The hydraulic connection between coastal confined aquifers and the sea: a tidal perspective

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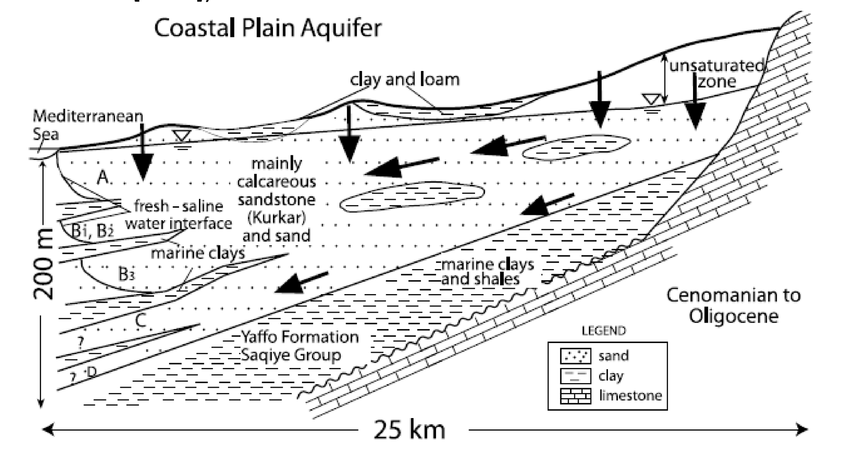
Objective:

This study attempts to develop a new method to test the connectivity between deep coastal sub-aquifers and the sea, using their response to tidal fluctuations.

Background:

The Quaternary coastal aquifer in Israel is subdivided into several sub-aquifers, separated by confining layers, whereby the upper one is phreatic (unit A) and the deeper ones are confined/semi-confined (units B-D). The hydraulic connection between the confined units and the sea is debatable. It was suggested that the lower sub-aquifers might be blocked to the sea, which is supported by several observations of old fresh water in the deeper sub-aquifers close to the shore.

Hydrogeological schematic cross section of a coastal aquifer (modified after Ecker [1999]):

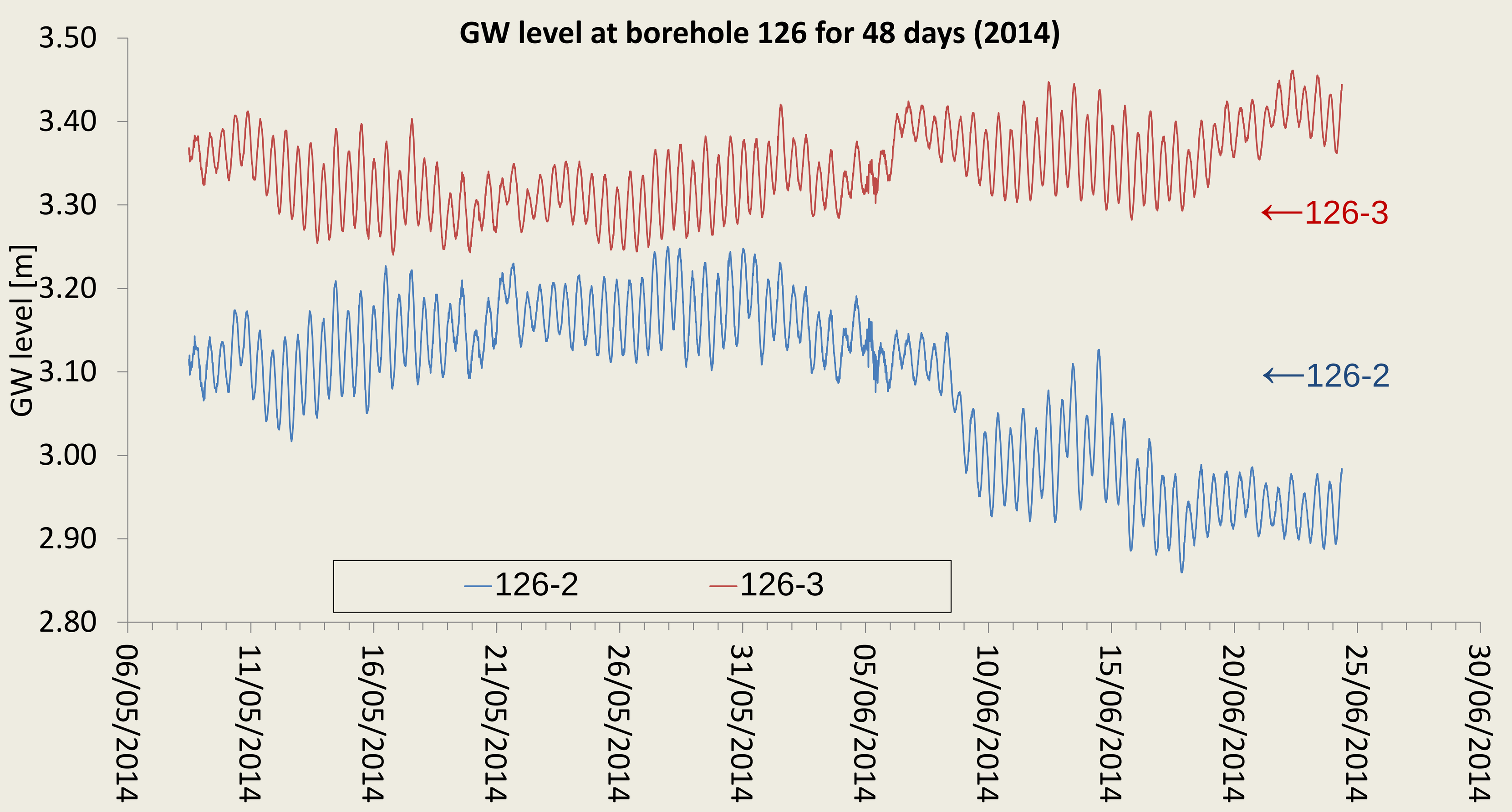


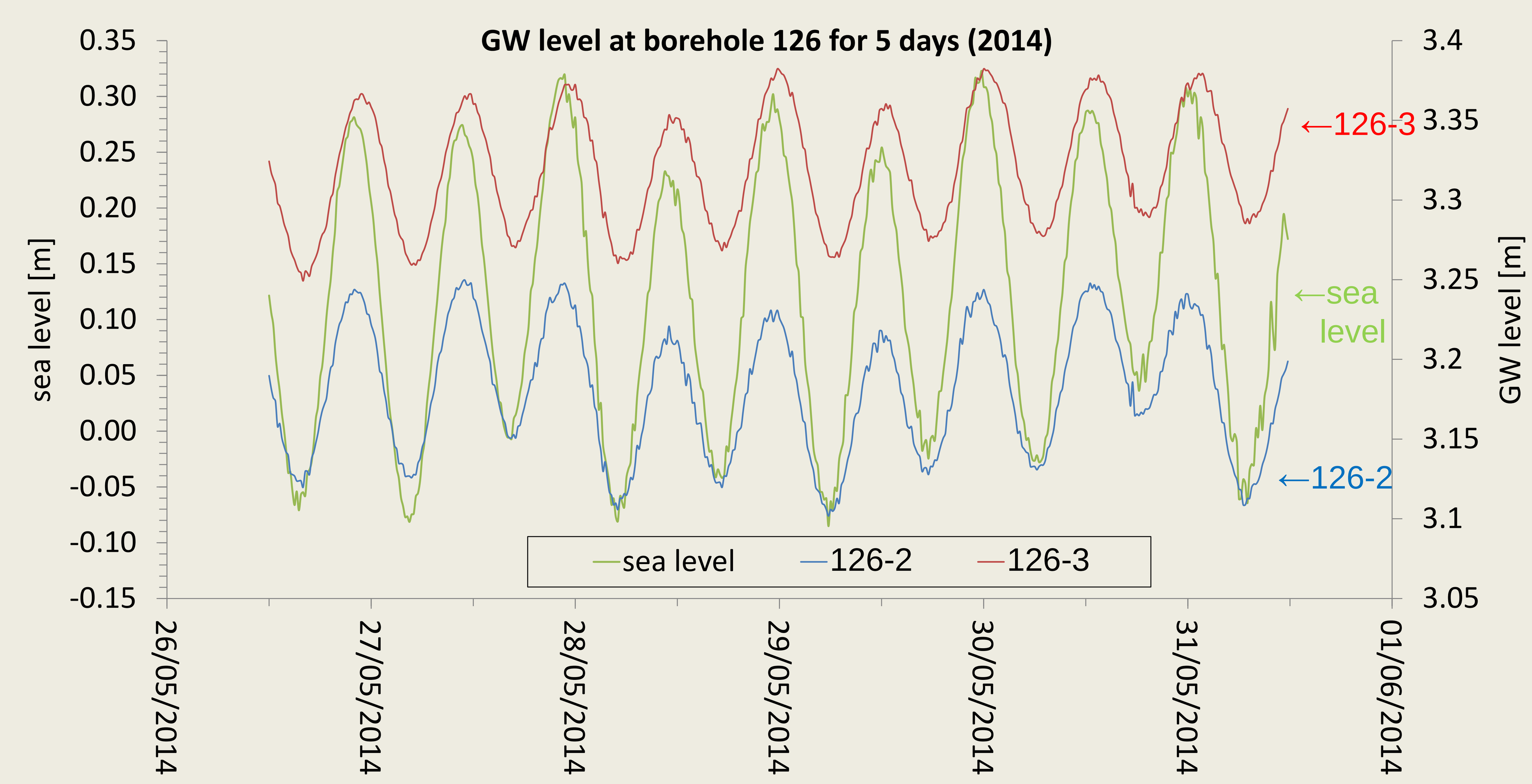
Methods:

- Groundwater level was measured in observation wells at different units of the coastal aquifer and at various distances from the shore.
- Sea level data was obtained from the IOLR Hadera MedGloss station.
- The data was analyzed by the fast Fourier transform (FFT) function in AutoSignal Software.
- All time series have been subjected to an extensive Fourier domain filtering and component isolation procedure (Fourier Filtering and Reconstruction). This procedure toggle-selects frequency thresholds within the Fourier decomposition and uses an inverse FFT for the reconstruction. The data was filtered using the most dominant amplitude at the frequency range of 1.93-2 cpd, which includes the two main tidal constituent M_2 and S_2, respectively.
- The reconstructed data was analyzed by cross-correlation function in MATLAB for the determination of the time delay between two time series (sea level and GWL) shifted in time relative to one another. The maximum of the cross-correlation function indicates the point in time where the signals are best aligned, i.e. the time delay between seawater level and groundwater head fluctuation.

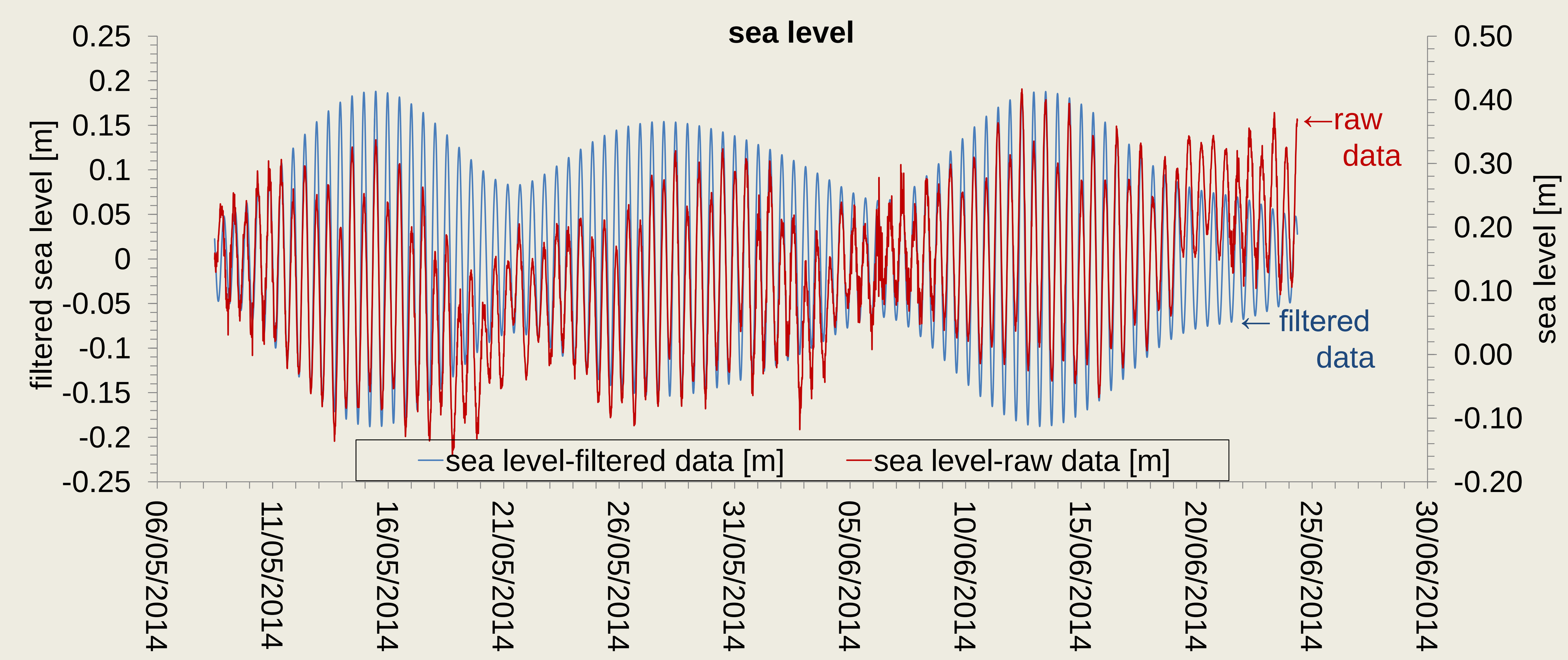
Results and discussion:

Borehole 126, Rishon-Lezion, 50 m from shore.
126-2 opened to B3
12-3 opened to B1-2



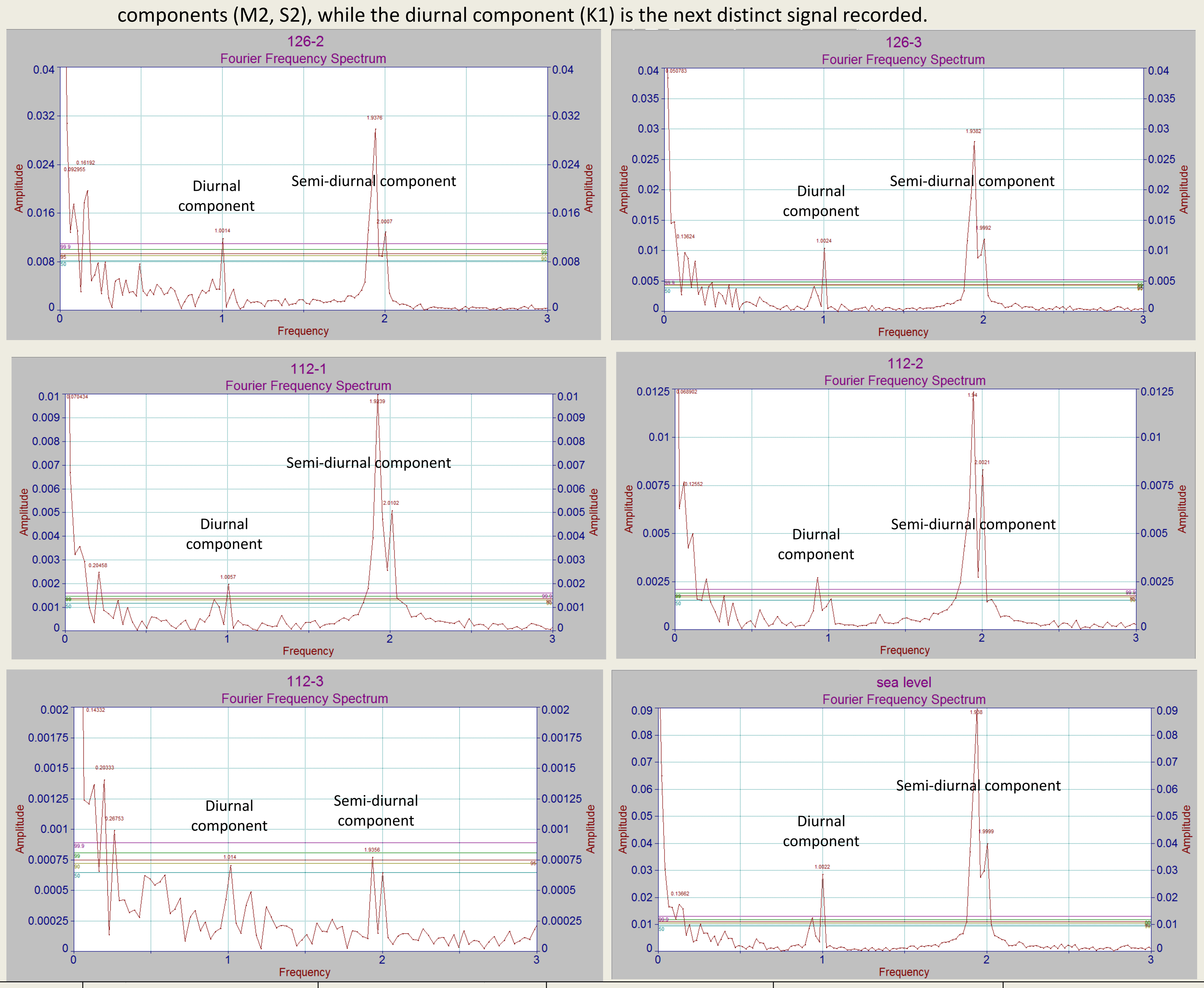


Sea level measurements from the IOLR Hadera MedGloss station:



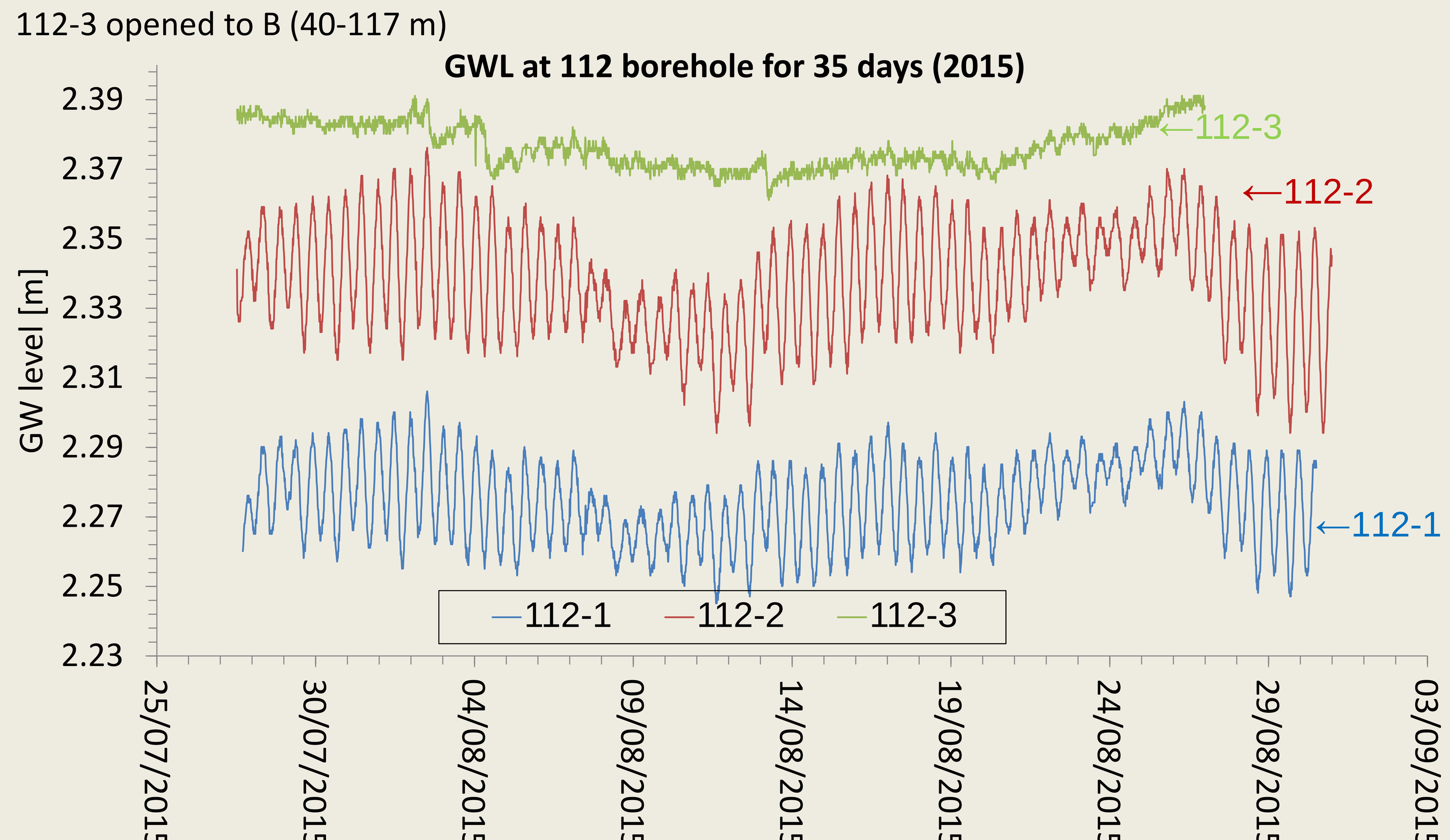
Fourier analysis:

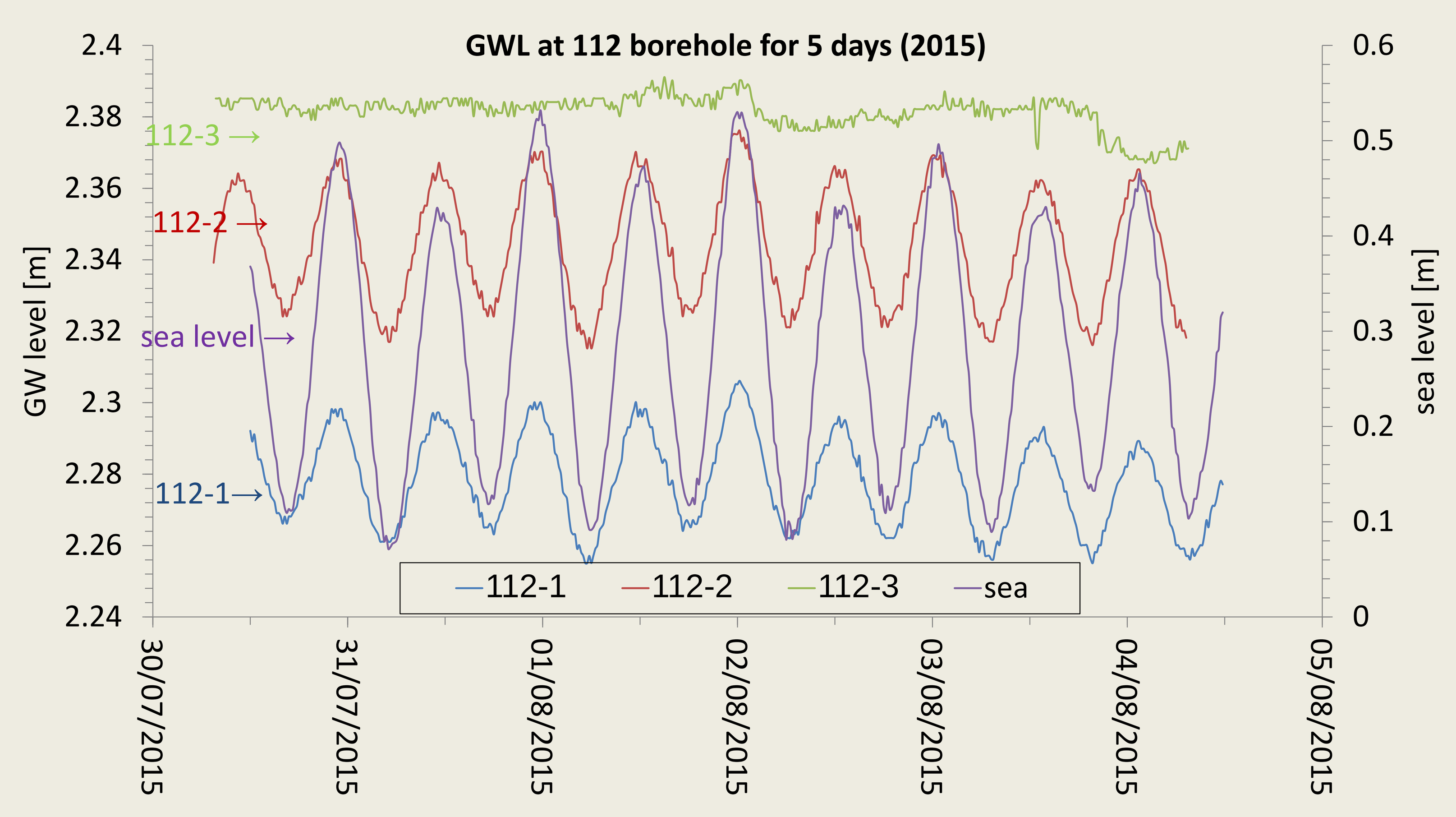
The results of Fourier analysis indicate that the most dominant frequencies in all datasets are the semi-diurnal tidal components (M2, S2), while the diurnal component (K1) is the next distinct signal recorded.



126-2		126-3		112-1		112-2		112-3		sea level	
Frequency (cpd)	Amplitude (cm)	Frequency (cpd)	Amplitude (cm)	Frequency (cpd)	Amplitude (cm)	Frequency (cpd)	Amplitude (cm)	Frequency (cpd)	Amplitude (cm)	Frequency (cpd)	Amplitude (cm)
1.001	1.194	1.002	1.042	1.006	0.197	0.928	0.272	1.014	0.072	1.002	2.867
1.938	3.048	1.938	2.846	1.924	0.999	1.940	1.257	1.936	0.078	1.938	9.119
2.001	1.342	1.999	1.255	2.010	0.511	2.002	0.834	2.004	0.065	2.000	4.175

Borehole 112, Ashdod, 800 m from shore.
112-1 opened to D (177-191 m)
112-2 opened to C (138-167 m)
112-3 opened to B (40-117 m)

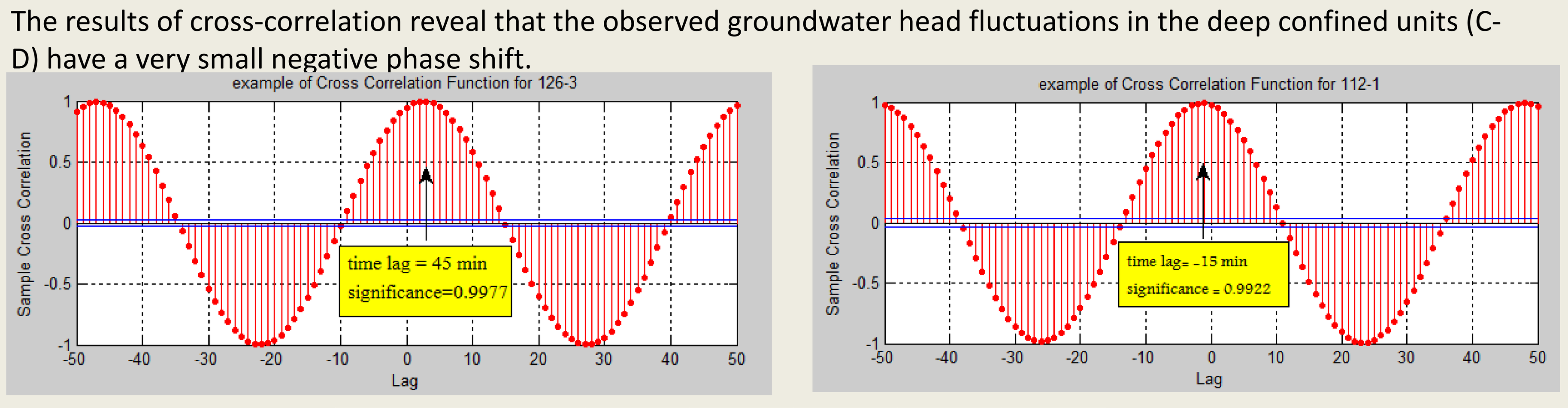




Groundwater of all units shows tidal patterns. Nevertheless, the tidal signals are much more prominent in the deeper confined units (C-D), including the low frequency periods (e.g. the spring-neap cycle, Mf-Mm), while in the phreatic and semi-confined units (A-B) signals are more irregular and disrupted.

Cross-correlation analysis:

The results of cross-correlation reveal that the observed groundwater head fluctuations in the deep confined units (C-D) have a very small negative phase shift.



	126-2	126-3	112-1	112-2	112-3
significance	0.997	0.9977	0.9922	0.9922	0.7438
Time lag (min)	0	45	-15	-15	60

Summary and conclusions:

The results of cross-correlation and time series of groundwater fluctuations indicate that signals at confined units of various depths are in phase. This could suggest that the tidal signals in the confined units are dominated by tidal loading* rather than by actual seawater intrusion into the aquifer, which should be further studied.

***tidal loading** acts through the offshore extending roof of the confining layer by causing elastic compression and expansion of both the aquifer skeleton and the pore water.