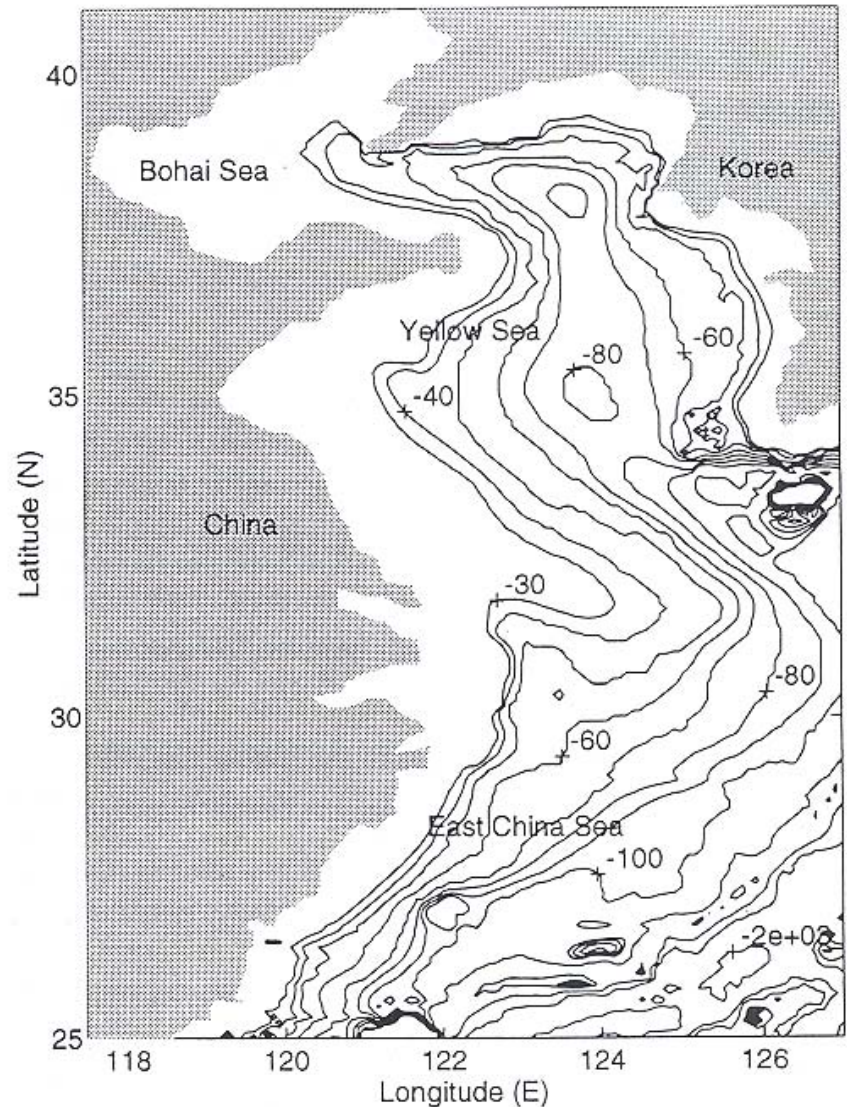
- Four Bottom Sediment types

1. Mud
2. Sand
3. Gravel
4. Rock

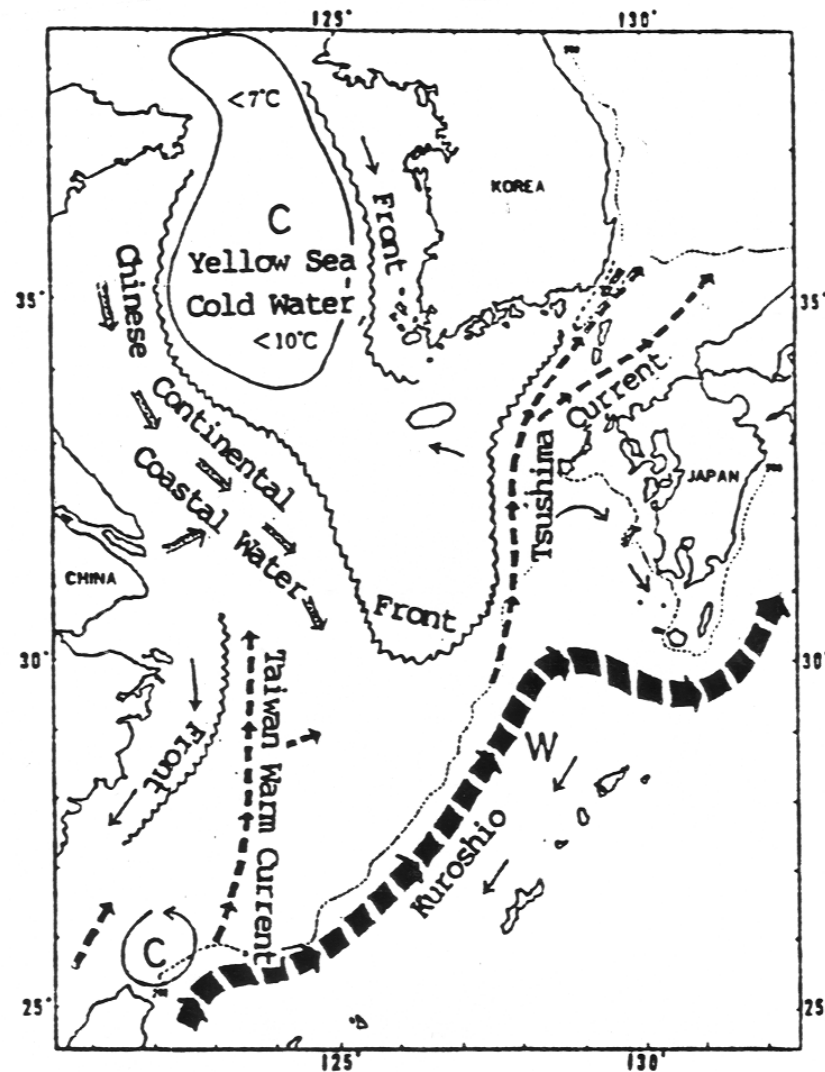


# Yellow Sea Bottom Topography

- 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**.



# Water Mass Distribution (Kondo 1985)



# Oceanographic Data Sets

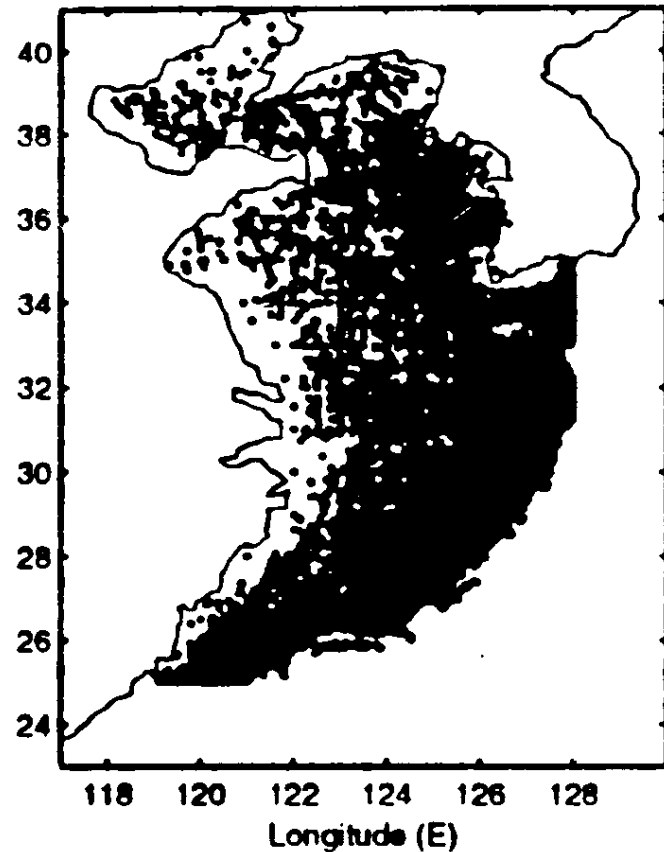
- Master Oceanographic Observational Data Set (MOODS)
- Generalized Digital Environmental Model (GDEM)
- Modular Ocean Data Assimilation System (MODAS)

# Master Oceanographic Observational Data Set (MOODS)

- Historical world wide observational oceanographic profile data base dating back to 1920.
- Consist of:
  - Temperature only profiles
  - Both Temperature and Salinity Profiles
  - Sound Speed profiles
  - Surface Temperatures
- Biggest limitation is its irregular distribution over time and space.

# MOODS (T, S) Stations

- More than 50,000 profiles





# Seasonal Temperature Profile Structures

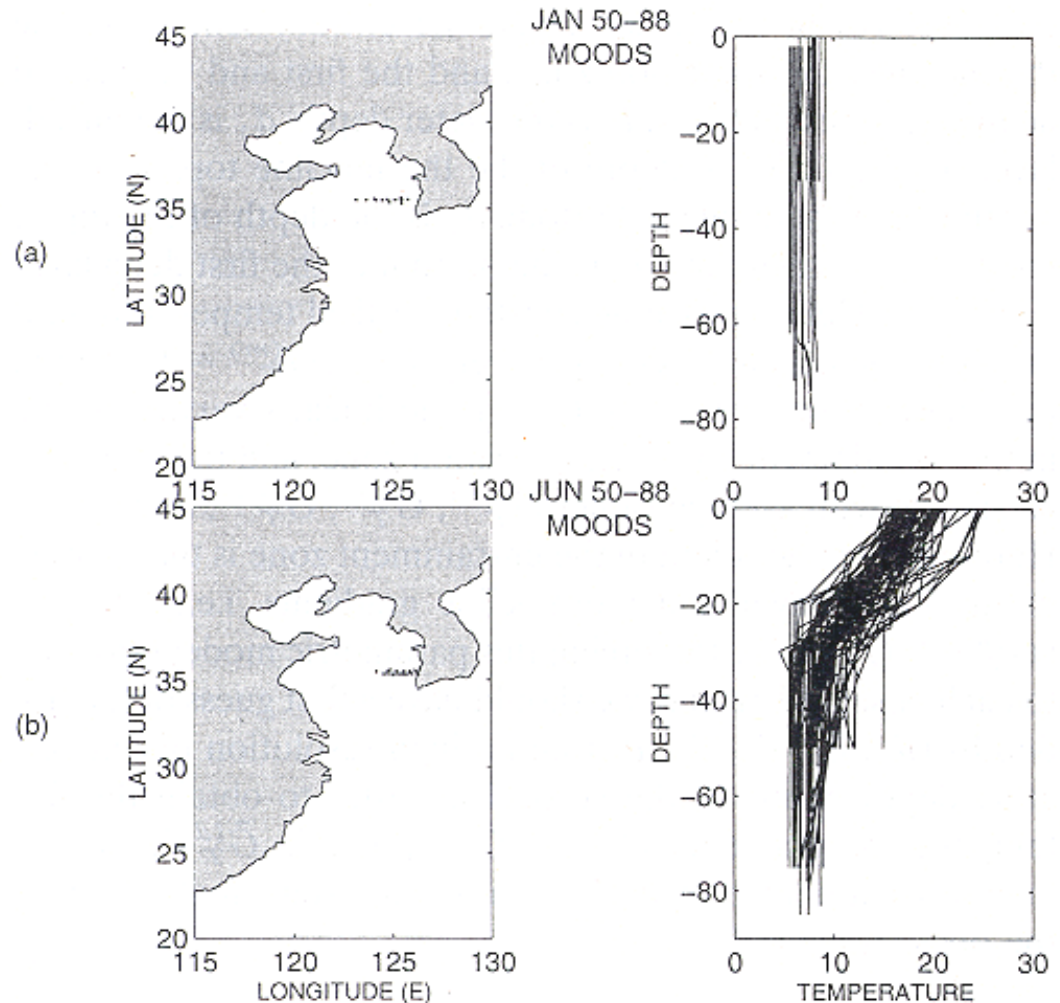
- (a) Winter and Fall Temperature Profile Structure.

- Isothermal

- (b) Spring and Summer Temperature Profile Structure.

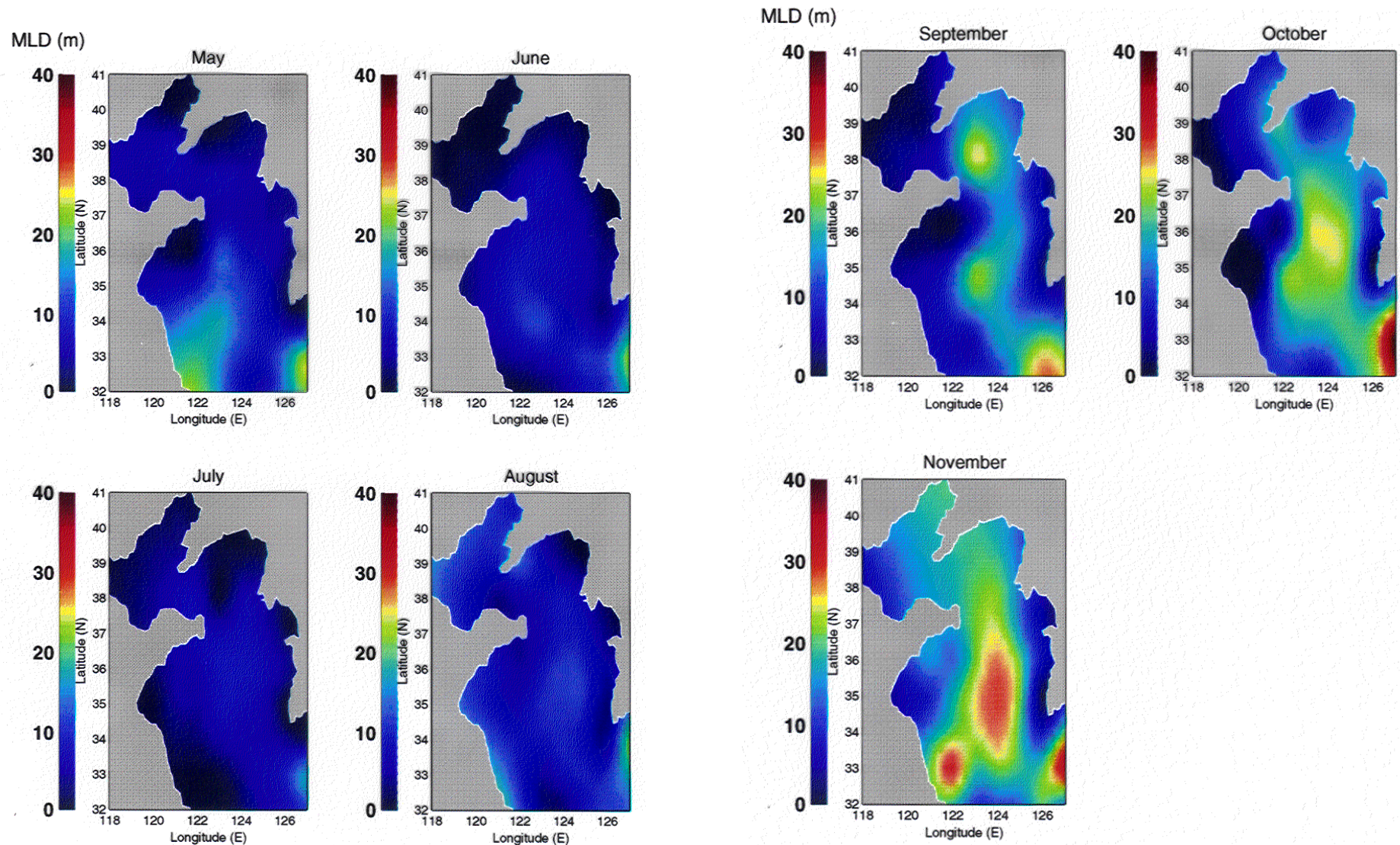
- Multi-layer

- Mixed layer
- Thermocline
- Deep Layer



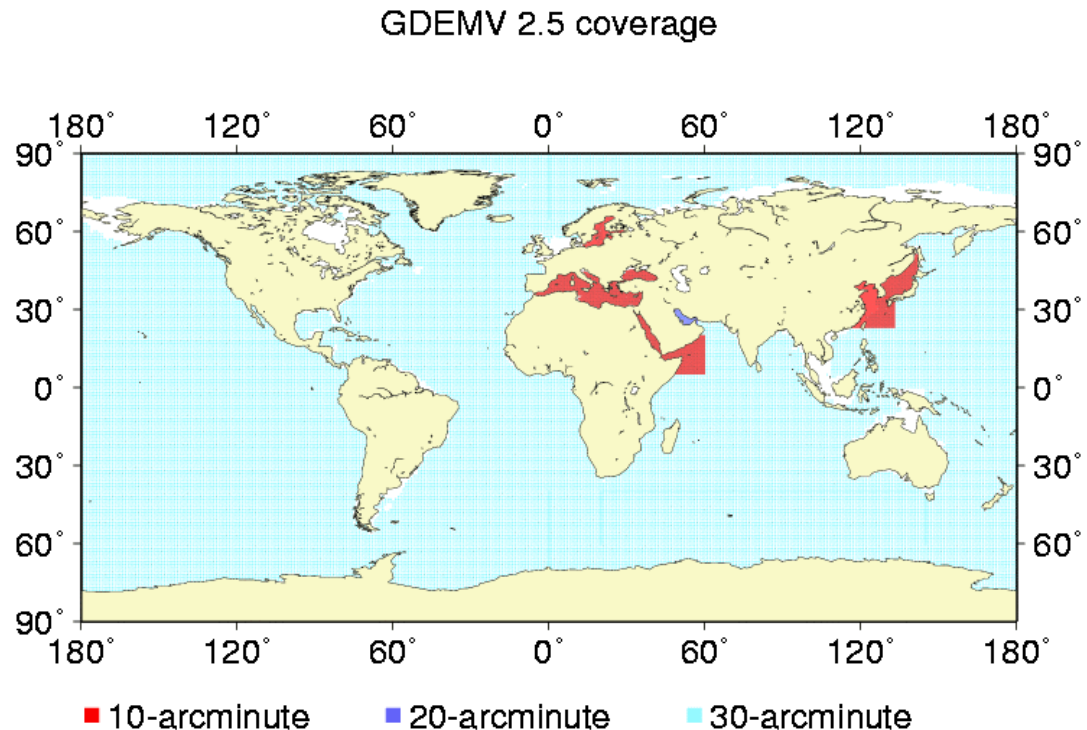


# Mixed Layer Depth (One Layer from Dec to April)



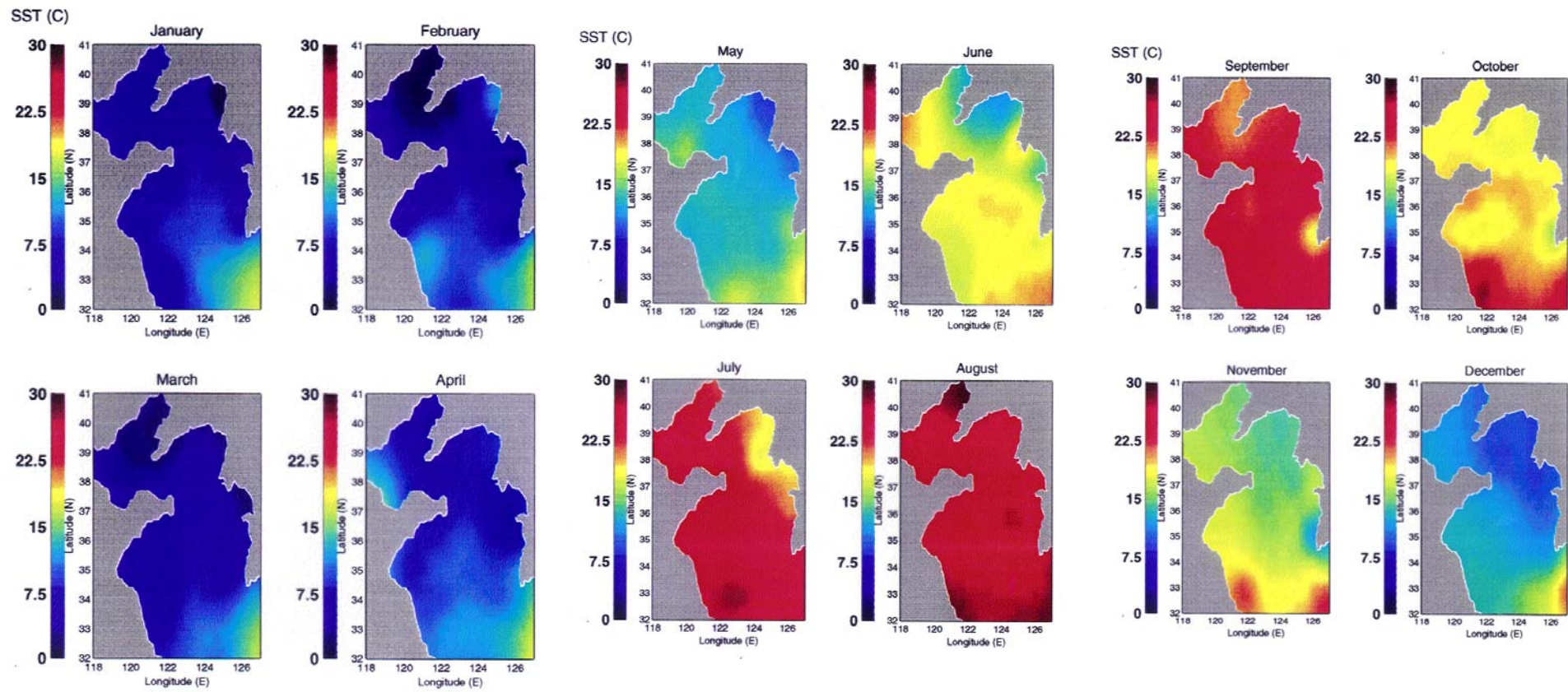
# Generalized Digital Environmental Model (GDEM)

- 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'.



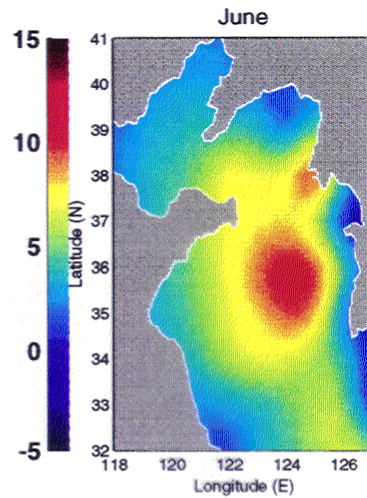
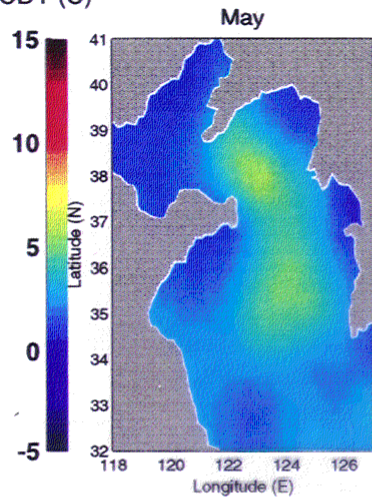


# Monthly Mean SST from GDEM

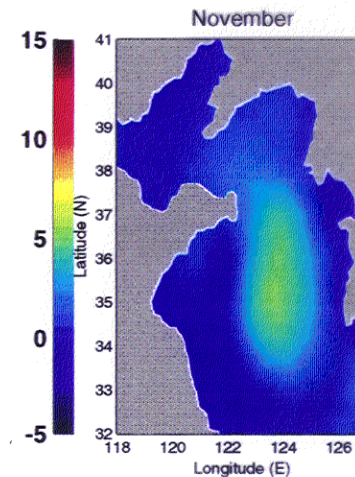
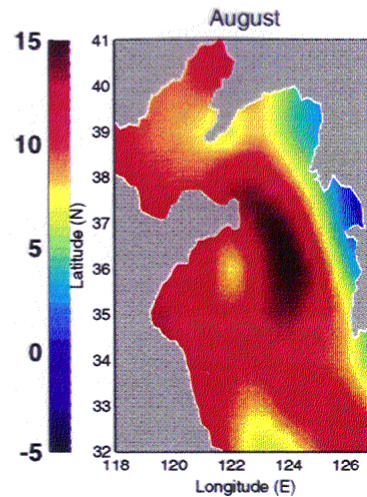
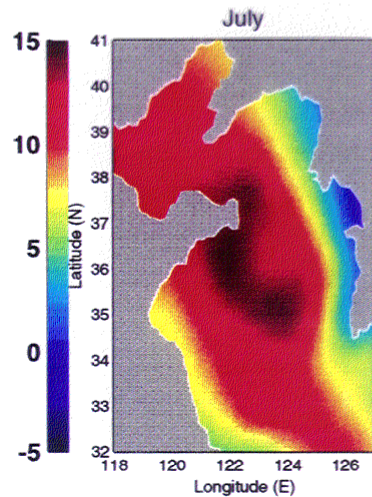
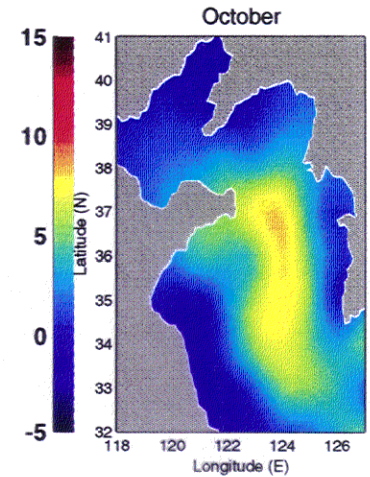
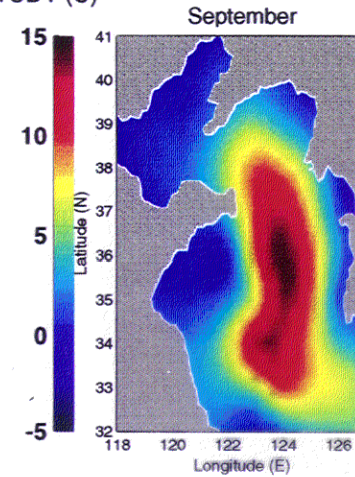


# Thermocline Temperature Difference

TCDT (C)

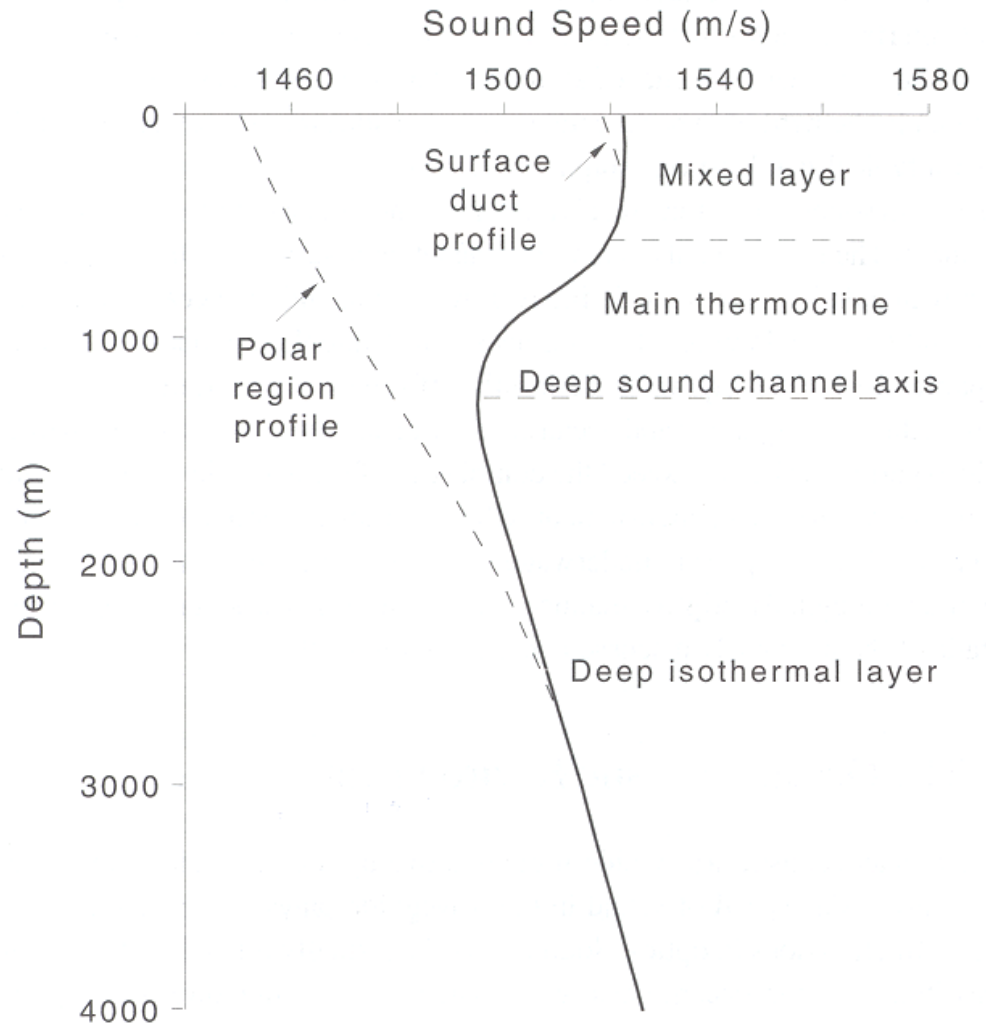


TCDT (C)



# Sound Speed Profile

- **Mixed layer**
  - **Surface duct** may be generated with a negative shift in SST
- **Main Thermocline**
- **Deep Sound Channel Axis**
- **Deep Isothermal Layer**



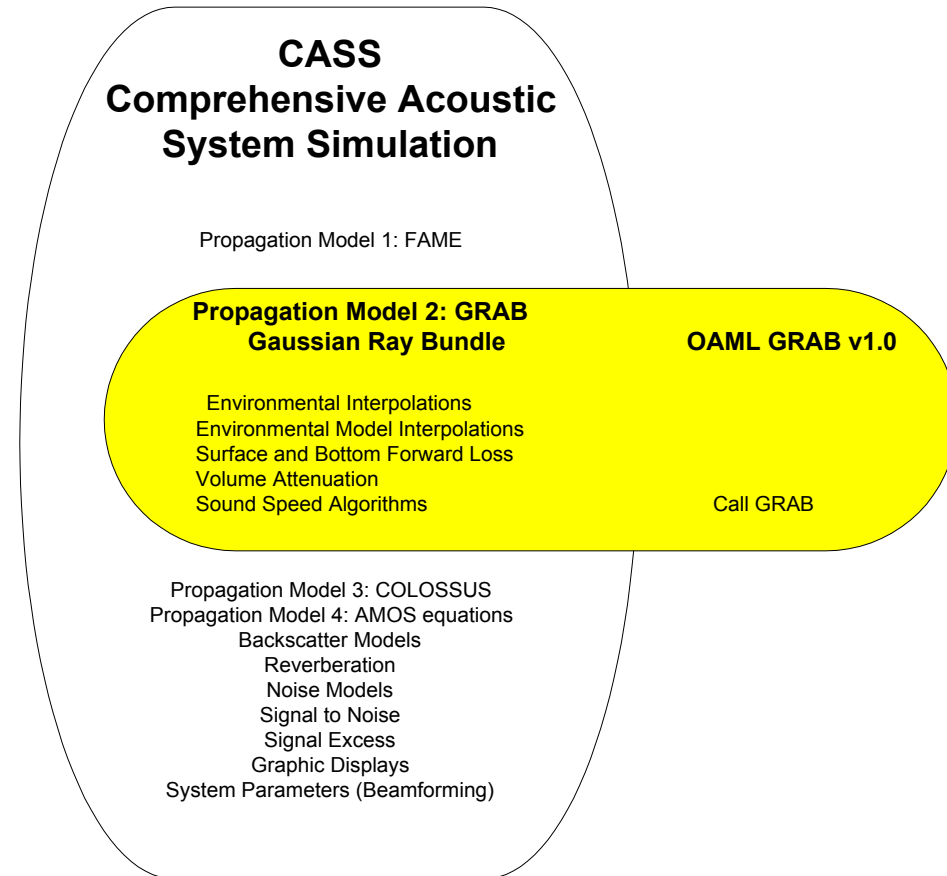


# Comprehensive Acoustic Simulation System/Gaussian Ray Bundle (CASS/GRAB)

- 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.



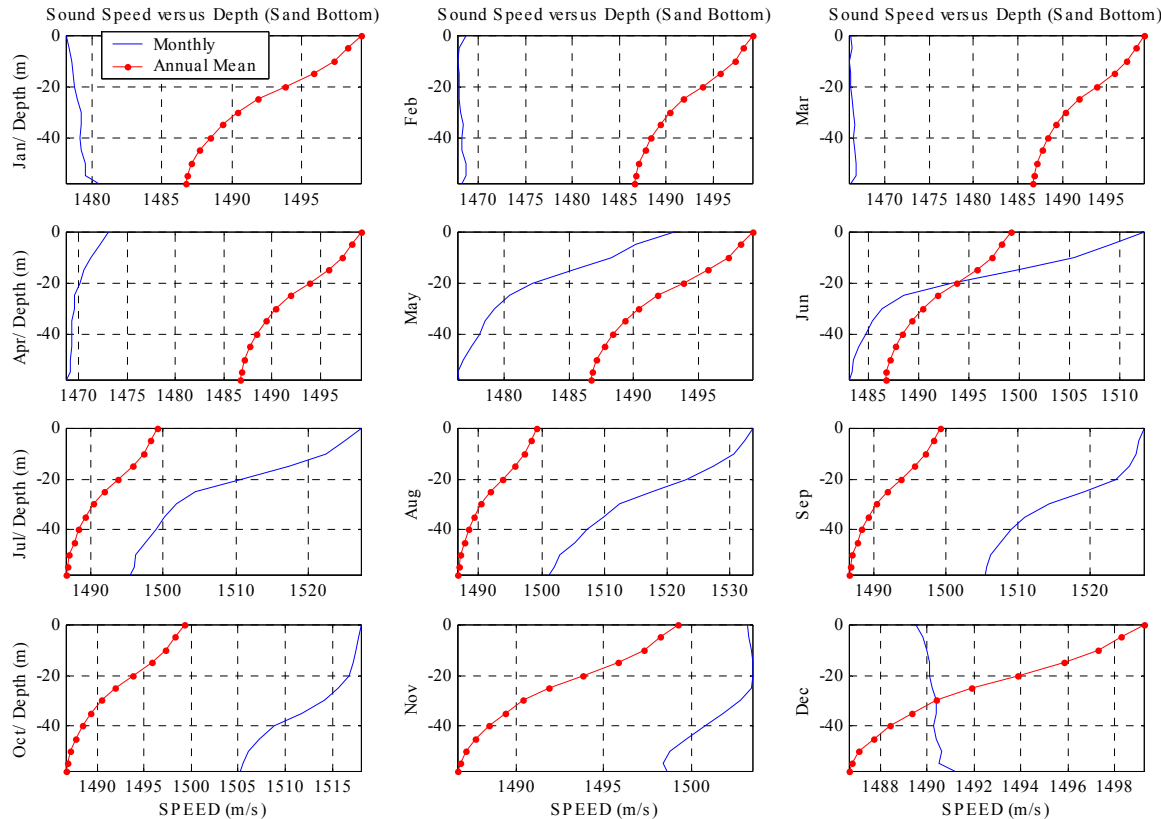


# Comprehensive Acoustic Simulation System/Gaussian Ray Bundle (CASS/GRAB)

- 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.
- GRAB calculates amplitude globally by distributing the amplitudes according to the Gaussian equation

$$\Psi_v = \frac{\beta_{v,0} \Gamma_v^2}{\sqrt{2\pi} \sigma_v p_{r,v} r} \exp\left\{-0.5\left[(z - z_v) / \sigma_v\right]^2\right\}$$

# Monthly and Annual Mean Sound Speed Comparison

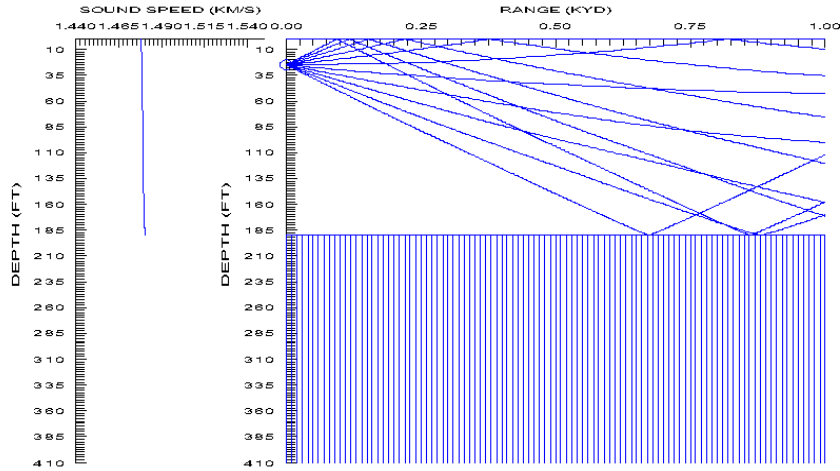


- Sound Speed profiles transition from Isotherm in the winter to Multi-layer in the Summer

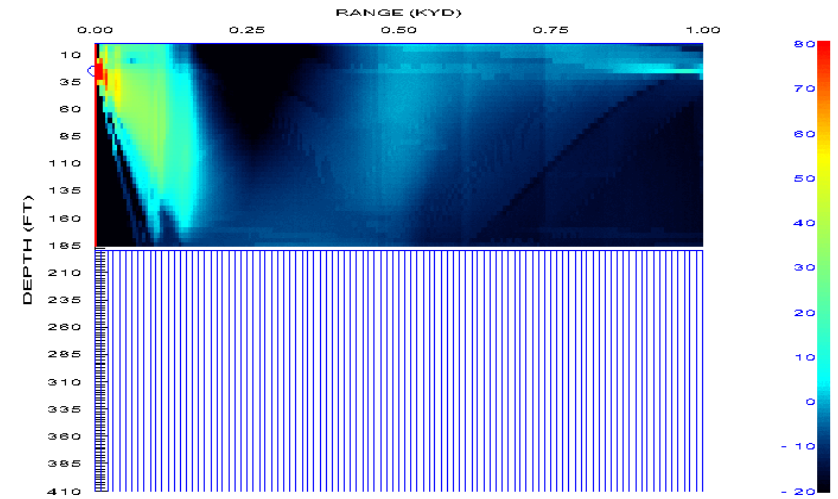
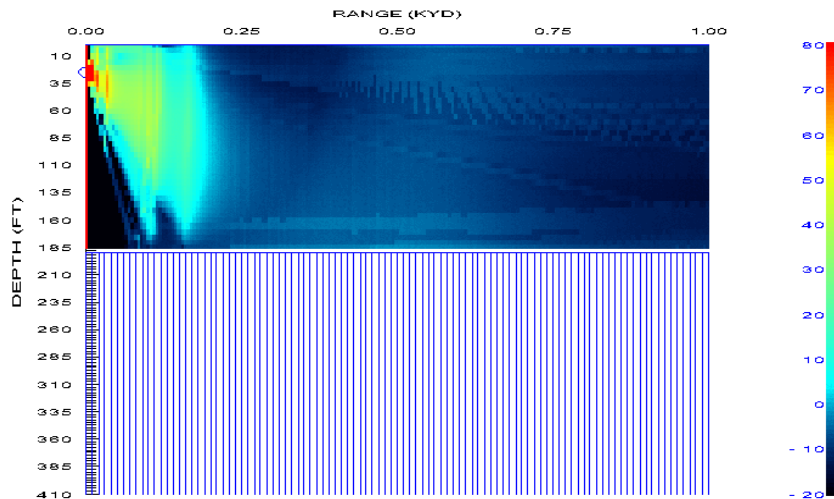
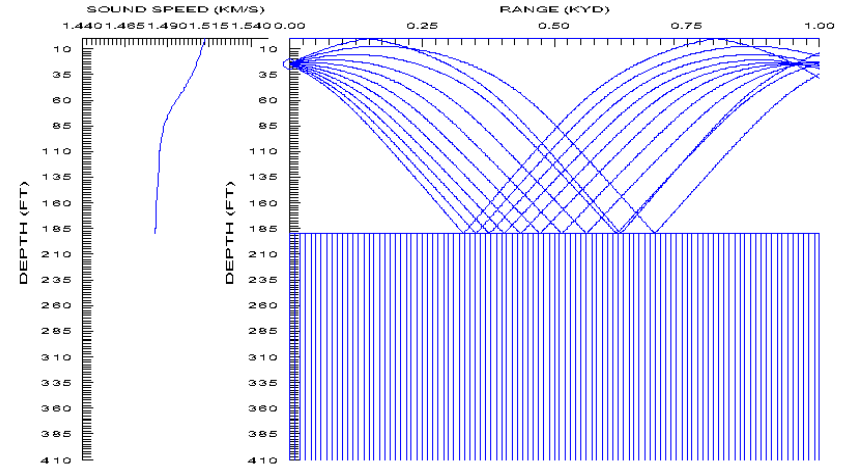
# GDEM Seasonal Variability for Signal Excess

**GDEM /January/ Sand/ SD = 25 ft**      **GDEM /June/ Sand/ SD = 25 ft**

Ray Trace +/-5 degrees by 1 degree



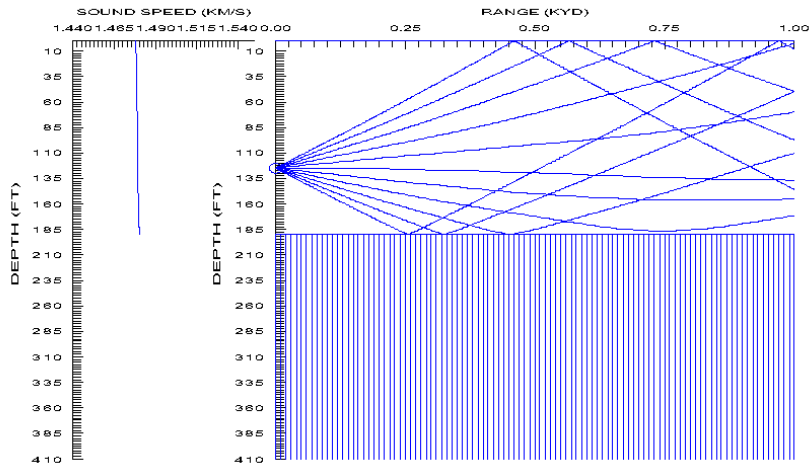
Ray Trace +/-5 degrees by 1 degree



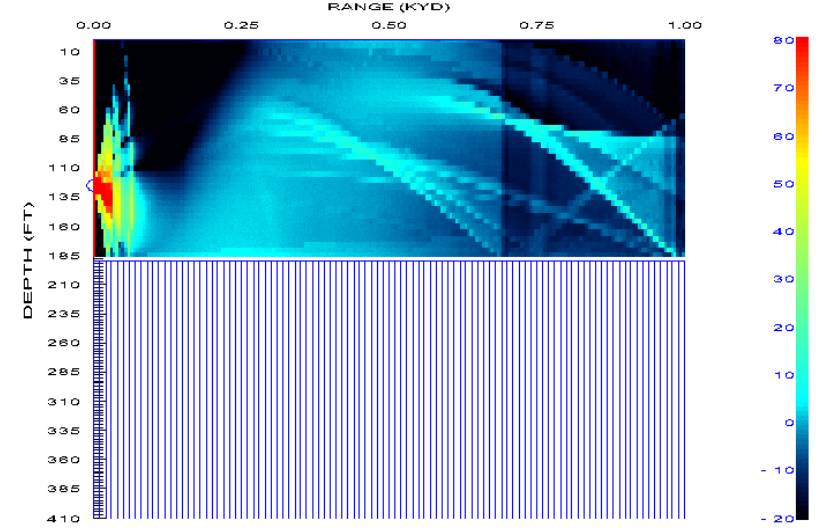
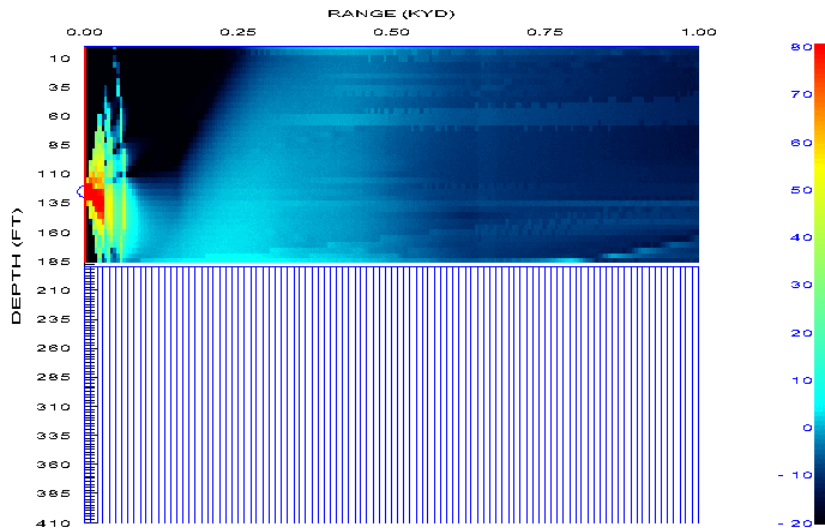
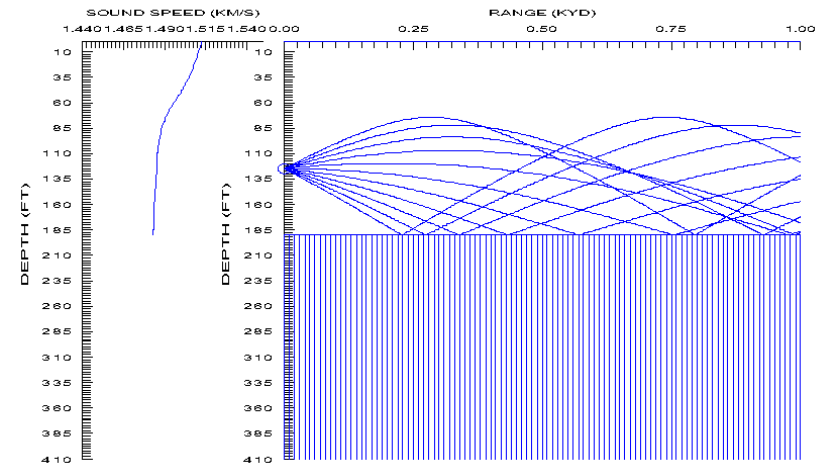
# GDEM Seasonal Variability for Signal Excess

**GDEM /January/ Sand/ SD = 125 ft    GDEM /June/ Sand/ SD = 125 ft**

Ray Trace +/-5 degrees by 1 degree

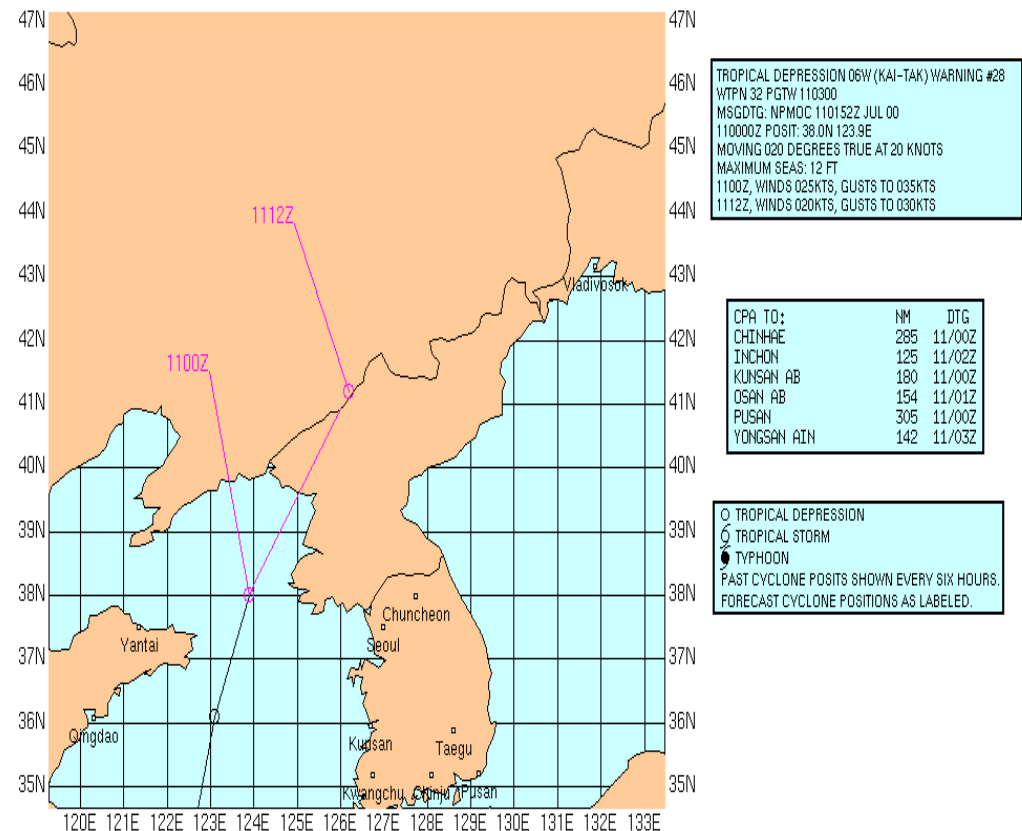


Ray Trace +/-5 degrees by 1 degree



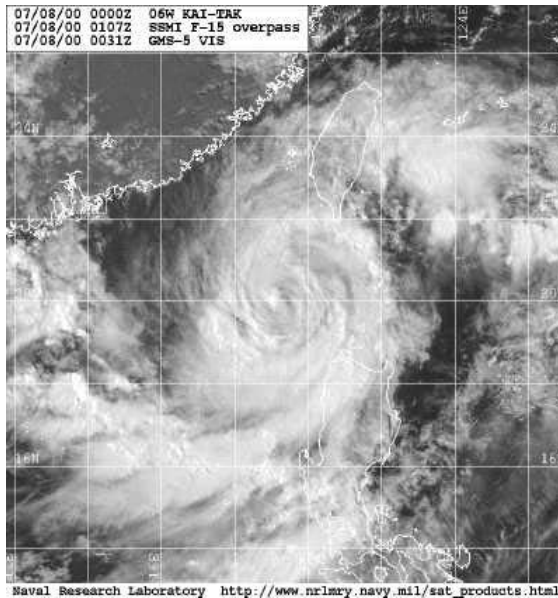
# Acoustic Transmission Under Severe Weather Events

- Track of Tropical Depression Kai-Tak over the Yellow Sea for 10-11 July 2000

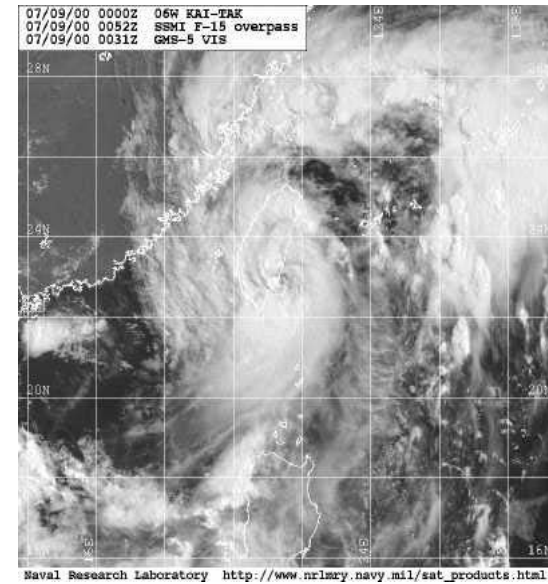


# Satellite Images of Tropical Depression Kai-Tak

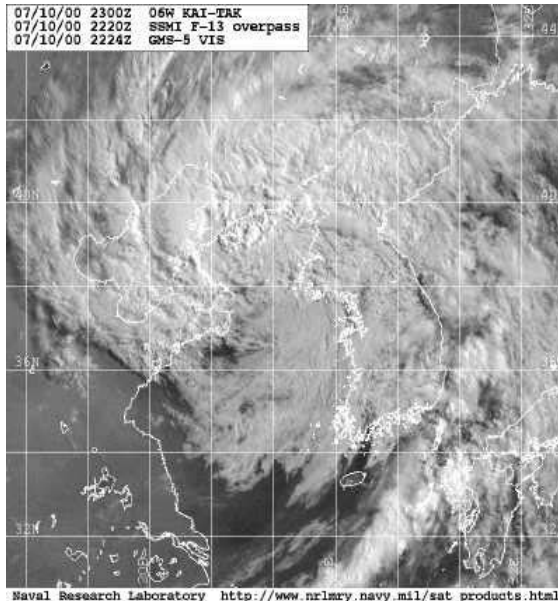
**July 8, 2000  
Tropical  
Cyclone  
over the  
East China  
Sea**



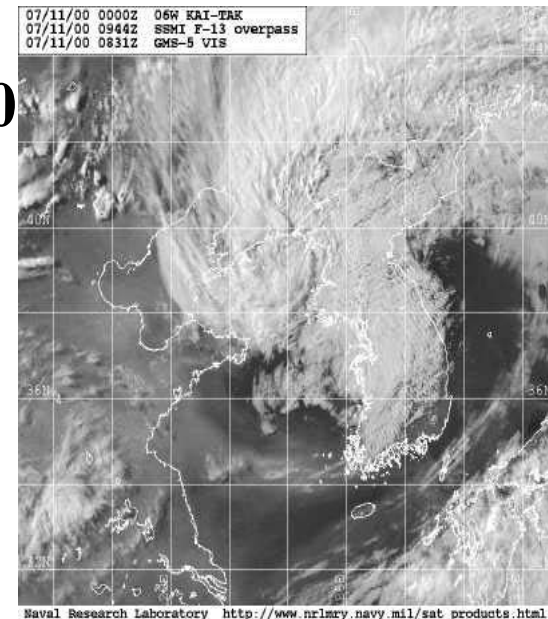
**July 9, 2000  
Tropical  
Cyclone  
over the  
Northern  
East China  
Sea**



**July 10, 2000  
Tropical  
Depression  
over the  
Yellow Sea**



**July 11, 2000  
Tropical  
Depression  
over the  
Northern  
Yellow Sea**

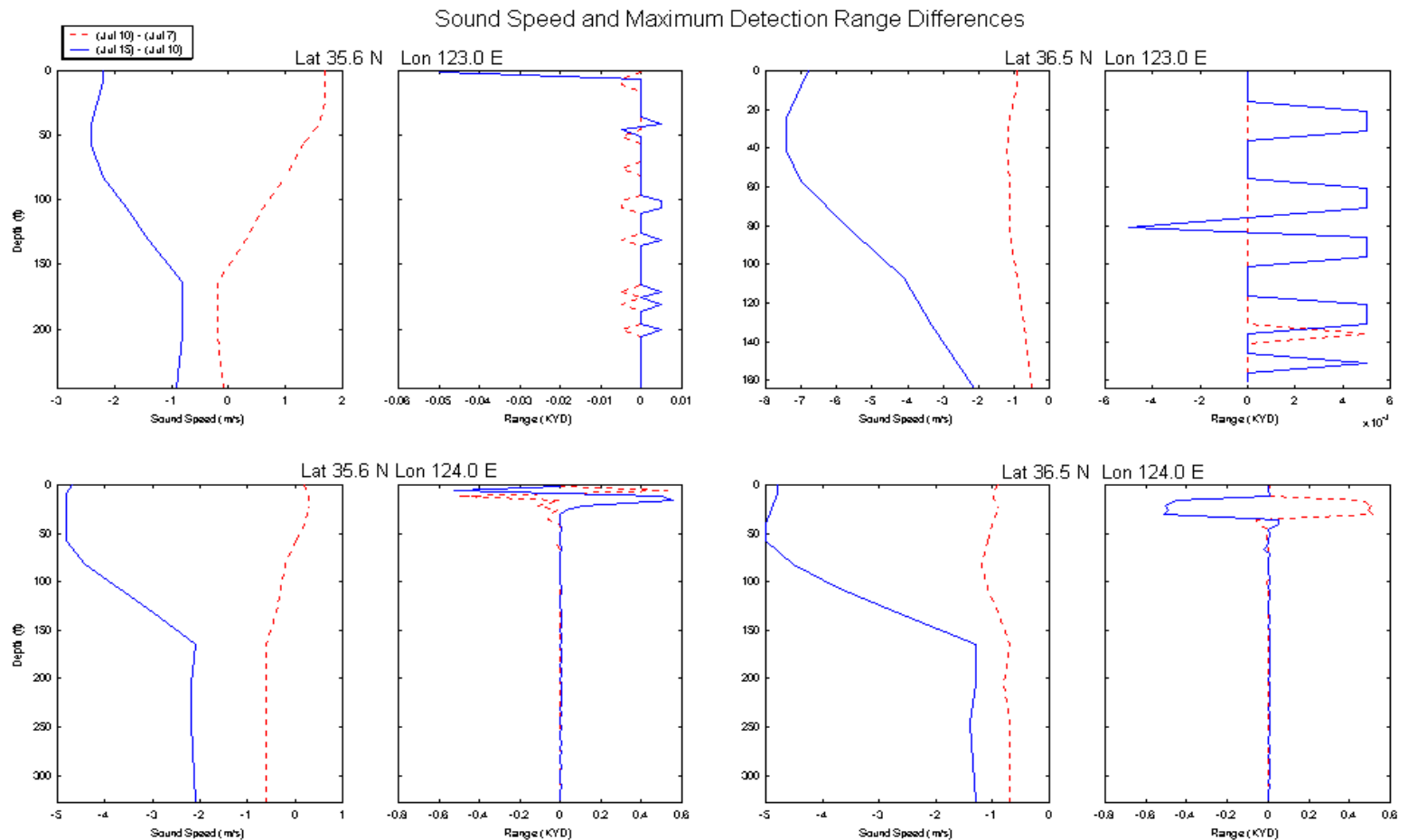


# Synoptic T, S Data Set (MODAS)

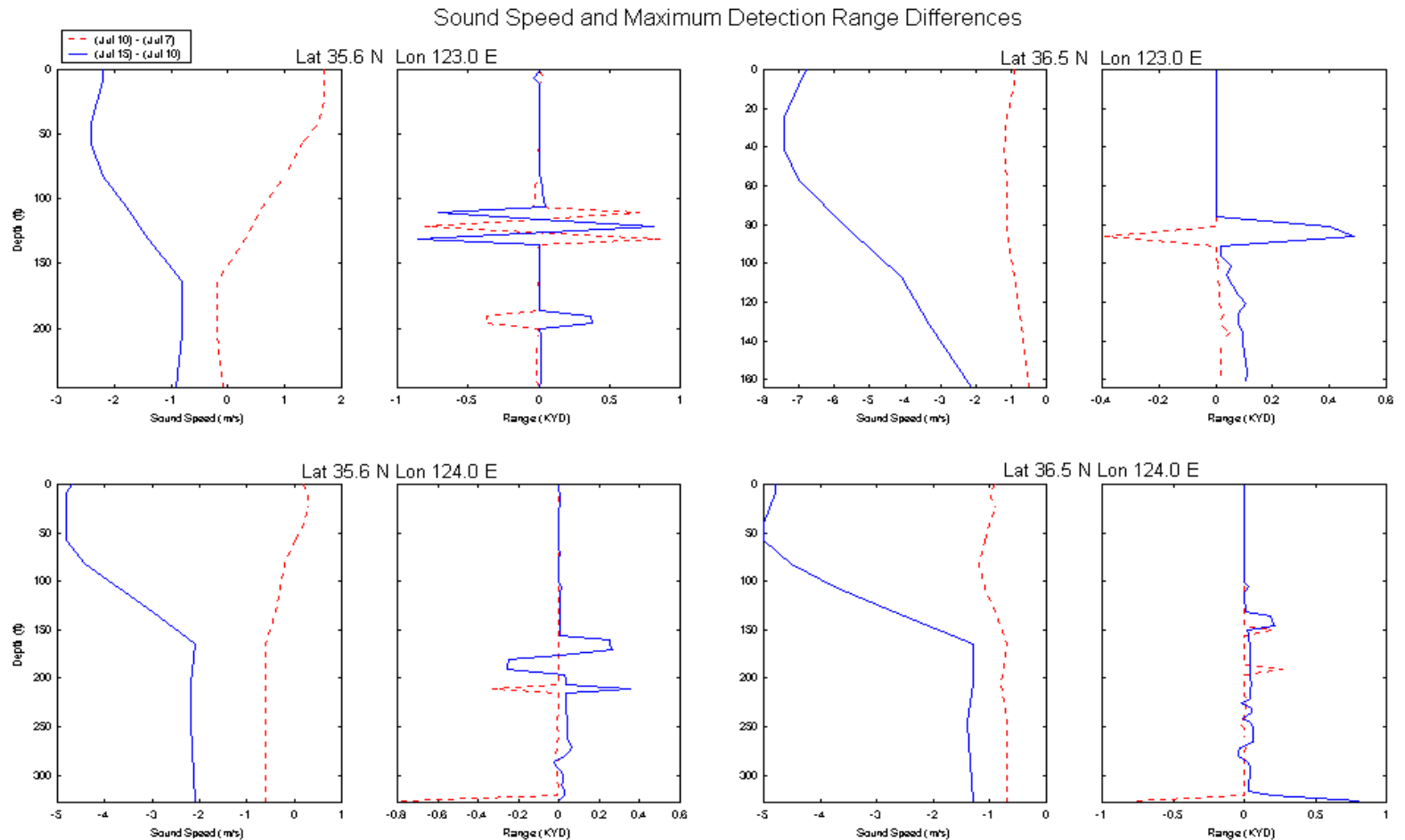
- Modular Ocean Data Assimilation System (MODAS)
- 3 D T, S Fields Twice Daily



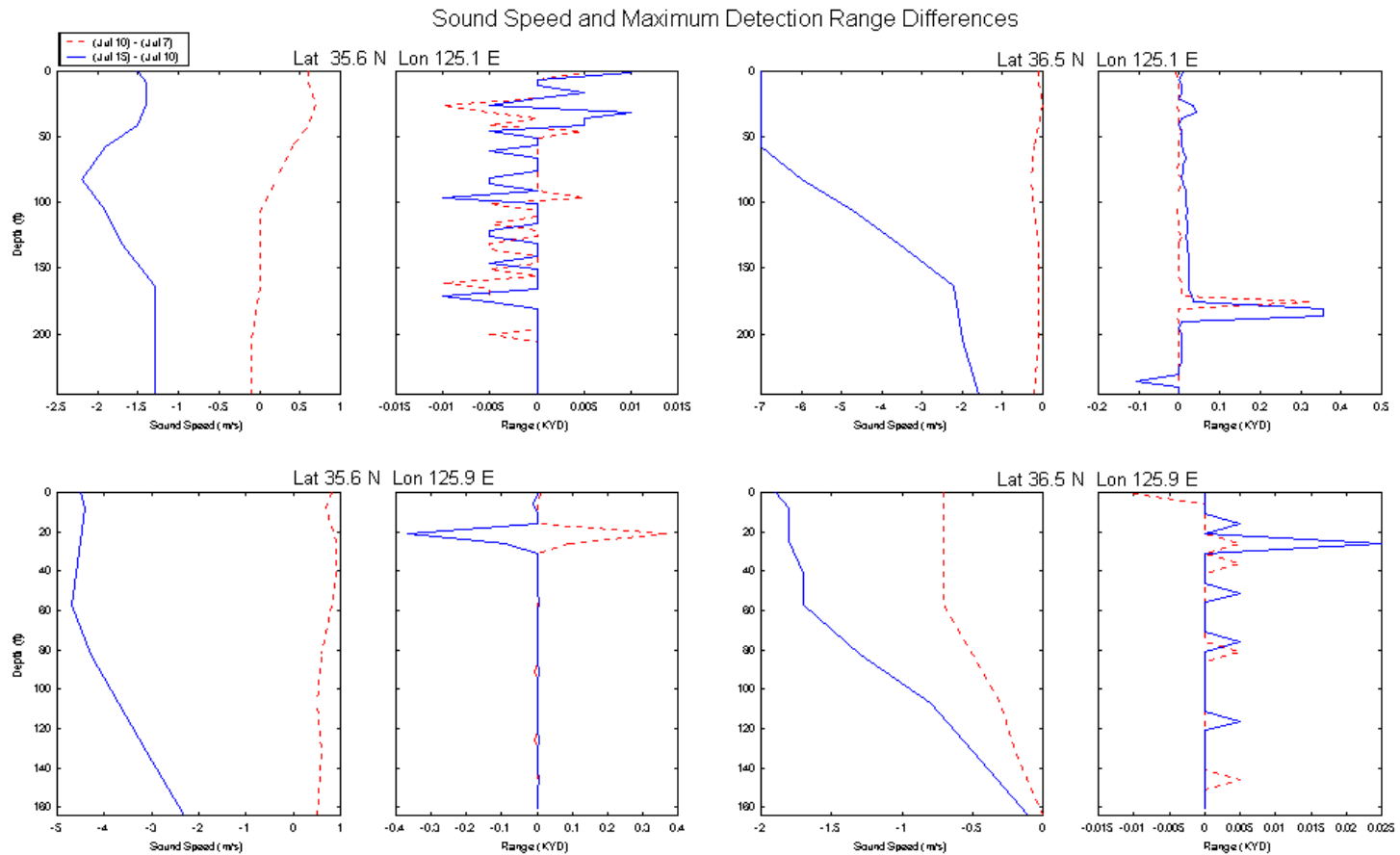
# Sound Speed and Maximum Detection Range Differences Differences for a Mud Bottom region and a Source Depth of 25 ft



# Sound Speed and Maximum Detection Range Differences for a Mud Bottom region and a Source Depth of 125 ft

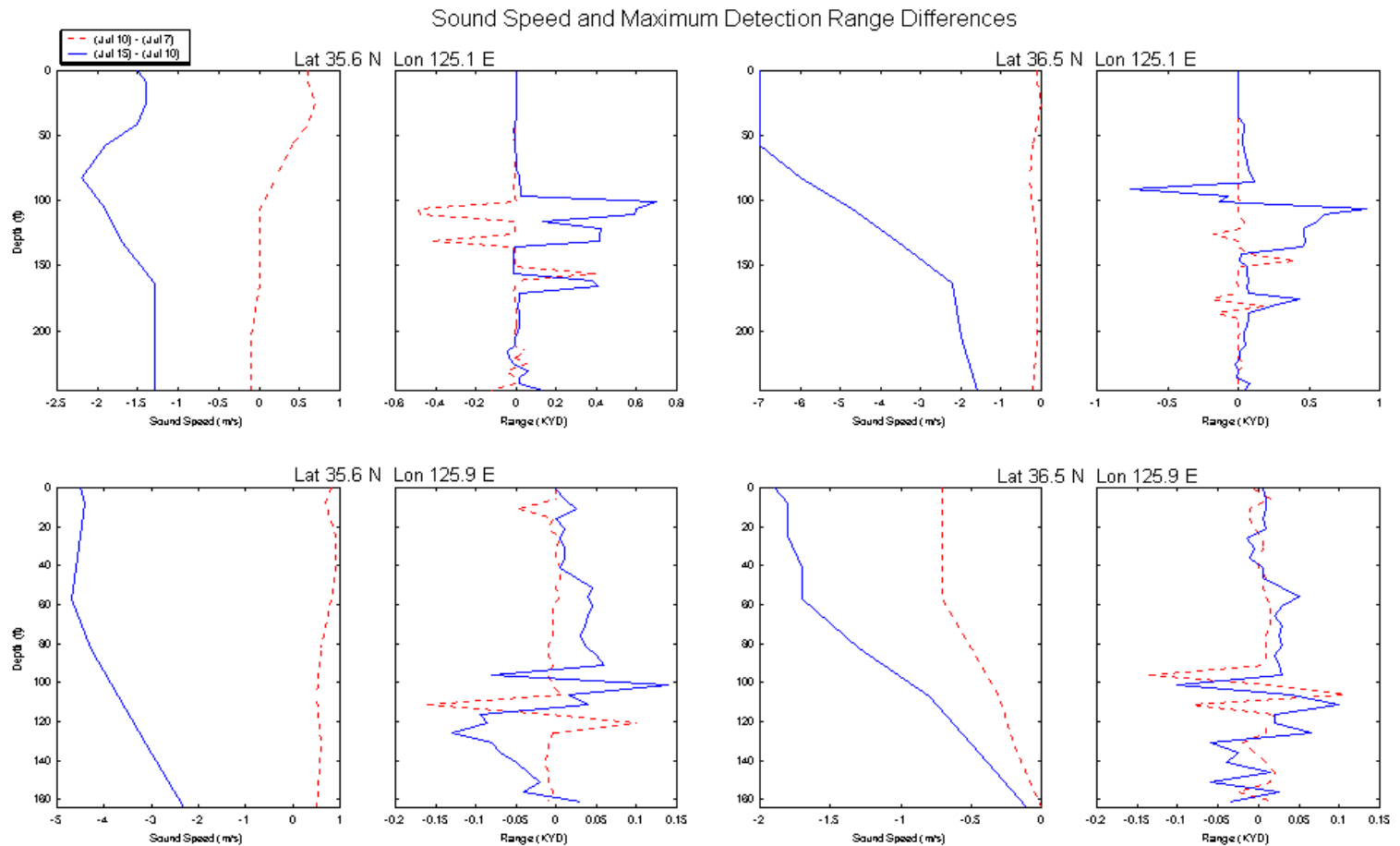


# Sound Speed and Maximum Detection Range Differences for a Sand Bottom region and a Source Depth of 25 ft



# Sound Speed and Maximum Detection Range Differences

## Differences for a Sand Bottom region and a Source Depth of 125 ft



# Maximum Significant Acoustic Difference in Detection Ranges Before and After the Tropical Depression

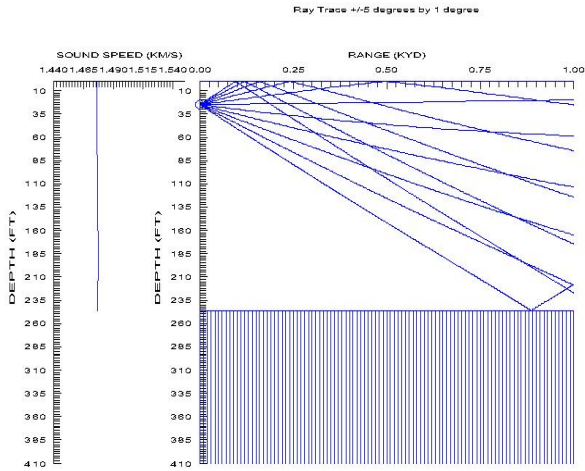
Target Depth	Source Depth = 25 ft			
	Mud		Sand	
	July 10 – July 7	July 15 – July 10	July 10 – July 7	July 15 – July 10
26 ft	Lat 36.5N Lon 124.0E 490 yds	Lat 36.5N Lon 124.0E 490 yds	None	None
Bottom	None	None	None	None

# Maximum Significant Acoustic Difference in Detection Ranges Before and After the Tropical Depression

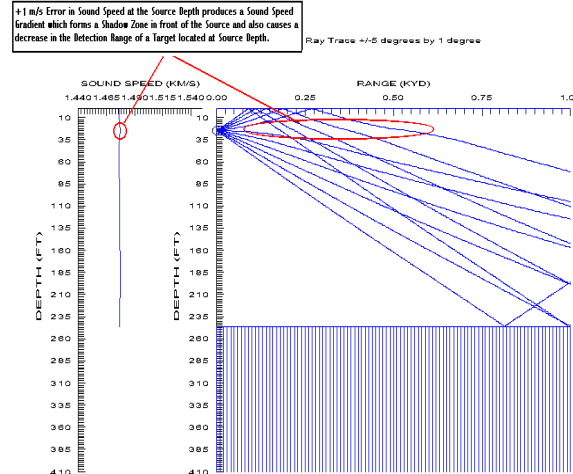
Target Depth	Source Depth = 125 ft			
	Mud		Sand	
	July 10 – July 7	July 15 – July 10	July 10 – July 7	July 15 – July 10
<b>26 ft</b>	None	None	None	None
<b>Bottom</b>	Lat 36.5N Lon 124.0E <b>790 yds</b>	Lat 36.5N Lon 124.0E <b>810 yds</b>	None	None

# Effect of Sound Speed Error at Source Depth

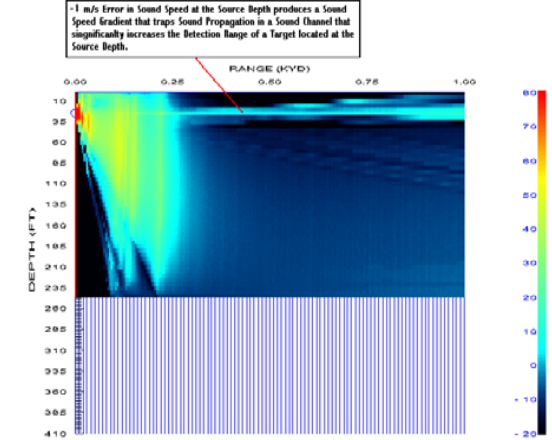
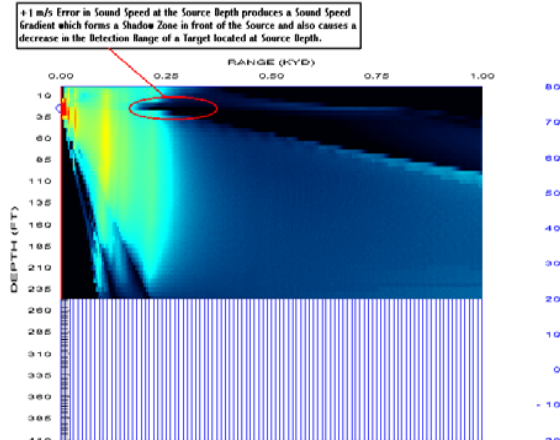
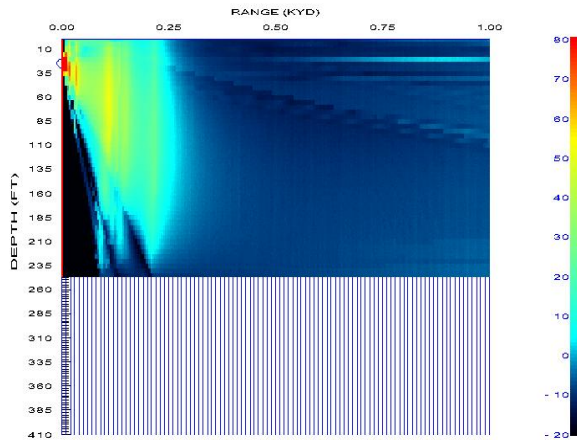
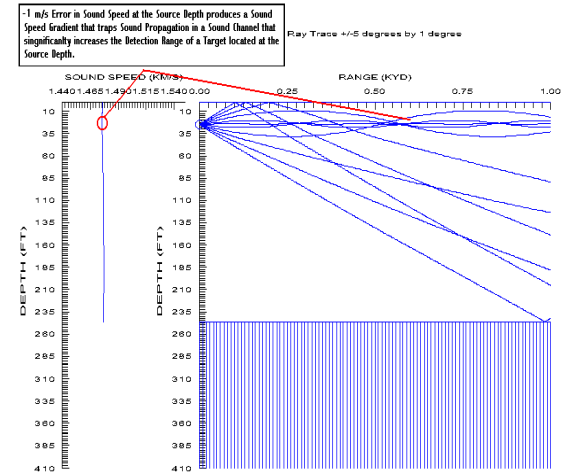
## No Error



## +1 m/s Error



## -1 m/s Error





# Conclusion

- Strong seasonal variability in thermohaline structure
- Strong seasonal variability in acoustic transmission (detection range, signal excess)
- Effect of the tropical cyclone on acoustic transmission
- Error propagation from sound speed profile to signal excess