



# Propagating Scattering Strength and Incident/Scattered Field Uncertainty Through to Reverberation Uncertainty

Kevin LePage

NRL

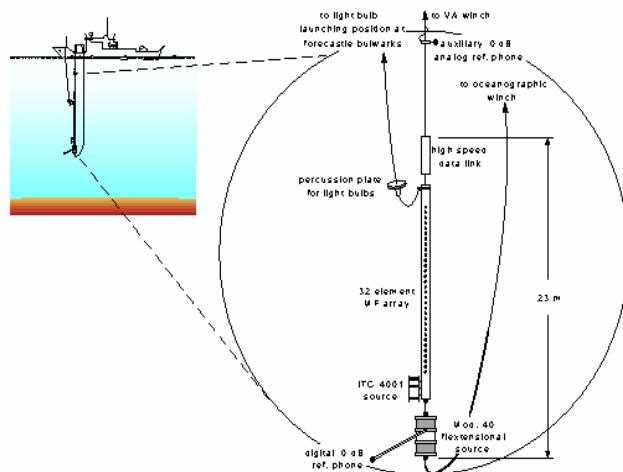


# Uncertainty of Reverberation

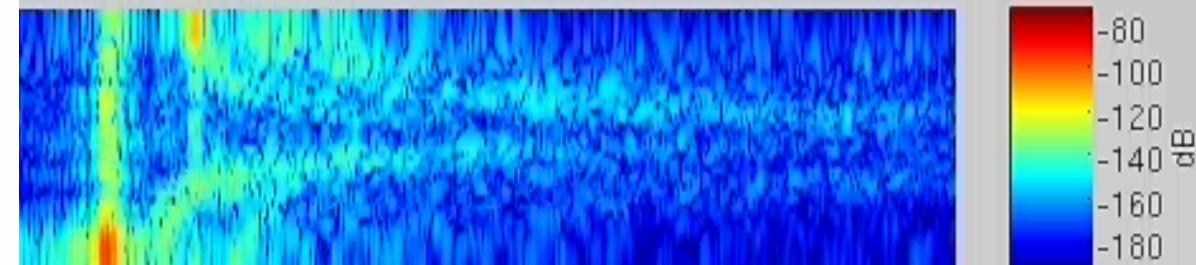
- Uncertainty of Scattering Strength estimate
  - Limited sample size
  - Uncertainty of geometry
- Uncertainty of propagation
  - Vs range
  - Vs angle
  - Angle uncertainty



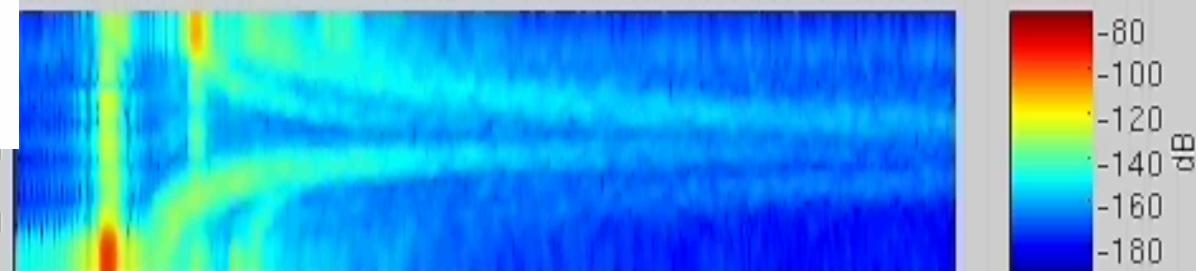
# Data Site 4 3600 Hz



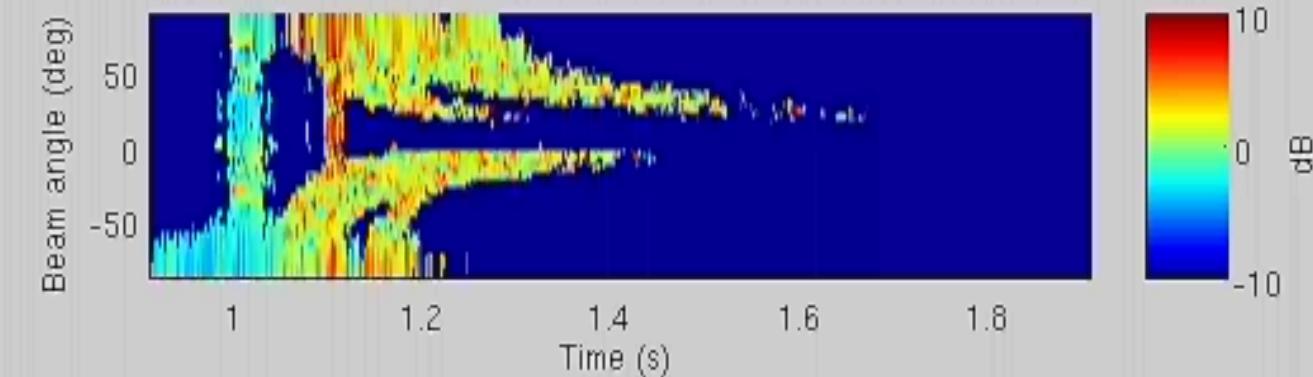
boundary2k-vetra-s4a-sb-11-1-2, snapshot 12, 3600 Hz, 150 Hz BW



y2k-vetra-s4a-sb-14-1-2 mean, 42 out of 121 averages, 3600 Hz, 150 Hz BW



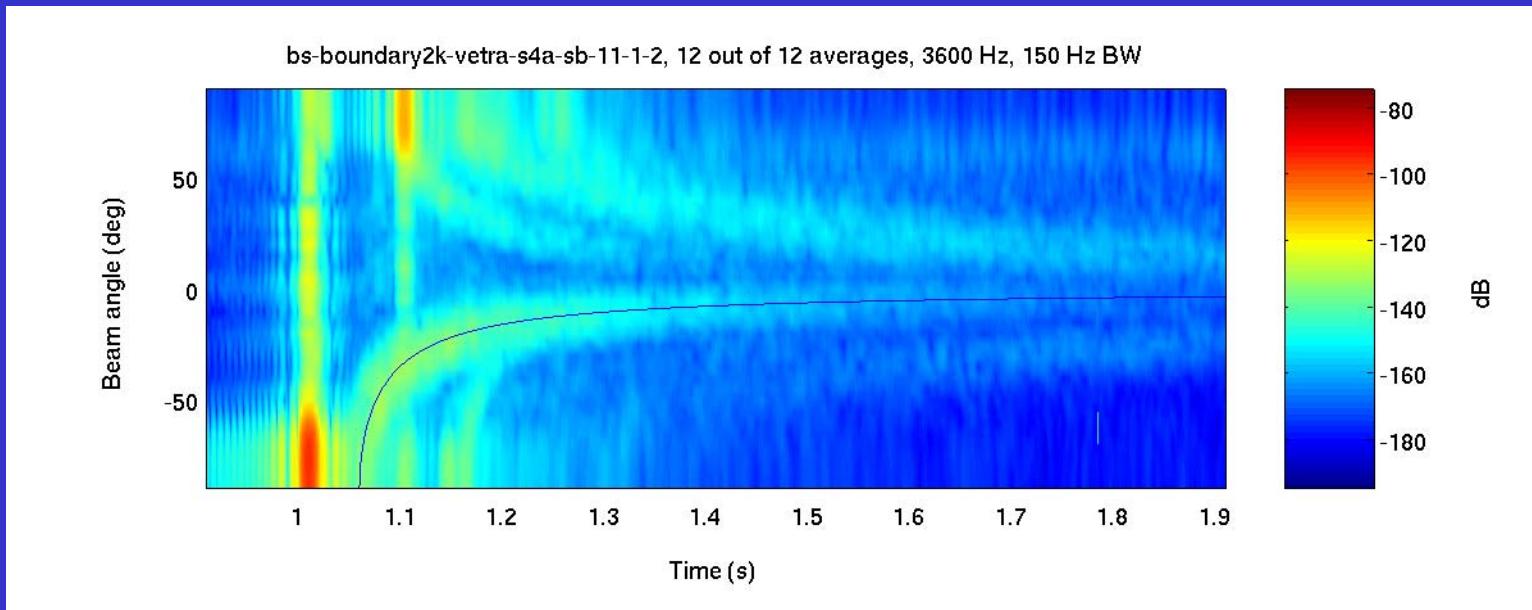
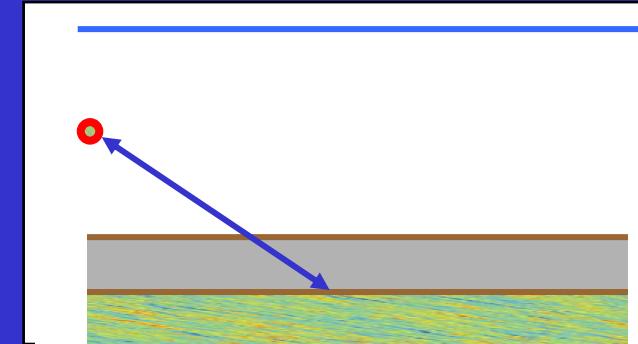
bs-boundary2k-vetra-s4a-sb-21-1-2 SI, 12 out of 12 averages, 3600 Hz, 150 Hz BW





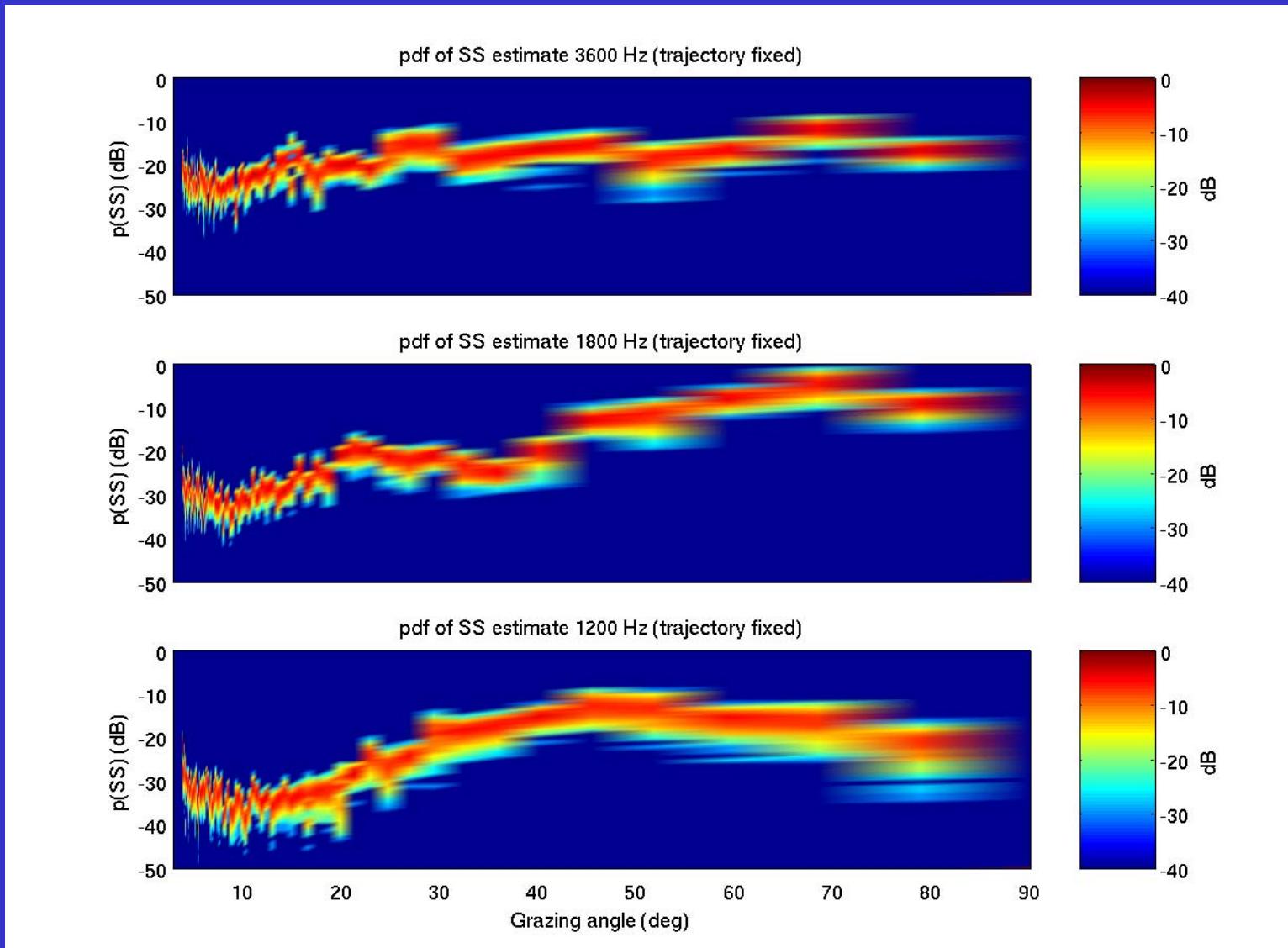
# Scatterer Horizon Trajectory

- Basement-sediment interface



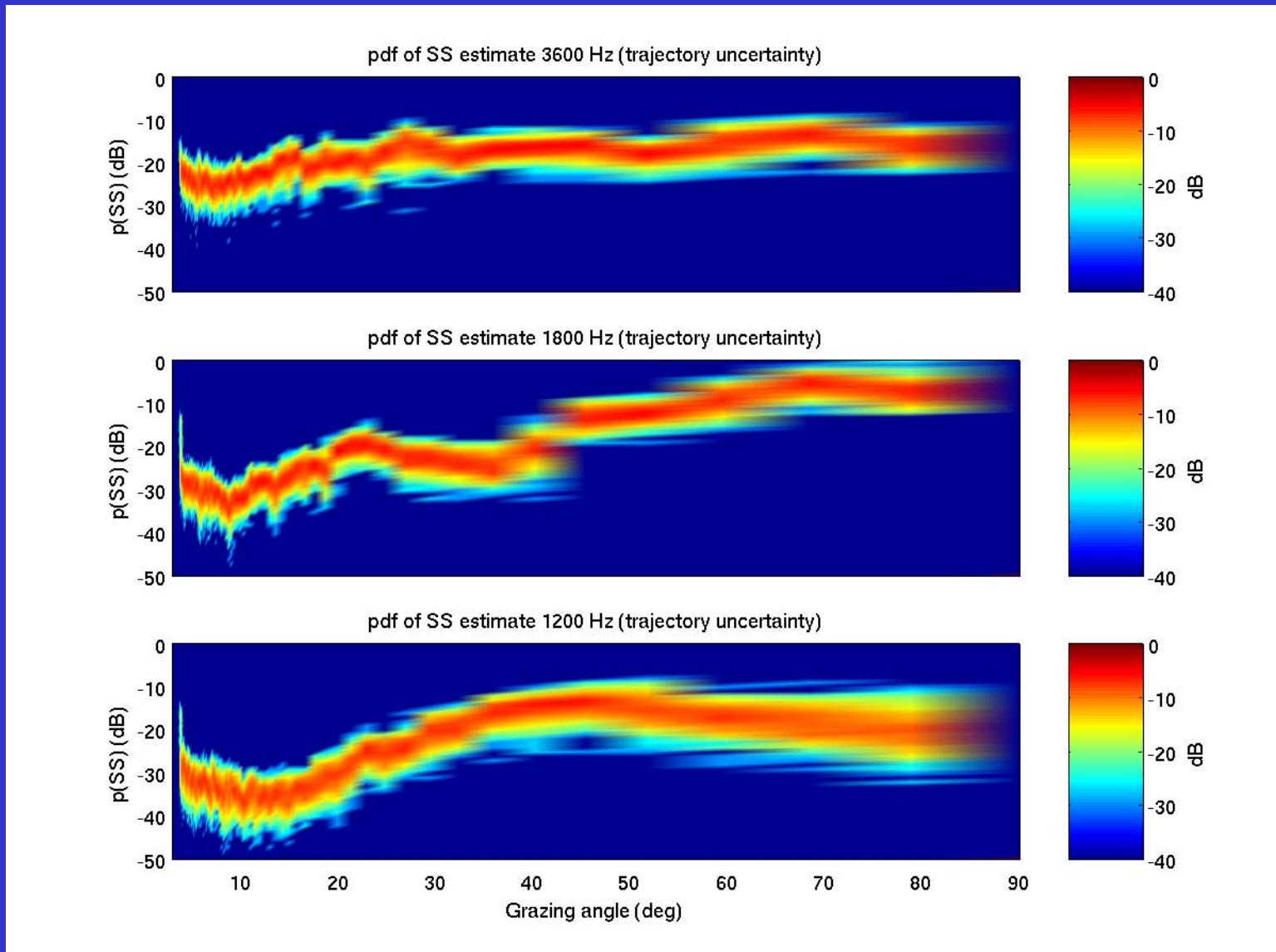


# pdf of SS Estimates Site 4 Malta Plateau: Trajectory Certain





# pdf of SS Estimates Site 4 Malta Plateau: Trajectory Uncertain





# Uncertainty of Reverberation

- Uncertainty of Scattering Strength estimate
  - Limited sample size
  - Uncertainty of geometry
- Uncertainty of propagation
  - Vs range
  - Vs angle
  - Angle uncertainty



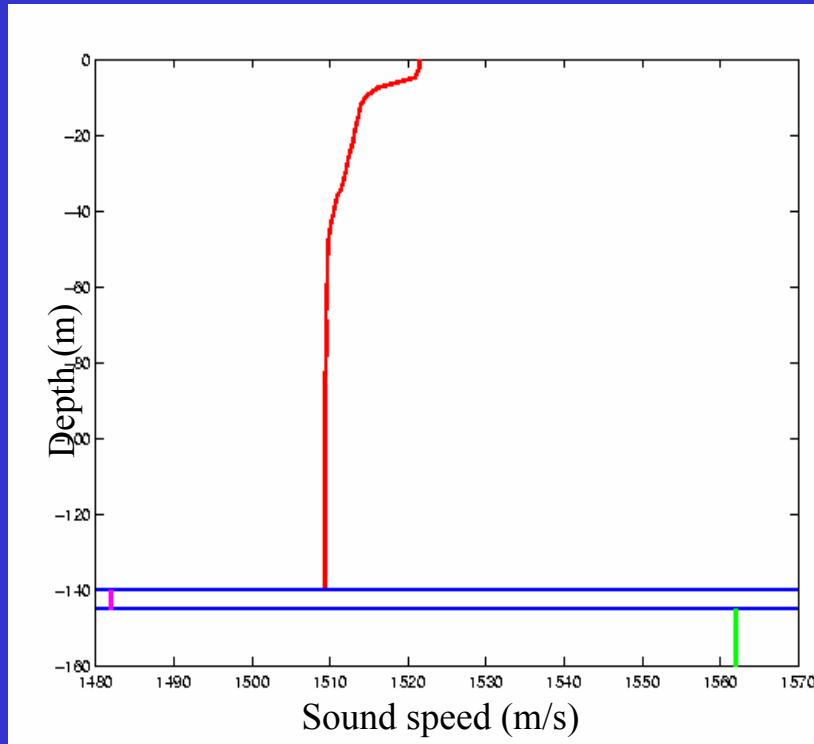
# Propagation Scenarios Examined

- Oceanography
  - Shallow water
  - North Elba bottom
  - 1 G-M (Elliott et al.)
- NJ Strataform
  - Fast bottom (1730 m/s, Mayer measurements)
  - Stochastic realization (Goff, 30 m/s rms,  $l_x$  12.6 km,  $l_z$  1 m,  $D$  3.7)
- Eel River Strataform
  - Slow bottom (1560 m/s, Goff measurements)
  - Stochastic realization (Goff, 39 m/s rms,  $l_x$  2.9 km,  $l_z$  25 cm,  $D$  3.7)

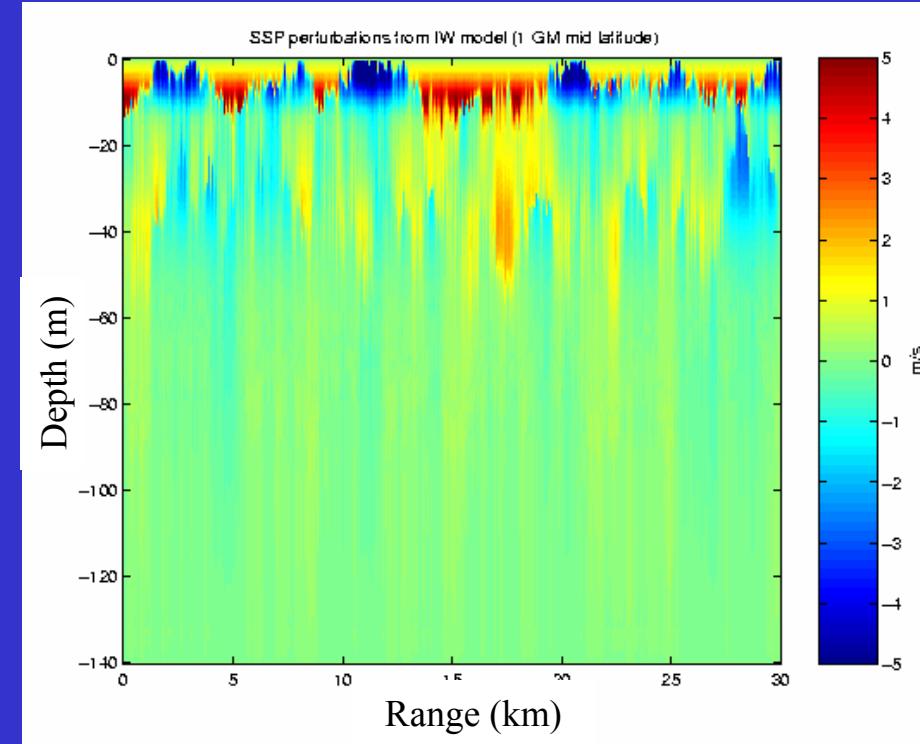


# Oceanographic Variability

- Sound speed profile



- Internal wave realization

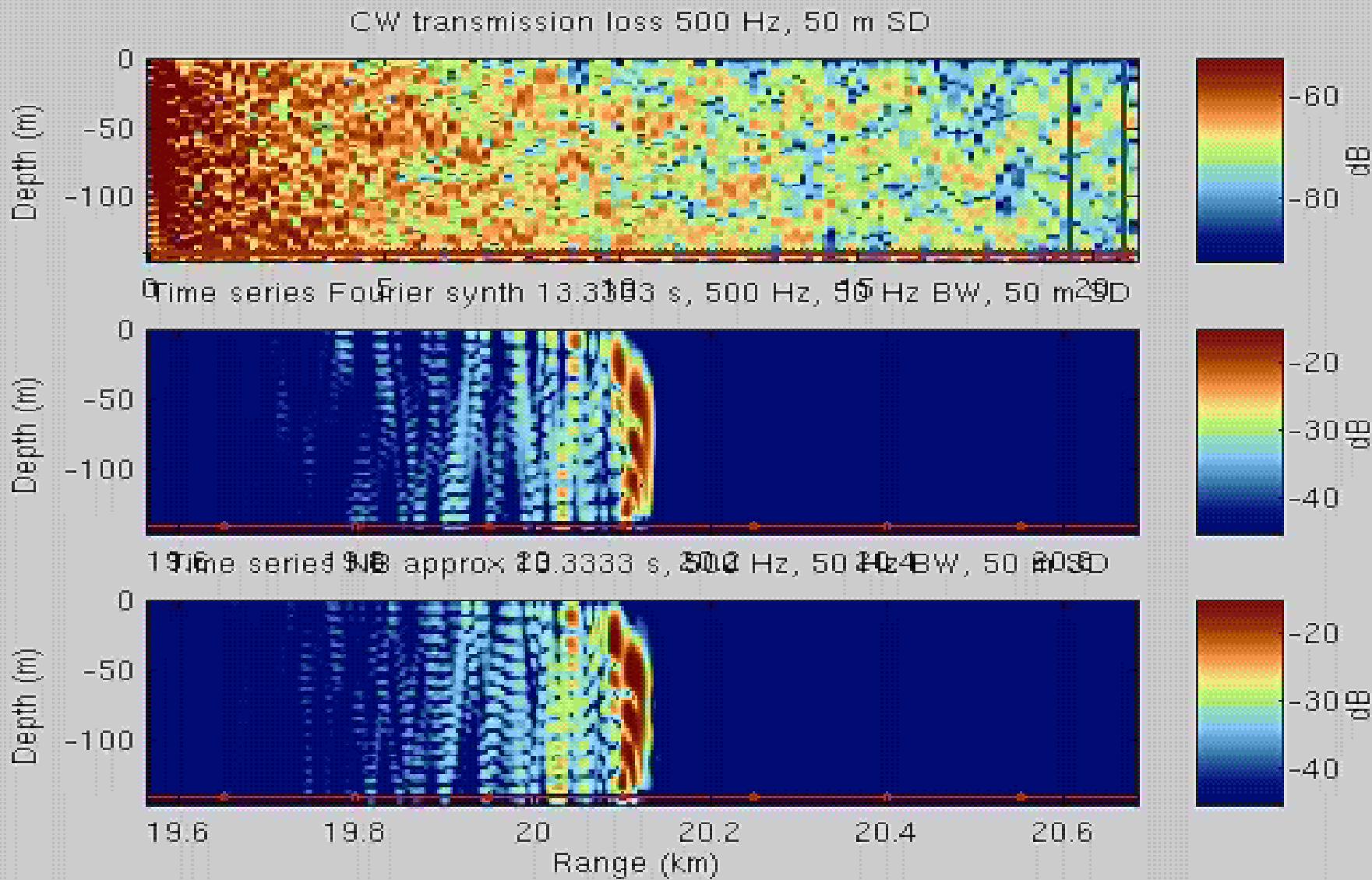


- downward refracting
- slow sediment layer
- 23 modes @ 500 Hz

- mean subtracted
- PROSIM model



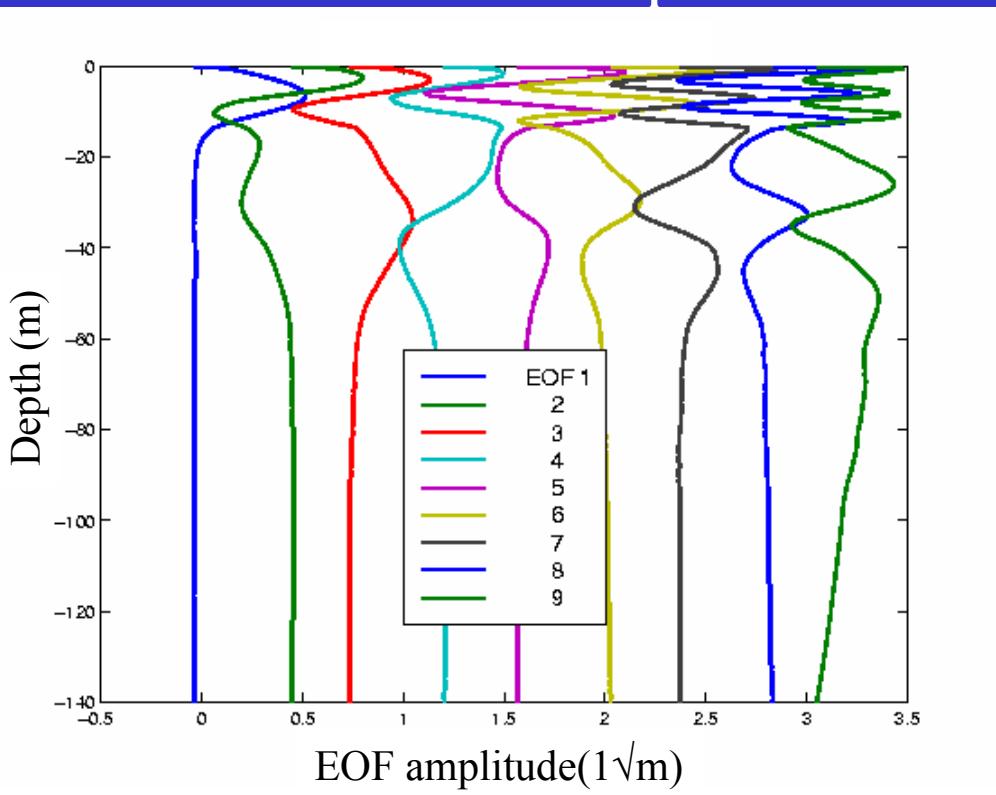
# Coupled Calculation: Oceanographic Signal Variability



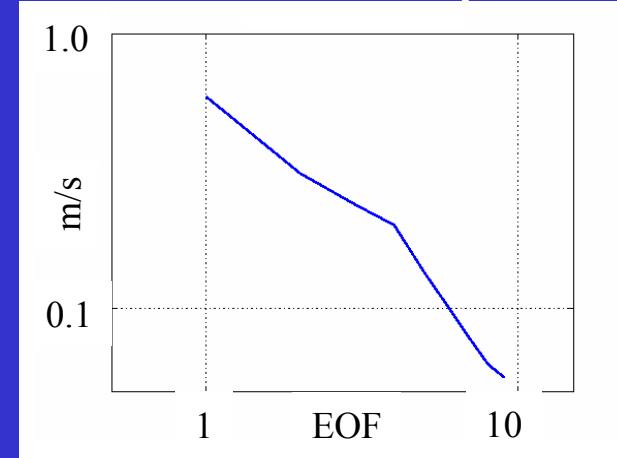


# Statistical Characterization of Oceanographic Variability

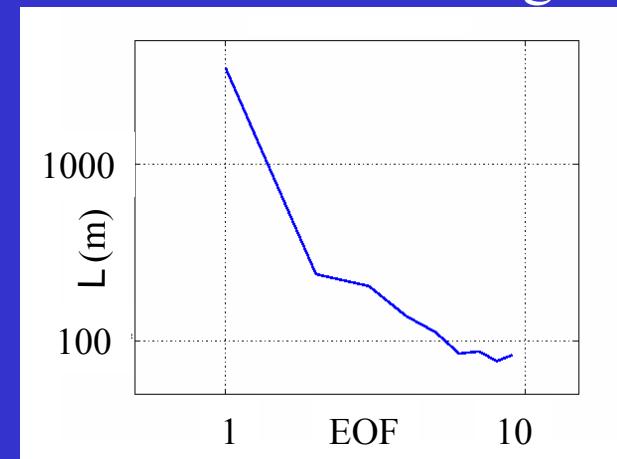
- EOF mode shapes



EOF rms sound speed

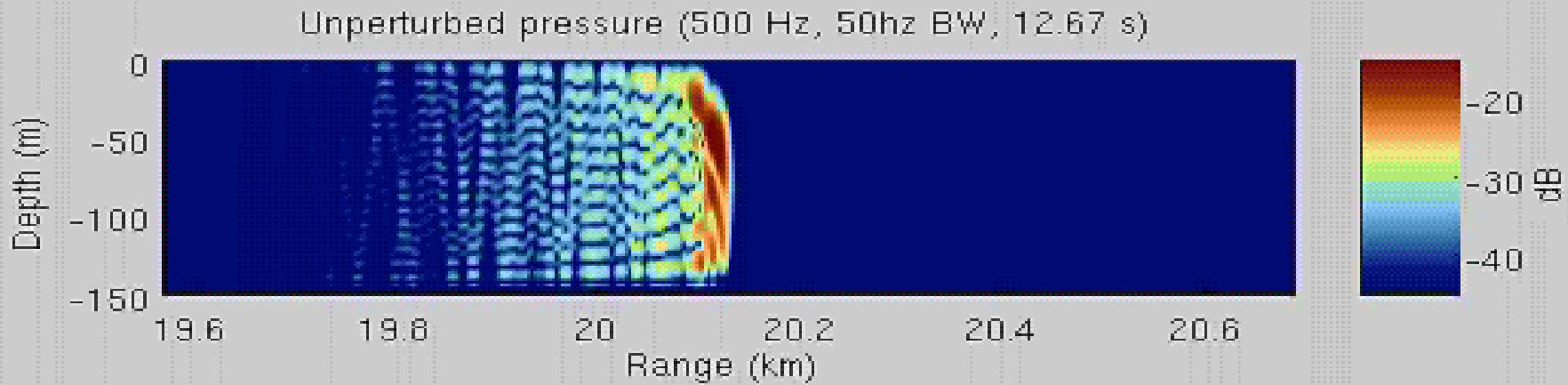
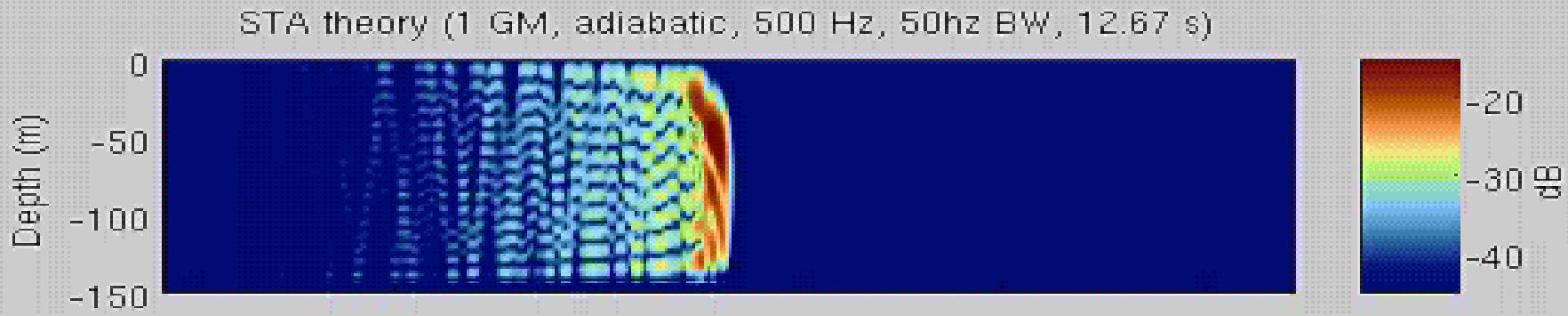


EOF correlation length scale



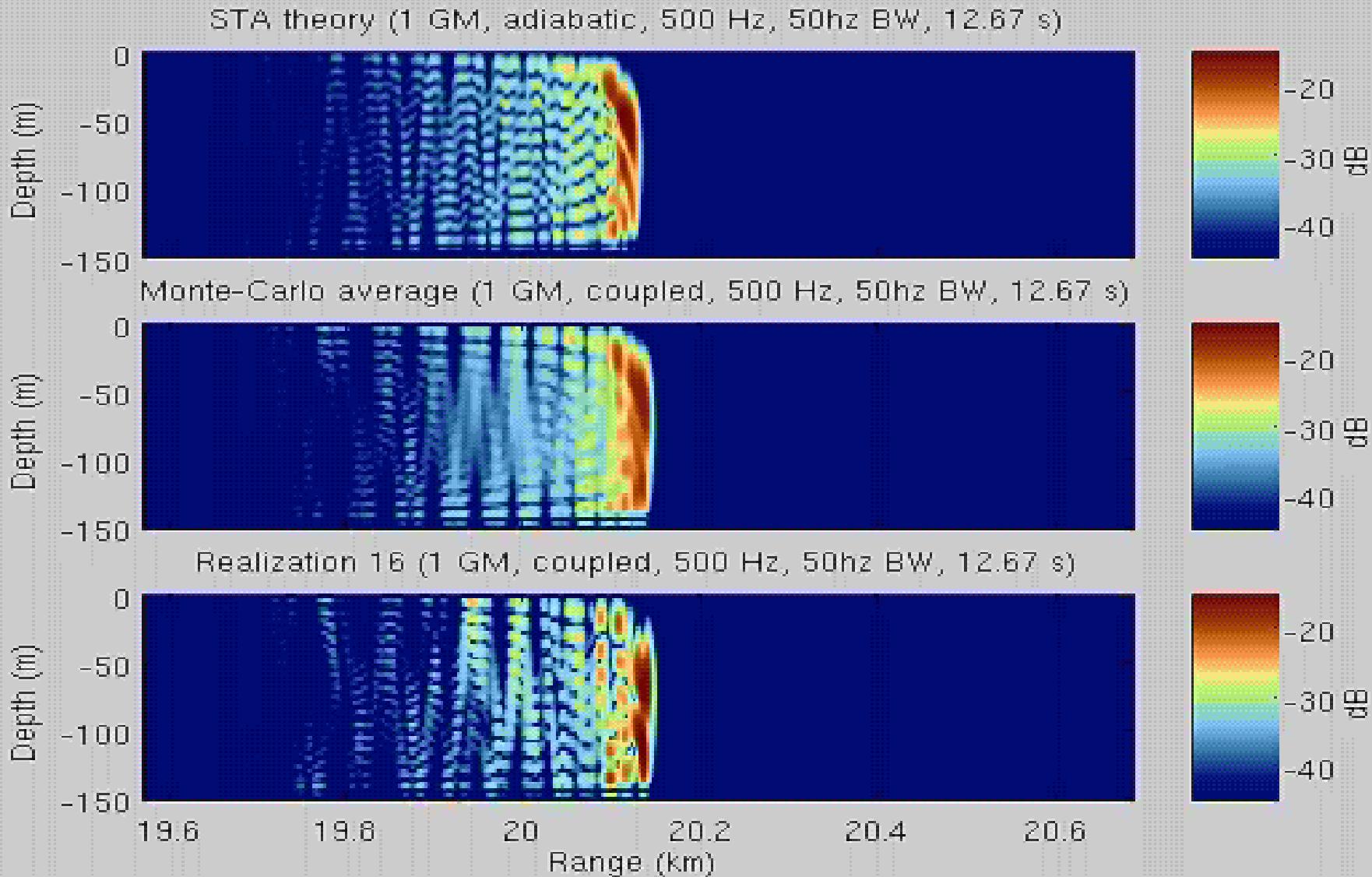


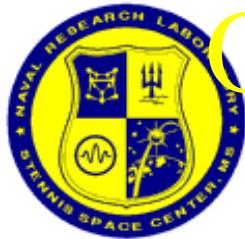
# Oceanography: Adiabatic Theory of Signal Variability



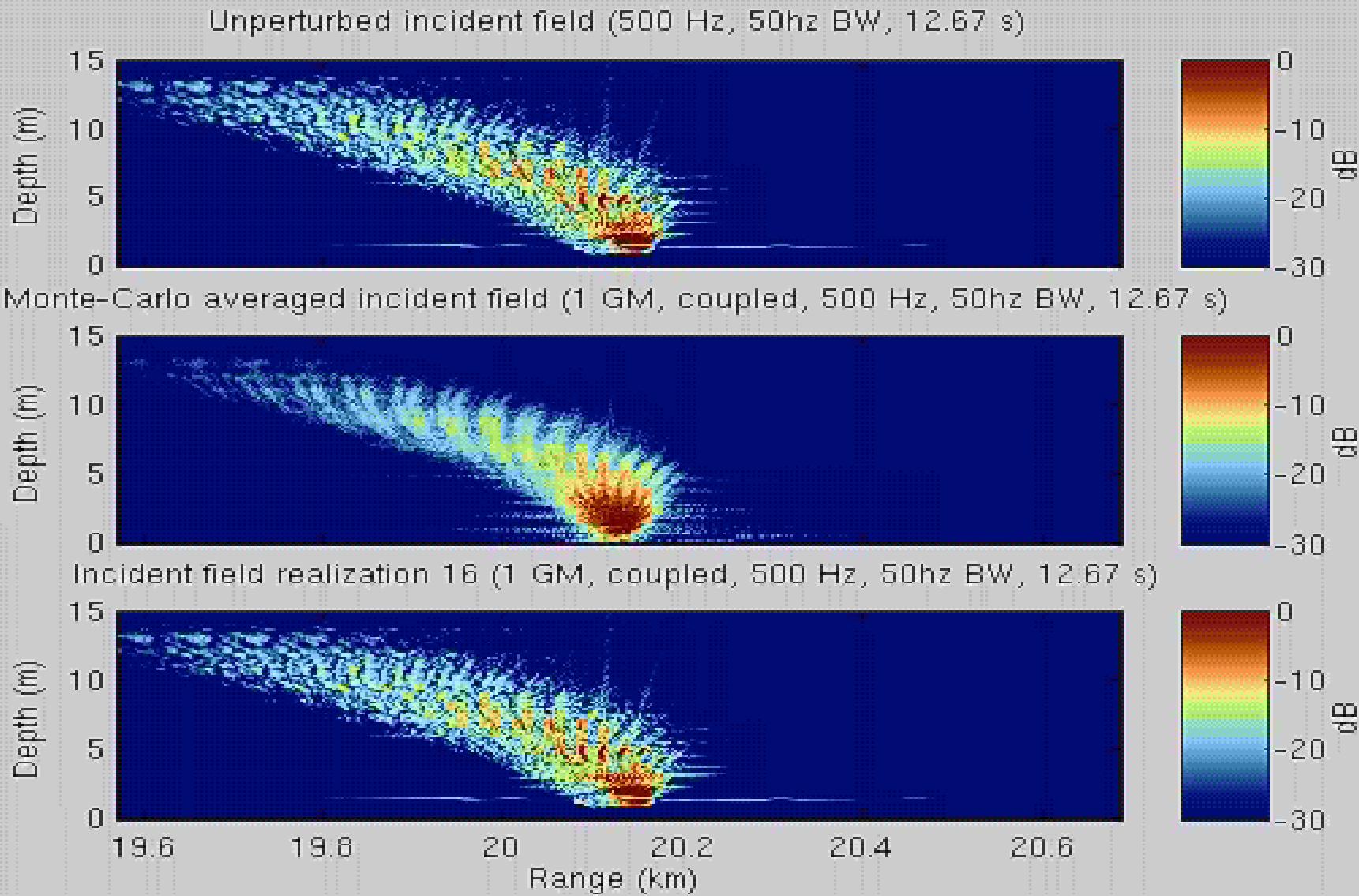


# Oceanography: Expected Value of STA Theory vs Monte-Carlo





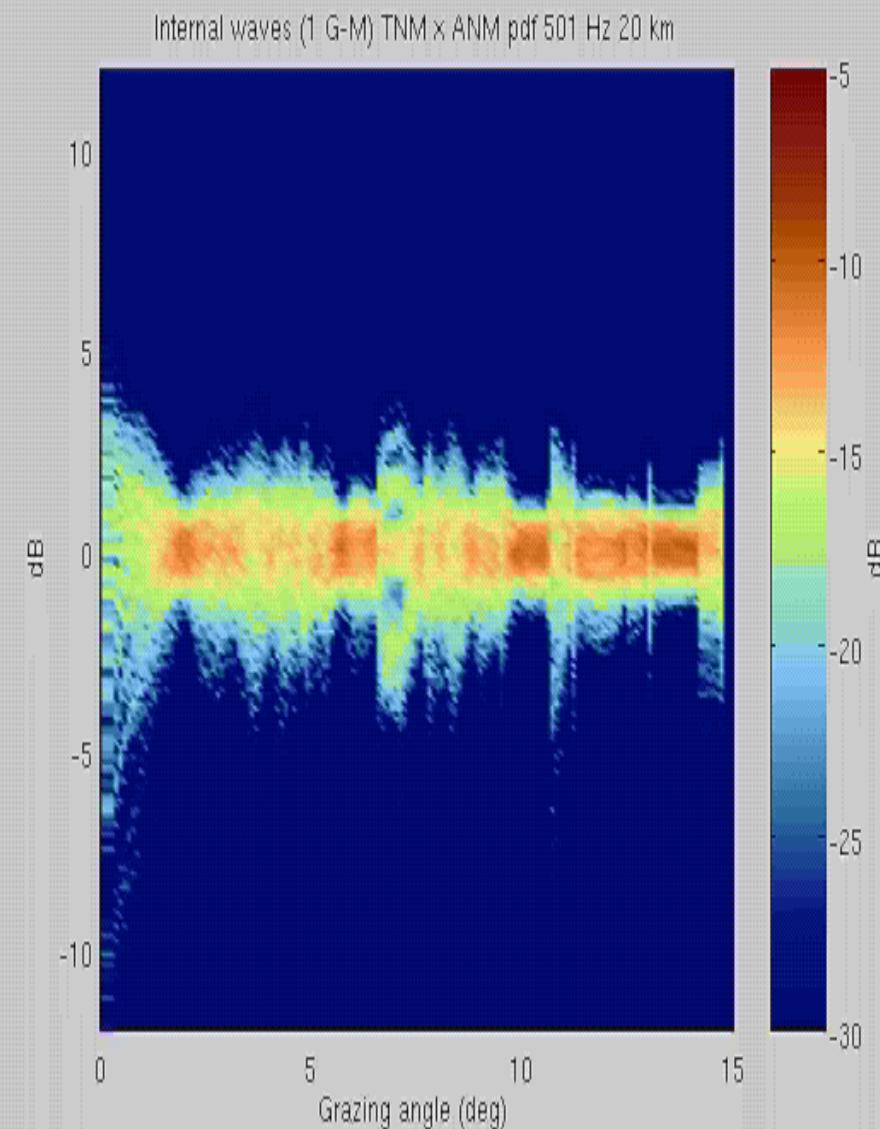
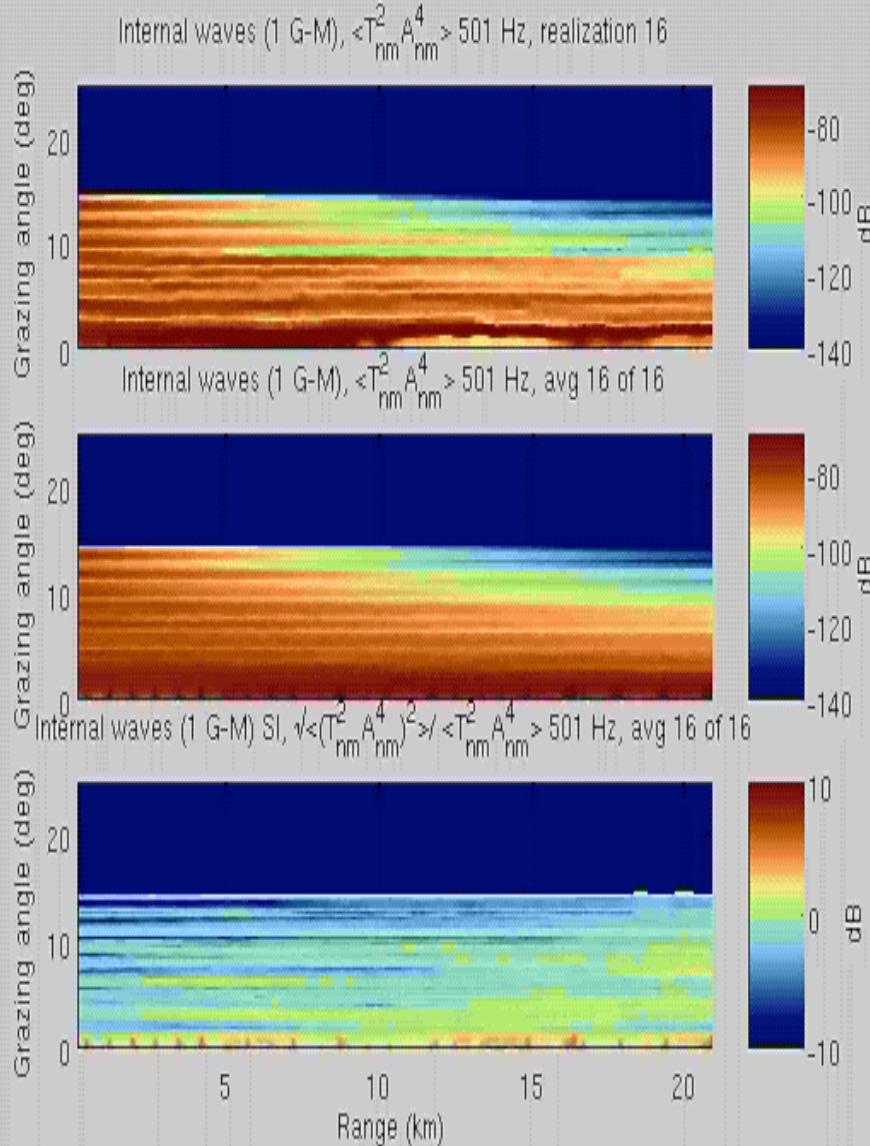
# Oceanography: Variability of Field Incident on Bottom Scatterers





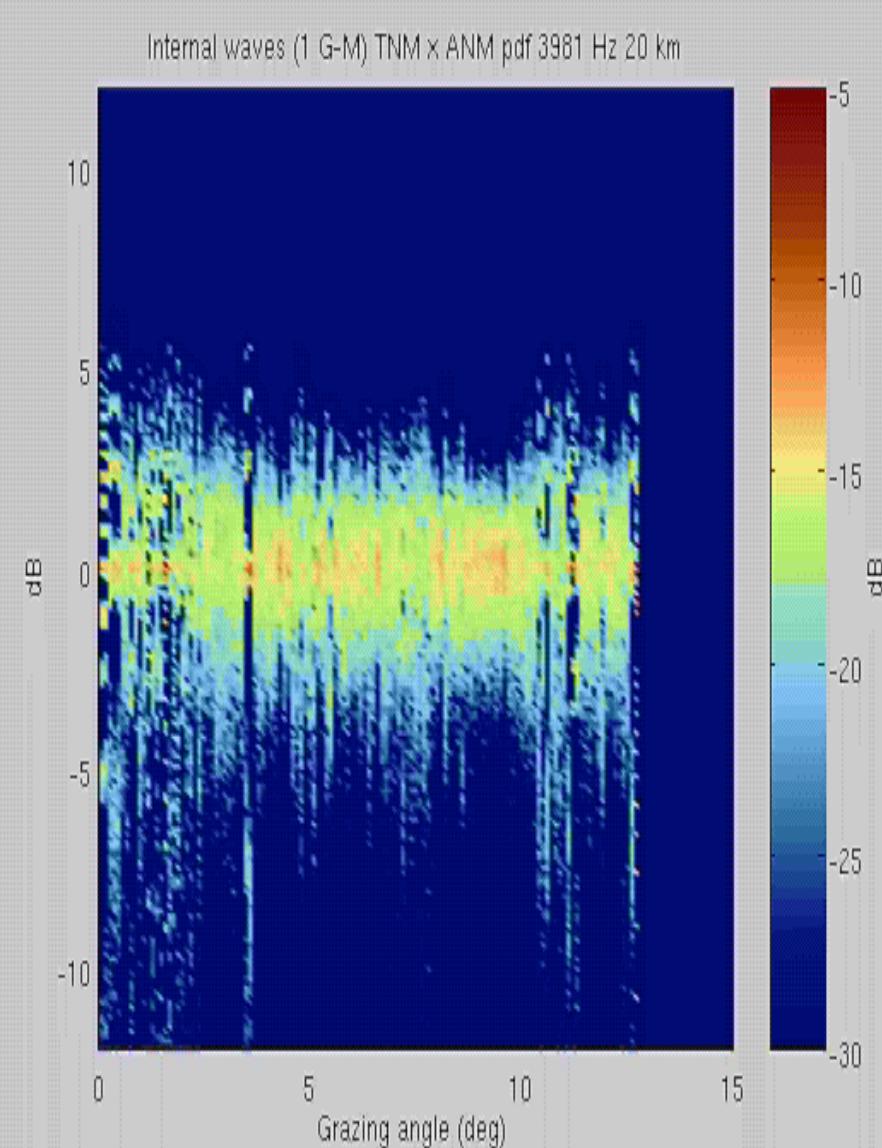
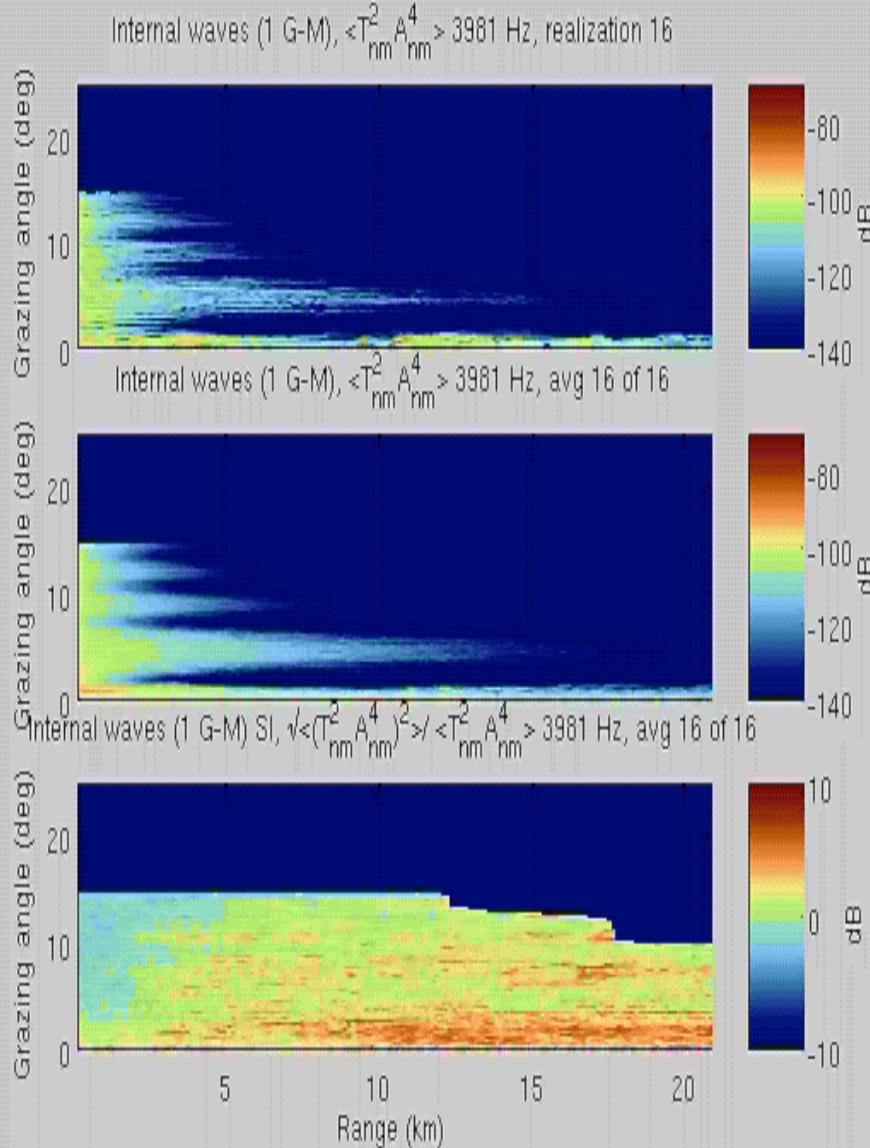
# Incident Spectrum

## Oceanography 500 Hz



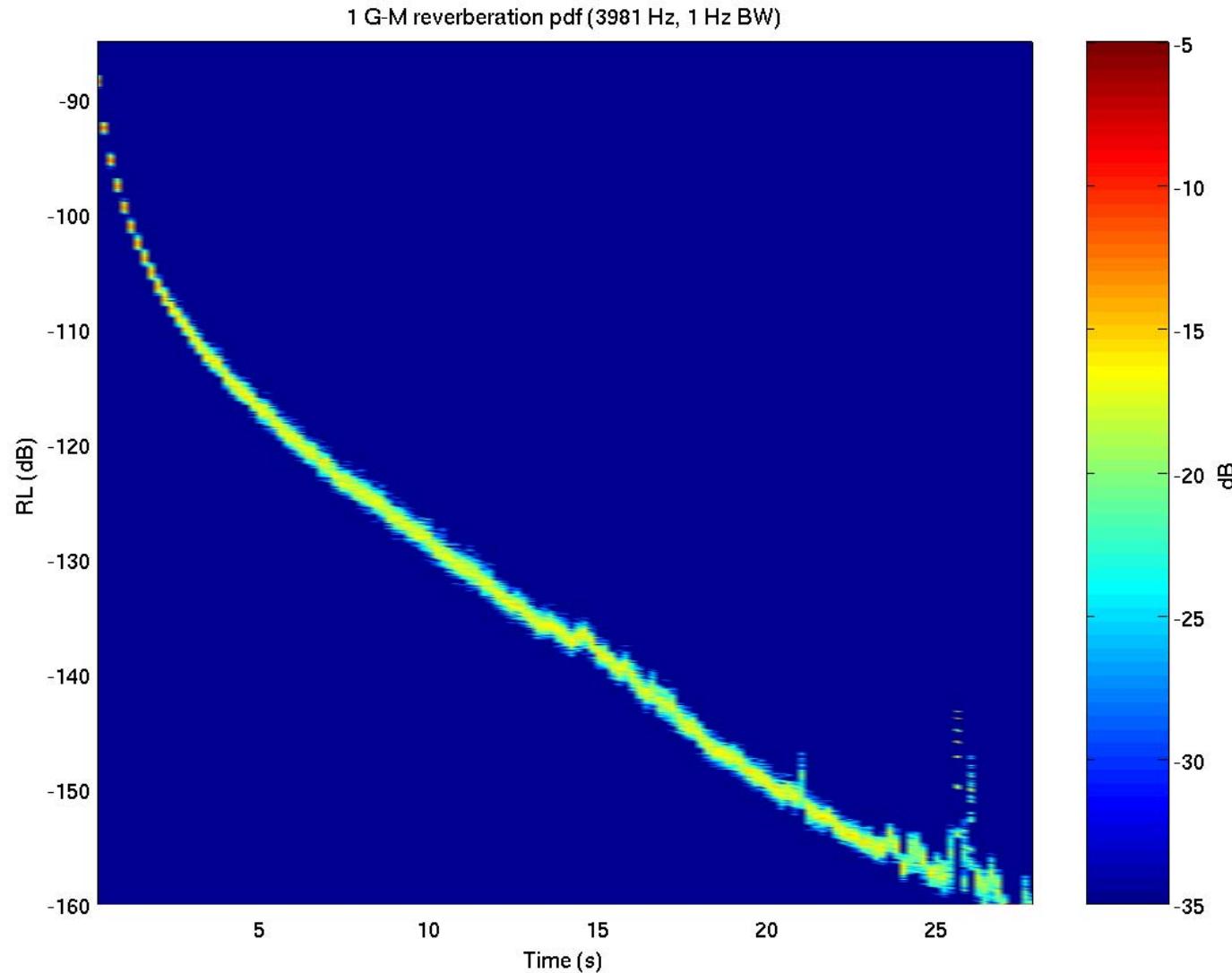


# Incident Spectrum Oceanography 4 kHz





# Resulting Reverb Uncertainty pdf for Oceanography 4 kHz





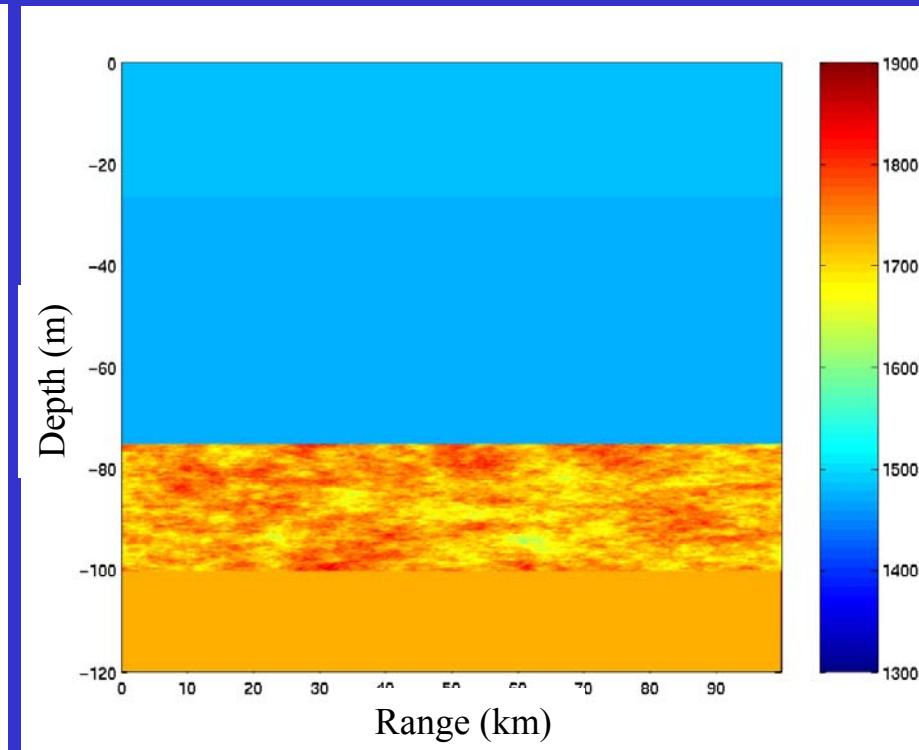
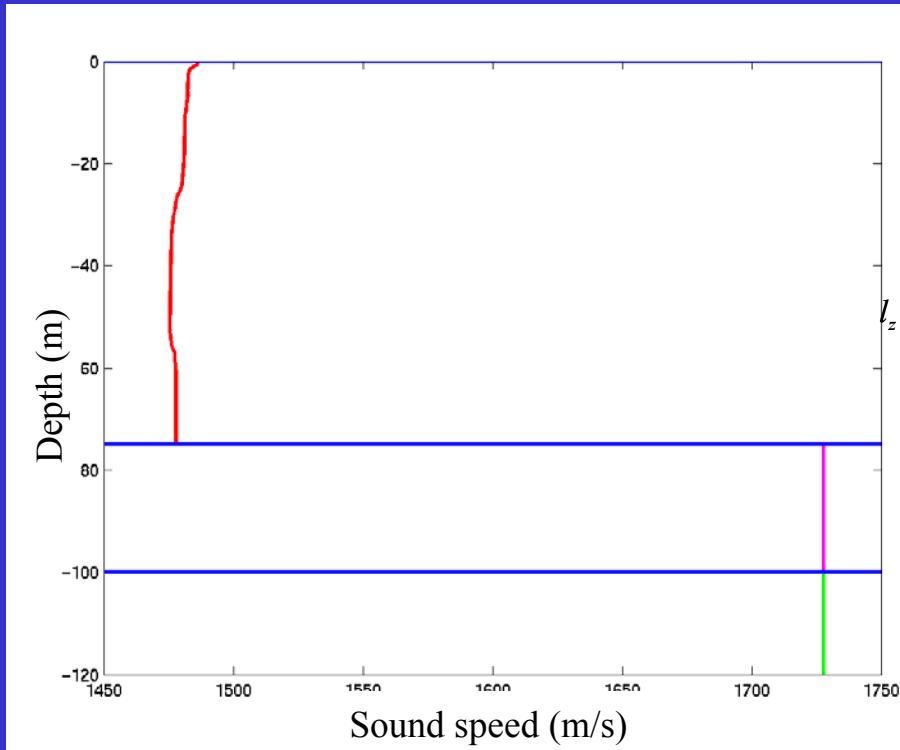
# NJ Strataform Propagation Scenario

- Oceanography
  - Shallow water
  - North Elba bottom
  - 1 G-M (Elliott et al.)
- NJ Strataform
  - Fast bottom (1730 m/s, Mayer measurements)
  - Stochastic realization (Goff, 30 m/s rms,  $l_x$  12.6 km,  $l_z$  1 m,  $D$  3.7)
- Eel River Strataform
  - Slow bottom (1560 m/s, Goff measurements)
  - Stochastic realization (Goff, 39 m/s rms,  $l_x$  2.9 km,  $l_z$  25 cm,  $D$  3.7)



# NJ Shelf: Stratiform Bottom Sound Speed Variability

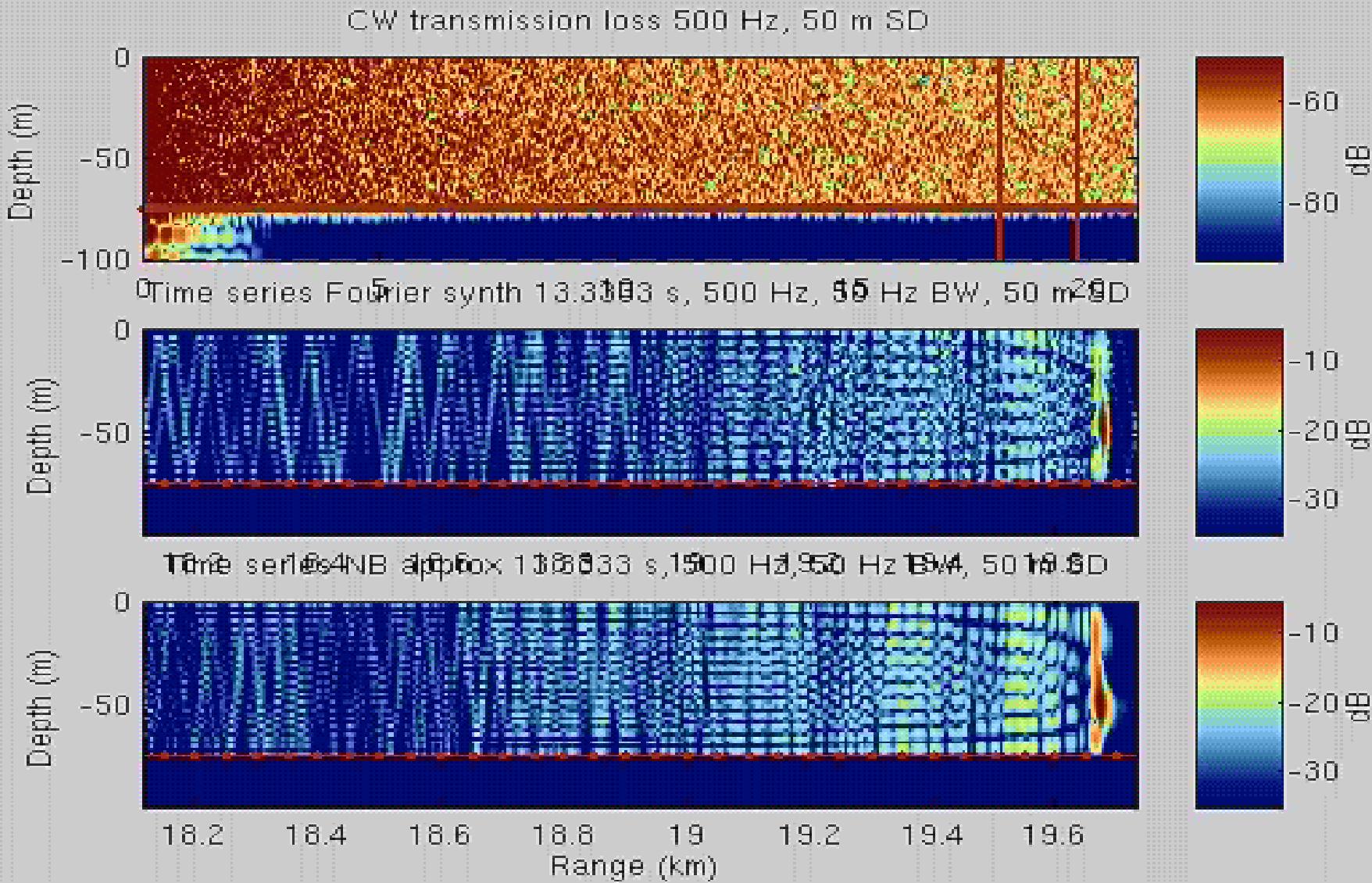
- Sound speed profile
- Bottom sound speed realization



- downward refracting
- fast sediment layer
- 35 modes @ 500 Hz
- Measurements Mayer et al.
- Stochastic realization Goff
- Guesstimate of  $l_z$



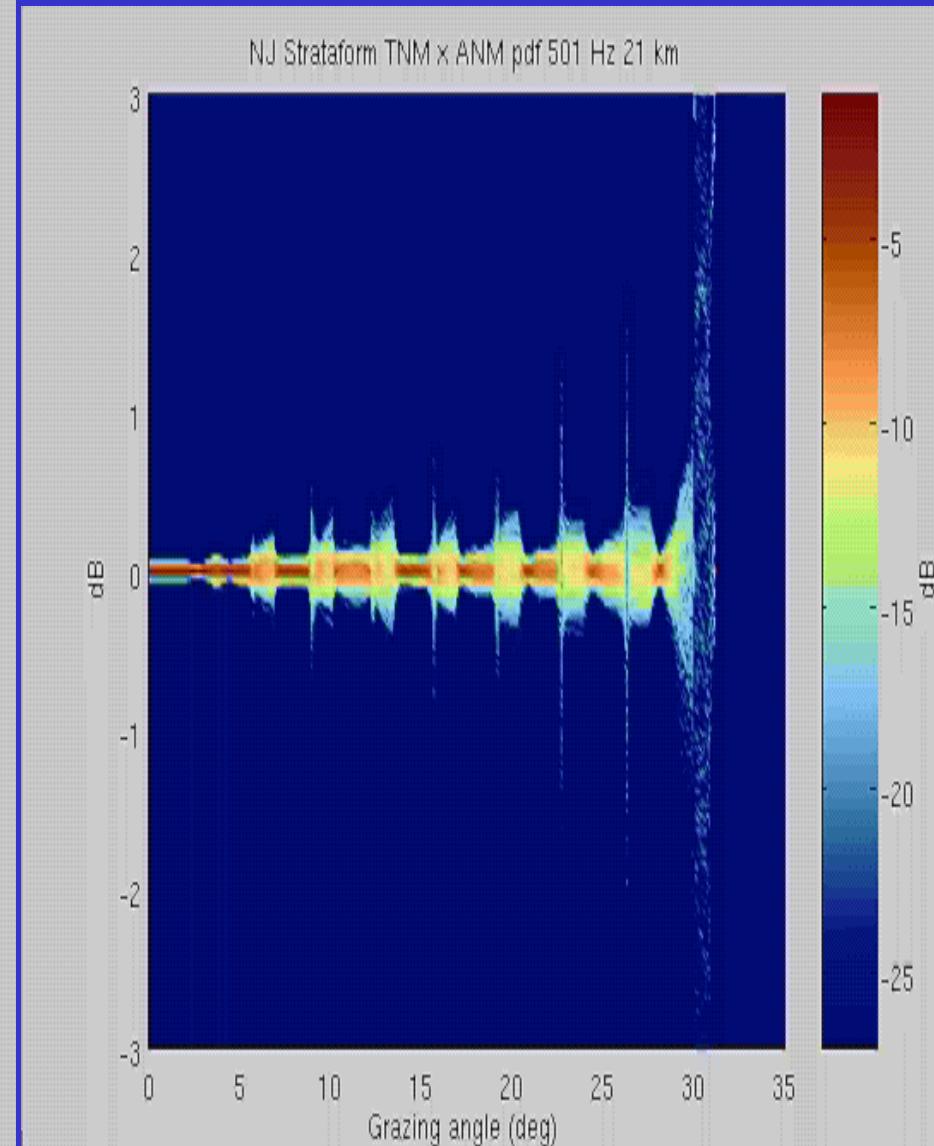
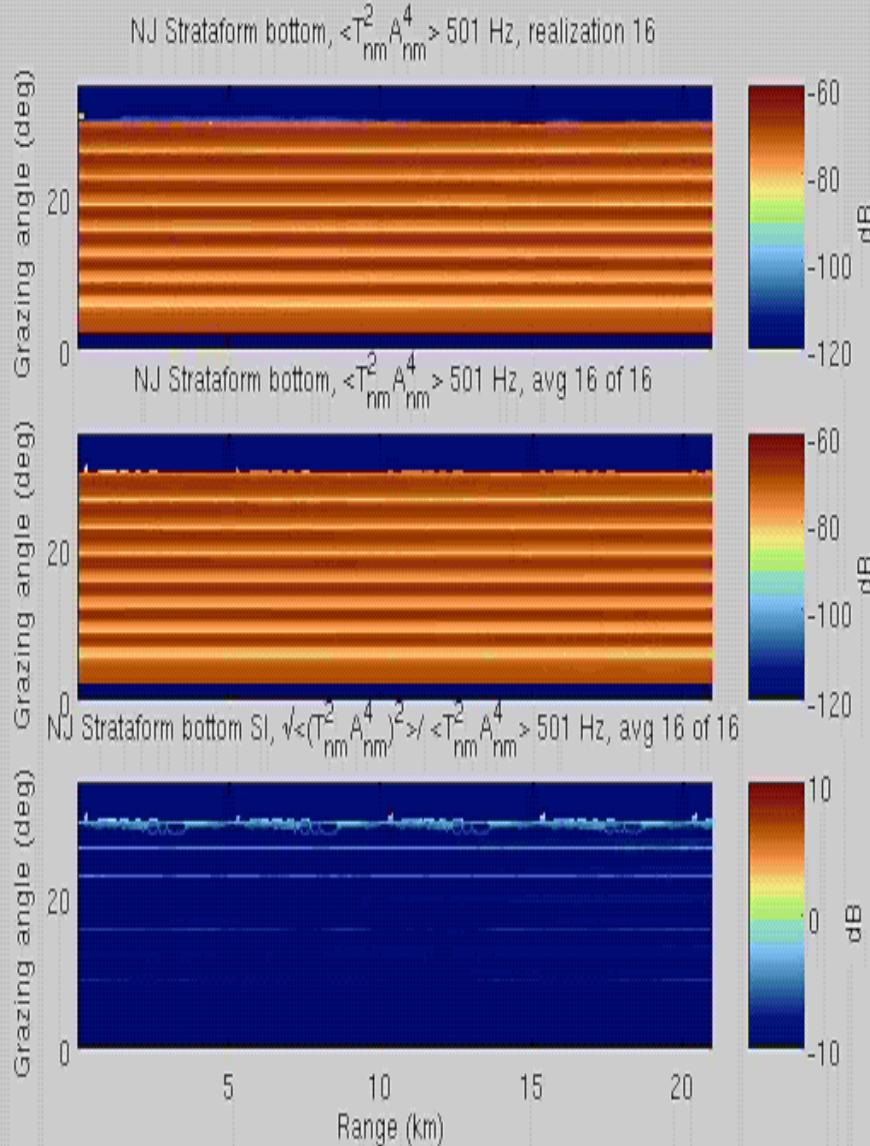
# Coupled Calculation: NJ Bottom Signal Variability





# Incident Spectrum

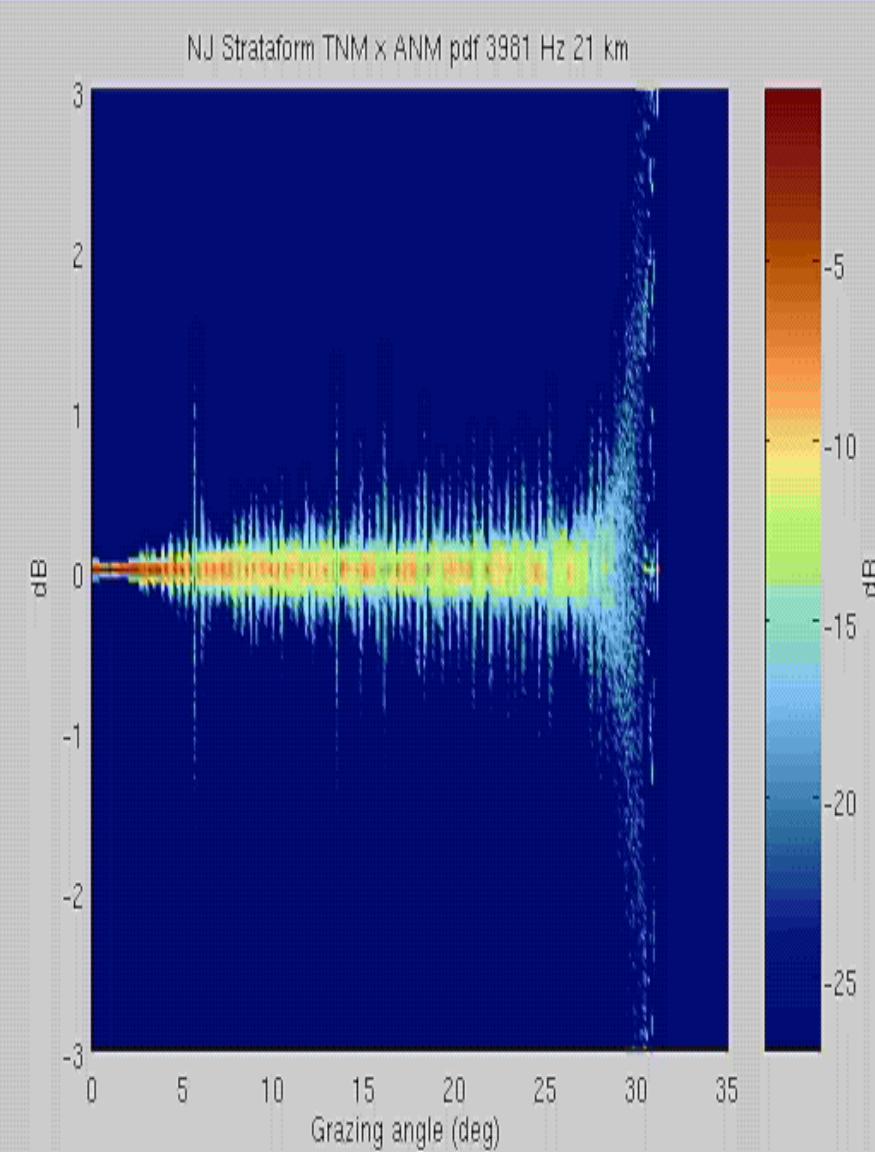
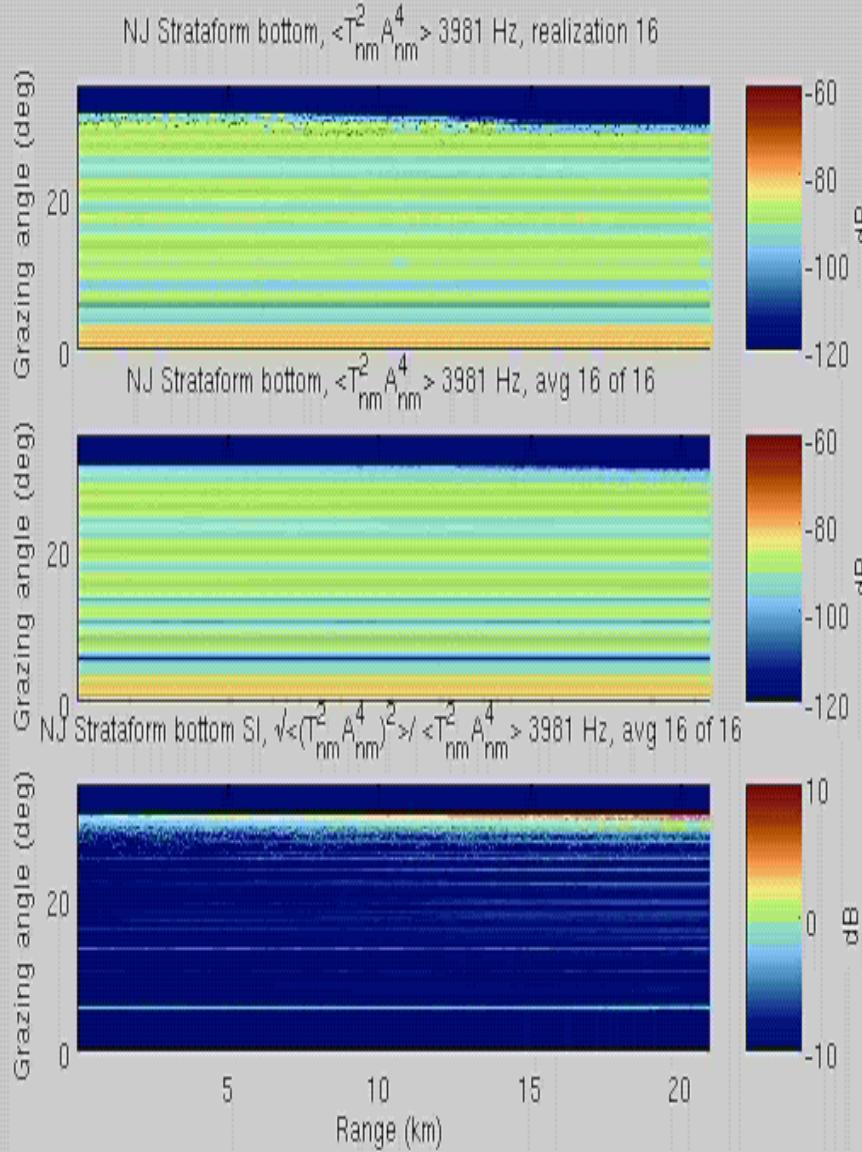
## NJ Bottom 500 Hz





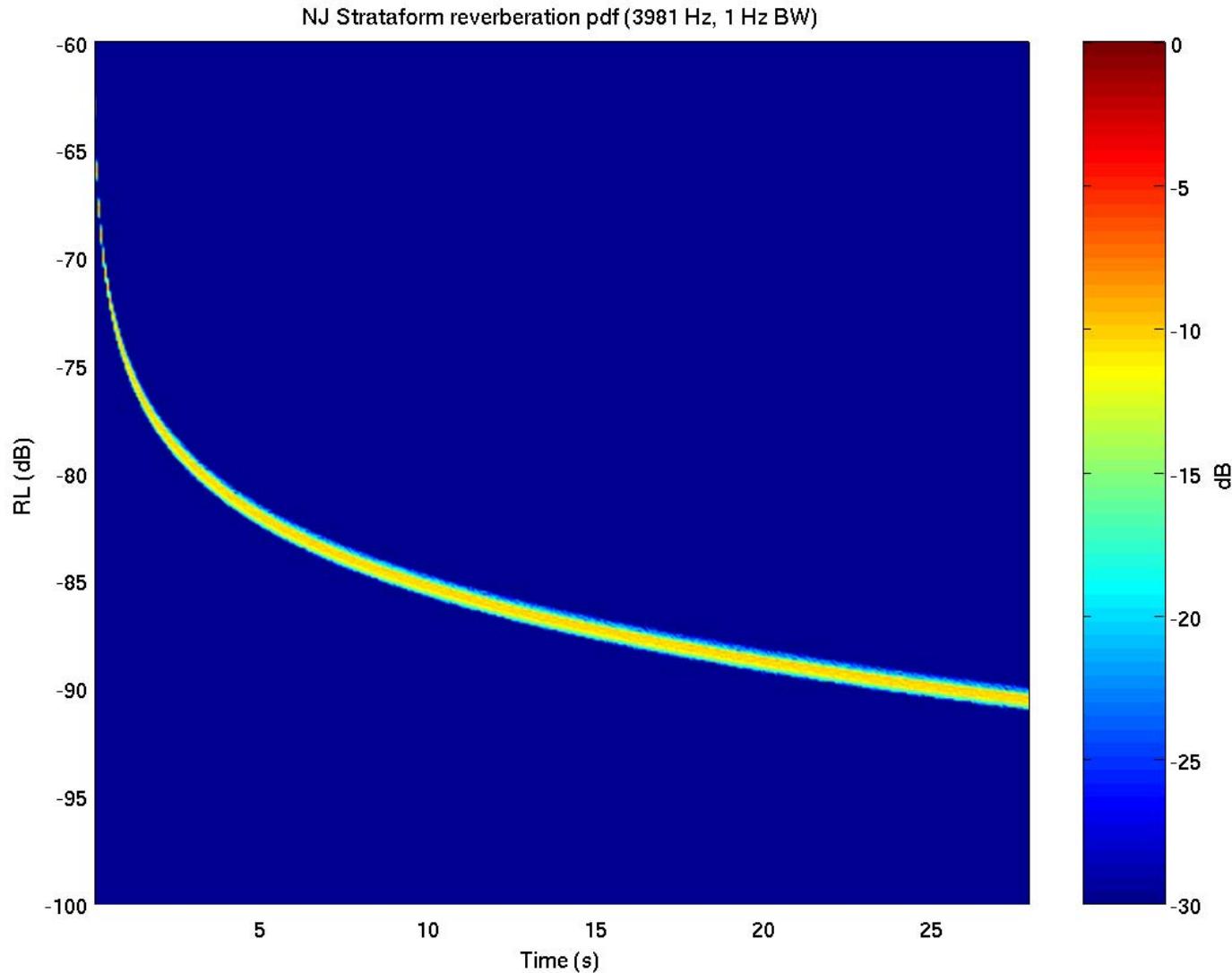
# Incident Spectrum

## NJ Bottom 4 kHz





# Resulting Reverb Uncertainty pdf for NJ Strataform 4 kHz





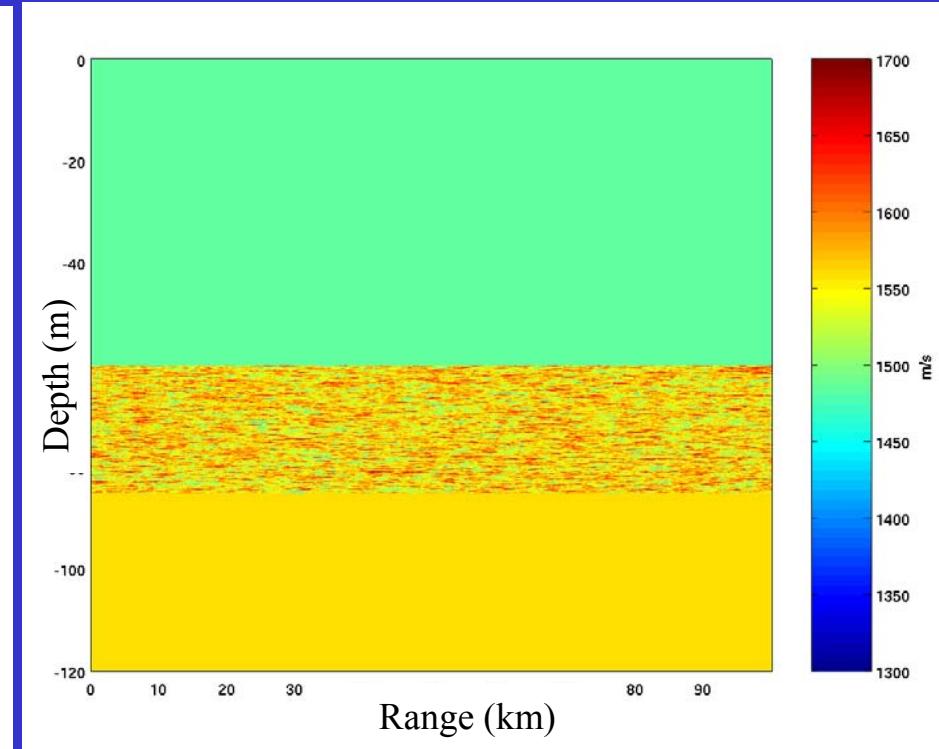
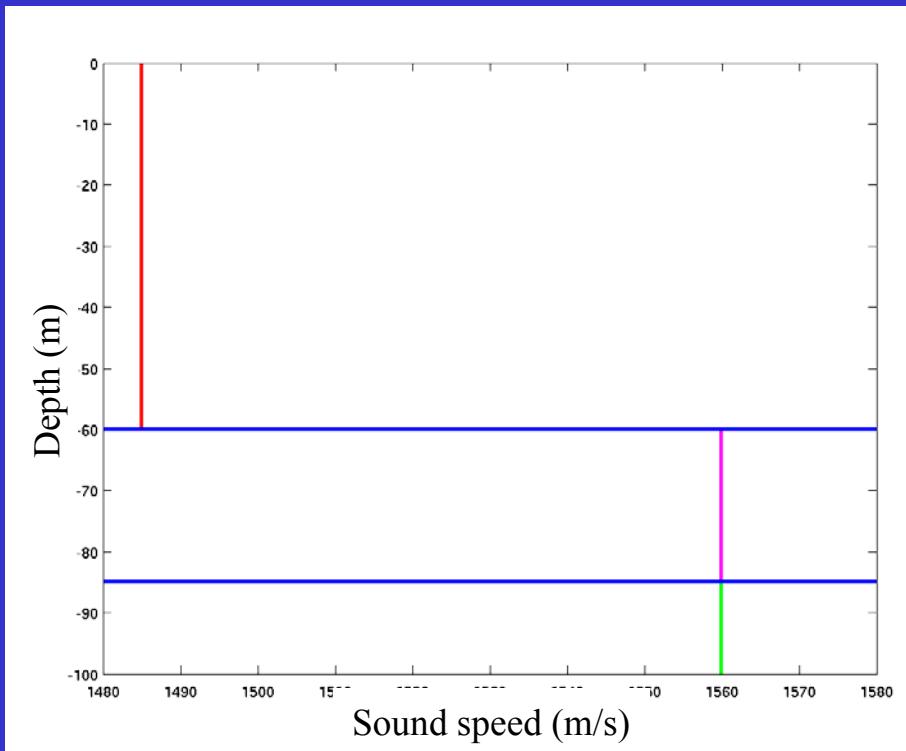
# Eel River Strataform Propagation Scenario

- Oceanography
  - Shallow water
  - North Elba bottom
  - 1 G-M (Elliott et al.)
- NJ Strataform
  - Fast bottom (1730 m/s, Mayer measurements)
  - Stochastic realization (Goff, 30 m/s rms,  $l_x$  12.6 km,  $l_z$  1 m,  $D$  3.7)
- Eel River Strataform
  - Slow bottom (1560 m/s, Goff measurements)
  - Stochastic realization (Goff, 39 m/s rms,  $l_x$  2.9 km,  $l_z$  25 cm,  $D$  3.7)



# Eel River: Stratiform Bottom Sound Speed Variability

- Sound speed profile
- Bottom sound speed realization

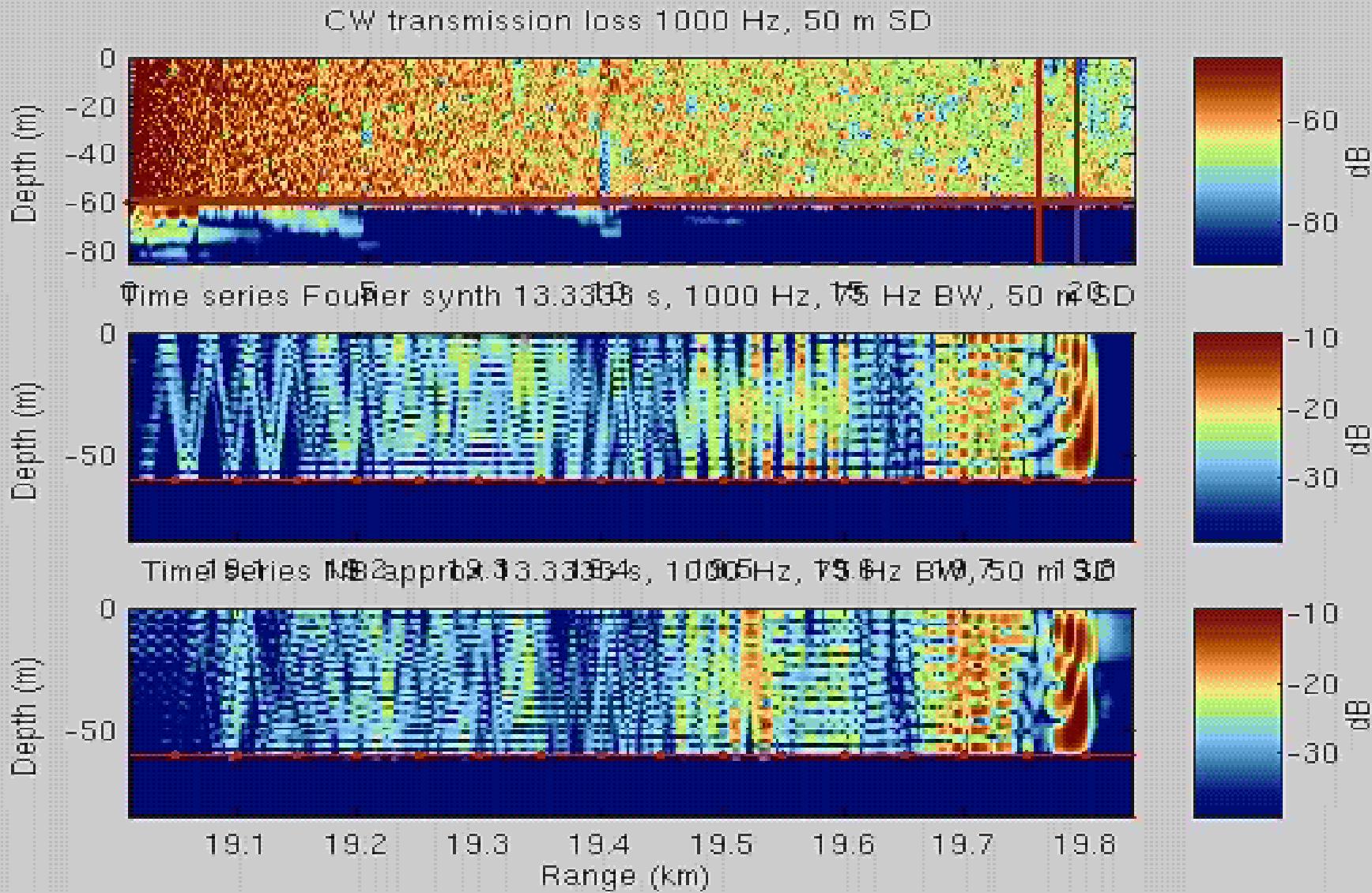


- downward refracting
- Slower silty sediment layer
- 12 modes @ 500 Hz

- Measurements Goff et al.
- Stochastic realization Goff
- Measured  $l_z$



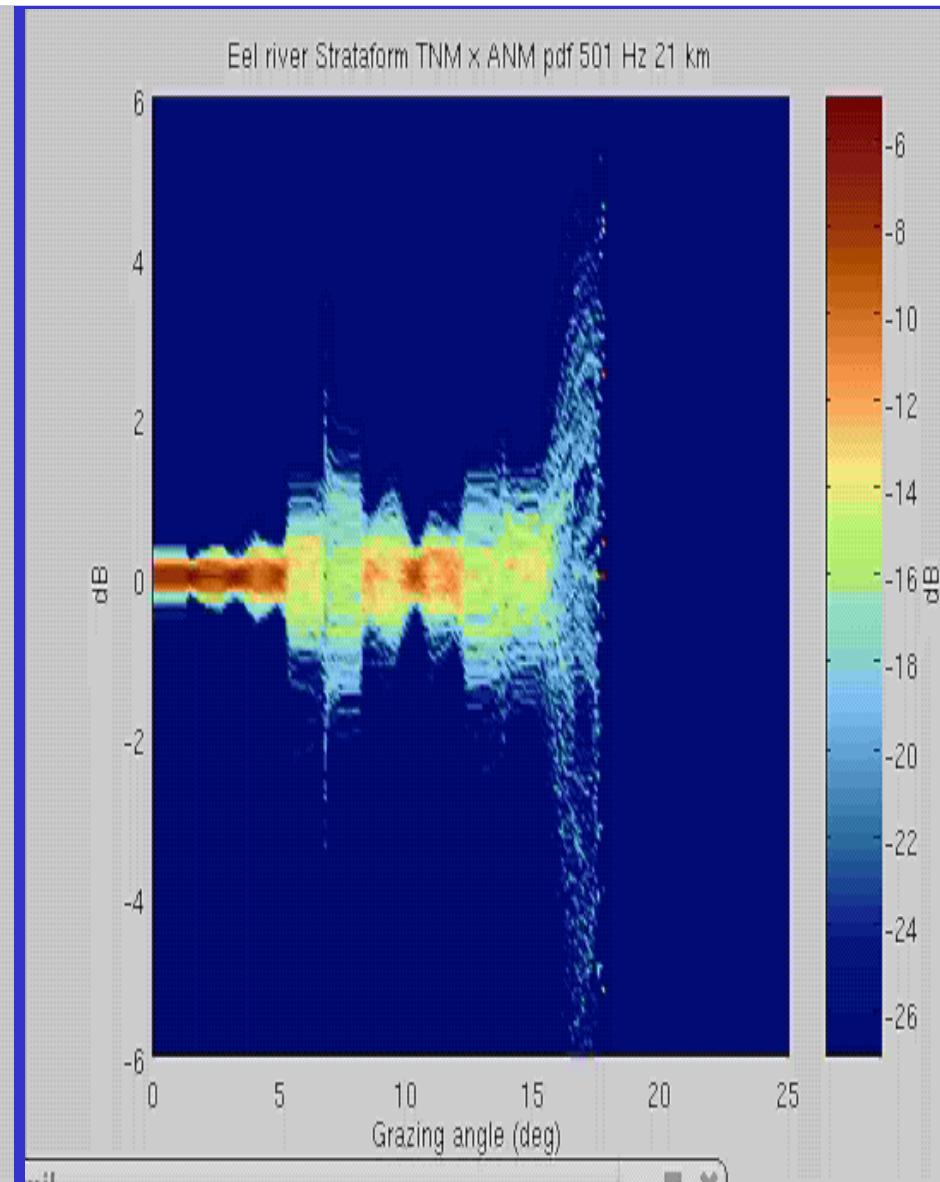
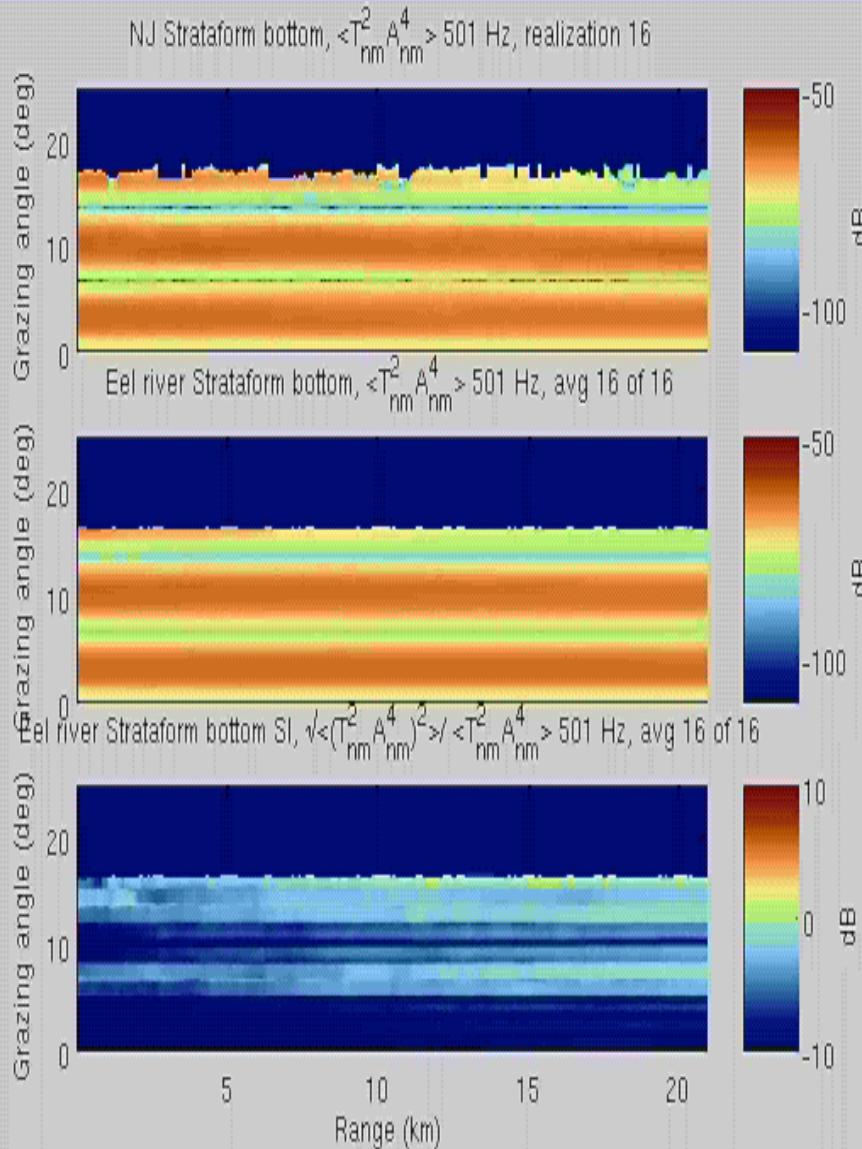
# Coupled Calculation: Eel River Bottom Signal Variability





# Incident Spectrum

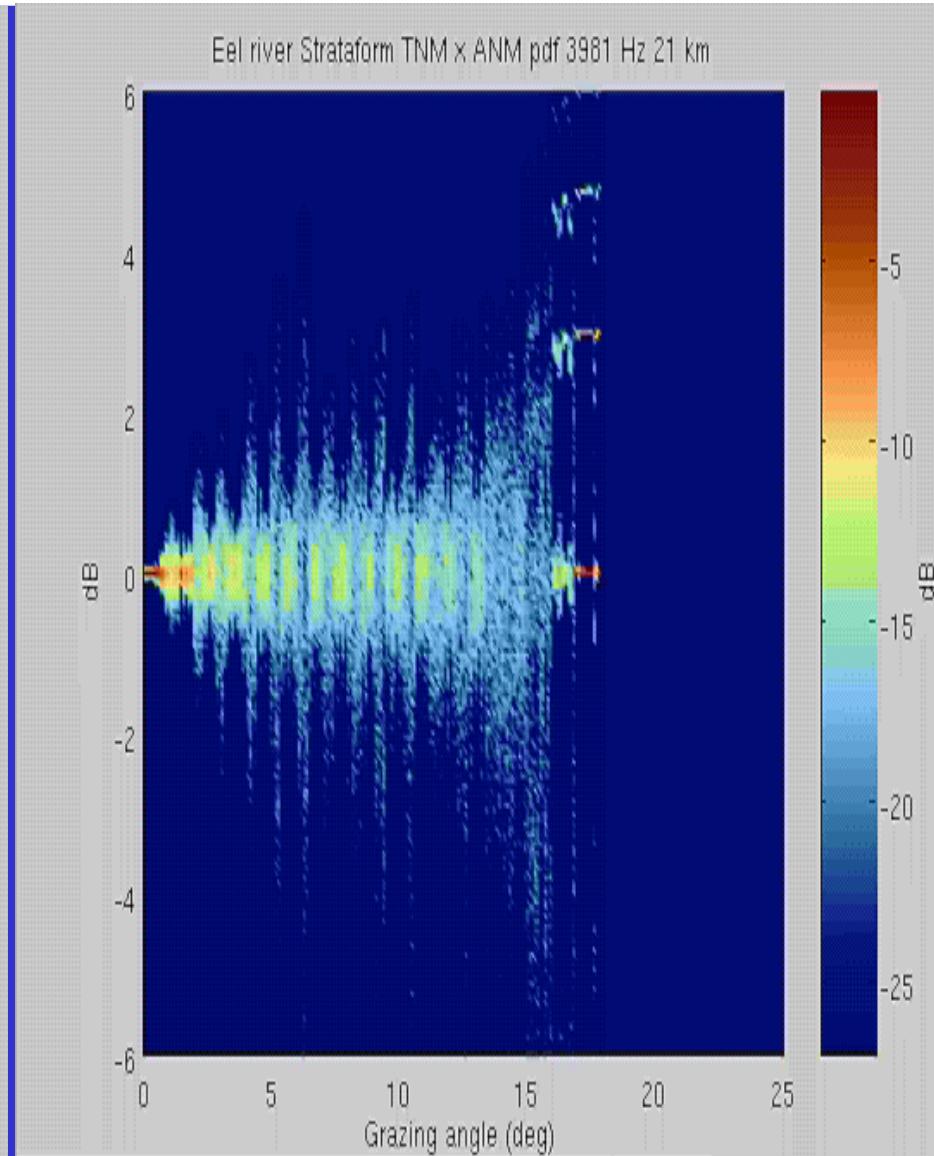
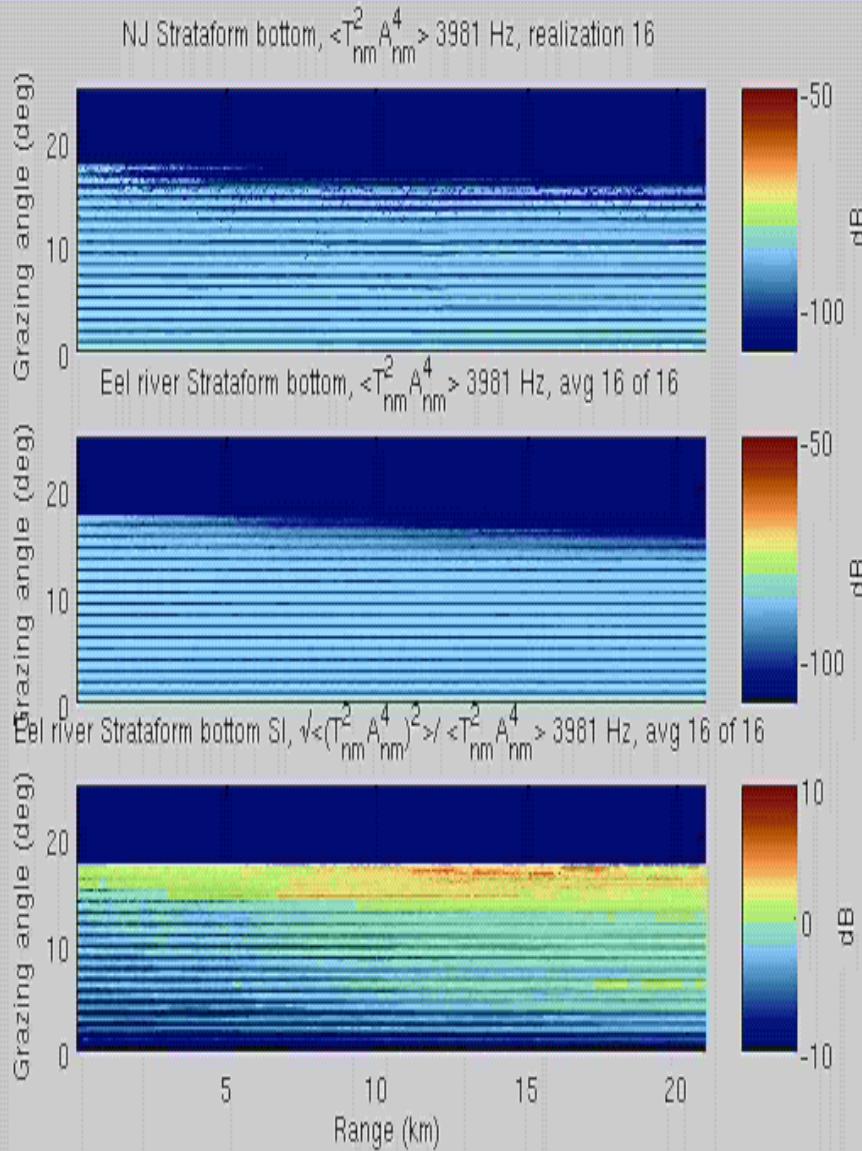
## Eel River Bottom 500 Hz





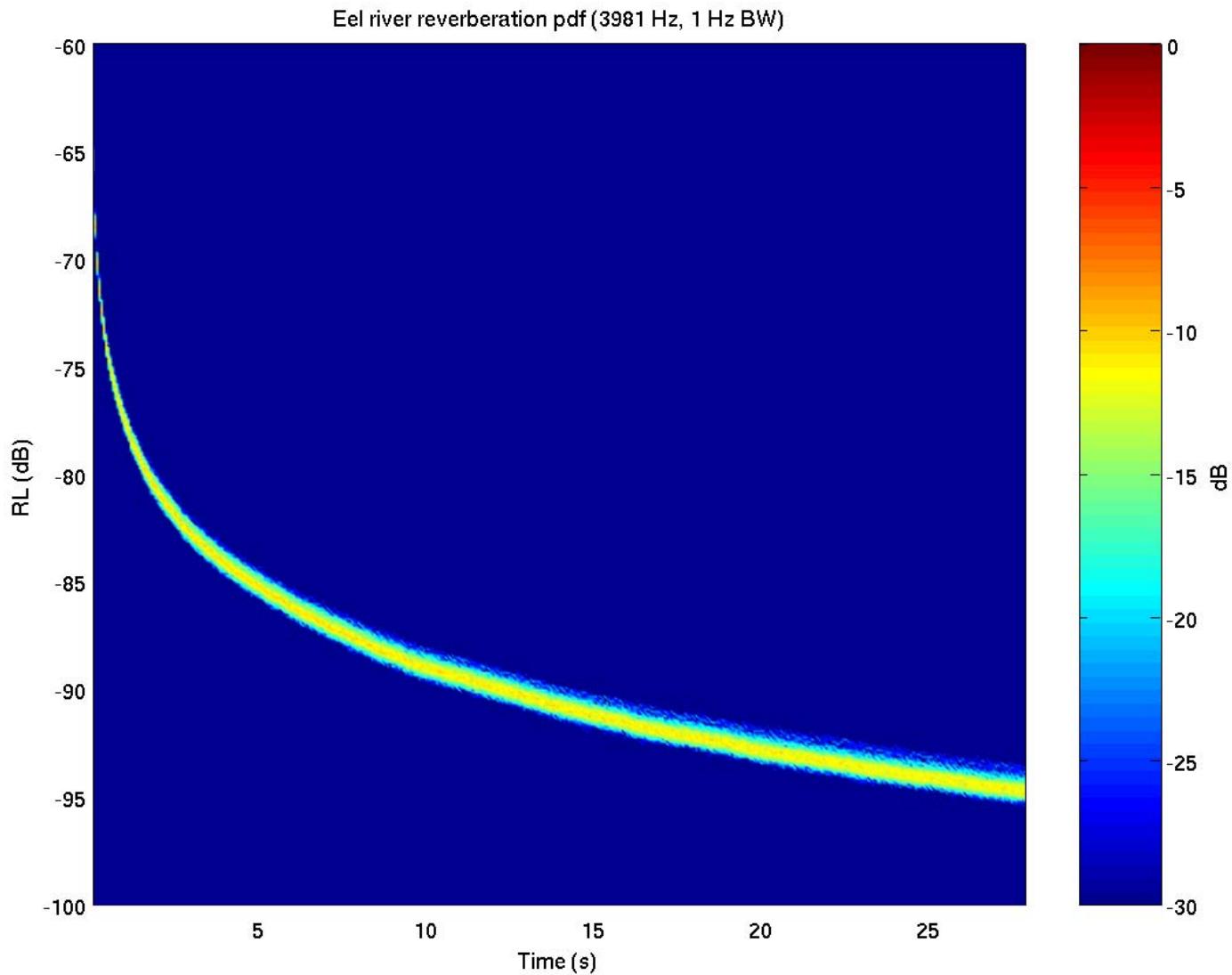
# Incident Spectrum

## Eel River Bottom 4 kHz





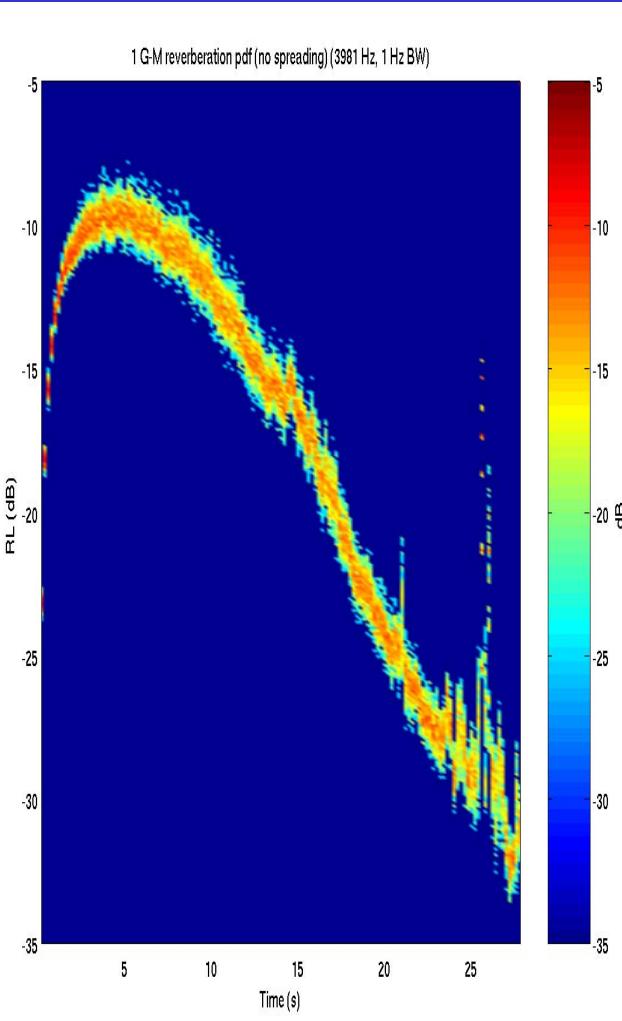
# Resulting Reverberation Uncertainty pdf for Eel River Strataform 4 kHz



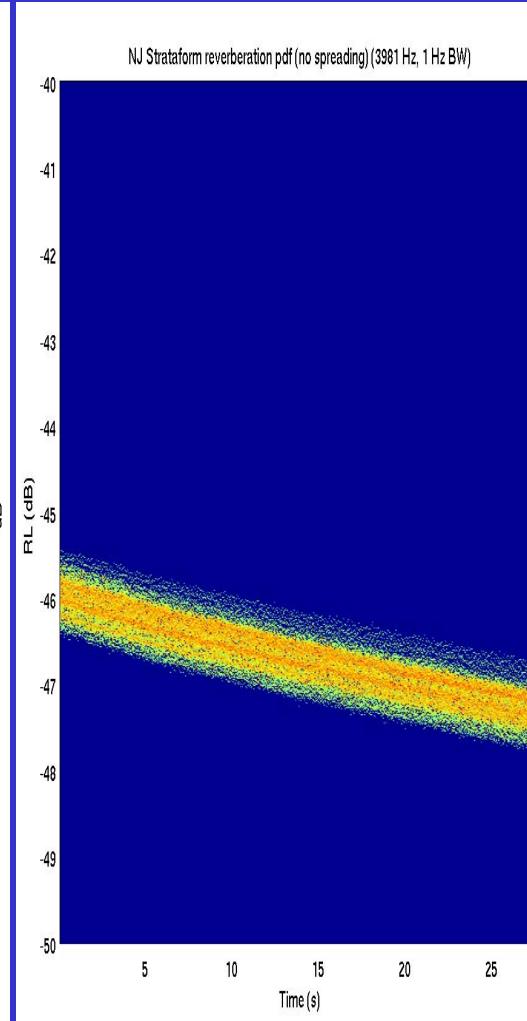


# Reverberation Uncertainty Comparison

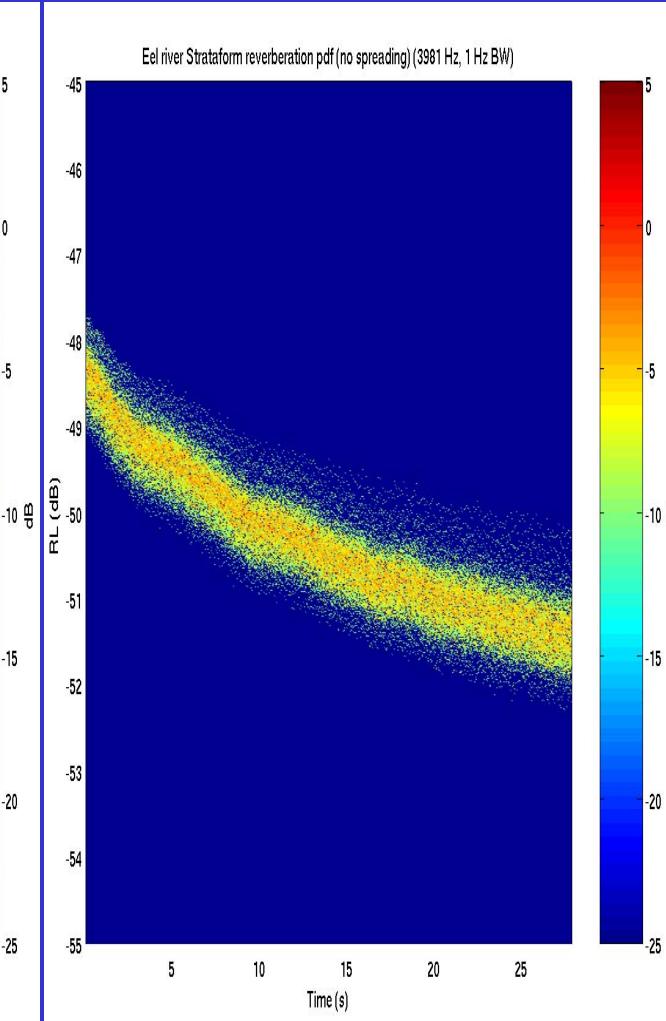
Oceanography



NJ Strataform



Eel River Strataform





# Conclusions

- Different induced reverberation uncertainty for different propagation environments and uncertainty mechanisms
  - For Oceanography over slow sediment and bottom 1-2 dB variance RL
  - For NJ Strataform (fast bottom) 0.5 dB
  - For Eel River Strataform (slow bottom) 0.5 dB with longer tails
- Results assume uncorrelated Scattering Strength uncertainty

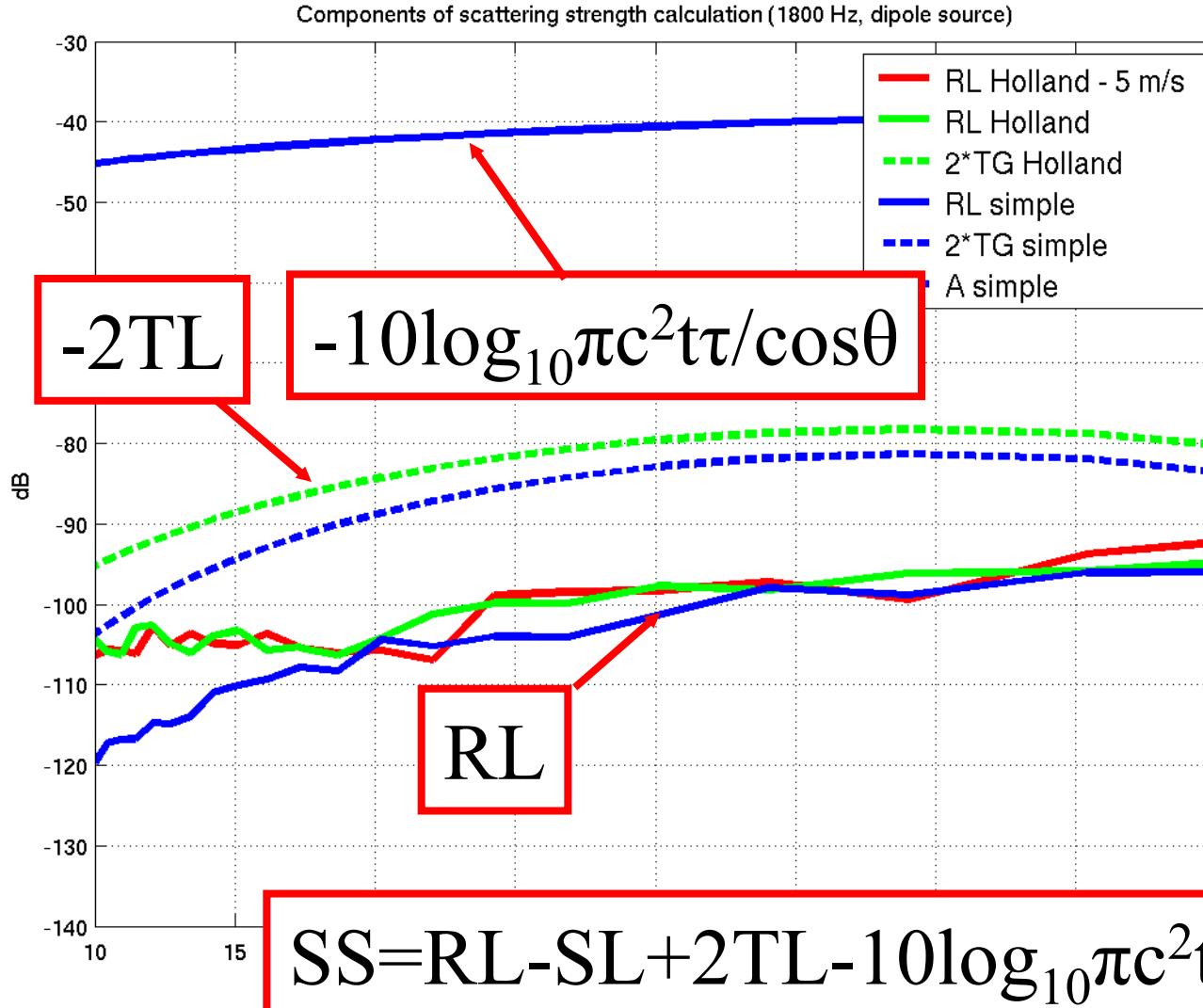


# Future Issues: Reverberation Uncertainty

- Effects of general background property uncertainty
- Effects of bandwidth/coherent effects
  - Full scattering matrix required
- Extend results to target scatter uncertainty
  - Is TL uncertainty really much higher than RL for same oceanographic/bottom uncertainty
  - How important are coherent propagation effects and bandwidth



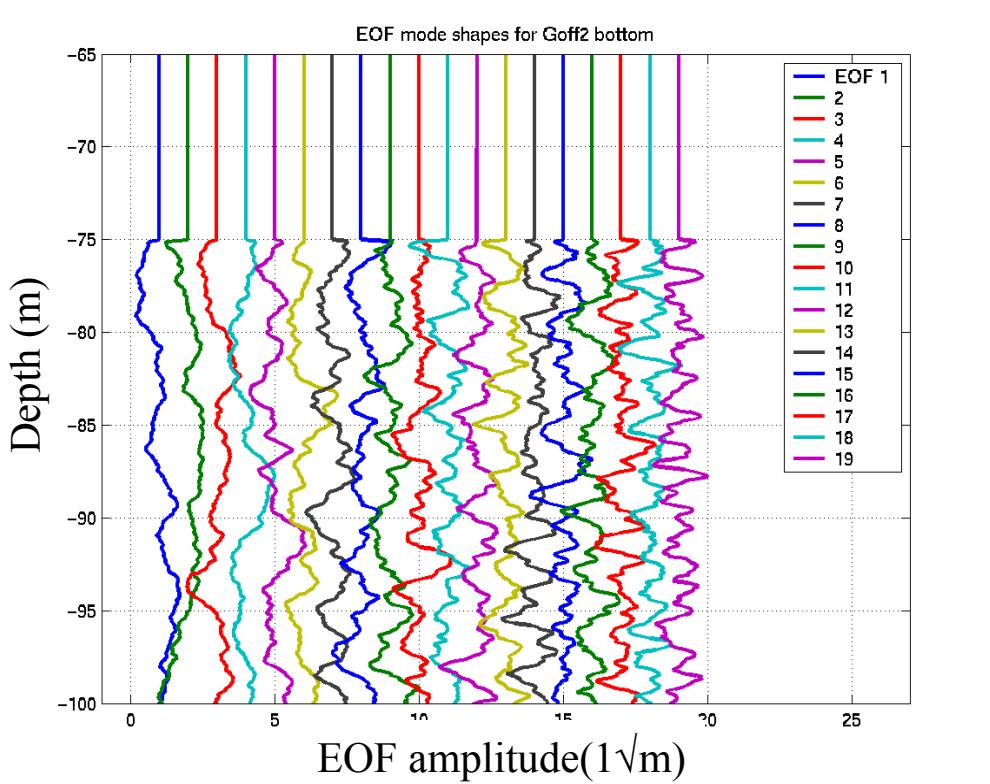
# SS Estimate Components Sediment Volume



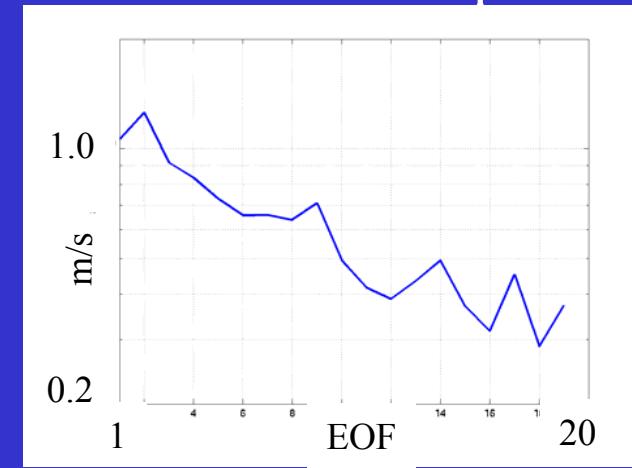


# NJ Shelf EOFs: Stratiform Bottom Sound Speed

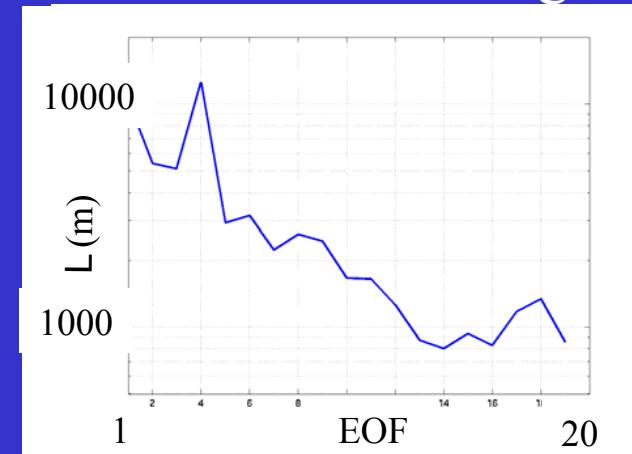
- EOF mode shapes



EOF rms sound speed

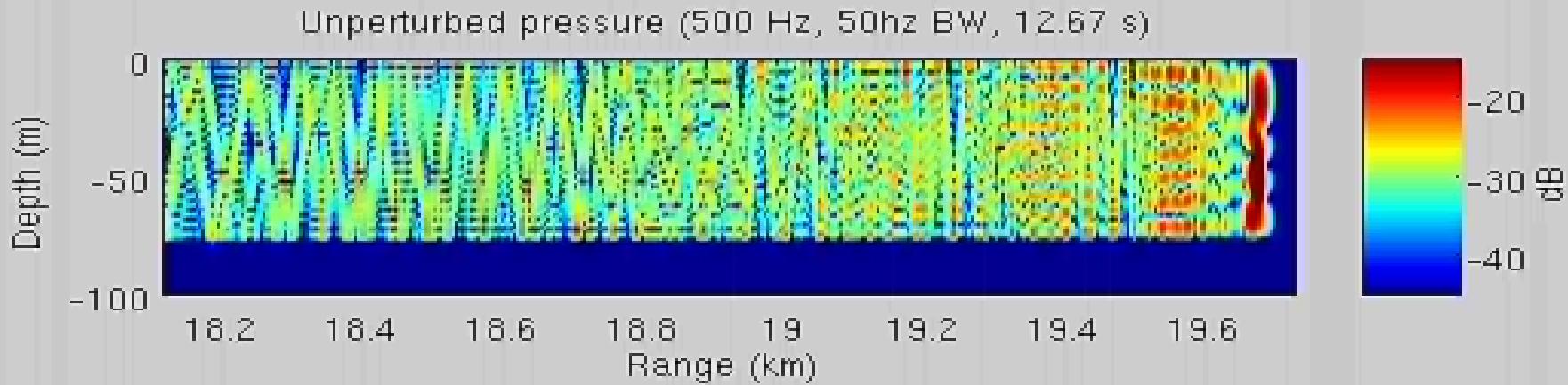
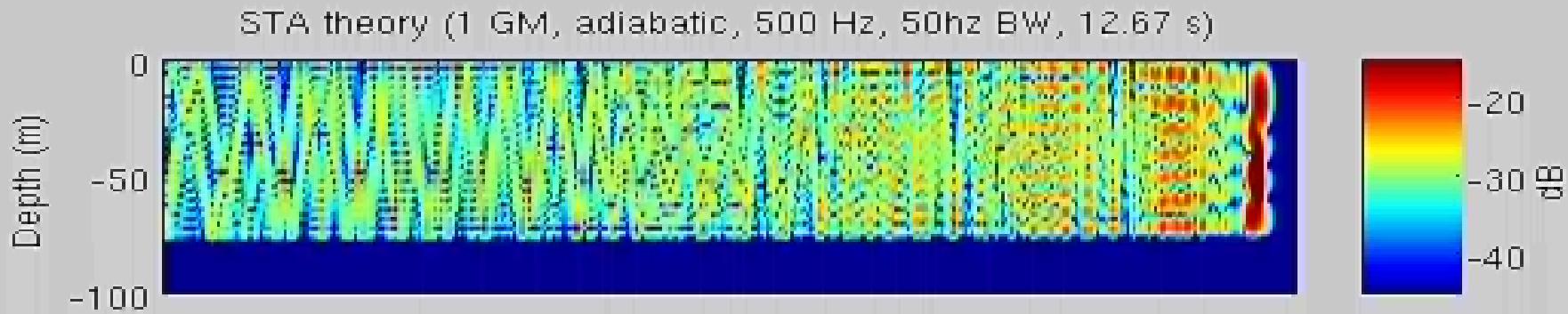


EOF correlation length scale



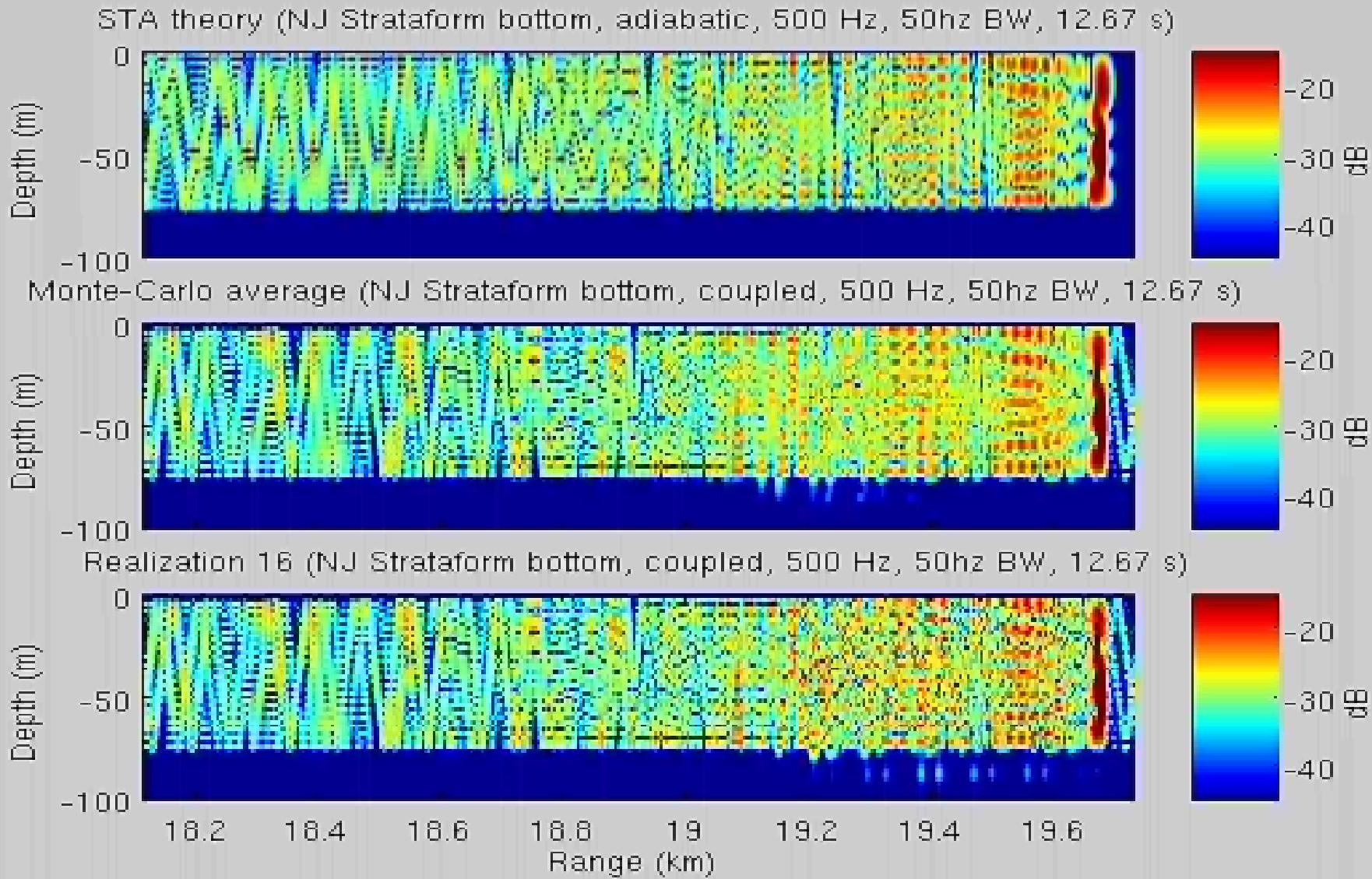


# NJ Strataform Bottom: Adiabatic Theory of Signal Variability





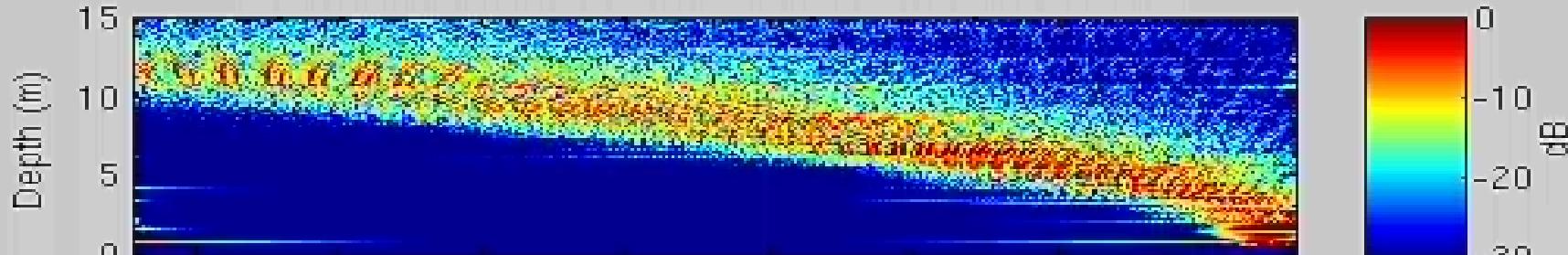
# NJ Bottom: Expected Value of STA Theory vs Monte-Carlo



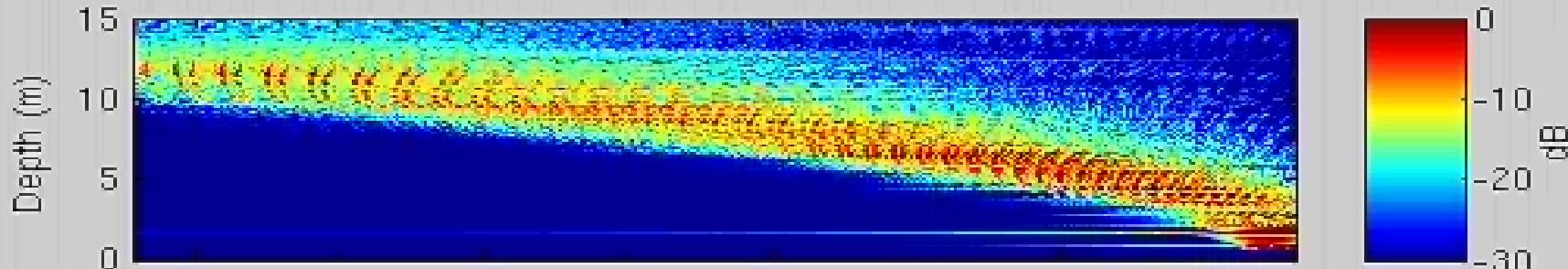


# NJ Bottom: Variability of Field Incident on Bottom Scatterers

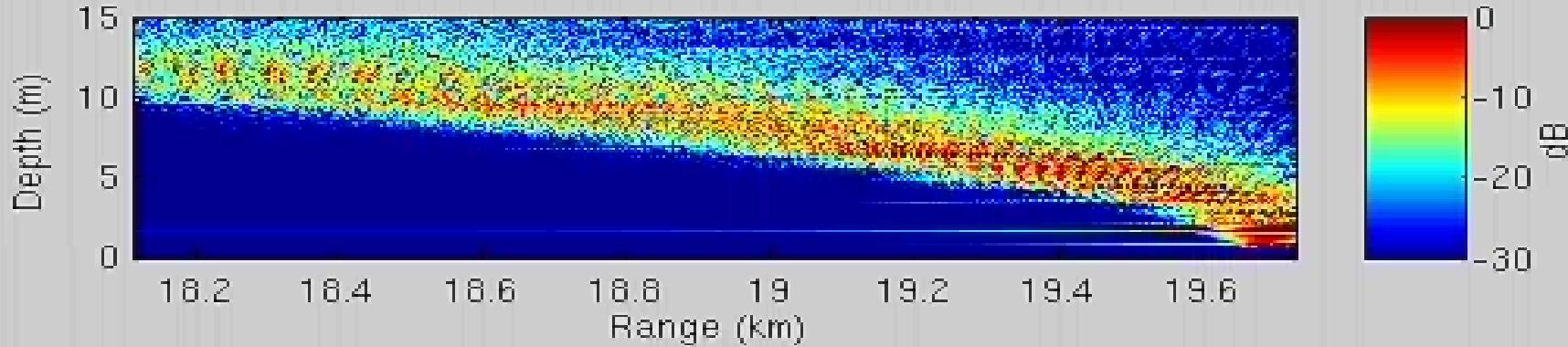
Unperturbed incident field (500 Hz, 50hz BW, 12.67 s)



Monte-Carlo averaged incident field (NJ Strataform bottom, coupled, 500 Hz, 50hz BW, 12.67 s)



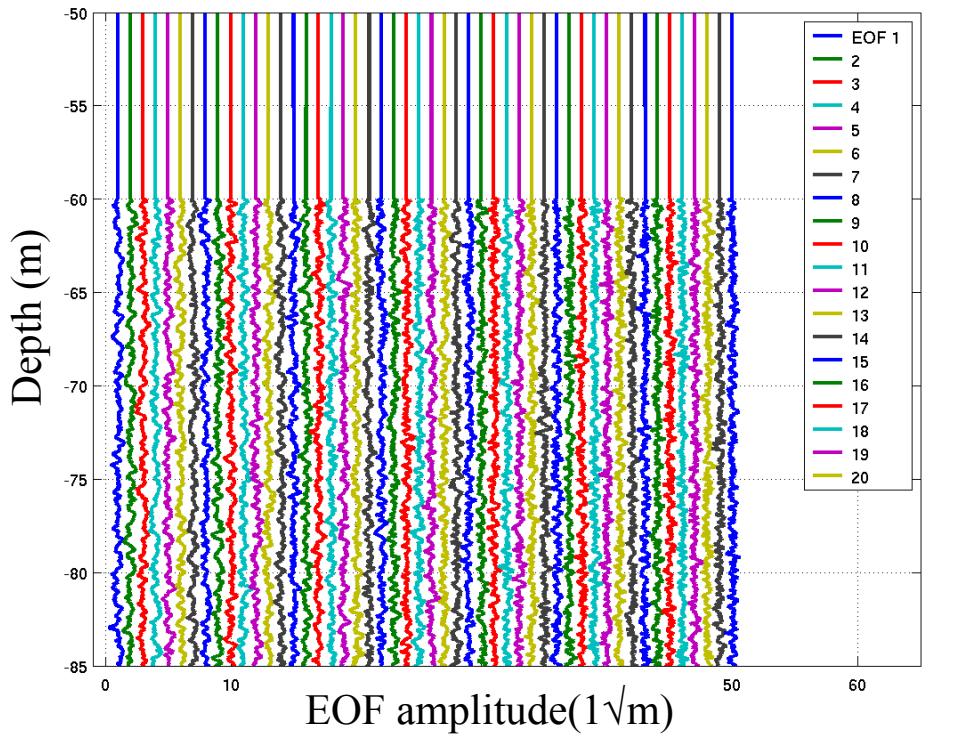
Incident field realization 16 (NJ Strataform bottom, coupled, 500 Hz, 50hz BW, 12.67 s)



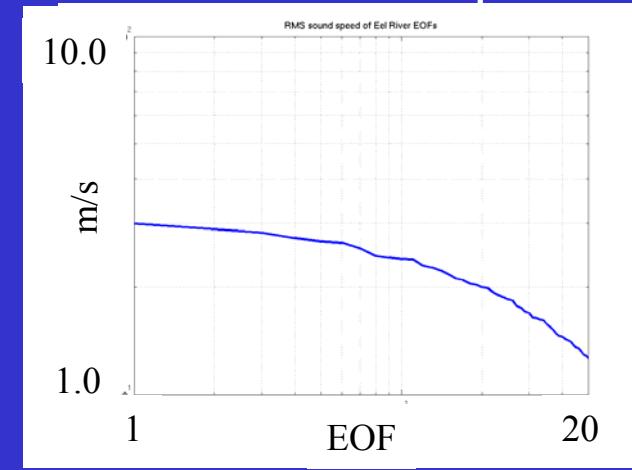


# Eel River EOFs: Stratiform Bottom Sound Speed

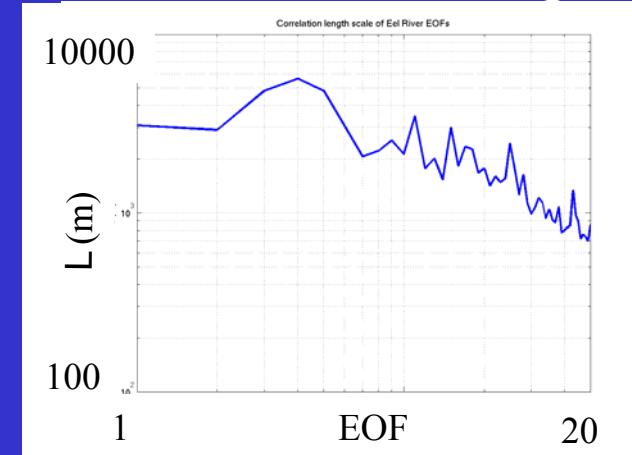
- EOF mode shapes



EOF rms sound speed

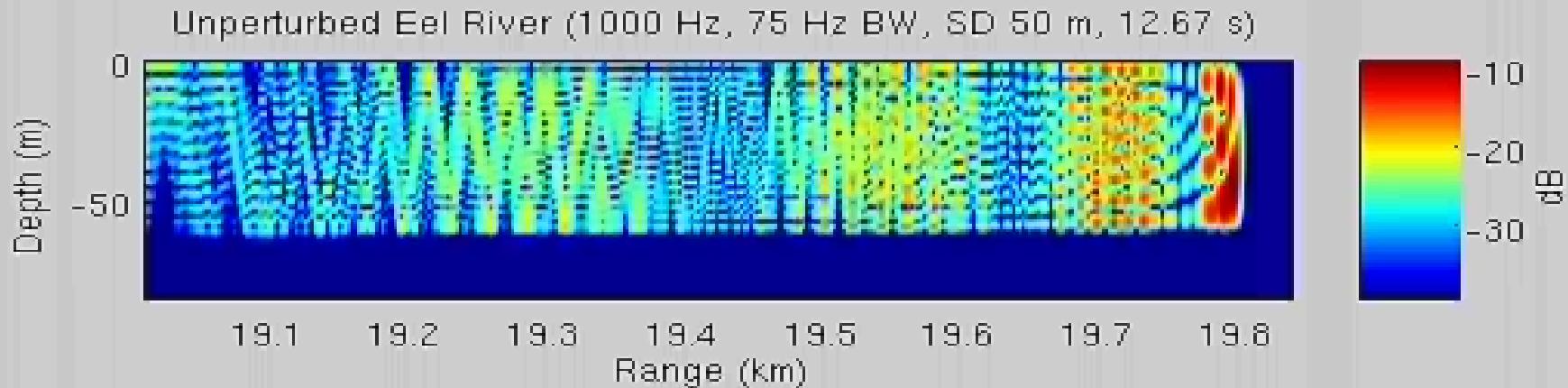
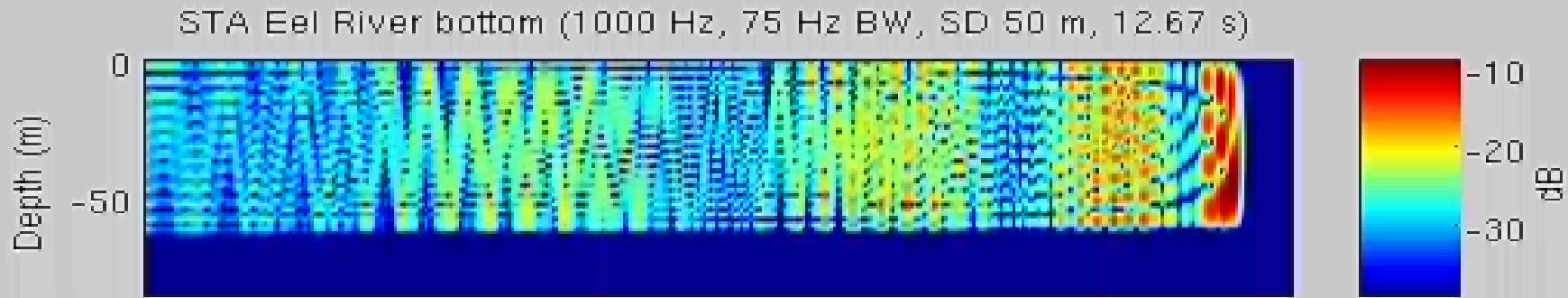


EOF correlation length scale



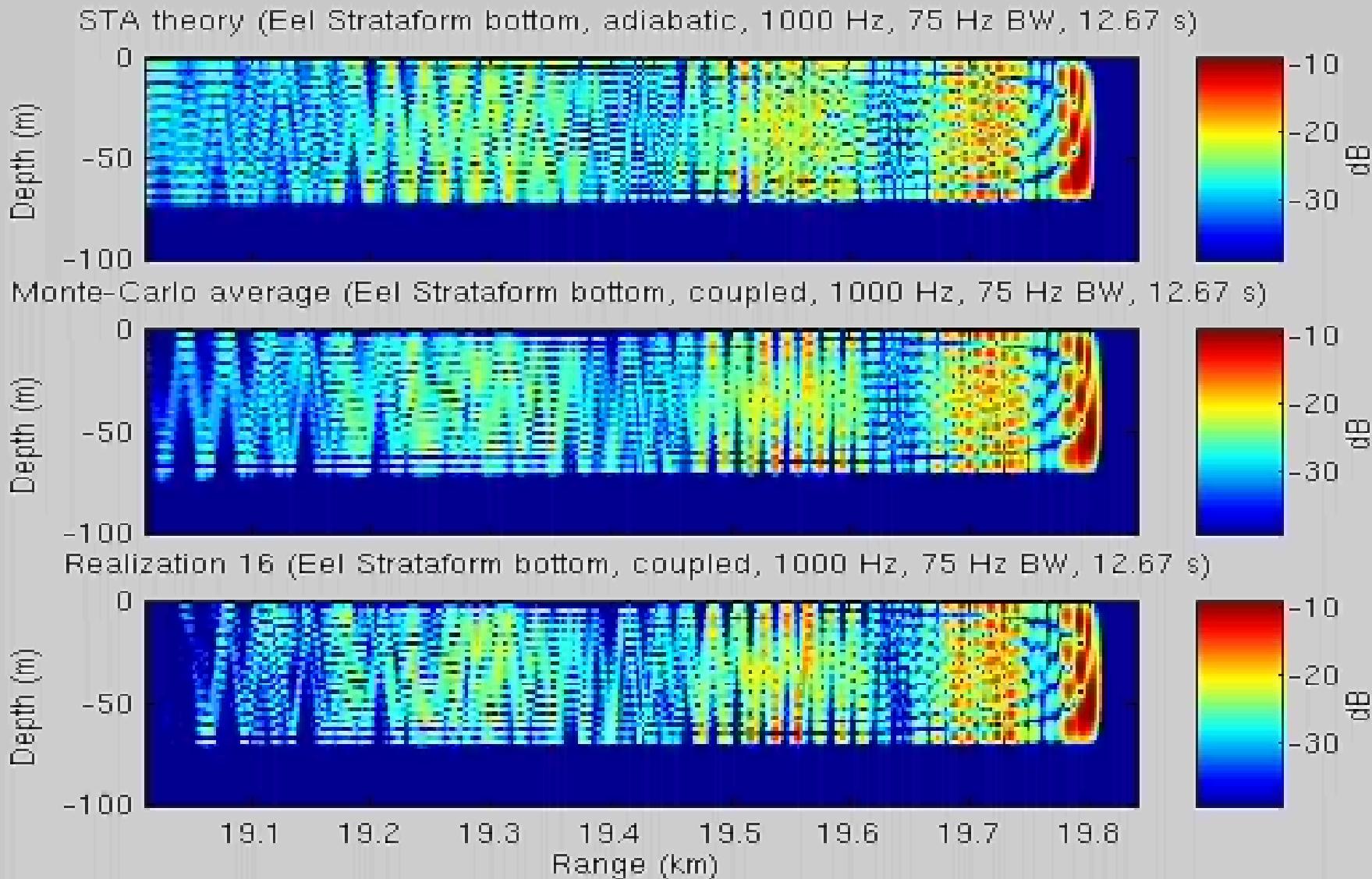


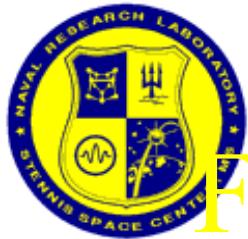
# Eel River Strataform Bottom: Adiabatic Theory of Signal Variability





# Eel River Bottom: Expected Value of STA Theory vs Monte-Carlo





# Eel River Bottom: Variability of Field Incident on Bottom Scatterers

