Global Change and Space Science

Does Space Geodesy Fit?

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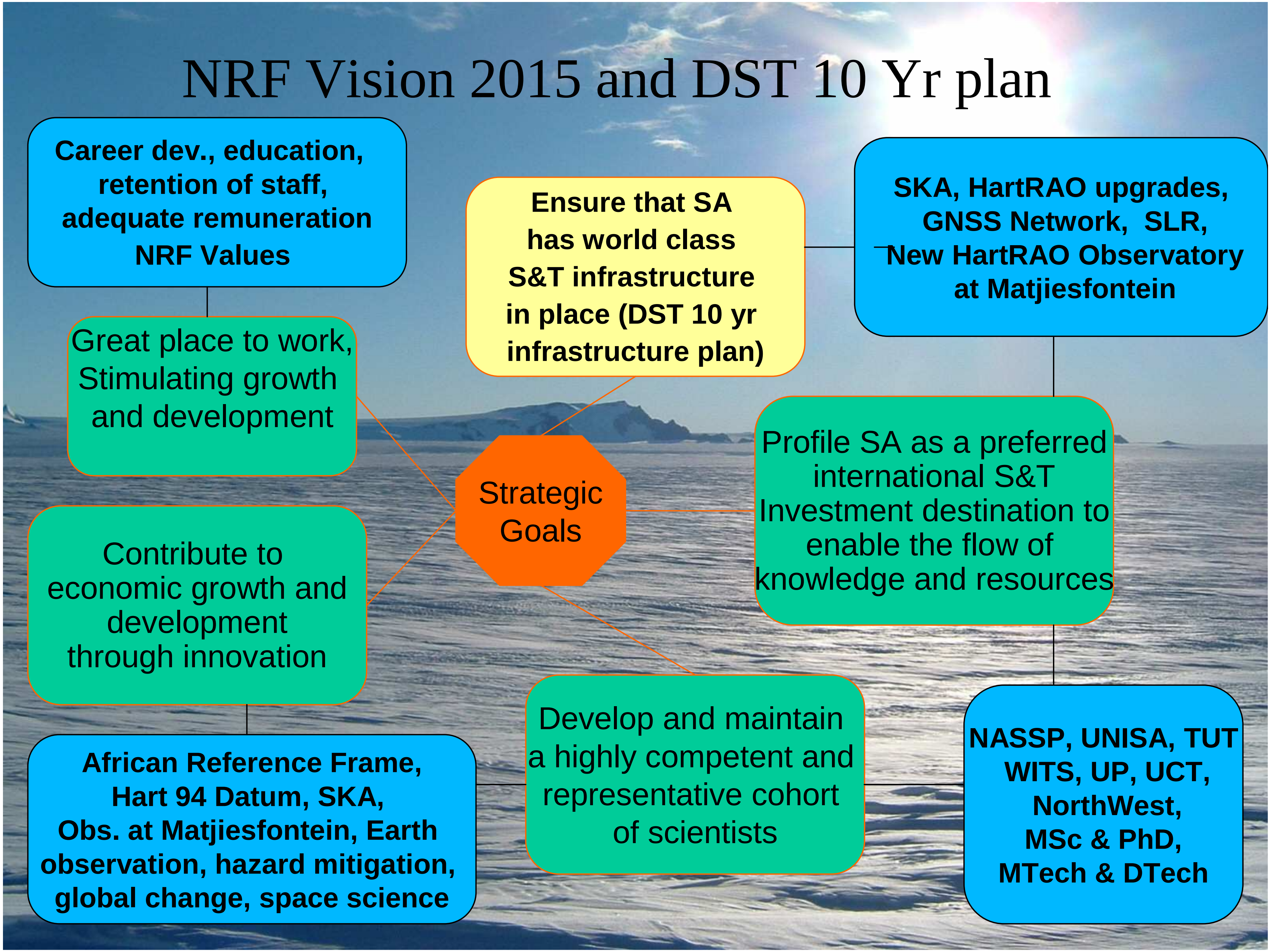
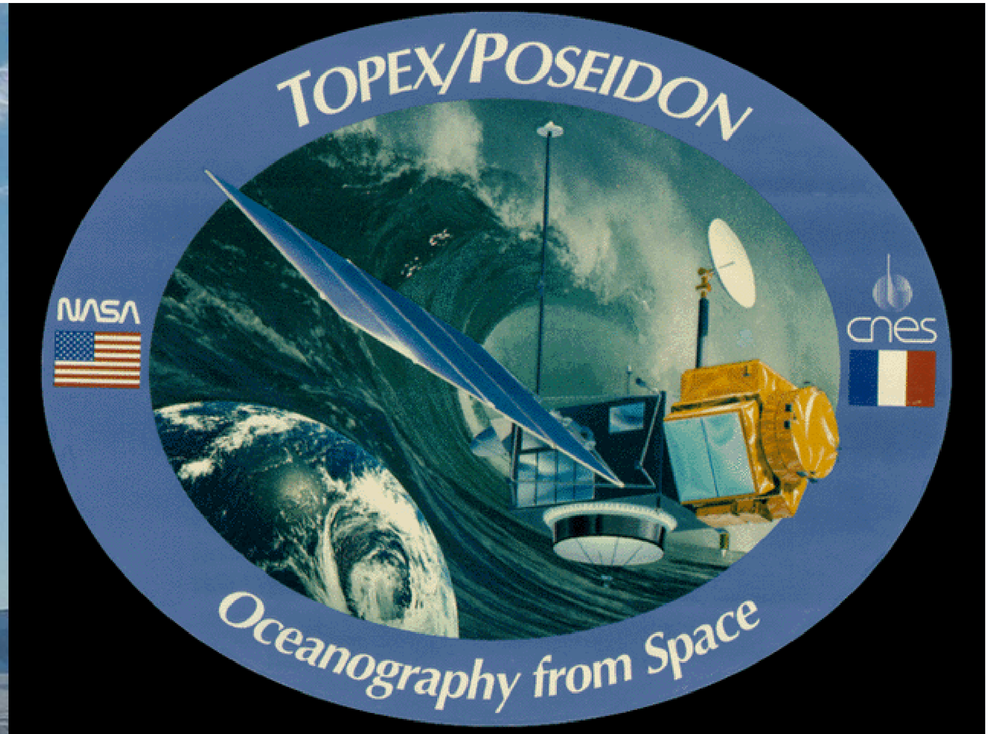
HartRAO and Univ. Pretoria

DST GRAND CHALLENGES

Matjiesfontein 16 March, 2009

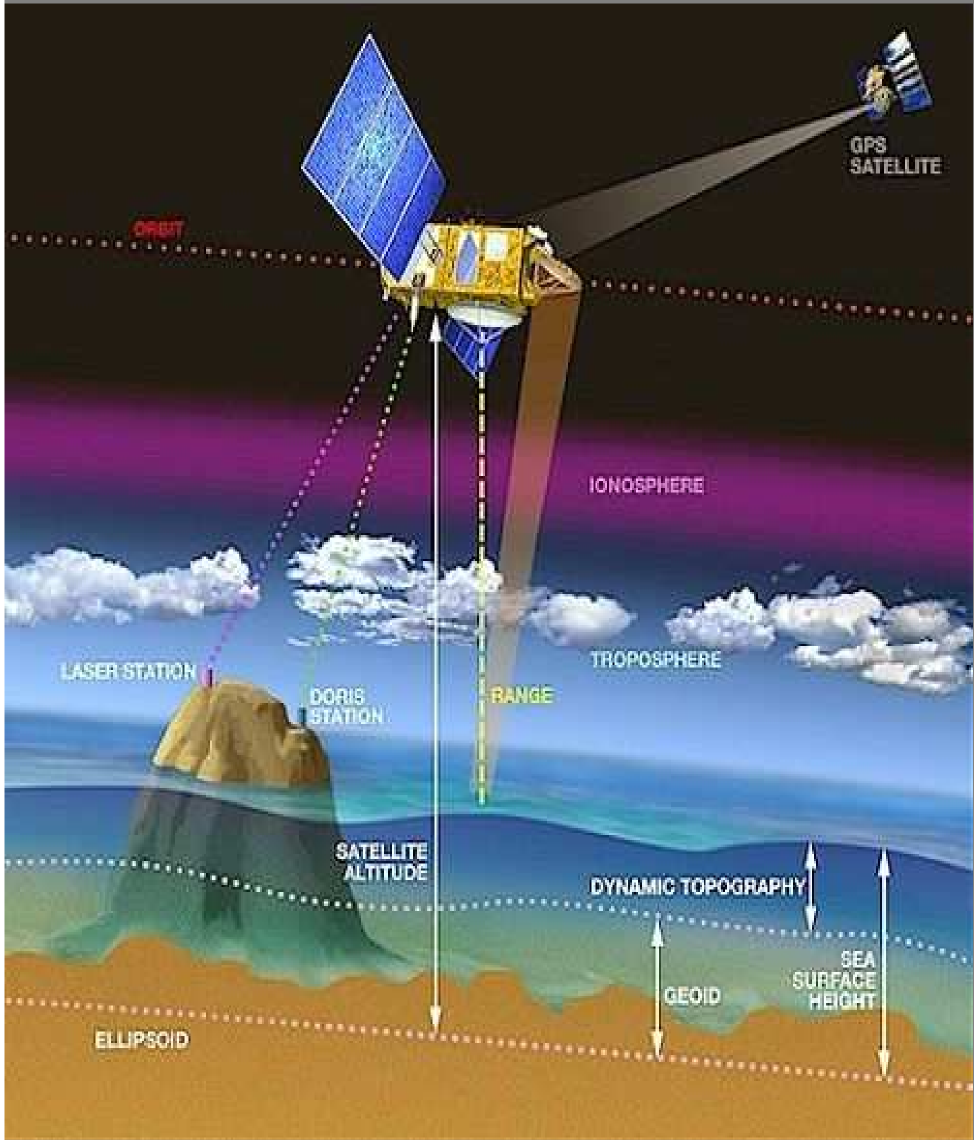

NRF Vision 2015 and DST 10 Yr plan
Career dev., education, retention of staff, adequate remuneration NRF Values
Great place to work, Stimulating growth and development
Ensure that SA has world class S&T infrastructure in place (DST 10 yr infrastructure plan)
SKA, HartRAO upgrades, GNSS Network, SLR, New HartRAO Observatory at Matjiesfontein
Strategic Goals
Profile SA as a preferred international S&T Investment destination to enable the flow of knowledge and resources
Contribute to economic growth and development through innovation
African Reference Frame, Hart 94 Datum, SKA, Obs. at Matjiesfontein, Earth observation, hazard mitigation, global change, space science
Develop and maintain a highly competent and representative cohort of scientists
NASSP, UNISA, TUT WITS, UP, UCT, NorthWest, MSc & PhD, MTech & DTech

Global Change?
How large is your globe?



- **Global as defined currently in the GCGC Science Plan is too parochial**
- **The Earth system consists of more than Land, Ocean and Atmosphere**
- **Land should include the solid Earth, and include what that entails**
- **Humans have expanded their sphere of activity, sphere of measurements, sphere of knowledge**
- **Global… *is larger* in 2009 than in 1909, from the core of the Earth to the "land" and to nearby space**

What is Global in a modern sense as applied to Global Change that will affect life on Earth?



- **Global change is an integrated phenomena that influences our world (how big is our world really? Where does it start and stop?)**

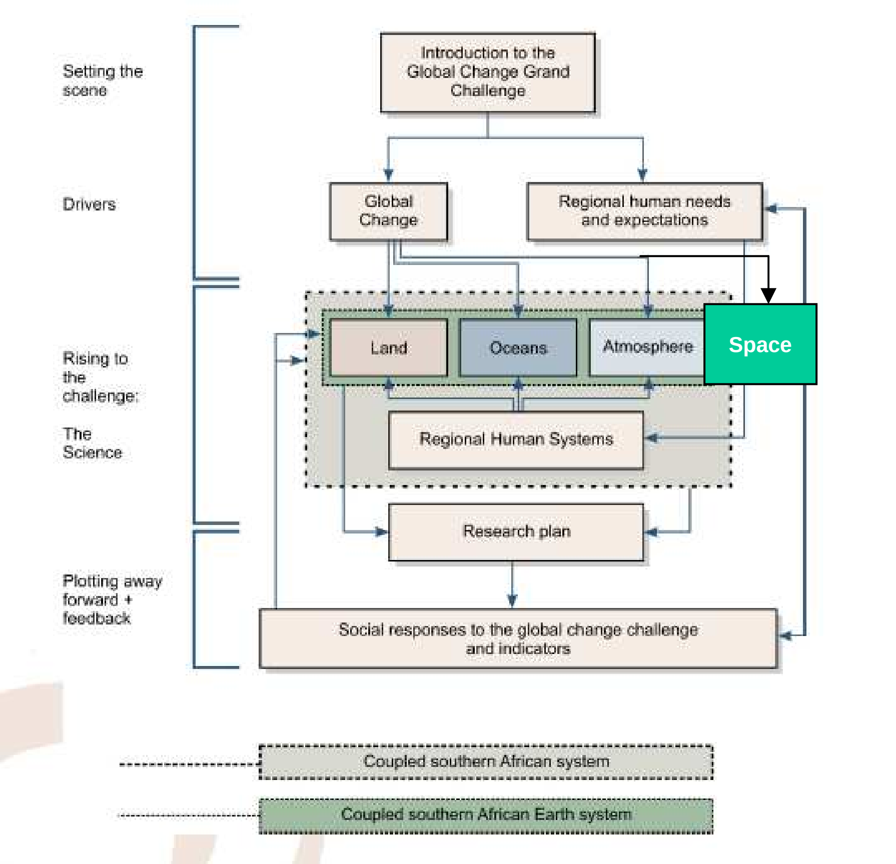
- **There are several phenomena that are not part of the classical definition of Ocean, Land and Atmosphere which influence our world and the way which we view (measure and experience) the Earth, which affect *our experience* of "change"**

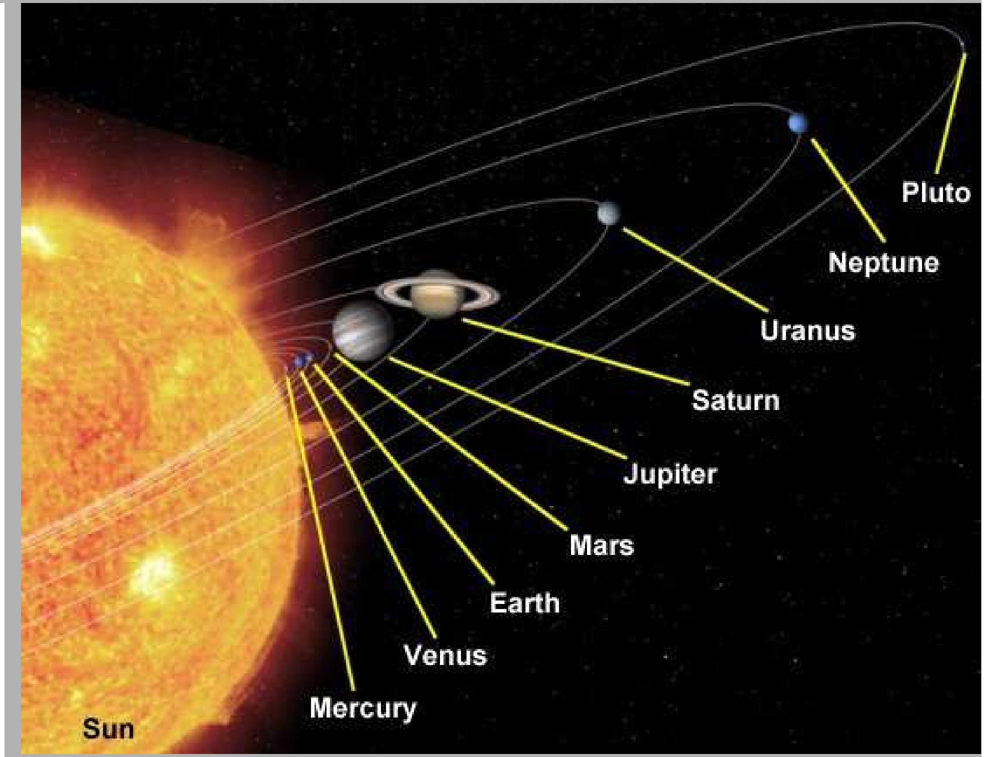
- **These phenomena extend from the core of the Earth, beyond the atmosphere and includes the local Solar System area.**

- **Examples; plate tectonics, geological history of the Earth; ionosphere, magnetosphere, Earth's gravity field, Sun, Moon, large planets etc. i.e. local "SPACE"**

- **Time scale; Geological records already tell the story of global change throughout the history of Earth i.e. turn the clock back 3.5 billion years**

Our picture needs to change to include a 4th leg





The Earth is not isolated or insulated from its partners in space

We need to realise we live in space, Earth exists in space, is continuously influenced by the Sun, Moon, gravity and magnetic field, solar wind etc. and space will play an ever increasing role in our lives. Components of space affect our measurement tools, their accuracy; this influences our perception of "Global Change" in different arenas

Many measurements of "Global Change" utilise satellite data; these data are coupled in a complex way, e.g. orbits are influenced by the Earth's gravity field and Solar wind, many measurements cannot be made accurately enough to measure "Global Change" if the orbits are not very accurately determined

Example:

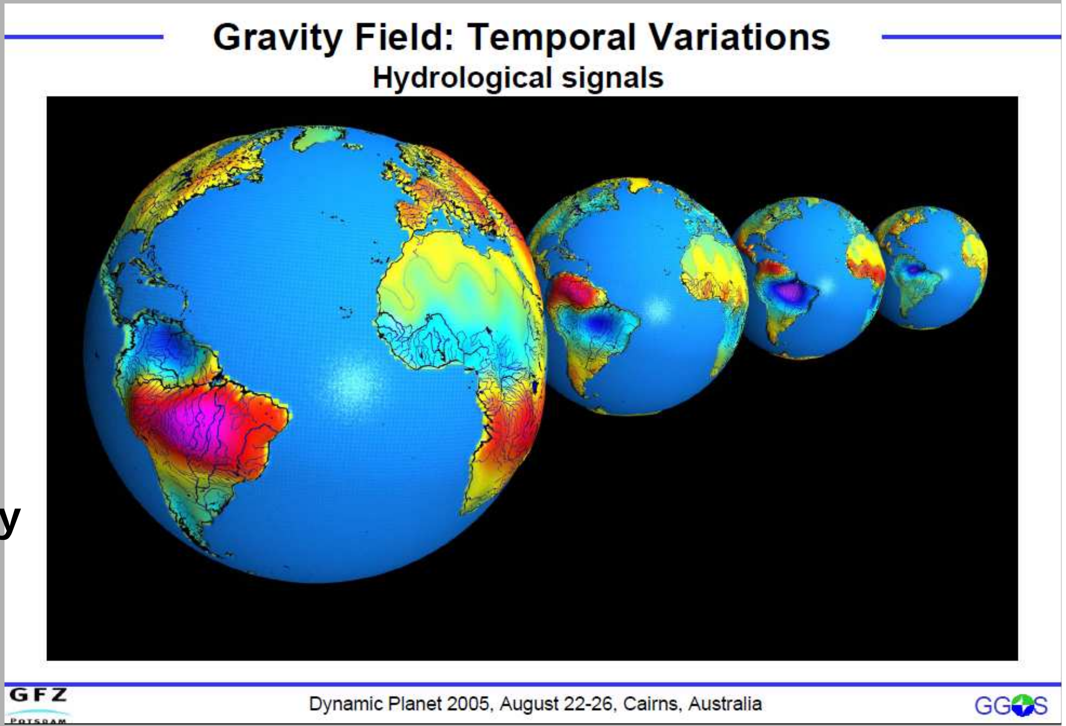
The static gravity field is modulated by:

- **Earth tide (caused by Moon and Sun)**
- **Ocean**
- **Ice sheets**
- **Groundwater**

•The Global Change "signal", should therefore incorporate the changing gravity field, in space,

•If the gravity field is well known, in an inverse sense one can then determine temporal variations in global hydrological signals (GRACE A and B, tracked by Satellite Laser Ranging)

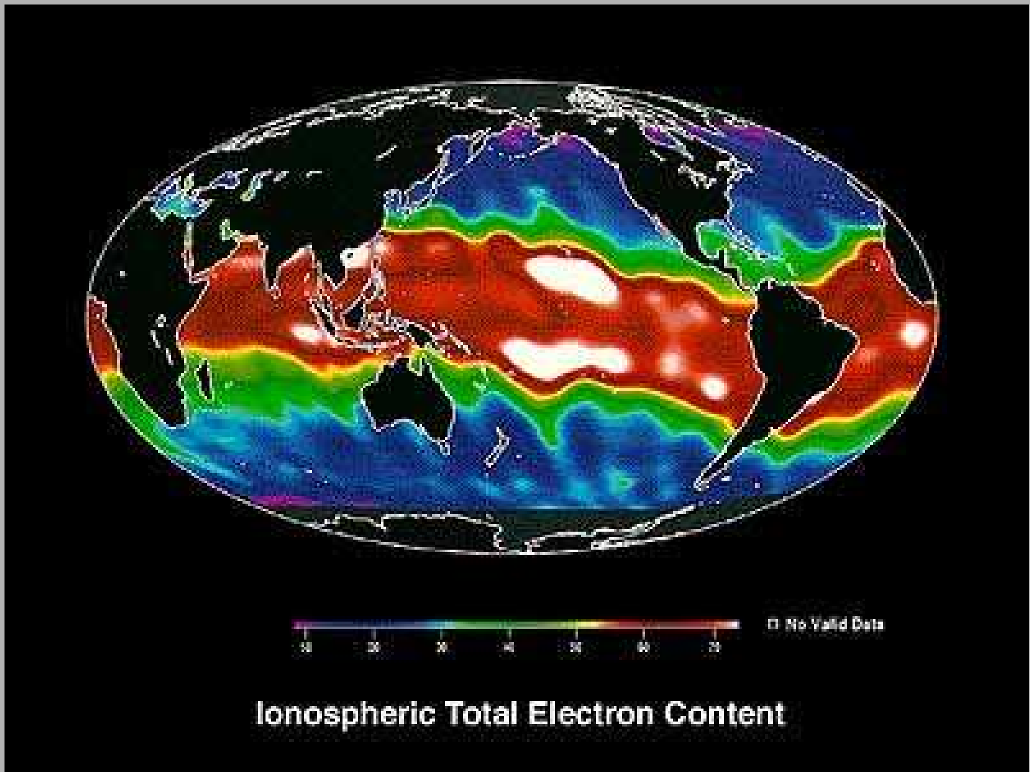
•For SLR to be accurate we need to know other parameters, e.g. atmospheric parameters, Earth tide, pole tide, atmospheric tide, ocean loading, plate tectonics etc.

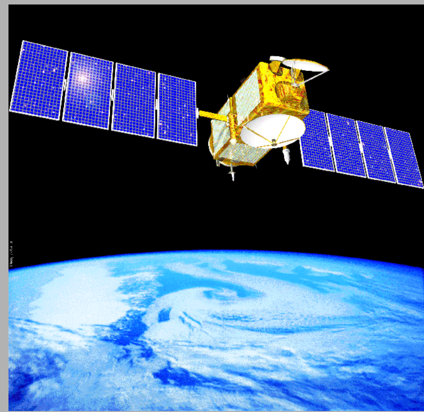


The parameters we measure, and the techniques we use, couple in a complex way through the Earth System, comprised of, Earth, Ocean, Atmosphere and Space.

We cannot afford to exclude one part of the Global Change system, or to give it a smaller role

Radar altimetry satellites; TOPEX/Poseidon, JASON (orbits calibrated by SLR)

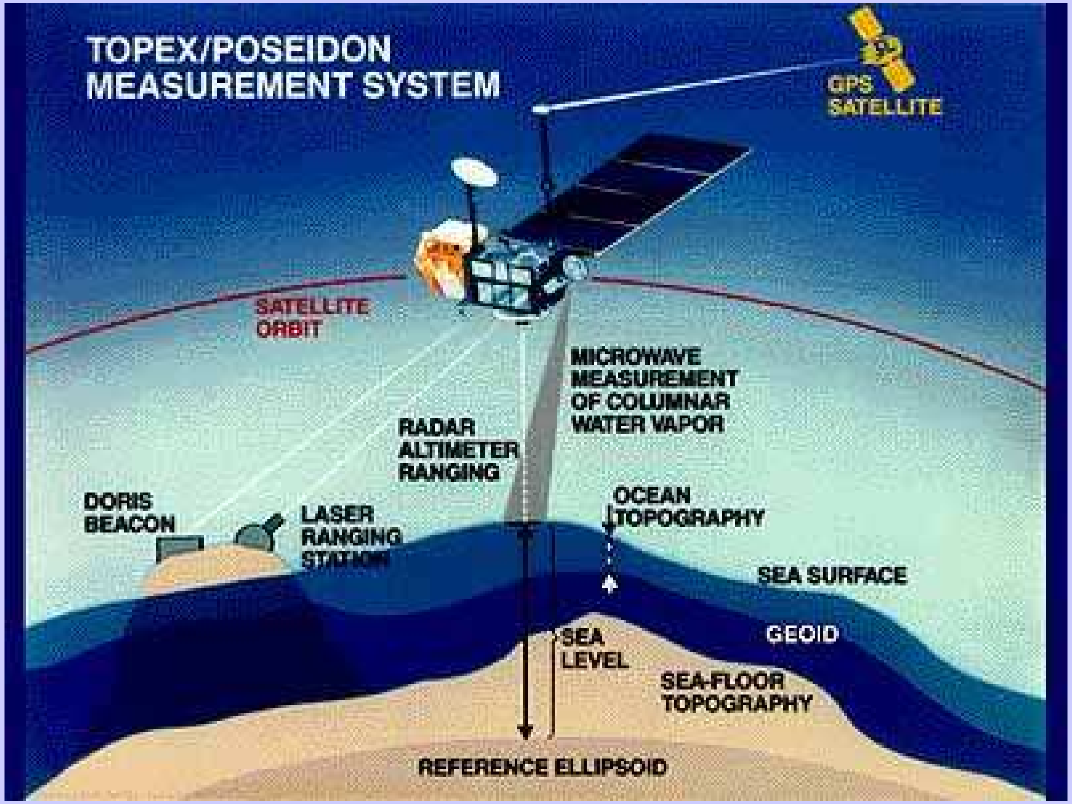




Free electrons are present in the earth's ionosphere. As with water vapor (dispersive for Satellite Laser Ranging), these electrons delay the return of the radar pulse from the altimeter and thus interfere with the accuracy of sea-level measurements.

To correct for this delay the altimeter takes measurements at two radio frequencies. The difference between the two measurements provides both a measure of the electron content and a correction for the range delay. Similar arguments for VLBI, DORIS, GNSS. Studying the ionosphere is crucial to high accuracy measurements of the ocean, earth and atmosphere.

Example: Sea surface height, changing or not changing? Is the global climate changing or not….



Non-uniform mass distribution in the Earth leads to a gravitation field of the Earth that is also not uniform. These mass distributions have a varying component as the variations of the atmosphere, solid Earth, oceans, and land bound water distributions affects gravity continuously

These subtle variations of the gravitation field influence both the ocean surface and the satellite orbit.

Studying, measuring and continuously improving our knowledge of the Earth's gravity field is crucial to measure global change in ocean levels, ice sheet levels and the complex interaction between the atmosphere, earth and oceans.

So, if we know these things, and if there are many other examples of these complex interactions which indicate that for the Earth System of today and tomorrow, space is an integral and essential main component…

What is being done by the global community? By South Africa? Science requirements…do we have the research platforms?

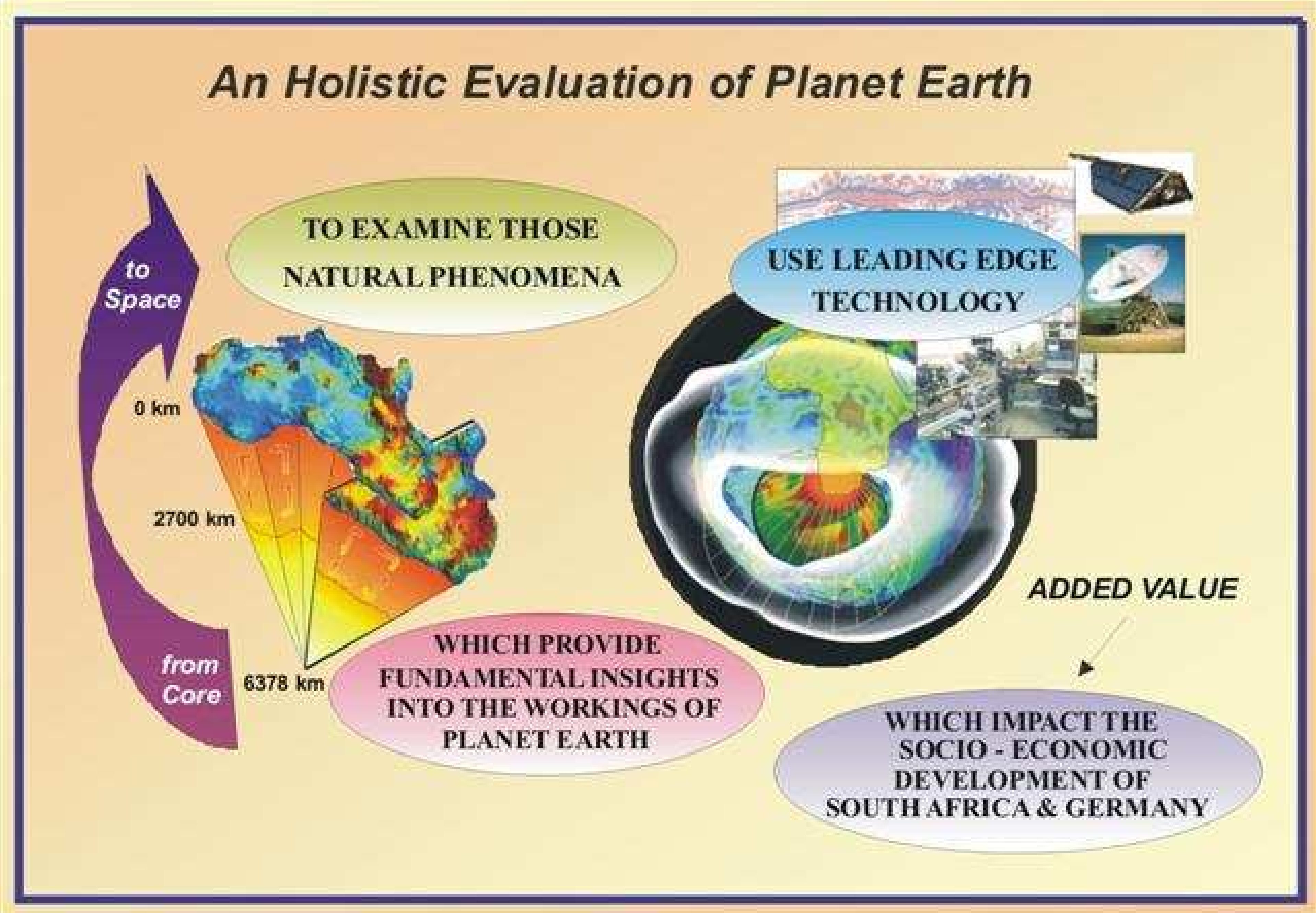
South Africa and Germany
http://www.inkaba.org

INKABA yeAFRICA

- German and South African Earth Scientists have developed a program to study structure and development of southern Africa from the core through the mantle to the surface and beyond, including the oceans, ionosphere, magnetosphere, Solar sphere and Earth’s gravity field.

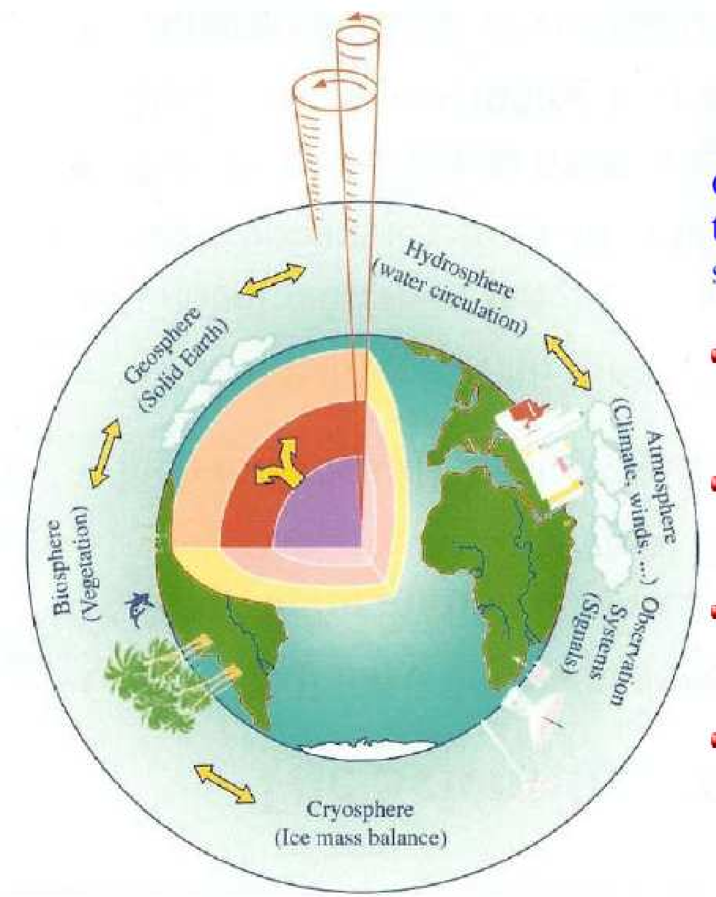
- From the German side AWI, BGR, GFZ (Potsdam) participate in the program, a number of South African institutions take part (UCT, Univ. of KwaZulu Natal, Council for Geoscience, HartRAO, Univ. of Pretoria, Univ. of the Western Cape, CSIR, HMO and many more).

Inkaba yeAfrica



Global Geodetic Community
Initiated a project “Global Geodetic Observing System” (GGOS) (A project within GEOSS)

The Users and Their Requirements



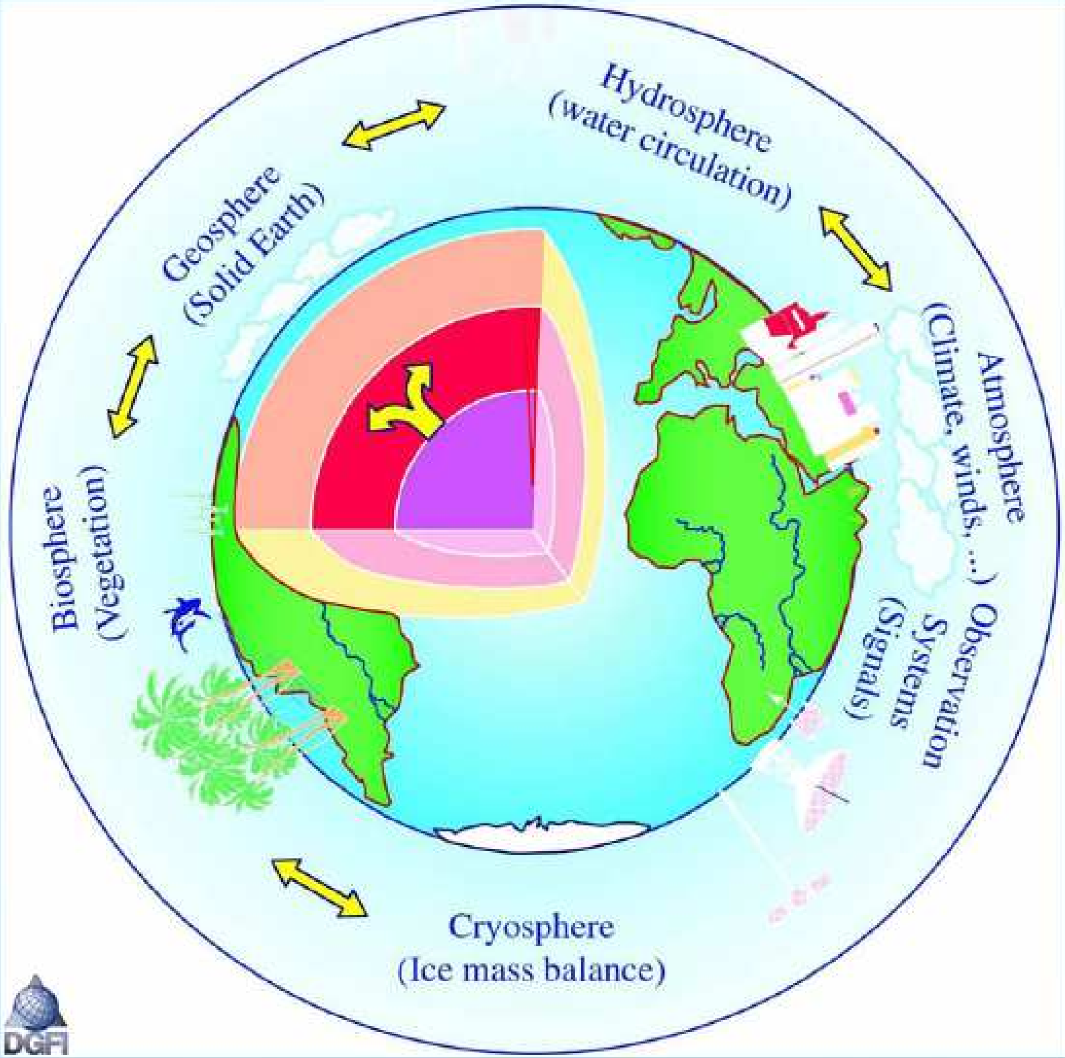
Geodesy's contribution to Geosciences

Geodesy provides information on mass transport and dynamics of the Earth system:

- Deformation of the solid Earth, (geometry and kinematics)
- Mass transport in the Earth system (gravity field, Earth rotation,
- Atmosphere-Ocean dynamics (Earth rotation)
- Global water cycle (gravity field, satellite altimetry, atmospheric sounding)

GGOS recognises that many global change measurements will depend on millimetre level positioning, highly accurate earth orientation parameters, and an accurate gravity field

The Vision of GGOS



... in order to achieve better understanding of geodynamic & global change processes

...

as a basis for Earth science research.

GGOS

The Users and Their Requirements

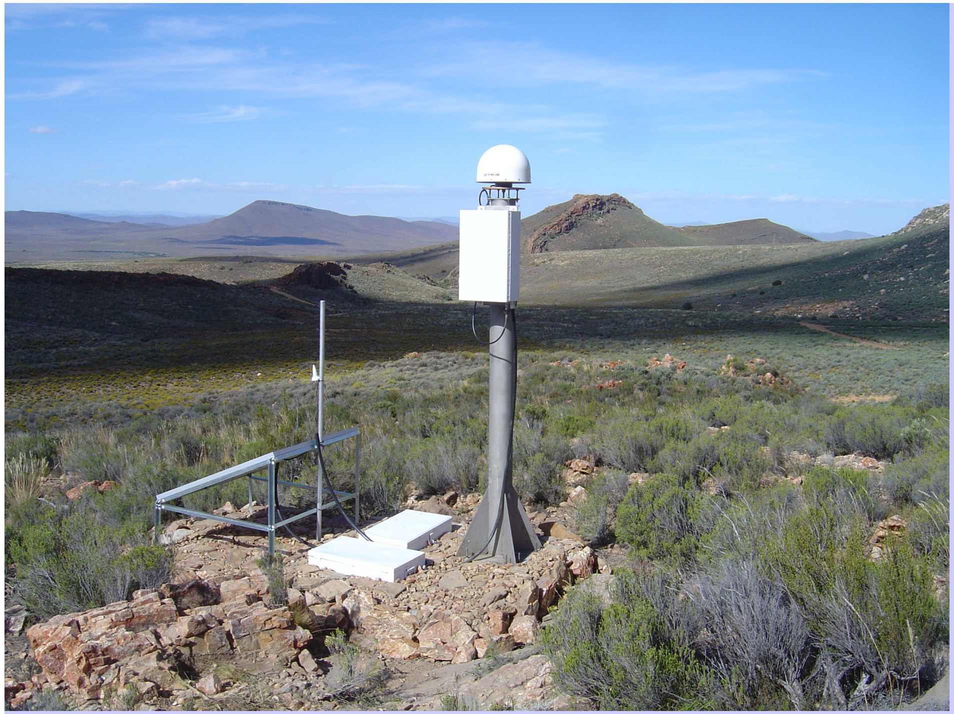
Application	Parameter	Accuracy	S.R.	T.R.	Fr.	R.
Mantle convection and plate tectonics	3-d velocities	< 1 mm/yr	n/a	n/a	G	several decades and longer
	static geoid	$< 10^{-9}$	n/a	n/a	G	
	secular strain rate	10^{-15} s^{-1}	10^3 km	n/a	G	
Postglacial rebound	3-d velocities	< 1 mm/yr	10^2 km	n/a	G	several decades and longer
	geoid	$< 10^{-9}$	n/a	n/a	G	
	strain rates	10^{-15} s^{-1}	10^2 km	n/a	G	
	Earth rotation	0.1 mas/yr	n/a	n/a	G	
	local sea level	< 1 mm/yr	2 to $10 \cdot 10^2$ km	n/a	G	
Climate change, including present changes in ice sheets and sea level	3-d displacements	1 mm	10^2 km	months	G	decades
	3-d velocities	< 1 mm/yr	$< 10^2$ km	n/a	G	decades
	local gravity	< 0.3 μGal	$< 10^2$ km	n/a	L	decades
	geoid	< 10 mm	200 km	n/a	G	decades
	Earth rotation	0.1 mas/yr				
	local sea level	< 1 mm/yr	10^2 km	months	n/a	decades
Ocean circulation	gravity field	$< 10^{-9}$	10^2 km	months	G	decades
Hydrological cycle	gravity field	$< 10^{-9}$	10^2 km	months	G	decades
	3-d displacements	< 1 mm	10^2 km	months	G	decades
Seasonal variations	gravity field	$< 10^{-9}$	10^2 km	months	G	decades
	local gravity	< 1 μGal	n/a	months	L	decades
	3-d displacements	< 1 mm	10^2 km	months	G	decades
	Earth rotation	1 mas				
Atmospheric circulation	Earth rotation	1 mas		days		decades
Earth tides	gravity	0.01 μGal	10^3 km	hours	G	years
	3-d displacements	1 mm	10^3 km	hours	G	years
	strain	10^{-15} s^{-1}				
Surface loading	3-d displacements	< 1 mm	10^2	< 1 day	G	years
	local gravity	0.1 μGal				

Plag (2005)

The Users and Their Requirements

Application	Parameter	Accuracy	S.R.	T.R.	Fr.	R.
Seismotectonics	3-d displacements strain	1 mm	$< 10^2$ km	days	G	hours to years
Volcanoes	3-d displacements gravity	1 mm 1 μgal	1 to 10^2 km			years
Earthquakes, tsunamis	3-d displacements local gravity earth rotation	1 mm to 1 cm 0.3 μGal	$< 10^2$ km	sec to days		

Plag (2005)



South Africa…..response to position South Africa as a participant in IyA and GGOS, need a state of the art Space Geodesy Observatory to participate at appropriate level

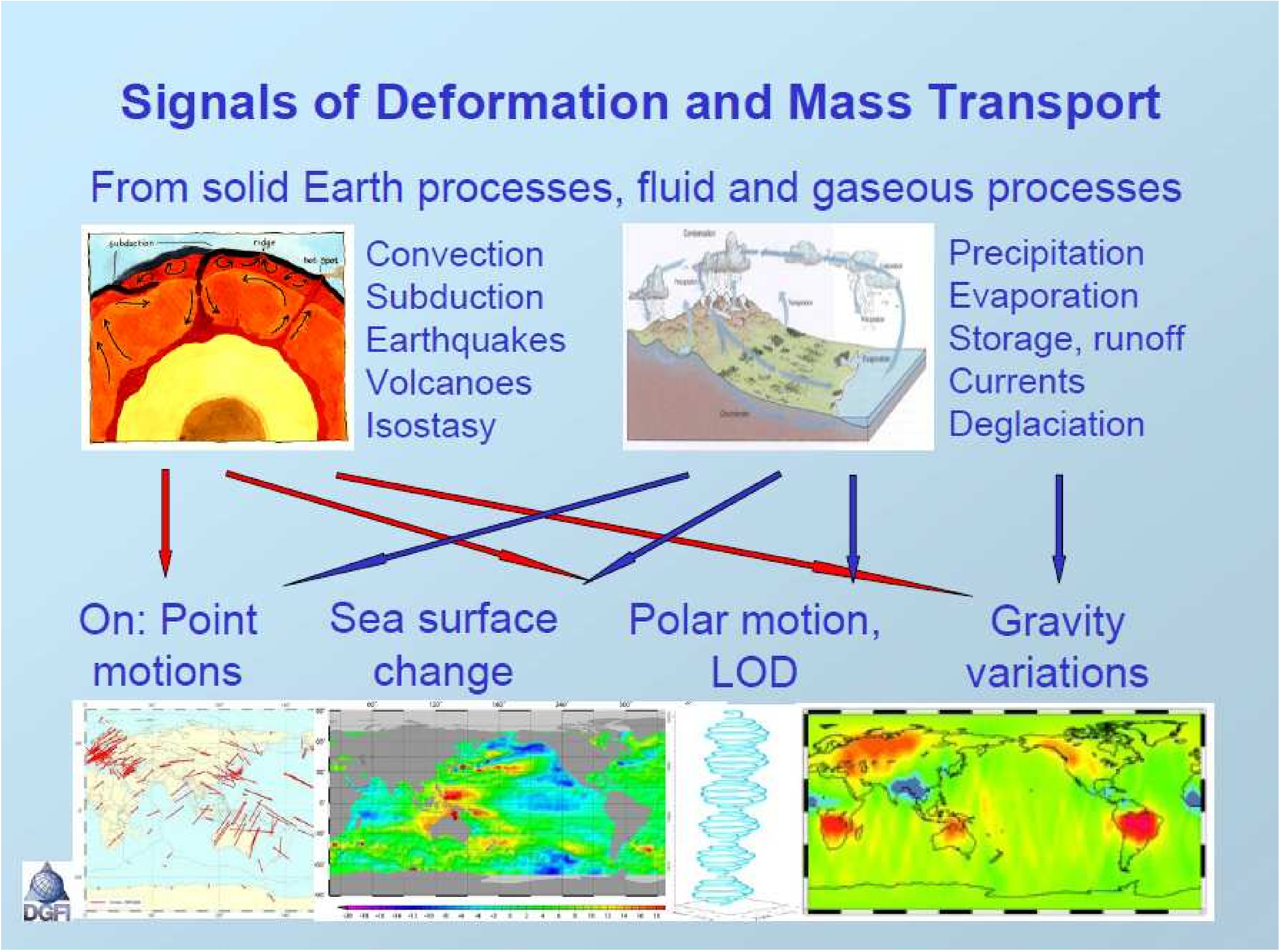
First instrument: GNSS system
Developing: 1 metre optical telescope from France for Satellite and Lunar Laser Ranging

Proposed new Space Geodesy Observatory at Matjiesfontein (semi-desert environment) (we can use +R10 M), unique global location

To include:

- Satellite and Lunar Laser Ranging (orbit calibration, gravity studies)
- French DORIS system (orbit calibration)
- Geodetic VLBI for Earth orientation parameters and Celestial Reference Frame
- GNSS network southern Africa region, southern Ocean and Antarctica, (calibration of ocean level measurements, plate tectonics, ionosphere and atmospheric studies)
- Geophysical instrumentation (gravimeter, seismometer etc.)
- Solar telescope
- etc.

GGOS science rationale



Source: Herman Drewes, DGFI, Munich

The Earth System is integrated and its systems are inter-dependent

Examples of Signals of Geophysical Processes Affecting Different Geodetic Parameters

Process	acts as	affects
Core/mantle convection	- plates' driving force	→ point position
	- mass displacement	→ gravity field
	- angular momentum	→ Earth rotation
Precipitation	- ground water storage	→ gravity field
	- moment of inertia	→ Earth rotation
	- flowing off	→ sea surface
Atmospheric and oceanic currents	- loading force	→ point position
	- pressure	→ sea surface
	- pressure, AAM, OAM	→ Earth rotation

DGFI GGOS

Examples of Geodetic Parameters Affected by Different Geophysical Processes

Parameters	affected by	of processes in
Point positions	- plate motions	geosphere (solid)
	- loading effects	ocean, atmosphere
Sea / Crustal surface	- flowing off water	geo-/hydrosphere
	- air pressure	atmosphere
Earth rotation	- winds, air pressure	atmosphere
	- deformation	geosphere (solid)
Gravity field	- ground water	geo-/hydrosphere
	- deformation	geosphere (solid)

→ All parameters reflect integrated effects of System Earth.

DGFI

GGOS

Summary

- The Earth System today consists of the solid Earth, Ocean, Atmosphere and nearby Space.
- Global change is only measurable if we consider the total picture, as the system has intricate links, energy exchanges and interdependencies.
- Our measurement techniques rely on the total picture, and the total picture on our measurements.
- Projects such as IyA, GGOS, Space Geodesy Observatory at Matjiesfontein, provide a means to explore the interdependencies of the four components of the Earth System, which eventually deliver products which make "Global Change" really measureable and quantifiable at time scales ranging from millions of years ago to right now.
- These projects are part of a global (international) network of similar projects, working together, with a common objective, long term, accurate and reliable measurements of global change, changes which include climate, as well as "our Globe's" many other parameters.


Thank You!