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

AVHRR FCDR

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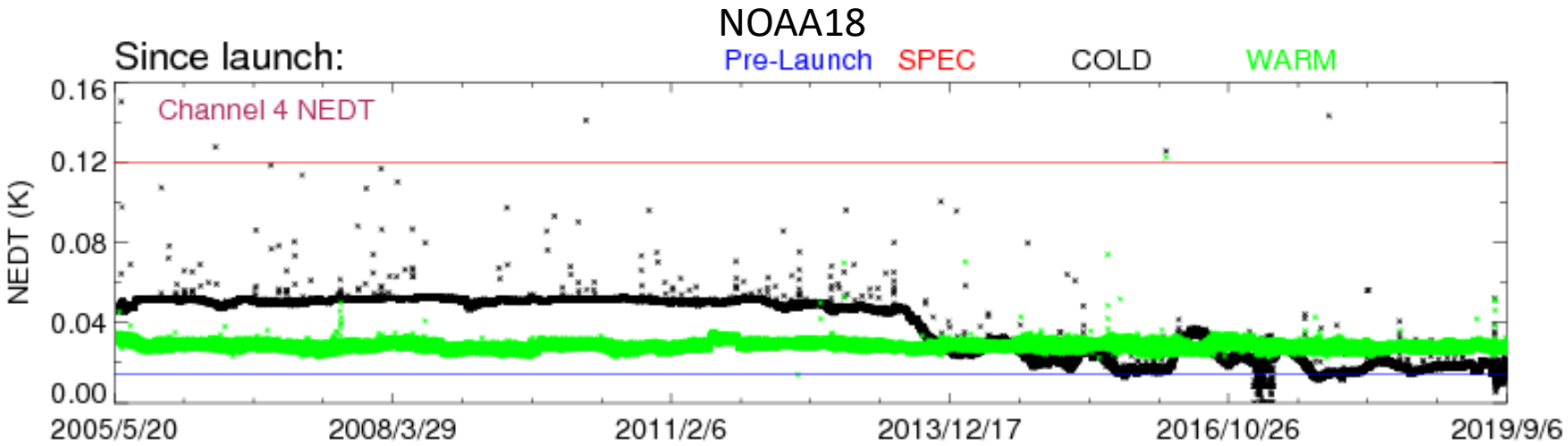
Calibration of AVHRR before FIDUCEO

- A number of different calibration schemes were used over the AVHRR lifetime
  - Simple linear model for all channels (TIROS-N to NOAA-8)
  - Non-linear correction from lookup table (NOAA-9 to NOAA-12)
  - Non-linear correction from lookup tables including a “negative radiance of space” term (NOAA-14)
  - Walton et al. Non-linear correction to a linear radiance (not physically based) plus a ‘negative radiance of space’ (NOAA-15 onward)
- Definite problems with pre-launch data
  - Aimed at 0.5K accuracy at best (1K for AVHRR/1 and AVHRR/2)
  - Problems with stray light. temperature drifts etc.

Pre FIDUCEO uncertainties

- Very limited uncertainty information
  - Quoted value of 0.12K has often been used
    - This is, in fact, the design specification for the AVHRR/3 sensors
  - Graphs of NeΔT are available from NOAA
    - But not the values themselves…



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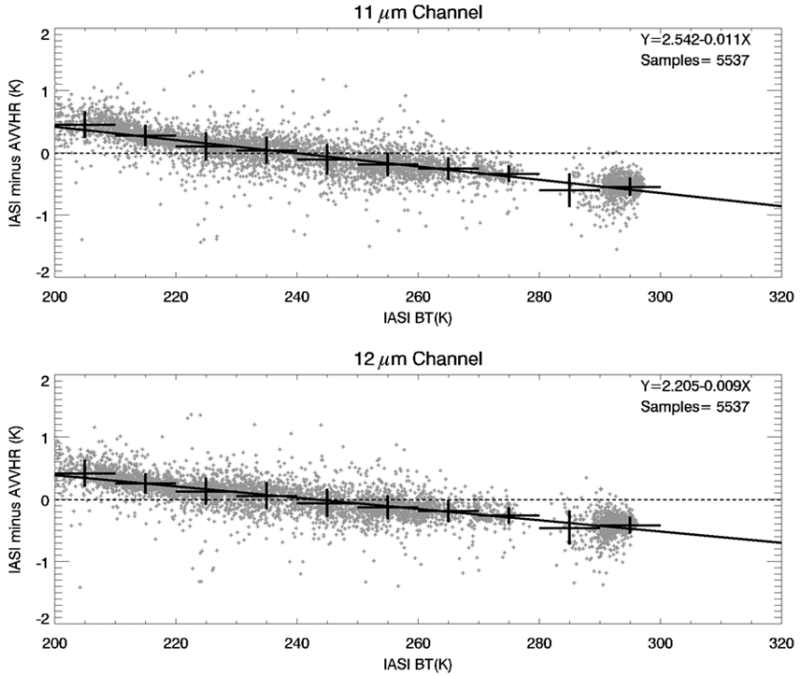
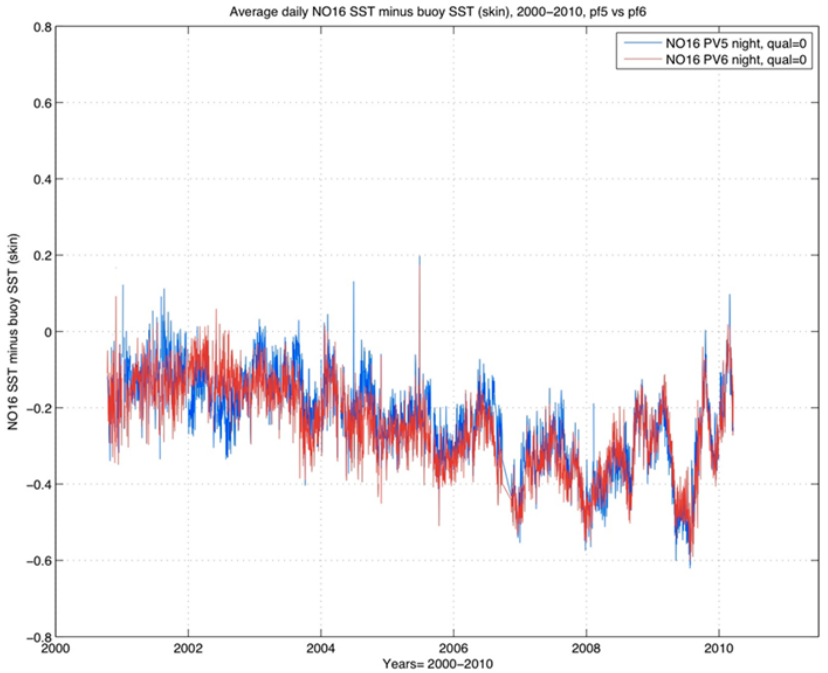
AVHRR pre FIDUCEO - biases

- Clear biases in the AVHRR radiances (IR)



Scene temperature dependent biases



Simple SST (constant retrieval coefficients) vs insitu show impact of time dependent biases related to instrument temperature

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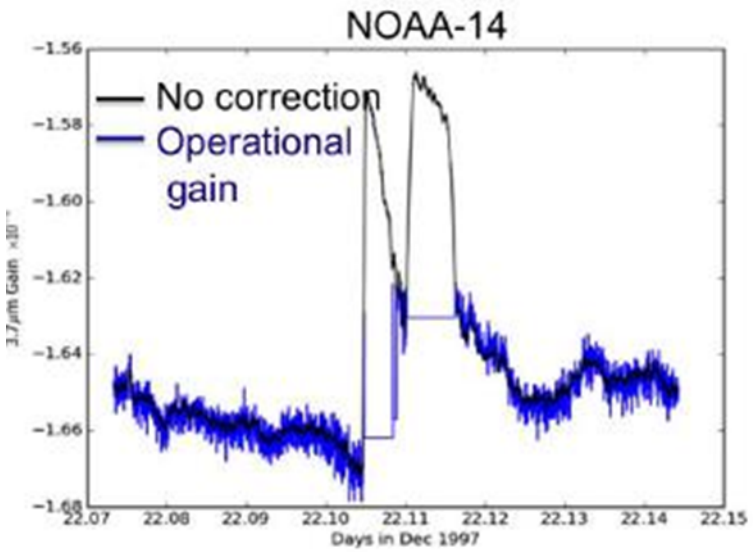
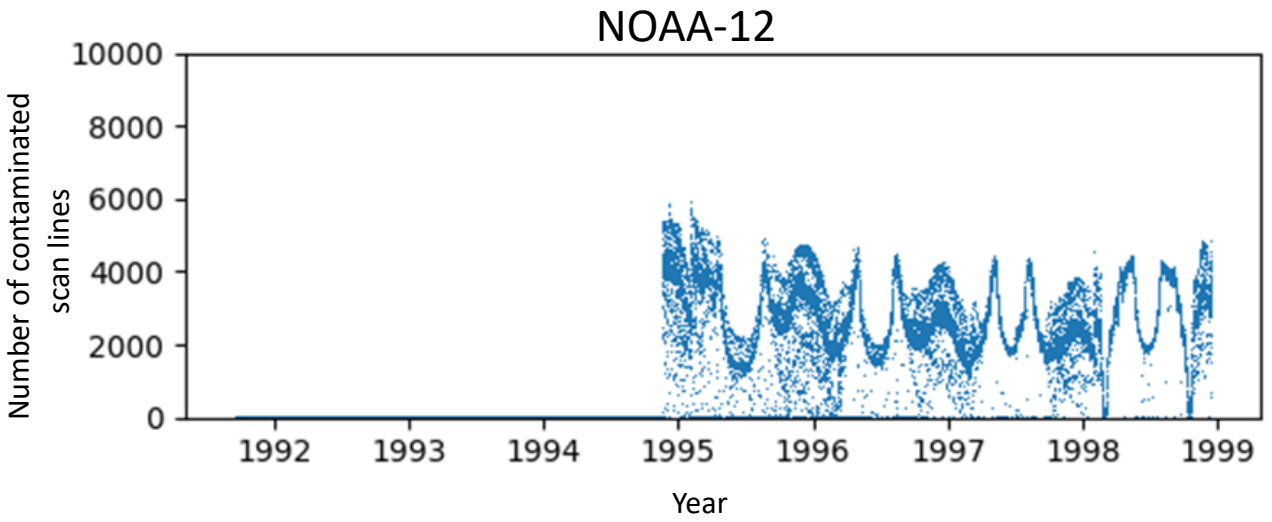
Solar contamination

- Known for both calibration system and Earth view
  - Operational correction from late 1994 only



Operational version of correction.
Linear model of gain only.



Algorithm after late 1994 only

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Operational AVHRR issues

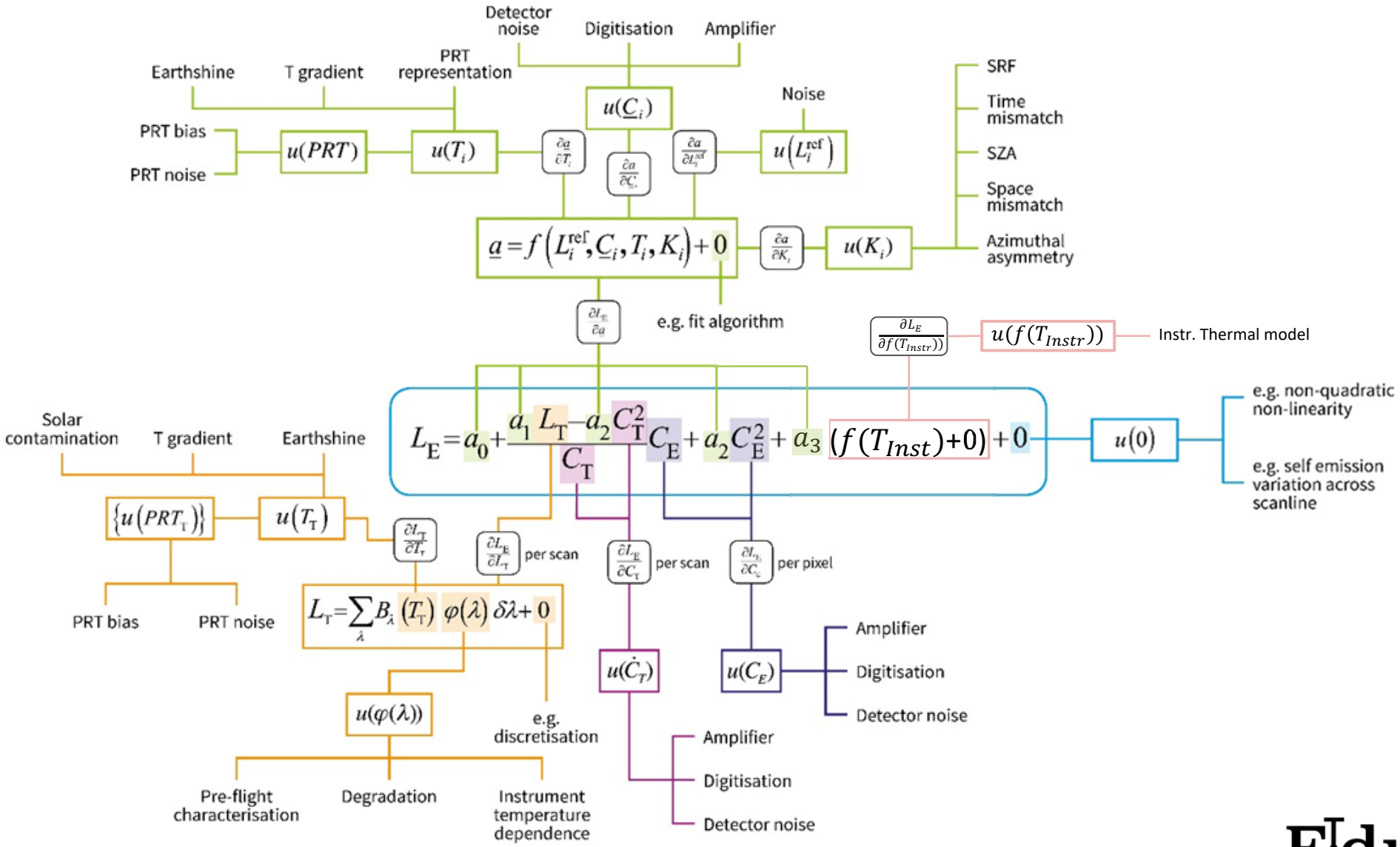
- Multiple calibration algorithm in NOAA Level 1B
  - Many people reprocess using Walton et al. calibration for all AVHRRs
    - Walton et al. algorithm is not physically based
  - Sensors not harmonised
- Pixel level uncertainties not available
  - And associated error correlation information…
- Scene temperature and time/instrument temperature dependent biases of up to 0.5K
- Geolocation errors
- Simple solar contamination algorithm
  - Only exist from late 1994
  - Doesn't resolve underlying thermal environment of IWCT issues
  - Earth view contamination not flagged

Measurement equation and Uncertainty Diagram

Solves unphysical Walton et al. measurement equation

Has Tinstr terms

Is Harmonised



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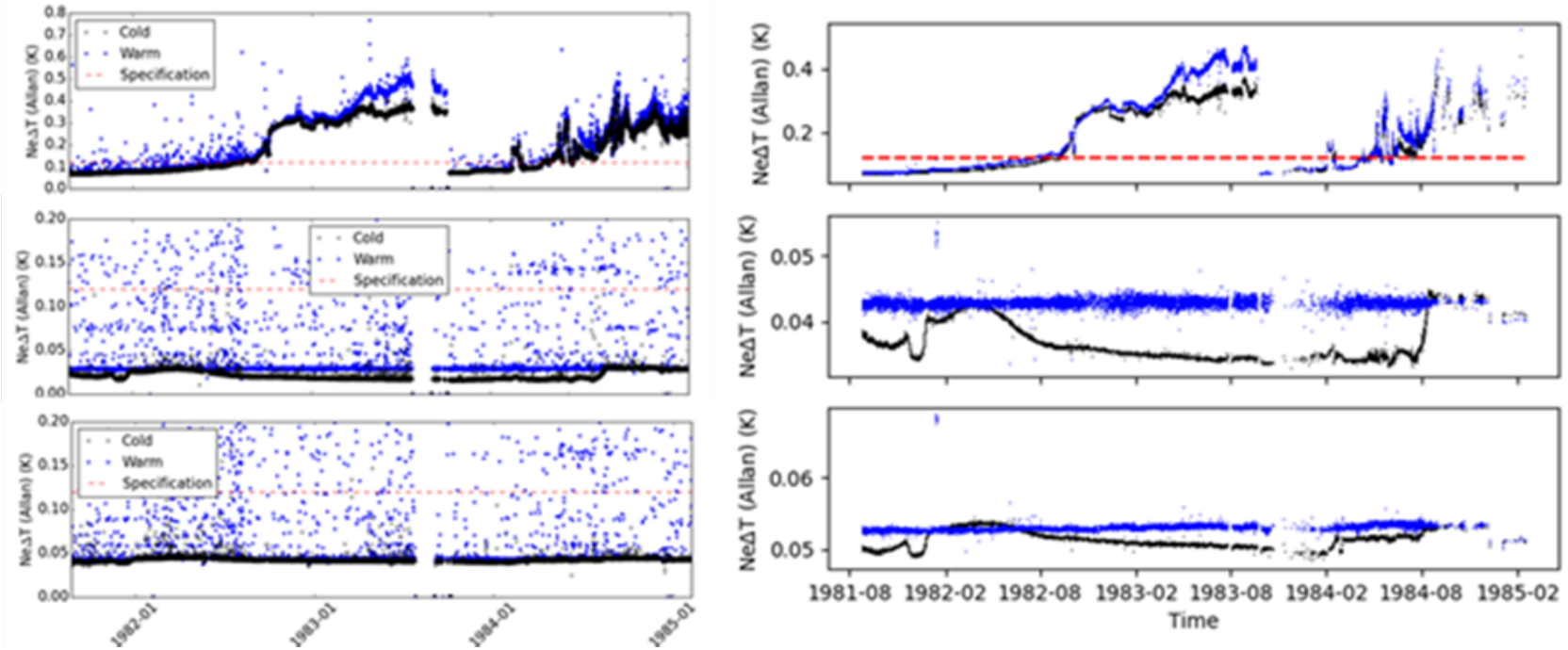
Noise estimation

- Filter outliers and use Allan deviation for noise estimates
  - Can then get noise from IWCT (Warm) views

Earth view noise taken from IWCT noise

- Assume space clamp can cause variation
- **Provided at the pixel level**



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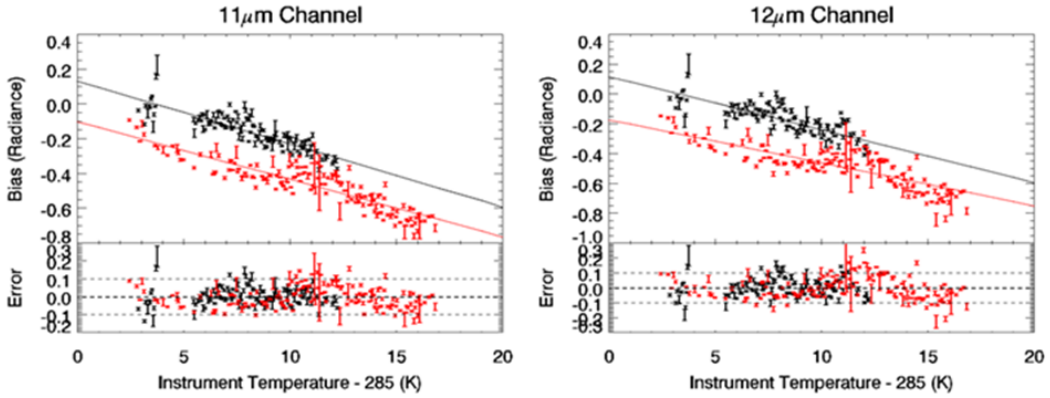
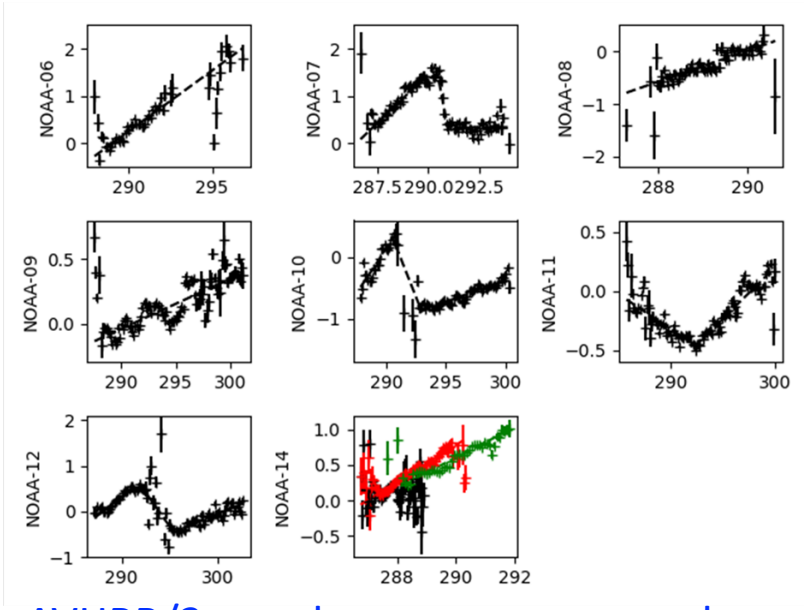
Thermal environment term

- $f(T_{Instr})$ term for evolution of thermal environment
  - Included as part of harmonisation process
  - Currently a simple linear function of instrument temperature



Linear model can work well but can also be a function of time (NOAA-16 case shown)

- Time dependence can also be seen



For AVHRR/2s can be even more complex

- This level of detail not implemented in current FCDR

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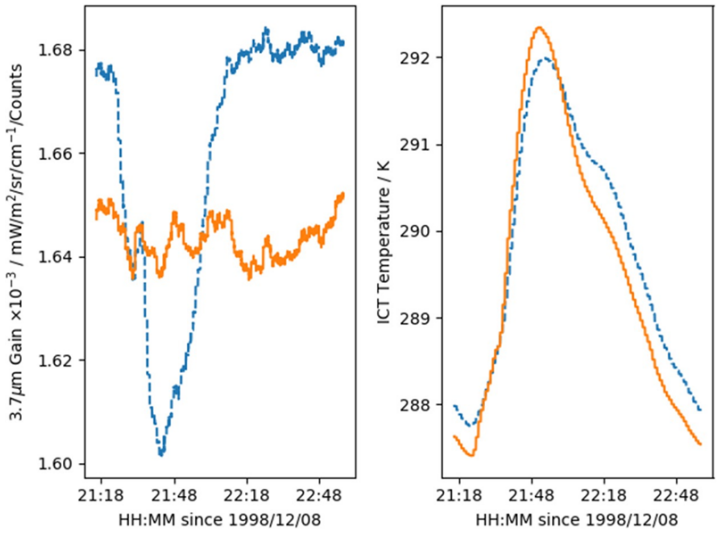
IWCT issues

- Not only solar contamination but also variations in thermal gradients
  - FCDR has a model for gradients
  - Updated solar contamination model
  - Flag for solar radiance seen in Earth view data



Model for IWCT temperature correction to give linear 3.7μm gain (linear detector)

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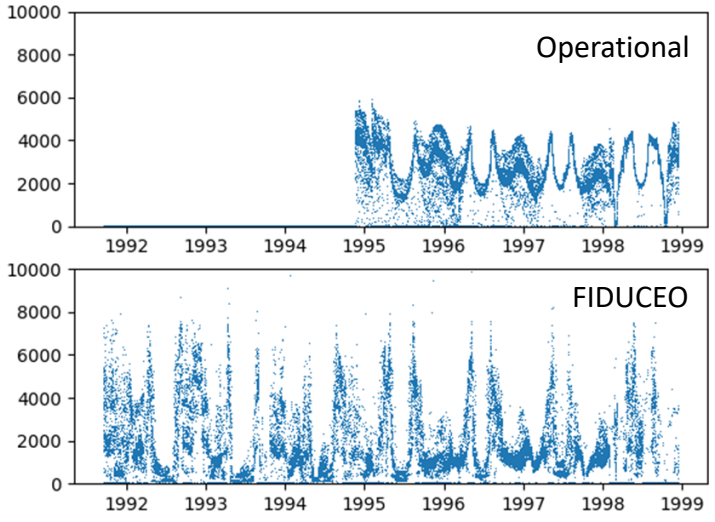

Solar contamination available for all sensors/all times

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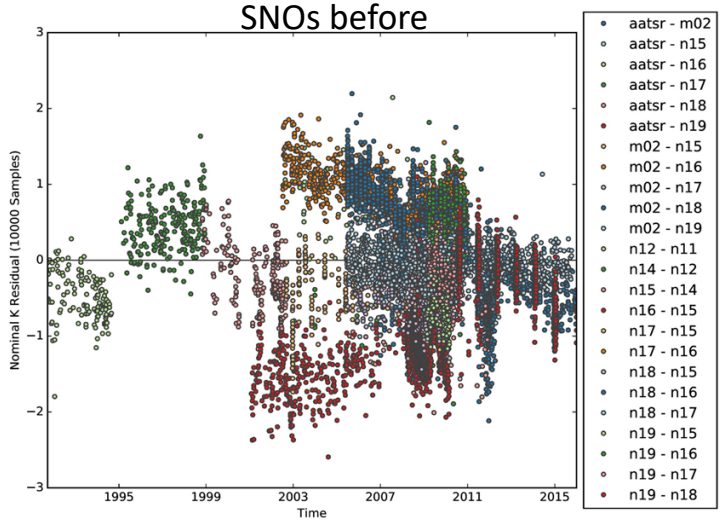
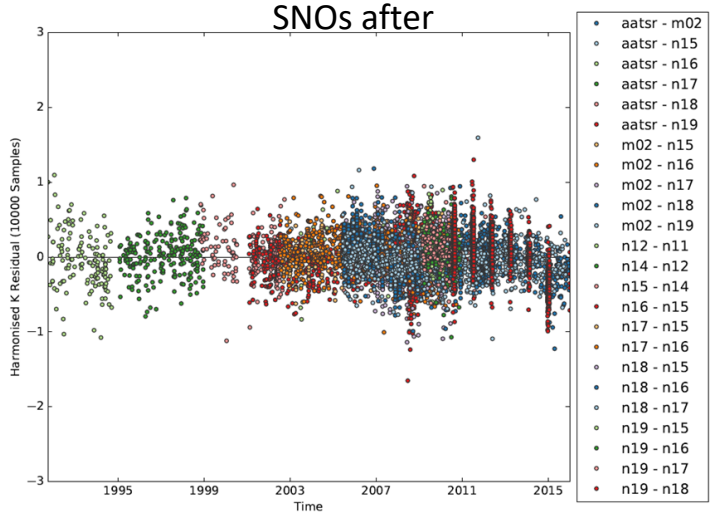
AVHRR Harmonisation

- Still ‘work in progress’
- Harmonised to MMS SNO data only
  - Solar contamination filtering applied for 3.7µm channel
- Harmonisation process works well (internal consistency)
- Problems for more general case (all scene temperatures)
  - Particularly for the 3.7µm channel
- Need updated matchup data **plus associated uncertainties**
  - Uncertainties on different methods the real unknown

SNOs before

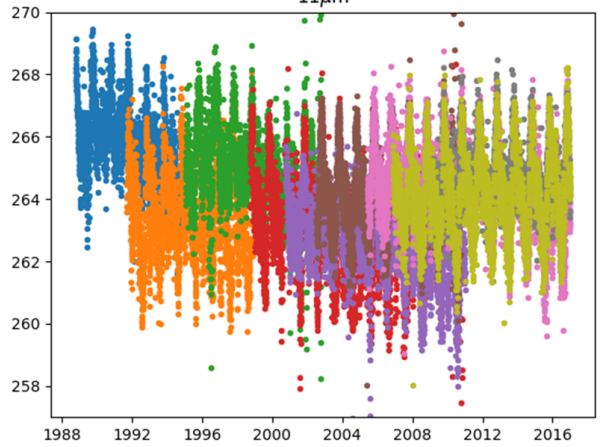


SNOs after

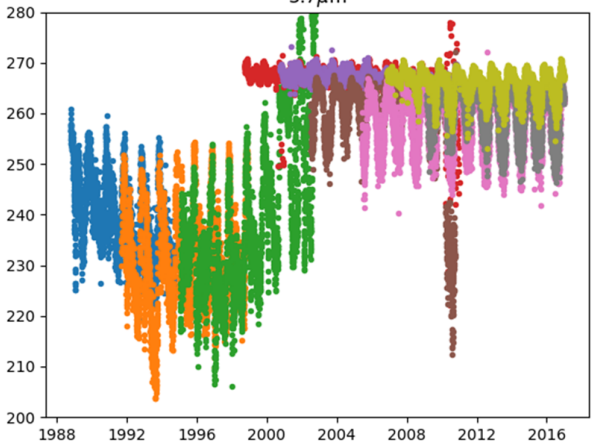


Daily average BT

11µm



3.7µm



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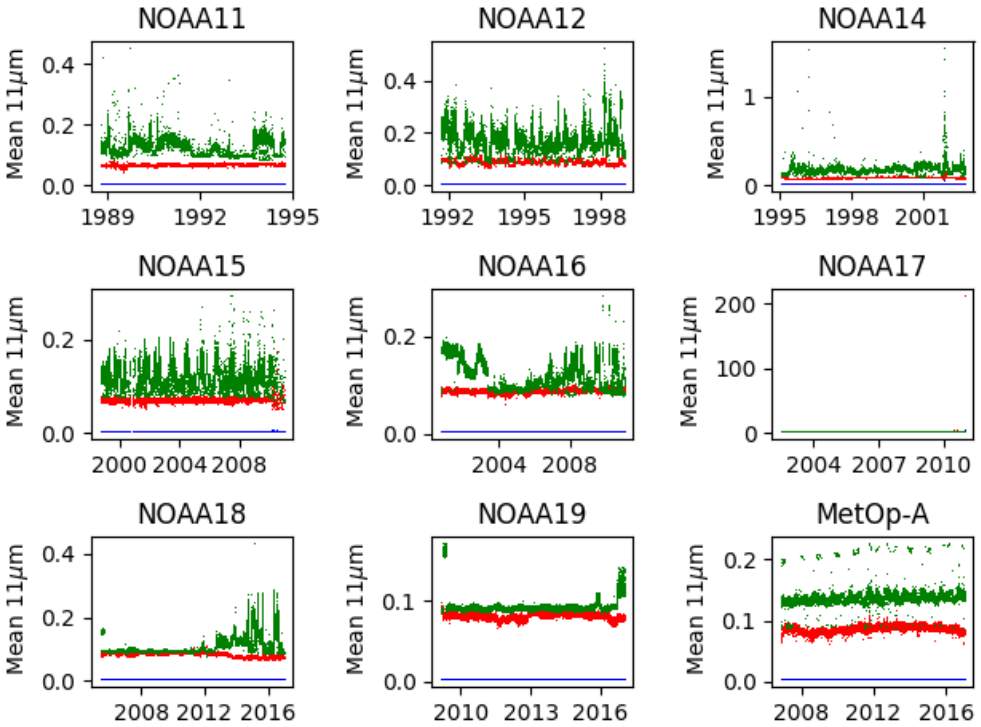
Uncertainties

- Three uncertainty components available plus covariance information (including channel-to-channel) for visible and IR channels

Independent
Structured
Common



IR Channels
Correlation Matrix

$$\begin{pmatrix} 1.0 & 0.0209 & 0.0209 \\ 0.0209 & 1.0 & 0.9958 \\ 0.0209 & 0.9958 & 1.0 \end{pmatrix}$$

IR Channels
Covariance Matrix

$$\begin{pmatrix} 0.1074 & 0.0017 & 0.0016 \\ 0.0017 & 0.0726 & 0.0689 \\ 0.0016 & 0.0689 & 0.0714 \end{pmatrix}$$

Example channel to channel correlation/covariance information for one pixel

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Conclusions

- There are many sources of error in the current operational AVHRR Level 1 dataset
  - Non-physical measurement equation, solar contamination, calibration target errors, evolving thermal state errors, noise etc.
- We have developed models and methods to reduce these errors significantly and derive associated uncertainties
  - New measurement equation (physically based), use of Allan deviation (choice of Earth view noise), new solar contamination algorithm for all sensors (no operational algorithm before 1995), IWCT thermal gradient estimator (one of the largest sources of error), thermal environment model (long term trend), updated geolocation (pyGAC)
- Everything has an uncertainty at the pixel level which is translated to FIDUCEO Easy (3 component) format including error correlation terms (spatial and spectral)
  - CURUC techniques applied
  - Much more detailed than simple global NeΔT currently available
- Harmonised data to SNO like matches
  - FCDR back to NOAA-11 to MetOp-A (1988-2016) due to problems with matchups
    - Earliest sensors are real problem (no 12µm channel NOAA-10,8,6,TIROS-N) small overlaps with NOAA-08
  - Technique in place. Sampling of required parameter space limited by current matchups so harmonisation parameters sub-optimal
    - Different techniques needed to improve sampling but techniques also need associated uncertainty analysis
  - More complex thermal environment model may be needed to derive best harmonised dataset

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