D1.1 User Requirements Report

Gerrit Holl, Chris Merchant, Jon Mittaz, Rhona Phipps

University of Reading

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Table 1: Signatures

	Name	Organisation	Signature
Written by	Gerrit Holl	University of Reading	
Written by	Chris Merchant	University of Reading	
Written by	Jon Mittaz	University of Reading	
Reviewed by			

Table 2: Distribution

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Executive Summary

An assessment of user requirements for Fundamental Climate Data Records (FCDRs) was undertaken using two sources: a set of 16 interviews with current FCDR users, and a review of prior literature. From this assessment, requirements for Fidelity and Uncertainty for Climate and Earth Observation (FIDUCEO) were defined as follows. The remainder of the document contains a detailed specification of how these requirements were derived.

Summary of FIDUECO requirements:

(The complete list of all requirements is in Section 11).

The tables below sort the requirements under
- Content,
- Documentation
- Access
- Process and
- Recommendations

Note that due to the requirements generated, some requirements are listed under both content and documentation.

Content	
FIDUCEO-1	Fundamental Climate data Records (FCDRs) should contain information to assist producers of Climate Data Records (CDRs) and other derived geophysical products to estimate uncertainty and provide traceability information required by their users
FIDUCEO-4	FCDR uncertainty information must include a description of error correlations sufficient for CDR producers to account for error correlations propagated from the FCDR in their CDR.
FIDUCEO-7	To support provision of comparable uncertainty information in derived products,FCDRs should either (i) include uncertainty estimates separated into compon- ents having distinct error correlation structures, or (ii) be represented as an FCDR ensemble, where this is the more feasible and valid approach.
FIDUCEO-8	FCDRs and documentation should support CDR creators to assess the expected performance of derived CDRs against quantitative requirements, such as those of Global Climate Observing System (GCOS)
FIDUCEO-9	FCDR products should enable CDR producers to generate a variety of forms of uncertainty information required by CDR users.
FIDUCEO-10	FCDRs should include pixel-level uncertainties in cases where there is variation in the uncertainty at FCDR pixel level, since some CDR producers require to produce pixel-level uncertainty information.
FIDUCEO-14	FCDR products should include all necessary and established systematic corrections (such as due to calibration), rather than require CDR producers to apply additional corrections.
FIDUCEO-15	FCDR products should not include any duplications of data.
FIDUCEO-16	FCDR products should flag all corrupted data, including missing scanlines.

FIDUCEO-17	FCDR products should have complete and correct metadata.
FIDUCEO-18	All known and established corrections for timing, geolocation, and viewing geometry of pixels should be applied in the FCDR record and described in associated documentation. Associated uncertainties should also be included or described.
FIDUCEO-19	FCDR products should be quality-controlled at pixel, scan-line, and orbit-file level to minimise errors in calibration, geolocation, and data.
FIDUCEO-24	FCDR uncertainties should include an estimate of the radiometric/calibration uncertainty/channel instrument noise based on in-space measurements.
FIDUCEO-25	FCDR uncertainty information should include a detailed breakdown of the uncertainty budget, i.e. a quantified contribution for each known source of error.
FIDUCEO-27	FCDR should characterise across-scan bias / scan asymmetry, where relevant.
FIDUCEO-28	Instrumental drift, step and trend artefacts should be minimized in FCDR products
FIDUCEO-37	FCDRs should include all feasible telemetry information and metadata that are potentially relevant to FCDR applications.

Requirements related to documentation/ supplementary information to be provided.

Documentation	
FIDUCEO-2	FCDR producers should provide documented advice on how their FCDRs enable generation of uncertainty and traceability information in CDRs derived from them.
FIDUCEO-3	The uncertainty model used to create uncertainty information included in FCDRs must be characterised and clearly documented.
FIDUCEO-5	FCDR products should be provided with a product user guide. This should include an explanation of the origin and use of traceable uncertainties.
FIDUCEO-6	FCDR documentation should make use of standard metrological definitions of uncertainty vocabulary in order to maximise clarity.
FIDUCEO-8	FCDRs and documentation should support CDR creators to assess the expected performance of derived CDRs against quantitative requirements, such as those of Global Climate Observing System (GCOS).
FIDUCEO-18	All known and established corrections for timing, geolocation, and viewing geometry of pixels should be applied in the FCDR record and described in associated documentation. Associated uncertainties should also be included or described.
FIDUCEO-20	Uncertainty information in FCDRs should have a basis published in peer- reviewed literature to build the confidence any FCDR needs.
FIDUCEO-22	FCDRs should contain well-documented information about stability.
FIDUCEO-26	FCDR product documentation should include a characterisation of uncertainty in spectral response functions so FCDR users can use this in their radiative transfer modelling.
FIDUCEO-29	Stability information should be provided in an easy to use format.

FIDUCEO-30	FCDR documentation should explain how the FCDR stability is presented in the FCDR, and give guidance on how to infer CDR-level stability from FCDR stability information.
FIDUCEO-31	Relevant information in pre-launch data should be used to produce an FCDR such that FCDR users do not need to worry about pre-launch data.
FIDUCEO-32	FCDR producers should facilitate access to pre-launch data or other instrumental characterisations used in generating their FCDRs that are relevant to development of derived geophysical products.
FIDUCEO-34	FCDR producers need to clearly explain what form of harmonisation has been applied, and give uncertainty estimates for harmonisation.
FIDUCEO-36	The FCDR should come with full and quantitative documentation on how the FCDR was produced.
FIDUCEO-39	FCDR data and documentation should contain sufficient information for replication in a single location.

Access	
FIDUCEO-12	FCDR products should be readily accessible.
FIDUCEO-13	Data should be easy to read and formats should be well-documented
FIDUCEO-35	FCDR should be contained in NetCDF with CF-compliant names, and should be self-describing.
FIDUCEO-38	Distribution of FCDR data should accommodate users who cannot deal with full data volume.

Process	
FIDUCEO-40	FCDR producers should validate the provided uncertainty information.

Recommendations	
FIDUCEO-21	Uncertainty and stability information in FCDRs should encapsulate and apply understanding of instrument behaviour.
FIDUCEO-23	FCDR producers should make use of available historical monitoring information, including instrumental and non-instrumental events.
FIDUCEO-33	Historic FCDR data should be reprocessed when definitions and formats are changed for data from newer missions so that a consistent archive is available.

1. Introduction

1.1. Purpose and Scope

Fidelity and Uncertainty for Climate and Earth Observation (FIDUCEO) is a Horizon 2020 (H2020) project to bring the rigour of metrology to the science of Earth observation from space. It will produce several Fundamental Climate Data Records (FCDRs), i.e. time series of calibrated sensor radiances with traceable uncertainties, with a length relevant for climate users. To aid in this task, a survey was carried out to assess the requirements of FCDR users. This document describes the results of this survey. More information on FIDUCEO can be found at http://www.fiduceo.eu.

Secondly, this document derives requirements from the results of the survey. Each requirement is assigned a unique identifier. The format of the identifier is FIDUCEO-*n*, where *n* is a the user requirement number. Requirements are identified at each subsection level. In the main document, all requirements are generic and apply to all FCDRs. Some users mentioned specific user/ operational constraints for FCDR's and these are included for completeness in Appendix A.

1.2. Applicable and reference documents

[RD-1] Claire Bulgin and Chris Merchant. *Requirements Baseline Document*. Tech. rep. University of Reading, 2014.

[RD-2] GCOS. *Systematic observation requirements for satellite based data products for climate*. Tech. rep. 154. World Meteorological Organization, Dec. 2011.

[RD-3] *International vocabulary of metrology – Basic and general concepts and associated terms (VIM)*. JCGM 200:2012 (JCGM). 2012.

[RD-4] H. M. Mäkelä and J. Schultz. *Gap Analysis for Integrated Atmospheric ECV CLImate Monitoring: Report on results of user survey*. Tech. rep. Finnish Meteorological Institutie, July 2015. URL: http://www.gaia-clim.eu/.

[RD-5] A. Marks et al. *Results from the QA4ECV Survey on Quality Assurance in Satellite Data Products*. Tech. rep. 6529. NPL, 2014.

[RD-6] Nick A. Rayner et al. *Sea Surface Temperature User Workshop on Uncertainty*. Tech. rep. Met Office, 2014.

1.3. Glossary

AATSR Advanced Along-Track Scanning Radiometer.
AMSR Advanced Microwave Scanning Radiometer.
AMSU Advanced Microwave Sounding Unit.
AOD Aerosol Optical Depth.
ASAR Advanced Synthetic Aperture Radar.
ASCAT Advanced SCATterometer.
ATSR Along-Track Scanning Radiometer.
AVHRR Advanced Very High Resolution Radiometer.

BT Brightness Temperature.

CCI Climate Change Initiative.
CDR Climate Data Record.
CFC Cloud Fractional Cover.
CLARA CLoud, ALbedo, and RAdiation dataset.
CLASS Comprehensive Large Array-data Stewardship System.
CTH Cloud Top Height.

ECV Essential Climate Variable.
ENVISAT Environmental Satellite.
EPS European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Polar System.
ERS European Remote sensing Satellite.
ESA European Space Agency.
EUMETSAT European Organisation for the Exploitation of Meteorological Satellites.

FCDR Fundamental Climate Data Record.
FIDUCEO Fidelity and Uncertainty for Climate and Earth Observation.

GAC Global Area Coverage.
GAIA-CLIM Gap Analysis for Integrated Atmospheric ECV CLImate Monitoring.
GCOS Global Climate Observing System.
GEO GEOstationary orbit.
GOSAT Green-house gas Observing Satellite.
GPCP Global Precipitation Climatology Project.
GSICS Global Space-based Inter-Calibration System.

H2020 Horizon 2020.
HIRS High-resolution Infrared Radiation Sounder.

IASI Infrared Atmospheric Sounding Interferometer.
IR Infra-Red.

LEO Low Earth Orbit.
LST Lake Surface Temperature.
LTAN Local Time Ascending Node.

MERIS Medium Resolution Imaging Spectrometer.
MHS Microwave Humidity Sounder.
MODIS Moderate-resolution Imaging Spectro-radiometer.
MVIRI Meteosat Visible Infra-Red Imager.

NASA National Aeronautics and Space Administration.
NOAA National Oceanic and Atmospheric Administration.
NPL National Physical Laboratories.

NWP Numerical Weather Prediction.

PR Precipitation Rate.
PRT Platinum Resistance Thermometer.

QA Quality Assurance.
QA4ECV Quality Assurance for Essential Climate Variables.

RA Radar Altimetry.
RFI Radio Frequency Interference.
RH Relative Humidity.

SAR Synthetic Aperture Radar.
SCIAMACHY Scanning Imaging Absorption Spectrometer for Atmospheric Cartography.
SeaWIFS Sea-viewing Wide Field-of-view Sensor.
SEC Surface Elevation Change.
SEVIRI Spinning Enhanced Visible Infra-Red Imager.
SG Second Generation.
SIRAL SAR Interferometric Radar Altimeter.
SMOS Soil Moisture, Ocean Salinity.
SNO Simultaneous Nadir Observation.
SRF Spectral Response Function.
SSM/T Special Sensor Microwave/Temperature.
SST Sea Surface Temperature.

TANSO Thermal And Near infrared Sensor for carbon Observations.
TRMM Tropical Rainfall Measuring Mission.

UTH Upper Tropospheric Humidity.

VIIRS Visible/Infrared Imager Radiometer Suite.
VIM Vocabulaire Internationale de Métrologie.

2. Related surveys

2.1. QA4ECV survey

The Quality Assurance for Essential Climate Variables (QA4ECV) User Requirements Survey was carried out by National Physical Laboratories (NPL) in 2014 [RD-5]. It consisted of two parts:

- A questionnaire was sent directly to many thousands of users of satellite-derived Essential Climate Variables (ECVs) (when covering time scales relevant to climate, those are equivalent to Climate Data Records (CDRs)) who filled out the questions themselves. The survey focussed on quality flags, traceability, uncertainty, and validation. It found that users want satellite-derived products to contain all aspects of Quality Assurance (QA) information, but that uncertainty and traceability information are often insufficiently available, and that quality flags are often insufficient (the GlobTemp project summarised below in section 2.4 found the same).
- QA4ECV also interviewed six producers of ECV data sets (ocean colour, soil moisture, leaf area index, carbon dioxide and methane, ozone, and clouds). This is comparable to the interviews with FCDR users carried out by FIDUCEO, but the FIDUCEO questionnaire is more detailed and broader in both scope and audience. Among other results, the QA4ECV interviews found that ECV producers consider they provide “quality indicators appropriate for the users needs” and that “all the necessary traceability and quality information is provided within the supplementary documentation”.

These two results show that there is a discrepancy between what CDR producers consider is included with the products they produce, and what CDR users would like to see in the products they use.

2.2. SST uncertainties

In November 2014, the Met Office hosted a workshop on uncertainties for users of satellite-derived Sea Surface Temperature (SST) measurements [RD-6]. The workshop was organised within the European Space Agency (ESA) SST Climate Change Initiative (CCI) project. The aim of the workshop was a two-way dialogue about uncertainties. Although many results are specific to SST, some are relevant for CDRs and FCDRs in general. For example, “Participants recommended that full characterisation and clear documentation of the error model was needed and either that these uncertainty components should be provided together with correlation information, or that their complex behaviour should be encapsulated in an ensemble as currently done by some providers of centennial-scale SST data.” This recommendation applies fully to any CDR and FCDR.

2.3. GAIA-CLIM

The Gap Analysis for Integrated Atmospheric ECV CLImate Monitoring (GAIA-CLIM) project focusses on sub-orbital calibration and validation of satellite data products. The project recently concluded a user survey [RD-4] that includes some aspects of interest to FIDUCEO. Users completed the survey on their own.

The GAIA-CLIM survey included three questions on uncertainties. The survey found that on a scale from 1 to 5, 75 respondents rated their expertise in using gross uncertainty estimates 3.7, and in using traceable uncertainties 2.8, with other categories in-between. It also found that the majority of surveyed people (85 %) use uncertainty estimates. Out of four proposed alternative ways to disseminate documentation (including documentation on uncertainties), GAIA-CLIM survey participants prefer a classical user guide document over peer reviewed papers, a help desk, or an online training course.

2.4. GlobTemp

In 2014, the GlobTemp project delivered a Requirements Baseline Document for land surface temperature users [RD-1], i.e. CDR users. This document reports on the results of a user questionnaire undertaken as a survey completed by 71 users. The GlobTemp survey included nine questions on uncertainties and related aspects.

The GlobTemp survey found that for some terms related to errors and uncertainties, there is no consensus in what those terms mean specifically. They found that a large majority of users would like uncertainty information to be split into components, It then went into some detail on how users want CDR uncertainties to be presented and what should be in it.

The document also describes a discussion on errors and uncertainties during a user consultation meeting. Among other things, CDR users reported that there is typically not enough uncertainty information presented (the same conclusion emerged from the QA4ECV survey referred to in section 2.1).

2.5. Requirements from related surveys

Table 4 shows requirements from related surveys.

Table 4: FIDUCEO requirements from related surveys

no.	Requirement	Comment
FIDUCEO-1	Fundamental Climate Data Records (FCDRs) should contain information to assist producers of Climate Data Records (CDRs) and other derived geophysical products to estimate uncertainty and provide traceability information required by their users.	From QA4ECV survey [RD-5].
FIDUCEO-2	FCDR producers should provide documented advice on how their FCDRs enable generation of uncertainty and traceability information in CDRs derived from them.	From QA4ECV survey [RD-5].
FIDUCEO-3	The uncertainty model used to create uncertainty information included in FCDRs must be characterised and clearly documented.	From SST uncertainty workshop [RD-6].
FIDUCEO-4	FCDR uncertainty information must include a description of error correlations sufficient for CDR producers to account for error correlations propagated from the FCDR in their CDR.	Error correlations at CDR level are additionally introduced by the retrieval process, which should be modelled by CDR producers. From SST uncertainty work- shop [RD-6].
FIDUCEO-5	FCDR products should be provided with a product user guide.	
FIDUCEO-6	FCDR documentation should make use of standard metrological definitions of uncertainty vocabulary in order to maximise clarity.	From GAIA-CLIM [RD-4]. This should include an explanation of the origin and use of traceable uncertainties. In FIDUCEO, the standard used will be the Vocabulaire Internationale de Métrologie (VIM) [RD-3].
FIDUCEO-7	To support provision of comparable uncertainty information in derived products, FCDRs should either (i) include uncertainty estimates separated into components having distinct error correlation structures, or (ii) be represented as an FCDR ensemble, where this is the more feasible and valid approach.	From GlobTemp [RD-1].

3. FIDUCEO survey design and requirements gathering

3.1. Survey design

The FIDUCEO survey was carried out through structured interviews. In this structured interview, a FIDUCEO scientist (Gerrit Holl, who also wrote this report) interviews an FCDR user (who is also a CDR producer) and fills in the survey immediately, i.e. while performing the interview (see below for definitions of CDR and FCDR). Prior experience has shown that this gives a more complete and consistent response than the situation where users fill in a survey unsupervised. The structured interview assures that for each interviewee, questions are interpreted as intended, and a lively conversation is beneficial for the open-ended questions included in the survey. The downside of the structured interview approach is that it is labour-intensive, and therefore the sample size will be necessarily smaller than with a traditional survey approach.

The survey was designed to contain many open-ended questions. Although closed multiple-choice questions are faster to answer and the answers are easier to analyse, open-ended questions give greater freedom to describe details and clarifications.

The target audience for the survey are any users of level-1 passive remote satellite measurements of the Earth atmosphere and surface, who use these measurements to derive geophysical quantities. Here, level-1 means calibrated satellite radiances or reflectances. Some users perform their own calibrations or calculate their own level-1 measurements before deriving geophysical quantities. When those level-1 measurements span a long enough time series to be relevant for climate studies, we call them FCDRs. Reflectances are visible or near-infrared, whereas radiances are at infrared or microwave wavelengths. The FCDR users interviewed for FIDUCEO then use these measurements to derive CDRs. CDRs are geophysical quantities such as sea surface temperature, cloud top height, or upper tropospheric humidity (see Table 6 for a full table of CDRs produced by FIDUCEO interviewees).

The survey consists of several sections:

- Basic information about the interviewee: name, location, nature of employer;
- questions on the CDR the interviewee, or his/her group, develops: user requirements, achievements, etc.;
- questions about uncertainty information in the CDR produced;
- questions about the nature of the underlying FCDR data: type of data, list of sensors;
- for each sensor listed, questions about how experiences with obtaining and reading the data, availability of uncertainty and stability information, pre-launch data, and harmonisation;
- and finally, questions about non-FCDR uncertainties affecting the CDR, requirements related to FCDR product formats, and closing questions.

The survey is included in full in Appendix C from page 62 onwards.

The survey does not aim to obtain a statistically significant sample, nor a statistically representative sample. Answers may or may not be representative for the user community as a whole. However, the survey does aim to include users from a variety of backgrounds. In total, 48 participants were invited for an interview. Invitees were chosen based on the personal networks of FIDUCEO team members. Out of 48 invitees, 16 interviews were held. Most interviews were held with a single person, but some interviews were held with two people simultaneously. In this report, interviews with two people simultaneously are presented identically to interviews with one person only.

It should be noted that there are systemic biases present in this survey. For example, some questions relate to user experiences in downloading and reading the data. The survey primarily interviews experienced users, and mostly considers FCDRs that they are actively using or are planning to use soon. This introduces a bias to questions on how easy or difficult users find it to obtain or read FCDRs. There are likely other biases present.

3.2. Approach to defining requirements

Requirements are derived in either of the following ways:

- From earlier surveys, as shown in section 2.
- From a closed-ended question, an omission in current data availability is apparent. For example, if many people find a particular process difficult, there is a need for it to be easier. In this case, the requirement is that this process needs to be easier.
- From the responses to an open-ended question, a problem, omission, etc. in existing practices is determined. For example, if users say that overlapping data files are problematic (and have no advantages for the user), the requirement follows that there should be no such overlaps.
- The user directly states the requirement.

Due to the small sample size of the survey, no quantitative thresholds are used for any requirement. Rather, all requirements derived from the responses of at least one survey participant are listed.

Requirements are listed in tables at the end of relevant subsections. In some cases, several subsections are grouped into a single table, with the requirements listed at the last of those subsections. Within the table, requirements are labelled FIDUCEO-xx, where xx is the number of the requirement. The order of the requirements follows roughly the order of the survey, but is otherwise arbitrary and does not carry any meaning for priority or otherwise.

During the course of FIDUCEO, requirements will be regularly reviewed. Based on lessons learned, requirements may be added, removed, or revised.

4. Basic information

The survey starts with basic information to put the FCDR user in context, such as name, institution, location, and user involvement in FCDRs overall.

Table 5: Country and nature of institutes of interviewees. When a single interview was held with more than one person, it is counted as one.

	a	b	c	d	e
United Kingdom	2		2	1	5
Germany	1	1	2		4
United States	2				2
Sweden	1				1
Switzerland	1				1
Belgium				1	1
Denmark			1		1
Austria			1		1
Total	7	1	6	2	16

[a] National agency [b] National research institute [c] University
[d] Private company [e] Total

Table 5 shows a summary of the nature of the institutes for all interviewees surveyed. Approximately half of the interviewed people are at national meteorological agencies. Most of the others are at universities. Two participants work at private companies, with a single one located at a national research institute.

Although the survey did aim to find participants from all parts of the world, most participants are located within Europe. Only two interviews were held with people based in the United States, and none with people based elsewhere in the world.

5. CDRs

FIDUCEO interviews focus on people who use FCDRs to produce CDRs. They are therefore both data users and data producers. We asked several questions about the nature of the CDR produced by the interviewee.

Table 6 summarises the FCDRs used by participants, and the CDRs created. The five core FCDRs to be generated by FIDUCEO are all represented, with a single survey participant using SSM/T-2 for UTH, and several participants using AVHRR for a total of five different CDRs. Overall, a large variety of FCDRs and CDRs are represented.

5.1. CDR requirement and achievements

In a pair of questions, we asked survey participants about user requirements on their CDR, as well as estimated achievements against these requirements. For both, we asked the following properties:

- Uncertainty (random effects)
- Uncertainty (systematic effects)
- Long-term stability
- Spatial resolution
- Temporal resolution
- Timeliness (climate applications)
- Length of record

In case of user requirements, the approach of CDR producers varies. Most (12 out of 16, or 75 %) of interviewees) mentioned the Global Climate Observing System (GCOS)-154 requirements [RD-2], but many consider it is not directly applicable. Participants were also asked to comment on user requirements and on whether or not their CDR fulfills those requirements. Some CDRs meet requirements, and some CDRs are produced on a best-effort basis. For the remainder (i.e. where the CDR does not meet user requirements), participants were asked whether this was due to sensor limitations. Several people answered "yes", nobody answered "no", but most answers were nuanced, with responses including "yes, in some cases", "yes, for some aspects", and "yes, but [this is] not the only reason".

A selection of interviewee comments on user requirements and estimated achievements:

- "*GCOS 154 term accuracy not really correctly used in metrological term, not very happy with how it was defined, therefore we set our own requirements. GCOS does not correctly distinguish between different uncertainty types, not according to the metrological guide.*"
- "*Different kinds of requirements: on instruments, on different kind of products, etc. Depends on level-2, level-3. Depends on the user. Complicated question. Internal requirements and international programs. For example, Global Precipitation Climatology Project (GPCP) has different requirements from National Oceanic and Atmospheric Administration (NOAA).*"

Table 6: FCDRs and CDRs discussed. Note that this table only concerns CDRs produced by interviewed FCDR users. In this table, each X means that one or more survey participants use the FCDR indicated at the top to produce the CDR indicated on the left. For example, CTH has been produced from Advanced Very High Resolution Radiometer (AVHRR) and High-resolution Infrared Radiation Sounder (HIRS), but those are two different CTH products, produced by different people at different institutes. Less used FCDRs only used for a single CDR are shown as table notes.

	1	**2**	**3**	**4**	**5**	6	7	8	9	10	11	Other
Aerosol Optical Depth (AOD)	X					X	X			X	X	
water-leaving radiance											X	a
Upper Tropospheric Humidity (UTH)			X		X				X			
SST	X					X						
Cloud Fractional Cover (CFC)		X					X					
xCO2										X		b
Precipitation Rate (PR)			X					X				
cloud amount	X											
Cloud Top Height (CTH)	X			X								
tropospheric aerosol		X										
temperature profiles				X								
Lake Surface Temperature (LST)	X	X				X					X	
Surface Elevation Change (SEC)												c
Soil moisture												d

[1] **AVHRR** [2] **Meteosat Visible Infra-Red Imager (MVIRI)**
[3] **Advanced Microwave Sounding Unit (AMSU)-B/Microwave Humidity Sounder (MHS)**
[4] **HIRS** [5] **Special Sensor Microwave/Temperature (SSM/T)-2** [6] Along-Track Scanning Radiometer (ATSR)-1/ATSR-2/Advanced Along-Track Scanning Radiometer (AATSR)
[7] Spinning Enhanced Visible Infra-Red Imager (SEVIRI) [8] AMSU-A [9] Infrared Atmospheric Sounding Interferometer (IASI) [10] Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (SCIAMACHY) [11] Moderate-resolution Imaging Spectro-radiometer (MODIS)
[a] Sea-viewing Wide Field-of-view Sensor (SeaWIFS), Medium Resolution Imaging Spectrometer (MERIS), Visible/Infrared Imager Radiometer Suite (VIIRS) [b] Thermal And Near infrared Sensor for carbon Observations (TANSO) [c] European Remote sensing Satellite (ERS) Radar Altimetry (RA) / Environmental Satellite (ENVISAT) RA-2, SAR Interferometric Radar Altimeter (SIRAL)
[d] MetOp Advanced SCATterometer (ASCAT), ERS scatterometer, Advanced Microwave Scanning Radiometer (AMSR)-E / AMSR-2, Soil Moisture, Ocean Salinity (SMOS), Tropical Rainfall Measuring Mission (TRMM), ENVISAT Advanced Synthetic Aperture Radar (ASAR), Sentinel-1

- "*With higher spatial resolutions, there would be new application areas with new users.*"
- "*Range of requirements depending on user. Simple table is oversimplification. What users want is often unreasonable. They would like zero systematic and random error.*"
- "*GCOS requirement does not specify random vs. systematic.*"
- "*Random uncertainty less important as long as it's stable, can still detect climate change.*"
- "*Systematic effects impossible to estimate due to missing reference data.*" [Referring to ground validation of CDR]
- "*We know the limitations before we set the requirements.*"

The exact numbers for requirements and achievements for CDRs are not listed here, as they cannot be compared between different CDRs.

5.2. FIDUCEO requirements

Table 7: FIDUCEO requirements from CDR questions

no.	Requirement	Comment
FIDUCEO-8	FCDRs and documentation should support CDR creators to assess the expected performance of derived CDRs against quantitative requirements, such as those of GCOS.	This becomes more feasible if GCOS and other requirement setting bodies adhere to metrological vocabulary; doing so is a recommendation from FIDUCEO to GCOS.

Table 7 shows requirements from CDR questions.

6. Uncertainty information in CDR

In the next part of the survey, we asked participants three questions about uncertainty information they provide in their CDR.

6.1. Uncertainty information provided to CDR users

First, we asked CDR producers what uncertainty information they provide to their users. This issue was also addressed by the QA4ECV survey (see section 2.1), where it was found all data suppliers provide quality flags and consider they have provided all necessary traceability and quality information within supplementary documentation, but that users disagree. The QA4ECV survey did not go into any detail.

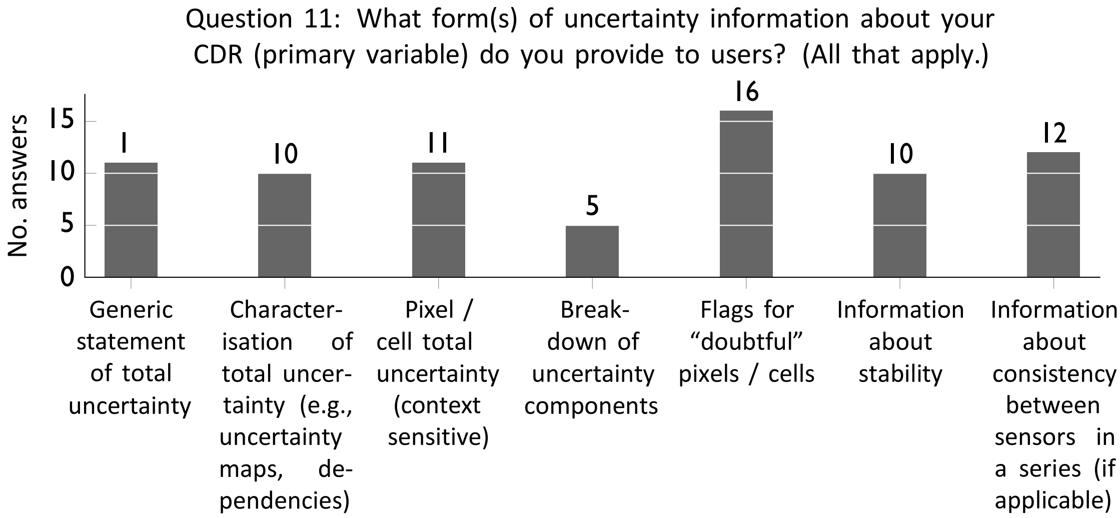

Figure 1: Uncertainty information provided in CDR.

Figure 1 summarises the total answer counts of the first CDR-uncertainty question, and Table 8 on page 24 shows an overview of all answers sorted by CDR. All survey participants provide, at the very least, flags for doubtful pixels to their users. This result is consistent with what was found by the QA4ECV survey. A majority of surveyed CDR producers go beyond flags, and provide quantitative uncertainty estimates, generic or pixel-level. Five surveyed CDR producers provide a breakdown in uncertainty components. Two users who do not currently provide uncertainty breakdowns qualified this further. One survey participant remarked that he was not sure to what degree it was possible, and one other said they could do it but that nobody asked for it:

- “*Breakdown is desirable, but to which level it is possible not sure. Breakdown of main compon-ents should be there, but perhaps not all.*”
- “*Could do breakdown, but takes up a lot of space and nobody has asked for it.*”

Table 8: Reported answers to question 11: What form(s) of uncertainty information about your CDR (primary variable) do you provide to users? (All that apply.) Although the first column shows CDRs, each row of the table corresponds to an individual interview. Where a CDR appears multiple times in the table, this means different survey participants produce the same CDR.

	A	B	C	D	E	F	G
Aerosol optical depth	X	X	X		X	X	X
Aerosol optical depth	X	X	X		X		X
Cloud amount and cloud top height		X			X	X	X
Cloud fractional cover (CFC)	X	X			X	X	X
Cloud top height/pressure/temperature			X		X		
Land surface temperature [proposed]	X		X		X	X	X
Precipitation rate	X			X	X	X	X
Sea surface temperature	X	X	X	X	X	X	X
Soil moisture	X	X	X		X		X
Surface elevation change (SEC) (ice sheet)			X		X	X	X
Temperature at SPL		X			X	X	X
Tropospheric aerosol			X	X	X		
UTH	X				X		
Upper tropospheric humudity	X	X	X	X	X	X	X
Water-leaving radiance	X	X	X	X	X		
xCO2	X	X	X		X	X	X

[A] Generic statement of total uncertainty [B] Characterisation of total uncertainty (e.g., uncertainty maps, dependencies) [C] Pixel / cell total uncertainty (context sensitive) [D] Breakdown of uncertainty components [E] Flags for "doubtful" pixels / cells [F] Information about stability [G] Information about consistency between sensors in a series (if applicable)

Moreover, two participants state that although they are not currently providing stability and consistency information, they do plan to do so in a later version of the product.

6.2. FCDR uncertainty propagation to CDR

Next, participants were asked how they use FCDR uncertainty information to inform CDR uncertainties, if at all. Where CDR producers provide uncertainty information, this may either be derived from uncertainties and flags available in the underlying FCDR, or it may be derived from other sources (or a combination of both).

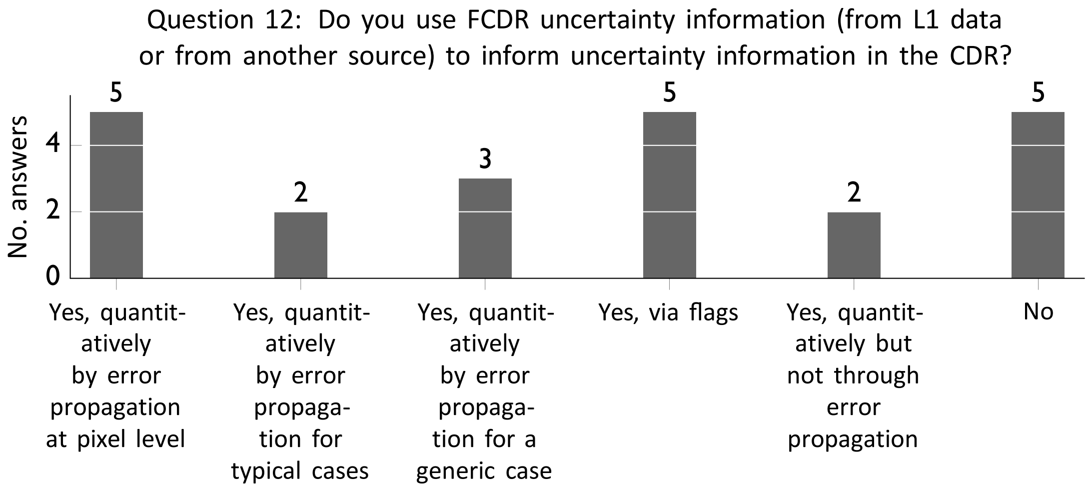

Figure 2: Use of FCDR uncertainties.

Figure 2 shows a summary of answers gives by interview participants on how they use FCDR uncertainty information. A listing of all answers sorted by FCDR is provided in Table 9 on page 26. Figure and table show that, from the surveyed participants, 11 use FCDR uncertainty information (including flags) and 5 do not. For the ones who do not propagate FCDR uncertainty information at all, two comment that uncertainties are from the retrieval/processing only, one comments that uncertainty estimates are based only on comparison of end products (validation or cross-validation), and one comments that this is due to the lack of uncertainty information in the FCDR.

Two participants answered "Quantitatively but not through error propagation". One of those estimated pixel-level uncertainty directly from a model using level-0 data, the other based on comparisons with in-situ data, noting that it is "*difficult to get the right information on uncertainties from an FCDR*".

The only participant who answered "yes" to each of the first four alternatives, was referring not to an existing product, but to a proposed project to derive land surface temperature from MVIRI/SEVIRI, MODIS, AVHRR, and ATSR, awaiting quantified uncertainty estimates in each of those FCDRs. Four others propagate errors on a pixel level bases:

- One user reports using "*pre-launch calibration information to derive uncertainty on a pixel*

Table 9: Do you use FCDR uncertainty information (from L1 data or from another source) to inform uncertainty information in the CDR? Multiple answers are possible.

	A	B	C	D	E	F
Aerosol optical depth			X			
Aerosol optical depth	X					
Cloud amount and cloud top height						X
Cloud fractional cover (CFC)						X
Cloud top height/pressure/temperature						X
Land surface temperature [proposed]	X	X	X	X		
Precipitation rate				X		
Sea surface temperature		X			X	
Soil moisture	X			X		
Surface elevation change (SEC) (ice sheet)						X
Temperature at SPL						X
Tropospheric aerosol	X					
UTH				X		
Upper tropospheric humudity			X			
Water-leaving radiance				X	X	
xCO2	X					

[A] Yes, quantitatively by error propagation at pixel level
[B] Yes, quantitatively by error propagation for typical cases
[C] Yes, quantitatively by error propagation for a generic case
[D] Yes, via flags
[E] Yes, quantitatively but not through error propagation [F] No

level" in at least some cases, using ATSR/AATSR, MODIS, AVHRR, and SEVIRI[1].

- one produces xCO2 from ENVISAT-SCIAMACHY and Green-house gas Observing Satellite (GOSAT)-TANSO,
- one produces tropospheric aerosol from MVIRI,
- and one derives soil moisture from the scatterometers MetOp ASCAT and the ERS scatterometer.

6.3. Spatial error correlations

The final CDR question was about spatial error correlations. In full, the question was:

[1]Within FIDUCEO, we use very specific definitions, and by "pixel-level uncertainties", we mean metrologically traceable uncertainties at a pixel level, rather than propagation for typical cases at a pixel level. This caveat may apply to subsequent examples as well.

Question 13: *Different effects lead to errors with a range of degrees of correlation between L1/FCDR radiances, with different spatio-temporal correlation scales, different strengths of correlation between wavelengths, etc. Do you account for error correlations (including locally systematic effects) in your CDR?* (Open-ended question)

The survey found that most interviewed FCDR producers do not account for error correlations in their CDR, but most also indicate they are working on it or planning to work on it.

- Four survey participants account for error correlations to some degree. One participant answered "*yes, badly*", another answered "*yes, a bit*", whereas two participants answer positively without similar qualifications.
- Ten surveyed CDR producers answered that they do not take this into account. Out of those, seven stated they wished or planned to consider this, and one said it cannot be done.
- For one participant, the consideration of error correlations is intrinsic in the data processing.

6.4. FIDUCEO requirements

Table 10: FIDUCEO requirements from CDR uncertainty questions

no.	Requirement	Comment
FIDUCEO-9	FCDR products should enable CDR producers to generate a variety of forms of uncertainty information required by CDR users.	This requirement is met if uncertainties at pixel level are provided, as this is a basis for less detailed information.
FIDUCEO-10	FCDRs should include pixel-level uncertainties in cases where there is variation in the uncertainty at FCDR pixel level, since some CDR producers require to produce pixel-level uncertainty information.	It is suspected that this applies to all FCDRs.
FIDUCEO-4	FCDR uncertainty information must include a description of error correlations sufficient for CDR producers to account for error correlations propagated from the FCDR in their CDR.	This repeated requirement also clearly emerges from the CDR uncertainty questions.

Table 10 shows requirements derived from CDR uncertainty questions. See also Table 19 on page 47 for requirements from FCDR uncertainty questions.

7. FCDR information

In the next section, survey participants were asked about the data they work with. First, they were asked questions about their FCDRs in general. Then, the survey included a series of questions repeated for each FCDR. Between them, survey participants used 35 FCDRs (an overview of all FCDRs used is shown in Table 6).

7.1. Overview questions

The overview questions started with a query on the nature of the FCDR data used for CDR production (part of the spectrum, active/passive).

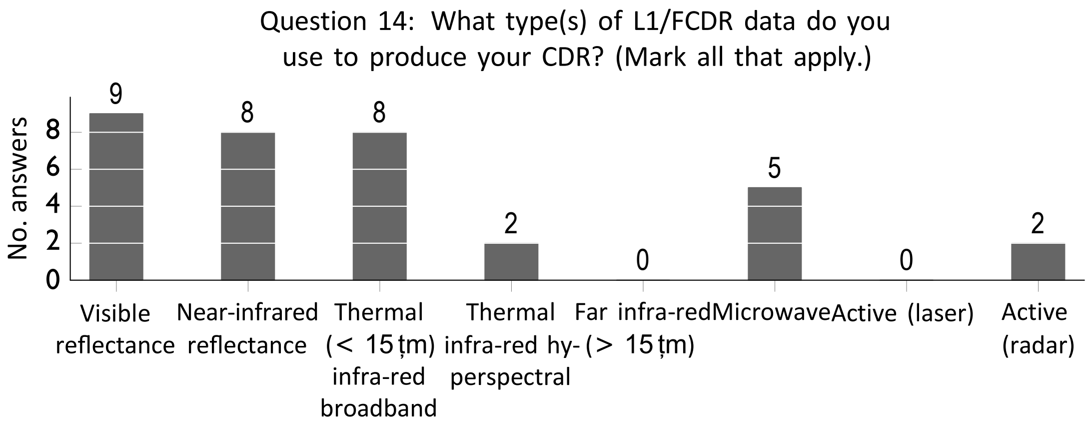

Figure 3: Overview of the nature of L1/FCDR data used for CDR production.

Figure 3 shows a summary of what kind of level-1 measurements FIDUCEO survey participants work with. The figure shows that the common types of level-1 measurements — visible reflectance, near-infrared reflectance, and thermal infra-red broadband radiances — are all well-represented in the FCDRs used by survey participants, and that several use passive microwave measurements as well. A few people work with hyperspectral or radar measurements, and nobody with far infrared or LIDAR. The FCDRs produced by FIDUCEO include visible, near-infrared, thermal infrared, and microwave, and are thus well-represented in the survey. Far infrared/sub-millimetre instruments are rare in Earth observation, and LIDAR instruments are relatively new (and relatively uncommon) and do not cover climate-relevant timescales or spatial coverage. Hence, the omission of far infrared and LIDAR users in the survey is not a problem for FIDUCEO. A full list of sensors is shown in the introduction in Table 6.

The next question asked about the orbital configuration for the FCDR: polar, geostationary, etc.

Figure 4 shows that the majority of surveyed FCDRs are carried on satellites in sun-synchronous Low Earth Orbit (LEO), with a minority in GEOstationary orbit (GEO). All FCDRs generated by FIDUCEO are carried in LEO or GEO. Considering that users use both LEO and GEO data, FIDUCEO FCDRs should cover both LEO and GEO. None of the survey participants reported any sensors on platforms in any

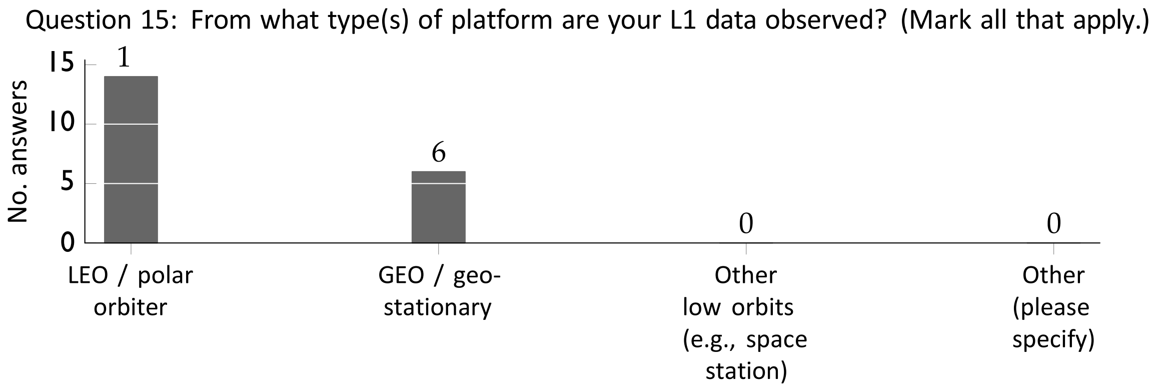

Figure 4: Orbital configurations for FCDRs used by survey participants.

other orbits[2].

7.2. Questions on specific FCDRs

The series of questions describing in the following sections were repeated for every FCDR, for a total of 35 FCDRs in 16 interviews.

7.2.1. Obtaining FCDR data

7.2.1.1. Survey results The first FCDR-specific question was about user experience in obtaining data: how easy or difficult it was.

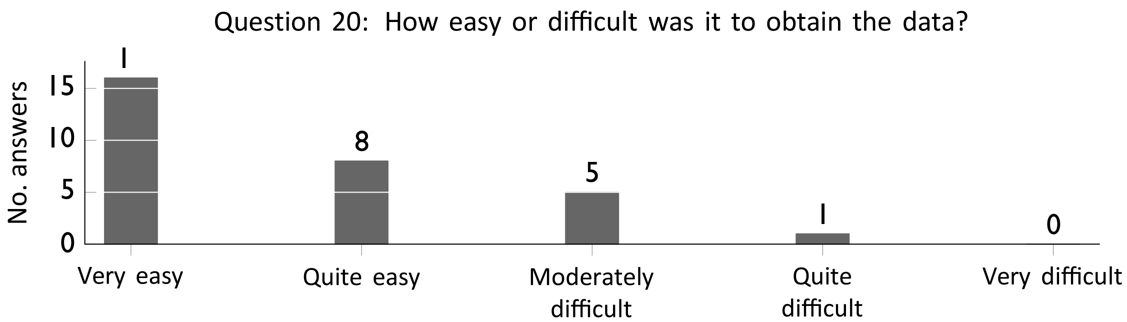

Figure 5: FCDR user experience in obtaining data. Note that some users skipped this question when the data were obtained by someone else.

Figure 5 shows an overview of user experiences in obtaining data for particular FCDRs. A full listing of individual answers, sorted by FCDR, is shown in Table 11 (page 30). Table and figure show that

[2]One participant did report using the tropical orbiter TRMM, but as he used 7 different FCDRs, we skipped discussion on TRMM and 2 others in the interest of time.

Table 11: Reported answers to question 20: How easy or difficult was it to obtain the data?

	A	B	C	D	E
AMSU-A	X				
AMSU-B / MHS	X				
AMSU-B / MHS					
AMSU-B / MHS	X				
ATSR		X			
ATSR	X				
ATSR / AATSR	X				
ATSR-2 / AATSR			X		
AVHRR		X			
AVHRR	X				
AVHRR					
AVHRR			X		
AVHRR (GAC)	X				
ERS RA / Envisat RA2		X			
ERSSAR / ENVISAT ASAR				X	
ERS scatterometer		X			
HIRS	X				
HIRS (longwave channels)	X				
IASI	X				
MERIS		X			
MODIS		X			
MODIS	X				
MVIRI			X		
MVIRI			X		
MVIRI / SEVIRI		X			
MetOp ASCAT	X				
SCIAMACHY	X				
SEAWIFS	X				
SEVIRI	X				
SEVIRI			X		
SSM T/2					
TANSO		X			
VIIRS	X				

[A] Very easy [B] Quite easy
[C] Moderately difficult [D] Quite difficult
[E] Very difficult

most survey participants do not report major difficulties in obtaining FCDR data. However, many users qualify that is because

- data were obtained by somebody else,
- data were already present on the system,
- or there was a long-standing cooperation with the data provider.

Hence, data that is very easy to obtain for one user may be moderately difficult to obtain for another.

Users mostly obtain data from NOAA, National Aeronautics and Space Administration (NASA), ESA, or EUMETSAT. One user reported obtaining ERS-Synthetic Aperture Radar (SAR) data from ESA to be quite difficult. Two users reported they found it moderately difficult to get MVIRI data from the EUMETSAT archive, although others found this quite easy. One user found it moderately difficult to obtain ATSR data from ESA. Finally, two survey participants considered it moderately difficult to obtain AVHRR data from NOAA Comprehensive Large Array-data Stewardship System (CLASS) and SEVIRI data from EUMETSAT, respectively.

As noted in section 3.1, FIDUCEO interviews are biased to experienced users. It is likely that this introduces a bias in the results presented in Figure 5 and Table 11, as obtaining FCDR data might be considerably more difficult for inexperienced users.

Table 12: FIDUCEO requirements from questions on obtaining FCDR data

no.	Requirement	Comment
FIDUCEO-12	FCDR products should be readily accessible.	

7.2.1.2. FIDUCEO requirements Table 12 shows requirements derived from questions on obtaining FCDR data.

7.2.2. Reading FCDR data

7.2.2.1. Survey results The next question is similar to the previous question, but related to reading the data rather than obtaining it.

Figure 6 and Table 13 (page 32) show answers to this question. The table and figure show that most users do not report major difficulties reading level-1 satellite data. This is despite a wide variety of file formats. However, like the variation in experience with obtaining the data, the variation in experience with reading data from the same FCDR may be more related to the background expertise of users and the groups they are working in, than to the variety of support from level-1 data providers. Users who consider it easy to read satellite data usually qualify this by commenting it is easy for them because they have long in-house experience, but that it is probably not easy for others. Among the specific comments given by users:

Table 13: Reported answers to question 21: how easy or difficult was it to read the data?

	A	B	C	D	E
AMSU-A		X			
AMSU-B / MHS		X			
AMSU-B / MHS				X	
AMSU-B / MHS		X			
ATSR		X			
ATSR			X		
ATSR / AATSR	X				
ATSR-2 / AATSR		X			
AVHRR		X			
AVHRR	X				
AVHRR					
AVHRR		X			
AVHRR (GAC)			X		
ERS RA / Envisat RA2			X		
ERSSAR / ENVISAT ASAR		X			
ERS scatterometer		X			
HIRS		X			
HIRS (longwave channels)		X			
IASI		X			
MERIS	X				
MODIS	X				
MODIS	X				
MVIRI			X		
MVIRI					X
MVIRI / SEVIRI		X			
MetOp ASCAT		X			
SCIAMACHY	X				
SEAWIFS	X				
SEVIRI	X				
SEVIRI				X	
SSM T/2					
TANSO		X			
VIIRS	X				

[A] Very easy [B] Quite easy
[C] Moderately difficult [D] Quite difficult
[E] Very difficult

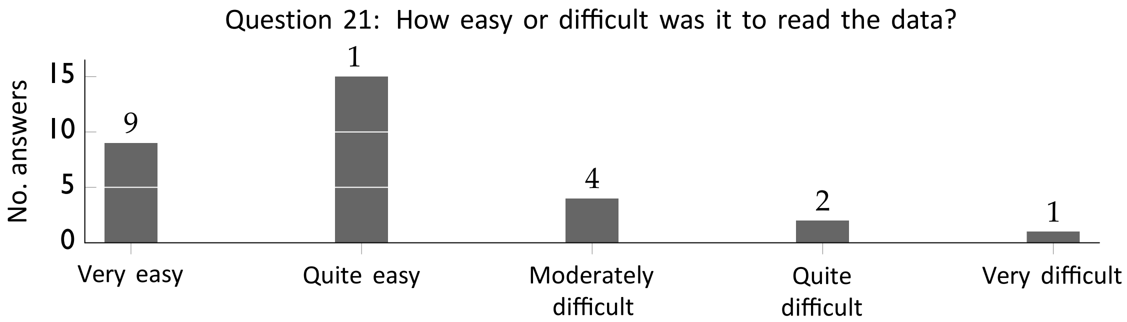

Figure 6: FCDR user experience in reading data.

- (on ATSR): "*ENVISAT product format. Product handbook is long and boring; it looks well-documented, at least the file format. But actually interpreting the data is harder.*"
- (on MVIRI): "*It's a native format, encrypted in the sense that it is not trivial to know what fields to use, how to use the data if not familiar.*"
- (on MVIRI): "*Specialised EUMETSAT file format (OpenMTP). People need to write their own reading routine. There is also a NetCDF version available, but it does not contain necessary metadata such as quality flags.*"
- (on AVHRR): "*We needed to develop reading routines. Documentation was adequate, but also quite some things were not described. Process of Platinum Resistance Thermometer (PRT) Infra-Red (IR) calibration was not always as described.*"
- (on the ERS scatterometer): "*20 years ago found it difficult but with experience it's easy*"
- (on ATSR): "*A bit of confusion on the calibration documentation, was not very clear that an additional correction needed to be applied.*"

The caveat on biases noted in section 7.2.1 applies equally to the question of reading FCDR data. The survey interviewed mostly experienced FCDR users, for whom reading data may be easy after many years. This does not mean it is easy for a newcomer, and should not be taken as evidence that existing file format practices are suitable.

7.2.2.2. FIDUCEO requirements Table 14 shows requirements derived from survey questions on reading FCDR data.

7.2.3. Problems with FCDR data

Next, users were asked to describe problems they had found with the FCDR data. Here, we split the description of problems into general comments and in comments specific to a particular FCDR, with a focus on FCDRs to be reprocessed FIDUCEO.

Table 14: FIDUCEO requirements from questions on reading FCDR data

no.	Requirement	Comment
FIDUCEO-13	Data should be easy to read and formats should be well-documented.	See also requirements on formats in section 9.2.
FIDUCEO-14	FCDR products should include all necessary and established systematic corrections (such as due to calibration), rather than require CDR producers to apply additional corrections.	

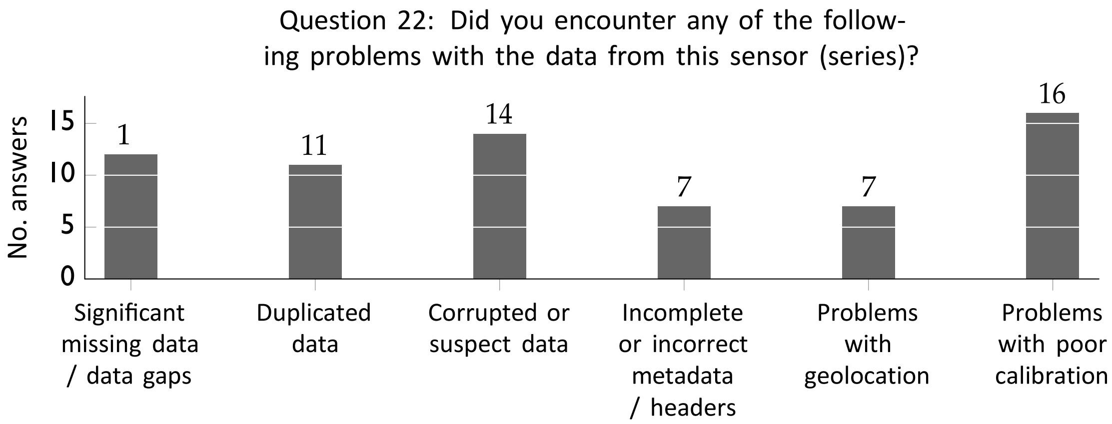

Figure 7: Problems reported with FCDRs. Note that here, every FCDR is counted once for every survey participant using it. Hence, some FCDRs are counted more than once. The total number of survey-FCDRs is 35.

7.2.3.1. Overview Figure 7 summarises users' reported problems with FCDRs. A complete listing of answers to the multiple-choice question, sorted by FCDR, is presented in Table 15 on page 35. The figure shows that problems with poor calibration are reported most frequently, with 16 cases where survey participants report this problem for an FCDR they are using. This accounts for almost half (45.7 %) of the 35 cases surveyed. Users report corrupted or suspect data slightly less often. Reported least of all are incomplete or incorrect metadata / headers and problems with geolocation. A closer look at Table 15 reveals that reported problems per FCDR vary from none at all to everything. However, it also reveals that this is true even within the same FCDR. For example, four survey participants use ATSR / AATSR data. Although they agree that they did not encounter incomplete or incorrect metadata, they disagree widely on the other problem categories, with two users encountering almost all problem categories, and two encountering none at all. Similar disagreements can be seen for all other FCDRs with multiple surveyed users: AMSU-B/MHS, MODIS, MVIRI, and SEVIRI. This shows that interpretation of problems is subjective and some problems may be identified

Table 15: Reported answers for question 22: Did you encounter any of the following problems with the data from this sensor (series)?

	A	B	C	D	E	F
AMSU-A		X		X	X	X
AMSU-B / MHS		X	X	X		X
AMSU-B / MHS		X	X	X		
AMSU-B / MHS	X					X
ATSR	X	X	X		X	X
ATSR	X	X	X		X	X
ATSR / AATSR						
ATSR-2 / AATSR						
AVHRR	X	X	X			X
AVHRR					X	X
AVHRR	X			X		
AVHRR	X	X	X			X
AVHRR (GAC)	X	X	X	X	X	X
ERS RA / Envisat RA2						
ERSSAR / ENVISAT ASAR			X			
ERS scatterometer	X	X	X			X
HIRS			X			
HIRS (longwave channels)			X			
IASI						
MERIS	X	X				
MODIS	X					
MODIS						X
MVIRI	X		X	X	X	X
MVIRI			X	X	X	X
MVIRI / SEVIRI						
MetOp ASCAT		X				X
SCIAMACHY						X
SEAWIFS	X					
SEVIRI						
SEVIRI						X
SSM T/2						
TANSO						
VIIRS			X			

[A] Significant missing data / data gaps [B] Duplicated data [C] Corrupted or suspect data [D] Incomplete or incorrect metadata / headers [E] Problems with geolocation [F] Problems with poor calibration by some users, but not by others. Therefore, the absence of reported problems in an instrument with only a single use case does not constitute evidence of a problem-free FCDR, but may simply mean that the user has had limited experience.

7.2.3.2. User comments Survey participants report many specific problems with FCDRs, in particular for AVHRR, AMSU, and ATSR. Below is an overview of some of the issues reported during the survey, with a particular focus on FCDRs considered by FIDUCEO.

7.2.3.2.1. AVHRR Below is a list of specific problems with AVHRR reported in survey interviews:

- "*Missing scanlines.*"
- "*Some individual orbits missing.*"
- "*In preparation for CLoud, ALbedo, and RAdiation dataset (CLARA)-A1, we learned about problems with calibration. PRT measurements sequence was often not as it should be. Might affect more than 10 % of all Global Area Coverage (GAC) orbits. Led to an underestimate of IR BT of up to 3K (orbit may start correctly but then starting at some scanline it would be wrong until the end of the orbit). Errors were correlated in all channels so not too bad for CLARA but same level-1C used by OSI-SAF (SST) leading to serious problems. This problem is not well documented by NOAA.* ***Should not just follow documentation but carefully check scanline by scanline.*** *We have experience and documented our experience.*"
- "*Data gaps quite horrible. Normally missing scanlines should be indicated as missing. But sometimes lines are missing completely which is problematic for processing.*"
- "*Duplicated data. Two consecutive GAC orbits always have a considerable overlap, at least 10 % is included in both files. Need to get rid of that in CDR.*"
- "*A lot of corrupted or suspect data or metadata. Incorrect time information. Scanline time information completely weird, you have to check the data. Earlier AVHRRs (until AVHRR/3 came @ NOAA-15) have serious clock errors (monitored by U. Miami for afternoon satellites, up to 20-30 km error), this leads to geolocation errors. No such estimation for morning satellites. Less of a problem for more recent AVHRRs.*"
- "*For next CLARA we plan to make available level-1C data, with a long detailed document of everything we have done and all details on corrupt data etc.*"
- "*Headers could be better.*"
- "*AVHRR was not designed with calibration in mind. It would be unfair to ask for good calibration.*"
- "*Geolocation needs some manual interaction.*"

- "*Calibration is a problem for AVHRR.*"
- "*A lot of problems. Missing scanlines, orbit lengths, etc. Need to manually check each orbit. Still find new problems. Not sure about incomplete/incorrect metadata/headers. Geolocation was OK.*"

7.2.3.2.2. MVIRI The following MVIRI problems were reported in survey interviews:

- "*For geostationary data, satellite drift is a problem, not anymore geostationary after a while. This drift leads to problems with the data, and L1 data not designed to account for this.*"
- "*Incorrect sun angle computation. Leads to both geolocation and calibration problems.*"
- "*Old MVIRI full images sometimes have weird geometrical structures that are hard to identify when processing on a pixel level (correlated errors).*"

7.2.3.2.3. AMSU-B/MHS In interviews, users reported the following problems with AMSU-B/MHS:

- "*Some channels on some satellites have gaps. Missing of problematic data is due to problems with instruments.*"
- "*Instrument problems with poor calibration in some cases.*"
- "*Duplicates between orbit files.*"
- "*Corrupted data due to Radio Frequency Interference (RFI). Channels become noisy. NOAA-16 became too noisy.*"
- "*Metadata was separate on NOAA website, but not comprehensive*"
- "*RFI issues on NOAA-15 and -17 led to corrupted data. NOAA-15 data before late 1999 unusable for climate purposes. After that RFI problem was corrected. Also on -17 but much less. Corrected early.*"
- "*Timing problem on NOAA-17.*"
- "*Calibration AMSU-B and MHS is a problem, inter-satellite calibration to correct this. AMSU-B water vapour channels degraded quickly. MHS is much better.*"
- "*MetOp-A MHS scan asymmetry problem. MHS channel 3 on either -19 or -A drifted out of NedT bounds but eventually stabilised.*"

7.2.3.2.4. HIRS Only two survey participants used HIRS, and for one, HIRS data were already preprocessed and therefore free of major problems. The remaining user noted on HIRS:

- "*Orbital data files have overlaps. Older data occasionally have some missing data but not significant. Suspect data often related to sensor problems. Not sure about geolocation or poor calibration problems.* "

7.2.3.2.5. SSM/T-2 FIDUCEO has not yet interviewed anybody who has already used measurements from SSM/T-2. The sole interviewee who described using SSM/T-2 measurement was describing an intention and has not actually used it yet.

7.2.3.2.6. Other FCDR Users also reported problems with the non-FIDUCEO instruments ATSR, SCIAMACHY, AMSU-A, and others. However, as this survey focusses in particular on FCDRs of interest to FIDUCEO, those are omitted from the report in the interest of brevity.

Table 16: FIDUCEO requirements from questions on problems encountered with FCDR data

no.	Requirement	Comment
FIDUCEO-15	FCDR products should not include any duplications of data.	E.g., no overlaps of successive FCDR files.
FIDUCEO-16	FCDR products should flag all corrupted data, including missing scanlines.	
FIDUCEO-17	FCDR products should have complete and correct metadata.	
FIDUCEO-18	All known and established corrections for timing, geolocation, and viewing geometry of pixels should be applied in the FCDR record and described in associated documentation. Associated uncertainties should also be included or described.	Including sun angle computations.
FIDUCEO-19	FCDR products should be quality-controlled at pixel, scan-line, and orbit-file level to minimise errors in calibration, geolocation, and data.	Includes identification of issues such as RFI problems, scan asymmetry problems, problems with AVHRR PRT measurement sequence, etc.

7.2.3.3. FIDUCEO requirements Table 16 shows requirements derived from questions on problems encountered with FCDR data.

7.2.4. Uncertainty information in FCDR

As an essential aim of the FIDUCEO project is to include traceable uncertainties with FCDRs, the survey includes a series of questions related to uncertainty, stability, and harmonisation information in FCDRs. As before with the question about reported problems, we split the results in a general part and a part on comments for specific FCDRs.

Table 17: Reported answers for question 23: What form(s) of uncertainty information about the input FCDR radiances are available from the FCDR provider?

	A	B	C	D	E	F	G
AMSU-A					X		
AMSU-B / MHS					X		
AMSU-B / MHS	X				X	X	
AMSU-B / MHS	X				X		
ATSR	X				X		
ATSR	X				X	X	
ATSR / AATSR		X					X
ATSR-2 / AATSR	X				X		
AVHRR	X	X			X		X
AVHRR							
AVHRR	X				X		
AVHRR	X				X		
AVHRR (GAC)	X				X		
ERS RA / Envisat RA2					X		X
ERSSAR / ENVISAT ASAR	X						
ERS scatterometer	X	X	X	X	X	X	X
HIRS							
HIRS (longwave channels)							
IASI							
MERIS	X				X		
MODIS	X	X	X		X	X	X
MODIS	X				X	X	
MVIRI		X					
MVIRI							
MVIRI / SEVIRI	X				X		
MetOp ASCAT	X	X	X	X	X	X	X
SCIAMACHY	X	X	X	X	X	X	
SEAWIFS	X				X	X	
SEVIRI	X		X				
SEVIRI	X	X			X		
SSM T/2	X						
TANSO	X	X	X	X	X	X	
VIIRS	X				X	X	

[A] Generic statement of total uncertainty
[B] Characterisation of total uncertainty (e.g., uncertainty maps, dependencies) [C] Pixel / cell total uncertainty (context sensitive) [D] Breakdown of uncertainty components
[E] Flags for “doubtful” pixels / cells
[F] Information about stability [G] Information about consistency between sensors in a series (if applicable)

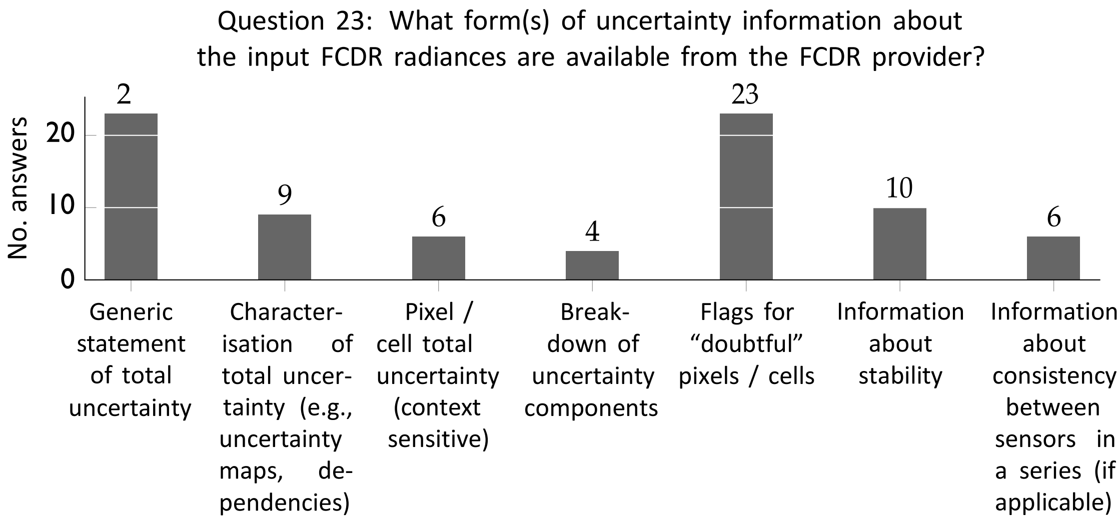

Figure 8: Availability of uncertainties and related information in FCDRs used by survey participants. Note that here, each FCDR is counted once for each survey participant.

7.2.4.1. Overview Figure 8 shows an overview of uncertainty information present in FCDRs used by interviewed survey participants. A complete listing of answers per user and FCDR is presented in Table 17 on page 39. When interpreting the answers, it is important to note again that FIDUCEO uses very specific definitions for total uncertainty, pixel-level uncertainty, etc., derived from metrological guides [RD-3]. FCDR users answering the question do not necessarily use the same definition — for example, where interviewed FCDR users may consider SEVIRI to contain context-sensitive pixel-level uncertainties or a characterisation of the total uncertainty, this is not the case considering definitions used by FIDUCEO. Keeping this in mind. the figure shows that a majority of FCDRs used includes a generic statement of total uncertainty and/or flags for "doubtful" pixels/cells, but that most do not go beyond that. This question is related to an earlier question in the survey (with results presented in Figure 2), where users were asked if they propagate FCDR uncertainties into their CDRs, and where some commented that this is difficult in absence of sufficient information in the FCDR. A closer look at Table 17 shows that uncertainty information in FCDRs varies from nothing at all (HIRS) to all listed categories (ERS scatterometer). There are some inconsistencies in answers reported by different users (for example, for AVHRR, MODIS, and ATSR, among others), but they are less severe than for the answers to question 22 (Table 15 on page 35).

7.2.4.2. User comments FIDUCEO interviewees were asked to clarify their answers on uncertainty information. For the FIDUCEO-relevant FCDRs, a selection of comments is listed below.

7.2.4.2.1. AVHRR

- "*We get information on intercalibration. Look at stability in level-2 and level-3 data. Work together with NOAA for intercalibration and characterisation. Information we get directly* *from NOAA."*

- "*Published calibration coefficients. Files do have flags but have not worked with them. As we have own receiving system, we do not get data from an external provider and may miss some information.* "

7.2.4.2.2. AMSU

- "*We're making FCDRs. NOAA operations sends out a notice when there is a problem with a channel. Notices historically not officially archived for earlier data, for newer data there is an archive. Notices include relevant information about stability.*"
- "*Total uncertainty, a specified NE∆T is given*[3]*, can be compared to estimate from data. Can try to work out what the noise is from the data themselves. Stability is specified but not verified.*"
- "*Too little. Some information about noise levels of individual channels.*"

7.2.4.2.3. MVIRI

- "*One global intercalibration factor per day, RMS associated with intercalibration against HIRS, channels almost the same. Daily regression against HIRS spectral responses, try to simulate channels from HIRS. Only for thermal channels.*"
- "*Nothing available. Data not calibrated. Only purpose of the data was to locate pictures of the cloud.*"

7.2.4.2.4. HIRS "*Not sufficient. Not much available on stability or consistency for the long-wave channels. Some estimates within own group. Studies on longwave channels under development, not yet published.*"

7.2.4.2.5. SSM-T/2 "*Not sure. Very little information.*"

7.2.4.2.6. Other FCDR As FIDUCEO focusses on the FCDRs listed above, here we list only briefly what survey participants have reported on uncertainty information for other FCDRs.

- (On SeaWIFS): "*Uncertainty information is [only] from validation studies.*"
- (On ERS Scatterometer): "*Transponder campaigns during commissioning, not systematic afterwards. Calibration from stable natural targets (tropical forest).*"
- (On SEVIRI): "*There are operational reports of uncertainty characterisation. Flags of radiometric and geometric performance. Per-scene uncertainty characterisation per channel.*"
- (On MODIS): "*Similar but not as good as ATSR. Stability and consistency in auxiliary papers.*"

[3]Note that a specified NE∆T is typically a design specification and not an uncertainty based on calibration (pre-launch or in-orbit), and that the total uncertainty consists of more components than detector uncertainty.

7.2.4.3. FIDUCEO requirements See paragraph 7.2.6.6 on page 46 for requirements derived from uncertainty-related questions.

7.2.5. Trust in FCDR uncertainties

Uncertainty information is only useful if users trust that it is reliable. Therefore, the survey includes a question asking users to describe to what degree they trust reported uncertainties and if they do anything to check those. The following first presents an overall overview of how users trust uncertainties, and then FCDR-specific comments including how users handle cases where they believe uncertainty estimates to be inadequate.

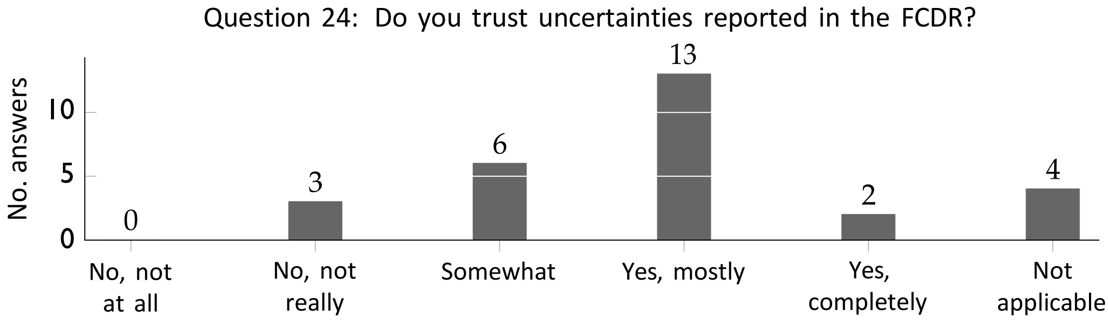

Figure 9: Trust in uncertainties reported in FCDR

7.2.5.1. Overview As summarised in Figure 9, for a majority of cases, users do mostly trust reported uncertainties, with only 3 cases of "not really". As shown in Table 18 (page 43), two of those cases relate to AVHRR and one to AMSU-B/MHS, both sensors for which FIDUCEO will produce a new FCDRs with newly calculated uncertainties. On the other hand, one user answered that he trusts AVHRR uncertainties completely.

7.2.5.2. User comments In the interview, users were asked if they do anything to check/verify reported uncertainties, or to estimate their own when reported uncertainties are not available or considered reliable. For the FIDUCEO-relevant FCDRs, below is a selection of comments made by users.

7.2.5.2.1. AVHRR

- "*NOAA provides equations and constants to convert level-1b radiances to level-1c intercalibrated radiances, we still check if the results are self-consistent.* "
- "*Not enough, many problems go unreported.*" (See also subparagraph 7.2.3.2.1 on page 36.)
- "*FIDUCEO, new dataset with lower and better quantified uncertainty.*"
- "*We use a 3rd party's estimate.*"

Table 18: Answers to question 24: Do you trust uncertainties reported in the FCDR?

	A	B	C	D	E	F
AMSU-A			X			
AMSU-B / MHS			X			
AMSU-B / MHS		X				
AMSU-B / MHS						
ATSR			X			
ATSR						
ATSR / AATSR					X	
ATSR-2 / AATSR				X		
AVHRR					X	
AVHRR						X
AVHRR		X				
AVHRR						
AVHRR (GAC)		X				
ERS RA / Envisat RA2				X		
ERSSAR / ENVISAT ASAR				X		
ERS scatterometer				X		
HIRS						X
HIRS (longwave channels)						X
IASI						
MERIS				X		
MODIS				X		
MODIS				X		
MVIRI				X		
MVIRI						X
MVIRI / SEVIRI			X			
MetOp ASCAT				X		
SCIAMACHY			X			
SEAWIFS				X		
SEVIRI				X		
SEVIRI				X		
SSM T/2						
TANSO			X			
VIIRS				X		

[A] No, not at all [B] No, not really [C] Somewhat
[D] Yes, mostly [E] Yes, completely [F] Not applicable

7.2.5.2.2. MVIRI

- "*Informative, maybe some exceptions. Used the data only in an exploratory way, no further checks yet.*"
- "*I perform a quality screening, Remove outliers. And do a ten day moving average of the intercalibration factors.*"

7.2.5.2.3. AMSU

- "*What they provide is useful, but we do additional checks. Also working on own FCDR.*"
- "*Try to verify. Such as by comparing to NWP. See also above.*"

7.2.5.2.4. HIRS "*Nothing currently. Retrieval does not consider any uncertainty.*"

7.2.5.2.5. Other A selection of answers relating to non-FIDUCEO FCDRs:

- (On ERS RA / ENVISAT / RA-2): "*Verified by some checks; remaining trends seem physical and consistent with independent measurements.*"
- (On MetOp ASCAT, ERS scatterometer): "*We trust them but we still do our own checks.*"
- (On SeaWIFS, MODIS, MERIS, VIIRS): "*We look at regional uncertainties for regional studies.*"
- (On SCIAMACHY and TANSO): "*We get spectra, those have absorption lines. Continuum between absorption lines. We do checks if the uncertainty information is consistent with the scatter/noise of the radiances. I.e. 10 wavelengths next to each other should have a certain std.dev etc. Mostly we find that the information is consistent.*"
- (On ERS-SAR / ENVISAT-SAR): "*Manual/visual checks to reject scenes that are not useful.*"
- (On ATSR): "*Example: initially stated 50 mK accuracy, later discovered 0.2 K problem in 12 µm channel. We were checking things as we processed the data.*"

7.2.5.3. FIDUCEO requirements See paragraph 7.2.6.6 on page 46 for requirements derived from uncertainty-related questions.

7.2.6. Additionally desired uncertainty information

Next, we asked users what additional uncertainty information they would desire:

> **Question 25:** *Please describe any L1/FCDR uncertainty information that you could use in CDR development / production, but is unavailable in your input data.* (Open-ended question)

Below, we report the answers for FCDRs of direct interest to FIDUCEO.

7.2.6.1. AVHRR

- *"Would be very useful to have clear information about stability, accuracy, and variability of the accuracy (precision). Flag information about how useful/trustworthy the intercalibration information is, on a pixel-basis. (Many problems with early 3.9 µm AVHRR.)"*
- *"Effort in describing data is good, but information is not complete. Not sure about exact answer, but retrospectively always information one would wish one had access to. In particular information related to monitoring. Big issue is the behaviour of the 3.7 µm data. Had big noise problem in early AVHRR versions. Should be a way of continuously monitoring the level of the 3.7 µm noise problem (ch 3B). Very important, unique channel."*
- *"Anything helps: generic statement, critical cases, pixel-level uncertainties."*
- *"Quite happy with what exists, but continued research is welcome."*
- *"Estimates of actual radiometric/calibration uncertainties. Could/should use stability and harmonisation information."*

7.2.6.2. MVIRI

- *"More detailed information on the uncertainty budget to propagate to FCDR. You would want in an FCDR that systematic effects have been corrected and that the time series are stable, so only random effects remain. Free from non-climatic effects."*
- *"I have the intercalibration only for the thermal channels, it would be good to have it for shortwave channels."*
- *"Developed a model to characterise the uncertainty in the spectral response. Used this model to characterise this. Propagated in the uncertainty of the calibration and as a systematic error in the CDR."*
- *"Could use operational Global Space-based Inter-Calibration System (GSICS) intercalibration factors for SEVIRI. This exists but I'm not using it. Further information, I probably wouldn't use. Would be impossible to do a per-pixel uncertainty. If it was provided I probably wouldn't trust it."*

7.2.6.3. HIRS

- *"Pixel level uncertainties. Information about sensor problems. Calibration problems. Other relevant information."*
- *"Stability and harmonisation information for FCDR, to see that there is no spurious trend and no jumps between satellites. Flags would be very helpful (use/not use etc.). Gives information on confidence. Quantitative uncertainties are less important and not urgently needed. However if uncertainty is too large, this can be communicated through a flag. We would rather use this for a use/not use basis, than to propagate uncertainties."*

7.2.6.4. AMSU

- "*Uncertainties on the channel radiances. Characterisation of across-scan bias. The more detail the better. Historical disconnect between the engineering side and data users.*"
- "*Channel instrument.noise based on in-space measurements. Good description of event history (when and what and implications)*"
- "*Original characterisation information. Hard to say in a few sentences. Pre-launch and commissioning/checkout phase information. Science characterisation phases. Not sure yet, need to think of what exactly to ask people.*"

7.2.6.5. Other FCDR For FCDRs not directly related to FIDUCEO, a selection of comments:

- (on ATSR): "*Not aware of any cases where we would have benefited from per-pixel information. Uncertainty overall small.*"
- (on ATSR): Radiometric noises.
- (on MetOp ASCAT): "*Existing calibration in intermittent on campaign basis. Permanent calibration would be even better. Will be on future instrument (EPS-SG).*"
- (on SeaWIFS): "*More information on the instrument performance. With digging enough it might be available, but not easy to get.*"
- (on ERS-RA and ENVISAT RA-2): "*Pre-cleared preview check. Applies for older data.*"

7.2.6.6. FIDUCEO requirements Table 19 shows the requirements derived from questions on uncertainties, trust in uncertainties, and additionally desired uncertainty information. Note that other relevant requirements were already derived based on answers to questions on uncertainties in CDRs, as listed in Table 10 on page 27.

7.2.7. Temporal stability information

Next, the survey included a question about temporal stability:

> **Question 26:** *Describe what, if any, information is provided with L1/FCDR data about temporal stability. ('With the data" includes provision of information in reports and papers linked explicitly to the dataset repository.)* (Open-ended question)

Rather than direct quotes, below is a summary of what users reported.

For most FCDRs, little information is provided about temporal stability. For HIRS, AVHRR and MVIRI, none of the interviewed users are aware for any information provided on instrumental temporal stability. However, there is information on the related problem of orbital drift. In the case of HIRS and AVHRR (on polar orbiting satellites) this leads to a shift in equator passing time, and for MVIRI (on geostationary satellites) this leads to observations no longer being geostationary. Although it

Table 19: FIDUCEO requirements from questions on uncertainties

no.	Requirement	Comment
FIDUCEO-20	Uncertainty information in FCDRs should have a basis published in peer-reviewed literature to build the confidence any FCDR needs.	This is additional to product documentation. The extra effort involved here entails extra funding for this to be achievable.
FIDUCEO-21	Uncertainty and stability information in FCDRs should encapsulate and apply understanding of instrument behaviour.	For future missions, this should be built into the FCDR specification process, based on a metrological analysis of the sensor. This is a FIDUCEO recommendation to space agencies.
FIDUCEO-22	FCDRs should contain well-documented information about stability.	Noted in relation to AVHRR, this applies more broadly.
FIDUCEO-23	FCDR producers should make use of available historical monitoring information, including instrumental and non-instrumental events.	A dedicated archive of events would be beneficial. This is a FIDUCEO recommendation to space agencies.
FIDUCEO-24	FCDR uncertainties should include an estimate of the radiometric/calibration uncertainty/channel instrument noise based on in-space measurements.	Noted in relation to AVHRR/AMSU.
FIDUCEO-25	FCDR uncertainty information should include a de- tailed breakdown of the uncertainty budget, i.e. a quantified contribution for each known source of error.	Noted in relation to MVIRI.
FIDUCEO-26	FCDR product documentation should include a characterisation of uncertainty in spectral response functions so FCDR users can use this in their radiative transfer modelling.	Noted in context of MVIRI, applies more broadly.
FIDUCEO-27	FCDR should characterise across-scan bias / scan asymmetry, where relevant.	Noted in relation to AMSU.

could be considered rather a geolocation than an instrument issue, both are problematic for long FCDR time series considerations.

For AMSU, there is some information in regular notices and in the literature, although this is "*not as detailed as desirable*". The survey did not acquire relevant information for SSM/T-2.

Considering instruments outside of the direct scope of FIDUCEO, users of ATSR data report there has been work on assessing stability explicitly and implicitly. MetOp ASCAT has offline temporal stability information. For the research instruments ERS-RA / ENVISAT-RA2, SeaWIFS, ERS scatterometer, and MODIS, as well as for SEVIRI and VIIRS, users report various degrees of stability information is available, either from data providers or from cooperating groups.

Finally, a user reports that for SEVIRI, graphs and reports on stability are available but not very useful: "*Not using [SEVIRI graphs and reports], they are in written form so difficult to ingest in processing software. But even if it was in the data files I still wouldn't use it. What we need is the instantaneous uncertainty so we can use it in the error propagation.*" Although this comment was relating to SEVIRI, it would equally apply for other instruments.

7.2.8. Stability requirements

7.2.8.1. Survey results The next question relates to stability requirements on the FCDR as dictated by CDR stability requirements:

> **Question 27:** *What is the stability requirement for L1/FCDR radiances that corresponds to your CDR stability requirement? (Please describe how this is calculated.)* (Open-ended question)

In most cases, the interviewed FCDR users are unable to answer this question quantitatively. The ones who do attempt an answer at all, often answer with a disclaimer.

- (AVHRR or HIRS for CTH): "*0.2 K/decade*"
- (ERS RA/ENVISAT RA-2 for SEC) "*We look at CDR level, some cm/year. Our requirement less stringent than the requirement of ocean users.*"
- (MetOp ASCAT / ERS scatterometer for soil moisture): "*Not easy. Sensitivity varies over the globe. What's enough for grassland is not good enough for densely vegetated areas. Estimate: 0.05 dB/decade*"
- (ATSR or AVHRR for AOD): "*Instrument may not be the least stable component in the chain.*"
- (SeaWIFS and others for water leaving radiance): "*Calculation by looking at trends in existing data. It's complicated because for ocean colour, multiple wavelengths are used. Uncertainties in relative or absolute terms may or may not remain the same across the spectrum. Implications for the algorithm. May be based on ratios so some errors may get cancelled out. No simple answer.*"
- (AMSU-B/MHS for UTH): One answer: "*To meet the stability requirement of 0.3 %/decade, translates to 0.1 K/decade*", another answer: "*The CDR should be 1 %. Relative Humidity (RH)*

→Brightness Temperature (BT) relationship is exponential. Small change in BT has big effect on RH. Stability should be around 0.5 K" (Gives same answer for SSM/T-2).

- (MVIRI for CFC): "*We only have an absolute requirement (1 % absolute accuracy on reflection for the solar channels), but no direct requirement on the temporal stability. Not so simple to calculate because it is not a linear relation.*"
- (HIRS for temperature profiles): "*To meet GCOS 0.05 K/decade, would need HIRS BT of 0.05 K/decade*"

Table 20: FIDUCEO requirements from questions on stability

no.	Requirement	Comment
FIDUCEO-28	Instrumental drift, step and trend artefacts should be minimized in FCDR products.	Requirement based on comment made in relation to uncertainties. Requirement can apply only for time series within the same instrument copy. This does not imply that FCDRs should have adjustments for geophysical trends (such as drift in local time of orbit),
FIDUCEO-29	Stability information should be provided in an easy to use format.	A SEVIRI user notes that the form in which stability information is communicated is difficult to use in processing software.
FIDUCEO-30	FCDR documentation should explain how the FCDR stability is presented in the FCDR, and give guidance on how to infer CDR-level stability from FCDR stability information.	Other sources of instability may be introduced in the CDR retrieval process. This does not address issues around aliasing of high-frequency effects into a long term behaviour.

7.2.8.2. FIDUCEO requirements Table 20 shows requirements derived from questions on stability

7.2.9. Pre-launch data

The next question is about pre-launch data. Before an instrument is launched, characteristics are measured in a laboratory. Such pre-launch data can be useful for users of level-1 measurements. Table 21 shows that some FCDR users have access to pre-launch data, but most do not. The ones that do include users of AMSU-B/MHS, ATSR, AVHRR, MODIS, MVIRI, MetOp ASCAT, SCIAMACHY, and SEVIRI.

Table 21: Question 28: Do you have access to pre-launch data?

Answer	Count
Yes	8
No	23

7.2.9.1. Needs for additional pre-launch data Along with the question on the availability of pre-launch data was a question whether users would require additional pre-launch data. Most users report they do not need this. In particular, they expect that any relevant information that may be contained in pre-launch information, should be taken care of the producing the FCDR, and that the FCDR is therefore self-contained and ready to be used for CDR production. Users who do report needing them, rather need them for working on the FCDR than on the CDR. A user working on AMSU (-A and -B) notes:

"*Instrument calibration for nonlinearity. Antenna pattern measurements. We use what is available. Those are the main things. What was done was adequate for instrument specifications for operational use, but not adequate for climate applications. Disconnect.*"

7.2.9.2. FIDUCEO requirements Table 22 shows requirements derived from question on pre-launch data.

7.2.10. Harmonisation

The final three questions specific to each FCDR related to harmonisation. By "harmonisation", FIDUCEO means an attempt to make sure that a data record made up of multiple sensors has had artefacts removed as much as possible, and that information from one sensor is consistent with information from another sensor. Forcing data from different sensors to be the same without understanding where differences are coming from is not harmonisation. The survey included three questions on harmonisation:

> **Question 30:** *Are you aware of any measures taken to harmonise the L1/FCDR radiances you use?* (Open-ended question)
>
> **Question 31:** *Does absence of L1/FCDR harmonisation lead to discontinuity (or the need to make adjustments) in your CDR?* (Open-ended question)
>
> **Question 32:** *Please state / describe your requirements for L1/FCDR harmonisation to aid your CDR* (Open-ended question)

Although those questions were intended specifically for each FCDR, they also trigger comments on harmonisation in general. Some general comments users gave on harmonisation:

- "*Each instrument is different. Correct way to test climate models is to use instrument simulators. OK if things disagree provided there is a good reason. Harmonisation should be done at level-2 data. Vital to level-2 harmonisation: confidence in calibration.*"

Table 22: FIDUCEO requirements from questions on pre-launch data

no.	Requirement	Comment
FIDUCEO-31	Relevant information in pre-launch data should be used to produce an FCDR such that FCDR users do not need to worry about pre-launch data.	
FIDUCEO-32	FCDR producers should facilitate access to prelaunch data or other instrumental characterisations used in generating their FCDRs that are relevant to development of derived geophysical products.	Although most FCDR should not need to analyse pre-launch data in detail, some pre-launch data (such as Spectral Response Functions (SRFs)) is useful in CDR production. Moreover, pre-launch data needs to be available where used for FCDR production, as part of the complete documentation that FIDUCEO must provide. In general, space agencies should ensure all pre-launch testing data are openly and freely available from long-term archives.

- For many polar orbiting satellites, equatorial overpass time (Local Time Ascending Node (LTAN)) changes as a function of time due to orbital drift. When a new satellite replaces the old one, observations may revert to the nominal overpass time. This will cause a discontinuity in observations that is not due to instrumental changes. Some FCDR users consider that this time change is the main problem.

- "*Aim of FCDR is so that one does not see the switch between satellites (apart from changing LTAN).*"

7.2.10.1. AVHRR Five surveyed users have used AVHRR in their work. Four had specific comments not covered by the generic harmonisation remarks noted above.

- "*Intercalibration based on SNOs and matched observations at stable observation targets such as Greenland or Sahara*[4]*. Not sure if correction applied at NOAA is based on instrument understanding or if it's empirical. We get the results from them.*"

  "*No adjustments done.*"

  "*Cannot say a number [for harmonisation requirements], (...) work done at NOAA meets requirements.*" E.g. one can not see the switch.

- "*For CLARA-A1, used visible harmonisation prepared by Andy Heidinger (2010 IJRS, based on MODIS) for PATMOS. Mixture of references. For IR nothing.*"

  "*Still some remaining problems in visible. IR much better because of on-board calibration. Mostly good enough for cloud processing*"

  "*Difficult question [on harmonisation requirements].*"

- "*[AVHRR harmonisation is] tricky, because satellite overpass time change is main problem.*"

  "*Shifting and changing overpass times cause critical disruption for clouds. For aerosols, less severe.*"

  "*[Harmonisation should be] 1 % and better, [based on an] educated guess rather than in-depth study.*"

- Not aware of any harmonisation efforts, but FIDUCEO will fix this. This does lead to discontinuities. The requirement is the "*ability to use RTTOV to perform optimal estimation and get consistent record. Harmonisation should be at least 50 mK/decade.*"

7.2.10.2. AMSU

- "*Yes. We are working on differences using reanalysis.*"

  "*[A lack of harmonisation] would [lead to discontinuity], but we produced the CDR after those instruments. Note that in Numerical Weather Prediction (NWP) we bias-correct the data*

[4] Only for shortwave/visible channels.

against the model, removing the discontinuity. Based primarily on observation statistics, but not really an understanding of whats happening with the instrument."

Harmonisation requirement is for the difference to be "*within the uncertainty*".

- "*Different people have taken different approaches. Non-linearity. What has been done is rather forcing [homogenisation] than deeper understanding. Some has been done, but more thorough work is needed.*"

  "*The L1/FCDR were forced to agree and the CDR does not need further adjustments.*"

  Harmonisation should be equal or better than 0.1 K

- "*We have done [harmonisation] it on the FCDR we generated. Not sure what EUMETSAT are doing for MHS.*"

  Omitting harmonisation would lead to discontinuities.

  Harmonisation difference should be "< 1 K*, depends on the channel. Without removing the diurnal effect, hard to decide what the difference should be.*"

7.2.10.3. HIRS

- "*Working on [harmonisation] myself. It is definitely necessary.*"

  Harmonisation requirements are "*derived from GCOS stability requirements*".

- "*[There exists] some work at NOAA with Simultaneous Nadir Observations (SNOs) back to NOAA-8/9, could be used as a basis.*"

  On the absence of harmonisation: "*We see jumps but we are not sure where they come from. Under investigation.*"

  On harmonisation requirements: "*Same as for AVHRR. But for HIRS there are also changes in central wavelength and bandwidth, needs a special treatment for each HIRS instrument. If the FCDR can consider this, then the radiative transfer in the retrieval will be easier as it will not need to consider each satellite separately. Harder to realise. Some jumps are too strong to completely consider, but there are some smaller changes due to bad/incorrect ground calibration that can be considered. E.g. small changes in SRF.*"

7.2.10.4. MVIRI Three MVIRI users commented on harmonisation, but nobody had numbers on harmonisation requirements.

- "*EUMETSAT initiative, but only water vapour and thermal IR channels, not visible.*"

  On absence of harmonisation, this "*most likely would*" cause discontinuities (but CDR is only proposed).

- "*EUMETSAT tries to normalise MVIRI by intercalibrating each to a common reference (HIRS), that is the closest to normalisation undertaken. But there has been no testing if this meets the harmonisation/stability requirements.*"

  "*Cannot answer [on the impact of absence of harmonisation] because we haven't produced the CDR yet.*"

  Requirements on harmonisation "*should include the classical radiance intercalibration and should also include a conversion to a sensor-invariant sensor response function.*"

- "*FIDUCEO is the first genuine attempt*" at harmonisation..

  Without harmonisation "*We could clearly see a jump in the time series. We did some empirical adjustment.*"

7.2.10.5. SSM/T-2 Only a single FIDUCEO survey participant talked about SSM/T-2, but he did not yet have enough experience to comment on harmonisation.

7.2.10.6. Others Some of the comments users of other FCDRs gave are also of interest to FIDUCEO. A selection:

- Users of ATSR note that discontinuities are small. One user notes that CDRs from different ATSRs "*should be considered as slightly different products*".

- For MetOp ASCAT, "*EUMETSAT has harmonisation by multiple calibration strategies. For example calibration transponder campaign, would notice immediately if MetOp-A/MetOp-B copies are drifting. Both empirical and bases on understanding of causes. Reprocessing done on a regular basis.*"

  On the other hand, for the predecessor instrument ERS scatterometer, the same user notes that "*progress has been extremely slow due to lack of funding*", and would like in general to see "*more frequent reprocessing. With every new generation of instruments, new standard. For example, should be a new reprocessing after the EUMETSAT Polar System (EPS)-Second Generation (SG) will be launched, because of changing definitions, formats, etc. Not so much that it becomes more correct but rather more consistent with modern working practices.*"

7.2.10.7. FIDUCEO requirements Table 23 shows requirements derived from questions on harmonisation

Table 23: FIDUCEO requirements from questions on harmonisation

no.	Requirement	Comment
FIDUCEO-33	Historic FCDR data should be reprocessed when definitions and formats are changed for data from newer missions, so that a consistent archive is available..	Noted in relation to MetOp AS-CAT, applies more broadly. With every new generation of instru- ments, definitions and formats tend to be updated. This is a FIDUCEO recommendation to space agencies.
FIDUCEO-34	FCDR producers need to clearly explain what form of harmonisation has been applied, and give uncertainty estimates for harmonisation.	The difference between har-monisation and homogenisa-tion (making all sensors look identical) should be explained.

8. Other forms of uncertainty

After the FCDR-specific questions were completed for all FCDRs, we asked users what other forms of uncertainty were important:

> **Question 108:** *Other than L1/FCDR radiance uncertainty, what forms of uncertainty are significant for your CDR? (E.g., geolocation effects, classification errors...)* (Open-ended question)

All users name significant sources of uncertainty that are not coming from FCDR radiances. Some aspects that are mentioned:

- Uncertainty due to correcting for changing LTAN in CDR processing.
- Geolocation/navigation uncertainty. Severity of the problem depends on the spatial resolution of the target CDR, but uncertainty needs to be quantified. This is particularly important for users using auxiliary information such as land-water masks, or for CDRs where satellite and sun angles are directly important for the retrieval (sun glint). Therefore uncertainty of components (satellite and sun angles) should be included.
- Uncertainties on anything that is corrected for, such as channel characteristics.
- Uncertainties in auxiliary data, such as reanalysis data, spectroscopy, other radiative transfer properties.
- Limitations in forward model.
- Limitations in inverse model. For some, uncertainties in FCDR are "*significantly less important than model uncertainties*"
- Assumptions that are necessary to make in any ill-posed problem such as an inverse retrieval: a priori information.
- Detection of clouds and/or precipitation.
- Instrumental problems.

9. File formats

9.1. Survey results

FIDUCEO will reprocess FCDRs and distribute the result to the public. Therefore, it is important to know user requirements on file formats:

> **Question 109:** *Please describe any requirements related to L1/FCDR product formats. These may include, for example: file format type, use of standard names, and information (such as variables) that should be included.* (Open-ended question)

Almost all users describe that they would like to read FCDRs in NetCDF with CF-compliant names. However, they do not agree about all other aspects. Whereas some users prefer files that include as much as possible, others prefer files that contain only the minimal parameters needed to calculate reprocessed FCDRs and associated uncertainties. A selection of comments made by users:

- "*People like easy to use data format that includes all, but also want an acceptable data volume. Globtemp has split in core file and aux file for different uses.*"
- "*FCDR clean from overlaps.*"
- "*Clear documentation on what was done to produce the FCDR, complete information, full chain.*"
- "*Prefer a complete orbit with filler values for missing data, than an incomplete orbit.*"
- "*Standard names. ESA does this well, big help. Great help that data moved to NetCDF, although SAR data remains in ESA format and little push from community.*"
- "*Should be enough information to read the data (well-documented), structure of binary file. For users, the more information the better. Would like to have information even if you don't need it now, because might need it in the future.*"
- "*NetCDF/HDF would be good (was not case for SCIAMACHY). Currently files are huge. Should be two versions of the product: a small version suitable for many users who can't download and store terabytes; one for power users who need additional information.*"
- "*Depends on user. Some users want lowest data possible like L-0 is L-1a, does not need to be in NetCDF. Not able to recommend. Important that all relevant information is included in raw data. Format issue is more important for higher level data. No big need to reformat low level data.*"
- "*FCDR do not need to repeat the original data, we already have the original data (uncalibrated L1.5). What we need is very small NetCDF files with only intercalibration factors, to apply the transformation on the original data ourselves. We do not want to download terabytes again.*"
- "*Access to radiance, time of acquisition, sun and viewing angles. Should be in something like NetCDF. FIDUCEO will do this.*"

9.2. FIDUCEO requirements

Table 24: FIDUCEO requirements from questions on formats

no.	Requirement	Comment
FIDUCEO-35	FCDR should be contained in NetCDF with CF-compliant names, and should be self-describing.	Noted by many.
FIDUCEO-36	The FCDR should come with full and quantitative documentation on how the FCDR was produced.	This is additional to the User's Guide. The User's Guide contains information relevant for people using the FCDR, but additional inform- ation is needed for people seeking to reproduce the FCDR production.
FIDUCEO-37	FCDRs should include all feasible telemetry information and metadata that are potentially relevant to FCDR applications.	Users might need this metadata in the future. Files will be very large, some metadata may be in auxiliary files. This could include instrument telemetry of potential relevance to instrumental behavior, even where there is no calibration impact currently known.
FIDUCEO-38	Distribution of FCDR data should accom- modate users who cannot deal with full data volume.	Truly achieving this level of detail entails considerable effort and is costly. Balanced against this is the fact that FCDRs are a critical legacy. of environmental information.
FIDUCEO-39	FCDR data and documentation should contain sufficient information for replication, in a single location.	

Requirements derived from questions on file formats are shown in Table 24.

10. Final user remarks

10.1. Survey results

A subset of survey participants use FCDRs that will be produced in the FIDUCEO project. FIDUCEO is looking for trailblazer ("beta") users. Table 25 shows that a majority of interviewees is willing to be a trailblazer user to aid FIDUCEO by testing early versions of FCDRs.

Table 25: Question 110: Are you available to be a trailblazer user?

Answer	Count
Yes	9
No	5

Closing the interview, survey participants had the opportunity to give some final comments on issues that were not considered in the survey.

- "*Currently satellite data at much higher spatial resolution than climate models, but this difference is getting smaller as regional climate models are moving down to km-scale.*"
- "*We would like an as complete HIRS dataset as possible, from 1978 to 2016.*"
- "*Need to discriminate between climate mission and the use of existing data like AVHRR or MVIRI trying to use for climate.*"
- "*Important is to have confidence in the uncertainty and for the user to use this.*"

10.2. FIDUCEO requirements

Table 26: FIDUCEO requirements from final comments

no.	Requirement	Comment
FIDUCEO-40	FCDR producers should validate the provided uncertainty information.	

Table 26 shows user requirements derived from final comments in this section.

11 List of all FIDUCEO requirements

FIDUCEO-1 Fundamental Climate data Records (FCDRs) should contain information to assist producers of Climate Data Records (CDRs) and other derived geophysical products to estimate uncertainty and provide traceability information required by their users.

FIDUCEO-2 FCDR producers should provide documented advice on how their FCDRs enable generation of uncertainty and traceability information in CDRs derived from them.

FIDUCEO-3 The uncertainty model used to create uncertainty information included in FCDRs must be characterised and clearly documented.

FIDUCEO-4 FCDR uncertainty information must include a description of error correlations sufficient for CDR producers to account for error correlations propagated from the FCDR in their CDR.

FIDUCEO-5 FCDR products should be provided with a product user guide. This should include an explanation of the origin and use of traceable uncertainties.

FIDUCEO-6 FCDR documentation should make use of standard metrological definitions of uncertainty vocabulary in order to maximise clarity.

FIDUCEO-7 To support provision of comparable uncertainty information in derived products, FCDRs should either (i) include uncertainty estimates separated into compon- ents having distinct error correlation structures, or (ii) be represented as an FCDR ensemble, where this is the more feasible and valid approach.

FIDUCEO-8 FCDRs and documentation should support CDR creators to assess the expected performance of derived CDRs against quantitative requirements, such as those of Global Climate Observing System (GCOS)

FIDUCEO-9 FCDR products should enable CDR producers to generate a variety of forms of uncertainty information required by CDR users.

FIDUCEO-10 FCDRs should include pixel-level uncertainties in cases where there is variation in the uncertainty at FCDR pixel level, since some CDR producers require to produce pixel-level uncertainty information.

FIDUCEO-11 (duplicate, therefore number removed)

FIDUCEO-12 FCDR products should be readily accessible.

FIDUCEO-13 Data should be easy to read and formats should be well-documented.

FIDUCEO-14 FCDR products should include all necessary and established systematic corrections (such as due to calibration), rather than require CDR producers to apply additional corrections.

FIDUCEO-15 FCDR products should not include any duplications of data.

FIDUCEO-16 FCDR products should flag all corrupted data, including missing scanlines.

FIDUCEO-17 FCDR products should have complete and correct metadata.

FIDUCEO-18 All known and established corrections for timing, geolocation, and viewing geometry of pixels should be applied in the FCDR record and described in associated documentation. Associated uncertainties should also be included or described.

FIDUCEO-19 FCDR products should be quality-controlled at pixel, scan-line, and orbit-file level to minimise errors in calibration, geolocation, and data.

FIDUCEO-20 Uncertainty information in FCDRs should have a basis published in peer-reviewed literature to build the confidence any FCDR needs.

FIDUCEO-21 Uncertainty and stability information in FCDRs should encapsulate and apply understanding of instrument behaviour.

FIDUCEO-22 FCDRs should contain well-documented information about stability.

FIDUCEO-23 FCDR producers should make use of available historical monitoring information, including instrumental and non-instrumental events.

FIDUCEO-24 FCDR uncertainties should include an estimate of the radiometric/calibration uncertainty/channel instrument noise based on in-space measurements.

FIDUCEO-25 FCDR uncertainty information should include a detailed breakdown of the uncertainty budget, i.e. a quantified contribution for each known source of error.

FIDUCEO-26 FCDR product documentation should include a characterisation of uncertainty in spectral response functions so FCDR users can use this in their radiative transfer modelling.

FIDUCEO-27 FCDR should characterise across-scan bias / scan asymmetry, where relevant.

FIDUCEO-28 Instrumental drift, step and trend artefacts should be minimized in FCDR products.

FIDUCEO-29 Stability information should be provided in an easy to use format.

FIDUCEO-30 FCDR documentation should explain how the FCDR stability is presented in the FCDR, and give guidance on how to infer CDR-level stability from FCDR stability information.

FIDUCEO-31 Relevant information in pre-launch data should be used to produce an FCDR such that FCDR users do not need to worry about pre-launch data.

FIDUCEO-32 FCDR producers should facilitate access to pre-launch data or other instrumental characterisations used in generating their FCDRs that are relevant to development of derived geophysical products.

FIDUCEO-33 Historic FCDR data should be reprocessed when definitions and formats are changed for data from newer missions so that a consistent archive is available.

FIDUCEO-34 FCDR producers need to clearly explain what form of harmonisation has been applied, and give uncertainty estimates for harmonisation.

FIDUCEO-35 FCDR should be contained in NetCDF with CF-compliant names, and should be self-describing.

FIDUCEO-36 The FCDR should come with full and quantitative documentation on how the FCDR was produced.

FIDUCEO-37 FCDRs should include all feasible telemetry information and metadata that are potentially relevant to FCDR applications.

FIDUCEO-38 Distribution of FCDR data should accommodate users who cannot deal with full data volume.

FIDUCEO-39 FCDR data and documentation should contain sufficient information for replication in a single location.

FIDUCEO-40 FCDR producers should validate the provided uncertainty information.

A. Implications for specific sensors

Some users quantified numbers and suggestions that may be relevant only for particular FCDRs and specific sensors. These are listed below, for completeness, but are not included in the generic list of requirements.

- AVHRR GAC PRT measurement sequence needs to be checked.
- HIRS needs to be more stable than 0.2 K/decade for the production of CTH.
- HIRS needs to be more stable than 0.05 K/decade for the production of SST.
- AMSU needs to be more stable than 0.1 K/decade for the production of UTH.
- AVHRR harmonisation should be better than 50 mK/decade.
- AVHRR harmonisation should be better than 1 %, according to an “educated guess” by an AVHRR user.
- AMSU harmonisation should be better than 0.1 K
- FCDR for HIRS should consider changes in SRFs.
- FCDR for HIRS should consider changes due to bad/incorrect ground calibration.
- MVIRI needs a harmonisation tested against requirements. Existing EUMETSAT initiative based on HIRS reference is untested against requirements.

B. Requirements not included with FIDUCEO

Some requirements are relevant and on-topic for FIDUCEO, but are in their application inconsistent with the metrological approach that FIDUCEO takes. A selection of such requirements is listed in Table 27. Most are related to the difference between harmonisation and homogenisation.

Table 27: Deferred requirements

Requirement	Comment
Harmonisation should include a conversion to a sensor-invariant sensor response function.	This was noted in relation to MVIRI, but may apply more broadly. This requirement is out of scope for FIDUCEO, because if the same channel on subsequent sensors is different, the FCDR radiances should be different. FIDUCEO will clearly document those differences and it is up to the CDR producer to include this information in their processing, such that no differences are observed at the CDR level.
FCDR user should not see the switch between satellites, apart from a possible LTAN switch.	
Instrument differences should be smaller than their uncertainties.	Noted in relation to AMSU. This requirement cannot be met if the actual spectral response shift causes larger differences.
Harmonisation should include classical radiance intercalibration.	Noted in relation to MVIRI. However, classical radiance intercalibration tends to be homogenisation, not harmonisation, and may not take care of the causes of radiance differences.
FIDUCEO should adjust for satellite drift.	The desire has been mentioned for an FCDR where orbital drift has been corrected. FIDUCEO will calculate the correct geolocation and associated uncertainties, but will not attempt to correct radiances to a different time/location for either GEO or LEO satellites. If orbit-related artefacts are minimized at FCDR level, the appropriate stage for adjustment is arguably at the point of CDR generation.

C. Full survey

The full survey is attached in the following pages. Within the survey, questions 1832 are repeated six times, corresponding to up to six answers in question 16. The repeated questions are omitted from this document. Therefore, question 32 is followed by question 108.

Welcome to this structured questionnaire from the FIDUCEO project

You are being interviewed on your experiences and requirements as a user of "Level 1" satellite data for climate applications.

"Level 1" data are usually defined as calibrated radiances (or equivalent, such as brightness temperature) obtained by satellite-borne sensors, with time and geolocation information for each observation.

Where L1 data cover a time scale relevant to climate applications, and are thought to have applications that are informative about climatic variability and change, they may be referred to as Fundamental Climate Data Records (FCDRs). From FCDRs, specialist users are able to generate (Thematic) Climate Data Records (CDRs). In the context of the EU Horizon 2020 project FIDUCEO, we are interested in the experiences and requirements of such specialist users.

FIDUCEO stands for Fidelity and Uncertainty in Climate Data Records from Earth Observation. The project kicked-off in March 2015. Within the project, we will create new FCDRs and CDRs using metrological principles. However, for the purpose of this interview, we are interested in your experiences and requirements with any level 1 data you use to generate geophysical data relevant to climate, either covered by FIDUCEO or not.

General information about you

These questions are to help us put your interest in and use of FCDRs in context

1. Address

Name

Institution

City/Town

Country

Email Address

2. Which term best describes the institution/company for which you use FCDRs?

- ○ University
- ○ National research institute
- ○ International research institute
- ○ National agency (weather/climate/environment)
- ○ Private company
- ○ Other (please specify)

3. How much of your role, or that of the group which you lead, involves working with L1/FCDR satellite measurements?

- ☐ Major focus on FCDR data themselves
- ☐ Major focus on deriving information from FCDR data / working a lot with FCDR data
- ☐ Major focus not on FCDR data, but we work a little with FCDR data in our application

4. Additional comments / explanation

What climate data record you produce / develop

This page asks about the nature of the climate data record (CDR) you produce / develop. If you produce more than one different CDR, the interviewer will start a new survey for the second and any subsequent CDRs. Treat a set of related variables derived jointly from a common set of L1/FCDR inputs for the same locations as a single CDR.

5. What is (are) the geophysical variable(s) in your CDR? We will mainly explore requirements in relation to the primary variable in your products.

Primary	
Secondary	
Tertiary	

The following questions should be answered in relation to the primary geophysical variable. Recall that by CDR users, we mean specifically people and institutes who use the product for studying climate, such as addressed by the GCOS Systematic Observation Requirements for Satellite-based Products for Climate.

6. Please state or estimate user requirements for your CDR (primary variable), if relevant (otherwise, indicate later why not).

Uncertainty (random effects)	
Uncertainty (systematic effects)	
Long-term stability	
Spatial resolution	
Temporal resolution	
Timeliness (climate applications)	
Length of record	

7. On what statement of requirements are the above based?

8. Please elaborate on any of the above, and add other user requirements not addressed above

9. Please state the (estimated) achievement against these requirements. If there are differences between historic, recent, or upcoming data, please indicate this.

Uncertainty (random effects)

Uncertainty (systematic effects)

Long-term stability

Spatial resolution

Temporal resolution

Timeliness (climate applications)

Length of record

10. Where requirements are not achievable, comment on whether this is fundamentally due to limitations of the sensor series used. Note that we will discuss sensor and data issues in detail later.

Uncertainty information in your CDR

11. What form(s) of uncertainty information about your CDR (primary variable) do you provide to users? (All that apply.)

- ☐ Generic statement of total uncertainty
- ☐ Characterisation of total uncertainty (e.g., uncertainty maps, dependencies)
- ☐ Pixel / cell total uncertainty (context sensitive)
- ☐ Breakdown of uncertainty components
- ☐ Flags for "doubtful" pixels / cells
- ☐ Information about stability
- ☐ Information about consistency between sensors in a series (if applicable)

Comments / explanations

12. Do you use FCDR uncertainty information (from L1 data or from another source) to inform uncertainty information in the CDR?

- ☐ Yes, quantitatively by error propagation at pixel level
- ☐ Yes, quantitatively by error propagation for typical cases
- ☐ Yes, quantitatively by error propagation for a generic case
- ☐ Yes, via flags
- ☐ Yes, quantitatively but not through error propagation
- ☐ No

Comments / explanations

13. Different effects lead to errors with a range of degrees of correlation between L1/FCDR radiances, with different spatio-temporal correlation scales, different strengths of correlation between wavelengths, etc. Do you account for error correlations (including locally systematic effects) in your CDR?

What data you work with

14. What type(s) of L1/FCDR data do you use to produce your CDR? (Mark all that apply.)

- [ ] Visible reflectance
- [ ] Near-infrared reflectance
- [ ] Thermal (<15 µm) infra-red broadband
- [ ] Thermal infra-red hyperspectral
- [ ] Far infra-red (>15 µm)
- [ ] Microwave
- [ ] Active (laser)
- [ ] Active (radar)
- [ ] Other (please specify)

15. From what type(s) of platform are your L1 data observed? (Mark all that apply.)

- [ ] LEO / polar orbiter
- [ ] GEO / geostationary
- [ ] Other low orbits (e.g., space station)
- [ ] Other (please specify)

16. Please list each sensor (or sensor series) whose L1/FCDR data you use for ONE particular CDR you produce / develop.

1.
2.
3.
4.
5.
6.

17. Additional comments / explanation

Further information on sensor (series) 1

If you entered a value for box 1 in question 16, please fill this page in relation to that answer.

18. Name of sensor (or sensor series)

19. How do/did you obtain the data?

20. How easy or difficult was it to obtain the data?

Very easy	Quite easy	Moderately difficult	Quite difficult	Very difficult
○	○	○	○	○

Please elaborate.

21. How easy or difficult was it to read the data?

Very easy	Quite easy	Moderately difficult	Quite difficult	Very difficult
○	○	○	○	○

Please elaborate. For example, consider if reading routines were available and if documentation was adequate.

22. Did you encounter any of the following problems with the data from this sensor (series)?

- [ ] Significant missing data / data gaps
- [ ] Duplicated data
- [ ] Corrupted or suspect data
- [ ] Incomplete or incorrect metadata / headers
- [ ] Problems with geolocation
- [ ] Problems with poor calibration

Please elaborate on the answer(s) above

23. What form(s) of uncertainty information about the input FCDR radiances are available from the FCDR provider?

- [ ] Generic statement of total uncertainty
- [ ] Characterisation of total uncertainty (e.g., uncertainty maps, dependencies)
- [ ] Pixel / cell total uncertainty (context sensitive)
- [ ] Breakdown of uncertainty components
- [ ] Flags for "doubtful" pixels / cells
- [ ] Information about stability
- [ ] Information about consistency between sensors in a series (if applicable)

Comments / explanations

24. Do you trust uncertainties reported in the FCDR?

No, not at all	No, not really	Somewhat	Yes, mostly	Yes, completely	Not applicable
○	○	○	○	○	○

If you do not, what do you do to compensate for this, if anything?

25. Please describe any L1/FCDR uncertainty information that you could use in CDR development / production, but that is unavailable in your input data.

26. Describe what, if any, information is provided with L1/FCDR data about temporal stability. ('With the data" includes provision of information in reports and papers linked explicitly to the dataset repository.)

27. What is the stability requirement for L1/FCDR radiances that corresponds to your CDR stability requirement? (Please describe how this is calculated.)

28. Do you have access to unprocessed pre-launch data?

- ○ Yes
- ○ No

Please elaborate.

29. What (if any) unprocessed pre-launch data could you use that you do not already have?

The next three questions are only applicable if you used different copies of (nearly) the same sensor on different platforms. By “harmonisation”, we mean an attempt to make sure that a data record made up of multiple sensors has had artefacts removed as much as possible, and that information from one sensor is consistent with information from another sensor. Forcing data from different sensors to be the same without understanding where differences are coming from is not harmonisation.

30. Are you aware of any measures taken to harmonise the L1/FCDR radiances you use?

31. Does absence of L1/FCDR harmonisation lead to discontinuity (or the need to make adjustments) in your CDR?

32. Please state / describe your requirements for L1/FCDR harmonisation to aid your CDR.

Final questions

108. Other than L1/FCDR radiance uncertainty, what forms of uncertainty are significant for your CDR? (E.g., geolocation effects, classification errors...)

109. Please describe any requirements related to L1/FCDR product formats. These may include, for example: file format type, use of standard names, and information (such as variables) that should be included.

By spring 2017, we will deliver FCDRs for AVHRR, HIRS, MVIRI, SSM/T2, AMSU-B, and MHS. Prior to that, we will have trial versions of FCDRs. We are looking for people who are willing to be trailblazer users, i.e. to use and provide feedback on FCDRs before the first full version of the FCDRs are published.

110. Are you available to be a trailblazer user?

- ◯ Yes
- ◯ No

THANK YOU FOR YOUR HELP WITH THIS SURVEY

111. Please note any final comments here