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Gap Analysis for Integrated Atmospheric ECV Climate Monitoring: Report on outcomes of 2nd User Worskhop



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Executive Summary

The second user workshop of the GAIA-CLIM project was held from November 21 to 24 in Brussels, Belgium, and brought together users and GAIA-CLIM partners with the aim of getting feedback on the Gaps Assessment and Impacts Document (GAID) version 3 – in order to move to v4, D6.7, and to prepare the prioritization of the gaps (Task 6.3). At the same time, feedback on the Virtual Observatory (VO) – of which a development version was available during the Workshop – was also sought.

The workshop was organized with a focus on discussions and demonstrations. Amongst the principal outcomes were:

- The Gap Assessments and Impacts Document (GAID) has the potential to be a very useful resource for various users. The living GAID document is nicely complemented with an online version. Many good suggestions were made for moving from v3 to v4. These have been collected and collated and formed the basis for a new template according to which gap owners will re-formulate their gaps before the next General Assembly (GA) – see Annex B. It was also observed during the workshop that the total number of gaps could be reduced by eliminating redundant gaps, merging overlapping gaps, etc. The online version will be augmented by more cross-section features, partially based on categorizing some fields in the gaps description according to a fixed vocabulary, available through drop-down menus.
- Input to GAID v4 will be available at the next GAIA-CLIM General Assembly in February 2017. The GAID v4 will be finalized shortly thereafter (end of February 2017) and this version will be the basis for further outreach to users.
- The current development version of the VO was available during this 2nd User Workshop, including the 3D meta data visualization tool and the GRUAN processor. The demonstrated capability was received quite enthusiastically by the attendees who confirmed that the VO already satisfied many user needs. Suggestions for additional features and improvements have been made and will be considered for implementation. It was strongly suggested to release a version to the public such that more users can test it.
- The user engagement will no longer be sought through workshops (a third User Workshop was planned in the Grant Agreement) but rather through visits to the user's home base, a so-called Roadshow. This roadshow will happen between March and November 2017; the selected

users to be visited by consortium partners will be identified during the General Assembly in February 2017.

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's success is to a large extent dependent on interacting with data users and providers, three substantive user workshops were foreseen as part of the outreach and user engagement, work package 6. This interaction allows for the gathering of feedback at different points in the life of the project 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 Second User Workshop and highlights the most salient outcomes and implications for the project going forwards.

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

2.1 Organisation

The meeting took place from November 21 noontime to November 24 noontime, at the Belgian Science Policy Offices (Belspo), Brussels, Belgium. The Workshop was organized and led by the task leader (Martine De Mazière and Nathalie Kalb, 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 host (Belspo). This workshop location was chosen because the use of the meeting rooms is free of charge for BIRA-IASB, and are located suitably close to the central railway station, to the center of town and to the hotels.

On the occasion of bringing together GAIA-CLIM partners to meet in person, a short Project Management meeting was held in the evening of Nov. 23, and a project review meeting took place in the afternoon of Nov. 24 following the User Workshop. These meetings afforded an opportunity to reflect upon the outcomes and to plan subsequent steps.

2.2 Attendance

Invitations for the 2nd User Workshop were disseminated via the GAIA-CLIM web page, via user email lists and to directly and indirectly connected EU, ESA, and Copernicus projects participants. In addition invitations were offered via several direct emails to identified key participants including those survey respondents who had expressed an interest in engagement and participants to the 1st 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. In the end, 31 registrations were received and 5 participants signed up for remote attendance – see Table 1; furthermore, two BIRA-IASB colleagues agreed to make a dedicated presentation about their expertise beneficial to GAIA-CLIM. Unfortunately, we noted that most participants were project partners or colleagues from project partners and only 7 external users attended the workshop. For further information on aspects pertaining to representativity - see wrap-up of Days 1 and 2 (Section 3.1).

Table 1: Summary of participants and their attendance at the Second User Workshop. For comparison, participants external to GAIA-CLIM are coloured green. The last 4 columns indicate attendance on days 1 to 4: y stands for ‘yes’, n stands for ‘no’.

Name		Email	Institution	1	2	3	4
Dr. BROGNIEZ	Helene	helene.brogniez@latmos.ipsl.fr	LATMOS	n	n	y	y
Dr. HOLL	Gerrit	g.holl@reading.ac.uk	Department of Meteorology, University of Reading	n	n	y	y
Dr. MEIER	Arndt	Arndt.Meier@eumetsat.int	EUMETSAT	n	n	y	y
Dr. SCHULZ	Jörg	joerg.schulz@eumetsat.int	EUMETSAT	n	n	y	y
Dr. TRENT	Tim	tjt11@le.ac.uk	University of Leicester, Space Research Centre, Department of Physics & Astronomy	n	n	y	n
Mr. DESCLOITRES	Jacques	Jacques.Descloîtres@univ-lille1.fr	University of Lille / ICARE	n	n	y	y
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Dr. VAN GENT	Jeroen	Jeroen.vanGent@bira-iasb.be	BIRA-IASB	y	y	y	y
Dr. BELL	William	william.bell@metoffice.gov.uk	Met Office	y	y	y	y
Dr. BURGDORF	Martin	martin.burgdorf@uni-hamburg.de	Universität Hamburg	y	y	y	y
Dr. CARMINATI	Fabien	Fabien.carminati@metoffice.gov.uk	MetOffice	y	y	y	y
Dr. DAVY	Richard	richard.davy@nersc.no	NERSC	y	y	y	y
Prof. DE MAZIÈRE	Martine	martine.demaziere@aeronomie.be	BIRA-IASB	y	y	y	y
Dr. HENDRICK	Francois	franch@oma.be	BIRA-IASB	y	y	y	y
Dr. KEERNIK	Hannes	hkeernik@gmail.com	Tallinn University of Technology	n	y	y	n
Dr. LAMBERT	Jean-Christopher	j-c.lambert@aeronomie.be	Royal Belgian Institute for Space Aeronomy (IASB-BIRA)	y	y	y	y

Dr. LAWRENCE	Heather	heather.lawrence@ecmwf.int	ECMWF	y	y	y	y
Dr. MADONNA	FABIO	fabio.madonna@imaa.cnr.it	CNR-IMAA	y	y	y	y
Dr. MASO	Joan	joan.maso@uab.cat	CREAF	y	y	y	n
Dr. MULLER	Jean-François	jfm@aeronomie.be	BIRA-IASB	y	y	n	n
Dr. STAVRAKOU	Jenny	jenny@aeronomie.be	Royal Belgian Institute for Space Aeronomy	y	y	y	y
Dr. VAN WEELE	Michiel	weeelevm@knmi.nl	KNMI	y	y	y	n
Dr. VERHOELST	Tijl	tijl.verhoelst@aeronomie.be	Royal Belgian Institute for Space Aeronomy	y	y	y	y
Dr. VIGOUROUX	Corinne	corinne.vigouroux@aeronomie.be	BIRA-IASB	y	y	y	y
Mr. GARDINER	Tom	tom.gardiner@npl.co.uk	NPL	y	y	n	n
Mr. LANGEROCK	Bavo	bavo.langerock@aeronomie.be	BIRA	y	y	y	y
Mrs. KALB	Nathalie	nathalie.kalb@aeronomie.be	BIRA-IASB	y	y	y	y
Mrs. PEUBEY-HOGAN	Carole	Carole.Peubey@ecmwf.int	ECMWF	n	y	y	y
Ms. VOCES	Corinne	corinne.voces@nuim.ie	NUIM	y	y	y	y
Prof. DE LEEUW	Gerrit	gerrit.leeuw@fmi.fi	FMI & amp	y	y	y	y
Prof. THORNE	Peter	peter.thorne@nuim.ie	NUIM	y	y	y	y
Dr. KACIK	Monika	Monika.KACIK@ec.europa.eu	REA / EU	y	n	n	y

Remote attendees

Dr. FASSO	Alessandro	alessandro.fasso@unibg.it	University Bergamo	n	n	y	y
Dr. REALE	Tony	Tony.Reale@noaa.gov	NOAA	n	n	y	y
Dr. RANNAT	Kalev	kalev.rannat@gmail.com	Tallinn University of Technology	n	n	y	y
Dr. BOJINSKI	Stephan	sbojinski@wmo.int	WMO / Advisory Committee of GAIA-CLIM	y	y	y	Y
Dr. KREHER	Karin	karin@bodekerscientific.com	Bodeker Scientific	n	y	y	Y

2.3 Specific objectives of the Second User Workshop

- The primary goal of the workshop was to get user feedback on the Gaps Analysis and Impacts Document (GAID, document and online version) version 3 for preparing the next version, and to collect user ideas for preparing Task 6.3 “Prioritising potential gap remedies and improvements in capabilities”.
- The secondary objective was to give a demonstration of the current status of the Virtual Observatory (VO) and to get user feedback on that for guiding the further implementation.
- The third objective of the workshop was to outline the strategy for Task 6.1.4 “Final workshop with external users”

The intention of the meeting was to be a very interactive workshop with plenty of time for discussions and for the demonstration of the VO. Therefore, the participants of the meeting received in advance of the meeting the Gaps Assessment and Impacts Document (GAID) version 3 as delivered to the Commission and the link to the on-line catalogue and feedback tool. This material as well as the agenda including specific questions provided the context for the presentations, demonstrations and plenary discussions undertaken at the workshop. The attendees were also invited in advance of the workshop to present a use case for the VO on Day 3 of the Workshop. The agenda topics were also organized following such specific objectives, so there was a clear split between the GAID and the VO discussions days (days 1 and 2, and days 3 and 4, resp.) enabling attendees to choose the day(s) of highest interest for them.

Agenda

The agenda of the workshop is included under Annex A.

3. Second User Workshop: Presentations and Discussions

All the presentations are available on the GAIA-CLIM web site

<http://www.gaia-clim.eu/pdfpage/second-user-workshop-presentations>

3.1 Days 1 and 2

3.1.1. Opening talks

Martine De Mazière opened the workshop and **Nathalie Kalb** explained the logistic details for the week.

Martine then provided an introduction to the User Workshop in the context of GAIA-CLIM and in the broader frame of the Copernicus programme needs:

- Prioritized needs for further observational sub-orbital capacity targeted at enhancing satellite calibration and validation capabilities
- Enhance ability to utilize truly reference quality traceable measurements in support of satellite data characterisation

She highlighted how a key aspect of GAIA-CLIM is user engagement throughout the project, and reminded the audience of the 1st User Workshop and associated report, D6.3. The specific aims of the 2nd User Workshop were stated (see section 2.3).

A tour de table was made asking the attendees to indicate their major interest and application in order to define the break-out groups compositions; initially the applications had been identified as climate research, climate services, and satellite validation but it turned out that this split-up of the group was not fully appropriate due to their range of expertise.

Martine De Mazière also reminded the attendees of the invitation to present a use case for the VO on Day 3.

Peter Thorne then provided an overview of the GAIA-CLIM project aims and the underlying methodological rationale for the project and where we are currently. He highlighted that the project consists of several interlinked work packages with the main user interaction foreseen through the Virtual Observatory and documentation of gaps (GAID, living document). He pointed out the achievements to date:

1. Sub-orbital measurement maturity assessment and metadata
2. Traceability chains
3. GRUAN data processor
4. GAID

The rest of the first 2 meeting days was devoted to discussing the Gap Assessments and Impacts Document (GAID) that was presented by M. Van Weele, task leader, and by R. Davy, responsible for implementing the online gaps catalogue and associated tools.

M. Van Weele gave an adapted presentation of the one previously given at the ConnectinGEO workshop (Laxenburg, Oct 2016).

He focussed on two principal tasks:

- To review what we have in GAIDv3 and provide ideas on how to improve. We must ask ourselves how useful the gap assessment process is to users.
- To consider how we can use the gaps and the information that we have for the prioritization exercise.

He also clarified the main innovations that have occurred in moving to GAIDv3 viz:

- A common template;
- A requirement for a SMART formulation of the gaps remedies;
- Further detail in description of the categories and information included; and
- Added flexibility of an on line catalogue with feedback options implemented.

The purposes of the GAID document are: (1) to provide the latest status of the on-line catalogue, (2) to provide an analysis of the latest list of gaps by cross section, and (3) to serve as an outreach tool.

He briefly updated participants on the upcoming activities foreseen in the remainder of the project that pertain to the GAID process:

- Updates to the on-line catalogue, (Nov 16 -Feb 2017) (including gap versioning, potential new or retired gaps, interactive tools, i.e. added value of search by multiple fields);
- GAID v4 due Feb 2017;
- Prioritisation of gaps (task 6.3) starting in March 2017.

Discussion

Joan Masó, from ConnectinGEO, <http://www.connectingeo.net/>, which has undergone a similar exercise queried how standardised the on line catalogue could be. A lot of the fields seem to be free text, so this might make them difficult to classify. He requested clarification on what vocabulary GAIA-CLIM are using. For example, the field ‘time bound’ could provide a better definition of ‘long term’. He urged GAIA-CLIM to harmonise and define timings and other aspects that would allow greater comparability between gaps in the catalogue. Michiel agreed that we haven’t yet sufficiently harmonised. So the next step will be to better define aspects such as the timings and to quantify them.

Joan Masó noted that another thing that they are missing in ConnectinGEO and he believed GAIA-CLIM are missing too is ‘Who is going to be responsible to fix the gap’? Michiel noted that this will be part of the next step (the prioritisation and the recommendation on what we think are priorities). We will finalise the GAID exercise by prioritising and providing a set of prioritized recommendations to the Commission.

Peter Thorne clarified that probably the model we will use is the GCOS Implementation Plan, and rather than identifying an individual actor or naming a particular organisation, we should suggest a more generic actor, for example ‘metrological organisation’.

Richard Davy demonstrated the on- line version of the GAID catalogue

The catalogue is able to be updated in real time. The indexing is organized by WP in which they originated. Gaps that are retired are no longer visible in the catalogue. To enable tracking between versions the gap unique identifier number in the form: GXXX is similarly retired. Richard invited feedback with regards to format, ease of navigation, and desired additional functionalities to inform subsequent development steps.

Joan Masó in his invited talk introduced the ConnectinGEO project and the Global Earth Observation System of Systems (GEOSS), and clarified the links between the gaps analyses performed in ConnectinGEO on the one hand, and GAIA-CLIM on the other hand. ConnectinGEO is an H2020 funded project under SC5. It constitutes a contribution of the EU to GEOSS, focusing on a gap analysis in GEOSS, and the building of a European Network of Earth Observation Networks (ENEON).

He pointed out the methodology used in ConnectinGEO for collecting, classifying and reporting the gaps, including the heritage from early versions of the GAIA-CLIM GAID, and for prioritization of the gaps. He noted with appreciation the collaboration between ConnectinGEO and GAIA-CLIM throughout the development of their respective gap assessment and prioritization activities which have served to aid both projects.

Joan noted an increasing interest in a comprehensive review and assessment in informing user requirements exercises. GEOSS goes from user needs to organisational requirements focusing on Sustainable Development Goals (SDGs). The GEOSS User needs and gap analysis aims to establish a comprehensive overview of user needs and observational requirements and to carry out gap analyses to identify gaps in observations and derived products meeting these requirements and needs. In this way, ConnectinGEO has identified 218 gaps coming from a collaborative table of which ~ 70 are coming from v2 of the GAID from the GAIA-CLIM project.

The ConnectingGEO user feedback system uses the web application platform TWiki. The gaps table includes a gap description, thread, editor, traceability, purpose, review, remedy, feasibility (technical), impact and cost. From these fields the prioritisation can be organised, although scoring is dependent on the criteria that will be selected.

Joan closed the presentation by noting that the next GEO work programme symposium will be held back to back with the International Symposium of Remote SEnsing (ISRSE), May 2017. There shall be a session on gap assessments and GAIA-CLIM were encouraged to submit an abstract to the event. Such an abstract was subsequently submitted and accepted for an oral presentation.

Discussion

Peter Thorne thanked Joan for his presentation and inviting us to ConnectinGEO workshop. He noted that it highlights the importance of learning from each other. GAIA-CLIM has recently been invited to provide input to next Copernicus, NEXTSPACE, which is doing a gap analysis as well. There seems to be a limit of understanding of a good common methodology for gap analysis.

Peter also noted the risk that had also been highlighted at the ConnectinGEO meeting of concentrating too much on gaps and giving the idea to funders that they can cut other ongoing activities. How do we marry the positive aspects of a gap analysis informing development pathways without inadvertently creating new gaps? How do we make clear that it is unwise to address a gap by pulling resources from elsewhere without at a minimum assessing the potential impacts when we do the prioritization of gaps? Earth System monitoring is a multi-decadal inter-generational challenge and requires sustained capabilities that, ideally, will improve over time.

Michiel suggested that there are fulfilled and unfulfilled user needs and we should focus on unfulfilled user needs, rather than on fulfilled gaps. Monika Kacik (GAIA-CLIM's project officer) noted that this was a good point. However, unfortunately there is not an easy answer to this but it requires strategic thinking. How you indicate the importance of the gaps in your document and the prioritization are extremely tricky but important steps. Looking at the gaps some of the remedies are very targeted and perhaps it would add value to outline the steps that we think would be necessary for the remedy to take place.

Peter agreed that we need more detail in some of the gaps, new fields and prioritisation and this is something to which we are hoping the users can provide some valuable feedback. We have engaged with users but we wonder what else can we do in the limited ability to get user engagement. This was subsequently discussed in more detail.

3.1.2 Discussion with all participants in breakout groups

Three breakout groups were formed, and two breakout sessions were organised with facilitators Peter Thorne, Heather Lawrence, and Richard Davy for the first session and Martine De Mazière, Corinne Voces and Bill Bell for the second session. Each session was followed by a plenary feedback discussion.

The groups were given specific questions to guide the discussions. There was some inevitable degree of repetition of discussion across several of the different questions as common themes arose. Therefore, hereinafter we repeat all the questions and summarize the results from the breakout discussions according to the common themes of interest and points of attention.

Guiding questions:

- *What is your perception of the bottom-up process of gap identification in GAIA-CLIM: Strengths / Weaknesses etc.*
- *How useful is the gap assessment process to users? Can we maybe improve its utility?*
- *Do you agree that the current 88 gaps in the catalogue are actually gaps? (see the gap catalogue provided)*
- *Do you miss gaps or e.g. important elements in the current gaps?*
- *Would you like to see another structure of the document/ other cross sections / further analysis of the gaps / interactive tools for the on-line catalogue?*

- *Which gaps have the most impact on your work? What would be needed to remedy? What is the risk for not resolving the gap on short / long term? Which gaps do you specifically encounter when running your application? Are these listed / sufficiently well scoped and formulated?*
- *Can you suggest any additional (future) work programme / activity to resolve one of the current gaps? Can you assess feasibility and distinguish between amount of effort (costs?) expected?*

Discussions

Top-down versus bottom-up approaches

The first breakout group raised the issue of a top-down versus bottom-up approach. ConnectingGeo used a top-down approach and started by identifying goals, defining associated variables, and finally identifying gaps e.g. 16 goals, 100 targets, 200 indicators for targets. Other groups /users thought that the bottom up-approach employed by GAIA-CLIM seems to be a good approach, and that making use of the expertise within GAIA-CLIM in this manner to drive the gap process from the expert perspective makes sense. So the question arises: which lessons are to be learned from GAIA-CLIM and ConnectinGEO when they have undertaken fundamentally distinct approaches to gap identification? Is there value in one approach over the other? What lessons could / should be drawn for such assessments in the future?

This arose a discussion of key differences between ConnectingGeo and GAIA-CLIM gap assessment exercise remits. GAIA-CLIM is concerned with identifying gaps in our capacity to validate Earth Observation (EO) data from satellite (i.e. not concerned with identifying gaps in our capacity to measure per se). Whereas ConnectinGEO is also concerned with capability to measure Essential Variables (EVs) defined by GEOSS and others.

It was further noted that the gap should be explicitly tied to those satellite validation requirements that its resolution would aid.

Stakeholder engagement

The second group raised a concern that the GAID process should include stronger and more sustained input from relevant stakeholders, and particularly satellite agencies, including non-European agencies. The satellite agencies are the primary parties generally tasked with post-launch Cal/Val - it is important that the needs, and gaps, of these communities (for validation) are captured. Jean-Christopher Lambert commented that at least for composition this perspective is already likely to be well covered in GAIA-CLIM. It was suggested to use the complete list of European (Sentinels, and MetOp-SG and MTG) missions and associated ECVs & instruments as a basis for identifying Cal/Val teams, and to target these teams for input to GAID v4 & v5. It is important that the final version of the GAID is comprehensive in this respect.

This discussion led to a query as to whether there was a need for an internal or external reviewer. But the GAID remit even though limited to the GAIA-CLIM remit is still incredibly broad. Therefore, any single reviewer would need to cover multiple expertises. It was suggested that GAIA-CLIM and FIDUCEO which are closely related projects could consider more formally reviewing each other's work.

Heterogeneity in current GAID gaps

Differing levels of gap inclusion led to concern from some that the gap process did not necessarily look joined-up. For example, G2.02, which pertains to missing profile data in the first few hundred metres (missing profile segment), when made generic also pertains to several non-lidar techniques and should be generalized, or alternatively, additional gaps should be added for all similarly impacted instruments. It does not make sense to raise this only for lidars. Martine noted that in looking at the document, some gaps appear to be too specific: is that level of detail/ specificity important and for whom? Perhaps this level of questioning will be part of the prioritization exercise. We should try to merge some of the gaps or to formulate gaps at a higher (less specific) level. She suggested that one approach we could consider would be to adopt a tiered structure of gaps? Tom Gardiner suggested that when groupings are done for the different categories, some gaps with the same issues can also be allocated. In this way sorting of gaps would also support the prioritization exercise at a later point. For example, we have limited aircraft observations in Eastern Europe (G1.14) but we probably have similar issues of limited data elsewhere too. It was also noted as an issue to have access to the same level of detail across the areas for which the consortium doesn't have the expertise. A suggestion was made to undertake grouping of common issues in one overarching gap and then link to individual detailed gaps as examples or 'sub'gaps. Another potential avenue to consider is to review across the project the level of buy-in and input, and address perceived weak-input-areas presently.

It was again stressed that heterogeneity in current GAID entries concerning the time scale and other assessable metrics of the remedy needs to be addressed. See also the discussion around better indexing of gaps through increased usage of a common vocabulary and collection template.

It was noted that still in GAIDv3 was evidence of distinct levels of engagement in the process by the underlying WPs. It was suggested that we take one WP that had thoroughly documented gaps e.g. WP2, and ascertain whether this was because they had engaged more holistically with the process or whether it rather reflected real differences in the number of gaps between underlying WPs.

Accessibility of current GAID

In regard to ordering / collection of gaps, Martin Burgdorf clarified that from an external user perspective the GAID can appear overwhelming. He suggested that you don't want to have too many gaps, then it becomes unmanageable both internally and externally. For example, for the aircraft gap (G1.14) we could find the right type of users and engage them to participate. Martine suggested that an option for the cases like the aircraft gap is that we state the information we know but mentioning that it is incomplete.

Overall, current categories were generally felt by all breakout groups to be a useful way to order things. Greater use of categories would help increase the utility of both the GAID and the online catalogue of gaps.

Indexing / making sense of the large set of gaps

Tom Gardiner noted that every gap is relevant but they apply at vastly different scales. If and when GAIA-CLIM were to start grouping gaps it would be useful to understand common issues across a family of grouped gaps. Having a list of gaps is good in the sense that it can help you to identify common issues and this should be considered in going to the next GAID version.

Richard Davy noted that the use of the cross-sections tool will be useful to find common themes. Martin Burgdorf said that as a user he found some gaps are too general and somewhat vague, and wondered whether we can use the cross-sections in those cases. Tom Gardiner suggested that it would be a good idea to have a drop down list to further sort current categories.

Martine noted a point raised at Joan Masó's presentation, it would be desirable to better standardize terminology. It would also be beneficial to be able to sort gaps for example by the shortest time, by the lowest cost, etc, but at present the terminology (e.g., for time scale) is too generic to do this sorting/ranking. Quantifiable metrics would enable 'weighing' a gap and therefore facilitate prioritisation. One way we could approach the problem is categorizing the remedies, for example gaps that can be solved through a technological remedy, other gaps can maybe be solved by research activities, for example working on the traceability chains. This categorizing of remedies could also be an important step that will facilitate the prioritization exercise.

It was recognized that the current quick overview in the GAID with in-depth website entries is good. However, not all users are online and many users may prefer to explore the data offline. Therefore there was an identified user need to make GAID information available in a widely accessible format - e.g. Excel format, .csv.

Repetition of information

Also raised by Martine was a query as to the usefulness of information repeated throughout several gaps (e.g., no data available in country(ies) X). This repetition should be actively minimized in the next version of the GAID. Joan Masó noted that it would be useful to identify those users affected by non-mitigation of a given gap.

Additional cross-sections

It was broadly agreed that the GAID would benefit from an expanded set of assessable cross-section metrics. Each gap should be formulated according to a well-defined vocabulary to make the GAID easily searchable. WPs should agree on an expanded vocabulary to use (instruments, ECVs, chemical species, statistical techniques / terms, networks, domains). Can we find what users have searched for thus far to drive this? Richard Davy clarified that to date insufficient usage had accrued to justify such

an approach. Possible additional fields upon which to perform or make possible the performing of user-driven cross-sections mentioned were:

- Impact (high, med, low)
- Cost
- time scale,
- User
- Links to other gaps
- Main missions impacted by each gap (Sentinel, METOP, MSG/MTG, NPOESS etc.)

These fields need to be filterable. In terms of the cross sections GAIA-CLIM will need to prioritise and to quantify impact; for example, a gap might have a high impact but low relevance to the particular problem of satellite cal/val. Prioritisation shall require a combination of different considerations.

Ensuring gaps are real gaps

Some users queried whether all the gaps were real gaps. There exist examples (G2.22, G2.21, G2.35) where it's not clear they are gaps simply from the gap title. GAIA-CLIM participants need to reformulate gap descriptions to be clear on first glance what the nature of the gap is. It was further stressed that GAIA-CLIM need to make sure that the gap and the remedy are not 'confused': some gaps are formulated rather as a remedy than as a gap. To make sure a gap is really a gap, it must be linked to a requirement – more specifically to a requirement for validation of satellite ECV data.

Traceability of gaps to underlying literature

It was noted that references and reports should be included where possible. Current gaps are very reference light which is frustrating from a user perspective if they want to better understand the scientific / technical underpinning of the gap. More thorough use of referencing may help to improve accessibility for users.

Ensuring actionable gap remedies?

There was then a discussion around the remedies as they stood in GAIDv3. Solutions are helpful, but we need more detail to make them actionable. They should be able to be taken and modified relatively simply to constitute a description of work in a funding call. In some cases, notes in the gap descriptions were felt to be needed to be more specific. There is still a degree of heterogeneity in v3 of the GAID in regards to the degree of detail. There is a very important need to be specific in gap descriptions. Specifically, it is key to formulate the gaps and remedies in such a way as to avoid the possibility of (un)intentional mis-interpretations.

Martine noted again that some of the gaps seem difficult to remedy as currently formulated. It was queried how useful such information is for the user. Related to this it was again stressed that the process needs to target specific users. Specifically, satellite agencies and the Commission need to find this useful and take notice of / make use of the process if it is to result in concrete outcomes. It was

recognized that users rarely read documentation for reasons of time and / or interest. The GAID and the on-line catalogue need to be made more user friendly where possible.

Another question is that if some gaps are to be solved through one action happening, or a chain of actions, or something that the entire community needs to change, for example a policy, then how do we make these actions actionable in order to solve the gap? How do we make clear to users such critical dependencies?

Following, discussion on this point, an extra process was seen as required which pro-actively sought the input of key stakeholders. This process needs to be appealing to the target users in order to reach active participation. It was suggested that GAIA-CLIM should consult the Commission as the intended primary customer of the recommendations document. The EU wants recommendations for future work programmes. We should publish the recommendations adopting the style of a work programme and seek the EU input in this process pro-actively.

GAID process as an educational tool / user resource

Martin Burgdorf noted that in his opinion as a user the gaps assessment is a good resource to users, since it is useful for some people to have that inventory and to understand the limits, for example, in traceability. Even if the responsibility for a remedy lies often at a higher level than the user it is a potentially useful resource to them. Tom Gardiner noted that information can be relevant at different levels. For example, for some users as an inventory and for funders to understand gaps and prioritise as required. Fabio Madonna noted a very positive experience with the gaps for maturity-matrix definition. It was generally agreed that the GAID could constitute a useful educational resource for users.

Taking care to ensure against mission creep

The point was raised that we need to be wary of mission creep. Specifically, GAIA-CLIM need to be mindful of the distinction between gaps in observational capability & gaps in capacity to validate Earth Observation satellite data. For example, G1.14 Lack of aircraft observations in Eastern Europe, does it represent a gap in the context of GAIA-CLIM? The key point is to ask what would a lack of aircraft observations prevent us from validation?

Missing educational gaps

It was noted by numerous groups, and following a similar discussion within ConnectinGEO, that thus far there were no educational related gaps. There was a rich set of specific technical gaps but underpinning many of these are educational gaps. These gaps relate both to training future generations of scientists to ensure a robust non-satellite EO capability moving forwards, but also educating users to ensure adequate use. There is little value in addressing many of the more technical gaps already identified without ensuring a sustainable capability and a cognizant user base.

Focus upon core GAIA-CLIM project purpose

It was suggested that GAIA-CLIM should better focus on a subset of gaps addressing clearly satellite validation/calibration. This may be achieved through more effective consultation with the user community in the final stages of the project as mentioned previously. It is key that GAIA-CLIM identifies and reaches out effectively to the key stakeholders. We should identify common gaps that affect multiple key stakeholders. In that context, prioritization may be aided by consideration of a more common level assessment. For example, considering all gaps related to uncertainty as a group rather than individually.

It was stressed that gap prioritization should not ignore internal to project expertise. In many cases the impacts may be best assessed internally.

FIDUCEO collaboration

It was stressed that there would be added value in increased communicating with FIDUCEO. Especially for remediation which may be aided by ongoing work in FIDUCEO. But also gaps which impact the FIDUCEO project may be a key aspect in subsequent prioritization aspects if elements of both projects become part of the sustained Copernicus program.

Uncertainty information

Currently, availability of metrologically robust and consistent uncertainty information is a big problem for ground-based observations. We must provide to the user a correct uncertainty assessment. This necessarily includes understanding contributions from correlated, structured-random and random uncertainties. There is a need for harmonization. It was recognized that many of the gaps, particularly those identified by WPs 2 and 3, touched on these aspects.

Data access gaps

Technical gaps in capabilities to access / work with data were recognized as being the major impediment to current use of non-satellite measurements to characterize satellite-based EO measurements. This shall be partially remedied by the VO and also the Copernicus in-situ call C3S311a_Lot3 award if contract negotiations are successfully concluded on the latter which is led by GAIA-CLIM participants.

Importance of having multiple posited remedies

The costs associated with a given gap remedy are intrinsically interlinked with the scale and ambition of the posited remedies. For most gaps there must exist multiple possible pathways to remedy yet in GAID v3 most entries have only one associated remedy. It would aid the prioritization exercise if the next version of the GAID had a greater range of remedies per gap. It may be that there are lower risk remedies that ameliorate but don't entirely remedy gaps.

Metrics and mechanisms to support prioritization

Technical viability and cost are already covered in the GAID but, as noted previously, its application has been heterogeneous across the current catalogue. Impact is also an important metric that needs better elucidation. In particular, the benefits to resolution as well as risks associated with non-resolution should be recognized appropriately. Feasibility versus impact is likely the ultimate pay-off in any prioritization aspects (where feasibility includes economic and technical viability as well as timeliness).

The next version of the GAID requires sufficient filtering opportunities to support different user groups needs. Users should be able to generate their own cross-sections based upon having a sufficient number of gap aspects quantified and presented in a sufficiently similar fashion using a common vocabulary and format.

Prioritisation document

The general feeling from the breakout groups was that the Task 6.3 outcome should be a short document with only a few recommendations, spelled out very clearly. It should avoid recommending work on gaps that were sufficiently well addressed already in GAIA-CLIM or FIDUCEO.

3.1.3 Subsequent plenary based discussion

Learning lessons from prior gap analyses / informing future gap analyses

Tom Gardiner and Martin Burgdorf noted that if we compare to / collaborate with others doing gap analyses, this would potentially offer more value. If there are other existing processes done, even for different purposes, it is useful to compare them and have a standardised way of doing these analyses. There was potential value foreseen in a methodological paper that documented the lessons learnt as gap analyses are becoming increasingly frequent components of major projects. Yet there is a lack of standardization / best practices and thus a risk of both reinvention of approaches and heterogeneity of approaches leading to a reduced utility both of individual gap analyses and the family of gap analyses.

Towards the next GAID version

It was agreed that in support of user outreach activities the next GAID v4 release should be a near complete version. This arose the question as to how do we prepare version 4? Several suggestions were forthcoming which informed the proposal for a new gaps template (see later discussion and associated annex):

- Joan Masó noted the need for an improved section on intended audience in the introduction to better justify the process to the external users and ensure buy-in.
- Gaps should be framed in terms of scientific needs – e.g., not missing observations in South America but X satellite is missing observations in low albedo environment.

- GAIA-CLIM must be mindful of the eventual audience and purpose of a set of prioritized recommendations. So each gap needs to be sufficiently comprehensive and coherent to constitute a statement of work. The problem needs to be sufficiently well described to satisfy this requirement. Gaps should be formulated as addressing requirements. This requires a well-defined scope. Can take an example as a satellite validation requirement - top-down approach on driving requirement. This would be distinct from the bottom-up approach adopted thus far.
- Scale of work is different for different gap types e.g. some will only require a PhD / postdoc work, while others may constitute multi-party, multi-year efforts. Different sizes of projects need to be clearly reflected in remedies along with potential actors. This would augment existing elements as a basis for recommendations / prioritisation (timescale, cost, feasibility / likelihood, risk, impact, end-users).
- For technical gaps, Joan Masó recommended the use of Technological Readiness Level (TRL) indicators which are used throughout the satellite industry.
- It was suggested to relate gaps to validation requirements and / or specific applications to make it appealing to Agencies. This should be included as an option for cross-sections.
- Based upon a revised GAID v4 it is important to be able to attribute scale and type of remedy to build recommendations that could be used to build work programmes.
- Martin Burgdorf noted that Table 1 in GAIDv3 is very useful and provides a good overview of results. He suggested that this is perhaps something that we should have more of.

It was further noted that if a gap does not meet the level of clarity and compellingness that we require, then we should not be afraid to remove it from GAID v4. Furthermore, we should actively pursue the coalescing of gaps to avoid egregious overlap between presented gaps.

Tijl Verhoelst and Fabio Madonna raised the potential role of internal reviewers in GAID v4 for acceptance of a gap. This would assure some minimal set of standards had been reached sufficiently to justify its inclusion.

User engagement

It was agreed that GAID v4 should be a basis for the outreach to users on the roadshow (Sec 3.1.6) so it needs to be sufficiently polished. The outreach should use standard collection tools to collate the results. The GAID v5 will then be an iteration that folds in the feedback from users. To aid this it shall be necessary to add to the GAID a section more explicitly outlining who the customer /audience / user is. It is also necessary to explicitly document what the interest / scope of GAIA-CLIM is. Equally, it is necessary to recognise possible interest to a broader audience e.g. individual academics. It is likely to be necessary to make recommendations that are specific to the end-user / customer. So GAIA-CLIM may associate recommendations with distinct users.

A question was raised as to how to address potential conflicts between internal (GAIA-CLIM) and external users. Both sets may bring important viewpoints and this process shall need to be managed accordingly.

Then it was queried how do GAIA-CLIM effectively sample users? The project can't meet all users so we must ensure a representative sample of views are canvassed.

Prioritisation

Prioritisation was recognized as a vexed issue. Whilst we shouldn't disregard gaps that aren't fitting to validation, it will be necessary to prioritise those that fit the GAIA-CLIM project remit. Joan Masó noted that ConnectinGEO had used a mathematical approach combining several of the gap fields (cost, impact, feasibility, timeliness) and suggested that a similar approach may be applicable here. An alternative prioritization may be to map onto existing internationally adopted requirements, such as those arising from the GCOS Implementation Plan or implicit in IPCC assessments. The question was raised whether we should go to users with our initial set of priorities and ask for their input? Provides a means to get buy-in to our priorities but risks biasing the outreach activity. This issue was left unresolved and shall be discussed at the General Assembly.

3.1.4 Feedback from selected users

Following the breakouts and plenary discussions feedback was solicited from a selection of users. This feedback led to some further discussions.

Feedback from J. Masó

Joan Masó stressed the need to continue to share information between ConnectinGEO and GAIA-CLIM on methodology for gap assessment. Since there is a regular repetition of gap analyses it would make sense to work on formalizing a common framework for identifying / describing gaps which would aid all projects and also end users. Priorities should be identified by some score based upon remedies, high impact / low cost / high feasibility; but this is only for sorting, then undoubtedly need expert solicitation process to move towards prioritization.

An executive summary is an important step, but keeping the full list alive and up-to-date is also important. Ultimately the gaps themselves constitute the foundation of the process. GAIA-CLIM should strive to implement and improve an interactive online implementation and an iterative process for feedback from users.

To ensure wider buy-in he stressed the need to try to get the wider horizon of GEO SBA 5 (Societal Benefit Areas) and SDG (Sustainable Development Goals), and the bigger picture of the Earth System.

Discussion

Martin Burgdorf stressed that ConnectinGEO has approached the assessment as a top-down exercise and this potentially helped address weaknesses of bottom-up processes. Joan Masó stressed the value of looking from both perspectives. You don't need to replace gaps, but see what you have from that perspective i.e. what are the goals.

Jean-Christopher Lambert stressed that cost as criteria is overly perspective. Costs are required to be balanced against likely benefits. However, experience shows that not all benefits are apparent prior to addressing a gap. Often the largest benefits were not envisaged at outset of a given project / program.

Feedback from Copernicus Climate Change Service (C3S): C. Peubey

Carole Peubey presented a summary C3S: the objectives, the different components, the evolution from research to operational services, the current status, and the requirements for observations. At the end Carole presented some potential 'gaps' which may fall within the remit of GAIA-CLIM from the point of view of C3S.

Discussion

Fabio Madonna noted that GAIA-CLIM is seeking to develop GAIA-CLIM tools into Copernicus and have answered an ITT from Copernicus regarding provision of baseline and reference quality measurements. Subsequent to the workshop the proposed tender was invited forwards and negotiations with ECMWF are ongoing at the time of submission of the present deliverable.

Gerrit de Leeuw noted that many groups are now working under a diverse range of contracts with ECMWF to develop services. He wondered whether there are any plans to bring these groups together for homogenization? Carole Peubey noted the question but could not provide any details at the time.

Bill Bell noted that the VO and the GRUAN simulator constituted offline tools. Is this type of approach an envisaged routine operation for satellite assessment under C3S? Carole Peubey clarified that any new dataset that came from EUMESAT could be run through this. Bill Bell noted that in that case it is important to follow up on characterizing the random part of uncertainty from forecast tools.

Martin Burgdorf wondered how C3S intends to scale / use the calibrations arising from GAIA-CLIM and FIDUCEO? Carole suggested one practical application would be to compare before and after calibration prior to assimilation into ERA5.

Stephan Bojinski noted that part of C3S intended role is to capture gaps in services and build bridges to research. Is this a custodian to manage and maintain these gap analyses after the ConnectinGEO and GAIA-CLIM projects finish? Such gap assessments are inherently living processes and will undoubtedly age rapidly if not taken over on a sustained basis. Carole Peubey was not in a position to provide a definitive response to the question, but noted its potential import.

Feedback from advisory Panel: Stephan Bojinski (remote)

Stephan Bojinski provided some feedback on the GAIDv3.

1) Feedback on specific gaps

- Governance gap on lack of comprehensive overview on which networks exist and under what ownership. Emphasize the inconsistencies that were raised in this gap.
- Gap related to microwave measurements G2.14: systematic bias there that isn't understood, there have been dedicated workshops on this. No owner for this gap – needs fuller description.

2) Feedback on management of GAID process

- The website is a useful way to provide feedback – he has provided feedback already. However, care needed here. For example, G1.03 is inconsistent with GAIDv3; G1.10 is not online [both since corrected].
- Prioritise and attribute the gaps to ensure legacy.
- The GAID will become outdated quickly, who should be owner of this process? It should ideally be part of C3S as it fits their remit and such an approach provides a long-term custodian.
- Space agencies working on responding to GCOS Implementation Plan (IP), eg., in CEOS WG on Climate. GAIA-CLIM can refer to GCOS IP and gaps that respond to the IP may be a way to prioritise.
- C3S, Sentinel MAGs, ESA CCI projects are preferred interlocutors and can help addressing gaps.

Discussion

Michiel van Weele asked whether Stephan Bojinski had any insights on how to undertake the prioritization exercise in a rigorous manner. Stephan suggest concentrating on what outreach can be addressed within the project. Validation is clear driver – it is core of GAIA-CLIM – talk to mission managers of satellites and modellers.

3.1.5 Comments from WP1 to WP5 leaders

Fabio Madonna (WP1) Three points to re-raise

- (1) How important is strategy followed by agencies for funding – we should be focusing on convincing them what is the priority.
- (2) Focus on scientific objectives (we should not lose our identity) and demonstrate usefulness for SDG.

(3) Are the gaps consistent with the exercise on maturity matrix exercise and the work done in WP1 ?

Jean-Christopher Lambert (WP3) Top-down approach desirable for funding agencies – this is the approach they are used to and is implicit in their funding methods. Need to find a way to harmonise the two (bottom-up and top-down) approaches. Suggests an introductory section on high-level requirements and involvement of CEOS- ACC group.

Bill Bell (WP4) Need to focus more sharply on audience for GAID. We should address life of GAID beyond the project – should be mindful of this.

Martine De Mazière (WP6) had a question to Stephan – you mentioned satellite and model validation, they have different requirements, we focus more on satellite. But with C3S we should reach out more to modellers, e.g. in the SPARC community – they have a dedicated group for gaps. Stephan Bojinski clarified that in his view GAIA-CLIM is a pathfinder for this, hence emphasis on suggesting that C3S becomes the custodian of this.

3.1.6 New template for GAID v4 and wrapping up.

To wrap up all the discussions and feedbacks, Peter Thorne and Michiel van Weele lead a discussion about a new template for the gaps collection and re-writing and restructuring GAID v4.

- ✓ Selected points from the discussions were highlighted.
- ✓ Coalescing gaps to aggregated gaps
 - Who decides that an existing gap is sub-critical? We need criteria; it is up to the group to decide, not down to an individual
 - Who culls gaps and why?
- ✓ Timeline
 - New template for GAID v4 inputs and 3-4 worked examples should be available mid-Dec. 2016 (ideally 1 per WP)
 - Individual gap owners should revise their gaps by 31st Jan. 2017
 - GAID v4 delivery end of Feb
 - Initial prioritisation presented at GA (to form basis for feedback)
 - Recommendations based upon a priori and a posteriori collection
- ✓ Possible extra fields for a gap
 - How key is the gap to a defined and associated user?
 - Likely funding agency and actors to address gap
 - TRL for technological gaps

- Technical feasibility (already addressed?)
- Scale of required work (already addressed?)
- Impacts to end-users
- Operational missions impacted (incl. int'l)
- Other associated gaps in GAID (with justification as to why and what relationship – sibling, parent-child etc.)
- Who is impacted by / benefits from resolving the gap, directly and indirectly? Incl. societal benefit areas (SBA) / SDGs
- Indexing by vocabulary

Subsequent to the workshop a modified template for the collection of gaps under GAID v4 was circulated to all gap owners in early January 2017. This responds to all points raised in the preceding discussion. This template is given in Annex B. In addition, two examples were circulated to aid compilers (not shown).

Because of the difficulty to attract users to the Workshops under Task 6.1 to date, alternative outreach actions beyond GAID v4 were discussed:

- It was decided to propose that the third User Workshop will be replaced by personal meetings with selected users (GAIA-CLIM will go on the road and meet users) between March and November 2017
- The key user groups to visit will be decided at GA
- Who will visit whom will also be decided then
- It was recognized as important to agree standard outreach materials and template for input / feedback collection.

Following the workshop, a proposal was developed and submitted to the project officer for approval. This is given in Annex C. The proposal shall form the basis for reimagining outreach activities in the remainder of the GAIA-CLIM project.

Discussion

Tom Gardiner stressed that remedies should include a list of types of work. Peter Thorne noted that we could also add a list of benefits a user would obtain from remedying the gap. This and risks to non-resolution may have probabilities associated with them. E.g. Low probability of solar storm taking out a given satellite, but important to describe impact.

Jean-Christopher Lambert and Fabio Madonna noted concern about definitions for cost as any such categorization is essentially arbitrary. Instead and / or in addition it would be worthwhile to focus on which funding agencies are applicable for the given gaps. Stephan Bojinski agrees that cost is a hard one to estimate and unclear if they are used by funding agencies given their ambiguity. Where did that idea for costs come from? What is the Project Officer's opinion? Risk = hazard * vulnerability. Can you use that approach here? Peter Thorne clarified that cost estimates was an interpretation of the SMART analysis, but Peter shares the concerns which is why we have very broad categories.

Michiel van Weele stressed the need to make GAID users aware that we shouldn't create new gaps from swapping out funding. Hence need some context for gaps with respect to what is in place and the need for funders to first and foremost protect critical capabilities.

Martine De Mazière enquired whether we expect to have some priority list ready in time for the GA? Peter noted that this would depend upon degree of progress with implementing GAID v4 by then. In principal, we can present a strawman so that we can initiate the discussion as to how to make priorities if there are sufficient submissions by then.

3.1.7 Closure of Days 1 and 2 of the Workshop

The first part of the Workshop was closed by thanking all attendees for very intensive work and fruitful discussions. There then followed a short introduction to the agenda for the next day and a half, i.e., the second part of the Workshop focusing on the Virtual Observatory (VO).

3.2 Days 3 and 4

Martine De Mazière opened this second part of the workshop and **Nathalie Kalb** explained the logistic details for the next days. A new tour de Table then occurred with brief presentations of all attendees. This identified that most users are interested in satellite cal/val.

3.2.1 Update on progress on the VO and related activities

Arndt Meier gave a brief presentation of the Virtual Observatory development thus far. He highlighted both the high-level design objectives and the implementation to date. The VO shall consist of an object-oriented DB practically implemented as a Mongo DB. The backbone format for output following the initial user survey shall be netCDF although data maybe also will be made available via e.g. HDF5. The full original metadata will be able to be served in whichever format. He then provided

a brief update as to current status and outlook. He closed by inviting users to participate in the VO demonstration and provide feedback on whether the VO meets their envisaged needs. Case studies were welcomed.

Discussion

Bill Bell raised that model fields should be able to be received and ingested seamlessly. Arndt confirmed that this remained the intention but clarified that EUMETSAT have software challenges to overcome.

Martin Burgdorf asked about metadata and data and how we can know we have everything we want. Arndt clarified that we are only really searching for a subset that we can use as a demonstrator project (cf. GAIA-CLIM Reference Observations Readiness Table). We do not need everything at this juncture. There may also be a delay between creating reference quality measurement chains and their uptake by instrument operators. If the VO is successful there may be opportunities to expand and operationalize the service subsequent to the GAIA-CLIM project's completion.

Bavo Langerock asked whether there shall be a manual or description of the website? Arndt clarified that yes, a manual was to be produced toward end of project; but for the data contributors: so long as they you give reasonably and consistently formatted data the VO will work

Bavo requested further particulars on the architecture of the database. Arndt clarified that GAIA-CLIM follow the roadmap agreed upon during the last GA and we adapt it to needs as we ingest actual data. For a demonstrator, which is really what GAIA-CLIM is, we only need one server and we need not get too fancy. There will be some discussion as to how to store the collocations with related NWP data and errors, but this is more about the structure of certain data records.

Fabio Madonna presented the current status of the 3D visualization tools via a short demonstration. The visualization tools enable the user to select regions and / or measurement types along with match-up bounds to discover what data may be available for their particular application. Underlying the tool is discovery metadata and measurement maturity assessment scores derived by Tasks 1.1 and 1.2.

Discussion

Helene Brogniez asked about 'ixion' orbital software tool usage which uses NORAD and allows overpass co-location. She will pass the details to Fabio and WP5. Joerg Schulz raised CODA as a new tool used for Sentinel-3 at EUMETSAT to search within a domain and make orbit match-ups. Fabio

noted these tools and that they would be considered in finalization of the visualization tools over coming months.

Tijl Verhoelst presented OSSSMOSE and how it will/can be used in the VO. His presentation included some quantitative examples and questions to the users as to what features they want to use and how they want to use them, e.g., how do they want to use co-location mismatch evaluations? what features of OSSSMOSE and the work in WP3 do they want to use in the VO ?

Discussion

Martine asked about the smoothing error maps which appear very specific. In practice can this be made more flexible? Tijl clarified that the provision would be flexible by seasonality and vertical range. Jean-Christopher highlighted that user needs should drive this and that further user input was required.

Tim Trent noted that for surface sensitive satellite channels the surface topography has a large impact. Can this be captured? Tijl clarified that it was considered for some ECVs but not necessarily those of interest to all users.

Tim then asked whether the error estimate was based upon several re-analyses. Tijl said some assessment had been performed to date but was limited. Joerg clarified that we should keep in mind that GAIA-CLIM is a demonstrator project. We should document potential limitations / future work.

Bill Bell asked for the clarification of the underlying problem approach: could one use high resolution humidity model and radiosonde data to create a similar set of estimates? Could that quantify the effects? Tijl clarified that in theory this should be possible.

Arndt suggested a gallery of case study plots to support the VO, e.g., as part of the user guide. Fabio further stressed the importance of retaining spatio-temporal correlation scale information. Joerg suggested that this work could be used to make a greater case for instrument operators to ensure co-located observations to minimise mismatch effects that otherwise accrue. The VO can demonstrate the value of a good co-location.

Bill Bell and Fabien Carminati presented an update on the GRUAN processor outlining its background and the actual design. The NWPSAF Radiance Simulator RTTOV is basis for development of the GRUAN processor. The tool allows comparisons in model space and radiance space. For now, the GRUAN processor focuses on microwave observations.

Discussion

Helene Brogniez enquired around what is implied by RT model uncertainties. Are there plans to include these in the processor? Fabien and Bill clarified that it is not currently planned to consider or include this aspect. Such matters are about spectroscopic modelling and thus fall outside the GAIA-CLIM remit. That is not to say that they are not important as recognized by Helene and co-authors for 183GHz wing measurements.

Tony Reale recognized that the processor samples the profile every 15-seconds but wondered what was done about the NWP model-run time differences? This may be an additional source of uncertainty. Further, forecasts have already assimilated the satellite. How does the (forecast – observation) compare to what the GRUAN processor shows? Fabien clarified that this had not been covered yet.

Simulation of microwave instruments is currently undertaken. It was queried whether you also looking also at IR? Temperature and water vapour also have signatures in the IR spectrum and their use might help e.g. FIDUCEO target instruments. It was clarified that although not done presently in principal the method is extendable to any radiance capable of being simulated by RTTOV which includes the IR spectrum. Joerg urged consideration.

1. Links to FIDUCEO – HIRS channels should be a priority to meet FIDUCEO collaboration requirements
2. IASI : could we compare to PC scores rather than spectral?

Bill clarified that IASI and CRIS simulations planned looking at errors in radiance space; PC-score will be in RTTOV12

Can we get a handle on the co-location uncertainty that could at a minimum be applied generically? It was clarified that we can look at the differences due to the interpolation arising from the model. This is the power of the work being undertaken under WP4.

It was noted that model performance degrades in the vertical. For the stratosphere and above could you use GPS-RO instead of the model to interpolate to TOA? It was clarified in response that the Issue is to get a sufficiently exact co-location. Could use the climatology but this would result in a higher error if thinking about NRT.

It is important to span the uncertainty in the fast transfer model aspect in your GRUAN TOA estimates if it is to be useful in the comparison to satellites. Could an additional fast radiative transfer code be used to get a handle on this. It was clarified that this is less important in NWP to GRUAN comparison (the originally envisaged application of the processor) as the uncertainty is perfectly correlated in that case. Could use alternative fast transfer models or earlier versions of RTTOV to get a handle. Bill clarified that there was not resource within GAIA-CLIM to get hold of spectroscopic issues at the fundamental level.

Heather Lawrence highlighted the role of the gap document to help highlight what may occur in future.

Finally, it was queried whether a timestamp can be added? This can be done easily and shall be taken into account in subsequent developments.

3.2.2 Use cases

Tony Reale provided some input on his views as a result of several years of development of NPROVS and, more latterly, NPROVS+ platforms. These undertake similar core functionality to that envisaged for the VO. NOAA remains keen to explore synergies with GAIA-CLIM.

Martin Burgdorf presented three slides providing an overview of plans for AMSU-B/MHS/SSMT2 work in FIDUCEO. FIDUCEO is doing metrological traceability of the satellite measurements. He would like to compare the AMSU-B/MHS/SSMT2 data to the GRUAN radiosondes.

Carol Peubey implied primarily an indirect benefit to reanalyses characterisation / validation using the measurements provided by GAIA-CLIM, e.g., T in stratosphere is not verified at all for now. Could a similar facility to the GRUAN processor be extended to other instruments e.g. lidars? GRUAN processor may help overall reanalysis comparisons. Questions were raised around can the VO visualize satellite viewing/scanning angle? Can it visualize sonde track using sonde GPS info?

Helene Brogniez queried what the co-location match-up criteria were. Arndt clarified that it would follow the profile.

3.2.3 Hands-on sessions and related discussions

The attendees (including Monika) had a chance to sit together with Arndt Meier, Hannes Keernik and Fabio Madonna to exercise the VO and the 3D visualization tools, respectively. The hands-on sessions were spread over the afternoon of day 3 and the morning of day 4 and provided a useful list of specific recommendations on changes to functionality and graphical design.

These sessions were preceded by a plenary discussion about the uncertainties addressing the question what do we want to see in the VO when it comes to uncertainties?

Bavo Langerock gave an introductory talk about uncertainties that touched on different ways these could be quantified and served to end users. Given the mix of measurement uncertainties involved, the range of instrument techniques, and the need to account for the effects of non-coincidence of the

satellite and non-satellite measurement it is clear that the challenge is non-facile. Bavo's talk pertained primarily to presenting uncertainties as covariances. Fabio pointed out that WP2 is trying to create the common approach to uncertainty information. He noted that lidars can also provide covariances.

Discussion about how to make the uncertainty information useable and actionable?

Peter Thorne opened the discussion by querying whether instead of providing one profile and its uncertainty covariance, can't we provide an ensemble of profiles corresponding to the covariance? Is this not easier for the users? In other words: create post-facto distribution draw from covariance matrix?

Bavo noted that this requires the covariances to have been adequately quantified including all off-diagonal elements. He queried whether this is really of interest to the users.

Jacques Descloîtres queried how to account for structured random (e.g., under/overestimation depending on season) that persist in space or time? How to communicate such uncertainties that have a partially systematic effect? Bavo noted that this would require reporting uncertainties with a structure not available in the classical PDF type approach. Fabio urged a degree of pragmatism as we can't generate such info for past measurements. The user needs to be able to use the information that we present. What can be presented depends upon what is available both now and in the past.

Alessandro Fasso presented the work done by his team in WP3, i.e., statistical approach to co-location mismatch. Results were shown for radiosonde co-location effects on several pressure levels for varying time and space offsets over Central Europe. Generally, the co-location mismatch becomes large at several hundred kilometres distance and several hours offset under most ambient conditions.

Discussion

Tijl noted that it was nice to see that smoothing IASI over time in agreement with integration time of lidar provides good agreement. He wondered how to make sure that smoothing does not smooth out other errors in the data?

Jeroen Van Gent (on behalf of Gaia Pinardi) presented 'Tools developed for validation activities in the frame of O3MSAF', from which some ideas might be re-used in the VO. This work relates to collation of Ozone co-locations for satellite validation. The processor had undergone a very recent update and this update was outlined.

Discussion

Joerg Schulz queried whether the tool allows us to compare versions - i.e. can we see the difference between different versions? Jeroen clarified that no, currently you can only switch from one to the other - but this is a good idea so maybe for the future.

Joerg then asked whether they are planning to extend this to IASI level 2? Jeroen responded that this may be done in the future but they have not put a time-frame on it yet. It would make sense to do something like that.

Then followed a *plenary discussion following: ‘**Reflection on the use of OSSSMOSE in the context of the VO’, introduced by Tijl:***

Tijl noted that it is important to be aware of what the end user will need for the uncertainties. Specific examples are:

- ➔ Information content should be added to the data e.g. vertical/horizontal ranges of sensitivity
- ➔ Vertical and Horizontal smoothing?
- ➔ Important that we should be aware of how uncertainties are propagated into level 3 data ; this may add some further uncertainties

Jean-Christopher added a further comment following Tijl’s presentation: We know that the user community would like 5-day variability, however it is hard to get 5-day variability from the measurement networks in GAIA-CLIM as we don’t have enough data. Tools like OSSSMOSE can add to this.

Discussion led by Tijl:

Gerrit de Leeuw noted that OSSSMOSE is for total column ozone which does not have much horizontal variability and queried how much is what was shown relevant for other trace gases with larger horizontal variability e.g. aerosol, NO₂. Can this be generalised? Tijl responded that yes, the horizontal smoothing errors are larger for aerosol, but the challenges are also larger for the models so it’s harder to simulate these types of gas. However, we might be able to do something statistical i.e. predict that the pdf will have a certain width. Jean-Christopher further clarified that for stratospheric NO₂ the method is ready to be used but for tropospheric NO₂ more work still needs to be done, it is still in research mode.

Martine raised a question: Regarding collocation criteria do the plots you show include smoothing effects as well as co-location mismatch? Tijl confirmed that yes, such effects are accounted for.

G. Holl enquired as to whether GAIA-CLIM have considered uncertainty regarding information content (state-dependent uncertainty)? For example, in FIDUCEO this issue comes up with spectral response function of HIRS: the uncertainty in the spectral response function leads to uncertainty in the weighting function. Tijl agreed that this is a big challenge. Bill Bell noted that it is a problem generally

also for humidity because the Jacobians for humidity sounders are state-dependent. To make progress in this you need to know the uncertainties in your humidity field and the best estimates come from flow-dependent uncertainties from NWP models.

Then followed a plenary discussion following: ***'The role of NWP in the VO also with respect to estimating variability and uncertainties in water vapour, introduced and led by Bill Bell:***

Helene Brogniez commented on the idea presented by Bill to use a regional NWP model with 1 km resolution (e.g. the Met Office's regional model) to estimate spatial smoothing errors. She suggested that while this is a good idea there is still the problem that even if you use a high resolution model you will not capture all of the humidity errors - is 1 km enough for humidity? Bill agreed this was a good point and commented that we could first try to validate the model for this work, perhaps by looking at MWR humidity-sensitive observations to also look at the behaviour of the humidity field from high resolution observations and then see how well the 1-km model captures the same features seen by the high resolution observations.

Helene also made the comment that the ICON DWD model is very good - we could consider using that one instead? Bill responded that this is a good idea and we need to think about it. We would also need to think about how we could validate it, to check that the model is realistic for humidity.

Helene also commented on spectroscopy uncertainties and whether or not we can account for these: in her opinion the best we can do is go to the modelers and ask them for the uncertainties. Bill commented that the uncertainty due to the parametrization in going from LBL to the GRUAN processor can be evaluated but the one due to the parameters themselves needs spectroscopy experts.

Peter Thorne then commented firstly that we need to recognise and document the gap in spectroscopy. Secondly he asked a question to both Tijl and Bill: Both Bill and Tijl were involved in a collaboration, co-ordinated through the International Space Science Institute (SSI, Bern), on the topic 'Validation of Earth Observation Data: the point-to-area problem' -> could this work help us with the VO? Bill responded that the exercise was concerned more with comparing validation approaches across communities and it has taken time to come to a common agreement on a clear description of problem. Realistically, there will be no software outputs that would be of use to the VO. Tijl clarified that the project was more about scale (aka *point-2-area*, or *representativeness*) issues and a discussion about methodologies in different communities (land surface, ocean and atmosphere). There will be a review paper coming out from the meeting that is currently in preparation.

Arndt Meier raised a couple of open questions from the perspective of WP5. Firstly, we should consider using NWP fields to take out the time difference mismatch in the VO. This will boost the statistics on how many matches we could get from satellite to radiosondes. Secondly, should we implement co-location between 3 datasets: NWP, satellite, ground-based ?

Work package 2 representatives suggested that they may have closed the uncertainty gap on spectroscopy – work package 4 should perhaps talk to them. Bill replied that he was not sure that they were looking at the exactly the same spectroscopic parameters – for example the spectral ranges of interest to ground-based FTIR (window regions of the thermal IR for measurements of trace gases) are not the same regions of interest for satellite-based remote sensing of temperature and humidity (CO₂ and H₂O ‘sounding’ bands, for example). Uncertainties in spectroscopic parameters (encompassing both coefficients and lineshape models) are very complex and it is probably beyond the scope of the GAIA-CLIM project to make a significant impact here. Nevertheless, what we can achieve in the GAIA-CLIM project is to carefully document current issues with spectroscopy, and set out our requirements in the gap analysis.

Joerg asked whether we can also smooth over time using NWP as well as smoothing in space? e.g. average the GRUAN measurements over time. Bill replied that we could try to better match the NWP-satellite spatial scales by ‘merging’ satellite data, as we do in NWP (for some instruments).

3.2.4 Feedback from hands-on sessions about 3-D visualisation tools and VO

Helene Brogniez (user): Regarding the 3-D visualization tool, one thing that would make it easier to manage is that when you select a variable and then a polar orbiting satellite it could be useful to have the width of the swath, to make sure your selected network is seen by the selected satellite. Fabio noted this good comment, and stressed that the tool is still in alpha version and we still need to test it extensively and further develop it in manners such as this.

Jaques Descloitres (rapporteur feedback from one-on-one session): Users expect that the VO, if successful, becomes a kind of one-stop shop for facilitating access to and analysis of satellite to non-satellite technique co-locations. There are a lot of ground-based observations. Having satellite-to-satellite, satellite-to-model, satellite-to-ground-based co-locations all served consistently would be useful. In the VO we focus on reference products mostly. However, we would also benefit from other datasets and this tool could be helpful for other comparisons e.g. satellite to satellite comparison. Users had stressed that it would be useful to get access to a beta-version for testing in their own time.

Carole Peubey (user, Copernicus Re-Analysis): Carole agreed with Helene that the width of the swath would be useful but it also depends on how the (VO and 3D-visualisation tool) will work together - it would be nice to see a concrete example for users of how they work together. Arndt clarified that yes we need to consolidate them and this will happen over the next few months. Carole commented that it is good to have NWP and re-analysis data included, as their main interest will be to validate these fields.

Martin Burgdorf (user, FIDUCEO): Congratulations to the team who have worked on the tools, they are impressive already and would be very useful and appreciated by the community. How will you get feedback from people in the future for the VO? Provide access to test-versions and organize Webex to

exchange ideas? Arndt clarified that perhaps at Reading for the General Assembly people can have another go with the updated version. We may also visit users in the future, or have a webex individually with users. Martin agreed that a 'roadshow' is a good idea, from experience in a previous project this was very efficient

Fabio (rapporteur feedback from one on one session): Regarding visualisation of satellite geometry there were some contradictory requests - some users would like to see everything, some would like to see the radiosonde starting point and bursting point of balloon etc. etc.. Also, it was noted that in the 3D visualization tool once an ECV is selected it would be good to only see the related satellites as options for the comparison.

Joerg Schulz (rapporteur feedback from one on one session): There were no comments asking to add more data - this is encouraging, as it means the back-end stuff is working really well so that we can concentrate on representing uncertainties now. Regarding observational data and the parameter lists automatic filtering concerning the pairs needs to be fixed. There was some discussion on how the search should be organised and what should be retained. Joerg suggests that the order should be:

- Start from a network list,
- Choose stations over a selected area,
- Choose parameters,
- Then output of available data, times, number of data granules and total volume (size of files to download).

There was a lot of discussion on the graphics themselves: choice of axis (log, linear), parameter space, e.g., relative humidity should have conversions to specific humidity, conversions to different units. Several users queried how the metadata was to be visualized in the VO. Users noted the need for more interaction between WP5 and the other WPs and discussion about implementation of uncertainties.

Following his feedback, Joerg then gave a brief demonstration of the CODA EUMETSAT online tool for satellites which only provides access to Level 1 data, and shows plots of the orbit path. This may have aspects that are useful for subsequent VO development.

Arndt Meier (summary): Arndt noted that it was a very worthwhile session to have direct interaction with users and thanked the users for their active engagement. Most of the comments the users made were expected, which is good news. The feedback was very constructive, and it was good to take the opportunity to get this feedback, even though the VO was not really ready for prime time. A more complete working version of the VO should be delivered by summer. We need at least a roadmap for implementation of NWP and for dealing with issues related with water vapour.

3.2.5 Closure of Days 3 and 4 of the Workshop

Joerg Schulz, Arndt Meier and Bill Bell presented closing remarks to formally close the VO-related segment of the workshop. Joerg noted that it's good that we now have a good selection of reference data, Fabio's tool can now be used, the project has grown very much together, and the actions are much more targeted now which is promising. The challenge is now on the uncertainties: it's a discussion we need to finish in February. For the real implementation, however, we need to make sure we are very practical in our decisions in February at the GA to make sure we don't overload the programmers.

Arndt noted that WP5 very strongly need input from WP2 and WP3 to get a handle on the errors – we need to have a discussion about this. How will we handle uncertainties on water vapour? Perhaps we should have a think tank with Bill, Tijl and Jean-Christopher and think about the best way forwards.

Bill stressed that the workshop had been really useful for fleshing out ideas on how we might calculate smoothing errors for humidity. The ideas are quite challenging to deliver, however, and we couldn't do this in 6 weeks before the general assembly, but we can make progress in the final 12 months of the project. Joerg noted that the problem is perhaps not so bad for humidity as don't forget we are still working in radiance space. Arndt noted that they currently plan to ingest 10 x 10 degrees NWP data around the GRUAN sites so that in the future we might be able to use this data to calculate uncertainties, etc.

3.3 Closure of the 2nd User Workshop

Peter Thorne then made some closing remarks, thanking those who attended, and particularly Nathalie for all her help with the technical side of things. We took a lot from the workshop – we need to re-imagine key aspects of GAID and we agreed a roadmap that is practical and good going forwards. We will take away that we should be going to key users rather than expecting them to come to us. It was good to see an early version of the VO.

Martine De Mazière then made closing remarks, echoing what Peter had said and thanking participants for being active throughout the workshop, as asked for at the start.

4. Concluding remarks and principal outcomes

The user workshop brought together a group of active researchers (partners in GAIA-CLIM and external users) who provided very valuable input. The plenary and breakout group discussions were very productive. It was very useful that the attendees including the GAIA-CLIM partners took the time to reflect on the GAID and the VO – for which the online experiences with an early version, even though incomplete, were very useful.

4.1 Principal outcomes concerning the GAID

- Based on the inputs received during the workshop, a new template was developed and circulated (Annex 2) to improve the gap description, to add new fields of interest, and to stick to a common vocabulary in order to improve cross-section capabilities and provide a basis for prioritization. Gaps will also be merged or removed if common issues are apparent or if redundancy is observed.
- Additional features will be added to the online catalogue, including drop down menus to categorize the gaps and to enable more on-line user driven cross section capabilities and interactivity and feedback options.
- GAID v4 initial version will be available by the GA in February based upon the new template. It will be the version that will be communicated externally.
- The prioritization effort (Task 6.3) will start from the basis of GAID v4 with an initial discussion during the GA in February 2017.

4.2 Outcomes with regards to the VO

- An early version of the VO that was made available during this 2nd User Workshop, including the 3D visualization tool. Presentations on the GRUAN processor and the intentions about the take-up of OSSSMOSE results, was received enthusiastically by the attendees.
- Various suggestions have been made to add features and to improve on some aspects.
- We need some more discussions during the GA in February 2017, especially about how to deal on the computation and representation of uncertainties.
- There will be a new chance during the GA to ‘play’ with a more advanced VO demo version.
- At some point in time, a formal beta version should be released such that more users can test it.

4.3 Outcomes with respect to next steps in WP6

- Engaging with users has turned out to be difficult, therefore, instead of organizing a third User Workshop, GAIA-CLIM proposed to the project officer (M. Kacik) to pro-actively meet selected users (Annex 3). The selection of users will be defined during the GA in February 2017. The funds initially allocated in WP6 for the third User Workshop will be used to support this ‘roadshow’.
- Material will be prepared to go on the road: GAID v4, a beta version of the VO, templates or tools for collecting user feedback, possibly additional material to be discussed during the GA.

Annex A: Workshop agenda

(Some minor re-scheduling took place in real time during the workshop)

GAIA-CLIM Second User Workshop

November 21-24, 2016

Location: Belgian Science Policy, Avenue Louise 231 Louizalaan, B-1050
Brussels, Belgium

Hosts: M. De Mazière and Nathalie Kalb

Royal Belgian Institute for Space Aeronomy (BIRA-IASB)

martine.demaziere@aeronomie.be, nathalie.kalb@aeronomie.be

AGENDA – v2

Note : The workshop is intended to be very interactive, so it is best that you bring a laptop with you. Also, on Wednesday, we will discuss the Virtual Observatory. There is a timeslot in the agenda during which you can present in a few minutes a use case, i.e., a case that you would like to handle through the VO interface. So please think about your interest in the VO and present that to the group.

Day 1 – Monday November 21: GAID

Note: GAID available online at <http://www.gaia-clim.eu/page/gaid> and the gaps therein are available through <http://www.gaia-clim.eu/page/gap-reference-list>.

(Remote connections 13:40 – 15:00 Stephan Bojinski)

Moderators: M. De Mazière and M. van Weele

Rapporteur: C. Voces (NUIM)

13:30 Welcome and logistics: M. De Mazière & N. Kalb

13:40 Presentation of the status of the GAIA-CLIM project by P. Thorne, coordinator

14:00 Objectives of the Workshop: M. De Mazière



14:10 Tour de Table: participants are asked to identify their application (cf break-out groups)

14:30 Presentation of the Gaps Assessment and Impacts Document (GAID v3), by M. van Weele

14:45 Web tools to facilitate visualization and feedback on gaps: R. Davy

15:10 Invited talk: How does the GAIA-CLIM GAID fit into the wider context of GEOSS? (J. Maso, coordinator of the ConnectinGEO project)

15:30 *Coffee/tea break*

16:00 Discussion with all participants in breakout groups per (self-identified) primary application area. All breakout groups will be facilitated by one or more GAIA-CLIM project participants in attendance ; each group shall indicate a rapporteur.

Proposed groups:

1. Climate research;
2. Climate services;
3. Satellite and model validation;

Facilitators : Peter, Heather, Richard

➤ Questions to be discussed:

- Your perception of strengths and weaknesses of how GAIA-CLIM is currently identifying and documenting gaps, and of the structure of the GAID ?
- Usefulness or otherwise of the gap assessments process to users?
- Do you agree that all the gaps currently listed are actually gaps?
- Would you like to see other useful X-sections of gaps?
- Do you require additional interactive facilities on the Web to fully explore the gaps?

17:20 *Adjourn for the day*

Day 2 – Tuesday November 22: GAID: prioritization, feedback and summary

Moderators: F. Madonna and P. Thorne

Rapporteur: R. Davy (NERSC)

(Remote connections 9:00-12:30 k. Kreher; 15:30 – 17:00 Stephan Bojinski)

9:00 Feedback from breakout groups (20' per group + 10' discussion time)

10:30 Remediation of the gaps and criteria for prioritization, incl. questions: P. Thorne

10:50 *Coffee/tea break*

11:20 Continuation of breakout groups

Facilitators: Martine, Corinne Voces, Bill

- Questions to focus on :
 - Which gaps in the non-satellite observations do you encounter when ‘running’ your application? i.e., Identification of missing gaps we may wish to add
 - Which gaps are most harmful to your application (cf. prioritization)?
 - Can you suggest any additional work program / activity to resolve a current gap?
 - Do you have an idea of the feasibility and the cost of remedying gaps?

12:30 *Lunch break*

13:30 Feedback from breakout groups (20’ per group + 10’ discussion time)

15:00 *Coffee/tea break*

15:30 Feedback from ESA and EU Copernicus: Carole Peubey

16:00 Feedback from GEOSS: Joan Maso

16:20 Feedback from Advisory Panel: Stephan Bojinski (remotely)

16:40 Comments from WP1 to WP5 leaders

17:00 Wrap-up and conclusions: M. Van Weele

17:20 Introduction to the subject of Wednesday & Thursday: the Virtual Observatory: A. Meier

17:30 *Adjourn for the day*

19:30 *Social Dinner (at own cost, details to be given on site)*

Day 3 – Wednesday November 23: Virtual Observatory

Moderators: J.C. Lambert and J. Schulz

Rapporteur: G. De Leeuw (FMI)

(Remote connections 8:30 - 12:30 Tony Reale & Alessandro Fasso & K. Kreher; 9:00 – 10:45 Stephan Bojinski & Kalev Rannat; 11:20 – 12:30 Kalev Rannat; 15:45-16:30 Alessandro Fasso & Stephan Bojinski & Kalev Rannat)

8:30 Welcome and logistics: M. De Mazière & N. Kalb

8:40 Tour de Table: participants are asked to identify their application (cf break-out groups) and primary interest in the Virtual Observatory (VO).

9:00 Outline of Virtual Observatory: A. Meier

9:30 3D visualization tools: Fabio Madonna

9:45 OSSSMOSE underpinning the VO: T. Verhoelst

10:15 The GRUAN processor: B. Bell & F. Carminati

10:45 *Coffee/tea break*

11:15 Organisation of the 1-on-1 hands-on sessions and the parallel discussion on errors and ways how to visualize errors: Arndt Meier

11:20 Users are invited to outline the kind of studies they would like to do with the VO (5 min each, welcome to show one or two slides): all interested users

(+ Gaia Pinardi)

Ca. 11:50/12:00 Error and error visualization discussion.

Conveners: Jean-Christopher Lambert, Tijn Verhoelst, Bavo Langerock

Plenary as a kick-off: Three examples of errors typically reported for an in-situ sonde profile (e.g. GRUAN), total column instrument (e.g. Dobson/Brewer) and ground-based remote sensing profile (e.g. LIDAR or FTIR) : Bavo Langerock & Karin Kreher (10-15 min)

For the next 2 hours, splitting into 2 groups:

A) Main room: basically everyone who is not in a one-on-one.

Rapporteur: Martine

Users interested in a one-on-one will get together in small groups for about 20 min and then return to the discussion A).

- a. 30 min plenary on what errors should be exposed in the VO and how? Total error? Sums of systematic and statistical errors each? Individual error sources? To what level? Always report all potential errors ? Set non-reported errors with a flag or value to “not reported” or “Known to be irrelevant” or “known to be less than x permil”? All in same file? Auxiliary file for detailed errors? Etc

Moderators: J.-C. Lambert & Gerrit de Leeuw

- b. 30 min plenary to discuss on how to visualize errors. In 3D? 2D for individual profiles (think radio sonde)? Mean over many such profiles? Zonal means? Monthly means? Running means? Visualisation of averaging kernels? Footprints (where does the signal come from)? Etc.

Moderators: T. Verhoelst & Francois Hendrick

B1) One-on-one hands on session with the VO: Arndt Meier + Jacques Descloitres (Notes)

B2) One-on-one hands on session with the VO: Hannes Keernik + Joerg Schulz (notes)

B3) One-on-one hands on session with 3D tools: Fabio Madonna + Corinne Vigouroux (notes)

12:30 to 13:30 *Lunch break*

Continuation of above sessions

15:15 – 15:45 *Coffee/tea break*

15:45 Reflection on Stat4col, led by Alessandro Fasso (remote) & Fabio Madonna

16:05 Wrap-up from the error and error visualisation sessions and from the breakout groups (Martine)

16:30 *Adjourn for the day*

Day 4 – Thursday November 24: Virtual Observatory: feedback & summary

Moderators: B. Bell and A. Meier

Rapporteur: H. Lawrence (ECMWF)

(Remote connections 9:00 -10:30-12:00 Tony Reale & Kalev Rannat – K. Kreher; 11:10 – 12:00 Kalev Rannat)

9:00 Continuation of one-on-one sessions

9:30 Tools developed for validation activities in the frame of O3MSAF (J. Van Gent & G. Pinardi)

9:45 Reflection on the use of OSSSMOSE in the context of the VO, led by Jean Christopher Lambert & Tijl Verhoelst

10:05 The role of NWP in the VO also with respect to estimating variability and uncertainties in water vapour, led by Bill Bell

10:25 *Coffee/tea break*

10:55 Feedback from one-on-one sessions – note-takers and users will be asked to come up front and say a few words.

11:20 Wrap-up and conclusions: A. Meier & J. Schulz & Martine

11:50 Way forward in GAIA-CLIM: M. De Mazière & P. Thorne

12:00 *Adjourn the Workshop / lunch provided*

Annex B: GAID v4 gap template

Important notice

Before you start filling in the gap presented in this document please consider first , using the gaps as presented in GAIDv3,

- 1. whether there are critical (technical, time) dependent gaps related to your gap**
- 2. whether there are gaps you consider to overlap with/constitute a subset to your gap**

If there are gaps identified in #2 above that you think need to be retired / merged with your gap, or if you think your gap needs to be retired, please inform us by sending an e-mail using the GAID mail account:
[**gaid@gaia-clim.eu**](mailto:gaid@gaia-clim.eu)

Please include in that mail details on which related gaps you have identified and what you would propose by way of resolution (merger, retirement of gaps, refinement etc.).

Please send us any such e-mail a.s.a.p. to prevent unnecessary delays. We shall then instigate a discussion amongst the gap owners to resolve the issues identified. This discussion should be closed BEFORE you start editing your gap to avoid wasting your valuable time.

GAP TEMPLATE

Gn.mm Gap Title

The gap title should be sufficiently short though specific, it should not allow misinterpretations or multiple interpretations, and it should be user- and impact oriented (see below for the user categories).

Change the title of the gap if necessary

Gap Abstract (in 100-150 words)

The gap abstract should clarify the gap in a few very clearly written sentences that are understandable for users / relevant stakeholders.

Add a gap abstract in a few sentences (max. of 150 words)

Part I Gap Description

(1) Primary Gap Type

- i. Spatiotemporal coverage
- ii. Vertical domain and/or vertical resolution
- iii. Knowledge of uncertainty budget and calibration
- iv. Uncertainty in relation to comparator measures
- v. Technical (missing tools, formats etc.)
- vi. Parameter (missing auxiliary data etc.)
- vii. Governance (missing documentation, cooperation etc.)

Select one gap type from (i) to (vii) for this gap

(2) Secondary Gap Type(s)

Select any additionally relevant gap type from the seven gap types or leave blank for this gap

(3) ECVs Impacted

The GAIA-CLIM primary ECVs include:

- i. Temperature
- ii. Water vapour
- iii. Ozone
- iv. Aerosols
- v. Carbon Dioxide
- vi. Methane
- vii. All of the above six ECVs

Select at least one and up to six ECVs from the list for this gap

(4) User Categories / Application Areas Impacted

The GAIA-CLIM targeted user categories / application areas include:

- i. Operational services and service development (*meteorological services, environmental services, Copernicus services C3S & CAMS, operational data assimilation development, etc.*)
- ii. International (collaboration) frameworks (*SDGs, space agency, EU institutions, WMO programmes/frameworks etc.*)
- iii. Climate research (*research groups working on development, validation and improvement of ECV Climate Data Records*)

Select at least one and up to three user categories/application areas from the list for this gap

(5) Non-satellite Instrument Techniques Involved

The GAIA-CLIM targeted instrument techniques include:

- i. Radiosonde
- ii. Ozonesonde
- iii. Lidar
- iv. FPH/CFH
- v. Microwave Radiometer
- vi. FTIR
- vii. Brewer/Dobson
- viii. UV/VIS zenith DOAS
- ix. UV/VIS MAXDOAS
- x. Pandora
- xi. GNSS-PW
- xii. other non-GAIA-CLIM targeted instrument techniques, please specify:
- xiii. independent of instrument technique

Select one or more of the instrument techniques involved for this gap

(6) Related Gaps

Another gap identified within GAIA-CLIM might be critical (technical, timewise) dependent on the resolution of this gap, or v.v.

- Identify Critical Dependent Gap(s): Gn.mm (if any, up to 5)
- The critical dependent gap should be addressed before / with / after this gap. For technical but not time dependent gaps select 'with'
- Describe how the gaps are critically dependent upon one another (up to 100 words)

!!!!!!Please see the action on related gaps on top of this template document before filling in your full gap template to prevent unnecessary work!!!!

- To be addressed before/with/after the current gap

- Argument: ""

(7) Gap Detailed Description

The gap detailed description should be able to be used e.g. in a funding call.

Copy and paste existing text from the GAIDv3 gap. Edit to make specific and not allow multiple interpretations, and user and impact oriented.

(8) Operational Space Missions or Space Instruments impacted

The gap should be related to the (improvement of the) validation of space observations of the targeted ECV(s). Also a certain class of space instrumentation / missions can be selected.

- i. Copernicus Sentinel 3
- ii. Copernicus Sentinel 4/5
- iii. Meteosat Second Generation (MSG)
- iv. Meteosat Third Generation (MTG)
- v. MetOp
- vi. MetOp-SG
- vii. Polar orbiters
- viii. Geostationary satellites
- ix. Microwave nadir
- x. Infrared nadir
- xi. UV/VIS nadir
- xii. Active sensors
- xiii. Passive sensors
- xiv. GNSS-RO
- xv. Other, please specify:
- xvi. Independent of specific space mission or space instruments

Select the (current/future) space missions / instrumentation or techniques relevant for this gap (at least one)

(9) Validation Aspects Addressed

At least the lowest product level should be provided. Higher level products are dependent on (derived from) lower level products, i.e. Level-2 from Level-1, Level-3 and Level-4 from Level-2.

- i. Radiance (Level 1 product)
- ii. Geophysical product (Level 2 product)
- iii. Gridded product (Level 3)
- iv. Assimilated product (Level 4)
- v. Time series and trends
- vi. Representativity (spatial, temporal)
- vii. Calibration (relative, absolute)
- viii. Spectroscopy
- ix. Specific pixel types (ocean, land, desert, tropical, polar, etc.), please specify:
- x. Auxiliary parameters (clouds, lightpath, surface albedo, emissivity)
- xi. Other, please specify:

Select the (primary) validation aspects addressed with this gap (at least one)

(10) Expected Gap Status after GAIA-CLIM

There are three possible status for the gap after the end of the GAIA-CLIM project:

- i. GAIA-CLIM will close this gap
- ii. GAIA-CLIM will partly close this gap, please specify (up to 200 words):
- iii. After GAIA-CLIM this gap is likely to remain

Select gap status. For option ii, copy gap text from GAID v3 'Activities within GAIA-CLIM to this gap' and edit as necessary

Part II Benefits to Resolution and Risks to Non-Resolution

(1) Table summarising the benefits to gap resolution

Identified Benefit	User category / application area benefitted	Probability of benefit being realised	Impacts
Describe benefit (up to 100 words)	Identify user category / application area benefitted	High, medium, low [Select one or two*]	Describe user impact, impact on provision of Copernicus services, etc.

Please insert multiple rows in the Benefits table.

Note: it is important that more than one benefit (for users) is identified

(2) Table summarising the risks to non-resolution of the gap

Identified Risk	User category / application area at risk	Probability of occurrence if gap not remedied	Impacts
Describe risk (up to 100 words)	Identify user category / application area benefitted	High, medium, low [Select one or two*]	Describe user impact, impact on provision of Copernicus services, etc.

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Please insert multiple rows in the Risk table.

Note: it is important that more than one risk (for users) by non-resolution is identified

The GAIA-CLIM targeted user categories / application areas include:

- i. Operational services and service development (*meteorological services, environmental services, Copernicus services C3S & CAMS, operational data assimilation development, etc.*)
- ii. International (collaboration) frameworks (*SDGs, space agency, EU institutions, WMO programmes/frameworks etc.*)
- iii. Climate research (*research groups working on development, validation and improvement of ECV Climate Data Records*)

* Probability categories: high / medium-high / medium / medium-low / low **Part III Gap Remedies**

Please consider if more than one remedy could be identified and repeat the next steps for each of the identified remedies.

It is recommended that more than one remedy is identified and that the remedies are distinct in their expected viability for the outcome of success preferably at least one remedy should be achievable) and/or e.g. the scale of work / time bound / cost estimate.

For each Gap Remedy Identified:

(1) Primary Gap Remedy Type

The remedy could involve different types of action. The primary remedy types include:

- i. Technical
- ii. Laboratory
- iii. Deployment
- iv. Research
- v. Education/Training
- vi. Governance

Select the primary remedy type

(2) Secondary Gap Remedy Type(s)

Select any additionally relevant remedy type from the above six options or leave blank for this remedy

(3) Specific Remedy Proposed

The description of the specific remedy proposed may plausibly constitute a description of work in a funding call.

Copy in the current text from the GAID v3 and edit as necessary to meet this revised guidance.

(4) Relevance

The relevance to remedy the gap with the specific remedy proposed should be substantiated in free text.

Copy in the current text from the GAID v3 and edit as necessary.

(5) Measurable Outcome of Success

The measurable outcome of success for the specific remedy proposed.

Copy in the current text from the GAID v3 and edit as necessary.

(6) Expected Viability for the Outcome of Success

A preliminary indication might be given on the expected viability of the outcome of success for the specific remedy proposed ('Is the remedy achievable?'). The expected viability might be low, medium or high.

*Select one or two levels of expected viability from [Low / Medium / High]**

Note: If the Technical remedy type is chosen then in addition a Technology Readiness Level (TRL) of 1-9 could be assigned (optionally). The TRL that best describes the level of technology readiness should be based upon the criteria from <http://www.hq.nasa.gov/office/codeq/trl/trl.pdf>

Select TRL from 1-9

* Probability categories: high / medium-high / medium / medium-low / low

(7) Scale of Work

The scale of work involved for the specific remedy proposed could be either performed individually, by a single institution, by a consortium or through a programmatic multi-year multi-institution activity.

Select one or two scales of work from

- i. Individually
- ii. Single institution
- iii. Consortium
- iv. Programmatic multi-year, multi-institution activity
- v. Other, please specify:

(8) Time Bound to Remedy

The time needed to complete the resolution of this gap from funding inception might be estimated.

Select one or two time bounds:

- i. Less than 1 year
- ii. Less than 3 years
- iii. Less than 5 years
- iv. Less than 10 years
- v. More than 10 years

(9) Indicative Cost Estimate (investment)

Given the time bound and scale of work a preliminary investment cost estimate might be given for specific proposed remedy. These costs are assumed one-time investments costs and exclude reoccurring operational costs (see below).

Currency: Meuro

Select one or two cost estimates:

- i. Low cost (<1 million)
- ii. Medium cost (<5 million)
- iii. High cost (>5 million)
- iv. Very high cost (>10 million)]
- v. Unknown costs, please explain in less than 100 words

(10) Indicative Cost Estimate (exploitation)

Are there annually reoccurring costs involved in this gap remedy?

Yes/No

If Yes, can you give an indicative exploitation cost estimate on annual basis (keuro/ year):

(11) Potential Actors

Different actors might be envisaged to take up the specific remedy proposed. Please indicate potential actors.

Select one or more potential actors:

- i. EU H2020 funding
- ii. Copernicus funding
- iii. National funding agencies
- iv. National Meteorological Services
- v. WMO
- vi. ESA, Eumetsat or other Space agency
- vii. Academia, individual research institutes
- viii. SMEs/industry
- ix. National Measurement Institutes
- x. Other, please specify:

Annex C – Proposed modified outreach strategy

Proposal to revise outreach strategy for GAIA-CLIM

Issue:

The outreach work package has now hosted two user workshops in Rome and Brussels. Despite substantial efforts to engage users via: individual invites, personal contacts, relevant listservs etc., and the provision of travel support via the dedicated support fund, user uptake has been limited. Feedback received from users has been hugely valuable, but to gain buy-in to both the virtual observatory and the gap assessment process broader user consultation is required in the final part of the project than we have been able to achieve to date.

Proposal:

Instead of a stand-alone third user workshop as envisaged in the grant agreement we propose the following:

1. Outreach to key selected users (Annex 1) between April and November 2017. Outreach shall be to pay visits to the target party by selected members of the GAIA-CLIM community most relevant to each party. Each visit would be accompanied by an overview, in depth discussion of the gap assessment and resulting prioritisation (specifically requesting feedback), and a demonstration of the Virtual Observatory facility. Feedback from each visit would be collated in a standardized manner and fed back to relevant Work Packages.
2. Attendance at key community meetings such as International Symposium on Remote Sensing of the Environment and the International TOVS Study Conference (ITSC) that shall occur during 2017 (Annex 2). Although to some extent already foreseen this would constitute a more holistic approach.
3. An in-depth in-person consultation with the Commission, ESA and principals from CAS/C3S to discuss results

In addition, at this time we are investigating holding a 'final' General Assembly at EUMETSAT immediately before or after the ITSC conference (29 Nov – 5 Dec) in late 2017 subject to availability of facilities. This may allow us to start with a user demonstration meeting with those ITSC delegates able to extend their stay that would constitute a third user workshop a little later than envisaged in the Grant Agreement. This would potentially allow outreach to a broad audience at low cost to the project.

We propose holding our General Assembly in late 2017 so that we can still make modifications thereafter prior to project end.

Costs elements (time and resources):

We propose an overall project resource neutral solution. The major resource reallocation is associated with #1 and #2 above. Several partners have time allocation in WP6 that can be spent on arranging and executing the user site visits and attending relevant meetings. NUIM can also reallocate some resource from WP7 to WP6

(cost neutral) if necessary. Partners are still proposed to use their original WP6 allocations otherwise at this juncture.

The original grant agreement has a substantive user engagement support fund administered by BIRA-IASB. Of this fund after the second user workshop a substantive proportion remains. We propose that what remains of this fund be used to support partner travel to execute the site visits and meeting outreach. This could either be administered by BIRA-IASB or achieved via partner resource reallocations. The impacted partners are the larger partners so this constitutes in all cases a small percentage change. From a project perspective we would prefer the latter. The number of visits and meeting attendances will be driven by time and meeting support available. WP6 and WP7 shall ensure relevant prioritisation is undertaken and manage the process.

Deliverables modifications required

Retitle and rescope the current Deliverable 6.9 to be ‘Report on external stakeholder consultation exercise’ and to contain a summary with a series of appendices (in a consistent format) detailing the outcomes of each visit (one format) and conference attendance (different format).

Timing remains M34 and ownership remains with BIRA.

Other modifications required

If the third user workshop is not held per the proposal above Milestone 10 (holding that meeting) shall need to be redacted and subsequent milestones reindexed accordingly.

If the GA is to be amended then Task 6.1.4 should be retitled to ‘External stakeholder consultation activities’ and the description changed to reflect the above proposal.

Annex 1 – possible site visit targets

Possible target users include:

- WMO (GCOS, WCRP, Satellite observations, Commission for Climatology, WMO Integrated Observing System, GEOSS)
- ESA including CCI/CCI+ projects e.g. at CMUG
- Meteo France
- DWD
- EUMETSAT SAFs – at a minimum CM-SAF and AC-SAF
- Relevant EUMETSAT/ESA instrument teams
- International space agencies / Met Services

A typical site visit would consist of 2-3 relevant experts from GAIA-CLIM.

In addition some larger partners (ECMWF, MO, FMI, KNMI) constitute users and these partners shall be encouraged to interact internally with relevant colleagues who may constitute end-users.

Annex 2 – possible meetings to target

- CEOS-CGMS WG Climate
- ESA CCI / EUMETSAT SAFs workshop on uncertainty (if goes ahead in timeframe)
- International TOVS Study Conference
- EMS 2017, Dublin
- International Symposium on Remote Sensing of the Environment, 8-12/5/17, Pretoria, South Africa
- EUMETSAT conference
- AGU 2017
- CEOS AC-VC-13
- NDACC SC meeting, Argentina, 6-12/11/2017
- IWGGMS@ FMI, Helsinki (June 6-8, 2017)
- GRUAN ICM-9, Helsinki (June 11-15, 2017)
- ILRC 29 June 25-30, 2017
- EGU General Assembly 2017, 23–28 April 2017, Vienna, Austria
- AMT4SentinelFRM International Workshop, 20/06/2017 to 21/06/2017, Plymouth, UK