MVCORS – the first permanent GNSS network of Maldives

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SUMMARY

The advent of the modern space-geodetic techniques, namely GNSS (Global Navigation Satellite Systes), has revolutionized how surveying and precise positioning are carried out nowadays in a much more efficient way. In addition, CORS (Continuously Operating Satellite Systems) are also nowadays the norm all over the world to define and maintain national reference frames. In fact, the national reference frame plays a vital role in the economic development of any country by delimiting and monitoring changes in property, environment, and biodiversity. It is a pivotal infrastructure by providing the foundation for all geo-referencing activities. Consequently, it is essential to ensure its consistency and accuracy over the entire territory of any given country.

The Republic of Maldives is formed by 22 geographical atolls comprising of about 1200 islands (with about 200 islands inhabited) spread over an area of 90 000km2. Most of the islands are not inter-visible which has prevented the creation of a classical national datum. The only classical datum for Maldives was Gan 1970 based on the International ellipsoid but it was lacking a proper and national materialization.

Foresight Surveyors has initiated in 2021 the installation of MVCORS, a network of CORS stations, currently with 8 stations, distributed all over Maldives, with the aim to optimize their surveying activities. But MVCORS has also the potential to define and materialize the first national reference frame of Maldives.

This work details the current status of the implementation of MVCORS, with a particular focus on the physical installations in a difficult environment and also the remote management of the stations are being carried out through dedicated software. The computation of the coordinates of the stations with respect to the latest realization of ITRS (International Terrestrial Reference System) with the goal of have a single and consistent reference frame all over the territory of Maldives is also discussed. Finally, the link with a future national vertical datum, which is a paramount issue in Maldives, is also examined in detail.

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1. INTRODUCTION

Nowadays, the realization of the national reference frame through a network of CORS (Continuously Operating Reference Stations) is the approach used by most of the countries worldwide. It permits to guarantee continuously the quality of all reference points by monitoring their behaviour (which is not possible at geodetic markers which can be destroyed, vandalized, moved) and to optimize resources since the CORS sites can also be used as reference for local geo-referencing activities, permitting that a single equipment (rover) be sufficient to acquire the position of points (in real-time or post-processing) with respect to the national reference frame without the need to access geodetic passive markers that are often at locations with difficult access.

The Republic of Maldives lies in two rows of atolls in the Indian Ocean that stretches for approximately 820km from 7 degrees north to 1 degree south, with the greatest width from west to east being 130km. The territory embraces a total area of 90,000 sq km but that includes the sea, which forms 99.6% of the Maldives. The land area of all the islands amounts to 298 sq km.

This dispersion, with most of the atolls not inter-visible led that no national-wide datum has been established in the country (Mugnier, 2006). The only geodetic datum considered for use onshore over the entire territory of Maldives was Gan 1970, referenced to the International 1924 ellipsoid and the Greenwich prime meridian. However, it was defined by "information from various industry sources" (IHO, 2022) and its relation with WGS84 is very inaccurate: the transformation published by NIMA (1997) based only in three translations have errors of ± 25m.

The approach until the present to take advantage of the modern geodetic and topographic techniques of surveying is to create local datums at each islands / group of islands. However, such approach, although sufficient to many local applications, prevents a consistent integration of the geo-information acquired in the country, particularly applications that require a national management.

2. MVCORS

MVCORS is a project promoted and funded by Foresight Surveyors. This company focuses on providing geo-referencing services all over the territory of the Republic of Maldives. They have soon realized that the implementation of a network of CORS stations would be the most efficient way to provide accurate reference points for dissemination of RTK corrections in the most economic active atolls and also to permit the densification of control episodic points using the CORS as reference at more distant locations.

Figure 1 shows the entire MVCORS once the project will be fully completed (left) and also the eight stations already installed in the Phase I (right). It is foreseen a total number of 21 stations covering the entire territory of Maldives.

Figure 1 – Distribution of the MVCORS stations when the project has been fully completed (left) and current distribution of installed stations (right)

The equipment for all stations in Phase I has been provided by ComNav, a partner of Foresight Surveyors. The antennas (CNTAT600) are of choke-ring type having official calibration at the latest IGS (International GNSS Service) antex file (IGS, 2022).

Figure 2 shows three examples of the installations of the Phase I stations. The antennas are mounted using self-centering mount devices that guarantee that the antennas are horizontal and proper oriented to North.

To manage the communications and the management (conversion to RINEX, storage, and dissemination) of the acquire data, Foresight Surveyors has partner with MIRASpaco, a spin-off company of University of Beira Interior in Portugal. MIRASpaco has provided an integrated solution that, making using of routers with proprietary firmware, permits the remote access to the stations without the need of a public static IP thus significantly lowering the costs. This solution also incorporates MIRAnet (cf. Figure 1), which is a management software for CORS networks that also incorporates a caster allowing the access also to the RTK solutions for all MVCORS stations.

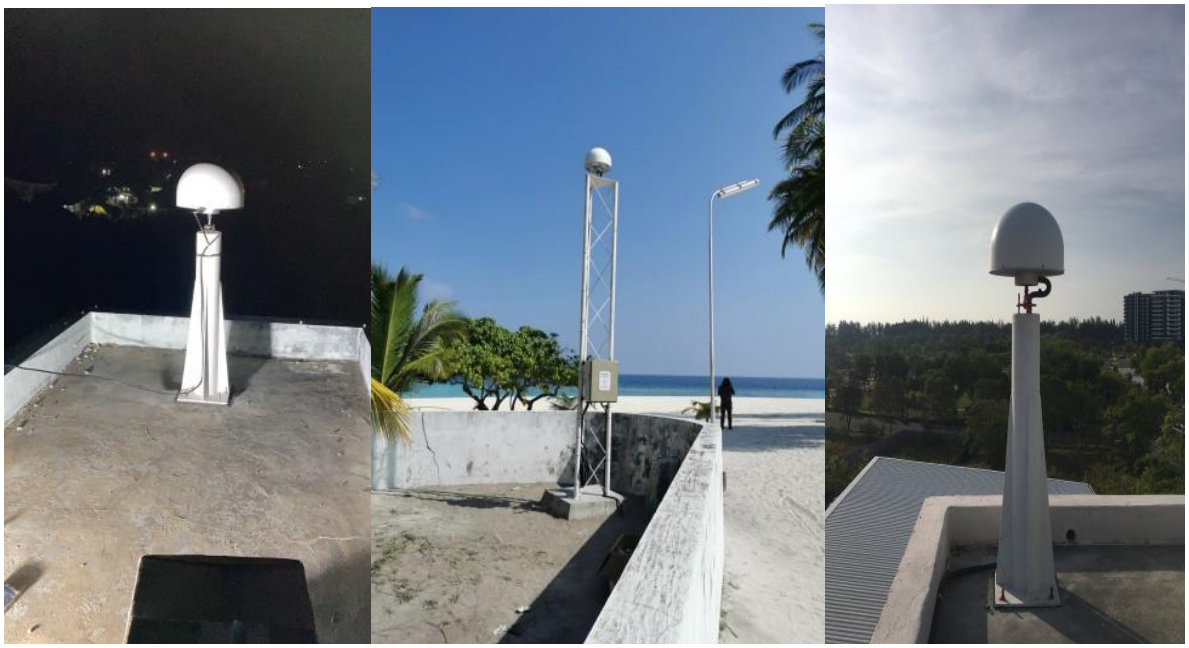

Figure 2 – Examples of MVCORS installations in Addu (ADDH), Kudarikilu (KDRK) and Malé (MALC), from left to right

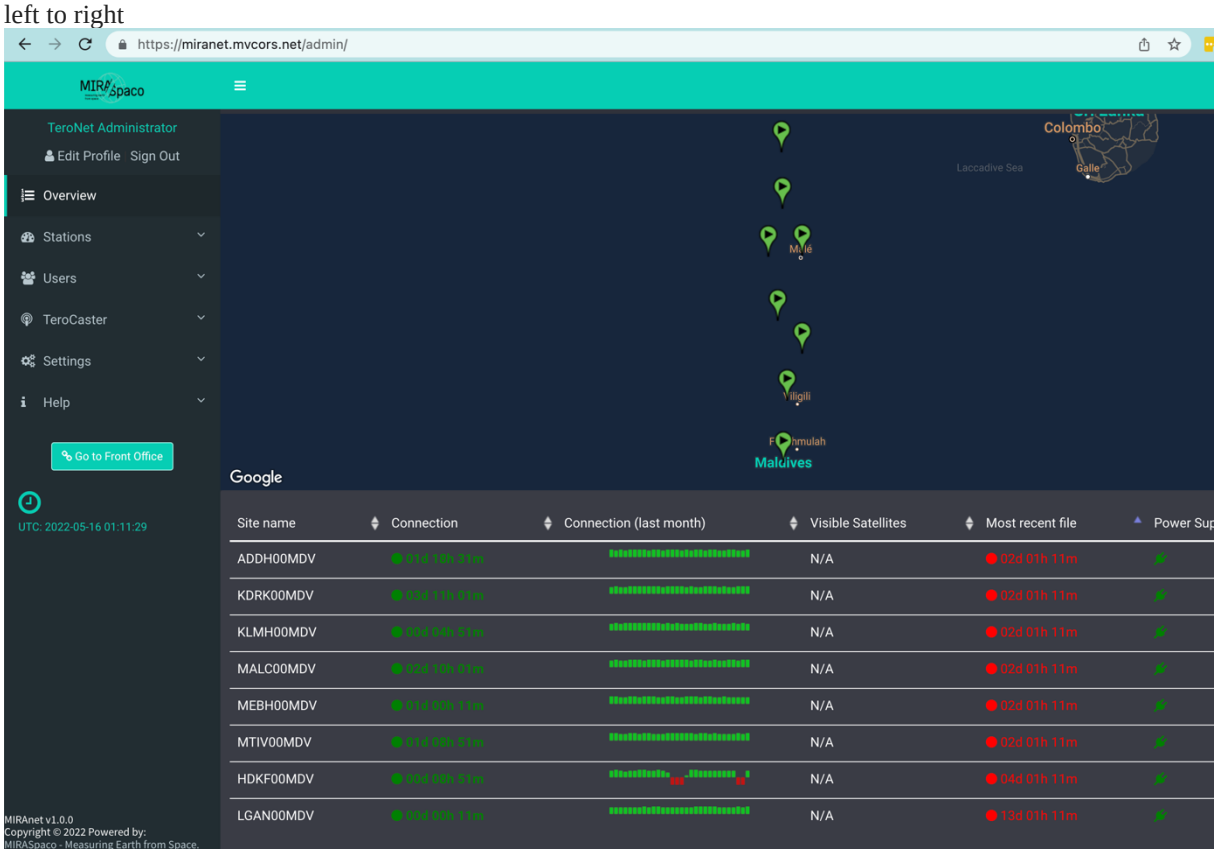

Figure 3 – MIRAnet front-end for the management of the MVCORS network.

3. ESTIMATION OF MVCORS COORDINATES

The normal procedure to materialize a national reference frame with respect to the latest realization of ITRS, which is currently ITRF2020 that has been released in April 2022 (ITRF2020, 2022) through a network of CORS is by selecting a period of several days (1-2 weeks) where the data for all stations are simultaneously collected and processed. The positions of these stations are estimated with respect to the ITRFxxxx for each day with the best position computed by performing a weighted average (with outlier removal) of the daily positions for the selected period. Any displacements (few tenths of millimeters) due to tectonic motions can be neglected and normally the reference epoch is selected to be the middle of the observation period.

In the case of MVCORS, the positions for the stations of Phase I were first computed with respect to ITRF2014 because there are still not products (orbits and clocks) in ITRF2020 that permit the direct computation in this global reference frame. The coordinates were finally computed with respect to ITRF2020 by applying the provided transformation parameters between ITRF2014 and ITRF2020 (ITRF2014toITRF2020, 2022).

Figure 4 illustrates the procedures to compute the unique combined solution for MVCORS with respect to ITRF2014.

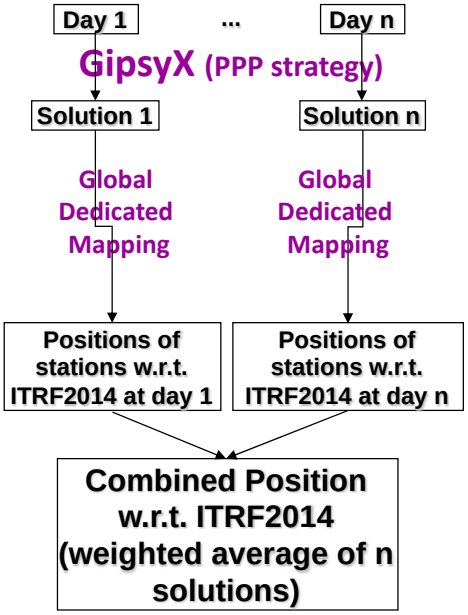

Figure 4 – Steps to compute the solution w.r.t. ITRF2014 for all CORS stations

A unique set of positions is computed for a selected reference epoch (normally in the middle of the campaign) by combining several daily solutions into a unique combined solution. There are two main reasons to perform this step:

- The estimated combined position using several days is more reliable than a single daily estimate (it is assumed that the change of the site position due to tectonic motions is negligible for a period of a few weeks), since daily outliers can be identified and removed during the combination phase.

- The daily repeatabilities provide a more realistic quantification of the (combined) position solution uncertainty than the value derived from the daily solution formal uncertainties (which are too optimistic).

The daily solutions of the positions of the permanent GNSS stations were computed with the GipsyX software package using the PPP - Precise Point Positioning strategy. The most recent version of this software was used (Bertinger et al., 2020). PPP is very efficient from a computational point-of-view (the required computational resources grows linearly with the number of stations) and it provides similar quality as other software packages (e.g., GAMIT or BERNESE) and approaches (e.g., double differencing).

The mapping into ITRF2014 of the daily solutions was carried out by estimating a seven-parameter Helmert transformation using several dozens of IGS (International GNSS Service) stations globally distributed as reference. The core of this reference network is the set of IGS14 stations.

Finally, the unique solution for all CORS stations, computed using as reference epoch the middle of the campaign of observations was estimated by performing a weighted average of the daily solutions, using dedicated scripts developed at University of Beira Interior.

Table 1 shows the weighted root-mean-square of the residuals for the combined solution using a period of 15 days (April 2022, 13-28). It shows very good repeatabilities with 1-2 millimetres in the horizontal components and few millimetres in the vertical component, leading to the conclusion that these stations are stable and capable of providing a very robust materialization of a new reference frame for the Republic of Maldives.

Table 1 – r.m.s. of the residuals (daily solutions minus averaged solution) per coordinate and number of used solutions

SITE	E (mm)	N (mm)	U (mm)	# Days
ADDH	1.9	1.6	6.1	15
HDKF	1.8	1.6	4.3	15
KDRK	1.9	0.9	5.2	14
KLMH	1.9	1.2	5.1	15
LGAN	2.0	1.5	4.0	13
MALC	1.9	1.6	6.0	12
MEBH	1.3	1.4	5.7	15
MTIV	1.4	1.4	3.8	14

4. CONCLUSIONS

MVCORS, the first CORS network of Maldives, is capable to permanently realize a new and modern reference frame for the entire Republic of Maldives.

The eight installed CORS stations installed in the Phase I are already serving the geo-referencing activities in Maldives providing a very accurate and uniform datum that can be accessible by any user (https://miranet.mvcors.net).

The MVCORS network will be further capable to assist the Republic of Maldives in monitoring natural hazards, particularly related with sea level variations, when a consistent geoid undulation model will be implemented for the entire country. The usage of global models has uncertainties at decimetre level as shown in Figure 5 where can also be observed that there is a 5m difference in geoid undulation between the north and the south part of the Maldives. In addition, the difference from the centre of each atoll and the outer boundary is also of the order of 0.5 m. This demonstrates the need for a geoid model to convert GNSS derived ellipsoidal heights into orthometric heights and make full use of MVCORS as support of all geo-referencing activities in Maldives.

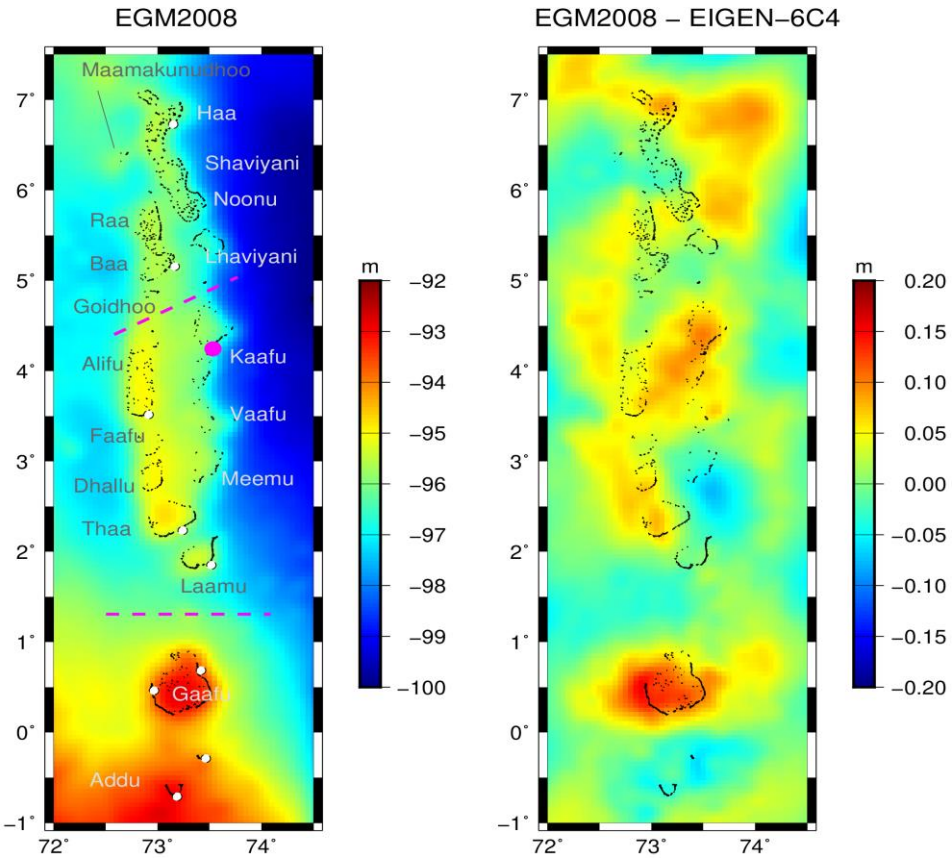

Figure 5 – Variations of two absolute geoid models (EGM2008 and EIGEN-6C4) over Maldives.

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