Giant Magellan Telescope Site Evaluation and Characterization at Las Campanas Observatory

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ABSTRACT

Las Campanas Observatory has been designated as the location for the Giant Magellan Telescope (GMT). We report results obtained since the commencement, in 2005, of a systematic site testing campaign at LCO. Meteorological (cloud cover, temperature, pressure, wind, and humidity) and DIMM seeing data have been obtained at three potential sites, and are compared with identical data taken at the site of the twin Magellan 6.5m telescopes. In addition, measurements of the turbulence profile of the free-atmosphere above LCO have been collected with a MASS/DIMM. We examine the contribution to the seeing arising from turbulence in the ground layer (defined here as below an altitude of 500 m) through the difference between the turbulence integrals in the full atmosphere (as measured by DIMM) and in the free atmosphere (as measured by MASS). Additionally, we consider photometric quality, light pollution, and precipitable water vapor at LCO.

Keywords: site characterization, turbulence profile, seeing, precipitable water vapor, meteorological characteristics, ground layer seeing

1. INTRODUCTION

The Giant Magellan Telescope (GMT) Science Working Group determined that Las Campanas Observatory (LCO) has the potential to meet its science goals.[1] The GMT project is in the fortunate position of having clear access to a developed site with a long history of excellent performance. Light pollution is negligible and likely to remain so for decades to come. The seeing quality is as good or better than other developed sites in Chile. Furthermore, the weather pattern has been stable for more than 30 years. Our site testing effort is, therefore, concentrated on identifying the best peak within LCO in terms of seeing, turbulence profile, and wind speeds. Additionally, quantifying the potential impact of precipitable water vapor on GMT mid-infrared science goals requires further characterization in terms of both precision and time variability. In preparation for a report that will form the basis for the site selection, this paper describes our ongoing site testing efforts in the context of known properties based on the history of almost 40 years of operations at the site.

1.1 LCO DESCRIPTION

The Carnegie Institution of Washington established LCO in 1969 to build the Swope 1-m telescope in 1971 and the du Pont 2.5-m telescope in 1977. The purchase of the land was arranged by Horace Babcock, then the Observatory's director. The property (see Figure 1) is approximately $200\,\mathrm{km}^2$ and located just north of the European Southern Observatory's La Silla. LCO became the Observatories primary observing site in 1986 with the transfer of Mt. Wilson, in Southern California, to the Mount Wilson Institute. The twin Magellan 6.5-m telescopes, completed in 2001, are operated by Carnegie for the Magellan consortium including Harvard, MIT, and the Universities of Arizona and Michigan in addition to Cargnegie. Also located at LCO but not operated by Carnegie are the 1.3-m Warsaw telescope, a NASA Telescopes in Education remotely operated 35-cm telescope and one telescopes in the Birmingham Solar Oscillations Network (BiSON)*. Given the long operational baseline, a fair amount was known about the LCO site when the current GMT site testing effort began. What follows is a summary of that information. Many more details can be found in Ref. 1.

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*http://bison.ph.bham.ac.uk/about/whatwedo.html

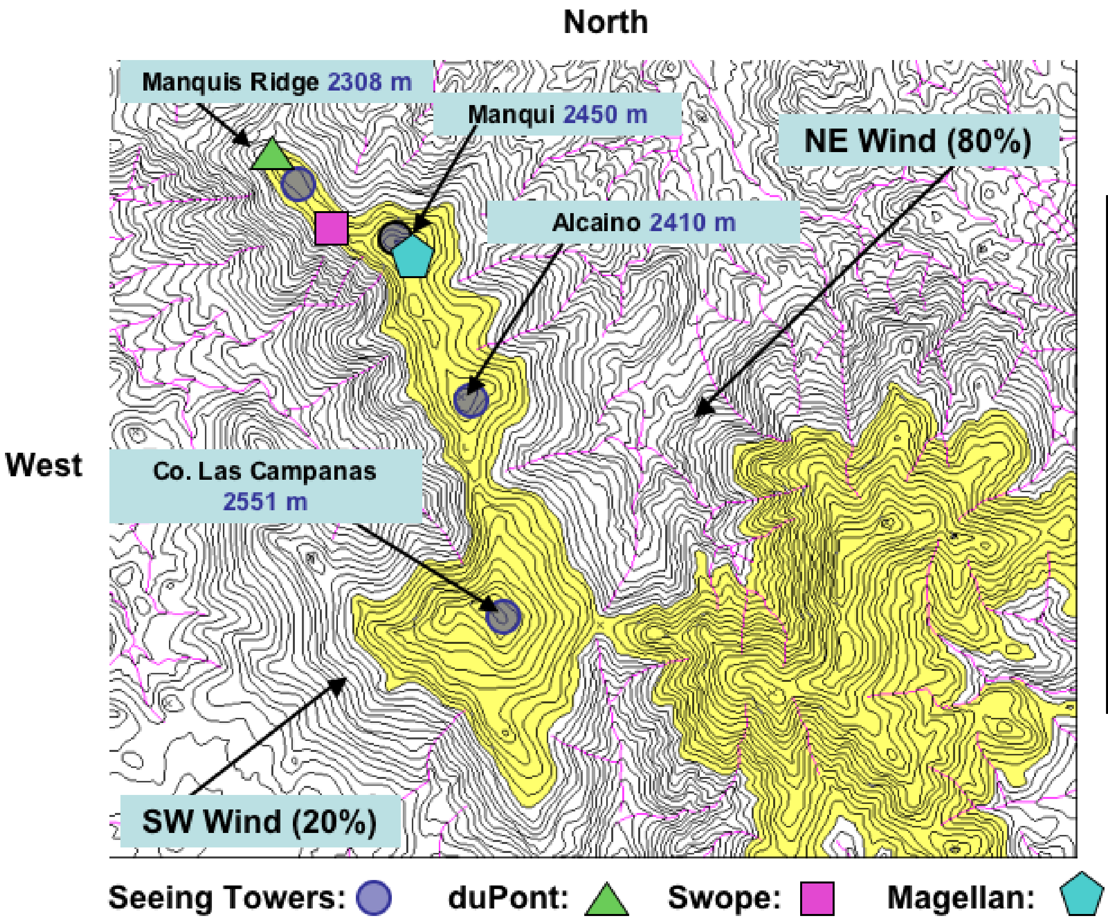


Figure 1. Topographic map showing the peaks within the LCO property including some current facilities and potential GMT sites. The purple circles show the locations of site testing towers. The sites of the du Pont, Swope, and Magellan telescopes are also indicated. The prevailing wind directions of 80% from the NE and 20% from the SW are also shown.

The study of world levels of artificial sky brightness[2] based on Satellite imagery obtained in 1996-1997 shows that LCO is located outside any regions of increased brightness. Strong light pollution laws implemented by the Chilean Government in 1998 and small population growth in the nearest towns suggests that light pollution will remain negligible in the future.[1]

The fraction of photometric and otherwise usable nights at LCO can be assessed from a number of sources including, the Swope, duPont, and Magellan telescope logs (from which there is no obvious long term trend in the fraction of usable nights apparent in the almost 40-year history of LCO), the Global Oscillations Network Group Site survey,[3] nearby La Silla Observatory cloud cover statistics[†], and remote sensing studies.[4] The results from these widely varying and independent sources are generally consistent and indicate that the average photometric fraction is 60-65%, with ∼85% of the potential observing time useful.[1]

The meteorological measurements made during the Magellan Telescopes Site Survey included wind speed and direction and temperature. The wind direction at all three sites is highly bimodal (∼80% of the time from NE and ∼20% from SW). There is a wind speed trend with altitude such that Cerro Las Campanas is the windiest site resulting in 2-3% of otherwise useable observing time with wind speeds in excess of the current Magellan limit of 15.6m/s whereas this is 1% at Manqui, the Magellan Telescopes location.

[†] http://www.eso.org/gen-fac/pubs/astclim/lasilla/

Historical measurements of precipitable water vapor are essentially non-existent. Useful information, however, can be gleaned from modest amounts of data that exist for the nearby observatories of La Silla, Tololo, and Pachon. During the VLT site survey (1983-89) at La Silla, measurements were made using a mid-IR sky radiance monitor where the absolute scale of PWV was deteremined via simultaneous coude spectroscopy of a water vapor line at 694.38 nm.[5] They found that the summertime PWV median is ~ 6 mm and in winter it is ~ 2 mm. Also, the first quartile in winter is ~ 1.5 mm.

Throughout the LCO property, median seeing values range from $0.6''$-$0.7''$. The Magellan Telescopes Site Survey[6,7] tested three sites at LCO (Manquis Ridge, Manqui, and Campanas Peak). The seeing at Manquis Ridge was found to be slightly worse ($0.05'' \pm 0.02''$) than that at Manqui, the site of the current Magellan telescopes. The seeing at Campanas Peak was inferred, based on a smaller data set, to be similar to that at Manqui. Image quality of the Magellan Clay 6.5-m telescope as measured from guide camera images indicates that the seeing at Manqui has not changed significantly since the Magellan Site Testing measurements made 18 years ago.[1] Furthermore, Magellan guide camera seeing measurements indicate a seasonal variation such that the mean seeing during the Southern summer is approximately $0.1''$ better than the mean during the winter.

2. SITE EVALUATION PROGRAM

An extensive site testing program has been underway for approximately three years to identify the best available location within the LCO property for the GMT. We are measuring meteorological characteristics (pressure, temperature, humidity, and wind) and seeing at four sites within the LCO property (see Figure 1). The turbulence profile of the free atmosphere (above 500m), precipitable water vapor, cloud cover and light pollution complement the site specific quantities. A description of the sites and the instruments in use follows.

Cerro Manqui is home to the Magellan telescopes. Although there is not sufficient space to add another large telescope, it is the best characterized site at LCO and therefore it serves as a reference. The Manquis Ridge site, between the du Pont and Swope telescopes, is the lowest altitude site. The Magellan site survey found it to have slightly poorer seeing than Manqui but also lower wind speeds. Cerro Las Campanas is the highest of our sites and was found by the Magellan site survey to have seeing similar to Manqui but significantly higher wind speeds. Furthermore, it has sufficient space for a large telescope and support facilities and is the presumed site for GMT. Finally Alcaino, in between Co. Las Campanas and Manqui and nearly the same altitude as Manqui, was the site of the Nagoya 5-m radio telescope until 2004. It was not included in the Magellan site survey and the current studies provide the first detailed examination of its properties.

Cloud cover and light pollution are being monitored through the use of the Campanas All-Sky Camera (CASCA) which was provided by CTIO and LSST as a copy of the Tololo All-Sky Camera (TASCA).[8] It is installed near the Swope telescope and takes images of the entire sky in four standard broadband filters (B, R, Z, and Y) regularly throughout the night. Sodium filter images are taken twice nightly to monitor light pollution. Software under development by the LSST project will eventually be available for analyzing the CASCA images to give quantitative, real-time information on the sky transparency. Visual estimates of cloud cover are also recorded by the site testing operators several times a night.

Other meteorological data are being collected using weather stations manufactured by Davis Instruments Corp and mounted on 10-m towers. A Weather Monitor II station was used on Manqui between 2000 and 2005. Two newer models (Vantage Pro and Vantage Pro2) which utilize the same basic sensor technology to measure temperature, humidity, atmospheric pressure, and wind speed and direction have been in use since 2005 at all four sites.

Given our lack of previous information regarding precipitable water vapor, we elected to approach the problem with redundancy. A 225 GHz tipping radiometer (Tipper) belonging to the Arizona Radio Observatory was loaned to LCO during the Southern winter months of 2005. This instrument measures the opacity due to the wing of a strong water vapor absorption line at 183 GHz. The resulting opacity at 1.2 cm can be directly related to the PWV using optical echelle spectra for calibration. Additionally an IRMA (Infrared Radiometer for Millimeter Astronomy[‡] from the University of Lethbridge Astronomical Instrumentation Group has been deployed at LCO.

[‡]http://research.uleth.ca/irma/

IRMA monitors a spectral emission line of water vapor at a wavelength of $\sim 20\,\mu$. The advantage of working at this wavelength is that the water lines are very strong and uncontaminated allowing good signal-to-noise measurements to be achieved on very short time scales. IRMA has also been adopted by the TMT project for measuring PWV and one of their units will visit LCO this coming winter for cross-calibration purposes.

The seeing is being monitored at each of the four sites through the use of differential image motion monitors (DIMM) in 7-m towers. The DIMM, first implemented in a modern fashion by Sarazin and Roddier,[9] functions by relating the FWHM from a long exposure in a large telescope to variances in the difference in the motion of two images of the same star through the use of Kolmogorov turbulence theory. The two images are created by placing a mask with two sub-apertures containing prisms at the front of the optical tube. The GMT instruments, using commercially available equipment like Meade telescopes and SBIG CCD cameras, are based on the CTIO RoboDIMM[§] but have several improvements. Image quality has been improved by using two, thinner prisms as opposed to one thicker prism and an open aperture. Following a technique developed by the TMT project, the CDIMM (Carnegie DIMM[¶]) software uses a drift scan readout mode which allows for many more image motion measurements to be made per minute and thus improved statistics.

Christoph Birk at Carnegie was responsible for developing our code. It can work in two different data acquisition modes (one each for the SBIG ST5 sub-raster image mode and SBIG ST7 continuous readout mode) and is easily changed between the two. It can control both the Meade LX200 and RCX400 telescope and features a star catalog and sky map. It controls both the telescope motion and the focus. A spiral search pattern allows the operation to be almost automatic. Additionally it can also act as supervisor to Turbina, the MASS control program.

Turbulence in the atmosphere above 500 m is being monitored by MASS, a multi-aperture scintillation sensor.[10] The spatial scale of the scintillation variation depends on the distance to the layer in which the turbulence giving rise to the wave front phase disturbance exists. Thus, the turbulence profile at a small number of discrete layers can be restored by fitting a model to the differences between the scintillation indices within four concentric apertures. The GMT MASS has an accompanying DIMM built into it. Instead of having prisms in a mask at the end of the optical tube, the two images are created by small mirrors in the pupil plane of the MASS instrument. This instrument, known as a MASS/DIMM, was fabricated and provided by CTIO[‖] and put into operation in a tower at the Magellan telescopes site (Manqui). Since the MASS operates only above 500 m , the profiles are valid for all nearby sites. In addition to the turbulence profile, the MASS also measures free atmospheric seeing (essentially the integral of the turbulence profile), the adaptive optics time constant and the isoplanatic angle due to the free atmosphere. The difference between the total DIMM and the free atmosphere MASS turbulent integrals is a measure of the portion of the total seeing contributed by a ground layer.

Higher resolution turbulence profiles have been collected at the duPont telescope on the Manquis Ridge in campaign mode using the ANU 24x24 SLODAR instrument. These measurements are discussed separately in these proceedings.[11,12]

A database[**] is under developement to aid in the analysis and presentation of this extensive data set.

3. SEEING AND METOEROLOGICAL DATA ANALYSIS

Since April 2005 we have collected DIMM seeing measurements on 752, 719, and 706 nights at Manquis Ridge, Manqui, and Alcaino, respectively. The DIMM at Co. Las Campanas became operational in September 2005 and we have a total of 665 nights of seeing measurements. The efficiencies at each four sites ranges from 63% at Alcaino to 68% at Co. Las Campanas. This is reasonable assuming a usable fraction of ∼85% and considering loss due to equipment failures or operator illness and vacation. There are 414 nights in common between all four sites and all months are well sampled except July and August when bad weather is more likely to cause closure. This is already six times more data collected during the Magellan Site Survey that totaled 61 nights.

[§](http://www.ctio.noao.edu//telescopes/dimm/dimm.html

[¶]http://www.ociw.edu/ birk/CDIMM/

[‖]http://www.ctio.noao.edu/%7Eatokovin/profiler/

[**]Along with other GMT site testing information, it can be found at: http://www.lco.cl/lco/operations-inf/gmt-site-testing-1

The analysis of the full data set is ongoing. In the following analysis that includes both meteorological data and DIMM data from all four sites as well as MASS data, we have limited ourselves to one full year of data taken beginning in January 2007.

3.1 Seeing and Turbulence Profiles

The DIMM measurements have been filtered to remove poor quality data due three possible criteria: focus, read noise, and the number of measurements during one minute. We measure focus using the mean separation of the two images throughout a minute of measurements. Nominal focus is determined on a night with good seeing by varying the focus and maximizing the Strehl ratio. The CDIMM software is designed to keep the mean separation within a range of 1 pixel on either side of the nominal focus. There are, however, some measurements throughout the night but especially at the beginning of the night that need to be removed because the separation is outside the nominal range. Additionally the MASS/DIMM does not have automatic focus control as there is not space for a micro-focus controller between the instrument and the telescope mount. The operators monitor the focus and adjust it as needed but naturally this leads to a higher percentage of MASS/DIMM measurements taken out of focus that need to be removed. The filters for read noise and the number of measurements allow for the removal of suspect quality data due to clouds or tracking errors.

The MASS data has been reprocessed using a new version of Turbina[13] to correct for the effect of strong scintillation under poor seeing conditions.[14] Strong scintillation affects the turbulence profile and free atmosphere seeing by over-estimating turbulence and spreading turbulence to lower levels. We examined the sensitivity of the possible errors due to incorrectly determined parameters (such as the instrument magnification or the non-Poisson and non-linearity characteristics of the detectors) and found the maximum bias to be on the order $\pm 0.05''$ and similar to that found by Els et.*al*.[15]

In order to compare concurrent measurements from each site, the timestamps from the DIMM, MASS, and meteorological data for the entire year were matched to timestamps of one of the DIMMs to find the closest measurement within one minute. Each instrument takes approximately one measurement per minute so using a shorter timescale significantly reduces the number of matches.

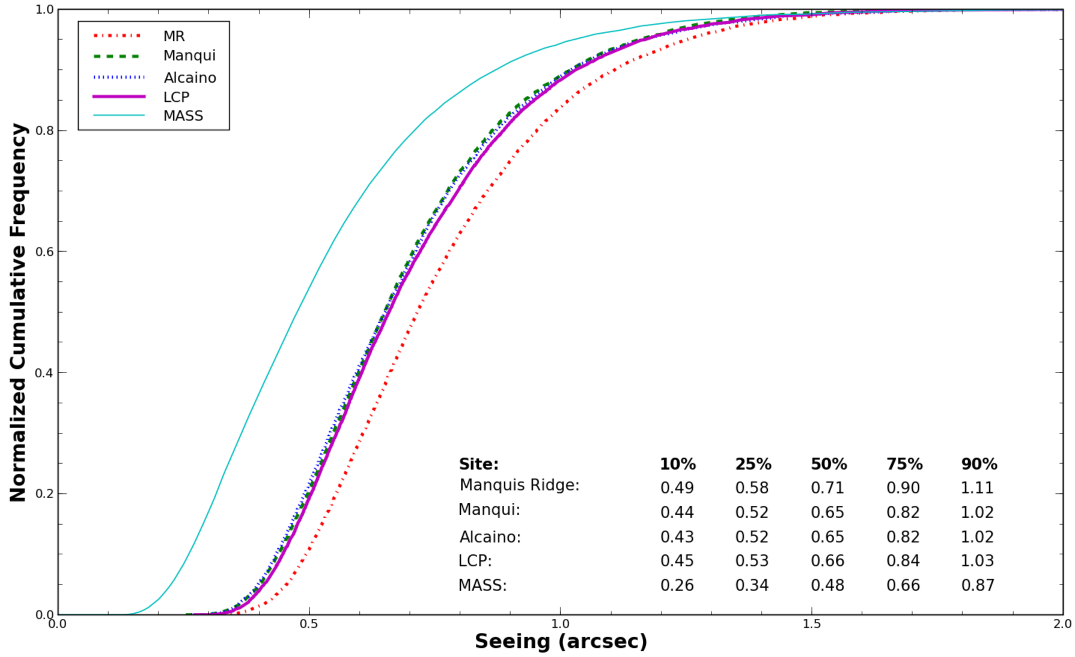
Figure 2 shows the normalized cumulative histograms for the seeing measured by the DIMMs at the four sites. The seeing at Cerros Alcaino, Manqui, and Las Campanas (LCP) have extremely similar distributions while the Manquis Ridge site clearly shows a degradation of about $0.05''$ in the median. The free atmosphere median seeing is $0.48''$ demonstrating the possibilities in the absence of the contribution from the ground layer.

The seeing, β, contribution by the ground layer (defined here as lower than 500 m) can be inferred from the MASS and DIMM measurements at each matching time in the following manner:

$$\beta_{GL} = |\beta^{\frac{5}{3}}_{DIMM} - \beta^{\frac{5}{3}}_{MASS}|^{\frac{3}{5}} \tag{1}$$

The absolute value is used only in computing statistical distributions. This need arises due to that fact that some small percentage (2-20%) of matched MASS and DIMM measurements result in what could be termed a negative ground layer seeing values in the sense that the MASS measurement is larger than the DIMM measurement. This is, of course, not physically possible but is a result non-zero errors and the subtraction of quantities of similar magnitudes. The range in the percentage of negative ground layer seeing arises when considering selections of data filtered for scintillation index in the A channel of the MASS. The correction made in the mass reprocessing for strong scintillation is not perfect and this effect can be seen by examining the percentage of negative ground layer found in samples with varying scintillation indices. The sample presented in this analysis is not filtered for scintillation index since this would introduce a bias towards better seeing. But in this case, one must realize that the ground layer as determined from data that has not been filtered for scintillation index will be less accurate.

The ground layer can be examined at each site using the MASS located at the Manqui site if we assume that the turbulence above 500 m is similar over the entire property. Furthermore, the thickness of the ground layer probed at each site varies depending on the altitude of each site. The cumulative histograms of the fraction of the total seeing found in the ground layer are shown in the bottom of Figure 2 along with appropriate ground layer thicknesses. Under median conditions, all four sites contain approximately 60% of the seeing within the ground



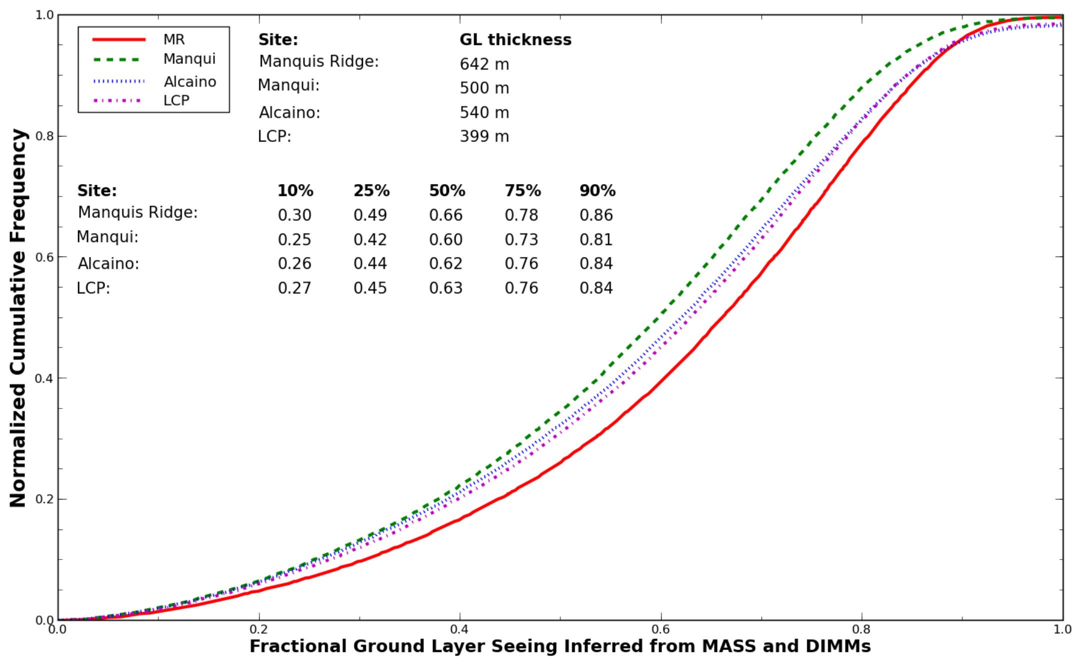


Figure 2. Top: Normalized cumulative histograms of the MASS free atmosphere seeing and the DIMM seeing at all four sites for a period of one year beginning January 2007.
Bottom: Normalized cumulative histogram of the fraction of the total seeing found in the found in the ground layer as inferred by the MASS and the DIMM at each site for a period of one year beginning January 2007.

Table 1. Seasonal variation in the median seeing (″) at each site and in the free atmosphere

Location	Seeing		Ground Layer Seeing	
	Summer	Winter	Summer	Winter
Manquis Ridge	0.71	0.74	0.44	0.42
Cerro Manqui	0.64	0.68	0.35	0.35
Cerro Alcaino	0.64	0.67	0.38	0.31
Cerro Las Campanas	0.64	0.73	0.38	0.40
Free Atmosphere	0.47	0.52		

layer. The differences between the sites do not vary strictly with altitude and thus ground layer thickness. This could be due to morphological effects but is more likely attributable to noise inherent in the subtraction of two similar numbers.

To examine the the free atmosphere turbulence profiles from the MASS in a statistical manner we have sorted them by a seeing criteria and then averaged the profiles within groups based on the seeing percentiles. We chose three groups to represent the best (70-80%), typical (45-55%), and worst (20-30%). We also chose to sort by three different seeing criteria (total, free atmosphere, and ground layer). In each grouping there were more than 4000 profiles. In the case where the profiles were sorted by total seeing the resulting average profiles, shown in the top of Figure 3, are very similar in the upper atmosphere but diverge at the boundary layer whereas those sorted by free atmosphere seeing, shown in middle of Figure 3, are more divergent throughout the atmosphere except at the very top layer. Finally, those sorted by ground layer seeing, as seen at the bottom of Figure 3 show very little difference except near the boundary layer. This supports the idea that the turbulence in the ground layer is in fact independent from that in the free atmosphere[16] but that there is a transition zone near 0.5 to 1 km.

3.1.1 Seasonal variation in the seeing

The seasonal variation in the seeing statistics is examined by taking the medians over six month periods. The shift between the seasons is taken as the equinoxes such that winter includes March 22 through September 21 and summer includes September 22 through March 21. Table 1 shows that the seeing is generally better in the summer than in the winter at all four sites and in the free atmosphere. This trend does not continue to the seeing in the ground layer where at some sites, Manquis Ridge and Cerro Alcaino, the opposite is true. Cerro Manqui shows no seasonal change in ground layer seeing and at Cerro Las Campanas the ground layer seeing follows the same trend as the seeing.

3.2 Meteorological Data

Preliminary studies (summarized from Ref 1) based on data at the Manqui site going back to 2002 confirmed the highly bimodal nature of wind direction as found by the Magellan site survey. Futhermore, the SW component is stronger in Southern summer than in winter, and also stronger during the first half of the night. We have also confirmed that Co. Las Campanas is windier than Manqui and discovered that Alcaino has wind speed characteristics very similar to Manqui which is not surprising given their similar altitudes. Furthermore, humidity statistics show a strong seasonal variation whereby, the winter months are the driest, consistent with that seen at nearby La Silla in the VLT site survey.[5]

This study focuses on the meteorological data taken during DIMM operation in order to look for correlations between the two data sets. Therefore, the statistical distributions of wind speed and humidity presented in Table 2 are valid during conditions useable for astronomy but do not represent the overall meteorological conditions at the sites. The same argument is valid for the wind direction histogram that can be seen in Figure 4.

3.3 Correlation of Wind and Seeing

The seeing appears to be weakly correlated to the wind speed although the trend varies site to site. In Figure 5, Manquis Ridge and Alcaino show the most pronounced trends while at Manqui and Co. Las Campanas the trend is flatter out to a higher wind speeds. The ground layer seeing at Manquis Ridge (also shown in Figure 5) also shows a trend with wind speed and a peak near zero wind speed but the correlation at the other sites is less marked.

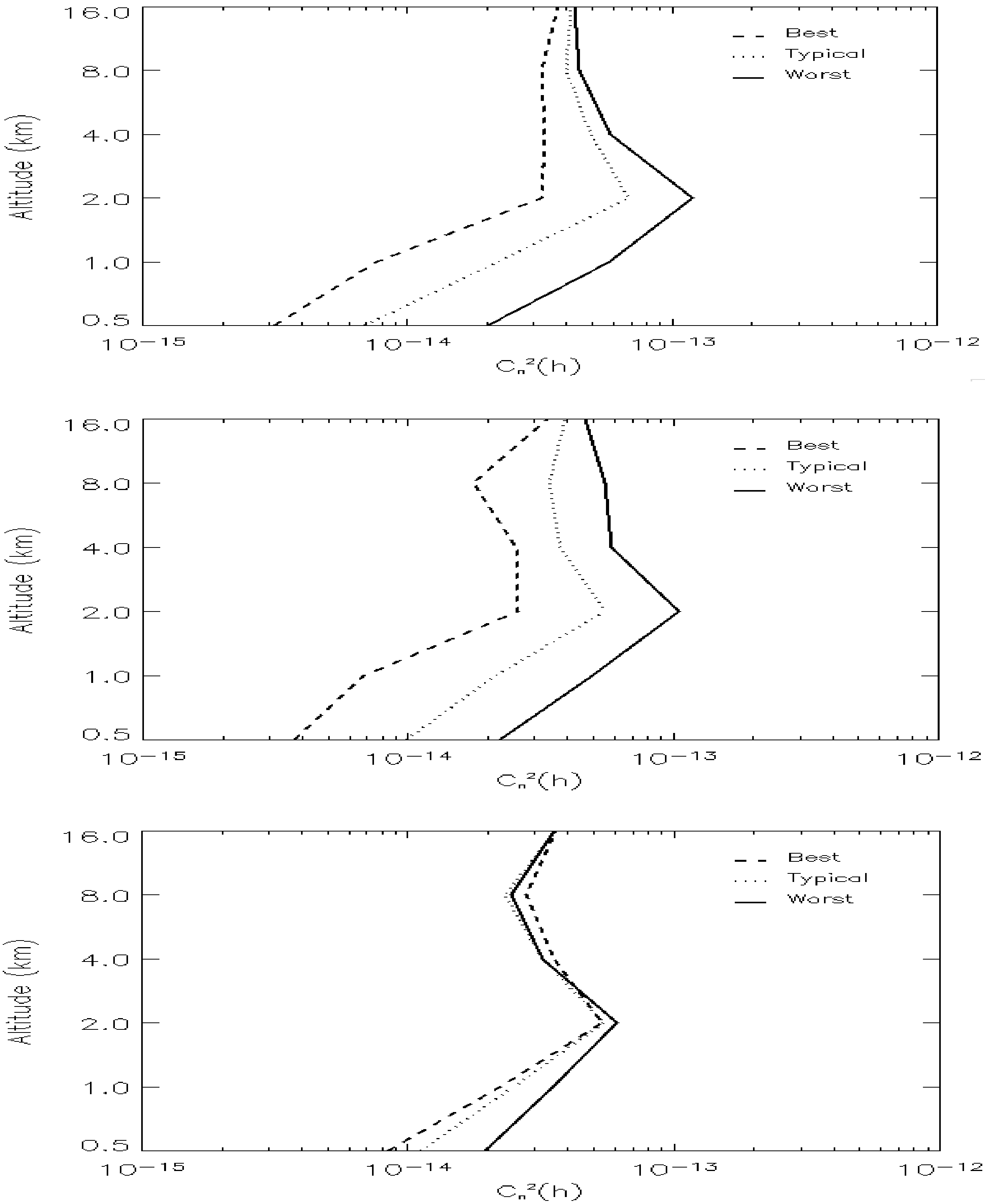


Figure 3. Average MASS profiles within the best (20-30%), typical (45-55%), and worst (70-80%) bins sorted by total seeing (top), sorted by free atmosphere seeing (middle), and sorted by ground layer seeing (bottom)

Table 2. Statistical distributions of wind speed and humidity valid during conditions useable for astronomy

Location	10%	25%	50%	75%	90%
Wind Speed (m/s)					
Manquis Ridge	0.0	2.7	4.4	7.0	9.7
Cerro Manqui	1.3	2.7	5.3	8.4	10.6
Cerro Alcaino	0.9	2.2	4.0	6.2	8.0
Cerro Las Campanas	1.8	3.1	5.7	8.4	10.6
Humidity (%))					
Manquis Ridge	23	31	43	53	70
Cerro Manqui	22	28	38	51	59
Cerro Alcaino	21	28	38	52	68
Cerro Las Campanas	23	31	40	51	66

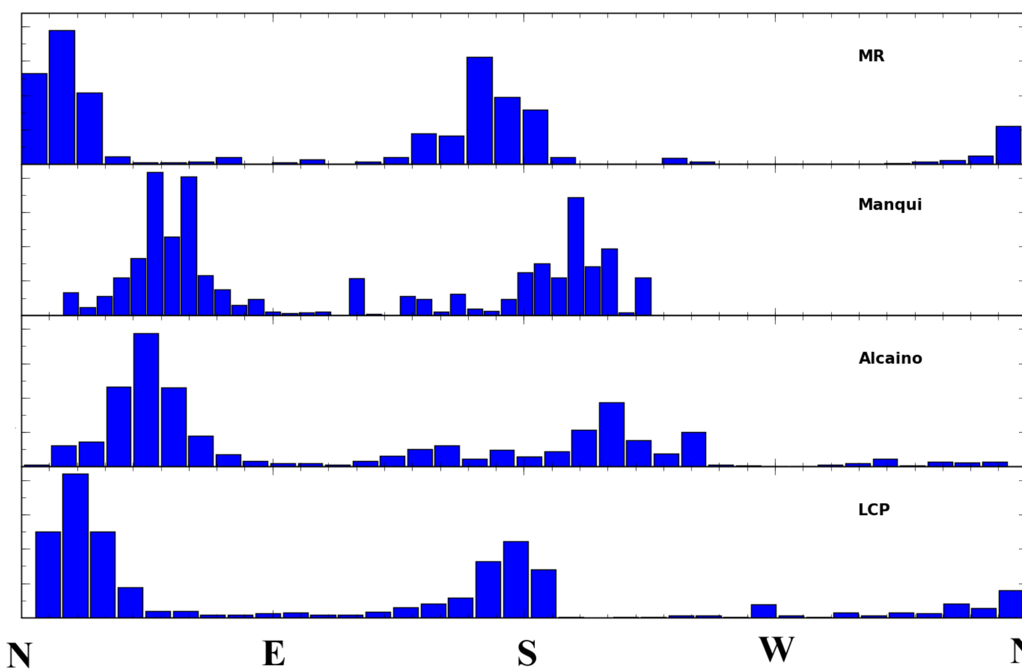


Figure 4. Normalized histogram of the wind direction during conditions useable for astronomy at all four sites

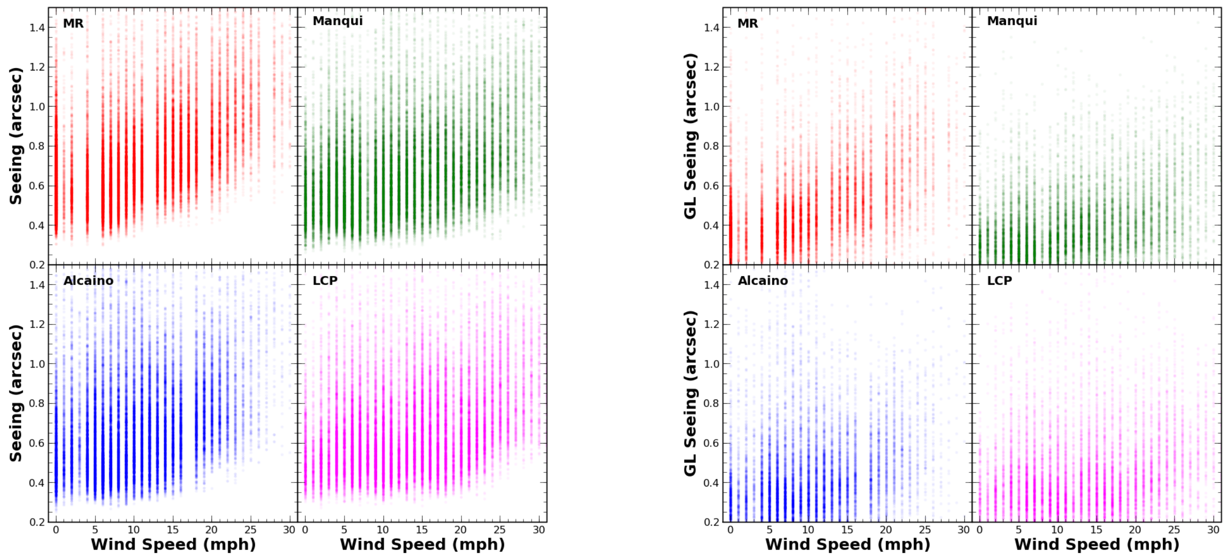


Figure 5. Correlation of wind speed to DIMM seeing (left) and to ground layer seeing (right) at all four sites

4. PRECIPITABLE WATER VAPOR

An important objective of the GMT site evaluation is to characterize the column of precipitable water vapor found over the LCO site. Absolute calibration is an important part of relating the column of precipitable water vapor to its various effects such as increased thermal-IR background, decreased transparency, and the introduction of extraneous spectral features.

Absolute calibration is achieved through High-dispersion spectroscopy of certain weak H_2O absorption lines in the optical and near-IR wavelength regions. Swings et.*al*[17] combined high resolution echelle spectroscopy of a water vapor line at 694.38 nm with a technique devised by Brault et.*al*[18] to calibrate mid-infrared sky radiance measurements obtained at the La Silla Observatory during the VLT site survey. Fractional populations in energy levels corresponding to wavelengths between 590-730 nm are temperature insensitive over temperatures found in Earth's atmosphere. This allows a robust measurement of PWV without a detailed model atmosphere as long as the lines are unsaturated.

We have extended this method with improved partition functions and additional lines. Rapidly rotating A and B type stars with magnitudes between 4 and 6 are readily observed with the MIKE echelle spectrograph on the Magellan Clay telescope. This method is not practical for constant monitoring of the PWV, but provides an excellent tool for verifying the absolute calibration.

An excellent correlation was obtained between MIKE PWV measurements and 225 GHz Tipper opacities. The calibrated tipper PWV data for 29 clear nights in Southern winter 2005 shown in Figure 6 give a median of 2.8 ± 0.3 mm, in agreement with VLT Site Testing measurements at La Silla. To determine how much useful time is availalable for mid-infrared work we characterized periods of low PWV that are longer than 2 hours. Furthermore, in the Southern hemisphere winter months, we can expect good conditions for infrared observing ($\lesssim 1.5$ mm) at the tenth percentile level. During the Tipper campaign it was found that $14 \pm 7\%$ of the clear night time occurs in blocks longer than two hours during which the PWV is less than 1.5 mm. That percentage rises to $25 \pm 10\%$ when considering PWV less than 2.0 mm. Extrapolating this to all of wintertime, 15-25 % or up to 270 hours spread over periods ranging from 2 hours to more than 3 contiguous days could be useful for mid-infrared work. Further details of both the calibration method and the results from the 2005 Tipper campaign can be found in Ref 19.

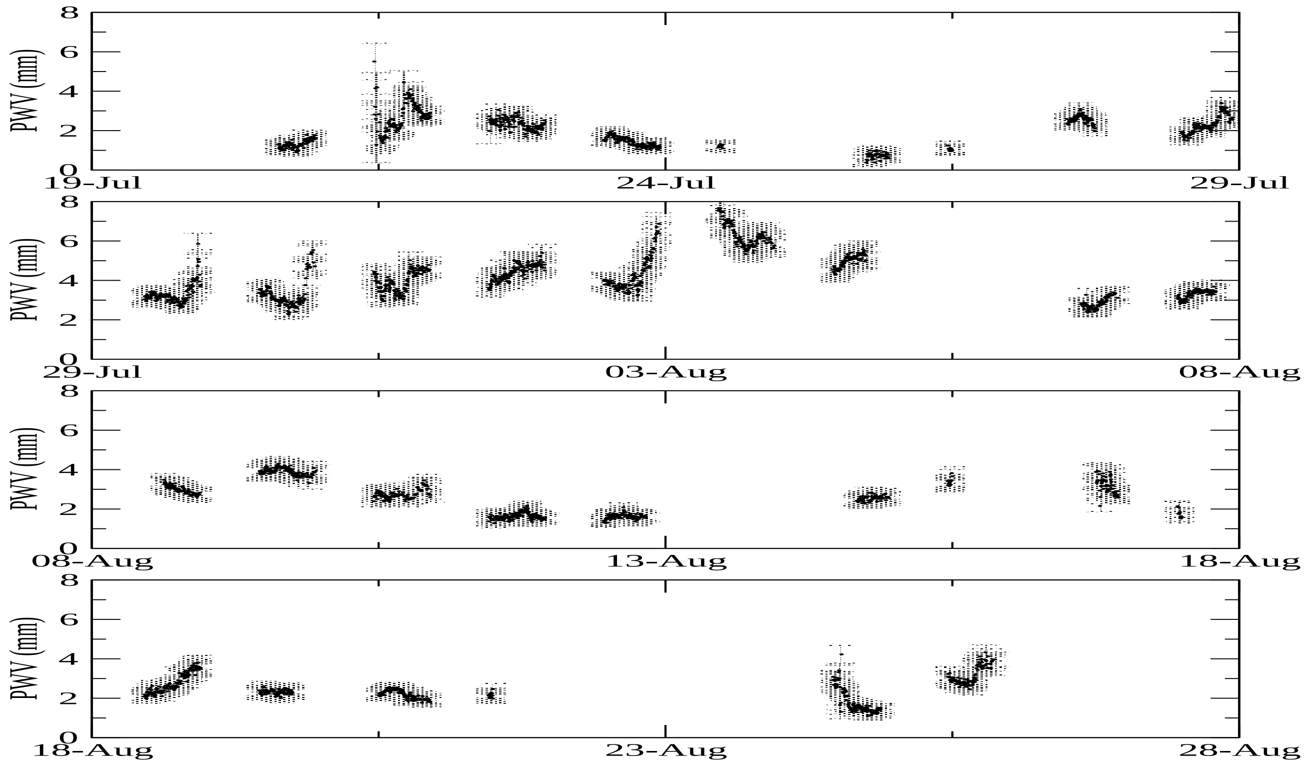


Figure 6. Clear night-time PWV as a function of time during our campaign. Uncertainties are indicated in gray.

An IRMA has been measuring PWV at LCO since Sept 2007. The calibration of these data in an ongoing project and further details can be found in these proceedings.[20] A preliminary calibration using only 9 MIKE measurements gives a median value during the 9 months not including winter of 2.3 mm. The reader is cautioned that this is a preliminary figure and the error estimates are not yet well determined.

5. CONCLUSIONS

The long history of excellent conditions at LCO, concerns regarding biases in short-term site surveys, and limited resources led the GMT project to focus its site evaluation activities to certain peaks within the LCO property. LCO has dark skies, little or no risk of future light pollution, excellent seeing, moderate winds and a high fraction of clear nights. The primary downside of LCO, and any moderate elevation site in Chile, is its mediocre mid-IR performance much of the year. For this reason, we have focused on characterizing the precipitable water vapor, especially in the winter months when it is lowest, to allow for a final determination of how long it would take to complete the mid-IR science goals. This upcoming winter season we will have two IRMA units working side-by-side to finalize the details of the calibration and increase the likelihood of collecting data during this important season. The final site evaluation at LCO will take into account seeing (both image quality and stability), wind speeds, and ground layer characteristics. However, it is presumed that Cerro Las Campanas will be the site of the GMT given the confirmation of the good seeing and meteorological characteristics found to date.

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