

NPS Night Skies Data Interpretation Guide

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1 Document Purpose

This document explains the measurements reported in NPS Night Skies Data Night Reports. A data night report provides a summary of the measurements and associated images taken in one night. For details about equipment used, data collection methods, and analysis procedures, please refer to the related sections in the Night Skies Data Report: Photometric Assessment of Night Sky Quality—Chaco Culture National Historical Park Natural Resource Report on IRMA and the references therein.

2 General Attributes in the Cover Page

A report is named using a 4-letter park code followed by the date in YYMMDD format. The date is defined at the start of data collection in Universal Time.

2.1 Data Night Attributes

- Longitude: site longitude in decimal degrees taken with a GPS. West is negative.
- Latitude: site latitude in decimal degrees taken with a GPS. South is negative.
- Elevation: elevation above mean sea level in meters taken with a GPS.
- Camera: the camera manufacturer, such as SBIG (Santa Barbara Instruments Group) or ML (MicroLine), followed by an internally assigned identification number.
- # of sets: number of data sets collected; each set of images covers the entire sky.
- Exposure: exposure (or integration) time in seconds of each image.
- Air Temp: air temperature in °C measured at the start of image acquisition.
- R.H.: relative humidity in % measured at the start of image acquisition.
- Wind Speed: average wind speed in mph measured at the start of image acquisition.

- ZLM: zenith limiting magnitude; the apparent magnitude of the faintest star visible with the naked eye towards the zenith. Magnitude is a measure of an astronomical source’s brightness on an inverted logarithmic scale. Brighter sources have smaller magnitudes. A magnitude 0 star is one hundred times brighter than a magnitude 5 star. ZLM often depends on the observer, and will increase with the eye’s dark adaptation. On a clear dark night without light pollution, the limiting magnitude will be greater than 6.
- BORTLE: Bortle class. A nine-level numeric scale that measures the night sky’s brightness of a particular location based on visual observations. It quantifies the observability of celestial objects and the interference caused by light pollution. The rating of one indicates pristine night sky and nine indicates heavily light-polluted sky.
- SQM: Unihedron Sky Quality Meter measurement in magnitude per square arcsecond ($\text{mag}/\text{arcsec}^2$) aimed at the zenith.
- OBS_1, OBS_2, OBS_3: Name(s) of the observer(s).

2.2 Data Set Attributes

- Data Set: Data set number.
- Quality Flags: Usable – Y or N (yes or no), whether the final data product passes the overall visual quality inspection. Collection – the quality of data collection, including factors such as performance of camera and mount, accuracy of mount setup, and presence of stray light. Processing – the quality of data processing, including image calibration, atmospheric extinction calculation, and instrument zeropoint calculation. Atmosphere – a visual assessment of the atmospheric quality, where excellent transparency and steadiness, low relative humidity, and the complete absence of clouds or smoke plumes is the best. The last three quality flags are ranked from 1 to 5 where 1 is the poorest and 5 is the best.
- Natural Sky Model: Zenith airglow – the amount of natural airglow used at the zenith in modeling the natural sky. The unit is in micro-candela per square meter ($\mu\text{cd}/\text{m}^2$). Fit Quality – visual assessment of how well the natural sky model fits the natural sky in the data on a scale of 1 (poorest) to 5 (best). Natural sky model fit notes – additional notes by the data processor.
- Extinction: Extinction coefficient – the amount of light attenuated due to absorption and/or scattering. The unit is in magnitude per airmass. The higher the extinction, the more opaque the atmosphere. Standard error of Y – a measure of how well a regression line fits the observed data (0.03 or smaller is excellent while 0.06 and larger is poor). # stars used and # stars rejected – the Number of reference stars used and rejected in determining the extinction coefficient.
- Collection Properties: % Clouds – percentage of cloud cover during the observation over the entire sky. Ave. Point Error – the average error of pointing the camera at

the commanded position in degrees. Less than 0.25 is excellent, more than 0.5 is poor. Max Point Error – the maximum pointing error of the camera in degrees. Less than 0.4 is excellent, more than 1.0 is poor. total bias drift – the total change of the read noise in Analog Digital Unit (ADU) over the course of the data set. More than 10 ADU drift may indicate a camera problem.

3 Populated Places Table

We list the nearby cities ranked according to their brightness predicted by Walker’s Law:

$$I = 0.01 P d^{-2.5}, \quad (1)$$

where I is the Walker’s value indicating the skyglow level above the natural background, P is the human population size taken from 2010 US Census Data, and d is the distance to the population center in kilometers. At each observing location, we calculate the azimuth and apparent width of each population center based on the city centroid and the recorded city area. Because Walker’s Law is a simple model, the order of the predicted skyglow might not perfectly match the order of the imaged light dome brightness.

4 Images and Sky Brightness Metrics

Each page in this section shows two panoramic images associated with each data set. The date and time are in local mean time (LMT). The top image shows the observed night sky, which contains light from both natural and artificial sources. We use magnitude per square arcsecond for measuring the sky surface brightness. A sky surface brightness of 22 mag/arcsec² would be considered pristine, and a sky surface brightness < 20 mag/arcsec² would be considered greatly deviated from the natural condition. The warmer colors in these images represent brighter skies. In the top image, purple and dark blue colors indicate unpolluted sky, and the Milky Way under the natural condition appears green in this color scheme. The bottom image shows only the skyglow from artificial sources. Light domes along the horizon from the nearby area are more apparent in this bottom image.

4.1 Photometry of All Sources

- Average Sky Luminance: average sky brightness containing all light sources measured in mag/arcsec² and $\mu\text{cd}/\text{m}^2$. The natural reference is 21.6 mag/arcsec² or 250 $\mu\text{cd}/\text{m}^2$.
- Zenith Luminance: zenith sky brightness containing all light sources. This measure is calculated from the median pixel value of an approximately one degree diameter circle centered on the zenith. 22.0 mag/arcsec² or 172 $\mu\text{cd}/\text{m}^2$ is generally considered to represent the darkest part of pristine skies. Any value lower (brighter) than 21.3 mag/arcsec² usually indicates significantly degraded sky quality, unless the Milky Way is overhead or the natural airglow or the zodiacal light is bright.

- **Brightest Luminance:** brightest sky brightness containing all light sources. The brightest part of the Milky Way is 19.6 mag/arcsec² or 1500 $\mu\text{cd}/\text{m}^2$. Brighter values will begin to impair dark adaptation, and values brighter than 17.0 mag/arcsec² can cast shadows.
- **Synthetic SQM:** the hypothetical SQM value approximated from the image containing all light sources.
- **Total luminous emittance:** the total luminous flux from the sky if all the light were collected into a point, like a star. This value excludes the light from individual stars and planets and glare from unshielded lights but includes the Milky Way, airglow, zodiacal light, and skyglow. It can be compared with the moon at various phases: magnitude -8 at crescent, -11 at half phase, and -12.5 at full phase. A value larger (darker) than -7.0 is exceptionally dark; between -7.5 and -7.0 is typical for near pristine locations. A value smaller (brighter) than -8.0 usually indicates significantly degraded sky quality.
- **Illuminance:** the amount of visible light incident on a unit surface area in millilux (mlux). The impact from a light source is weighted by the cosine of its angle of incidence. The horizontal illuminance describes the amount of light landing on a horizontal surface. It provides the illuminance measurement of the entire sky at a glance but is not sensitive to skyglow near the horizon. The vertical illuminance describes the light striking a vertical surface. The vertical illuminance better reflects the brightness of sources near the horizon. Since a vertical surface can be held facing many different directions, we report the vertical illuminance measured at the direction that gives the largest value. The natural reference condition for moonless nights is 0.8 mlux for horizontal and 0.4 mlux for vertical illuminance.

4.2 Photometry of Artificial Skyglow

- **Sky Quality Index (SQI):** this index is no longer being used.
- **Average Sky Luminance:** average skyglow brightness in $\mu\text{cd}/\text{m}^2$.
- **Average Sky Luminance to zenith angle (ZA) 80°:** average skyglow brightness in $\mu\text{cd}/\text{m}^2$ from zenith to 80° down towards the horizon.
- **Average Sky Luminance to ZA 70°:** average skyglow brightness in $\mu\text{cd}/\text{m}^2$ from zenith to 70° down towards the horizon.
- **Zenith Luminance:** skyglow brightness at zenith in $\mu\text{cd}/\text{m}^2$.
- **Brightest Luminance:** brightest skyglow brightness in $\mu\text{cd}/\text{m}^2$.
- **All-sky light pollution ratio (ALR):** the total skyglow brightness divided by the natural dark sky set at 250 $\mu\text{cd}/\text{m}^2$. If the sky is completely free of skyglow, this ratio is zero. Generally, ALR values less than 0.3 indicate excellent conditions, 0.3 to 2.0 indicate impaired sky quality (though areas of the sky may reveal important natural features), and greater than 2.0 indicate the natural night sky is not readily visible.

- **Total luminous emittance:** the total luminous flux from skyglow if all the light were collected into a point, like a star. For comparison, Sirius or Jupiter has magnitude of -2, Venus -4, crescent moon -8, half moon -11, and full moon -12.5.
- **Illuminance:** the illuminance values from skyglow. See the *Illuminance* entry in the previous subsection for result interpretation.

Glossary

airglow Naturally occurring light emitted from the gases in the upper atmosphere. It often appears as a vague and smooth light in the sky that is brighter toward the horizon as compared to the zenith. However, it can sometimes have a banded or wispy character and change in the timescale of minutes. 2

airmass A measure of the amount of air through which light from outside the atmosphere must pass to reach the observer. It is expressed as a ratio of the atmospheric thickness at the zenith. Mathematically, the airmass equals the secant of the zenith angle. 2

angle of incidence The angle between a light ray's path striking a surface and a line perpendicular to the surface (sometimes called "normal" to a surface). 4

azimuth Angle eastward of true north along the horizon. Moving clockwise on a 360 degree circle, north has azimuth 0°, east 90°, south 180°, and west 270°. 3

dark adaptation The process by which the eye becomes adapted to dim environments. 2

extinction The attenuation of light due to absorption and/or scattering. 2

local mean time (LMT) Local mean time is a form of solar time that corrects the variations of local apparent time, forming a uniform time scale at a specific longitude. 3

skyglow Anthropogenic light scattered or reflected off of air molecules and atmospheric aerosols, leading to a brightening of the night sky. Skyglow is generally regarded as an aesthetic degradation of the night sky, and will illuminate an observer and the landscape unnaturally. 3

zenith The point on the celestial sphere directly overhead. 2

zenith angle (ZA) Angular distance between zenith and a point on the celestial sphere. The astronomical horizon has a zenith angle of 90°. 4

zodiacal light A faint, smooth, and elongated swath of light visible in the night sky. The Zodiacal light appears as a noticeable cone of light near the sun, most visible immediately after evening twilight in the west and immediately before morning twilight in the east. It is caused by sunlight reflected off the dust particles in orbit around the sun. 3

NPS NIGHT SKIES PROGRAM DATA NIGHT REPORT

BITH191028

Big Thicket N PRES

Lance Rosier Unit

28-Oct-19



Data Night Attributes

Longitude:	-94.51310	Camera:	ML 3	Air temp. (C):	18.4	ZLM:	5.60	OBS_1:	L Hung
Latitude:	30.27909	# of sets:	2	R. H. (%):	89.7	BORTLE:	5	OBS_2:	S Anderson
Elevation (m):	27	Exposure (secs):	10	Wind Speed (mph):	0	SQM:	20.70	OBS_3:	

NARRATIVE: Lots of trees blocking the horizon. Clear sky. There is an oil and gas field at the end of the road. Sky looks brightest towards WSW. The light dome extends all the way to zenith. Milky Way looks faint overhead.

Data Set Attributes

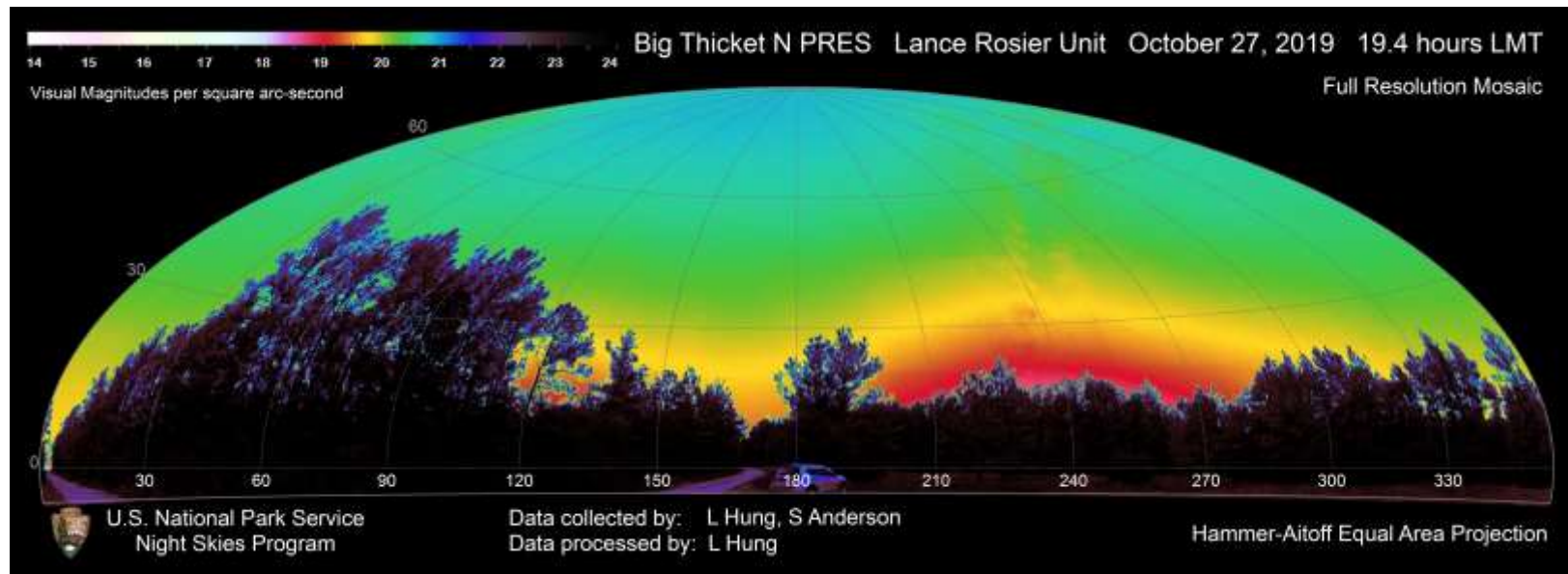
Data Set	Quality Flags				Natural Sky Model			Extinction				Collection Properties			
	Use-able	Col-lection	Pro-cessing	Atmo-sphere:	Zenith airglow ($\mu\text{cd}/\text{m}^2$)	Fit quality	Natural sky model fit notes	Ext. coeff. (mag/airmass)	Std err Y	# stars used	# stars reject	% Clouds	Ave. Point Error	Max Point Error	total bias drift
1	Y	5	5	3	64	5		0.266	0.16	95	8	0	0.25	0.48	1.0
2	Y	5	5	3	64	5		0.227	0.03	92	2	0	0.25	0.48	1.1

Populated Places

Place	Population (2010)	Distance (km)	Azimuth	Walker's	Apparent Half-Width (degrees)
Houston city	2,099,451	100.6	237	2.067	12.5
Beaumont city	118,296	41.4	121	1.073	11.3
Lumberton city	11,943	29.3	95	0.256	6.4
Pasadena city	149,043	92.3	222	0.182	3.7
Baytown city	71,802	72.7	217	0.159	4.3
Atascocita CDP	65,844	73.6	243	0.141	3.5
Port Arthur city	53,818	72.2	133	0.121	6.3
Sour Lake city	1,813	19.3	146	0.111	3.8
Silsbee city	6,611	33.1	77	0.105	4.3
The Woodlands CDP	93,847	96.3	263	0.103	3.6
Liberty city	8,397	37.0	226	0.101	8.9
Kountze city	2,123	21.6	61	0.098	4.8
Spring CDP	54,298	87.1	254	0.077	2.9
Pinewood Estates CDP	1,678	21.8	122	0.076	8.6
League City city	83,560	104.8	213	0.074	3.6
Conroe city	56,207	91.9	273	0.069	4.1
Pearland city	91,252	112.0	224	0.069	3.2
Channelview CDP	38,289	79.1	227	0.069	2.5
Nederland city	17,547	60.0	125	0.063	2.1
Vidor city	10,579	52.8	108	0.052	3.4
Dallas city	1,197,816	351.6	323	0.052	2.7
Dayton city	7,242	45.8	234	0.051	5.2
La Porte city	33,800	85.3	217	0.050	2.6
Austin city	790,390	311.2	271	0.046	2.9
Deer Park city	32,010	87.8	222	0.044	1.9
Texas City city	45,099	100.8	201	0.044	4.1
San Antonio city	1,327,407	396.8	258	0.042	2.8
Groves city	16,144	68.2	123	0.042	1.7
Daisetta city	966	22.1	214	0.042	2.9
Hull CDP	669	19.2	220	0.041	3.8
Lake Charles city	71,993	124.9	94	0.041	2.7
Port Neches city	13,040	63.7	124	0.040	2.4
Sugar Land city	78,817	131.5	235	0.040	2.2
Orange city	18,595	74.5	104	0.039	3.2

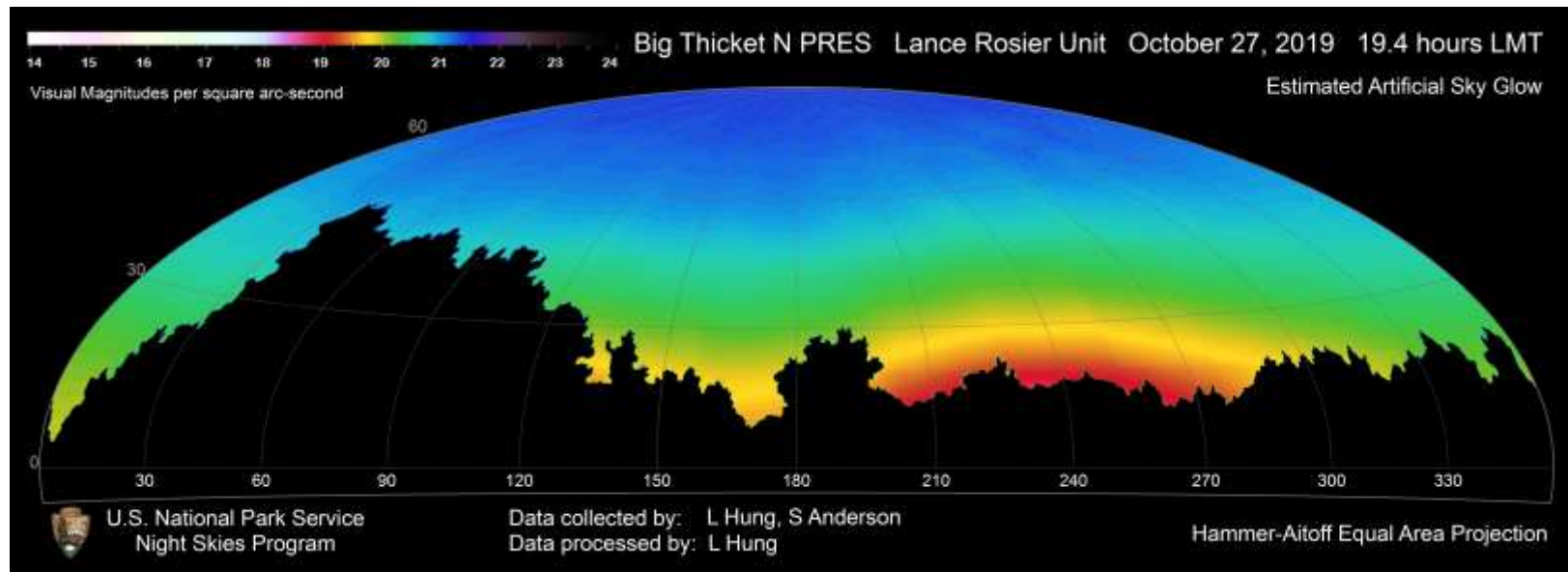
Missouri City city	67,358	126.6	231	0.037	2.2
Cloverleaf CDP	22,942	83.7	229	0.036	1.1
Bevil Oaks city	1,274	27.3	121	0.033	2.7
Cleveland city	7,675	56.7	277	0.032	2.8
Huntsville city	38,548	110.3	296	0.030	2.8
Friendswood city	35,805	108.3	218	0.029	2.2
Wildwood CDP	1,235	28.2	13	0.029	3.9
Humble city	15,133	79.5	246	0.027	2.0
Fort Worth city	741,206	386.2	317	0.025	2.5
Galveston city	47,743	129.5	200	0.025	2.6
Hardin city	819	26.0	236	0.024	3.2
College Station city	93,857	174.2	282	0.023	2.1
Lufkin city	35,067	117.6	350	0.023	2.6
West Livingston CDP	8,071	67.4	314	0.022	3.8
China city	1,160	31.4	147	0.021	1.9
Shreveport city	199,311	252.5	16	0.020	2.1
Mission Bend CDP	36,501	128.7	240	0.019	0.9
Aldine CDP	15,869	92.5	244	0.019	1.6
Bridge City city	7,840	70.2	113	0.019	1.8
South Houston city	16,983	97.2	225	0.018	0.9
Central Gardens CDP	4,347	57.2	124	0.018	1.4
Livingston town	5,335	62.8	320	0.017	2.4
Bryan city	76,201	182.6	284	0.017	1.9
Alvin city	24,236	116.9	216	0.016	2.2
Dickinson city	18,680	105.8	210	0.016	1.5
Highlands CDP	7,522	73.7	225	0.016	1.6
Winnie CDP	3,254	52.9	166	0.016	2.0
Seabrook city	11,952	89.2	211	0.016	1.3
Sulphur city	20,410	111.3	92	0.016	1.5
Ames city	1,003	33.8	220	0.015	2.8
Fannett CDP	2,252	47.0	146	0.015	3.5
Arlington city	365,438	365.5	318	0.014	1.4
Mont Belvieu city	3,835	59.2	217	0.014	3.4
Lafayette city	120,623	238.3	91	0.014	1.5
Galena Park city	10,887	91.3	230	0.014	1.3
Jacinto City city	10,553	90.3	231	0.014	0.8

Nome city	588	28.8	159	0.013	2.0
Bellaire city	16,855	111.6	235	0.013	0.9
Nacogdoches city	32,996	148.7	355	0.012	1.8
West University Place city	14,787	108.3	235	0.012	0.7
Baton Rouge city	229,493	325.3	86	0.012	1.4
Shepherd city	2,319	53.0	296	0.011	2.4
Big Thicket Lake Estates CD	742	33.7	314	0.011	2.4
Woodville town	2,586	55.6	9	0.011	1.7
Fresno CDP	19,069	123.8	228	0.011	1.3
Evadale CDP	1,483	44.6	83	0.011	4.8
Rosenberg city	30,618	149.6	237	0.011	1.6
La Marque city	14,509	111.3	205	0.011	1.7
Tyler city	96,900	238.4	342	0.011	1.6
Mauriceville CDP	3,252	61.8	95	0.011	2.4
Corpus Christi city	305,215	381.5	223	0.011	1.7
Jasper city	7,590	87.1	35	0.011	1.9
Stafford city	17,693	124.7	235	0.010	1.1
Devers city	447	28.7	194	0.010	2.5
Webster city	10,400	101.3	215	0.010	1.3
Plano city	259,841	373.5	326	0.010	1.2
Garland city	226,876	354.4	326	0.010	1.1
Bacliff CDP	8,619	97.2	208	0.009	0.9
Buna CDP	2,142	56.0	71	0.009	2.3
Tomball city	10,753	108.2	260	0.009	1.6
Santa Fe city	12,222	114.2	210	0.009	1.9
Cinco Ranch CDP	18,274	134.2	244	0.009	0.9
Waco city	124,805	291.9	300	0.009	1.7
New Orleans city	343,829	440.0	92	0.008	1.5
Warren CDP	757	38.3	15	0.008	2.8
Anahuac city	2,243	59.3	196	0.008	1.3



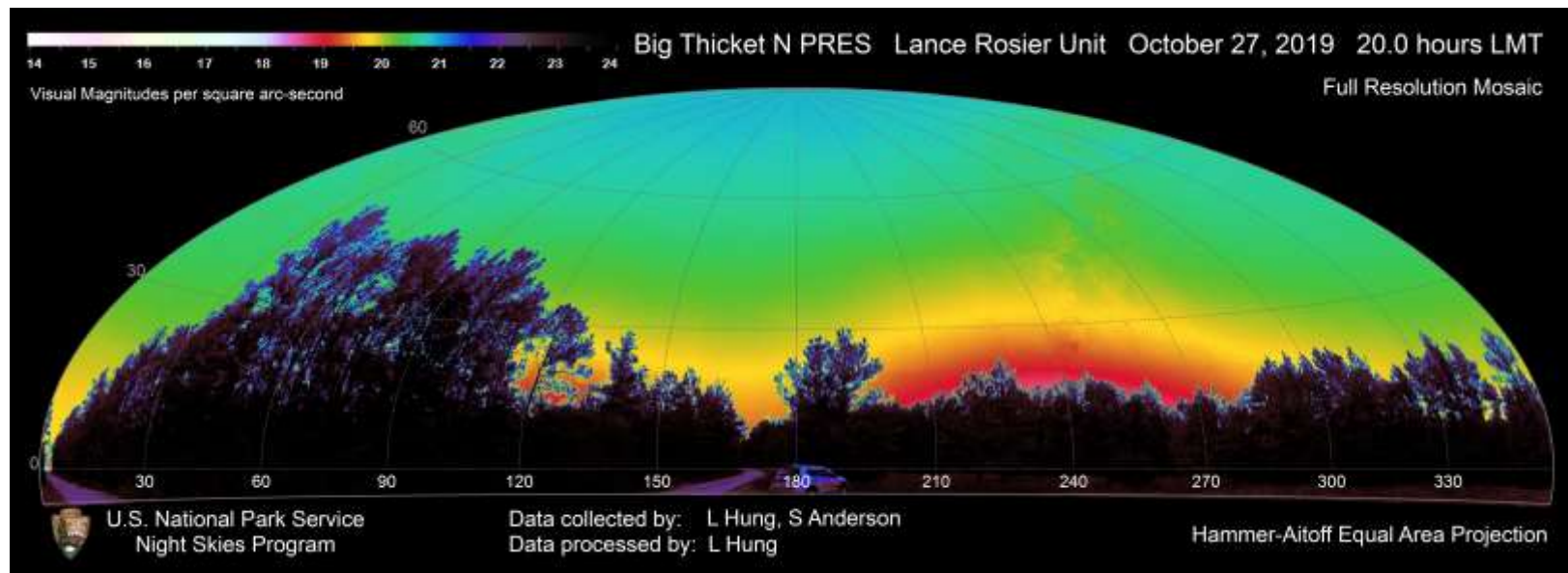
PHOTOMETRY OF ALL SOURCES

Average Sky Luminance (mag arcsec ⁻²)	Average Sky Luminance (μcd/m ²)	Zenith Luminance (mag arcsec ⁻²)	Zenith Luminance (μcd/m ²)	Brightest luminance (mag arcsec ⁻²)	Brightest luminance	Synthetic SQM (mag arcsec ⁻²)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
20.18	916	20.86	489	17.81	8,124	20.53	-7.90	2.131	1.304



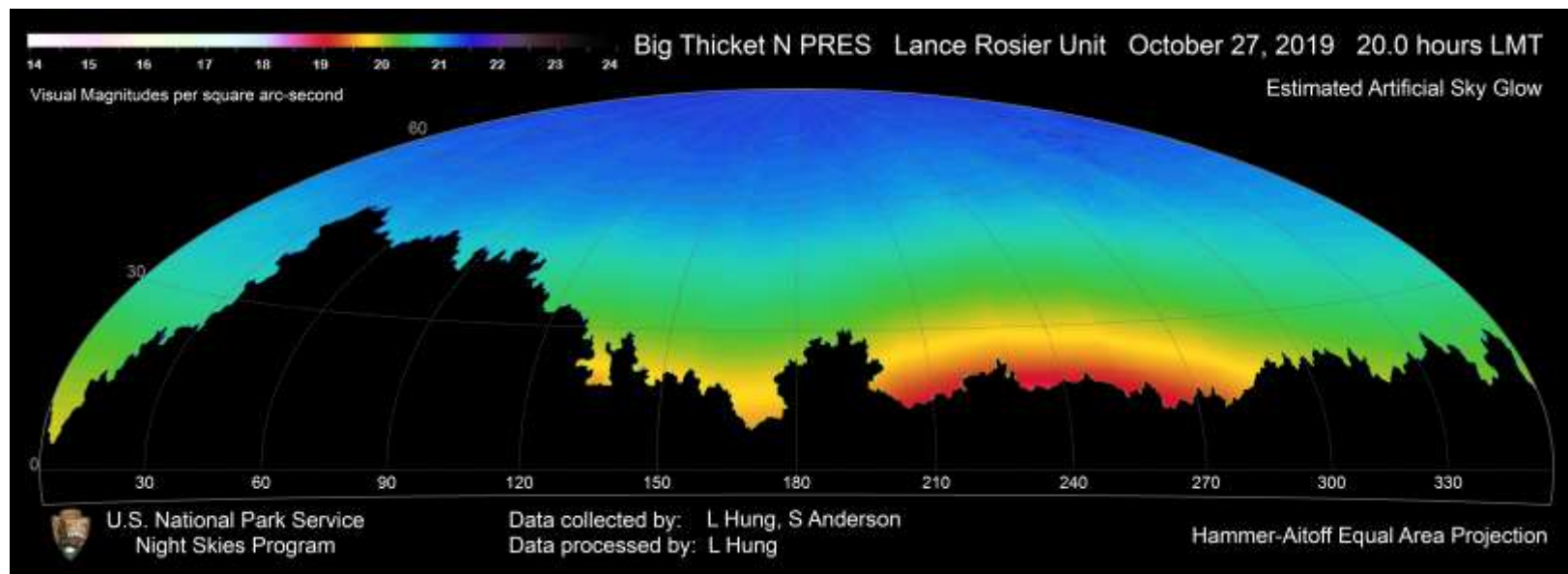
PHOTOMETRY OF ARTIFICIAL SKYGLOW

Sky Quality Index (SQI)	Average Sky Luminance (μcd/m ²)	Average Sky Luminance to zenith angle 80°	Average Sky Luminance to zenith angle 70°	Zenith Luminance	Brightest luminance (μcd/m ²)	All-sky light pollution ratio (ALR)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
44.6	697	696.5	642.3	318	3,270	2.81	-7.51	1.497	0.987



PHOTOMETRY OF ALL SOURCES

Average Sky Luminance (mag arcsec ⁻²)	Average Sky Luminance (μcd/m ²)	Zenith Luminance (mag arcsec ⁻²)	Zenith Luminance (μcd/m ²)	Brightest luminance (mag arcsec ⁻²)	Brightest luminance	Synthetic SQM (mag arcsec ⁻²)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Max Vert
20.21	894	20.88	483	17.82	8,065	20.55	-7.88	2.088	1.266



PHOTOMETRY OF ARTIFICIAL SKYGLOW

Sky Quality Index (SQI)	Average Sky Luminance (μcd/m ²)	Average Sky Luminance to zenith angle 80°	Average Sky Luminance to zenith angle 70°	Zenith Luminance	Brightest luminance (μcd/m ²)	All-sky light pollution ratio (ALR)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Max Vert
45.2	672	671.4	617.8	315	3,272	2.71	-7.47	1.445	0.951