

ANISOTROPY OF THE UNDERWATER LIGHT FIELD: DEVELOPMENT OF A RADIANCE CAMERA

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Summary :

The Bidirectionality of the marine reflectance, which derives from the anisotropy of the underwater light field, is an important parameter in ocean optics and ocean color remote sensing. A predictive model exists [1] for case 1 waters, whereas there is presently no model for optically-complex case 2 waters.

We present here the development of an underwater multi-spectral "radiance camera". This instrument is characterized by a large-angle optic, a high-sensitivity CMOS and a compact design. The design of the camera is presented, and results from its characterization and from initial field experiments in the Mediterranean sea are shown.

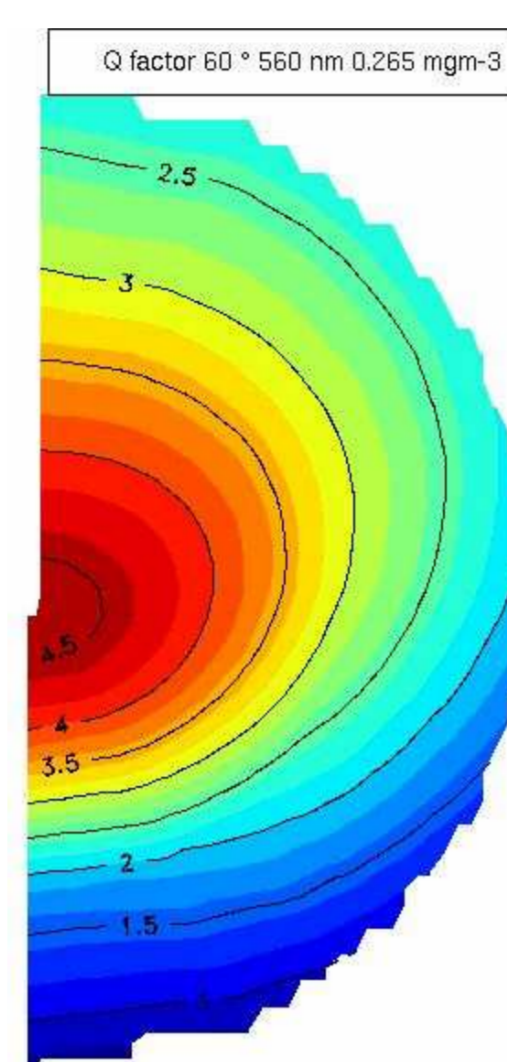
Anisotropy of the underwater light field :

The Bidirectionality of the marine reflectance can be expressed as the ratio between the upwelling irradiance (E_u) and the upwelling radiance (L_u) in a given direction :

$$Q(\lambda, \theta_v, \theta_s, \Delta\phi, \text{IOPs}) = \frac{E_u(\lambda, \theta_s, \text{IOPs})}{L_u(\lambda, \theta_v, \theta_s, \Delta\phi, \text{IOPs})}$$

Q depends on :

- The sun position (θ_s)
- The observation direction ($\theta_v, \Delta\phi$)
- Water optical properties (IOPs, in particular the Volume Scattering Function)
- The wavelength (λ)



(Right) : Q output from the model [1]

The radiance camera :

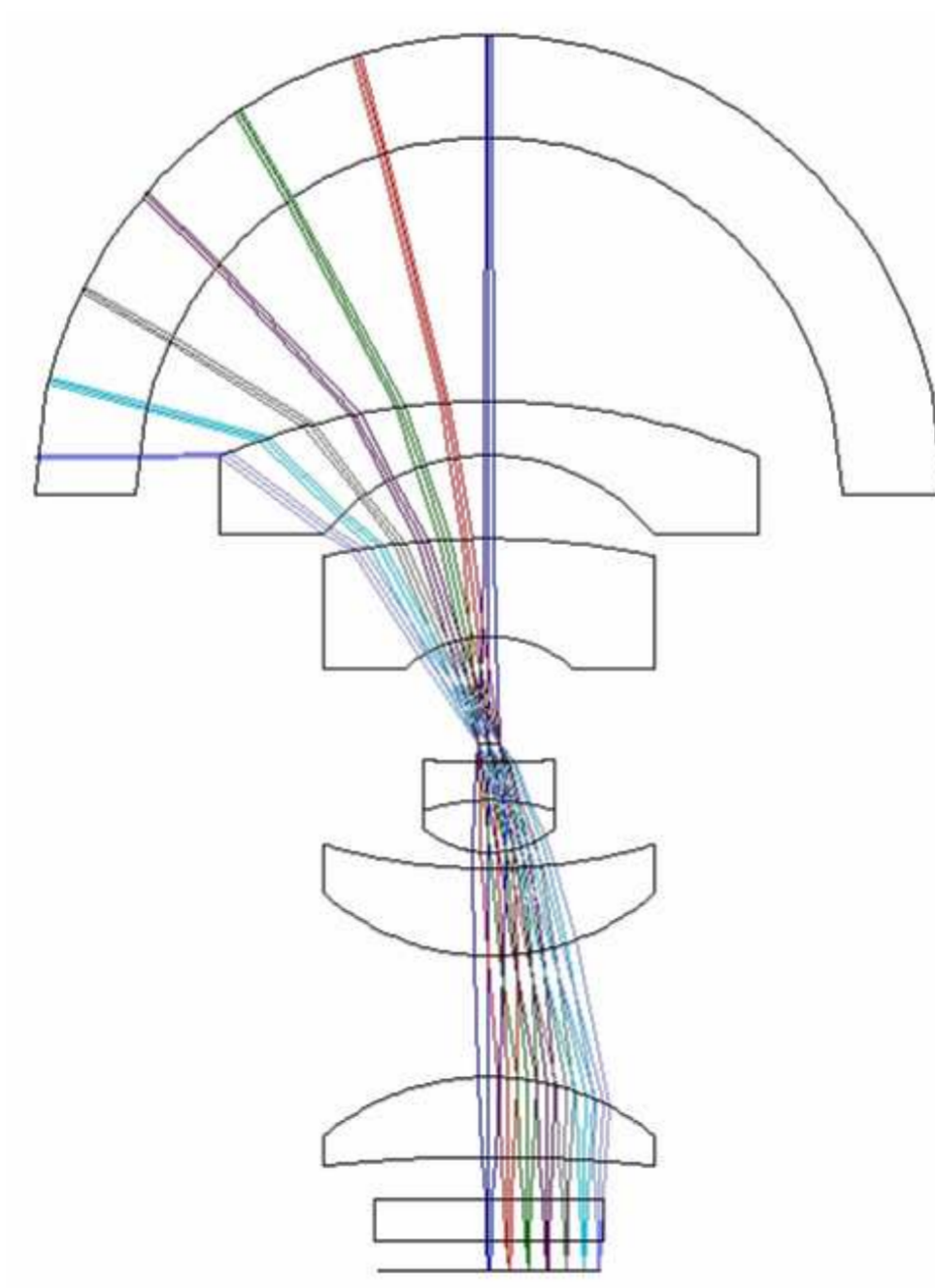
This development was funded by the French space agency (CNES). The design was proposed by the CIMEL company. The overall project is supervised by the Laboratoire d'Océanographie de Villefranche.

characteristics :

- radiance measurement on a full hemisphere (184° field of view).
- measurements capability of upwelling or downwelling light field.
- multispectral measurements (406, 438, 494, 510, 560 and 628 nm)
- extremely compact design to reduce self-shading (Ø96 * 260 mm)
- High sensitive CMOS sensor, 12 bit digitization, HD format (1920 x 1080)
- Telecentric, non achromatic, patented fish-eye optics
- Auxiliary sensors : Compass, depth sensor, tilt sensor, Int. Temp. & humidity
- Deployment capability down to 100m depth



View from the rear deck of the R/V "Atalante"



Optics design (patented)



The radiance Camera

Initial characterization results:

1) Angular resolution :

better than 1°

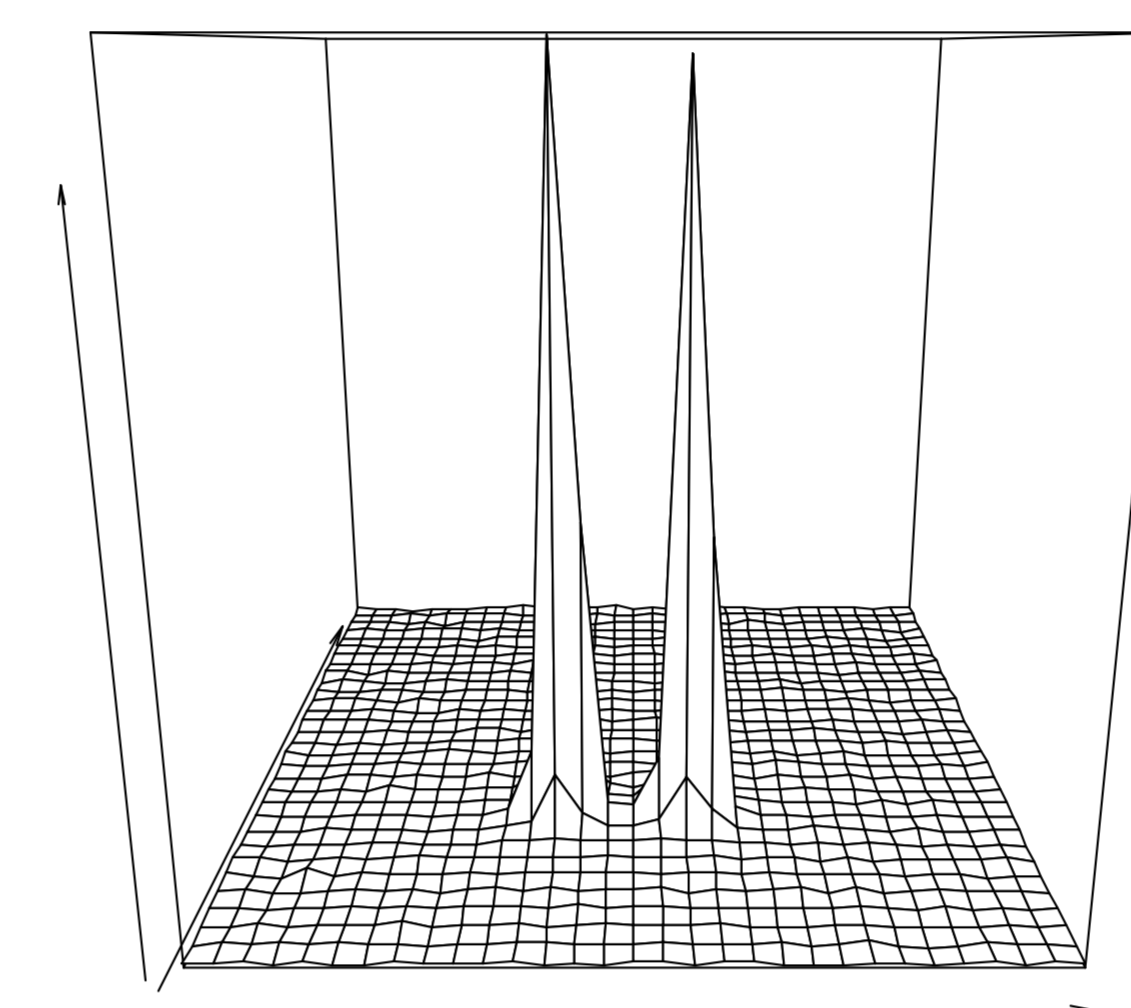
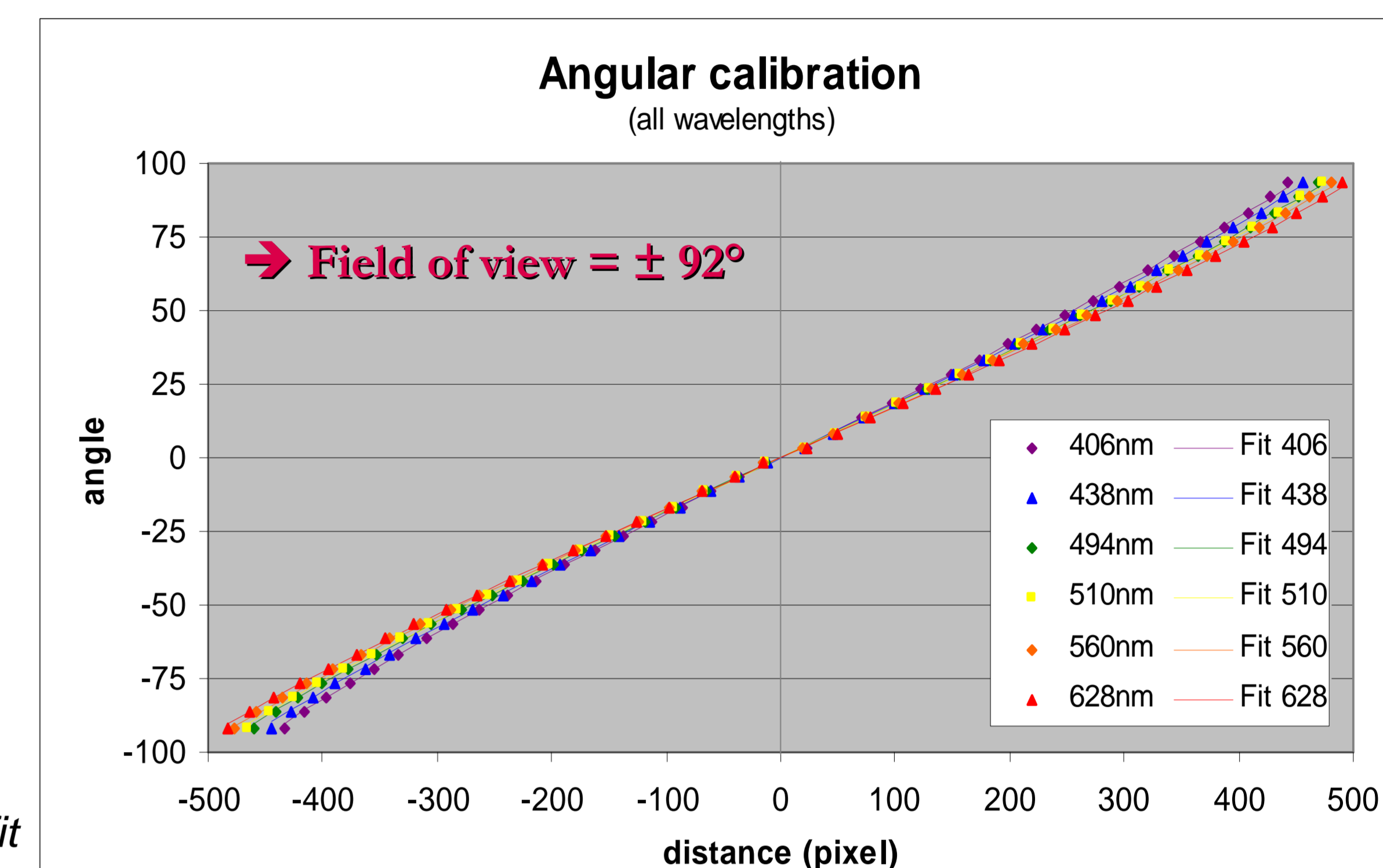


Image of 2 collimated beams spaced by 1°
@ 406 nm, 30*30 pixels

(right) geometric experimental data and fit

2) Geometric characterization : $\theta = a(\lambda).r^3(\lambda, \theta) + b(\lambda).r(\lambda, \theta)$



3) Sensitivity : from 5 $\mu\text{Wm}^{-2}\text{nm}^{-1}\text{sr}^{-1}$ @ 406 nm to 1 $\mu\text{Wm}^{-2}\text{nm}^{-1}\text{sr}^{-1}$ @ 628 nm

The sensitivity is sufficient to measure upwelling radiance at depth.

4) Rolloff : The rolloff is the increase in radiance attenuation for increasing view angle (due to the optic).

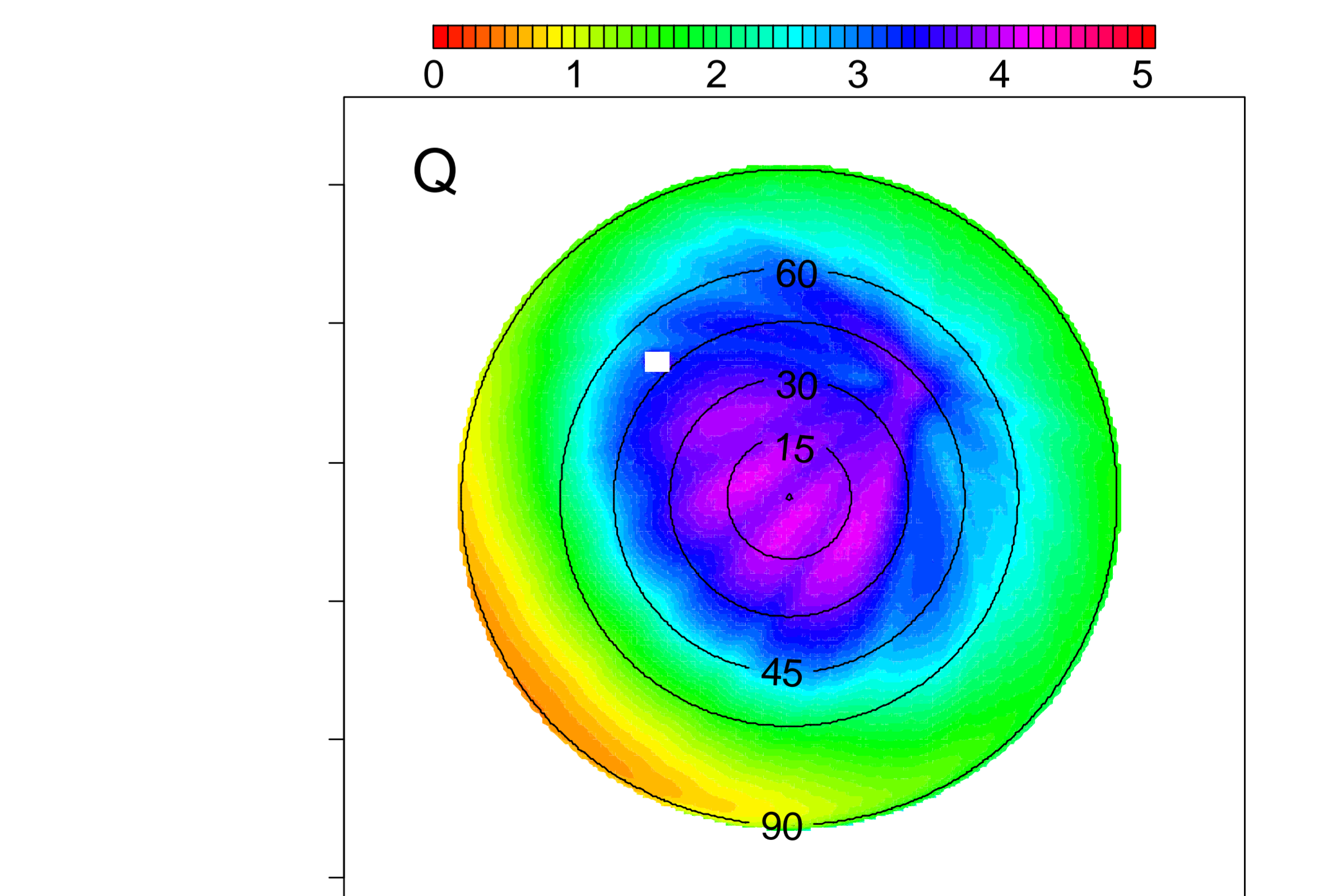
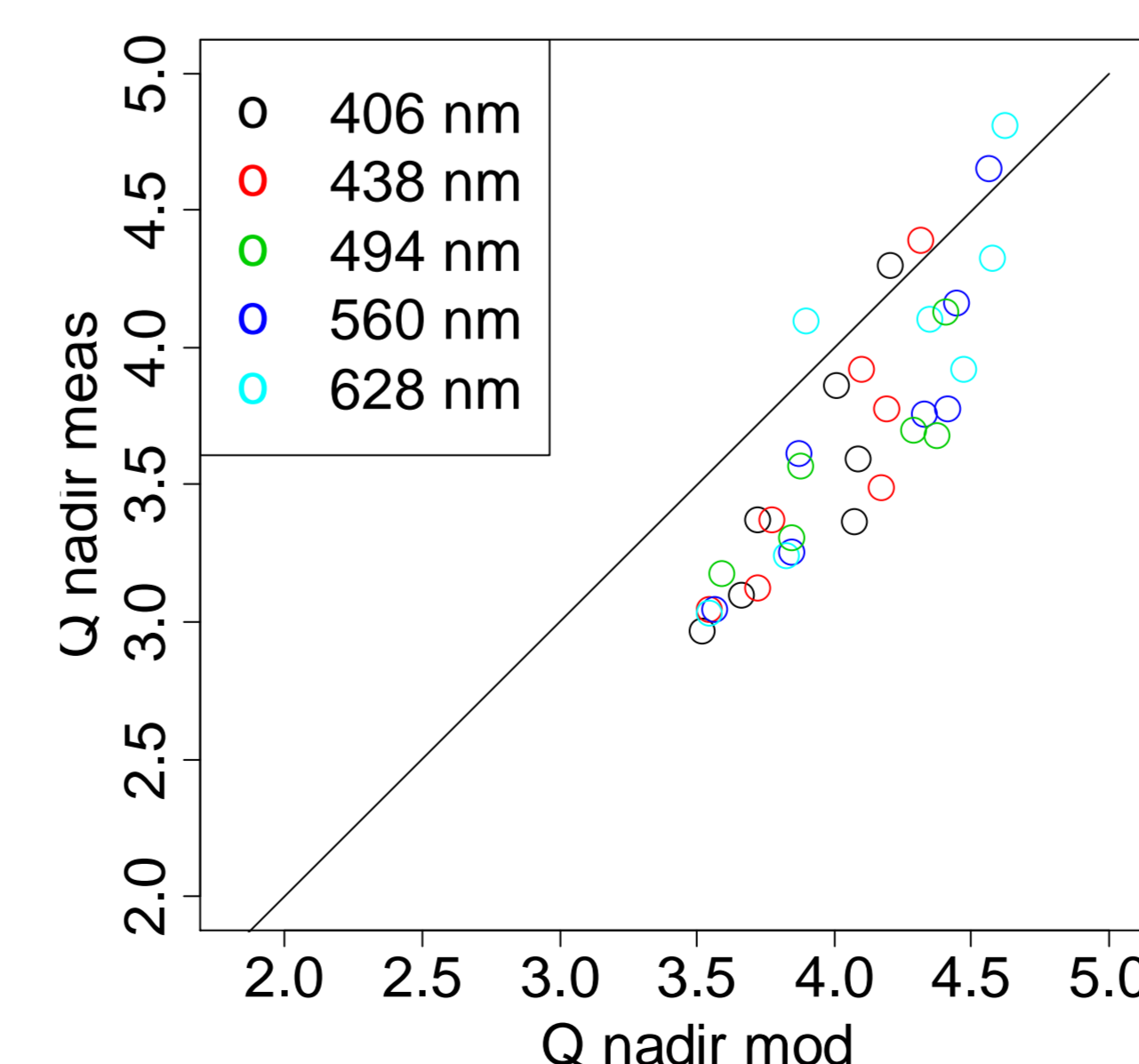
The attenuation at 80° is 25% @ 628 nm and less than 10% for other wavelengths.

Preliminary field results :

The camera was tested in may 2008 during a cruise in the Mediterranean sea ("Optic-Med").



Camera deployed at surface to measure
upwelling radiance



Q measurement, 560 nm, $\theta_s = 60^\circ$; [Chla]=0.265 mg.m⁻³
Qnadir expected for case 1 water : 4.4 (sr)

(Left) : Measurements of Qnadir versus prediction [1] for 7 coastal stations. [Chla] varying from 0.1 to 1.3 mg.m⁻³.