EarthCARE Science Working Groups

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EarthCARE is now providing a wealth of new information on atmospheric properties and processes, but a coordinated collaborative effort is needed to use it to tackle big questions in weather and climate science. At the EarthCARE Science and Validation workshop in Oxford in June 2026, and confirmed at the QWG in September, it was decided that **Science Working Groups** should be set up in key areas to address these questions. There are many ways that these could be configured, but after extensive discussion we propose the following:

1. Evaluating high-resolution models of clouds and convection
2. Improving the treatment of aerosols in models
3. Aerosol-cloud interactions
4. From cloud and precipitation processes to climate sensitivity
5. EarthCARE simulators for weather and climate
6. Long-term climate records

While the Working Groups each have a broad scope, we envisage that they would each be composed of a number much more focussed **Projects** where most of the collaborative work would take place. The remainder of this document describes the motivation behind each Working Group and the proposed Projects so far, although these are subject to change and refinement when the groups meet.

Guidelines:

- We are focussing on challenges that require extensive collaboration to make progress, so each Working Group should incorporate a **wide range of expertise** from algorithm developers to modellers, and seek to connect with the wider scientific community where appropriate. We need a good representation from Europe, Japan and beyond, a significant involvement of Early Career Researchers (including in leadership roles), and to involve scientists working on related satellite missions (present and future).
- In contrast to the grand challenges presented by the Working Groups, the individual Projects should be SMART, that is focus on a **specific** problem, be **measurable** and **achievable**, be **relevant** to the aims of the Working Group, and be **time-bound**.
- **Open communication**, including a web presence to advertise the group to all who are interested (at www.earthcarescience.net), quasi-regular meetings (although in some cases most of the meetings will take place in Projects), a dynamic collaborative space to share ideas and materials, clear lines of communication with ESA and JAXA, and reporting progress at EarthCARE Science & Validation Workshops and QWG meetings.
- We will need to be **flexible:** this document is a starting point, but the groups will need to refine their own scope and direction according to what they see as the most important challenges and opportunities. Additional groups may be required in future, for example to tackle "gaps" such as the stratosphere.

The activities proposed in this document are currently unfunded. The initial aim is to bring people together who are already working on EarthCARE with their own funding, to help them to tackle bigger problems by working together. By nurturing discussions between scientists on how EarthCARE can be used to tackle the grand challenges in weather and climate science, we hope that opportunities for securing funding for some of this work will be identified. And by broadening the EarthCARE user base and making EarthCARE relevant for a wider range of downstream applications, EarthCARE work should become eligible for a more diverse range of funding streams.

1. Evaluating high-resolution models of clouds and convection

Purpose: *To use EarthCARE observations to evaluate and improve high-resolution atmospheric models.*
Leads: Masaki Satoh and Bjorn Stevens.
High-resolution atmospheric models, in which individual storm systems are explicitly resolved rather than being parameterized, are now widely used both for operational limited-area forecasting and for climate research. However, even when run at resolutions of 1 km or better, they can fail to realistically represent the organization of convective cloud systems, and still rely on uncertain microphysical parametrizations. EarthCARE observes storm systems with unprecedented detail and accuracy, and in particular its new Doppler measurements are providing new insights to constrain models. This Working Group conducts intercomparisons of high-resolution model simulations focusing on a range of weather phenomena, and uses EarthCARE to evaluate and improve them.

Project 1.1: ECOMIP – The EarthCARE-ORCESTRA Model Intercomparison Project (in progress)

Purpose: *To compare and evaluate high-resolution numerical simulations of weather systems observed during the tropical Atlantic field experiment ORCESTRA (Aug-Sept 2024).*
Web site: https://www.earthcarescience.net/projects/ecomip
This project has been running for over a year and a protocol paper for the simulations is currently in review (Roh et al. 2026, https://doi.org/10.5194/egusphere-2026-3606) with examples from the 3 September 2024 case.

Project 1.2: ETCMIP – The EarthCARE Tropical Cyclone Model Intercomparison Project (in progress)

Purpose: *To evaluate and improve high-resolution numerical simulations of tropical cyclones using EarthCARE and other satellite observations, including macrophysical structure, cloud microphysics and vertical motion.*
Web site: https://www.earthcarescience.net/projects/etcmip
This project arose from the exciting observations EarthCARE made through the eyes of Hurricane Humberto and Typhoon Sinlaku, and the simulations that several groups made spontaneously of these events. It formalises such simulations so that detailed comparisons are possible between models and with EarthCARE. See also Huang et al. (2006, https://doi.org/10.5194/egusphere-2026-2530).

2. Improving the treatment of aerosols in models

Purpose: *To improve the distribution, transport and direct radiative effects of aerosols in weather, climate and air-quality models.*
Leads: Oleg Dubovik, Moritz Haarig, Peter Hill, Tomoaki Nishizawa, Philip Stier, Kentaroh Suzuki, Ulla Wandinger.
ATLID is a game changer for global aerosol measurements, providing the first unambiguous global 3D distributions of aerosol extinction coefficient, the most important property for radiative transfer, as well as information on cloud type. This Working Group will use EarthCARE observations to evaluate and improve the treatment of aerosols in weather forecast models (where solar heating of aerosols can affect the evolution of weather systems), air-quality models (where extreme pollution is important for human health) and climate models (where the direct radiative effect of aerosols is a key source of uncertainty).

Project 2.1: ECOMIP-Aerosol (in progress)

Purpose: *To compare and evaluate prognostic aerosol models during the ORCESTRA period.*
Summary: Using particularly the case of 13 August 2024 (and possibly the full month of August), EarthCARE observations and sub-orbital measurements (airborne, ground/sea-based) will be used to evaluate predictions of the extinction coefficient and other properties of Saharan dust, central-African biomass burning, and Canadian wildfire smoke, as they are carried over the Atlantic. Models participating so far include IFS-COMPO (i.e. CAMS), NICAM-SPRINTARS and ICON-HAM-lite.

Project 2.2: Level-3 aerosol extinction datasets

Purpose: *To generate a consensus, validated Level-3 aerosol monthly-mean extinction product.*
A gridded monthly-mean Level-3 aerosol product would open up a number of important downstream applications, including evaluating air-quality and climate models, generating climatologies for weather forecast models, and understanding trends and seasonal/inter-annual variability. This should be done collaboratively as work is still needed on the products (e.g. consistency with the new lidar ocean surface constraint and with MSI solar reflectance, improved cloud/aerosol discrimination, and cross-validation with European and Japanese products). There may be the need to provide a simulator package for consistently aggregating model results given that EarthCARE does not observe aerosols in cloud.

Project 2.3: The climatic impact of the 2025 Canadian wildfires

Purpose: *To use the Canadian wildfires of summer 2025 to evaluate numerous aspects of aerosol models and ultimately to estimate the climatic impact of this exceptional event (follow-on from Project 2.1).*
Summary: Very much a follow-up to ECOMIP-Aerosol, this event (primarily from late May to July 2025) allows multiple aspects of aerosol models to be evaluated: emission rates, injection heights, self-lofting of plumes due to solar heating of the absorbing aerosol, long-range transport, mixing across the tropopause in both directions, and radiative calculations. A key question we then hope to answer with EarthCARE and potentially sub-orbital network observations (e.g. ACTRIS), is what was the climatic impact of this event, particularly in the context of the Rosu et al. (2025) study that suggested the 2023 Canadian smoke to have cooled the northern hemisphere by almost 1 K. This would demonstrate the relevance of EarthCARE for topical issues in climate science.

Project 2.4: Level-3 dataset of detailed aerosol properties

Once we have an extinction product we can extend to other more derived properties, such as single-scattering albedo (crucial for solar heating which drives winds), CCN and ice-nucleating particle concentrations, mass, size, type and minerology. This will leverage work from other aerosol projects (e.g. AIRSENSE) and require additional datasets such as PACE.

3. Aerosol-Cloud Interactions

Purpose: *To exploit EarthCARE to improve our understanding of aerosol-cloud interactions (ACI) and to explore the implications for radiative forcing feeding into improved climate models.*
Leads: Jens Redemann, Patric Seifert, Philip Stier, Kentaroh Suzuki.
Aerosol-cloud interactions, including effects on precipitation formation, are a large source of uncertainty in radiative forcing and climate projections. This is a challenging problem, but with arguably the most accurate ever spaceborne measurements of aerosols, clouds and light precipitation, EarthCARE is well placed to make progress in this area.

Projects

This working group potentially covers many different activities and ACI mechanisms that need to be studied in different ways. The division into more focussed Projects would need to be decided by the Working Group when it meets, but some ideas for activities are as follows:

- Re-doing earlier ACI analysis for boundary-layer clouds (such as Ma et al., Nature Comms 2018) given improvements since the CloudSat-CALIPSO era, specifically: (1) better aerosol measurements from EarthCARE including aerosol type and a sensitivity to AOD<0.1, (2) better cloud retrievals including updrafts and drizzle rates, and (3) better models particularly in terms of resolution.
- Aerosol-convection interactions, exploring observational constraints from EarthCARE observations in combination with geostationary imagers providing the context of the convective lifecycle. There is potential for an extension to compare the properties of convection observed with CloudSat-CALIPSO and EarthCARE on either side of the East Asian clean-up in the 2010s.
- Learning from natural laboratories such as ship tracks, and contributing to the ACPC Ship-MIP initiative.
- Coordinate activities on aerosol interaction with ice clouds, for example using EarthCARE's retrievals of aerosol properties and ice microphysics to determine whether the presence of dust or smoke systematically changes ice-cloud number concentration and size.

These activities would benefit from the synergy with ground-based observations (ACTRIS/Cloudnet, DoE/ARM) for detailed process understanding, verification of correlations and evaluation of microphysical retrievals.

4. From cloud and precipitation processes to climate sensitivity

Purpose: *To use EarthCARE to improve understanding of cloud and precipitation processes, and from that to improve estimates of climate sensitivity.*
Leads: Pavlos Kollias, Hajime Okamoto, Kentaroh Suzuki, Yoko Tsushima.
EarthCARE is fundamentally a process mission and its novel observations (particularly Doppler velocity) are already providing tantalizing glimpses of cloud processes that were previously unmeasurable from space. Cloud feedbacks remain the largest source of uncertainty in climate projections, ultimately because we don't know how cloud processes will change in a warmer world. This Working Group will bridge the divide between EarthCARE observations and Earth-system models, not only to improve cloud and precipitation processes in models but also to quantify the impact of improvements on estimates of climate sensitivity.

Project 4.1: FallspeedMIP (in progress)

Purpose: *To quantify the impact of knowledge of cloud and precipitation fallspeeds on climate projections and climate sensitivity.*
EarthCARE's CPR provides the first ever global measurements of reflectivity-weighted hydrometeor fallspeed, and has already been used to guide significant changes to the parameterization of ice and snow fallspeeds in some models, e.g. adding a dependency on riming. There is also a great opportunity to improve rain fallspeeds, and in particular to identify whether the fallspeeds of warm rain (drizzle) and "cold" rain (i.e. that originating from melting ice) are different, and how they depend on rain rates. Note that most models do not distinguish between these two types of rain, which may be partly responsible for persistent problems with the representation of low clouds in global models such as stratocumulus that is too dim yet precipitates too often. The aim of this Project is first to characterize fallspeeds versus (say) rain/snow rate or ice water content, rain type, and air density. We would then bring together a community of climate modellers who can implement these relationships in their model, perhaps via improving the size distribution shapes of cloud and precipitation, optionally retune the model, then run simulations to determine the impact on climate projection and the model's estimated climate sensitivity.

Other projects

EarthCARE has the potential to provide numerous other important insights into specific cloud and precipitation processes, which through collaboration between observational experts and modellers we hope could lead to a better weather forecasts and a better understanding of the role of clouds in the climate system. For example:

- EarthCARE has shown how gravity waves can trigger the formation of more reflective/emissive clouds and even rapid nucleation of large numbers of small ice crystals: what is the importance of this and can it be modelled? How else do updrafts and turbulence affect cloud physics?
- CALIPSO produced important statistics on the occurrence of stratiform supercooled water clouds that informed model developments leading to a reduction in the magnitude of the negative cloud feedbacks associated with these clouds. What more can we learn about the dynamics and microphysics of mixed-phase clouds from EarthCARE, and can we refine estimates of the climate sensitivity from this cloud type?
- How best can we characterise the size distribution of ice clouds and their evolution into snow?
- What determines the evolution of boundary layer cloud regimes from closed to open cells, both in the subtropics and in cold-air outbreaks? Low clouds are of course a key source of uncertainty.
- How can we use the synergy of CPR, MSI and geostationary imagery (e.g. GEO-RING) to understand and model the evolution of deep convective clouds?
- How can we overcome the difficulties with the folding of EarthCARE's Doppler measurements to learn about updrafts in deep convection?

5. EarthCARE simulators for weather and climate

Purpose: *To generate a set of publicly available simulators for the EarthCARE radar and lidar, and to promote their use both to evaluate climate models and as the forward models for use in data assimilation*.
Leads: Helene Chepfer, Yasukata Ikuta, Kamil Mroz.
Instrument simulators underpin data assimilation in weather forecasting and are often used to evaluate climate models in observation space, but most weather and climate models are not ready to simulate EarthCARE's new observations. Moreover, large differences can exist between simulators due to the assumptions they make. This Working Group aims to overcome these problems, establish best practice, and to promote wider uptake of EarthCARE data for both data assimilation and climate model evaluation. It also would be useful to engage with scientists for future radar and lidar missions to ensure their instruments can be simulated. While there is no significant overlap between the specific applications to weather and climate (Projects 5.2 and 5.3 below), the intercomparison of simulators is common to both and should be done together (Project 5.1).

Project 5.1: Simulator intercomparison

Purpose: *To intercompare radar and lidar simulators for EarthCARE, establish best practice and provide a set of consolidated publicly available simulators*.
An intercomparison would be performed between radar and lidar simulators addressing the role of ice particle scattering assumptions, size distributions, multiple scattering, treatment of sub-grid heterogeneity and overlap, and fallspeed assumptions. Simulators could include COSP, ZmVar (used at ECMWF), RTTOV, J-Sim, ECSIM, the "multiscatter" model used by ACM-CAP and the simulator in AC-CLP. Where necessary, external data will be used to establish the most accurate assumptions and algorithms.

Project 5.2: Support assimilation of EarthCARE at forecasting centres

Purpose: *To share knowledge and code to encourage EarthCARE assimilation at a wider range of weather centres than just ECMWF, including TL/AD codes*.
Detailed activities to be determined.

Project 5.3: Encourage evaluation of climate models using EarthCARE

Purpose: *To provide and encourage the use of a consolidated EarthCARE simulator (e.g. as part of COSP) for evaluating IPCC climate models in observation space*.
Detailed activities to be determined.

6. Long-term climate records

Purpose: *To generate the datasets necessary for climate trend analysis spanning from CloudSat/CALIPSO to EarthCARE.*

Leads: Helene Chepfer, Anja Hünerbein, Shannon Mason, Hajime Okamoto, Mark Richardson.

We now have 20 years of active cloud measurements from space so ought to be able to begin to detect cloud trends fingerprinting climate sensitivity. However, the A-Train and EarthCARE instruments are rather different from each other, not only in terms of the availability of Doppler and HSRL information, but also in terms of sensitivity. Two approaches can be envisaged to detect robust trends:

- *Trends in observation space:* to obtain consistent observational datasets across this period it would be necessary to first produce degraded observations, for example capping the radar sensitivity to -25 dBZ for the entire period and merging lidar's Mie channel with a scaled version of the Rayleigh to convert from 355 nm to 532 nm. This dataset could be used to detect trends in cloud height, occurrence and backscatter values
- *Trends in retrieval space:* by running both A-Train and degraded EarthCARE algorithms on the whole period, it would be possible to look for trends in retrieved cloud microphysical properties. It would be important to compare the degraded EarthCARE algorithms (i.e. those that do not use Doppler or HSRL information) with the full EarthCARE algorithms, if necessary adjusting the prior information to ensure that the retrievals produce the same average cloud properties. This could help improving the retrievals applied to CloudSat/CALIPSO data, as well as quantifying the added value from EarthCARE's superior measurements. Note that this activity may need substantial time and computational resource to achieve.

In the longer term, a sub-project of this group could combine these datasets with passive sounders (e.g. GEO-RING) to increase coverage and obtain a more comprehensive 3D cloud climatology including detailed cloud microphysical and radiative properties (e.g., https://doi.org/10.1029/2025GL121014).

Of all the Working Groups, this one is perhaps the most dependent on funding. In Autumn 2026, ESA issued a cloud/aerosol CCI call that includes the following requirement: "a cloud profile climatology shall be developed by merging EarthCare/ATLID+CPR and Cloudsat+CALIPSO data". Therefore, one role of this group could be to provide a forum for communication between groups that have separate funding to build long-term datasets. An argument could be made to delay the start of this Working Group until a larger dataset from EarthCARE has been gathered, and the other Working Groups have been established.