GGOS 2020

The Global Geodetic Observing System: Meeting the Requirements of a Global Society on a Changing Planet in 2020

Chapter 9: “The Future GGOS”

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Table of Contents

Remarks for a Common Understand

GGOS has two very different meanings, that should not be confused:

- **$GGOS_1$:** the actual infrastructure, the actual observing system, consisting of many different instrument types, satellite missions etc. and the
- **$GGOS_2$:** the organization GGOS consisting of components like Steering Committee, WGs, etc.

Chapter 9 talks about the first (**$GGOS_1$**), the actual observing system, i.e., an integration of observation technologies and operational processing chains into one system.The individual parts of the system are coordinated by various IAG Services.

$GGOS_1$ has as its core and most important basis the instrumental infrastructure, but is much more:

- Instrumentation (ground- and space-based sensors)
- Data infrastructure (communication, archives, …)
- Operational data analysis and modeling chains
- GGOS Portal

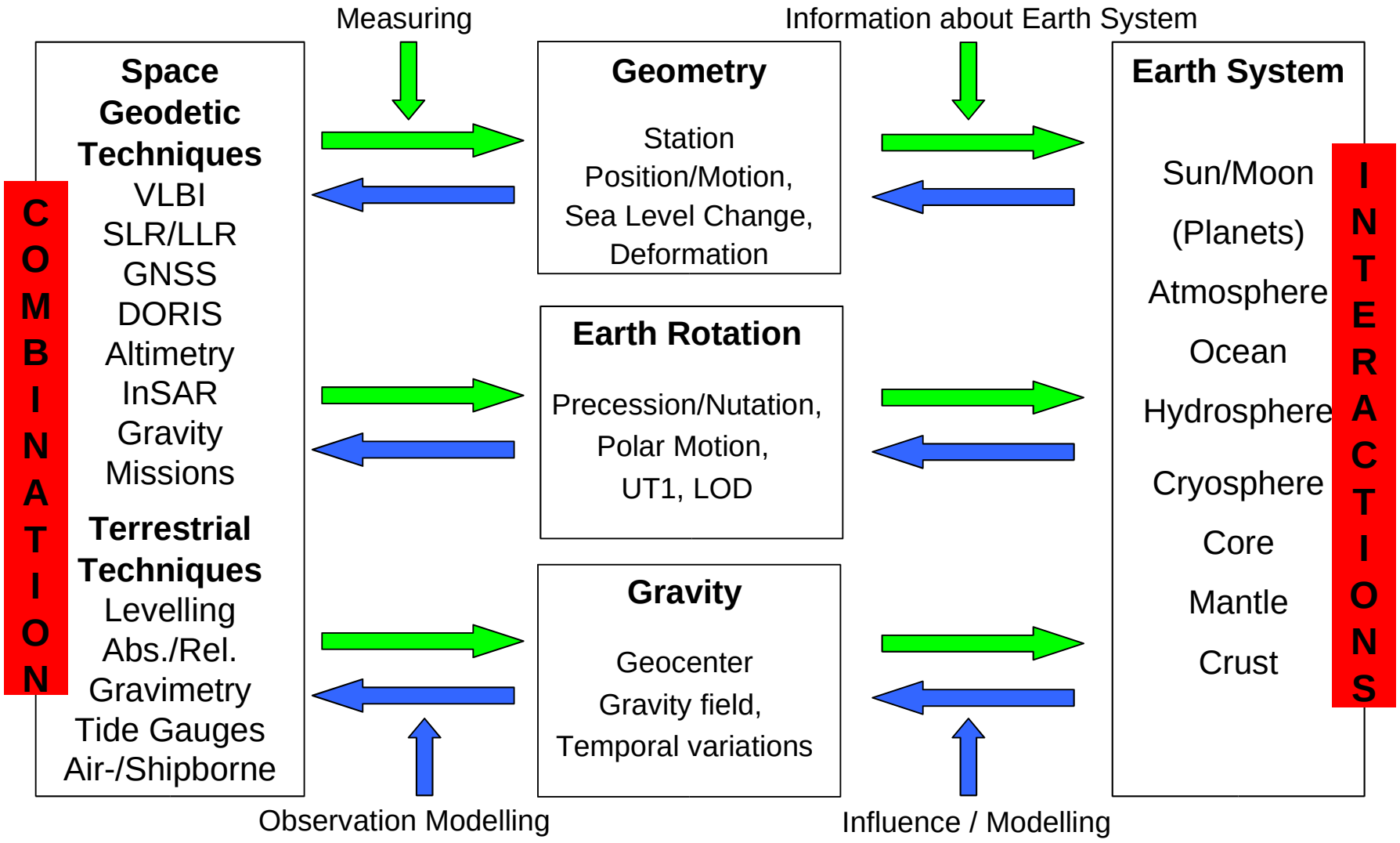
Table of Contents: Chapter 9

1. **The Overall System Design**
2. **The Observing System Design: The Five Levels**
3. **Level 1: Ground-Based Infrastructure**
   - Networks: IGS, IVS, ILRS, IDS, gravimetry, tide gauges, ocean bottom geodetic sensors,
   - Co-location, fundamental sites, auxiliary data
4. **Level 2: Satellite Missions: Low Earth Orbiters and Their Applications**
   - Gravity, ocean and ice altimetry, SAR and optical
   - Future concept
   - Co-location onboard satellites
   - Airborne and shipborne sensors
5. **Level 3: GNSS and Laser Ranging Satellites**
   - Global Navigation Satellite Systems
   - Laser Ranging Satellites
6. **Level 4: Planetary Missions**
7. **Level 5: Extragalactic Objects**

Table of Contents: Chapter 9

1. **Data Flow, Communications and Data Management**
2. **The GGOS Portal**
3. **Data Analysis, Combination, Modeling and Products**
   - Data Analysis
   - Combination and Integration
   - 4D Earth system modeling
   - GGOS Set of Consistent Products
4. **Service: the Application Network**

Measuring and Modeling the Earth's System



Parts of the future GGOS

- **Instrumentation:**

  Global terrestrial networks of observatories, Earth observing satellites and planetary missions

- **Data infrastructure:**

  Data transfer, communication links, data management and archiving systems, data and product dissemination centers, web pages, etc.

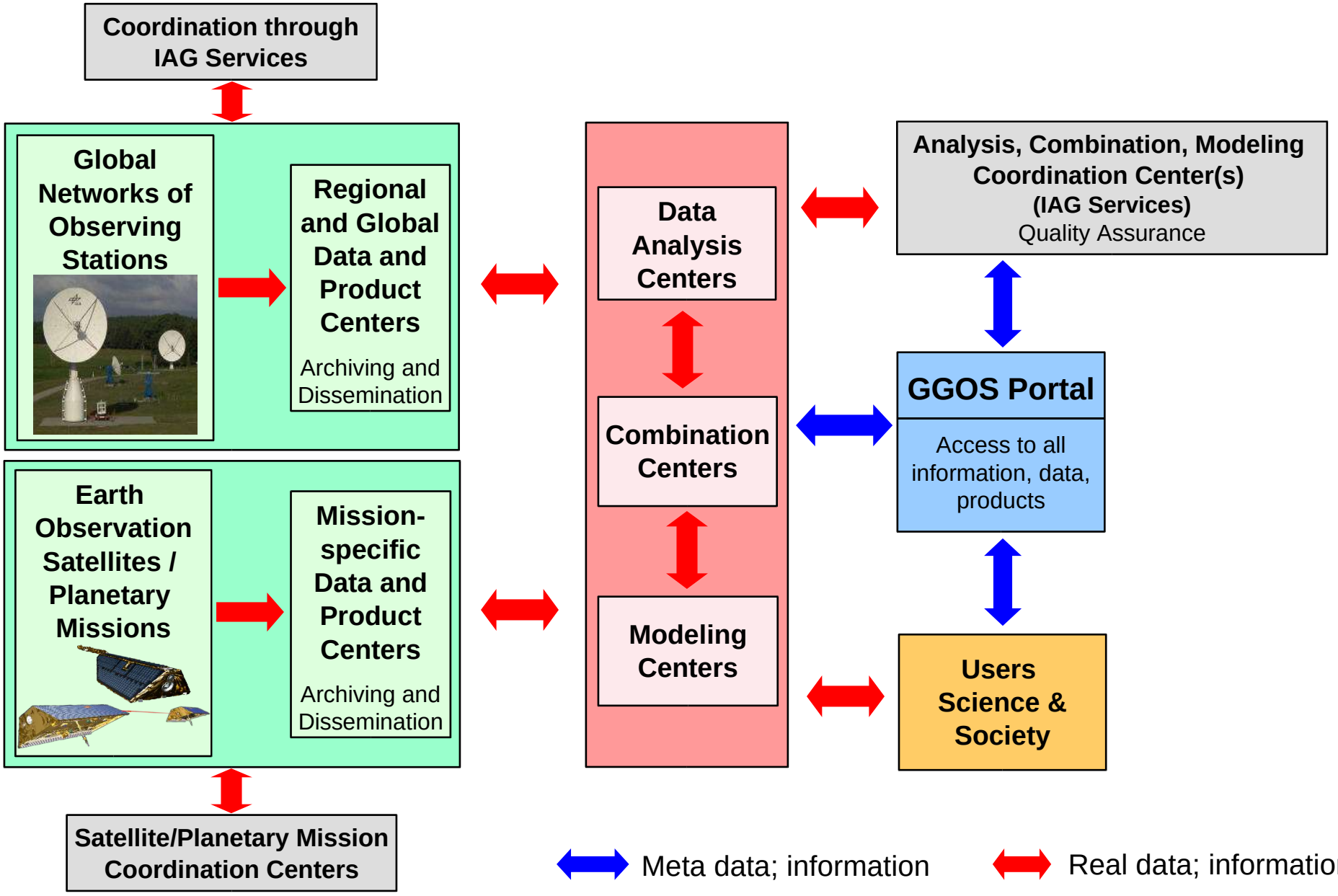
- **GGOS Portal:**

  A unique access point for all GGOS products with a database of relevant metadata according to international standards.

- **Data analysis, combination, modeling:**

  Complete and consistent data processing chains ranging from the acquisition and processing of vast amounts of observational data to its consistent integration and assimilation into complex numerical models of the Earth system.

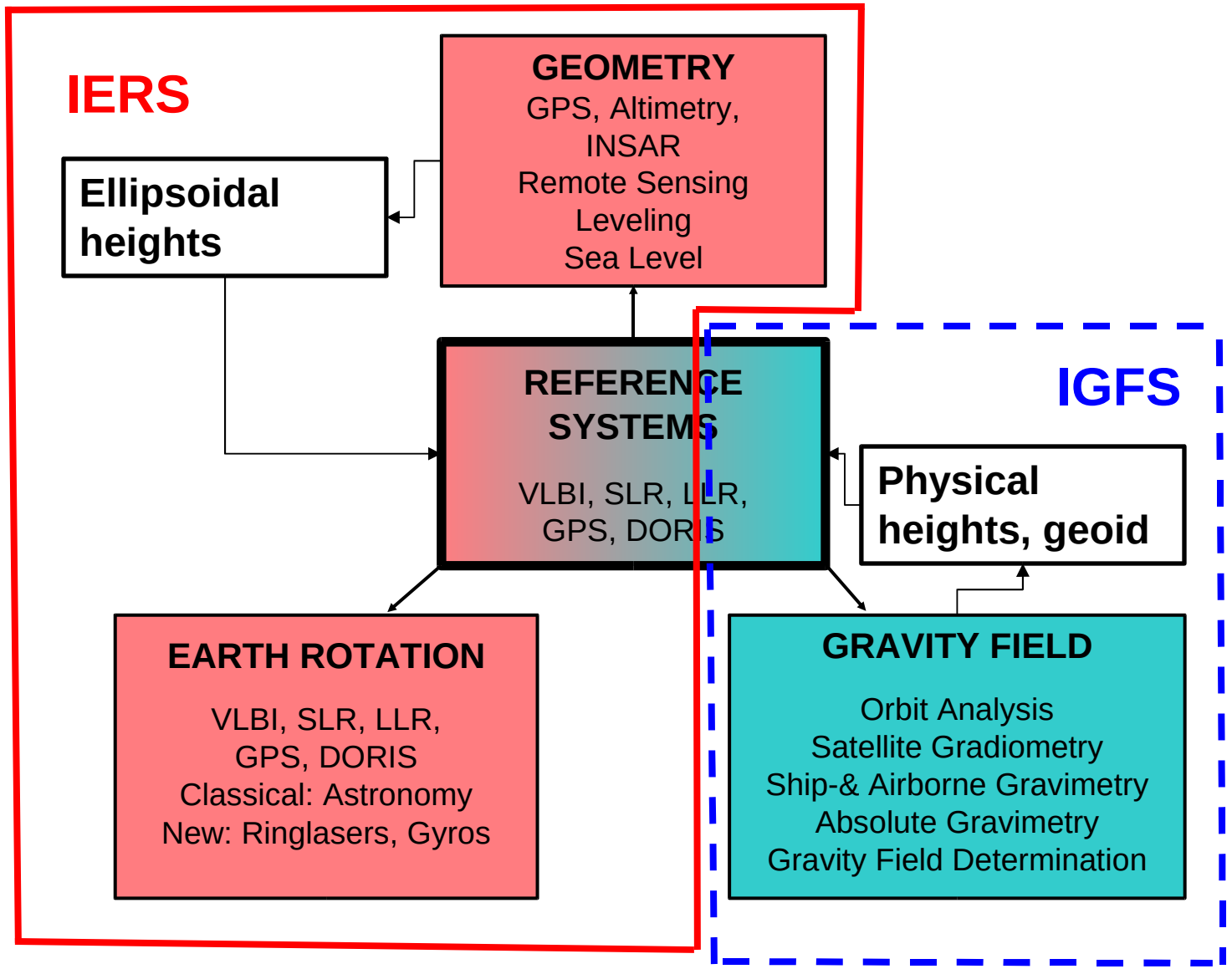
Structure of GGOS 2020 (Technical Part)



Missing Technical Components

- **Coordination of satellite missions for GGOS**
  - WG or Coordination Center ?
- **„Modeling Centers“ that model Earth system components and their interactions and analyze/use various global geophysical fluids data (atmosphere, oceans, hydrosphere, cryosphere, solid Earth, …)**
  - Attached to GGFC or different unit ?
- **Combination Centers combining geometry, Earth rotation and gravity**
  - Extension of IERS and IGFS ?
- **Coordination of planetary missions with geodetic techniques**
  - Part of satellite mission coord. ?
- **GGOS Portal with meta data and relevant information**
  - New component ?
  - Together with a CB ?

Combination Tasks and Centers (IERS/IGFS)

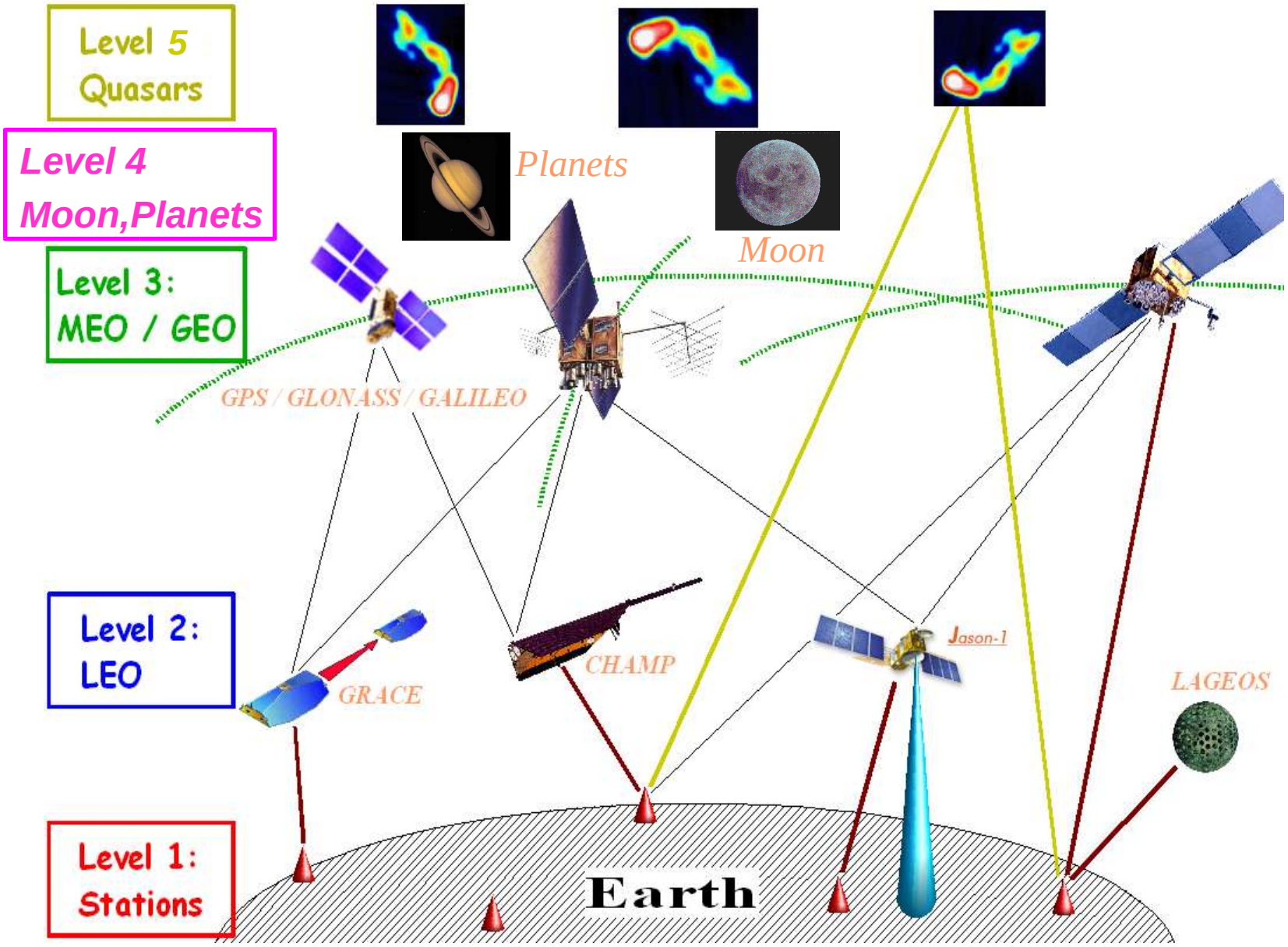


GGOS 2020 Instrumentation

Five levels of objects that are observing or are being observed in GGOS 2020:

- Level 1: the terrestrial geodetic infrastructure
- Level 2: the LEO (Low Earth Orbiter) satellite missions
- Level 3: the GNSS and the Satellite Laser Ranging (SLR) satellites
- Level 4: the planetary missions and geodetic infrastructure on planets
- Level 5: the stars and extragalactic objects

Integration of 5 Levels into a GGOS



Level 1: Ground-Based Infrastructure

Individual Networks:

- Station networks of VLBI, SLR/LLR, GNSS, DORIS
- Permanent absolute and superconducting gravimeters; tide gauges
- Air-borne, ship-borne data aquisition
- Common data commun. and infrastructure for all techniques (archiving, …)
- RT data transfer; new communication technologies for remote areas

~30 Fundamental Stations:

- Co-location of several techniques; 1 mm local ties re-measured yearly, additional sensors (meteo, WVR, ultra-stable oscillators, gravimeters, seismometer, tiltmeters, …), highly automated, 24-hour/365 days
- Latest technologies:
  - **GNSS: all GNSS, 50 Hz real-time data, 3 receivers/antennas, …**
  - **SLR: kHz, fast telescopes, two colors, transponders on Moon/planets**
  - **VLBI: continuous obs., new/multiple telescopes, real-time, obs. of (GNSS) satellites, space VLBI, …**

Densification with GNSS stations: ~ 1000 GNSS stations, stable monuments

Level 2: LEOs Missions Relevant to GGOS

Already existing missions and funded future missions:

Mission	Type	Mission Duration
CHAMP	Gravity/ magnetic field/ atmosphere	2000 – 2009
GRACE	Gravity, atmosphere	2002 – 2010
GOCE	Gravity (stationary, high-resolution)	2007 – 2009
TOPEX-POSEIDON	Ocean altimetry	1992 – 2004
Jason-1	Ocean altimetry	2001 – 2007
ICESAT	Ice altimetry	2003 – 2008
CRYOSAT-2	Ice altimetry	2009 – 2011
ERS-2	Altimetry/ climate/ environment	1995 – 2008
ENVISAT	Altimetry/ climate/ environment	2002 – 2008
TerraSAR-X	SAR/ InSAR/ atmosphere	2007 – 2010
TanDEM-X	SAR/ InSAR/ atmosphere	2009 – 2011
EnMAP	Optical / hyperspectral	2010 – 2013
SWARM	Magnetic field	2009 – 2014

Level 2: LEO Satellite Missions

Satellite Missions:

- Continuous observations over decades, long time series (trends)
- Chains of satellite missions (altimetry, gravity, InSAR, …)
- Constellations of satellites (COSMIC, SWARM, …), micro- and nano-satellites
- Formation flying: several satellites forming “one large instrument”
- Near real-time data transfer (inter-satellite comm.) and analysis (early warning systems)
- Development of new sensors and technologies (e.g., GNSS reflectometry and scatterometry, laser interferometry between satellites, ultra-stable oscillators in space)
- Satellites allowing co-location of space geodetic techniques (GNSS receiver , SLR retroreflector, VLBI emitter, gradiometer; SLR on GNSS satellites, VLBI in space, transponders on planets, …)

Level 3, 4, 5: GNSS + Extraterrestrial

GNSS and SLR Satellites:

- More than 100 GNSS satellites in 2020: GPS (24/32) , GLONASS (24/19), GALILEO (30/1), QZSS (3), COMPASS (?), …
- Cheap Lageos-type satellies with laser retroreflectors and with GNSS receivers forming a network in space with internally 1 mm accuracy (distances up to 14’000 km)

Geodetic Planetary Missions:

- Bepi Colombo, Mars missions, lunar exploration, …

Stars (observed with CCD cameras or in future with GAIA)

Quasars

Processing, Analysis, Combination

Processing and Analysis:

- Fully automated processing in near real-time or even in real-time (early warning systems, GNSS seismology, atmosphere sounding, …)
- Full reprocessing capabilities for all data available, long consistent time series
- Combination of all data types on the observation level
- Combination with LEO data (co-location, gravity, geocenter, atmosphere, …)
- Combination with satellite altimetry data (and with InSAR ?)
- Combination with terrestrial data (e.g. gravity field, …)
- Combination of different analysis centers (redundancy, reliability, accuracy, …)

Improvements in modeling, parameterization, conventions

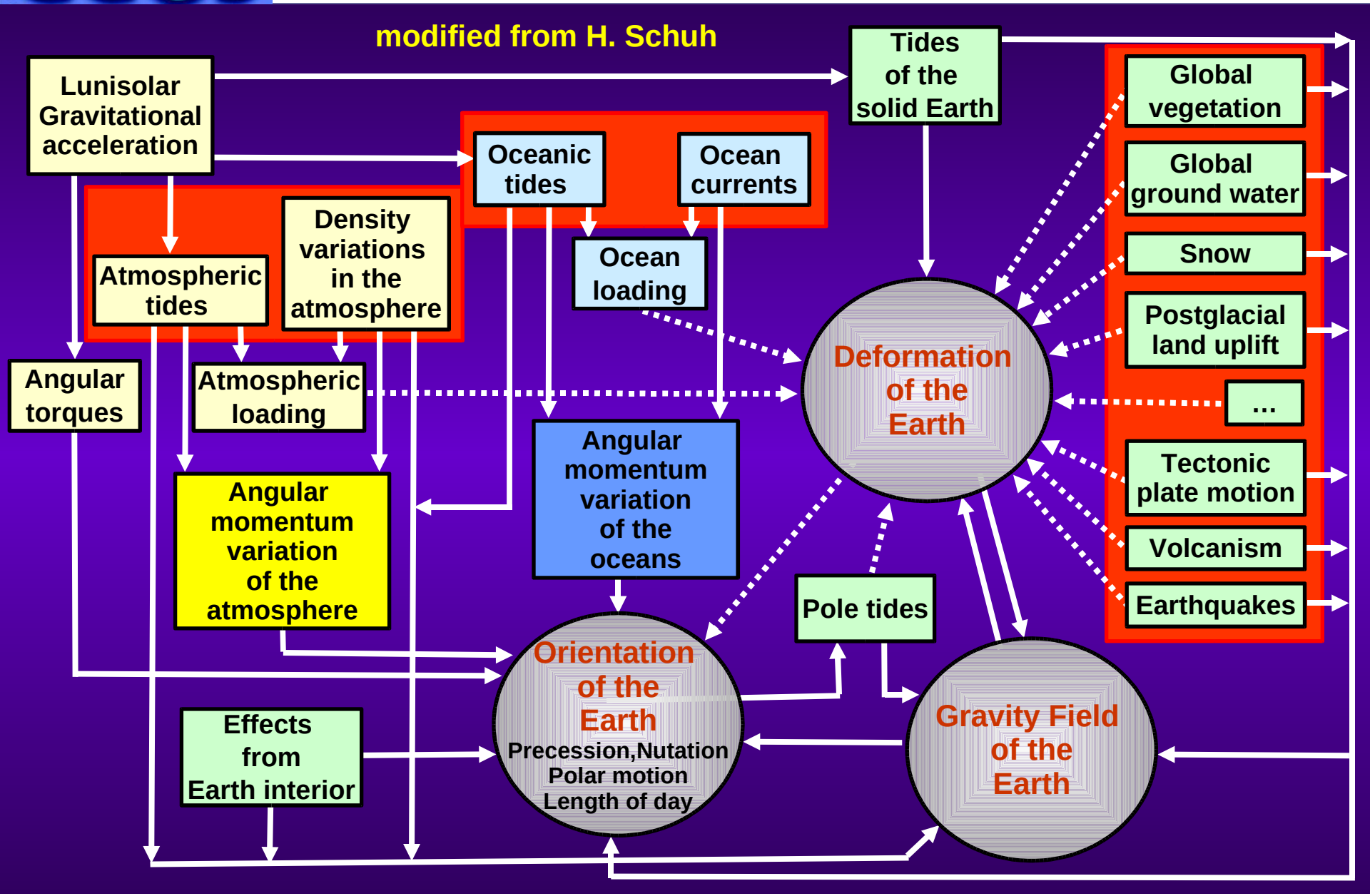
Supercomputers, visualization

GGOS: Future Combination Space

Parameter space for a rigorous combination:

	Parameter Type	VLBI	GPS/ GLON.	DORIS/ PRARE	SLR	LLR	Alti- metry	
ICRF	QuasarCoord. (ICRF	X						Earth Rotation
	Nutation	X	(X)		(X)	X		
	Polar Motion	X	X	X	X	X		
	UT1	X						
	Length of Day (LOD		X	X	X	X		
ITRF	Coord.+Veloc.(ITRF	X	X	X	X	X	(X)	
	Geocenter		X	X	X		X	Gravity Field
	Gravity Field		X	X	X	(X)	X	
	Orbits		X	X	X	X	X	
	LEO Orbits		X	X	X		X	
Atmosphere	Ionosphere	X	X	X			X	
	Troposphere	X	X	X			X	
	Time/Freq.; Clocks	(X)	X		(X)			

4D Models of the Earth System Interactions



The GGOS Portal

- The IAG Services already produce very important and valuable products to be promoted by GGOS
- Promotion of these products for Earth sciences and applications through an internet portal
- **GGOS Portal:**
  - One access point (entry door) for all geodetic products relevant in the frame work of GGOS
  - Access not to the products themselves, but to the meta data. The products are available at the individual services data centers.
  - Start with the burning questions of society and lead the way from there to the products, their characteristics, location, availability, latency, accuracy

Next Steps

Make a clear distinction between Chapter 9 and 10 (technical and organizational)

Ask co-authors for additional text pieces and reviewing of the various subchapters (next 2-3 weeks)

Iteration with co-authors

March 26-30, 2007 (1 week completely free; together with Hans-Peter Plag at one place):

- Finalization of Chapter 9
- Review of the entire document GGOS2020

More Details (1)

8.1 The overall system specification [Rothacher]

- Overall design of the system, why do we need certain components ?
- System includes observations, data flow, products, models, portal, etc.

8.2 The overall system design: the four levels [Rothacher]

- Description of the four levels
- Importance of each level
- Complementarity of the levels
- Co-location of sensors (stations and satellites)

8.3 Level 1: Ground-based infrastructure

- Space geodetic networks (VLBI, SLR/LLR, GNSS, DORIS, …), network design, instrumentation, … [Ma, Pearlman, Rothacher, Willis]
- New observing technologies in these fields (VLBI2010, SLR2000, GNSS, …), frequencies, kHz, …
- Co-location of space geodetic networks with diverse sensors
- Terrestrial networks: superconducting and absolute gravimetry [Smith, Hinderer, Kenyon]
- Tide gauges [Schöne, Woodworth], ocean bottom geodesy [Sandwell, Purcell]
- Auxiliary networks, co-location (metrology, meteorology, seismometers, tilt meters, ring lasers, global geophysical fluids, …) [Senior, Van Dam, ???]
- Air-borne and ship-borne sensors (e.g., air-borne gravimetry, …) [Forsberg, Wang]

More Details (2)

8.4 Level 2: Satellite missions: Low Earth Orbiters and their applications

- Gravity missions (CHAMP, GRACE, GOCE, …) and follow-on [Tapley, Bettapur], Lageos-type
- Altimetry missions: ice and ocean (ERS-2, Jason-1, Envisat, ICESAT, Cryosat,…) [Bosch, C.K.Shum]
- InSAR missions: ERS-2, TerraSAR-X, TanDEM-X, …) [Donellan, Shimada (Japan), Germany]
- Magnetic field missions ??? [Lühr, Jakowski]
- Radio Occultation, reflectometry missions [Wickert, Rocken]
- Chains of satellites in time to generate continuous time series
- New mission concepts (laser links, GNSS reflectometry, …) [Zuffada,Martin-Neira, Reigber, Hajj]
- High-accuracy clocks in space (ACES, …) [Senior, France]
- Planetary geodetic sensors [Dehant]
- Give a lot of web pages, use tables

Modeling, Conventions, Interpretation