Capturing Uncertainty: Internal Waves

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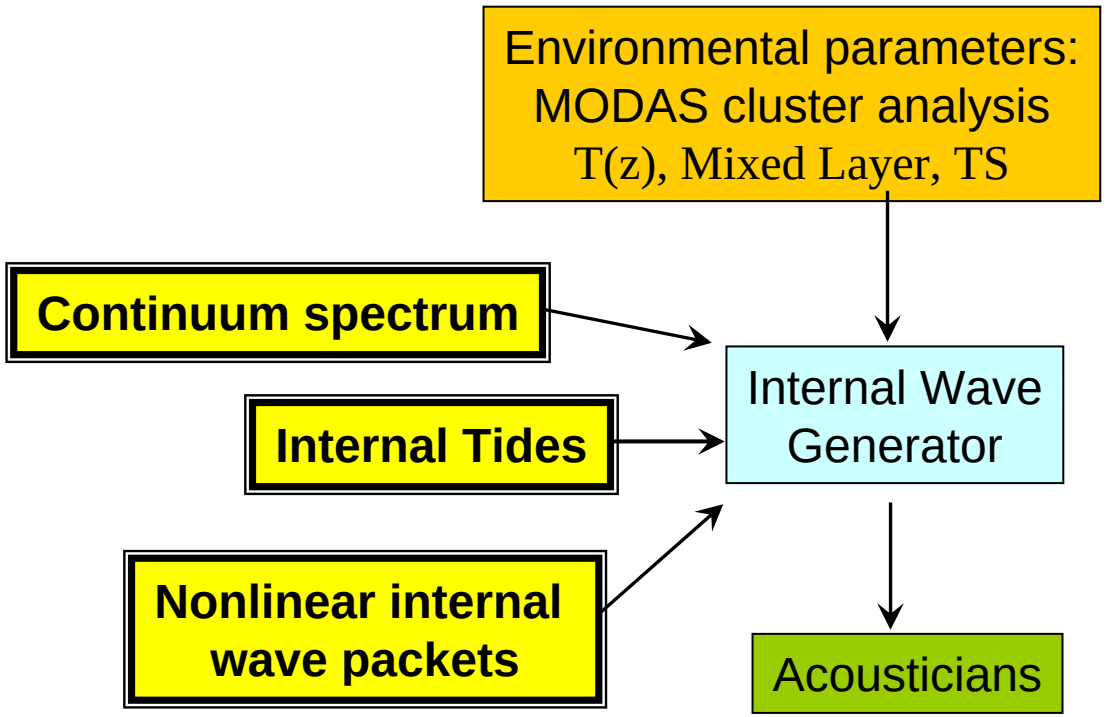
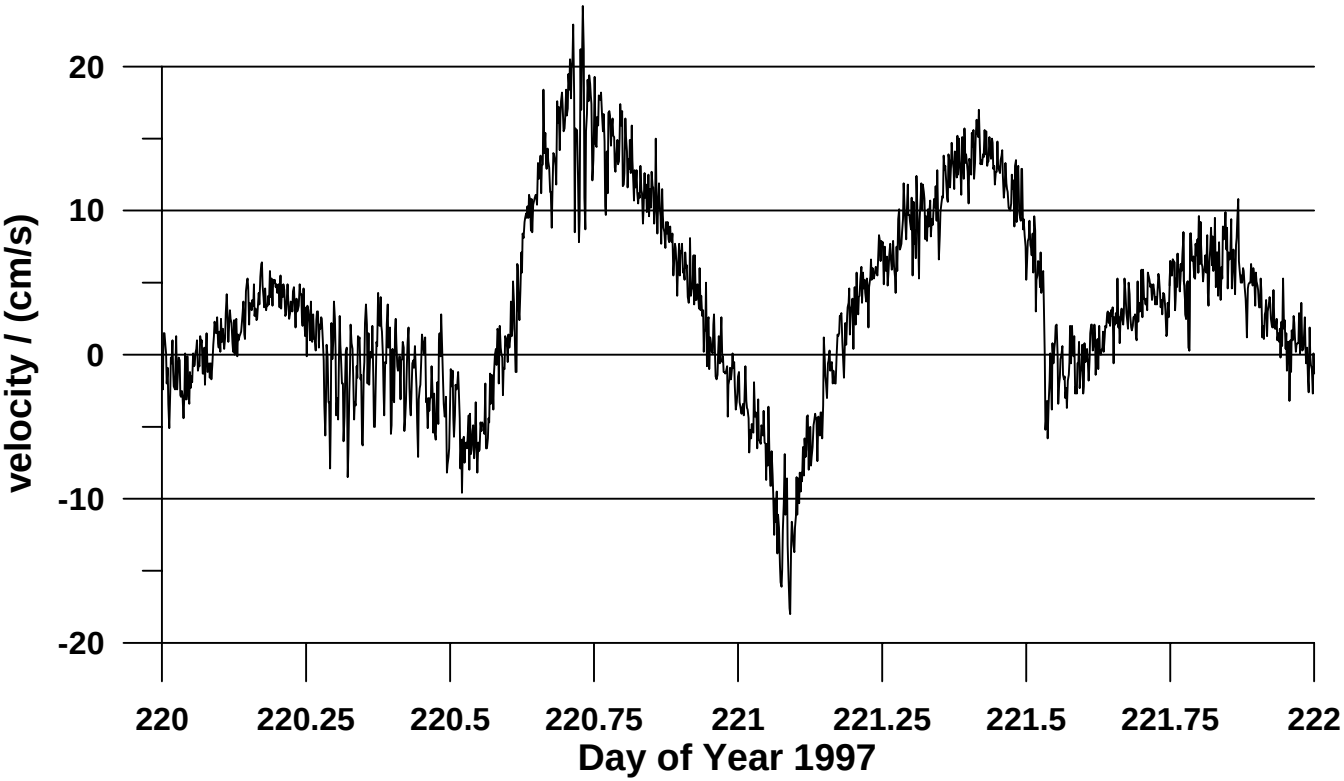
Objectives:

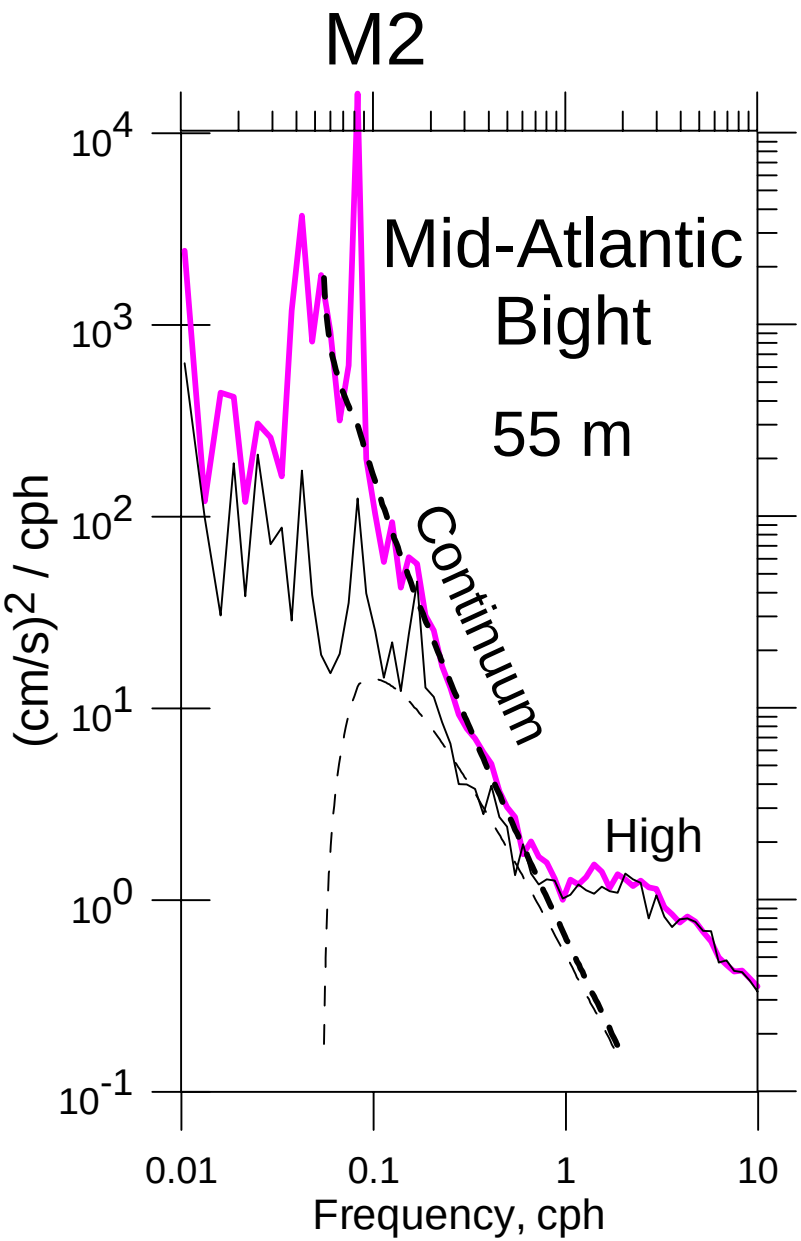
- Quantify the variability of the sound speed field in space and time due to internal waves
- Provide random realizations to the acousticians
- Assess the importance of internal waves on the overall uncertainty

Approach:

- For random background internal waves, use the Garrett-Munk type spectrum:
  - modified for shallow water (Mid-Atlantic Bight, E. China Sea)
  - deep water (NORPAC)
- Add the effects of nonlinear internal wave packets and internal tide
- Iterate with acousticians and signal processors to determine which specific features of internal waves are important

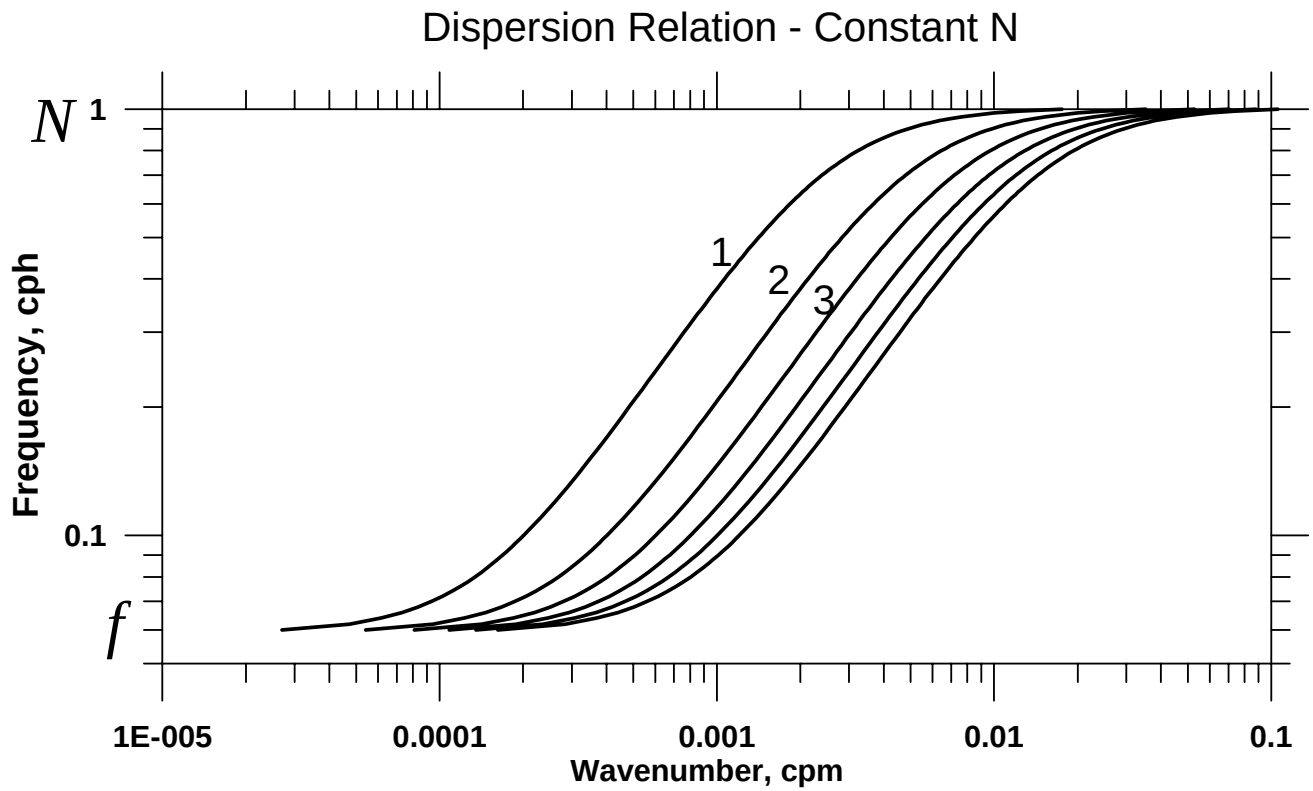

Environmental parameters:
MODAS cluster analysis
T(z), Mixed Layer, TS
Continuum spectrum
Internal Tides
Nonlinear internal wave packets
Internal Wave Generator
Acousticians


20
10
0
-10
-20
velocity / (cm/s)
220
220.25
220.5
220.75
221
221.25
221.5
221.75
222
Day of Year 1997


M2
Mid-Atlantic
Bight
55 m
Continuum
High
(cm/s)2 / cph
10^4
10^3
10^2
10^1
10^0
10^-1
0.01
0.1
1
10
Frequency, cph

$$\zeta(x, y, z, t) = \iiint A(\omega, k, l)$$

$$\times \psi(z) \exp(kx + ly - \omega t)\, dk\, dl\, d\omega$$



Garrett-Munk:

$$A^2(j,\omega) = Eb^2 N_0^2 B(\omega) H(j)$$

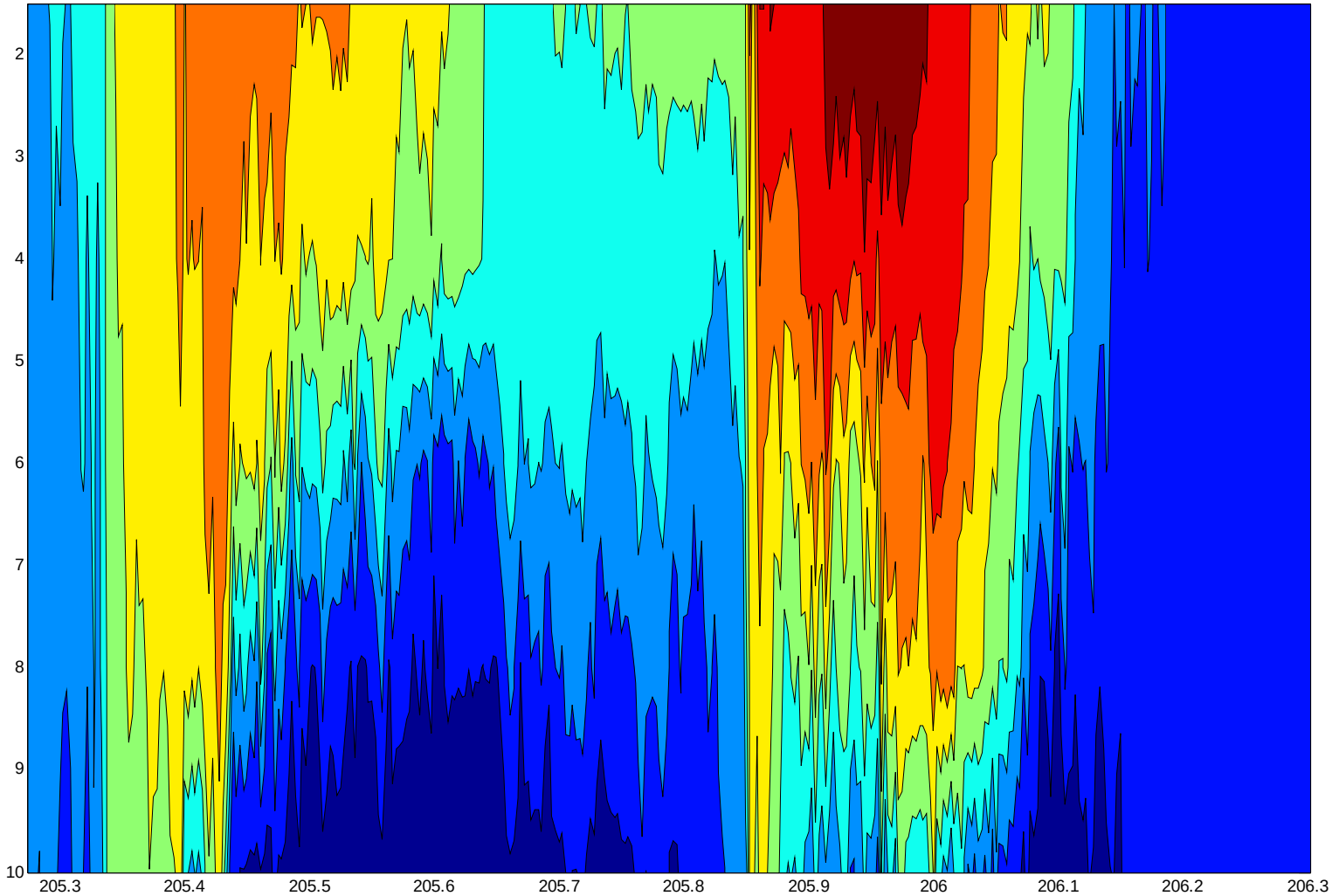
Modified Garrett-Munk (Levine, 2002):

$$A^2(j,\omega) = E_{ref}\, \hat{B}(\omega) H(j)$$

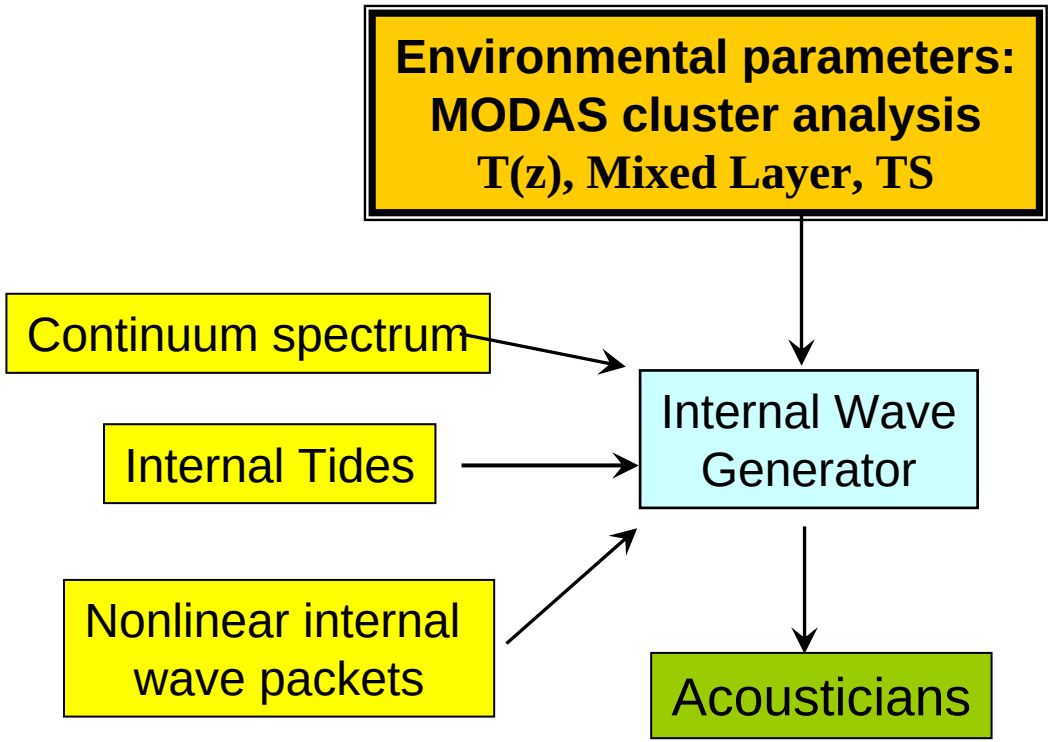
Random $\sum_{k,l,\omega} \Rightarrow \zeta(x,z)$

surface

12 hours (~ 21 km)



10m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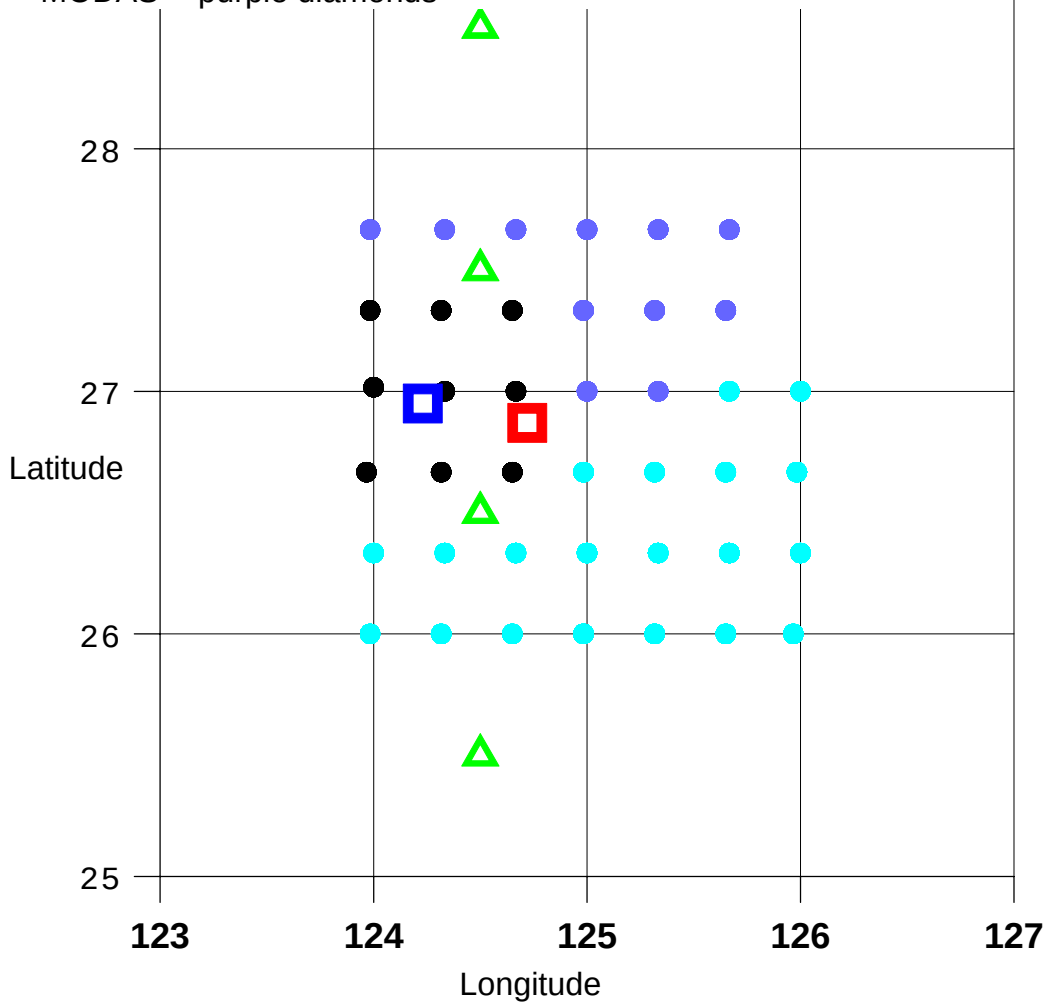
XBT134 --
Center -- black dots -- 110-160; 317-423
Deep -- light blue dots -- 221-274; 427-959
Other -- purple dots - 3-107; 163-219; 278-313; 973-1012
Levitus -- Aug -- Green lines -- along 124.5; 25.5 to 28.5
Reynolds -- blue sq (17:18); red sq (21:14)
MODAS -- purple diamonds



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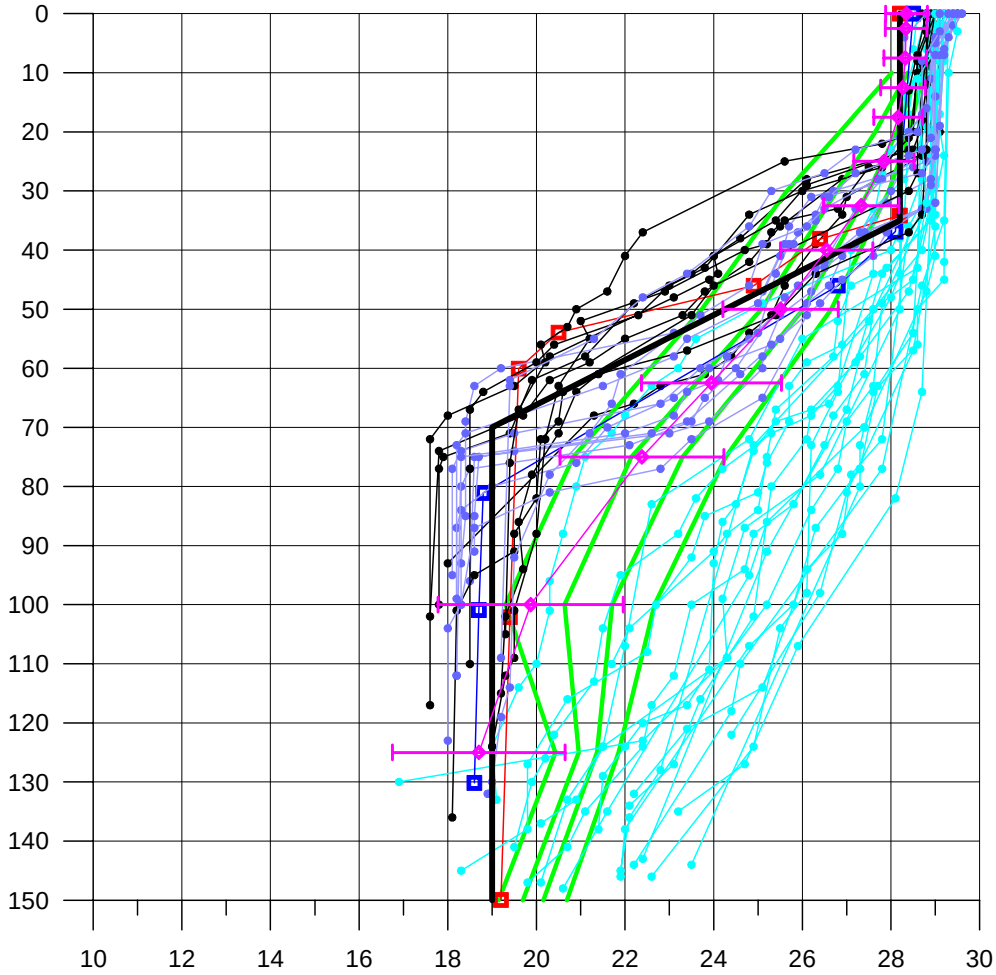
xbt2.grf
6/8/04



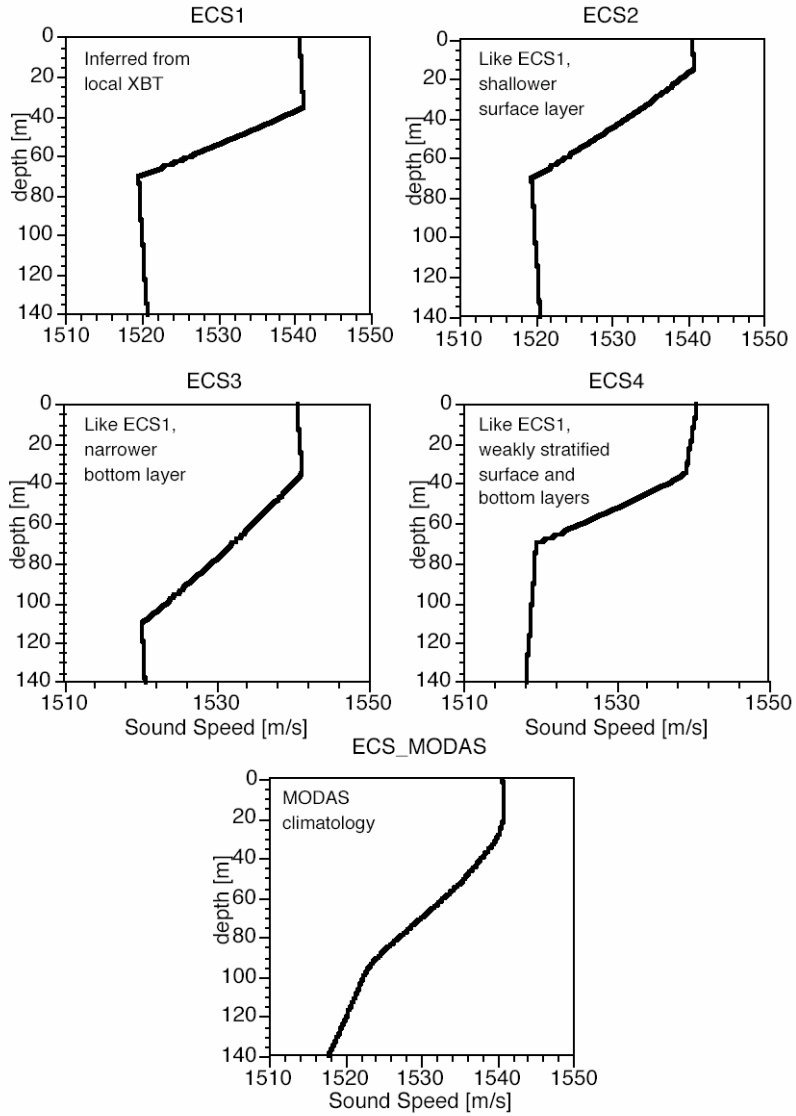
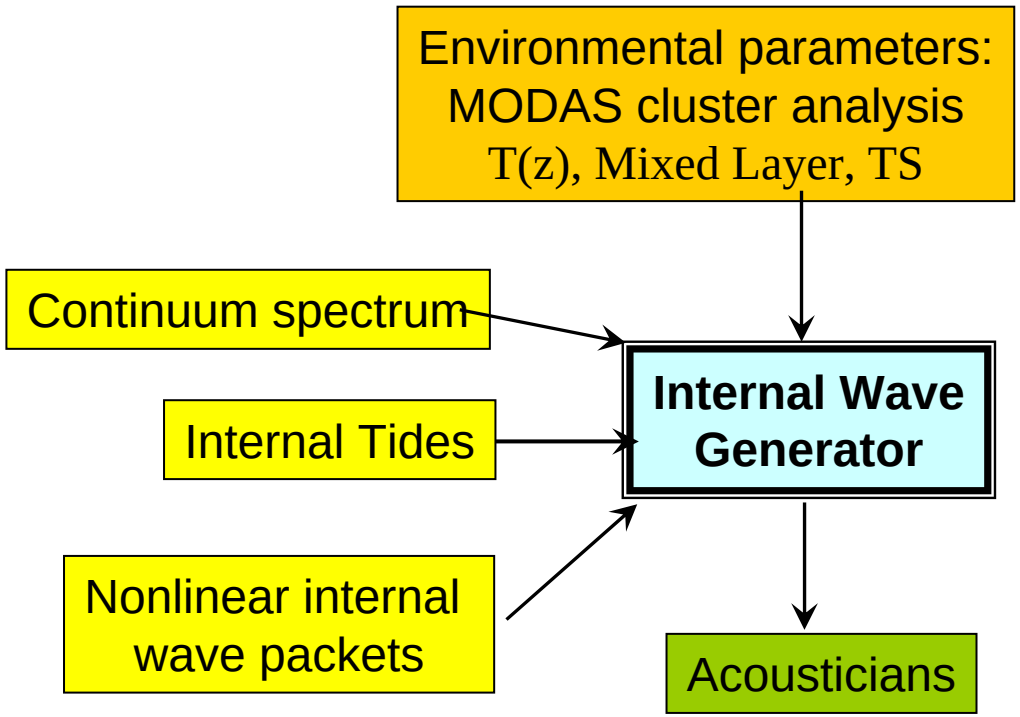


Figure 1. Five deterministic SSP scenarios for the East China Sea in August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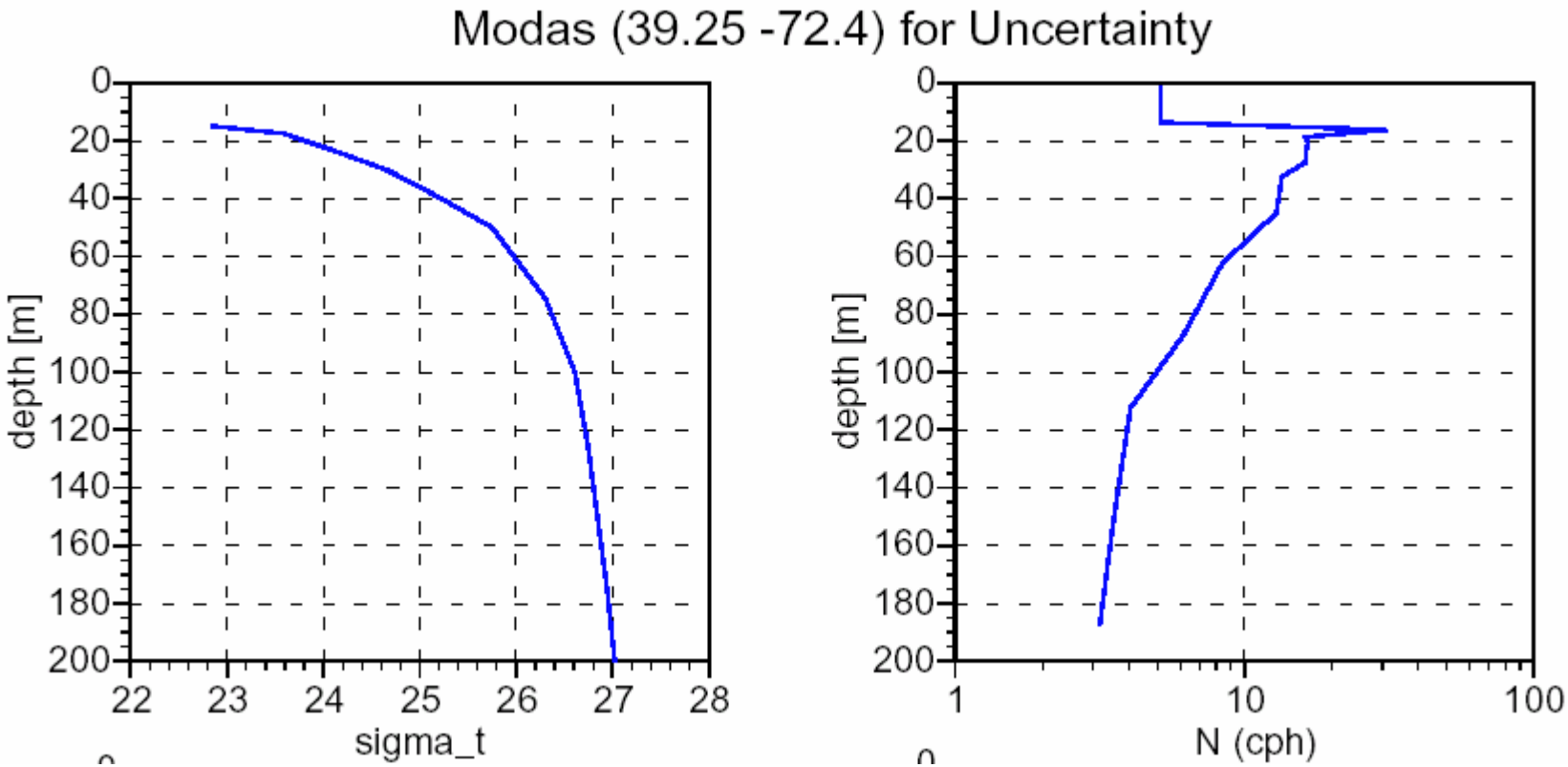
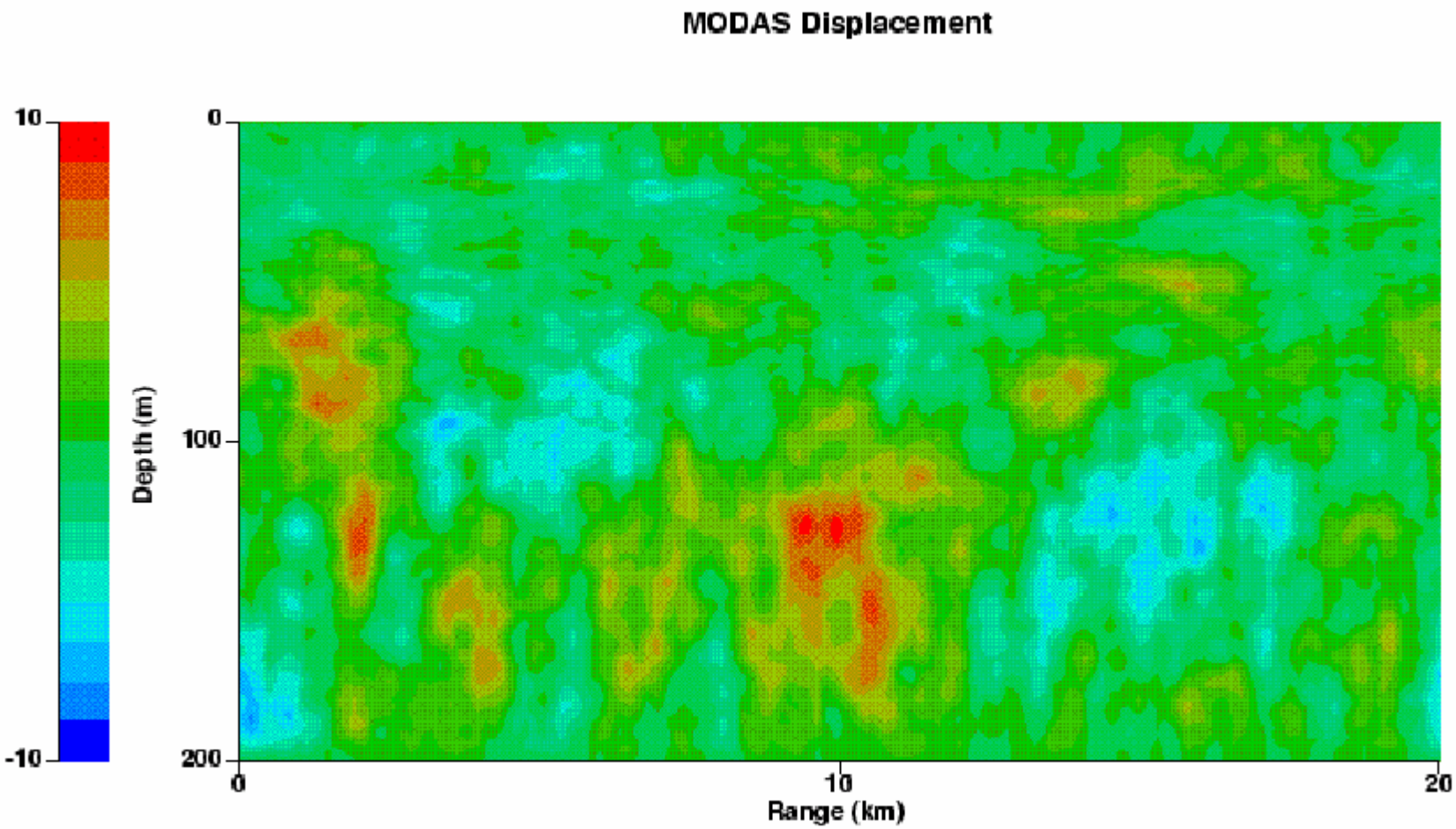
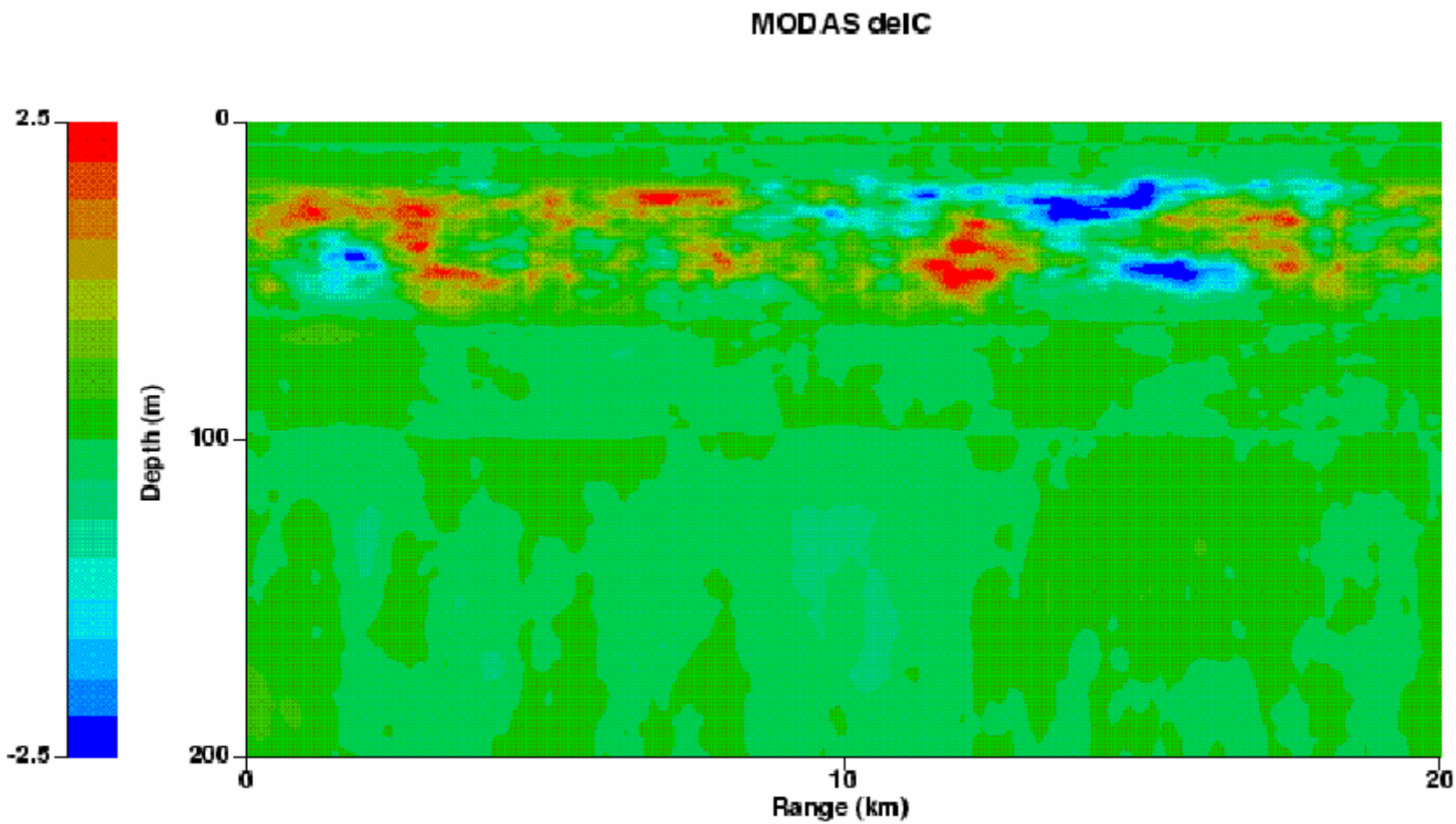
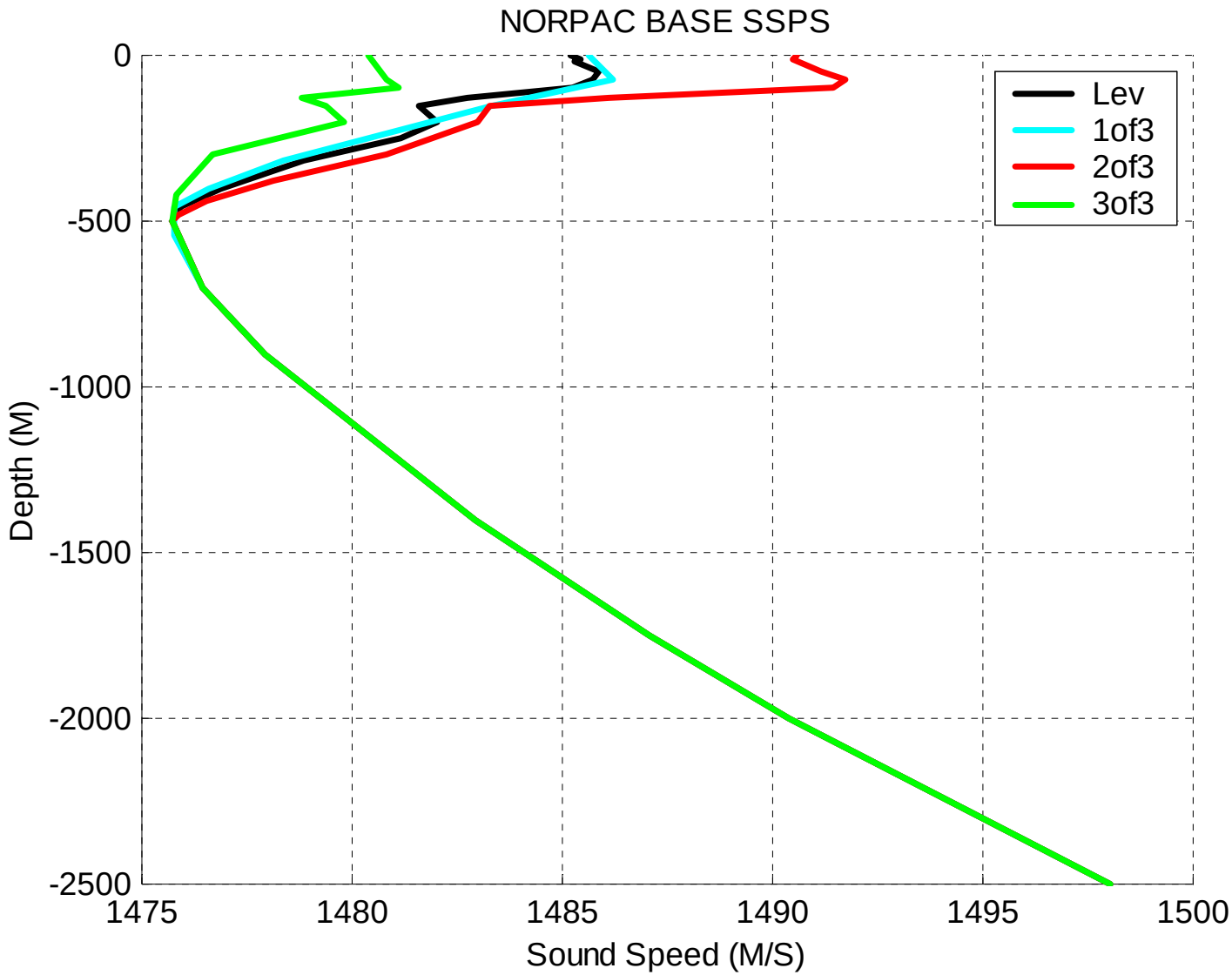
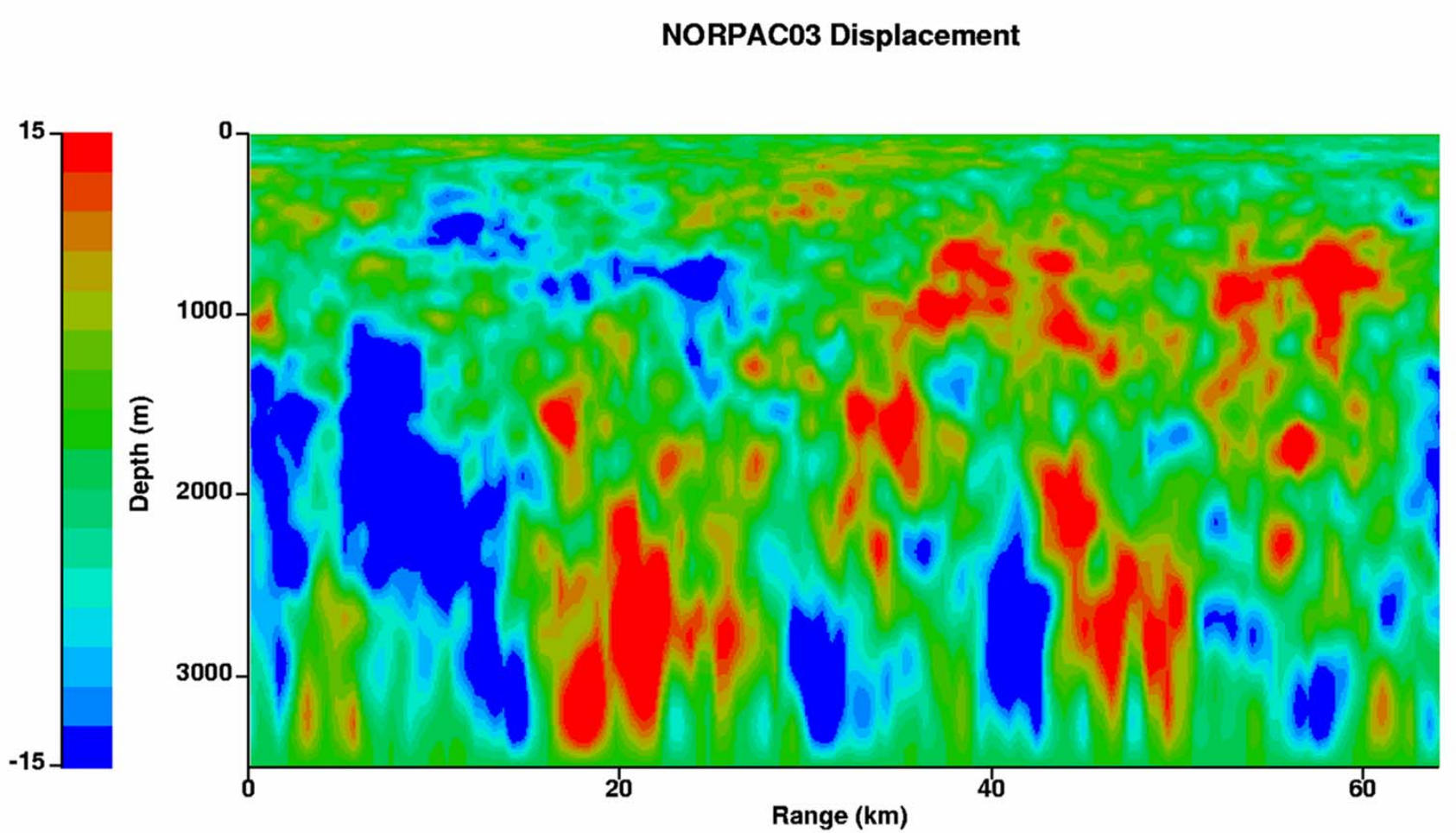
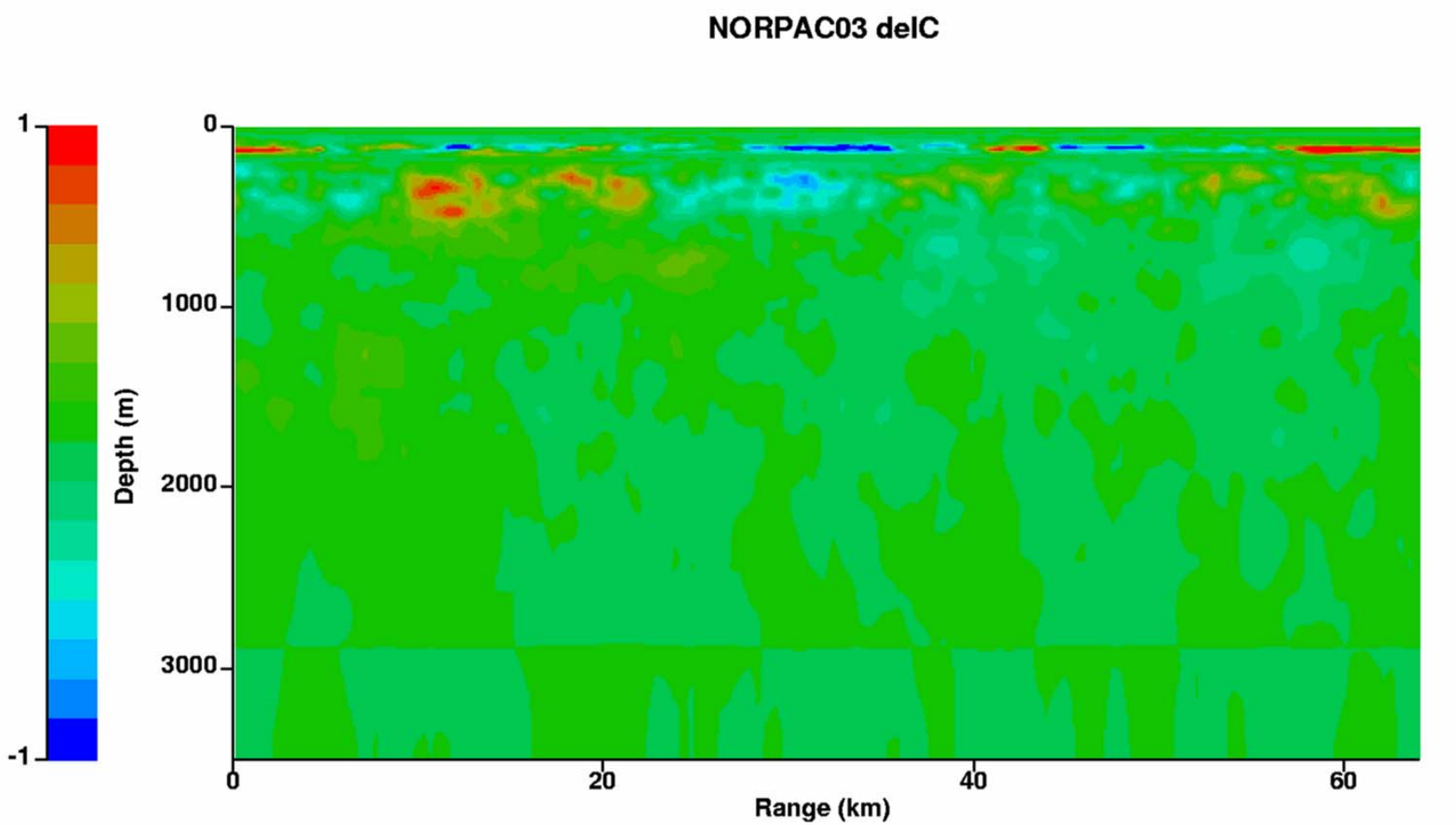

Modas (39.25 -72.4) for Uncertainty
depth [m]
0
20
40
60
80
100
120
140
160
180
200
22
23
24
25
26
27
28
sigma_t
depth [m]
1
10
100
N (cph)


MODAS Displacement
10
-10
0
100
200
Depth (m)
0
10
20
Range (km)


MODAS delC
2.5
-2.5
Depth (m)
0
100
200
0
10
20
Range (km)


NORPAC BASE SSPS
Depth (M)
0
-500
-1000
-1500
-2000
-2500
1475
1480
1485
1490
1495
1500
Sound Speed (M/S)
Lev
1of3
2of3
3of3


NORPAC03 Displacement
15
-15
0
1000
2000
3000
Depth (m)
0
20
40
60
Range (km)


NORPAC03 delC
1
-1
Depth (m)
0
1000
2000
3000
0
20
40
60
Range (km)

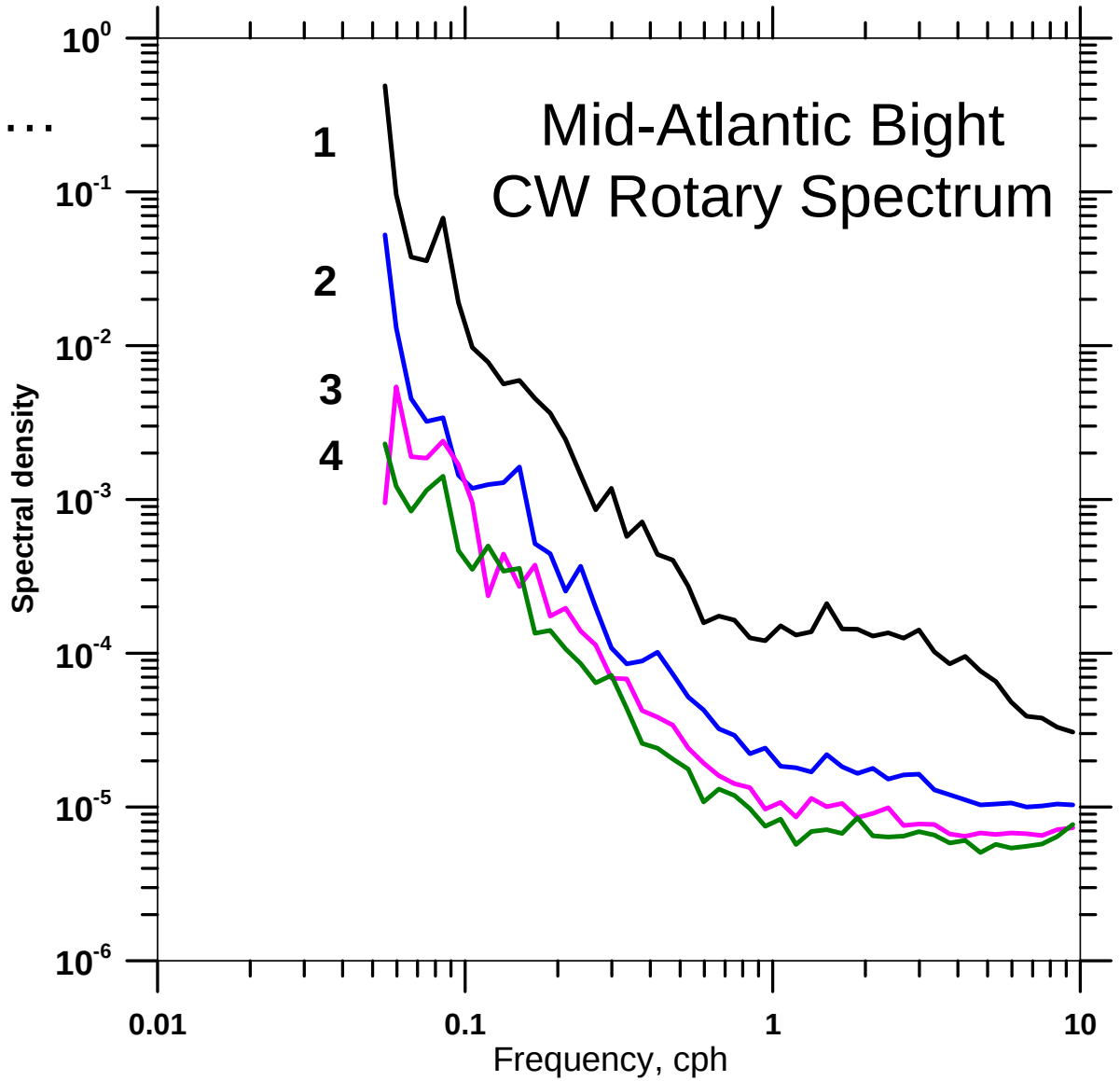
In addition to introducing variability into the acoustic propagation...

Internal Wave advances:

* Manuscript **- Refining the "Modified GM" spectrum** (Levine, 2002)
  Improved description of shallow water internal wave field
  Used moored data from Mid-Atlantic Bight (CMO, SAS Primer)

* Methodology can be applied to other archived time series data
  Improved the **internal wave climatology for shallow water**

For example…


Mid-Atlantic Bight
CW Rotary Spectrum
1
2
3
4
Spectral density
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0.01
0.1
1
10
Frequency, cph