Notes on the seeing at Mauna Kea for NGAO

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Seeing variability at Mauna Kea:

Last week I was tasked by the NGAO science committee to make some estimate of the variability in seeing that we would actually have at Mauna Kea and what kind of variability we could expect. I looked over my notes and found two sources with large numbers of seeing measurements which can be converted to r0. These are the Subaru telescope guider images (http://www.naoj.org/Observing/Telescope/Image/seeing.html) and the CFHT HR cam data (Racine et. al PASP 1991). These sources report FWHM values that can be used to estimate the "seeing" for the free atmosphere or equivalently the Fried parameter r_0. The average values of r_0 from these studies are 22 cm and 21 cm respectively. These data must be processed in various ways to convert raw image FWHM to r_0 values at 0.5 μm wavelength, these include the effect of instrument aberrations, local dome and mirror seeing, wind shake, partial atmospheric correction (HR cam only) and finite outer scale. In light of these effects and the fact that the Keck dome will have some "dome seeing" component I suggest a value of 18 cm be used in simulation of NGAO. The distributions presented by these two sources show variations the seeing that correspond to r0 variations that are about +/- 4 cm around the median with a long tail going to bad seeing values. The distributions are typically clipped at low seeing values by optical aberration in the telescope and instrument. I suggest that r_0 values of 14 cm and 22 cm be used to bound the performance envelope of NGAO. Designing NGAO for the worst possible poor seeing cases, r_0 values of 10-5 cm, is probably not cost effective with current technology.

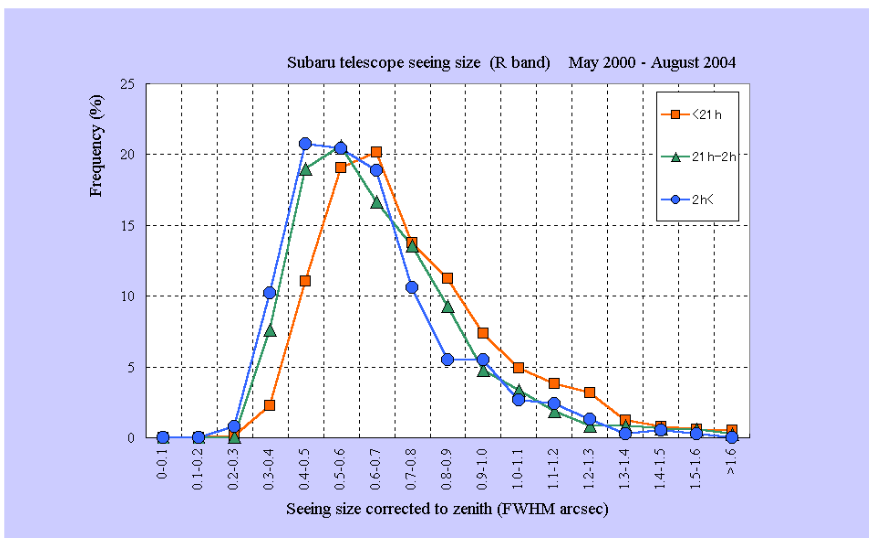

Figure 1 The FWHM histogram of Subaru telescope guider images. We estimated the free atmosphere seeing from the light blue curve, this curve represent data taken in the early morning when local seeing effect are expected to be at a minimum. The effect of telescope vibration, tracking errors, and finite outer scale are not accounted for in these data. The date must also be converted to a standard wavelength of 0.5 microns from the original R band. Converting seeing at R band of 0.45 arc seconds to 0.5 mm results in a r0 of 21 cm. (see web site for more details).

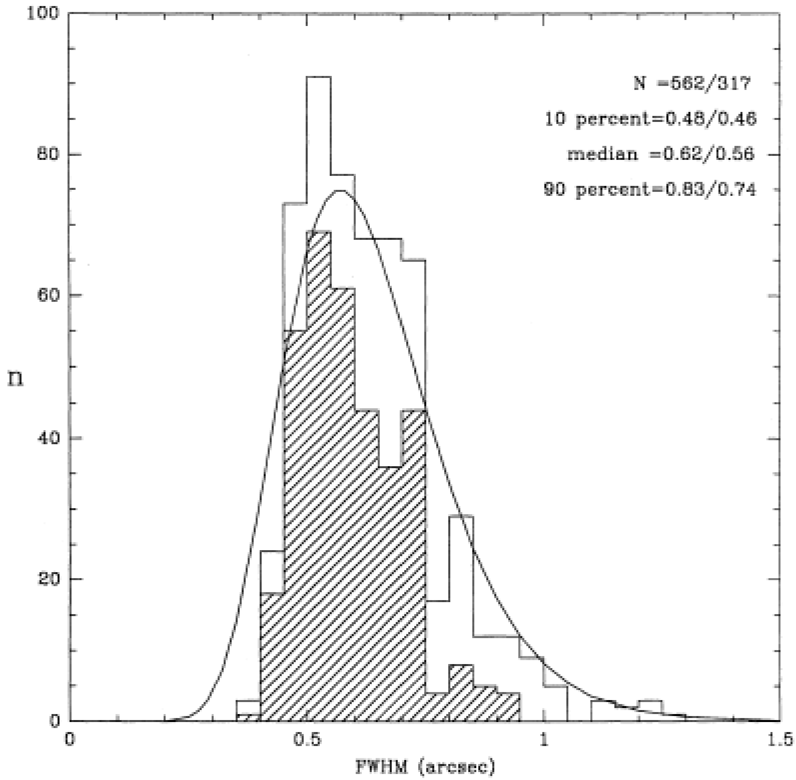

Figure 2 The original uncorrected HR-Cam data from Racine et al. 1991. The original paper give free atmosphere values of seeing at a wavelength of 0.7 μm of 0.43 arc sec and a r0 of 32 cm after correction for local seeing and tip-tilt tracking from the HR-CAM instrument. Converting to a standard wavelength of 0.5 mm the r0 value is 22 cm. See original paper for further details

Observations of the Galactic Center:

The highest elevation that the Galactic Center reaches from Hawaii is approximately 40 degrees. The change is zenith distance corresponds to rescaling the r0 at zenith by a factor of (sec z) $^{-3/5}$. The proposed typical resulting rescaled Fried parameter is 14 cm.

Variability in simulation “seeing”:

In NGAO simulations the atmosphere is generated using random numbers, as with any finite sample of a random distribution the estimate of a given statistic will be different than the parent distribution. I produced 10 independent runs (each 1 sec.) of the LAOS simulation of the narrow field AO system (KPAO) the simulation reports the uncorrected tip-tilt removed wavefront variance as a diagnostic of the simulation. The open-loop variances can be converted to r_0 using the well know formula from Noll.

$$\sigma^2 = 0.134\left(\frac{D}{r_0}\right)^{5/3}$$

Using this method the reported r0 for the 10 simulation runs was as given in the table below in meters:

0.18
0.27
0.21
0.21
0.19
0.15
0.19
0.19
0.21
0.21
0.22

The average of these values is 21 cm with a standard deviation of 3 cm which is close to the requested value of 18 cm for r_0. Using each of these one second PSF independently in a simulation of a scientific observation would span a range in r0 from 27 cm to 15 cm. This is larger than the range suggested above.