Product user guide – HIRS FCDR release 1.0

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1 Contents

2 Introduction

2.1 Scope

This document describes the v1.0 HIRS "easy" FCDR data files released in the autumn of 2019. The released data record contains nearly 40 years of data and can be considered the initial version of the FCDR, i.e. a data record long enough to generate climate data records (CDRs) for climate research. This guide gives:

1. An overview of the specifications of the data record;
2. Scientific records on the generation, definition, and algorithms of the data record;
3. Information on limitations of the current version of the data record;
4. Technical details on the format and on how to access the data.

2.2 Version Control

Version	Reason	Reviewer	Date of Issue
0.1	Initial pre-Beta version		Autumn 2017
1.0	Release of FCDR	JM	August 2019

2.3 Applicable and Reference Documents

- FIDUCEO website, http://www.fiduceo.eu/
- D2-2, Report on the HIRS FCDR: Uncertainty (contact fiduceo-coordinator@lists.reading.ac.uk)
- D2-2a, Principles of FCDR Effects Tables (contact fiduceo-coordinator@lists.reading.ac.uk)
- CF-standards version 1.7, http://cfconventions.org/Data/cf-conventions/cf-conventions-1.7/cf-conventions.html

2.4 Glossary

BT	Brightness Temperature
CPIDS	Calibration Parameters Instrument Data Set
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FCDR	Fundamental Climate Data Record
FIDUCEO	Fidelity and Uncertainty in Climate data records for Earth Observation
FOV	Field Of View
HIRS	High-resolution Infrared Radiation Sounder
IASI	Infrared Atmospheric Sounding Interferometer
ICCT	Internal Cold Calibration Target
IWCT	Internal Warm Calibration Target
NCC	National Calibration Center
NESDIS	National Environmental Satellite, Data, and Information Service
NOAA	National Oceanic and Atmospheric Administration
PRT	Platinum Resistance Thermometer
SNO	Simultaneous Nadir Observation
SRF	Spectral Response Function
STAR	Center for Satellite Applications and Research
TIROS	Television Infra-Red Observation Satellite
CEDA	Centre for Environmental Data Archiving

CLASS	Comprehensive Large-Array Stewardship System
CF	Climate and Forecast
FTP	File Transfer Protocol

3 FCDR overview characteristics

General	FCDR name	FIDUCEO FCDR HIRS Brightness Temperatures with uncertainties (harmonised)
	FCDR reference	Papers in preparation
	FCDR digital identifier(s)	DOI to be issued later
	FCDR description	Recalibrated brightness temperatures for HIRS for all editions of HIRS/2, HIRS/2I, HIRS/3, and HIRS/4, with metrologically traceable uncertainty estimates. This version is harmonised and anchored to IASI via MetopA.
	FCDR type	HIRS FCDR
	FCDR period	1985-03-10—2016-12-31 (1978-10-31—1980-01-20 as bonus)
	FCDR satellites	• NOAA-9 • NOAA-10 • NOAA-11 • NOAA-12 • NOAA-14 • NOAA-15 • NOAA-16 • NOAA-17 • NOAA-18 • NOAA-19 • MetOp-A • MetOp-B
	FCDR content	Brightness temperatures and uncertainties generated with FCDR_HIRS version 1.00.
In	Instrument name	High-resolution Infrared Radiation Sounder (HIRS)

	Instrument description	HIRS is a scanning radiometer. It scans the Earth in 56 Earth views per scan line. At each view, it stops to rapidly scan 20 channels by rotating a filter wheel, through which the radiation falls on any of three detectors. The channel suite consists of twelve longwave channels using a HgCdTe detector (6.52—14.95 μm), seven shortwave channels with a InSb detector (3.76—4.57 μm), and one visible channel. An overview of the channels is given later.

Data	Input data	• Core input data are L1B data files obtained from the NOAA CLASS archive. • Spectral response functions are obtained from NOAA NESDIS STAR • PRT coefficients are obtained from CPIDS and also provided by NOAA
	Output data	HIRS "easy" FCDR including brightness temperatures and uncertainties split into random and nonrandom components Each HIRS Easy FCDR file contains: • Basic telemetry: longitude, latitude, time, satellite and solar angles; • Brightness temperatures for channels 1--19; • Independent and structured uncertainty for channels 1--19; • A lookup table to convert between radiances and brightness temperatures for channels 1—19; • A channel error correlation matrix; • Two bitfields indicating identified problems with the data. For any data field that varies across the channels (such as brightness temperatures and their uncertainties), channel is a dimension in addition to scan position (x) and scanline (y).
	Format	The data are provided in NetCDF4 format and comply with the CF standards version 1.7, where possible.
Access	CEDA	The data are hosted by CEDA. The pre-beta version is available on request by contacting the FIDUCEO team at fiduceo-coordinator@lists.reading.ac.uk
	Delivery	Available through CEDA by FTP
Resolution	Horizontal	Footprint size varies from 10 km at nadir for NOAA-15 onwards to 68x35 km^2 for NOAA-14 and before at the edge of the scan. Footprints are not contiguous but significant gaps exist.
	Vertical	Surface and sounding channels, resolution depends on atmospheric state

	Temporal	Polar-orbiting ; most places seen at least daily but less frequently at same angle
Physical Content	FCDR physical quantity	The core physical quantity consists of Planck Brightness Temperatures for each channel for each Earth view. Associated information stored in the same files are latitudes, longitudes, independent uncertainties, and structured uncertainties. A Full FCDR will be released later and will contain, among other things, a more detailed breakdown of the uncertainties.
	FCDR physical description	The data are distributed as one file per orbit, with a total of 569560 files. Total size per satellite is: NOAA-9 8.3 GB, NOAA-10 6.9 GB, NOAA-11 26 GB, NOAA-12 23 GB, NOAA-14 40 GB, NOAA-15 63 GB, NOAA-16 97 GB, NOAA-17 34 GB, NOAA-18 43 GB, NOAA-19 38 GB, MetOp-A 49 GB, MetOp-B 97 GB.
Uncertainty target	Accuracy	Metrologically traceable uncertainties provided for each measurement.
	Precision	BTs and their uncertainties are stored with a precision of 0.01K.
	Stability	See D4.6 HIRS section
	Known problems	Please see the appendix for detailed information on known problems.
Data record characteristics	The data record is continuous, with most of the time several satellites operational at the same time.	

4 Description of HIRS

HIRS is a passive infrared radiometer with 20 channels measuring in the infrared and visible. The first edition was launched on-board NIMBUS-6 in 1975. The first edition covered by the FIDUCEO HIRS FCDR is HIRS/2, launched on TIROS-N in 1978. However, data for 1978—1981 is provided only on a best-effort basis, and the actual FIDUCEO deliverable only covers 1982—2016, and thus starts with NOAA-6. See Table 1 for an overview of HIRS instruments covered by FIDUCEO.

Table 1: HIRS editions covered by FIDUCEO

Generation	Satellite	Start	End
HIRS/2	TIROS-N	1978-10-30	1980-01-20
HIRS/2	NOAA-6/A	1979-06-30	1983-03-05
HIRS/2	NOAA-7/C	1981-08-31	1985-02-01
HIRS/2	NOAA-8/E	1983-05-10	1985-10-13
HIRS/2	NOAA-9/F	1985-02-28	1988-11-06
HIRS/2	NOAA-10/G	1986-11-30	1991-09-16
HIRS/2I	NOAA-11/H	1988-11-11	1998-12-30
HIRS/2	NOAA-12/D	1991-09-20	1998-12-14
-	NOAA-13	Launch failure	
HIRS/2I	NOAA-14/J	1995-01-18	2006-10-09
HIRS/3	NOAA-15/K	1999-01-01	2017-11-08
HIRS/3	NOAA-16/L	2001-01-01	2014-06-05
HIRS/3	NOAA-17/M	2002-07-10	2013-04-09
HIRS/4	NOAA-18/N	2005-06-05	2018-08-30
HIRS/4	NOAA-19/N’	2009-04-01	2018-05-30
HIRS/4	MetOp-A	2006-11-30	2018-05-30
HIRS/4	MetOp-B	2013-01-20	2018-05-30

Note that this table corresponds to “theoretical” instrument lifetime and current HIRS FCDR data availability is more limited for several reasons, some of which are covered in the appendix.

The 20 channels of HIRS consist of 19 infrared channels, including 12 using an HgCdTe detector and 7 using an InSb detector. Channel 20 is a visible channel and not processed by FIDUCEO. Table 2 contains an overview of the channels covered by HIRS.

Table 2: Overview of HIRS channels.

Channel	Wavelength [μm]	Detector	Notes
1	14.95	HgCdTe	
2	14.70	HgCdTe	
3	14.47	HgCdTe	
4	14.21	HgCdTe	
5	13.95	HgCdTe	
6	13.65	HgCdTe	
7	13.34	HgCdTe	
8	11.11	HgCdTe	
9	9.71	HgCdTe	
10	8.2 / 12.47	HgCdTe	HIRS-2 / rest
11	7.33	HgCdTe	
12	6.7 / 6.52	HgCdTe	HIRS-2 / rest
13	4.57	InSb	
14	4.52	InSb	
15	4.67	InSb	
16	4.42	InSb	
17	4.18	InSb	
18	3.97	InSb	
19	3.76	InSb	
20	0.69	Si	

The FCDR of recalibrated IR radiances and metrologically traceable uncertainties corresponds to Task 4.1 in the Horizon-2020 project FIDUCEO (see http://www.fiduceo.eu).

5 Differences with existing products

The FIDUCEO HIRS FCDR differs in various ways from existing HIRS level-1 data, such as processed by NOAA or EUMETSAT:

- The calibration has been improved with a measurement function approach, including an improved self-emission model;
- metrologically traceable uncertainties have been derived.
- The HIRS FCDR has been harmonised, ensuring that all HIRS sensors are calibrated consistently to a common reference (in this case, IASI)

6 Calibration and uncertainty approach[1]

The HIRS FCDR is built on the measurement function which calculates the Earth Radiance L_{E} from the Earth Count C_{E}. A correction is made for the instrument self-emission radiance in Earth view, $L_{\mathrm{self,E}}$, which is a function of the instrument temperature, T_{inst} and an offset correction is determined from the averaged space view counts during the calibration cycle, $\bar{C}_{\mathrm{S}}$. T_{inst} is estimated for every scanline. The measurement function is

$$L_{\mathrm{E}} = \alpha\left(C_{\mathrm{E}} - \bar{C}_{\mathrm{S}}\right) + a_1\left(C_{\mathrm{E}}^2 - \bar{C}_{\mathrm{S}}^2\right) - \left(L_{\mathrm{self,E}}\left(T_{\mathrm{inst}}\right) - L_{\mathrm{self,S}}\left(T_{\mathrm{inst}}\right)\right) + a_3 + 0. \quad \text{Eq 6-1}$$

The 0 term represents the assumption that this form of the equation is valid and, for example, that there are no higher order nonlinearities. The nonlinearity coefficient a_1 and offset a_3 are coefficients to be determined during harmonisation to a reference sensor.

The gain term is determined from the calibration cycle measurements of the IWCT and space views, as

$$\alpha = -\frac{\tilde{L}_{\mathrm{IWCT}} + L_{\mathrm{self,IWCT}}\left(T_{\mathrm{inst}}\right) - L_{\mathrm{self,S}}\left(T_{\mathrm{inst}}\right) - a_1\left(\bar{C}_{\mathrm{IWCT}}^2 - \bar{C}_{\mathrm{S}}^2\right)}{\bar{C}_{\mathrm{IWCT}} - \bar{C}_{\mathrm{S}}}. \quad \text{Eq 6-2}$$

where, $\tilde{L}_{\mathrm{IWCT}}$ is the band-integrated IWCT radiance, $L_{\mathrm{self,IWCT}}$ is the self-emission radiance when viewing the IWCT, $L_{\mathrm{self,S}}\left(T_{\mathrm{inst}}\right)$ is the self-emission radiance when viewing space and $\bar{C}_{\mathrm{IWCT}}, \bar{C}_{\mathrm{S}}$ are the measured counts when viewing the IWCT and space respectively, averaged over the different individual measurements in the calibration cycle. Space and IWCT counts are updated every calibration cycle (40 scanlines).

The band-integrated IWCT radiance is conceptually[2] given by

$$\tilde{L}_{\mathrm{IWCT}} = \int\left(\left(\varepsilon_{ch} + a_2\right)L_{\mathrm{BB}}\left(\lambda, T_{\mathrm{IWCT}}\right) + \left(1 - \varepsilon_{ch} - a_2\right)L_{\mathrm{refl}}\left(\lambda\right)\right)\xi_{ch}\left(\lambda\right)\mathrm{d}\lambda + 0. \quad \text{Eq 6-3}$$

[1] This section is mostly copied from D2-2

[2] At present the band-integrated IWCT radiance is calculated according to Eq. 6-5.

where, $\varepsilon\left(\lambda_{ch,\mathrm{c}}, T_{\mathrm{IWCT}}\right)$ is the emissivity of the IWCT (stated by Wang, Cao, and Ciren (2007) to be 0.98), a_2 is a correction to this tabulated emissivity that is determined through harmonisation and $\xi_{ch}(\lambda)$ is the normalised spectral response function. Although physically, ε may be expected to change as a function of temperature or wavelength, we assume constant emissivity within each channel; any deviation should be encompassed in the uncertainty associated with a_2, which can differ per channel. The IWCT radiance is given by Planck's law,

$$L_{\mathrm{BB}}\left(\lambda, T_{\mathrm{IWCT}}\right)=c_{1,L} \Big/ \left(\lambda^5\left(\exp\left[c_2 / \lambda T_{\mathrm{IWCT}}\right]\right)-1\right), \qquad \textit{Eq 6-4}$$

Where $c_{1,L}=2hc^2$ is the first radiation constant for radiance, and $c_2=hc/k_{\mathrm{B}}$ is the second radiation constant. The term L_{refl} is the radiance reflected by the IWCT from other sources, which needs to be modelled with the details yet to be determined (this may be part of the harmonisation); in the present version it is set to zero. In practice this integral is calculated from discrete values of the spectral response function using the trapezium rule. The +0 term represents the extent to which that calculation does not represent the true band-integrated radiance, for example due to the numerical determination of the integral.

As a temporary measure in the present version, the band-integrated IWCT radiance is approximated using band coefficients, to ease the propagation of uncertainties:

$$\tilde{L}_{\mathrm{IWCT}}=\left(\varepsilon_{ch}+a_2\right) L_{\mathrm{BB}}\left(\lambda_{\mathrm{eff},ch}, c_{\mathrm{a},ch}+c_{\mathrm{b},ch} T_{\mathrm{IWCT}}\right)+\left(1-\varepsilon_{ch}-a_2\right) L_{\mathrm{refl}}\left(\lambda_{\mathrm{eff},ch}\right) \qquad \textit{Eq 6-5}$$

where the temperature corrections, $c_{\mathrm{a},ch}, c_{\mathrm{b},ch}$ and effective wavelength, $\lambda_{\mathrm{eff},ch}$ are determined from the SRF by a fitting process.

The temperature of the IWCT is calculated from a simple mean of the temperatures obtained from N platinum resistance thermometers (PRTs) mounted on the IWCT. N is 4 for HIRS/2 and HIRS/3, and N is 5 for HIRS/4. The PRTs measure a count which is converted to temperature using a calibration equation expressed as a fifth order polynomial. The calibration coefficients for the PRTs were determined prelaunch through comparison with a more accurate thermometer at different temperatures.

The self-emission radiances given in *Eq 6-1* and *Eq 6-2* for the Earth, Space and IWCT views ($v=$ E,S,IWCT respectively) are in principle determined by

$$L_{\mathrm{self},v}\left(T_{\mathrm{inst}}\right)=\sum_i\left[\Omega_{v,i} \int \xi_{ch}(\lambda)\, \varepsilon_i\left(\lambda_{ch,\mathrm{c}}, T_i\right) L_{\mathrm{BB}}\left(\lambda, T_i\right) \mathrm{d}\lambda\right]+0 . \qquad \textit{Eq 6-6}$$

where the sum is performed over different […] components i, which have a field of view $\Omega_{v,i}$ in that view and an emissivity at the channel wavelength of $\varepsilon_i\left(\lambda_{ch,\mathrm{c}}, T_i\right)$ and a temperature T_i and are treated as grey-bodies, using the Planck equation multiplied by an emissivity. However, in practice we have insufficient information to determine all the view factors, and not all components in the field of view have their temperatures measured. In practice, the self-emission is currently estimated with:

$$L_{\mathrm{self},y}=\sum_i k_i T_i^4+0 . \qquad \textit{Eq 6-7}$$

where i refers to different temperatures, currently the baseplate, internal warm calibration target, scanmirror, scanmotor, and secondary telescope. The coefficients are trained using linear regression in a moving 24-hour window and updated every 6 hours.

The $+0$ term accounts for the assumptions implicit in this simplified model.

6.1 Measurement Function Diagram

Figure 1 illustrates the measurement function diagram for HIRS, with the sources of uncertainty at the end. Note that some details are still subject to change.

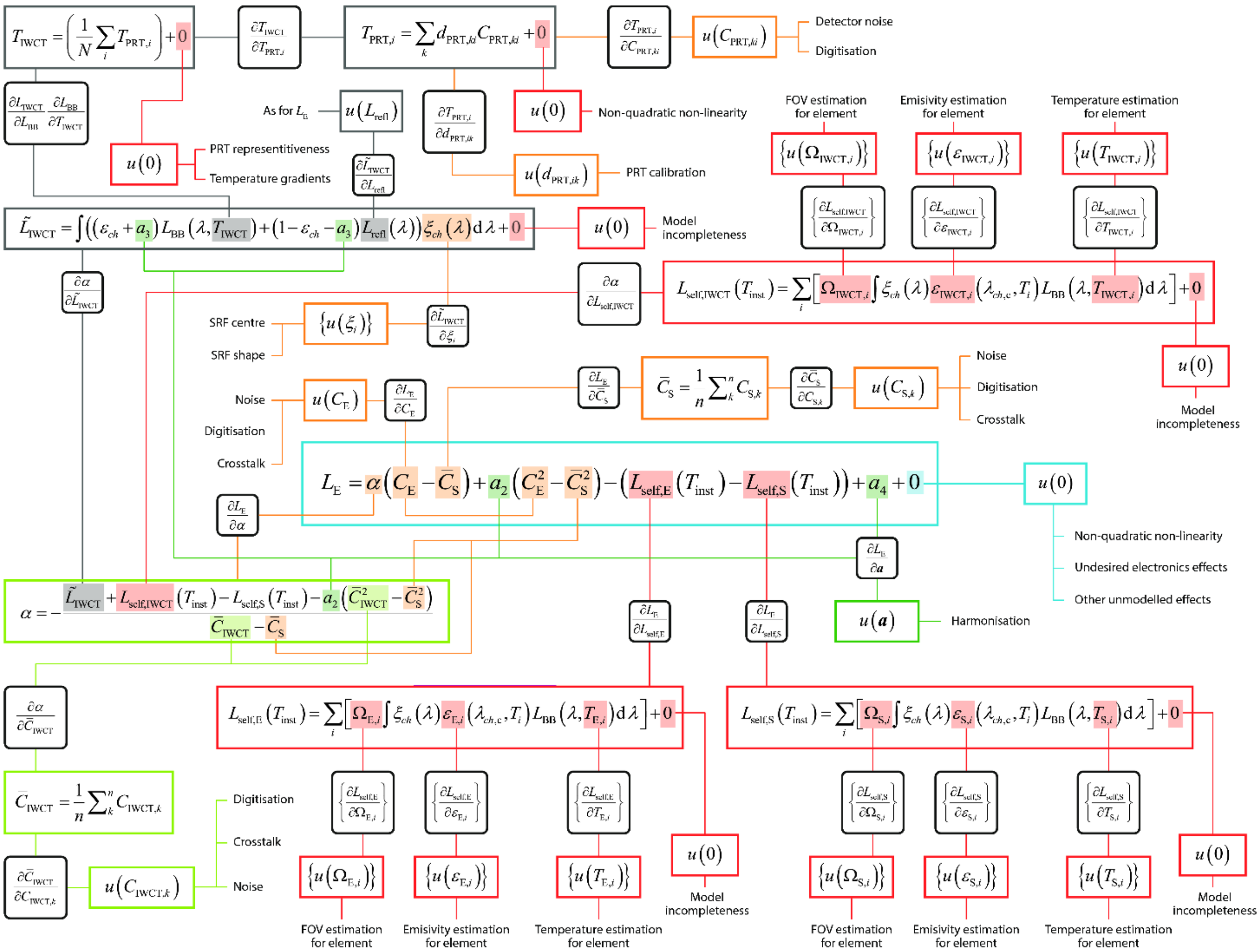

Figure 1: Measurement function diagram (preliminary version)

6.2 Self-emission

The HIRS optical train and detector are not cooled. Therefore, any measurement is contaminated by large amounts of self-emission, such as indicated in the measurement function. If this self-emission were constant, it would be cancelled out due to calibration. Self-emission does vary as a function of instrument temperature (as one would expect), in particular on an orbital timescale. Self-emission also leads to variations in the gain, because of the non-linear response of the detector. Although this is corrected for by the calibration, those calibrations are too infrequent and a model is needed to estimate self-emission between the calibrations.

To estimate self-emission perfectly, one would need to know the temperature, emissivity, and solid angle, for all components directly visible by the detector. One would additionally need to know how any other radiation is reflected onto the detector. This would require substantially more information both before launch and in-orbit than is actually being measured. Therefore, self-emission is approximated as shown in Eq. 6-7.

HIRS reports temperatures for the following components:

- Patch
- Filter wheel motor
- Scan motor
- Internal warm calibration target
- Internal cold calibration target (HIRS/2 only)
- Primary telescope
- Secondary telescope
- Tertiary telescope (HIRS/4 only)
- Electronics
- Baseplate
- Scan mirror

Although this is not enough to make a complete model of self-emission, it is likely enough to make a sufficiently approximate model. This model is being developed by studying what components or combination thereof most accurately predict the Δ in self-emission between calibration cycles. The thermal environment within an instrument can change if HIRS is switched off and on again, or if another instrument on the same satellite is switched on and off again, and certainly as the orbit drifts over time. Therefore, coefficients in such a model need to be continuously updated, and uncertainties need to be continuously estimated.

6.3 Structured, common and independent uncertainties

6.3.1 Principles

The FIDUCEO approach to uncertainty analysis and metrological traceability is to start with the measurement function, which is the function that is used to obtain a measured output quantity value from input quantity values. The measurement function takes a general form $Y = f(X_1, X_2, \ldots, X_N) + 0$, where the output quantity Y is determined from the input quantities, the X_i. We include a "plus zero" to explicitly represent assumptions (in the form of effects expected to have zero mean) built into the form of the measurement equation.

The Guide to the Expression of Uncertainty in Measurement (GUM) describes the propagation of uncertainty through a measurement function. For this we need to consider each source of uncertainty associated with each of the input quantities and consider the error covariance between any two input quantities. We do this by considering the underlying physical effects that cause (unknown) errors in each input quantity.

For the development of an FCDR, the measurement function is that which converts raw data (e.g. measured counts and calibration target values) into the FCDR quantity (e.g. radiance or reflectance). In almost all cases, the input effects are metrologically independent (they have no common error) and the propagation of uncertainty requires only information on the magnitude of the uncertainty associated with each effect and the sensitivity coefficient that converts the uncertainty in that effect into the uncertainty associated with the FCDR measurand (e.g. radiance).

For the development of a CDR, however, the measurement function often takes as input FCDR values from different spectral bands, along with additional inputs relating to the model used. This means that we require an understanding of the error covariance between the FCDR quantities as measured in different spectral bands. Furthermore gridded, filled or smoothed products the measurement function combines data from different spatial pixels. We therefore need an understanding of the error covariance between the FCDR quantities as measured in different pixels of an image.

To account for this, the full FCDR development in FIDUCEO has included an analysis of the error correlation structure across spectral bands and across space (from pixel to pixel within a scanline and from scanline to scanline within an orbit/image). Information about this process is given in the D2-2 reports.

We are currently considering methods for sharing this information in a manageable format with CDR developers. This will include three formats: the full-FCDR, which will be useable only by experts, but which will contain all error covariance information, the easy-FCDR, which will provide some indicative error covariance information and the ensemble-FCDR which will provide multiple potential error images that can be used in the CDR generation algorithm and which will have the error correlation form 'embedded' in the statistical generation.

This is provided as:

- Uncertainties considered as three components: independent, common and structured
- A typical error correlation matrix for spectral-band to spectral-band error correlations
- A typical scale for the error correlation for structured effects

Note that this information is a significant simplification of the full situation, but it provides valuable information.

6.3.2 Using the typical scale for structured effects

Information is provided to perform a full analysis of the spatial error correlation. This is alongside the typical correlation scale for the errors in the structured effect. To interpret this simply, some basic rules can be considered.

Typically this information is given in the form of a number of scanlines over which the structured effects can be considered correlated. If no information is provided about pixels within a scanline, we can assume that structured effects are also fully correlated from pixel to pixel within a scanline.

If we are averaging n scanlines, each containing m pixels and the correlation length scale is L scanlines, then:

- The uncertainty associated with independent effects can be considered to reduce by $\sqrt{n \times m}$
- If $n < L$, then the uncertainty associated with structured effects is not reduced by averaging
- If $n > L$, then the uncertainty associated with structured effects is reduced by $\sqrt{\mathrm{int}(n/L)}$, where the ratio n/L is rounded down to the nearest integer.

Within HIRS, the most important time scales for the structured effects are:

- 40 scanlines (256 seconds)
- 24 hours (from self-emission),
- and ∞, for spectral response function uncertainty

6.4 Because in HIRS each calibration window is fixed for a set of 40 adjacent scan lines, the advice above may provide an uncertainty that is slightly overestimated for a general case.Included effects

Full details of all effects included are described in D2-2. The pre-beta easy FCDR contains a subset of those effects.

- Uncertainty due to Earth counts noise. Estimated from the Allan deviation of 48 IWCT views and 48 space views. The magnitude of the uncertainty due to Earth counts noise is equal to the value contained in the easy FCDR data variable `u_independent`.
- Uncertainty due to calibration views (IWCT and space). Estimated as for Earth counts noise but this propagates into the calibration coefficients, and therefore is a structured effect. It is one of the components that makes up the easy FCDR data variable `u_structured`.
- Uncertainty due to spectral response function location. A detailed study of this is still in progress and will be part of the harmonisation. The uncertainty estimate is currently based on the spread of the SRFs between satellites. This will be updated in a next version of the FCDR. The magnitude is one of the components that makes up `u_structured`.
- Uncertainty due to the self-emission model. This also goes into `u_structured`.
- Uncertainty due to Earthshine, IWCT temperatures and gradients and non-linearities. These goes into the `u_common`.

7 Product definition

7.1 Product contents

The L1B data were generated on-board the HIRS instrument on various NOAA satellites, and subsequently processed by NOAA and archived in CLASS. The FIDUCEO team obtained the L1B data from the NOAA CLASS archive and processed it with version 0.2.2 of the FCDR_HIRS software, available at https://github.com/FIDUCEO/FCDR_HIRS .

HIRS FCDR files have been processed such that each file contains one orbit from equator to equator, as defined by the satellite sub-satellite point (or more precisely, its 28th ground pixel). There are no overlaps or gaps between adjacent orbit files. As a consequence, HIRS FCDR files do not correspond exactly to NOAA L1B files. The HIRS FCDR files describe what NOAA L1B files correspond to the generated contents.

Each HIRS Easy FCDR file contains:

- Basic telemetry: longitude, latitude, time, satellite zenith and azimuth angles, solar zenith and azimuth angles;
- Brightness temperatures for channels 1--19;
- Independent uncertainty information (also known as random uncertainty) for channels 1--19;

- Structured uncertainty information (also known as nonrandom or systematic uncertainty) for channels 1--19. This is a sum of all uncertainties that are not totally random from pixel to pixel;
- A lookup table to convert between radiances and brightness temperatures for channels 1—19;
- A channel error correlation matrix. This currently only considers the crosstalk effect, and does not currently consider the propagation from uncertainty effects shared between channels;
- Two bitfields indicating problems with the data. Please use those! See below for details.

The data may have the following dimensions:

- x – position along the scanline
- y – scanline number. The coordinates correspond to the scanline number in the original L1B files.
- channel – The channel number, 1—19.
- LUT_index – this dimension is only used by the data fields LUT_BT and LUT_radiance, which contain a lookup table to convert between radiance units and brightness temperatures.

The data files contain coordinates corresponding to each of the dimensions.

7.1.1 Bit masks

There are two data variables that communicate flags through bit masks. Both are set once per scanline. For both of them, the variable attributes flag_masks and flag_meanings are used as defined in the CF conventions. There is a list of bitmasks, and there is a list of flag names. The order is the same.

- quality_channel_bitmask. Set once per scanline and channel. Can contain the flags: DO_NOT_USE, UNCERTAINTY_SUSPICIOUS, SELF_EMISSION_FAILS, CALIBRATION_IMPOSSIBLE.
    - DO_NOT_USE means that for whatever reason, this data should not be used. This may either be copied directly from the corresponding L1B flag, or because there is some failure in estimating the value or uncertainty.
    - UNCERTAINTY_SUSPICIOUS is set when the process to estimate uncertainties had non-fatal problems. The associated radiance may or may not be accurate, but the uncertainty is probably inaccurate.
    - SELF_EMISSION_FAILS indicates that the model to estimate self-emission has failed. When this is set, DO_NOT_USE is also set.
    - CALIBRATION_IMPOSSIBLE is set when it was impossible to calibrate the channel for this scanline. DO_NOT_USE is also set.
- quality_scanline_bitmask. Set once per scanline. Valid across all channels. Can contain flags: DO_NOT_USE, SUSPECT_GEO, SUSPECT_TIME, SUSPECT_CALIB, SUSPECT_MIRROR_ANY, REDUCED_CONTEXT, UNCERTAINTY_SUSPICIOUS, BAD_TEMP_NO_RSELF.
    - DO_NOT_USE means no data for this channel should be used for any scanline. This is either due to ta problem detected in the FCDR processing, or copied directly from the L1B.
    - SUSPECT_GEO is set when any of the geolocated-related flags are set in the L1B. Values and uncertainty may be correct, but it is uncertain what geolocation they correspond to.
    - SUSPECT_TIME is set when any of the time-related flags are set in the L1B. Values and uncertainty may be correct, but it is uncertain what time --- and correspondingly, what location --- they correspond to.

- SUSPECT_CALIB is set when any of the calibration-related flags is set in the L1B, or a non-fatal calibration problem is detected in the FCDR processing. This is more serious as the radiance could be quite wrong. This may or may not be reflected by the uncertainty.
- SUSPECT_MIRROR_ANY is set when any of the mirror-related flags is set for any of the "minor frames" in the L1B; this derives from a set of L1B flag that exists once per scan position, plus another 8 at the end of each scan. When this is set, at least one, possibly all scan positions are suspect as there may have been a mirror problem.
- REDUCED_CONTEXT is a flag related to the self-emission model. Normally, the self-emission model is trained using a 24 hour (+/- 12 hour) window and updated every 6 hours. In case of severe data gaps or at the beginning or end of a mission, 24 hour of context is unavailable and this flag is set. This may mean the uncertainty on the self-emission model is larger, which the user might identify using the structured uncertainty.
- UNCERTAINTY_SUSPICIOUS is set when there is a non-fatal problem affecting the uncertainty estimate, affecting all channels on this scanline. Associated radiances should be fine.
- BAD_TEMP_NO_RSELF is set when the self-emission estimate was impossible for any channel, due to the absence of temperatures. The self-emission model relies on a set of temperature measurements. When those are not available, no self-emission is estimated and the self-emission model falls back on a "plan B". The associated uncertainty is set to be large. It is recommended not to use those radiances unless you really have to.

7.2 File format

Files are provided in NetCDF-4 and adhere to the CF Conventions v1.7 where possible. All data fields are internally compressed using parameters chosen based on the dynamic range of meaningful values. Filenames follow the FIDUCEO standard. The filenames have the following structure:

FIDUCEO_FCDR_L1C_HIRS{n}_{SATELLITE}_{STARTTIME}_{ENDTIME}_EASY_v1.0_fv2.0.0.nc

where {n} is either 2, 3, or 4, {SATELLITE} can be any of the HIRS-carrying satellites, {STARTTIME} is the date/time for the start of the orbit in UTC, with the format {YEAR}{MONTH}{DAY}{HOUR}{MINUTE}{SECOND}, {ENDTIME} is the date/time for the end of the orbit in UTC. The rest of the filename is constant throughout the present version of the HIRS FCDR easy pre-beta format. An example filename for HIRS/3 on NOAA-17 would be:

FIDUCEO_FCDR_L1C_HIRS3_NOAA17_20070822091134_20070822105108_EASY_v1.0_fv2.0.0.nc

The NetCDF format is self-documenting. Each file contains global attributes with general information, and a set of data variables. The names of data variables follow standard names from the CF Conventions for those cases where a standard name exists. Where no standard name exists, the FIDUCEO team has introduced a name not included in the standard. All data variables are stored as compressed scaled integers. Data variable attributes describe each variable and its scaling. The appendix contains an example of the headers for a particular file.

7.3 File sizes

A typical orbit file is around 3.1—3.5 MB for the easy FCDR. The total size for the entire dataset is 2.1 TB.

8 Example contents

The figures below show a few examples of the contents the FCDR.

Figure 2 – Time series of 25th, 50th and 75th percentile retrievals in the 11.1 µm channel, along with independent, structured and common error for the whole HIRS FCDR.

Figure 2 shows typical output from the harmonised FCDR. The brightness temperatures show very good continuity and agreement across the various sensors, and there are very few outlying points. Median retrievals across this period are typically 260 – 275 K, with a seasonal cycle, as is to be expected. The FIDUCEO FCDR, unlike other datasets, also contains uncertainties, split into the 3 categories outlined above. The independent uncertainty is, for most satellites, small, with limited jumps or change to the value throughout a satellites lifetime. NOAA 12 and NOAA 16 are exceptions, with a large jump in 1997 (NOAA 12) from around 0.05 K to 0.3 K, and a jump in 2004 (NOAA 16) from 0.02 K to around 0.1 K. There are also occasional spurious spikes in the uncertainty across the modern satellites. Both the structured and common uncertainties have a change in behaviour between the satellites of NOAA 14 and NOAA 15. In both cases, the median uncertainty reduces after NOAA 14, but in the structured uncertainty it becomes much less stable, with spurious spikes reaching values higher than pre-NOAA 14 and an inability to distinguish seasonal cycles. In the common uncertainty, the reduction is much greater, and post-NOAA 14 is much smoother.

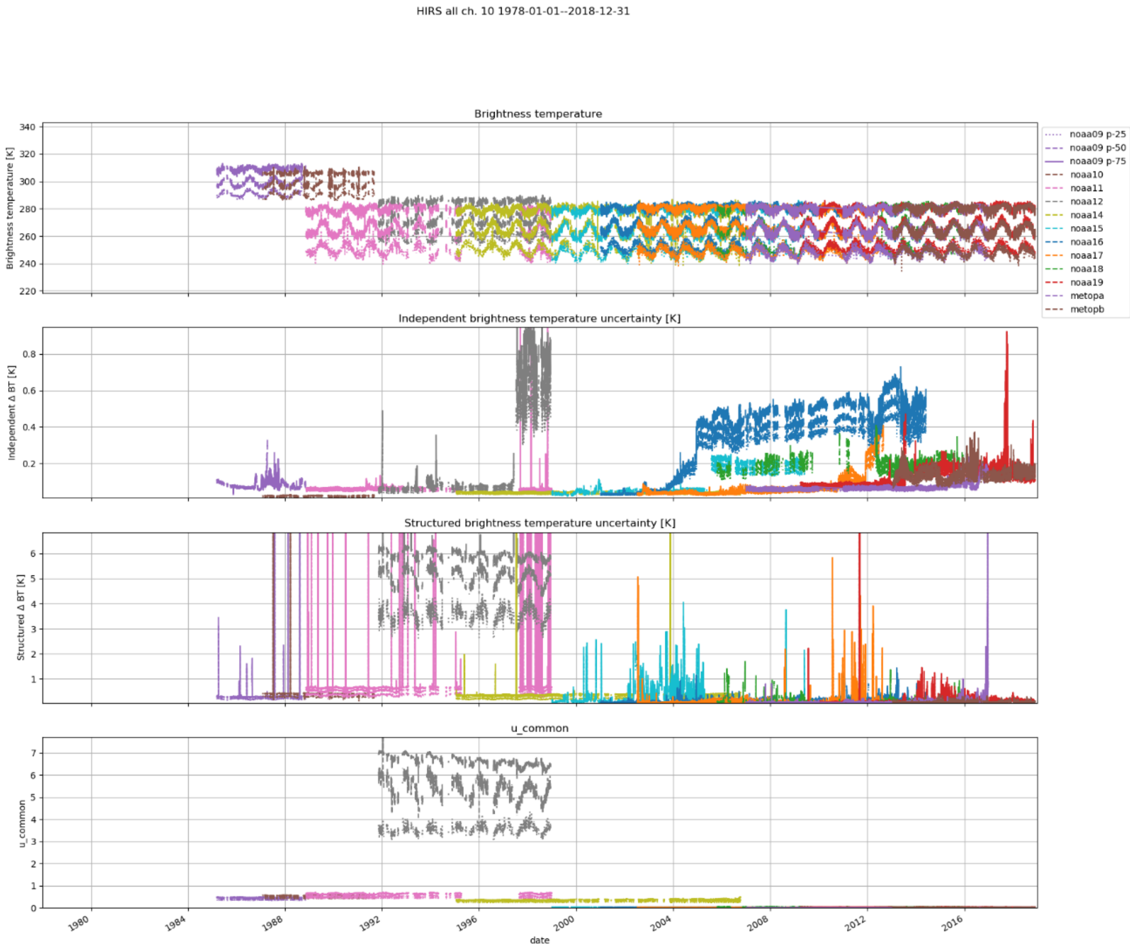

Figure 3 – As figure 2, but for the 8.1/12.5 μm channel (channel 10).

Most channels follow a very similar pattern to that seen in Figure 2 (2,3,4,5,6,7,8,9 and 11, which range from 7.3 – 14.9 μm). However, there are some exceptions. Figure 3 shows channel 10, which switches between the 8.1 and 12. 5 μm channel depending on the HIRS sensor onboard. The retrieved BT shows good agreement except for NOAA 09, 10 and 12. Here, NOAA 09 and 10 also show good agreement with each other. The pattern for uncertainties is similar to that seen in other channels, although there is an even larger increase in NOAA 12 structured and common uncertainties, which average around 5 K each, much higher than other satellites. There is also more outlying spikes in the structured uncertainty from earlier satellites compared with the other channels. A similar pattern with jumps are found in channels 12 and 17 (6.5 and 4.0 μm).

Figure 4 shows another example where the graphical representation of the data differs. For this, the 4.6 μm channel, a discrepancy can be seen in the brightness temperature retrievals between the end of NOAA 14 and beginning of NOAA 15. Previous satellite show good continuity with NOAA 14, whilst satellites after match well with NOAA 15. NOAA 15 also has a much larger independent and structured uncertainty in this channel compared with others, with uncertainty increasing throughout the satellite lifetime. This pattern is also seen in channels 14, 18 and 19 (4.5, 3.7 and 0.7 µm).

Figure 4 – As Figure 2, but for 4.6 µm (Channel 13).

Figure 5 shows a final example of a poor channel, channel 16 (4.1 µm). Here, values of the retrieved BT for NOAA 09, 10 and 14 are below 200 K, and often 0. These are not close to NOAA -15 onward values. NOAA 12 BT are also much lower than modern satellites, with an increased curve throughout the lifetime. The common uncertainties associated with these satellites are also much higher than for modern satellites, although independent uncertainties appear to be in line with Figure 4 for all satellites. This pattern is also similar to channel 1.

Throughout, it appears that NOAA 12 is problematic, whilst channels 12 – 19 show some various problems with either uncertainties or continuation of retrievals. We would suggest that users do not use channel 16 or channel 1 before NOAA 15, as there are clearly errors in the datasets before then. We also warn users about spurious structured uncertainties associated with all satellites in all channels.

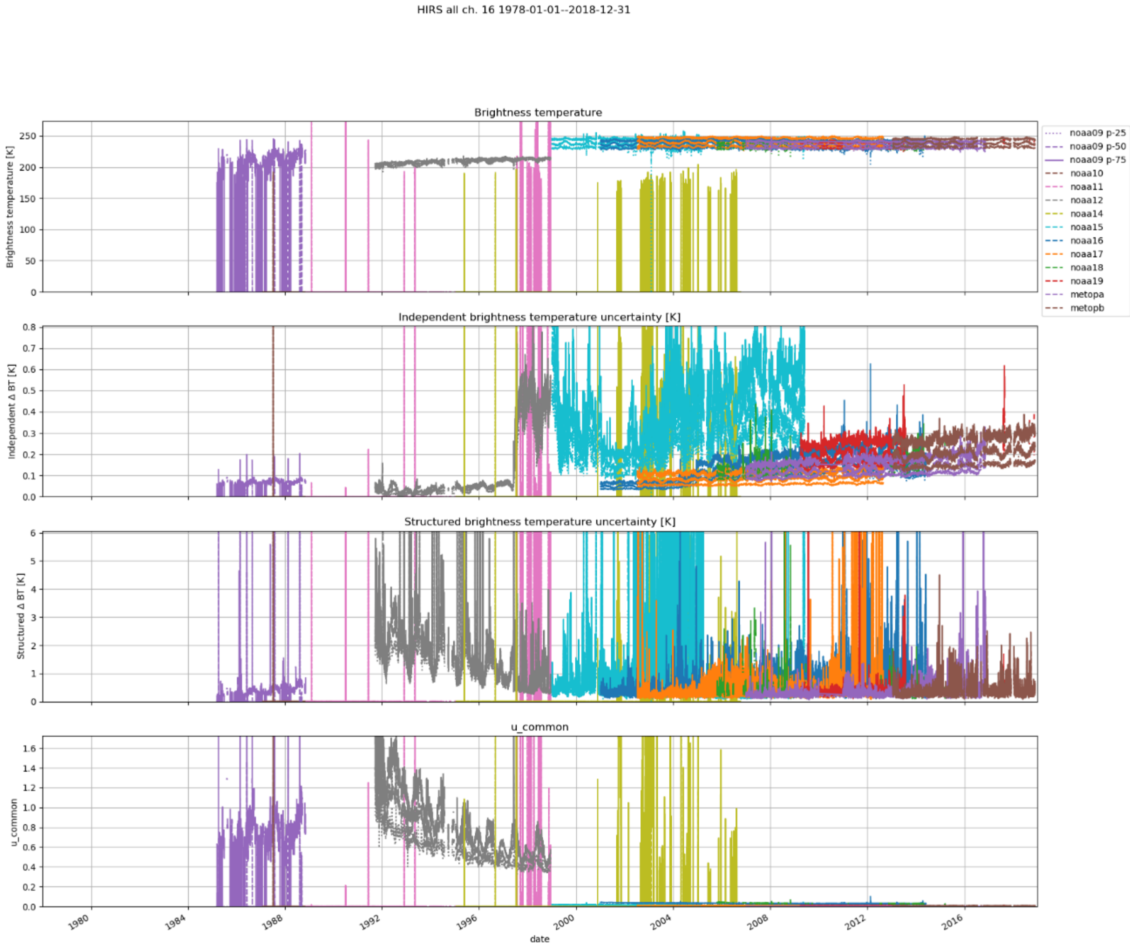

Figure 5 – As Figure 2, but for the 4.1 µm channel.

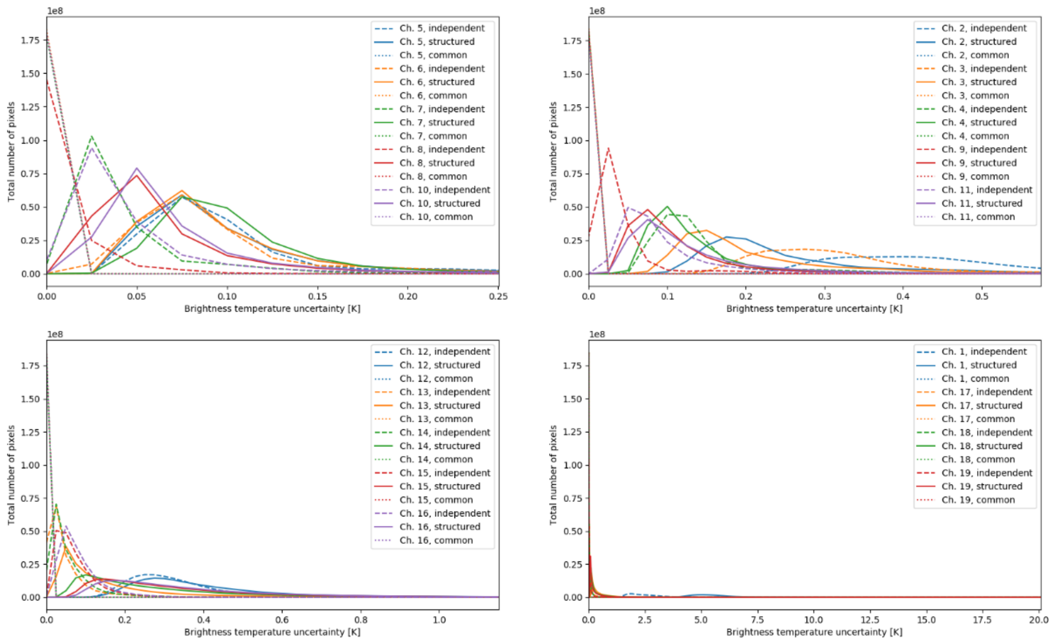

Figure 6 – Histograms of uncertainties for NOAA 17, covering all measurements and channels. Solid lines indicate structured uncertainties, whereas dashed lines illustrate independent uncertainties. The channels are sorted into panels according to the order of magnitude of their structured uncertainties

Figure 6 shows a histogram of structured, independent and common uncertainties for NOAA-17. Most uncertainties for most channels show a normal-based distribution, with a high value tail-end. Uncertainties in the channels plotted in the bottom right panel are the largest, with Channel 1 independent and structured uncertainties peaking at ~ 2.5 K and 5.0 K respectively. In almost all satellites, channel 1 has the largest uncertainties associated with it. Those with the lowest uncertainties are plotted in the top left, namely channels 5 – 8 and 10. Channels 5 – 8 also have the smallest uncertainties associated with them across all satellites, even on NOAA-12, which was shown to be unreliable in previous plots.

HIRS correlation works by an observation of IWCT and space for 48 views every 40 scanlines (replacing an Earth view scanline). When calculating the anomalies within those, it is apparent that there exist correlations within the "noise". This affects both calibration and Earth views and will be described in detail in an upcoming paper (Holl et al, 2017).

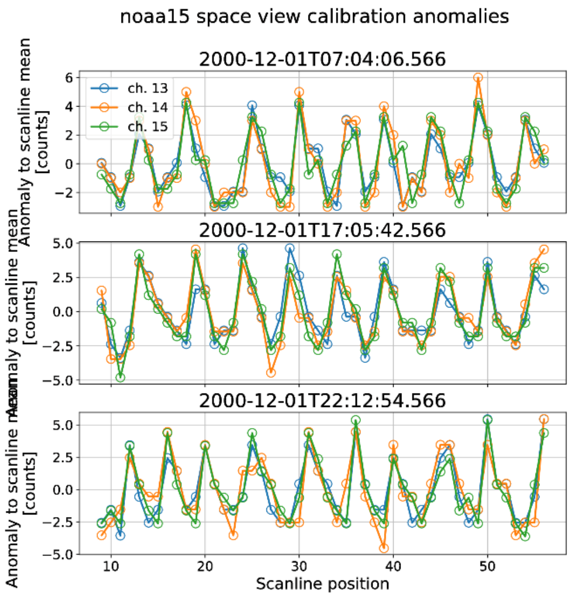

Figure 7: Calibration view anomalies for NOAA-15 shortwave channels

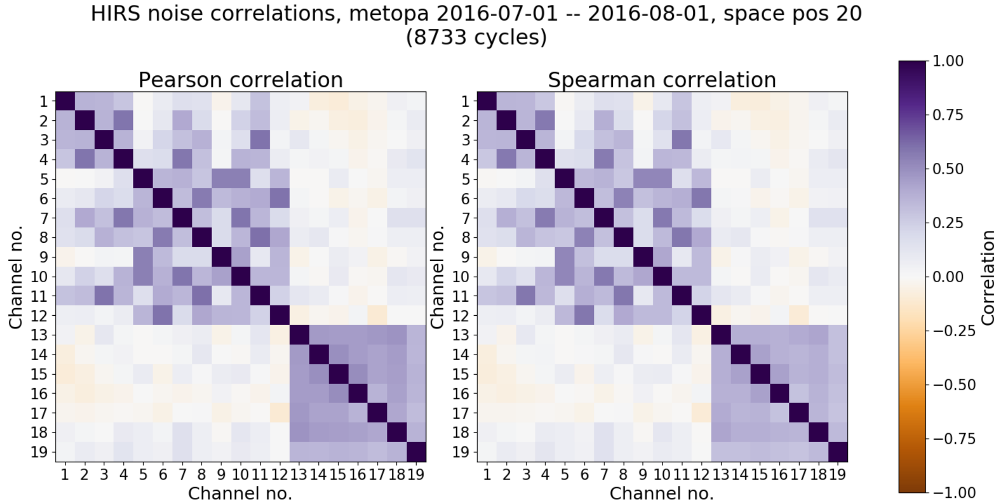

Figure 8: Correlation matrix (Pearson and Spearman) for noise on MetOp-A

Figure 7 shows the space view anomalies for three channels on NOAA-15. The figure illustrates their anomalies are mostly in agreement, therefore not arising from noise but from some sort of crosstalk. The figure also illustrates there is a strong periodic signal accepting all three. Figure 8 shows correlation matrices calculated between all 19 thermal channels on MetOp-A, for one month of measurements. We can clearly see there are positive error correlations for channels sharing the same detector. An upcoming paper (Holl et al, 2017) will describe this in detail.

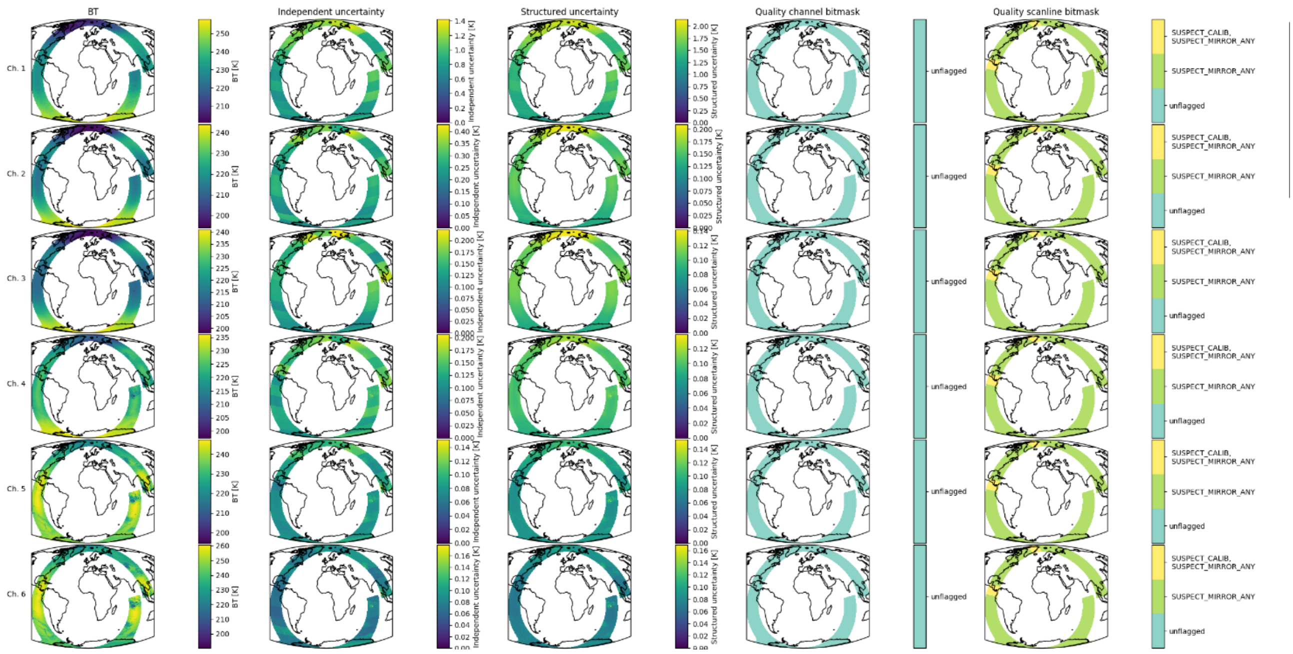

Figure 9: Example orbit for channels 1--6, MetOp-A, 2010-01-06 14:28—16:09.. The columns show: brightness temperatures, independent uncertainties, structured uncertainties, as well as the bitmasks.

Figure shows an example orbit for MetOp-A. For the examples here, the channel bitmask are all unflagged, but some data are flagged in the scanline bitmask.

A. Example header

The extract below shows the header for the FIDUCEO FCDR L1C file on NOAA-17, HIRS/3, containing data starting at 2010-03-13 00:35:44 UTC, ending at 2010-03-13 02:16:44, data version 1.0, format version 2.00. This corresponds to a single equator-to-equator orbit.

```
netcdf FIDUCEO_FCDR_L1C_HIRS2_NOAA09_19850924010748_19850924024946_EASY_v1.00_fv2.0.0 {
dimensions:
	y = 885 ;
	x = 56 ;
	channel = 19 ;
	n_wavelengths = 2751 ;
	lut_size = 101 ;
	delta_x = 56 ;
	delta_y = 442 ;
variables:
	short latitude(y, x) ;
		latitude:_FillValue = -32768s ;
		latitude:standard_name = "latitude" ;
		latitude:units = "degrees_north" ;
		latitude:add_offset = 0. ;
		latitude:scale_factor = 0.0027466658 ;
	short longitude(y, x) ;
		longitude:_FillValue = -32768s ;
		longitude:standard_name = "longitude" ;
		longitude:units = "degrees_east" ;
		longitude:add_offset = 0. ;
		longitude:scale_factor = 0.0054933317 ;
	ubyte quality_pixel_bitmask(y, x) ;
		quality_pixel_bitmask:standard_name = "status_flag" ;
		quality_pixel_bitmask:coordinates = "longitude latitude" ;
		quality_pixel_bitmask:flag_masks = "1, 2, 4, 8, 16, 32, 64, 128" ;
		quality_pixel_bitmask:flag_meanings = "invalid use_with_caution invalid_input invalid_geoloc invalid_time
sensor_error padded_data incomplete_channel_data" ;
	ushort data_quality_bitmask(y, x) ;
		data_quality_bitmask:flag_masks = "1, 2, 4" ;
		data_quality_bitmask:flag_meanings = "suspect_mirror outlier_nos uncertainty_too_large" ;
		data_quality_bitmask:standard_name = "status_flag" ;
		data_quality_bitmask:coordinates = "longitude latitude" ;
	short bt(channel, y, x) ;
		bt:_FillValue = -999s ;
		bt:standard_name = "toa_brightness_temperature" ;
		bt:long_name = "Brightness temperature, NOAA/EUMETSAT calibrated" ;
		bt:units = "K" ;
		bt:coordinates = "longitude latitude" ;
		bt:ancilliary_variables = "quality_scanline_bitmask quality_channel_bitmask" ;
		bt:add_offset = 150. ;
		bt:scale_factor = 0.01 ;
	ushort satellite_zenith_angle(y, x) ;
		satellite_zenith_angle:_FillValue = 65535US ;
		satellite_zenith_angle:standard_name = "platform_zenith_angle" ;
		satellite_zenith_angle:units = "degree" ;
		satellite_zenith_angle:coordinates = "longitude latitude" ;
		satellite_zenith_angle:add_offset = -180. ;
		satellite_zenith_angle:scale_factor = 0.01 ;
```

```
	ushort satellite_azimuth_angle(y, x) ;
		satellite_azimuth_angle:_FillValue = 65535US ;
		satellite_azimuth_angle:standard_name = "sensor_azimuth_angle" ;
		satellite_azimuth_angle:units = "degree" ;
		satellite_azimuth_angle:coordinates = "longitude latitude" ;
		satellite_azimuth_angle:long_name = "local_azimuth_angle" ;
		satellite_azimuth_angle:add_offset = -180. ;
		satellite_azimuth_angle:scale_factor = 0.01 ;
	ushort solar_zenith_angle(y, x) ;
		solar_zenith_angle:_FillValue = 65535US ;
		solar_zenith_angle:standard_name = "solar_zenith_angle" ;
		solar_zenith_angle:orig_name = "solar_zenith_angle" ;
		solar_zenith_angle:units = "degree" ;
		solar_zenith_angle:coordinates = "longitude latitude" ;
		solar_zenith_angle:add_offset = -180. ;
		solar_zenith_angle:scale_factor = 0.01 ;
	ushort solar_azimuth_angle(y, x) ;
		solar_azimuth_angle:_FillValue = 65535US ;
		solar_azimuth_angle:standard_name = "solar_azimuth_angle" ;
		solar_azimuth_angle:units = "degree" ;
		solar_azimuth_angle:coordinates = "longitude latitude" ;
		solar_azimuth_angle:add_offset = -180. ;
		solar_azimuth_angle:scale_factor = 0.01 ;
	uint time(y) ;
		time:_FillValue = 4294967295U ;
		time:standard_name = "time" ;
		time:long_name = "Acquisition time in seconds since 1970-01-01 00:00:00" ;
		time:units = "seconds since 1970-01-01" ;
		time:calendar = "proleptic_gregorian" ;
		time:add_offset = 496372068.256 ;
		time:scale_factor = 0.1 ;
	int quality_scanline_bitmask(y) ;
		quality_scanline_bitmask:standard_name = "status_flag" ;
		quality_scanline_bitmask:long_name = "quality_indicator_bitfield" ;
		quality_scanline_bitmask:flag_masks = "1, 2, 4, 8, 16" ;
		quality_scanline_bitmask:flag_meanings = "do_not_use_scan reduced_context bad_temp_no_rself suspect_geo suspect_time" ;
	short SRF_weights(channel, n_wavelengths) ;
		SRF_weights:_FillValue = -32768s ;
		SRF_weights:long_name = "Spectral Response Function weights" ;
		SRF_weights:description = "Per channel: weights for the relative spectral response function" ;
		SRF_weights:add_offset = 0. ;
		SRF_weights:scale_factor = 3.3e-05 ;
	int SRF_wavelengths(channel, n_wavelengths) ;
		SRF_wavelengths:_FillValue = -2147483648 ;
		SRF_wavelengths:long_name = "Spectral Response Function wavelengths" ;
		SRF_wavelengths:description = "Per channel: wavelengths for the relative spectral response function" ;
		SRF_wavelengths:units = "um" ;
		SRF_wavelengths:add_offset = 0. ;
		SRF_wavelengths:scale_factor = 0.0001 ;
	ubyte scanline_map_to_origl1bfile(y) ;
		scanline_map_to_origl1bfile:_FillValue = 255UB ;
		scanline_map_to_origl1bfile:long_name = "Indicator of original file" ;
		scanline_map_to_origl1bfile:description = "Indicator for mapping each line to its corresponding original level 1b file. See global attribute \'source\' for the filenames. 0 corresponds to 1st listed file, 1 to 2nd file." ;
```

```
	short scanline_origl1b(y) ;
		scanline_origl1b:_FillValue = -32767s ;
		scanline_origl1b:long_name = "Original_Scan_line_number" ;
		scanline_origl1b:description = "Original scan line numbers from corresponding l1b records" ;
	ubyte quality_channel_bitmask(y, channel) ;
		quality_channel_bitmask:standard_name = "status_flag" ;
		quality_channel_bitmask:long_name = "channel_quality_flags_bitfield" ;
		quality_channel_bitmask:flag_masks = "1, 2, 4, 8, 16" ;
		quality_channel_bitmask:flag_meanings = "do_not_use uncertainty_suspicious self_emission_fails calibration_impossible calibration_suspect" ;
	int64 x(x) ;
		x:long_name = "scan position" ;
		x:units = "dimensionless" ;
		x:valid_range = 1LL, 56LL ;
	int64 y(y) ;
		y:long_name = "scanline number" ;
		y:units = "dimensionless" ;
	int64 channel(channel) ;
		channel:long_name = "channel number" ;
		channel:units = "dimensionless" ;
		channel:valid_range = 1LL, 20LL ;
		channel:note = "channel 20 not calibrated by FIDUCEO" ;
	ushort u_independent(channel, y, x) ;
		u_independent:_FillValue = 65535US ;
		u_independent:long_name = "uncertainty from independent errors" ;
		u_independent:units = "K" ;
		u_independent:coordinates = "longitude latitude" ;
		u_independent:valid_min = 1LL ;
		u_independent:valid_max = 65534LL ;
		u_independent:add_offset = 0. ;
		u_independent:scale_factor = 0.001 ;
	ushort u_structured(channel, y, x) ;
		u_structured:_FillValue = 65535US ;
		u_structured:long_name = "uncertainty from structured errors" ;
		u_structured:units = "K" ;
		u_structured:coordinates = "longitude latitude" ;
		u_structured:valid_min = 1LL ;
		u_structured:valid_max = 65534LL ;
		u_structured:note = "contains uncertainties from fully systematic, and structured random effects.  For a more complete treatment, please use full FCDR." ;
		u_structured:add_offset = 0. ;
		u_structured:scale_factor = 0.001 ;
	ushort u_common(channel, y, x) ;
		u_common:_FillValue = 65535US ;
		u_common:long_name = "uncertainty from common errors" ;
		u_common:units = "K" ;
		u_common:coordinates = "longitude latitude" ;
		u_common:valid_min = 1LL ;
		u_common:valid_max = 65534LL ;
		u_common:add_offset = 0. ;
		u_common:scale_factor = 0.001 ;
	short channel_correlation_matrix_independent(channel, channel) ;
		channel_correlation_matrix_independent:_FillValue = -32768s ;
		channel_correlation_matrix_independent:long_name = "Channel_correlation_matrix_independent_effects" ;
		channel_correlation_matrix_independent:units = "1" ;
```

```
		channel_correlation_matrix_independent:valid_min = "-10000" ;
		channel_correlation_matrix_independent:valid_max = "10000" ;
		channel_correlation_matrix_independent:description = "Channel error correlation matrix for independent effects" ;
		channel_correlation_matrix_independent:add_offset = 0. ;
		channel_correlation_matrix_independent:scale_factor = 0.0001 ;
	short channel_correlation_matrix_structured(channel, channel) ;
		channel_correlation_matrix_structured:_FillValue = -32768s ;
		channel_correlation_matrix_structured:long_name = "Channel_correlation_matrix_structured_effects" ;
		channel_correlation_matrix_structured:units = "1" ;
		channel_correlation_matrix_structured:valid_min = "-10000" ;
		channel_correlation_matrix_structured:valid_max = "10000" ;
		channel_correlation_matrix_structured:description = "Channel error correlation matrix for structured effects" ;
		channel_correlation_matrix_structured:add_offset = 0. ;
		channel_correlation_matrix_structured:scale_factor = 0.0001 ;
	float lookup_table_BT(lut_size, channel) ;
		lookup_table_BT:_FillValue = NaNf ;
		lookup_table_BT:description = "Lookup table to convert radiance to brightness temperatures" ;
	float lookup_table_radiance(lut_size, channel) ;
		lookup_table_radiance:_FillValue = NaNf ;
		lookup_table_radiance:description = "Lookup table to convert brightness temperatures to radiance" ;
	float cross_element_correlation_coefficients(delta_x, channel) ;
		cross_element_correlation_coefficients:_FillValue = NaNf ;
		cross_element_correlation_coefficients:long_name = "cross_element_correlation_coefficients" ;
		cross_element_correlation_coefficients:description = "Correlation coefficients per channel for scanline correlation" ;
	float cross_line_correlation_coefficients(delta_y, channel) ;
		cross_line_correlation_coefficients:_FillValue = NaNf ;
		cross_line_correlation_coefficients:long_name = "cross_line_correlation_coefficients" ;
		cross_line_correlation_coefficients:description = "Correlation coefficients per channel for inter scanline correlation" ;

// global attributes:
		:Conventions = "CF-1.6" ;
		:licence = "This dataset is released for use under CC-BY licence (https://creativecommons.org/licenses/by/4.0/) and was developed in the EC FIDUCEO project \"Fidelity and Uncertainty in Climate Data Records from Earth Observations\". Grant Agreement: 638822." ;
		:writer_version = "2.0.0" ;
		:institution = "University of Reading" ;
		:title = "HIRS Easy FCDR" ;
		:source = "NSS.HIRX.NF.D85266.S2332.E0122.B0402829.GC, NSS.HIRX.NF.D85267.S0114.E0308.B0402930.WI" ;
		:history = "Produced on 2019-08-19T20:19:22Z.\nGenerated from L1B data using FCDR_HIRS.  See\nrelease notes for details on versions used." ;
		:references = "In preparation" ;
		:template_key = "HIRS2" ;
		:creator_url = "http://www.fiduceo.eu" ;
		:creator_name = "Gerrit Holl and the FIDUCEO team" ;
		:creator_email = "fiduceo-coordinator@lists.reading.ac.uk" ;
}
```

B Known problems

The current release of the HIRS FCDR has some of the limitations which have been discovered during the production process. These include:

- Only the “easy” FCDR is included. In the easy FCDR, all uncertainties from structured effects are added together. Therefore, more detailed information on the uncertainty correlations is lost.
- Some orbits are missing due to corrupted or otherwise problematic data that the processing software is not yet able to handle gracefully. This includes almost 3000 orbits with invalid latitude/longitude values, roughly 300 orbits corrupted by unphysical values of time, and 20 granules with missing headers. Considering that more than 600,000 orbit files were generated, those problems affect roughly 0.5% of the total data. There are 10 satellite-months where more than 50 orbits failed for the above reasons, with the worst case 96 failing orbits for NOAA-11 in November 1994.
- Some uncertainty estimates are too large. This problem is clearest for channels 17-19, where most orbits include some footprints with structured uncertainties of up to 100 K. This uncertainty is driven by the ad-hoc estimated uncertainty estimate on the SRF, awaiting a proper SRF uncertainty estimate. In some cases it is also wrong for channels 10 and 12. There are also cases where the estimate of either the independent or the structured uncertainty is too large due to an unknown cause. In general, channel 1 also has a large structured uncertainty but this may be due to the measurements and not indicate a problem in the processing.
- Channel 20 is missing. Although FIDUCEO does not plan to improve the calibration, or perform a metrologically traceable uncertainty analysis, or perform harmonisation, on channel 20, the data in this channel should still be copied over into the HIRS FCDR.
- The self-emission model is currently quite fragile, which leads to relatively many orbits with channels where all data are flagged due to a failing self-emission model. This is related to the incomplete detection of outliers.
- Currently, no gap-filling is implemented. The data record contains gaps both within and between orbits. This also means not every orbit is equator-to-equator.
- Not all effects are included yet.
- Error correlations between different effects are currently not considered.
- Some outliers are not properly detected/flagged. There are cases where brightness temperatures and their uncertainties are zero but where no corresponding flag is set. There are also cases where brightness temperatures are unphysically constant across or between scanlines, and where this is not properly detected. This may contribute to problems with the self-emission model. In other situations yet, brightness temperatures may be unphysically small or unphysically large. All those cases are more common in old HIRS (such as HIRS/2) than in newer HIRS.
- The emissivity estimate for the IWCT is currently taken from Wang, Cao, and Ciren (2007) as 0.98 but no justification is given therein. An uncertainty associated with the emissivity is not currently handled.
- Time sequence errors are not gracefully handled. There are cases where time goes backward. In the current version of the processing software, this leads to data-gaps as the software will skip the region where the proper time is ambiguous, and in the worst case skips the entire orbit.

- The choice of scanlines in overlapping regions in the L1B is currently oversimplified. Currently the software always picks the scanline in the older L1B file. In a next version, this will be decided on a case-by-case basis.
- In some cases, the calibration view of deep space is not actually viewing deep space. This is not currently systematically detected. Where this occurs, it may propagate into incorrect calibration estimates and/or too high structured uncertainty estimates through the uncertainty in offset and gain.
- In some cases, uncertainty estimates on the IWCT and space views differ significantly. This is currently not systematically detected and properly handled.
- The local zenith angle estimate for HIRS/2 is currently oversimplified. If you need this, please use with care.
- Channel 1, and perhaps other channels, may exhibit blocky behaviour corresponding to calibration cycles. This is most pronounced for old HIRS. Those cases may be associated with large uncertainties in the structured uncertainty, due to a large calibration uncertainty.