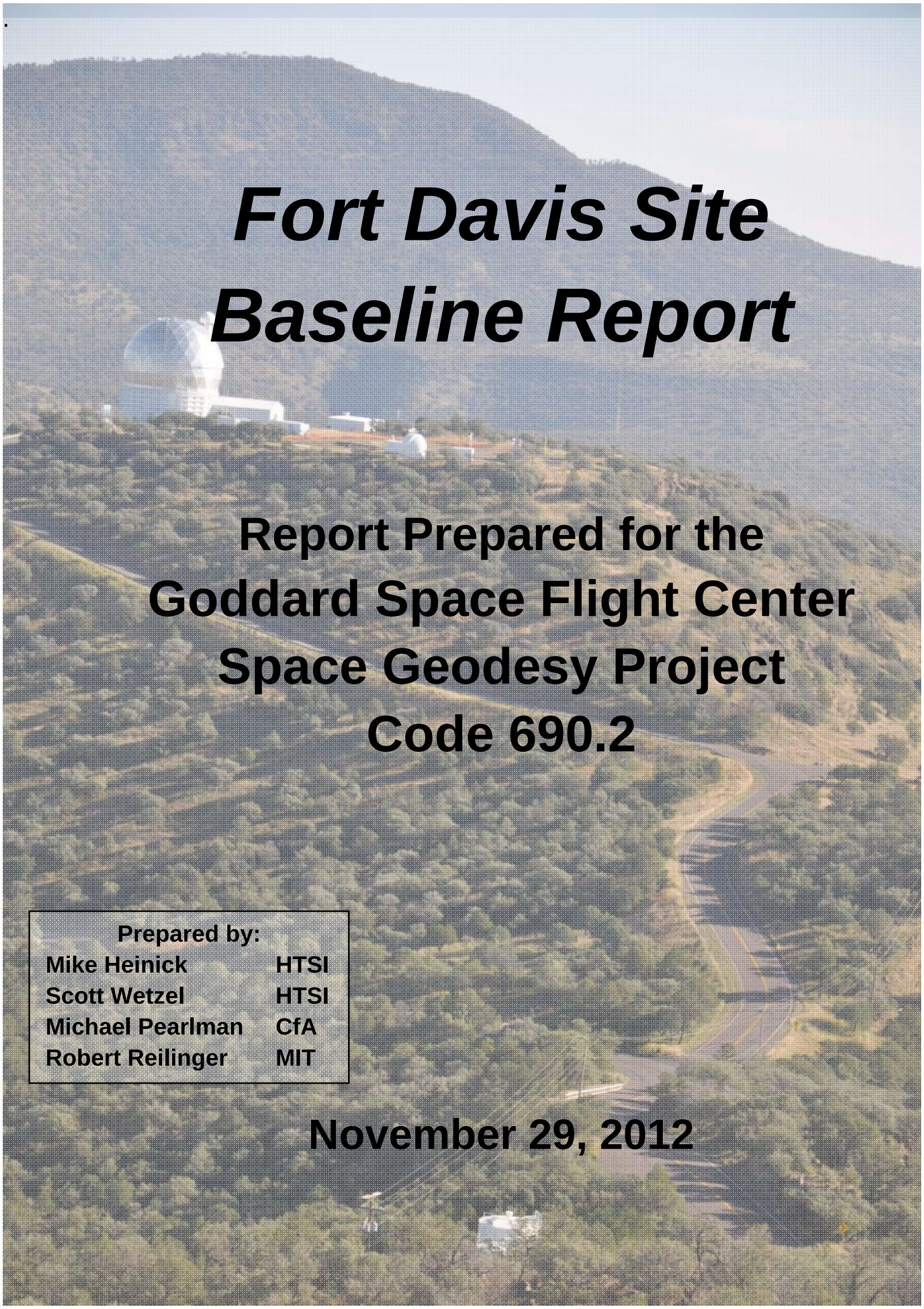

Fort Davis Site Baseline Report

Report Prepared for the Goddard Space Flight Center Space Geodesy Project Code 690.2

Prepared by:

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1.0 Acknowledgements

The authors would like to thank the following people for their extensive knowledge and information that contributed to the writing of this report. They include: Peter Shelus, Randy Ricklefs, and Srinivas Bettadpur from the University of Texas, Dave McCormick from NASA GSFC, Julie Horvath and Felipe Hall from Honeywell Technology Solutions Inc., and Michael Floyd and Robert King from MIT.

One component that is necessary for the success of NASA's Space Geodesy Project is the identification of key locations to populate the next generation space geodesy techniques to form a Fundamental Station. As part of the process, a baseline of each occupied NASA SLR and VLBI site and a few key GPS sites will be compared with the site criteria to determine viability for a Fundamental Station. This baseline information will then be used to evaluate other potential sites. With significant help from the above referenced people we were able to accumulate much of this information into a report that will help determine the next NASA Space Geodesy Network.

2.0 Executive Summary

One of the tasks under the NASA Space Geodesy Project (SGP) is to identify candidate locations for the new Fundamental Stations. A Fundamental station is one that ideally consists of the following space geodesy techniques, a next generation satellite laser ranging (NGSLR) ground system, a next generation very long baseline Interferometry (VLBI-2010) system, and an updated Global Navigation Satellite System (GNSS) ground system that has the capability to receive data from all GNSS satellite constellations. If a Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) system is also included, it would be an advantage. The requirements for this Fundamental Station can be found in the document, "*Site Requirements for GGOS Fundamental Stations*, 2011":
(http://cddis.gsfc.nasa.gov/docs/GGOS_SiteReqDoc.pdf)

The initial requirement of this project is to baseline the current NASA SLR, VLBI, and select GNSS sites to the requirements stated in the site requirement document. As NASA has a rich history of sites with 1 to all 4 techniques collocated, a baseline of each NASA site will allow for a better understanding of what existing and new sites will meet with the SGP requirements.

The fifth site to be base lined as part of the SGP is the Fort Davis, Texas, site at the McDonald Observatory. The McDonald Observatory site located near Ft. Davis, Texas, is located a remote area of Jeff Davis County and is collocated with a number of astronomical observatories. The Fort Davis site has been a pioneering site for lunar and satellite laser ranging development since the 1960's. The University of Texas at Austin developed and tested the Transportable Laser Ranging System, later known as TLRS-1, at the site during the late 1970's and early 1980's. The first acquisition of LAGEOS by the MLRS occurred in August, 1981, and the first lunar acquisition occurred in August, 1983. MLRS was relocated from its original location between Mt. Locke and Mt. Fowlkes to its current site on Mt. Fowlkes in 1988.

Currently at the site supporting space geodesy are the SLR and GNSS components. A VLBA site is located approximately 8 km from the system. A VLBI system was located near that site but stopped operations in the 1980's.

There is a strong relationship in space geodesy with the University of Texas in Austin and strong support for the McDonald site to support space geodetic systems. There is an experienced crew on site and a strong infrastructure support from the other observatories at the site to support as needed. While remote in location, there is an observatory community within the observatory grounds and small towns located in Ft. Davis, Alpine, Marfa and other surrounding communities that provide driving access to the observatory in under an hour.

Local infrastructure should be able to support an NGSLR, VLBI2010, GNSS, and VTS systems, however, no clear site for the VLBI2010 system has been identified as of yet and remains an action to occur. Also, a detailed RFI study is required to be taken, based on suggested

VLBI2010 system recommendations. Currently, the site does not have a high speed data capability to support e-VLBI, however, daily overnight currier services currently exists.

The site is among the best for cloud cover with an average of 76% track-able sky at the site. The McDonald Observatory uses a Boltwood II cloud sensor, installed in 2010, that stores data from the sensor at 1 minute intervals in a weather data archive. Since that time, over 1.2 million sky condition records were used to determine sky clarity. These numbers may be improved as 15% of these records were ambiguous, some of which may add to the 76% trackable number.

Other site infrastructure including power, safety and access are all very good, considering the remoteness of the site. Site stability is very acceptable.

Areas of concern include a viable place to put the VLBI2010 system. No potential site has been identified yet and remains an action. Also of concern is the availability of high speed data communications and an existing workforce to support the facility with the small but effective existing crew.

At the time of this report, a number of outstanding actions remain and should be completed as part of the study. These include but are not limited to:

1. Completion of a detailed RFI Study for broadband.
2. Local hydrology (well levels, aquifer characteristics) and relationship to apparent vertical site stability.
3. Inclusion of a local and regional tie maps.
4. Identification of a potential usable VLBI2010 site either close to the existing compound or within the larger observatory complex.
5. Description of available data communications network.
6. Inclusion of more recent and detailed photographs of the MLRS system, local site markers detail panoramic views of potential VLBI2010 and GNSS systems.

In summary, the McDonald Observatory site is rich history in space geodesy and has a very long time series for SLR and GNSS. Weather at the site is generally excellent for SLR ranging. It is a key ILRS and IGS site. Finding a suitable location and infrastructure for a VLBI2010 system may be problematic but not unsolvable. Additional RFI and sighting for a VLBI2010 system will be necessary. High speed communications for eVLBI is currently not available and an alternate solution would need to be identified unless use of daily overnight shipment is the solution. Other site infrastructure are good for such a remote site, however, staffing the site would need to be addressed. If the VLBI2010 site could be included, the McDonald Observatory site would be an excellent choice for a Fundamental Station for the SGP.

3.0 Introduction – Fort Davis Site Conditions for GGOS

This report describes the current conditions at the Fort Davis site in Texas that will determine the suitability of the site as a Fundamental Station for geodesy as described in the paper *Site Requirements for GGOS Fundamental Stations*, 2011. The information provided below will also provide a basis for comparison with other candidate sites during the site selection process.

The key elements that make up a Fundamental Station include a Next Generation Satellite Laser Ranging (NGSLR) system, a broadband capable Very Long Baseline Interferometry (VLBI2010) system and a Global Navigation Satellite System (GNSS) capable system. A DORIS system is desirable to the success of the Fundamental Station but is subject to the plan of the DORIS network.

The following sections will examine all of the components of the Site Requirements for a Fundamental Station and will provide a summary of this examination. While NASA has occupied these initial locations by either SLR, VLBI, GNSS, or combinations of 2 or all three techniques, no site is to be considered as an exact candidate for a Fundamental Station. Also, it is understood that none of the existing sites is an exact match to the requirements. Ideally, the requirements within the *Site Requirements for GGOS Fundamental Stations* would make the best site; however, there is probably not an existing NASA occupied site that meets all of the criteria. This report just provides a baseline of the existing sites and allows for an informed decision by the Space Geodesy Project (SGP) to make the next choices for a Fundamental Station.

4.0 Existing Techniques

Techniques currently active at the Fort Davis site include SLR and GPS.

VLBI – VLBI is not currently on site, however, there is a VLBA site located on a nearby ranch approximately 8 km from the MLRS.

National Radio Astronomy Observatory (NRAO) Very Long Baseline Array (VLBA) Site, Near Ft. Davis

Domes: 40442S017 PID: 7613 FD-VLBA

GNSS - A GPS antenna is installed at IGS station MDO1. The station was installed on June 3, 1993.

IGS MDO1 Station from MLRS

Domes: 40442M012 PID: AF9515 Code: MDO1 JPL: 4011-S

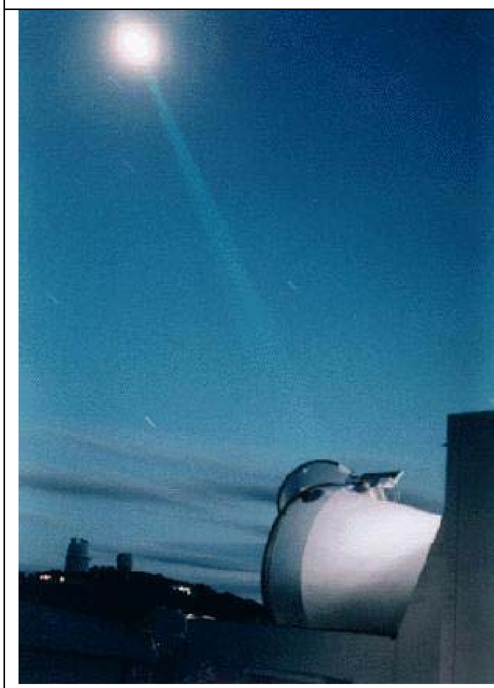
IGS MDO1 Station

Note: MLRS in background

DORIS –. DORIS is not currently on site.

SLR – The Fort Davis site has been a pioneering site for lunar and satellite laser ranging development since the 1960's. The University of Texas at Austin developed and tested the Transportable Laser Ranging System, later known as TLRS-1, at the site during the late 1970's and early 1980's. The first acquisition of LAGEOS by MLRS occurred in August, 1981, and the first lunar acquisition occurred in August, 1983. MLRS was originally located in the saddle region between Mt. Locke and Mt. Fowlkes in 1983, but was later moved in 1988 to its current site on Mt. Fowlkes to escape various problems with the first site.

MLRS



Note: These pictures were taken circa 1980's.

MLRS


5.0 Global Consideration for the Location

The Fort Davis site is remotely located in the Davis Mountains of west Texas.

Fort Davis on the North American Continent	
SGP Sites in U.S.A.	Fort Davis Region
	

5.1 Geometrical Distribution

Fort Davis is located west of the midpoint of the southern border of the continental United States in west Texas. Existing sites at Monument Peak in California and GGAO in Maryland are located west and east of the Fort Davis site.

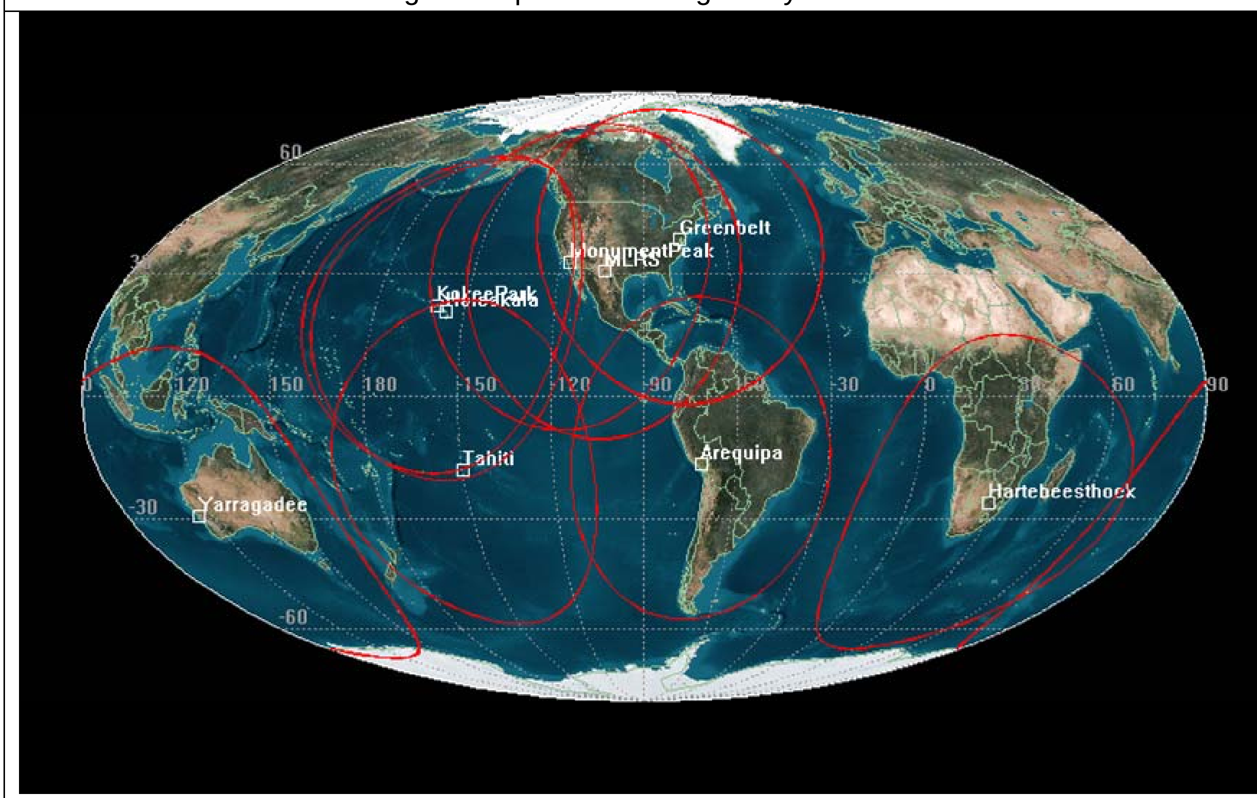
5.2 Technical Distribution

It is desired to have three well distributed stations on each tectonic plate. Fort Davis is located within the North American tectonic plate.

5.3 Technique Dependent Distribution

The location of the Fort Davis site near the west to east midpoint of the North American continent provides coverage of satellite tracks across the continent. The following plot displays the tracking coverage down to 20 degrees elevation for LAGEOS by the NASA SLR sites.

20 Degree Acquisition for Lageos by NASA Sites



6.0 Geology

See the report from MIT on the stability of the Fort Davis site included at the end of this document in Appendix A.

http://ceed.utpb.edu/geology-resources/west-texas-geology/

6.1 Substrate

See the report from MIT on the stability of the Fort Davis site included at the end of this document in Appendix A.

6.2 Tectonic Stability

A report from MIT on the stability of the Fort Davis site is included at the end of this document in Appendix A.

7.0 Site Area

The Fort Davis site is remotely located at an altitude of 2006.221m in the Davis Mountains of West Texas. The nearest town, Fort Davis, population ~1050, is over 15km away southeast of the site. There are nearby facilities and housing to support on-site and visiting personnel, guest observers, and visitors from the public to the observatories.

Fort Davis Site Region

Source: http://www.bing.com/maps/

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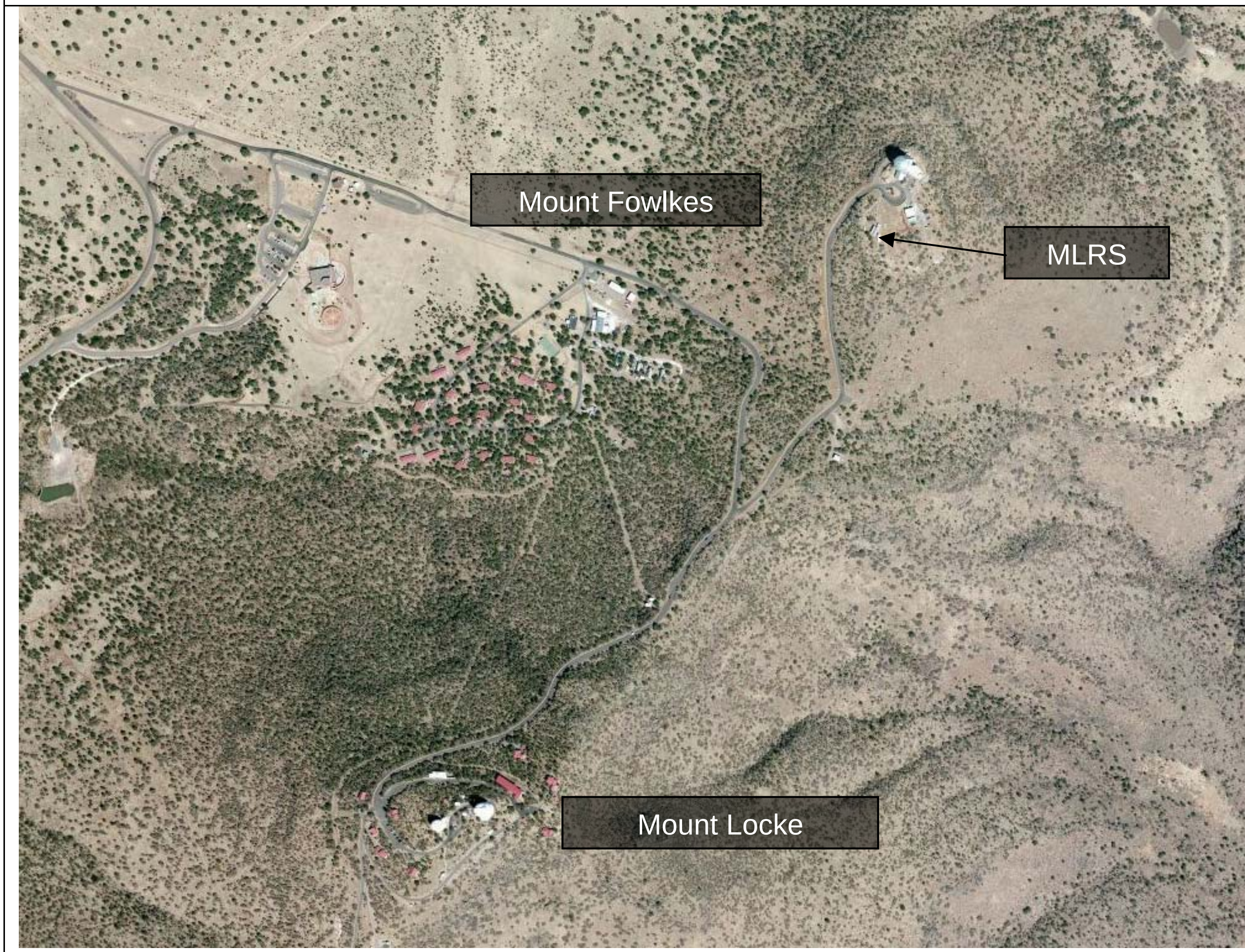
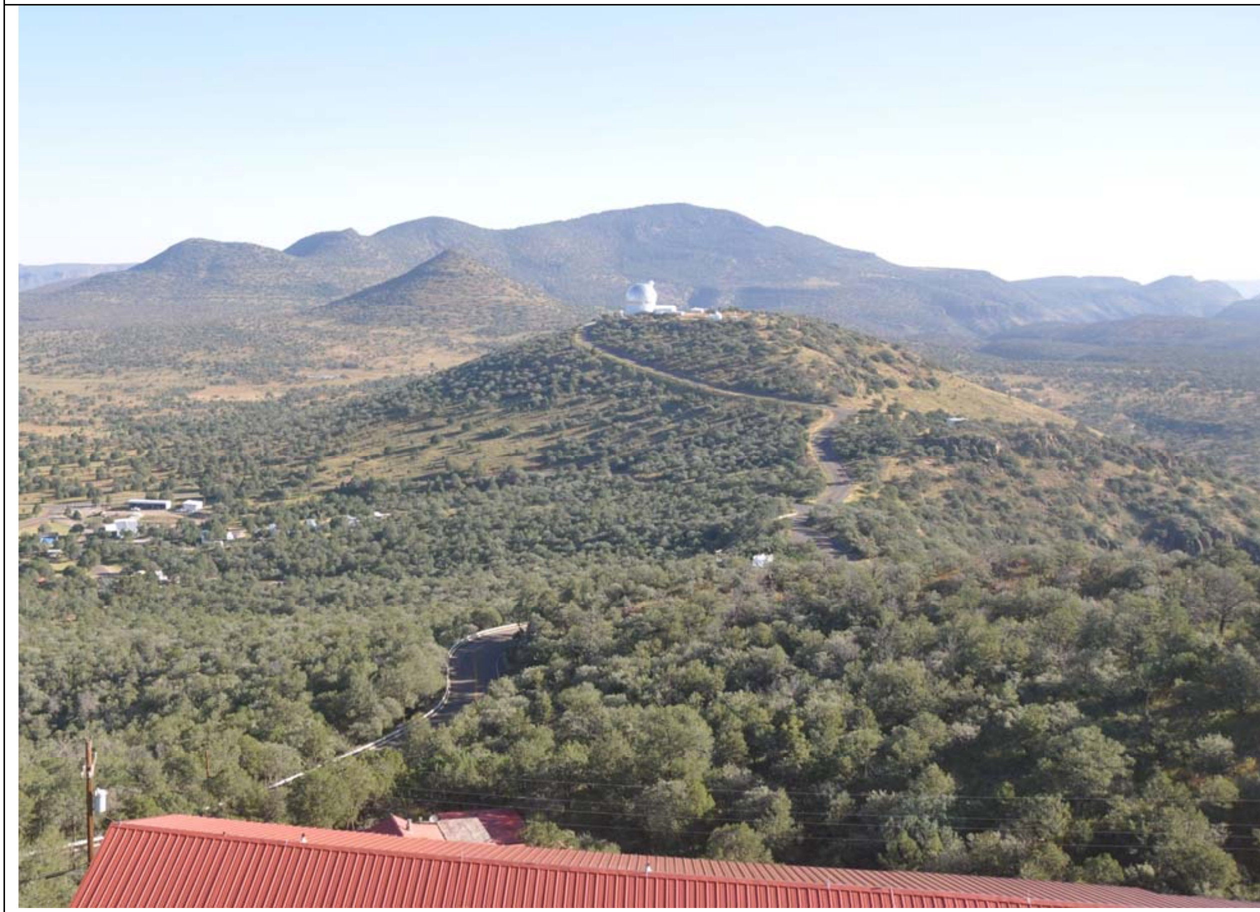
Distance From MLRS to VLBA Site ~8411 meters

Fort Davis Site



Source: http://www.bing.com/maps/

Mt. Fowlkes from Mt. Locke



7.1 Local Size

The Fort Davis site is spread over a large area, consisting of two main compounds, one on Mount Locke and the other 1.3km away toward the northeast on Mount Fowlkes, with a few additional facilities located between the two. The Mount Fowlkes compound contains the MLRS laser ranging system, the HET observatory, an observatory of the Las Cumbres Observatory Global Telescope Network (LCOGTN), and other facilities within an area of approximately 2.9 hectares.

Fort Davis Mount Fowlkes Site

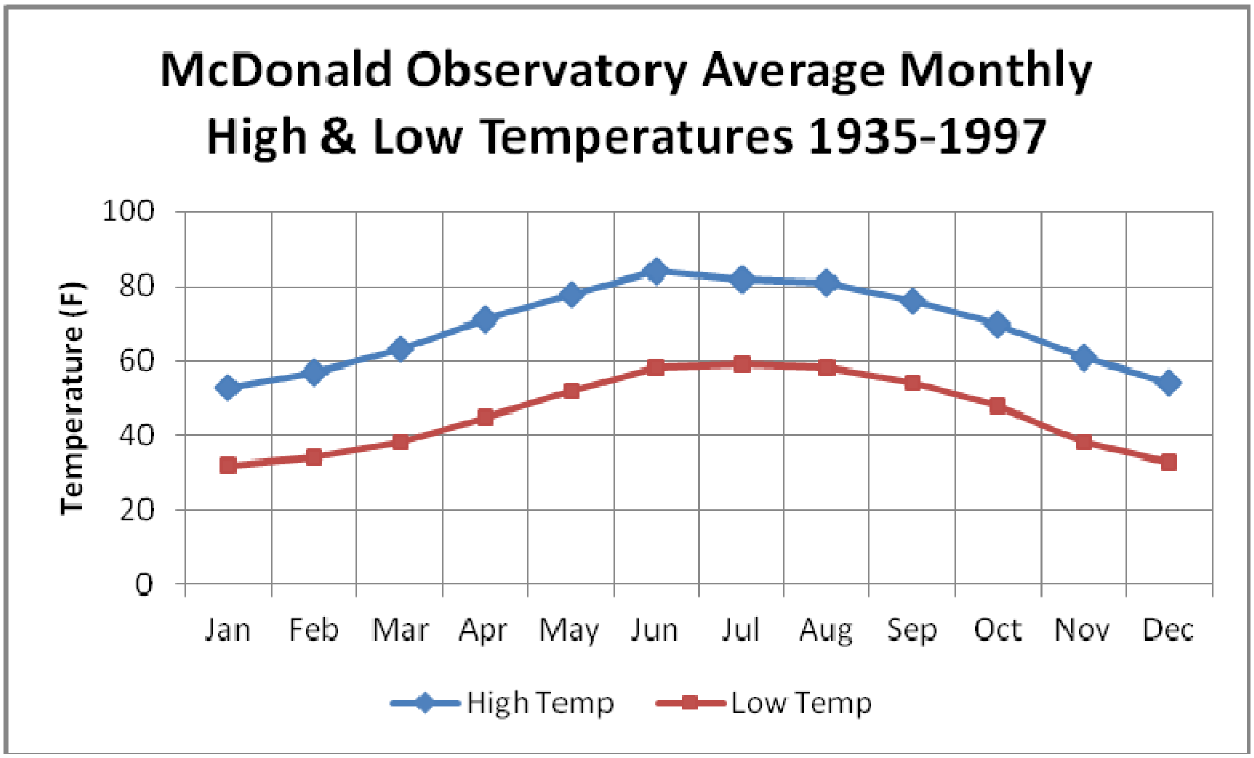
Source: http://maps.google.com/maps?hl=en&tab=wl

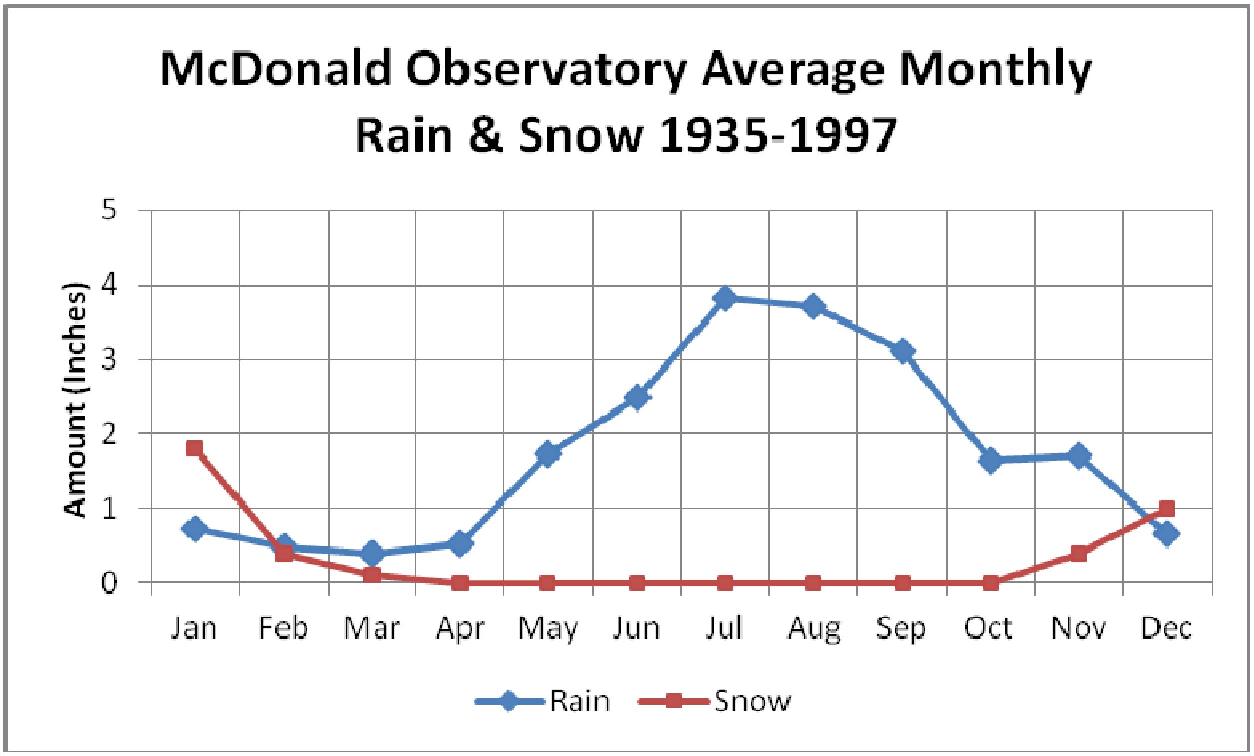
7.2 Weather & Sky Conditions

7.2.1 Climate

Climate in the Davis Mountains of Texas is described as moderate.

McDonald Observatory Average Monthly High & Low Temperatures (F) and Precipitation (Inches) For 1935 - 1997													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
HiTemp	53	57	63	71	78	84	82	81	76	70	61	54	
LoTemp	32	34	38	45	52	58	59	58	54	48	38	33	
Rain	0.72	0.49	0.40	0.52	1.72	2.49	3.83	3.71	3.11	1.65	1.70	0.65	
Snow	1.8	0.4	0.1	0	0	0	0	0	0	0	0.4	1.0	
Source of data: http://mcdonaldobservatory.org/visitors/weather & NOAA													



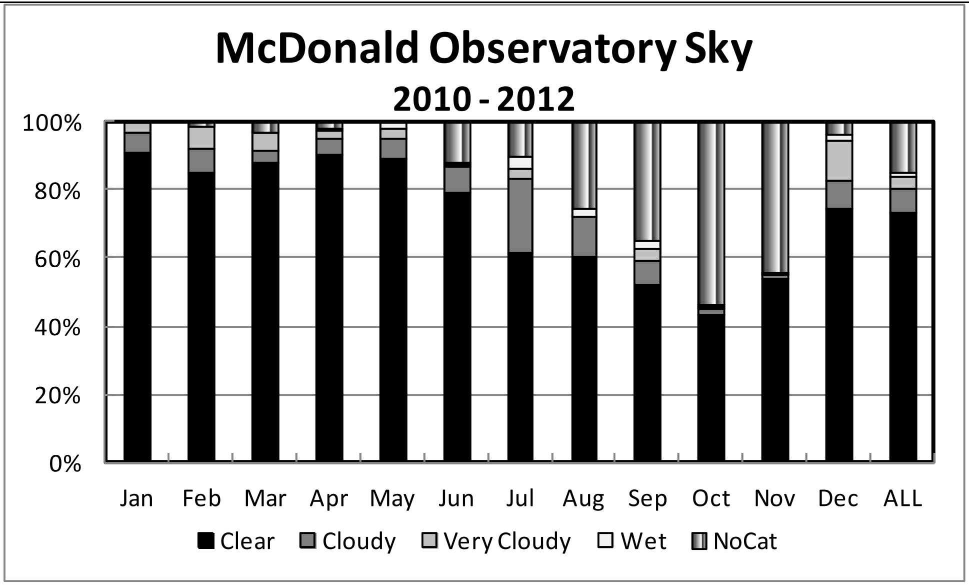

McDonald Observatory Average Monthly
Rain & Snow 1935-1997
Amount (Inches)
0
1
2
3
4
5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Rain
Snow

7.2.2 Sky Conditions

McDonald Observatory has a Boltwood II cloud sensor, installed in 2010, that stores data from the sensor at 1 minute intervals in a weather data archive. There is a sky condition item that classifies sky conditions as clear, cloudy, very cloudy, wet, and unknown (no cat). 1,274,396 sky condition records were extracted from the archive covering the period from installation to 9/27/2012. The data were then separated by month and sky condition and counted to determine the fraction of time for each sky condition.

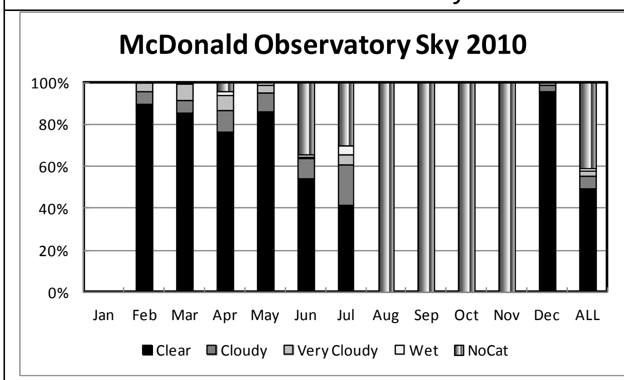
	Clear	Cloudy	Very Cloudy	Wet	No Cat
January	0.909132	0.058738	0.029986	0.002082	6.17E-05
February	0.854647	0.067171	0.063983	0.003521	0.010678
March	0.879786	0.04022	0.050681	0.001421	0.027892
April	0.903009	0.048567	0.026346	0.006237	0.015841
May	0.894296	0.05803	0.031939	0.013603	0.002133
June	0.793103	0.07744	0.003514	0.009571	0.116371
July	0.61872	0.213926	0.030466	0.033856	0.103032
August	0.60644	0.11454	0.002529	0.020456	0.256035
September	0.523542	0.069866	0.035817	0.023671	0.347104
October	0.432673	0.017593	0.006612	0.005778	0.537344
November	0.539668	0.013834	0.001365	0.004108	0.441025
December	0.743943	0.083479	0.116255	0.022511	0.033813
2010-2012	0.732624	0.074804	0.031407	0.012639	0.148526

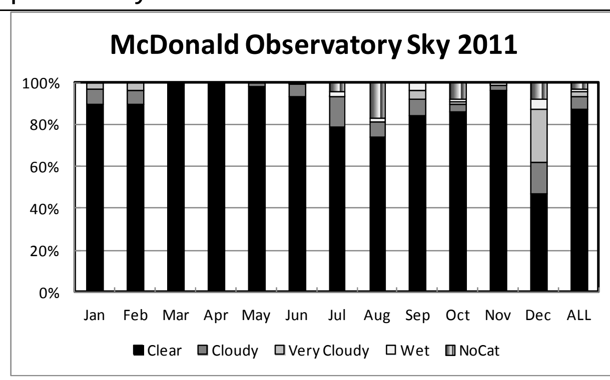
McDonald Observatory Sky Conditions from Boltwood Cloud Sensor

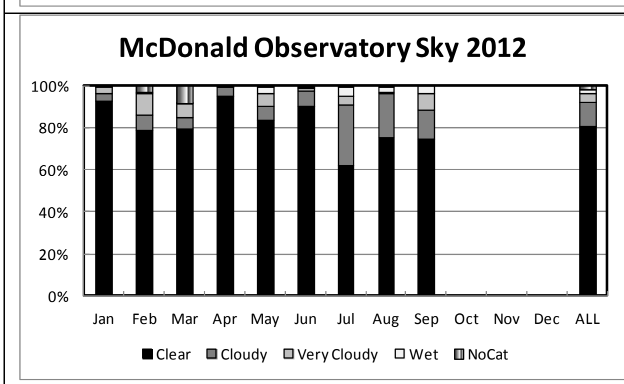


Source: http://weather.as.utexas.edu//cgi-bin/weather/weather-query.pl

Sky Conditions Separated by Year



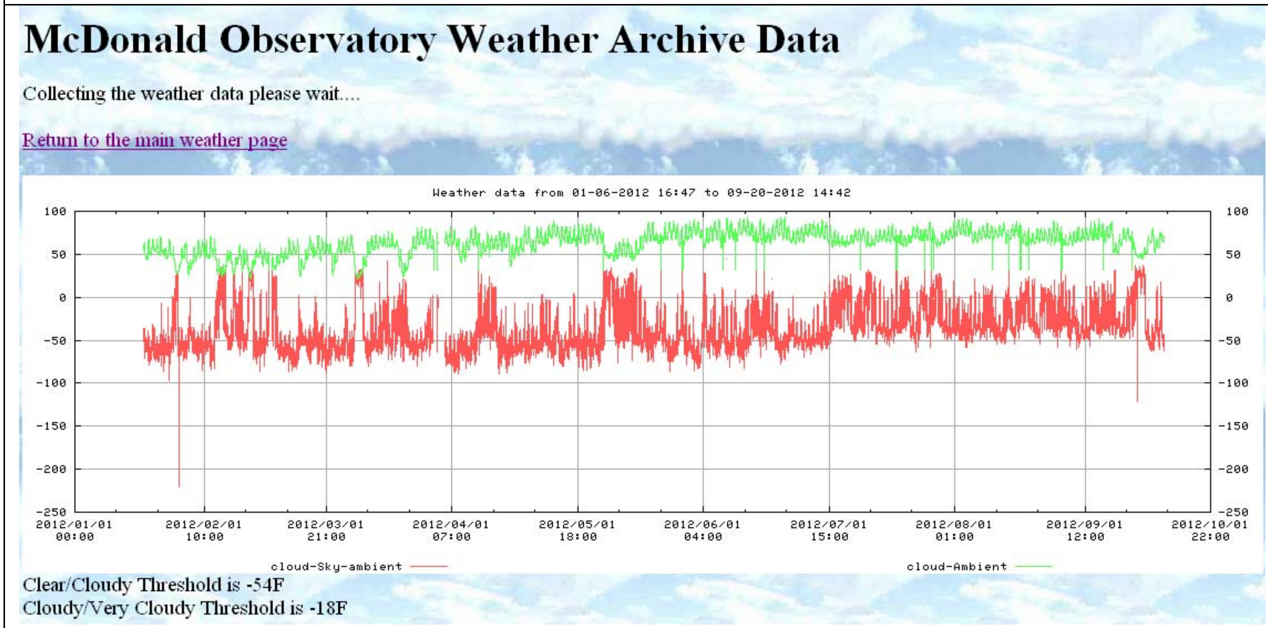


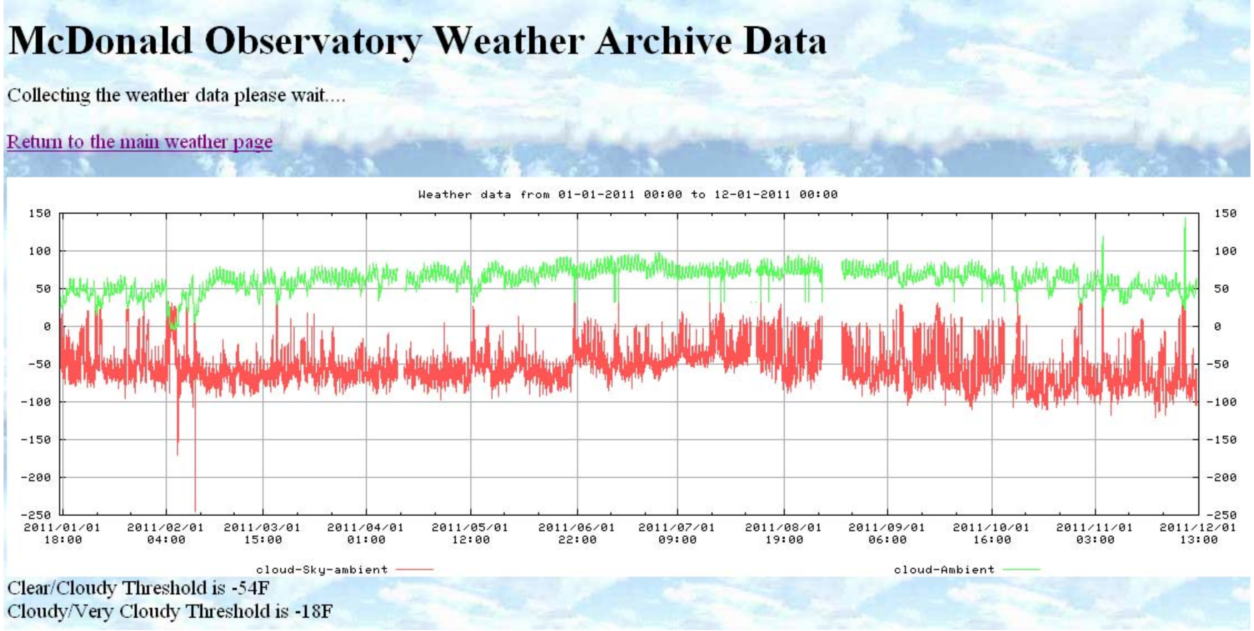


Source: http://weather.as.utexas.edu//cgi-bin/weather/weather-query.pl

Note: There was a problem with the cloud sensor in 2010 from July into December.

McDonald Observatory Sky and Ground Temperatures





Source: http://weather.as.utexas.edu//cgi-bin/weather/weather-query.pl

7.3 RF and Optical Interference

The remote location and dark skies of the Fort Davis site have made the site one of the best sites for astronomical observatories in the U.S.

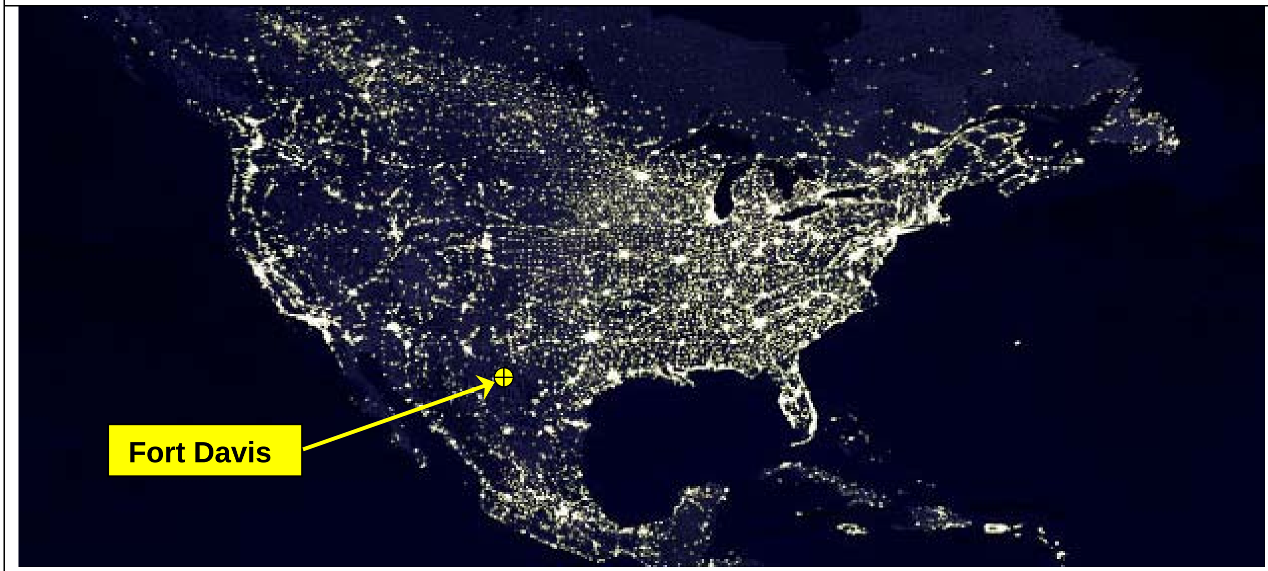
7.3.1 RF Interference

.Studies need to be performed.

7.3.2 Optical Interference

At 2006m altitude and the remote location, the clear night skies at the Fort Davis site are dark with minimal light pollution. The site and the surrounding area provide some of the best sky conditions for astronomical observatories in the U.S. Currently, there are no restrictions on laser ranging at the site to avoid interfering with observations being made by neighboring astronomical observatories, but the laser wavelength has been noticed in their data.

Fort Davis in Dark Skies



Source: http://apod.nasa.gov/apod/image/0011/earthlights2_dmsp_big.jpg

7.3.3. Other Possible Interference

None are identified at this time.

7.4 Horizon Conditions

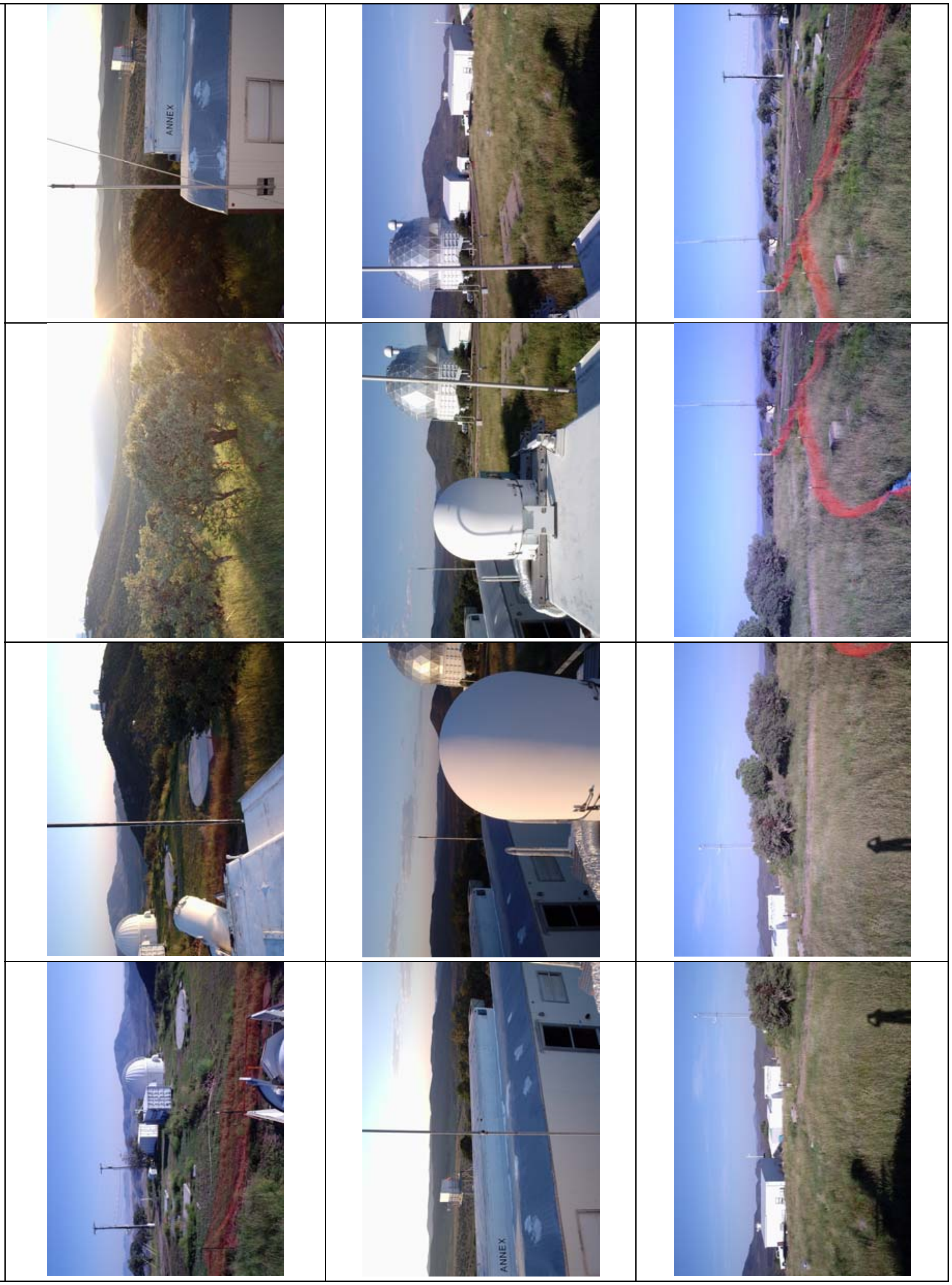
The *Site Requirements for GGOS Fundamental Stations* document states that, ideally, stations should have an obstruction free view down to 5 degrees elevation over 95% of the horizon.

At the Fort Davis site, as with any site, horizon conditions for each technique will vary depending on the location and height of each technique on the site. For SLR, the radar of the Laser Hazard Reduction System (LHRS) used for aircraft protection works best with a clear horizon within 400 meters free of trees, buildings, towers, and other tall objects that would contribute to ground clutter.

A determination for a VLBI2010 site needs to be made prior to finalizing the horizon conditions for such a station.

The following pages provide views of the horizon from various locations on the Mount Fowlkes part of the site.

Fort Davis Site – Fowlkes Mountain Horizon From MLRS



Fort Davis Site – Pan From South of MLRS

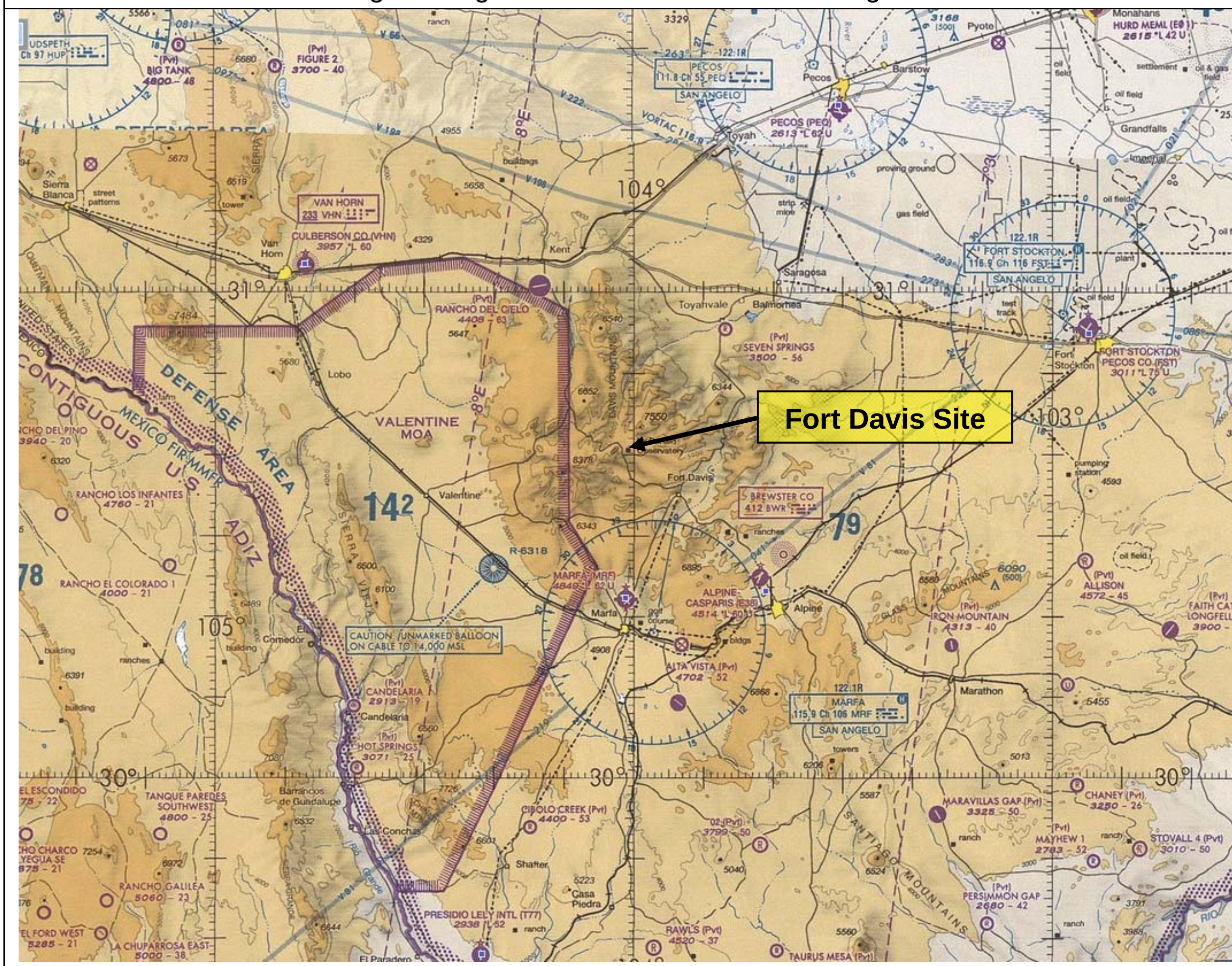
Fort Davis Site – Pan From South Pier

Fort Davis Site – Pan From East Pier

7.5 Air Traffic

The nearest major public airports are located in El Paso and Midland/Odessa. Both are over 220km away, 3 to 4 hour drives from the Fort Davis site. Texas has 303 public use airports. 80% of passengers fly out of the Dallas / Fort Worth and Houston airports located hundreds of miles to the east of the site. To the west of the site there is the large Valentine military operations area which is a non-free flying zone.

Flight Navigation Chart For Fort Davis Region



Source: http://vfrmap.com/

7.6 Aircraft Protection

For SLR, a HTSI Laser Hazard Reduction System (LHRS) automatically detects aircraft approaching the laser beam transmit path and blocks the laser transmission until the path is clear of aircraft. It is the current method of aircraft hazard avoidance at the Fort Davis site and at many of the other NASA SLR sites.

7.7 Communications

Digital communication is via OC-3 lines.

Current capacity is not sufficient for eVLBI. Other methods to support high speed (Gb/sec) would need to be brought into the area, or other means, like shipment of hard-drives, would be required to support the VLBI2010 operations.

There are daily UPS/FEDEx/etc. delivery and pick-ups at the observatory.

7.8 Land Ownership

The University of Texas at Austin owns the Fort Davis site.

7.9 Local Ground Geodetic Networks

7.9.1 Local Station Network

DOMES markers at Fort Davis:

DOMES No.	Description	Code
40442M001	MLRS, MOBLAS, TLRS-1 standard NASA disk	7086
40442M004	McDonald RM4 1977	
40442M005	MLRS, MOBLAS, TLRS-1 standard NASA disk	7885
40442M006	MLRS mark 7080 1988	7080
40442M008	Mobile VLBI and SLR mark 7850 1988	7850
40442M009	Mobile VLBI mark (Havard RM5 1977)	7900
40442M010	SLR Mark 7850	7897
40442M011	SLR Mark 7851	7851
40442M012	GPS Mark 4011-S	MDO1
40442S001	LLR MLRS	7086
40442S002	LLR McDonald 2	7206
40442S003	85 foot VLBI ref. point (HRAS 085)	7216
40442S017	VLBA antenna reference point	7613
Source: ITRF website http://itrf.ign.fr//site_info_and_select/site.php?SelecSite=404042		

Listing of markers from the NGS website centered on CORS station MDO1::

```
|Dist|PID...|H V|Vert_Source|Latitude.....|Longitude.....|Stab|C|Designation
|----|------|- -|-----------|-------------|--------------|----|-|-----------
| 0.0|AC5717|0 1|88/ADJUSTED|N304049.77258|W1040054.30052|D...|G|7850
| 0.0|AC5719|0 1|88/ADJUSTED|N304049.85081|W1040053.00404|C...|G|7850 RM 1
| 0.0|AC5720|. 1|88/ADJUSTED|N304050......|W1040057......|A...|G|7850 RM 2
| 0.0|AF9515|A .|...........|N304049.82376|W1040053.93784|....|S|MCDONALD CORS
MONUMENT
| 0.0|AF9514|A h|88/GPS OBS.|N304049.82376|W1040053.93784|....|G|MCDONALD VLBI STA
CORS ARP
| 0.0|AA7437|A h|88/GPS OBS.|N304049.82378|W1040053.93785|....|G|MCDONALD VLBI STA
CORS L1 PHASE CENTER
| 0.0|AC5722|. 1|88/ADJUSTED|N304050......|W1040056......|B...|G|MLRS TLRS
| 0.1|AC5721|. 1|88/ADJUSTED|N304051......|W1040059......|A...|G|7850 RM 3
| 0.1|AC5718|. 1|88/ADJUSTED|N304051......|W1040057......|C...|G|7851
| 0.2|BQ0326|. 1|88/ADJUSTED|N304042......|W1040057......|A...|G|C 1097
| 0.2|BQ0306|. 1|88/ADJUSTED|N304038......|W1040058......|A...|N|MOBLAS 7086 NASA
| 0.2|BQ0324|. 1|88/ADJUSTED|N304044......|W1040103......|A...|G|N 1098
| 0.2|BQ0303|. 1|88/ADJUSTED|N304038......|W1040058......|A...|G|VALIDATION RM 3
| 0.3|BQ0304|. 1|88/ADJUSTED|N304036......|W1040100......|A...|G|A 1097
| 0.3|BQ0305|. 1|88/ADJUSTED|N304037......|W1040101......|A...|G|B 1097
| 0.3|BQ0323|. 1|88/ADJUSTED|N304049......|W1040113......|D...|G|M 1098
| 0.3|BQ0307|. 1|88/ADJUSTED|N304037......|W1040059......|A...|G|MOBLAS EAST NASA
| 0.3|BQ0325|. 1|88/ADJUSTED|N304035......|W1040104......|C...|G|P 1098
| 0.3|BQ0301|. 1|88/ADJUSTED|N304037......|W1040059......|A...|G|VALIDATION RM 1
| 0.3|BQ0302|. 1|88/ADJUSTED|N304037......|W1040058......|A...|G|VALIDATION RM 2
| 0.5|BQ0327|. 1|88/ADJUSTED|N304028......|W1040112......|A...|G|Q 1098
| 0.7|BQ0294|. 1|88/ADJUSTED|N304018......|W1040118......|B...|N|MCDONALD OBSERVATORY
107
| 0.7|BQ0407|2 .|29/VERT ANG|N304018.36819|W1040119.16092|D...|G|MCDONALD OBSERVATORY
107 RESET
| 0.7|BQ0300|. 1|88/ADJUSTED|N304019......|W1040120......|C...|X|MCDONALD TIDE SITE CU
| 0.7|BQ0328|. 1|88/ADJUSTED|N304023......|W1040118......|C...|G|R 1098
| 0.7|BQ0292|. 1|88/ADJUSTED|N304020......|W1040123......|A...|G|S 1098
| 0.7|BQ0299|. 1|88/ADJUSTED|N304019......|W1040120......|D...|N|TLRS 7897 NASA
| 0.8|BQ0322|. 1|88/ADJUSTED|N304052......|W1040140......|A...|G|L 1098
| 0.8|BQ0295|1 1|88/ADJUSTED|N304016.77819|W1040122.34569|A...|G|MCDONALD
| 0.8|BQ0406|4 .|...........|N304017.52620|W1040122.02901|....|G|MCDONALD OBSERVATORY
| 0.8|BQ0296|A 1|88/ADJUSTED|N304016.54894|W1040122.86154|A...|G|MCDONALD RM 1
| 0.8|BQ0297|2 1|88/ADJUSTED|N304016.98453|W1040122.72486|A...|G|MCDONALD RM 2
| 0.8|BQ0298|1 1|88/ADJUSTED|N304017.48524|W1040121.20101|C...|G|MCDONALD RM 3
| 0.8|BQ0293|1 1|88/ADJUSTED|N304017.33710|W1040121.11054|C...|N|MCDONALD RM 4
| 0.8|BQ0289|. 1|88/ADJUSTED|N304018......|W1040126......|A...|G|T 1098
| 0.9|BQ0290|. 1|88/ADJUSTED|N304013......|W1040126......|C...|N|MCDONALD AA
| 0.9|BQ0291|. 1|88/ADJUSTED|N304014......|W1040126......|C...|N|MCDONALD CA
| 1.0|BQ0321|. 1|88/ADJUSTED|N304038......|W1040151......|A...|G|K 1098
| 1.1|BQ0320|. 1|88/ADJUSTED|N304020......|W1040152......|A...|G|J 1098
| 1.4|BQ0316|. 1|88/ADJUSTED|N303948......|W1040140......|A...|G|E 1098
| 1.5|BQ0317|. 1|88/ADJUSTED|N303955......|W1040155......|A...|G|F 1098
| 1.5|BQ0319|. 1|88/ADJUSTED|N304013......|W1040215......|A...|G|H 1098
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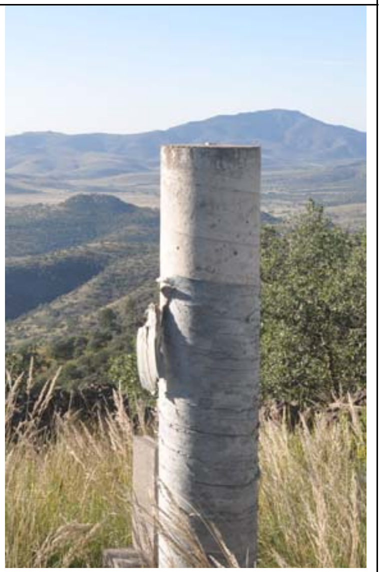
Sampling of Geodetic Markers & Calibration Piers

Source: http://maps.google.com/maps?hl=en&tab=wl

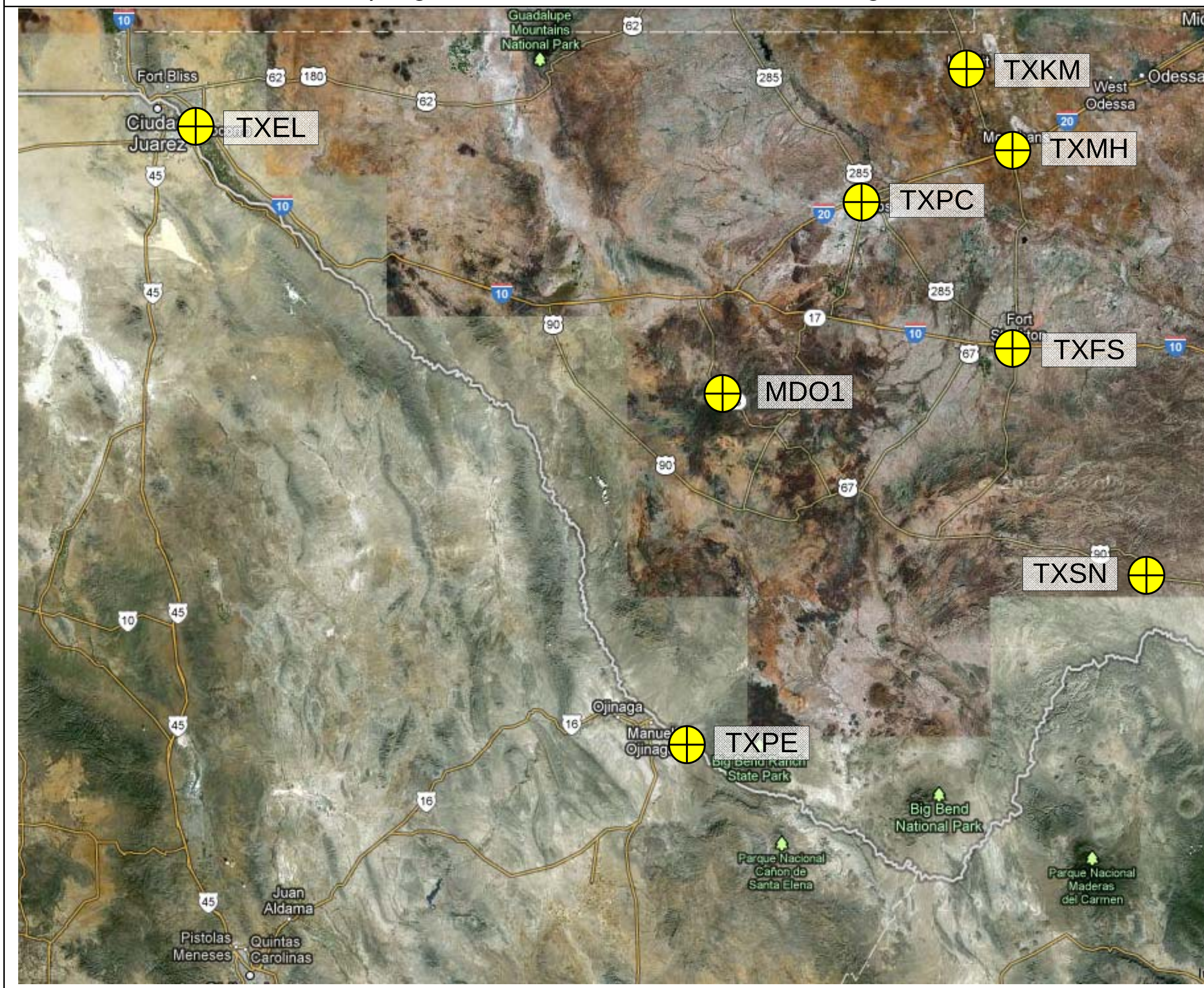
South Pier	
	

East Pier	
	

7.9.2 Regional Network

MDO1 is a CORS station and an IGS reference frame station, DOMES number 40442M012, PID AF9515, GPS ID 4011-S.

Sampling of CORS Stations in the MDO1 Region



Map Source: http://maps.google.com/maps?hl=en&tab=wl
CORS Source: http://www.ngs.noaa.gov/CORS/GoogleMap/CORS.shtml

7.10 Site Accessibility

The site is accessed via a 2 lane paved road, Route 78, off of Route 118 approximately 16 miles northwest of Fort Davis, Texas. Route 78 runs from the visitor center up to McDonald Observatory on Mount Locke, and State Spur 77 forks off of Route 78 to run up to the facilities on Mount Fowlkes.

The Road Up Mt. Fowlkes

7.11 Local Infrastructure and Accommodations

The Fort Davis site is remotely located within the Davis Mountains of west Texas. Typical drive times for the MLRS crew range from 10 minutes for those living just offsite adjacent to the observing sites to 30 – 60 minutes for those living in Fort Davis and communities farther away.

For visiting observers there is the Astronomers' Lodge at the Fort Davis site. For other visitors, there are accommodations in Fort Davis, Marfa, and Alpine.

7.12 Electrical Power

Current electrical power at the Fort Davis site is single phase 240VAC. If needed, the power would have to be upgraded to 3-phase power from WTU.

Source of Power – WTU supplies power to the Fort Davis site.

Available capacity – Dependent on the supplier to make upgrades to its equipment to support future requirements to meet power needs, but there is currently enough capacity to support all techniques at the site.

7.13 Technical and Personnel Support

The Fort Davis site currently has a Station Manager Engineer, 2 Observers, 1 part-time worker, Observatory Engineers, and physical plant personnel supporting MLRS.

The level of support suggested by the *Site Requirements for GGOS Core Sites* document is that the site will require a senior technician, eight shift technicians (2 per shift), a logistics and administrative officer, and a custodian.

7.14 Site Security

Site security is managed by the University of Texas at Austin. There are no physical gates or barriers limiting access to the site, just signs. The site is remote, and there are always a number of personnel on site supporting various projects.

7.15 Site Safety

McDonald Observatory maintains safety procedures and contact information for the Fort Davis site that are accessible through their website. Procedures and personnel are in place to handle emergencies should they occur. The Texas Forest Service fire danger level is monitored and a wildfire mitigation plan for McDonald Observatory has been established.

7.16 Local Commitment

Fort Davis / McDonald Observatory has been a major site for astronomical research for over 70 years. Over the years several large observatories have been located at the site. Routine lunar laser ranging has taken place at the site since the early 1970's. Communities in the west Texas region surrounding the site consider dark skies to be a valuable resource. The site is primarily funded through special items in the Texas state budget.

8.0 Concluding Remarks

The McDonald Observatory site has been a key site in NASA's SLR network. It's location in in West Texas, clear visibility and higher altitude makes it ideal for SLR. However, the smaller compound, unknown RFI issues and an unknown location for a potential VLBI2010 system and the remoteness make it difficult to locate a VLBI2010 system within the compound or very close to the existing SLR system. There are potential locations within the Observatory property that may allow for a VLBI2010 antenna that still need to be explored. Also, without current plans for high speed data transfer for eVLBI, data would need to be shipped daily by overnight carrier which is available on a daily basis to El Paso.

There is an excellent working relationship with the University of Texas who owns and operates the facility as well as many of the other observatories on the property. Finally, the existing crew, while highly competent will need to be supplemented with a skilled workforce to make this site truly successful.

9.0 Work to be completed

Additional work that needs to be completed for this assessment, include the following:

1. Completion of an RFI Study for broadband.
2. Local hydrology (well levels, aquifer characteristics) and relationship to apparent vertical site stability.
3. Inclusion of a local and regional tie maps.
4. Identification of a potential usable VLBI2010 site either close to the existing compound or within the larger observatory complex.
5. Description of available data communications network.
6. Inclusion of more recent and detailed photographs of the MLRS system, local site markers detail panoramic views of potential VLBI2010 and GNSS systems.

10.0 References

Cloud Sensor II User's Manual V0028, 2012,Diffraction Limited

Floyd, Michael; King, Robert; Reilinger, Robert; 2012, GGOS Site Stability Investigation

McDonald Observatory website, link: http://www.as.utexas.edu/mcdonald/ , accessed 10/12.

Appendix A: GGOS Site Stability Investigation From MIT

GGOS Site Stability Investigation, McDonald Radio Astronomical Observatory

Prepared by: Michael Floyd, Robert King, and Robert Reilinger, DEAPS, MIT (mfloyd@mit.du, rwk@chandler.mit.edu, reilinge@erl.mit.edu)

9 July 2012

Introduction:

Our principal objective is to investigate the level of stability for potential GGOS sites. GGOS requires site stability of 1 mm in 3-dimensions and long-term stability at the 0.1 mm/yr level. Determining whether specific sites meet GGOS stability requirements will require the most precise techniques available to monitor surface motion and very accurate estimates of short period motions due to tidal, loading, and local hydrologic effects as well as modeling systematic errors that can be difficult to distinguish from surface motions. Strain and tiltmeters (in boreholes or caves) and repeated precise leveling are the most precise ground deformation observation techniques on local scales. Leveling provides information only on vertical motions, is time consuming and is primarily useful for relatively local investigations. It also suffers from systematic errors in areas of high relief that need to be modeled. Strain and tilt meters are susceptible to very local conditions and are primarily useful for detecting short period "events" – determining actual ground deformation from strain measurements is non unique and non trivial. InSAR is not sufficiently precise to determine motions at this level of precision.

GPS offers the opportunity to investigate stability on local, regional, and global scales. GPS has demonstrated measurement precision as good as 0.2 mm horizontal and 1 mm vertical on short baselines and 0.5 mm horizontal and 1.5 mm vertical, and long-term stability at the level of 0.2 mm/yr horizontal and 0.5-1.0 mm/yr vertical on a global scale, in principal close to the precision needed to evaluate site stability at the level required by GGOS. To meet this level of precision requires accurate modeling of a range of factors that influence positioning estimates, including tectonic and magmatic deformation and other real surface movements over short time scales (e.g., tidal loading, hydrology) as well as apparent movements due to measurement errors (e.g., multipath changes, water vapor, monument stability).

Our initial investigation focuses on analysis of the GPS time series.

GPS time series analysis:
We did noise analysis for the GPS station operating at the Observatory (MD01). Figure 1 shows de-trended time series from the MIT global analysis. MD01 has sufficient data to provide useful results. 1-sigma uncertainties on velocity (a rough measure of the long term stability) are of the order 0.1 mm/yr in horizontal and about 0.4 mm/yr for the vertical component. Daily scatter in position (RMS and WRMS) is on the order of 2 mm in horizontal and 7 mm in the vertical. The magnitudes of the annual and semi-annual terms are annotated on the figures and are in the range of 0.1 – 0.6 mm in horizontal and 0.4 – 2.6 mm in vertical.

These variations reflect un-modeled atmospheric, site [multipath, water table changes, monument stability], tidal [solid, ocean loading], water table variations, instrument/antenna effects, and reference frame instability as well as any possible tectonic motions. Much more detailed analysis of the GPS time series and other relevant data is necessary to estimate the contribution of these different factors before it will be possible to provide more definitive bounds on site stability.

Tectonics/Geology:
The McDonald Observatory lies in the southern Rocky Mountain Province. Tertiary igneous rocks are the principal rocks exposed at the surface. The region is not seismically or volcanically active, although widely scattered, small (< M5.5) earthquakes occur infrequently. This site should not be affected by tectonic motions at the level required for GGOS site stability. Post-glacial rebound and variable ocean loading should also be negligible at the location of the Observatory (Sella et al., 2007, GRL).

Atmospheric:
The local climate is semi-arid with an average of only 14-18 inches (35-45 cm) of rain per year. While local conditions need to be considered when locating and monumenting instruments, weather should not be a significant factor for ground stability.

Local hydrology: Needs further study of aquifers and water utilization.

Conclusions/Recommendation for McDonald Radio Observatory GGOS site:

McDonald Observatory should be stable at the level required for GGOS Core Sites.

To Do:
Local hydrology (well levels, aquifer characteristics) and relationship to apparent vertical site stability. Network analysis of multiple stations (i.e., differencing station positions may help separate site stability from instrumental/wave propagation effects). We are not aware of any evidence for landslide activity, but this should be checked in more detail.

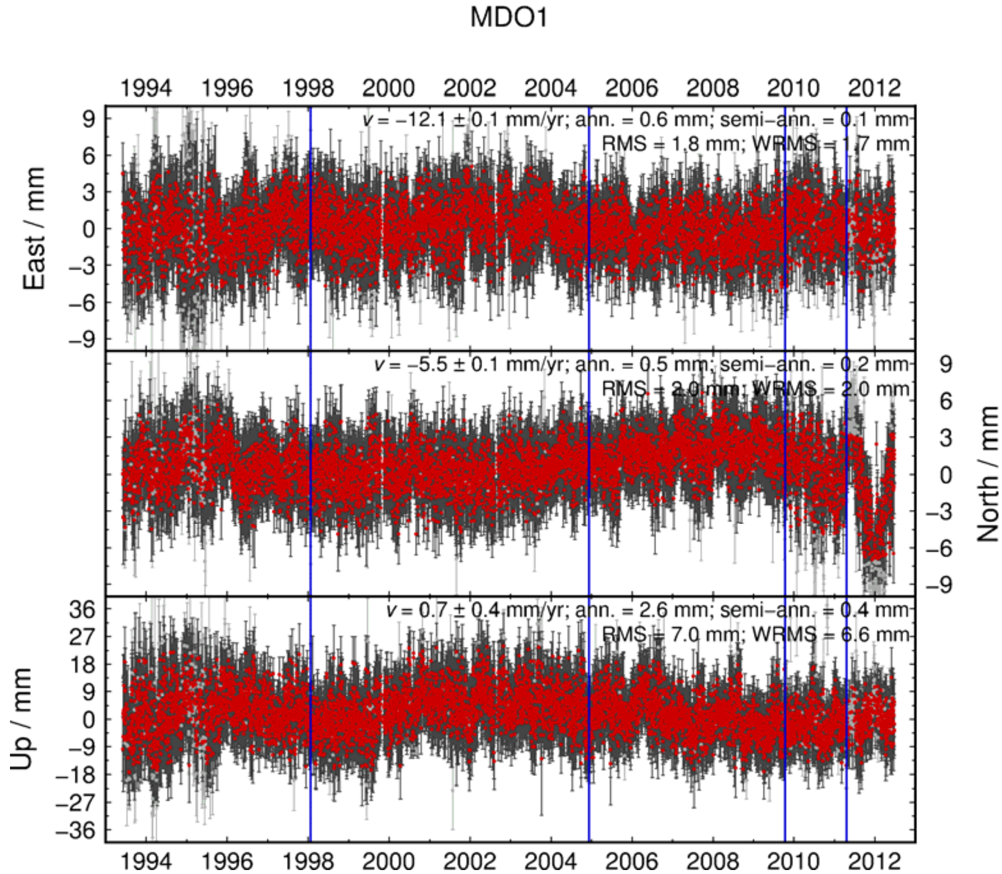


Figure 1. McDonald Observatory (MD01) GPS time series and statistics.

Appendix B: List of Acronyms

AEOS	Advanced Electro-Optical System
ANSS	Advanced National Seismic System
ATST	Advanced Technology Solar Telescope
CORS	Continuously Operating Reference Station
CSR	Center for Space Research
DOMES	Directory of MERIT Sites
DORIS	Doppler Orbitography and Radiopositioning Integrated by Satellite
FAA	Federal Aviation Administration
GGAO	Goddard Geophysical and Astronomical Observatory
GGOS	Global Geodetic Observing System
GNSS	Global Navigation Satellite System
GPS	Global Positioning Satellite
HTSI	Honeywell Technology Solutions Inc.
IAG	International Association of Geodesy
IDS	International DORIS Service
IfA	Institute for Astronomy
IGS	International GNSS Service
ILRS	International Laser Ranging Service
IVS	International VLBI Service for Geodesy and Astrometry
LAGEOS	Laser Geodynamic Satellite
LCO	Las Cumbres Observatory
LCOGTN	Las Cumbres Observatory Global Telescope Network
LLR	Lunar Laser Ranging
MIT	Massachusetts Institute of Technology
MOBLAS	MOBile Laser System
NASA	National Aeronautics and Space Administration
NGSLR	Next Generation Satellite Laser Ranging
NRAO	National Radio Astronomy Observatory
SGP	Space Geodesy Project
SLR	Satellite Laser Ranging
VLBA	Very Long Baseline Array
VLBI	Very Long Baseline Interferometry