Roll-out Status of the VGOS Network

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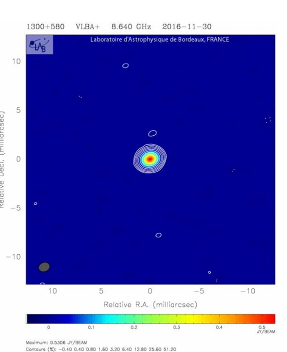
Introduction

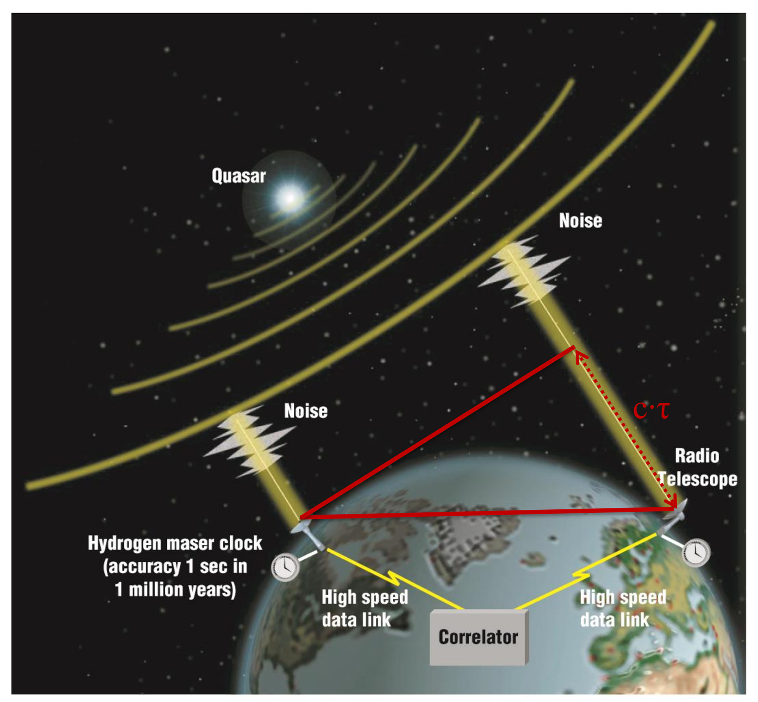
The member organizations of the International VLBI Service for Geodesy and Astrometry (IVS) operate an observational network of VLBI telescopes that currently consists of about 40 stations worldwide. This S/X VLBI network was developed mainly in the 1970s and 1980s. Due to the aging infrastructure but also because of demanding new scientific requirements, the larger IVS community planned and started to roll out the next-generation VLBI system called VGOS (VLBI Global Observing System) at existing and new sites over the last few years. The roll-out effort is ongoing and it is anticipated that the VGOS network may become fully operational in the early 2020s. Once VLBI products can be derived from the new system in an operational manner, the VGOS network will replace the legacy S/X network as the production system of the IVS.

How Geodetic VLBI Works

The VLBI observable is the difference in the arrival time of a radio signal (from a quasar) at two different radio telescopes. The measured time delay, using the speed of light, can be interpreted as a distance. The distance is the component of the baseline toward the source (quasar). By observing many sources, all components of the baseline can be determined.



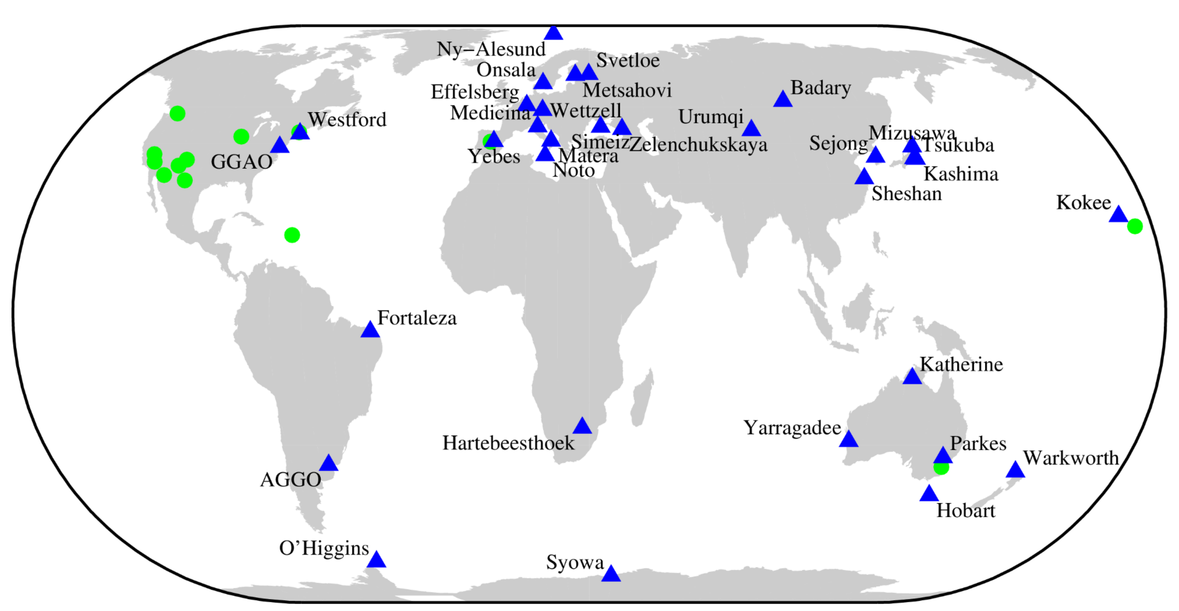
Compact radio source (quasar)



Principle of VLBI

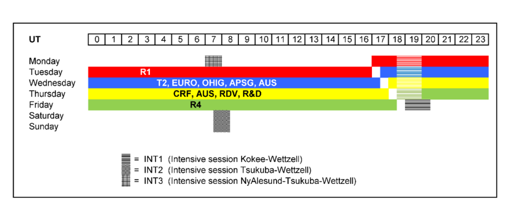
The Current Legacy S/X VLBI Network

The currently used legacy S/X observing network of the IVS consists of about 40 stations. This includes the IVS Network Stations as official member components of the IVS as well as several cooperating sites that contribute to the IVS observing program, in particular the ten stations of the VLBA and the three NASA DSN stations.



▲ *IVS Network Station* ● *Cooperating VLBI Site*

Distribution plot of the VLBI stations that contributed to the 2016 IVS Master Observing plan



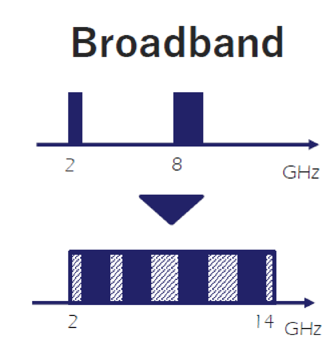
Typical IVS observing week in 2016

Hartebeesthoek

Legacy S/X vs. VGOS

When a larger number of legacy S/X antennas started to approach their end-of-lifetime, the IVS conceived a next-generation VLBI system which has come to be known as VGOS (VLBI Global Observing System). Unlike the legacy system, VGOS will be a dedicated instrument that is not intended to share antennas with other applications. In order to be able to satisfy increased scientific requirements, the new system was based on fulfilling three overarching criteria: (1) 1-mm position accuracy on global scales, (2) continuous measurements for time series of station positions and Earth orientation parameters, and (3) turnaround time to initial geodetic results of less than 24 hours. These criteria determined the definition of the specifications of the VGOS system.

	Legacy S/X System	VGOS System	Benefit
Antenna size	5–100 m dish	12–13 m dish	reduced cost
Slew speed	~20–200 deg/min	≥ 360 deg/min	more observations for troposphere
Sensitivity	200–15,000 SEFD	≤ 2,500 SEFD	more homogeneous
Frequency range	S/X band [2 bands]	~2–14 GHz [1 broadband w/ 4 bands]	increased sensitivity, data precision
Recording rate	128, 256, 512 Mbps	8, 16, 32 Gbps	increased sensitivity
Data transfer	usually e-transfer, some ship disks	e-transfer, ship disks when required	
Signal processing	analog/digital	digital	stable instrumentation

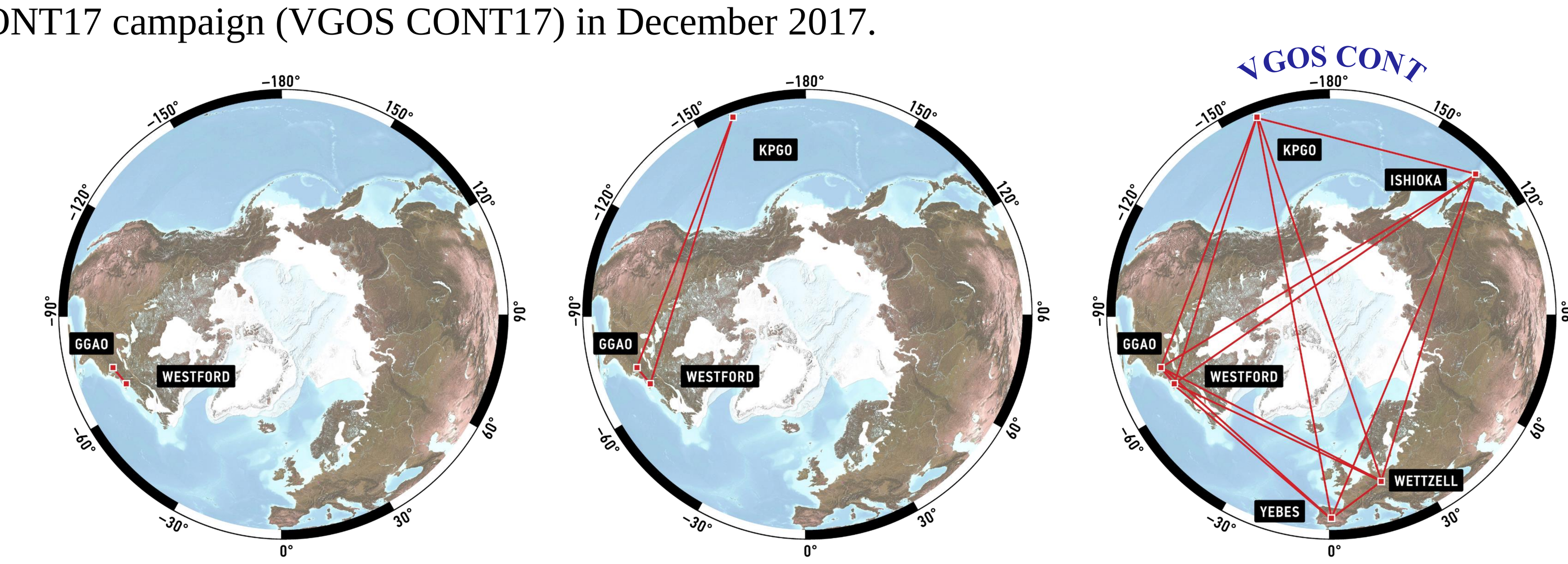


Selected characteristics of the current and future VLBI systems

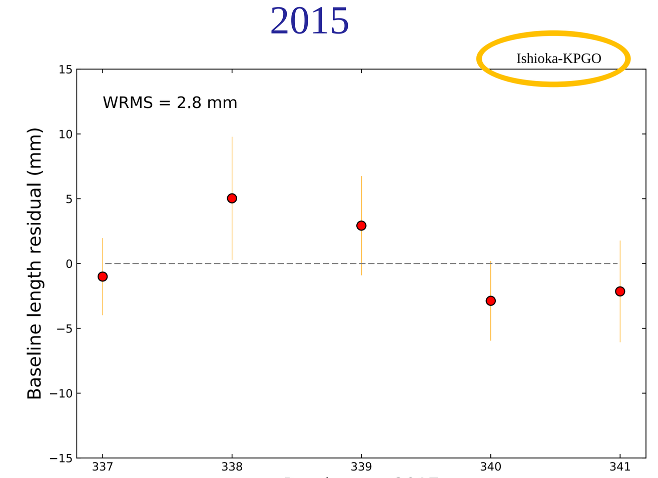
Once the specifications were set, work commenced on establishing an observing network in the early to mid 2010s. Since then, the network grew and continues to grow organically.

VGOS Roll-out Progress and Some Early Results

After first fringes with the VGOS broadband system some 1–2 years earlier, first actual geodetic results were determined on the demonstration baseline GGAO to Westford in late 2014. Adding further stations in North America, Europe, and Japan, a six-station network observed continuously for five days in the CONT17 campaign (VGOS CONT17) in December 2017.



2015 2016 2017

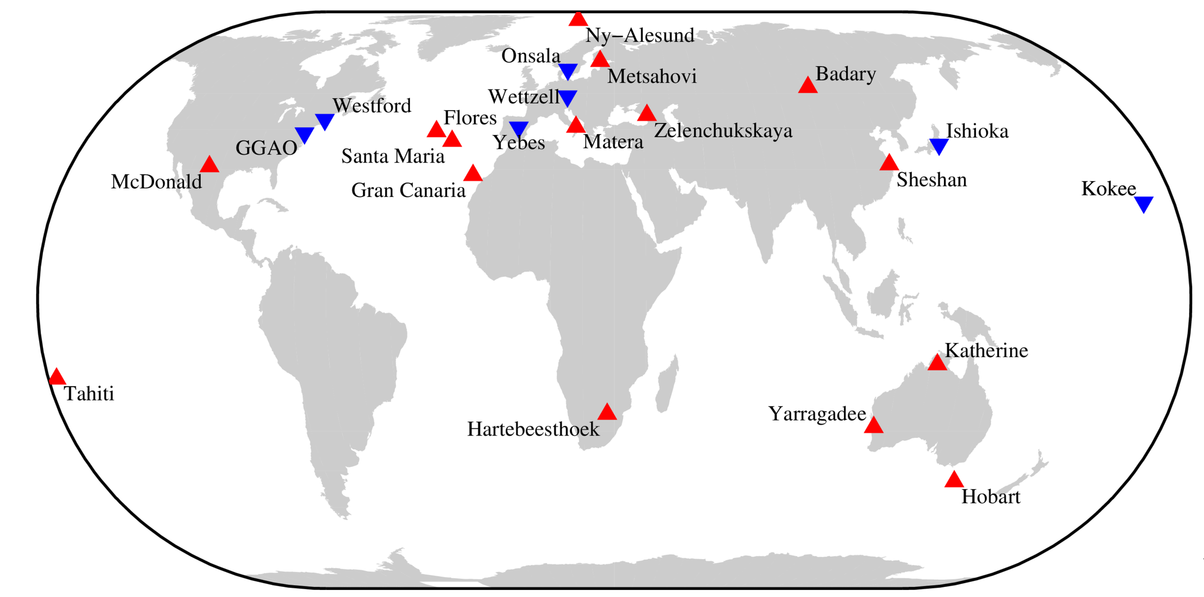


Some VGOS CONT17 results and beyond:

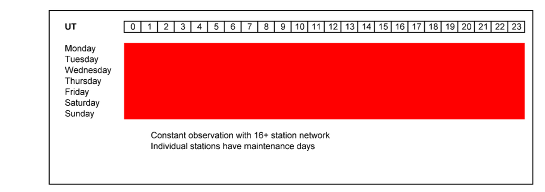
- The WRMS scatter of postfit delay residuals about the mean (not shown) is at the 4-mm level, which is a few times larger than implied by the measurement errors.
- The scatter of the long-term VGOS baseline length estimates is at the 1-mm level (Niell et al., 2018).
- Baseline length repeatability over the 5-day CONT17 sessions ranges between 1–8 mm. The Figure shows Ishioka–Kokee, with a WRMS scatter of 2.8 mm.

VGOS Broadband Network by the Early 2020s

The VGOS network is expected to continuously grow over the next several years and to reach some level of maturity in the early 2020s. By then, we expect to have a 22-station network available.



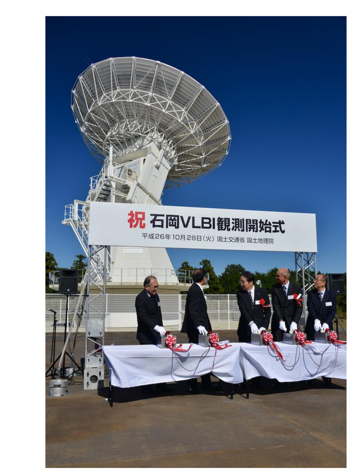
▼ *VGOS antenna broadband ready* ▲ *VGOS antenna under construction or planned*



Typical IVS observing week in the early 2020s

Station	Recent milestone	VGOS broadband
GGAO	VGOS CONT17	ready
Westford	VGOS CONT17	ready
Wettzell South	VGOS CONT17	ready
Yebes	VGOS CONT17	ready
Ishioka	VGOS CONT17	ready
Kokee Park	VGOS CONT17	ready
Onsala (Oe, Ow)	VGOS test sessions	ready
Badary	Fixed broadband system	2017 (S/X/Ka)
Zelenchukskaya	Fixed broadband system	2017 (S/X/Ka)
AuScope (Hobart)	VGOS fringe test with Ishioka	late 2018
AuScope (Yg, Ke)	Upgrade work in progress	2019
Santa Maria	Started S/X observing	2019
Sheshan	RT erected, signal chain work	2019
Ny-Ålesund	RTs erected, signal chain work	2019
HartRAO	RT erected, signal chain work	2019
Svetloe	RT erected, signal chain work	2019 (S/X/Ka)
McDonald	RT FAT done, civil works	end 2019
Gran Canaria	RT in warehouse, civil works	2020
Metsähovi	pedestal built, RT on site	2020
Tahiti	Site selected, RFI survey	2022
Brazil (Fortaleza)	Under discussion	2022
Flores	RFI surveys	2022+

Kokee



Ishioka

Onsala

Ny-Ålesund

Conclusion

The establishment of the VGOS observing network is making steady progress. By December 2018 some seven stations were broadband ready. Initial VGOS results were obtained in the VGOS CONT17 campaign. A focus for the VGOS project for the next several years will be the establishment of the necessary correlation and data transport/storage resources that will be necessary to transition the VGOS from its trial status to the operational system of the IVS.

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