Introduction to VLBI, IVS, VGOS, and GGOS

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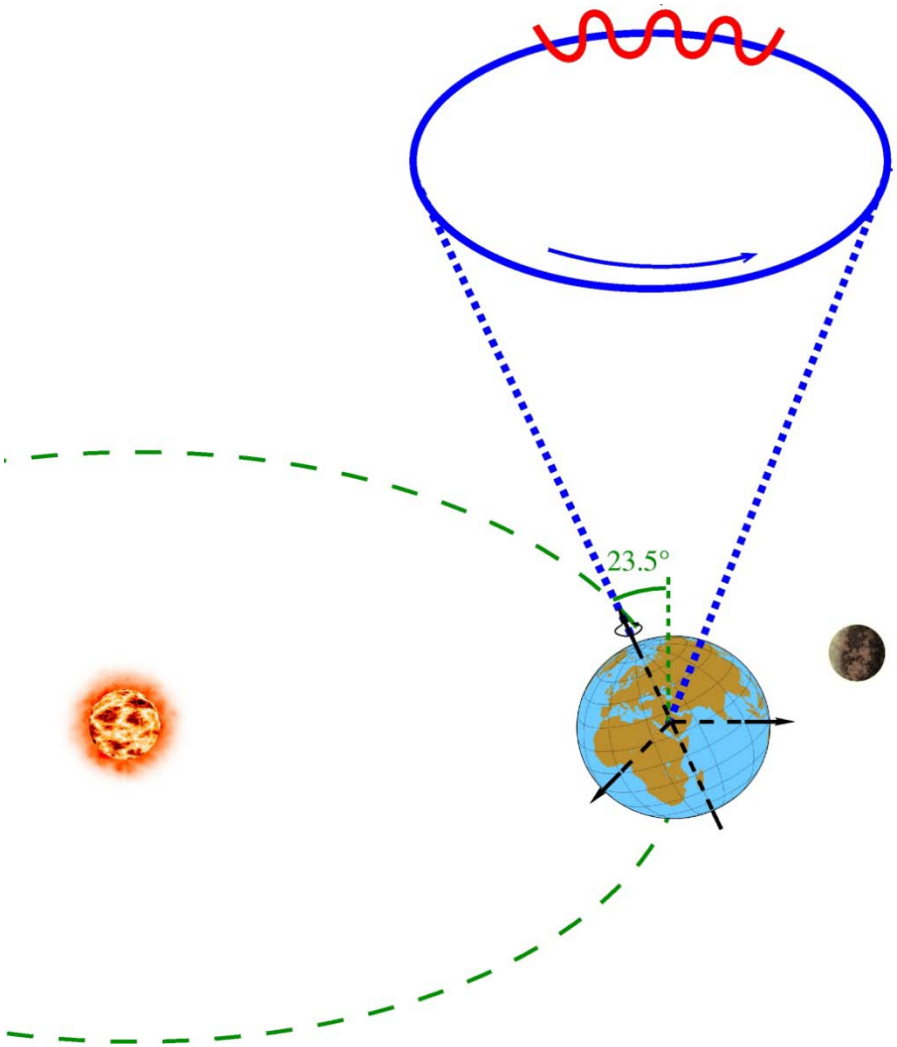
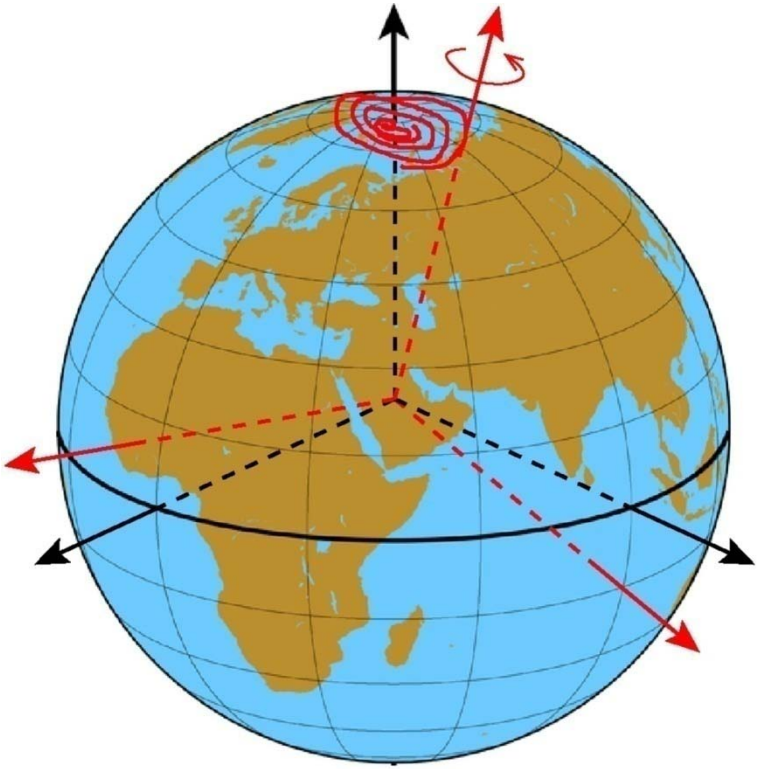
Outline

- Geodetic VLBI principles
  - Variable Earth rotation
  - Radio sources
  - Radio telescopes
  - Data flow and analysis
- International VLBI Service for Geodesy and Astrometry
  - Operations
  - Observing network
- VLBI Global Observing System
- Global Geodetic Observing System

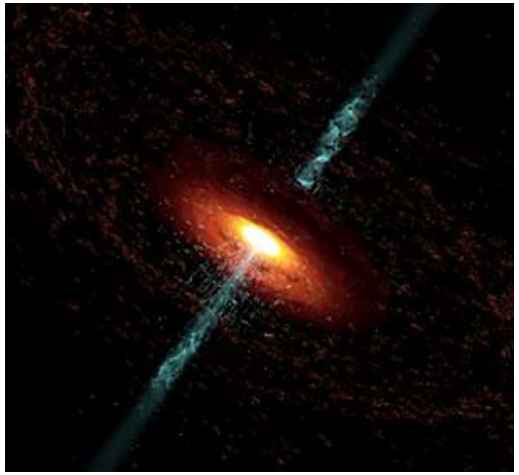
Earth orientation variations





Courtesy Thomas Artz.

Radio sources



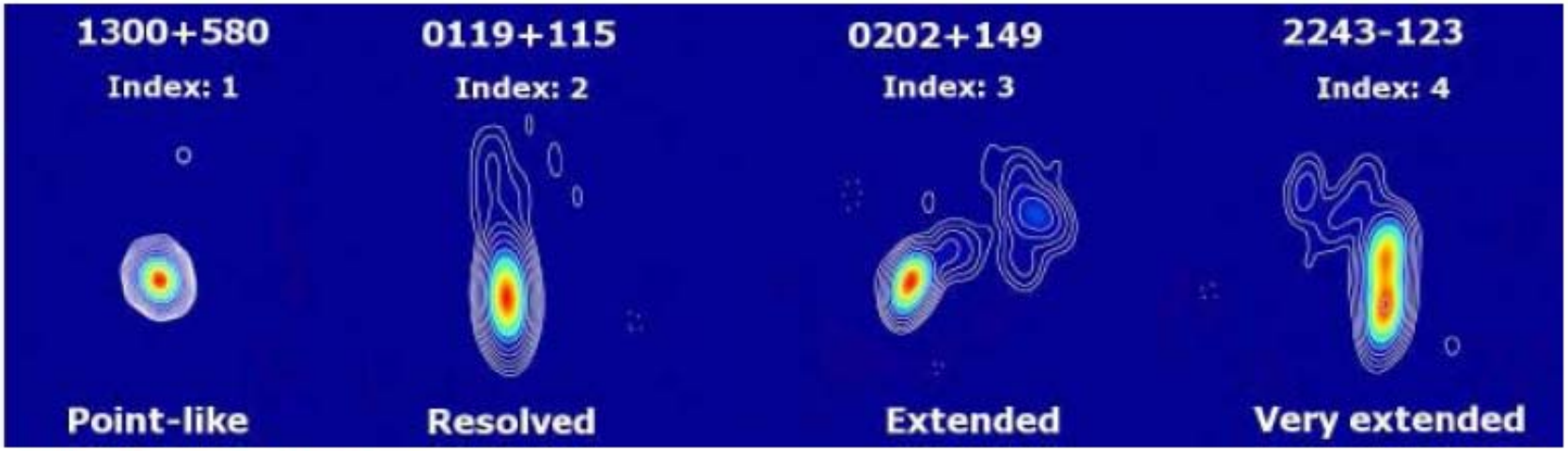
Active galactic nuclei, galaxies, quasars

Distance 2 – 8 billion light years

Point sources

No proper motions

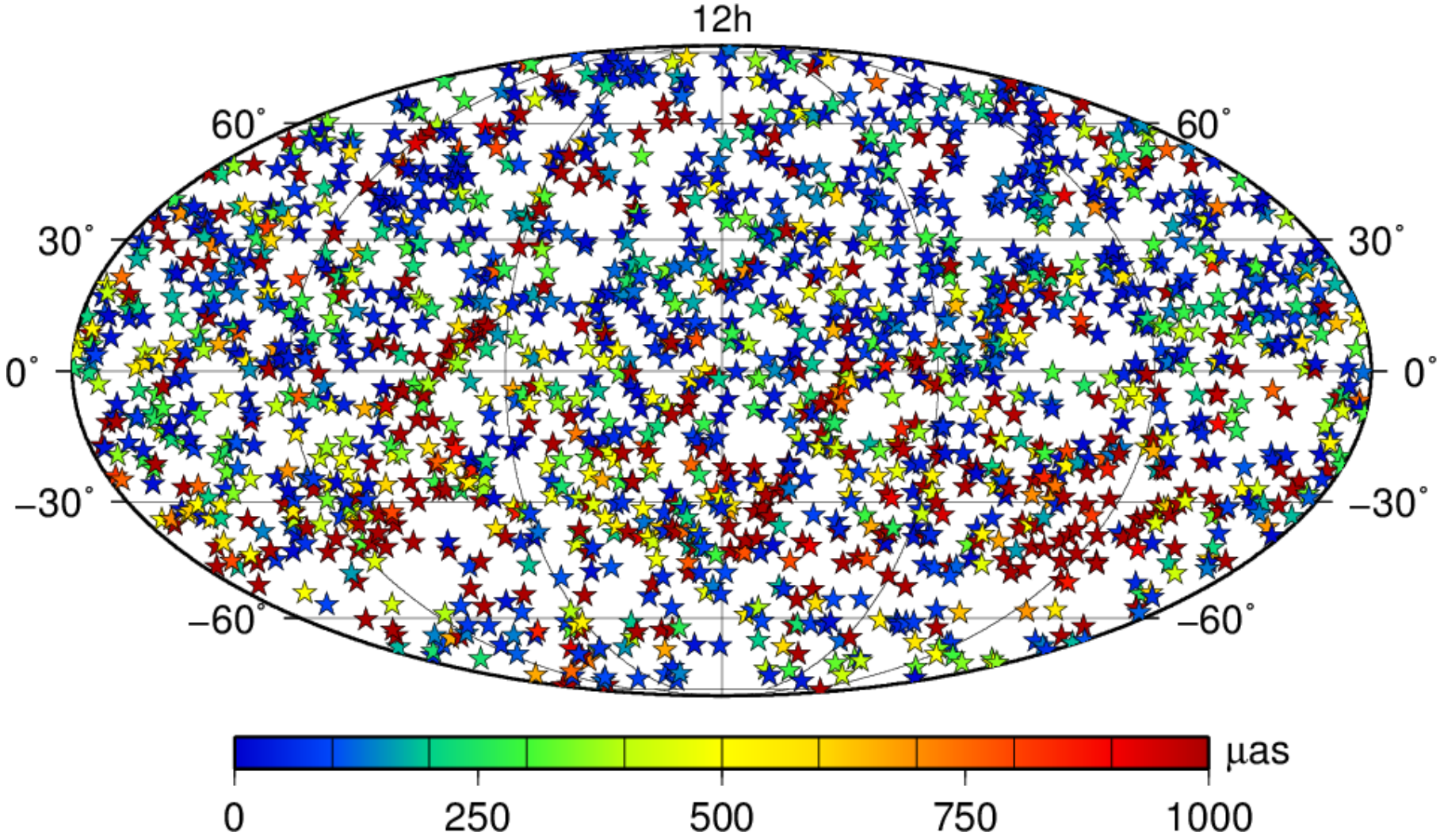
→quasi-inertial reference system



Collioud and Charlot (2009)

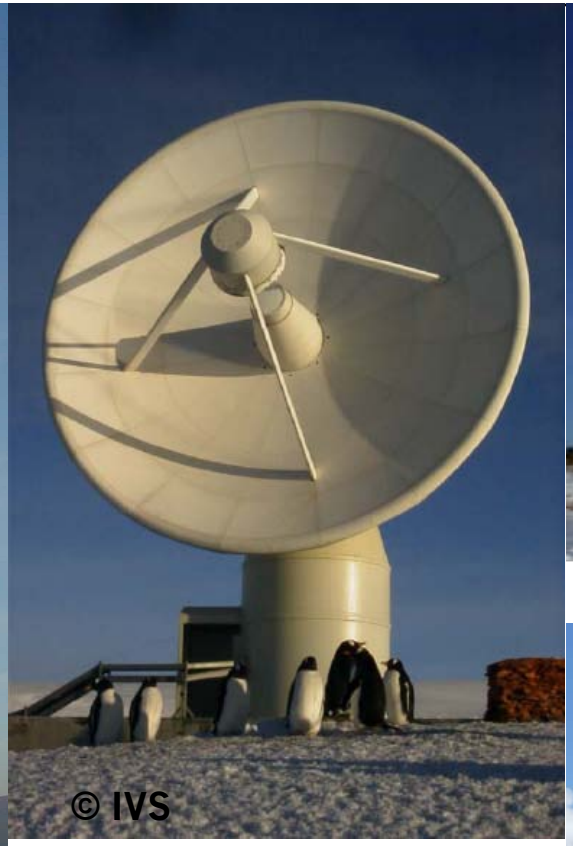
ICRF-2

International Celestial Reference Frame (ICRF)



Radio telescopes

Wettzell, Germany



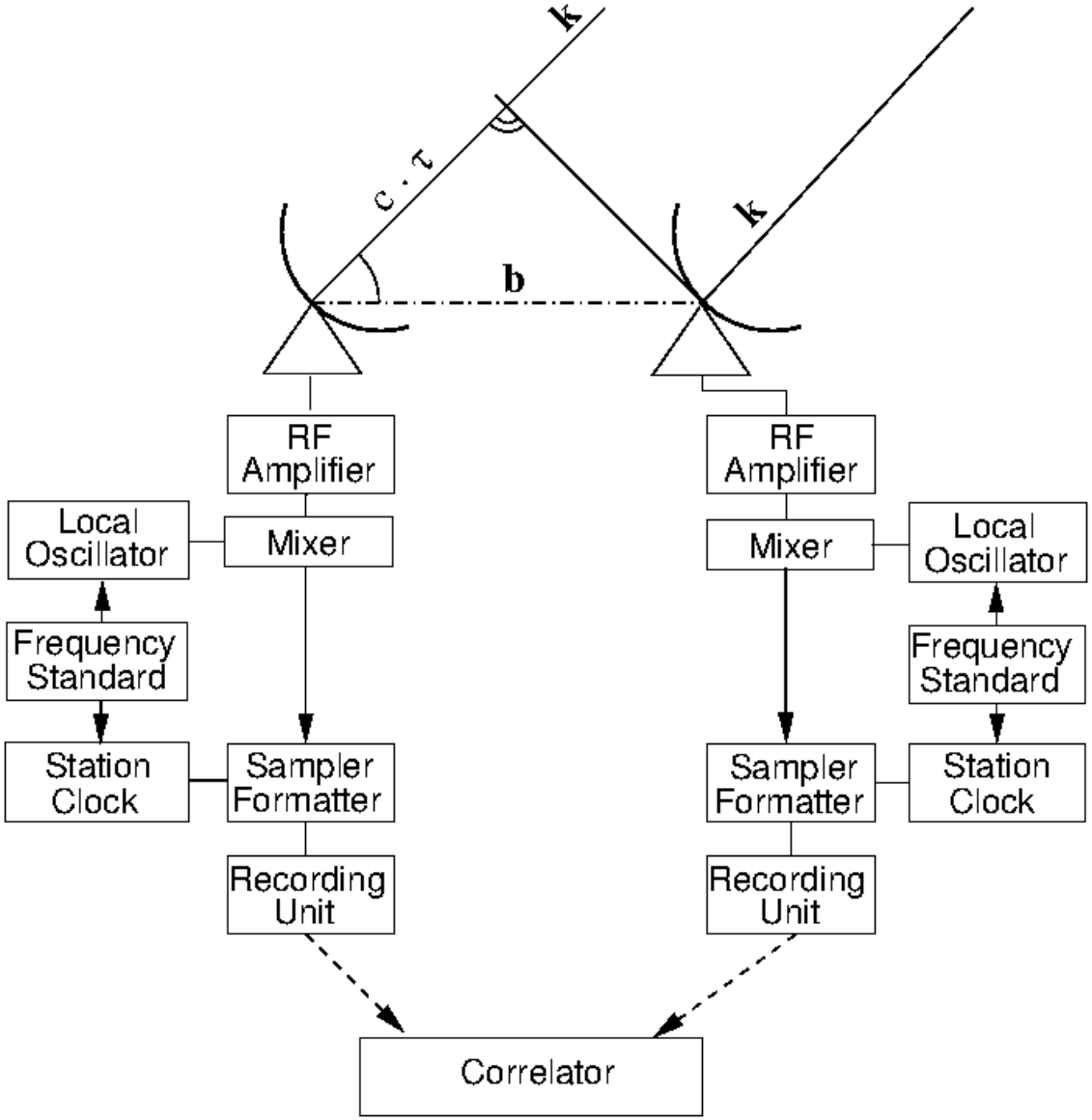
O,Higgins, Antarktica

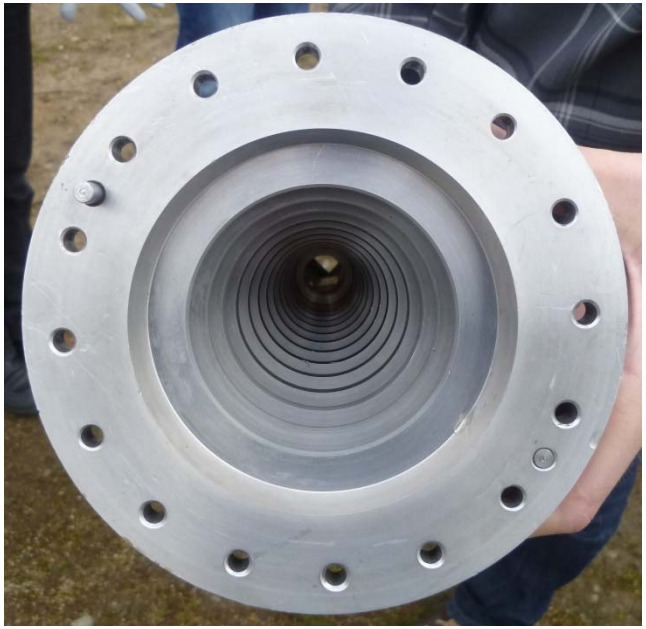
© BKG

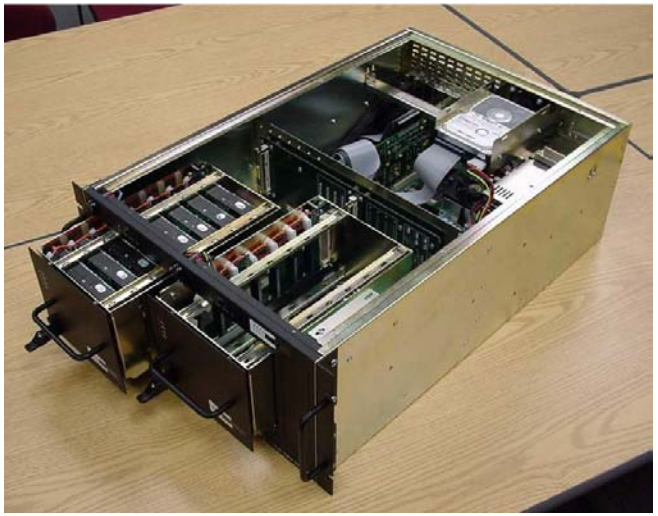
Urumqi, China

Effelsberg, Germany

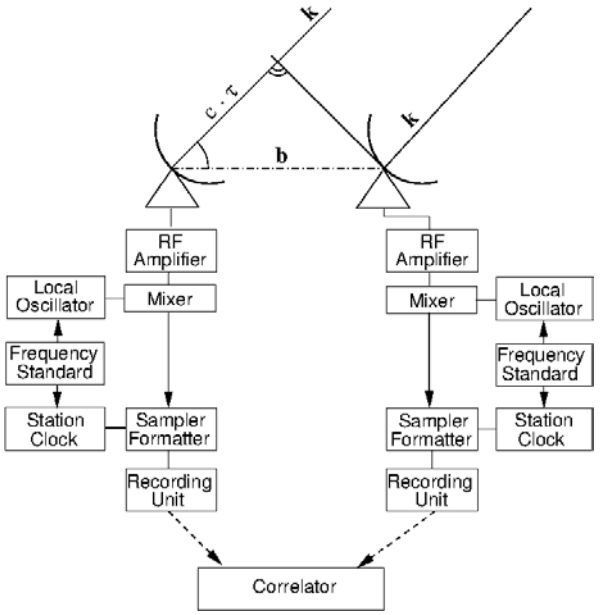
VLBI principles I

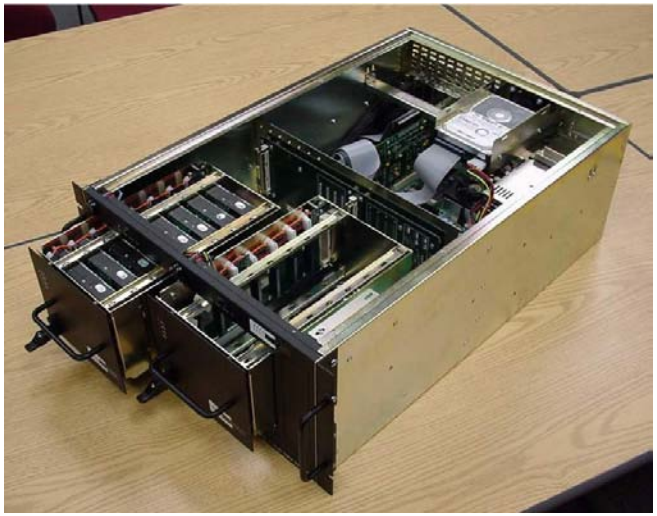






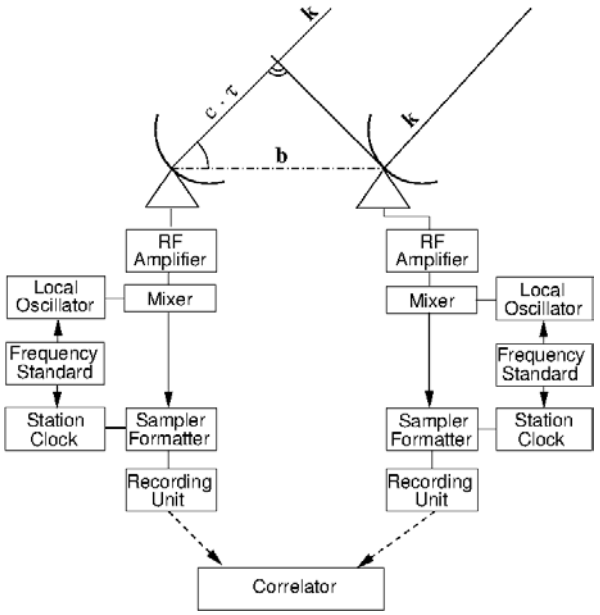
VLBI principles II

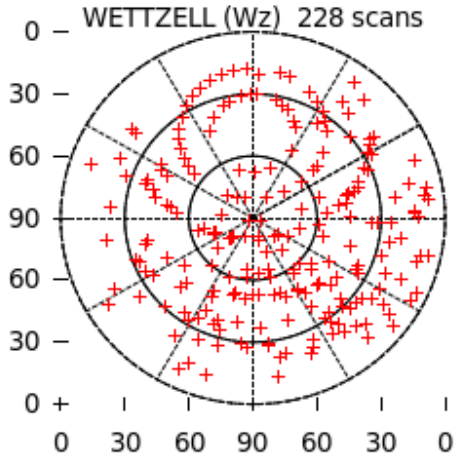




- Analog signals are digitized and time tagged
- Number of correlated bits determine accuracy
  → large bandwidth
- Data volume of several Terabyte per day
- Data transfer to correlator
  - By network links
  - By disk units
- Hydrogen masers
  - $\Delta f/f \approx 5 \cdot 10^{-15}$
  - Time synchronization ≤ 1 µs

VLBI principles III



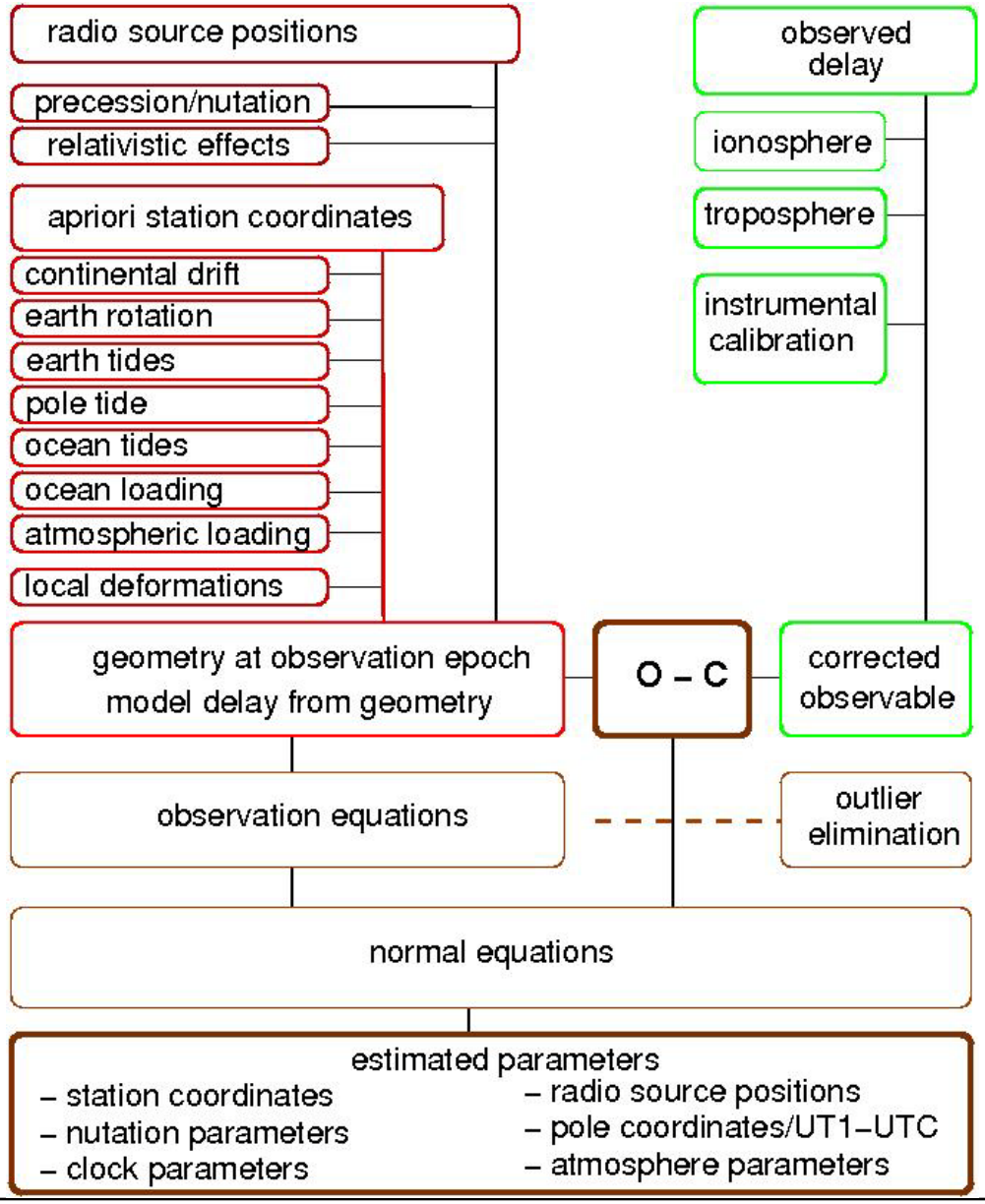


- Recording time 20 – 200 s (= 1 scan)
  (Integration time for signal-to-noise)
- Earth rotates
- Geometry not stationary
- Makes group delay determination complicated
- 1 scan produces one group delay/delay rate

- Multiple scans in one observing session
  (1hr or 24 hour duration)

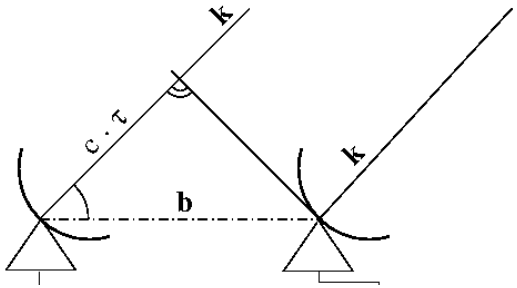
- Intermediate step:
  Correlation

Data analysis

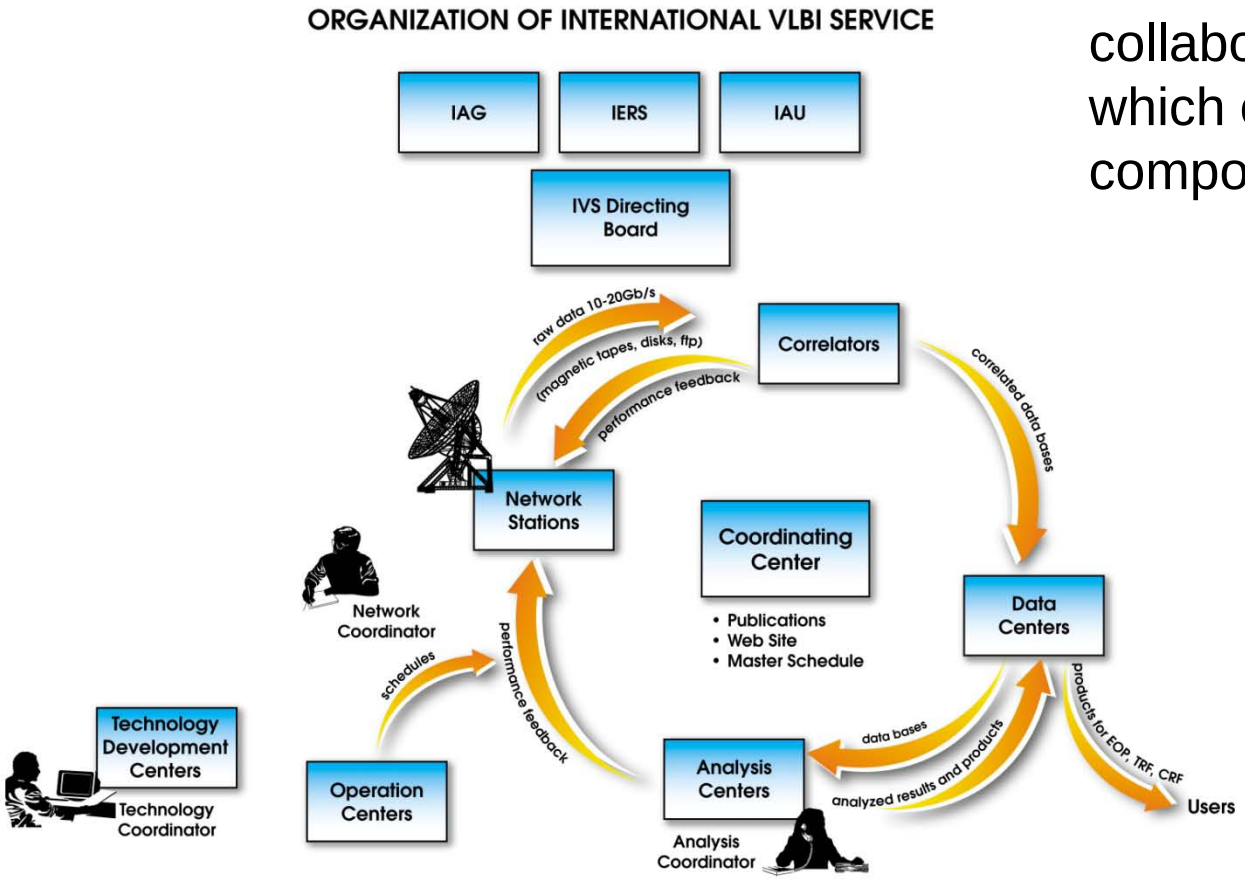


- Input 200 – 400 group delays per baseline per 24 hours

$$\tau = -\frac{1}{c}\vec{b} \cdot R(t) \cdot \vec{k}$$



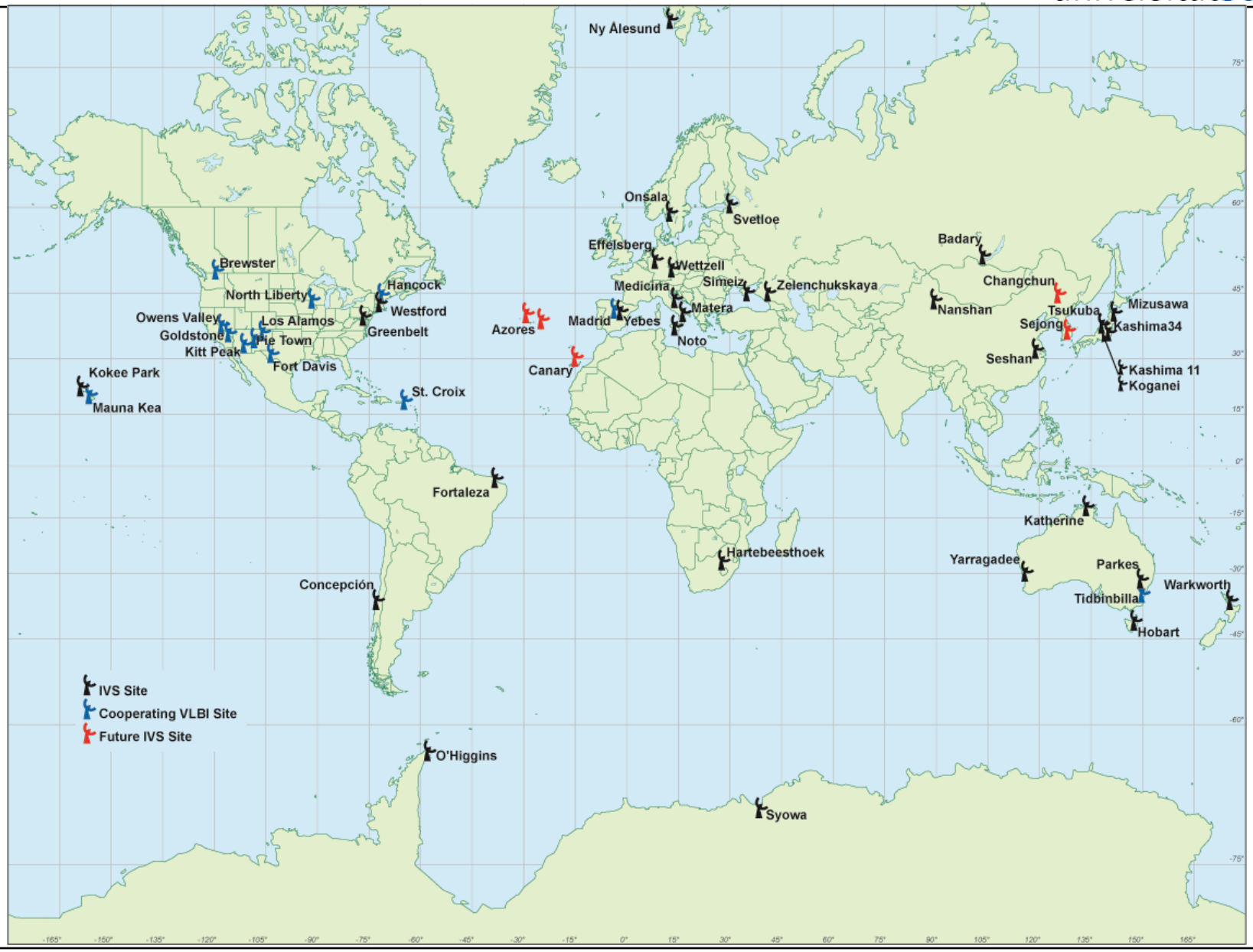
International VLBI Service for Geodesy and Astrometry



The IVS is an international collaboration of organizations which operate or support VLBI components

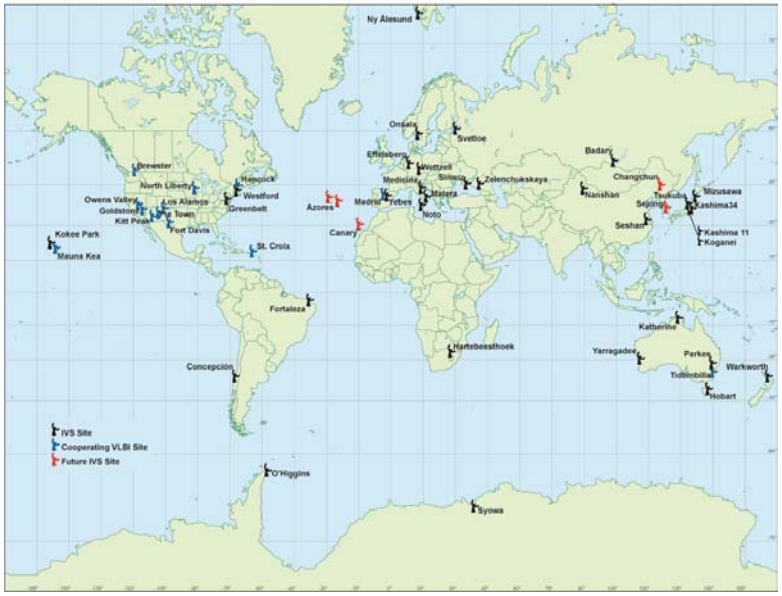
© IVS

IVS Observing network

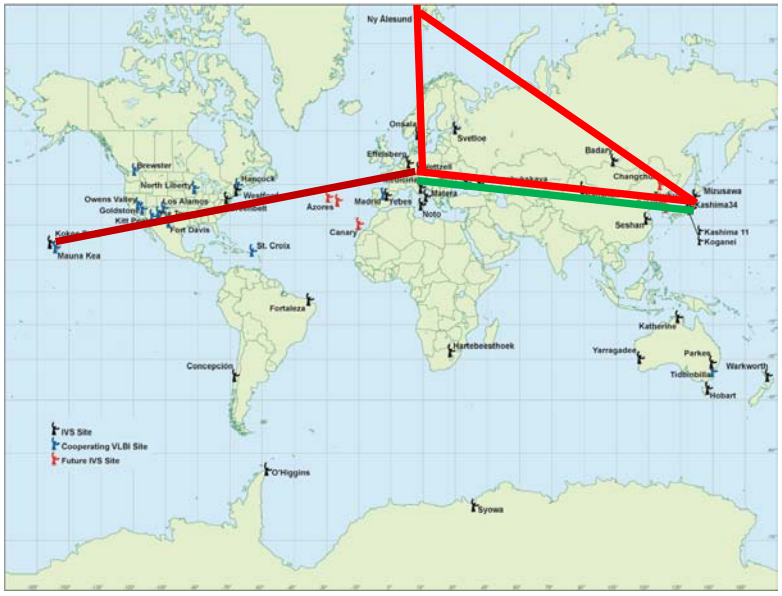


IVS Observing Sessions

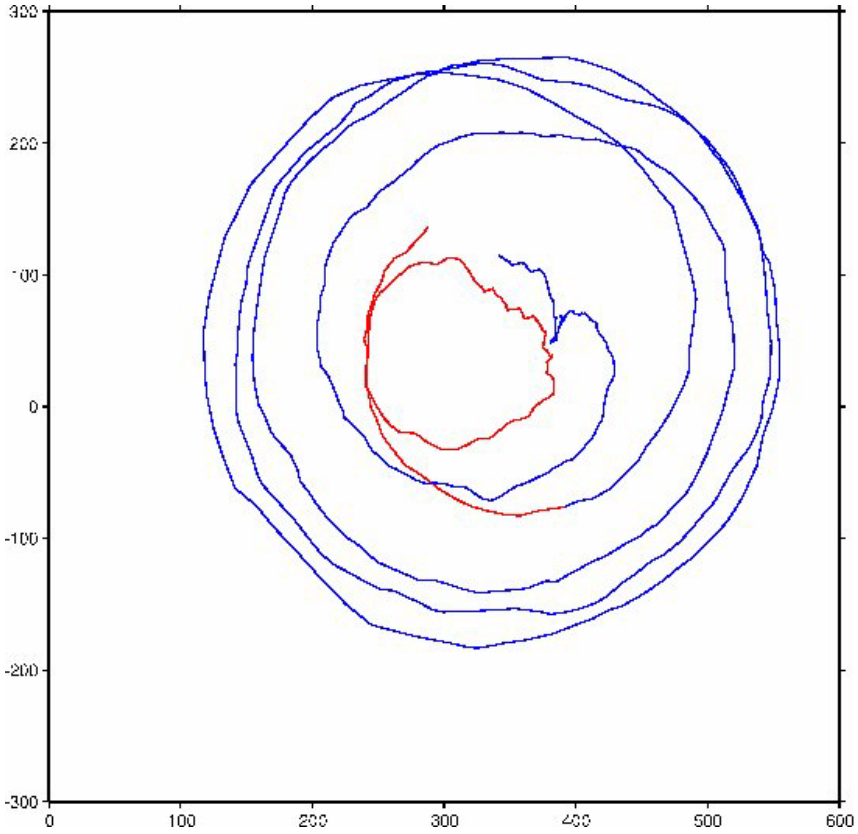
- Network sessions (24 hr duration)
  - R1, R4 for regular Earth orientation parameter determinations (8 – 10 telescopes)
  - T2, OHIG, EUROPE, AOV, for telescope coordinate determinations (up to 18 telescopes)
  - CRF for celestial reference frame (4 – 7 telescopes)

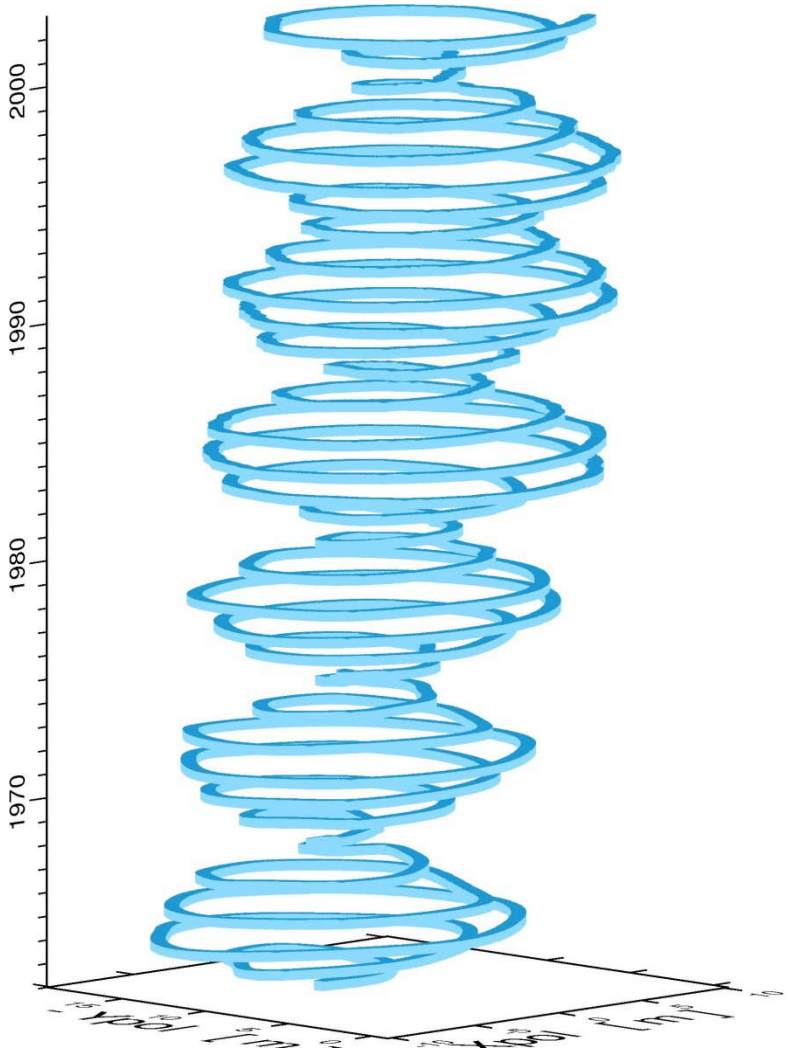


- Single baseline/triangle sessions (1 hr duration)
  - Daily sessions for the determination of UT1-UTC

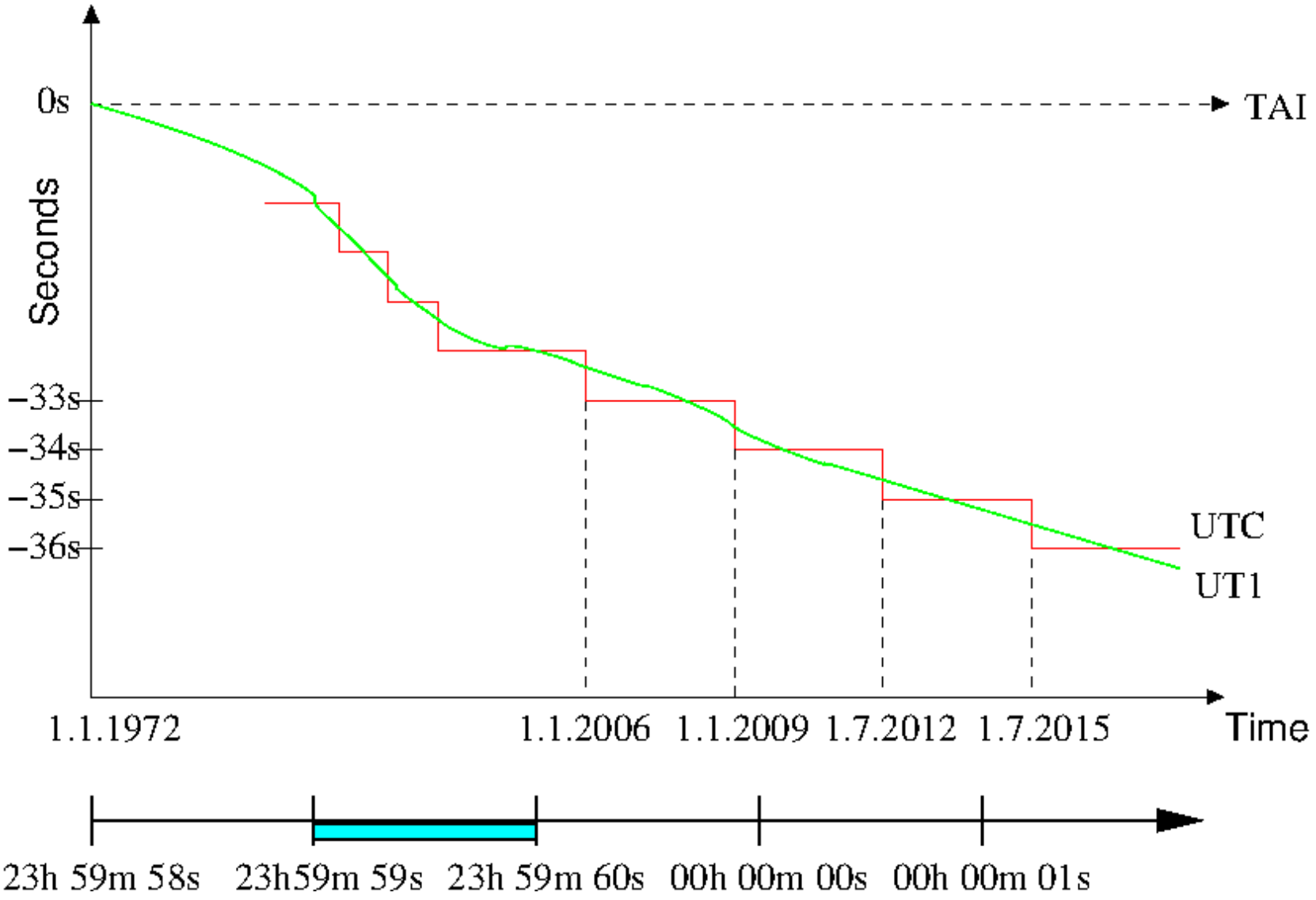


Polar motion

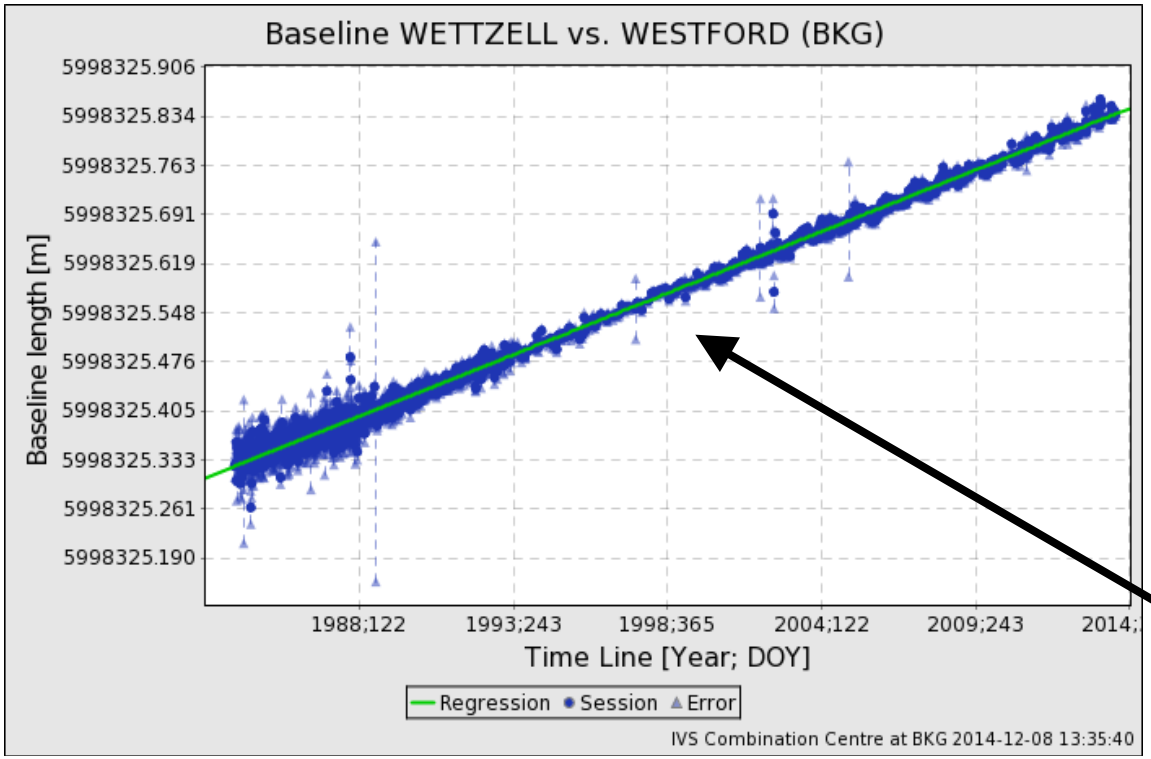


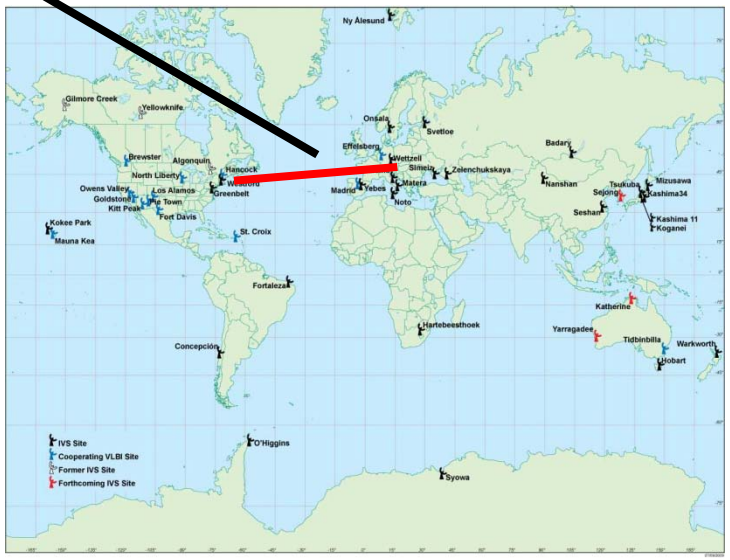


UT1-UTC

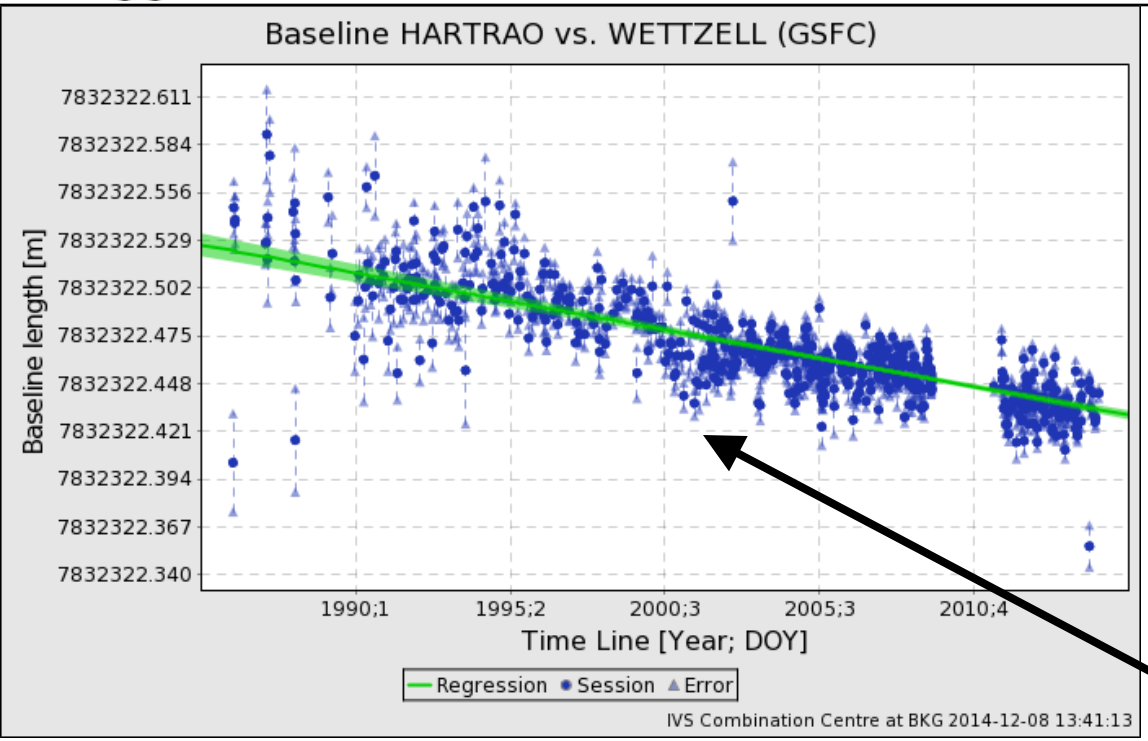

0s
TAI
Seconds
−33s
−34s
−35s
−36s
UTC
UT1
1.1.1972
1.1.2006
1.1.2009
1.7.2012
1.7.2015
Time
23h 59m 58s
23h59m 59s
23h 59m 60s
00h 00m 00s
00h 00m 01s

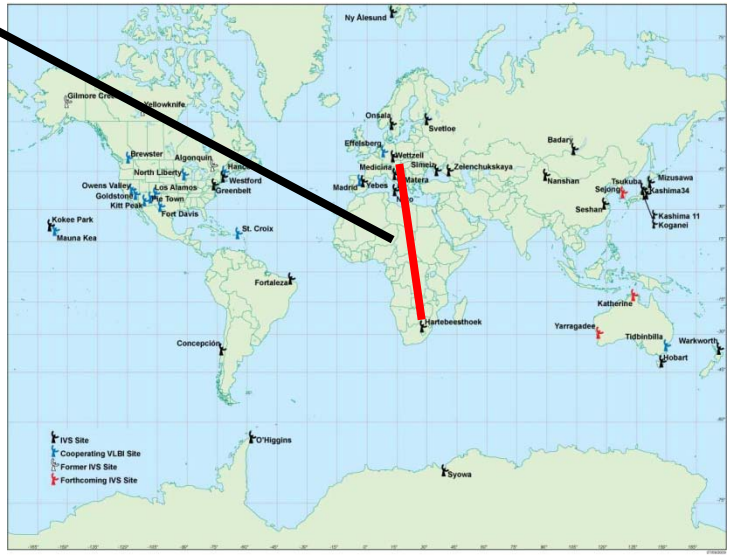
Westford - Wettzell



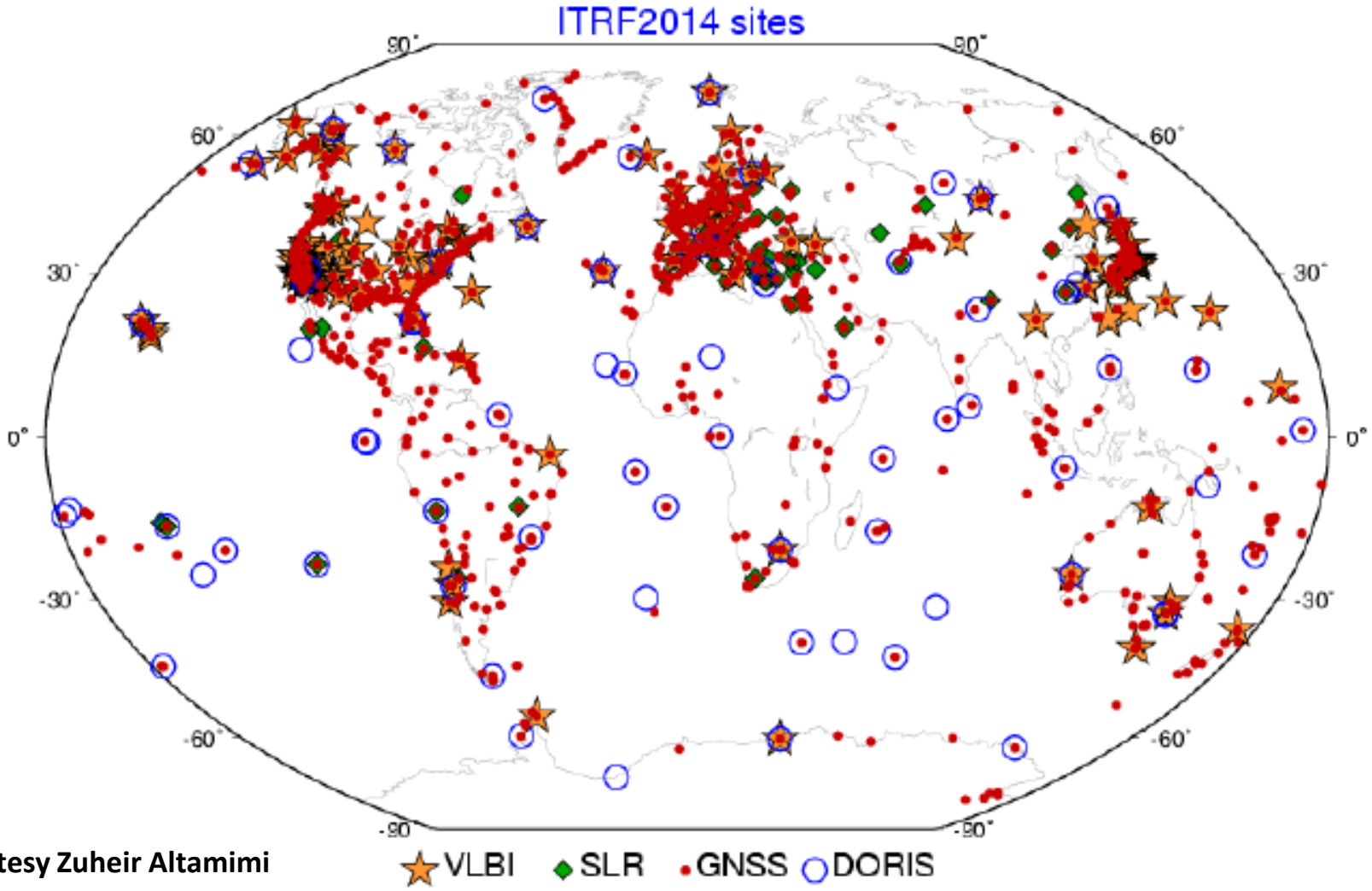


Wettzell - HartRAO





ITRF = International Terrestrial Reference Frame



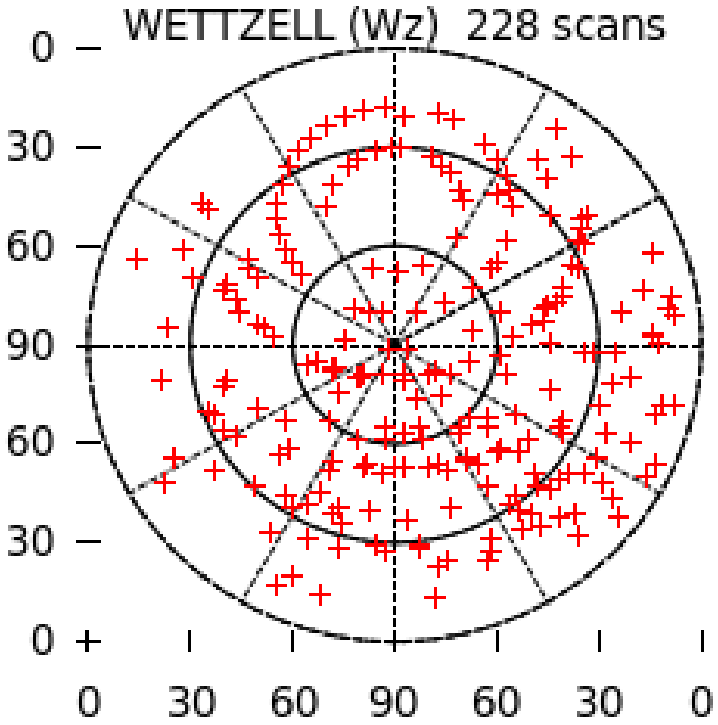
© Courtesy Zuheir Altamimi

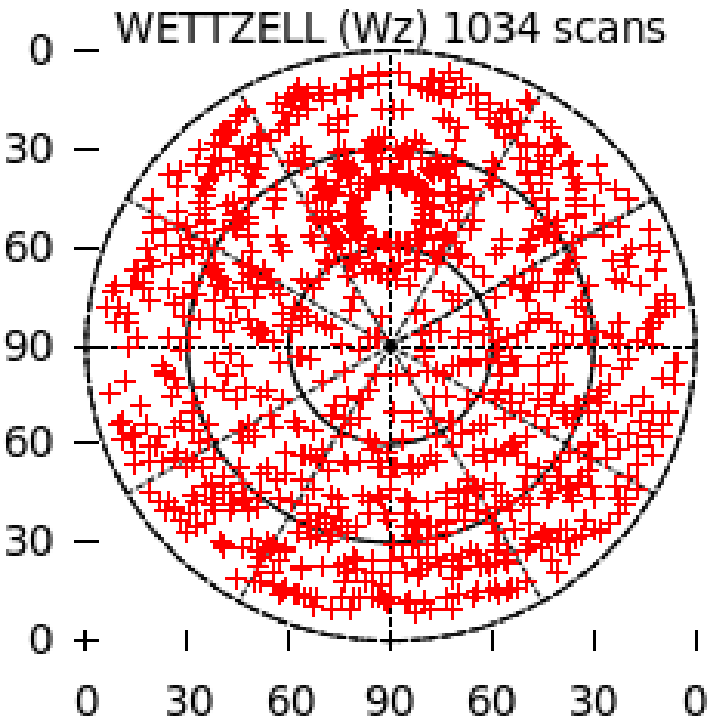
ITRF2014 STATION POSITIONS AT EPOCH 2010.0 AND VELOCITIES

VLBI STATIONS

DOMES NB.	SITE NAME	TECH. ID.	X/Vx	Y/Vy	Z/Vz	Sigmas		
					m/m/y			
10317S003	Ny-Alesund	VLBI 7331	1202462.5677	252734.4956	6237766.1746	0.0006	0.0006	0.0007
10317S003			-.01461	0.00759	0.01039	.00004	.00004	.00004
10402S002	Onsala	VLBI 7213	3370605.8407	711917.6739	5349830.8703	0.0007	0.0007	0.0007
10402S002			-.01437	0.01454	0.01042	.00004	.00004	.00004
10503S002	Metsahovi	VLBI 7385	2892584.8978	1311715.5529	5512640.1298	0.0009	0.0008	0.0012
10503S002			-.01643	0.01453	0.01001	.00006	.00006	.00007
12338S003	Badary	VLBI 7382	-838200.9878	3865751.5645	4987670.9035	0.0007	0.0008	0.0008
12338S003			-.02773	0.00046	-.00274	.00007	.00012	.00016
12350S001	Svetloe	VLBI 7380	2730173.7230	1562442.7504	5529969.1152	0.0007	0.0007	0.0007
12350S001			-.01863	0.01306	0.00793	.00005	.00005	.00007
12351S001	Zelenchukskaya	VLBI 7381	3451207.5991	3060375.3698	4391915.0186	0.0007	0.0007	0.0007
12351S001			-.02327	0.01308	0.00644	.00010	.00009	.00013
12711S001	Medicina	VLBI 7230	4461369.7463	919597.0658	4449559.3477	0.0010	0.0008	0.0010
12711S001			-.01827	0.01879	0.01136	.00005	.00004	.00005
12717S001	Noto	VLBI 7547	4934562.8871	1321201.4867	3806484.6874	0.0009	0.0007	0.0008
12717S001			-.01786	0.01752	0.01524	.00005	.00005	.00005
12734S005	Matera - ASI	VLBI 7243	4641938.5242	1393003.2627	4133325.7273	0.0007	0.0007	0.0007
12734S005			-.01886	0.01893	0.01443	.00004	.00004	.00004

- **New generation VLBI infrastructure**
  - **dense sampling of local sky for optimal estimation of atmosphere parameters**





VGOS

VLBI2010 Global Observing System became VLBI Global Observing System – VGOS

Small and agile telescopes

Large bandwidth (2 – 14 GHz [3 - 18])

Flexible frequency allocation

Dual linear polarization

Concept of VGOS

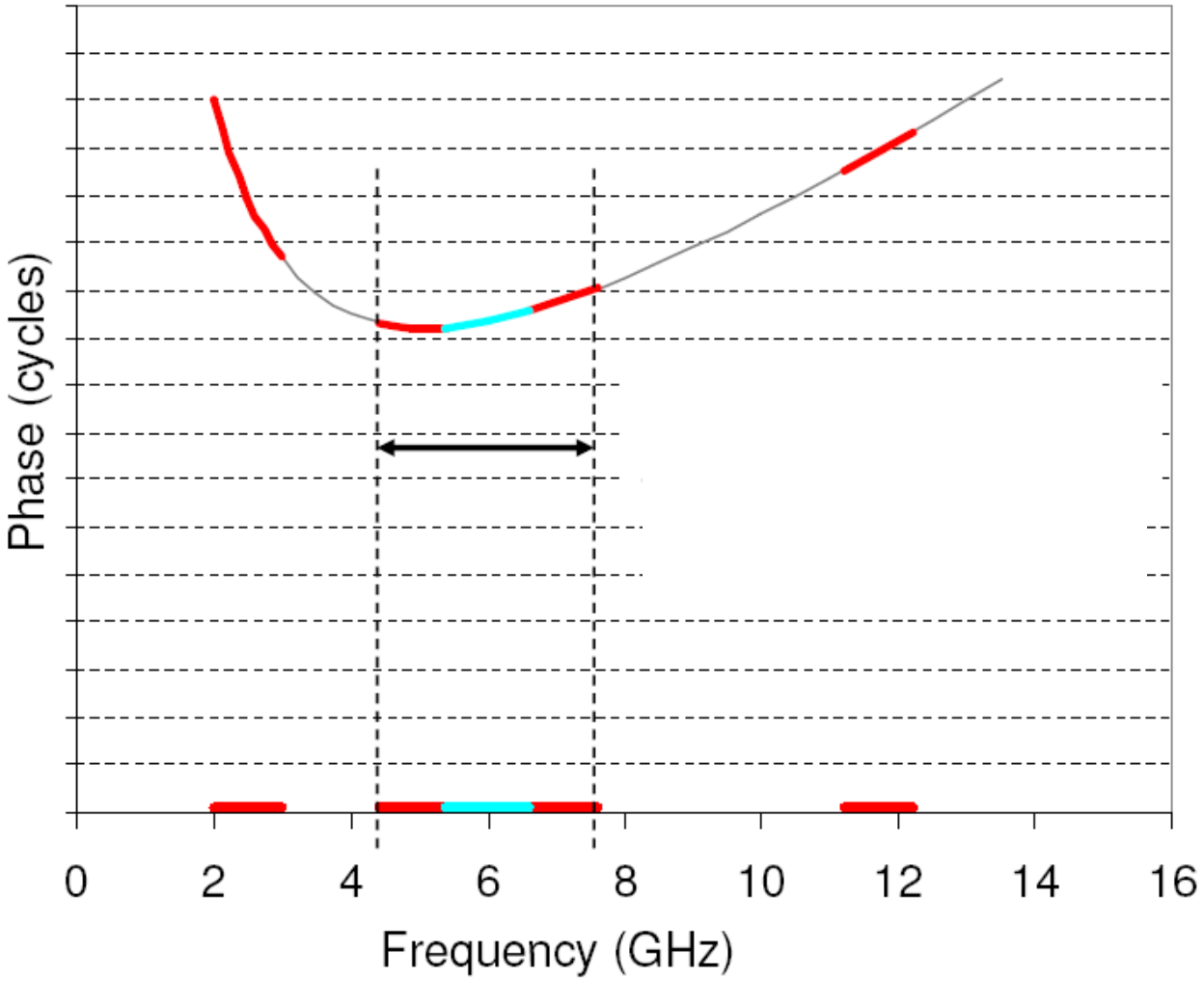
- **New generation VLBI infrastructure**
  - **dense sampling of atmosphere**
  - **agile telescopes**
    → small (12 – 13 m)
    12°/sec
  - **up to 2 observations per minute (2880/day)**

$$\sigma_\tau \propto \sqrt{\frac{1}{A_1 A_2 \cdot B}}$$

=> Large bandwidth needed

- **wide band receivers (2 – 14 GHz [3 - 18])**

VGOS Frequencies



Courtesy B. Petrachenko

VGOS Telecopes

Wettzell (DE)

Zelenchukskaya (RU)

Courtesy
A. Ipatov

Ishioka (JP) **Courtesy Y. Fukuzaki**

GGAO (US)

Courtesy A. Niell

Badary (RU)

Courtesy
A. Ipatov

STATUS OF THE SPANISH/PORTUGUESE RAEGE PROJECT

universitätbonn

Gómez-González et al .(2013)

Yebes (Spain)

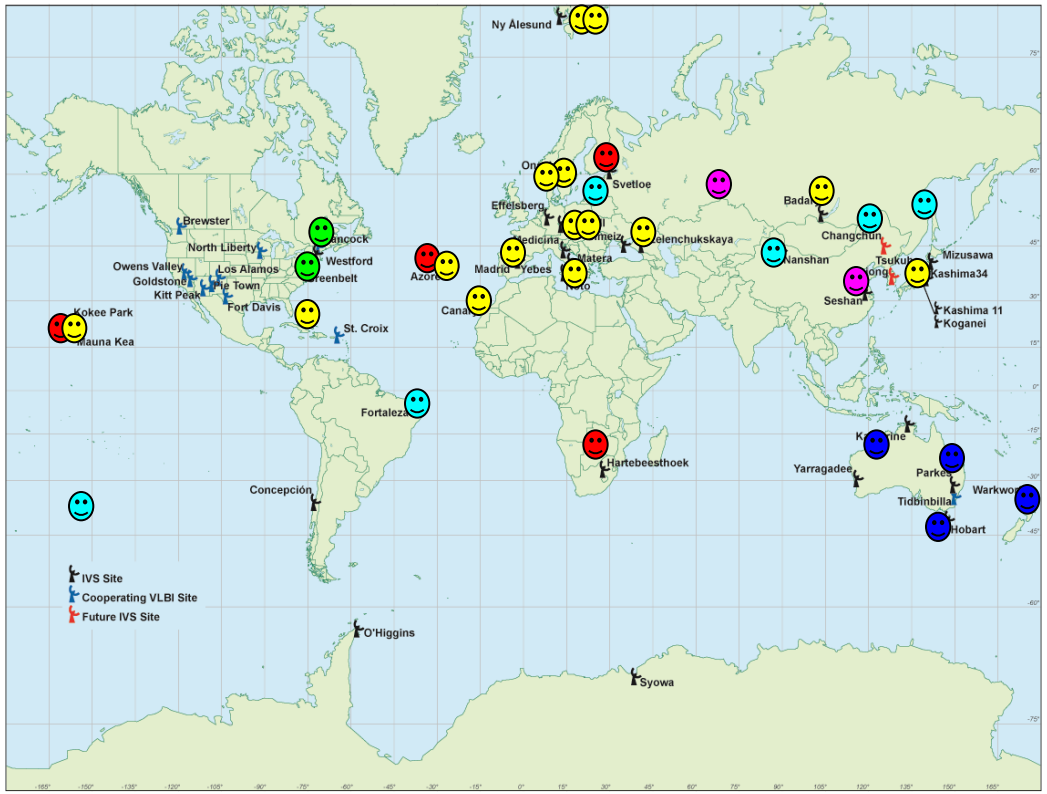
(August 2013) Courtesy: J.A. Lopez

Santa Maria (Eastern Azores)

(Sep. 2014) Courtesy: F. Colomer

VGOS World

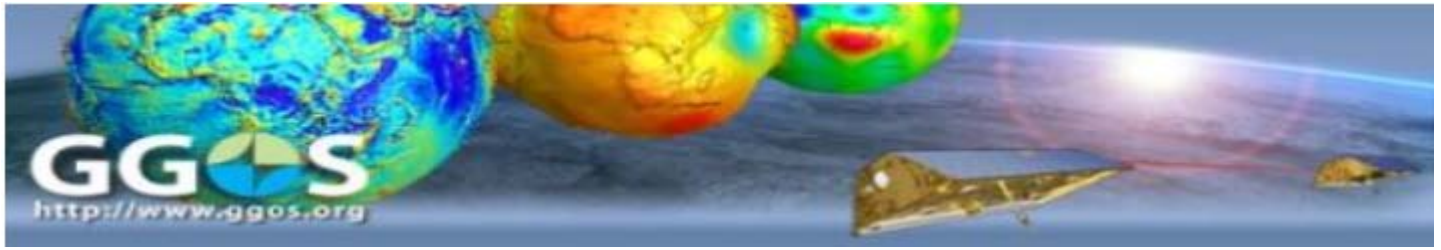
New VGOS radio telescopes for IVS



- operational
- under construction
- funded
- proposal submitted
- planning phase
- planning phase upgrade

Courtesy H.Hase/VPEG, based on available information January 2016

Global Geodetic Observing System



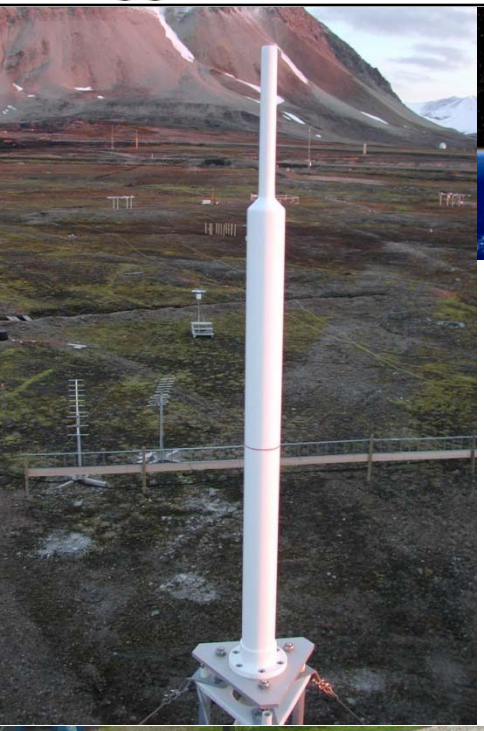
IVS → VGOS → GGOS

Global Geodetic Observing System
of the International Association of Geodesy (IAG)

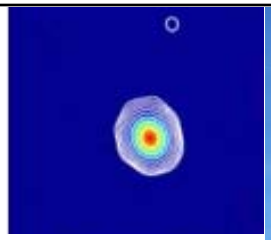
Contribution to GGOS

- Global distribution → Well-designed network
- Continuous → Economic operations
- Stable over decades → Monitoring of telescopes and local ties
- 1 mm/0.1 mm/y → Improved technology, better modeling

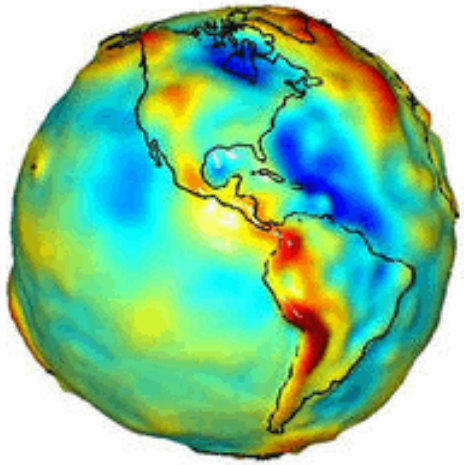
Global Geodetic Observing System



DORIS

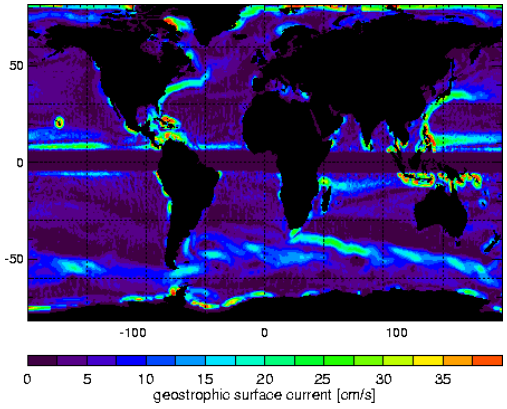


VLBI

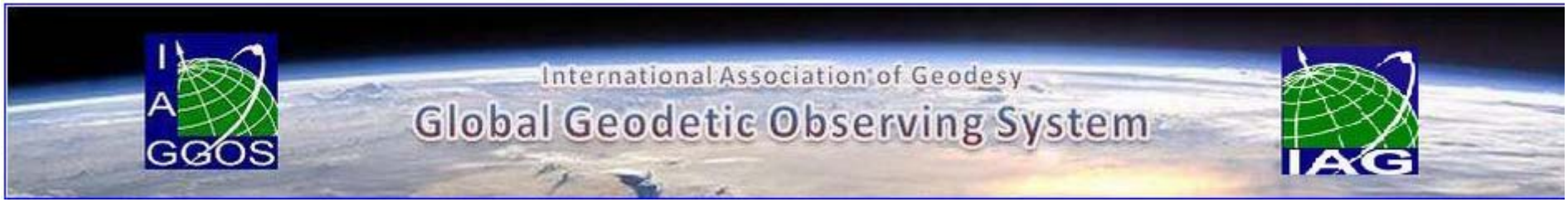


GPS

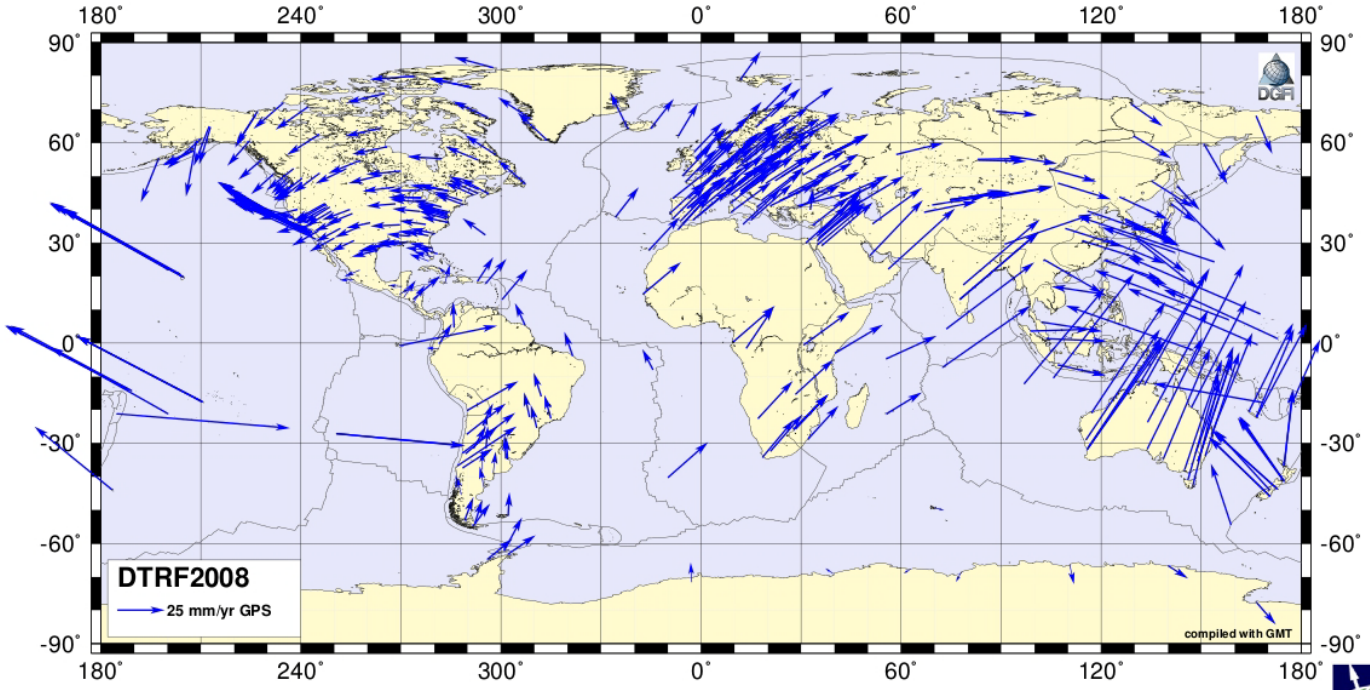
SLR



Global Geodetic Observing System



VGOS will be part of GGOS



International Association of Geodesy
150 years