Bundesamt für
Kartographie und Geodäsie

GGOS — The *Global Geodetic Observing System* and its Influence on Space Geodetic Infrastructure with focus on VLBI

Torben Schüler

Geodetic Observatory Wettzell
Federal Agency for Cartography and Geodesy

Goals and Contents

- GGOS
  - What is GGOS?
  - Drivers for GGOS
  - GGOS Infrastructure
  - GGOS as Observing System
  - GGOS Network and Geodetic Stations
  - Our Challenge ...
- System of Space Geodesy explained
  - VLBI, SLR, GNSS and their synergetic use
- GGOS Site Requirements with Focus on VLBI
- VLBI2010 and the Wettzell Twin Telescope(s)

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What is GGOS?
Global Geodetic Observing System

http://www.ggos.org/

International Association of Geodesy
Global Geodetic Observing System

HOME | About GGOS | Applications | Activities | News | GGOS Portal

HOME
- Introducing GGOS
- Mission
- Vision
- Objectives
- Products
- GGOS Portal

MEETINGS
- Meeting Calendar
- Past Meetings until 2011
- GGOS Coordinating Board
- GGOS Consortium
- GGOS related events

GGOS archive

EC Member login

SERVICE
- Library
- Links
- Legal & Privacy
- Contact

The Global Geodetic Observing System (GGOS)

GGOS is the Observing System of the **International Association of Geodesy** (IAG).

GGOS works with the IAG components to provide the geodetic infrastructure necessary for monitoring the Earth system and for global change research. It provides observations of the three fundamental geodetic observables and their variations, that is, the Earth's shape, the Earth's gravity field and the Earth's rotational motion.

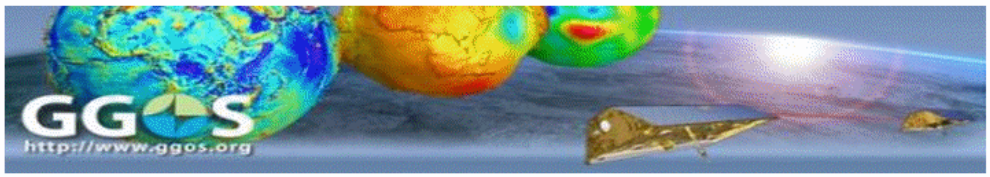
GGOS integrates different geodetic techniques, different models, different approaches in order to ensure a long-term, precise monitoring of the geodetic observables in agreement with the Integrated Global Observing Strategy (IGOS).

GGOS provides the observational basis to maintain a stable, accurate and global reference frame and in this function is crucial for all Earth observation and many practical applications.

GGOS contributes to the emerging Global Earth Observing System of Systems (GEOSS) not only with the accurate reference frame required for many components of GEOSS but also with observations related to the global hydrological cycle, the dynamics of atmosphere and oceans, and natural hazards and disasters.

GGOS acts as the interface between the geodetic services and external users such as the **Group on Earth Observation (GEO)** and United Nations authorities. A major goal is to ensure the interoperability of the services and GEOSS. With this the geodetic community can provide the global geosciences community with a powerful tool consisting mainly of high quality services, standards and references, and of theoretical and observational innovations.

The **GGOS Portal** will provide a unique access point to all geodetic products. Thus, the Portal will emphasize Geodesy´s contribution to Earth Observation for assessing geohazards and reducing disaster. The Portal consists of the GGOS Web site and the portal itself, comprising geoportal components like a clearinghouse, a map viewer, and a metadata editor. The GGOS Portal is currently under development.



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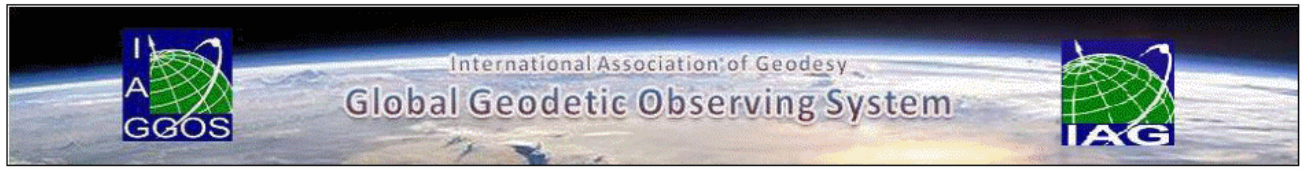

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GGOS [...] provides the **geodetic infrastructure** for
- monitoring the Earth system and for
- global change research.

accurate reference frame required for many components of GEOSS but also with observations related to the global hydrological cycle, the dynamics of atmosphere and oceans, and natural hazards and disasters.

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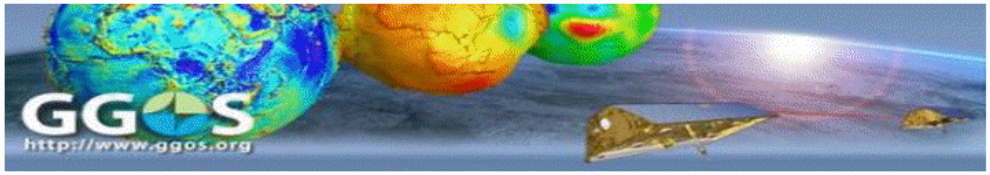

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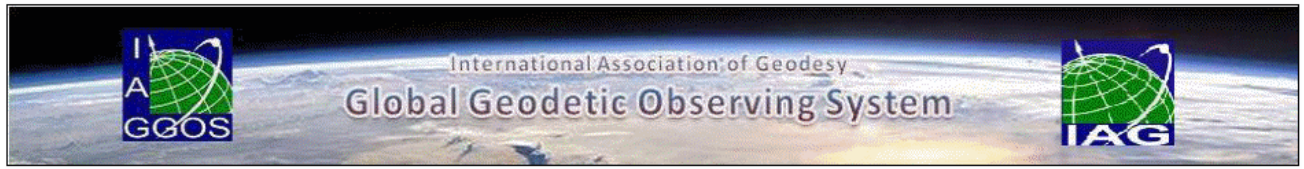

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It provides observations of the 3 fundamental geodetic observables and their variations:
- shape of the Earth ("geometry")
- gravity field of the Earth
- Earth rotation.

innovations.

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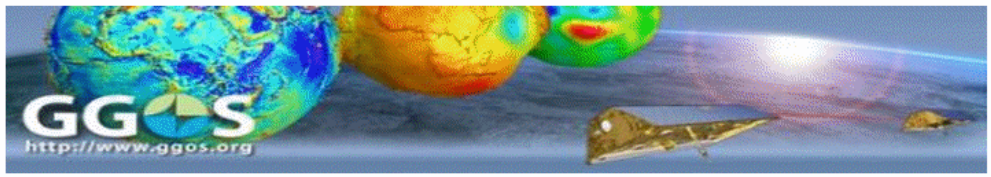

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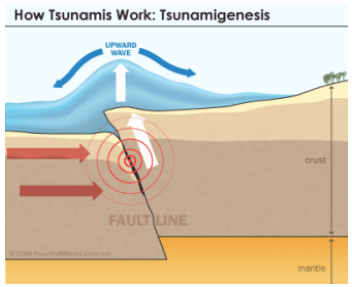
What is GGOS?
Global Geodetic Observing System

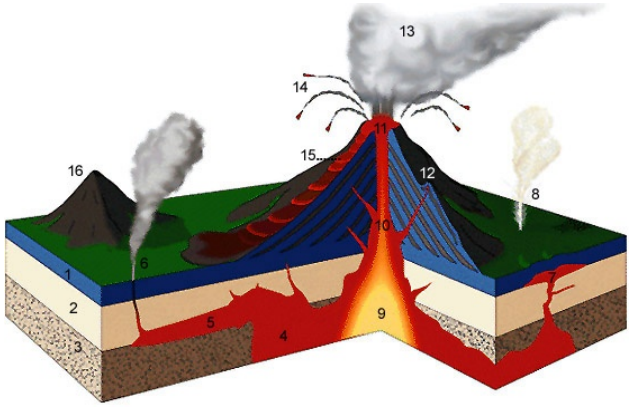
GGOS [... is] to ensure a long-term precise monitoring of the geodetic observables

GGOS Vision:
"Advancing our understanding of the dynamic Earth system by quantifying our planet's changes in space and time."

Drivers for GGOS

- Increasing number of natural hazards and disasters
  - ➔ Early prediction and warning



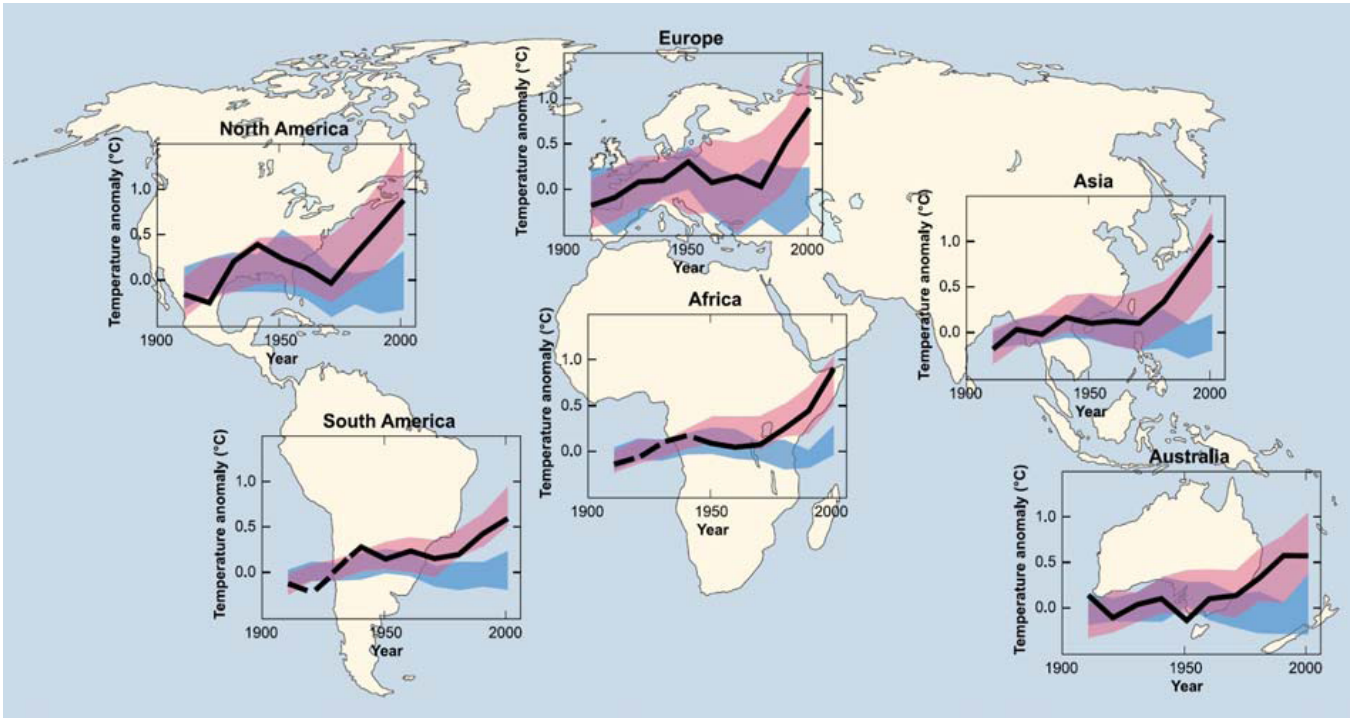


Drivers for GGOS

- Global climate change (monitoring)

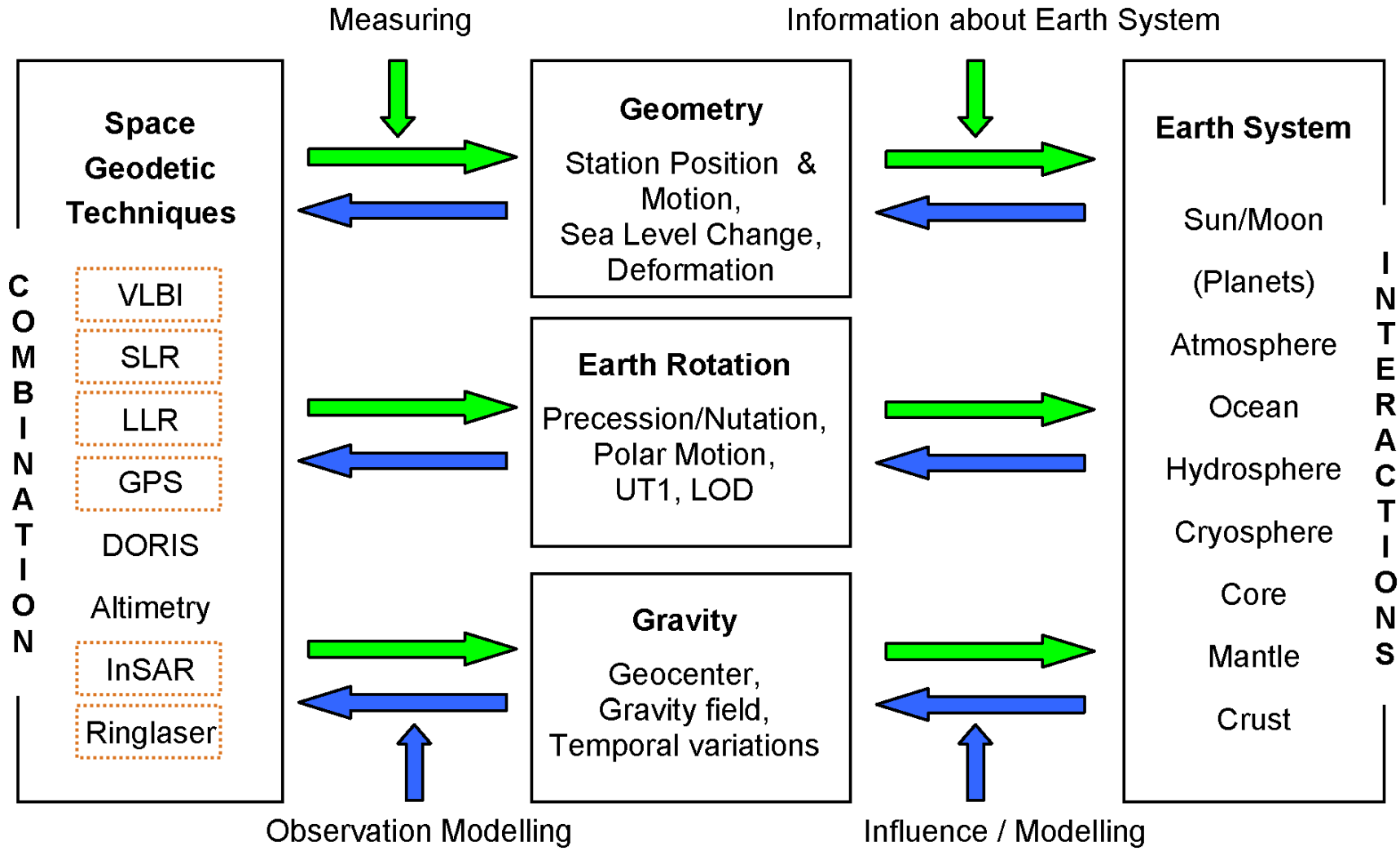
ipcc
INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP



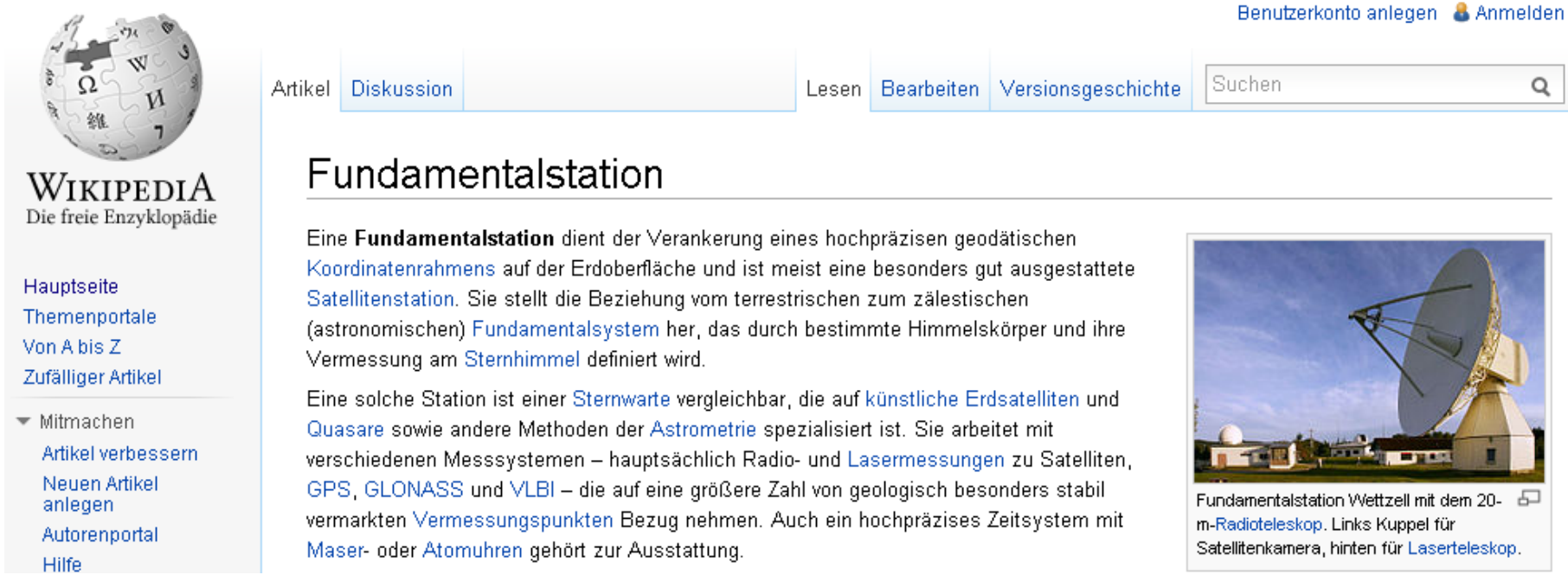
How (in which fields) can Geodesy contribute?

Co-located here at the Geodetic Observatory Wettzell?



GGOS Infrastructure, GGOS Site: Is this really new for Wettzell?

Basically not, because GO Wettzell is designed to fulfull the role of a ***Fundamental Station for Geodesy*** by co-location of all important space geodetic techniques at one site.



Benutzerkonto anlegen Anmelden

WIKIPEDIA
Die freie Enzyklopädie

Artikel | Diskussion | Lesen | Bearbeiten | Versionsgeschichte | Suchen

Hauptseite
Themenportale
Von A bis Z
Zufälliger Artikel
Mitmachen
Artikel verbessern
Neuen Artikel anlegen
Autorenportal
Hilfe

Fundamentalstation

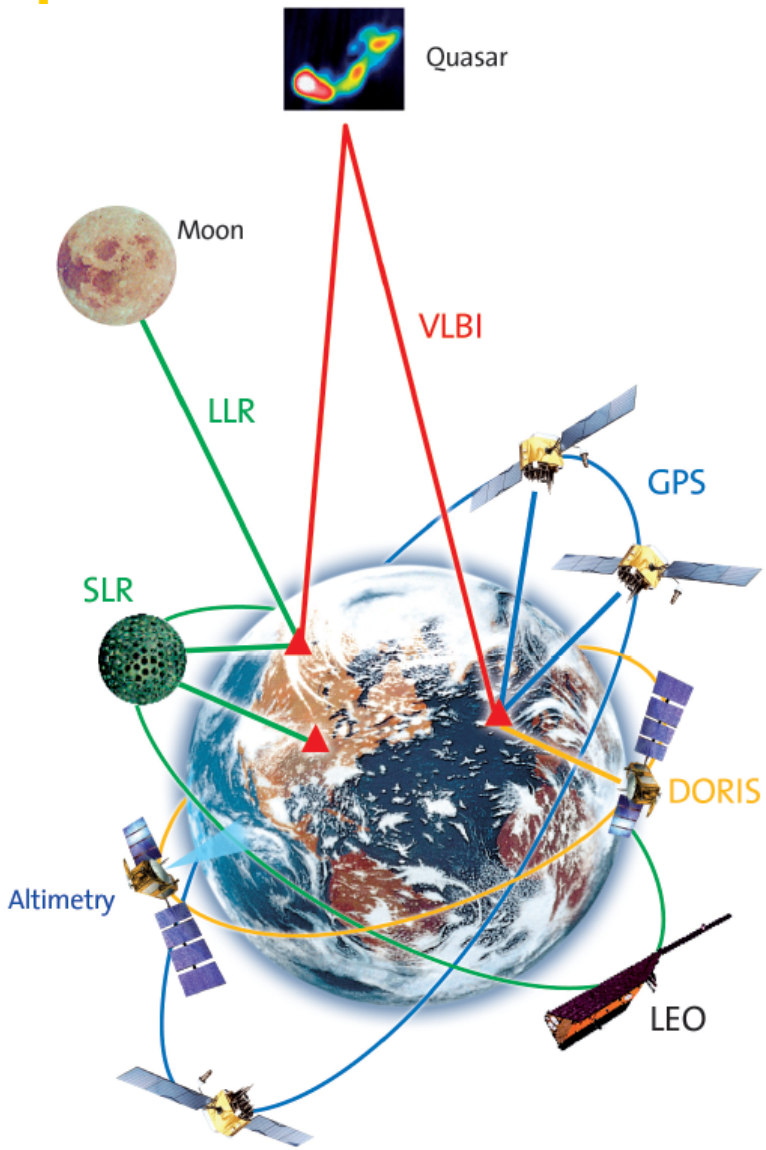
Eine **Fundamentalstation** dient der Verankerung eines hochpräzisen geodätischen Koordinatenrahmens auf der Erdoberfläche und ist meist eine besonders gut ausgestattete Satellitenstation. Sie stellt die Beziehung vom terrestrischen zum zälestischen (astronomischen) Fundamentalsystem her, das durch bestimmte Himmelskörper und ihre Vermessung am Sternhimmel definiert wird.

Eine solche Station ist einer Sternwarte vergleichbar, die auf künstliche Erdsatelliten und Quasare sowie andere Methoden der Astrometrie spezialisiert ist. Sie arbeitet mit verschiedenen Messsystemen – hauptsächlich Radio- und Lasermessungen zu Satelliten, GPS, GLONASS und VLBI – die auf eine größere Zahl von geologisch besonders stabil vermarkten Vermessungspunkten Bezug nehmen. Auch ein hochpräzises Zeitsystem mit Maser- oder Atomuhren gehört zur Ausstattung.

Fundamentalstation Wettzell mit dem 20-m-Radioteleskop. Links Kuppel für Satellitenkamera, hinten für Laserteleskop.

... but the GGOS initiative is a good opportunity for us to motivate our promoters in order to provide the funding necessary to renew our equipment.

What does GGOS Infrastructure mean? How is it composed of?



5 Layers of GGOS Observing Infrastructure

Level 1: Ground stations and terrestrial measurements

Level 2: Low Earth Orbiting Satellites (LEO)

Level 3: Medium and Geostationary Earth Orbiting Satellites (MEO/GEO)

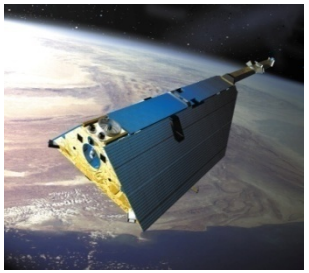
Level 4: Moon and planets

Level 5: Quasare

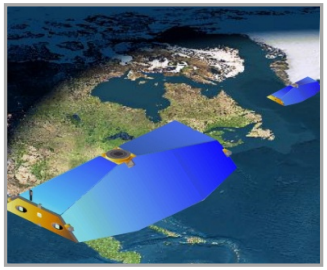
From: Plag et al. (2009)

GGOS as Observing System: Satellite Missions for Earth Physics

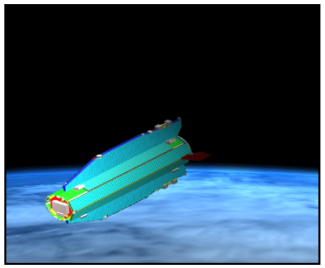
GRAVITY FIELD



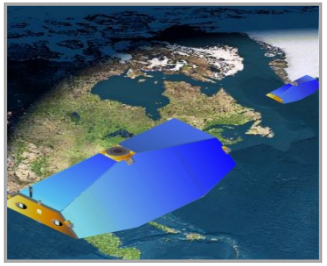
CHAMP



GRACE



GOCE

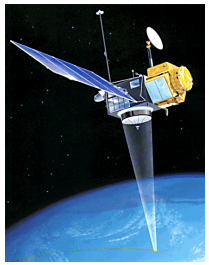


GRACE Follow-on
(from 2017)

…

GGOS as Observing System: Satellite Missions for Earth Physics

O C E A N A L T I M E T R Y



Topex/Poseidon

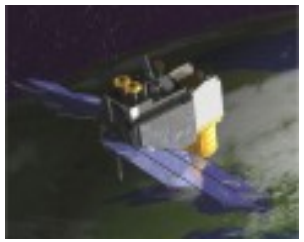
JASON-1

JASON-2

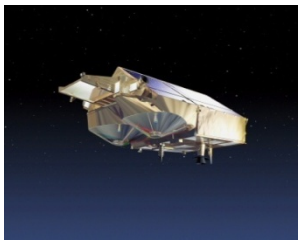
…

... and a number of others ...

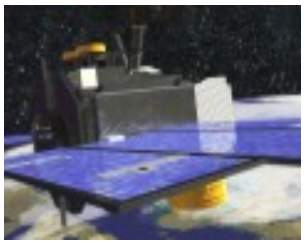
I C E A L T I M E T R Y



IceSat-1



Cryosat-2

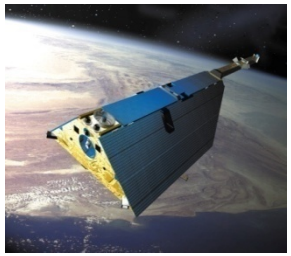


IceSat-2

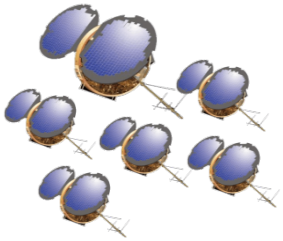
…

GGOS as Observing System: Satellite Missions for Earth Physics

A T M O S P H E R E



CHAMP



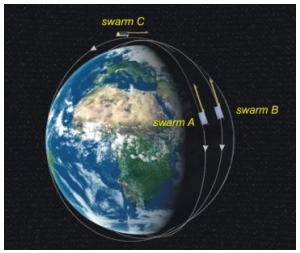
COSMIC

MetOp

…

M A G N E T O S P H E R E

CHAMP

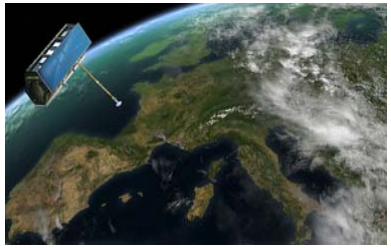


SWARM

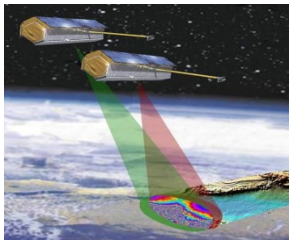
…

GGOS as Observing System: Satellite Missions for Earth Physics

E A R T H S U R F A C E



TerraSAR-X



TanDEM-X

…

+ new mission concepts, satellite constellation, micro satellites, etc. under consideration.

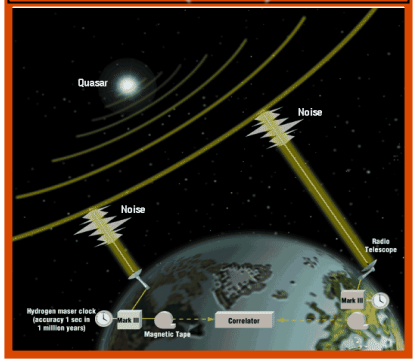
GGOS as Observing System: Geometry = ITRS/ITRF & ICRS/ICRF

International Terrestrial Reference Frame (ITRF)

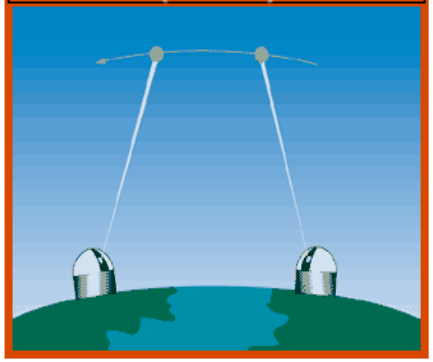
International Earth Rotation Service (IERS)

Quasar positions, precise GPS orbits und clocks, Earth rotation parameters, station coordinates

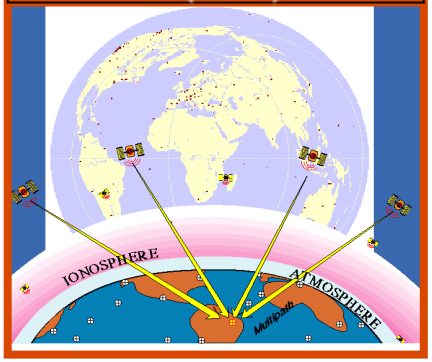
Very Long Baseline Interferometry (IVS)



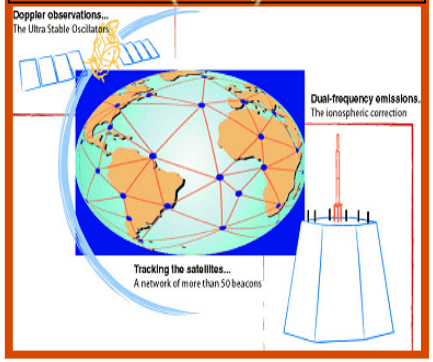
Satellite Laser Ranging (ILRS)



Global Navigation Satellite Systems (IGS)

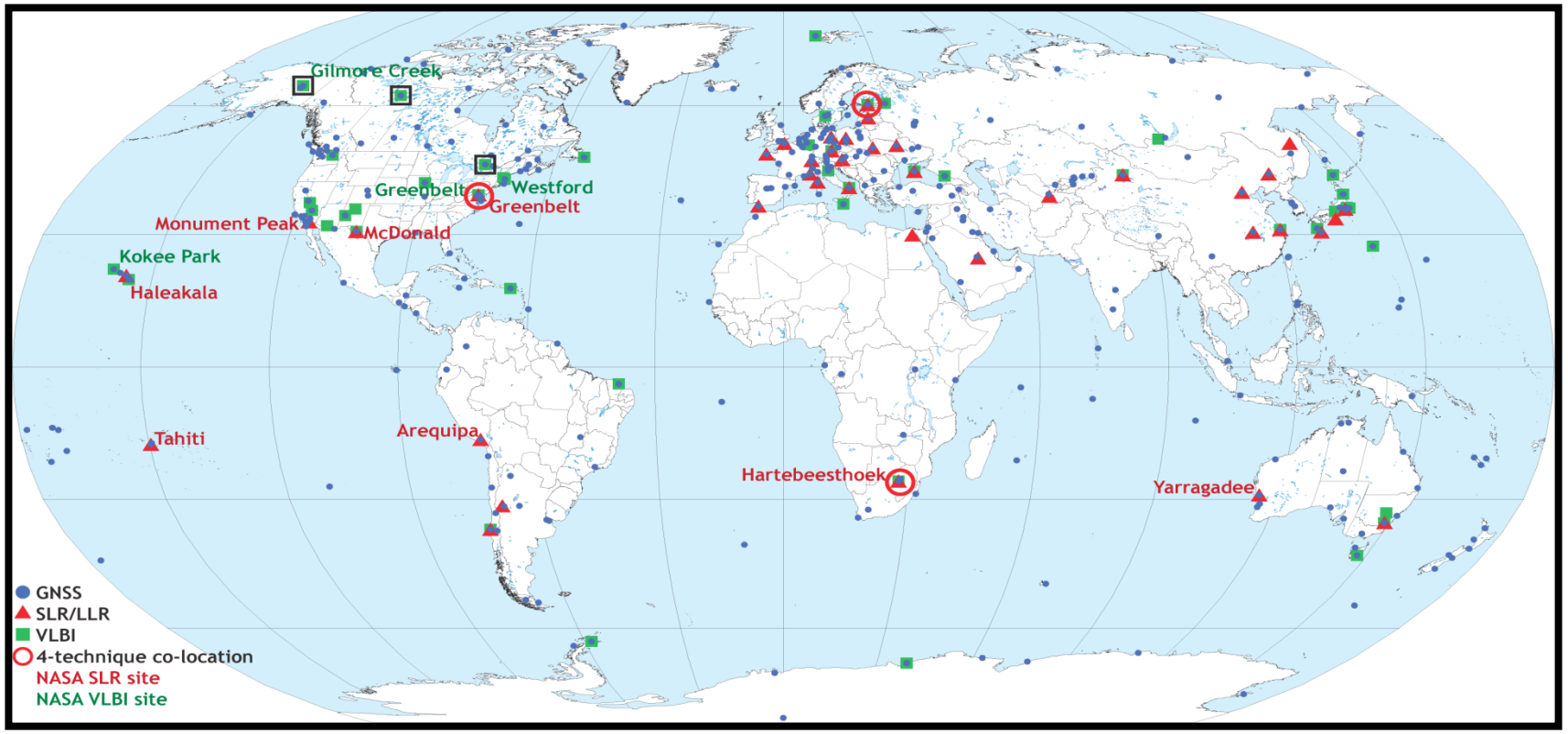


Doppler Orbit Determination and Radiopositioning Integrated on Satellite (IDS)



Global Network of Geodetic Stations
— Current Network —

Current global network of geodetic observatories and stations:



Source: NASA

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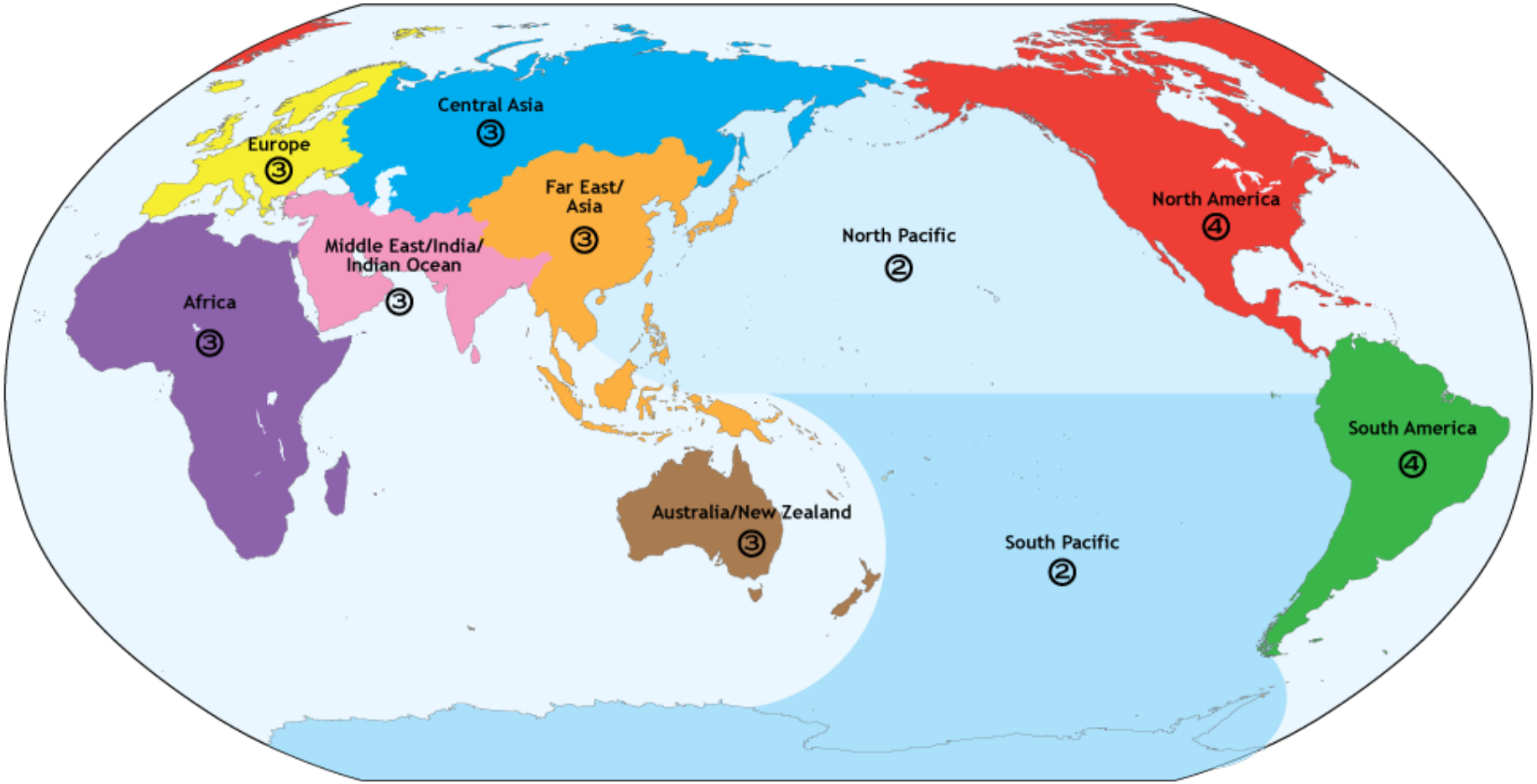
Global Network of Geodetic Stations
Future GGOS Core Sites (Distribution)



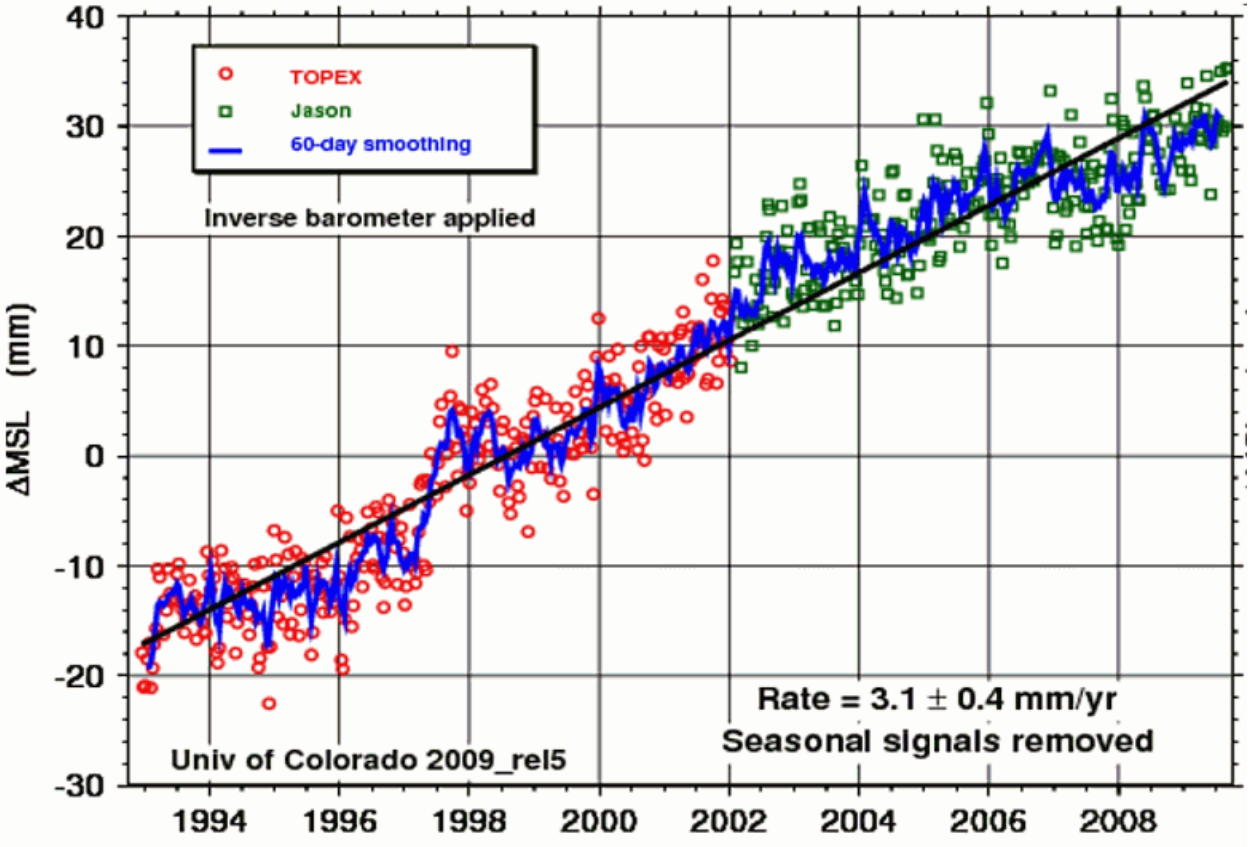
- GGOS target network design
  - 30 globally distributed, multi-technique co-located ground stations
  - 4 techniques/site

GGOS Member States with Core site activities:

United States	Germany	China
Korea	Australia	Russia
New Zealand	India	Saudi Arabia
South Africa	Spain	

Our Challenge Illustrated by a Prominent Example: *Sea Level Rise Monitoring*

Global mean sea level rise observed via satellite altimetry:



- Ocean altimetry satellites usually use GPS, DORIS and SLR for precise orbit determination
- Ellipsoidal height of satellite is derived
- Height difference to sea level is measured by radar altimeter
- Stable coordinate system is required

GGOS as an Observing System: *Technical Goals*

- Global accuracy of terrestrial reference frame:
  - accurate and accessible @ **1 mm** - level
    current state: around **1 cm (position)**
  - stability of **0.1 mm/a (velocity)**

  in ITRF (International Terrestrial Reference Frame)
- Continuous measurements (time series of Earth rotation parameters, station positions and baselines)
- Measurements in near real-time
- High reliability and redundancy
- Low construction and operating costs regarding the geodetic equipment

GGOS as an Observing System:
How to reach these goals ...

- Reduction of random and systematic errors of delay observables.
- Improvement of geographic distribution of antennas.

  [Notice: Wettzell is GGOS Legacy Site]
- Increase number of observations ...
- Development of new observing strategies.

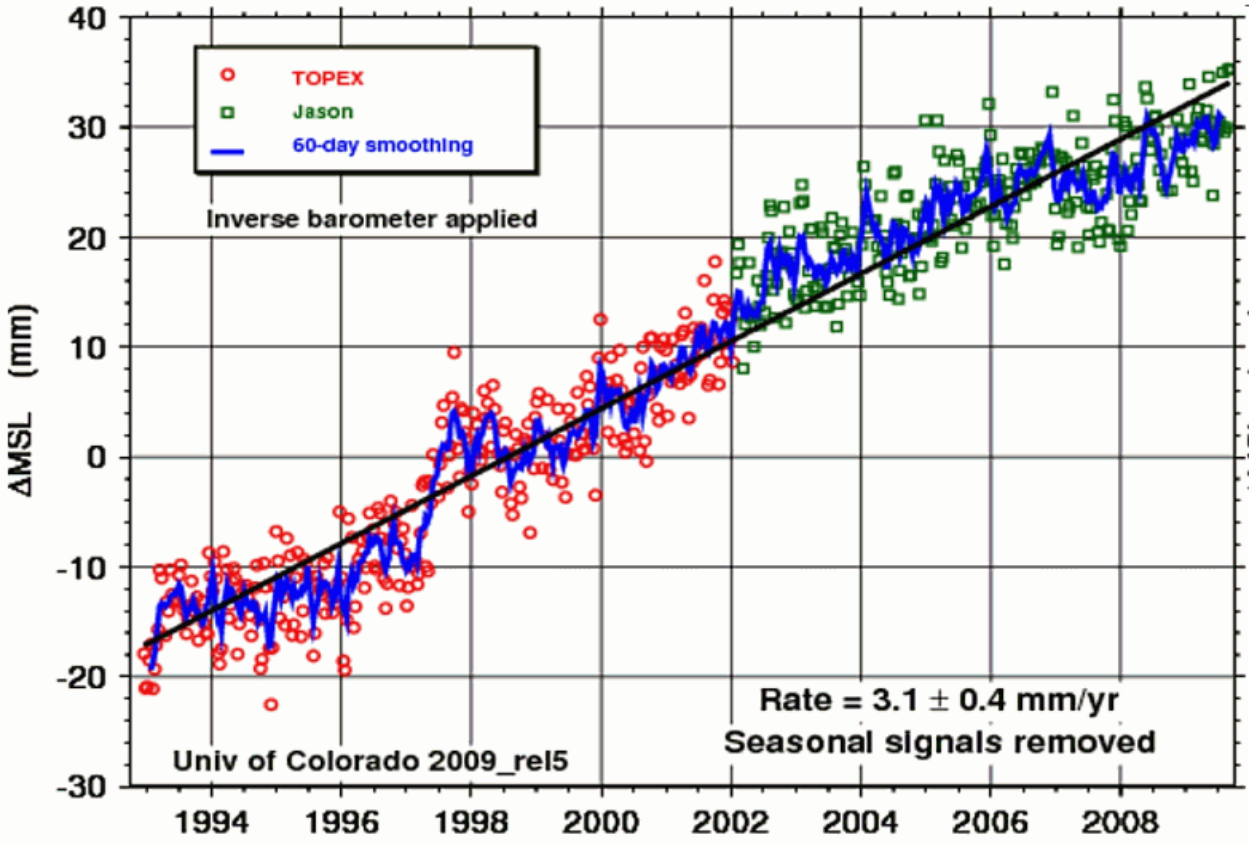
Our Challenge Illustrated by a Prominent Example: *Sea Level Rise Monitoring*

Uncertainty in the ITRF is the *largest source of error* in the global characterization of long-term sea level variation!

Error of 2 mm/a in relative velocity between Earth's mean surface and Earth's mass center results into
➢ **0.4 mm/a** of error in global mean sea level variation

Scale rate error of 0.1 ppb/a causes
➢ **0.6 mm/a** of apparent sea level change

see Velicogna, 2009



Compare with: Mass loss from Greenland ice sheet is approx. 200 Gt/a on average) which causes ➢ **0.7 mm/a** of sea level rise
Increase of mass loss is expected to be around an additional 30 Gt/a resulting into ➢ **0.1 mm/a** of sea level rise.

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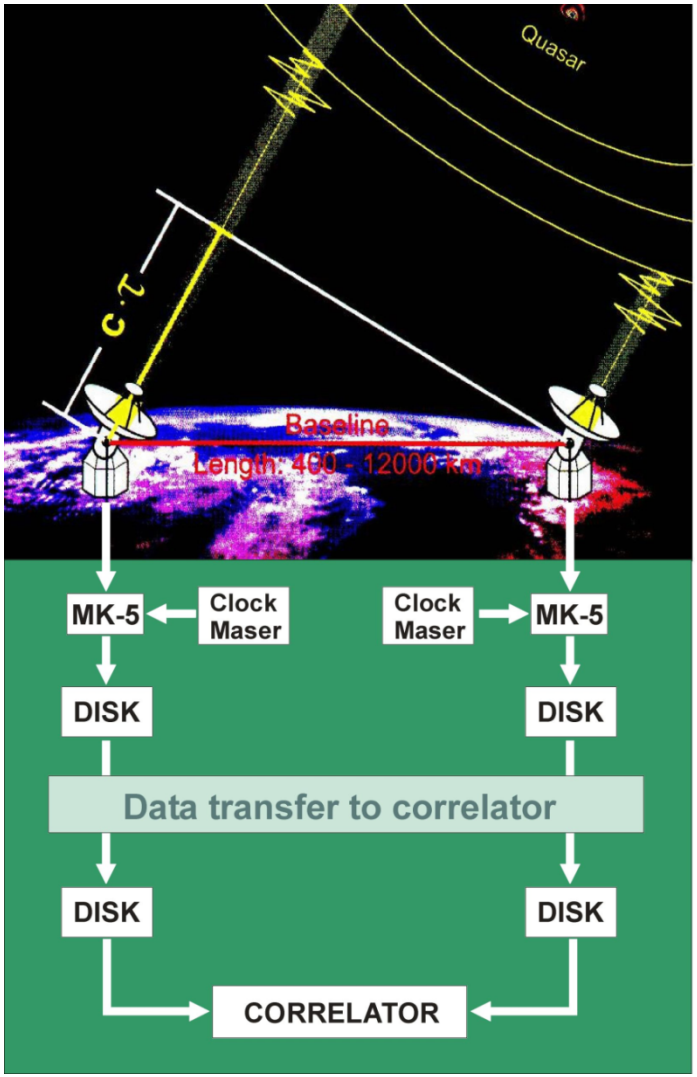
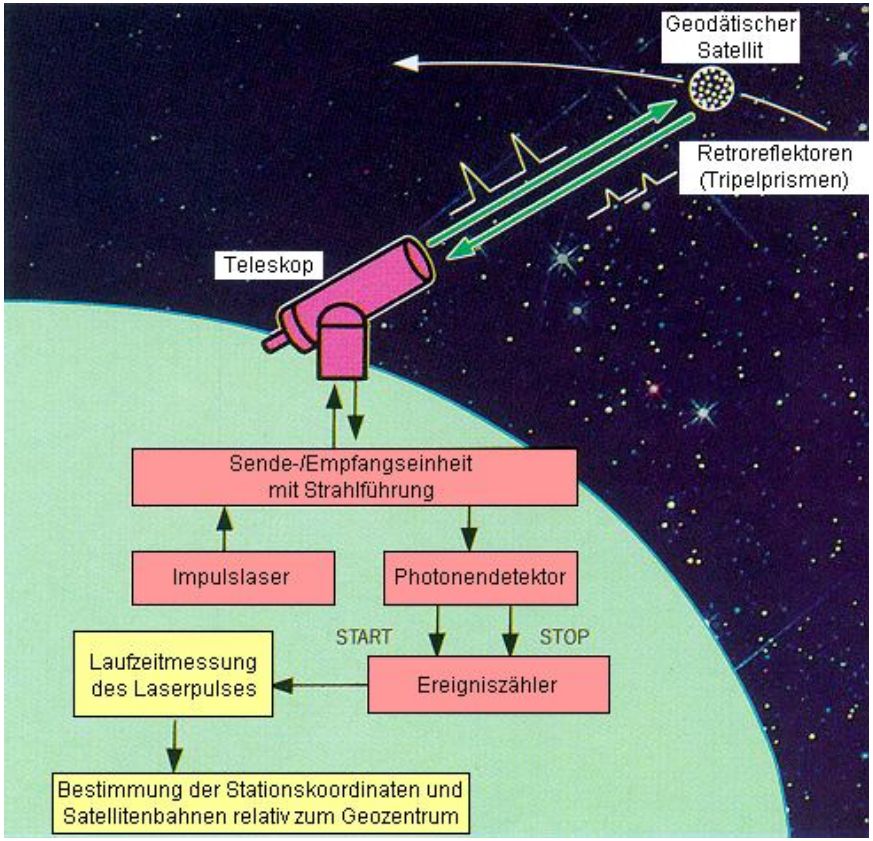
The Main Techniques of Space Geodesy: *Very Long Baseline Interferometry (VLBI)*



Principle:

- Well-known to the audience ...
- Geodetic VLBI telescopes are usually of relatively small aperture, because focus lies on mechanical stability (and speed)

The Main Techniques of Space Geodesy: *Satellite Laser Ranging (SLR)*

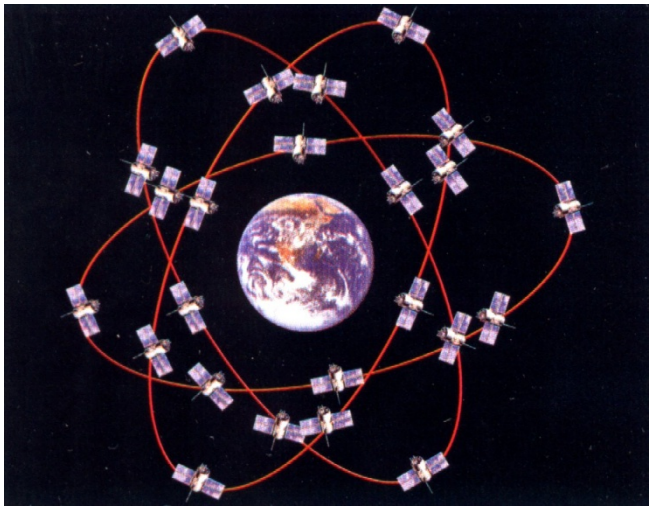


Principle:

- Generation of short but powerful laser pulses
- High-precision timer start upon departure of photons from the telescope
- Reflexion of laser pulse @ retro reflector(s) of the satellite
- Timer stops upon arrival of pulse at the telescope
- Determination of distance:

$$d = \Delta t/2 \bullet c$$

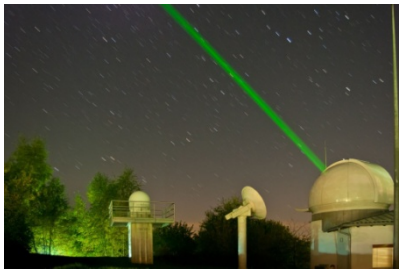
The Main Techniques of Space Geodesy: *Global Navigation Satellite Systems (GNSS)*



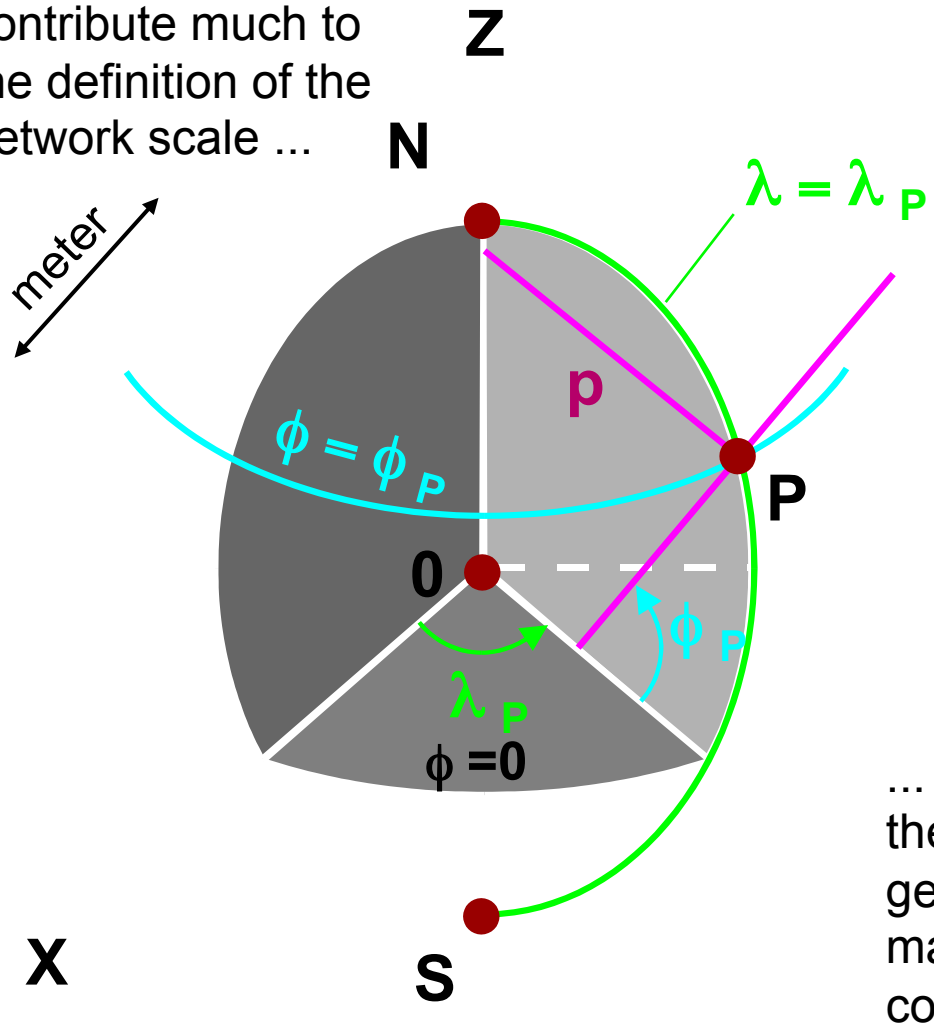
Principle:

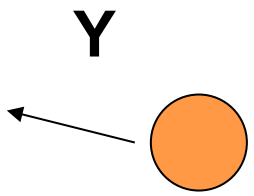
- Correlation of received navigation code signal modulated on 1.5 and 1.2 GHz carrier wave with code replica
- Determination of travel time, conversion into (pseudo-)range measurements
- Geodetic use: carrier phase tracking is of high importance, because of low noise level (precision of around 2 mm)
- USA: GPS; Russia: GLONASS; China: BeiDou; Europe: Galileo

The Main Techniques of Space Geodesy:
What do we need these for?



Satellite laser ranging contribute much to the definition of the network scale ...





... and is important for the determination of the geocenter = center of mass = origin of the coordinate system

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The Main Techniques of Space Geodesy:
What do we need these for?

	Parameter Typ	VLBI	GPS/ GLON.	DORIS/ PRARE	SLR	LLR	Alti- metrie	
	Quasar Koord. (ICRF)	X						
	Nutation	X	(X)		(X)	X		Erdrotation
pole position	Polschwankung	X	X	X	X	X		
	UT1	X						
	Tageslänge (LOD)		X	X	X	X		
sub-daily	Subtägliche ERPs	X	X					
ERP ocean tide amplitudes	ERP Ozeangezeiten-Amplituden	X	X		X		X	
xyz + velocities	Koord.+Geschw.(ITRF)	X	X	X	X	X	(X)	
geocenter = origin	Geozentrum		(X)	(X)	X		X	
gravity center	Gravitationsfeld		X	X	X	(X)	X	
satellite orbits	Bahnen		X	X	X	X	X	
	LEO-Bahnen		X	X	X		X	
	Ionosphäre	X	X	X			X	
	Troposphäre	X	X	X			X	
time/frequency transfer	Zeit/Freq. Transfer	(X)	X		(X)			

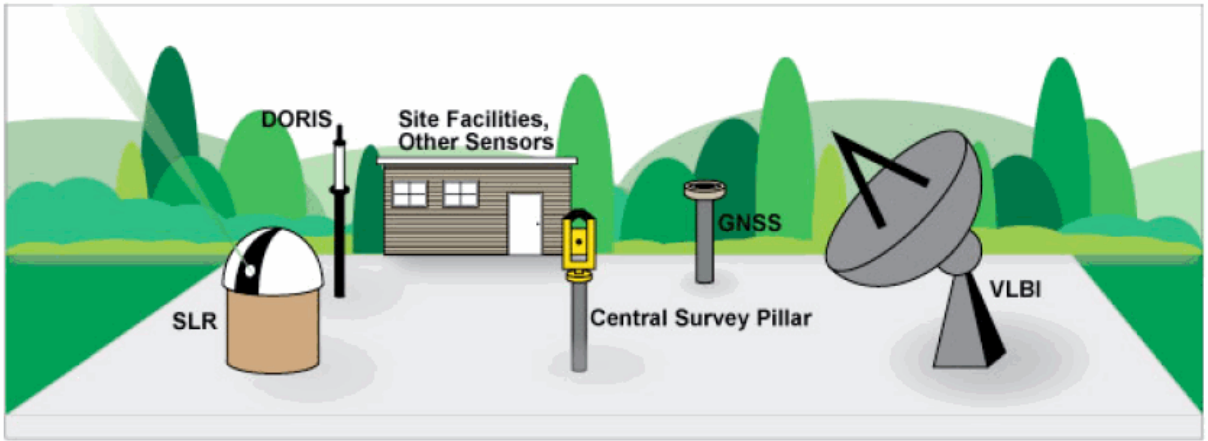
Goals and Contents

- GGOS
  - What is GGOS?
  - Drivers for GGOS
  - GGOS Infrastructure
  - GGOS as Observing System
  - GGOS Network and Geodetic Stations
  - Our Challenge ...
- System of Space Geodesy explained
  - VLBI, SLR, GNSS and their synergetic use
- GGOS Site Requirements with Focus on VLBI
- VLBI2010 and the Wettzell Twin Telescope(s)

GGOS Core Site:
Which requirements are to be met?

Global Geodetic Observing System (GGOS)

Site Requirements
for
GGOS Core Sites
(Revision 1a)



July 18, 2012

GGOS Core Site:
Frequencies Occupied

System	Broadcast		Receive	
	Frequency		Frequency	
SLR radar	9.4 GHz	Highly Directional 4 kW peak	NA	NA
VLBI			2 – 14 GHz	Highly Directional
GPS			1227.6 MHz (L1) 1575.4 MHz (L2) 1176.45 MHz (L5)	Hemispherical (sensitive down to the horizon)
Galileo			1.1 – 1.6 GHz	
GLONASS			1.1 – 1.6 GHz	
BeiDou COMPASS			1.1 – 1.6 GHz	
DORIS	401.25 MHz 2.036 GHz	Omni-Directional	NA	NA

new

potentially science fiction

GGOS Core Site:
Communication Requirements

System	Data Volume
SLR	10 GBytes/day
VLBI (legacy)	?
eVLBI	4 Gb/sec
GNSS*	130 Mbytes/day
DORIS	General communications
Control and Monitoring	?

Note: *baseline - raw 1s data with current satellites and constellations

Note:

Wettzell is currently equipped with a 2 GB internet connection (upload) which is basically sufficient for RTW's current operations.

However, with the additional two TWIN telescopes a multiple of this bandwidth will be needed (>10 Gbit/s).

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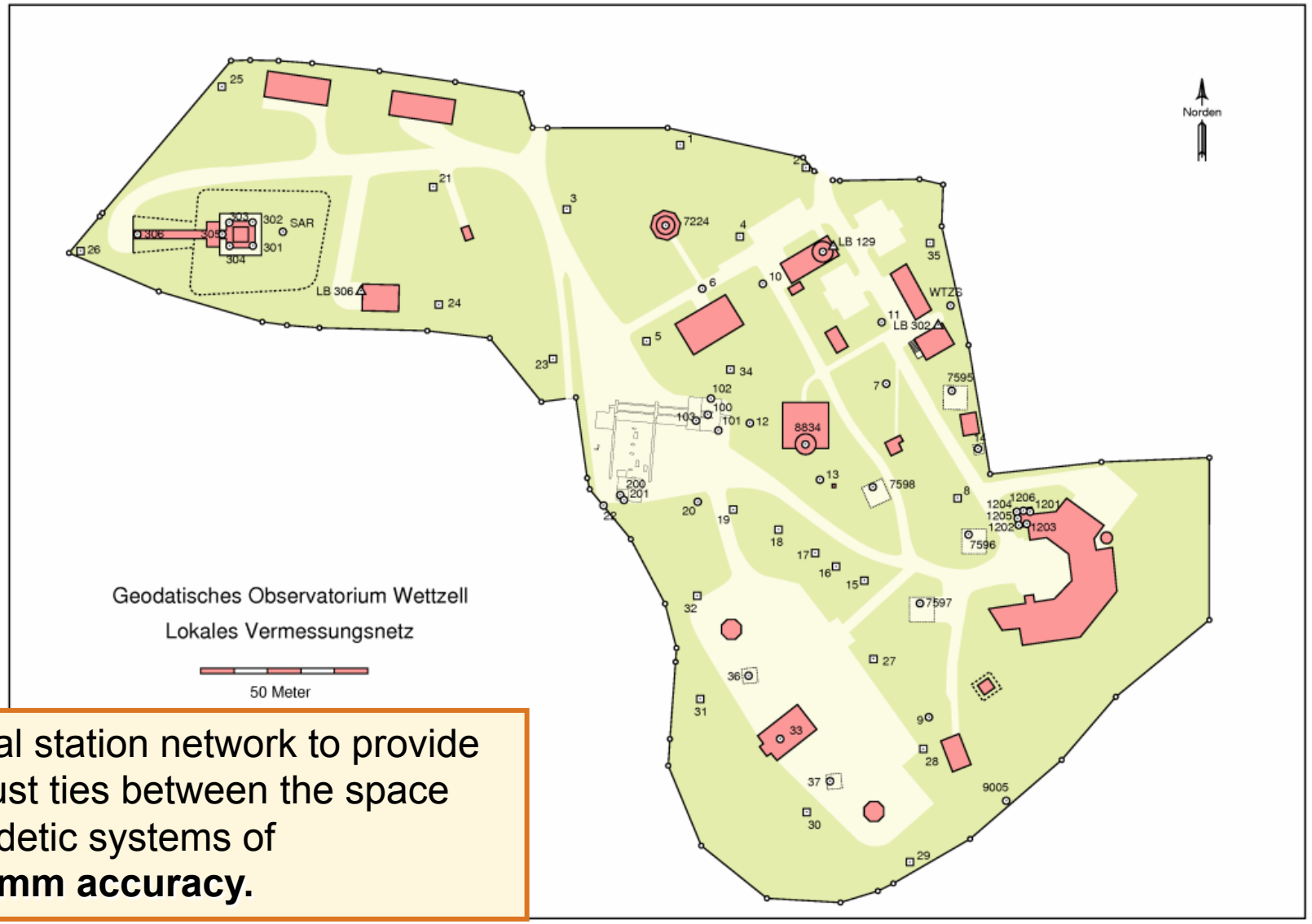
GGOS Core Site:
Requirements for Local Ties



Local station network to provide robust ties between the space geodetic systems of
< 1 mm accuracy.

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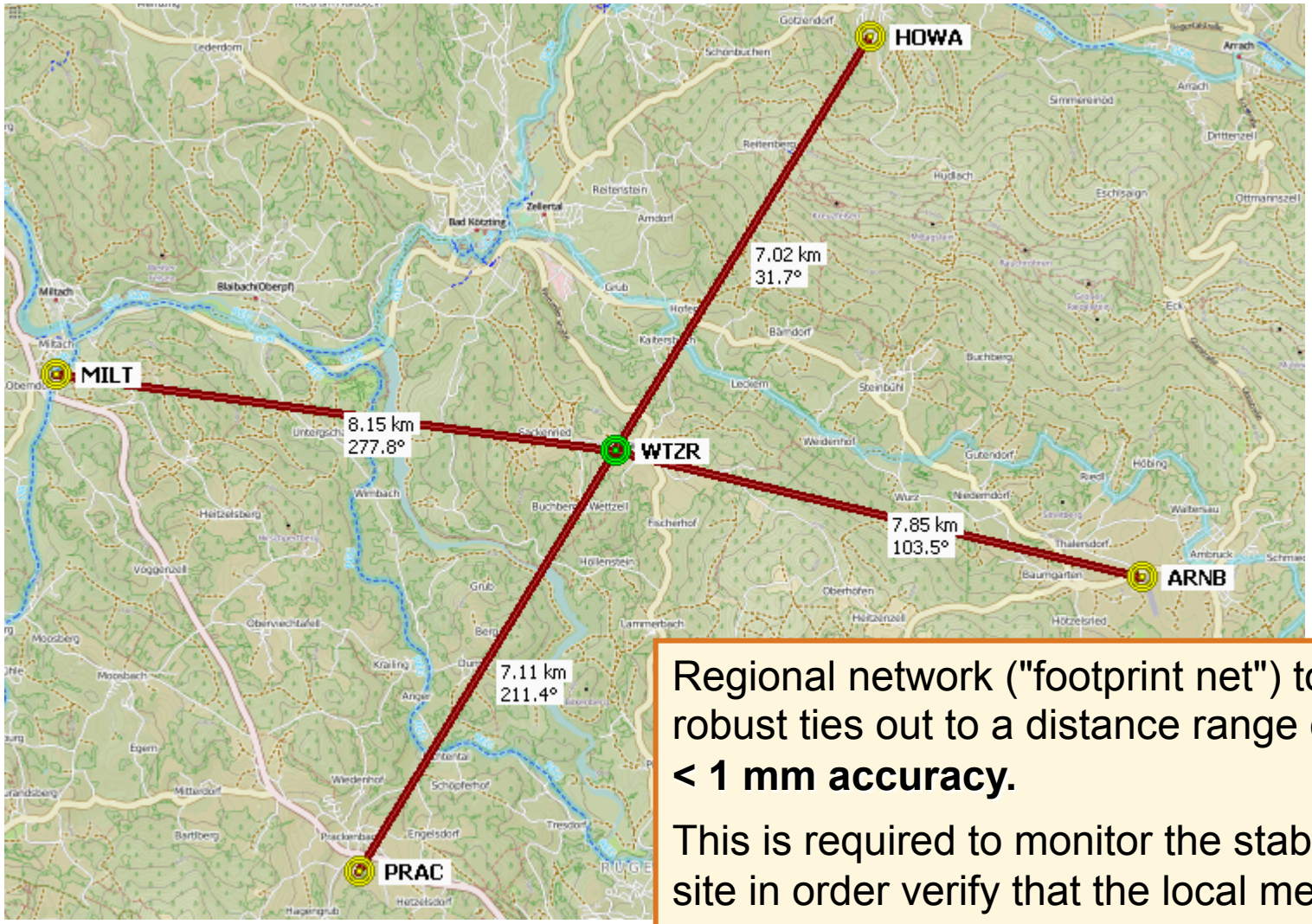
GGOS Core Site:
Requirements for Footprint Network



Regional network ("footprint net") to provide robust ties out to a distance range of 10-30 km **< 1 mm accuracy.**

This is required to monitor the stability of the site in order verify that the local measurements are regionally representative.

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GGOS Core Site:
Requirements from VLBI2010

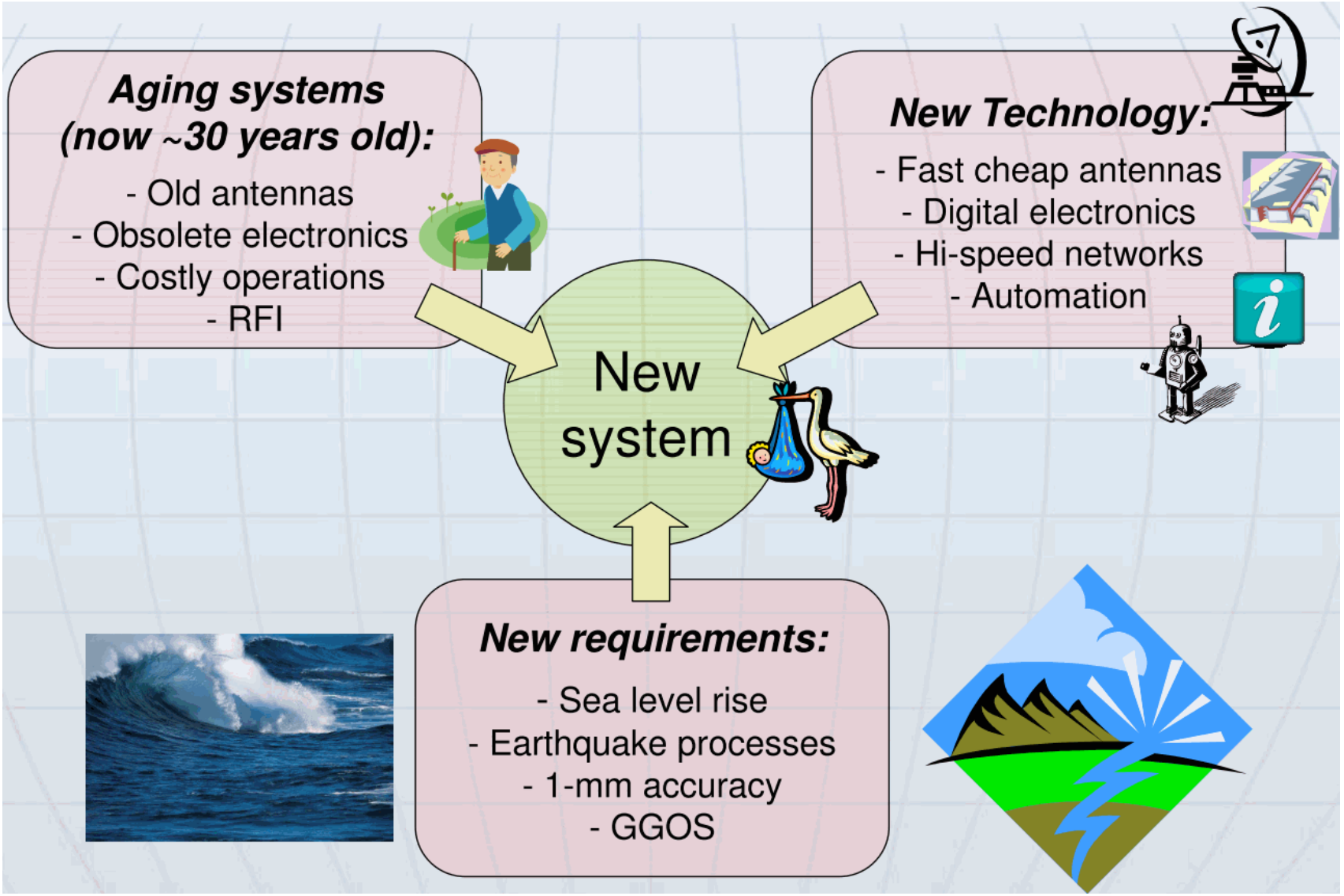
IVS Memorandum 2006-008v01

16 September 2004

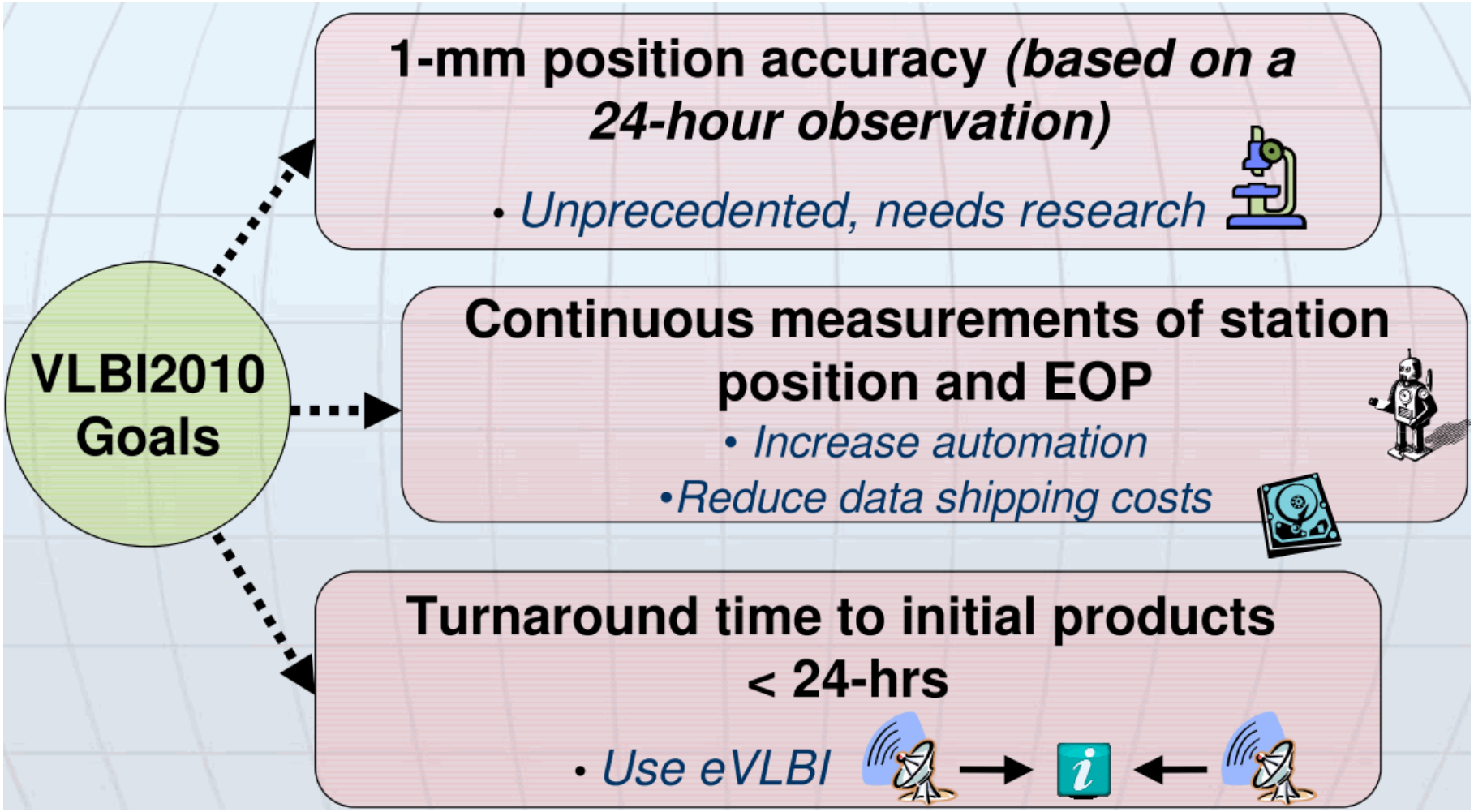
"VLBI2010: Current and Future Requirements for Geodetic VLBI Systems"

Arthur Niell, Alan Whitney, Bill Petrachenko, Wolfgang Schlüter, Nancy Vandenberg, Hayo Hase, Yasuhiro Koyama, Chopo Ma, Harald Schuh, Gino Tuccari

GGOS & VLBI2010:
Why is there a need for renewal?



VLBI 2010:
Main Goals and How-To



from: B. Petrachenko, IVS TecSpec Worksop, 1-2 March 2012, Wettzell

GGOS Core Site:
Basic VLBI Requirements

Core Site Description

The GGOS Core Site should have the following systems in place:

- VLBI

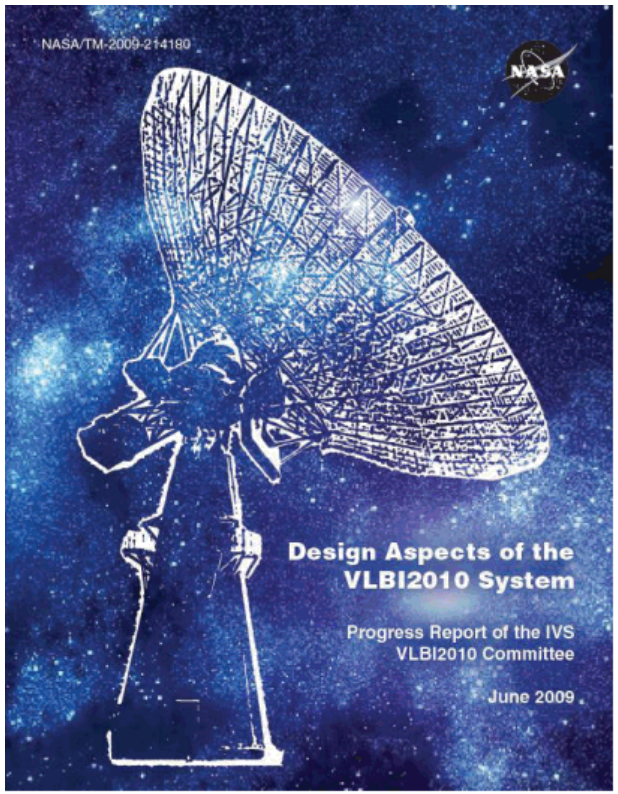
  The VLBI systems should be compatible with VLBI 2010 with the minimum following performance characteristics:

  - Antenna with azimuth slew rate >= 5 deg/sec and elevation slew rate >= 1.5 deg/sec; more advanced systems with slew rates of 12 deg/sec in azimuth and 5 deg/sec in elevation will add greater capability to the network and enhance data products;
  - Antenna SEFD <2500 J from 2 - 14 GHz;
  - Flexible placement of multiple 1 GHz bands from 2 - 14 GHz;
  - Recording rate up to 4 Gbps for each band;
  - Hydrogen maser frequency standard;
  - Remote monitor and control capability;
  - Broadband internet connection;
  - Modeling or monitoring of signal path length variation< 1mm;
  - Continuous operation capability.

  For more details see: http://www.haystack.mit.edu/geo/vlbi_td/2010/index.html

- Satellite Laser Ranging […]

VLBI2010:
Synopsis "OLD" versus "NEW"

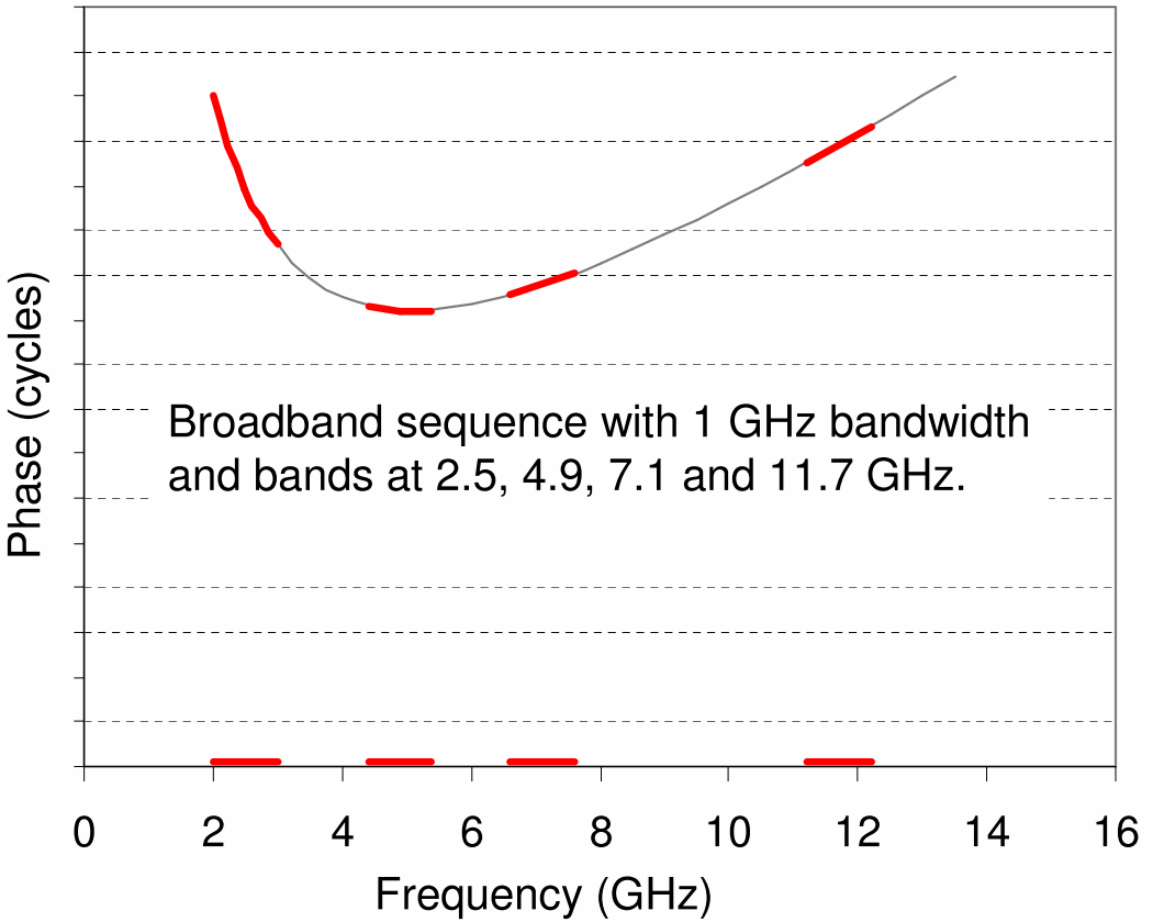


	Current	VLBI2010
antenna size	5–100 m dish	~ 12 m dish
slew speed	~20–200 deg/min	≥ 360 deg/min
sensitivity	200–15,000 SEFD	≤ 2,500 SEFD
frequency range	S/X band	~2–14 (18) GHz
recording rate	128, 256 Mbps	8–16 Gbps
data transfer	usually ship disks, some e-transfer	e-transfer, e-VLBI, ship disks when required

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

other aspects include: software correlation
automation of data analysis

VLBI2010 Wideband Feed:
Broadband Sequence



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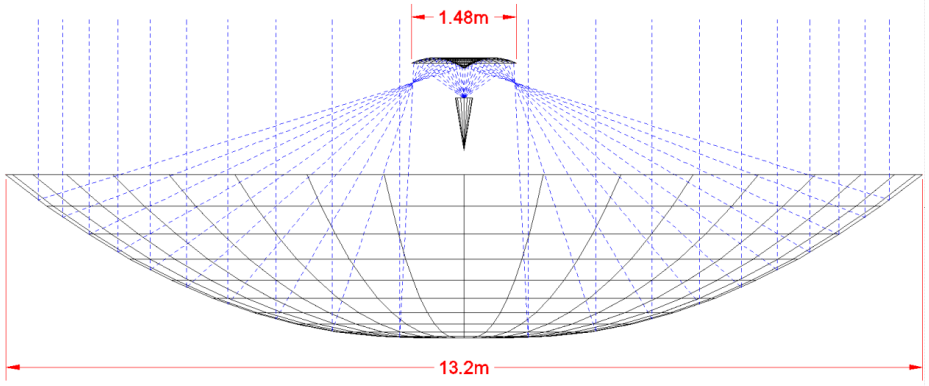
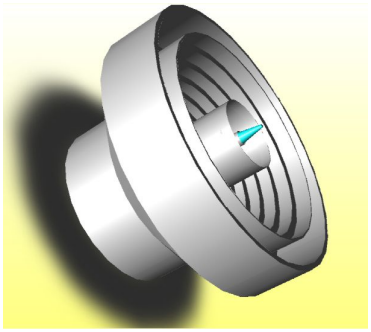
GGOS Core Site:
TWIN Telescopes - Basic Facts

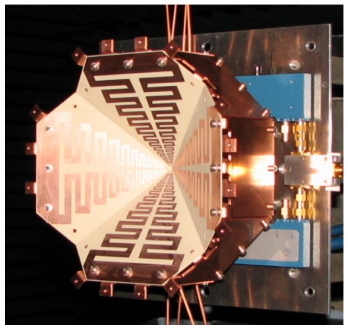
- 2 identical (mechanical) radio telescopes
- Main reflecotr: 13.2 m aperture
- Surface finish: <0.2 mm RMS
- ALMA mounting
- Sub-reflector with hexapod-mounting and ring focus optics
- Triband feed (TTW1, S/X/Ka) and broadband feed (TTW2, 2-14 GHz)
- Antenna speed: az. 12°/s, elevation 6°/s
- 27 bit encoder (0.01 arc sec)



Ringfokus-Optik



Triband-Feed
(S-, X-, Ka-Band)



‚Eleven '-Feed
(2 ... 11 GHz)

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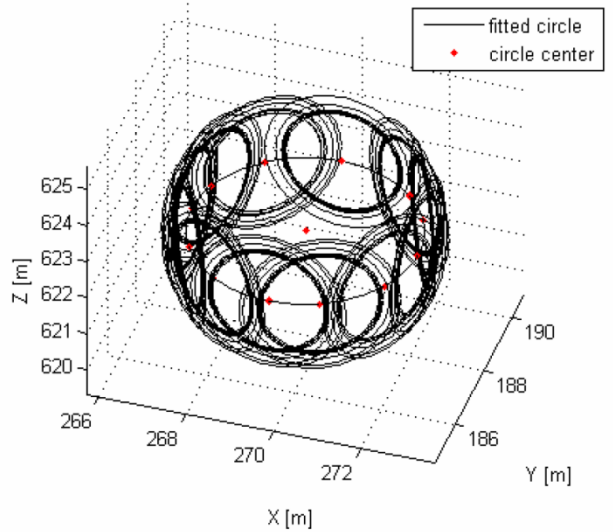
VLBI Telescope Reference Point:
Monitoring results for the "old" RTW

RTW (Lösler, 2008)

Tachymeter data:

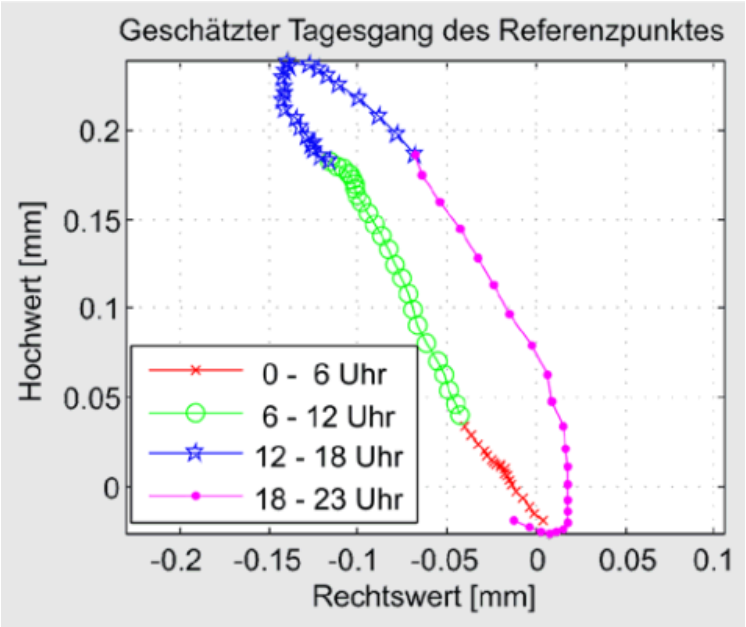
Method	East	North	Up
2D adjustment + height (NetzCG)	269.71713	187.69011	622.46484
3D adjustment (JAG3D)	269.71715	187.69011	622.46482
circle adjustment	269.71720	187.69008	622.46502
max. difference	**0.07 mm**	**0.03 mm**	**0.2 mm**



Laser tracker data:

Method	East	North	Up
3D adjustment (JAG3D)	269.71739	187.69056	622.46506
Difference to Tachymeter data	**0.24 mm**	**0.45 mm**	**0.24 mm**

VLBI Telescope Reference Point: *Concluding remarks*



- VLBI2010 and GGOS requirements for local ties are pointing towards an uncertainty well better than 1 mm.
- **Diurnal** and
- **seasonal** variations are to be investigated.
- VLBI2010 is recommending to monitor local ties to VLBI telescopes in a permanent fashion; such investigations are currently performed.