

**Gap Analysis for Integrated Atmospheric ECV Climate
Monitoring:
Report on outcomes of 1st User Worskhop**



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Executive Summary

The first user workshop of the GAIA-CLIM project was held in October 2015 in Rome, Italy and brought together selected users and GAIA-CLIM partners with the aim of gaining external input upon both the project progress to date and plans for the remainder of the project. External users were chosen for their range of expertise and to represent the broad potential data user base. Significant time was given over to plenary discussions to solicit views from users. Valuable feedback accrued from the workshop. Amongst the principal outcomes were:

- The Gap Assessments and Impacts Document has the potential to be a useful resource. The next version shall have a stronger pre-amble introduction to make clearer both its genesis and its intended applicability. Gaps related to governance and funding of non-satellite measurement systems need to be added. Efforts should be made to make the gaps description more specific and SMART and where possible to associate remedies which should include approximate costings and a risk-register approach so that prioritization can begin to be addressed. Towards the end of the second year some effort should be made to start to provide a priority upon each gap to aid the final year deliverable of a set of recommendations to the Commission and other stakeholders.
- The next user workshop should have available a version of the Virtual Observatory to interact with and provide feedback upon. Sufficient infrastructure and scheduled time is required to enable this. The particularity of the VO with respect to other existing tools should be its handling and documentation of uncertainties. It should consider educational aspects surrounding the appropriate usage of uncertainty information.
- There would be value to a piece in an appropriate journal that provides the background to GAIA-CLIM and its aims. This would help to build and sustain user engagement with the project.
- The future user workshops should consider involvement of experts from the terrestrial and ocean domains so that they are made aware of what we are doing and potential extensibility can be explored. Where possible GAIA-CLIM activities should be built with a view to such extension in future.

1 Introduction

GAIA-CLIM (Gap Analysis for Integrated Atmospheric ECV CLimate Monitoring) is one of the first H2020 space programme projects. It started in March 2015 and shall run through March 2018. The project is concerned with using available ground-based, balloon-borne, and aircraft data to provide a sub-orbital cal/val capability for satellite data products. As the project is keen on interacting with data users and providers, three user workshops are foreseen as part of the outreach and user engagement work package, in order to get feedback from various user communities on the plans, activities and outcomes of the project. Such feedback is key to ensuring project outcomes add scientific value to the European and international science and applications communities.

This deliverable reports upon the discussions that were held during the First User Workshop and highlights the most salient outcomes and implications for the project going forwards.

2 First User Workshop: where, when, who, and what for?

2.1 Organisation

The meeting took place on October 6 at CNR, Tor Vergata, Italy. The Workshop was led by the task leader (Martine De Mazière, BIRA-IASB) in collaboration with the task partners (NUIM, NERSC, NPL, ECMWF, FMI, KNMI, CNR, MO, BKS, EUMETSAT). Valuable support was provided by the local hosts and additional CNR personnel. The workshop location and date have been chosen to hold the workshop in conjunction with two other important international meetings taking place in Rome and Frascati in the same week, namely the AEROCOM, AEROSAT, and CCMI meetings, in order to attract potential key participants from these communities with expertise in the GAIA-CLIM target composition ECVs.

On the occasion of bringing together GAIA-CLIM partners to meet in person, a Project Management meeting was held directly following the User Workshop. This afforded an opportunity to reflect upon the outcomes and plan subsequent steps.

2.2 Attendance

Invitations for the User Workshop were disseminated via the GAIA-CLIM web page, and via several direct emails to identified key participants including those survey respondents who had expressed an interest in engagement. Also the attendants of the collocated meetings were invited to the User Workshop. Users were intended to represent expertise across the range of GAIA-CLIM target ECVs and to represent the full range of data users. Table 1 lists the 24 participants, including GAIA-CLIM representatives and representatives of a number of synergistic EU FP7 and H2020 projects. The users constituted a representative cross-section of the intended user community. At the start of the meeting, all the users in attendance were afforded the opportunity to briefly introduce themselves and provide an outline of their interests in the GAIA-CLIM project outcomes.

Table 1: Summary of participants of the First User Workshop

Participant	Institution	Country	Role	Relevant expertise
Dr. ABEN, ilse	SRON	Netherlands		GHG
Prof. BRAESICKE, Peter		Germany		Climate modeling
Dr. CASADIO, Stefano	ESA-ESRIN EOP-GMQ	Italy		Satellite / space agency point-of-view
Prof. DE LEEUW, Gerrit	FMI & UHEL	Finland	GAIA-CLIM participant	Aerosols
Dr. ESKEES, Henk	KNMI	Netherlands		Operational Validation of Copernicus Atmospheric Monitoring Services: trace gases, aerosol and GHG
Mr. LANGEROCK, Bavo	BIRA	Belgium	GAIA-CLIM partner	Expert in ground-based FTIR data retrievals and in implementation of operational validation of satellite and model data
Dr. MASÓ, Joan	CREAF	Spain	ConnectinGEO Coordinator	GEO
Dr. VAN WEELE, Michiel	KNMI	Netherlands	GAIA-CLIM GAID document lead	Aerosols and composition
Dr. WILLÉN, Ulrika	SMHI	Sweden		Meteorological data and models
Dr. WORDEN, Helen	NCAR	USA		Satellite retrievals and validation, oa GHG from TES
Mrs. MIKALSEN, Anna Christina	NERSC	Norway	GAIA-CLIM project manager	Various
Dr. GODIN-BEEKMANN, Sophie	CNRS	France		Ozone LIDAR expert
Dr. AÑEL, Juan Antonio	Universidade de Vigo & University of Oxfor	Spain & UK		upper troposphere and stratosphere
Dr. BELL, William	MO	United Kingdom	GAIA-CLIM WP4 lead	T, q
Dr. BROGNIEZ, Helene	LATMOS	France		Water vapor remote sensing and radiative transfer expert
Dr. BURGDORF, Martin	Universität Hamburg	Germany	FIDUCEO partner	Microwave remote sensing expert
Prof. DE MAZIERE, Martine	BIRA	Belgium	GAIA-CLIM WP6 lead	Composition and aerosols, ground-based and satellite data, validation
Dr. DIRKSEN, Ruud	DWD	Gemany	Head of GRUAN Lead	T, q

			Centre	
Dr. HASSLER, Birgit	NOAA CIRES	USA		Ozone trends
Dr. KREHER, Karin	BK Scientific GmbH	Germany	GAIA-CLIM WP2 lead	Composition
Dr. SCHULZ, Jörg	EUMETSAT	Germany	GAIA-CLIM WP5 lead	
Prof. THORNE, Peter	Maynooth University	Ireland	GAIA-CLIM coordinator	T, q
Dr. VERHOELST, Tijn	BIRA	Belgium	GAIA-CLIM WP3 co-lead	Ozone

2.3 Specific objectives of the First User Workshop

The workshop was scheduled for relatively early in the project, following the completion of the User Survey (D6.1) and the delivery of the first version of the Gaps Assessment and Impacts Document (GAID), and before initial versions of the Virtual Observatory (VO) facilities were to be available.

The specific objectives of the workshop were therefore to get (1) a check of the results of the User Survey, (2) feedback and inputs to the GAID v1, and (3) feedback and inputs to the user requirements for the VO.

Therefore, the participants of the meeting received several documents in advance of the meeting, specifically:

1. The Gaps Assessment and Impacts Document (GAID) version 1 as delivered to the Commission
2. A template for providing additional input to the GAID
3. A short presentation of the initial ideas concerning the planned development and foreseen functionalities of the VO
4. The version 1 of the GAIA-CLIM Task 1.1 report on system of systems approach adopted and rationale which had also been circulated internally and externally to the project for review at that time.

These materials provided the context for the presentations and plenary discussions undertaken at the workshop.

2.4 Agenda

The agenda was as follows:

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- | | |
|---------------|---|
| 9:00 | Welcome and introduction, M. De Mazière (BIRA-IASB) |
| 9:15 | Presentation of the GAIA-CLIM project, P. Thorne (NUIM) |
| 9:35 | Presentation of the results of the User Survey, G. de Leeuw (FMI) |
| 10:05 – 10:30 | Coffee / Tea break |
| 10:30 | Presentation of the first version of the Gaps Assessment and Impacts Document, M. van Weele (KNMI) |
| 11:00 | Discussion with all participants; moderators: G. de Leeuw and M. van Weele; rapporteur: A. Mikalsen (NERSC) |

12:00 – 13:00 **Lunch**

13:00 – 14:30 Presentations from selected users

- H. Eskes (KNMI): Use of surface in-situ, surface remote sensing, aircraft, balloon and satellite measurements for the validation of the MACC services: a wish list
- I. Aben (SRON): Needs for satellite validation of Greenhouse (related) gases, CO₂, CH₄, CO
- B. Hassler (NOAA): Ground-truthing long-term ozone trends from satellites
- R. Dirksen (DWD): The road towards a globally distributed network of reference observations of temperature and water vapor
- J. A. Añel (Universidade de Vigo & University of Oxford): Needs for improved knowledge of phenomena affecting UTLS and lower stratosphere

14:30 Let's start talking about uncertainties, B. Langerock & Tijn Verhoelst (BIRA-IASB)

15:00 – 15:20 **Coffee/ Tea break**

15:20 Initial ideas for the Virtual Observatory, J. Schulz (EUMETSAT)

15:50 Discussion with all participants; moderators: M. De Mazière & P. Thorne; rapporteur: K. Kreher (BKS)

16:45 Conclusions and way forward, M. De Mazière & P. Thorne

17:00 **End of meeting**

17:00-18:00 Debriefing with Project Management Team

3 First User Workshop: Presentations and Discussions

The presentations are available on the GAIA-CLIM web site¹.

Martine De Mazière opened the workshop providing an introduction to the User Workshop in the context of GAIA-CLIM and in the broader frame of the Copernicus programme. She highlighted how a key aspect of GAIA-CLIM is user engagement throughout the project. The workshop aims were stated as being gathering user input on needs, gaps and feedback on the ideas for the virtual observatory facility. The presence of a representative range of expertise was welcomed and users were encouraged to provide constructive feedback and suggestions throughout the day's proceedings.

¹ <http://www.gaia-clim.eu/projectmeeting/6-october-2015-0930-user-workshop>

Peter Thorne then provided an overview of the specific GAIA-CLIM project aims and the underlying methodological rationale for the project. He highlighted that the project consists of several interlinked work packages with the main user interaction foreseen through the Virtual Observatory and the outreach work package.

The rest of the meeting has been devoted mostly to the User Survey, Gap Assessments and Impacts Document (GAID) and Virtual Observatory (VO), as well as to invited talks from a number of users, and a talk about the evaluation of uncertainties as proposed in GAIA-CLIM. The latter talk was scheduled because it was clearly evident from the User Survey that users had concerns as to the nomenclature, evaluation, use and propagation of uncertainties. The invited talks had been selected such that the various target communities and Essential Climate Variables of GAIA-CLIM were covered. Two dedicated discussion sessions were planned to allow ample time for user input.

3.1 Presentation on the User Survey outcomes

Presentation:

Gerrit de Leeuw presented an overview of the User Survey outcomes. The user survey had been designed primarily to capture user requirements for the Virtual Observatory facility. He highlighted the degree of outreach that was made with a range of individual emails, listserv and oral invitations at appropriate meetings to participate. In spite of this concerted effort to reach out to potential users there were only 77 respondents (for further information on this and aspects pertaining to representativity - see the User Survey deliverable). Most respondents were interested in the climate application area. There were a broad range of user applications foreseen by respondents for both satellite and non-satellite data use with slightly more applications of non-satellite data than satellite data. The survey highlighted in particular that some users find uncertainty information hard to access and / or to use. The survey highlighted that existing facilities for visualisation and use of collocation databases were less used by respondents than their own tools or data portals that weren't specified in the survey. Gerrit closed by highlighting the key gaps identified by the user survey.

Questions:

- The use of the terminology within GAIA-CLIM 'sub-orbital' was questioned. A proposed alternative is 'non-space' or 'non-satellite'. J. Maso, coordinator of the ConnectinGEO project, stressed that the 'non-space' is also the terminology considered by the Group on Earth Observation (GEO).
- Ulrike Willén highlighted that NetCDF is important to modellers. OBS4MIP is interested in NetCDF for example. Gerrit noted that there was still a set of distinct communities that according to the User Survey may prefer non-NetCDF data. Conversion tools may be a solution for many such cases that enable the Virtual Observatory to concentrate upon NetCDF provision whilst also catering to the needs of others.

3.2 Presentation about version 1 of the GAID

Presentation:

Michiel van Weele presented the initial version of the GAID of which he is the editor. The specific aims of the GAID were outlined along with its relationship with the final deliverable providing a set of prioritized recommendations for subsequent activities. Its focus is upon the primary ECV targets of GAIA-CLIM (temperature, humidity, ozone, several greenhouse gases and aerosols). The GAID will help to identify and prioritize the final recommendations arising from the project.

Michiel highlighted how the GAID is an iterative process which shall benefit from input from both project partners and external users. External input shall be gathered both at the user workshops and on a more ad hoc basis through a dedicated section of the GAIA-CLIM project website available at <http://www.gaia-clim.eu/page/gaid>. The initial internal inputs were collected via a template that collected the gaps in a consistent manner in tabular format. Michiel has then categorised these into seven generic gap types.

Michiel stressed that the document was a living document, which will be updated approximately every six months. He identified several potential improvements envisaged and also stressed the need for community input and buy-in. The next iteration shall account for the feedback received from the User Workshop as well as revised input from the underlying work packages.

Questions to the audience:

A number of questions were prepared by Michiel, Peter Thorne, Anna Mikalsen and Martine De Mazière to launch the discussion:

- *Could the GAID (as an evolving document during GAIA-CLIM) in your opinion become useful as the technical background document on which basis to inform and convince science policy programmers about your research needs?*
- *Do you see significant gaps missing in the current version?*
- *Would you have concrete suggestions to improve (the description of) one of the identified gaps?*
- *Have the identified gaps an impact on our capabilities to support the climate observing system needs?*
- *Are there any ongoing research activities missing – that address some of the identified gaps?*
- *Do you see (additional) remedies that should be raised? If so, which ones?*

Discussion with the audience

- Sophie Godin-Beekmann requested clarification as to upon which documents the GAID was based? She noted that the GAID needs a stronger and clearer pre-ambule that provides a much clearer understanding of the basis for the document. For example: The GAID mentions a gap as to tropospheric ozone lidars, but does not mention stratospheric ozone lidars hosted by NDACC which presumably at least partially address this gap.

Michiel clarified how the initial gaps were identified from WPs 1 through 5 that listed gaps and a traceable account for the principal gaps that they currently foresaw that were germane to their

domain area. It is not yet made sufficiently clear in the doc, e.g. whether the gaps registered for the work package 2 issues refer only to the 6 instrument-ECV combinations that are the subject of their specific tasks or are to be broader. Michiel also noted that GAIA-CLIM did not ask for priorities when filling in the template at this stage but that such prioritization may be important later or picked up in the accompanying final year deliverable to be led by Peter Thorne.

Michiel noted that the document now needs to be improved and the internal deliverables and external input will greatly help to clarify the GAID. Michiel highlighted the great importance of expert inputs in helping to refine the GAID.

Martine suggested to circulate the GAID within the NDACC community, in order to get the desired feedback.

- Henk Eskes queried the timeline of the final recommendations deliverable - Will we wait for three years to put together the final priorities document? How will the priorities be stacked?

Peter clarified that the prioritisation will be collaborative and involve community consultation, in particular via the Final User Workshop where this will be discussed in detail to ensure that the priorities delivered to the Commission are more broadly representative. The preparation of this document will start in month 24 and be heavily informed by the GAID version that is available at that time. By that stage hopefully the GAID will be sufficiently mature that gaps, impacts, resolution pathways and potential prioritization can be clearly articulated.

- Birgit Hassler asked will GAIA-CLIM fix any of the currently identified gaps?

Michiel clarified that yes, to some degree this shall be the case. Whether or not the gap is envisaged to be addressed under GAIA-CLIM is one of the required descriptors for registering a gap arising from internally to the project. Nevertheless for gaps we do not envisage working upon, we still need to identify them and assess their likely impacts.

Martine highlighted that a possible valuable outcome could also indicate whether, how and where we would need a campaign or project / task for closing a gap. It is important to communicate such needs to the Commission and other stakeholders. Dr. J. Añel agreed with the importance of such an outcome.

Peter clarified that GAIA-CLIM is defining the metrological fundamental requirements to support addressing gaps which may include scientific innovation, additional measurement capabilities or improved inter-operability of existing measurement assets.

- Martine highlighted the need to make the gaps SMART (Specific, Measurable, Achievable, Realistic and Timebound) and talk more about the remedies. We have to better clarify what exactly is missing (the gap) so that we better can estimate the remaining work required to remedy it. If a

gap is covered during the lifetime of the project either as a result of GAIA-CLIM work or as a result of a third party effort, then it should be retired and disappear from the document. In this way, the GAID is potentially a good opportunity to address synergies of existing, partly overlapping networks.

- Joerg Schulz raised the issue of potential stratification of gaps. One such approach would be to stratify by envisaged costings. There could be a kind of ‘stratification’ in the order of budget need to close the gap, e.g., “small” or “large” corresponding to < or > 1 Million Euro, respectively, . This would also provide indications as to who would be the possible agents to address the gap and what funding mechanisms may be important. Such stratification has occurred in e.g. GCOS Implementation Plans in the past so maybe something that policy makers are used to dealing with.
- Fabio Madonna highlighted the need for finding synergies with those domains not explicitly covered within GAIA-CLIM. The ocean and terrestrial domains lack involvement in the project. We want to build tools in the VO that allow expansion to these other domains (ocean, land), but have to limit our immediate priorities in the frame of this project. Some text around such potential extensibility may be useful in future versions.
- J. Añel queried whether reports would be published via e.g. a WMO report route. It was also suggested that the subsequent user workshops should include ocean and terrestrial domain users to ensure exposure of these communities to the project outcomes and enable a dialogue. In his view, it would be highly valuable that the EU economically support the GRUAN project, at least for territories with measurement facilities operated by EU countries (including polar regions).

Peter Thorne replied that there is a potential for GCOS or WIGOS reports where appropriate. The Task 1.1 activity has already been requested by several WMO working bodies to be considered for such a route and other outcomes that are broadly relevant shall be considered for this route in addition to delivery to the Commission to increase exposure of the project outcomes to target audiences.

- Peter Braesicke highlighted that there exists a quasi-generic gap concerning the requirement to have access to data that enables the user to do the science. This is also true regarding the provision and use of uncertainties.

Peter Thorne highlighted that such gaps will become clearer when we have a preliminary version of the VO, when the gaps in requirements will be discoverable by users. The importance of having a VO mock-up early in the project lifecycle was stressed.

Joerg Schulz answered that the plan for the next User Workshop in Oct 2016 is to provide test pieces for the VO.

Martine highlighted that such gaps that relate to governance and discoverability were recognized as being so far poorly covered. This will be addressed in the next version of the GAID. She suggested that maybe ConnectinGEO could provide input on these aspects.

- Question from the audience: Is GAIA-CLIM not addressing uncertainty as gap in satellite observations such as spectroscopy?

Peter clarified that this is indeed important but that sadly, no, this was not within the scope of the call. The call was specifically and exclusively on enhancing the utility of “sub-orbital” data. Hopefully FIDUCEO can help on the common ECVs and instrument platforms.

- Henk Eskes perceived a need to review the gaps with external input, and update them and gain broader community buy-in. This should now be done actively rather than passively.

Michiel highlighted that it has been suggested to make the word version of the GAID accessible, to send in tracked changes. Such an approach may be feasible on an individual basis upon request. Nevertheless, a general open invitation to provide reviews in track-change mode seems inadvisable given that it would be not feasible to handle merging many different versions of the document.

- Martin Burgdorf raised the issue that we have already 80 gaps and that there will almost certainly be more gaps added. Is there a danger that it gets out of hand? Many gaps at the moment are somewhat ill-posed. We need to make them more actionable. There may be a limit to how far we can go with putting the specifics upon it. Are there gaps identified that aren't really gaps?

Michiel clarified that some gaps may be reassessed and / or removed and that indeed they should become more specific with each iteration of the living document as they become better defined. No upper-limit is foreseen to the number of gaps although every effort should be made to minimize the number and avoid placing gaps in the document that are either contested or frivolous. See in addition remarks above as to making the gaps SMART.

- Does a risk register approach help in the prioritisation of gaps? This was suggested by I. Aben, referring to what is done in the satellite world (ESA CCI programme), where scoring and categorization of likelihood of impact helps to better structure the large number of identified gaps.

Peter and Martine concurred that this would be a good suggestion and appropriate metrics should be defined with a preference to re-use of existing approaches.

3.3 Invited talks by selected users

Henk Eskes: Use of surface in-situ, surface remote sensing, aircraft, balloon and satellite measurements for the validation of the MACC services: a wish list

H. Eskes started with a talk on in-situ data usage in the Copernicus Atmospheric Monitoring Service (CAMS). The CAMS represents the operationalisation of the MACC (Monitoring Atmospheric Chemistry and Climate; <https://www.gmes-atmosphere.eu/>) system that will serve to support a range of applications. Tenders for specific CAMS service elements are out or closed; the contract negotiation for the validation service is almost completed. The validation service covers several trace gases, including greenhouse gases and aerosols. The validation of CAMS involves a broad range of networks and projects. CAMS contracts provide some support to the contributing networks but cannot cover their entire operation. The set of satellite products used for validation is distinct from that assimilated. Quarterly reporting is undertaken. The CAMS validation service heavily relies upon timely data availability for validation, within 1 month delay after acquisition at most. Long-time series are used for the validation of the reanalysis products. Gap-free records are required to monitor evolution of the service. There is still work to be done to create a complete validation service. CAMS validation uses the concept of skill scores. There may be cross-pollination of GAIA-CLIM WP1 to WP3 activities with the CAMS observations characterisation efforts. The sustainability of the underlying observations for CAMS validation depends upon third parties, which is a substantial potential weakness.

Ilse Aben: Needs for satellite validation of Greenhouse (related) gases, CO₂, CH₄, CO

I. Aben discussed the needs regarding Greenhouse gases (GHGs) with a focus upon the total column products, which are the most mature and have sensitivity all the way down to the surface. The Total Column Carbon Observing Network (TCCON) provides the primary validation data for satellite carbon measurements. There is a need for long-term funding commitments to assure the long-term characterization of the satellite record. But typically, at present, the funding for TCCON is project based and on a site-by-site basis. Who is the responsible entity for TCCON within Europe is an identified gap. This might well be a more generic problem across multiple networks. Data that is not freely available in Near Real Time (NRT) is an impediment to its usage in satellite characterisation / validation. There is a strong need for validation activities to make preliminary datasets available. A tiered network approach is being planned within TCCON with primary high quality sites as at present and then instruments with slightly lower capabilities but that are cheaper and more mobile and flexible to enable acquisition of spatial details. Vertically resolved data of GHGs is increasingly required to characterize new satellite measurements and a key current gap – the only such data currently available are from aircraft and periodic. The AIRCORE radiosonde profiling system (which captures air upon descent to get a vertical profile) is an option and a possible remedy but may be hard to deploy in regions with poor communications or that are highly populated. The AIRCORE profiles may also provide absolute calibration of TCCON products and of some NDACC products (CO and CH₄) with respect to WMO standards.

Birgit Hassler: Ground-truthing long-term ozone trends from satellites

B. Hassler provided a talk on the SI2N (SPARC/IOC/IGACO-O3/NDACC) issues with satellite ground-truthing ozone measurements. SI2N tried to update knowledge on changes in the vertical distribution of ozone. There are a large number of papers across several EGU journals and an ACP Special Issue that describe this effort and may be relevant to GAIA-CLIM. A lot of effort has been made on measurement characterisation and uncertainty quantification. It has been found that the simple approach for evaluating uncertainties underestimates these uncertainties. Satellite drifts are important and must be identified. There are distinctions between trends for measurements arising from different instrument-types, despite measuring nominally the same volume. Reconciling these yields questions about how to do this best from a scientific point of view.

In conclusion, she answered: “How can we reduce uncertainties? “ by:

“ (1) Make better use of high-quality ground-based measurements with their uncertainty estimates, and (2) Improve ground network homogeneity”

Three implications for the future have been highlighted and argued:

- High-quality ground-based instruments are critical for high-quality, well understood satellite measurements
- It is necessary to be selective as to which data (points) to use
- It is necessary to increase the information content and documentation of the data

R. Dirksen: The road towards a globally distributed network of reference observations of temperature and water vapor

R. Dirksen provided an overview of the GCOS Reference Upper-Air Network (GRUAN), starting with a rationale given from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5). He presented the humidity measurements made at the Lindenberg Observatory that show instrument-related jumps in their time series. GRUAN aims to provide reference quality measurements of temperature and humidity profiles in the first instance before then expanding to other ECVs. GRUAN would like to fill geographic gaps in the network and ensure applicability to satellite data characterisation. A pressing problem is to address change management driven by the upcoming phase out of the Vaisala RS92 sonde necessitating a RS92-RS41 (or other sonde) transition. The continuity of funding is an identified issue for the network not yet covered in the GAIA-CLIM GAID. Could additional targeted sonde launches increase the utility of GRUAN data for satellite characterisation? Almost certainly. But the real challenge is: where does the funding for these additional sondes come from? If we are serious about reference quality data then safeguarding raw data and metadata is key as this enables subsequent reprocessing..

Juan A. Añel: Needs for improved knowledge of phenomena affecting UTLS and lower stratosphere

J. Añel gave a talk on the UTLS region. He concentrated upon gaps under the 7 categories given in the first version of the GAID. The biggest gap in the UTLS region relates to vertical resolution of the data used to validate satellite measurements. The UTLS exhibits strong vertical gradients in a broad range of phenomena and ECVs. The lack of vertical resolution in available measurements significantly inhibits understanding of phenomena and trends in the UTLS region. A number of the ECVs in GAIA-CLIM need high vertical resolution in the UTLS region. Current validation is insufficient in the UTLS and this means the community typically resorts to use of some type of a model for validation, which is scientifically highly unsatisfactory. The vertical resolution issues could be addressed via GRUAN radiosondes and aircraft data. But there is a limit in campaign data. Having a small number of planes limits the ability to fully characterise satellites. His recommendation is that the EU should provide more aircraft facilities.

3.4 Presentation about suggested evaluations of uncertainties in GAIA-Clim

Bavo Langerock & Tijn Verhoelst: Let's start talking about uncertainties

These talks were given based upon feedback in the user survey that highlighted doubt on the part of many users' as to how to use the uncertainty information that may be provided by GAIA-CLIM. The major scientific innovation in GAIA-CLIM is the demonstration of the operational use of ground-based reference measurements and of uncertainty information to enable a proper characterization of the satellite instrument performance. It is therefore key that users become sensitized to and provide feedback upon the proposed uncertainty information to be provided.

B. Langerock provided a talk on uncertainty estimation using the ground-based remote-sensing Fourier-Transform InfraRed Spectrometry (FTIR) as an example. In the atmospheric measurement environment we almost invariably are considering uncertainties associated with measurements that are strictly not repeatable. Errors in the products retrieved with optimal estimation methods arise from the measurements, the a priori, and the model parameters used. He highlighted the distinction between systematic and random uncertainties and the way to calculate and propagate them and to report them in the data files – as it will likely be done in GAIA-CLIM WP2, Task 'CH₄, CO₂, O₃, and H₂O columns and profiles measured by FTS'.

T. Verhoelst outlined the potential use of uncertainties in comparisons between measurements. Even if two measurements are perfectly characterized without considering the collocation mismatch effects, one would almost invariably conclude there are significant differences. There are a range of approaches to account for the errors due to collocation mismatches and to minimise their impacts. For example, using something better justified than just a collocation radius. Several approaches shall be considered within GAIA-CLIM WP3: (1) data-based, (2) statistical modeling of differences,

developed by UBergamo, (3) - FMI developed parameterization of inhomogeneity of measurements, based on full-physics model, (4) the observing system simulation scheme developed by BIRA, providing an explicit simulation of the observing system.

3.5 Presentation and discussions about the Virtual Observatory

Presentation:

Joerg Schulz provided an overview of initial work on the virtual observatory developments thus far. He outlined the rationale for the VO as being a way to unearth and exploit reference-quality collocation data for satellite characterisation. They should be integrated with existing satellite-to-satellite data and NWP-feedback files to maximize their utility. The VO could eventually include climate model outputs. More effort is needed on improving understanding of the traceable uncertainty estimates. We shall end in a demonstrator mode in GAIA-CLIM, but with a roadmap to operations. The demonstrator shall build upon a number of pre-existing platforms, tools and capabilities. The following steps will be taken: User requirements Document (URD) → Design → Implementation of the demonstrator → Roadmap to operational mode. Inputs for the URD can be accepted until Feb. 2016.

Interested persons should contact Arndt Meier (Arndt.Meier@eumetsat.int).

Discussion with the audience

- The question was raised whether it is planned to use cloud products and a cloud catalogue in the VO?

Joerg Schulz clarified that cloud products have not yet been planned to become part of the VO. We could add classification information on clouds as meta data to comparisons but consideration of the cloud ECV is beyond what can be achieved by GAIA-CLIM. It's not likely to be included but we could possibly link the data to something else with cloud products.

The question is raised whether the ground-based data will come with cloud flags?

R. Dirksen answers that GRUAN metadata includes information on clouds as part of the provided metadata.

- Martine questioned the audience about the need for new tools in the GAIA-CLIM VO compared to what is already available? Joerg Schulz said that it is envisioned to provide online tools rather than software for download. This is because the project has no means to support users on software usage which would be an operational task. In can of course be done if the VO is operationalised as part of a Copernicus service.

Sophie Godin-Beekmann: The French community uses ICARE (<http://www.icare.univ-lille1.fr/>). There are other initiatives similar to GAIA-CLIM and e.g. also several US portals available which are very easy to use and where you can just get the data readily – hence, we need a point of difference for the GAIA-CLIM VO.

Peter Thorne clarified that GAIA-CLIM’s point of difference and added value was to be the traceable uncertainty estimates and publications to support these that usually don’t exist on other portals. For the GAIA-CLIM VO, we aim for higher scientific quality with non-satellite data of truly reference quality.

- Joerg Schulz stressed the need to talk to the relevant networks to find agreements to make the non-satellite data freely available via the VO,.
- P. Braesicke suggested to offer a facility to climate modelers where their data (e.g. water vapour) can be uploaded and in return, they get an assessment back. This was also considered for the FP7 NORS project (nors.aeronomie.be) but got never implemented because of lack of resources.

Joerg Schulz answered that this is an interesting idea that is unfortunately beyond the projects resources but it will be kept in mind when discussing the connection of the VO with climate model data.

P. Braesicke also mentions a possible competition with the Obs4MIP site (<https://www.earthsystemcog.org/projects/obs4mips/>). Answer: there is no competition: GAIA-CLIM rather enables quality assessment of satellite products for obs4mips using non satellite reference measurements.

- The synergies with FIDUCEO (www.fiduceo.eu) activities were questioned. Peter clarified that it would be nice to assess whether we had metrological closure on the comparison with FIDUCEO estimates that aim to also be metrologically traceable well characterized products.

Martin Burgdorf clarified that FIDUCEO aerosol products will become available too late so we need to use other existing products but that the upper tropospheric water vapour product may be available in time.

- Martine asked the question to the audience whether the VO could and should also have an educational function regarding uncertainties, and if so, what would be the best format? Should it be documents, open-source code, ...?

Joerg Schulz says that one option might be to develop tutorials (e.g. exercises on the web as tutorials, a multi-media approach might be useful); they don’t need to be long but are very motivational. “How to” documents need to be written to describe the comparison data sets.

B. Hassler highlighted that it needs to be explained in detail what the uncertainty exactly means.

Joerg responded that it might be an option to involve EUMESAT's training division to look at ways how to develop an educational functionality.

It was also suggested that, if the VO is a good and easy to use tool, it could be used educationally to train students (outreach).

4 Concluding remarks

Martine de Mazière and Peter Thorne thanked the participants for their attendance and active participation. They reflected that the input received was highly valuable and had helped to prioritise future workplan needs. Peter Thorne asked how can we better engage the researchers that didn't answer the survey and didn't come to the workshop? Brigid Hassler suggested we introduce GAIA-CLIM in a "very broad" journal such as EOS, SPARC Newsletter, GAW e-magazine, to spread the word about what we want to achieve with GAIA-CLIM and what the VO will provide.

The next user workshop will take place in Oct 2016 in Brussels, Belgium. It will include hands-on exercises with the VO. A somewhat longer workshop is therefore envisaged with greater opportunity for user interactions with project members.

5 Principal outcomes

The user workshop brought together a group of active researchers who provided valuable input. The principal implications for the future work of GAIA-CLIM are highlighted below.

5.1 Related to the GAID

- The next version of the GAID shall have a stronger pre-ambled introduction to make clearer both its genesis and its intended applicability.
- Gaps related to governance and funding of non-satellite measurement systems to be added in the next version.
- In the next version of the GAID efforts should be made to make the gaps description more specific and SMART and where possible to associate remedies which should include approximate costings and a risk-register approach so that prioritization can begin to be addressed.
- External inputs and feedbacks to the GAID must be searched for.
- Towards the end of the second year some effort should be made to start to provide a priority upon each gap to aid the final year deliverable of a set of recommendations to the Commission and other stakeholders.

- If GAIA-CLIM participants feel the next version of the GAID is sufficiently mature then this should be sent to key stakeholders to increase awareness to this effort and to explicitly (actively) request review and critical input.

5.2 Related to the VO

- The next user workshop should have available a version of the VO to interact with and provide feedback upon. Sufficient infrastructure and scheduled time is required to enable this.
- The VO should consider educational aspects surrounding the appropriate usage of uncertainty information.

5.3 Related to GAIA-CLIM more generally

- There would be value to a piece in an appropriate journal that provides the background to GAIA-CLIM and its aims. This would help to build and sustain user engagement with the project.
- The future user workshops should consider involvement of experts from the terrestrial and ocean domains so that they are made aware of what we are doing and potential extendibility can be explored. Where possible GAIA-CLIM activities should be built with a view to such extension in future.