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2004

## Improvement of Naval undersea capability using satellite data assimilation

Chu, Peter C.; Mancini, S.; Gottshall, E.; Cwalina, D.

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Chu, P.C., S. Mancini, E. Gottshall, D. Cwalina, Improvement of Naval undersea capability using satellite data assimilation, Seventy Second Military Operations Research Society Symposium, NPS, Monterey, California, 22-24 June 2004.

<https://hdl.handle.net/10945/42406>

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# Satellite Data Assimilation for Naval Undersea Capability

Peter C Chu and LCDR Steve Mancini (USN)  
Naval Postgraduate School  
CDR Eric Gottshall (USN)  
SPAWAR  
Dave Cwalina  
NUWC



# Purpose

- To define Navy altimeter requirements as a minimum number of satellite altimeters necessary to ensure maximum weapon effectiveness
- To determine the point at which additional altimeter input no longer increases weapon effectiveness

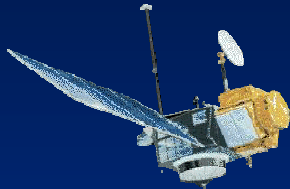


# Modular Ocean Data Assimilation System (MODAS)

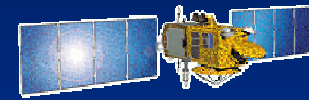
- 100 Separate programs
- Dynamic Climatology
- Relocatable Princeton Ocean Model
- SSH and SST from satellite altimeters
- 1/8 Degree Resolution



# U.S. Navy's MODAS System for Satellite Data Assimilation



Altimetry Data  
Archive



Data Processing

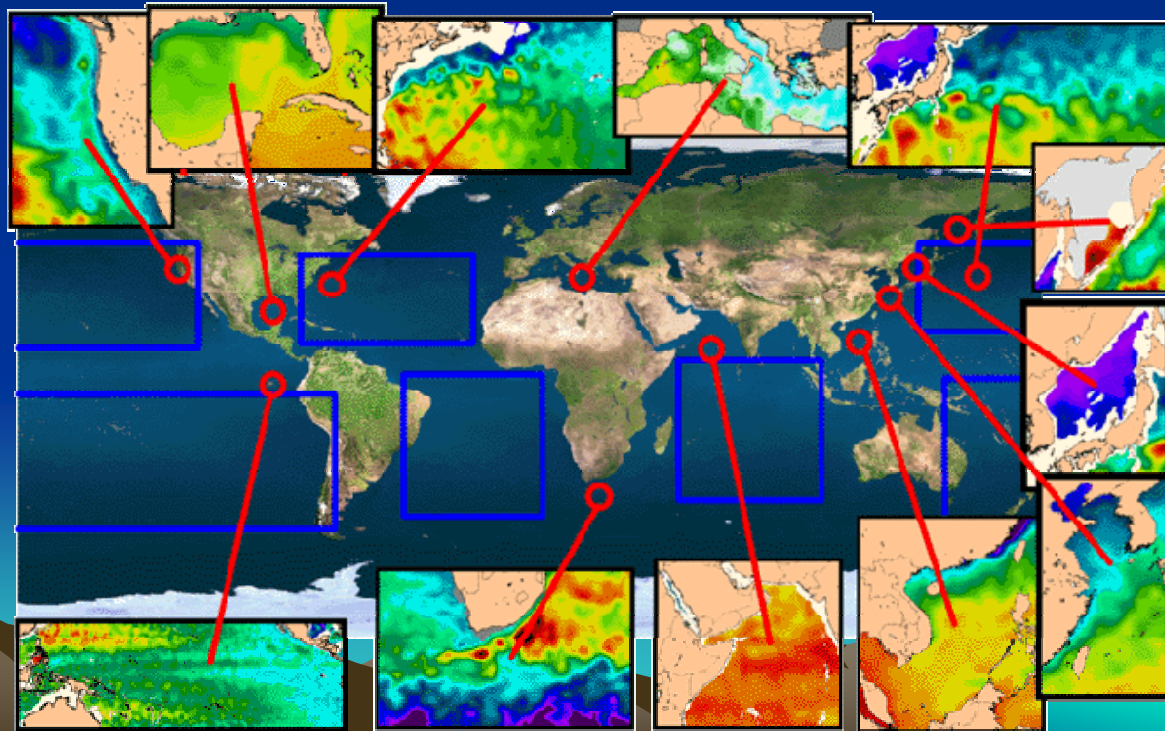
Data Sources

Applied  
Orbit Error  
Corrections

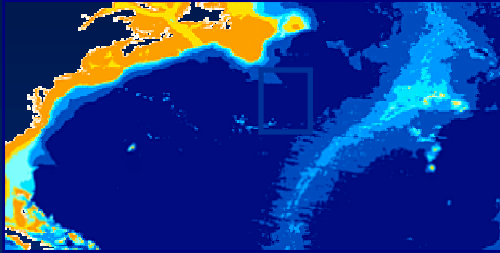
Altimetry  
Drop Plots

Percent of  
Data Utilized

Altimeter  
Intercomparisons



# MODAS



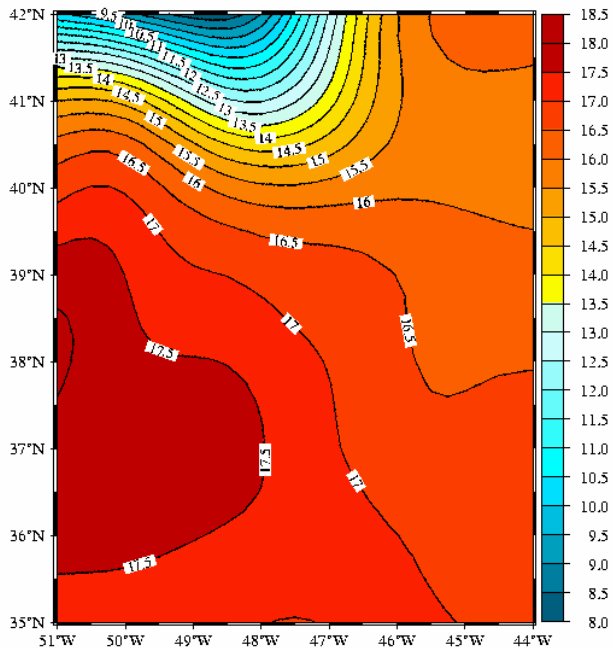
6-Aug-1995

200 m temperature  
Climatology

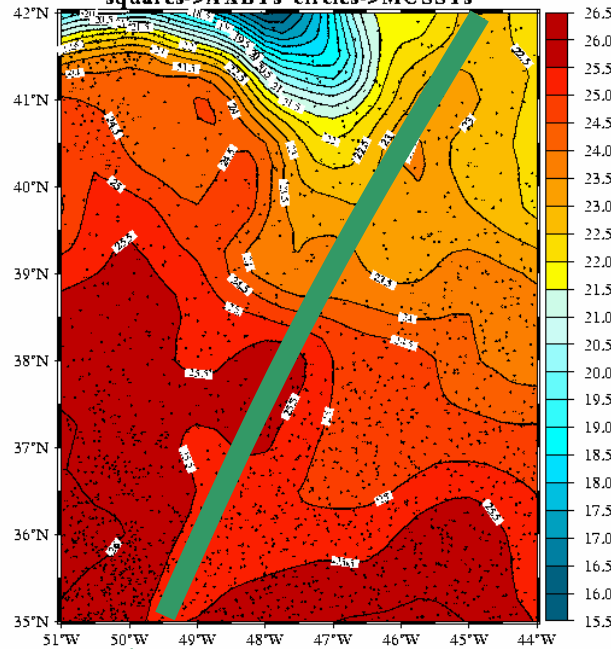
MODAS including MCSST  
does not significantly alter  
climatology

SSH reveals  
concealed ocean  
environment

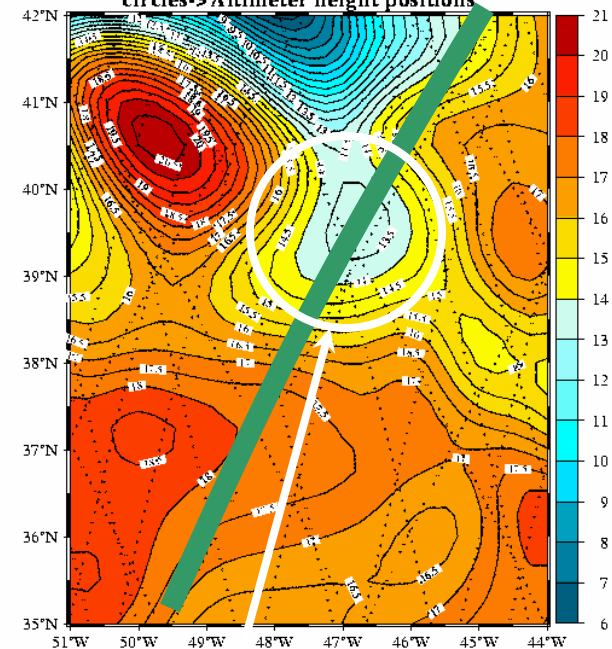
Climatological Temperature (Degs C)  
200 m 1995/08/06



Temperature (Degs C) from OI A analysis  
0 m 1995/08/06  
squares-> AXBTs circles-> MCSSTs



Climatological+SSH Temperature (Degs C)  
200 m 1995/08/06  
circles-> Altimeter height positions



AXBT Line

Points:  
MCSST

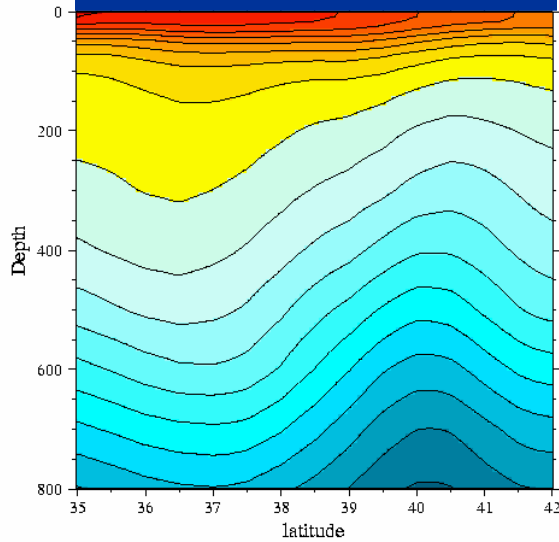
Cold core eddy

# MODAS

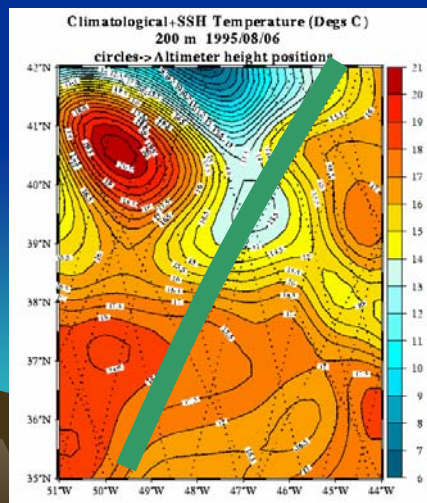
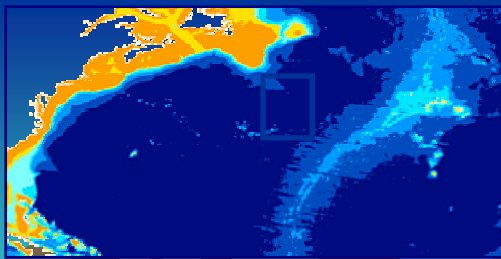
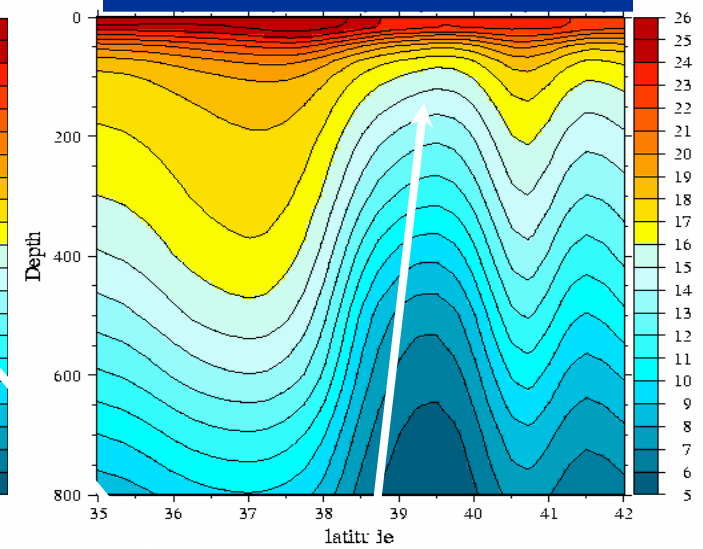
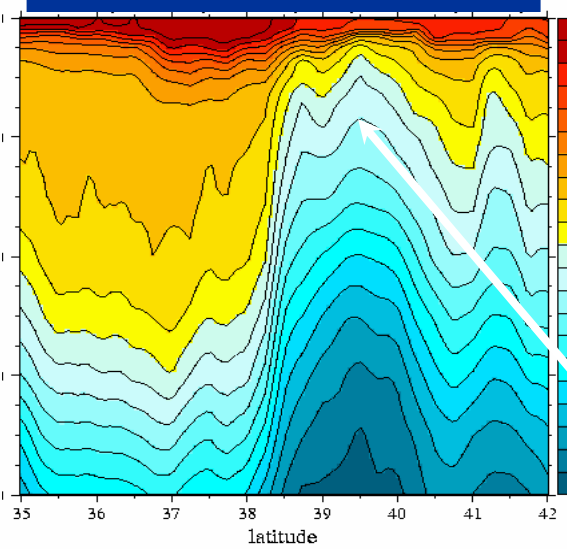
MODAS results

SSH + SST + Clim

Climatological Temp



AXBT Temp



Cold core eddy

MODAS  
Temperature  
at 200m

# Working Hypothesis

- MODAS with all satellite data assimilated provides more realistic ocean environment.
- Difference in weapon acoustic preset between using MODAS with Satellite and MODAS without satellite indicates the value-added of satellite data





# Procedures

- Compared 2 MODAS fields (with and without satellite data assimilation)
- Used a different metric for quantifying the effect on weapon presets

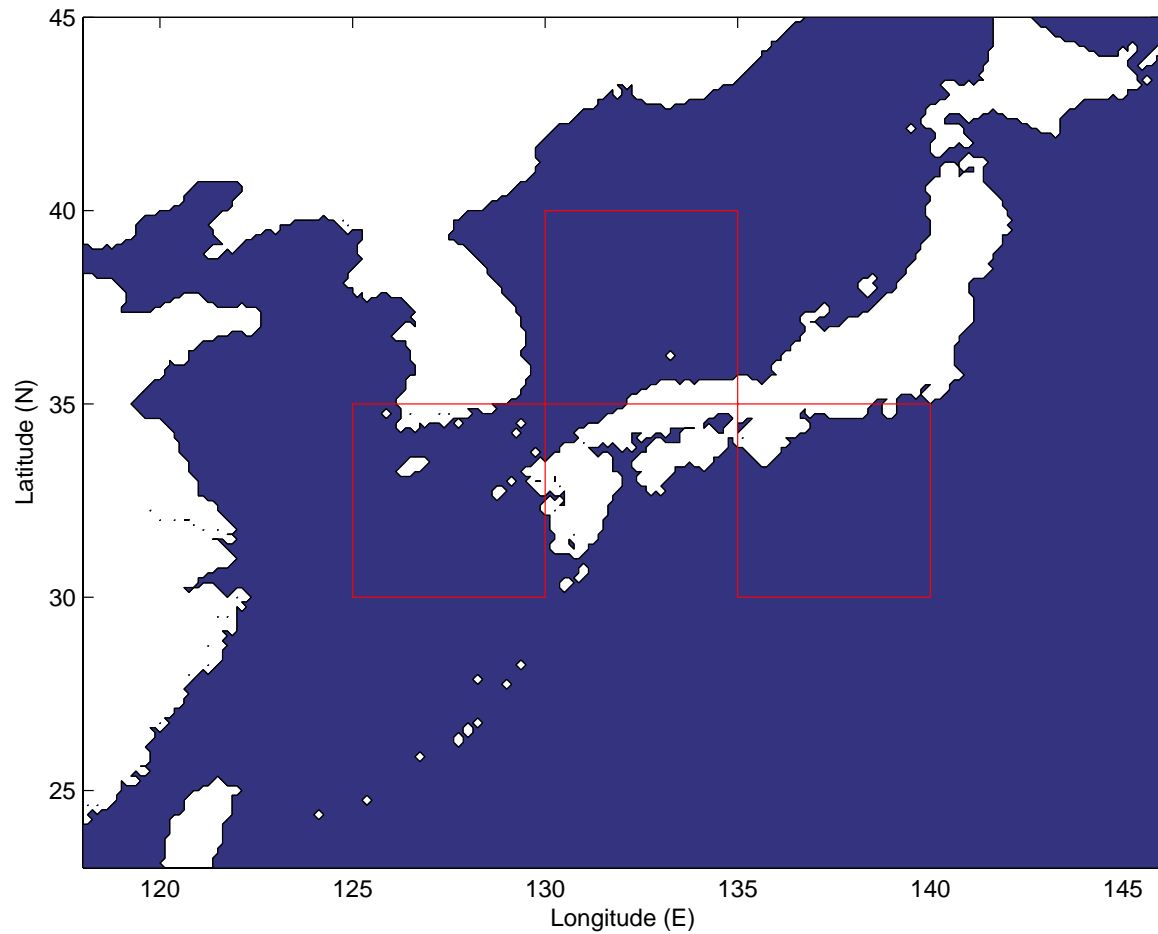


# Environmental Fields

- 2 MODAS data fields
  - one with assimilated data from 3 altimeters (TOPEX/Poseidon, GFO, and ERS-2)
  - one without altimeter data assimilated
- 2 dates
  - June 30, 2001
  - October 10, 2001
- 3 geographic areas (5 X 5 degree boxes)
  - Sea of Japan (SOJ): 35-40N, 130-135E
  - East China Sea (ECS): 30-35N, 125-130E
  - Kuroshio Current Area (KCA): 30-35N, 135-140E
- Resulting data set
  - 4,379 water column profiles

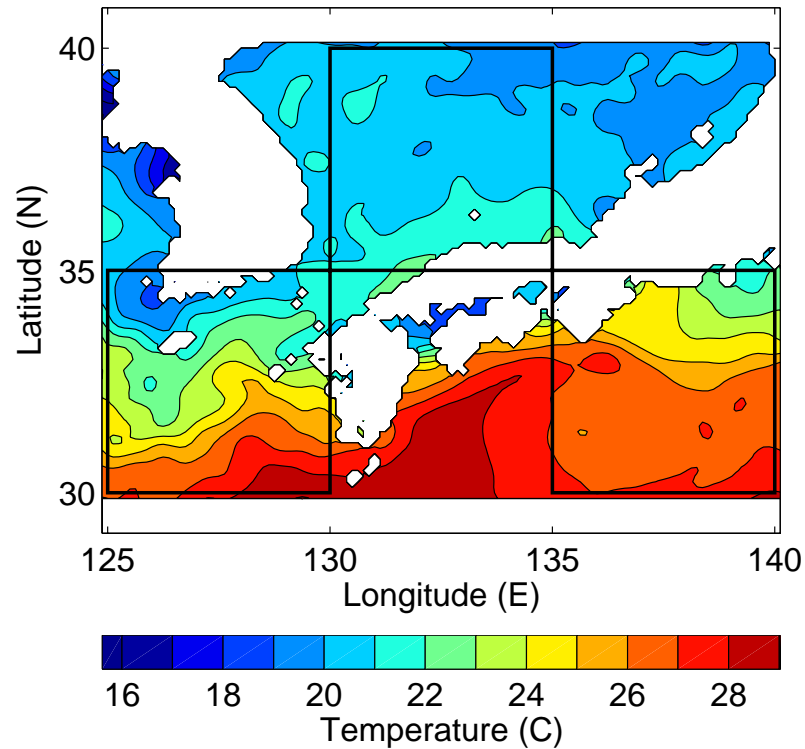


# Areas of Investigation

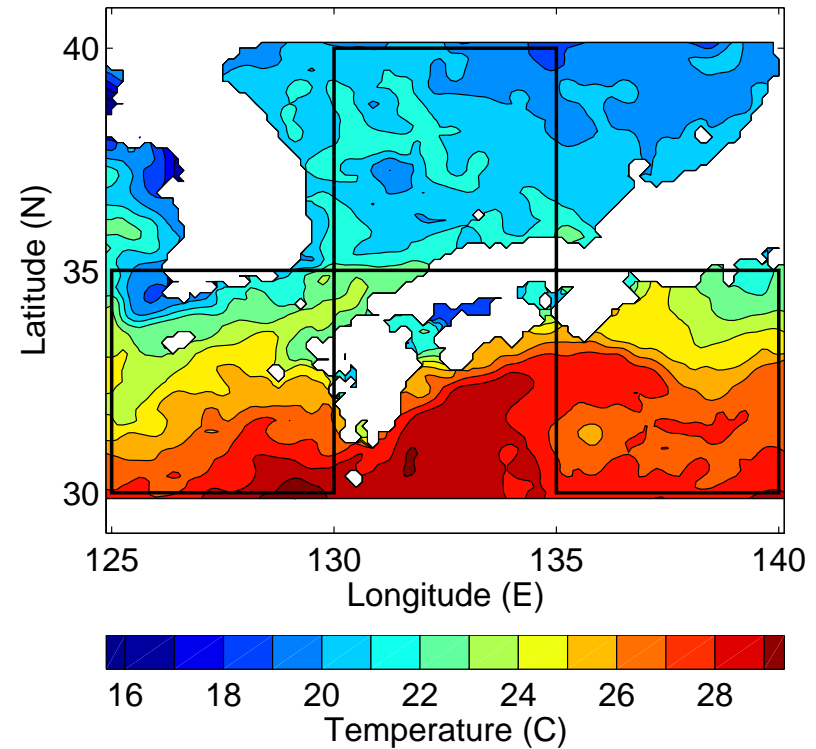


# Comparison of Sea Surface Temperature on Jun 30, 2001

MODAS Temperature WITH Altimeters

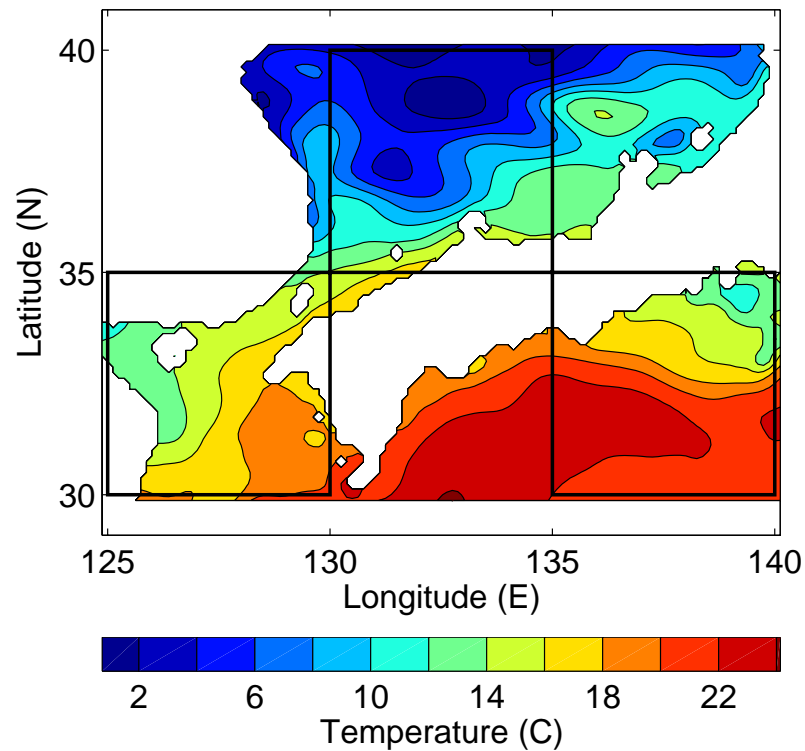


MODAS Temperature WITHOUT Altimeters

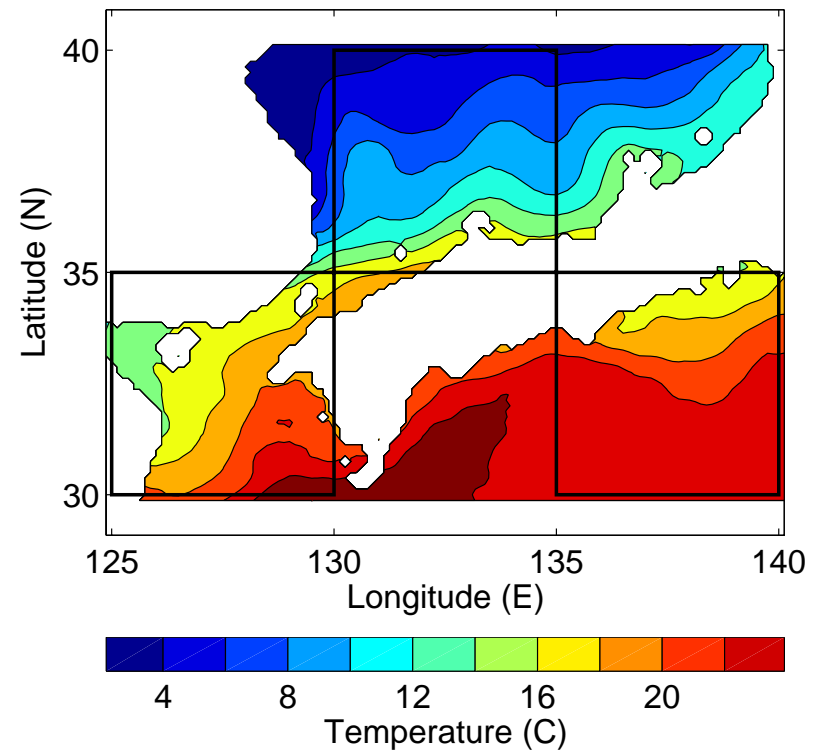


# Comparison of Temperature at 100 m on Jun 30, 2001

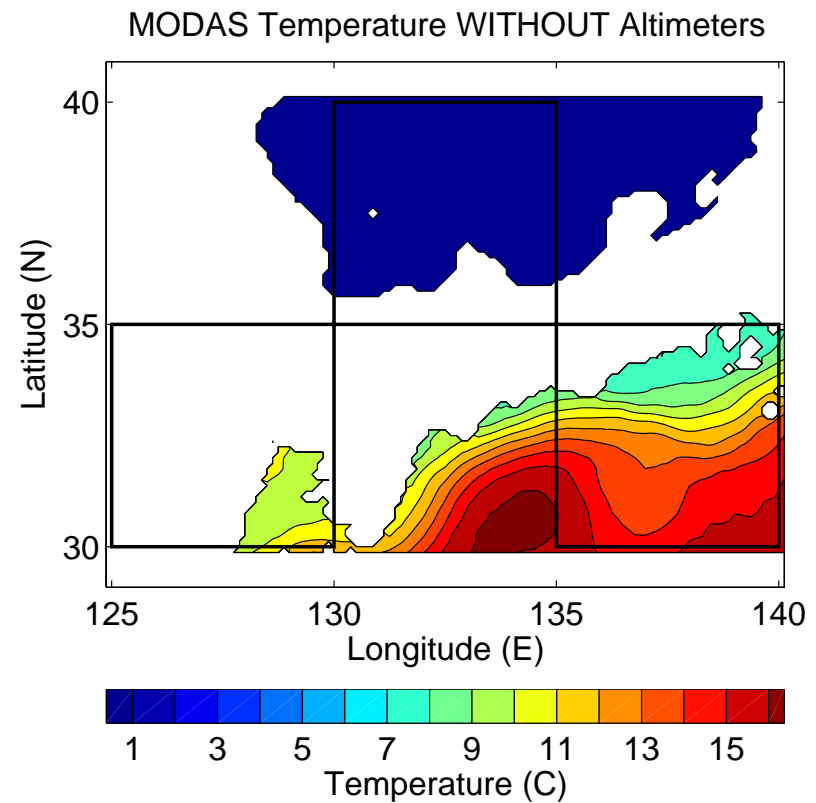
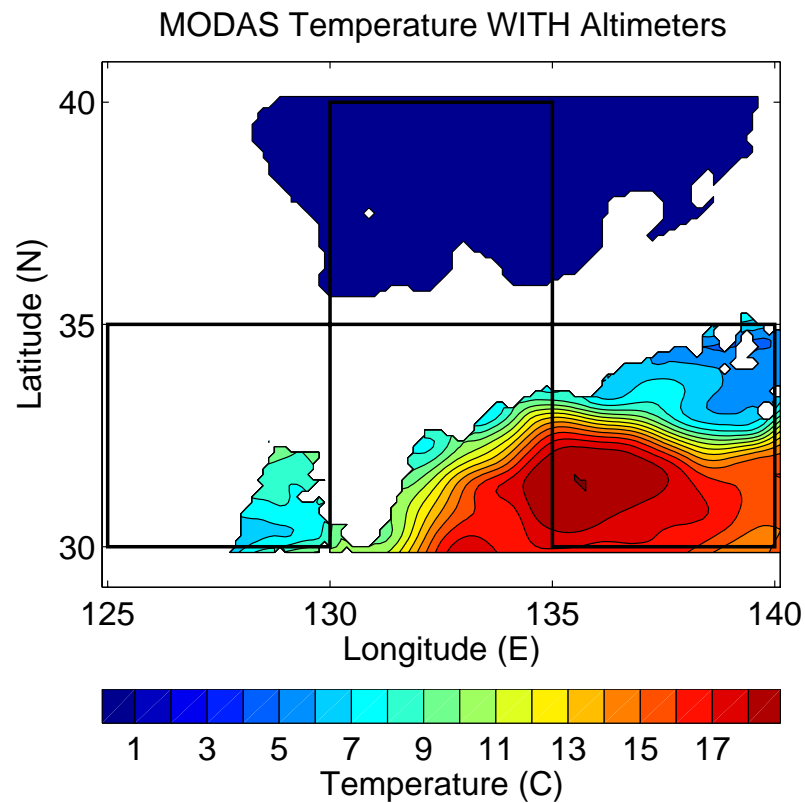
MODAS Temperature WITH Altimeters



MODAS Temperature WITHOUT Altimeters

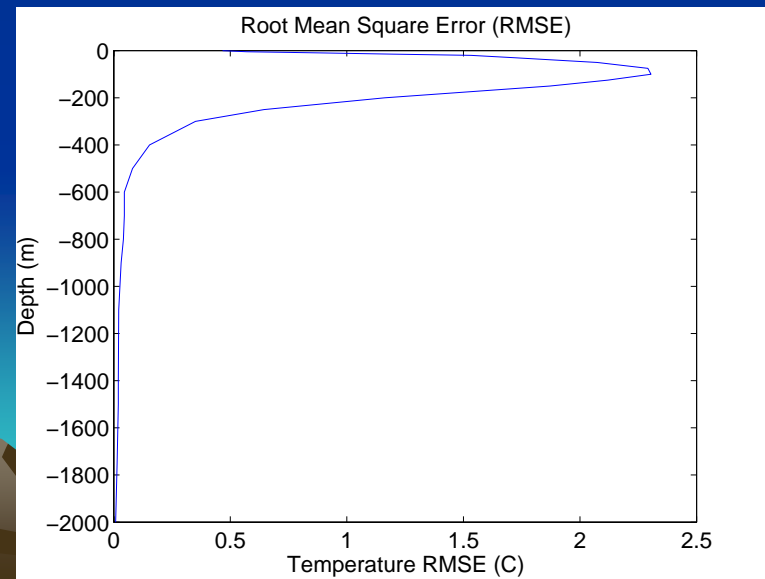
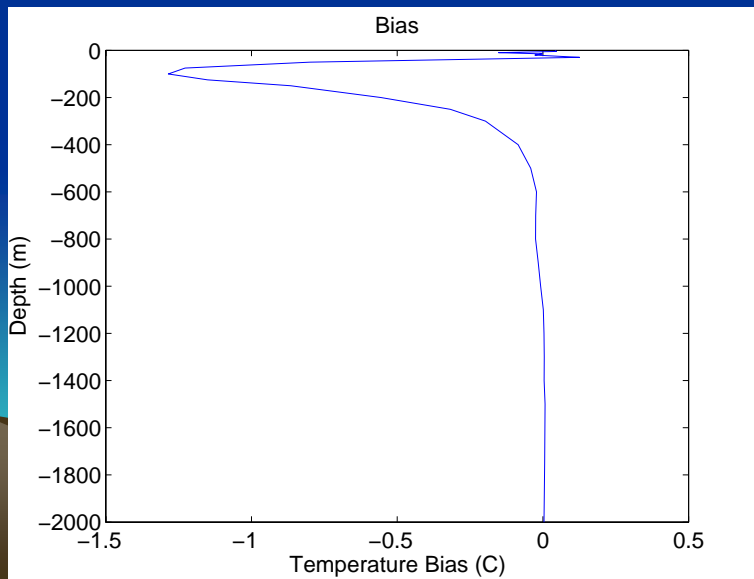
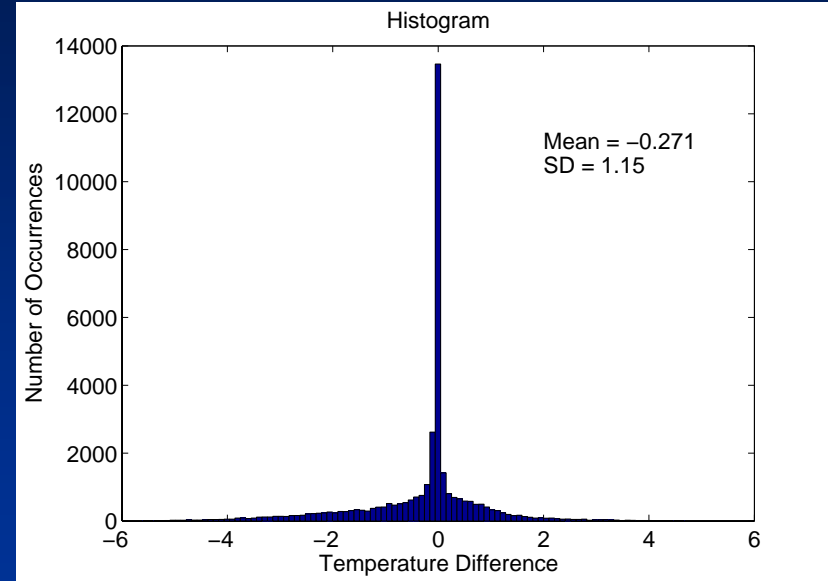
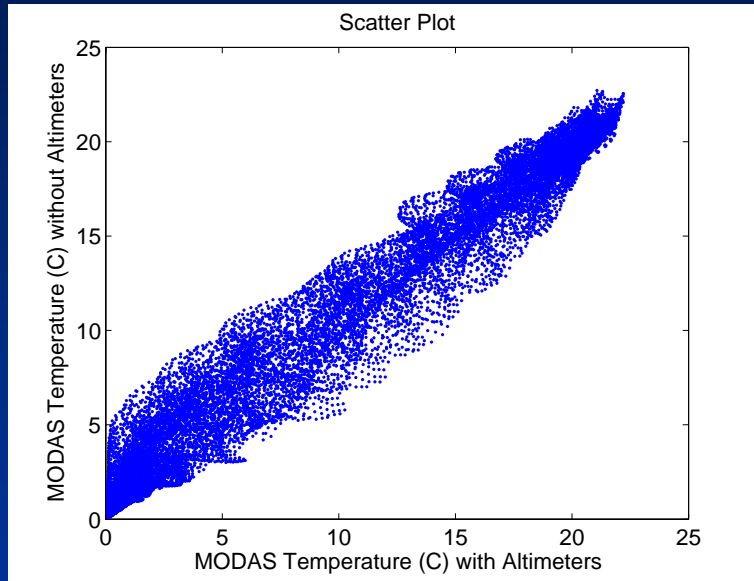


# Comparison of Temperature at 400 m on Jun 30, 2001



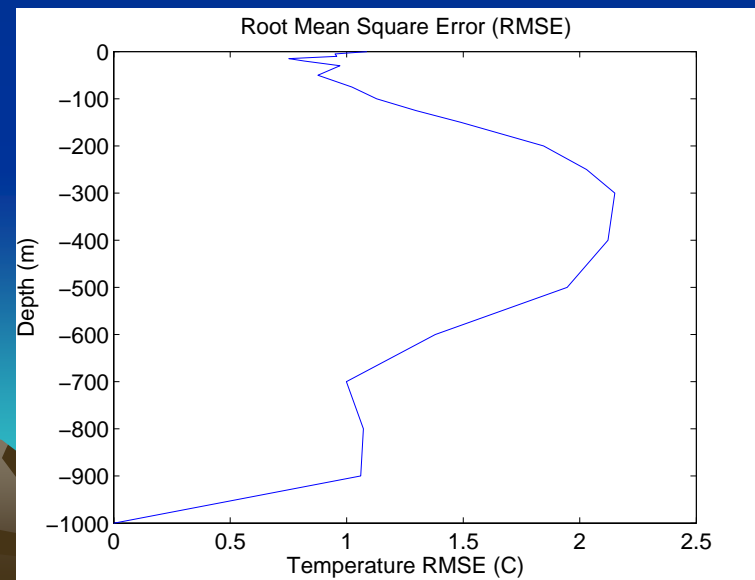
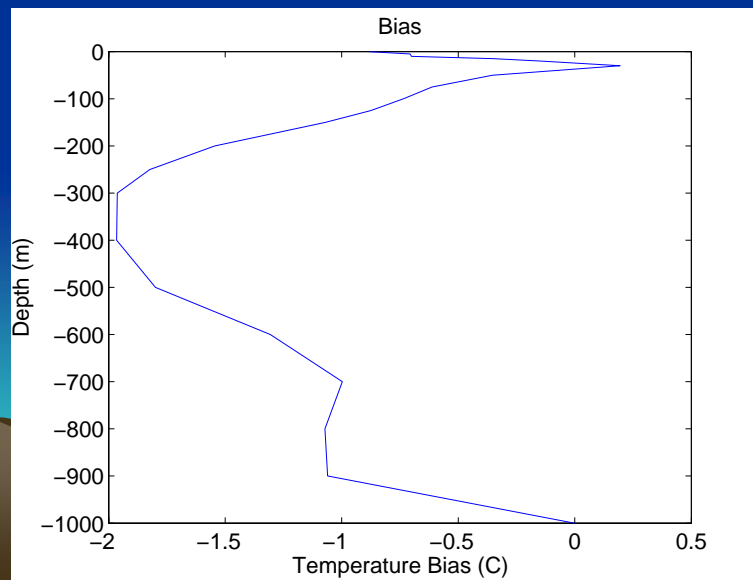
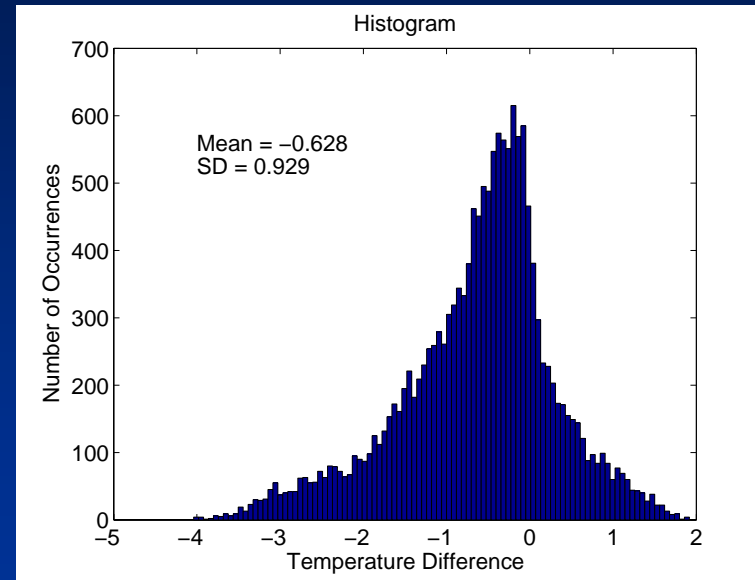
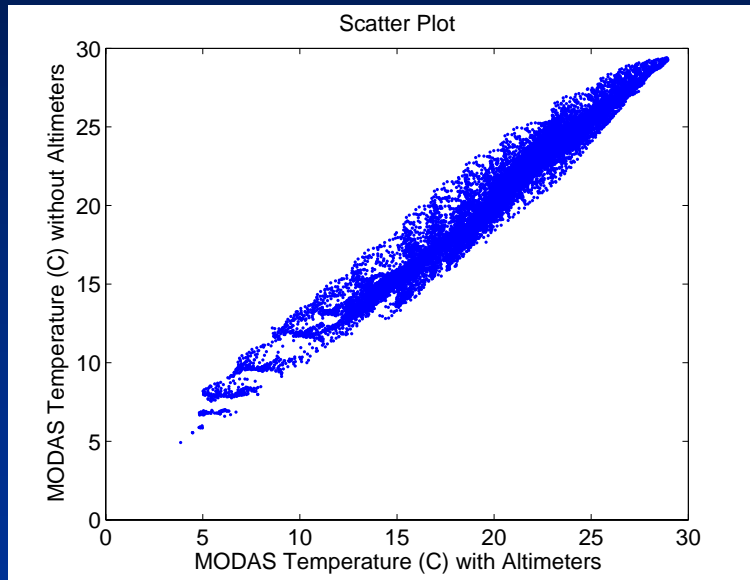
# Temperature Statistics for Japan/East Sea (JES)

## June 30, 2001



# Temperature Statistics for ECS

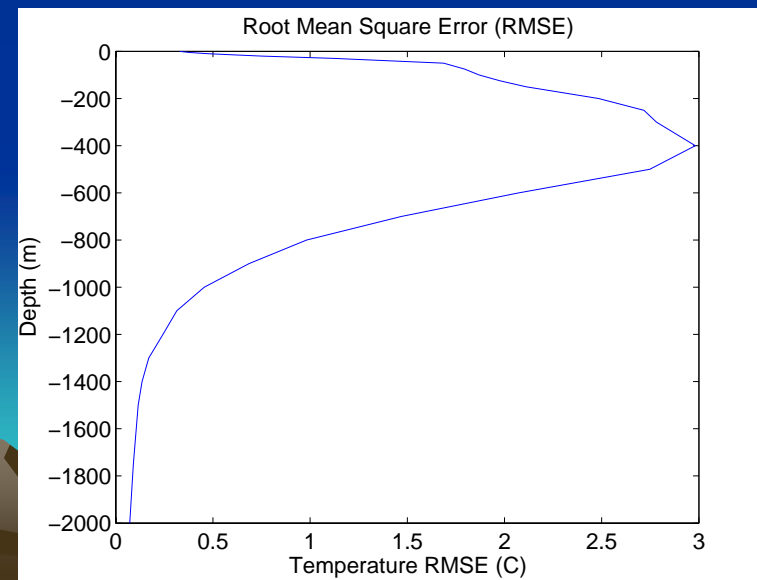
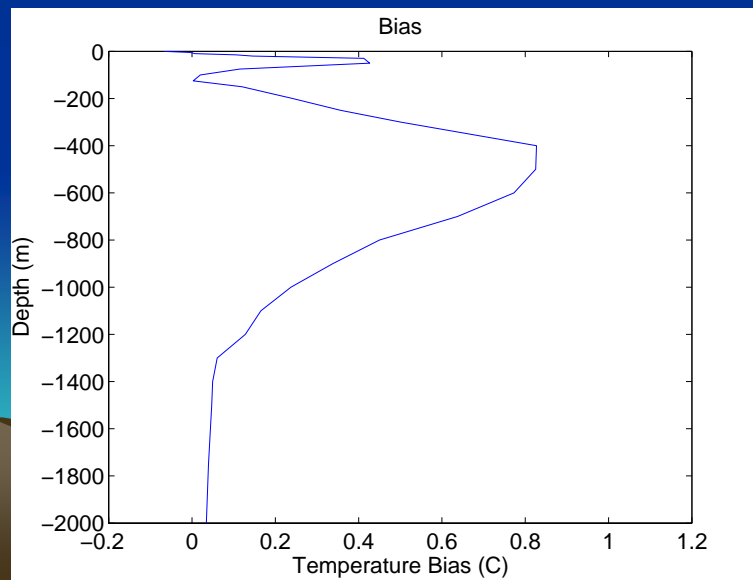
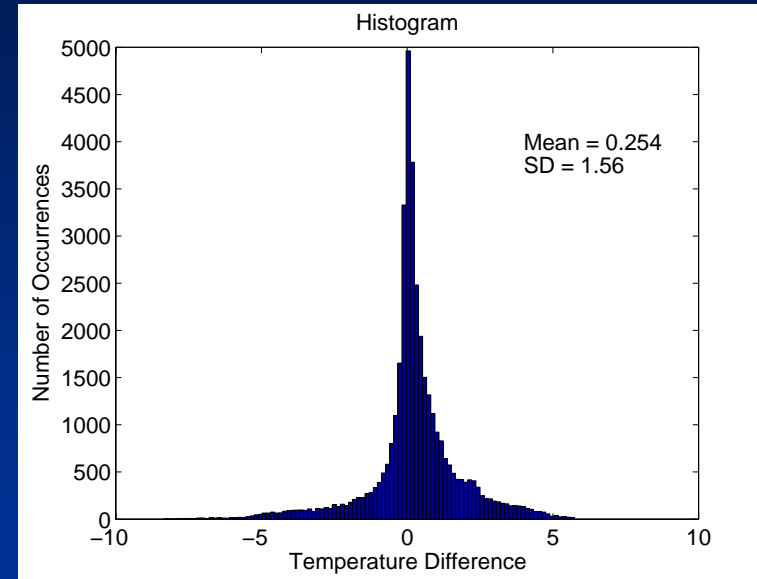
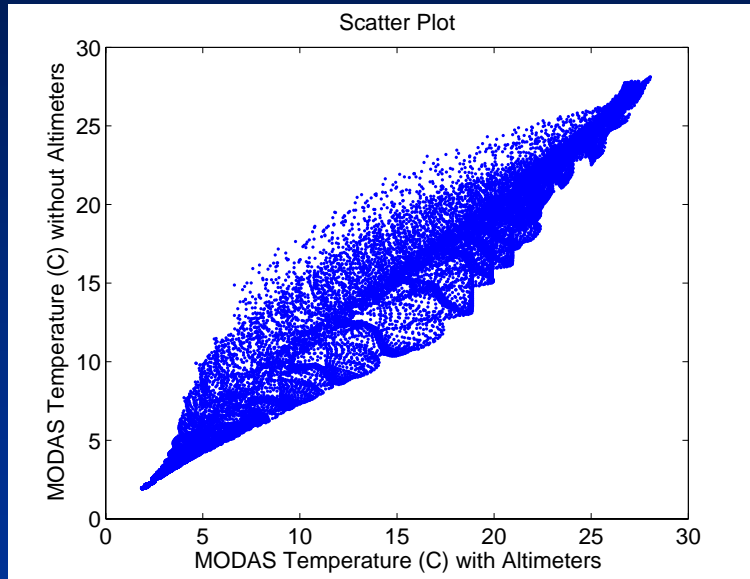
## Jun 30, 2001





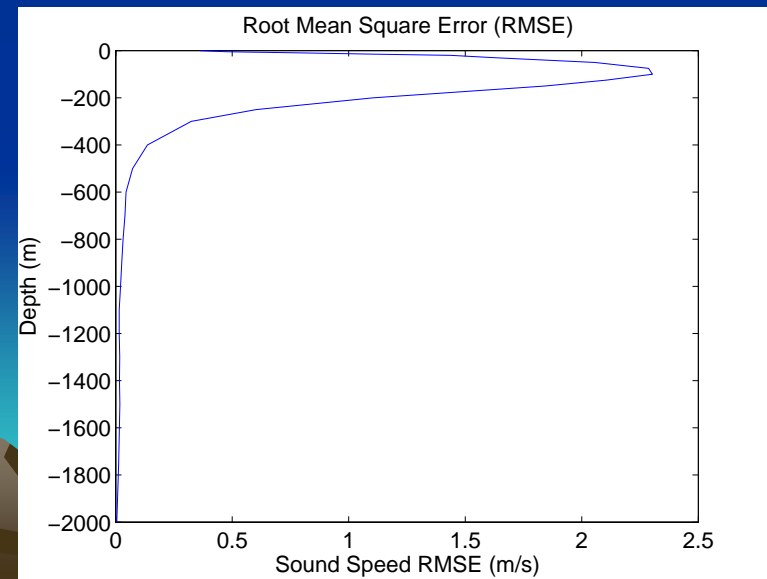
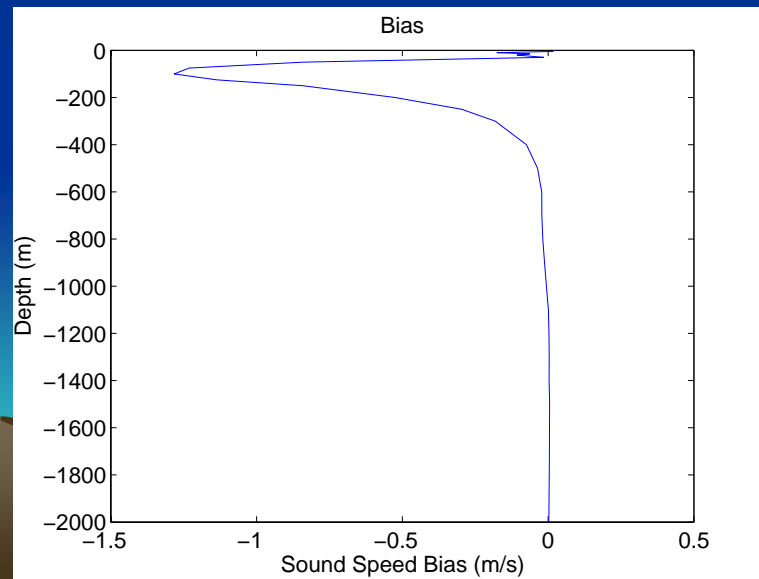
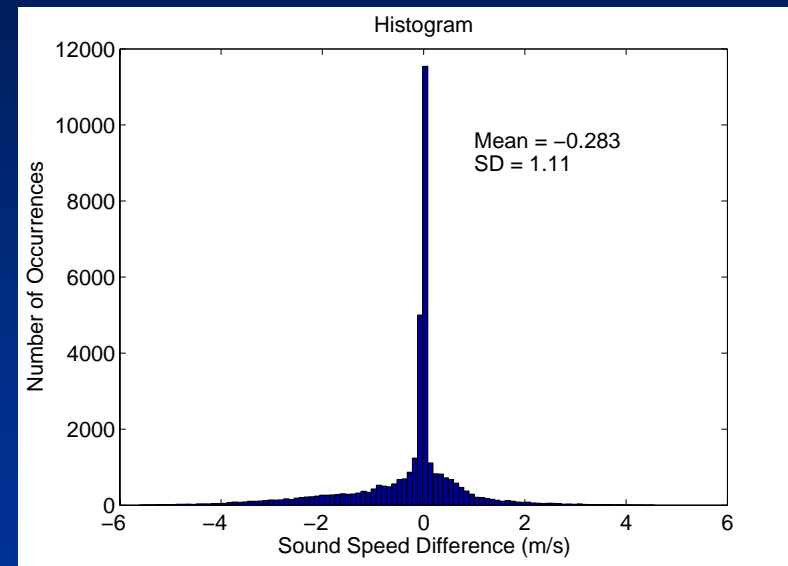
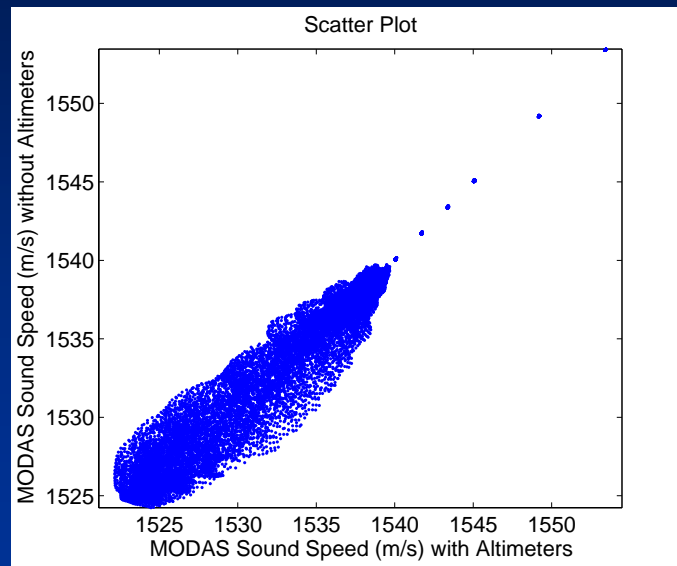
# Temperature Statistics for KCA

## Jun 30, 2001



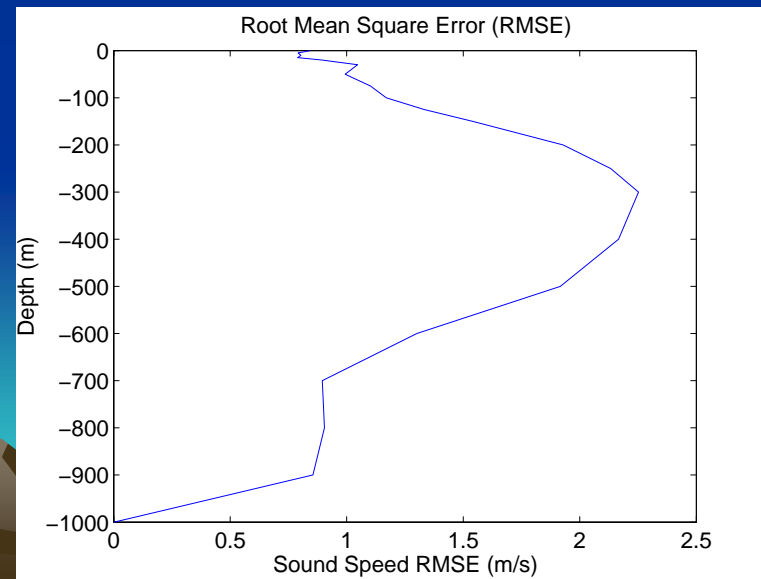
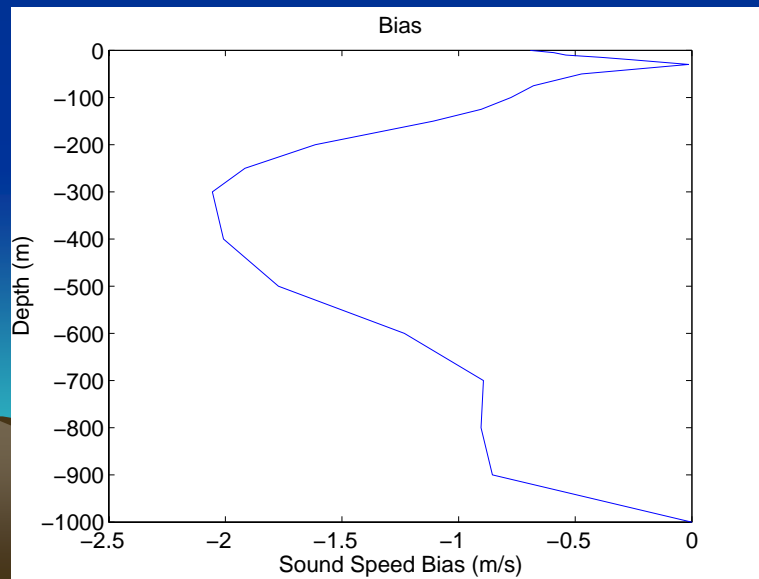
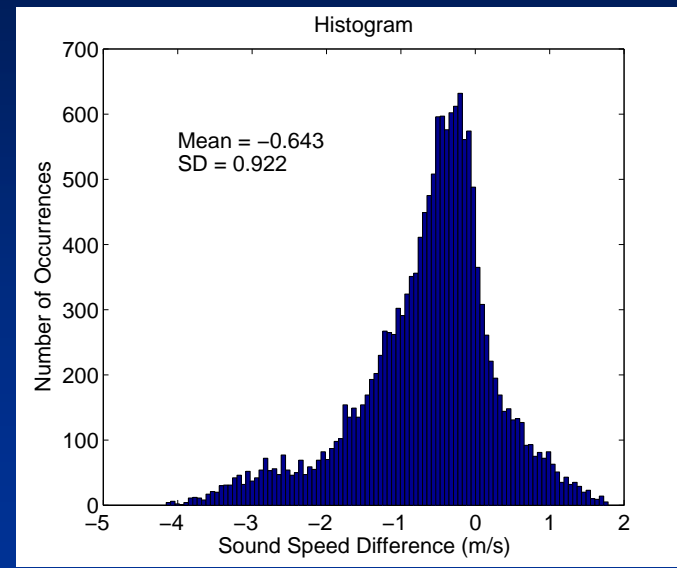
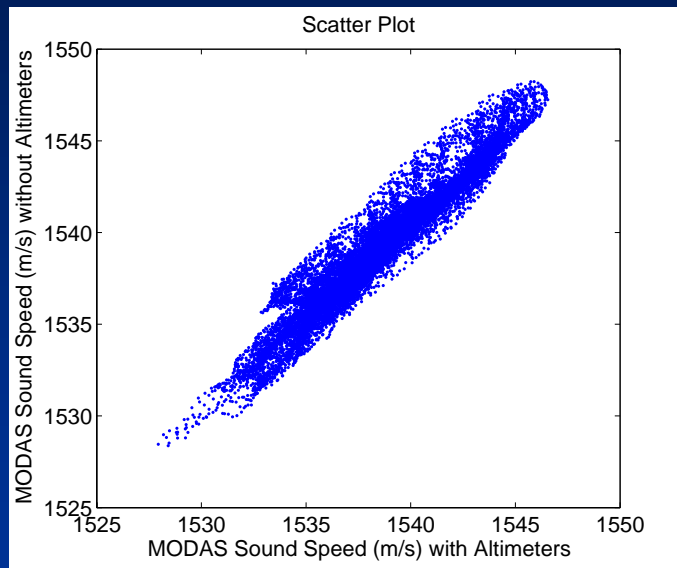
# Sound Speed Statistics for JES

## Jun 30, 2001



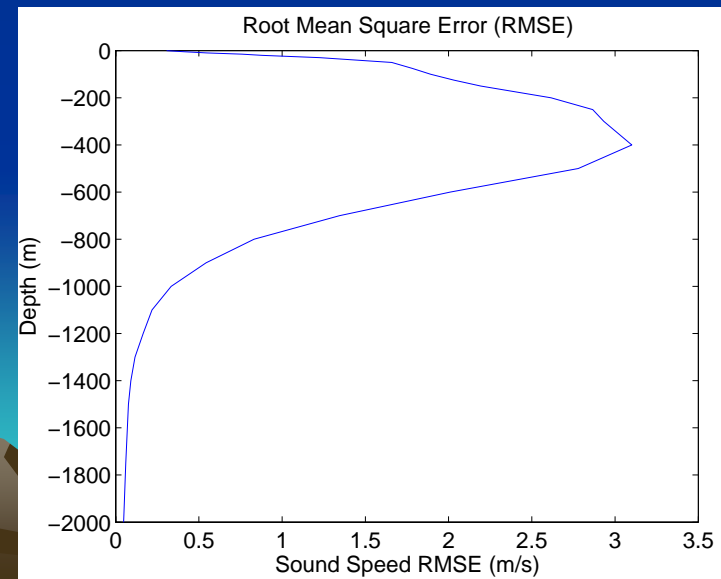
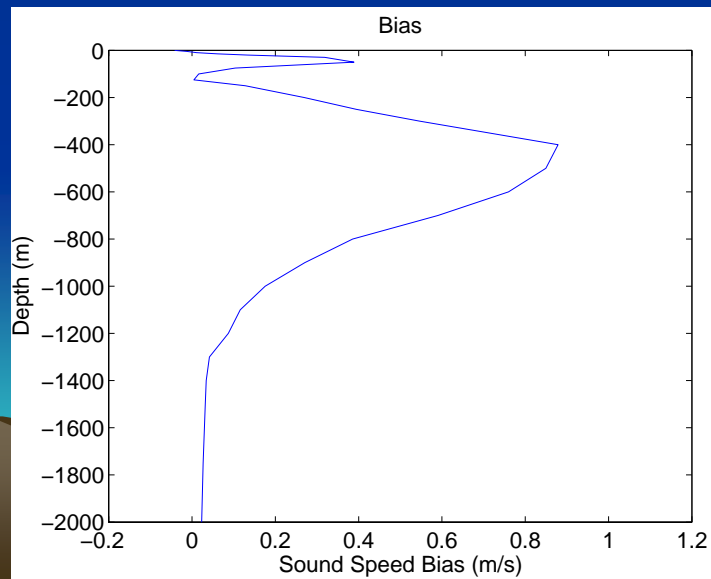
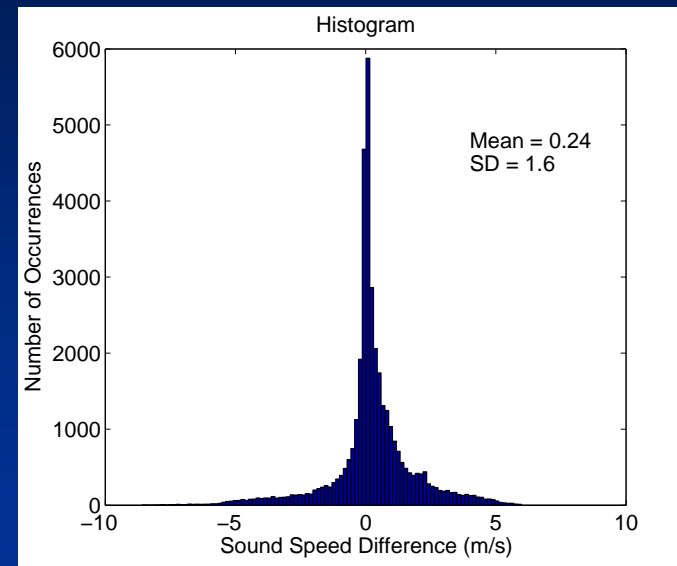
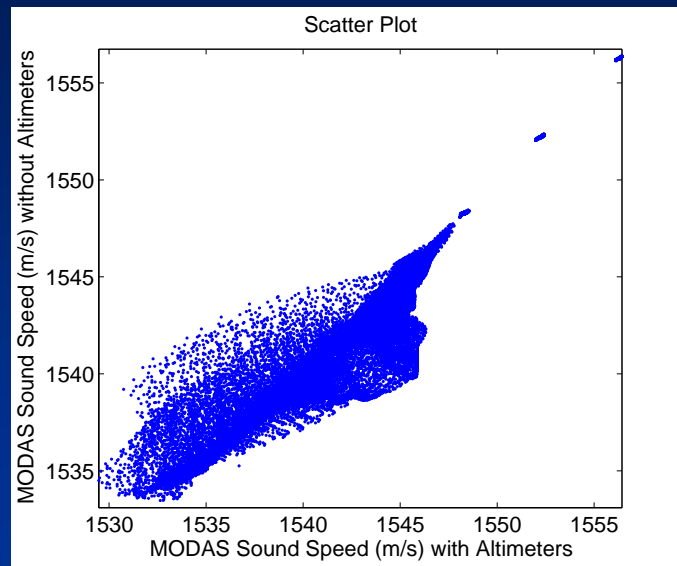
# Sound Speed Statistics for ECS

## Jun 30, 2001



# Sound Speed Statistics for KCA

## Jun 30, 2001



# Processing

- Naval Undersea Warfare Center Division Newport
- Weapon Acoustic Preset Program (WAPP)
  - Mk48 Acoustic Preset Calculation
  - Output: Percentage Area Coverage



# Development Efforts Background

- Torpedo Acoustic & Ballistic Preset Development Efforts Performed by NUWCDIVNPT, Combat Systems Department, Weapon Guidance and Control Branch (Code 2213)
- Additional Tactical Decision Aid and Modeling Development Efforts for Harpoon, Tomahawk, SLMM, ISLMM
- Points of Contact:
  - Gene Bessacini: [bessaciniea@npt.nuwc.navy.mil](mailto:bessaciniea@npt.nuwc.navy.mil)
  - David Cwalina: [cwalinads@npt.nuwc.navy.mil](mailto:cwalinads@npt.nuwc.navy.mil)



# Weapon Acoustic Preset Program (WAPP) Objectives

- To Provide the Fleet with an On-Board Automated Interactive Means for Generating Mk 48 & Mk 48 ADCAP Acoustic Presets and Visualizing Torpedo Performance
- Base Computations on In Situ Environmental, Tactical, Target, and Weapon Parameters
- Track the Evolution of Weapon, Tactical, Target, and Environmental Models
- Provide Interfaces to
- Support Fleet Exercises, Training, and Program Deliveries



# Acoustic Preset Program

- Mk 48 Acoustic Preset Program (M48APP)—Mk 48 Mod 3/4
- Mk 48 ADCAP Acoustic Preset Program (MAAPP)—ADCAP Baseline, Shallow, TPU
- Weapon's Acoustic Preset Program (WAPP)—Integrated Mk 48 and Mk 48 ADCAP Capability
- Programs Provide a Presetting Capability Based Upon:
  - A Common Graphics User Interface for the Entry of Environmental, Tactical, Target, and Weapon Data
  - A Common Computational Engine for the Generation of Accurate Acoustic Performance Predictions
  - Common Output in the Form of a Ranked Listset of Search Depth/Pitch Angle/LD/Effectiveness Values Along With an Acoustic Ray Trace and Signal Excess Map
  - Mk 48 Mod Specific Presets/Vehicle Dynamics/Acoustics & Signal Processing





# Program Evolution

- Initial Development of Mk 48 ADCAP Acoustic Preset Program to Support ADCAP Block I
- Incorporation of Shallow Water and Under Ice Capability
- Development of Mk 48 Mod 3/4 Presetting Capability
- Development of ADCAP Block II/Block IIA Capability
- Merge of
- High Frequency Environmental and Acoustic Sub-Model Update



# Support Status

- Royal Australian Navy—Mk 48 Acoustic Preset Program Part of Collins Class Augmentation System (CCAS)
  - HP TAC-3/4 Host under Unix
  - Configuration Managed Under Product Version Control (PVC)
  - Application Embedded in Overall Architecture
  - Documentation and Training Provided
  - Provides Environmental Data Entry for CCAS
  - Interfaces to Other Tactical Systems Specified
- Royal Canadian Navy—Mk 48 Acoustic Preset Program Rearchitected for Java
  - PC version under development



**File** **Changes** **Utilities** **Help**

**Surface Conditions**

Wind Speed (m/s):

Wave Height (m):

Sea State:

Rain:

Shipping Level:

**Bottom Conditions**

SSP Depth (m):

Bottom Type:

**Default Conditions**

VSS Background (dB):

Salinity:

Latitude:

Longitude:

**Mode Messages**

**Environmental Data**

Velocity in Metres/Second

Profile: default

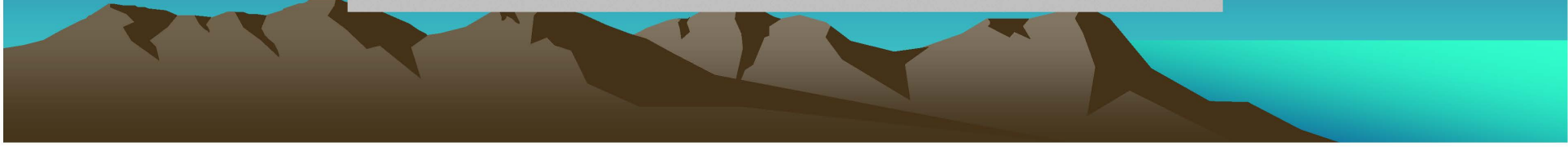
DTG:

Depth	Temp	Vel	VSS	Sal
0.0	20.44	1523.06	-75.00	35.00
76.2	19.06	1520.46	-75.00	35.00
91.4	17.50	1516.20	-75.00	35.00
213.4	12.67	1503.00	-75.00	35.00
243.8	12.22	1501.99	-75.00	35.00
304.8	11.44	1500.32	-75.00	35.00
1524.0	3.89	1491.84	-75.00	35.00

**Table Group Identifier**

Surfaced Target 3

Submerged Target 3



# Environmental Data Entry (EDE) Module

- Graphic Interface for Entry & Examination of Sound Speed Profile (Depth, Temperature, Sound Speed, Volume Scattering, Salinity) and Entry of Sea Surface/Sea Bottom Conditions
- Module Provides Manual Entry of Environmental Data for Op Area
  - US Systems Have Interface to Environmental Databases to Import System or Projected Environment
  - RAN Tactical Support System has Specification for Interface to Tactical Environment Sub-System (TESS) in Place
- Environmental Data is Associated to Preset Lists for Direct Recall of Computations



# EDE

## Sea Surface Conditions

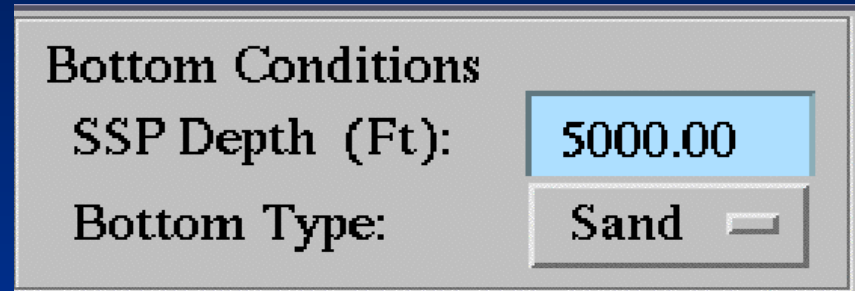
- Wind Speed/Wave Height/Sea State Coupled for Entry of Any Value
- Coupled By World Meteorological (WMO) or Beaufort Scale Convention
- Supports Sea States (0-9 WMO, 0-12 Beaufort) & Ice Cover

Surface Conditions	
Wind Speed (Kts):	<input type="text" value="5.00"/>
Wave Height (Ft):	<input type="text" value=".17"/>
Sea State:	<input type="text" value="1"/>
Rain:	<input type="text" value="None"/>
Shipping Level:	<input type="text" value="None"/>

# WAPP

## Environmental Data Entry (EDE) Module

- Sea Bottom Conditions
- Bottom Depth (Any Depth Shallower Than Last Point in Sound Speed Profile (SSP))
- Bottom Type
  - Mud/Sand (Lossy Bottoms)
  - Clay
  - Gravel
  - Rock



Bottom Conditions

SSP Depth (Ft): 5000.00

Bottom Type: Sand

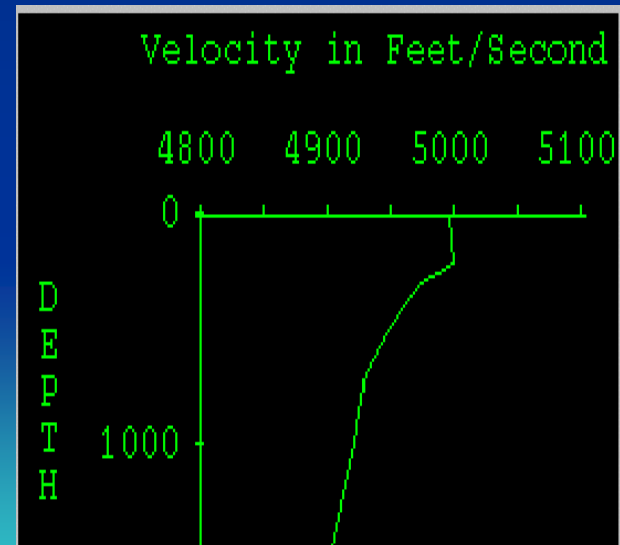
The screenshot shows a dialog box titled "Bottom Conditions" with a light gray background. It contains two input fields. The first is labeled "SSP Depth (Ft):" and has a text box containing the value "5000.00". The second is labeled "Bottom Type:" and has a dropdown menu currently displaying "Sand".

# EDE

## Water Column Characteristics

- Water Column Characteristics
- Sound Speed Profile
  - Depth(ft/m)
  - Temperature(°F/°C)
  - Sound Speed(ft/sec, m/sec)
  - Volume Scattering Strength (VSS) (dB)
  - Salinity (ppt)
- Entry of Temperature or Sound Speed Supported With Computation of Unknown Quantity

Depth	Temp	Vel	VSS	Sal
.0	68.80	4996.90	-75.00	35.00
213.0	68.80	5000.40	-75.00	35.00
250.0	66.30	4988.40	-75.00	35.00
300.0	63.50	4974.40	-75.00	35.00
500.0	58.50	4949.80	-75.00	35.00
700.0	54.80	4931.10	-75.00	35.00
800.0	54.00	4927.80	-75.00	35.00
1000.0	52.60	4922.30	-75.00	35.00
1500.0	48.30	4902.50	-75.00	35.00



# EDE

## Additional Fields

- Profile Name:  
Character String
- Table Group Identifier  
Associated with Profile
- Default Volume  
Scattering Strength  
(dB)
- Default Salinity (ppt)
- Lat/Long

Profile: default

DTG:

Table Group Identifier

Surfaced Target 3

Submerged Target 3

Default Conditions

VSS Background (dB): -75.00

Salinity: 35.00

Latitude: 45:00:00N

Longitude: 000:00:00E



# Acoustic Preset Module Display

File Compute Acoustic_Coverage Environment Utilities Help																																						
Settings	Selected	Computed																																				
Tactic	Unknown																																					
Sub Tactic	Normal																																					
Target Mode	Sub																																					
Search Depth (m)	SD																																					
Pitch Angle (deg)	PA																																					
Ceiling (m)	10																																					
Floor (m)	200																																					
Doppler Enable	Out																																					
Acoustic Search	Active																																					
Trajectory Mode	Direct																																					
Speed Combo	Hi/Med																																					
Ping Interval	Long																																					
Search Mode	Snake																																					
Ash	In																																					
DZOI S/D (m)	0 / 213																																					
NTS / NZE (dB)	10.0 / 85																																					
Tgt Doppler (Spd)	High																																					
Tet Max Depth (m)	213																																					
Weapon Type	Mk48 Mod 4																																					
Weapon Mod	War																																					
Laminar Dist (m)	0																																					
Effectiveness																																						
<b>Messages</b> Must Compute Acquisition First Select Compute Presets																																						
<b>Table Group Identifier</b> Surface Group Member 3 Sub Group Member 3																																						
<table border="1"> <thead> <tr> <th>SD</th> <th>PA</th> <th>LD</th> <th>EFF</th> </tr> </thead> <tbody> <tr><td>SD 1</td><td>PA 1</td><td>LD 1</td><td>EFF 1</td></tr> <tr><td>SD 2</td><td>PA 2</td><td>LD 2</td><td>EFF 2</td></tr> <tr><td>SD 3</td><td>PA 3</td><td>LD 3</td><td>EFF 3</td></tr> <tr><td>SD 4</td><td>PA 4</td><td>LD 4</td><td>EFF 4</td></tr> <tr><td>SD 5</td><td>PA 5</td><td>LD 5</td><td>EFF 5</td></tr> <tr><td>•</td><td>•</td><td>•</td><td>•</td></tr> <tr><td>•</td><td>•</td><td>•</td><td>•</td></tr> <tr><td>•</td><td>•</td><td>•</td><td>•</td></tr> </tbody> </table>			SD	PA	LD	EFF	SD 1	PA 1	LD 1	EFF 1	SD 2	PA 2	LD 2	EFF 2	SD 3	PA 3	LD 3	EFF 3	SD 4	PA 4	LD 4	EFF 4	SD 5	PA 5	LD 5	EFF 5	•	•	•	•	•	•	•	•	•	•	•	•
SD	PA	LD	EFF																																			
SD 1	PA 1	LD 1	EFF 1																																			
SD 2	PA 2	LD 2	EFF 2																																			
SD 3	PA 3	LD 3	EFF 3																																			
SD 4	PA 4	LD 4	EFF 4																																			
SD 5	PA 5	LD 5	EFF 5																																			
•	•	•	•																																			
•	•	•	•																																			
•	•	•	•																																			
Contact: ... Associated Tube																																						
WOG Status XXX Enable Run XXX Gyro Angle XXX Torpedo Course XXX Torpedo Run XXX Enable Run Offset XXX Fuel At Enable XXX																																						
RTE Mode Offset Tube																																						

# Acoustic Preset Module

## Preset Computation

- Compute Presets Selection Sets  
Weapon Default Presets Based Upon Tactical Guidance, Determines Valid Search Depth/Search Angle Selections, Ranks and Recommends Settings
- Rerank Allows for Deviation from Default Presets in the Computation of Presets
- Acquisition Allows User to Evaluate Any Allowable Preset Combination Via Ray Trace/Signal Excess Map

<u>C</u> ompute	
<u>P</u> resets	Ctrl-P
<u>R</u> erank	Ctrl-R
<u>A</u> cquisition	Ctrl-A



# Acoustic Preset Module

## Tactical Presets

- Entry of Tactical Preset Values via Pull-Down Menus Configured for Mod 3/4
- Sub-Set of Total Tactical Presets Used in Acoustic Preset Computations
- Remaining Tactical Presets Entered to Complete Tactic List for Transfer to Combat Control System

Target Mode	Sub	▾
Search Depth (m)	SD	▾
Pitch Angle (deg)	PA	▾
Ceiling (m)	10	▾
Floor (m)	200	▾
Doppler Enable	Out	▾
Acoustic Search	Active	▾
Trajectory Mode	Direct	▾
Speed Combo	Hi/Med	▾
Ping Interval	Long	▾
Search Mode	Snake	▾
Ash	In	▾

# Acoustic Preset Module

## Target Data

- Target Maximum Operating Depth Based on Target Classification
  - Limits Vertical Area Used in Acoustic Preset Computations
- Depth Zone of Interest (DZOI) Allows for Further Restriction of Target Region Based on Target Operating Characteristics
- Acoustic Target Strength (NTS dB)/Radiated Noise (NZE dBs)
- Anticipated Target Doppler (DIW, Low, High)

DZOI S/D (m)	0 / 213	...
NTS / NZE (dB)	10.0 / 85	...
Tgt Doppler (Spd)	High	☐
Tgt Max Depth (m)	213	

# Acoustic Preset Module

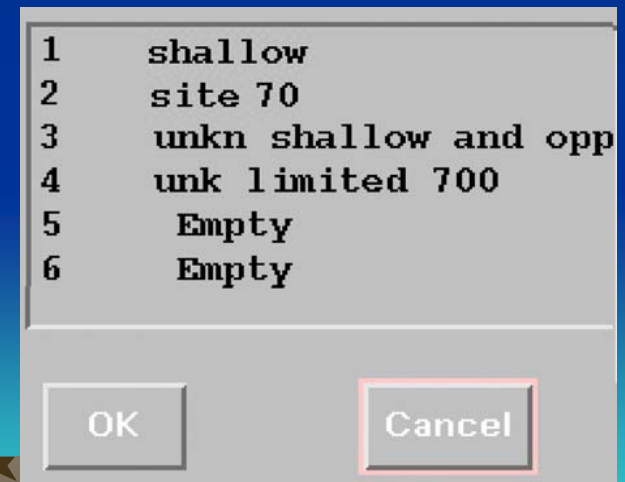
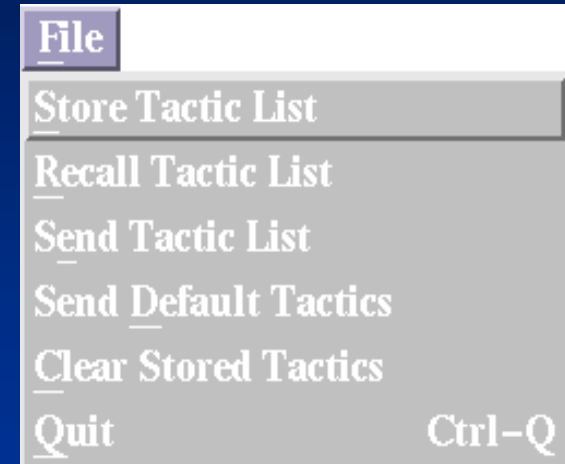
## Ranked Listset

- List Set of Search  
Depth/Pitch Angle/Laminar  
Distance/Effectiveness  
Values
- List Set Ranked Based on  
Acoustic Coverage  
Effectiveness and  
Recommendation Made  
Accounting for Cavitation and  
Depth Separation
- Laminar Distance Utilized in  
Weapon Order Generation  
for Gyro/RTE

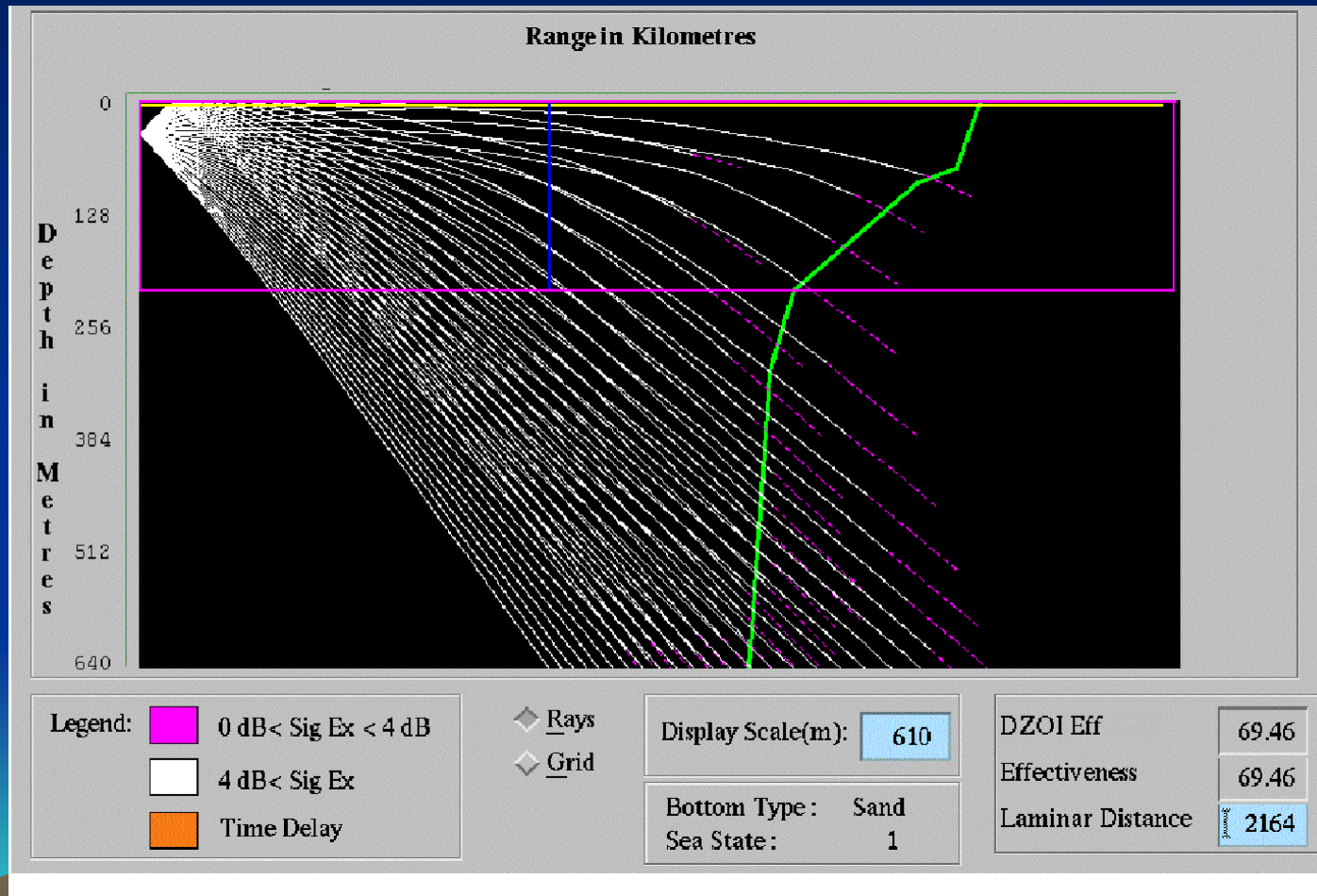
SD	PA	LD	EFF
SD 1	PA 1	LD 1	EFF1
SD 2	PA 2	LD 2	EFF2
SD 3	PA 3	LD 3	EFF3
SD 4	PA 4	LD 4	EFF4
SD 5	PA 5	LD 5	EFF5
•	•	•	•
•	•	•	•
•	•	•	•

# Acoustic Preset Module Tactic Lists

- Module Provides Capability to Store and Recall Tactical Preset Lists Along with Environmental Data, Scenario and Listset Data
- Data is Stored Local to Weapon's Module
- Lists May Be Transferred Via Network to Combat Control System
  - RAN Implementation Has Specification for Transfer to Engagement Sub-System (ESS)
  - Additional Window for Parameterization of Scenario/Environment for Transfer to Engagement Sub-System (ESS)



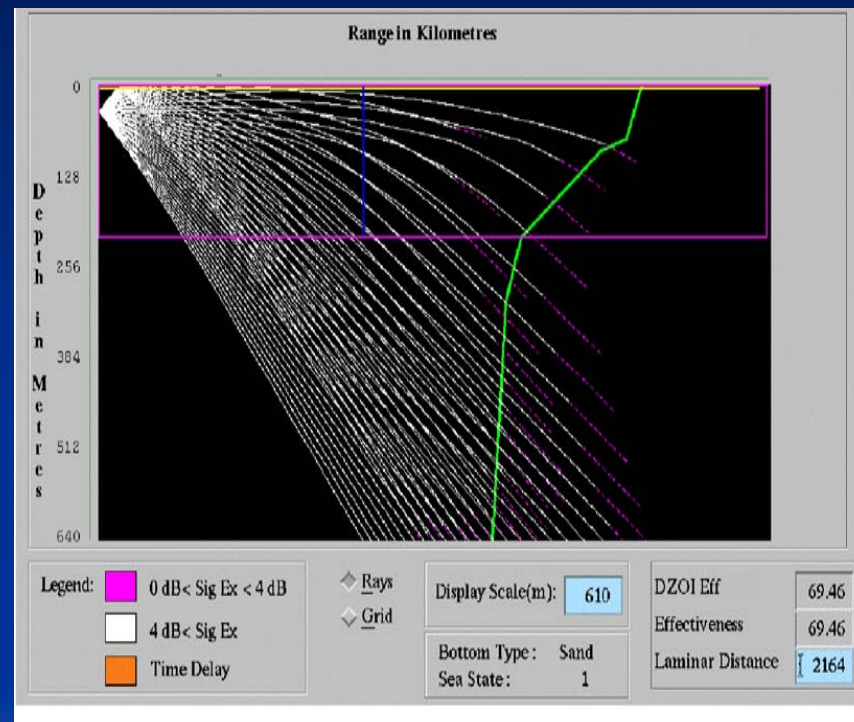
# Ray Trace Display



# Acoustic Preset Module

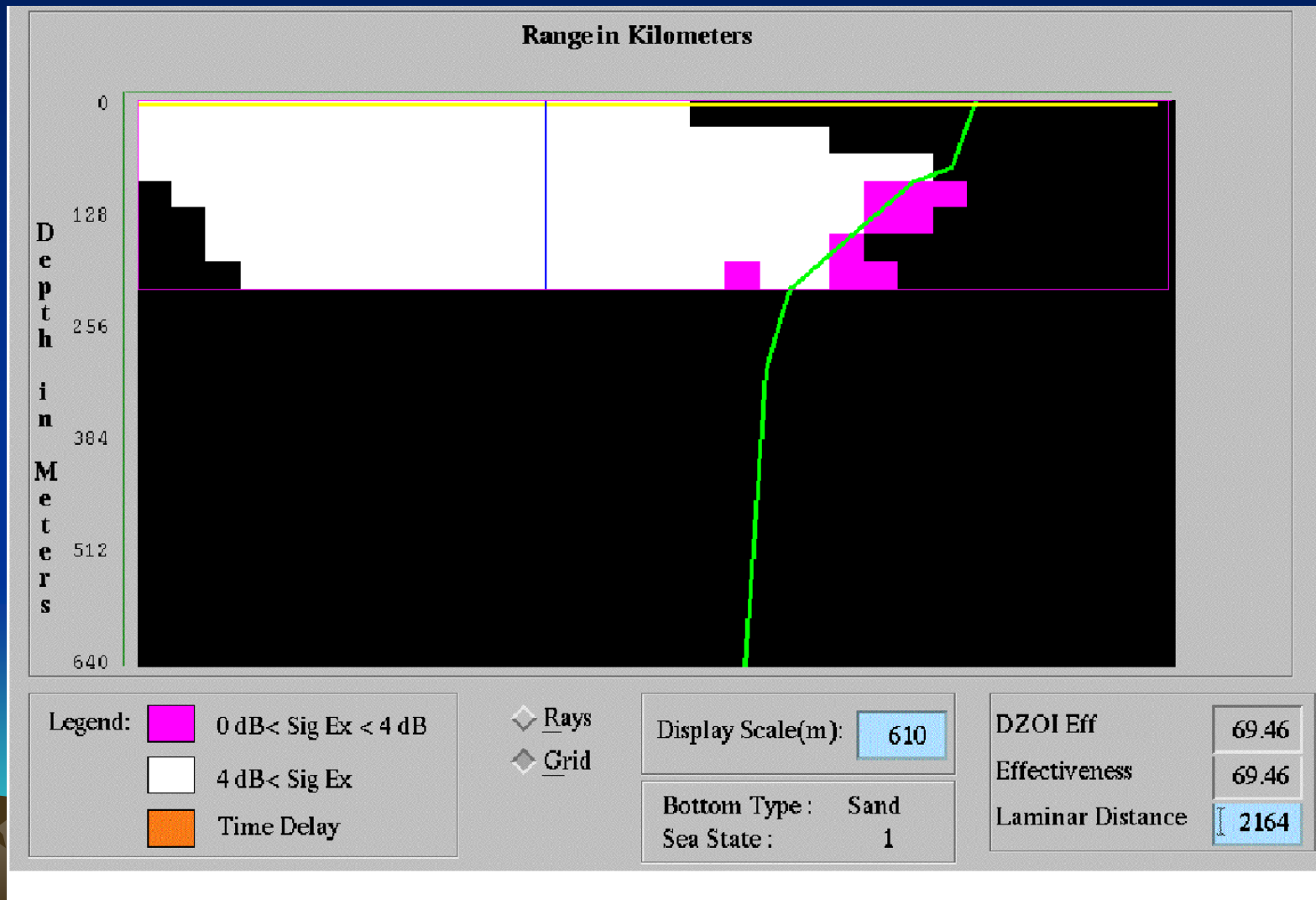
## Ray Trace Display

- Ray Trace Selectable from Pull-Down Menu
- Provide a Visual Interpretation of Mk 48 Acoustic Performance
- Impact of Boundary Interactions and Refraction Shown
- Variable Target Depth Bands(Near-Surface, Depth Zone of Interest, Target Max Depth)
- Effects of Reverberation Apparent for Low Doppler Targets





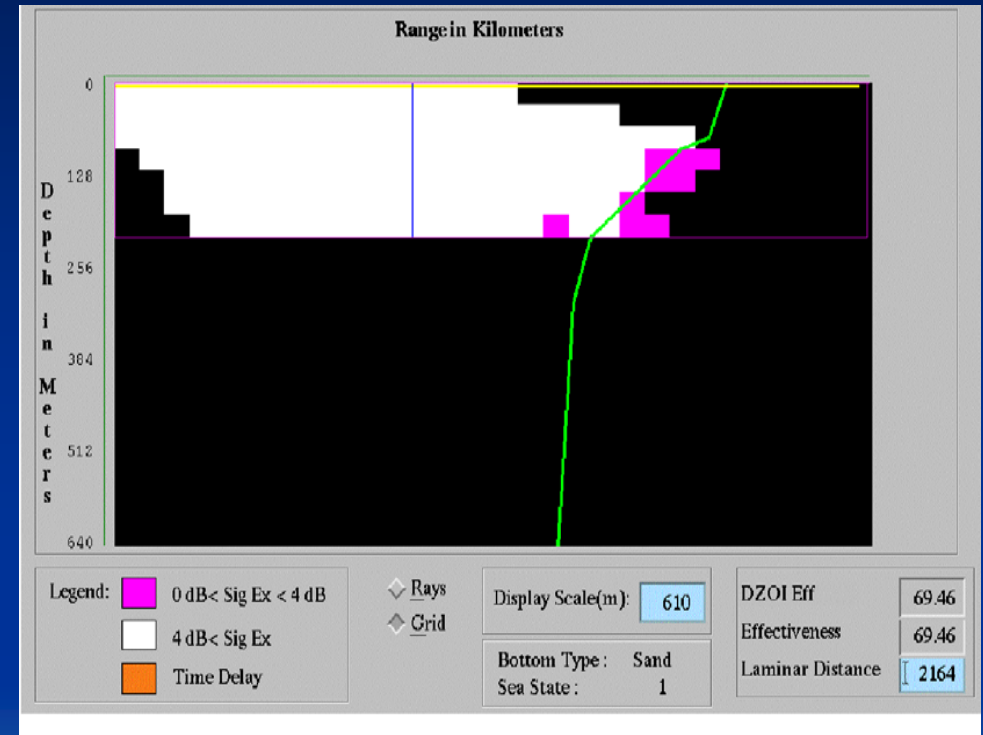
# Signal Excess Display



# Acoustic Preset Module

## Signal Excess Display

- Signal Excess Selectable from Pull-Down Menu
- Provide a Visual Interpretation of Mk 48 Acoustic Performance Over Depth Band of Target
- Effects of Ray Bending Apparent
- Effects of Reverberation Apparent for Low Doppler Targets



# Generated Output

- Coverage Area
  - Percentage of the search region with signal excess greater than a chosen threshold
- 5 Tactics Were Explored:
  - ASW with low Doppler, deep target
  - ASW with high Doppler, deep target
  - ASW with low Doppler, shallow target
  - ASUW with low Doppler, shallow target
  - ASUW with high Doppler, shallow target
- Values Normalized Over Acoustic Modes

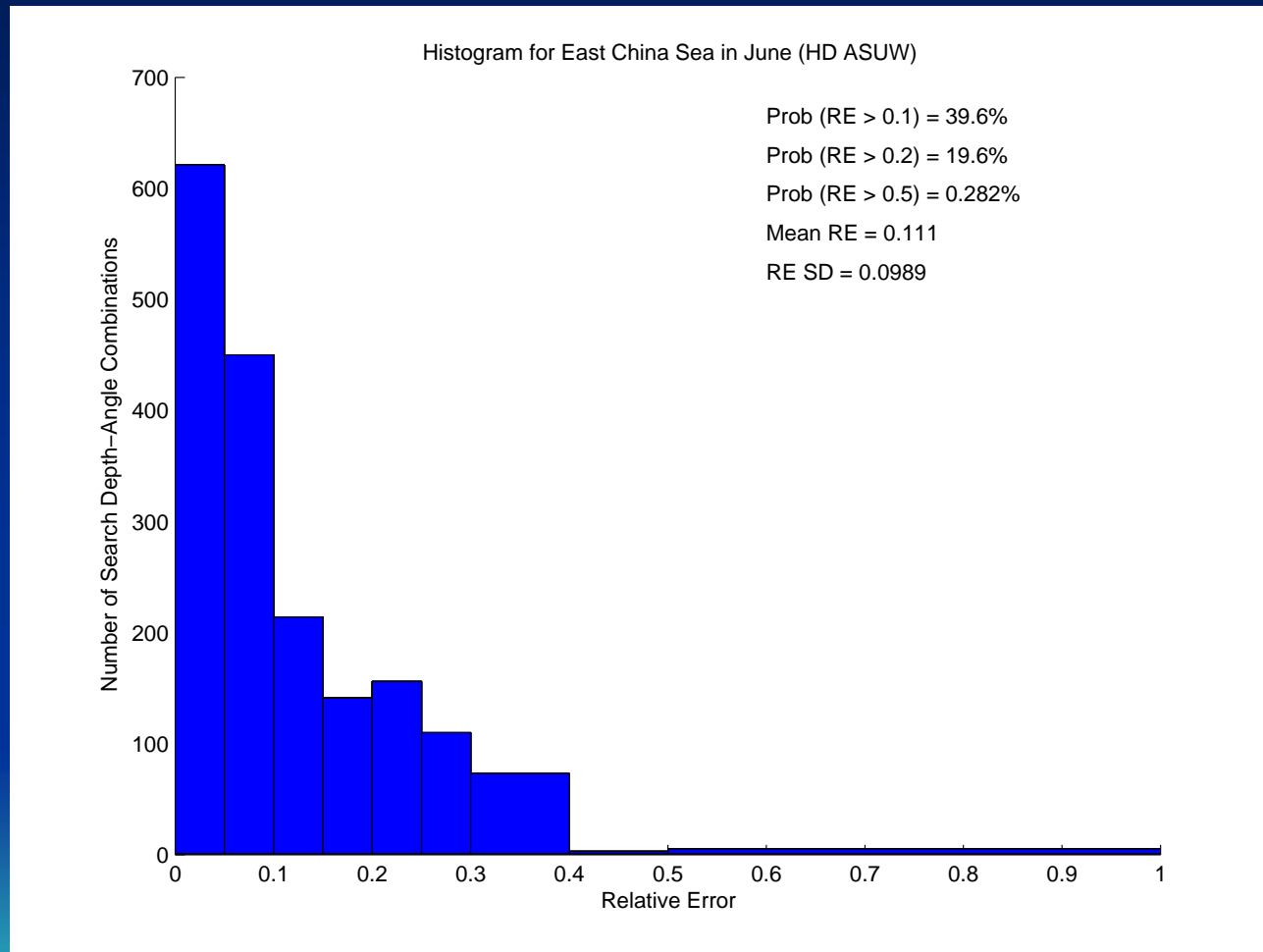


# Analysis of Output

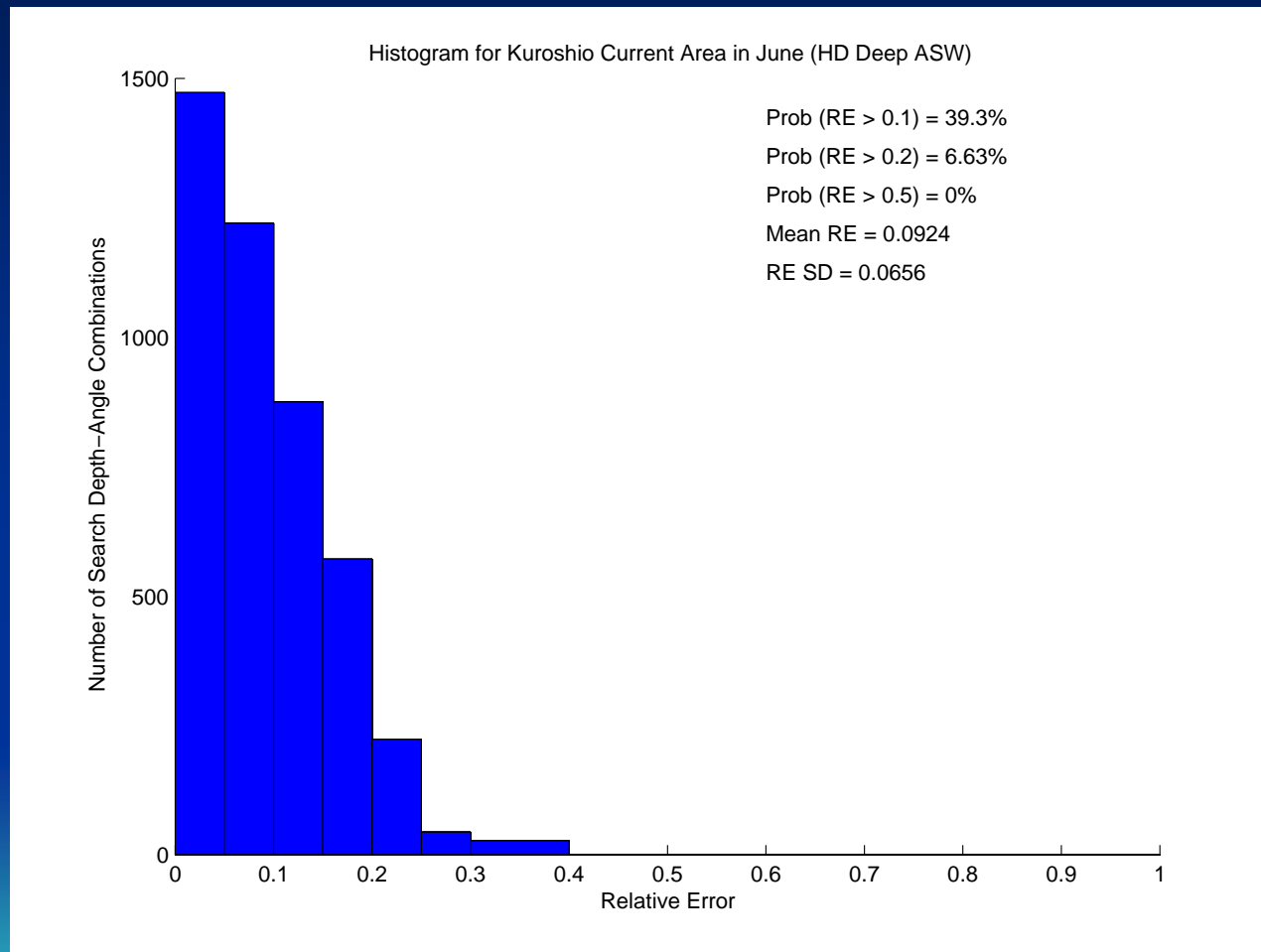
- Used a statistical software package to determine relative error (RE) in coverage area produced by the 2 different input fields
  - Compared coverage areas with positive signal excess
  - Only considered cases where a different search depth/angle combination was chosen by the WAPP
- Generated histograms that show the number of these combinations that fall into set RE ranges
  - Done for each region, time, and tactic



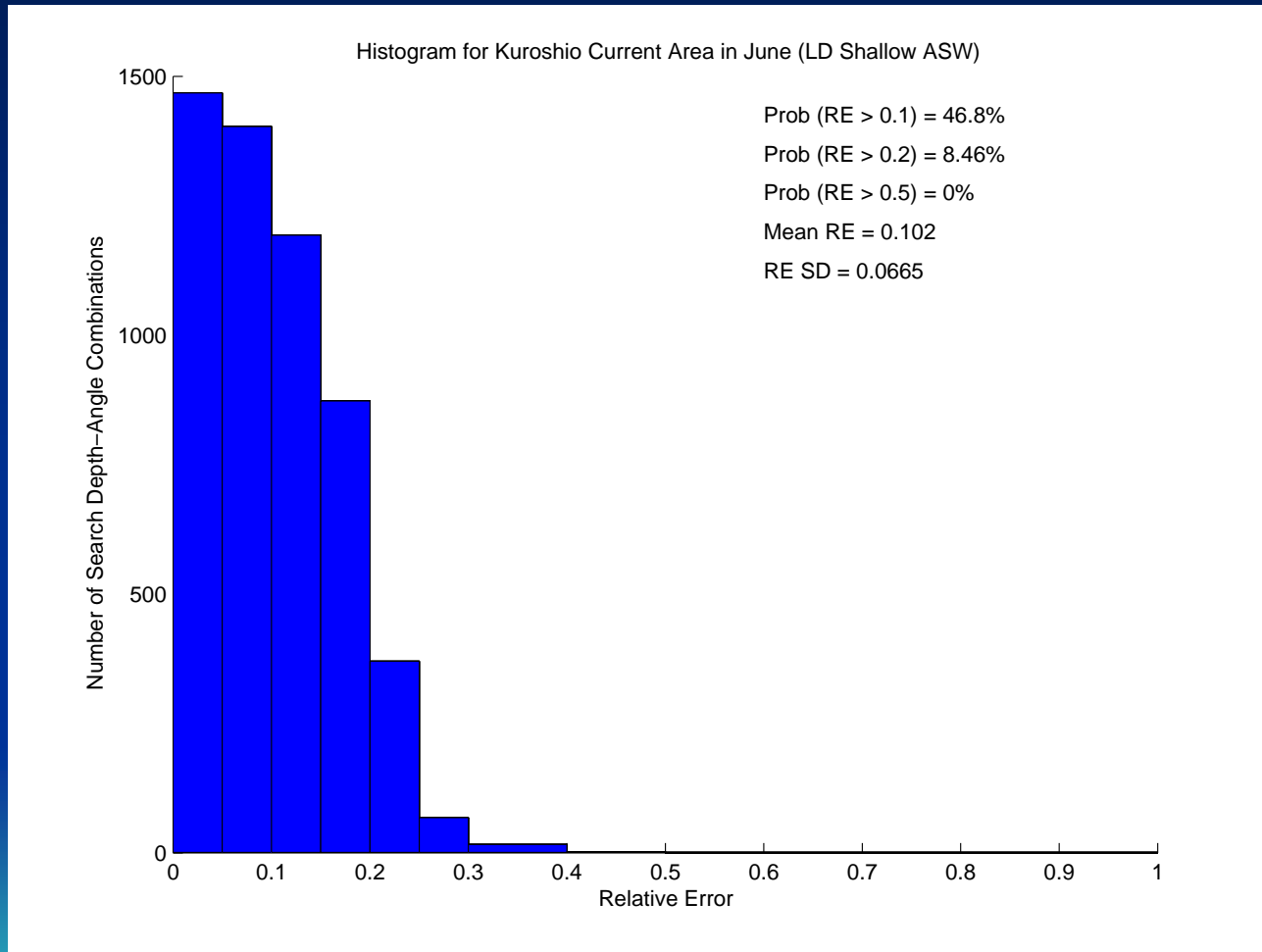
# East China Sea (June) HD ASUW



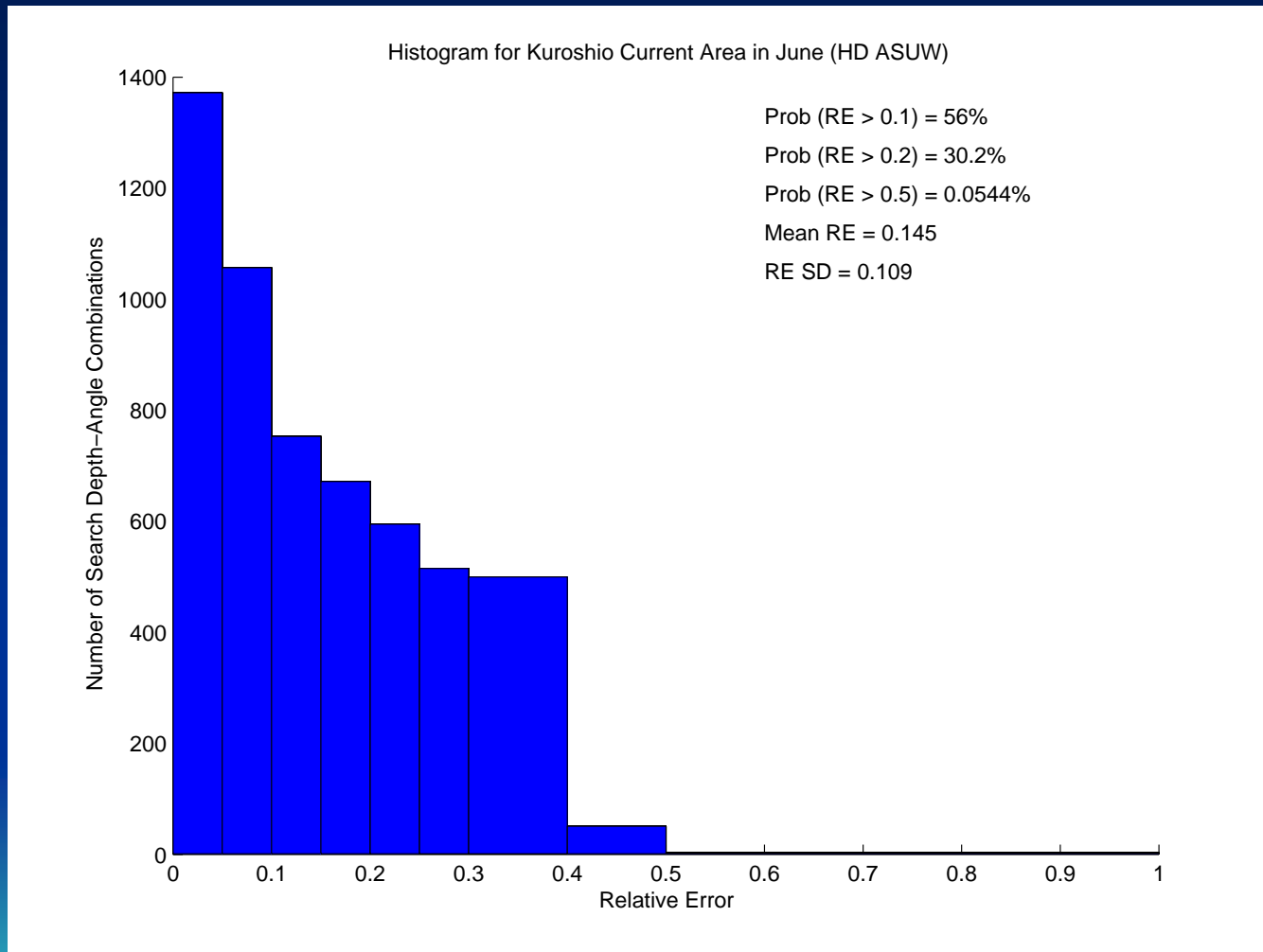
# Kuroshio Region (June) HD Deep ASW



# Kuroshio Region (June) LD Shallow ASW

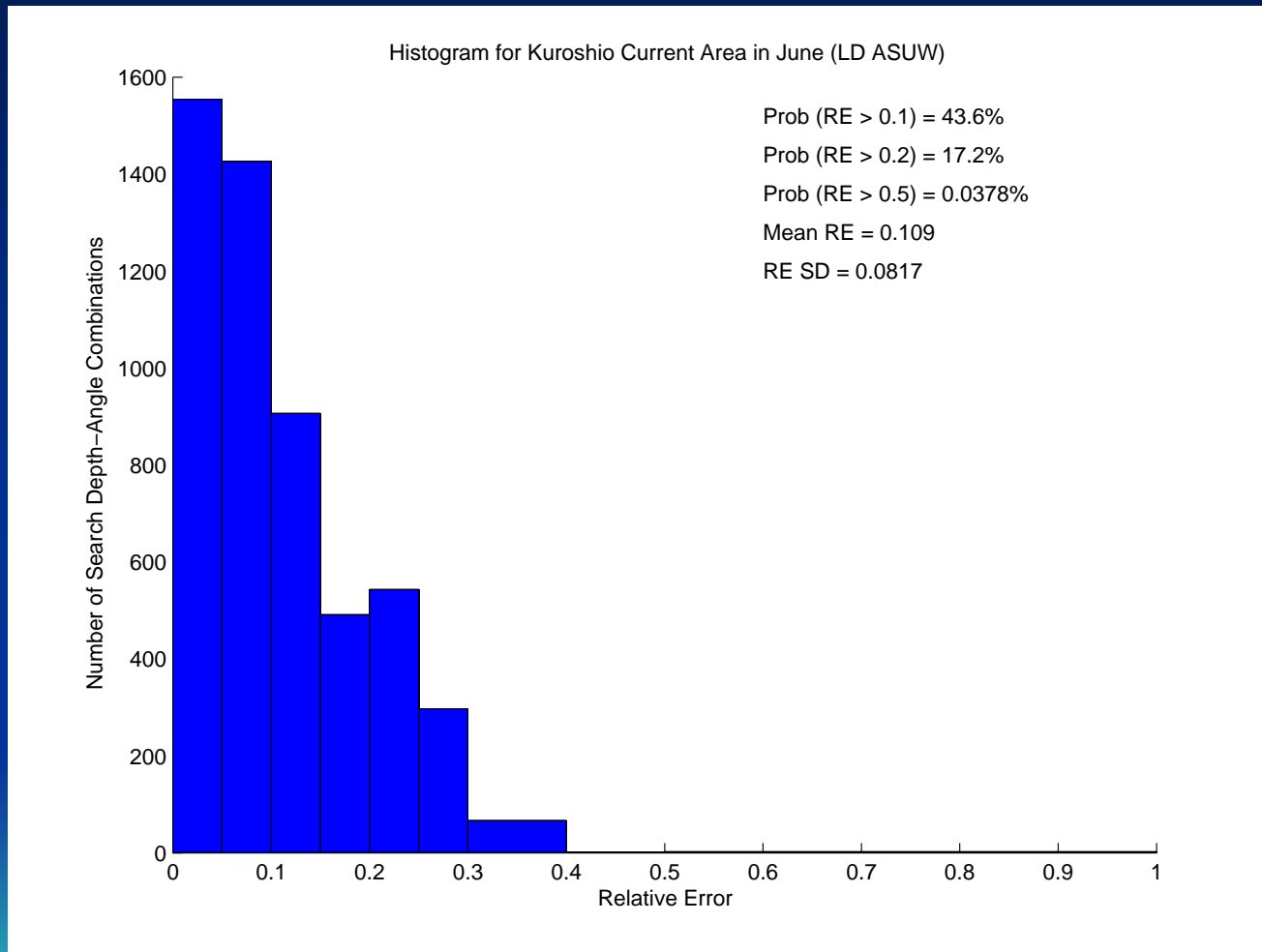


# Kuroshio (June) HD ASUW

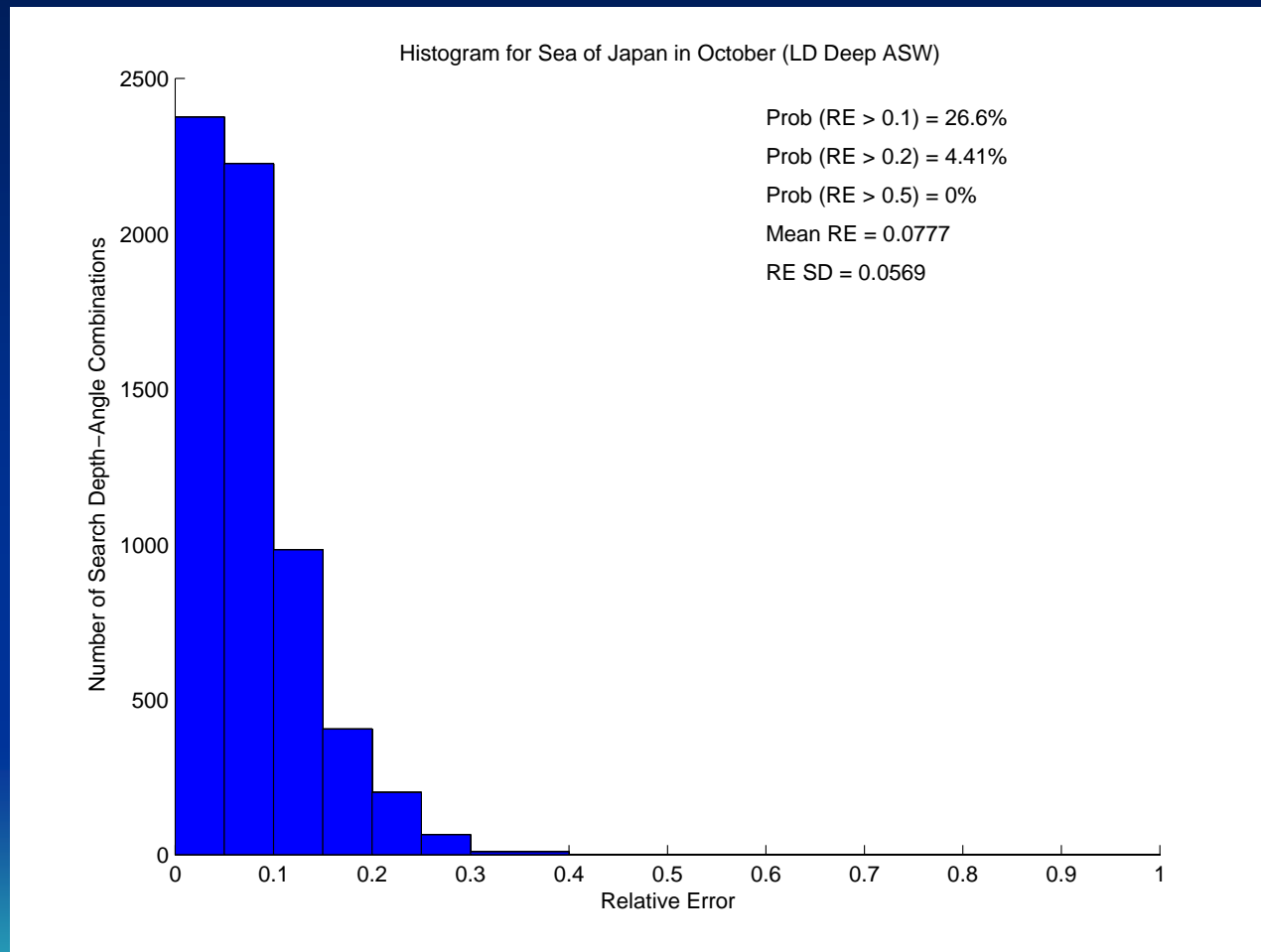




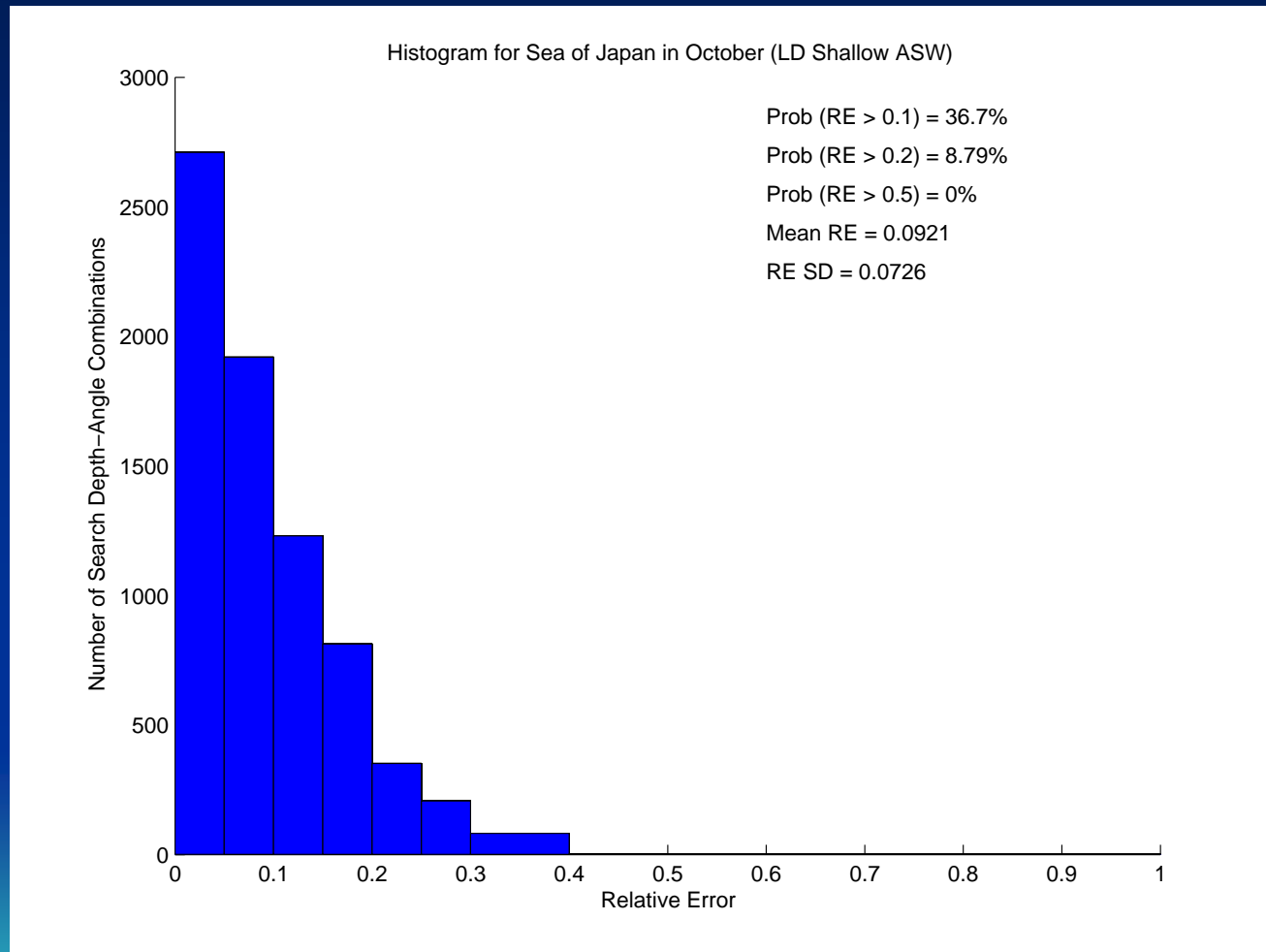
# Kuroshio (June) LD ASUW



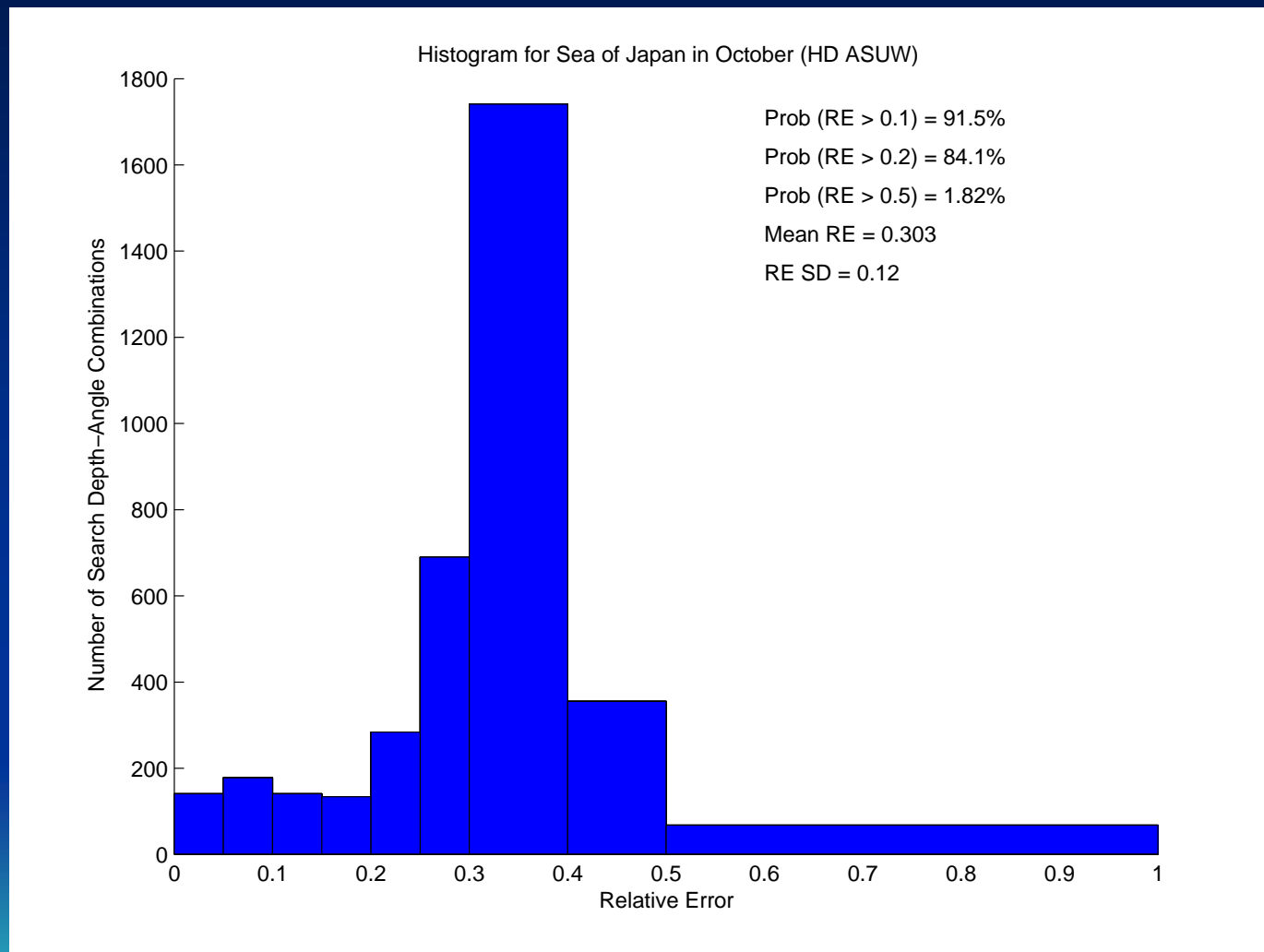
# JES (October) LD Deep ASW



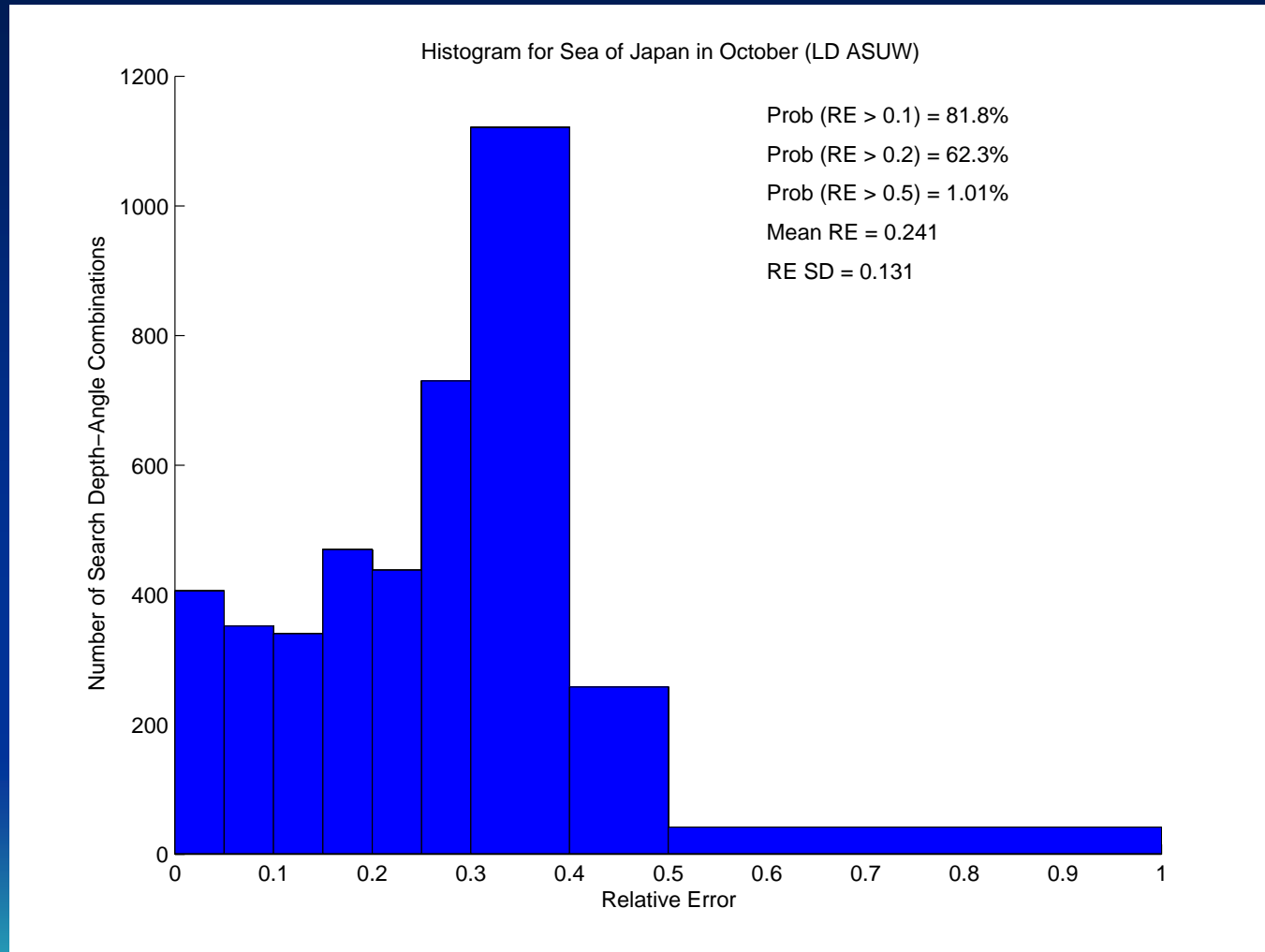
# JES (October) LD Shallow ASW



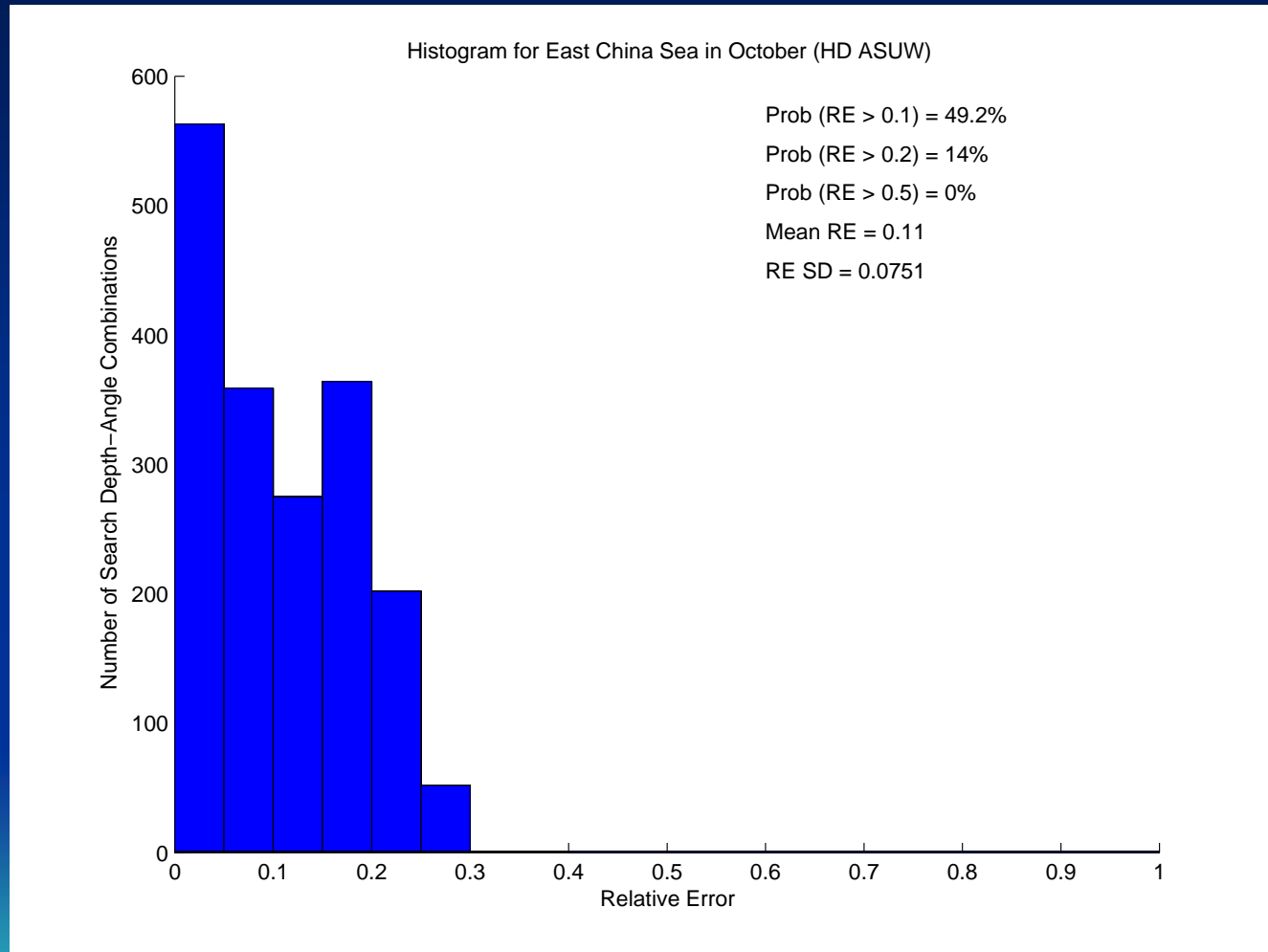
# JES (October) HD ASUW



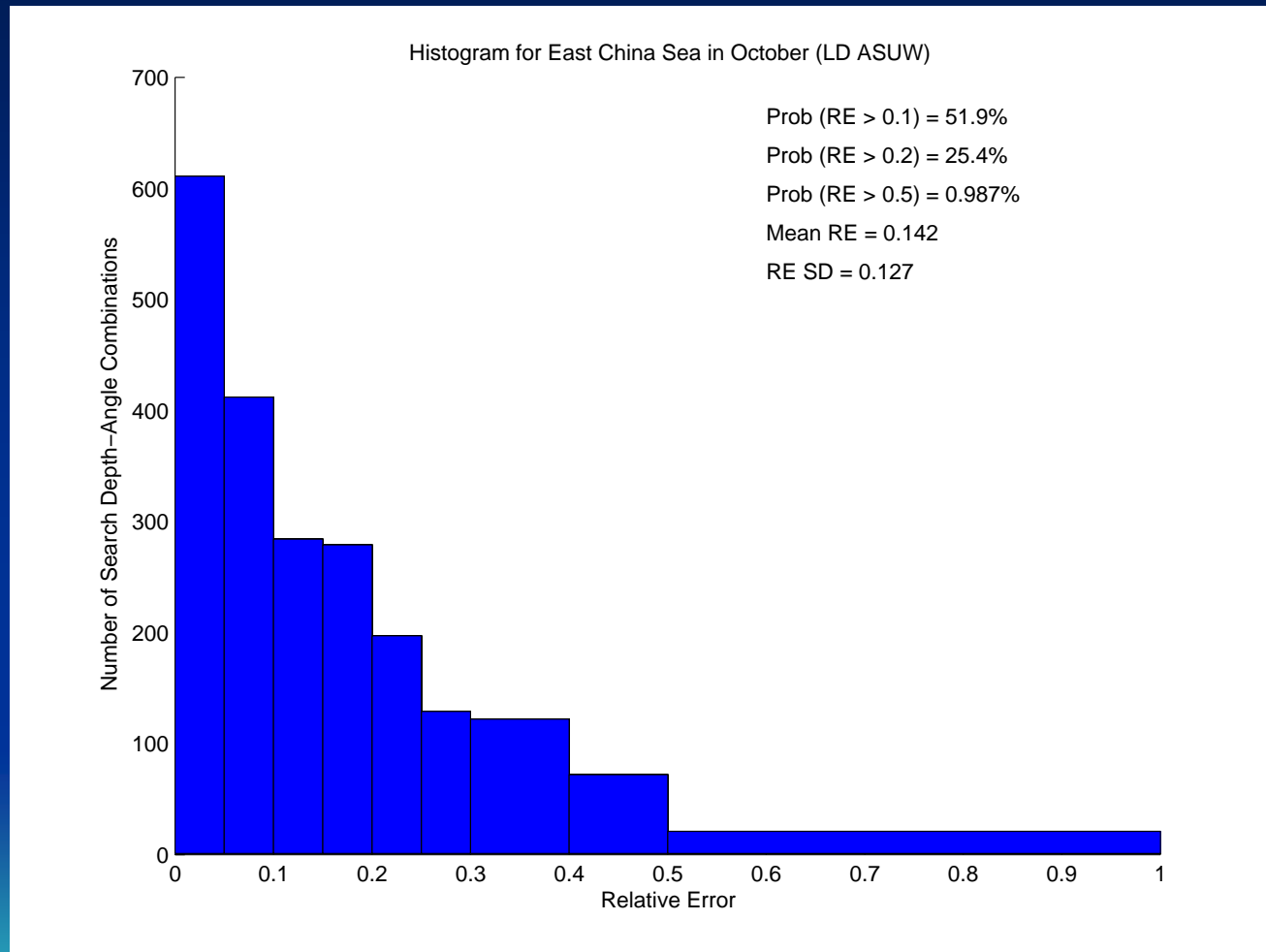
# JES (October) LD ASUW



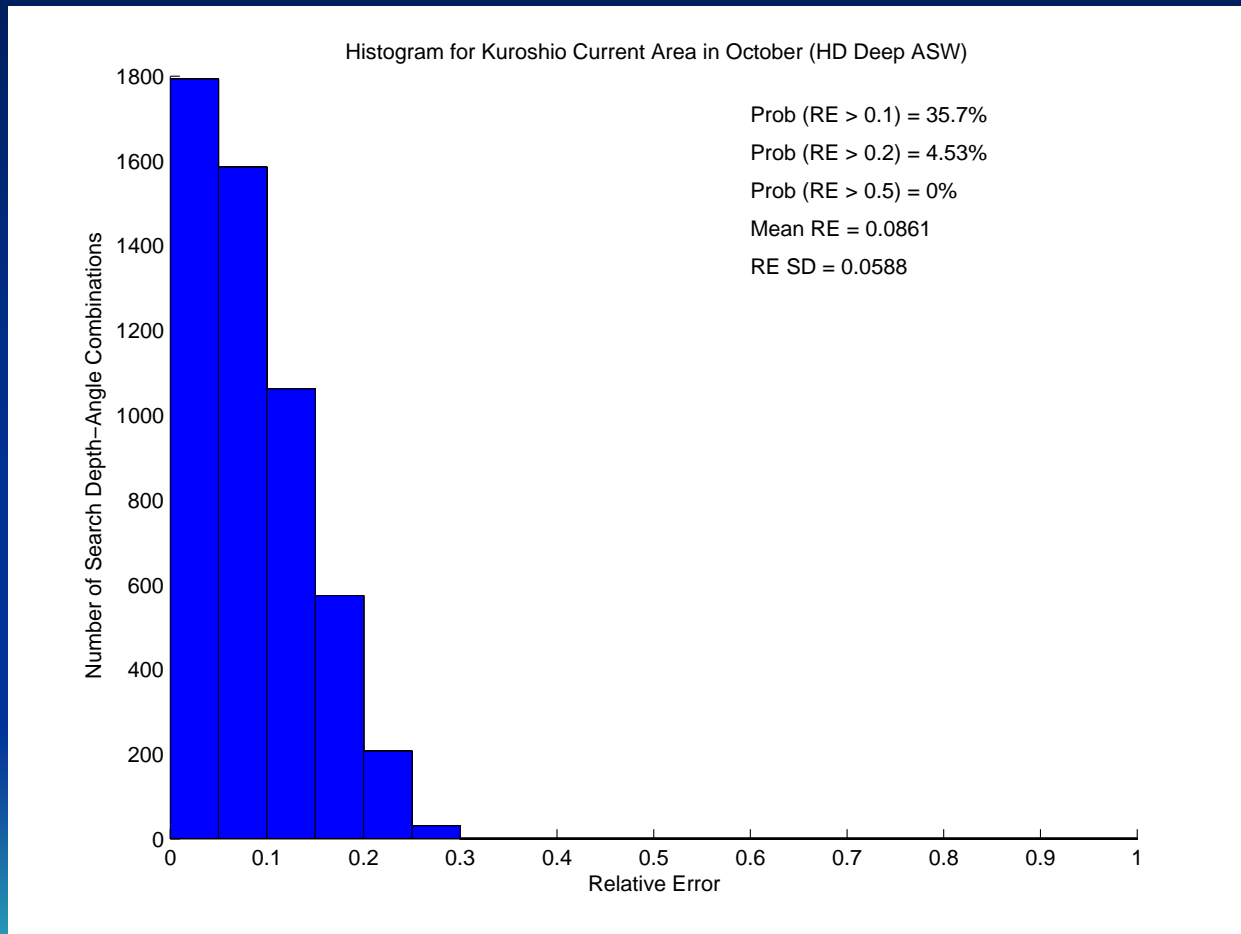
# East China Sea (October) HD ASUW



# East China Sea (October) LD ASUW

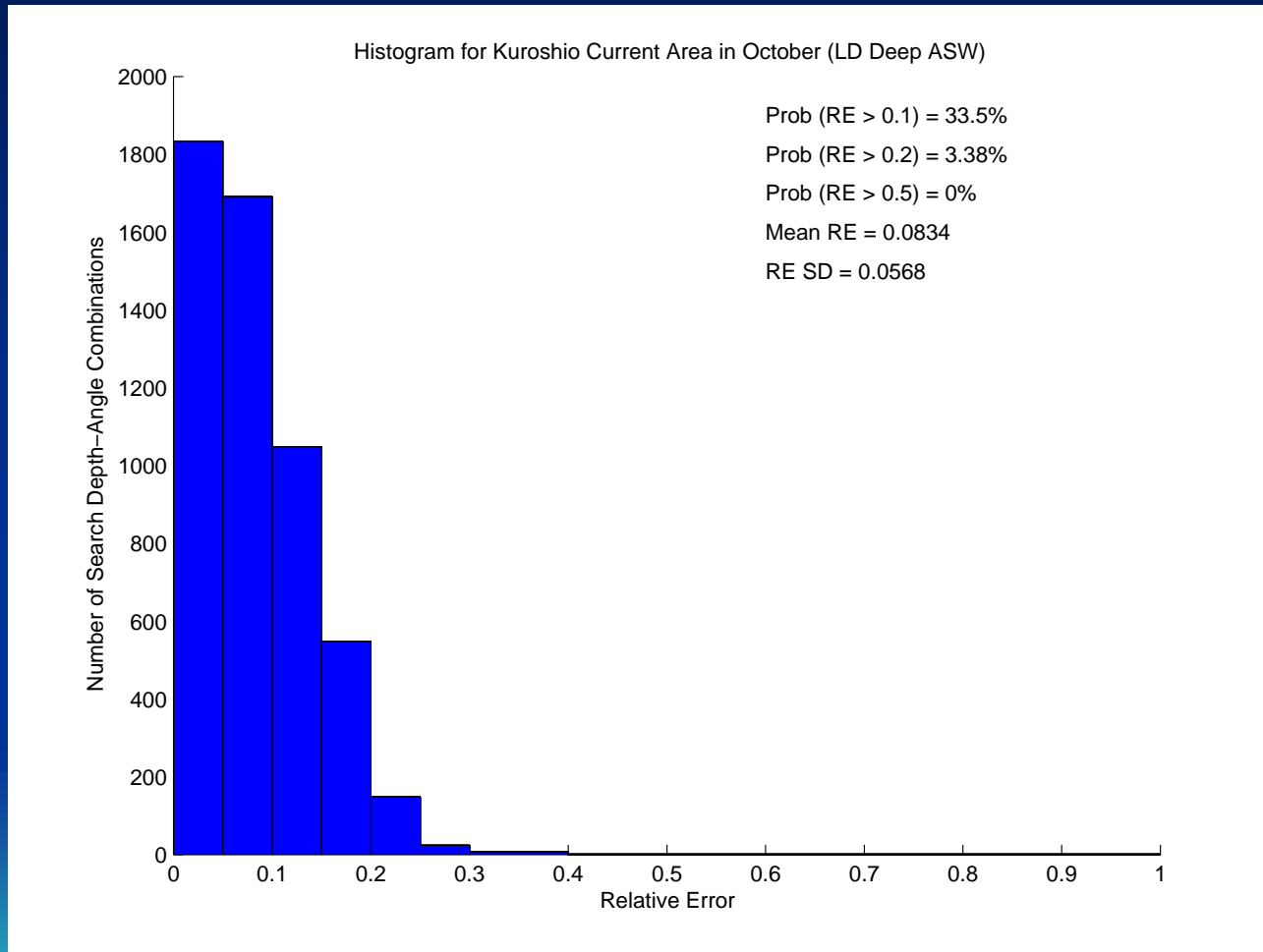


# Kuroshio (October) HD Deep ASW

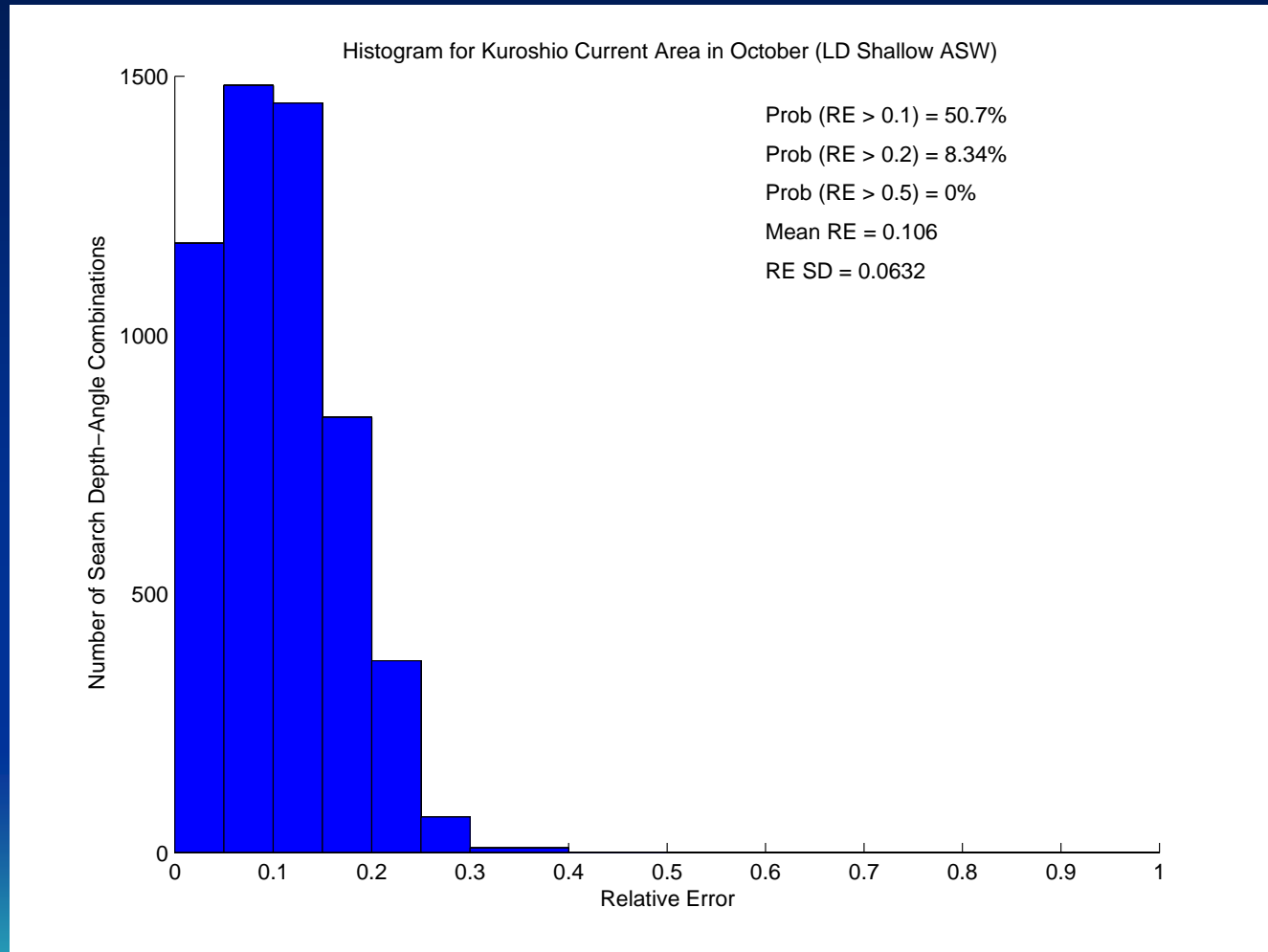




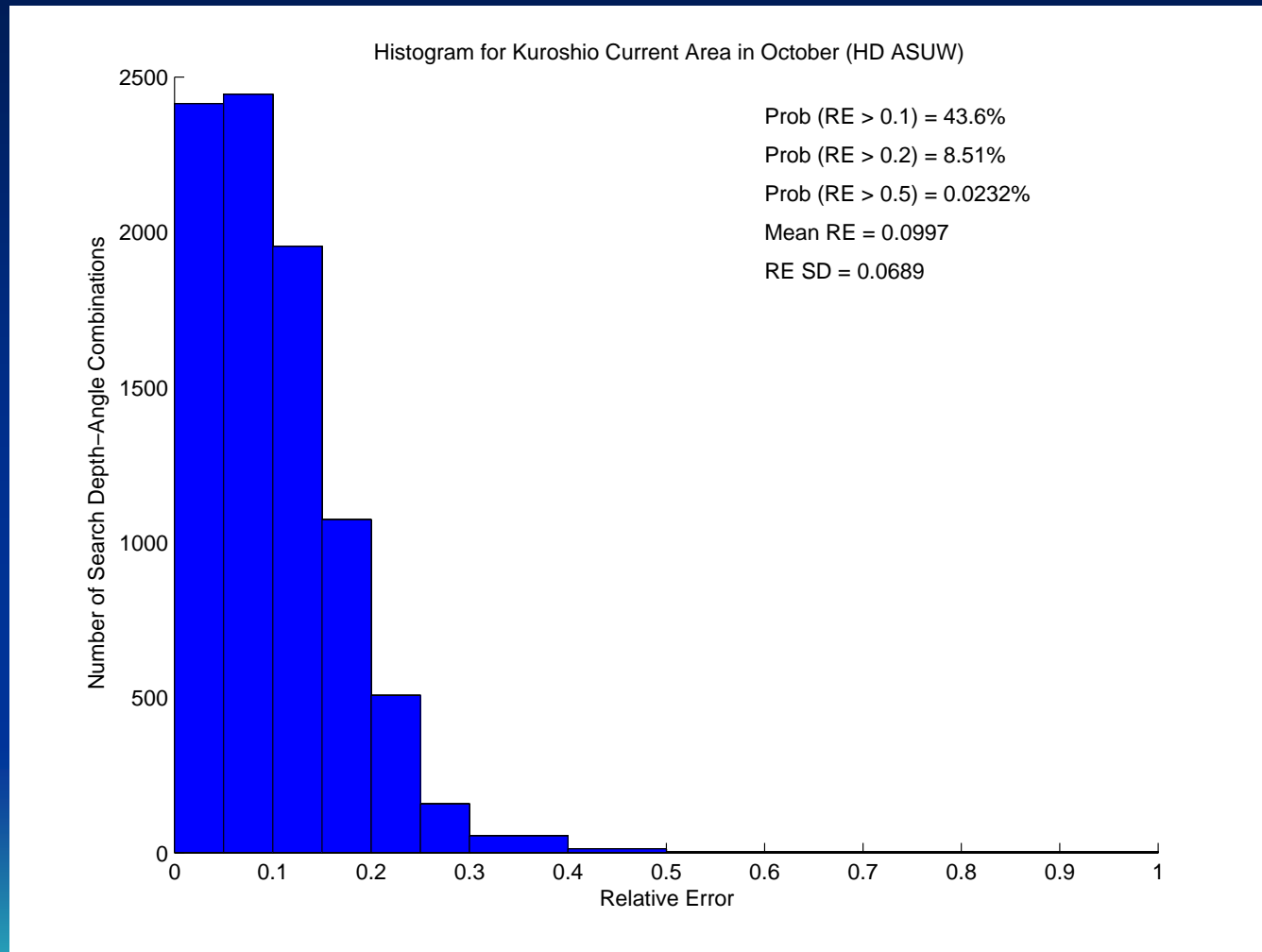
# Kuroshio (October) LD Deep ASW



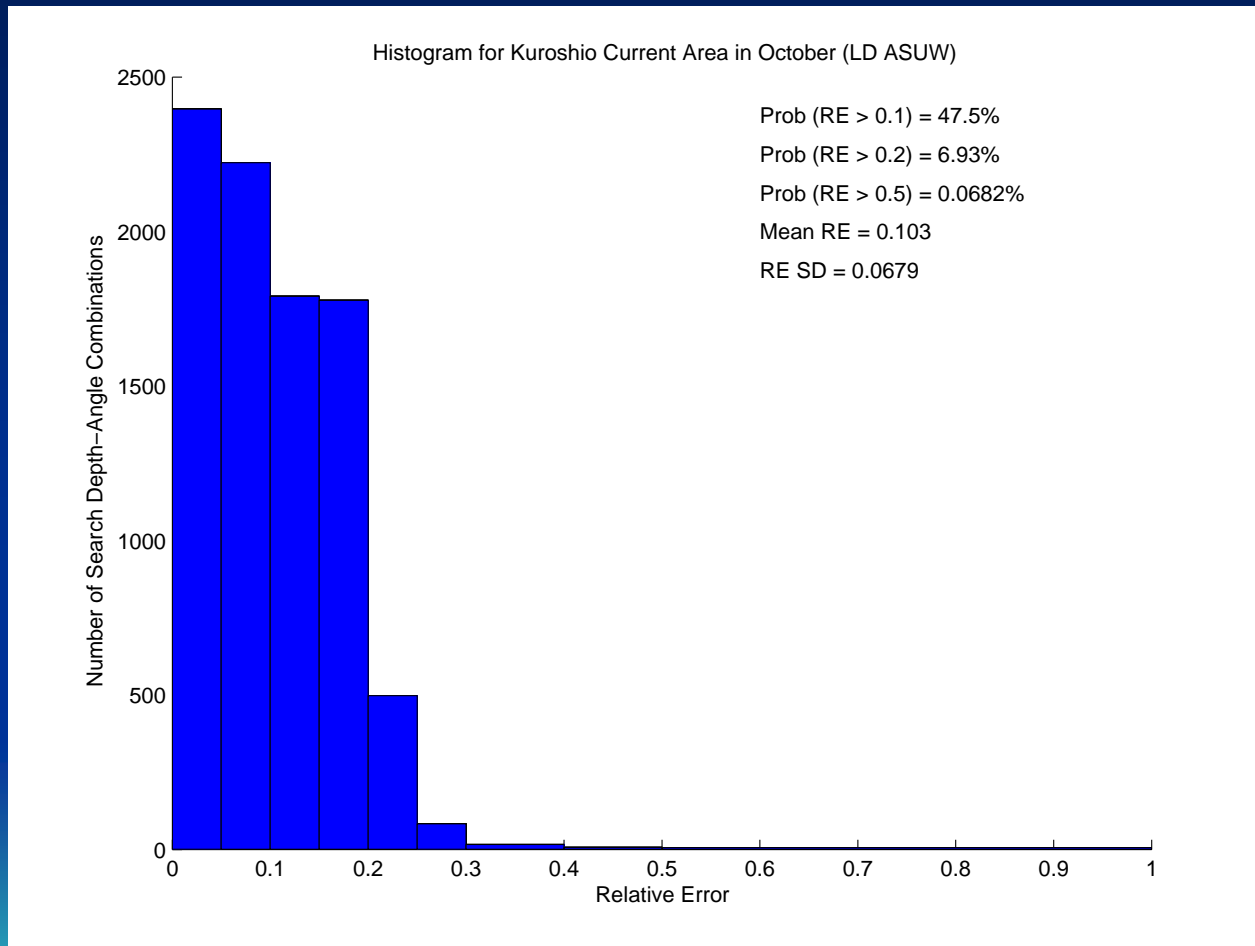
# Kuroshio (October) LD Shallow ASW



# Kuroshio (October) HD ASUW



# Kuroshio (October) LD ASUW



# Conclusions

- Coverage area with positive signal excess is an effective metric for comparing weapon presets
- Large difference was found in the weapon acoustic preset using MODAS with satellites and MODAS without satellite.
- This may imply the importance of satellite altimetry (such as GFO) for Naval operations



# Future Projects

- More Extensive Data Set
  - Observe changes over time and for different locations
  - Examine areas of strong thermal or salinity contrast
- Altimeter Investigation
  - Vary the number of altimeters and observe the effect on area coverage
  - Determine optimal number of altimeters required



**Questions?**

