united nations
educational, scientific
and cultural
organization

international atomic
energy agency

the
abdus salam
international centre for theoretical physics

School on "Exploring the Atmosphere by Remote Sensing Techniques"
18 October - 5 November 1999

1151-8

The Earth Observation Programme of the European Space Agency: *"The Living Planet Programme"*

C. Readings
Head - Earth Sciences Division
ESTEC
Noordwijk
The Netherlands

The Earth Observation Programme of the European Space Agency

The Living Planet Programme

C.J. READINGS

Head, Earth Sciences Division
Estec, Noordwijk, The Netherlands

Exploring the Atmosphere by Remote Sensing Techniques
22 October 1999, Trieste, Italy

ESA's Living Planet Programme
General Background

- Increasing public concern over the Earth, its environment and mankind's impact on it. Both regional and global:
    - Global concerns over Climate Warming, Ozone Depletion, Tropospheric Pollution, El Niño, etc.
    - Regional concerns over Sea Level Change, Fires in South East Asia, Floods in Europe, Droughts in the USA, etc.
- Establishment of the Intergovernmental Panel on Climate Change (IPCC) to advise on state of knowledge - reports highlight general lack of knowledge in many crucial areas.
- International research initiatives include the establishment of the World Climate Research Programme (WCRP) and the International Biosphere/Geosphere Programme (IG/BP).

ESA' Living Planet Programme
General Background (2)

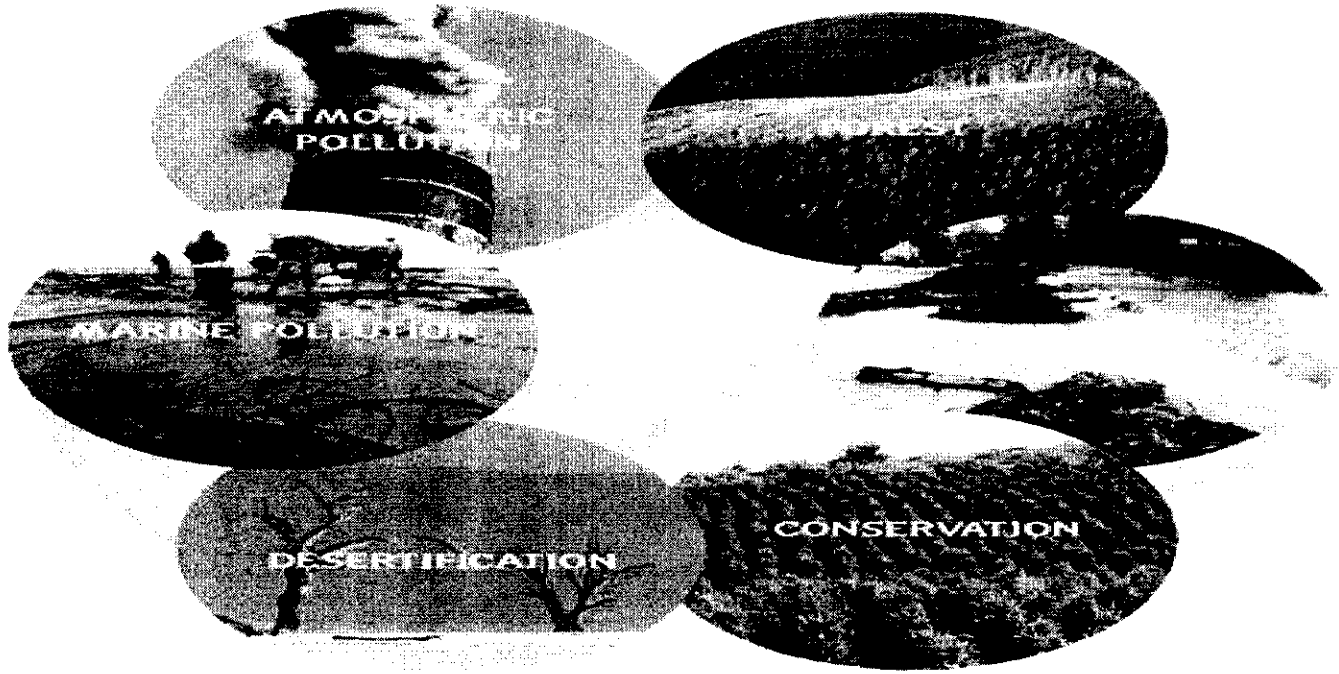

Figure 1.1 Specific issues within the elements of the Earth system of importance in the context of environment and climate

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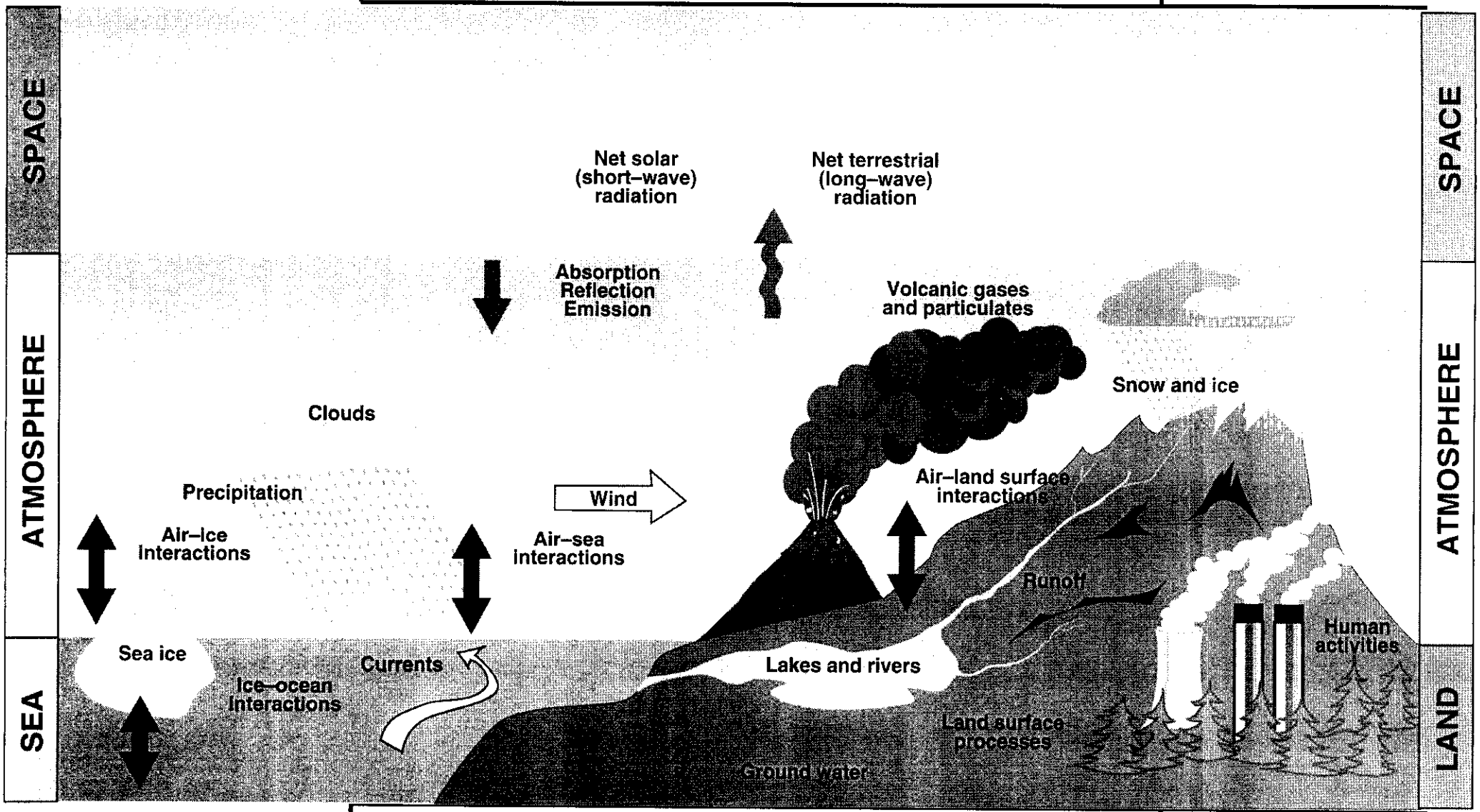
ESA' Living Planet Programme
The Underlying Rationale

- **The need to address public concerns about the Earth, its environment and mankind's impact on it.**
- **The Earth is a complex (and evolving) system which is not properly understood.**
- **Data required to improve knowledge of the processes involved, to develop and validate models.**
- **Space has a role to play in the helping to ensure the provision of the requisite data.**

ESA' Living Planet Programme
The Earth System



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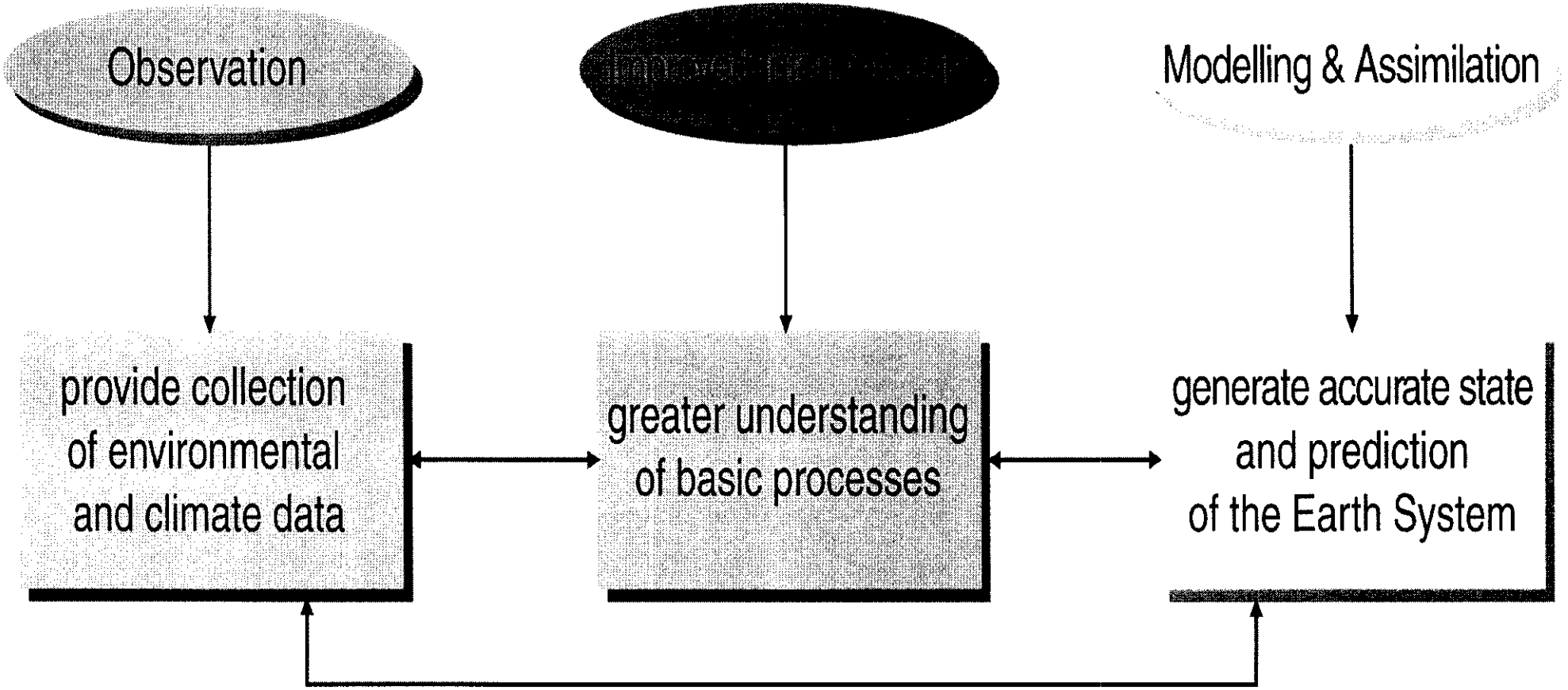
ESA' Living Planet Programme
The Earth System Model - key modules

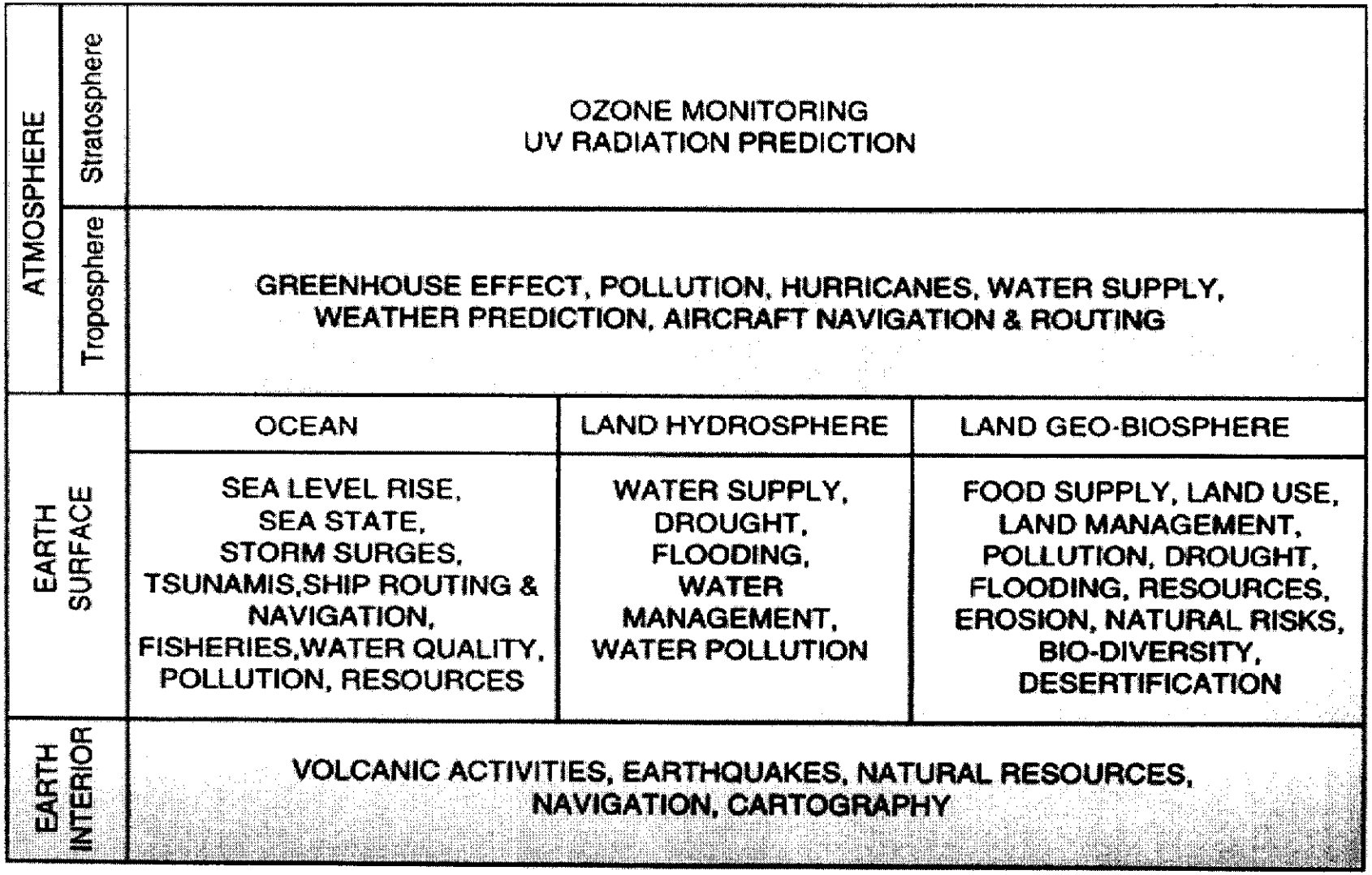


ESA' Living Planet Programme
Earth System Models (1)

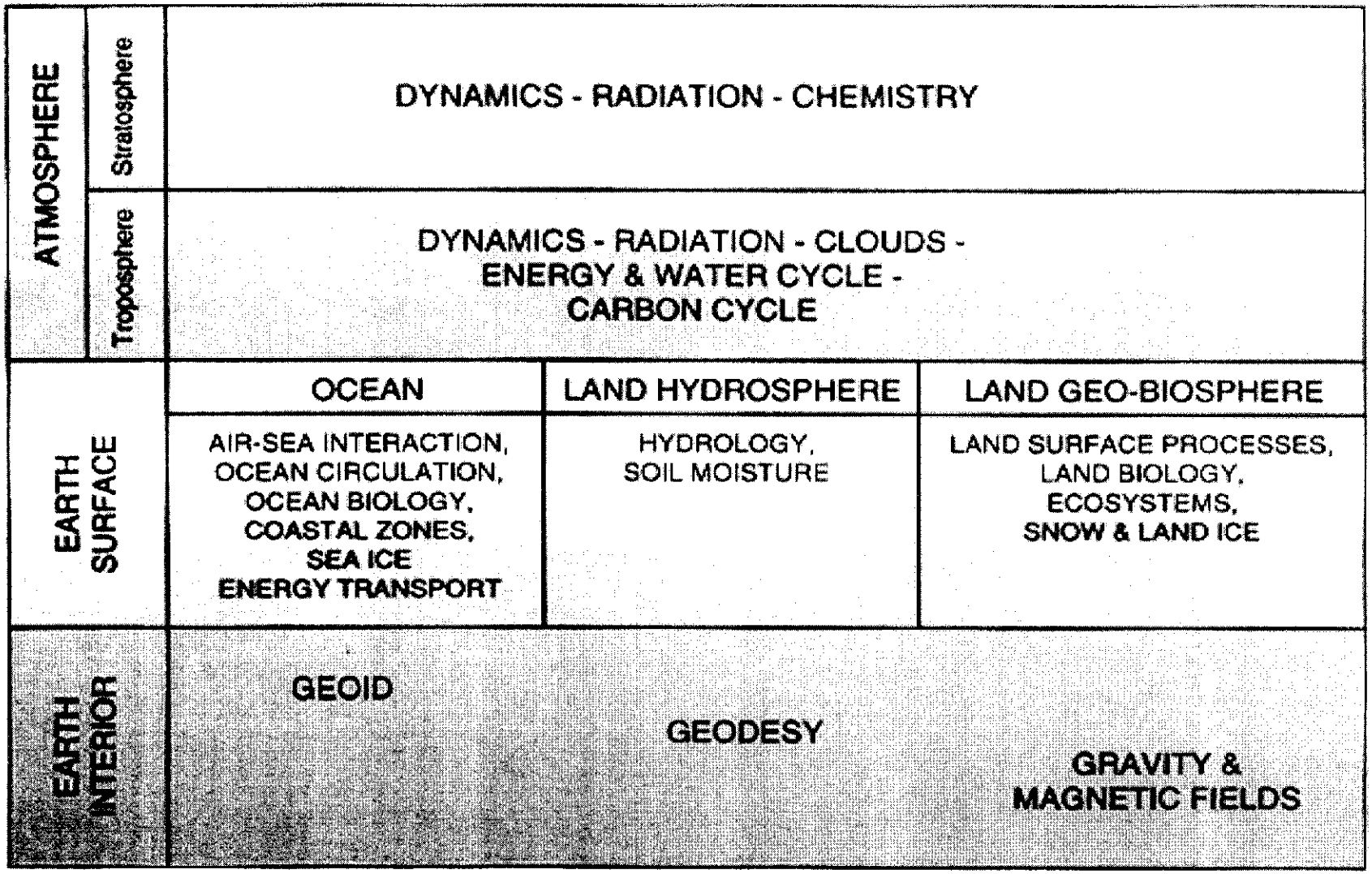
Understanding of the Earth will improve by the development and elaboration of global Earth System models which describe:

- **the evolution of the state and composition of the atmosphere**
- **the physical state of the ocean and cryosphere**
- **the physical state of the top few metres of soil and dynamical interactions with the Earth's interior**
- **the physical state of terrestrial vegetation**
- **the key bio-geochemical cycles which in turn require the representation of terrestrial and ocean biota**

ESA' Living Planet Programme
Natural Hazards and Applications



ESA' Living Planet Programme
The Hierachical Set of Earth System Models



The formulation of these models is difficult, especially as nonlinear nature of the processes involved. Requires simultaneous progress in three different areas :

- **Area 1 - to identify and increase understanding of the various processes involved to the point where they can be represented in models.**
- **Area 2 - to extend the existing hierarchy of Earth System models to include these processes.**
- **Area 3 - to ensure the provision of the relevant data for use in these models to help address the issues highlighted above.**

The provision of observations from space is of fundamental importance.

ESA' Living Planet Programme
The Overall Approach: The Four Themes

Four major interdisciplinary themes identified, each of which may encompass phenomena in several of the regimes:

- **Theme 1 - the Earth interior**
- **Theme 2 -the physical climate system**
- **Theme 3 - the geosphere-biosphere**
- **Theme 4 - the anthropogenic influences on the atmospheric and marine environment**

Between them these four Themes span the full Earth System and recognise the need for the detailed treatment of interactions between the various regimes.

ESA' Living Planet Programme
Links between the Themes and Elements of the Earth System

THEMES					
COMPONENTS		THEME 1 EARTH INTERIOR	THEME 2 PHYSICAL CLIMATE	THEME 3 GEO-BIOSPHERE	THEME 4 ANTHROPOGENIC IMPACT
ATMOSPHERE	STRATOSPHERE		✓	✓	✓
	TROPOSPHERE		✓	✓	✓
EARTH SURFACE	LAND	✓	✓	✓	✓
	OCEAN	✓	✓	✓	✓
EARTH INTERIOR		✓	✓	✓	

The ESA Living Planet Programme
The Earth Explorer Missions (1)

- Means of addressing objectives (see ESA SP-1227)
- Regular flight opportunities funded under the Earth Observation Envelope Programme
- Objectives of Earth Explorer Missions - research and development focussing on specific topics/techniques
- Two complementary types of Earth Explorer missions, namely:

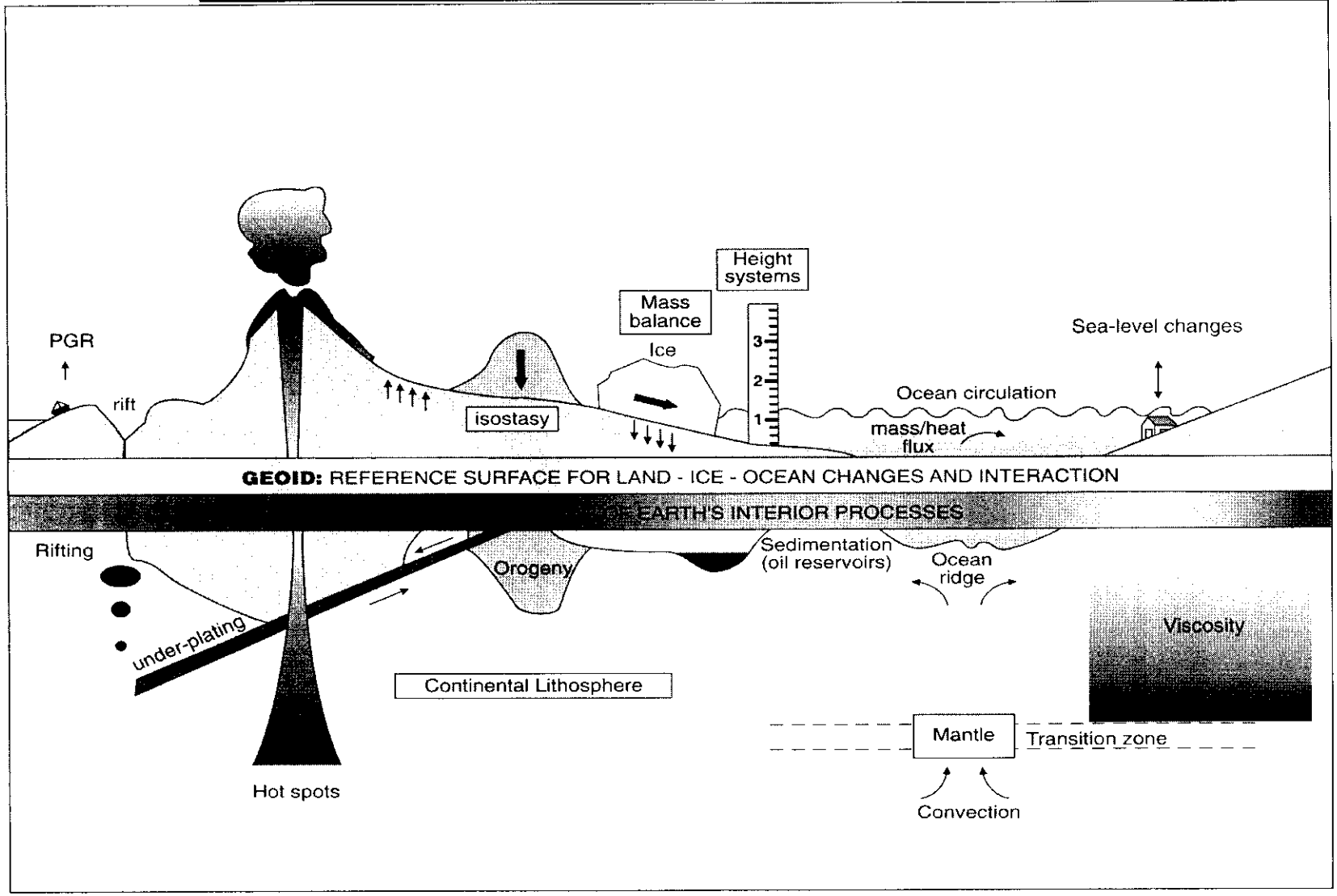
  Earth Explorer Core Missions - larger research/demonstration missions led by ESA.
  Earth Explorer Opportunity Missions - smaller research and demonstration missions not necessarily ESA led.

- Complemented by Earth Watch - thematic pre-operational missions focussing on specific emerging Earth Observation application areas

Theme 1 - Earth Interior

- Marine Geoid and its Impact on Ocean Circulation
- Gravity Field and Earth Interior Processes
- Magnetic Field and Earth Interior Processes
- Geodesy

ESA' Living Planet Programme
The Earth as a Dynamic System



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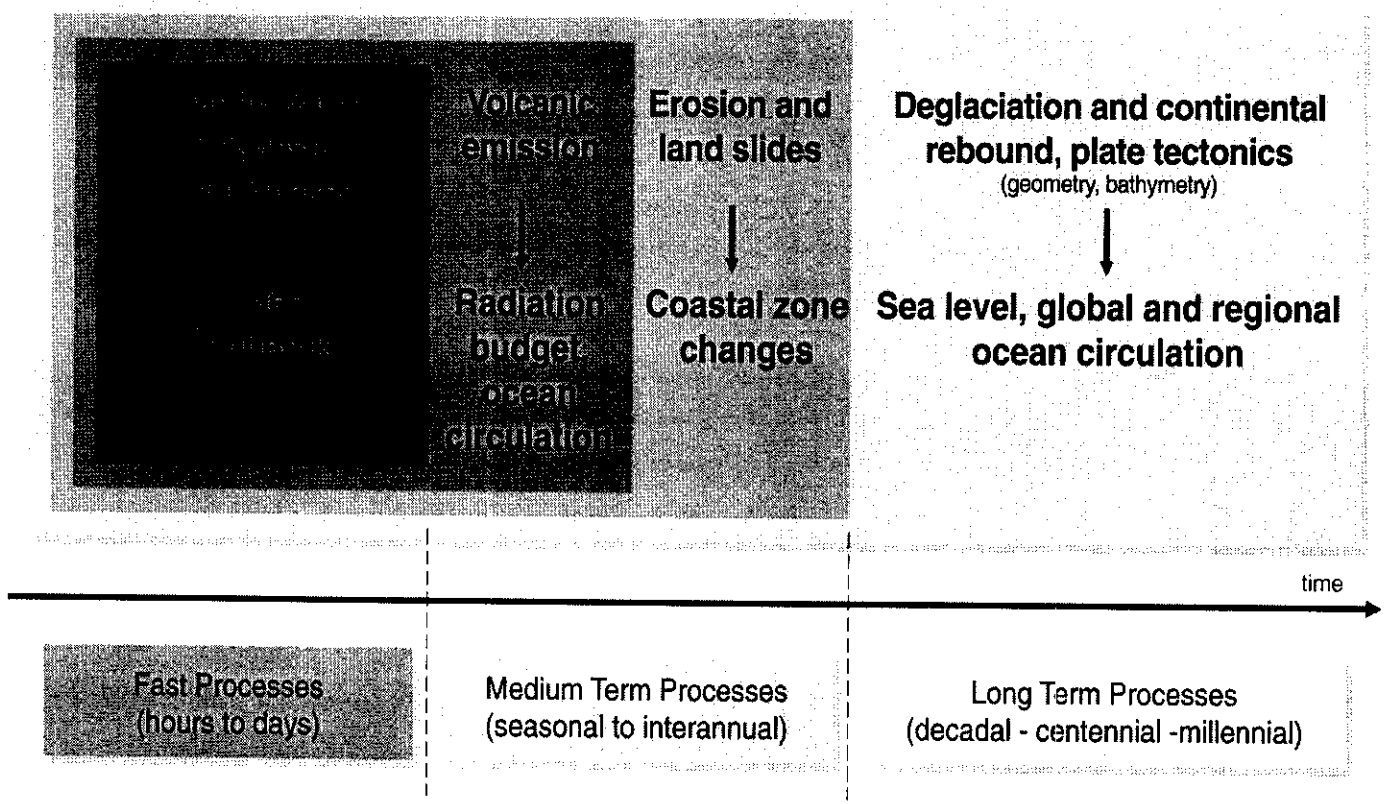
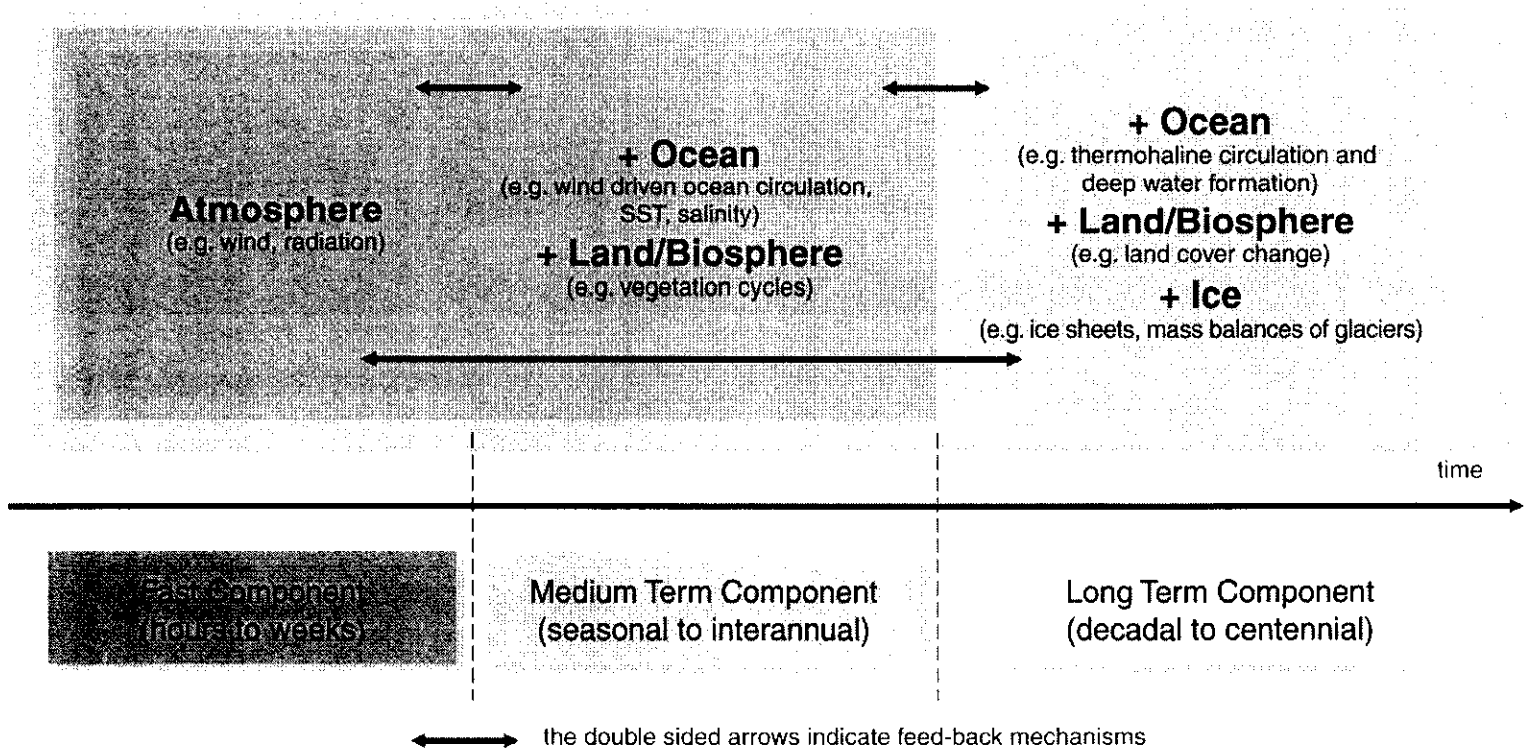
ESA' Living Planet Programme
Theme 1 - Earth Interior

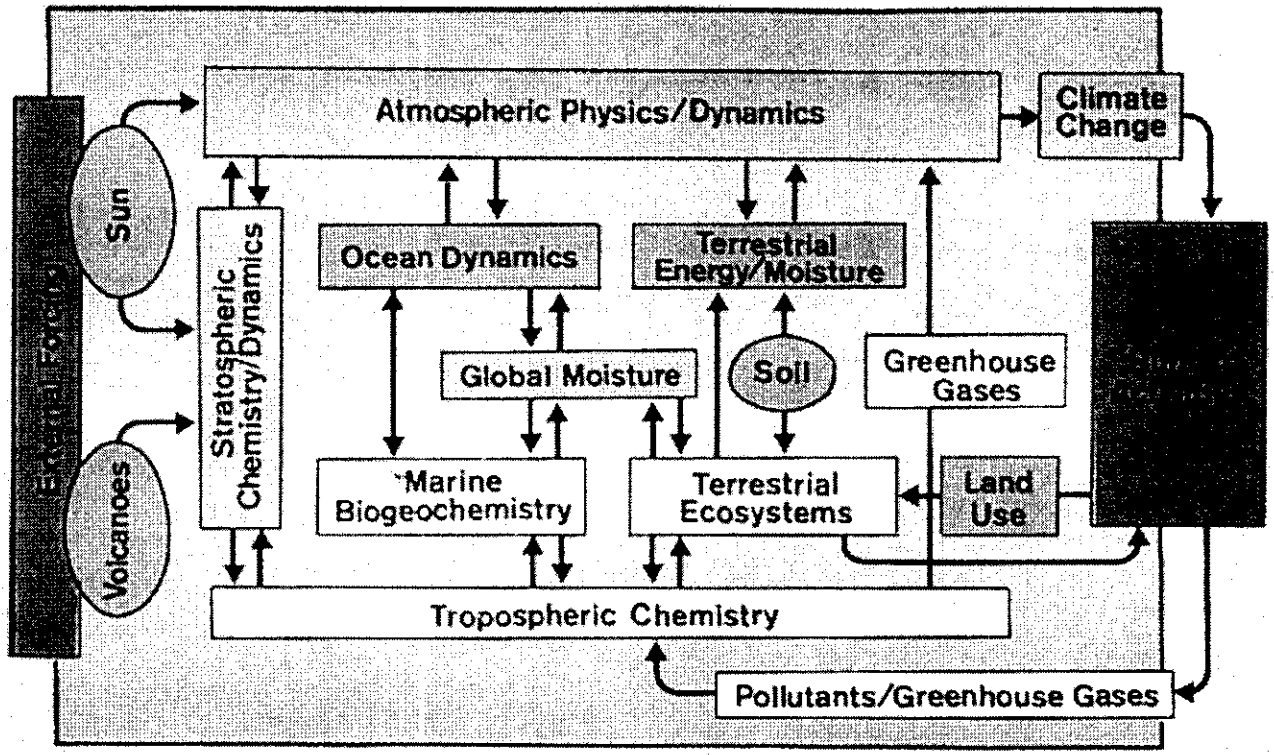


ESA' Living Planet Programme
Theme 2 - Physical Climate



ESA' Living Planet Programme
The Physical and Biophysical Systems

Physical Climate System

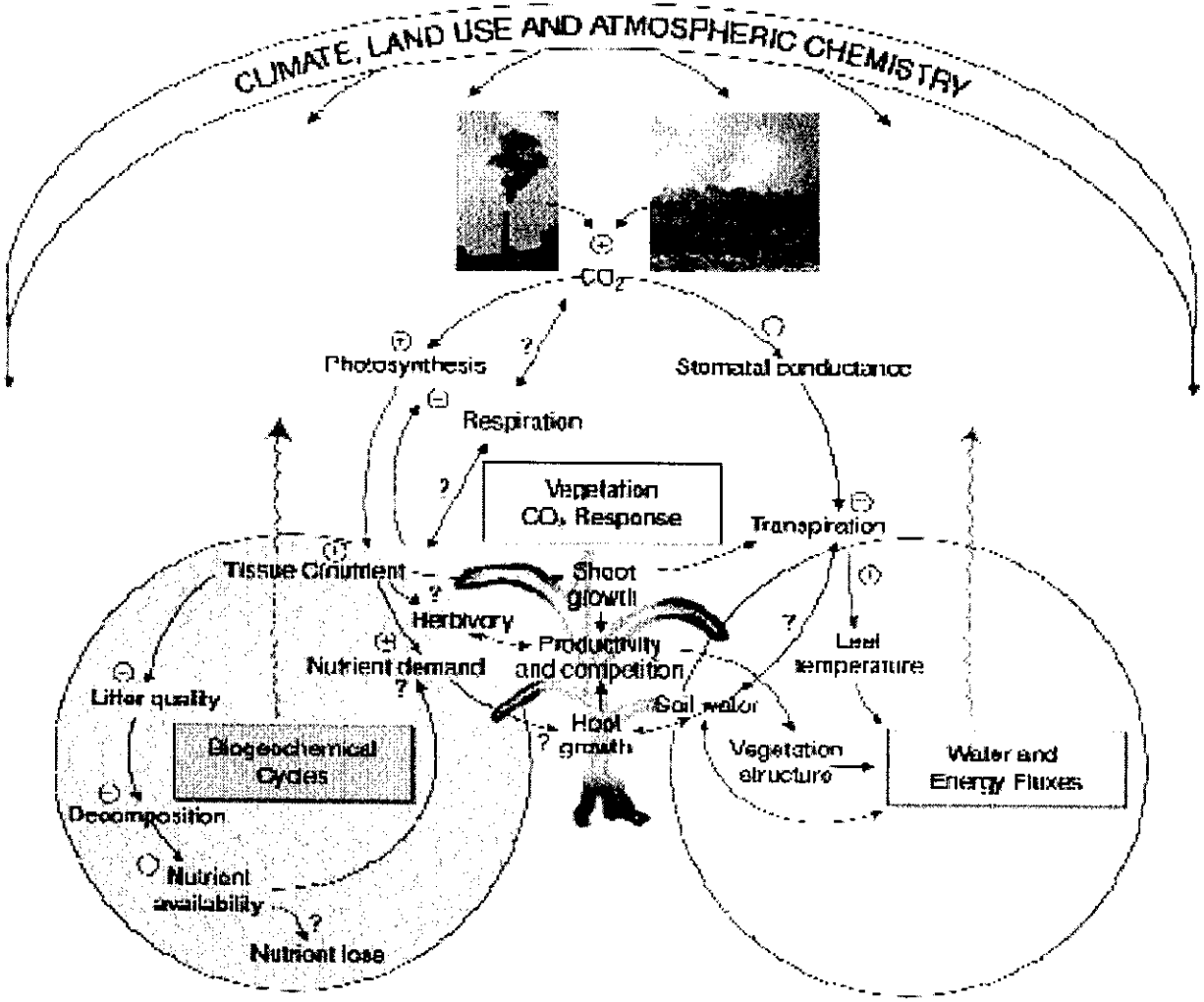


Biogeochemical Cycles

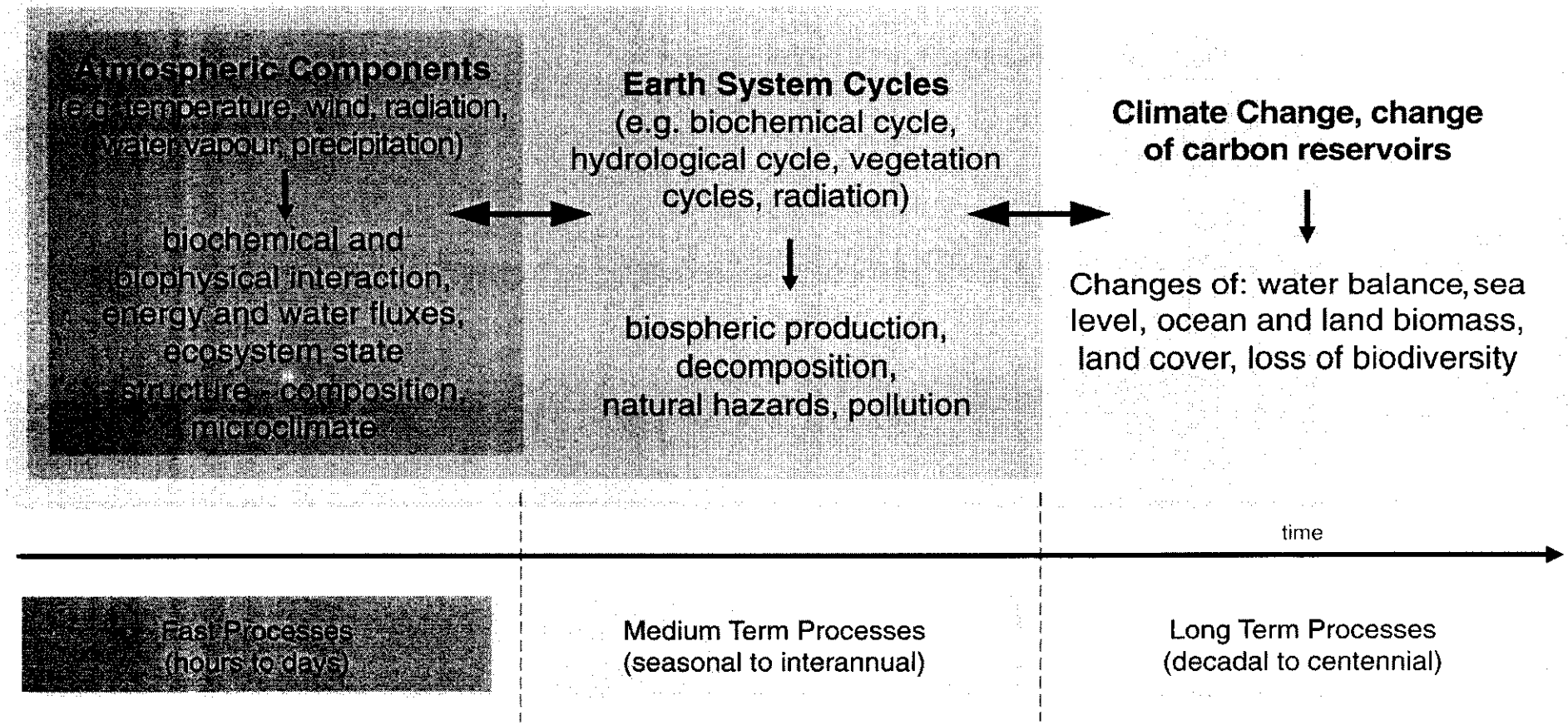
Theme 3 - Geosphere/Biosphere

- The Energy and Water Cycles
- The Bio-Chemical Cycles
- The Productivity of Different Ecosystems

ESA' Living Planet Programme
The Earth Model - Links



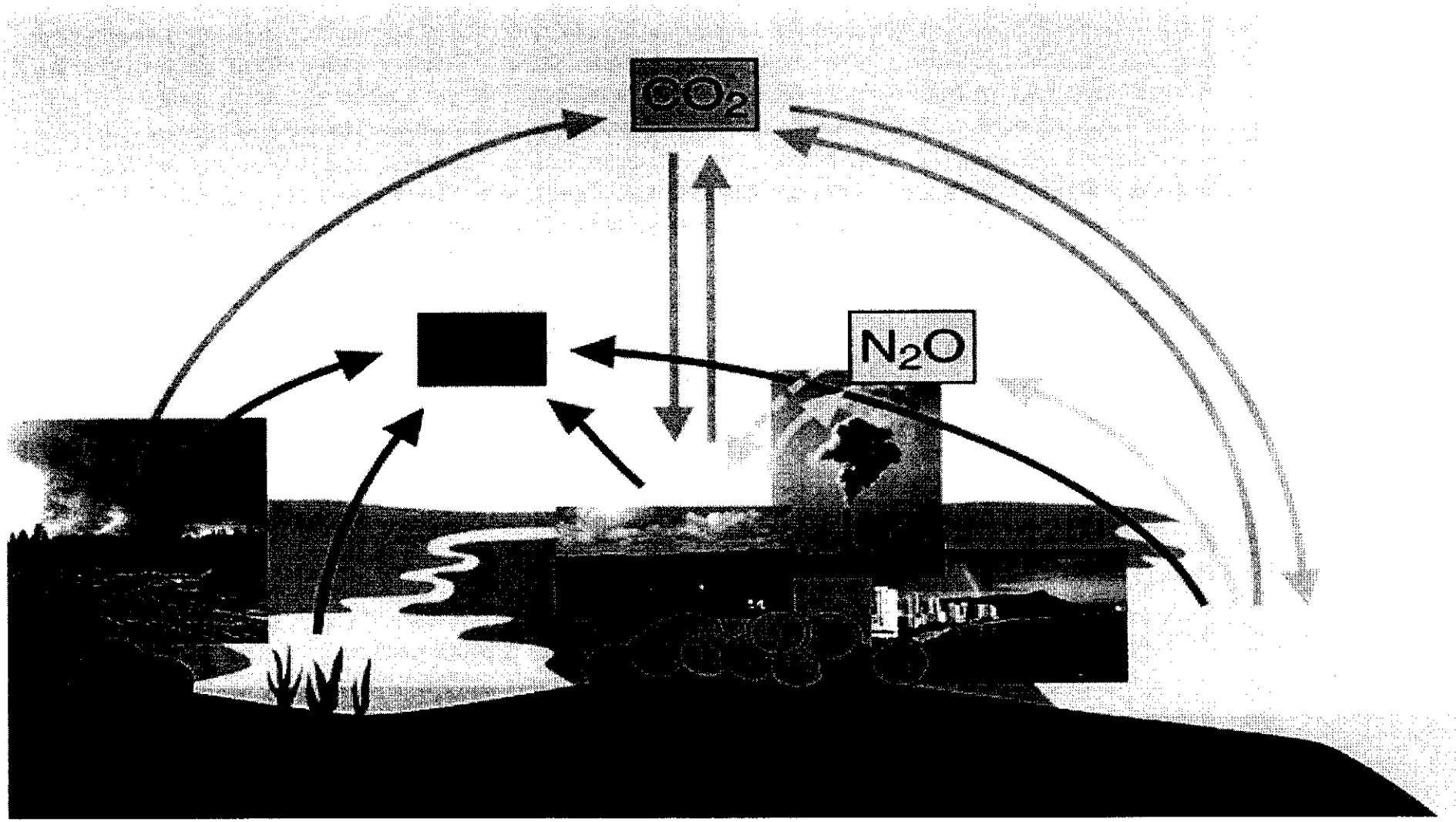
Examples for geo-biospheric interaction: The links between the components



Theme 4 - Atmosphere and Marine Environment: Anthropogenic Impact

- Changes in Atmospheric Composition Induced by Human Activity
- Chemical Processes in the Stratosphere and Upper Troposphere
- Marine Polution

ESA' Living Planet Programme
Chemical Interactions at the Surface



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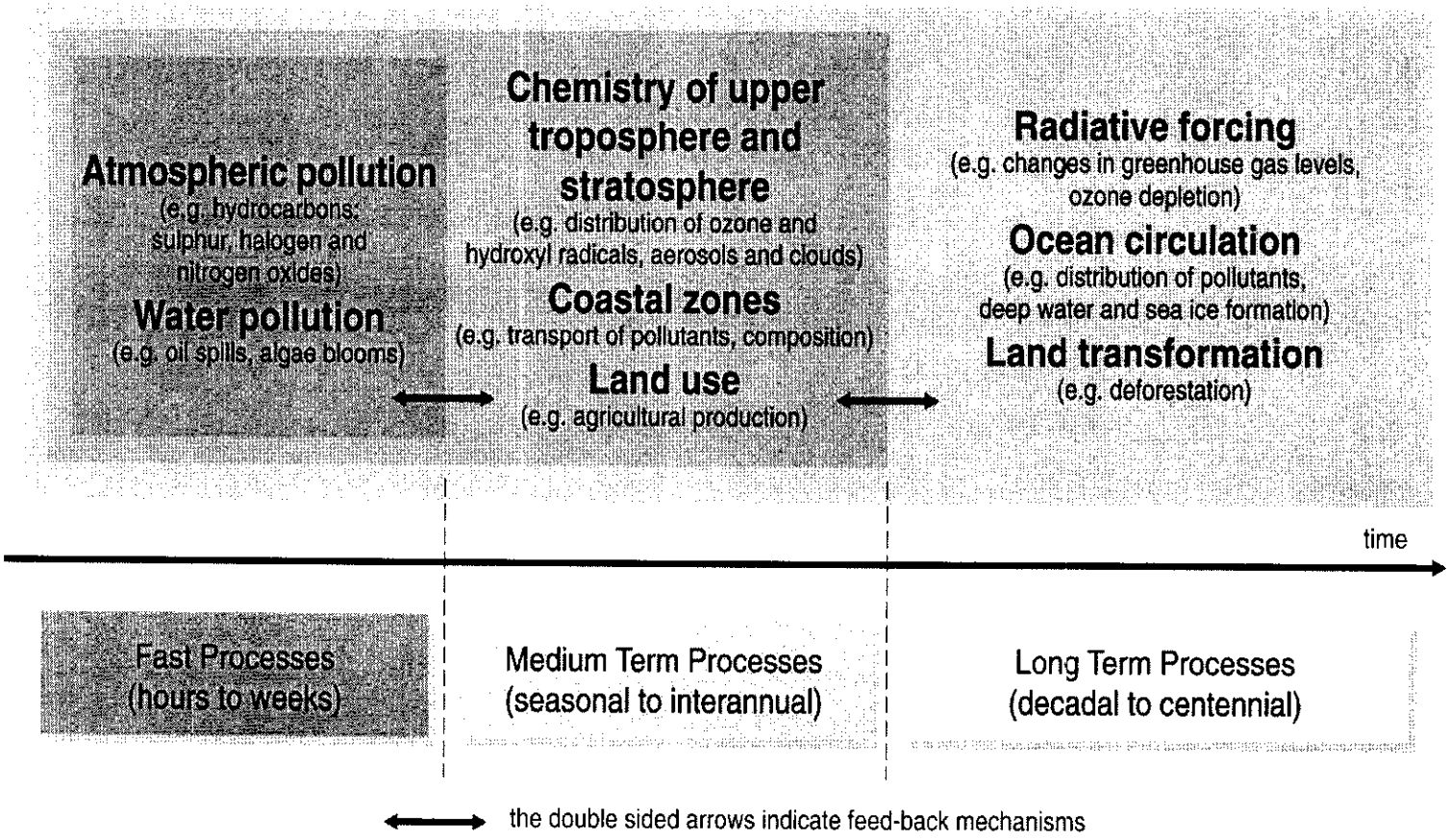
ESA' Living Planet Programme
Theme 4 - Anthropogenic Impacts



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The ESA Living Planet Programme
The Earth Explorer Missions (2)

- **Earth Explorer Core Missions:**

  Granada I (May 1996) - presentation of 9 missions for Phase A Study: 4 selected for Phase A study
  Granada II (October 1999) - presentation of 4 missions for Phase B Study and implementation: 2 to be selected

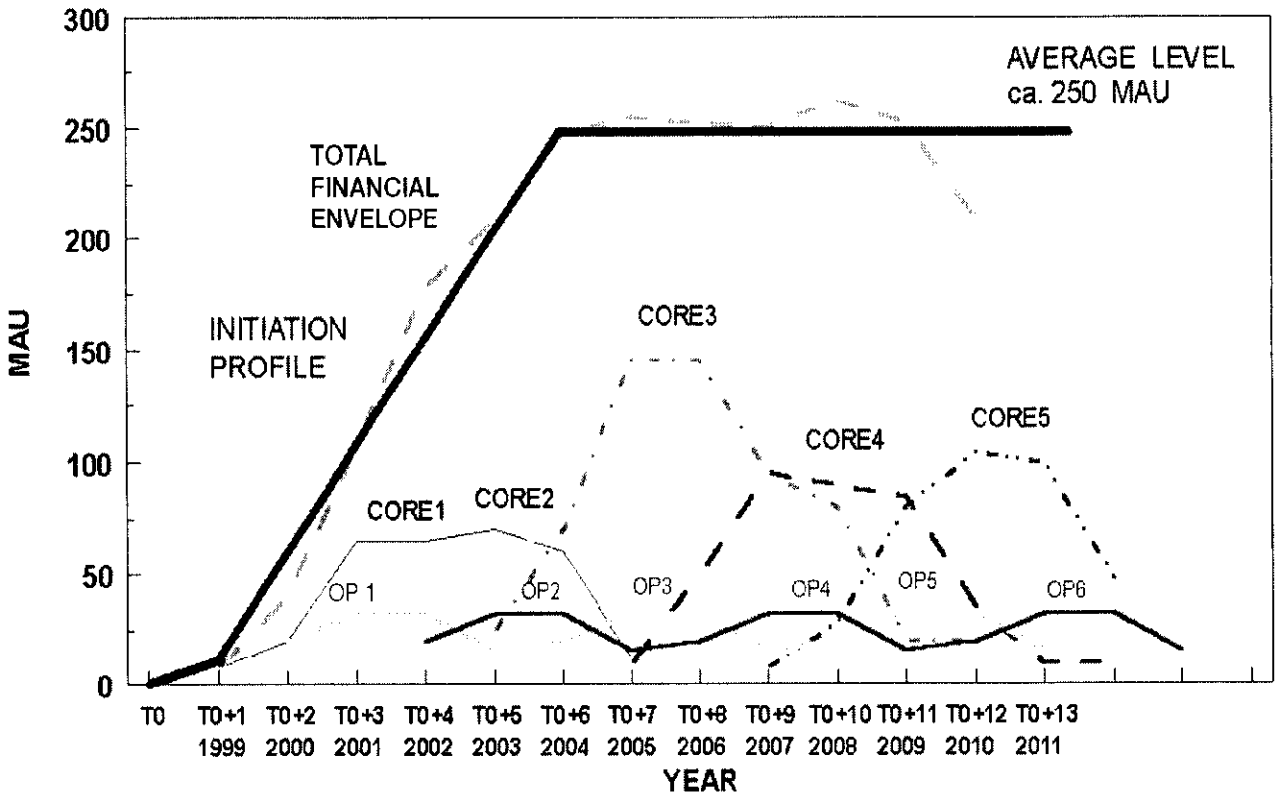
- **Earth Explorer Opportunity Missions:**

  First Call for Proposals (July 1998) - 27 proposals submitted: 5 missions recommended in order of priority by the Earth Sciences Advisory Committee for implementation (April 1999): recommendations endorsed by the Programme Board for Earth Observation

- **Cyclic selection process; further Calls and consultation meetings planned**

- **Information on *<http:/www.estec.esa.nl/explorer/>***

The ESA Living Planet Programme
The Earth Explorer Missions (3)



Exploring the Atmosphere by Remote Sensing Techniques
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Four candidate missions have been subjected to Phase A studies:

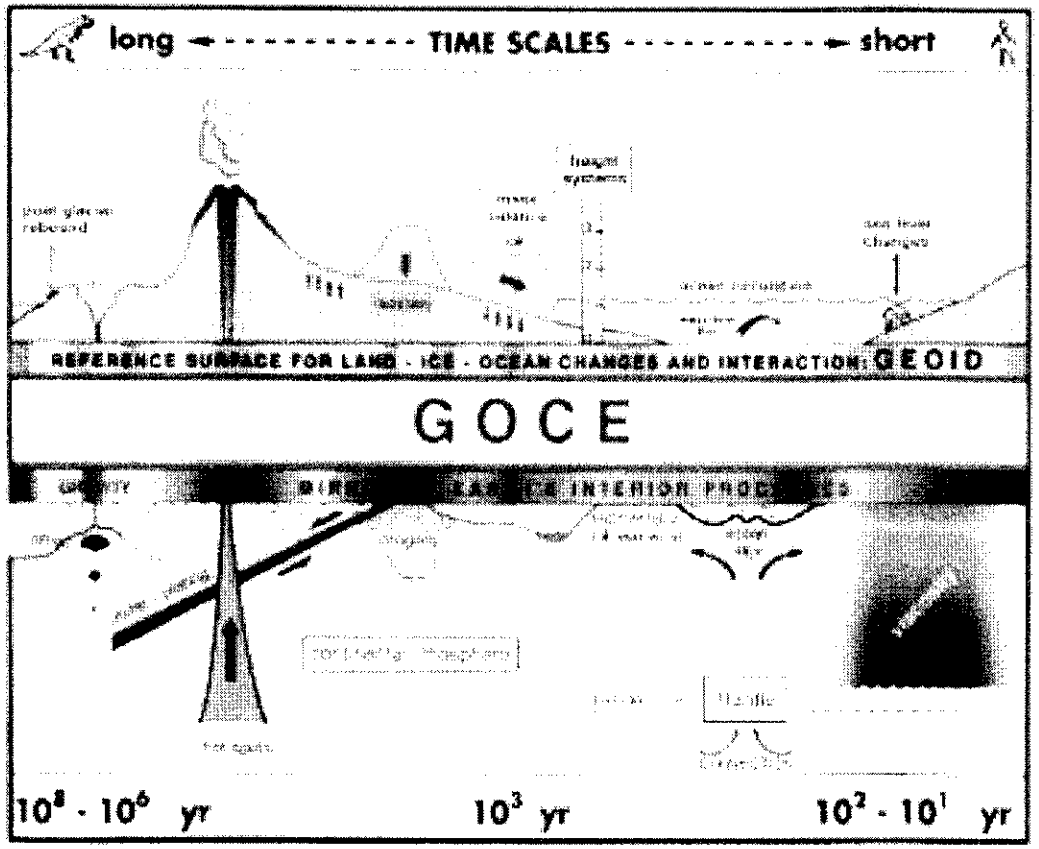
- Gravity Field and Steady-State Ocean Circulation Mission
- Earth Radiation Mission
- Land-Surface Processes and Interactions Mission
- Atmospheric Dynamics Mission

All four will be presented during the Granada II meeting: following Granada II two will be selected for implementation

Ice Sheet Melting

Earthquakes & volcanic activities

Global unification of height system



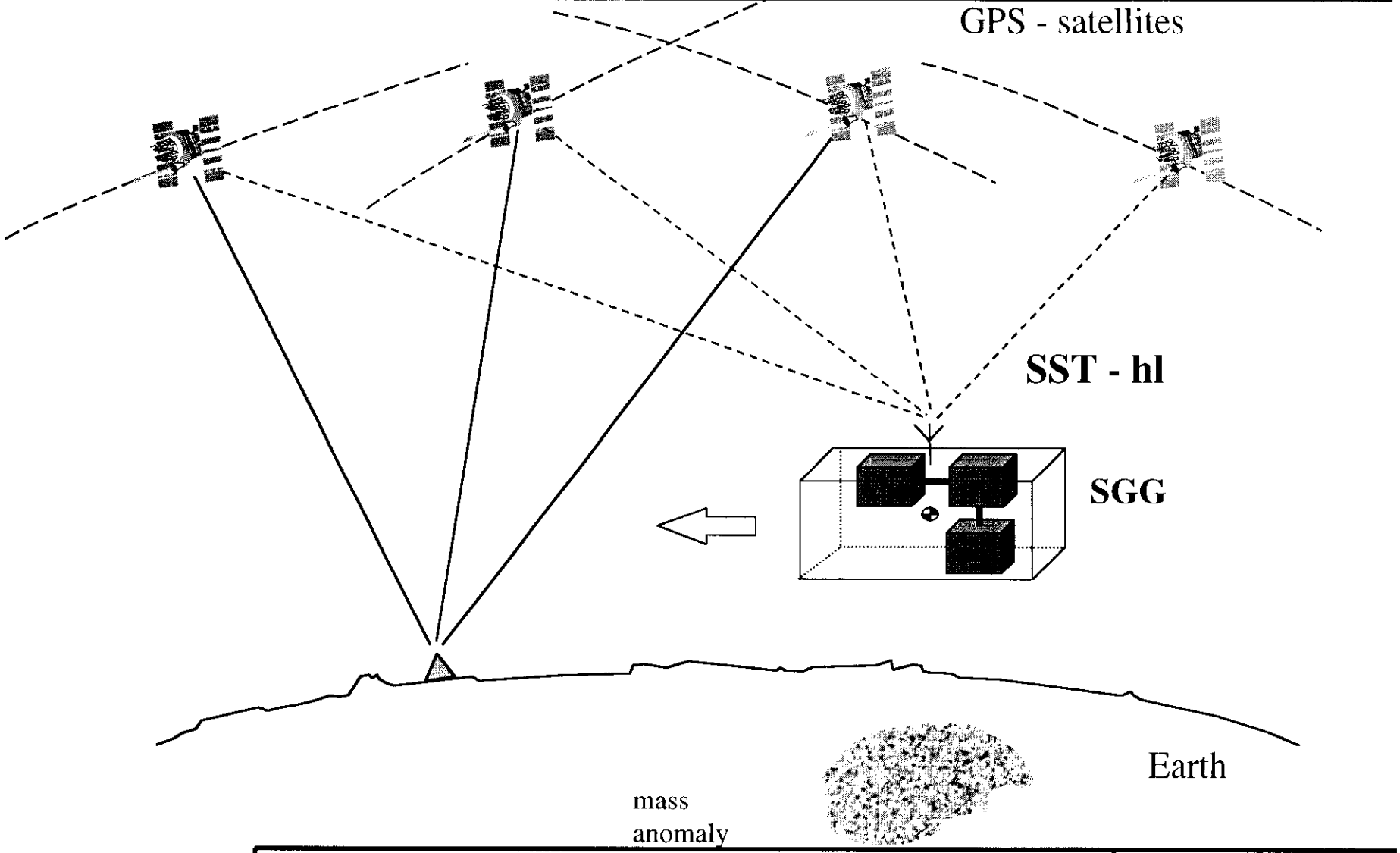
Thermohaline ocean circulation & heat transport

Sea level change

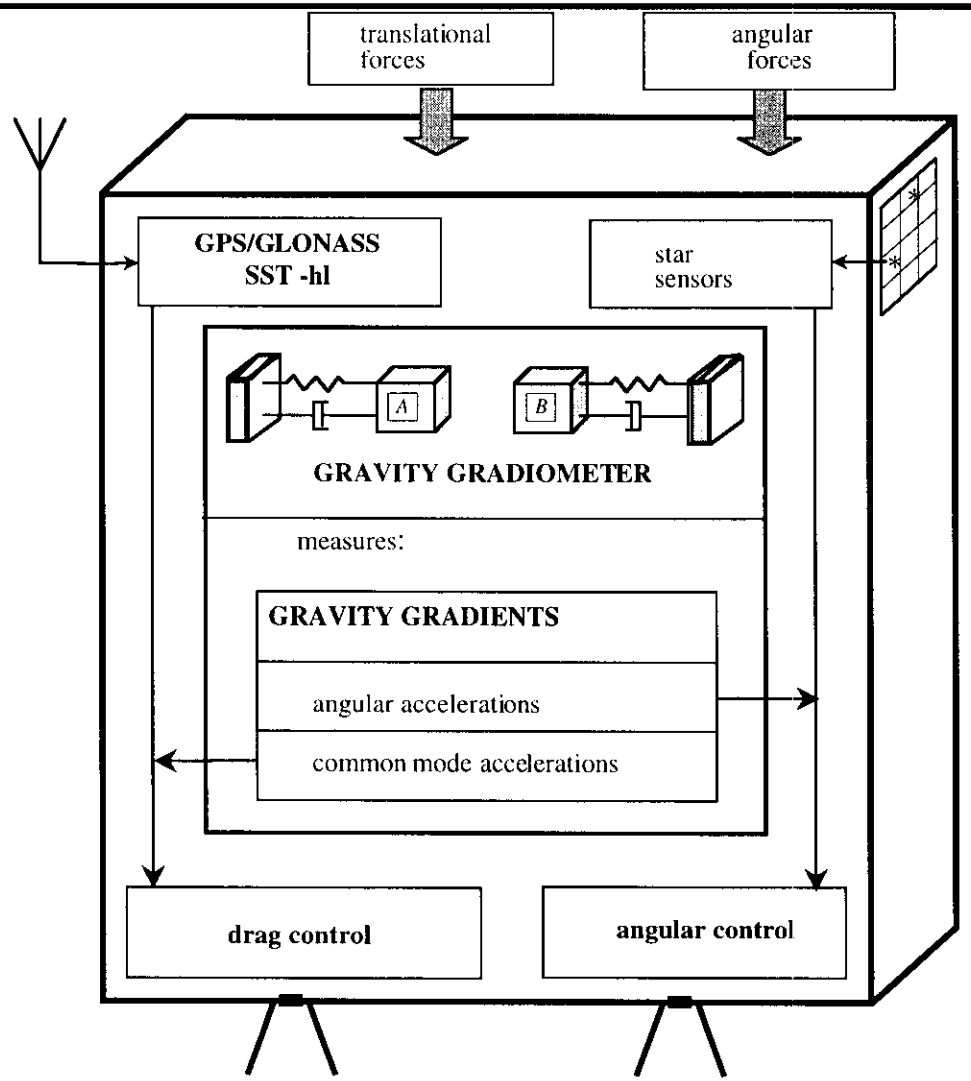
The Mission objectives are:

- determine the Earth's gravity field with an accuracy of
  1 mgal (1 mgal = 10^{-5} m/s^2)
- determine the geoid (= equipotential surface for a hypothetical ocean at rest) with an accuracy of 1 cm
- achieve this at length scales down to L = 100 km
  (degree and order 200)

The Earth Explorer Core Missions
Gravity Field and Steady-State Ocean Circulation Mission (3)



The Earth Explorer Core Missions
Gravity Field and Steady-State Ocean Circulation Mission (4)



Scientific Objectives

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These objectives are the result of joint Japanese - European discussions

Instrument Performance

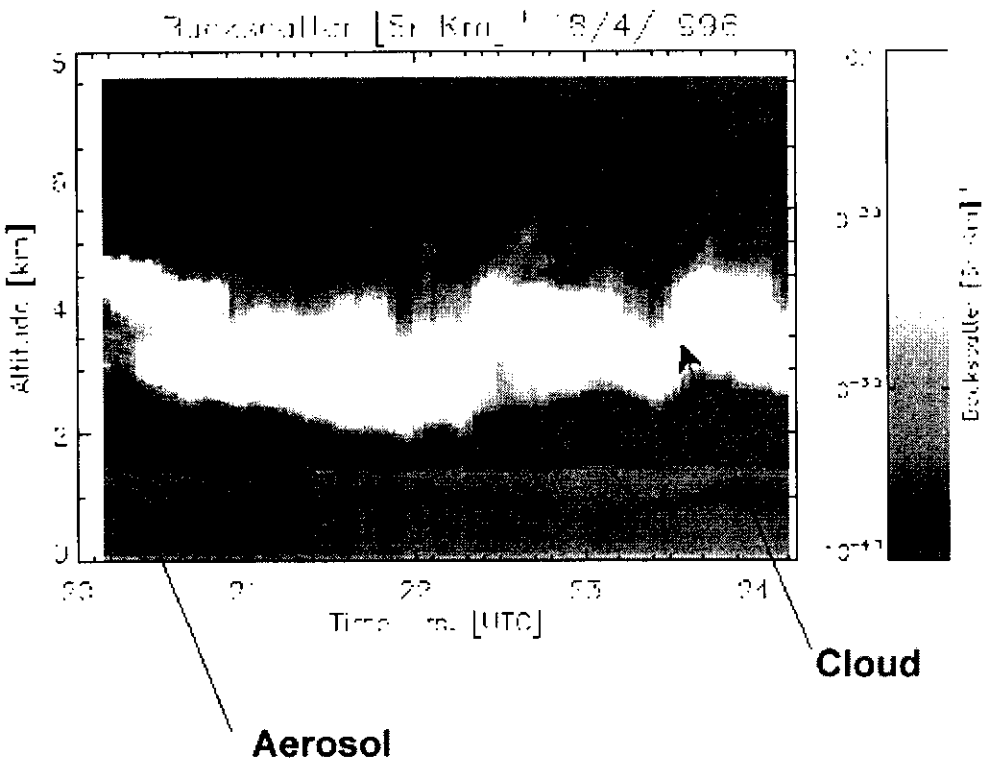
- **Lidar**
  - very **sensitive** for clouds and aerosols but **attenuated** by clouds
  - gate-by-gate **correction** of attenuation **unstable**
- **Radar**
  - good for ice clouds - potential **synergy** with lidar?
- **Multi-Spectral Imager**
  - can provide **horizontal structure**
- **Broad Band Radiometer**
  - can provide TOA **radiance constraint**

Radar/Lidar Synergy in Ice Clouds

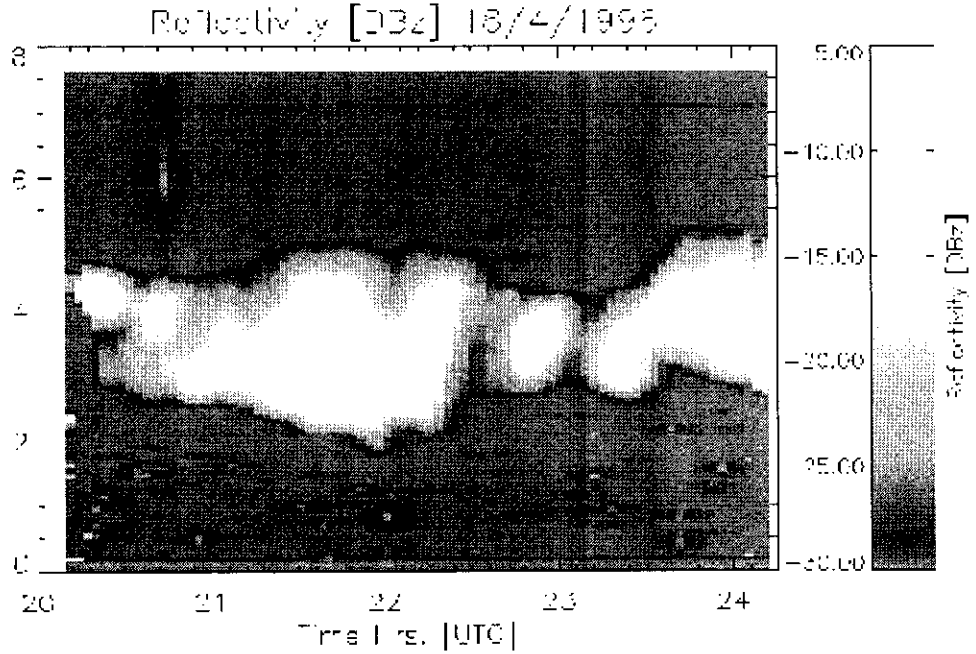
Radar/Lidar Retrieval - Example (I)

CLARA Campaign

Lidar (1μm)



Radar



Radar/Lidar Synergy

Effect of Separation - Cloud Variability

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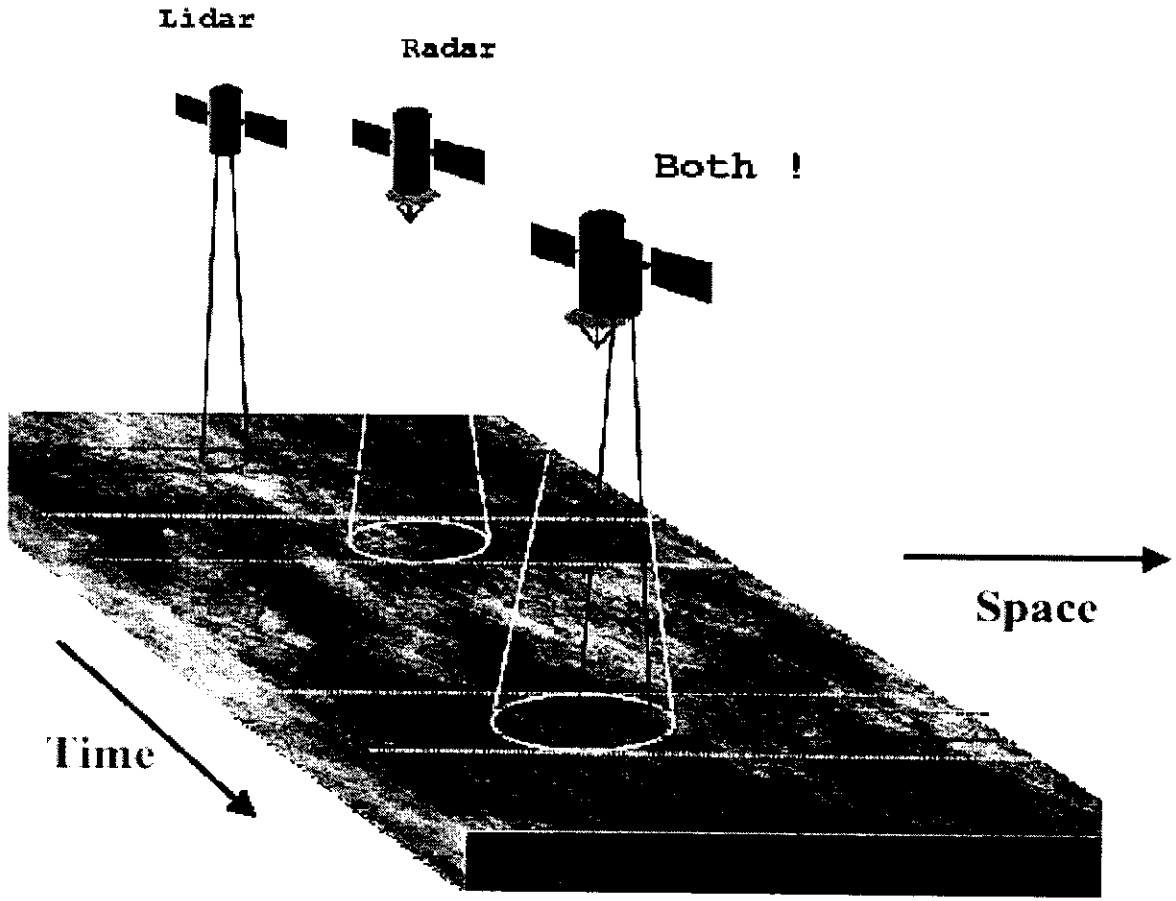
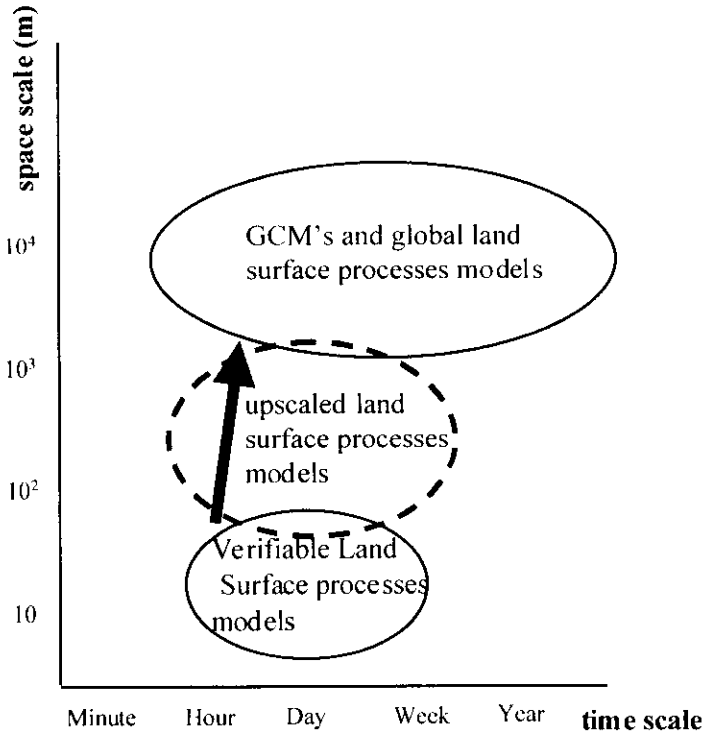
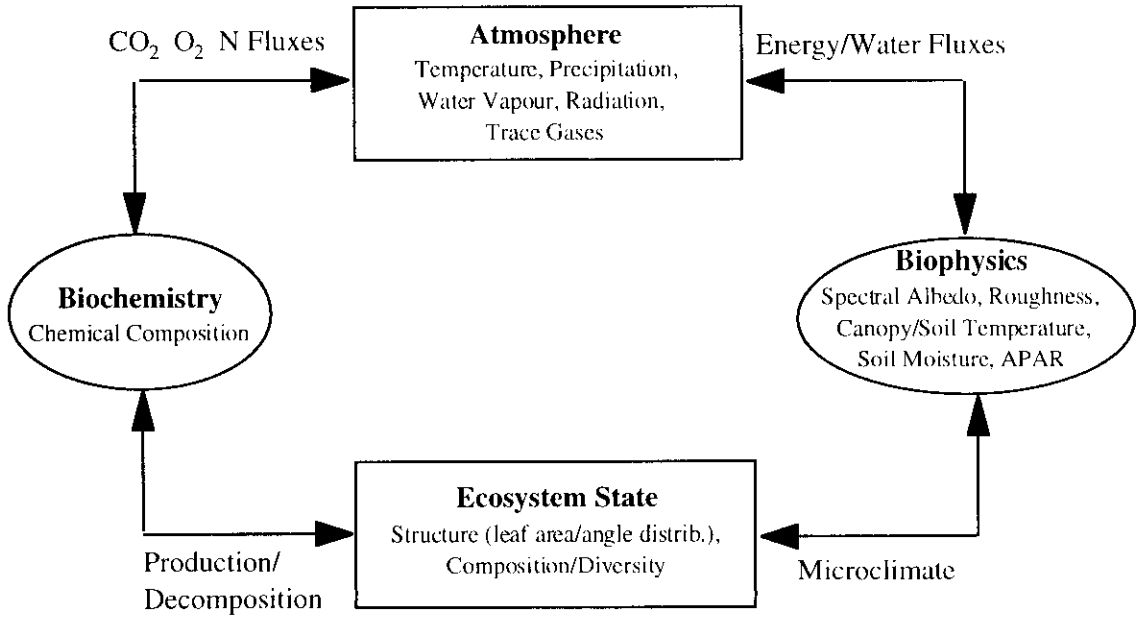


The prime objectives of this mission is to:

- **increase the understanding of biophysical processes and land/atmosphere interactions at the local scale**
- **advance understanding of these interactions, on a global scale.**

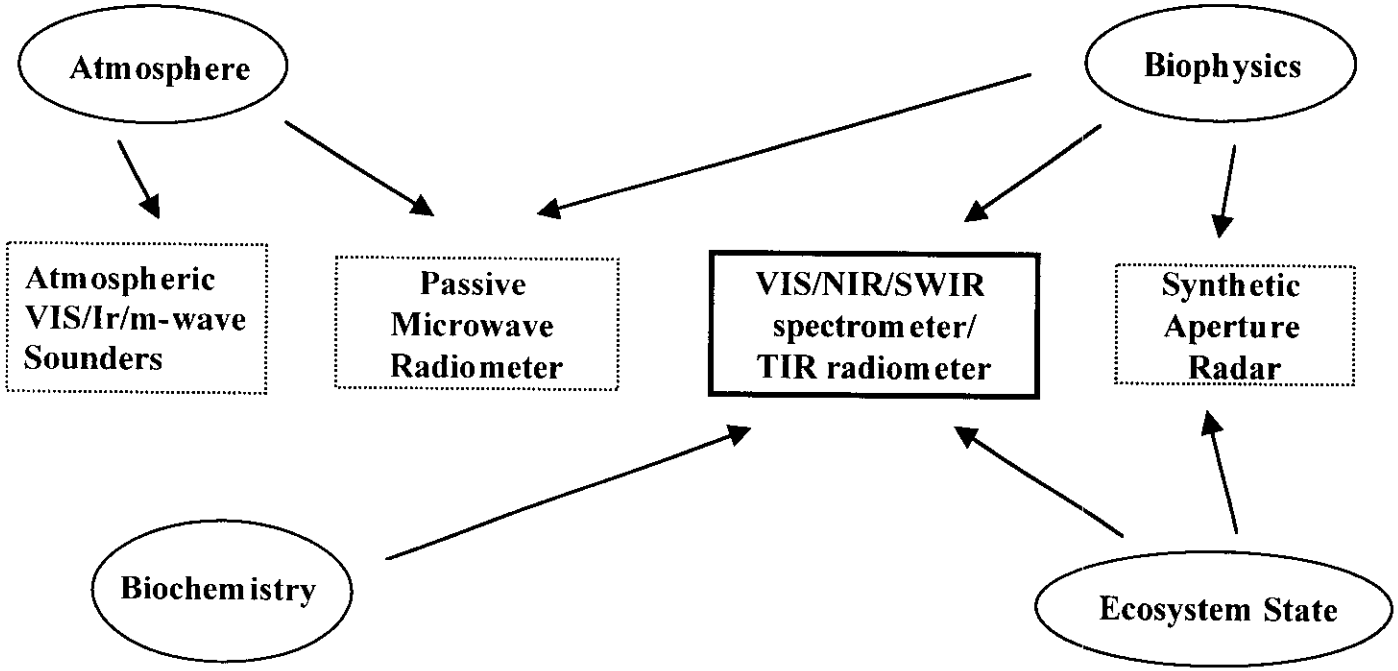


Scaling context of Land Surface Processes

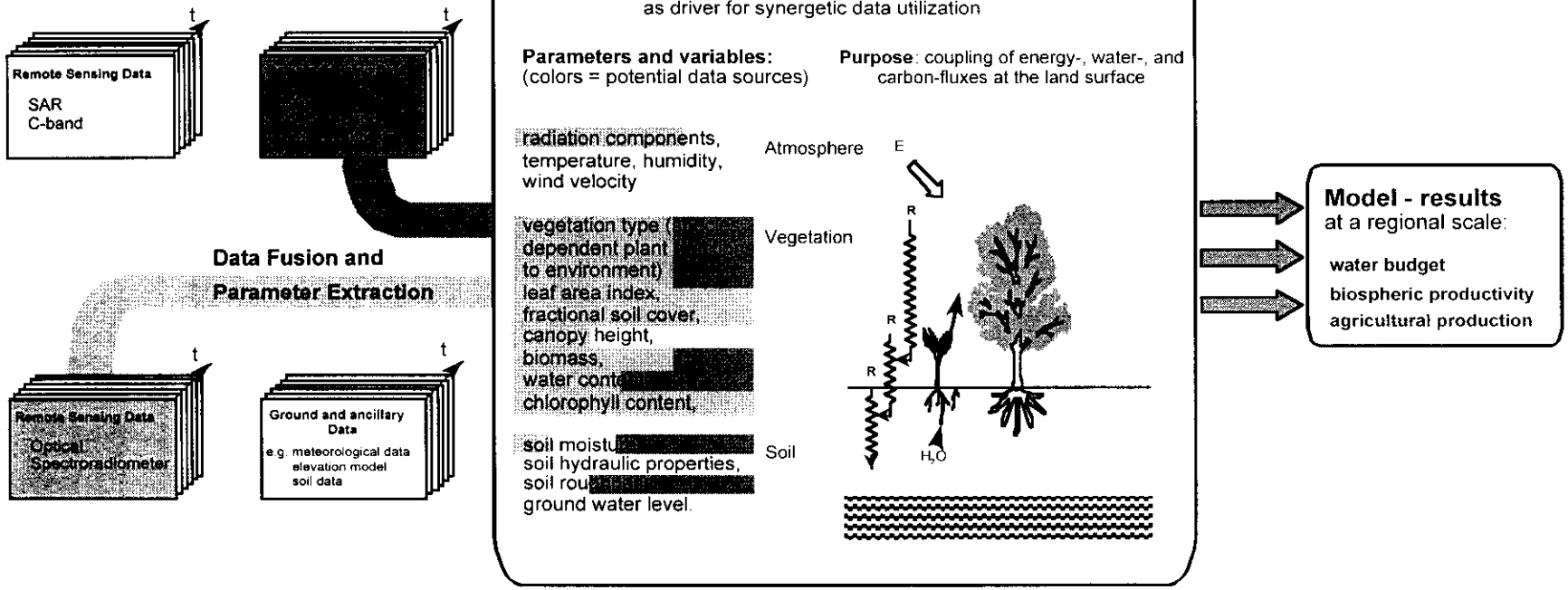


Biospheric Interactions and involved Process Variabes

Links between Process Variables and Candidate Mission Elements



SAR and Optical Spectroradiometer Data in Aggregated Models of Surface Processes



The preliminary ranges for the PRISM performance parameters are:

Spectral range:	**450 nm - 2350 nm at < 15 nm spectral sampling interval (spectral absorption features of vegetation and soils)** **8 - 8.5 μm, 8.6 - 9.1 surface temperature (vegetation and soils)**
Spatial sampling :	**around 50 m**
Swath width:	**around 50 km**
Pointing:	**across track depointing capability of about ± 30° for global access and BRDF measurements** **along track pointing ±70, ±60, ±45, 0 degrees for BRDF measurements**
Data transmission:	**Possibility of selection of bands tbd.(40 to 60 bands per scene), also for data reduction**

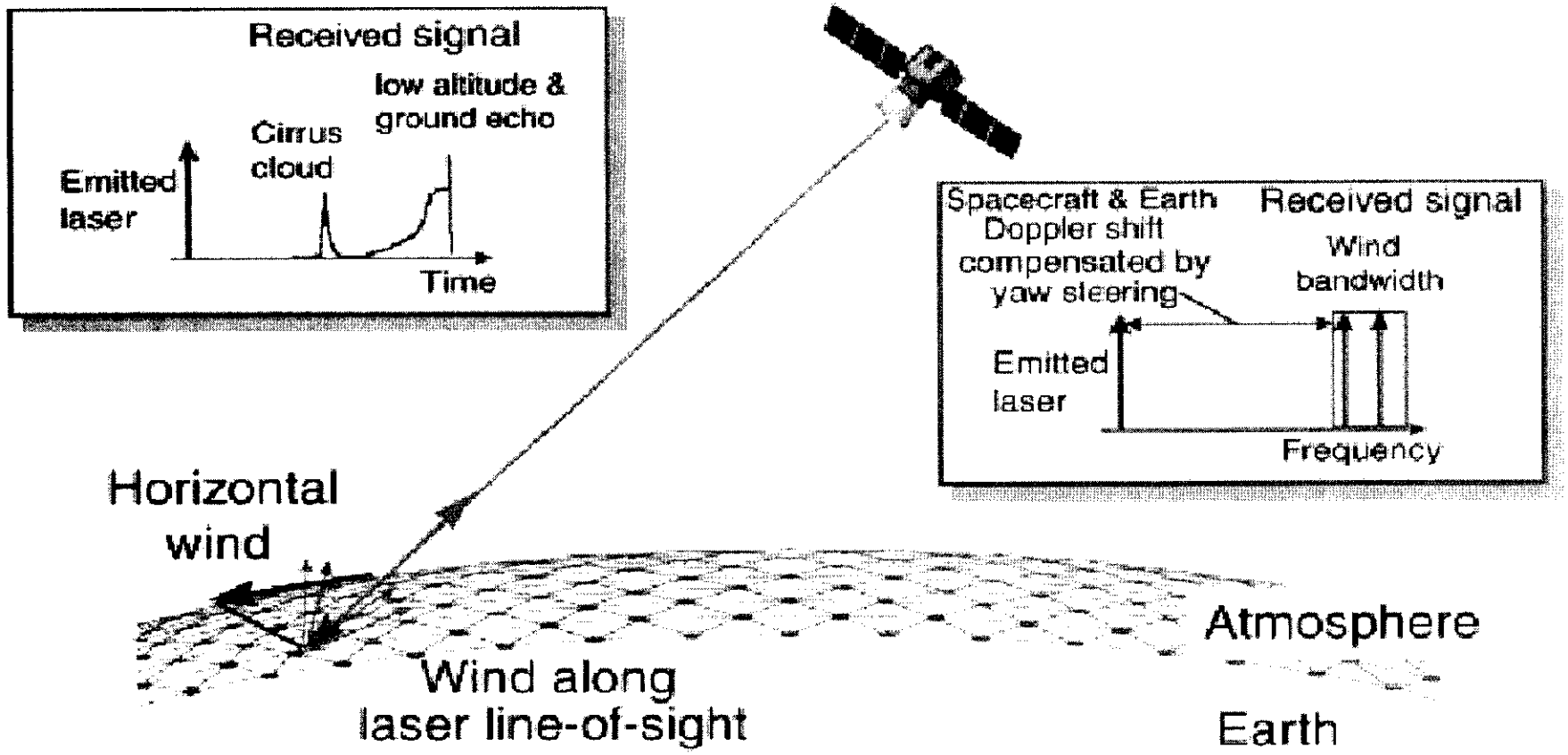
- ADM objectives
  - Improve understanding of atmospheric dynamics and global atmospheric transport
  - Improve understanding of global cycling of energy, water, aerosols, chemicals
- How is this achieved?
  - Improved analysis of the atmospheric state to provide a complete three-dimensional picture of the dynamical variables
- What are the benefits?
  - Improved parameterisation of atmospheric processes in models
  - Advanced climate and atmospheric flow modelling
  - Better initial conditions for weather forecasting

Observational Requirements

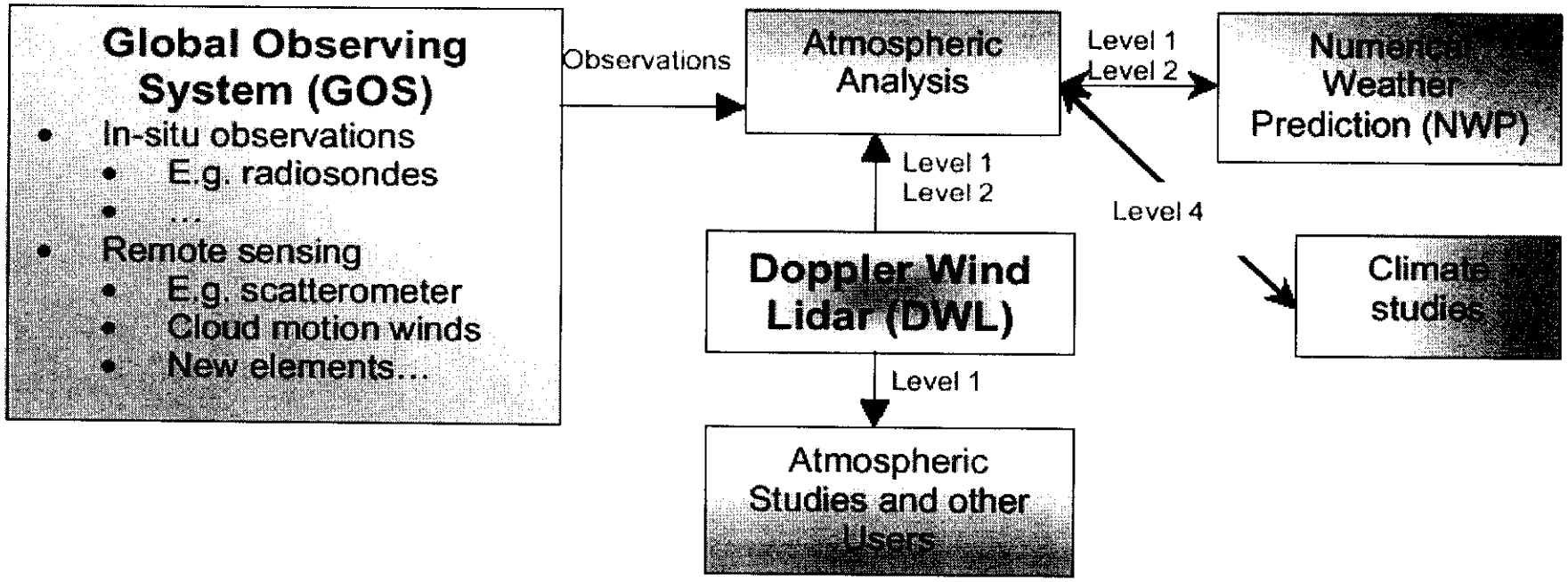
		PBL	Troposph.	Stratosph.
Vertical Domain	[km]	0-2	2-16	16-20
Vertical Resolution	[km]	0.5	1.0	2.0
Horizontal Domain			global	
Number of Profiles	[hour^{-1}]		100	
Profile Separation	[km]		> 200	
Temporal Sampling	[hour]		12	
Accuracy (Component)	[ms^{-1}]	2	2-3	3
Horizontal Integration	[km]		50	
Error Correlation			0.01	
Reliability	[%]		95	
Timeliness	[hour]		3	
Length of Observational Data Set	[yr]		3	

Space-Borne Doppler Wind Lidar

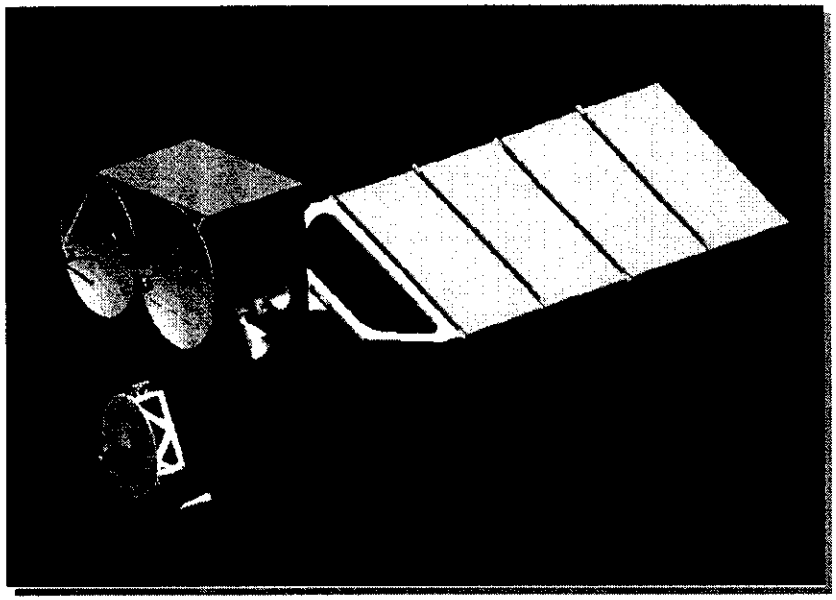
Operating principle:



Mission Elements



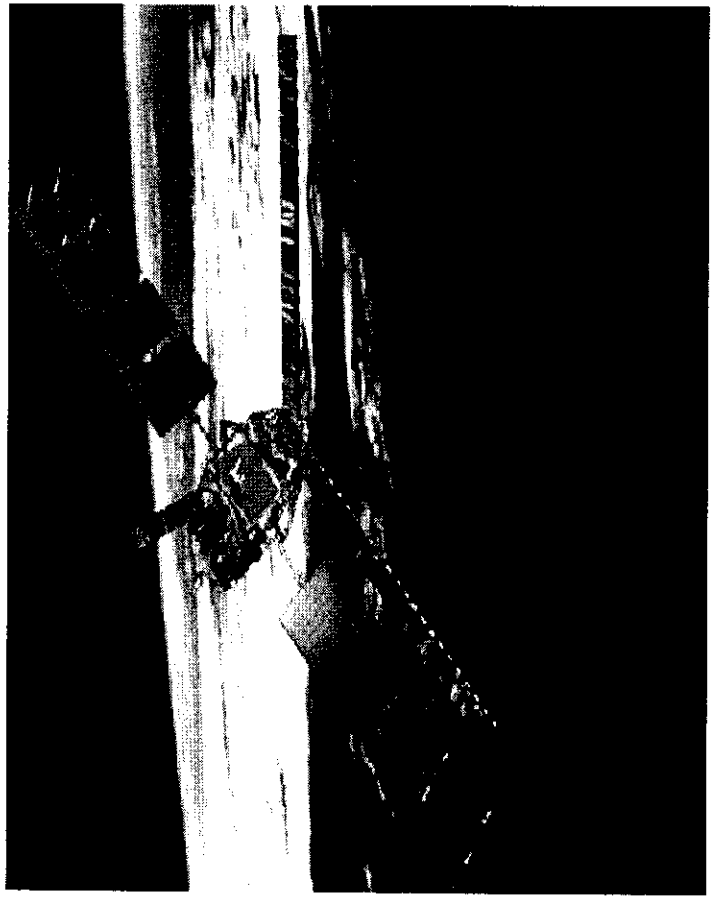
The Doppler Wind Lidar is the main innovation



CRYOSAT

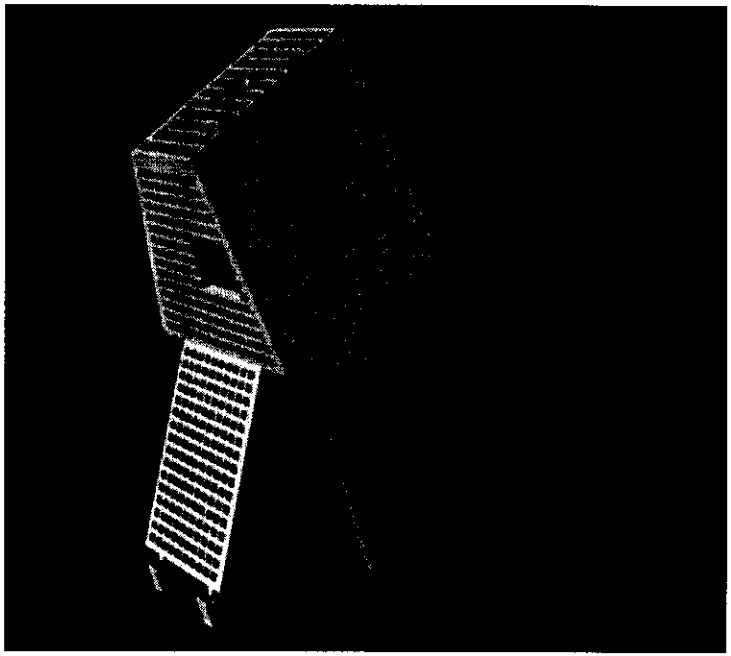
- For observing the ice sheets and sea ice to conduct research concerned with sea level rise and the role of fresh water in the climate system.
- Advanced microwave altimeter exploiting SAR and interferometric techniques in Ku-Band
- Selected for Phase A/B Study;

ESA' Living Planet Programme
The Earth Explorer Opportunity Missions (2)



SMOS - Soil Moisture and Ocean Salinity Satellite

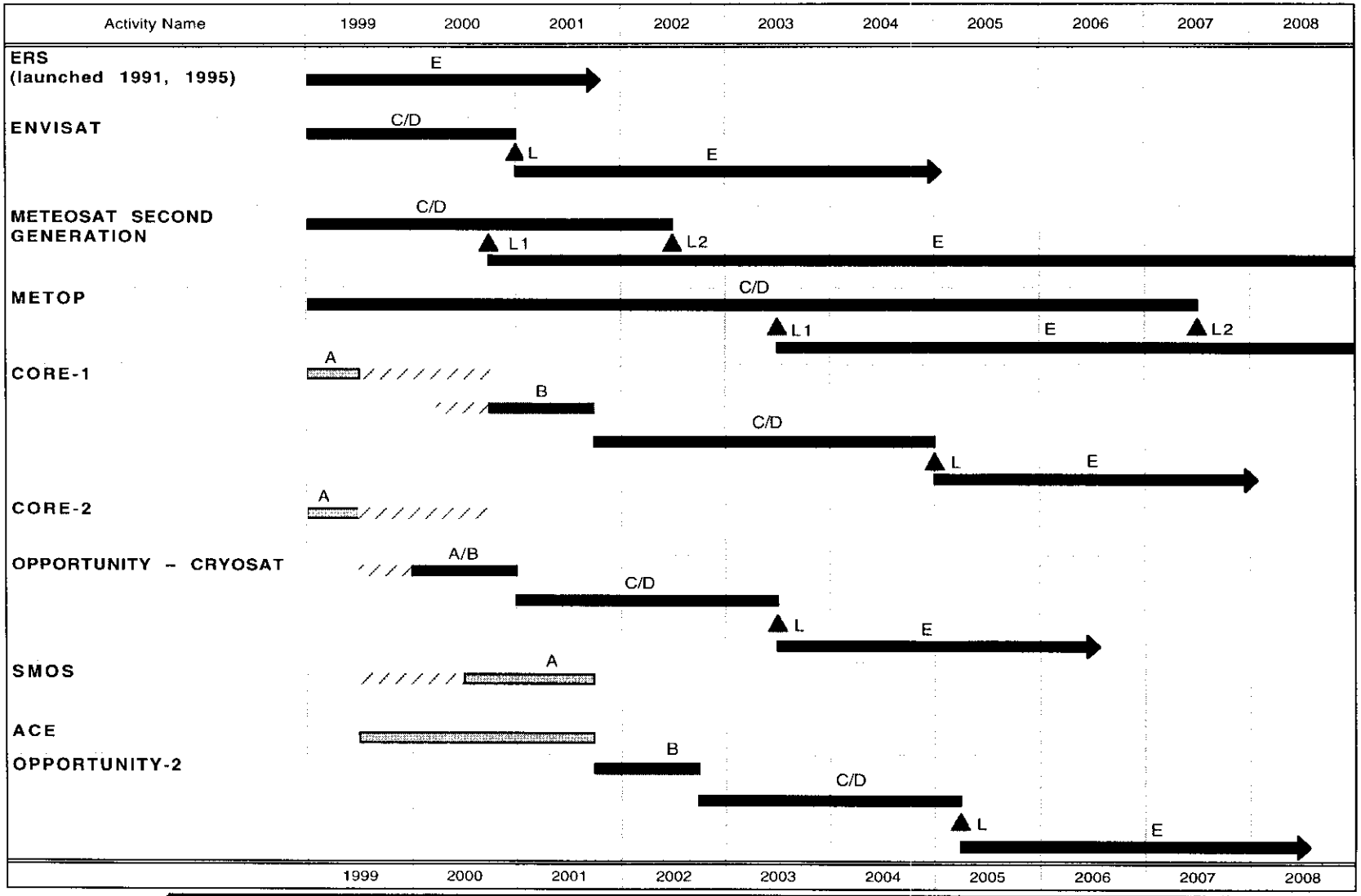
- **To observe ocean salinity, soil moisture, sea-ice and snow cover for meteorological, climatological, hydrological, oceanographical and glaciological studies.**
- **A passive microwave radiometer exploiting SAR and interferometric techniques at 1.4 GHz.**
- **Selected for extended Phase A Study**



ACE - Atmospheric Climate Experiment

- For monitoring temperature and water vapour in the lower stratosphere and upper troposphere for climate change research.
- Exploits the global satellite navigation systems to measure refractive index.
- Selected as the "hot" spare;.

ESA' Living Planet Programme
Overall Schedule



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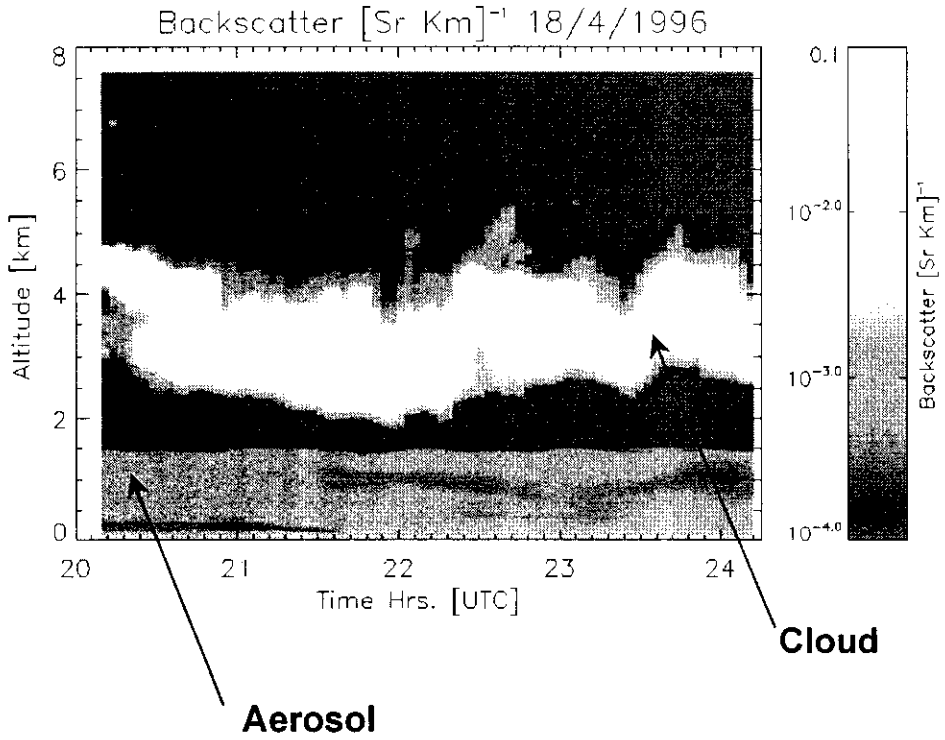
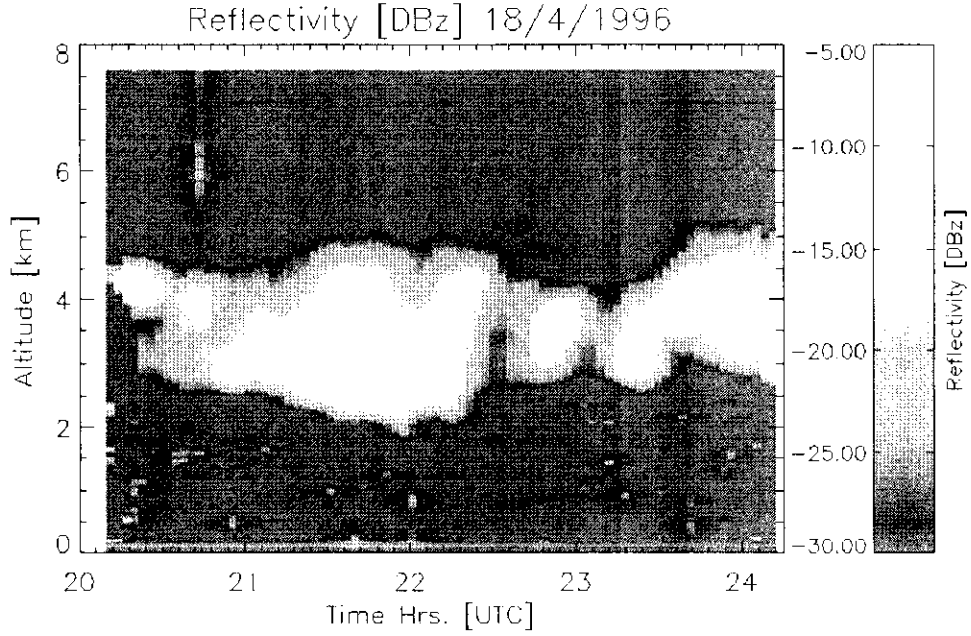


Radar



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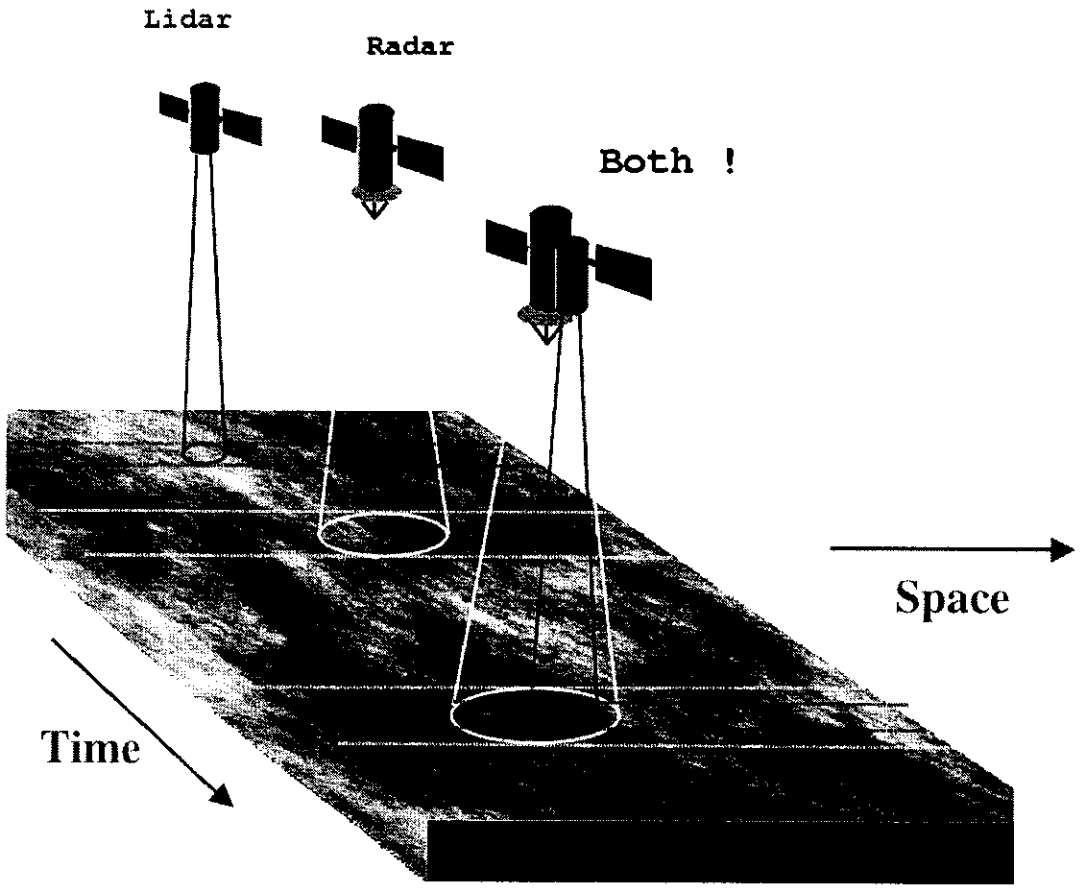

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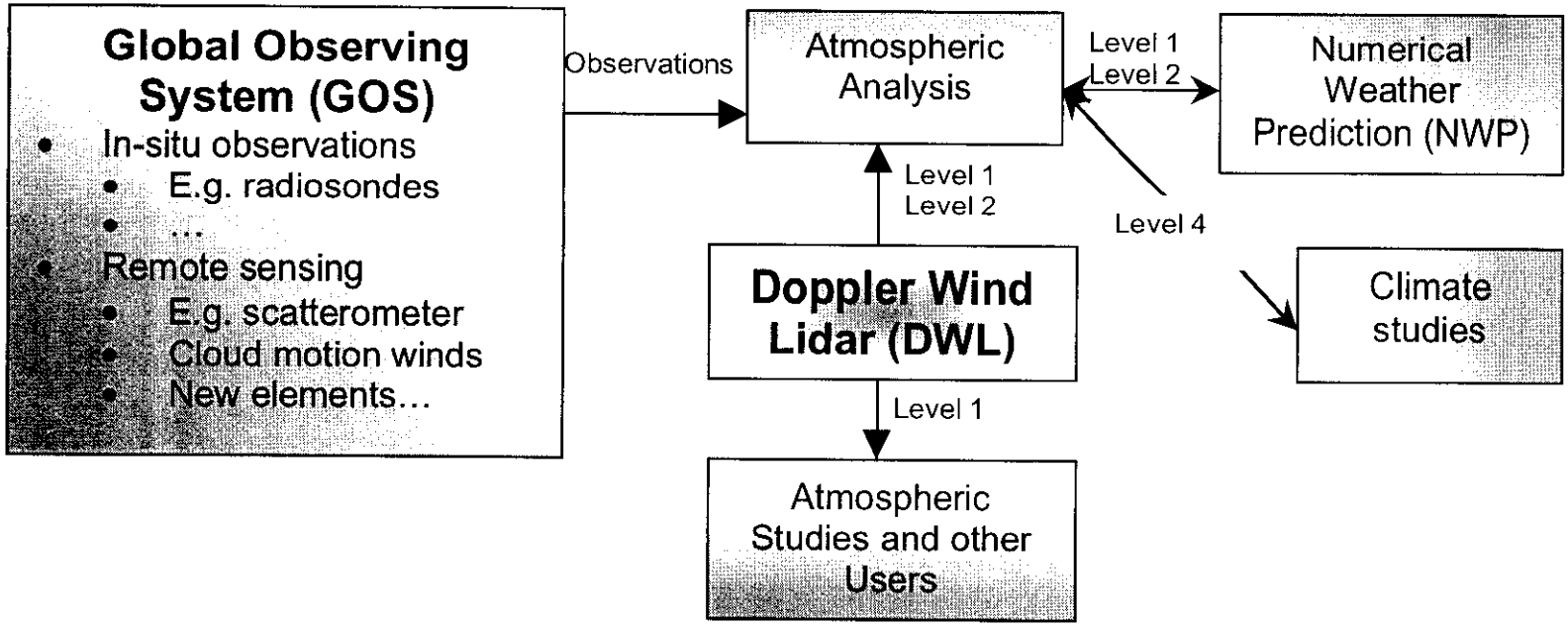
  - Improve understanding of global cycling of energy, water, aerosols, chemicals
- How is this achieved?
  - Improved analysis of the atmospheric state to provide a complete three-dimensional picture of the dynamical variables
- What are the benefits?
  - Improved parameterisation of atmospheric processes in models
  - Advanced climate and atmospheric flow modelling
  - Better initial conditions for weather forecasting

		Observational Requirements		
		PBL	Troposph.	Stratosph.
Vertical Domain	[km]	0-2	2-16	16-20
Vertical Resolution	[km]	0.5	1.0	2.0
Horizontal Domain			global	
Number of Profiles	[hour^{-1}]		100	
Profile Separation	[km]		> 200	
Temporal Sampling	[hour]		12	
Accuracy (Component)	[ms^{-1}]	2	2-3	3
Horizontal Integration	[km]		50	
Error Correlation			0.01	
Reliability	[%]		95	
Timeliness	[hour]		3	
Length of Observational Data Set	[yr]		3	



The Doppler Wind Lidar is the main innovation

Operating principle: