PAYNE INSTITUTE COMMENTARY SERIES: **COMMENTARY**

November 15, 2023

Prolonged Dimming of Ukrainian Urban Illumination: A Measure of Conflict's Impact

By M. Zhizhin

Variations in nighttime city illumination mirror regional socioeconomic trends. This correlation has been substantiated through multi-year and decadal analyses.

Natural disasters such as earthquakes, hurricanes or pandemics trigger a short-term dimming of city lights, followed by a rapid recovery [2]. The war in Ukraine, however, has induced a novel pattern of city lights changes: an abrupt and sustained decline in illumination from the outset of the conflict, persisting for two years with partial recovery observed in some cities.

The method

To investigate the alteration of nighttime illumination in Ukraine during the ongoing conflict, we compiled radiance profiles for the urban centers of 47 major Ukrainian cities with populations exceeding 100,000.

These radiance measurements, spanning from March 2012 to October 2023, were captured every night utilizing the Day-Night Band (DNB) sensor on the Suomi NPP satellite. The DNB data was collected within a 0.005-degree radius centered on city center coordinates provided by the Humanitarian OpenStreetMap Team [3].

The search radius employed aligns with the dimension of a single pixel in DNB imagery. To circumvent the influence of partially illuminated scenes during mid-latitude summers, we solely considered nighttime observations when the sun was more than 12 degrees below the horizon (nautical twilight).

Applying these constraints, we amassed a collection of approximately 60 nighttime radiance measurements per city center each month, totaling over 8,000 observations during the past eleven years. These observations underwent further filtering to retain only cloud-free satellite observations, as clouds can both obscure city lights (manifesting as lower radiance outliers) and reflect moonlight (manifesting as higher radiance outliers).

The resultant time series of cloud-free urban center radiance observations was segmented into stationary periods delineated by change points [4], where the average city lights radiance remained constant. Of particular interest were change points occurring after to the outbreak of the war on February 24, 2022. For these instances, the relative radiance alteration was quantified as a ratio, computed by dividing the pre-war mean radiance by the mean radiance within the subsequent stationary period following the change point.

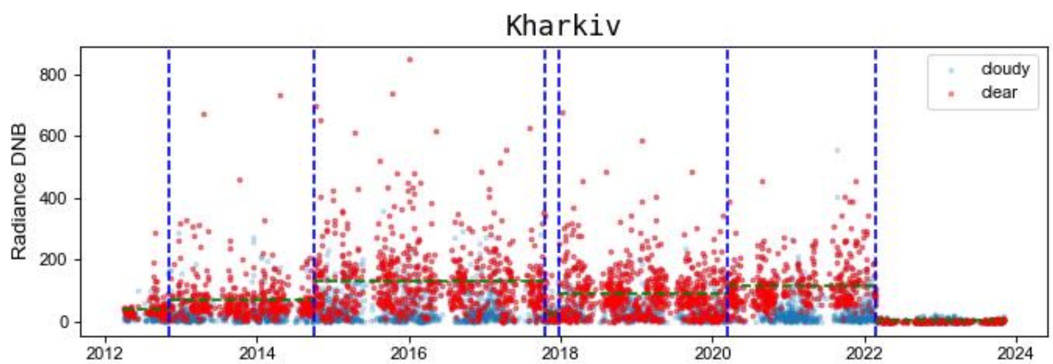
The result

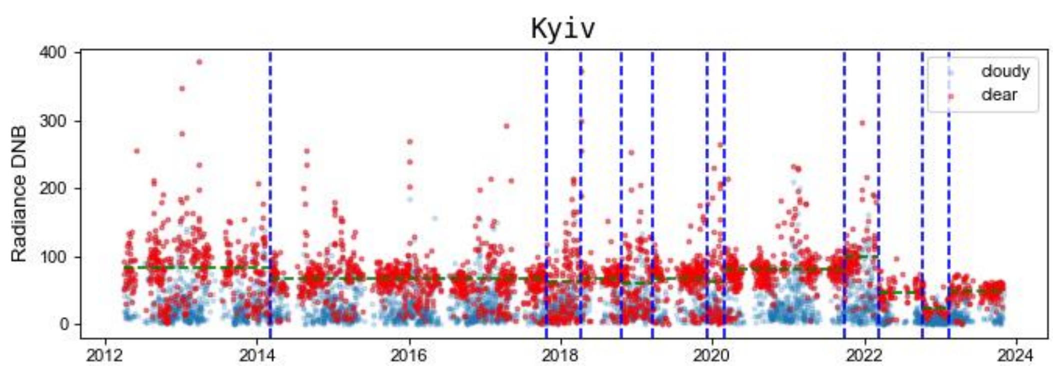
A comprehensive analysis of nighttime radiance profiles for 47 major Ukrainian cities revealed a significant and prolonged dimming of city lights following the onset of the conflict. The ratio of pre-war and post-war radiance values exhibited substantial variation, ranging from 60-80% in Russian-controlled cities to a mere 3-5% of the pre-war level in the eastern cities of Kharkiv and Dnipro, both with populations exceeding one million (Figure 1).

The Ukrainian capital, Kyiv, experienced a 47% reduction in illumination following February 2022. This dimming intensified in October 2022 following Russian missile attacks on Ukrainian infrastructure, plummeting to 25% of pre-war levels. However, a partial recovery was observed in February 2023, with illumination reaching 48% of its pre-war state.

Most major cities in western Ukraine, with the exception of Ivano-Frankivsk, exhibited a less severe dimming effect and exhibited a gradual recovery towards pre-war illumination levels. Figure 1 illustrates this trend by depicting the radiance profile for the western Ukrainian city of Chernivtsi.

In contrast, Russian-controlled cities in Crimea and eastern Ukraine, including Sevastopol, Simferopol, Melitopol, Donetsk, and Luhansk, displayed minimal or no changes in city lights radiance. The observed changes in these cities were comparable to variations between pre-war change points.





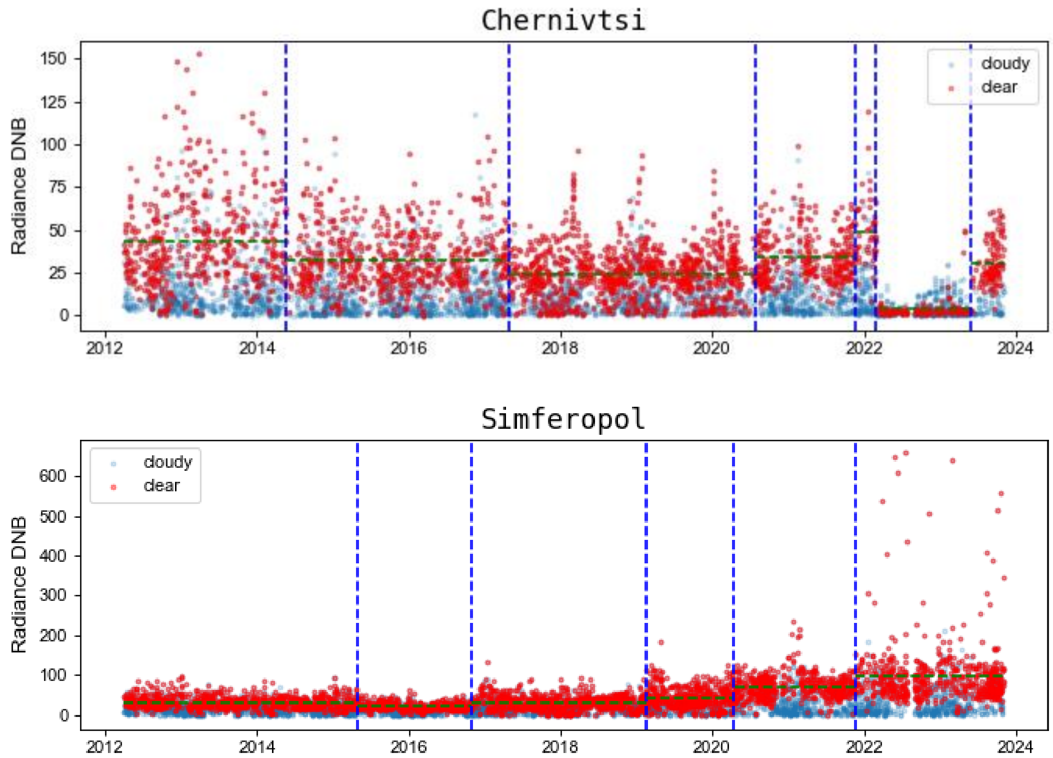


Figure 1. Segmented time series of urban center radiance for major Ukrainian cities.

Figure 2 visually depicts the spatial variation of city lights dimming in Ukraine following the outbreak of the conflict. The radius of the circle centered on each of the 47 major cities is inversely proportional to the ratio between the pre-war radiance and the mean radiance within the subsequent stationary period. Multiple circles with the same center illustrate the light ratios for the subsequent change points after the outbreak of the war. We have created a web page with interactive map combining the city lights change circles with the plots of the radiance profiles [5]

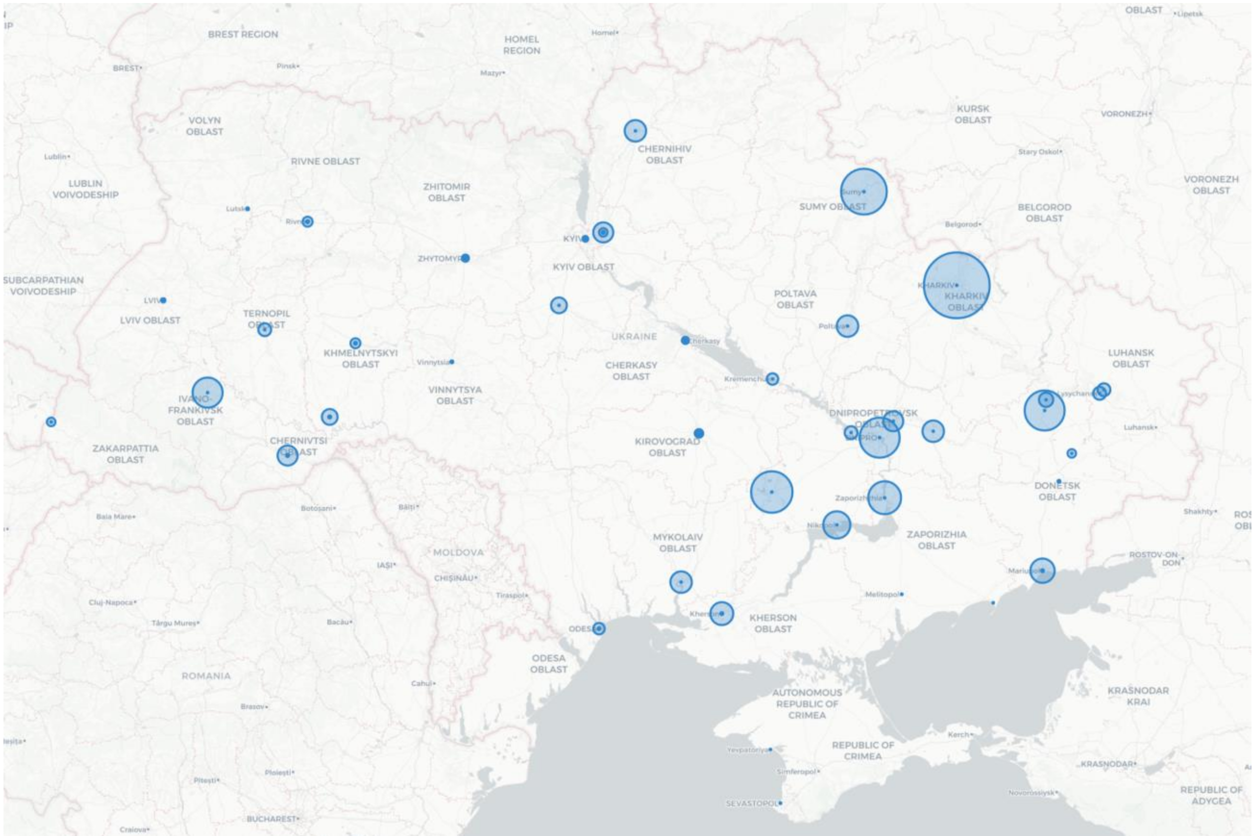


Figure 2. Map of nighttime city lights dimming in Ukraine following the onset of the conflict. The size of the circle corresponds to the magnitude of the radiance decrease. Larger circles indicate cities with a more significant drop in illumination.

Discussion

The change points in nighttime radiance profiles also coincide with the onset of the first phase of the Ukraine-Russian conflict in February-March 2014, which culminated in the annexation of Crimea and parts of the Donetsk and Luhansk regions. The dimming ratios observed in Donetsk and Luhansk following the 2014 crisis align closely with the per capita Gross Regional Product (GRP) trends reported in [6, Section 4.2] (Table 1).

Table 1. Stepwise change of the mean 〖ACTNL〗_DNB index before / after onset of the armed conflict

City	**Mean DNB radiance before 03.2014, nW**	**Mean DNB radiance after 03.2014, nW**	**Ratio of radiances before and after 03.2014**	**Regional drop in per capita GRP**
Kyiv	83.59	66.39	0.79	NA
Donetsk	85.62	50.64	0.59	43%
Luhansk	25.01	12.49	0.50	59%

Given the ongoing correlation observed between dimming and GRP ratios before and after the outbreak of the Ukrainian war, we can extrapolate the anticipated declines in GRP for various major city regions, as outlined in Table 2.

Table 2. Dimming ratios and anticipated GRP declines for major Ukranian cities

City	Latitude	Longitude	Change date	Dimming ratio	Population	Drop in GRP, %
Kharkiv	49.99232	36.2310146	2/27/2022	0.02	1,447,652	98
Sumy	50.91198	34.8027723	3/11/2022	0.03	267,633	97
Kryvyi Rih	47.91027	33.3917703	3/9/2022	0.03	656,700	97
Dnipro	48.46802	35.0417711	3/11/2022	0.04	1,080,486	96
Kramatorsk	48.73894	37.5843812	3/2/2022	0.04	159,445	96
Zaporizhzhia	47.85079	35.1182867	2/26/2022	0.04	706,116	96
Ivano-Frankivsk	48.92248	24.710334	2/25/2022	0.05	230,929	95
Nikopol	47.56921	34.3917272	3/11/2022	0.05	119,939	95
Mariupol	47.09576	37.5499621	3/13/2022	0.06	453,623	94
Pavlohrad	48.53168	35.8703695	2/24/2022	0.06	110,609	94
Mykolaiv	46.97586	31.9939666	2/21/2022	0.07	480,080	93
Chernihiv	51.4941	31.294332	3/9/2022	0.07	293,969	93
Poltava	49.58974	34.5507948	3/18/2022	0.07	297,600	93
Brovary	50.51112	30.7900482	3/26/2022	0.07	107,384	93
Chernivtsi	48.28647	25.9376532	3/10/2022	0.07	266,650	93
Novomoskovsk	48.63585	35.2595541	3/11/2022	0.07	124,787	93
Bila Tserkva	49.79697	30.1158069	3/11/2022	0.09	209,815	91
Lysychansk	48.91727	38.4285981	3/22/2022	0.10	105,682	90
Sloviansk	48.85227	37.6058241	3/6/2022	0.10	114,437	90
Ternopil	49.55579	25.5923753	2/25/2022	0.11	217,326	89
Sievierodonetsk	48.94787	38.4936475	2/23/2022	0.11	110,612	89
Kamianske	48.51677	34.6068797	3/11/2022	0.11	239,237	89
Kremenchuk	49.06296	33.403516	5/7/2022	0.12	226,400	88
Horlivka	48.30587	38.0027664	4/17/2022	0.15	289,872	85
Uzhhorod	48.62237	22.3022572	10/23/2022	0.17	114,867	83
Zhytomyr	50.26011	28.6696281	2/27/2022	0.18	267,610	82
Kropyvnytskyi	48.51058	32.2656283	2/26/2022	0.26	234,712	74
Lviv	49.84195	24.0315921	3/9/2022	0.39	724,822	61
Lutsk	50.74507	25.320078	2/21/2022	0.44	217,502	56
Kyiv	50.45003	30.5241361	3/11/2022	0.47	2,952,301	53
Cherkasy	49.44471	32.0588085	3/18/2022	0.48	274,343	52
Vinnytsia	49.23202	28.467975	3/21/2022	0.56	373,302	44
Rivne	50.61962	26.2513165	3/22/2022	0.56	245,323	44
Odesa	46.4843	30.7322878	2/25/2022	0.59	1,008,852	41
Kherson	46.64013	32.6143922	4/1/2022	0.61	294,941	39
Donetsk	48.01588	37.8013407	4/13/2022	0.61	929,063	39
Chernivtsi	48.28647	25.9376532	5/29/2023	0.62	266,650	38
Kamianets-Podilskyi	48.67813	26.5854027	2/25/2022	0.64	101,235	36
Khmelnytskyi	49.41964	26.9793793	3/18/2022	0.69	269,308	31

Berdiansk	46.75568	36.7887623	3/26/2022	0.73	116,450	27
Melitopol	46.84673	35.3827281	3/23/2022	0.76	156,917	24
Yevpatoriya	45.19076	33.3679049	6/7/2023	0.82	108,149	18
Sevastopol	44.60544	33.5220842	5/13/2022	0.83	522,057	17

References

[1] Noam Levin, Christopher C.M. Kyba, Qingling Zhang, Alejandro Sánchez de Miguel, Miguel O. Román, Xi Li, Boris A. Portnov, Andrew L. Molthan, Andreas Jechow, Steven D. Miller, Zhuosen Wang, Ranjay M. Shrestha, Christopher D. Elvidge, Remote sensing of night lights: A review and an outlook for the future, Remote Sens. Env., 237, 2020, 111443. https://doi.org/10.1016/j.rse.2019.111443

[2] Elvidge, C.D.; Ghosh, T.; Hsu, F.-C.; Zhizhin, M.; Bazilian, M. The Dimming of Lights in China during the COVID-19 Pandemic. Remote Sens. 2020, 12, 2851. https://doi.org/10.3390/rs12172851

[3] Humanitarian OpenStreetMap Team https://www.hotosm.org/

[4] R. Killick, P. Fearnhead, and I. Eckley. Optimal detection of changepoints with a linear computational cost. Journal of the American Statistical Association, 107(500):1590–1598, 2012

[5] Interactive map of dimming lights in Ukraine https://eogdata.mines.edu/wwwdata/hidden/ukraine/Ukraine_city_lights_2012-2023.html

[6] [4]. Julia Bluszcz, Marica Valente. The War in Europe: Economic Costs of the Ukrainian Conflict. URL: https://ideas.repec.org/p/diw/diwwpp/dp1804.html

The Payne Institute for Public Policy
COLORADO SCHOOL OF MINES

ABOUT THE AUTHOR

Mikhail Zhizhin
Research Associate, Earth Observation Group

Zhizhin Mikhail Nikolaevich, M.Sci in mathematics from the Moscow State University in 1984, Ph.D. in computational seismology and pattern recognition from the Russian Acad. Sci. in 1992. Research positions from 1987 to 2012 in geophysics, space research and nuclear physics at Russian Acad. Sci., later at NOAA and CU Boulder. Currently he is a researcher at the Earth Observation Group at Colorado School of Mines. His applied research fields evolved from high performance computing in seismology, geodynamics, terrestrial and space weather to deep learning in remote sensing. He is developing new machine learning algorithms to better understand the Nature with Big Data.

The Payne Institute for Public Policy
COLORADO SCHOOL OF MINES

ABOUT THE PAYNE INSTITUTE

The mission of the Payne Institute at Colorado School of Mines is to provide world-class scientific insights, helping to inform and shape public policy on earth resources, energy, and environment. The Institute was established with an endowment from Jim and Arlene Payne, and seeks to link the strong scientific and engineering research and expertise at Mines with issues related to public policy and national security.

The Payne Institute Commentary Series offers independent insights and research on a wide range of topics related to energy, natural resources, and environmental policy. The series accommodates three categories namely: Viewpoints, Essays, and Working Papers.

For more information about the Payne Institute please visit:

https://payneinstitute.mines.edu/