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Fidelity and Uncertainty in Climate Data Records from Earth Observation

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What are we about?

- **Need**: trustworthy information about climatic variability and change over decades
  - rigorous science, including improving prediction
  - decision making, e.g. putting the future in context
  - climate services, meeting information needs
- **Problem**: proving the "trustworthy" part is hard. Often hasn't been done well even for prominent, much-used data sets
- **FIDUCEO answer**: demonstrate "trustworthiness" across several FCDRs and CDRs and promote the methodologies across the EO-climate community
  - **methods, guidance and tools**

FIDUCEO FCDRs

DATASET	NATURE	POSSIBLE USES
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,…

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FIDUCEO CDRs

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 …

But what is new about the data?

- Harmonised
  - Different sensors measure different wavebands; it doesn't mean we pretend they are all the same
  - Given our instrument knowledge (SRF), the calibration of different sensors is reconciled
  - In other words, the differences between sensors are what we expect from know differences between instruments
  - This is a precursor for building a stable CDR from an FCDR
- Commonality of 'easy-FCDR' formats
  - netCDF, CF-convention
  - uncertainty vocabulary will need development

But what is new about the data?

- Uncertainty-quantified FCDR
  - At all data set scales (from pixel level in product through to multi-annual stability) there is adequate quantification of error distributions to propagate uncertainty across all data transformations (especially to CDR) accounting for error correlation structures
- Uncertainty-quantified CDR
  - Uncertainty information in product that (i) discriminates more and less certain data, (ii) is validated as being realistic in magnitude, (iii) is traceable back to the FCDR uncertainty information

Cascade uncertainty

L0

det. noise, digitisation, calibration, geolocation …

↓

L1b

propagation (random, systematic), inversion

↓

L2

propagation (rand., syst., locally syst.), sampling

↓

L3

extra-/interpolation, smoothing

↓

L4

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Cascade uncertainty

	L0
	↓
‘easy-FCDR’, all main components of uncertainty	**L1b**
	↓
FIDUCEO CDRs – uncertainty traceable to FCDR	**L2**
	↓
FIDUCEO L3 – uncertainty traceable to L2 CDR	**L3**
	↓
	L4

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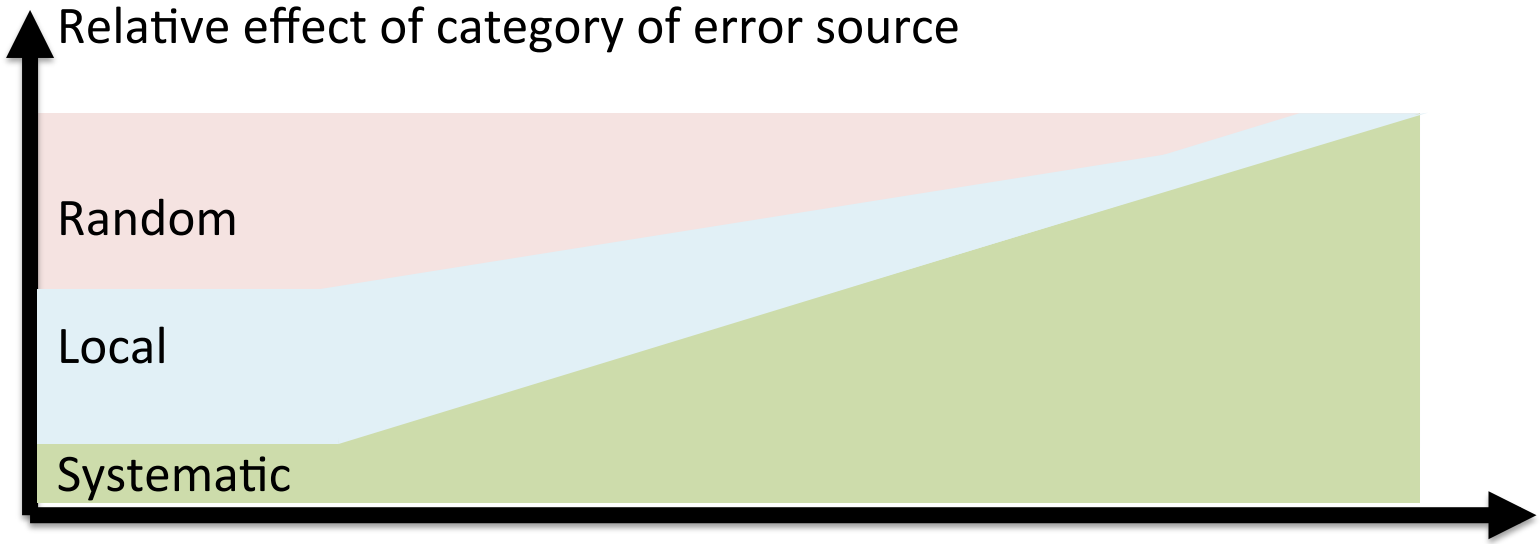
How?

- Working with NPL to transfer all applicable metrological principles and techniques
- **Every transformation from detection of radiance to geophysical product at L3 to be analysed** in terms of how it introduces and propagates error
  - fully traceable uncertainty estimates
- Tools that embody rigorous metrology in usable form
  - especially Monte Carlo propagation of error distributions through complex non-linear transformations

Need to consider all sources of uncertainty



L2	L3
full res	hi res		global
instant	daily		decadal
total u			stability

Earth Observation Simulation System

- Development for AVHRR under joint University of Reading and NPL funding until February 2015
- Development now continuing under FIDUCEO project
- Concept
  - complete simulation of a 'true-world' and an 'available-world' for a sensor
  - each component and data transformation is simulated
    - detector, amplifier, digitiser, on-board calibration …
  - real-world geo-location and cloud cover is used for entire mission

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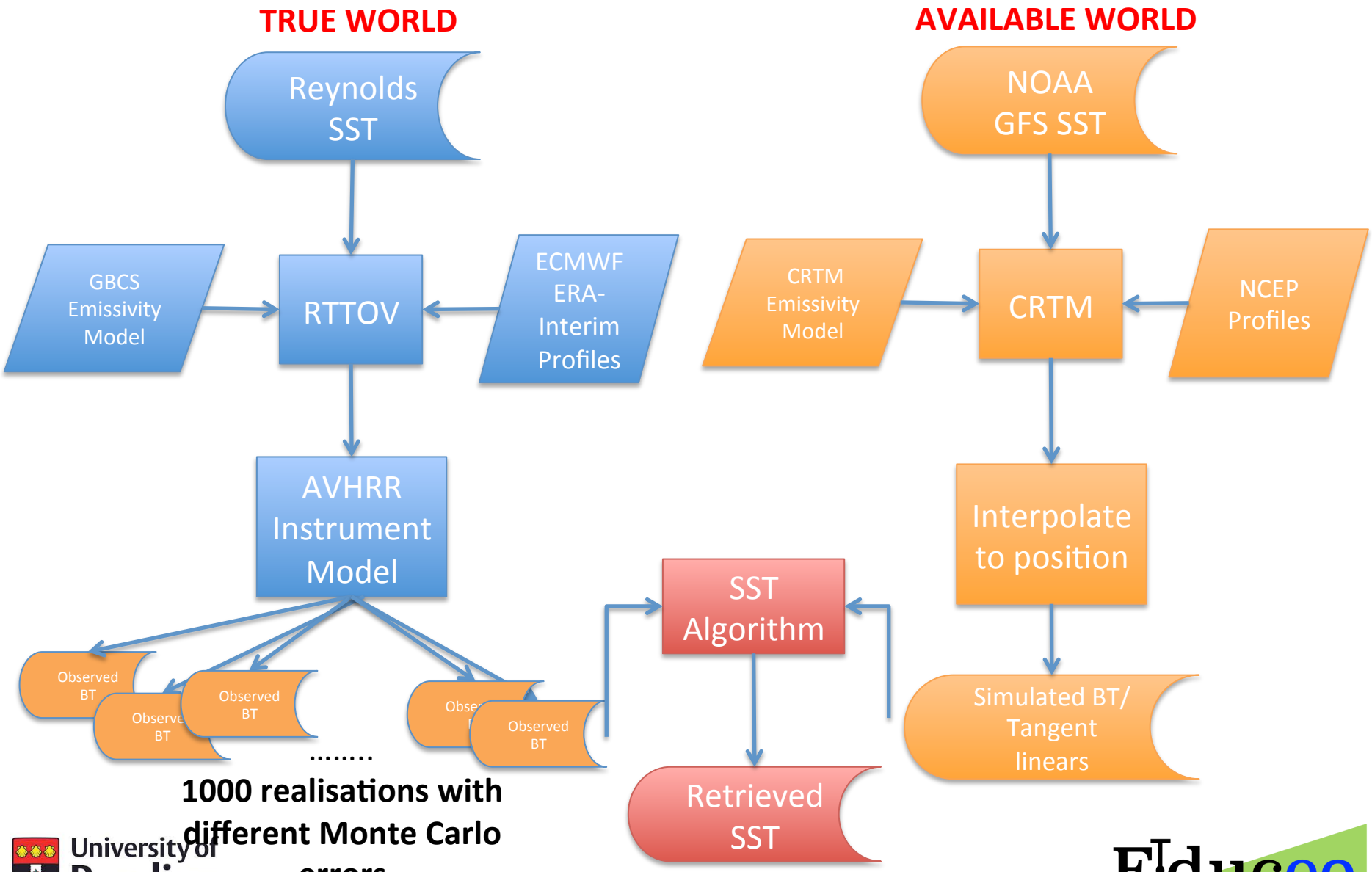

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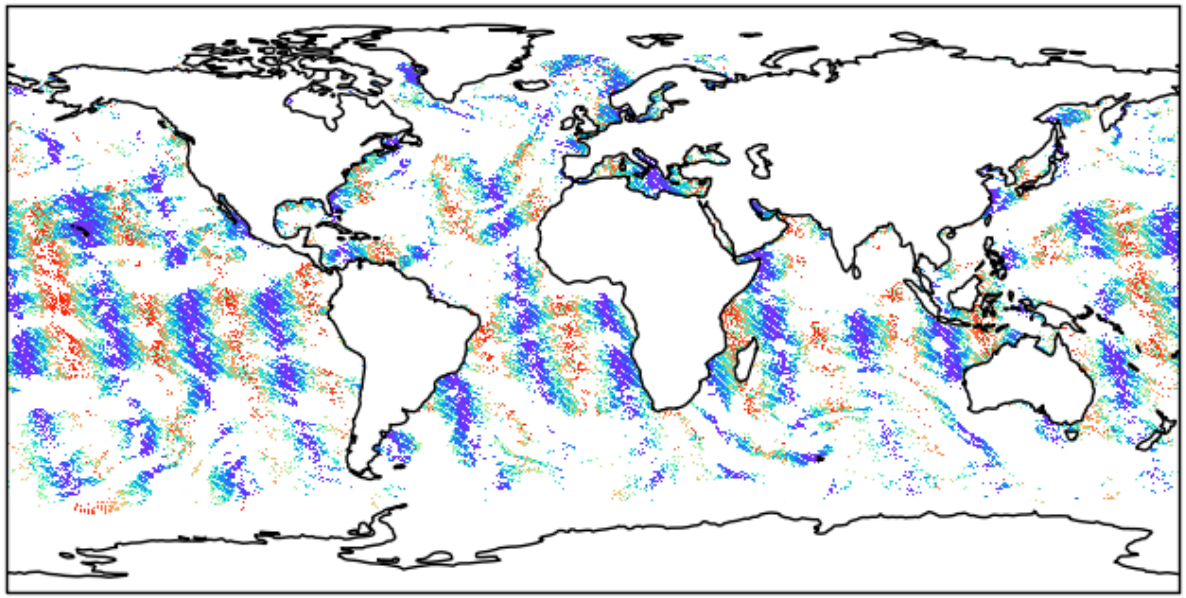
Simulations

- Use real AVHRR orbit data for locations/angles/timings
  - Clear-sky ocean data for this run
- Sub-sample of pixel locations–
  - AVHRR tie points as defined in ESA SST CCI processing =>
  - 137 points across track
  - Of order 650 along track per orbit

SatZA distribution of simulated data



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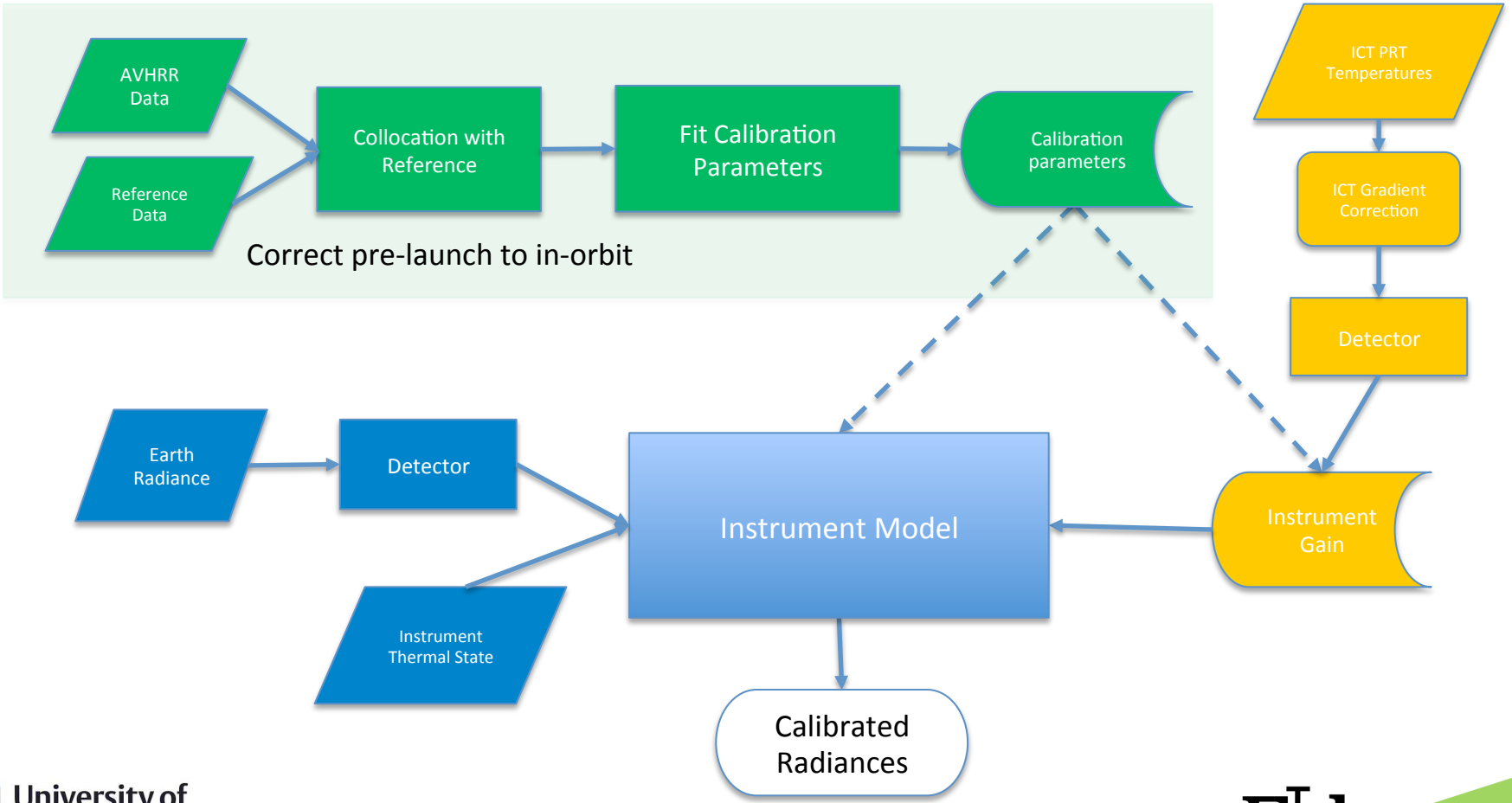
AVHRR Model



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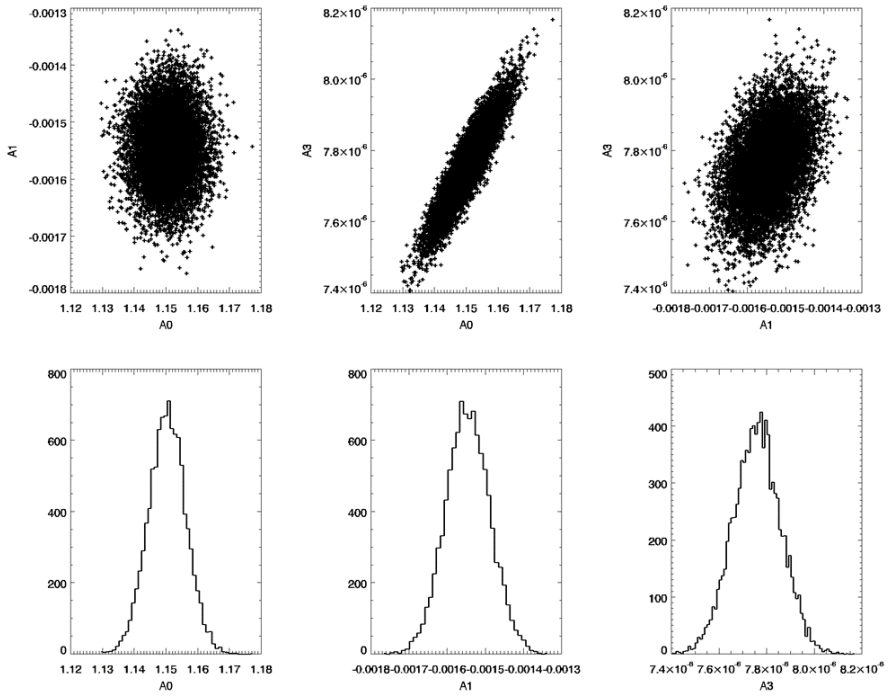
Uncertainties in on-orbit re-calibration

- Joint distributions of error on the calibration parameters, by simulating calibration process

For each Monte-Carlo run of main simulator use a different set of calibration parameters from the Monte-Carlo run of the re-fitting process.

Also gives uncertainties for use in Equation of Propagation on Uncertainty



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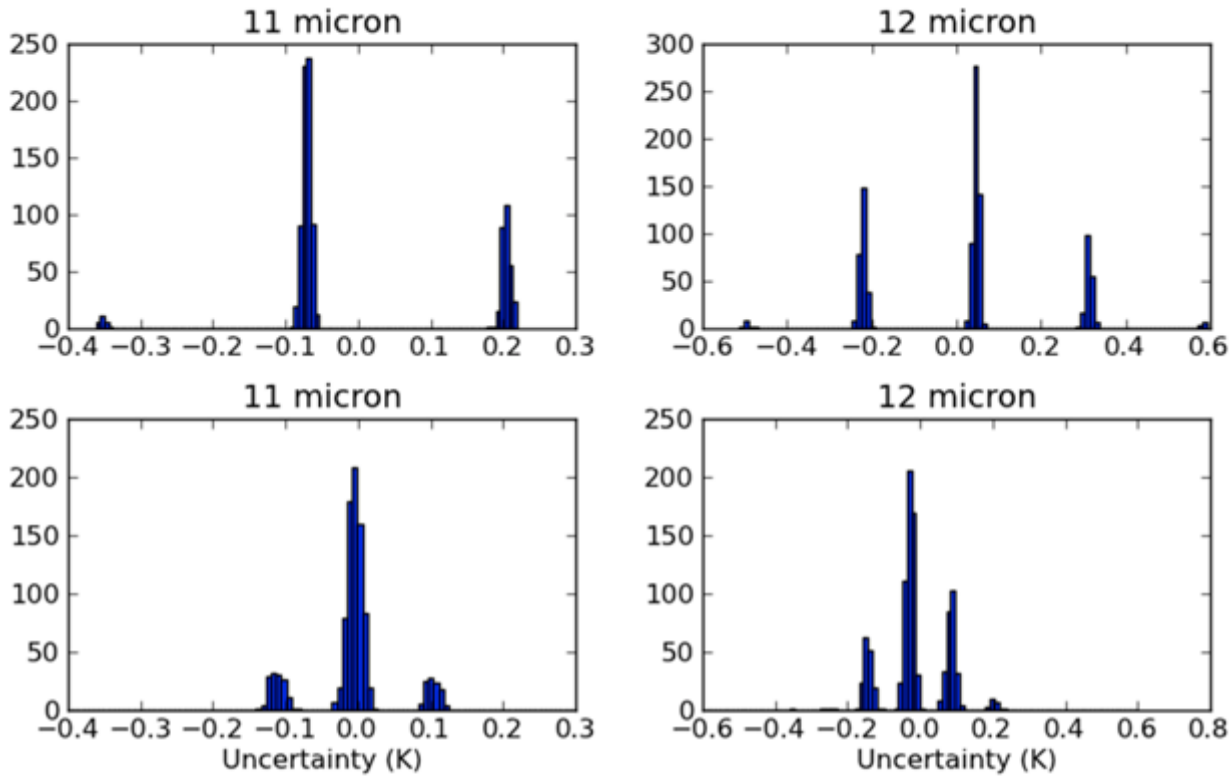
Distribution of random BT errors

230K

300K



Accounts for: digitization and noise effects in on-board calibration

Not convolved with error distribution for systematic calibration effects

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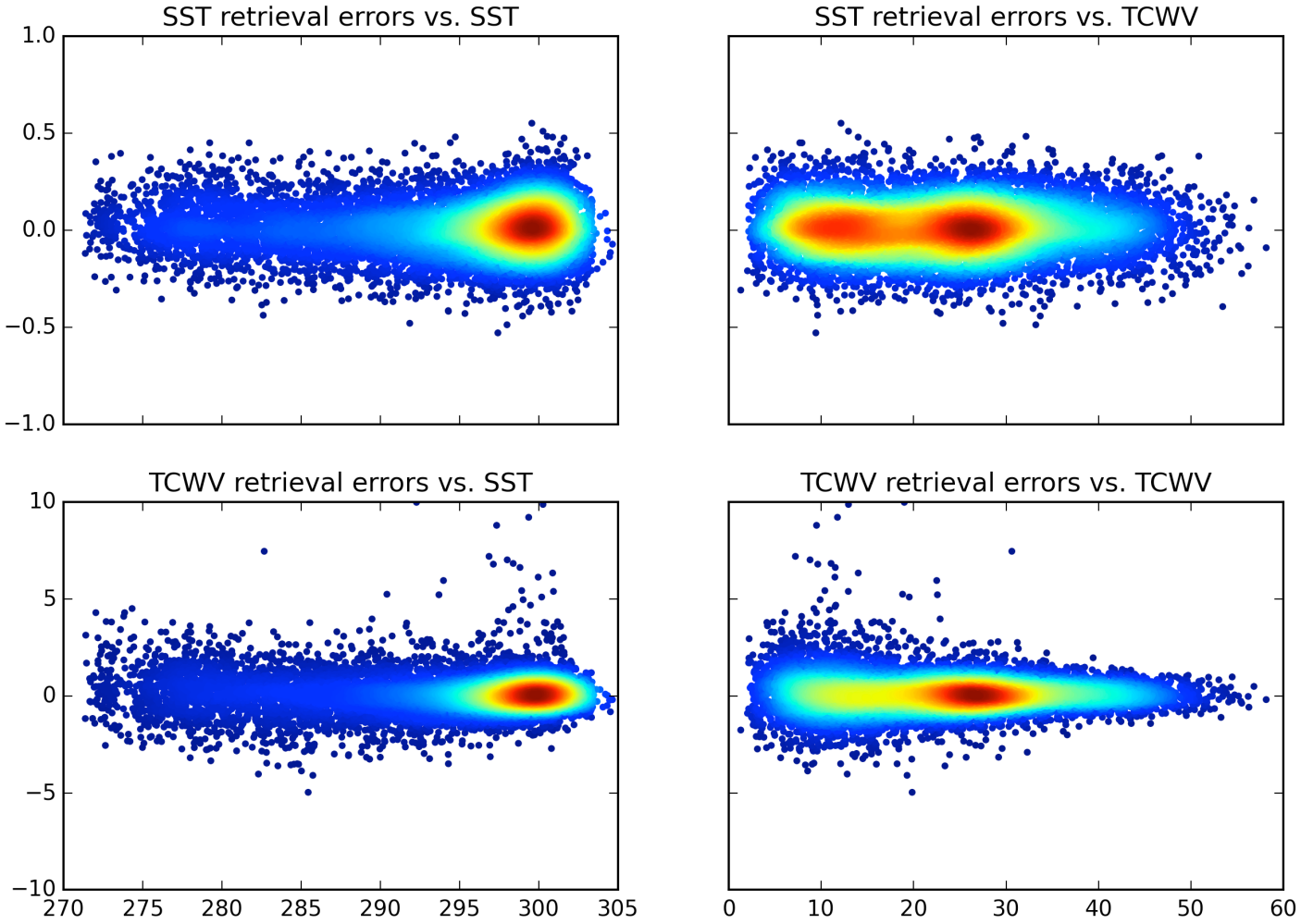
OE of SST (bias free)



Using available-world simulations to explore errors in physics-based OE retrieval

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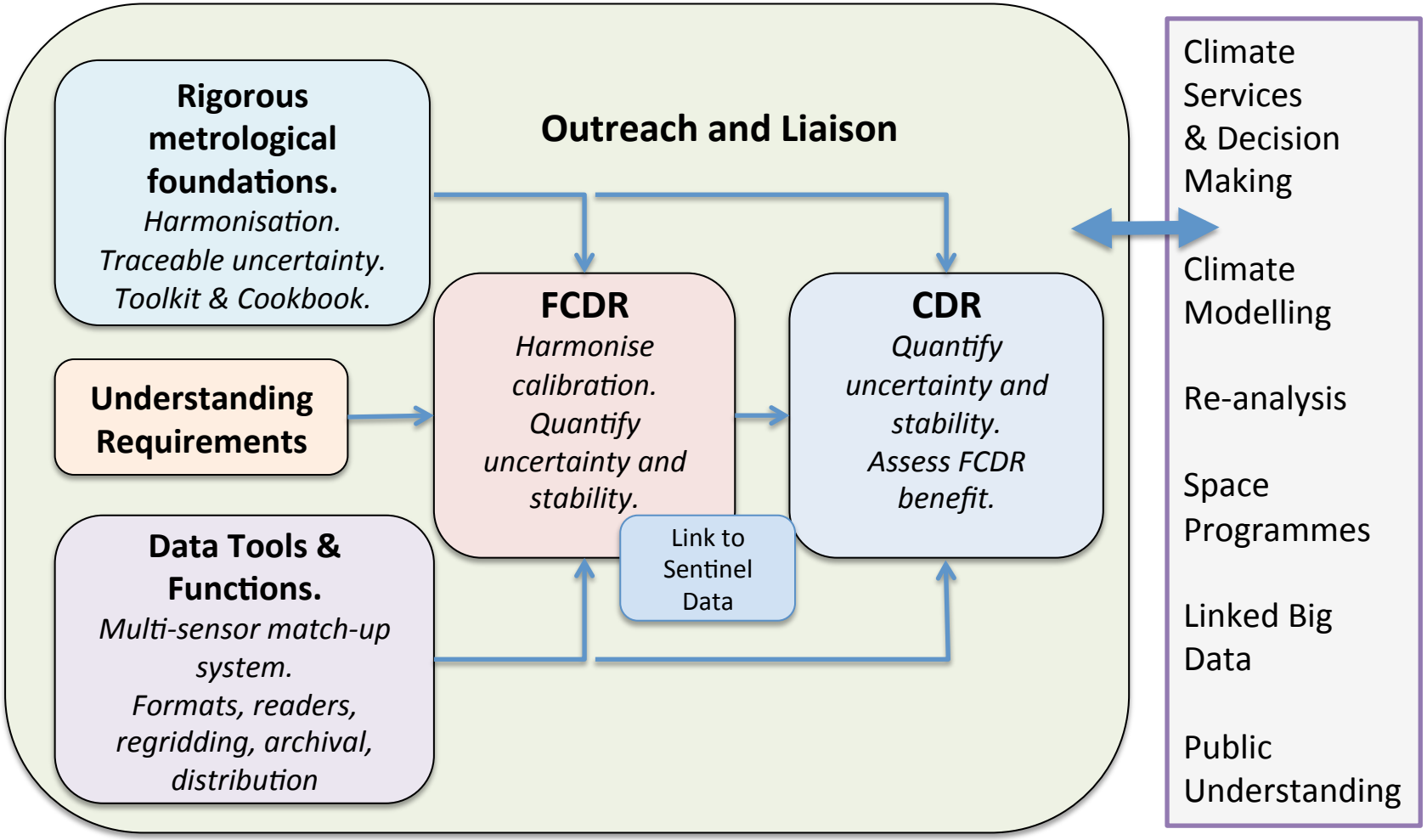

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Opportunities to be involved

- FCDR users – please allow us to interview you to understand FCDR user requirements
- FCDR/CDR users – would you like to be a “trail blazer”?
  - early access to easy-FCDR datasets and beta tools in exchange for feedback
- FIDUCEO workshops
  - September 2017
  - Autumn 2018
- Website, mailing-lists, blog etc coming …