Quantifying the uncertainty of geoacoustic parameter estimates in a dynamic environment using oceanographic data observed in the SW06 experiment

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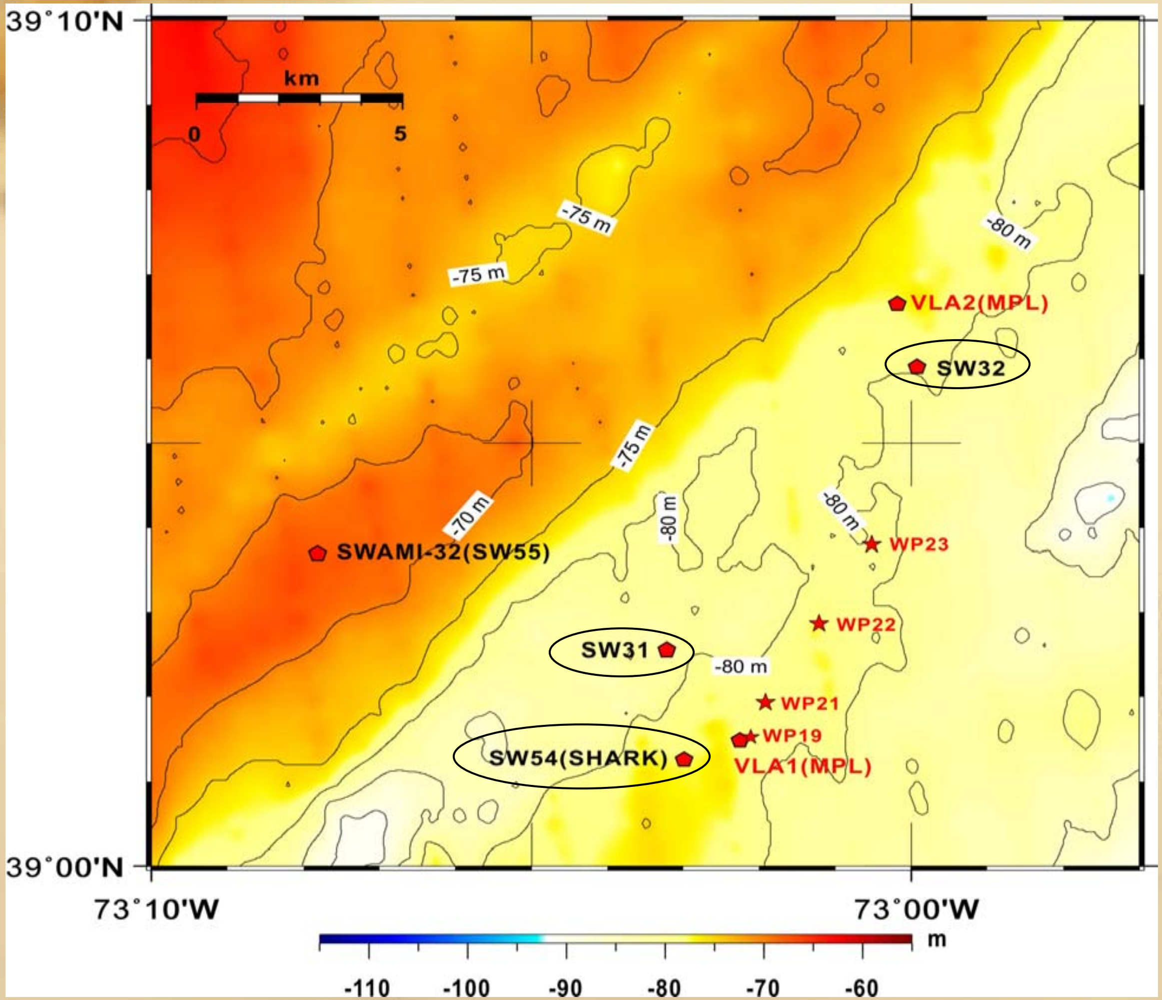
Objective:

Compare the effect of different SSP observations on geoacoustic inversion in a dynamic shallow water environment

Outline:

- Experimental site
- Oceanographic observations
- EOF analysis of water column SSP
- Bayesian inversion approach
- Discussion of the results
- Conclusions

Experimental Site



Acoustic Array (MPL):

- VLA1

Acoustic sources:

- WP21, 1 km
- WP22, 3 km
- Wp23, 5 km

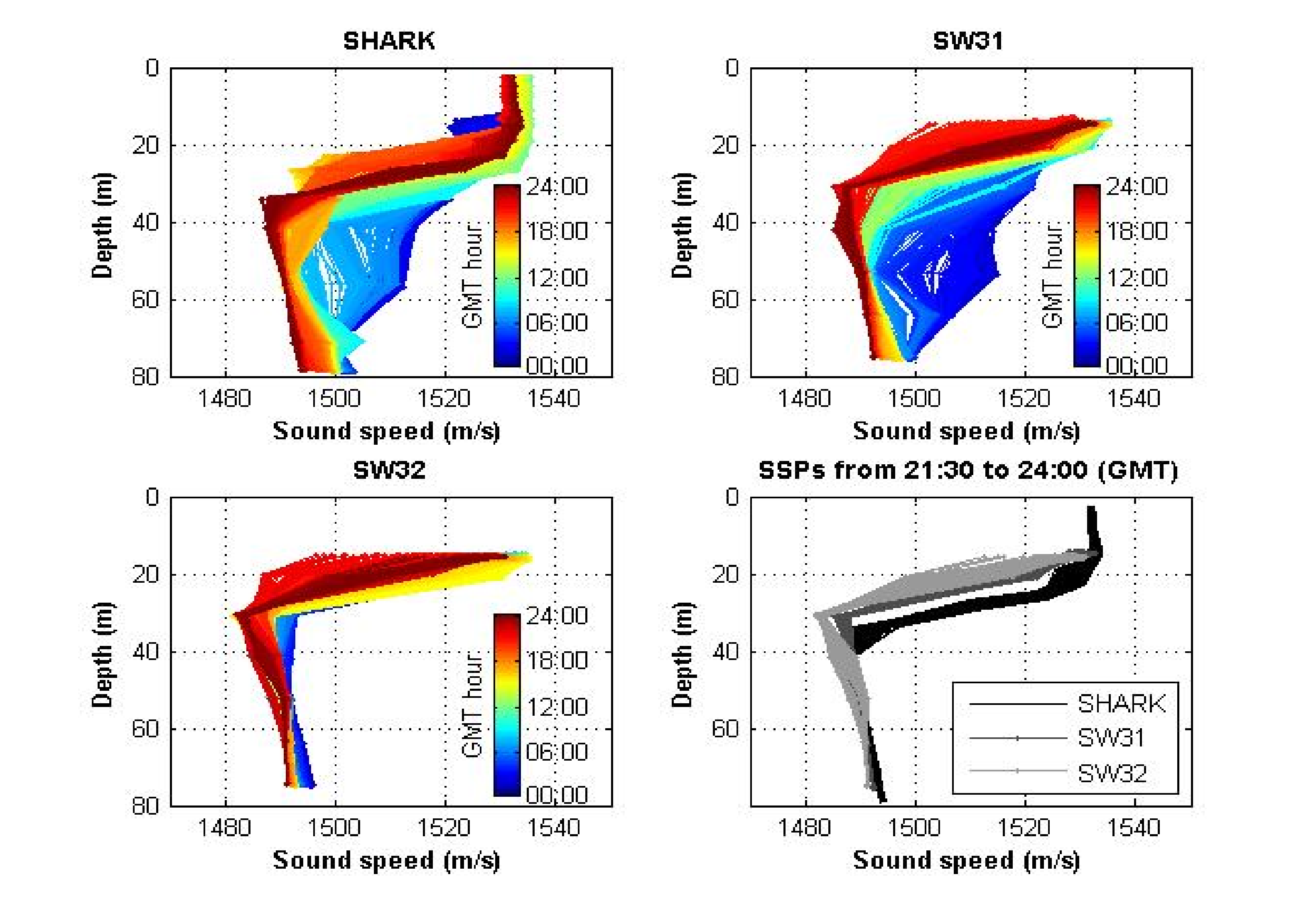
CTD casts:

- WP19, 2 (38 mins apart)
- WP21, 1
- WP22, 1
- WP23, 1

Environmental arrays (WHOI):

- SW31, SW32 and SW54

Oceanographic observations (JD239):



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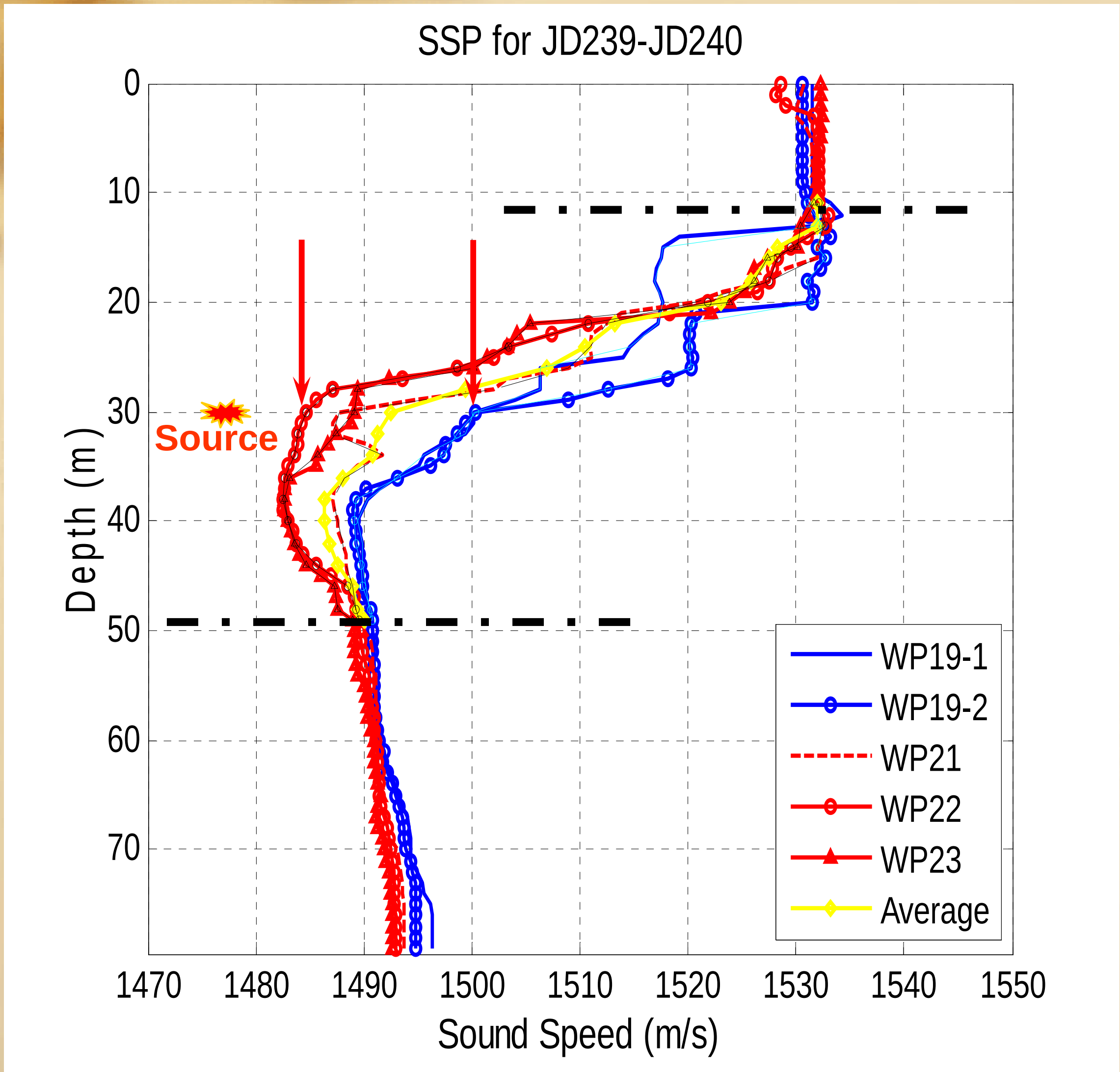
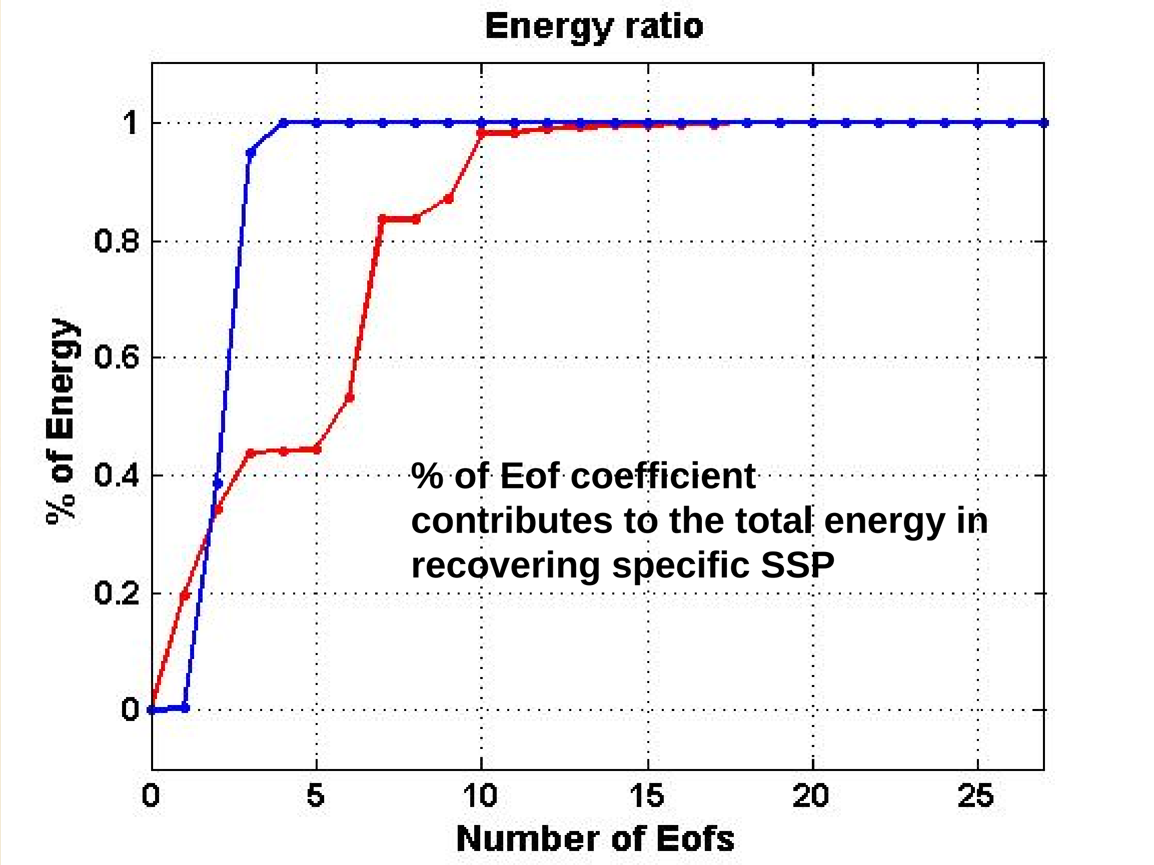
SSP casts at source stations



- Small sample set:
  - SSP casts obtained on the source ship within 4 hours along the track.
  - fit only the thermocline region in the inversion
- Large Sample set:
  - SSPs in the vicinity (SHARK, SW31 & SW32) within source transmission time + small sample set
  - invert for the whole profile in the water column

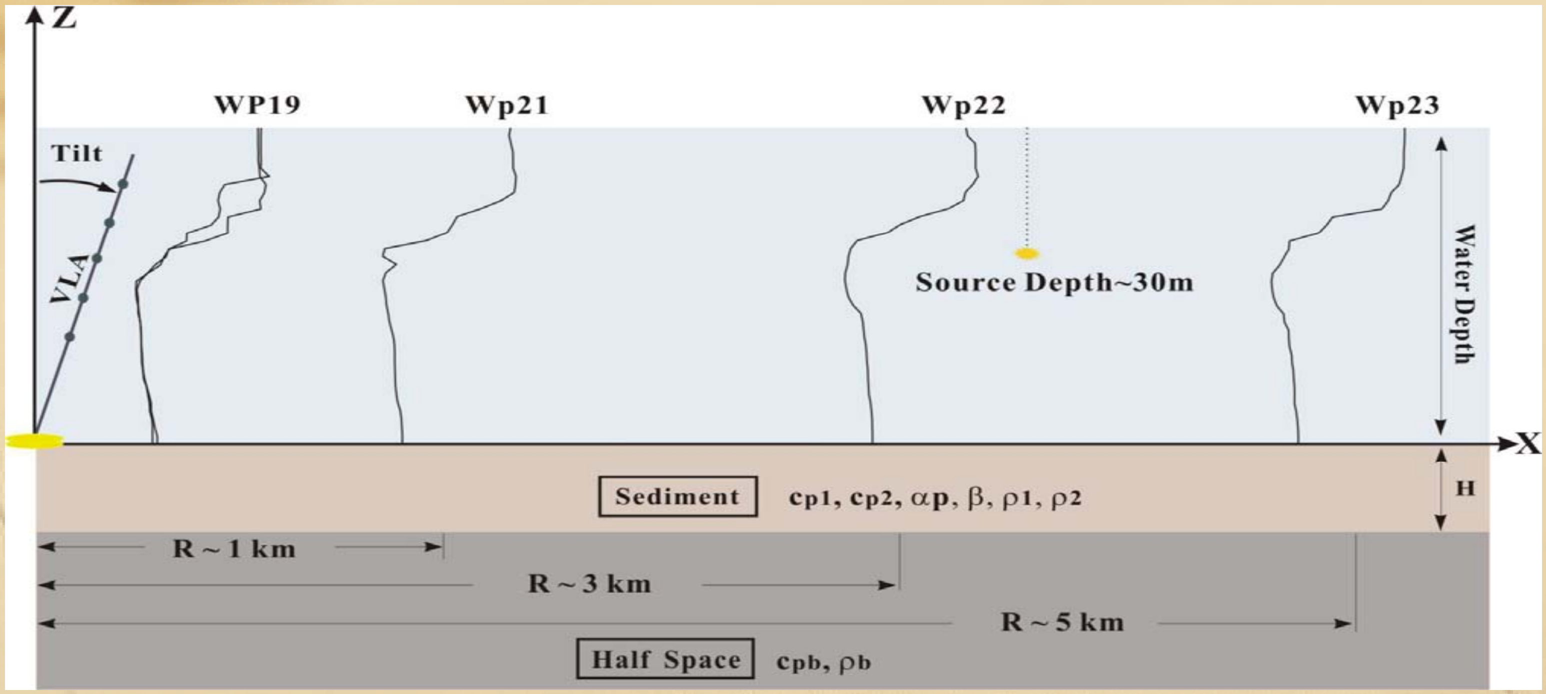
EOF analysis of ocean SSPs:



Small sample group

Large sample group

Geoacoustic model:



Geometric parameters: 4 (WD, R, SD and VLA tilt)

Geoacoustic parameters: 9 (H, c_1, c_2, c_b, ρ_1, ρ_2, ρ_b, α_{p1} and β)

Water column SSP: 4 (small sample set)

8 (Large sample set)

Total number of parameters: 17 / 21

Bayesian matched-field geoacoustic inversion:

- Bayes' rule:

$$P(\mathbf{m}\,|\,\mathbf{d}) = \frac{P(\mathbf{d}\,|\,\mathbf{m})P(\mathbf{m})}{P(\mathbf{d})}$$

$$\Rightarrow \quad P(\mathbf{m}\,|\,\mathbf{d}) \propto L(\mathbf{m})P(\mathbf{m}), \qquad L(\mathbf{m}) \propto \exp[-E(\mathbf{m})]$$

- Energy function:

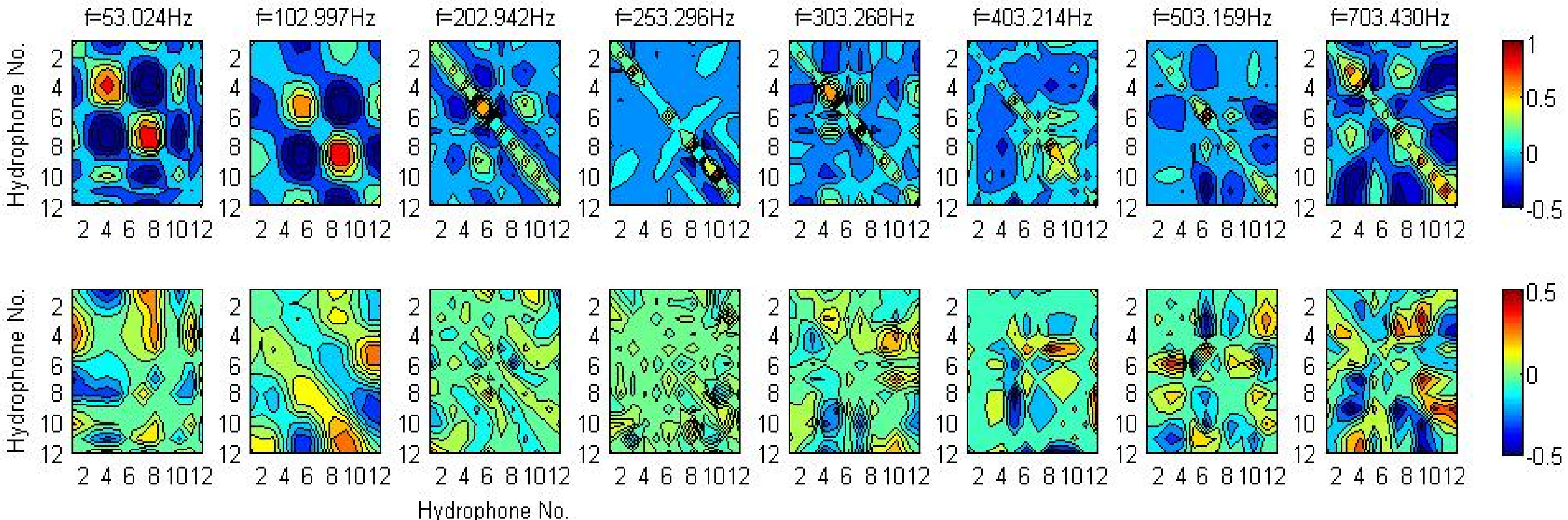
$$E(m) = \sum_{f=1}^{N_F}\left[(\vec{d}_f^{\,obs})^+ C_f^{-1}\vec{d}_f^{\,obs} - \frac{\left|\vec{p}_f^{\,+}(m)C_f^{-1}\vec{d}_f^{\,obs}\right|^2}{\vec{p}_f^{\,+}(m)C_f^{-1}\vec{p}_f(m)}\right]$$

- Data error covariance matrix estimation:

$$C_f = \frac{1}{n}\sum_{i=1}^{n}\left\{\left[\vec{r}_{fi}(m) - \left(\sum_{j=1}^{n}\vec{r}_{fj}(m)\right)/n\right]\left[\vec{r}_{fi}(m) - \left(\sum_{j=1}^{n}\vec{r}_{fj}(m)\right)/n\right]^+\right\}$$

Example of full covariance matrices:

real

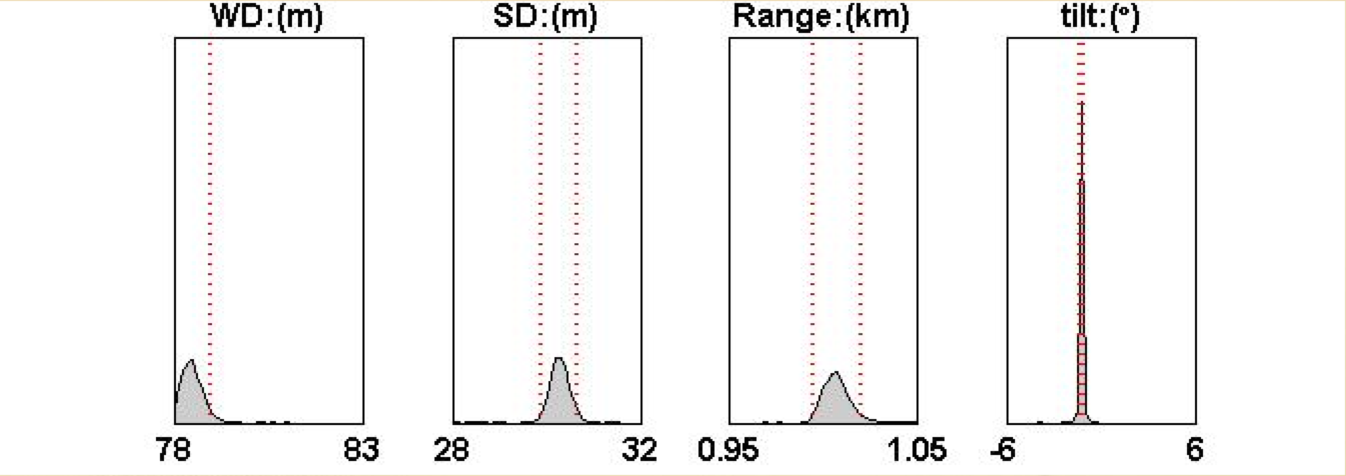


imaginary

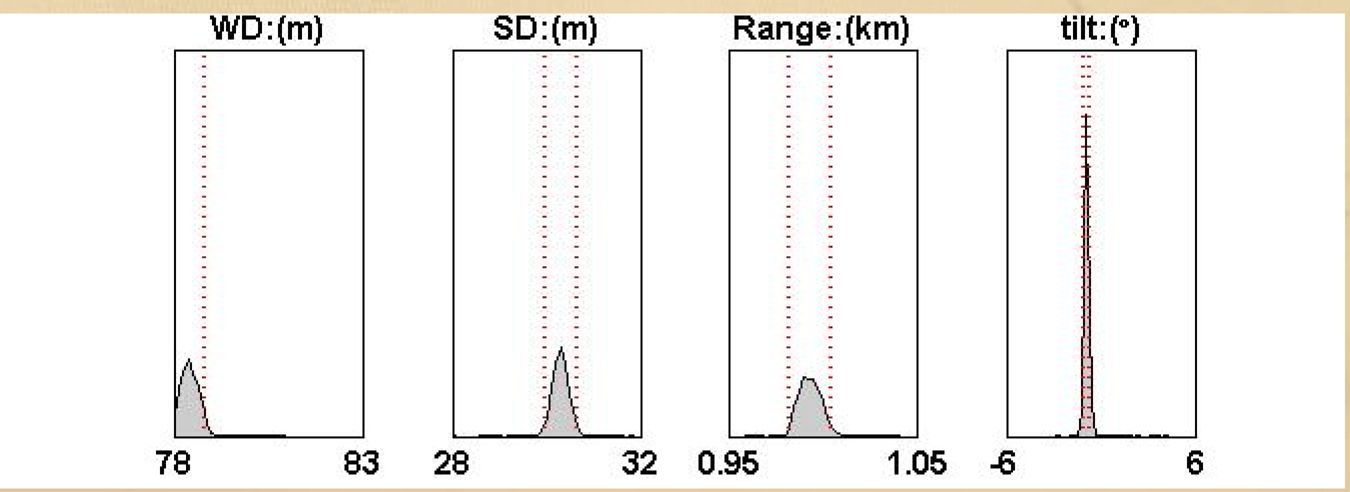
Data error covariance matrices for 1 km data

Example of inversion results: (1 km geometry)

Small SSP samples



Large SSP samples



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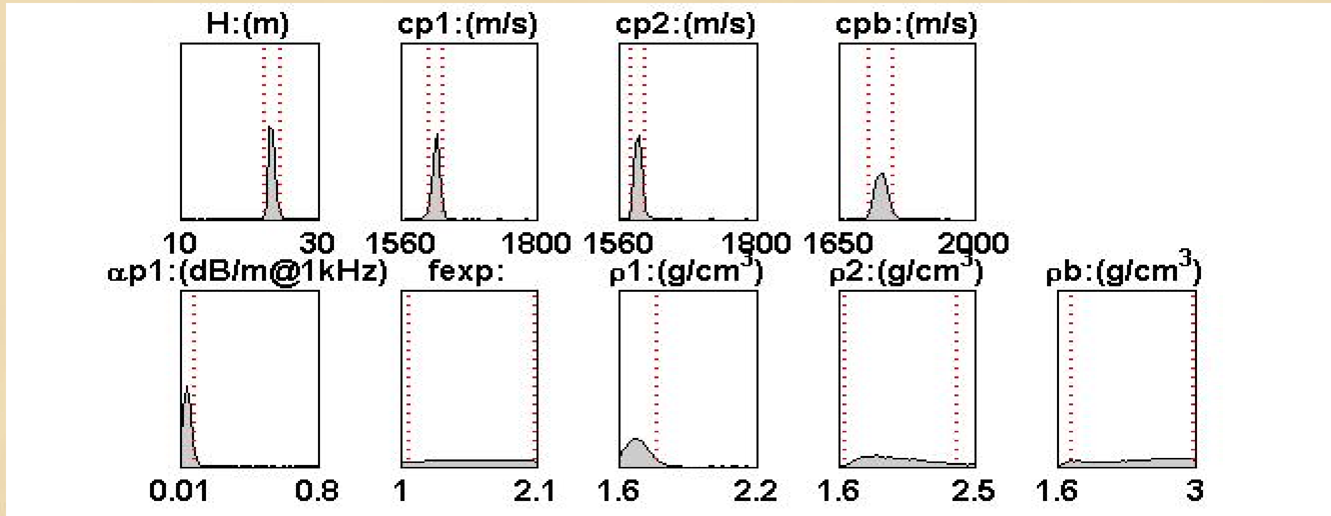
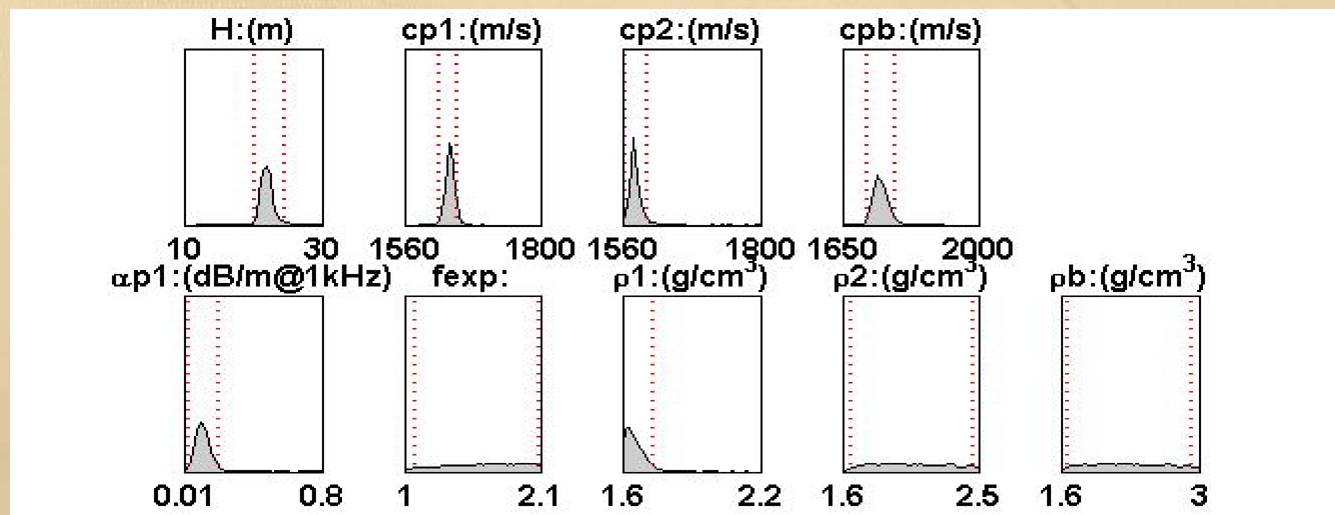
Example of inversion results: (1 km geoacoustics)

Small SSP samples

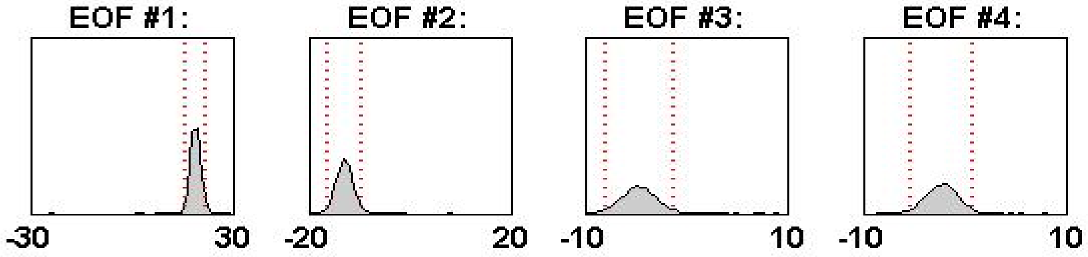


Large SSP samples

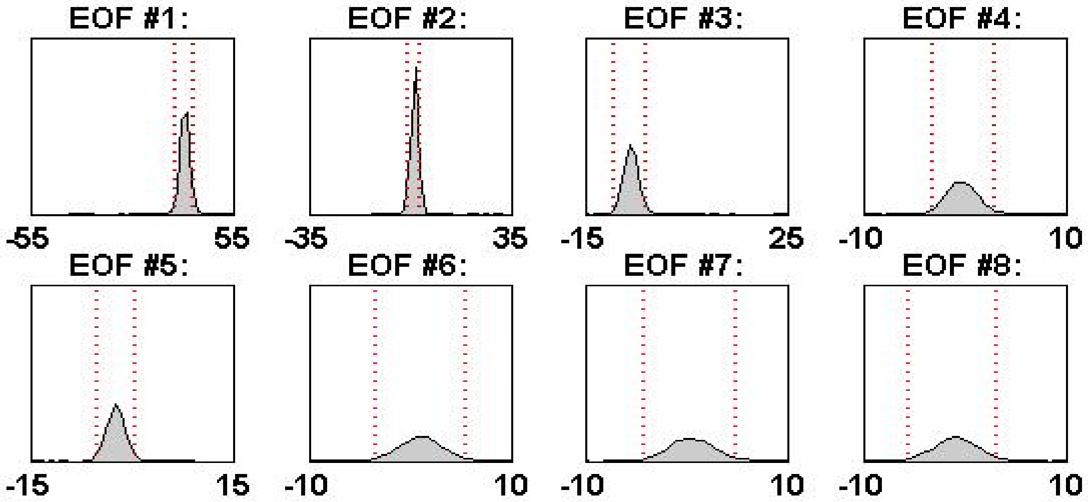


Example of inversion results: (1 km EOFs)

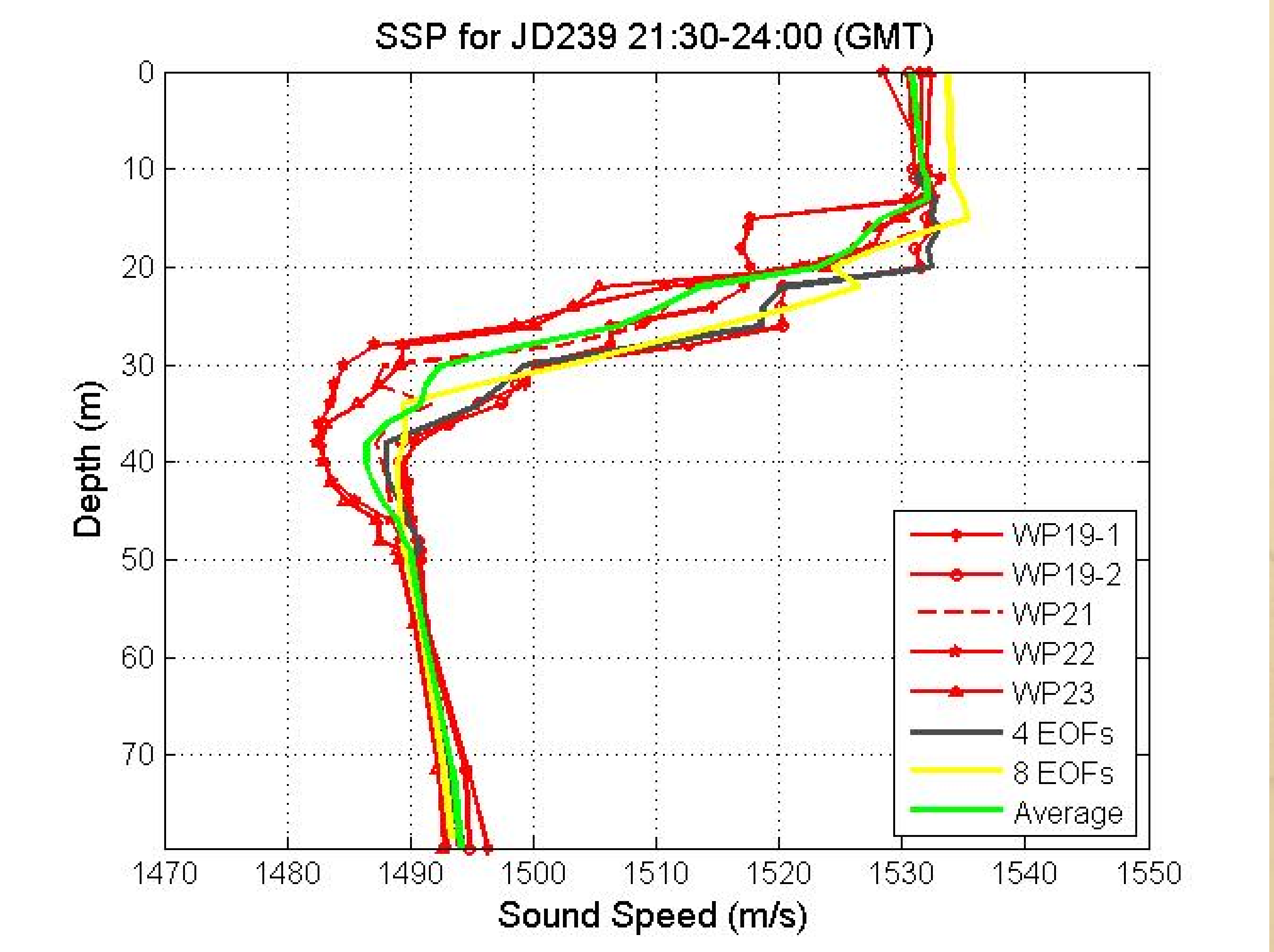
Small SSP samples



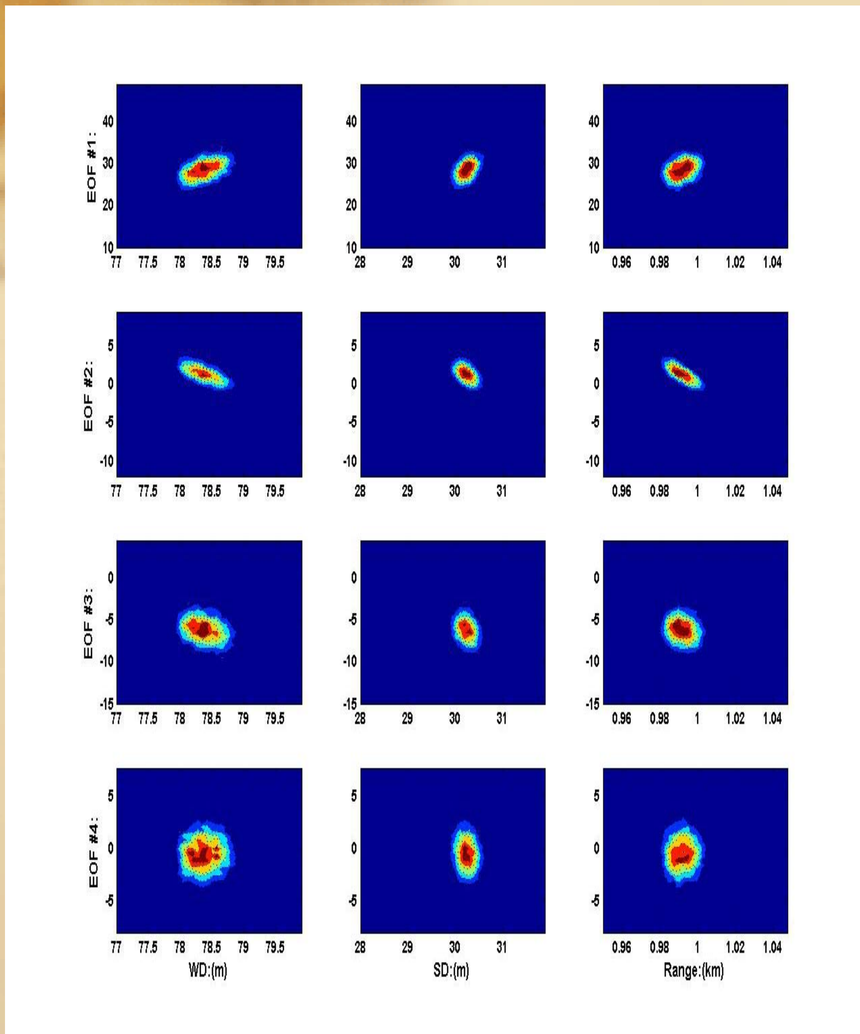
Large SSP samples

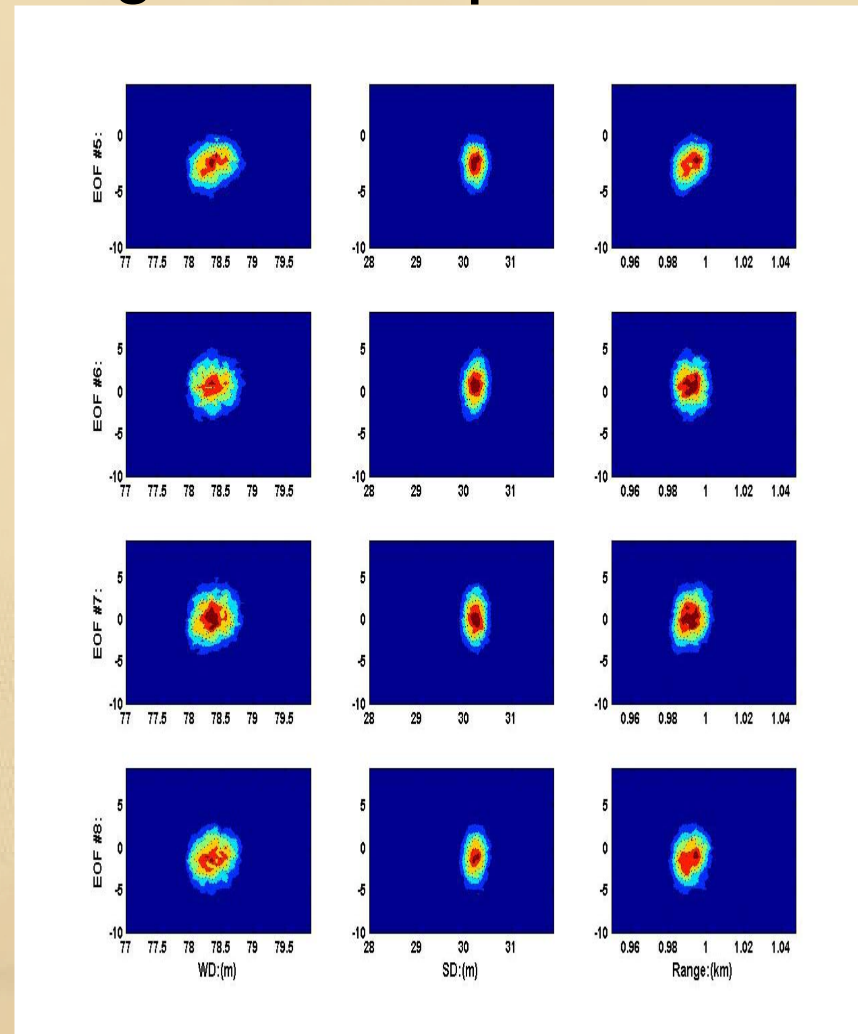


Inverted SSP for 1 km transmission



Correlation between EOFs and geometric parameters





- Expected correlations with geometric parameters

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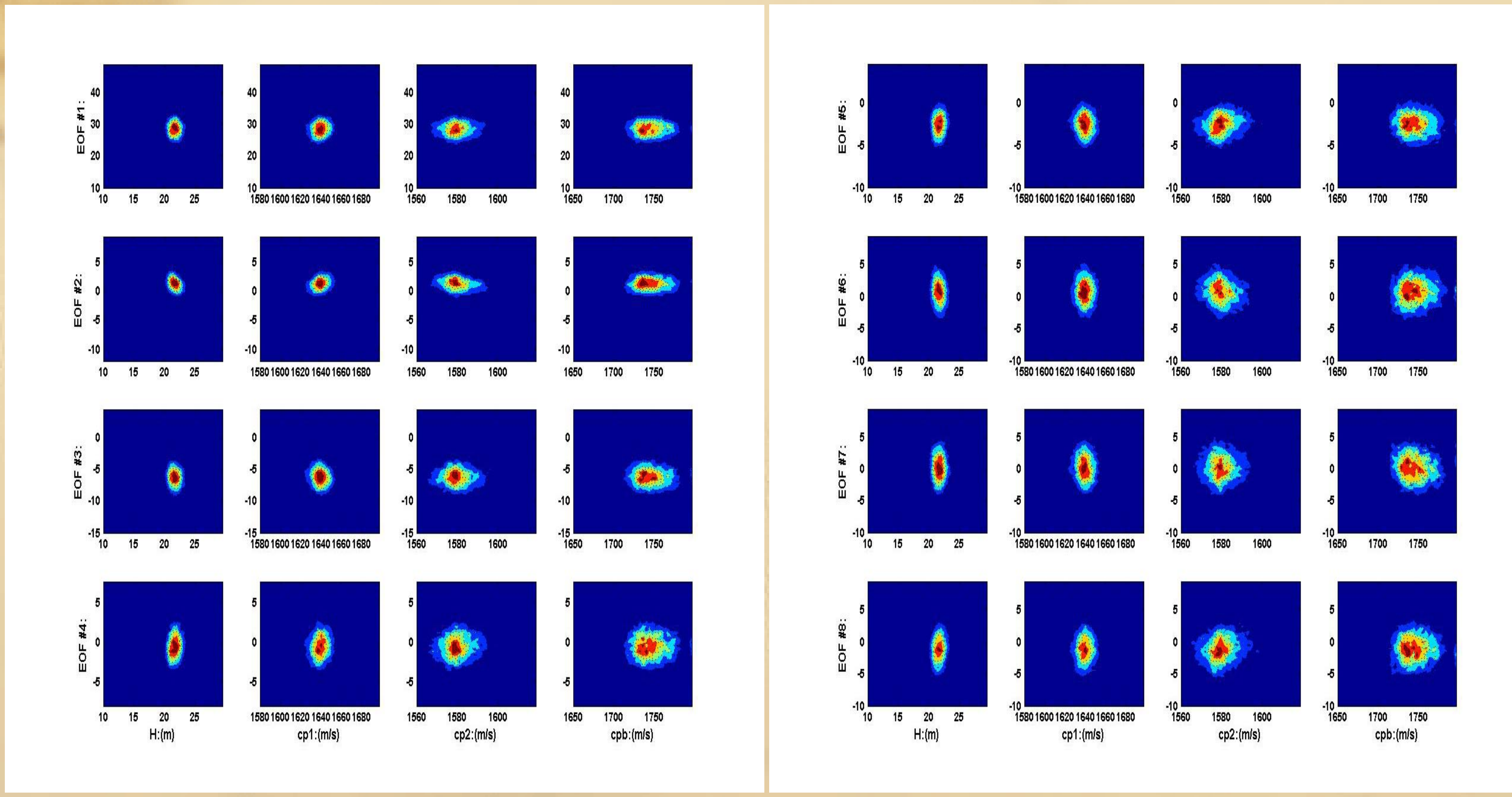
Correlation between EOFs and geoacoustic parameters



❖ Weak correlations with layer thickness and sound speed at sea bottom

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Conclusions:

- Water column sound speed profile has significant effect on geometric parameters and therefore affects geoacoustic parameter estimates
- Including SSP in the inversion improves the performance of matched field inversion in a dynamic environment. However the method is not suitable in a environment with strong internal wave activities
- The most relative ocean SSPs are more efficient in geoacoustic inversion
- Geoacoustic parameter estimates using different SSP observations are consistent with each other