PICARD-SOL
Presentation and Results

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and the Picard-Sol team

26 / 09 / 2013

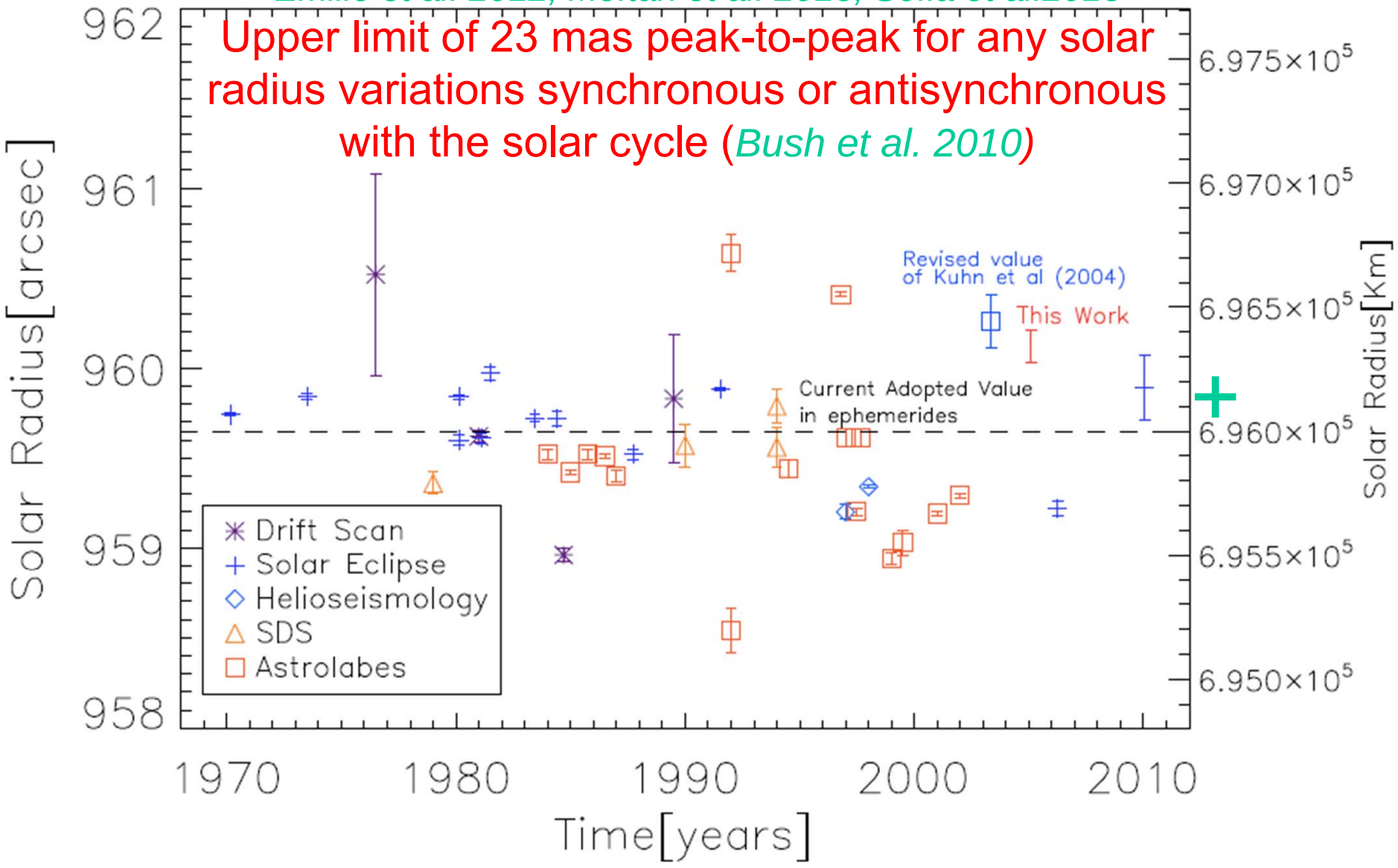
Outline of the presentation

- Historical context
- Instruments overview
- Solar diameter measurements SODISM2
- Refraction effect → correction
- Seeing effect → MISOLFA
- Other (aerosols, ...)

Context of the project

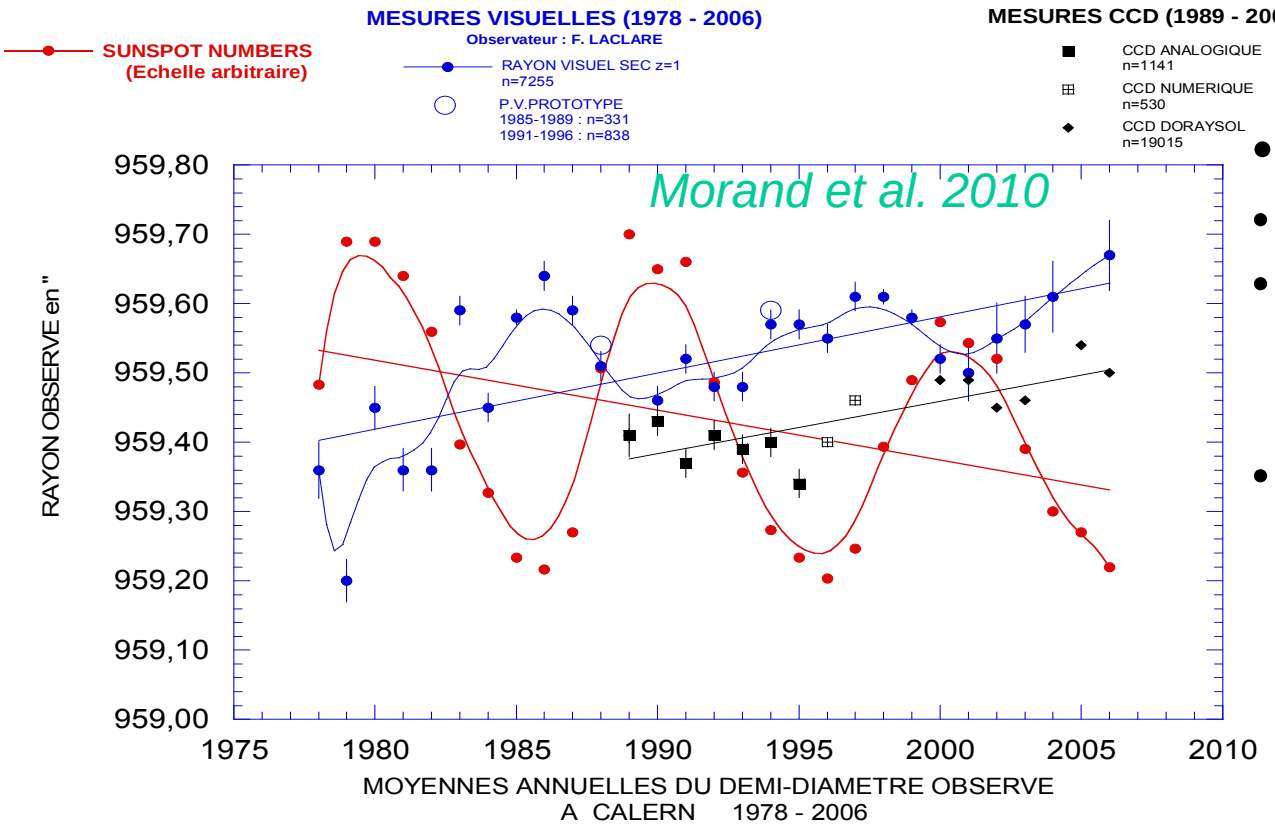
Emilio et al. 2012, Meftah et al. 2013, Sofia et al.2013

Upper limit of 23 mas peak-to-peak for any solar radius variations synchronous or antisynchronous with the solar cycle (*Bush et al. 2010*)



Introduction

Diameter measurements by astrolabes 1978-2006



- *28 years of observations*
- *~30000 measurements*
- *~200 mas variations anti-correlated with Solar Activity*
- *Coherent with SDS balloon flights but no confirmation from space observations so far*

True solar variations ? Earth atmospheric effects (possibly triggered by Solar Irradiance variations)?

PICARD-SOL objectives

- To continuously and simultaneously record radius, optical turbulence and global atmospheric parameters at different wavelengths
- To understand the influence of the atmosphere on the solar radius measurements
- To compare the solar radius measurements obtained with SODISM-II and other ground based and space instruments
- To continue solar radius measurements with ground based instruments after the space mission

Instrumentation overview

PICARD Mission d'étude des relations entre la variabilité solaire et le climat de la Terre. Mieux comprendre les changements climatiques par une meilleure connaissance du Soleil.

Picard-Sol instruments

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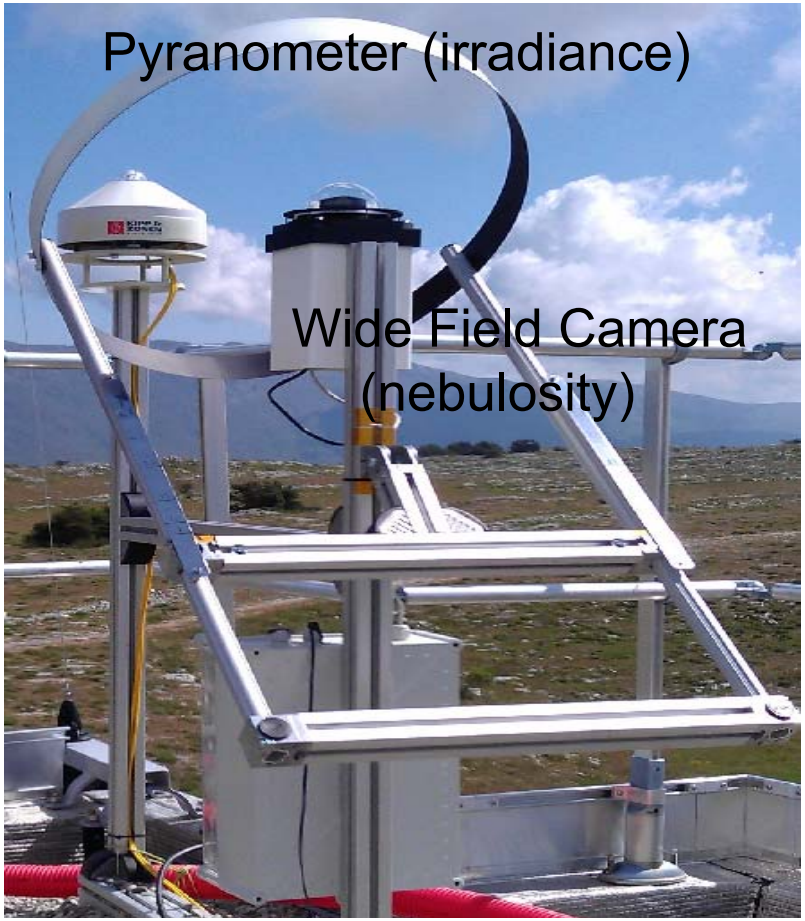
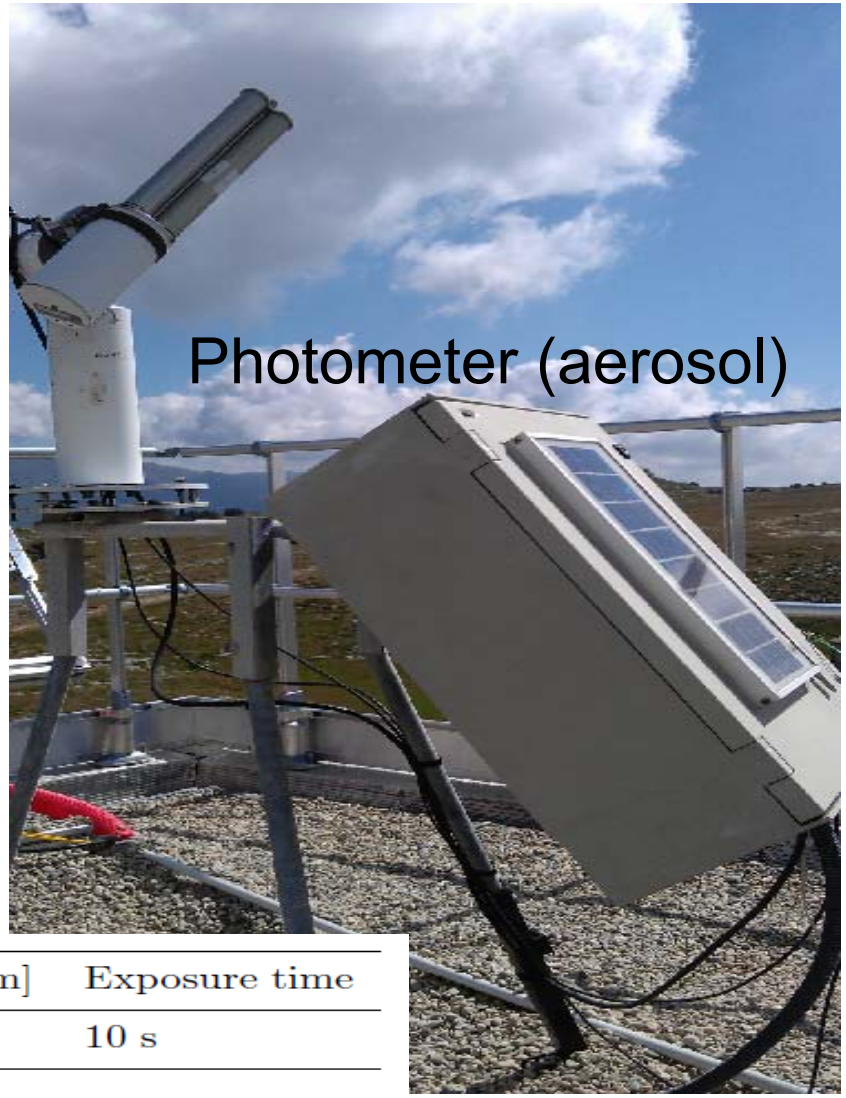
Picard-Sol instruments





Wavelengths λ [nm]	$\Delta\lambda$ [nm]	Exposure time
340, 380, 440, 500, 675, 870, and 1020	10	10 s

PICARD-SOL calibration steps and first results

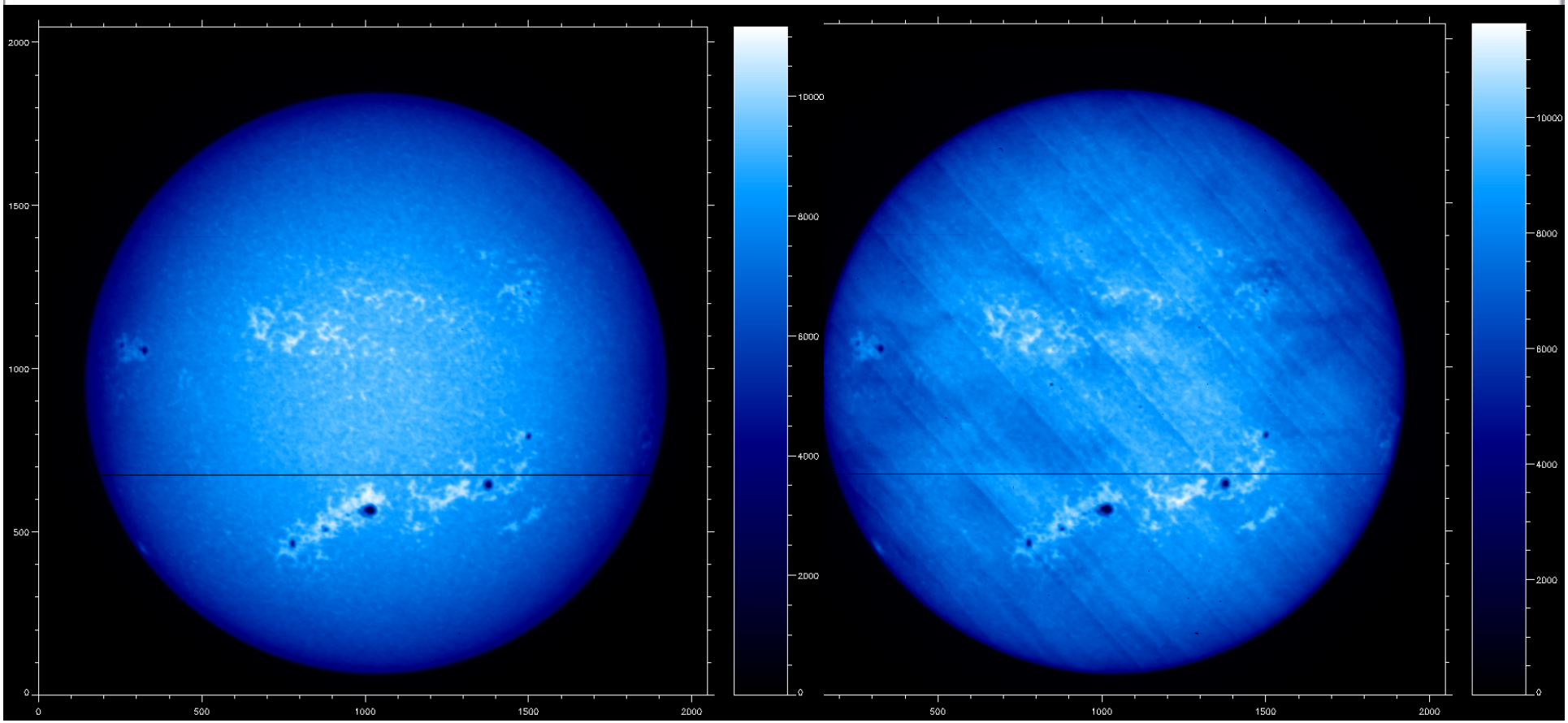
- Plate Scale (stars observations)
- Flat-fielding
- Astronomical refraction corrections
- Images quality and selection
- First results
- Optical turbulence effects
  - Simulations
  - MISOLFA measurements
  - Application to the mean radius

Flat-Field procedure

- Several methods are commonly used for Flat-fielding: Flat box, illuminated screen (domeflats), skyflat or twilight flat.
- Because of the entrance window we can not use these methods
- Solution: use of relatively shifted images (almost the same observational conditions) -> Kuhn method (*Kuhn et al. 1991*)
- SODISM-II acquires one image/minute -> very difficult to have a good flat-field (need of good and stable conditions).
- A new method based on contrast map is tested.

PICARD Mission d'étude des relations entre la variabilité solaire et le climat de la Terre. Mieux comprendre les changements climatiques par une meilleure connaissance du Soleil.

Flat-Field corrections contrast map method 393 nm



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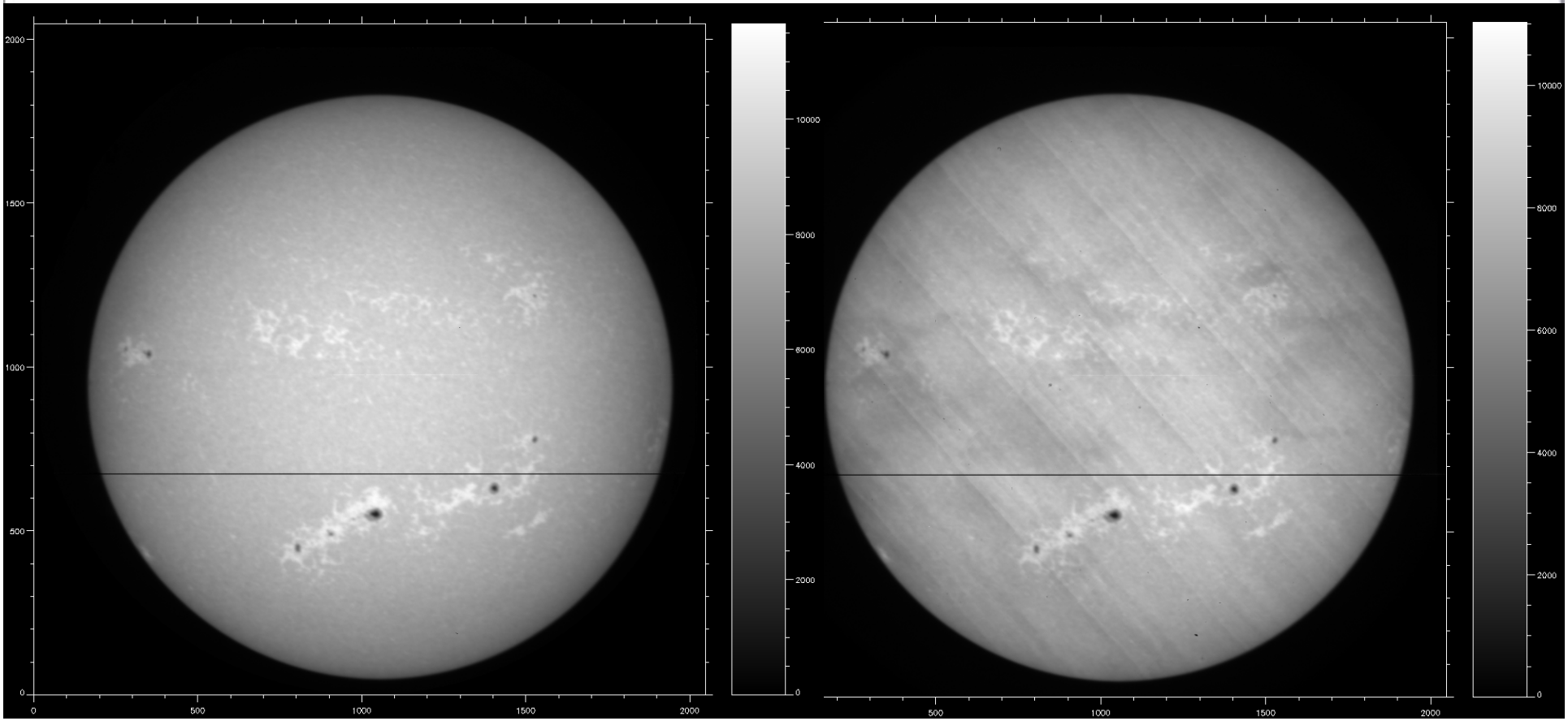
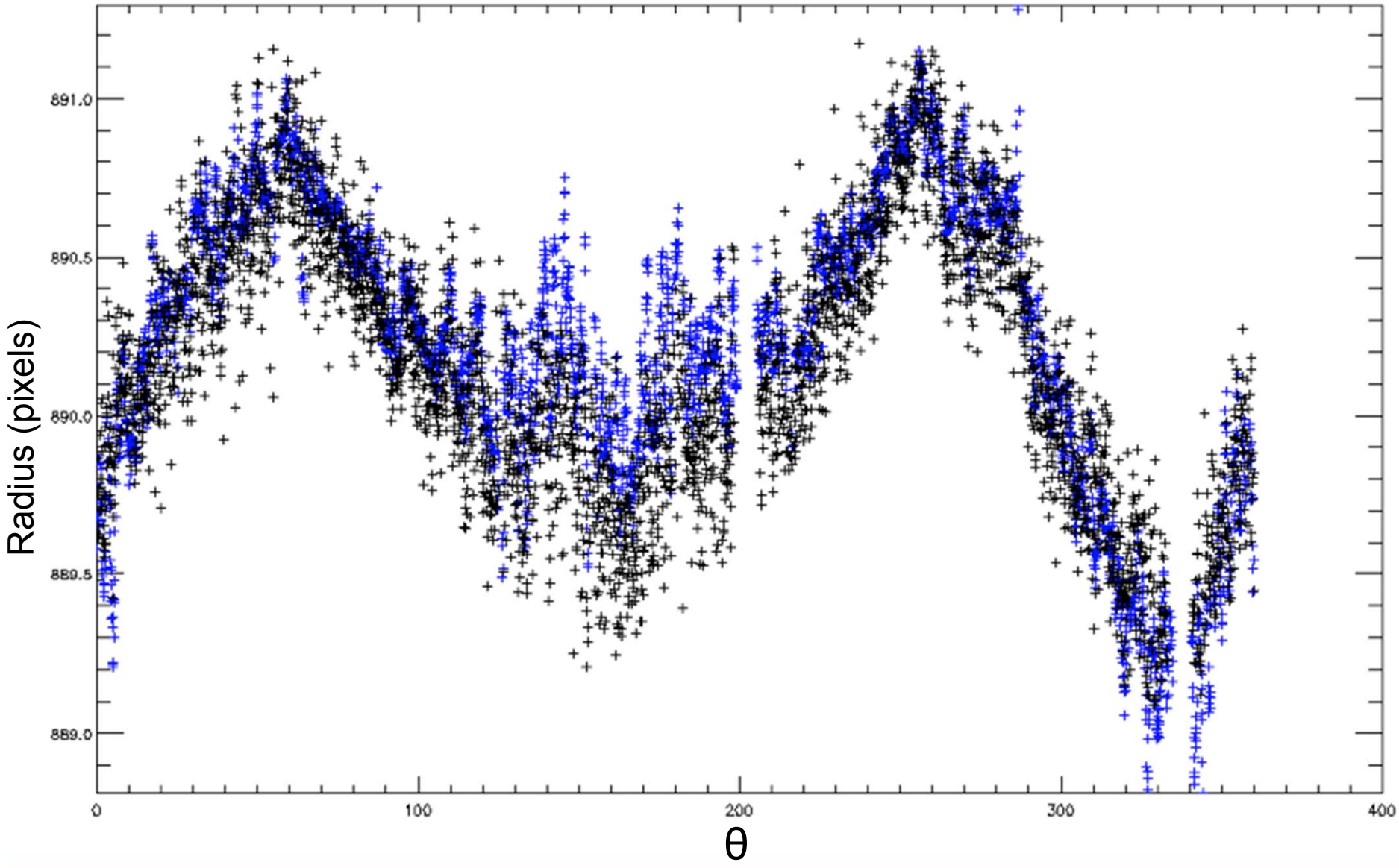


PICARD

Mission d'étude des relations entre la variabilité solaire et le climat de la Terre. Mieux comprendre les changements climatiques par une meilleure connaissance du Soleil.

LATMOS

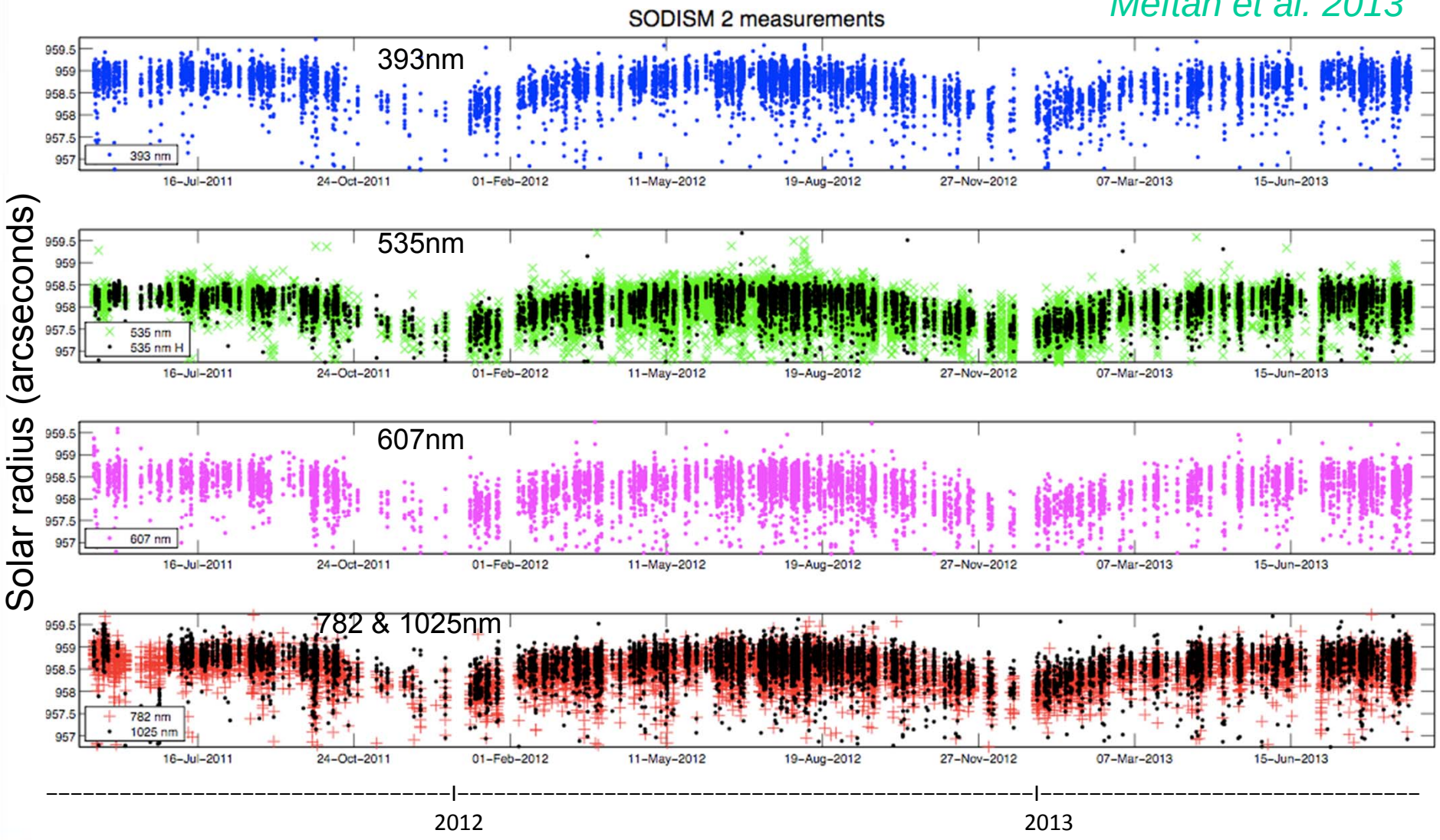
Raw shape



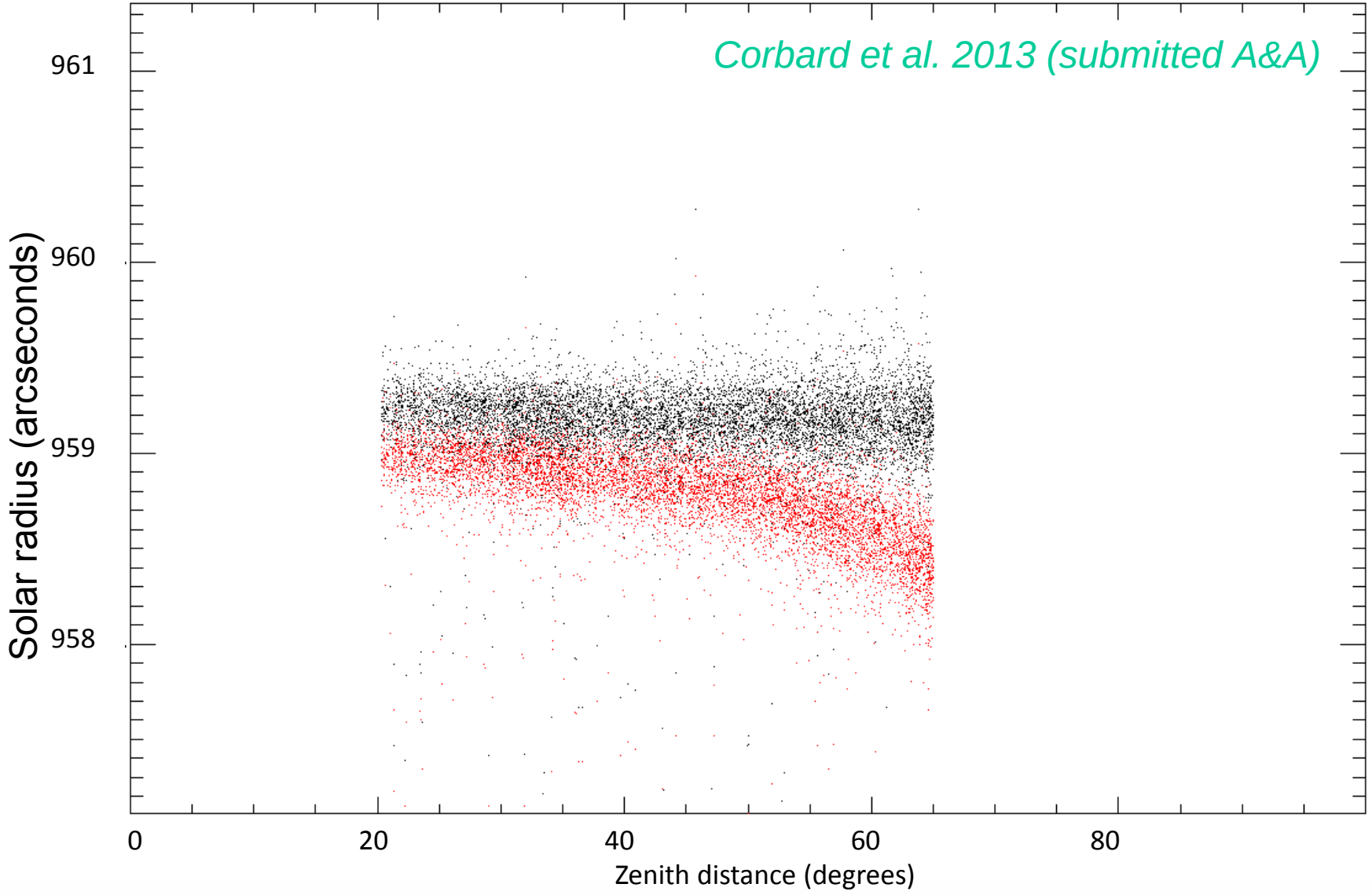
PICARD Mission d'étude des relations entre la variabilité solaire et le climat de la Terre. Mieux comprendre les changements climatiques par une meilleure connaissance du Soleil.

Radius before refraction correction

Meftah et al. 2013



Atmospheric refraction correction



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LATMOS

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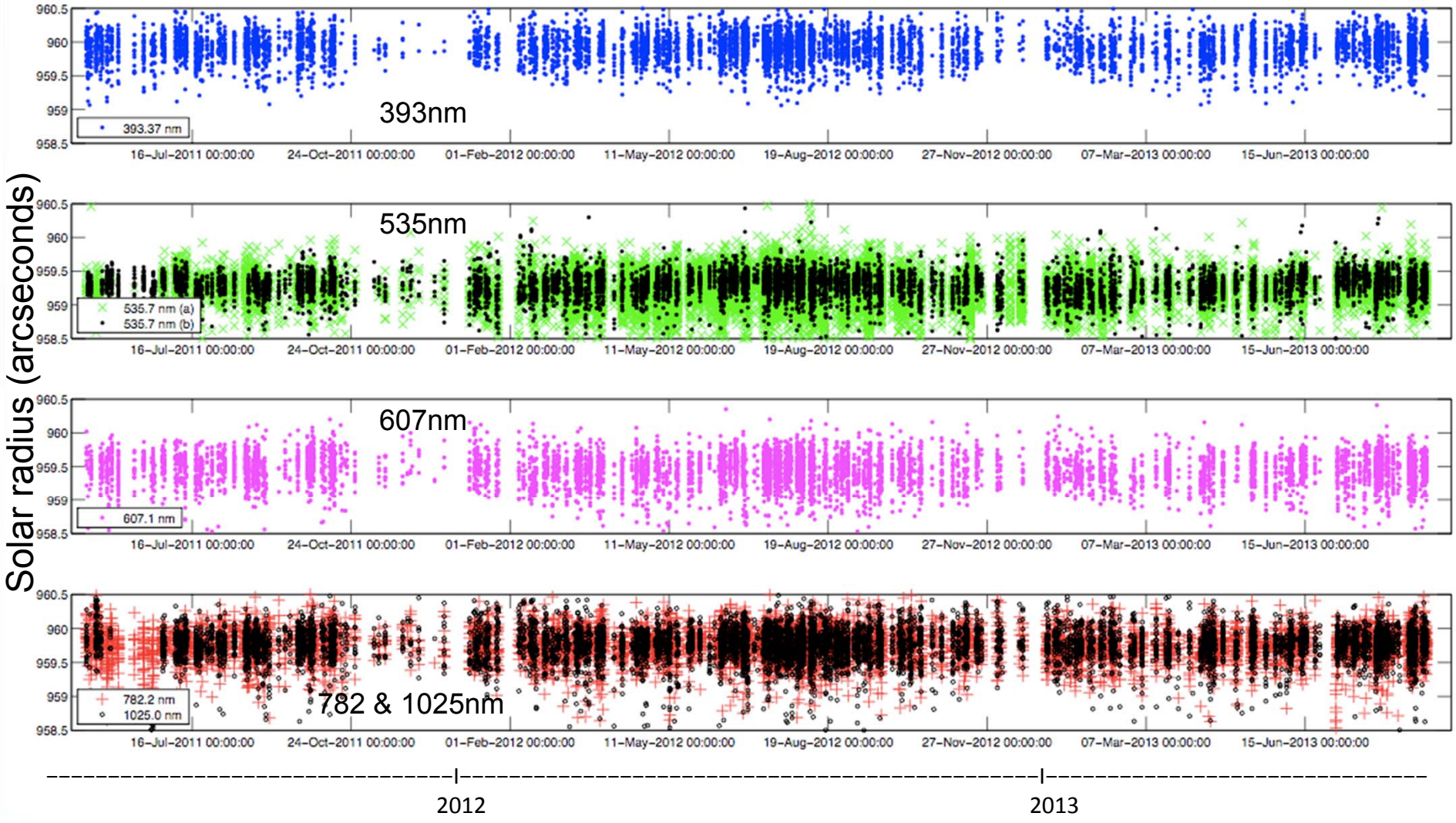

PICARD

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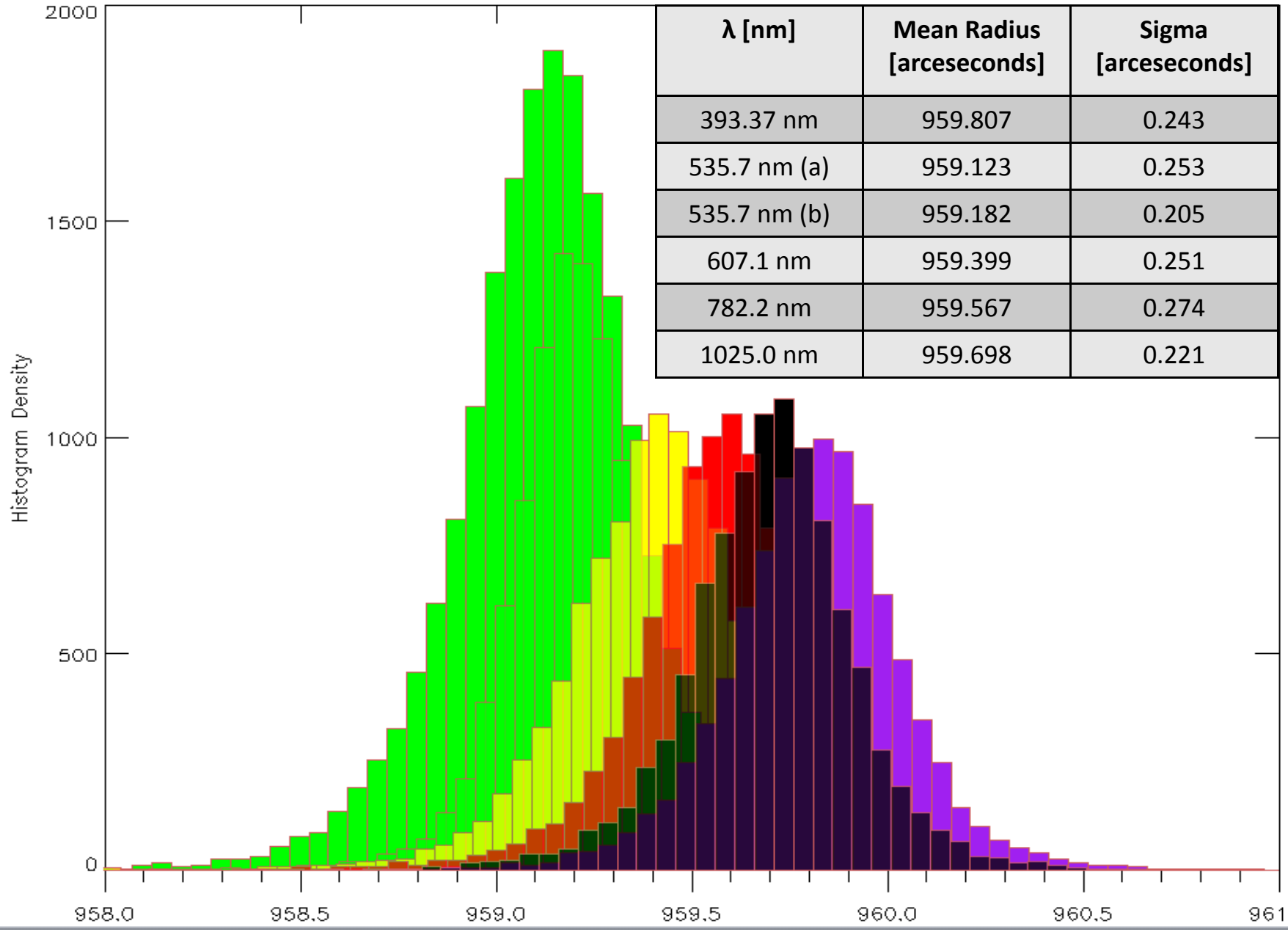
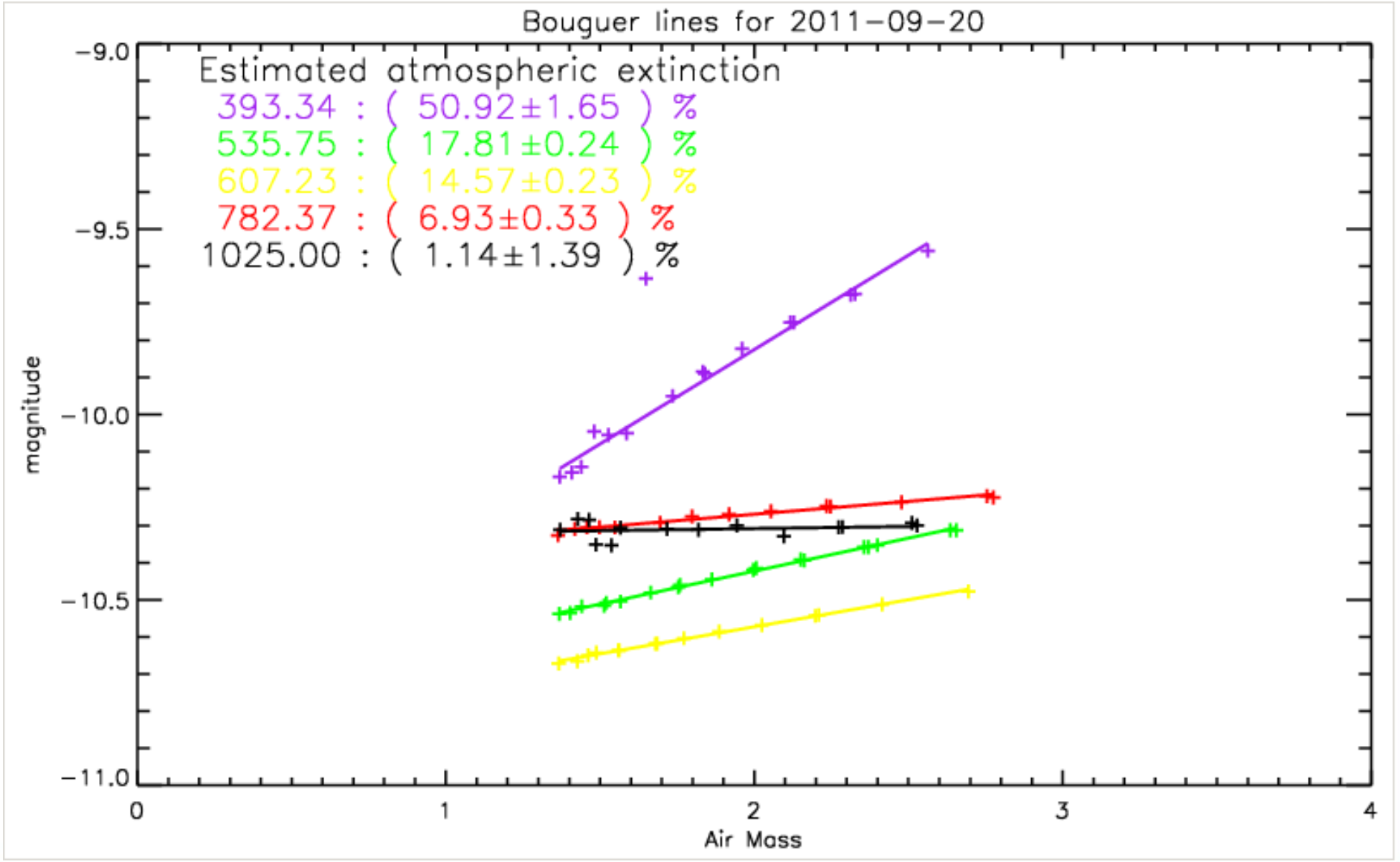
LATMOS

λ [nm]	Mean Radius [arceseconds]	Sigma [arceseconds]
393.37 nm	959.807	0.243
535.7 nm (a)	959.123	0.253
535.7 nm (b)	959.182	0.205
607.1 nm	959.399	0.251
782.2 nm	959.567	0.274
1025.0 nm	959.698	0.221

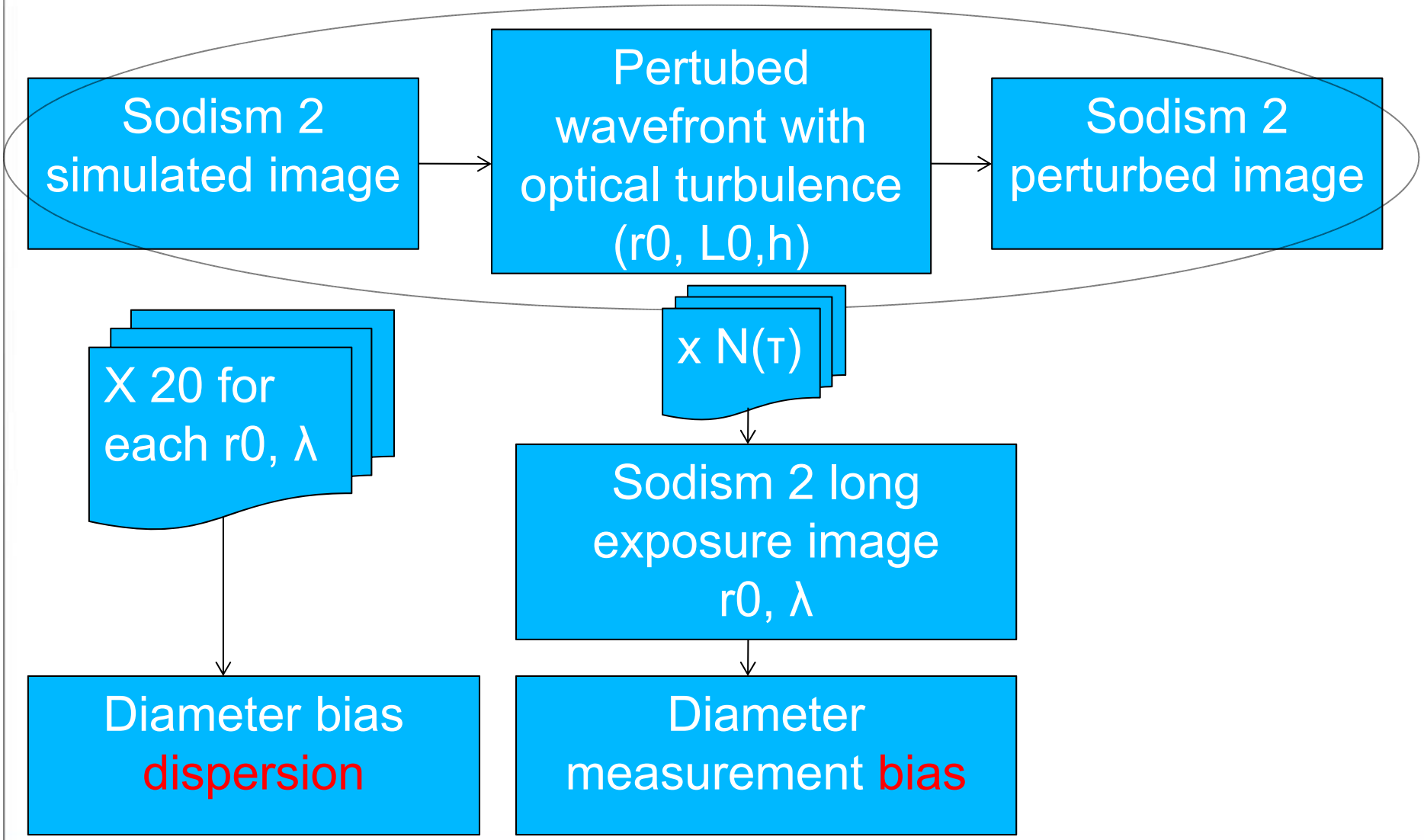


PICARD Mission d'étude des relations entre la variabilité solaire et le climat de la Terre. Mieux comprendre les changements climatiques par une meilleure connaissance du Soleil.

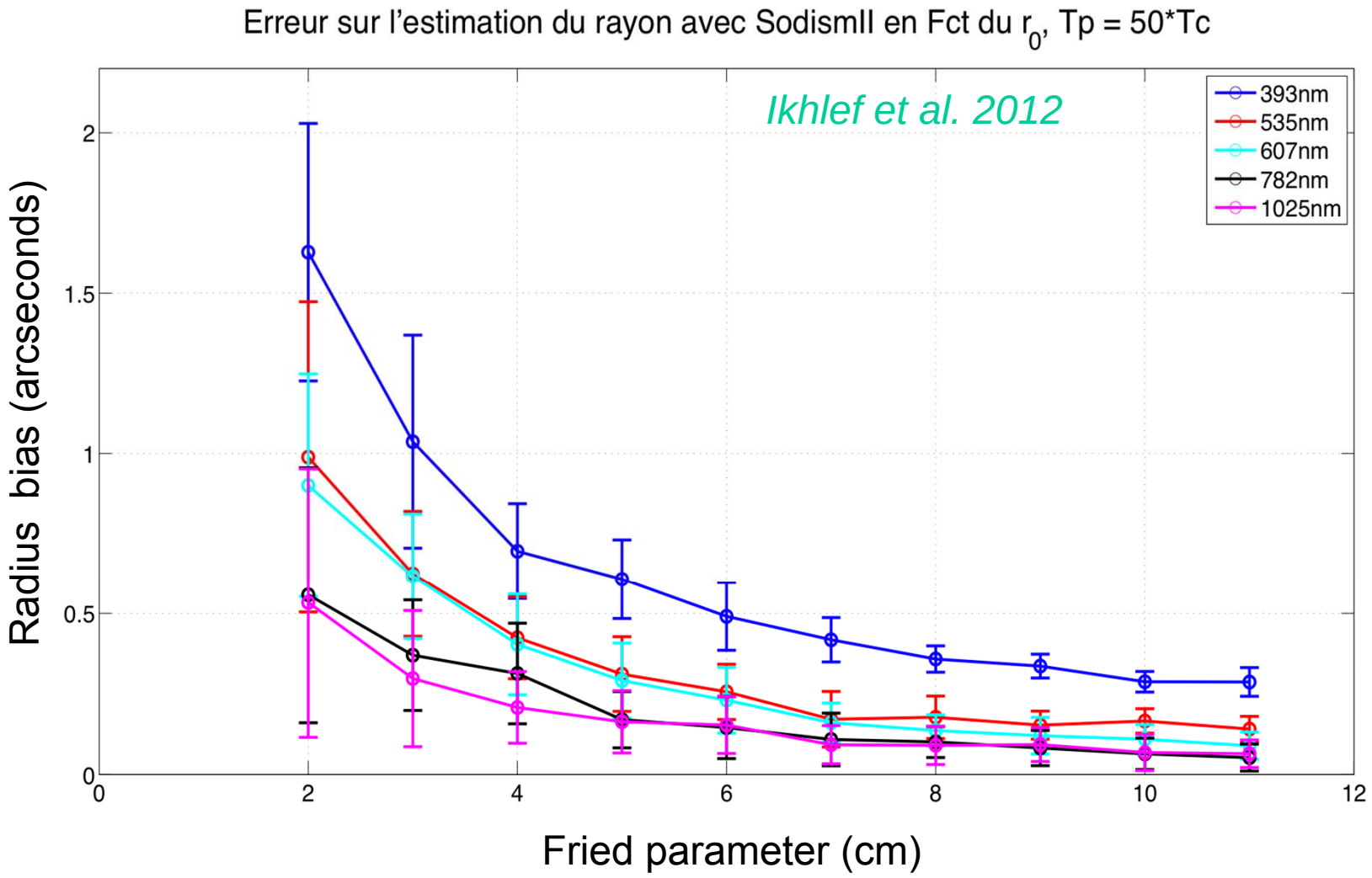
Bouguer image selection



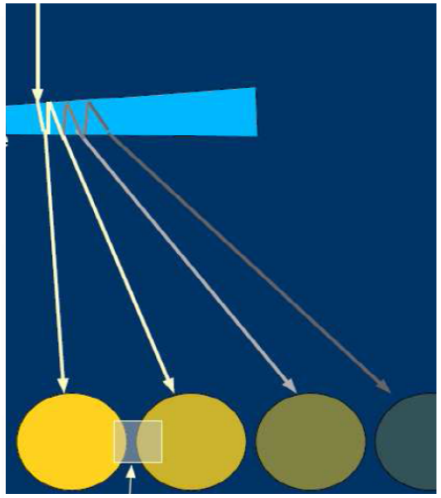
Optical turbulence effect - Numerical simulations

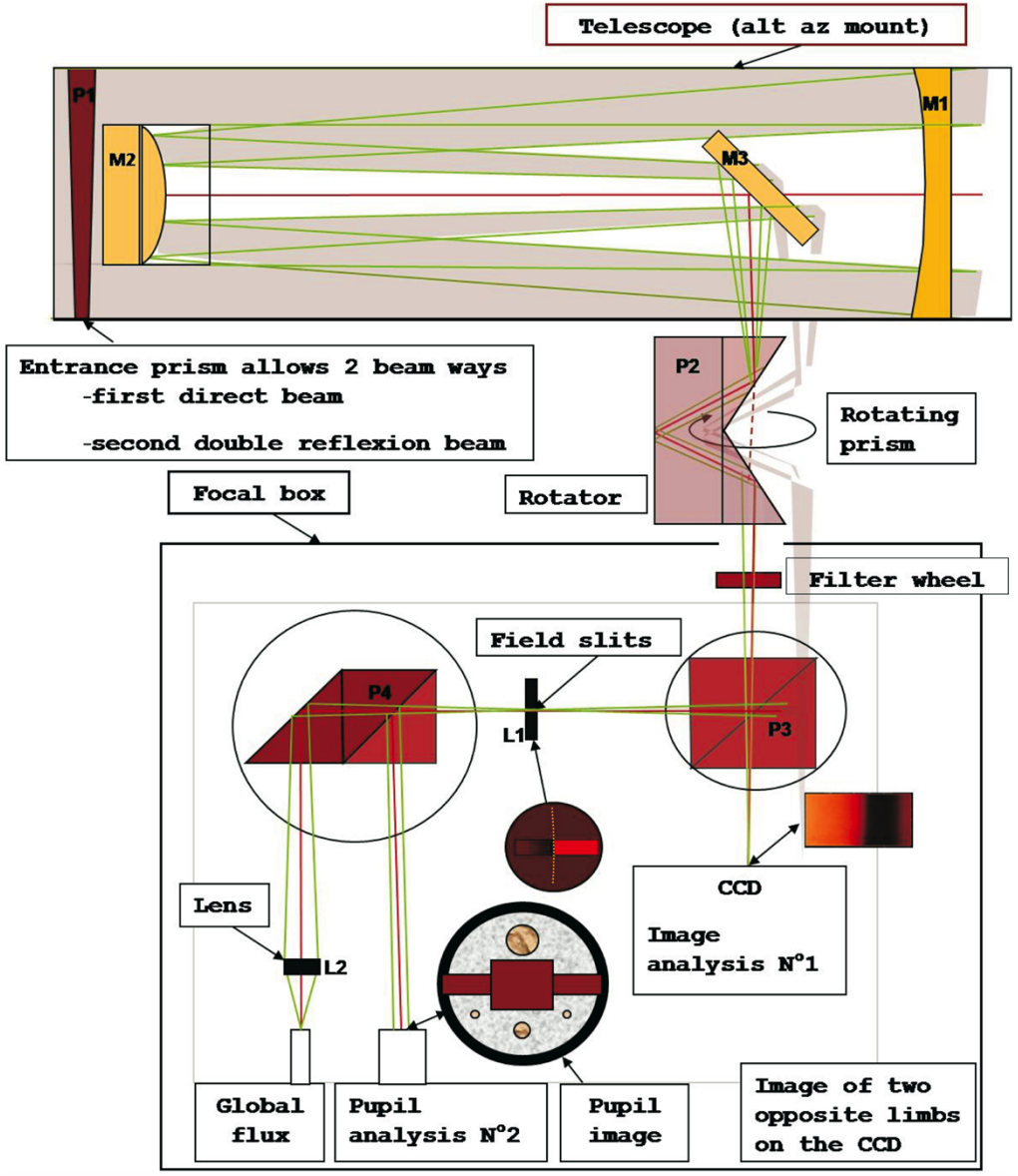


Seeing effect - Numerical simulations



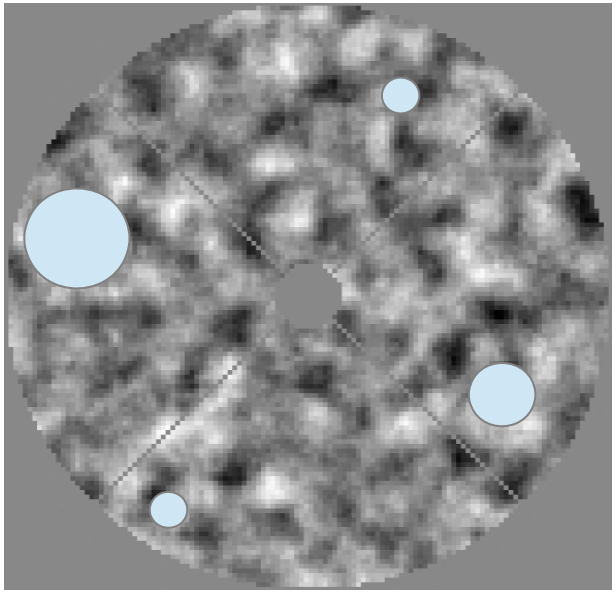
MISOLFA




Telescope (alt az mount)
P1
M1
M2
M3
Entrance prism allows 2 beam ways
-first direct beam
-second double reflexion beam
P2
Rotating prism
Rotator
Focal box
Filter wheel
Field slits
P4
L1
P3
CCD
Image analysis N°1
Lens
L2
Global flux
Pupil analysis N°2
Pupil image
Image of two opposite limbs on the CCD

Data processing

Pupil plane



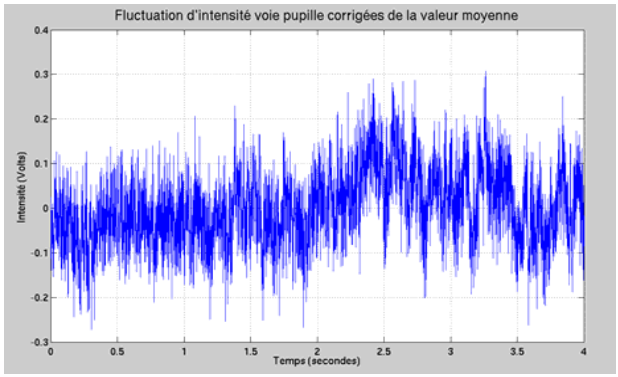
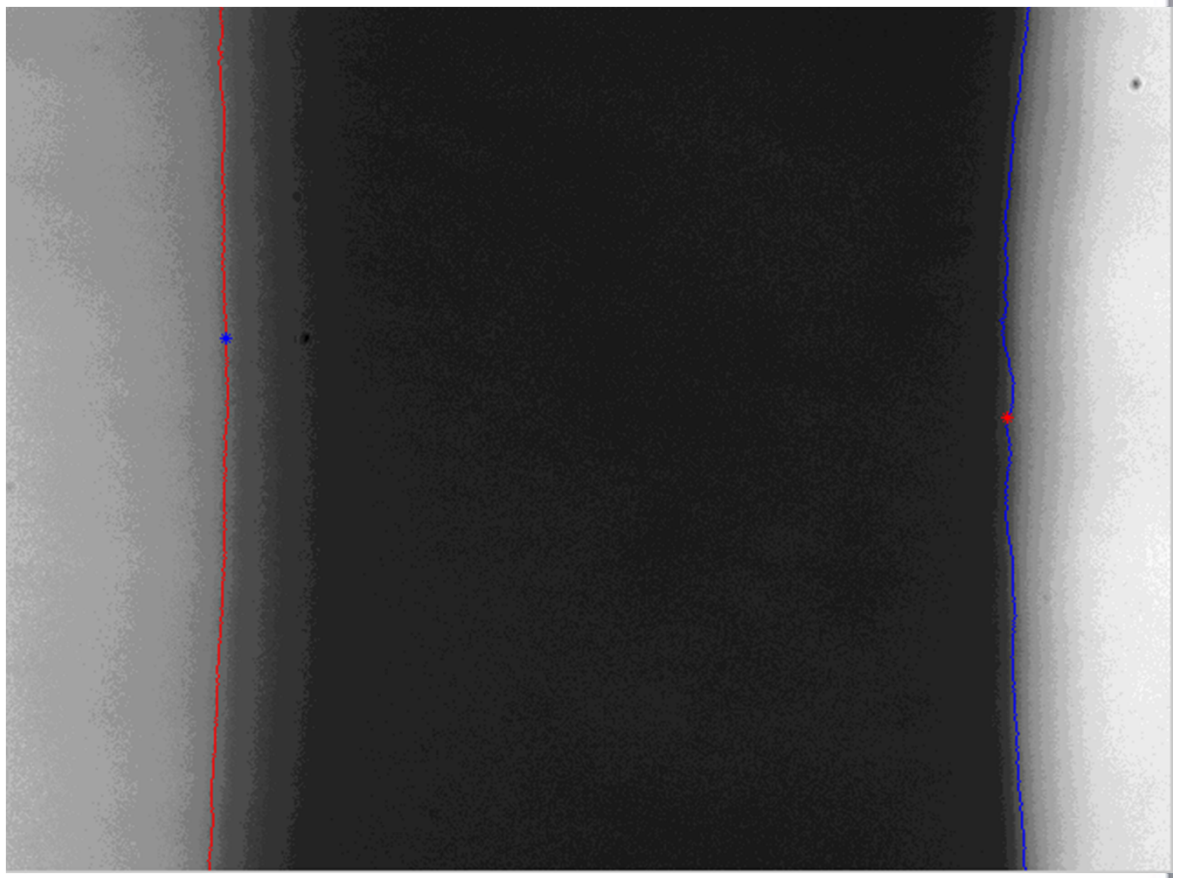


Image plane

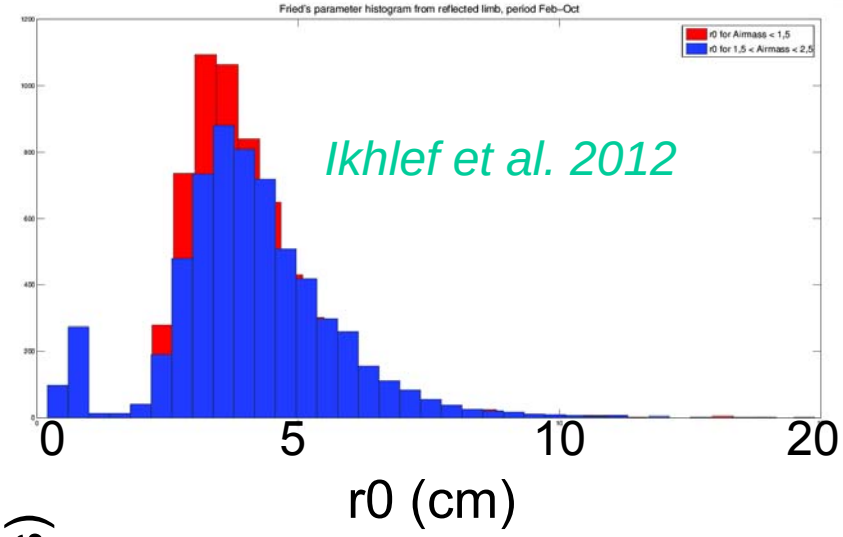


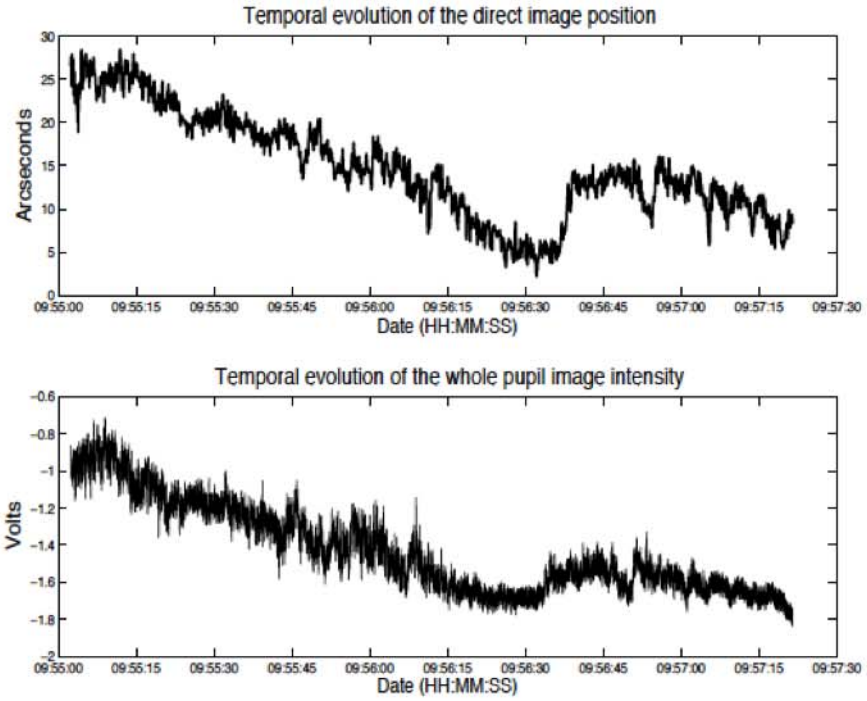
PICARD Mission d'étude des relations entre la variabilité solaire et le climat de la Terre. Mieux comprendre les changements climatiques par une meilleure connaissance du Soleil.

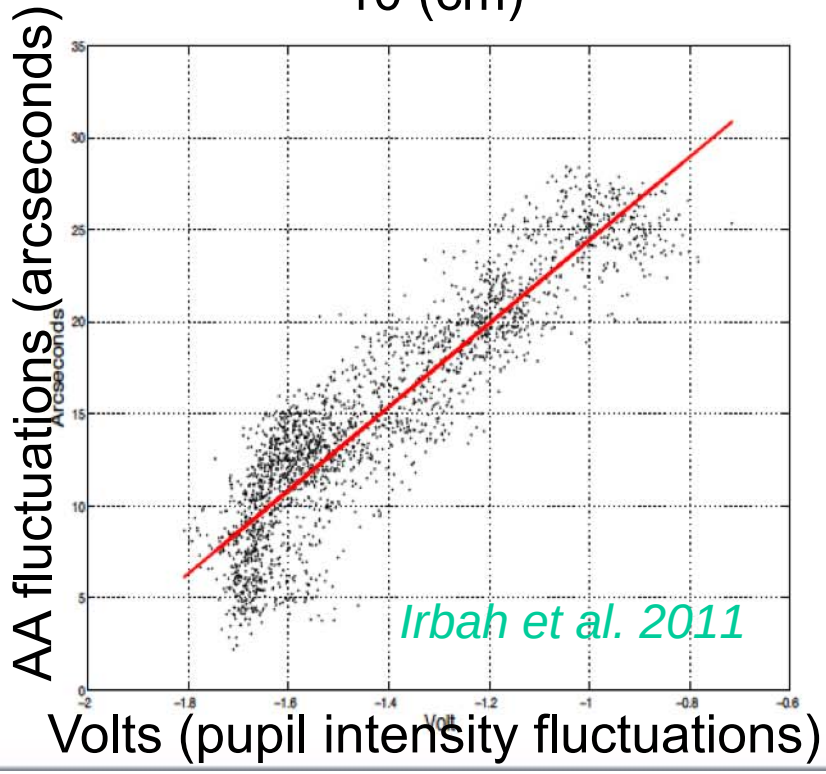
Results

Mesurements : MISOLFA

- Statistics r0: median value 3,86 cm
- First results from pupil plane observations (characteristic time)







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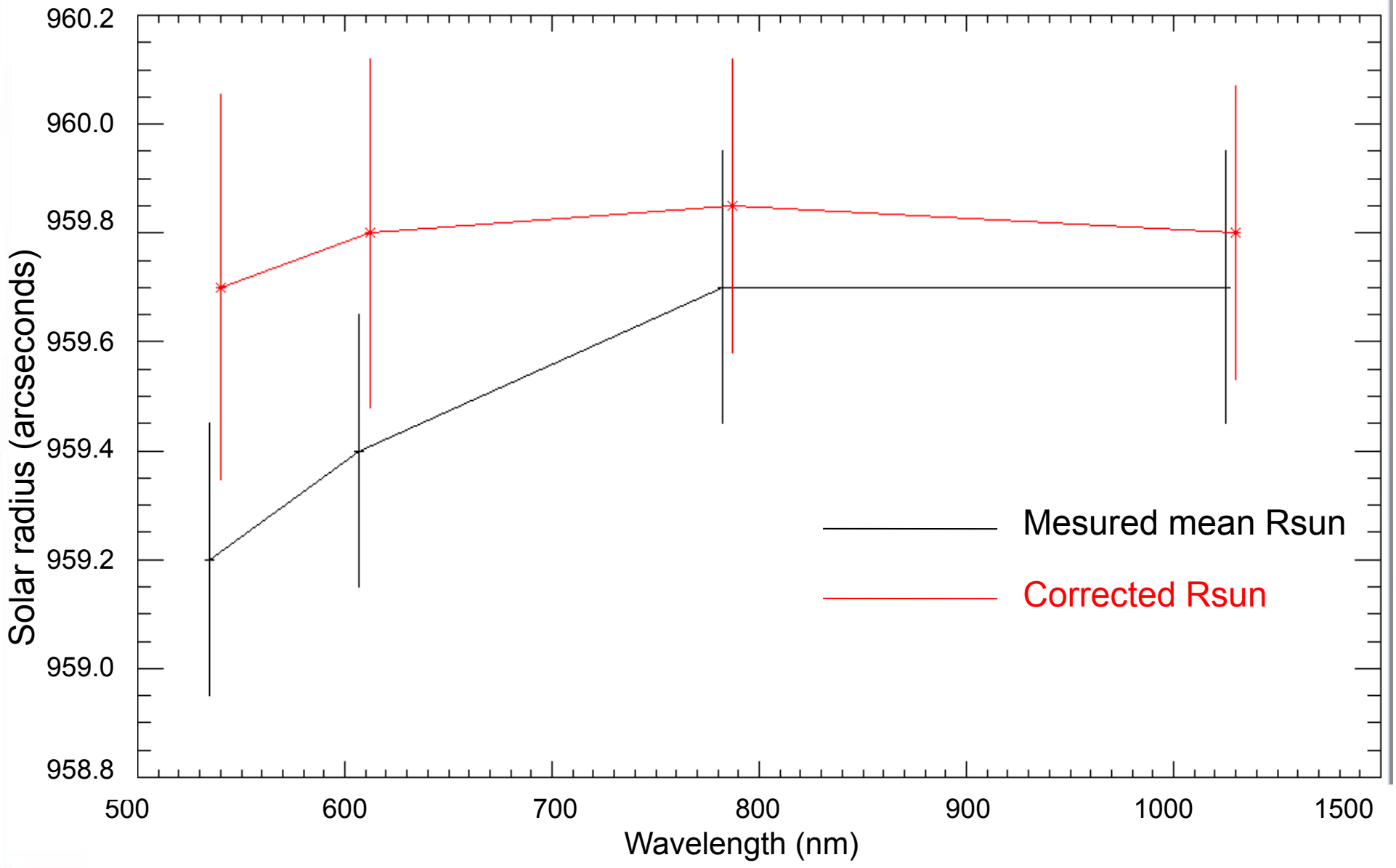
Correction on measured diameters



Conclusions and perspectives

- After 2,5 years of observations, we have a very good instrumental stability
- No significant trend in solar diameter detected so far
- About 200 mas of dispersion at the different wavelengths after astronomical refraction corrections
- Wavelength dependence partially explained by the bias introduced by optical turbulence
- Need a more complete exploitation of simultaneous observations SODISM-2/MISOLFA.
- Calibration of MISOLFA measurements with other instruments (S-DIMM, MOSP, PBL …)

Recent papers

- Corbard, T., Morand, F., Laclare, F., Ikhlef, R., Meftah, M., *"**On the importance of astronomical refraction for modern Solar astrometric measurements**"*, Submitted to Astronomy and Astrophysics, 2013
- Meftah, M., Hauchecorne, A., Crepel, M., Irbah, A., Corbard, T., Djafer, D. and Hochedez, J.F., *"**The Plate Scale of the SODISM Instrument and the Determination of the Solar Radius at 607.1 nm**"*, Solar Physics, vol. 286, 2013
- Meftah, M., Corbard, T., Irbah, A., Morand, F., Ikhlef, R., Renaud, C., Hauchecorne, A., Assus, P., Chauvineau, B., Crepel, M., Dalaudier, F., Djafer, D., Fodil, M., Laclare, F., Lesueur, P., Lin, M. and Poiet, G., *"**PICARD SOL, a new ground-based facility for long-term solar radius measurements: first results**"*, Journal of Physics: Conference Series, vol. 440, 2013
- Corbard, T., "***SODISM-2 A ground based multi-wavelength full disk solar imager***", Synoptic Network Workshop, Boulder,CO-USA, April 22/24 2013, under press 2013
- Ikhlef, R., Corbard, T., Irbah, A., Meftah, M., Morand, F., Fodil, M., Assus, P., Renaud, C., Chauvineau, B. and the Picard-Sol Team, "***MISOLFA : a seeing monitor for daytime turbulence parameters measurement***", European Astronomical Society Publications Series, vol. 55, 2012
- Ikhlef, R., Corbard, T., Irbah, A., Morand, F., Fodil, M., Chauvineau, B., Assus, P., Renaud, C., Meftah, M., Abbaki, S., Borgnino, J., Cissé, E.M., D'Almeida, E., Hauchecorne, A., Laclare, F., Lesueur, P., Lin, M., Martin, F., Poiet, G., Rouzé, M., Thuillier, G. and Ziad, A., "***Atmospheric seeing measurements obtained with MISOLFA in the framework of the PICARD Mission***", SPIE: Ground-based and Airborne Telescopes IV, vol. 8444, 2012

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- Meftah, M., Irbah, A., Corbard, T., Morand, F., Thuillier, G., Hauchecorne, A., Ikhlef, R., Rouze, M., Renaud, C., Djafer, D., Abbaki, S., Assus, P., Chauvineau, B., Cissé, E.M., Dalaudier, F., D'Almeida, Eric, Fodil, M., Laclare, F., Lesueur, P., Lin, M., Marcovici, J.P. and Poiet, G., "***PICARD SOL mission, a ground-based facility for long-term solar radius measurement***", SPIE: Ground-based and Airborne Instrumentation for Astronomy IV, vol. 8446, 2012

- Morand, F., Delmas, Ch., Corbard, T., Chauvineau, B., Irbah, A., Fodil, M. and Laclare, F., "***Solar radius measurements with the DORAYSOL instrument (1999-2006) at the Calern site of the observatoire de la Côte d'Azur***", Comptes Rendus Physique, vol. 11, 2011

- Irbah, A., Meftah, M., Corbard, T., Ikhlef, R., Morand, F., Assus, P., Fodil, M., Lin, M., Ducourt, E., Lesueur, P., Poiet, G., Renaud, C. and Rouze, M., "***Ground-based solar astrometric measurements during the PICARD mission***", SPIE - Optics in Atmospheric Propagation and Adaptive Systems XIV, eds. Stein, K. and Gonglewski, J.D., Prague, vol. 8178, 2011

- Irbah, A., Corbard, T., Assus, P., Borgnino, J., Dufour, C., Ikhlef, R., Martin, F., Meftah, M., Morand, F., Renaud, C. and Simon, E., "***The solar seeing monitor MISOLFA: presentation and first results***", SPIE - Society of Photo-Optical Instrumentation Engineers Conference Series, vol. 7735, 2010

- Corbard, T., Irbah, A., Assus, P., Dufour, C., Fodil, M., Morand, F., Renaud, C. and Simon, E., "***MISOLFA solar monitor for the ground PICARD program***", Astronomische Nachrichten, vol. 331, 2010