Relevant Oceanography

September 14, 2010

Delft University of Technology

What do we need?

- Sound speed $c = c\,(T,S,P)$
  - Spatial distribution
  - Temporal distribution
- Sea surface effects

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Temperature *T*

Spatial distribution at the sea surface

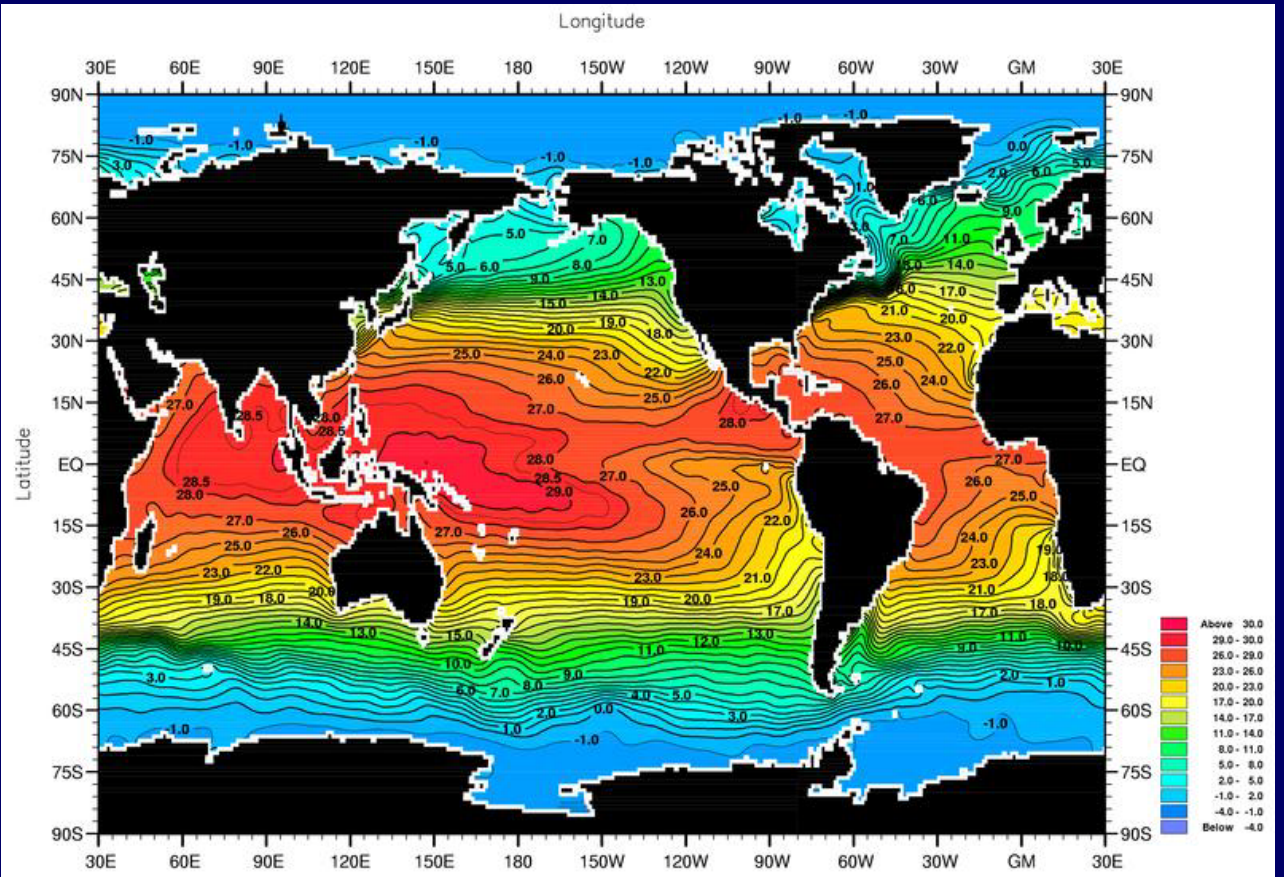

Fig. A2-1. Annual mean temperature (°C) at the surface.

Minimum Value= -1.93 Maximum Value= 29.93 Contour Interval: 1.00

World Ocean Atlas 2001
Ocean Climate Laboratory/NODC

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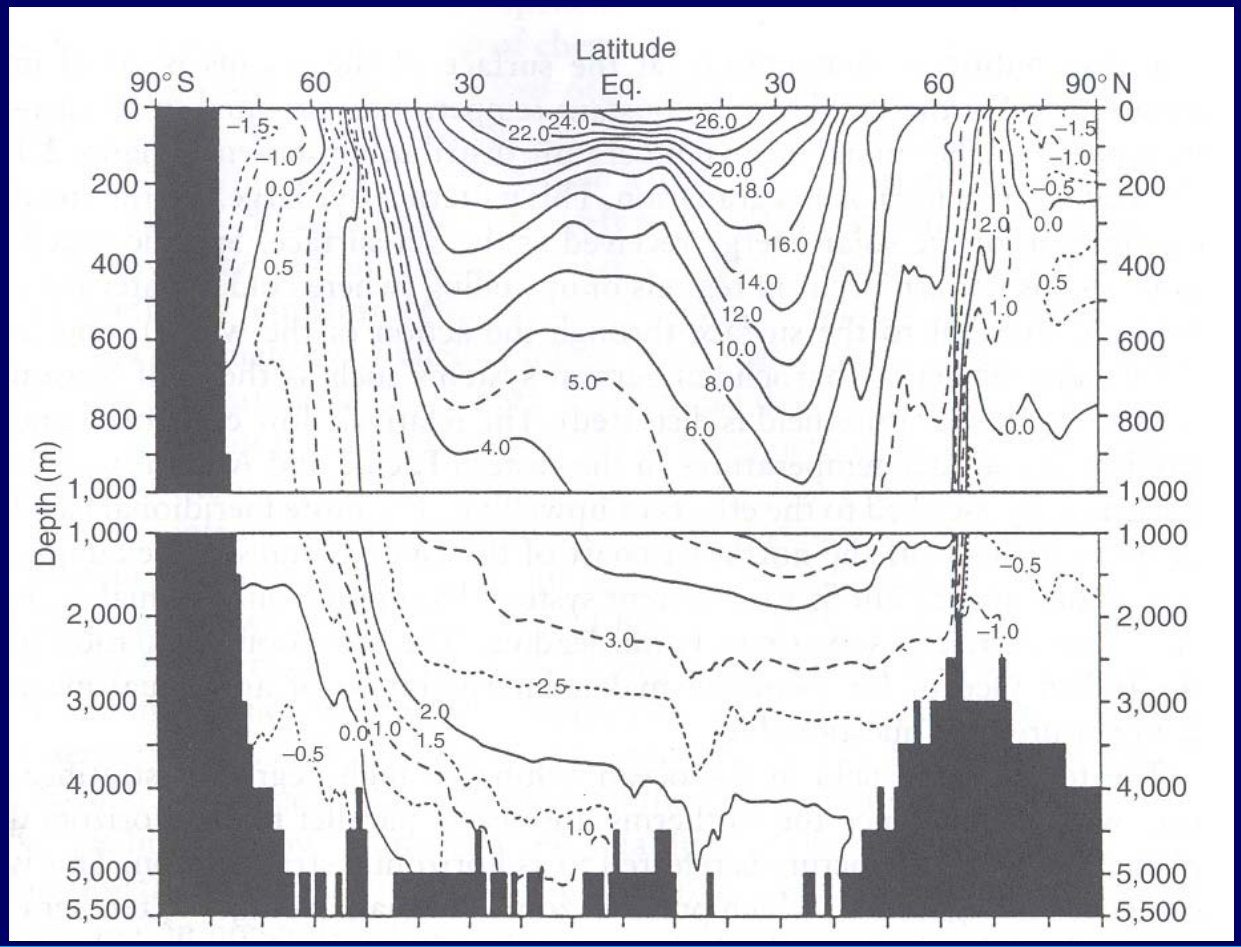
Temperature *T*

spatial distribution - depth dependence



Salinity *S*

Spatial distribution at the sea surface

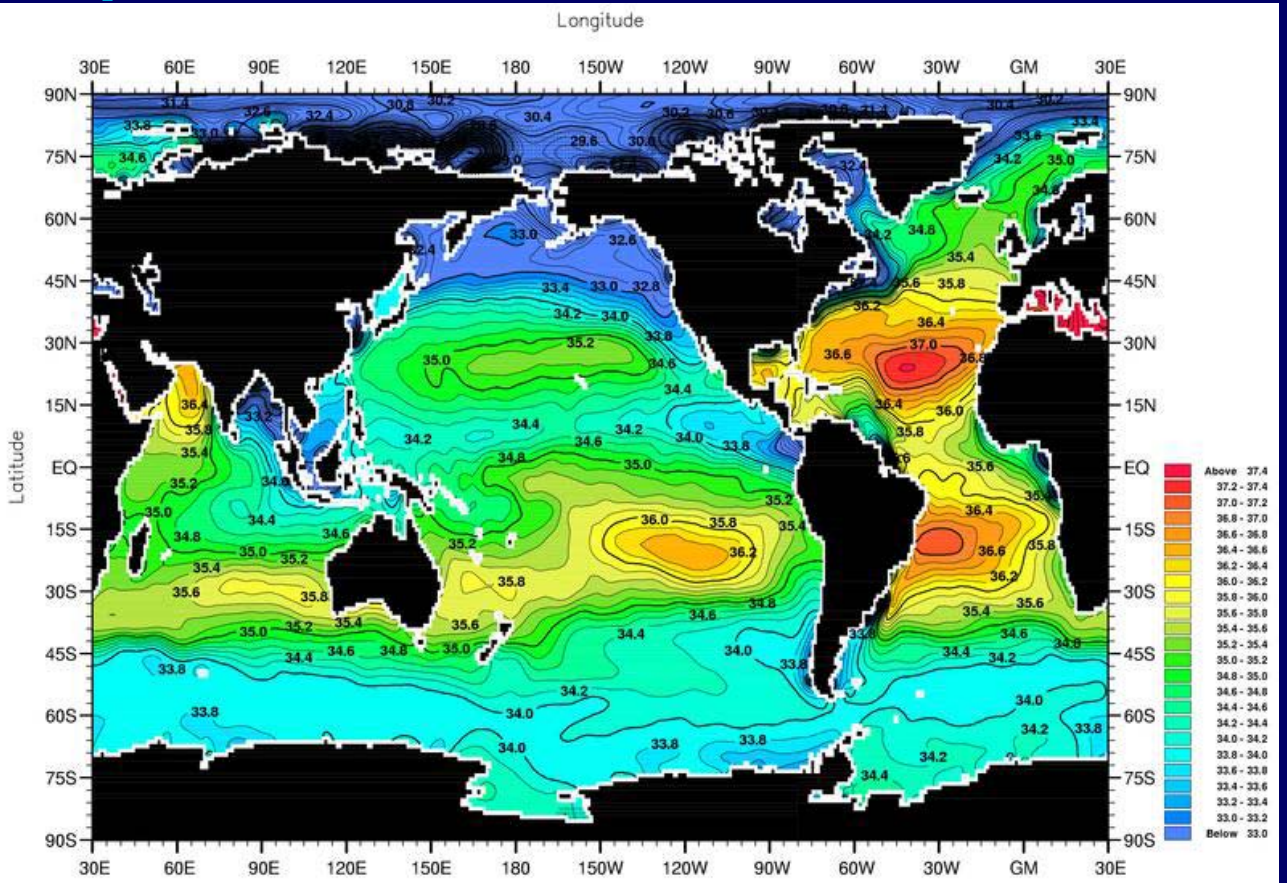


Fig. A2-1. Annual mean salinity (PSS) at the surface.

Minimum Value= 2.37 Maximum Value= 40.37 Contour Interval: 0.20

World Ocean Atlas 2001
Ocean Climate Laboratory/NODC

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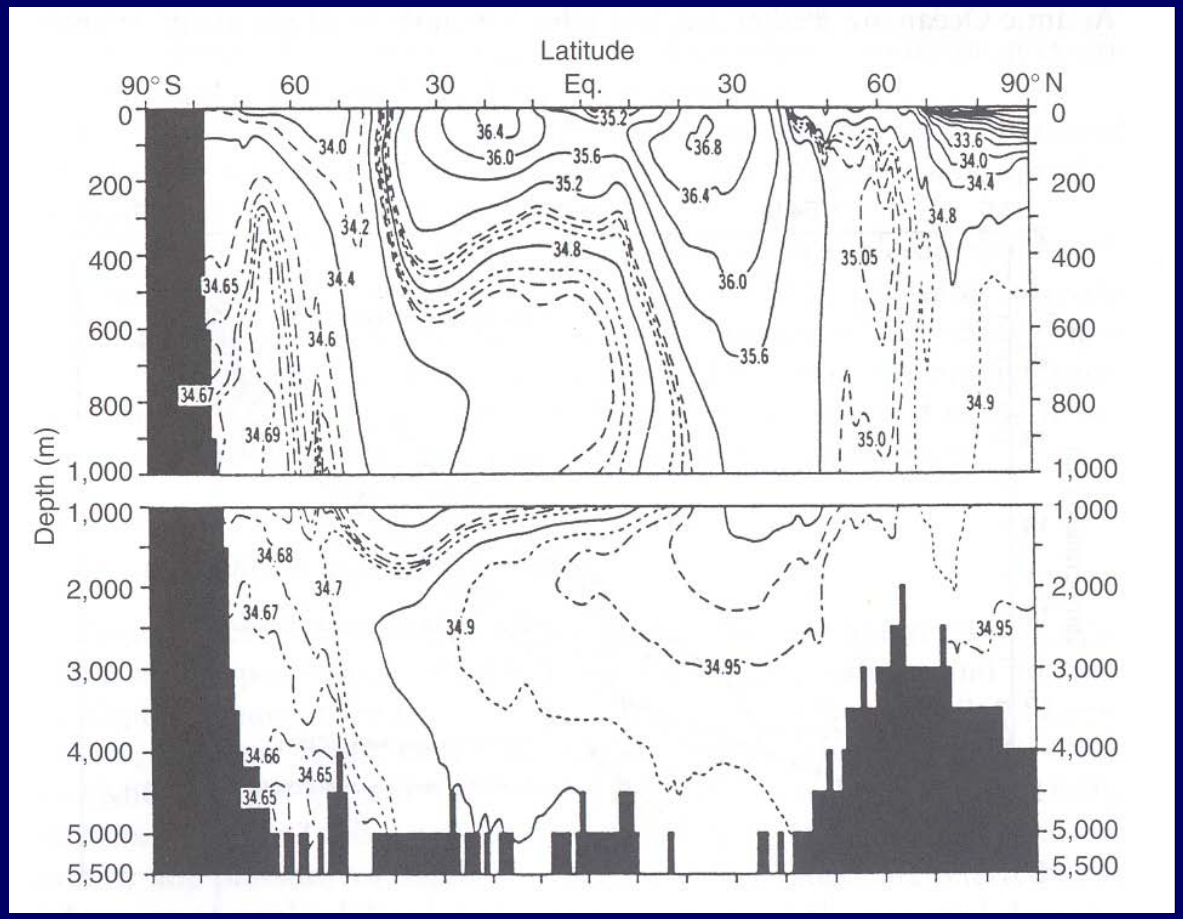
Salinity *S*

spatial distribution - depth dependence



Sound speed *c* (*T*,*S*,*P*)

Empirical relations, e.g. that of Medwin:

$$c = 1449.2 + 4.6T - 0.055T^2 + 0.00029T^3 + (1.34 - 0.01T)(S - 35) + 0.017z$$

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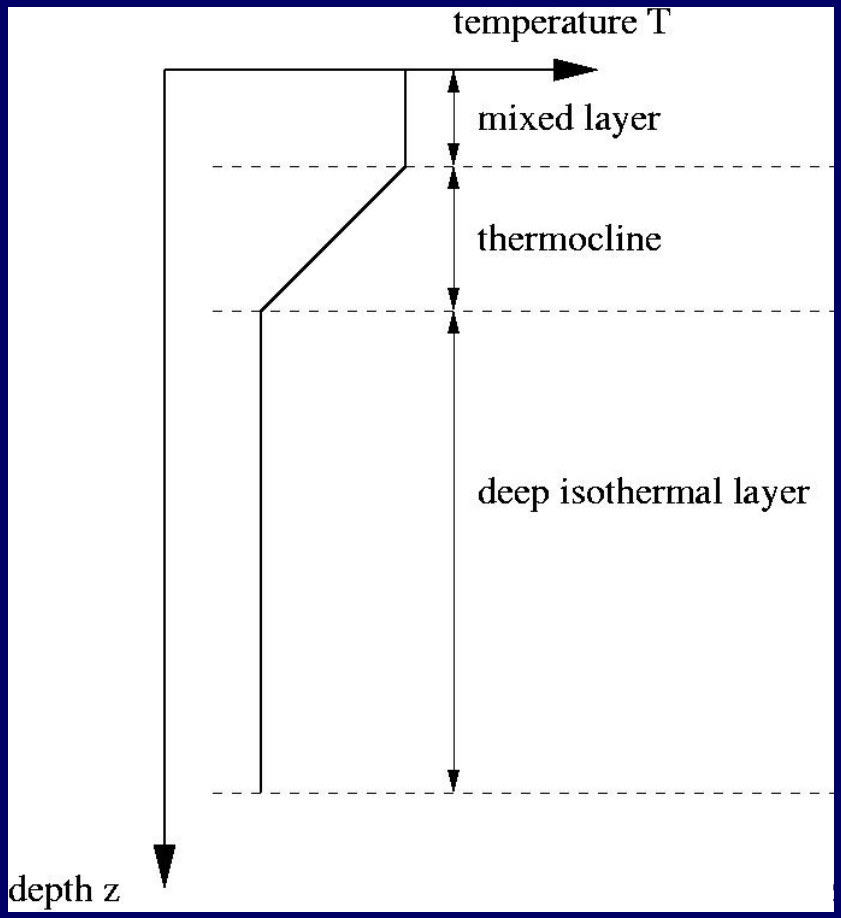
Sound speed measurements

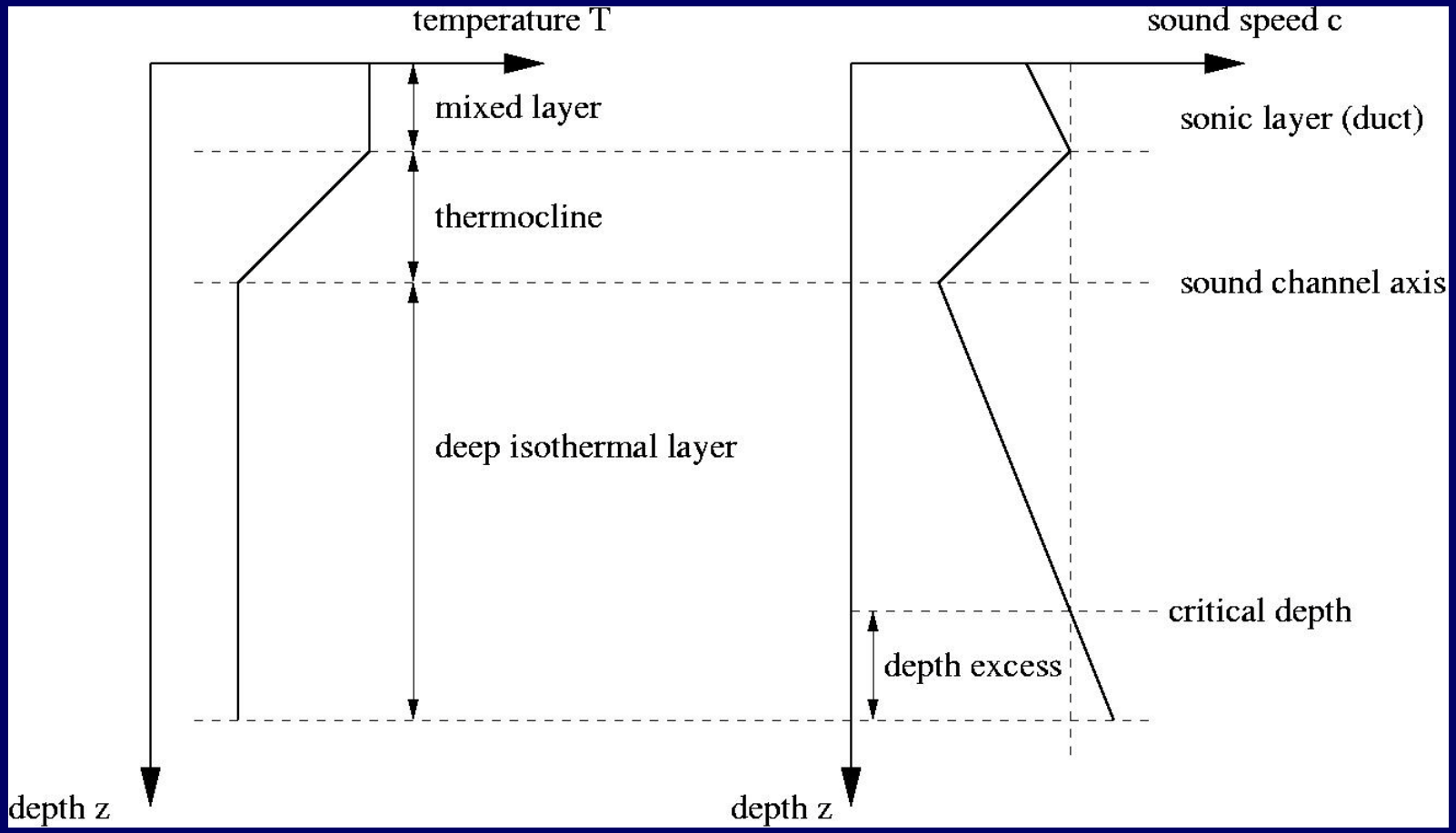
- XBT
- XSV
- CTD

Temperature profiles $T(z)$

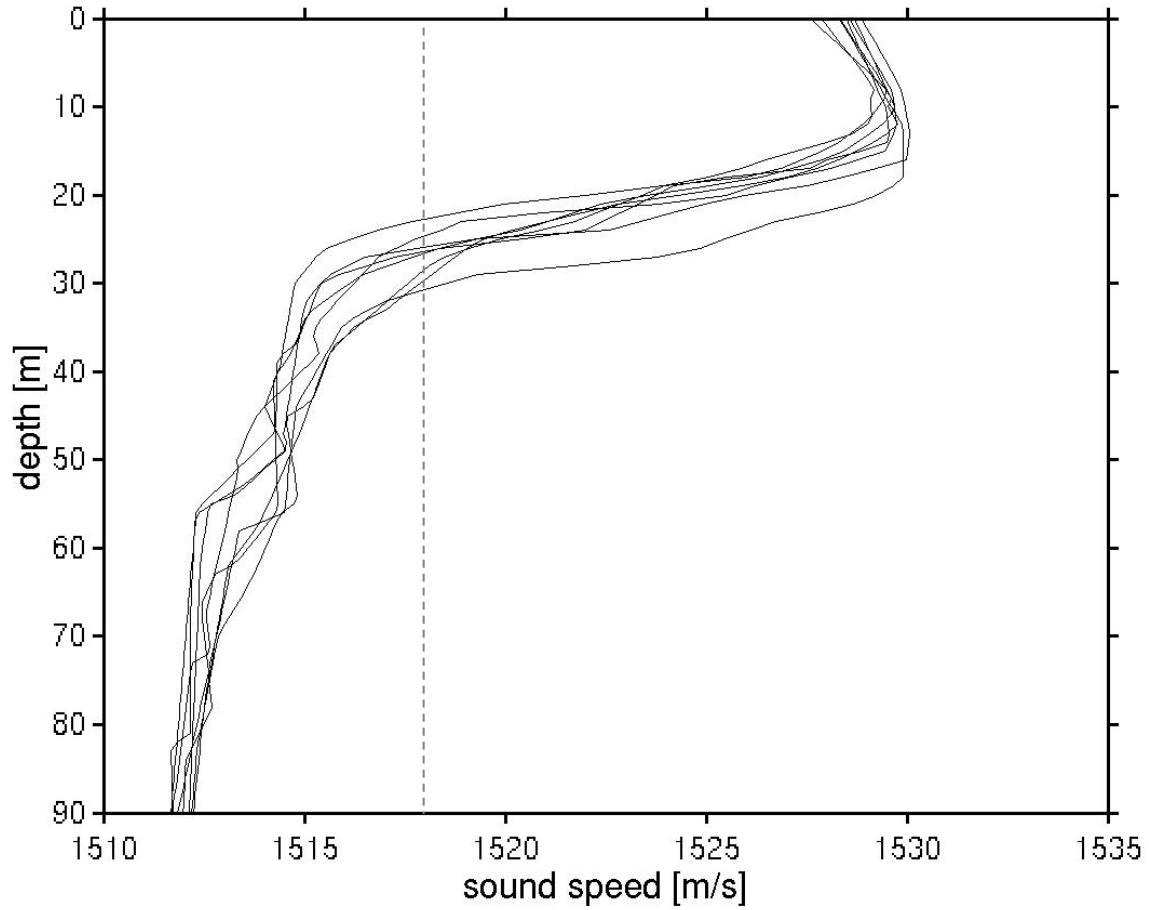


$$c = 1449.2 + 4.6T - 0.055T^2 + 0.00029T^3 + (1.34 - 0.01T)(S - 35) + 0.017\,z$$

Sound speed profiles *c* (*z*)



Sound speed profiles *c* (*z*) - measured



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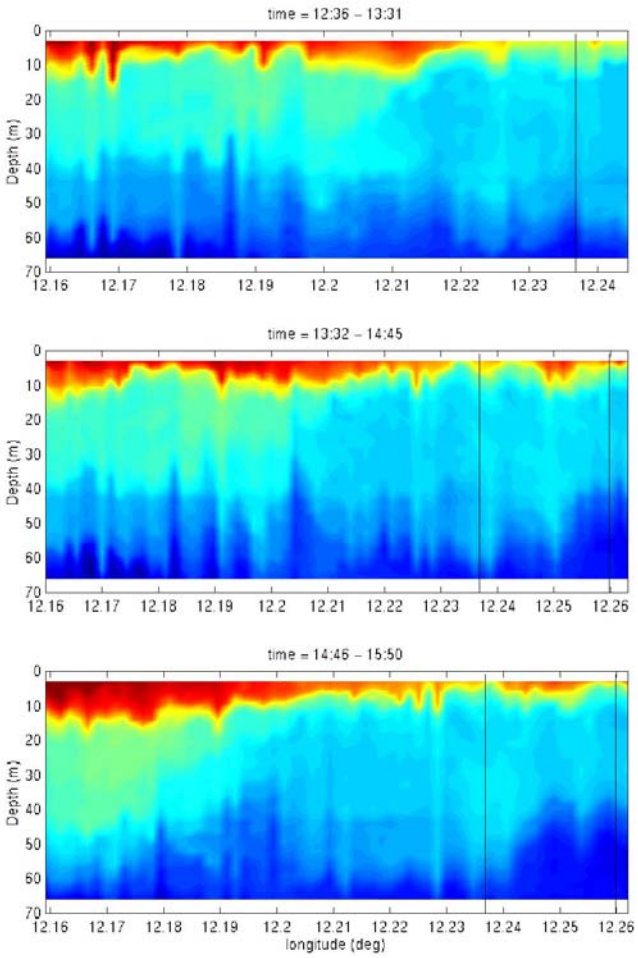
Sound speed profiles *c* (*z*) – measured, contn'd



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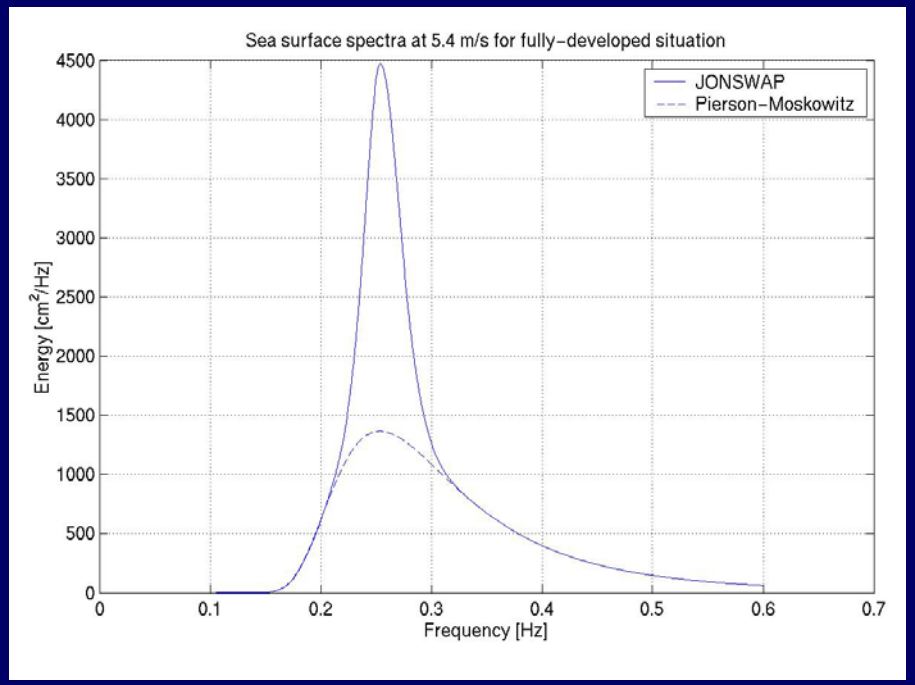
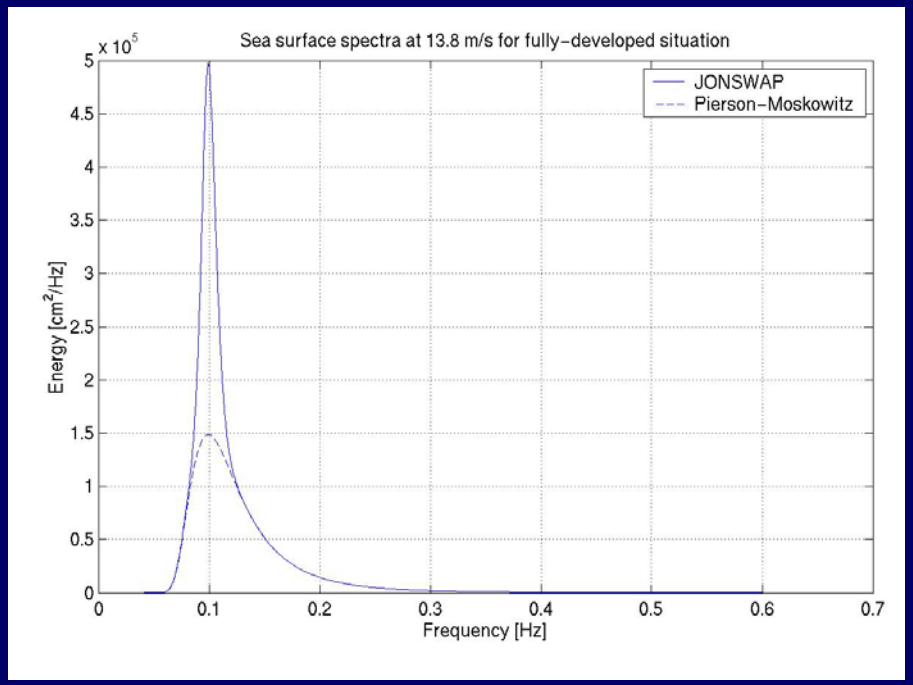
Sea surface
surface wave spectrum

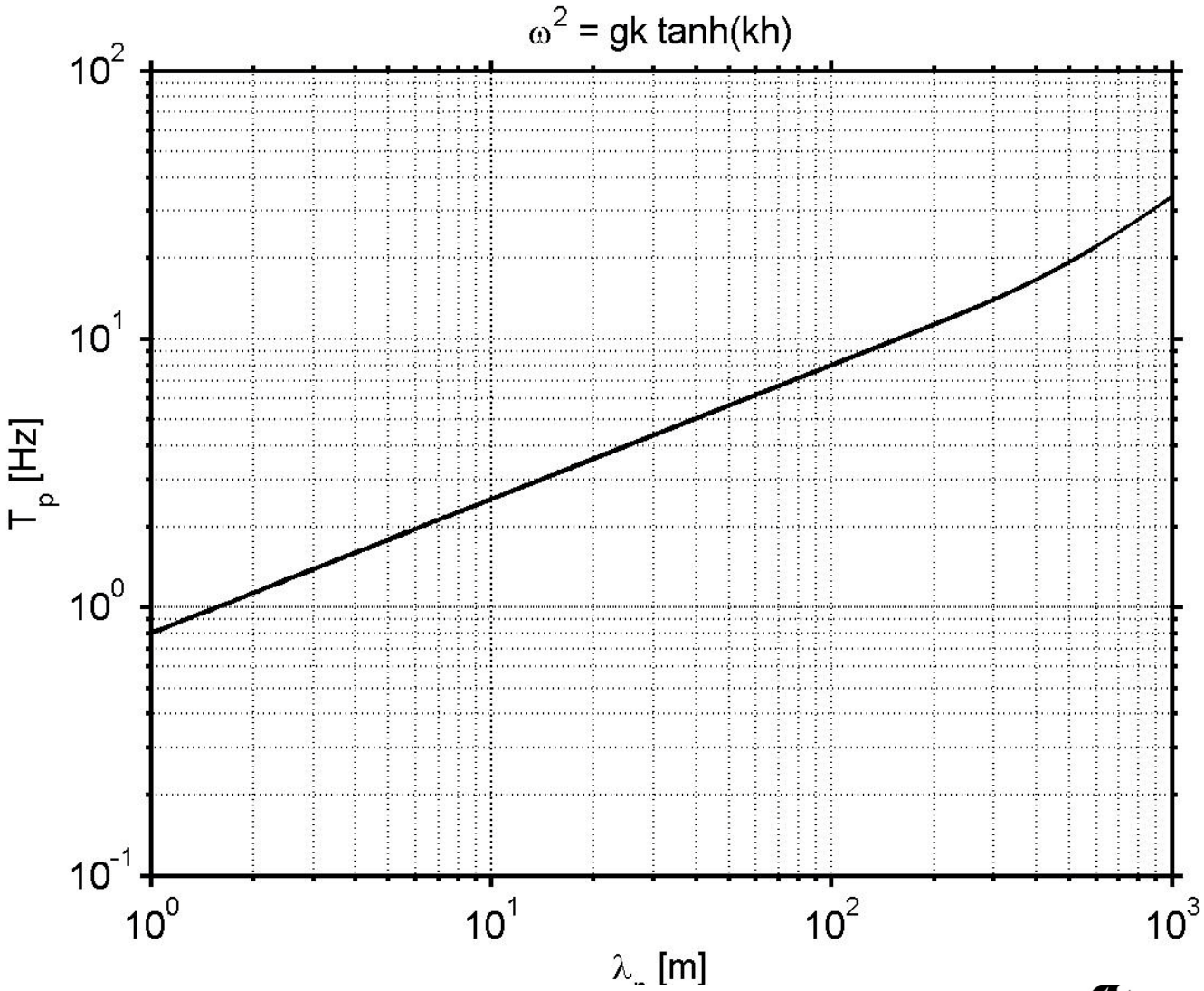
***U* = 5.4 m/s**



***U* = 13.8 m/s**



Sea surface
dispersion relation



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Sea surface
surface waves

Sea state	U [m/s]	c_{ph} [m/s]	T_p[s]	λ [m]	$H_{1/3}$ [m]
1	1.6	1.9	1.2	2.3	0.1
1, 2	3.3	3.8	2.4	9.0	0.3
2, 3	5.4	6.1	3.9	23.8	0.7
3, 4	7.9	9.1	5.8	52.5	1.5
4, 5	10.7	12.2	7.8	95.0	2.8
5	13.8	15.8	10.1	159	4.7
6	17.2	19.3	12.5	241	7.3
6	20.7	22.5	15.1	339	10.6

Sea surface - bubbles

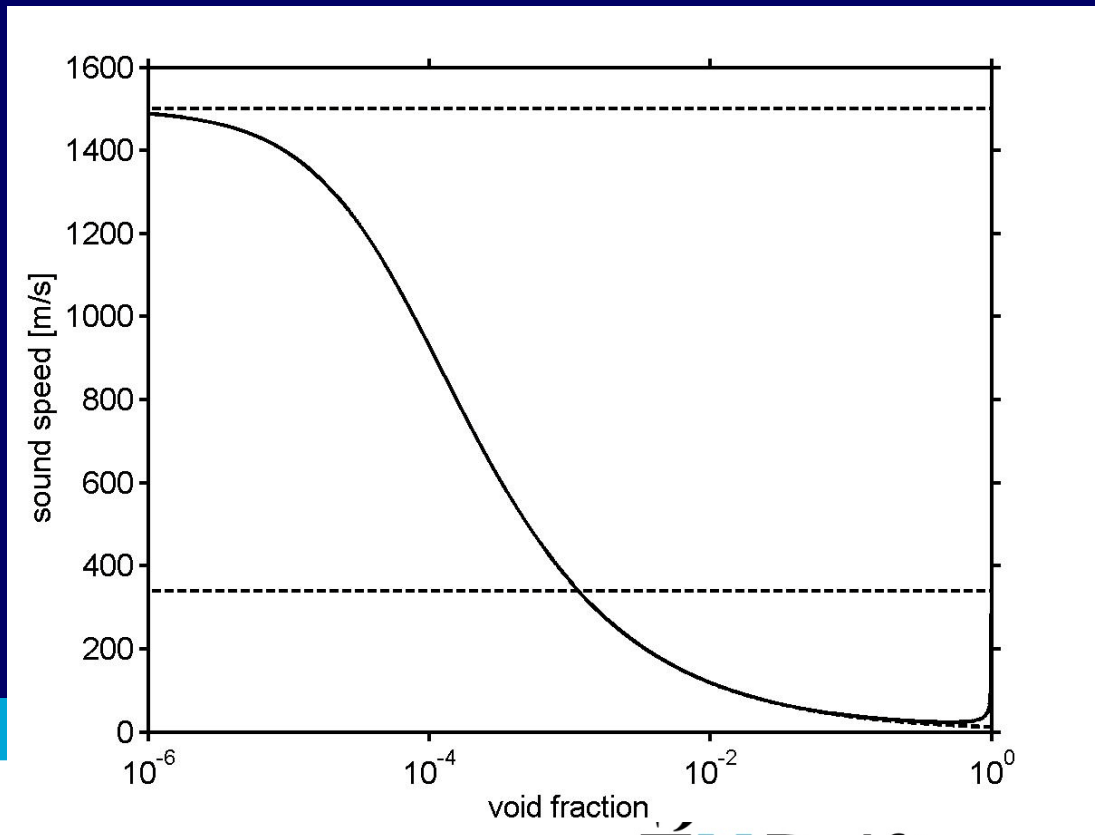
effect on sound speed - mixture theory

$$c_{\text{mixture}} = \sqrt{\frac{1}{\left[\beta\rho_{\text{air}} + (1-\beta)\rho_{\text{water}}\right]\left[\beta\kappa_{\text{air}} + (1-\beta)\kappa_{\text{water}}\right]}}$$

Density
Compressibility

$$c_{\text{water}} = \sqrt{\frac{1}{\rho_{\text{water}}\kappa_{\text{water}}}}$$ **= 1500 m/s**

$$c_{\text{air}} = \sqrt{\frac{1}{\rho_{\text{air}}\kappa_{\text{air}}}}$$ **= 340 m/s**



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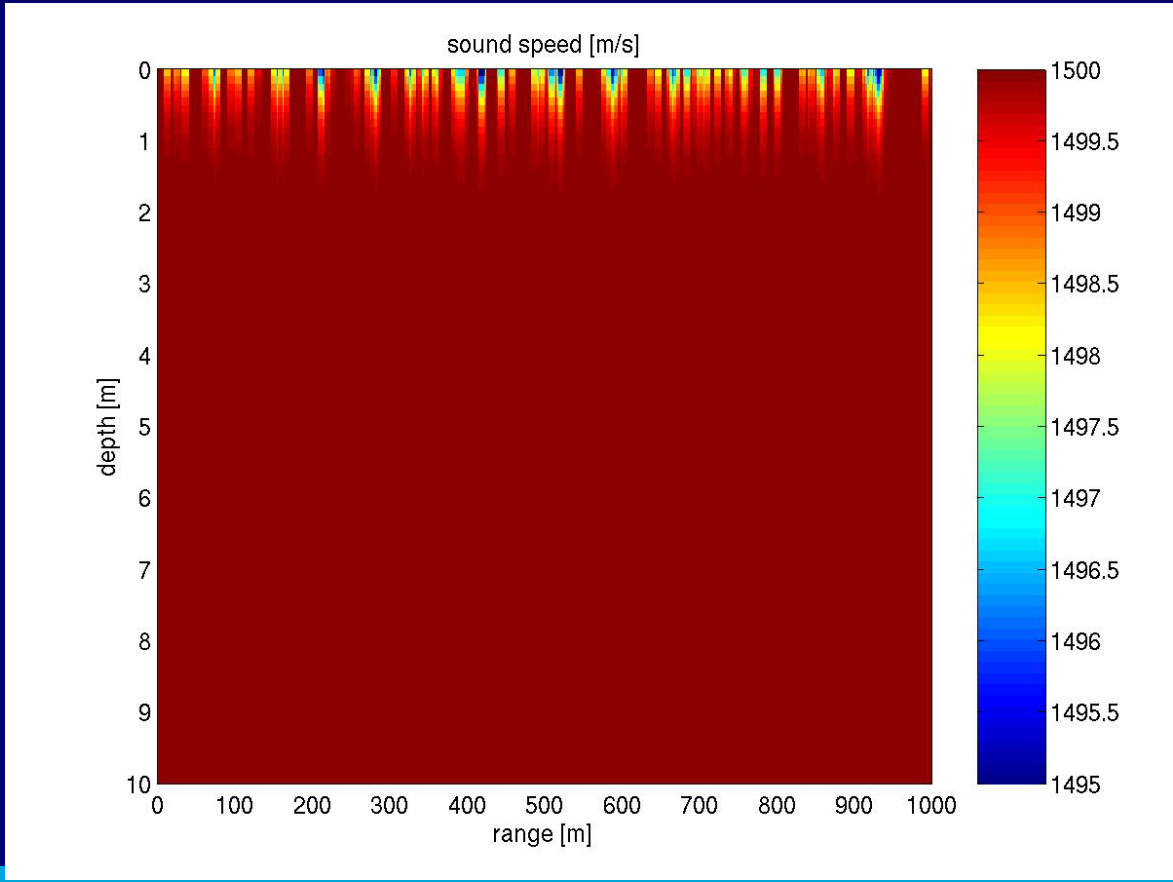
Sea surface - bubbles

modelling bubble distribution - effect on sound speed

***U* = 5.4 m/s**



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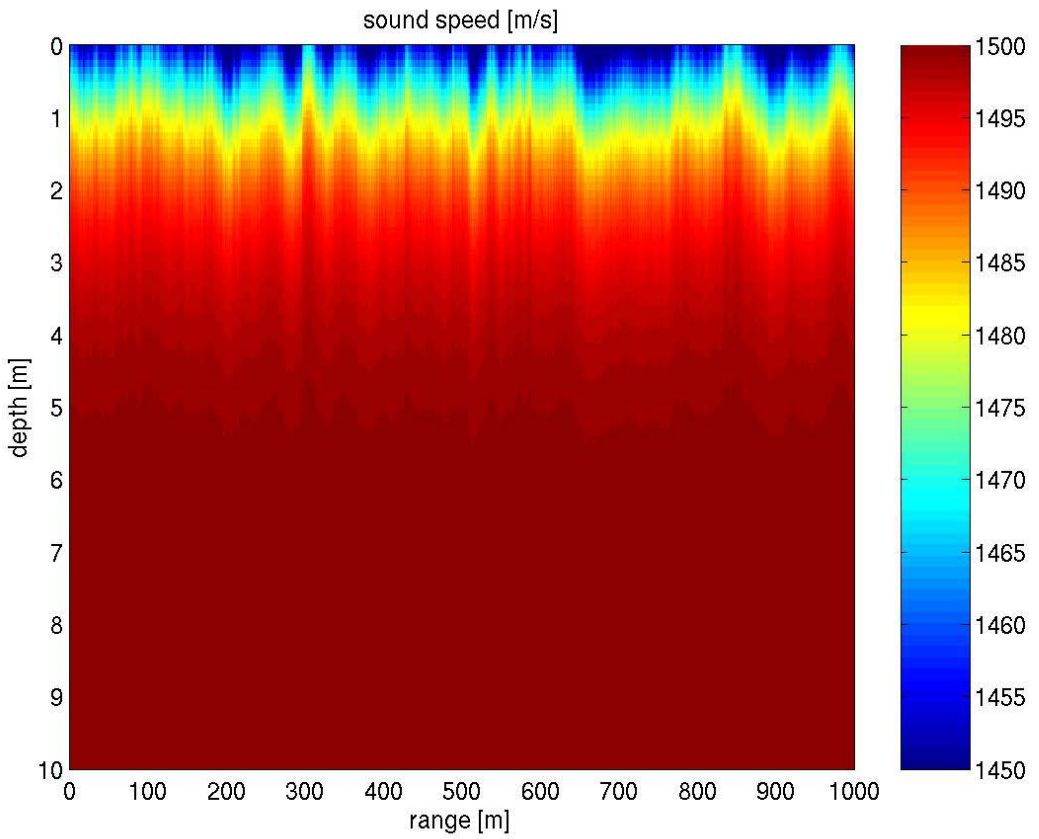
Sea surface - bubbles

modelling bubble distribution - effect on sound speed

***U* = 13.8 m/s**



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