Title : will be set by the publisher
Editors : will be set by the publisher
EAS Publications Series, Vol. ?, 2012

MISOLFA: A SEEING MONITOR FOR DAYTIME TURBULENCE PARAMETERS MEASUREMENT

Ikhlef R.[1], Corbard T.[1], Irbah A.[2], Meftah M.[2], Morand F.[1], Fodil M.[3], Assus P.[1], Renaud C.[1], Chauvineau B.[1] and the whole Picard-Sol team

Abstract. The Franco-Algerian Monitor of Solar Images (MISOLFA) was developped in order to study the effect of optical turbulence on diameter measurements from ground-based solar observations. Some first results obtained with MISOLFA are presented.

1 INTRODUCTION

Observations of the Sun at high angular resolution using ground-based telescopes require an accurate modelling of the optical effects induced by atmospheric turbulence. Following Irbah *et al.* (1994) and Lakhal *et al.* (1999), we expect diameter measurements to show a dependence not only with the seeing condition as represented by Fried's parameter r_0 but also with the turbulence characteristic time. MISOLFA was developped in this context at Calern Observatory (Observatoire de la Côte d'Azur) in order to characterize atmospheric turbulence while measuring solar diameter with SODISM-2, the ground-based replica of SODISM telescope onboard PICARD satellite (Thuillier *et al.* 2006, Meftah *et al.* 2010).

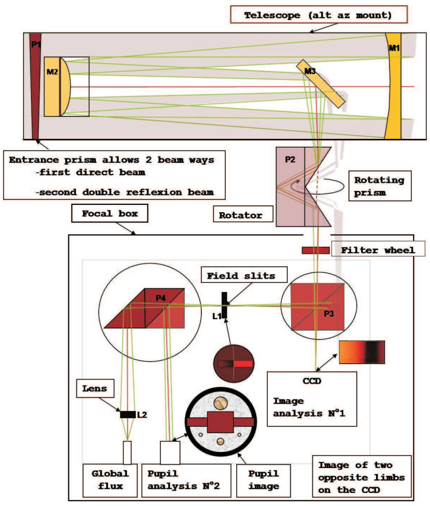
2 Presentation of MISOLFA, concept and measurement principle

Figure 1 shows the principle of the monitor. It is based on observation of Angle-of-Arrival (AA) fluctuations on both the image and pupil planes. In the image plane we record directly the AA-fluctuations using a CCD camera placed on images of the two opposite solar limbs which are parallel to the local horizon and therefore not affected by atmospheric refraction. A beam splitter creates the second way, in

[1] Université de Nice Sophia Antipolis, CNRS, Observatoire de la Côte d'Azur, BP 4229 06304 Nice Cedex 4, France; e-mail: corbard@oca.eu
[2] Université Versailles St-Quentin; CNRS/INSU, LATMOS-IPSL, Guyancourt, France
[3] CRAAG - Observatoire d'Alger BP 63 Bouzaréah Alger, Algérie

DOI: (will be inserted later)

which the telescope pupil is observed at high cadence by means of a lens through a narrow slit placed on the solar limb image. Several photodiodes record the intensity fluctuations relayed by optical fibers positioned on the image behind diaphragms of different sizes. From the statistical analysis of signals collected in both planes one can infer all the spatio-temporal parameters for a given model of optical turbulence. Instrumental parameters of MISOLFA are summarized in the table (see also Irbah *et al.* (2010, 2011) and Corbard *et al.* (2011)).



Telescope :	
Model	Cassegrain Coudé
Mount	Alt-Az
Aperture	$252mm$, $f/2.5$
Focal length	$10m$
Entrance prism :	
Angle	$10'54"$
External diameter	$270mm$
Internal diameter	$256mm$
Width	$35mm$
Filter :	
Diameter	$16mm$
Wavelength	$535.7nm$
CCD Camera :	
Model	PCO PixelFly VGA
Sensor	Sony ICX074AL
Exposure time	$0.001s$
Frame rate	$30\ frame/s$
Pixel size	$9.9\mu m$ ($0.2\ arcsec$)
Number of pixels	640 x 480
Diaphragm (slit) :	
Length	fiew mm
Width	$100\mu m$
Pupil way records cadence	1 KHz

Fig. 1. MISOLFA, Optical scheme and instrumental caracteristics.

3 Numerical simulations

Numerical simulations were made in order to check the faisibility of atmopspheric parameters extraction from image and pupil plane data. Using Nakajima (1988) method, we simulate a randomly perturbed wavefront assuming Von Kármán model and simulate MISOLFA images by randomly generating phase screens with the same input parameters (r_0, $\mathcal{L}_0$ the spatial coherence outer scale and h the altitude of the equivalent impulse layer). The number of images averaged gives the simulated turbulence characteristic time. Parameters extraction consists in edge detection, cross-correlation computation to obtain the structure function $d_\alpha(\theta)$ and a non linear fitting. Good results were obtained with different kinds of turbulence but showing a limitation in $\mathcal{L}_0$ estimation. For values greater than 60 m the merit fuction is not sensitive anymore to increasing outer scales.

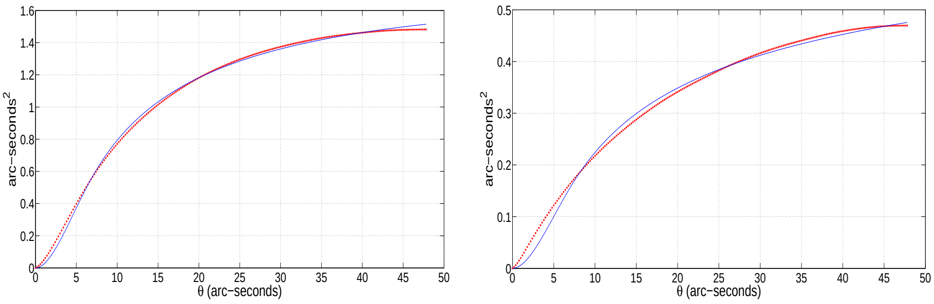


Fig. 2. Experimental structure functions (red) and their fit with Von Kármán model (blue) for two different days: December 14, 2009 (left) and Decmeber 9, 2009 (right)

4 Some recent results

Image-plane processing follows the same steps as for simulations after applying a wavelet flter to the images. The spatial parameters r_0, $\mathcal{L}_0$ and h are then estimated fitting $d_{\alpha Exp}(\theta)$ with the Von Kármán model. For example, for the two days shown on Fig. 2, we obtain r_0= 5.3 cm, $\mathcal{L}_0 > 60$ m, h= 7405 m and r_0= 2.7 cm, $\mathcal{L}_0 > 60$ m, h= 8791 m respectively.

Cumulative frequency distribution of Fried parameters is shown on Fig. 3. The two histograms correspond to Fried parameter measurements using the two opposite limbs monitored. The median values are equal to 3.86 cm and 3.78 cm respectively. These values are close to the average value of 4 cm previously obtained at Calern observatory (Morand *et al.* 2010).

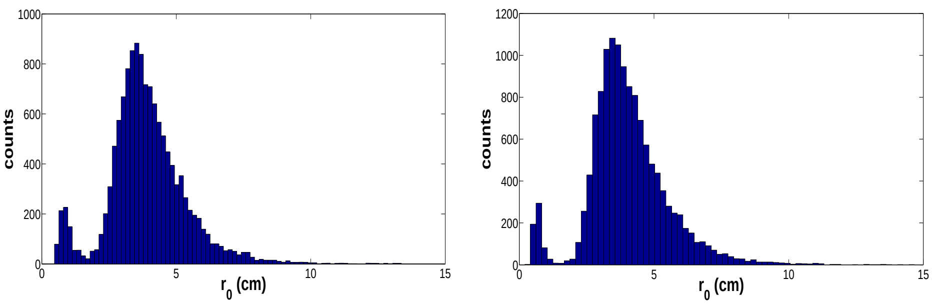


Fig. 3. Fried's parameter histogram of measurement performed between February and October 2011 from east (left) and west (right) solar limbs.

Monthly evolution of Fried parameter estimation shows that the best measurements were obtained on June 2011 with a median value of 4.4 cm. The two pics observed in the r_0 data histograms are not well explained and need more investigations.

Finaly, we use data of the pupil plane to estimate the correlations time of AA-fluctuations. Light fluctuations from pupil plane are converted to electrical signals by photodiodes with low noise electronics amplification device. Figure 4 (left) shows examples of intensity fluctuations recorded for several tens of seconds at a cadence of 1kHz on different days. The covariance function of each signal is computed (right panel) and the correlation time deduced. We find respectively 39, 65, 83, 72 and 70 milliseconds for the 5 AA-fluctuation samples of Fig. 4.

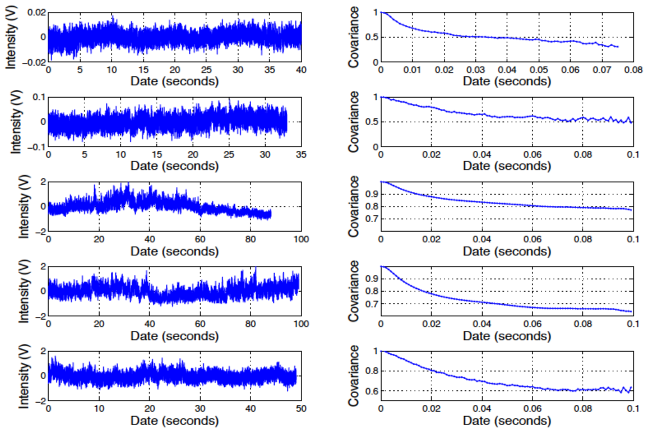


Fig. 4. Pupil plane signal (left) and covariance function (right) obtained for 3 different days. From top to bottom: June 6, June 9, June 27 (2 samples) and june 28, 2011.

References

Berdja, A., Irbah, A., Borgnino, J. & Martin, F. 2004, Proc. SPIE, 5237, p. 238

Corbard, T., Irbah, A., Assus, P., Dufour, C., Fodil, M., Morand, F., Renaud, C. & Simon, E. 2011, Astron. Nachr., 331, P58

Irbah, A., Laclare, F., Borgnino, J. & Merlin, G. 1994, Solar Phys., 149, 213

Irbah, A., Corbard, T., Assus, P., Borgnino, J., Dufour, C., Ikhlef, R., Martin, F., Meftah, M., Morand, F., Renaud, C. & Simon, E. 2010, Proc. SPIE, 7735, 77356F

Irbah, A., Meftah, M., Corbard, T., Ikhlef, R., Morand, F., Assus, P., Fodil, M., Lin, M., Ducourt, E., Lesueur, P., Poiet, G., Renaud, C. & Rouze, M. 2011, Proc. SPIE, 8178, 81780A

Lakhal, L., Irbah, A., Bouzaria, M., Borgnino, J., Laclare, F. & Delmas C. 1999, A&AS, 138, 155

Meftah, M., Meissonnier, M., Irbah, A., *et al.* 2010, Proc. SPIE 7731, 773145

Morand, F., Delmas, C., Corbard, T., Chauvineau, B., Irbah, A., Fodil, M. & Laclare, F. 2010, C. R. Acad. Sci. Paris, p. 660

Nakajima, T. 1988, J. Opt. Soc. Am. A.5, 963

Thuillier, G., Dewitte, S., Schmutz, W. & the PICARD team 2006, AdSpR, 38, 1792