Dome C site testing : long term statistics of integrated optical turbulence parameters at ground level

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We present long term site testing statistics based on DIMM and GSM data obtained at Dome C, Antarctica. These data have been collected on the bright star Canopus since the end of 2003. We give values of the integrated turbulence parameters in the visible (wavelength 500 nm). The median value we obtained for the seeing are 1.2 arcsec, 2.0 arcsec and 0.8 arcsec at respective elevations of 8m, 3m and 20m above the ground. The median thickness of the surface layer is between 27m and 35 m in winter. Above this height, the seeing is 0,4 arcsec 50% of the time.
The isoplanatic angle median value is 4.0 arcsec and the median outer scale is 7.5m. We found that both the seeing and the isoplanatic angle exhibit a strong dependence with the season (the seeing is larger in winter while the isoplanatic angle is smaller).

Seeing ε measurements

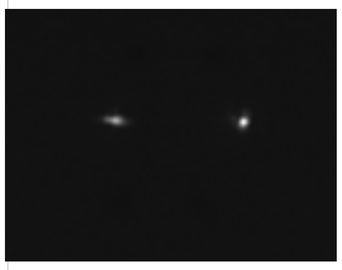
2 sub-pupils (1 with glass prism)

Celestron 11
d=28 cm, f = 2.8 m+2x barlow
tube in INVAR

2 holes mask on pupil
diam. D=6 cm
sep. B=20 cm

glass prism : deviation ~ 1 arcmin

CCD (PCO/Pixelfly)
max sensitivity=500 nm
pixel size=10 µm (+binning2x2)
Frame rate : 14 images/sec
thermostated at –10°C

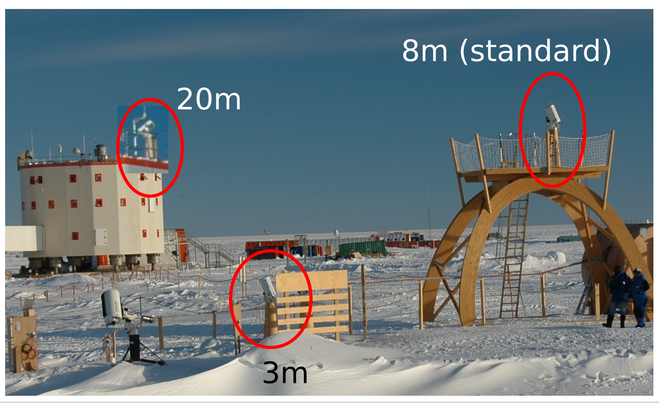


Exposure time 5 ms

Real-time estimation of barycenter positions

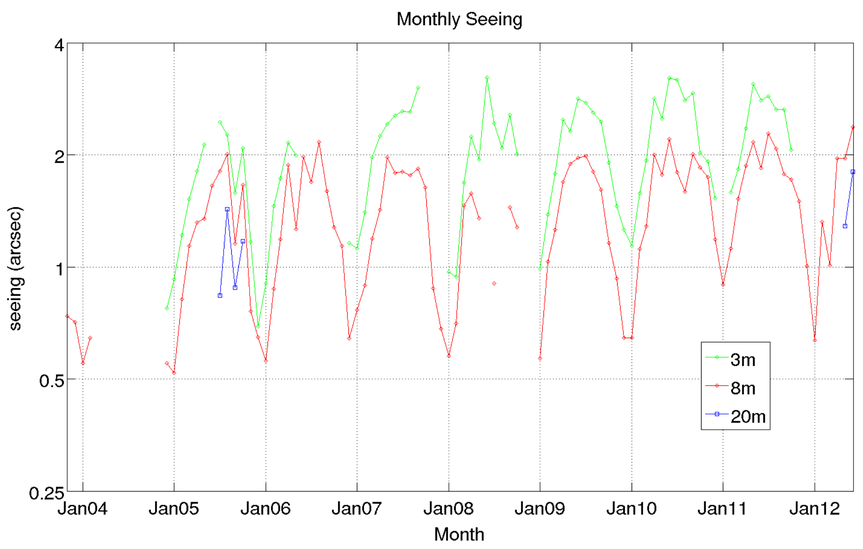
Computation of the variances σ_x,σ_y of transverse and longitudinal distances on sequences of 2mn (~ 6000 frames)

2 seeing values every 2 minutes (from σ_x,σ_y, Tokovinin 2002), averaged (rejected if their difference exceeds a threshold)



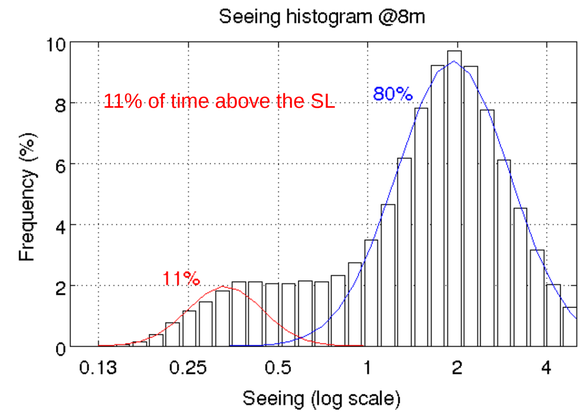
The standard DIMM is at the top of the arch (elevation h=8m above the ground).

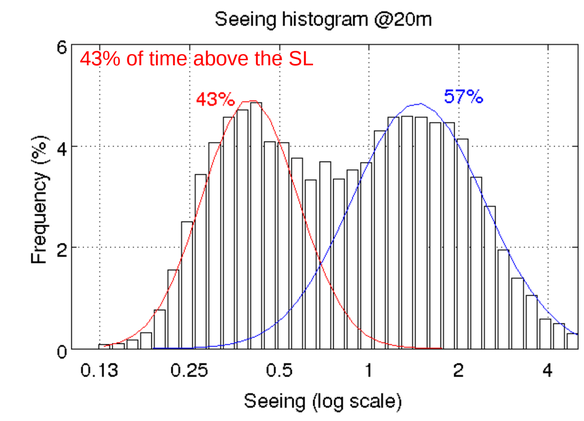
Additional DIMMs were deployed at h=3m (between 2005 and 2011) and on the roof of the calm building at h=20m (2005 and 2012).



Altitude	Period of observations	Median seeing winter (arcsec) April to September	Median seeing summer (arcsec) December-January
3 m	2005 to 2011	2,4 [1,8 – 3,2]	1,0 [0,7 – 1,3]
8 m	**Dec 2003-Jan 2004 Then dec 2004 to now**	**1,7 [1,0 – 2,4]**	**0,7 [0,4 – 0,8]**
20 m	July to October 2005 May – June 2012	0,85 [0,4 – 1,6] (Mauna Kea 0.6", Paranal 0.8 ")	N/A

Winter seeing histograms (April – September) show bimodal structure. The two regimes correspond to the DIMM either outside or inside the surface layer. Above the surface layer the median seeing is 0,4 arcsec.

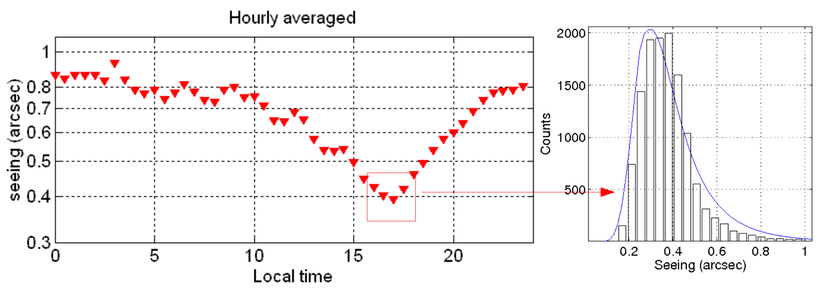




The summer situation

In summer the DIMM @8m is in the free atmosphere every day between 4 and 6pm.

Seeing=0.4'' [0.3 – 0.5]
(from 4 to 6pm)



Using 3 DIMMs at different elevation can give an estimation of the median thickness H_{sl} of the surface layer (Aristidi et al. 2009).

We found H_{sl} = 27m. Other estimation from balloon and Sonic data give 33m and 35m.

Isoplanatic angle θ_0 measurements

Principle : scintillation measurements of a point-source with a circular 10cm diameter pupil with 4 cm central obstruction (Loos & Hogge 1979)

Telescope & camera identical to the DIMM

Exposure time 5 ms

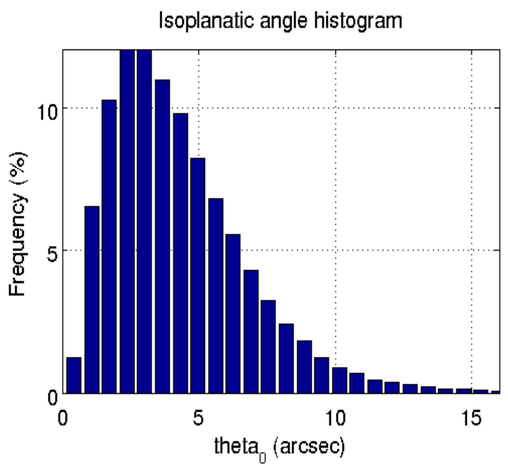
24/7 observations of Canopus

1 value of θ_0 per minute

$$s^2 = \left(\frac{\sigma_I}{\langle I \rangle}\right)^2$$

$$\theta_0^{-5/3} = K \cos z^{-8/3} s^2$$

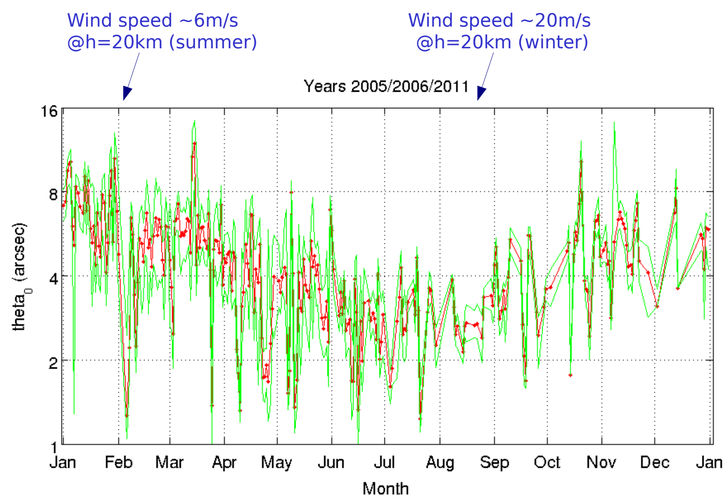
I : total intensity of the star in an 5ms exposure image
<*I*> : average over 1 mn (~ 6000 images) ; σ_I^2 = variance
z : zenital distance



Observation periods : 2005, 2006, 2011
Number of values : 90 491

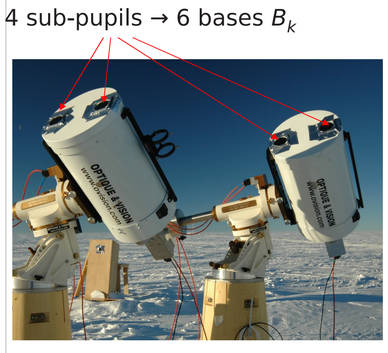
Median θ_0 : 4,1 " (Mauna Kea 1,9", Paranal 2,6")
Mean θ_0 : 4,6 "
75% percentile : 5,9 "
25% percentile : 2,7 "

Month-dependence of the isoplanatic angle. Best values are observed in summer when high altitude wind speeds are low (~6 m/s at h=20km).



Outer scale L_0 measurements

4 sub-pupils → 6 bases B_k

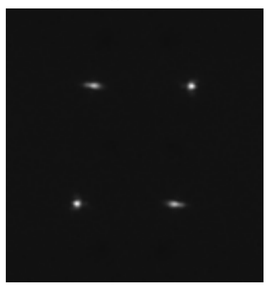


Generalized Seeing Monitor :

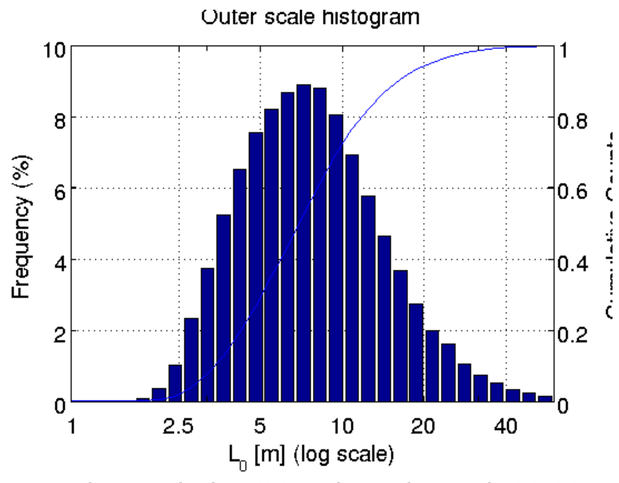
Two DIMM, synchronized at 1ms

24/7 observation of Canopus

4 sub-images of Canopus



- ❒ 4 sub-images (1 per pupil) every 14ms
- ❒ 6 covariances C(B_k) of sub-images motion averaged over 1-min sequences
- ❒ Fitting of Von-Karman-model on C(B_k) give 6 values of L_0 per mn (we retain the median of these 6 values)



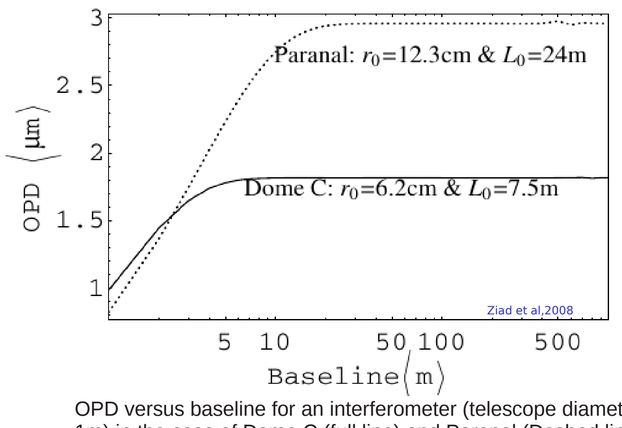
Observation periods : 2006 (March-May), 2008 to 2011
Nunber of values : 401 199

Median L_0 : 7,5 m (Mauna Kea 17m, Paranal 22m)
Mean L_0 : 9,4 m
75% percentile : 11.3 m
25% percentile : 5.1 m

Impact of the small L_0 on interferometry

The outer scale at Dome C is smaller than what is observed at temperate sites

Numerical computations (Ziad et al 2008) show that the fringe OPD for a 100m baseline is ~2 times smaller at Dome C than at Paranal, even with a poor seeing.



OPD versus baseline for an interferometer (telescope diameter 1m) in the case of Dome C (full line) and Paranal (Dashed line).