EarthCARE

The **Earth** **C**loud **A**erosol and **R**adiation **E**xplorer

with some remarks on other future ESA missions

Tobias Wehr
ESA/ESTEC, Noordwijk, The Netherlands
E-mail: Tobias.Wehr@esa.int

ESA's Living Planet Programme

www.esa.int/livingplanet

Earth Explorer
Research driven

Core Missions

GOCE
2009
in orbit

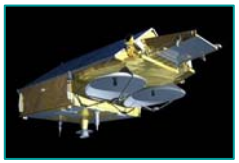
ADM-Aeolus
2011

EarthCARE
2013

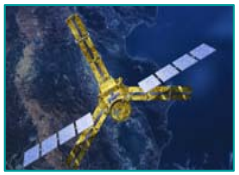
3 Candidates:
- **BIOMASS**
- **Core-H2O**
- **PREMIER**

Earth Explorer 7
2015

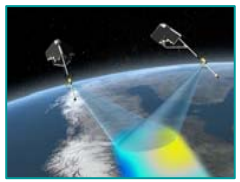
Opportunity Missions



CryoSat 2
2009



SMOS
2009



Swarm
2010

Earth Watch
Service driven

Coop. with EUMETSAT
- **Meteosat**
- **MSG**
- **MTG**
- **EPS**
- **Post EPS**

GMES
- **Sentinel 1**
  - SAR imaging
- **Sentinel 2**
  - Superspectral high res. land imaging
- **Sentinel 3**
  - Ocean monitoring, mid-/low res. imagery + SAR
- **Sentinel 4** (on MTG)
  - Atmospheric chemistry
- **Sentinel 5** (on Post-EPS)
  - Atmospheric chemistry
- **Sentinel 5-Precursor**
  - Atmospheric chemistry

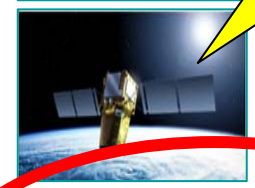
Overview ESA Missions

ADM-Aeolus – cloud and aerosol products as spin-off:
Height profiles of Mie & Rayleigh backscatter & extinction coefficients, scatter ratio and Lidar ratio → from this, retrieval of cloud and aerosol information possible (optical

Sentinal 4 / 5:
Chemistry package including O_2-A & O_2-O_2 band → cloud (height, opt. density, fraction), aerosol

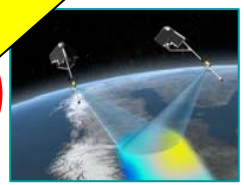
PREMIER: (one of 3 Core Mission candidates)
Atmospheric chemistry mission (boundary layer up to lower stratosphere)
→ MW limb sounder (310-360GHz), IR Limb sounder/cloud imager (FTS)

→ **enabling observation of cirrus cloud extinction (limb sounding)**



AD
20

SMOS
2009



Swarm
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3 Candidates:
- BIOMASS
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EPS
Post EPS

high res.
land imaging
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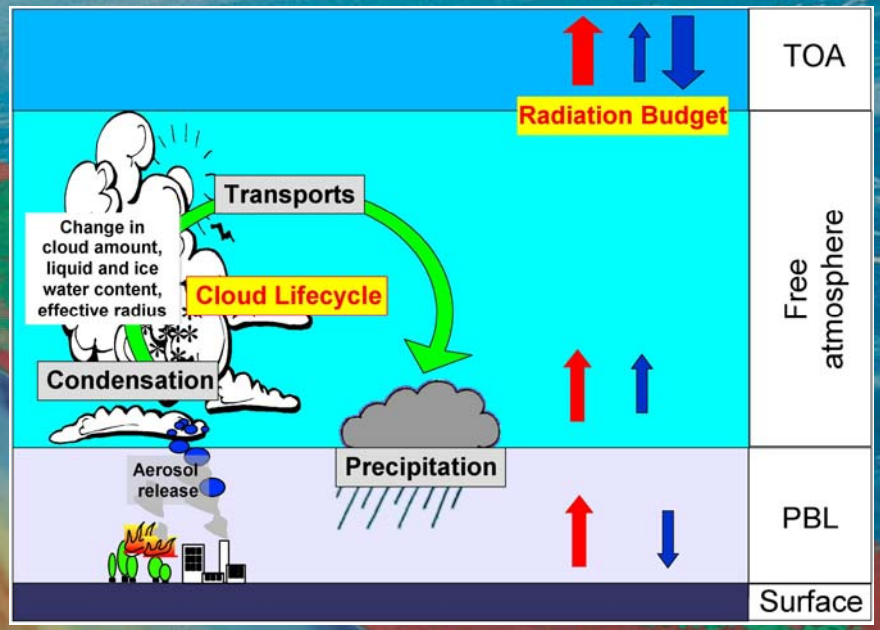
EarthCARE

Scope: Global simultaneous observations of

- Cloud profiles & aerosol profiles
- Cloud & aerosol in 2D
- Cloud-precipitation-convection
- Radiation and flux



Goals: Understand cloud-aerosol-radiation link

- Reconstruction of 3D cloud-aerosol scenes
- Evaluation with simultaneous broad-band radiation observations

Use of EarthCARE Data in Climate Modelling → How?

EarthCARE mission objectives:

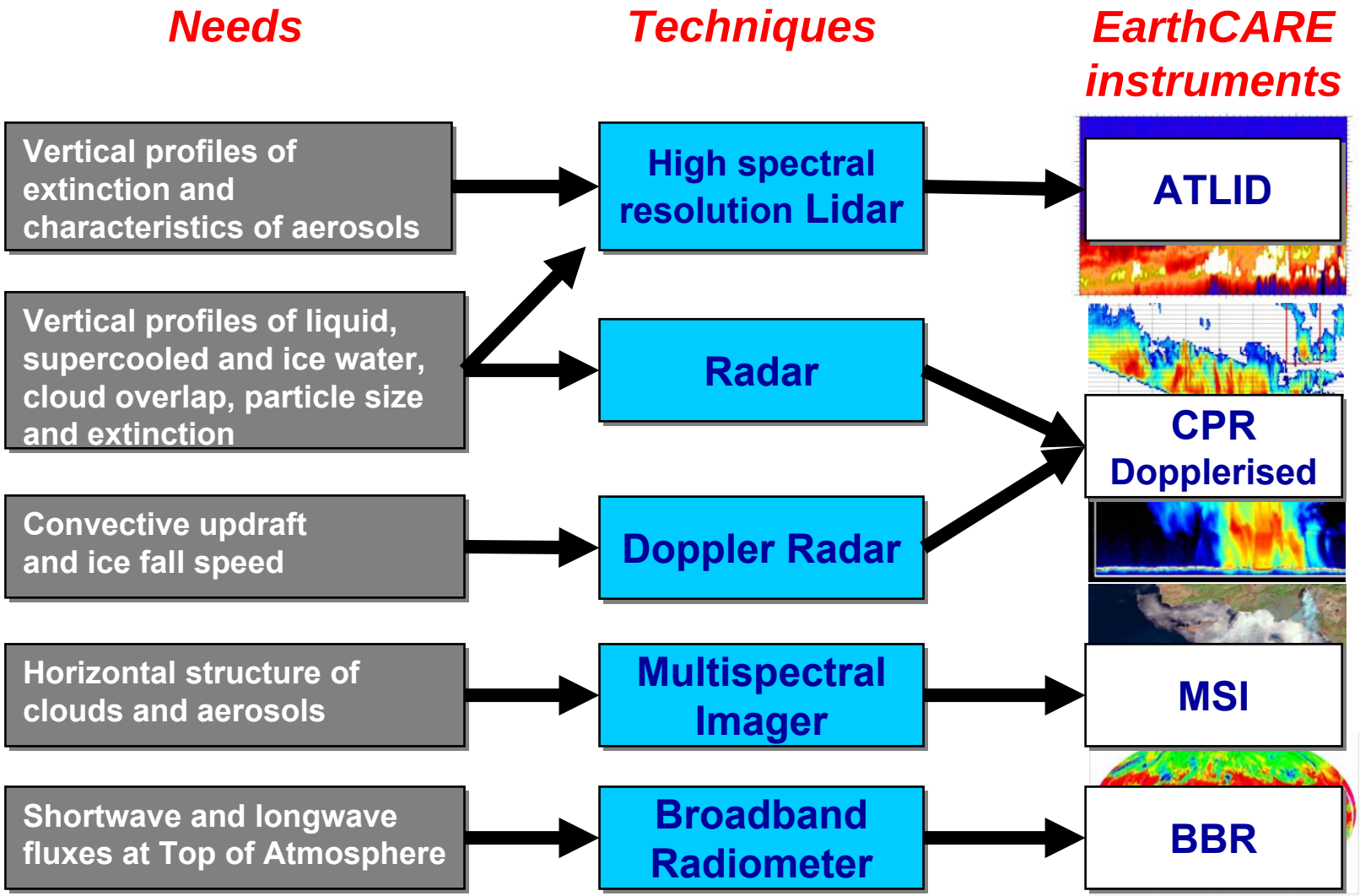
- **Improve understanding of cloud-aerosol-radiation interaction so as to include them correctly and reliably in climate and NWP models.**

Data product requirements from modellers?
In particular:
- spatial resolution?
- error quantifiers?
- product statistics?
- ...

Required global observations:

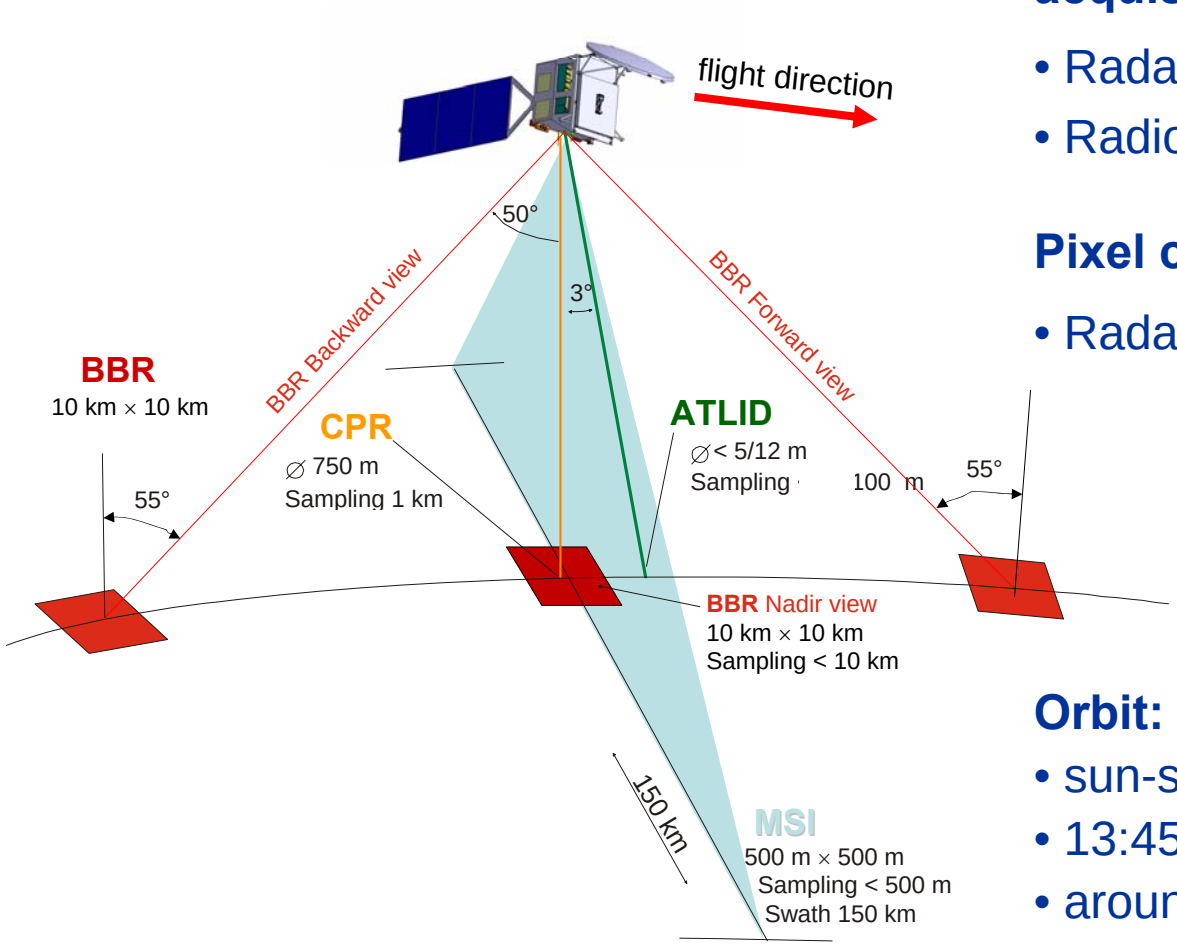
- Cloud distribution, including overlap / multi-layer
- Cloud-precipitation interactions and vertical motion within clouds
- Vertical distribution of liquid water and ice
- Vertical profiles of aerosols, also simultaneously with cloud observations
- Collocated and simultaneous observations of clouds, aerosols and (broad-band) radiation
- Reconstructed 3D-scenes of clouds and aerosols
- 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

Mission Concept – Observation Techniques



Temperature and humidity from operational analysis

Instruments viewing geometry



Time difference between acquisitions:

- Radar-Lidar: about 3 s
- Radiometer nadir-fw/bw: 77 s

Pixel co-location:

- Radar-Lidar: < 350 m RMS

Orbit:

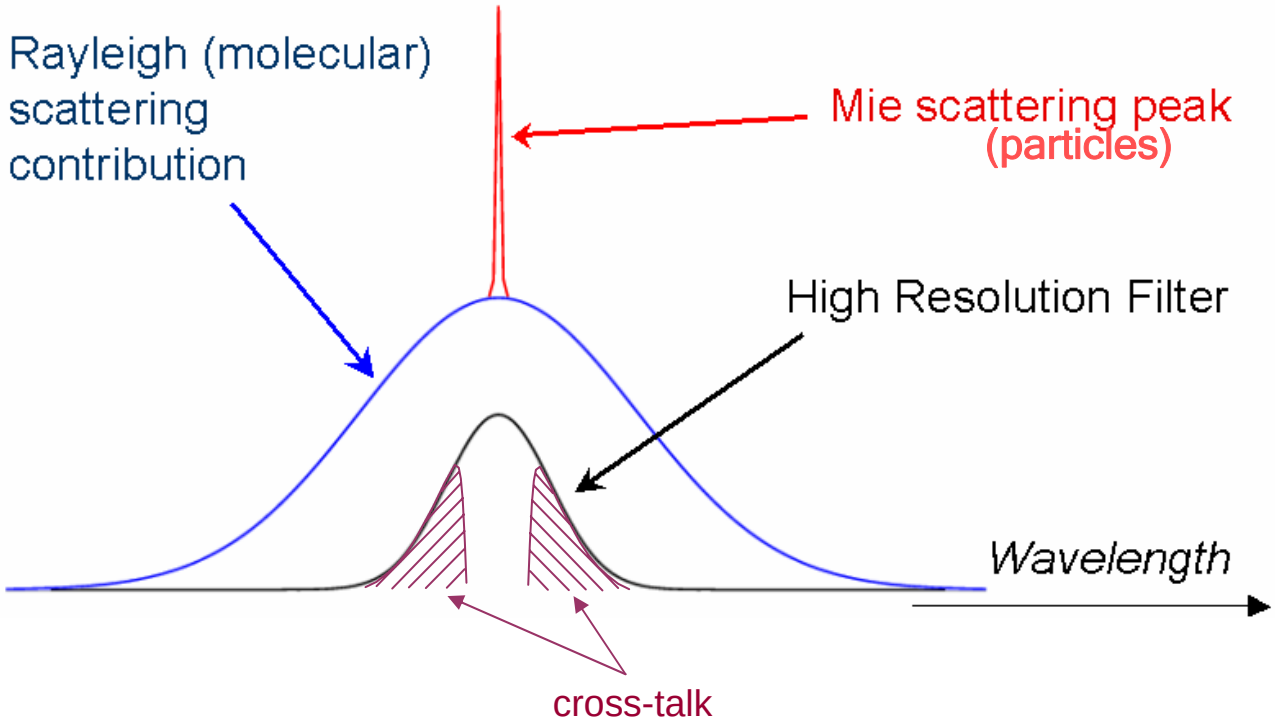
- sun-synch polar
- 13:45–14:00 LTDN
- around 400(-450) km

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:



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Cloud Profiling Radar (CPR), contribution of JAXA, built by NICT

- 94GHz with Doppler capability
- Sensitivity at least -35dBZ@20km height, Doppler accuracy: 1 m/s
- Sampling: horizontal: 500m, vertical 100m (vertical resolution 500m)
- Products: Z, vertical velocity, ice clouds, water clouds, (light) precip., ...

Multi-Spectral Imager (MSI)

- 4 solar channels: Vis (670nm), NIR (865nm), SWIR1&2 (1.65µm & 2.21µm)
  3 TIR channels: 8.80µm, 10.80µm, 12.00µm
- Nadir viewing push-broom, swath: -35km to +115km (to minimize sunglint), $(500m)^2$ res.
- Products: scene identification, 'imager cloud products' (ice clouds, water clouds), aerosols (limited over land), ...

Broad-Band Radiometer (BBR)

- Short-wave (0.25µm-4µm) and total wave channel (0.25µm-50µm)
- 3 views: nadir, foreward (55deg), backwards (-55deg), 10km x 10km pixels
- Products: TOA radiance and flux

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 “JMAG”
- Joint Algorithm Development Endeavour “JADE”

Technical Status (Europe)

- EarthCARE industrial contract status - Phase B-C/D-E1:
  - Contract with Astrium-GmbH signed in May 2008
  - Phase B activities started mid-February 2008
  - Industrial core team
    - **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
- EarthCARE Overall Schedule:
  - Phase B K/O: Mid-Feb 2008 - duration ~ 15 months
  - Phase C/D K/O: later in 2009 - duration ~ 50 months
  - Launch date: Sept 2013

Joint Mission Advisory Group:

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

Deceased member
Anthony Slingo

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

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

**Co-chairs and overall science leaders*

Agencies:

ESA EarthCARE Project Manager:	Alain Lefebvre
ESA EarthCARE Mission Scientist:	Tobias Wehr
JAXA EarthCARE CPR Project Manager:	Toshiyoshi Kimura
JAXA EarthCARE Mission Scientist:	Riko Oki

(Co-)PIs of current ESA studies:

Simulator (ECSIM):

David Donovan, KNMI	- end-to-end mission simulator

Level 2 algorithms:

Gerd-Jan van Zadelhoff	- 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	- Quantitative assessment of the operational value of of satellite Radar and Lidar measurements of clouds and aerosols using CloudSAT, CALIPSO

Proposed Level 2 Data Products

EarthCARE level-2 data products as suggested by level-2 study team (Donovan et al., 2009)

Proposed to JMAG

Level 2 data products and algorithms will be discussed at upcoming JMAG and JADE meetings in April 2009

I	Detection Mask	Target	Extinction Backscat.	Ice	Liquid	Precip.	Aerosol	Vertical Motion	Best estimate (+precip)
LEVEL 2a									
Radar	M, Mat *Hydrometeor mask*	M, Mat *Cloud/ Precip. Type*	—	M, Mat	M, Nov	M, Exp	—	M, Exp	—
Lidar	M, Mat	M, Nov	M, Nov	M, Nov	D, Exp	—	M, Nov (typing)	—	—
MSI	—	M, Mat *Cloud class, phase*	M, Mat *Optical properties*	M, Nov *IWP, r_e, optical depth*	M, Nov *LWP, r_e, optical depth*	D, Exp	M, Nov *Type, optical depth*	□	—
LEVEL 2b									
Radar Lidar	—	M, Nov	—	M, Mat	I, Exp	—	—	—	D, Exp
Lidar MSI	—	□	□	I, Nov	D, Exp	—	M, Nov	—	D, Exp
Radar MSI	—	□	—	D, Nov	D, Exp	—	—	—	D, Exp
Radar Lidar MSI	—	□	—	M, Nov	M, Exp	—	—	—	M, Exp
LEVEL 2b-2D and 2b-3D									
	MSI + L2a 2D and 3D scenes					Heating rate profiles			
L2b-2D	I, Mat *Cloud fraction and overlap on a pseudo-model grid along track*					I, Nov *Heating rates calculated using "best estimate" product along 2D swath (as CloudSat)*			
L2b-3D	I, Exp *3D Scene reconstruction using MSI*					I, Exp *Heating rates calculated on 3D scene (Need JMAG discussion)*			

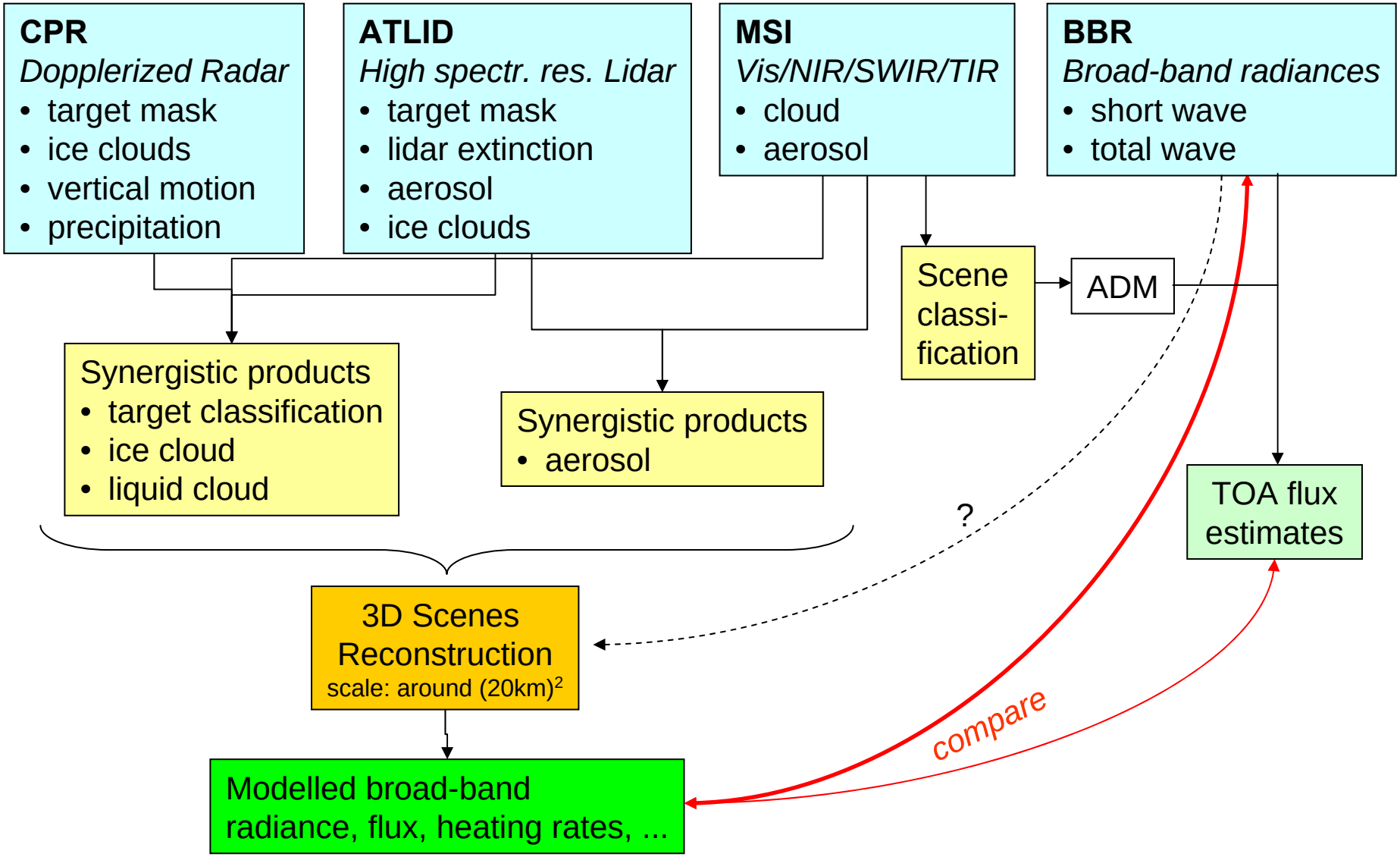
Legend

□ = Combination of L2a is still interesting

— = not applicable

Mandatory	Important	Lower priority: small addition to what is provided by other instruments	Develop for redundancy as limiting case of 3-instrument algorithm

Proposed Data Processing Chain



Modellers: Invitation to getting involved

The cloud / climate modelling community is invited to increase involvement in EarthCARE preparatory activities, in particular to

- Communicate the envisaged use of EarthCARE data,
- Help define data requirements, in particular related to data product spatial resolution and data product statistics (including error to be reported in data products).

Contact:

- Members of the Joint Mission Advisory Group
- Tobias Wehr

Science Community: Invitation to getting involved

EarthCARE workshops, to take place every ~2 years
Next workshop: 10-12 June 2009, Kyoto, Japan