

# Geographic Variation in Sperm Whale Echolocation Clicks

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# Relevance to DCLDE

- Click characteristics of individual sperm whales are known to vary, but geographic differences have not yet been documented
- Diversity in click characteristics = Diagnostic tool:
  - Ground-truthing during post-processing
  - Species ID during passive acoustic monitoring
- Implications for detector and classifier performance

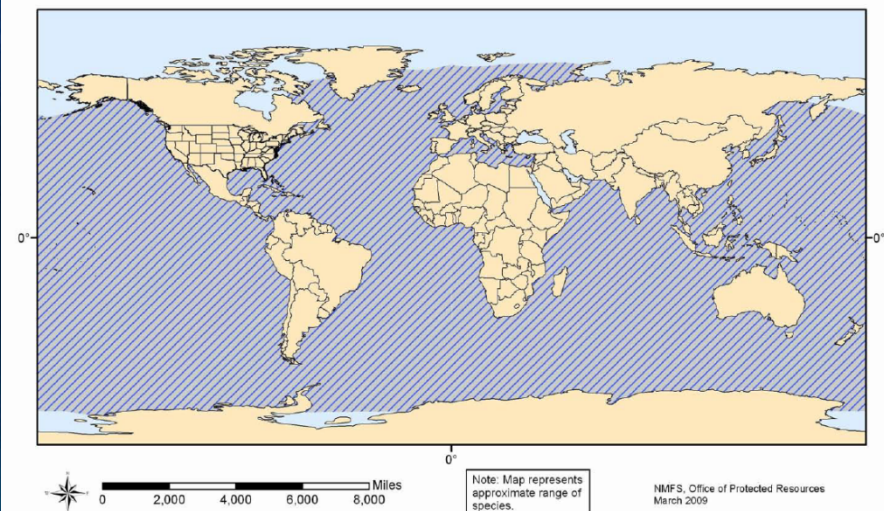


# Sperm Whales

- Deep-diving odontocetes
- Inhabit all oceans, predominantly in temperate and tropical waters
- Worldwide Estimate:
  - 300,000-450,000
- Click Types:
  - 'Usual' or 'Regular' clicks
  - 'Slow' clicks
  - 'Creaks' and 'Buzzes'
  - 'Codas'



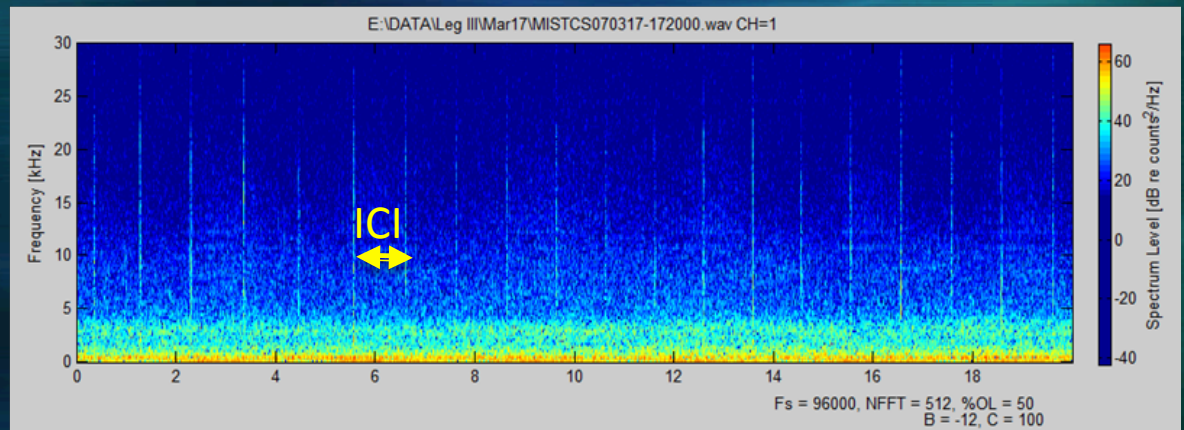
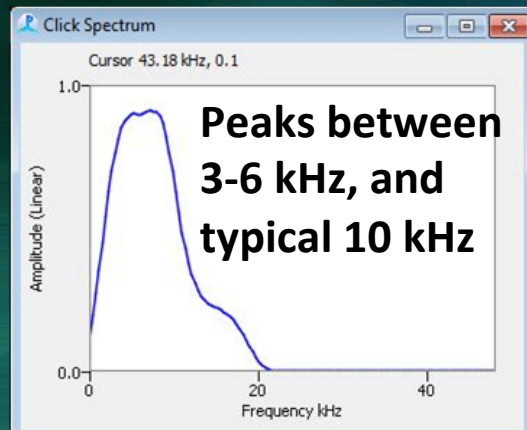
Sperm Whale Range



# Sperm Whale Click Types

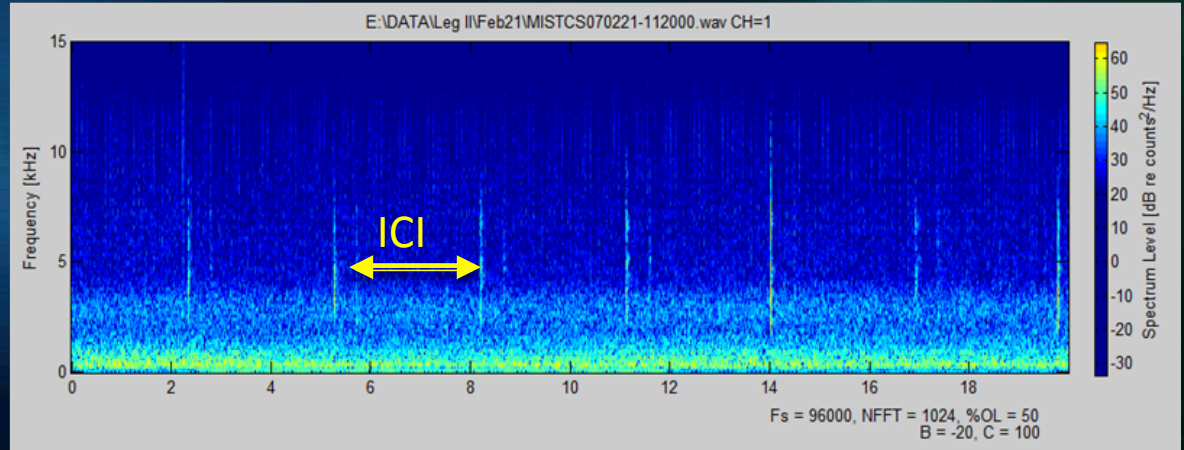
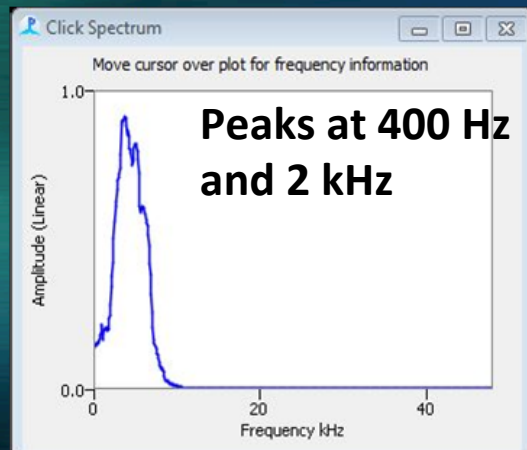
Regular (Usual)

All individuals



Slow

Mature Males



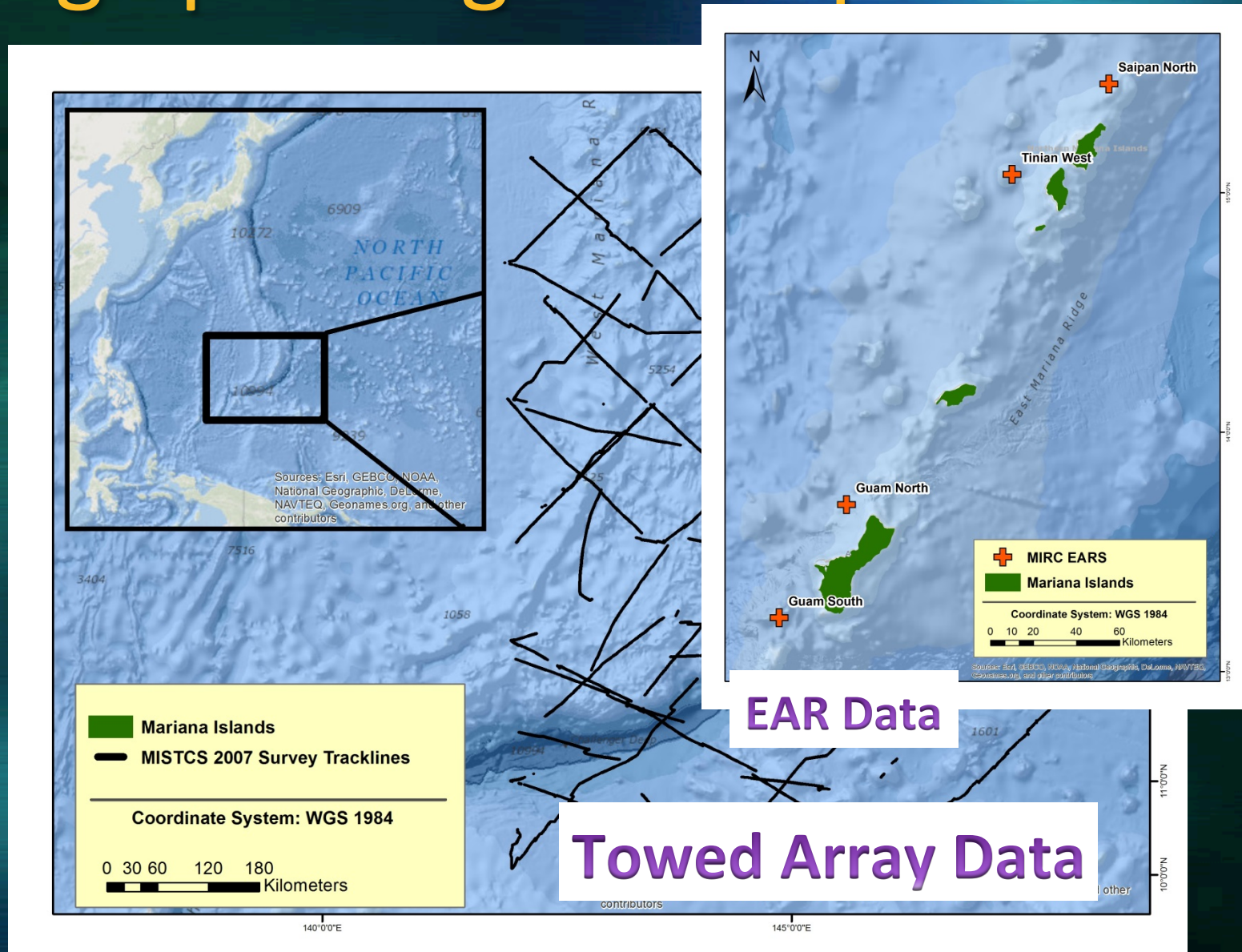


# Geographic Region Comparison

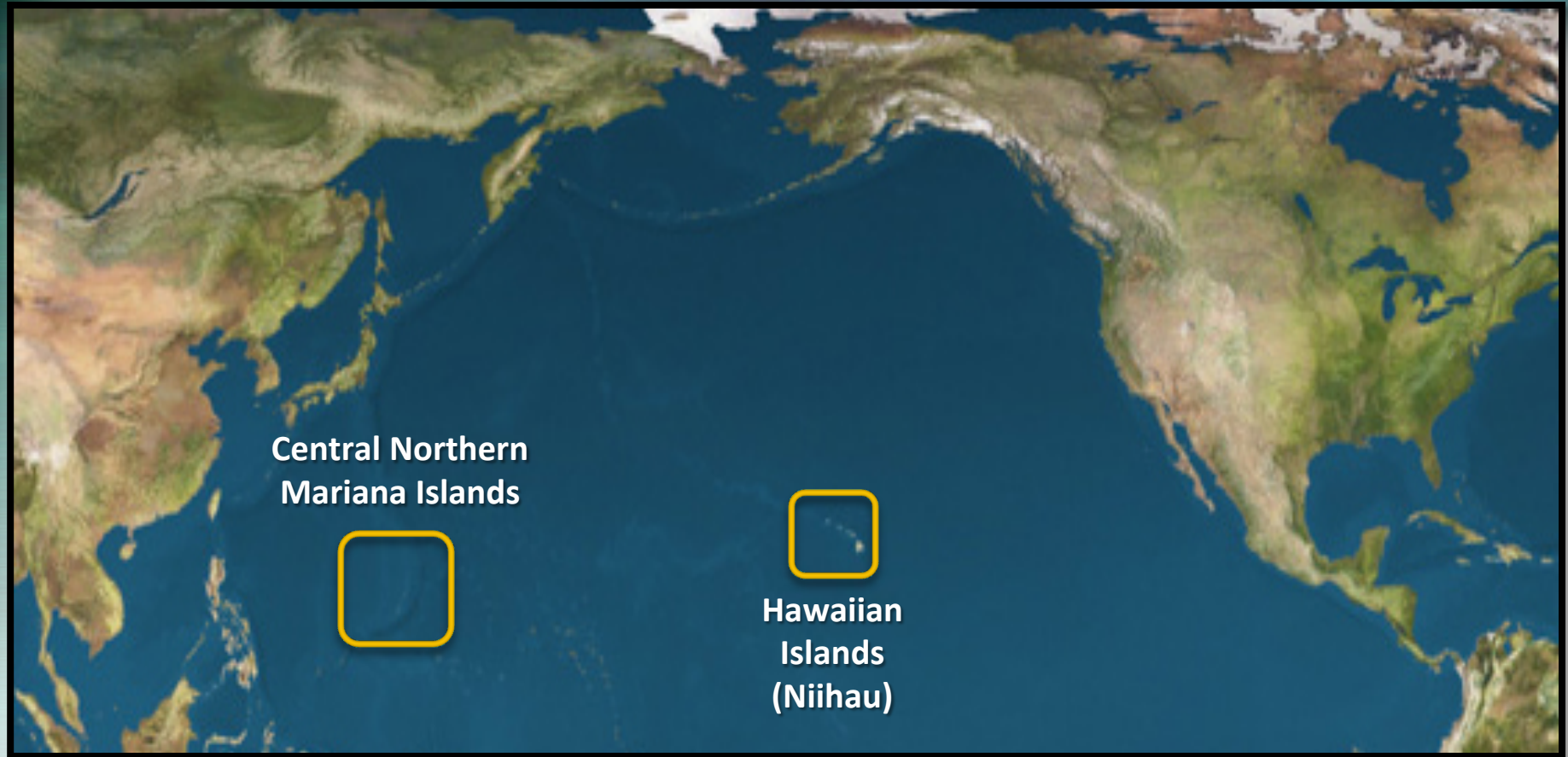




# Geographic Region Comparison

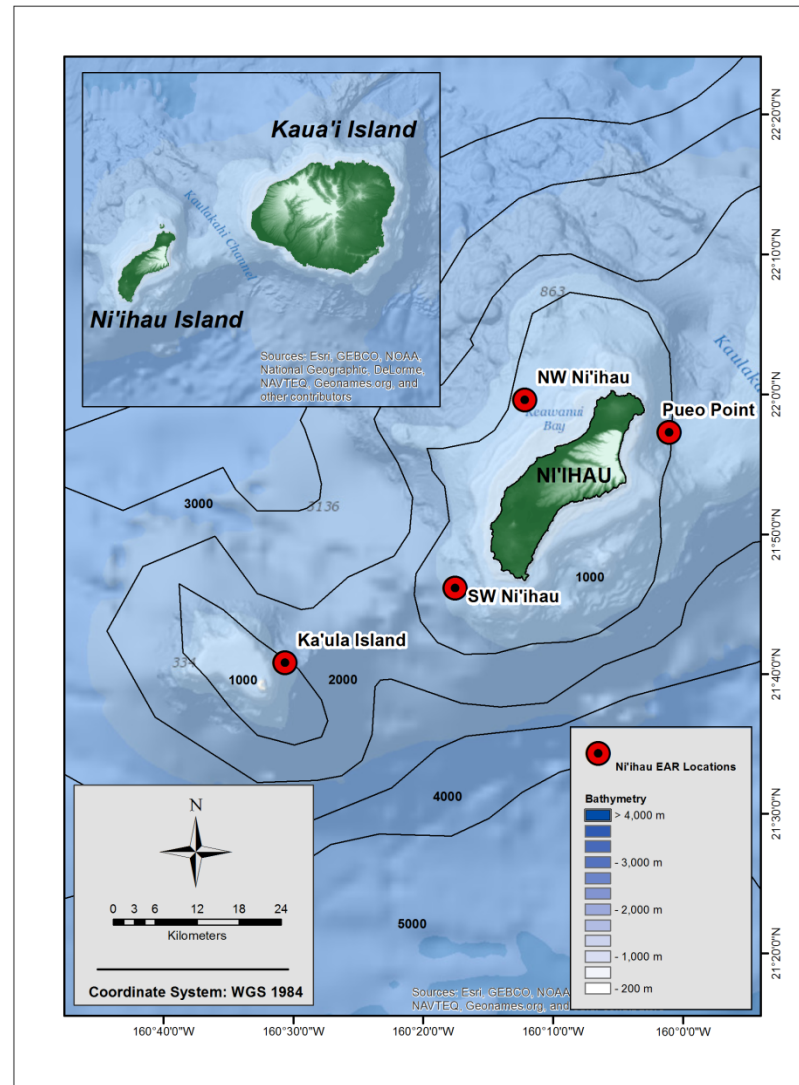


# Geographic Region Comparison

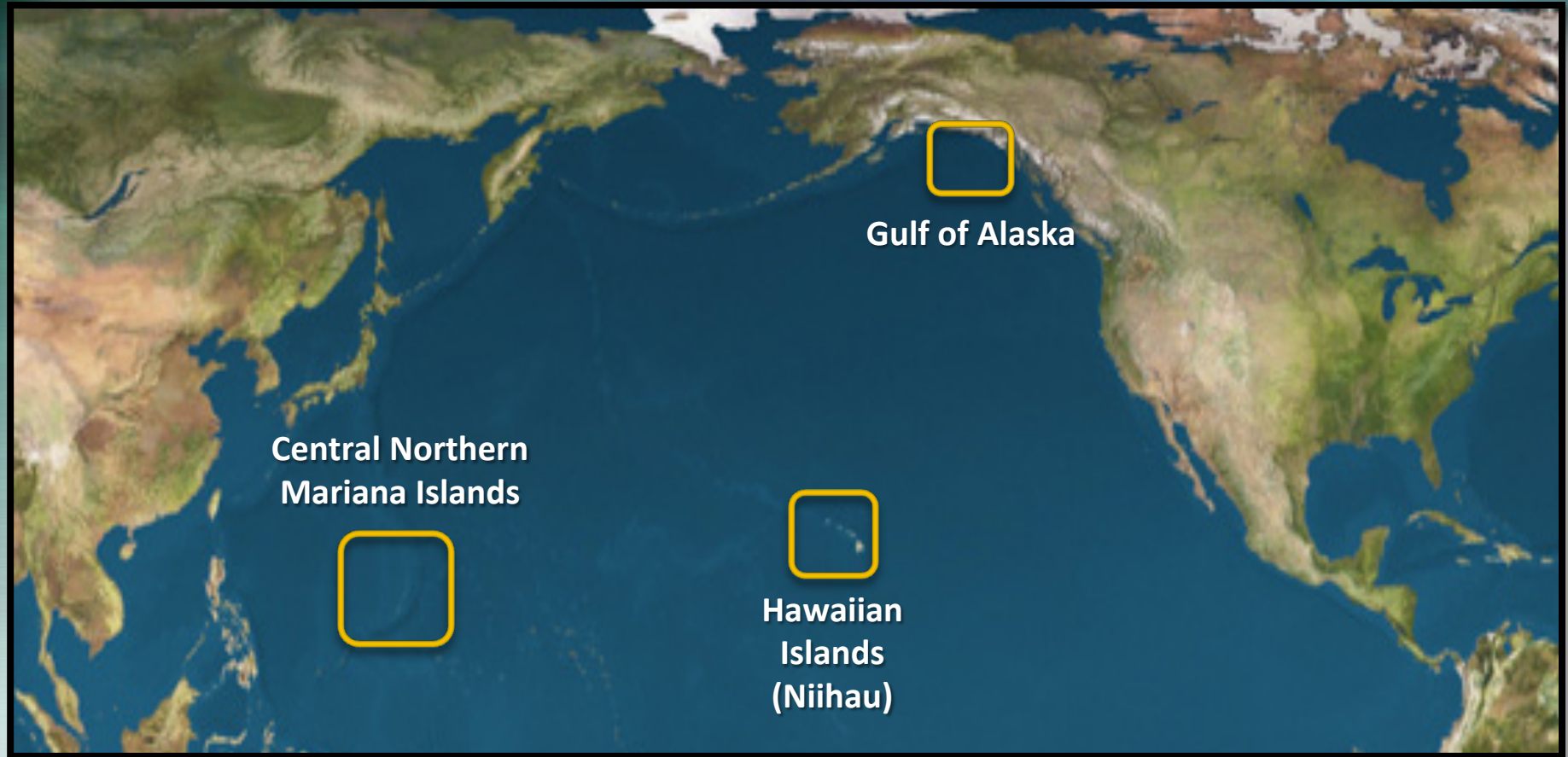




# Geographic Region Comparison

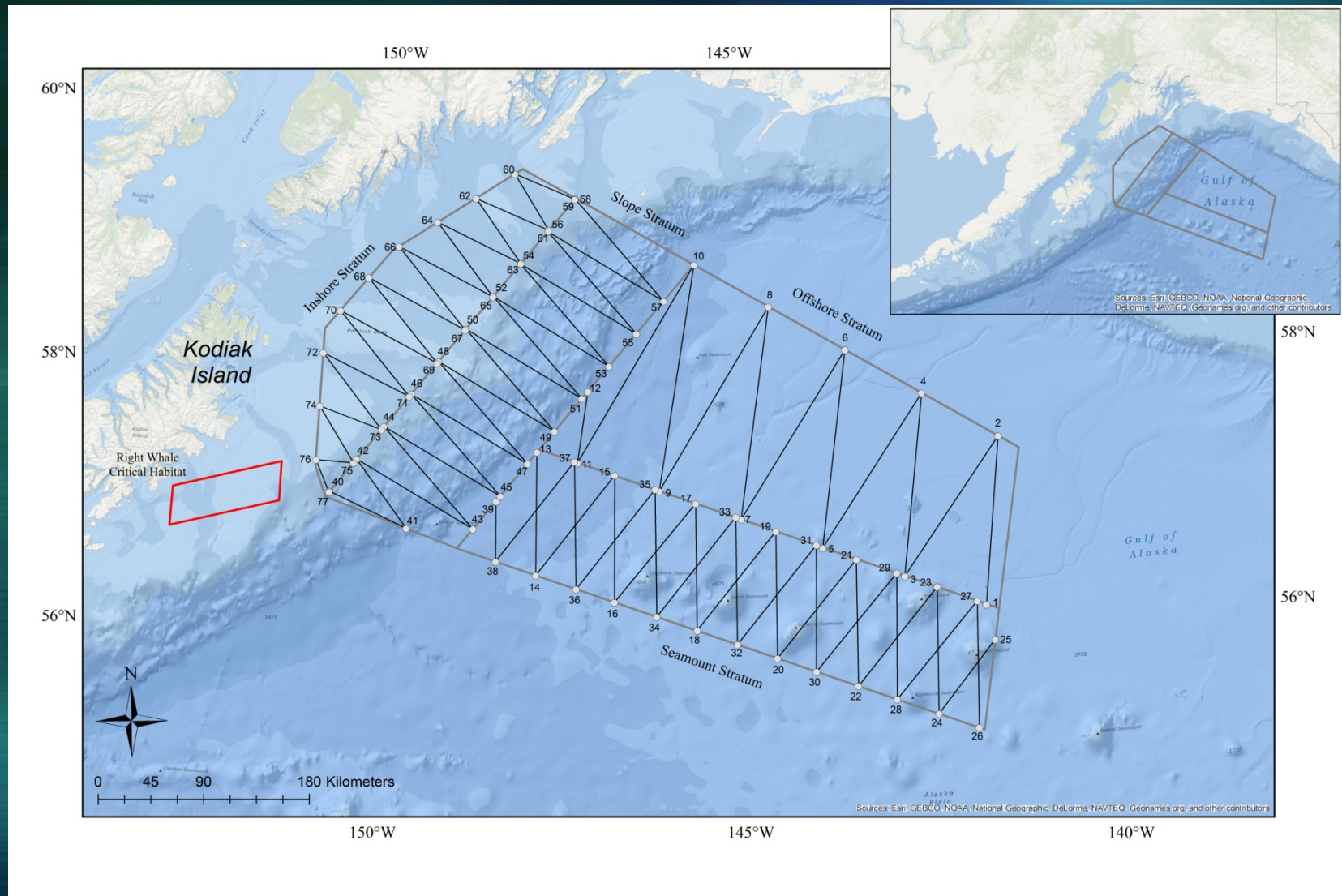


# Geographic Region Comparison

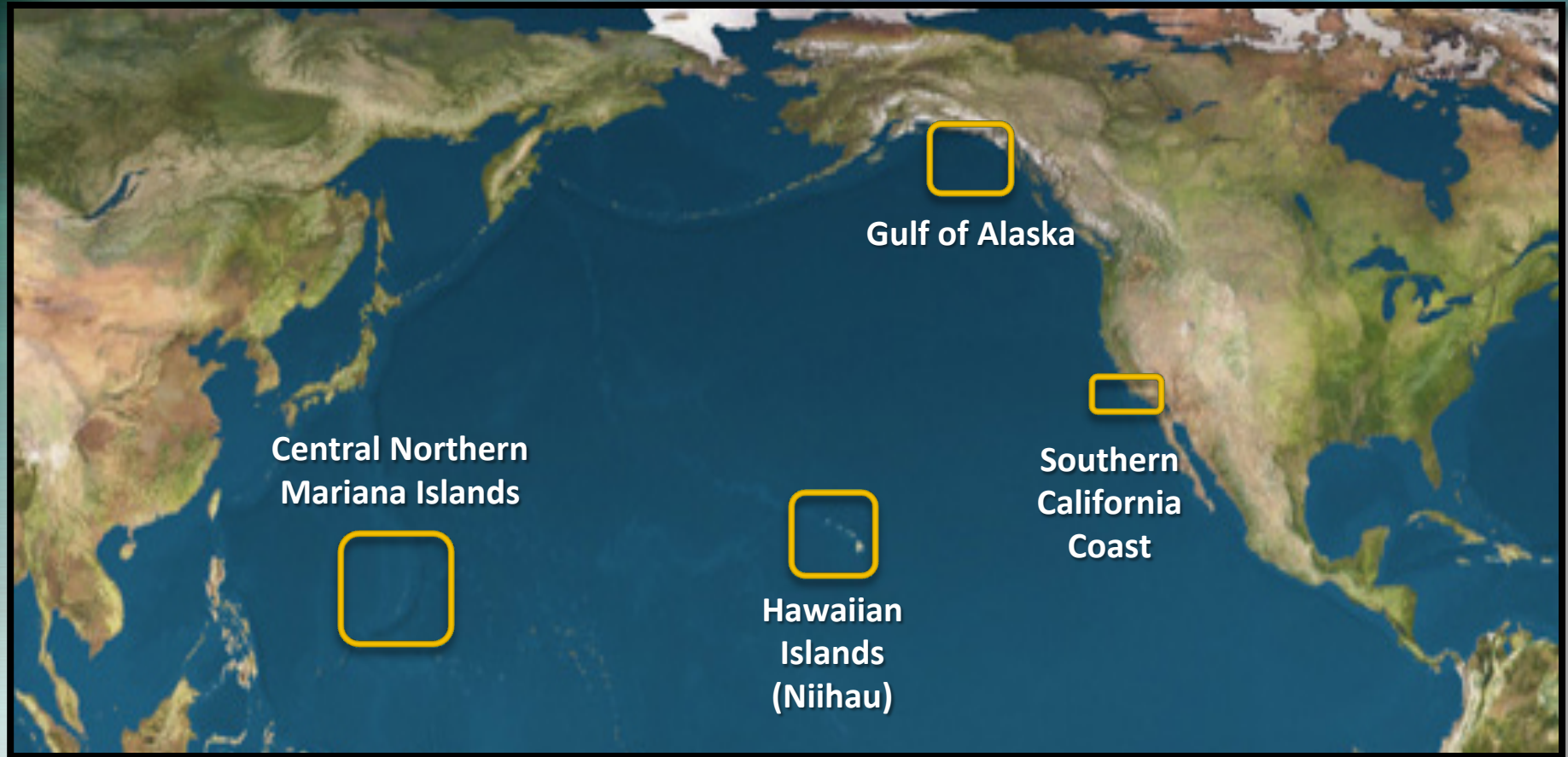




# Geographic Region Comparison



# Geographic Region Comparison



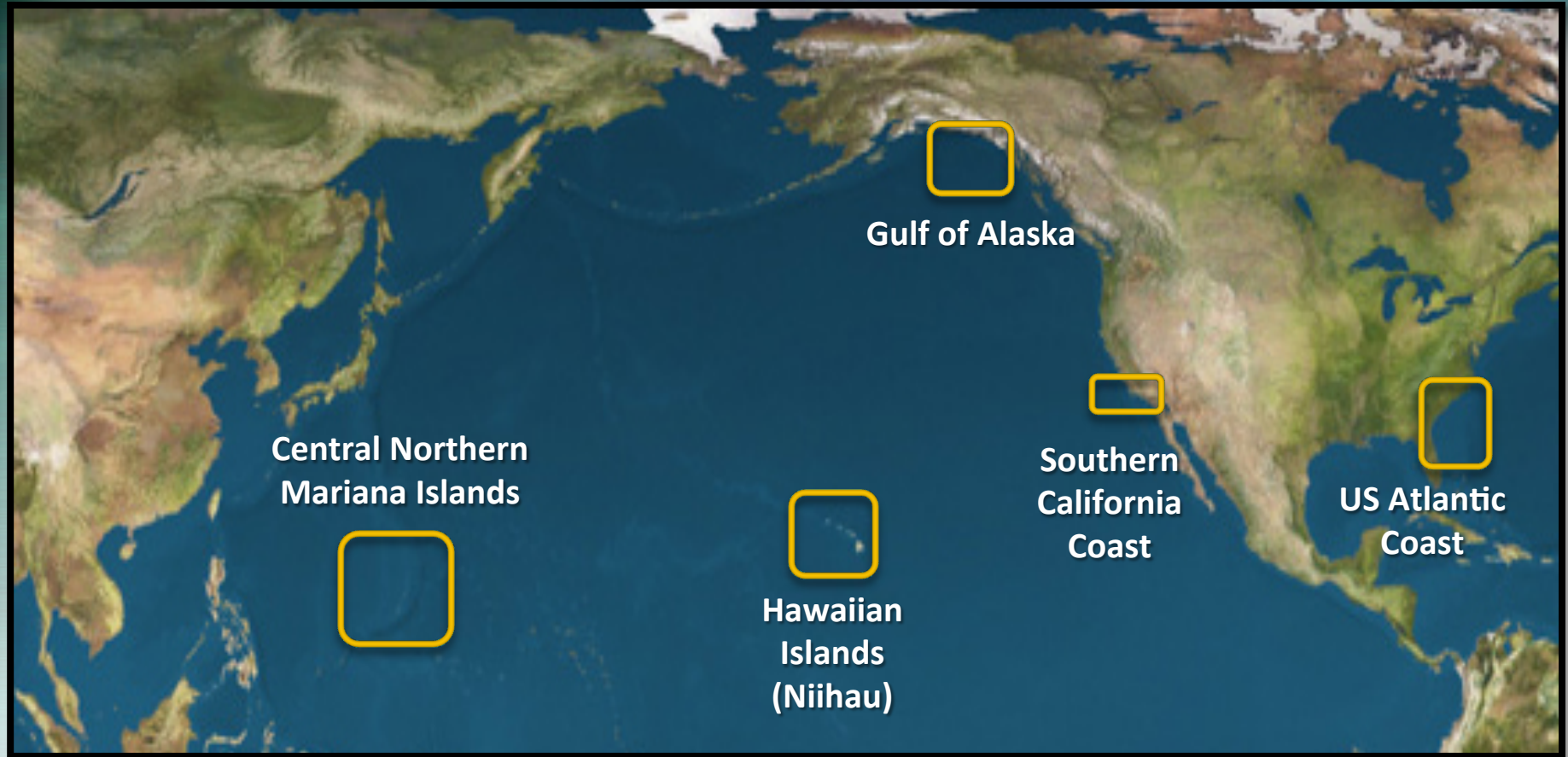


# Geographic Region Comparison



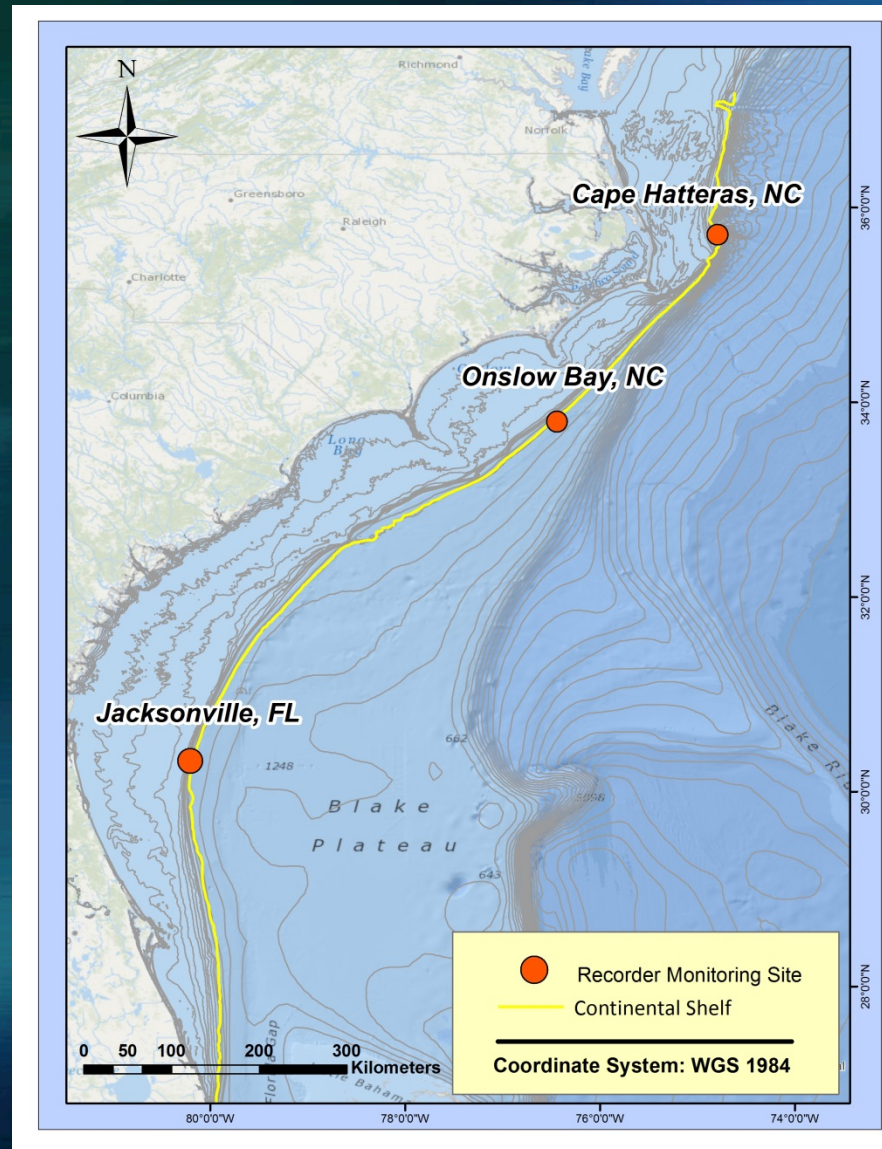
The linked image cannot be displayed. The file may have been moved, renamed, or deleted. Verify that the link points to the correct file and location.

# Geographic Region Comparison

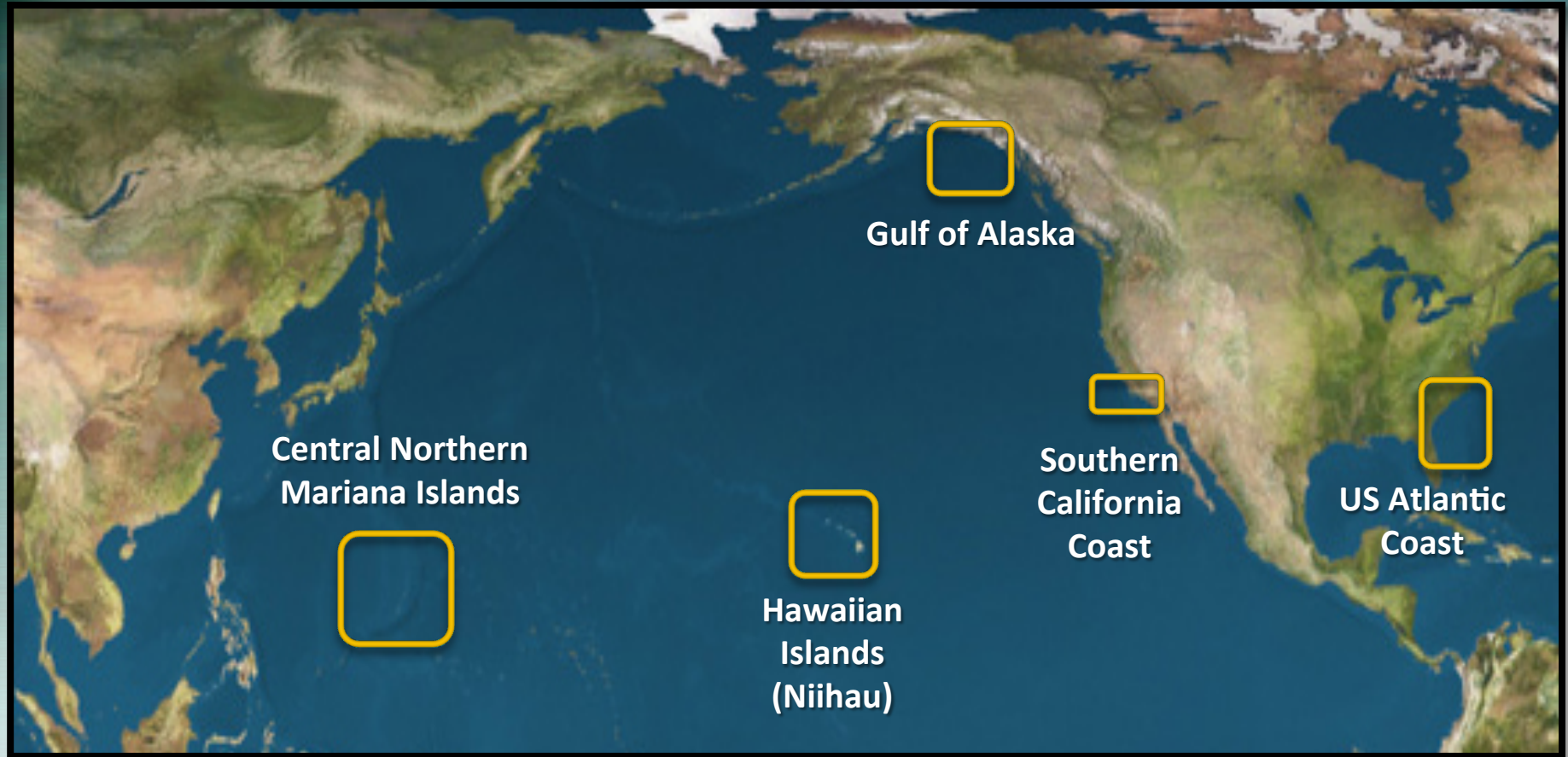




# Geographic Region Comparison



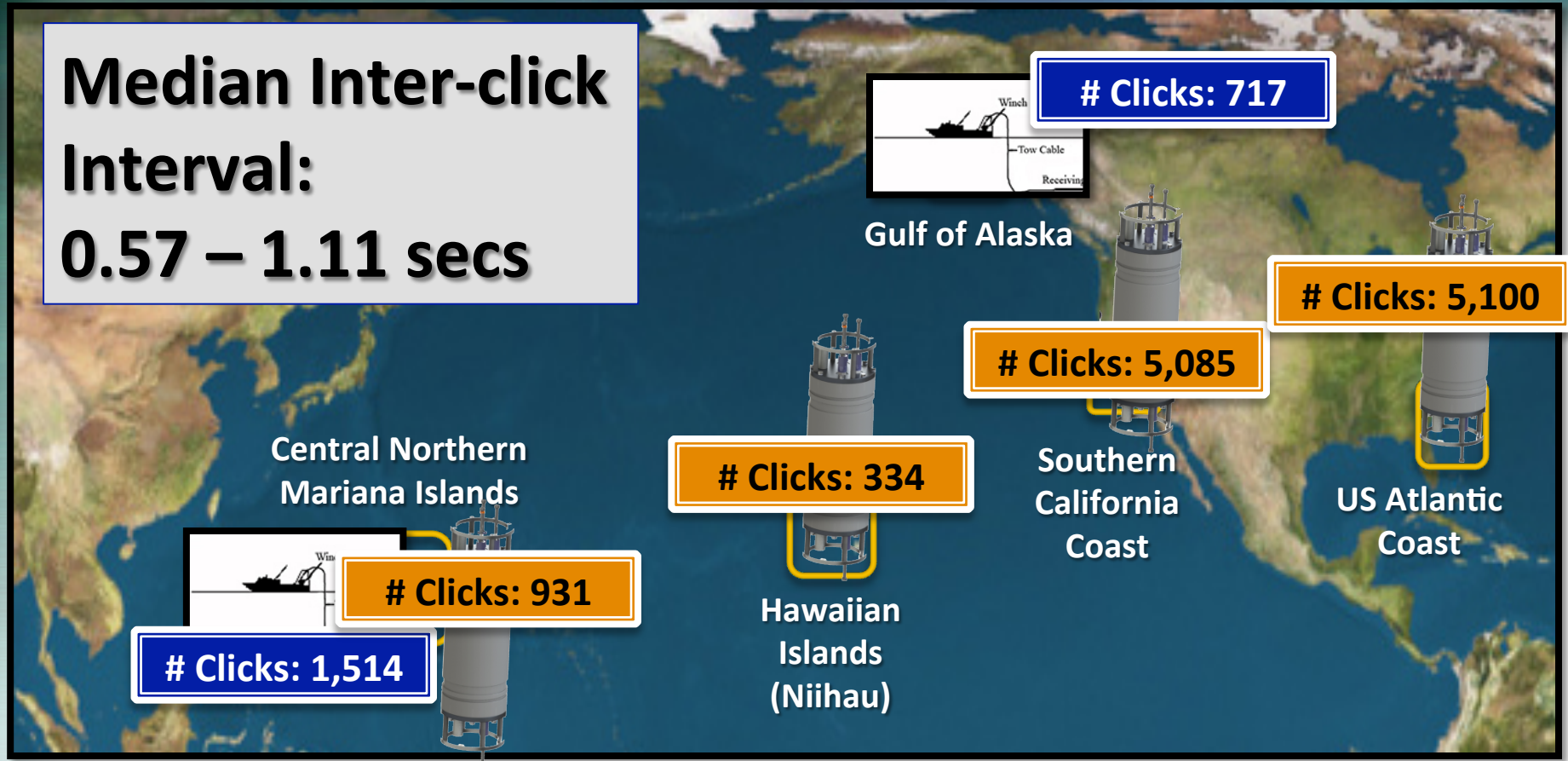
# Geographic Region Comparison





# Geographic Region Comparison

**Median Inter-click  
Interval:  
0.57 – 1.11 secs**



# Geographic Region Comparison

To Note!:

**All different systems**

**Seasonal variability**

**Variability in depth**



# Methods

# Methods

- Data were previously reviewed for sperm whales for each perspective project
- Encounters processed in PAMGuard (binary):



# Methods: PAMGuard Processing

The screenshot displays the PAMGuard software interface with the 'Classifier Parameters' dialog box open. The background shows the main application window with a file list, a 'Click Detector' panel, and a 'Click Waveform Display' plot. The 'Classifier Parameters' dialog box is titled 'Classifier Parameters' and contains several sections:

- General Options:** Name: Dolphin, Unique Code: 6, Symbol: (green diamond icon), Change... button.
- Channel options:** Require positive identification on only one channel (dropdown menu).
- Restrict parameter extraction to:** 128 samples (4.00 ms) around the click centre.
- Pre Filtering:** ☐ Enable. Pre filtering before classification can improve some species recognition. Band pass filter: 1.00 - 90.00 kHz. Filter Settings button.
- Click Length:** ☐ Enable. Click length is measured from the analytic waveform. Smoothing: 5 bins (must be odd); Threshold: 12.0 dB below maximum. Length range: 0.00 to 0.80 ms.
- Energy Bands:** ☒ Enable. Compare energy in different frequency bands. Frequency Range (Hz):
  - Test Band: 15000.0 to 16000.0, Threshold: 3.0 dB
  - Control Band: 5000.0 to 10000.0, Threshold: 3.0 dB
- Peak and Mean Frequency:**
  - Search and Integration range: 12000.0 to 16000.0 Hz; Smoothing: 5 bins
  - ☒ Enable. Peak frequency: 15000.0 to 16000.0 Hz
  - ☐ Enable. Peak width: 0.0 to 0.0 Hz; Threshold: 6.0 dB
  - ☐ Enable. Mean frequency: 0.0 to 0.0 Hz
- Zero Crossings:** ☐ Enable. Parameters extracted from zero crossings:
  - Number of zero crossings: 0 to 0
  - Zero crossing frequency sweep: 0.0 to 0.0 kHz/ms
- Select Alarm:** killer whale (dropdown menu). Max amount of time between detections: 0 ms.
- Note:** alarm is enabled/disabled on previous screen.

The bottom of the dialog box has 'Ok', 'Cancel', and 'Set Defaults' buttons. The background application window shows a file list with 'SAIPAN\_NORTH\_1\_349\_12\_0.aco', a 'Click Detector' panel with 'Clicks: 0' and 'Click Events: 0', and a 'Click Waveform Display' plot showing 'Click Amplitude (dB)' vs 'Time'.

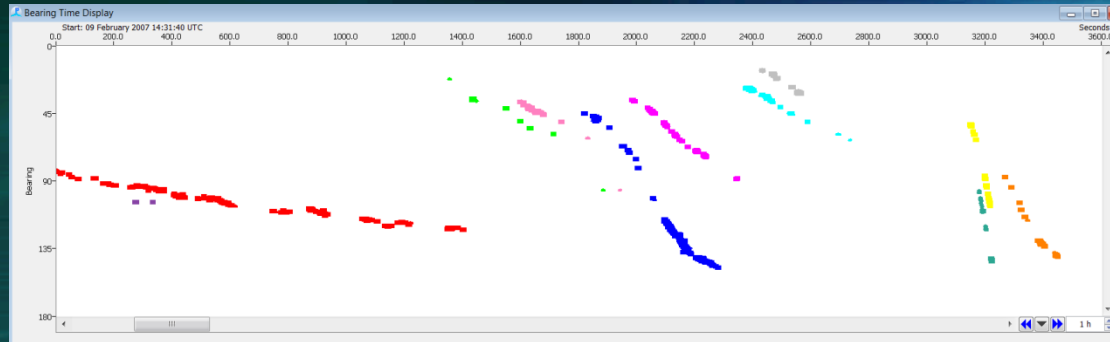
# Methods

- Data were previously identified as having sperm whale encounters prior to selection
- Encounters processed in PAMGuard (binary):
- PAMGuard ViewerMode:
  - Allows for selection of confirmed sperm whale clicks
  - Towed array click trains

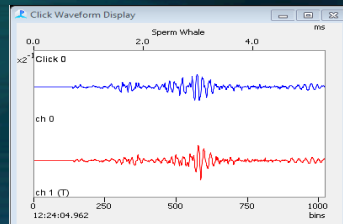


# PAMGuard's 'ViewerMode'

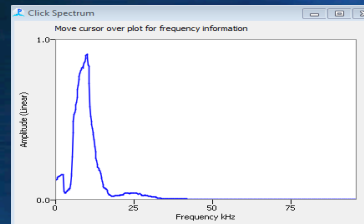
## I. Time/Bearing Display



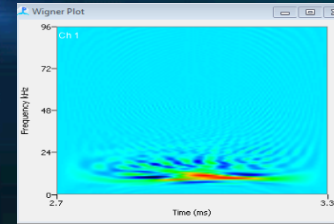
## II. Waveform



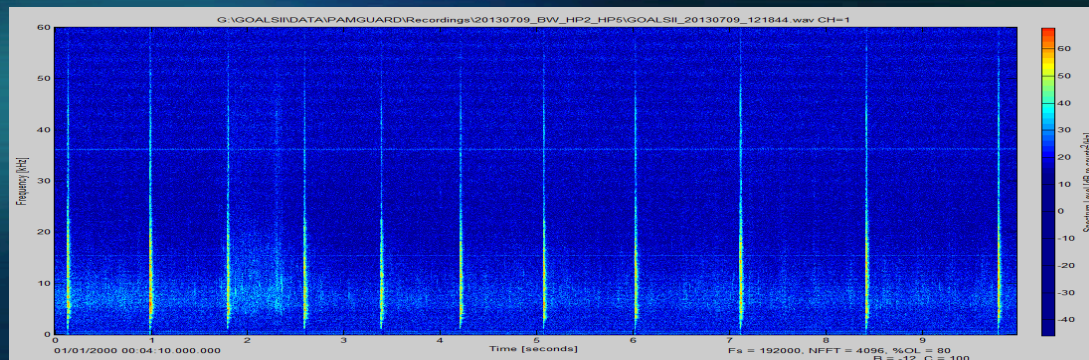
## III. Click Spectrum



## IV. Wigner Plot



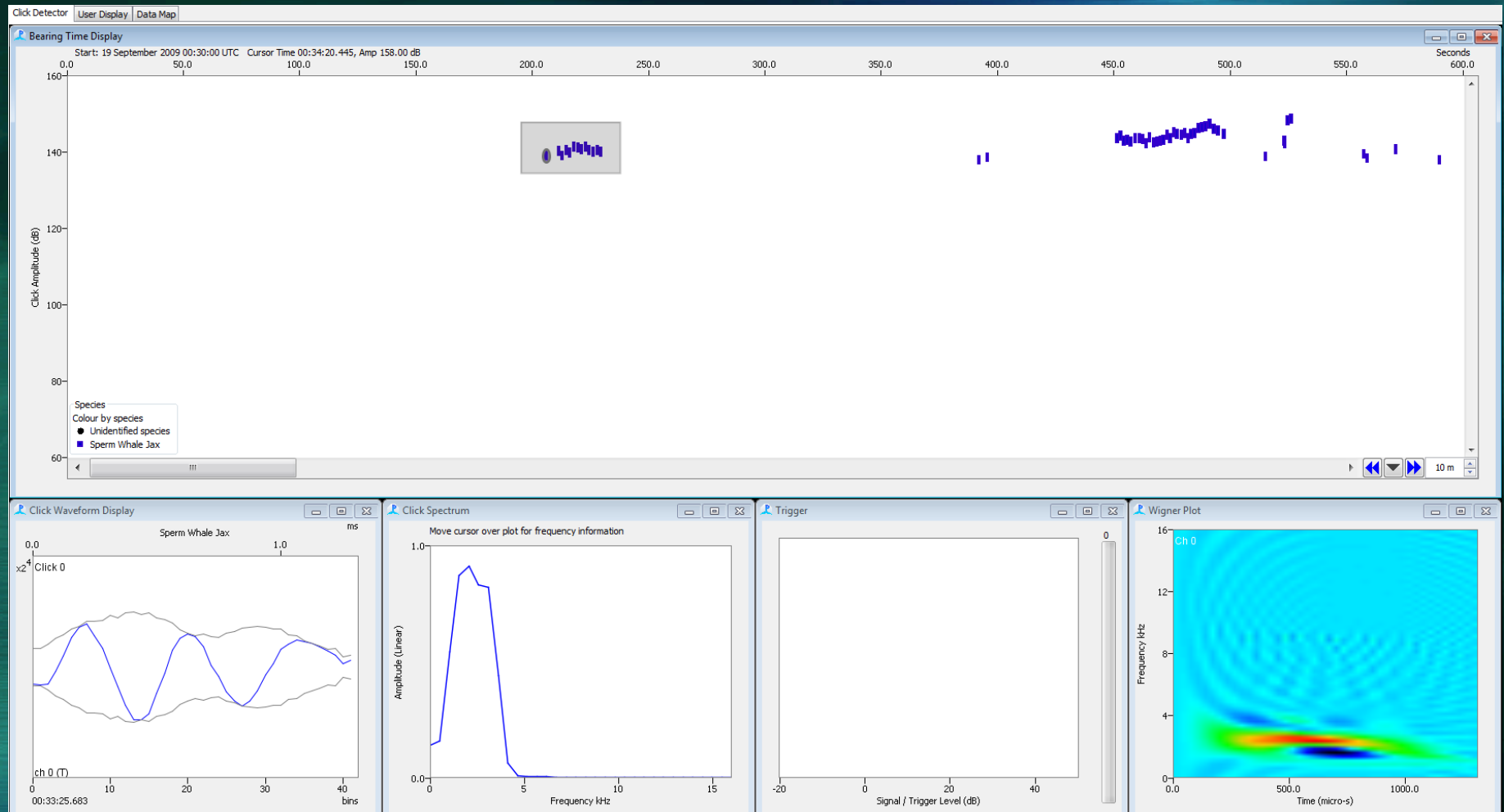
## V. Spectrogram



# Methods: Data Review

- Data were previously identified as having sperm whale encounters prior to selection
- Encounters processed in PAMGuard (binary):
- PAMGuard ViewerMode:
  - Allows for selection of confirmed sperm whale clicks
  - Towed array: click trains
  - Single channel: clicks with higher amplitude selected

# PAMGuard's 'ViewerMode'





# Methods: Data Review

- Data were previously identified as having sperm whale encounters prior to selection
- Encounters processed in PAMGuard (binary):
- PAMGuard ViewerMode:
  - Allows for selection of confirmed sperm whale clicks
  - Towed array click trains
  - Single recorder clicks with higher SNR (higher dB)
- ROCCA Module:
  - Click parameter extraction
  - Data exported

# Methods

- Click parameters measured in ROCCA include:
  - Duration
  - Center and Peak Frequency
  - 3dB & 10 dB Bandwidth
  - Sweep rate
  - ICI
  - # of zero crossings
- Performed Kruskal-Wallis statistical tests with post-hoc pairwise comparisons
  - Subset of 500 samples (332 for HI)

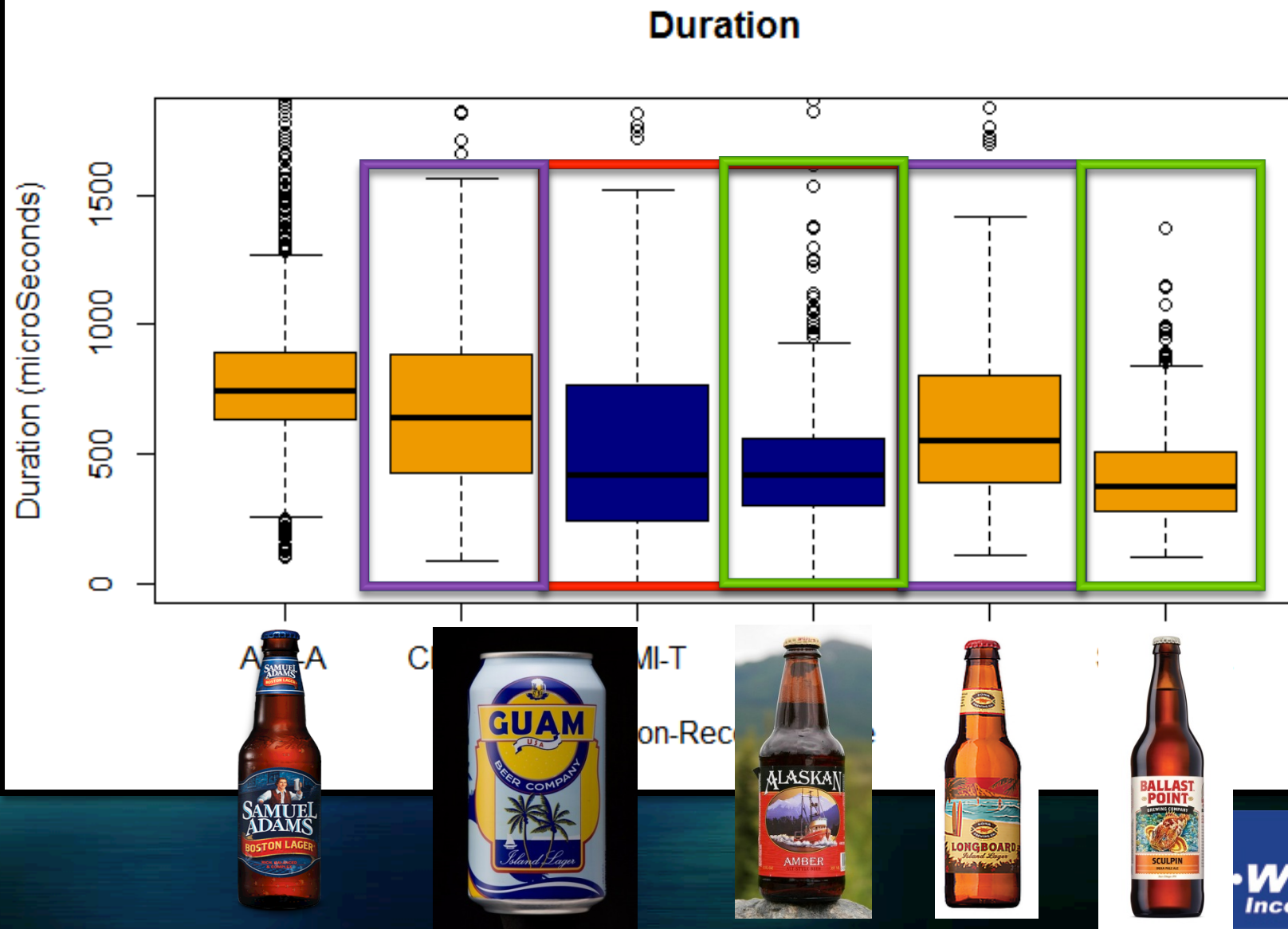
# Results & Discussion



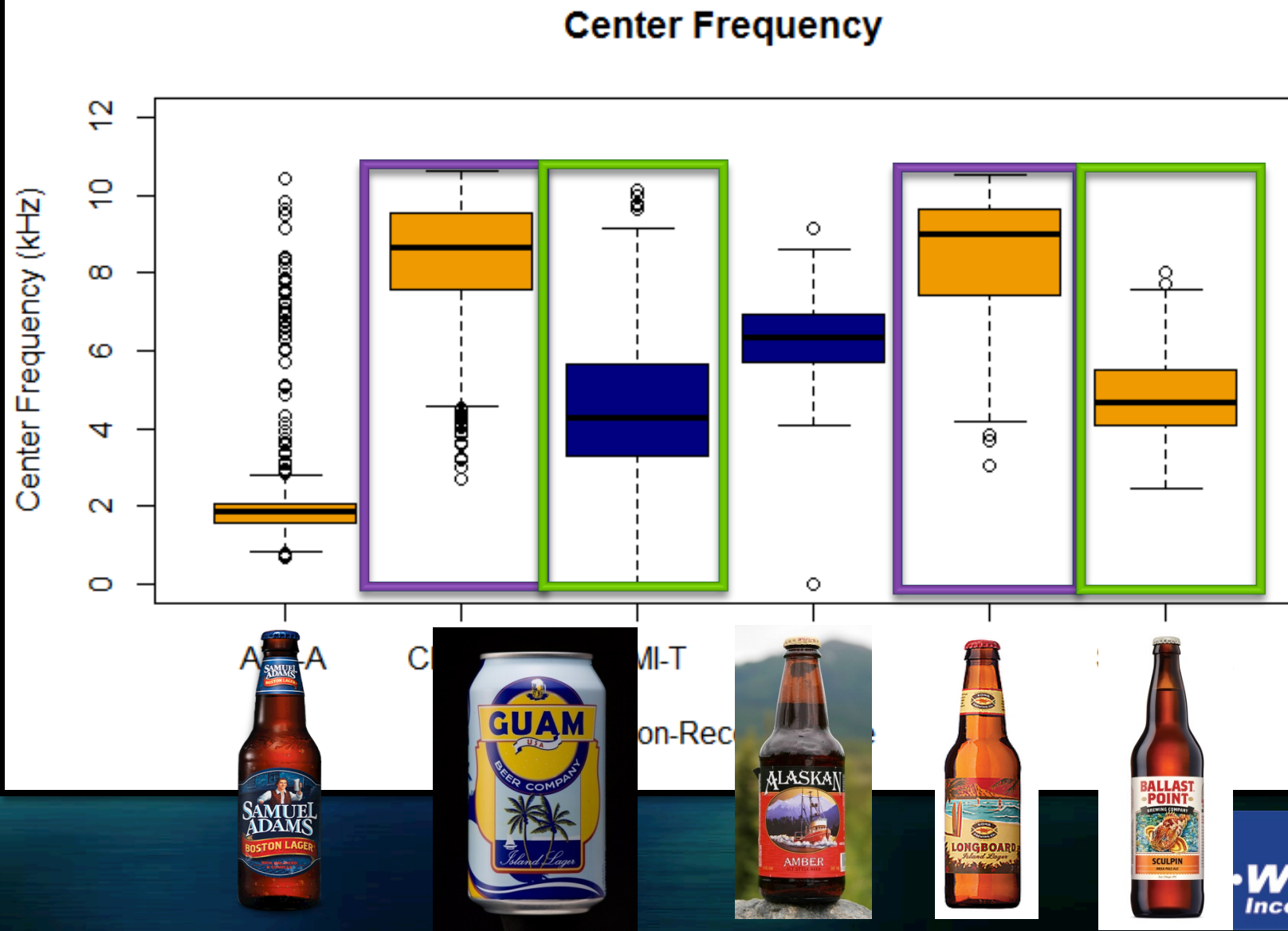
# Results

- Parameters compared and tested for all regions were:
  - Duration
  - Center Frequency
  - Peak Frequency

# Results – All Regions

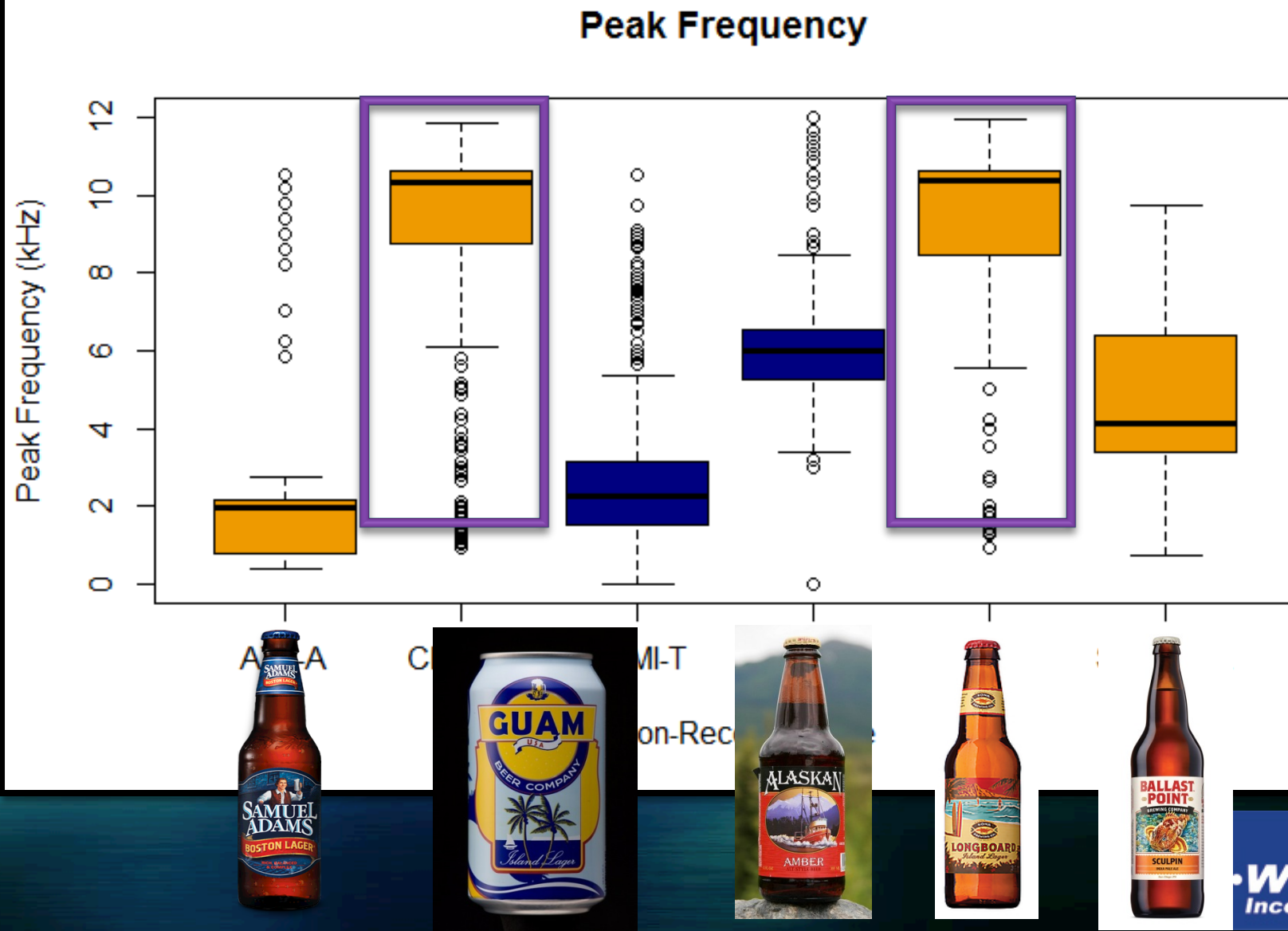


# Results – All Regions

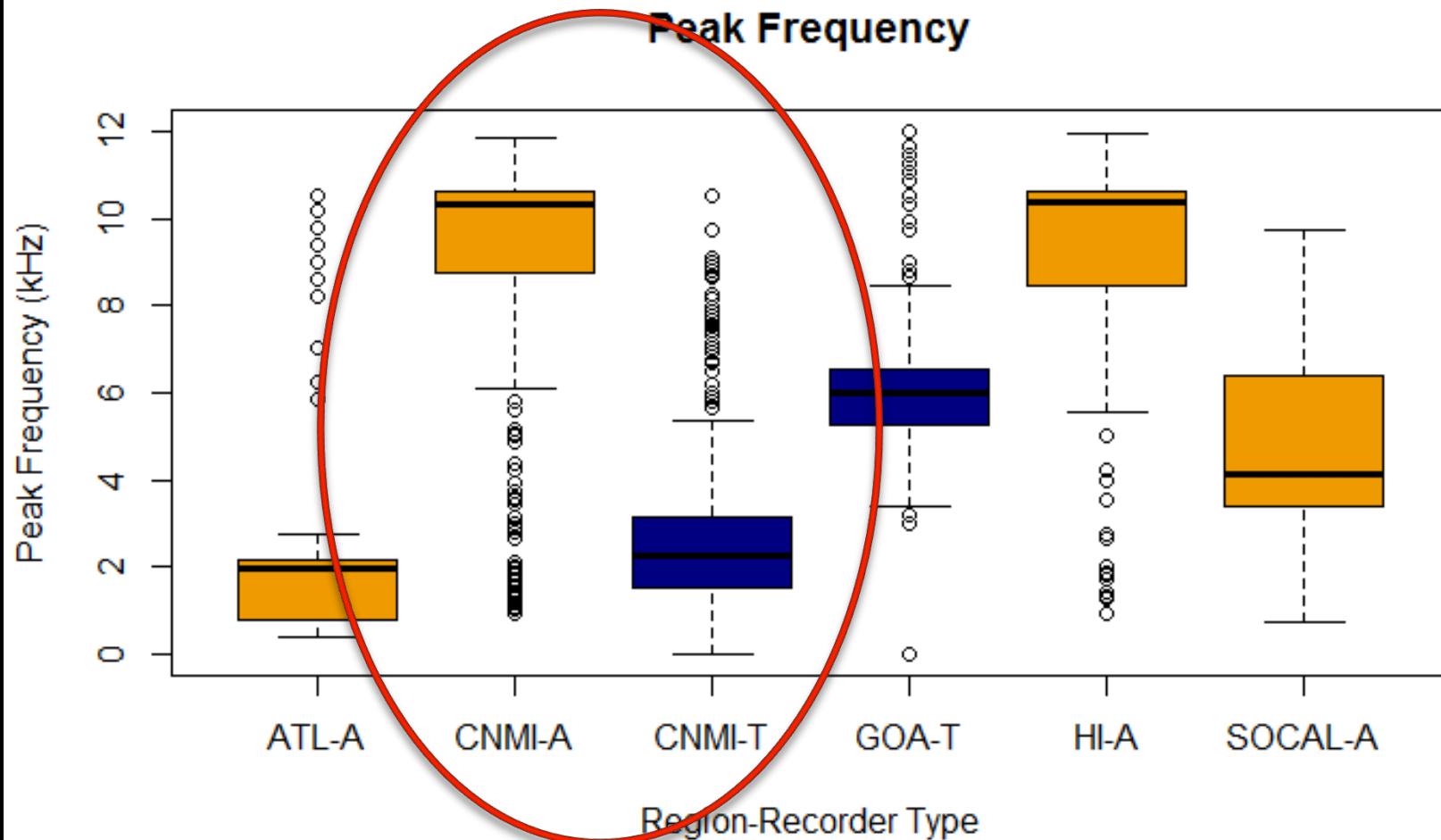




# Results – All Regions



# Results – Closer Look

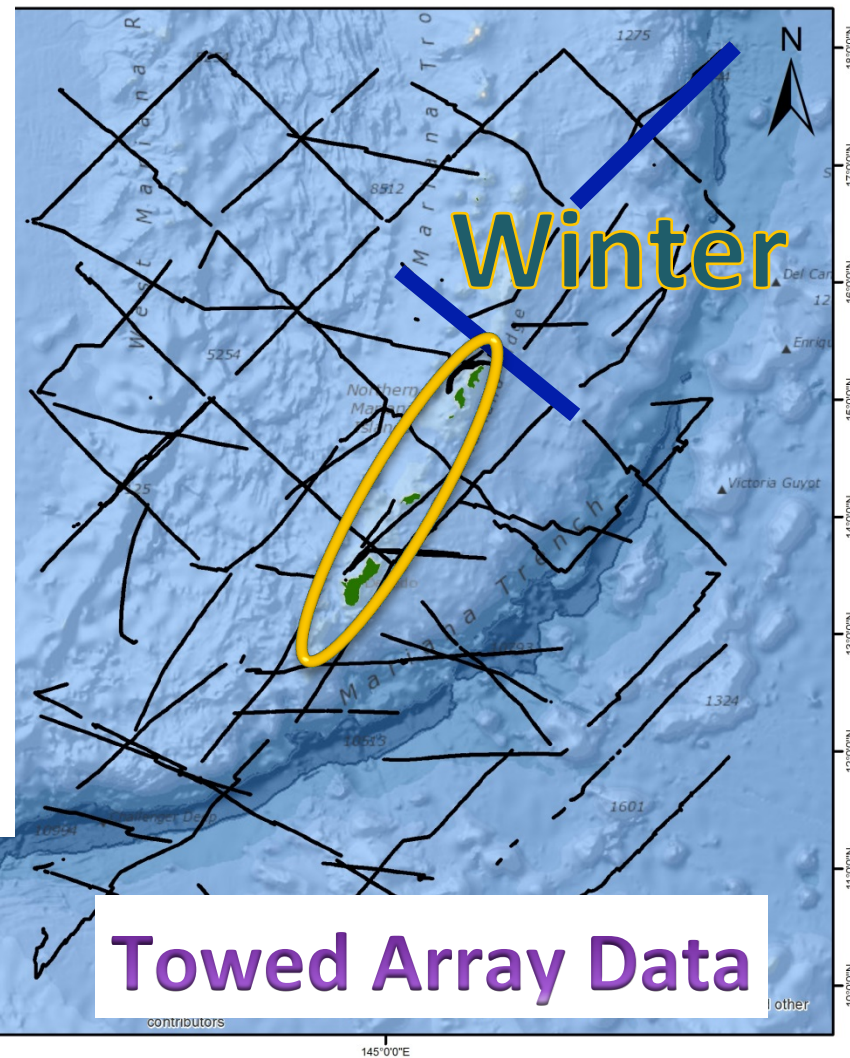
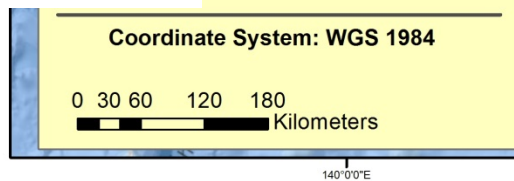


# Results – CNMI Encounters



EAR Data

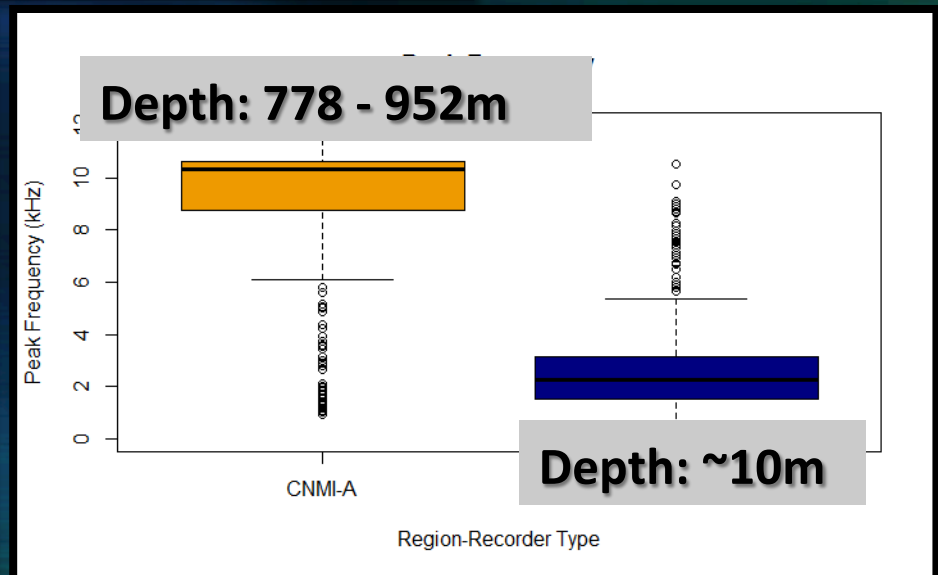
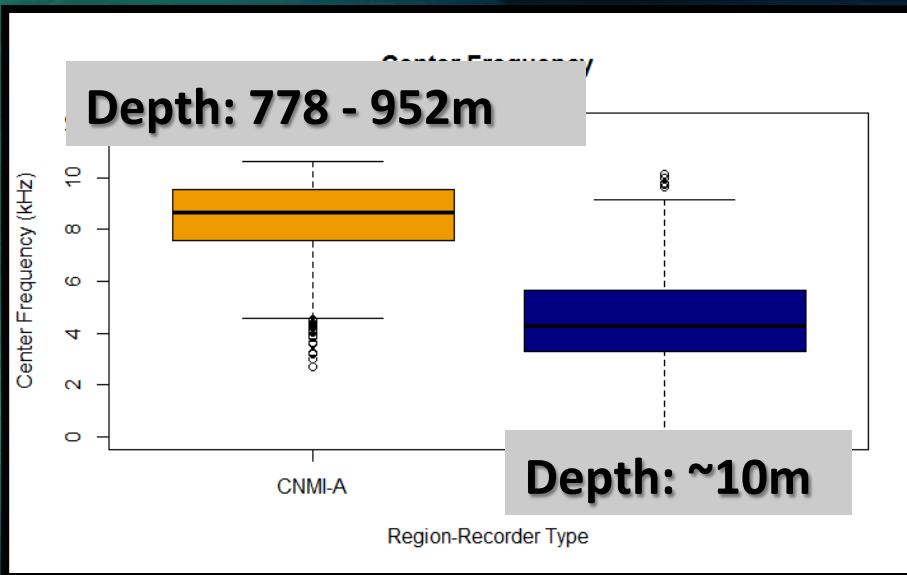
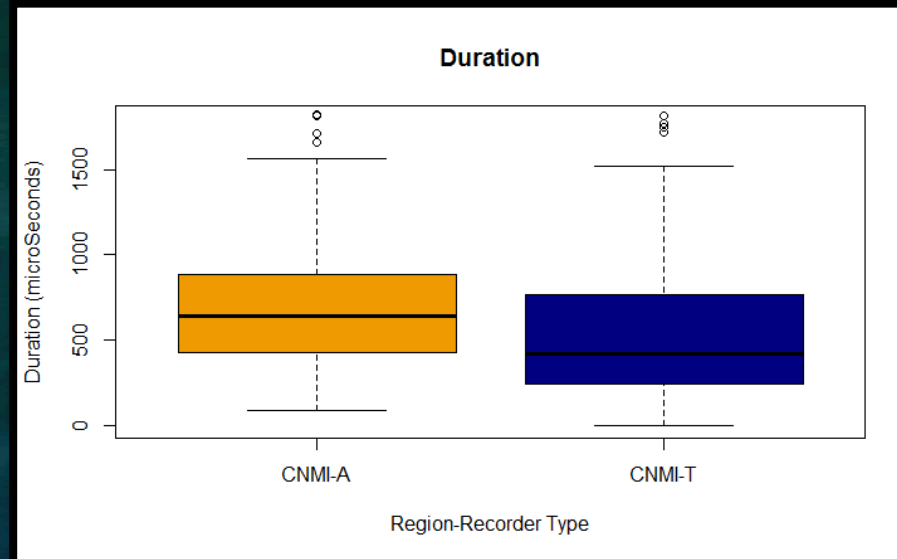
2007 Survey tracklines



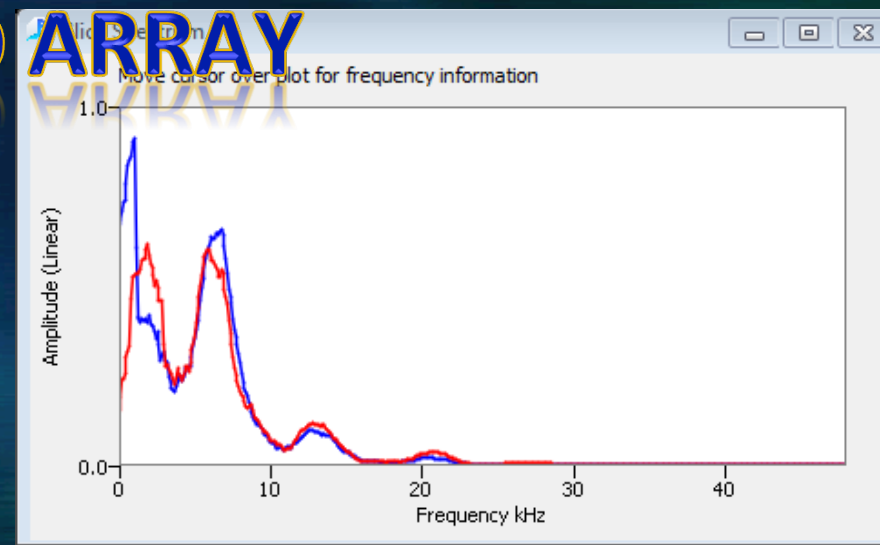
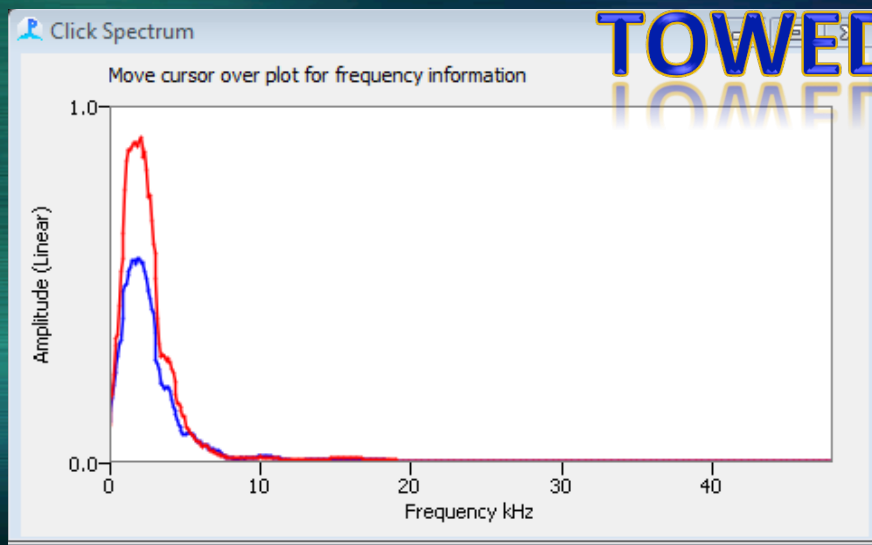
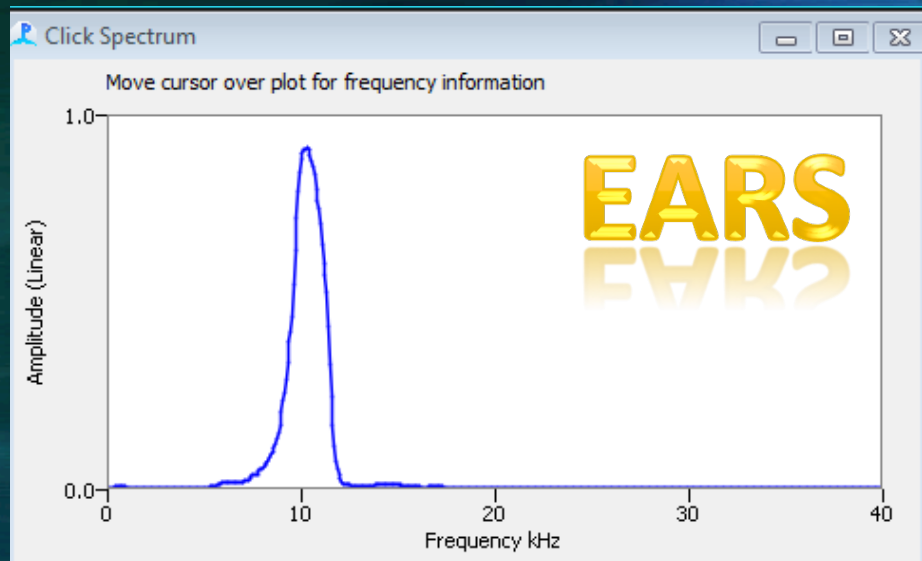


# Results – CNMI Recorder Type

All parameters significantly different

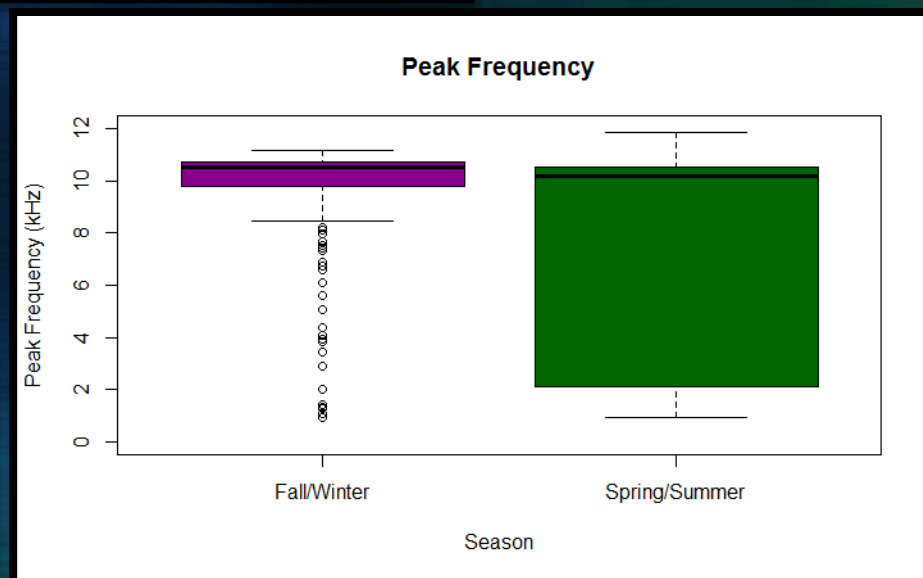
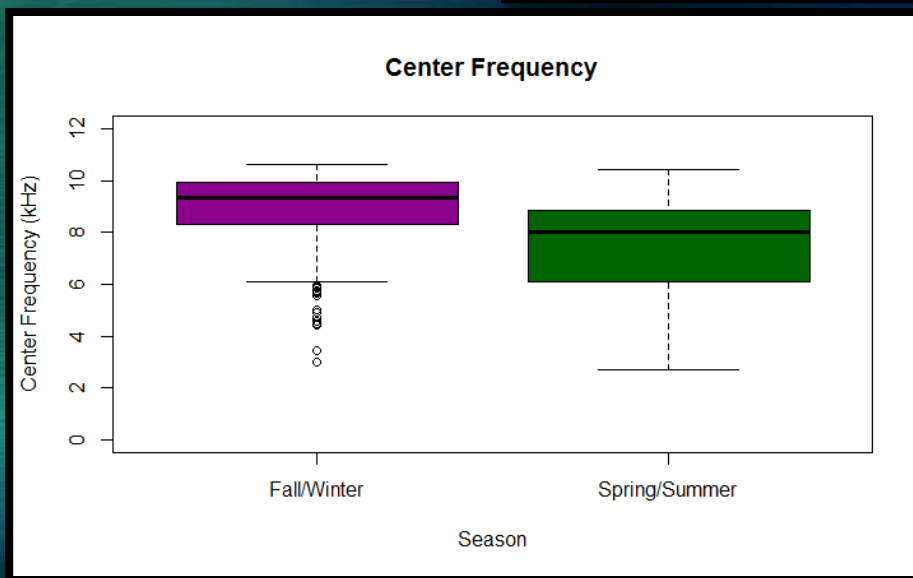
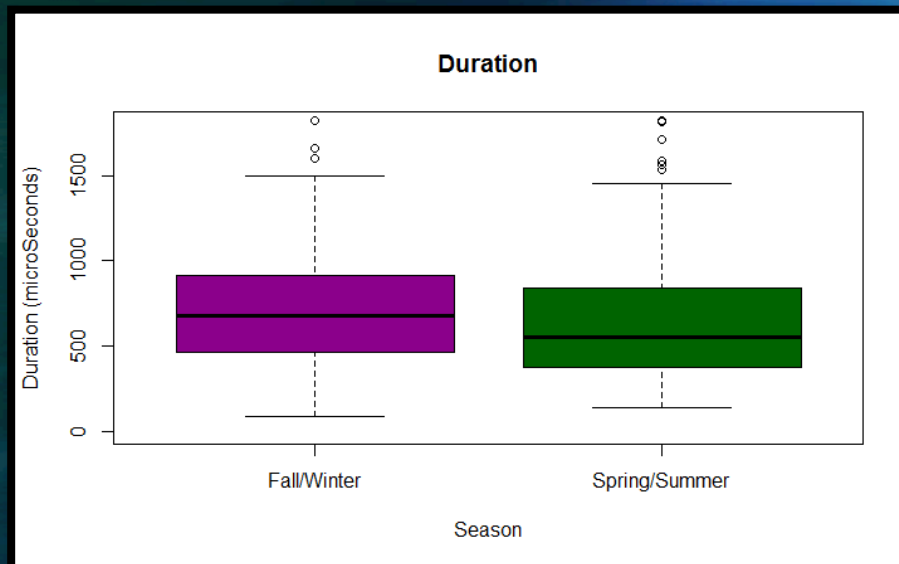


# Results – CNMI Recorder Type



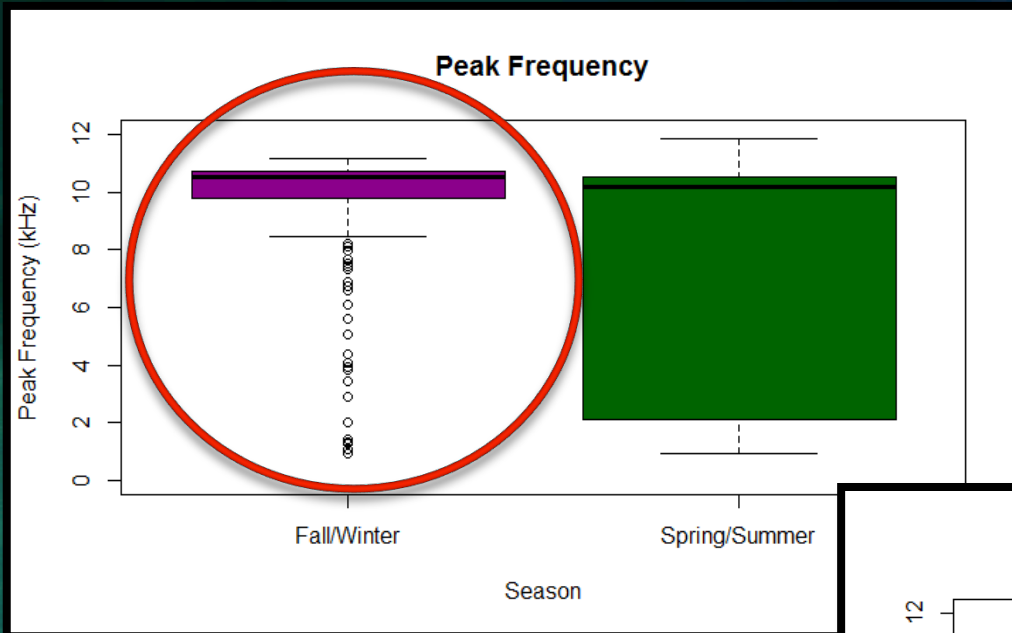
# Results – CNMI Season

Still significant differences in parameters

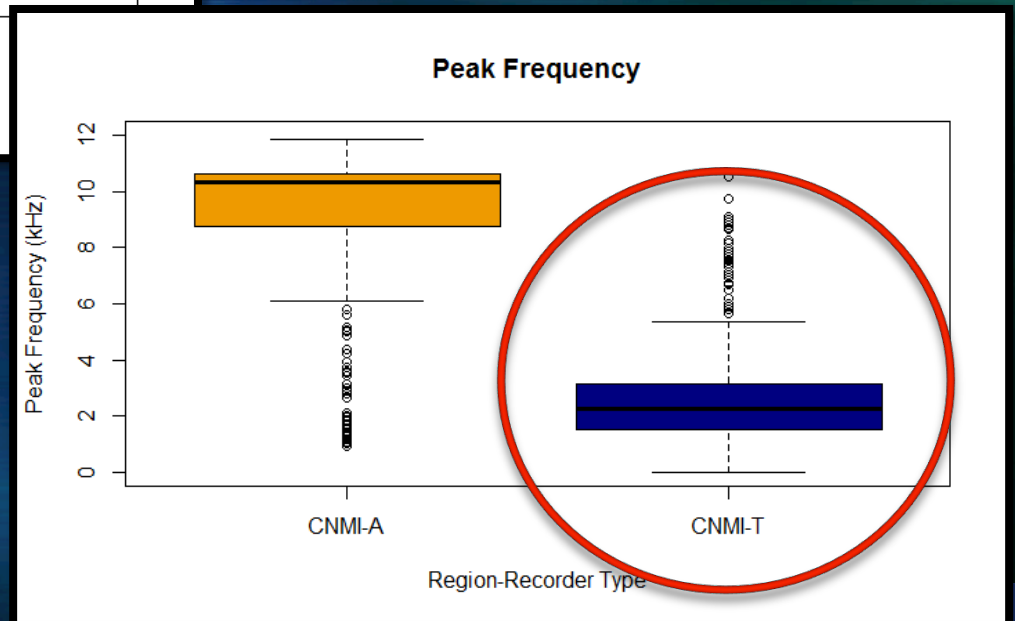




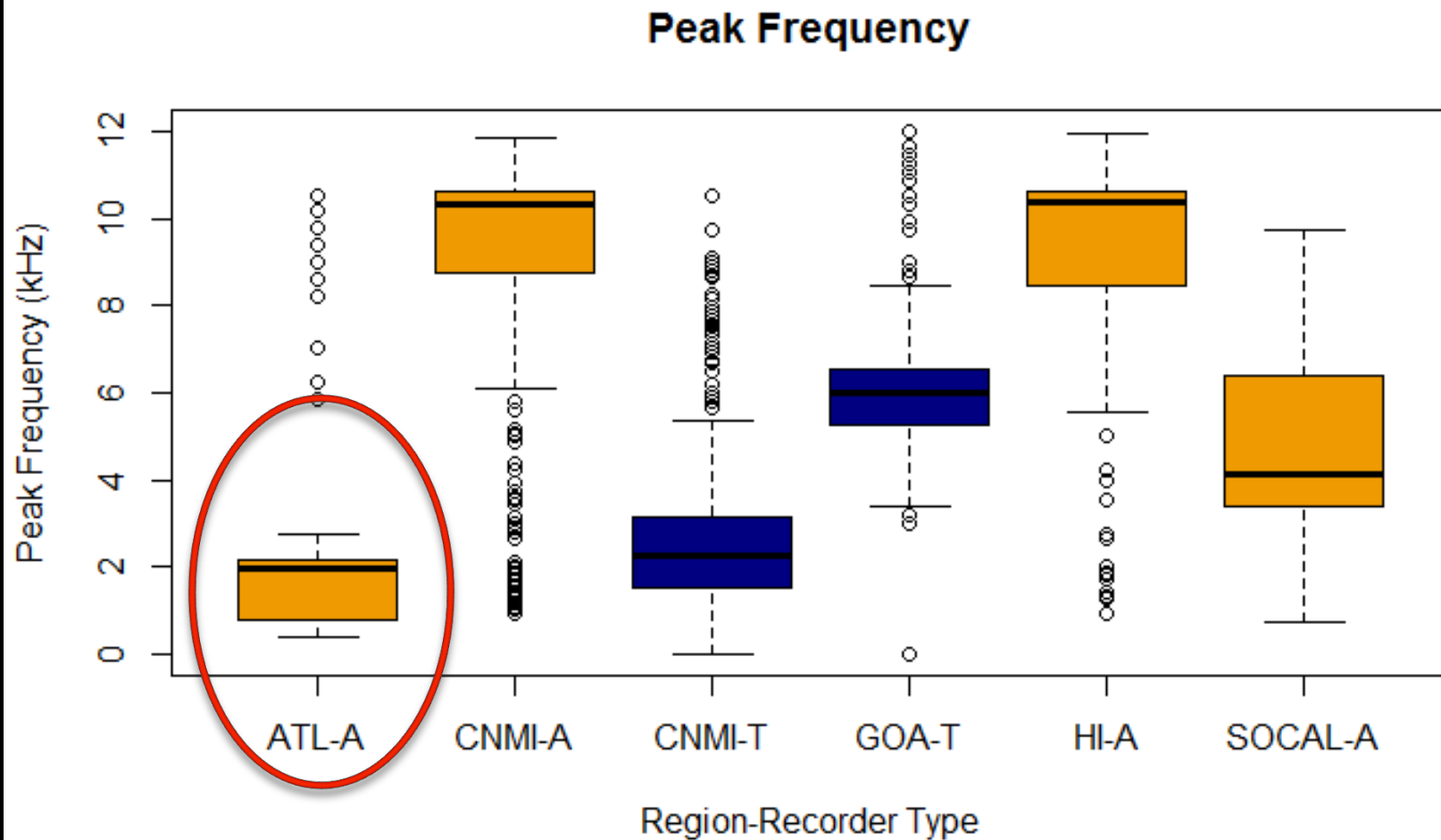
# Results – CNMI Season



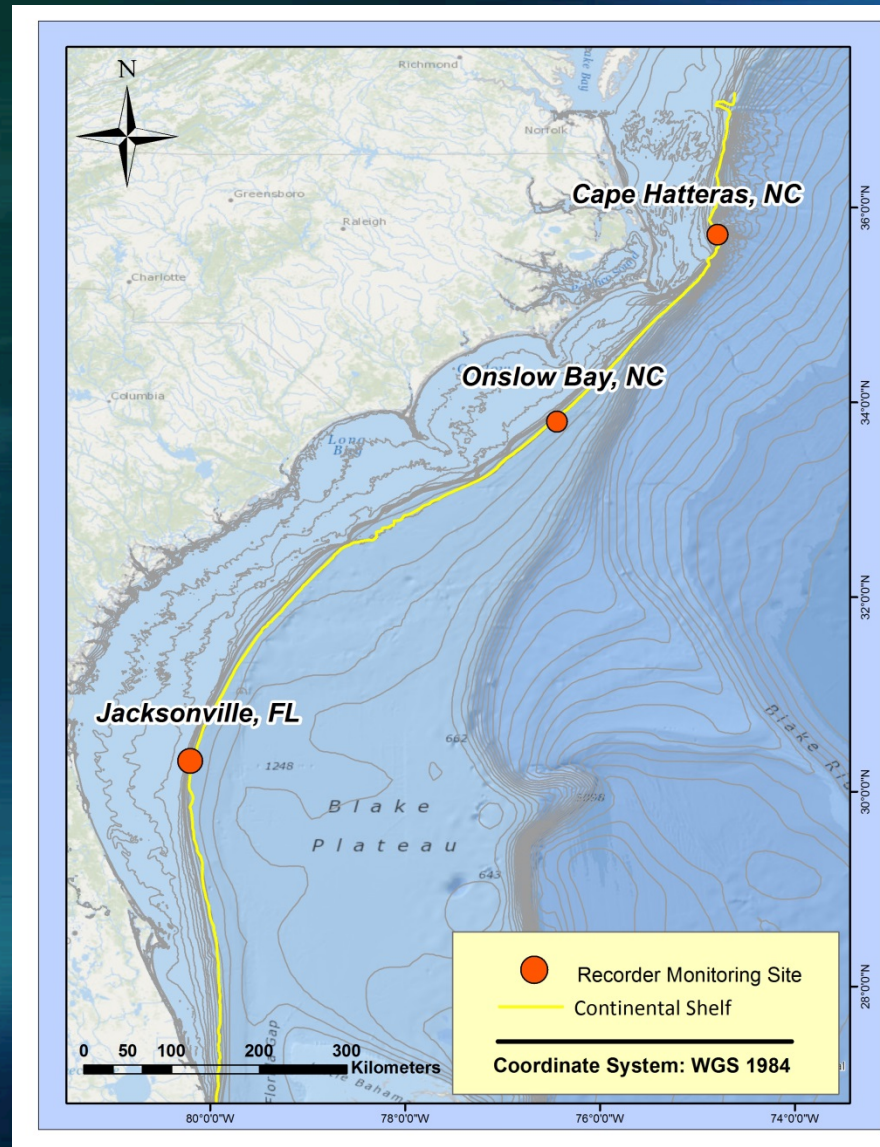
Same season =  
no obvious  
trends



# Results – Closer Look



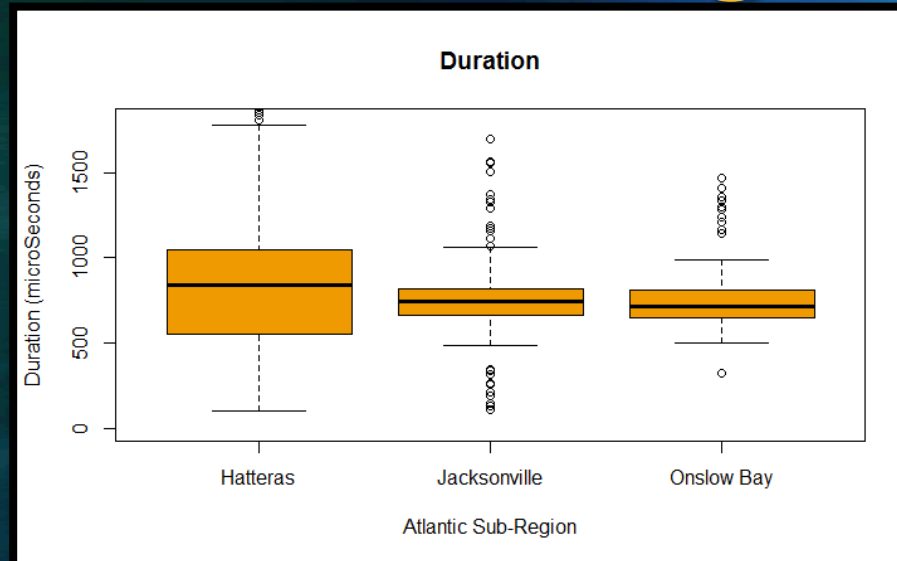
# Results – Atlantic Coast



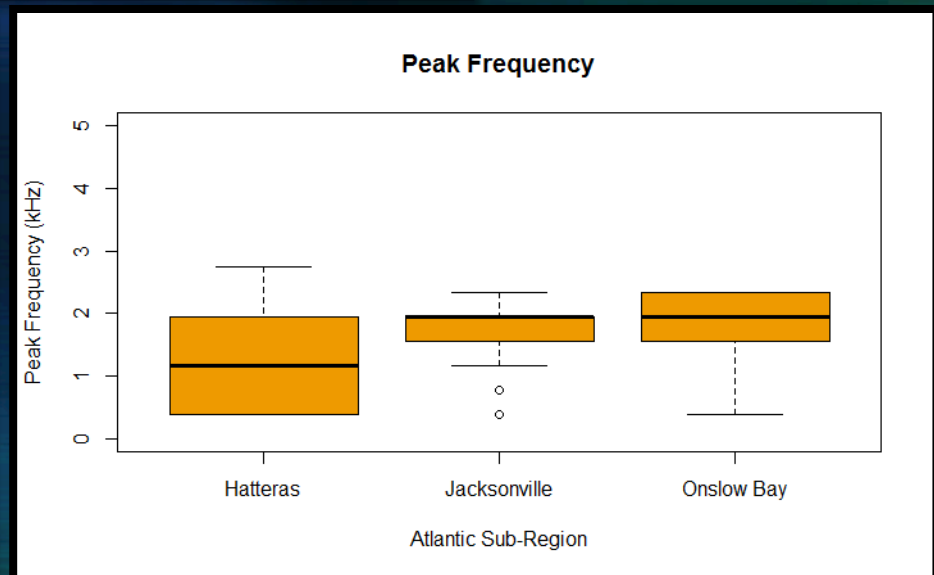
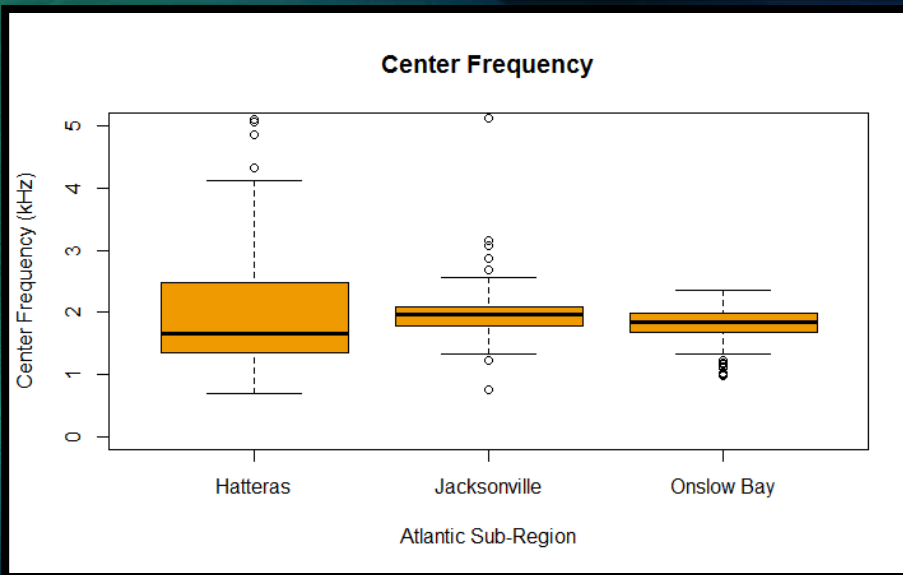


# Results – Atlantic Subregions

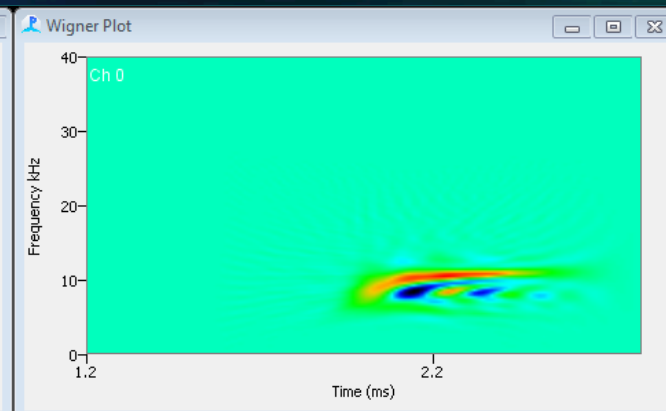
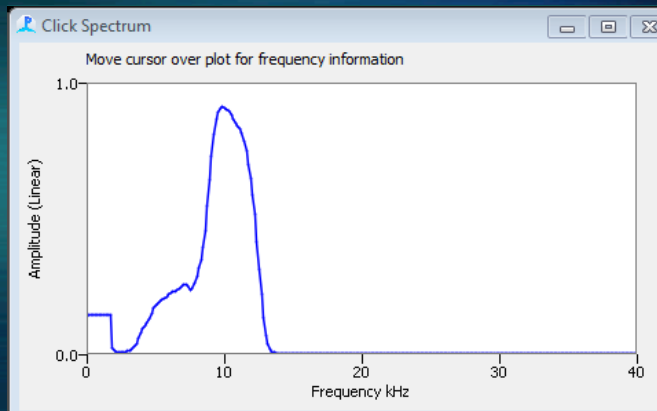
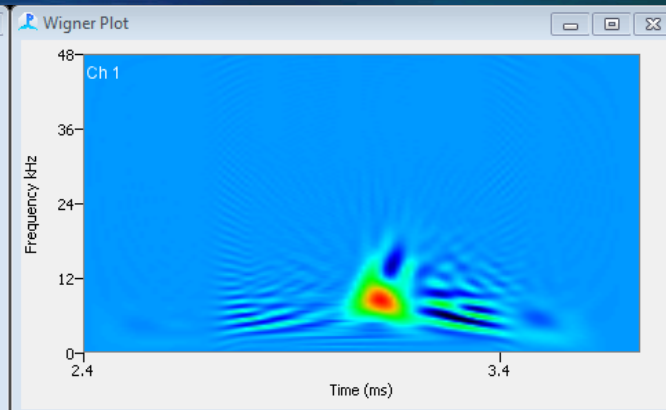
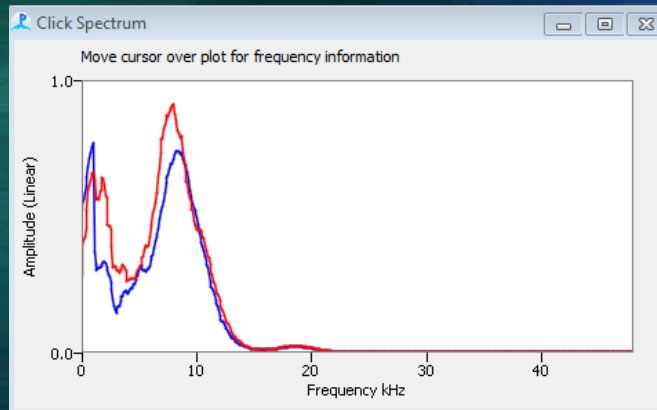
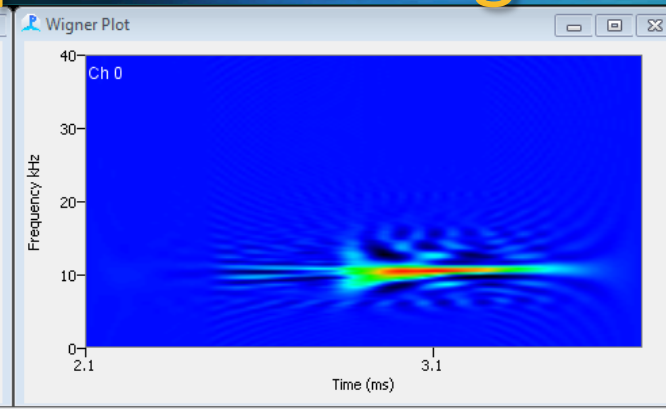
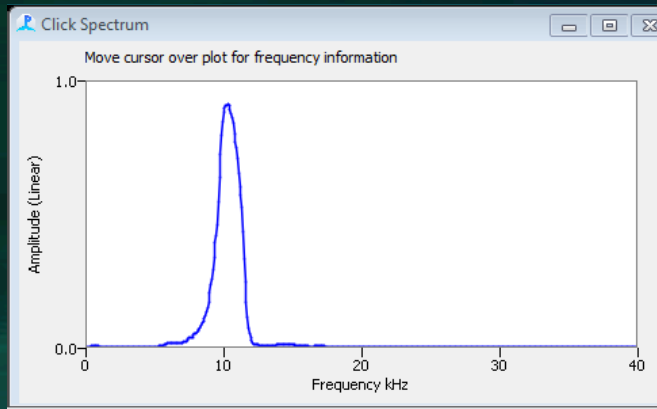
Center Freq sig  
different between  
OB/JAX & JAX/HAT



Peak Freq sig  
different between  
all sites



# Results – Common Spectrum & Wigner

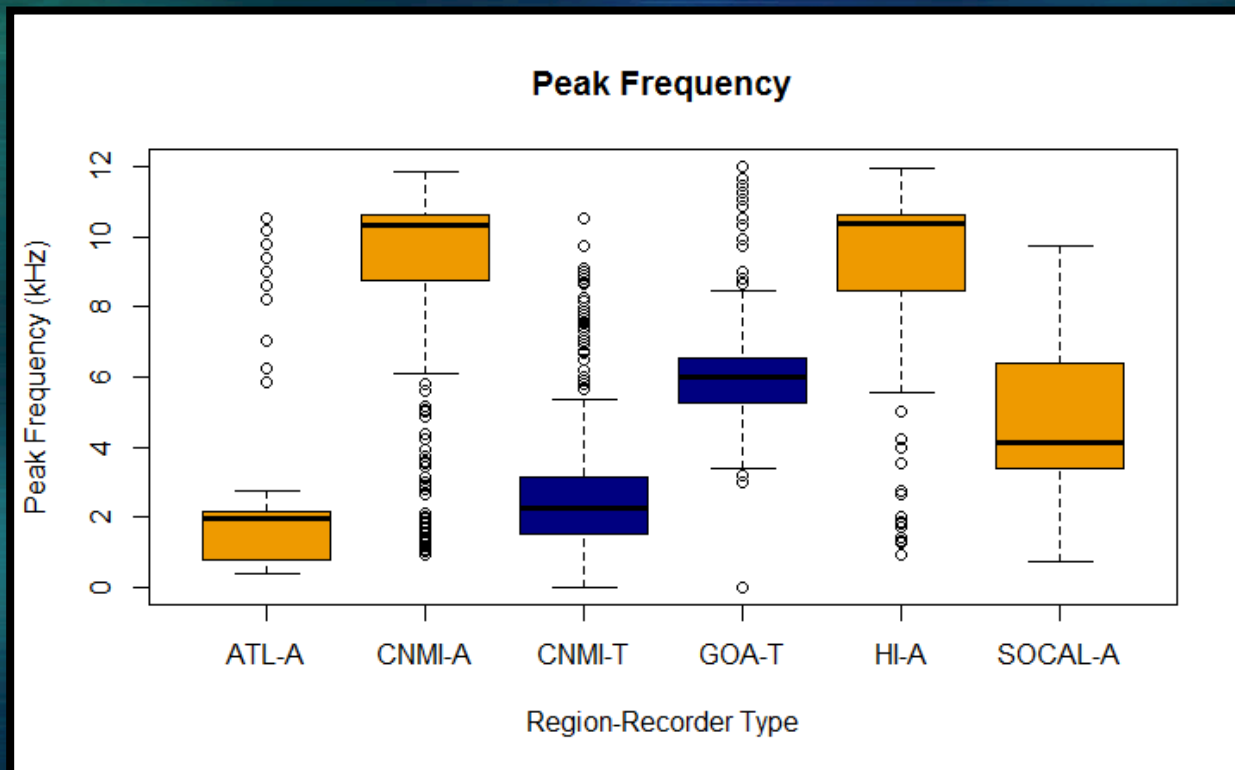


# Conclusions



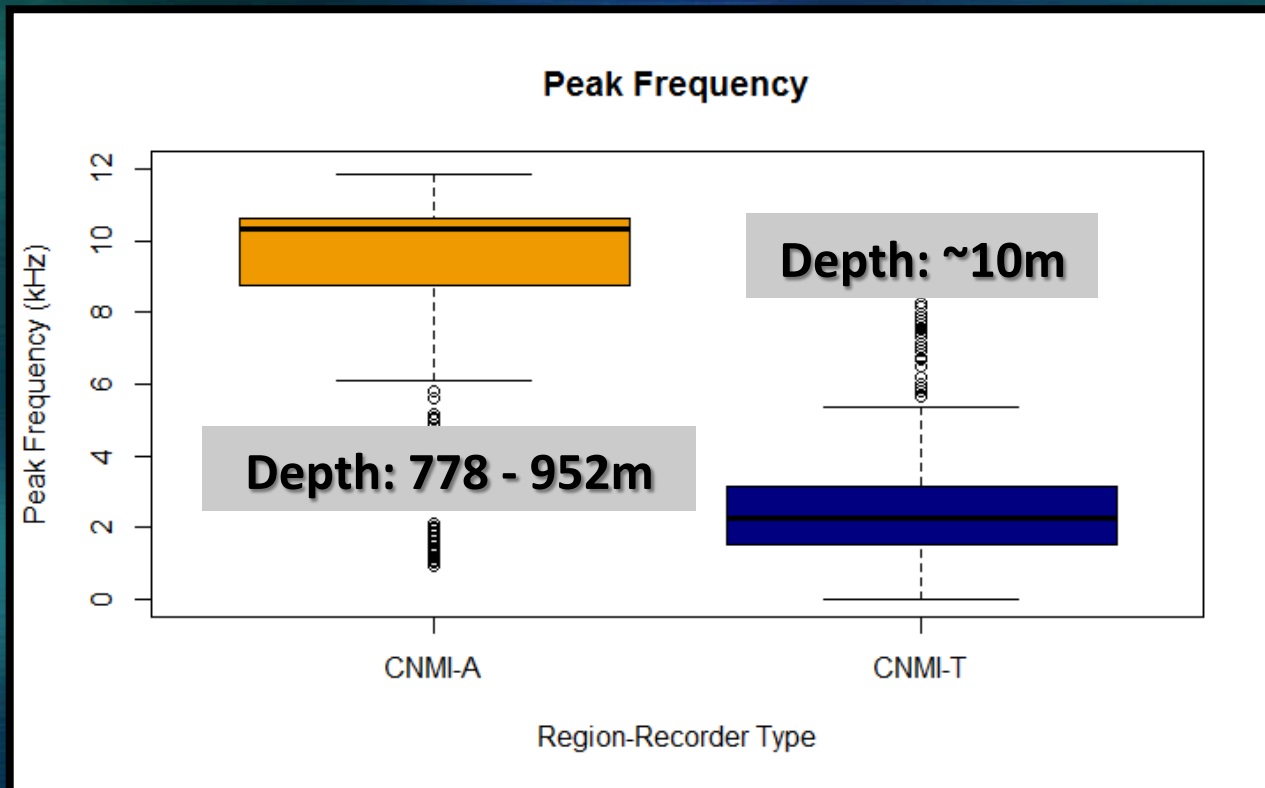
# Conclusions

- Geographic variation appears to exist for sperm whale regular clicks
  - Variation in all 3 parameters reviewed
  - Peak and center frequency



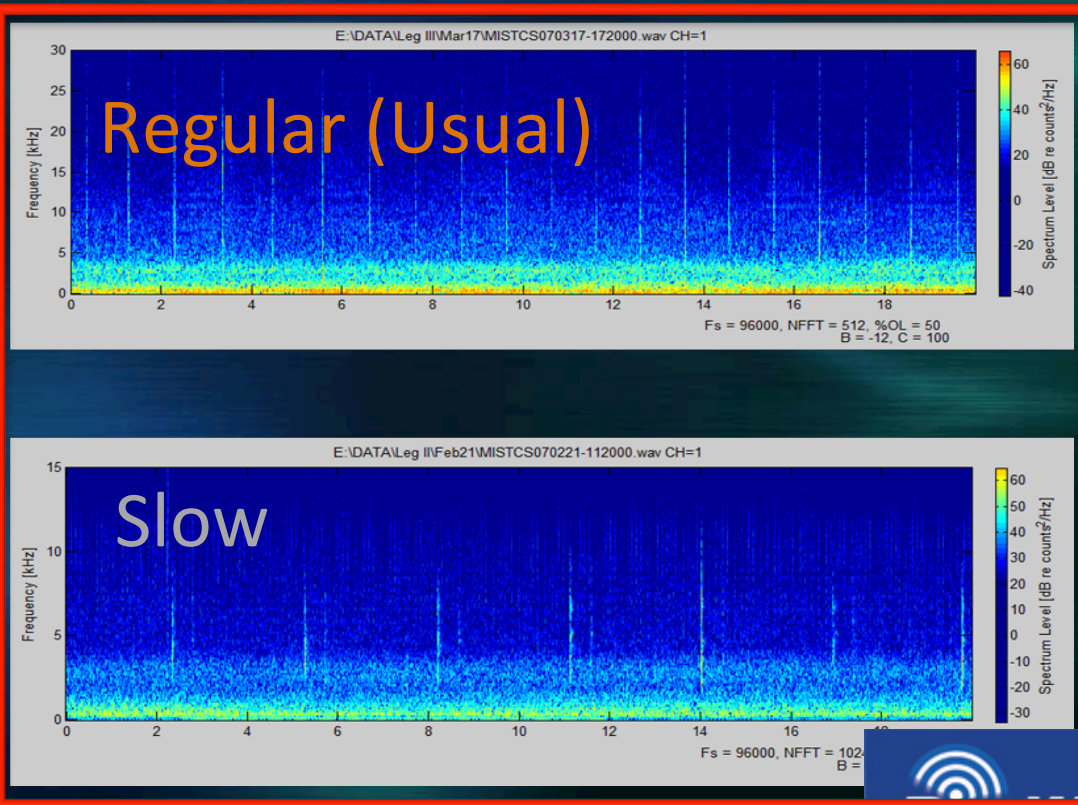
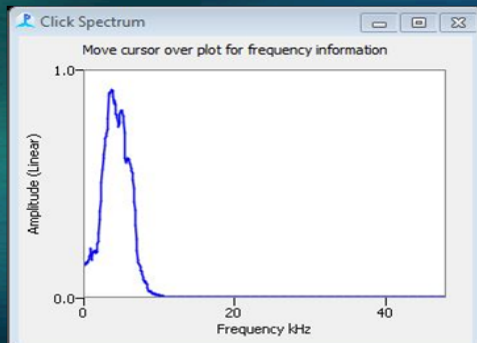
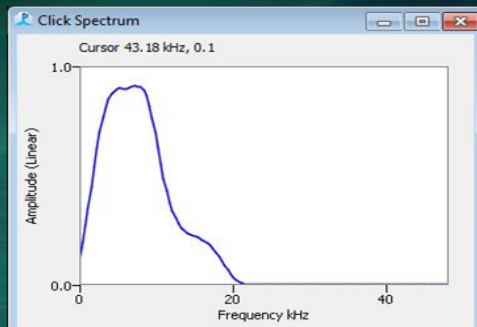
# Conclusions

- Possible difference attributable to recorder depth
  - Surface recorders may only be receiving certain frequency components of clicks



# Conclusions

- Click type definition
  - Peak/center frequencies less reliable parameter than ICI for characterizing 'regular' vs 'slow'





# Caveats

- Difference in acoustic monitoring systems
  - Hydrophone location – Surface vs. depth?
  - System noise, etc.
- Although similar hydrophone freq responses, difference in sensitivities, etc.
- Data collected in different seasons & years (may or may not have significant impact)
- Ecosystem & behavioral differences influencing clicks produced?:
  - Prey variability
  - Group composition

# Take Home Message

- Appears to be geographic variation in regular clicks:
  - Too many caveats?
- Monday: Analyst variability & performance
  - Need to provide information on potential variability for diagnostic purposes
- Tues: Parameter selection for classification
- Need to better understand the implications of biology on click characteristics



# Acknowledgements

- Office of Naval Research
- Living Marine Resources
- U.S. Navy (NAVFAC Pacific, & NAVFAC Atlantic)
- MISTCS passive acoustics team
- GOALS passive acoustic team
- SIO for SOCAL HARP Data
- HDR Inc. for contract support

**Thank you!**



*Photo Credit: Cory Hom-Weaver*