

Session 6: Contributions of African Geodesy: summary notes

GGOS-Africa 2026 Workshop, Nairobi · Tuesday 6 October 2026 · 14:01–15:04 EAT

Moderator: Bruno Kyamulesire

There is no Zoom transcript for this session. These notes are written from an automatic (whisper.cpp) transcript of the recording audio, cross-checked against the speakers' slides. Names, numbers and dates are less reliable than for the morning sessions. Please check against the recording before quoting anyone. The talks were given in a different order from the programme, and the interactive discussion was moved to Wednesday morning because of the Nairobi National Park excursion.

Key points

- **Astronomy and geodesy depend on each other.** Astronomers need precise position and time; geodesy needs the stars (now quasars) for position, time and Earth orientation. HartRAO in South Africa grew from a NASA deep-space tracking dish into a fundamental geodetic site, largely through **hosted equipment and donated or repurposed dishes**.
- **Ghana's converted telecom dish (Kuntunse) is now an operational radio astronomy and VLBI observatory**, training students from several African countries. More VLBI tests are planned for next year.
- **A joint astronomy–geodesy meeting at the IAU General Assembly next year (Rome)**, with a reciprocal session planned at the IAG.
- **Geodesy has redrawn Africa's plate map.** It now has Nubia, Somalia and smaller blocks (Victoria, Rovuma, Lwandle, and a possible "San" block). Nubia deforms at about 0.4–0.7 mm/yr, while the East African Rift moves about 4–5 mm/yr. So AFREF must decide between a **static, semi-dynamic or dynamic frame**. A new AFREF solution and tectonic model are planned for **2027–2028**.
- **Space weather is both a hazard and a research opportunity for geodesy.** Ionospheric scintillation (worst near the equator in the evening), satellite drag and power-grid effects all degrade GNSS. African groups are building TEC maps and machine-learning forecasts. GGOS has a Focus Area on Geodetic Space Weather Research.

Opening (Bruno Kyamulesire)

- The morning showed where politics matters. The afternoon is about applications, building real capacity, and attracting experts across generations.
- The astronomy talk went first to save time; Saria arrived slightly late.

Talks

Roelf Botha, Emmanuel Proven-Adzri and Jack Radcliffe: The Contribution of African Geodesy to Astronomy

Roelf Botha (HartRAO, South Africa): history and the South African story

- Astronomy goes back over 5,000 years; some of the oldest human structures align with solstices and equinoxes.
- **Alexandria** was the hub:
 - Aristarchus proposed the first heliocentric model.
 - Eratosthenes was the first known to calculate Earth's circumference and axial tilt, and founded scientific chronology.
 - Hipparchus invented geographical coordinates and ways to convert them to celestial ones.
 - Ptolemy compiled a star catalogue of about a thousand stars.
 - Hypatia improved instruments such as the astrolabe, which was used for time, latitude and even surveying heights.
- **A two-way relationship:** "astronomy requires geodesy, and geodesy requires astronomy" — they are "married to each other".

- **South Africa:**
 - The Royal Observatory at the Cape of Good Hope (1820) followed Lacaille’s mapping of the southern skies in the mid-1700s, needed for navigation around the Cape.
 - The observatory supplied the time service. The **noon gun on Signal Hill** in Cape Town is still triggered by the observatory, now from an atomic clock.
 - The Cape datum was anchored at Buffelsfontein, with time signals telegraphed from Greenwich to the Cape transit circle.
- **HartRAO timeline:**
 - The 26 m dish was started in 1960 as NASA Deep Space Station 51, for tracking probes and Moon missions (one of three stations around the globe for continuous coverage).
 - 1971: the **first intercontinental VLBI** (South Africa–Australia), part of early evidence for continental drift. It also supported Apollo 15.
 - 1973: NASA closed the station and it became a radio astronomy observatory under the South African government; hydrogen maser from 1995.
 - 1996: NASA GNSS reference station (exactly 30 years ago last month).
 - 1999: NASA mobile laser ranger (MOBLAS-6).
 - 2008: the 15 m SKA prototype dish, built for the SKA bid and donated, converted to geodetic VLBI.
 - About 2016: a Russian satellite laser ranger.
 - Government funding awarded about 2014 for a VGOS telescope; first fringes last year.
- **Hosted equipment:** “We didn’t need to pay money for this. They came and put it down at our site because we had a good site.” South Africa pays for operation and maintenance labour, a far better deal than building such instruments itself, and gains data and expertise.
- Hopes to see Kenya join this effort soon. The IAG and IAU structures (reference frames, Earth rotation, IERS, IVS) show how closely the two fields are linked.

Emmanuel Proven-Adzri (Ghana): the Ghana Radio Astronomy Observatory

- The observatory is a former telecom satellite dish from the 1980s, made redundant by fibre.
- It was converted through the SKA Africa partner programme, which required South Africa to include eight other African countries; this is how Ghana joined.
- **Commissioned in 2018.** It is now a fully operational radio astronomy observatory that also does VLBI (first in 2018). Further VLBI tests were delayed by technical issues and are now planned for next year.
- It also hosts a small antenna that downloads satellite data for US partners.
- It acts as a regional training centre: since 2020 it has trained students from many African countries (including Madagascar and Namibia).
- **New low-cost transient array telescope:** cheap 1.5 GHz antennas on fabricated arms, built in about a week. It gives a real-time view of transiting sources, including GNSS satellites, and is good for hands-on teaching.

Jack Radcliffe: joint astronomy–geodesy meeting

- A session is being organised at the **IAU General Assembly next year in Rome**, with two days on astronomy and geodesy together, and a reciprocal meeting is planned at the IAG.
- The aim is to show that astronomy, geodesy and space science are “stronger together”, and to keep geodesy at the front of policymakers’ minds. QR codes were on the slides.

Moderator: astronomy, geodesy and space weather need a “horizontal relationship” — “the observatories have the infrastructure, geodesy has the equations, space weather has the money.”

Elifuraha Saria: Contribution of African Geodesy to Geodynamics

(Ardhi University, Tanzania)

- **What geodesy measures:** position, velocity, non-linear and transient motion, uplift and subsidence, strain, gravity change (mass redistribution), Earth rotation, and atmospheric and hydrological signals. Tools: GNSS, DORIS, VLBI, gravity and InSAR.
- **Africa’s tectonics:**
 - Dominated by the slow rifting of **Nubia and Somalia**, with smaller subplates (Victoria, Rovuma, Lwandle) quantified about a decade ago.

- Collision with Arabia and Eurasia forms the Atlas mountains.
- Divergent boundaries at the Mid-Atlantic Ridge, Southwest Indian Ridge and East African Rift are tearing the continent apart.
- **From geology to geodesy:**
 - Before 2000, plate models (1960s–70s, NUVEL-1/1A) relied on marine magnetic anomalies and treated Africa as a single plate.
 - REVEL (2000) began adding geodesy. The first GNSS studies (Sella 2002; Prawirodirdjo and Bock 2004) separated Nubia and Somalia using only a handful of sites. Fernandes (2004) and Nocquet (2006, with DORIS) followed.
 - Calais et al. (2006) used earthquake slip vectors to identify the **Victoria plate**, with just one GPS site (Mbarara, Uganda).
 - Stamps et al. (2008) combined geology, slip vectors, DORIS and GPS into a full kinematic model.
- **Saria et al. 2013–2014:**
 - About 40 sites define Nubia (WRMS about 0.6 mm/yr).
 - Lwandle could not be determined at first: only one site in Madagascar, and at least three are needed. Training and new stations in Madagascar later helped.
 - The 2014 solution used 149 sites including campaigns. Stamps et al. (2021) extended it.
- **Implications for AFREF:**
 - Wedmore et al. (2021) found a distinct “San” block within Nubia, deforming at 0.4–0.7 mm/yr.
 - For a 2 cm survey tolerance, Nubia’s internal deformation takes about **30 years** to show, so anchoring AFREF on Nubia works. In the rift (Tanzania–Ethiopia, about 4–5 mm/yr) it takes only about **4–5 years**.
 - AFREF must therefore choose a **static, semi-dynamic or dynamic frame**.
- **Tanzania** is the most tectonically affected country, and its CORS network (about 22 stations) and Uganda’s are adding data.
- **Next AFREF project:** a more rigorous GNSS computation (IGS plus national CORS) by African analysis centres, planned for **2027–2028**. It will test whether a 7-block model (Nubia, San, Somalia, Victoria, Rovuma, Maasai, Lwandle) or fewer blocks fits best, giving an AFREF tectonic model.
- **Localised deformation:**
 - Volcano inflation and deflation (a volcano in Alaska; **Oi Doinyo Lengai**, Tanzania, the TZVOLCANO project).
 - InSAR for the 2009 Karonga (Malawi) earthquakes and the 2008 Lengai/Arusha events. InSAR showed the 2008 source was a nearby dyke, not the fault first mapped in the field.
 - The full earthquake cycle (inter-, co- and post-seismic) can be seen in GNSS time series (Tohoku 2011; Tanzania 2008).
- **GRACE and GNSS:**
 - Seasonal vertical GNSS signals match GRACE equivalent water height, for example at Ouagadougou on a station from the AMMA meteorological project.
 - Removing GRACE-derived loading reveals patterns (West Africa about 2 mm/yr, subsidence in the east).
 - ITRF now models such seasonal signals, but many issues remain before GRACE can directly correct GNSS.
- **Conclusion:** geodynamics in Africa improves as data and time spans grow. National CORS plus IGS data should give a new AFREF solution in 2027–2028, through African analysis centres, GGOS and UN-GGIM.

Paul Baki: Impact of Space Weather on Geodesy

(Physics, Earth and Environmental Sciences, Technical University of Kenya)

- **Space weather** means conditions between the Sun and Earth that affect space-based and ground technology.
- **Causes:** the solar wind, solar flares (X-rays arriving at light speed) and coronal mass ejections (12 hours to days). When the fields line up, the magnetosphere lets material in, causing geomagnetic storms.
- **The ionosphere** (about 50–1,000 km; D, E and F layers) affects radio propagation, and low-Earth-orbit satellites fly through it.
- **Impacts:**
 - Satellite electronics (a South African satellite once suffered space-weather damage) and astronauts.

- Polar flights.
- Geomagnetically induced currents in power grids that overheat transformers. Kenya’s “epileptic” power supply is partly space weather, and outages leave gaps in GNSS data.
- Undersea cables and oil pipelines.
- **Thermospheric drag** on LEO satellites, which complicates precise orbit determination.
- **Monitoring:** spacecraft at L1 (DSCOVR), GOES, SOHO/SDO; ground magnetometers, neutron monitors, solar telescopes and sudden-ionospheric-disturbance monitors. Effects can be seen but not yet predicted.
- **The geodesy-space weather nexus:**
 - Scintillation and TEC spikes cause cycle slips and positioning errors, sometimes skewed in particular directions, including vertical.
 - Both communities use GNSS. Space-weather researchers often mount receivers on rooftops, which is not good enough for geodesy.
- **African work:** TEC maps by region and season. Near the equator, errors are often worst in the evening. A colleague (Daniel) is using machine learning, aiming eventually to forecast.
- **Mitigation:** dual- and multi-frequency combinations remove first-order ionospheric delay, with higher-order corrections for ultra-precise work; IGS global ionosphere maps; network RTK/PPP corrections; solar indices (F10.7, Kp) in orbit propagators.
- GGOS has a **Focus Area on Geodetic Space Weather Research**. Reference: Cilliers and Lotz (2022), *Space weather impacts on Geodesy*.

Close of Day 2

- **The discussion was deferred:** questions for the Session 6 speakers should be noted and raised **Wednesday morning**. The day starts at 09:30 with about 30 minutes for this.
- At **10:00 Wednesday**, participants join the other GGOS affiliates at GGOS Days for their first session.
- Six vehicles were waiting for the Nairobi National Park excursion; participants needed identification documents to enter the park. The social dinner followed.

Actions and follow-ups mentioned

- Questions for Botha / Proven-Adzri / Radcliffe, Saria and Baki to be raised in the Wednesday 09:30 discussion slot.
- Joint astronomy–geodesy session at the IAU General Assembly 2027 (Rome) and a reciprocal one at the IAG; details via the QR codes on the slides.
- New AFREF solution and African tectonic block model planned for 2027–2028, through African analysis centres.
- Ghana VLBI tests planned for next year.