I revisited the optical turbulence profiles (OTP) because (1) we are considering the use of Rayleigh laser guide stars (rLGS) in IMAKA and (2) the narrow field-of-view for Imaka on CFHT corrects to higher altitudes. New profiles are determined from over three years of the MKAM MASS (2009-2013) and a re-binning of the Gemini Mauna Kea Ground-Layer study SLODAR/LOLAS profiles. The resulting profiles have finer sampling in both the ground-layer and the free-atmosphere than the previously used OTPs.

**Introduction**

The optical turbulence profiles used in the IMAKA simulations to date are shown in the Table below. These were derived from the Gemini Mauna Kea GL study (SLODAR/LOLAS) and Generalized SCIDAR data at the UH88” telescope. The profiles were heavily binned in the upper atmosphere since for the full one-degree field IMAKA the GLAO correction does not depend much on the distribution at high altitudes. Importantly note that the integrated free-atmosphere seeing was taken from the results of the Gemini MKGL study.

Table 1  CFHT/IMAKA simulation optical turbulence profiles used for Feasibility Study and Phase A (up to March 2013).

<table>
<thead>
<tr>
<th>Ground-Layer</th>
<th>GOOD</th>
<th>MED</th>
<th>BAD</th>
<th>Speed (m/s)</th>
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<tbody>
<tr>
<td>Alt</td>
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<td></td>
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<tr>
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<td>1.04E-013</td>
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<td>r0</td>
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<td>0.161</td>
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<td>Free-Atmosphere</td>
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<td>0.244</td>
<td>0.186</td>
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There are four components of the OTP that are reconsidered: CFHT dome seeing, the ground-layer, the free-atmosphere seeing, and finally the velocity of the layers.

**Dome Seeing**

I’ve taken the median value of CFHT (!) dome seeing (unvented) as the default. This has a value of 1.68e-13 m$^{1/3}$ ($r_{0,dome} = 23.5$cm).
Gemini MKGL study rebinning

The median profiles for the ground-layer profile (approximately 0 → 400m) are unchanged and taken from the Gemini Mauna Kea Ground-Layer study (Chun et al. 2009). I have however changed how these profiles are binned to fewer layers. In binning the 25%, 50%, and 75% profiles, I left the first three altitude bins at the measured resolution (15m), then binned the rest of the SLODAR layers up to 400 meters in three altitude bins. I preserve the zero-th and the 5/3-rd moments of the Cn² profile within the ground-layer so the altitudes of these three upper binned layers change from the past profiles.

MKAM MASS reanalysis

To obtain higher resolution profiles in the free-atmosphere, I reanalyzed of the all MKAM MASS data from 2009 to March 2013. This corresponds to about 3.5 years of data and nearly 250,000 profiles. The “remass” procedure was obtained from Victor Kornilov (MASS) back in 2010. This is the same remass script that runs nightly at CFHT on the MKAM MASS data (and is published on the CFHT web page) and has 12 layers from 500m to 22km.

The profiles were sorted by their integrated r₀ values (e.g. free-atmosphere seeing) and then the approximately 5000 profiles with r₀ values nearest to the 25%, 50%, and 75%-tile r₀ were averaged. The data split into two periods (1st half: 2009-June 2011 and all: 2009-March 2013) returned essentially the same results. The MASS profiles appear to resolve the decaying tail of the GL (500m-1km) and then show a broad set of layers from 4000-12000m above the site. The derived CN²(h) profiles are qualitatively very similar to CN²(h) profiles from Generalized SCIDAR runs (20 nights) on the UH88” telescope.

The MASS 25%,50%, and 75%-tile profiles were then binned down to 4 layers in a similar fashion the ground-layer profiles. Profiles were binned into the following altitude bins, then assigned an altitude which preserved the 5/3-rds moment of CN²(h)dh: 0.5-1.5km, 2-4km, 6-10km, h>10km. The 0.5-1.5km bin includes the “remains of the ground-layer” up to the wind velocity transition zone. There are three “FA” layers within the expected altitude of the Rayleigh laser guide star and one above. This gives us some fidelity on the cone effect as well as the option to explore rLGS at slightly higher altitudes.

Winds

The wind speeds and directions were derived from the CFHT/Gemini weather station, OTP data, and the Global Forecast System Model Upper Winds (2004-2011). The median ground wind speed is 6.5m/s from the East for the last ten years of data. The dome seeing characteristic frequency is ~0.1Hz based on OTP data at CFHT so we assign a wind speed of 0.4 m/s. The upper winds are derived from the “zero-hour” forecast from the GFS model winds. These are well fit by a constant wind speed of 5.6m/s plus a Gaussian with peak speed 16.7m/s at 7.6km above the site with a standard deviation in the height of 2.6 km. The median direction is from the West (actually 260 deg). The GFS model predicts a transition between the ground and the upper winds about 1-2 km above the site.

The median values have been assigned by hand to the layers in the OT profiles.
**IMAKA Profiles**

- What altitudes?
  - Within the GL (h<~400m) we have a thin layer that has a scale height of a few tens of meters. For a 0.11m subapertures (high order WFSing) a one-subap shear occurs between two extremes of the field (taken as 15’) at 25meters. I’ve taken 4 layers (0, 15m, 15+25=40m, 100-200m, and around 400m).
  - In the upper atmosphere we typically have a layer ~1-2km then layers high up around 4k-16km. Resolution in the upper atmosphere is needed to study the variation of the PSF over the field and the cone effect of the rLGS (especially with low-altitude beacons). Over the 15’ FOV if we have 20 PSF positions (PSF every 45arcsecs) we get a one-pupil shear between two adjacent PSFs at 5000m. Having a layer between 1-2 km and then another 5km higher seems a little coarse. Also at 10km rLGS metapupil is half the pupil size at 5km so we need a couple layers within this range. I’ve binned MASS layers at h<~1.5km, 2-4km, 6-10km, then h>10km (unsensed by rLGS). This binning puts a layer right at the peak of the wind velocity profile.

*Table 2. imaka Nine Cases (September 2013)*
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<th>GLmedFABad</th>
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<td>Cn2dh</td>
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<table>
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<th>GLgoodFABad</th>
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