DLR

esa

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TAKING THE PULSE OF OUR PLANET FROM SPACE

EUMETSAT ECMWF EUSPA

ESA Validation and Applications Preparation

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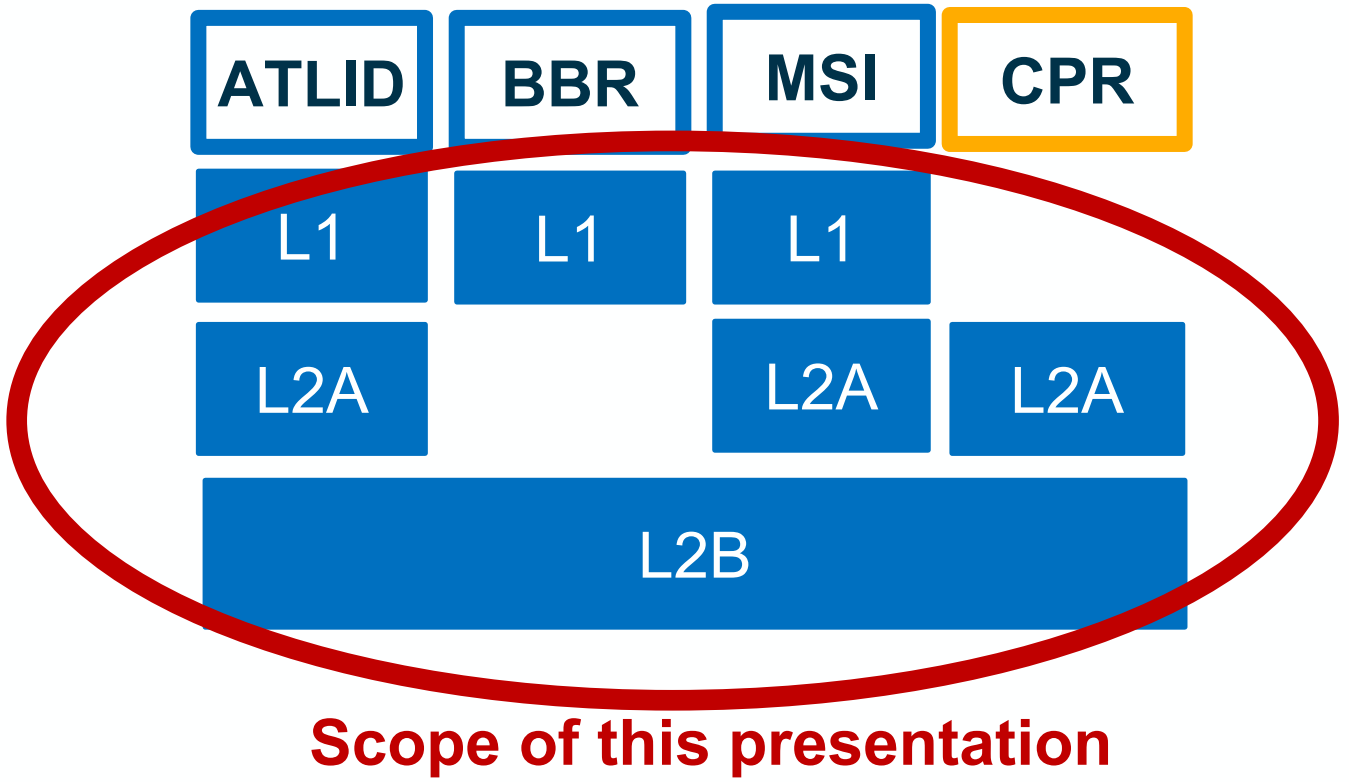
Thursday – 26.05.2022

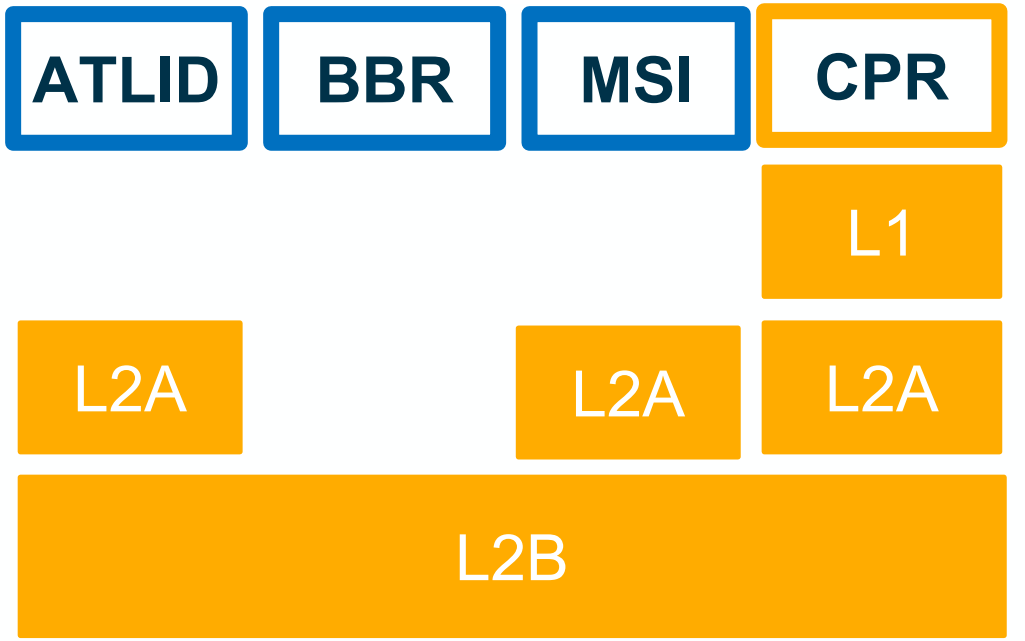
Validation Preparation

Presentation scope (1)

Each agency coordinates the validation of its own products



Scope of this presentation



Presentation scope (2)

Characterisation

Probing properties as a function of conditions – performed on-ground prior to launch but also in-orbit by **engineering teams**

Calibration

Quantitavely establishing system response in response to controlled signal inputs - idem

Verification

Assessment whether a system meets its specification – performed on-ground prior to launch from stimuli and simulated datasets **and in-orbit by analysing L0, L1, calibration, and L2 datasets by engineering teams and algorithm teams**

Validation

Assessment of the data quality **by independent means** – performed by the **validation** teams with correlative (“external”) data

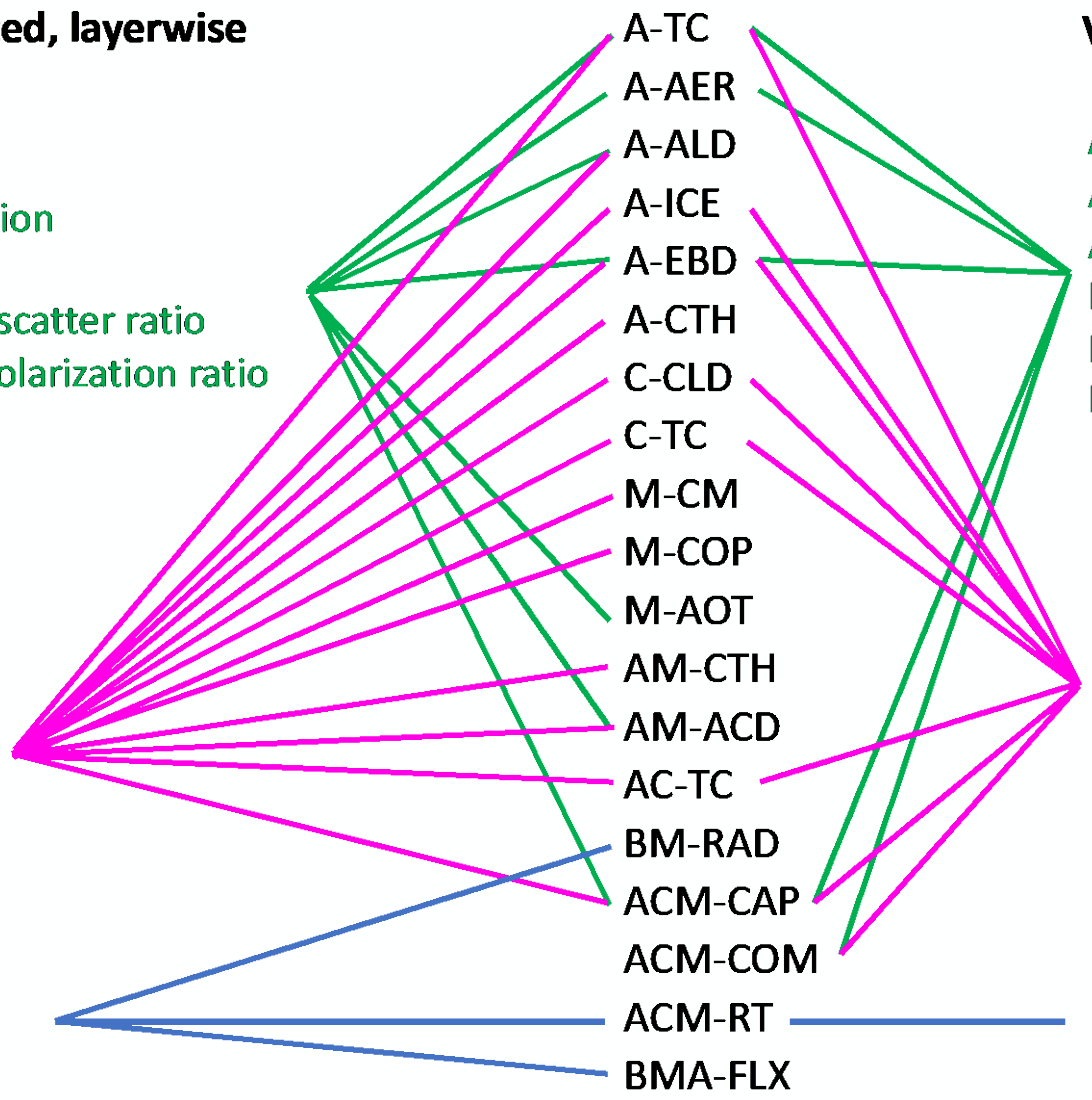
ESA EarthCARE L2 data products

Cloud-top, vertically integrated, layerwise

Aerosol
Aerosol layer height, classification
Optical thickness,
Layer-mean extinction-to-backscatter ratio
Layer-mean particle linear depolarization ratio
Angstrom exponent

Cloud and precipitation
Cloud-top height, phase, type
Optical thickness
Effective radius
Liquid, ice, rain water path
Surface snow rate
Surface rain rate

Radiation
Radiative fluxes at TOA
Broadband radiances at TOA



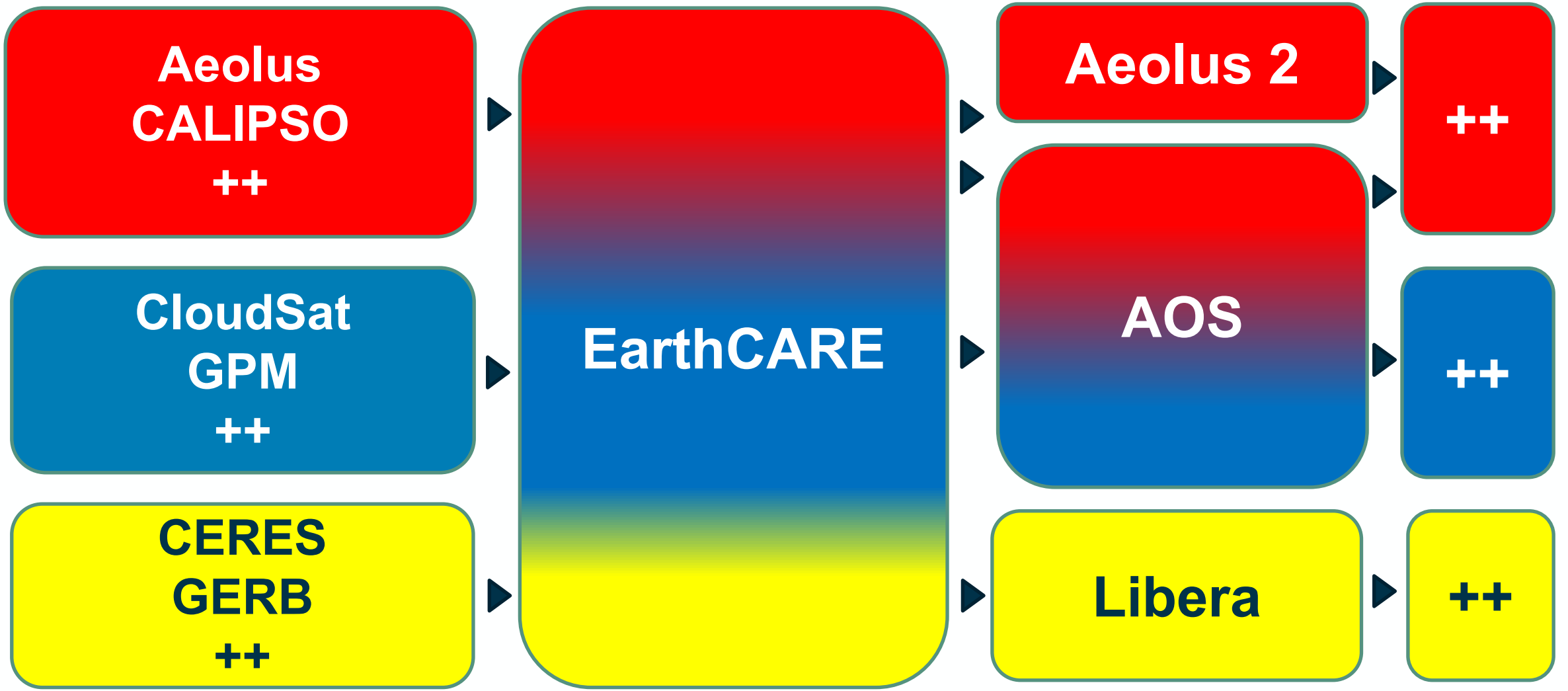
Vertical profiles

Aerosol
Aerosol fraction
Aerosol species
Extinction
Extinction-to-backscatter ratio
Particle linear depolarization ratio

Cloud and precipitation
Extinction
Effective radius
Liquid, ice, rain water content
Snow rate, median diameter
Rain rate, drop size
Cloud/precipitation fraction
Cloud/precipitation classification

Radiation
Broadband radiances
Radiative fluxes

Data record continuity (aerosol, cloud/precip, radiation)



EarthCARE validation challenges

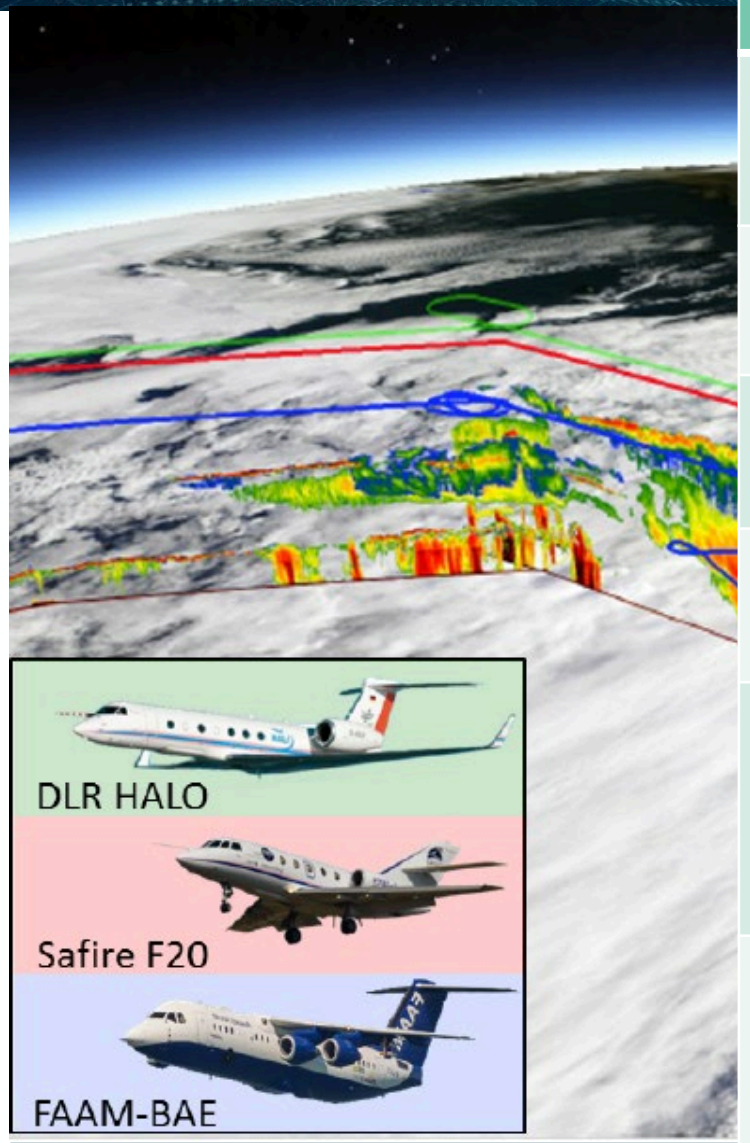
EarthCARE validation presents a **unique** combination of challenges

- The large **number** of different products and their **diversity**
- The **heterogeneity** of the validation community
- Synergistic products -> **synergistic validation**
- Difficult **sampling**

Validation approach

- **Pre-launch campaigns** and **Fiducial reference measurement** development activities for radars and lidars (FRM4RADAR, eVe, EMORAL) and **suborbital-to-orbital simulators**
- **Announcement of opportunity** for the validation community, incorporating PIs into the EarthCARE Validation Team, and fostering the interaction with national funding sources
- **Secure collocated airborne datasets,** covering diverse scenes, through collaboration with campaigns
- Collaboration with **networks,** e.g ACTRIS/ATMO-ACCESS
- ESA-JAXA coordination through the joint **Scientific Validation Implementation Plan**
- **Lessons learned / best practice convergence** on validation of aerosol, cloud and precipitation profiles in collaboration with CALIPSO, Cloudsat, Aeolus, and AOS scientists

Pre-launch validation campaigns



Campaign	Venue	Date	Platform(Institute)Payload	EarthCARE Objective
CLARE	UK	1998	C-130(UKMO) *in situ* F27(IPSL) radar, ++ Falcon (DLR) lidar, ++ Ground radar,lidar, ++	Mission pre-development
NARPEX	Arctic-Tropical Atlantic	2013 2014	HALO(DLR), radar, lidar, ++	Synergistic retrieval, radar calibration verification, calipso/cloudsat underflights
EPATAN (part of NAWDEX)	Island	2016	Falcon(LATMOS) radar, lidar, TIR++ HALO(DLR) radar, lidar, imager, ++ FAAM(UKMO) *in situ*	L2 algorithm verification (cloud regimes), calipso/cloudsat underflights
A-CARE (part of A-LIFE)	Cyprus	2017	Falcon(DLR) *in situ,* ++ Ground radar,lidar, ++	Microphysics, aersol classification verification, calipso/cloudsat underflghts
CADDIWA (part of JATAC)	Cape Verde	2021, 2022	Falcon(LATMOS) radar, lidar, *in situ*, ++ Ground radar, lidar, ++ Further datasets JATAC dataset also interesting also for EarthCARE: Cessna(UNG) *in situ*, CPEX-AW(NASA)radar++	L2 algorithm verification, (cloud, maritime aerosol, and desert dust regimes)
ACTIVATE and IMPACTS data exchange	Western Atantic US East Coast	2020 2021 2022 2020	King Air (NASA), lidar, ++ Falcon (NASA*) in situ*, ++ ER-2 (NASA), multiple radars, ++ P-3 (NASA), *in situ*	ACTIVATE and IMPACT had no EarthCARE campaign objectives. collaboration between NASA teams and ESA algorithm teams on datasets for algorithm verification

In-orbit Validation planning

- **Early underflights for L1 and L2 validation**
  - First ~2 months after launch several instruments will not yet be in nominal mode.
  - L1 product release to public is at L+6 months.
  - Ground sites will have **sparse** collocated datasets by then: -> airborne remote sensing
  - L1 validation requires **precise** collocation: -> airborne and mobile systems (also simultaneously: triple collocation)
  - Retrievals **assume** particle properties -> airborne in situ (tandem flights)
  - For land overpasses: low passes prior or after underflight, to measure albedo

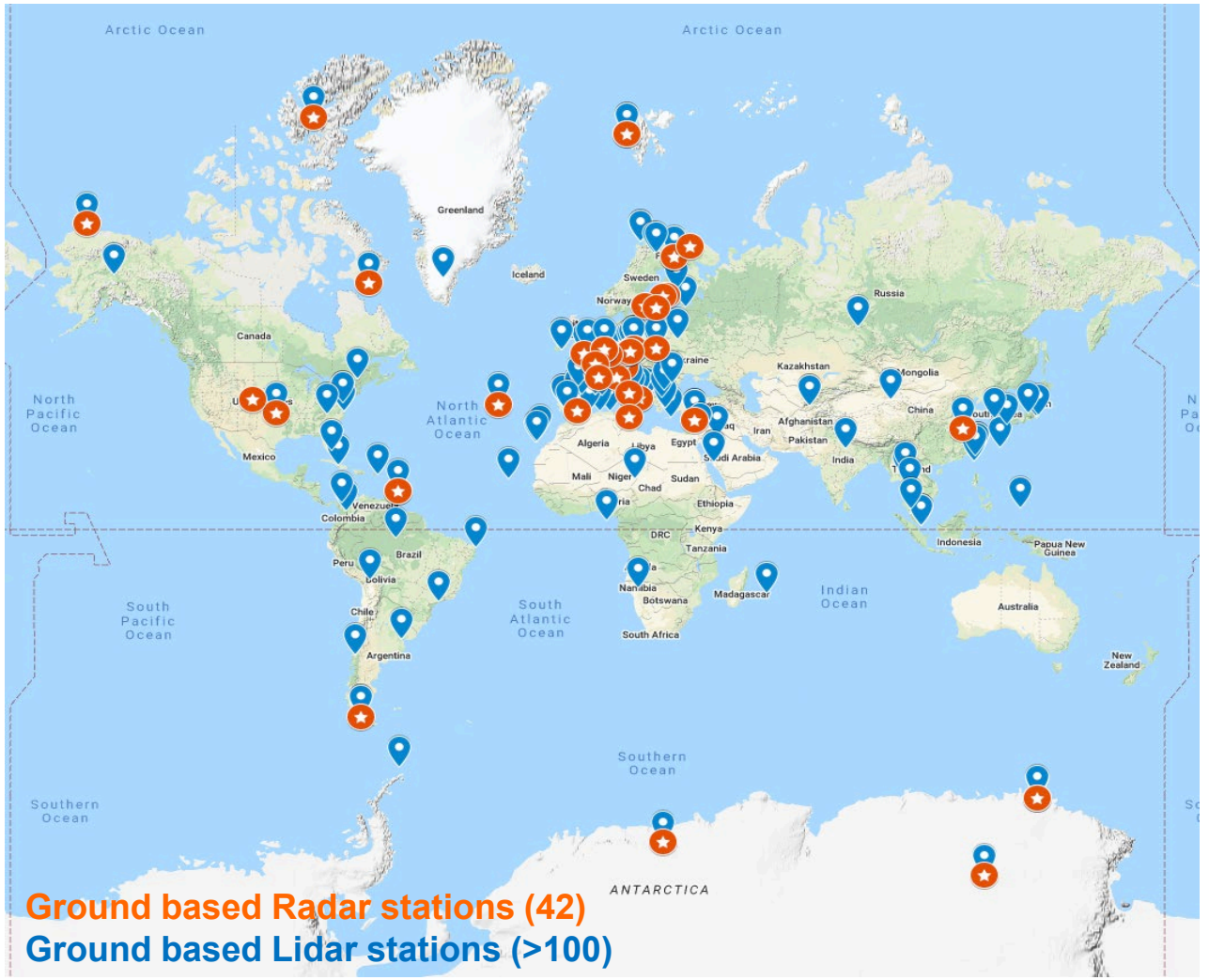
- **Parallel ground-based network data acquisition, continuously, over the mission lifetime**
  - Accumulation of datasets, using statistical and advection methods to **alleviate non-perfect** collocation
  - **Simultaneous** coverage of most **regions** and **conditions**, **continuous** coverage in time
  - **Synergistic** validation with multiple collocated instruments

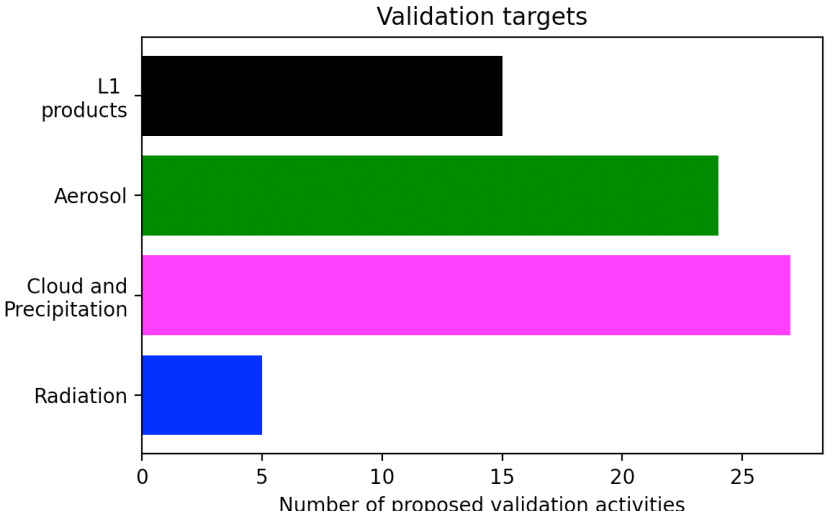
- **Further campaigns during the entire mission life time**.
  - **Multiple campaigns under different conditions**
  - **Synergistic** validation aircraft and ground based instruments)
  - Accumulate larger datasets in order to increase precision of quality assessment

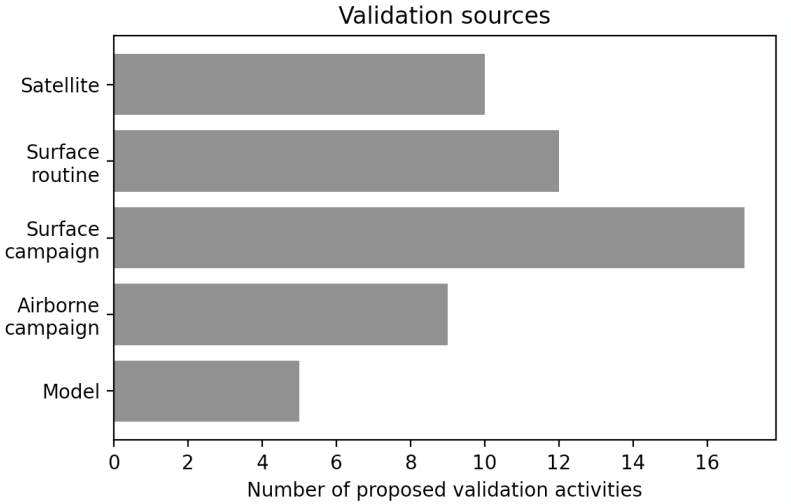
- **Systematic monitoring of radar and lidar data with NWP model (see part 2 of this presentation)**.

Coverage (geographical, targets, sources)

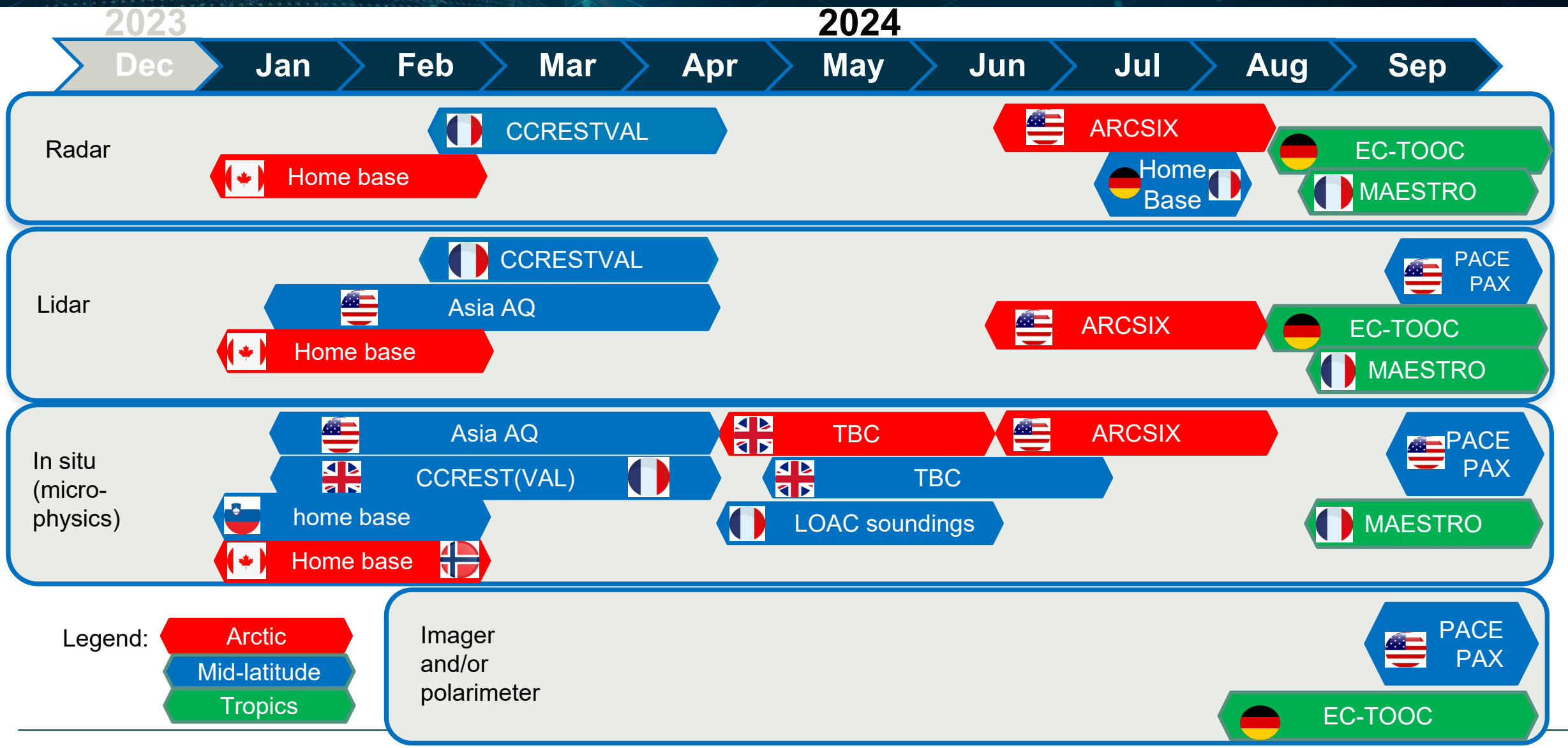
Geographical groundbased (for campaign coverage see next slide)







Campaign collaboration potential opportunities under consideration (assuming launch in Oct 2023)



Past ESA EarthCARE validation workshops

The set of 30+ AO proposals form an adequate validation programme if full funding is achieved

Clear need for common protocols for cloud and aerosol profile validation

- Enhance **maturity** and **thoroughness** of intercomparison methods
- **Guidance** and **knowledge transfer**
- Obtain **broader assessment of EarthCARE validation gaps** by engaging CloudSat, CALIPSO, AOS, Aeolus communities

Best practice for validation of cloud and aerosol profiles

- **Community consensus** on approaches for e.g.
  - data acquisition strategies
  - data intercomparison methods/strategies
  - combining remote sensing and in-situ measurements.
- **Different approaches** can and should co-exist, but should be unambiguously distinguished when interpreting results
- **Not specific to EarthCARE**; include lessons learned from past, current missions while keeping future missions in mind
- A **core working group** has been formed, which includes international experts in cloud, aerosol, radar, and lidar

Poster in A1.09

Defining validation protocols for space-borne aerosol and cloud profile products

(Eleni Marinou et al.)

Contribution from the wider community is needed and invited!

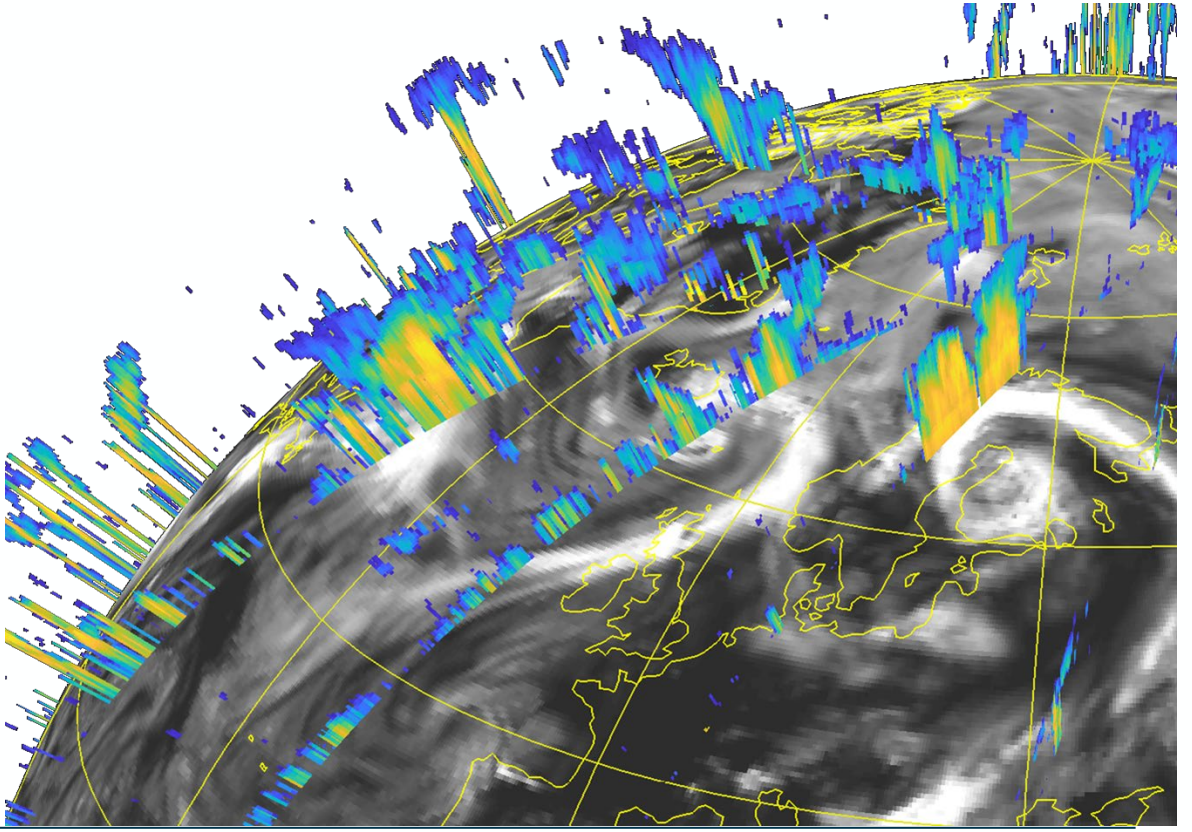
Applications Preparation

Preparations for EarthCARE assimilation – Radar and Lidar (PEARL)

European Centre for Medium-Range Weather Forecasts (ECMWF) is finalising preparations to assimilate EarthCARE observations thanks to the joint ECMWF-ESA project to maintain and improve developments for monitoring and potential assimilation of cloud radar reflectivity and lidar backscatter.

Three main benefits:

1. Observation data quality monitoring
2. Direct weather forecast improvements via data assimilation.
3. Forecast model validation using observation operators as instrument simulators



Observation data monitoring is a key component of data assimilation

All observations that are assimilated at ECMWF to produce the model initial conditions also enter data monitoring system:

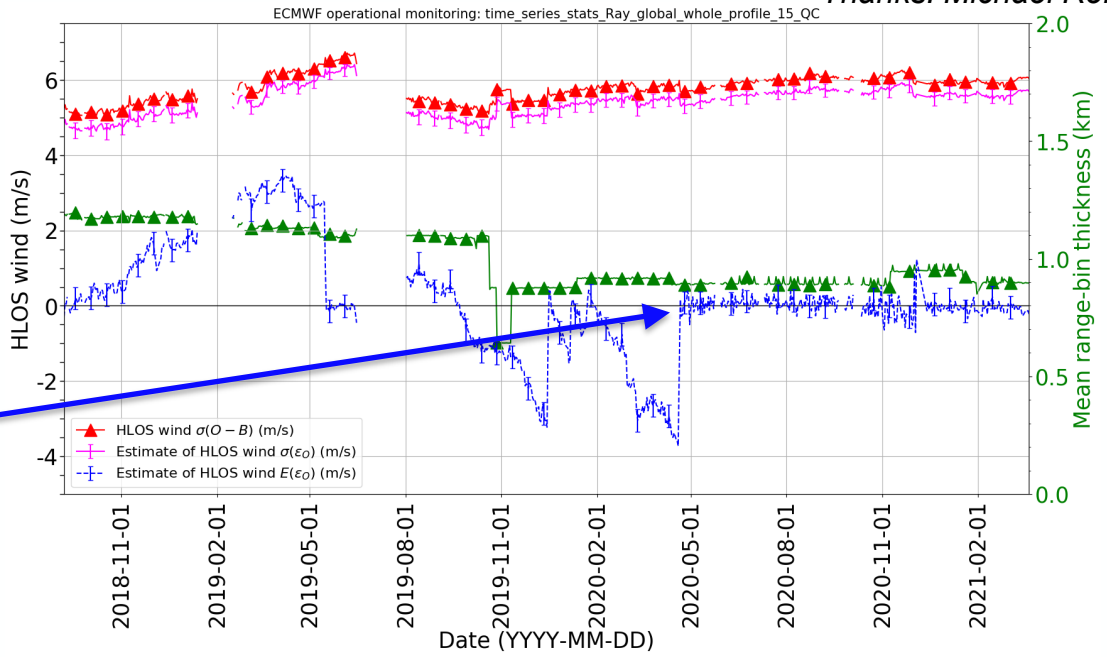
- Assesses the availability and **quality of observations** by comparing them against NWP model in near real-time.
- Use in-house instrument simulators to monitor biases and variability within 12-hour data assimilation.
- **Rapid detection of instrument issues** that could affect analysis.

Thanks: Michael Rennie

<u>Example: Long-term Aeolus L2B HLOS wind quality monitoring</u>

➢ Monitoring and correction of Aeolus horizontal line of sight (HLOS) winds against ECMWF model was pivotal to mission success!

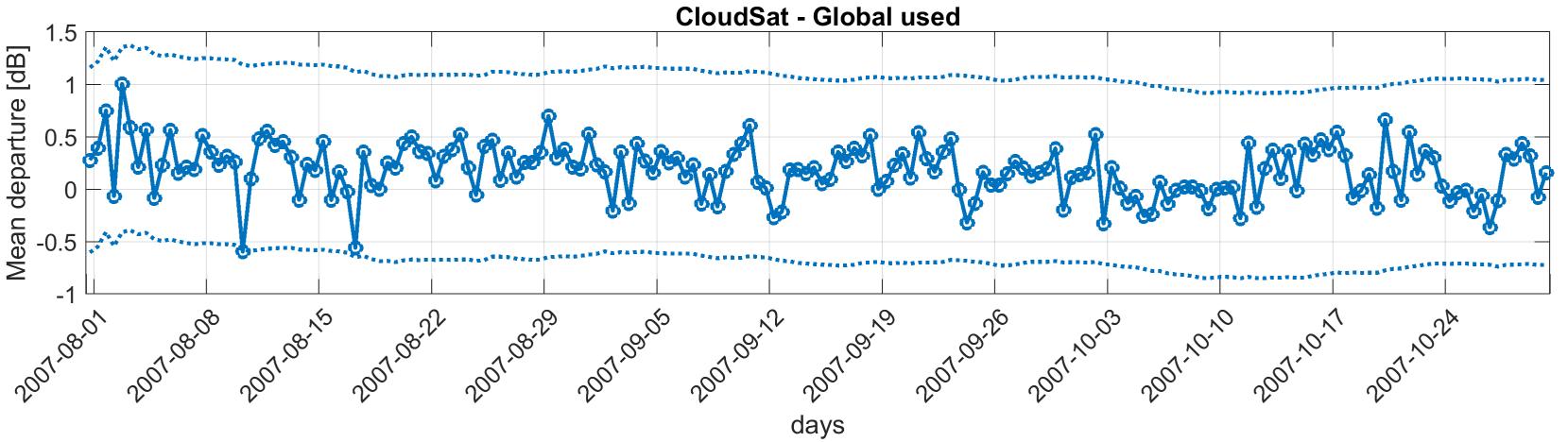
Degradations in HLOS winds improved due to telescope-mirror temperature dependent bias correction.



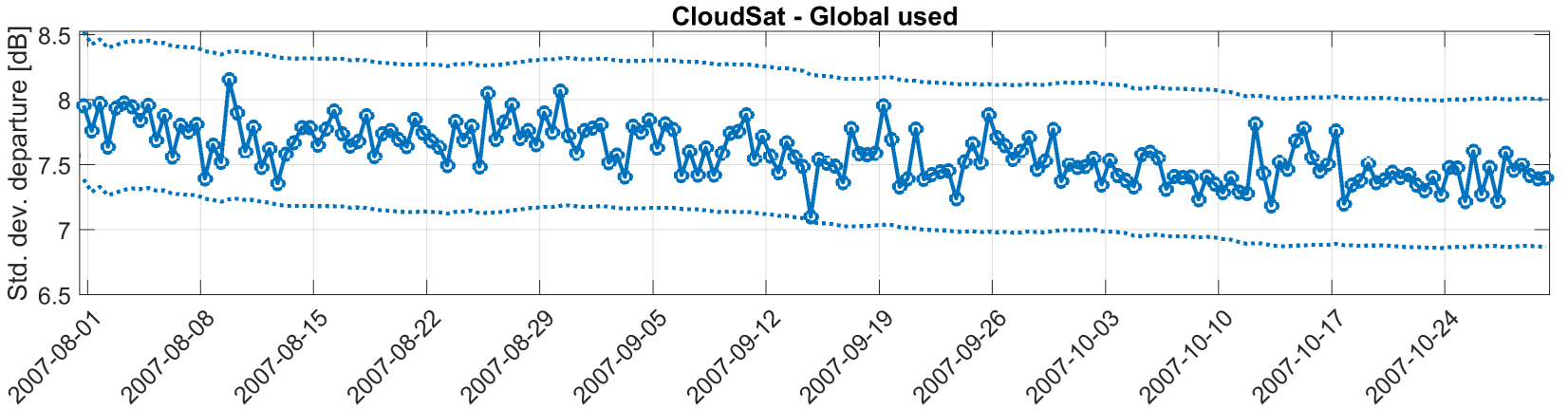
Monitoring cloud radar reflectivity from CloudSat against ECMWF model

- Subtle changes or drifts in calibration can be detected because of low variability in global mean, e.g., 1 dB biases in radar reflectivity would trigger ‘alarm’ within days.

Global mean



Global Std. dev.

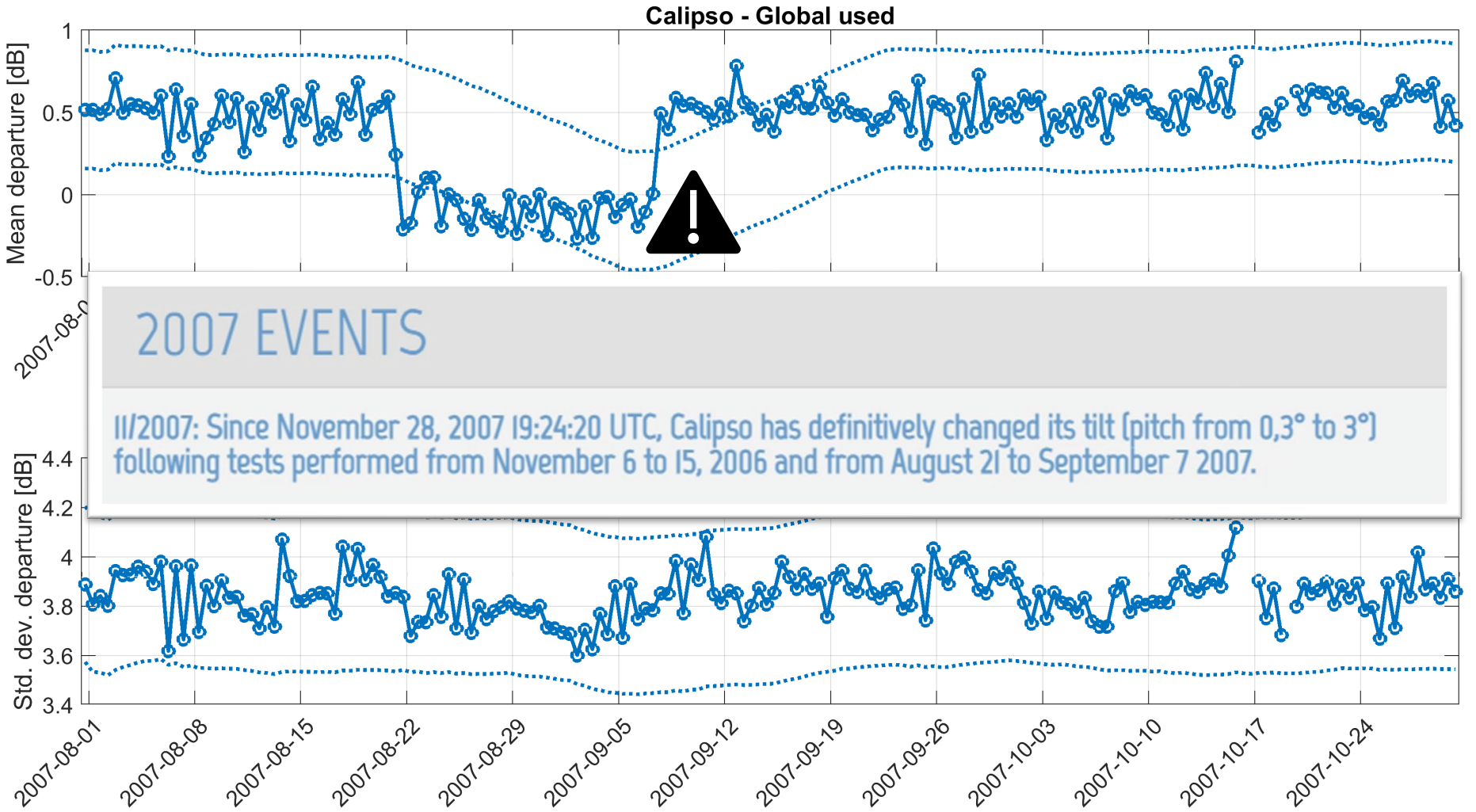


Each point represents 12-hour global statistics for all observations passing screening

Change in CALIPSO lidar tilting angle immediately detected

Global mean

Global Std. dev.



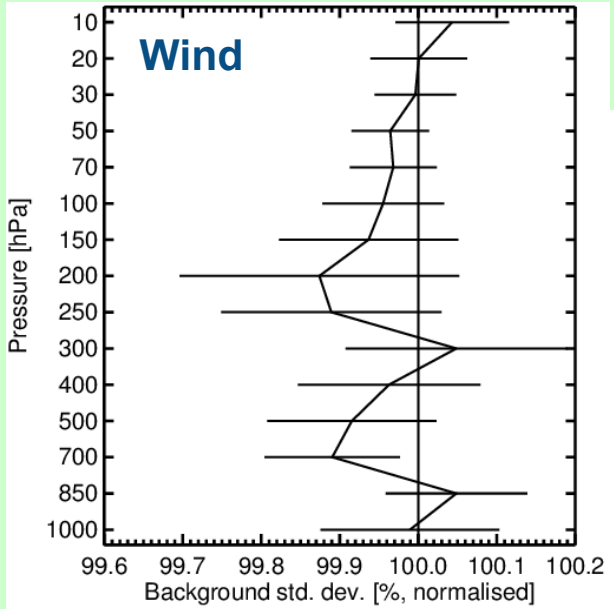
Reduction in specular reflection from ice crystals when lidar pointing off-nadir

What *direct* benefits can we expect from assimilating EarthCARE?

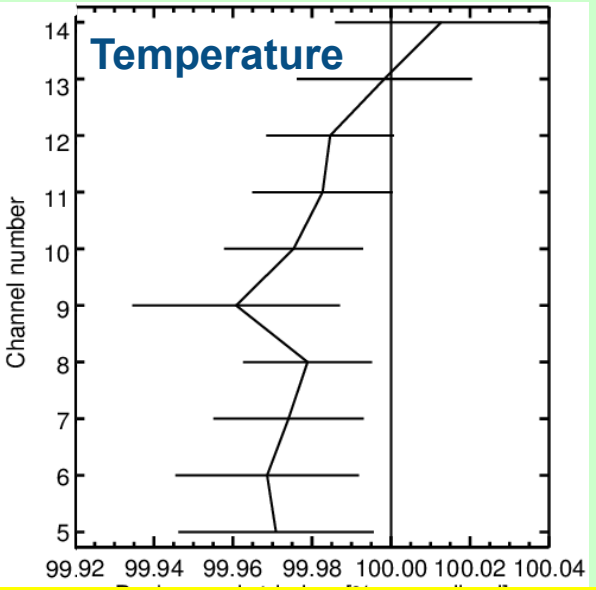
OSE: 11-month combined (01.08.2007 and 31.08.2008) CloudSat and CALIPSO observations in addition to regularly assimilated observations vs control

Improves fit to other assimilated observations

In-situ wind - Global

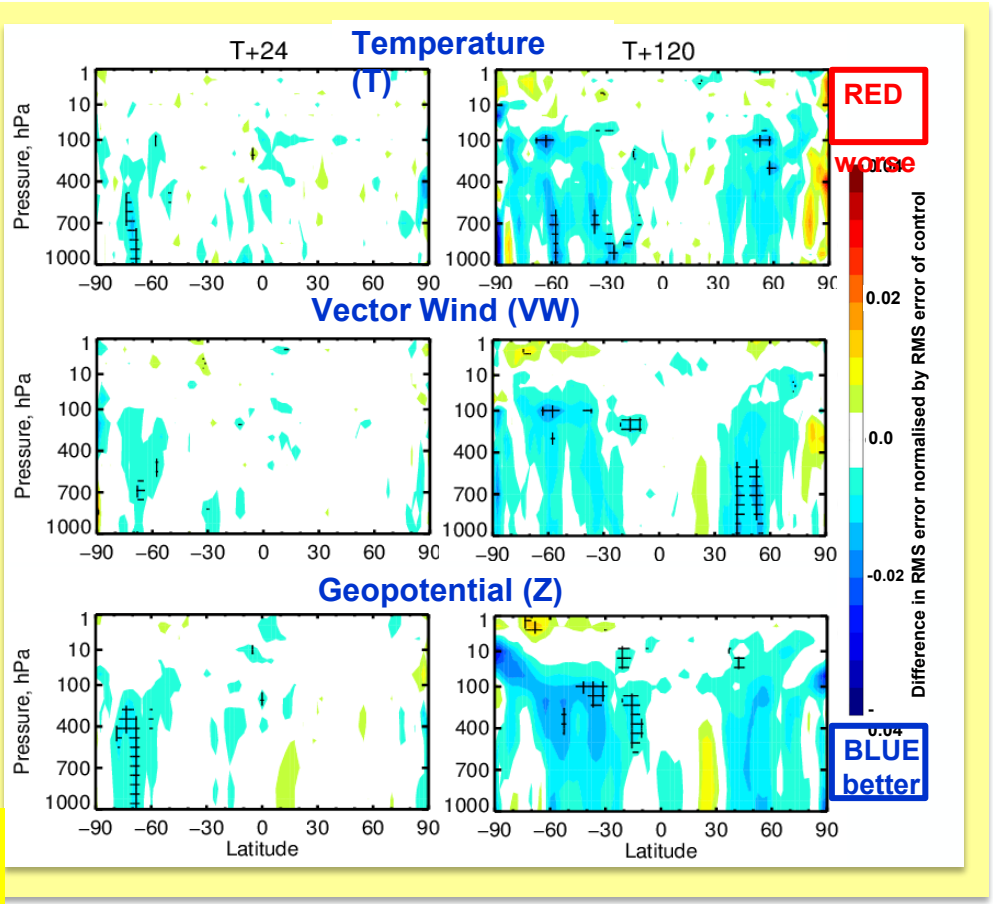


AMSUA - Global



➢ ***significant 0.5 - 1% improvements in global winds and temperature at day 5-6!***

Improvements to medium-range FC skill



See also: Janisková and Fielding, 2020: Direct 4D-Var assimilation of space-borne cloud radar and lidar observations. Part II: Impact on analysis and subsequent forecast. QJRMS https://doi.org/10.1002/qj.3879

Further Scientific Expoitation

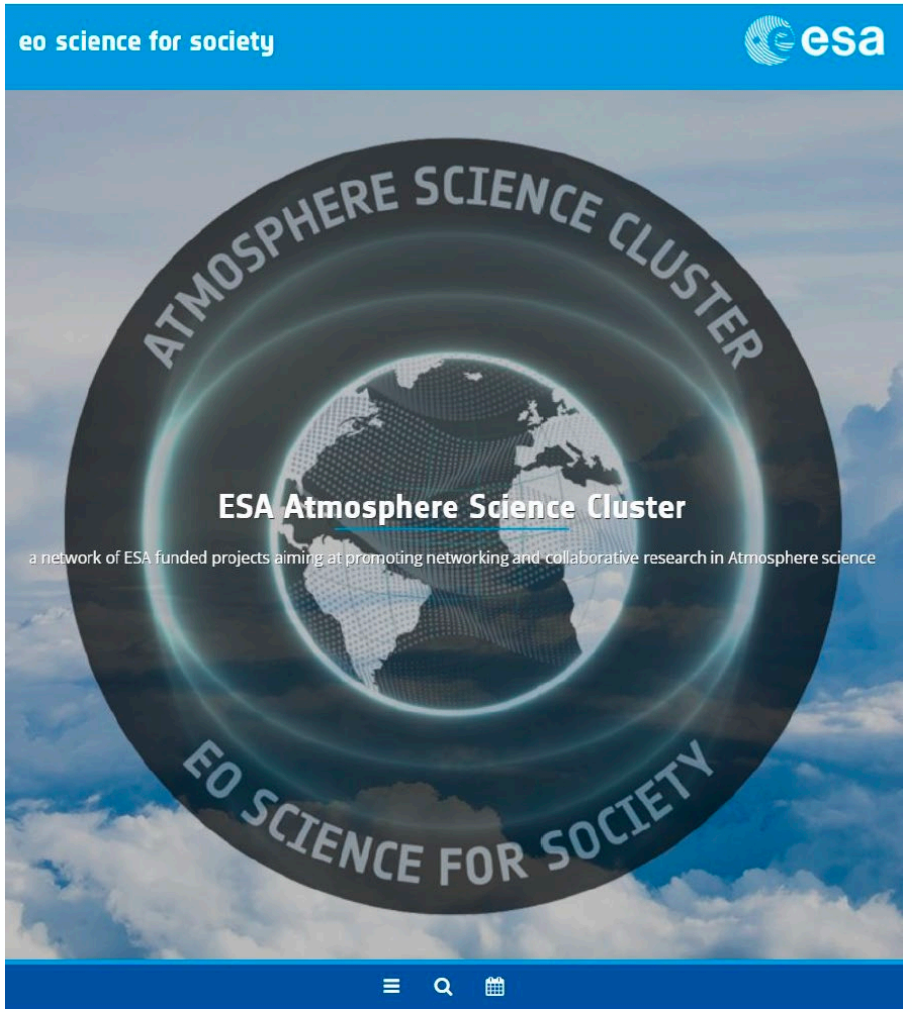
Scientific Exploitation: ATMOS'21 Recommendations

An extract of the many recommendations of the 2021 ATMOS conference

R-21	ESA to establish scientific community activities on stratospheric aerosol profiles, as they are currently not adequately covered in CCI+ and other ESA programs.
R-23	Beyond Multi-Angle Polarimeter prepare for future missions having the capability to measure aerosols such as EarthCARE, Aeolus follow-up, Sentinel-4, Sentinel-5, CO2M, and invest in well-defined aerosol products, which can also be validated with ground-based observations.
R-25	Promote synergy of retrievals from various space-borne instruments to compensate for individual weaknesses. Further bring aerosol communities together (e.g. IR, UV, troposphere, stratosphere).
R-26	ESA to further invest in synergetic retrievals from space-borne and ground-based instruments.
Various	Studies that enable improvements to cloud and aerosol retrievals from passive sensors

ESA will follow up (formulate a response to) the ATMOS recommendations from 2023 onwards. Many of these recommendations will be implemented under the Atmosphere Science Custer (next slide)

Scientific Exploitation: eo4society Atmosphere Science Cluster

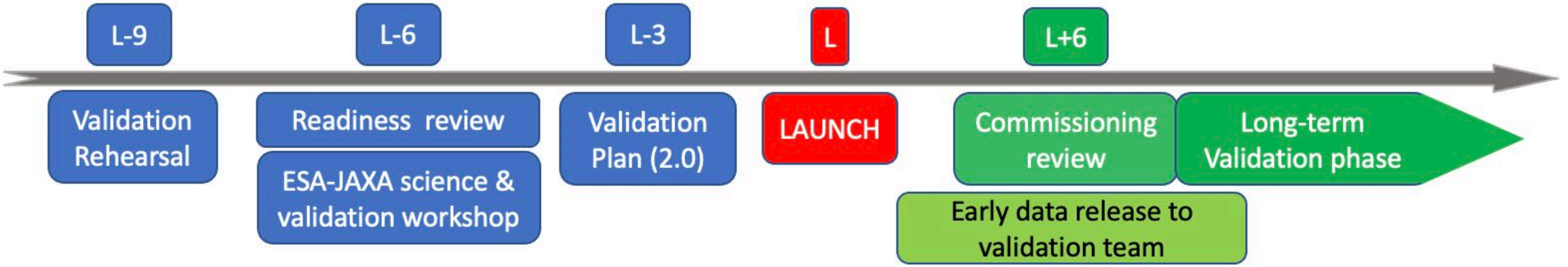


- Promoting networking, collaborative research, and fostering international collaboration in Atmospheric science;
- Involves ESA-funded projects and activities bringing together different expertise, data, and resources in a synergistic manner;
- ESA is contributing to establish a strong European Atmosphere research are in close collaboration with the European Commission Directorate General for Research and Innovation and other European and international partners.

https://eo4society.esa.int/communities/scientists/esa-atmosphere-science-cluster/

In closing

- Extensive validation preparations, involving a large community, on track for the intended October 2023 launch, and the detailed plan will be consolidated when there is clarity on launcher way forward
- Initiative to converge on best practices for aerosol and cloud profiles validation → POSTER!
- Near real-time monitoring of EarthCARE observations is an invaluable tool for validation of EarthCARE
- Assimilation of ATLID and CPR data is expected to have a significant positive impact on medium-range weather forecasts → POSTER!
- Scientific exploitation will be fostered by, e.g. Atmosphere Science Cluster, Climate Change Initative, …
- Milestones:



Posters

EarthCARE Poster session

Defining validation protocols for space-borne aerosol and cloud profile products

(E. Marinou et al.)

Progress in preparations towards monitoring & assimilation of EarthCARE observations at ECMWF

(M. Janisková & M. Fielding)