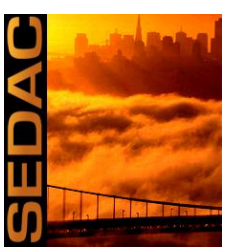

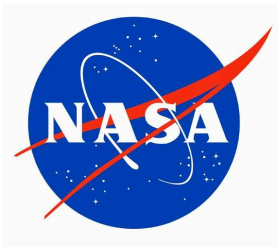

SEDAC Open Science Workshop Report

Hosted by the NASA Socioeconomic Data and Applications Center (SEDAC)

Lamont Campus, Columbia University

9 January 2024

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Columbia Climate School
Center for International Earth Science Information Network

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- Felipe Montealegre (UC Berkeley)
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- Cassie Nickles (NASA Physical Oceanography DAAC and Openscapes)
- Robert Quick (University of Indiana)
- Andy Zimmer (Montana State University)

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Executive Summary

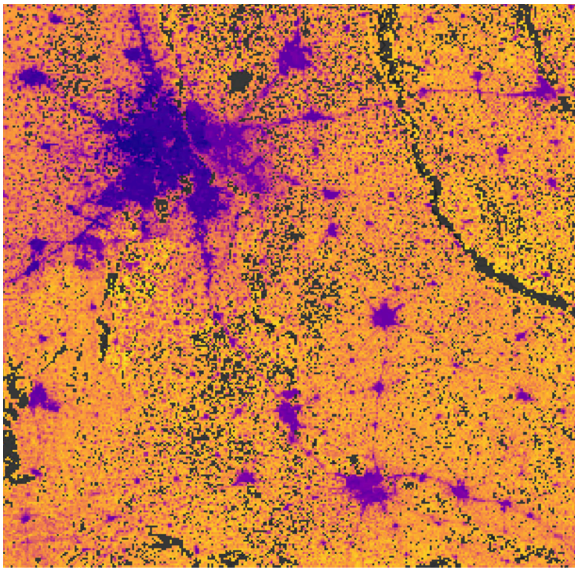
The SEDAC Open Science workshop, held on January 9, 2024, brought together 65 scientists and practitioners from a cross-section of disciplines all with an interest in how to apply open science approaches to the highly interdisciplinary study of human interactions in the environment. Expert presenters described OS approaches and workflows for the integration of satellite-derived measurements and socioeconomic data in areas such as climate hazard risk, public health, and societal impacts. Participants discussed the successes, challenges, and opportunities related to open science (OS) in scientific research, emphasizing the need for its effective implementation and engagement with stakeholders who may have different levels of understanding of OS approaches.

There was a general consensus that OS could potentially have a net positive impact on "speeding up" scientific discovery and progress in interdisciplinary research. It facilitates collaboration and removes underlying political and economic barriers that exist in scientific research. Challenges to effective and widespread OS that need to be addressed include: limited funding and human resources; limited data accessibility and interoperability; challenges to learning new practices; concerns about sharing imperfect or poorly documented code and data sets; the potential for revealing sensitive or private information; and inadvertently reinforcing existing inequalities because OS is not equally accessible and is often more "costly" in lower-resources settings. Emerging from these challenges, some key takeaways include: the need for continued funding and democratization of initiatives, since open science is not "free of charge" science, and can sometimes be more costly than traditional forms of science; the importance of governance of OS initiatives; barriers to OS adoption and resistance to change, including in academic settings; the need to promote inclusivity; and the importance of defining and addressing ethical considerations.

Despite its challenges, practicing OS can enhance decision-making, empower citizens, and bridge gaps between researchers and policymakers. Participants suggested that the next iteration of the SEDAC Open Science workshop should focus on "putting OS data to work" by involving more front-line stakeholders and decision-makers, especially often vulnerable groups who potentially stand to lose from open data, so that OS is practiced in a thoughtful manner that maximizes impact. There may also be potential for a workshop working with US-based end users of data, including public and private sector decision-makers, to better document and understand how OS principles and approaches can improve decision-making.

1.0 Welcome and Motivation

Kytt MacManus & Alex de Sherbinin (SEDAC)



SEDAC Assistant Systems Engineer **Kytt MacManus** opened the workshop with a warm welcome on behalf of the Climate School's Center for International Earth Science Information Network (CIESIN), which manages the SEDAC contract. He introduced the TOPS Code of Conduct[1] for workshop participation and went over the agenda.

SEDAC Manager **Alex de Sherbinin** spoke about SEDAC's mission and the purpose and expected outcomes of the workshop. SEDAC's mission is to produce, curate, and disseminate data focused on human interactions with the environment. SEDAC provides access to socioeconomic data sets that are complementary to NASA's satellite remote sensing assets, and functions as the information gateway between the physical sciences and the social sciences to enable a greater public understanding of the impacts of global environmental change and to enable better decision making. In the latter areas,

[1] https://doi.org/10.5281/zenodo.7626005

SEDAC meets the needs of its unique user community by serving as a bridge between science and the applied community, supporting the operational use of data. SEDAC has also had a strong role in helping NASA respond to President Biden's environmental justice executive order, [2] and its strategic plan calls for increasing access to high-quality data in the EJ domain and training in data analytics for EJ communities. Another of the pillars of SEDAC's strategic plan is to enhance existing tools and services and create new ones in support of open-source science and cloud-based user access, analysis, and applications.

SEDAC organized the workshop in the larger context of NASA's Transform to Open Science (TOPS) initiative and CIESIN's separate grant under TOPS, the Science Core Heuristics for Open Science Outcomes in Learning (SCHOOL) project. The workshop sought to better understand the unique needs among SEDAC's diverse user community and to provide the opportunity for exchange and networking among participants. The workshop was also intended to contribute to the TOPS and SCHOOL curriculum/modules, as well as future sessions of the NASA Applied Remote Sensing Training (ARSET) program.

Readers may find the following resources useful:

- SEDAC Datasets[3].
- FAIR Principles: Findability, Accessibility, Interoperability, and Reuse of Digital Assets[4].
- CARE Principles for Indigenous Data Governance[5].
- FACT SHEET: Biden-Harris Administration Announces New Actions to Advance Open and Equitable Research[6].

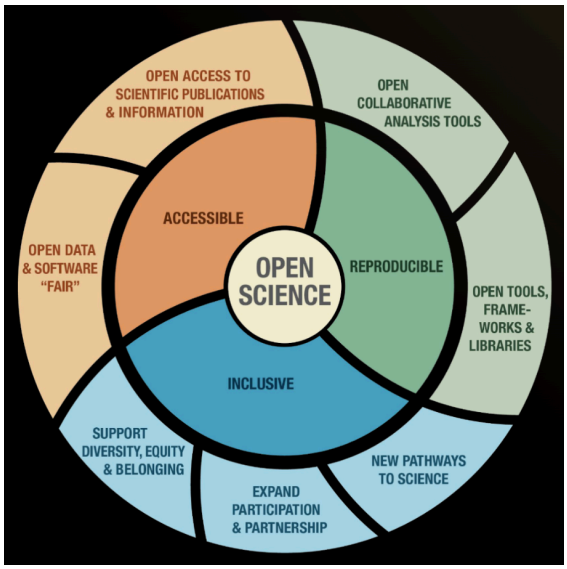
[2] https://www.whitehouse.gov/briefing-room/presidential-actions/2023/04/21/executive-order-on-revitalizing-our-nations-commitment-to-environmental-justice-for-all/ and https://www.earthdata.nasa.gov/topics/human-dimensions/social-behavior/environmental-justice
[3] https://sedac.ciesin.columbia.edu/data/sets/browse
[4] https://www.go-fair.org/fair-principles/
[5] https://www.gida-global.org/care
[6] https://www.whitehouse.gov/ostp/ news-updates/2023/01/11/fact-sheet-biden-harris-administration-announces-new-actions-to-advance-open-and-equitable-research/

2.0 Introductions to NASA Open Science Initiatives

2.1 NASA OSI, TOPS

Steven Crawford (NASA SMD)

"'Evolution' in the Open Source Science Initiative (OSSI) refers to helping communities adapt to new data science, open science, and technology."



Steven Crawford spoke on NASA's initiatives and policies that have been implemented or that NASA is rolling out to continue defining the Year of Open Science[7] for NASA and its partners. Dr. Crawford provided an update on NASA's Scientific Information Policy: NASA SciX, an open digital information system focused on literature; and Scixplorer.org, an open platform for publication and dataset identification. Amazon Web Services (AWS), where much of NASA's public data are stored and used, offers a wide range of free datasets and the ability to add more. NASA's cloud-based platforms and services, community support, and training are priorities, which NASA will be funding through the NSPIRES portal.[8]

The NASA Open-Source Science Initiative (OSSI), its evolution, and other OS initiatives address multiple dimensions to facilitate communities in their adoption of new data science skills and computing technologies. For example, the Transform to Open Science (TOPS) initiative offers an Open Science 101 Curriculum, covering core OS skills. NASA also funds workshops, conferences, open-source tools, machine learning, citizen science projects, and cloud computing. NASA emphasizes the need to share research data and software as they are developed to promote open scientific research. Cloud-based platforms like Mybinder, TOPS, OpenScapes, and GeeMap provide access to tools and computing. The Science Mission

[7] https://nasa.github.io/Transform-to-Open-Science/year-of-open-science/
[8] https://nspires.nasaprs.com/external/

Directorate (SMD) Hybrid Computing Environment will focus on providing computing resources, training, and repositories for shared data and software.

NASA's OSSI is evolving to aid communities in adopting new data science and technology through initiatives like TOPS, emphasizing education, workshops, and cloud computing for open scientific research.

2.2 TOPS-T SCHOOL Project

Kytt MacManus (SEDAC/CIESIN)

Kytt MacManus presented an overview of the Science Core Heuristics for Open Science Outcomes in Learning (SCHOOL)[9] project, part of the NASA Research Opportunities in Space and Earth Science (ROSES) TOPS-Training ScienceCore initiative, which follows up and extends pieces of training from Open Science 101. The SCHOOL project will produce online learning modules that utilize open science workflows to demonstrate the data science lifecycle in several earth science application areas. The modules emphasize inclusive teaching and interactive content focusing on teaching and learning methods such as Active Learning, using technologies such as Quarto and Jupyter books. The project will convene a workshop at the American Association of Geographers 2024 annual meeting in April 2024 to gather specifications and to hear from subject matter experts in the Health and Air Quality and Environmental Justice domains. SCHOOL has plans to develop an OS workshop for early career researchers from minority-serving institutions during the summer of 2024 in collaboration with Rob Quick, a workshop participant, of the CODATA-RDA Schools of Research Data Science (SoRDS) program.

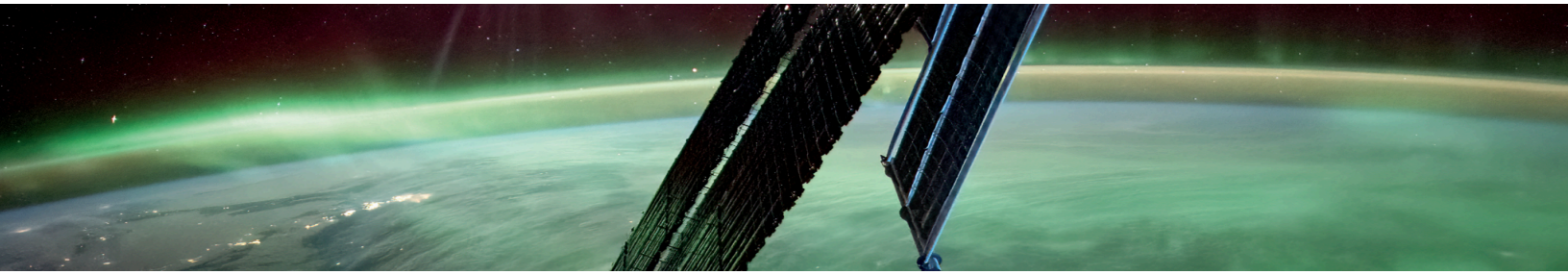
2.2 NASA Openscapes

Bri Lind (NASA/LPDAAC)

Bri Lind spoke on how the Openscapes initiative follows OS principles: More open, reproducible, efficient, diverse, equitable, inclusive, and kind. The aim is to focus on better science for the future, emphasizing inclusivity and collaboration. Openscapes facilitates a

[9] https://ciesin-geospatial.github.io/TOPSTSCHOOL/

mentor community and initiatives like the NASA EarthData Cloud Cookbook[10]. The community encourages connections and diversity, fostering creativity and knowledge. Openscapes teams and mentors collaborate to find solutions, with three main foci: Cloud-knowledge-based workshops, hackathons, and champions programs while embracing diversity both in person and online, supporting teams, and thinking and working together. The Openscapes meetings foster a kind and cooperative environment, moving away from traditional power dynamics and hierarchies. [11]



3.0 Showcasing Open Science Pioneering Work

3.1 Learning by Doing: Lessons from Three Open Science Projects

Tom Parris (ISciences)

Tom Parris showcased three collaborative projects that ISciences LLC developed and the lessons learned from each. ISciences has worked on geospatial analyses that span water, climate, human security, drought, and open-source modeling with a growing focus on open-source modeling. In the Water Security Indicator Model (WSIM)[12], a collaborative approach was taken involving analysts, hydrologists, and geospatial/software engineers, which has allowed for monthly public reporting of seasonal (projected) water surpluses and deficits.

[10] https://nasa-openscapes.github.io/earthdata-cloud-cookbook/
[11] Art by https://allisonhorst.com/
[12] https://www.isciences.com/water-security-indicator-model

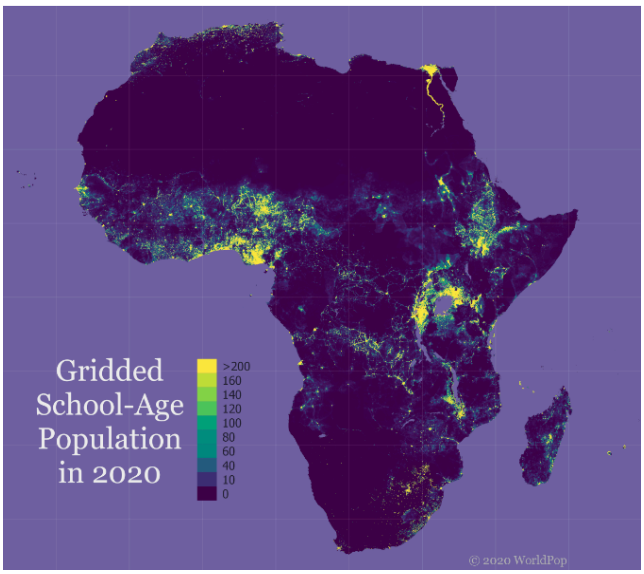
A notable tool, ExactExtract[13], has found widespread use in extracting grid cells based on vector data overlaps and population weighting, with discussions on integrating it into the Geospatial Data Abstraction Library (GDAL). Parris also presented the Data Analytics and Tools for Ecosecurity (DANTE) project[14], an effort funded by the US Army Corps of Engineers to provide an open-source software toolkit for systematic monitoring, forecasting, and analysis of environmental stresses and their impacts on security outcomes.

3.2 Open-Source Population and Demographic Data: Considerations and Integrations for Human-Environment Application

Andrea Gaughan (University of Louisville)

Andrea Gaughan showcased a variety of sociodemographic projects that involve open-source data. The projects practiced OS through spatial data integration and attention to the Findability, Accessibility, Interoperability, and Reuse (FAIR) Principles. There is, however, room for improvement to address scale issues, uncertainty quantification, and demographic data integration at various administrative levels. Initiatives discussed include the POPGRID Data Collaborative[15], which enables intercomparison of gridded population data from different sources through background information and a data comparison tool, the POPGRID Viewer.[16] She also described WorldPop[17], a project hosted by the University of Southampton on which she has been a longtime collaborator. WorldPop develops and disseminates modeled population grids, and publishes the input data and code behind the model so that it is available to other researchers to modify as they see fit.[18] The work is documented through numerous peer-reviewed articles.

[13] https://github.com/isciences/exactextract
[14] https://www.dante-project.org/
[15] https://www.popgrid.org/
[16] https://sedac.ciesin.columbia.edu/mapping/popgrid/
[17] https://www.worldpop.org/
[18] https://www.worldpop.org/tutorials/



Under National Science Foundation (NSF) funding, Gaughan worked on a project linking household survey data on food insecurity to precipitation data from the Climate Hazards Center InfraRed Precipitation with Station data (CHIRPS)[19] and land cover data and addressed several issues that arise when combining data in different formats (points, polygons, grids), representing different spatial and temporal scales, and collected at different levels (from satellites to field level). Figshare and GitHub were used to facilitate public accessibility to the datasets and collaboration with other researchers.[20]

3.3 Cloud-Based Open Science: Reflections Integrating Earth and Social Data

Carolynne Hultquist (University of Canterbury) &
Andy Zimmer (Montana State University)

Carolynne Hultquist and **Andy Zimmer** spoke on their experiences practicing collaborative OS through research that integrates Earth science with socioeconomic data. Emphasis was placed on best practices for cloud-based OS (in this case Microsoft Azure) aligning with goals of equitable data utilization. Their approach permits direct connections to social and population datasets in the cloud. Their practices for OS involve sharing intermediate products with the community and a commitment to making the process of data creation more open to the public, in the interest of transparency in data processing and validation.

They described work through a Group on Earth Observations (GEO)-Microsoft project focused on developing a global map of population exposure to extreme heat and flooding, using open-access data including the Annual Global High-Resolution Extreme Heat Estimates (GEHE).[21] Utilizing OS tools such as GitHub and Google Earth Engine, together with Azure's Planetary Computer, allows the project's analytic workflow to be shared, and fosters a culture where communication and feedback occur. However, they acknowledged some challenges, such

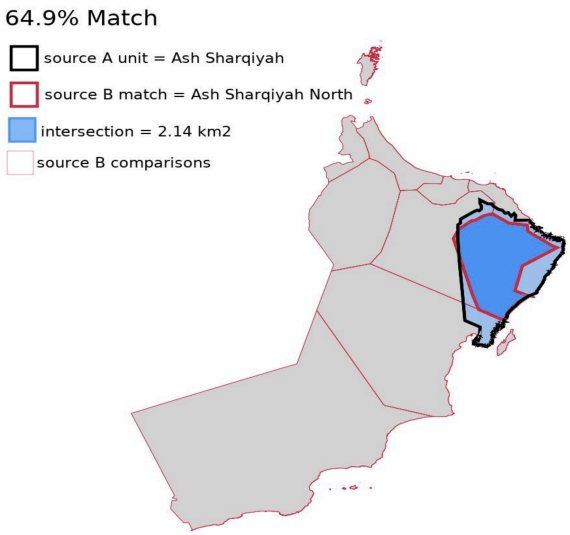
[19] https://www.chc.ucsb.edu/data/chirps
[20] https://doi.org/10.6084/m9.figshare.20459805.v1
[21] https://sedac.ciesin.columbia.edu/data/set/sdei-high-res-extreme-heat-estimates-1983-2016

as the inability to access data across multiple cloud platforms, necessitating the download and re-upload of data from one cloud platform to another.

3.4 Capturing the World's Boundaries One Vertex at a Time: the geoBoundaries Project

Dan Runfola (William and Mary)

Dan Runfola drew attention to the importance of administrative boundaries in interdisciplinary and socioeconomic research and the technical and political challenges in making these boundaries accessible. Tabular data from censuses and surveys need to be linked to accurate and authoritative boundaries at multiple levels (nation or admin0, state/province or admin1, county/district or admin2, etc.) to represent the data spatially. Applications such as population gridding index-based vulnerability and hotspot mapping rely on open access to administrative boundaries.



The geoBoundaries project aims to make administrative boundaries open data[22], with an API serving 60 terabytes per month to 750-1000 users weekly. The project compiles and processes authoritative boundary sources and undergoes nightly rebuilds to ensure validity. OS is a key factor in this research as it allows for improvements through an online community submission process. Technological approaches involve exploring Learning Landmarks Models (LLMs), satellite-based conflict identification, and addressing challenges in updating shoreline boundaries. Challenges in supporting OS arise from discrepancies in sources and methods, costs, and centralization. Future strategies for boundary development should include considering how countries define their boundaries at all levels, addressing the complexities of nesting of metadata and multi-level naming issues in administrative boundary datasets, and ongoing exploration of distributed approaches to support OS.

[22] https://www.geoboundaries.org/

4.0 Demonstrations Showcasing Workflows and Techniques

4.1 NASA Earthdata: Open Science Workflows & Techniques from Openscapes

Cassie Nickles (NASA/PODAAC)

Cassie Nickles gave an electric showcase of Openscapes, a NASA-funded mentor community committed to OS, the commonality of research, and data processing practices in the cloud. Dr. Nickles emphasized the importance of proper preprocessing in achieving accurate findings with recognition of potential pitfalls. The focus of this community is creating accessible, reproducible, and inclusive practices in OS. Out of the workshops led by Opensacpes, earthaccess[23], a Python library for NASA Earthdata, was developed to simplify access to NASA Earth data. Openscapes encourages interdisciplinary tutorials, and collaboration, and recognizes the cloud as a common ground for the public development of data and a forum to find commonality among NASA's data centers. Other notable resources developed with Openscapes include the Earthdata Cloud Cookbook[24] and the Physical Oceanography Distributed Active Archive Center (PO.DAAC) Cookbook.[25]

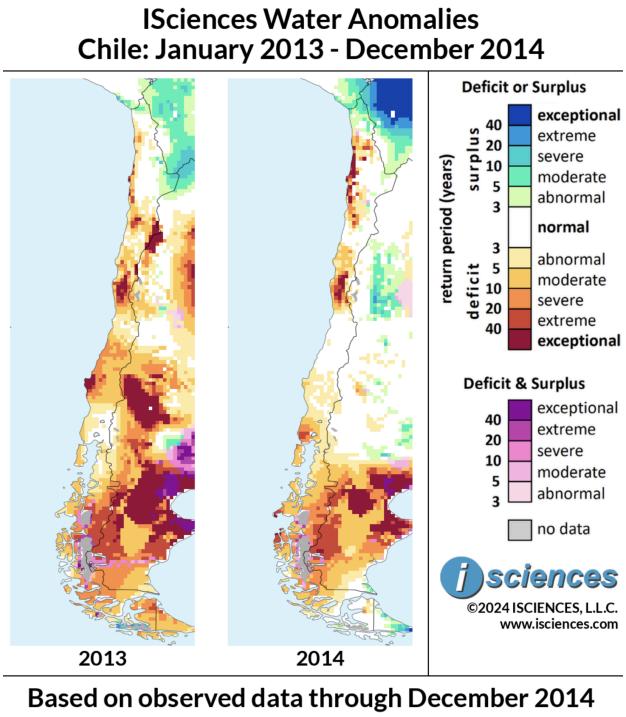
4.2 TOPS-SCHOOL WSIM (GLDAS): Lessons for Exploratory Drought and Flood Analysis

Josh Brinks (ISciences)

Josh Brinks spoke on the lessons from the Science Core Heuristics for Open Science Outcomes in Learning (SCHOOL) project, the Water Security (WSIM-GLDAS) Monthly Grids dataset[26], and practicing OS. He focused on the importance of packaging code for the replication of scientific studies accompanied by robust documentation. The SCHOOL project has made

[23] https://github.com/nsidc/earthaccess
[24] https://nasa-openscapes.github.io/earthdata-cloud-cookbook/
[25] https://podaac.github.io/tutorials/
[26] https://sedac.ciesin.columbia.edu/data/set/water-wsim-gldas-v1

transparency in team processes and decisions a priority by inviting the research community to contribute to the learning modules under development, as well as incorporating narratives, technical details, and coding for a comprehensive approach to OS in research. The development processes of these OS efforts encompass various components, including cloud data acquisition, on-the-fly visualization, and near-real-time data analysis. The tailored content is aimed at undergraduate students and above. Despite limited funding, outreach plans are in place with hopes for support from NASA, and there is openness about the challenges and potential need for assistance. The collaborative approach encourages community collaboration and seeks input and contributions for the project.



4.3 Examining Environmental Justice through Open Source, Cloud-Native Tools

Carl Boettiger (UC Berkeley) &

Felipe Montealegre (UC Berkeley)

Carl Boettiger and **Felipe Montealegre** presented a new approach to how OS can be practiced through enhanced building blocks and reduced reliance on complex integrations. They emphasized the need for more modular learning content for cloud-native systems, drawing an analogy to Lego bricks to underscore the necessity for improved building blocks. The modular design of data and tools democratizes the process, empowers a broader audience to address use cases while maintaining best practices, and allows data scientists to understand user needs more effectively. This design of data and tools aims to cater to a broader audience, reflecting on the importance of data scientists understanding user needs. The speakers acknowledged the significant impact of the Artificial Intelligence (AI) boom and the overabundance of data. The OS theme of environmental justice is incorporated to advocate for cloud-native and open-source approaches, navigating the challenges of integrating AI and abundant data. For example, the NASA TOPS-T: Cloud Native Geospatial in R & Python[27] seeks to introduce cloud-native

[27] https://boettiger-lab.github.io/nasa-topst-env-justice/

approaches to geospatial analysis in R & Python through the lens of EJ applications. Several packages have been developed as a result of these collaborative efforts, namely the earthdatalogin package in R[28] and the earthaccess package in Python[29], which streamline access to NASA data on the cloud. They emphasized that cloud-native doesn't necessarily mean "cloud computing"; rather scientists can request just the bits of data they need while working locally.

earthdatalogin

5.0 Focused Breakout Sessions

5.1 Ethical Considerations

Susana Adamo (CIESIN) &

Nita Bharti (Penn State)

Susana Adamo and **Nita Bharti** led a breakout session focused on the critical call for ethical considerations in OS research practices. The discussion focused on how to better promote inclusivity and address potential risks and impacts on vulnerable communities as a result of research. The session delved into topics of access to knowledge, economic barriers, and privacy concerns within research. Participants explored the relationship between opening access to knowledge and the financial burden on researchers that is incurred from practicing OS. Suggestions from the discussion included emphasizing the need for equitable science funding and advocating for the allocation of funding specifically for co-researchers, especially those from vulnerable populations.

[28] https://boettiger-lab.github.io/earthdatalogin/
[29] https://earthaccess.readthedocs.io/en/latest/

The discussion continued around exploring strategies to improve equity without exploiting existing inequities, the challenges of data ownership, particularly in resource-limited areas, and the need for collaboration and openness in engaging with academics raising questions about what institutional changes need to happen and how, particularly among well-resourced institutions in the "Global North" and funding agencies, to enable equitable inclusion of vulnerable populations in OS, and to prevent the exploitation of existing inequalities. The session also considered the FAIR principles, and the Collective Benefit, Authority to Control, Responsibility, and Ethics (CARE) Principles for Indigenous Data Governance, brainstorming on better ways to make them common practice in research, and the increased incorporation of traditional knowledge.

5.2 Climate Impacts and Societal Concerns

Roman Hoffmann (IIASA) &

Khandaker Jafor Ahmed (Georgetown University)

Roman Hoffmann and **Khandaker Jafor Ahmed** first presented their OS approaches to data integration on climate change impacts on demographic processes such as migration and fertility, as well as its role in driving critical infrastructure and future planning. The discussion that followed explored the intersection of climate change, environmental issues, and population dynamics. Climate data challenges were discussed, covering issues of access, expertise, model choices, and scale of analysis. An example mentioned was the Bangladesh Environmental Migration Survey (BEMS) data, highlighting the inclusive nature of OS in understanding heterogeneous climate impacts. OS provided opportunities to raise awareness about climate change-related issues. At the same time, there are challenges, including biases in access and interoperability challenges in low-income countries, issues with the cloud business model, and uneven research distribution and data integration among regions. The discussion emphasized the need to transition from science to activism and proposed a workshop empowering environmental justice researchers and communities.

The group discussed the question of whether OS can do a better job of providing information for adaptation decision-making than traditional science. Many groups such as First Street and Jupiter Intelligence are providing climate information for adaptation, yet the data and methodologies are proprietary. OS could result in more transparent, peer-reviewed approaches to the provision of climate risk information for public decision-making, though metrics would need to be developed to quantify if decisions are better using OS approaches than through closed processes and black-box algorithms.

5.3 Open Science Education

Rob Quick (University of Indiana) &
Kytt MacManus (CIESIN)

Rob Quick and **Kytt MacManus** led a discussion on OS education covering topics including inquiries into the acceptance of OS across institutions and disciplines. The discussion acknowledged the opportunities that OS education can provide, particularly its ability to foster collaboration or uncover underlying drivers of social inequity in STEM education, but a majority of the discussion focused on challenges to practicing OS education. Open Science education is underfunded, but suggestions were proposed to alter funding mechanisms to incorporate OS requirements in research and training. Democratization initiatives face hurdles in integrating new technologies into curricula, particularly for underfunded communities. Attention areas for education and training are highlighted, including integrating code throughout the life cycle for openness, and positive views on data publication for tenure and grant funding. Successful OS education must facilitate feedback and inclusivity, and overcome hurdles that prevent researchers and educators from sharing their progress and work. The session also delved into ethical considerations, touching on the distinction between access and openness, involving diverse perspectives from the ground up, and understanding varied needs.