Fluctuation of mid-frequency propagation in shallow water

DJ Tang, Frank Heneye, Zhongkang Wang, Kevin Williams, Dan Rouseff, Peter Dahl ,Jorge Quijano, and Jee Woong Choi

Applied Physics Laboratory, University of Washington

3.Motivation
4.Measurement of 2-10 kHz propagation in 80 m water.
Aug. 11 2006
5.Mean transmission loss and model/data comparison
6.Intensity fluctuation
7.Discussion and future directions

Motivation

- Intensity fluctuation creates uncertainty affecting sonar performance in shallow water
- There is little shallow water mid-frequency (1-10 kHz) data suitable for addressing fluctuations in acoustic propagation and accompanied by detailed environmental measurements
- Past work:

  Ewart and Reynolds, (1984): Deep water, scintillation

  Duda, Lynch, Newhall, Wu, and. Chiu, (2004): SCS, 400 Hz
  Fredricks, Colosi, Lynch, Gawarkiewicz, and Chiu (2005): low-frequency, New England shelf

  Pasewark, Wolf, Orr, and Lynch (2002): low-frequency, New England shelf

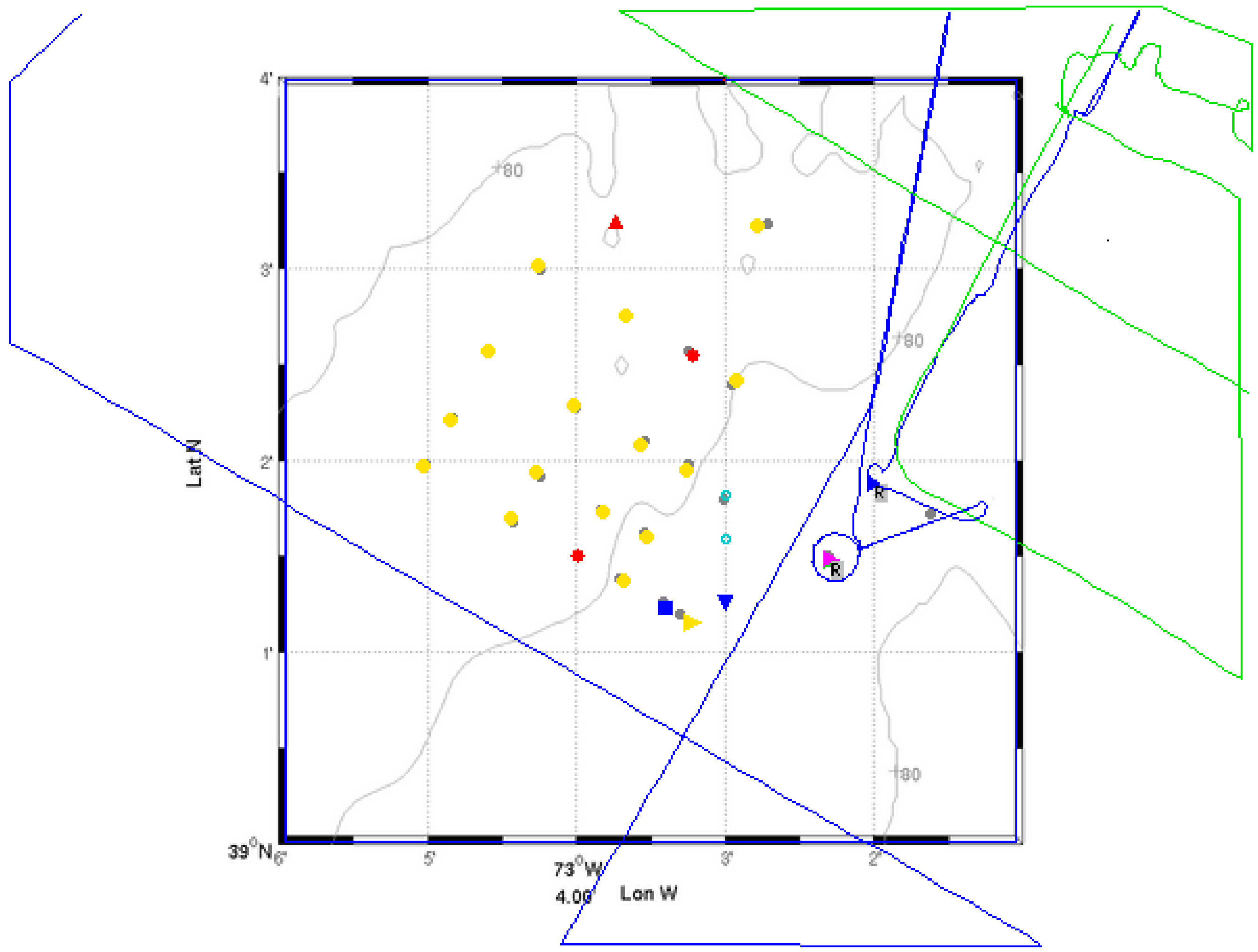
  Simmen, Flatte, DeFerrari, Nguyen, and Williams (1999): Caustics

  DeFerrari, Williams, and Nguyen (2003): caustics

  Lyons, Bradley, Culver, and Becker (2006): not yet published

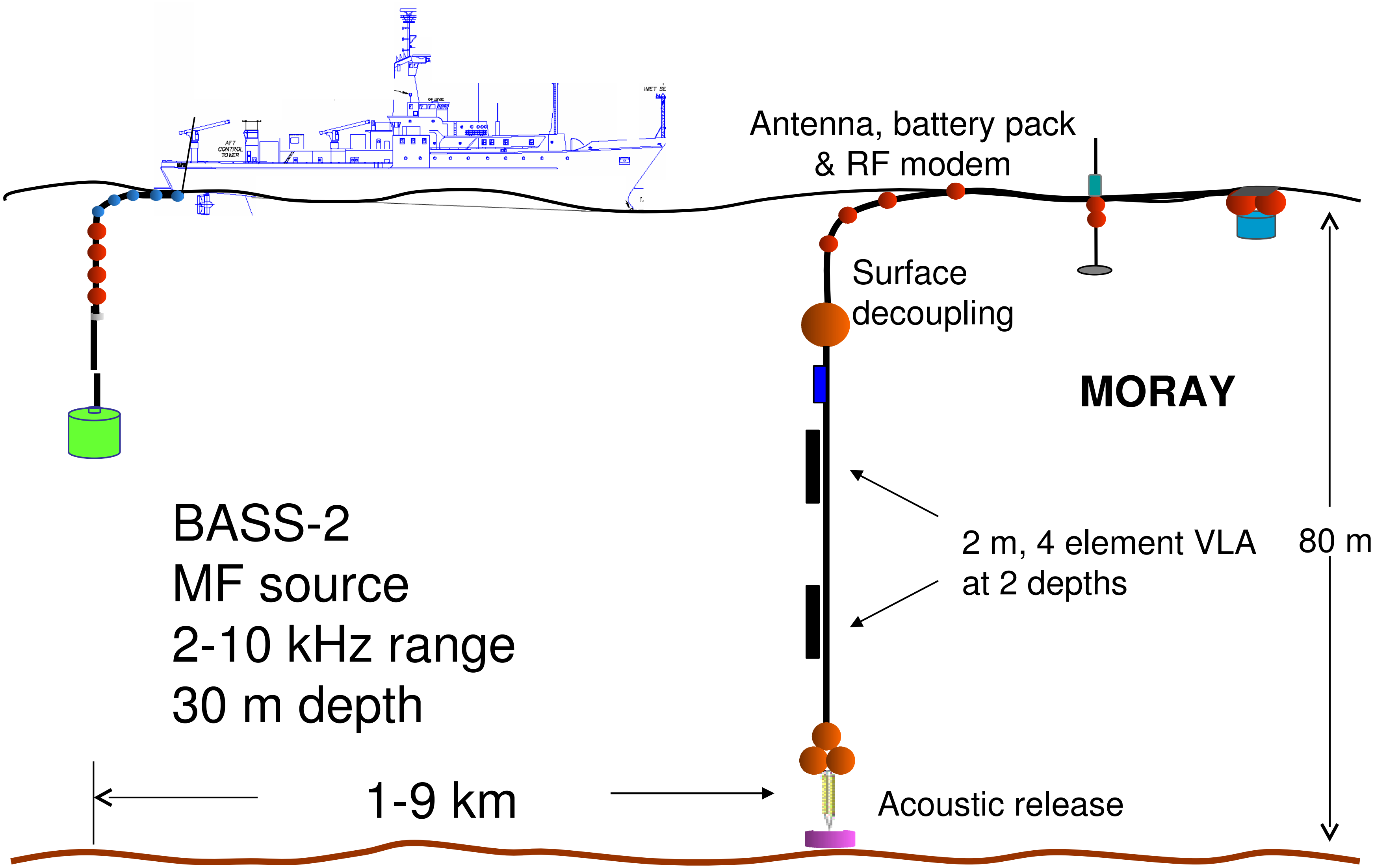
- Goal: Understand intensity fluctuations with measured environments

Measurement: 9 stations on 80m isobath, 1, 2, ..,9 km stations, 100 pings at each. 2-10 kHz 20 ms-long FM sweep



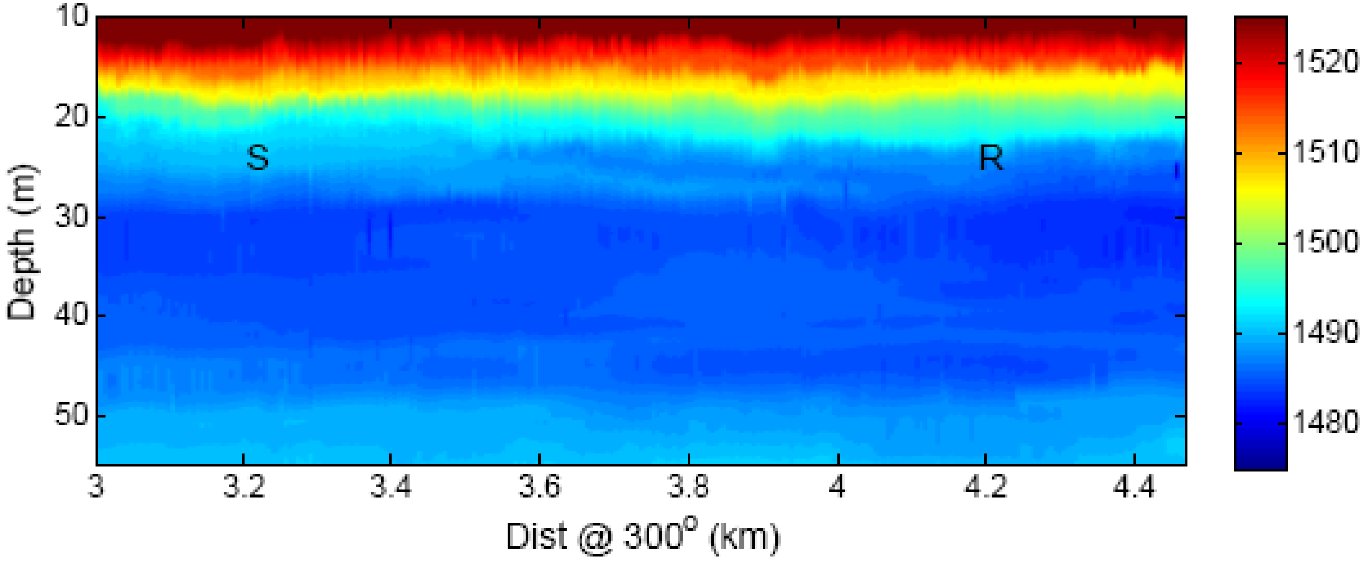
MPL/UVic and DRDC took measurements along same track on different days

Measurement



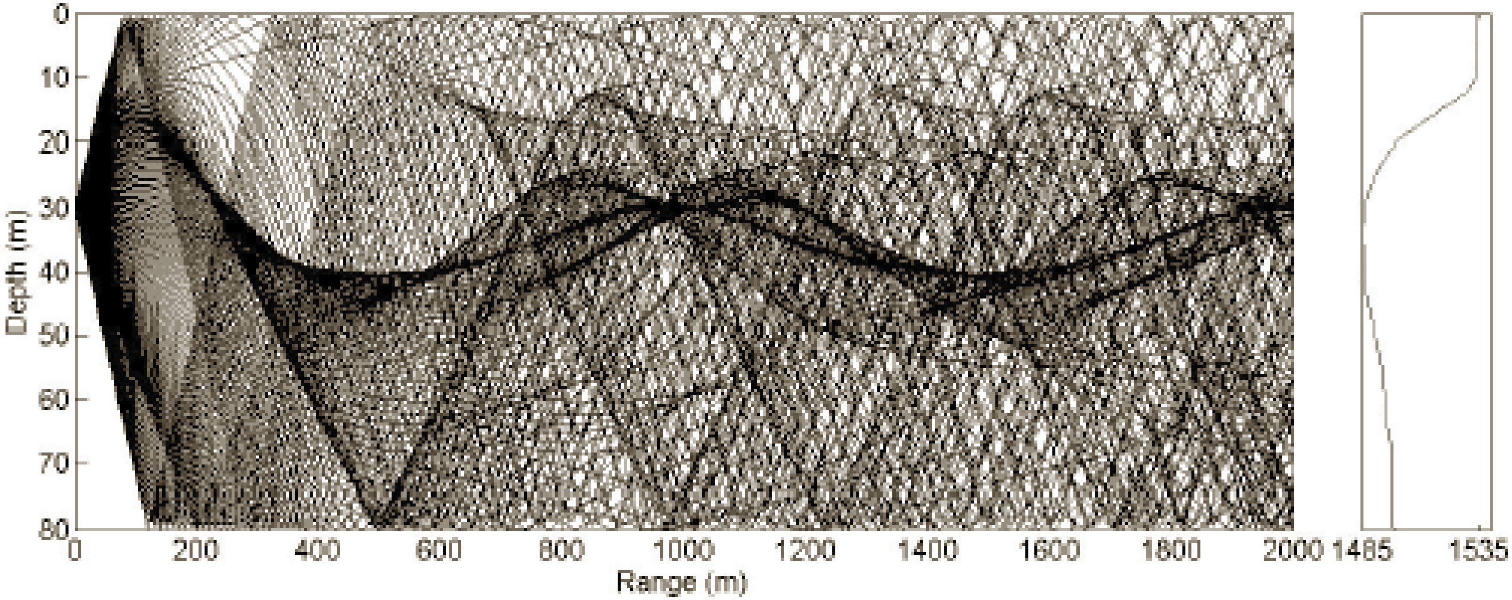
Measurement: 2D SSP measured by a towed CTD Chain at 1 km range station (*UW02, 9:20*).

- Sound channel,
- No large internal waves,
- Some spice observed
- Complex range-dependent structure

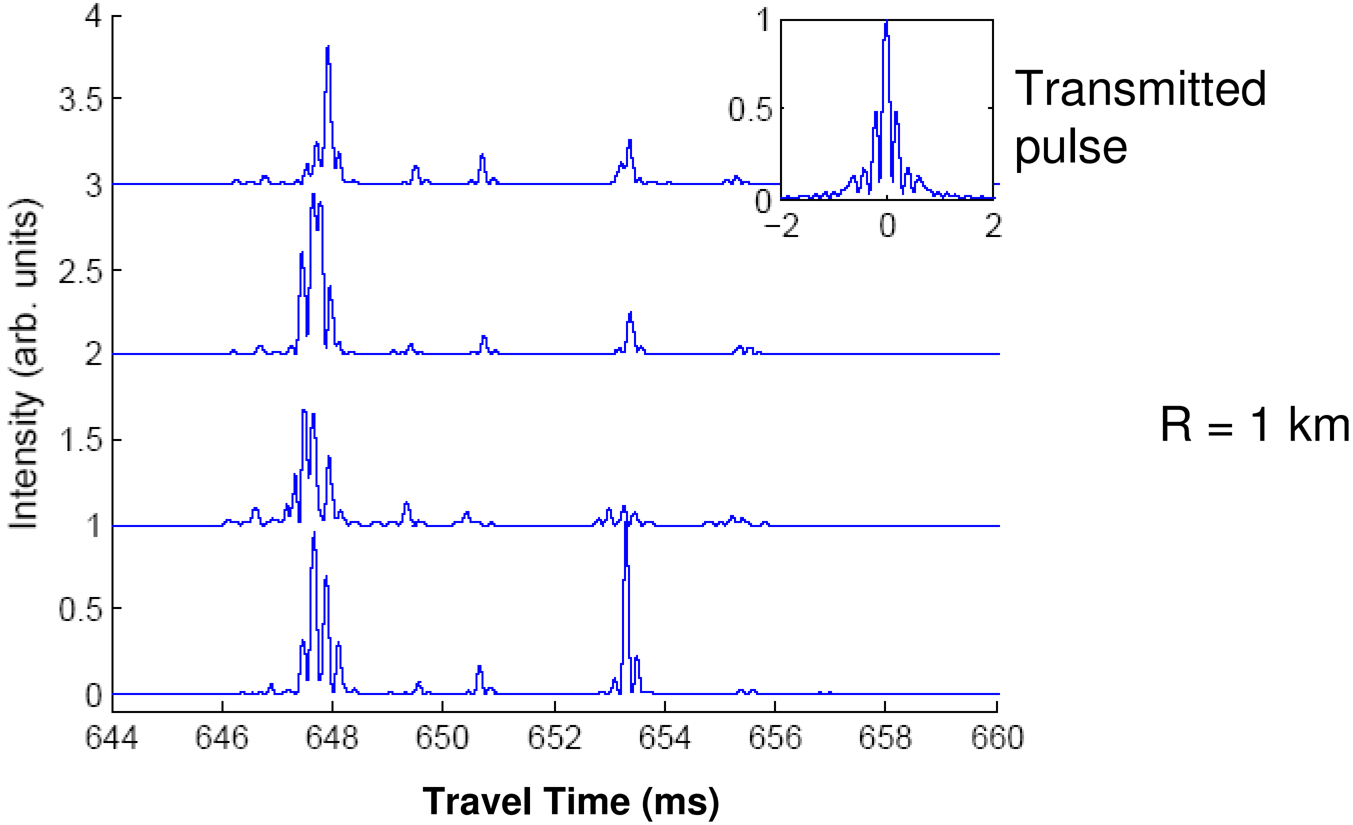


Sound Speed Profile and range-independent ray tracing to 2 km:

Propagation is dominated by trapped energy in the channel

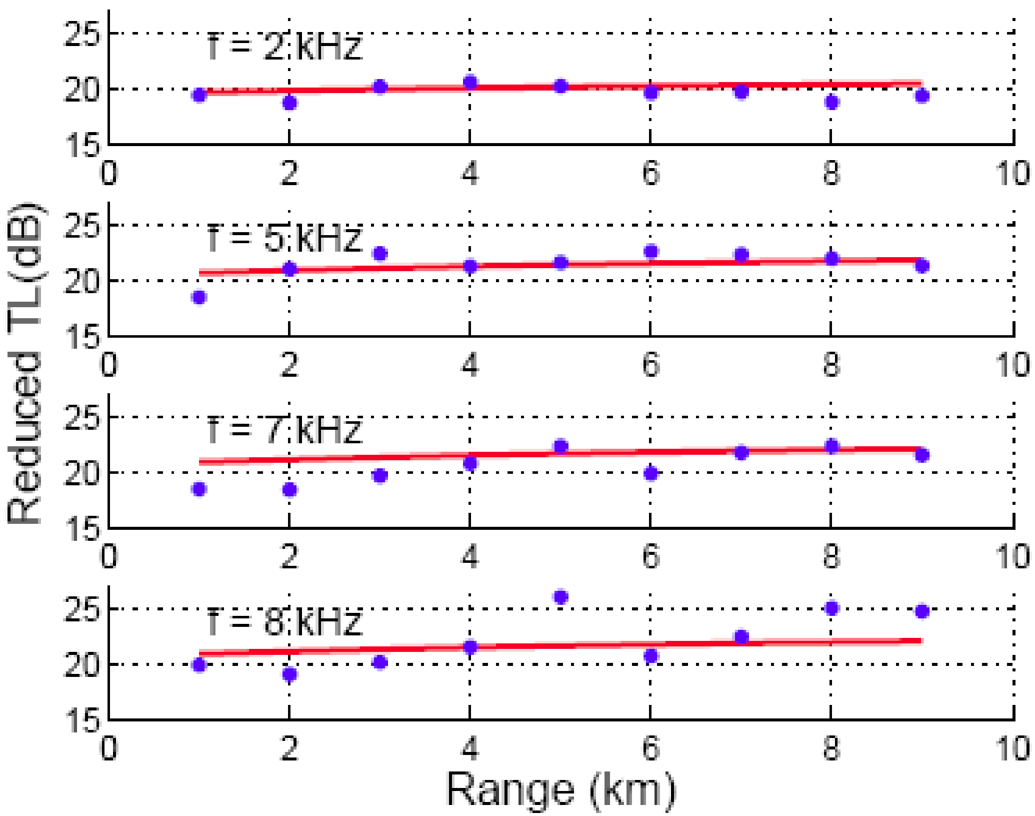


Pulse Compressed Acoustic Data



TL – model/data comparison
Environmental Input:

The mean field is modeled by spreading loss + seawater absorption with random phase modes. The mode cutoff is assumed to be at the bottom critical angle.

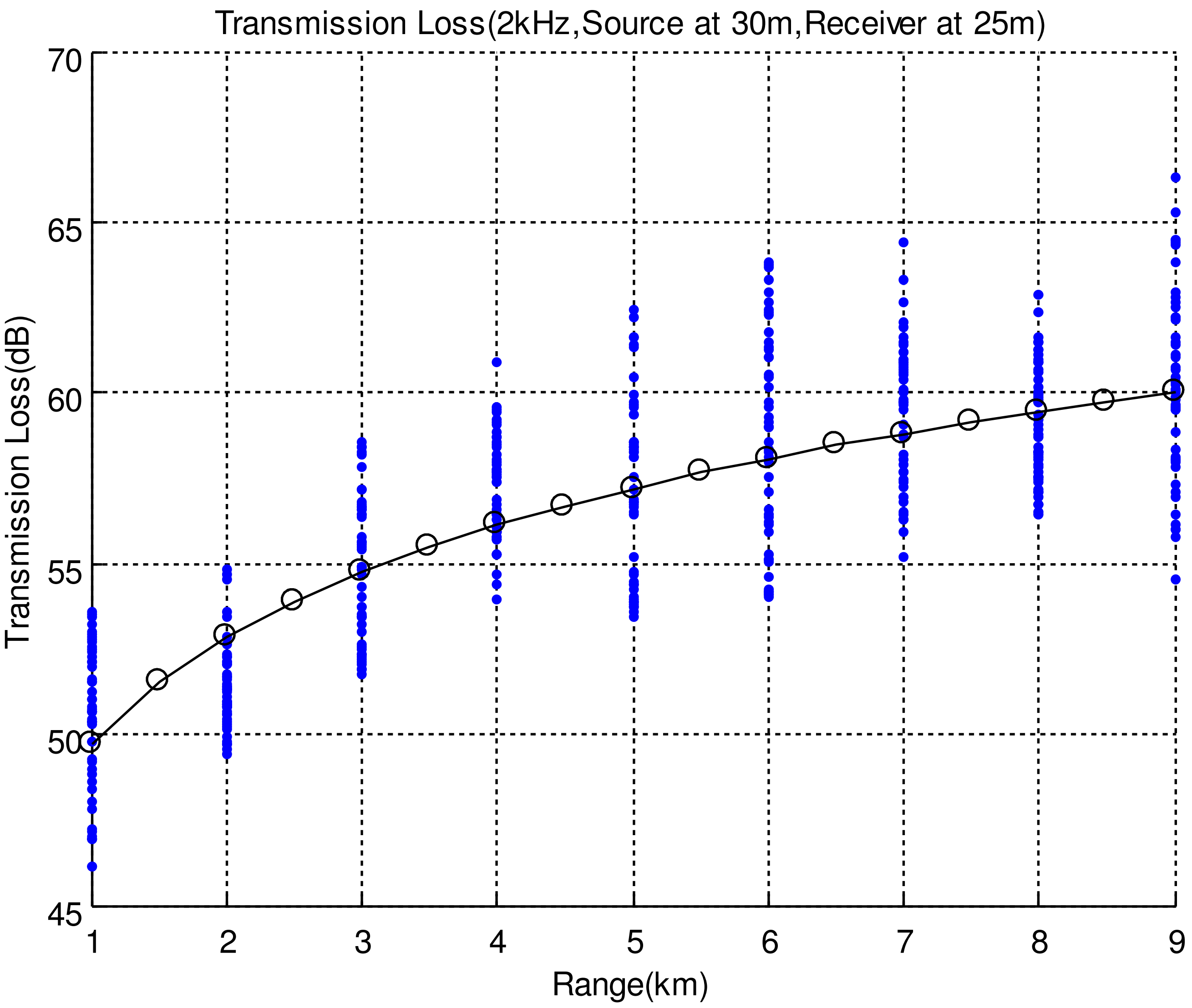


Modes computed by:

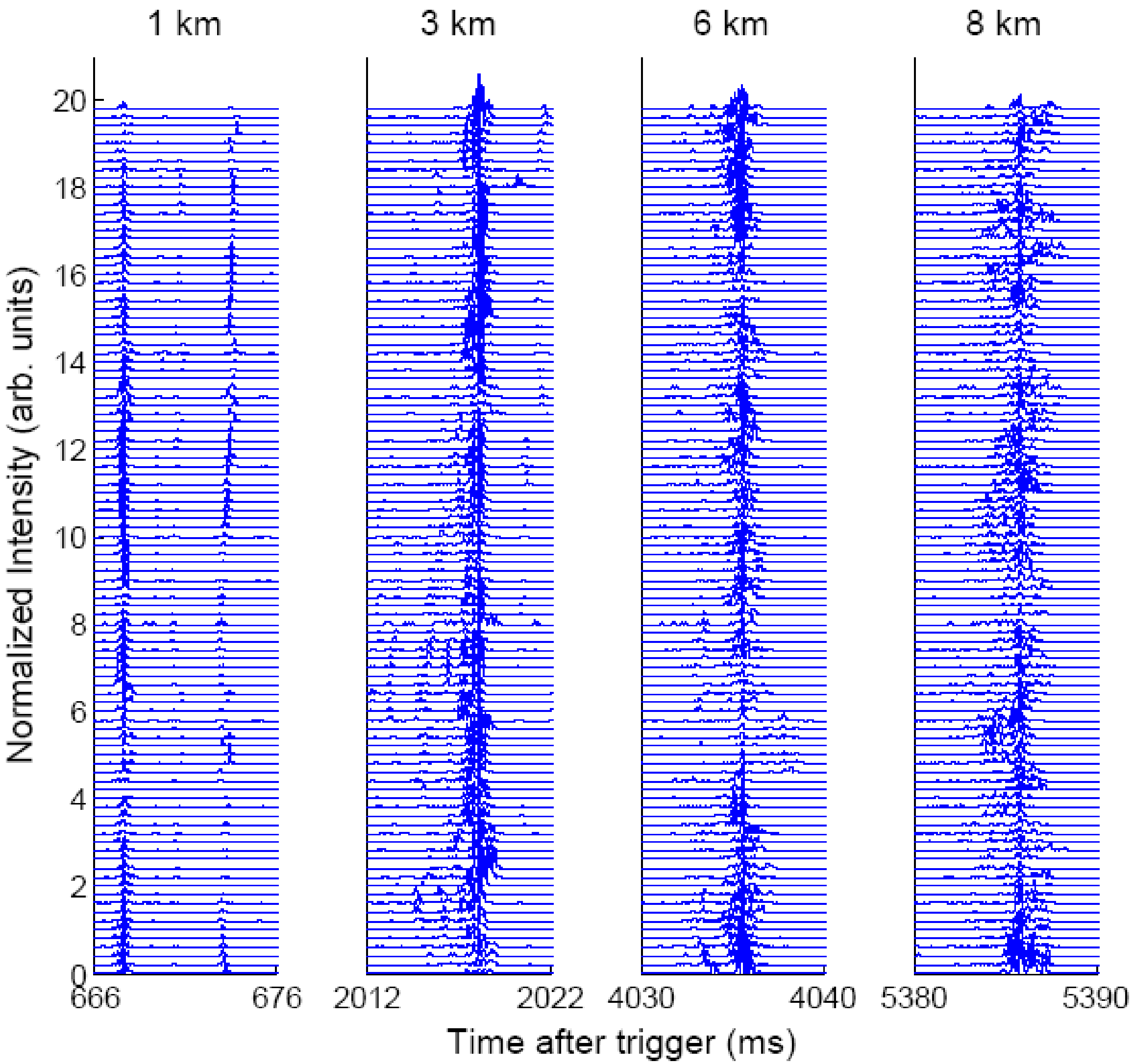
Water column: measured SSP without fluctuations

Bottom: homogeneous half-space (from SAMS *UW03/2 8:20*):

However, TL fluctuates as much as 12 dB



Ping-to-ping fluctuation at representative ranges



Broadband deep fades observed

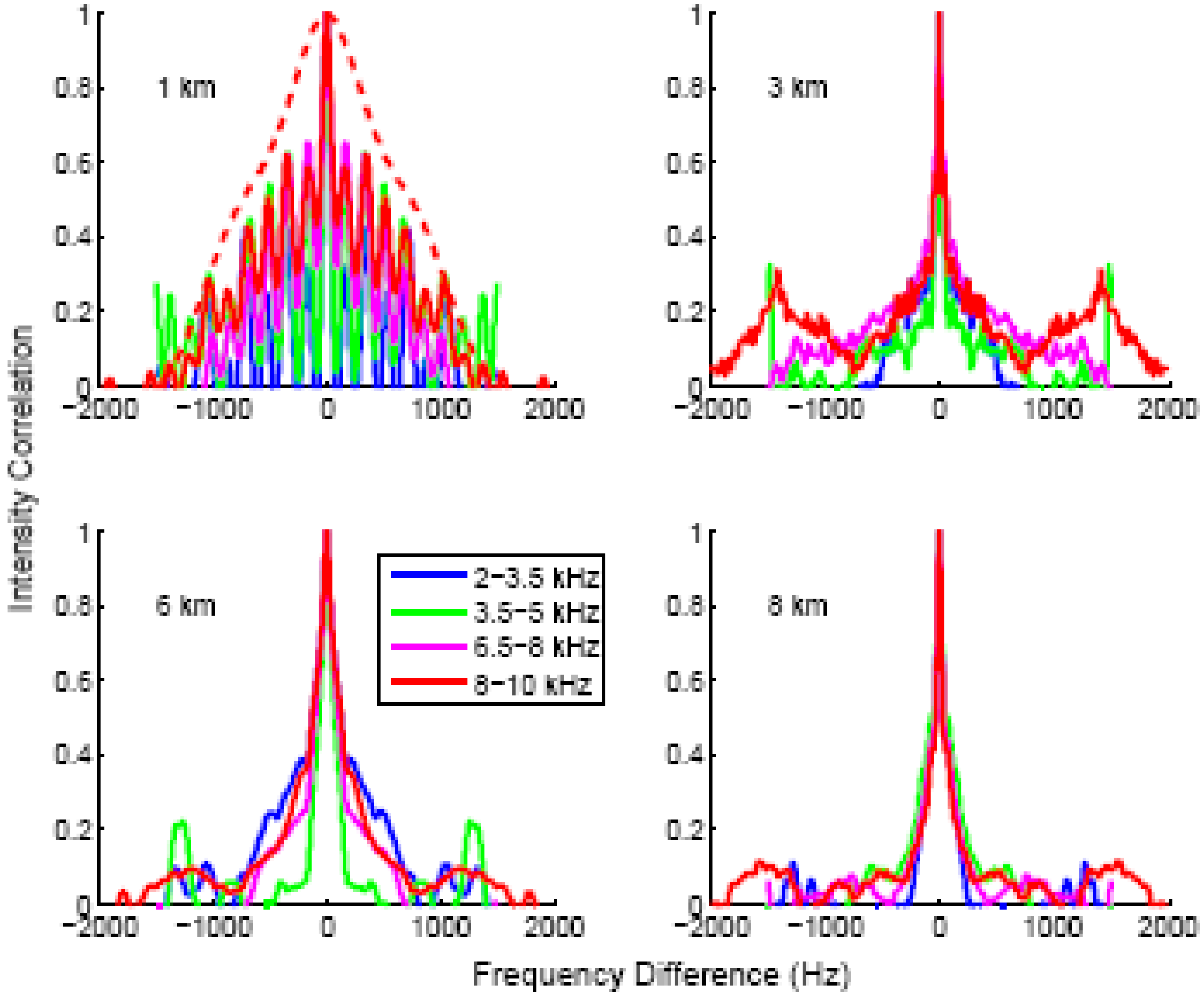
Intensity fluctuations -- scintillation index

Theories address single-frequency scintillation index

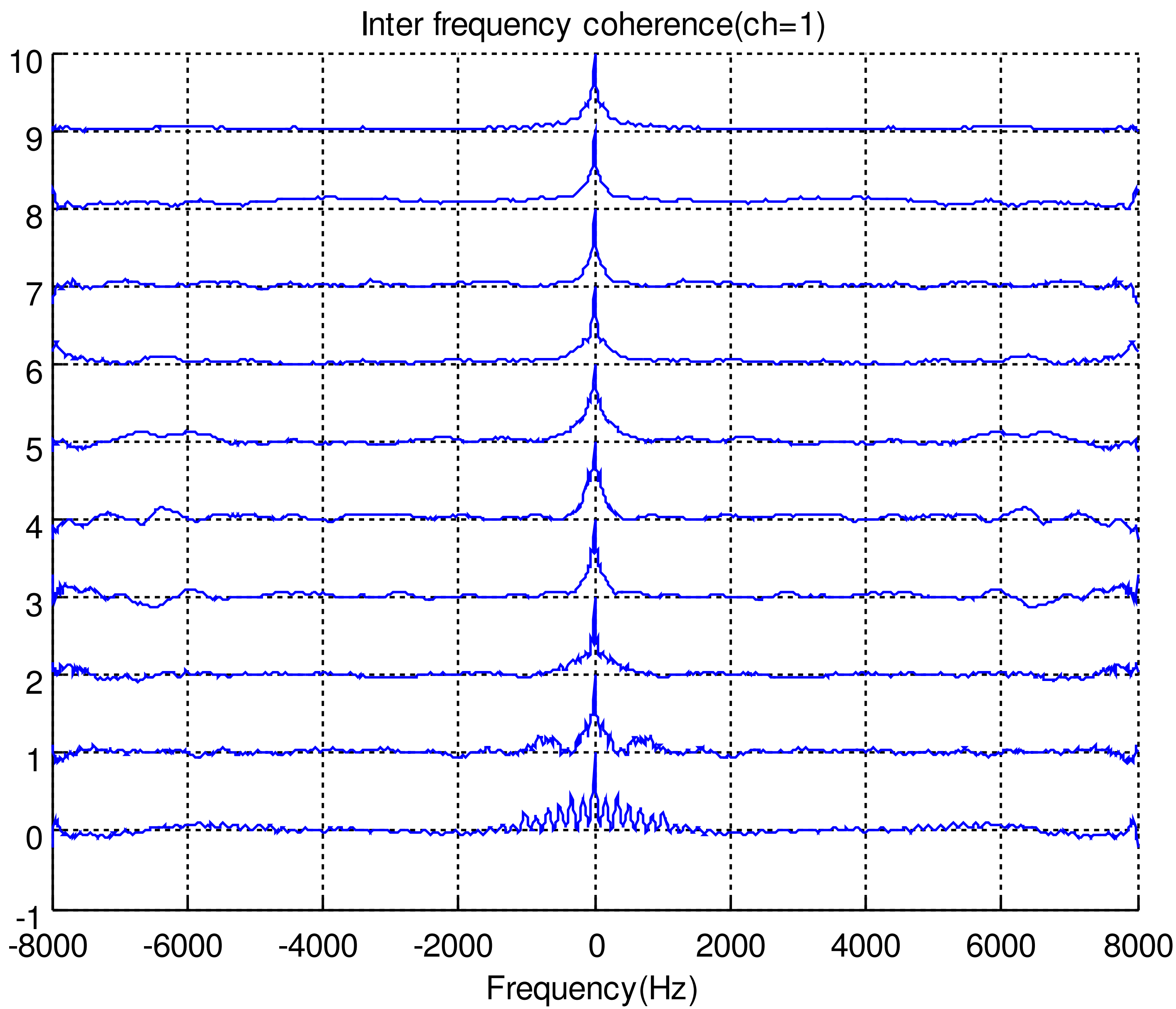
With a broadband measurement, the scintillation index generally is smaller.

How narrow does the bandwidth have to be so that the single-frequency SI is estimated?

Look at cross-frequency intensity correlation to answer this Question.



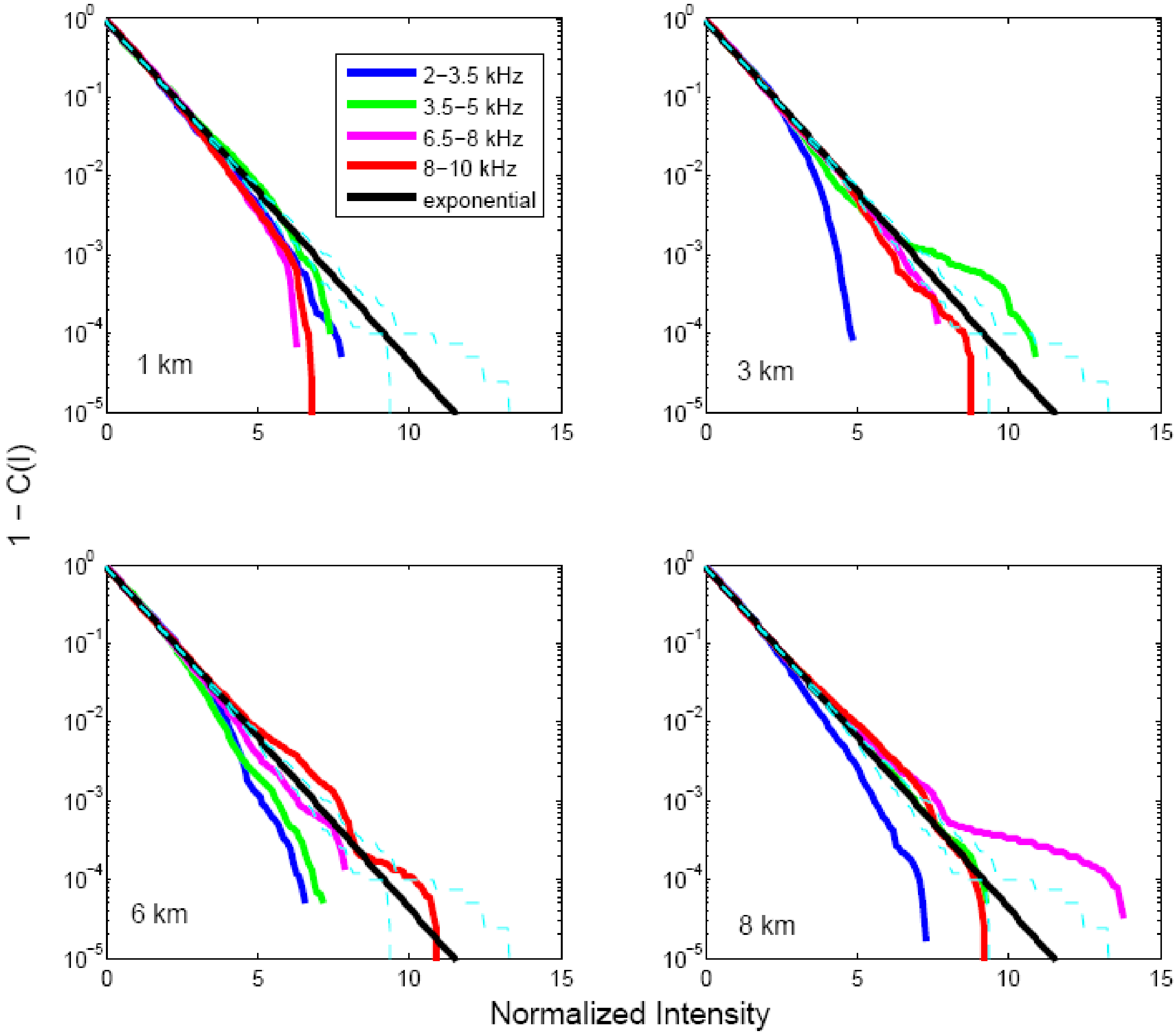
1 km
3 km
6 km
8 km
2−3.5 kHz
3.5−5 kHz
6.5−8 kHz
8−10 kHz
Intensity Correlation
Frequency Difference (Hz)
0
0.2
0.4
0.6
0.8
1
−2000
−1000
1000
2000


Inter frequency coherence(ch=1)
10
9
8
7
6
5
4
3
2
1
0
-1
-8000
-6000
-4000
-2000
0
2000
4000
6000
8000
Frequency(Hz)

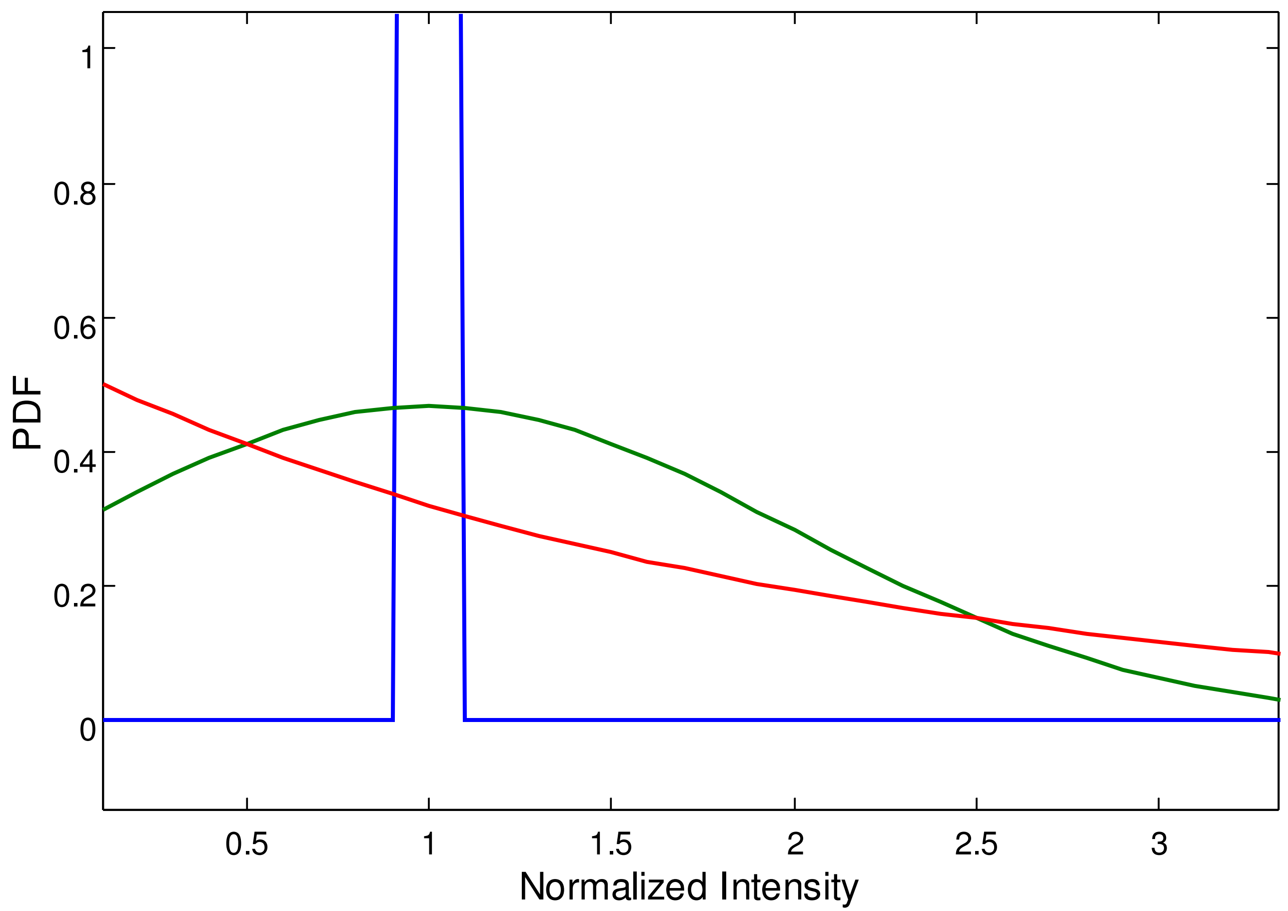
Cumulative Distribution Function (CDF): 10 Hz bandwidth. CDF's averaged over 1 kHz band.
CDF is exponential (unexpected):

Zero intensity most probable (deep fades)

SI = 1



Comparison of PDF's



Discussion

3. *Mean TL is well described by a simple incoherent mode model*

5. *Fluctuations due to water column variability*

7. *Narrow cross frequency correlation (100 Hz) for most range-frequency combinations, but much greater than the 10 Hz band used for intensity distribution*

9. *Scintillation index ≈ 1 and deep fades ⇒ nearly saturated.*

11. *Fluctuation and deep fades have implications to sonar signal processing and bottom inversions*

Future Directions – modeling observed strong fluctuations

3. *Develop a model, such as the moments equations, to quantitatively compare with data (hard)*

5. *Test the validity of assumptions made in transport theory (Dozier and Tappert) then apply to data comparison*

7. *Numerical simulations (PE) and comparison with data*

Future Directions – oceanography

3. *Internal wave spectrum to be confirmed*

5. *Is such a spectrum sufficient on time and spatial scales where acoustic predictions are needed*

7. *Is spice important. If so, how to deal with it*

Future Directions – acoustic measurement

3. *Need fixed source and receivers to measure the mean coherent field over time and space*