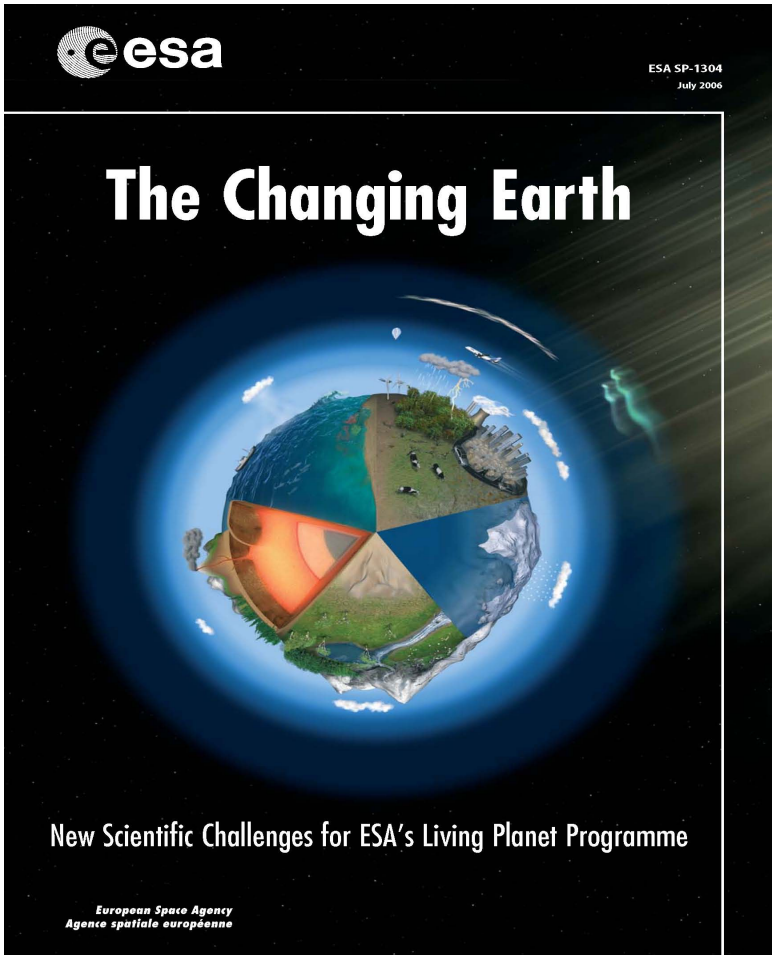
EarthCARE

The Earth Cloud Aerosol and Radiation Explorer

Tobias Wehr
ESA/ESTEC, Noordwijk, The Netherlands

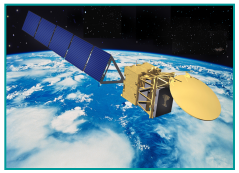
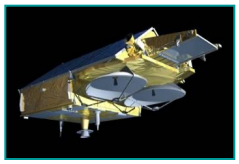
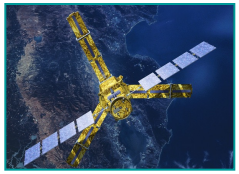
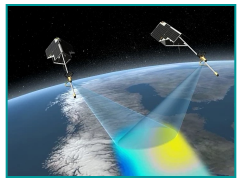
ESA's Living Planet Programme



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

ESA's Living Planet Programme

www.esa.int/livingplanet

- **Earth Explorer** — Research driven
  - **Core Missions**
    -  GOCE 2008
    -  ADM-Aeolus 2010
    -  EarthCARE 2013
    - ? Earth Explorer 7 2015
  - **Opportunity Missions**
    -  CryoSat 2 2009
    -  SMOS 2009
    -  Swarm 2010
- **Earth Watch** — Service driven
  - **coop. with EUMETSAT**
    - Meteosat
    - MSG
    - MTG
    - EPS
    - Post EPS
  - **GMES**
    - Sentinel 1
    - Sentinel 2
    - Sentinel 3
    - Sentinel 4
    - Sentinel 5

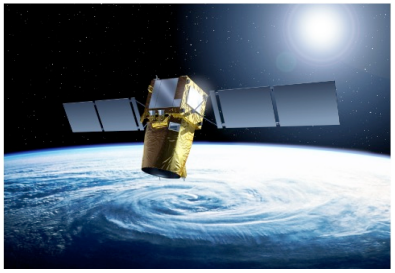
Six Approved Earth Explorer Missions

GOCE

Gravity Field and Steady State Ocean Circulation Explorer

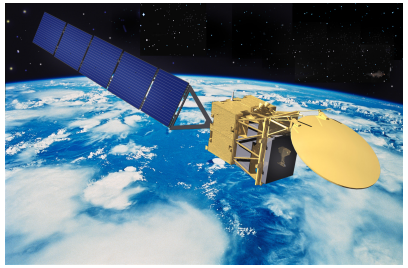
ADM-Aeolus

Atmospheric Dynamics Mission

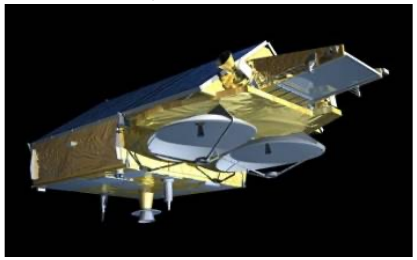


EarthCARE

Cloud, Aerosols & Radiation Explorer

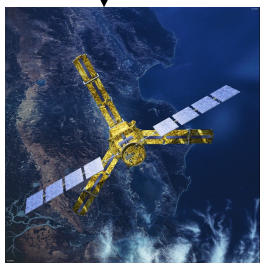


2005 2006 2007 2008 2009 2010 2011 2012 2013



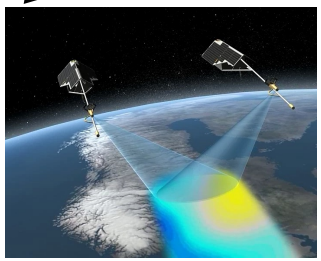
Cryosat 1 & 2

Sea Ice thickness and Ice sheet topography



SMOS

Soil Moisture and Ocean Salinity



Swarm

Geomagnetic field survey

Candidates for the Seventh Earth Explorer

- ***BIOMASS***

  A BIOMASS Monitoring Mission for Carbon Assessment

- **Core-H2O**

  Cold Regions Hydrology High-resolution Observatory

- ***FLEX***

  FLuorescence Explorer

- ***TRAQ***

  TRopospheric composition and Air Quality

- ***PREMIER***

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

- ***A-SCOPE***

  Advanced Space Carbon and Climate Observation of Planet Earth

Mission Advisory Groups formed and several rounds of meetings taken place since Nov. 2006 (Mission Requirement Document preparation => derivation of technical requirements).

Two parallel Industrial Mission Assessment studies underway – to assess each concept

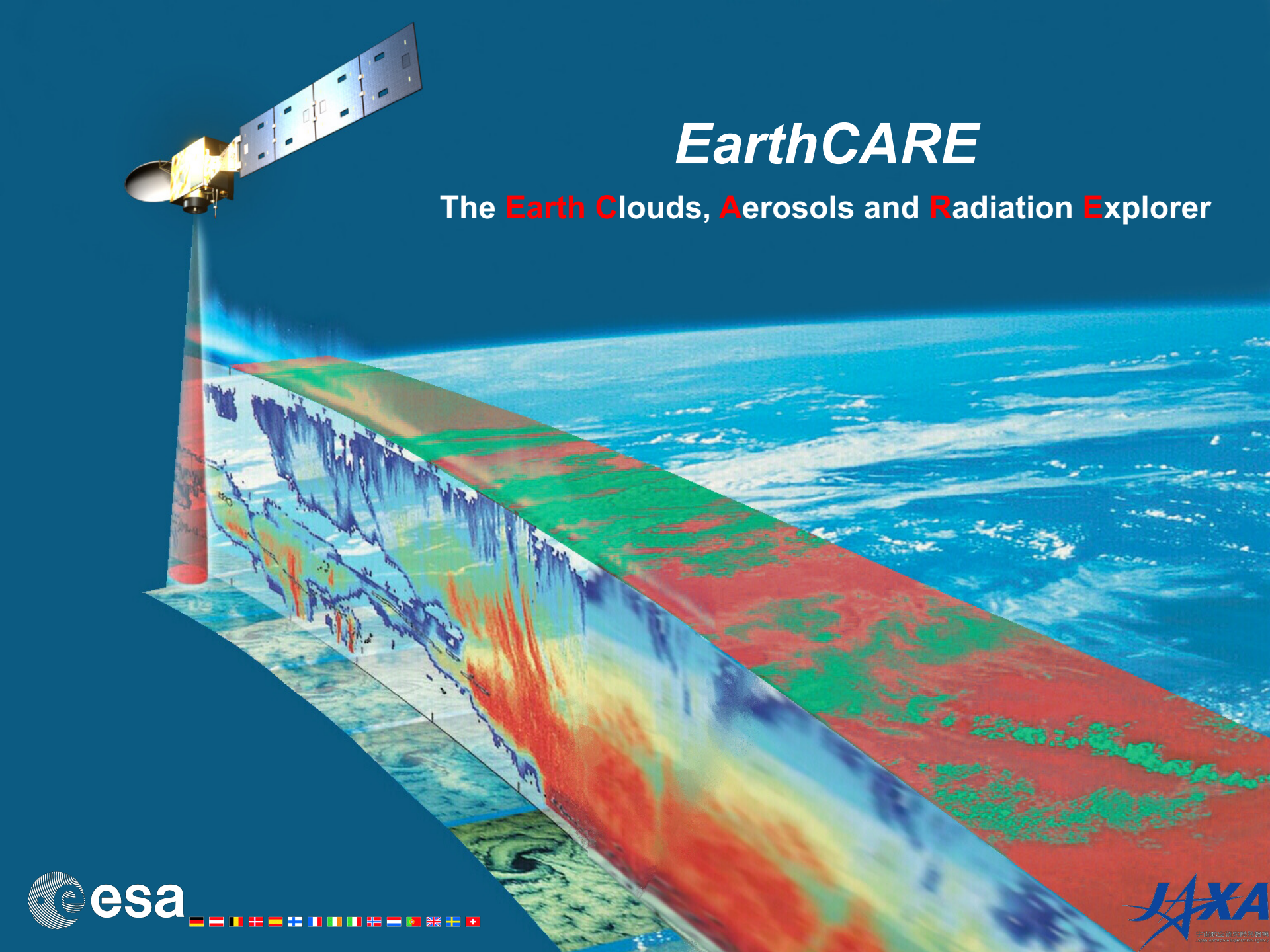
Global Monitoring for Environment and Security (GMES)

A System developed in conjunction with EU and other partners
to provide timely and adequate information delivery

ESA GMES Space Component

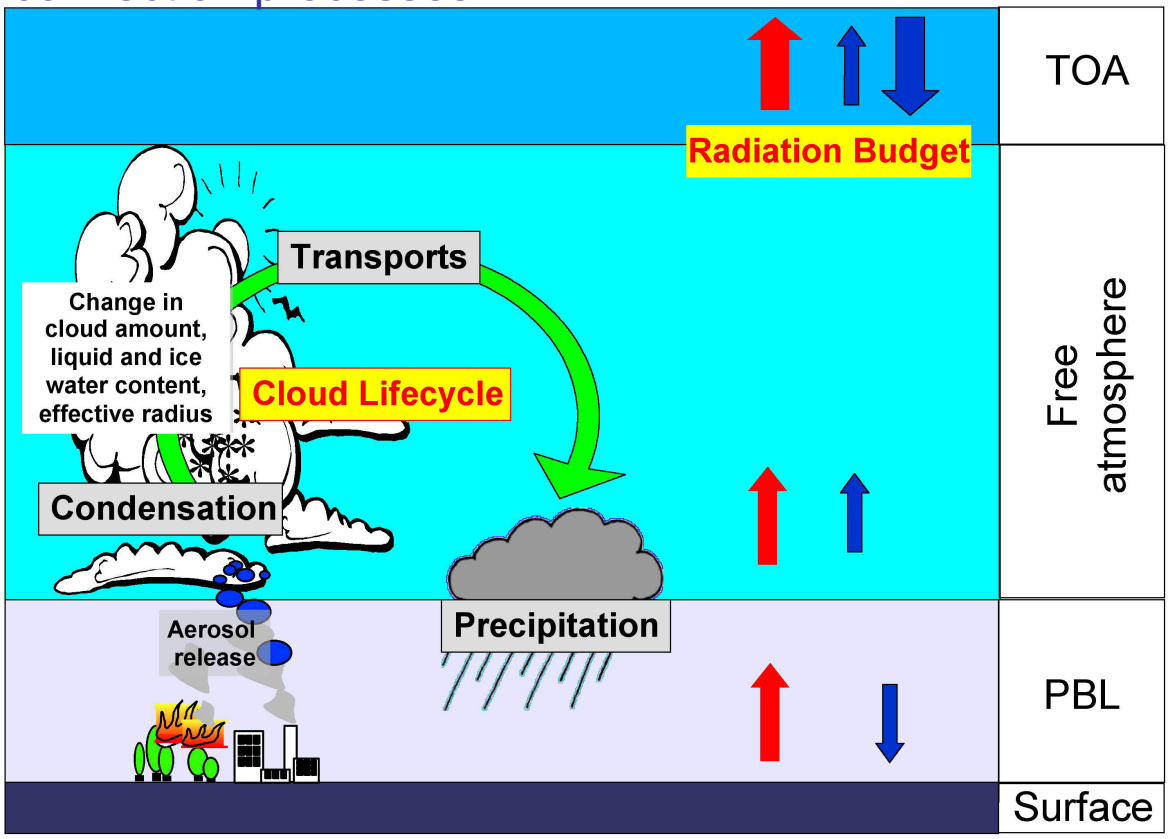
- **Sentinel 1 – SAR imaging**
  - Continuity of established SAR applications, interferometry
- **Sentinel 2 – Superspectral imaging**
  - Continuity of Landsat/SPOT class measurements
- **Sentinel 3 – Ocean monitoring**
  - Wide-swath multi-spectral sensors, SAR altimeter
- **Sentinels 4/5 – Geostationary & LEO atmospheric chemistry**
  - Atmospheric composition monitoring, trans-boundary pollution
  - Based on IGACO requirements et al.

In addition: study of fire-detecting and monitoring IR sensor (Fuego IR Element)


EarthCARE
The Earth Clouds, Aerosols and Radiation Explorer
esa
JAXA

The Earth Explorer Core Mission EarthCARE

Scope: Global simultaneous observations of cloud-aerosol-radiation and cloud-aerosol-precipitation-convection processes.



Goal: Reconstruction of vertical cloud/aerosol profiles and combine these with across-track imager information to derive accurately instantaneous radiative fluxes

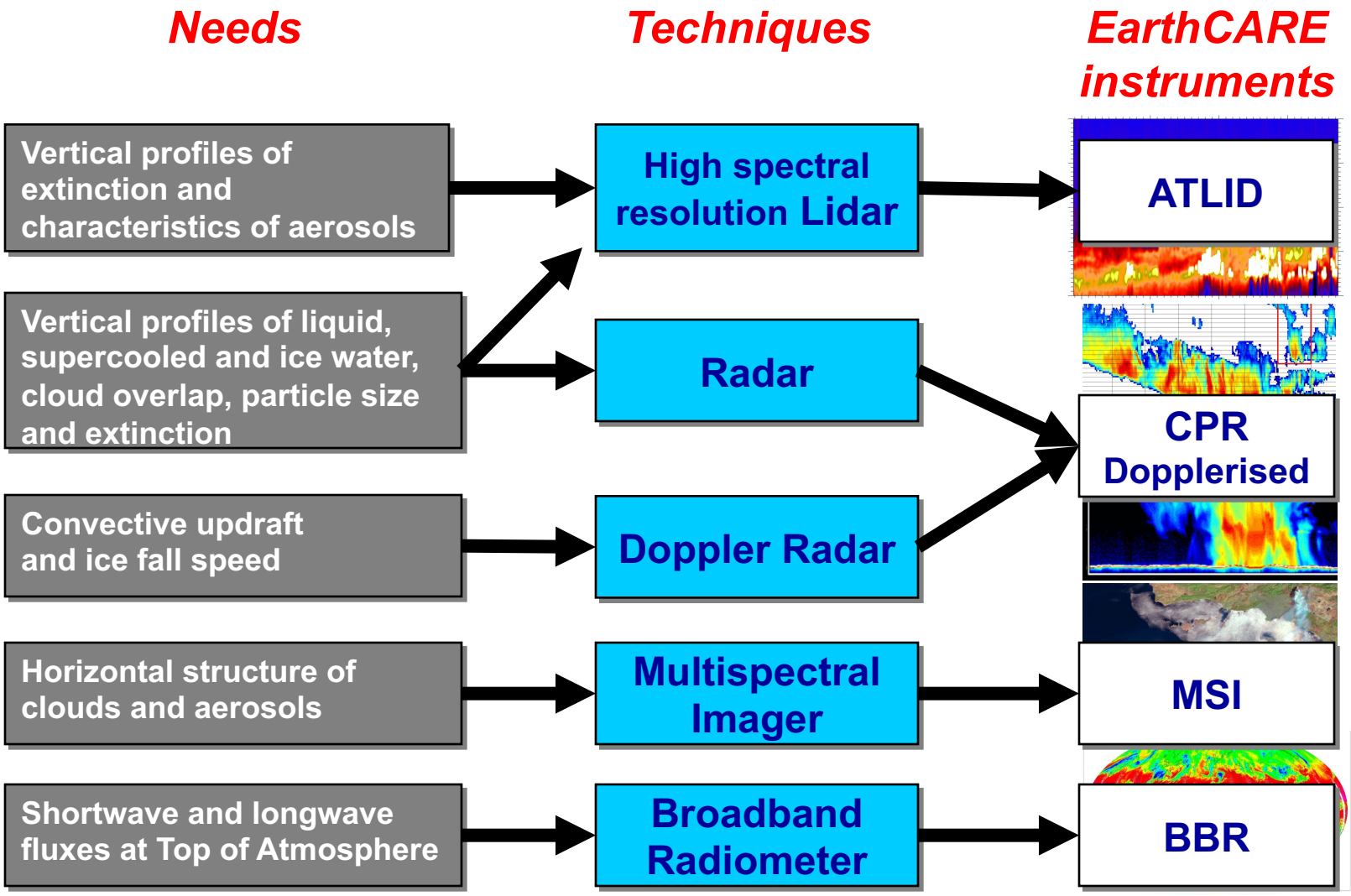
EarthCARE Mission Objectives:

Improve the understanding of cloud-aerosol-radiation interactions and provide an appropriate data basis for required GCM improvements.

Required global observations:

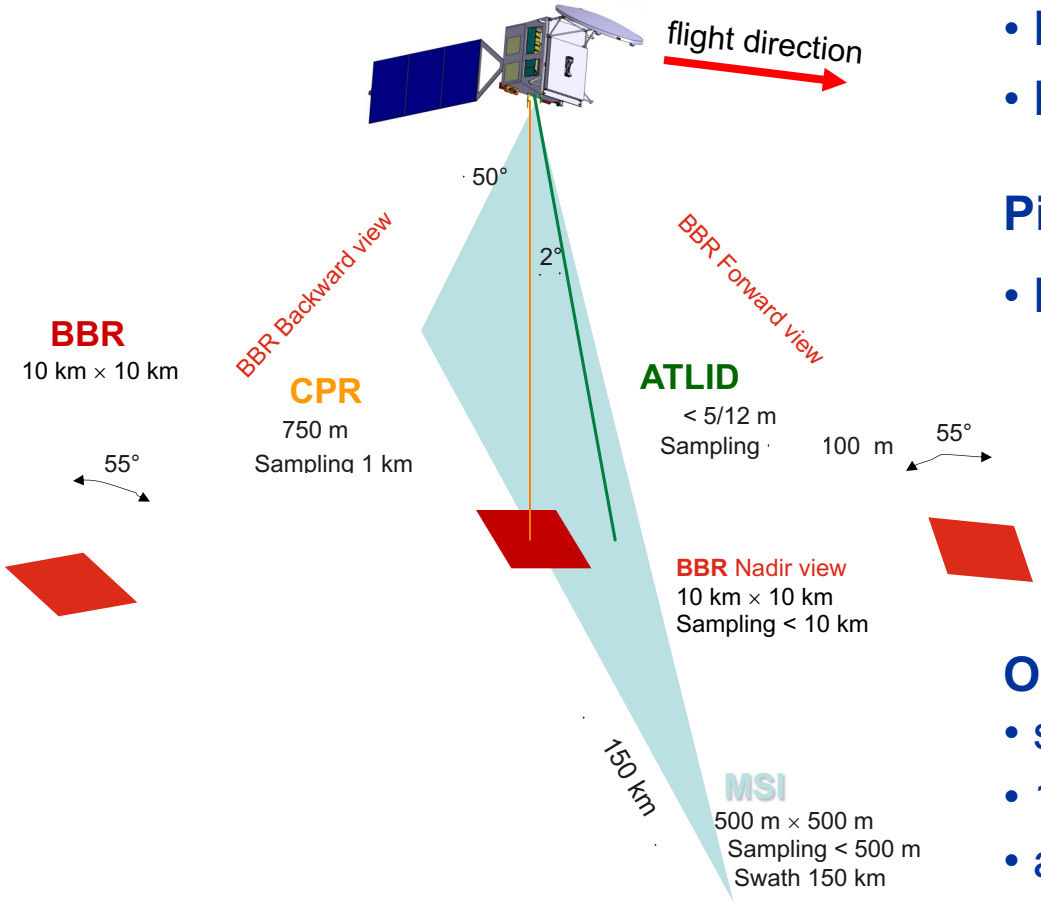
- Cloud distribution, including overlap
- Cloud-precip interactions and vertical motion within clouds
- Vertical distribution of liquid water and ice
- Vertical profiles of aerosols, also simultaneously with cloud observations
- Reconstructed 3D-scenes of clouds and aerosols
- Collocated and simultaneous observations of clouds, aerosols and radiation
- Radiative transfer calculations on reconstructed cloud and aerosol scenes to derive heating rates & flux and compare this to observed collocated TOA broad-band fluxes, on 10km x 10km pixel level

Observation Technique – Mission Concept



Temperature and humidity from operational analysis

Instruments viewing geometry



Time difference between acquisitions:

- Radar-Lidar: 2.2 s
- Radiometer nadir-fw/bw: 77 s

Pixel co-location:

- Radar-Lidar: < 350 m RMS

Orbit:

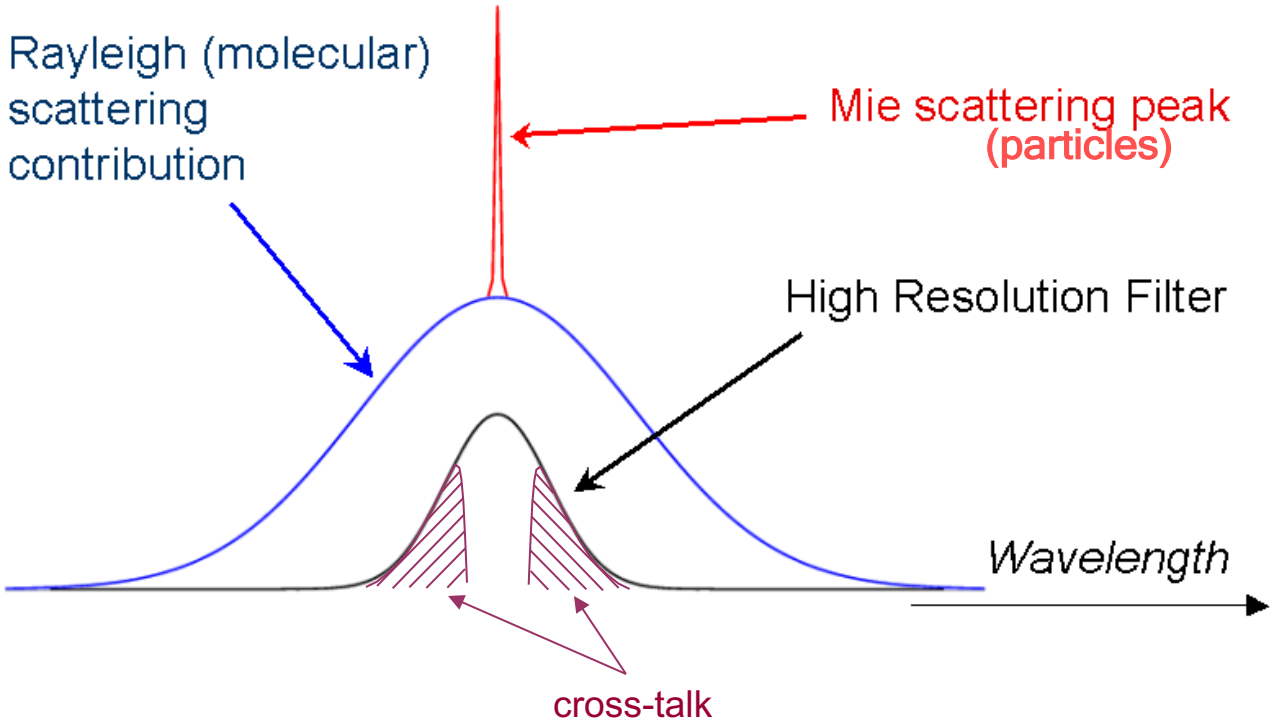
- sun-synch polar
- 13:45–14:00 LTDN
- around 400(-450) km

INSTRUMENTS

ATmospheric LIDar (ATLID)

- Backscatter UV (355nm, circular pol.) with high spectral resolution receiver (HSRL)
- 3 channels receiver: Rayleigh scatter, co-polar Mie, cross-polar Mie
- Sampling: horizontal: 200m (=2x100m integrated), vertical: 100m
- 2 to 3 deg (tbd) off-nadir (backwards) pointing to reduce specular reflection on ice clouds
- Products: extinction, backscatter, aerosol, ice clouds, ...

HSRL:



Programmatic Aspects

Overall Schedule

- 2004: Selected for implementation by ESA
- 2006: Completion of extended Phase A study
- 2007: Japanese cooperation confirmed
- 2008: Start Phase B, followed by Phases C/D, E1
- 2013: Launch, design mission life time 3 years

Co-operation with Japan

- JAXA / NICT provides Doppler radar
- Co-operation for science preparation and exploitation
- Joint Mission Advisory Group
- Joint retrieval algorithms development


27 May 2007
Vertragsunterzeichnung EarthCARE
Signature of the EarthCARE satellite

Technical Status In Europe

- EarthCARE industrial contract status - Phase B-C/D-E1:
  - Contract with Astrium-GmbH signed in May 2008 at ILA Berlin in presence of German Chancellor Dr. Angela Merkel
  - Phase B activities started mid-February 2007
  - All core-team kicked-off at same session
    - Spacecraft Prime: Astrium GmbH
    - Base-Platform: Astrium-Ltd
    - ATLID: Astrium-SAS with G.A as sub-contractor
    - BBR: SEA with RAL as sub-contractor
    - MSI: SSTL with TNO as sub-contractor
    - Full industrial team to be completed during phase B
- EarthCARE Overall Schedule:
  - Phase B K/O: Mid-Feb 2008 - duration ~ 15 months
  - Phase C/D K/O: June 2009 - duration ~ 50 months
  - Launch date: Sept 2013

Science Activities

Joint Mission Advisory Group:

Howard Barker
Anton Beljaars
Franz Berger
Jean-Pierre Blanchet
David Donovan
Martial Haeffelin
Anthony J. Illingworth*
Gelsomina Pappalardo
Jaques Pelon
Anthony Slingo
Ulla Wandinger

**Co-chairs and overall science leaders*

Hiroshi Kumagai
Takashi Nakajima
Terry Nakajima*
Hajime Okamoto
Nobue Sugimoto
Yukari Takayabu

Observers:
John Bates
Graham Feingold
Graeme Stephens
Deborah Vane
David Winker

Agencies:

ESA EarthCARE Mission Scientist:	Tobias Wehr
ESA EarthCARE Project Manager:	Alain Lefebvre and team
JAXA EarthCARE CPR Project Manager:	Toshiyoshi Kimura and team

(Co-)PIs of current ESA studies:

Simulator (ECSIM):

David Donovan, KNMI

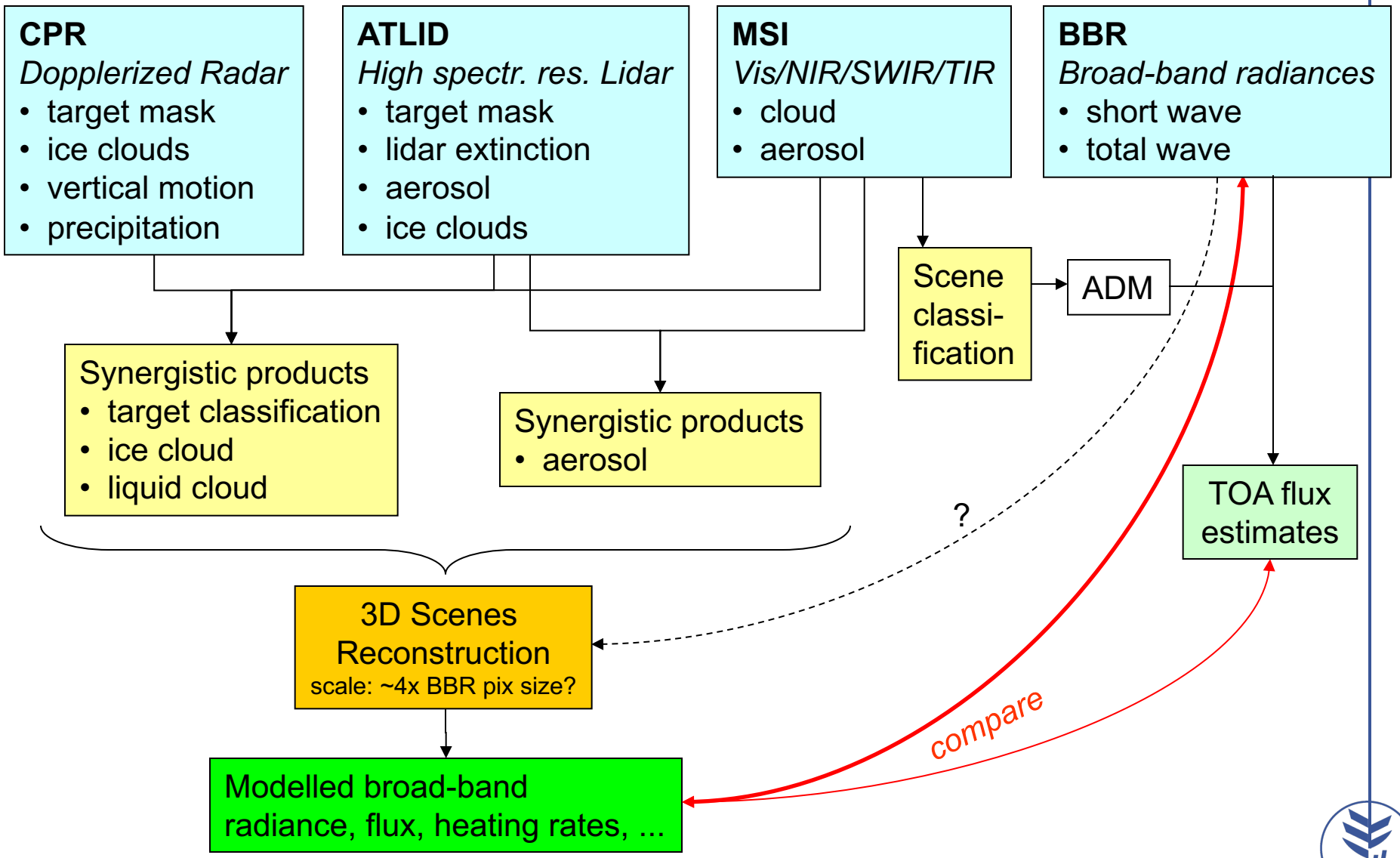
Level 2 algorithms:

Gerd-Jan van Zadelhoff, KNMI	- lidar algorithms
Pavlos Kollias, McGill University	- radar algorithms
Franz Berger, DWD	- imager cloud algorithms
Wolfgang von Hoyningen-Huene & Alexander Kokhanovski, Univ. Bremen	- imager aerosol algorithms
Robin Hogan, Univ. Reading	- syngergistic cloud and aerosol algorithms
Howard Barker, Environment Canada	- radiative transfer: mod. vs. obs. radiation
Carlos Domenech-Garcia, ESA/ESTEC	- broad-band flux retrievals using ADMs
David Donovan, KNMI	- lidar, radar, imager, radiometer, synergy

NWP impact:

Marta Janiskova & Peter Bauer, ECMWF

Data Products and Processing Chain under Consideration



2-years Project to start September 2008:

QuARL – Quantitative Assessment of the Operational Value of of Space-Borne Radar and Lidar Measurements of Cloud and Aerosol Profiles

Marta JANISKOVÁ and Peter BAUER, ECMWF

Despite the importance of clouds in the atmosphere, there is still no explicit analysis of clouds in global data assimilation systems.

Cloud contributions to the satellite radiances are (mostly) removed from the assimilation system.

This study:

- Develop strategies to assimilate radar and lidar observations (1D-var, 4D-var)

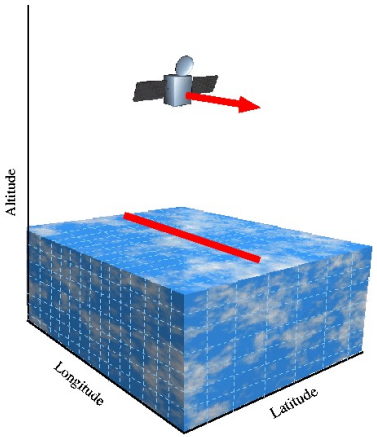
This includes:

- Forward operator developments
- Verification/validation of cloud and aerosol parameterisations
- Quality assessment of cloud screening and height assignments in atm. motion vectors
- Strategies for lidar and radar data quality monitoring
- Assimilation experiments

Test data sets: CloudSAT CPR and CALIOP

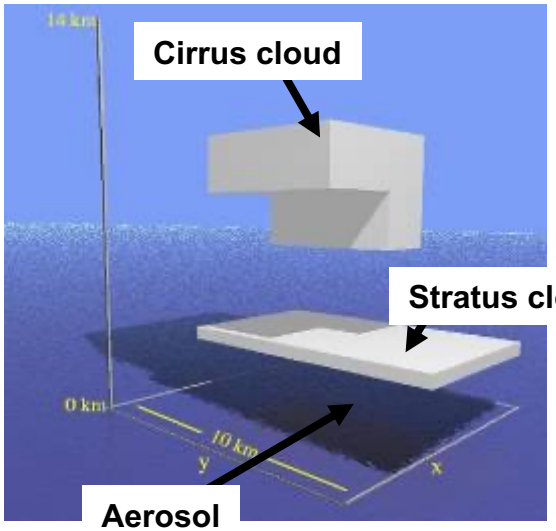
The EarthCARE Simulator

D. Donovan et al.



- Simple scenes or complex scenes with highly detailed cloud and aerosol microphysics
- Resolution down to 25 m
- 3-dimensional Monte-Carlo radiative transfer code for long- and short-wave radiation including multiple scattering (also for lidar)
- Instrument characteristics including noise, sampling and footprints
- Retrieval algorithms implemented (and growing!)

Example of 'simple' scene (scale of BBR footprint)



EarthCARE Simulator (cont.)

MSI image

synthetic 3D scene

extinction

simulated measurements

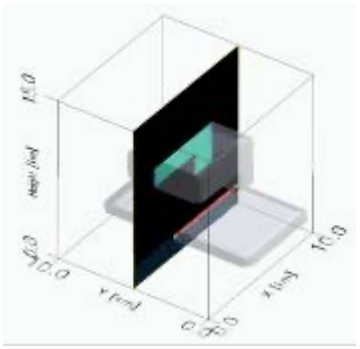
co-polar Mie

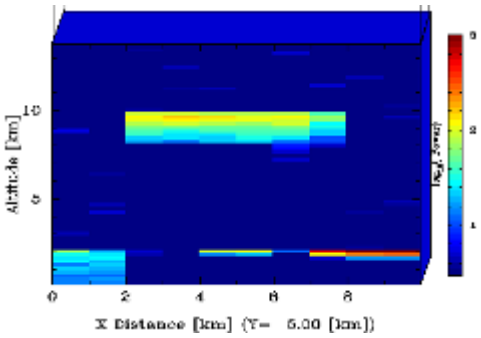
Retrieval profiles

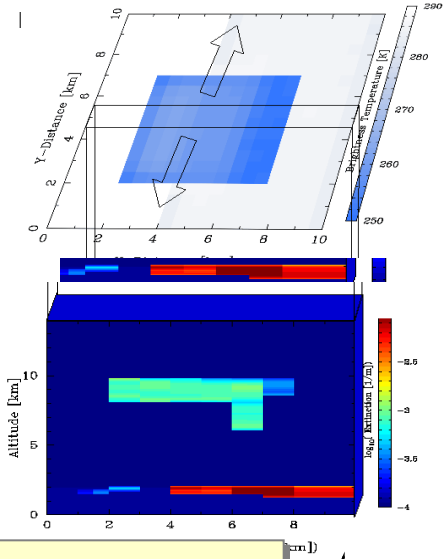
extinction

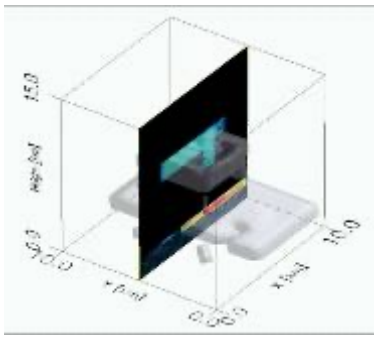
reconstructed 3D scene

extinction









TOA radiation :
SW: 244.0 W/m²
LW: 238.6 W/m²

Differences :
SW: 5.0 W / m² < 10 W / m²
LW: 2.3 W / m² < 10 W / m²

TOA radiation :
SW: 249.0 W/m²
LW: 236.3 W/m²

Level 2 Developments (near future ~3-4 years)

Ongoing

- CASPER study → first element of cloud / aerosol products development
- AMARSI study → EarthCARE (and Sentinel-3) aerosols from imagers
- ADM developments for broad-band TOA flux estimates (radiometer)
- ECSIM (EarthCARE Simulator) → end-to-end analysis and algorithm development tool
- Start of co-ordination European/Canadian-Japanese L2 developments

Necessary next steps (2009 - ...)

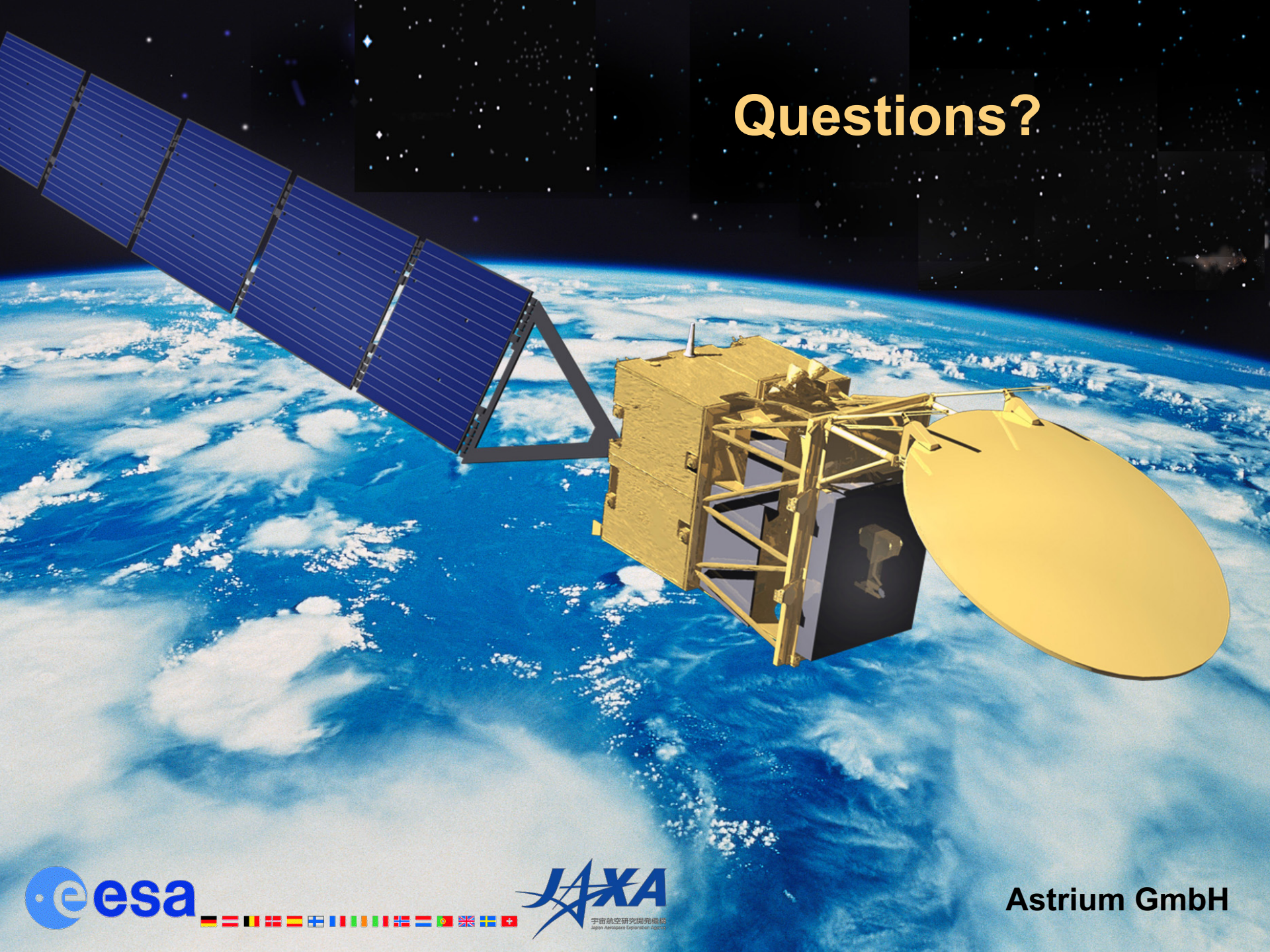
- Clouds and aerosols (CASPER follow-on activities): comprehensive suite of single-instrument products, Doppler modelling, multi-instruments synergistic products (including variational schemes), 3-D scene reconstruction → *As far as possible also drawing on experiences of CloudSAT, CALIPSO, MERIS/MODIS, ...*
- Radiation: (1) Continuation of ADM developments (CERES?),
  (2) The 'Radiation Bracket': Take retrieved 3D-cloud/aerosol scenes → model TOA radiances → compare to measured broad-band (SW, TW) radiances → assess retrieval quality, calculate fluxes, heating rates, ...

Getting Involved with EarthCARE

Most effective: bring along your own funding and team up
Might also work: respond to study ITTs (if you are in Europe or Canada)

Attend EarthCARE Workshops: about every ~two years
Next workshop: Kyoto, Japan, June 2009 (to be announced)

Latest workshop: ESA/ESTEC, Netherlands, May 2007



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Japan Aerospace Exploration Agency

Astrium GmbH