Atmospheric Time Constants at Paranal during VLTI VINCI & Siderostats Commissioning

VLT-ASM
INTERNAL
MEMO
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1. SYNOPTIC CONDITIONS

The motion of the atmosphere at the latitude of Paranal is driven by the subtropical jet stream whose characteristic velocity is generally measured at 200 mb, or about 12 km above sea level. A jet stream can be seen as a tube of about 200 km in diameter having a core of fastest winds surrounded by slower wind, circling the earth from west to east with a *wavy* pattern. The wind speed can reach 80 m/s at the core, whose North-South position is changing with time as a function of the pressure systems. In northern Chile, the subtropical jet position oscillates within a latitude range including Paranal and La Silla. As can be seen on Fig. 1, the wind velocity can easily change by a factor of 1 to 4 in a matter of a few days. The seasonal distribution of the wind velocity at 200 mb above Paranal (Fig. 2) shows a peak of activity in winter (July-September) and a calm period in Summer (January-August).

2. LOCAL COHERENCE TIME

The wavefront coherence time τ_0 relevant for adaptive optics is given by Roddier (1981):

$$\tau_0 = 0.31 \frac{r_0}{V_0}, \tag{1}$$

where V_0 is the average velocity of the turbulence defined by Roddier et al. (1982)

$$V_0 = \left[\frac{\int_0^\infty C_n^2(h) V(h)^{\frac{5}{3}} \mathrm{d}h}{\int_0^\infty C_n^2(h) \mathrm{d}h} \right]^{\frac{3}{5}}. \tag{2}$$

When turbulence profiles are not available, it is nevertheless possible to estimate the velocity of the turbulence using the model proposed by Sarazin & Tokovinin (2001) for the chilean sites:

$$V_0 \simeq Max(V_{ground}, 0.4 V_{200mb}), \text{ m/s} \tag{3}$$

which leads to an estimate of τ_0 within relative mean and rms errors of 4% and 19% respectively (computed over 35 real profiles from Paranal and Pachon).

At Paranal, the ECMWF 6-hourly analyses and forecasts of V_{200mb} are interpolated and combined with 10 mn averages of local wind conditions to estimate V_0. The seeing measured by the DIMM, binned with a 10 mn gaussian window, enters in Equ. 1 as $FWHM = \lambda / r_0$ with $\lambda = 0.5\mu$.

Figures 3 and 4 demonstrate the variability of τ_0 in the course of two nights, in opposite synoptic situations. The night of Fig. 3 with low wind conditions presents large seeing variations which are reproduced in the time constant. Conversely on Fig. 4 with equally large seeing variations, the jet stream limits the variations of τ_0 to the lower part of the range.

Finally, the period 10-25 March 2001 shown on Fig. 5, with 20 and 5 percentiles respectively equal to 11 and 7.6 ms was significantly better than what is to be expected at Paranal on a yearly basis (Table 1).

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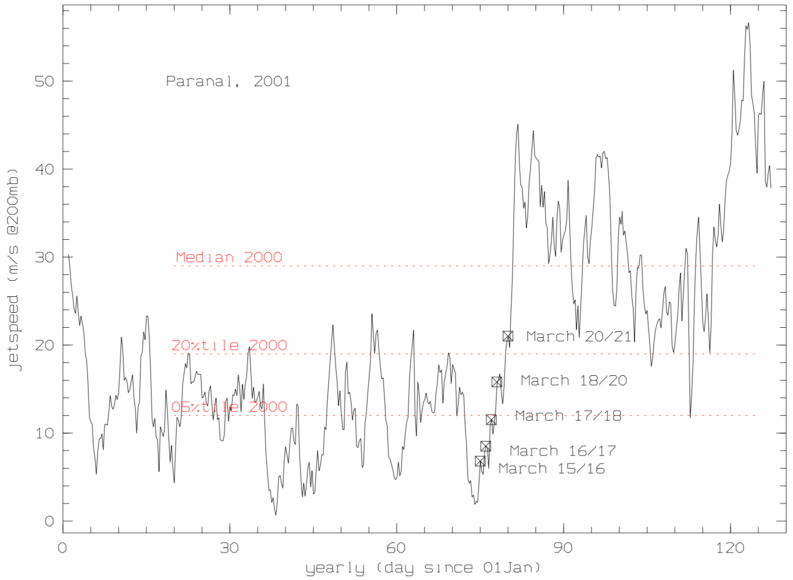

Figure 1. Wind velocity at 200 mB (ca. 12 km asl) above Paranal in the summer of 2001. The VLTI test period enlighted took place during the transition marking the arrival of the jet stream above the observatory. The dotted lines correspond to the statistics of the previous year.

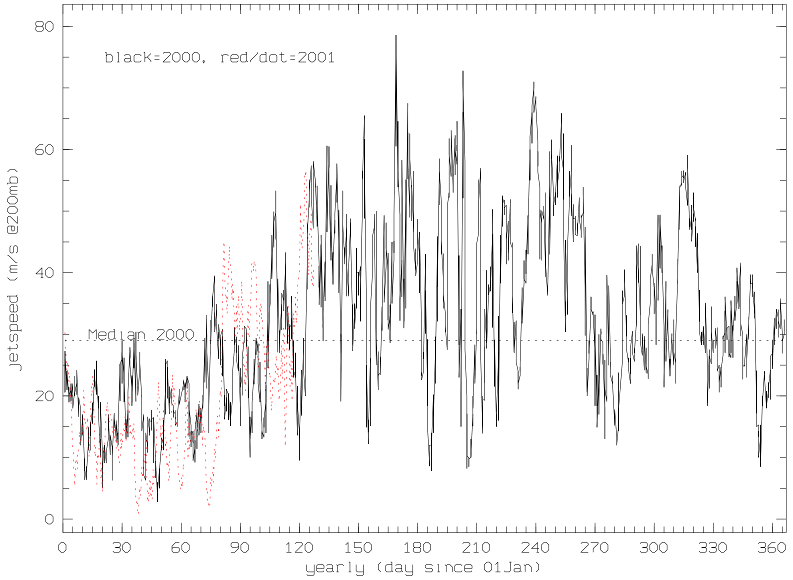

Figure 2. Comparison of the wind velocity at 200 mB (ca. 12 km asl) above Paranal during 2000 (black line) and in the summer of 2001 (red dots) which shows on both years a steady increase during the month of march. The extremely low velocities of mid-march 2001 were however somewhat exceptional. The dotted line corresponds to the yearly median for 2000.

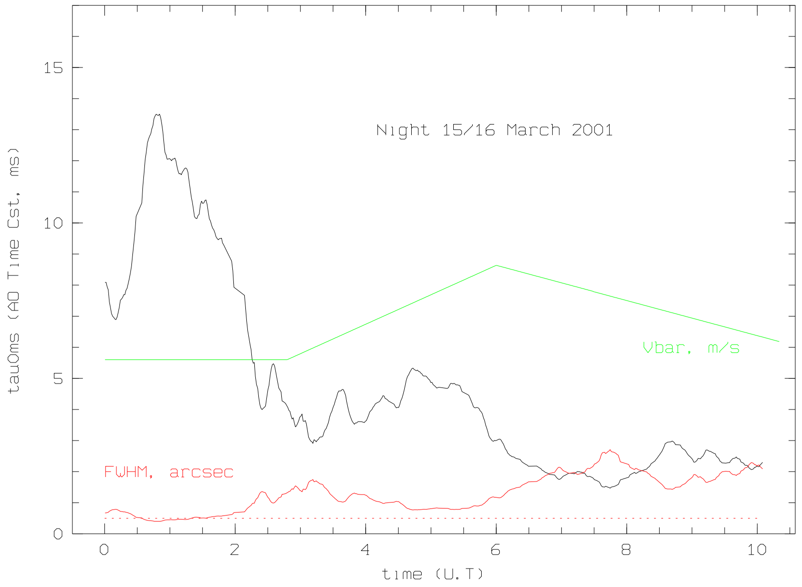

Figure 3. Coherence time at Paranal during the night of 15/16 March 2001: the seeing (lower curve with dashed line indicating 0.5") and the wavefront velocity (segmented line) are overplotted. Only during the first hours of the night could the site benefit from the unusually calm wind conditions at high altitude. An increase of the seeing (up to 2") and of the wind velocity at ground level contributed to reduce significantly the time constant.

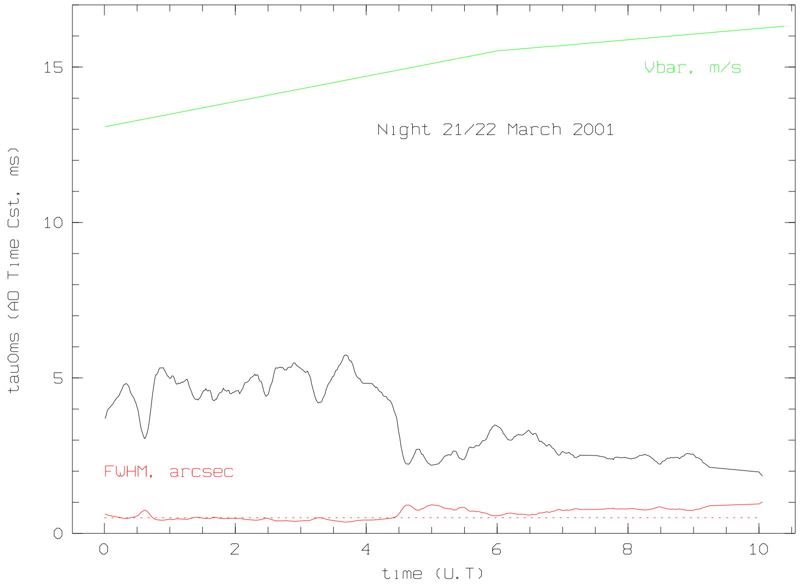

Figure 4. Coherence time at Paranal during the night of 21/22 March 2001: the seeing (lower curve with dashed line indicating 0.5") and the wavefront velocity (segmented line) are overplotted. Excellent seeing conditions and moderate wind at ground level during the first hours of the night contributed to maintain the time constant above the yearly median, inspite of fairly strong wind at high altitude.

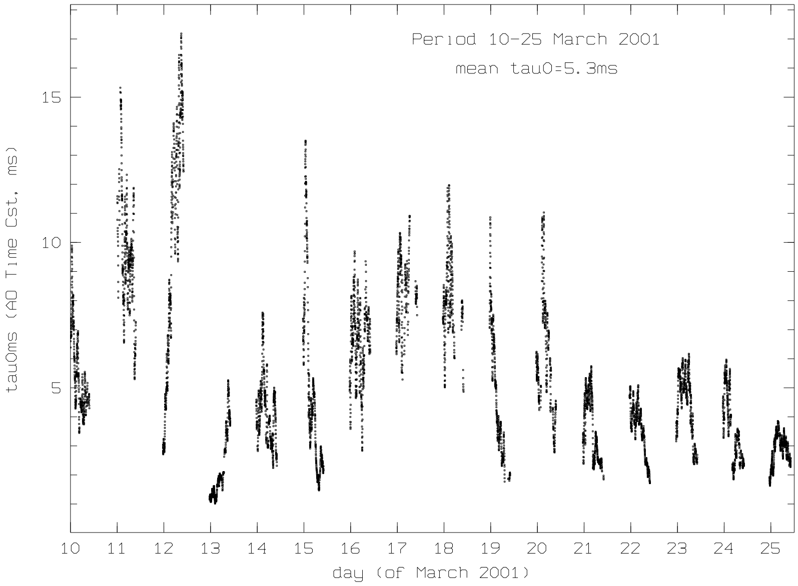

Figure 5. Coherence time at Paranal during the period 10-25 March 2001: The mean τ_0 was 35% larger than the yearly mean for 2000 (see Table 1).

Table 1. Summary of AO related observing conditions at Paranal during 2000, for observation at 0.5 μm, at zenith, averaged over 10 mn.

Parameter	best 5%	best 20%	50%	mean
Seeing, arcsec	0.43	0.56	0.75	0.86
200mb Wind, m/s	12	19	29	32
τ_0, ms	8.5	5.8	3.6	3.9
θ_0, arcsec	4.1	3.3	2.6	2.6

APPENDIX: DEFINITION OF THE COHERENCE TIME FOR INTERFEROMETRY

The coherence time τ_0(for adaptive optics) is the time interval over which the phase fluctuations in any position on the pupil have a variance of 1 square radian. In interferometric mode, Linfield et al (2001) define a *two aperture variance coherence time* characterizing the interferometer phase fluctuations, which can be directly related to τ_0. Moreover, as for r_0, the coherence time τ_0, defined at 0.5μ, can be converted to other wavelengths following a $\lambda^{6/5}$ dependency. Using these definitions, one obtains for the present configuration (SBL: short baseline, ie. smaller than the outer scale equal to 15-25 m at Paranal) at 2.2 μm $\tau_{SBL} = 15.3\tau_0$ (Koehler, 2001). For large baselines (LBL: ie. larger than the outer scale), using the experimental results of Linfield et al (2001) at Palomar (the spectral slope saturates at 1.45 instead of 5/3 with a 100 m baseline), the time constant increases by about 35% to $\tau_{LBL} = 20.9\tau_0$.

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