A Metrologically Traceable Uncertainty Analysis for 40 Years of Satellite Measurements from the High Resolution Infrared Radiation Sounder (HIRS)

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The information presented here and the results shown represented the state of the analysis at November 2017. For the latest version of the measurement equation and project results, please refer to the FIDUCEO project team.

High resolution Infrared Radiation Sounder

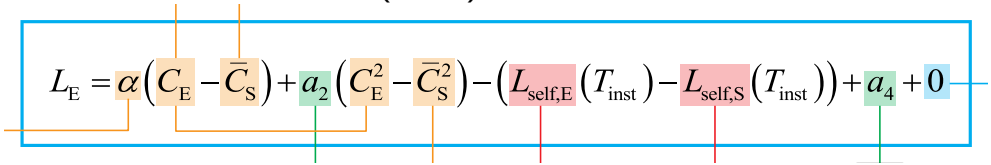
EUMETSAT

- The **H**igh resolution **I**nfrared **R**adiation **S**ounder (HIRS) is a series of operational atmospheric sounders.
- 20-channel infrared radiometer dating back to 1975. Nonstop coverage 1978–2017.
- Designed for weather observations. Suppose someone wants to use it to study climate — where would they start?
- The answer lies in metrology — the science of measurement.
- Therefore, let us introduce...

What is FIDUCEO?

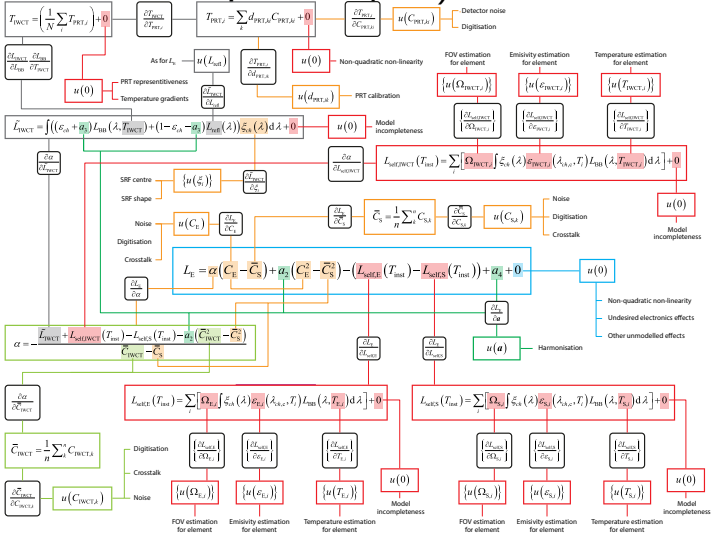
- **Fid**elity and **U**ncertainty in **C**limate data records from **E**arth **O**bservations.
- Develop a widely applicable basis for the metrology of Earth observation.
- Establish uncertainty-quantified evidence base for long-term global change from Earth observation.
- Develop Fundamental Climate Data Records (FCDRs) for several instruments: HIRS, AVHRR, MVIRI, and microwave sensors SSM/T2, AMSU-B, MHS. First versions available now.
- Develop Climate Data Records (CDRs) for tropospheric humidity, aerosol, sea surface temperature. Available next year.
- How do we get there. . . ?

Measurement equation (core)



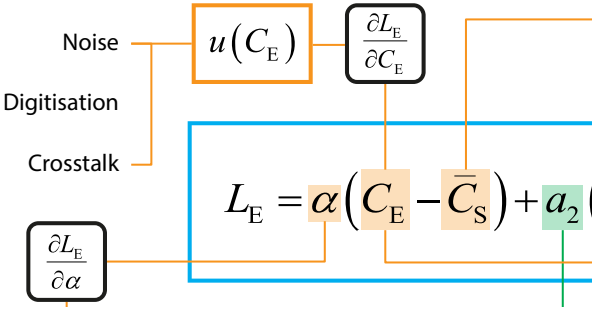
- Measurement equation relates measured quantities (such as calibration counts and Earth counts) to desired quantity (calibrated Earth radiances or brightness temperatures).
- FIDUCEO improves existing calibrations for the entire time period.
- Includes **metrologically traceable uncertainty estimates** associated with each term, including **correlation structures**.
- Derived from our best understanding of the instrument physics.
- Starting point to determine all sources of uncertainty.

Measurement equation (full)



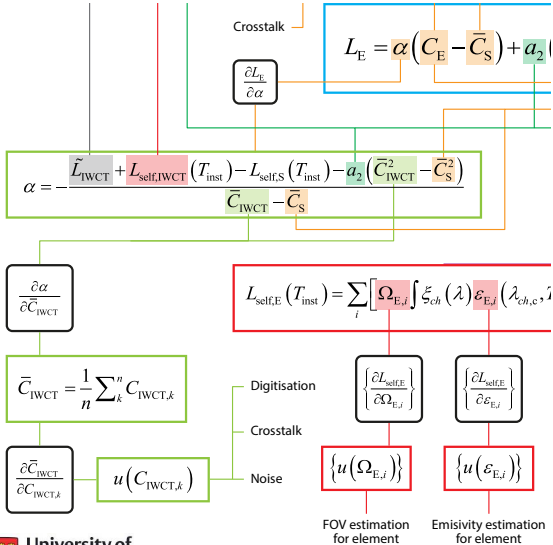
Graphics by National Physical Laboratories (NPL)

Measurement equation: independent effect example



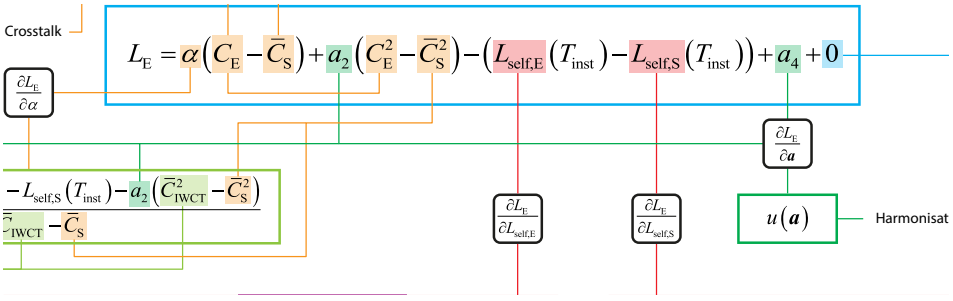
- An **independent** effect causes an error that is uncorrelated from pixel-to-pixel.
- Example: Noise and digitisation cause uncertainty in Earth counts $u(C_E)$, propagating to Earth radiance L_E.

Measurement equation: structured effect example



- A **structured** effect causes an error that is **correlated** from pixel-to-pixel.
- Example: Noise and digitisation cause uncertainty in Internal Warm Calibration Target (IWCT) counts C_{IWCT}, propagating to slope α and Earth radiance L_E
- But calibration parameters updated only every 40 scanlines, introducing a **correlated error** on that length scale — but not longer!

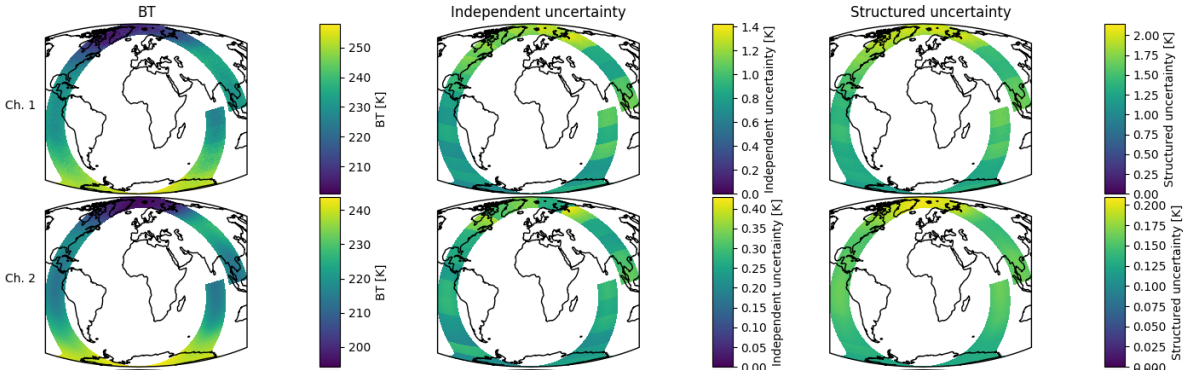
Measurement equation: harmonisation example



- **Harmonisation** considers any effects that are constant throughout a single sensor, and uses collocations to ensure consistency between sensors.
- Example: Error in detector nonlinearity (a_2) uncertainty is (assumed to be) constant for a single sensor, but may differ between sensors.

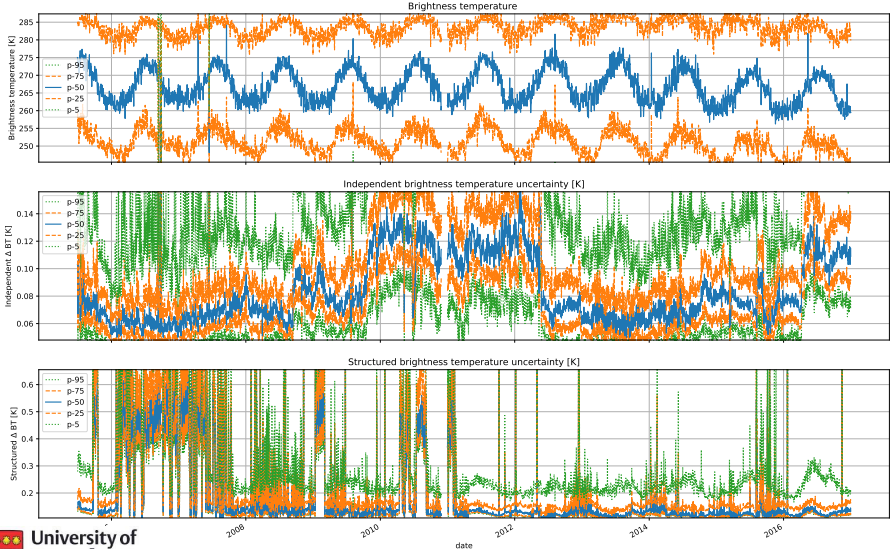
Extracts from FCDR

MetOp-A FCDR orbit example



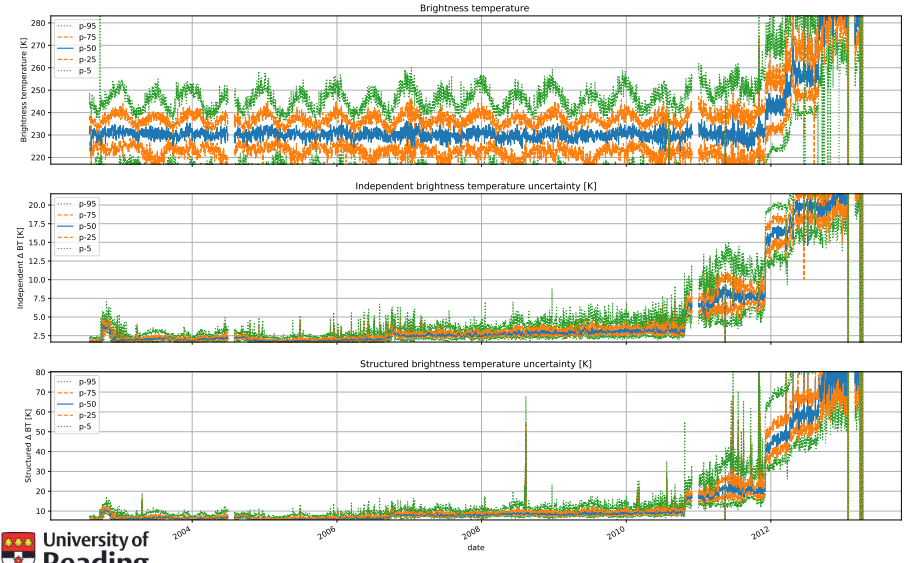
FIDUCEO provides those uncertainties per pixel, with the data.

Uncertainty components in easy FCDR



- NOAA-18 Ch. 8 2005–2016: Uncertainties show channel performs well.
- NOAA-17 Ch. 1 2002–2013: Uncertainties capture channel problems correctly.

Uncertainty components in easy FCDR



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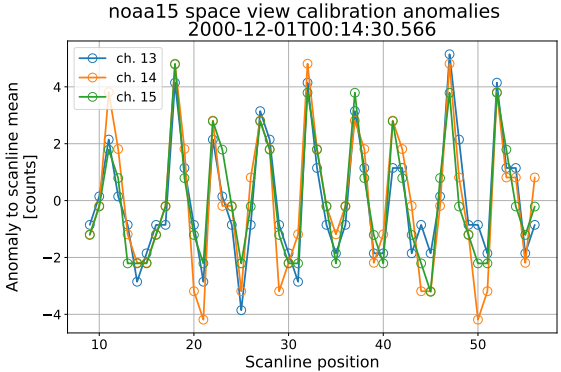
HIRS calibration cycle

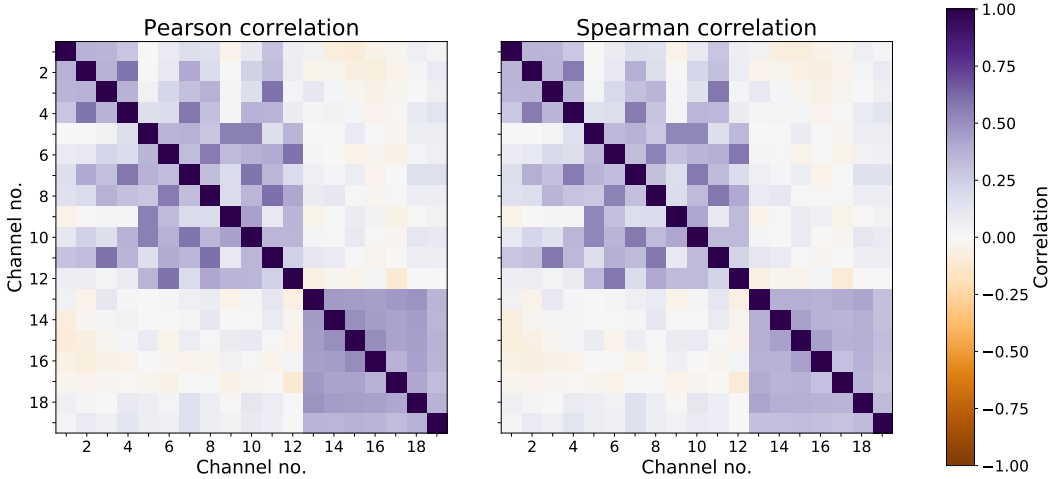


Holl et al, 2017, in preparation

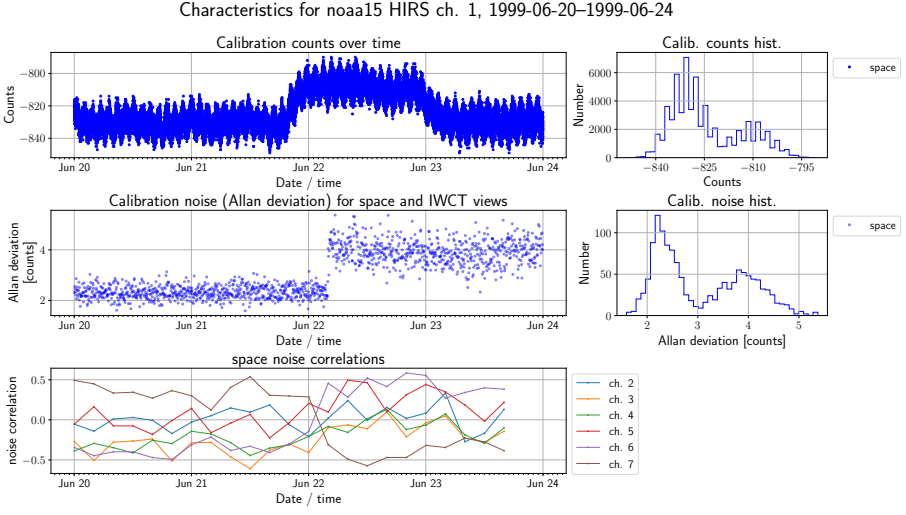
- Every 256 seconds, instead of scanning the Earth, HIRS looks at space and calibration target 56 times each.
- Mean value is typically taken as calibration value, but there is more information:
  - Allan deviation to determine noise in non-stationary time series,
  - taking anomalies,
  - correlations between channels,
  - and periodic extraneous signals.

Instrument error correlation matrix between channels

HIRS noise correlations, metopa 2016-07-01 -- 2016-08-01, space pos 20
(8727 cycles)



Correlation matrix timeseries



The new FIDUCEO HIRS FCDR

- **Available now**: Complete HIRS dataset (1978–2017) with new calibration, new self-emission model, and metrologically traceable uncertainty estimates — `http://www.fiduceo.eu`.
- January 2018: Harmonised FCDR.
- More or less complicated formats available, depending on user need.
- User workshop in Lisbon (Portugal), 17–19 April 2018.

Conclusions and next steps

- FIDUCEO marries Earth Observation to metrology.
- FIDUCEO produces an FCDR for nearly 40 years of HIRS.
- The FCDR improves upon existing datasets by:
  - Improving the calibration.
  - Adding metrologically traceable uncertainties per component.
  - Includes estimates of error correlations.
- Beta version available for testing.
- User workshop in Lisbon (Portugal), 17–19 April 2018.

http://www.fiduceo.eu

Acknowledgements

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