Coastal Studies Institute
UNIVERSITY OF NORTH CAROLINA

Detection of dolphin burst-pulses off Cape Hatteras, North Carolina, correlated to oceanographic features

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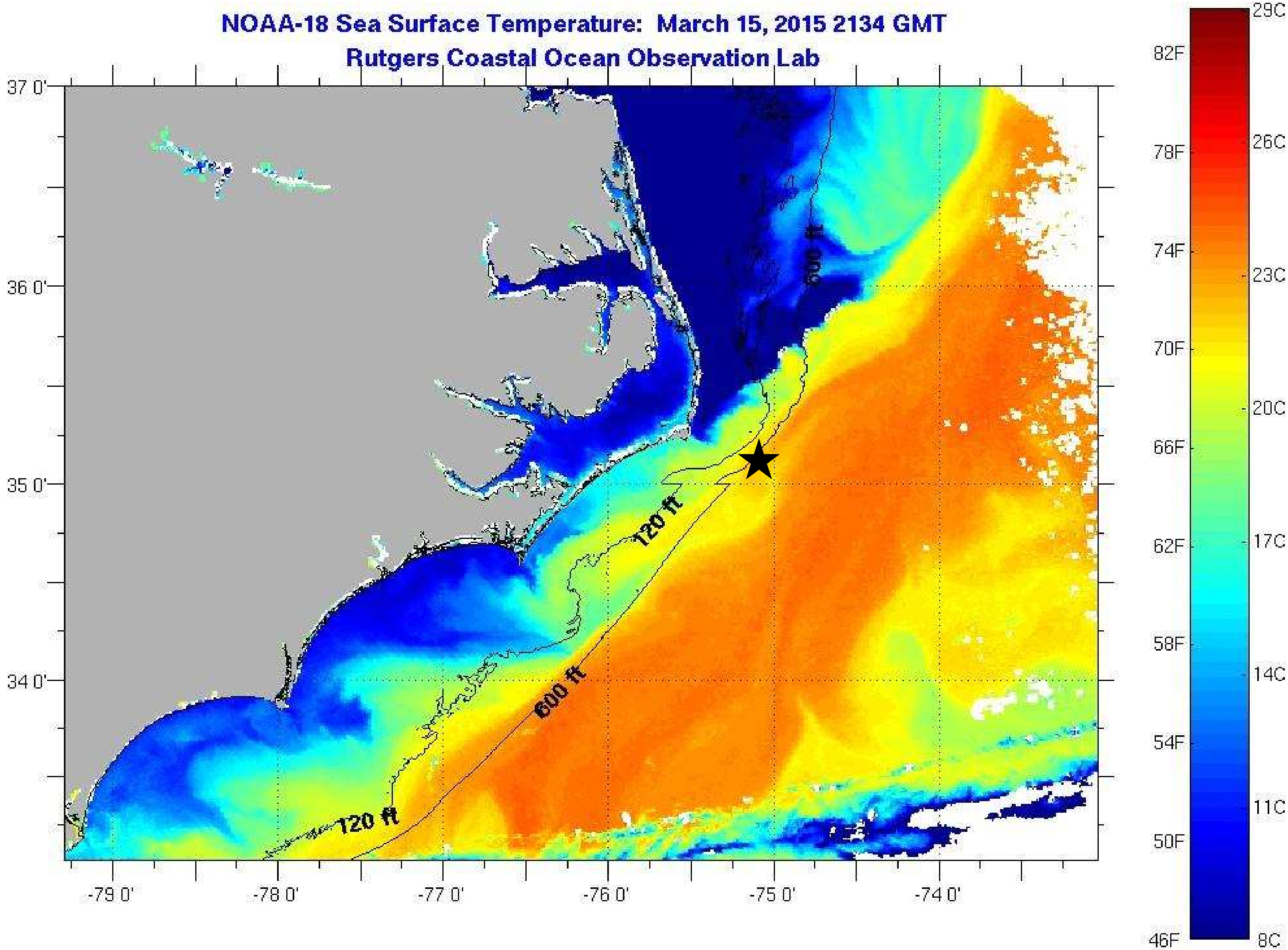
Outline

1. Introduction
2. Signals of Interest (Whistles and “Quacks”)
3. Detection
4. Correlating Detections with Gulf Stream Position
5. Summary
6. Next Steps

Introduction



Satellite image of sea surface temperature (SST) near Cape Hatteras on March 15, 2015, from Rutgers Coastal Ocean Observation Lab (COOL), using AVHRR. I've added a star to show the location of our mooring, at a depth of ~230m.

Introduction

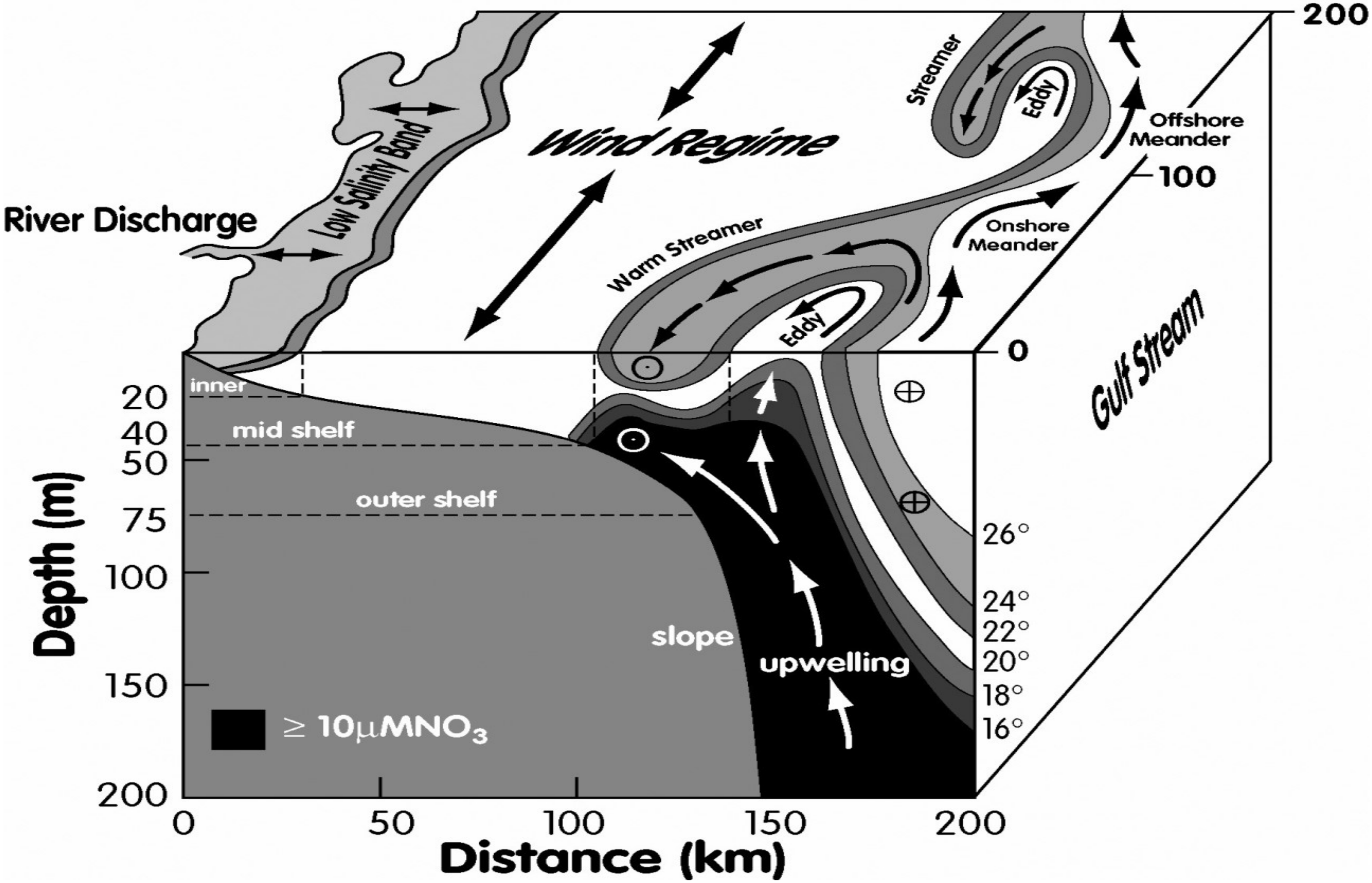


Figure from Jahnke and Blanton, 2010

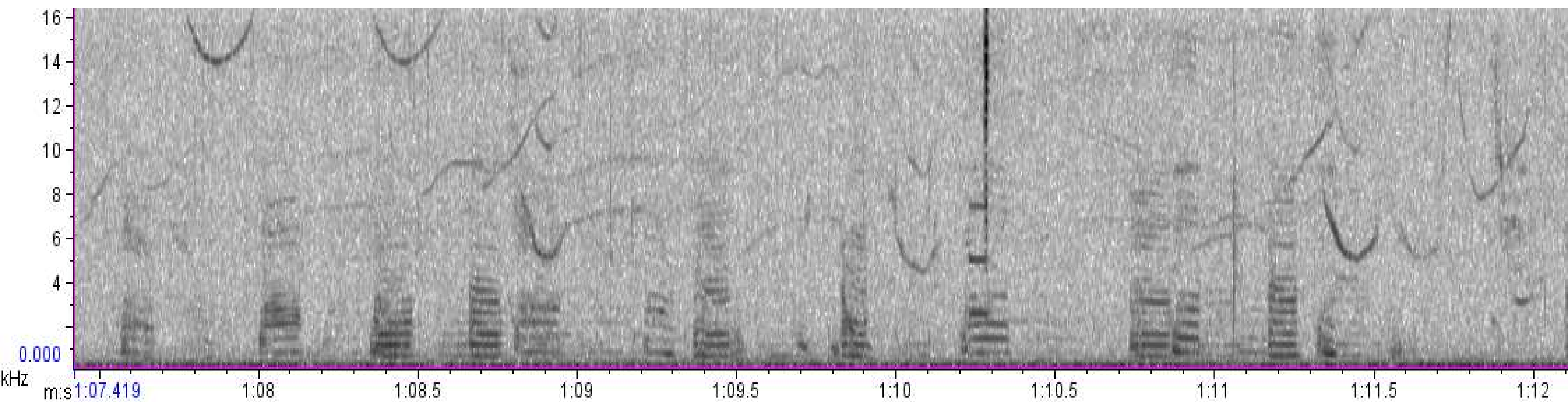
Introduction

Instruments on the mooring:

- AURAL-M2 hydrophone
  - Sampling under water sound at max rate of 32768 samples/second
  - Sampling for 5 minutes out of every half-hour
- CTD
  - Temperature (at the bottom)
  - Salinity (at the bottom)
  - Pressure (at the bottom)
- Acoustic Doppler Current Profiler (ADCP)
  - Velocity field (above the mooring)
  - Acoustic backscatter field (above the mooring)

Signals of Interest

Example of “quacks” (spectrogram + sound)



Detection: Whistles

For each of the 20,000+ wav files (5-minute recording interval):

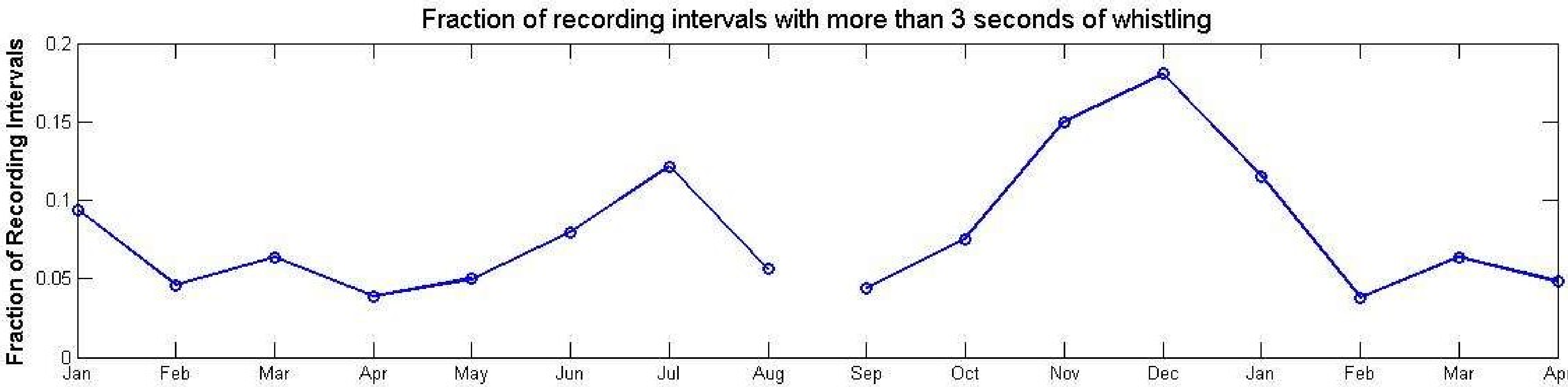
- Skip recording interval if it's too noisy.
- Remove instrument noise
- High-pass filter with cut-off frequency of 1 kHz.
- Call **Silbido** to detect whistles
  - beta2 version at http://roch.sdsu.edu/index.php/software/
  - SNR threshold of 10 dB
- Process the returned detection event.
- Automated post-processing to remove some anthropogenic sounds.
- Add up the duration of whistling (in seconds) per 5-minute recording interval. This is the *vocalization metric* for whistles.

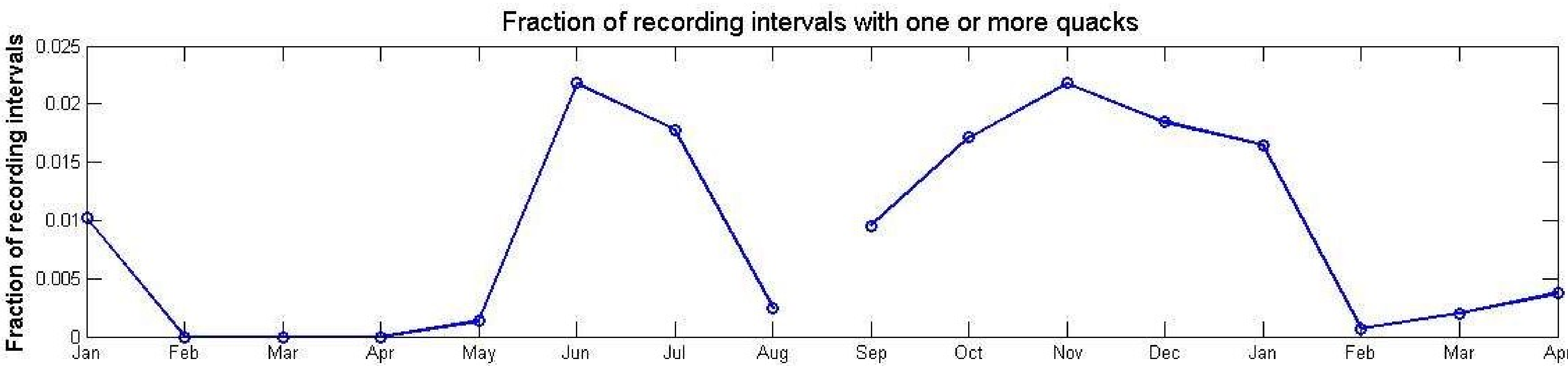
Detection: “Quacks” or “Barks”

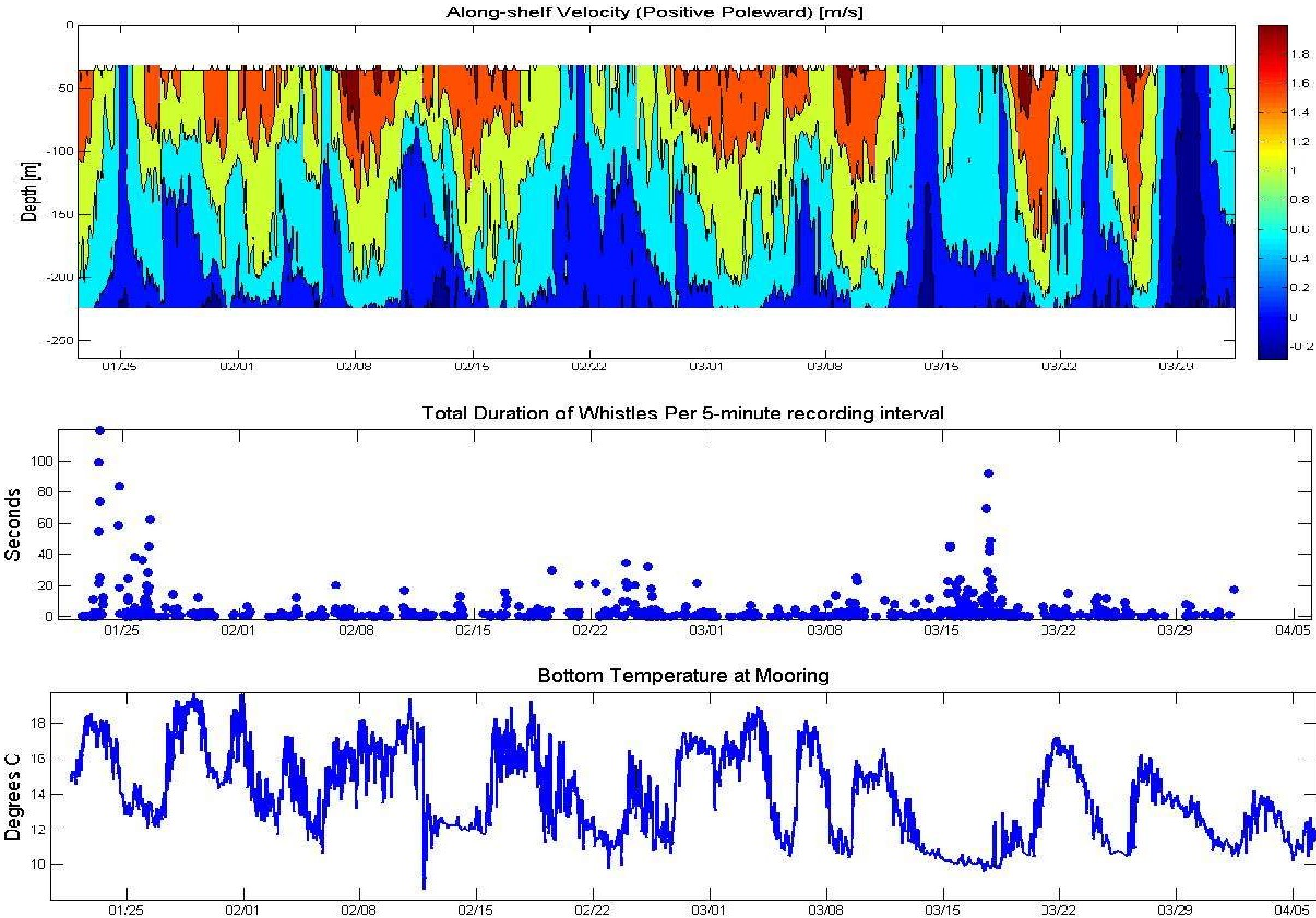
For each of the 20,000+ wav files (5-minute recording interval):

- Skip recording interval if it’s too noisy.
- Remove instrument noise
- Bandpass filter (100 to 6000 Hz)
- Apply **swipep pitch detector** to overlapping time windows, specifying a detection threshold and a range of possible pitch values (300 – 1000 Hz)
    - implementation in matlab at https://www.cise.ufl.edu/~acamacho/publications/swipep.m
- Identify which recording intervals had one or more detections
- Manually remove false alarms

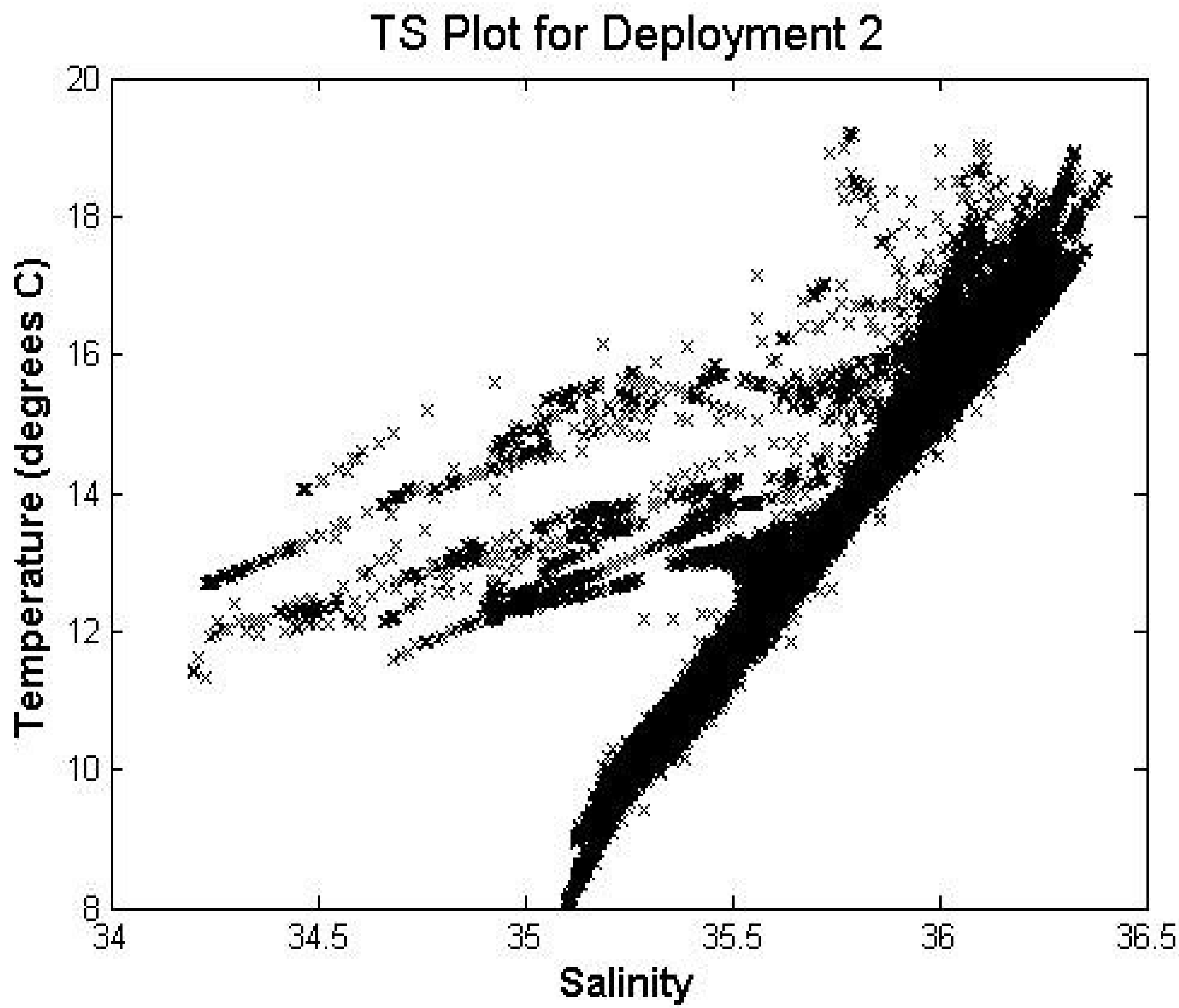
Detection: Temporal Patterns



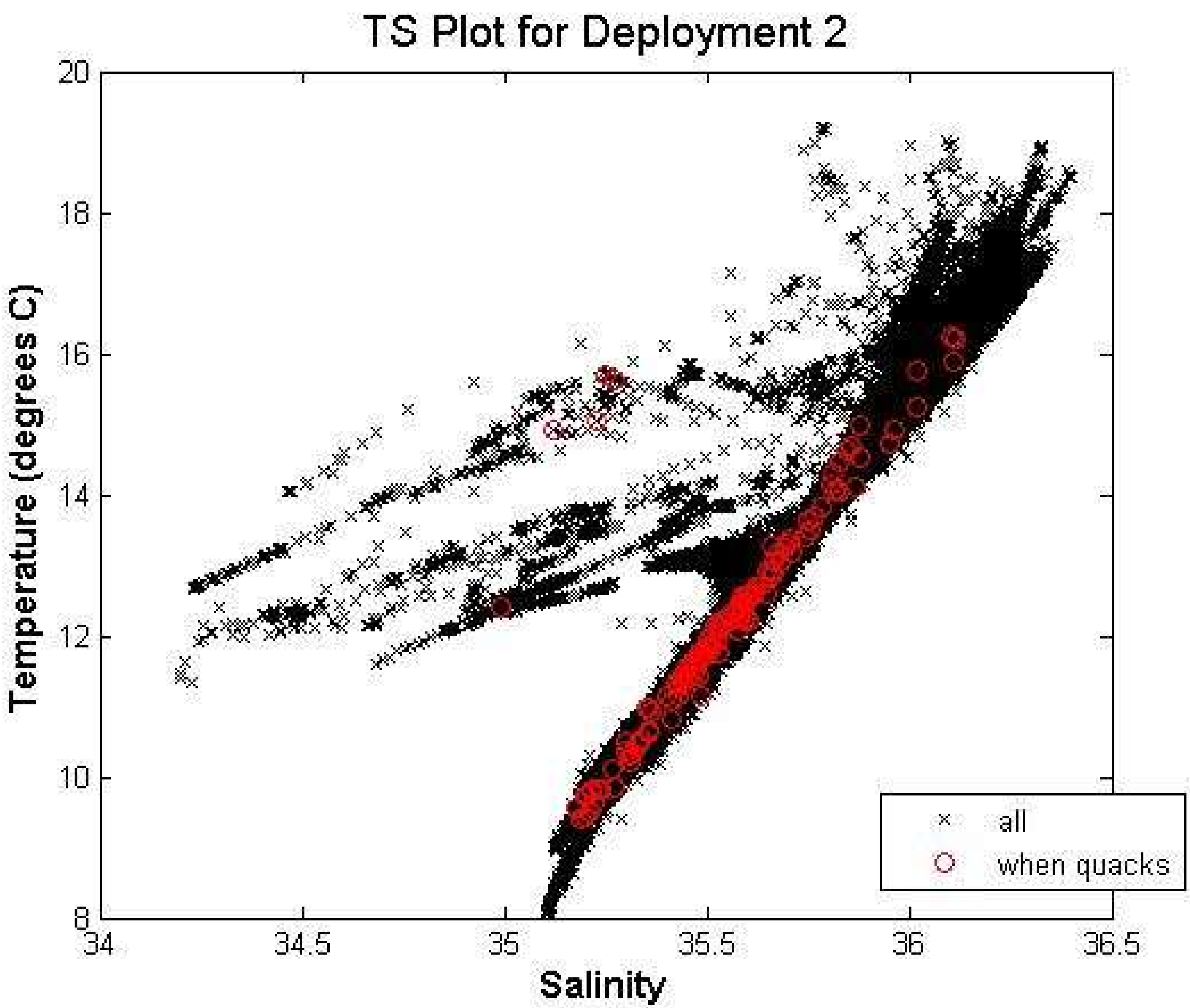



Along-shelf Velocity (Positive Poleward) [m/s]
Depth [m]
0
-50
-100
-150
-200
-250
01/25
02/01
02/08
02/15
02/22
03/01
03/08
03/15
03/22
03/29
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
Total Duration of Whistles Per 5-minute recording interval
Seconds
100
80
60
40
20
0
01/25
02/01
02/08
02/15
02/22
03/01
03/08
03/15
03/22
03/29
04/05
Bottom Temperature at Mooring
Degrees C
18
16
14
12
10
01/25
02/01
02/08
02/15
02/22
03/01
03/08
03/15
03/22
03/29
04/05

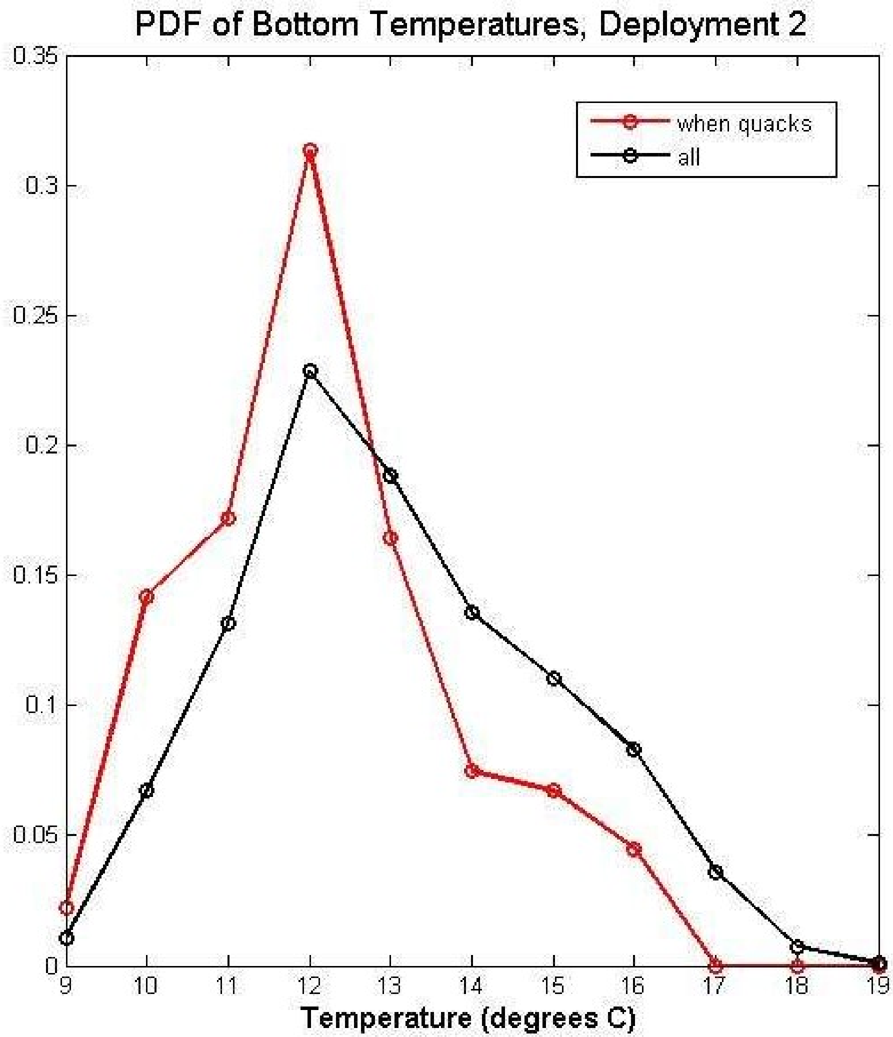
Correlating Detections with Gulf Stream Position

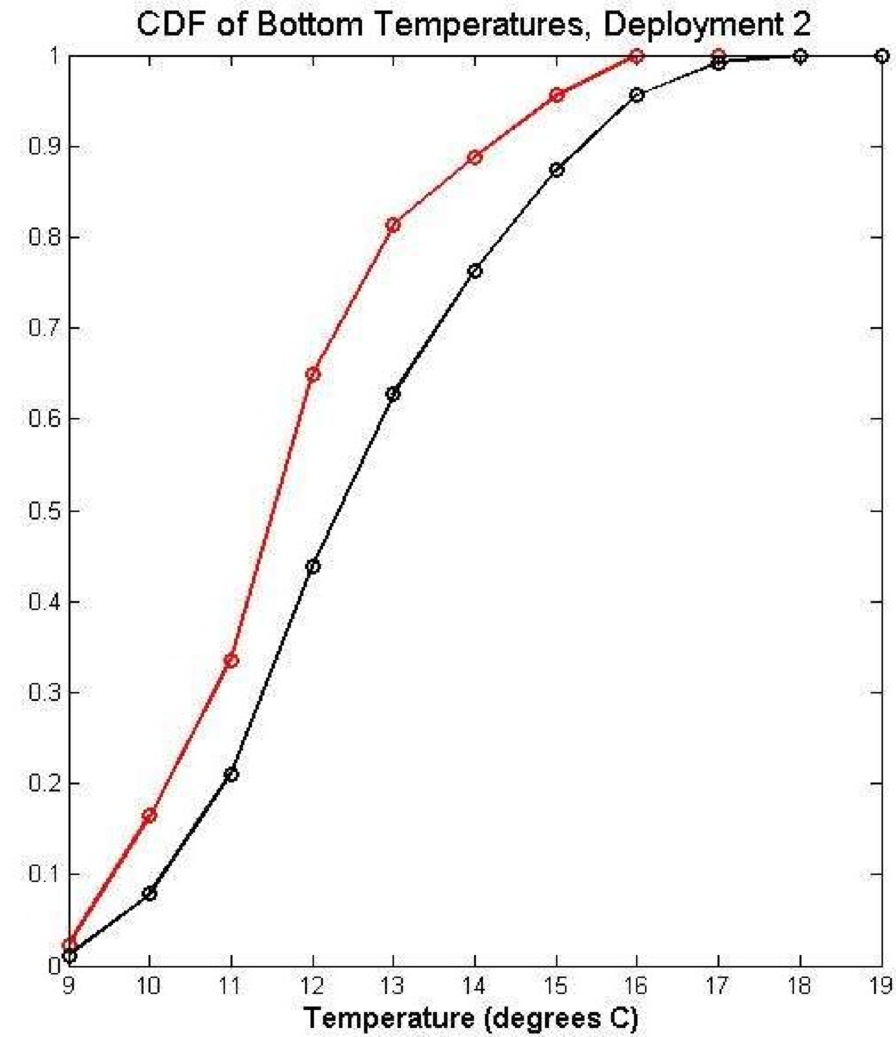


Correlating Detections with Gulf Stream Position



Correlating Detections with Gulf Stream Position





Correlating Detections with Gulf Stream Position

If, instead, we use a GAM…

Formula: presence ~ s(temperature) + s(salinity)

R-sq.(adj) = 0.000502
Deviance explained = 1.99%

So, this approach of using PDFs and KS test can be better in some case than GAM for revealing a relationship between the biological (presence/absence) data and the physical data (T,S).

See Woodworth P.A., Schorr G.S., Baird R.W., Webster D.L., McSweeney D.L., Hanson M.B., Andrews R.D., and J.J. Polovina. (2012). Eddies as offshore foraging grounds for melon-headed whales (*Peponocephala electra*). Marine Mammal Science 28: 638-647.

Outline

1. Introduction
2. Signals of Interest (Whistles and "Quacks")
3. Detection
4. **Correlating Detections with Gulf Stream Position**
   a) **Is correlation "Real" (biological)…**
   b) or is it environmental:
      i. Acoustic propagation related to Gulf Stream position?
      ii. Acoustic noise related to Gulf Stream position?
   c) or both?
5. Summary
6. Next Steps

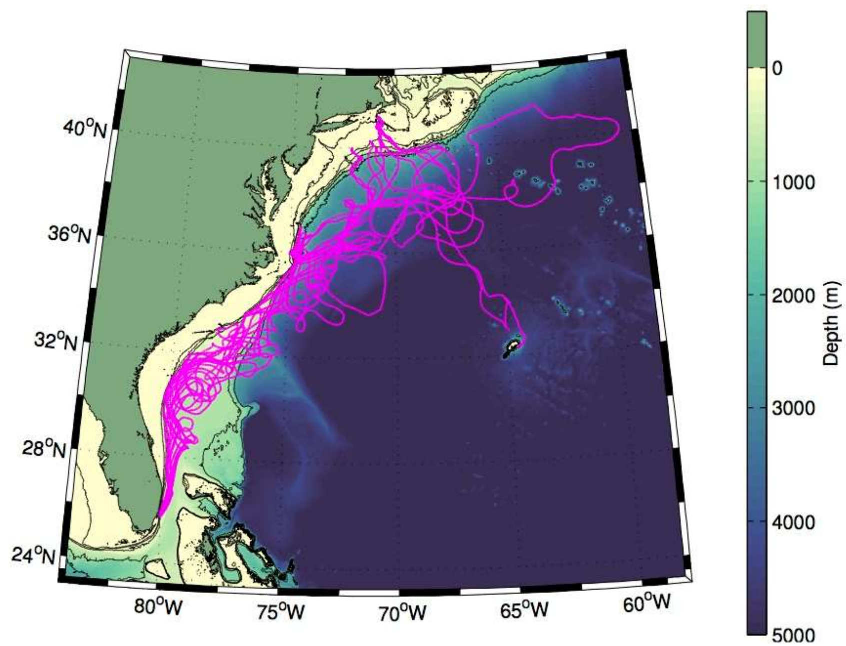
Acoustic Propagation

Would like to model the acoustic propagation under two scenarios:

1) Transect when Gulf Stream meander at crest
2) Transect when Gulf Stream meander at trough

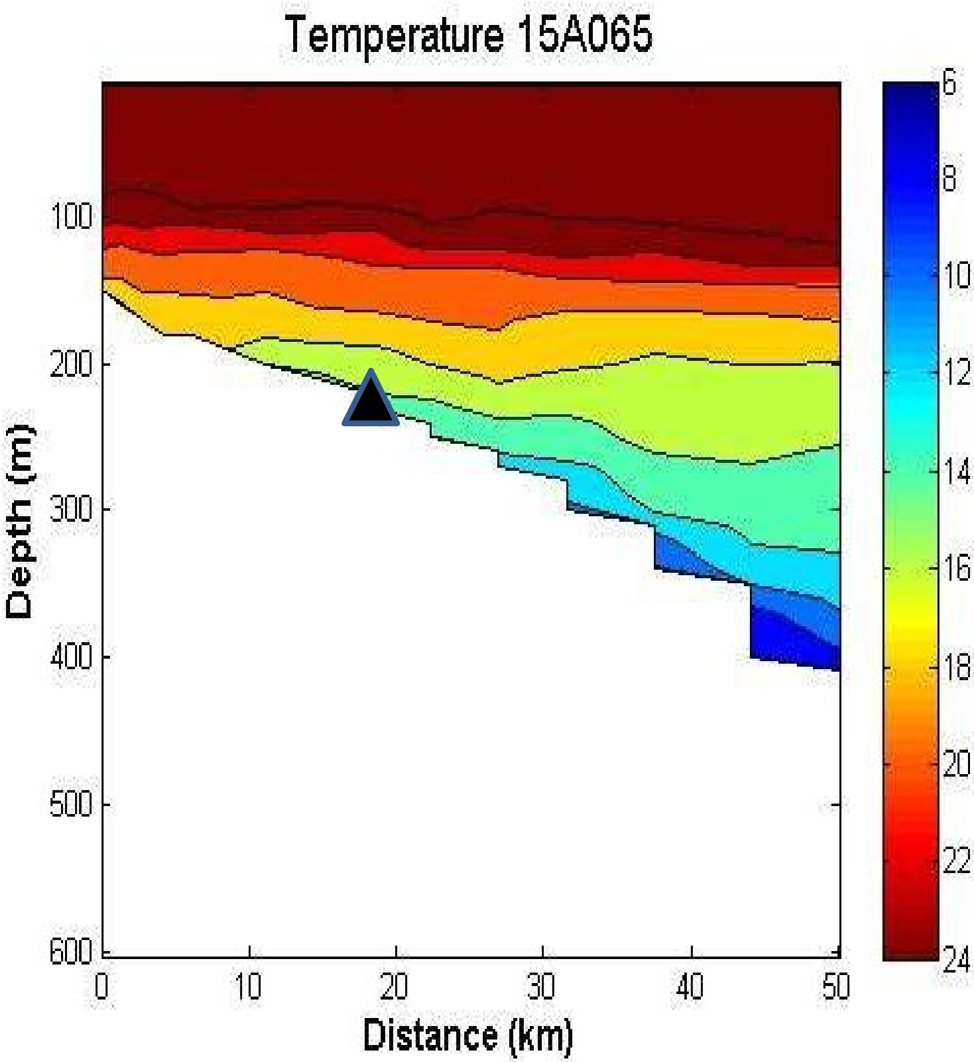
…but, all we have is T,S at one point (230m deep, at bottom)

Get glider data.

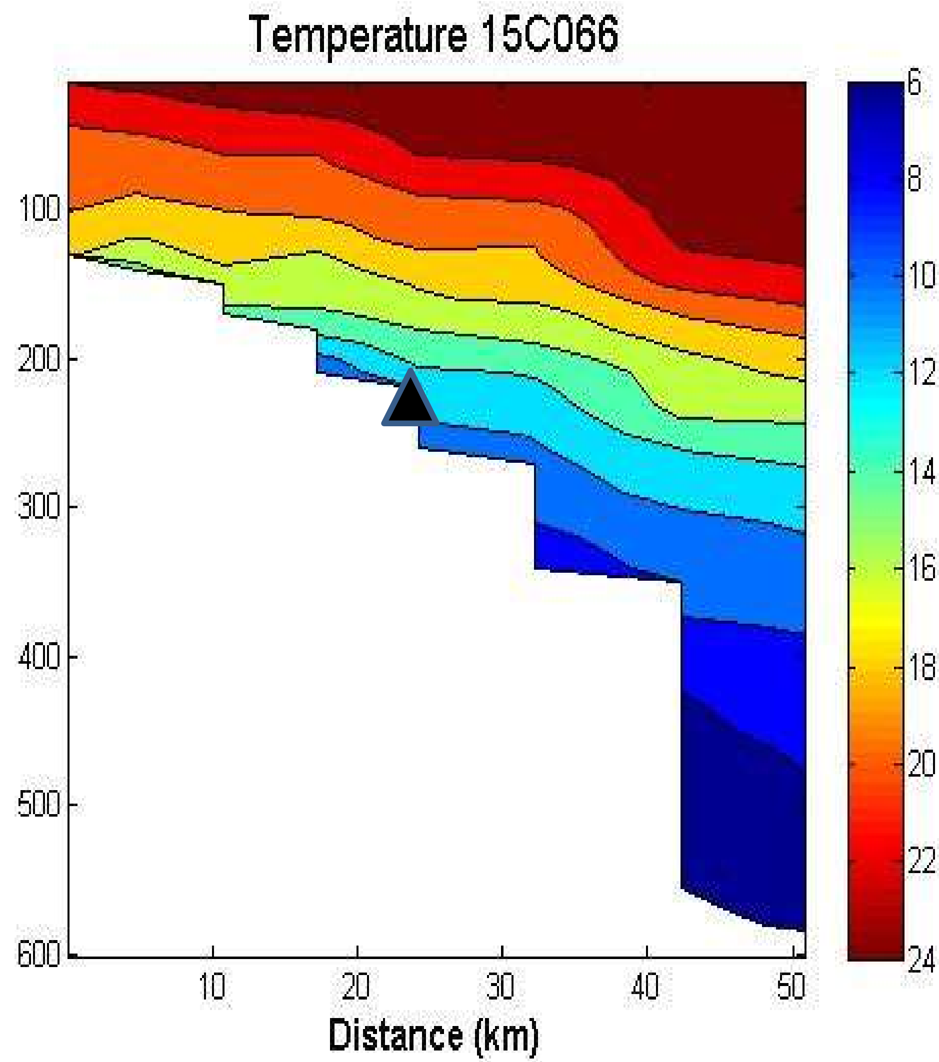


From http://rtodd.whoi.edu/wp-content/uploads/all_GS_tracks_for_web.jpg

Acoustic Propagation

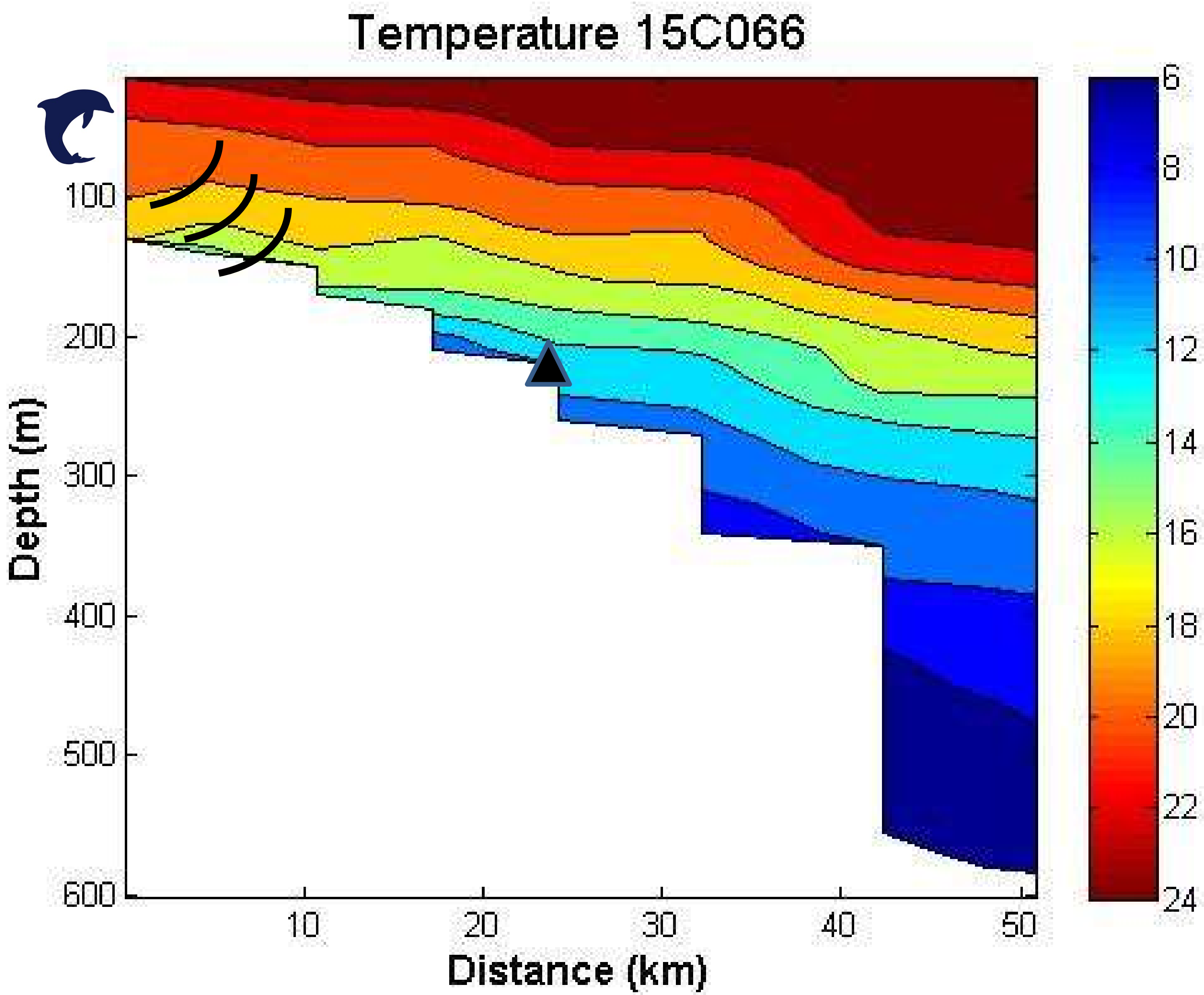


Isotherms flat, T>14C at bottom=230m

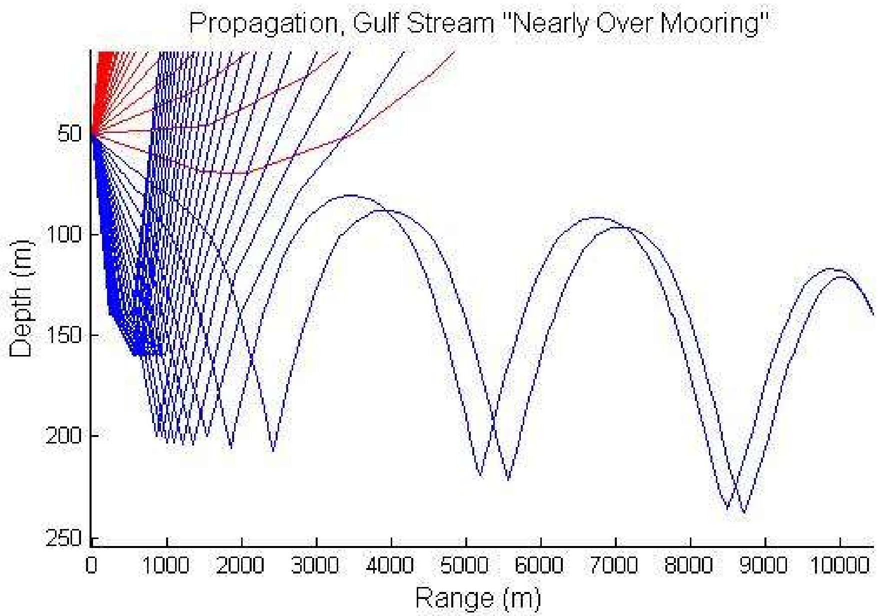


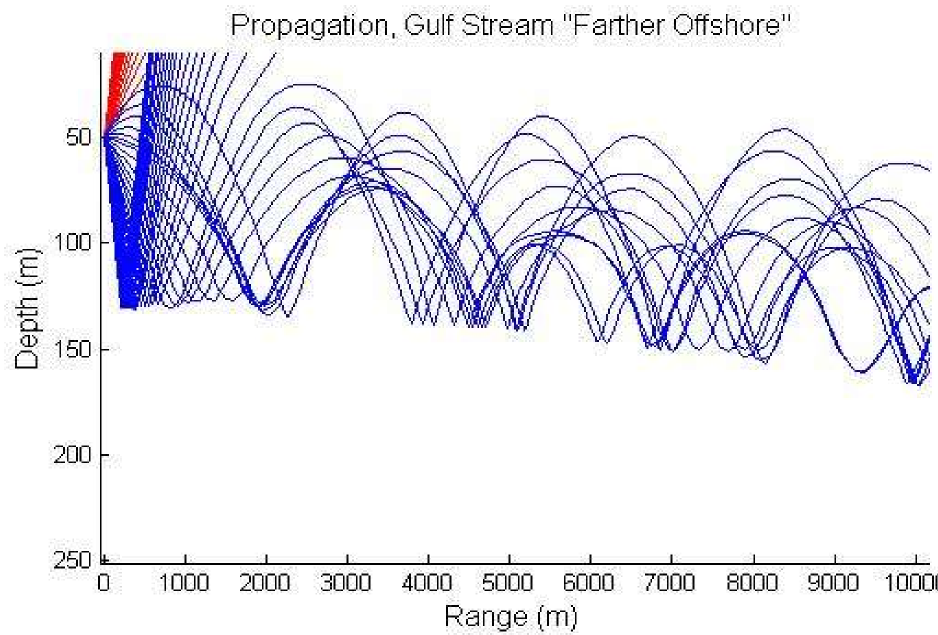
Isotherms tilted, T<12C at bottom=230m

Acoustic Propagation



Acoustic Propagation





Isotherms flat, T>14C at bottom=230m

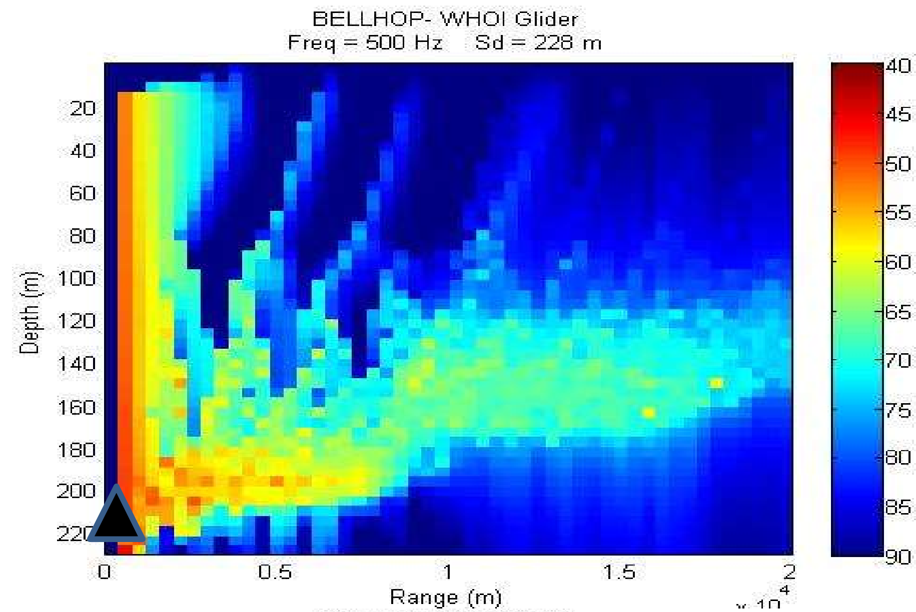
Only rays within a 1.5 degree arc can propagate more than 2km down the slope for this scenario.

Isotherms tilted, T<12C at bottom=230m

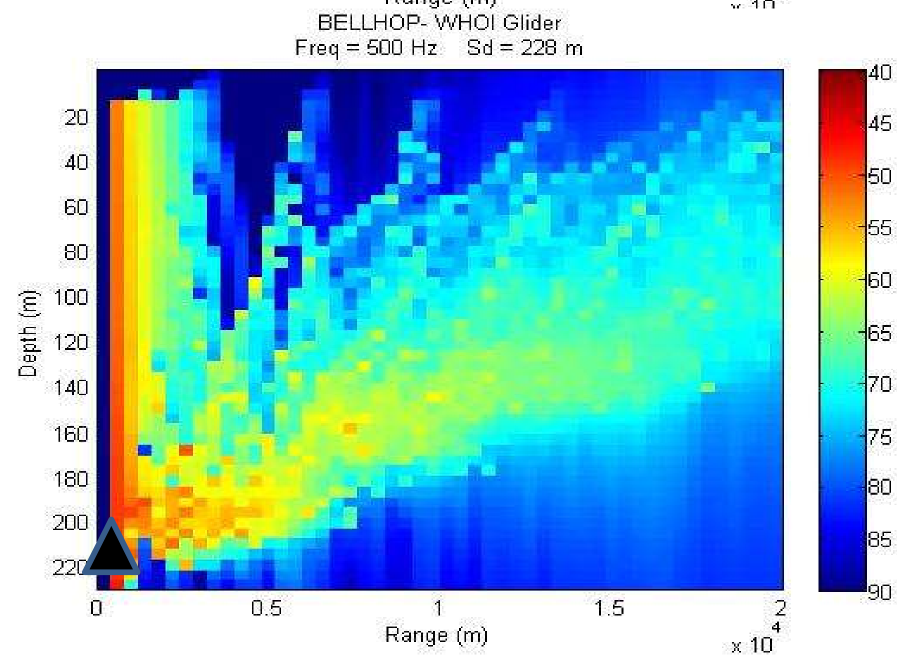
Rays within a 10 degree arc can propagate more than 2km down the slope for this scenario.

Acoustic Propagation

Isotherms flat, T>14C at bottom=230m

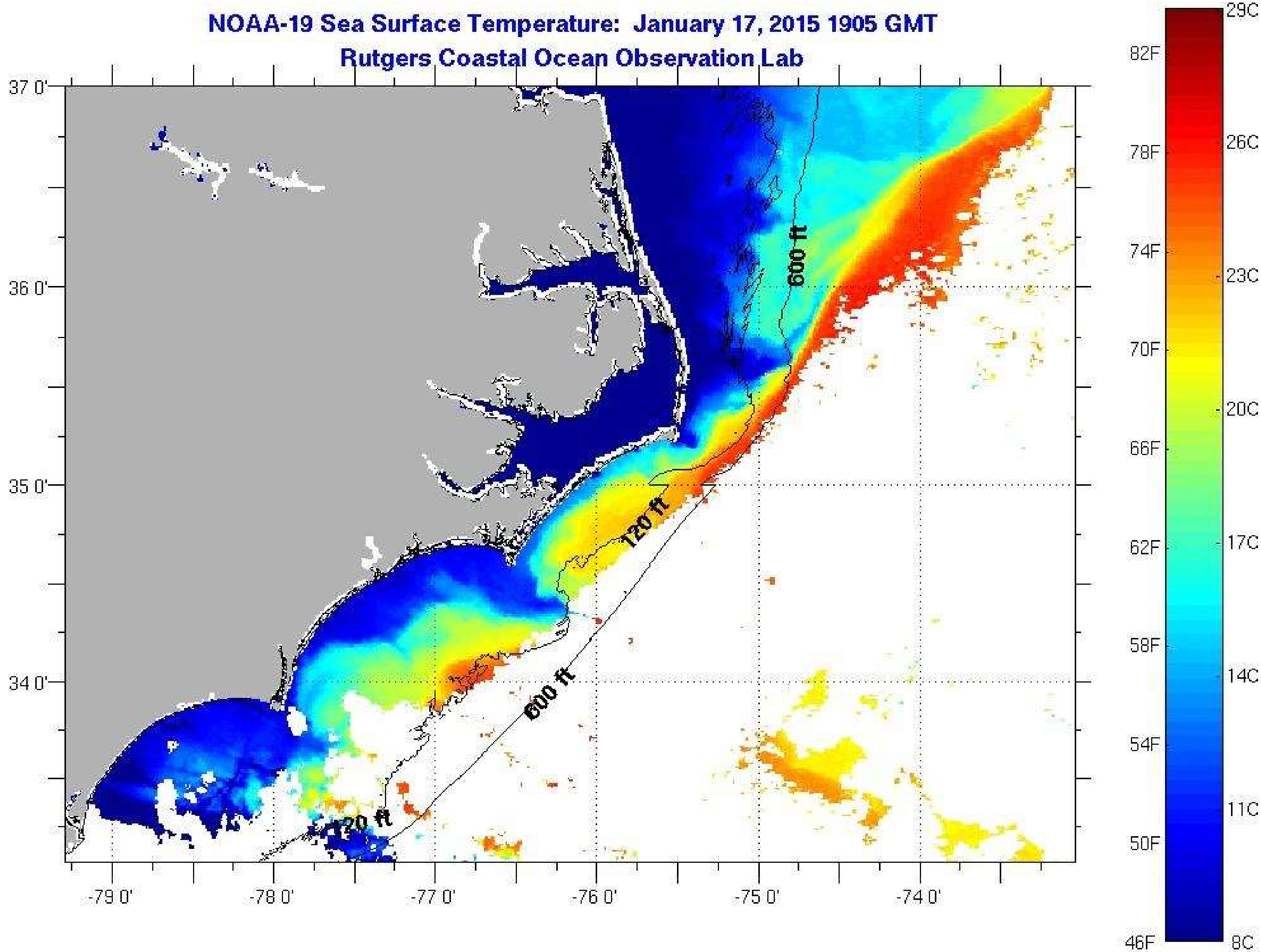


Isotherms tilted, T<12C at bottom=230m

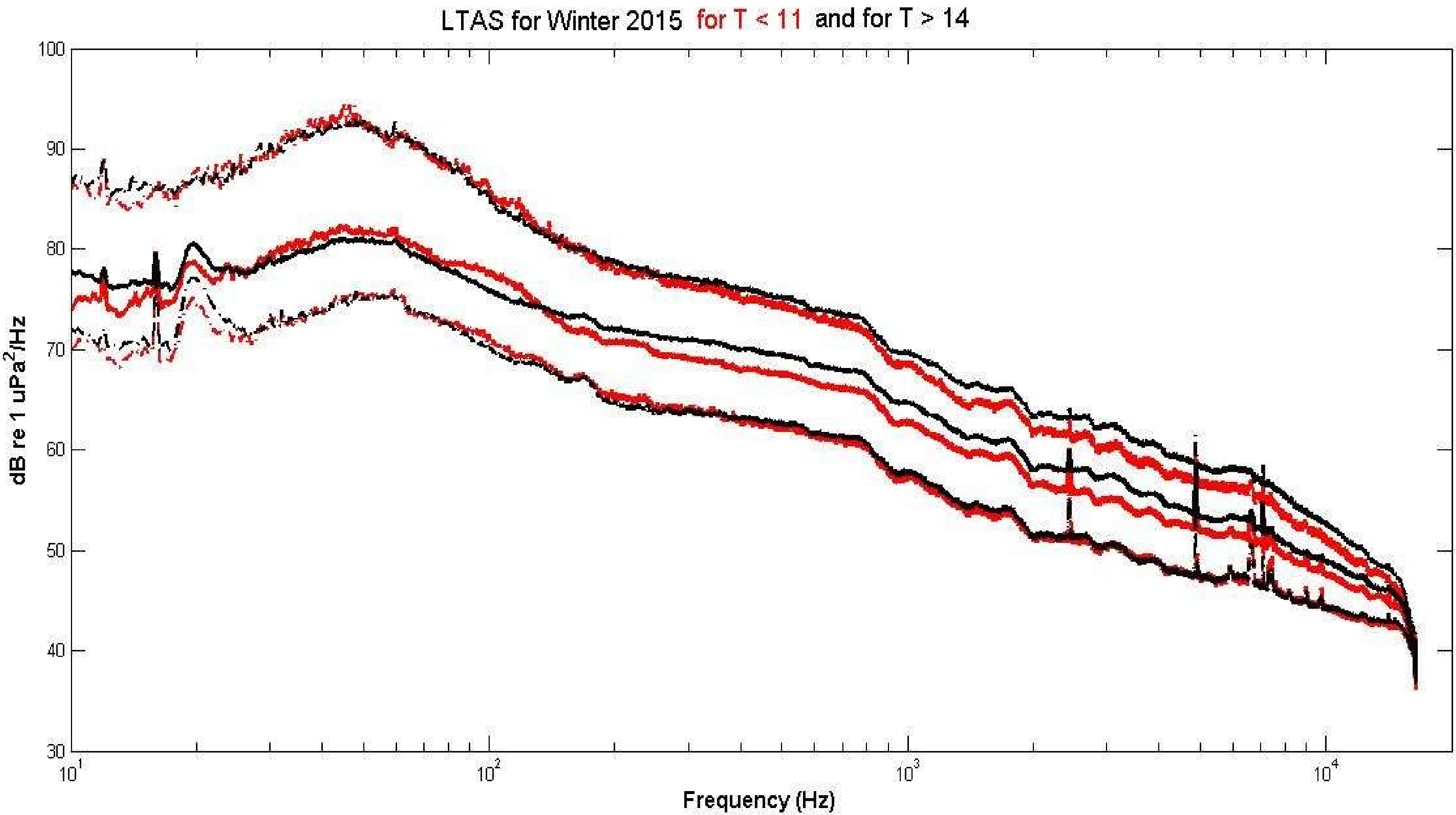


Distance Shoreward

Acoustic Noise



Acoustic Noise



In **black**: LTAS (10%, median, 90%) for the recording intervals when bottom **T > 14 C**

In **red**: LTAS (10%, median, 90%) for the recording intervals when bottom **T < 11 C**

Summary

- Temporal pattern for quacks similar to that of whistles. (Recording intervals with quacks are a subset of the recording intervals with whistles.)

- Dolphin quacks observed when water at the bottom was cooler, fresher
  - i.e. when Gulf Stream farther offshore and…
  - The mooring is in a meander trough

- **Highlights the advantage of a probabilistic approach for comparing biological and physical data**

Summary

- The upwelling of nutrient-rich water could be attracting the dolphins (and their prey)…

- Or, it is possible that it’s just easier to detect these signals when the Gulf Stream is farther offshore:
  - …due to enhanced propagation of the signal?
  - …due to relative proximity of the front?

- Or, all of the above?

- **Highlights the need to have measurements of the temperature and salinity fields to feed the acoustic propagation model.**

Next Steps

- More data
  - …to look for seasonal trends
- Transects that show upwelling
- Improve detector for “quacks”
  - …tweak to reduce false alarms

Acknowledgements

- We would like to thank Sara Haines of the University of North Carolina at Chapel Hill for processing CTD and ADCP data.
- We acknowledge the support of Dr. Robert Todd of WHOI for his glider transects, used as input to the propagation model.
- This project was funded by the North Carolina Renewable Ocean Energy Program.

References

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swipep implementation in matlab at https://www.cise.ufl.edu/~acamacho/publications/swipep.m

Satellite images from Rutgers Coastal Ocean Observation Lab (COOL) at
https://marine.rutgers.edu/cool/sat_data/?nothumbs=0&product=sst&region=capehat

Extra Slides