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Editorial

Innovative use of space-based technologies to address climate change and related global health crises

Introduction

Health professionals have long campaigned to recognize the connections between climate change and health. Extreme weather events, together with critical changes to Earth systems, biodiversity loss, and ecosystem collapse, have been reported as the three primary climate issues to influence global risks over this decade [1]. The delicate balance of our global landscape has been recently tested, including unprecedented rainfalls leading to flooding in central Europe, Pakistan, Spain, and United Arab Emirates (UAE), widespread droughts in North and South America, active hurricane season in the Atlantic basin, and wildfires in Greece and North America. Ambient and indoor air pollution remains a significant concern leading to 6.7 million premature annual deaths. These emerging and re-emerging risks are linked to climate change and can negatively impact physical and mental health, economic livelihood, energy production, food security, and property damage across the globe [2].

At the first-ever Health Day during the 28th United Nations Climate Change Conference (COP28) in the UAE, leaders urged immediate action to combat the climate crisis, placing technology and innovation at the helm. The UAE space agency, together with 20 other space agencies, supported the inaugural Space Agencies Leaders' Summit at COP28, which focused on building technology-focused sustainable solutions to combat climate change. In addition, the Space for Climate Observatory (SCO) initiative was established in 2019, to coordinate the efforts of international space agencies and organizations in monitoring and addressing climate change. The SCO initiative focuses on collecting, analyzing, and sharing satellite-derived environmental data to identify and mitigate the impacts of climate change on a global scale, in collaboration with public and private entities [3]. With previous contributions in environmental monitoring that support public health [4–6], we propose that space technology can help global leaders and health professionals better understand how the changing Earth's systems impact health and simultaneously accelerate progress toward achieving the ambitious targets of the 2030 Agenda for Sustainable Development.

As physicians and other health professionals become familiar with the One Health concept (human-animal-environment nexus), they can adopt a holistic perspective to examine the complex global health challenges and encourage the 4C's (collaboration, communication, cooperation, capacity building) in multidisciplinary and multisectoral teams [7]. Satellite missions, such as Aura, DMSat-1, GOSAT, Landsat, MetOp, SciSat-1/ACE, and Sentinel series, collect critical data that can help monitor dynamic variations of diverse environmental parameters of atmospheric (e.g. particulate matter, greenhouse gas emissions like carbon dioxide, methane, nitrogen dioxide, and ozone), terrestrial (e.g. vegetation), and aquatic ecosystems (e.g. chlorophyll, sea salinity). This space-based information can also be incorporated with in situ, epidemiological, and qualitative data sources, to help health professionals better understand how the natural and anthropogenic ecosystem changes are influencing the planet's delicate balance of living organisms. These data support the coordination of preventive care and public health interventions using indices (e.g. Air Quality Index, AQI; Air Quality Health Index, AQHI), case studies (e.g. Global Heat Health Information Network, GHHIN), reports (e.g. National Integrated Drought Information System, NIDIS; GEOGLAM Crop Monitor), and seasonal or global forecasts for arboviral disease transmission (e.g. ArboMAP, CHIKrisk). Health professionals can hence use these Earth observations to tailor their health messaging and recommendations for populations at increased risk of exposure (e.g. elderly, youth, individuals with chronic respiratory or cardiovascular diseases) to harmful emissions, pathogens or environmental conditions.

In this editorial, we provide a few innovative examples within three areas: air quality, infectious diseases, and extreme weather events and related disasters. We demonstrate how health professionals can utilize space-based technologies and promote the One Health concept in their research collaborations, clinical and public health decision-making, and health messaging related to the effects of climate change.

Air quality

Air quality is directly linked with climate change, as higher temperatures can elicit chemical reactions that produce ozone as well as result in longer bloom seasons that increase allergens (due to pollen concentration). Furthermore, heatwaves and drier conditions can lead to wildfires and dust storms, and agricultural practices can contribute to greenhouse gas emissions like methane. Unveiled during COP28, the U.S. Greenhouse Gas Center, an interagency collaboration between National Aeronautics and Space Administration (NASA), Environmental Protection Agency (EPA), National Institute of Standards and Technology (NIST), and National Oceanic and Atmospheric Administration (NOAA), offers open-source data and tools to analyze and manage greenhouse gas emissions to combat climate change [8]. This resource provides researchers and stakeholders with the ability to access information detailing human activities' impact on greenhouse gas emissions on land and in the ocean. Another initiative that aims to improve our ability to predict long-term climate conditions is the Atmosphere Observing System (AOS), an international multi-satellite mission (led by NASA) with the Canadian Space Agency (CSA), National Centre for Space Studies (CNES), German Aerospace Center

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(DRL), and Japan Aerospace Exploration Agency (JAXA) space agencies [9,10] supporting four satellites to collect aerosol, cloud, convection, and precipitation measurements. International partners including the Canadian Space Agency (CSA) will be participating by including instruments on their own satellite as well as on NASA's satellite, that focuses on two satellites in a polar orbit (AOS-Sky, AOS-High altitude Aerosol Water vapor Clouds, HAWCsat) and two satellites in a 55° inclined orbit (AOS-Storm; AOS-Precipitation Measuring Mission, AOS-PMM) [9,10].

Other space-based technologies that will revolutionize air quality monitoring include the NASA Tropospheric Emissions: Monitoring of Pollution (TEMPO) instrument launched in 2023, and the NASA Multi-Angle Imager for Aerosols (MAIA) instrument planned for launch in 2026. TEMPO, as the first space-based instrument to monitor daytime air pollution on an hourly basis over greater North America, is in geostationary orbit and can help track harmful emissions from sources such as automobiles, wildfires, and refineries. TEMPO completes a global air quality constellation with the Republic of Korea's Geostationary Environment Monitoring Spectrometer (GEMS) launched in 2020, and the European Space Agency's Copernicus Sentinel-4 (future launch) [11]. MAIA, in collaboration with the Italian Space Agency (Agenzia Spaziale Italiana), offers an innovative partnership with epidemiologists and health organizations to assess linkages between different types of particulate matter and health outcomes (e.g. adverse birth outcomes, cardiovascular and respiratory disease, premature deaths) across selected target areas with ongoing population cohort studies. Recognizing that 99 % of the global population inhales poor air quality (exceeding the World Health Organization's guidelines), health professionals can expand their knowledge on air pollution risks, identify data portals and visualizations to illustrate air pollution trends, and strengthen health messaging with patients and community members.

Infectious diseases

Remote sensing data have been useful tools to support global health response efforts during the Ebola outbreak, COVID-19 pandemic, and polio vaccine distributions [12,13]. These environmental observations can monitor variations in vegetation, land surface temperature, and precipitation (e.g. Landsat, Terra, Global Precipitation Measurement), which can influence vector suitability and risk of disease transmission. This information can be integrated with public health surveillance data (historical and current cases) and sophisticated machine-learning models, to develop disease risk maps and algorithms for disease early warning systems (e.g. ArboMAP, CHIK-risk, Vibrio Prediction Hub). The Landsat mission, a collaboration between NASA and U.S. Geological Survey, launched the Landsat 9 instrument in 2021, as a continuation of monitoring global land surface since 1972. Landsat Next, with expected launch in late 2030 or early 2031, will have higher temporal, spatial, and spectral resolutions (6-day temporal revisit vs 16-day repeat interval of Landsat 9).

With record-breaking global temperatures affecting vector adaptation and habitat expansion on land, aquatic organisms (e.g. phytoplankton like *Karenia brevis*) and pathogens (e.g. *Vibrio cholerae*) can influence microbial growth and survival, increasing risk of enteric diseases [2]. To help monitor ocean health, the NASA Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) instrument, launched in 2023, will evaluate particle sizes and compositions of ocean color, aerosols, and cloud data, which enhance our understanding of the ocean and atmosphere exchanging carbon dioxide. This information can encourage research collaborations to assess any imbalance of water quality, which can exacerbate temperature and salinity conditions, and hence impact coral health, algal blooms (e.g. Gulf of Mexico Coastal Ocean Observing System), and coastal pathogens. Health professionals, who understand health risks associated with exposure to infectious agents, can complement their professional toolkit with existing data models, algorithms, and dashboards, which can serve as prompt alerts and tangible recommendations when in direct interactions with patients and the public.

Extreme weather events and related disasters

With increasing reports of extreme weather disasters, space-based technologies have the potential to strengthen emergency response through early detection, mitigation, and prevention [1,4]. As warmer water temperatures are linked to evaporation, increased moisture remains in the atmosphere and leads to intense rainfall. A hurricane may develop once these conditions are combined with low wind shear and pre-existing weather disturbance, and may be influenced by large-scale climate changes (e.g. El Niño, La Niña) in different basins. In addition to tropical storms, torrential rainfall leading to flooding, as well as more frequent and intense droughts, demonstrate the fragility of surrounding ecosystems amidst climate change, which can be observed with Landsat 9 images.

To support disaster management across sectors, the United Nations Office for Outer Space Affairs (UNOOSA) established the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER), to ensure that all nations can access and use relevant space-based data [6]. Notably, over 12 space agencies joined the International Charter on Space and Major Disasters, which immediately responds to disasters and provides satellite images to help assess the initial impact, monitor the disaster, and aid in recovery efforts [4,6,14]. Since its inception, the Charter has been utilized over 925 times for diverse humanitarian requests, including flooding in Brazil, Kenya, and Pakistan [14] [Fig. 1].

Furthermore, the NASA-ISRO Synthetic Aperture Radar (NISAR) satellite is a collaboration between NASA and the Indian Space Research Organization (ISRO) that aims to monitor natural hazards and environmental changes. NISAR, which is currently slated for a 2025 launch, is designed to study the changes to the Earth's surface (e.g. land deformation, ice sheet) and monitor natural hazards like earthquakes and volcanoes [15]. Thus, space-based technologies and data can enhance health professionals' ability to understand, prepare for, and respond to climate change, extreme weather events, and related disasters.

Conclusion

Recognizing that global health systems are challenged by limited resources and workforce shortages, health professionals can collaborate with community stakeholders to lead efforts that incorporate space-based technologies to enhance climate-related decision-making. Space-based tools, including remote sensing data and technologies, offer unique insights that can strengthen climate resilience, support sustainable policies, and enable real-time monitoring to address the escalating global environmental challenges.

The space sector drives innovation in climate change and global health through technologies and data analytics from space exploration and satellite monitoring. Upcoming international space collaborations, such as the Artemis missions, aim to advance scientific cooperation, including addressing health and human performance for long-duration space missions. Addressing these challenges can also support global crises related to climate change affecting our planet, such as food and water insecurity, remote healthcare monitoring and delivery, and infectious disease transmission.

To fulfill the commitments of building climate-resilient health systems, over 80 countries have pledged the delivery of climate-resilient and low carbon healthcare services [16,17]. The success of these initiatives, however, depends on accurate and comprehensive environmental data, models, and algorithms. Leveraging space-based technologies to incorporate these data and enhance stakeholder

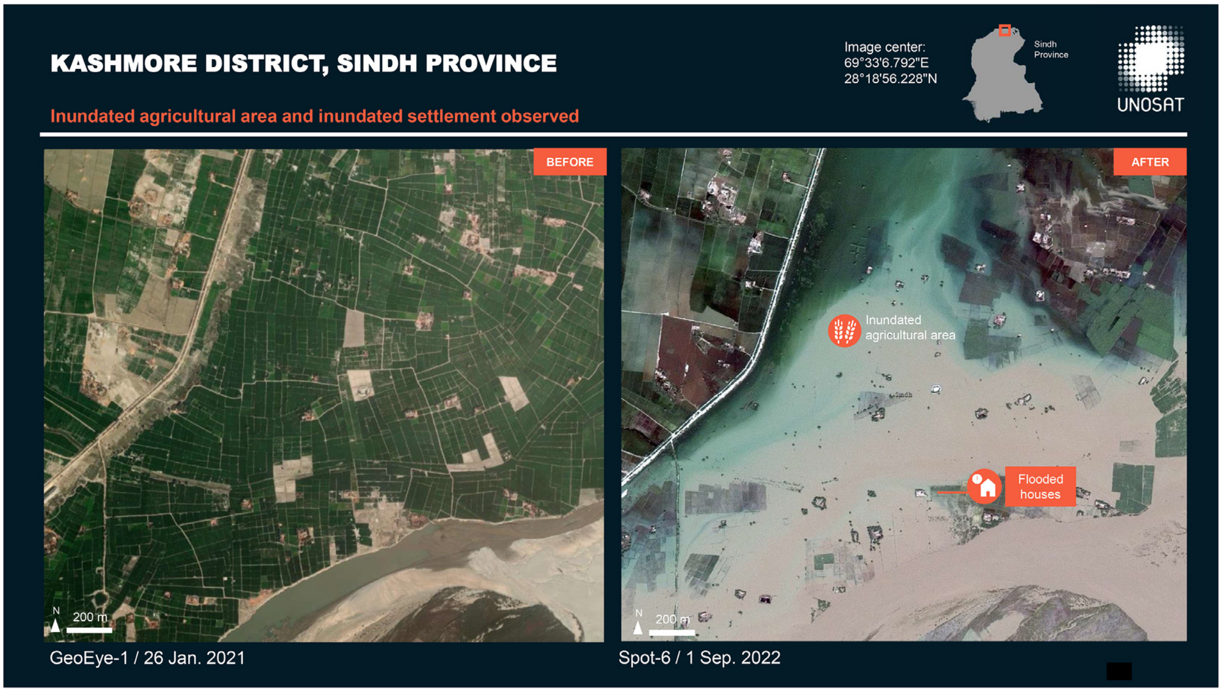

Fig. 1. An International Charter satellite image of the climate-related floods in Pakistan (Kashmore District, Sindh Province), resulting in an inundated agricultural area and settlement observed on September 1, 2022 (right), compared to non-inundated landscape on January 26, 2021. Copyright: SPOT material © Airbus DS and GeoEye. International Charter satellite images were produced with appropriate authorization by UNITAR-UNOSAT.

engagement can significantly enhance the effectiveness of these adaptation strategies and consistent inclusion of space assets in climate and health planning [18].

As global leaders accelerate progress to achieve the indicators and targets of the 17 Sustainable Development Goals, health professionals play a crucial role in shaping and executing national action plans to mitigate environmental risks to population health. By aligning activities with the six action tracks of the *One Health Joint Plan of Action 2022–2026*, health leaders can promote multidisciplinary collaborations, support collective action, and develop toolkits that combine geoscience and health data to strengthen environmental health strategies and decision-support tools and policies [7]. Robust collaborations can hasten scientific applications to integrate space-based technologies in addressing climate change, air pollution, infectious disease prevention and control, and disaster preparedness, providing a platform for scientific dialogue and a voice to vulnerable communities affected by the changing Earth's landscapes.

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The authors declare no competing interests.

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Supplementary materials

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