Uncertainty due to 3-D Coastal Oceanography with Practical Implications

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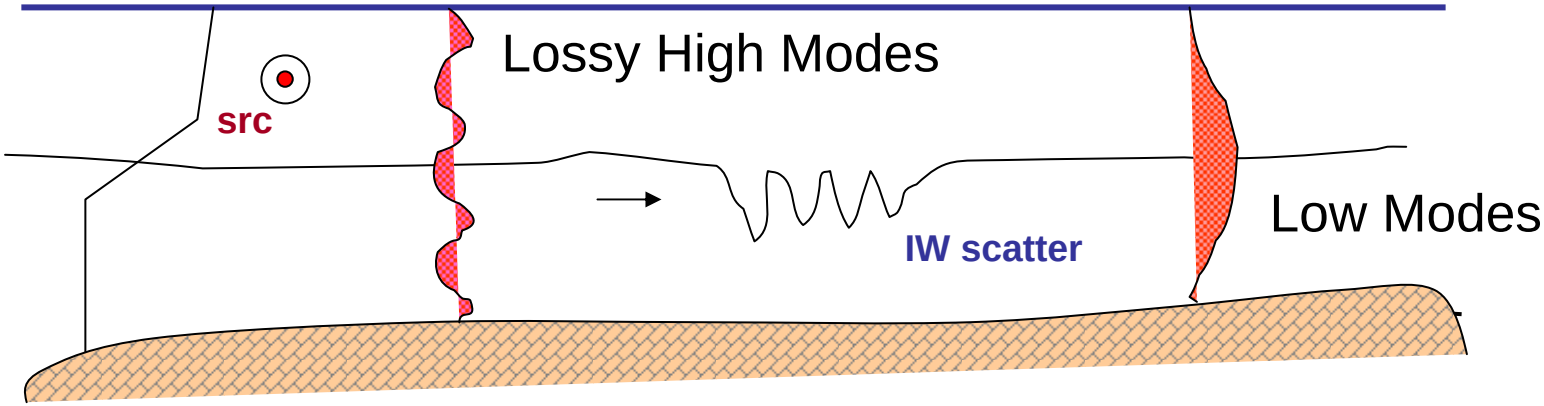
WHOI

Some Shallow Water Internal Wave and Front Induced Acoustic Effects and Their Navy Implications

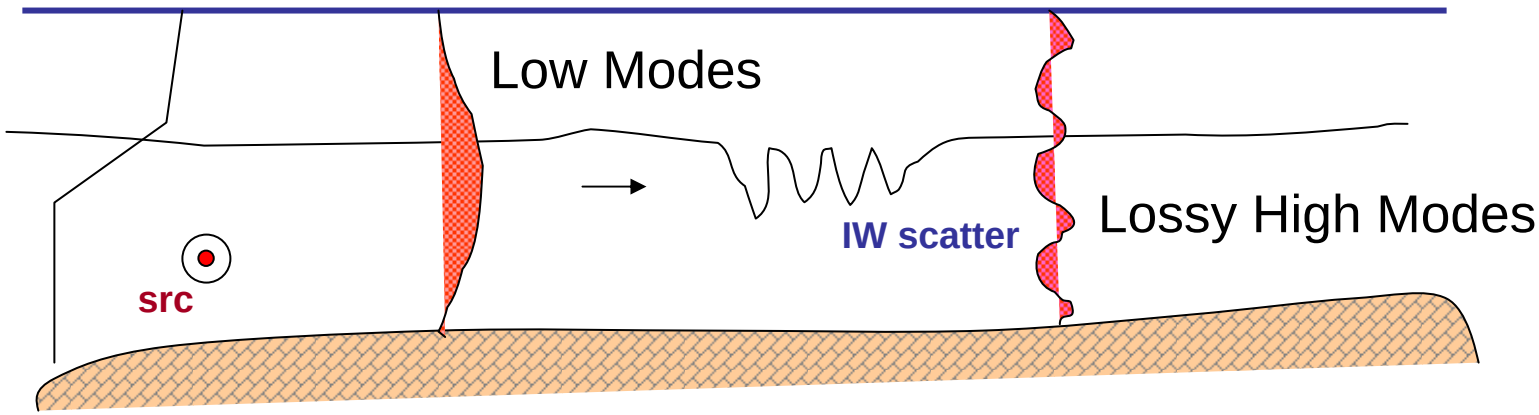
1) Across IW wave crest scattering effects
   a) Signal attenuation,
   b) Signal amplification,
   c) Increased water column illumination and
   d) Filling in the shallow water noise notch.
2) Along crest ducting between internal waves.
3) Along front and along internal wave propagation effects.
   a) Lloyd's mirror
   b) The ocean whispering gallery

* Discussion and naval implications after each

IW Induced Propagation Gain/Loss Cases



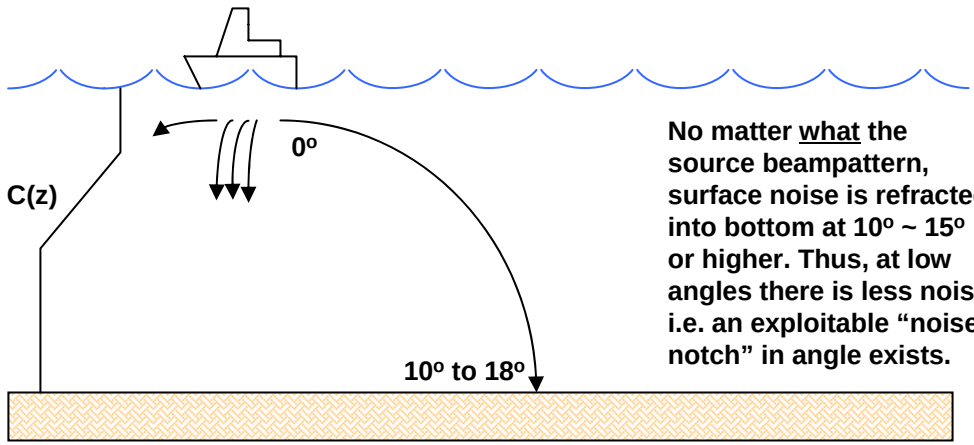
PRIMER Noise Case – Net Amplification



Zhou Yellow Sea Case – Net Attenuation

Noise notch elimination by IW mode coupling

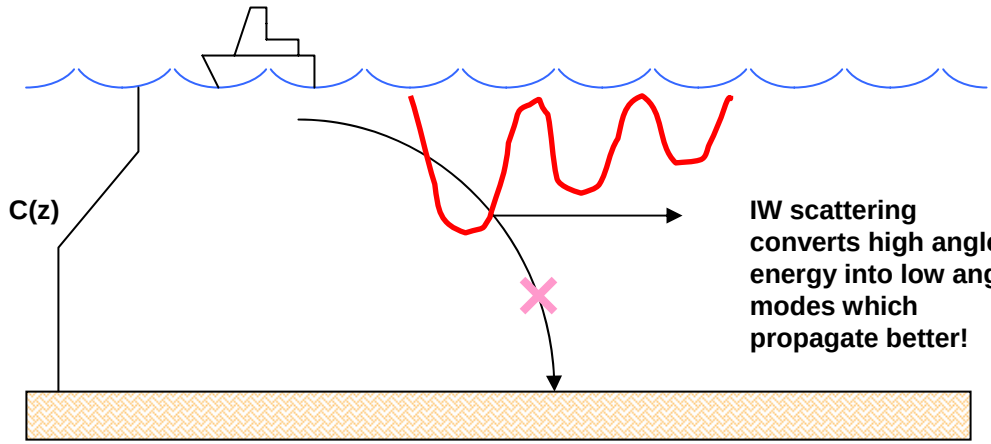
Case 1



No matter <u>what</u> the source beampattern, surface noise is refracted into bottom at 10º ~ 15º or higher. Thus, at low angles there is less noise, i.e. an exploitable "noise notch" in angle exists.

- **The above high angle noise attenuates more quickly with range.**

Case 2



IW scattering converts high angle energy into low angle modes which propagate better!

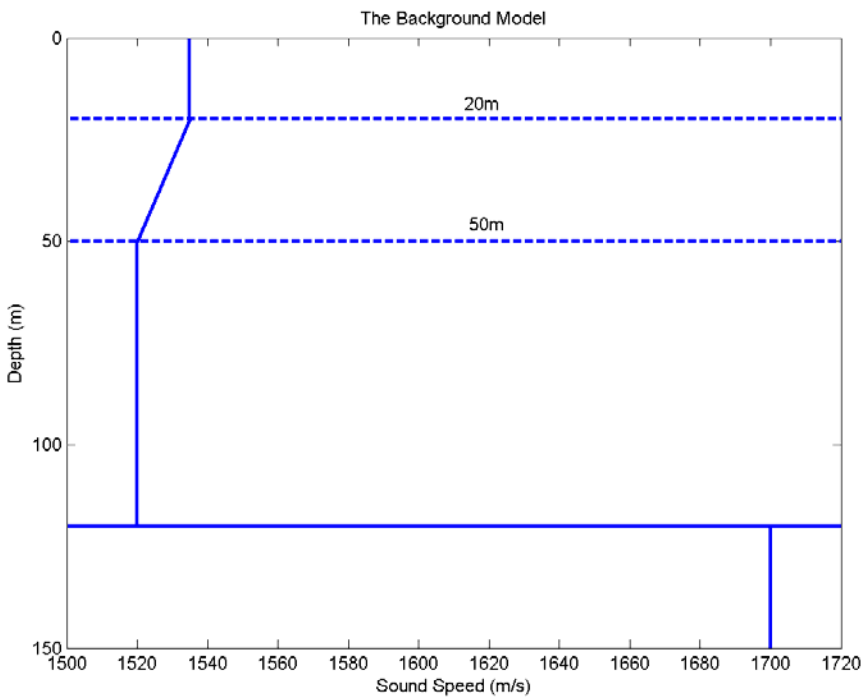
- **IW scattering can fill in the SW "Noise Notch"!!**

Implications of Across IW Crest Scattering of LF Sound

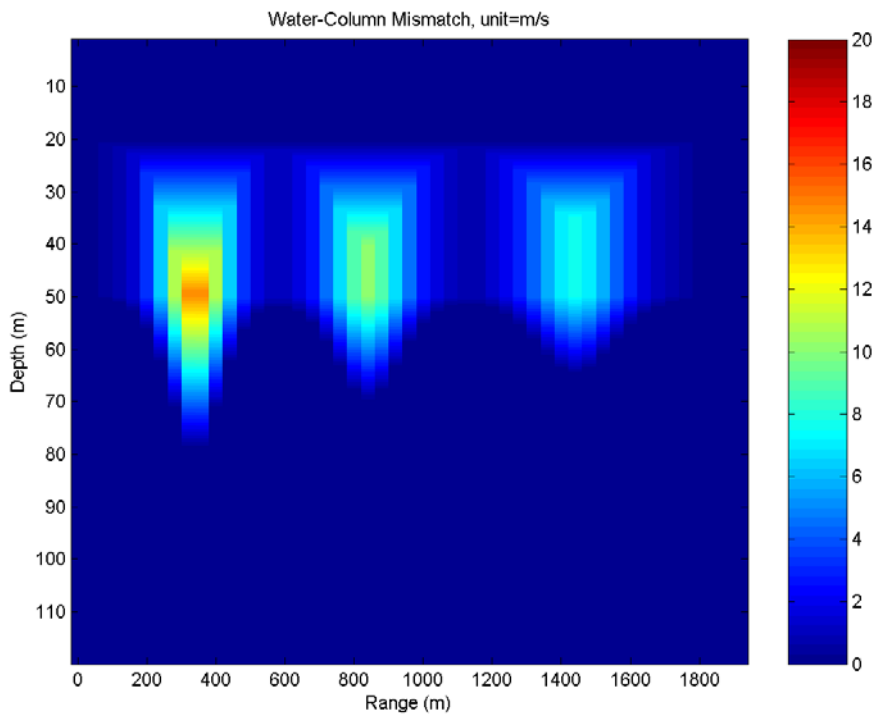
- Bias of the TL curves is the most serious effect
  - Unless you include IW's (where they are strong), you can't predict the TL at a site, even if you know the bottom!
  - If you survey the bottom, and don't account for IW's (where they are strong), you will get the wrong bottom soundspeed and attenuation.

Water column soliton train – unaccounted for water column variability !!

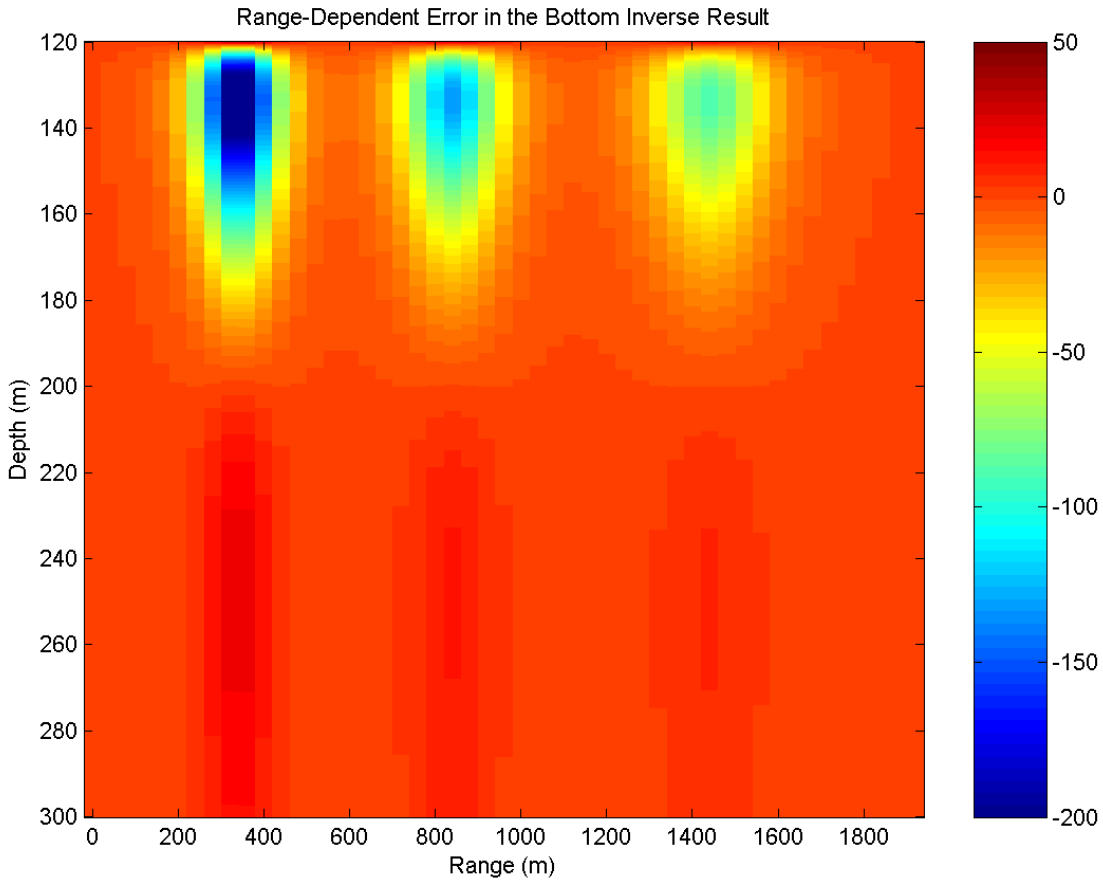
Background Model



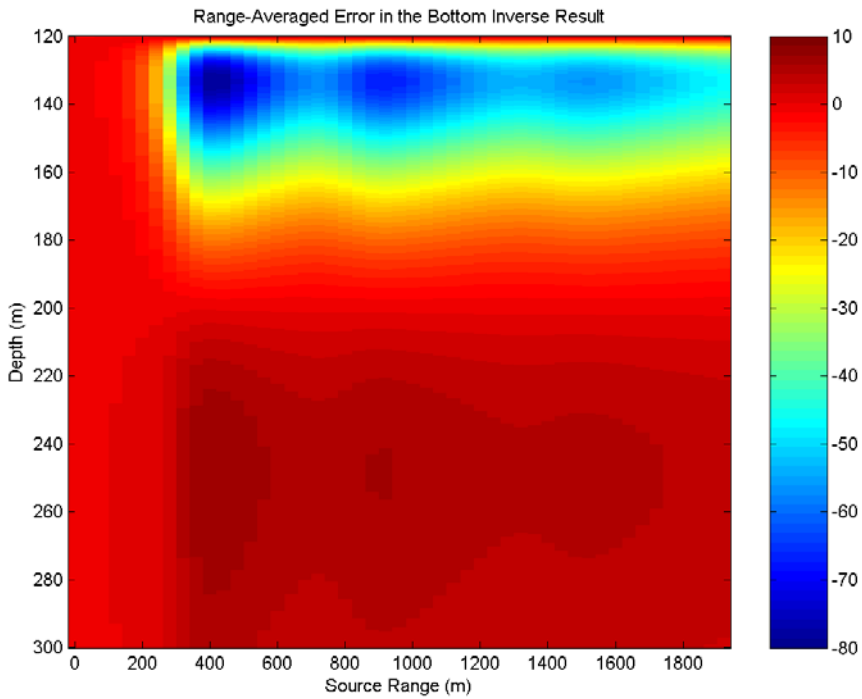
Watercolumn Mismatch

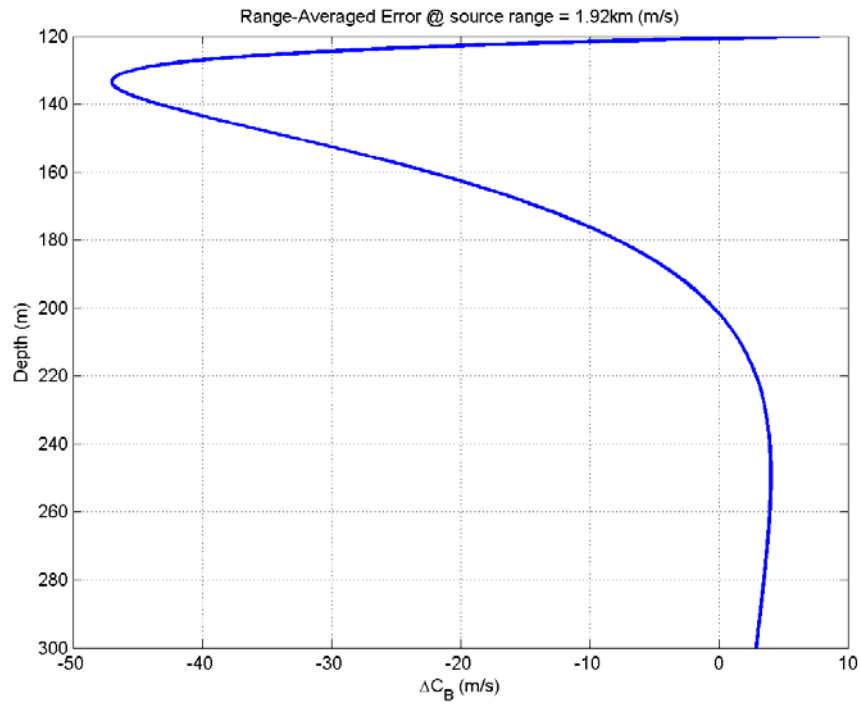


Effects of unaccounted for soliton train on bottom inverse



Range averaged error vs range and at 1.92 km





Implications of Across IW Crest Scattering of LF Sound (cont'd)

- Change in the acoustic fluctuation level is small for towed array, but large for any fixed S/R system
  - Towed array sees ~5.6 dB variation (CW) just from crossing over multipaths. IW's change this only a little for across crest geometry.
  - Fixed array would see no fluctuation for a static ocean. IW's change this to ~5.6 dB saturated scattering level.

Implications of Across IW Crest Scattering of LF Sound (cont'd)

- IW scatter induced mode "repopulation" fills in shadow areas in water column
  - Illuminates targets normal TL calculations would say are hidden
  - Fills in SW noise notch
  - Can potentially correlate signal and noise in an area (affects processing schemes)

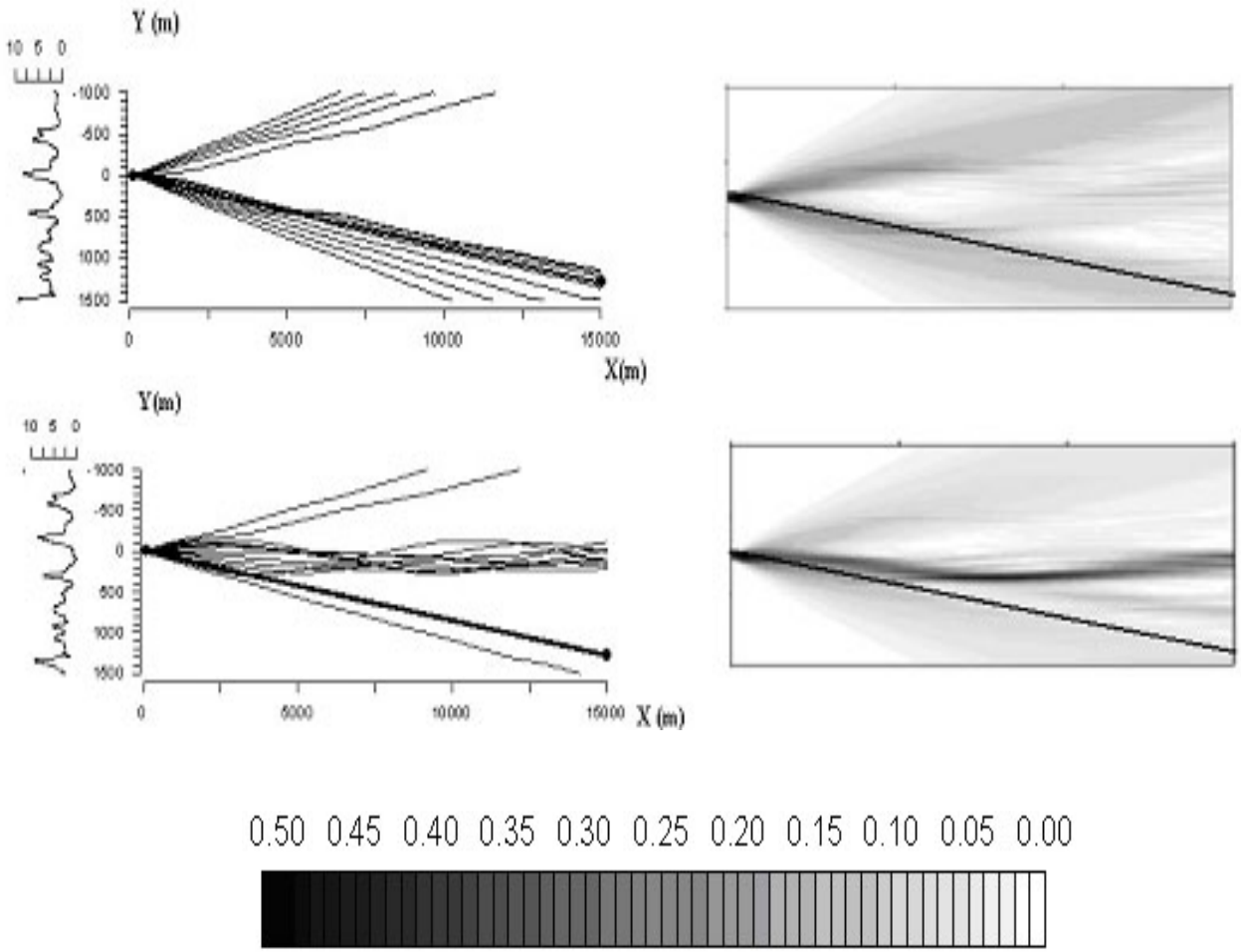
3-D acoustics effects due to 3-D oceanography

- Ducting between solitons
- Lloyd's mirror reflections from fronts and nonlinear internal waves
- Whispering gallery mode ducting between bathymetry and fronts/IW's

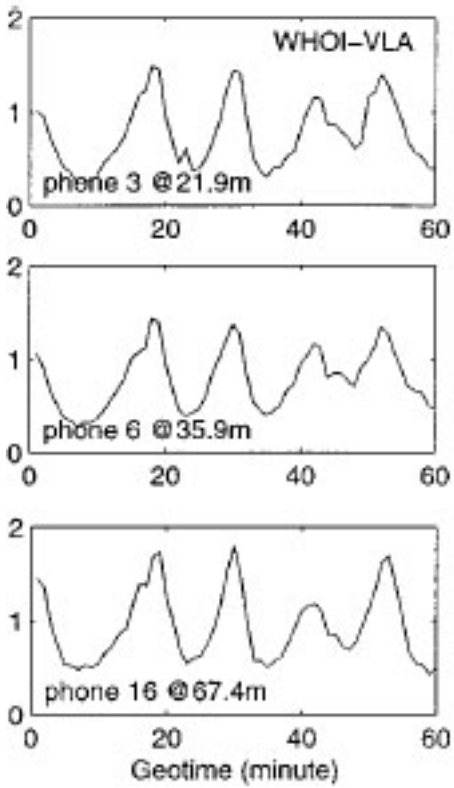
Along I.W. Crest and Along Front Effects (explanation of picture slide)

- Sound ducting between solitons has been experimentally observed, and is described in a current paper (Badiey et al, submitted to JASA 2004)
  - Is probably a common effect
  - Is a strong effect (~ 8-10 dB extra SNR detected)
  - We have first order understanding, are fine tuning our picture of this

Ducting and antiducting due to internal solitary waves

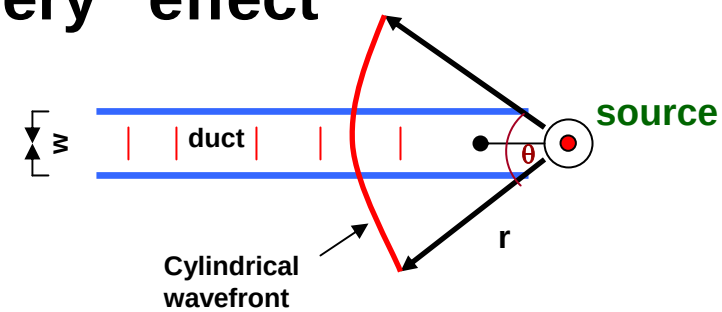


Experimentally Observed Ducting Signals in SWARM



Mean intensity increase due to ducting (no spreading vs. cylindrical spreading)

For IW duct and frontal "whispering gallery" effect



R = Ratio of areas = $r\theta_c/w$

IW duct (r_1=20 km, w = 1 km, θ_c = 7.5^o)

10 log R = 7.18 dB

WG for Front (r_1=20 km, w = 3 km, θ_c = 15°)

10 log R = 5.4 dB

3-D acoustics effects due to 3-D oceanography

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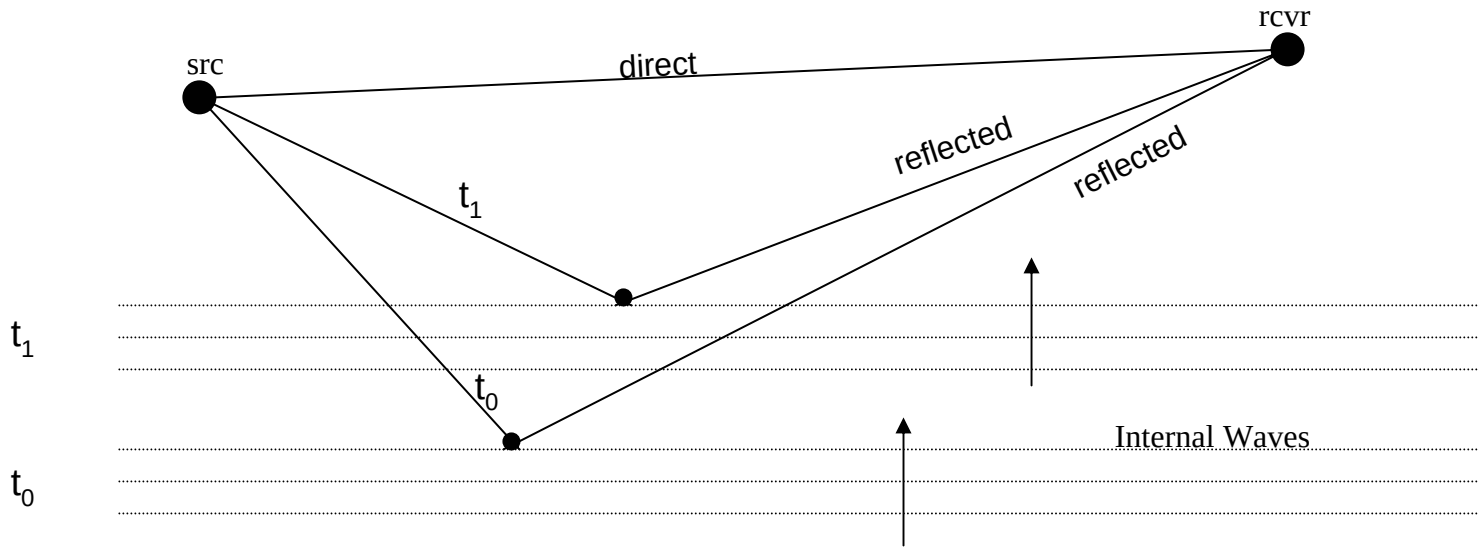
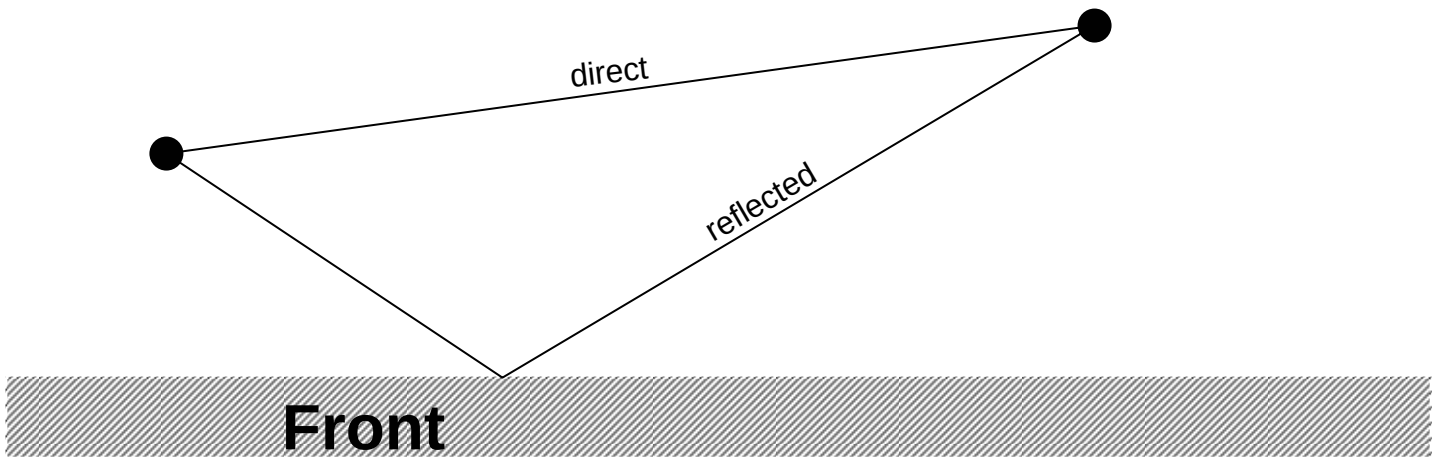
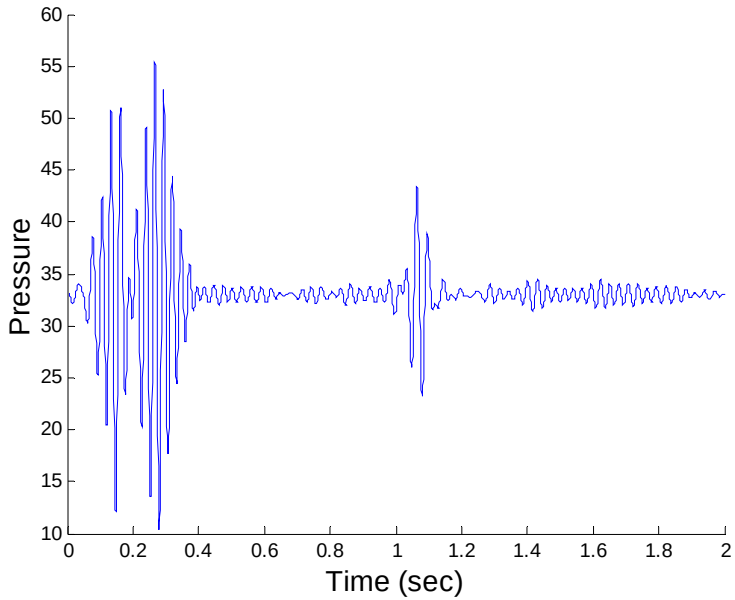
- Lloyd's mirror reflections from fronts and nonlinear internal waves
- Whispering gallery mode ducting between bathymetry and fronts/IW's

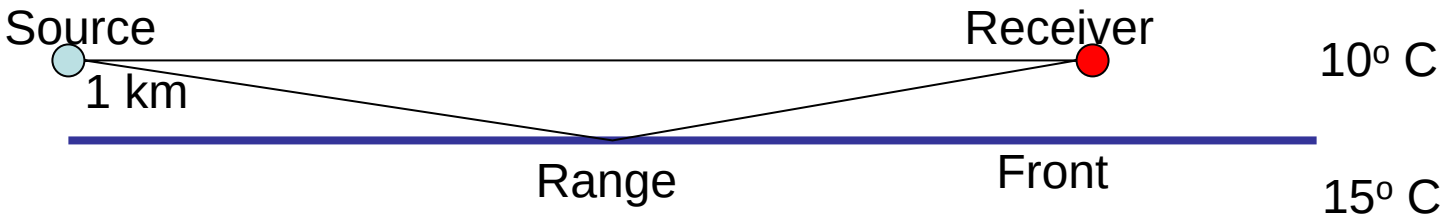

rcvr
src
direct
reflected
reflected
t_1
t_1
t_0
t_0
Internal Waves

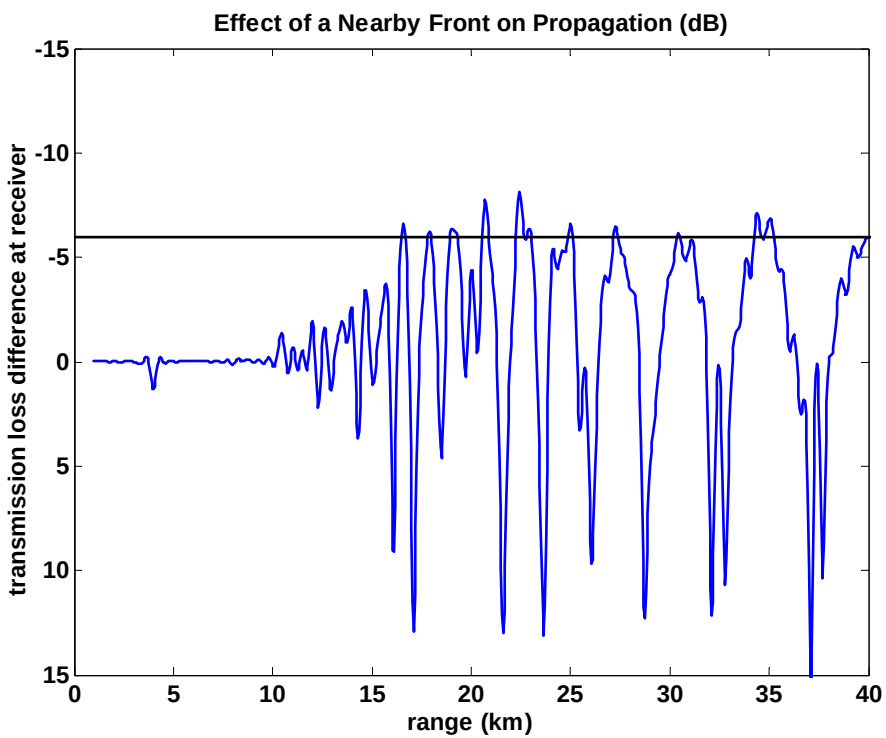

direct
reflected
Front

Possible time domain observation of Lloyd's mirror reflection off of shelfbreak front in SWARM



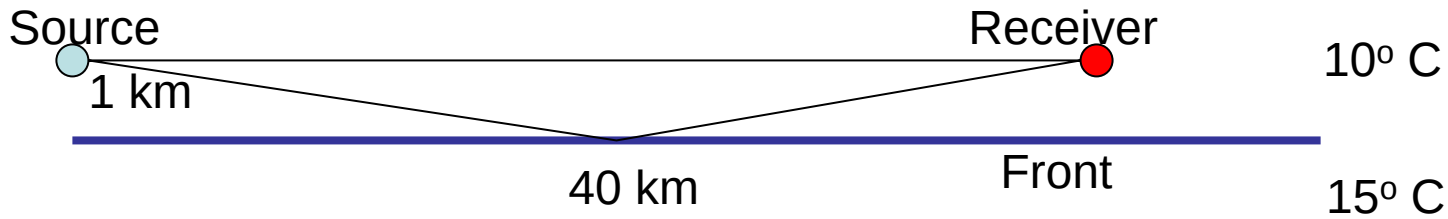
Frontal Reflection Effects on CW TL

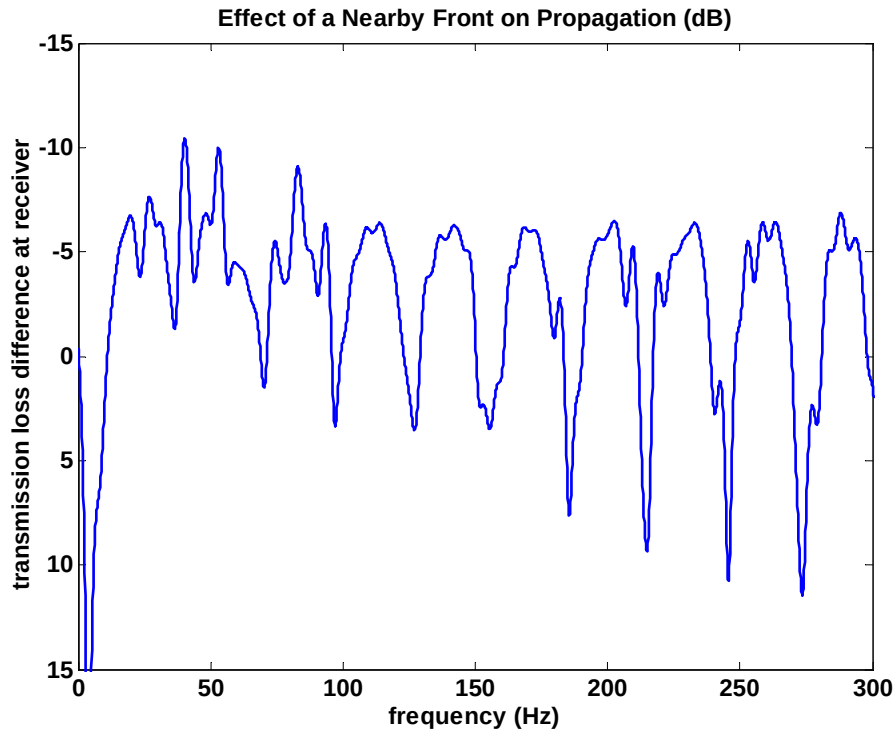




Fixed frequency= 200 Hz
Varying range

Frontal Reflection Effects on CW TL





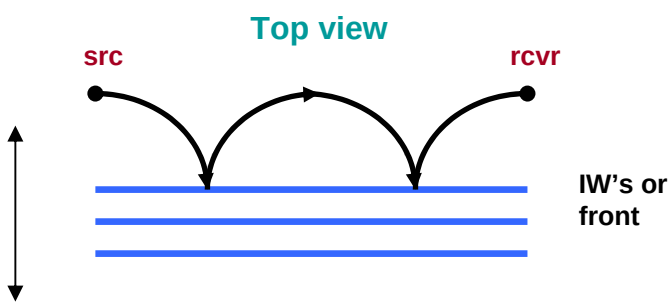
Fixed range = 40 km
Varying frequency

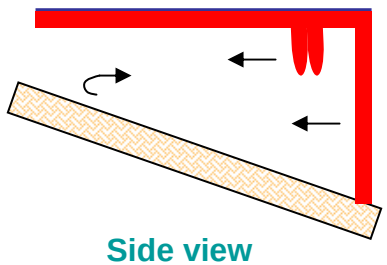
3-D acoustics effects due to 3-D oceanography

- Ducting between solitons
- Lloyd's mirror reflections from fronts and nonlinear internal waves
- Whispering gallery mode ducting between bathymetry and fronts/IW's

Hypothetical Whispering Gallery Modes

- With a seaward bathymetric slope, the Lloyd's mirror geometry becomes a "Whispering Gallery" duct
- This is potentially a strong duct
- Seek experimental verification – along front propagation





Whispering gallery modes due to front or IW's

Implications of 3-D SW acoustics effects discussed

- Have seen 6-8 dB fluctuation in broadband signals due to internal wave ducting
  - This is in addition to the normal multipath interference fluctuations, so will be added to these on towed array
  - See 6-8 gain, then large null, so get a strong fade in and out of signal
  - Gives beam wobble of +/- 5 degrees (Finette)
  - Gives smaller usable array correlation length (Finette)
  - Along crest IW ducting also affects PL estimates and bottom parameter surveys, like across crest case

Implications of 3-D SW acoustics effects discussed (cont'd)

- The side reflection and ducting by fronts and IW's are new effects that need further experimental verification and quantification
  - They can produce a substantial increase/decrease in sound level, and can potentially be exploited tactically

Some conclusions and recommendations (JFL)

- Continue work to make “Atlas of coastal IW’s”, with eye to how these affect acoustics and other Navy interests
- Develop tactical “rules of thumb” based on what we have learned from 6.1 basic research
- Continue looking at how coastal IWs and fronts affect acoustics (NJ 2006 experiment and others)
- Determine which parts of coastal ocean variability are uncertain, and which might be predictable