

**Haze and Visibility Research
In the
Paso del Norte and West Texas**



**December 2002 – August 2003
FINAL REPORT FOR PROJECT 582-3-60797
FY 2003**

**To the
Texas Commission on Environmental Quality
(Formerly Texas Natural Resource Conservation Commission)
Technical Analysis Division**

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Executive Summary

This is a report of visibility research activities undertaken by the Center for Environmental Resource Management, University of Texas at El Paso on behalf of the Texas Commission on Environmental Quality (formerly, Texas Natural Resource Conservation Commission). In this report, the performance data for digital image acquisition and archiving at each of several urban El Paso sites and West Texas National Park or rural sites, collectively denoted as “wilderness.” is presented. In general, the urban El Paso sites operated 80% or more of the time, as they are available for convenient maintenance of hardware and re-establishment of the dial-up connection to the UTEP server. Wilderness site up time varied from 70% up-time for The McDonald Observatory (University of Texas, Austin) site which was enabled to send large (400kB) files quickly over the U.T. system internet to a nominal 50% time for the National Park Service images archived also by this project, and thence, to 20% time for the new Big Bend installation (stopped by lightning). TCEQ Region VI coordinated a new deployment of a Guadalupe Mountain National Park camera; that site has operated continuously since installation in July 2003.

In the image parameters section, a site image is presented along with the “regions of interest” (ROI) for quality assurance and visibility indexing of the systems. The ROI for each image is integrated and average pixel brightness is determined. The values obtained for the period of this study (December 2002 to July 2003) are interpreted in terms of a contrast ratio (CR) where adequate contrast of juxtaposed image sections can be identified or in terms of brightness variation, which is indexed as the coefficient of variation (CV) for chosen ROI.

An initial examination of the relationship of image visibility parameters and reported air quality and meteorological data by TCEQ was performed and will be continued as part of an ongoing graduate research project. The results of multiple regression analysis with an image contrast value as the dependent variable and various of the air quality and

meteorological values as independent variables indicated that about 70% of the variation in contrast ($R^2 \approx 0.7$) could be explained on the basis of gaseous urban aerosol component concentrations, various meteorological values, and the solar radiation flux for the preceding hour. The inclusion of $PM_{2.5}$ or PM_{10} from geographically peripheral CAMS sites did not markedly improve the statistical associations. The presumption at this time is that the gaseous components are more ubiquitously distributed and measured, and therefore, represent a better characterization of the urban aerosol in the camera sight path (for the long term El Paso downtown view from Chelsea). This latter observation is salient because of the limited $PM_{2.5}$ measurement locations. A comparison to the one short range (meters) visibility monitor data at Ascarate Park (CAMS 37) showed remarkable agreement with the 6000-meter path from Chelsea 1 to downtown even though the park was behind the Chelsea 1 site by several kilometers in the opposite direction. This separation did lead to dramatic differences in visibility on occasion but agreement was more common than not. This work also is being continued as part of a graduate research project that is ongoing under separate auspices.

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I. Introduction

This is the final report for a series of visibility activities undertaken by the Center for Environmental Resource Management of the University of Texas at El Paso on behalf of the Texas Commission on Environmental Quality (formerly, Texas Natural Resource Conservation Commission). In this report, the performance data for digital image acquisition and archiving at each of several urban El Paso sites and West Texas National Park or rural sites collectively denoted as “wilderness.” is presented in Section II. In Section III, site images are presented along with “regions of interest” (ROI) for quality assurance and visibility indexing of the scenes. Where adequate contrast of juxtaposed image sections can be identified, the values obtained for the period of this study (December 2002 to July 2003) are interpreted in terms of a contrast ratio (CR). Otherwise, brightness variation is indexed as the coefficient of variation (CV) existing for a chosen ROI.

A long-standing interest has been to get to the point where some continuous $PM_{2.5}$ data was available for image sections chosen for either CR or CV. The interest in $PM_{2.5}$ derives for the fact that the visible part of the particulate matter size fraction is 0.4 to 0.8 μm approximate diameter and is contained in the $PM_{2.5}$ fraction obtained by current sampling systems based on effective aerodynamic diameter separations. Section IV shows some early results of an ongoing graduate research project of one of us (D. Raina) where the correlation of various air quality parameters reported by TCEQ and the image parameters computed from pixel brightness levels in various ROI are presented.

In this report, we also have examined the correlation image parameters with PM_{10} values available from two CAMS sites that geographically bracket the main view path of the longest installed visibility site (Chelsea 1) in El Paso (Orquiz, Li, et. al. 2001). The mean value of the $PM_{2.5}$ fraction is about 25% by mass of the PM_{10} in El Paso. Additionally, we address in Section IV the influence of solar radiation (various times of the year at the same MST or GMT) on the intrinsic contrast of chosen targets. Finally, the Visibility

values obtained from CAMS 37 have been compared to that of the Contrast Ratio values calculated for the different sites as part of the contract. The CAMS 37 site uses the Visibility Sensor – Model 6230 A, manufactured by the Belford Co.

Nine digital image systems operating under the auspices of the Texas Commission on Environmental Quality (TCEQ) were originally deployed at some time during the period of this interim report and were continuously acquiring and transmitting images to the University of Texas Regional Haze archive server (See list in Table I). Since the original deployment of some of these cameras, two were uninstalled during the fall of 2003 in the course of activities carried out under the auspices of TCEQ Region VI. Of these two, one was redeployed in July 2003 at in a new location at Guadalupe Mountain National Park. The other is the Midland camera originally located near the edge of the Permian Basin.

The UTEP program has archived in the past, five sets of daily images from the Paso del Norte urban network and 4 sets of daily images from sites in west Texas. In north to south order, the west Texas sites are Midland-Odessa (Permian Basin), Guadalupe Mountain National Park (near Carlsbad Caverns National Park), an interstitial area surveyed from The McDonald Observatory atop Mt. Locke near Ft. Davis, TX, and Big Bend National Park (the view extends to the Sierra del Carmen in Mexico).

This project has digitally stored images from all the visibility imaging sites. The first, and most extensive, results are from the archive of urban Paso del Norte digital images taken at the Chelsea Retirement Home in El Paso with a westerly view of downtown El Paso and the Sierra de Juarez. The last deployed system in August of 2002 was at The McDonald Observatory, Ft. Davis, TX, and introduced a changeover from remote systems using Windows 98 and Kodak DC290 cameras to systems using Windows 2000 and Olympus C2100 cameras.

The performance data for the digital camera systems is given in Section II in terms of figures and charts showing number of days per month from inception (December 2000)

to February 28, 2003 that the unit was judged operational. Generally, this is interpreted as over 50 percent of the possible images were archived. This study found similar image quality for the Kodak DC260 used originally in the Big Bend Regional Aerosol and Visibility Observation (BRAVO) study and currently at BBNP, the Kodak DC290's initially deployed for this project, and the Olympus C2100 recently deployed. Improved reliability of systems (especially those ca. 300 miles from the UTEP laboratories) was the anticipated result of the changeover to the Olympus C2100. However, improvements in configuration of DC290 systems have been made and existing such systems are not being replaced. The Big Bend data is, to date, from the National Park Service camera. Permission to install a TCEQ camera has been obtained and therefore, images from a second BBNP camera are expected later in FY 2003.

The Data Appendix DVD accompanying the report contains the spreadsheets with these data and the image archive and also, a “. PDF” copy of the report. The images and data for this digital visibility imaging project have been deposited with the University of Texas El Paso Library, Special Collections, from which they can also be retrieved upon request.

This project has put in place the initial TNRCC web server technology for the Visibility Camera Program at <http://cams.utep.edu>, featuring a satellite image of the Paso del Norte Air shed with site " yellow dot" icons. Summary of archive numbers are given in Section II.

The image files are 40KB in size except Mc Donald's where they are about 400KB transferred over a LAN connection.

Table I.1: TCEQ West Texas Visibility Camera Systems

Name	Location	Description	Camera Type	Communication
Chelsea 1	Chelsea Retirement Center Roof	Westerly View of Downtown El Paso and distant Sierras de Juarez	Kodak DC290	Modem
Chelsea 2	Chelsea Retirement Center Roof	Southerly View toward Ciudad Juarez	Kodak DC290	Modem
Ranger 1	Ranger Peak	Southerly View toward Juarez from Ranger Peak Aerial Tramway	Kodak DC290	Modem
Ranger 2	Ranger Peak	Southwesterly View of Juarez includes Downtown El Paso and UTEP	Kodak DC290	Modem
GMNP	Guadalupe Mountain National Park	Easterly view from Dell City.	Kodak DC290	Modem
UGLC	UTEP Undergraduate Learning Center Roof	Southerly view of IH-10, railway and Ciudad Juarez and mountains.	Panasonic WV CP450	LAN
McDonald	McDonald Observatory catwalk of 107” telescope.	Southerly view of various mountain peaks and ranges	Olympus 2100	LAN
BBNP 1	Big Bend National Park (NPS site)	Southerly view of Sierra del Carmen Mountains	Kodak DC260	Modem
BBNP 2	Big Bend National Park (TCEQ site)	Easterly view Chisos Mountain Lodge	Kodak DC290	Modem

II. Summary of Site Operating Days

The following are the charts that represent the number of days the cameras were operational, it also includes the time period for the current contract.

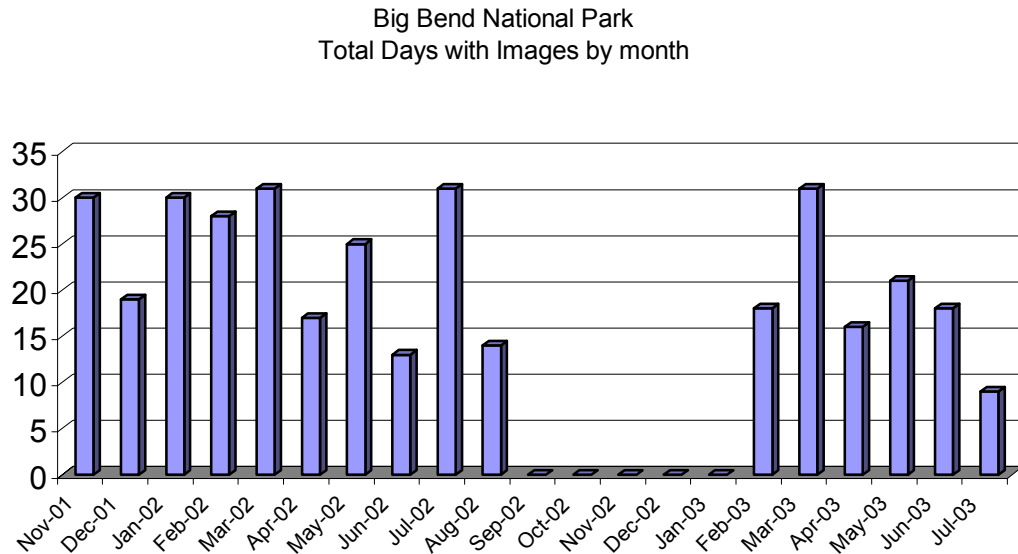


Fig. II.1. Big Bend National Park camera (Kodak DC260). National Park Service maintains this camera. Images are obtained by saving the image from their web site. Single archived images taken at 3:00 pm local time, can be viewed from the National Park Service website:

<http://www2.nature.nps.gov/ard/cams/bibe/bibejpgfram.cfm>

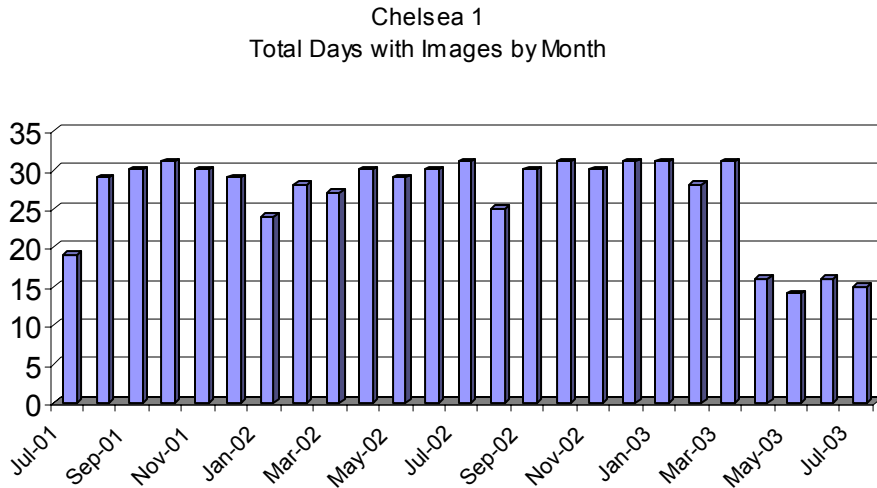


Fig. II.2. Chelsea 1 is the original site in December 2000, but archiving records at UTEP only extend from July 2001. Back up CD's from the site does exist.

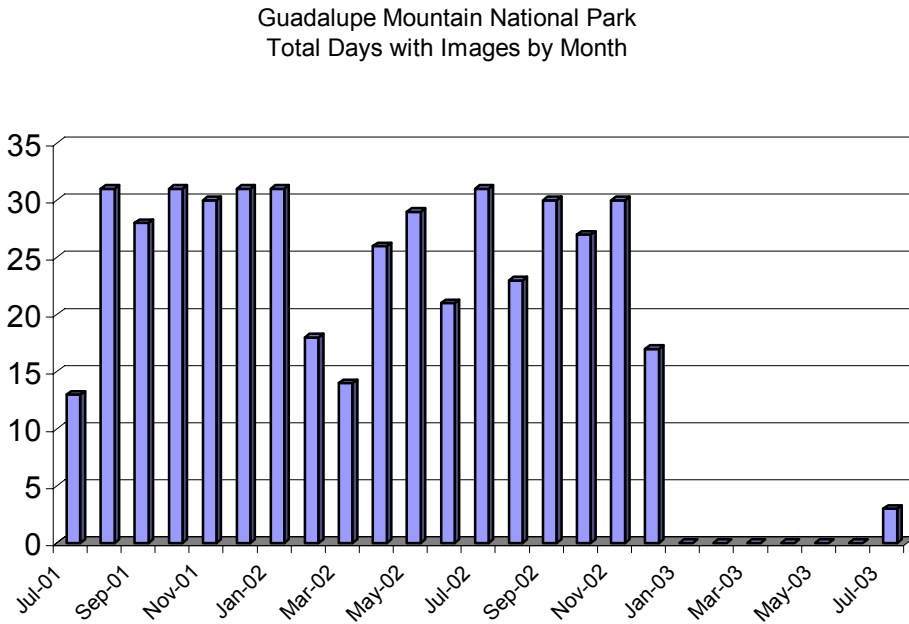


Fig. II.3. Guadalupe Mountain National Park was deployed in 2001 and uninstalled for a move to a new location by TCEQ Region VI. It has now been relocated to a new site by TCEQ and UTEP in July 2003.

UTEP Undergraduate Learning Center
Total Days with Images by Month

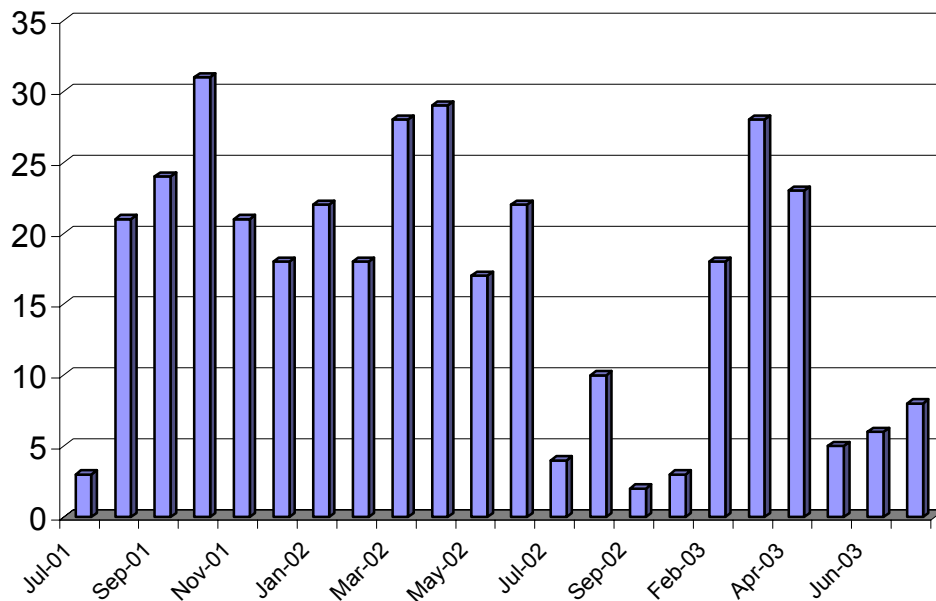


Fig. II.4. UTEP Undergraduate Learning Center (UGLC). This site is a live video camera from which periodic images are archived. The UGLC camera is a Panasonic video camera connected to a Panasonic NT104 network and Internet server. Images are displayed live via internal proprietary java scripting by Panasonic. Images are collected from the web page using a recorded sequence includes an image save routine. Reliability of the image archives is dependent on network and Internet conditions. Local archive of the images is possible through a video recorder.

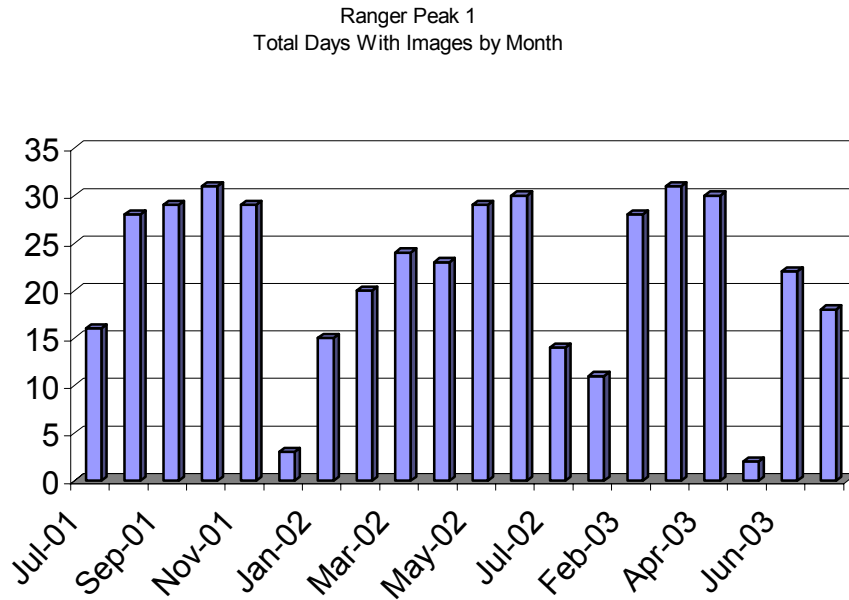


Fig. II.5. Ranger Peak 1 in the Franklin Mountains overlooking El Paso and Ciudad Juarez.

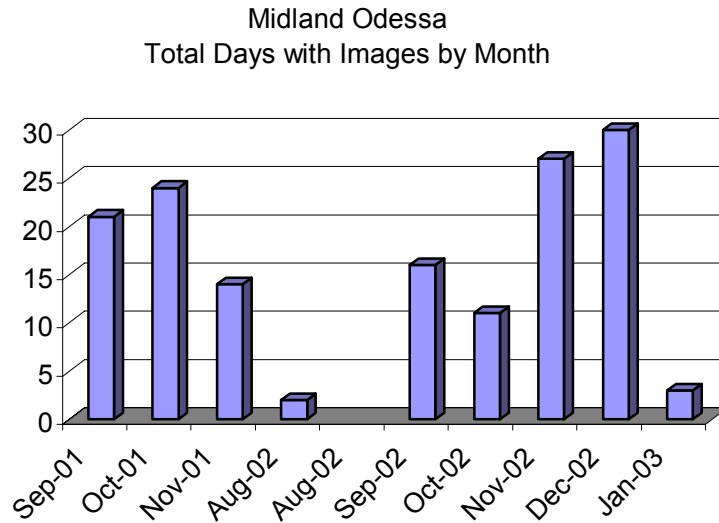


Fig. II.6. Midland-Odessa camera originally placed in the TCEQ offices in September 2001 for testing. In late August, it was deployed at the Bob Derrington Water Treatment plant south of Odessa with a westerly view of the plains east of Guadalupe Mountain National Park. TCEQ Region VI uninstalled this camera on October 10, 2002 for potential relocation. Images during testing are not included in the tabulation. This camera was relocated to Big Bend National Park (Stopped by lightning).

Chelsea 2
Total Days with Images by Month

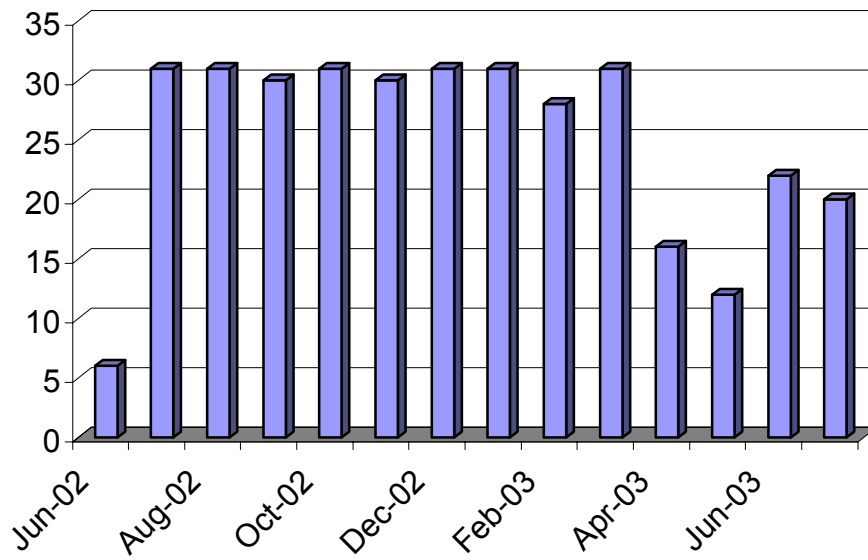


Fig. II.7. Chelsea 2 provides a southerly view toward Cd. Juarez.

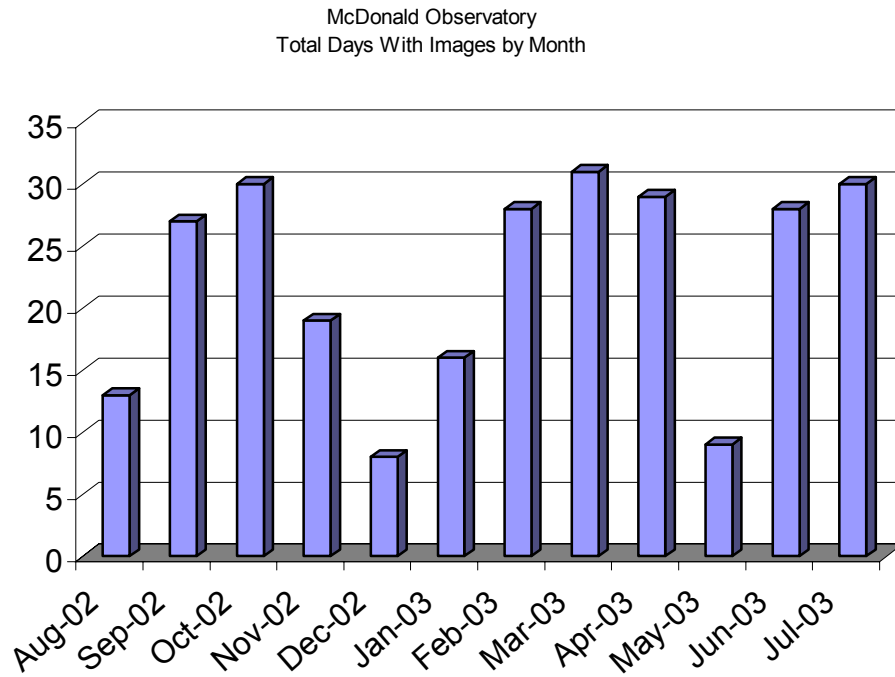


Fig. II.8. McDonald Observatory camera is located on the catwalk of the 107-inch telescope and provides a southerly view of various mountain ranges and peaks. The system resides permanently on the local area network and is accessible via the Internet.

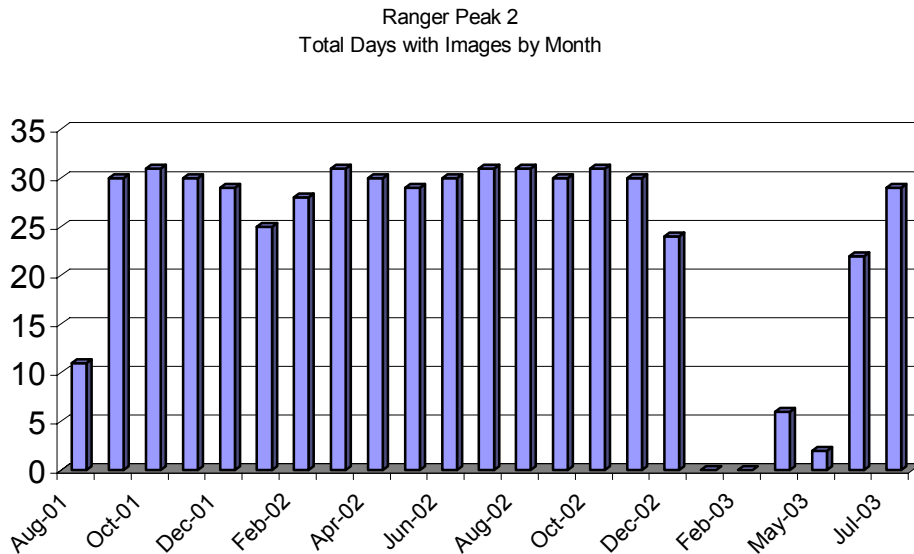


Fig. II.9. Ranger Peak 2 supplements the images from Ranger 1. It was temporarily removed by TCEQ in December of 2002.

Observations and Conclusions:

The visibility camera systems have presented a number of challenges to provide for reliability and image quality. The factors include Internet status, computer-camera software, operating systems, communications, system security and others. In summary, the Kodak DC290 systems have proven to be reliable with the ability to restart the systems remotely. The Olympus system has been most robust. Restarting the computer, loss of connectivity or other factors have no affect on the ability to activate the software and restart collection of images. In general, the “ARS DIGICAM” software and systems have been reliable, relatively easy to maintain, and provide high quality images for documentation and analysis of visibility.

The archive results for this report are not completely representative of the complete available archive of images from these systems. In some cases, a communication or file transfer problem exists and images being recorded on the local attached computer were not transmitted to the ftp and archives at UTEP. During the course of this project, however, the missing archives will be obtained and added to those available at <ftp://tnrcc.utep.edu> for download via the Internet.

III. Regions of Interest and Results for the Contrast Ratio and Coefficient of Variation Analysis for the nine visibility imaging sites

Contrast Ratio (CR) analysis and Contrast Variance (CV) analysis are being performed on the images at defined times each day that provide acceptable target contrast. The theoretical foundation for our analyses derives from the classical approach described in Von Koschmieder's *Habilitationschrift* (Koschmieder, 1924, Pt. I and II). The first use of the present adaptation by us was described by Turner and Parks (Turner, 1998) for digitized TNRCC video images. Application of an older form of NIH IMAGE[©] has been shown to be a facile means to get the basic data out of images as integrals of pixels brightness from selected ROI's (Parks 2002, and Sawant 2002). The current work uses IMAGE-J[©] (Image 2002), a JAVA language based incarnation of the earlier form which features a variety of operational improvements.

Contrast Ratio and Contrast Variation are collectively referred to as Visual Air Quality (VAQ) factors. They are defined by the following equation:

$$\text{Contrast Ratio: } CR = \frac{\text{Mean (Bright ROI)} - \text{Mean (Dark ROI)}}{\text{Mean (Bright ROI)}} \quad \text{Eq. III.1}$$

$$\text{Contrast Variation: } CV = \frac{\text{SD (ROI)}}{\text{Mean (ROI)}} \quad \text{Eq. III.2}$$

Where;

SD (ROI) = Standard Deviation of the pixel intensities (0 – 255).

Mean (ROI) = the mean of the pixel light intensities.

Where possible (dark and light targets), CR is used. Where no discrete targets exist, CV is used.

In some instances the CR values obtained are negative, this is attributed to the fact that on that particular day the sky was darker as compared to the ridge and hence the change in values of the mean and thereby in the CV.

Methods & Materials:

1. The images were analyzed using ImageJ 1.29x Analysis software.
2. The data in Section IV has been analyzed using SPSS statistical package.

Chelsea (Site 1):

This camera located atop the Chelsea Retirement Home, produces a westerly view of downtown El Paso and distant Sierra de Juarez. The classic view has now been used for over 10 years, it is the best-studied and understood site. Regions of Interest are marked and labeled in the various figures.

CR Analysis - The four ROI's that have been used for the TNRCC (now TCEQ) contracts for 2001 and 2002, have been retained.



Fig. III.1

CR values are being computed for the downtown target buildings (A; B) located approximately 5 km from the Chelsea site. CR is also being computed for the edge of the Sierra de Juarez for a ridge-sky two-target basis (C; D) at ca. 12 km.

CV Analysis - Contrast Variance (CV) would be used to look at the spread of color pixel values for urban zones in El Paso (E) and Ciudad Juarez (F).

A ROI encompassing both the black and the white target has been evaluated and can be used to calculate the CV values, for this view.

In addition the complete image could be used as ROI for CV or Fourier Transform and spatial frequency evaluation. Spatial frequency can approach zero in parts of the image during heavy inversions and the total image during sand storms (wind events).

Results:

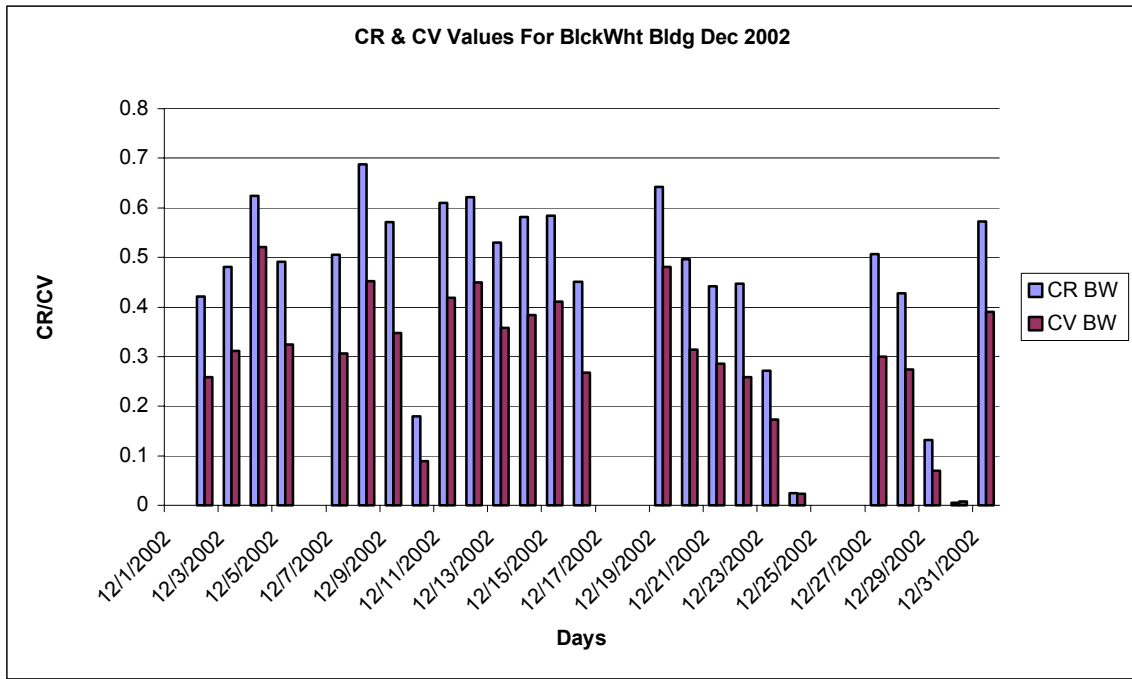


Fig. III.2 CR & CV Values for the Black & White building-Dec 2002

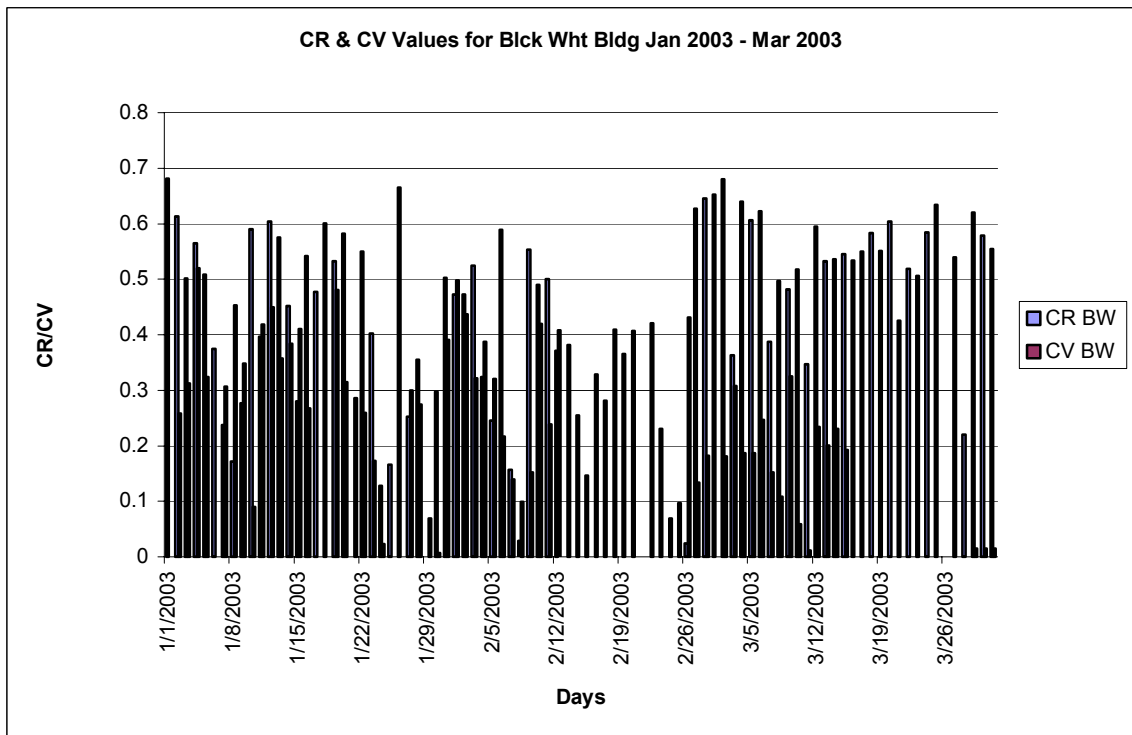


Fig. III.3 CR & CV Values for the Black & White building-Jan - Mar 2003

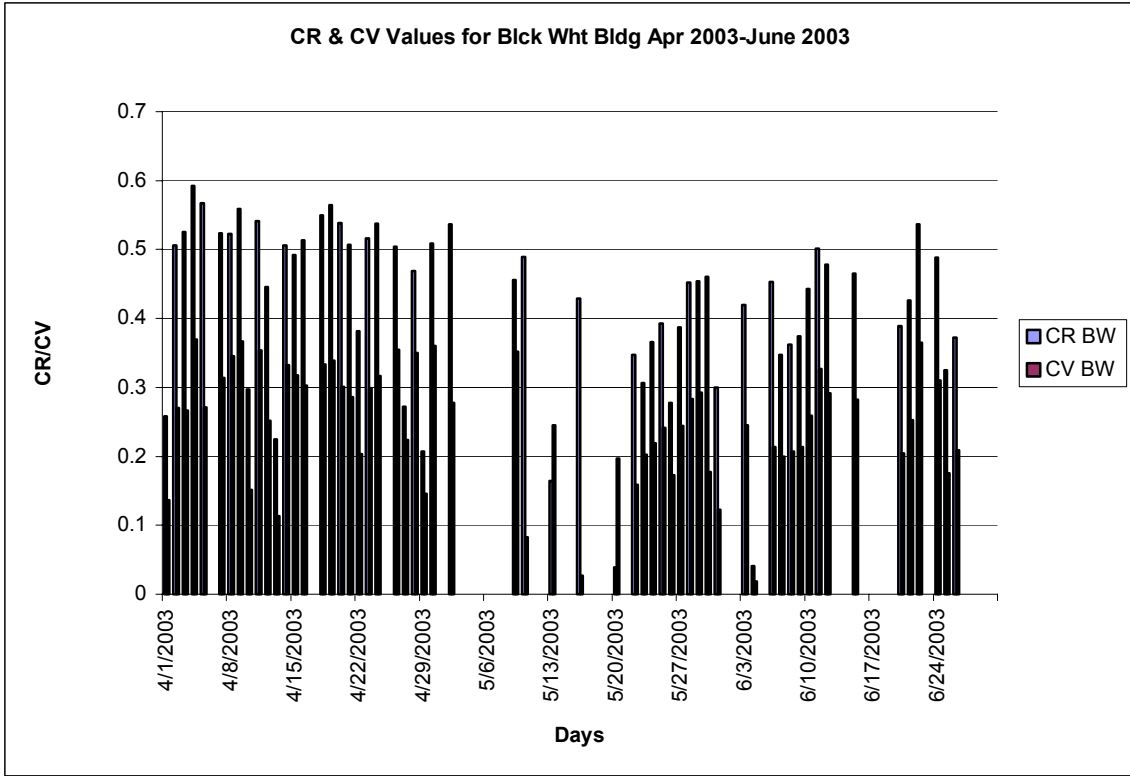


Fig. III.4 CR & CV Values for the Black & White building-Apr – June 2003

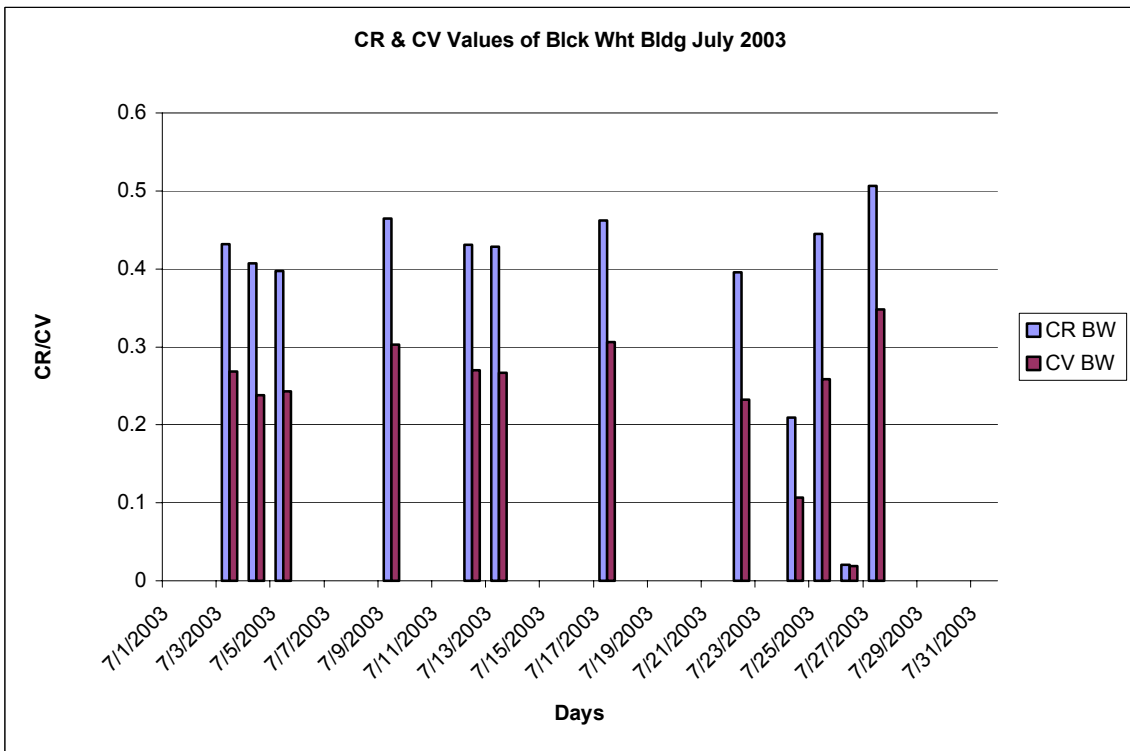


Fig. III.5 CR & CV Values for the Black & White building-July 2003

Quality Assurance for the Equipment:

The quality assurance protocol assumes that a sufficiently close target to the camera will be minimally affected by haze. This is approximately true except for unique events like sand storms, snow etc. An example from Chelsea 1 is given. An ROI under the bridge next to the freeway is selected and CV Analysis revealed that the camera functioned satisfactorily.



Fig. III.5.a

The result of the QA test is displayed below;

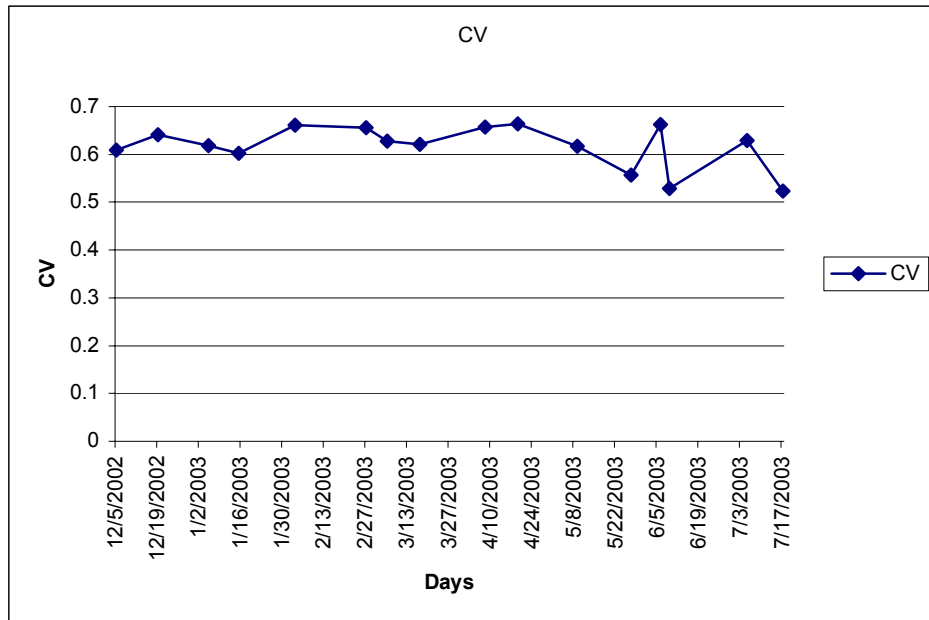


Fig. III.6 CV values for the Contract Period for ROI under bridge

Chelsea (Site2):

This camera is located on the Chelsea Building but has a different view than the Southerly direction toward Ciudad Juarez.



Fig. III.7

CR Analysis -

The CR Analysis has been performed on the mountain (A) and the sky (B).

CV Analysis -

The ridge of the mountain with respect to the sky (C) has been used to calculate the value of CV.

RESULTS:

CR & CV for Ridge-Sky & CV for the common ROI (Dec 2002)

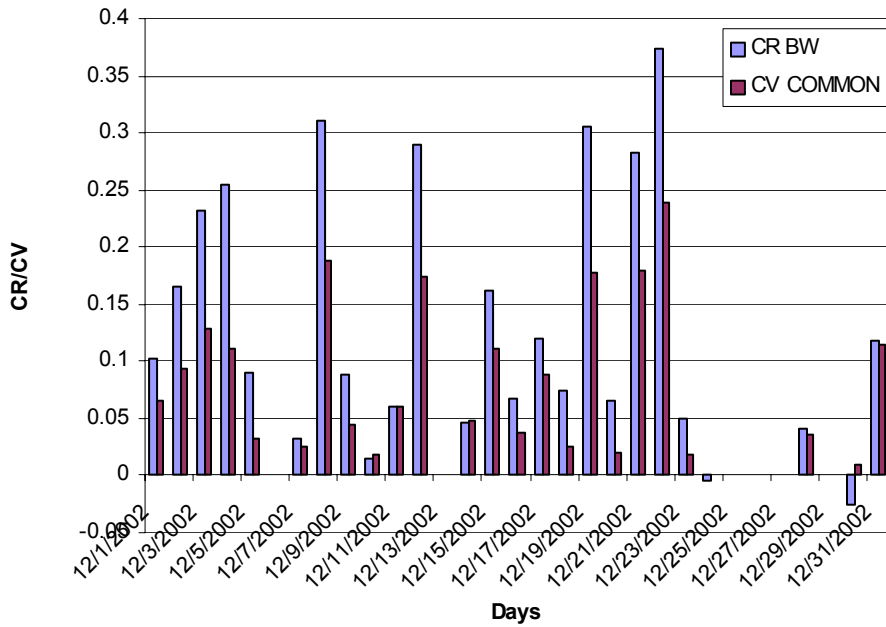


Fig. III.8 CR & CV values for the Ridge-Sky ROI-Dec 2002

CR/CV for Chelsea 2 Ridge-Sky and Common ROI

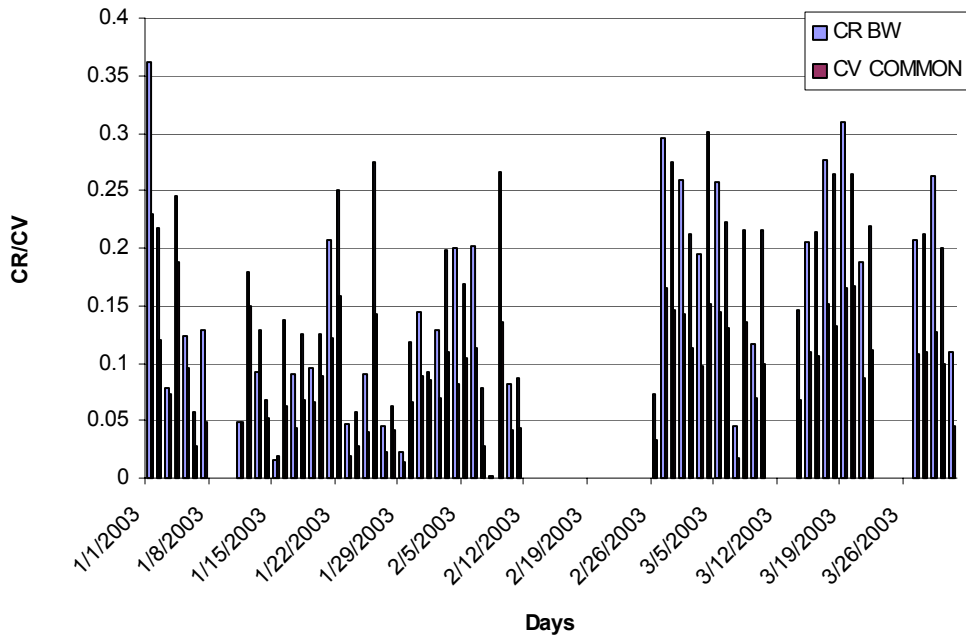


Fig. III.9 CR & CV values for the Ridge-Sky ROI-Jan – Mar 2003

CR for Ridge-Sky and CV for common ROI Apr 03-Jun 03

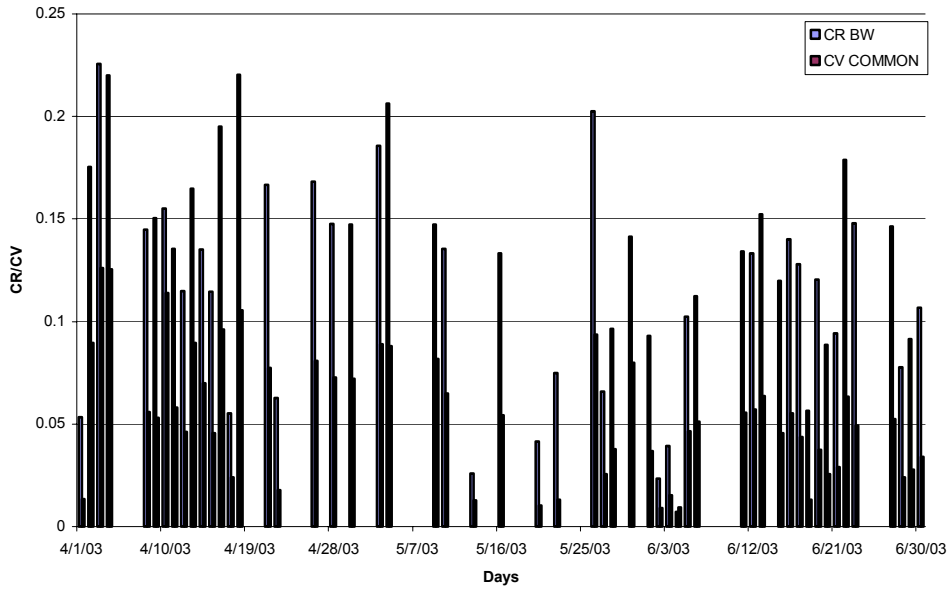


Fig. III.10 CR & CV values for the Ridge-Sky ROI-Apr – June 2003

CR Ridge-Sky CV Common ROI Jul 2003

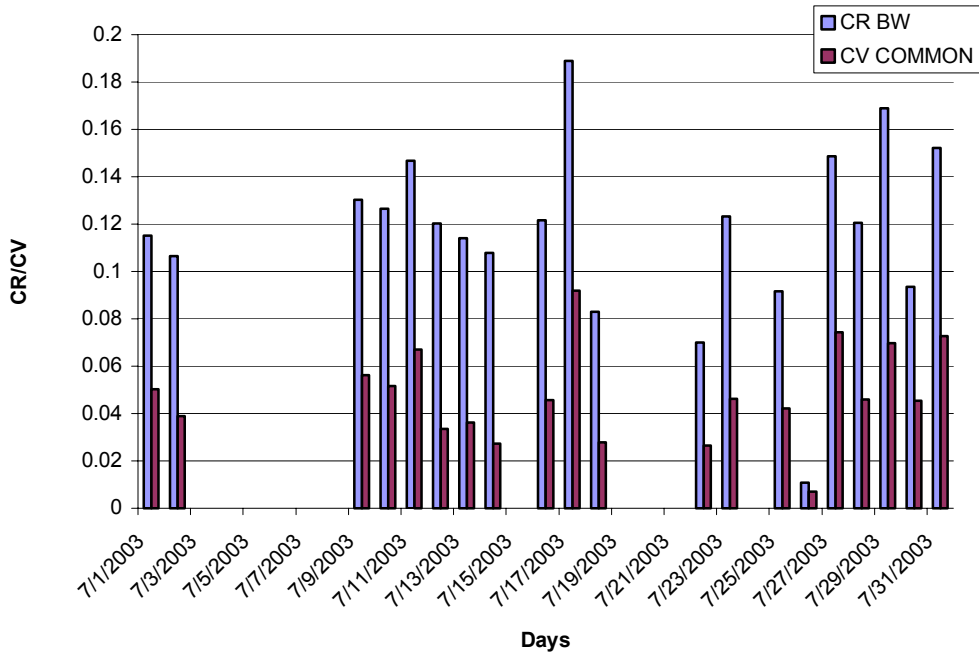


Fig. III.11 CR & CV values for the Ridge-Sky ROI-July 2003

Ranger Peak (Site1):

This camera has a Southerly View toward Juarez from Ranger Peak Aerial Tramway.

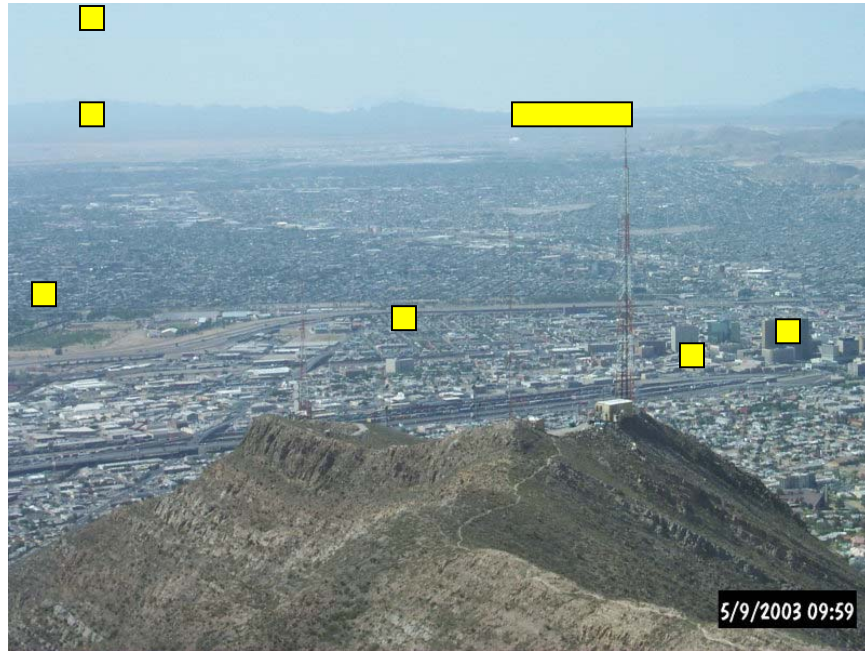


Fig. III.12

CR Analysis - Fig 3 shows the region of interest for the view from ranger peak 1. The contrast was taken between the mountain and sky and black building and White building.

CV Analysis - The Coefficient of Variation analysis was performed on the block in Downtown El Paso and another Block in Ciudad Juarez. Also, a new ROI is to be added that encompasses the mountain ridge.

Results:

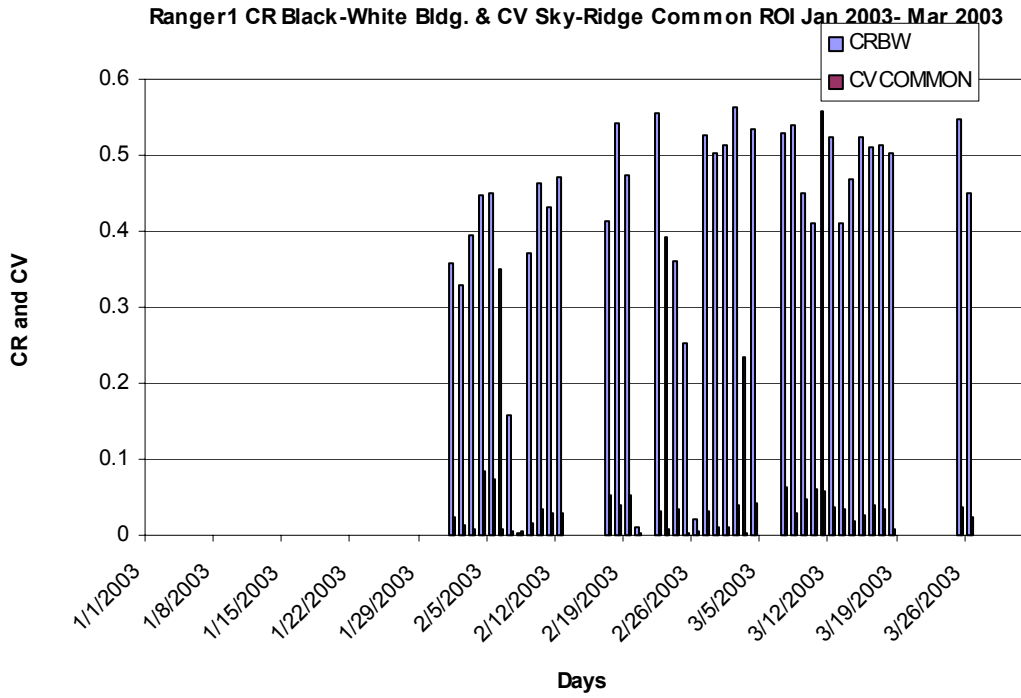


Fig. III.13 CR & CV values for Ranger 1 Jan – Mar 2003

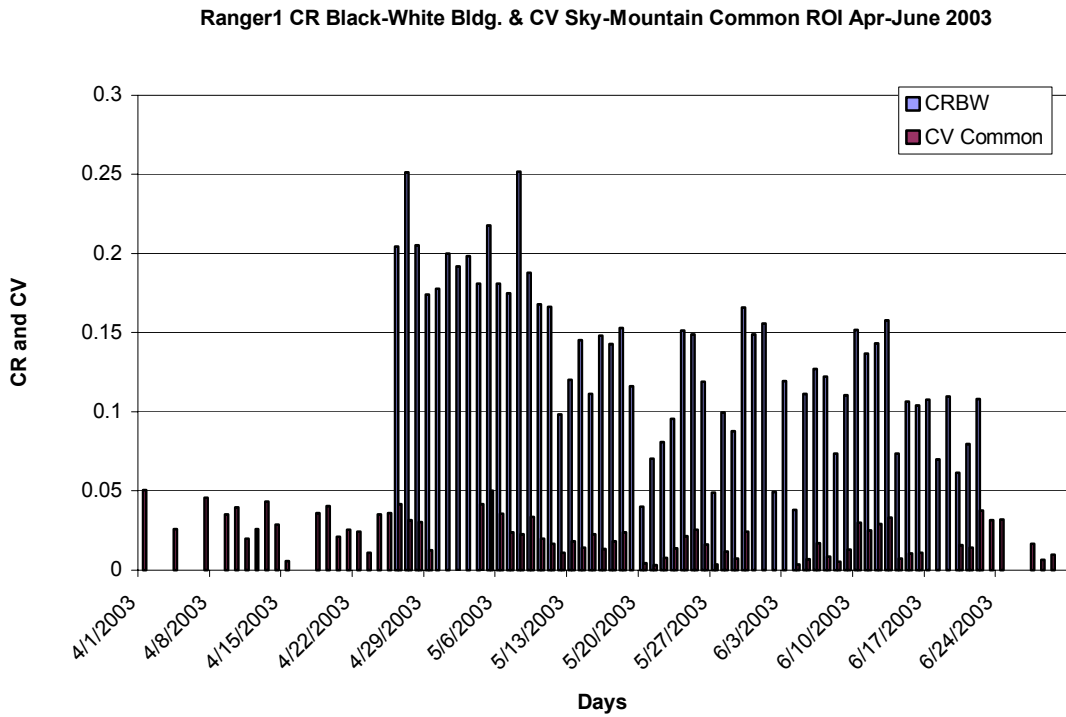


Fig. III.14 CR & CV values for Ranger 1 Apr-May 2003

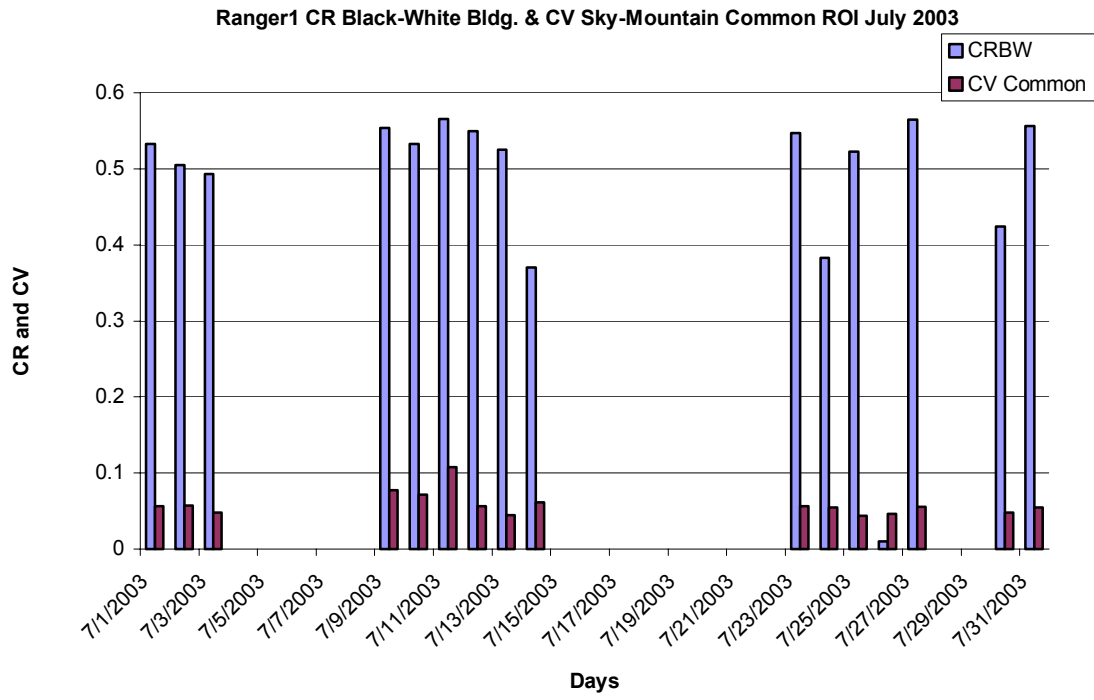


Fig. III.15 CR & CV values for Ranger 1 July 2003

Ranger Peak (Site2):

The Camera has a Southwesterly View of Juarez including Downtown El Paso and UTEP.

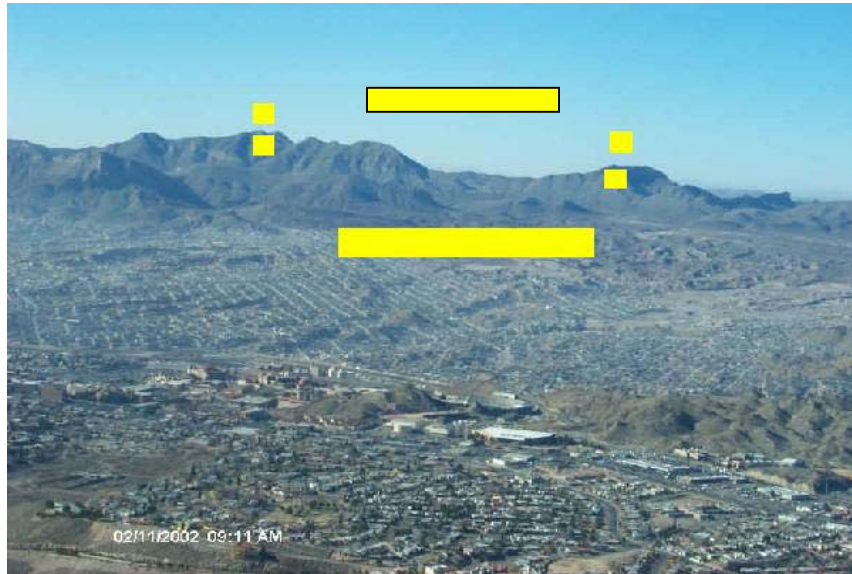


Fig. III.16

CR Analysis – The contrast ratio was performed for the mountain ridge with respect to the sky. Two different lengths of ROI's were taken as shown in the Fig. III.16 above.

RESULTS:

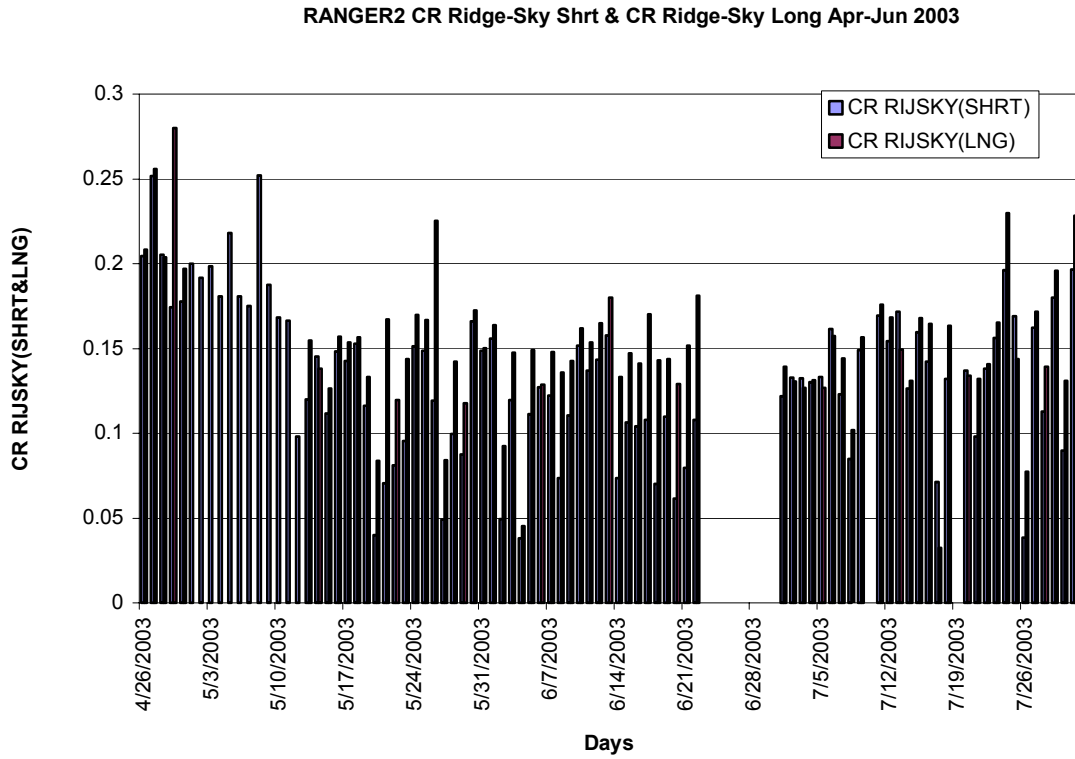


Fig. III.17 CR Ridge-Sky short & CR Ridge-Sky long ROI Apr-Jun 2003

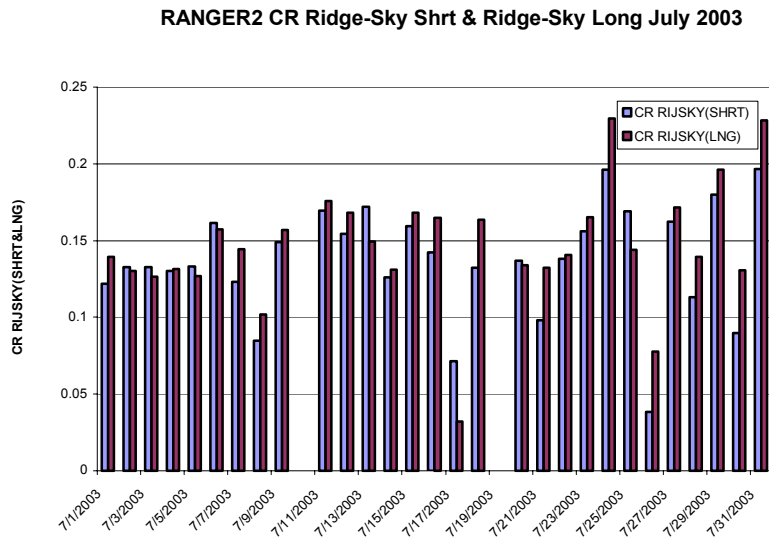


Fig. III.18 CR Ridge-Sky short & CR Ridge-Sky long ROI-July - 2003

UGLC:

This is the Southerly view of IH-10, railway and Ciudad Juarez and mountains.



Fig. III.19

CR Analysis: The CR analysis was performed for the mountain ridge with respect to the sky.

CV Analysis: The CV analysis was performed by taking a ROI that encompasses the ridge of the mountain and the sky.

RESULTS:

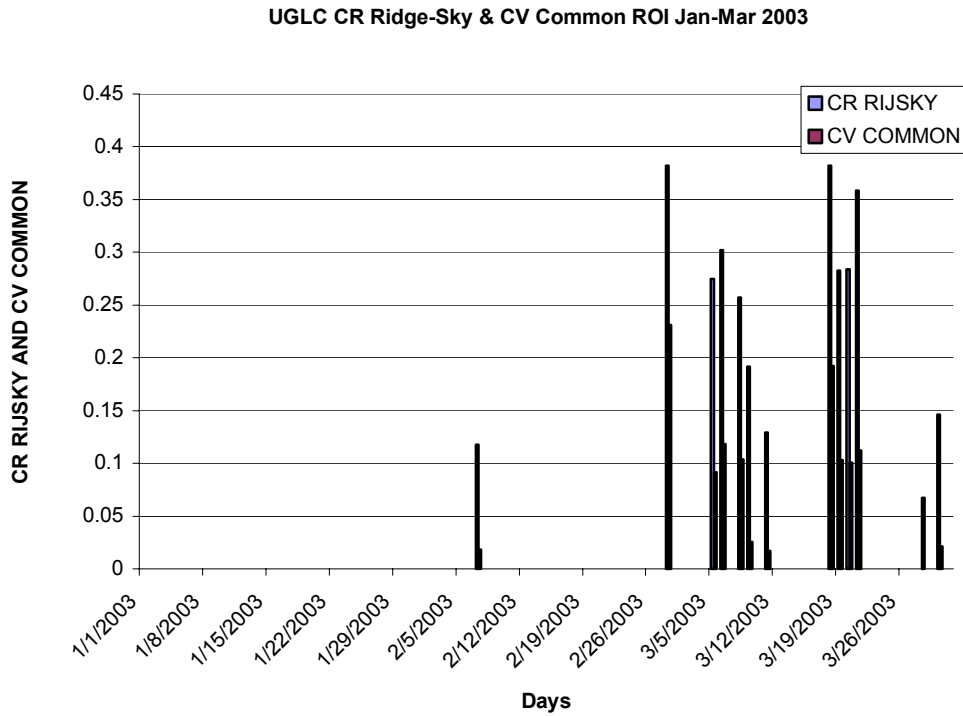


Fig. III.20 CR Ridge-Sky & CV Common ROI Jan-Mar 2003

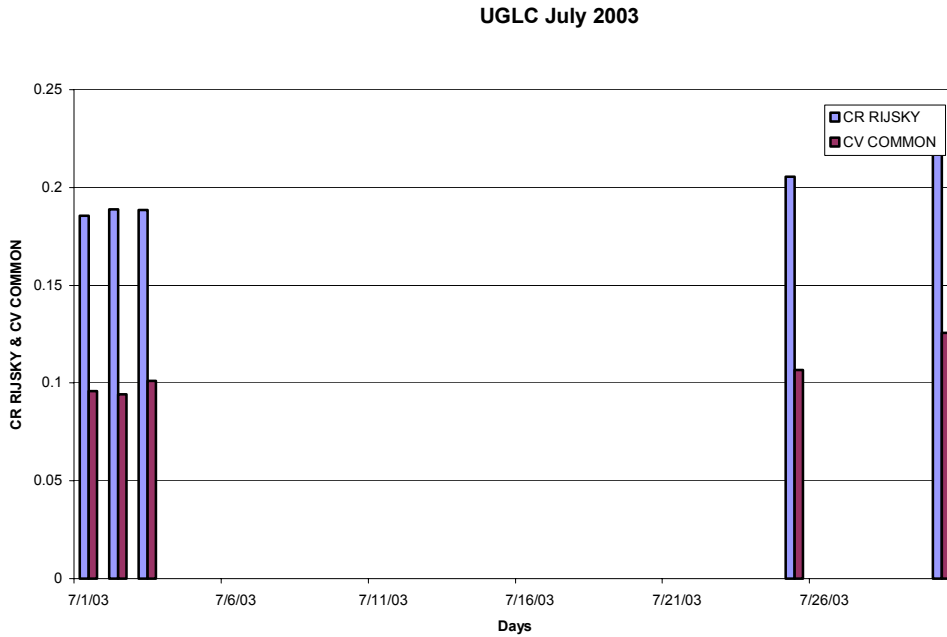


Fig. III.21 CR Ridge-Sky & CV Common ROI July 2003

McDonald Observatory:

This view gives the southerly view from the observatory of various mountain peaks and ranges.

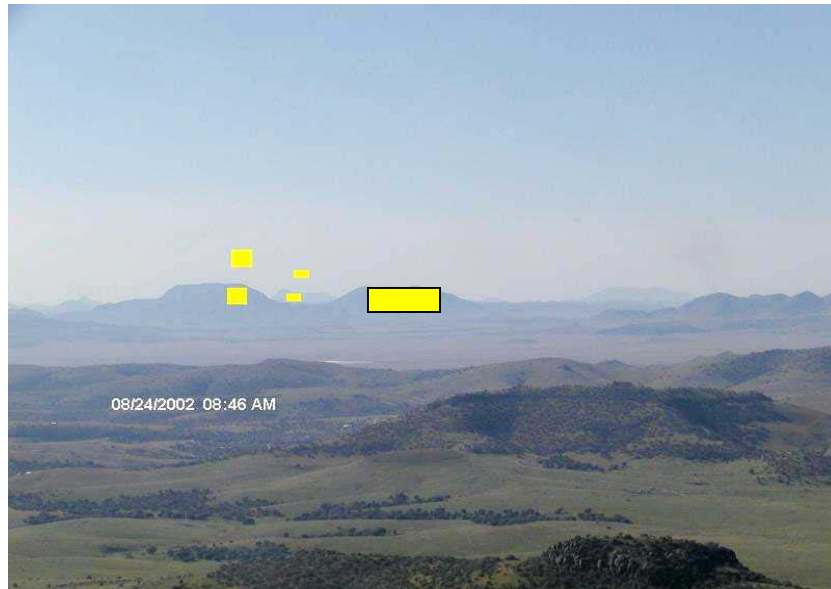


Fig. III.22 The McDonald Observatory, Department of Astronomy, University of Texas at Austin, atop Mt. Locke (altitude ca. 2200 meters). The central peak in the “notch” of Twin Mountains is Cathedral Peak in Big Bend National Park at a distance of ca. 65 km.

CR Analysis:

This was performed by taking a ROI on the twin mountain and compare it to that of the ROI of sky above it.

The same procedure was adopted for the Cathedral Peak, which is at a distance of 65 km from the camera site.

CV Analysis was performed by taking a ROI encompassing the twin mountain ridge and the sky together.

RESULTS:

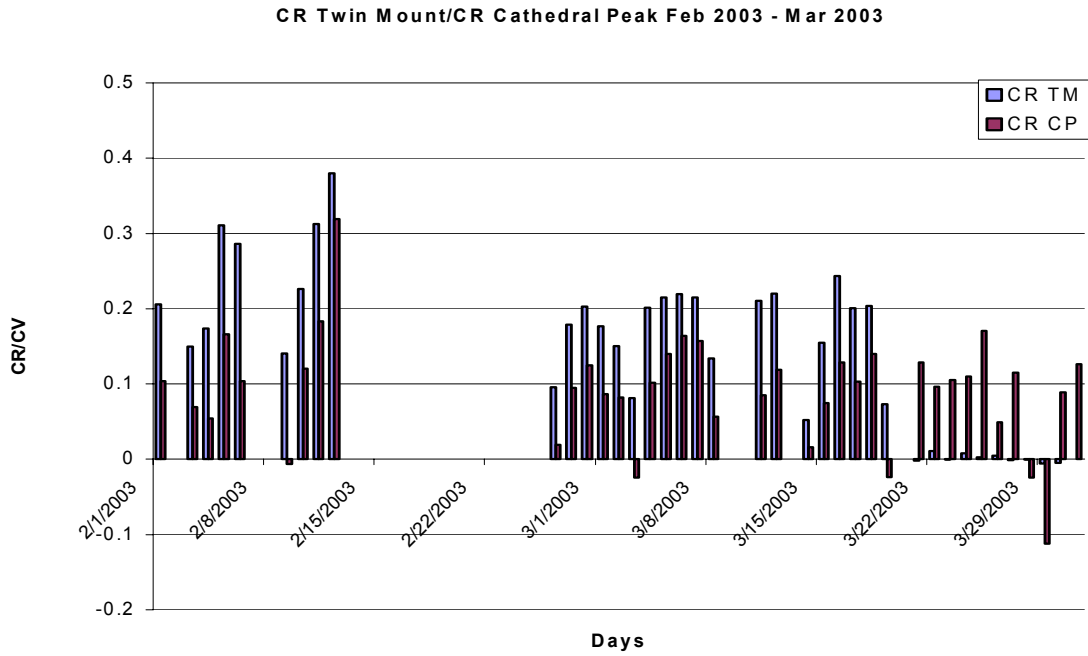


Fig. III.23 CR Twin Mountains/CR Twin Mountains Feb – Mar 2003

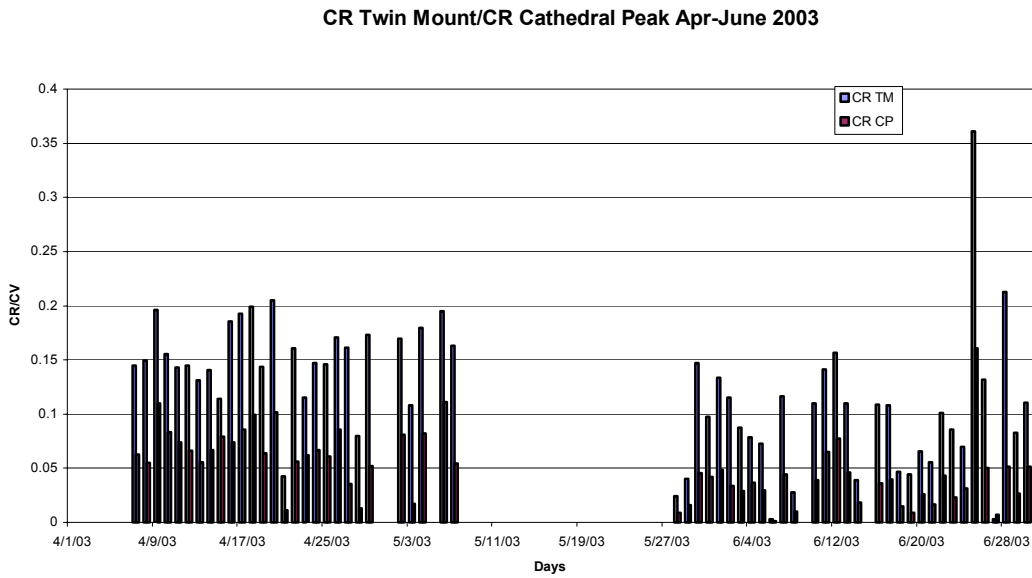


Fig. III.24 CR Twin Mountains/CR Twin Mountains Apr – Jun 2003

CR Twin Mount/CR Cathedral Peak July 2003

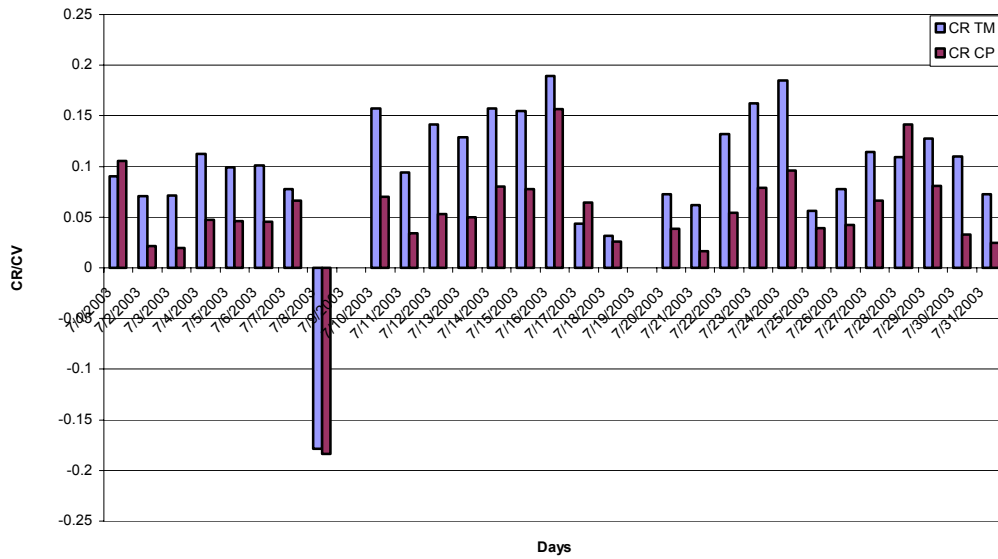


Fig. III.25 CR Twin Mountains/CR Twin Mountains July 2003

Quality Assurance for the Equipment:

The Quality Assurance was performed by taking an ROI on the handrail, which is at a distance of about 2 meters from the camera, and a CV Analysis revealed that the camera functioned satisfactorily during the duration of the project. A couple of images were taken every month, for the entire contract period.

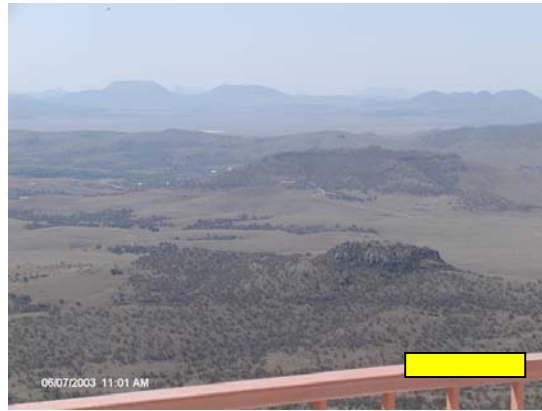


Fig III.26 The ROI on the handrail at Mc Donald Observatory

Results:

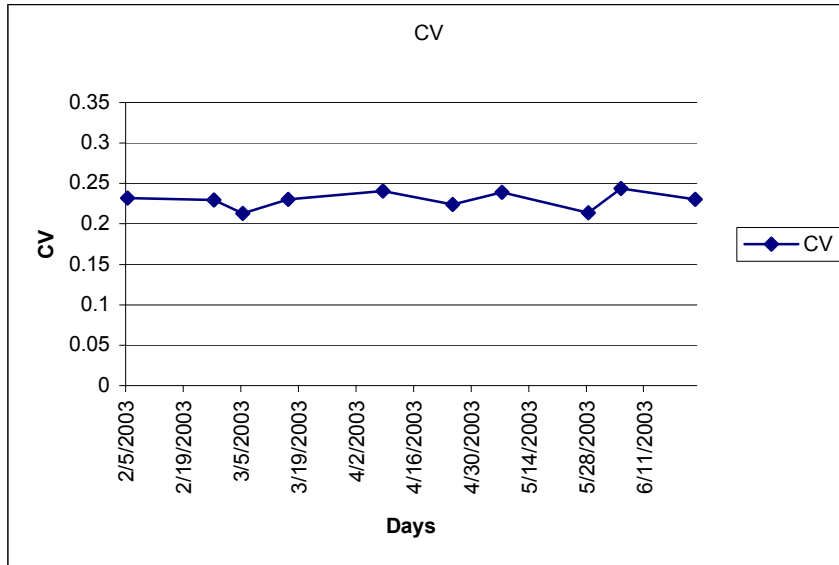


Fig. III.27 CV values for the ROI on the handrail

BBNP:

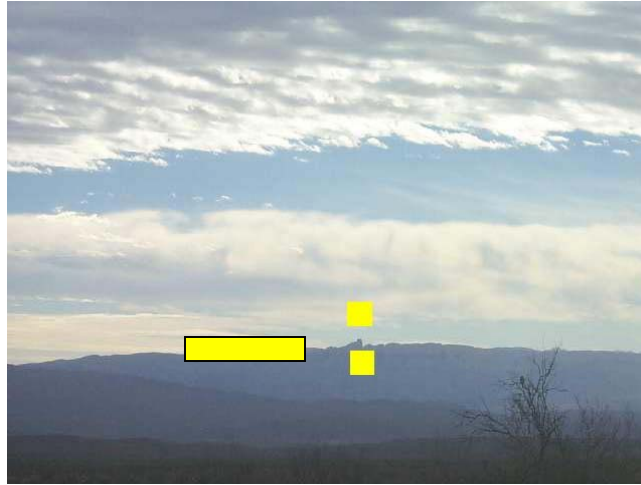


Fig. III.28

CR Analysis: The contrast ratio analysis was performed by taking the contrast of an ROI on the mountain with respect to that of the sky.

CV Analysis: was performed by taking the ROI encompassing both the sky and the ridge together.

Results:

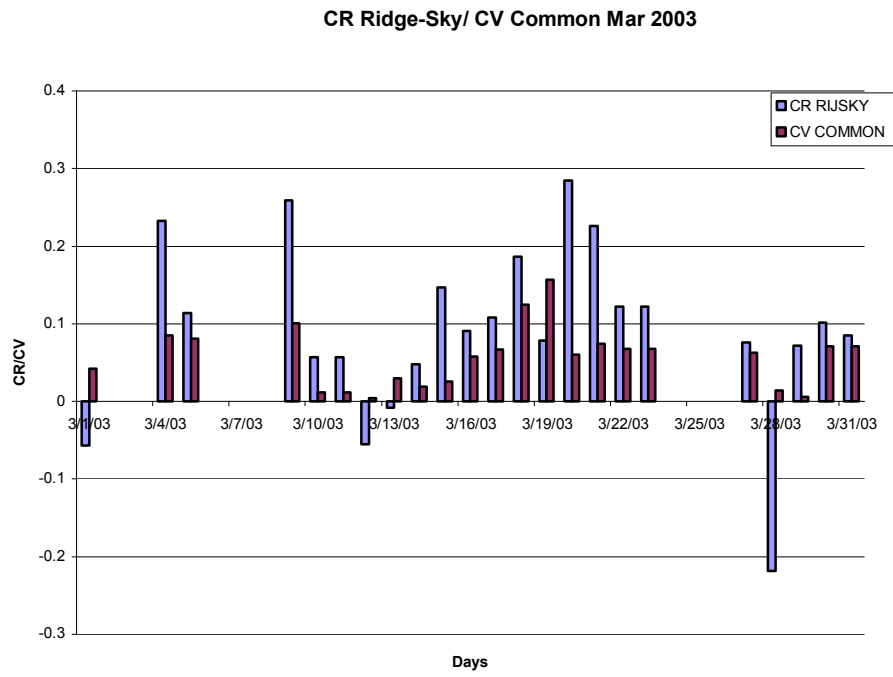


Fig. III.28 CR Ridge-Sky/CV Common ROI Mar 2003

CR Ridge-Sky/CV Common ROI Apr 2003-June 2003

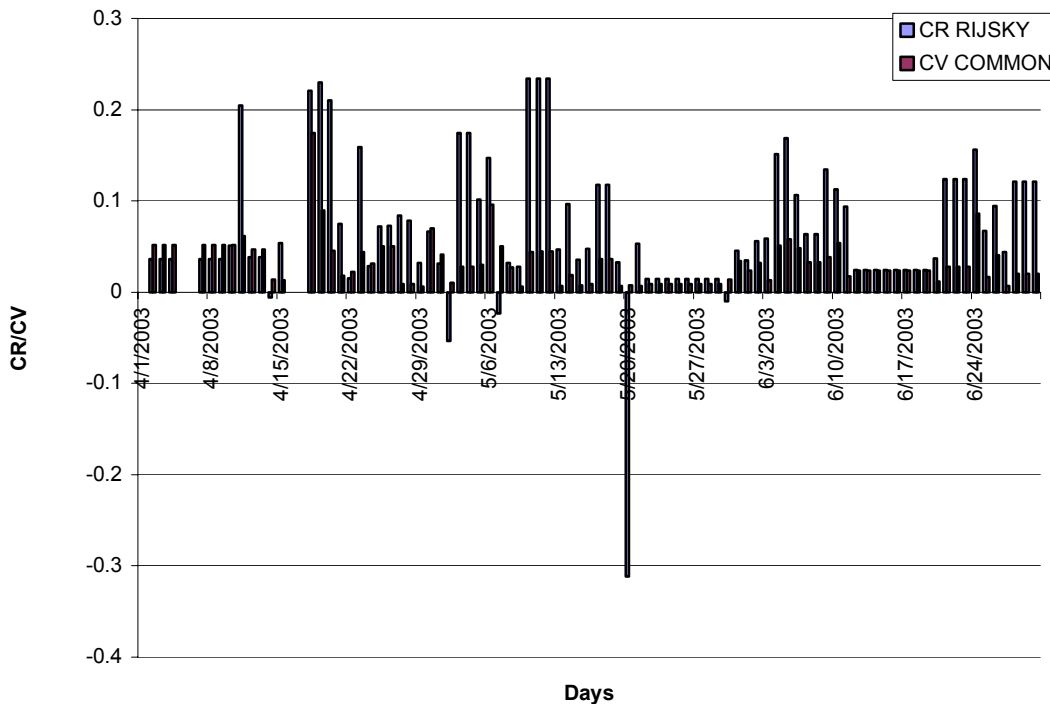


Fig. III.29 CR Ridge-Sky/CV Common ROI Apr - June 2003

CR Ridg-Sky/CV Common ROI July 2003

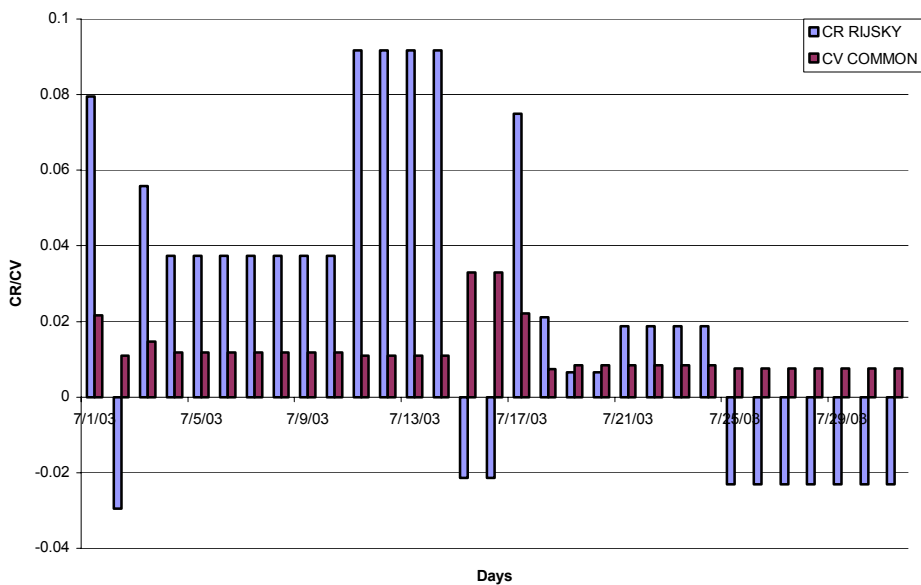


Fig. III.30 CR Ridge-Sky/CV Common ROI July 2003

New Big Bend Site (Chisos Lodge) – Westerly View:

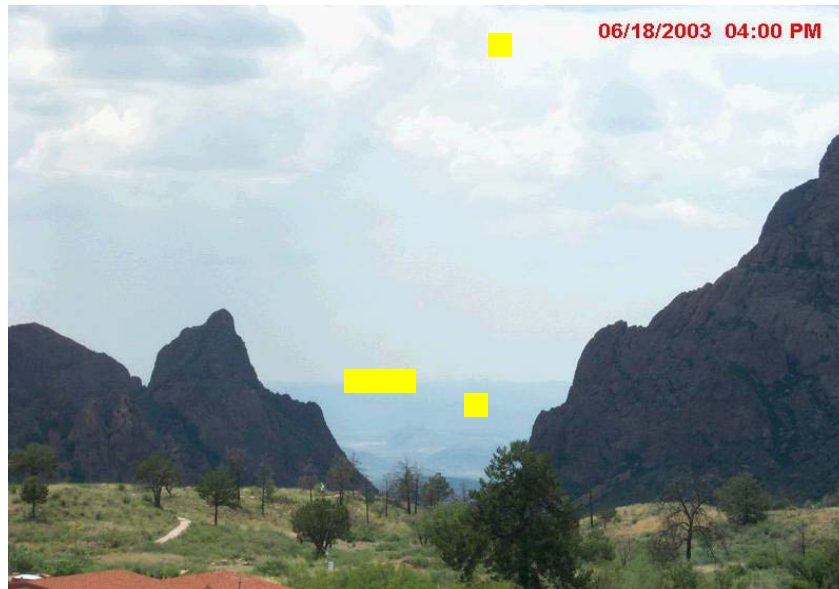


Fig. III.31

CR Analysis: This was performed by taking a ROI on the mountain and compare it to that of the ROI of sky above it.

CV Analysis: This was performed by taking an ROI encompassing the ridge and the sky at the distance.

Results:

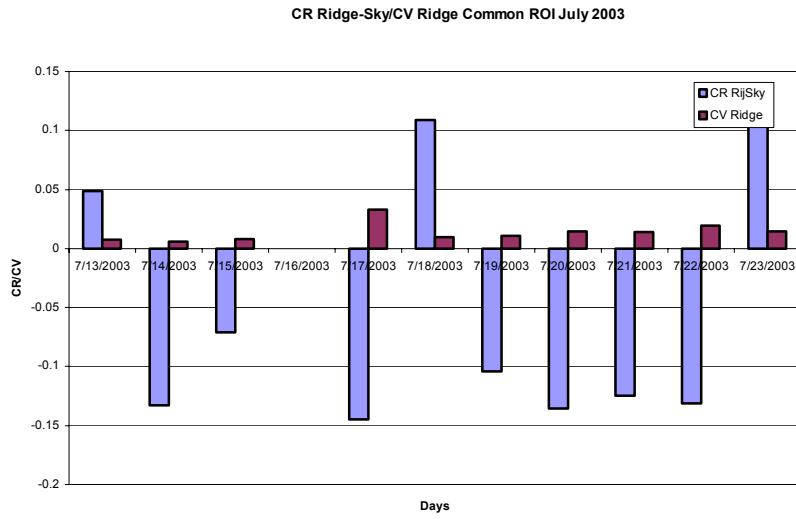


Fig. III.32 CR Ridge-Sky/CV Common ROI July 2003

Guadalupe Mountain National Park (New):

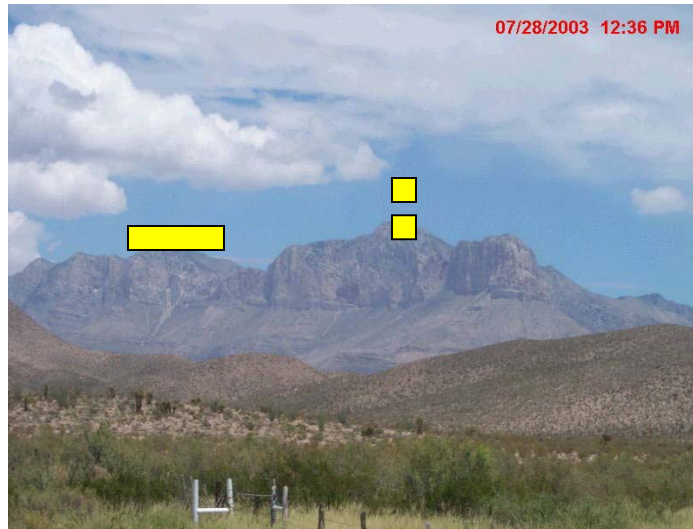


Fig. III.33

Last 2002 views were early December 2002. This camera was uninstalled by TCEQ Region 6 for re-deployment at a location approximately 15km west of the current site. The Camera has been reinstalled at a new location in July 2003 by TCEQ and UTEP.

CR Analysis. : The CR was computed using the ROI's shown by the small squares and Equation III.1.

CV Analysis: This was performed by taking an ROI encompassing the ridge and the sky at the distance of the mountain and Equation III.2

Results:

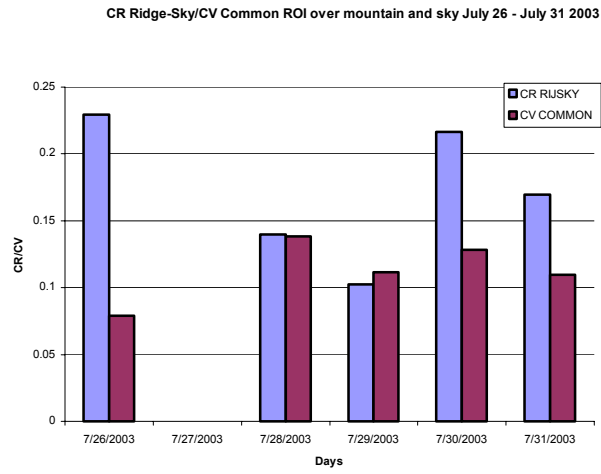


Fig. III.34 CR Ridge-Sky/CV Common ROI July 26-31, 2003

IV: Additional Analysis of Air Quality Parameters and Visibility

Visibility impairment primarily takes place as a consequence of light scattering by particles in the Accumulation Mode. It has been reported recently that for El Paso there is a significant correlation between CO and both ultra-fine and accumulation mode (those between 0.1 and 1 microns in diameter) particle count. The Pearson correlation coefficient (r) values reported are 0.81 (r^2 ca. 0.64) and 0.87 (r^2 ca.0.7) respectively. (Noble et. al. 2003). This finding is particularly important in the examination of the relationship of TCEQ reported air quality data and the results of visibility image analyses for the traditional downtown black-white building target (Chelsea 1). Data sets from most CAMS stations contain CO, whereas, PM_{2.5} (a putatively important indice of visibility) is only available at CAMS sites peripherally positioned to the Chelsea 1 field of view.

The analytical work in this section is largely derived from a current, in progress Master of Science project by one of us (Raina 2003). It is included as a useful tool for the possible applications or interpretation of the analytical data described in this section. The work described herein is based on the long term (12 years) traditional westerly field of view from Chelsea 1 toward downtown El Paso initiated by Stuart Dattner (TCEQ Technical Analysis Division).

An *a priori* interest in PM_{2.5} derives for the fact that the visible part of the particulate matter size fraction is 0.4 to 0.8 μm approximate physical diameter and is contained in the PM_{2.5} fraction obtained by current sampling systems based on effective aerodynamic diameter separations. Various multiple linear regression analyses have been performed with the data from the contract period with variables, PM_{2.5}, PM₁₀, CO, NO_x, Wind Speed, Relative Humidity, Sun Angle and Azimuth against the dependent variable, Contrast Ratio (CR)(see for example, Table IV.1). The CR data was that of the images analyzed. The air quality data was obtained from the TCEQ monitored CAMS sites in El Paso (CAMS 12, 37, 40,41).

The additional variables notably improved the understanding of the important factors influencing CR in the downtown Chelsea images over the simple comparison of CR-Complement ($1 - \text{CR}$ chosen for presentation convenience) and $\text{PM}_{2.5}$ from CAMS 12 (UTEP) and CAMS 41 (Sun Metro) or the comparison to average PM_{10} from Chamizal (CAMS 40) and UTEP (CAMS 12). The latter two CAMS sites are located on north and south sides, respectively, of the field of view of Chelsea 1.

Preliminary Data Analysis:

The search for correlations of the CR data with air quality and meteorological data was addressed with the statistical software, SPSS. The various analyses described herein were performed for a December, January, February group of days and for a May, June, July group of warm days. The difference in winter and summer visibility situations is readily apparent from the images (Section III) and the hours of sunlight prior to the 9 AM analysis time chosen vary from 0.5 to 3.

The first results obtained are presented in Figures IV.1 a, b, c, d. They are the elementary comparison of $\text{PM}_{2.5}$ or PM_{10} with CR. These results are presented two ways. One as a plot and one as a 3D plot of the uncertainty distribution about the curve of maximum likelihood (straight lines in the 2D plots). With the geographic constraints on $\text{PM}_{2.5}$ and PM_{10} measurements (deriving from CAMS site location), it is not surprising that the Correlation Coefficients (indicating the variability of Y explained by association with X) for CR versus PM are ca. 0.15 to 0.3.

Subsequent addition of all the air quality and meteorology data improved the correlation coefficients to 0.6 to 0.7. (See Figure IV.2). However, it was suspected that the correlation of CR with vapor phase components of the urban aerosol — notably fine particle coupled CO — available from most CAMS sites, might represent an improved demonstration of the relationship of CR and typical reported air quality and meteorological values.

Multiple regression results for three sites, CAMS 12, CAMS 37, and CAMS 41, representing sites to the north, behind, and ahead of the field of view of Chelsea 1 are given in Table IV.1. These results do not include any PM data. The R^2 value, in at least one case (Sun Metro), improved by removing the PM_{2.5} data as a variable. This is presently attributed to the site of PM_{2.5} data collection being physically located behind the downtown buildings and removed from the “line-of-sight” through the field of view that is integrated by the methods used herein and described in Section III.

CR complement with PM2.5

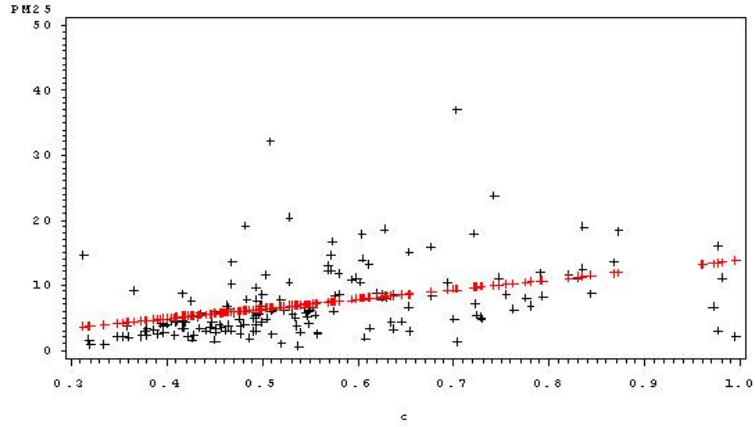


Fig. IV.1a. Scatter plot of C-Comp versus $PM_{2.5}$ from CAMS 12 (above)

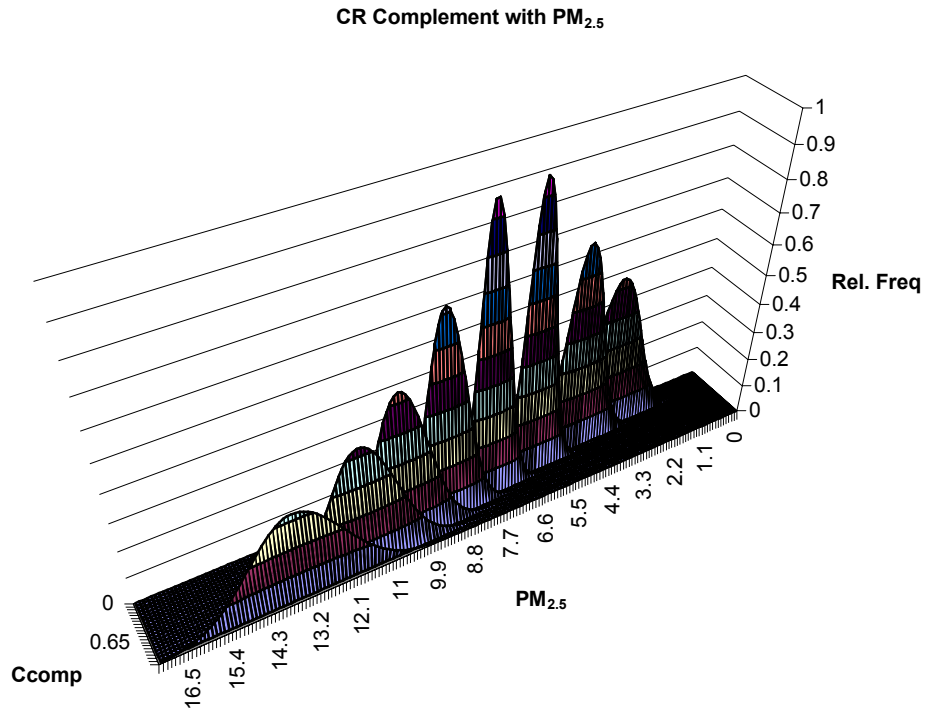


Fig. IV 1b. Probability distribution about the red line of Fig IV.1a above.

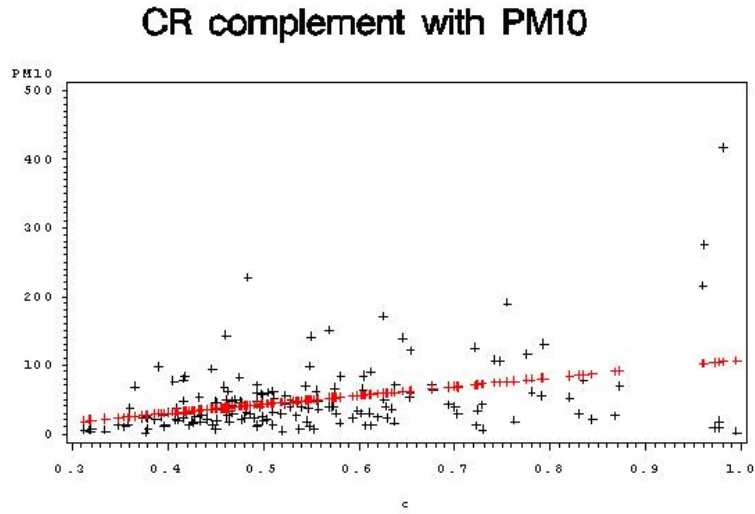


Fig. IV.1c. Scatter plot of PM_{2.5} average data from CAMS 12 and CAMS 40 versus C-comp

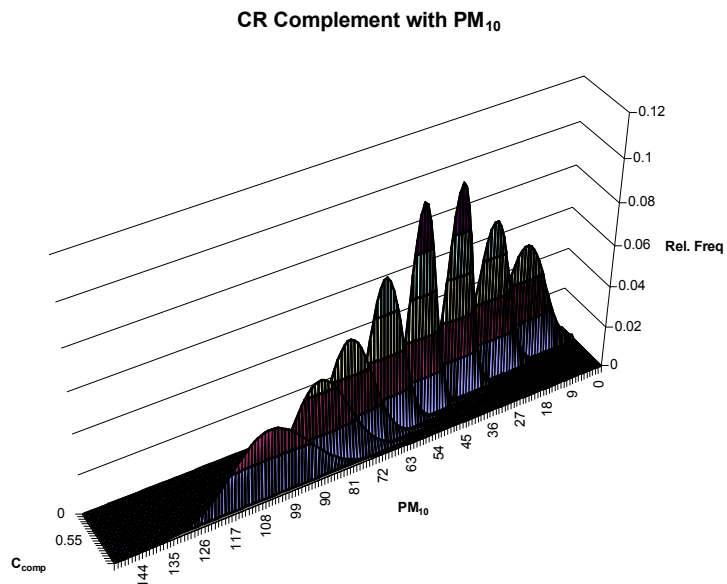


Fig. IV.1d. Probability distribution about the red line of Figure IV.1c.

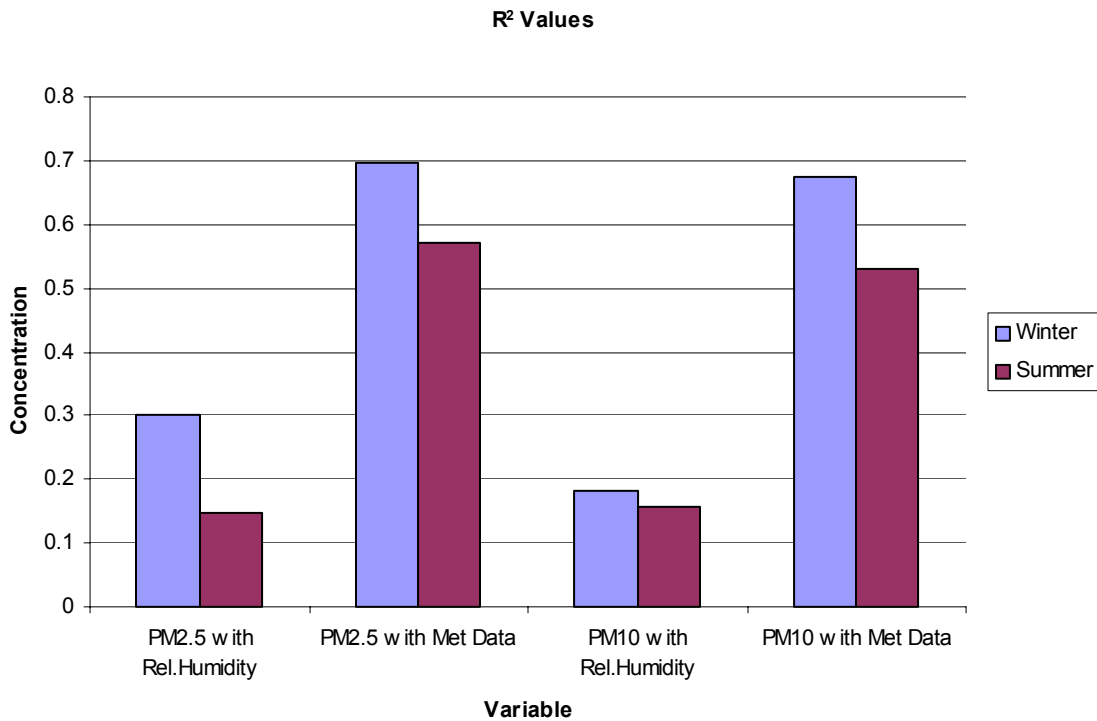


Fig. IV.2. Comparison of Correlation Coefficients from multiple regression of either a limited air quality data set or data sets (marked “with met”) that include all the meteorological and air quality data.

During the winter (Dec, 02-Feb, 03), PM_{2.5} and relative humidity explains only 30% of the variability associated with visibility. On the other hand up to 70% of the variability can be explained with all meteorological and air quality data.

Table V.1. Multiple regression coefficients (c) and Coefficient of Determination (R²) for comparison of CR to various gas phase urban aerosol components and meteorological data

Parameters/coefficients	CAMS12 (UTEP)	CAMS37 (Ascarate)	CAMS41 (Chamizal)
Constant	0.553955315	0.331308595	0.637027331
CO_1_PPM	-0.144260345	0.032924972	-0.252941274
NOx_1_ppb	-0.001014248	-0.001524366	0.000884885
O3_2_PPb	-0.003454084	-0.002079178	0.002681624
WSR_1 mph	-0.01093396	0.002399688	-0.013540955
Out Temp_1 deg F	-0.000834302	-0.002557625	-0.003147041
Rel. Humid_1 %	-0.003277048	-0.002779647	-0.003139329
Solar Rad_1 Ly/min	0.673898816	0.890823854	0.602488015
R ²	0.643	0.541	0.762

In the summer (May, 03-Jul, 03) variability up to 15% can be explained when PM_{2.5} is analyzed with relative humidity. Similarly the explainable variability for all meteorological factors is 50 to 70%. Subsequently, three CAMS sites data sets for the vapor phase and meteorological data alone (no PM) was compared to CR. These intriguing results are contained in Table IV.1. These preliminary results suggest that indeed, the vapor phase fraction (most likely CO) is an important influence on CR and visibility.

Lastly, it has been possible to make a comparison of CR for the downtown Chelsea 1 field of view with the Visibility data reported on the TCEQ air data web URL from Ascarate Park. Ascarate (CAMS 37) is located physically behind Chelsea 1 in an easterly direction. The visibility unit has a relatively short path length (on the order of meters) in comparison to the path length from Chelsea 1 to downtown, which is ca. 6000 meters. The results are shown in Figure V.3. Extensive data cleaning has not been performed. For example, the one point a approximately CR = 0 is presumed to be an event that dramatically affected the 6000 meter Chelsea 1 view and not the orders of magnitude shorter Ascarate Park measurement. Given the physical separation and the different measurement methods, the agreement is notable.

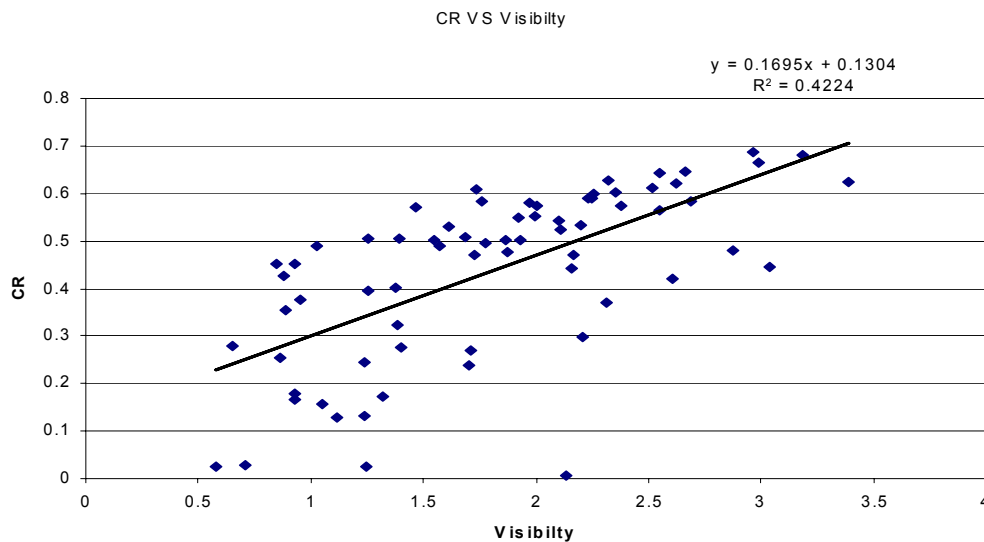


Fig. V.3. Comparison of CR values from Chelsea 1 (Black-White building) and the reported Visibility in miles from the monitor at Ascarate Park (CAMS 37).

The four outliers correspond to days, which are relatively infrequent in El Paso. They represent situations, which are typically “off-scale” for the present 6000-meter path used to compute CR or CV for downtown. They are included here for completeness. Without these points, R^2 is ca. 0.45.

V. References

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