Satellite Data Assimilation for Naval Undersea Capability

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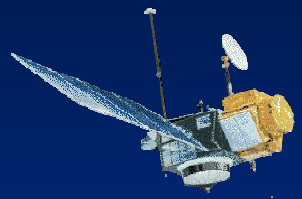
Purpose

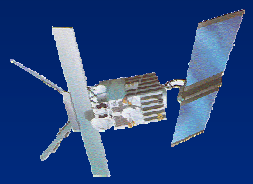
- To define Navy altimeter requirements as a minimum number of satellite altimeters necessary to ensure maximum weapon effectiveness
- To determine the point at which additional altimeter input no longer increases weapon effectiveness

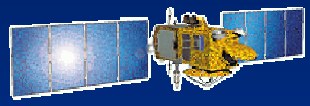
Modular Ocean Data Assimilation System **(MODAS)**

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

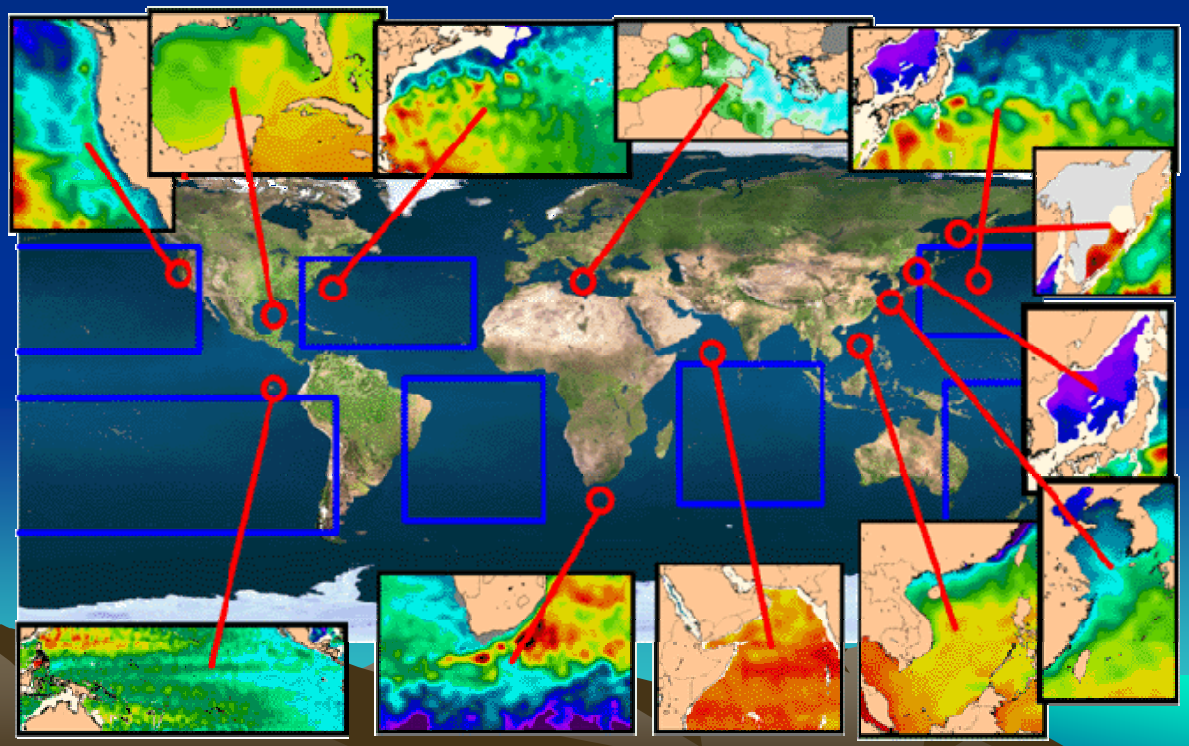
U.S. Navy's MODAS System for Satellite Data Assimilation



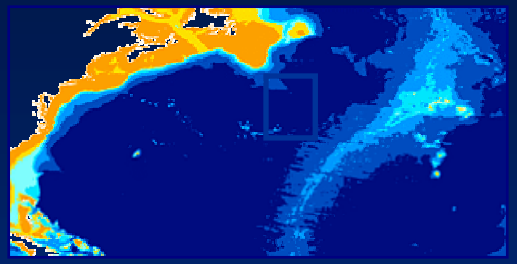




- Altimetry Data Archive
- Data Processing
- Data Sources
- Applied Orbit Error Corrections
- Altimetry Drop Plots
- Percent of Data Utilized
- Altimeter Intercomparisons



MODAS

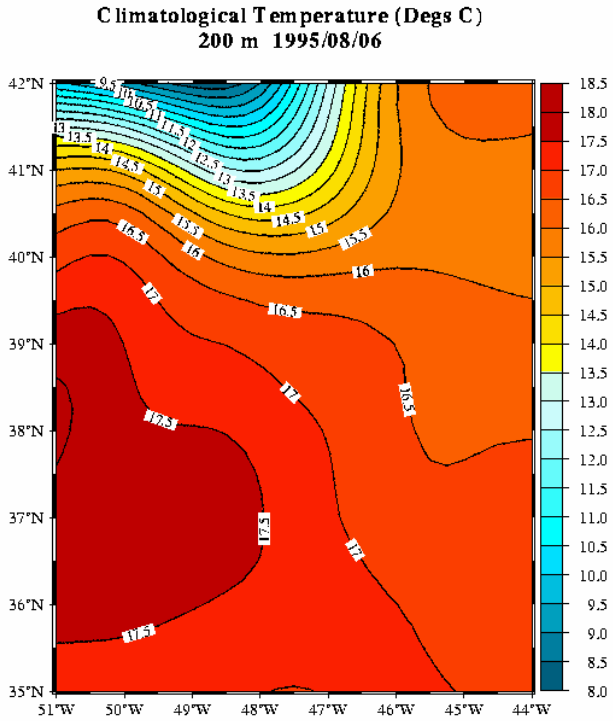


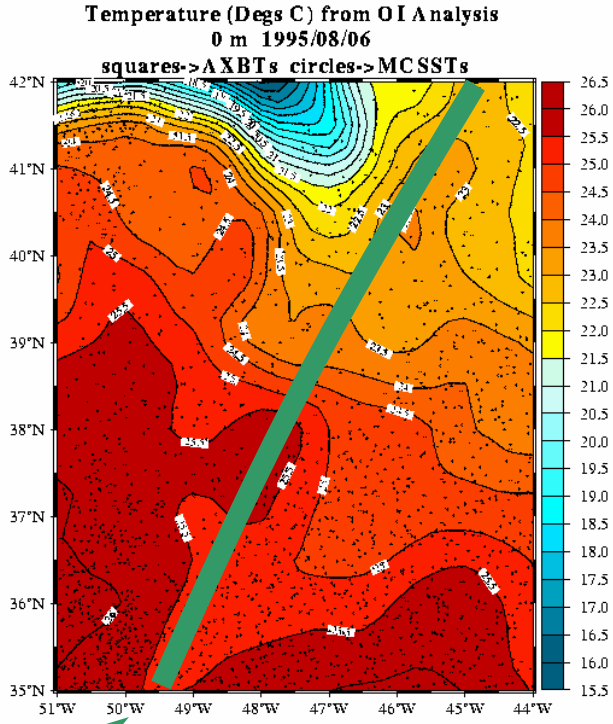
6-Aug-1995

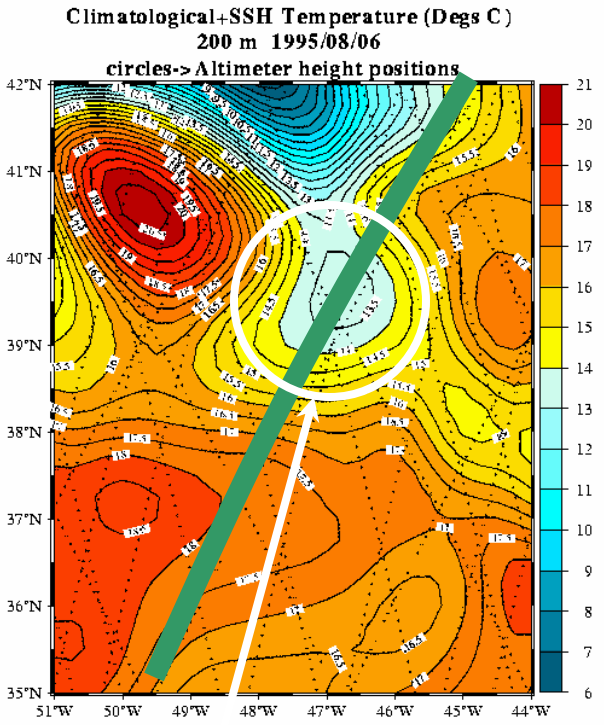
200 m temperature Climatology

MODAS including MCSST does not significantly alter climatology

SSH reveals concealed ocean environment







AXBT Line

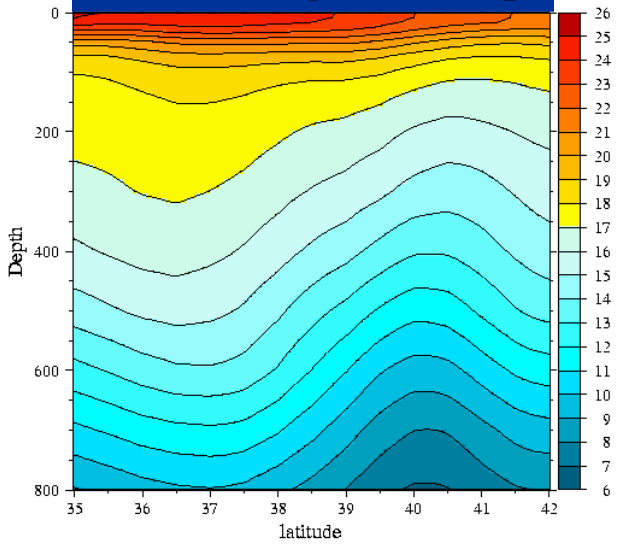
Points: MCSST

Cold core eddy

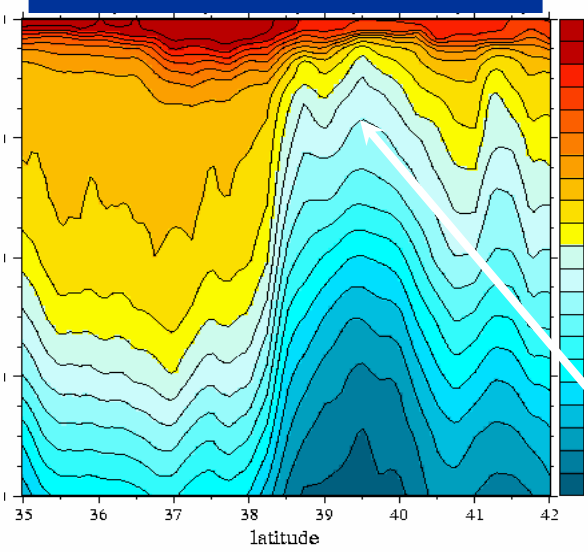
MODAS

MODAS results

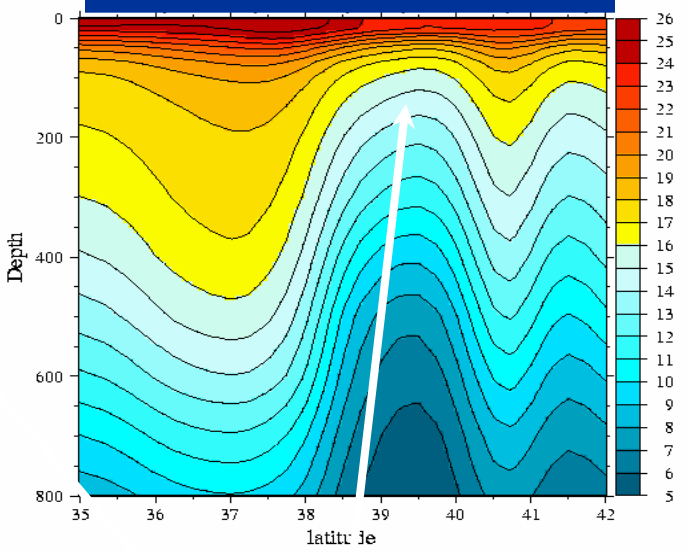
Climatological Temp

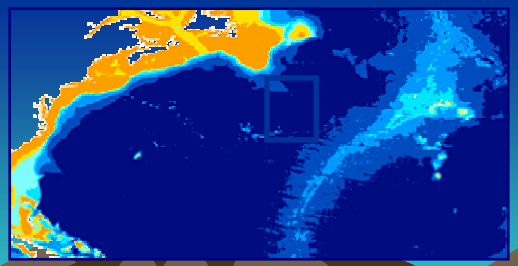


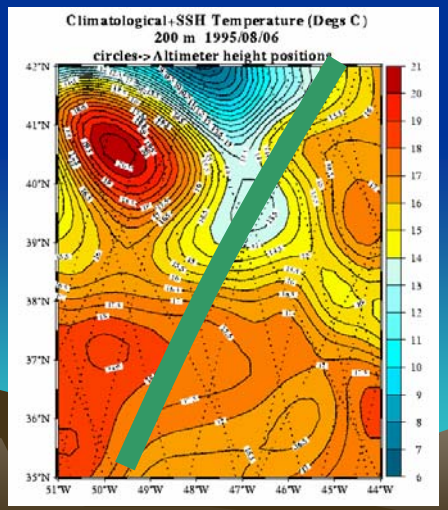
AXBT Temp



SSH + SST + Clim







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

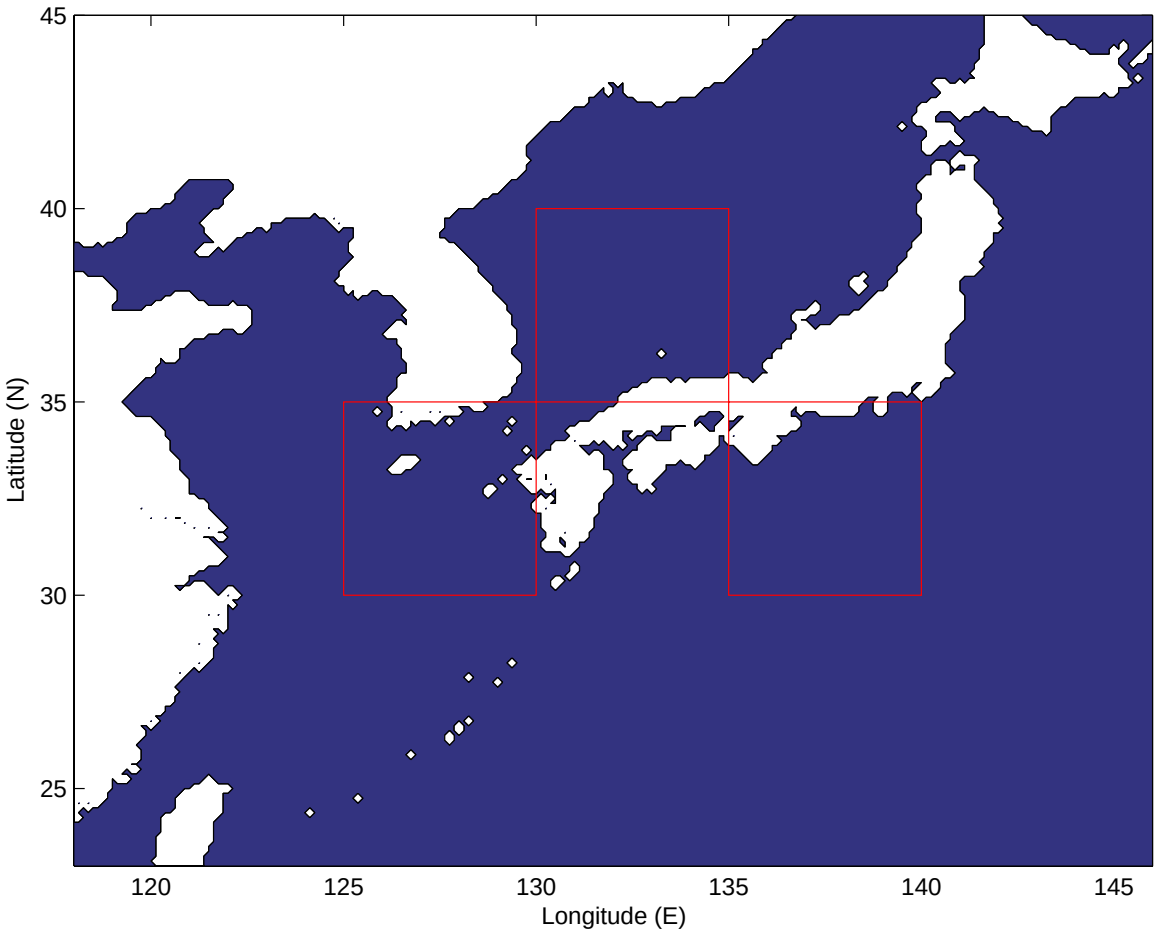
- Compared 2 MODAS fields (with and without satellite data assimilation)

- Used a different metric for quantifying the effect on weapon presets

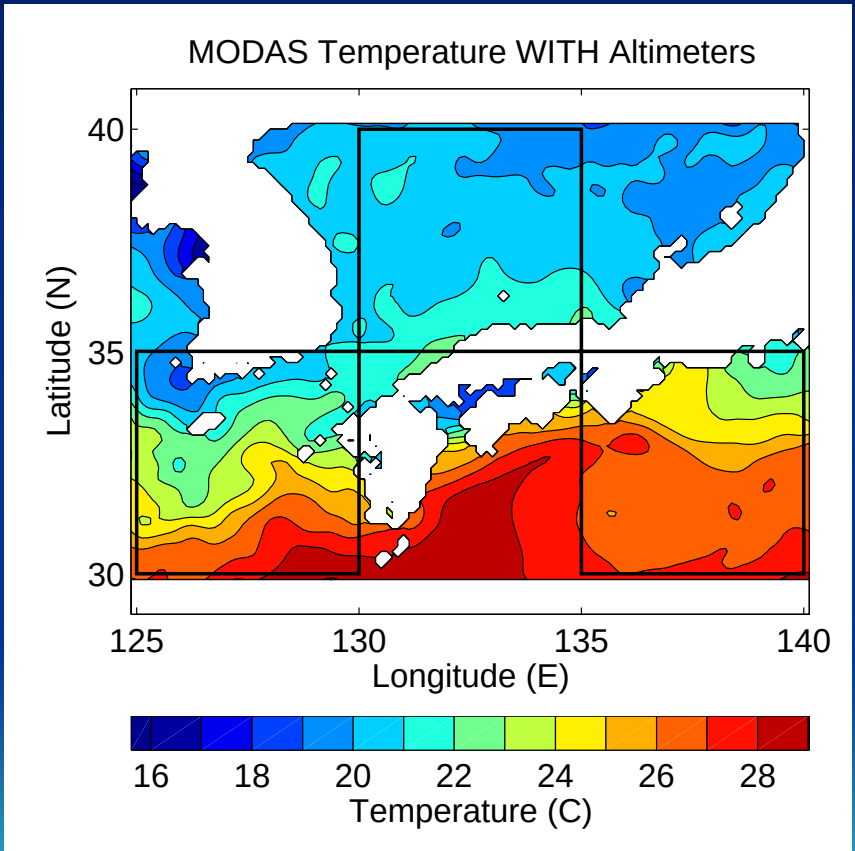
Environmental Fields

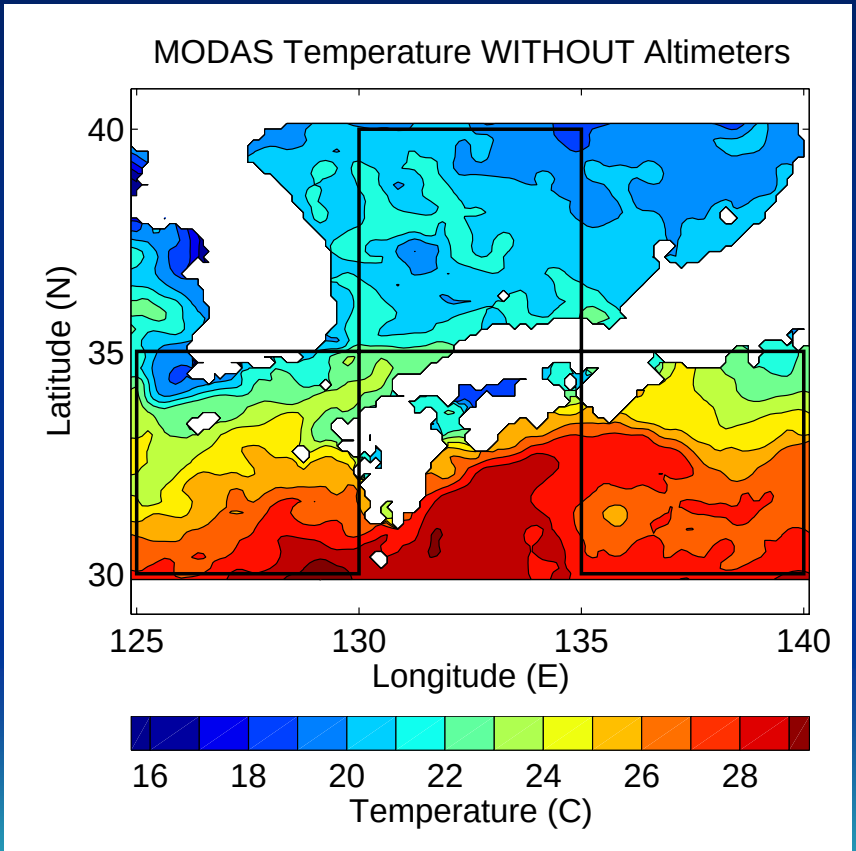
- 2 MODAS data fields
  - one with assimilated data from 3 altimeters (TOPEX/Poseidon, GFO, and ERS-2)
  - one without altimeter data assimilated
- 2 dates
  - June 30, 2001
  - October 10, 2001
- 3 geographic areas (5 X 5 degree boxes)
  - Sea of Japan (SOJ): 35-40N, 130-135E
  - East China Sea (ECS):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

Areas of Investigation

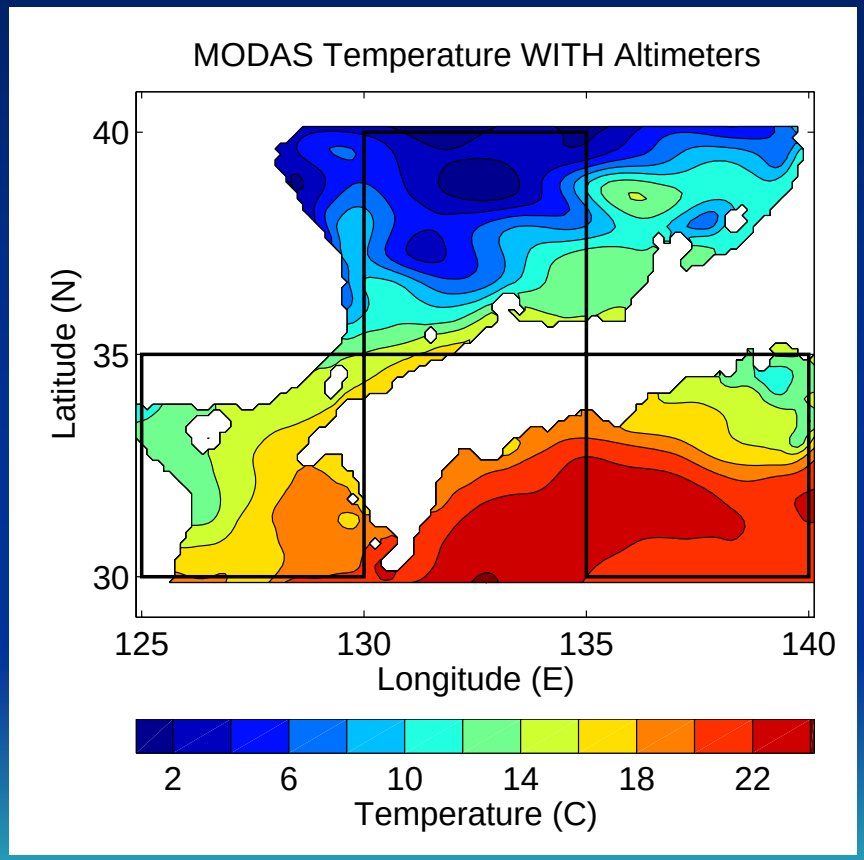


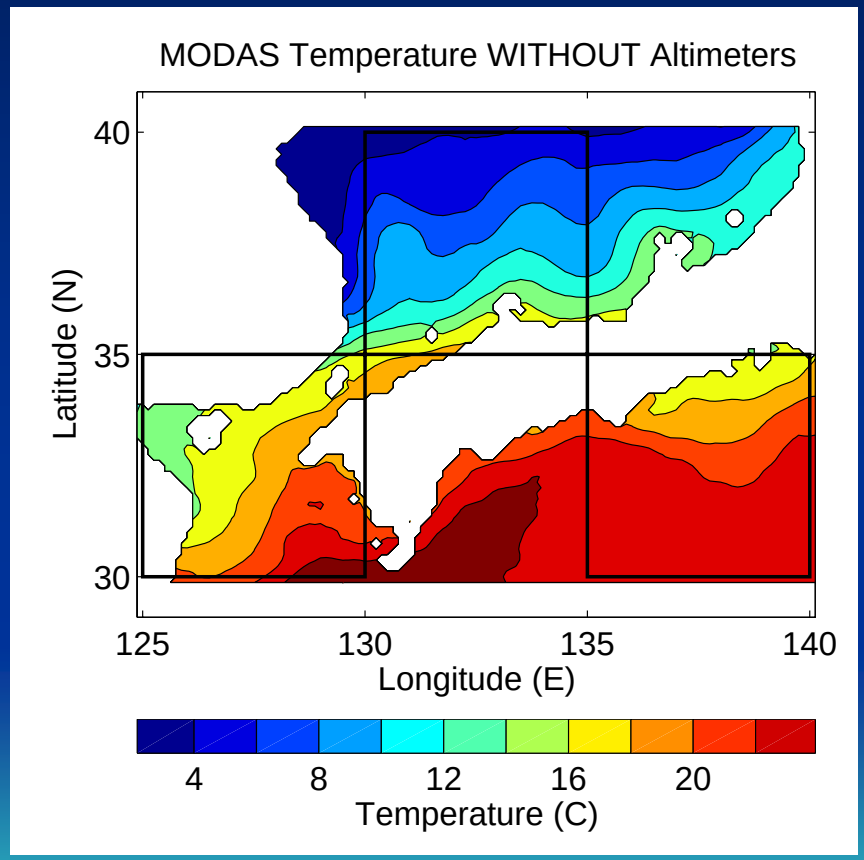
Comparison of Sea Surface Temperature on Jun 30, 2001



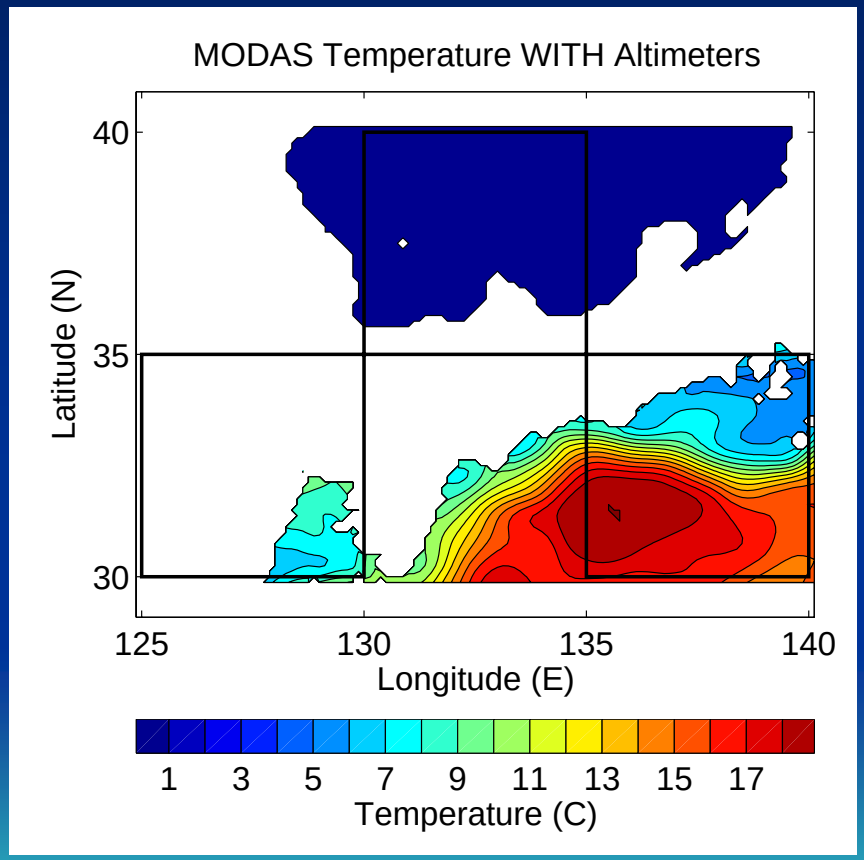


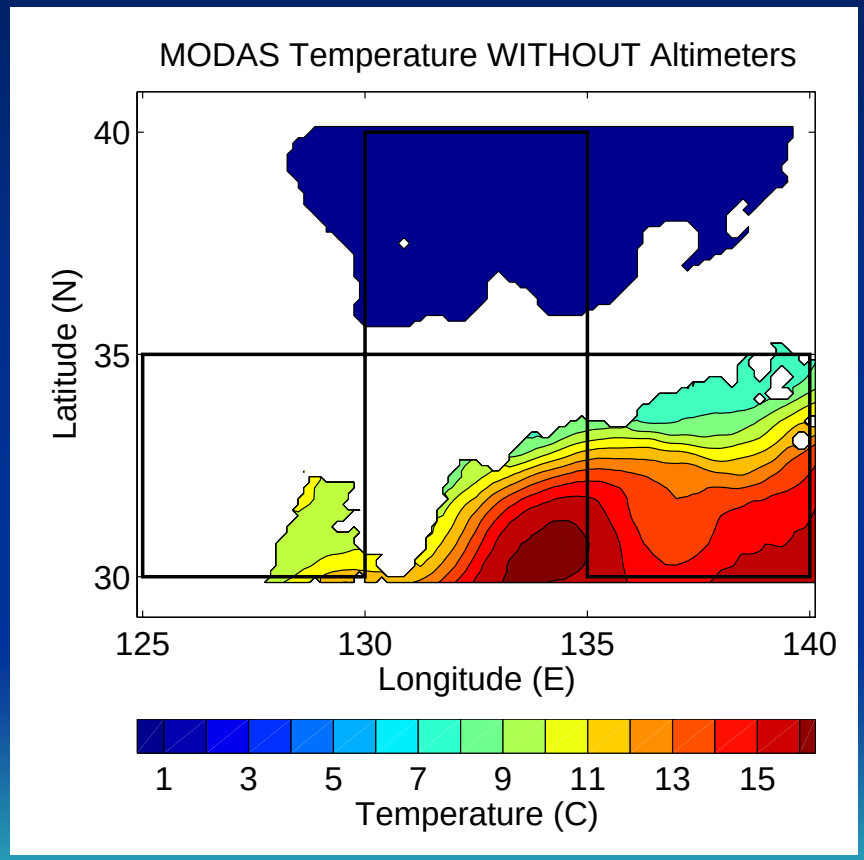
Comparison of Temperature at 100 m on Jun 30, 2001



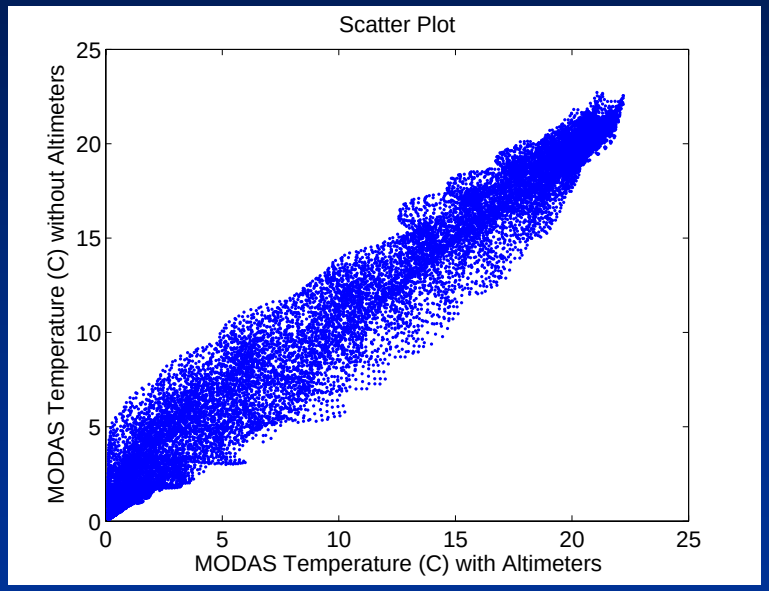


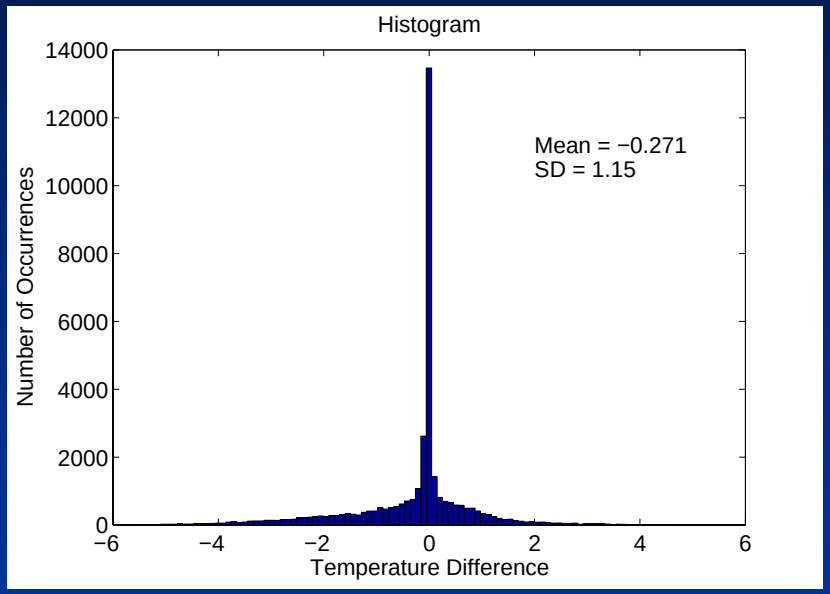
Comparison of Temperature at 400 m on Jun 30, 2001

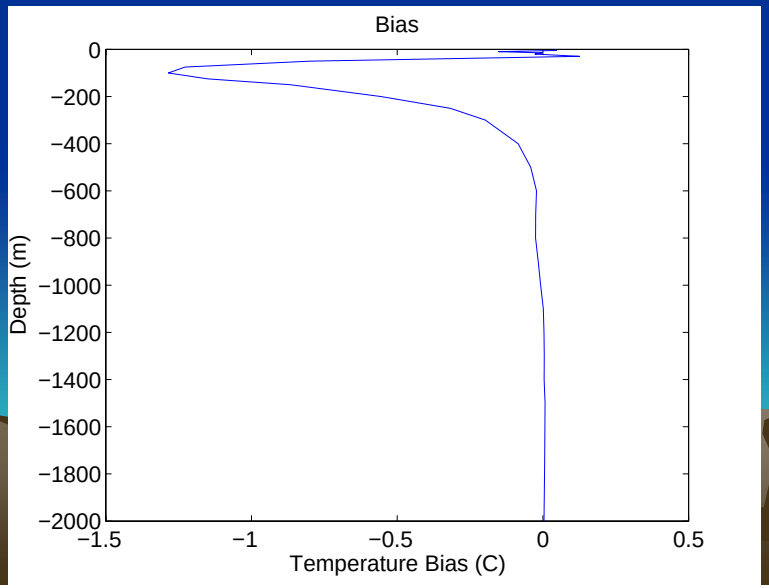


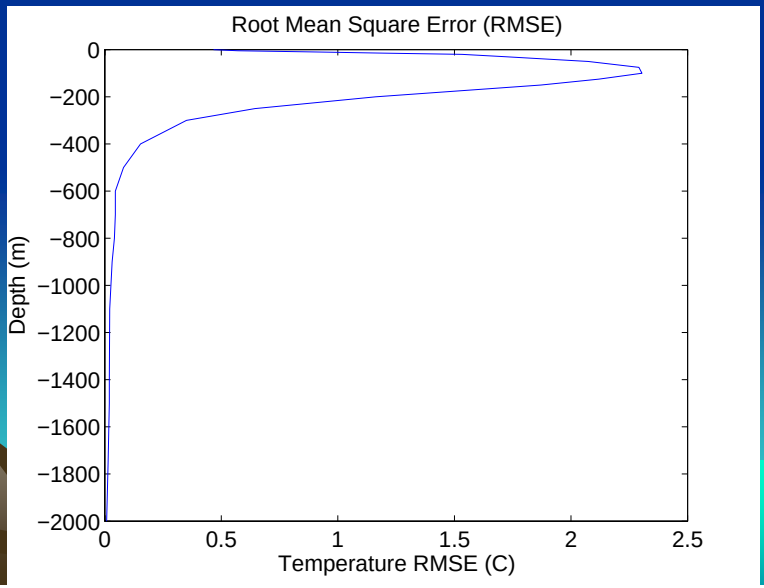


Temperature Statistics for Japan/East Sea (JES)
June 30, 2001

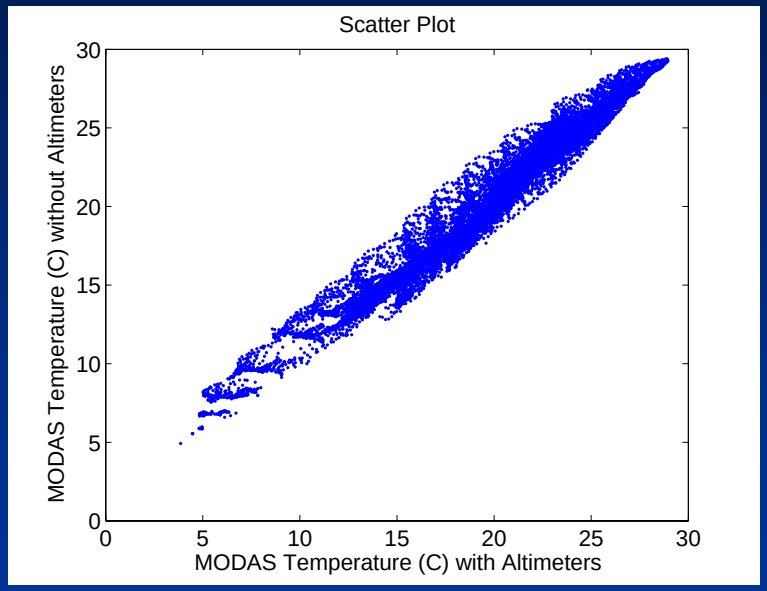


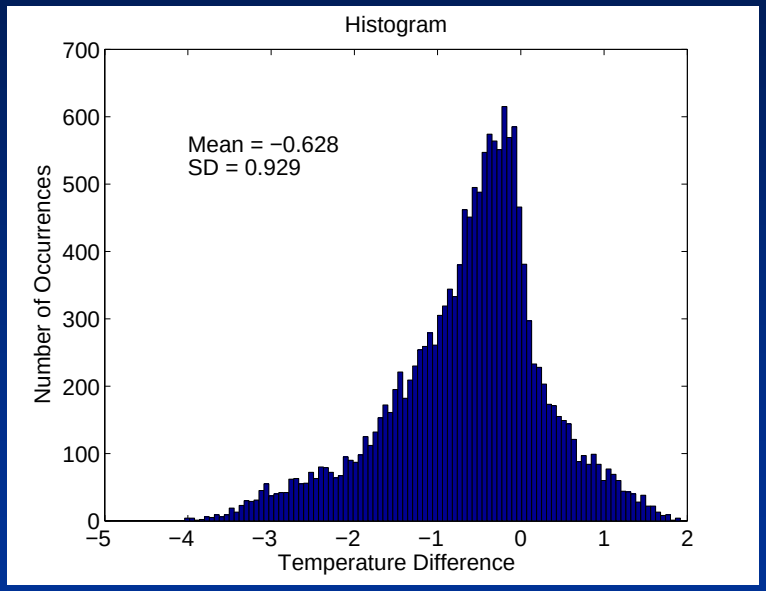


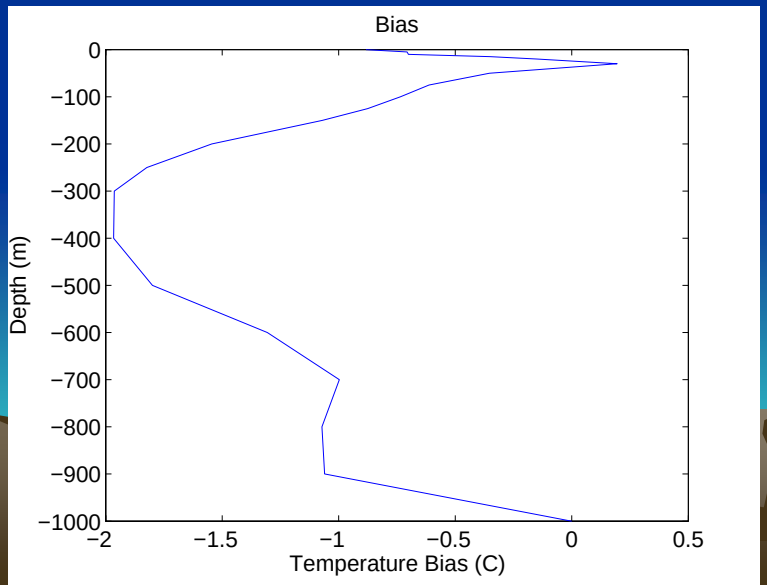


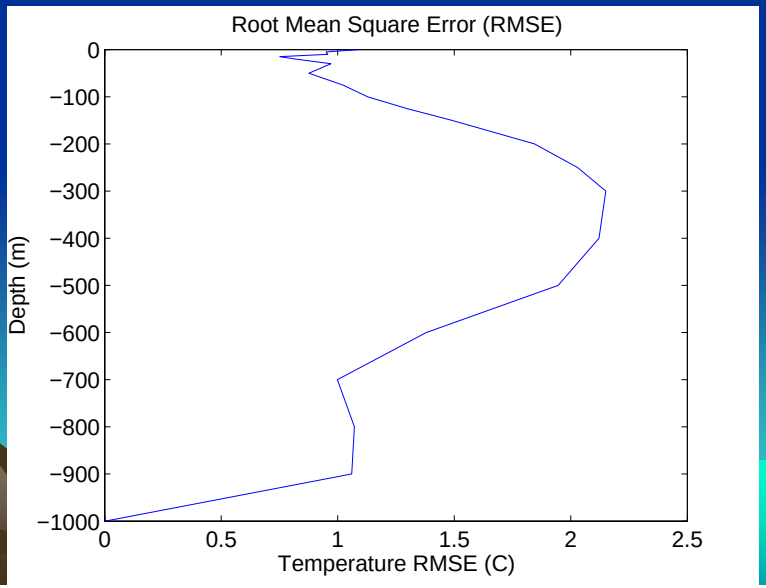


Temperature Statistics for ECS Jun 30, 2001

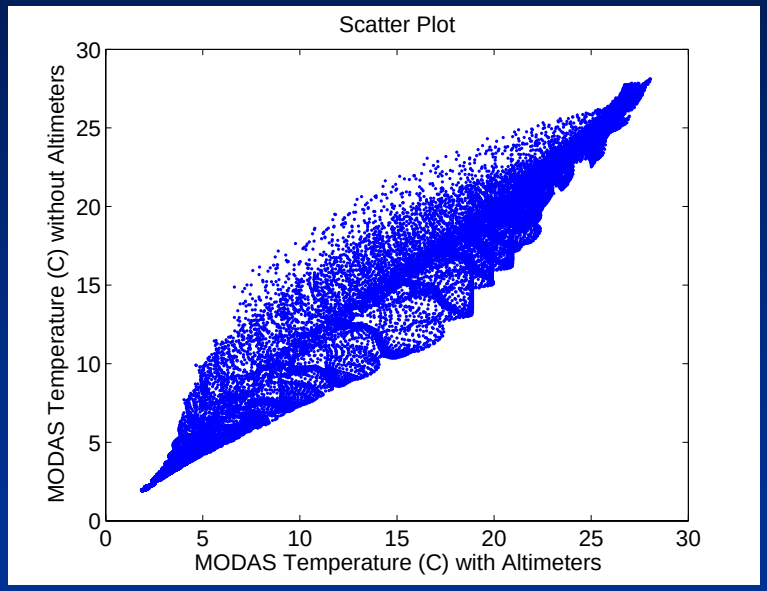


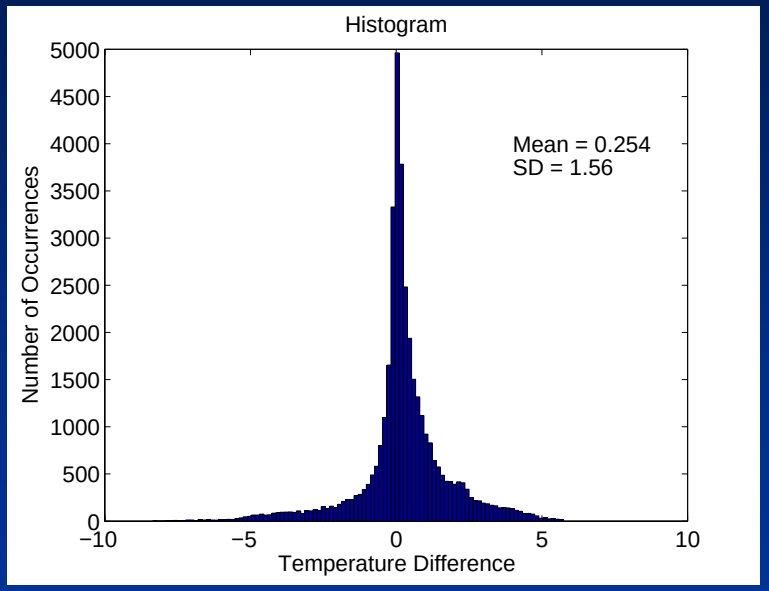


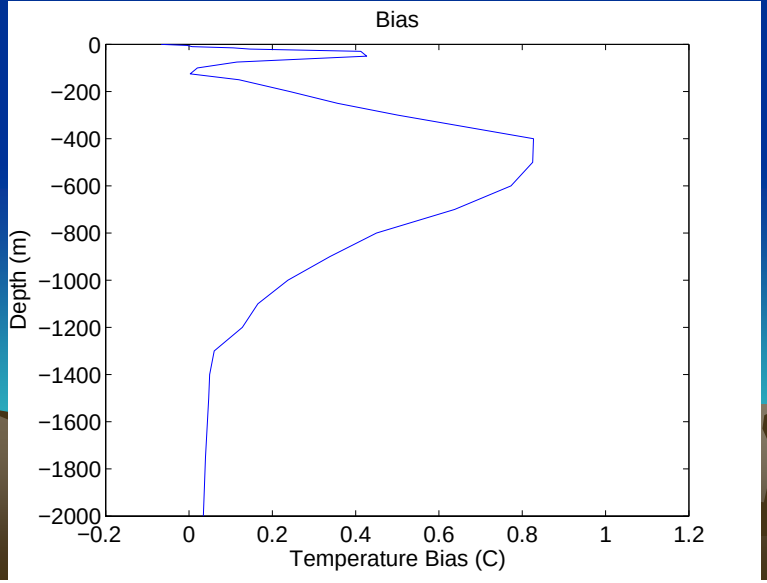


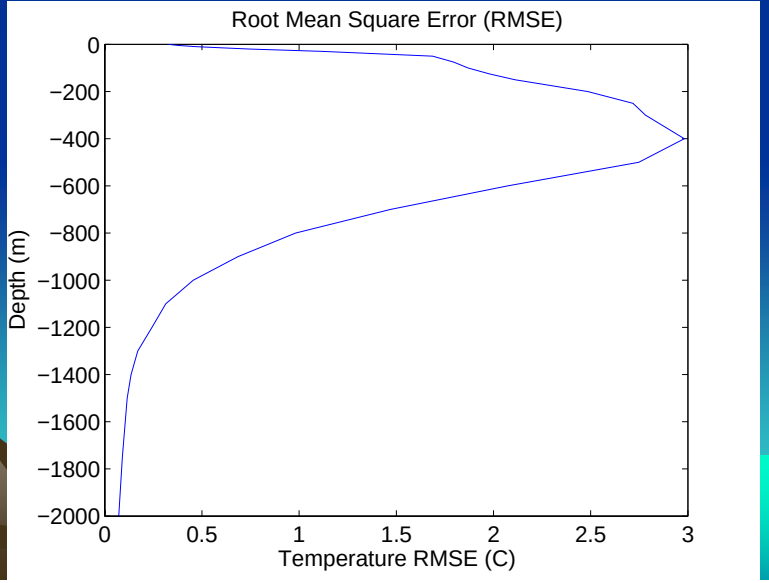


Temperature Statistics for KCA Jun 30, 2001

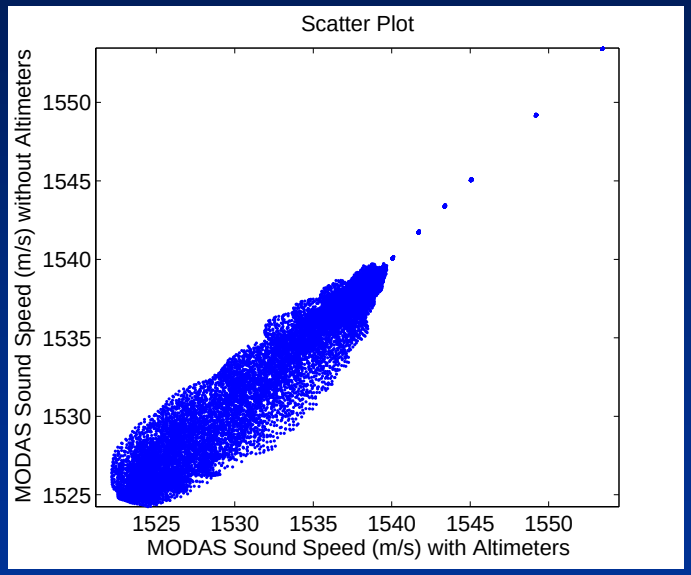


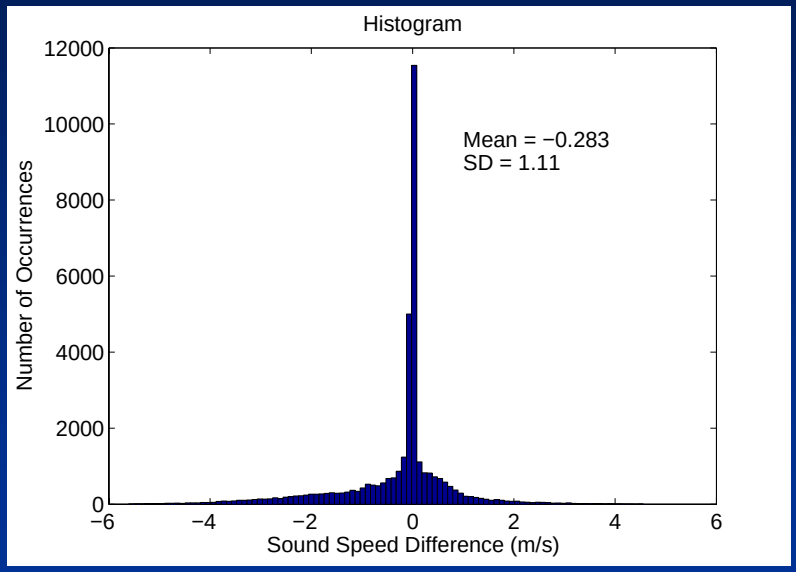


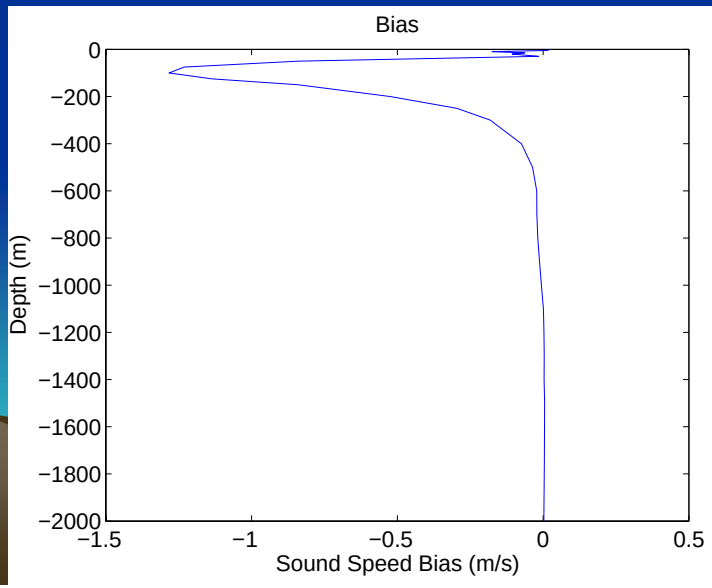


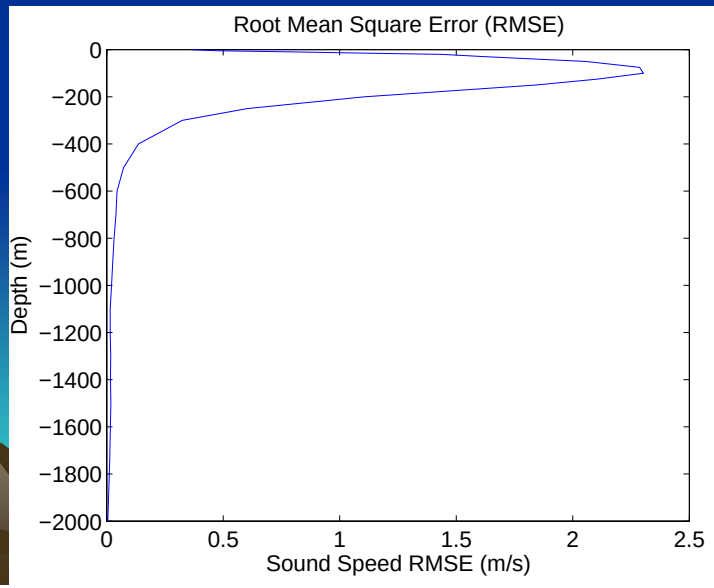


Sound Speed Statistics for JES Jun 30, 2001

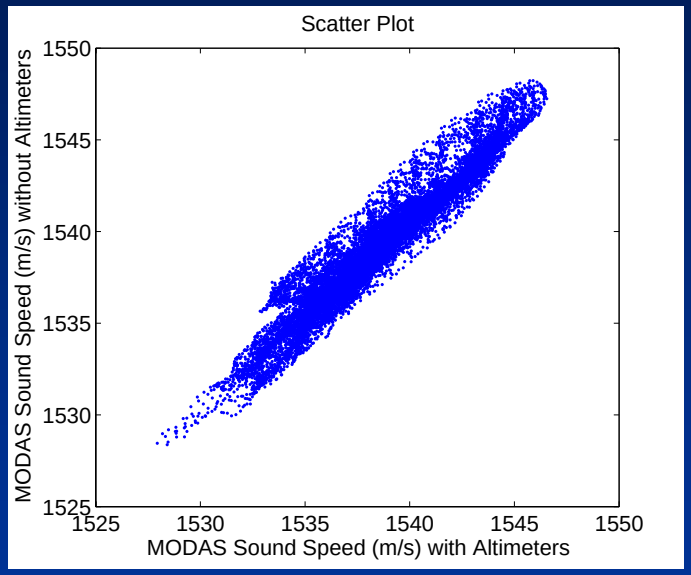


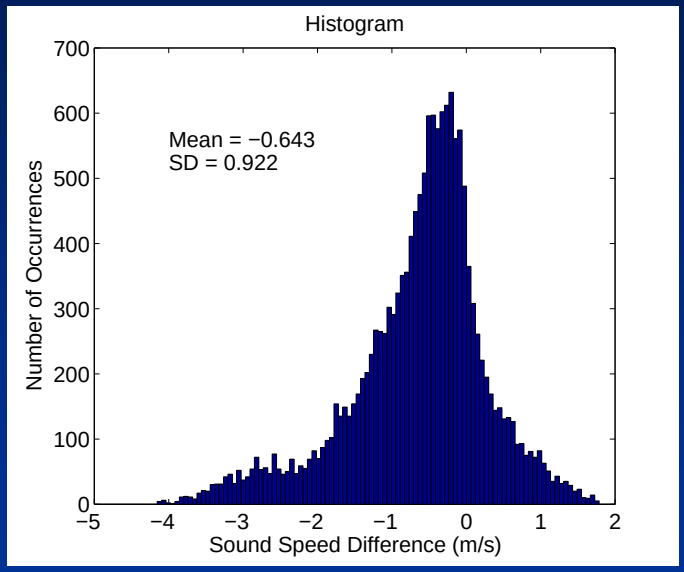


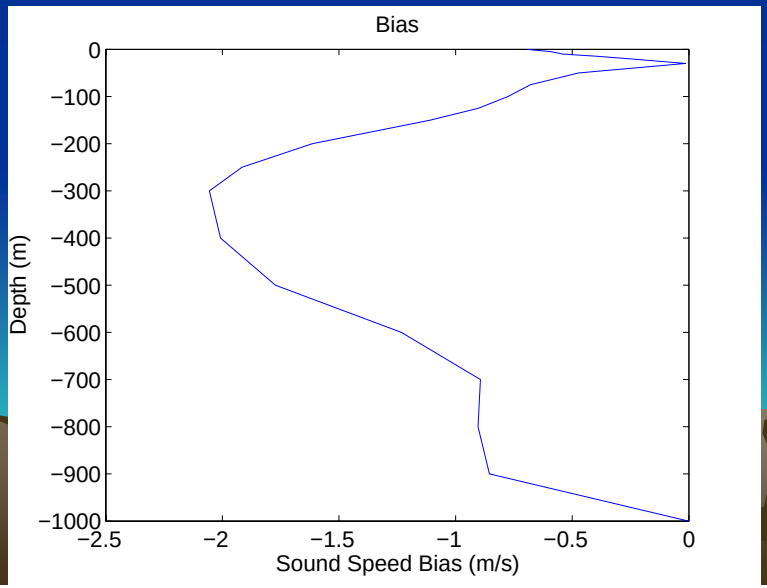


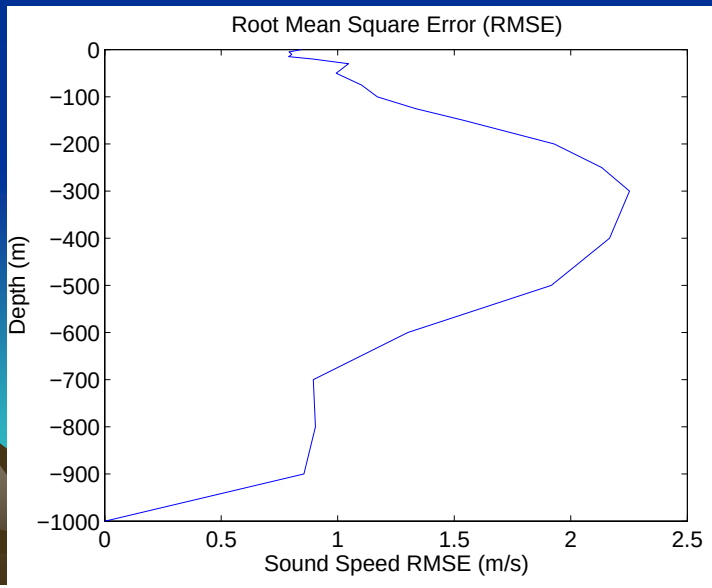


Sound Speed Statistics for ECS Jun 30, 2001

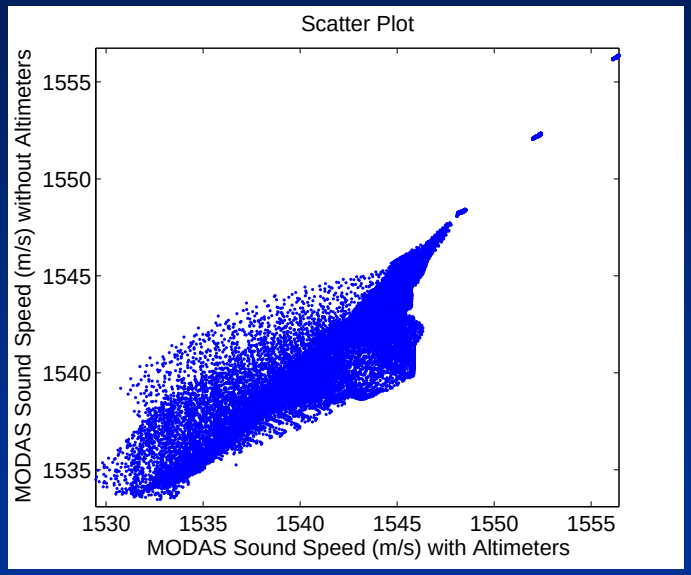


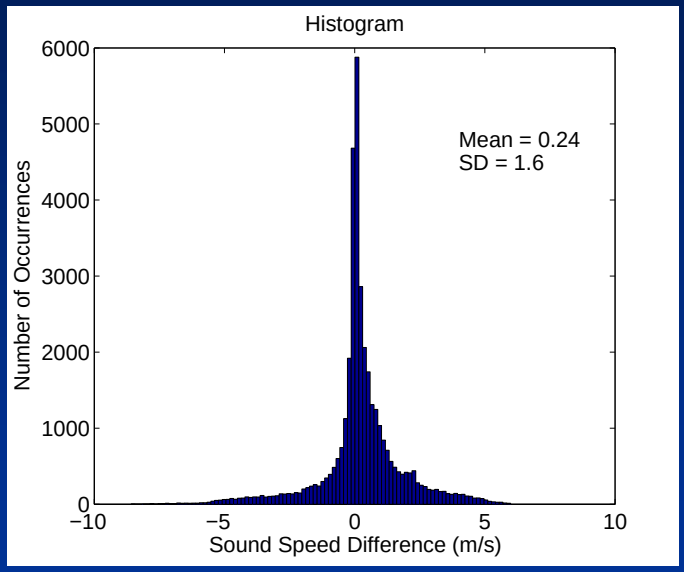


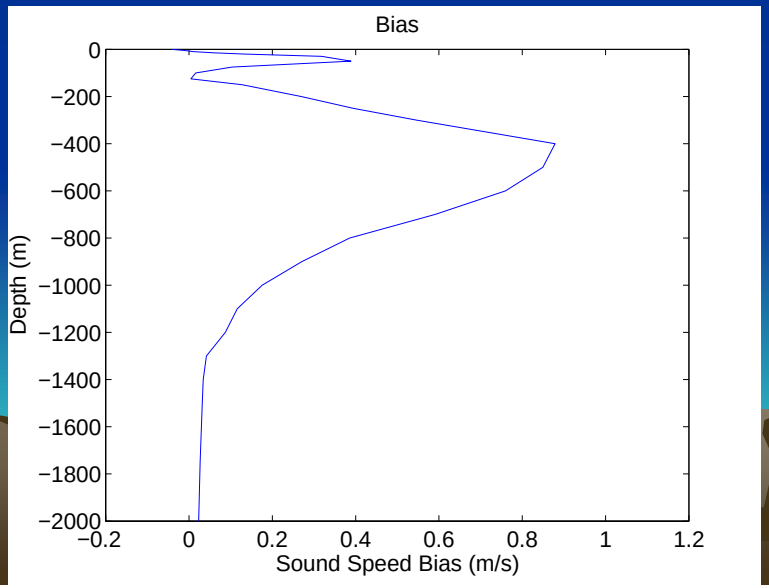


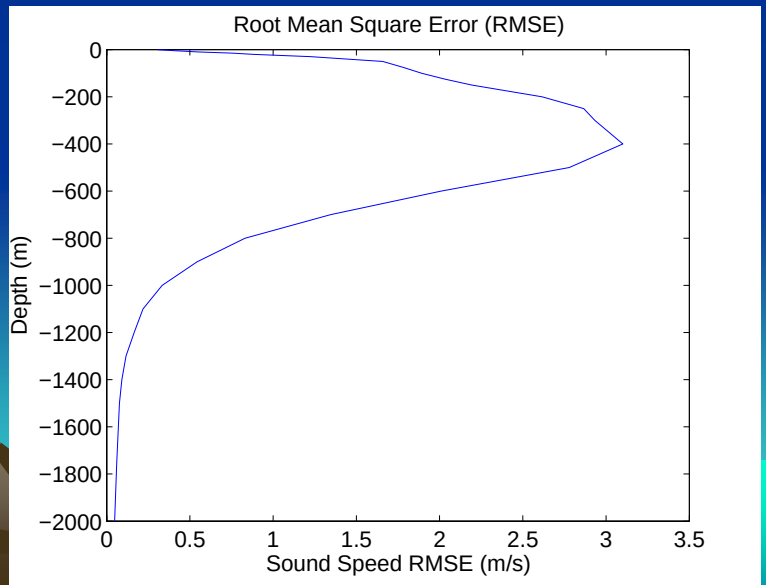


Sound Speed Statistics for KCA Jun 30, 2001









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
  - David Cwalina: 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):	2.57
Wave Height (m):	0.05
Sea State:	1
Rain:	None
Shipping Level:	None

Mode Messages

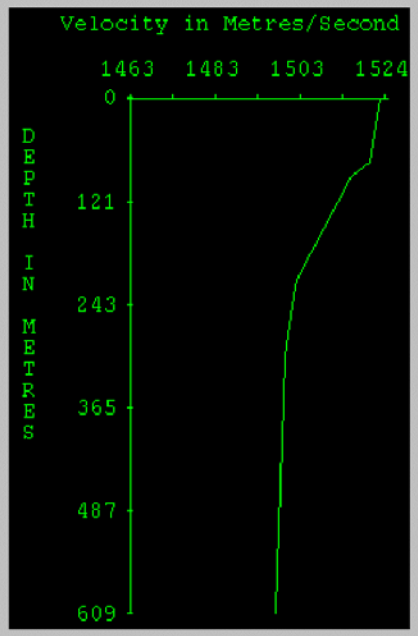
Bottom Conditions

SSP Depth (m):	1524.00
Bottom Type:	Sand

Default Conditions

VSS Background (dB):	-75.00
Salinity:	35.00
Latitude:	45:00:00N
Longitude:	000:00:00E

Environmental Data



Profile : defalt

DTG:

Table Group Identifier

Surfaced Target	3
Submerged Target	3

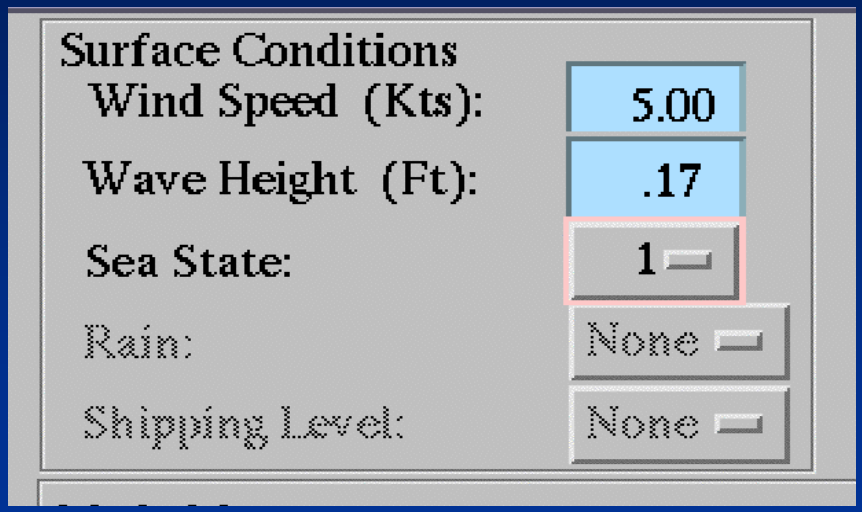
Depth	Temp	Vel	VSS	Sal
0.0	20.44	1523.06	-75.00	35.00
76.2	19.06	1520.46	-75.00	35.00
91.4	17.50	1516.20	-75.00	35.00
213.4	12.67	1503.00	-75.00	35.00
243.8	12.22	1501.99	-75.00	35.00
304.8	11.44	1500.32	-75.00	35.00
1524.0	3.89	1491.84	-75.00	35.00

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

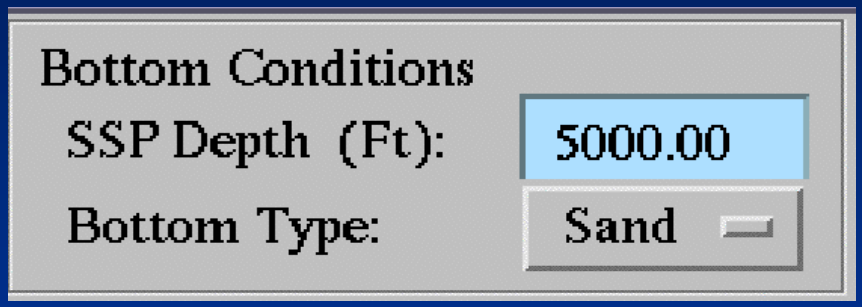
EDE
Sea Surface Conditions

- 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



WAPP
Environmental Data Entry (EDE) Module

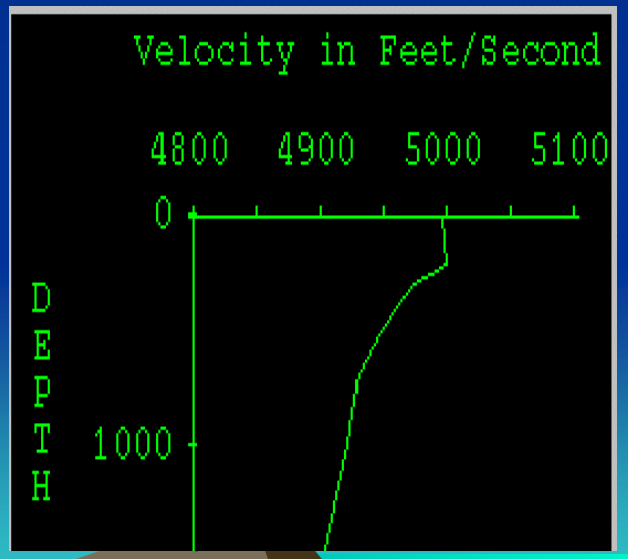
- Sea Bottom Conditions
- Bottom Depth (Any Depth Shallower Than Last Point in Sound Speed Profile (SSP))
- Bottom Type
  - Mud/Sand (Lossy Bottoms)
  - Clay
  - Gravel
  - Rock



EDE
Water Column Characteristics

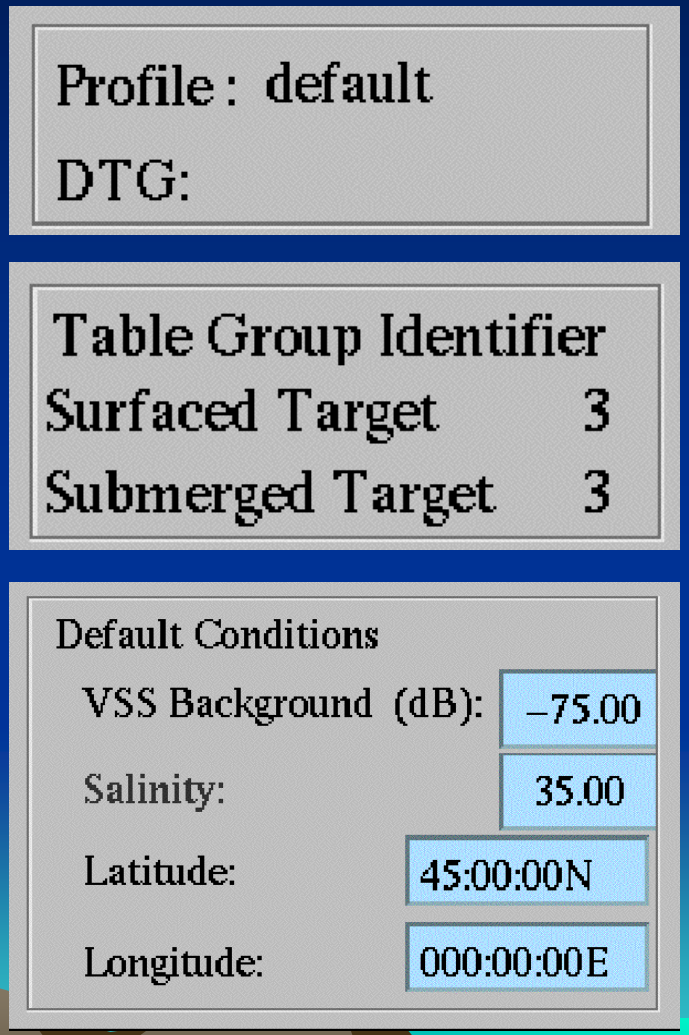
- Water Column Characteristics
- Sound Speed Profile
  - Depth(ft/m)
  - Temperature(˚F/˚C)
  - Sound Speed(ft/sec, m/sec)
  - Volume Scattering Strength (VSS) (dB)
  - Salinity (ppt)
- Entry of Temperature or Sound Speed Supported With Computation of Unknown Quantity

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

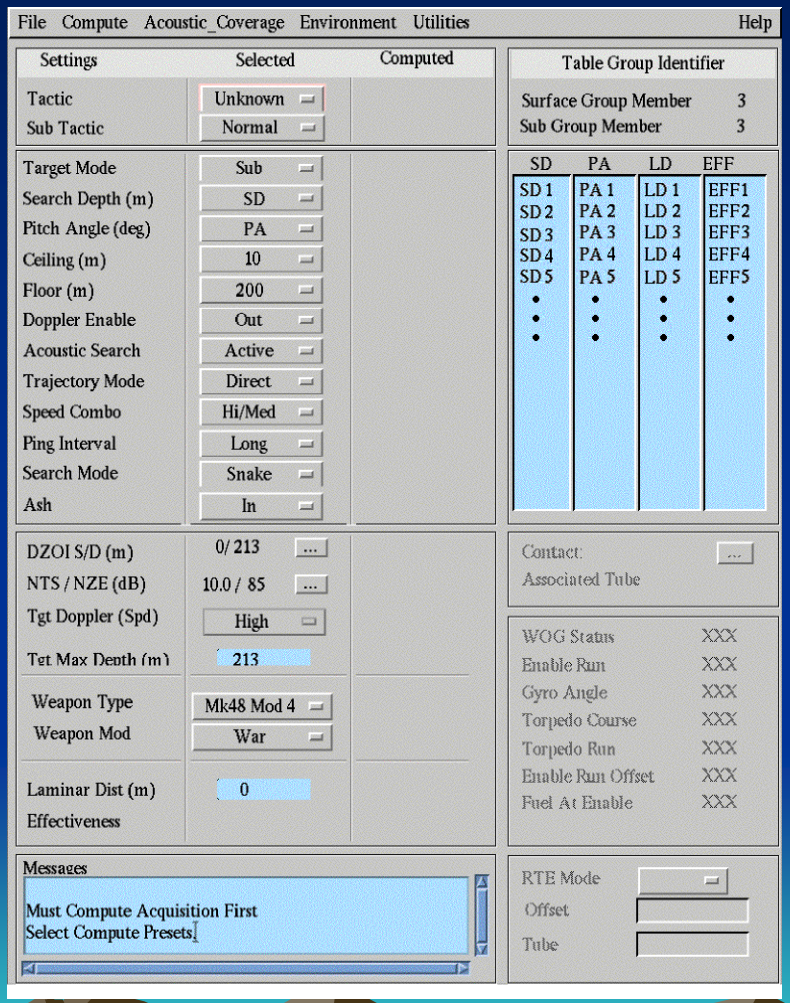


EDE
Additional Fields

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

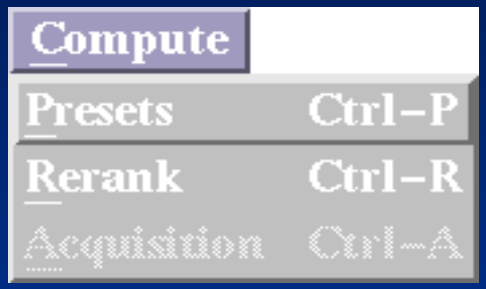


Acoustic Preset Module Display



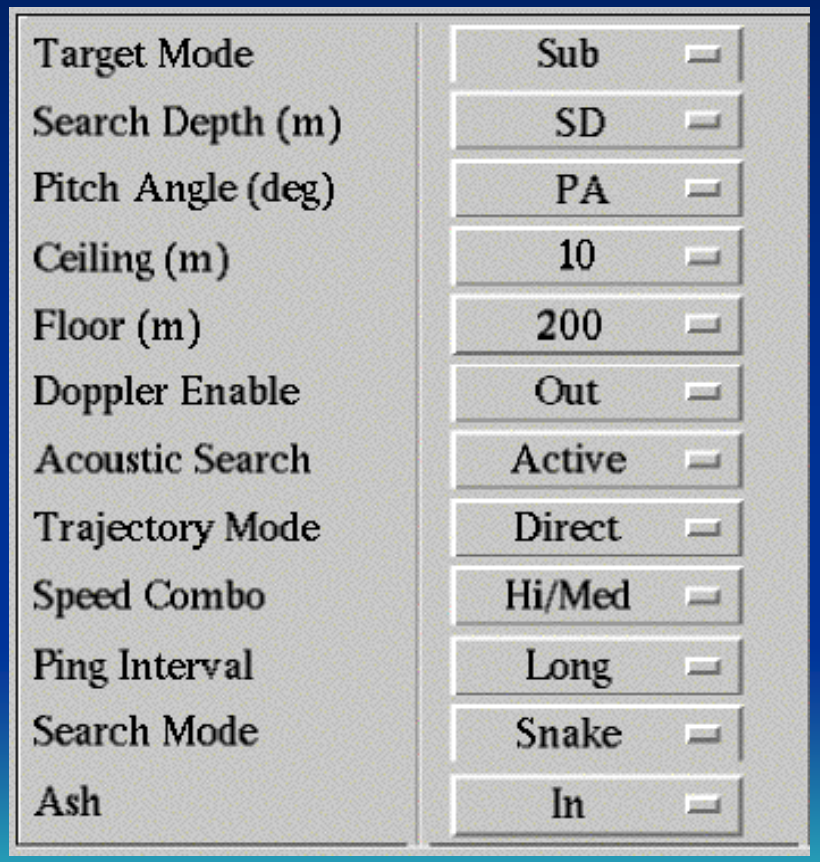
Acoustic Preset Module
Preset Computation

- 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



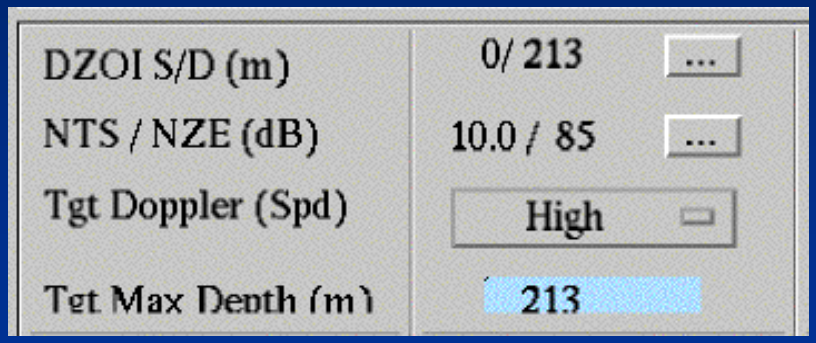
Acoustic Preset Module Tactical Presets

- 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



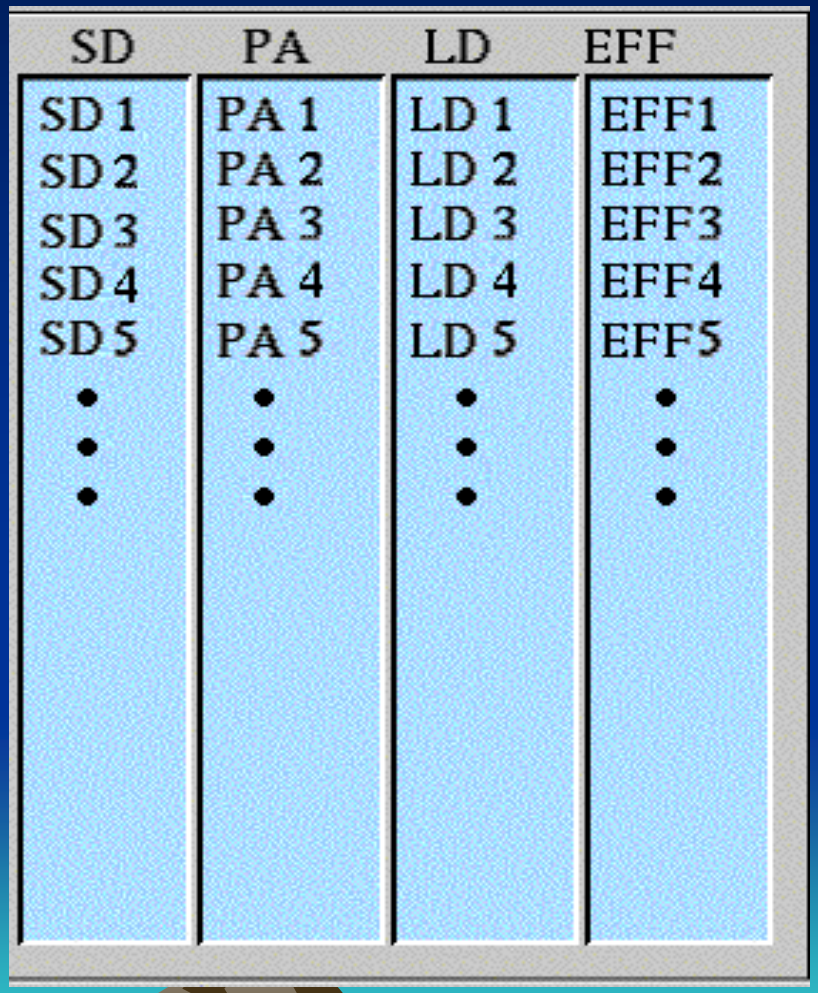
Acoustic Preset Module Target Data

- 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)



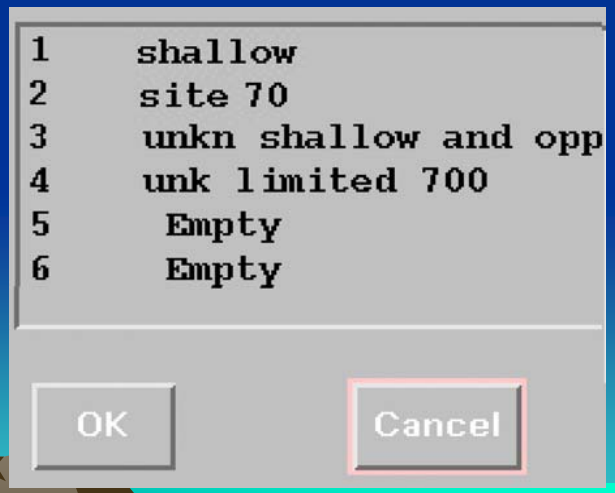
Acoustic Preset Module Ranked Listset

- 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

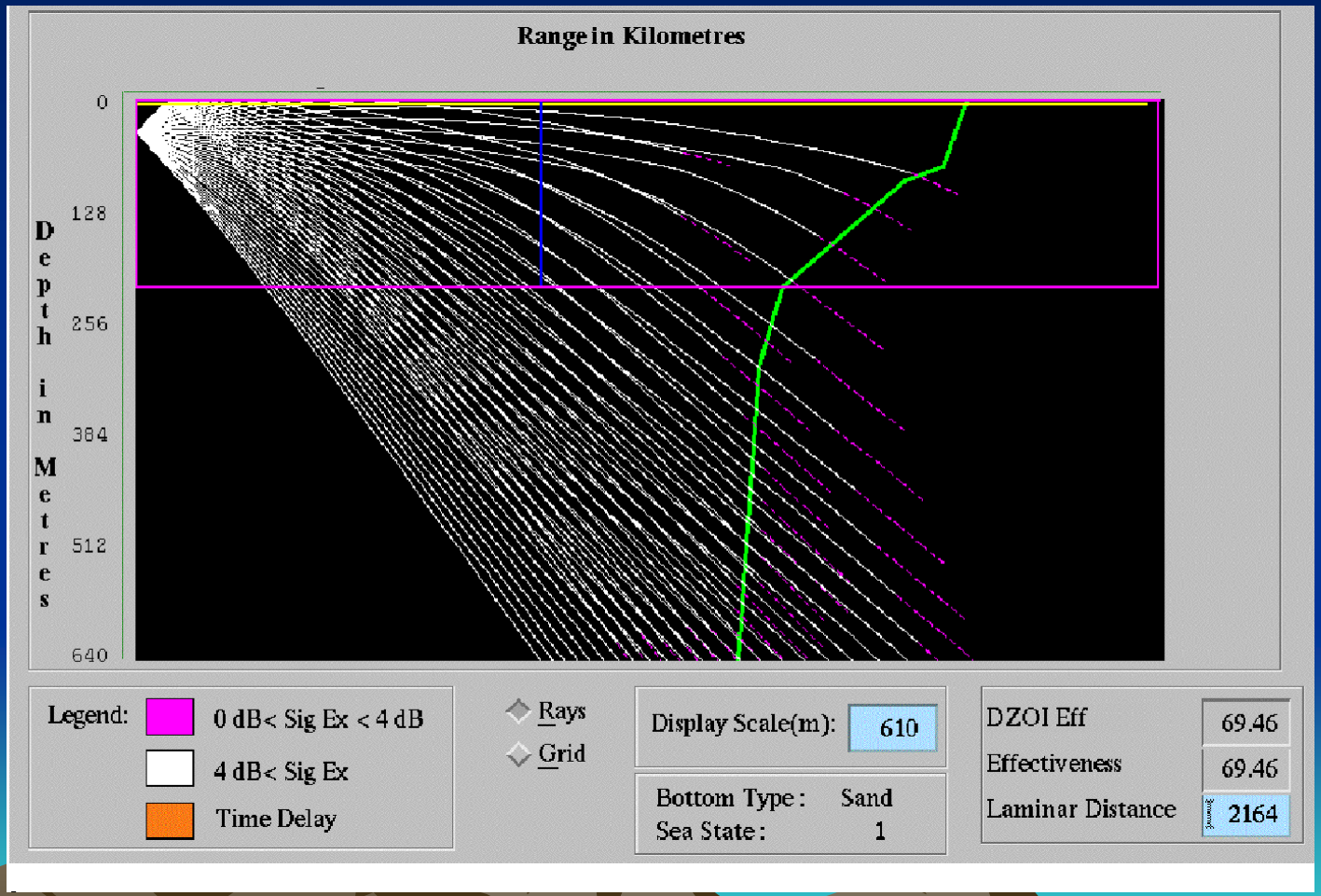


Acoustic Preset Module Tactic Lists

- 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)

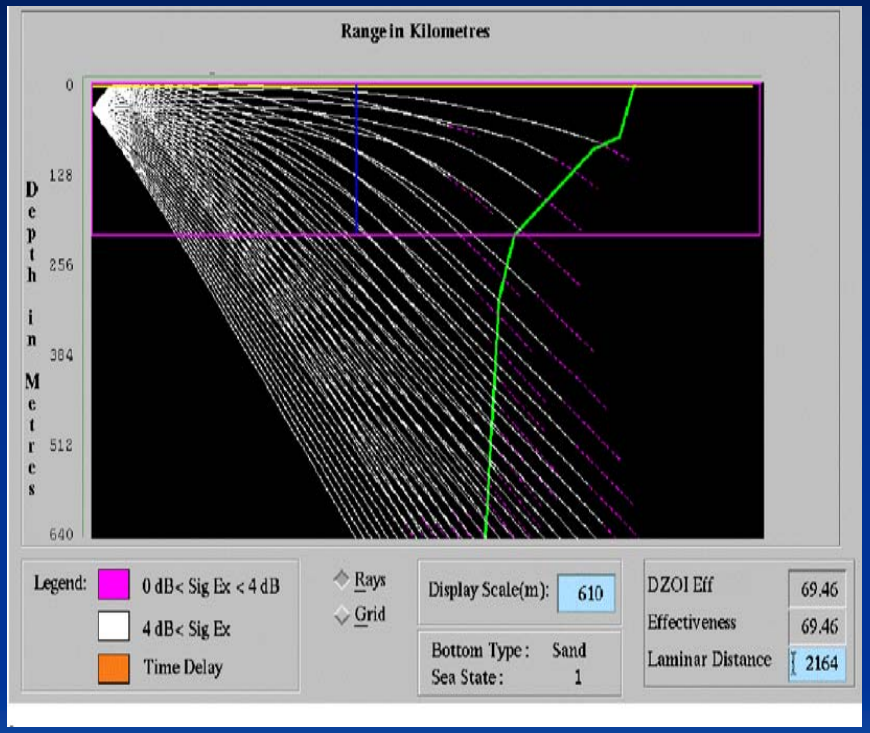


Ray Trace Display

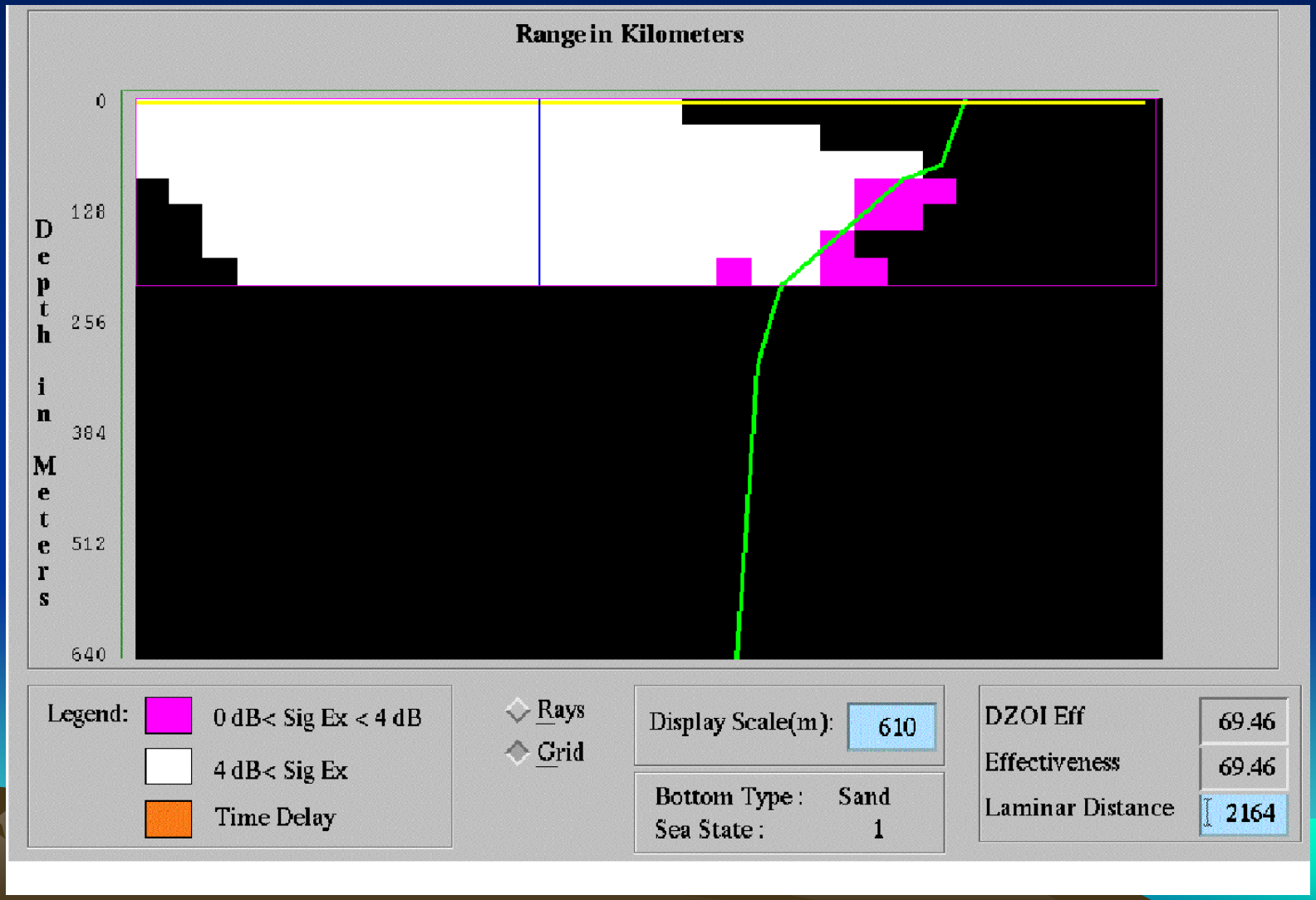


Acoustic Preset Module
Ray Trace Display

- 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

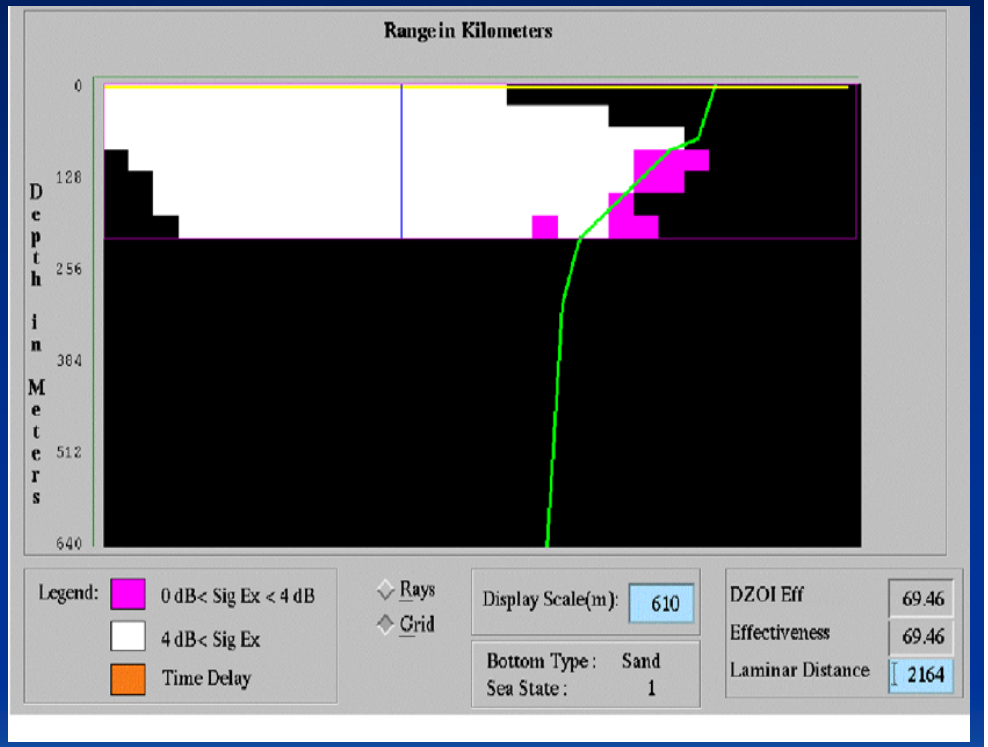


Signal Excess Display



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



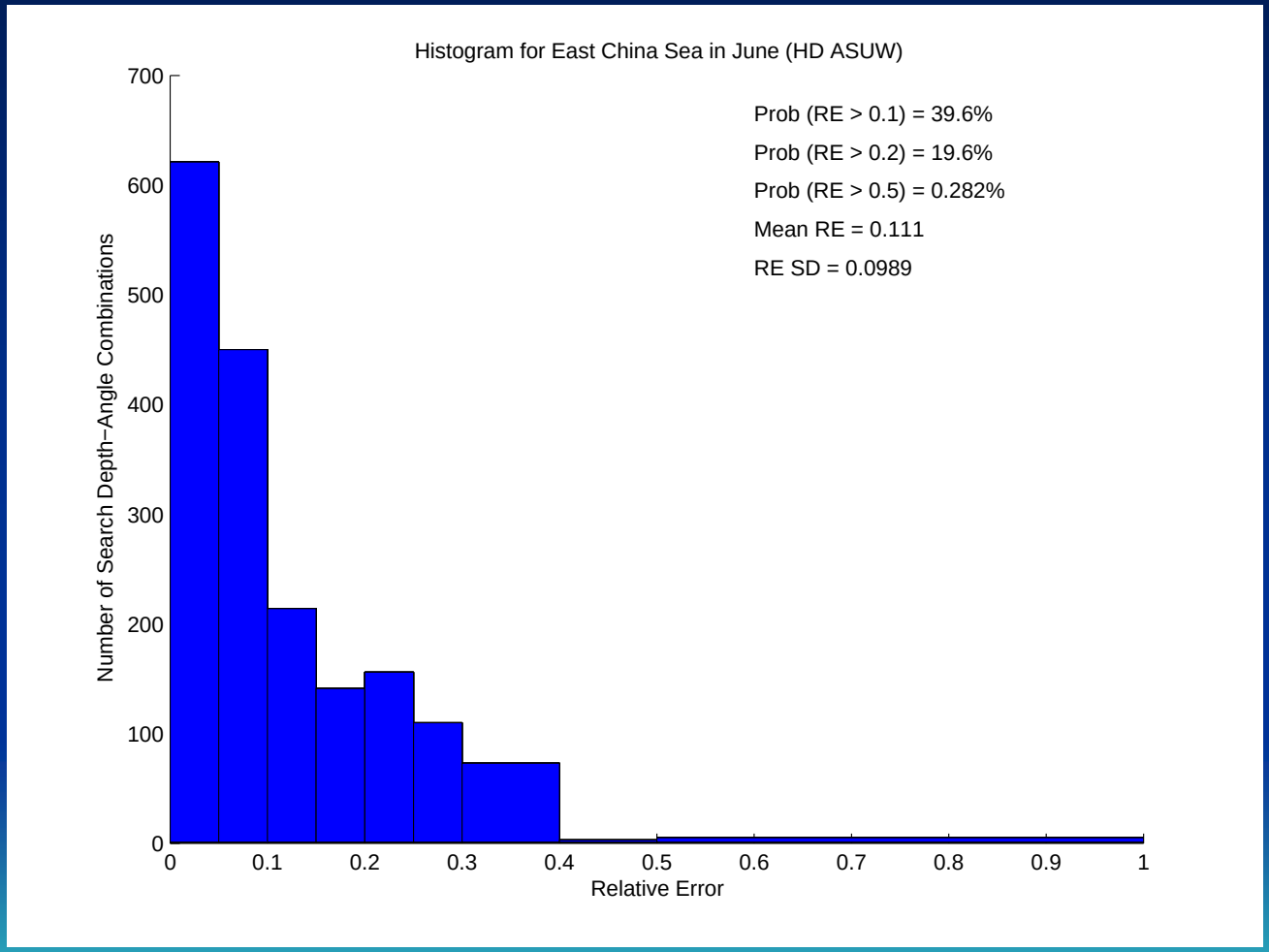
Generated Output

- 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

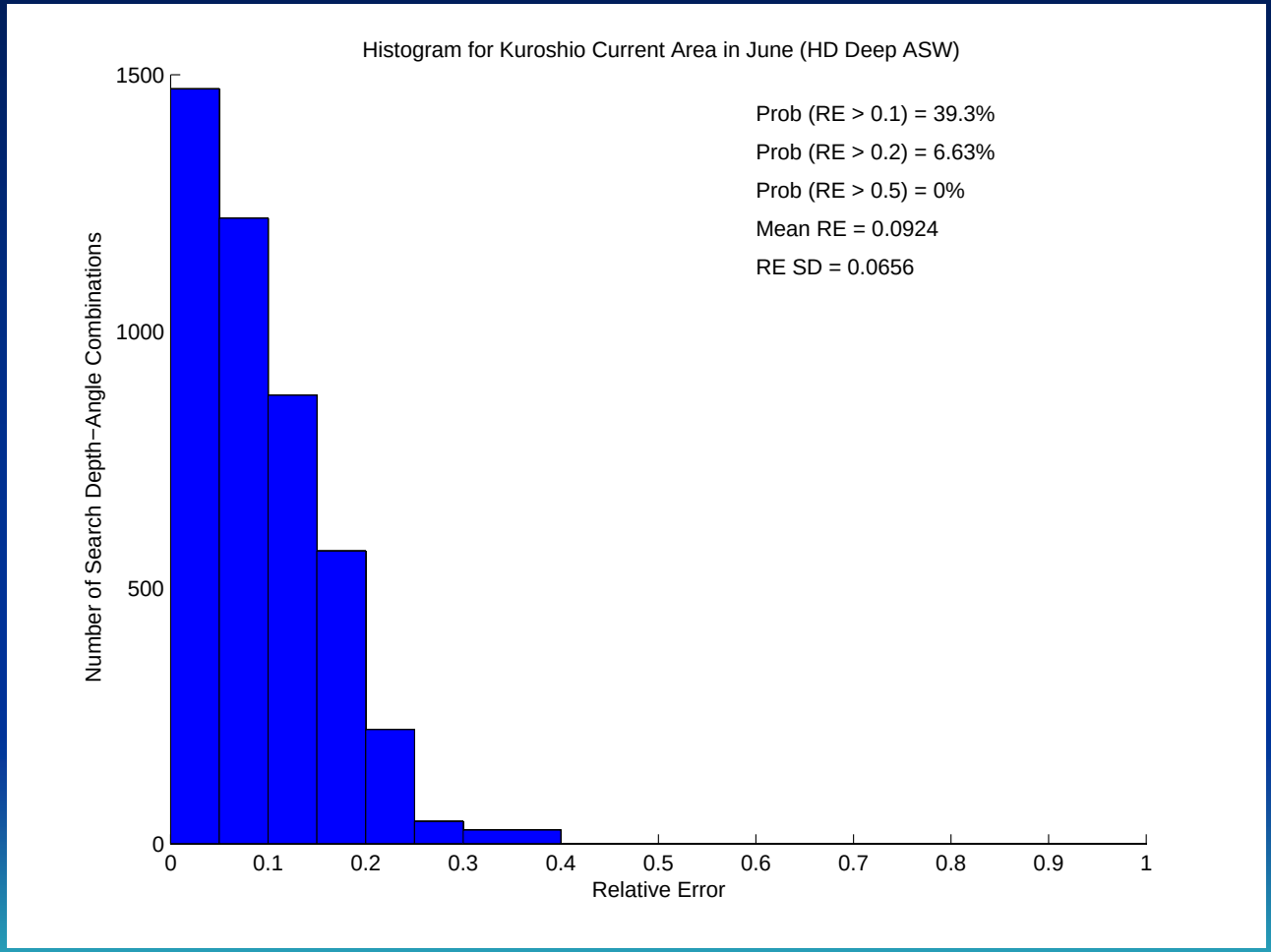
Analysis of Output

- 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

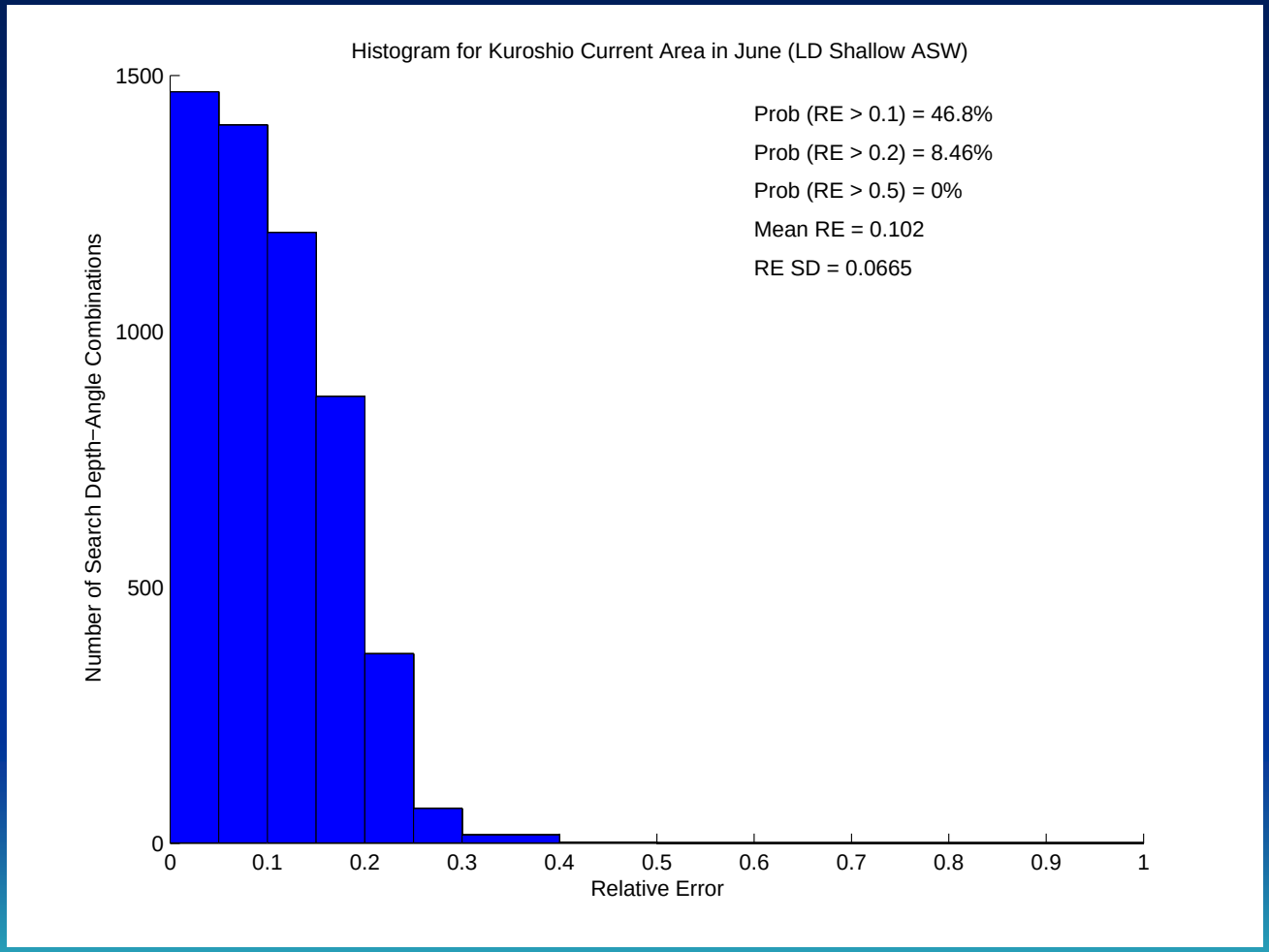
East China Sea (June) HD ASUW



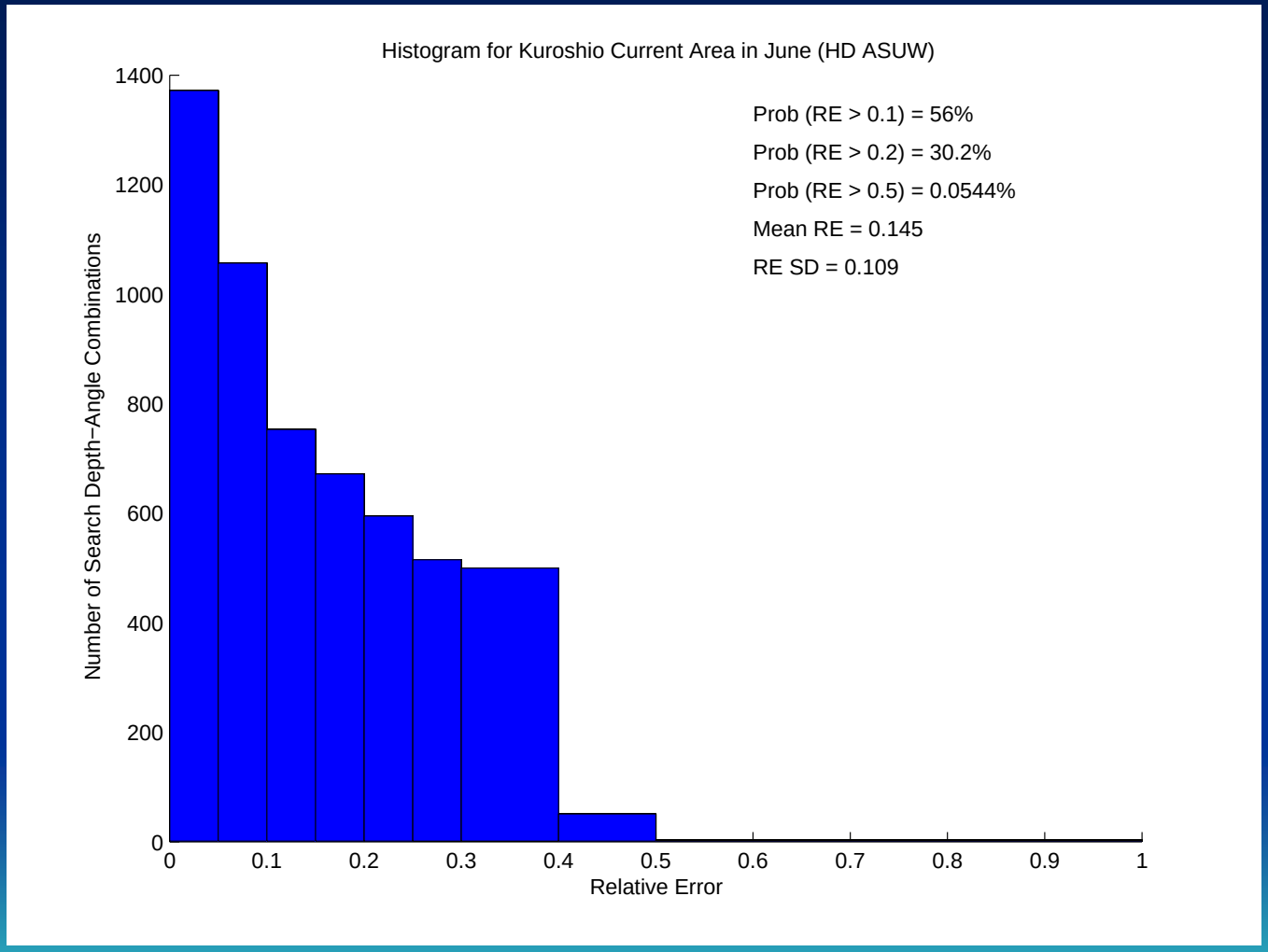
Kuroshio Region (June) HD Deep ASW



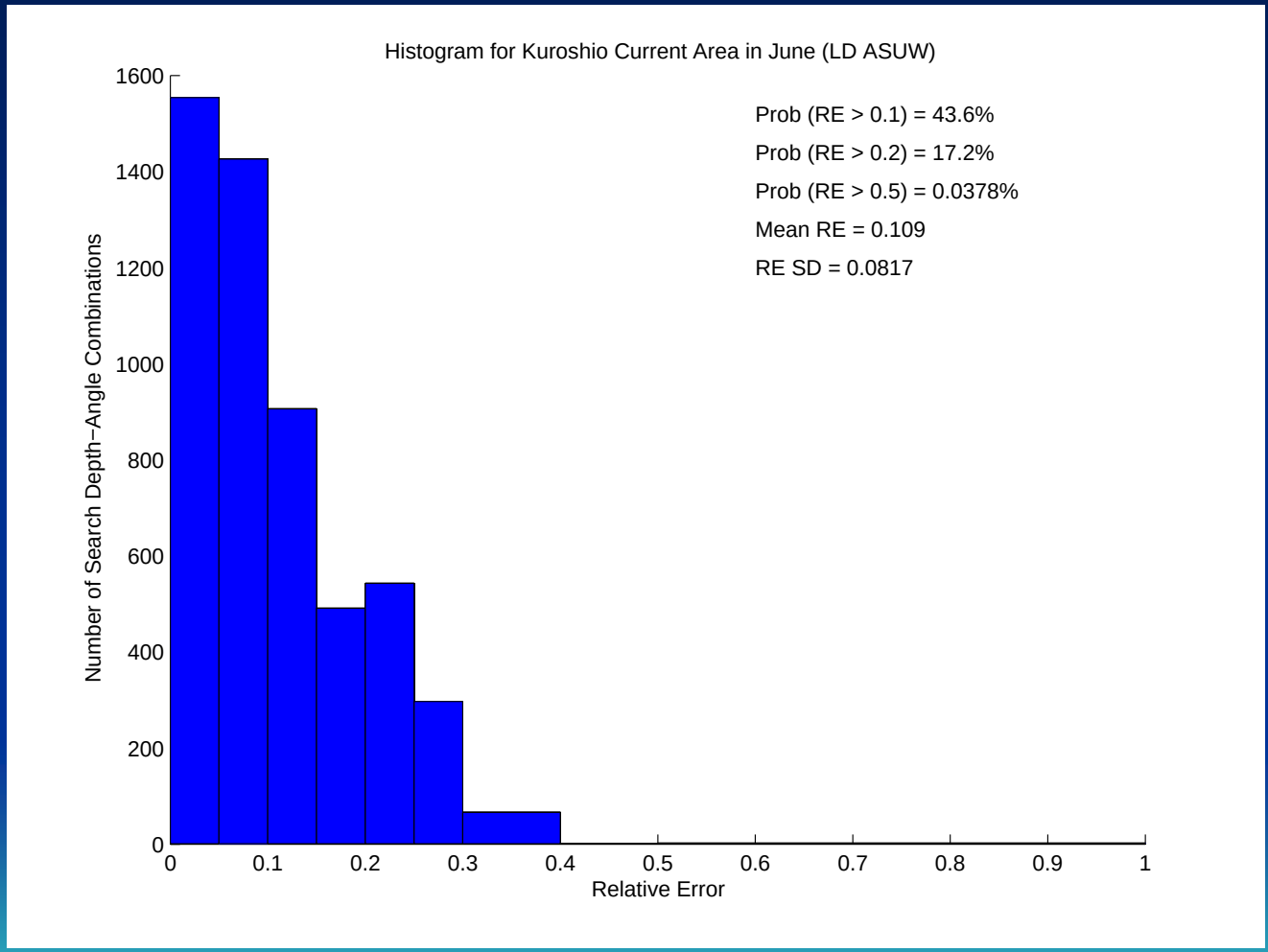
Kuroshio Region (June) LD Shallow ASW



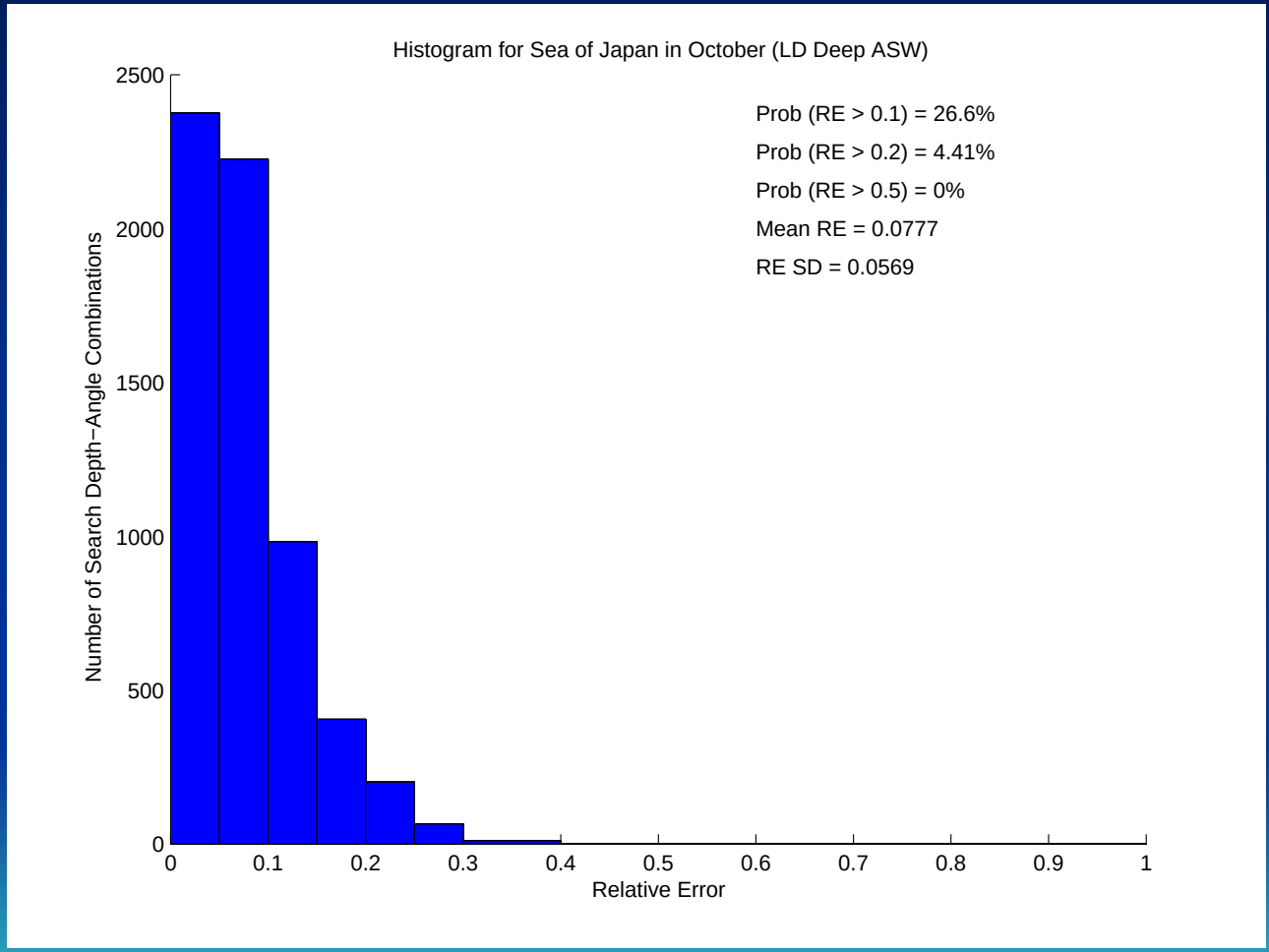
Kuroshio (June) HD ASUW



Kuroshio (June) LD ASUW



JES (October) LD Deep ASW



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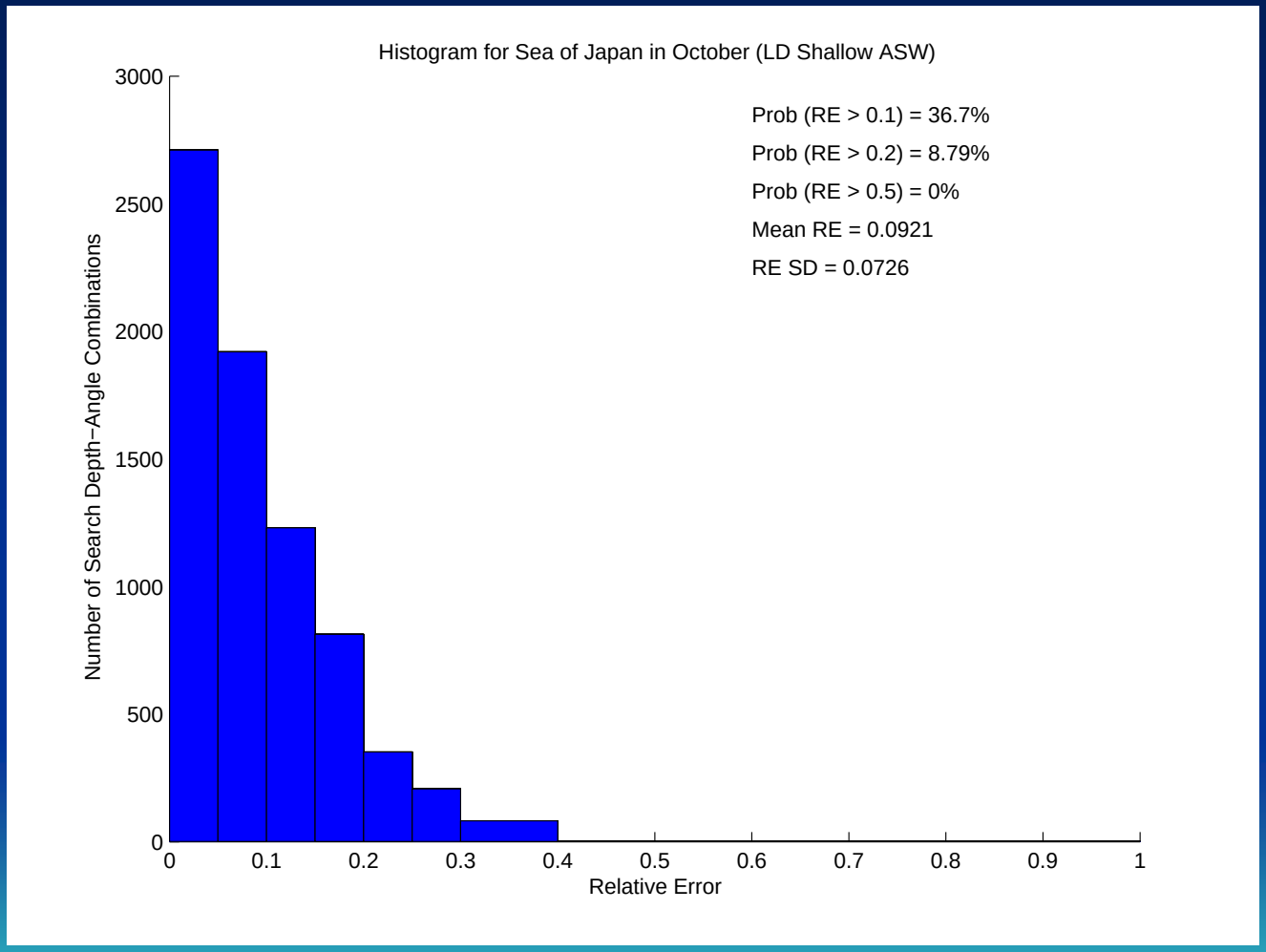
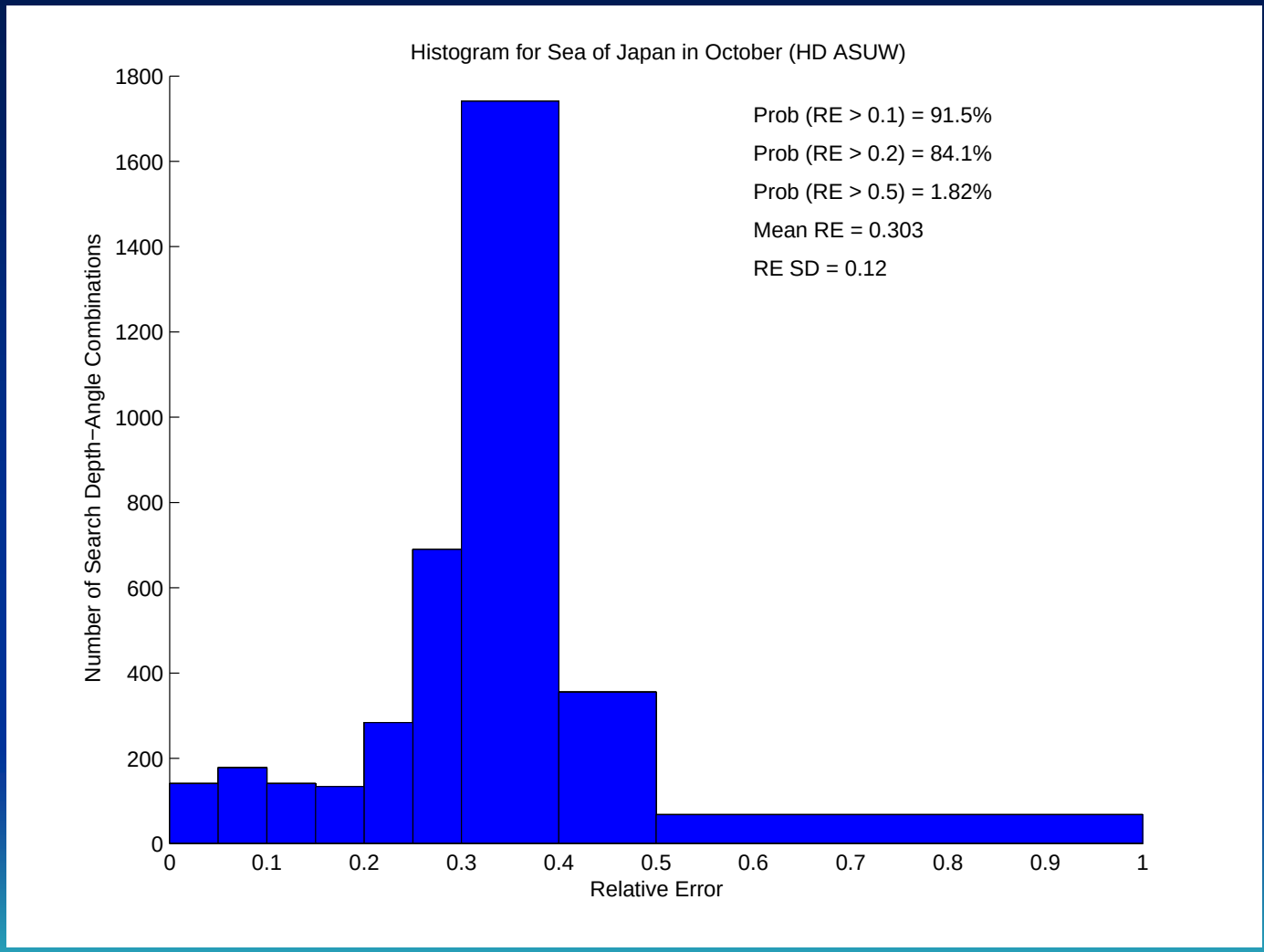
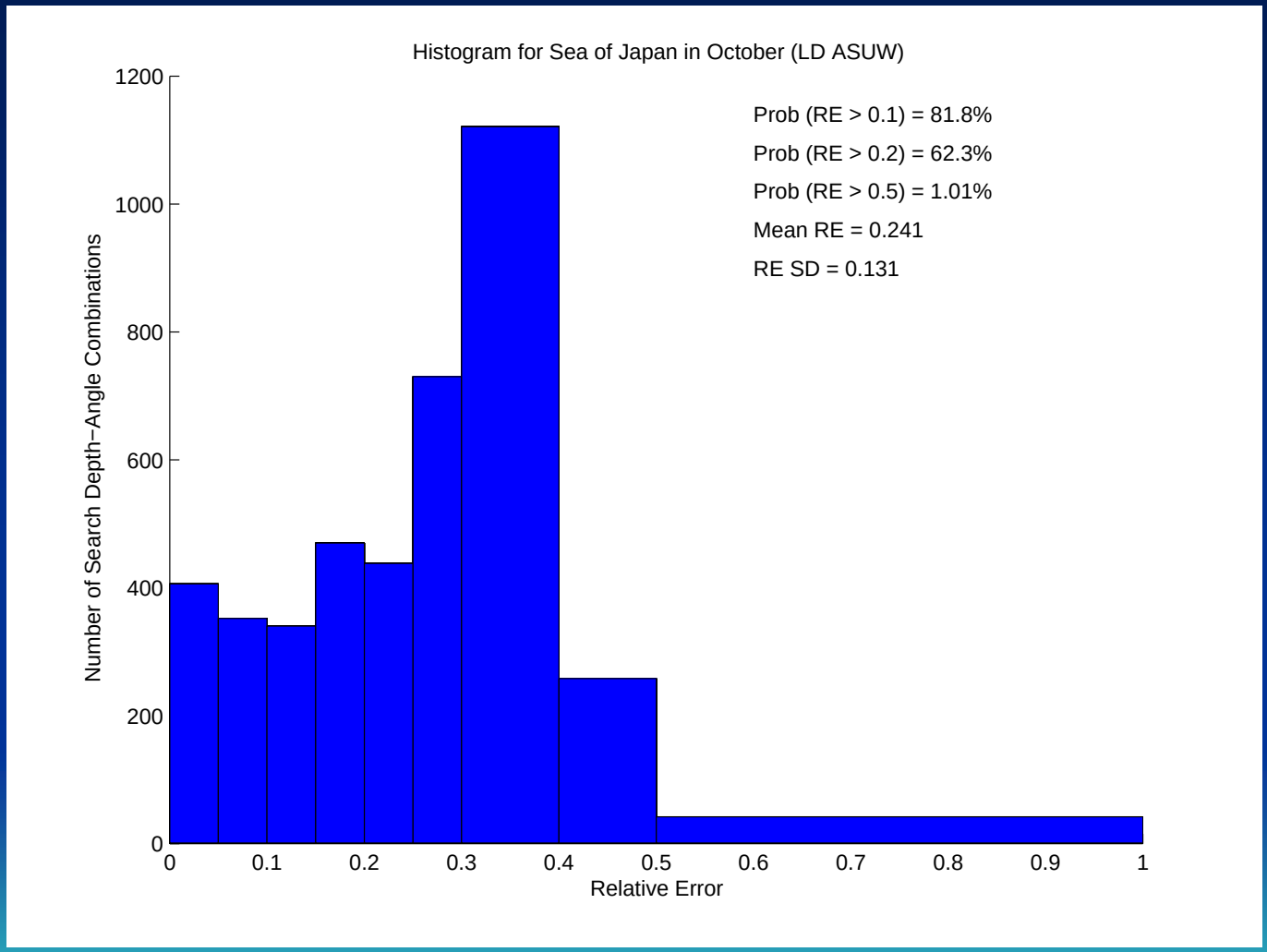


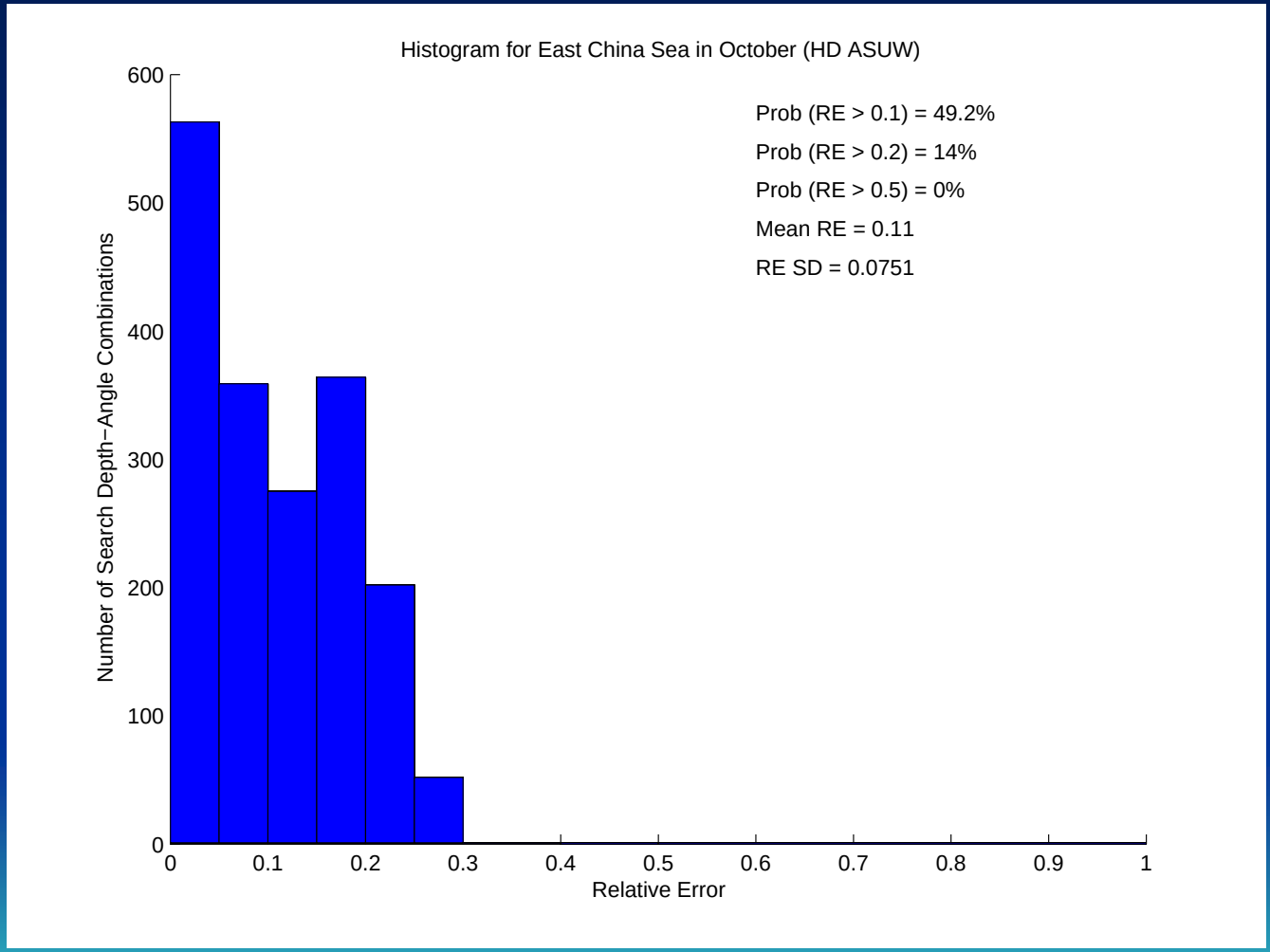
JES (October) HD ASUW



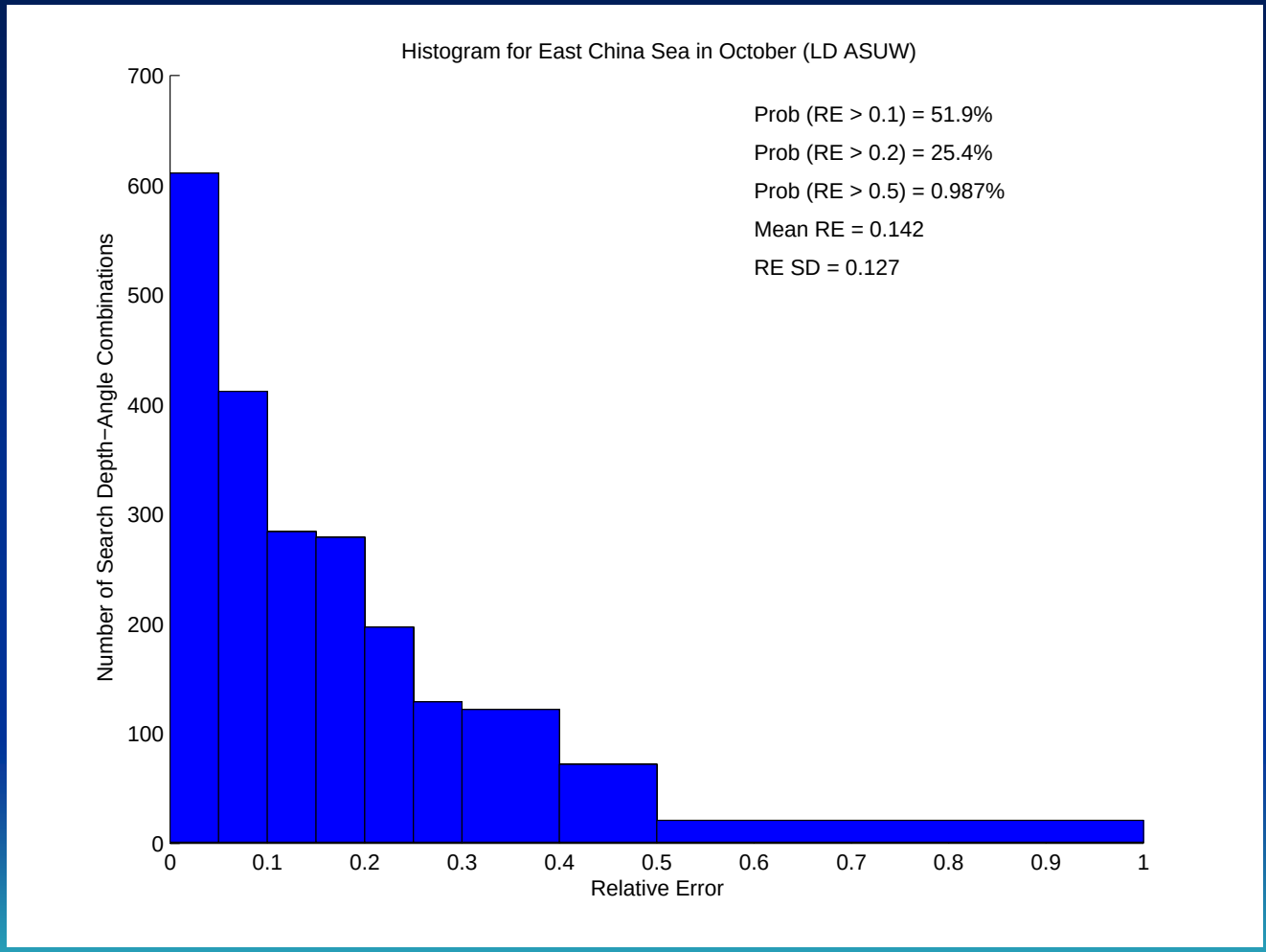
JES (October) LD ASUW



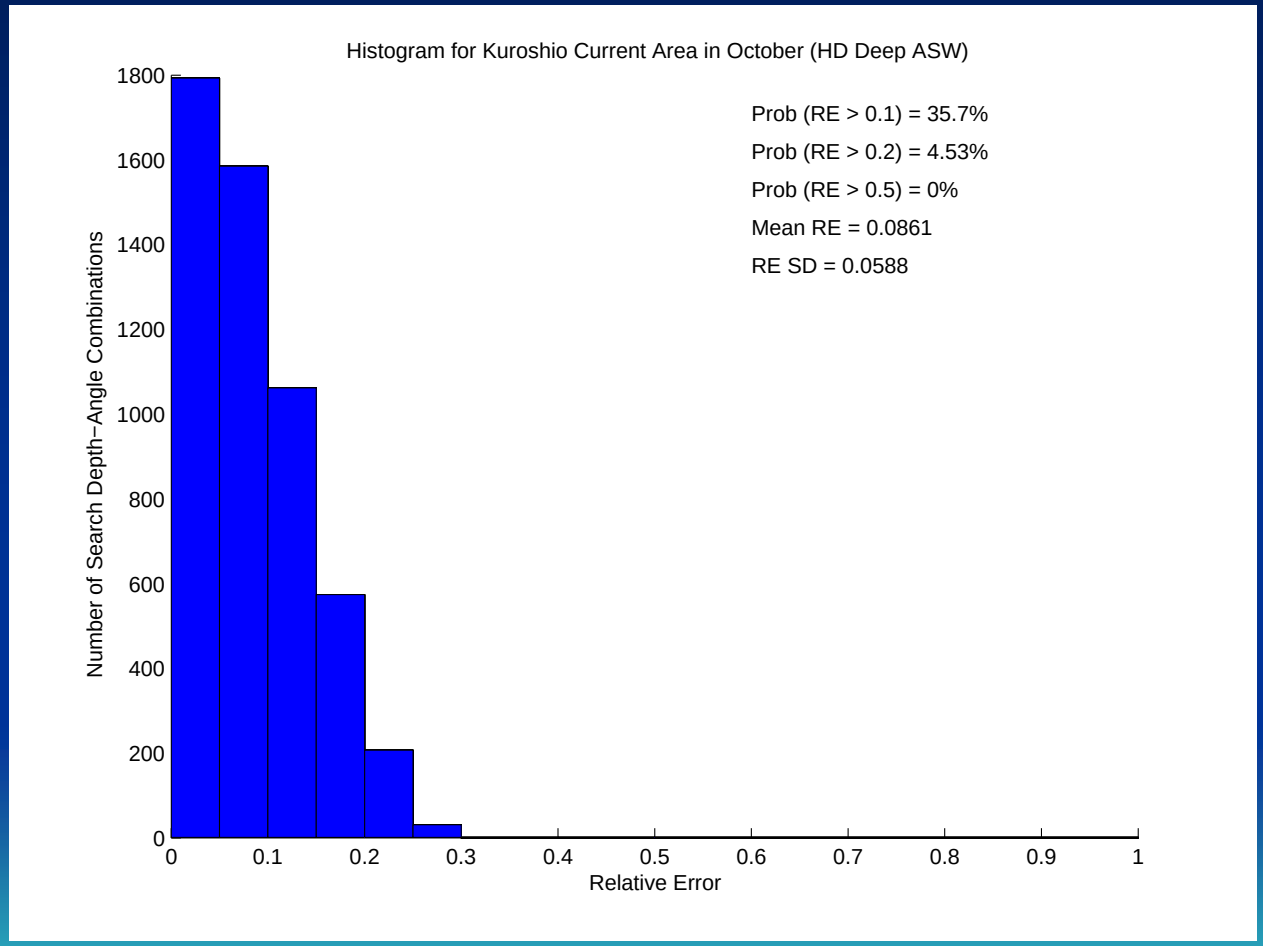
East China Sea (October) HD ASUW



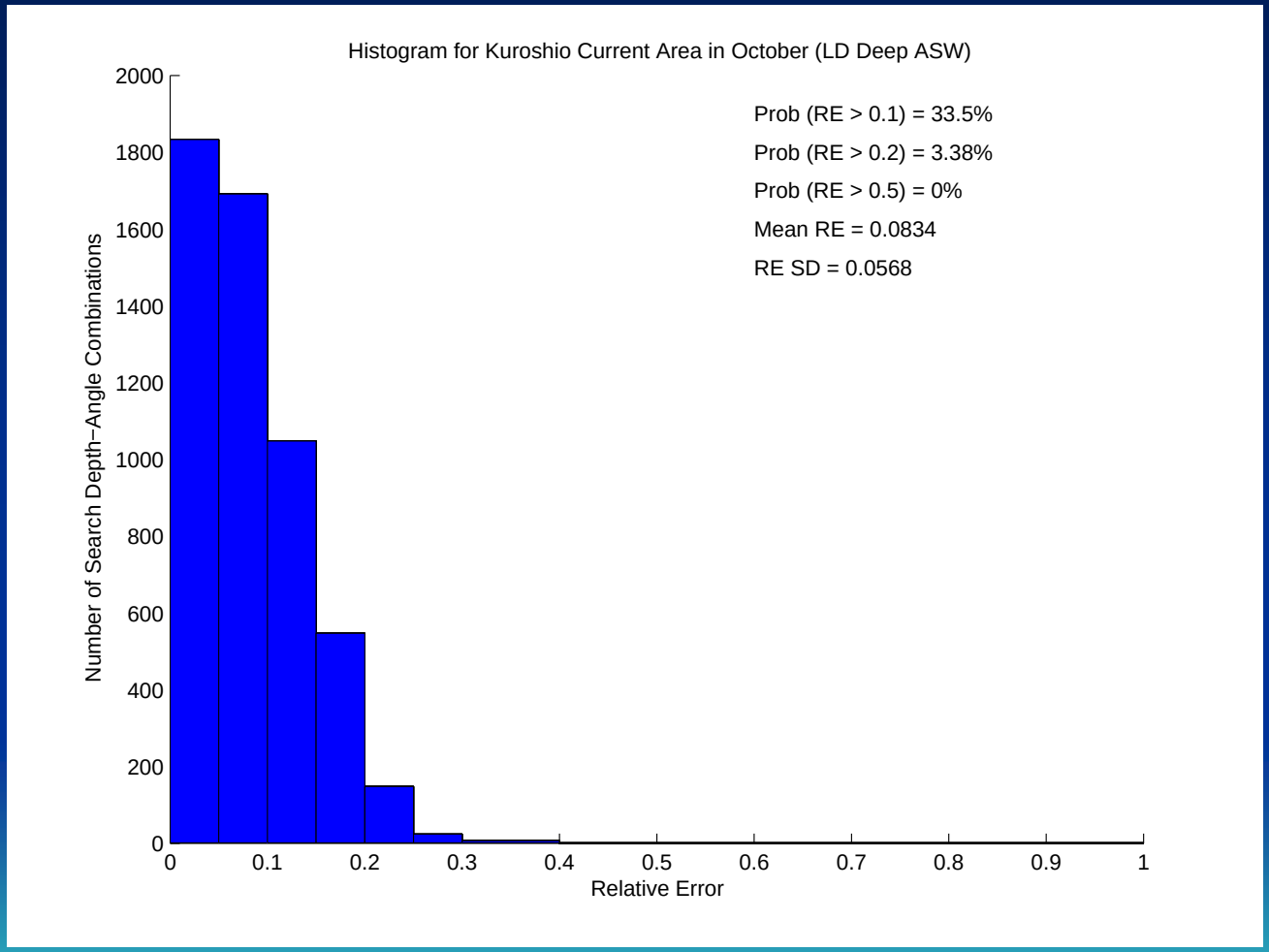
East China Sea (October) LD ASUW



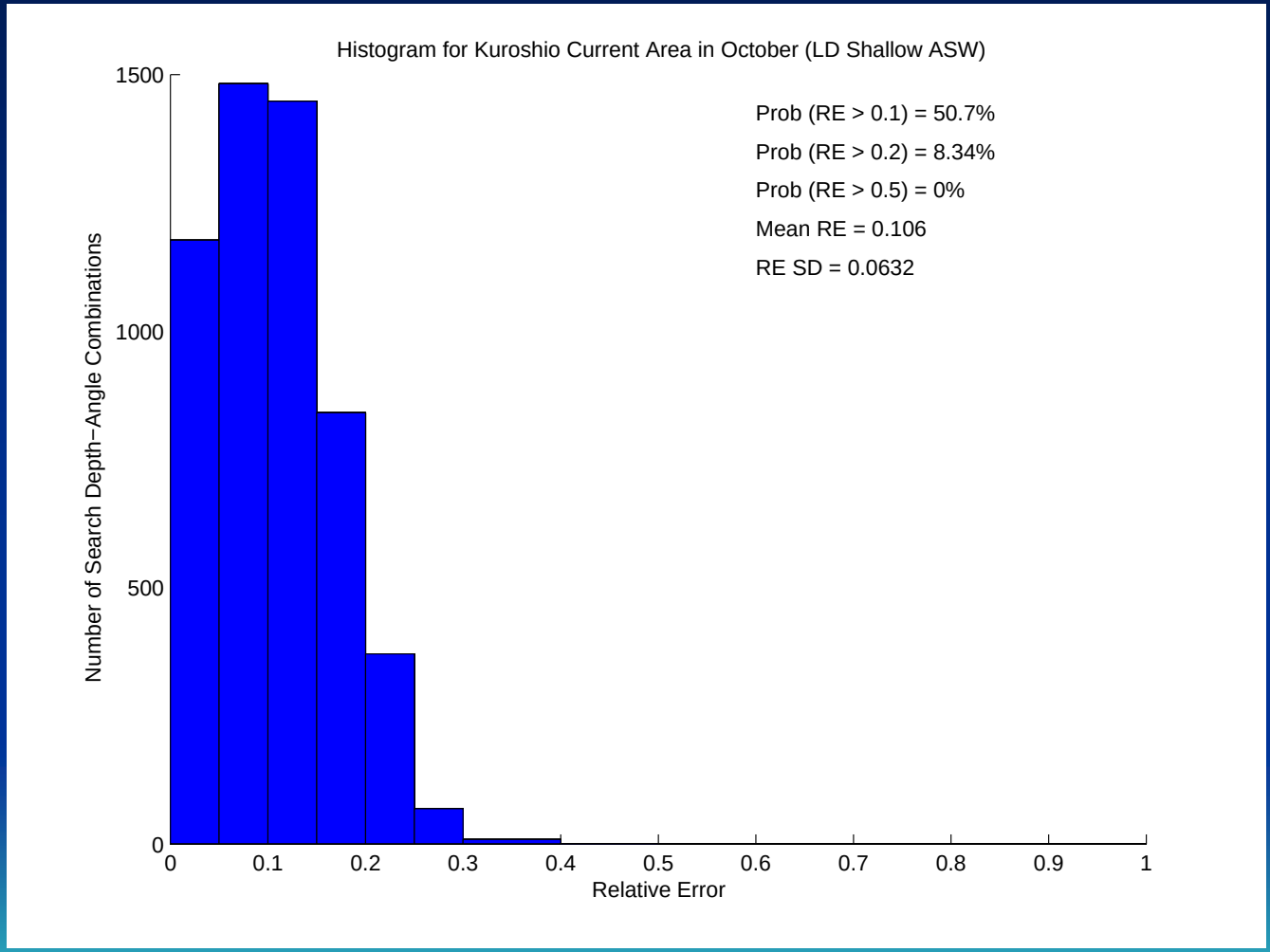
Kuroshio (October) HD Deep ASW



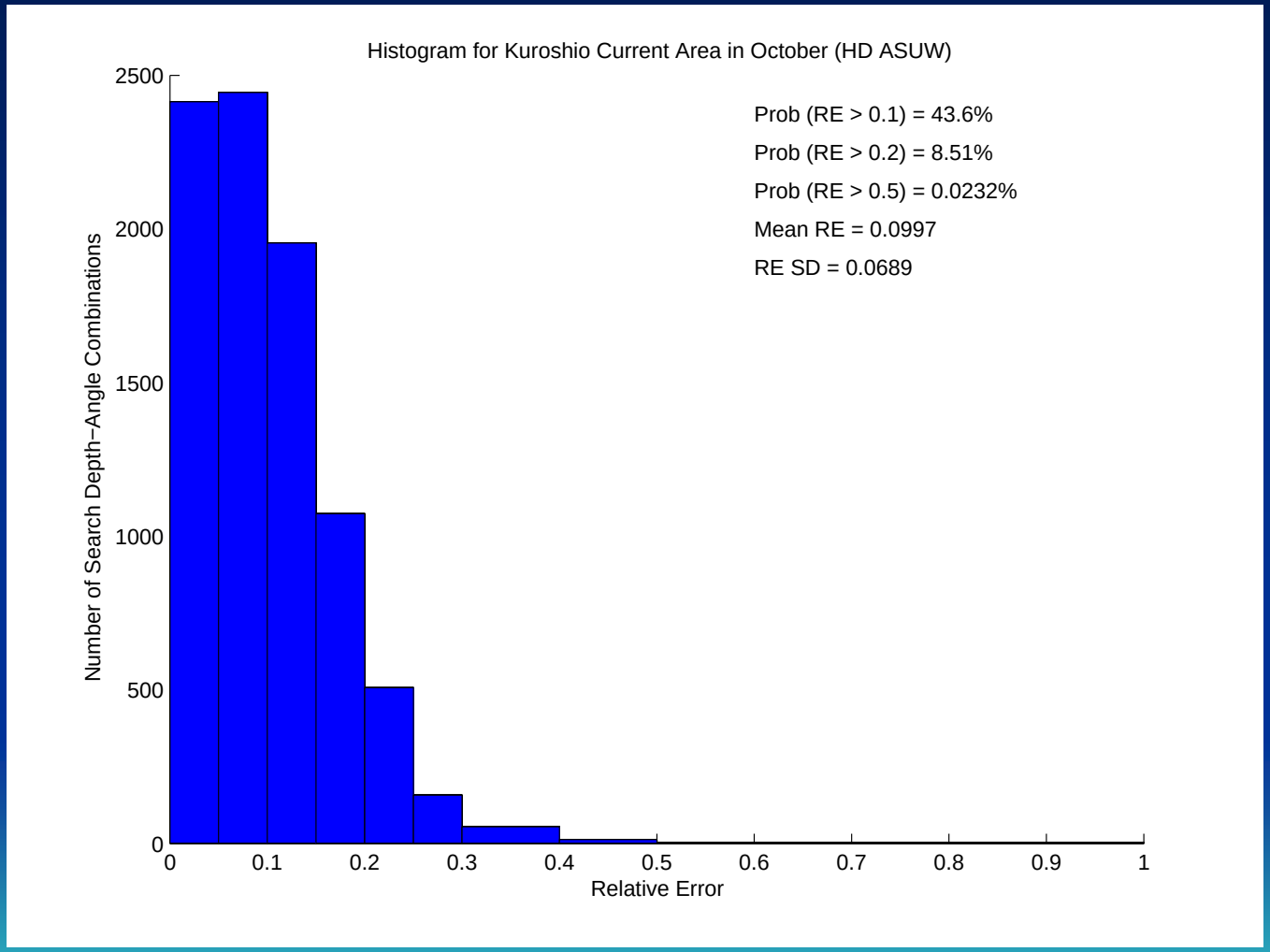
Kuroshio (October) LD Deep ASW



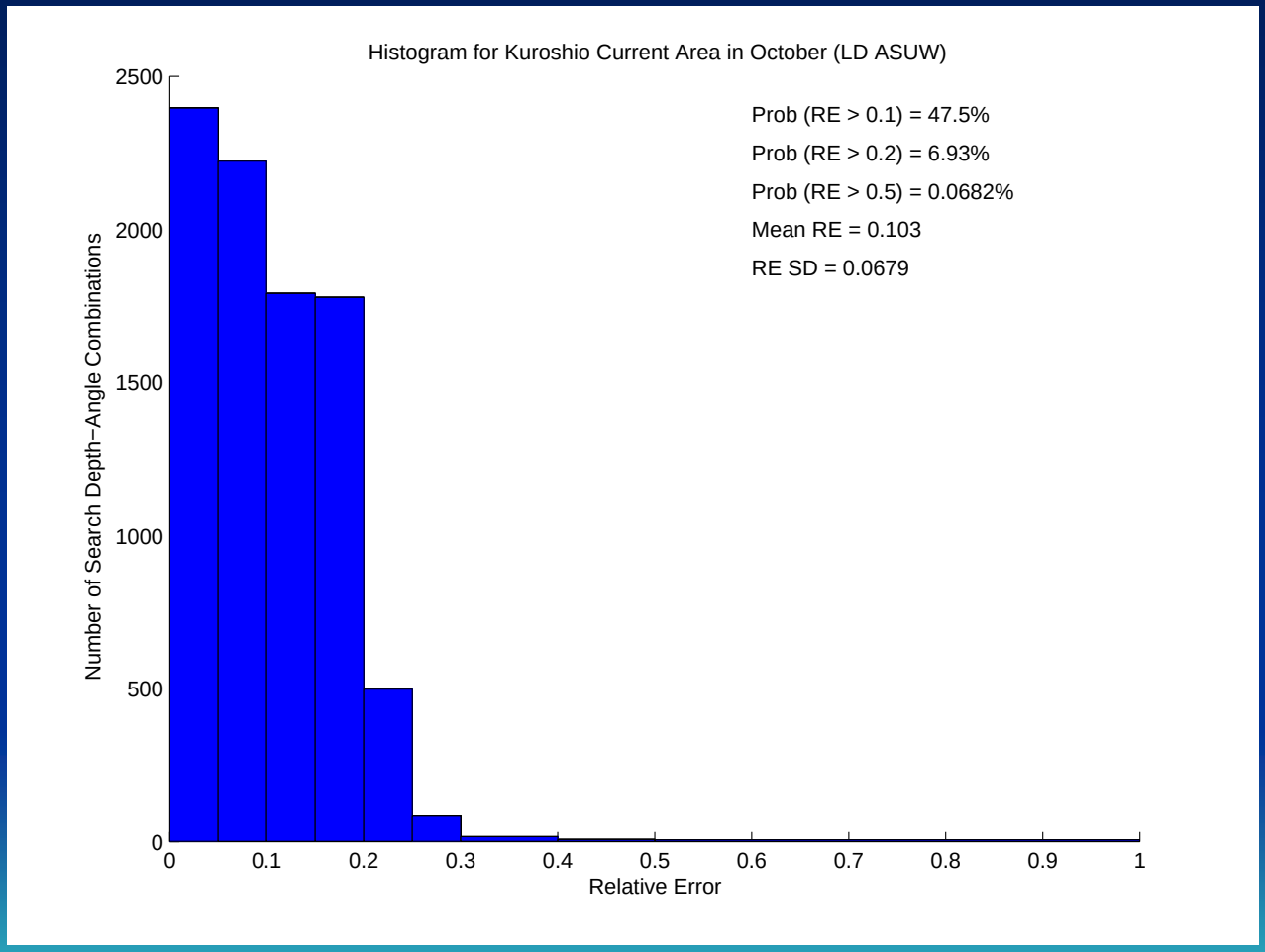
Kuroshio (October) LD Shallow ASW



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?