# Arrival time variations of pulses in shallow water and low frequency acoustical underwater positioning

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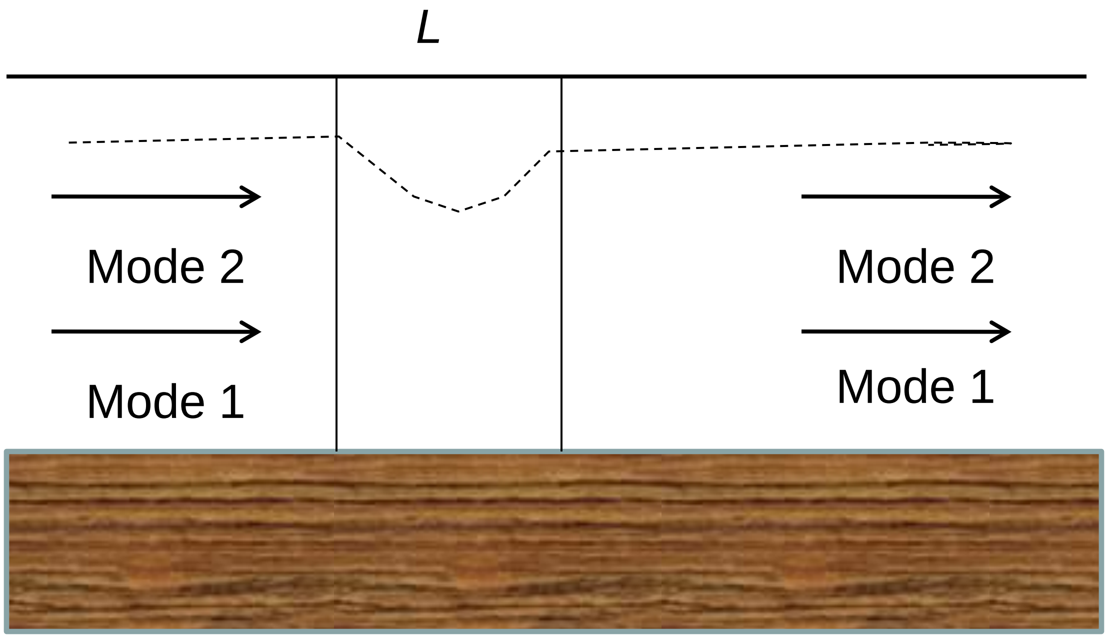
# Overview

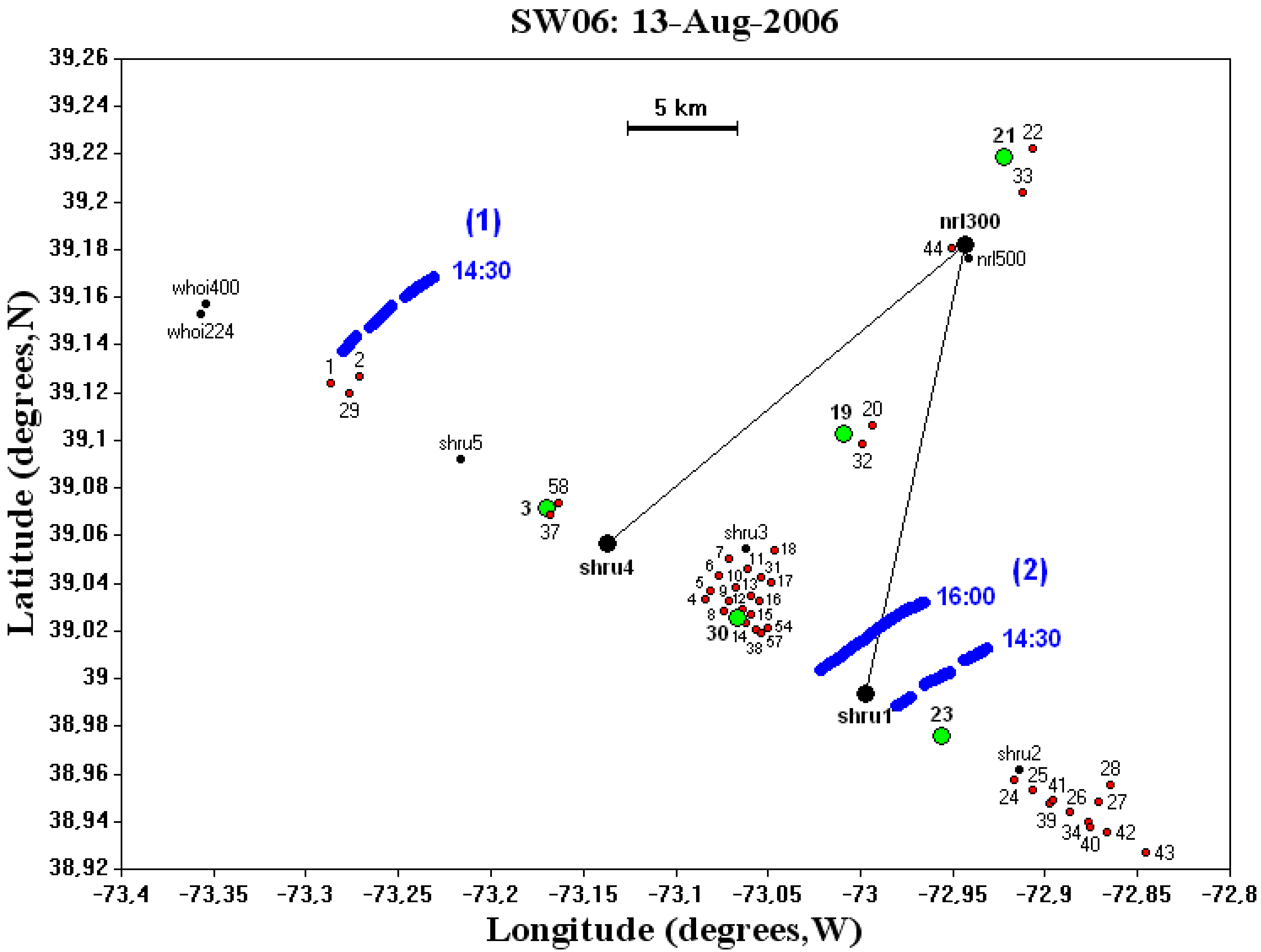
- We consider fluctuations of arrival time of low frequency sound pulses in shallow water during long time (about 9h) using experimental material of SW’06.
- We have sound source (NRL300) radiating LFM pulses with frequency band 270-330 Hz. As an example we consider a few acoustic tracks with SHRUs as receivers. There were train of nonlinear internal waves  passing through acoustic tracks
- On the base of measurements of arrival times of sound pulses from fixed source with known position it is possible to establish position of receiver (for example AUV). Using data of SW06 modeling of algorithm positioning is carried out

# Simple estimations

We will make sure that arrival time fluctuations of separate modes are comparatively small even in presence of internal solitons.

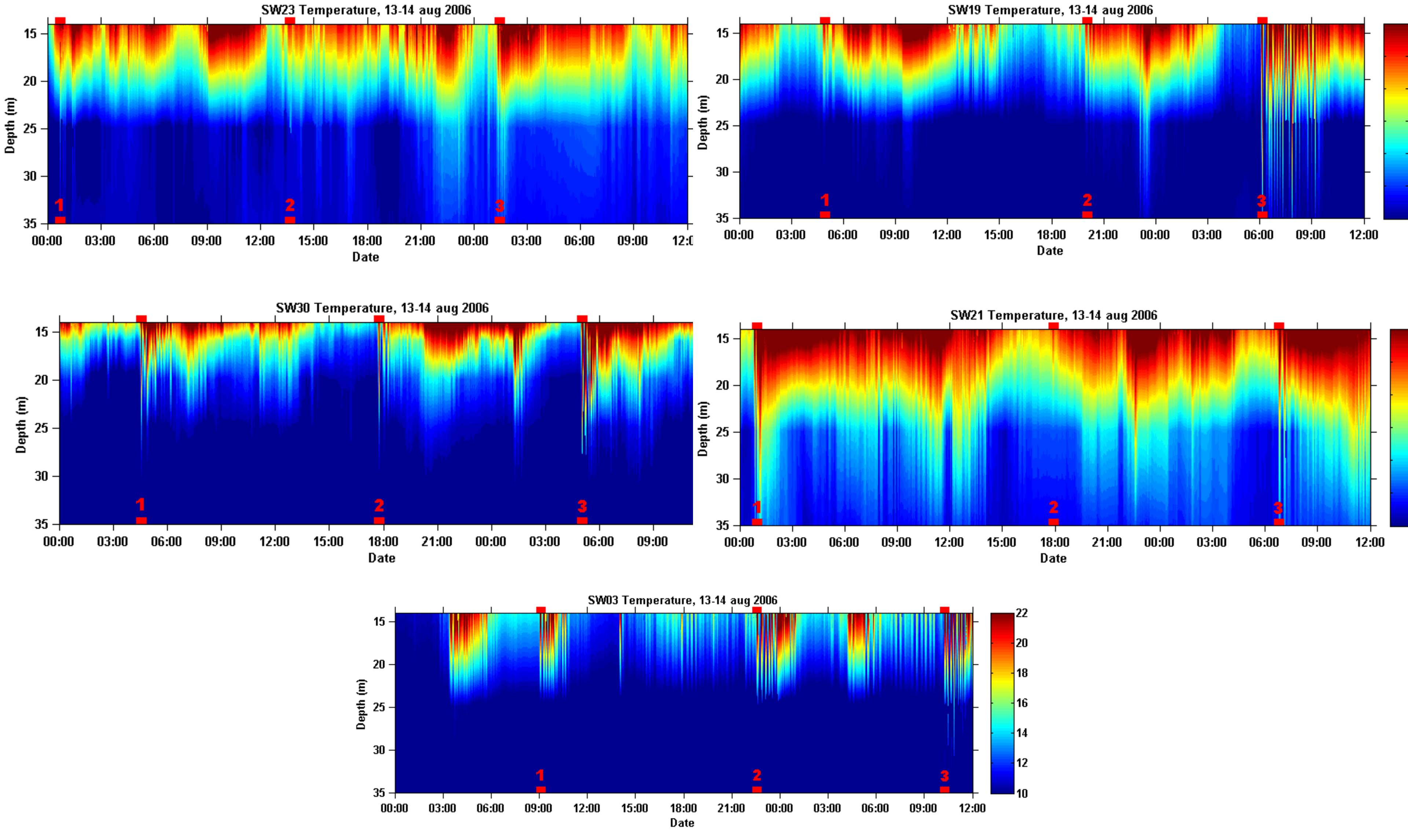



$\Delta\tau \sim 1\text{–}2$ msec for $L \sim 500$ m



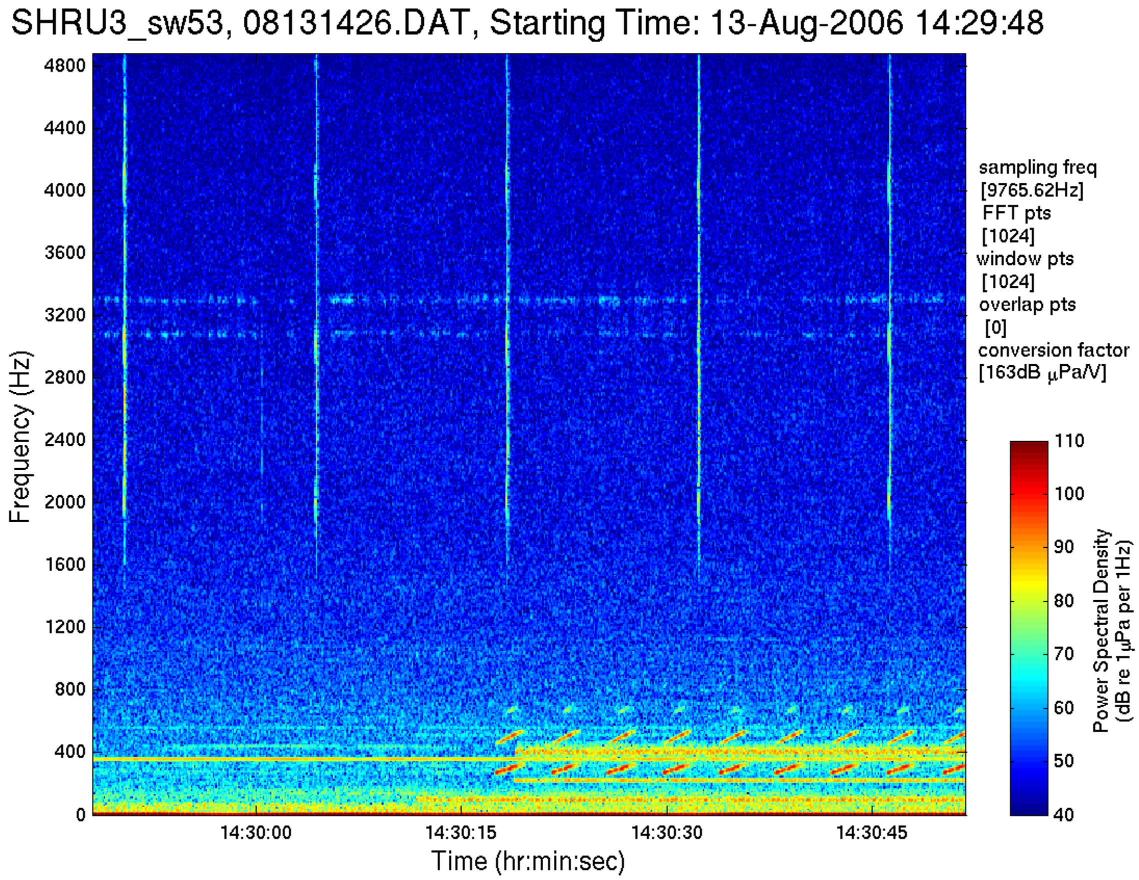

Scheme of SW06 and acoustic tracks from the source where we consider fluctuations of the signals. Green circles are thermistor strings, used for pictures. Time interval 14:30-22:00 GMT

# Temperature records of thermistor strings SW23 ,SW30, SW19, SW21,SW3



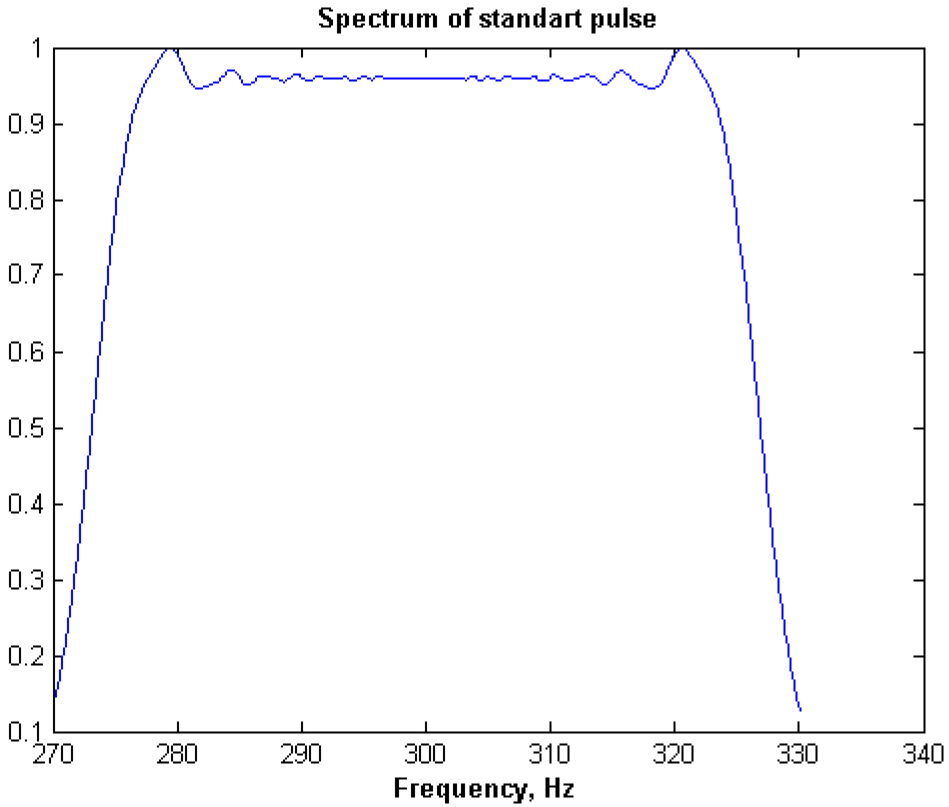

1,2,3 denote times of arrival of soliton trains

# Spectrogram of pulses received by SHRU3




We consider pulses, radiated by NRL 300 Hz (LFM), since 14:30:15 GMT till 22:00 GMT (13.08.2006).

# Spectrum of radiated pulse



Result of match-filtering of pulses is determined by expression

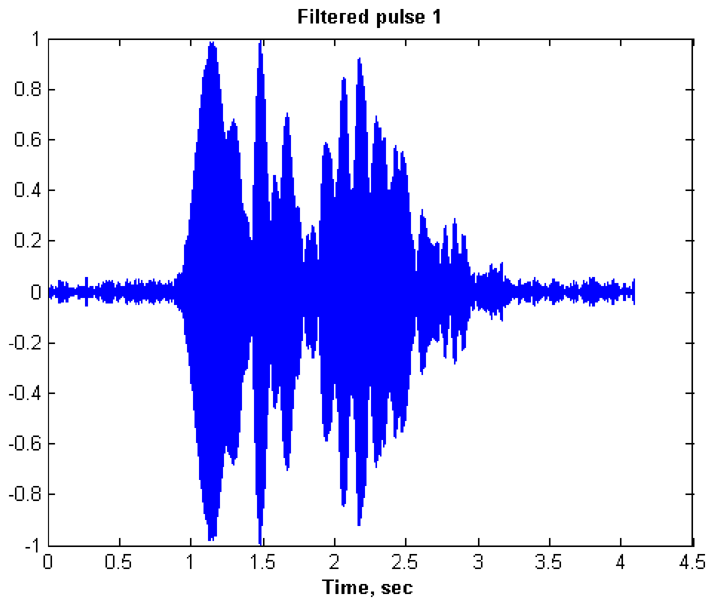
$$s_{filt}(t) = \left| \mathbf{F}^{-1}[g(\omega) g_{st}^{*}(\omega)] \right|$$

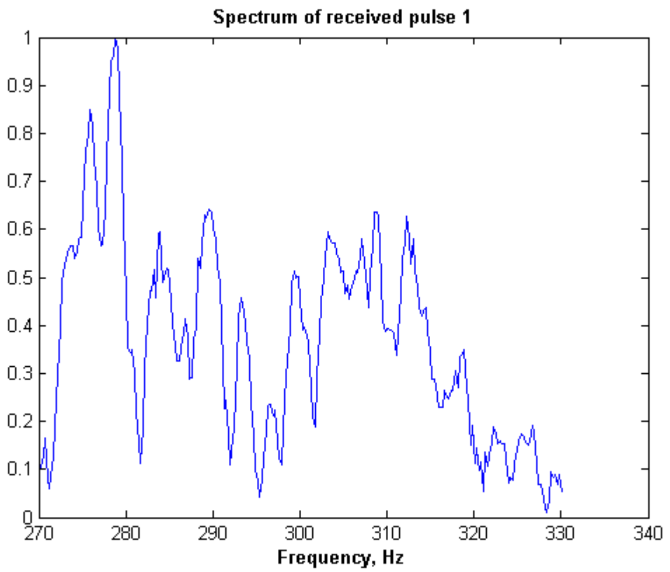
Where $\mathbf{F}^{-1}[\cdot]$ Is inverse Fourier transform

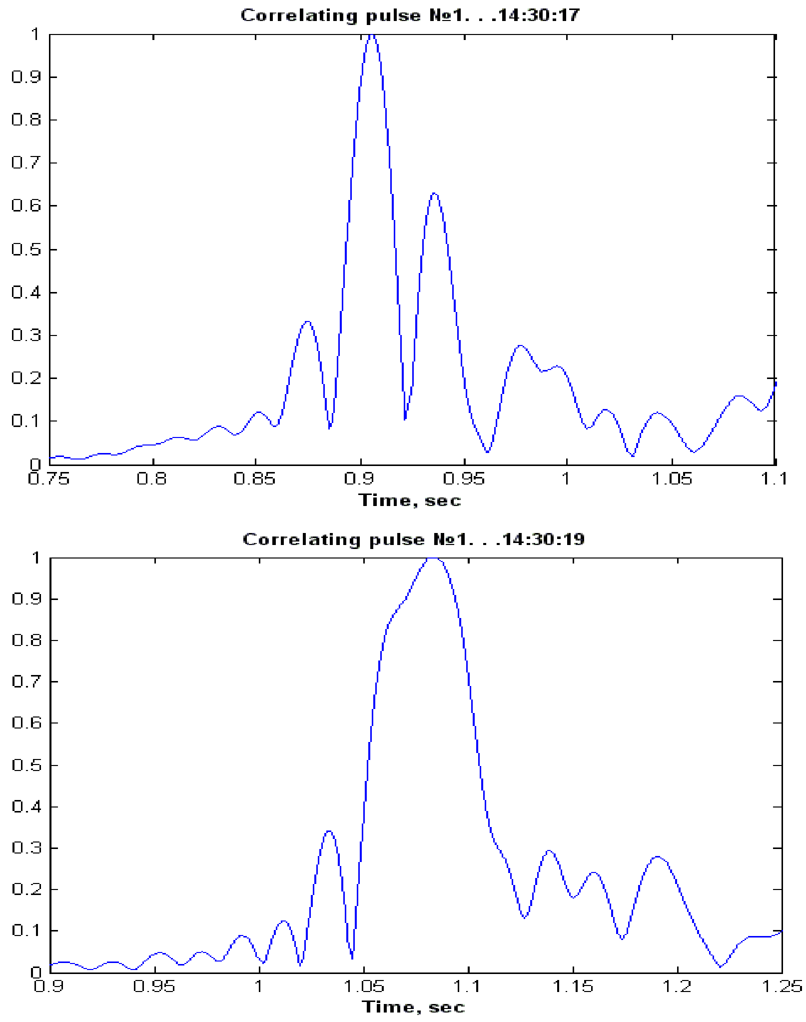
$g(\omega)$ is spectrum of received signal

$g_{st}^{*}(\omega)$ is complex conjugate spectrum of standard (radiated) signal

# Match-filtered pulse and its spectrum

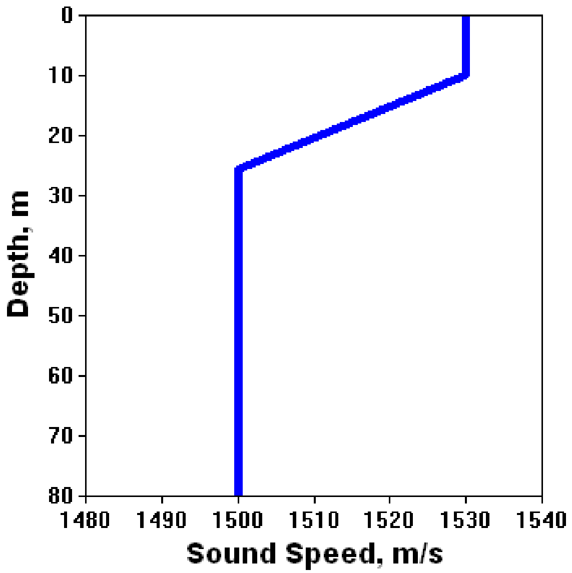




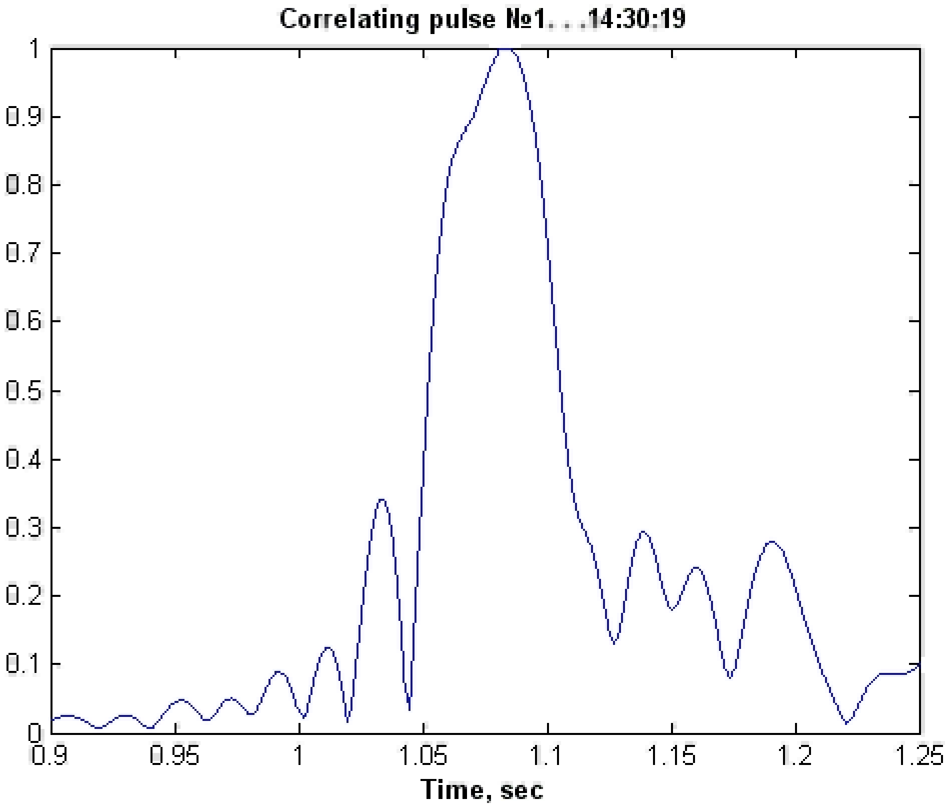

Typical match-filtered received pulse. We see modal decomposition due to intermodal dispersion. Time interval between maximums ~25 ms corresponds To interval between the 1$^{st}$ and the 2$^{nd}$ modes for given distance . In the second figure maximums are not resolved

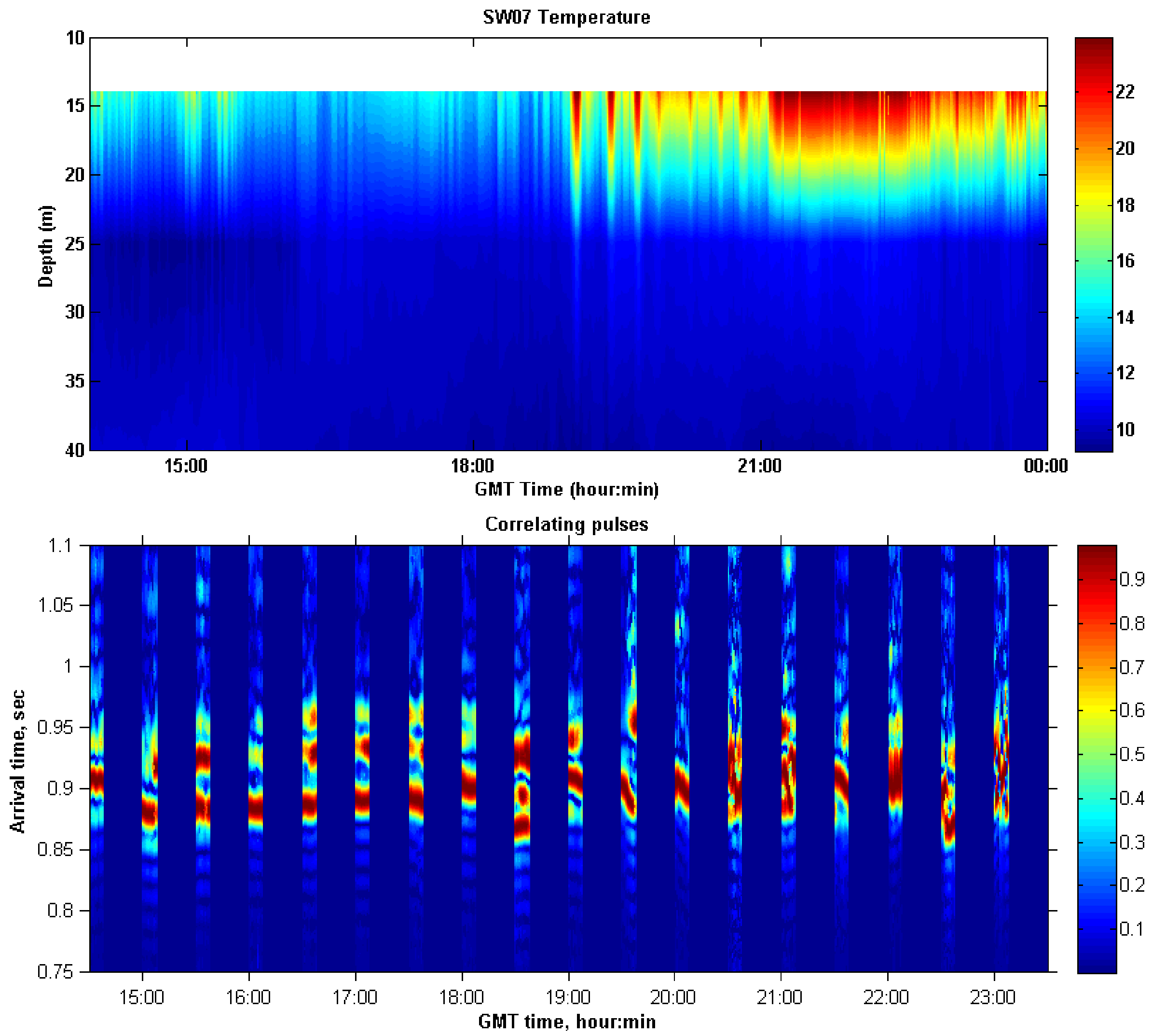
Length of and acoustic track  NRL300-SHRU3 is about 17617 м. Group velocity of sound pulses can be estimated using sound speed profile and standard calculations.



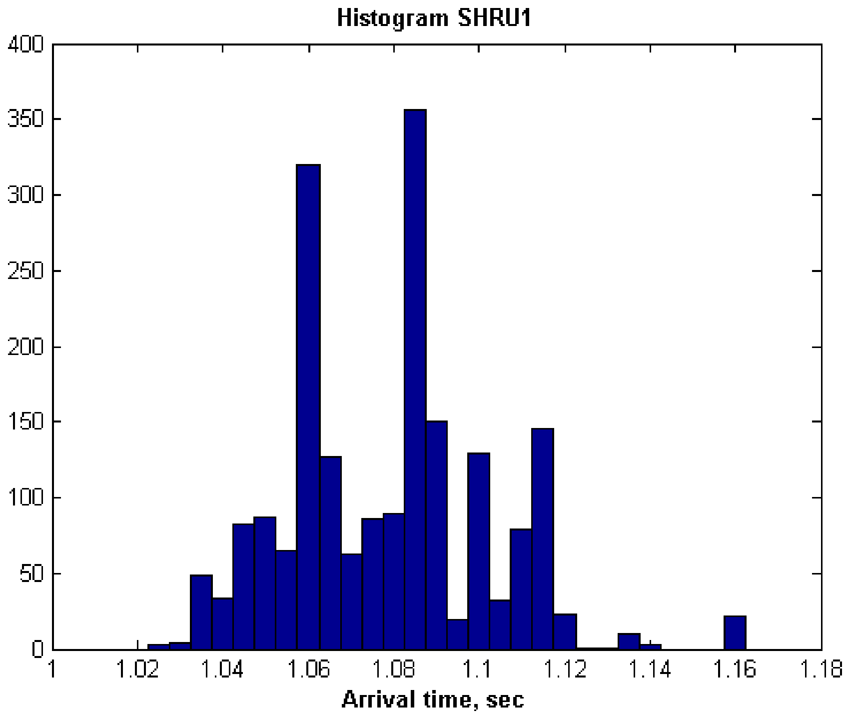

| mode number | Group velocity, m/s |
|---|---|
| 1 | 1499.3 |
| 2 | 1497.3 |
| 3 | 1494.1 |
| 4 | 1490.2 |
| 5 | 1486.7 |

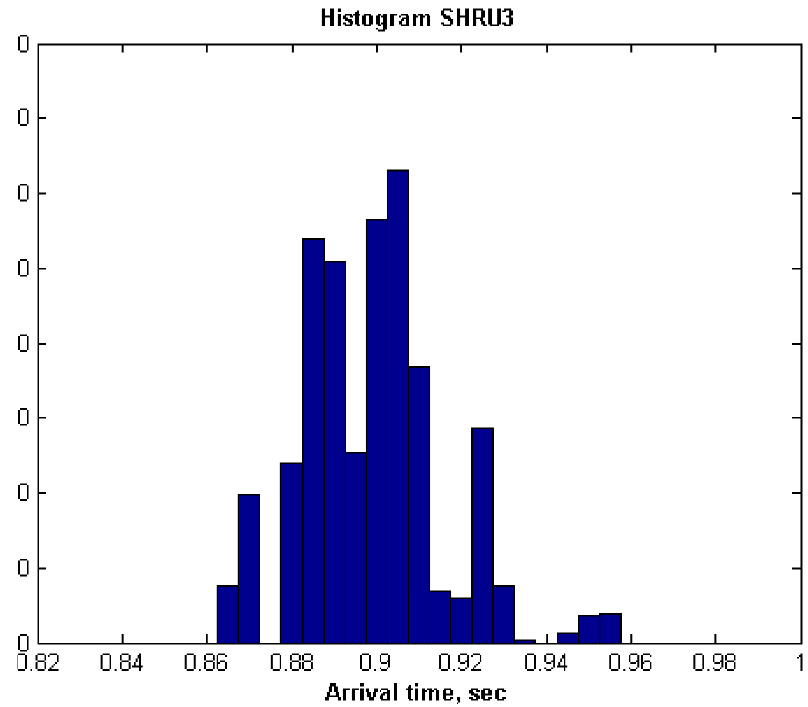
# All pulses at the SHRU1



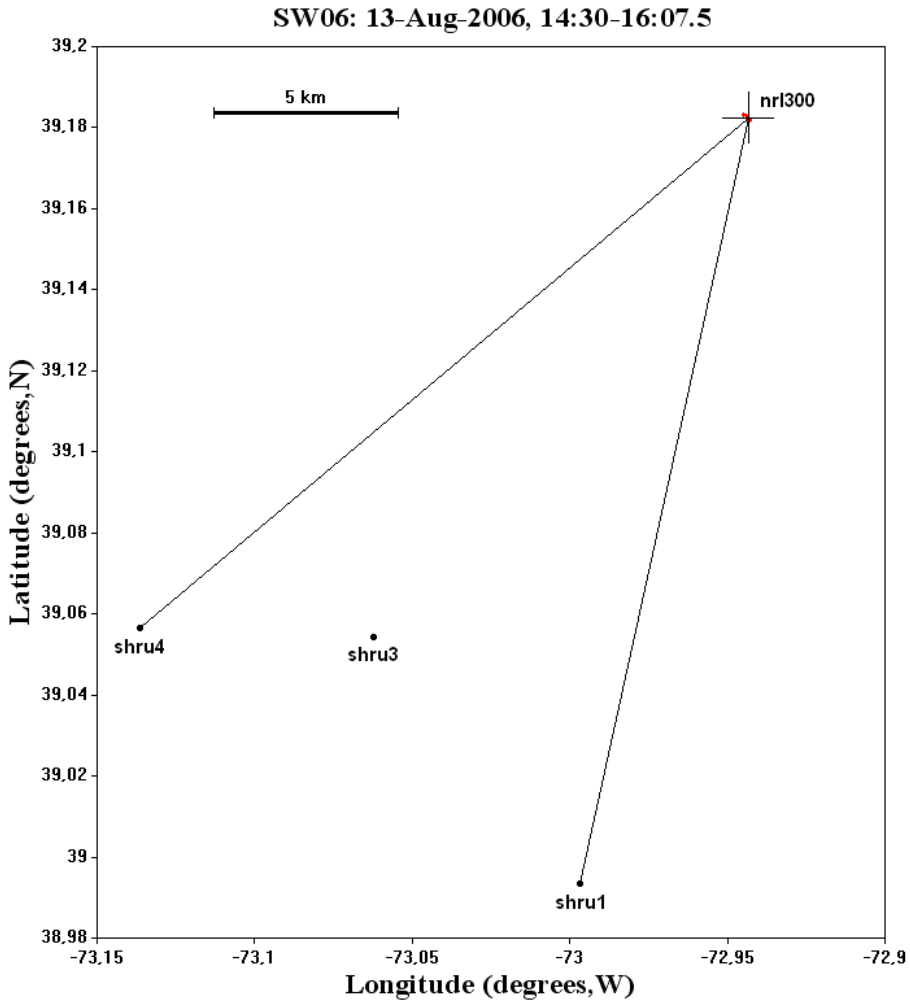



We see significant fluctuations at ~18:30 where IS achieves SHRU3

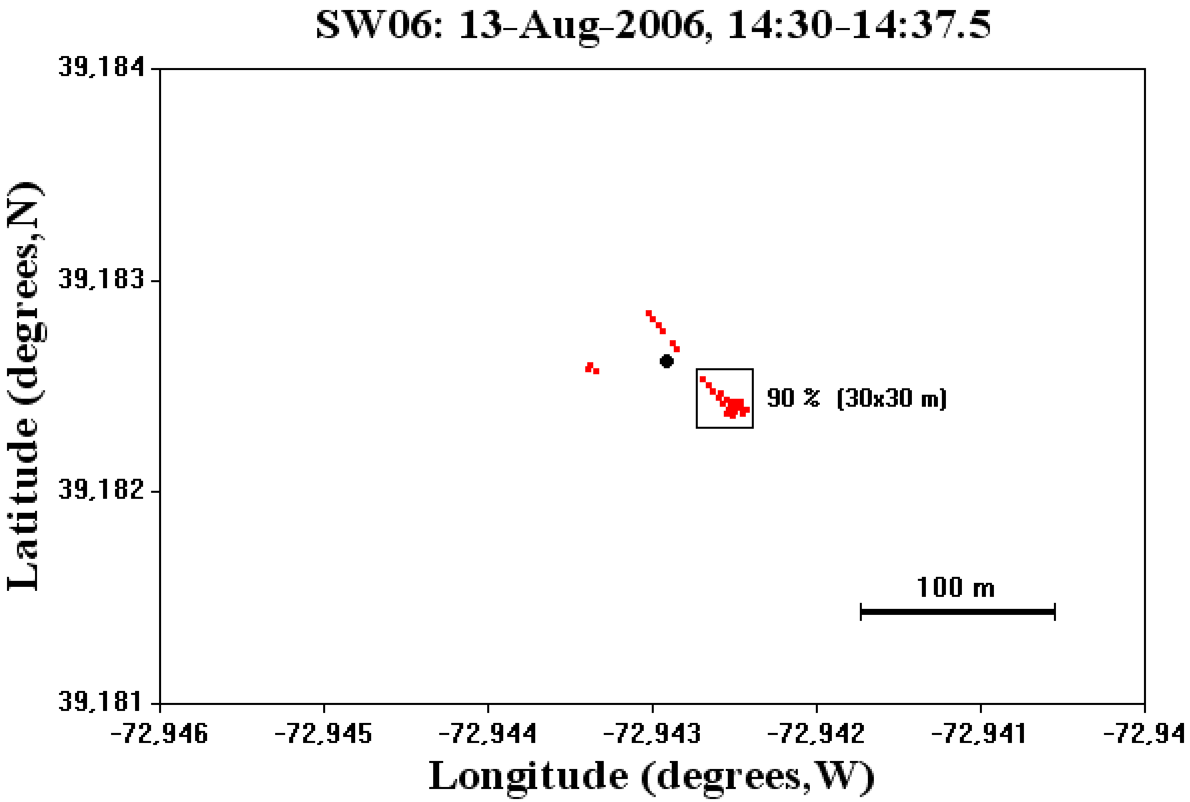



So we have comparatively unstable pulses at SHRU3 in comparison with SHRU1. Remark that in many modes propagation we see significant fluctuations of temporal position of global maximum. Accuracy to position of the separate mode is ~0.01 sec. Histograms are made using 1980 pulses during ~ 8.5 hours.




Scheme of positioning using arrival times from two receivers (SHRU1 and SHRU4). Red spots denote are of positions




Red spots denote are of positions, determined using arrival times during time period 14:30-14:37.5

# Conclusion

- Temporal fluctuations of arrival times in presence of perturbation of water layer are of the order 10 msec
- Arrival times of separated modes more stable than arrival times of pulses envelope
- Using arrival times of synchronized sources it is possible to implement acoustical positioning with accuracy 10-15 m in area up to a few thousend of squared km