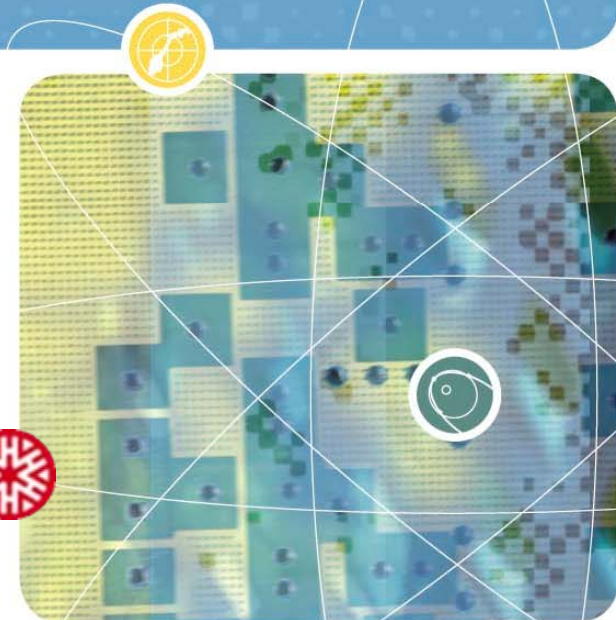


Classification of water masses using empirical orthogonal functions (EOF)



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Jonsmod 2012





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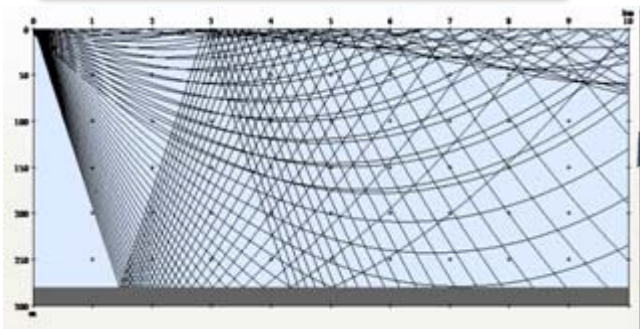
“Classification of water masses using empirical orthogonal functions (EOF)”

1. Motivation
2. Method theory
3. Example data set
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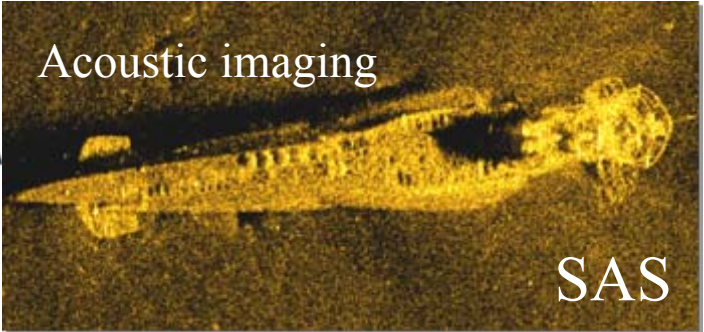
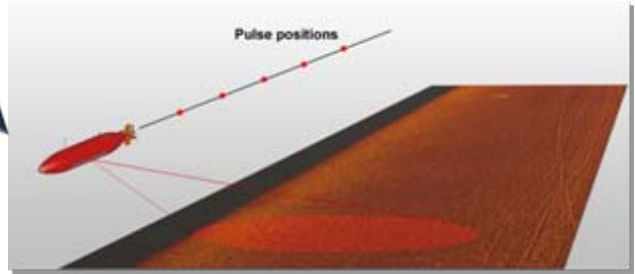


Temperature profiles

Salinity profiles

Pressure profiles

Vertical sound speed profiles crucial for accuracy in the modelled acoustic field¹⁻²



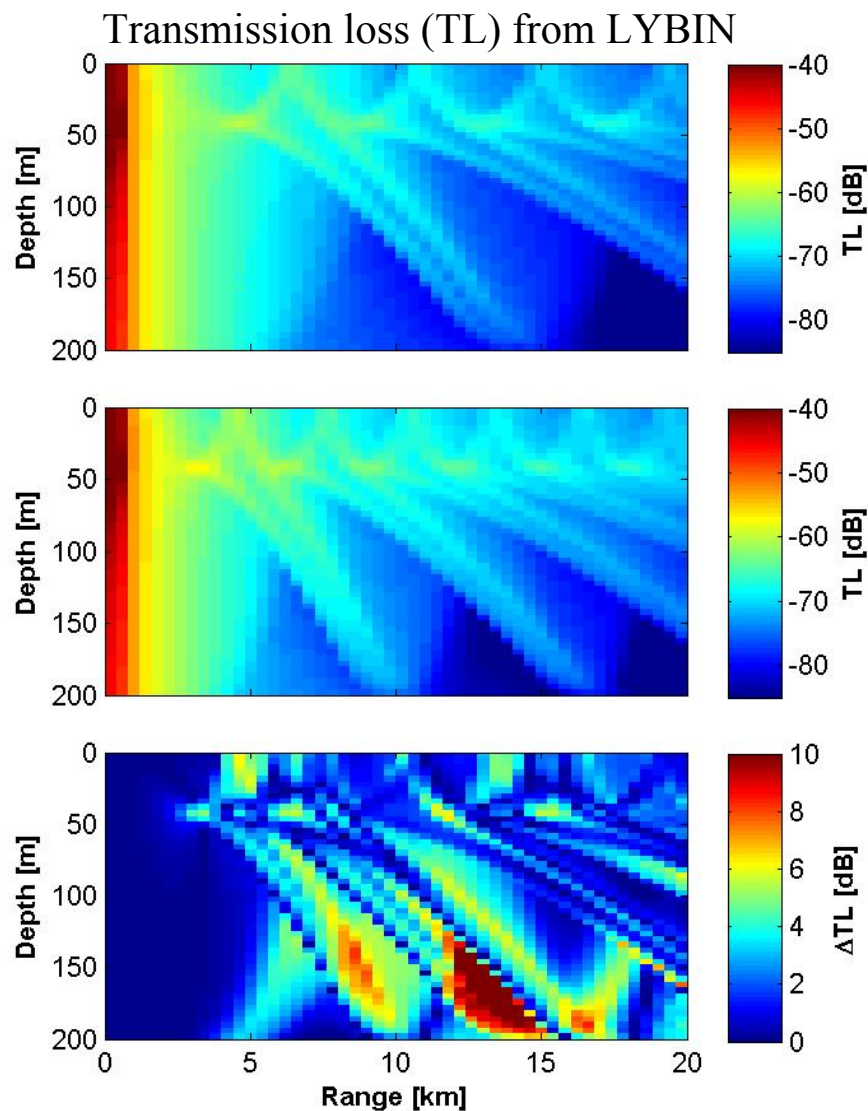
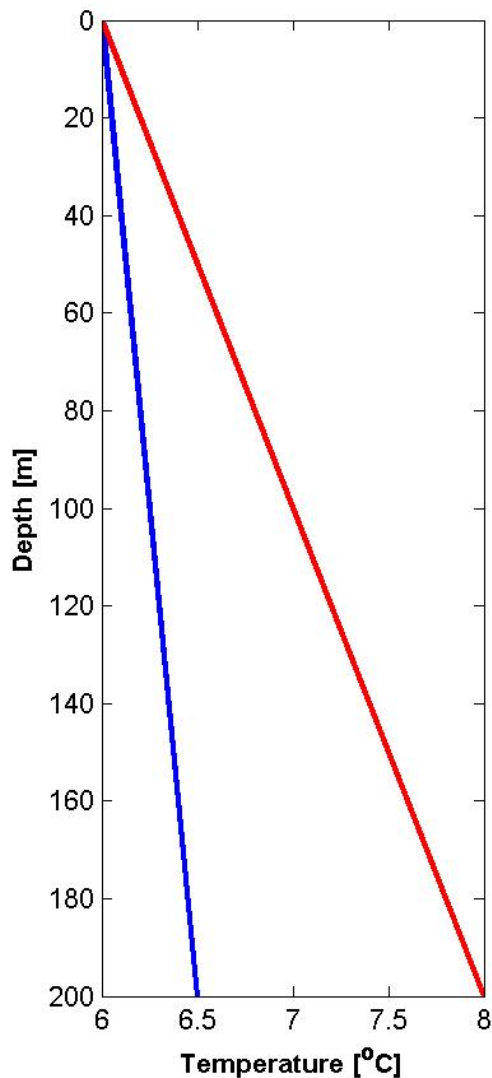
etc.

1: K.R. James and D.R. Dowling, *A method for approximating acoustic-field-amplitude uncertainty caused by environmental uncertainties*, J. Acoust. Soc. Am., vol 124 (3), 2008.

2: K. LePage, *Modeling Propagation and Reverberation Sensitivity to Oceanographic and Seabed Variability*, IEEE J. Oceanic Eng., vol. 31 (2), April 2006.



Acoustic sensitivity to vertical profile



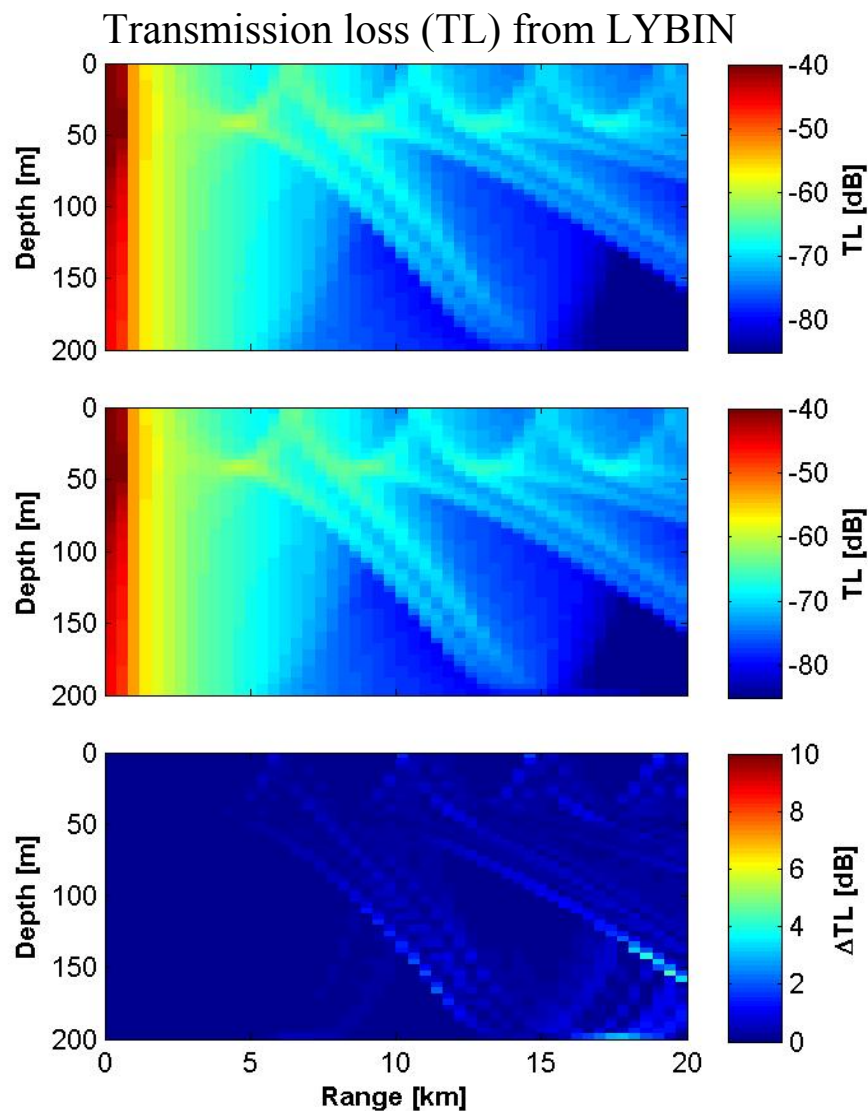
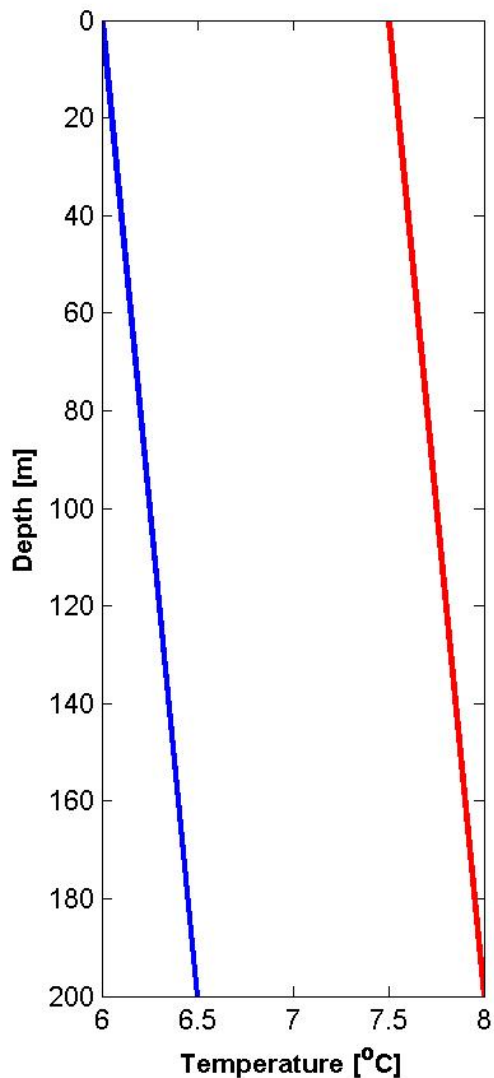
Corresponds to
true profile

Corresponds to
error-induced
profile

The difference



Acoustic sensitivity to vertical profile



Corresponds to
true profile

Corresponds to
error-induced
profile

The difference



Empirical orthogonal functions (EOF) in literature

- EOFs first used in oceanography in the 1970s¹
- EOFs combined with clustering:
 - widely used for seabed classification²
 - recently used on modeled oceanography (sound speed profiles)³⁻⁴

1: Preisendorfer, R. W. (1988). *Principal Component Analysis in Meteorology and Oceanography*. Elsevier. Curtis D. Mobley

2: Milligan S, LeBlanc L, Middleton F (1978) *Statistical grouping of acoustic reflection profiles*. The Journal of the Acoustic Society of America 64(3):795–807

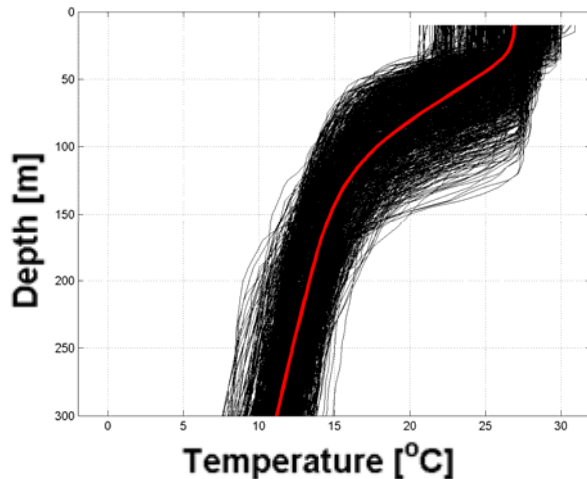
3: Jenssen J K, Hjelmervik K T, Østenstad P (2012) *Finding Acoustically Stable Areas Through Empirical Orthogonal Function (EOF) Classification*. The journal of Oceanic Engineering 37 (1): 103-111

4: Hjelmervik K T, Jenssen J K, Østenstad P (2012) *Classification of acoustically stable areas using empirical orthogonal functions*. Journal of Ocean Dynamics, 62 (2): 253-264

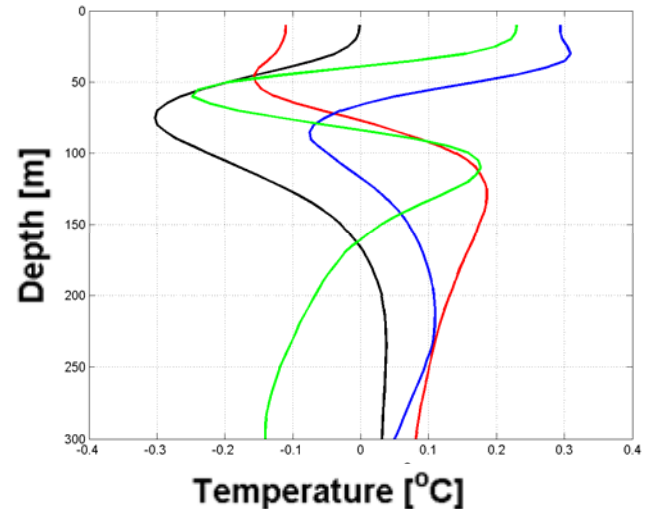


Empirical orthogonal functions (EOF)

EOF-analysis is a powerful tool for representing vertical profiles using only a few coefficients (typically 2-5).



$$R_{xx}u_n = \lambda_n u_n$$

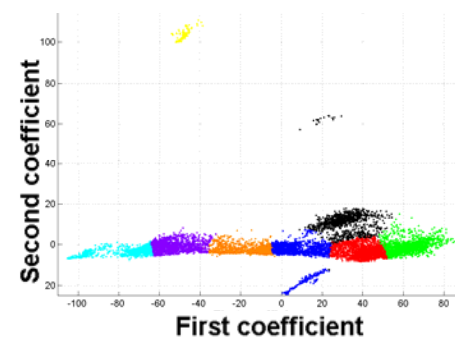
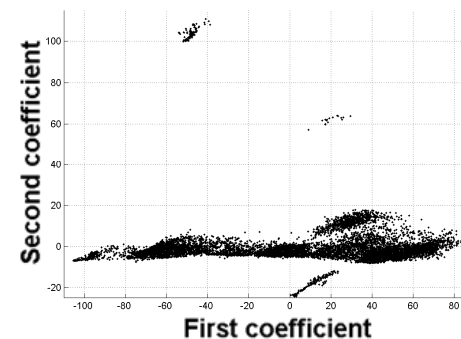
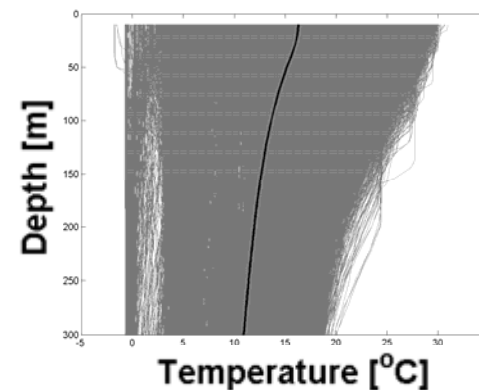
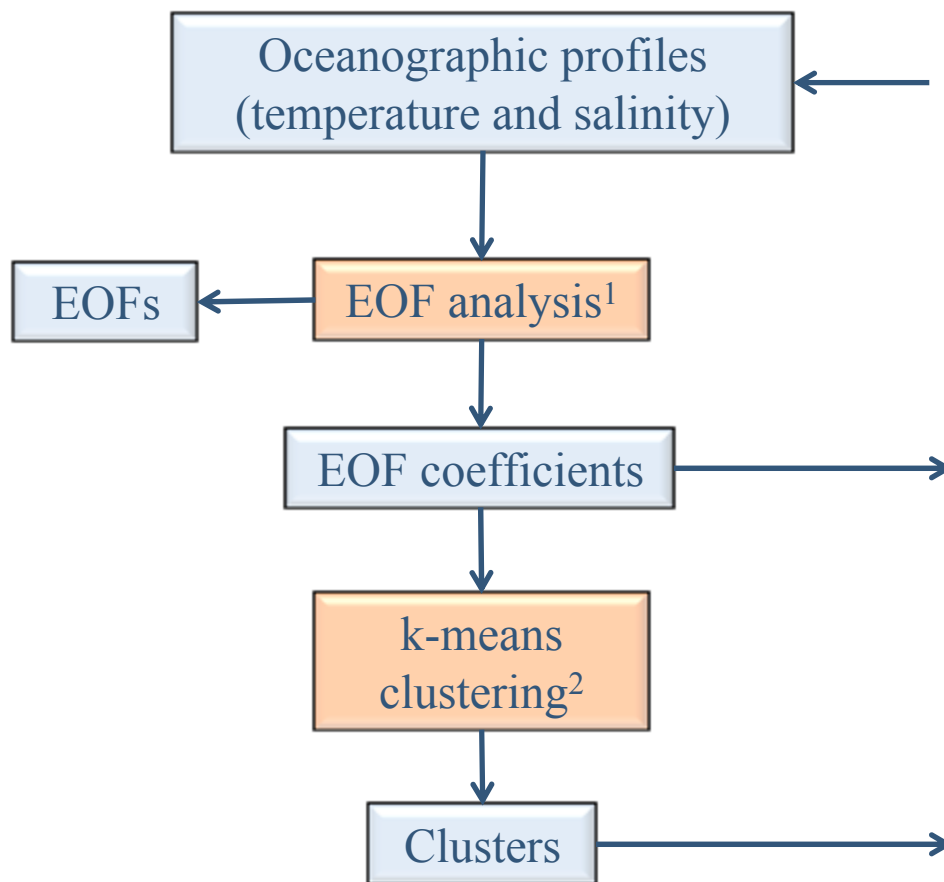


- R_{xx} : covariance matrix
- u_n : EOFs (eigenvectors)
- λ_n : eigenvalues
- $\kappa_{i,n}$: EOF-coefficients

$$c_i(z) = \bar{c}(z) + \sum_{n=1}^N \kappa_{i,n} u_n(z)$$



EOF and clustering method



1: Preisendorfer, R. W. (1988). *Principal Component Analysis in Meteorology and Oceanography*. Elsevier. Curtis D. Mobley

2: J. B. MacQueen (1967): "Some Methods for classification and Analysis of Multivariate Observations, *Proceedings of 5-th Berkeley Symposium on Mathematical Statistics and Probability*". Berkeley: University of California Press. 1:281-297



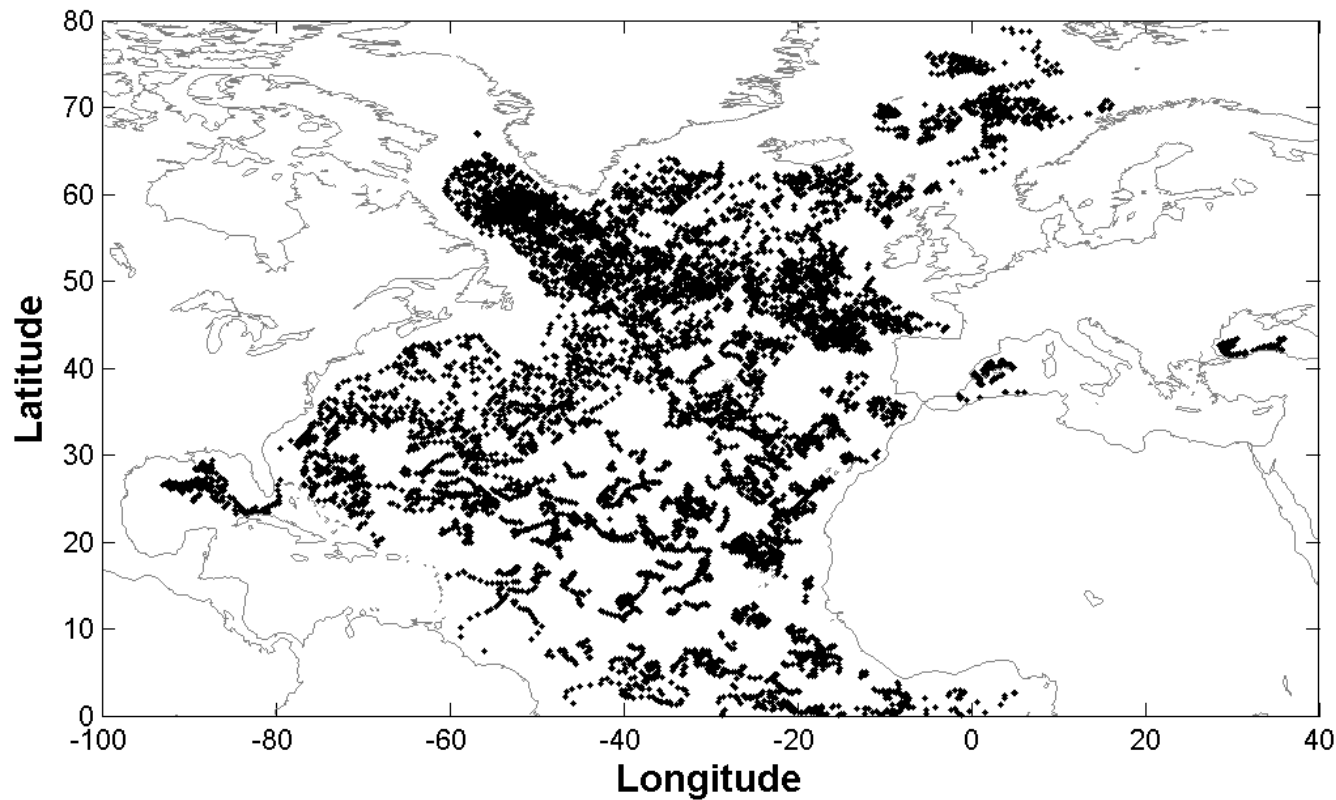
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Example area

9400 ARGO profiles¹ from 2011

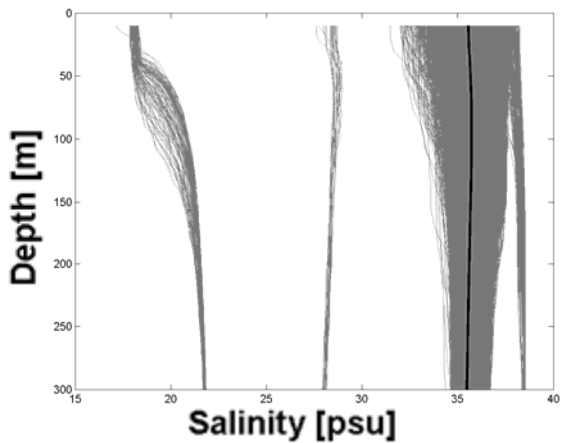
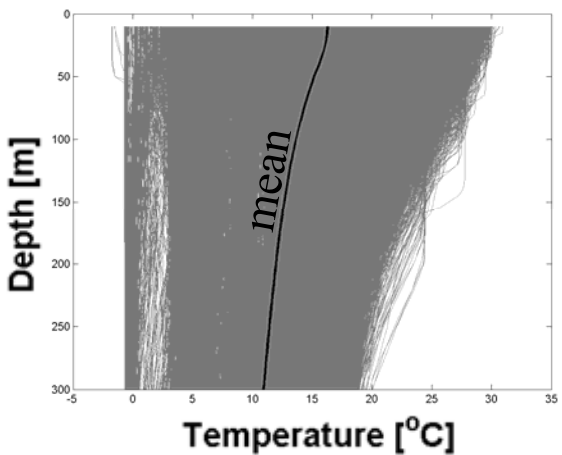


1: These data were collected and made freely available by the Coriolis project and programmes that contribute to it (<http://www.coriolis.eu.org>).

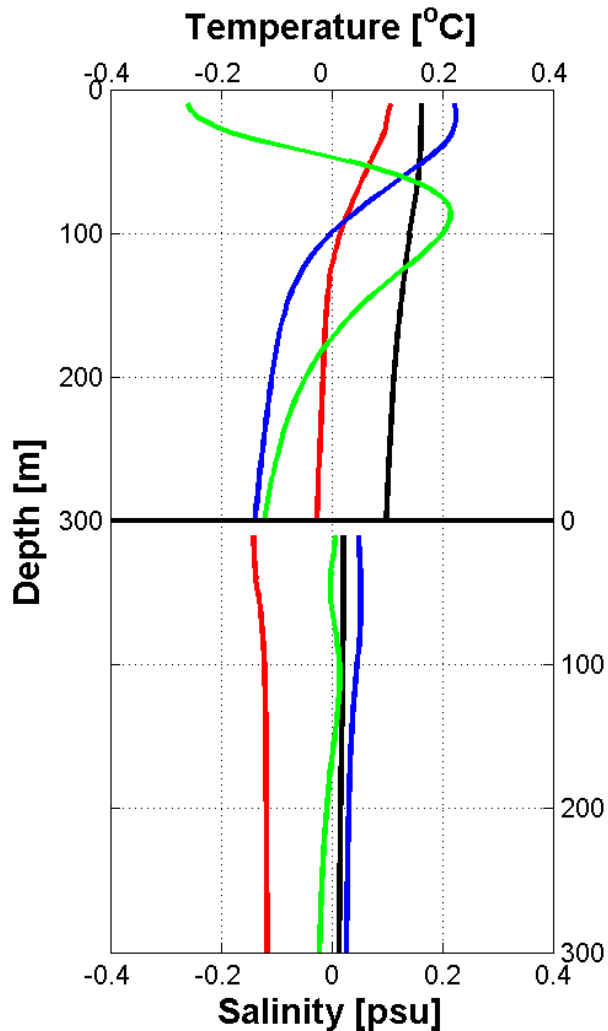


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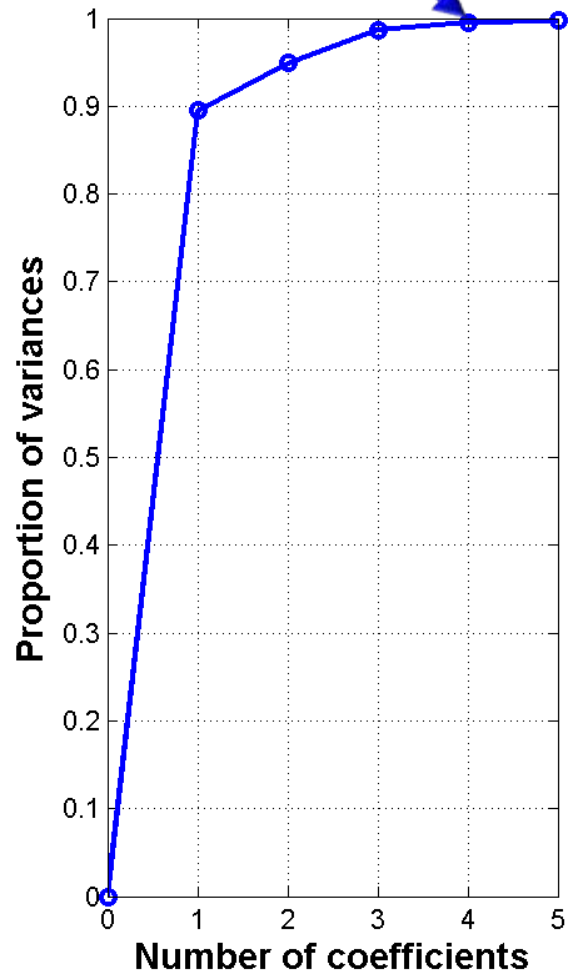
Data set



EOFs



99% of energy when using 4 coefficients



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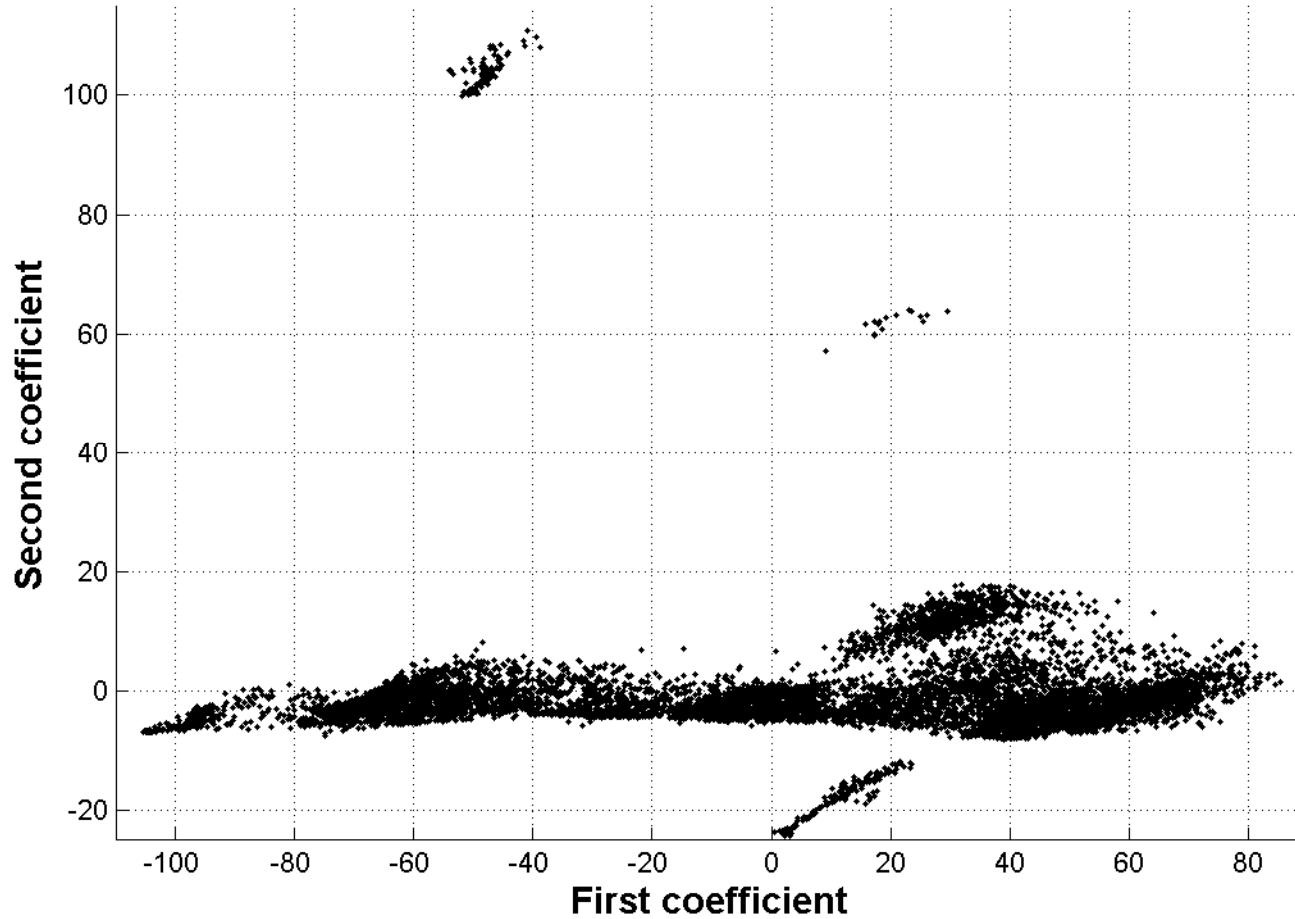




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EOF-coefficients

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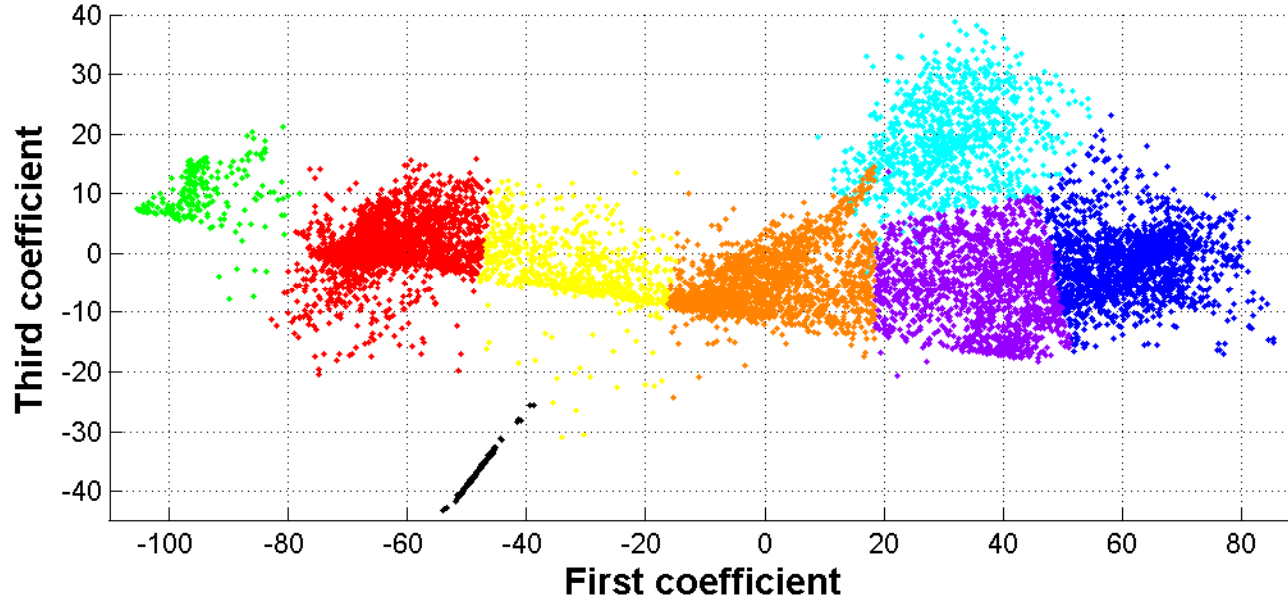




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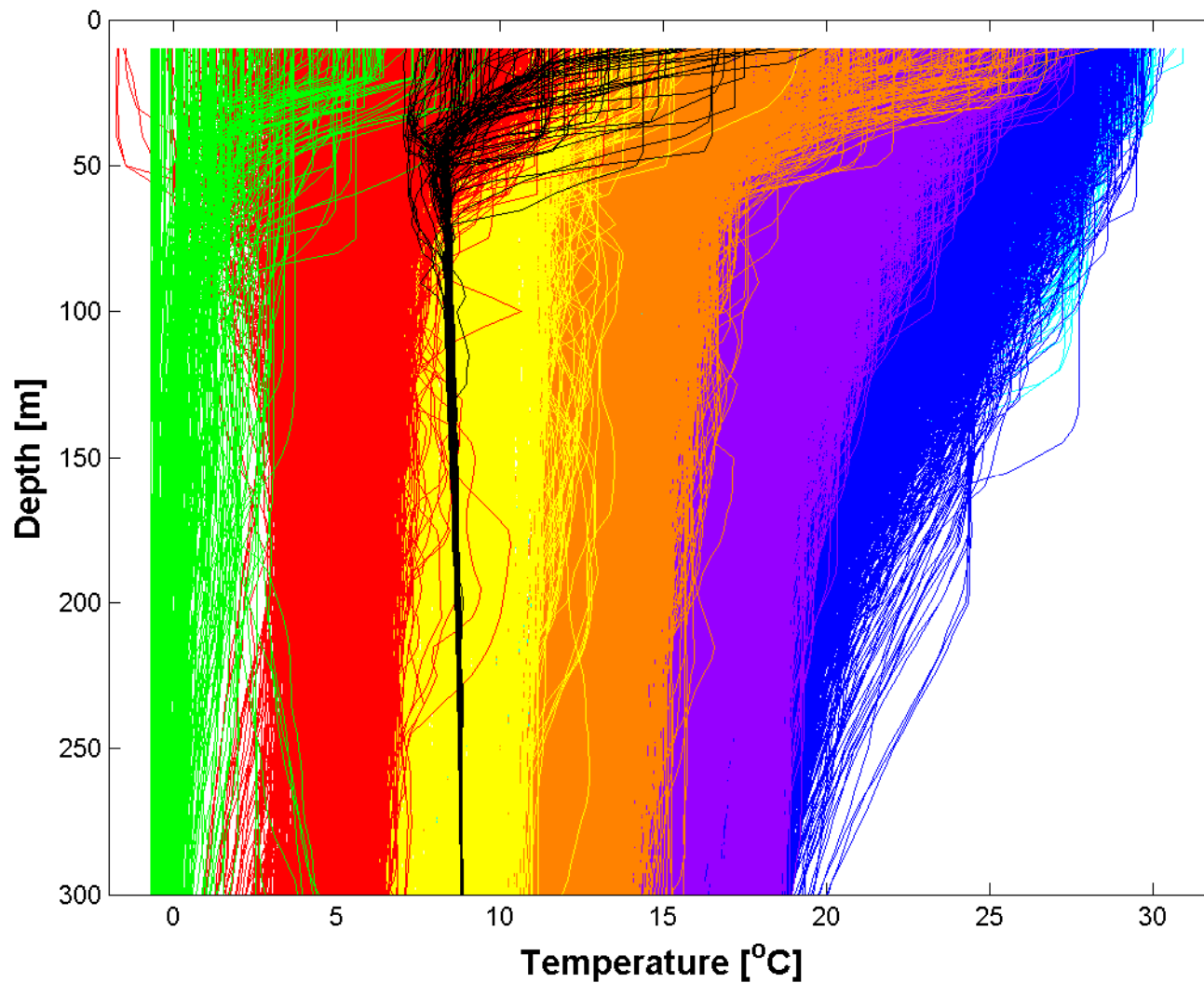
Clustered EOF-coefficients

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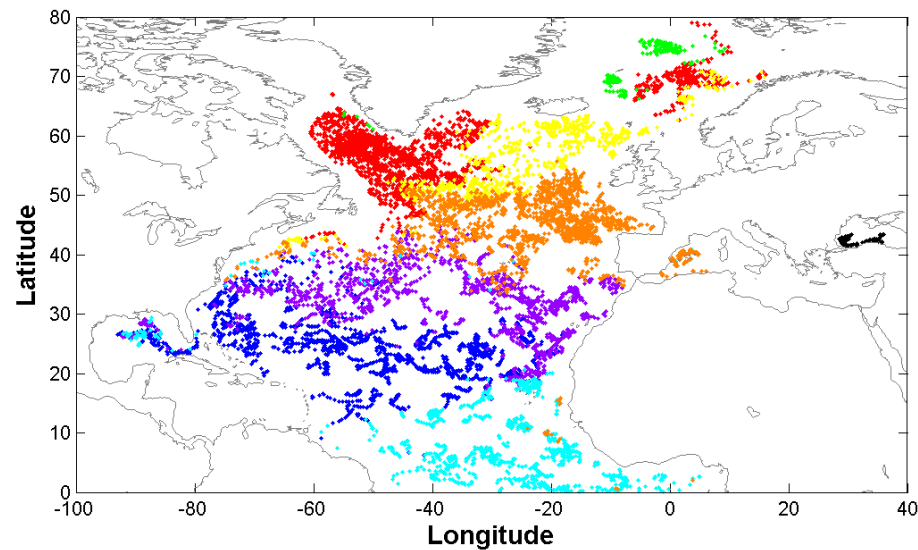
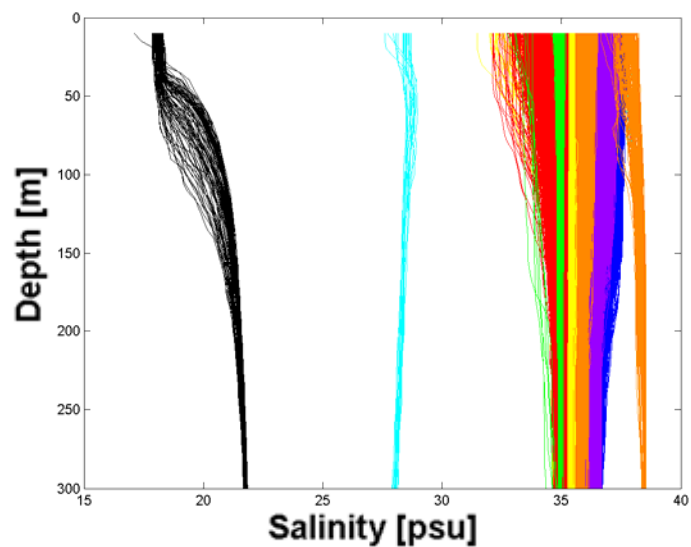
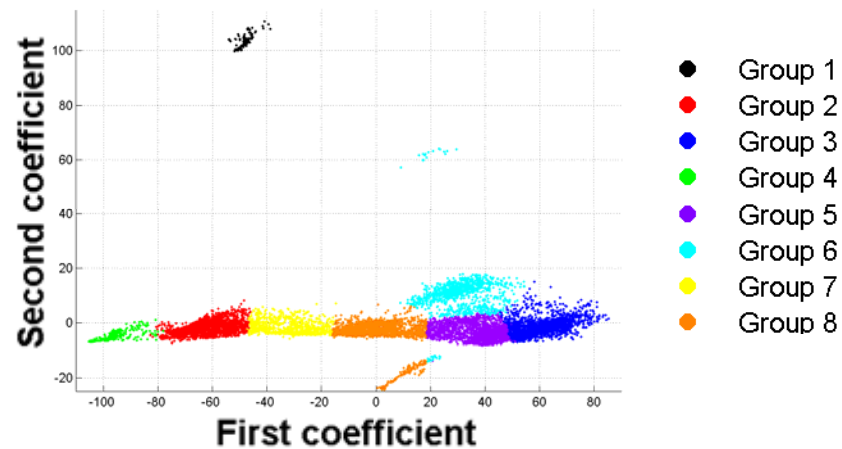
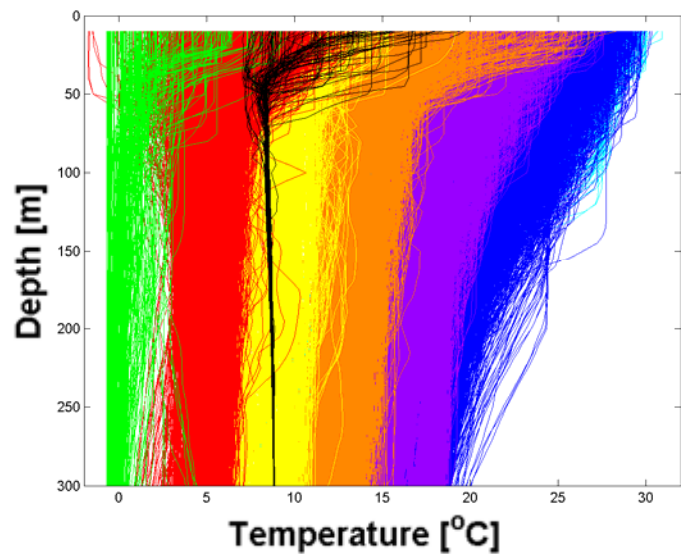


Clustered temperature profiles





Clustered profiles





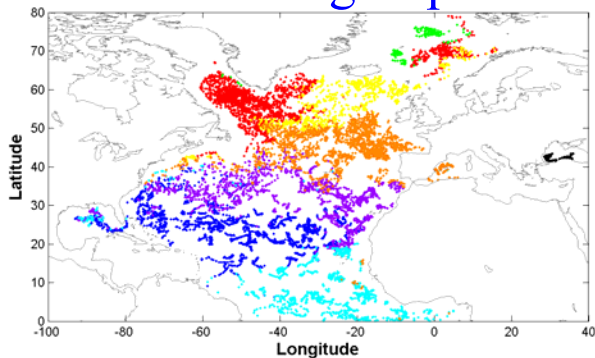
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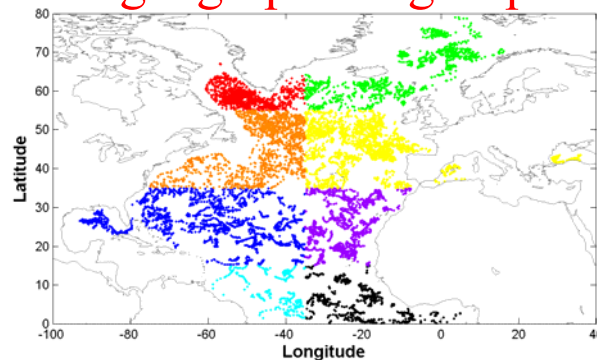


Comparison with geographical groups

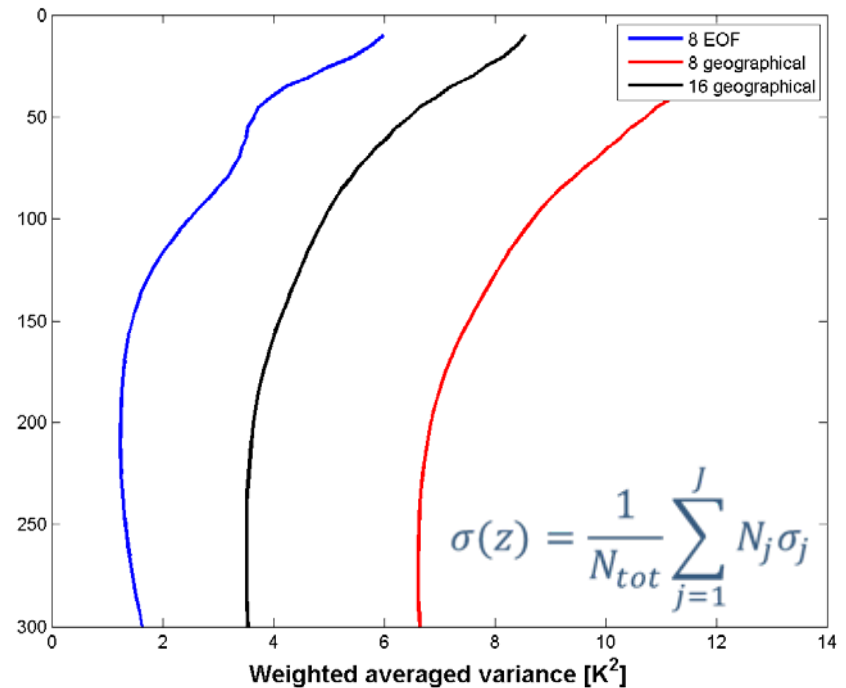
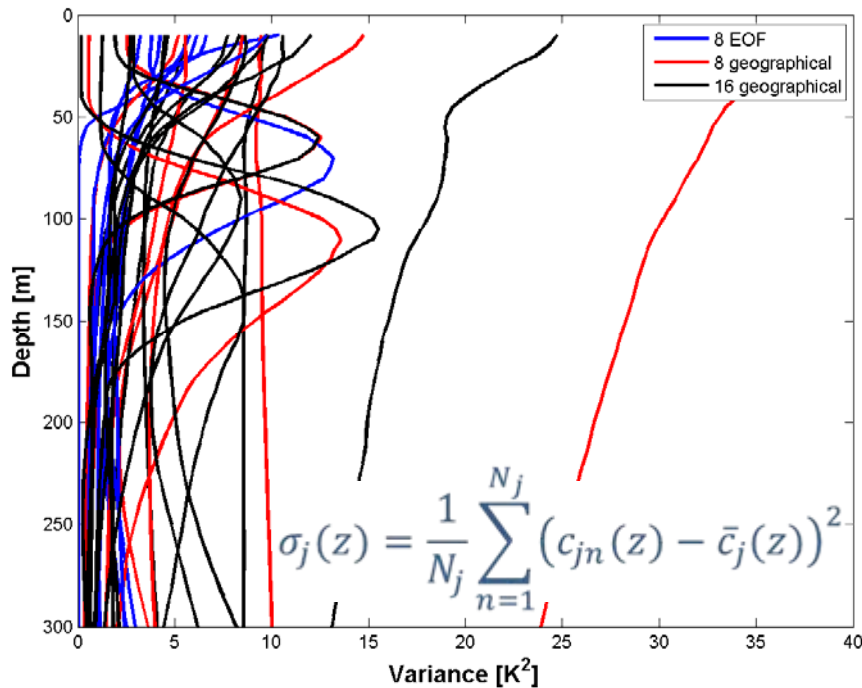
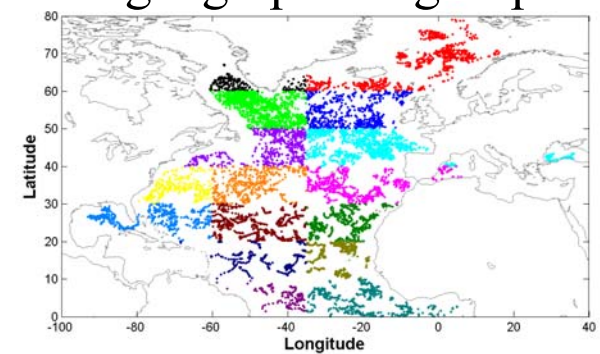
8 EOF groups



8 geographical groups

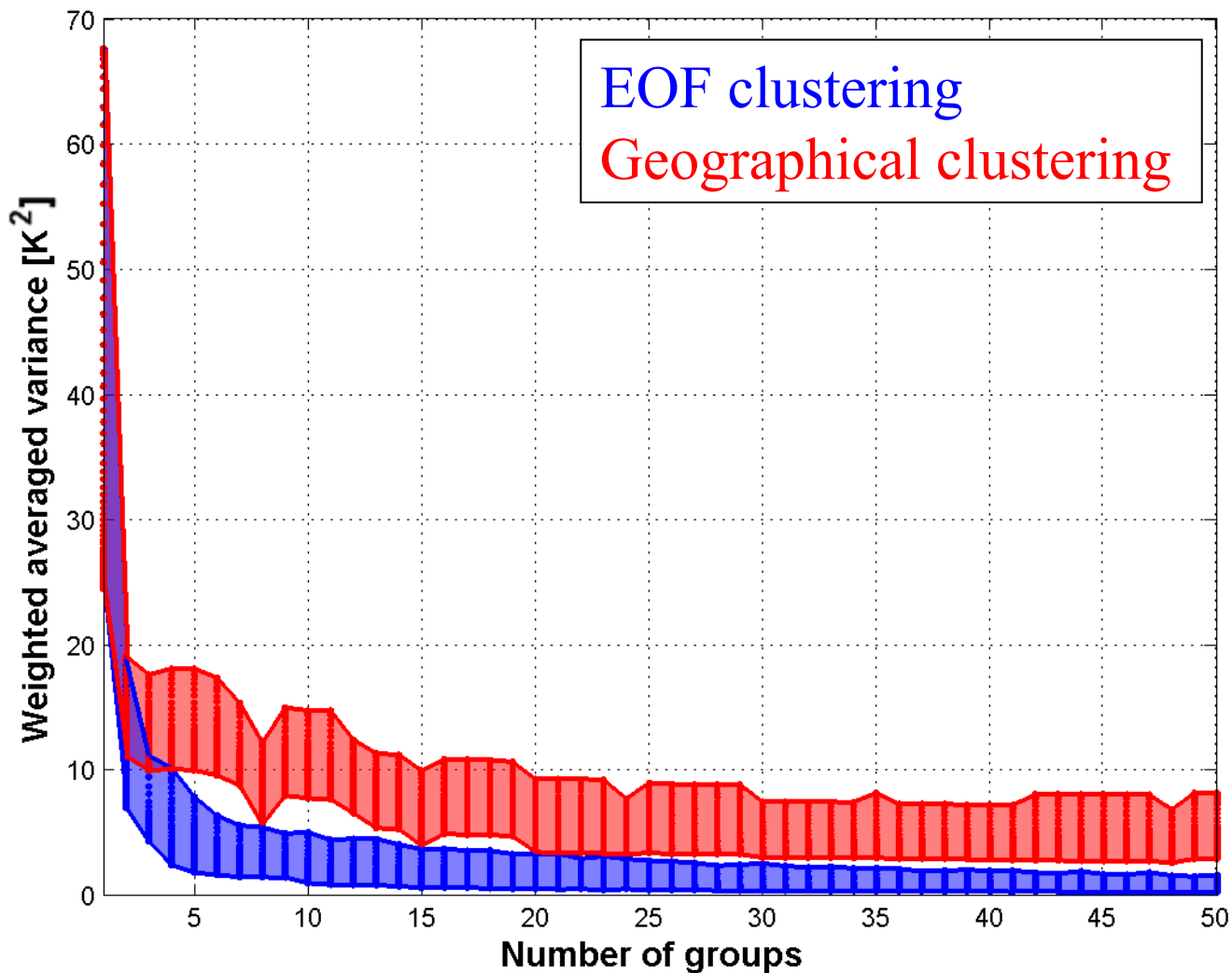


16 geographical groups





Comparison with geographical groups





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Summary

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- Vertical profiles are important for several acoustic applications
- EOF coefficients are an efficient tool to represent vertical profiles
- Clustering on EOF coefficients require fewer groups than geographical clustering

Thank you!