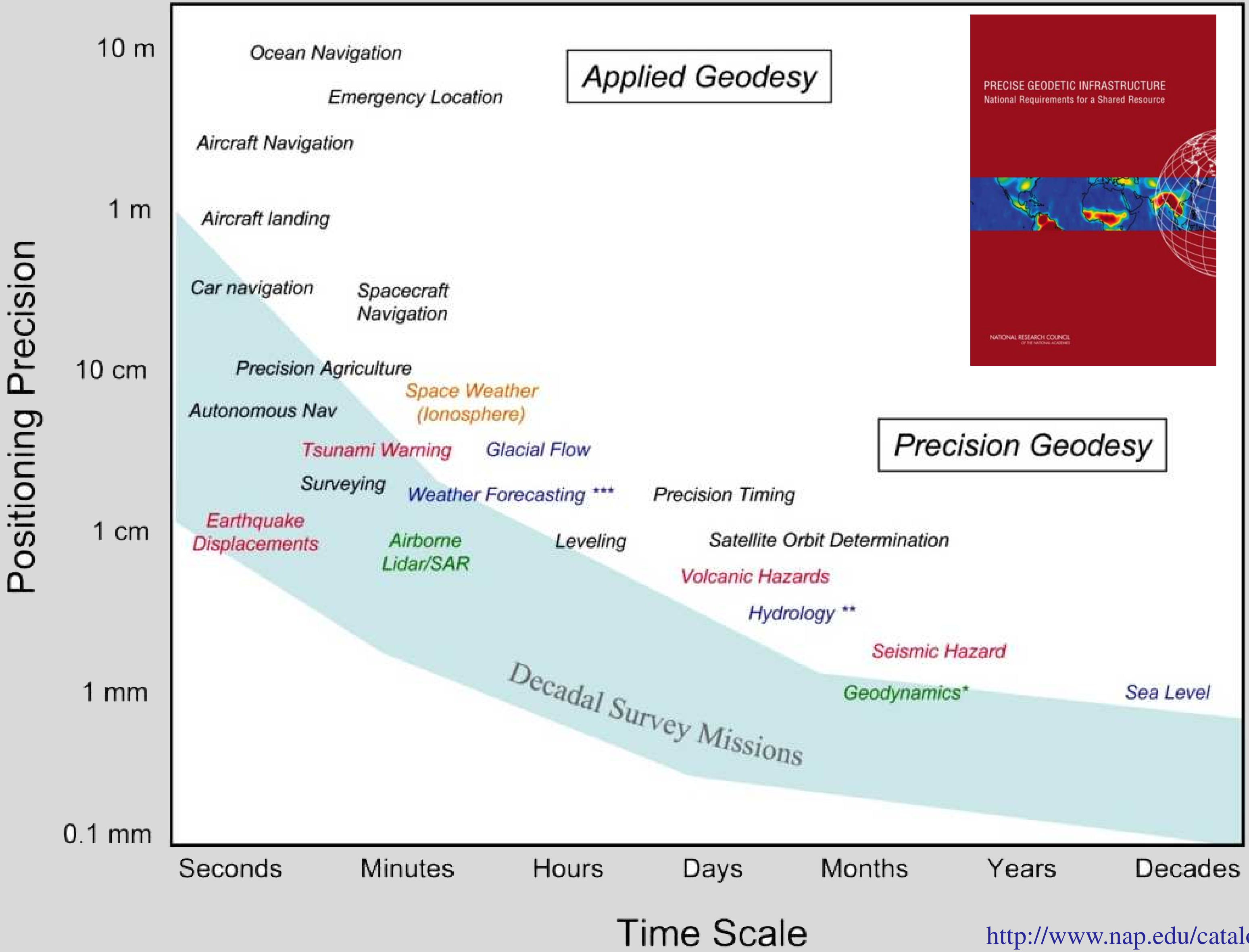
Geodetic VLBI: Science, IVS, etc.

John Gipson
NVI,Inc/NASA GSFC

2019 Workshop on Regional VLBI
Mexico City,Mexico

Space Geodesy Provides Positioning, Navigation, and Timing Reference Frames and Earth System Observations



http://www.nap.edu/catalog/12954.html

Who Am I?

PhD in Theoretical Particle Physics

Started doing VLBI ~ 1985.

Senior scientist in the NASA Goddard VLBI group

Specialty is analysis (and scheduling)

Special interest in Earth Orientation

IVS Analysis Coordinator

John.M.Gipson@nasa.gov

Agenda

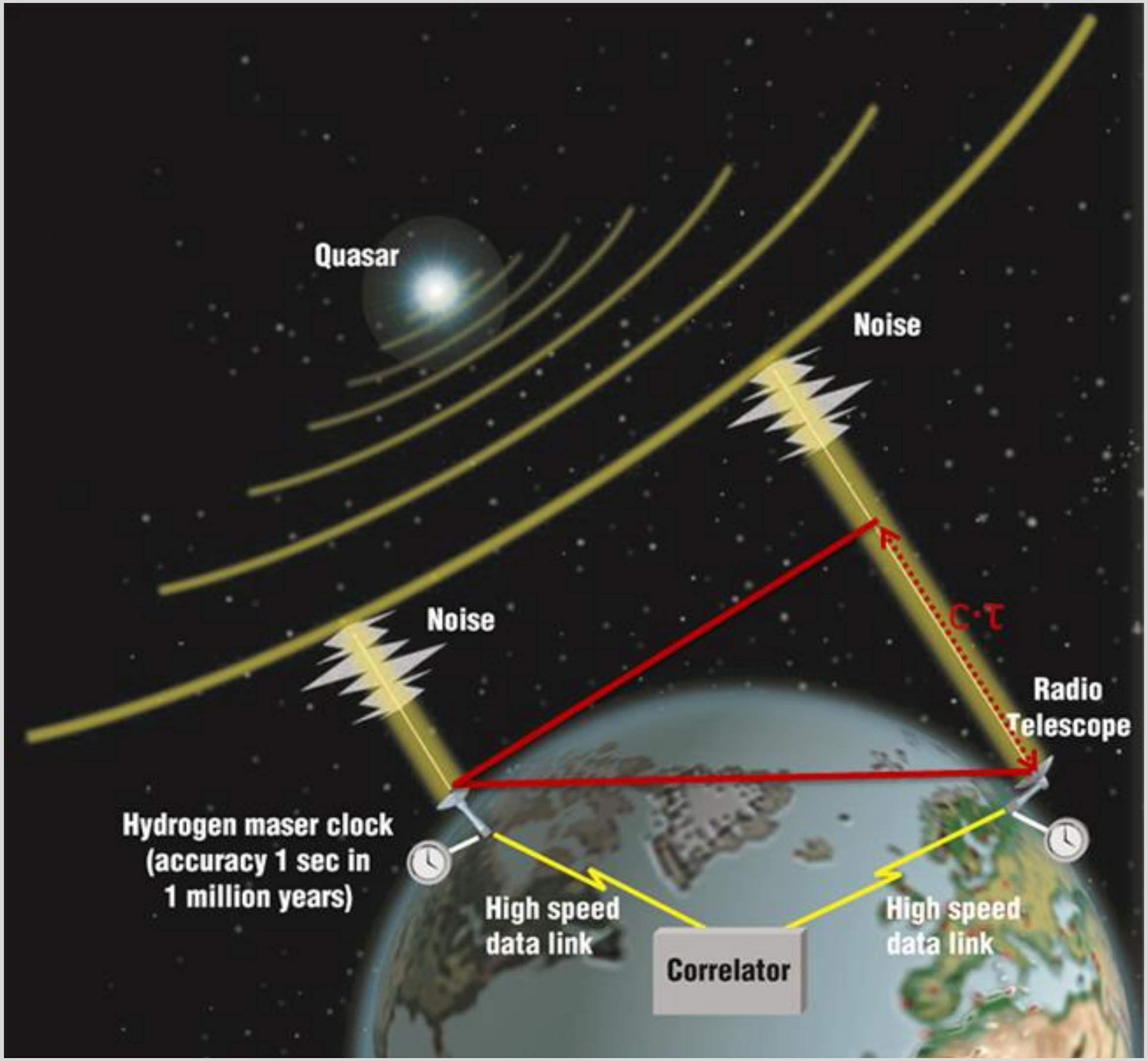
Overview of Geodetic VLBI

The IVS Organization

The International Celestial Reference Frame

Earth Orientation Parameters

What is VLBI?



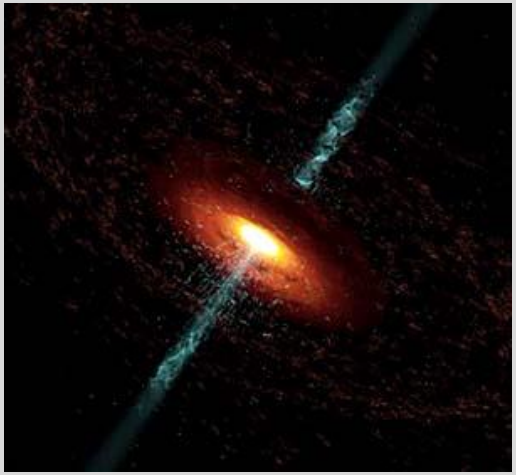
The VLBI observable is the difference in arrival time of the signal at the two antennas.

By looking at a variety of sources you can determine the vector connecting the two antennas.

The signal is very weak which means you need large antennas.

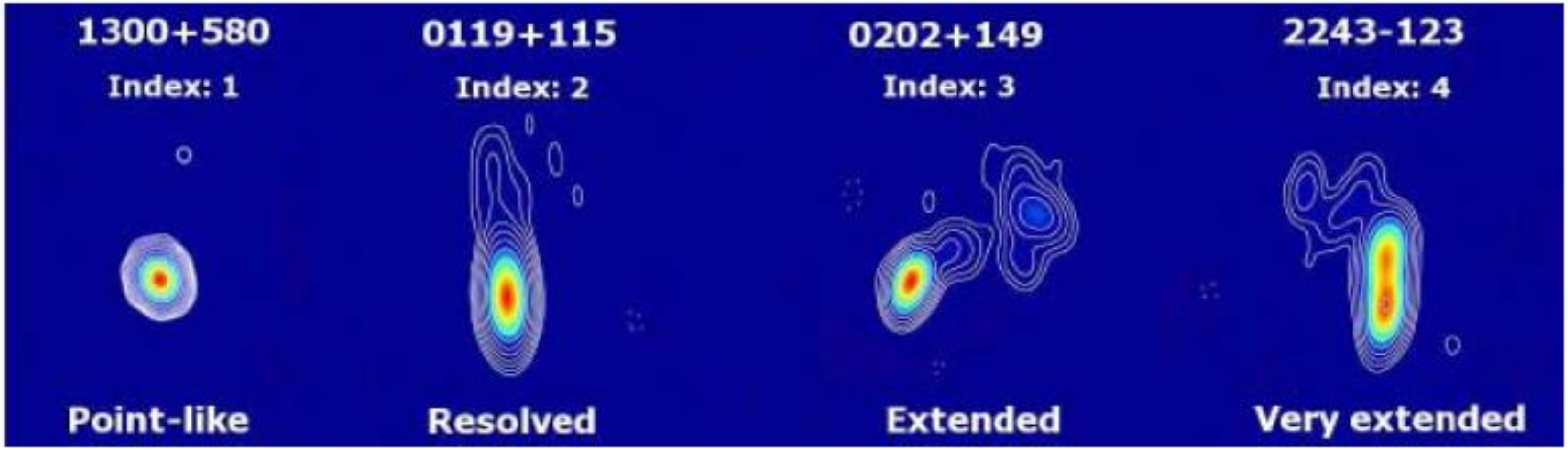
Anything that affects the delay is a candidate for estimation.

Radio sources



Active galactic nuclei, galaxies, quasars
Distance 2 – 8 billion light years
Point sources

→quasi-inertial reference system



Collioud and Charlot (2009)

We want sources with no structure!

Ugly!!

Some IVS Radio telescopes

Greenbelt, USA

O,Higgins, Antarctica

© BKG

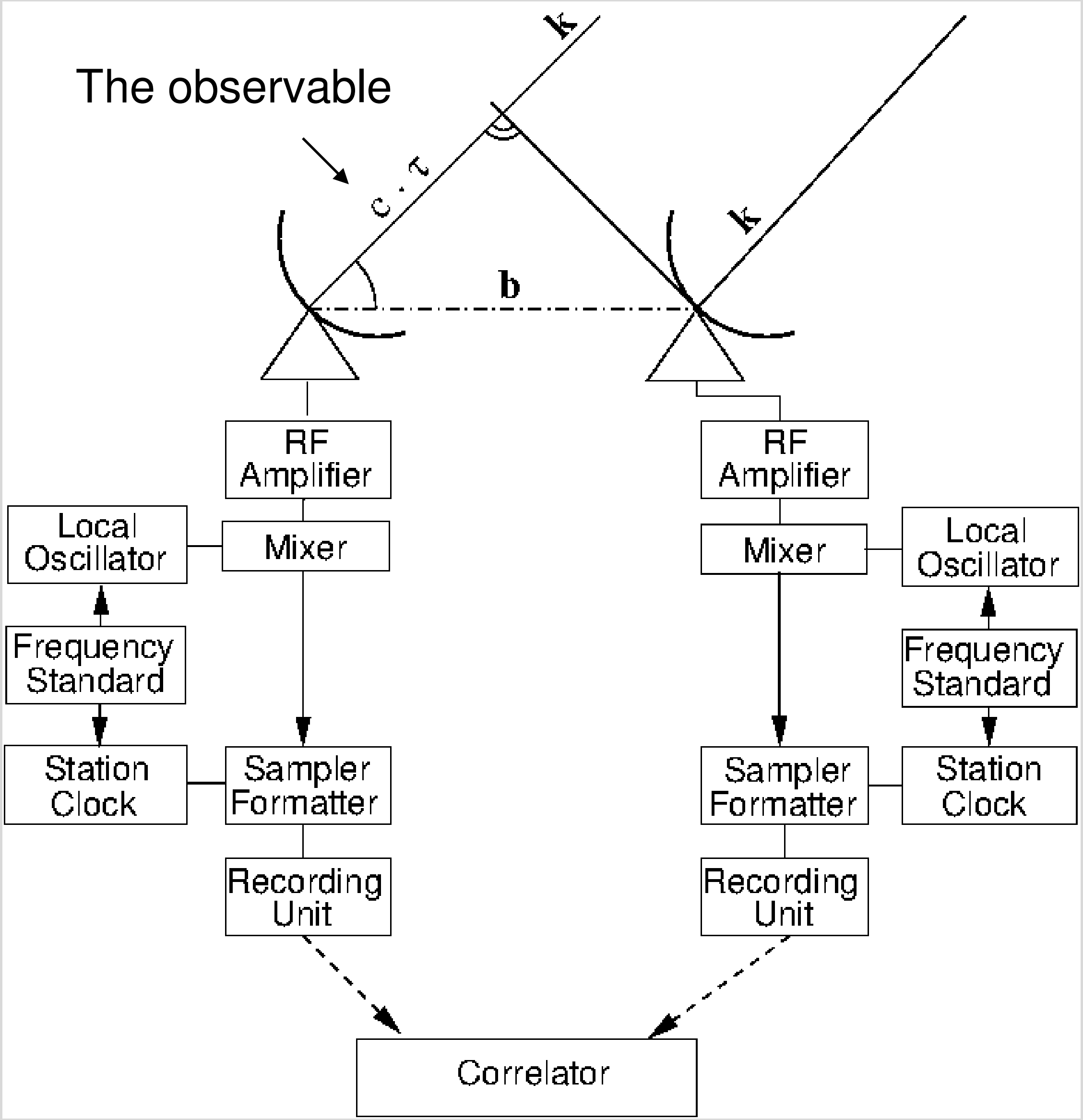
Urumqi, China

Ishioka, Japan

+ 40 more

Effelsberg, Germany

VLBI principles I



Number of correlated bits determine accuracy

Can increase accuracy by:

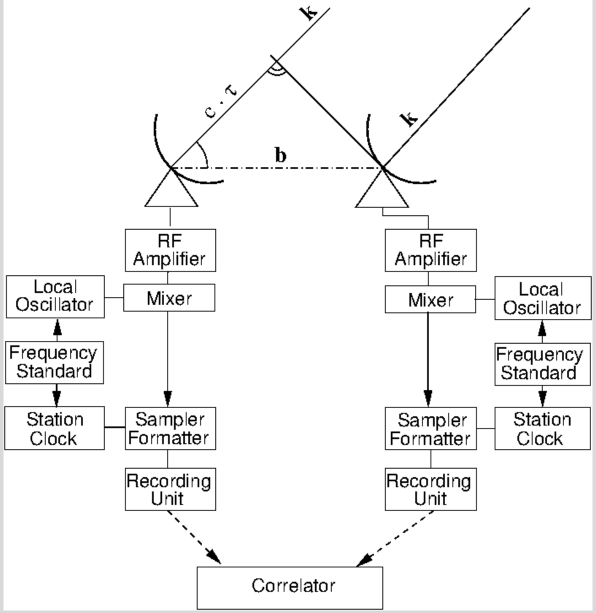
- More Bandwidth
- Increased scan length

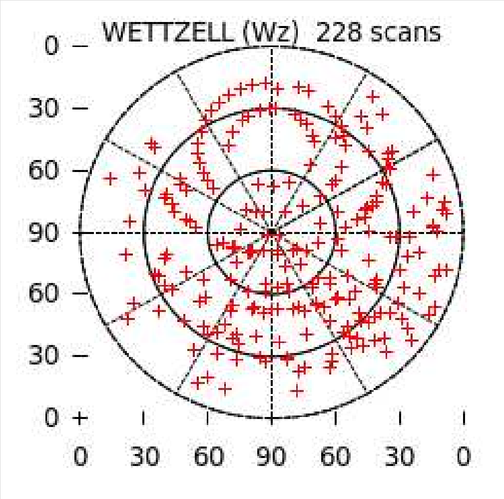
Data volume of several TeraByte per day

Data transfer to correlator

- Originally recorded on video tape.
- Now recorded on computer disks
- By transfer over the internet: eVLBI

VLBI principles II

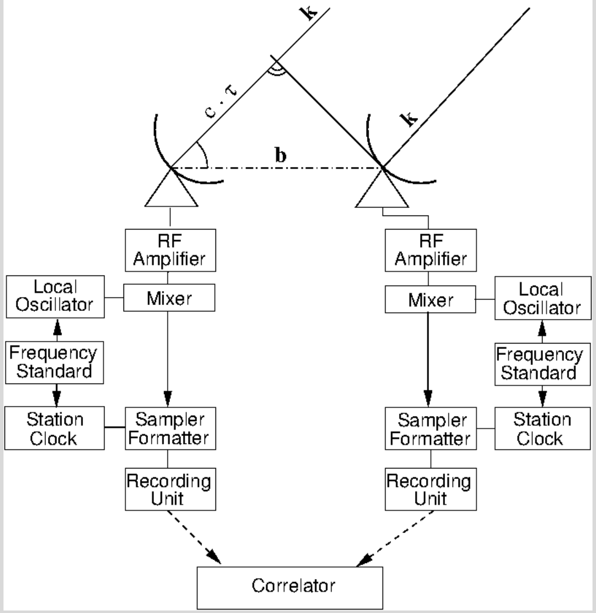


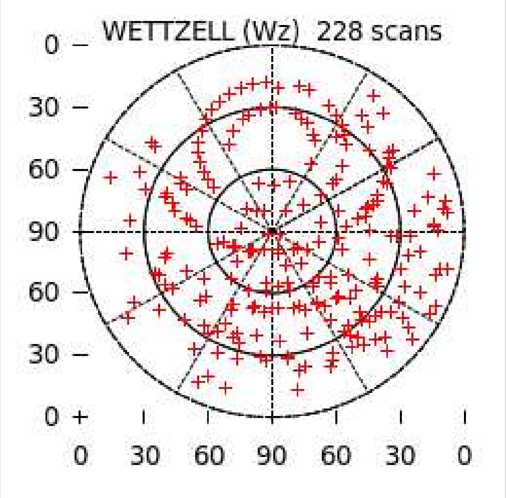


Number of scans limited by:

- Slew speed of antenna
- Required SNR: Higher SNR => longer scans

VLBI principles II



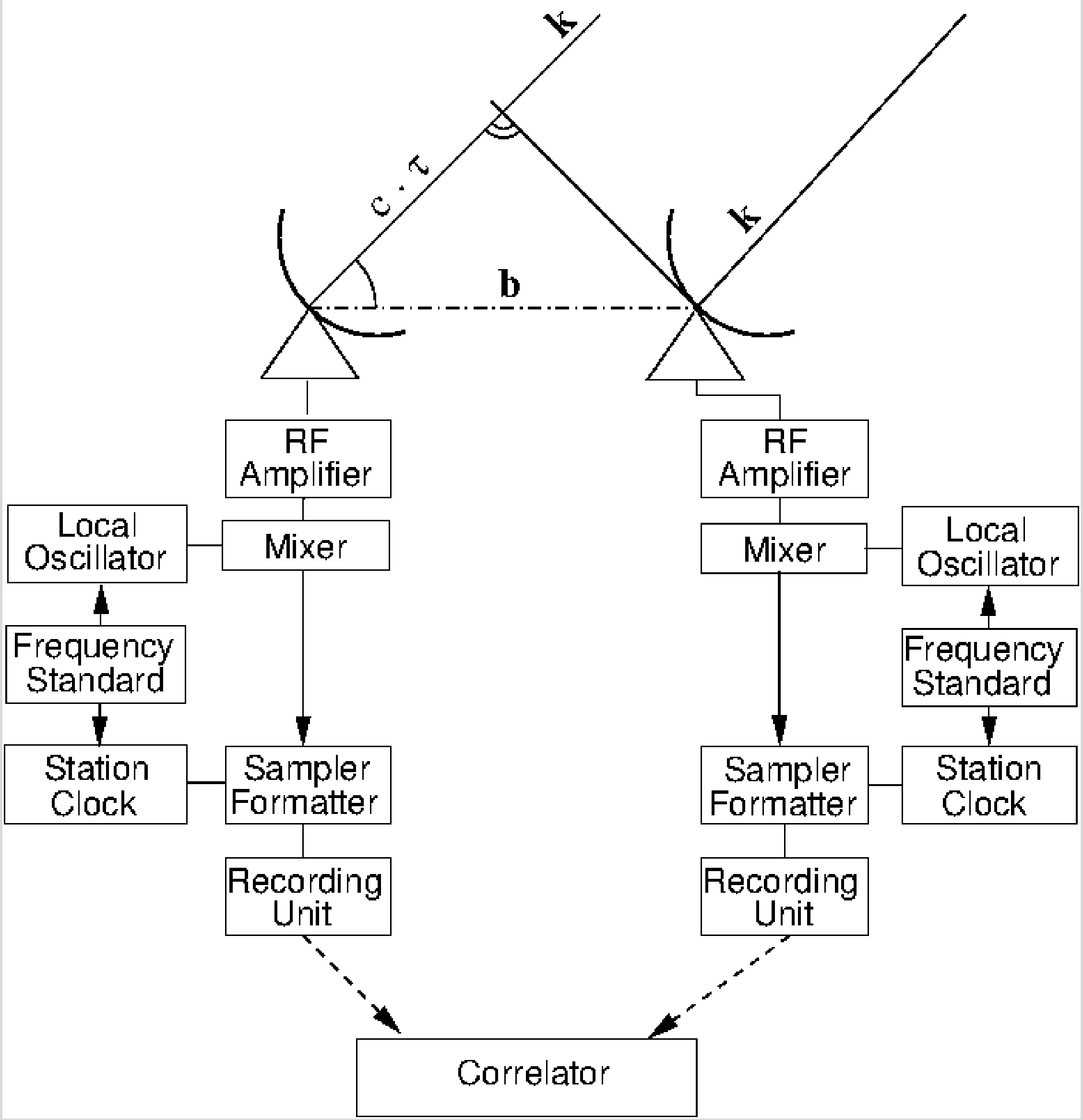


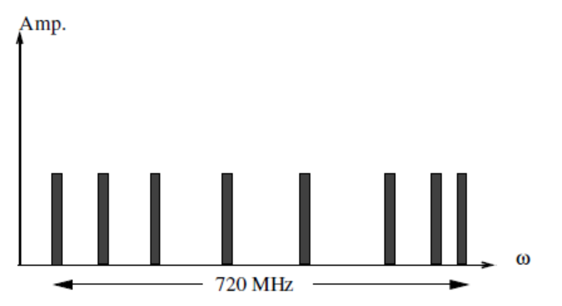
- Recording time 20 – 200 s (= 1 scan) (Integration time for signal-to-noise)
- Earth rotates
- Geometry not stationary
- Makes group delay determination complicated
- 1 scan produces one group delay/delay rate

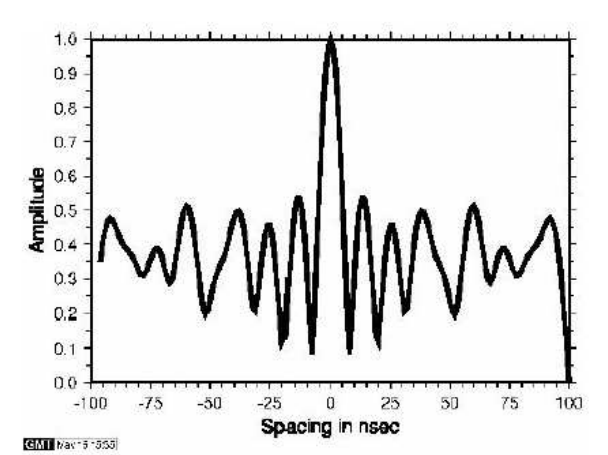
- Multiple scans in one observing session (1hr or 24 hour duration)

- Intermediate step: Correlation

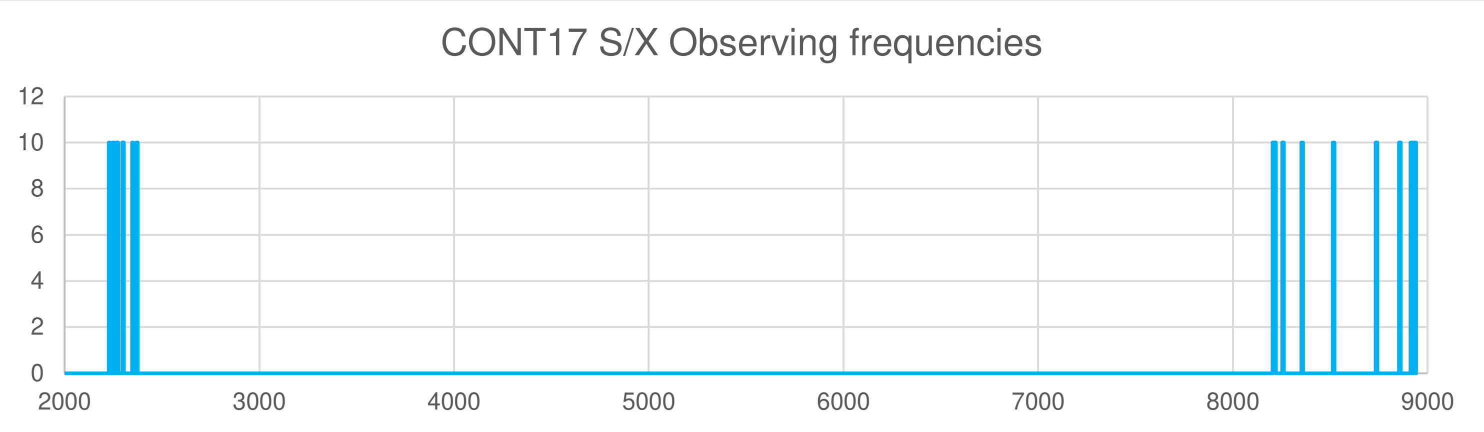
VLBI principles II

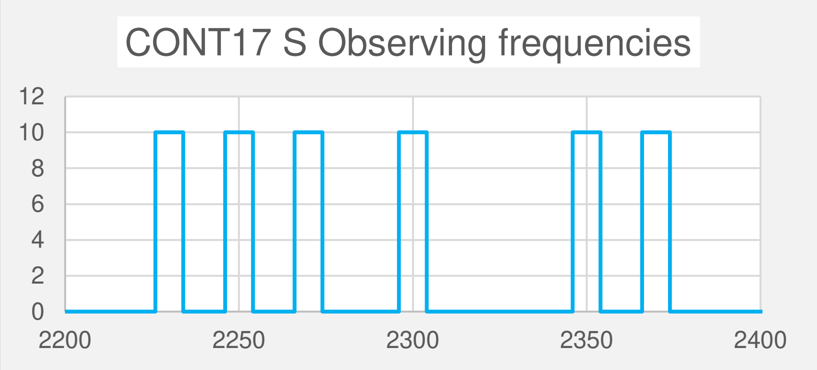


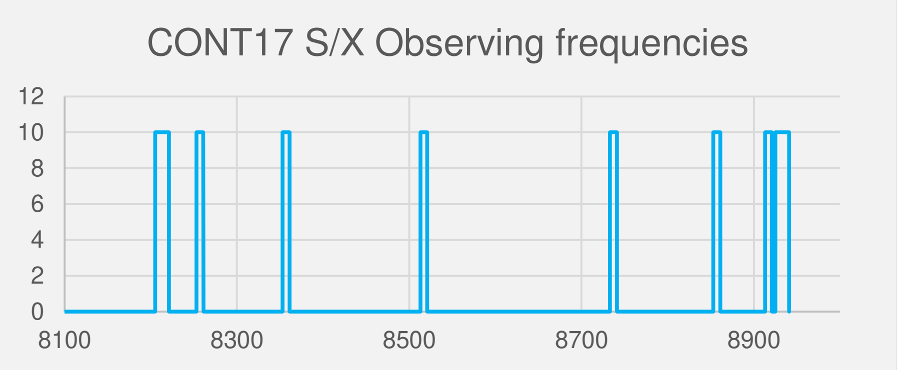




S/X Observing Bands







Placement of bands chosen to have
A) high peak and
B) minimize side lobes when you do FFT

Need to observe at 2-bands to correct for ionosphere

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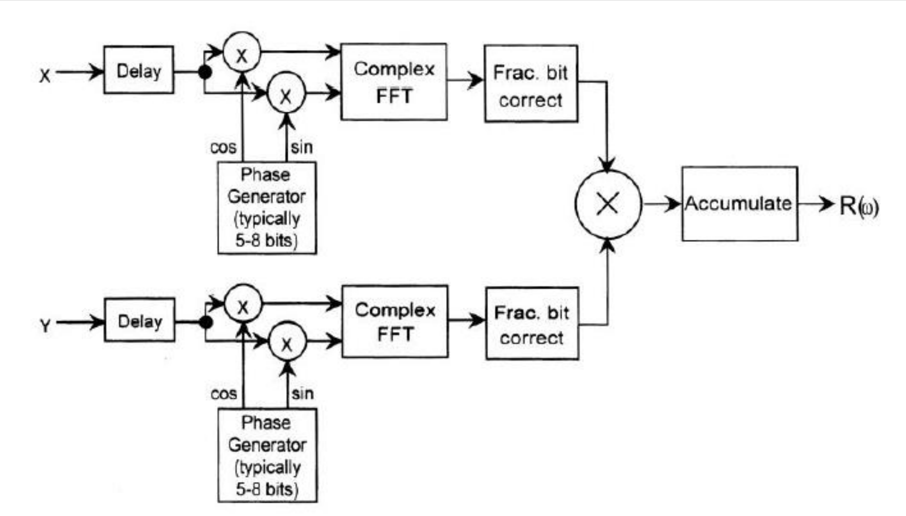
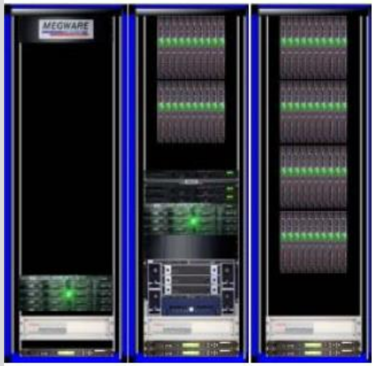
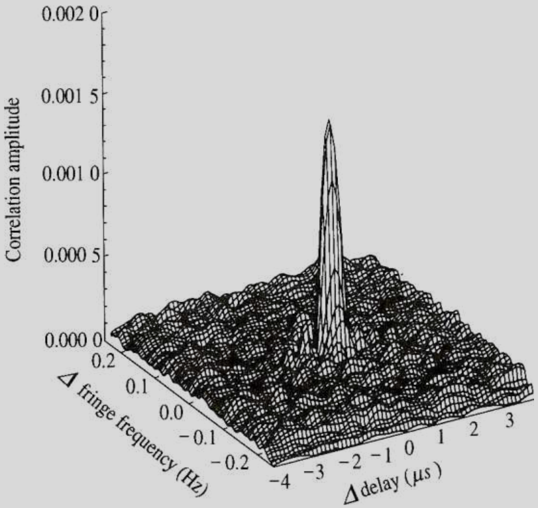
Correlation

Cross correlation process





Fringe fitting = Search for max. correlation amplitude (time lag and fringe rate)



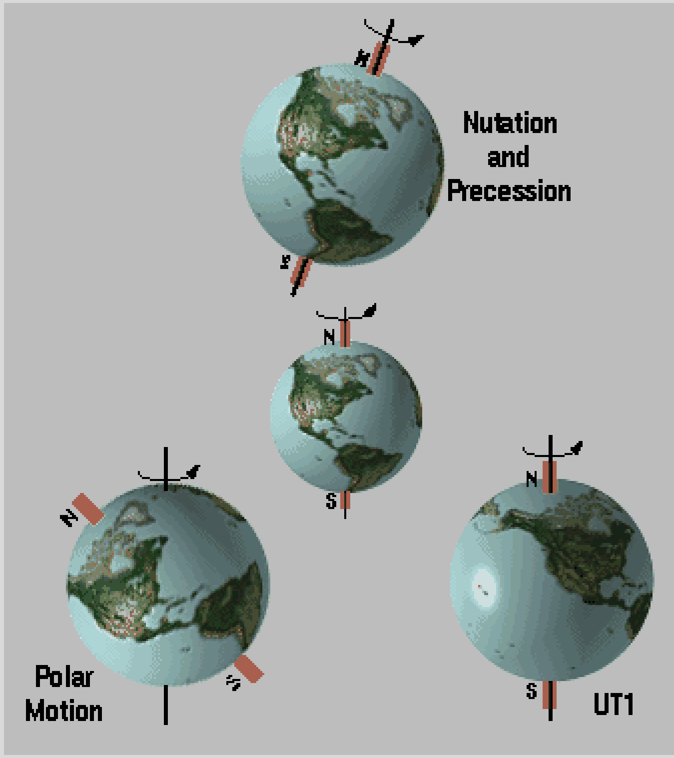
What affects the VLBI Delay?(1)

Anything that affects the delay must be calculated/ calibrated and/or is a candidate for prediction.

- Station related effects.
  - Station position
  - Earth tides
  - Loading (atmosphere, ocean, hydrology)
  - Pole tide
- Source related effects:
  - Position of sources
  - Core shift
  - Source structure

What affects the VLBI Delay?(2)

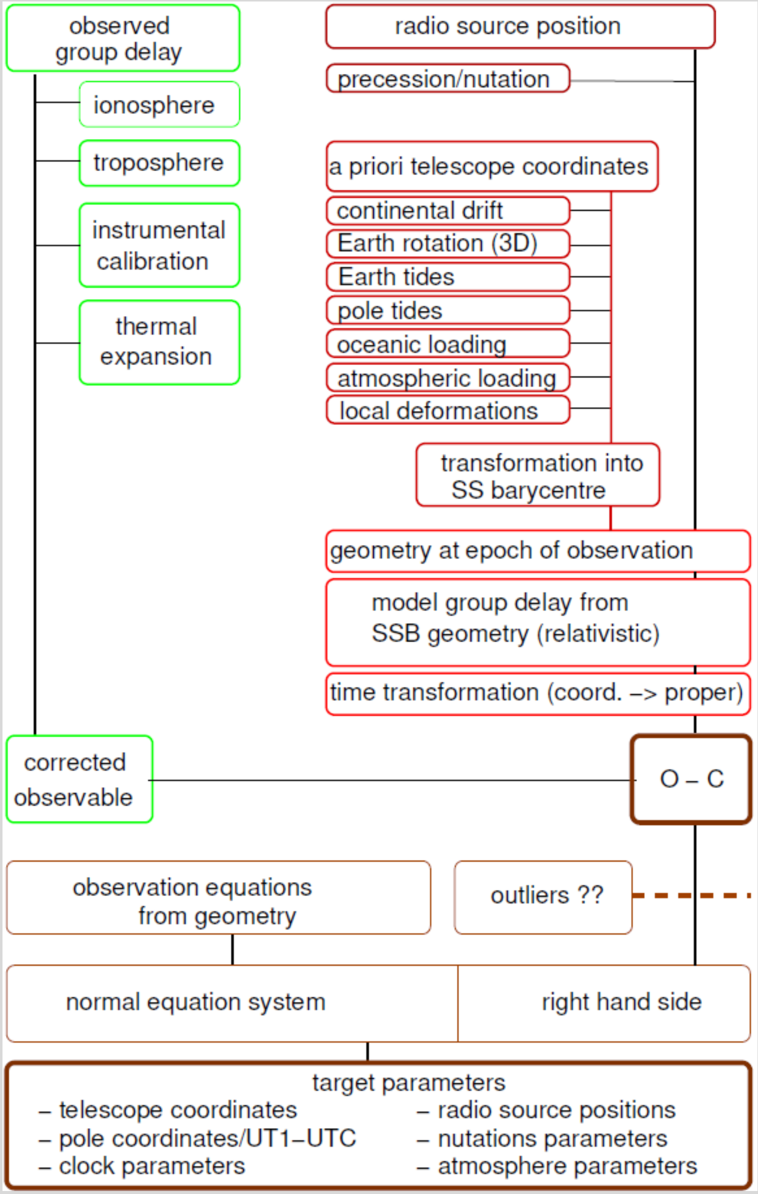
- Earth orientation Parameters ("EOP"): Orientation of the TRF with respect to the CRF
  - Precession/Nutation: Orientation of the spin axis in space
  - Polar Motion: Location of the spin axis on the Earth.
  - UT1: Rotation about the spin axis



What affects the VLBI Delay?(3)

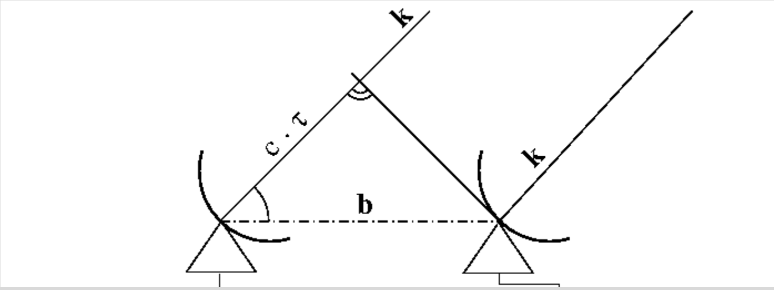
- Source structure
  - Becoming major research area
- Miscellaneous things
  - Ionospheric Delay
  - Tropospheric Delay
  - General relativistic effects
  - Antenna Thermal deformation
  - Antenna Gravitational deformation
  - Changes in cable length
  - Clock drift
  - RFI
  - …

Data analysis

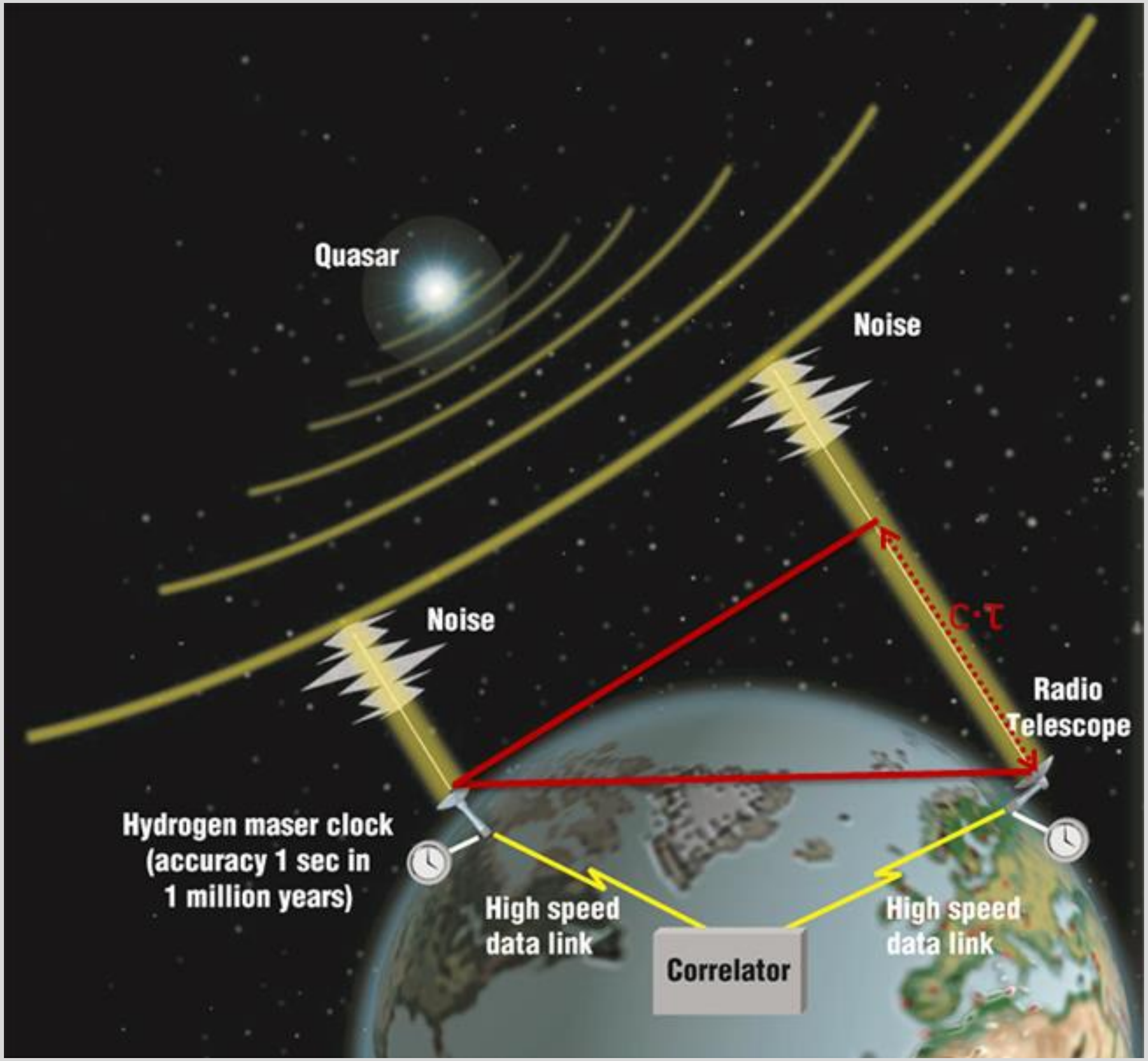


- 3000-30,000 observations per 24 hour session.
- Typically each station has 200-400 scans/session

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



VLBI is Cooperative



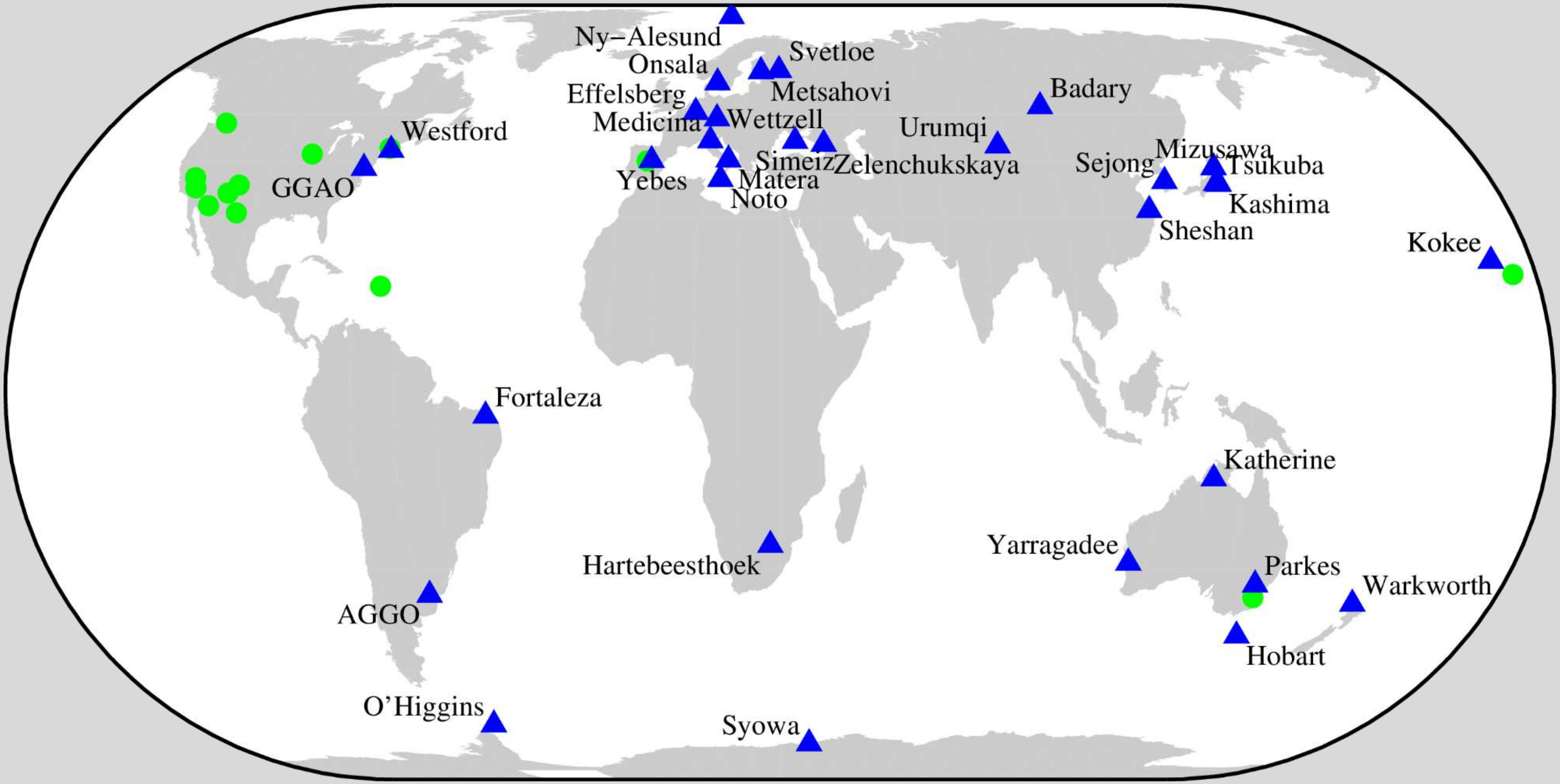
You need 2 (or more) antennas observing the same source at the same time.

One VLBI antenna is like one hand clapping.

This means that you need to plan and coordinate observations ahead of time.

The organization that coordinates geodetic VLBI is:
International
VLBI
Service for
Geodesy & Astronomy

IVS and Cooperating Stations

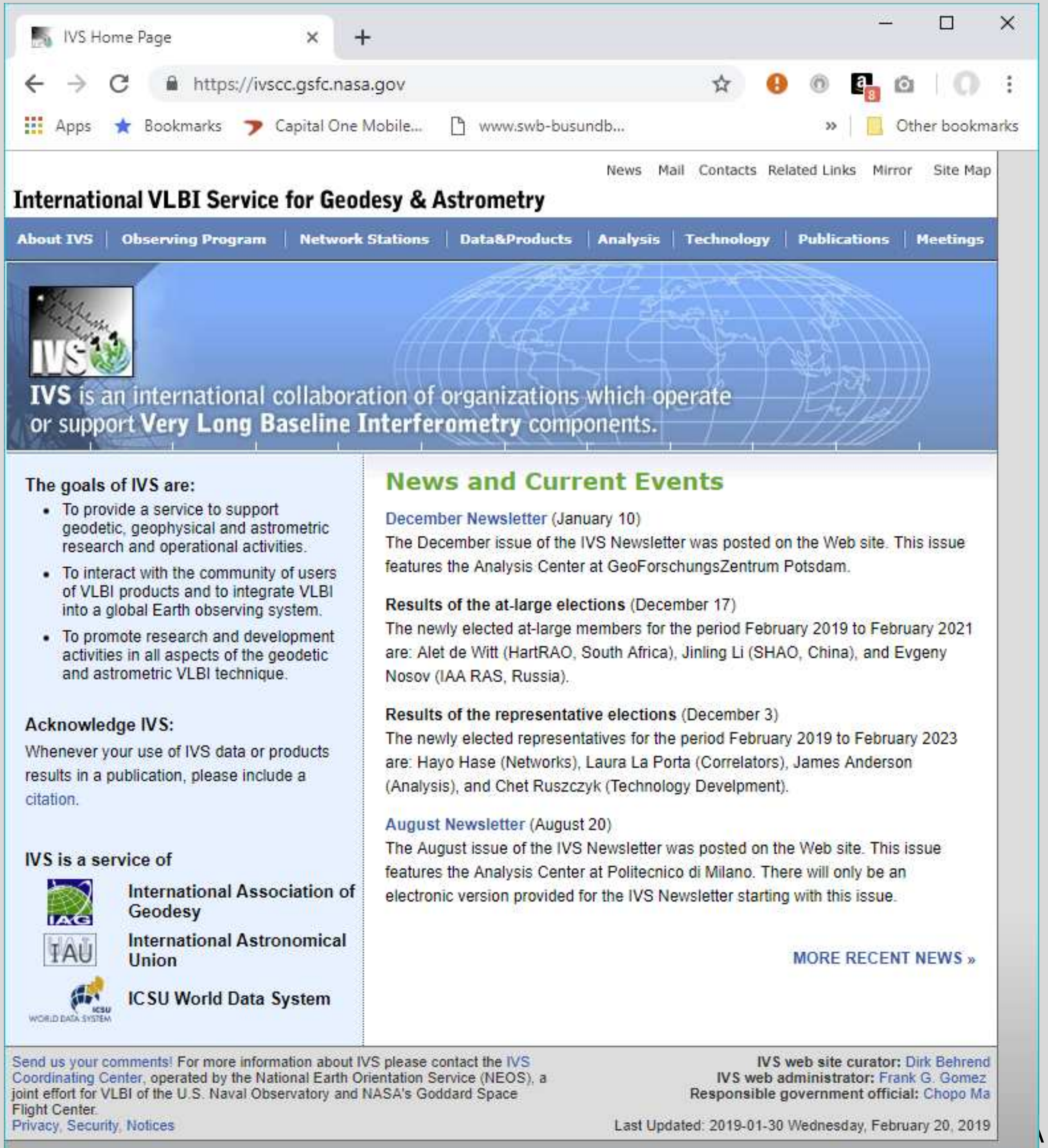


Does not include decommissioned or mobile VLBI sites

▲ IVS Network Station

● Some Cooperating VLBI Site

IVS home page



https://ivscc.gsfc.nasa.gov

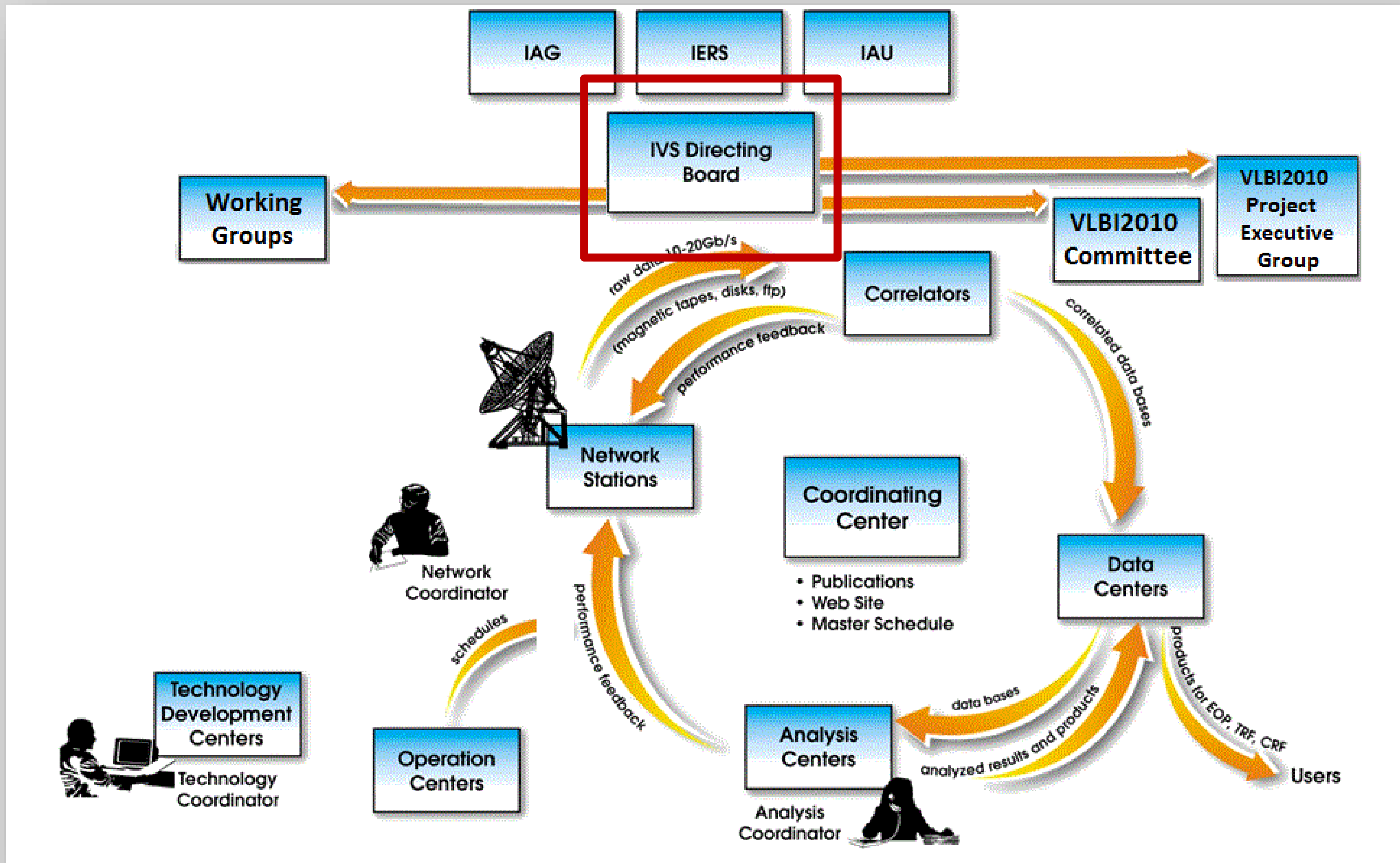
Link to all things IVS.

IVS is a service of:

- International Association of Geodesy
- International Astronomical Union
- ICSU World Data System

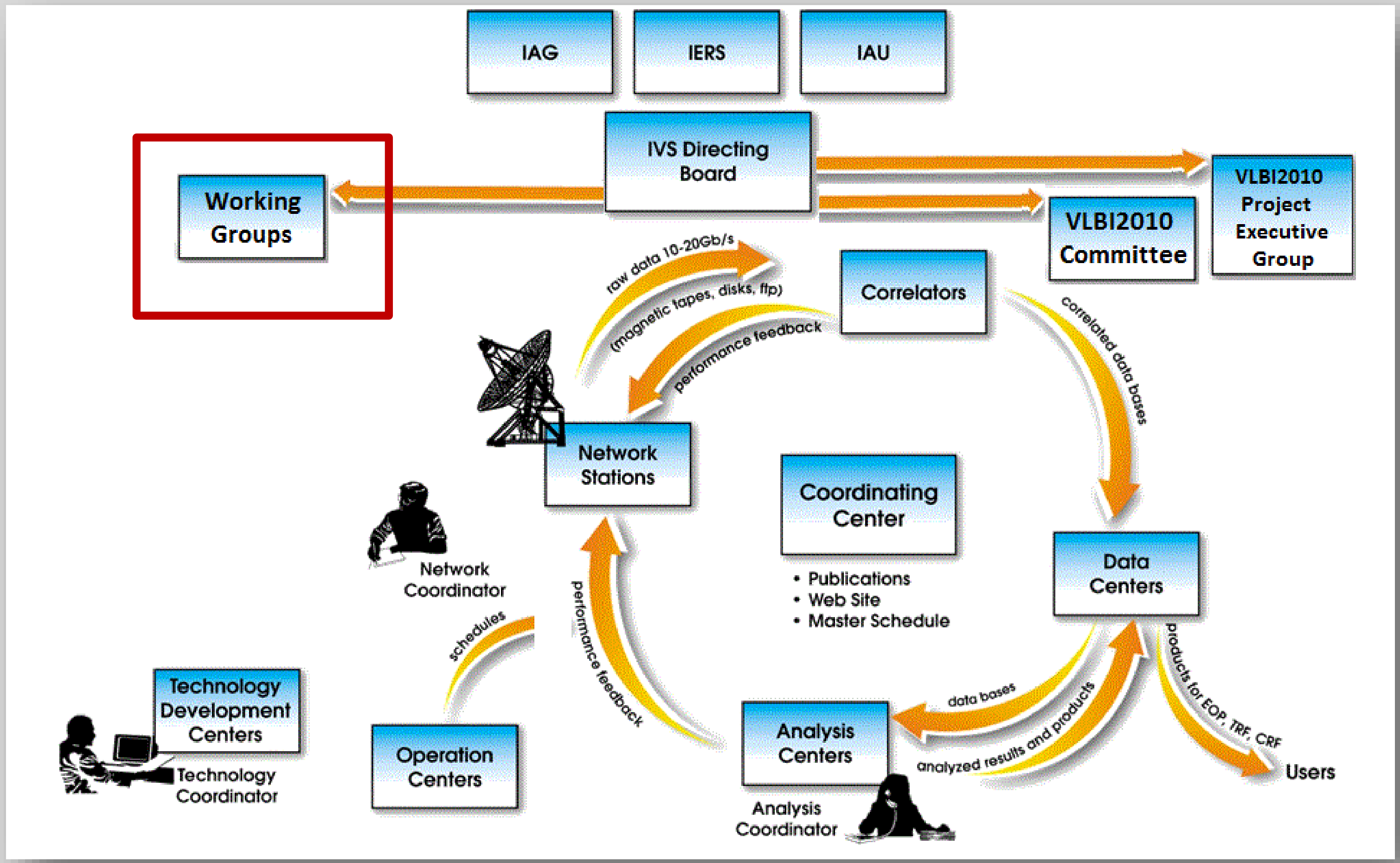
Part of GGOS:
Global Geodetic Observing System

IVS Components



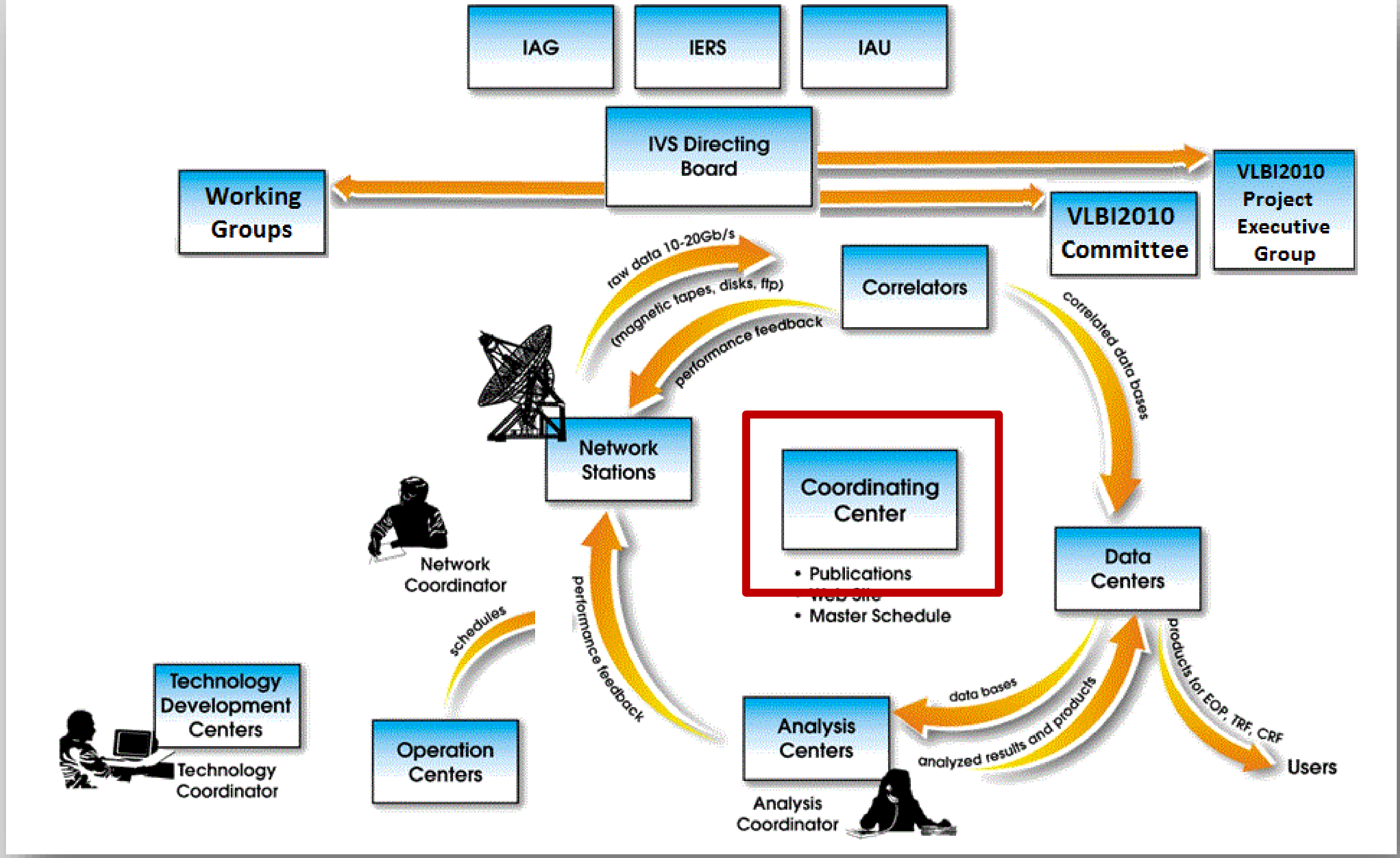
The IVS Directing Board provides overall guidance.
16 members on the IVS board.

IVS Components



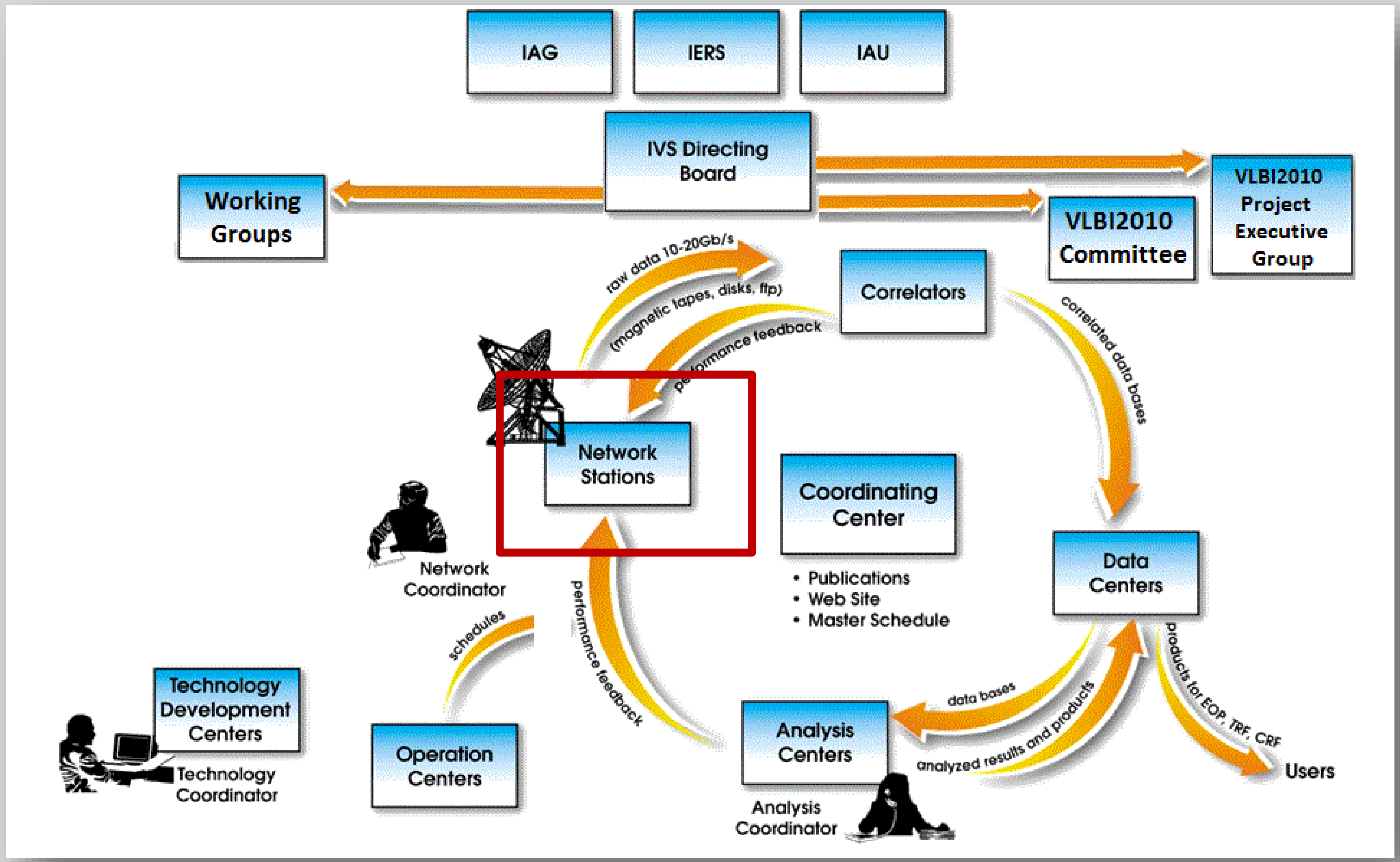
Working groups have a finite charter and address a specific task.
There have been 8 working groups.
Latest was on Galactic Aberration.

IVS Components



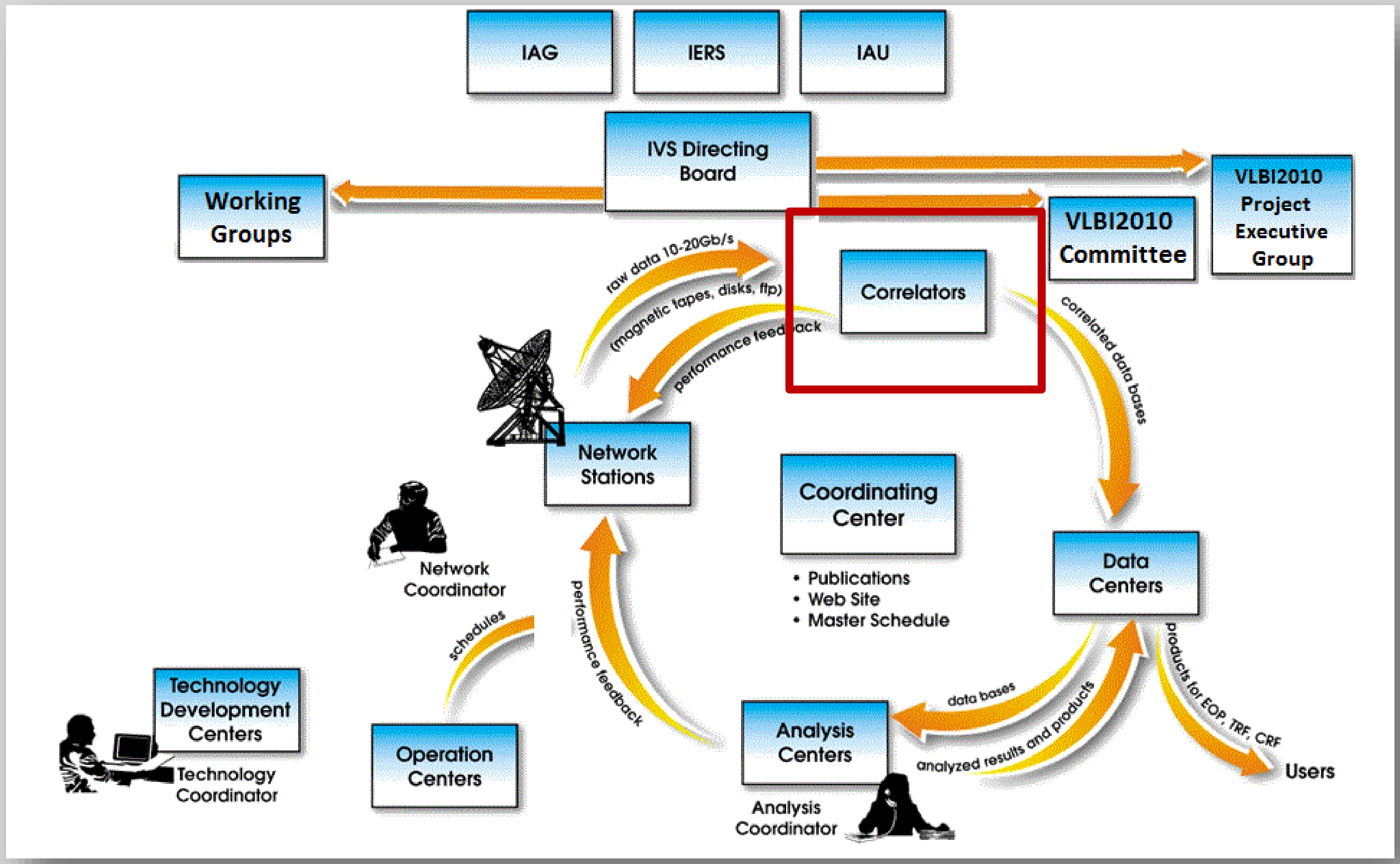
The coordinating center provides overall coordination.
Only 1 of these.

IVS Components



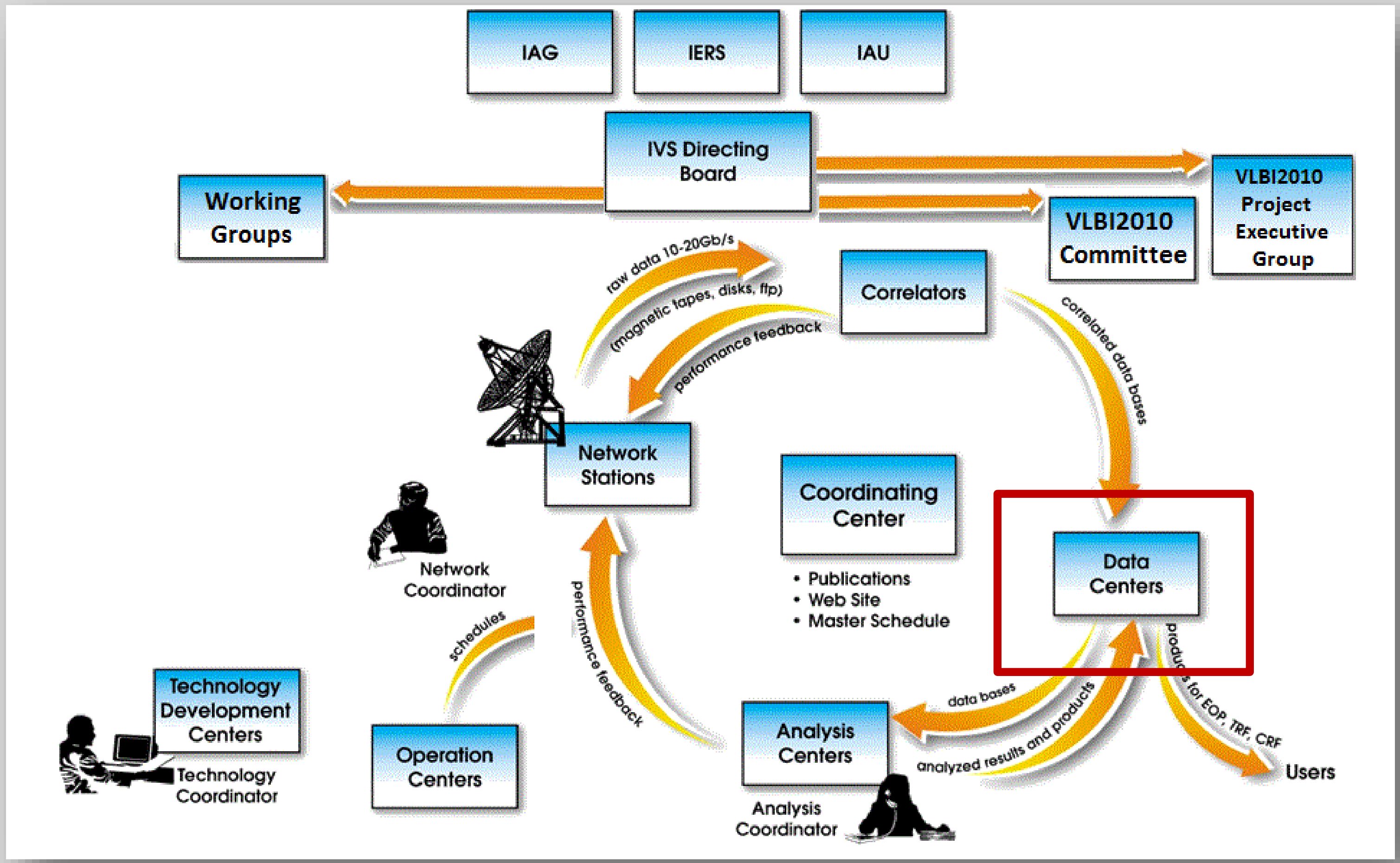
Stations take the data.
About 40 IVS stations, and ~30 cooperating stations.

IVS Components



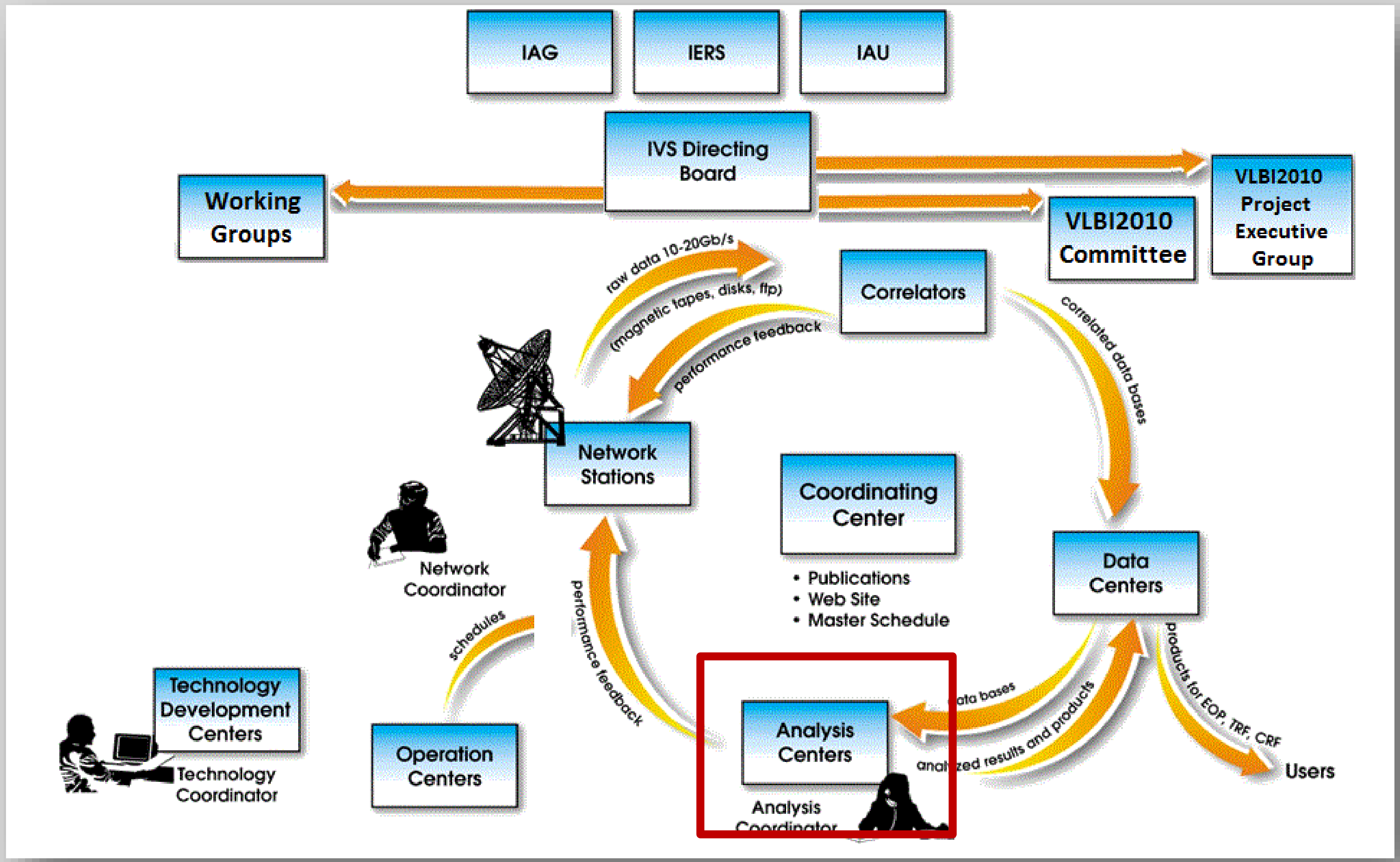
Correlators correlate the data.
~5-10 IVS correlators

IVS Components



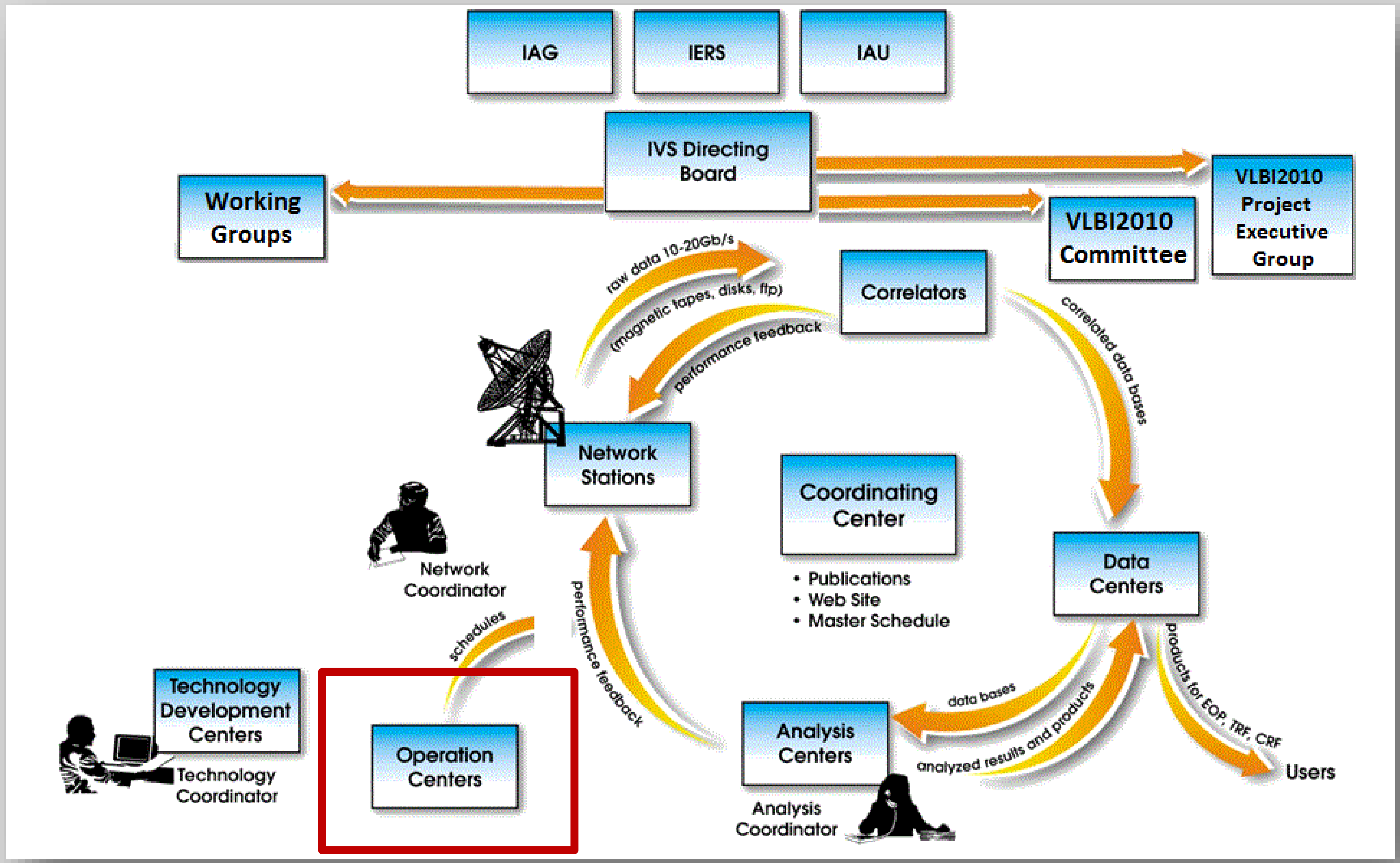
Data centers store IVS data.
3 of these which are mirrored.

IVS Components



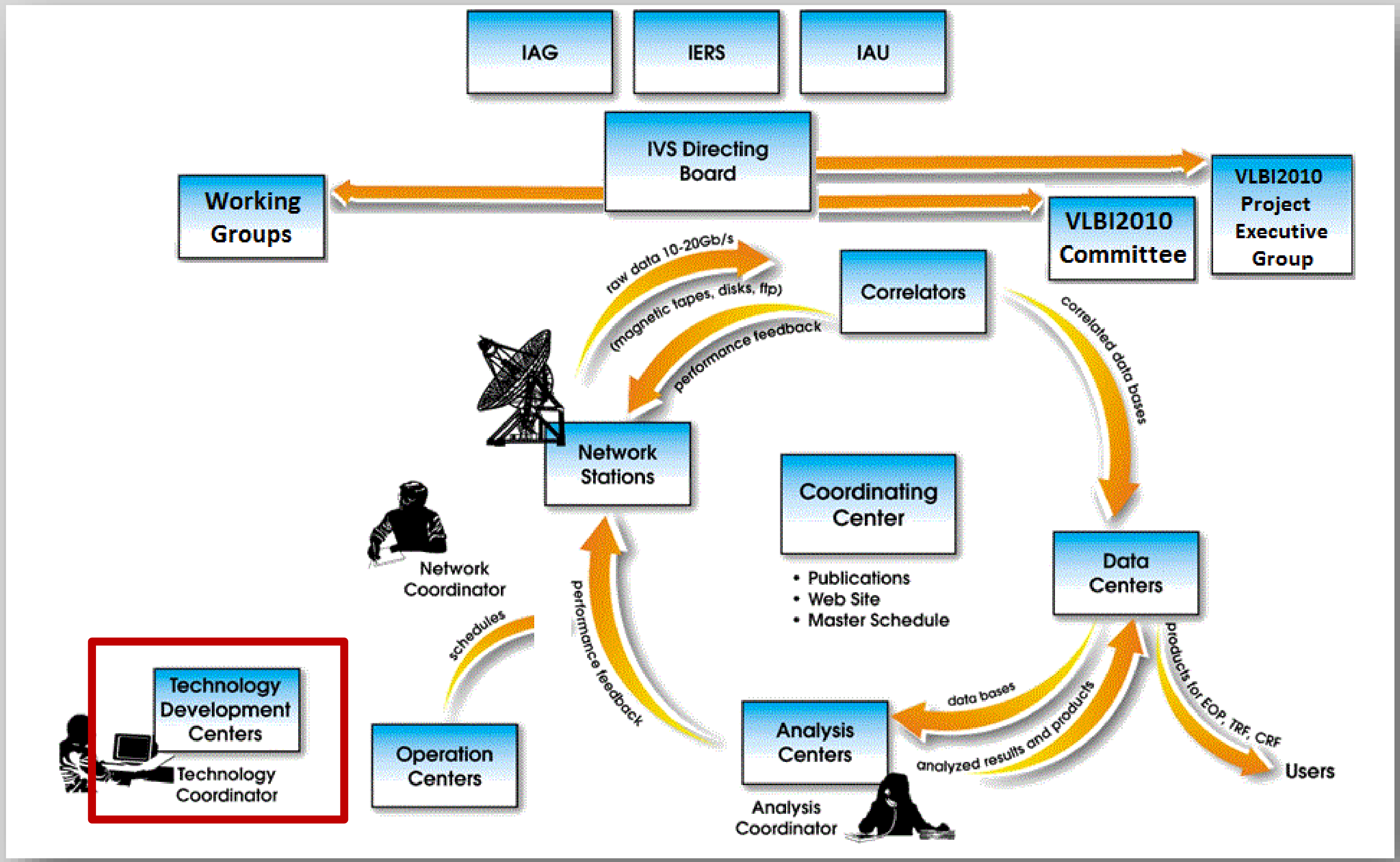
Analysis centers analyze the data.
~10-20 of these
A few (~3) have primary responsibility for initial processing.

IVS Components



Operations centers are responsible for producing specific schedules.
~5 of these

IVS Components



Technology development centers focus on improving specifc aspects of IVS. This can be hardware or software.
~10-20 of these

Important IVS Meetings (1)

- IVS General Meeting.
  - Even years
  - Roughly 150 participants. Meeting and splinter meetings last ~1 week.
  - 2018 in Svalbard, Norway
  - 2020 in Annapolis, USA
- EVGA Meeting.
  - Even years.
  - Roughly 100 participants. Meeting and splinter meetings last ~1 week
  - 2017 in Gothenburg, Sweden
  - 2019 in Las Palmas (Canary Islands),Spain

Important IVS Meetings (2)

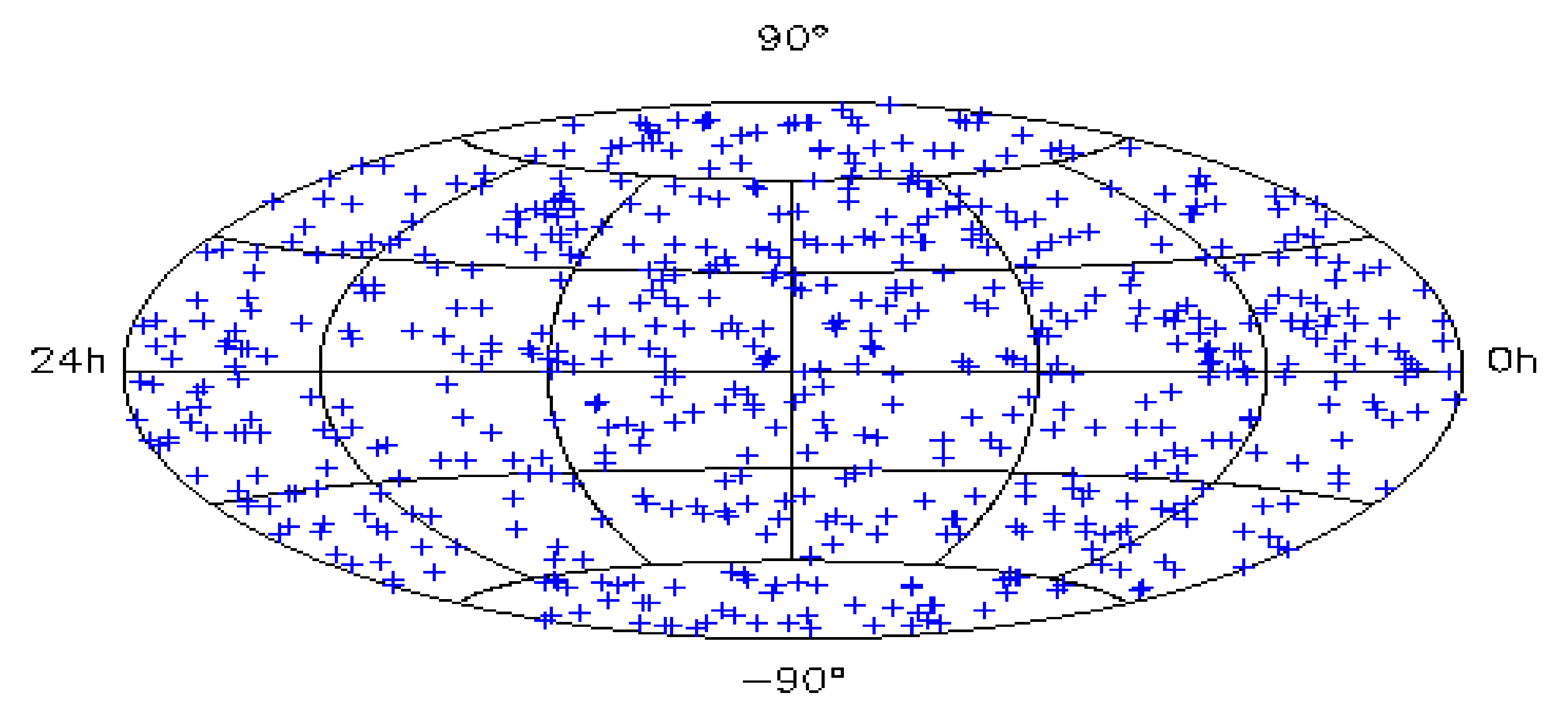
- IVS Analysis Workshop
  - Every year.
  - Occurs in conjunction with IVS-GM or EVGA
- Technical Operations Workshop.
  - Odd years.
  - Geared towards station operators
- IVS VLBI school
  - Every three years.
  - Occurs in conjunction with IVS-GM or EVGA

What is the ICRF?

International Celestial Reference Frame

- The position of some set of celestial objects in a consistent reference frame.
- Early realizations used the positions of optical sources determined by optical astronomy.
  - The last was the “Fifth Fundamental Catalog” FK5 in 1988.
- In 1995 the ICRF was defined in terms of the positions of quasars determined by VLBI.

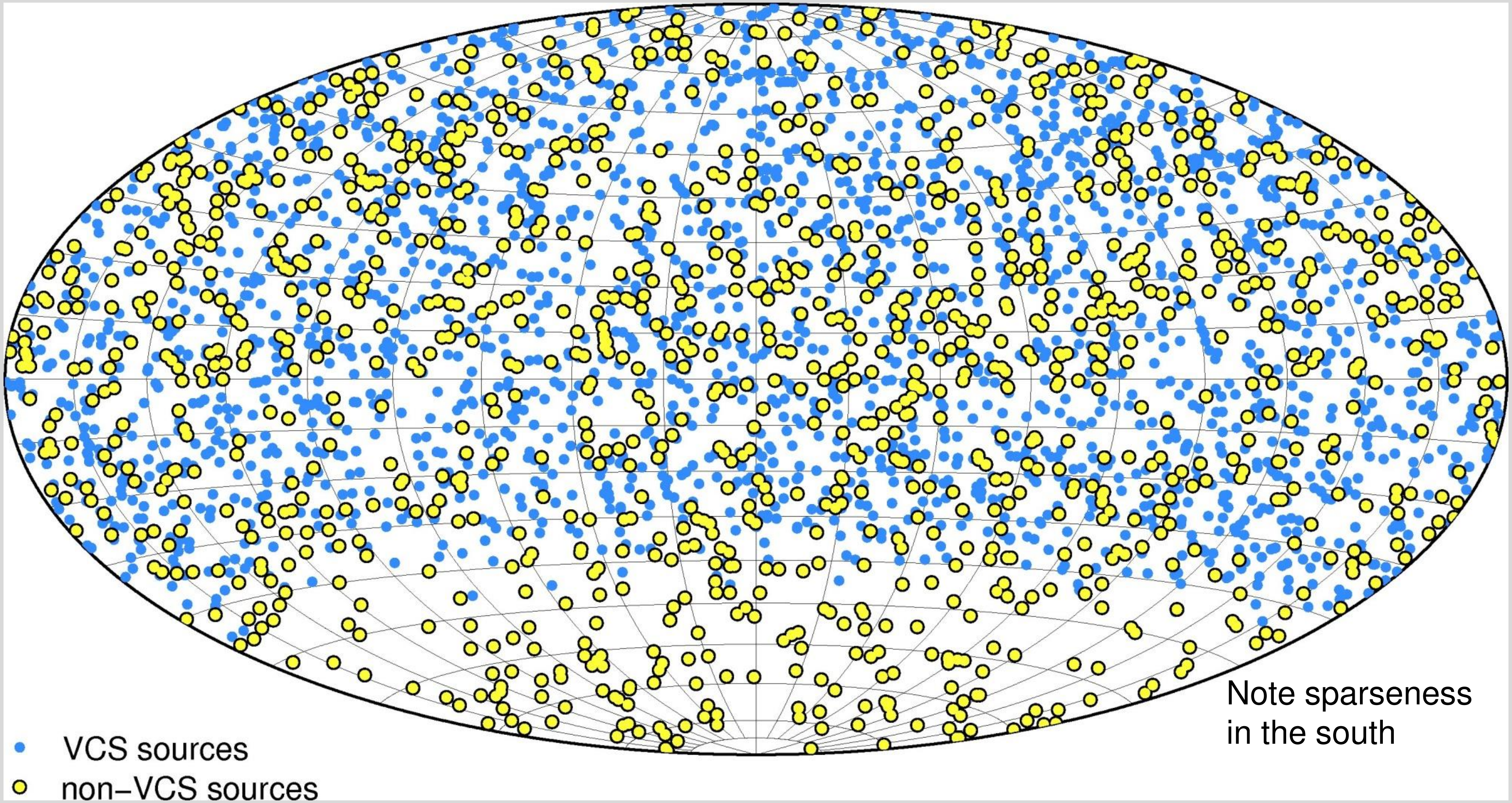
ICRF1: Adopted 1998



212 “Defining” Sources
396 Additional

Noise floor ~250 microarcseconds

ICRF2: Adopted by IAU in 2009

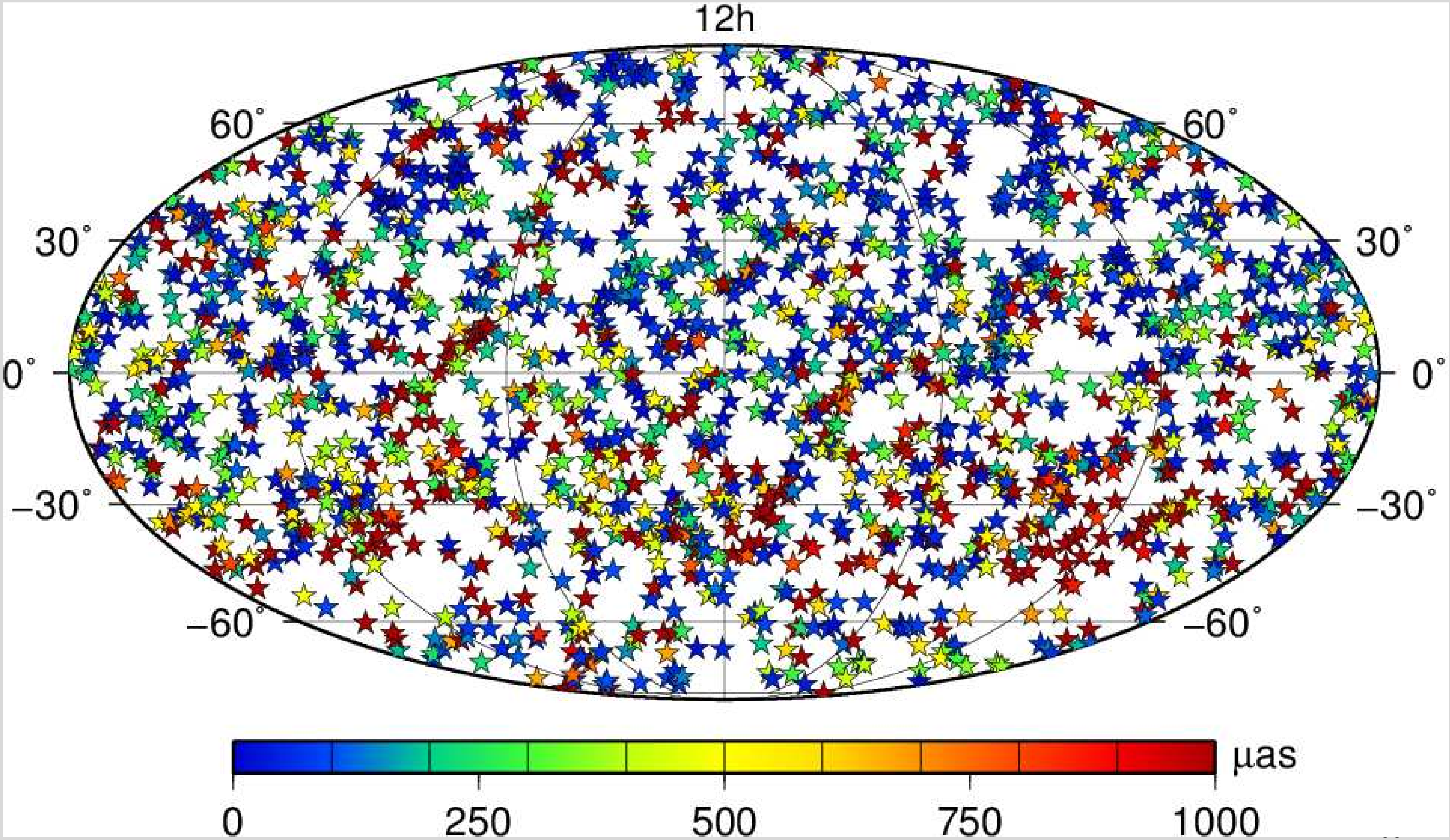


295 Defining sources (97 of them in ICRF1)
3019 Other sources
Noise floor ~40 microarcseconds

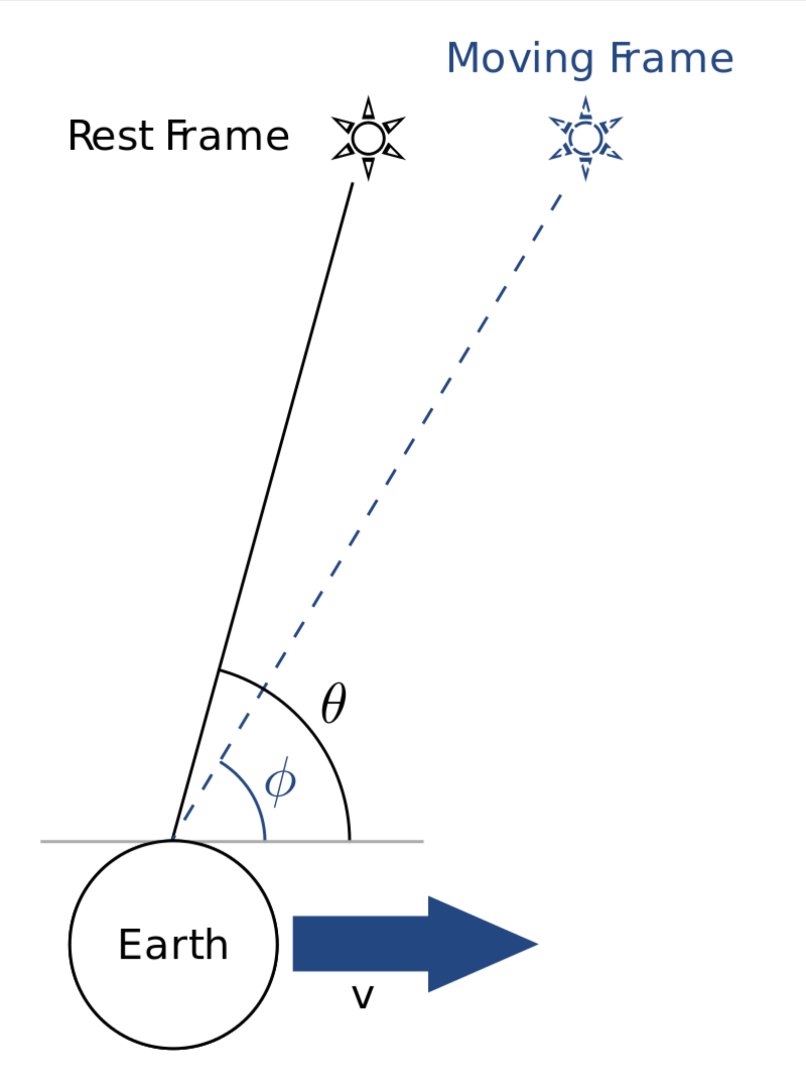
ICRF3: Adopted August, 2018
303 Defining sources
4233 Other sources
Includes Galactic Aberration

ICRF-2: Precision

International Celestial Reference Frame (ICRF)



Aberration

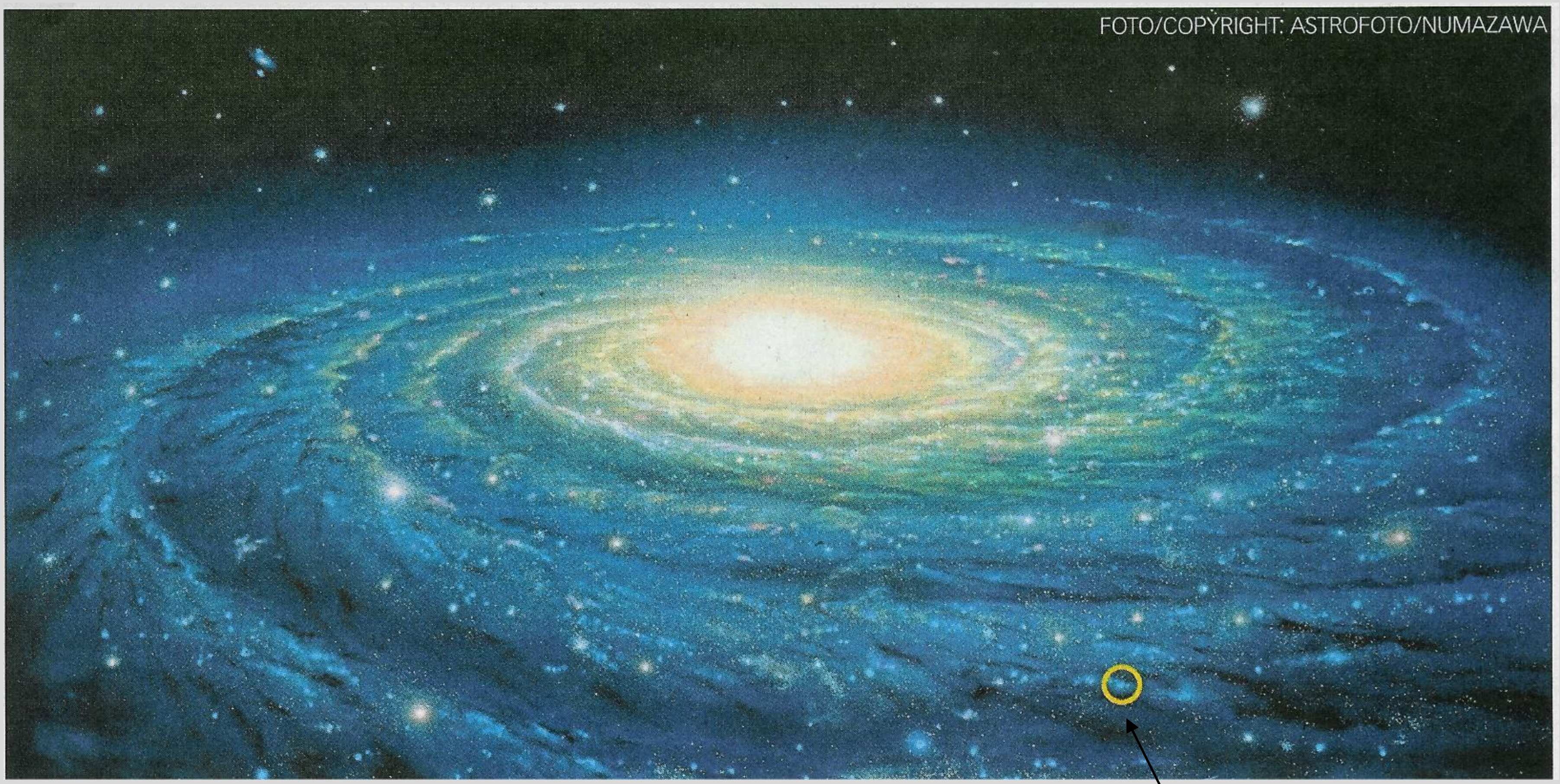


The movement of the Earth causes an apparent change in the position of a source.

If the velocity is constant, this is just a constant shift.

If the velocity changes over time, the apparent source position will change over time.

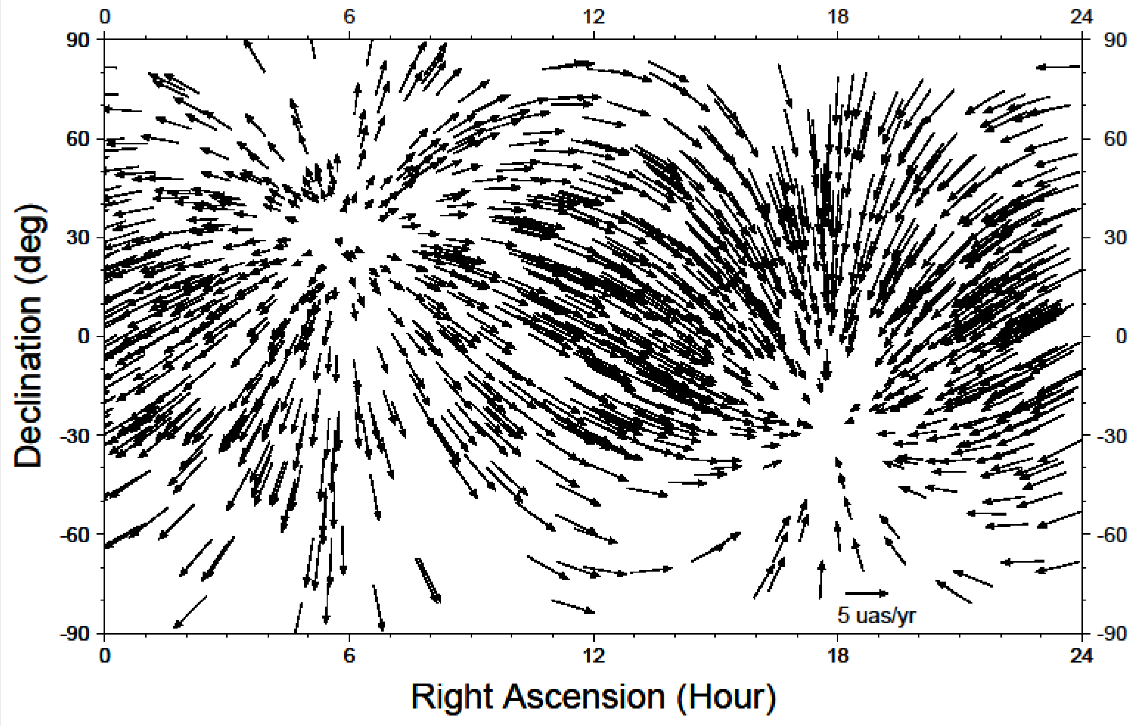
Galactic aberation



You are here

As the Earth rotates around the galaxy, the direction of the velocity changes.

Galactic abberation



Remember: Noise floor of ICRF is 40 uas!

ICRF3 used 5.8 µas/yr. Value from a recent VLBI solution.

Stellar astronomy:

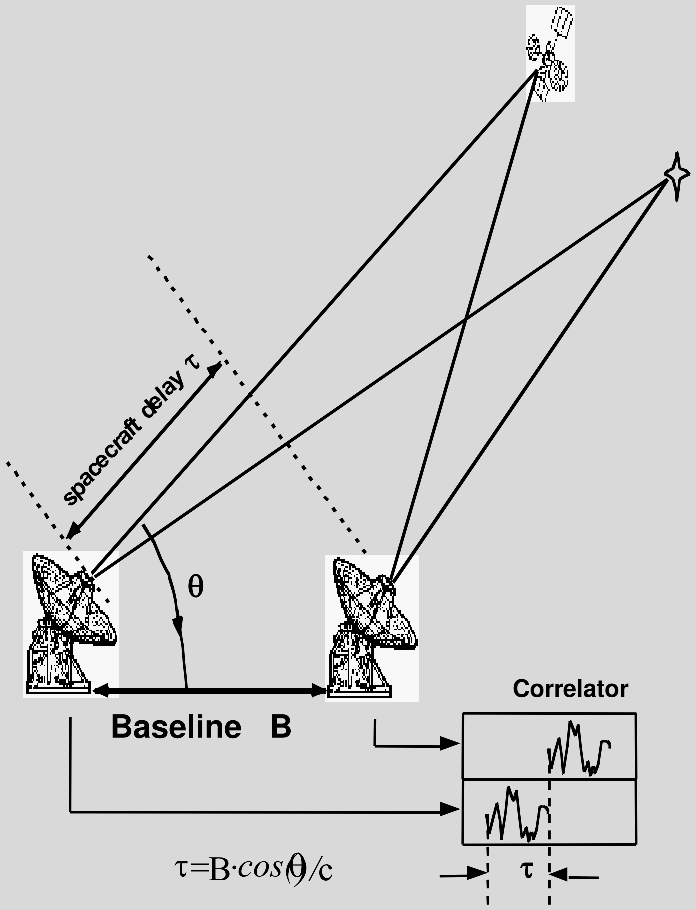
range of 6 estimates: [4.8 - 5.4] µas/yr
mean = 5.0 µas/yr ;
Standard deviation of estimates = 0.21

ICRF and Spacecraft Navigation

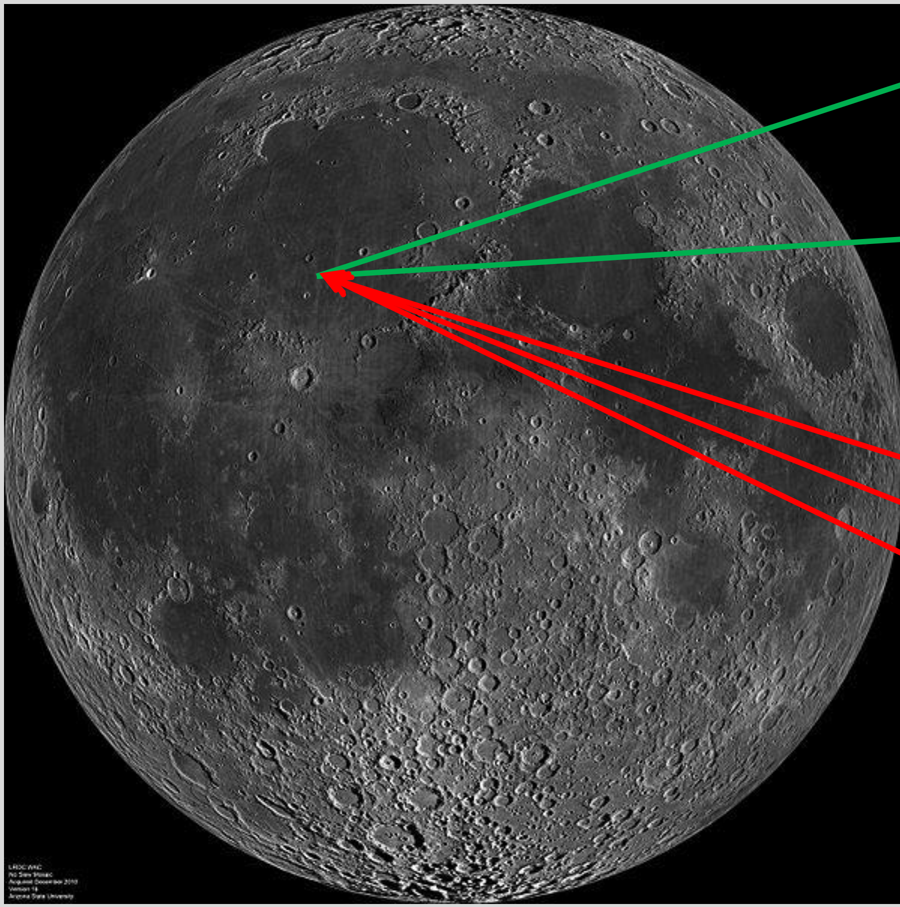
VLBI is used in spacecraft navigation to determine the angular position of spacecraft.

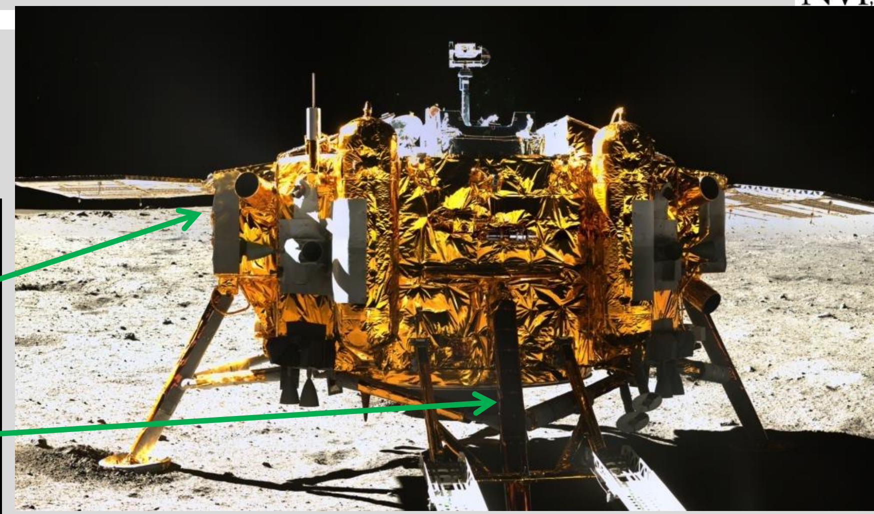
This complements other techniques (radar, laser) which measure the range to the spacecraft.

JPL uses this routinely in deep space navigation.

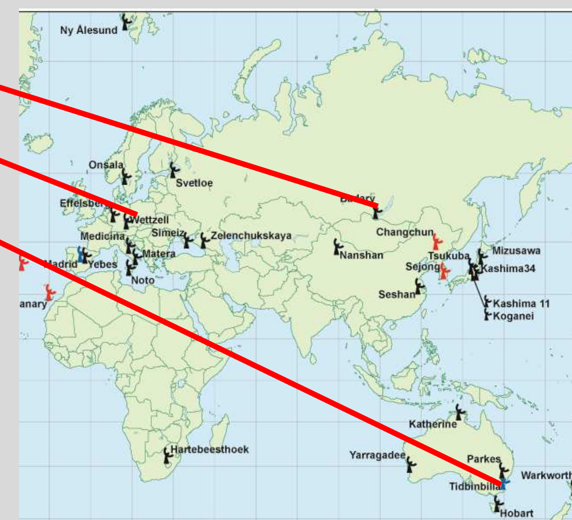


Chang'E-3 lander

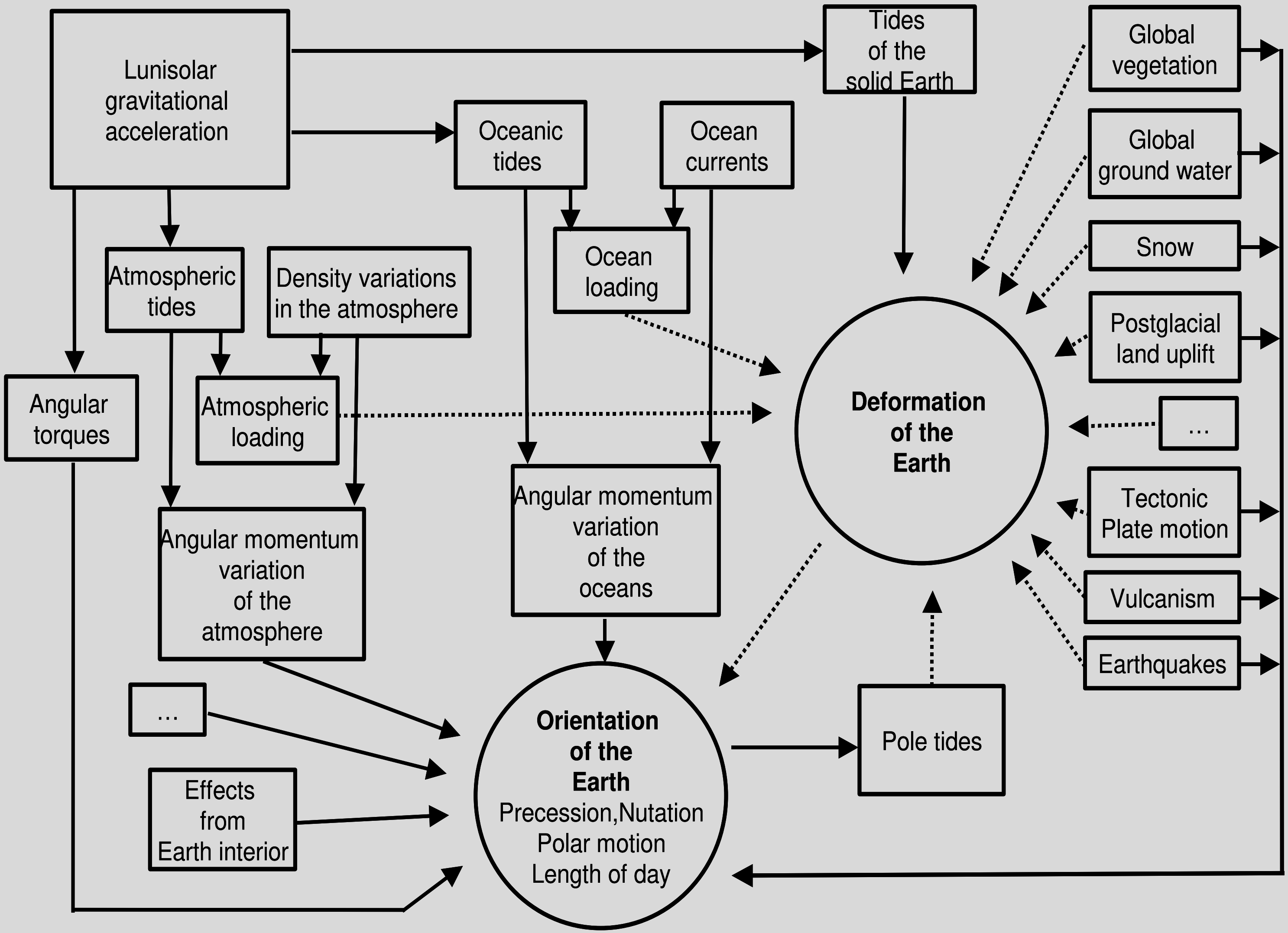




Picture taken by Yutu rover (2012.12) –
Courtesy Tang Geshi

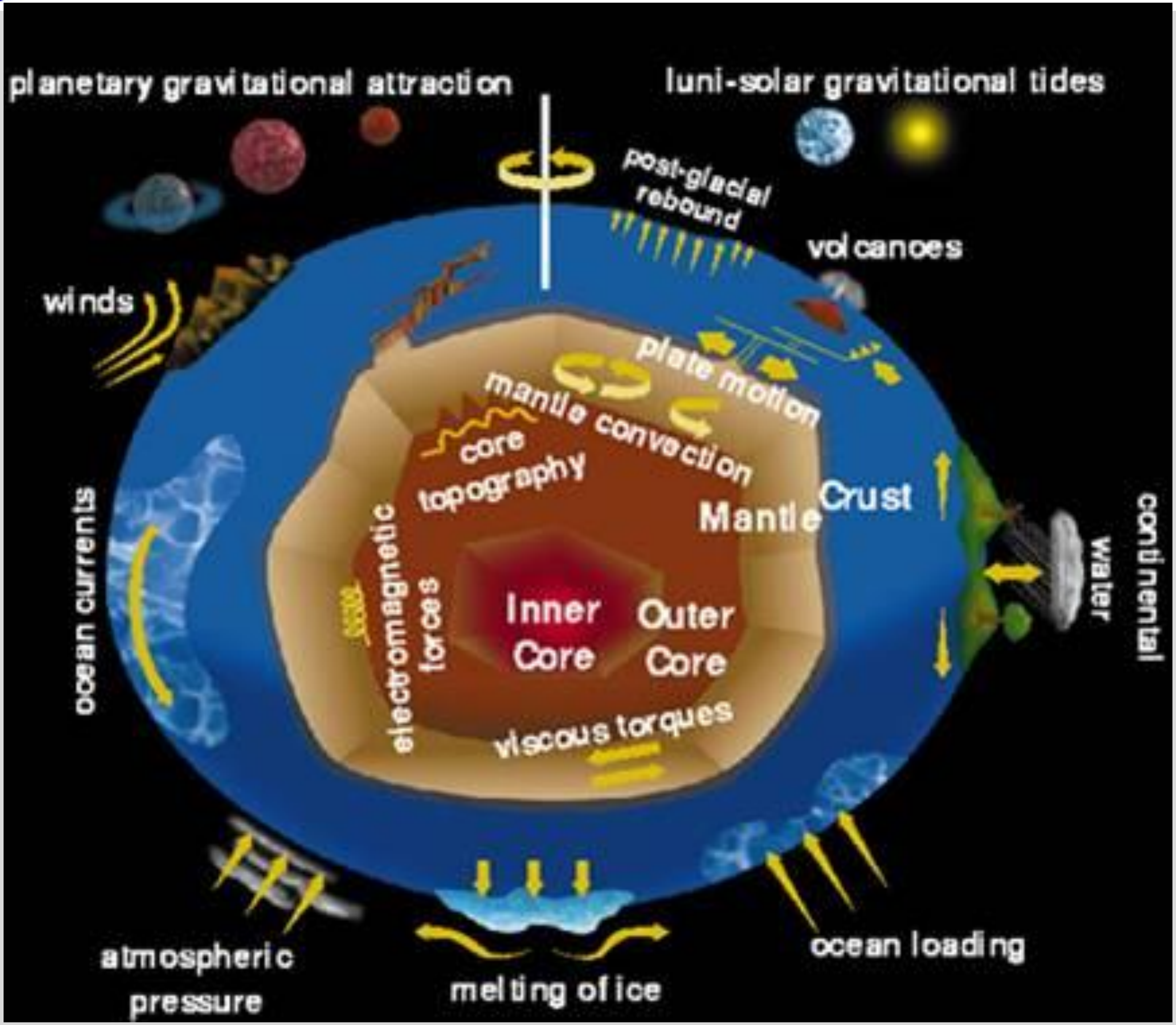


Interactions of Earth System



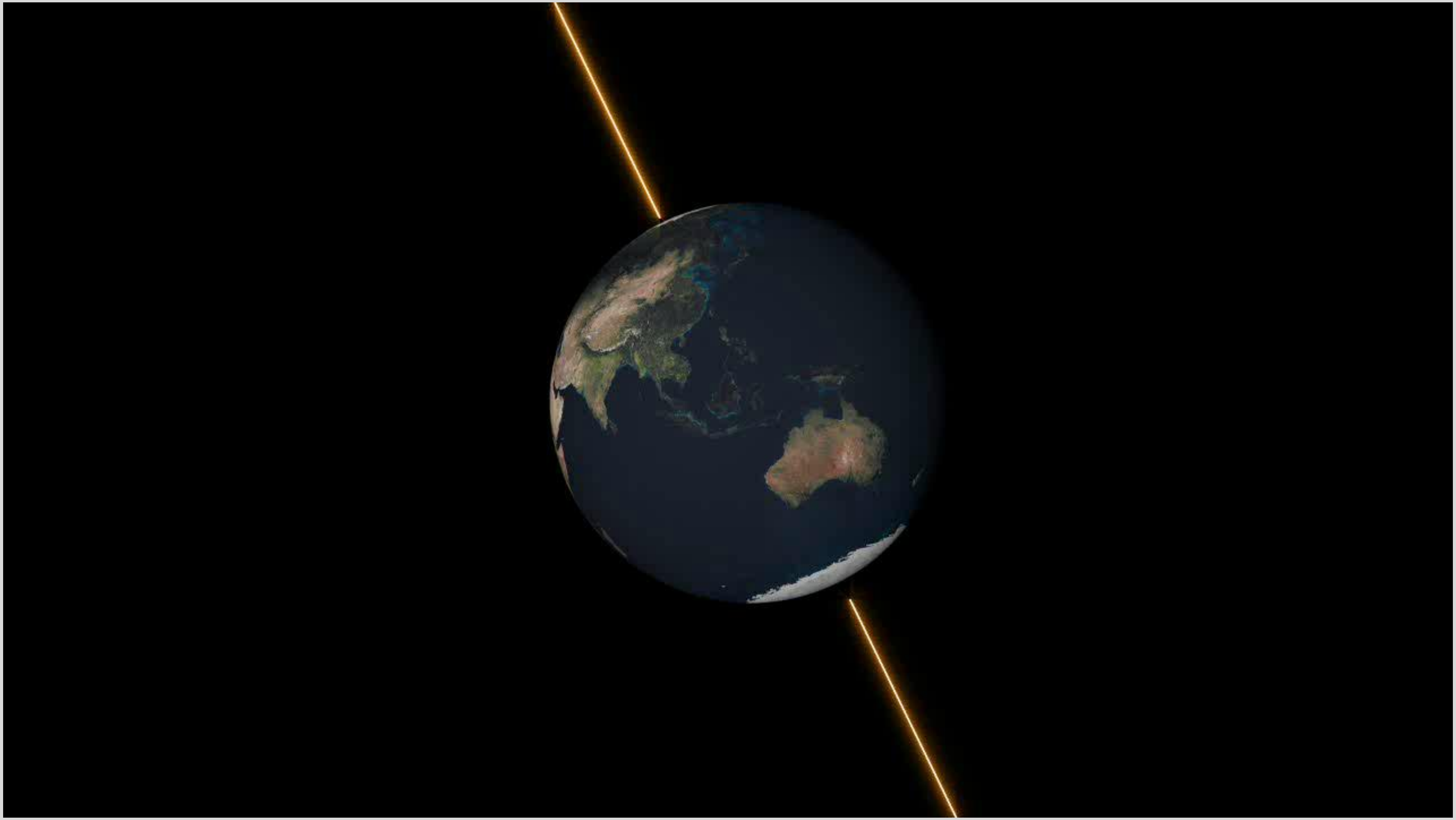
After Schuh and Haas, 1995 (modified)

Things that affect the Earth

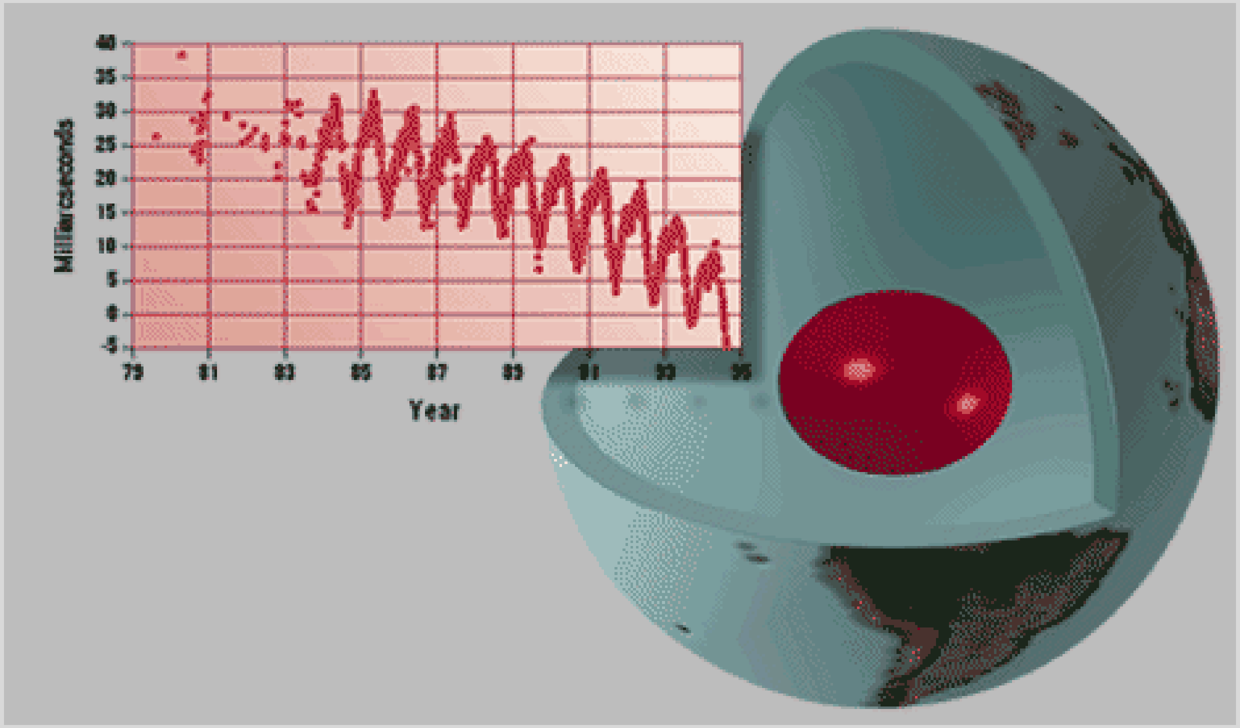


After Lambeck

Precession and Nutation



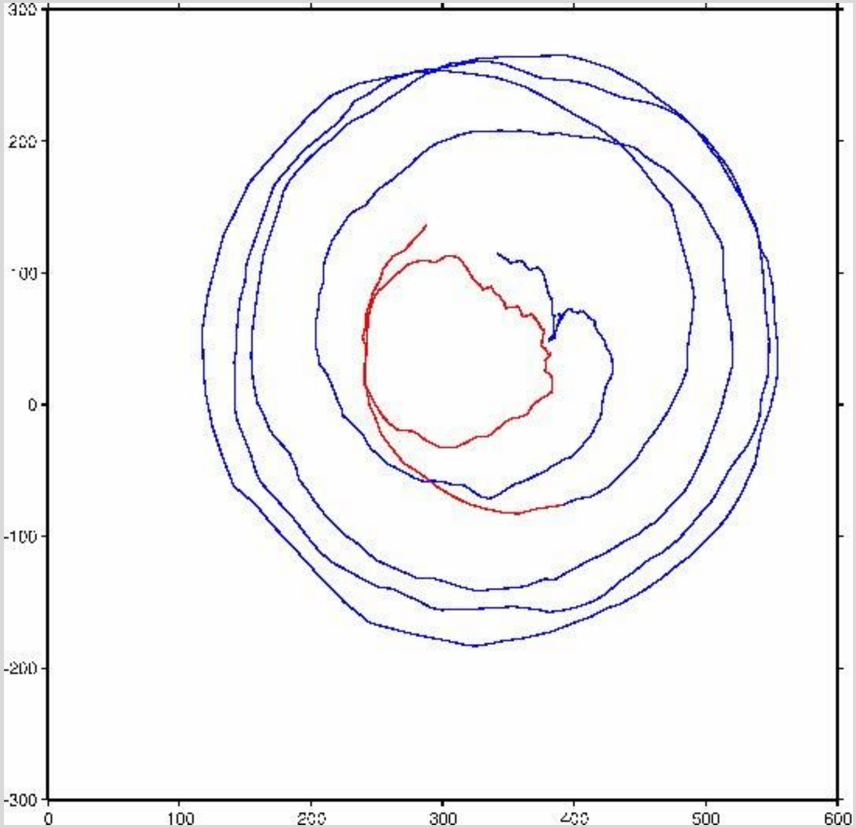
Nutation

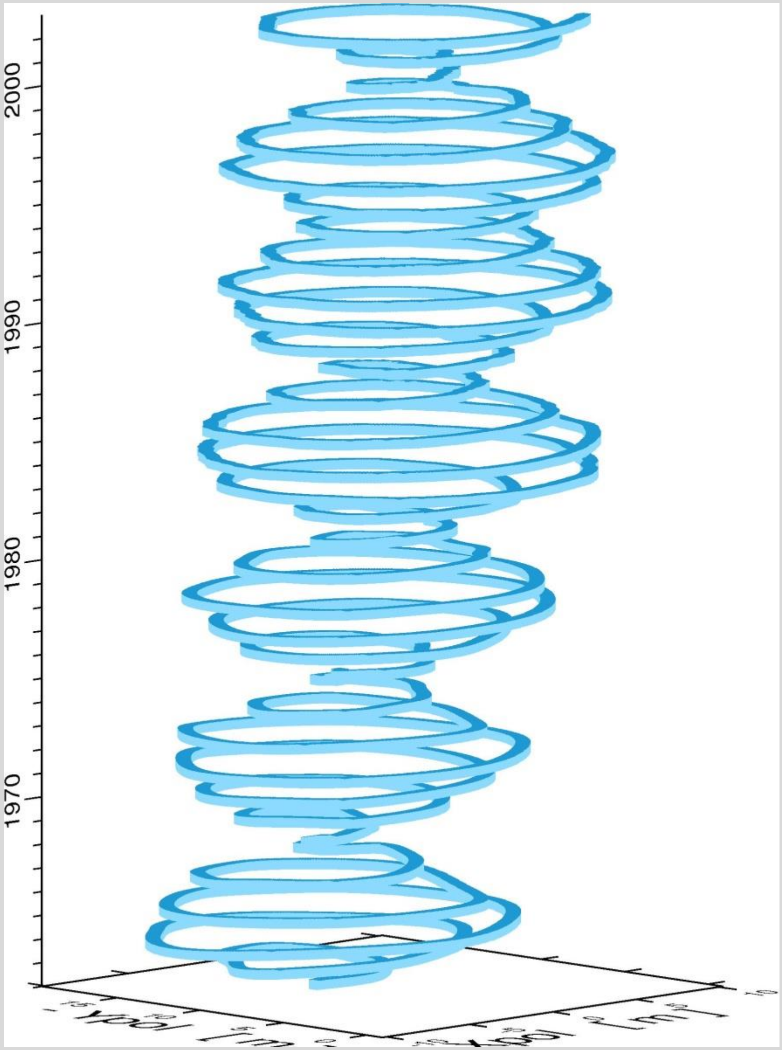


Nutation is due to gravitational torques on the Earth.
By measuring nutation we can determine properties of the interior of the earth.

These measurements provide the most accurate model of the elipticity of the inner core

Polar motion

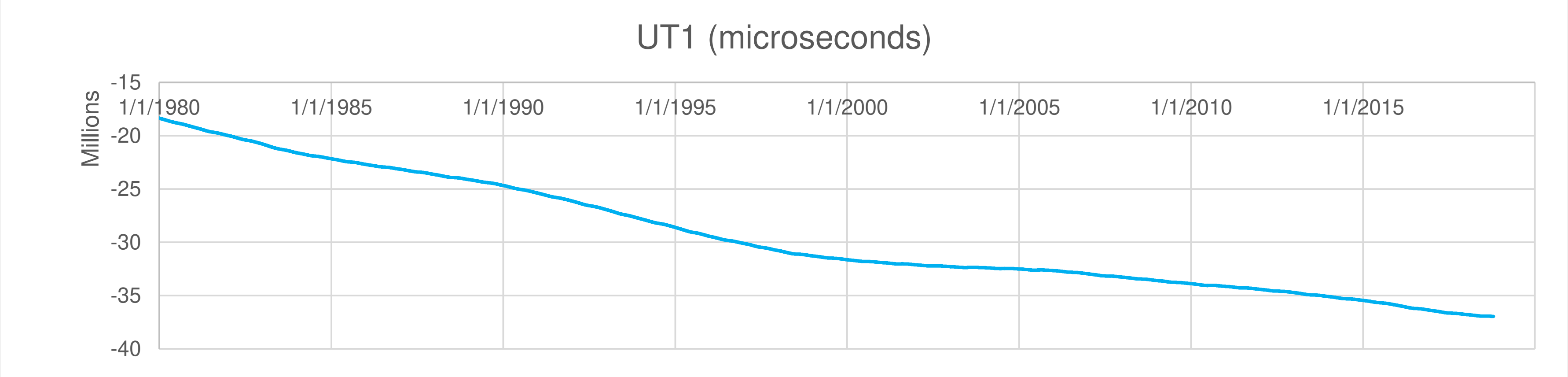


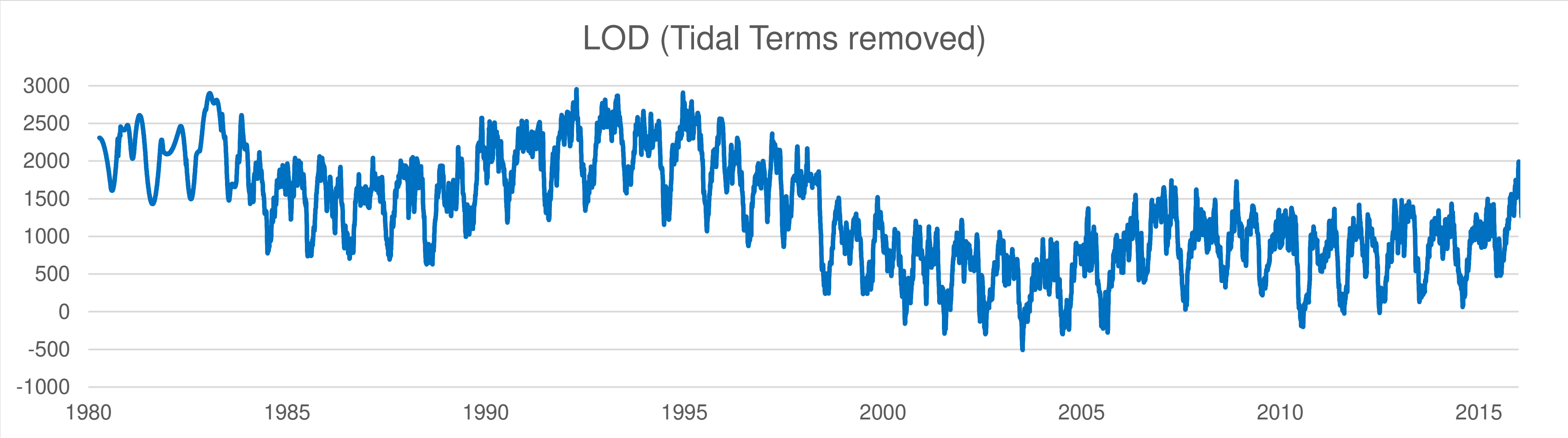


Size is roughly that of a baseline diamond (90ft=27m)
Direction of motion is clockwise

Two dominant periods: 365d and 435d
Beating causes change in size.

UT1 and Length of Day (LOD)





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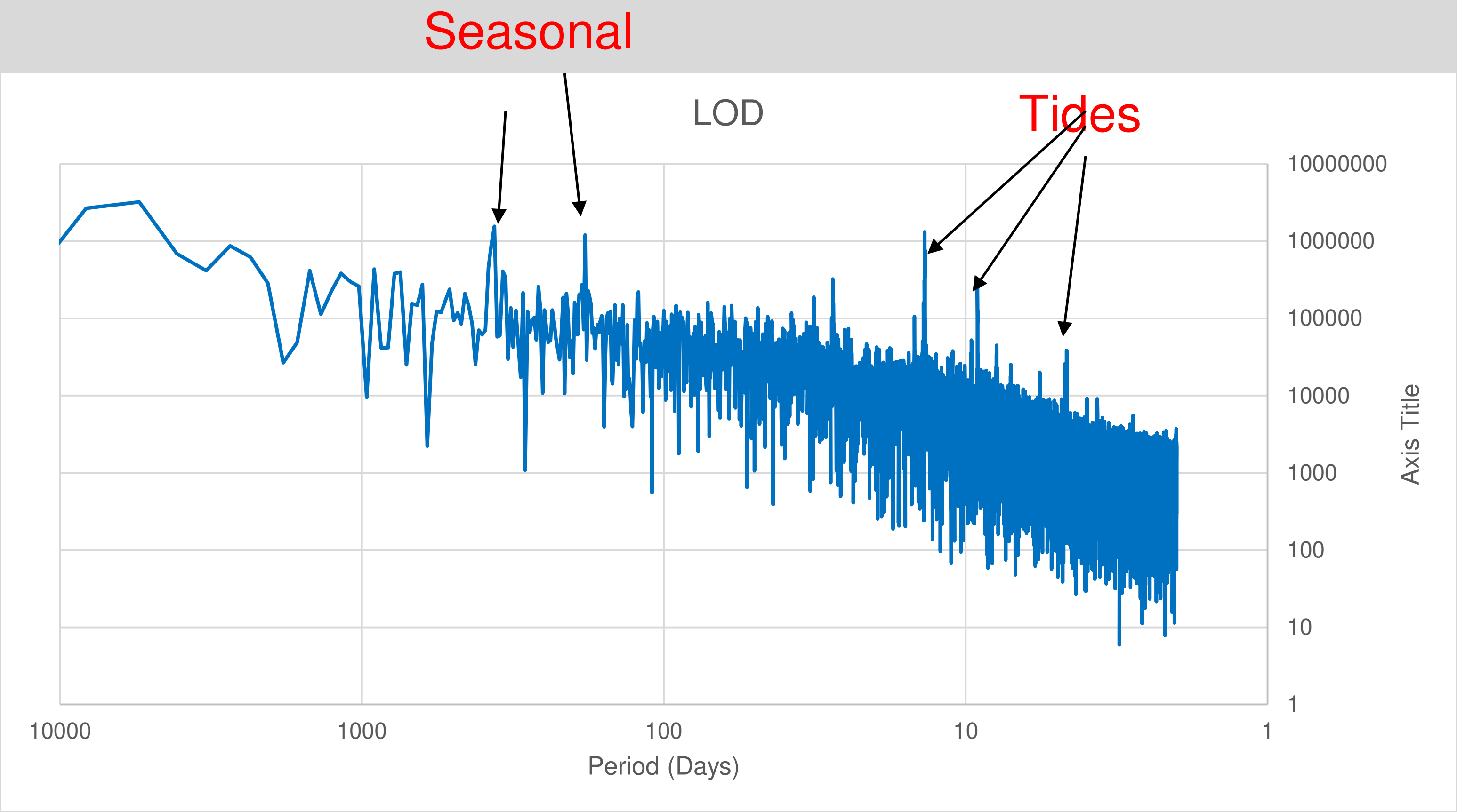
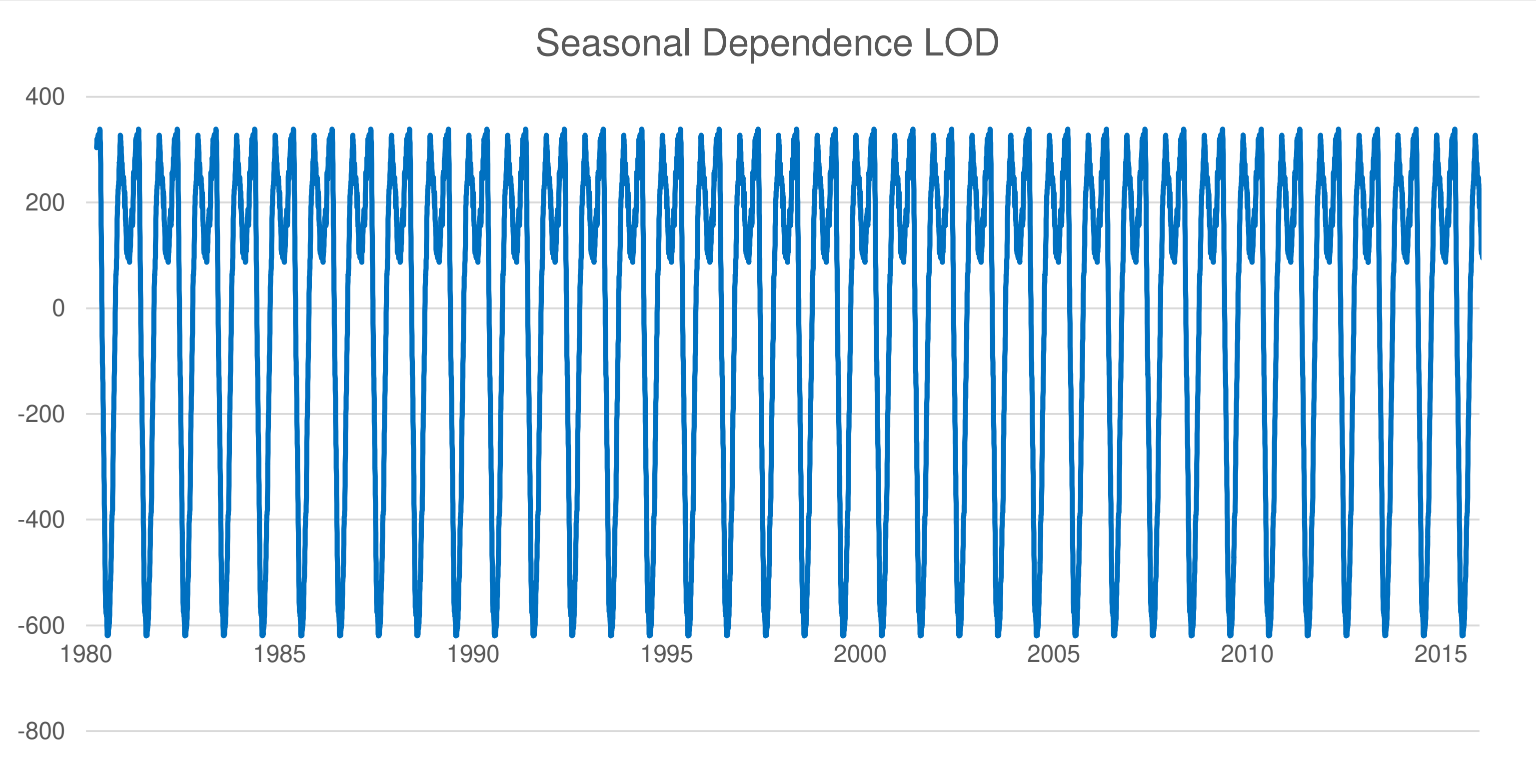
Spectrum of LOD



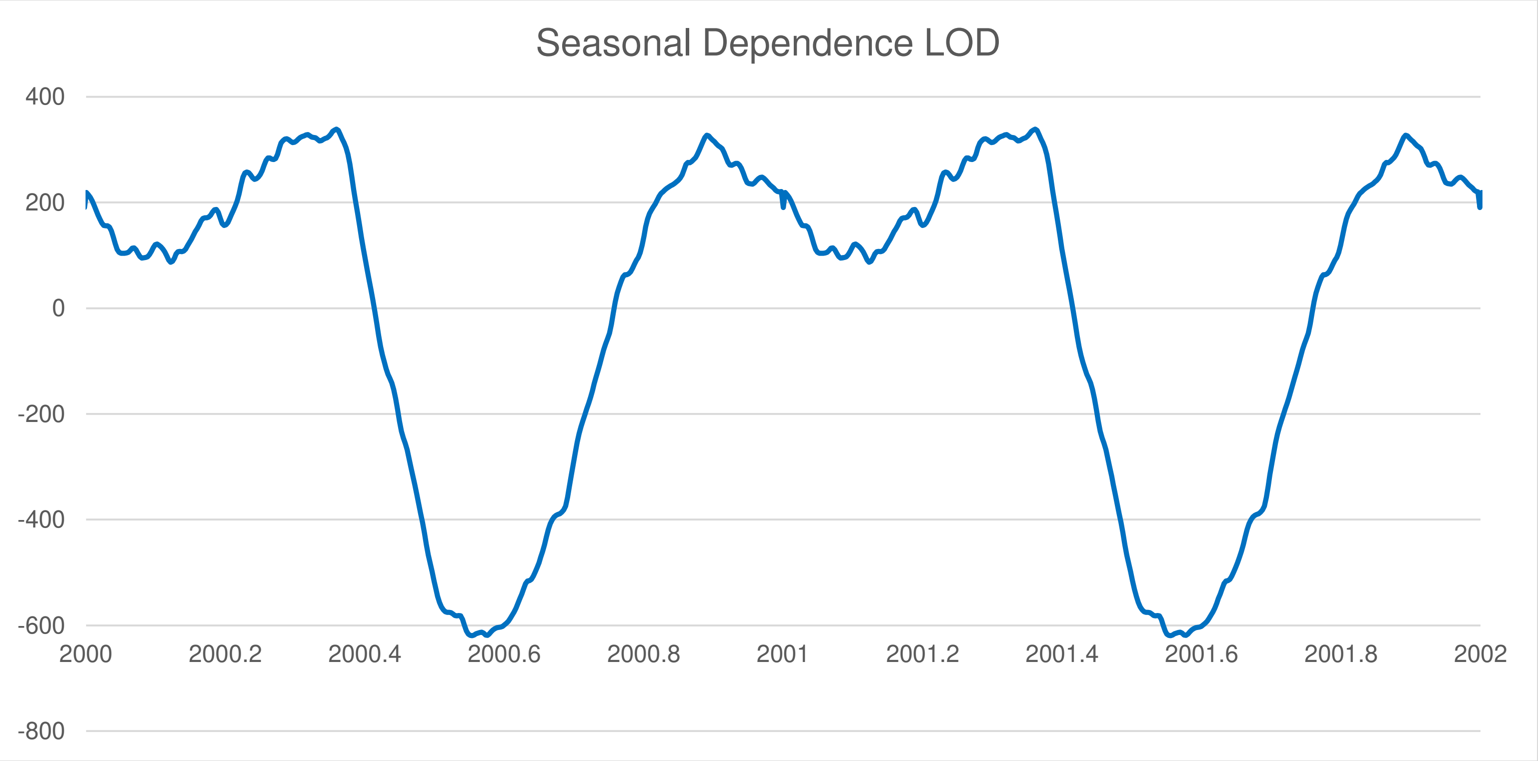
Seasonal Terms



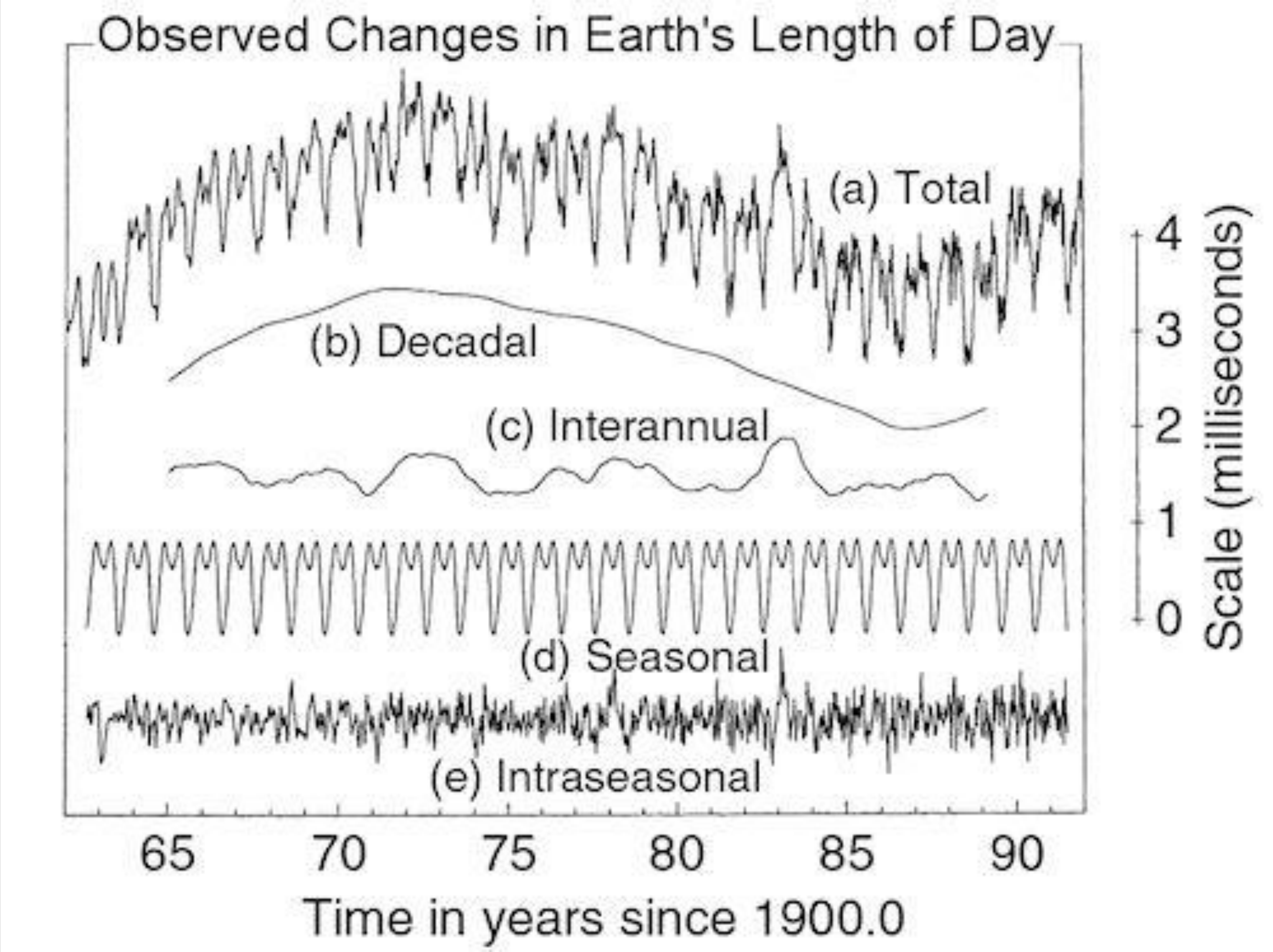
The day is about 1ms longer in Northern Hemisphere winter.

More angular momentum in the atmosphere.

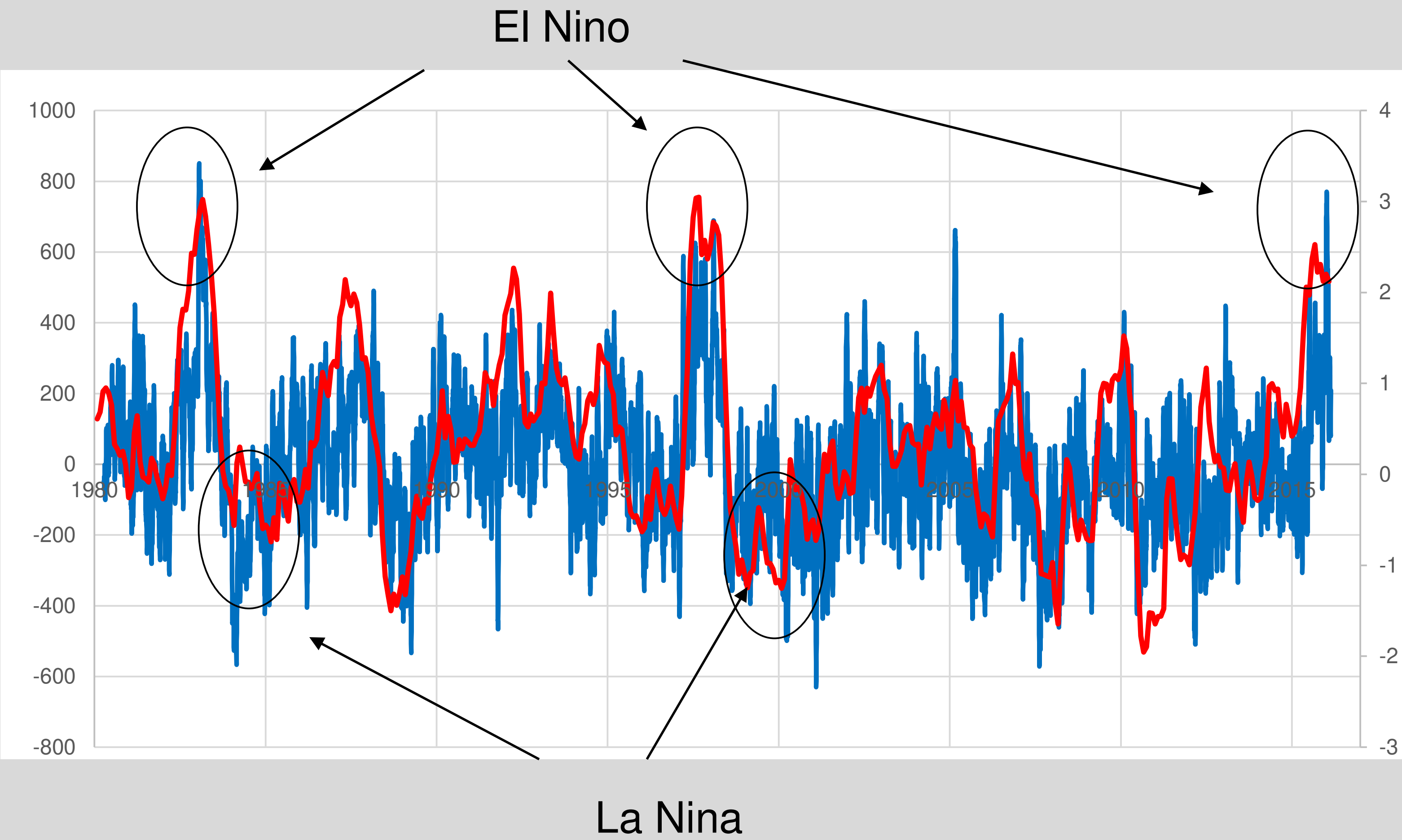
Seasonal Behavior



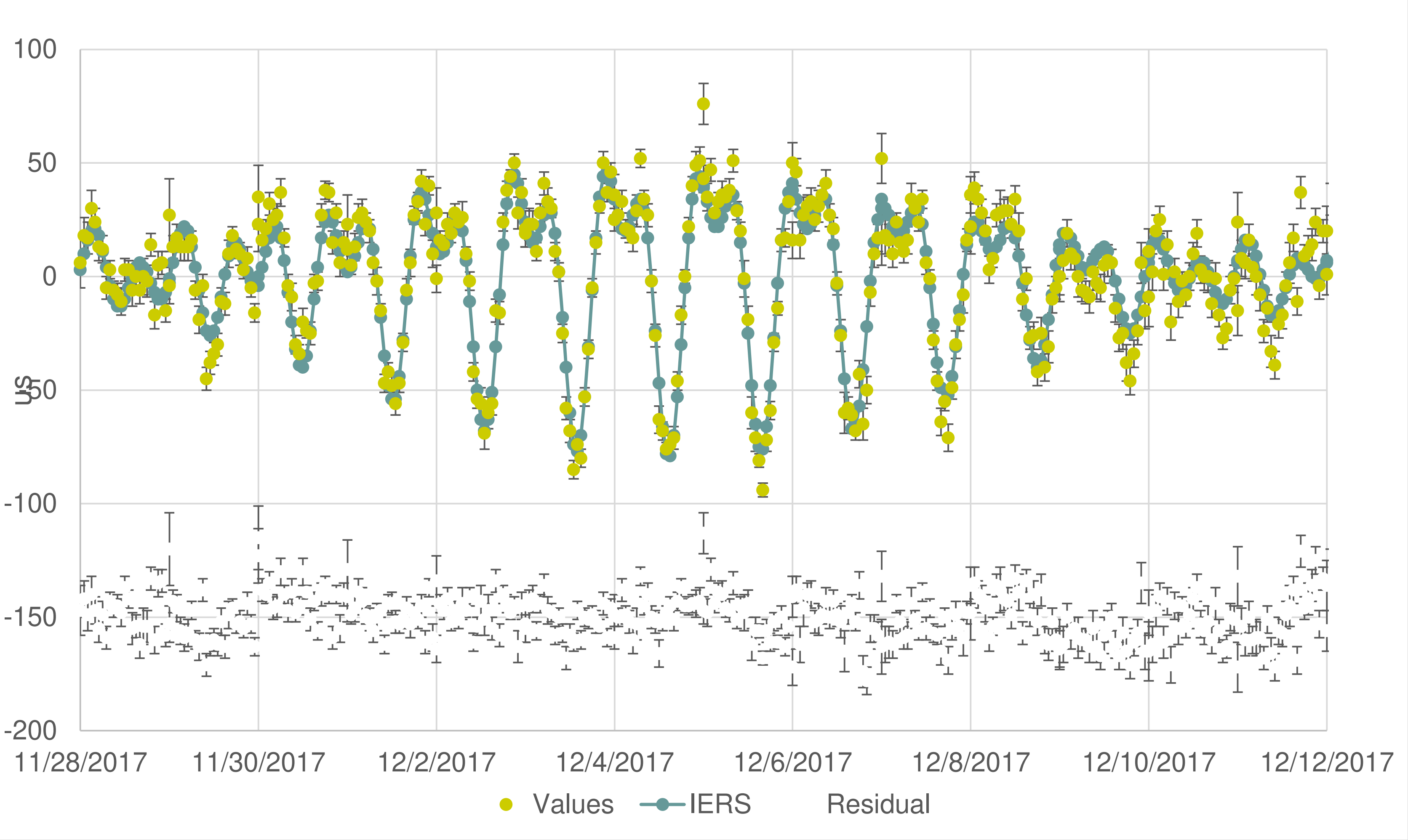
Decomposition of LOD



MEI & Residual LOD



Sub-daily EOP variation



Questions & Comments

?

Geodetic VLBI: VGOS+ ITRF…

John Gipson

NVI,Inc/NASA GSFC

2019 Workshop on Regional VLBI

Mexico City,Mexico

Agenda

The VLBI Terrestrial Reference Frame

Gravitational Deformation of Antennas

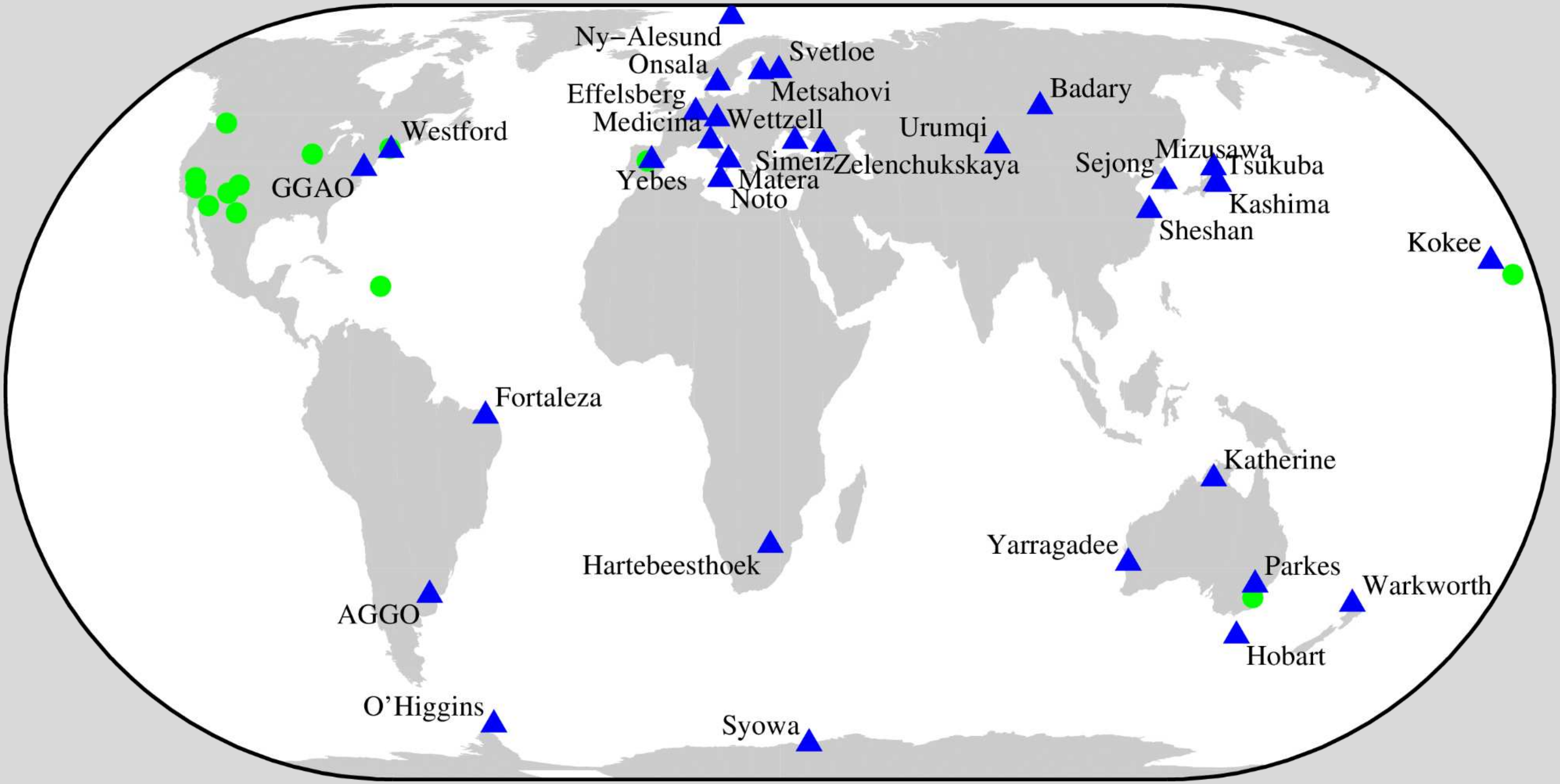
VLBI Geodetic Observing System (VGOS)

The International Terrestrial Reference Frame

Other Space Geodesy Techniques

Global Geodetic Observing System

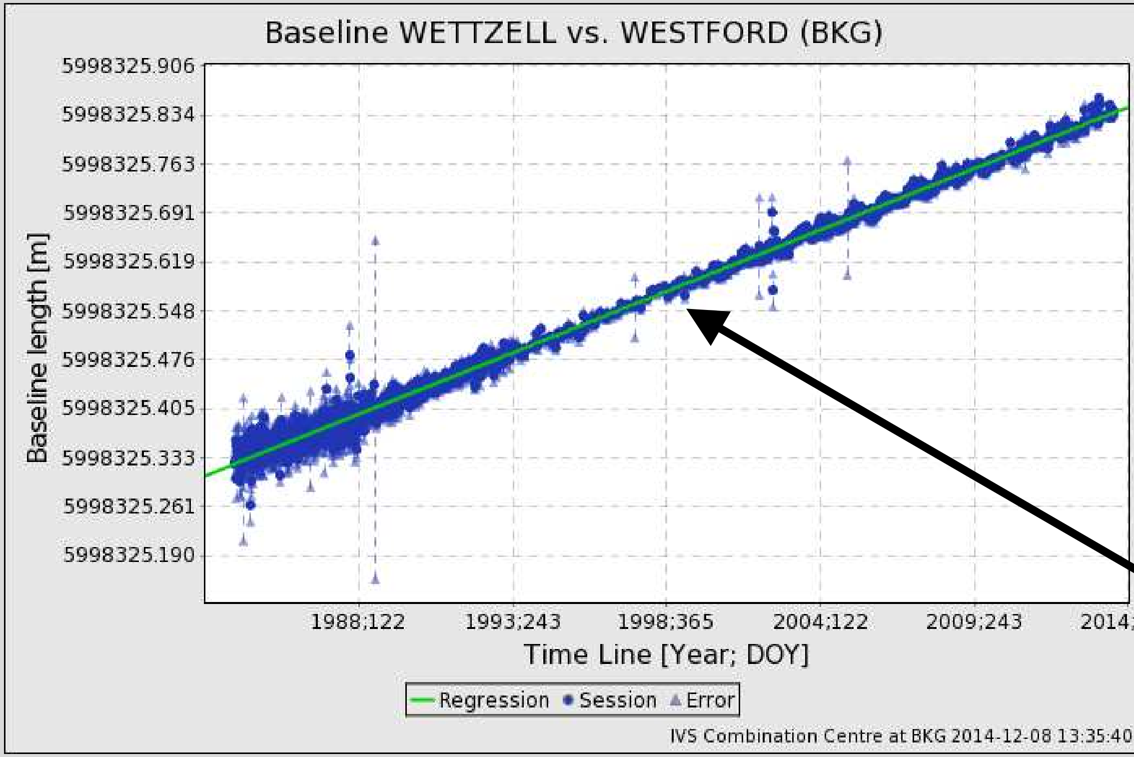
IVS and Cooperating Stations



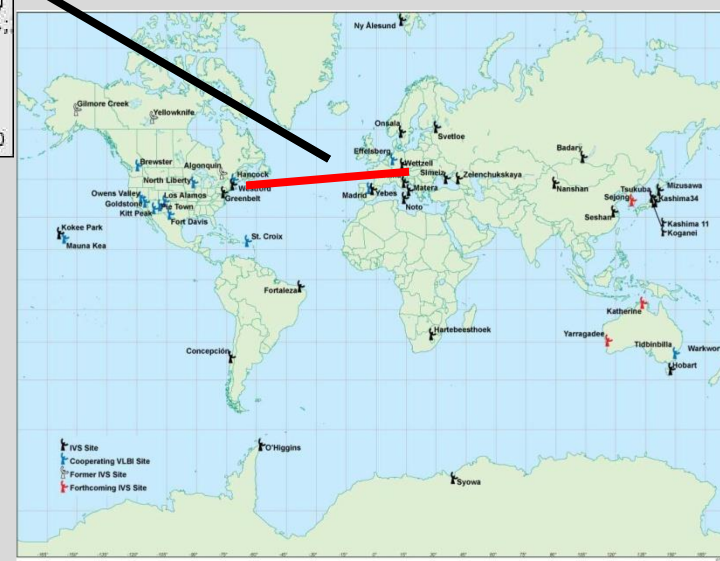
Does not include decommissioned or mobile VLBI sites

▲ IVS Network Station
● Some Cooperating VLBI Site

Westford - Wettzell

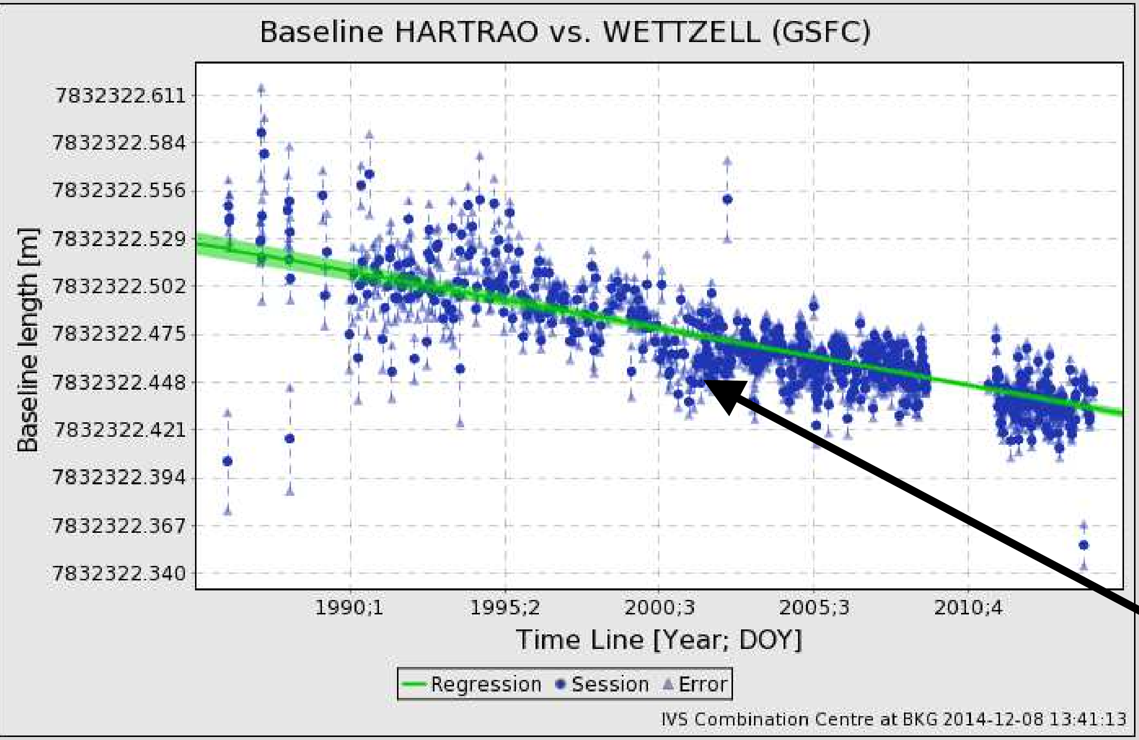


In 30 years the distance increased by ~0.5 m

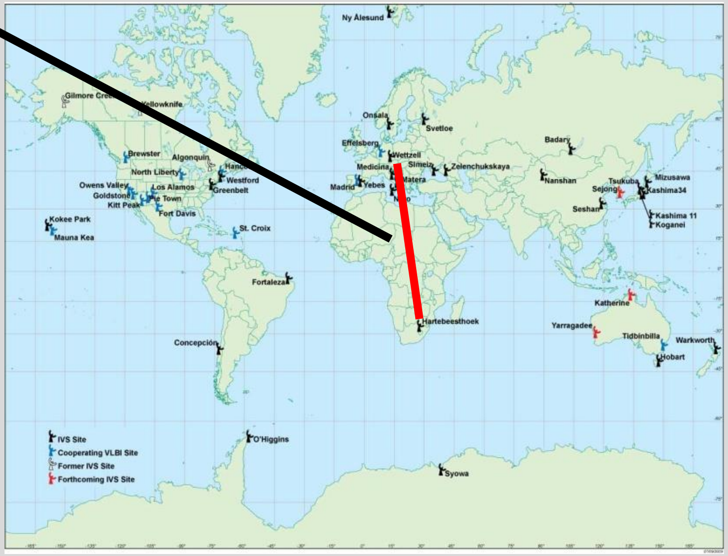


VLBI was the first technique to demonstrate that continental drift happens in real time!

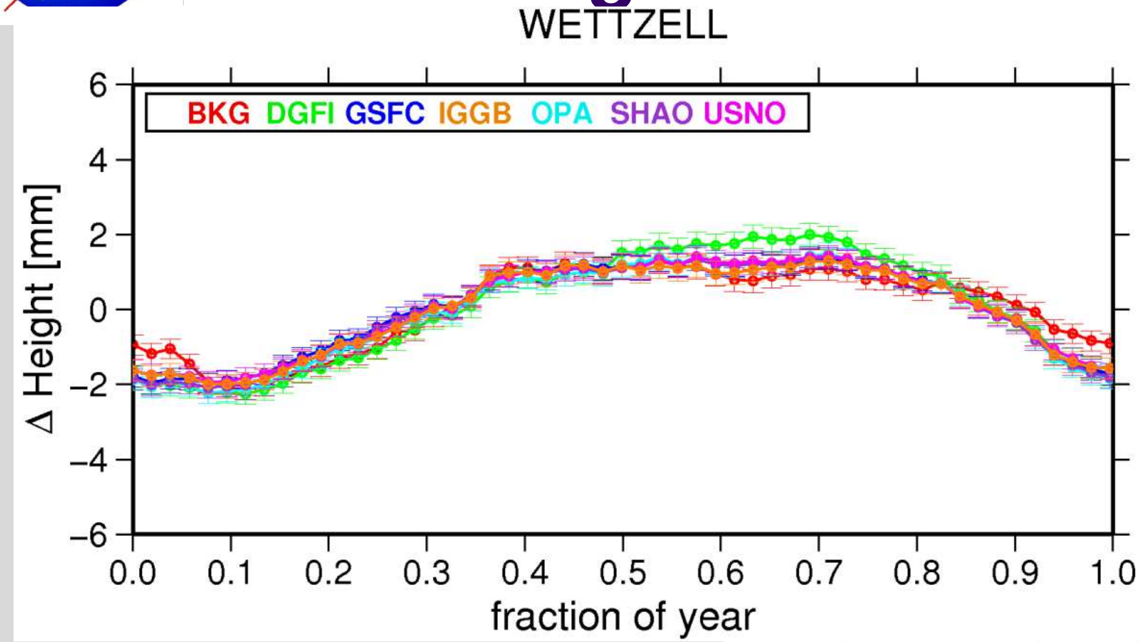
Europe – South Africa

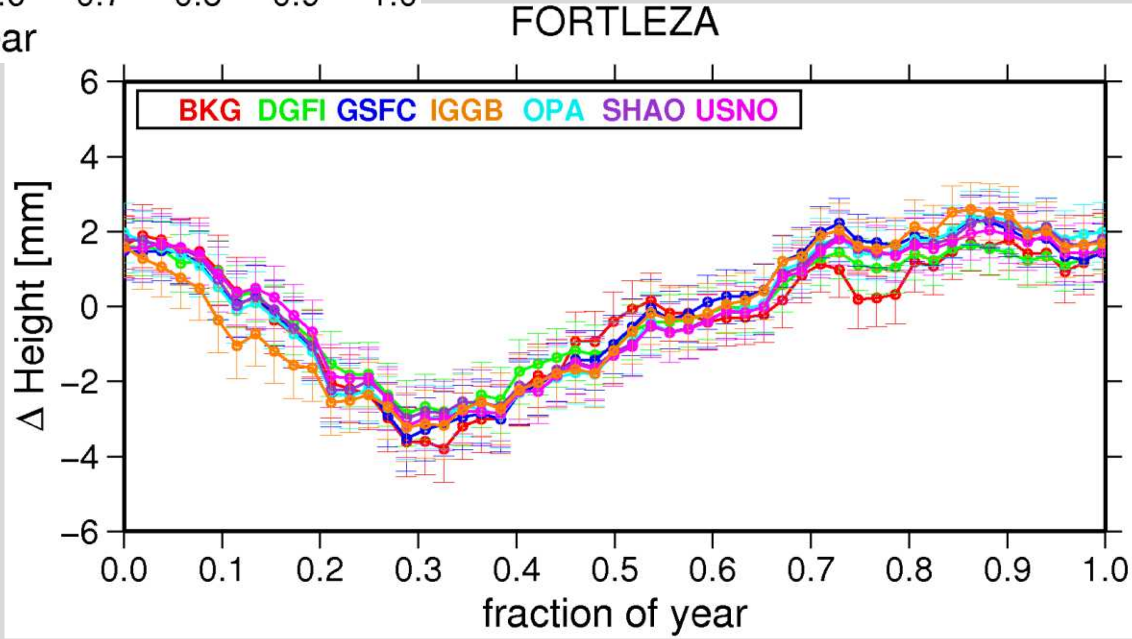


In 20 years distance decreased by a few cm.



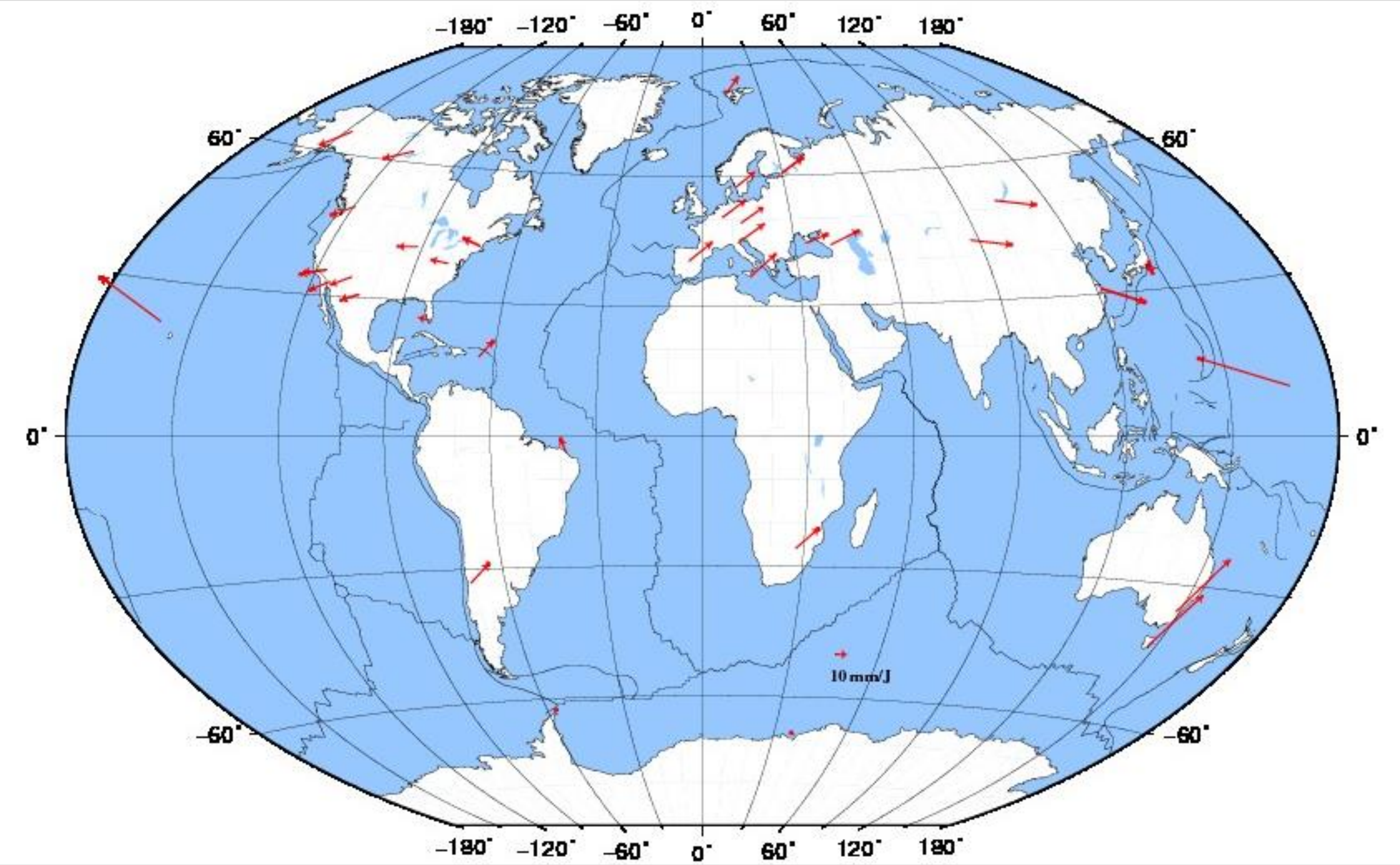
Annual signal in station heights





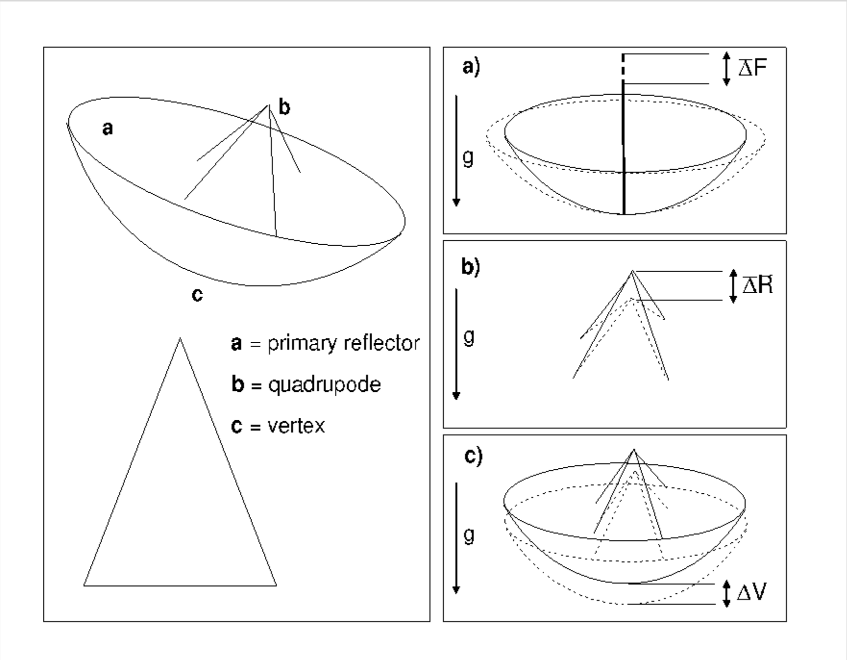
VLBI Terrestrial Reference Frame

Positions and velocities



VLBI and SLR define the scale of ITRF2014

Gravitational Deformation



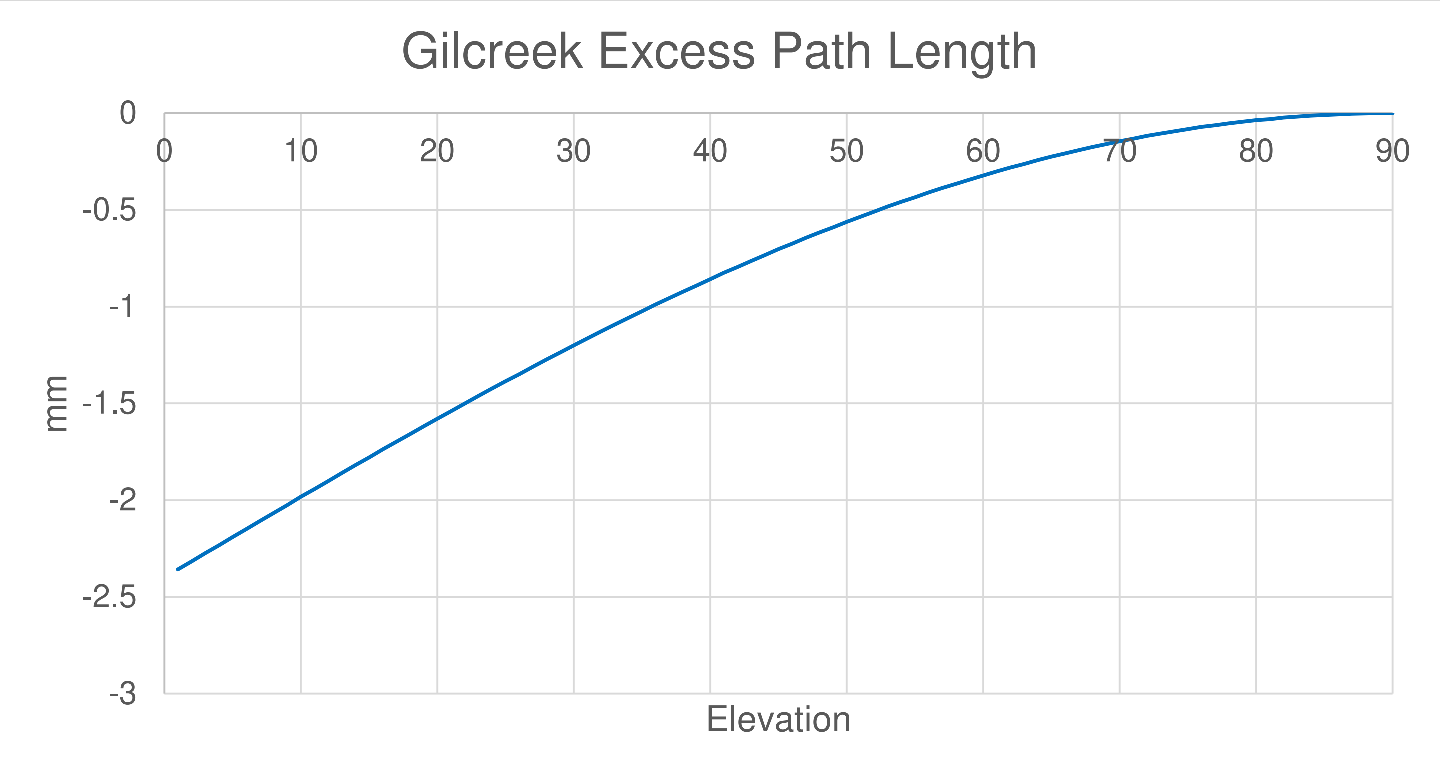
Clark and Thomsen (1988) model for signal path delay depends on variations of

1) focal length
2) vertex position
3) receiver position

$$\Delta L(e) = \alpha_F \Delta F(e) + \alpha_V \Delta V(e) + 2\alpha_R \Delta R(e)$$

- Coefficients depend on dimensions and structure of antenna
- The functions F, V and R have to be measured or modeled for each antenna

Effect at Gilcreek



$\Delta L(el) = 2.4(\sin(el) - 1)mm \longrightarrow$ Change in up estimate of 2.4 mm

At the time (1988—30 years ago!) this was considered a small effect, which is why no one paid much attention.

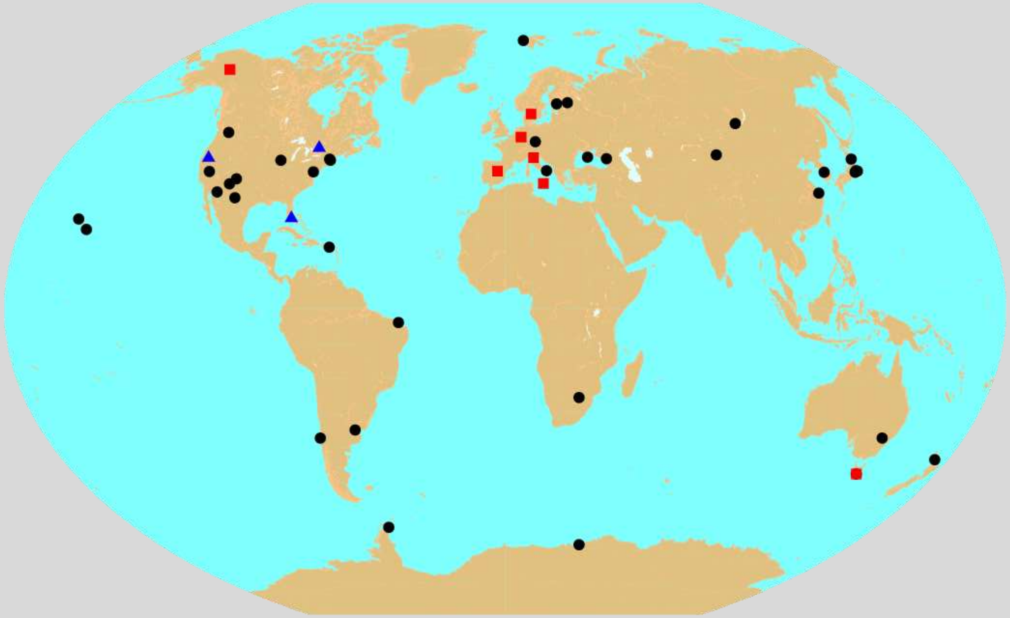
Antennas with models

When	Where	Who
1988	Gilcreek 26M	Clark & Thomsen
2005	Hobart 26M	Dawson et al *(Never published)*
2009	Medicina 32M Noto 32M	Sarti, Negusini, Abbondanza
2014	Yebes 40M	Nothnagel, et al
2014	Efflesberg 100M	Atz, Springer, Nothnagel
2018	Onsala60	Nothnagel et al

Each author gives a different functional form for $\Delta L(el)$

- This makes it difficult to incorporate in an antenna
- Difficult to understand what the effect on estimated parameters will be

IVS Antennas with Models



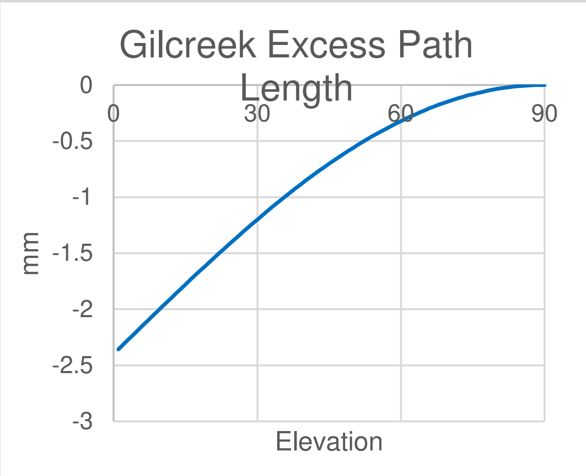
• VLBI antennas ▪ VLBI antennas with models ▴ defunct VLBI antennas

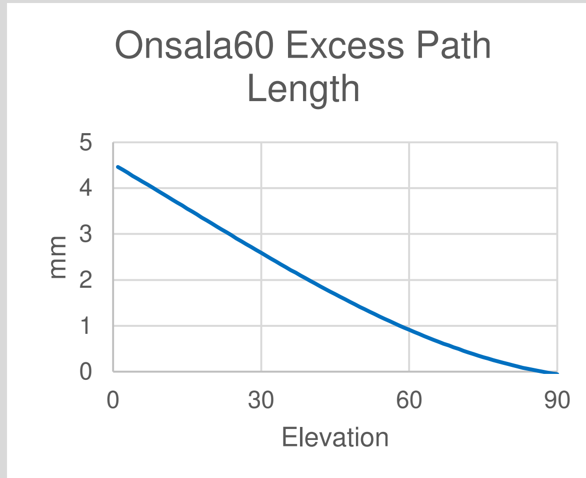
Only a small minority of VLBI antennas have models.

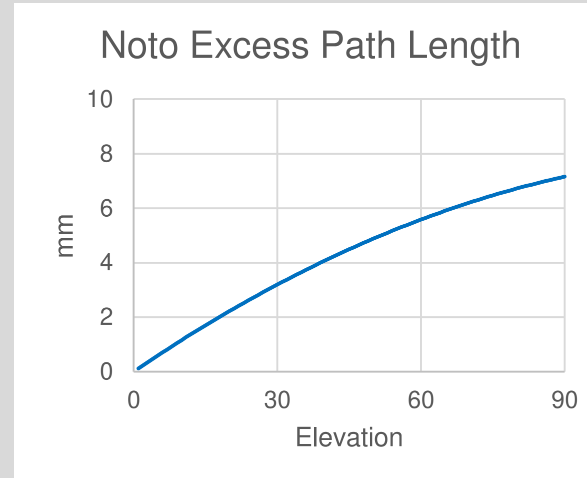
Some antennas were destroyed or decommissioned, and it is unlikely we will ever have models for these.

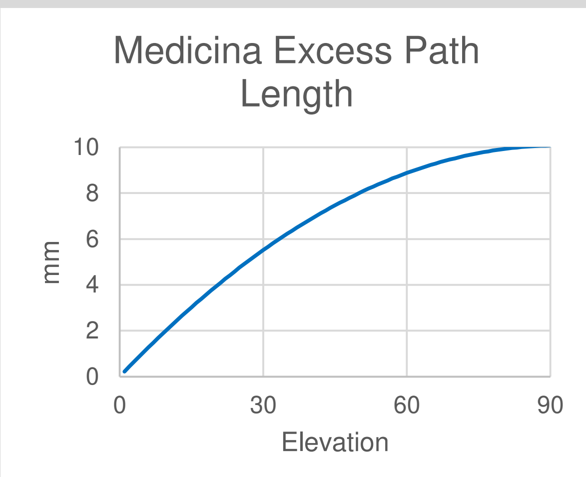
This figure only lists *some* of the defunct

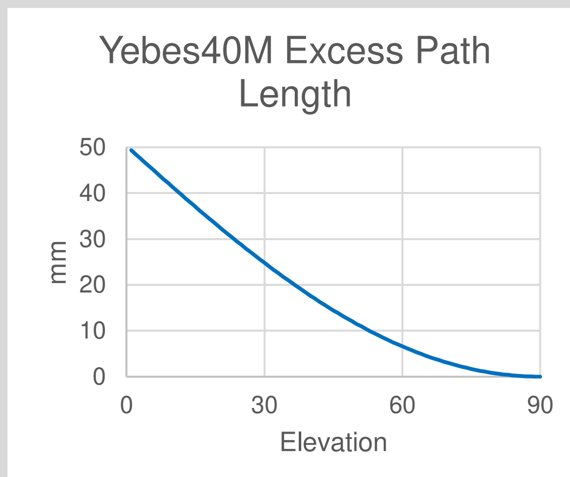
Summary of Models

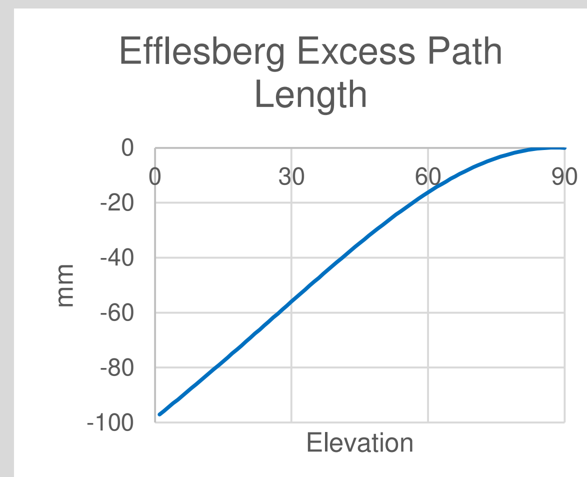












Models vary in sign and magnitude between different antennas.

John Gipson NVI, Inc./NASA GSFC

Estimates

Approach:
For each antenna, do a least squares fit to the delay of the form:

$$\Delta L(el) \approx \frac{A}{\sin(el)} + C + U\sin(el) \quad [+X\cos(el)]$$

We estimate the coefficients A, C, U and X, where the last term is optional.

The physical interpretation is:
A→ Change in Atmosphere
C→ Change in Clock
U→ Change in Up
X→ Change in axis offset (if estimated)

Results of Least Squares Fit

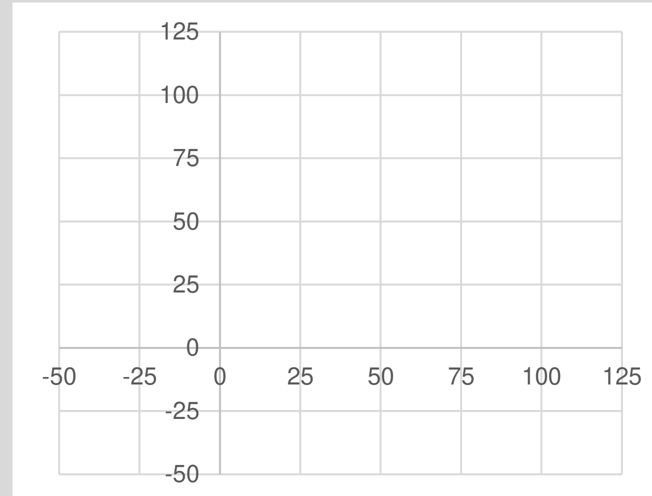
		ATM	CLK	UP
	WRMS	1/Sin(el)	1	Sin(el)
EFLESBERG	1.02	2.12	-117.16	114.33
GILCREEK	0.00	0.00	-2.40	2.40
MEDICINA	0.04	-0.13	-1.29	8.93
NOTO	0.15	0.11	-0.72	7.32
ONSALA60	0.08	-0.10	1.72	-5.07
YEBES40M	0.04	0.10	49.38	-49.53

Last column is 'predicted' change in Up due to applying model.

Fit Delay curve from 7-90 degrees.

Predicted and actual change in Up

	Size(M)	Predicted (mm)	Actual (mm)
EFLESBERG	100	114.3	118.70
GILCREEK	26	2.4	2.46
MEDICINA	32	8.9	8.87
NOTO	32	7.3	7.26
ONSALA60	20	-5.1	-4.92
YEBES40M	40	-49.5	-37.44



Sarti, Abbondanza, Petrov and Negusini (2011) found a change in local Up of
8.9 for Medicina and 6.7 for Noto

For most antennas there is good agreement between predicated and actual change in lo

The notable exception is YEBES40M which I will discuss later.

VLBI Geodetic Observing System

Goals:

Position precision of ~1mm

Stability of 0.1 mm/year

Globally distributed VLBI network of ~30 sites

24/7 measurement

Near real time EOP.

How can VLBI get to GGOS goals?

$$\sigma_{UEN}^2 = \frac{\sigma_{obs}^2}{N} + \sigma_{modeling}^2$$

To reduce σ_{obs}^2 need to record more bits:

- Increase scan time
- Increase BW

To increase N need to

- Reduce scan time
- Reduce slewing time

Did a series of Monte Carlo simulations with values for different values for

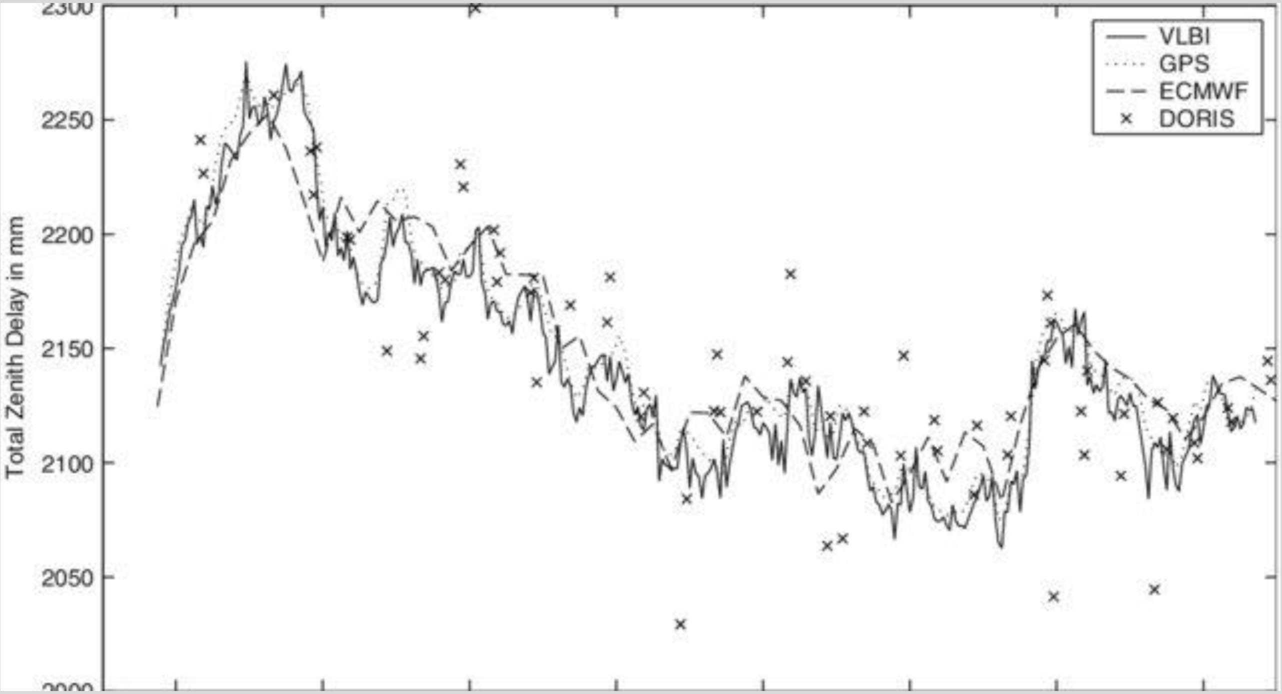
- σ_{obs}
- Clock stability
- Atmospheric turbulence

Key findings:

- Once you get below 2-5 ps for σ_{obs} little additional improvement.
- Dominant remaining source of error is atmosphere mismodeling.
    - Which can be somewhat fixed by dense sampling.

The Atmosphere

Kokee Park

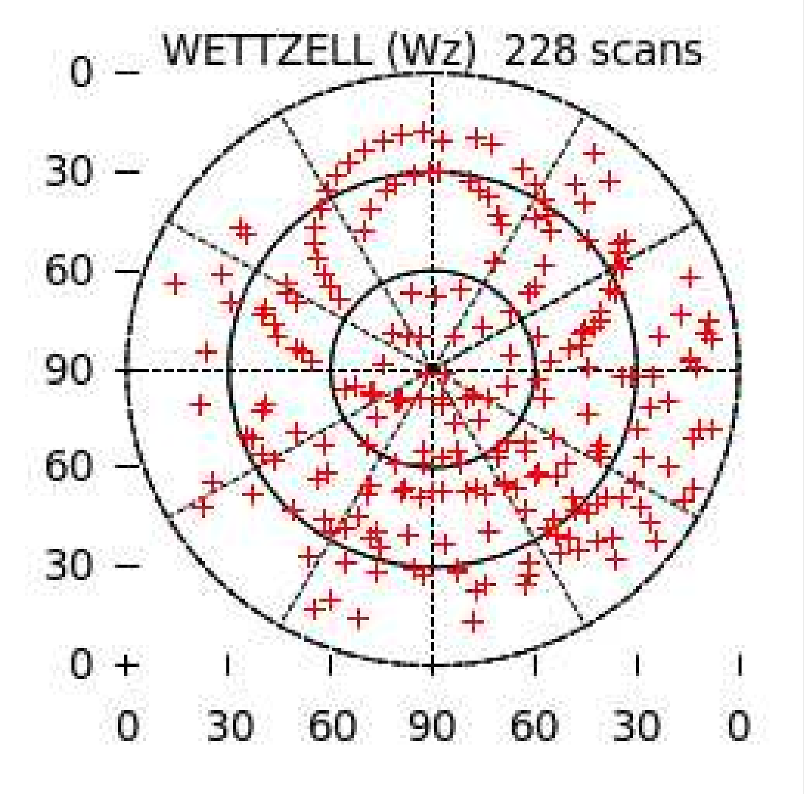


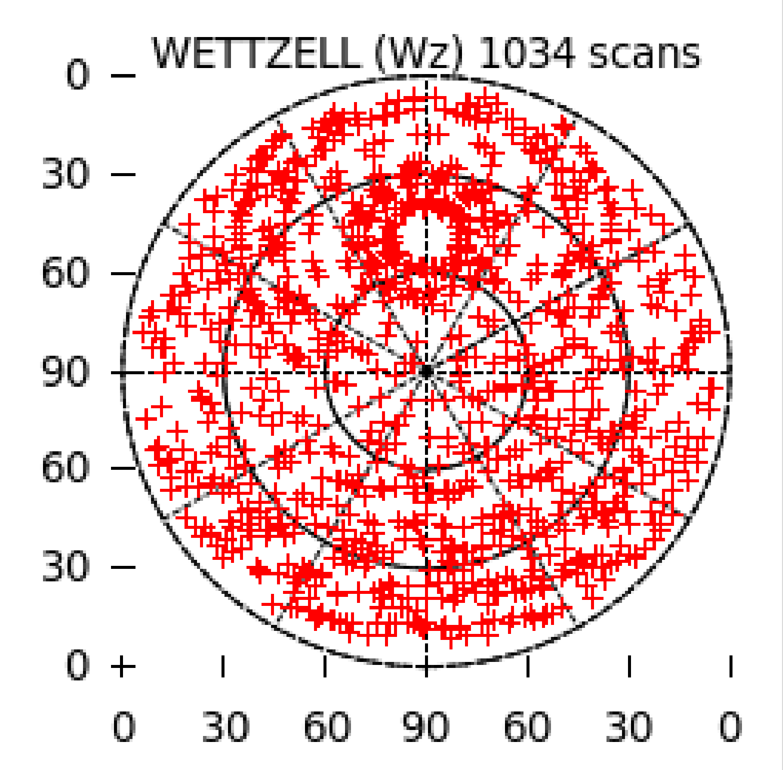
Atmosphere modeled as a piece-wise-linear function, and estimated from the data.

VLBI Global Observing System (VGOS)

Mismodeled atmospheric delay is dominant error source.

One way to reduce is increase the sampling of the sky.





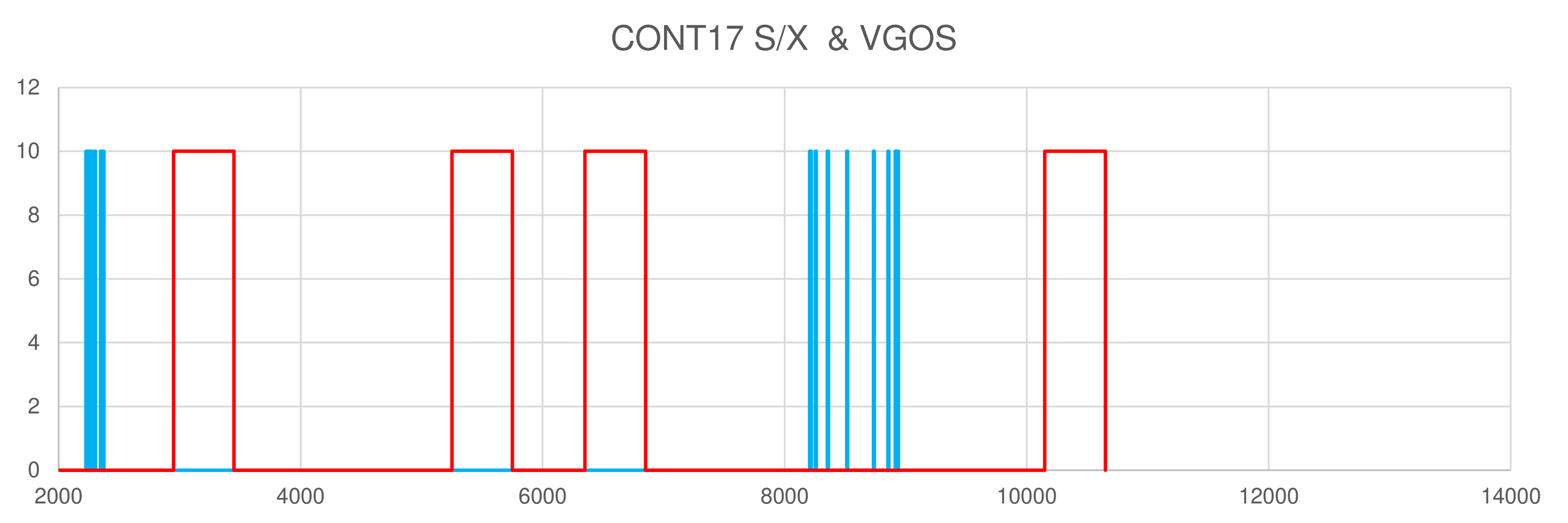
Concept of VGOS

- **New generation VLBI infrastructure**
  - **dense sampling of atmosphere**
  - **agile telescopes**
    → small (12 – 13 m) 12º/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])
- Flexible frequency allocation
- Dual linear polarization

CONT17 VGOS Bands



Max observing frequency

4 bands, each band 500 MHz wide

SNR ~ A*SQRT(#Bits)=A*SQRT(2*4 * 500e6)= A*63.3e3

4 times the SNR as S/X
Compensates for (12/20)^2 = 36% factor due to antenna size

Future VGOS sessions will be more sensitive because they will observe more of the 2-14 GHz band.

VGOS Summary – V2C Progress Report

- “Design Aspects of the VLBI2010 System”
  - *Name later changed to VGOS*

	Current	VLBI2010
antenna size	5–100 m dish	~ 12 m dish
slew speed	~20–200 deg/min	≥ 360 deg/min
sensitivity	200–15,000 SEFD	≤ 2,500 SEFD
frequency range	S/X band	~2–14 (18) GHz
recording rate	128-512 Mbps	8–16 Gbps
data transfer	usually ship disks, some e-transfer	e-transfer, e-VLBI, ship disks when required

https://ivscc.gsfc.nasa.gov/pub/misc/V2C/TM-2009-214180.pdf

VGOS Telecopes

Wettzell (DE)

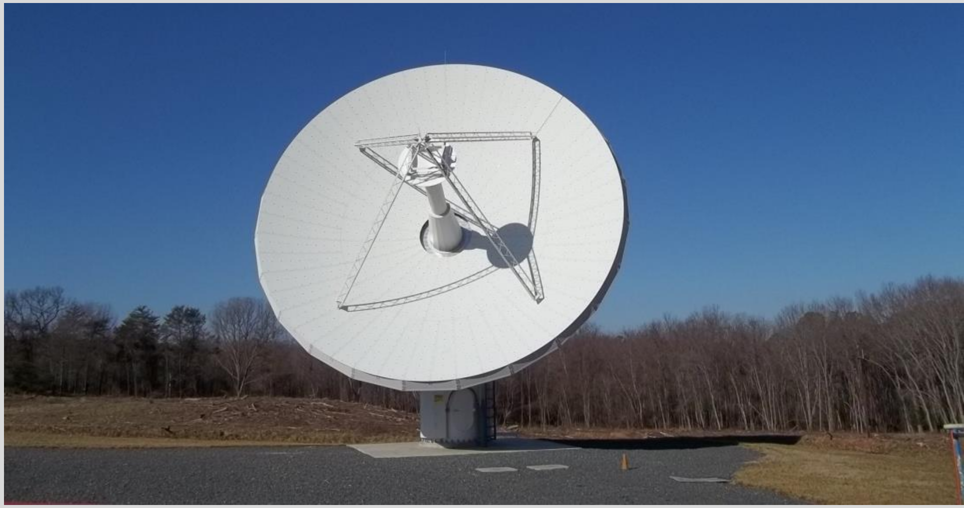
Zelenchukskaya (RU)

Courtesy
A. Ipatov

Ishioka (JP) Courtesy Y. Fukuzaki

GGAO (US)

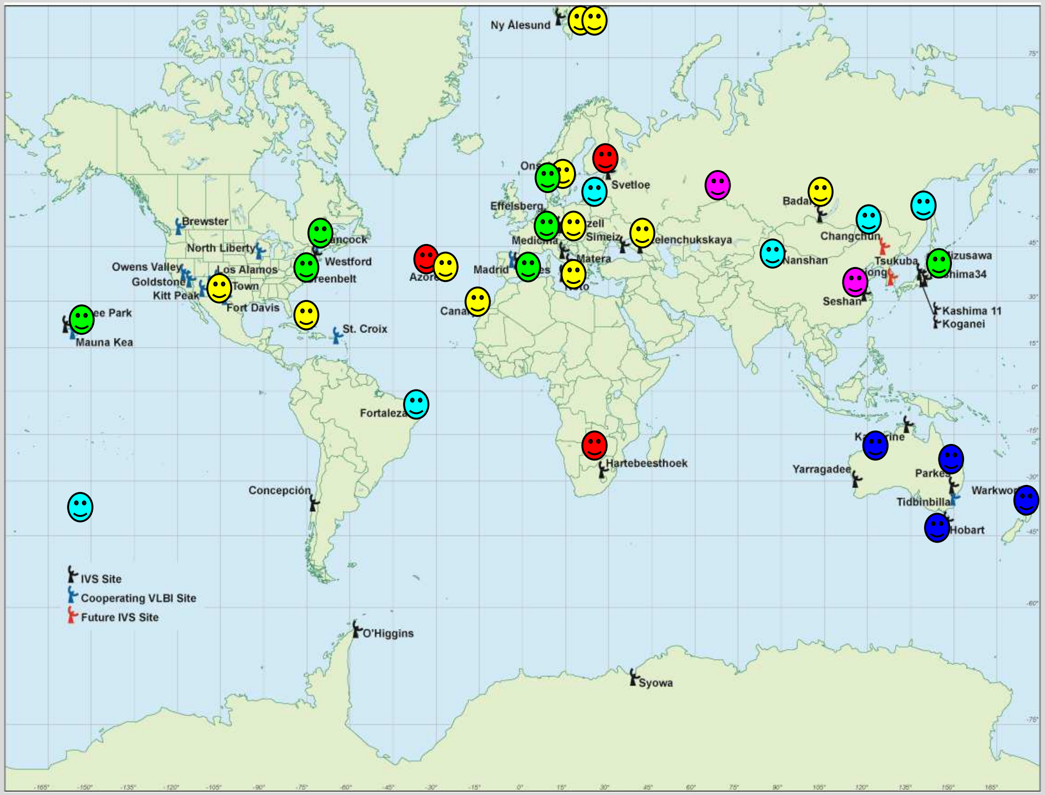
Courtesy A. Niell



Badary (RU)

Courtesy
A. Ipatov

New VGOS Telescopes for IVS



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

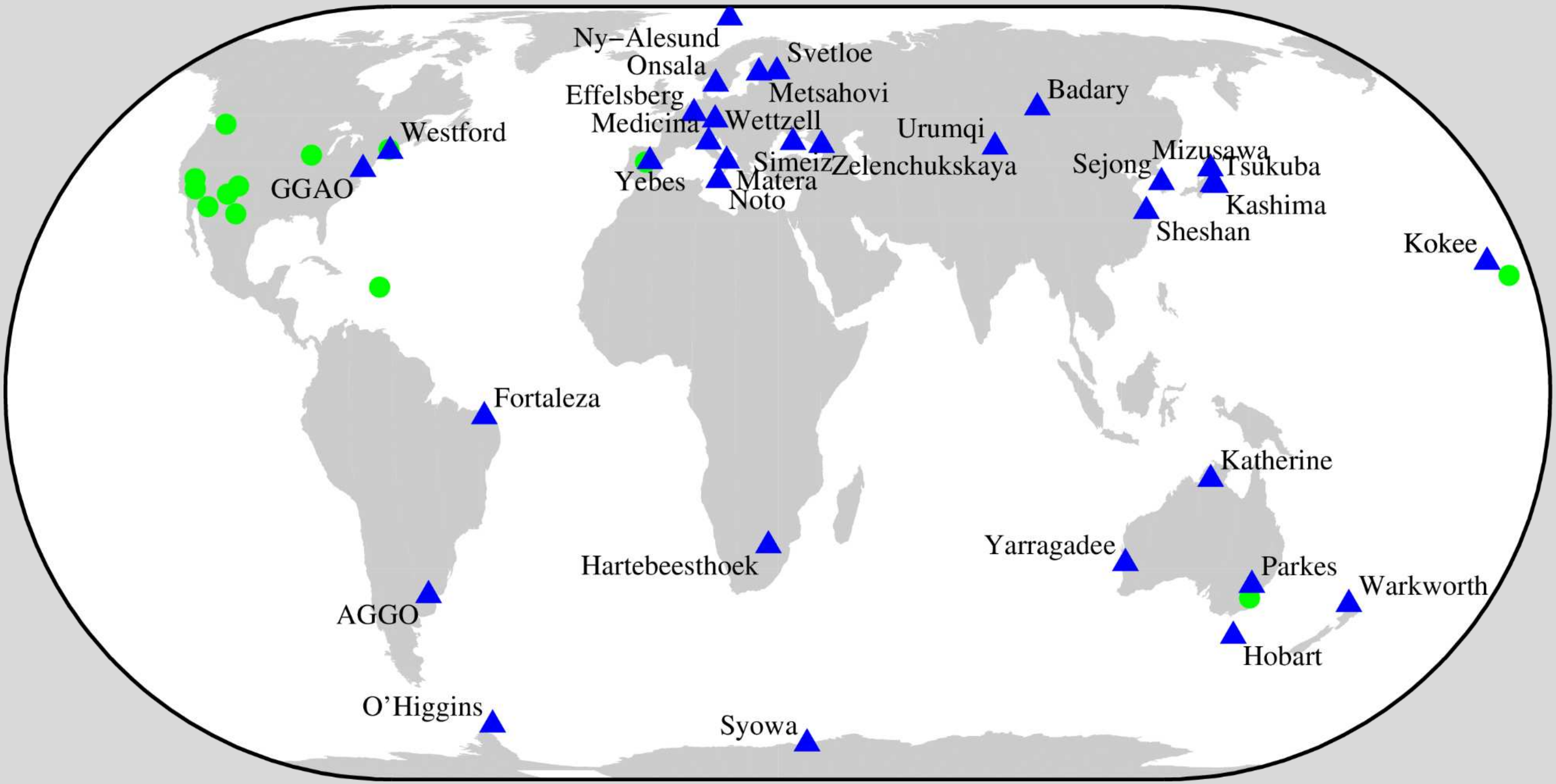
Data current as of Dec 2018

Need more stations in the southern hemisphere!

International Terrestrial Reference Frame (ITRF)

- Provides the stable coordinate system that allows us to measure change (link measurements) over space, time and evolving technologies.
- An accurate, stable set of station positions and velocities.
- Foundation for virtually all space-based and ground-based metric observations of the Earth.
- Established and maintained by the global space geodetic networks.
- Network measurements must be precise, continuous, and worldwide.
- Must be robust, reliable, geographically distributed
  - proper density over the continents and oceans
  - interconnected by co-location of different observing techniques

IVS and Cooperating Stations



Does not include decommissioned
or mobile VLBI sites

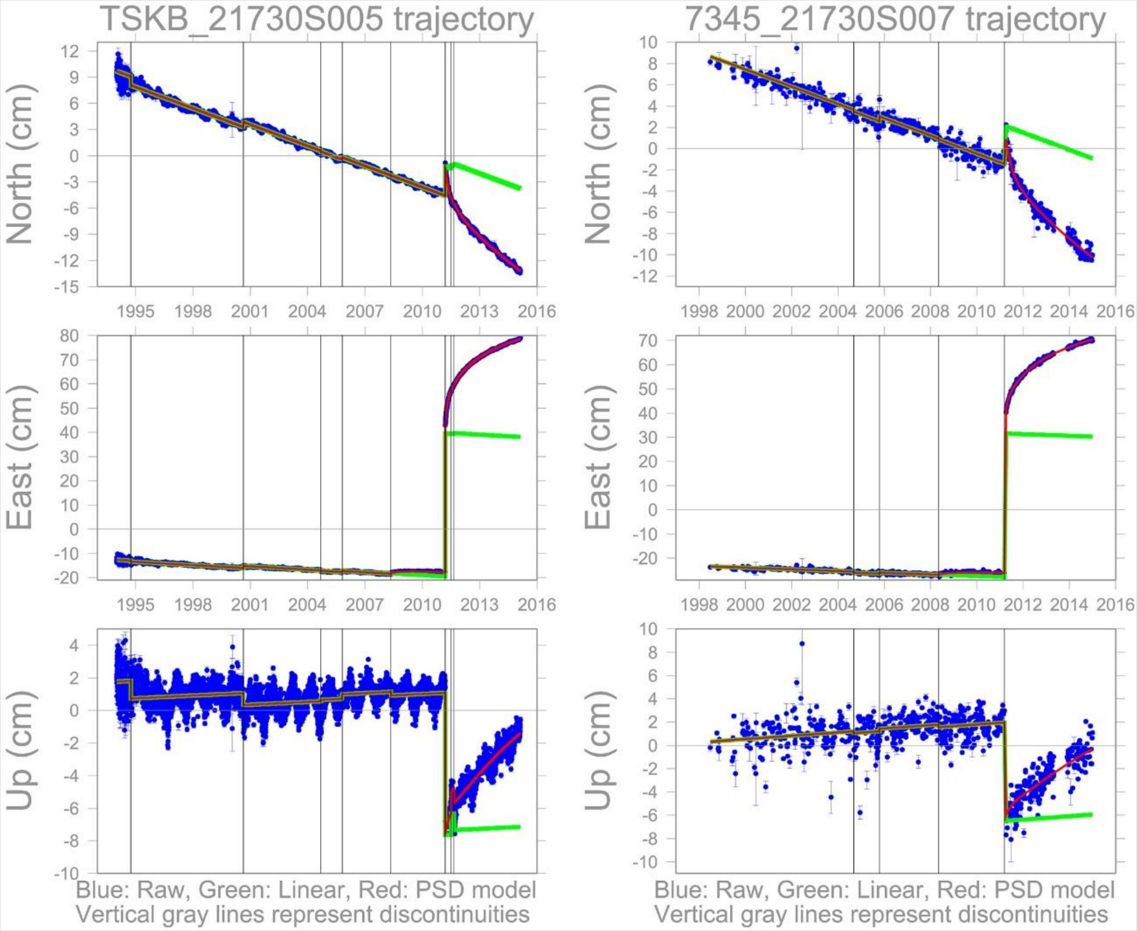
▲ IVS Network Station
● Some Cooperating VLBI Site

All sites in ITRF2014

VLBI, SLR, GNSS and DORIS

Figure taken from CDDIS

Tsukuba post-seismic movement



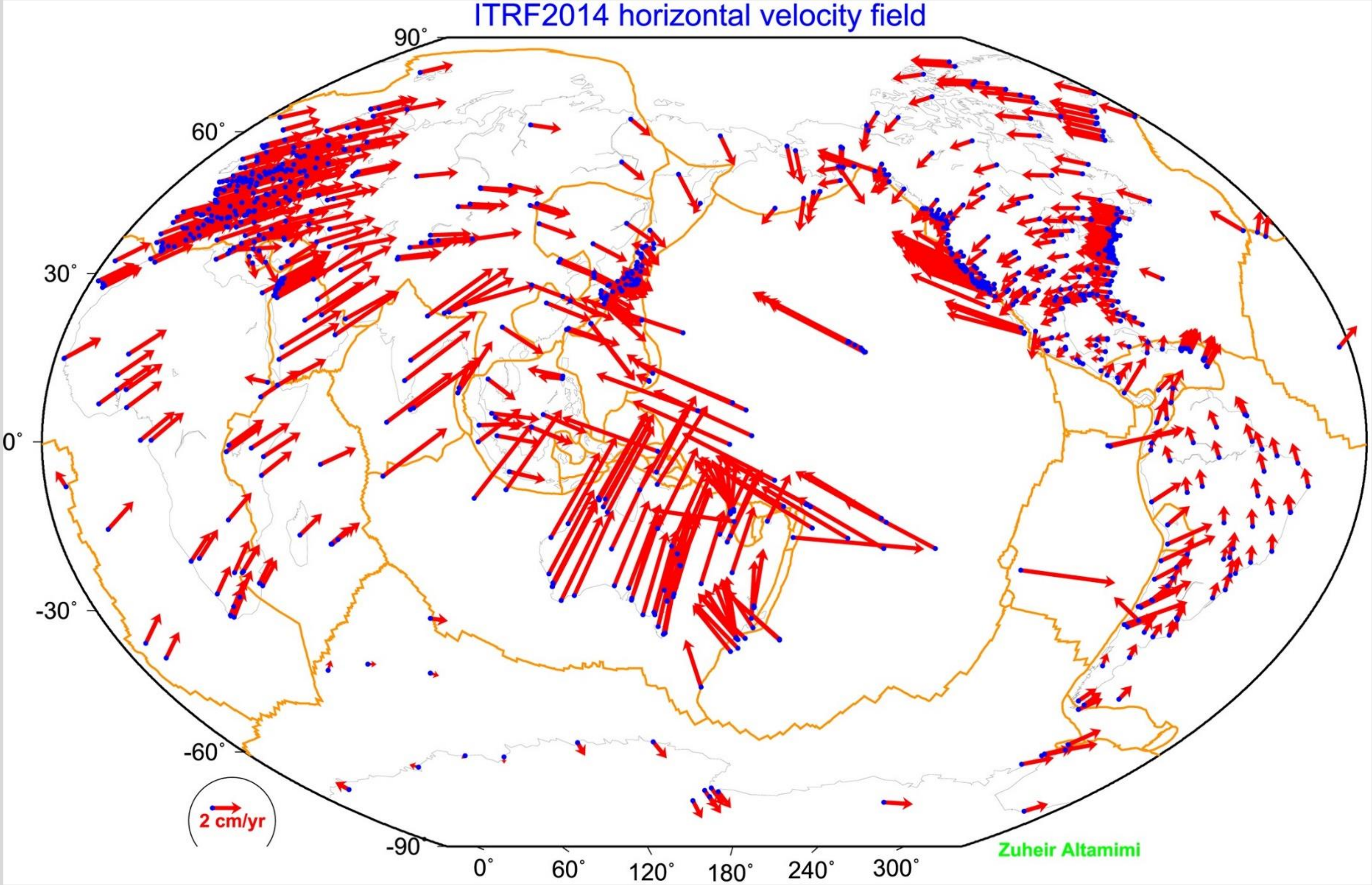
Green line is linear motion

Red line is post-seismic model.

GPS measurements

VLBI measurements

2014 Horizontal Velocity Field



ITRF2014 & Surveying

ITRF2014 replaces, and is more accurate than previous global coordinate systems. As techniques improves, have more stations and greater accuracy.

- Agrees with original WGS84 at the 1 meter level
- Agrees with revised WGS84 (which used GPS in its definition) at the 5 cm level.
  - WGS84 is the coordinate system of GPS
- Agrees with ITRF2005 at the few cm.
  - GTRF (Galileo Terrestrial Reference Systems) is identical to ITRF2005

ITRF2014

Uses Earth Centered, Earth Fixed Frame

Goal is to have a coordinate system that spans the world with:

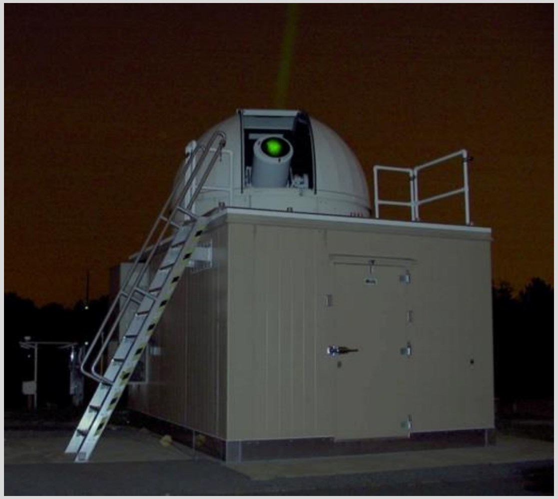
- 1 mm accuracy
- 0.1 mm/yr stability.
- Currently about a factor of 3-5 away from this.

For each site:

- Position
- Velocity
- Sometimes… post-seismic deformation models

Space Geodetic Systems

Very Long Baseline Interferometry (VLBI)

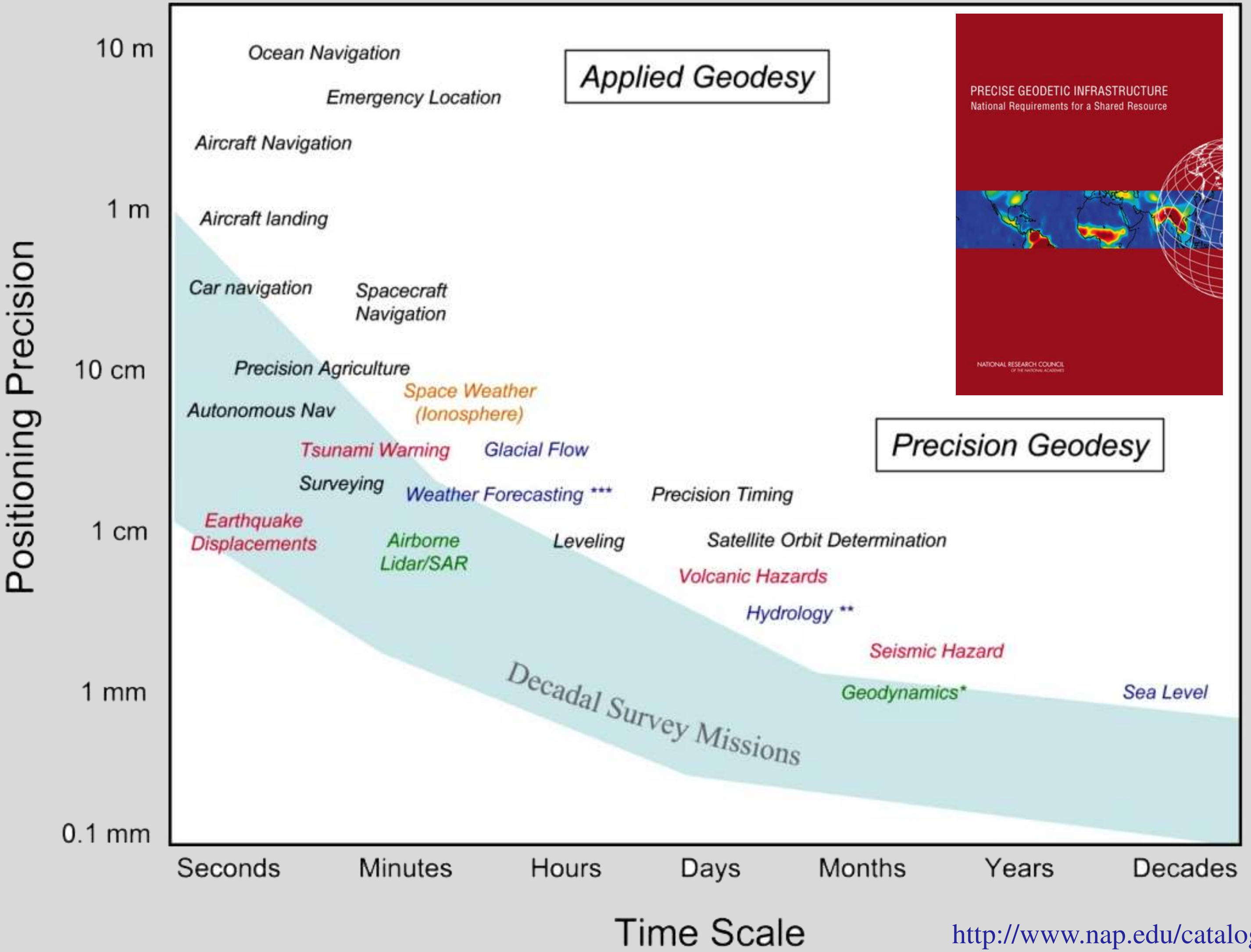


Satellite Laser Ranging (SLR)

Global Navigation Satellite System (GNSS)

Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS)

Space Geodesy Provides Positioning, Navigation, and Timing Reference Frames and Earth System Observations



http://www.nap.edu/catalog/12954.html

NASA SGP website

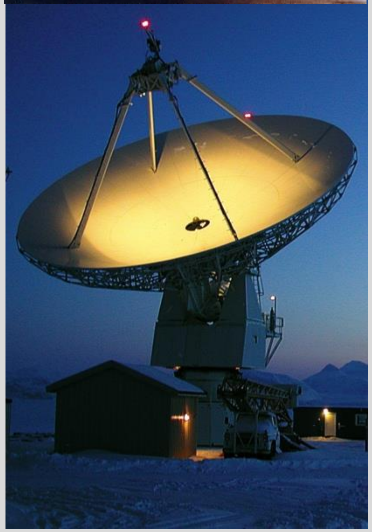
https://space-geodesy-nasa.gov

Good overview on:

1. Space geodesy
2. NASA' Space Geodesy Project.

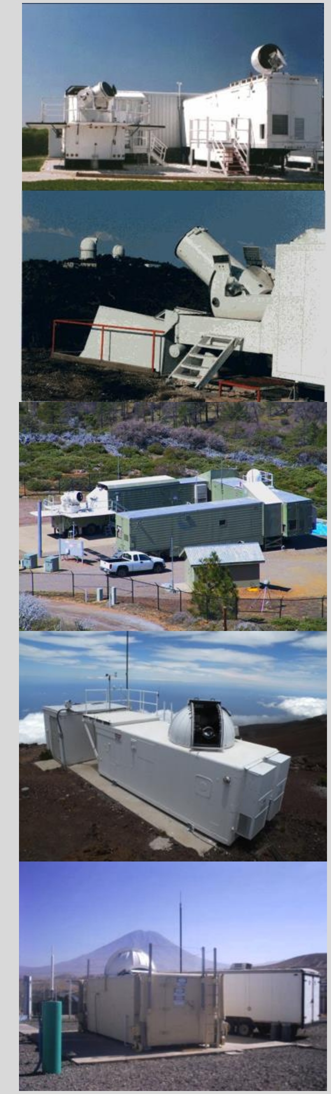
Very Long Baseline Interferometry (VLBI)

- 40 IVS stations worldwide acquiring data, some daily.
  - ~20-30 cooperating stations
  - NASA runs 3 VLBI sites (and number is growing)
  - Provides support for 3 partner sites.
- Observable is difference in arrival time of signal originating from quasar
  - Signal is weak→antennas must be large
- Determines:
  - Station position
  - Scale
  - Source position
  - EOP
  - Scale
- Cost of new VGOS antenna ~$10M
  - Please take all cost numbers as very approximate.



Satellite Laser Ranging (SLR)

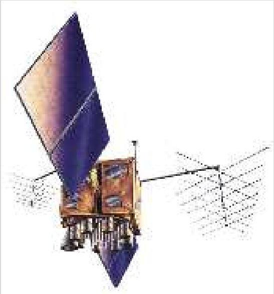
- Currently 23 operational stations worldwide acquiring data daily.
  - NASA runs 5 SLR sites
  - Provides support for 3 partner sites
- Observable is round trip travel time of laser signal.
- Determine:
  - Station position
  - Scale
  - Orbits
- Cost: ~$10M



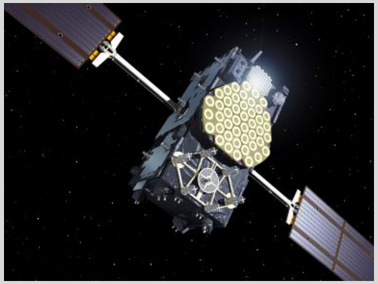
Global Navigation Satellite Systems (GNSS)

NVI, INC.

- 440 GNSS tracking stations within the International GNSS Service (IGS) network.
  - 68 NASA Stations
  - 1000s of other stations
- Signal is transmitted by satellite and detected by ground based receiver.
- Determine
  - Station position
  - Polar Motion
  - Orbits
- Cost: $10K-$50K



GPS



Galileo

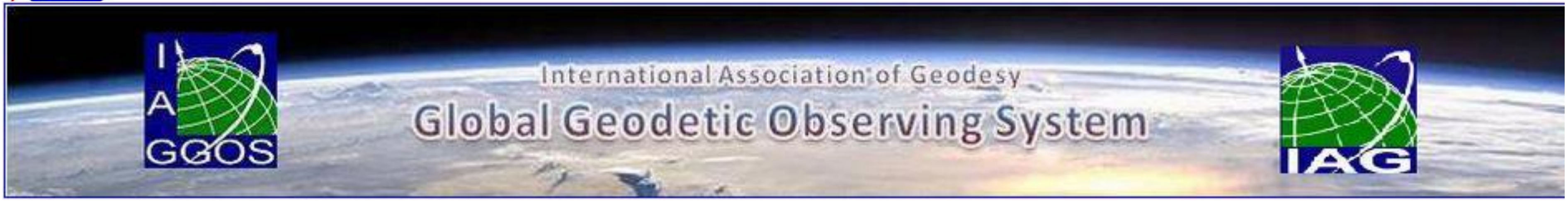
GLONASS

DORIS

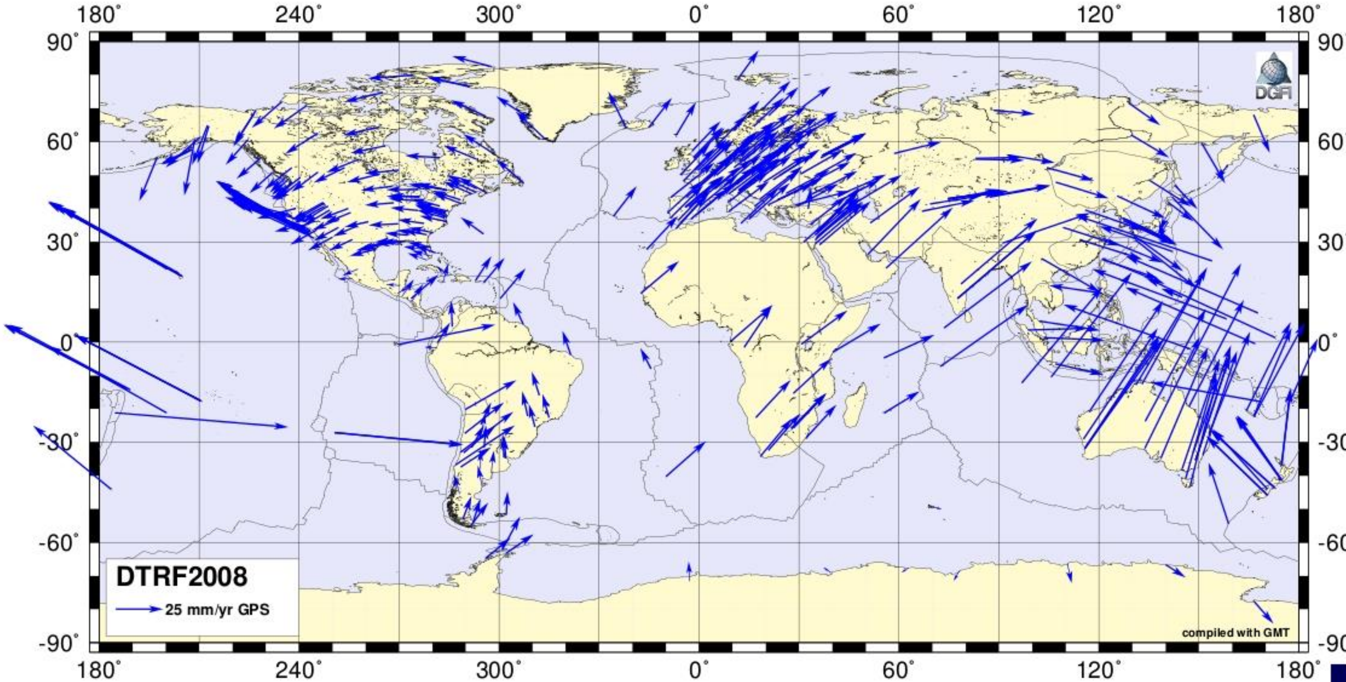
- Currently 60 operational stations worldwide acquiring data daily.
- Signal originates on ground, and received by satellite.
- Determine:
  - Station position
  - Orbits
- Cost: Can't buy.

Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS)

Global Geodetic Observing System



VGOS is part of GGOS



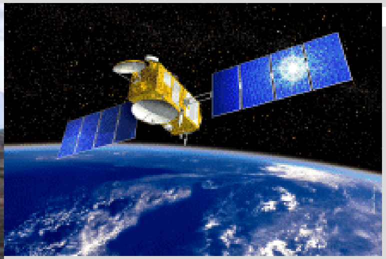
International Association of Geodesy

150 years

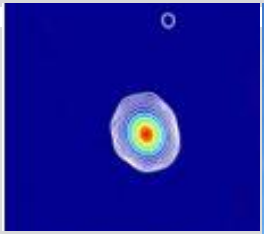
CORE Sites

- Each technique has strengths and weaknesses.
- The best results come from combining the techniques
- This requires having two or more techniques at each site.
  - You also need good local surveying ties
- A CORE site has all 4 techniques
- Goal is to have ~30 globally distributed CORE sites
- NASA is planning on running 10 CORE sites
- NASA currently has 3 CORE sites
  - Greenbelt, Maryland. First prototype.
  - Kokee Park,Hawaii. Second site.
  - McDonald, Texas Operational later this year.

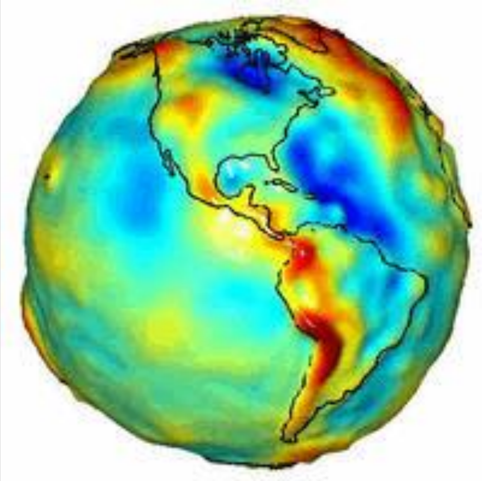
Global Geodetic Observing System



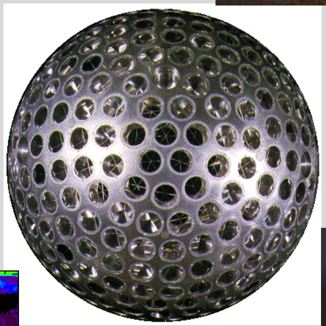
DORIS



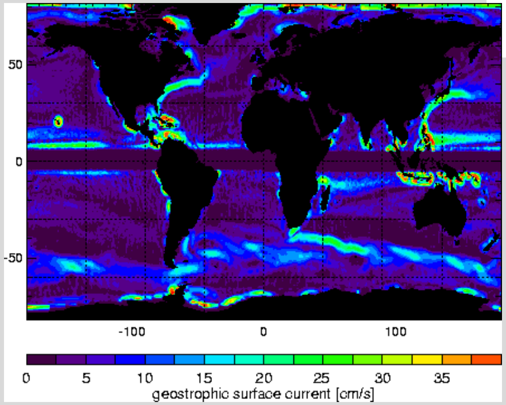
VLBI



GPS



SLR



The Geodetic Measurement System

VLBI
- Orientation of ITRF with respect to ICRF
- ITRF Scale

SLR
- Origin of ITRF (Earth's CM)
- ITRF Scale
- Position spacecraft in ITRF ("Orbits")

GNSS
- Precise monitoring of Polar Motion and Rotation Rate
- Position spacecraft in ITRF ("Orbits")
- Position instruments on Land and Sea (Tide Gauges and Buoys, Geodetic Instruments)

DORIS
- Position spacecraft in ITRF ("Orbits")
- Enhances global distribution of ITRF Station positions and velocities

Technique Connectivity (Station Co-Location)

Fully Define ITRF

VTS: ITRF Performance Improvement

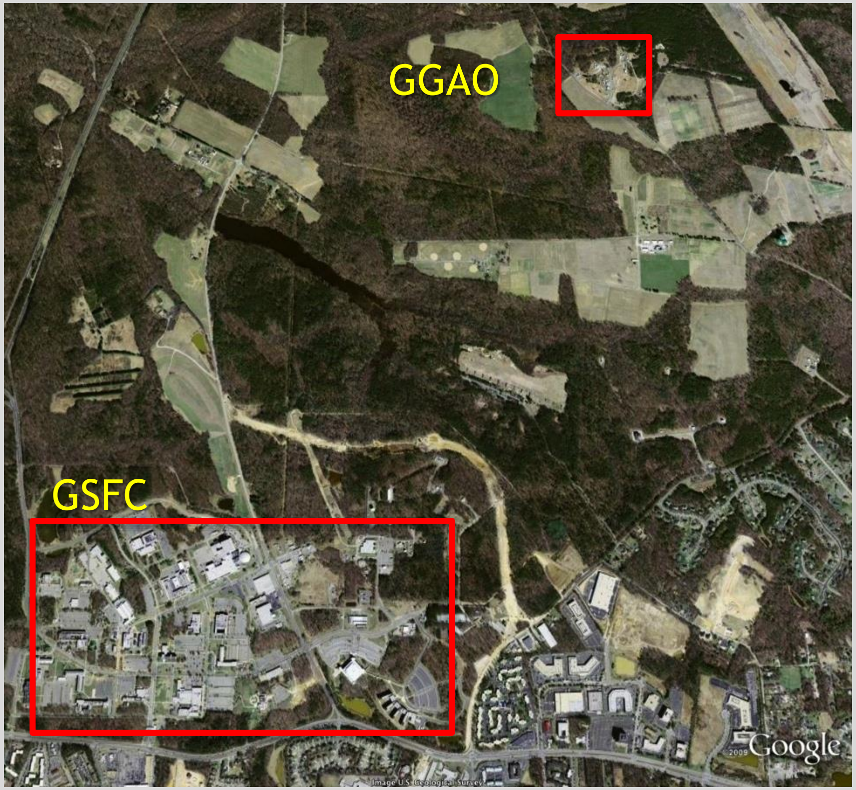
Origin, Scale, Orientation

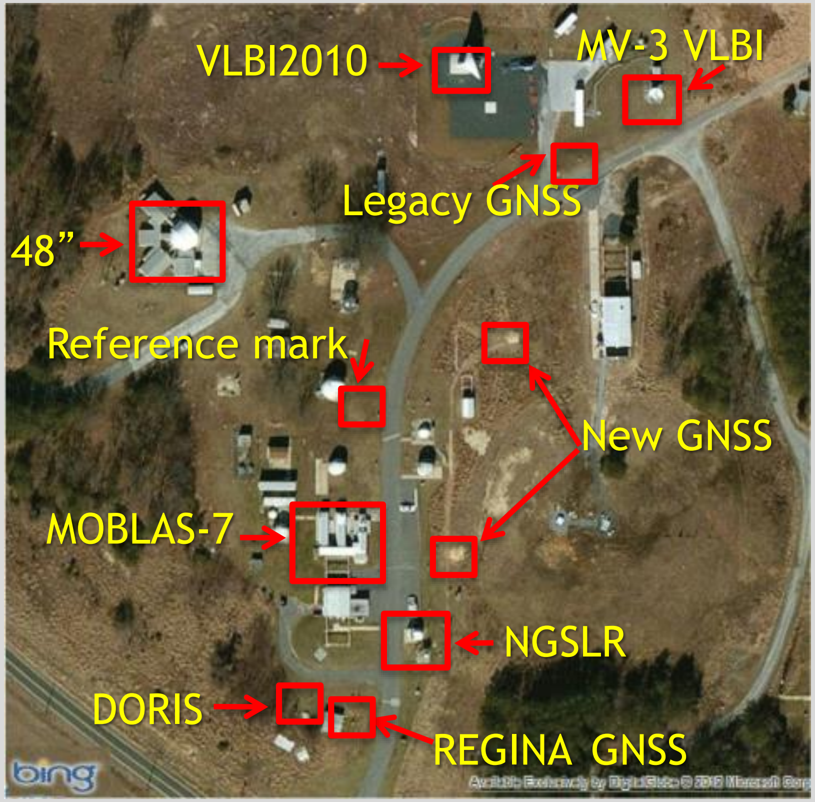
Low-Density Global Distribution

High-Density Global Distribution

Prototype Next Generation Geodetic Site at GGAO

- Goddard Geophysical and Astronomical Observatory (GGAO) is located 5 km from Goddard Space Flight Center in the middle of the Beltsville Agricultural Research Center. GGAO is one of the few sites in the world to have all four geodetic techniques co-located at a single location.



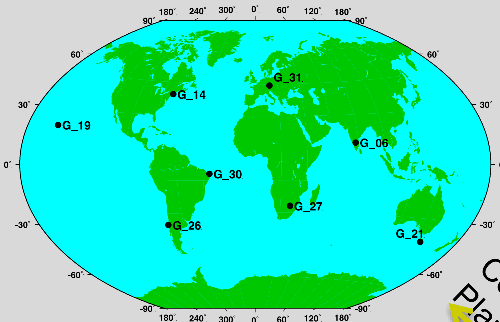


Geodetic Observatory Wettzell

Site Selections: Ideal versus Reality

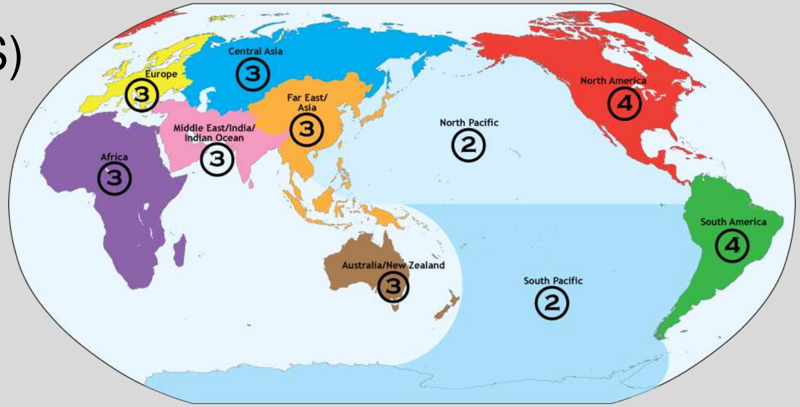
NVI, INC.

Current Co-located Sites (VLBI, SLR, GNSS)



Ideal

4 Stations per Site



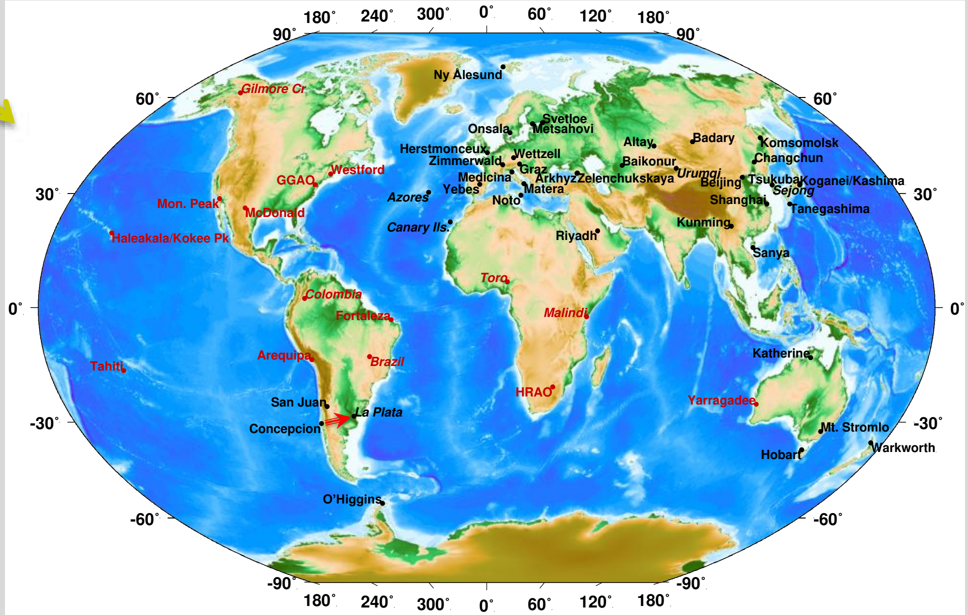
Conceptual Network Distribution

Reality Circle

Agreements, NASA Contributions, International Plans, GGOS Call

- Operational, Technology, Deployment Costs
- Site Assessments
- ITRF Performance Predictions
- Phasing Plan
- Other factors

Iterative Analysis



Current & Proposed Sites under Discussion

GGOS Site Requirements Document

Global Geodetic Observing System (GGOS)

**Site Requirements
for
GGOS Core Sites**

August 1, 2011

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- Introduction and Justification
  - What is a Fundamental Station?
  - Why do we need the Reference Frame?
  - Why do we need a global network?
  - What is the current situation?
  - What do we need?
- Site Conditions
  - Global consideration for the location
  - Geology
  - Site area
  - Weather and sky conditions
  - Radio frequency and optical Interference
  - Horizon conditions
  - Air traffic and aircraft Protection
  - Communications
  - Land ownership
  - Local ground geodetic networks
  - Site Accessibility
  - Local infrastructure and accmmodations
  - Electric power
  - Site security and safety
  - Local commitment

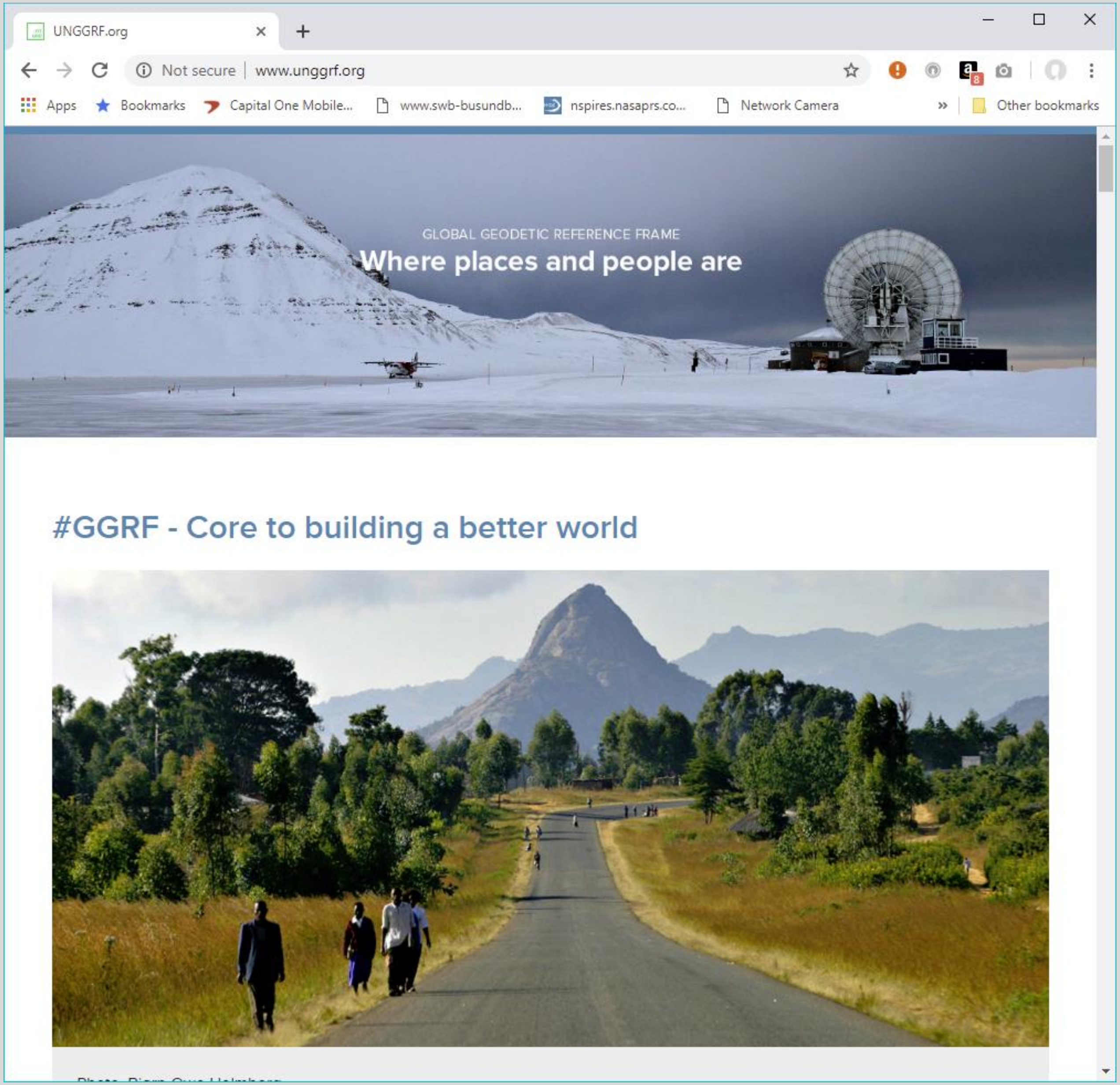
(http://cddis.gsfc.nasa.gov/docs/GGOS_SiteReqDoc.pdf)

UN Adopted 1st Geospatial Resolution

- **Global Geodetic Reference Frame (ITRF and ICRF combination) for Sustainable Development (GGRF) resolution *- No. A/69/L.53 -***
- **adopted by the United Nations General Assembly on 26th of Feb, 2015**
- **co-sponsored by 52 Member States including Japan**
- … first resolution recognizing the importance of a globally coordinated approach to geodesy – the discipline focused on accurately measuring the shape, rotation and gravitational field of planet Earth.
- The General Assembly resolution, *A Global Geodetic Reference Frame for Sustainable Development*, outlines the value of ground-based obserations and remote satellite sensing when tracking changes in populations, ice caps, oceans and the atmosphere over time.

Introduced by Ambassador Peter Thomson, Fiji

Global Geodetic Reference Frame



www.unggrf.org

Inaugural Meeting: Mexico City in 2017

UNGGRF.org

Not secure | www.unggrf.org

Apps | Bookmarks | Capital One Mobile... | www.swb-busundb... | nspires.nasaprs.co... | Network Camera | Other bookmarks

Strengthening the role of geodesy

Mexico City: The inaugural meeting for the United Nations Subcommittee on Geodesy was convened on November 26th and

Summary:VGOS & GGOS

- Challenging program with very important science and societal benefits
- Technologies are maturing; new technologies are on the horizon
- Global distribution is essential; success needs the enhanced networks that will depend on partnerships
- Very large opportunity for participation in analysis and scientific research
- Need to engage young scientists and students

Questions?

Thanks for your attention!

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