CONT14: Preparation and Prospects

Dirk Behrend, Cynthia Thomas, Ed Himwich, Dan MacMillan

Abstract In May 2014, a network of seventeen stations at sixteen sites will observe the next continuous VLBI campaign named CONT14. From May 6 through May 20, ten northern hemisphere and seven southern hemisphere stations will record S/X VLBI data for fifteen continuous UT days at a rate of 512 Mbps. This campaign is the continuation of similar campaigns loosely organized every three years. We discuss the preparation work such as allocation of station, media, and correlator resources and the observational procedure that will ensure that the best possible S/X VLBI data set be recorded. With a network size of seventeen stations, CONT14 is a precursor of continuous VGOS-type observing but with the S/X system. In the next several years, continuous VGOS observing on the broadband system will become a reality. With this in mind, we provide an outlook on future prospects of CONT campaigns.

Keywords CONT14, media, stations

1 Introduction

The Continuous VLBI Campaign 2014 (CONT14) will be a continuation of the series of very successful continuous VLBI campaigns that were observed at irregular intervals since 1994. The most recent CONT campaigns were observed in roughly three-year intervals (see Table 1).

The planning and organization of CONT14 commenced more than a year before the actual observing date. First, the general time frame was decided by the IVS Coordinating Center and the Observing Program Committee (OPC) to be spring 2014 (to sample a different time of the year). Then, the actual observing dates were fixed in correspondence with the EVN and other VLBI groups to May 6–20, 2014.

NVI, Inc.

Table 1 History of CONT campaigns.

Campaign	Network size	Observing month
CONT94	two 7-station networks	January 1994
CONT95	6-station network	August 1995
CONT96	5-station network	September/October 1996
CONT02	8-station network	October 2002
CONT05	11-station network	September 2005
CONT08	11-station network	August 2008
CONT11	14-station network	September 2011
CONT14	17-station network	May 2014

2 Resource Allocation: Media, Correlator, and Stations

The next step of the preparation was resource allocation. In an iterative process, the station, correlator, and media resources were evaluated and then eventually fixed. For the media it was determined that in order to keep the same observing rate as in the CONT11 campaign, additional media purchases were necessary.

We estimated that 142 modules were needed to support CONT14. Most of those are supported through new purchases and loans (110 modules). Several stations/agencies agreed on purchasing media to support the CONT14 campaign (see Table 2).

In order to allow the Hobart 26-m antenna (Ho) to participate, UTas will provide their own modules to

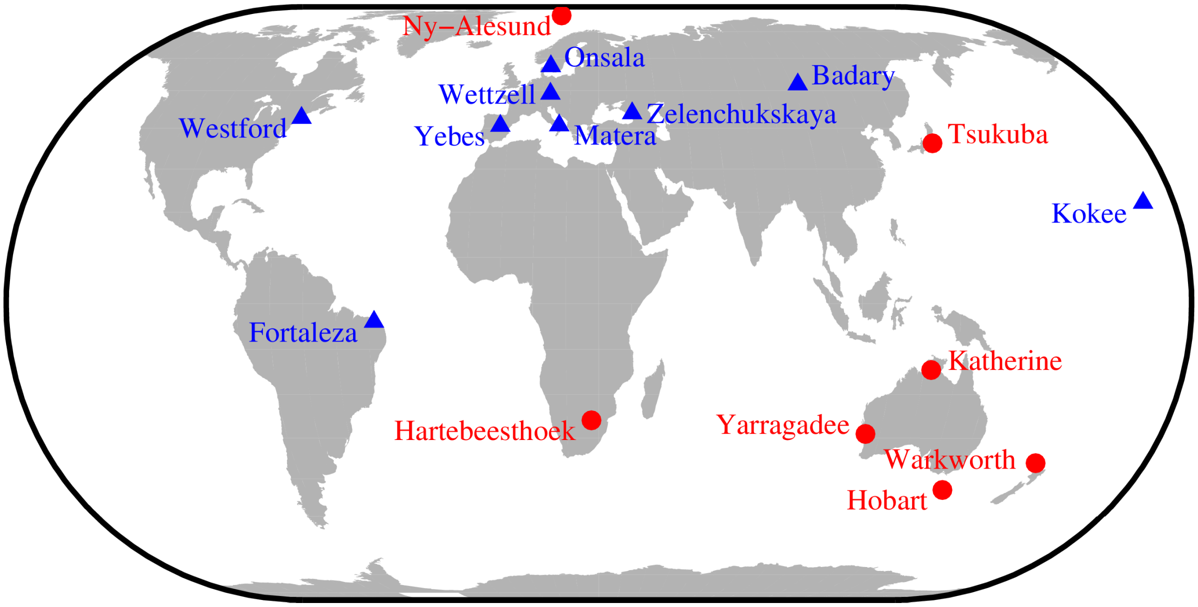

Fig. 1 The observing network of seventeen stations at sixteen sites for the CONT14 campaign. The sites in red (circles) will e-transfer their data to the correlator, whereas the blue sites (triangles) will physically ship their recording modules.

Table 2 Media purchases in support of the CONT14 campaign.

Agency	Module size	Quantity	Comment
AuScope	16 TB	24	Hb, Ke, Yg (on loan)
HartRAO	16 TB	12	
IAA	8 TB	10	Bd, Zc (on loan)
Matera	8 TB	10	
NASA	8 TB	20	Ft, Wf
Ny-Ålesund	8 TB	10	
Onsala	8 TB	10	
Wettzell	4 TB & 8 TB	6 & 4	6*4-TB, 4*8-TB
Yebes	16 TB	4	

support their participation. The remaining 32 modules come from the geodetic media pool.

Correlation will be done at a single correlator. This will simplify the logistics and ensure consistency of results; furthermore, it will provide the correlator with experience in handling a VGOS-type load. The Bonn Correlator at MPIfR agreed to take on the task of being the correlation facility for the entire campaign. Bonn will use their implementation of the DiFX software correlator.

There will be sixteen VLBI sites participating in the campaign (see Figure 1). At Hobart, both the 26-m and the 12-m telescopes will observe, resulting in seventeen VLBI observing stations in total for CONT14. The observing network can be characterized by the following items:

- ten northern hemisphere and seven southern hemisphere stations;
- reasonable global coverage with network size reaching VGOS requirements; a more optimal coverage would require more stations in Africa, North America, and South America, as well as Southeast Asia and Oceania;
- no broadband station will participate in CONT14: the processing of mixed-mode observing is not operational yet.

Because of the latter item, the 12-m antenna at GGAO dropped out of the original station list, and Westford will observe using their legacy S/X system.

Four R&D sessions (RD1309, RD1310, RD1401, and RD1402) were dedicated to check out the observing mode at the participating stations and to ensure that the stations are in good operating condition before CONT14.

3 Observational Procedure

An hour before the start of CONT14, a station sanity check in the form of a rapid fringe test will be performed. All stations will observe one or two 20-second scans and immediately e-transfer their data to the Bonn Correlator. Finding fringes for all stations will verify that all stations are in good working condition and set up correctly. Otherwise corrective action can be taken.

The schedules of CONT14 have the following characteristics:

- Fifteen consecutive session days are observed with three minutes between days for schedule changes (continuous VLBI).
- The observing days run from 0 UT to 24 UT (UT-day observing) in order to yield the most accurate combination and comparison of results from other space geodetic techniques.
- The observational data rate is 512 Mbps, which is identical to the setup of the CONT11 campaign.
- The Int1, Int2, and Ru-U Intensive sessions will take place as scheduled and have precedence over CONT14. There is no Int3 Intensive session scheduled during CONT14. The Intensives were considered in the CONT14 schedules.

The total number of scans scheduled for the campaign is 24,336, resulting in 302,115 campaign observations. These numbers, however, include the tag-along periods during the maintenance checks (see below). The actual observation count will thus be slightly smaller.

In order to avoid observational gaps in the overall network, station check times were fixed in staggered fashion at convenient and well-coordinated times for the stations (see Figure 2). These station check times are used from the second to the fourteenth day of CONT14; no maintenance checks are scheduled for the first and last days of CONT14.

For the case that a station completes its checks before the end of the check time slot, each station is tagged along for its check period. The two-hour slots for the Intensive stations (Bd, Kk, Ts, Wz, and Zc) are aligned with their respective Intensive (Int1, Int2, or Ru-U) observation periods. These stations first observe their Intensive sessions (90 min) and then perform their checks (30 min).

For recording purposes, the individual days of CONT14 are grouped into sets of session days (recording groups) in order to share modules between days. One, two, three, or four session days will be recorded onto one module. The recording groups will typically end with an equivalent of an R1 or R4 session (rapid-turnaraound session, R-session, cf. Table 3). This alignment allows the data of the R-sessions to be transported (shipped or e-transferred) immediately after the session so that the 15-day time delay goal for the R-sessions can be met.

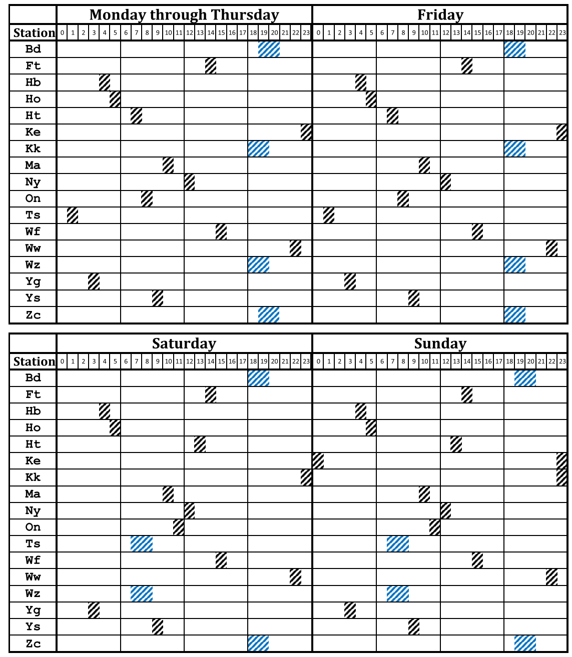

Fig. 2 Graphical display of the slots for station checks for the regular stations (1-hour slots, black) and the Intensive stations (2-hour slots, blue). The 2-hour slots actually commence 15 min past the hour.

Table 3 R1 and R4 equivalents of the CONT14 session days.

CONT14 day	Actual date	Day of year	Equivalent
C1401	May 06, 2014	126	R1
C1403	May 08, 2014	128	R4
C1407	May 12, 2014	132	R1
C1410	May 15, 2014	135	R4
C1414	May 19, 2014	139	R1

The R-sessions will be correlated and analyzed immediately and the results posted to the Data Center. Once the entire campaign has been analyzed, the results will be updated with a final version.

With up to four sessions recorded onto one module, a single module may contain more than 1,023 scans. As 1,023 scans per module was the upper limit for the Mark 5 directory listing, an upgrade to the Mark 5 software was prepared and rolled out under the leadership of Chet Ruszczyk from Haystack Observatory. The updated version of the Mark 5 software now supports a large directory structure with up to 65,536 entries.

The data transport to the correlator is done either by the physical shipment of modules or by the electronic transfer of data (e-transfer). As indicated in Figure 1, seven sites (eight stations) e-transfer all of their data to the correlator, whereas nine stations ship their modules. Fortaleza, which was included in the count of nine, is a special case: the station ships the modules to the Washington Correlator, and from there it is e-transferred to the Bonn Correlator. Hence, about half of the data of the CONT14 campaign are electronically transferred. This is a significant step towards realizing VGOS-type operations.

4 Simulation Results

Accompanying the steps of resource allocation and schedule writing, simulations have been run using the *Solve* software in order to determine the optimal network and scheduling parameters. The optimization was based on simulated formal errors for the EOP, number of observations, number of scans per hour, sky coverage, and robustness. In a final step, the eventually chosen schedules were analyzed w.r.t. their EOP performance and compared to the performance of previous CONT campaigns.

The simulation results for the individual fifteen days of CONT14 only vary marginally; hence, their differences are not reported here. The picture changes when comparing the simulation results of the first day for the last five CONT campaigns (including CONT14). For this purpose the formal EOP uncertainties were computed using two different *Solve* solutions.

The first solution is a standard TRF-type solution with station velocities estimated, i.e., similar to operational analysis except that the simulation databases were added to the analysis of all sessions observed from 1980 through 2013 (see Table 4). It is interesting to note that the CONT session formal errors for the ERP (X, Y, and dUT1) increased since CONT05. The reason for this is that the uncertainties of the station positions increase as the campaign epochs occur further away from the midpoint of the data span of the solution. This increase is due to the error in the estimated positions caused by the error in the estimated site velocities. It is simply a consequence of making a linear fit of a span of data.

Table 4 Simulated EOP formal errors with station velocities estimated in the *Solve* run.

Campaign	X [μas]	Y [μas]	dUT1 [μs]	ψ [μas]	ε [μas]
CONT02	43.1	33.6	1.7	83.2	36.8
CONT05	29.7	29.4	1.3	60.0	22.2
CONT08	30.1	30.6	1.3	41.4	16.5
CONT11	32.9	34.1	1.4	32.6	13.2
CONT14	36.2	38.2	1.5	31.1	11.7

In the second *Solve* solution, no velocities were estimated (see Table 5). In this solution we note a clear and steady improvement in ERP formal errors since CONT02. The effect of the increase in network size and global coverage and, to a lesser extent, of the increased data rate becomes apparent, while it was diluted by the effect of the velocity error in the first solution. The improvement of results from CONT11 to CONT14 is small because they have networks of similar sizes (14 versus 17 stations) and a very similar geographic distribution.

Table 5 Simulated EOP formal errors with station velocities fixed in the *Solve* run.

Campaign	X [μas]	Y [μas]	dUT1 [μs]	ψ [μas]	ε [μas]
CONT02	40.0	29.7	1.6	83.2	36.8
CONT05	21.2	20.8	1.0	60.0	22.2
CONT08	16.2	16.1	0.8	41.4	16.5
CONT11	12.9	13.2	0.7	32.6	13.2
CONT14	11.2	12.1	0.7	31.1	11.7

While the simulated formal errors for the ERP are too optimistic in the second solution, the relative quality of the CONT campaigns is represented correctly. More representative error estimates could be obtained using Monte-Carlo simulations with realistic troposphere, clock, and observation noise models.

5 Conclusions and Outlook

The preparation work for the CONT14 campaign was completed, and the stage is set for another successful continuous VLBI campaign. CONT14 is the largest such campaign in terms of network size and number of observations/scans. It also ranks first in the amount of data being transferred electronically (about half of the data).

Because of its network size, CONT14 is a precursor of continuous VGOS-type observing but with the S/X system. Assuming three-year gaps between future CONT campaigns, we can anticipate that by 2017, an extended VGOS pilot project with the broadband system will be in place, and by 2020, continuous 24/7 VGOS observing will be fully operational.

In 2020, the main purpose for a CONT campaign—namely continuous VLBI observing—will already be fulfilled by the standard VGOS observing. With this in mind, the following scenarios could be envisioned for future CONT campaigns:

- observe a CONT campaign with the legacy S/X system in parallel to the VGOS system;
- observe a mixed CONT campaign of legacy S/X stations and broadband VGOS stations.

It is conceivable that both types of CONT campaigns will be organized. A mixed CONT campaign could be observed in 2017 (CONT17) and a final legacy CONT in 2020 (CONT20). Further discussions are needed before a final decision can be made.

More information about CONT14 can be found at: `http://ivscc.gsfc.nasa.gov/program/cont14/`.