Ukraine's Emerging Problems of Climatic Impact and War Require Extending Climate and Water Resource Monitoring

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https://ceobs.org

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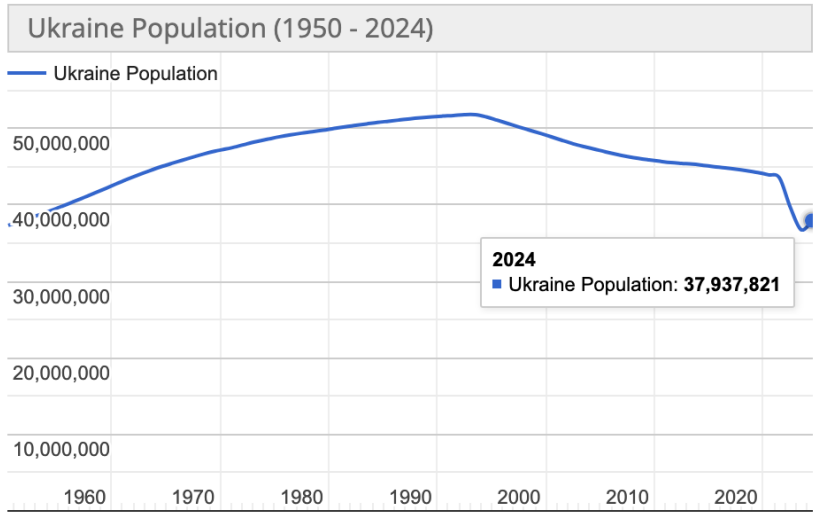
Goals

- Evidence of dramatic changes in climatic conditions and water resources in Ukraine
- Examples of how military actions deteriorated freshwater resources and destroyed the water infrastructure in Ukraine
- Need for advanced monitoring and modeling
- Concluding remarks

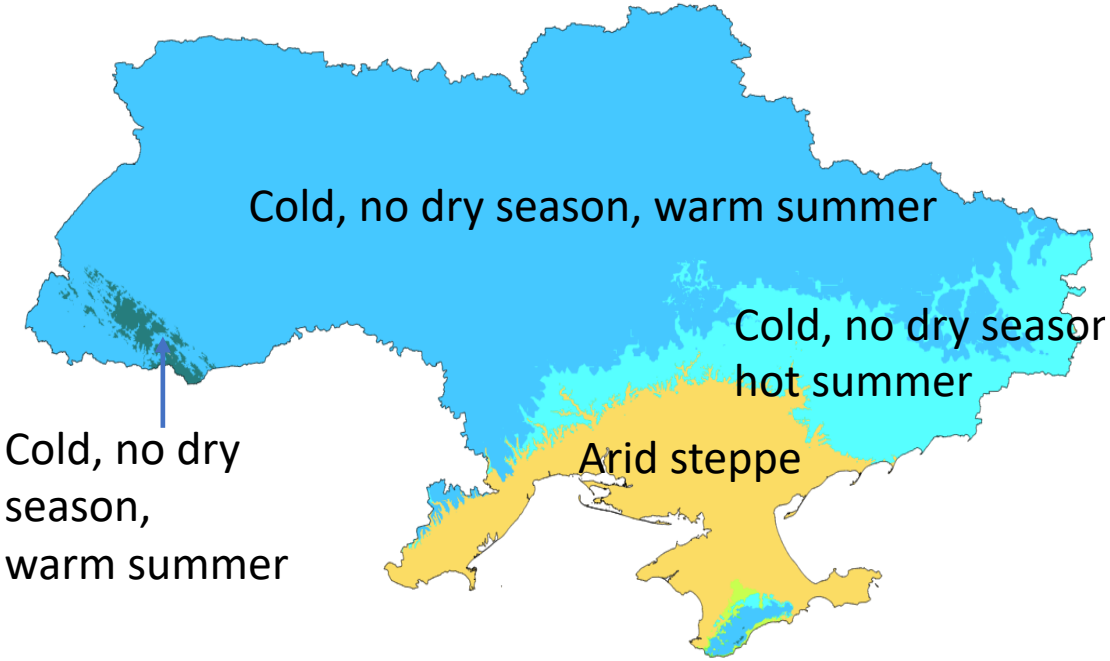
Physical geography map of Ukraine



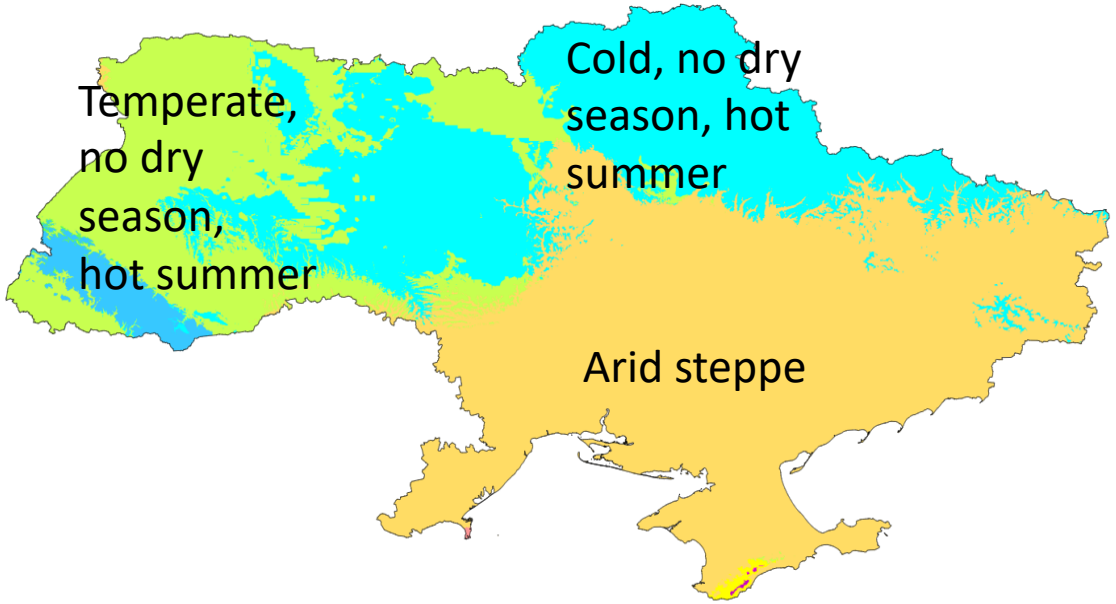
- Ukraine's population is 0.46% of the total world population.
- Ranks 41st in the list of countries.
- The population density is 63 per km^2
- The total land area is 579,320 km^2 (223,677 sq. miles)
- 81.9 % of the population is in urban areas

Köppen–Geiger climate classification maps

1980-2016



2071-2100

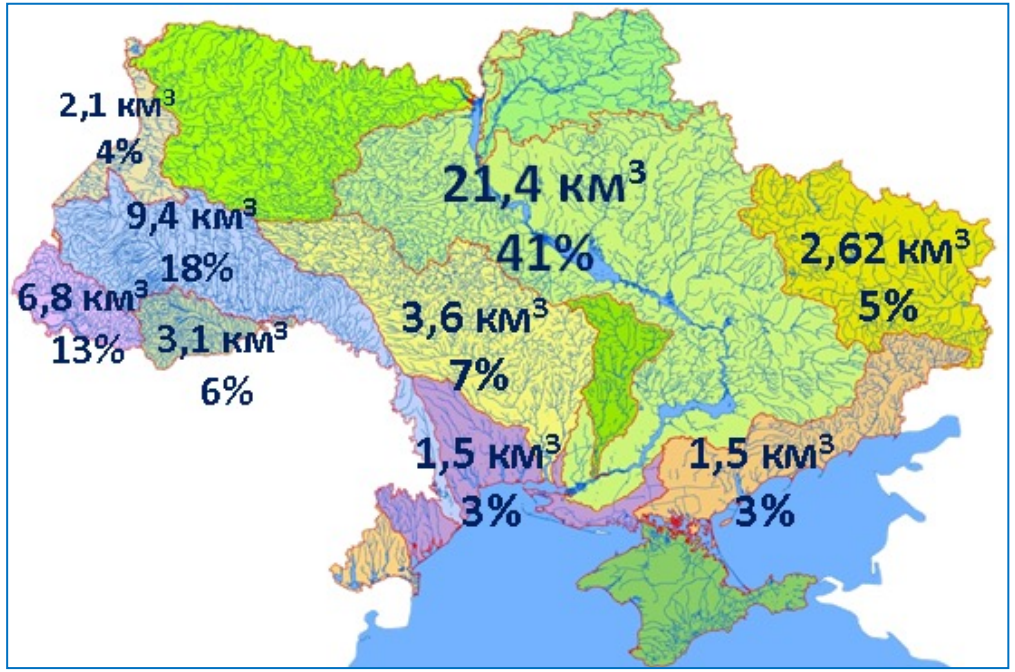


Beck, H.E. et al., "Present and future Köppen-Geiger Classification," *Scientific Data*. DOI:10.1038/sdata.2018.214.

https://en.wikipedia.org/wiki/Geography_of_Ukraine#/media/File:Koppen-Geiger_Map_UKR_present.svg

Ukraine is one of the least water-supplied countries: 32nd among 40 countries in Europe

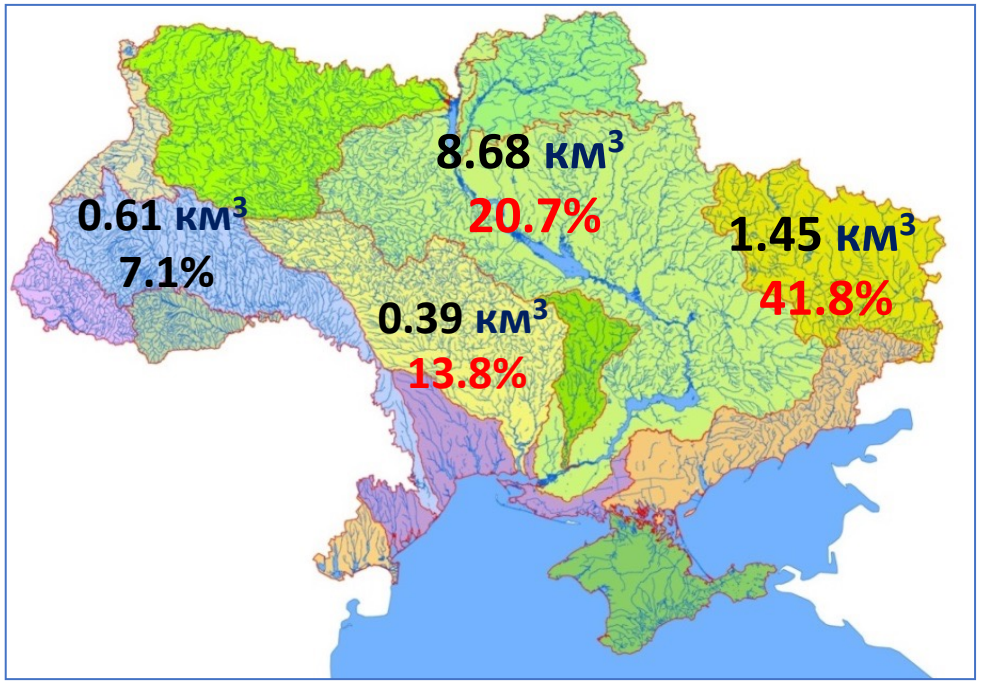
Water resources in river basins



75% of the water supply is taken from rivers

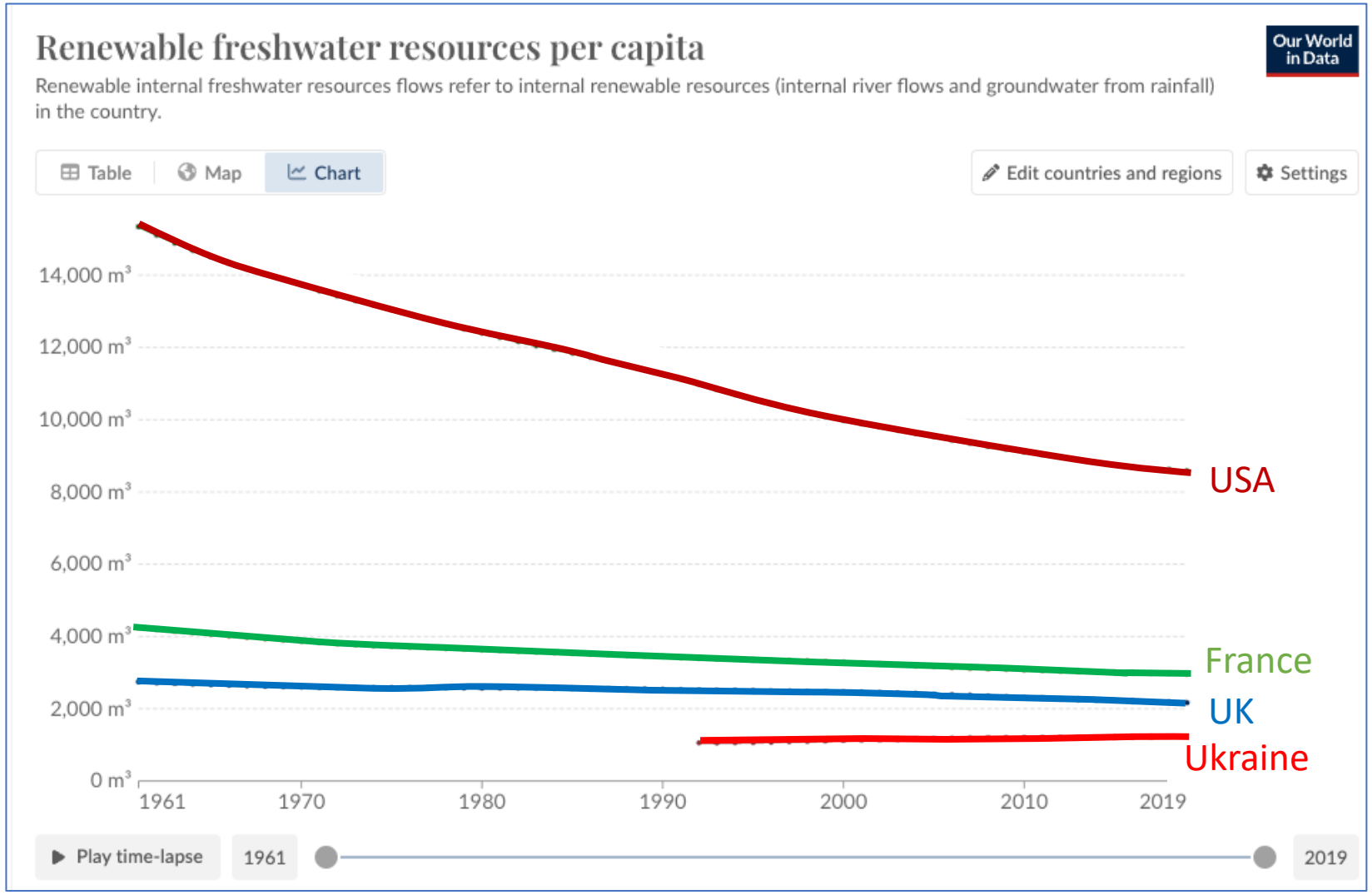
Ukraine is ranked 124th on the list of 181 countries worldwide. Local river resources provide a little more than 1.0 thousand m^3 per 1 person per year

Water intake in river basins >10%



Water intake from river basins (% of runoff) exceeds environmentally acceptable water intake of 10%

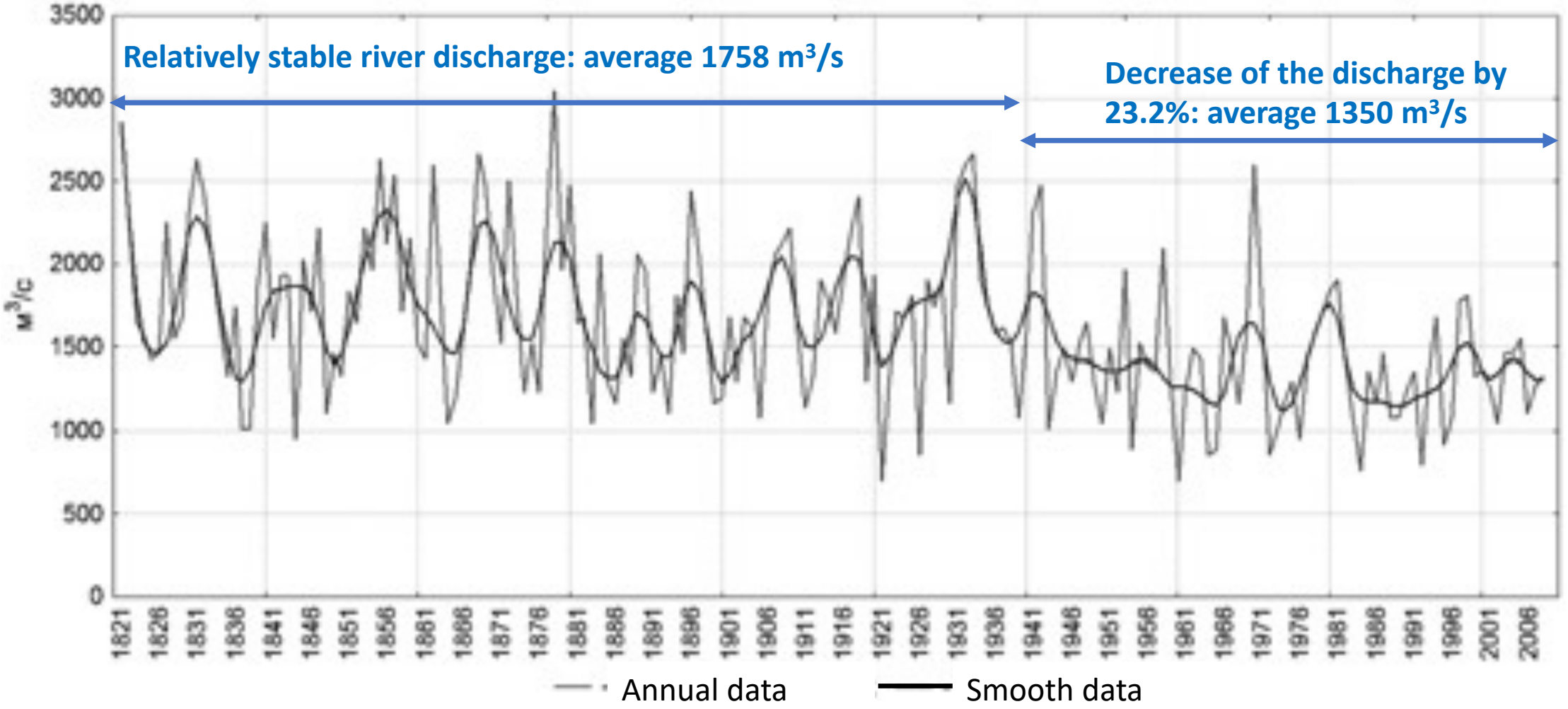
Renewable freshwater resources per capita are below the standard (Internal river flows and groundwater from rainfall)



According to UNESCO, Ukraine has been classified as a water-stressed country because of <1.7 thousand cubic meters of water per capita per year.

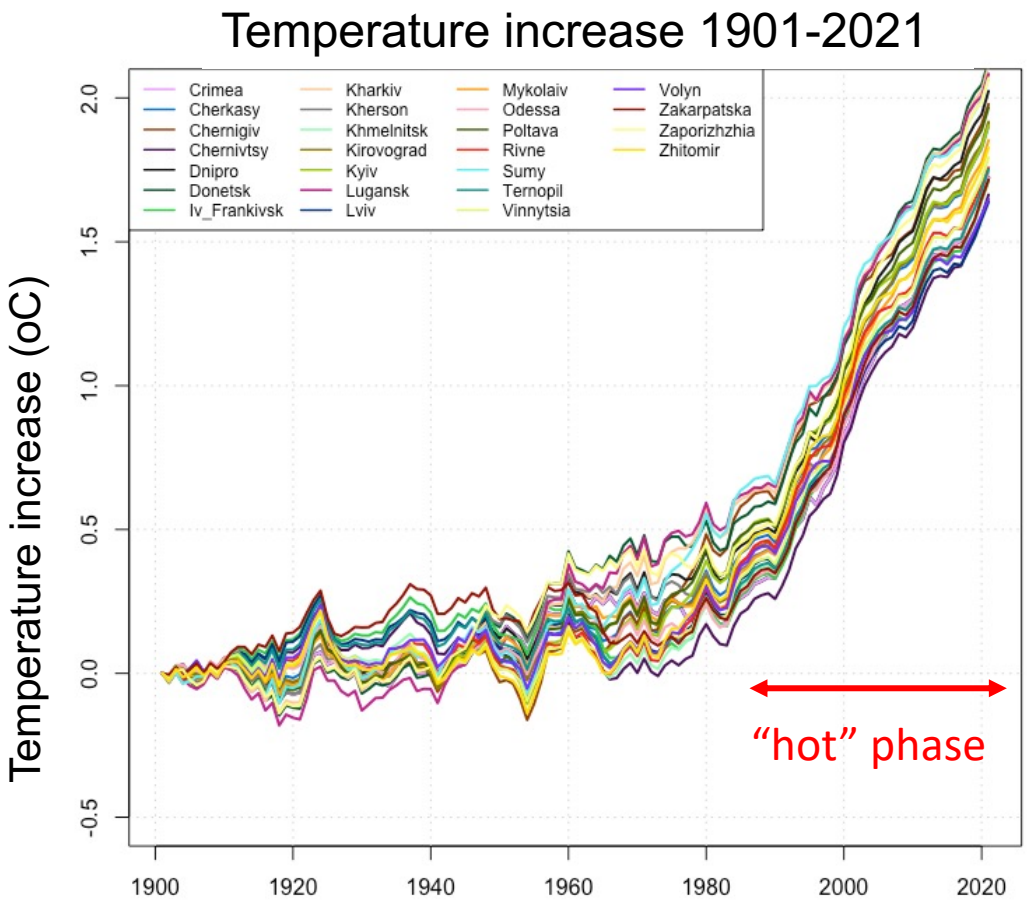
Source: Food and Agriculture Organization of the United Nations (via World Bank)
https://ourworldindata.org/grapher/renewable-water-resources-per-capita?country=USA~UKR~FRA~GBR

The annual decrease of the Dnieper River discharge started in the 1940s

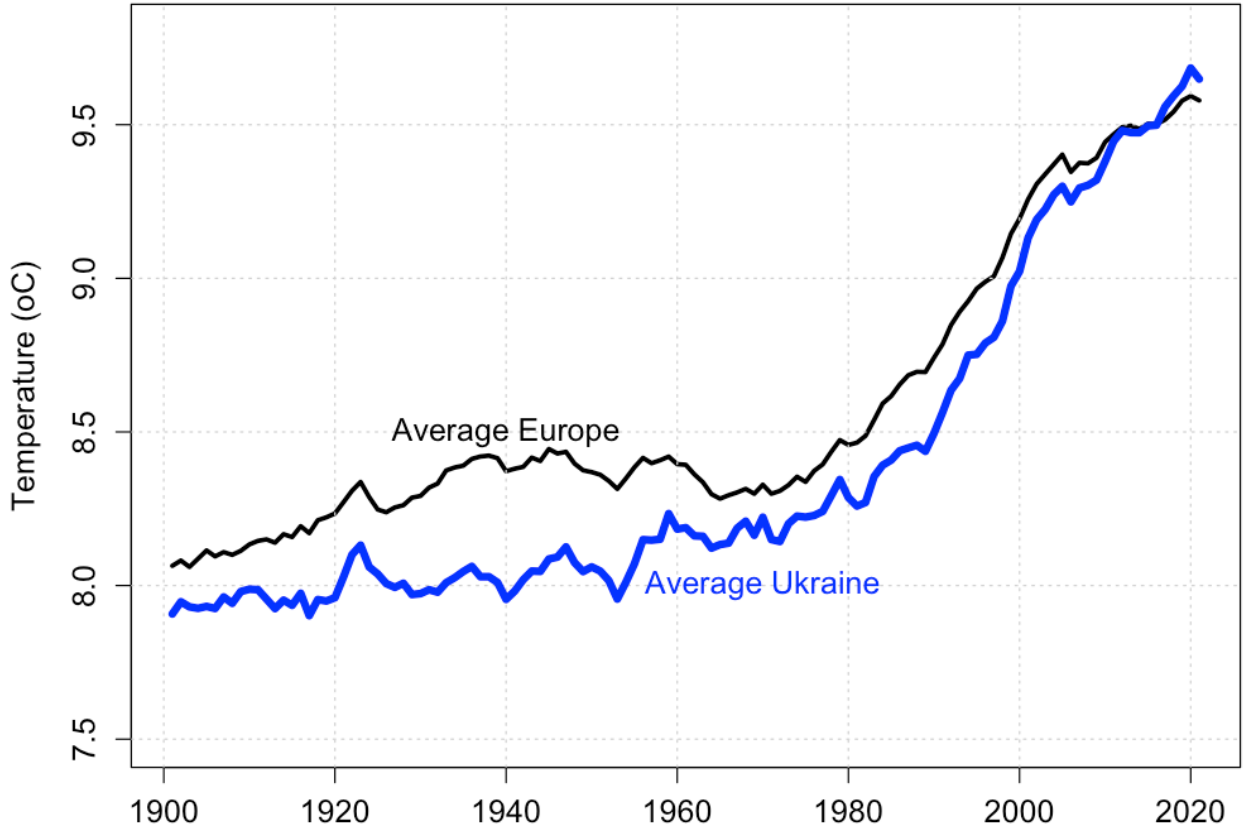


F. N. Lisetskii, V. F. Stolba, V. I. Pichura. Periodicity of climatic, hydrological and lacustrine sedimentation processes in the south of the East-European plain, Regional Environme n tal Issues, 4, 19-25, 2013

The “hot phase” of climate warming started in 1980s



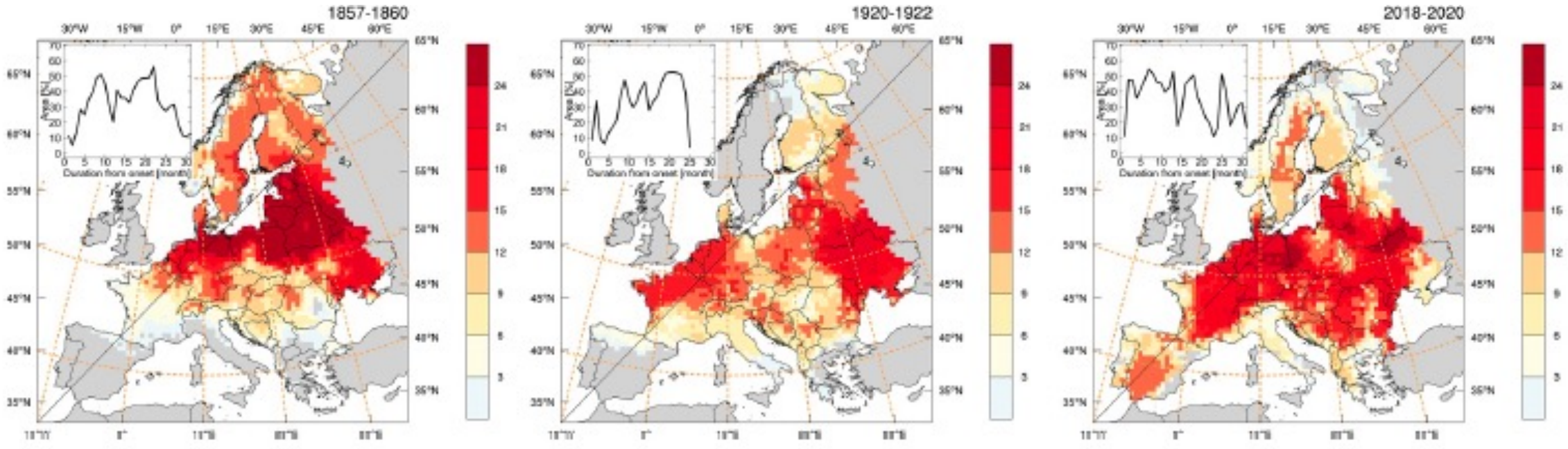
The 30-year average temperature trends in Europe and Ukraine are comparable



Source: the Climate Change Knowledge Portal https://climateknowledgeportal.worldbank.org/country/ukraine/climate-data-historical

The climate warming events in Ukraine are not unique to Europe and were observed in the past

Spatial maps depicting the droughts in Europe



The inset plot shows the temporal evolution of the areal coverage from the onset of the corresponding event (Rakovec et al., 2022)

Earth's Future

RESEARCH ARTICLE
10.1029/2021EF002394

The 2018–2020 Multi-Year Drought Sets a New Benchmark in Europe

Oldrich Rakovec[1,2], Luis Samaniego[1], Vittal Hari[1,3], Yannis Markonis[2], Vojtěch Moravec[2,4], Stephan Thober[1], Martin Hanel[2,4], and Rohini Kumar[1]

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Key Points:

- The 2018–2020 multi-year drought shows unprecedented level of intensity during the past 250 years
- The 2018–2020 event reached record-breaking +2.8 K temperature anomaly and negatively impacted major crops
- Future drought events reach comparable intensity of 2018–2020 but with considerably longer durations

Supporting Information:

Supporting Information may be found in the online version of this article.

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Citation:

Rakovec, O., Samaniego, L., Hari, V., Markonis, Y., Moravec, V., Thober, S., et al. (2022). The 2018–2020 multi-year drought sets a new benchmark in Europe. *Earth's Future*, *10*, e2021EF002394. https://doi.org/10.1029/2021EF002394

Received 25 AUG 2021
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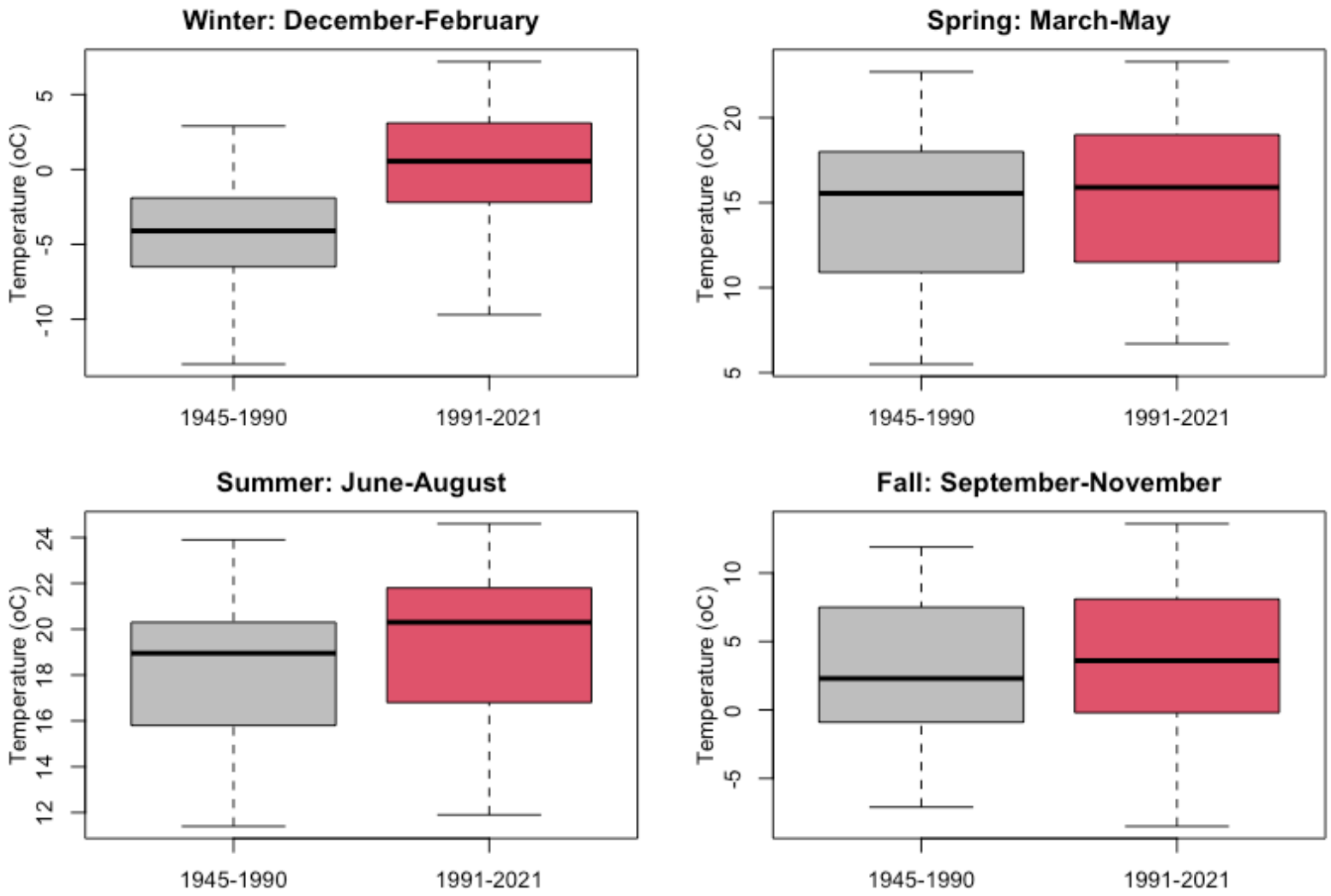
Abstract During the period 2018–2020, Europe experienced a series of hot and dry weather conditions with significant socioeconomic and environmental consequences. Yet, the extremity of these multi-year dry conditions is not recognized. Here, we provide a comprehensive spatio-temporal assessment of the drought hazard over Europe by benchmarking past exceptional events during the period from 1766 to 2020. We identified the 2018–2020 drought event as a new benchmark having an unprecedented intensity that persisted for more than 2 years, exhibiting a mean areal coverage of 35.6% and an average duration of 12.2 months. What makes this event truly exceptional compared with past events is its near-surface air temperature anomaly reaching +2.8 K, which constitutes a further evidence that the ongoing global warming is exacerbating present drought events. Furthermore, future events based on climate model simulations Coupled Model Intercomparison Project v5 suggest that Europe should be prepared for events of comparable intensity as the 2018–2020 event but with durations longer than any of those experienced in the last 250 years. Our study thus emphasizes the urgent need for adaption and mitigation strategies to cope with such multi-year drought events across Europe.

Plain Language Summary This manuscript demonstrates that the 2018–2020 multi-year drought event constitutes a new benchmark in Europe, with an unprecedented level of intensity over the past 250 years. What makes this event truly exceptional compared with past events is its temperature anomaly reaching +2.8 K. This finding provides new evidence that the ongoing global warming exacerbates current drought events. The key message of this study is that the projected future events across the European continent will have a comparable intensity as the 2018–2020 drought but exhibit considerably longer durations than any of those observed during the last 250 years. Our analysis also shows that these exceptional temperature-enhanced droughts significantly negatively impact commodity crops across Europe.

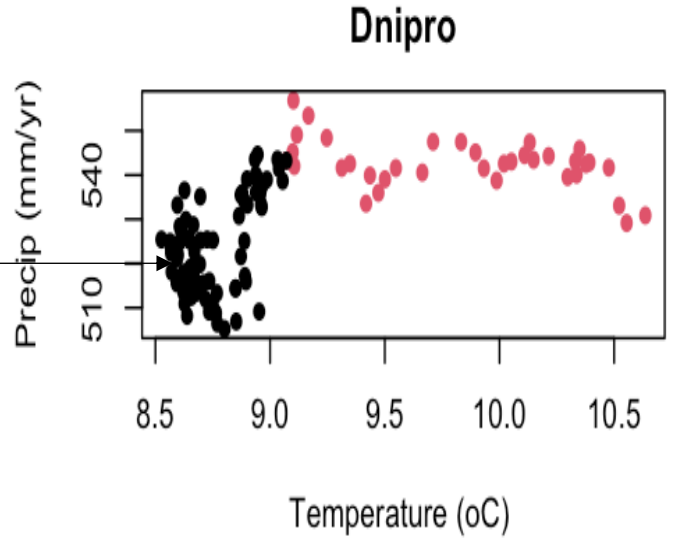
"Europe should be prepared for events of comparable intensity as the 2018–2020 event but with durations longer than any of those experienced in the last 250 years. Our study thus emphasizes the urgent need for adaption and mitigation strategies to cope with such multi-year drought events across Europe."

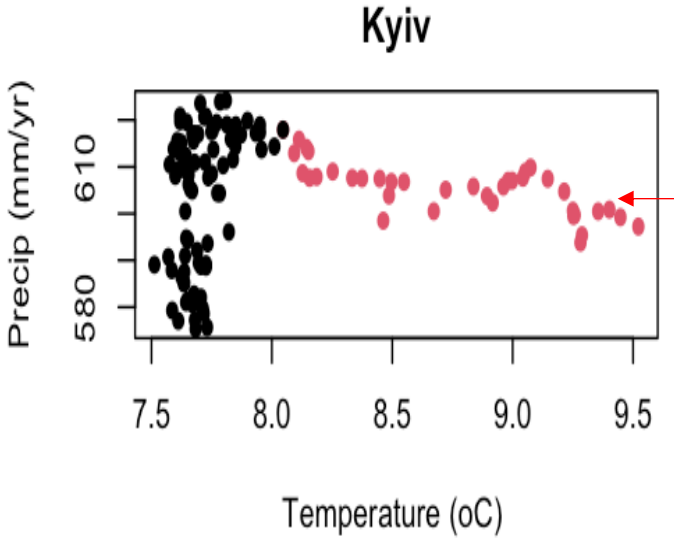
Temperature increased more significantly in winter and summer (Kyiv region)



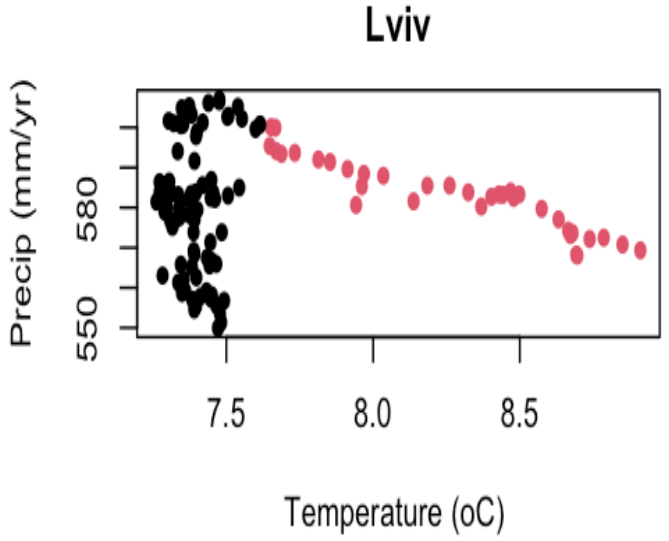
The relationship between temperature and precipitation

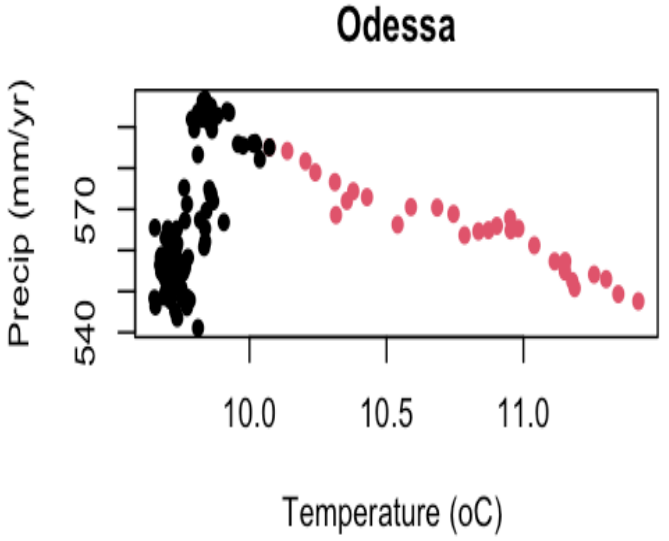
Before the hot phase: precipitation increases as temperature increases



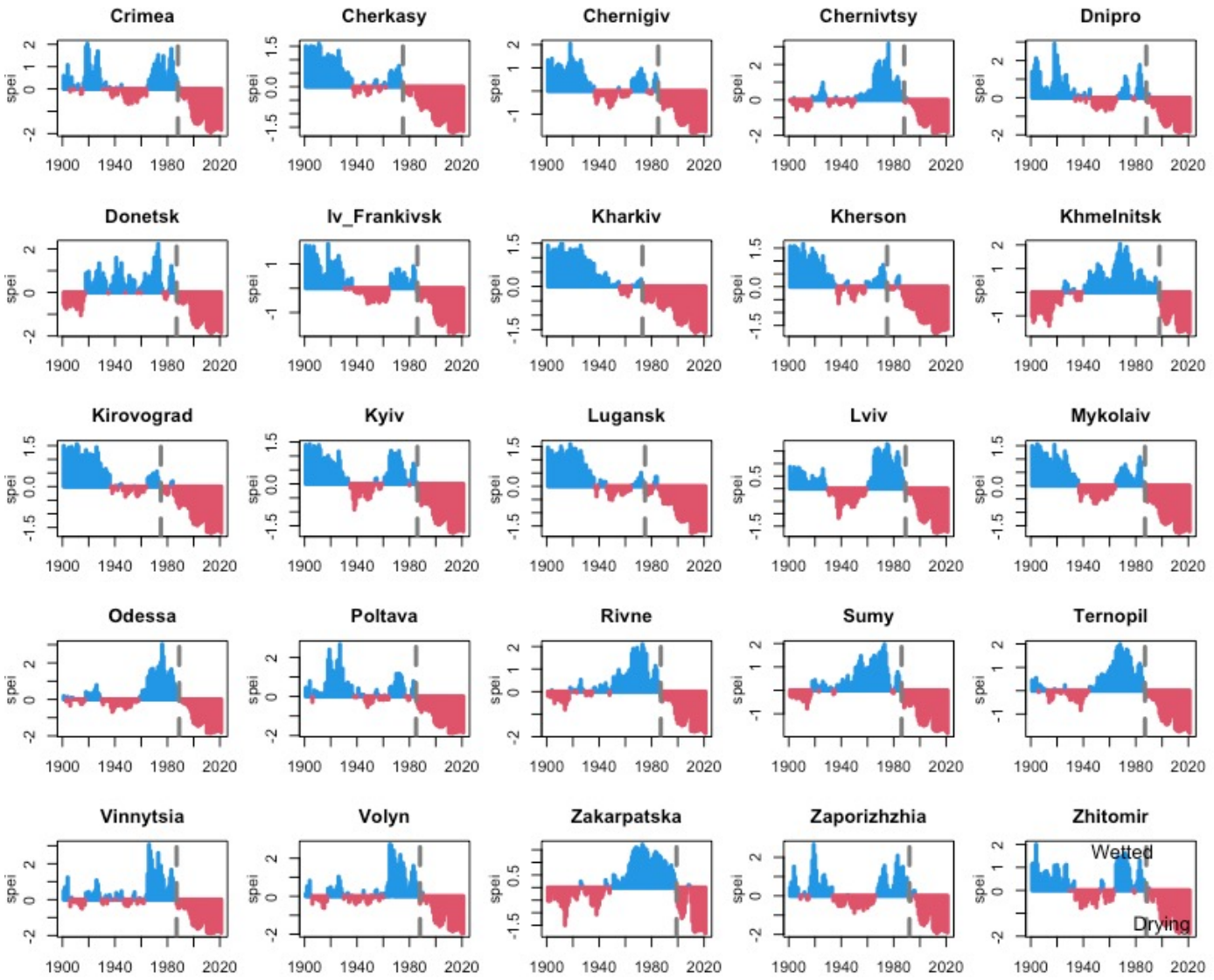


Hot phase: precipitation remains the same or decreases



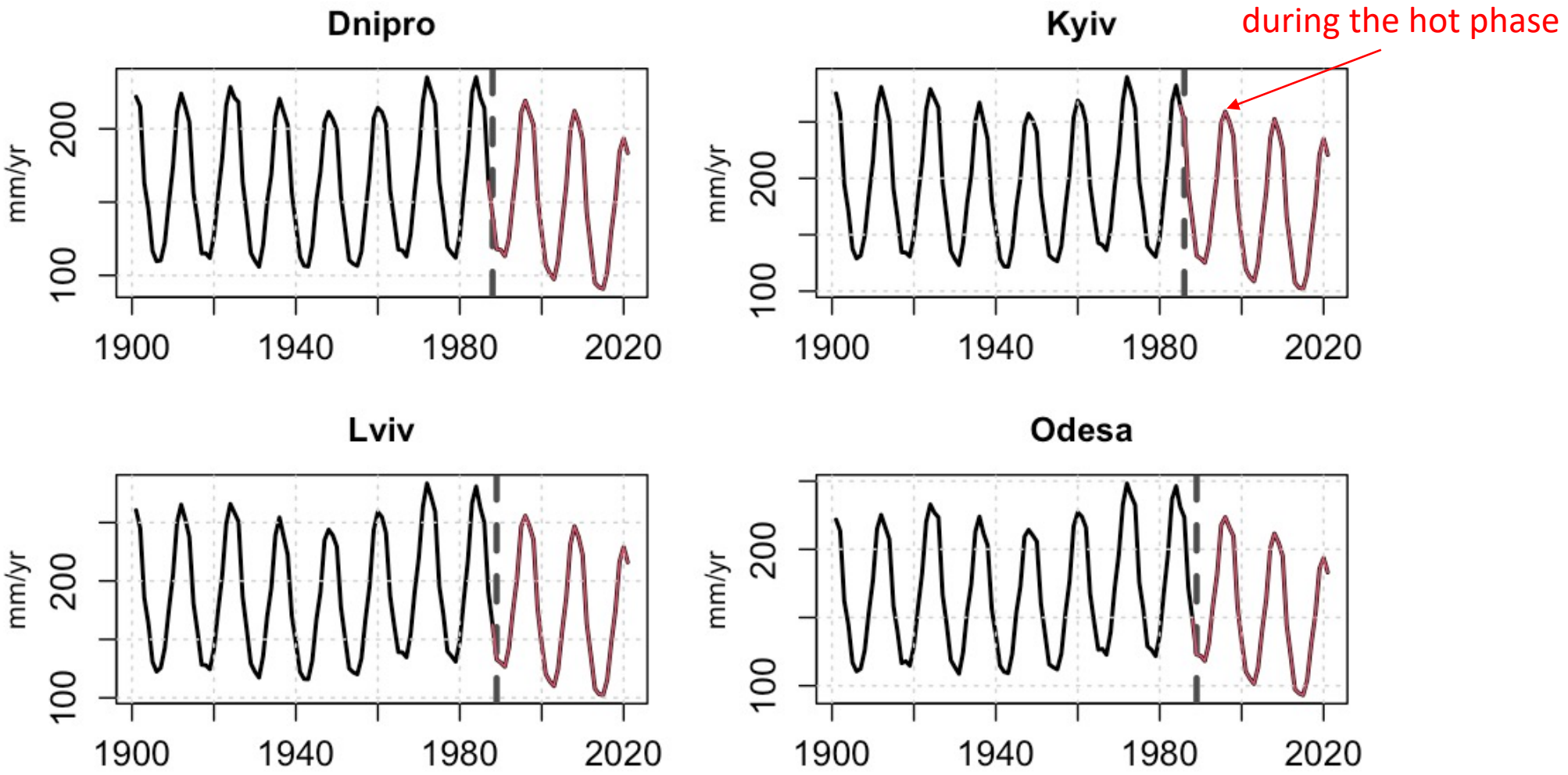


Standard Precipitation Evapotranspiration Index (SPEI) time series indicates dramatic climate warming



Vertical dashed lines are the beginning of the “hot” phase

Infiltration/groundwater recharge + surface runoff decreased during the hot phase



Impact of the Russian invasion on water resources and water infrastructure

A, B: The demolition of the dam by Ukrainian forces on the Irpin River on February 26, 2022, caused flooding in the Vyshhorod district of Kyiv region, which prevented the advancing of Russian troops toward Kyiv.

C: Craters formed by shells on the floodplain of the Irpin River.

D: Water in the Kamyshevakha River polluted by mine waters (picture taken in 2021).

E: Damaged pipe near Kiselevka village in the Kherson region (April 2022).

F: People are in line for drinking water in Mykolayiv (April 2022)

Many wells were installed where residents can access drinkable water, but the water crisis remains acute.

Shumilova, O., et al. Impact of the Russia–Ukraine armed conflict on water resources and water infrastructure. Nat Sustain 6, 578–586 (2023). https://doi.org/10.1038/s41893-023-01068-x

Blowing up the Kakhovka HPP dam is a major act of ecocide committed by Russia during the full-scale invasion of Ukraine.

https://www.dw.com/en/ukraine-updates-kakhovka-dam-blast-threatens-water-supply/a-65883850

Recreating the Kakhovka reservoir has no alternative

- Provide the population of Ukraine with drinking water,
- Restore navigation on the Dnipro River,
- Ensure water supply to the cooling ponds of the Zaporizhzhia Nuclear Power Plant,
- Supply water for irrigation and to Crimea.

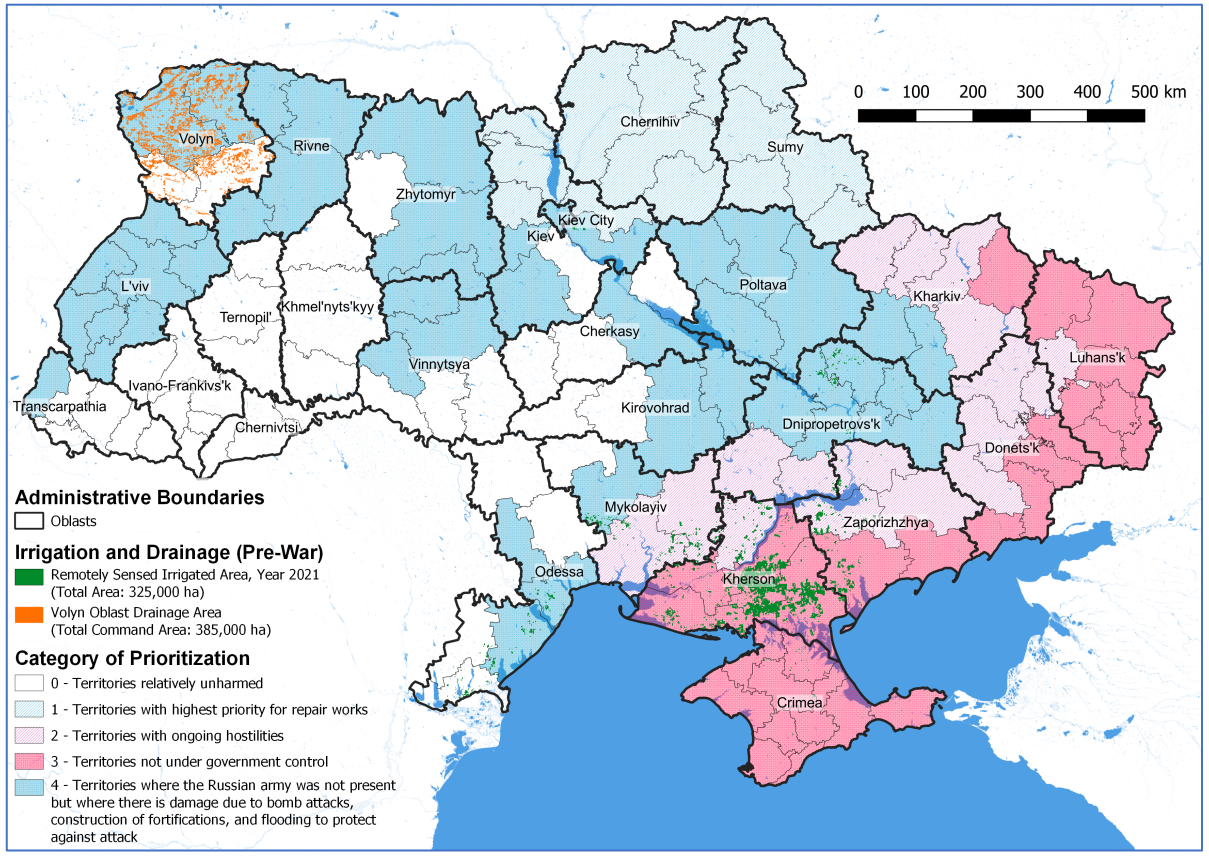
To address all these issues, a dam is necessary to accumulate the water lost after the Kakhovka Hydropower Plant explosion.

https://en.uhe.gov.ua/news/recreating-kakhovka-reservoir-has-no-alternative#:~:text=%22For%20our%20country%2C%20the%20restoration,Zaporizhzhia%20Nuclear%20Power%20Plant%2C%20and

The largest in Europe, Zaporizhzhia NPP, is in the occupied city Energodar on the banks of the Kakhovka reservoir.

- The primary source of cooling water drained away after the Kakhovka dam was destroyed.
- 11 groundwater pumping wells have become operational at the occupied Zaporizhzhia NPP to secure sufficient cooling water for the six reactor units.
- A safety analysis of the NPP stability due to the water withdrawal is needed.

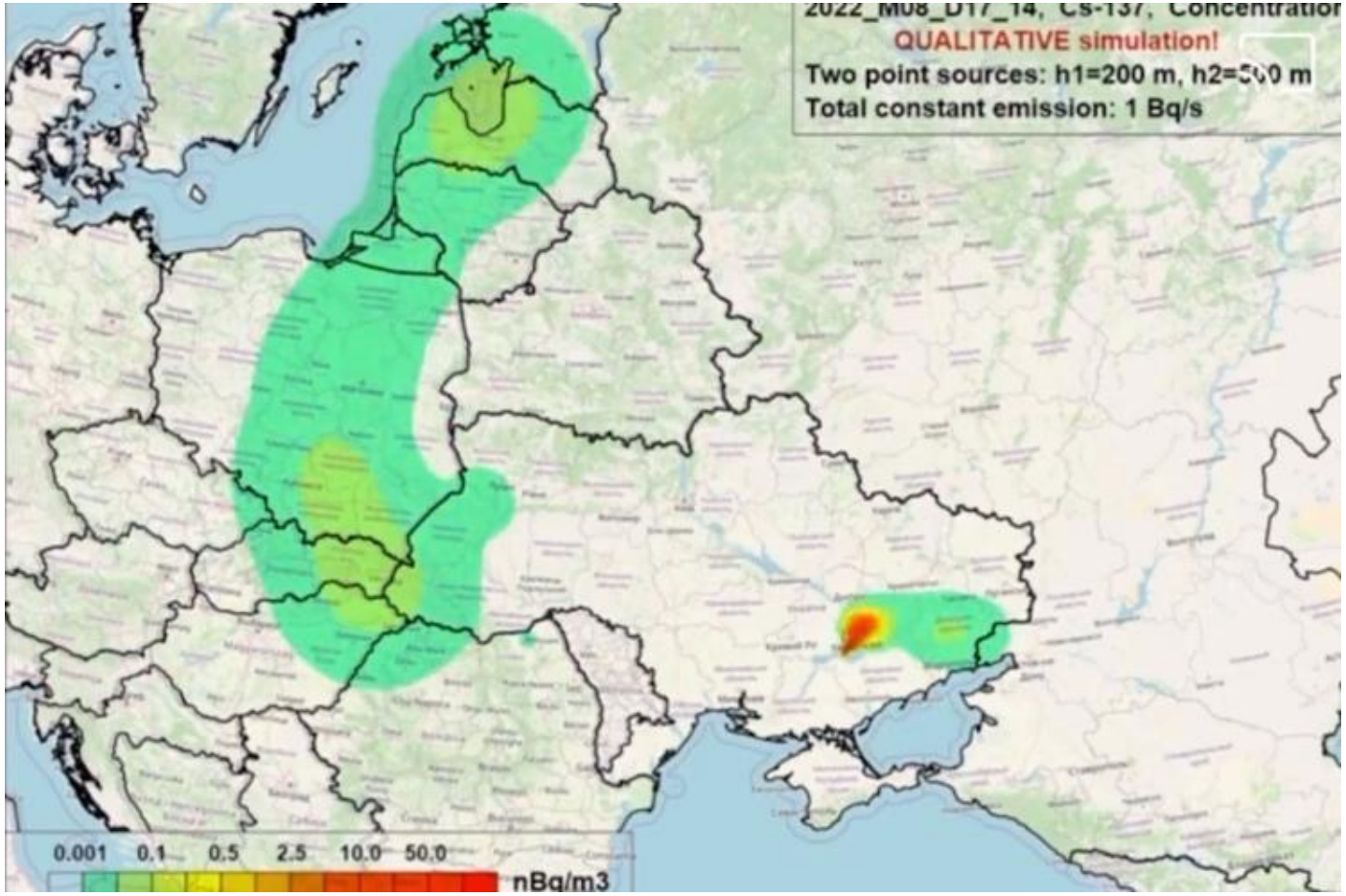
Ukraine's toxic water crisis has been escalating since the Russian invasion, and the consequences will be enormous.



- Ammunition and military equipment have been dumped into the nation's rivers and streams, releasing heavy metals and other toxins.
- Strikes on oil depots and industrial facilities have further poisoned water supplies.
- https://cf-particle-html.eip.telegraph.co.uk/e200164a-0fd3-476f-8936-8c0022ee035b.html

https://www.hydrosolutions.ch/projects/comprehensive-water-energy-security-analysis-for-the-irrigation-sector-in-ukraine

A possible disaster at the Zaporizhzhia nuclear plant or other Ukrainian NPPs could affect European countries

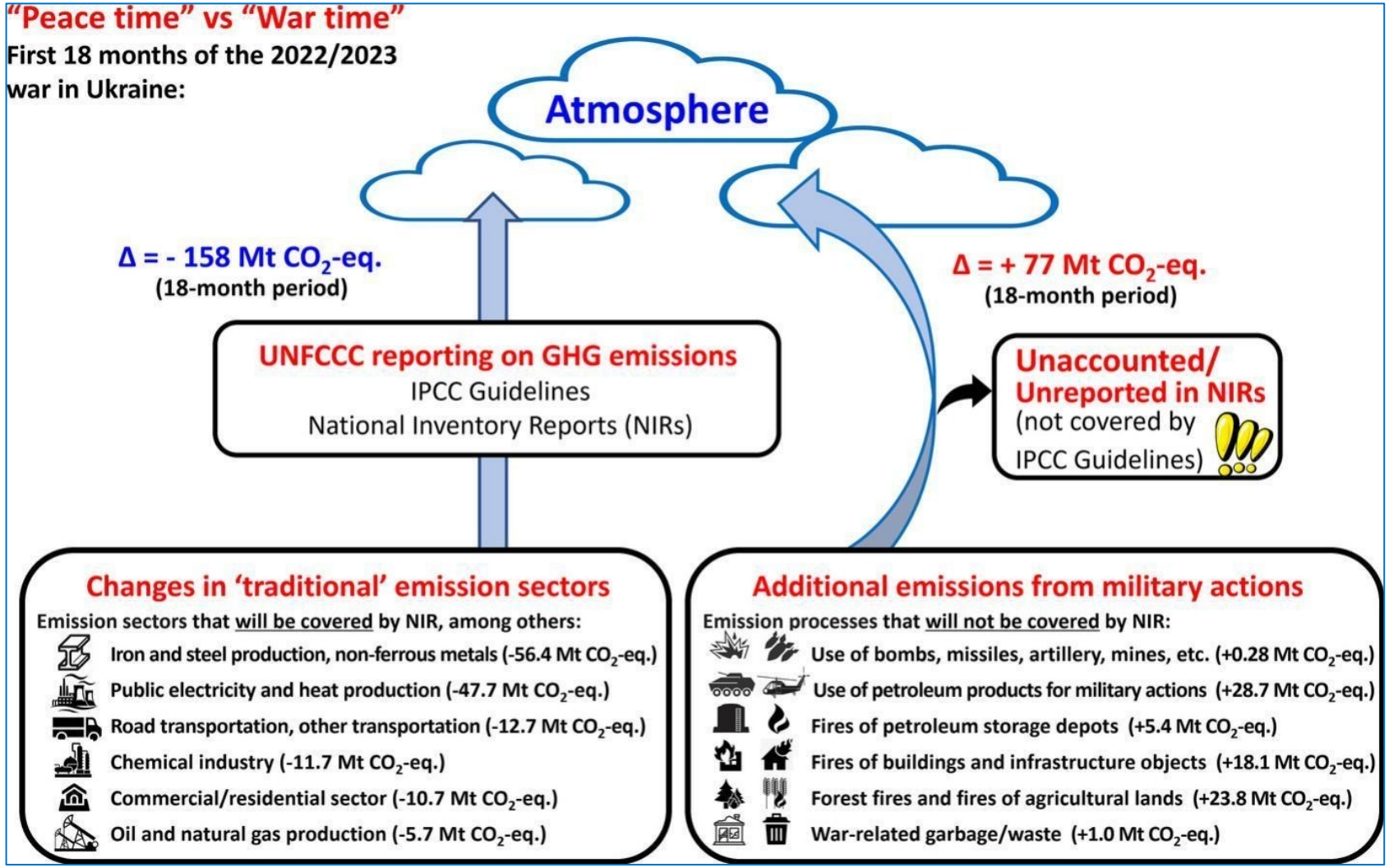


https://nypost.com/2022/08/19/map-predicts-fallout-from-disaster-at-ukrainian-nuclear-plant/

Based on simulations of the Ukrainian Hydrometeorological Institute

Significant GHG emissions caused by military actions in Ukraine

(a) bombs, missiles, or mines;
(b) petroleum products;
(c) fires at petroleum depots;
(d) fires of buildings and infrastructure;
(e) forest fires and on agricultural lands;
(f) emissions from garbage/waste.

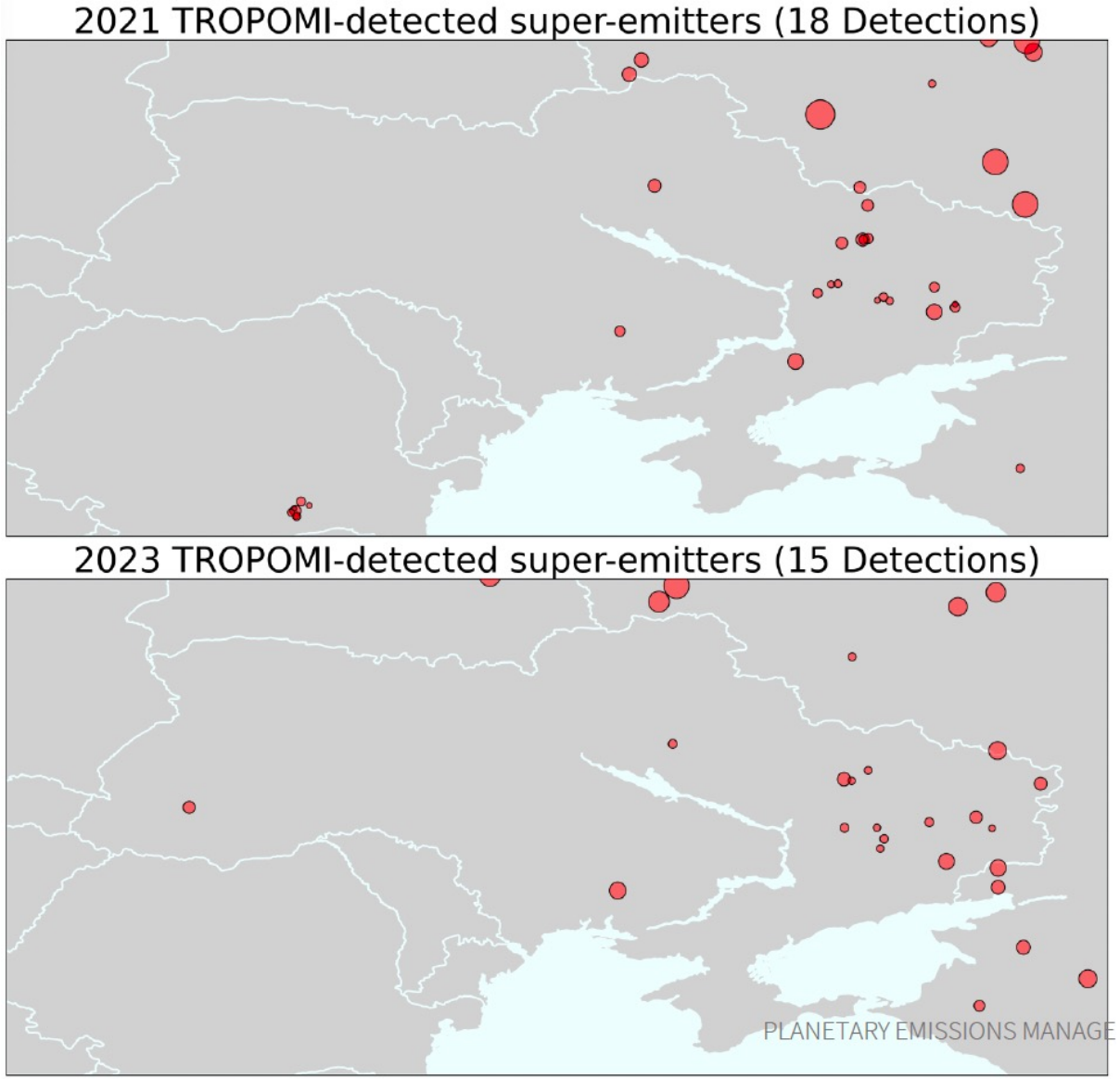


R.Bun et al., Tracking unaccounted greenhouse gas emissions due to the war in Ukraine since 2022, Science of The Total Environment, Vol. 914, 2024.

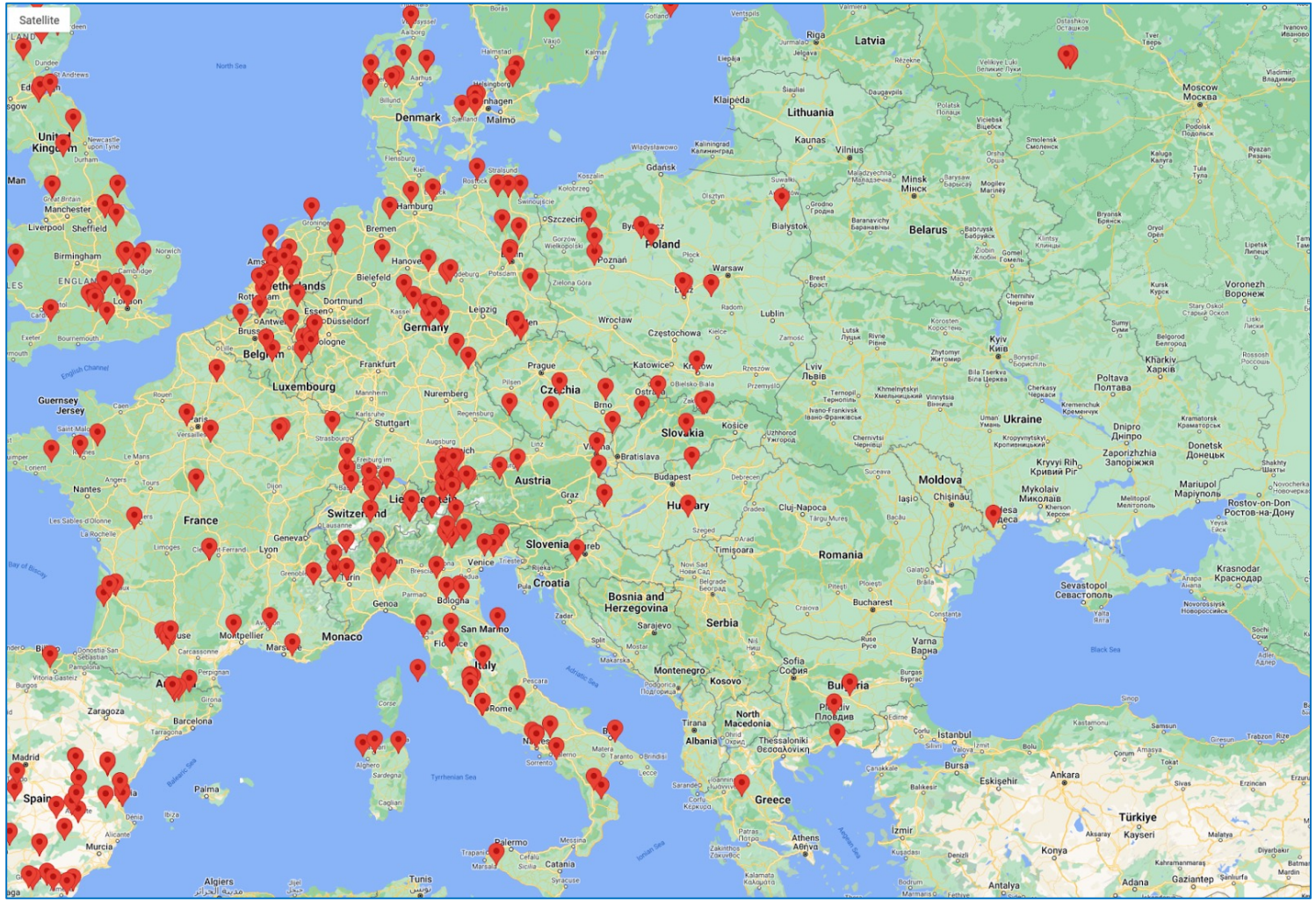
SRON TROPOMI Satellite Imaging of CH_4 Plumes in Ukraine Proposal of Planetary Emission Management, Inc.

- SRON, the Dutch National Expertise Institute for Scientific Space Research, is a key part of the Netherlands Research Institute (Sron.nl/role/).
- The TROPOMI satellite instrument provides global coverage of atmospheric methane columns at 7 x 5.5 km^2 resolution.
- These observations allow the detection of individual methane plumes from persistent and transient sources.

The slide is courtesy of Bruno Marino, CEO of PEM, Inc.



An extension of the FLUXNET global network of eddy covariance towers across Ukraine will help in developing reliable 3D climatic models and assessing the GHG emissions and their impact on Ukraine and surrounding European regions.

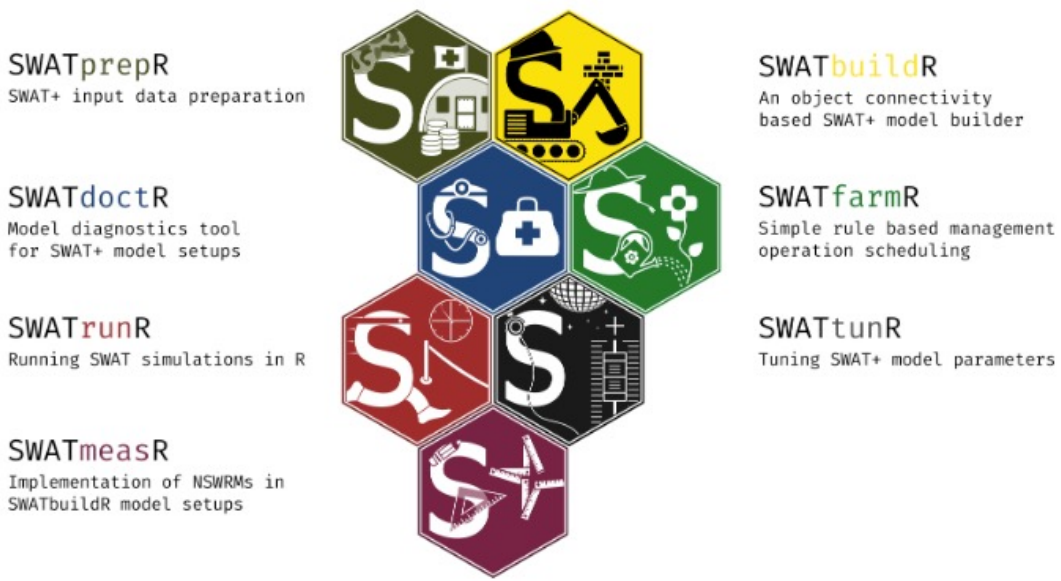


SWATprepR

devel version 1.0.5 | last commit june | lifecycle stable | repo status Active | code size 193 kB | license MIT
doi https://doi.org/10.1186/s12302-024-00873-1

The goal of `SWATprepR` is to help with the SWAT+ model input data preparation. There are mostly functions, which were developed for the implementation of modeling tasks in the OPTAIN project. These tools are intended to fill the gaps in the SWAT+ workflow along side the main tools developed by Christoph Schuerz. Therefore, we highly recommend trying and using these tools:

- SWATbuildR[1] - R tool for building SWAT+ setups;
- SWATbuildR[^1] - R tool for building SWAT+ setups;
- SWATfarmR - R tool for preparing management schedules for SWAT model;
- SWATdoctR - A collection of functions in R and routines for SWAT model calibration and model diagnostics;
- SWATrunR - R tool for running SWAT models for different parameters and scenarios.
- SWATtunR - R tool for soft & hard calibration, validation of SWAT+ models
- SWATmeasR[2] - R tool for implementing Natural/Small Water Retention Measures (NSWRMs) in the SWAT+ models and running scenarios.



Concluding remarks

- Climate warming and the Russian invasion adversely affected Ukraine's water resources and infrastructure, necessitating the design of a renewable energy-powered, decentralized drinking water supply and treatment distribution system in Ukraine.

- Accurate data collection at local and regional scales and the application of modern big data analytics are necessary to transform the governance of water, energy, and human networks in Ukraine.