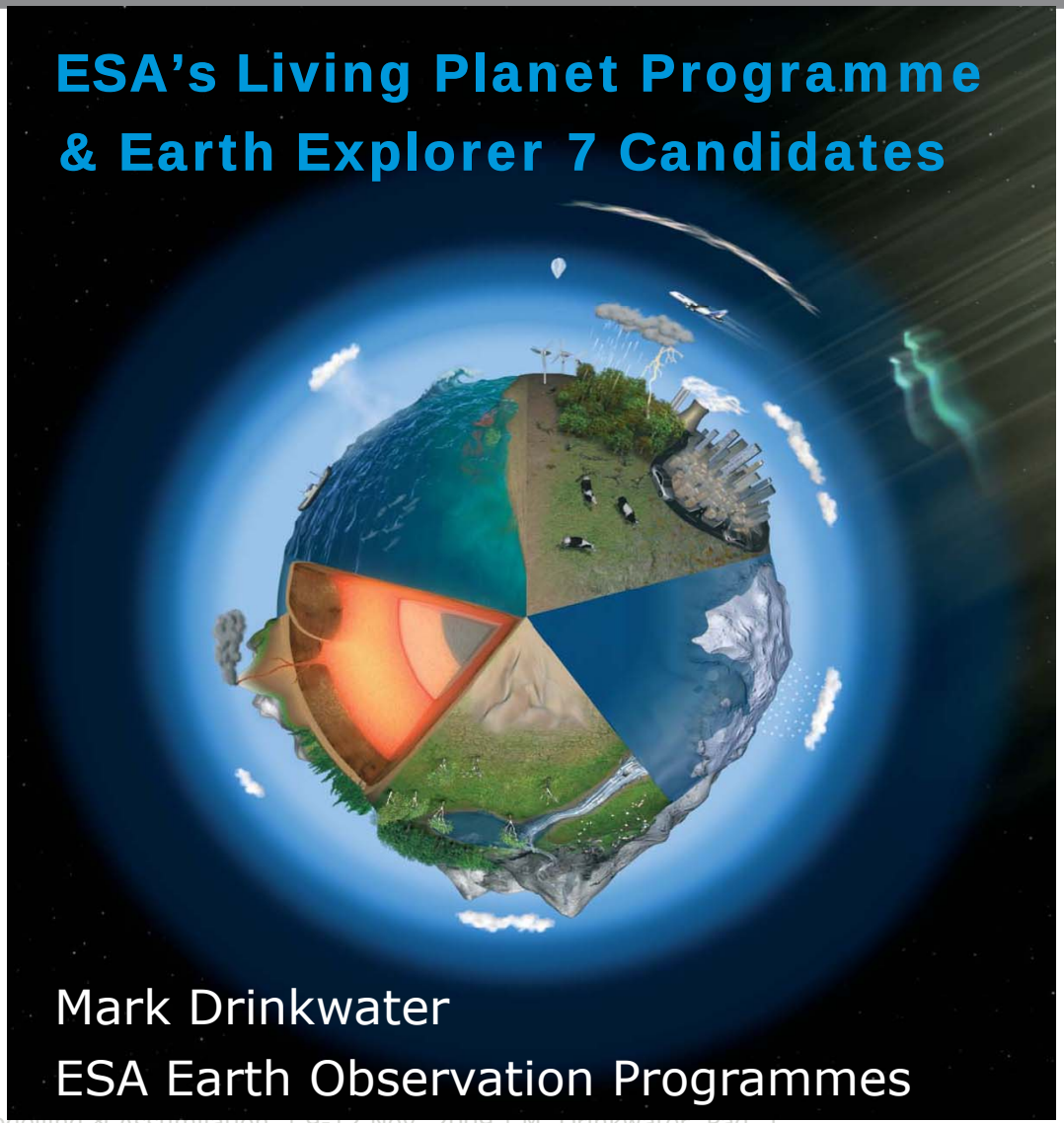
ESA's Living Planet Programme & Earth Explorer 7 Candidates



Mark Drinkwater
ESA Earth Observation Programmes

ESA's "Living Planet" Programme (LPP)

ESA's Living Planet Programme (LPP) comprises two main components:

- a science and research element including **Earth Explorer missions**,
- the **Earth Watch** element.

Earth Watch delivers Earth observation data for use in operational services, and includes the well-established meteorological missions with **Eumetsat,** and also new missions focusing on the environment and civil security under the **GMES** initiative.

Science and Research Element of LPP

Earth Explorers
The Living Planet Programme
European Space Agency

Focus on:

Hydrosphere

Atmosphere

Geosphere

Cryosphere

Biosphere

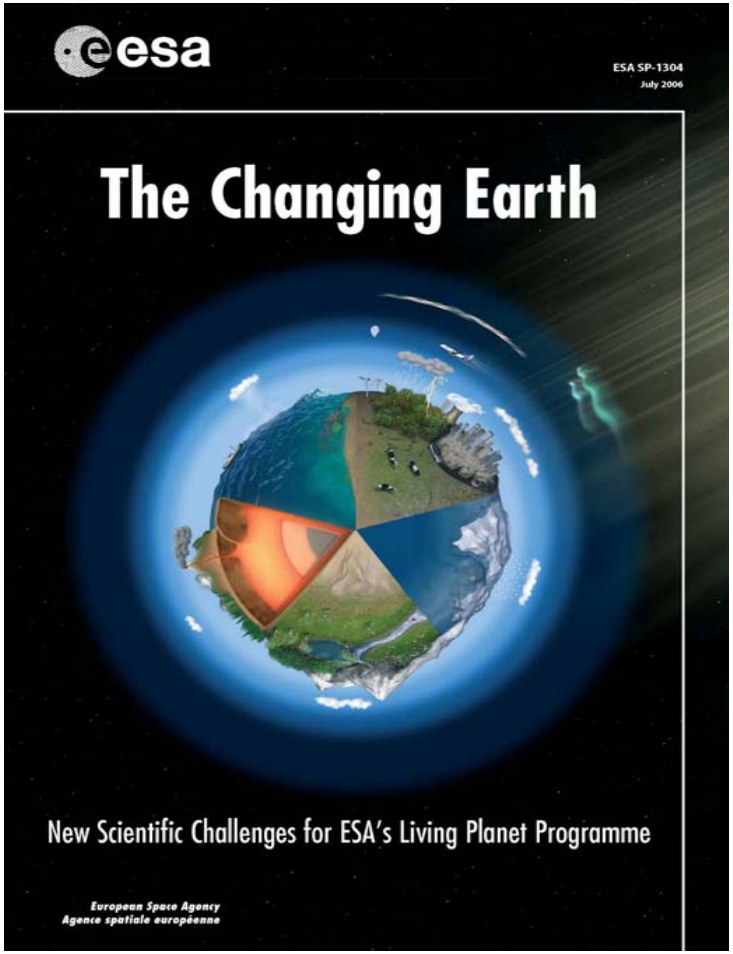
To:

- ***Improve the understanding of the interactions between components of the Earth System***
- ***Understand the impact of human activities on natural Earth processes***

Key Scientific Challenges identified in "The Changing Earth", ESA SP-1304

See: www.esa.int/livingplanet

Scientific challenges for ESA's LPP



- Updated Science Strategy for ESA's LPP, after broad user consultation
- SP-1304 identifies key scientific challenges for: hydrosphere, atmosphere, cryosphere, biosphere and geosphere
- Emphasis on the Earth system approach, where interactions and interfaces between different parts of the Earth system are fundamental

ESA's Living Planet Programme Missions

Earth Explorer
Research driven

Core Missions

GOCE
Launched
17/3/09

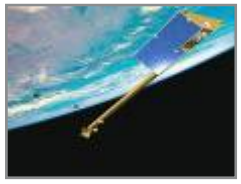
ADM-Aeolus
2010

EarthCARE
2013

Opportunity Missions

CryoSat 2
2010

SMOS
Launched
2/11/09



Swarm
2010

? **Earth Explorer 7**
2016

Earth Watch
Operational Service driven

Meteorology
- **Meteosat**
- **MSG**
- **EPS (MetOp)**
- **MTG**
- **Post EPS**

GMES
- **Sentinel 1**
- **Sentinel 2**
- **Sentinel 3**
- **Sentinel 4 (MTG-S)**
- **Sentinel 5**
- **Sentinel 5p**

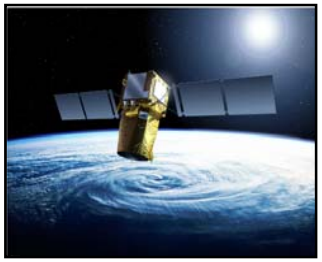
www.esa.int/livingplanet

3 Candidate Core Explorers

ESA Earth Explorers 1 - 6

GOCE
Gravity Field and Steady State Ocean Circulation Explorer

ADM-Aeolus
Atmospheric Dynamics Mission



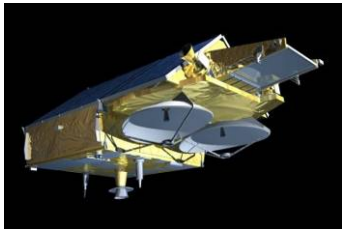
EarthCARE
Cloud, Aerosols & Radiation Explorer

Core

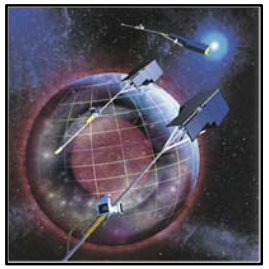
2008 ***2009*** ***2010*** ***2011*** ***2012*** ***2013***

Opportunity

SMOS
Soil Moisture and Ocean Salinity



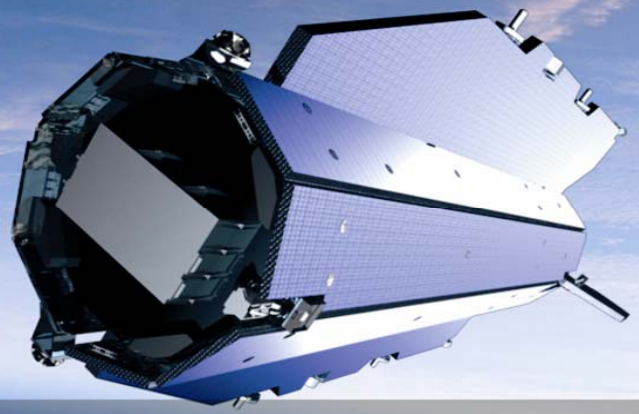
CryoSat-2
Sea Ice thickness and Ice sheet topography



Swarm
Geomagnetic field survey

GOCE: ESA's Gravity Mission

The Gravity field and steady-state Ocean Circulation Explorer (GOCE)



Its objectives are to improve understanding of:

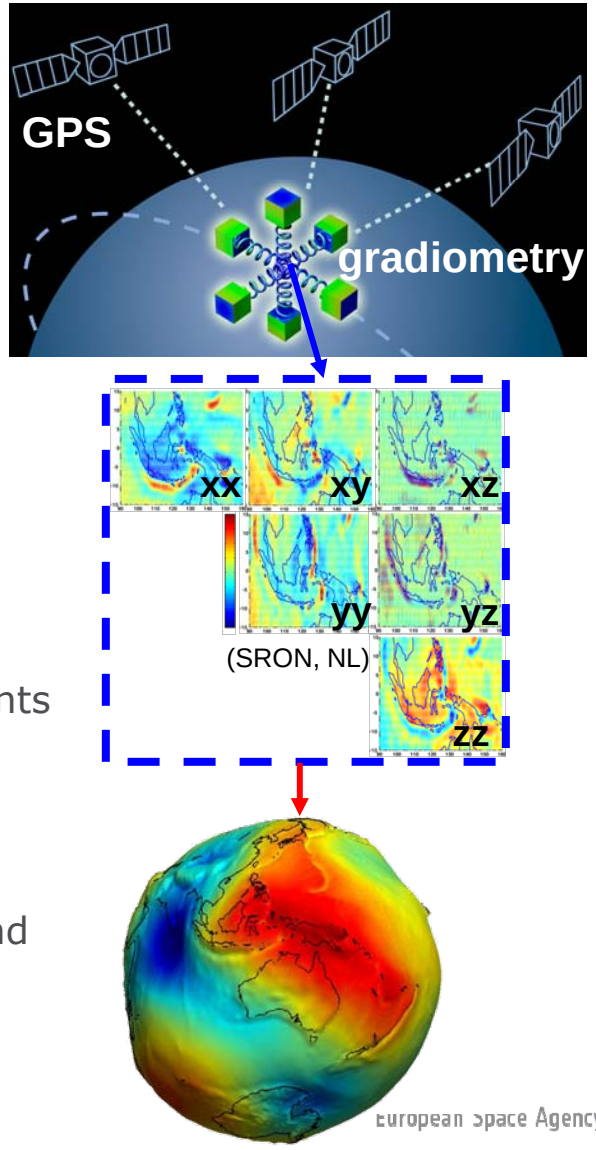
- global ocean circulation and transfer of heat
- physics of the Earth's interior (lithosphere & mantle)
- sea level records, topographic processes, evolution of ice sheets and sea level change

www.esa.int/livingplanet/goce

GOCE: Gravity Mission

Approach

- Combination of *satellite gradiometry* and *high-low satellite-to-satellite tracking* at ± 260km altitude
- Develop improved model of the static gravity field and geoid to a resolution of 100 km with 1 mGal* 1-2cm accuracy, respectively
- (*1 mGal = 10^{-5} m/s^2 - or 1 millionth of *g*)



Benefits

- An accurate marine geoid for absolute ocean currents and sea-ice thickness derivation
- Improved constraints for Earth-interior modelling calculation of rates of glacial isostatic adjustment
- Unified global height reference for land, sea, ice and surveying applications

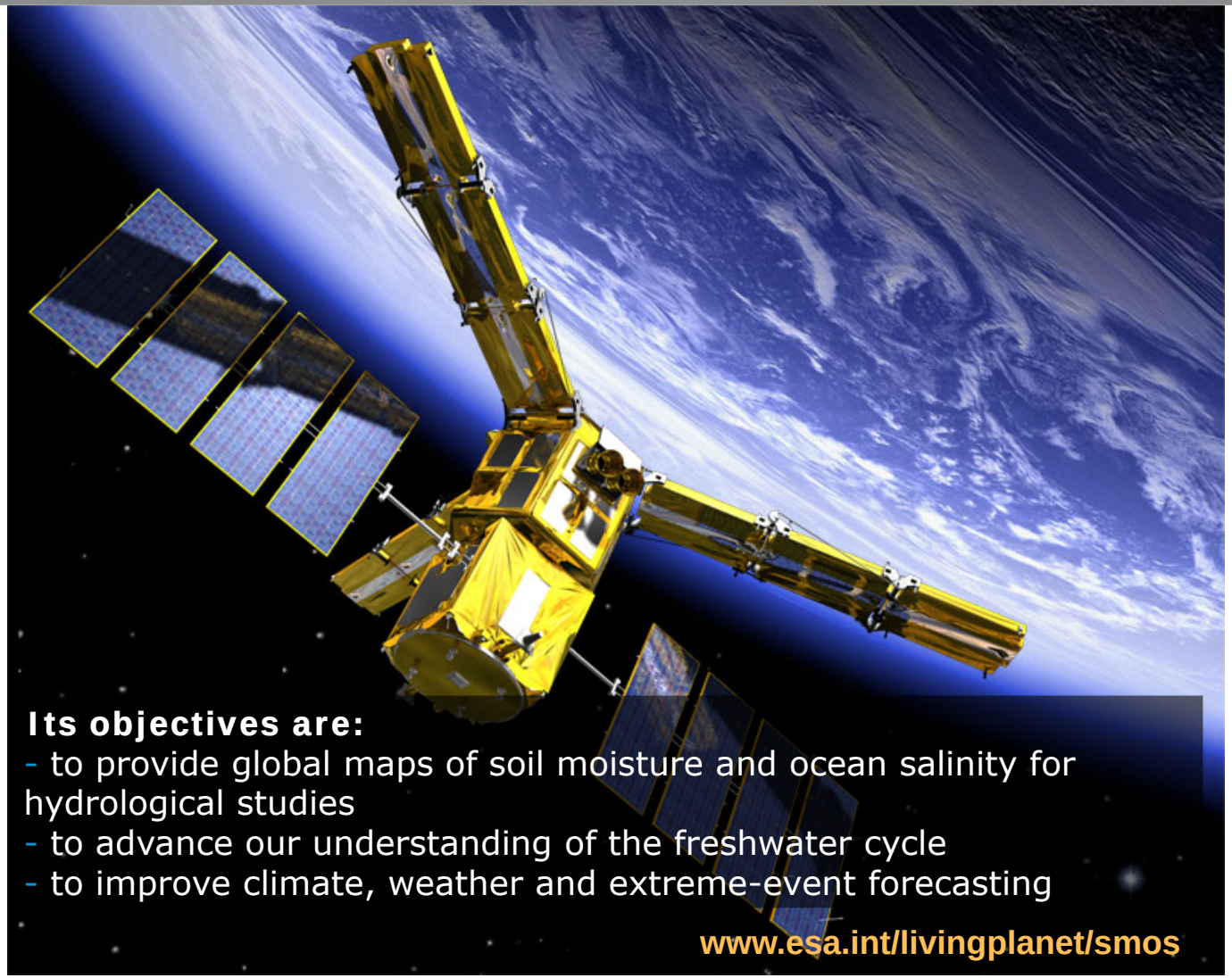
www.esa.int/livingplanet/goce

GOCE: successful launch: 17 Mar. 2009

ESA's Gravity Mission

- GOCE was successfully launched from Plesetsk on 17 March, 2009.
- GOCE was formally declared ready for work on 20 March. LEOP confirmed that all control systems are operating normally.
- The mission achieved all commissioning milestones, including switching on the electric ion propulsion, switching into Drag-Free Attitude Control mode and lowering the orbit to the planned altitude of 260 km.
- GOCE is currently taking gravity gradient measurements in the first of 3 Measurement Operations Phases (each of 6 months duration).

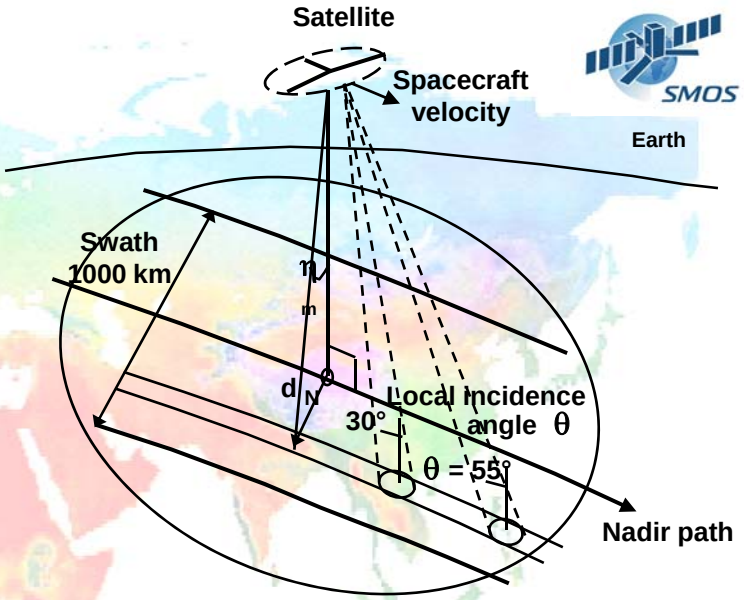
SMOS: Water Mission



The SMOS Mission

Approach

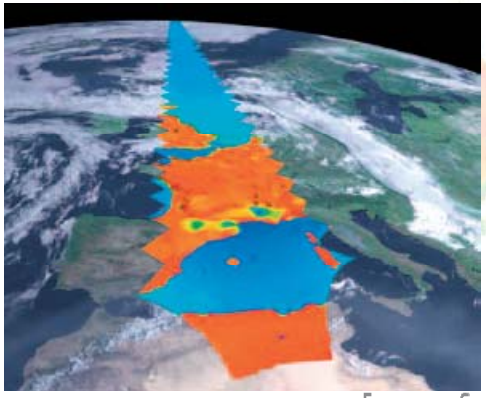
- Dual-pol., multi-angular, L-band brightness temperature measurement acquired by a 2D interferometer
- Combination of incidence, azimuth angles
- Estimates of global soil moisture and ocean salinity



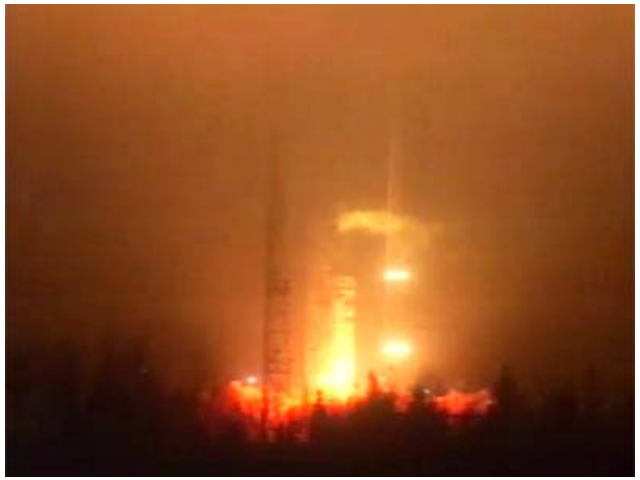
Benefits

- hydrology applications
- improved numerical weather prediction
- improved ocean circulation/hydrology
- model state estimates
- potential cryospheric applications

$$Tb = f(\nu, p, \theta, T, SM, SSS, ...)$$



SMOS: successful launch: 2 Nov. 2009



ESA's Water Mission

- SMOS was successfully launched together with PROBA-2 from Plesetsk on 2 November, 2009.
- Mission Control Centre in Toulouse, France
- MIRAS Antenna successfully deployed on 3 November
- Currently undergoing system checks and commissioning activities
- Nominal commissioning phase of 6 months before start of 3 years operations

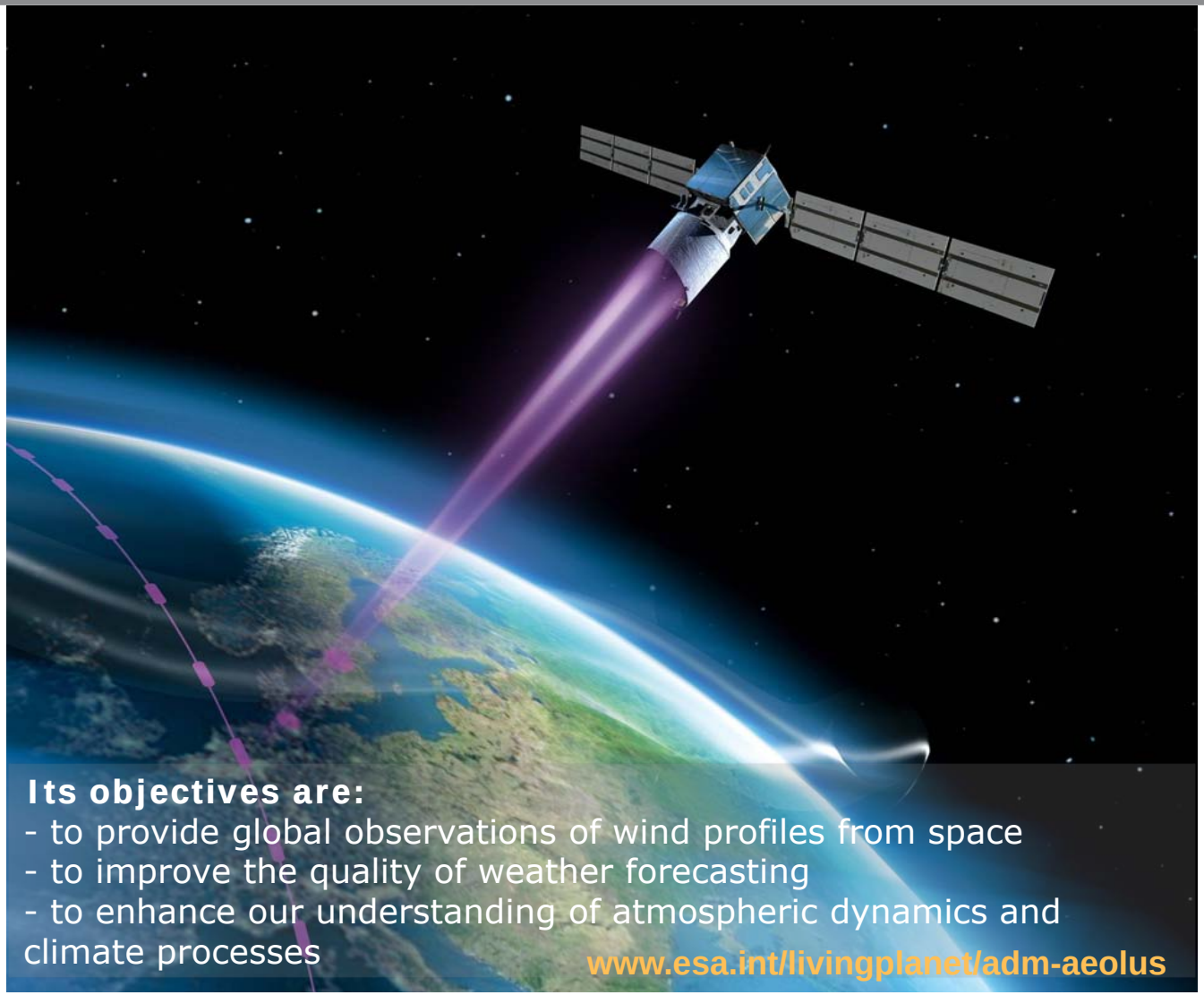
CryoSat: ESA's Ice Mission

Its objectives are to improve our understanding of:

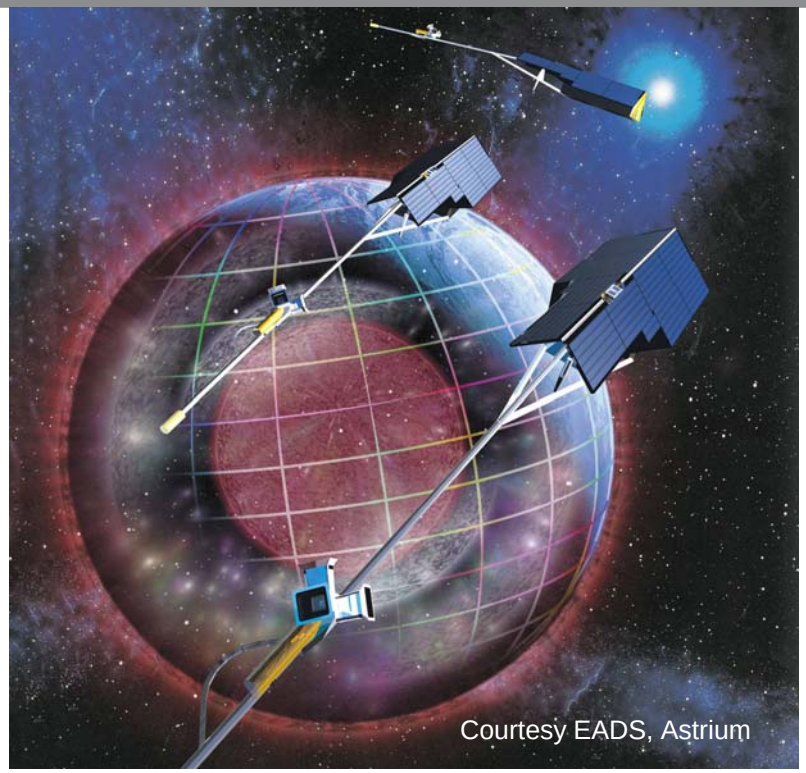
- thickness and mass fluctuations of polar land and marine ice
- to quantify rates of thinning/thickening due to climate variations

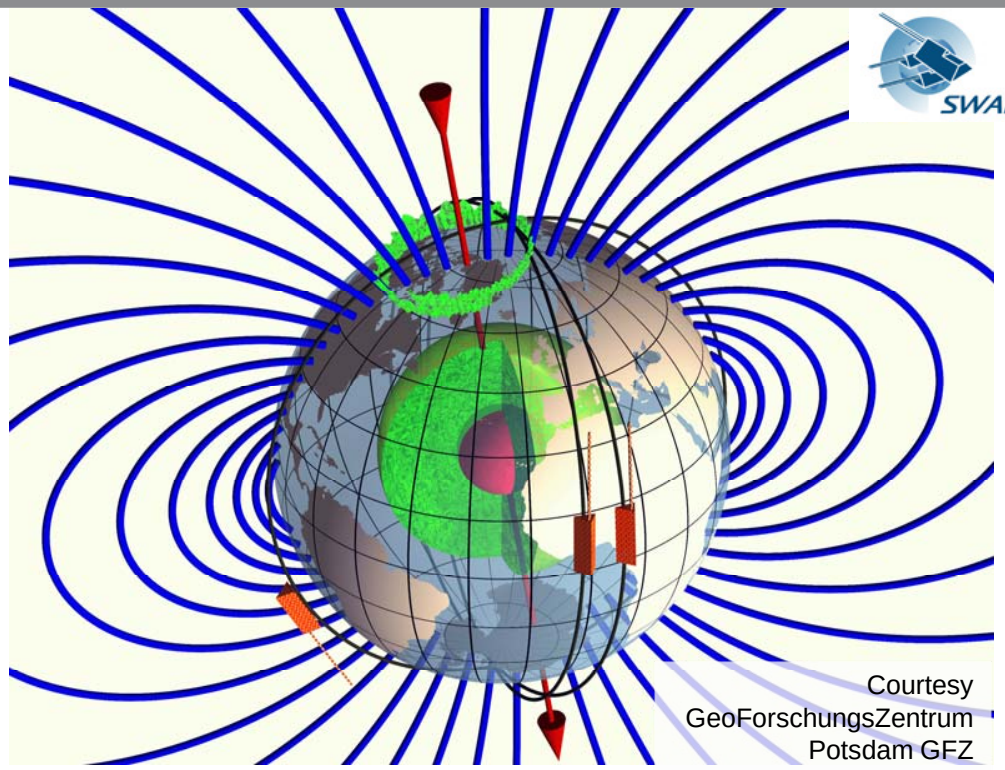
www.esa.int/livingplanet/cryosat

ADM-Aeolus: Wind Mission



Swarm: Magnetic Mission



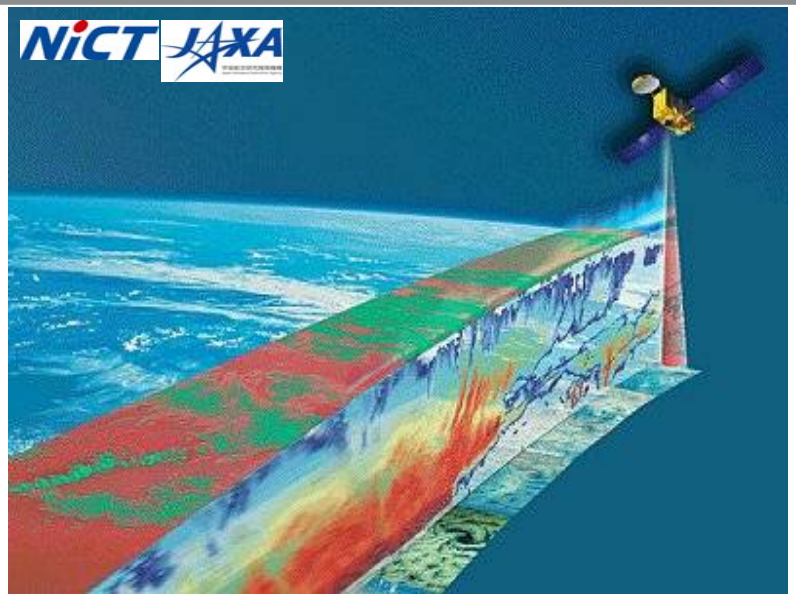


The objectives of the Swarm constellation are:

- to provide the best-ever survey of the Earth's geomagnetic field and its variation in time
- to use these data to gain new insight into the Earth's interior and climate.

www.esa.int/livingplanet/swarm

EarthCARE: Cloud & Aerosol Mission



EarthCARE is a joint European - Japanese mission

Its objectives are:

- to improve process understanding of cloud-aerosol-radiation interactions
- to measure parameters to be included in models
- to improve climate and weather model predictions

www.esa.int/livingplanet/earthcare

Candidate EE7 Missions

- **BIOMASS**
  A BIOMASS Monitoring Mission for Carbon Assessment

- **FLEX**
  FLuorescence Explorer

- **CoreH2O**
  Cold Regions Hydrology High-resolution Observatory

- **A-SCOPE**
  Advanced Space Carbon and Climate Observation of Planet Earth

- **PREMIER**
  PRocess Exploration through Measurements of Infrared and millimetre-wave Emitted Radiation

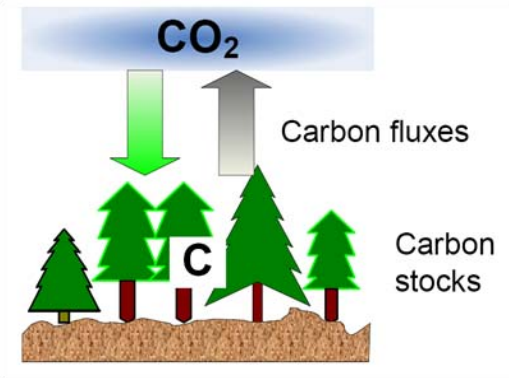
- **TRAQ**
  TRopospheric composition and Air Quality

Two parallel Phase A Industrial Mission Assessment studies underway for 3 down-selected concepts highlighted in red

BIOMASS - Candidate Mission

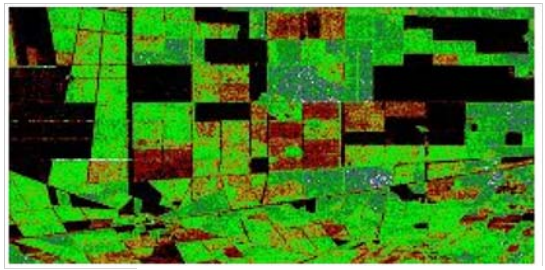
Primary Objective:

To measure above-ground forest biomass, forest extent and forest biomass change over time

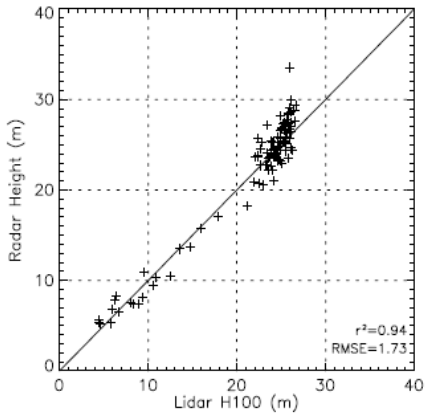


Scientific Impact:

To improve the quantification of the global terrestrial carbon cycle by linking BIOMASS mission products with global vegetation models



Tropical forest height from P-band polarimetric interferometry



Technical Concept:

Instrument:	P-Band polarimetric SAR
Duration:	5 years
Repeat Time:	25-45 days
Spatial Res:	50 x 50m (≥ 4 looks)
Instrument Modes:	Strip map or dual-beam acquisition
	Interferometry
	Global coverage (swathwidth of 60-100km)
	25-30 degrees incidence angle

CoReH2O – Candidate Mission

Primary Objective:

Quantify amount and variability of freshwater stored in seasonal snow packs, and snow accumulation on glaciers

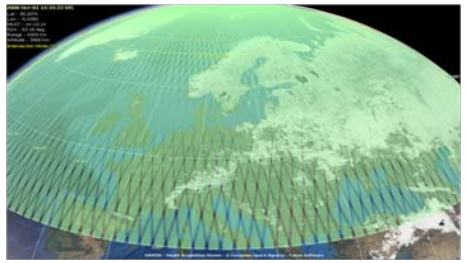
Scientific Impact:

To improve hydrological and climate modelling and Numerical Weather Prediction by incorporation of direct observations of snow mass and snow mass variability

Technical Concept:

Instrument:	SAR in Ku- (17.2 GHz) and X-Band (9.6 GHz), co- and cross-polarisation
Repeat Time:	3 and 15 days / Dawn/Dusk orbits
Spatial Res.:	50 x 50 m (5 looks), ScanSAR (Swath ≥ 100 km)
Two mission phases:	Phase 1 (3d repeat): regional high-density time/space repeat coverage
	Phase 2 (15 d repeat) Near global coverage of snow and ice areas

Coverage map for Phase 1 (3 days repeat cycle)



Coverage map for Phase 2 (15 days repeat cycle)

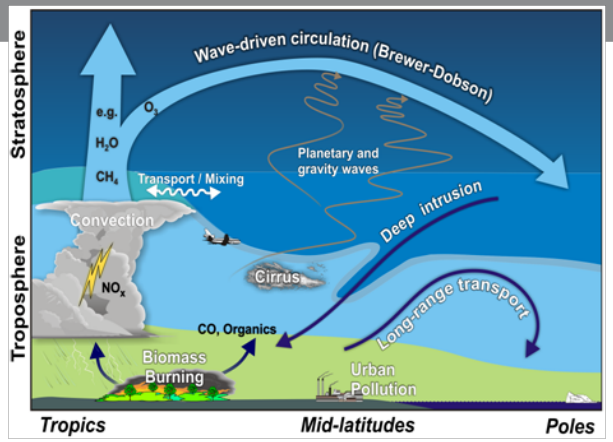
PREMIER – Candidate Mission

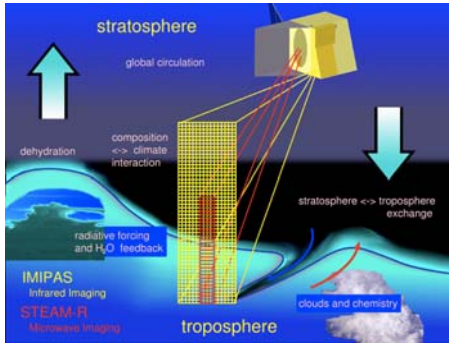
Primary Objective:

To characterise dynamical and chemical exchange processes in the upper troposphere / lower stratosphere (i.e. tropopause region)

Scientific Impact:

To make observations to characterise and model the key dynamical and chemical processes linking atmospheric composition with Earth's radiation balance and climate





Technical concept:

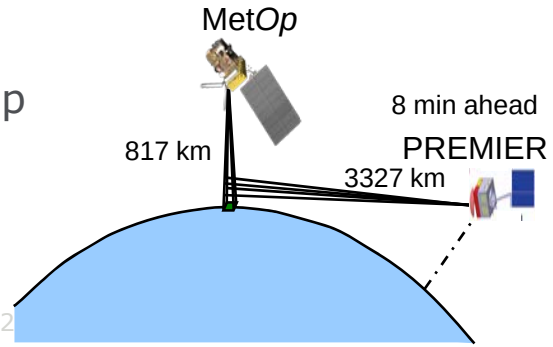
Payload: - mm-wave push-broom limb spectrometer

- infrared limb-imaging spectrometer

Spatial Res.: 6-55 km vertical

Orbit: sun-synchronous, in tandem with Metop global coverage

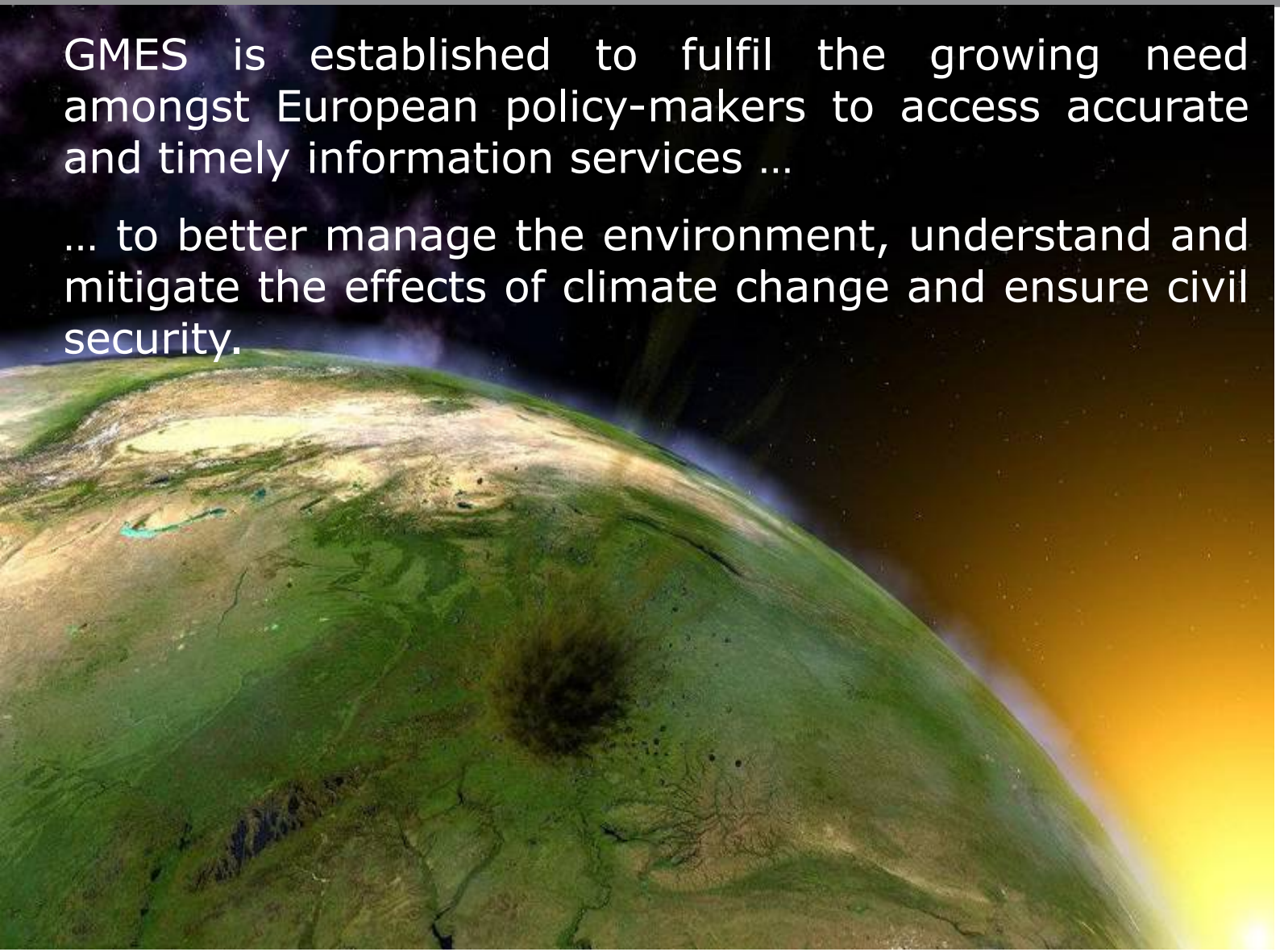
Lifetime: 4 years



Global Monitoring for Environment and Security (GMES)

GMES is established to fulfil the growing need amongst European policy-makers to access accurate and timely information services …

… to better manage the environment, understand and mitigate the effects of climate change and ensure civil security.



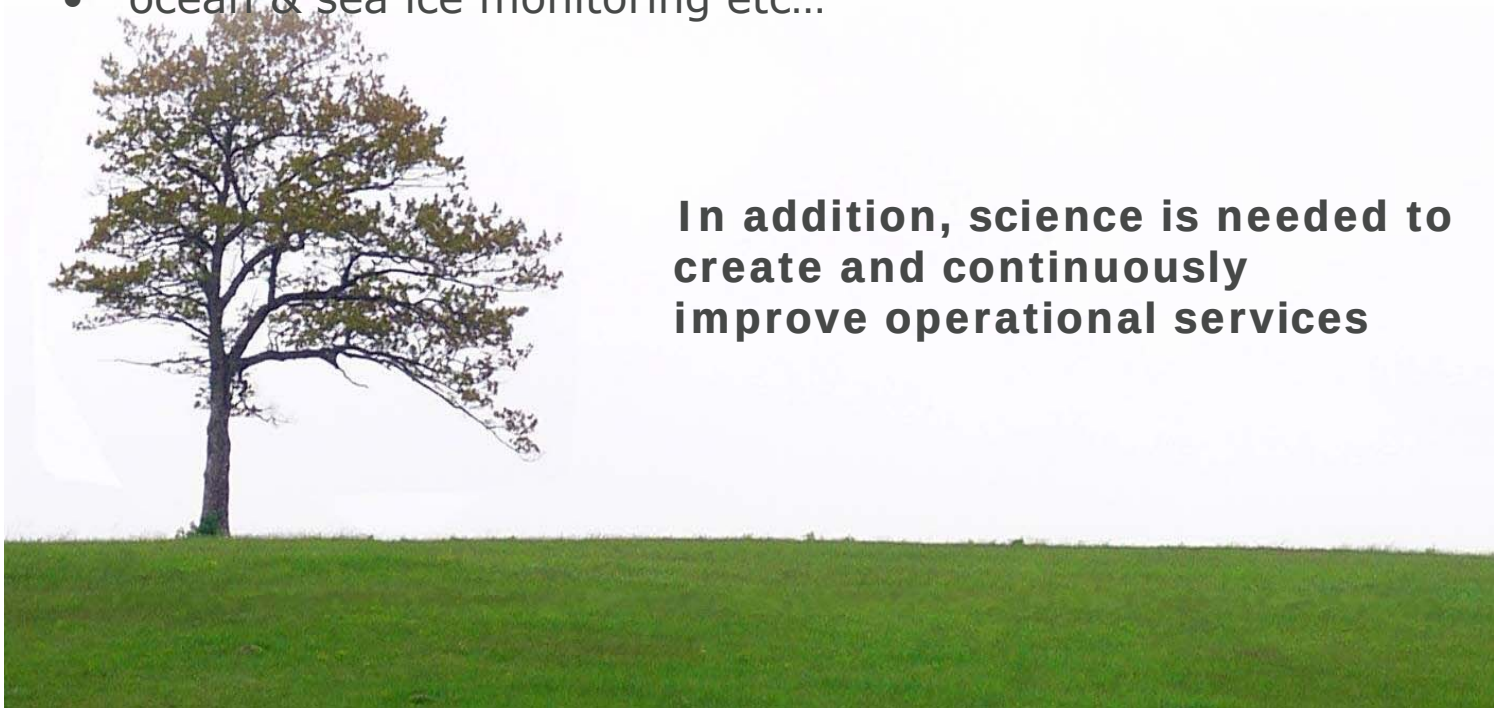
GMES
We care for a safer world

European Space Agency

Goal of GMES

GMES aims at developing operational services, following the example of meteorology, but for other domains such as:

- emergency management
- air quality monitoring
- land monitoring
- ocean & sea ice monitoring etc…



In addition, science is needed to create and continuously improve operational services

GMES dedicated missions: Sentinels

Sentinel 1 – SAR imaging

All weather, day/night applications, interferometry

2012

Sentinel 2 – Multispectral imaging

Land applications: urban, forest, agriculture, etc.
Continuity of Landsat, SPOT data

2013

Sentinel 3 – Ocean and global land monitoring

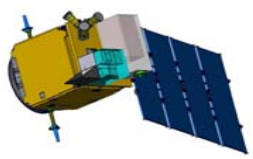
Wide-swath ocean color, vegetation, sea/land surface temperature, altimetry

2013

Sentinel 4 (MTG-S) – Geostationary atmospheric

Atmospheric composition monitoring, trans-boundary pollution

2018+



Sentinel 5 and Precursor – Low-orbit atmospheric

Atmospheric composition monitoring

2015, 2020+

C-band SAR mission

Applications:

- monitoring sea ice zones and the Arctic environment
- surveillance of marine environment
- monitoring land surface motion risks
- mapping in support of humanitarian aid in crisis situations

4 nominal operation modes:

- Strip map (80 km swath, 5x5 m res.)
- Interferometric wide swath (250 km swath, 20x5m res.)
- Extra Wide Swath (400 km swath, 25x100 m res.)
- Wave (5x20 m res.)

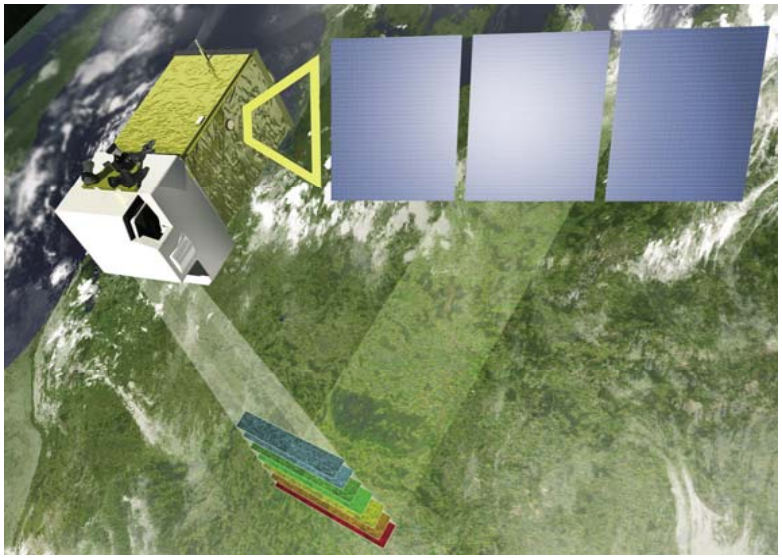
2300 kg spacecraft mass

Sun synchronous orbit at 693 Km mean altitude

12 days repeat cycle

7 years design life time, consumables for 12 years

Multi-spectral Land imaging mission



Applications:

- Generic land cover maps
- risk mapping and fast images for disaster relief
- generation of leaf coverage, leaf chlorophyll content and leaf water content

Pushbroom filter based multi-spectral imager with 13 spectral bands (VNIR & SWIR)

Spatial resolution: 10, 20 and 60 m

Field of view: 290 km

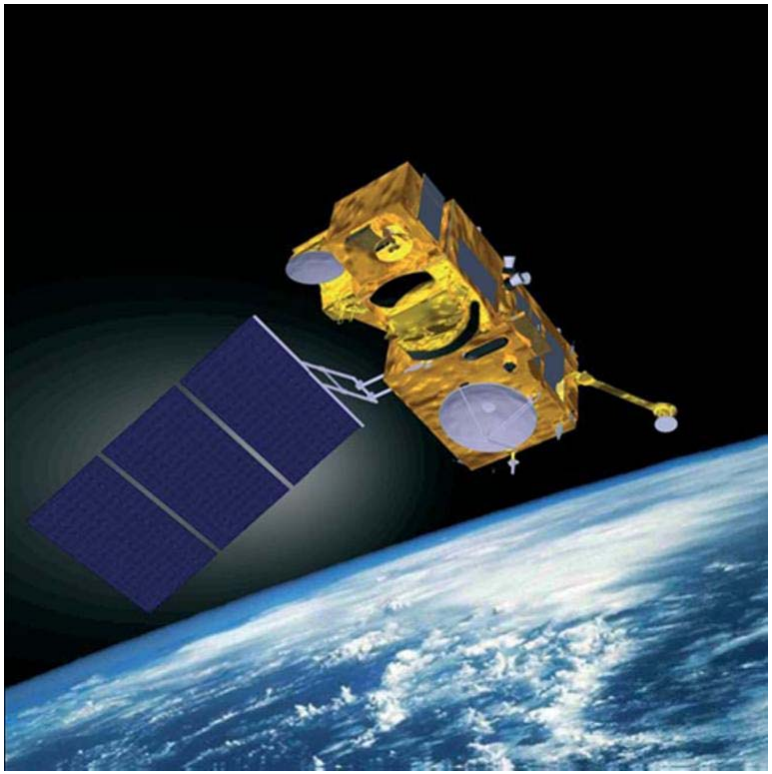
1098 kg spacecraft mass

10 days repeat cycle

Sun synchronous orbit at 786 km mean altitude

7 years design life time, consumables for 12 years

Global Ocean & Land mission



Applications:

- Sea/land colour data and surface temperature
- sea surface and land ice topography
- coastal zones, inland water and sea ice topography
- vegetation products
- Aerosol products

1198 kg spacecraft mass

Sun synchronous orbit at 814.5 km mean altitude over geoid

27 days repeat cycle

7 years design life time, consumables for 12 years

GEO atmospheric composition mission

Applications:

- monitoring changes in the atmospheric composition (e.g. ozone, NO_2, SO_2, BrO, formaldehyde and aerosol) at high temporal resolution
- troposphere variability

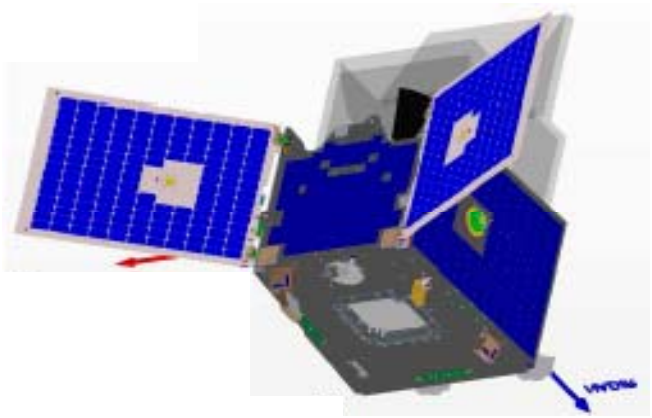
Narrow field spectrometer covering UV (290-400 nm), visible (400-500 nm) and near-IR (755-775 nm) bands

Spatial sampling 5-50 km and spectral resolution between 0.05 nm and 1 nm (depending on band)

Geostationary orbit, at 0º longitude

Embarked on MTG-S and operated by EUMETSAT

LEO atmospheric composition mission



Applications:

- monitoring changes in the atmospheric composition (e.g. ozone, NO_2, SO_2, BrO, CO, CH_4 formaldehyde and aerosol) at high temporal (daily) resolution
- troposphere variability

LEO UVNS instrument with priority bands in the UV, VIS, NIR and SWIR.

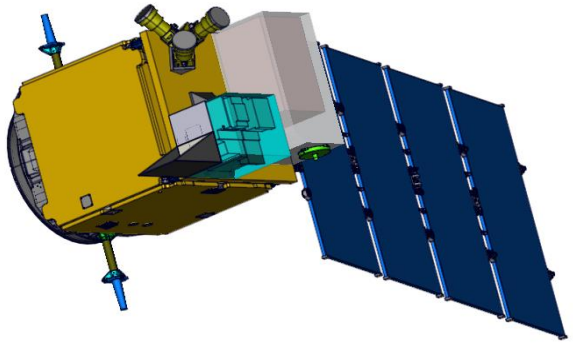
Spatial resolution ~10x10 km

Sun synchronous orbit at a reference altitude of 828km; LTAN 13:30hrs.

Sentinel-5 precursor to fill data gap (2013-2019) in critical data streams from Envisat/Sciamachy, Aura/OMI

Sentinel-5

LEO atmospheric composition mission



Applications:

- monitoring changes in the atmospheric composition (e.g. ozone, NO_2, SO_2, BrO, CO, CH_4 formaldehyde and aerosol) at high temporal (daily) resolution
- troposphere variability

LEO UVNS instrument with priority bands: UV1, UV2, VIS12, NIR and SWIR-3. Option also includes VIS 3, SWIR 1 and SWIR 2 channels.

Spatial resolution ~10x10 km

Low Earth orbit (reference altitude of about 817 km)

Sentinel-5 embarked on post-EPS and operated by EUMETSAT

Conclusions

- ESA's Living Planet Programme features exciting new Earth Observation missions focusing on specific scientific or operational goals
- First Earth Explorer mission GOCE launched on 17 March 2009 – presently undergoing in-orbit commissioning
- Five science-driven Earth Explorers approved and under development (Three Candidates for 7th EE in Phase A Study)
- 4 operational GMES Sentinel missions (1A, 2A, 3A, 5p) approved and under development
- Sentinel-4/-5 mission concepts under study and presently under consideration
- ESA to launch a succession of EO satellite missions over the next decade – with which to address key elements of the Earth system