Measurements of water transparency South-West of Greece

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Abstract

The water transparency of the Mediterranean Sea, South-West of Pylos, Greece, was measured aboard the R/V “KELDISH” using a highly collimated bean spectrophotometer with a wavelength range of 300nm to 650nm. Water samples were collected from various locations and depths, down to 4000m. The water attenuation coefficient, at the range of 470-490nm, was found to be between $0.025m^{-1}$ and $0.04m^{-1}$. The shape of the variations of the attenuation coefficient of the light was also measured in situ as a function of depth by deploying an autonomous nodule. Crude results were also obtained with a nephelometer.

1. Spectrophotometer

One of the fundamental parameters in the design of underwater experiments in large water bodies (10^4 to 10^6 m^3), for the detection of muons and neutrinos with photomeasurement (like NESTOR), is the sea water transparency. It is important to know the dependence of absorption, scattering and total light attenuation with the wavelength.

The transparency of the waters at the south-east part of the Ionian Sea and at depth from surface down to 4000m depth was studied during the 29^{th} cruise of "Akademic Keldish" (October-November 1992) with the measurement of the attenuation of a well collimated light beam (collimation better than 30').

The spectrum of the attenuation coefficient was measured with a diffraction grating Spectrophotometer, fig.la. Two cells were used, the "long" cell was l.l0m long and the "short" cell 0.l0m long. Both cells had quartz windows. The light source was an ultraviolet lamp.

A photomultiplier was used as photodetector. The wavelength region of the instrument was 310nm to 610nm[1]. The water sample, after it had reached room temperature, was introduced into the two cells. Then a set of measurements were made. For each wavelength, both the long and the short cell were introduced into the light path alternately using a pivoting system and the corresponding photocurrents F_l and F_s of the photomultiplier were recorded. Also, each time the dark current F_o of the photomultiplier was recorded. The light attenuation coefficient was then calculated with the equation:

$$\varepsilon = \ln\left[\left(F_s - F_o\right)/\left(F_l - F_o\right)\right]/L \qquad \text{Eq.1}$$

where L=(long cell length - short length)=1.00 m

The set of measurements was repeated with a second water sample taken the same time as the first one and the mean and the standard deviation of the attenuation coefficient of both measurements were calculated. The standard deviation was less than 0.010 m^{-1} [1] .

The water samples were taken with the hydrophysic mechanism "ROZETT". This system have an instrument to measure accurately the depth from which each water sample was taken. In total, the spectrum of 47 water samples from different location and from various depth levels, including the surface level, were measured.

The light attenuation coefficient is shown in fig.2a versus the wavelength for water samples taken from the location 36°37'2N, 21°30'9E and from depths 0m, 70m, 500m, 1500m, 2500m, 3500m and 3870m. In fig.2b to fig.2g similar graphs are plotted for samples taken from other locations. The spectrum has a typical shape of very clear waters, with a minimum at the 470-490nm region. The minimum values of light attenuation coefficient e is between $0.025m^{-1}$ and $0.04m^{-1}$ and the general shape of this curve is in general agreement with the reference 2 and with values obtained in 1985 for samples in 4000m depth at the location 36°33'N, 21°08'E[3]. In fig.3 the summary of the light attenuation coefficient of 470nm wavelength versus the depth is plotted. It is interesting that no minimum of attenuation coefficient was found near the sea bottom (the deepest sample were- taken 30m above the sea floor), but below the depth of 1500m the water transparency seems to be uniform in all locations.

The steep increase of the attenuation coefficient at large wavelength is attributed to the absorption of pure water, i.e. by the water molecule. The high light attenuation coefficient at the ultraviolet region is determined by the light absorbed and light scattered from the organic material diluted in water while the clear water contribution in negligible[4]. The smooth curve of the spectrum at this region indicates that the contribution of the suspended material to the total attenuation at the region 390-530nm is quite important.

The function $\varepsilon(\lambda)-\varepsilon_{clear\ \mathrm{water}}(\lambda)$, where $\varepsilon_{c.w}(\lambda)$ is the clear water coefficient, was parameterised as a function of λ^{-v}, where λ is the wavelength. It was determined that the value of the parameter v is equal to 1.9. This suggests the importance of the contribution of the small particles to the scattering since it is known that the wavelength variation of the scattering follows the formula λ^{-v} and the value of v for large particles (bigger than lμm) is of the order of 0.3, while for smaller particles (less than 1μm) is about 1.7 to 2.0. [5]

Based on the data, the ratio $\Lambda = \sigma / \varepsilon$, where σ is the scattering coefficient and ε is the attenuation coefficient, was estimated. In reference [6], for the Mediterranean Sea between depths of 100m to 150m using the solar light in the wavelength region 495±35n0 ± 0.04 when ε = 0.025 m^{-1} (fig.4). Assuming that the attenuation due to scattering in the deep water compared to the total light attenuation does not increase with the depth, the absorption coefficient a is calculated equal to (0.015±0.002)m^{-1} or absorption length L = (67±8) m.

2. The autonomous module

The light attenuation with the depth, was recorded continuously in two location. For these measurements a special device was attached below the "ROZETT", the "autonomous module", fig.lb. The autonomous module used has a water-tight housing with power supply, an incadecent lamp, collimators, split mirrors, photomultiplier and a window. The collimated light beam was guided out, through the window to the sea, towards a 180° reflector. The light beam was then reflected and returned into the housing to the photomultiplier where the light intensity was recorded. The total light path in the water was 3m. A filter was used to select light of 490-530nm wavelength.

This instrument could only measure the relative light attenuation to a reference depth. This reference depth was 1m below the surface and the reference attenuation length was measured with the above mentioned spectrophotometer. In fig.5 the attenuation length, measured with the autonomous module, is plotted versus the depth. It is clear that below the 5OOm depth, there is not any significant variation of the attenuation length with the depth and it agrees with the shape of the spectrophotometer measurements taken in the same wavelength (fig.3).

3. The nephelometer

The nephelometer, fig.lc, was a device to measure the light scattered on water particles. It was attached below the "ROZETT". This device was a water-tight housing with power supply, a flash tube FX101 illuminating the water and a photomultiplier (Hamamatsu R-5O8). The photomultiplier was measuring the light scattered at 90°. In fig.6 the scattered light versus the depth is plotted. It should be noted that no filter was used in the nephelometer, which in general is a crude device.

4. 4 . Conclusions

The main future of the water that was examined is the high transparency in the visible region of the spectrum with a minimum attenuation at wavelengths 470-490nm. The attenuation coefficient is found to be between 0.025m^{-1} to 0.04m^{-1}, i.e. attenuation length between 25m to 5Om and the absorption length calculated to be equal to (67±8)m.

A study of the size of the suspended particles should be done. This will lead to a better estimation of the contribution of small and large particles in the overall scattering.

5. References

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4. Sorokina H.A. et al., Preprint Acad.Scien .Ukraina.Sevastopol (1988)
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6. Prokudina T.M., pelevin B.N., Optic of Ocean and atmospher , Leningrad, Nauka ,1972 ,p .157

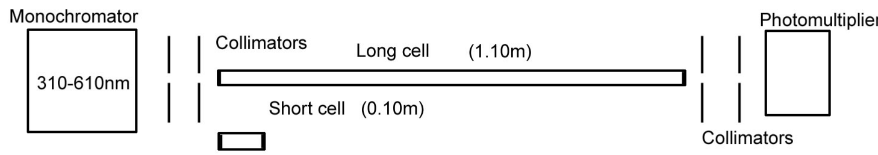

Fig.1a Diagram of the spectrophotometer

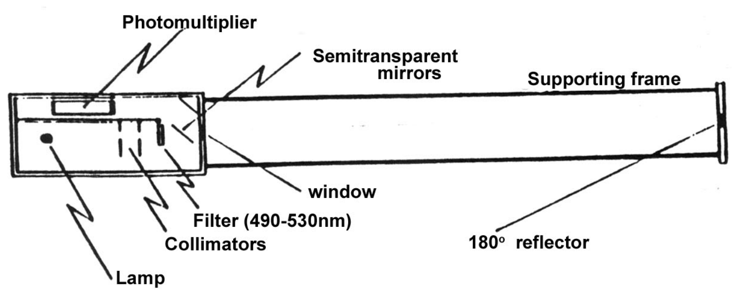

Fig. 1b Diagram pf the "autonomous module"

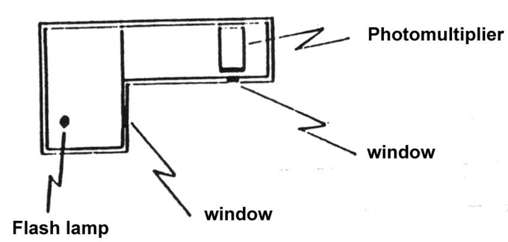

Fig. 1c Diagram of the nephelometer

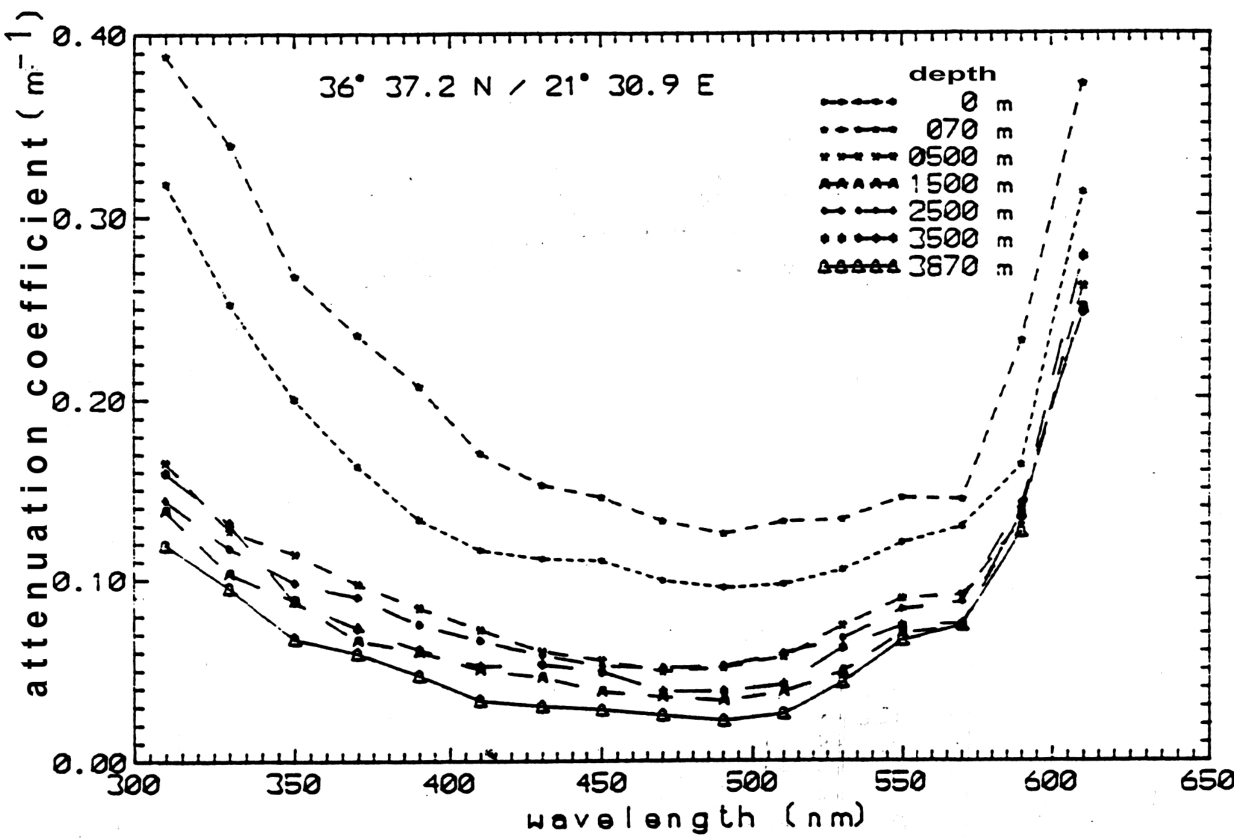

Fig. 2a Attenuation coefficient versus wavelength

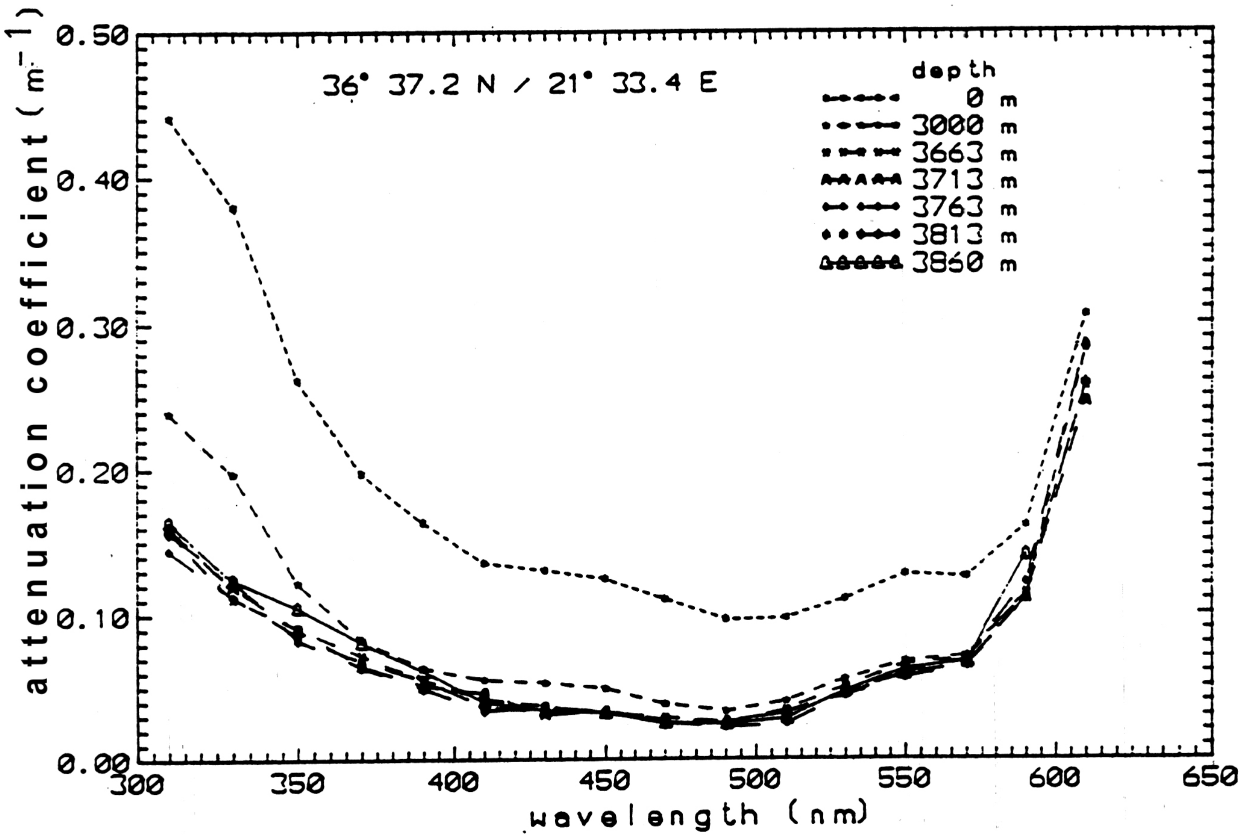
36° 37.2 N / 21° 33.4 E
depth
0 m
3000 m
3663 m
3713 m
3763 m
3813 m
3860 m
attenuation coefficient (m⁻¹)
0.00
0.10
0.20
0.30
0.40
0.50
300
350
400
450
500
550
600
650
wavelength (nm)

Fig. 2b

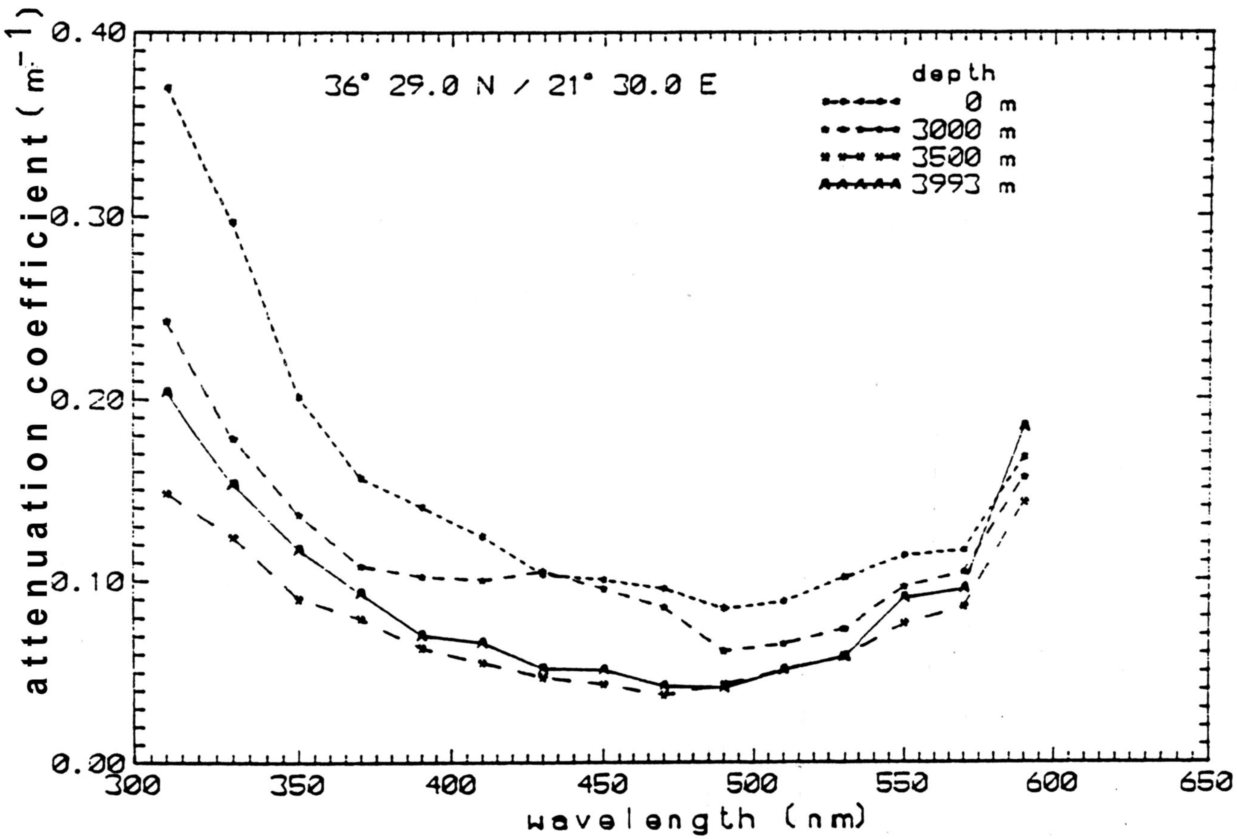
attenuation coefficient (m⁻¹)
36° 29.0 N / 21° 30.0 E
depth
0 m
3000 m
3500 m
3993 m
0.40
0.30
0.20
0.10
0.00
300
350
400
450
500
550
600
650
wavelength (nm)

Fig. 2c

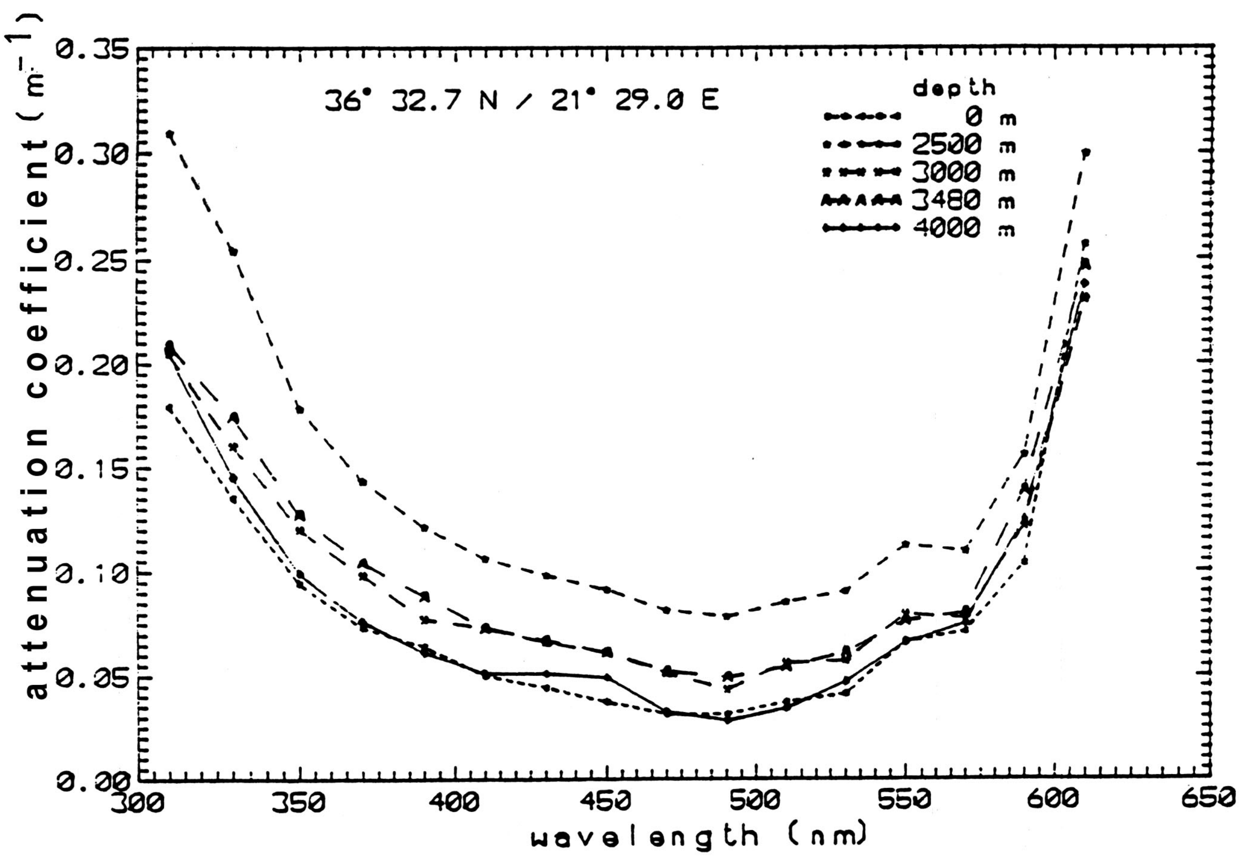
36° 32.7 N / 21° 29.0 E
depth
0 m
2500 m
3000 m
3480 m
4000 m
attenuation coefficient (m⁻¹)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
300
350
400
450
500
550
600
650
wavelength (nm)

Fig. 2d

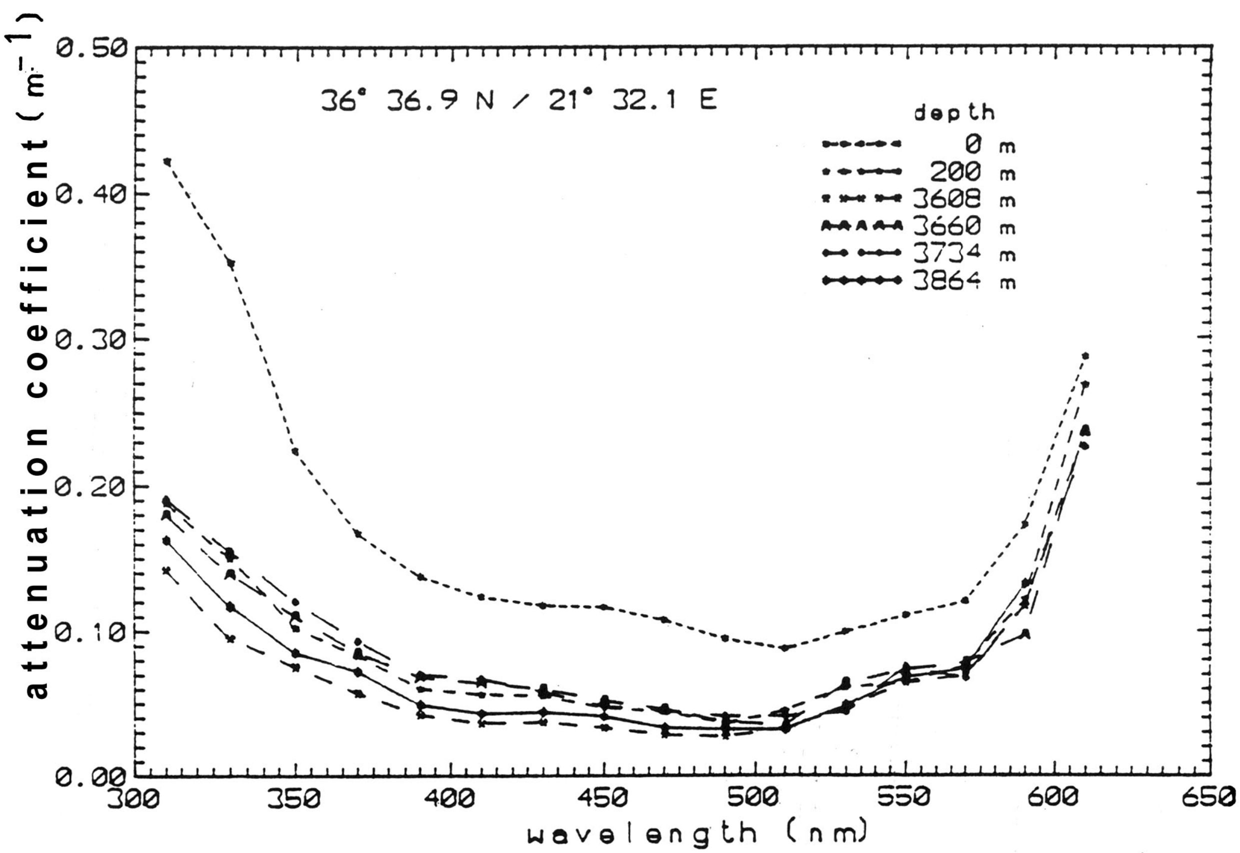
36° 36.9 N / 21° 32.1 E
depth
0 m
200 m
3608 m
3660 m
3734 m
3864 m
attenuation coefficient (m⁻¹)
0.00
0.10
0.20
0.30
0.40
0.50
300
350
400
450
500
550
600
650
wavelength (nm)

Fig. 2e

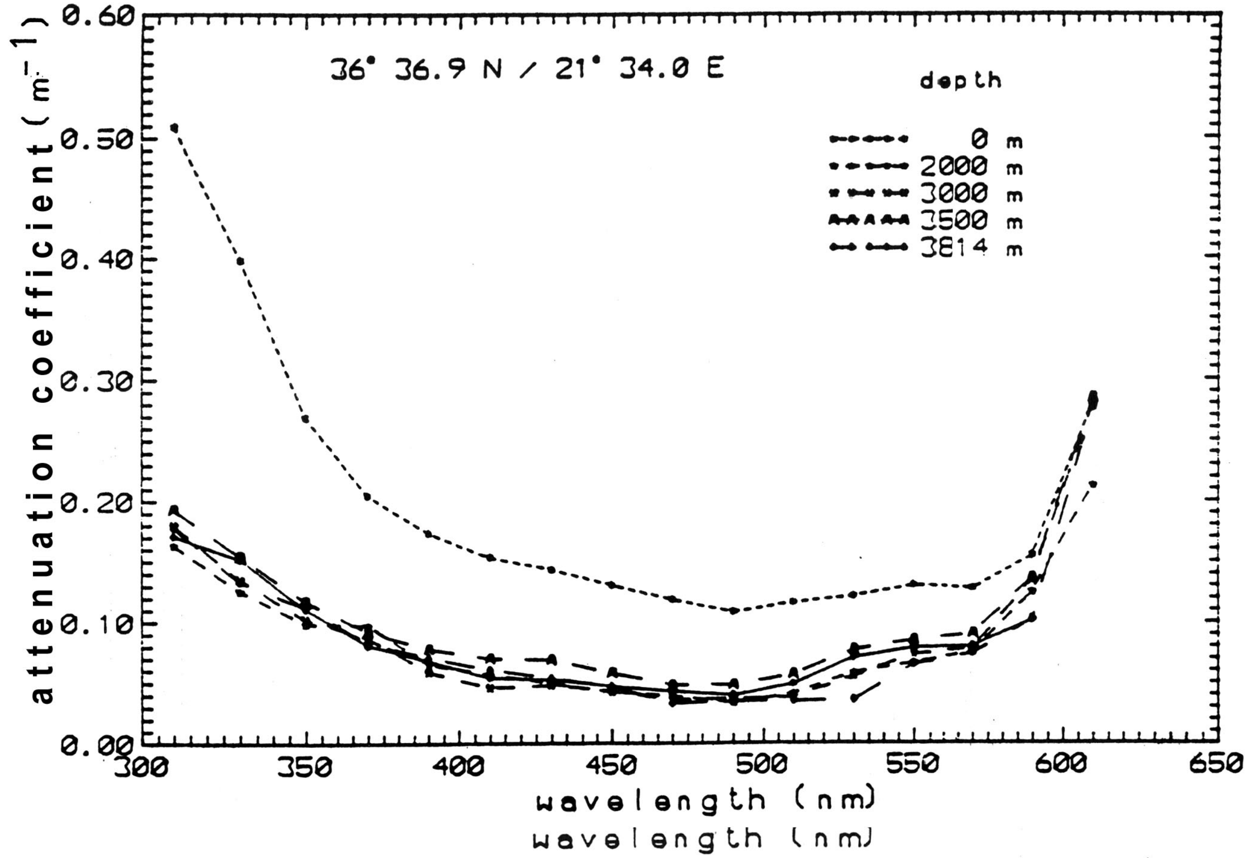
36° 36.9 N / 21° 34.0 E
depth
0 m
2000 m
3000 m
3500 m
3814 m
attenuation coefficient (m⁻¹)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
300
350
400
450
500
550
600
650
wavelength (nm)
wavelength (nm)

Fig. 2 f

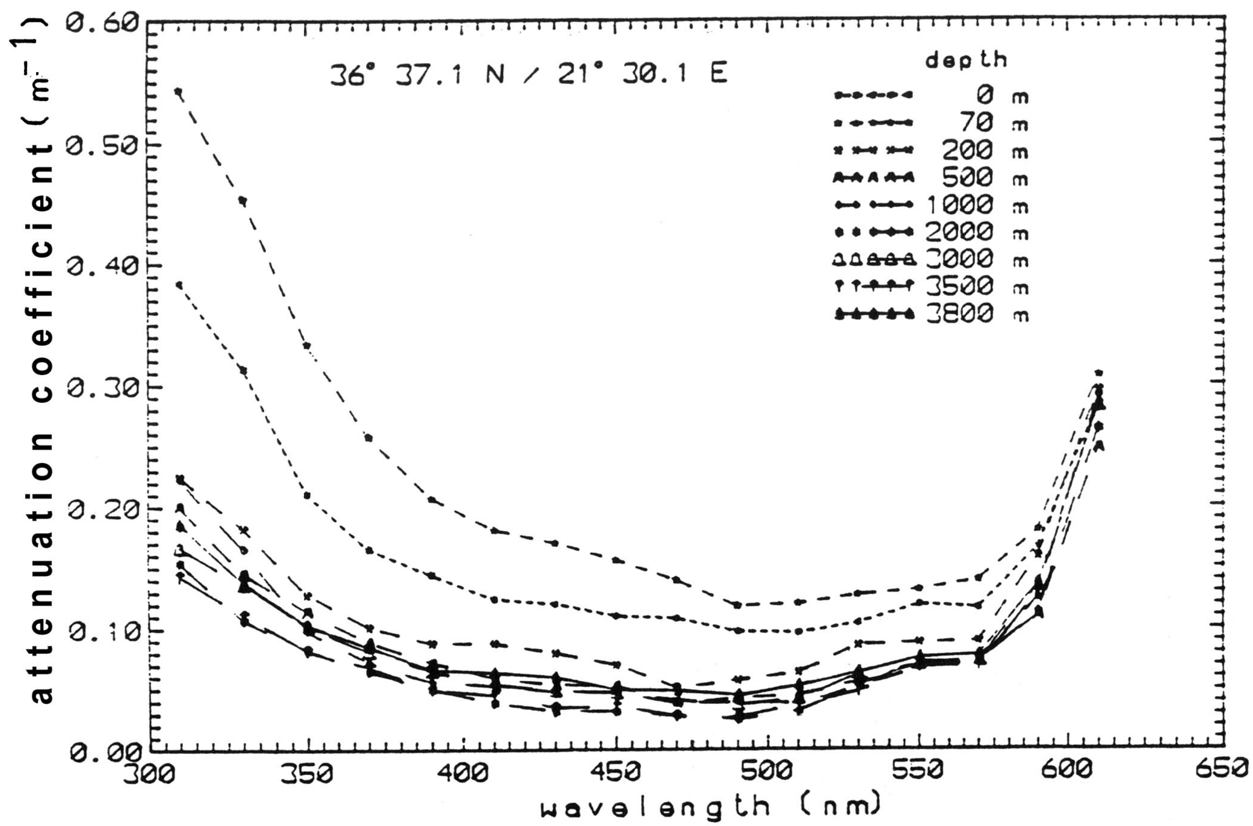
36° 37.1 N / 21° 30.1 E
depth
0 m
70 m
200 m
500 m
1000 m
2000 m
3000 m
3500 m
3800 m
attenuation coefficient (m⁻¹)
0.60
0.50
0.40
0.30
0.20
0.10
0.00
300
350
400
450
500
550
600
650
wavelength (nm)

Fig. 2g

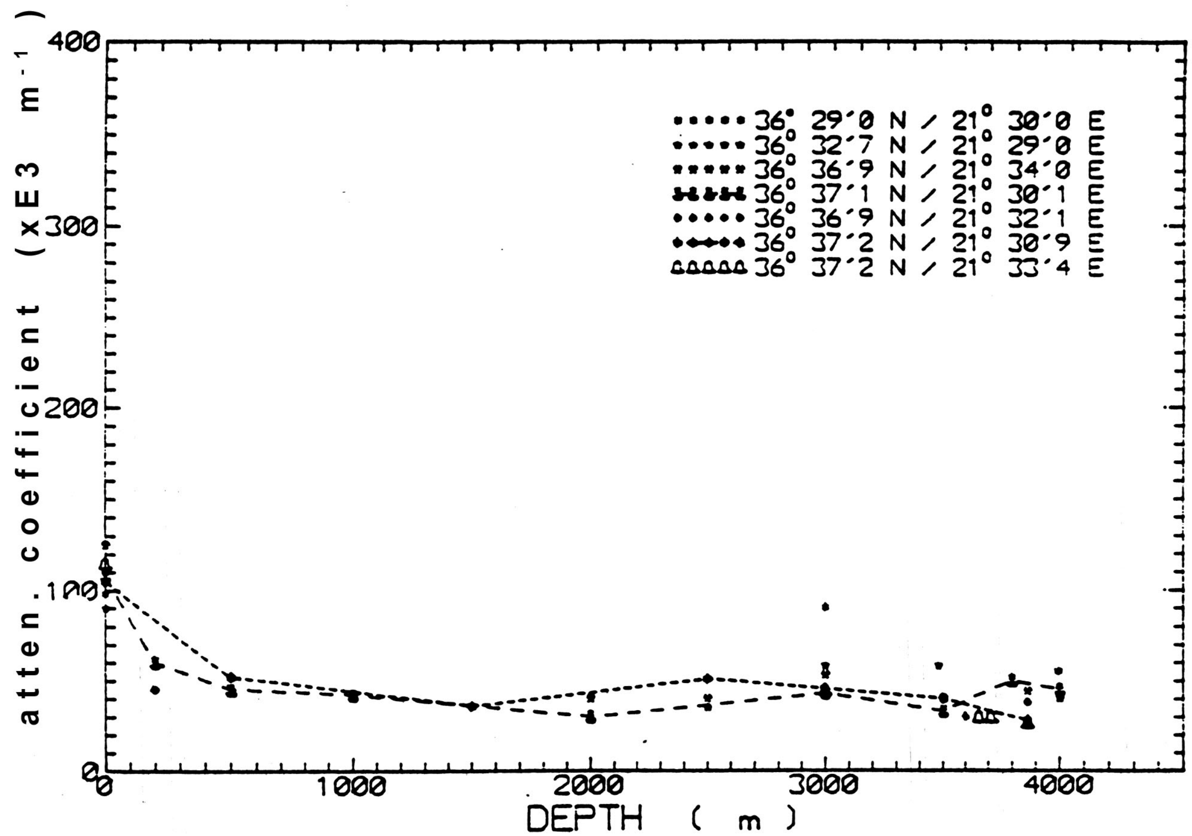

Fig.3 Attenuation coefficient versus depth, as measured with the specrophotometer at 470nm wavelength

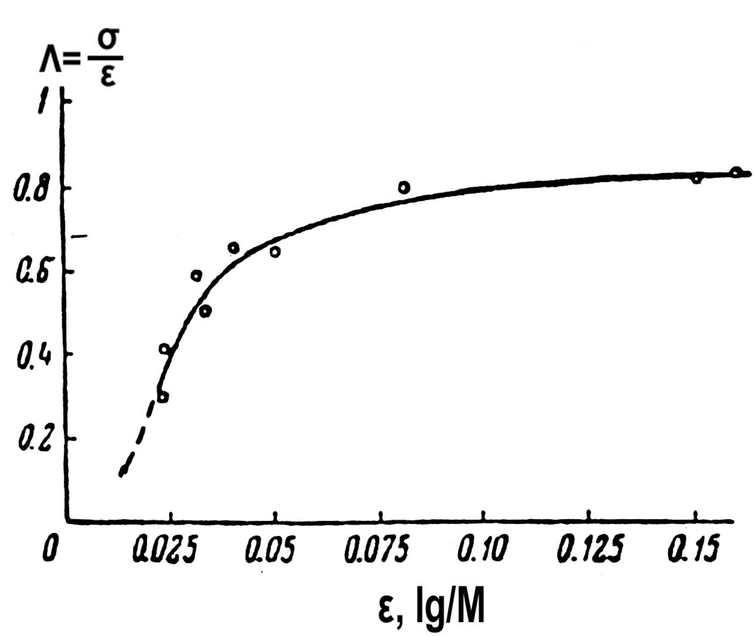

Fig. 4 The Λ versus the attenuation coefficient, as published in reference 6.

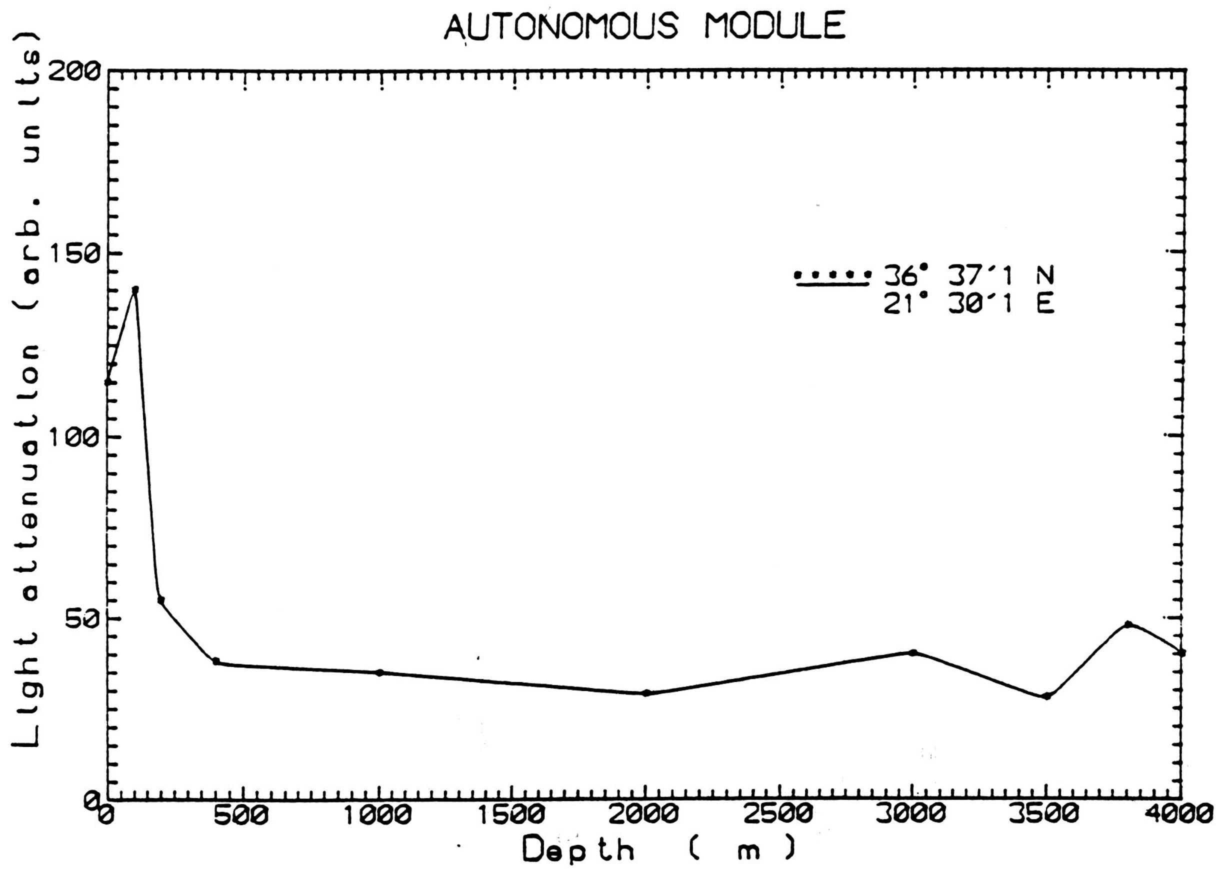

Fig. 5 Attenuation coefficient versus depth, measured with autonomous module

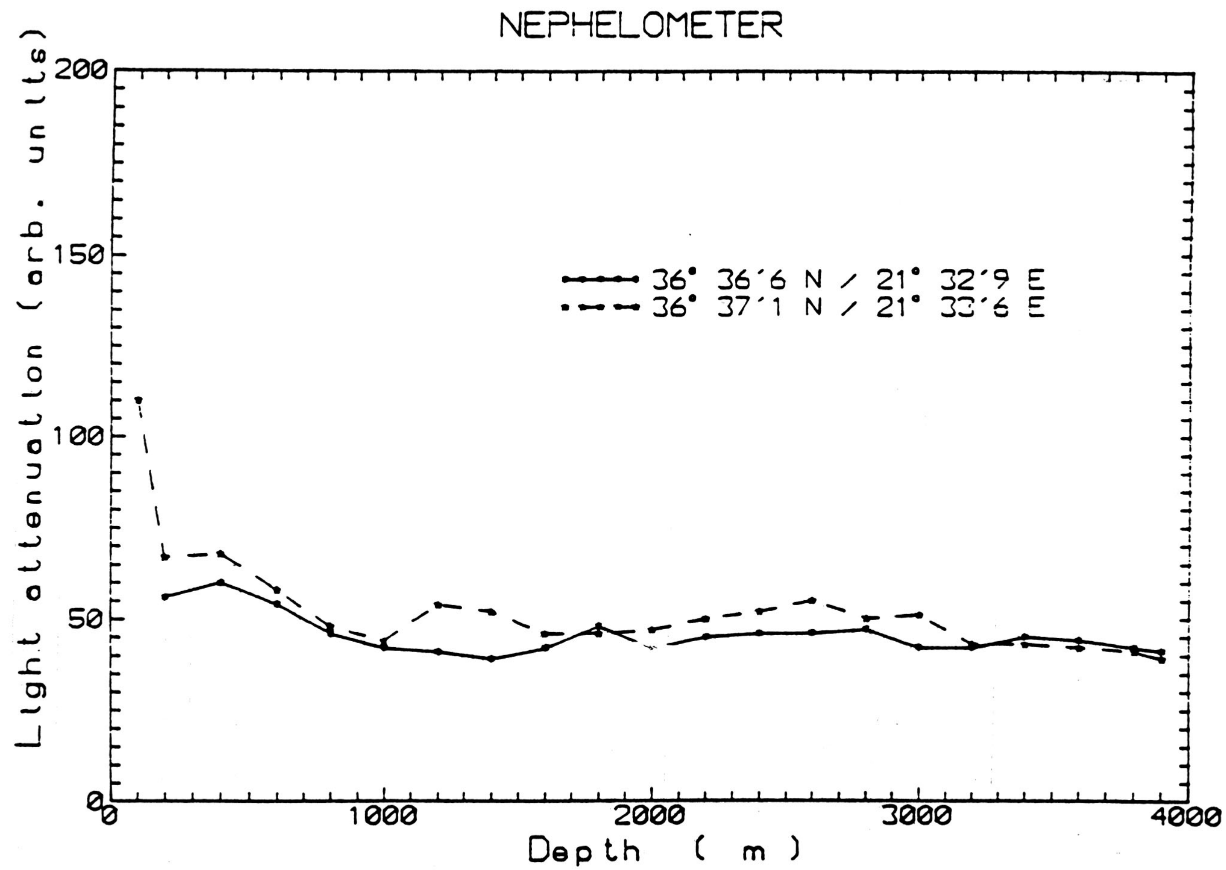

Fig. 6 The light attenuation measured with the nephelometer