



# ***Monument Peak Site Baseline Report***

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

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## **1.0 Acknowledgements**

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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](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 forth NASA owned and operated site to be baselined as part of the SGP is the Monument Peak, California site. The Monument Peak site is located in Southern California, approximately 70 km East of San Diego, within the confines of the Cleveland National Forest. Access from San Diego to the site is via Interstate 8 to Sunrise Hwy. The site sits at approximately 6,150 feet, is remote and experiences weather conditions ranging from desert to heavy rains and even snow during the mid to late Winter months. Skies at the site, are generally clear, especially during the non-rainy season and excellent for SLR activities.

The Monument Peak compound size is approximately 0.22 hectares, which is too small to have all techniques supported. This also does not include the areas where the two calibration piers are located.

Currently, the space geodetic techniques that are located at this site include the MOBILAS-4 SLR system, which has occupied this site since 1981. Also at the site is the GNSS antenna. A DORIS antenna was located at the site and remains physically at the site, but has been turned off and has not been operating since 2010 due to RFI issues to a local television station who has a license to operate at that frequency. Monument Peak also hosts an EarthScope seismic station.

Due to the site topography it is not practical to locate a 12 meter VLBI2010 antenna within the existing compound, nor within a few hundred meters from the compound. Additionally, a potential significant RFI source is located near the compound with others, including an FAA approach radar located within 1 mile of the site. A detailed RFI study of the existing compound and other potential VLBI2010 sites would need to be performed prior to committing to place a

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VLBI system in Monument Peak. Other sites have been considered for a VLBI2010 system and currently include near the SLR calibration pier A and approximately 1 mile from the site at a reclaimed USAF facility. Further studies of these sites and potentially others would require an on-site visit during RFI testing. These other potential sites would also require an amendment to the existing agreement between NASA and the National Park Service to be negotiated.

Other site infrastructure including power, safety, security and access are all very good, considering the remoteness of the site. For communications, the SLR and GNSS stations rely on a wireless communications link through the High Performance Wireless Research and Education Network (HPWREN), who provides wireless communications up to 155Mbps. This would not meet the requirements for eVLBI data transfer. There are also traditional phone lines available to the area but in the past have been not very reliable. Local commitment for the site is good with positive relationships with local authorities and a good working relationship with the National Park Service. Geologically, the site, located in Southern California falls within a seismically active area within the "Greater" San Andreas Fault system, about 15 km west of the Elsinore Fault.

Areas of concern include a viable place to put the VLBI2010 system, as it cannot be accommodated in the existing compound and a site within a few hundred meters is not practical. Also of concern is the availability of high speed data communications and an existing workforce to support the facility. In the past, it has been difficult to staff the system due to its remoteness. Also, finding contractors to support the site has also been problematic due to the remoteness, causing delays in support and a greater expense, all which have been overcome in the past to an extent.

Things that need to be completed for this site 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. Improved cloud coverage data.
5. Identification of a usable VLBI2010 site either close to the existing compound or within the larger gated area.

In summary, the Monument Peak site has a very long time series for SLR and GNSS. Weather at the site is generally excellent for SLR ranging as has been demonstrated for over 30 years. It is a key ILRS and IGS site. DORIS is not possible due to issues experienced at the site in recent years. Finding a suitable location and infrastructure may be problematic but not solvable with several potential sites at first look. 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. 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 Monument Peak site would be an excellent choice for a Fundamental Station for the SGP.

### **3.0 Introduction – Monument Peak Site Conditions for GGOS**

This report describes the current conditions at the Monument Peak site in California 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 Monument Peak include SLR, GPS, and EarthScope. A DORIS site was operational; however it was removed due to interference with a local television station's emergency broadcast signal. While the antenna remains, it is not operational or functional.

VLBI – VLBI is not currently on site. In the past VLBI occupied the site periodically with trailer mounted 5-meter antennas on MV-2 and MV-3 from 1981 to 1990. These were referenced to the Old Aries Mark (7220) and the Monument Peak NCMN 1983 Mark (7274).

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GNSS - A GPS antenna is installed at IGS station MONP.

IGS MONP Station



Domes: 40497M004 PID: AF9705 Code: MONP

Note: EarthScope station SCS1 behind MONP in picture



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DORIS –.The Starrec type antenna was installed at geodetic station MONB in November, 2005. The antenna was changed and redesignated as station MOOB in December, 2007. MOOB continued to operate until being de-energized on February 4, 2010 due to RFI issues with a local television station's emergency broadcast signal.

Doris Antenna MOOB



Source: DORIS website <http://ids-doris.org/network/sitelogs/station.html?code=MONB>

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DORIS MOOB, GNSS MONP, and EarthScope SCS1



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SLR – SLR has occupied Monument Peak with the MOBLAS-4 system starting in 1981.

MOBLAS-4



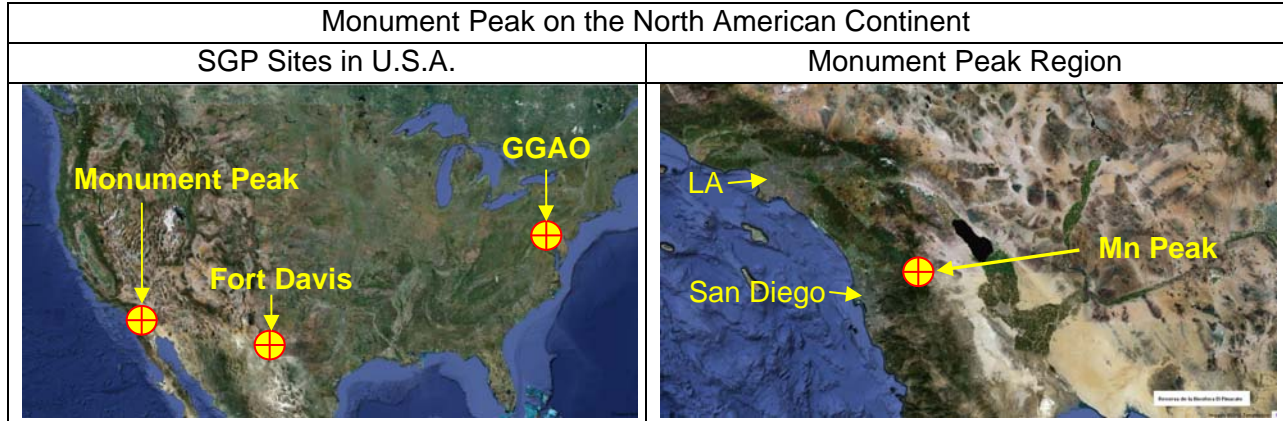
MOBLAS-4



EarthScope – An EarthScope seismic station SCS1 has been generating broadband seismic data since October of 2006 at a rate of 1 sample per second. See, [www.earthscope.org](http://www.earthscope.org) for more information.

## 5.0 Global Consideration for the Location

The Monument Peak site is located in the mountains of southern California near the west coast of the North American continent.



### 5.1 Geometrical Distribution

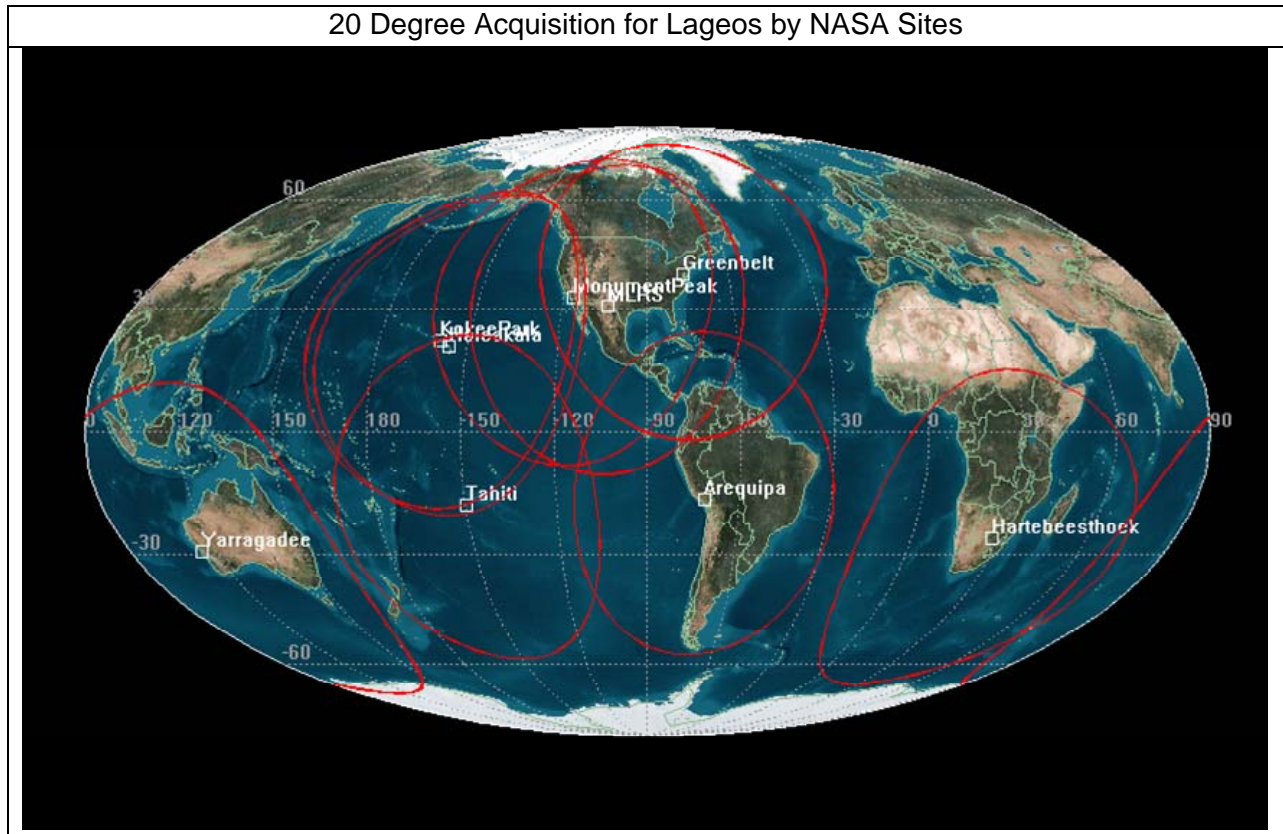
Monument Peak is located near the west coast of the United States in southern California. Existing sites at Fort Davis, Texas, and Greenbelt, Maryland, are located to the east. To the west, there are existing sites, Haleakala and Kokee Park, in Hawaii.

### 5.2 Technical Distribution

It is desired to have three well distributed stations on each tectonic plate. Monument peak is located within the boundary zone between the Pacific tectonic plate and the North American tectonic plate. Roughly 80% of its motion is with the Pacific tectonic plate.

### 5.3 Technique Dependent Distribution

The location of Monument Peak on the west coast of the North American continent provides coverage of satellite tracks over the North Pacific Ocean. The following plot displays the tracking coverage down to 20 degrees elevation for LAGEOS by the NASA SLR sites. VLBI



## 6.0 Geology

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

### 6.1 Substrate

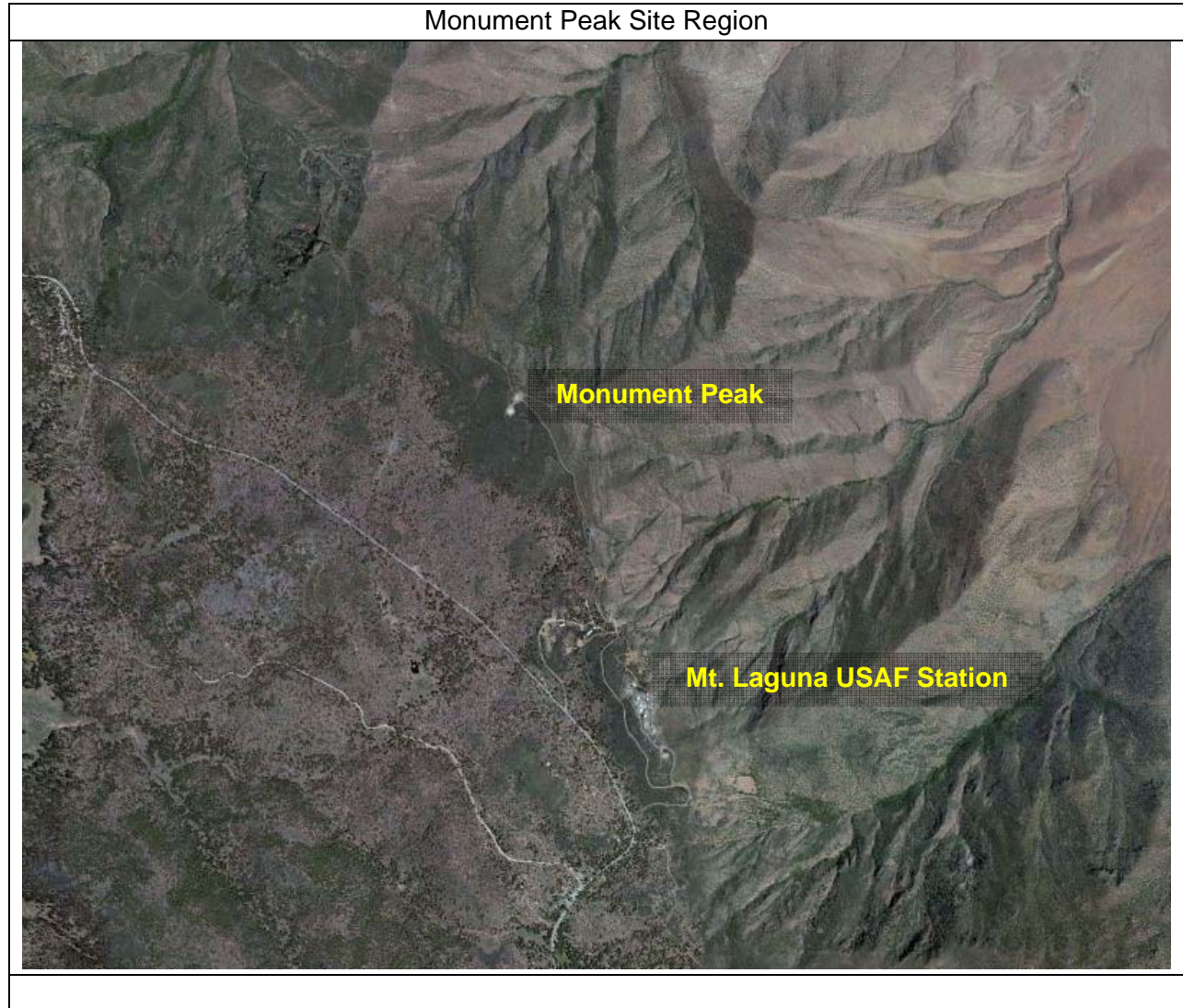
See the report from MIT on the stability of the Monument Peak site included at the end of this document in Appendix A.

### 6.2 Tectonic Stability

Monument Peak sits within the boundary zone strain field between the North American and Pacific tectonic plates which are moving ~50mm/yr relative to one another. A report from MIT on the stability of the Monument Peak site is included at the end of this document in Appendix A.

## 7.0 Site Area

The Monument Peak site is located at an altitude of 1837m in the mountains of the Cleveland National Forest in southern California roughly 70km east of San Diego.



### 7.1 Local Size

The Monument Peak MOBLAS SLR compound spans an area of ~0.22 hectares, about one tenth the minimum area specified in the requirements document. With the rough terrain surrounding the station, it is difficult to locate a VLBI2010 system within the existing compound. The past occupations from the Mobile VLBI systems were directly next to the MOBLAS system. This is not an acceptable location for a 12 meter VLBI2010 antenna for many reasons, including size and RFI.

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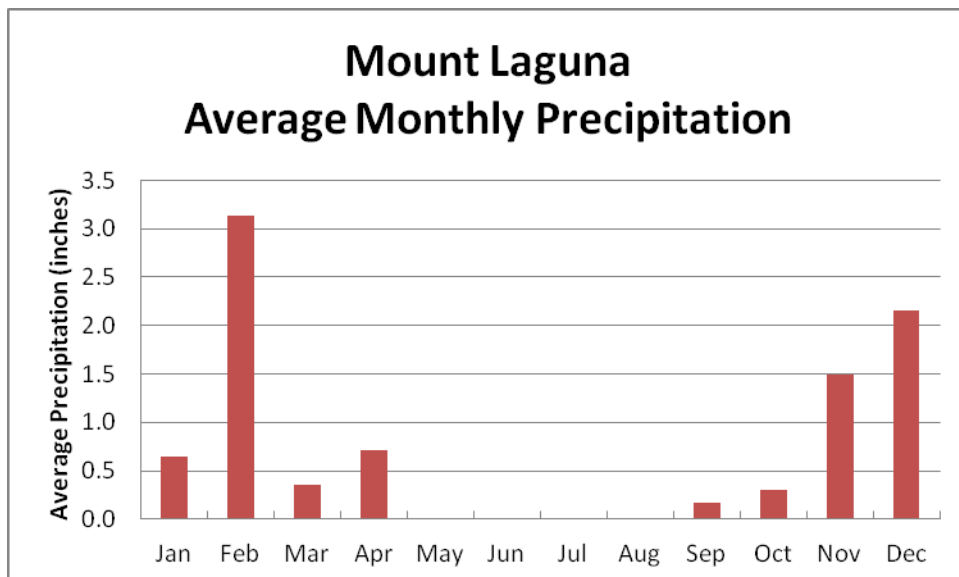
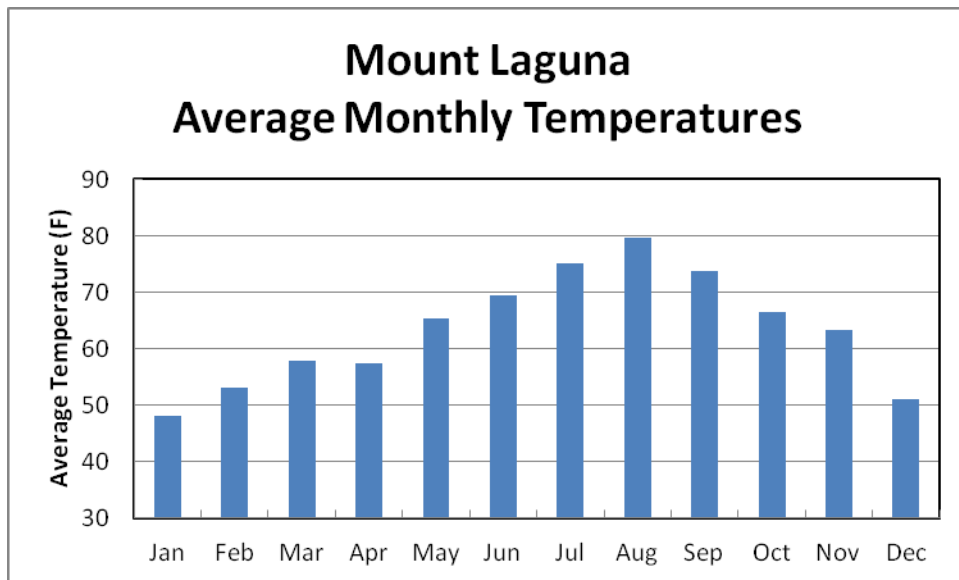
## 7.2 Weather & Sky Conditions

### 7.2.1 Climate

The climate of the Cleveland National Forest as a whole is generally described as warm, dry Mediterranean.

Mount Laguna Monthly Average Temperatures (F) and Precipitation (Inches)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
Temp	48.0	53.2	57.8	57.4	65.3	69.4	75.1	79.6	73.7	66.6	63.4	51.0	63.4
Precip	0.65	3.14	0.36	0.71	0.01	0.00	0.00	0.00	0.17	0.30	1.50	2.16	0.75

Source of data: <http://climate.fizber.com/california-city-mount-laguna-climate.html>





### **7.2.2 Sky Conditions**

There is no all sky camera located at the Monument Peak site to provide sky coverage data. Empirically, based on over 25 years of knowledge of the site, it is known that the skies around Monument Peak are excellent for SLR, except for the rainy seasons, which also include periods of snow in the mid to late Winter season, as shown in the precipitation table above. It is estimated that track-able weather is available at the Monument Peak site at about the 70%-75% or better level. Data mining of historical tracking logs can be performed as data is made available, but may only give a subjective view as the data was not designed for sky coverage. This can be done during the next phase of this study.

The Mount Laguna Observatory, located 5.5km to the south of the Monument Peak site and operated by San Diego State University, provides the following description of sky conditions at the observatory on their website at <http://mintaka.sdsu.edu/MLO/FACILITIES/Facilities.html> :

“Sky conditions at MLO are photometric 60% of the time and spectroscopic 75% of the time. The poorer weather usually occurs in late Winter and early Spring (February and March). The Summer monsoon conditions that plague Kitt Peak in July and August are greatly moderated at MLO. The sky glow from San Diego and other urban areas contributes only about 5% at the zenith on moonless nights. Thus, on these dark nights, the sky brightness at the zenith in the Johnson B filter averages 22.8 magnitudes per square arcsecond. Seeing is generally less than two arcseconds and frequently less than one arcsecond. “

## **7.3 RF and Optical Interference**

The remote location of the Monument Peak site within the Cleveland National Forest more than 70km east of San Diego reduces the number of sources of offsite interference compared to a site located in a more populated region. However, there are a number communication towers located close to, and within direct line of sight of, the site and a high power FAA antenna within 1.5 miles of the site. Based on this a detailed RFI study should be performed at any and all potential VLBI2010 locations.

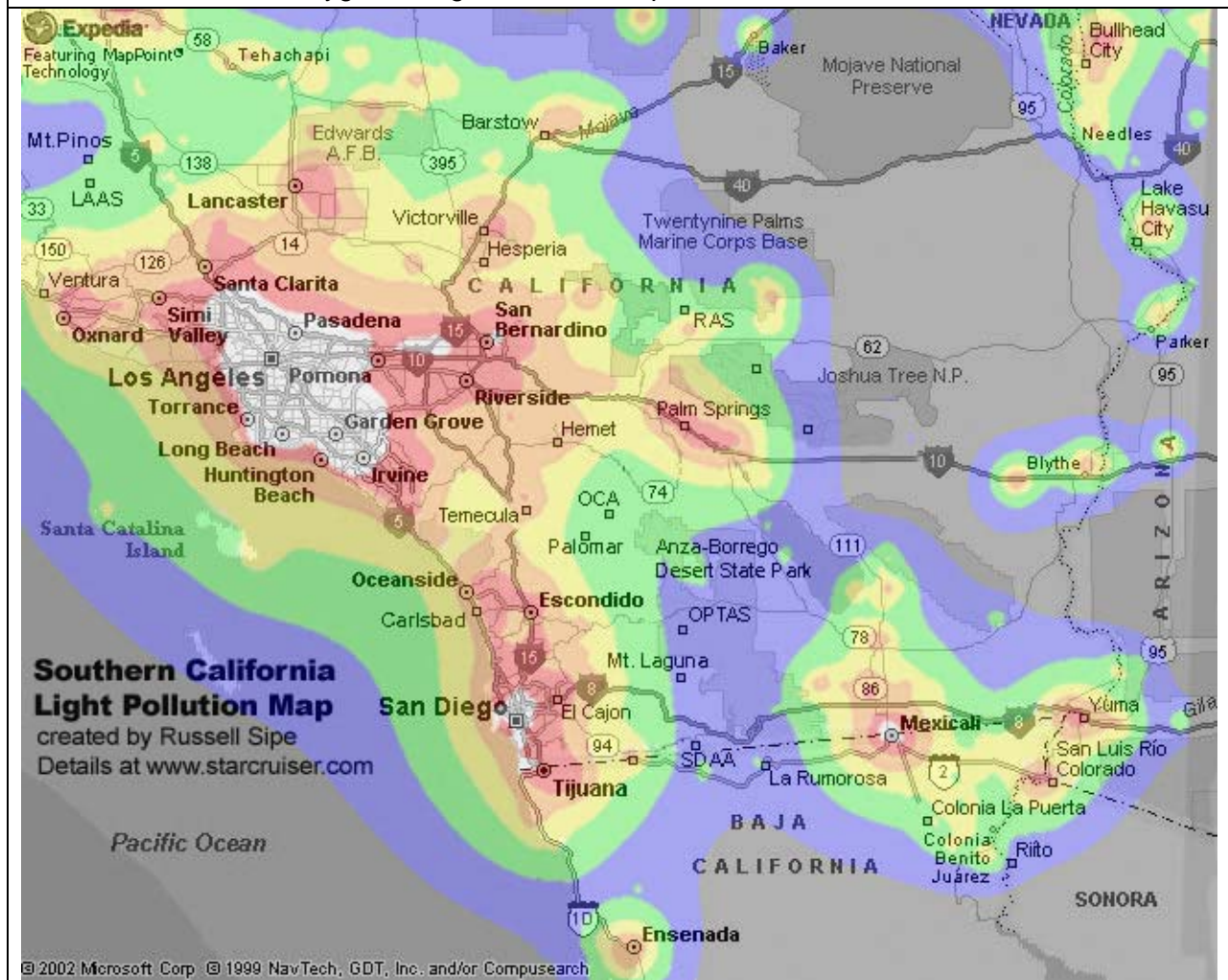
### **7.3.1 RF Interference**

.Studies need to be performed.

### **7.3.2 Optical Interference**

At 1837m altitude and the remote location, the clear night skies at Monument Peak are dark and transparent with minimal light pollution.

Skyglow – Light Pollution Map of Southern California



Source: Russell Sipe, 2002 [http://www.sipe.com/starcruser/observatory/html/observations\\_report03\\_01.html](http://www.sipe.com/starcruser/observatory/html/observations_report03_01.html) 2002  
 Adapted from Cinzano et al. 2001 "The first World Atlas of the artificial night sky brightness."

The data employed were obtained by the US Air Force Defense Meteorological Satellite Program to model artificial sky brightness (Cinzano et al., 2001). The sky brightness (skyglow) values were overlaid onto a map of Southern California (Sipe, 2002), which clearly shows the effects of light pollution from urban development.

The seven color-coded zones correspond to:

1. Black – Natural skyglow, with only traces of light pollution
2. Blue – Light pollution a maximum 10% increase over natural skyglow
3. Green – Light pollution a maximum 50% increase over natural skyglow
4. Yellow – Light pollution a maximum 100% increase over natural skyglow
5. Orange – Milky Way no longer visible (rural areas adjacent to suburbs)
6. Red – Less than 100 of the brightest stars visible (suburban areas)
7. White – Only the brightest stars visible (urban core areas)

Source: [http://www.sdcounty.ca.gov/dplu/docs/Dark\\_Skies\\_Guidelines.pdf](http://www.sdcounty.ca.gov/dplu/docs/Dark_Skies_Guidelines.pdf)

From the San Diego guidelines:

Presently at Mount Laguna, the skyglow in the “visual” or yellow region of the spectrum is less than 10% above the natural level at the zenith on dark moonless nights. However, total skyglow there has increased by 50% over the last 30 years, and the increase has been in all wavelengths (colors). Over the last 20 years, such measures at the zenith have shown about a 30% increase in the blue and yellow spectrum, and much less in the red. In the red spectrum, Mount Laguna Observatory is still a very viable dark astronomical site, comparable to the very remote and dark site at Apache Point, New Mexico. From Mount Laguna, the view of the sky toward the City of San Diego appears much brighter to the naked eye than it did 20 years ago, but much of it is in the isolated wavelength of the sodium D-lines at 5900 Angstroms, which can be effectively removed by electronic detectors via filtering (Etzel, March 2002).

### **7.3.3. Other Possible Interference**

None are identified at this time.

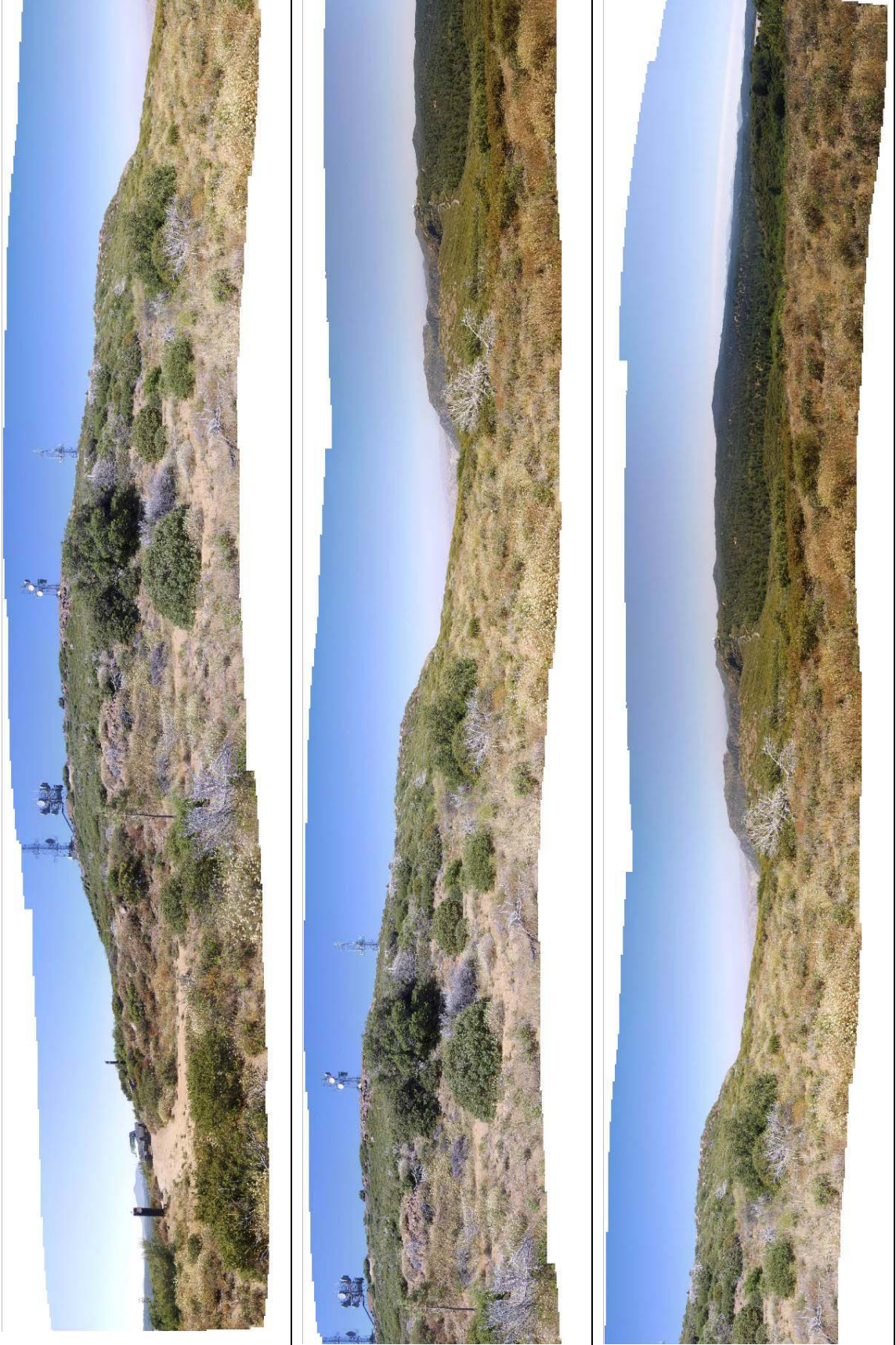
### **7.4 Horizon Conditions**

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.

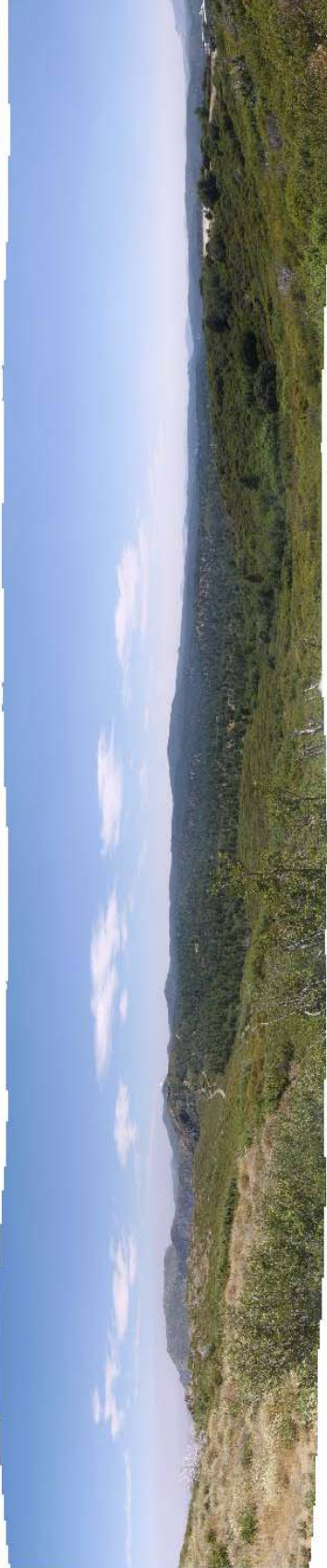
At Monument Peak, as with any site, horizon conditions for each technique will vary depending on the location and height of each technique on the site. For SLR, the radar of the Laser Hazard Reduction System (LHRS) used for aircraft protection works best with a clear horizon within 400 meters free of 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. If a VLBI2010 station were to be located near the SLR calibration pier A, it is located on the hillside to the East of the SLR station which allows for below horizon viewing angles, but is also in direct line of site of the SLR LHRS and the HPWREN antennas, as well as other local antennas. If the closed USAF site were to be considered, a detailed horizon map is required, however, there should be fairly clear sky below the horizon to the East, but trees around other areas. Panoramic photos of each area are located below.

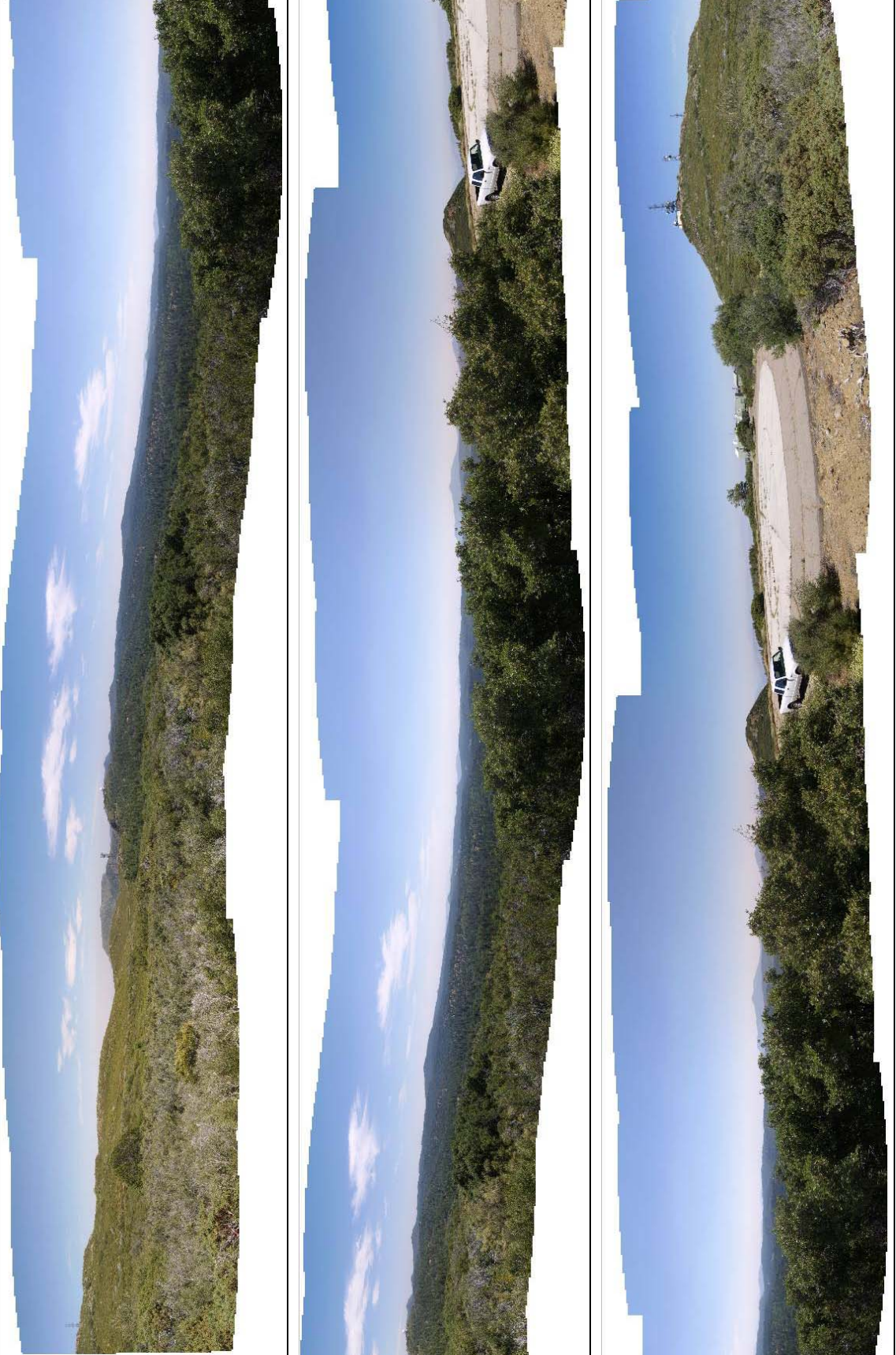
Horizon at Potential VLBI Site Near Calibration Pier A



Horizon at Calibration Pier A



Horizon at Calibration Pier C



Horizon at Potential VLBI Site at AFB Site



Calibration Piers to MOBLAS-4



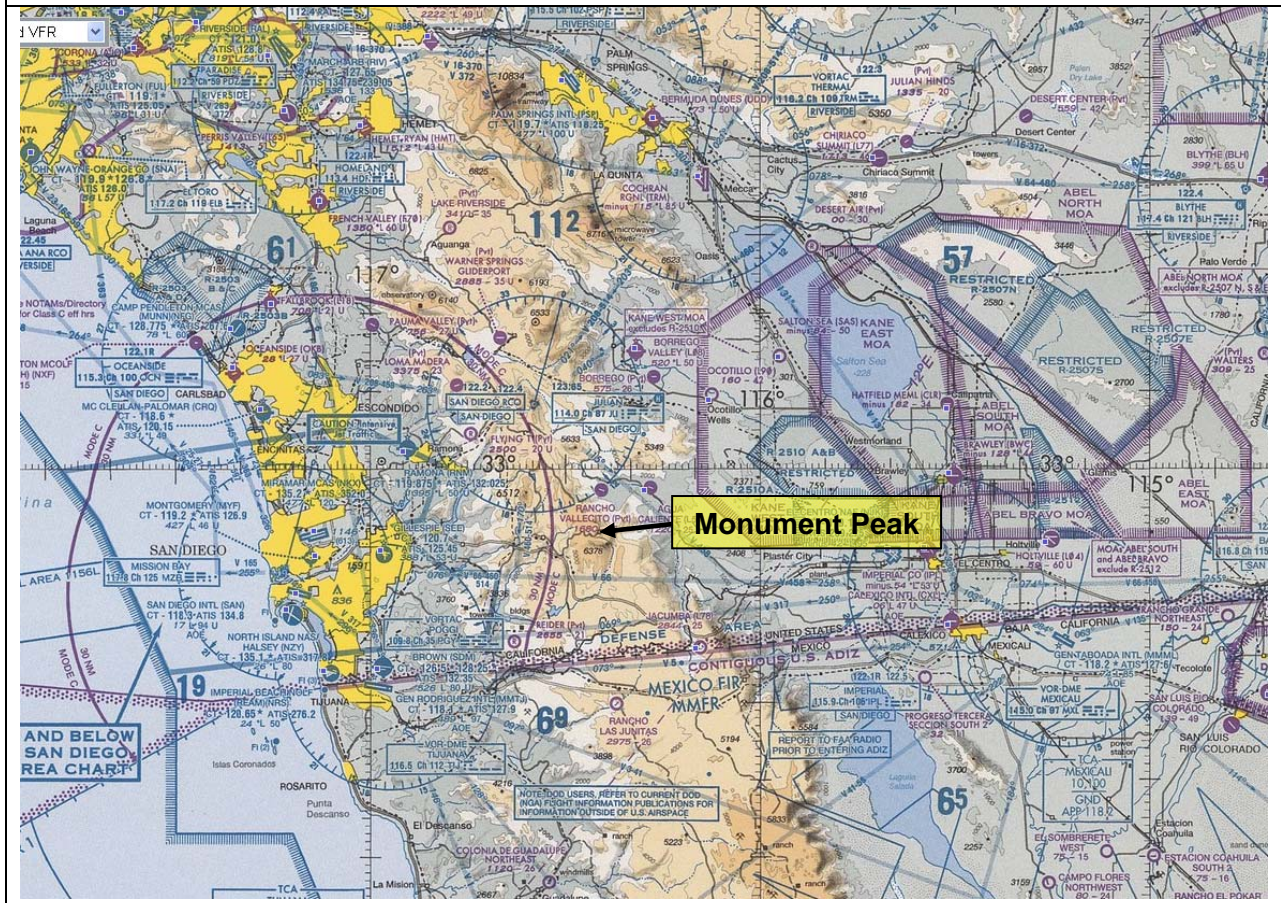
### ***7.5 Air Traffic***

From Wikipedia : [http://en.wikipedia.org/wiki/San\\_Diego\\_International\\_Airport](http://en.wikipedia.org/wiki/San_Diego_International_Airport) "San Diego International is the second busiest single-runway commercial service airport in the world, with approximately 550 departures and arrivals carrying 50,000 passengers each day, and a total of 16,890,722 passengers in 2011."



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## Flight Navigation Chart For Monument Peak Region



Source: <http://vfrmap.com/?type=vfrc&lat=32.734&lon=-117.190&zoom=10>

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## Airports in the Monument Peak Region



## ***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 Monument Peak site and at many of the other NASA SLR sites.

## ***7.7 Communications***

Digital communication is accessed using the HPWREN network. Maximum possible full duplex capacity would be 155Mbps. Current actual usage is much less. This will not meet the requirement 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.

## ***7.8 Land Ownership***

The Monument Peak site is located on federally owned land within the Cleveland National Forest. There is an active agreement between the National Park Service and NASA for the existing MOBLAS site. If additional land were to be required, an amendment to the agreement would be required and would take up to 2 years to process. Land in that area is also classified as public/recreational, and to occupy additional space in the area may become an issue. This would need to be worked in cooperation with the National Park Service, before committing to expanding the existing compound or using new space.

## 7.9 Local Ground Geodetic Networks

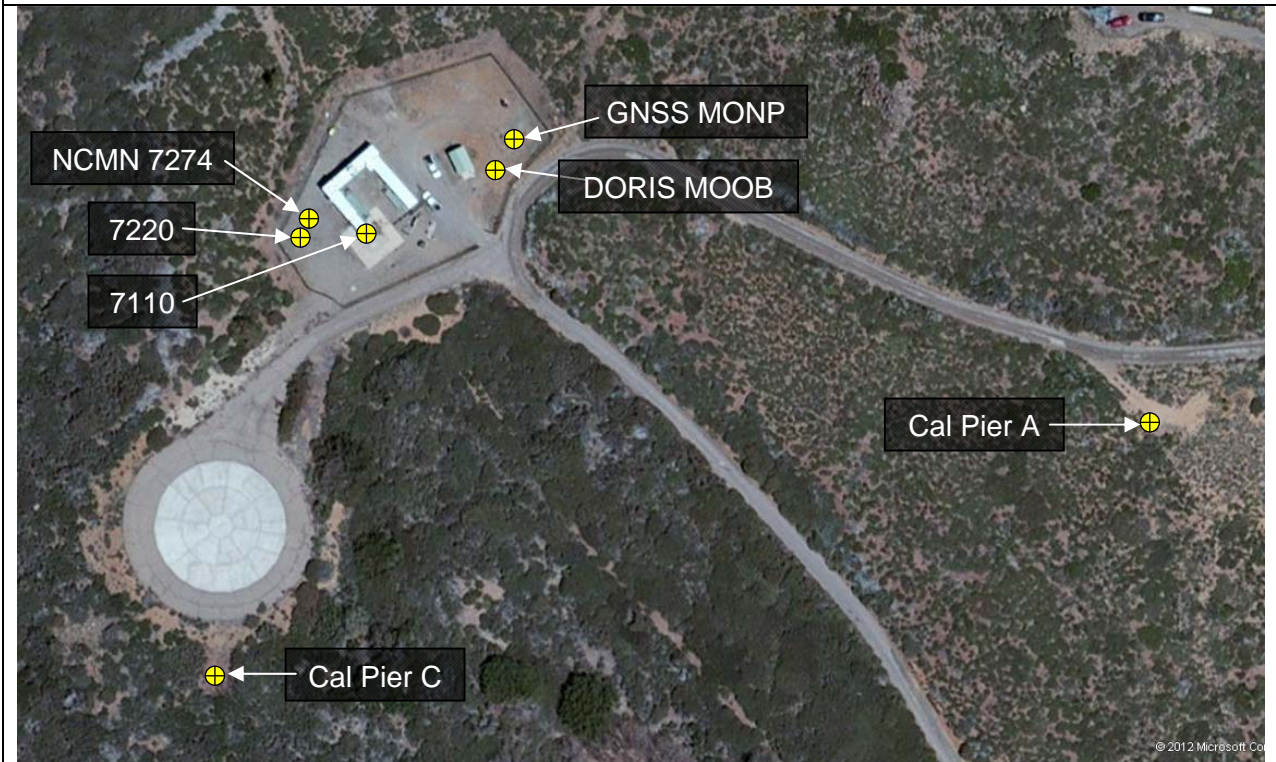
### 7.9.1 Local Station Network

DOMES markers at Monument Peak:

DOMES No.	Description	Code
40497M001	ORT station 7110-1981 Standard NASA disk	7110
40497M002	ARIES ORION sta 7220-1981	7220
40497M003	NCMN 1983 mobile VLBI NGS disk	7274
40497M004	PGGA Mark (GPS) PID: AF9705	MONP
40497M005	Domed brass screw on the DORIS concrete pillar	
40497S001	Goddard Mobile Laser / IAR ML0308	
40497S002	Goddard Mobile Laser / IAR ML0404	
40497S003	Laser TLRs-1 72201101 TL0124/IAR	
40497S004	Laser TLRs-1 72201102 TL0132/IAR	
40497S005	Laser TL0134	
40497S006	Laser MOBLAS-4 / IAR ML0406	
40497S007	Laser TLRs-1 72201103 TL0133/IAR	
40497S008	DORIS antenna reference point Starec type	MONB
40497S009	DORIS antenna reference point Starec type	MOOB
Source: ITRF website <a href="http://itrf.ign.fr/site_info_and_select/site.php?SelecSite=404111&amp;begin=1">http://itrf.ign.fr/site_info_and_select/site.php?SelecSite=404111&amp;begin=1</a>		

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Sampling of Geodetic Markers & Calibration Piers (FIXED DORIS LOCATION) and mention an issue with the website....

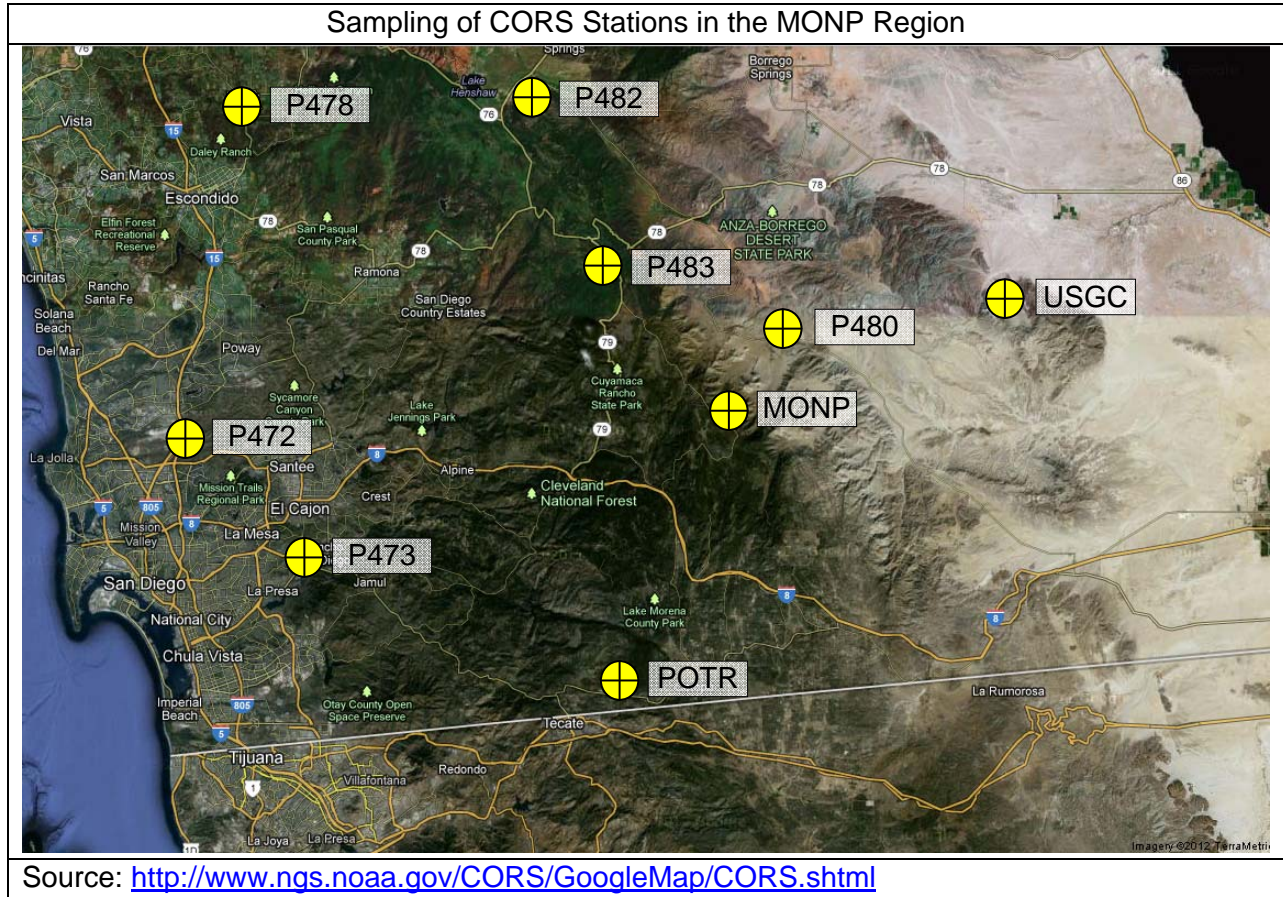


Source of satellite view: <http://www.bing.com/maps/>

(DOMES information: - [http://itrf.ign.fr/site\\_info\\_and\\_select/site.php](http://itrf.ign.fr/site_info_and_select/site.php) )

### 7.9.2 Regional Network

MONP, mounted on a deep drill brace monument, is a CORS station and an IGS reference frame station, DOMES number 40497M004, PID AF9705.



### 7.10 Site Accessibility

The site is accessed via a 2 lane paved mountain road designated Drd100419-1, which is accessed from Sunrise Highway. The distance on Drd100419-1 from Sunrise Highway to the site is approximately 3 km (1.9 miles). The distance on Sunrise Highway to Interstate 8 is approximately 16.3 km (10.1 miles).





### ***7.11 Local Infrastructure and Accommodations***

The Monument Peak site is remotely located within the Cleveland National Forest 70km east of San Diego. The current MOBILAS-4 crew lives in El Cajon, CA. Typical drive times are 45 minutes. The crew uses GSA provided vehicles to get to the site due to the conditions of the site roads and distance. There are many hotels in El Cajon, and accommodations may be found in Pine Valley which is about a 25 minute drive from the site.

### ***7.12 Electrical Power***

The Monument Peak site receives its electrical power from SDGE.

Source of Power - SDGE delivers power to the Monument Peak site.

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

Reliability – There have been power dropouts during periods of high wind and scheduled maintenance. Additionally, there have been times when SDGE has been forced to either plan or implement rolling brownouts in the area due to capacity issues on the main power grid.

### ***7.13 Technical and Personnel Support***

The Monument Peak site currently has 2 operators for the MOBILAS-4 SLR station.

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. This is a concern as it has been difficult in the past to find and hire additional staff at the SLR site, due mostly to the site being so remote.

### ***7.14 Site Security***

The Monument Peak facility is remote site, located off of a scenic hi-way as part of the Cleveland National Forest. Prior to arriving at the site compound, there is a locked gate that can only be opened by users of the area and local emergency personnel. Approximately 1 mile from the locked gate, a chain link fence with barbed wire at the top surrounds the actual site compound. If a VLBI2010 system were to be located at a site not within the existing SLR

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compound, a similar chain link fence would be configured to secure that site. National Park security is responsible for security in the National Forest.



### ***7.15 Site Safety***

Monument Peak, as part of the NASA network, is covered by NASA safety regulations and practices to prevent injury or fire, and to ensure proper handling and storage of potentially hazardous materials. Procedures are in place to handle emergencies should they occur. There is a local fire station within approximately 5 miles from the station. They have access through the main gate near the FAA facility.

### ***7.16 Local Commitment***

NASA has an existing agreement with the National Park Service for the Cleveland National Forest that is valid until 2015. Renewal of the agreement for the existing facility should be requested 1 year prior to expiration. If a VLBI2010 system or another location within the Monument Peak area were to be considered, an amendment to the existing agreement would



take 18 – 24 months to process. The local crew for the SLR station are experienced professionals with a minimum of 25 years experience each. The site has, however been understaffed for a number of years due to funding and difficulty in hiring technically skilled people to work in a remote location. With the addition of a VLBI2010 system, more people would need to be brought in to support the SGP site than currently exist.

## 8.0 Concluding Remarks

The Monument Peak SLR site has been a key site in NASA's SLR network. It's location in the Western US, clear visibility and high altitude make it ideal for SLR. However, the small compound, potential RFI issues, and remoteness make it difficult to locate a VLBI2010 system within the compound or very close to the existing SLR system. However, there are possibilities to locate a VLBI2010 system within a mile from the existing compound to support a Fundamental Station. A good working relationship with the National Park Service will help work through the requirements to locate another space geodetic technique within the Monument Peak area, if there are no RFI issues. 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:

6. Completion of an RFI Study for broadband.
7. Local hydrology (well levels, aquifer characteristics) and relationship to apparent vertical site stability.
8. Inclusion of a local and regional tie maps.
9. Improved cloud coverage data.
10. Identification of a usable VLBI2010 site either close to the existing compound or within the larger gated area.

## 10.0 References

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Fay, N. P., and E. D. Humphreys (2005), Fault slip rates, effects of elastic heterogeneity on geodetic data, and the strength of the lower crust in the Salton Trough region, southern California, *J. Geophys. Res.*, 110, B09401, doi:10.1029/2004JB003548.

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

## Appendix A: GGOS Site Stability Investigation From MIT

GGOS Site Stability Investigation, Monument Peak, California

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### 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 (MONP). Figure 1 shows de-trended time series from the MIT global analysis. MONP 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 0.2 mm/yr for the vertical component. Daily scatter in position (RMS and WRMS) is on the order of 2 mm in horizontal and 5 mm in the vertical. The magnitudes of the annual and semi-annual terms are annotated on the figures and are in the range of 0.2 – 0.4 mm in horizontal and 0.3 – 4 mm in vertical.

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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 Monument Peak Observatory lies in the Laguna Mountains approximately 80 km east of San Diego, California. The range is part of the California Peninsula Ranges that are dominated by Mesozoic granitic rocks. The area is within the deformation zone of the “Greater” San Andreas Fault system and roughly 15 km west of the Elsinore Fault. Numerous small faults and substantial seismicity (Figure 2) occur within the Laguna Mountains. The site lies within the elastic strain field of a number of significant faults.

### Atmospheric:

The Laguna Mountains where the Observatory is located has moderate climate (temperatures average between 0 – 30°C and an average of ~30 inches (75 cm) of rain per year with most rainfall in the winter months). 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 Monument Peak Observatory GGOS site:

Monument Peak is located in tectonically active area of S. California (Figure 2). Although the site appears relatively stable over the longer term as indicated by the small uncertainties on horizontal velocities (0.1 mm/yr), it is influenced by elastic strain accumulation associated with the NA-Pacific plate boundary. This location will require detailed monitoring and modeling of tectonic motions in order to meet GGOS stability requirements.

### 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.

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MONP

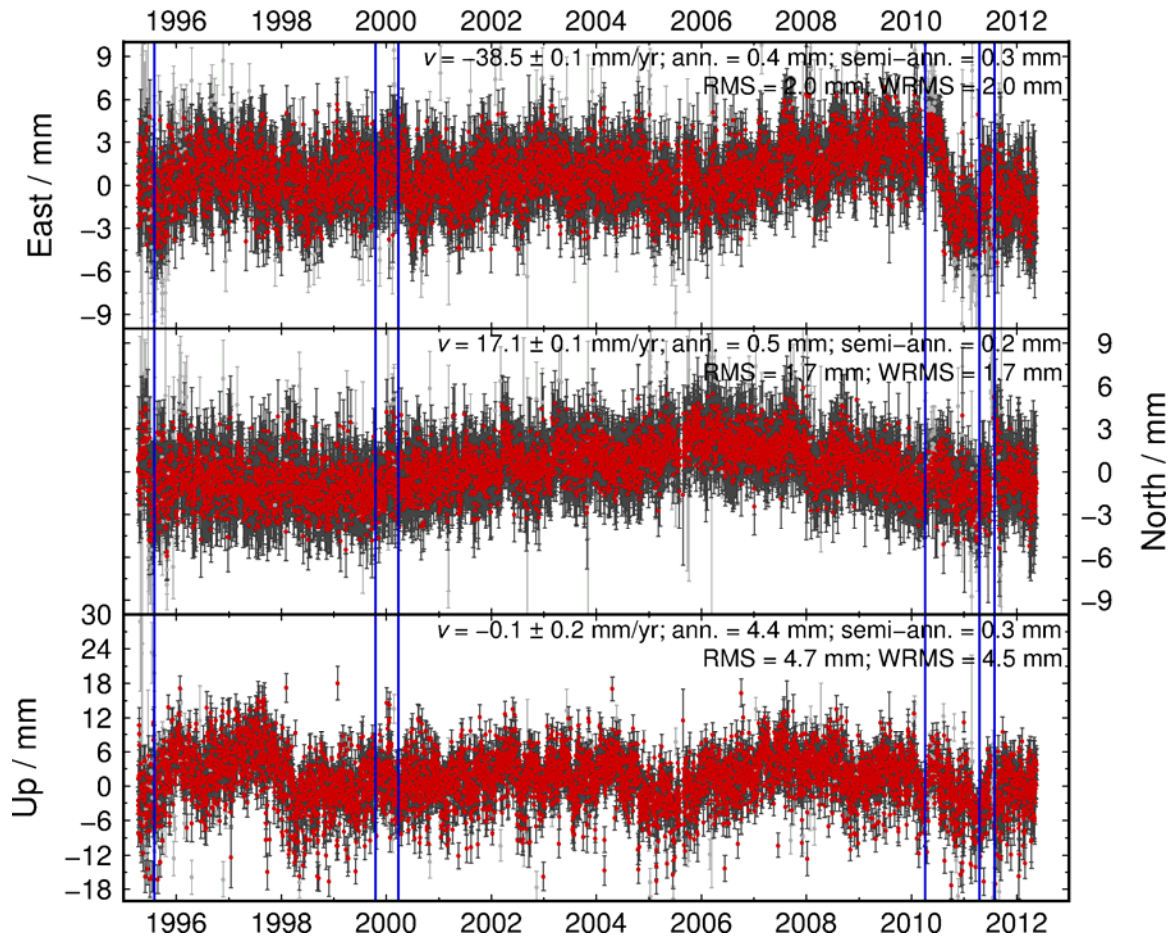


Figure 1. Monument Peak (MONP) GPS time series and statistics.

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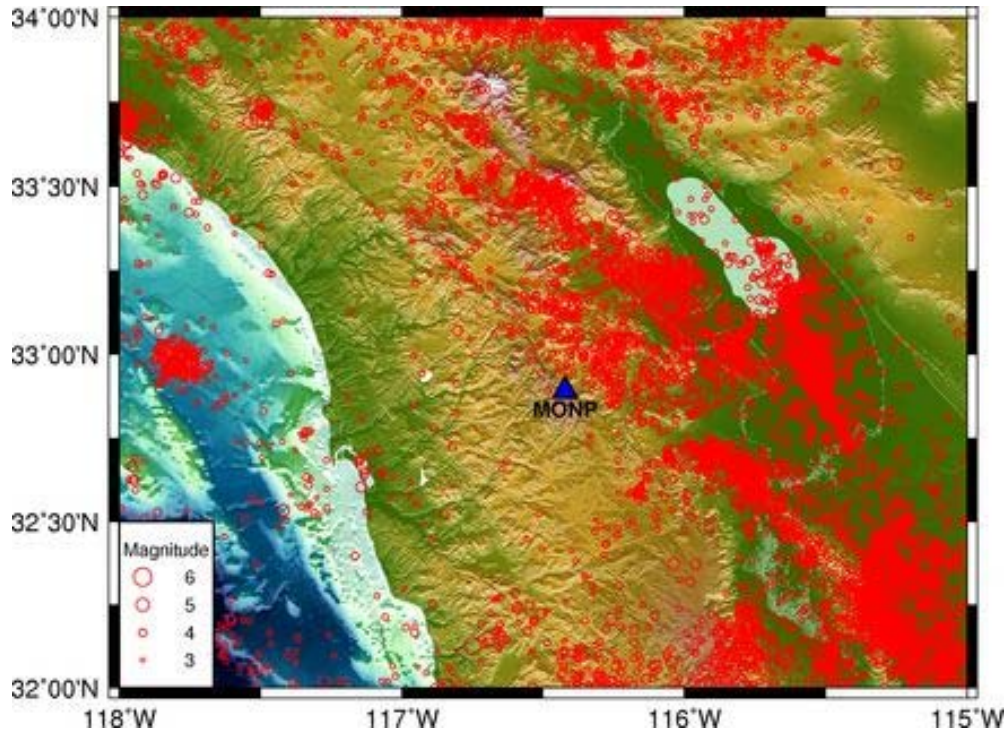


Figure 2. Seismicity ( $M \geq 3$ ) from the SCEC catalog. Blue triangle is the location of the observatory.

## Appendix B: List of Acronyms

AEOS	Advanced Electro-Optical System
ANSS	Advanced National Seismic System
CORS	Continuously Operating Reference Station
DOMES	Directory of MERIT Sites
DORIS	Doppler Orbitography and Radiopositioning Integrated by Satellite
FAA	Federal Aviation Administration
GGOS	Global Geodetic Observing System
GNSS	Global Navigation Satellite System
GPS	Global Positioning Satellite
HPWREN	High Performance Wireless Research and Education Network
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
MIT	Massachusetts Institute of Technology
MOBLAS	MOBile Laser System
MSSS	Maui Space Surveillance Site
NASA	National Aeronautics and Space Administration
NGSLR	Next Generation Satellite Laser Ranging
SGP	Space Geodesy Project
SLR	Satellite Laser Ranging
VLBI	Very Long Baseline Interferometry