FIDUCEO has received funding from the European Union's Horizon 2020 Programme for Research and Innovation, under Grant Agreement no. 638822

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(FIDelity and Uncertainty in Climate data records from Earth Observations)

Jörg Schulz on behalf of the FIDUCEO consortium

Background

Four year European Commission project FIDUCEO,"Fidelity and Uncertainty in Climate Data Records from Earth Observations"

- Aims to create selected new FCDRs/CDRs utilizing the science of metrology

Project start: March 2015

Project end: Feb 2019

12 project partners led by the University of Reading (PI's are Chris Merchant and Jon Mittaz), EUMETSAT, NPL, STFC, University of Hamburg, University of Leicester, Assimila, Fastopt, Rayference, IPMA, Brockmann Consulting and DLR.

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Why is it important to take a new approach to FCDR/CDR generation?

- Past history has shown that much of the satellite data used as FCDRs/CDRs can have significant biases/errors associated with them
  - Not good for climate studies
  - Need to provide answers to the question
    - **"To what level can I trust this data?"**
  - How can we approach both satellite calibration and CDR algorithms to reduce the introduction of possible errors into the data?
  - How can we demonstrate the trustworthiness of the data?
- Complimentary approach to other initiatives
  - NOAA NCEI CDRP has similar aims
  - FIDUCEO intends to really concentrate on the concept of traceable uncertainties

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What are the aims of FIDUCEO?

- Derive methods and best practice for Fundamental Climate Data Records (Level 1) for a range of instruments taking a metrological approach
- Derive methods and best practice for Climate Data Records (Level 2+) for a range of ECVs taking a metrological approach
- Create traceable uncertainties
  - Provides evidence of all processes involved in deriving the data
  - Good quality and documented uncertainties required for Climate use
- Provide data in easy to use formats including pixel level uncertainties
- Provide cookbooks and toolkits on best practice methods

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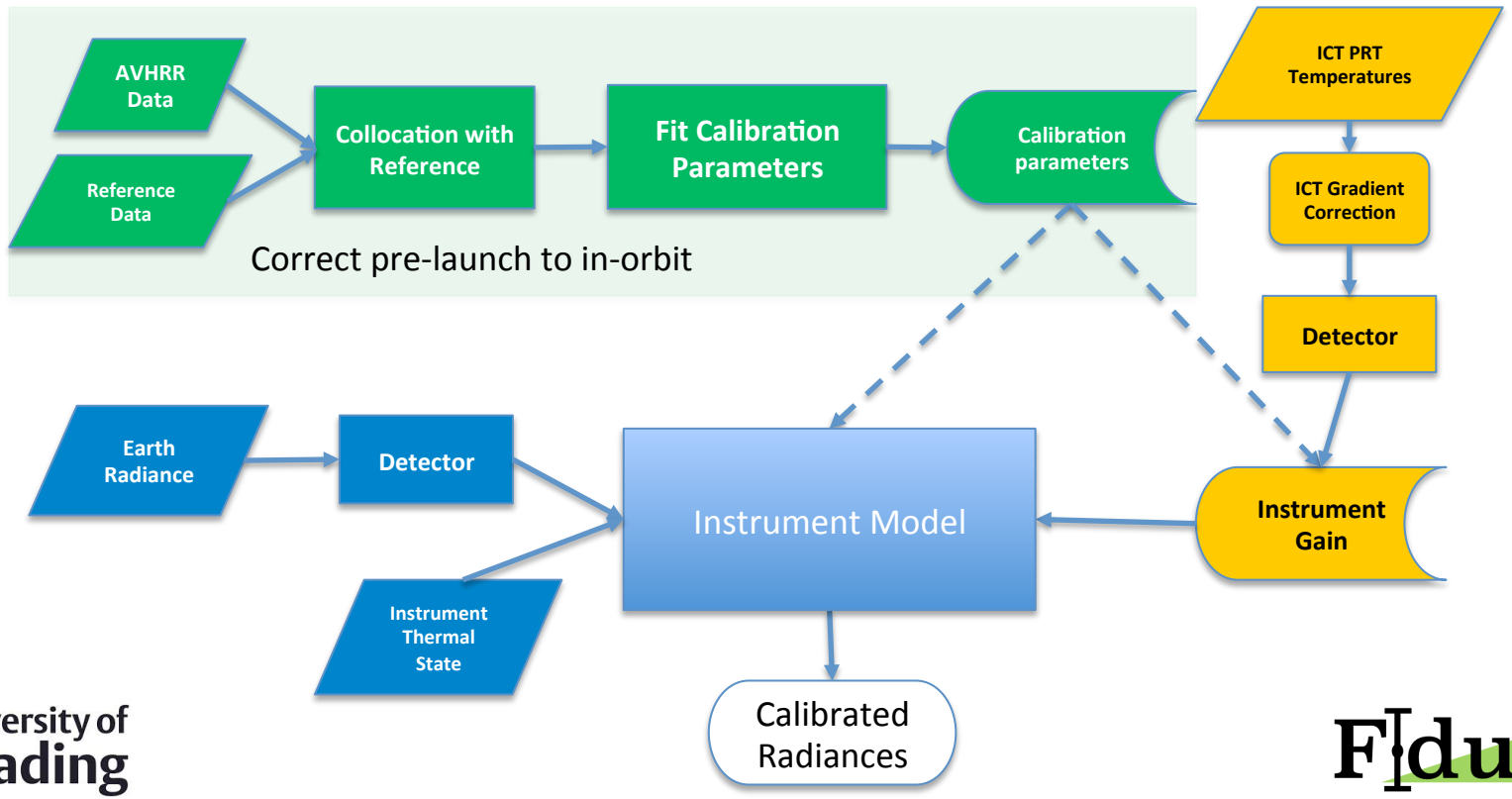
A Metrological Approach

- Metrology is the science of measurement
- Provides a framework for the assessment of the quality/usability of the end product
  - Traceability chains
    - Must be quantitative
    - Should detail all linkages and processes so can easily assess the data processing chain
      - Where does all the information used come from?
      - **Should highlight all assumptions made**
    - Enables potential problems in analysis to be highlighted/spotted
    - Provides documentary evidence for the final uncertainties
  - Rigorous analysis of uncertainties
    - Includes random , systematic and correlation (structural) effects
    - Important for Climate analysis is that the different types of uncertainties are handled correctly
      - E.g. random and systematic cases average very differently

Eg Traceability Chain for the AVHRR

- Breakdown into each process to create radiances
- Use metrologically accepted techniques
  - E.g. Monte-Carlo simulations



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Example: Uncertainties on the Collocation Fitting process

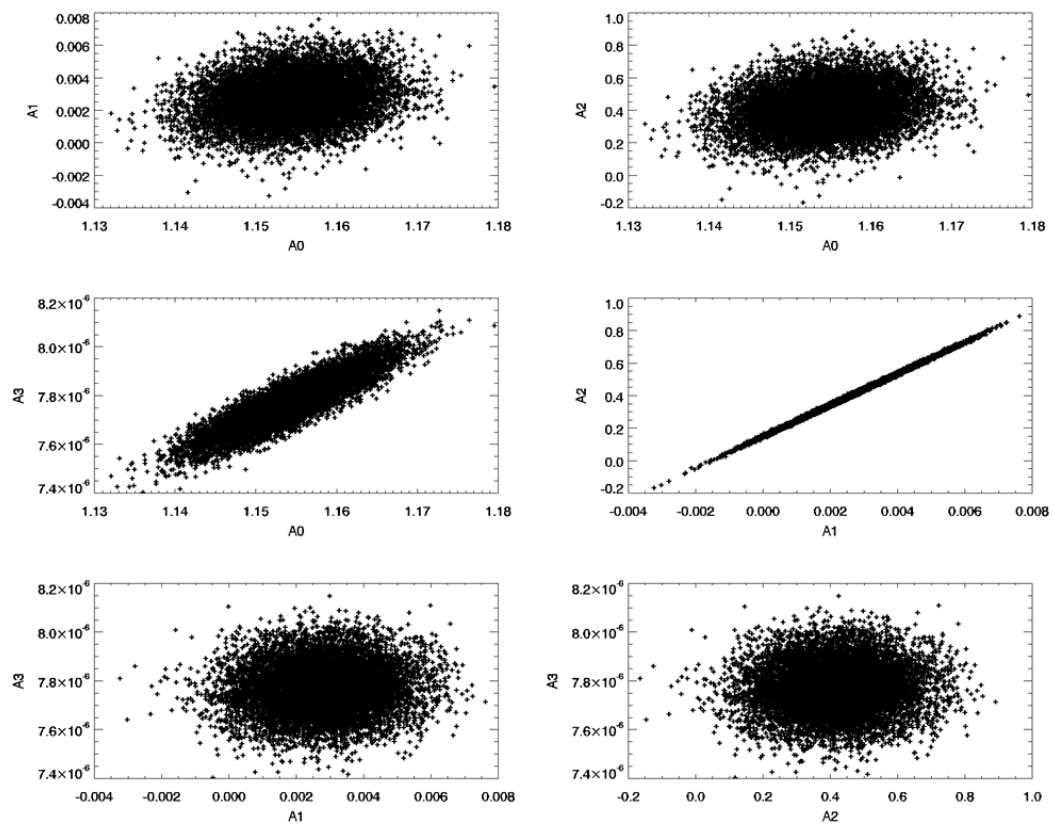
$$R_B = a_0 + \frac{(\varepsilon + a_1)\left(C_s - C_{ICT}\right) - a_2 - a_3\left(C_s - C_{ICT}\right)^2}{\left(C_s - C_{ICT}\right)}\left(C_s - C_B\right) + a_3\left(C_s - C_B\right)^2$$

Very strong correlation between parameters a1 and a2

- Uniqueness issue so remove parameter a2
  - Note uncertainty study has lead to modification of original calibration equation

Strong correllation between A0 and A3

- This will affect the final uncertainty budget



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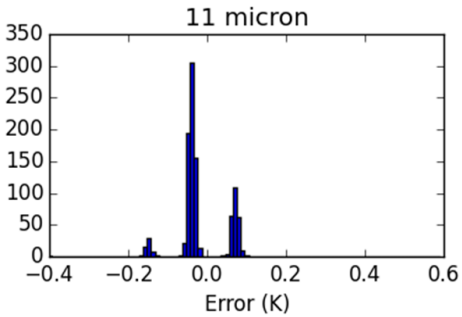
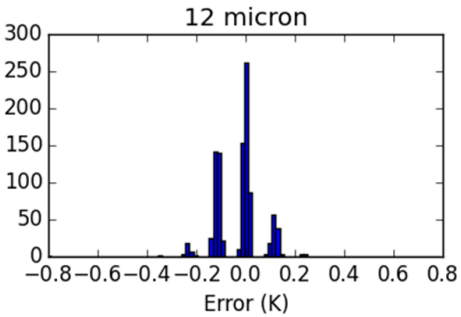
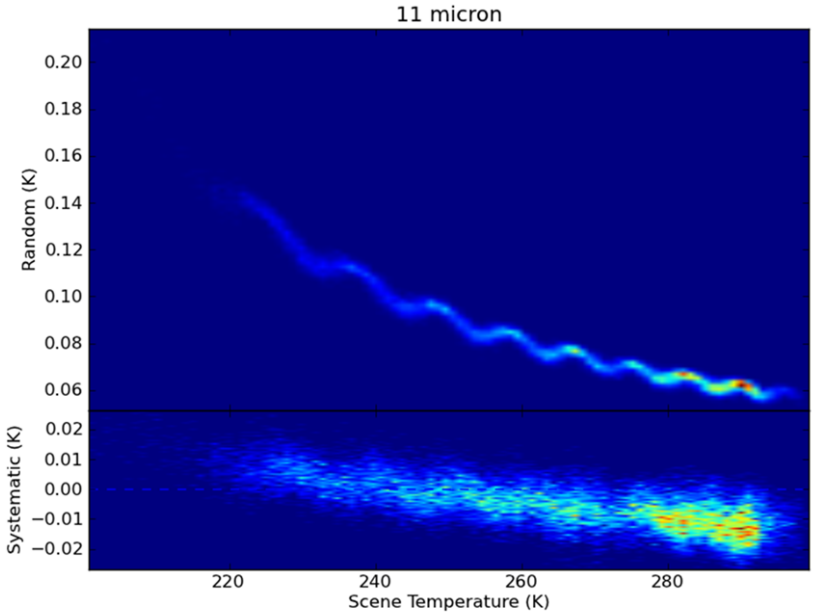
Level 1 Uncertainties

- Leads to a more detailed understanding of Level 1 Uncertainties







- Monte-Carlo PDF for a scene temperature of 290K
- Note impact of digitisation on PDF

- Split errors into random and systematic components

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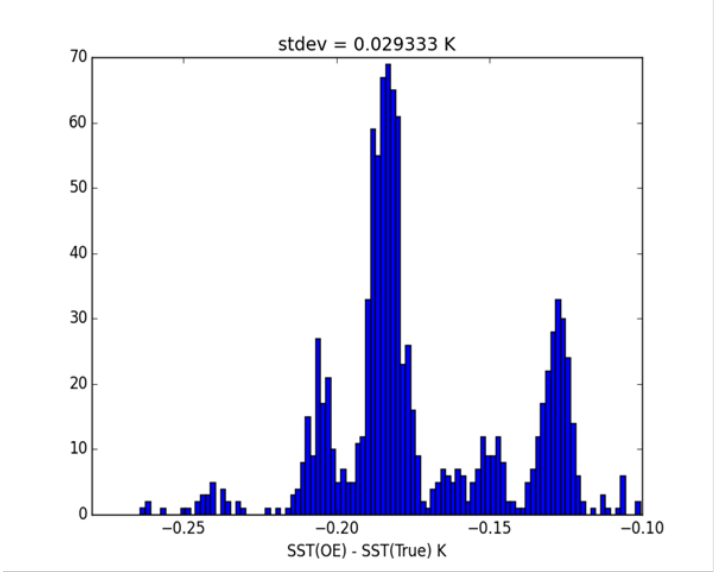
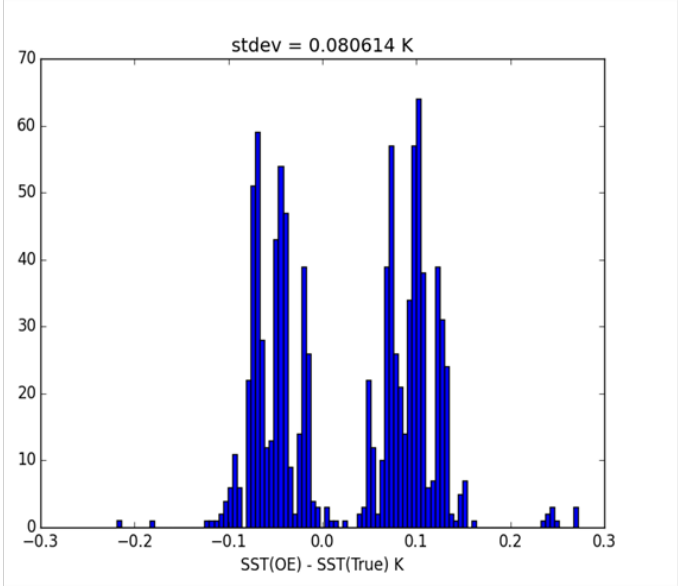
Level 2 Uncertainties

- Again for the AVHRR – retrieving SST using Monte-Carlo BTs from instrument model
- Modelling observed and Radiative Transfer Modelled (RTM) BTs
  - SST Retrieval use Optimal Estimation (e.g. Merchant et al. 2008)





- Monte-Carlo PDFs of the SST error for two different cases
- Note PDF is not Gaussian due primarily to digitisation effects

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What has been learnt…

- From taking a metrological approach to the calibration of the AVHRR new understanding of the instrument has been gained
  - Uncertainty estimation has lead to a modification of the calibration equation
  - Correlation between parameters now included as part of the uncertainty calculation
  - Estimates of uncertainties due to fundamental detector physics can now be included
  - Importance of instrument digitisation has been highlighted
- Taking a metrological approach give not only traceable uncertainties but also leads to new understanding of instruments
  - Will also be true for the Level 2 (CDR) data
    - e.g. non-Gaussian nature of SST retrievals due to AVHRR Level 1 digitisation
  - But also shows the level of detail that will be required

Uncertainties: The bigger picture

- So going through the process of traceability is beneficial but also
  - The uncertainty is not just a single number and there will be a range of uncertainties, both random and systematic
    - ESA CCI SST project provides four components of uncertainty
  - Combining different uncertainty components is not necessarily trivial
    - Deal with random and systematic cases differently plus impact of correlations plus uncertainties may be applicable at different spatial/temporal scales
- FIDUCEO will provide these different components plus tools to manipulate them properly
- Will apply to a range of FCDRs and CDRs

FCDR Data

DATASET	NATURE	USE
AVHRR FCDR	Harmonised infra-red radiances and best available reflectance radiances, 1982 - 2016	SST, LSWT, aerosol, LST, phenology, cloud properties, surface reflectance …
HIRS FCDR	Harmonised infra-red radiances, 1982 - 2016	Atmospheric humidity, NWP re-analysis, stratospheric aerosol …
MW Sounder FCDR	Harmonised microwave BTs for AMSU-B and equivalent channels, 1992 – 2016	Atmospheric humidity, NWP re-analysis …
Meteosat VIS FCDR	Improved visible spectral response functions and radiance 1982 to 2016	Albedo, aerosol, NWP re-analysis, cloud, wind motion vectors,…

Available from Summer 2017

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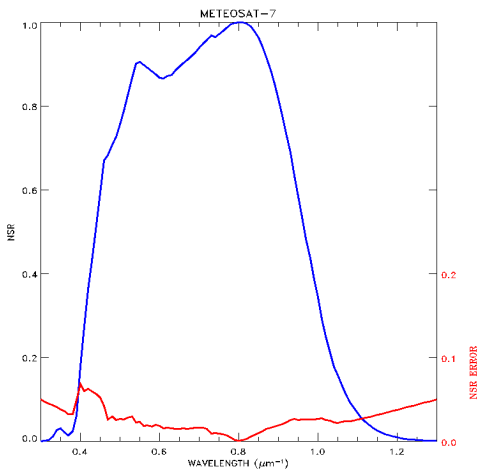
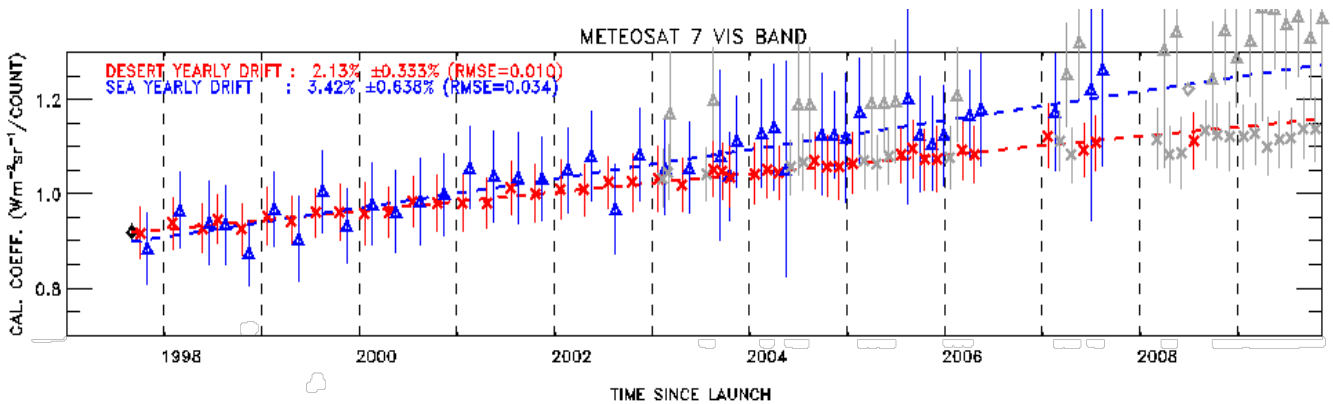
Example of the Meteosat MVIRI VIS





$$K = \gamma \int_{\lambda} \xi(\lambda) R(\lambda)\, d\lambda + K_0$$

where γ is the instrument gain, $\xi(\lambda)$ is the normalized sensor spectral response, $R(\lambda)$ is the spectral radiance at the telescope entrance and K_0 the instrument offset.

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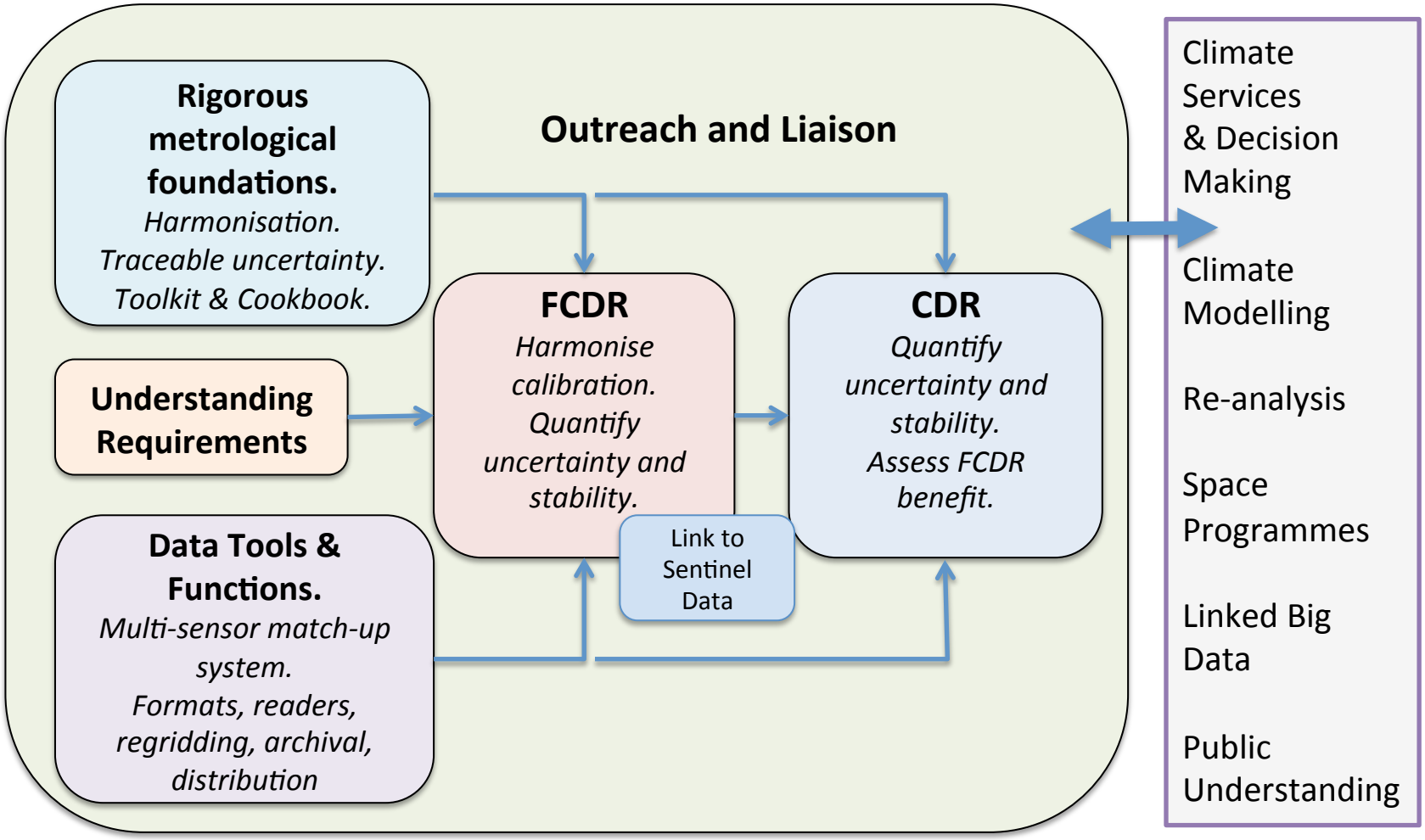
CDR Data

DATASET	NATURE	USE
Surface Temperature CDRs	Ensemble SST and lake surface water temperature	Most of climate science … model evaluation, re-analysis, derived/synthesis products ..
UTH CDR	From HIRS and MW, 1992 - 2016	Sensitive climate change metric, re-analysis …
Albedo and aerosol CDRs	From M5 – 7 (1995 – 2006)	Climate forcing and change, health …
Aerosol CDR	2002-2012 aerosol for Europe and Africa from AVHRR	Climate forcing and change, health …

Available from Summer 2019

FIDUCEO Framework for FCDRs and CDRs

- Framework documents are/will be produced for FCDRs and CDRS
  - 1st draft of Framework document for FCDRs delivered to European Commission
  - Framework document will be iterated for 18 months based on what is learnt in generating FCDRs
  - Framework document for CDRs will be written when CDR work starts and delivered at the end of the project
- Will document FIDUCEO best practice processes
- Will also provide tools and cookbooks to help with applying the Framework to other FCDRs/CDRs
- Workshops and Outreach also included
  - Two workshops will be held in Lisbon, Portugal
    - Sept. 2017 and Nov 2018



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- FIDUCEO will apply the science of metrology to the production of both FCDRs and CDRs
- Will provide four new FCDRs with traceable uncertainties
  - AVHRR, HIRS, MVIRI (visible channel), NOAA MW sounders
  - Available from Summer 2017
- Will provide four new CDRs/demonstration products with traceable uncertainties
  - SST/Lake Surface Water Temperature, UTH, Aerosol and Surface Albedo
  - Available from Summer 2019
- All data to be provided in new 'easy-to-use' formats
- Cookbooks and tools will be provided along with 2 workshops

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