Scientific challenges and technological limitations in ESA's Earth Observation Programme

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Earth Observation Programmes Directorate

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- **Very brief introduction to ESA's Living Planet Programme**

- **Earth Observation Technology Challenges**

ESA's LIVING PLANET PROGRAMME

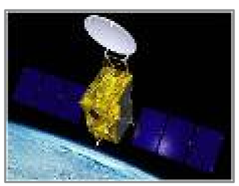
esa

Earth Explorers
Research

Core Missions


GOCE 2009


ADM-Aeolus 2012

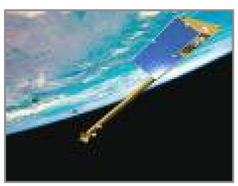

EarthCARE 2014

?
Earth Expl 7 2017 (BIOMASS, CoReH2O, PREMIER)

Opportunity Missions


CryoSat 2 2010


SMOS 2009


Swarm 2012

?
Earth Expl 8 2018 (CarbonSat, Flex)

Earth Watch missions
Operational Service

EUMETSAT
- **Meteosat**
- **MSG**
- **EPS (MetOp)**
- **MTG**
- **MetOp SG**

GMES (EU)
- **Sentinel 1**
- **Sentinel 2**
- **Sentinel 3**
- **Sentinel 4**
- **Sentinel 5 / 5P**

ESA'S GRAVITY MISSION

GOCE (GRAVITY FIELD AND STEADY STATE OCEAN CIRCULATION EXPLORER)

– global ocean circulation and transfer of heat

– physics of the Earth's interior (lithosphere & mantle)

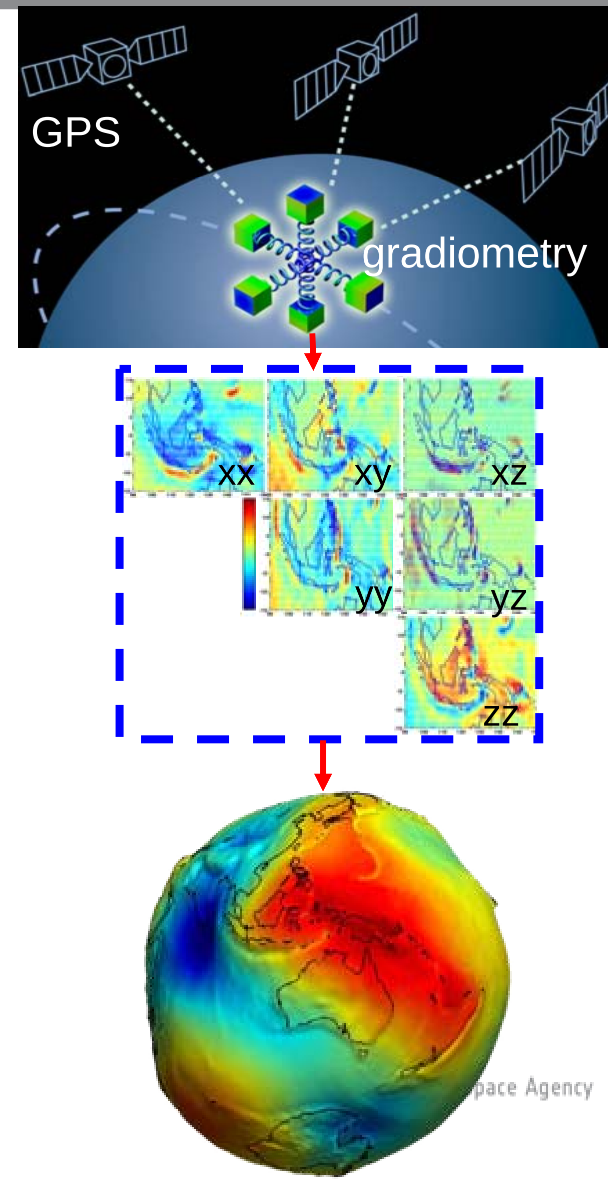
– sea level records, topographic processes, evolution of ice sheets and sea level change

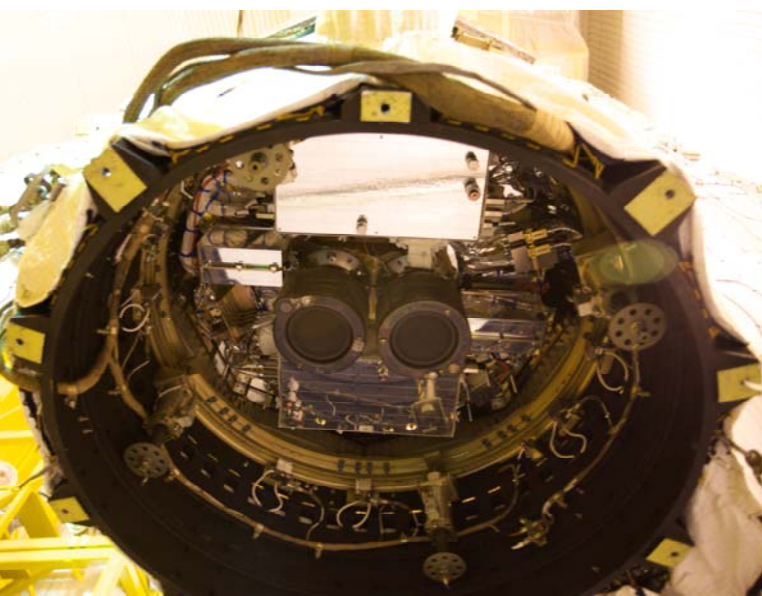
PRIME EXAMPLE OF EARTH SCIENCE ADVANCEMENT THROUGH NEW TECHNOLOGIES, AS IN GENERAL FOR ALL EARTH EXPLORERS

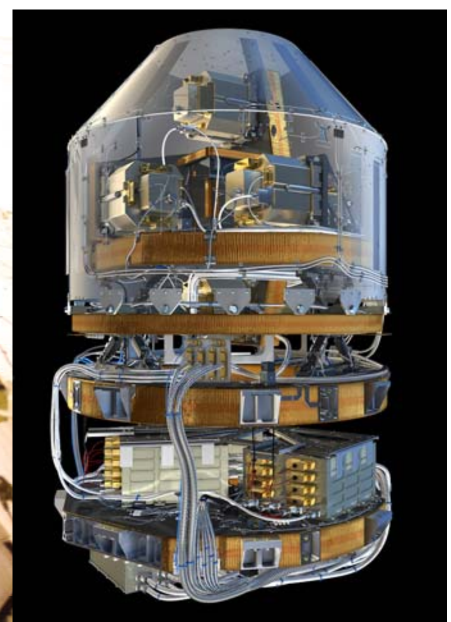
THE FIRST EARTH EXPLORER MISSION

WHAT MAKES THE GOCE SATELLITE SO UNIQUE?

- First gravity gradiometer in space
- Accelerometers with sensitivity at pico-g level
- Extremely low orbit (255 km), controlled to a few metres and determined to ~ 1 cm
- First active air drag compensation by electric propulsion
- Perfectly quiet on-board environment





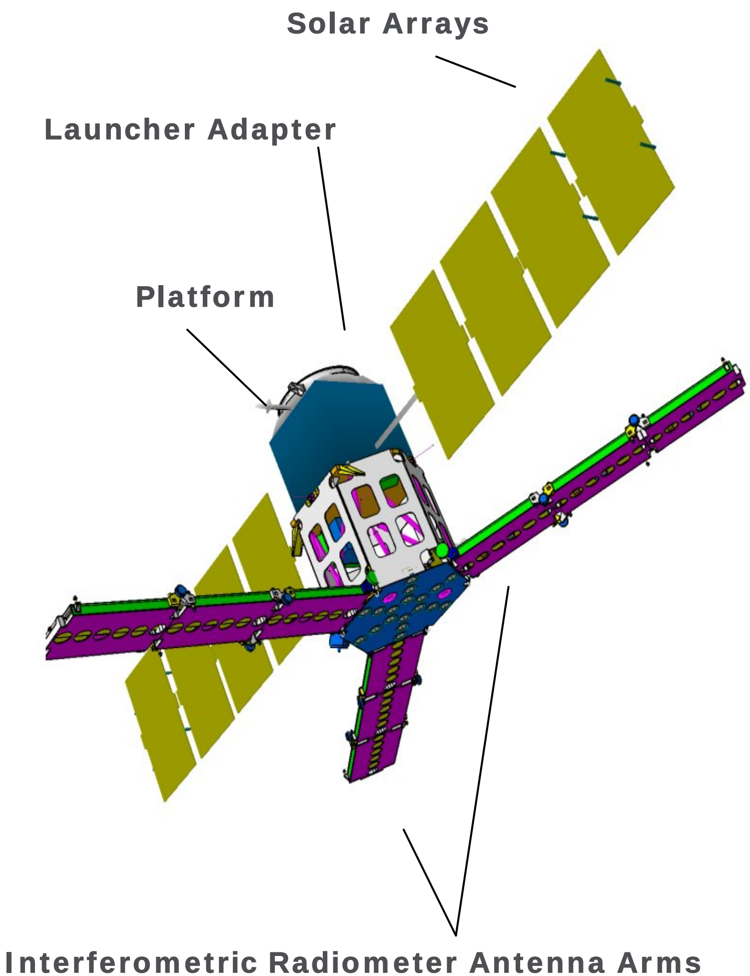


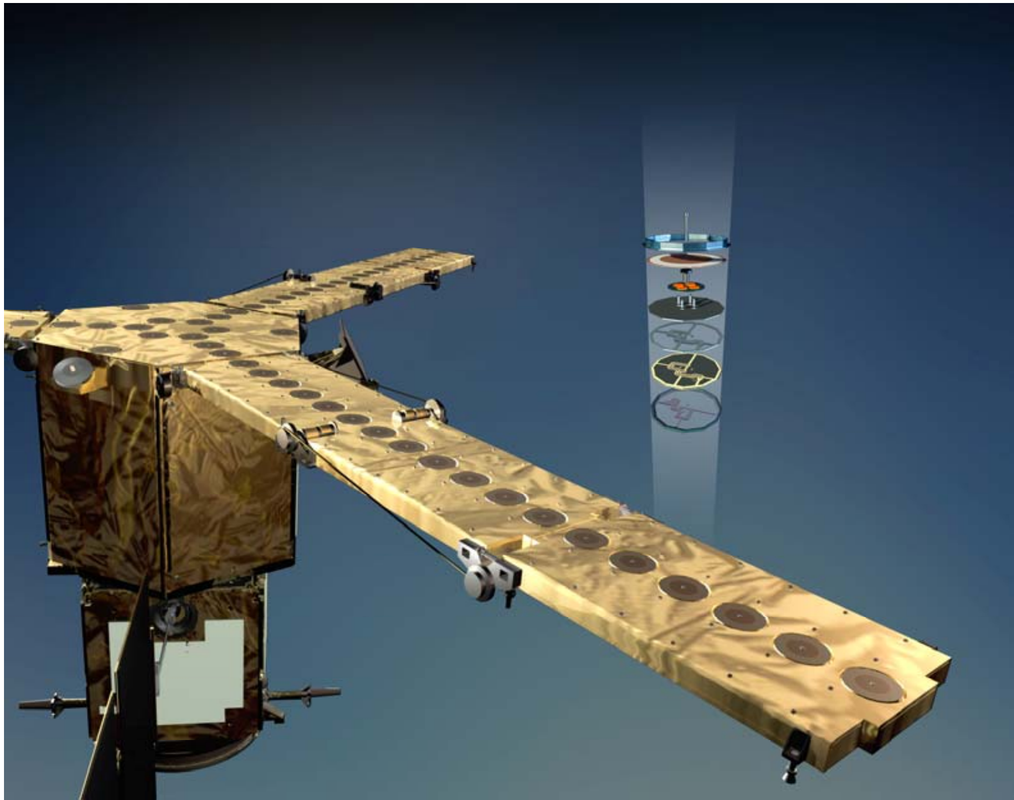
SMOS (SOIL MOISTURE AND OCEAN SALINITY MISSION)

- Provide global maps of soil moisture and ocean salinity for hydrological studies
- Advance understanding of the water cycle
- improve climate, weather and extreme-event forecasting

SMOS: RADIOMETRY WITH APERTURE SYNTHESIS

microwave radiometer
at L band: 1.4 GHz
2D interferometry (from 72 receivers)
multi-incident angles (0°- 55°)
polarimetric observations





EarthCARE

a joint ESA – JAXA (Japan) mission:

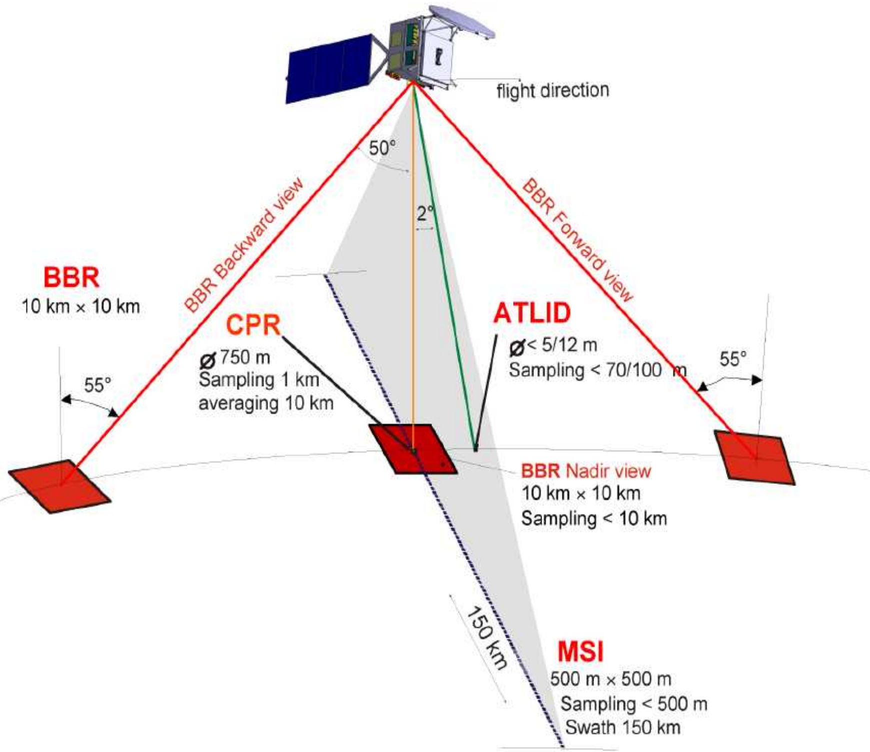
- to quantify and thus improve understanding of cloud-aerosol-radiation interactions
- to include such parameters correctly and reliably in climate and weather prediction models

ESA'S CLOUD & AEROSOL MISSION

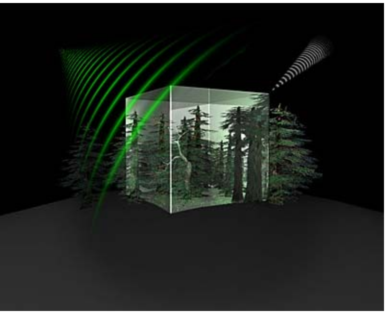
Needs	*Techniques/ Instruments*
Vertical profiles of extinction and characteristics of aerosols	High spectral resolution Lidar
Vertical profiles of liquid, super-cooled and ice water, cloud overlap, particle size and extinction	High spectral resolution Lidar; Radar
Convective updraft and ice fall speed	Doppler Radar
Horizontal structure of clouds and aerosols	Multi-spectral Imager
Shortwave and longwave fluxes at Top of Atmosphere	Broadband Radiometer

Four instruments:

- ATLID lidar
- CPR radar (JAXA)
- Multi-Spectral Imager
- Broad Band Radiometer

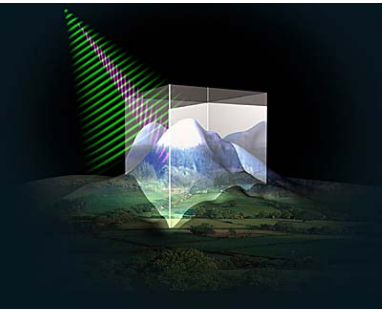


EARTH EXPLORER 7: PHASE A STUDIES



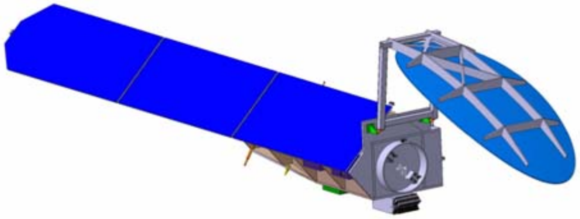
BIOMASS

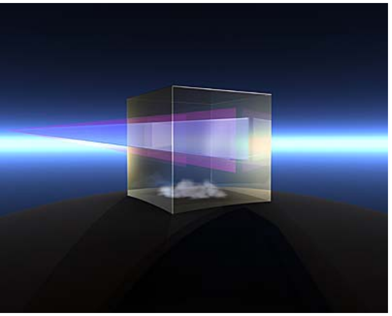
A satellite carrying a P-band SAR to provide continuous global interferometric and polarimetric radar observations of forested areas



CoReH2O

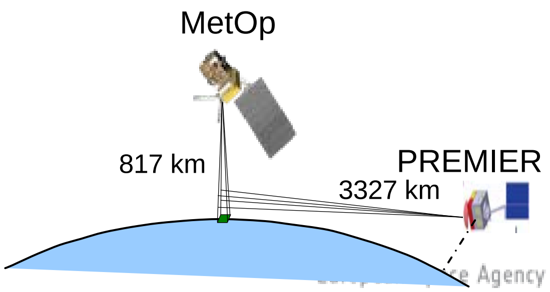
A satellite with dual frequency (X, Ku), dual-polarisation SAR to observe snow / ice at high spatial resolution





PREMIER

A satellite carrying an infrared limb-imaging spectrometer and a mm-wave limb-sounder to measure 3D fields of atmospheric composition in upper troposphere and lower stratosphere



EO technology challenges

- Microwave technologies:
  - Large antennas (passive/active)
  - Power sources (tubes, solid-state)
  - Receivers (mm- and sub-mm wave)
  - On-board electronics (SAR)

- Optical technologies:
  - High-performance spectrometers
  - Laser sources for lidars
  - Detectors

detectors

- Generally large signal, high-speed operation
- Large format required (1D or 2D)
- Cooling capabilities limited
  - Passive: 100 K
  - Active: 50 K

What about a detector without or drastically reduced dark signal to avoid cooling needs?

Laser development

Background: Lasers in Space applications

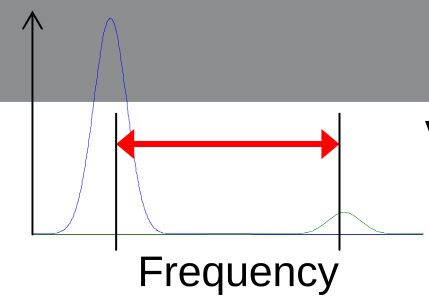
Telemetry
- Ranging
  - metrology Earth-satellite
  - metrology between satellites (LISA)
  - formation flying (PROBA3)
- Altimetry
  - for Earth geodesy, canopy height
  - for planetary mission's (BepiColombo)

Telecommunication
- Laser link (ARTEMIS)

Earth Observation
- Wind (ADM-Aeolus)
- Aerosols, Clouds (EarthCARE)
- Trace gases concentration (WALES, A-SCOPE, ACCURATE, MERLIN)
- Gravity waves (Mesospheric lidars)

Background: Lidar principles

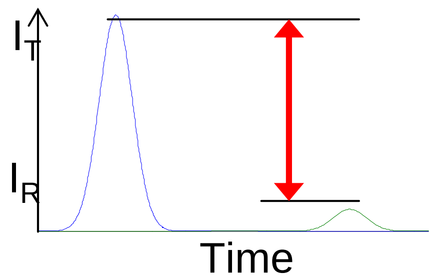
Doppler lidar
- Wind vectors



Velocity = $\lambda/2*\Delta f$

ADM-Aeolus

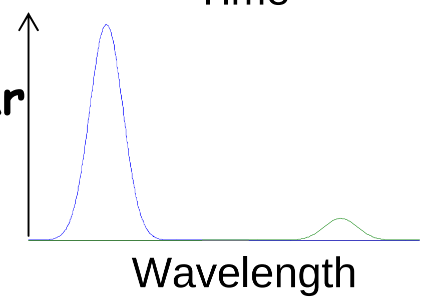
Backscatter lidar
- Cloud vertical profile
- Aerosol vertical profile



Extinction = I_R/I_T

EarthCARE

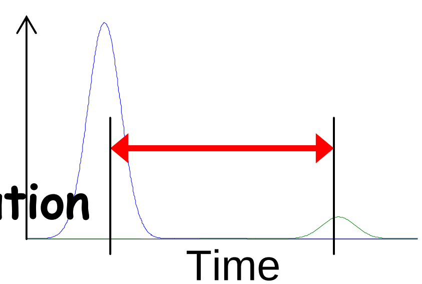
Differential absorption lidar
- Trace gases concentration



Concentration = $\mathrm{Log}(I_{\lambda on}/I_{\lambda off})$

A-SCOPE
WALES
ACCURATE

Altimetry lidar
- Ranging
- Vegetation canopy distribution



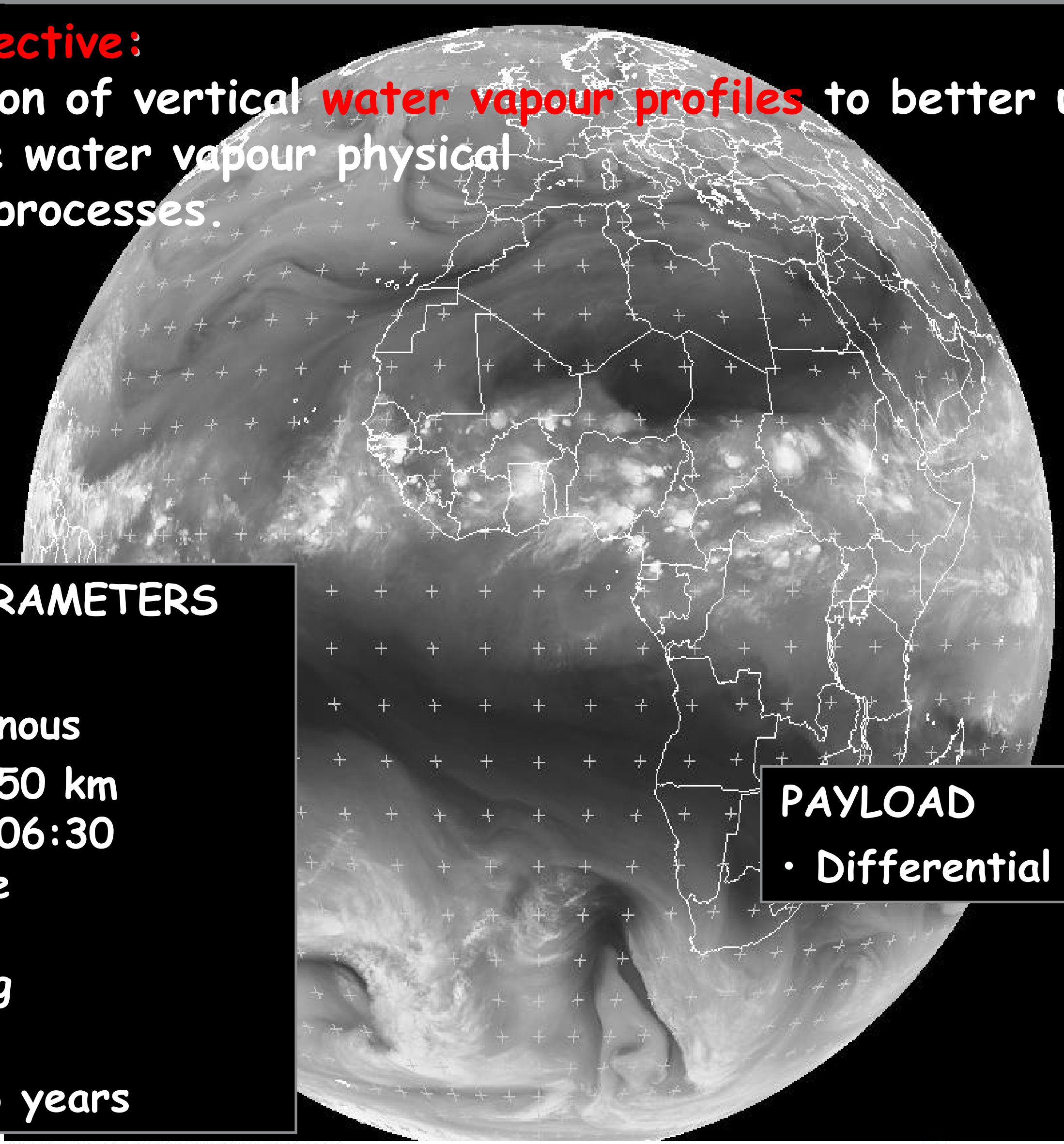
Range = $c\Delta t/2$

BepiColombo
A-SCOPE

esa

Scientific objective:

The observation of vertical **water vapour profiles** to better understand and model the water vapour physical and chemical processes.



MET9 WV062 2010-06-20 21:00 UTC

EUMETSAT

MISSION PARAMETERS

Orbit:

- Sun-synchronous
- Altitude ~ 450 km
- Local time ~06:30 ascending node

Mass: 1500 kg
Power: 3 kW

Mission life: 3 years

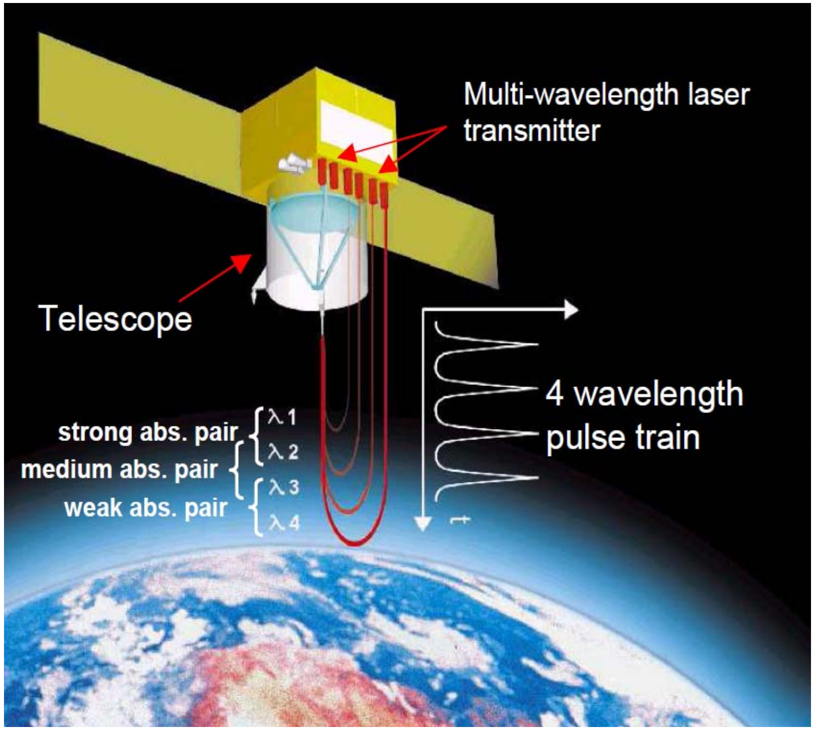
PAYLOAD

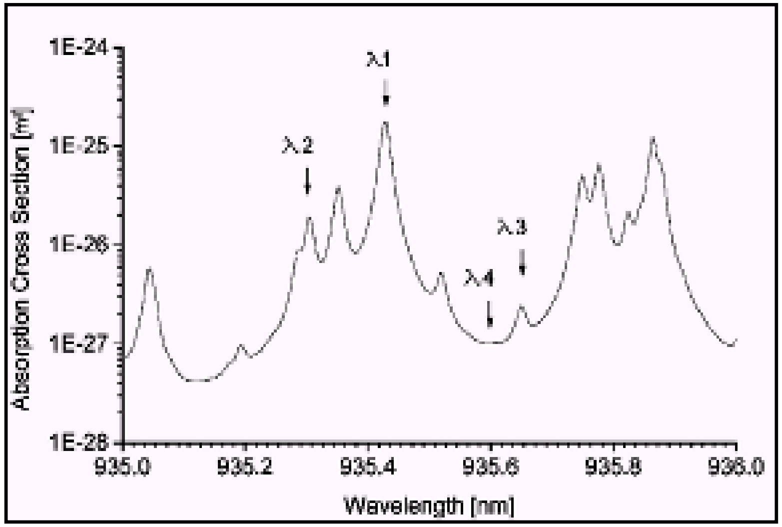
- Differential Absorption Lidar

Water Vapour Lidar Experiment in Space: WALES

Observation requirements:

	PBL	Low Tropo-sphere	High Tropo-sphere	Low Strato-sphere
Vertical domain [km]	0-2	0-5	5-10	10-16
Vertical resolution	1 km			2 km
Horizontal resolution	25 km	100 km	150 km	200 km
Random error	< 20 %			
Bias	< 5 %			

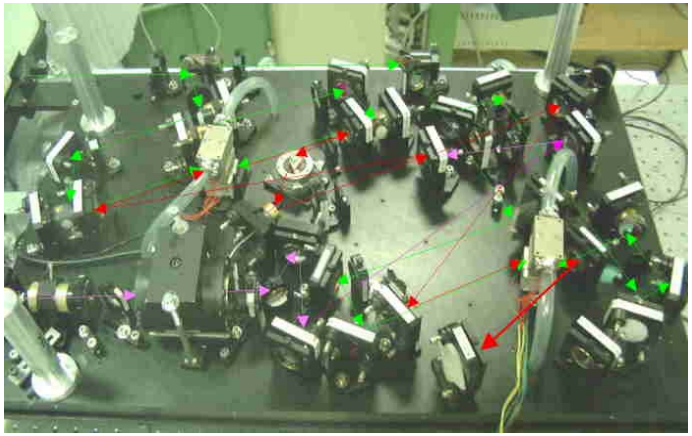




Water Vapour Lidar Experiment in Space: WALES

Instrument requirements.

Parameters	Value
Transmitter	
Wavelength	4 around 935 nm
Pulse energy	75 mJ
Repetition rate	25 Hz (4 pulses in 40 ms)
Frequency accuracy	< 60 MHz
Linewidth	< 160 MHz
Spectral purity	> 99.9 %
Receive Telescope	
Telescope diameter	1.75 @ 2 m
FOV	115 urad
Receiver	
Background rejection	
Bandwidth	2 nm
Peak transmission	80 %
Tunable Filter	
Peak transmission	50%
Bandwidth	40 pm
Finesse	>150
Detector	
QE	0.6



Ti-Sa laser breadboard

Technology limitations

- Limited R&D sources,
- no “mass market”,
- little push from other customers
- European source !