PAYNE COMMENTARY SERIES: RESEARCH

Satellite Data Provides Insights about the Russian Invasion of Ukraine

By Brooke Bowser, Feng-Chi Hsu, Tilottama Ghosh, Gregory Clough, Christopher Elvidge, Tamara Sparks, Mikhail Zhizhin, and Morgan Bazilian

The night's darkness still lingered as residents of Kyiv, Ukraine, awoke to the sound of explosions in the early morning of February 24. Missiles struck the capital city just minutes after Russian President Vladimir Putin announced a special military operation in Ukraine. The attacks quickly spread across central and eastern Ukraine, and the fighting continues as Russian forces target Ukraine's cities and military bases.

The Payne Institute's Earth Observation Group (EOG) can capture a unique view of the ongoing conflict in Ukraine using satellite data provided by the Visible Infrared Imaging Radiometer Suite (VIIRS) onboard a Joint Polar Satellite System co-operated by NOAA and NASA. The EOG's VIIRS Nighttime Lights (VNL) product can display nighttime lights while the group's VIIRS Nightfire (VNF) product can detect thermal anomalies on the Earth's surface.

February 24 & February 25

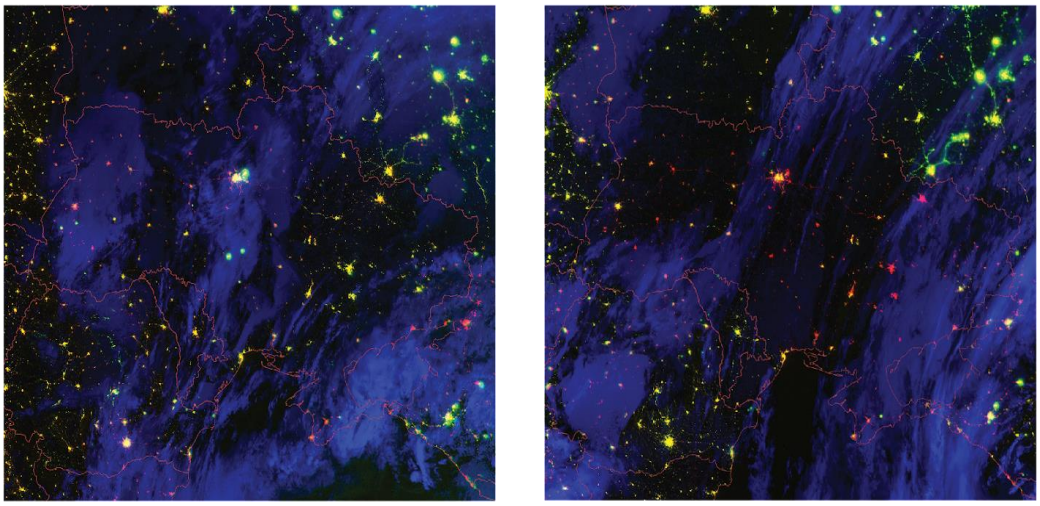

Figure 1: The nighttime light images of February 24 (prior to Russia's invasion) and February 25 (the first night following Russia's attack). The red indicates the brightness has decreased, the yellow indicates the brightness is similar to usual, and the green indicates the brightness has increased.

As the fighting began, a curfew was announced and thousands of residents fled the Kyiv while others prepared to fight or took shelter in underground metro stations. The abrupt change in activity following the day of the invasion was captured in EOG data. While the lights of Ukrainian cities on February 24 show relatively normal brightness levels, the image from one day later tells a different story. On the night of February 25, the first night after Russia's attack, the city lights of Kyiv dimmed.

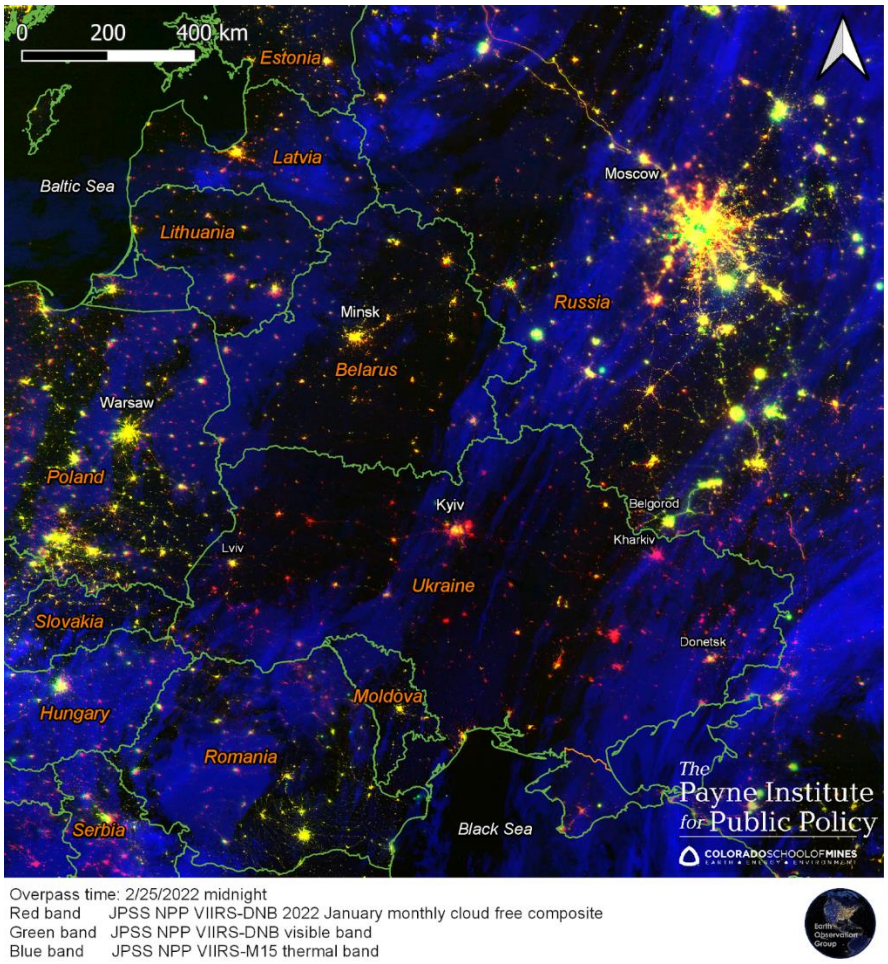

Figure 2: An image showing lights of Ukraine and surrounding countries on February 25, the first night following Russia's invasion.

With strict curfews and hundreds of thousands of people fleeing their homes across the country, many cities in Ukraine have shown similar patterns of dimming. The difference is particularly clear when comparing Ukraine's cities to those of surrounding countries, which largely seem to be experiencing normal brightness levels without disruption.

February 26

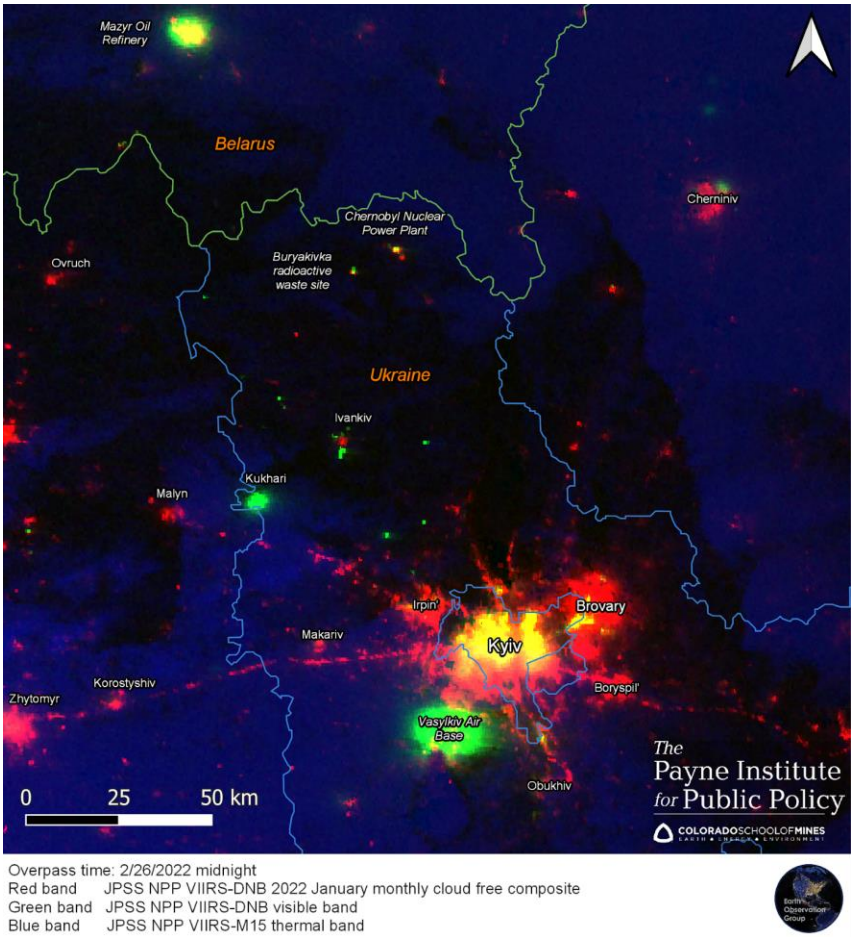

Figure 3: A zoomed in view of Kyiv and nearby locations with unusual light patterns on the night of February 26.

There are some notable exceptions to the overall dimming of city lights across Ukraine. The western city of Lviv, for example, appeared to have similar brightness levels even after Russia's initial attacks across the country. Lviv has a curfew like Kyiv, but it has also become an active hub for soldiers being sent to fight in the east and residents fleeing the country or taking shelter from the fighting. Additionally, staff for NATO and the U.S. Embassy are working in Lviv after being relocated from Kyiv as tensions rose prior to Russia's invasion.

To the north, the Chernobyl Nuclear Plant, which was seized by Russian forces, also displayed bright lights despite normally being dark. Following the site's capture, Ukraine officials reported that there was a slight increase in radiation levels from the plant, but it was likely due to military activity stirring up the radioactive topsoil. The Buryakivka radioactive waste site, which is within the 2,600 kilometers (1,000 square mile) exclusion site surrounding Chernobyl, also showed brighter lights than usual on February 26.

The city of Vasylkiv, which is 30 kilometers (18 miles) south of Kyiv, displayed a large increase in brightness due to a massive fire that broke out when fighting at an air base caused a nearby oil storage facility to explode. The flames lit up the sky outside of the capital city and residents were told to close their windows to protect themselves from the fire's harmful smoke and fumes.

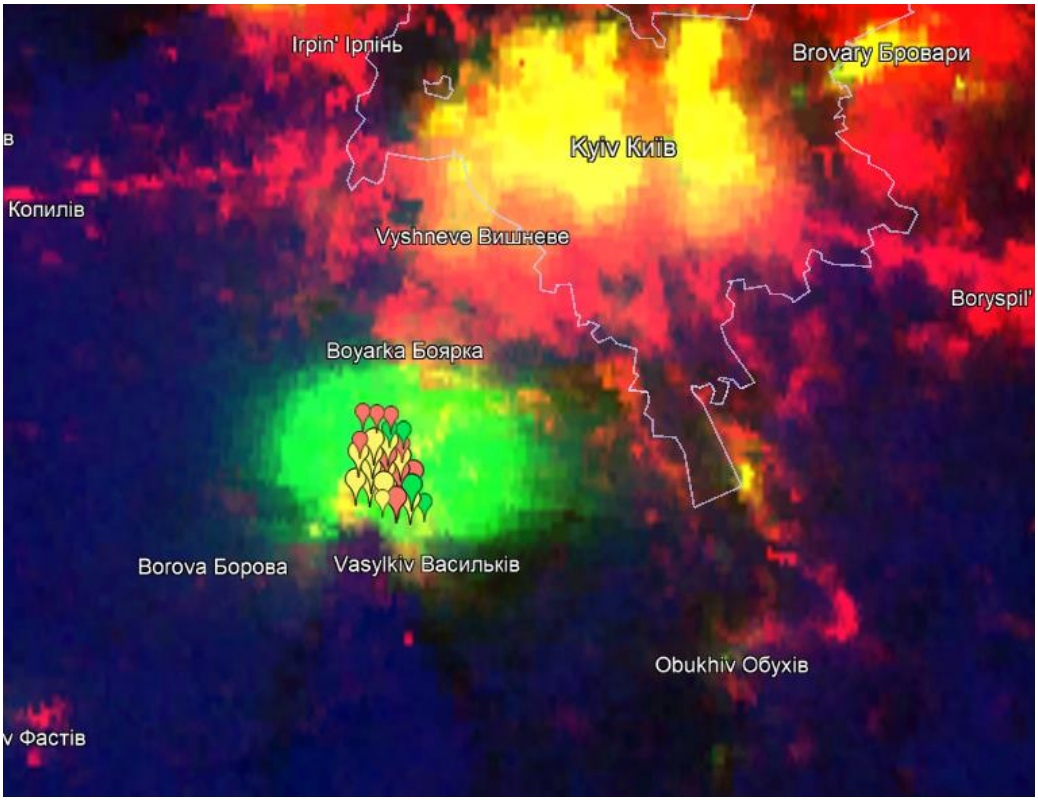

Figure 4. The EOG detected both the visible light and heat created by a large fire near the Vasylkiv Air Base on the night of February 26. The green light indicates brighter-than-normal conditions, and the colors of the pushpins indicate the temperature of the fire, with yellow over 1100°C and red over 1300°C.

In addition to the brightness detected by the EOG's VNL, the intense heat of the fire was also detected by the group's VNF product. The fire was detected in multiple pixels on satellite images, which means it covered several square kilometers. The EOG determined that the fire's temperature was around 1300°C (2372°F), which is typical for oil- and gas-fueled fires, but is much hotter than forest fires, which have temperatures closer to 700°C (1292°F).

The EOG's nighttime images detected other locations that appear brighter than usual, but the source of these lights remains unknown. The pattern suggests that it may be due to more military activity. For example, the VNL showed bright lights outside of the town Ivankiv, which is about 30 miles north of Kyiv and likely provides Russian forces with strategic access to the capital.

Similarly, the Mazyr oil refinery located north of Ukraine in Belarus, an ally of Russia, also displayed bright lights on February 26. In the days leading up to the invasion of Ukraine, Russia assembled additional troops and equipment in Mazyr and has continued to concentrate forces there in the days since.

February 28

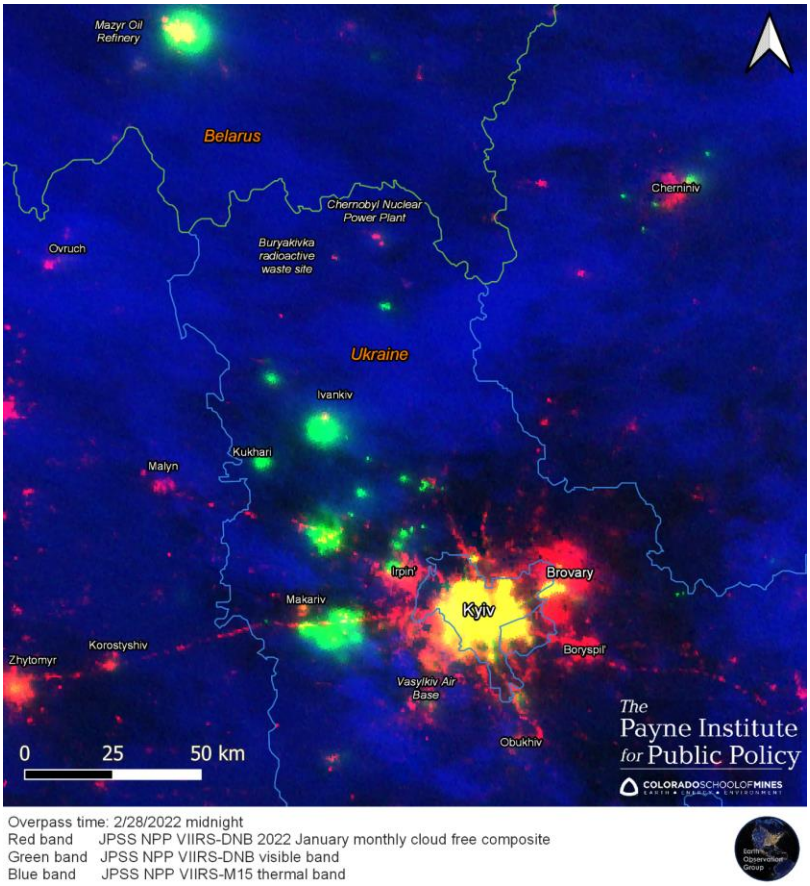

Figure 5. An image detected on February 28 showed increased light activity moving toward the city of Kyiv.

During the night of February 28, light activity west of Kyiv began to increase in both number and size.

Reports of military activity indicate that some of the lights may be Russian forces moving toward the capital city. The city of Ivankiv had previously seen an increase in brightness, but by February 28, the light activity had grown significantly. Meanwhile, reports showed a 40-mile-long Russian military convoy starting in Ivankiv and approaching Kyiv.

There are also VNF detections in some of the bright areas of new lights, including Ivankiv and Borodyanka, which means there may also be fires in these cities. Military activity has been reported in Borodyanka, and videos verified by the New York Times show extensive damage and fire in two apartment buildings following Russian airstrikes.

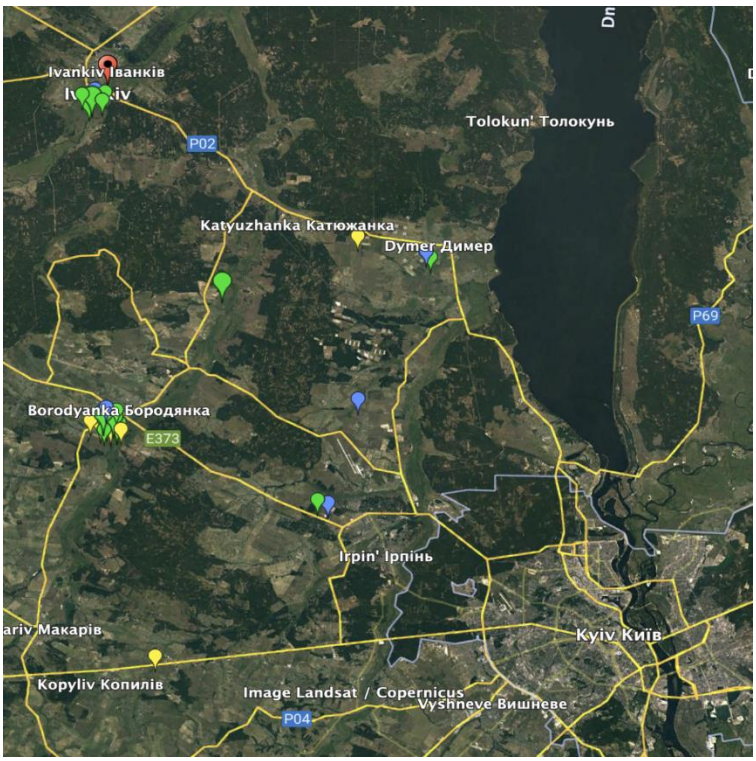

Figure 6. VNF detections indicate potential fires in multiple locations to the west of Kyiv.

As events continue to unfold, the EOG will use additional data and on-the-ground reports to adjust its analysis to provide further insight on the conflict in Ukraine.

About the Authors

Brooke Bowser
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Brooke Bowser is a recent graduate from the University of Wisconsin – Madison where she earned a degree in environmental Sciences and Life Sciences Communication. Her background in ecological research and environmental communications led to her development as a science writer striving to craft engaging and accessible science stories.

Gregory Clough
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Greg Clough has over 20 years of professional experience in operations, finance, administration and project management. He has a bachelor's degree in History from the University of Colorado and a master's degree in Advanced International Studies from the Diplomatic Academy of Vienna. Previously he was the Director of the international NGO, Oceans Beyond Piracy.

Christopher Elvidge
Senior Research Associate, Director of Earth Observation Group

Christopher D. Elvidge has decades of experience with satellite low light imaging data, starting in 1994. He pioneered nighttime satellite observation on visible lights, heat sources including gas flares and wild fires, as well as bright lit fishing vessels. He led the development of these nighttime remote sensed products with images from DMSP, JPSS, and Landsat satellites. These data are very popular and used globally in both public and private sectors. As of February 2018, he has more than 11,000 scholarly publication citations.

Tilottama (Tilo) Ghosh
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Tilottama Ghosh is currently a Research Associate with the Earth Observation Group at the Payne Institute for Public Policy. She completed her PhD in geography from the University of Denver in March 2010. Her training and educational background in geography, demography, economics, remote sensing, and Geographic Information Systems (GIS) helped to shape-up her interests, career and passion. Her research interests include human geography, nighttime lights remote sensing, sustainable science, and spatio-temporal research using remote sensing, and Geographic Information Systems (GIS).

Feng-Chi, Hsu
Research Associate, Earth Observation Group

Fen-Chi Hsu was born and raised in Taiwan. He was a trained engineer in Environmental Engineering, later found his passion in remote sensing. He received his PhD degree in the University of Tokyo in 2012, and started working in Earth Observation Group with Dr. Elvidge in the same year. Since then he has learned the secrets of nighttime light production and helped develop critical algorithms for new products as well as tools for robust processing. Besides being a researcher in remote sensing, he is also building up his skill set as a full stack system administrator as well as a web application designer.

About the Authors *(continued)*

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Tamara grew up in Colorado before moving to California to study chemistry, first receiving a B.S. in Chemistry from Westmont College in Santa Barbara, CA and then a Ph.D. in Physical Chemistry from the University of California, Berkeley. While at Berkeley, she specialized in studying urban air quality, including measuring atmospheric nitrogen oxides from aircraft and investigating the effect of nitrogen oxide chemistry on air pollution. After graduating, she spent two years at the California Department of Public Health studying the composition of particulate matter in wildfire smoke and modeling the spread of SARS-CoV-2 via exhaled droplets. She returned to Colorado to join the Earth Observation Group at the Payne Institute to work on the VIIRS Nightfire (VNF) product. When not working, she enjoys hiking, reading, playing board games, and cooking.

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Zhizhin Mikhail Nikolaevich, M.Sci. degree in game theory in 1984 from Mathematical Department of the Moscow State University, Ph.D. in computational seismology and pattern recognition in 1992 from the Schmidt Institute of Physics of the Earth, Russian Academy of Sciences.

Morgan D. Bazilian
Director, Payne Institute and Professor of Public Policy

Morgan Bazilian is the Director of the Payne Institute and a Professor of public policy at the Colorado School of Mines. Previously, he was lead energy specialist at the World Bank. He has over two decades of experience in the energy sector and is regarded as a leading expert in international affairs, policy and investment. He is a Member of the Council on Foreign Relations.

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