Turbulent measurements in North Western Mediterranean using SCAMP (Self Contained Autonoumous MicroProfiler)

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The energy and temperature dissipation rates.

The budget equation:

$$\frac{\partial}{\partial t}\rho/2\overline{\left(u'^2+v'^2+w'^2\right)}=-\bar{\rho}\,\overline{\left(u'w'\right)}\frac{\partial\bar{u}}{\partial z}-g\overline{\left(\rho'w'\right)}-\bar{\rho}\,\varepsilon$$

- Turbulent kinetic energy
- Turbulent motion
- Potential energy
- Molecular diffusion dissipation

$$\varepsilon=-\nu\overline{\frac{\partial u'_i}{\partial x_j}\left(\frac{\partial u'_i}{\partial x_j}+\frac{\partial u'_j}{\partial x_i}\right)}$$

The budget equation:

$$\frac{\partial\overline{\left(T'\right)^2}}{\partial t}=-2\overline{\left(w'T'\right)}\frac{\partial\bar{T}}{\partial z}-\chi$$

- Variance of thermal anomalies
- Turbulent heat flux
- Molecular heat diffusion

$$\chi=2\mathrm{D}\overline{\left(\nabla T'^2\right)}\ ,$$

where D is thermal diffusivity

Turbulent lengthscales

Lengtscale	Symbol	Definition	Interpretation
Ozmidov	L_0	$(\varepsilon/N^3)^{1/2}$	The scale at which buoyancy forces balance inertial forces
Kolmogorov	L_k	$(\nu^3/\varepsilon\ )^{1/4}$	The scale at which viscous forces balance inertial forces
Batchelor	L_B	$D^{1/2}(\nu^3/\varepsilon)^{1/4}$	The scale at which molecular diffusion smooths locally enhanced scalar gradients

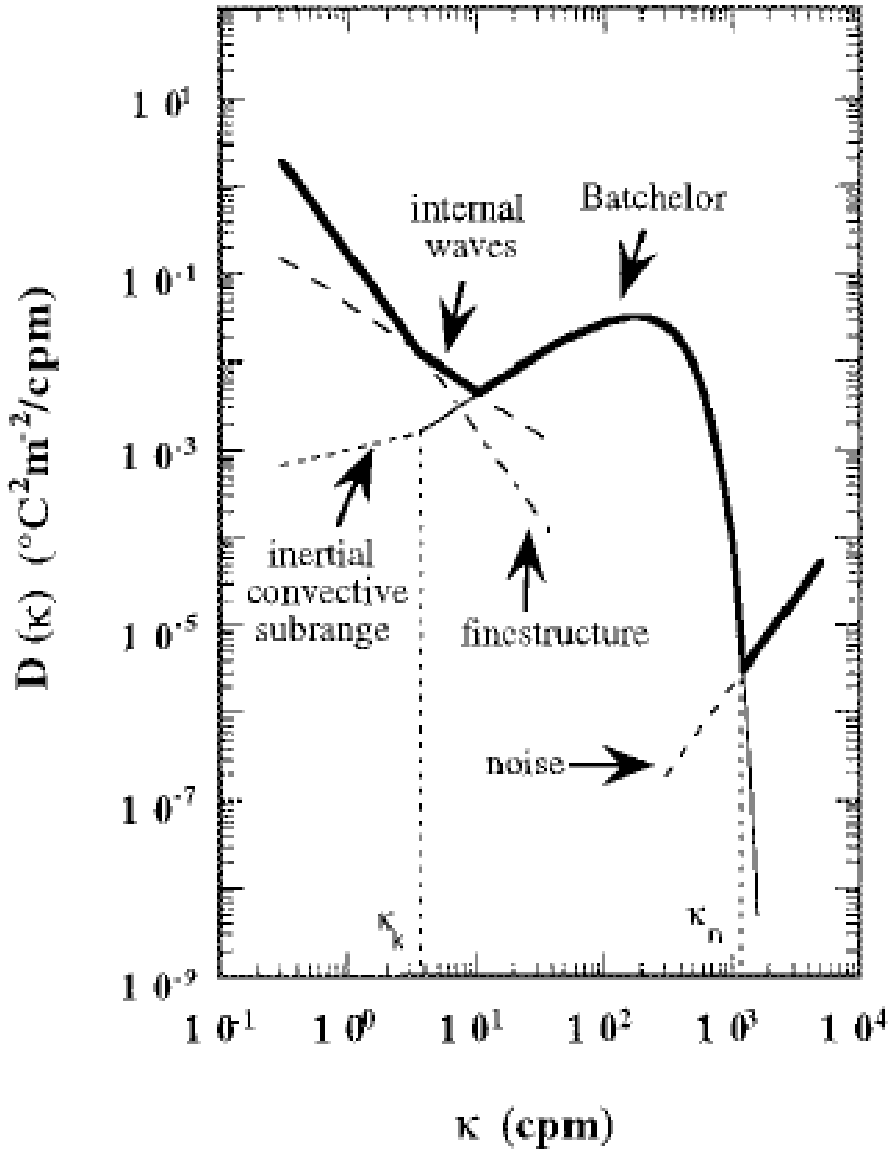
Batchelor spectrum

Small-scale behaviour of passively convected, diffusive scalars in the presence of turbulence.

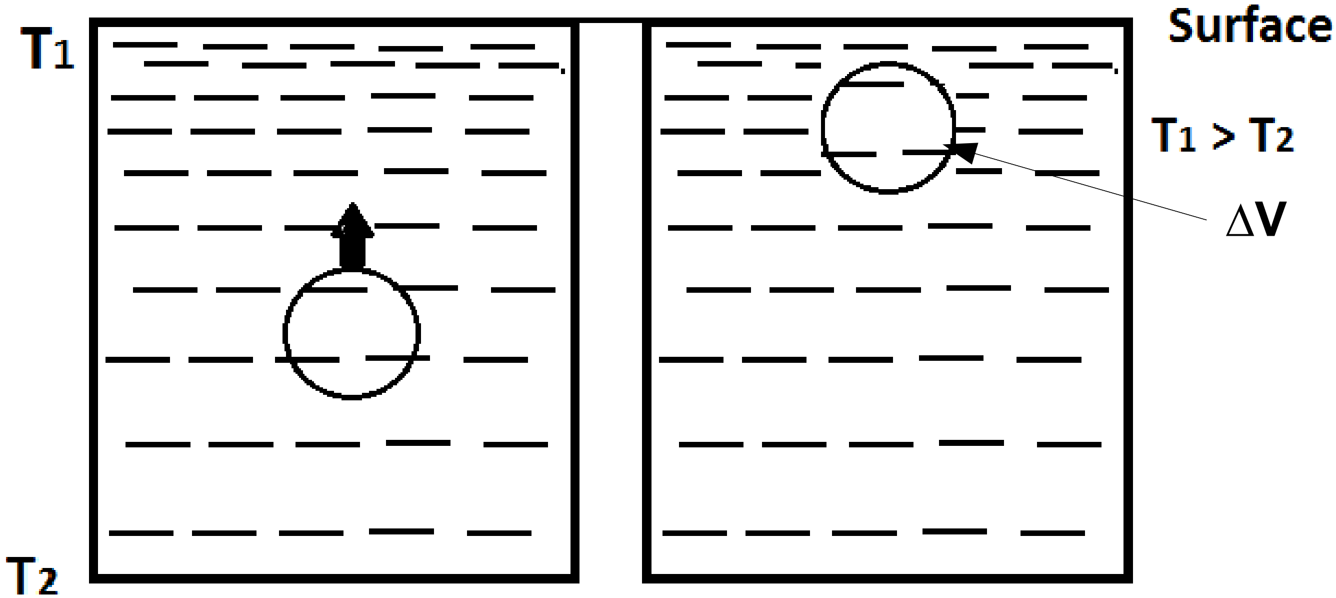
$$S_B(k;k_B,\chi)=(q/2)^{1/2}\chi k_B^{-1} D^{-1} f(\alpha)$$

where

$$\alpha = k k_B^{-1}\sqrt{2}$$



Brunt–Väisälä frequency



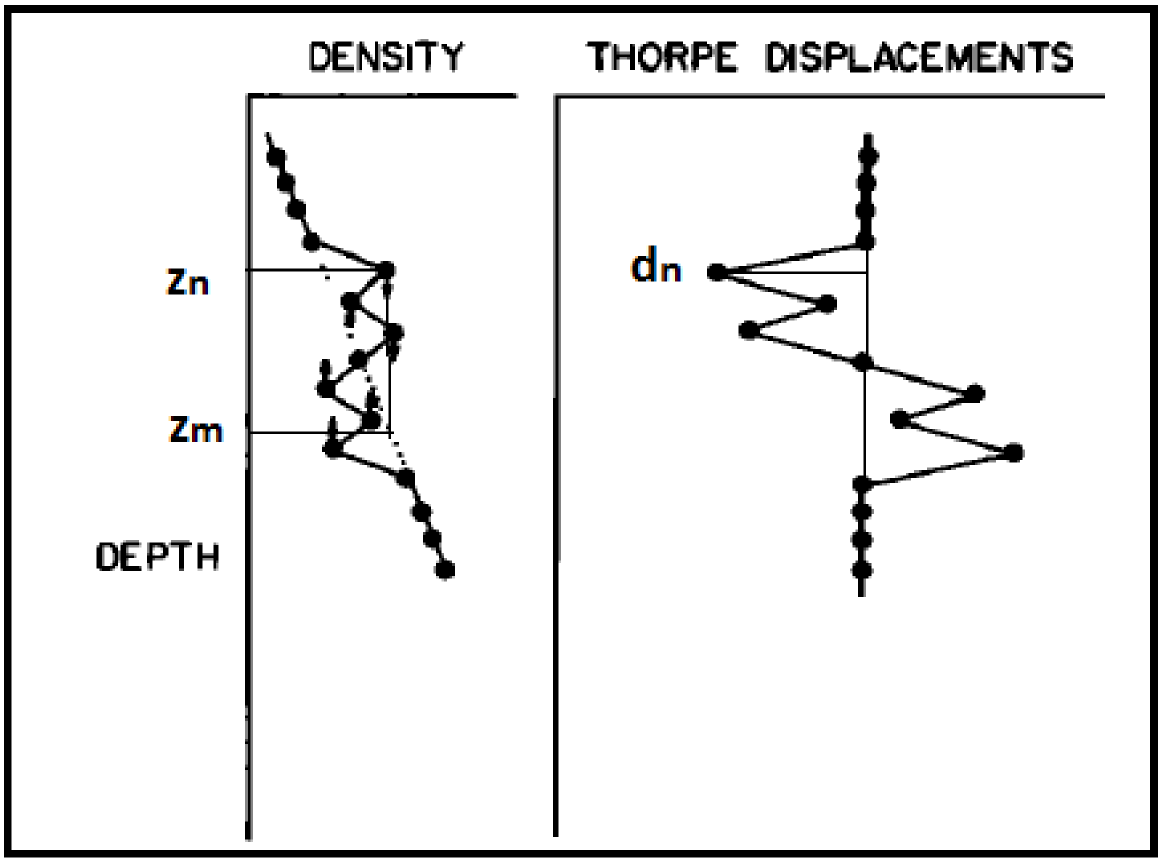
- •ΔV does not strive to return to initial position → unstable stratification

- •ΔV strive to return to initial position → stable stratification

Frequancy of the inertianal oscillations of the volume of water in case of stable stratification of the ocean:

$$N^2 = \frac{g}{\rho_0}\frac{\partial \rho}{\partial z}$$ - Brunt–Väisälä frequency

Thrope scale



Thrope displacement:

$$d_n = z_m - z_n$$

Thrope scale:

$$L_T = (\overline{d^2})^{1/2}$$

Thrope scale scale is proportional to the mean eddy size as long as the mean horizontal density gradient is much smaller than vertical gradient

Osborn's method

$$\overline{u'w'}\frac{\partial \bar{u}}{\partial z} = -\varepsilon - \frac{\overline{\rho' w'} g}{\bar{\rho}}$$

Turbulent production

Dissipation

Work against buoyancy

Richardson flux number: $$R_f = \frac{\dfrac{\overline{\rho' w'} g}{\bar{\rho}}}{\overline{u'w'}\dfrac{\partial \bar{u}}{\partial z}} = \frac{Work\ against\ buoyancy}{Turbulent\ production}$$

Critical flux Richardson number — maximum value of R_f, above which the turbulent cannot appear. $R_{fcrit} = 0.15$ (Ellison 1957)

Osborn's method

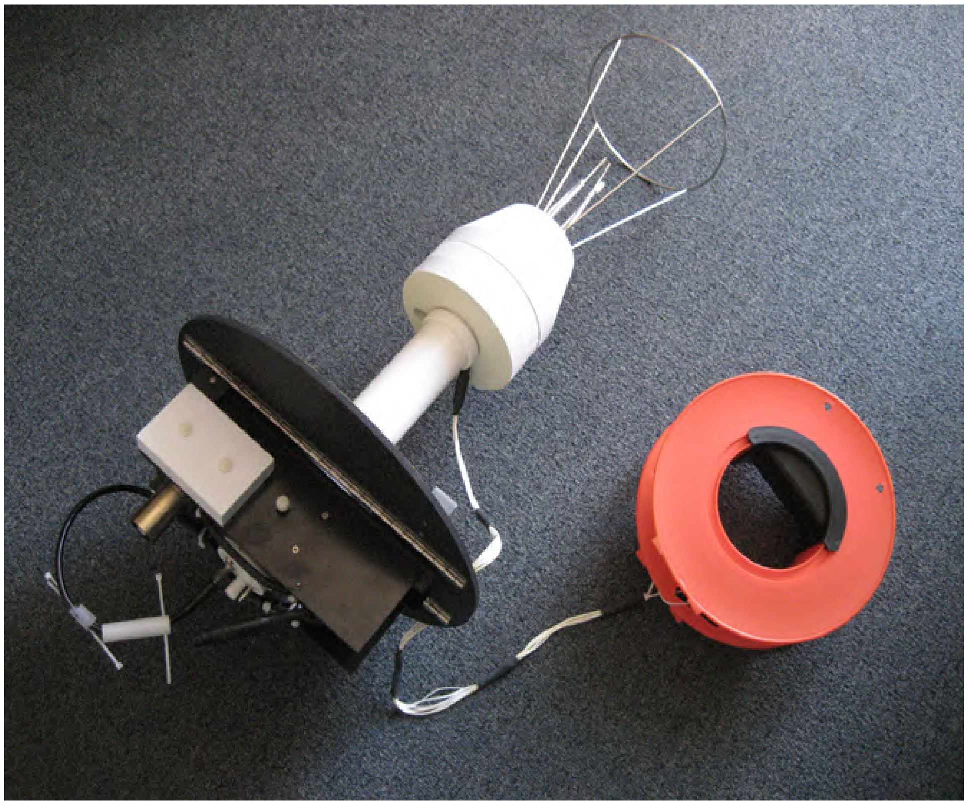
Buoyancy flux : $B = -\overline{b'w'} = K_b \frac{\partial b}{\partial z}$, $N^2 = \frac{\partial b}{\partial z}$

Buoyancy fluctuations: $b' = -(g/\rho)\rho'$

Coefficient of eddy diffusivity: $K_b = \frac{g\,\overline{w'\rho'}\,\bar{\rho}^{-1}}{N^2}$

$$K_b = \frac{R_f \varepsilon}{(1-R_f)N^2} \leqslant 0.2\frac{\varepsilon}{N^2}$$

Self Contained Autonomus MicroProfiler (SCAMP)



Measurements on a small scale (≈ 1mm)

Frequency measures: 100Hz

Light ≈ 6kg

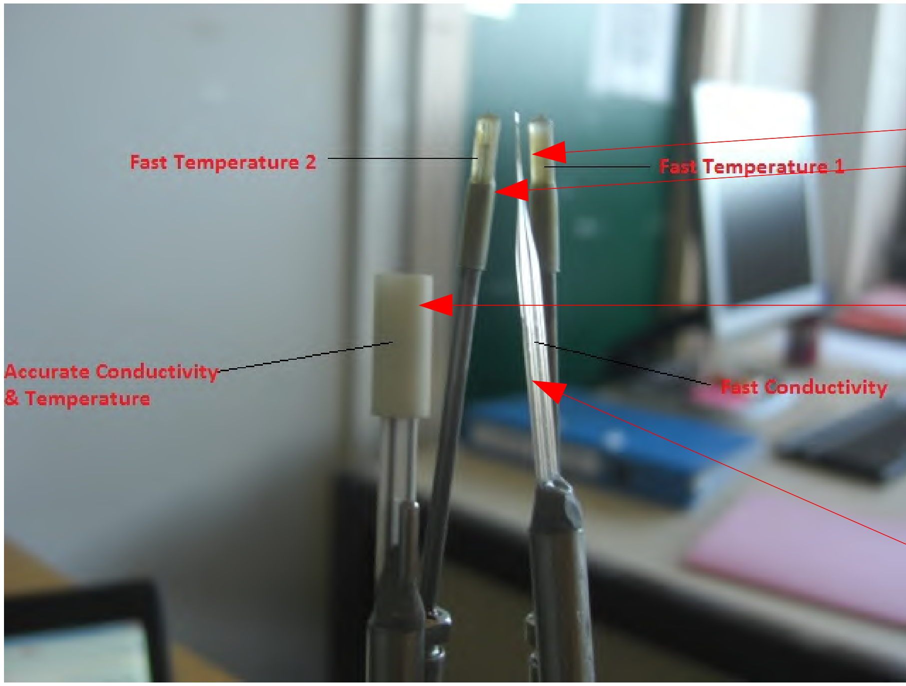
Move Free (fall and rise)

Travel speed ≈ 10cm/s

Maximum depth: 100m

manufactured by Presecion Measurement Engineering, California

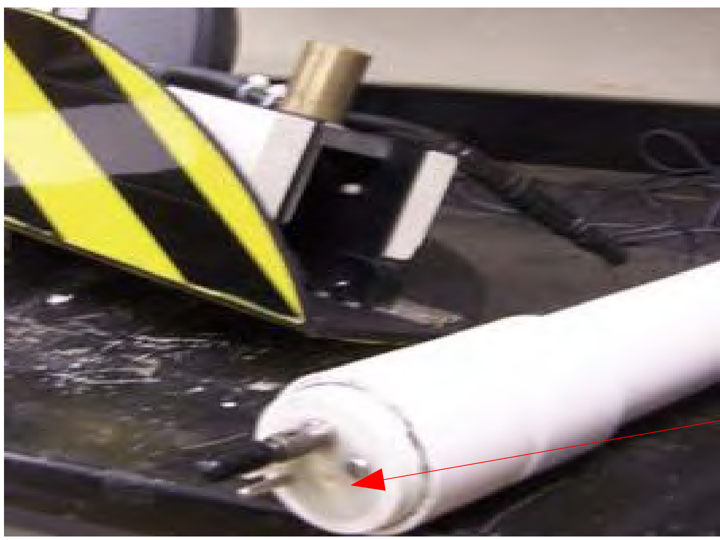
SCAMP SENSORS



Two Thermometrics FP07 fast-response (time constant~7ms) thermistors

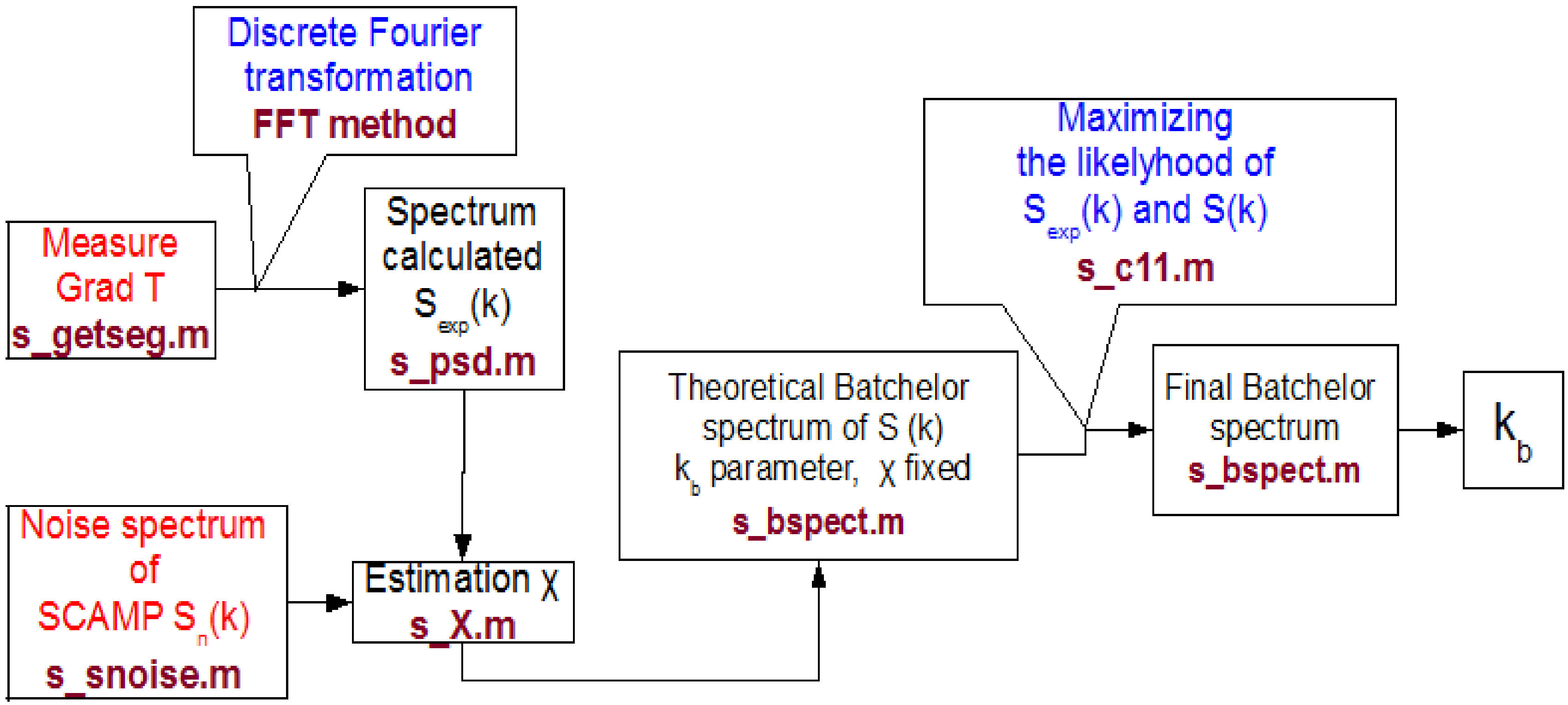
Temperature (Thermometrics T1201 thermistor, time constant~ms) and conductivity (PME 4-electrode ceramic, spatial resolution~cm) sensor pair

Four-electrode microconductivity sensor (spatial resolution~mm)

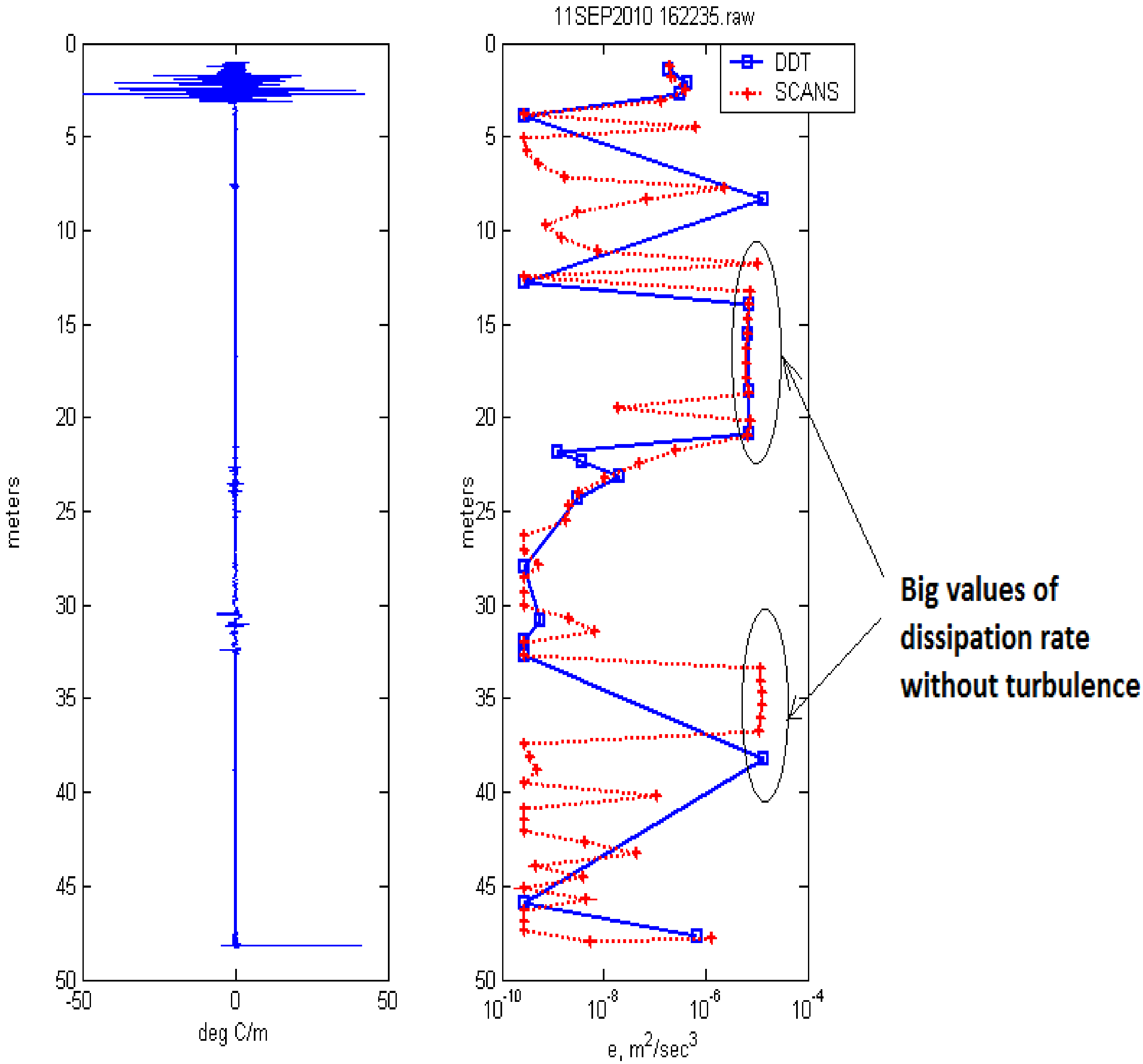


Pressure sensor (Keller PSI PAA-10)

Estimation of kb.



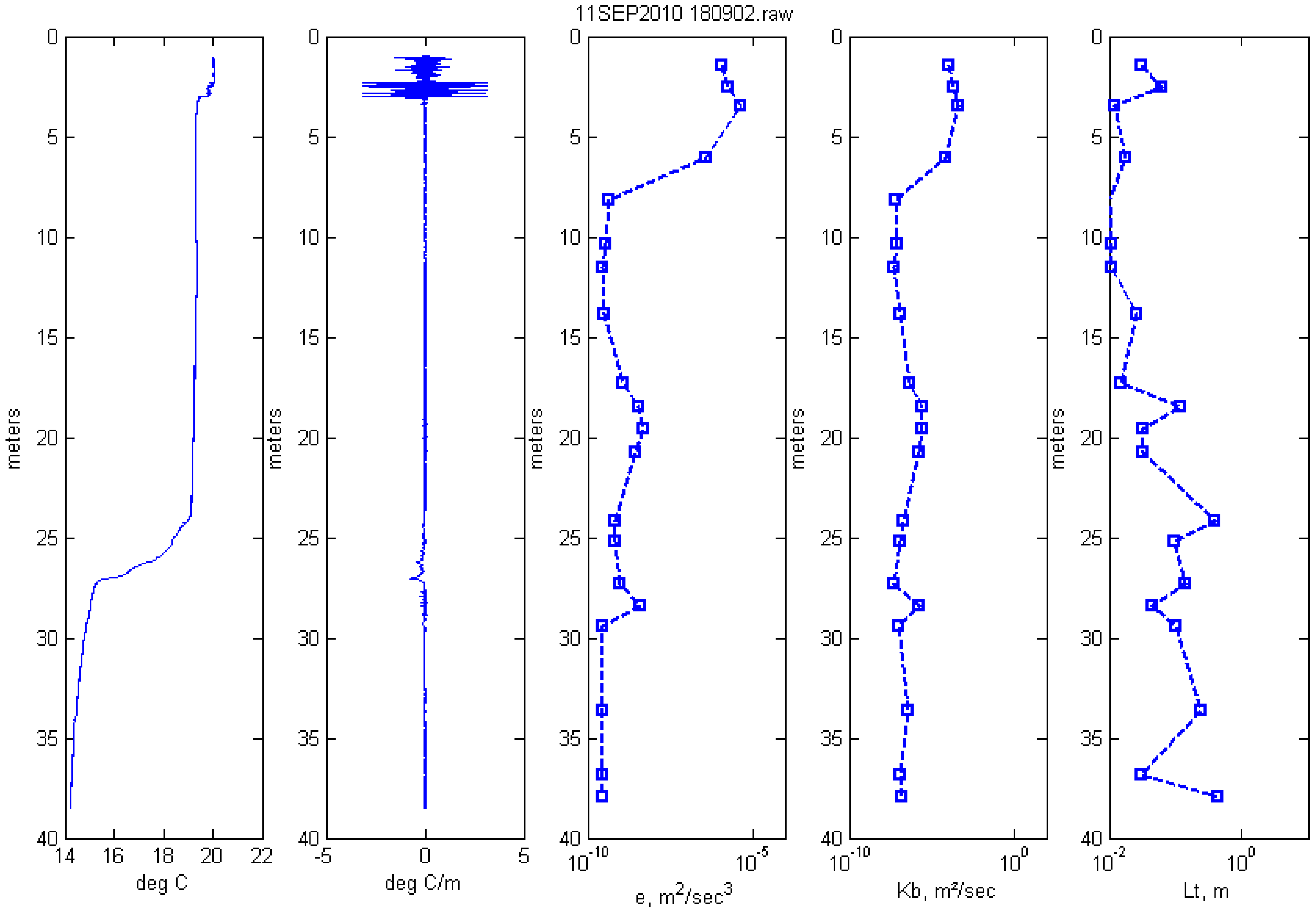
Segmentation



2 methods:

- Complex, statistical-stationarity, based-methods (ddt)
- Small fixed-size bins (scans)

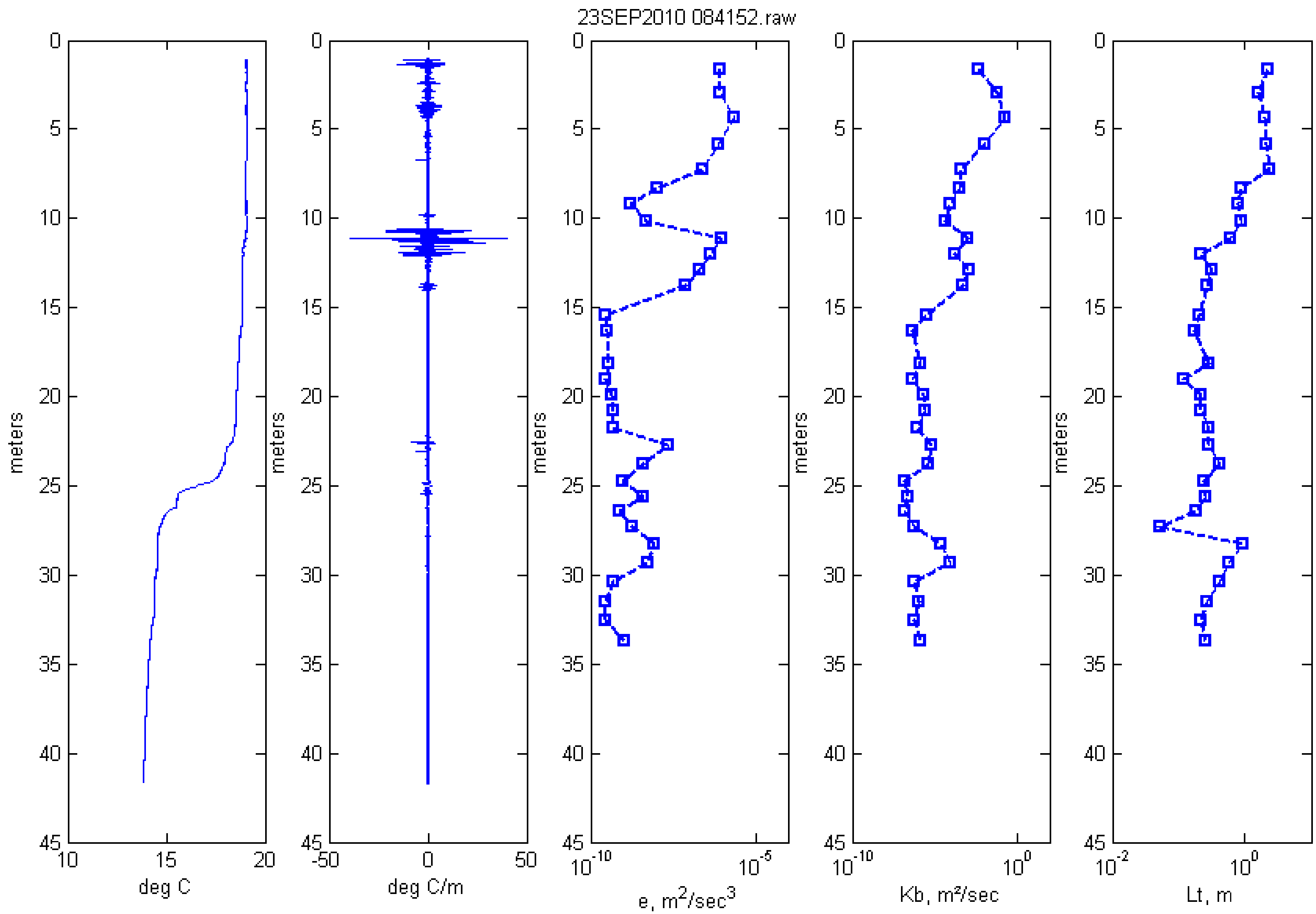
Profile 11SEP2010 180902. Calm conditions. Diurnal thermocline.



Profile 11SEP2010 180902. Calm conditions. Diurnal thermocline.

Depth, m	Eddy diffusivity, Kb, m^2/s	Thrope scale, Lt, m	Dissipation rate, ε, m^2/s^3
1-4	10^{-4}	0,03	10^{-6}
8-12	10^{-8}	0,01	10^{-10}
13-37	$10^{-6}\div 10^{-7}$	0,1÷0,01	$10^{-9}\div 10^{-10}$

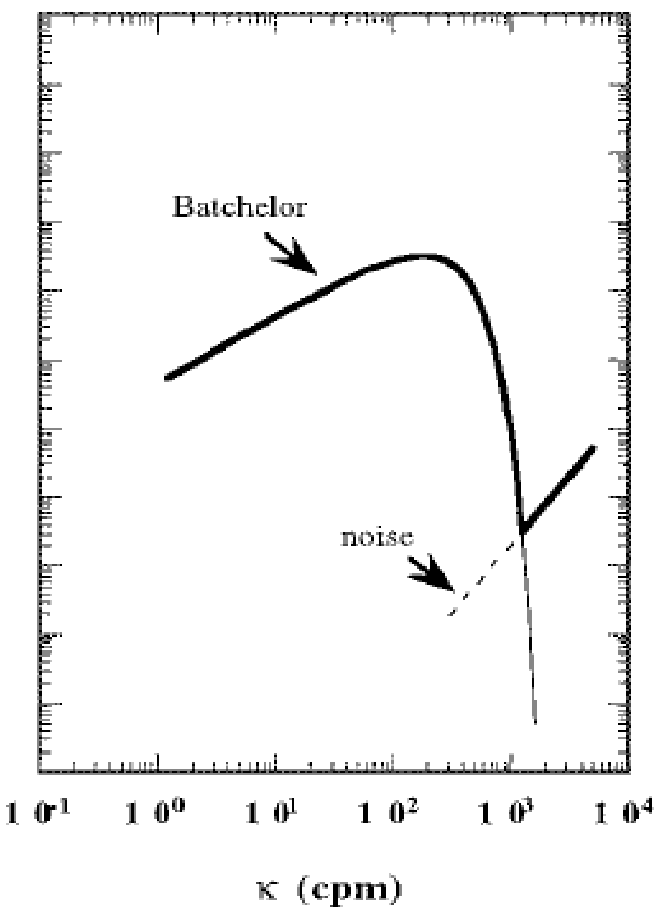
Profile 23SEP2010 084152. Calm morning after wind night conditions (6-7 m/s)



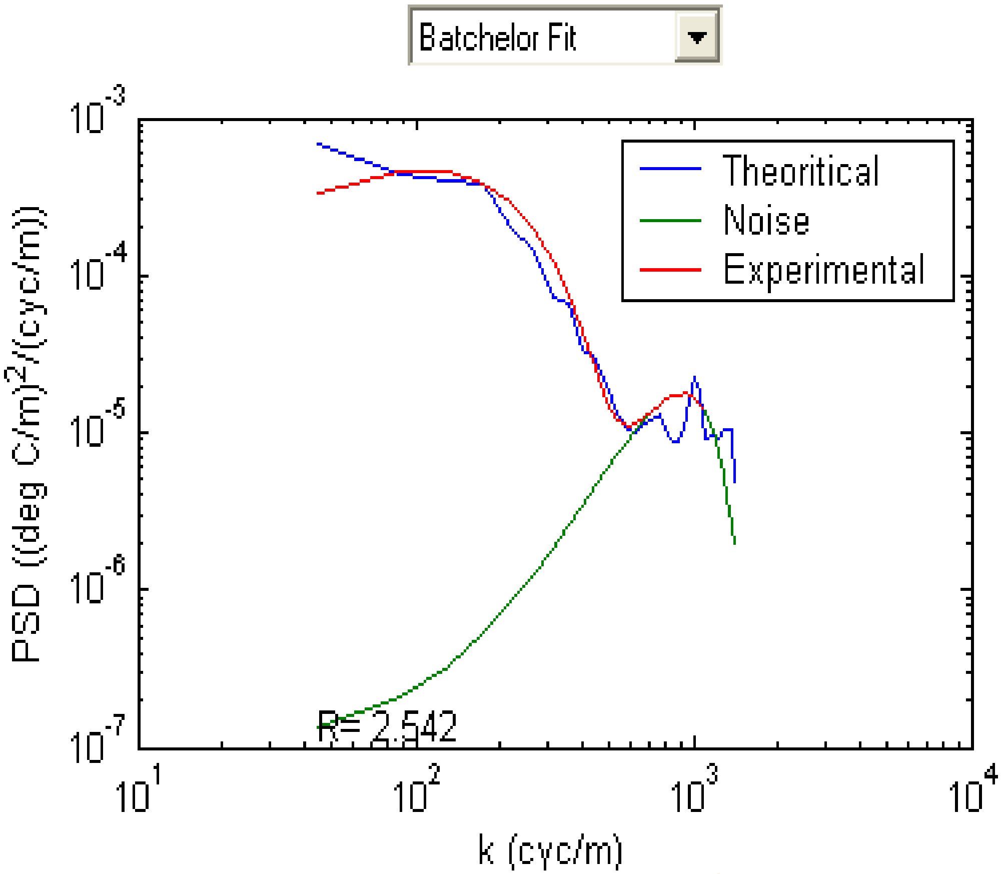
Profile 23SEP2010 084152. Calm morning after wind night conditions (6-7 m/s)

Depth, m	Eddy diffusivity, Kb, m^2/s	Thrope scale, Lt, m	Dissipation rate, ε, m^2/s^3
1-6	$10^{-3}\div10^{-1}$	2	$10^{-7}\div 10^{-6}$
7-10	$10^{-5}\div10^{-4}$	1÷2	$10^{-9}\div 10^{-7}$
10-14	$10^{-4}\div 10^{-3}$	0,2÷0,6	$10^{-8}\div 10^{-7}$
15- 24	$10^{-7}\div 10^{-6}$	0,1÷0,4	$10^{-10}\div 10^{-8}$
25 - 27	10^{-7}	0,05÷0,2	$10^{-10}\div 10^{-9}$

Profile 23SEP2010 112935. Wind conditions (wind speed = 5 m/s)

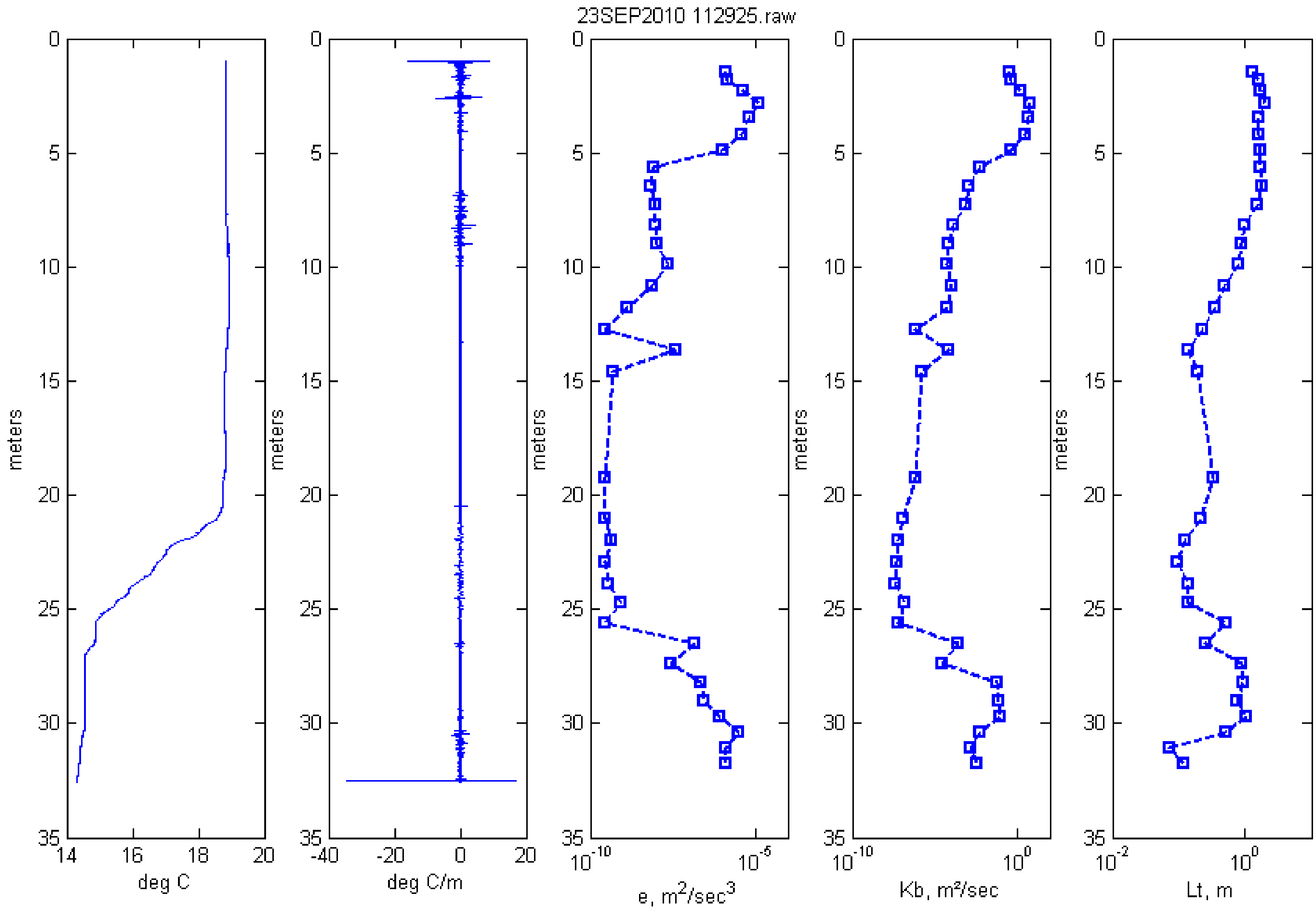


Example of the spectrum in the wind mixed layer (Luketina, Imberger 2001)



Spectrum from profile 23SEP2010 112935 depth 1 — 2 m

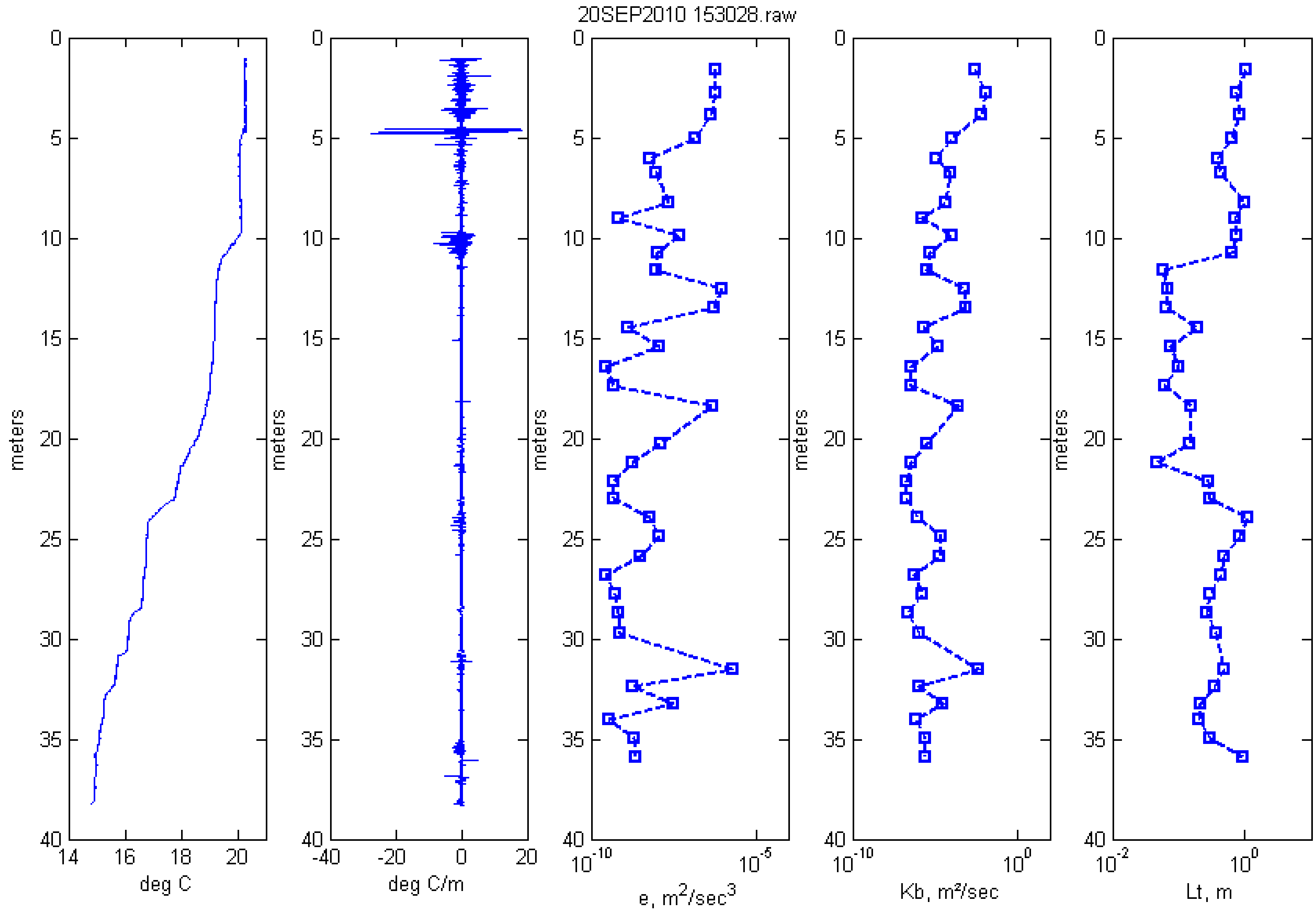
Profile 23SEP2010 112935. Wind conditions (wind speed = 5 m/s)



Profile 23SEP2010 112935. Wind conditions (wind speed = 5 m/s)

Depth, m	Eddy diffusivity, Kb, m^2/s	Thrope scale, Lt, m	Dissipation rate, ε, m^2/s^3
1-5	0,1-1	1.6	$10^{-6} \div 10^{-5}$
5-8	$10^{-4} \div 10^{-3}$	1.6	10^{-9}
8-10	$10^{-4} \div 10^{-5}$	0,5÷1	$10^{-9} \div 10^{-8}$
14-25	$10^{-8} \div 10^{-6}$	0,1÷0,5	10^{-10}

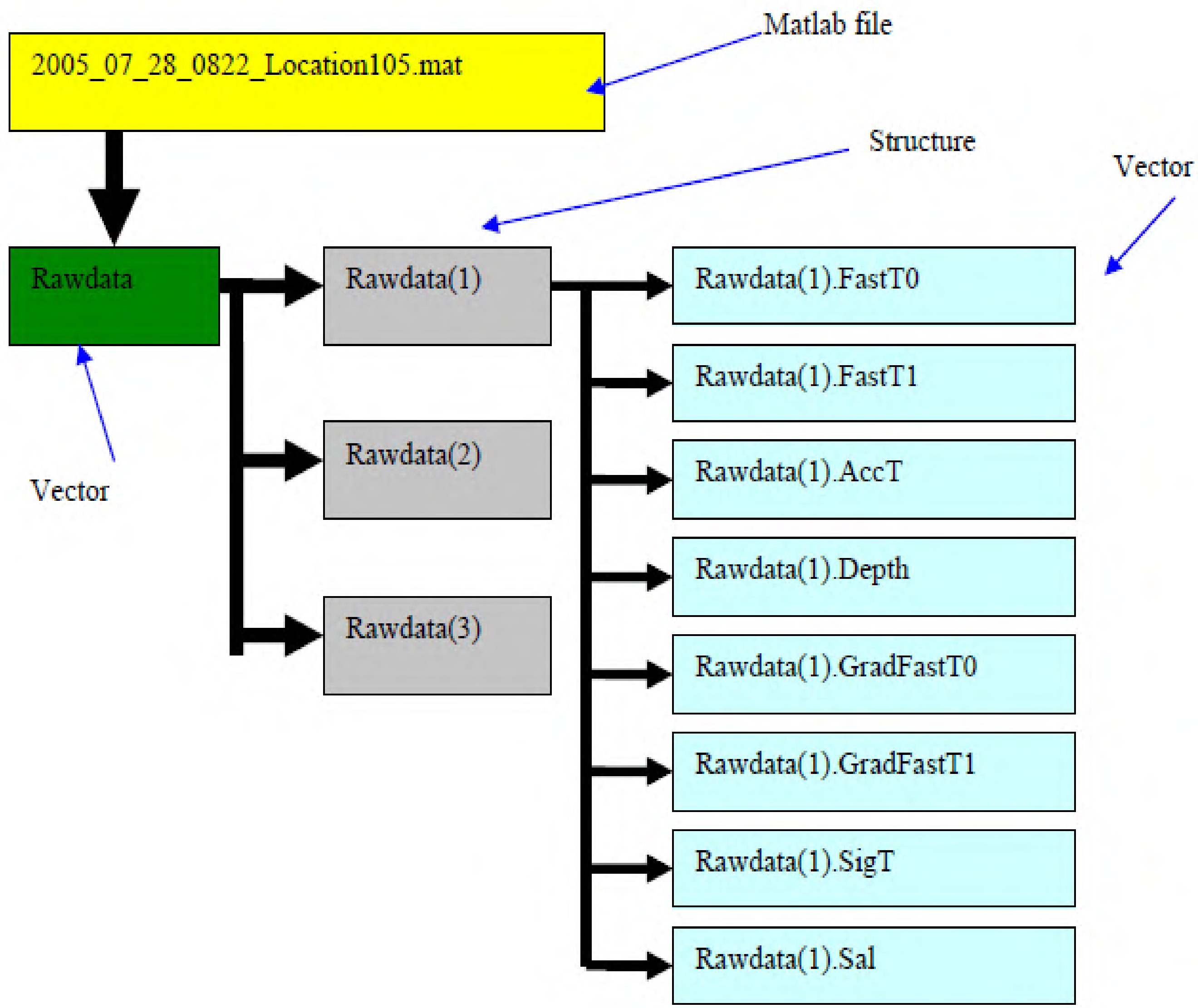
Profile 20SEP2010 153028. «Step» temperature profile.

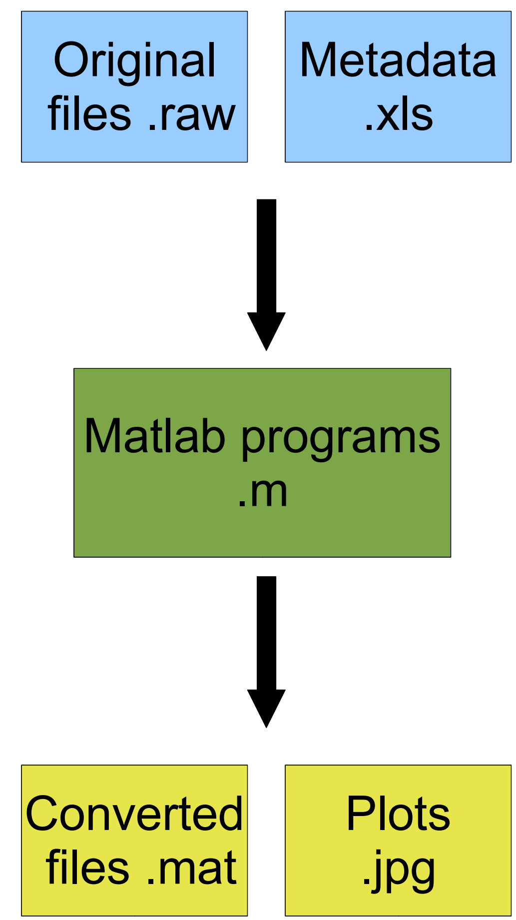


Profile 20SEP2010 153028. «Step» temperature profile.

Depth, m	Eddy diffusivity, Kb, m^2/s	Thrope scale, Lt, m	Dissipation rate, ε, m^2/s^3
1-5	$10^{-4}\div10^{-2}$	0,6÷1	10^{-7}
6-9	$10^{-5}\div10^{-4}$	0,4÷1	$10^{-10}\div 10^{-8}$
10-12	10^{-6}	0,01÷0,1	$10^{-9}\div 10^{-8}$
12,5 – 13,5	10^{-4}	0,06	10^{-7}
14 – 17	$10^{-7}\div10^{-5}$	0,01÷0,1	$10^{-10}\div 10^{-8}$
18	10^{-4}	0,1	10^{-7}
20 - 24	$10^{-7}\div10^{-6}$	0,01÷0,1	$10^{-10}\div 10^{-8}$
25 - 26	10^{-5}	0,6	$10^{-9}\div 10^{-8}$

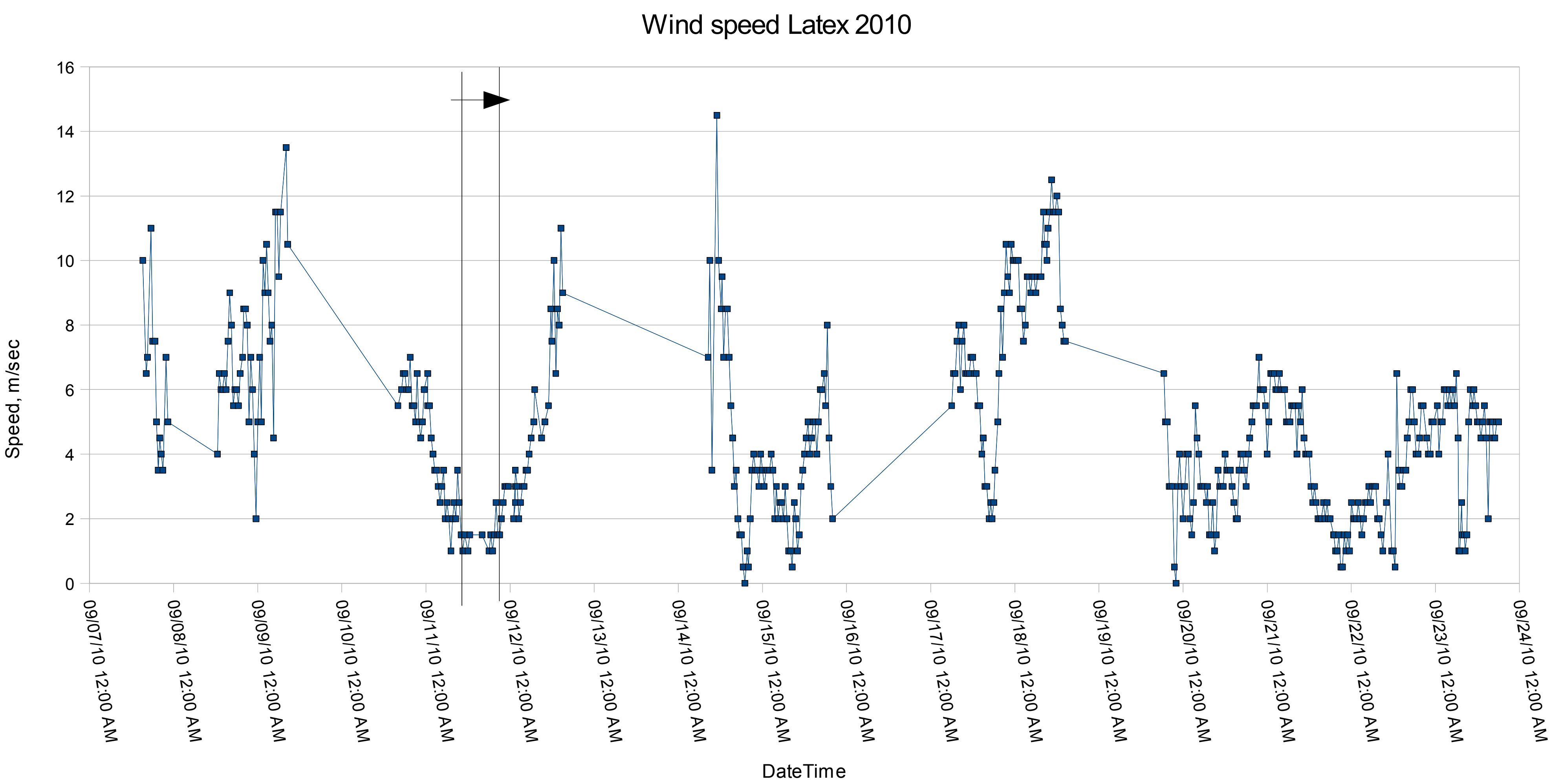
SCAMP Matlab program modifications by Hodges et al. 2006





Conclusions

- Big values of coefficient of eddy diffusivity (0,1 — 1) are observed in profile, taken during the wind conditions at depth 1 — 5 m with sizes of vertical overturnes in the order of 1 m. Also these layer is charactizied by large values of turbulence dissipation rate (up to 10^{-5})
- In diurnal thermocline the values of Kb are estimated as 10^{-4} and sizes of the the overturnes in order 0,01 with dissipation rate 10^{-6}.
- In the regions of the seasonal thermocline decrease to 10^{-8} .



Wind speed Latex 2010
Speed, m/sec
16
14
12
10
8
6
4
2
0
09/07/10 12:00 AM
09/08/10 12:00 AM
09/09/10 12:00 AM
09/10/10 12:00 AM
09/11/10 12:00 AM
09/12/10 12:00 AM
09/13/10 12:00 AM
09/14/10 12:00 AM
09/15/10 12:00 AM
09/16/10 12:00 AM
09/17/10 12:00 AM
09/18/10 12:00 AM
09/19/10 12:00 AM
09/20/10 12:00 AM
09/21/10 12:00 AM
09/22/10 12:00 AM
09/23/10 12:00 AM
09/24/10 12:00 AM
DateTime