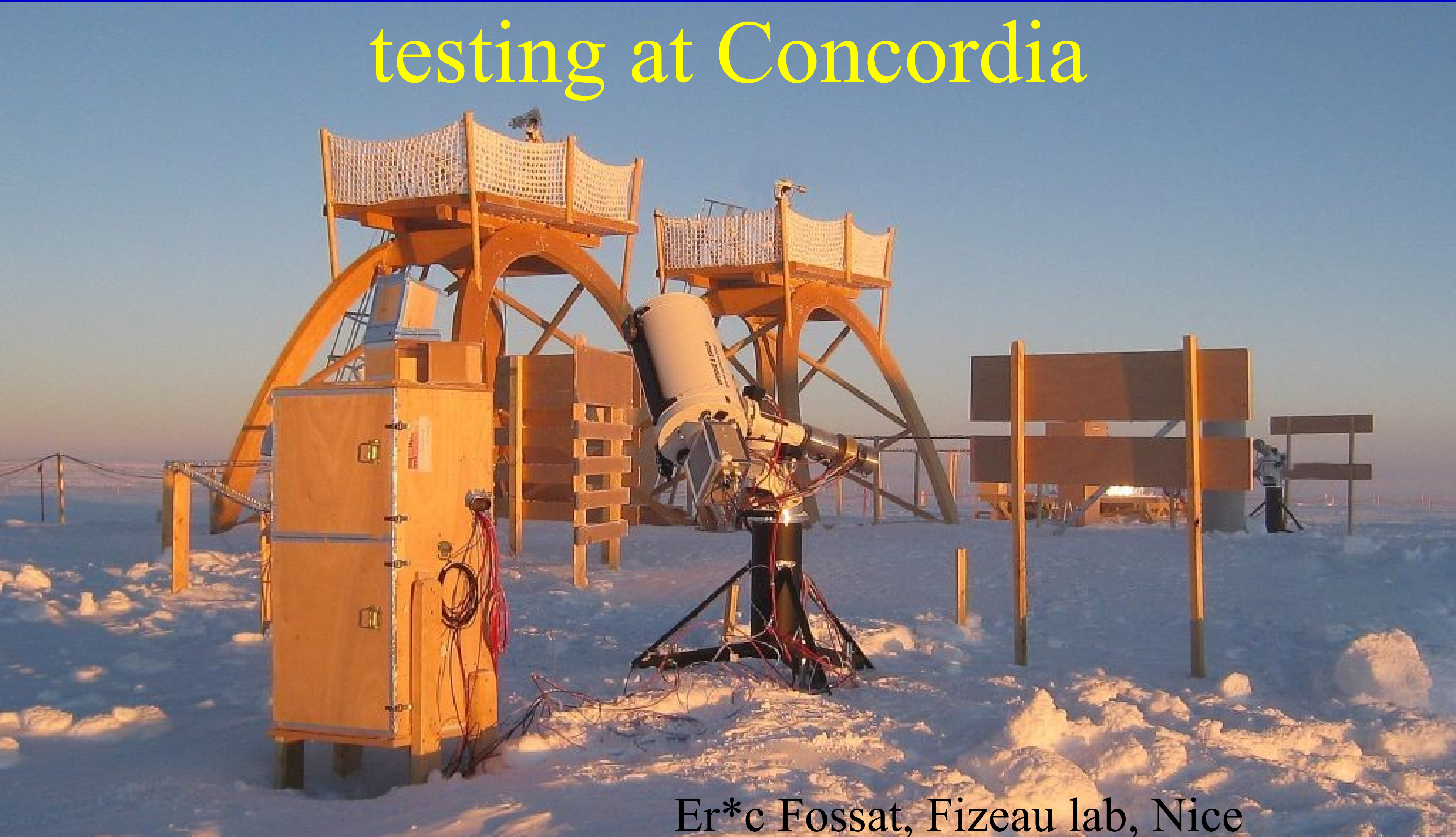
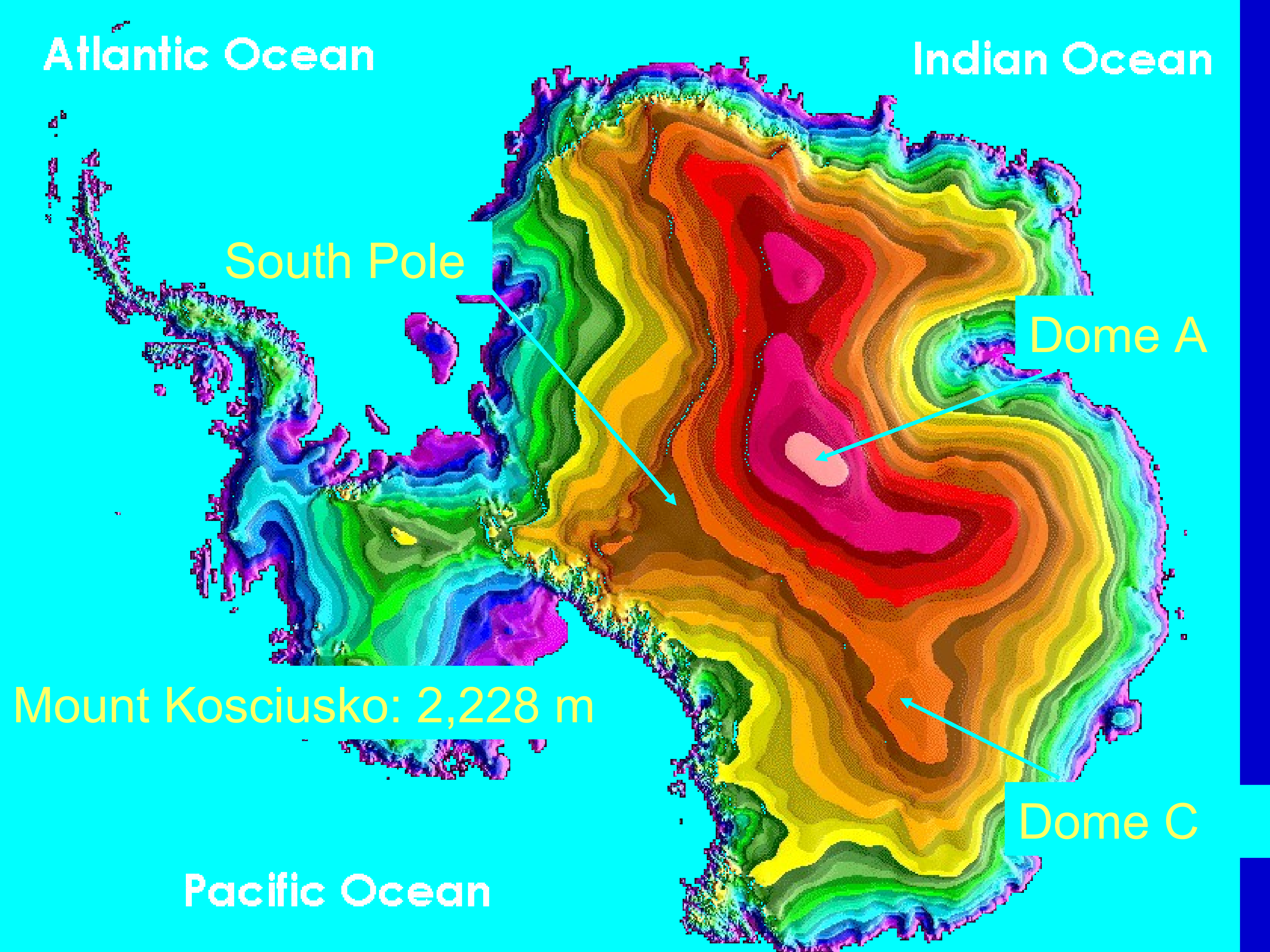
Some results after 10 years of site testing at Concordia



Er*c Fossat, Fizeau lab, Nice

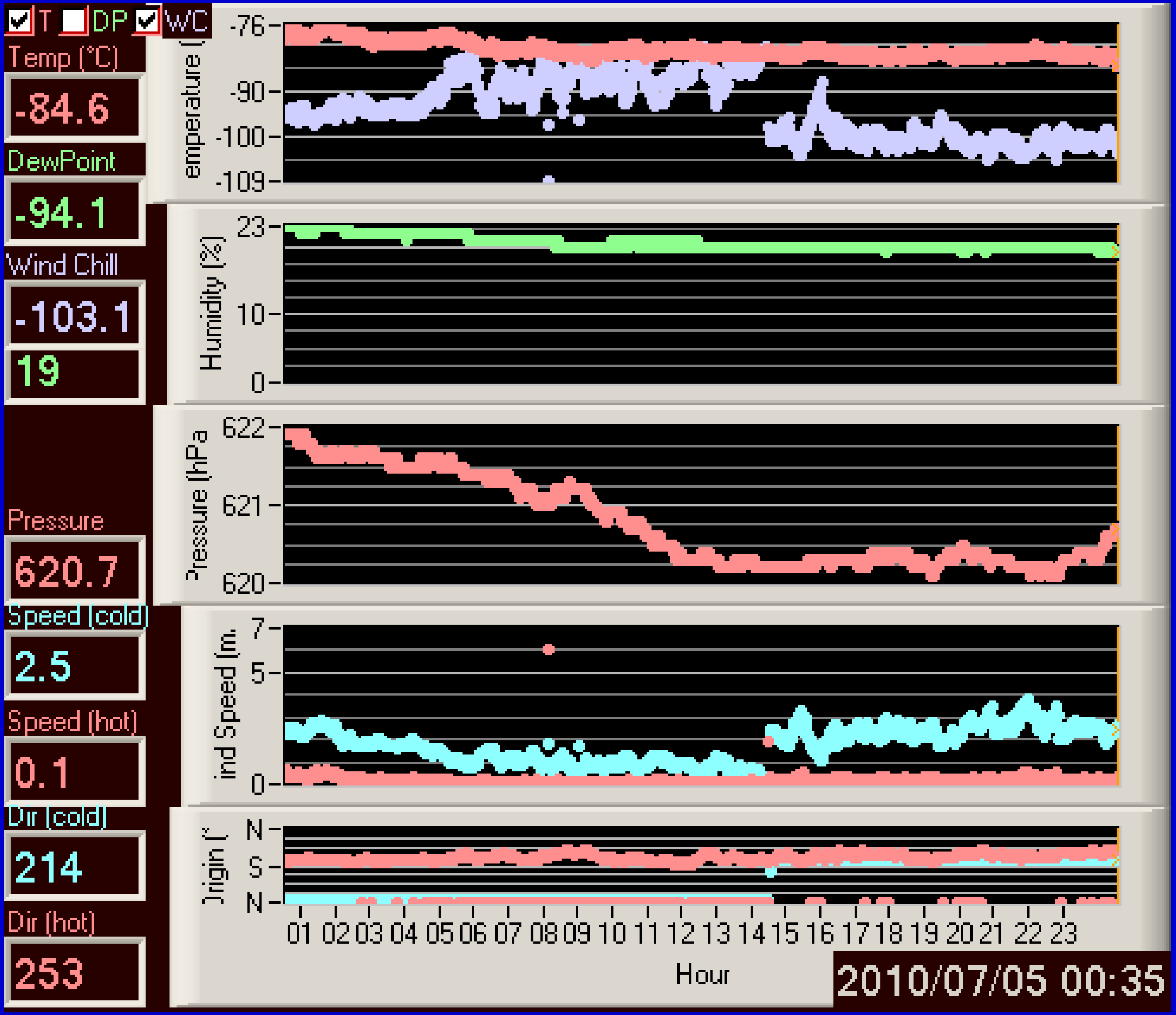
Site2010, Kislovodsk

- In the name of the Fizeau laboratory (Nice) extended site testing team: Aziz Ziad, Hervé Trinquet, Eric Aristidi, Jean Vernin, Lyu Abe, F.X. Schmider, J.B. Daban, J.P. Rivet, Richard Douet, Yan Fantei, and the winter-over heroes: Karim Agabi (Project Scientist, two winters!), Eric Aristidi, François Jeanneaux, Djamel Mekarnia, Erick Bondoux, Zalpha Challita, Cyprien Pouzenc, Denis Peterman.


Atlantic Ocean
Indian Ocean
South Pole
Dome A
Mount Kosciusko: 2,228 m
Dome C
Pacific Ocean

Dumont d’Urville, just for the beauty of the place

Astro-Concordia site testing equipment.
Altitudes are defined within one meter or so!



T
DP
WC
Temp (°C)
-84.6
DewPoint
-94.1
Wind Chill
-103.1
19
Pressure
620.7
Speed (cold)
2.5
Speed (hot)
0.1
Dir (cold)
214
Dir (hot)
253
emperature (
-76
-90
-100
-109
Humidity (%)
23
10
0
Pressure (hPa
622
621
620
ind Speed (m.
7
5
0
Origin (°
N
S
N
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour
2010/07/05 00:35

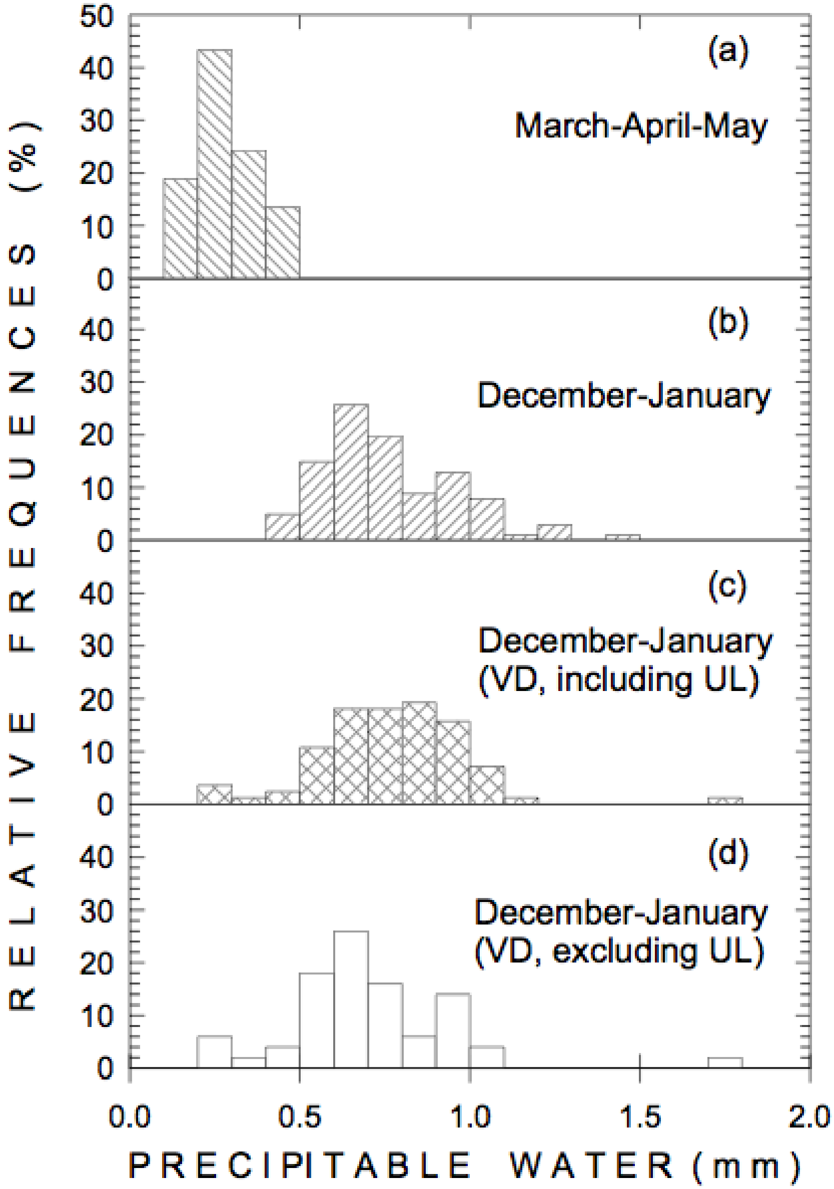
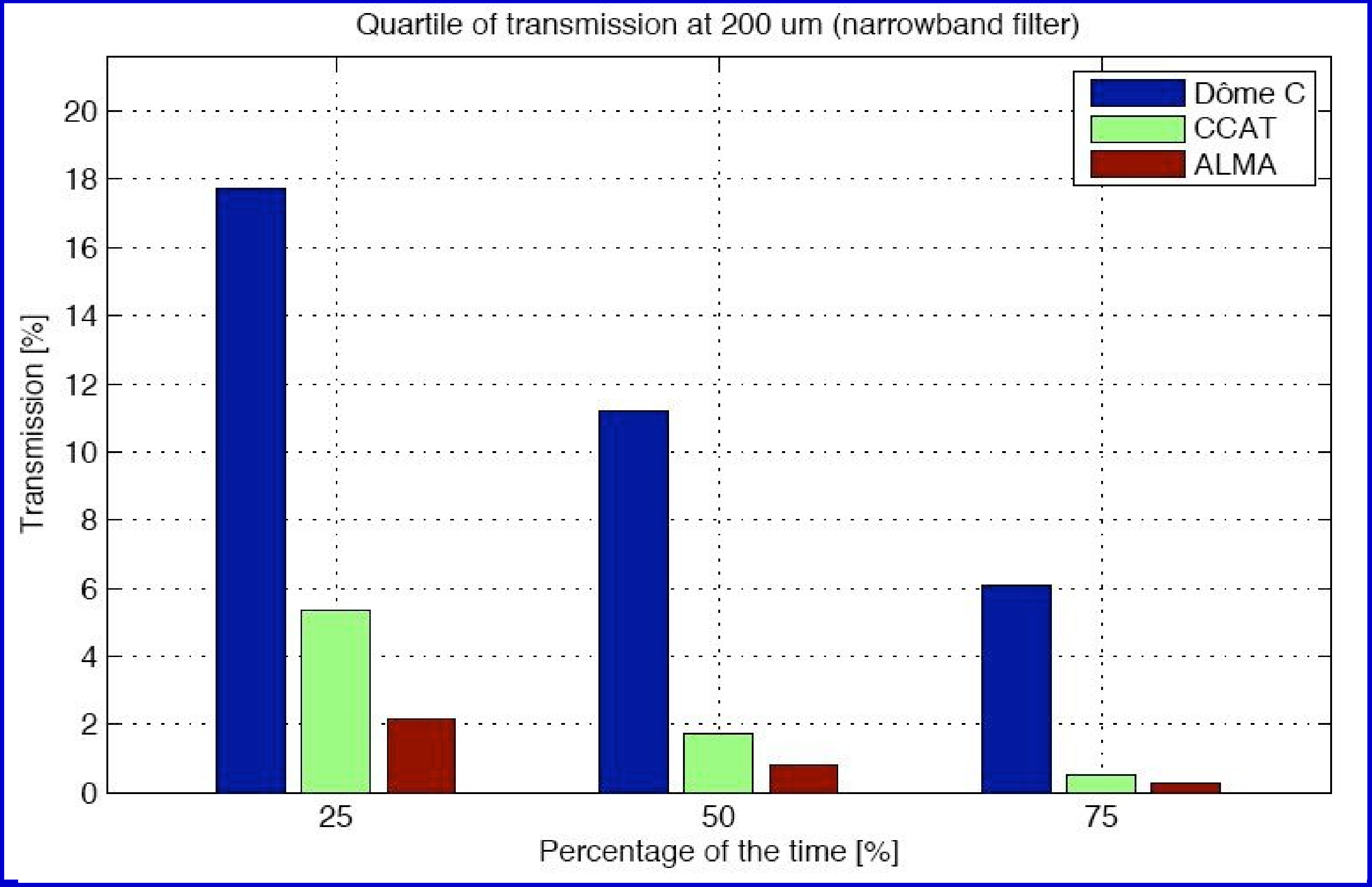
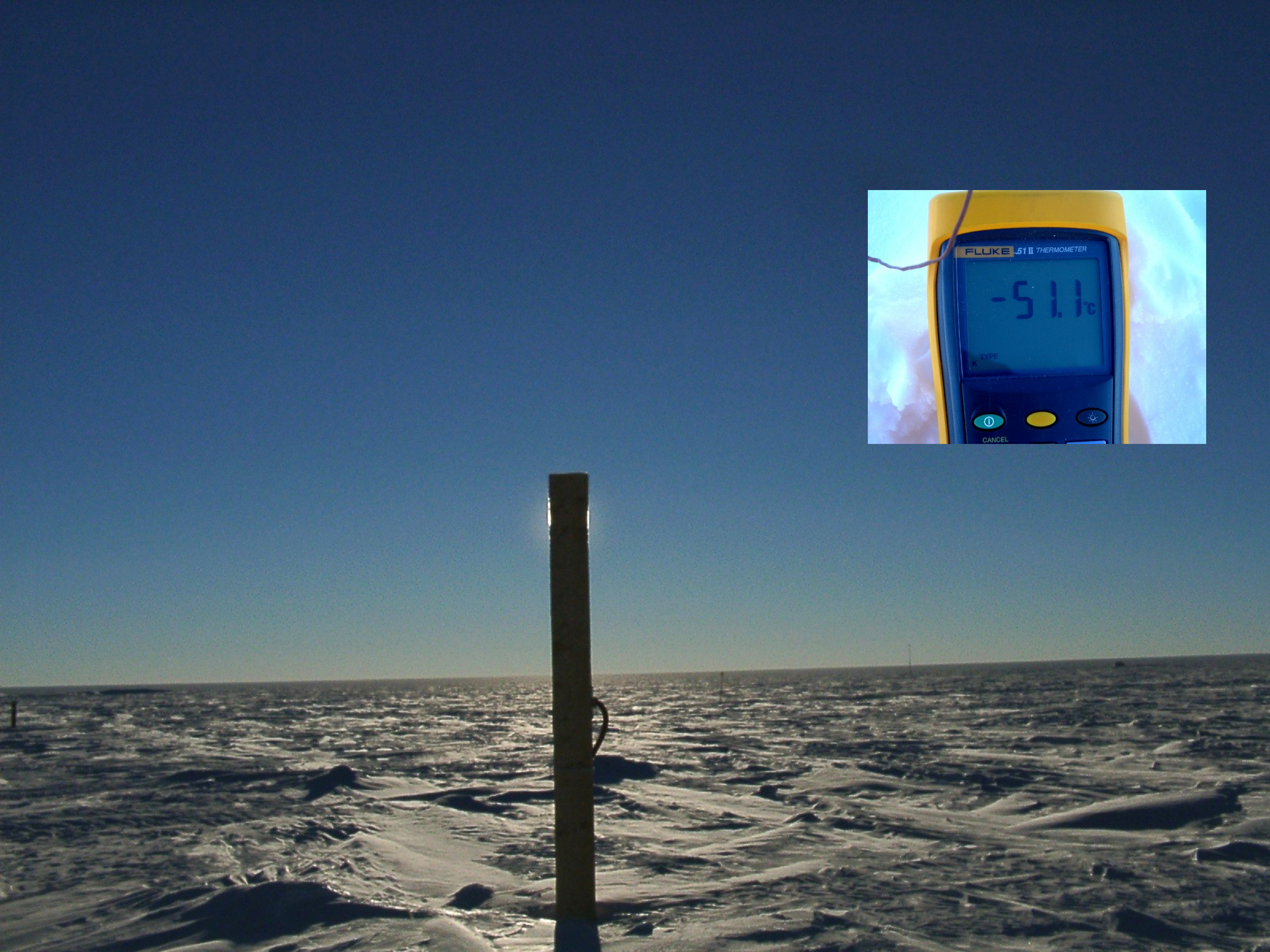


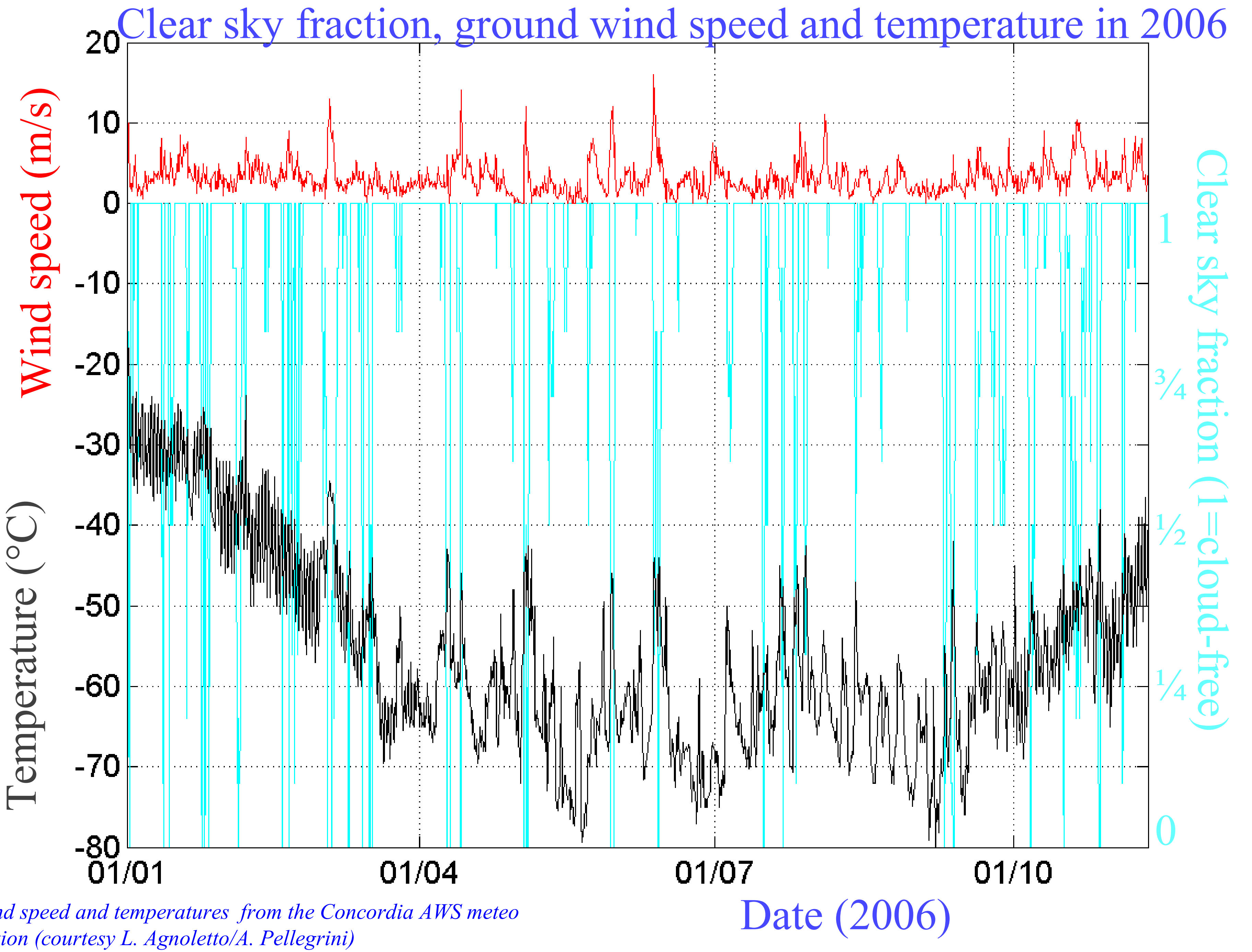
Figure 7.- Comparison among the relative frequency histograms of precipitable water *W* obtained for the following data-sets: (a) the present March/April/May data-set; (b) the present December/ January data-set; (c) the VD (Valenziano and Dall'Oglio, 1999) data-set including the Upper Limit (UL) data; and (d) the VD data-set excluding the UL data.

FIGURE 7

Transmission @ 350 and 200µm




FLUKE 51 II THERMOMETER
-51.1 °C
K TYPE
CANCEL

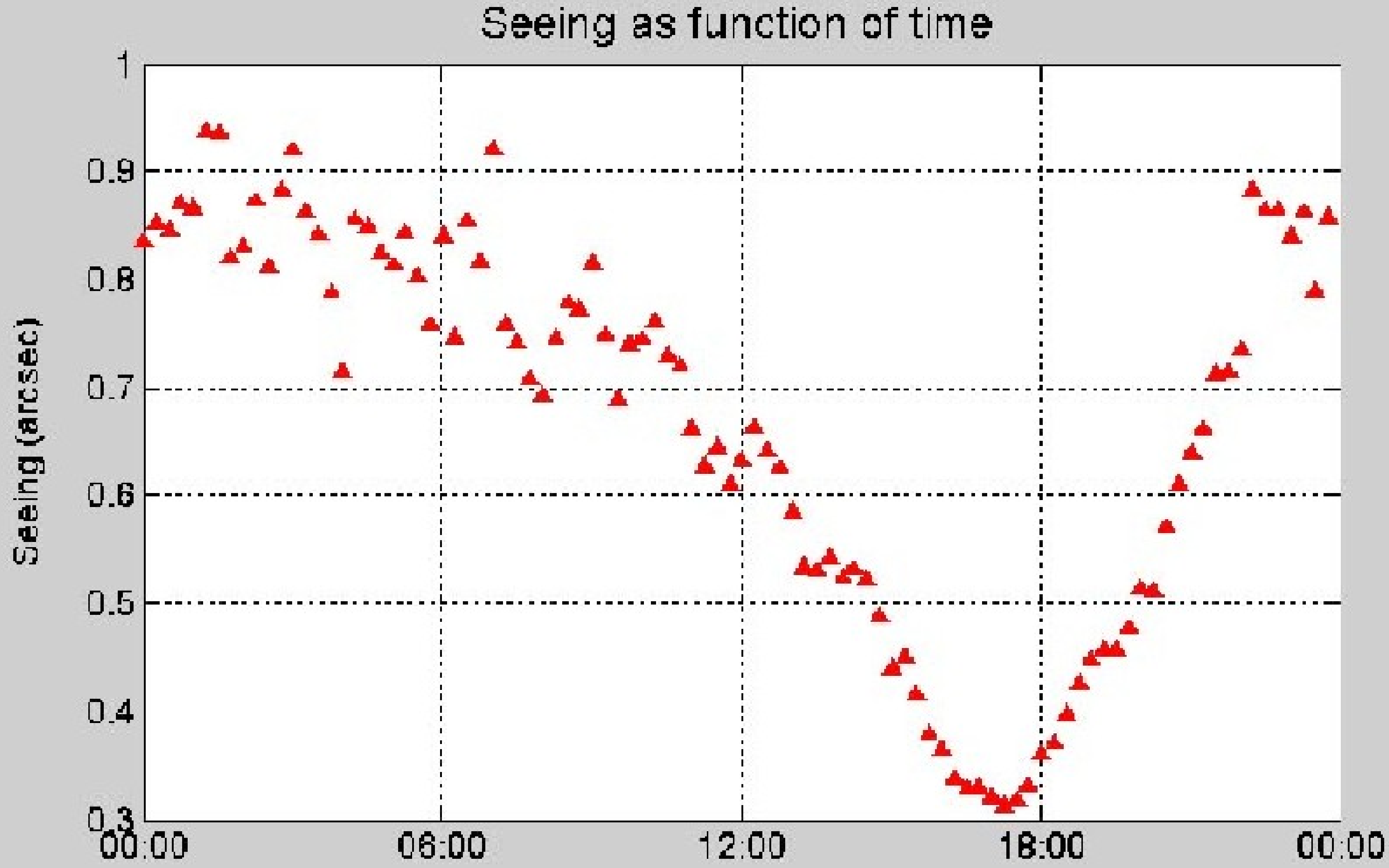


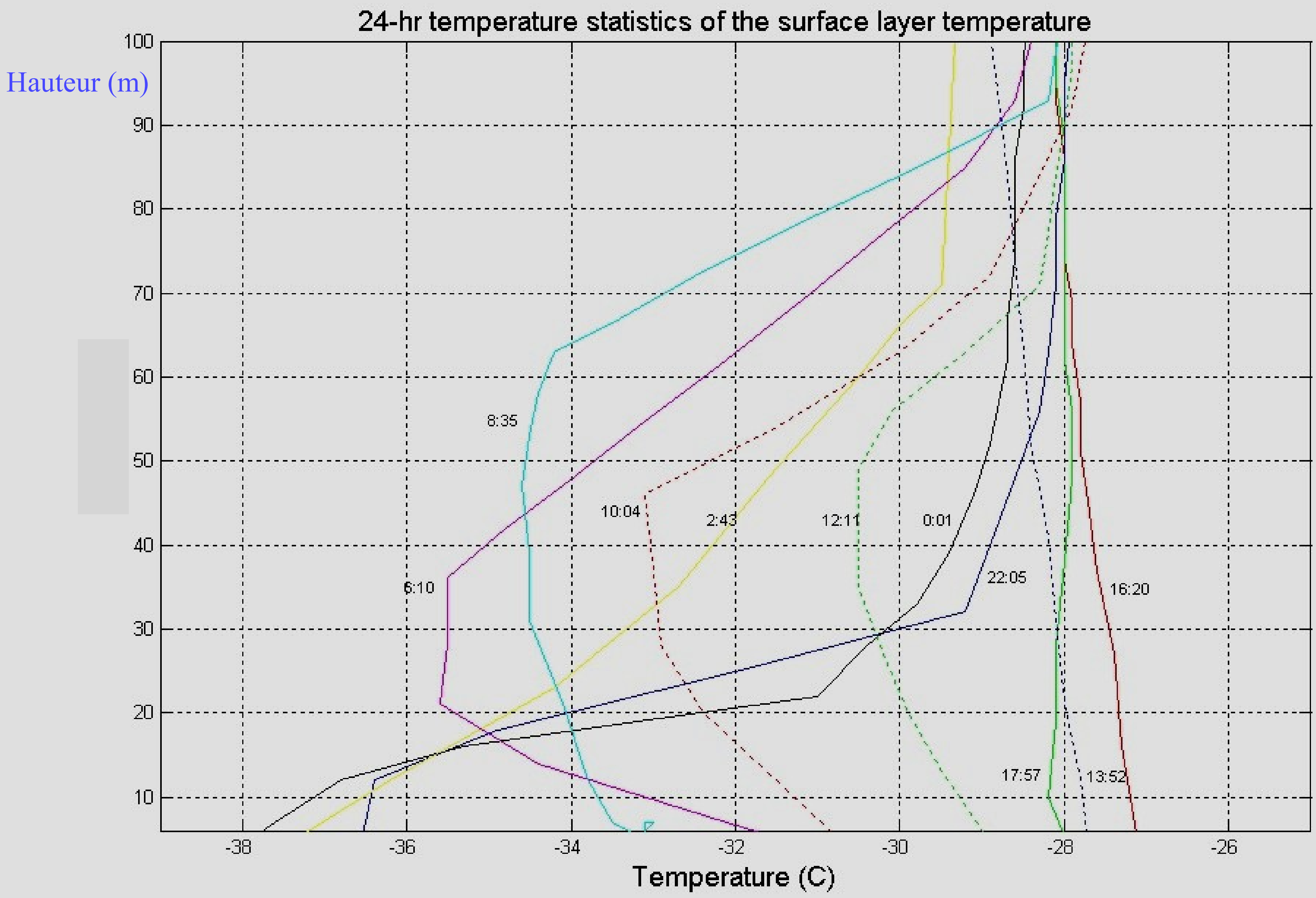
Wind speed and temperatures from the Concordia AWS meteo station (courtesy L. Agnoletto/A. Pellegrini)


A.S.T.E.P

about turbulence

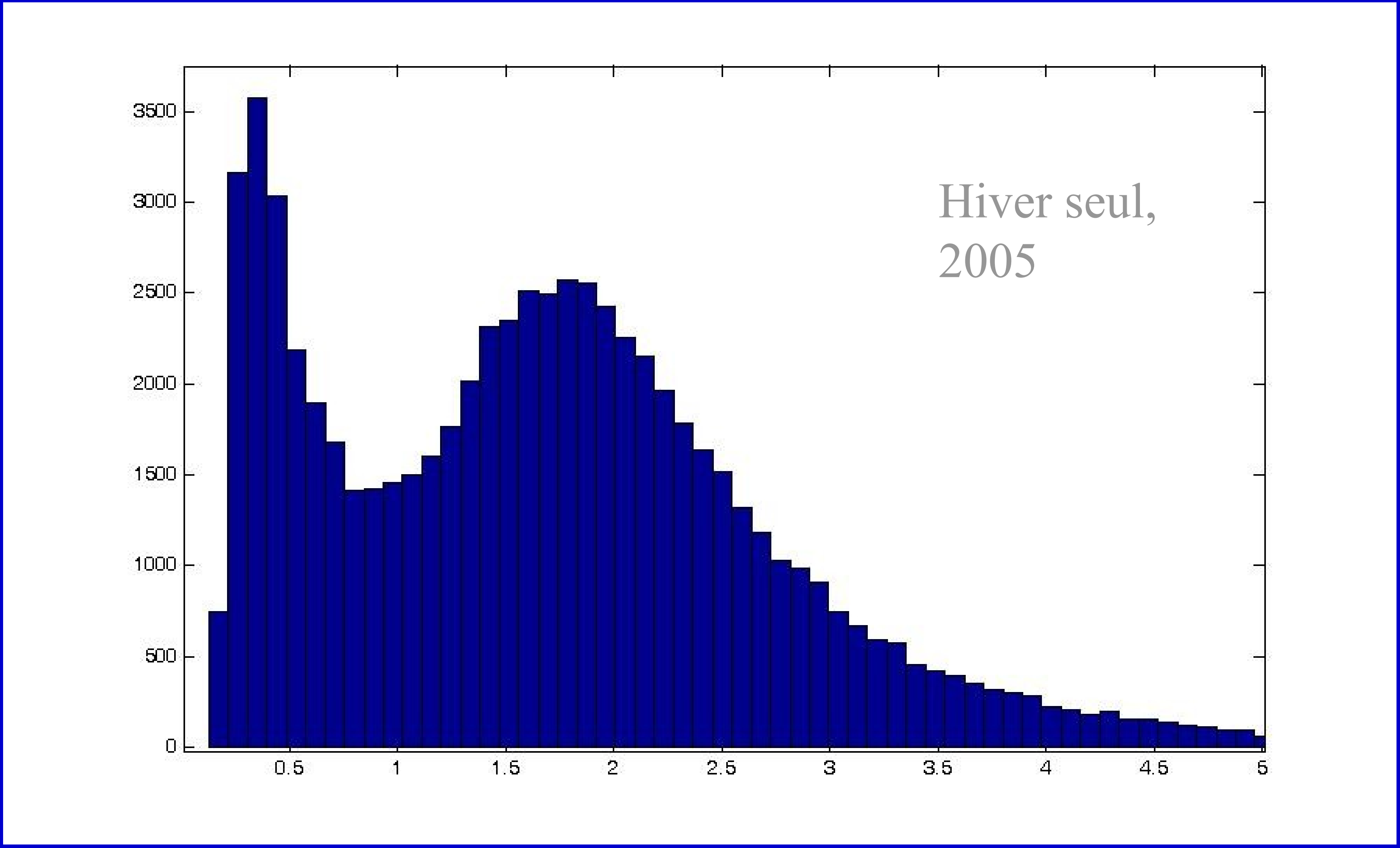
First surprise : The summer seeing

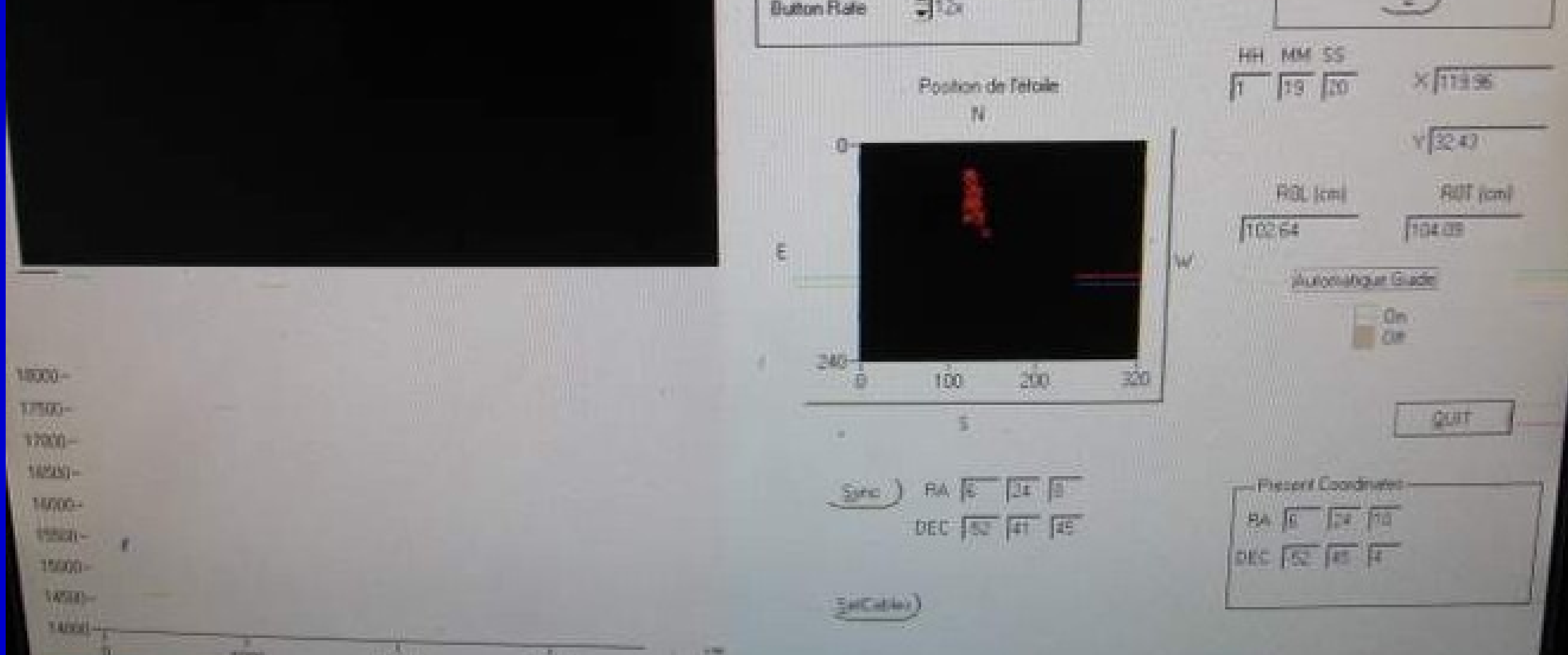


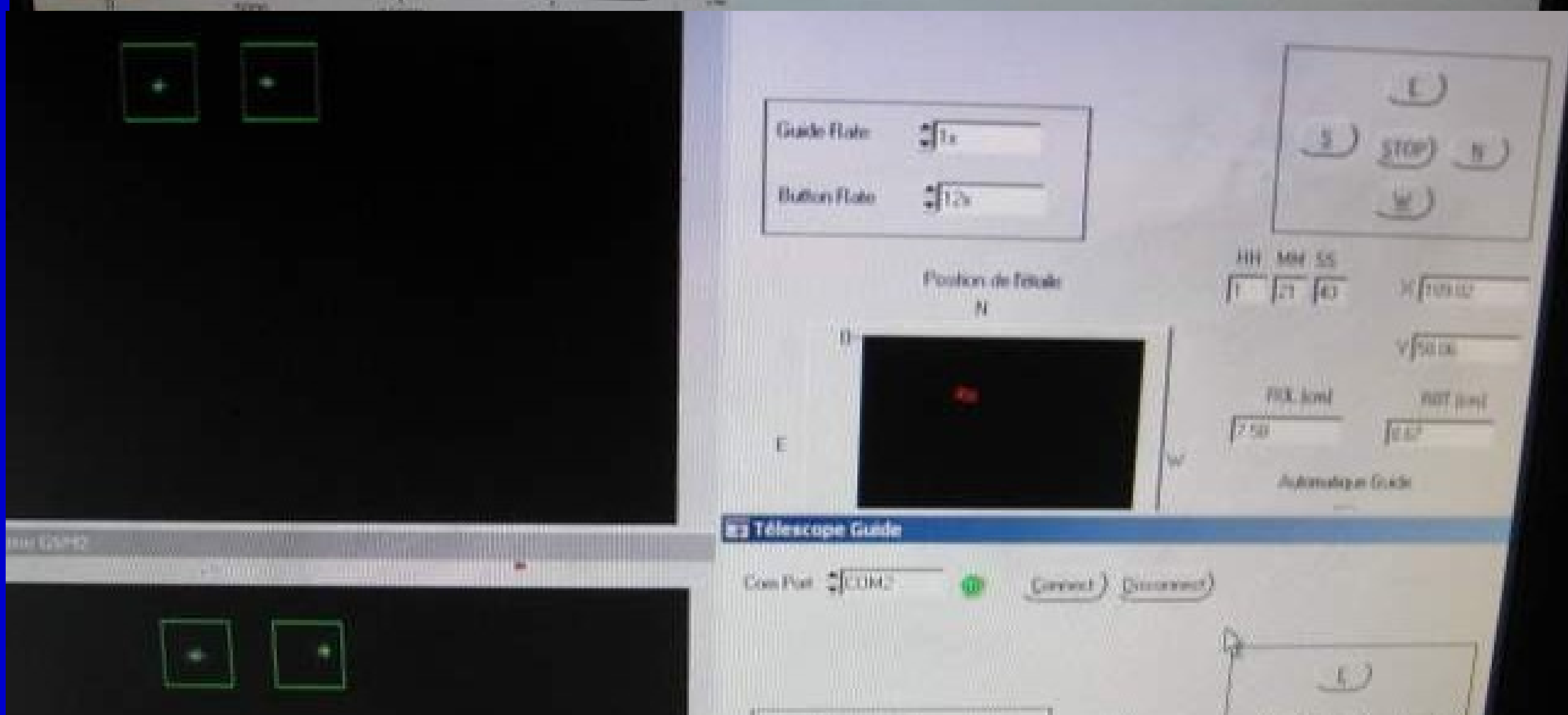


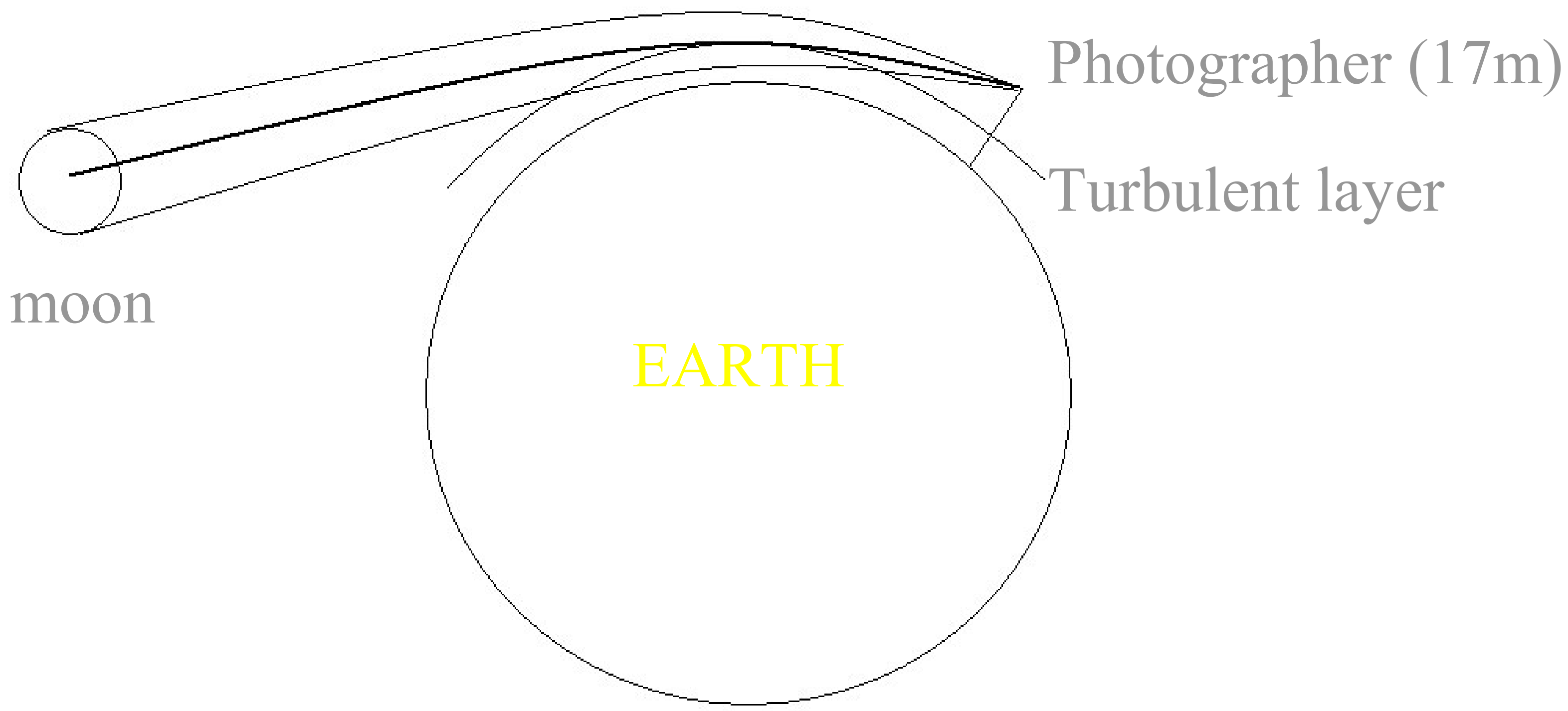
24-hr temperature statistics of the surface layer temperature
Hauteur (m)
100
90
80
70
60
50
40
30
20
10
-38
-36
-34
-32
-30
-28
-26
Temperature (C)
8:35
10:04
2:43
12:11
0:01
6:10
22:05
16:20
17:57
13:52

Winter histogram



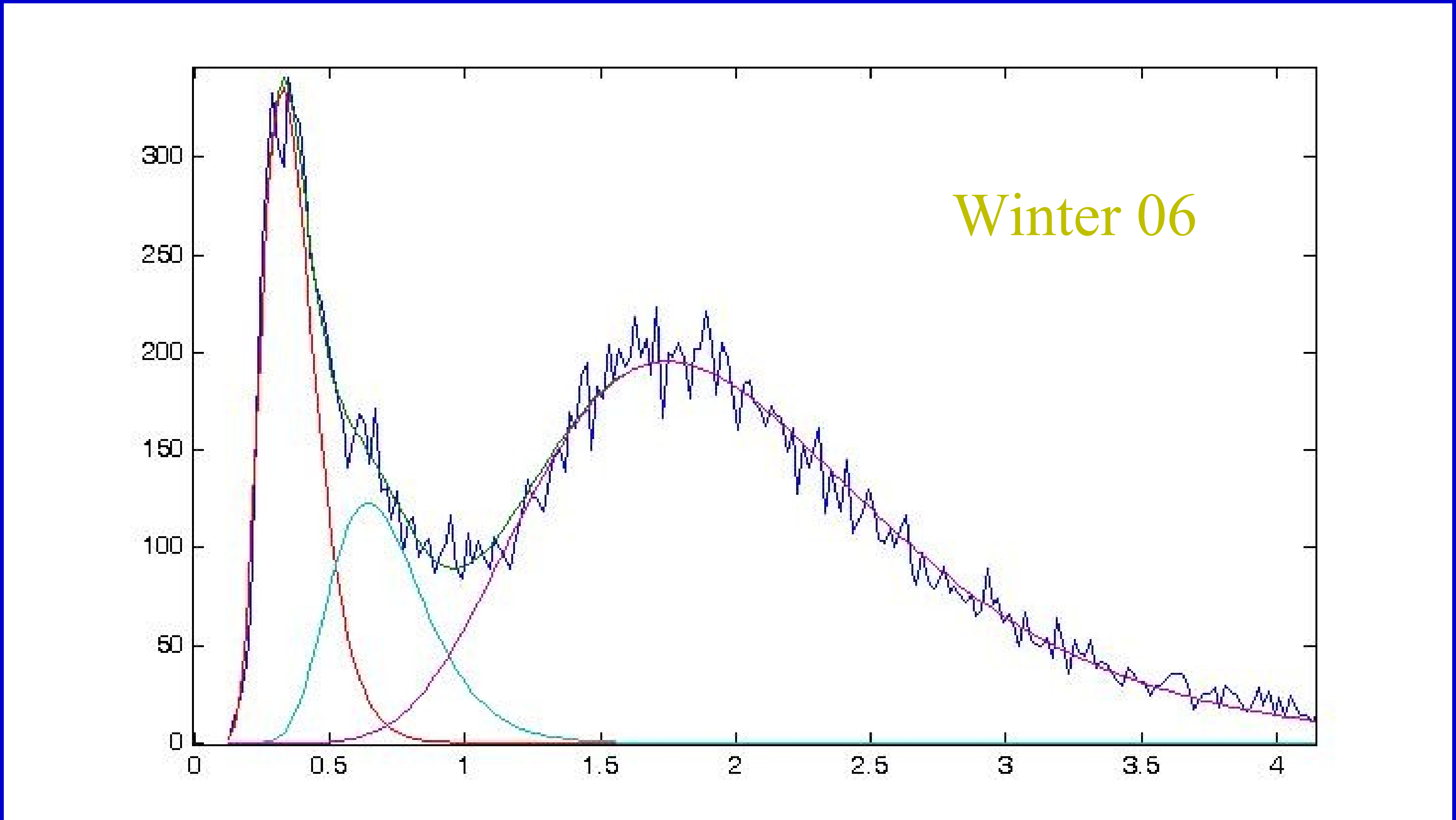

Button Rate
HH MM SS
Position de l'étoile
N
E
W
S
RGL (cm)
RDT (cm)
Automatique Guide
On
Off
QUIT
Sync
RA
DEC
Present Coordinates
SetCables


Guide Rate
Button Rate
STOP
HH MM SS
Position de l'étoile
N
E
W
Automatique Guide
Télescope Guide
Com Port
COM2
Connect
Disconnect

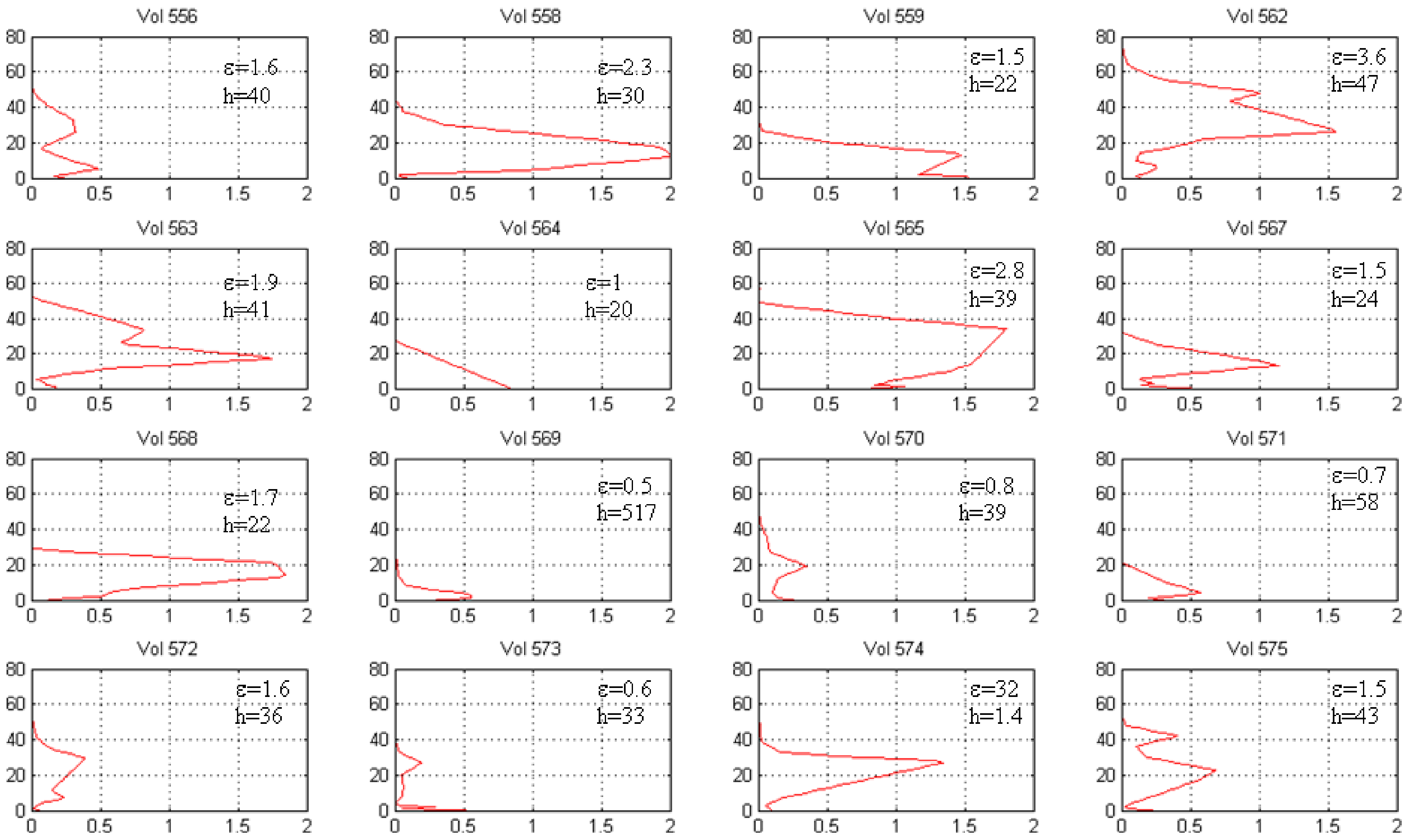


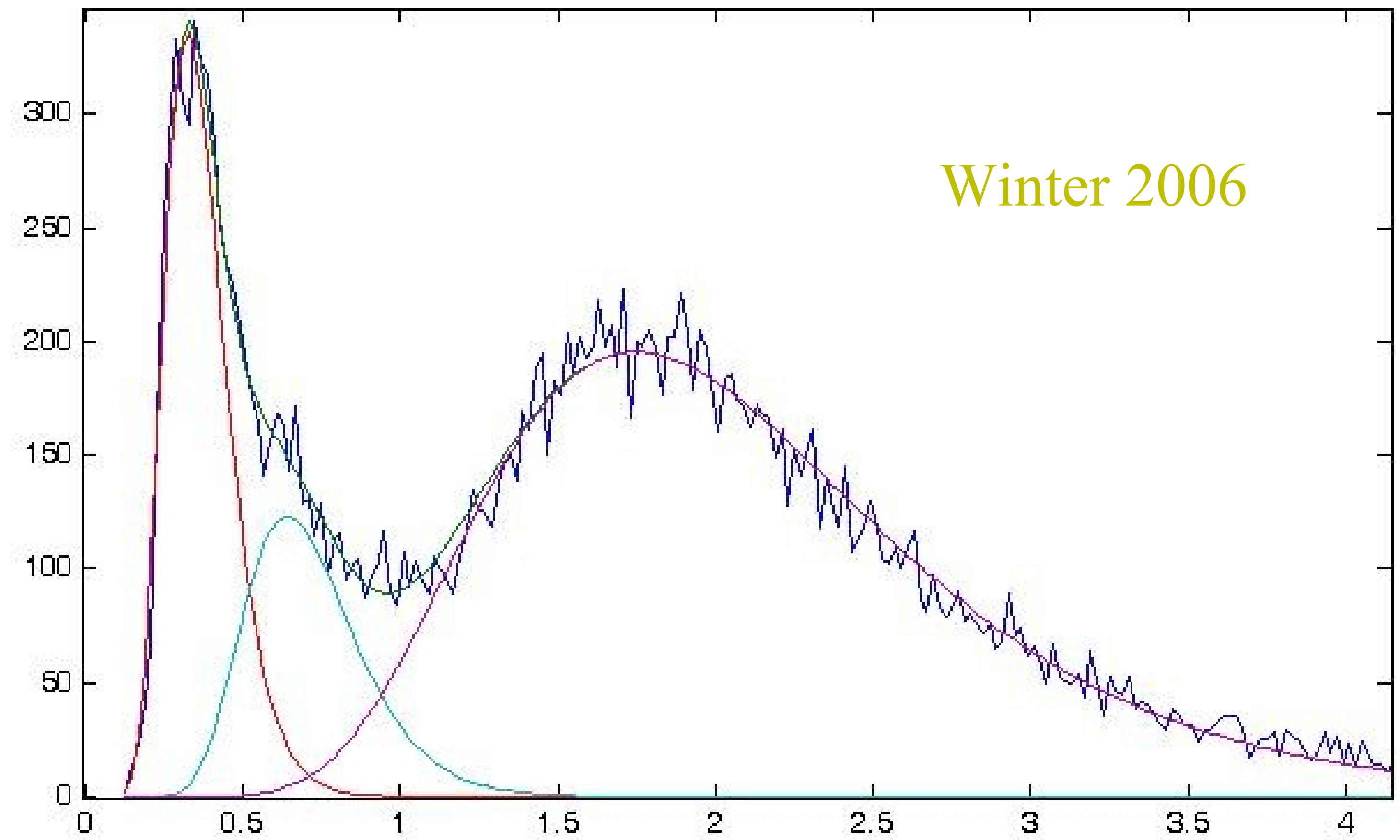
Photographer (17m)
Turbulent layer
moon
EARTH

- An example of a fit on a winter histogram
- 3 log-normal functions are needed for a perfect fit
- - one for the free atmosphere seeing
- - one for the bad seeing inside the SL
- - one for intermediate case, that provides a statistical estimation of the non sharpness of the SL upper limit, less than 1 m or the existence of a second faint turbulent layer

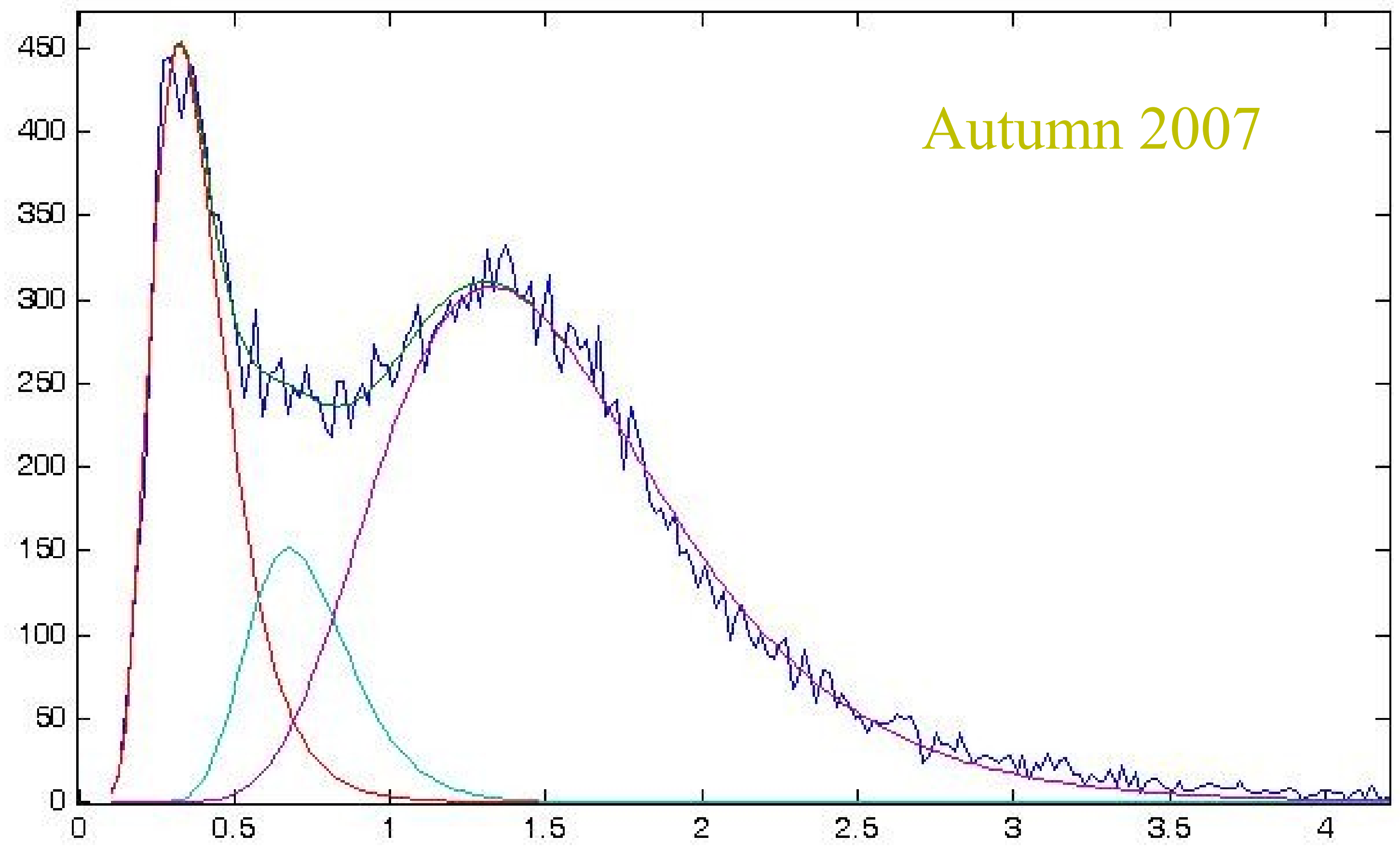


examples of Cn^2 profiles (2005)

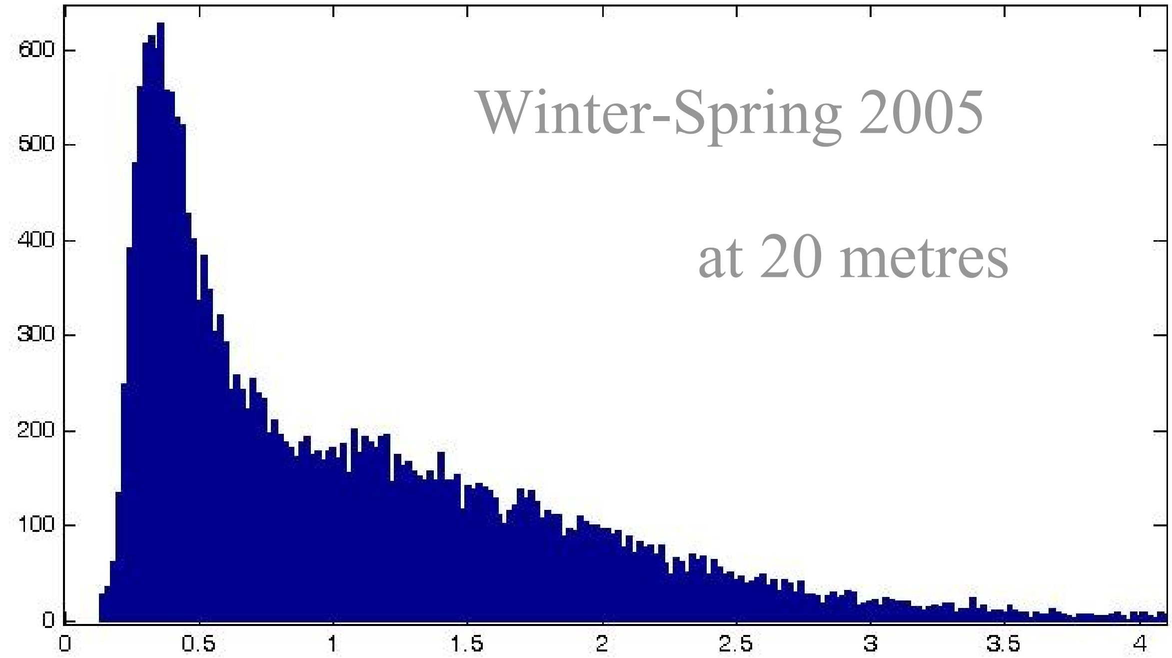




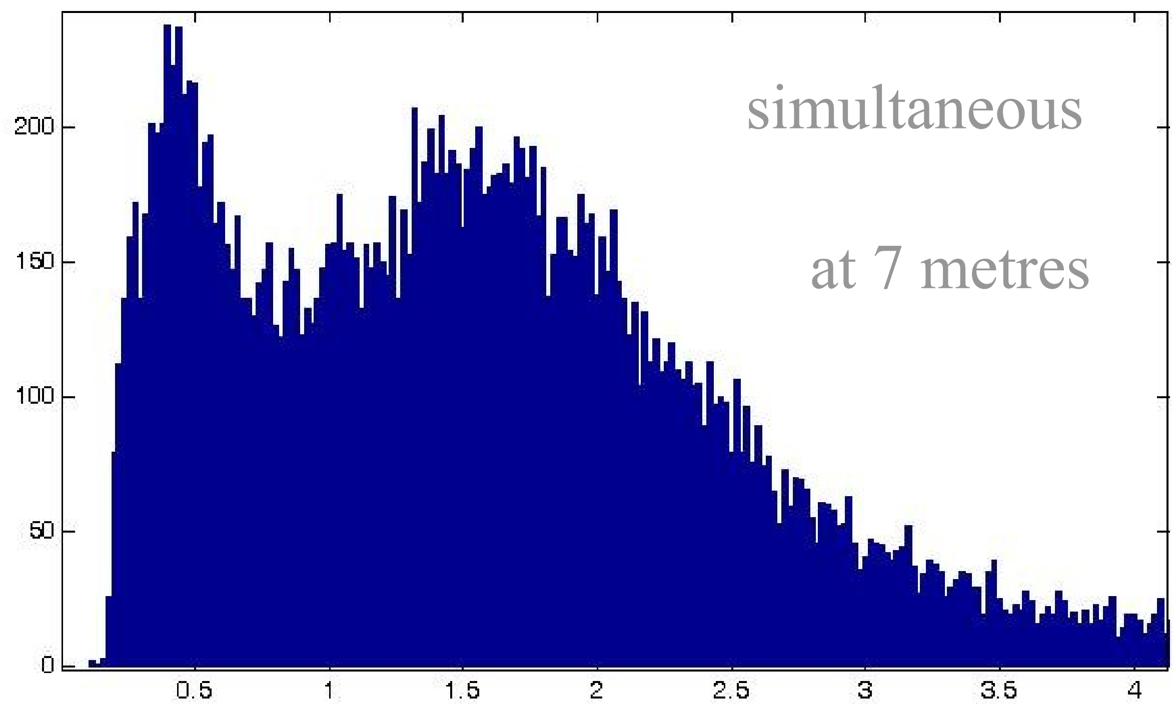
Winter 2006
300
250
200
150
100
50
0
0
0.5
1
1.5
2
2.5
3
3.5
4



Autumn 2007
450
400
350
300
250
200
150
100
50
0
0
0.5
1
1.5
2
2.5
3
3.5
4

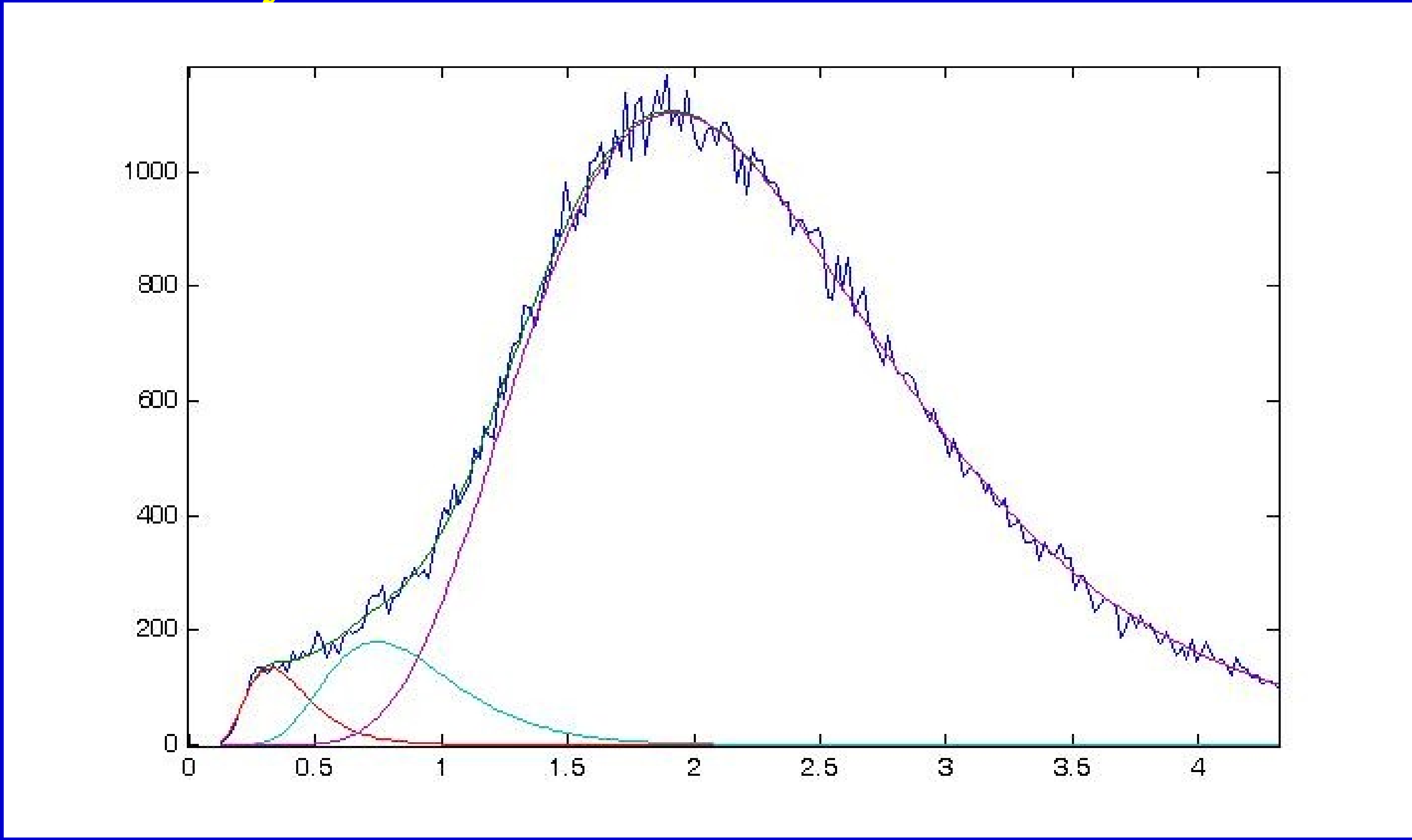


Winter-Spring 2005
at 20 metres
0
100
200
300
400
500
600
0
0.5
1
1.5
2
2.5
3
3.5
4

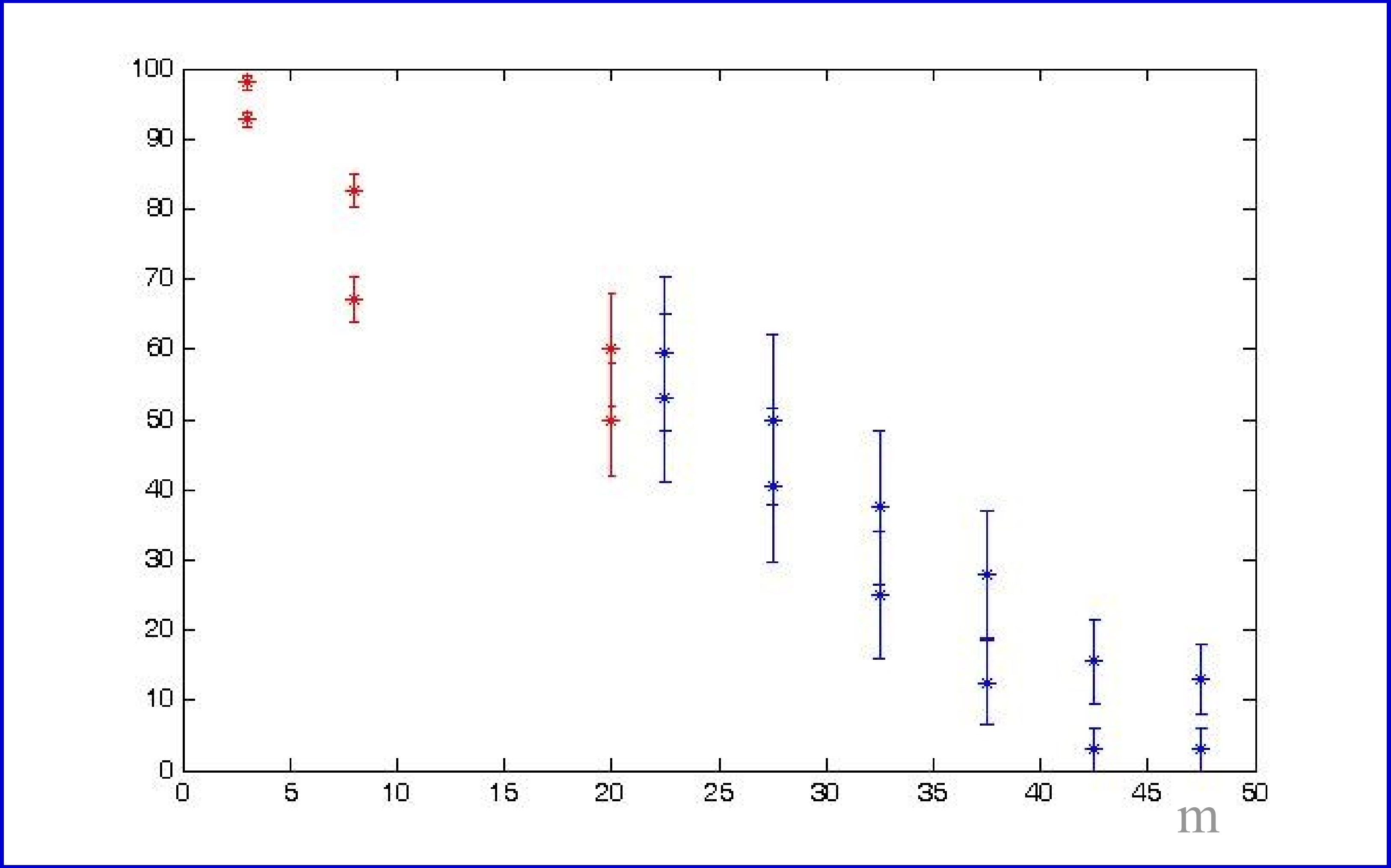


simultaneous
at 7 metres
0
50
100
150
200
0.5
1
1.5
2
2.5
3
3.5
4

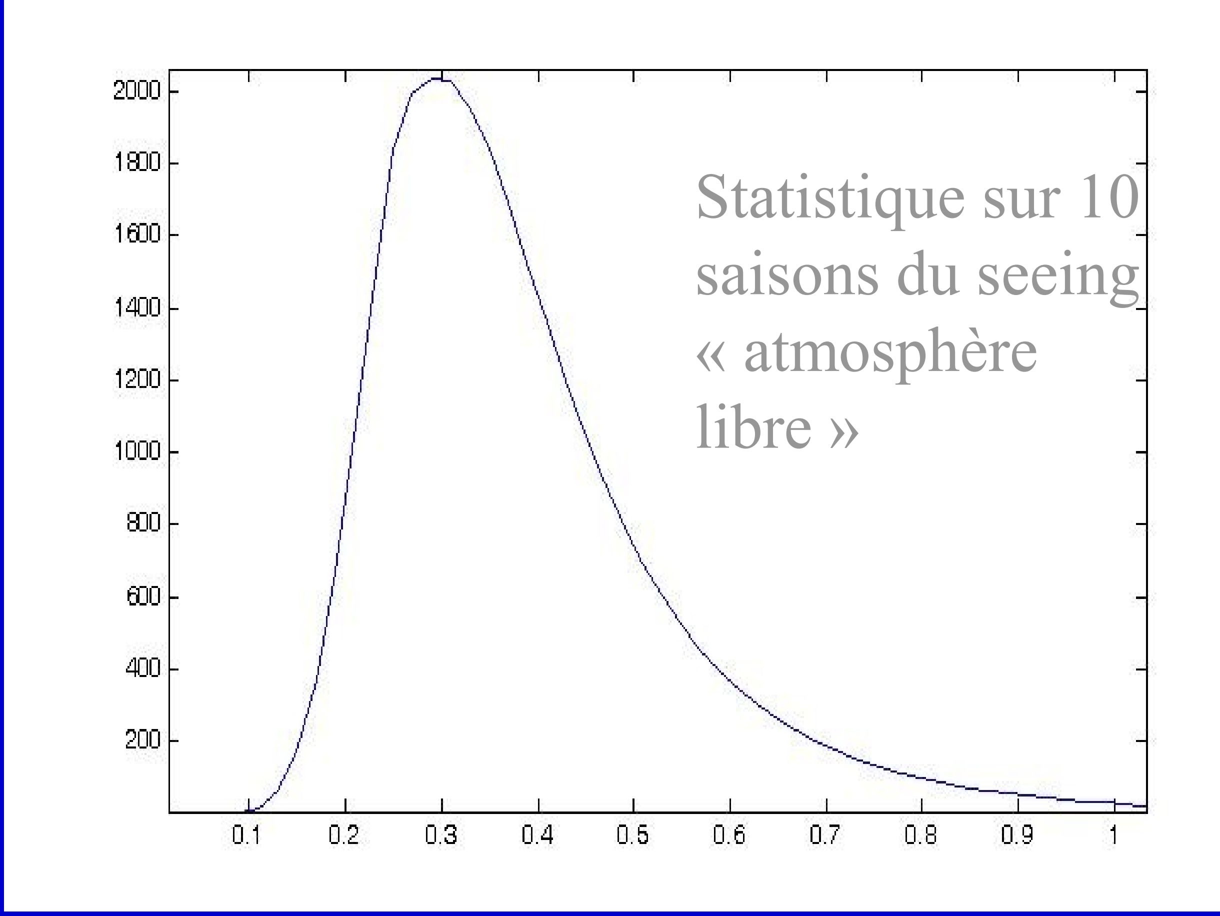
- There is more: the seeing down near the surface, at about 2m50
- It still shows between 1 and 2% of free atmosphere seeing with exactly the same distribution!

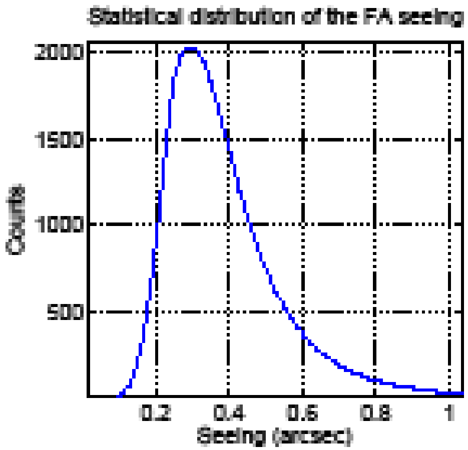


Probabilities



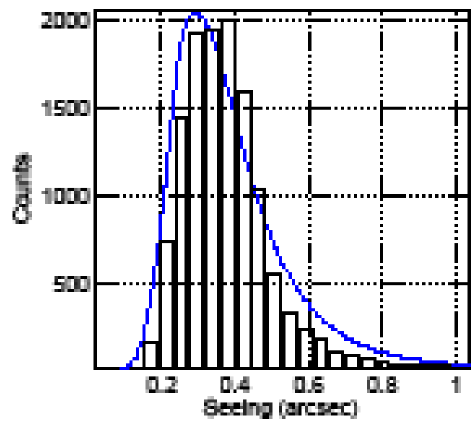
- We can then sum 10 fits (30 months) of free atmosphere histograms, and obtain a very precise distribution of the « free atmosphere seeing ». It proves to be the same at 3m, 8m or 20m, just more frequent higher and higher. It is also season independent, including in summer at 17: local time!
- Some key numbers:
- P(10m) = 23%
- P(25m) = 50%
- Seeing(Pmax) = 0.29
- Median seeing= 0.34





FA seeing	arcsec
Mean	0.38
Median	0.36
P_{75}	0.46
P_{25}	0.28

Fig. 14. Distribution of the ASL seeing at Concordia, measured during 10 seasons between 2005 and 2008, and excluding summers. The table on the right is the corresponding statistics.



4pm – 6pm	stat :
Mean	0.38
Median	0.36
P_{75}	0.43
P_{25}	0.29
Min	0.15
Max	1.4

Fig. 15. Histogram and statistics of the seeing values corresponding to the period 4pm-6pm in summer (December and January). The superimposed solid curve is the ASL seeing distribution.

2.6. The peculiar case of the summer seeing

In summer, the SL gets much weaker as both the temperature and the wind speed gradients are significantly weaker than in cold seasons. As already mentioned several times (i.e. Aristidi et al. 2005), they even disappear every day at 5 p.m, while these gradients are similar to the winter conditions at local midnights. This seeing depending strongly on local time does not permit the histograms to discriminate different situations that are not sharply separated. Actually the summer histograms tend to show a unique log normal distribution (Fig. 15), with a mean seeing being much better than in other seasons but with the ASL seeing being lost in the mixing of all different situations. Only the daily average at 5 p.m permits to confirm that

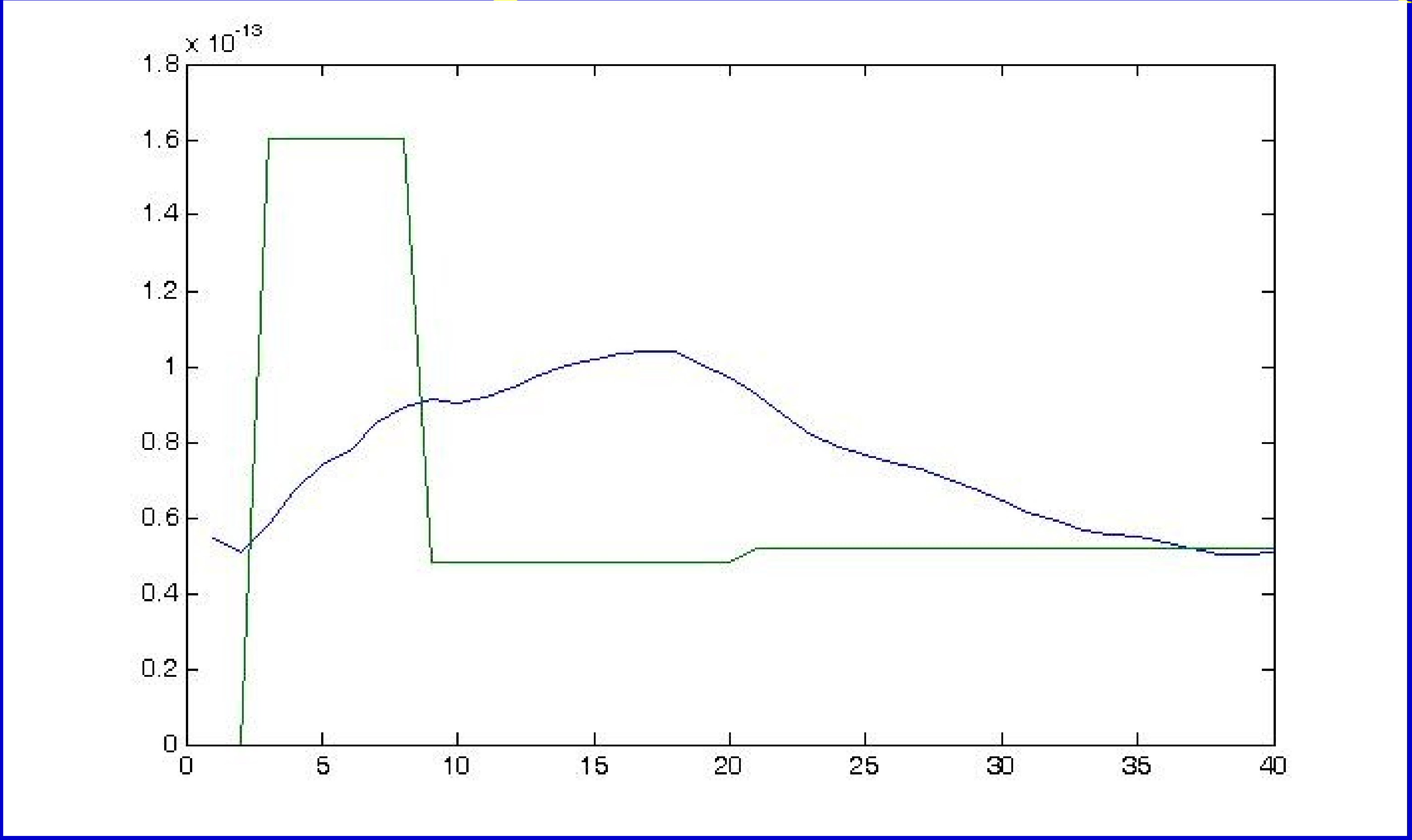
timate the characteristic time of seeing fluctuations as a function of the seeing. It is quite a difficult question as we lack many very long sequences of uninterrupted data sets. For various technical reasons, our data sequences are suffering interruptions that make this specific statistical study somewhat inaccurate.

We define here an interval of stability as a continuous period of time in which the seeing is less than a given threshold s_0. We denote as t_s its length. In this interval, we allow the seeing to be greater or equal to s_0 during 10% of t_s. For example if the seeing is less than 0.5 arcsec during one hour with a small interruption of 5 minutes, this interruption is neglected and t_s will be set to one

Content of the SL in unit of C_n^2

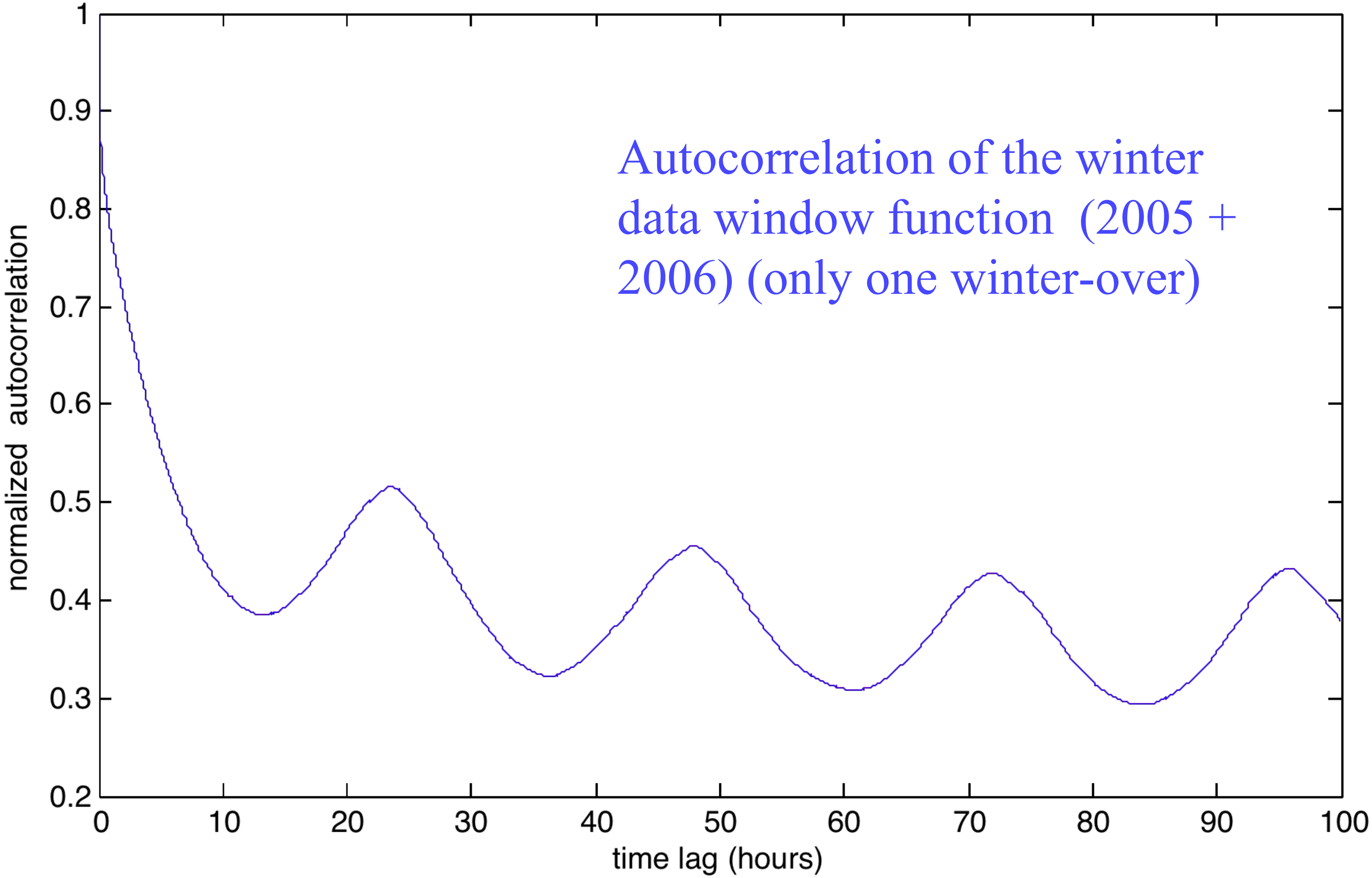
- Two measurements:
- The 32 winter radiosoundings, in-situ measurements
- The « right sides » of the histograms, if first expressed in (seeing)$^{5/3}$, then translated in C_n^2
- Exploiting histograms at 3 altitudes provides a 3-level SL content.
- A third method remains to be exploited: the sonics histograms. That’s under study (cooperation between us at Nice, Tony Travouillon at Cal’Tech and Christophe Genthon at LGGE, Grenoble)

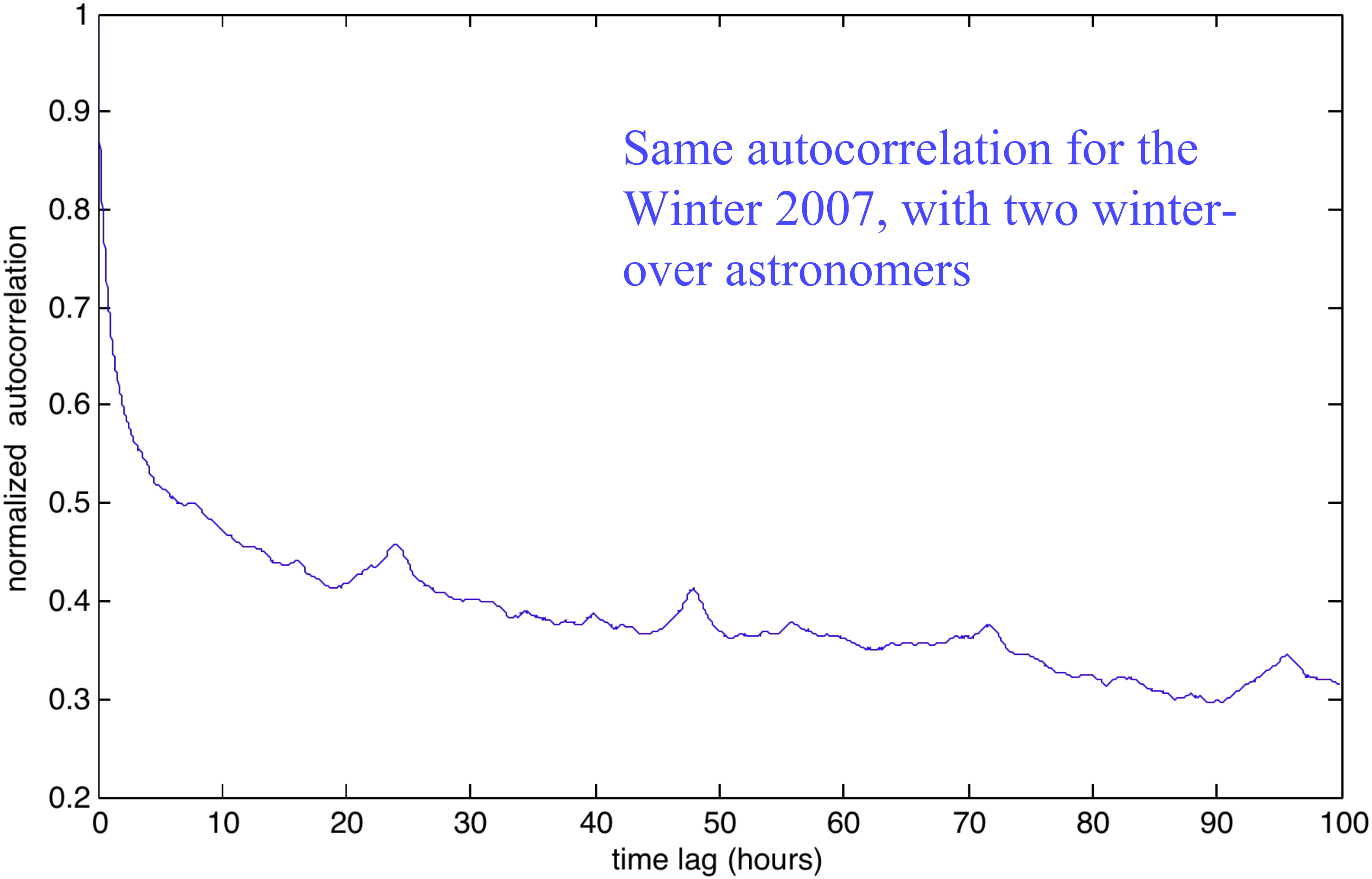
- Two new key numbers:
- 95% of the C_n^2 is inside the SL
- Yes, you read well: 95%
- At 25m on average 75% are below the telescope!



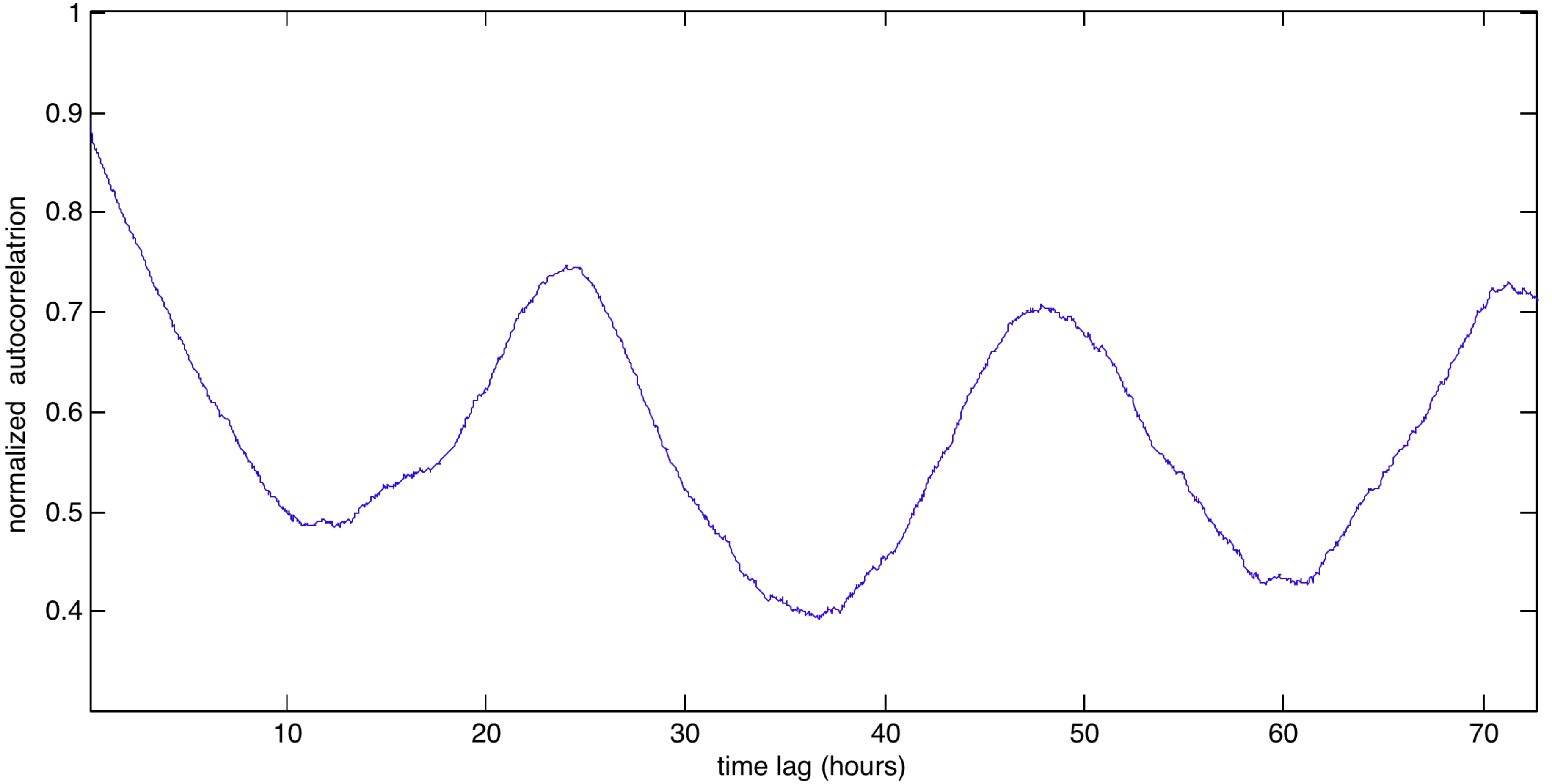
Next question

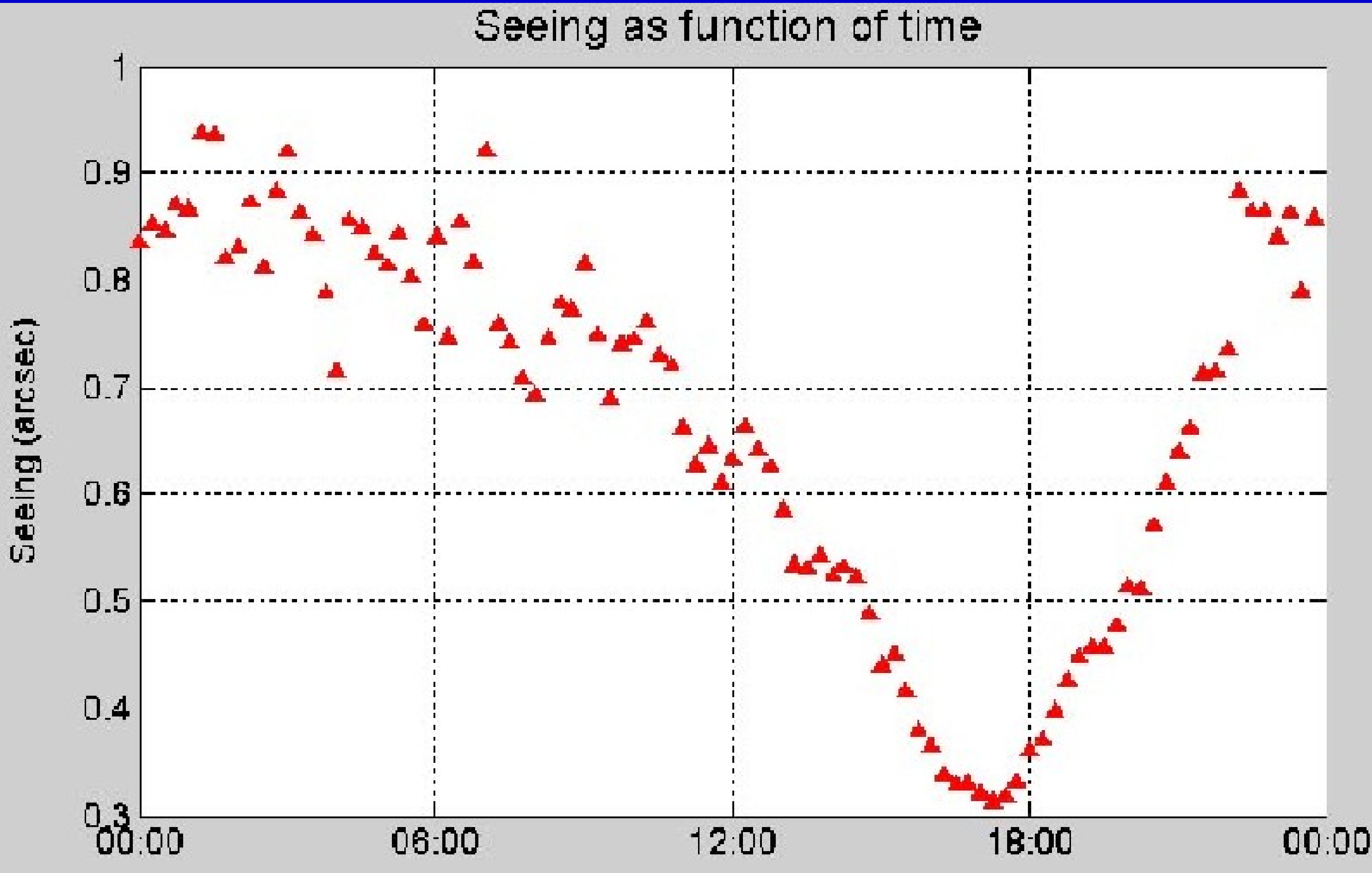
- What is the temporal distribution of these 15 to 20% of goog seeing at 8m or 40% of good seeing at 20m ?
- This question is not trivial because the data sets are not continuous
- A deconvolution of the data window must first be processed
- A simple method has been extensively exploited in helioseismology: a division of autocorrelations


Autocorrelation of the winter data window function (2005 + 2006) (only one winter-over)
normalized autocorrelation
time lag (hours)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
10
20
30
40
50
60
70
80
90
100

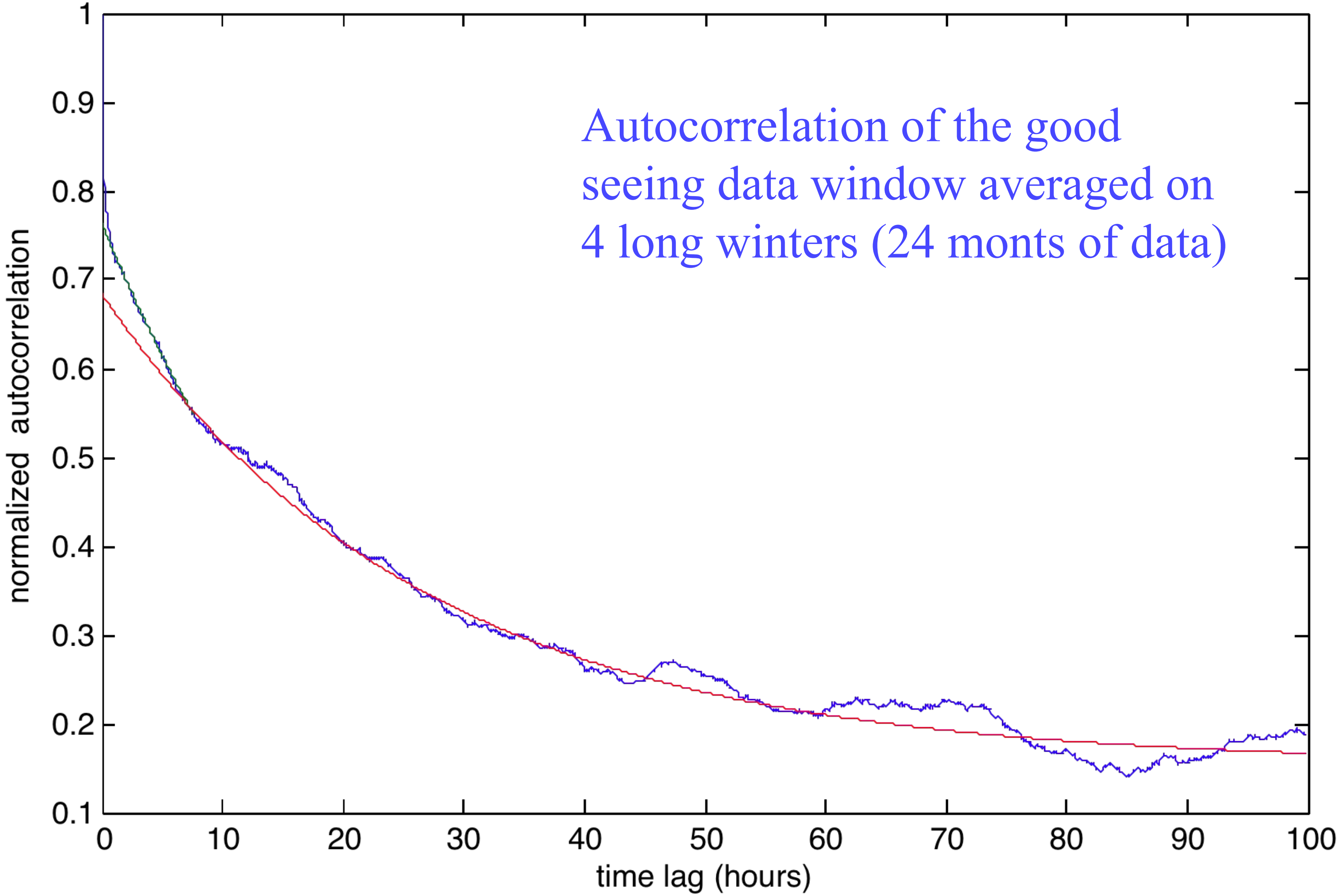

Same autocorrelation for the Winter 2007, with two winter-over astronomers
normalized autocorrelation
time lag (hours)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
10
20
30
40
50
60
70
80
90
100

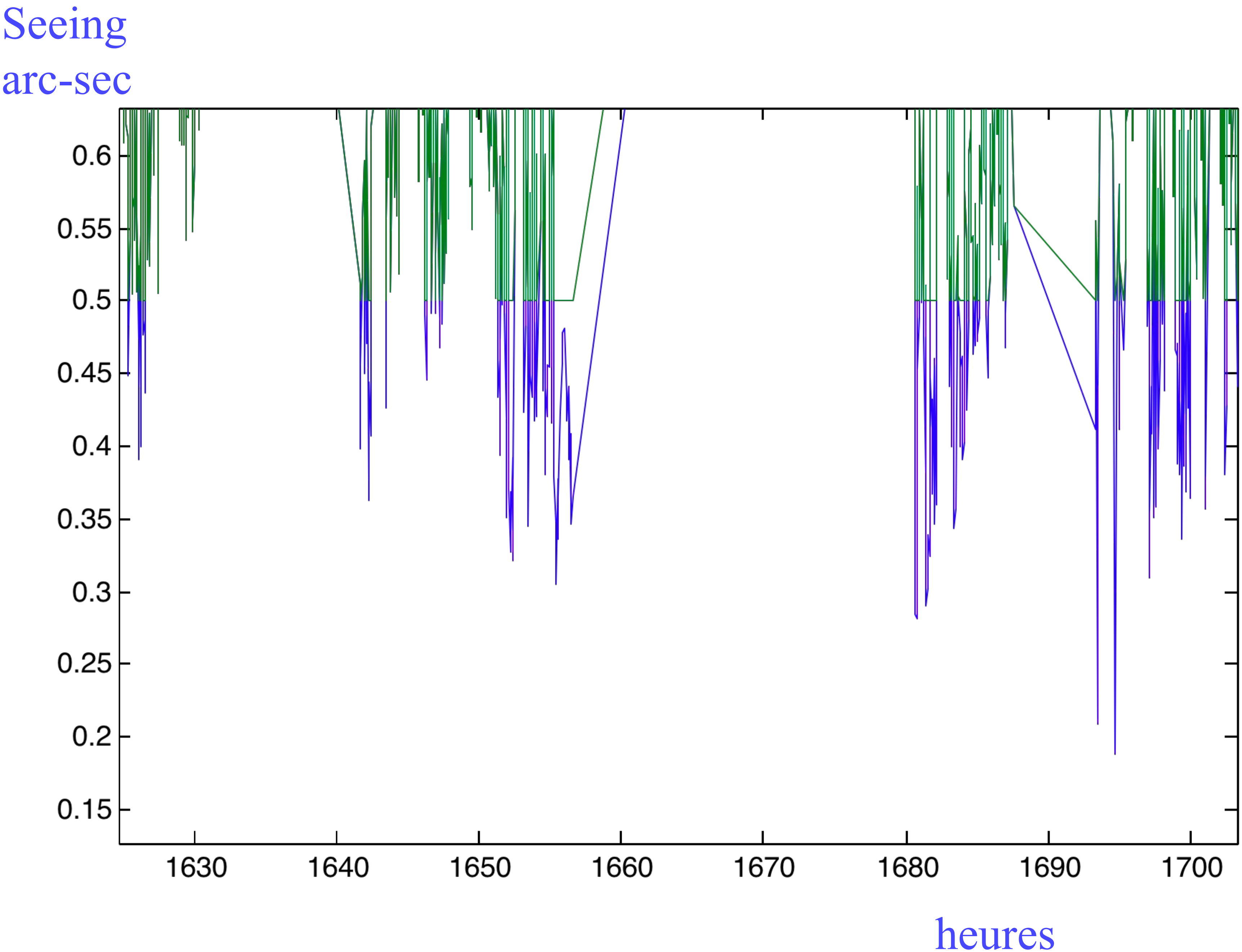
Autocorrelation of the good seeing window function after deconvolution, averaged on 5 summer seasons (over 15 months of data)



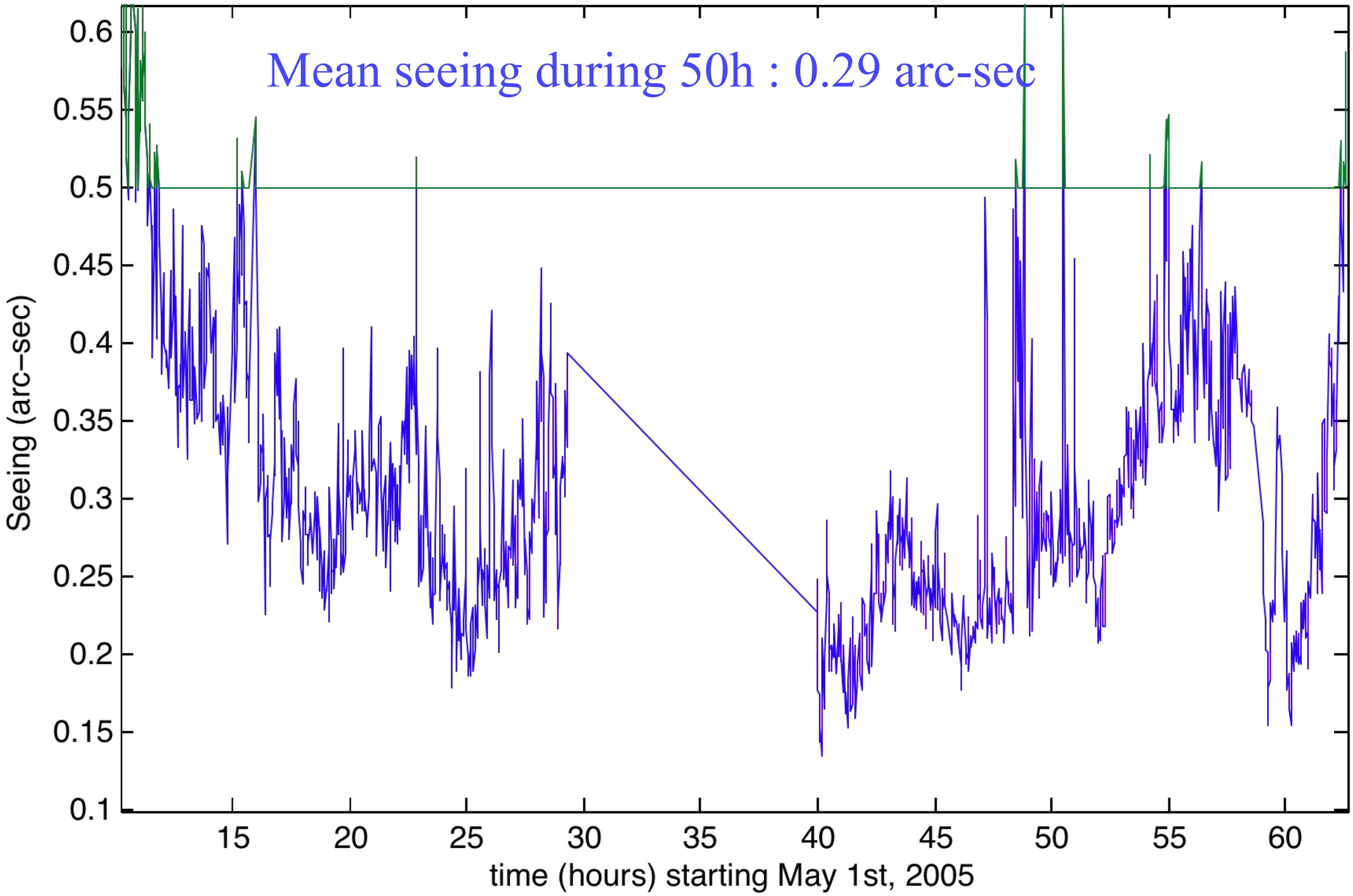


Seeing as function of time
Seeing (arcsec)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
00:00
06:00
12:00
18:00
00:00

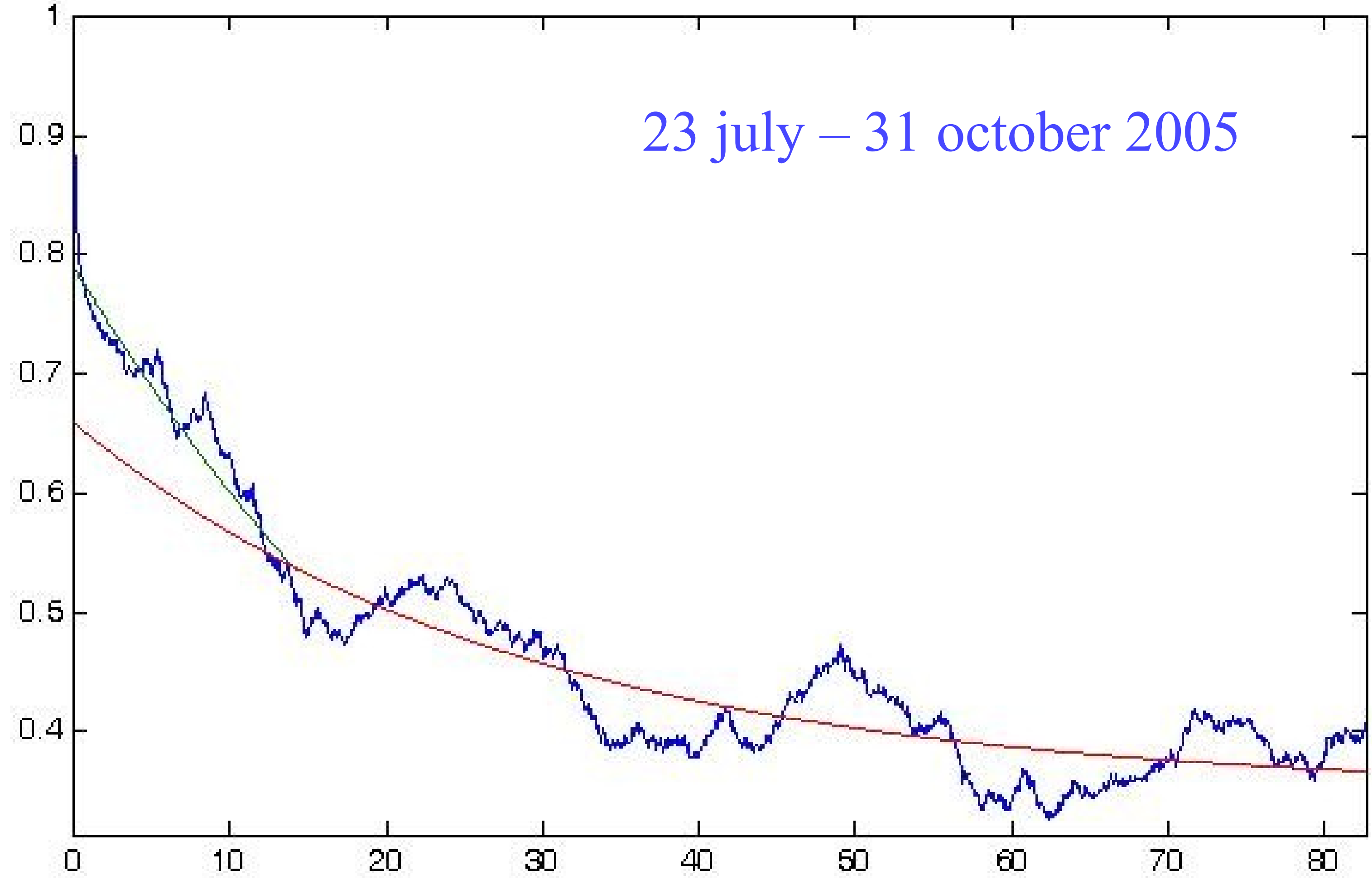

Autocorrelation of the good seeing data window averaged on 4 long winters (24 monts of data)
normalized autocorrelation
time lag (hours)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10
20
30
40
50
60
70
80
90
100


Seeing
arc-sec
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
1630
1640
1650
1660
1670
1680
1690
1700
heures

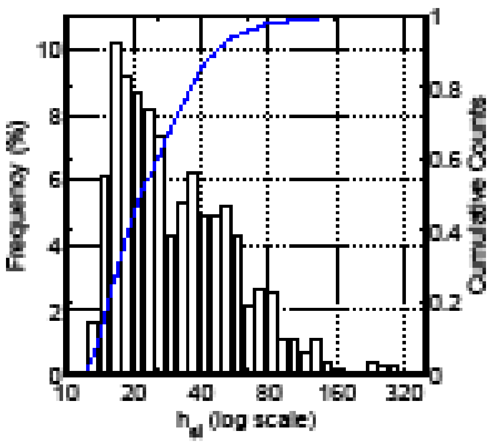
An example at 8 meters



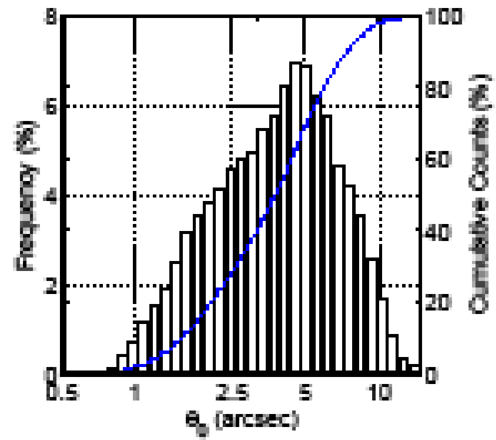
3 months at 20 m



Isoplanatic angle (Aristidi & Ziad)



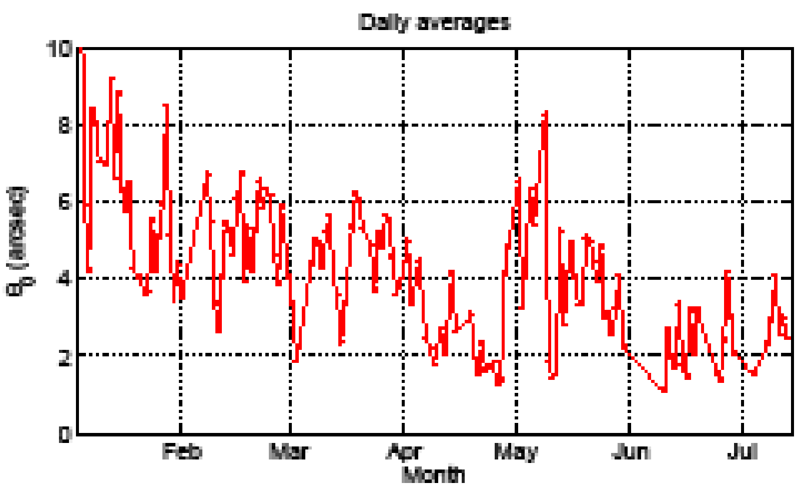
h_{sl} stat	m
Mean	40
Median	28
P_{75}	47
P_{25}	20
Min	13
Max	361



θ_0 stat	m
Mean	4.3
Median	3.9
P_{75}	5.7
P_{25}	2.4
Min	0.4
Max	23.4

Fig. 7. Histogram and statistics of the thickness of the surface layer computed for seeing measurements at 3 different heights.

Fig. 9. Isoplanatic angle histograms and statistics. Values are in arcsec.



balloons equipped with radio-sounding instrumentation, that give a mean thickness of 33 m for a total number of 35 balloons launched during the winter 2005 (Trinquet et al, 2008). The last method is the atmospheric modelling, able to predict with a good reliability the existence of the turbulent boundary layer, and that predicts a thickness of about 30 m at Dome C. These 4 numbers are impressively consistent and nobody to-day can really doubt of this order of magnitude of 30 meters.

Acknowledgements. We wish to thank both Polar Insitutes,IPEV and PNRA

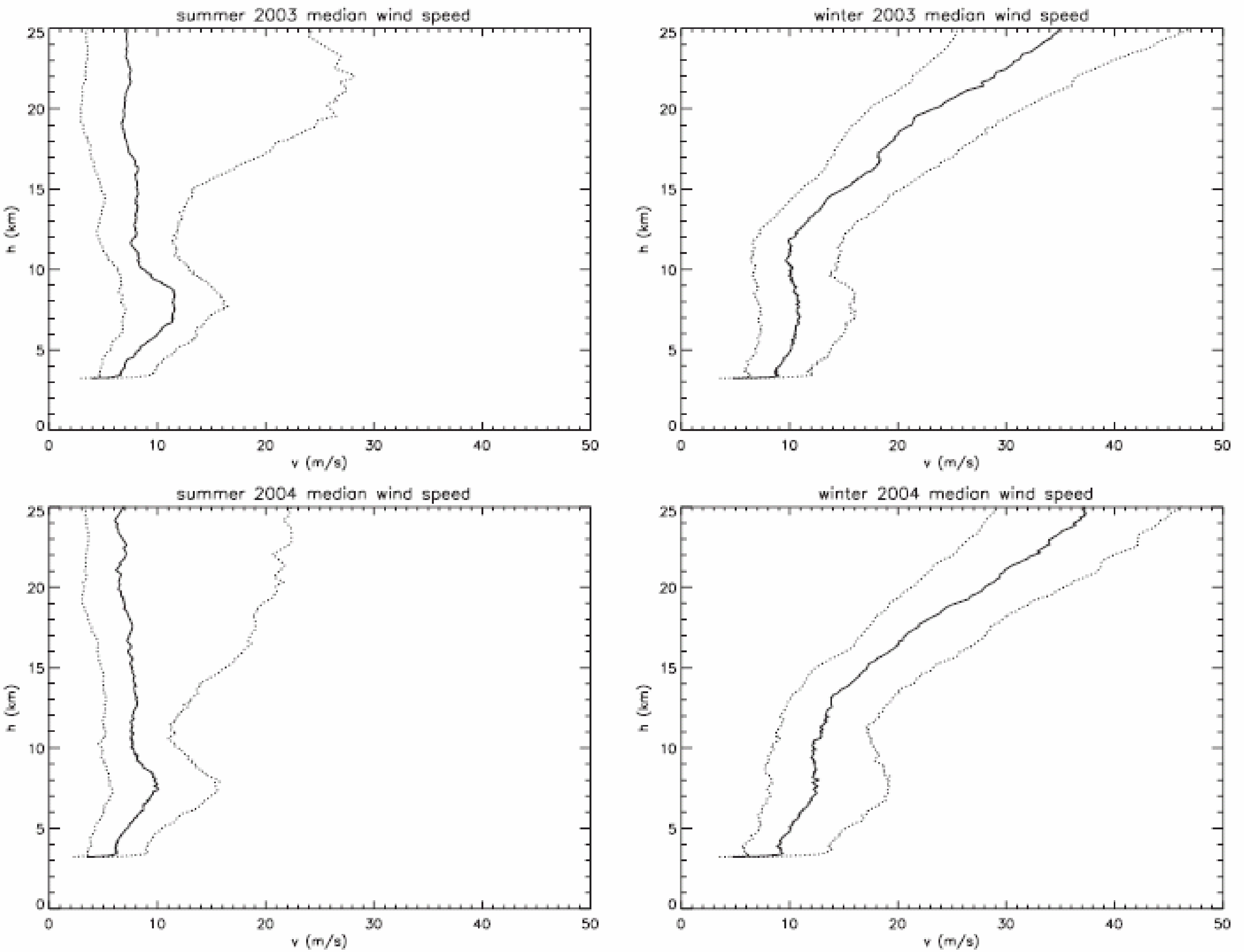


Fig. 3.— Summer (left) and winter (right) median wind speed vertical profile estimated in 2003 (top) and 2004 (bottom). The first and third quartiles are shown with a dotted line.

To-day conclusion

- At 8 m high in winter, once every 10 days on average, a good seeing (0.3 arc-sec on average)episode provides at least two days filled at 75% or more, with individual runs not shorter than 7.5 hours.
- At 20 m, it happens twice more frequently (5 days mean recurrence instead of 10), with individual runs twice longer (15 hours instead of 7.5)

Nébuleuse de la carène, 8h20 de pose par -72C, Cyprien Pouzenc