

# AmLight - Maximizing Technological Advancements in Research and Education; Network Connectivity for Open Science between South Africa, the US, and South America

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**Abstract:** Connecting South and North America with Africa via a South Atlantic high-performance Research & Education Network (REN) has become a strategic priority. Africa offers unique biological, astronomical, environmental, geological, anthropological, and cultural resources, making it a valuable partner in global research and education. Enhanced technological and social connections between the United States, Brazil, and Africa are advancing research in multiple disciplines. The high-performance networking infrastructure of AmLight-ExP, in collaboration with the South African National Research and Education Network, provides unprecedented resources for open science research and education communities. This paper presents the architecture, capabilities, and impact of the AmLight-ExP network, highlighting its role in fostering international collaboration and addressing significant scientific challenges.

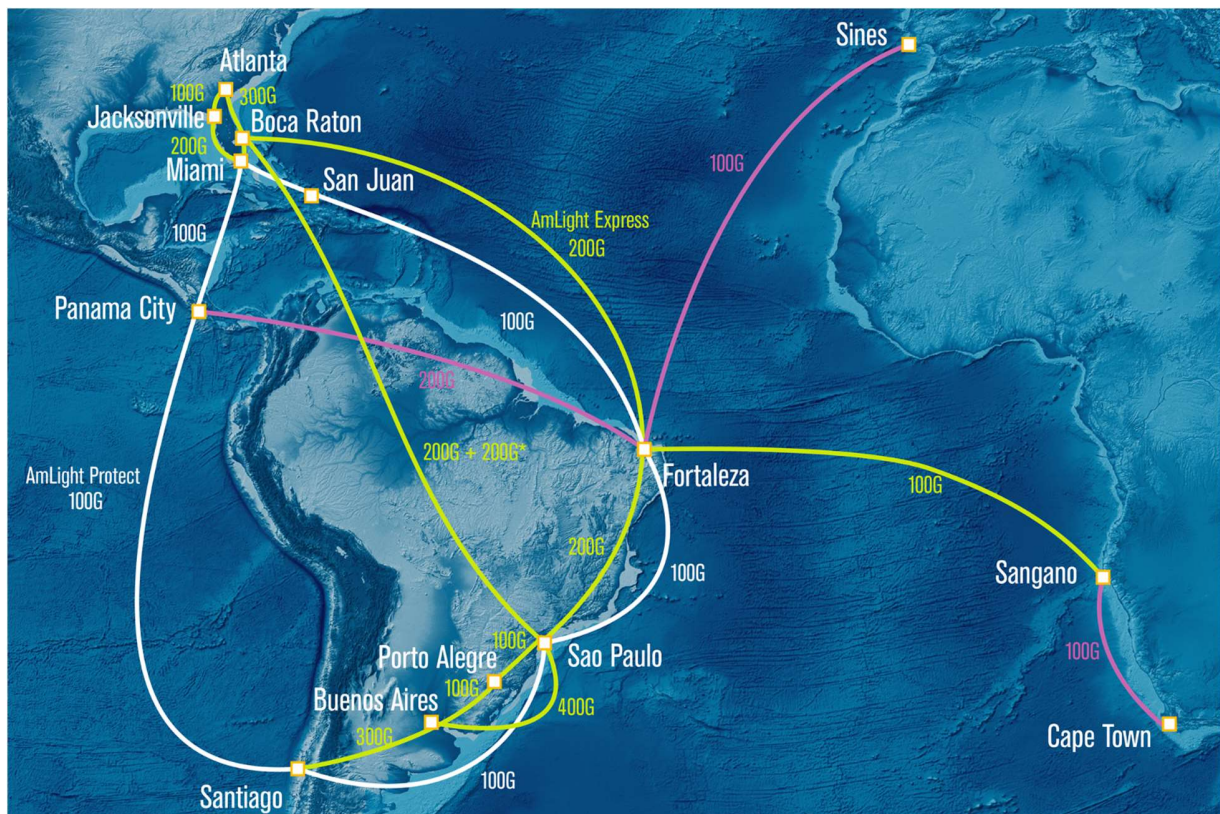
**Keywords:** Research and Educational Networks (REN), Open Science Research, AmLight ExP

## 1. Introduction

Connecting South and North America with Africa via a South Atlantic high-performance Research & Education Network (REN) has become an increasingly strategic priority [1]. Africa offers unique resources for research and education communities, including biological,

environmental, geological, anthropological, and cultural assets. Enhancing technological and social connections between the US, Brazil, and Africa will advance research in atmospheric and geosciences, materials sciences, tropical diseases, biology, astronomy, and other disciplines. High-performance networking has already shown dramatic benefits across all areas of science and engineering.

We present AmLight Express and Protect (AmLight-ExP), a collaboration with the South African NREN, which provides unprecedented resources for open science research and education communities. Overview of the AmLight Network Connectivity is represented in Figure 1.



**Figure 1 AmLight-ExP Network Connections**

AmLight ExP (*Figure 1*) is a hybrid network that utilizes optical spectrum (Express) and leased capacity (Protect) to create a reliable, cutting-edge infrastructure for research and education. It is interconnected through AMERICAS PATHway (AMPATH) and Open Exchange Points in Brazil, Chile, Panama, and other locations. The consortium members include Florida International University (FIU), the Association of Universities for Research in Astronomy (AURA) [2], the Vera Rubin Observatory [3], Rede Nacional De Ensino E Pesquisa (RNP) [4], the Rednesp (Research and Education Network at São Paulo)[5], Cooperación Latino Americana de Redes Avanzadas (RedCLARA) [6], Red Universitaria Nacional (REUNA) [7], Florida Lambda Rail (FLR) [8], Telecom Italia Sparkle [9], Angola Cables [10], and Internet2 [11].

Established in 2001, AMPATH is an Open R&E Exchange Point (RXP) in Miami, Florida, managed by the Center for Internet Augmented Research and Assessment (CIARA) at FIU.

AMPATH serves as the premier interconnection point for the US, Latin American, and Caribbean RENS. It is recognized as a major research facility by the US National Science Foundation (NSF) and the US Department of Energy (DOE), supporting international e-Science initiatives.

AmLight ExP Network currently consists of:

- 600G of upstream bandwidth between the U.S., Latin America, Caribbean, and 100G to South Africa in Cape Town.
- Open Exchange Points (OXPs) with Points of Presence (PoPs) in: Florida (3), Brazil(2), Chile, Puerto Rico, Panama, and South Africa, New: Georgia (Atlanta), Argentina (Buenos Aires)
- Production Software-defined networking (SDN) Infrastructure since 2014
- Deeply Programmable R&E Network Infrastructure
- Highly instrumented: PerfSONAR, sFlow, Juniper Telemetry Interface (JTI), In-band Network Telemetry (INT)

## **2. Network performance during SC23 & the Bridging Europe, Africa, and the Americas (BEAA) collaboration**

The roles and responsibilities of the de facto South African NREN (SA NREN) are distributed between the South African National Research Network (SANReN) group at the Council for Scientific and Industrial Research (CSIR) and the Tertiary Education and Research Network of South Africa (TENET).

The SANReN group [12] is responsible for the design, acquisition, and roll-out of national and international capacity for the South Africa R&E community, as well as the development and incubation of advanced services. It forms part of a comprehensive South African government approach to cyberinfrastructure geared at ensuring the successful participation of South African researchers in the global knowledge production endeavor.

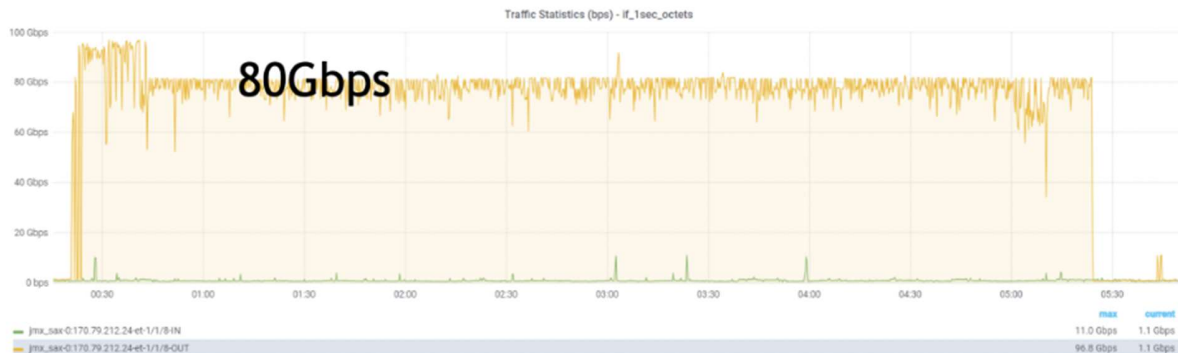
SANReN is a key component of the National Integrated Cyberinfrastructure System (NICIS) [13], alongside the Centre for High-Performance Computing (CHPC) [14] and the Data Intensive Research Initiative of South Africa (DIRISA) [15]. NICIS is hosted at the CSIR as a Centre and managed and implemented by the CSIR's Next Generation Enterprises and Institutions (NGEI) cluster [16]. TENET operates the SANReN network under the terms of a collaboration agreement with the CSIR

The Tertiary Education and Research Network of South Africa (TENET) [17]'s main purpose is to secure, for the benefit of South African universities and associated research and support institutions, internet access and Information Technology services. TENET is a service organization and is committed to service excellence and to services that are strongly aligned and consistent with the organizational requirements of the user community. TENET operates the SANReN network under the terms of a collaboration agreement with the CSIR.

Leveraging the infrastructure deployed as part of the AmLight-ExP collaboration using the South Atlantic Cable System (SACS) connecting South African to the US, the SANReN 100Gbps Data Transfer Nodes (DTNs) were demonstrated at the Supercomputing23 conference hosted in Denver,

Colorado last year. The link capacity was filled to +/- 98%. The demonstration group, “achieved an astonishing 2.5 Tb/s in data transmission between the conference venue and points in the US, Brazil, and South Africa.”

This collaboration offered a unique opportunity to work alongside the South African NREN, encompassing African involvement in the experiments while closely monitoring the performance of the AmLight-ExP’s SACS link [18][19] through various experiments arranged for the Supercomputing Conference (SC23) [20].



**Figure 2 HPC in South Africa leveraging the AmLight’s 100G link to Africa**

### **Miami to Cape Town**

The AmLight and SANReN teams completed the 100 Gbps throughput tests between the United States and South Africa through the South Atlantic Cable System (SACS) link during October and November 2023. Endpoint locations were Miami in the US and Cape Town in South Africa. The AmLight team was able to provision a 100G server in Miami for SC23 tests.

The path used for the 100Gbps test between Miami and Cape Town was via Miami - Fortaleza - Africa, and it achieved a 70 Gbps transfer rate from Miami to Cape Town. This was accomplished using the iperf3 tool, running four processes of 20Gbps each simultaneously and a Transmission Control Protocol (TCP) window of 400MB.

### **Bridging Europe, Africa, and the Americas (BEAA) – New Collaboration for shared transoceanic R&E networking resilience**

Seven leading regional and national Research and Education networks and organizations across multiple continents announced the establishment of the "Bridging Europe, Africa and the Americas" (BEAA) Collaboration, aiming to increase the resilience of their networks across a set of transoceanic links that interconnect their communities in Eastern and Southern Africa, Europe and Latin America.

The BEAA Collaboration was formalized through a Memorandum of Understanding (MoU), signed between AmLight/Florida International University Board of Trustees, GÉANT, RedCLARA, RNP, the CSIR, TENET and the UbuntuNet Alliance. All partners agreed to

collaborate for an initial period of three years by providing mutual backup through high-capacity links and resources. There has been consensus that the MoU should be extended after the initial three-year period.

The agreement enabled back-up connectivity, ensuring that advanced Research and Education collaborations among the regions would continue even in case of service outages. Participating organizations will use the capacity provided by the agreed-up arrangements to carry high volumes of data required for data-intensive research, including Earth Observation (EO) data from the European Union's Copernicus programme.

In March 2024, four submarine cables on the West Coast of Africa (WACS, Sat-3, ACE, and MainOne) were severed near the Ivory Coast, causing major internet issues across the continent [21]. The cable owners' response was swift, and much of the affected traffic quickly migrated to other neighboring cables, like Google's Equiano system. The AmLight SACS academic link showed a significant increase in traffic.

This R&E collaboration between Europe, Africa, and the Americas, or the BEAA agreement, showcased an increasingly resilient, flexible, and interconnected global R&E networking ecosystem, able to support scientists worldwide in tackling the big scientific challenges of our times.

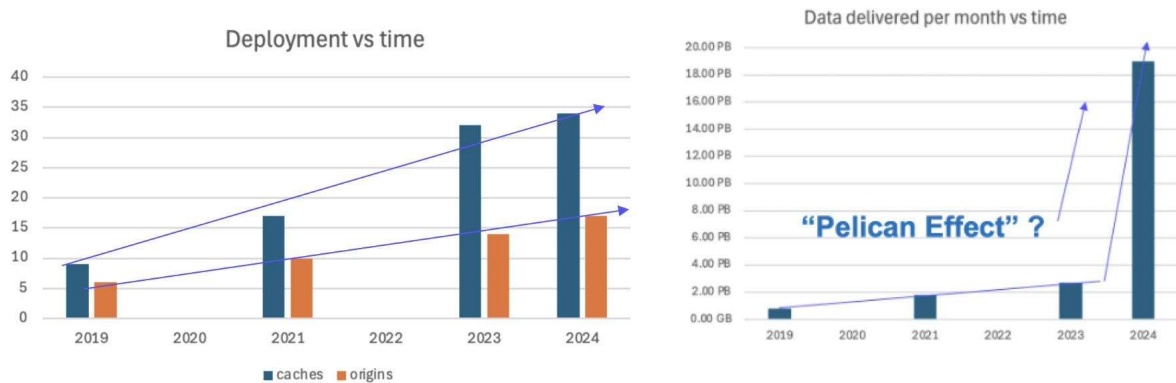
The following section outlines the science drivers currently supported or anticipated to be supported through the collaboration for shared transoceanic Research & Education Networks.

### **3. Open Science Grid (OSG)**

Open Science Grid (OSG) [22] provides common services and support for resource providers and scientific institutions using a distributed fabric of high-throughput computational services. The OSG does not own resources but provides software and services to users and resource providers alike to enable the opportunistic usage and sharing of resources. A challenge OSG faces is how to populate its caches from its Origins while experiencing the least amount of delay from the network. OSG lacks data about latency and distance between its Caches and Origins. This distance can be round-trip time (RTT) or geographical distance. Currently, 35 institutions contribute to Open Science Data Federation (OSDF), 17 Origins, and 34 caches across five continents, as shown in Figure 3.



**Figure 3 Institutions Contribute to Open Science Data Federation (OSDF) Today**



**Figure 4 Deployment statistics and Data volume delivered per month 2019 - 2024**

The Open Science Data Federation (OSDF) has experienced a 7x increase in usage over the past year (Figure 4), with its caching system saving more than 75% of a 100G transnational network pipe. Approximately one-third of all OSPool users now utilize OSDF, accounting for about 10% of total reads. The top projects using OSDF span various fields, including Biology, Physics, Math, Chemistry, and Geological & Earth Sciences. Usage patterns differ between international collaborations and OSPool users, and there is a growing usage of OSDF from outside the Open Science Grid (OSG).

By leveraging the OXP Orchestrators at the exchange points and telemetry reports, OSG users can benefit from having more flexibility to define services and path metrics, better network topology visualization, and better utilization reports.

Currently, there is a discussion on how to deploy OSG caches in South America similar to the OSG cache installed in the Sao Paulo Research and Analysis Center (SPRACE) [23] data center in 2023. Over 1.2PB jobs from Ligo, FermiLab, PATH Facility, OSPool, and others are reading from this cache. Also, there is an ongoing discussion with the OSG team and the CHPC community in South Africa about deploying an OSG data federation cache in Africa. As a next step, a larger group of South African researchers could be invited into the collaboration.

## 4. Astronomy

### **South African Astronomical Observatory (SAAO)**

The South African Astronomical Observatory (SAAO) [24] is a facility of the National Research Foundation (NRF) [25], which operates optical telescopes, outreach and research located in Sutherland under the Department of Science and Innovation (DSI). The Southern African Large Telescope (SALT) [26] is the largest single optical telescope in the southern hemisphere and among the largest in the world managed by SAAO. SALT is funded by a consortium of international partners from South Africa, the U.S., Germany, Poland, India, the U.K., and New Zealand. Other SAAO Hosted Research Telescopes are BiSON [27], KELT-South [28], LCOGT [29], MONET [30], Solaris [31], SuperWASP-South [32]. The SAAO facility is connected to the SANReN network.

### **MeerKAT / Square Kilometre Array (SKA) observatory**

MeerKAT is a radio telescope consisting of 64 antennas in the Northern Cape of South Africa [33]. MeerKAT was incorporated into the first phase of the Square Kilometre Array (SKA) in 2003 and was launched in 2018. There is an extension of 16 SKA1-MID dishes on baselines up to 17 km, with a new correlator and science processor. MeerKAT is being incorporated into the SKA. MeerKAT is now operationally oversubscribed. Many datasets are no longer proprietary and are available through the archive interface [34]. Over 324 refereed publications cite MeerKAT data [35] for significant science discoveries.

The SKA telescope consists of instruments on two continents: around 131,000 antennae will make up the SKA-Low telescope in Australia, while 197 dishes will comprise the SKA-Mid telescope in South Africa. Scientists are expected to conduct the first observations in 2024 using four dishes and six antenna arrays. The SKA-Mid dishes, each 50 feet across, will detect radio waves between 350 megahertz and 15.4 gigahertz, and the dishes will span 93 miles. SKA-Mid will also include the 64-dish MeerKAT telescope, which has already been built [36]. The goal is for construction to be complete by the end of 2030.

### **Very-long-baseline Interferometry (VLBI)**

VLBI was used to create the first image of a black hole, imaged by the Event Horizon Telescope and published in April 2019 [37]. VLBI [38] radio astronomy collaborations include data from Hartebeesthoek Radio Astronomy Observatory (HartRAO) in South Africa [39]. The HartRAO is a radio astronomy observatory located about 50 km west of Johannesburg in South Africa. It is a national research facility run by South Africa's NRF. The HartRAO facility is connected to the SANReN network. There is a Layer2 link setup between HartRAO and the European VLBI Network (EVN) correlator in the Netherlands. Their other traffic flows over Layer3 paths.

The University of Pretoria (UP) hosts a dedicated computing cluster for data processing of 10s-100s of galaxies from the VLBI instruments, however, they are currently limited by the capabilities of the computational cluster and the international bandwidth provisioned to the university. SANReN is currently working with UP to retrieve this data by installing JIVE software for VLBI on the newly installed 100Gbps in Teraco Isando datacenter in Johannesburg. The data will then be forwarded to the computational cluster for processing.

Another area of international collaboration is the Maser Monitoring Organization (M2O), where HartRAO works with groups in Japan, Poland, Russia, and the USA to detect, confirm, and monitor the flaring and periodic activity of astrophysical masers.

The current IVS correlators are at USNO in Washington DC, MIT Haystack Observatory in Massachusetts, MPiFR in Bonn (Germany), Shanghai Astronomical Observatory (China), Vienna Scientific Cluster (Austria), and University of Tasmania in Hobart (Australia).

HartRAO team is working with AmLight and TENET to find a solution to send data to its US collaborators at the National Radio astronomy Observatory's (NRAO's) Very Long Baseline Array (VLBA) correlator in Socorro, New Mexico, USA. Data continues to be sent to Massachusetts and shipped on physical disk packs. AmLight and TENET are collaborating with HartRAO and NRAO to provision a Layer2 path to Socorro to facilitate data transfers.

## **5. Cryogenic Electron Microscopy (cryo-EM)**

Cryogenic Electron Microscopy (cryo-EM) has led to a revolution in the field of biomolecular research, including research into harmful viruses such as the Human Immunodeficiency Virus and Tuberculosis, as well as cancer and bacteria. There has been an explosion of research with these technologically advanced instruments within the United States, which now houses over 100 cryo-EM. These instruments are now able to generate movies of the experiments, providing an unprecedented view of the specimen. One observing session can generate anywhere between 1-10 TB of raw data. However, there are no cryo-EMs in Africa, even though there are African researchers learning how to use these powerful instruments and developing cutting-edge research projects that involve the use of cryo-EM. There is currently an untapped potential for remote collaboration between US scientists and African scientists, especially with the research and education networks (RENs) primed to support the data volumes generated by the newest cryo-EMs. The potentially beneficial collaboration between the AmLight ExP network, SANReN and TENET with the University of Cape Town (UCT) and the US NSF and NIH-supported researchers to expand remote observation pilot programs to African researchers should be explored.

## **6. Other Science Drivers**

Multiple ongoing collaborative projects between researchers from the US, Brazil, and African communities can potentially benefit from the South Atlantic's network connections. Here, we present only a few major projects involving medical, agricultural, and genomics research.

### **Brazilian Research and Educational Network (RNP) applications**

RNP supports many science drivers that are complementary to collaboration with African research interests. An agricultural collaborative research involving pest control on army worm (*lagarta do cartucho*) attacking maize and sorghum is conducted between Brazil, the US, South Africa, and nine other African countries and supported by Embrapa (Brazilian Corporation for Agricultural

Research in the Ministry of Agriculture) [40]. Multiple ongoing collaborative medical projects with the African nations of the Community of Portuguese-Speaking Countries (CPLP) are established by the Brazilian Ministry of Health - Osvaldo Cruz Institute (FIOCRUZ) [41] in collaboration with the National Institute of Health in Mozambique on clinical research and clinical tests. CPLP consists of the following countries: African countries: Angola, Cape Verde, Equatorial Guinea, Guinea-Bissau, Mozambique, and São Tomé and Príncipe. Non-African full members: Brazil, Portugal, and Timor-Leste. The scope of those projects includes infectious diseases such as Malaria, STI, AIDS, Viral Hepatitis, and Tuberculosis. Another FIOCRUZ and Federal University of Rio de Janeiro (UFRJ) [42] project in Angola is collaborating with the National Institute for Health Research (NIHR) of the Angolan Ministry of Health de Angola, currently investigating the genotyping and resistance of HIV-1 to anti-retroviral drugs.

The Atlantic International Research Centre (AIR-Centre) [43] has agreements between the EU-BR-ZA for collaborative research activities in the South Atlantic and Southern Oceans. The ambition of the AIR Centre is to be a long-term platform for North-South, South-North, East-West, and West-East collaboration in the Atlantic towards a holistic, integrative, and systemic approach to knowledge on space, oceans, climate change impacts, energy, and data sciences while fostering an inclusive perspective to science, technology, and economic development [44].

### **National Institutes of Health (NIH)**

The National Institutes of Health (NIH) has invested about \$74.5 million over five years to advance data science, catalyze innovation, and spur health discoveries across Africa. Under its new Harnessing Data Science for Health Discovery and Innovation in Africa (DS-I Africa) program [45], the NIH is issuing 19 awards to support research and training activities. DS-I Africa is an NIH Common Fund program supported by the Office of the Director and 11 NIH Institutes, Centers, and Offices. The goal is to establish a consortium consisting of a data science platform and coordinating center, seven research hubs, seven data science research training programs, and four projects focused on studying data science research's ethical, legal, and social implications.

The research hubs [46], all of which are led by African institutions, apply novel approaches to data analysis and Artificial Intelligence (AI) to address critical health issues, including:

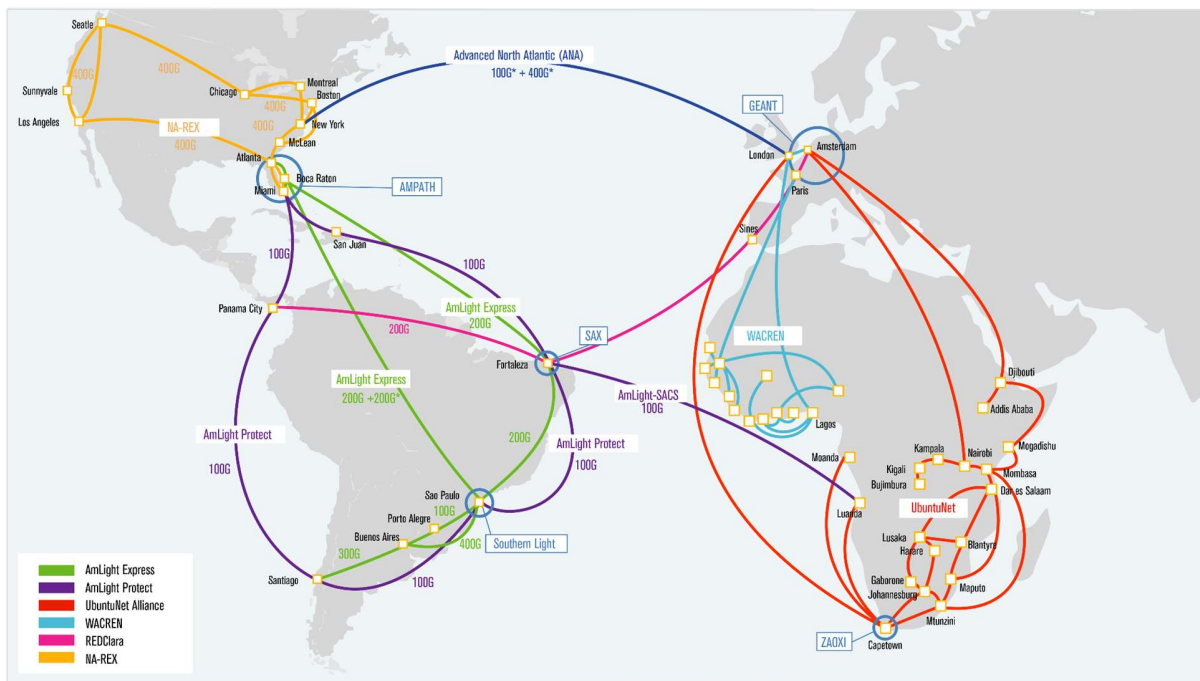
- Scientists in Kenya leverage large, existing data sets to develop and validate AI models to identify women at risk for poor pregnancy outcomes and to identify adolescents and young healthcare workers at risk of depression and suicide ideation.
- A hub in Nigeria studied Severe Acute Respiratory Syndrome Coronavirus-2 (SARS - CoV-2 and HIV to use data to improve pandemic preparedness.
- In Uganda, researchers are advancing data science for medical imaging, with efforts to improve diagnoses of eye disease and cervical cancer.
- Nigerian scientists also study antimicrobial resistance and the dynamics of disease transmission, develop a portable screening tool for bacterial infections and test a potential antimicrobial compound.
- A project based in Cameroon investigates ways to decrease the burden of injuries and surgical diseases and improve access to quality surgical care across the continent.
- Researchers from a hub in South Africa studied multi-disease morbidity by analyzing clinical and genomic data to provide actionable insights to reduce disease burden and improve overall health.

- A project in South Africa develops innovative solutions to mitigate the health impacts of climate change throughout the region, with initial studies of clinical outcomes of heat exposure on pregnant women, newborns, and people living in urban areas.

The AmLight team has engaged NIH researchers involved in these NIH research hubs to explore solutions for having the Research and Educational Networks in Africa support data transfers between the hubs and the NIH.

## 7. Conclusion and suggested next steps

AmLight-Exp represents a significant advancement in global research and education networking. By leveraging optical spectrum and leased capacity, it provides a robust and cutting-edge infrastructure connecting the US, Latin America, and Africa. The consortium's collaborative efforts, including key institutions like FIU, AURA, LSST, RNP, ANSP, RedCLARA, REUNA, FLR, Telecom Italia Sparkle, Angola Cables, and Internet2, exemplify the power of international cooperation in driving scientific progress.



**Figure 4 NRENs Interconnecting Higher Education institutions**

The successful demonstrations, including the 100Gbps throughput tests between the US and South Africa and the turbocharging of the WACS/SACS/AmLight link during the SC23 conference, underscore the network's capability to support data-intensive research across diverse fields. The BEAA collaboration further enhances network resilience, ensuring continuous connectivity for advanced research even during service outages. Regional RENs, such as WACREN and UbuntuNet Alliance (Figure 4), continue interconnecting Higher Education institutions across Africa which can further enable the collaborative research across continents.

Moreover, deploying OSG caches in South America and potential expansions to Africa highlight the network's flexibility and critical role in supporting high-throughput computational services. Collaborative projects in astronomy, medical research, agriculture, and genomics between the US, Brazil, and African nations demonstrate the network's broad impact.

In conclusion, AmLight-ExP not only enhances the technological infrastructure for research and education but also fosters a collaborative ecosystem that bridges continents, enabling scientists worldwide to tackle some of our most pressing scientific challenges. The ongoing efforts to integrate advanced instruments like cryo-EM and VLBI further exemplify the network's potential to revolutionize research methodologies and outcomes.

## 8. Acknowledgments

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