Hayo Hase et al.: The Emerging VGOS Network of the IVS, IVS 2012 General Meeting Proceedings, p.8–12
http://ivscc.gsfc.nasa.gov/publications/gm2012/hase.pdf

The Emerging VGOS Network of the IVS

Hayo Hase [1], *Dirk Behrend* [2], *Chopo Ma* [3], *Bill Petrachenko* [4], *Harald Schuh* [5], *Alan Whitney* [6]

[1)] *Bundesamt für Kartographie und Geodäsie, Geodetic Observatory TIGO*
[2)] *NVI Inc./NASA Goddard Space Flight Center*
[3)] *NASA Goddard Space Flight Center*
[4)] *Natural Resources Canada*
[5)] *Vienna University of Technology, Institute of Geodesy and Geophysics*
[6)] *MIT Haystack Observatory*

Contact author: Hayo Hase, e-mail: hayo.hase@bkg.bund.de

Abstract

The VLBI2010 concept was developed by the International VLBI Service for Geodesy and Astrometry (IVS) in order to create the next generation VLBI system needed to meet the goals of the Global Geodetic Observing System (GGOS) of the International Association of Geodesy (IAG). In December 2010, the IVS VLBI2010 Project Executive Group (V2PEG) conducted a survey among existing IVS network stations to measure awareness of VLBI2010 and to learn about modernization plans towards VLBI2010. The results of this survey indicate that most of the IVS network stations are already planning the transition to VLBI2010 capabilities. The survey indicated that up to 20 new radio telescopes at 17 sites with VLBI2010 compliance could become operational by 2018. A sufficient number of VLBI2010-compatible radio telescopes should be available by 2015 to support initial VLBI2010 operations.

1. Introduction

The year 2002 saw the creation of the intergovernmental Group on Earth Observations (GEO) as a means to exploit the growing potential of Earth observations to support decision making processes. As necessary support tool GEO commenced to construct the Global Earth Observing System of Systems (GEOSS) of which the Global Geodetic Observing System (GGOS) of the International Association of Geodesy (IAG) is a building stone. For GGOS the envisaged goals were defined to obtain accuracies of 1 mm in position and 0.1 mm/year in velocity, to have continuous observations for time series of station positions and Earth orientation parameters, and to obtain a turnaround time to initial geodetic products of less than 24 hours. The realization of these goals calls on the IVS community to improve its performance to VLBI2010 standards in the next-generation network.

In parallel and in response to the GGOS activities, the IVS established dedicated groups and committees to define and implement the new VLBI2010 technology and the next-generation network. Working Group 2 on "Product Specifications and Observing Programs" was tasked with the definition of the VLBI2010 measurement goals and the proposal of corresponding observing programs. The Working Group 2 report [1] was completed in 2002. The follow-up IVS Working Group 3 on "VLBI2010" was created in September 2003. It examined current and future requirements for VLBI geodetic systems, including all components from antenna to analysis, and published a report with recommendations for a new generation of systems. The final report [2] was presented

in 2005. The global measurement goals of 1 mm position error and 0.1 mm/year site velocity error require new radio telescope designs, new VLBI receiving and recording systems, and new concepts for data transmission and correlation, as well as updated software for scheduling, data analysis, and archiving.

In September 2005, the VLBI2010 Committee (V2C) was established in order to encourage the realization of the WG3 recommendations. As a major milestone, the V2C published a progress report [3] in June 2009 summarizing the VLBI2010 development activities and main characteristics. In response to the progress report, the IVS created the VLBI2010 Project Executive Group (V2PEG) in 2009 to provide strategic leadership to the VLBI2010 project and guide the transition from the VLBI2010 development phase to the VLBI2010 implementation phase. V2PEG is also the primary point of contact for VLBI2010-related questions from institutions that are interested either in upgrading existing VLBI operations to VLBI2010 compatibility or in building new compatible systems.

In 2010, the V2PEG conducted a survey among existing IVS network stations in order to gather information about individual VLBI2010 plans, to trigger VLBI2010 discussion at the network station level, and to solicit input on what the V2PEG can do to provide the best support to individual VLBI2010 projects. A summary of the survey and the results obtained were published in 2011 [4, 5, 6]. About a year after the original survey (January 2012), the V2PEG did a follow-up survey to reconfirm existing plans and to capture any possible changes. The second survey quintessentially corroborated the validity of the original plans with a number of individual projects pushed back by about a year. Hence, the survey results of 2011 remain valid and can be looked up in the aforementioned references. Still, it is worthwhile to repeat the more general findings:

- By 2015, a sufficient number of VLBI2010 compatible radio telescopes will be available for significant, but not full-time, VLBI2010 operations (Figure 1).
- By 2018, approximately 20 new radio telescopes at 17 sites operated by IVS network station institutions will be available for full-time VLBI2010 observations (Figure 2). Additional new stations may also join if approved and constructed.
- Even in 2018, the American/Pacific region will still lack presence of VLBI2010 network stations, though a 10-station NASA network covering some of this area may eventually be built.
- Through at least 2015, observations by a large number of legacy S/X-band telescopes will still be supported for data continuity, astrometry, and space applications.
- Many network stations need technical consultation about VLBI2010, as well as support letters to be successful with the administration and funding level.

The development of the VLBI2010 network in the next five years is described in Section 2.

2. The Upcoming VGOS Network

In early March 2012 the V2PEG and the V2C organized a very well-attended VLBI2010 Workshop on Technical Specifications in Bad Kötzting (Wettzell), Germany. This workshop brought together experts in VLBI2010 technology with station managers and engineers in order to provide a better understanding of the VLBI2010 concept. The directly following IVS General Meeting in Madrid, Spain was held under the theme “Launching the Next-Generation IVS Network”. And it

was in Madrid that the new network was inaugurated as the *VLBI2010 Global Observing System (VGOS)*. On completion VGOS will be a global network of new fast radio telescopes (up to 12 deg/s) and high capacity data acquisition systems (up to 8 Gbps) optimized for Earth orientation and the terrestrial reference frame. VGOS will be the VLBI component of the Global Geodetic Observing System (GGOS).

On the basis of the IVS network station survey, a world map can be created showing the existing S/X stations and the emerging VGOS network of VLBI2010 stations. The VGOS network will evolve gradually over the years adding new stations on an annual basis. Figure 1 shows the upcoming VGOS network stations by the year 2015. The Voronoi diagram over an equal-area projection of the world map shows the representing area in preserved scale of each station [7]. The larger the surrounding area of one particular station, the less dense is the global network in this area.

Figure 2 shows the more complete VGOS network stations as of 2018. More stations in North and South America, Africa, India, and on southern ocean islands are desirable for a more homogeneous distribution. The global coverage improves if new VGOS network stations and existing S/X-band network stations are considered as a single global network. However, the situation in the southern hemisphere remains insufficient (Figure 3).

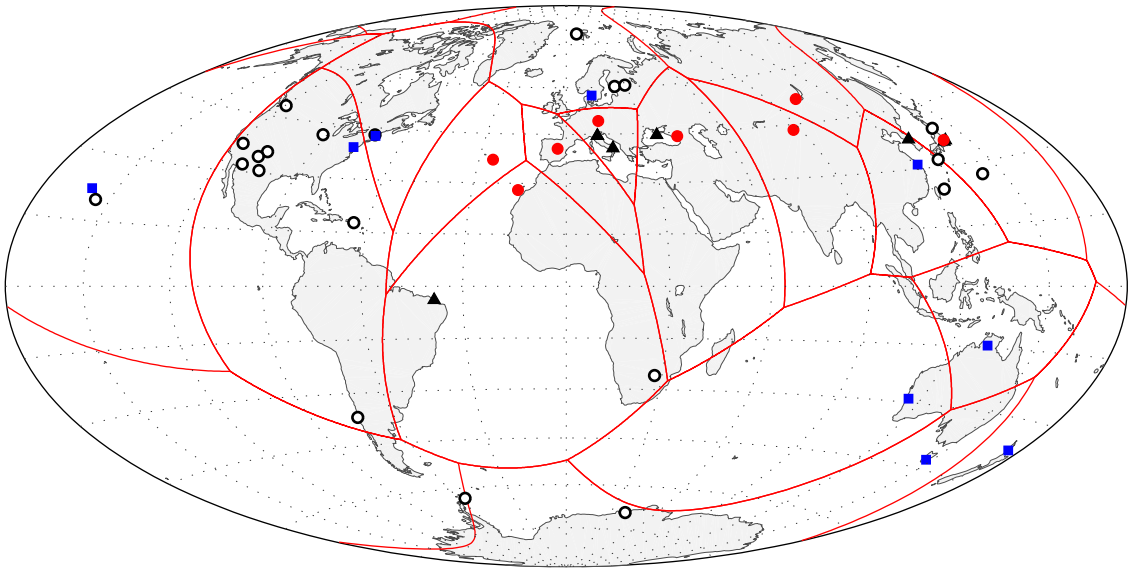

Figure 1. Predicted VGOS network for 2015: This map shows a Voronoi diagram over an equal-area projection based on new VGOS stations marked with red circles ● (very fast moving telescopes) and blue squares ■ (fast moving telescopes). Approximately 13 stations will be available, allowing significant, but not full-time, VGOS observations. The Voronoi diagram shows the lines of maximum distance to the VGOS network stations and hence shows the representing area of the sites. The upgraded legacy telescopes (marked with black triangles ▲) and S/X sites without major upgrades (marked with hollow circles O) were not considered in the Voronoi computation.

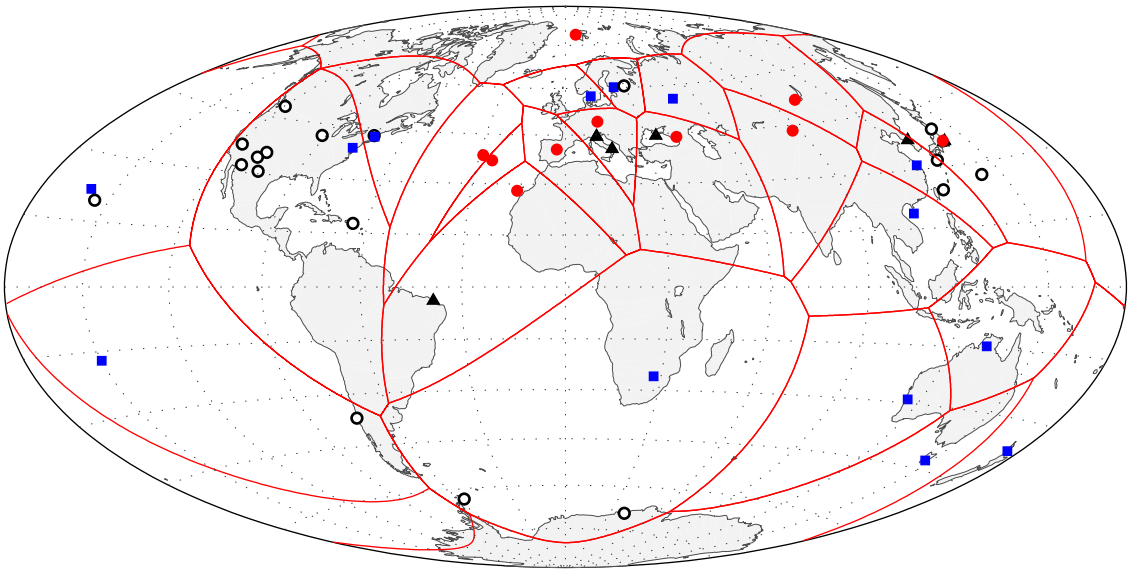

Figure 2. Predicted VGOS network for 2018: Approximately 20 stations will be available for full-time observations. Additional sites in Tahiti, Nigeria, Saudi Arabia, and India may join the IVS network if funding is approved. The Voronoi diagram is based only on the new VGOS stations.

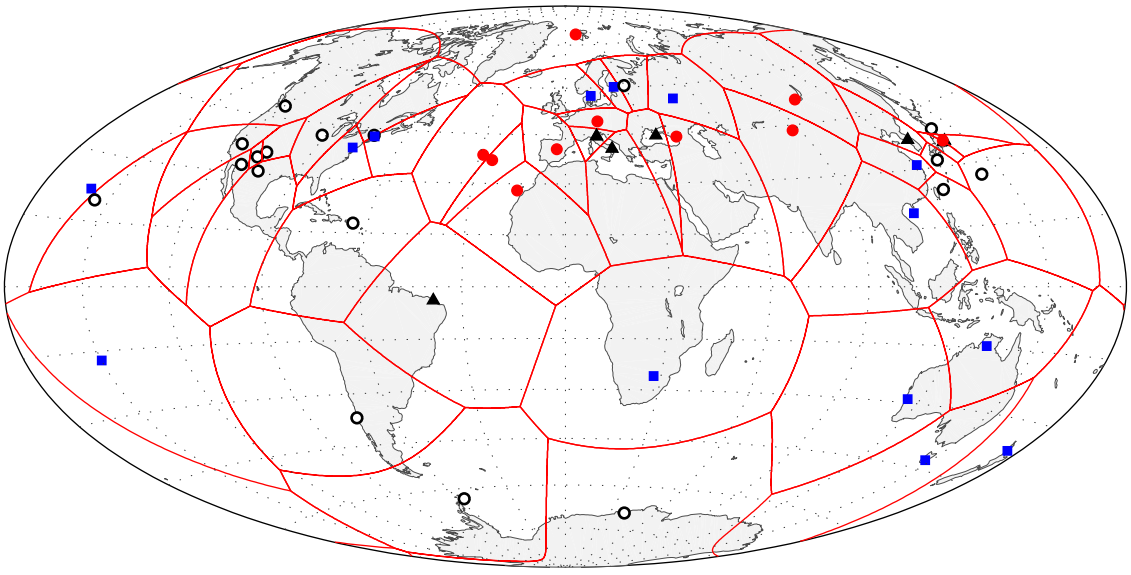

Figure 3. Predicted total IVS network for 2018: The IVS global network will consist of new VGOS network stations, of upgraded stations, and of the legacy S/X network stations. The Voronoi diagram is based on all network stations. Although an improved global coverage is given, the distribution is not homogeneous and should be denser in the southern hemisphere.

3. Conclusions

A highly capable VGOS network will be implemented within the next 5–7 years. New broadband 2–14 GHz observation modes will come into regular operation from 2015 onwards, with full operation by about 2018. The current S/X operation mode will be maintained in parallel at a number of legacy stations for data continuity, astrometry, and space applications. In the long term the VGOS will significantly outperform the current standard S/X band observation modes and thus meet the goals of GGOS. A special effort is necessary to extend the global distribution of VGOS sites in the southern hemisphere.

Acknowledgements

This document could only be prepared based on the frank and open response of the IVS network stations to the V2PEG survey request. This excellent feedback and collaboration is gratefully acknowledged. The authors wish to thank all individuals who have been advancing the idea of VGOS and are helping to make VGOS become a reality. Special thanks to Felipe Pedreros who contributed the figures of this article.

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