Referee #1

We thank very much to the referee 1 for his/her careful reading of our manuscript helping us to consider various important aspects of this research.
Following are responses to the referee's queries:

I. The authors make no mention of Adriatic seiches, yet this is an important Adriatic response to forcing (Ceroveˇcki et al., 1997; Leder & Orli´c, 2004, and references therein).
The fundamental period is between 21 and 22 hours which is close to the K1 tidal period at 23.9 hours. The data windowing used for the rotary spectra are too short to separate seiches from K1, and from Figure 12 it seems likely that the wavelet analysis cannot distinguish between these two periods either. The harmonic analyses over 3 months or even over 30 days should be able to separate these periods (some nonstationary seiche energy might bleed into UPS1 or OO1 constituent solutions). The model of Leder & Orlić (2004) shows 20 cm/s intensification during an Adriatic seiche at or very near the location of station St2 (Figure 13 in that paper). Some further analysis and discussion is needed to show that the non-stationary diurnal waves seen in Figure 10 (a & b) cannot be at least partially explained as Adriatic seiches.

Ceroveˇcki, I., Orli´c, M., Hendershott, M.C., Adriatic seiche decay and energy loss to the Mediterranean, Deep-Sea Research I, Vol. 44, No. 12, pp. 2007-2029, 1997.

Leder, N., Orli´c, M., Fundamental Adriatic seiche recorded by current meters, Annales Geophysicae, Vol. 22, pp. 1449-1464, 2004.

REPLY: The seiches in Adriatic are an important response to forcing, but they are found almost exclusively during the late autumn/winter period of the year (Cerovecki et al. 1997; Leder and Orlic 2004) due to the presence of low air pressure/sirocco wind events, while we see intensification of the diurnal signal only during summer/stratified season when generally synoptic disturbances are absent. Moreover, the strong intensification is present just at the shelf break (St2) and with much less energy at the coastal mooring St1, where on the contrary the seiches should be stronger due to shallower water depth (Leder and Orlic 2004). In addition, the intensification varies with depth reaching the maximum near the bottom, where seiches should be weaker due to bottom friction. Furthermore, analysis of ECMWF wind time series for year 1995 near location St2 shows that no significant sirocco wind episodes occurred during that summer. Rotary spectra for St2 surface and bottom (hourly) currents have been re-calculated with 512-points window (instead the 256-windowing data length), in order to resolve seiches from the diurnal signal. No separate peak is seen at seiche frequency even if some energy is present (Fig. 1).

II. The tidal analysis done over 2-3 month periods fails to account for significant Adriatic tides known to exist at P1 and K2 frequencies, and the use of 35 constituents over this short of a period will produce non-significant solutions for most of these constituents. The neglect of P1 is particularly significant to the findings of the paper because it beats with K1 frequencies at a 6 month period. A quick test with values appropriate for the Adriatic shows that the neglect of P1 in a 3-month long harmonic analysis will produce two peaks in solutions for K1 (one in summer and one in winter) with a false intensification of values around 13% higher. This effect could entirely explain the intensification observed at St3 and therefore speculation on pages 450-451 that this level of intensification could be influenced by diurnal internal waves should be removed. It seems unlikely that this effect could entirely account for the intensification observed at St2, but this possibility needs to be investigated in the paper before conclusions should be drawn about diurnal internal waves. Harmonic analysis can be done with large gaps in coverage due to the stationary of the tides, and therefore all seven of the principal tides of the Adriatic (Cushman-Roisin et al., 2001) could likely be resolved for all stations by analyzing the entire time records of the observations together. A focused analysis on summer intensification at St2 could then be done using wavelets or other non-stationary analyses on the tidal residuals. t_tide automatically produces an error analysis for tidal solutions that indicates signal to noise ration and marks constituents that cannot be significantly distinguished from noise or the continuum. Once such an analysis is done and significant tidal constituents are determined, there is no benefit to continuing to analyze for the non-significant constituents (fitting to noise). If they are kept, then there is no reason to report their values as in Figure 6 since these values are not significantly determined. Figure 6 could be made clearer if only 7 constituents were reported rather than 16.

REPLY: The number of tidal constituents in the harmonic analysis is selected by the program t_tide on the basis of the series length, and, accordingly, all independent constituents are determined. Harmonic analysis, however, has been repeated for the longest time series available for each current-meter (i.e., St2 bottom May-Nov 1995, St1 bottom May 1994-May95, St3 three levels according to Fig.2a). The astronomic tide is subtracted and the remaining non-tidal signal in the time series is evaluated. Constituents P1 and K1 are resolved with the harmonic analysis on this unified time series, but not in the 30-day moving harmonic analysis one. This means that the amplification seen at station St3 twice a year may be explained to some extent by the beating of K1 and P1 at six month period, as suggested by referee, and verified by synthetic superposition of the two tidal components with coefficients obtained by the harmonic analysis. However, the beating effect is small (13%), and cannot explain the intensification at St2 where P1 is resolved and the intensification is two or three times the tidal amplitude found during winter.
Harmonic analysis was re-done with the longest available data series at all locations. It turned out, however, that the intensification of the diurnal signal still remained at St2. In particular, harmonic analysis of the bottom current-meter time-series at St2 from mid May until mid November 1995 (about six months long) is able to resolve between different diurnal frequency in the tidal band (ALP1, 2Q1, Q1, O1, TAU1, BET1, NO1, P1, K1, PHI1, J1, SO1, OO1, UPS1). In this case, the K1 intensification with respect to the preceding Nov-Jan time interval is not so prominent, what we attribute to the inclusion of the autumn period into analysis.
The spectra of the non-tidal signal (obtained as mentioned before) also show a peak at K1 frequency in the bottom layer at St2 and St1 during summer-time, together with a peak at inertial frequency in the upper layer at St1 and St2 in the same summer period. There is still significant energy level at the diurnal frequency, variable in time (not shown) by means of the wavelet analysis of the non-tidal signal.
Figure 6 of our paper has been modified as suggested considering only the significant constituents.

III. There was insufficient analysis and discussion presented on the mechanisms for generating topographically trapped diurnal internal waves at this location. On page 452, it is stated that the presence of these internal diurnal waves was confirmed by the phase shift between the diurnal signal in the coastal sea level and in the currents at location St2, but no evidence is offered on how this phase shift differs from the general solution for sea level and current K1 phase difference, or exclusion of superpositions of barotropic K1 waves that might create the observed phase differences. Lack of coherence between sea level and currents is also given as confirmation of internal diurnal waves on page 452, but the statements on page 451 that multiple coherences are often close to 1 and that partial coherences with wind components were rarely significant implies that sea level and currents are coherent. The statement on page 451 seems to be backed up by Figure 13, panels b & d. In fact, I would expect that sea level and internal diurnal wave currents would be coherent if the currents are observed near the generation point of the diurnal internal wave as found by Beckenback & Terrill (2008). The analysis of VM-ADCP data from 2007 in Figure 15 and page 452 over two days duration are insufficient to draw conclusions regarding diurnal internal waves as processes such as seiches have not been excluded and differences from normal barotropic tide conditions are not discussed. The paper could benefit from some further analysis and discussion on the exact mechanisms of generation of topographically trapped diurnal internal waves in this region, their cross shelf structure, and their quantitative dependence on stratification rather than rely on qualitative comparisons to Beckenback & Terrill (2008).

REPLY: Malacic et al. (2000) showed that K1 tidal component in the Adriatic is represented by a topographic wave propagating across the basin from the eastern coast to the western shoreline, with phase differences of 15-20°. Book et al. (2009) found that along a cross-basin line in the northern/central Adriatic the K1 phase for the currents is between 324° and 336°, while the one for the sea level is between 52° and 60°, with a difference between them around 270°. Here, analysis of the K1 tidal constituent at all stations along the Otranto section, shows a phase between 330° and 360° for the current and 45° for the sea level at the Otranto coastal station, giving differences in phase between the sea level and the currents between 285°-315°. In particular, at station St2, the phase for the current is 333° and the phase difference with the sea level is 285°. The mechanism for generating topographically trapped diurnal waves should be found in the interaction with the topography of the barotropic K1 wave while crossing the strait, in particular at the shelf edge. The reduced bottom depth at the shelf edge triggers the internal wave (as in the case of stratified system) with frequency of the forcing K1 wave. As the diurnal frequency is below the inertial frequency for this latitude, the wave (hybrid between Kelvin and shelf wave) results to be trapped both in vertical and in the horizontal, and "propagates" along the isobaths. In order to better analyze the internal wave, also temperature measured at current-meters at St2 has been considered. In the figure below (Fig 2) red line represents the top level (56 m) at St2, while the black line represents the bottom one (105 m). In the bottom, there is an oscillation evident in mid- and at end of July, and at the end of August 1995. The same signal is not so evident in the top series. The wavelet analysis has thus been applied to temperature and wind stress (instead of wind components) and the diurnal spectra of all quantities (u/v-current component and temperature at St2, sea level, wind stress) have been extracted (Fig 3). In very few events, the wind stress has a peak in correspondence of the ones for diurnal temperature. Moreover, both current components have a peak in agreement with the temperature peaks. Peaks in the diurnal u-comp are more pronounced (not shown), showing that the forcing of such waves should be in the same direction, i.e east-west propagation direction of the barotropic K1 tidal component. The peaks in the temperature diurnal spectra are often not coincident in time in the top and bottom layers but this can be a function of the vertical temperature gradients: from CTD data, the top current meter is in a zone of vertical temperature gradient, while the bottom one is in a zone of horizontal temperature gradients, as shown for the month of August 1995 (fig. 5) . Also peaks in the diurnal coastal sea level are not always present during these events. Anyhow, the most prominent diurnal peaks in temperature are seen at the bottom. This, with an intensification of diurnal signal at bottom, should evidence generation by the topography of the wave trapped near the bottom along the bathymetry. Coherences have therefore been calculated in order to better understand the possible cause of the diurnal peaks in the bottom temperature. Here we will focus on the events characterized by the most prominent peaks in the temperature, leaving the study of the remaining events to a more detailed study foreseen in the future on the observed phenomena and their relationship with the coastal trapped waves. Again no significant partial coherence with wind is seen when considering current, temperature and wind stress, while coherence between current components and temperature is significant. This, together with coherence with sea level (Fig, 13 of the paper) implies that the waves are locally generated.
In order to understand the behaviour of such waves, a 24h-centred bandpass filter has been applied to sea level and currents (Fig 6 red=top, black=bottom, green=sea level). The filtered data have been zoomed for the event at the end of July 1995 and a very small phase shift is found between top and bottom current components, probably indicating a vertical component in the phase velocity of the trapped wave. A larger phase shift is found between sea level and the v-curr component with

respect to the u-current. This implies that the across-shelf motion of the wave is limited, as it is for a trapped wave along isobaths. Taking into account the general solution phase shift (of about 270°), we tried to evaluate if this phase shift is compatible with a wave travelling along the isobaths from Otranto station latitude, to station St2. The distance to travel is 31.5 km, in a time of 9.4-11.5 hours (from the "phase shift difference", that varies in time during the length of the event): this gives a phase velocity of 0.8-0.9 m/s. If we consider, as a first approximation an internal Kelvin wave in a stratified system such as ours with Drho = 4, rho=1029, and H'=30 m, we obtain a velocity of 1.1 m/s that is compatible with the phase speed. Moreover, the first baroclinic mode calculated from the Brunt-Väisälä frequency profile has a velocity of 0.8 m/s. Finally, such time delays (11.5 hours is almost half the diurnal period) can have the effect of superposing constructively with the wave generated at location St2, with the effect of increasing the amplification of diurnal signal.
However, there are still question and points to be clarified within this topic and further calculation and analysis will be developed in a future work.
These considerations will improve chapter 5 of the manuscript.

IV. The authors discount the possibility for the extension of the low-frequency limit of the internal wave spectrum to diurnal frequencies at these latitudes on the basis of the stratification suppressing errors from using the traditional approximation for f. However, this is not the only mechanism for extension of the limit and any region with strong enough relative vorticity can effectively change the limits for the internal wave spectrum within the region (Kunze et al., 1995). For the shelf at Otranto, reasonable possibilities exist through either anti-cyclonic eddies propagating down the Italian coast or simply the anti-cyclonic inshore side of a sheared slope current. E.g., a 50 cm/s current shear over a horizontal distance of 20 km shifts the longest period for internal waves at 40_N to 25 hours, and therefore it would be possible for a diurnal internal wave to exist within the shear zone independent of topography. Although such explanations seem less likely than topographically trapped modes, this possibility should not be excluded on the basis of stratification alone as was done on page 449.

Kunze, E., Schmitt, R.W., Toole, J.M., The energy balance in a warm-core ring’s nearinertial critical layer, Journal of Physical Oceanography, Vol. 25, pp. 942-957, 1995.

REPLY: The low-frequency limit extension described by Kunze (1985) for zones of negative relative vorticity, is an interesting alternative explanation but not very likely applicable at the study region, where horizontal current shears in both directions are not as high as 50 cm/s over an horizontal distance of 20 km. Anti-cyclonic eddies found in the deepest part of this transect (St3-St6) were estimated to have a peak azimuthal velocity between 12 and 21 cm/s and radius of 10-18 km (Ursella et al. 2011) whose relative vorticity is thus not able to shift enough the longest period for internal waves (period equal to about 21h) .

V. The observations used in this paper span a 13 year time period but there is no mention of nodal corrections being used in the tidal analysis. Modulation of diurnal tidal constituents is generally stronger than modulation of semidiurnal constituents. K1 amplification is 11% (Munk & Bills, 2007). This is unlikely to explain the intensification seen at St2, but it should be accounted for in all constituents used, especially when comparing tidal results a decade apart.

Munk, W., Bills, B., Tides and Climate: Some Speculation, Journal of Physical Oceanography, Vol. 37, pp. 135-147, 2007.

REPLY: The program t_tide by default takes into account nodal corrections.

VI. Both Klai´c et al. (2009) and Book et al. (2009) could be added to the reference list as the former paper is the most comprehensive study of sea-land breezes for the Adriatic and the latter shows that incident and reflected Kelvin waves and Topographic Rossby waves are all needed to describe diurnal tides for the Adriatic. Figure 8 (bottom left) from Klai´c et al. (2009) is particularly supportive to the analysis that argues against sea-land breezes causing St2 intensification as it shows a minimum in landsea breezes on the western side of the Strait of Otranto. Book et al. (2009) is relevant because a superposition of two oppositely traveling Kelvin waves in a channel will produce various phase differences between sea level and current in their combination and this could possibly explain the phase differences shown in Figure 14.

Book, J.W., Perkins, H., Wimbush, M., North Adriatic tides: observations, variational data assimilation modeling, and linear tide dynamics, Geofizika, Vol. 26, No. 2, pp. 115-143, 2009.

Klai´c, Z.B., Pasari´c, Z., Tudor, M., On the interplay between sea-land breezes and Etesian winds over the Adriatic, Journal of Marine Systems, Vol. 78, pp. S101-S118, 2009.

REPLY: Suggested references have been added to our list and all proposed minor changes have been taken into account in the text.

Technical Comments:

VII. picnocline on page 448 should be pycnocline

REPLY: Done

VIII. Shouldn't signal propagation on page 452 be phase propagation?

REPLY: yes

IX. Dark bands in panel *a* of Figure 2 marking P1, P2, and P3, completely obscure the bars that give the timing of available data.

REPLY: we will check it, as in the pdf version of the manuscript we had from OS, the bands do not obscure the bars.

X. As stated above, the use of non-significant tidal constituents in Figure 6 makes the patterns of the significant ones harder to see.

REPLY: Figure 6 has been re-done

XI. The use of black and grey bars in Figure 8 and Figure 9 creates a graphic that is difficult to understand. Why not use simple lines and points rather than an overlapping bar chart?

REPLY: Ok

XII. There is a mathematical 180° ambiguity in tidal ellipse orientation, so the values in Figure 9 around 90° and those around 270° are really the same. 180° should be subtracted from all values that exceed 180° tilt in this Figure and the data should be replotted using a smaller range of orientations (maximum 180_ range).

REPLY: Ok

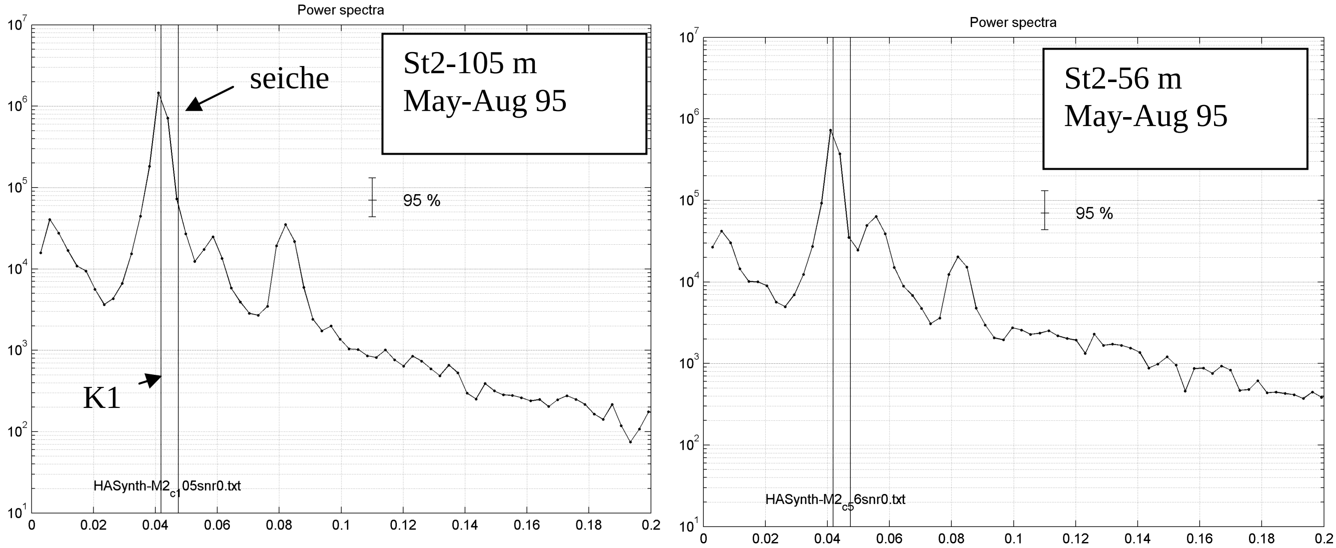
XIII. It is difficult to see the grey line in Figure 10 panels (a) and (b).

REPLY: Ok

XIV. The notation used in Figure 13 is difficult to understand. Could notations like YX1-X2 be replaced with more explanatory labels like partial coherence U-wind?

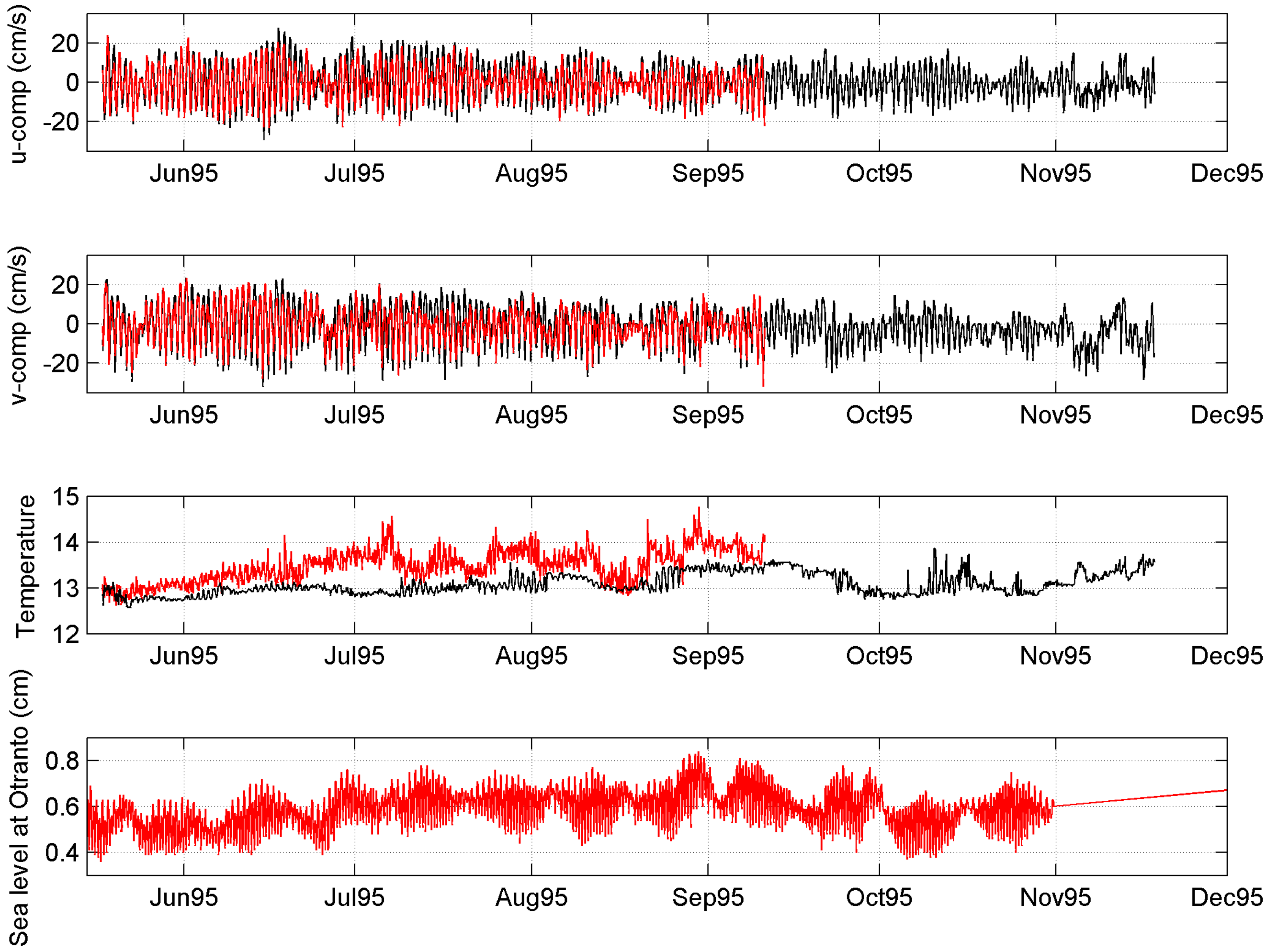
REPLY: Ok

All mentioned figures above will be re-done following suggestions



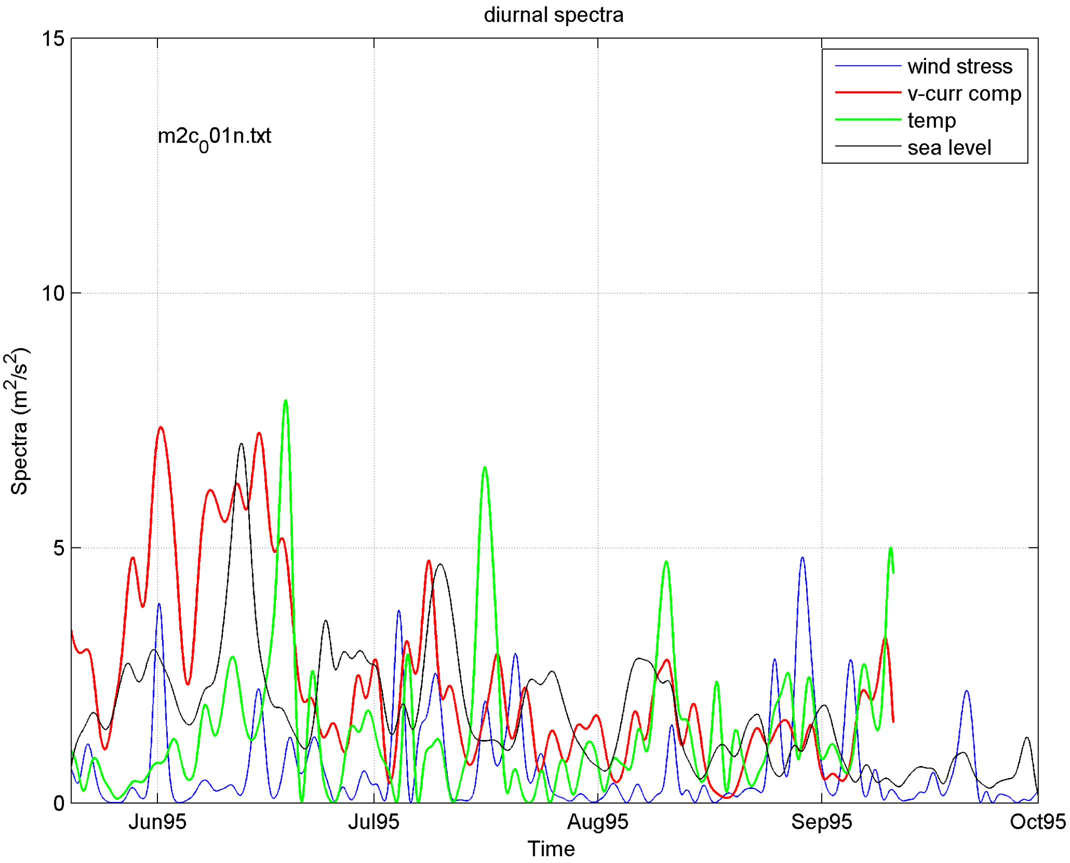
Power spectra
seiche
St2-105 m
May-Aug 95
95 %
K1
HASynth-M2_c105snr0.txt
Power spectra
St2-56 m
May-Aug 95
95 %
HASynth-M2_c56snr0.txt

Fig 1

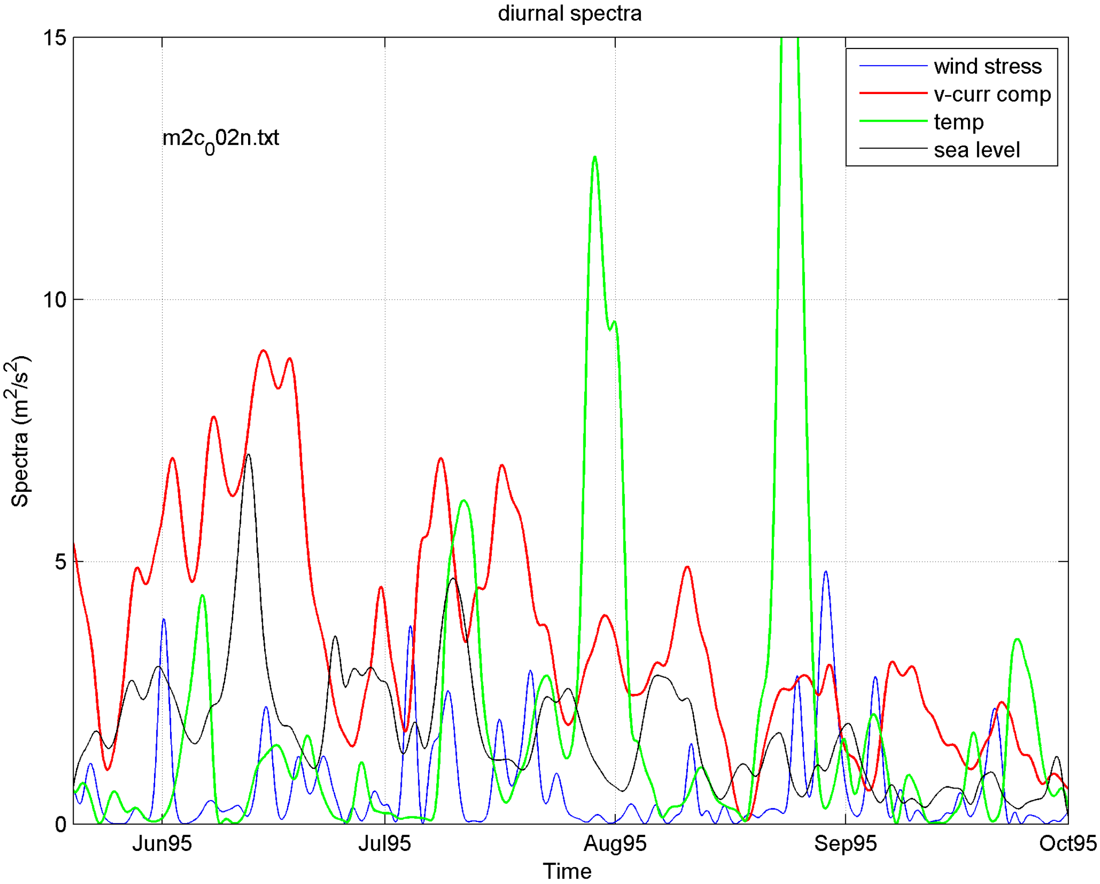


u-comp (cm/s)
v-comp (cm/s)
Temperature
Sea level at Otranto (cm)
Jun95
Jul95
Aug95
Sep95
Oct95
Nov95
Dec95

Fig 2



Top CM



Bottom CM

Fig 3

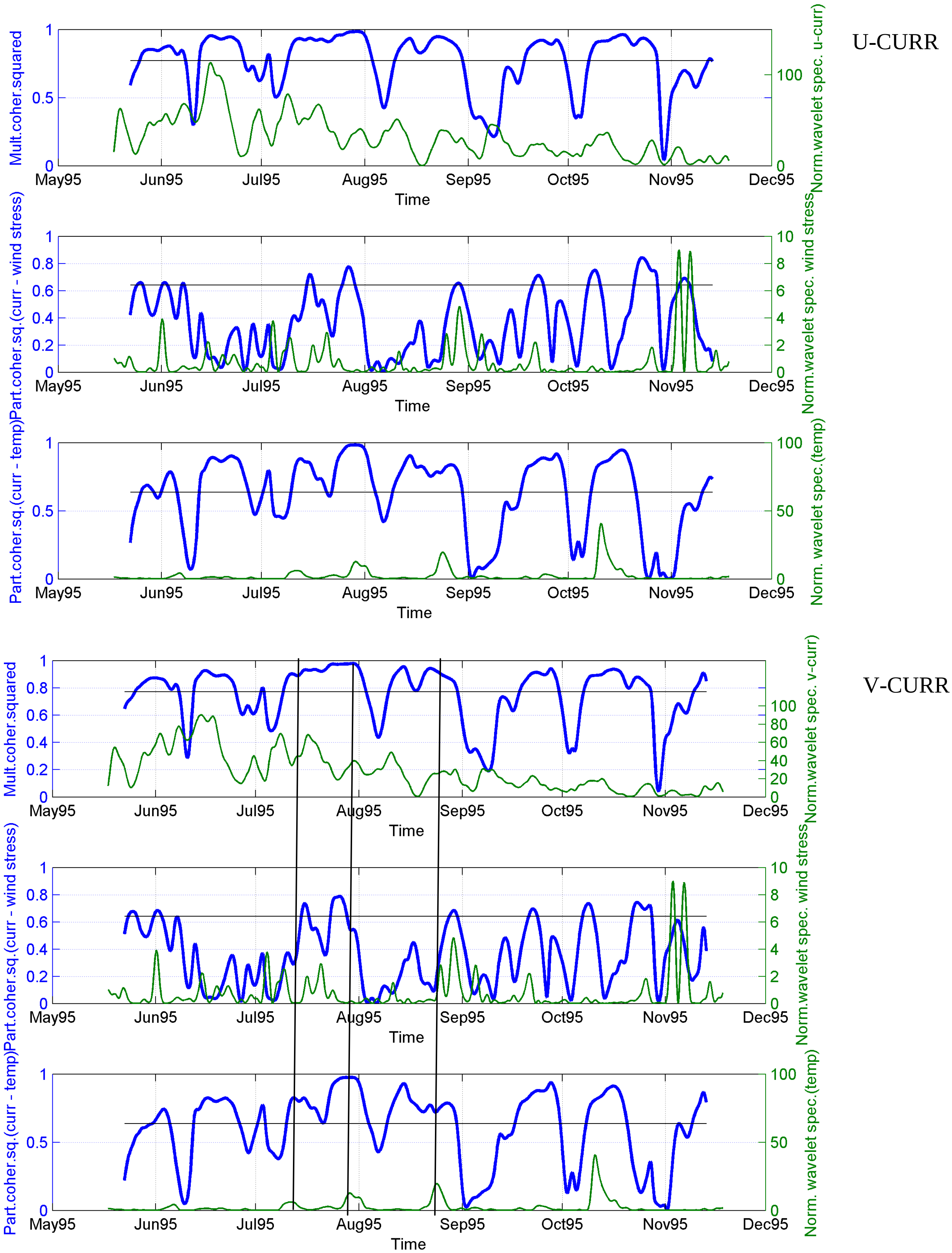
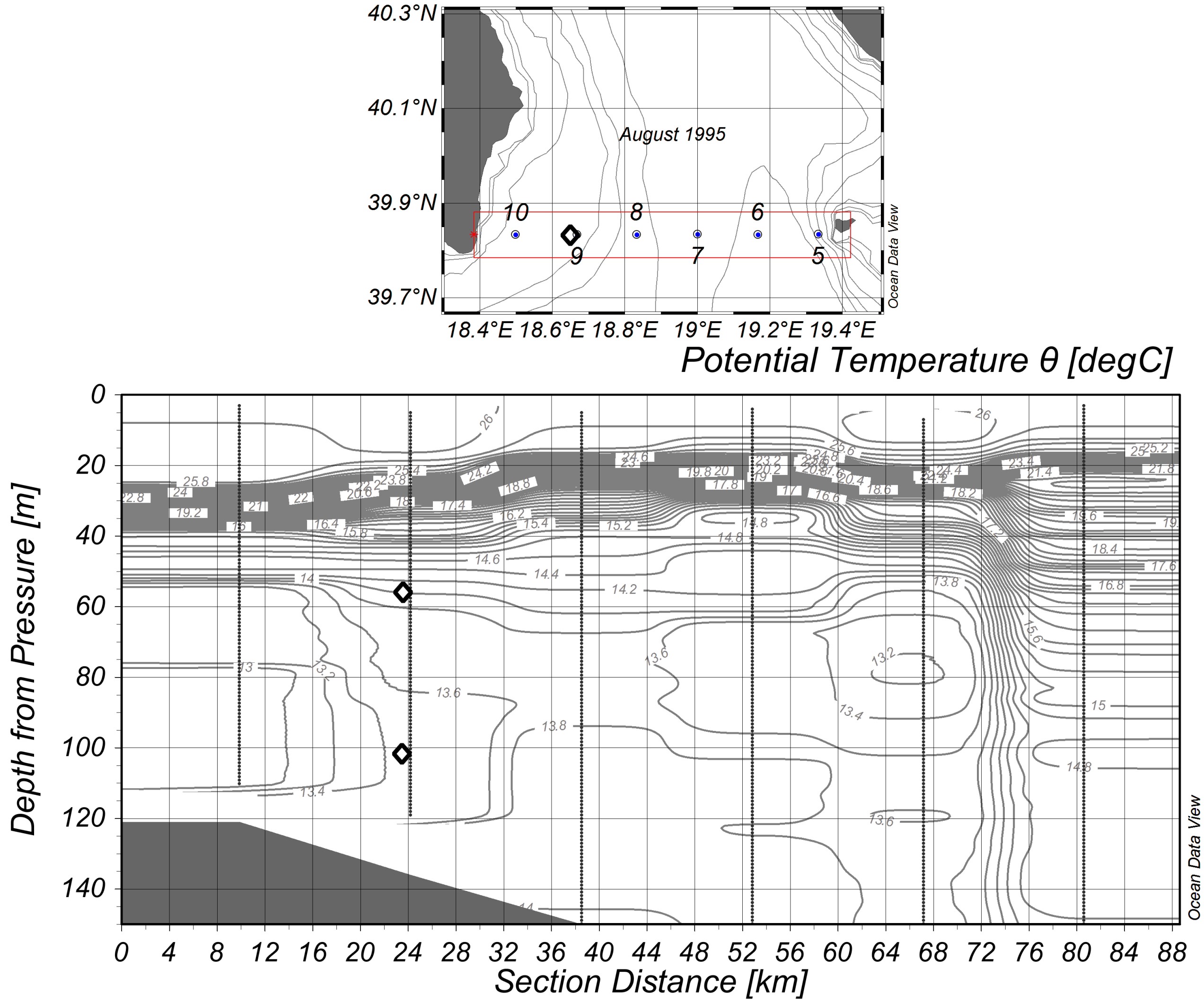
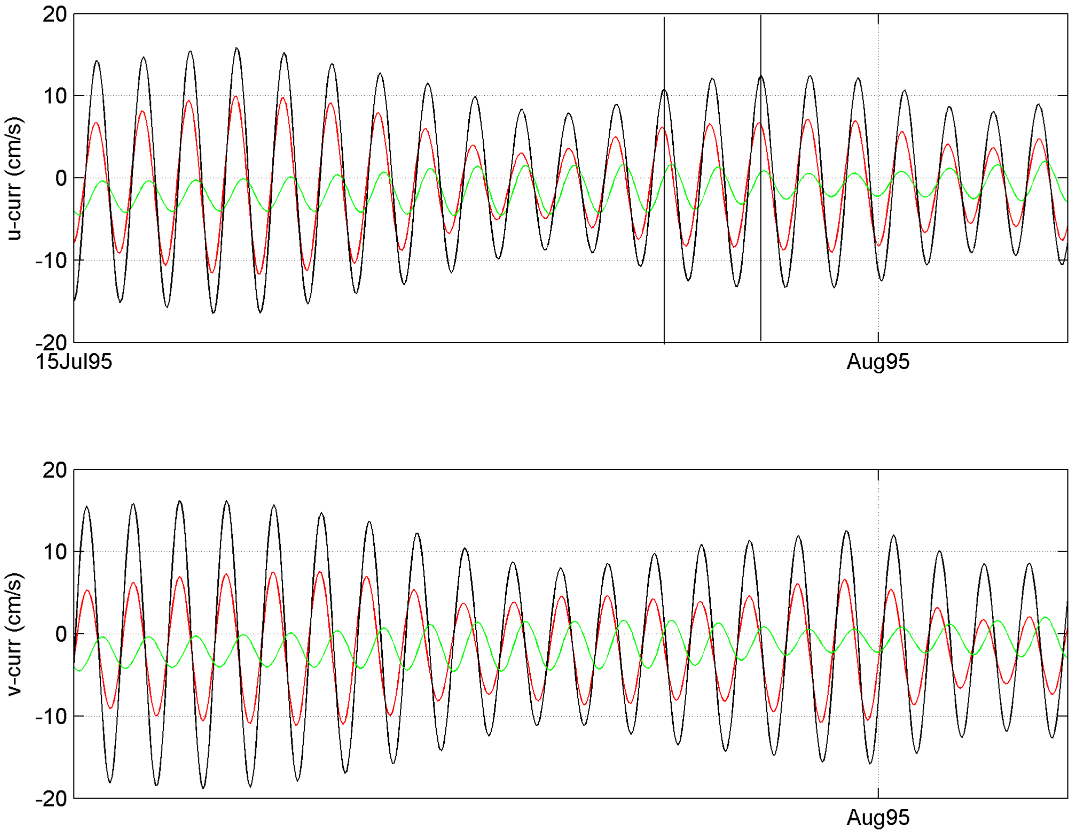

U-CURR
V-CURR
Mult.coher.squared
Norm.wavelet spec. u-curr)
Part.coher.sq.(curr - wind stress)
Norm.wavelet spec. wind stress
Part.coher.sq.(curr - temp)
Norm. wavelet spec.(temp)
Norm.wavelet spec. v-curr)
May95
Jun95
Jul95
Aug95
Sep95
Oct95
Nov95
Dec95
Time

Fig. 4



40.3°N
40.1°N
39.9°N
39.7°N
August 1995
10
8
6
9
7
5
18.4°E 18.6°E 18.8°E 19°E 19.2°E 19.4°E
Ocean Data View
Potential Temperature θ [degC]
Depth from Pressure [m]
Section Distance [km]

Fig.5


20
10
0
-10
-20
u-curr (cm/s)
15Jul95
Aug95
20
10
0
-10
-20
v-curr (cm/s)
Aug95
Fig.6