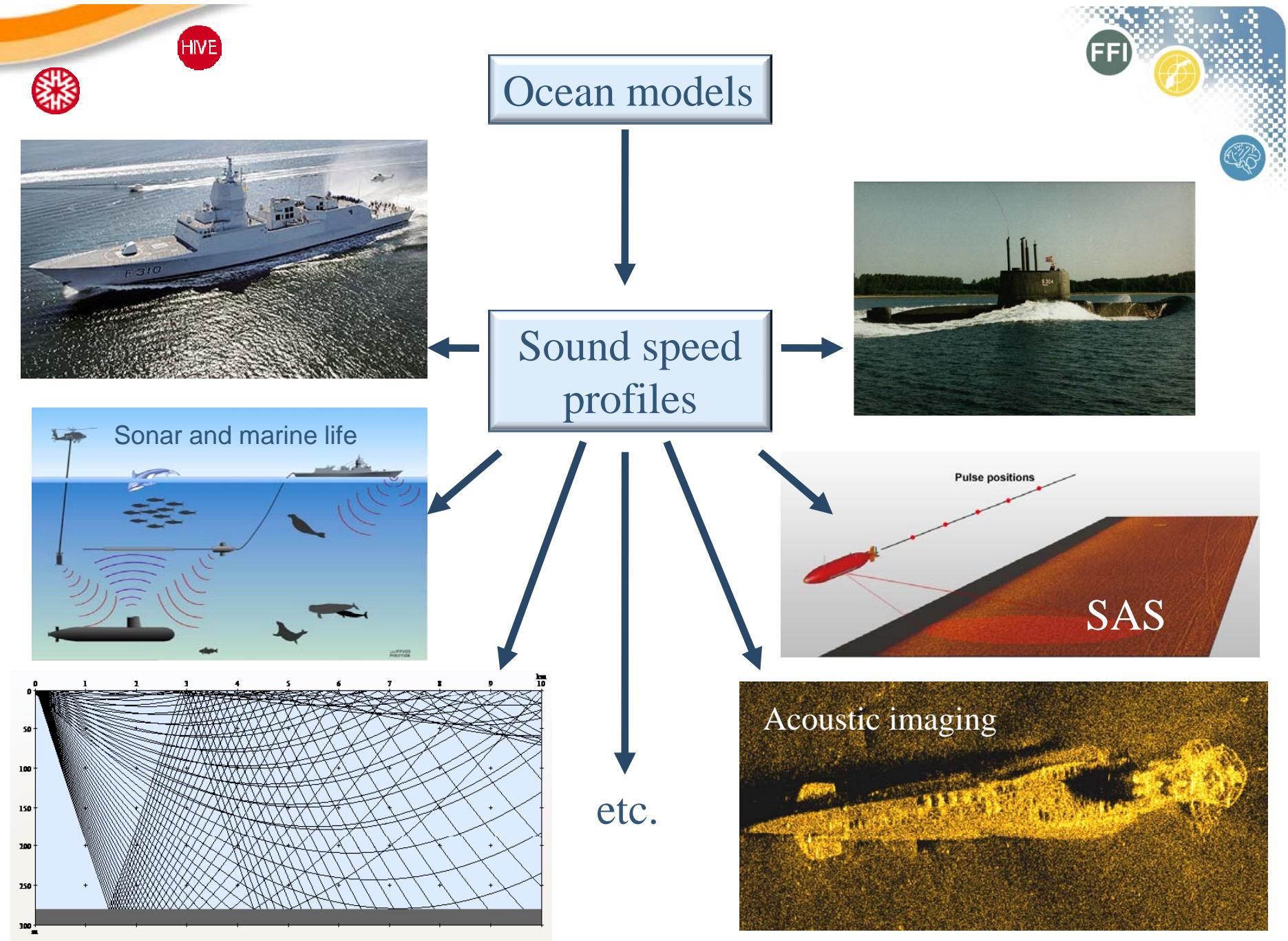


Ocean Model Validation Methods







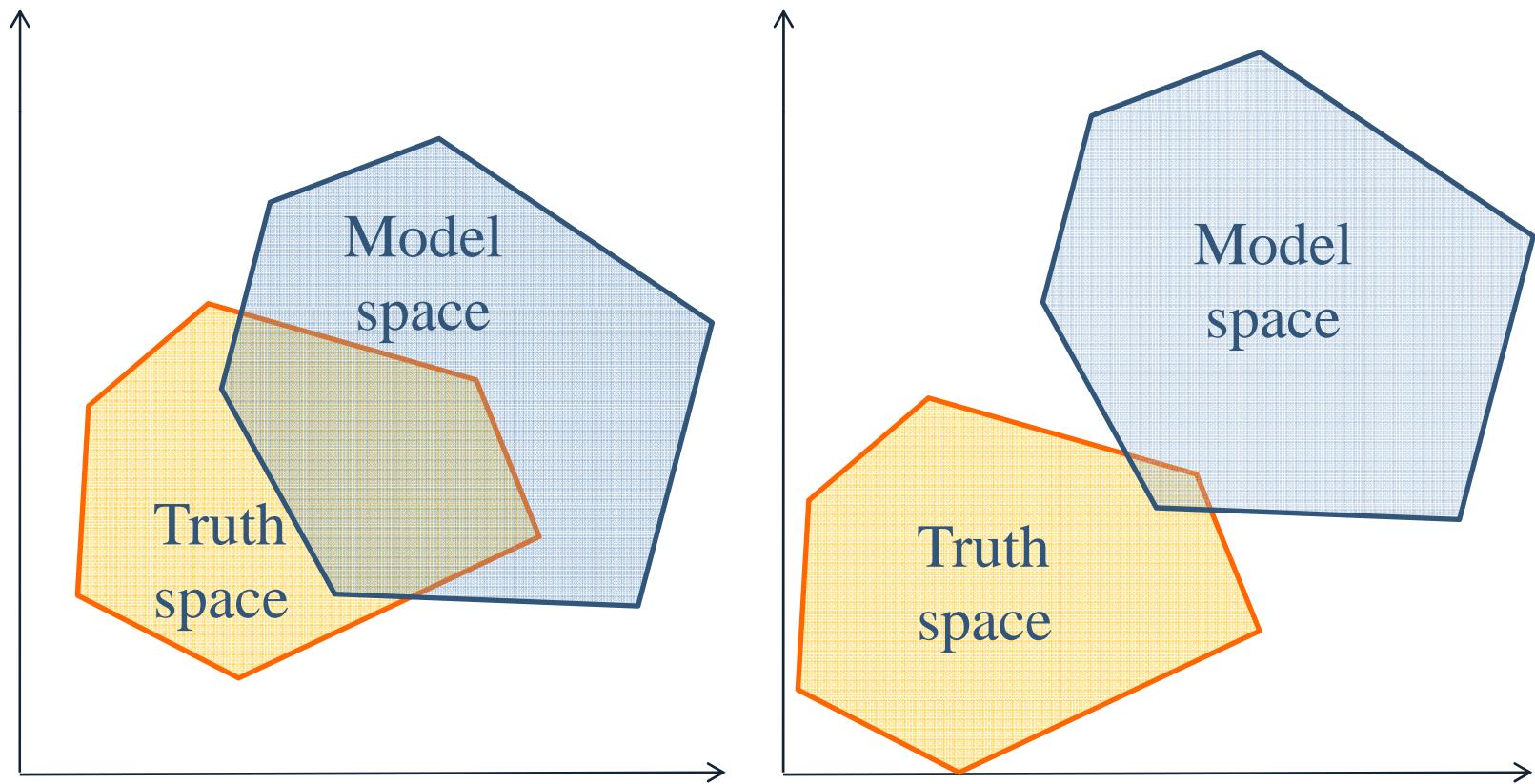
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Objective

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To determine how well model space represents truth space





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How can we determine if model space includes truth space?

- Direct comparison methods
 - One to one comparisons of data sets
- Statistical comparison methods
 - Comparisons of statistical properties extracted from data sets



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Direct comparison methods

- Time series
(Albretsen 2010, Aoki 2003, George 2007, Halliwell 2009, Kourafalou 2009, Logutov 2008, Siegle 2004, Twight 2009, Vaz 2005, Xue 2010)
- Vertical sections
(Albretsen 2010, Danilov 2010, Golenko 2008, Grawe 2009, Yosuke 2003)
- Horizontal fields
(Albretsen 2010, Grawe 2009, Magaldi 2010, Vaz 2005, Xue 2010)
- Vertical profiles
(Klein 1999, Kourafalou 2009)
- Scatter plots
(Albretsen 2010, Dick 1999, Horstmann 2004)



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Statistical comparison methods

- Mean moment
(Alvera 2009, Dick 1999, George 2007, Grawe 2009, Horstmann 2004, Kourafalou 2009, LaCasce 2005, Twight 2009, Yosuke 2003)
- Standard deviation
(Alvera 2009, Dick 1999, Horstmann 2004, Kourafalou 2009, LaCasce 2005, Yosuke 2003)
- RMS error
(Alvera 2009, Horstmann 2004, Twight 2009)
- Correlation
(Aoki 2007, Horstmann 2004, Kourafalou 2009, LaCasce 2005)
- Probability density functions
(Albretsen 2010, LaCasce 2005)
- Taylor diagram
(Halliwell 2009, Taylor 2001)



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Contents



- Example data set
- Direct comparisons
 - horizontal sections
- Statistical methods
 - Taylor diagram
 - Depth dependent probability density functions (PDF's)
- Methods proposed
 - Comparison methods using empirical orthogonal function (EOF) analysis
 - Percentiles in EOF coefficient space



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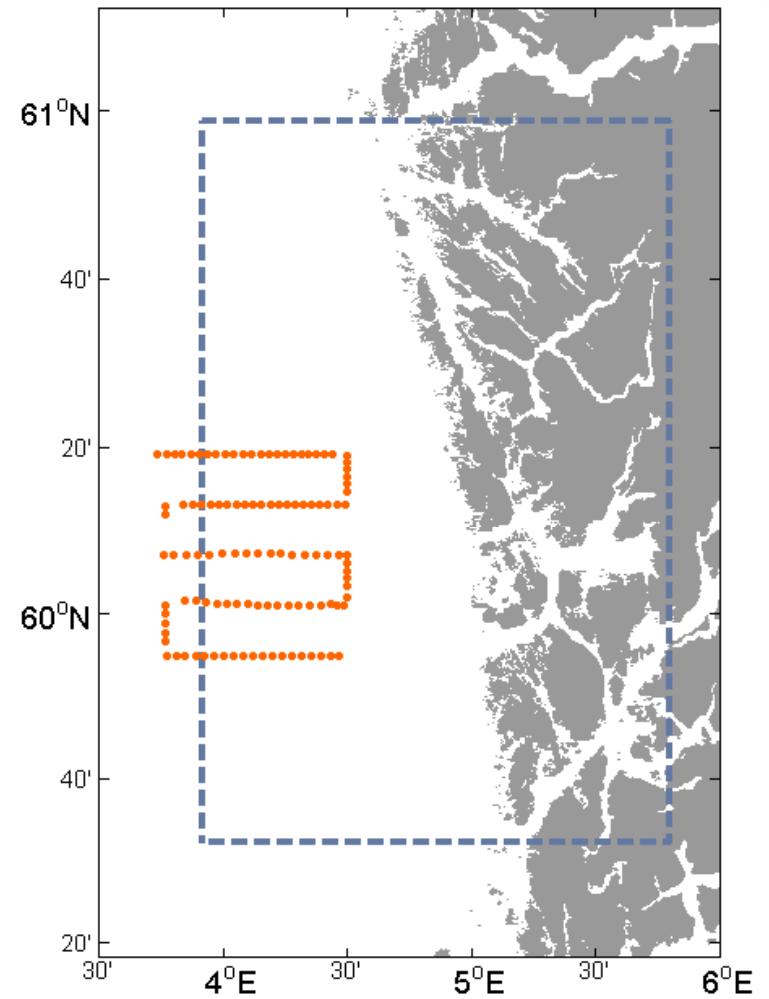
Example area



Modelled and observed temperature, salinity, and sound speed profiles:

- 130 000 modelled profiles (MI-POM). Delivered by the Norwegian Meteorological Institute (met.no)
- 113 observed profiles obtained using a Moving Vessel Profiler. Delivered by FFI's research vessel HU Sverdrup II.

January 2010





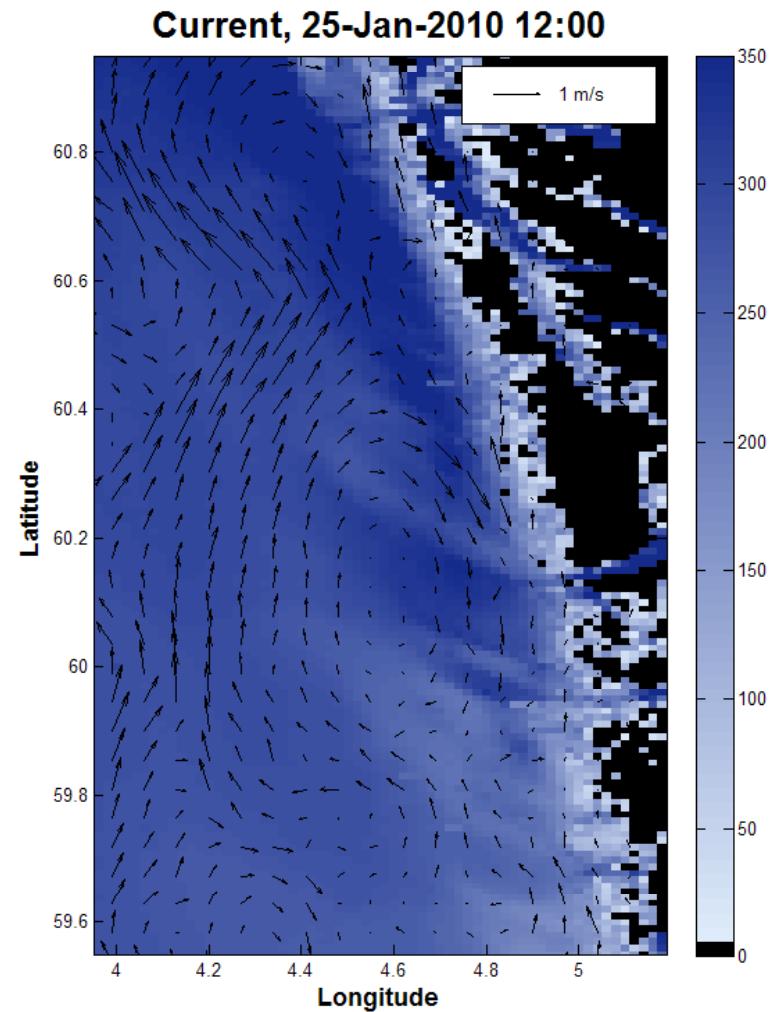
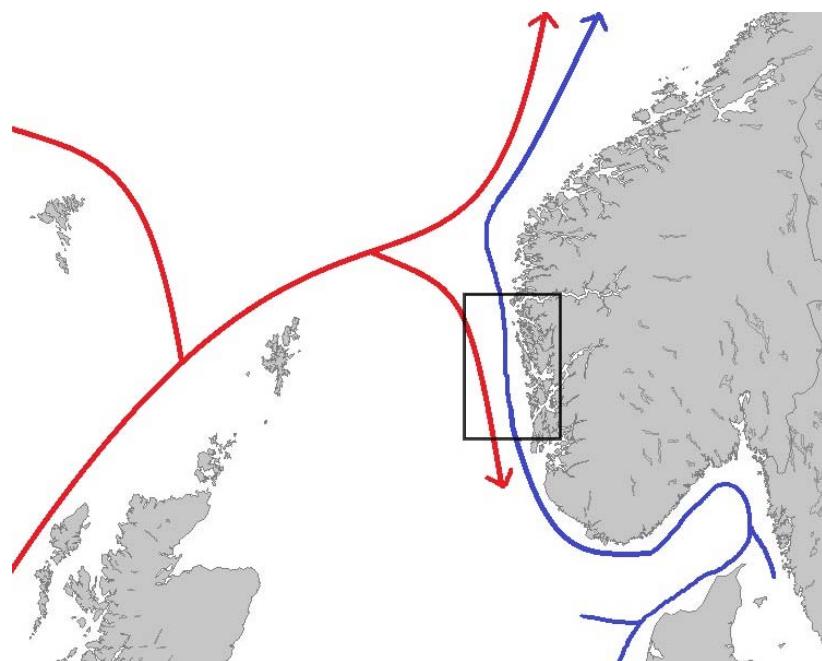
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Example area

- North Atlantic current from north (warm and saline)
- Coastal current from Baltic Sea (cold and less saline)



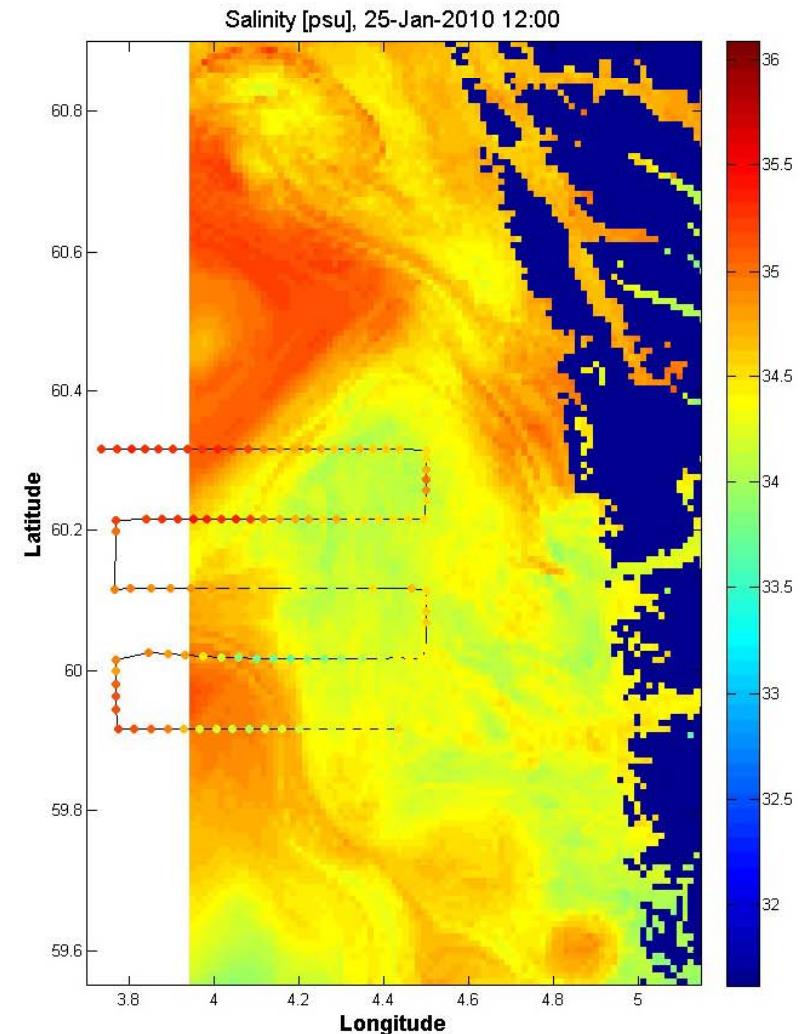
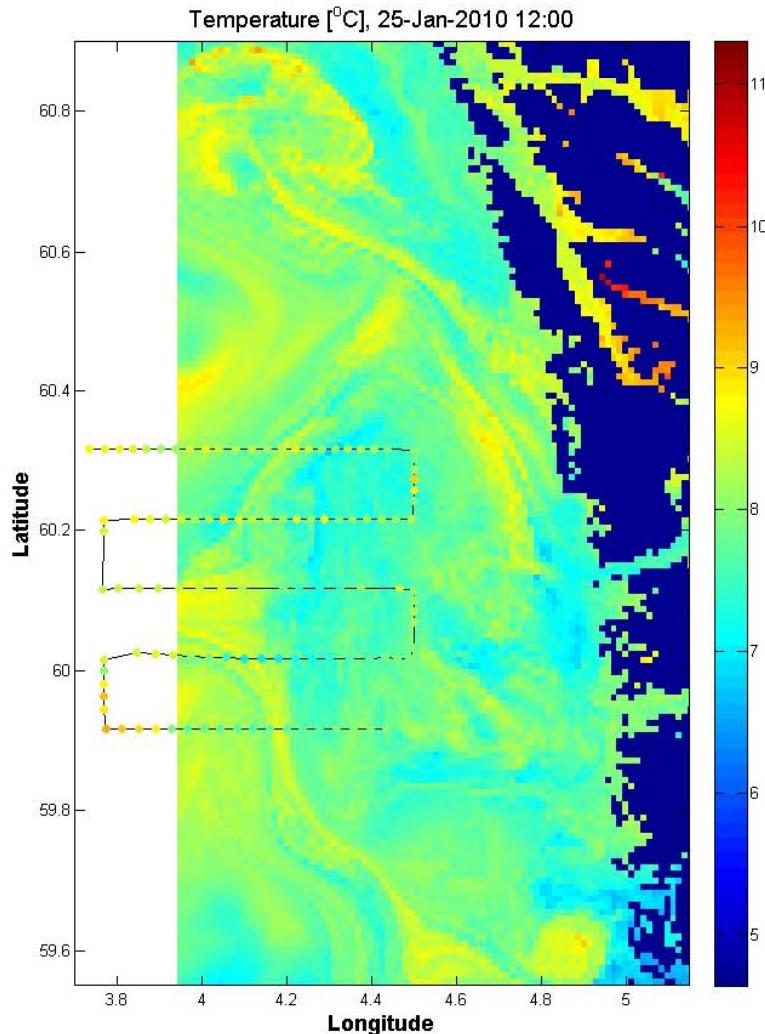


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Temperature and salinity (100m depth)



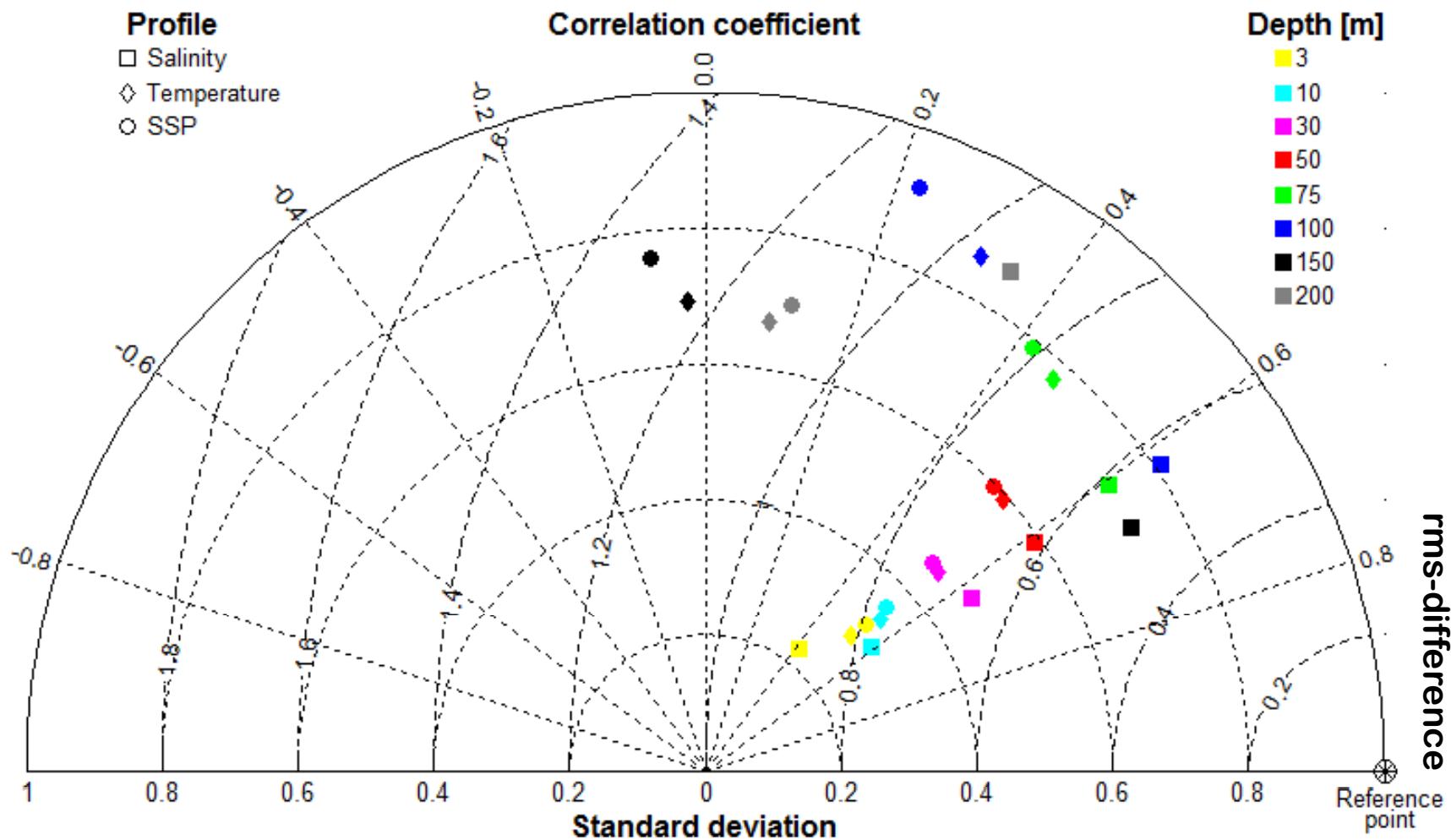


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Normalised Taylor diagram



Taylor (2001), J Geophys Res.



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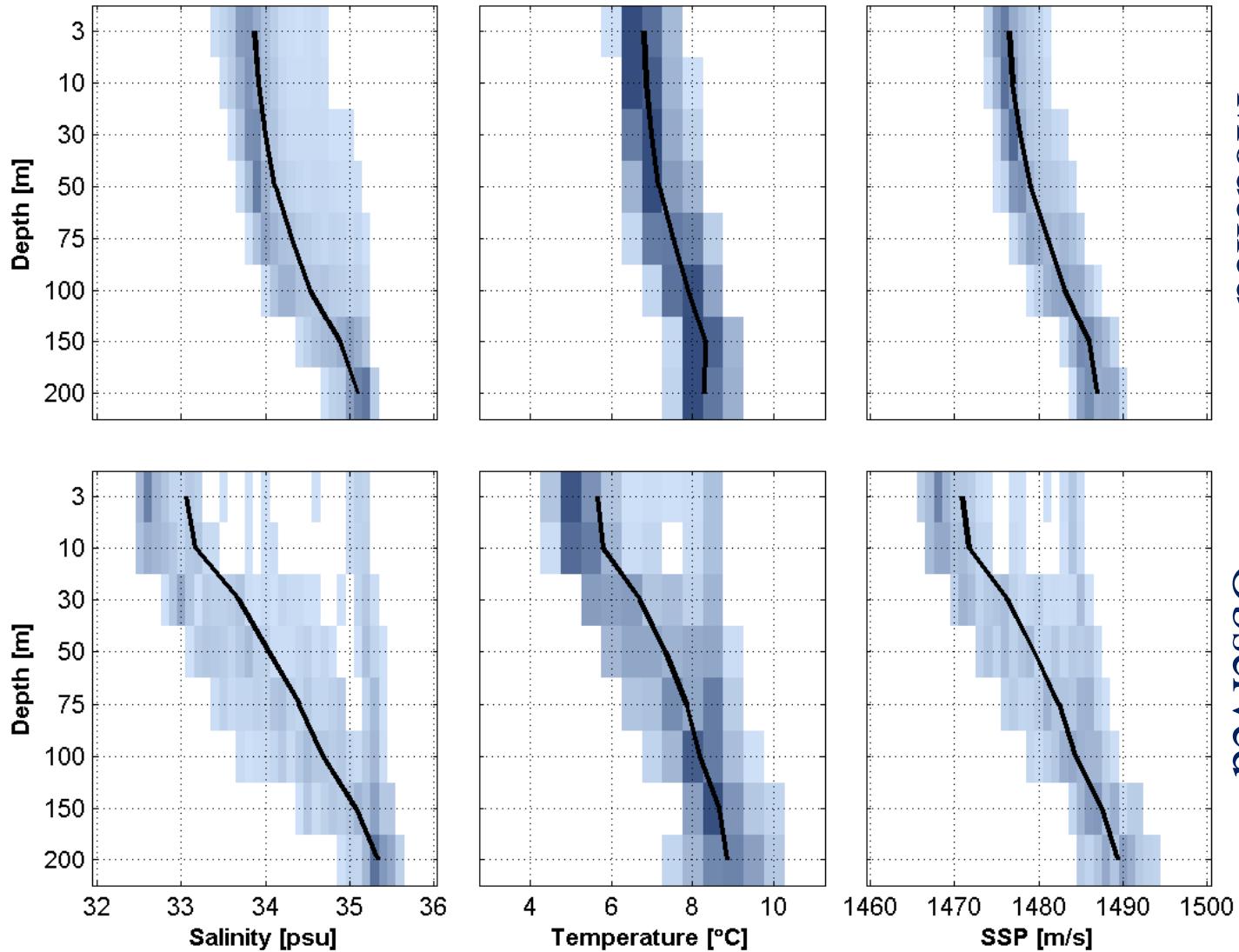
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Depth dependent PDFs

Modelled

Observed





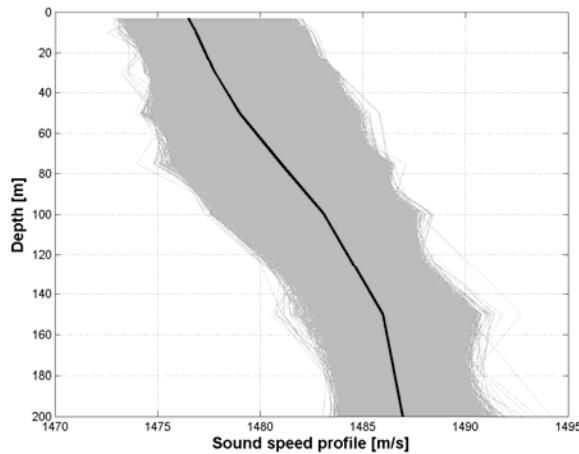
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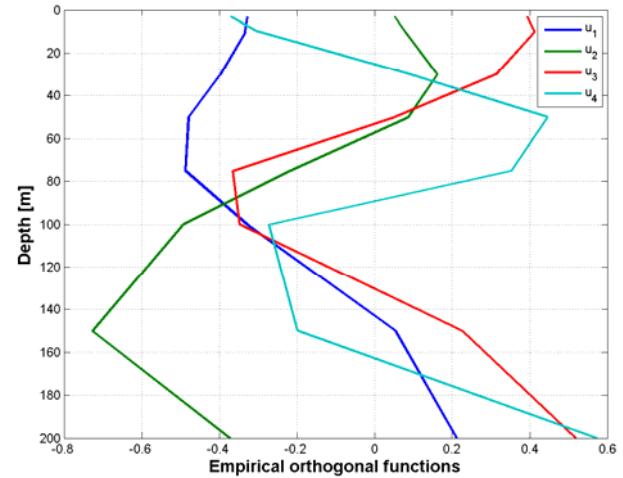
Empirical orthogonal functions

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



$$\mathbf{R}_x \mathbf{u}_k = \lambda_k \mathbf{u}_k$$

→



\mathbf{u}_k : EOFs (eigenvectors)

κ_k : EOF-coefficients

\mathbf{R}_x : covariance matrix

λ_k : eigenvalues

$$c_i[n] - \bar{c}[n] = \sum_{k=1}^{N-1} \kappa_k u_k[n]$$



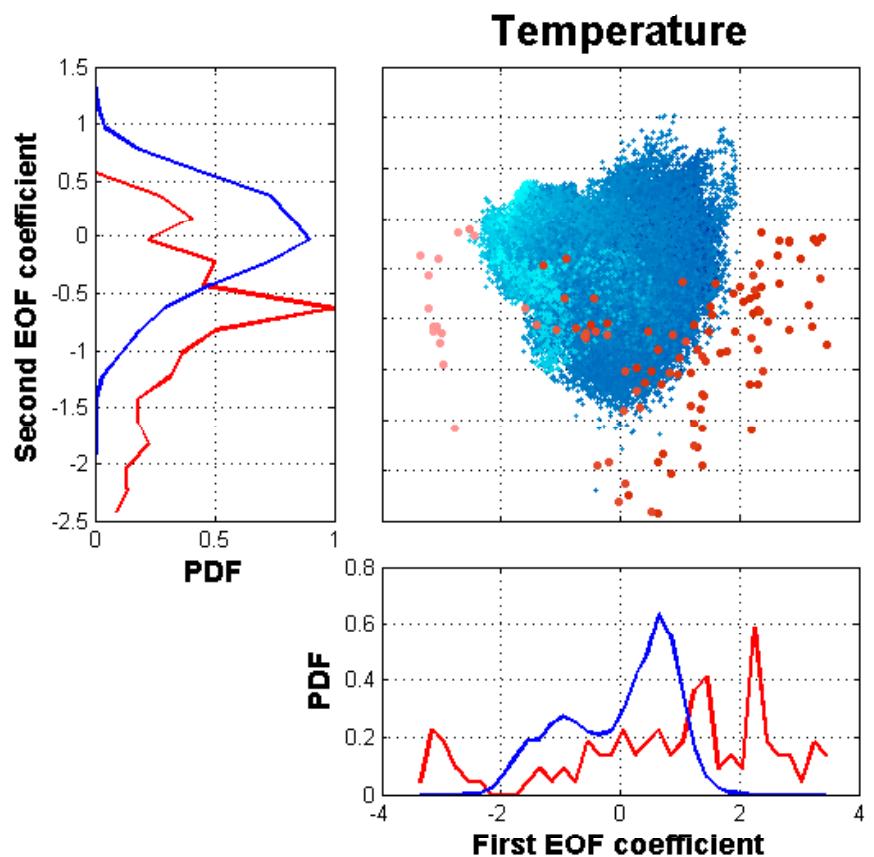
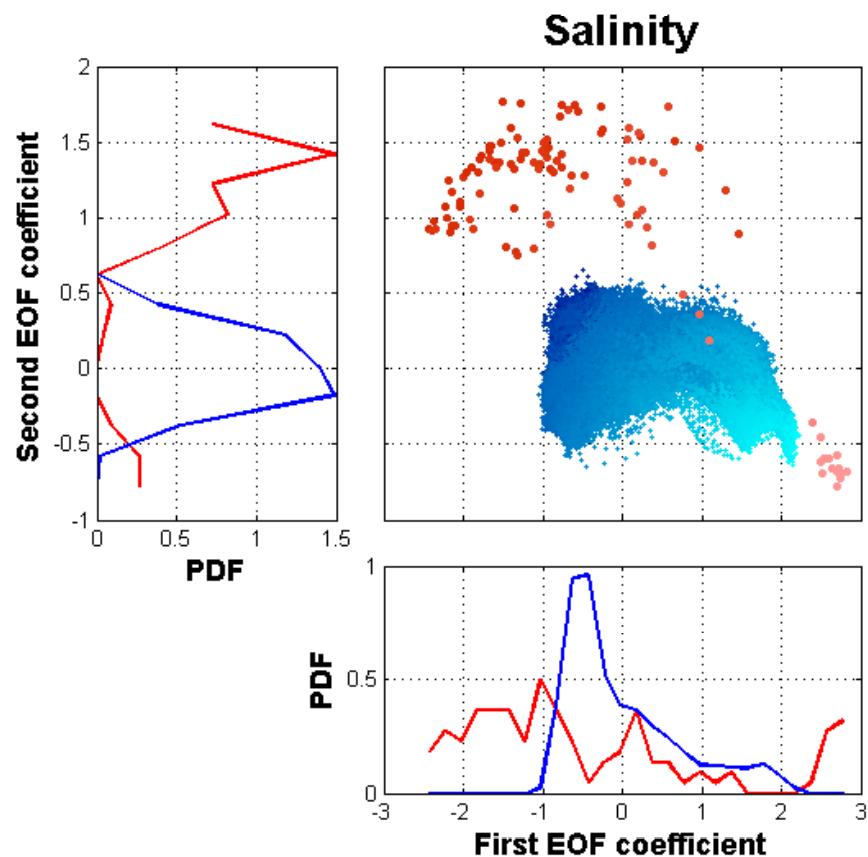
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EOF coefficient space

FFI



Modelled
Observed





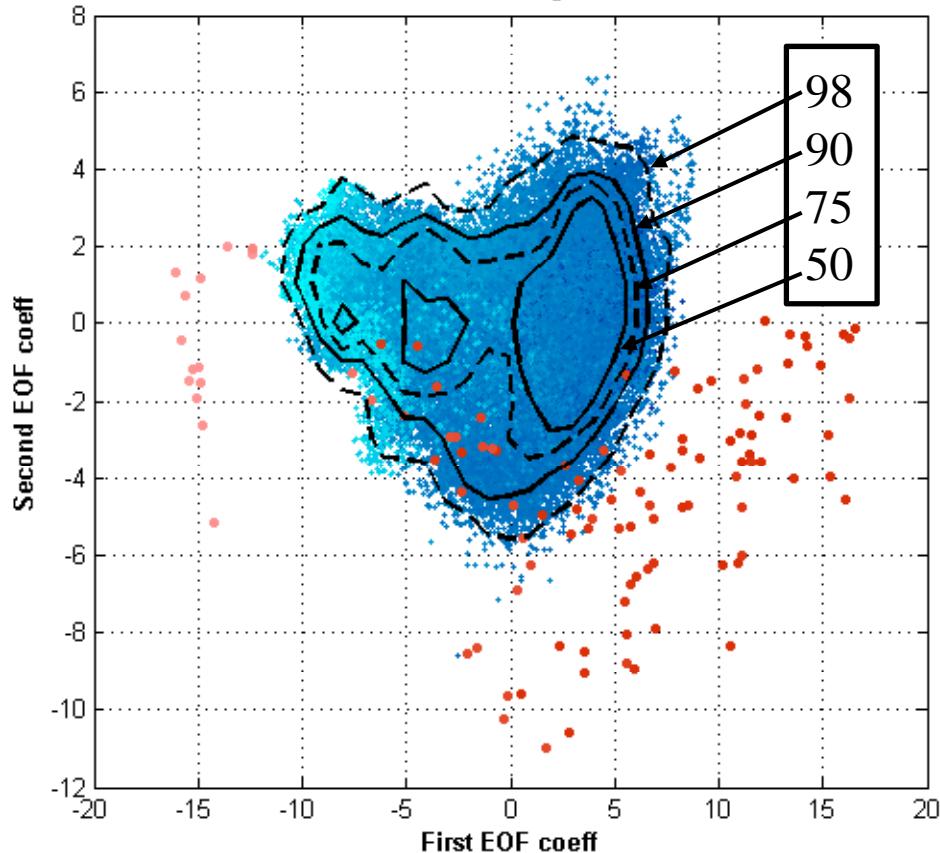
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Percentiles in EOF coefficient space

Sound speed



Modelled
Observed

Model space percentile [%]	Observations in model space [%]
50	0.9
75	1.8
90	12
98	16



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Summary



- Brief account of comparison methods used in literature.
Two groups:
 1. Direct comparison methods:
 - most used; time series and cross sections
 - may be misleading
 2. Statistical comparison methods:
 - most used; two first moments
 - Taylor diagram and depth dependent PDFs
- Percentile in EOF space:
 - EOF allows inclusion of gradients
 - particularly useful in tomography schemes
 - quality represented by a single value