A Metrological Approach to Producing Harmonised Fundamental Climate Data Records From Long-Term Sensor Series Data

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A METROLOGICAL APPROACH TO PRODUCING HARMONISED FUNDAMENTAL CLIMATE DATA RECORDS FROM LONG-TERM SENSOR SERIES DATA

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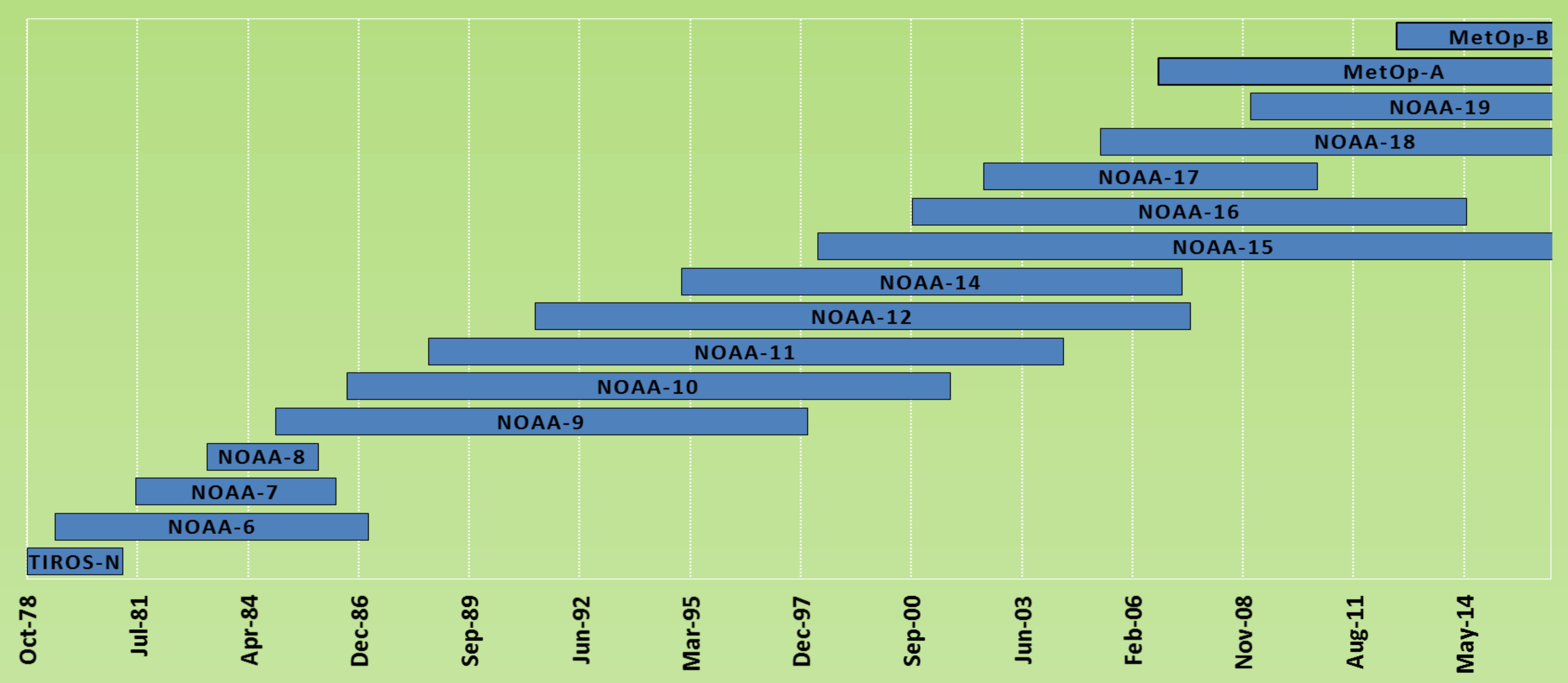

Fig. 1 – Timeline of the series of the NOAA and MetOp satellites which carry the AVHRR, HIRS and microwave sensor series – amongst the longest continuous satellite data records.

What is an FCDR?

A recent discussion at a FIDUCEO project workshop the definition of a fundamental climate data record was agreed as:

An FCDR consists of a continuous, harmonised record of calibrated, geolocated, uncertainty-quantified sensor observations in geophysical units (such as radiance), together with all ancillary and underlying data used to calibrate the observations and estimate uncertainty.

The FIDUCEO project is generating harmonised FCDRs for the AVHRR, HIRS and microwave sensor series which have flown aboard the NOAA and MetOp satellites (see Fig. 1).

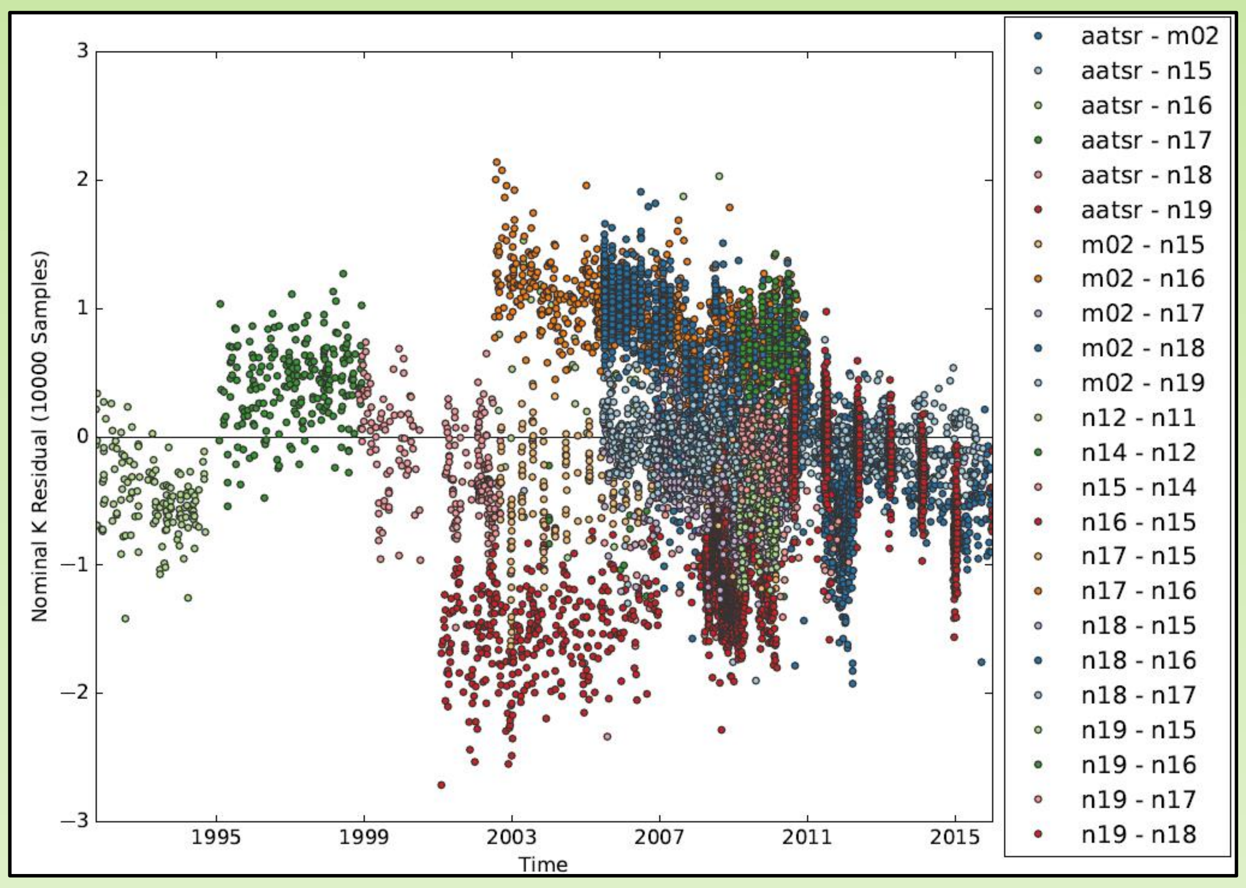

Fig. 2 – K evaluated for 10,000 randomly sampled AVHRR series match-ups with the operational calibration. Each colour represents matchups from a different sensor pair. Sensor to sensor differences are at levels that will not be negligible in terms of their impact on derived climate variables.

Why do we need to harmonise FCDRs?

For a matchups between sensors *i* and *j* one can compare their *expected difference*, *K*, to their *measured difference*,

$$K - (L_i - L_j)$$

For well calibrated sensors this would be close to zero. For historic satellite data, however, this is often far from the case (see Fig. 2) and so a recalibration or harmonisation is required.

$$F \equiv (\boldsymbol{K}-\overline{\boldsymbol{K}})^{\mathrm{T}} V_{\boldsymbol{K}}^{-1} (\boldsymbol{K}-\overline{\boldsymbol{K}}) + (\boldsymbol{L}_{\mathrm{ref}}-\overline{\boldsymbol{L}}_{\mathrm{ref}})^{\mathrm{T}} V_{\boldsymbol{L}_{\mathrm{ref}}}^{-1} (\boldsymbol{L}_{\mathrm{ref}}-\overline{\boldsymbol{L}}_{\mathrm{ref}}) + (\boldsymbol{X}-\overline{\boldsymbol{X}})^{\mathrm{T}} V_{\boldsymbol{X}}^{-1} (\boldsymbol{X}-\overline{\boldsymbol{X}})$$

Eqn. 1 – The errors-in-variables cost function minimised during harmonisation. For the series matchups $\boldsymbol{X}$ are the sensor state variables, $\boldsymbol{L}_{\mathrm{ref}}$ are the reference sensor measurements and $\boldsymbol{K}$ are the expected sensor-to-sensor differences. The overbar indicates estimates of the data values. $V_{\boldsymbol{K}}$, $V_{\boldsymbol{L}_{\mathrm{ref}}}$ and $V_{\boldsymbol{X}}$ are the error covariance matrices for $\boldsymbol{K}, \boldsymbol{L}_{\mathrm{ref}}$ and $\boldsymbol{X}$ respectively.

How should we harmonise FCDRs?

To harmonise FCDRs we try to reconcile the *expected* and *measured* matchup differences for the full set of match-up observations between series sensors and reference sensor(s). Given that each series sensor has a measurement equation,

$$L = f(X, a)$$

- X – sensor state variables
- a – calibration parameters

the problem then becomes a large non-linear regression problem solving for new calibration parameters for all series sensor.

Since the data is highly error-correlated simplistic fitting algorithms (e.g. least squares) give biased solutions, a more rigorous errors-in-variables approach is therefore required (see Eqn. 1 for the cost function).

Our approach and preliminary results

Existing errors-in-variables solvers cannot tractably compute a solution for the large matchup datasets required while respecting their full error covariance information, therefore we have developed a set of new algorithms to for this (to be described in future publications).

The project's FCDRs are currently in final preparation, however, preliminary results are available for the AVHRR harmonisation – produced using our *marginalised EIV* algorithm. Considered were AVHRRs from NOAA-11 on with the AATSR as the reference. These combine to give an input dataset containing over >10^8 matchups. Fig. 3 shows the improvement of the harmonised calibration, compared to the operational data in Fig. 2.

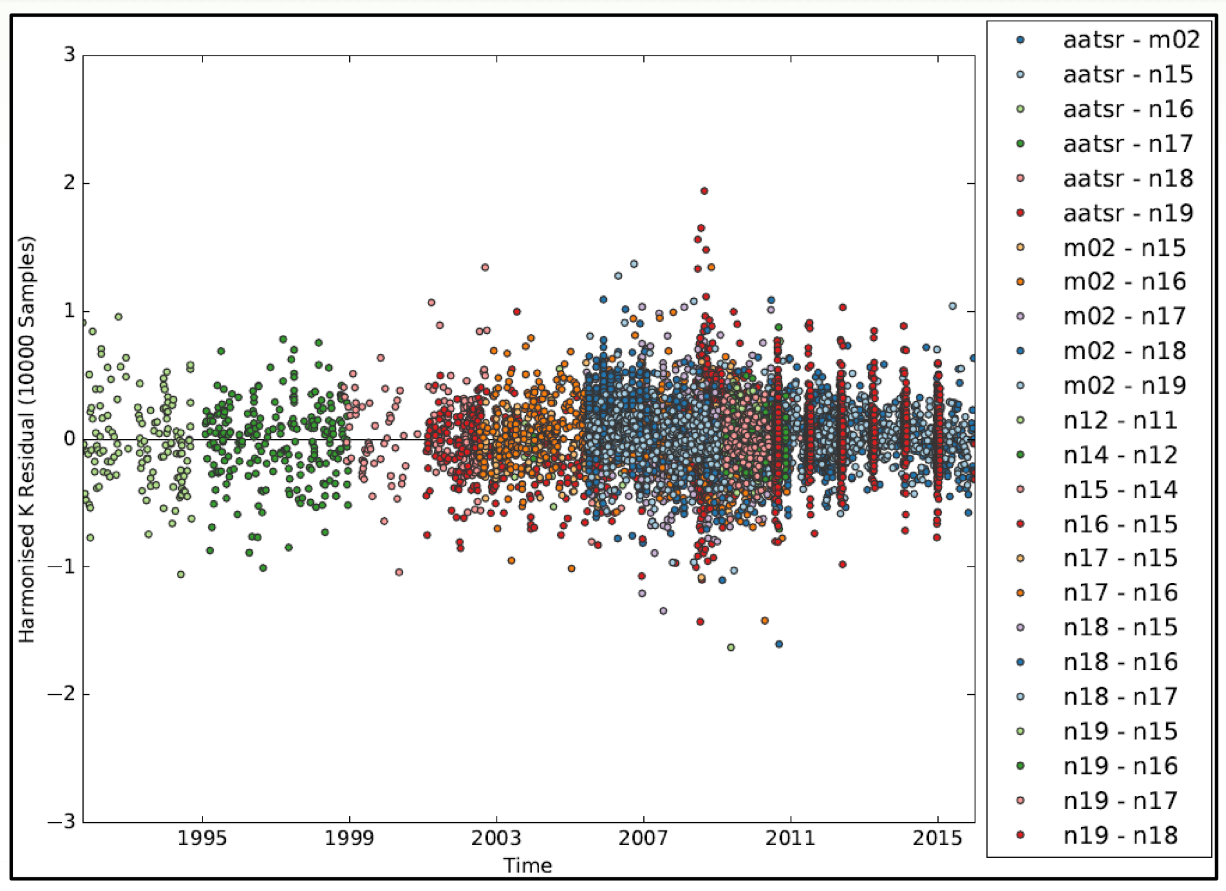

Fig. 3 – K again evaluated for 10,000 randomly sampled AVHRR series match-ups now with the harmonised calibration. A big improvement in sensor-to-sensor agreement and calibration stability is clear.

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