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Importance of uncertainty estimates at Level-1 satellite data for SST CDRs retrievals; progress made within FIDUCEO

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FIdelity and Uncertainty in Climate data records from Earth Observation

Overview of the project

- Funded by the Horizon 2020 Framework Programme (EC)
- A lot of partners: University of Reading, Eumetsat, University of Hamburg, DLR, NPL…
- 4-years project that started in March 2015
  - Project aims to apply metrological principles to historic EO satellite data
- **Fundamental Climate Date Records** (FCDRs) from AVHRR, HIRS, MW sounders, MVIRI
- **Climate Data Records** (CDRs) will be developped from FCDRs
  - SST, Upper Tropospheric Humidity, Aerosols, albedos
- Main dates:
  - April-May 2017: Preliminary FCDRS including the AVHRR
  - 2019 : **SST CDRs with uncertainty ensemble data**

What are the aims of FIDUCEO?

- Derive methods and best practice **for FCDRs** (Level 1) and for **CDRs**(Level 2+) for a range of instruments 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/useability of the end product
  - Rigorous analysis of uncertainties
  - Traceability of uncertainties
    - 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

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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 developed 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?

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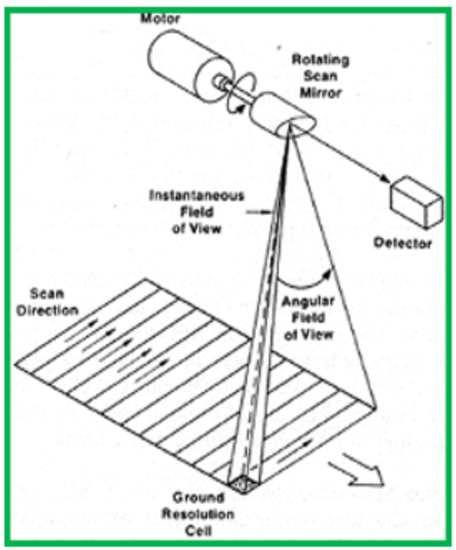
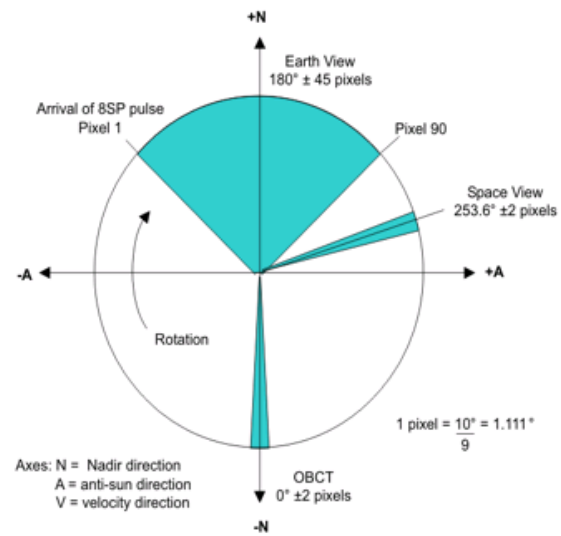
AVHRR measurements

- **Mission since 1978**: one of the longest continuous global satellite records.

- **On-board calibration for each scan lines:**

10 obs. of on-board reference (internal calibration target) +space

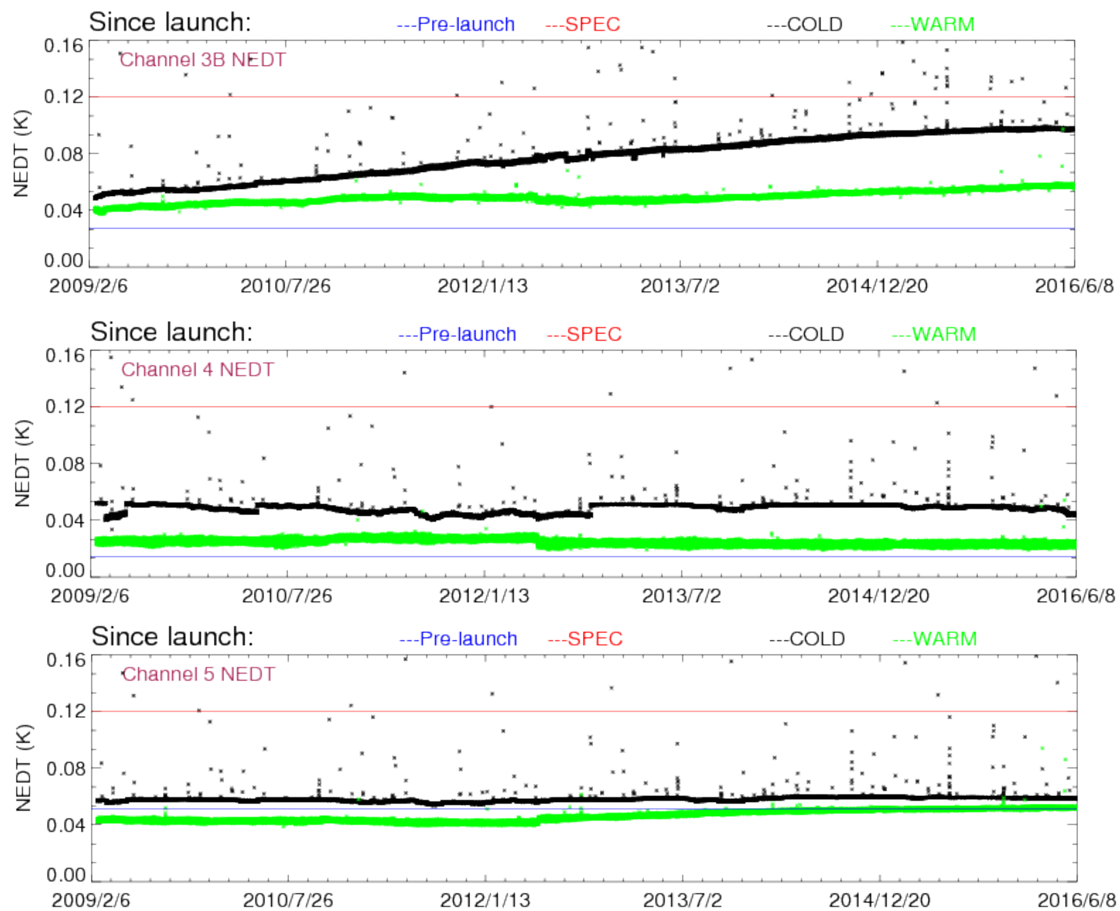




AVHRR measurements

- One of the fundamental source of uncertainty is instrumental noise:
  - Error due to badly characterized calibration system
  - Thermal noise of the detector
  - Etc…
- Random component of the instrument noise can be measured from:
  - Space view measurements
  - Internal calibration target measurements
  - (Uniform scenes)

How to estimate the uncertainties?



NOAA, Star
http://www.star.nesdis.noaa.gov/icvs/

HOWEVER it is far more complex

➡ In this work we are studying the uncertainties caused by instrumental noise for the AVHRR

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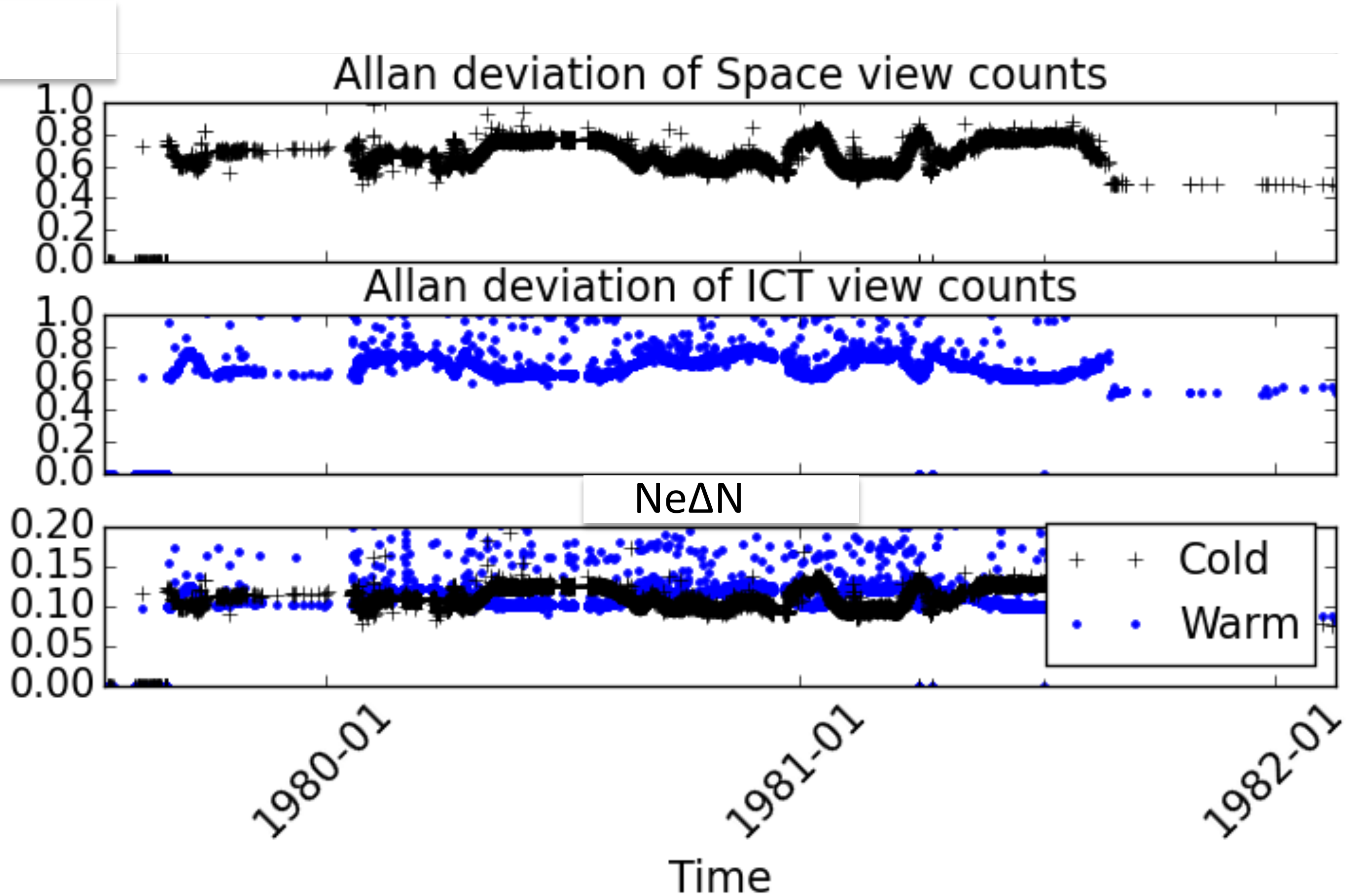
Noise is different according to what we are looking: Space or Internal calibration target

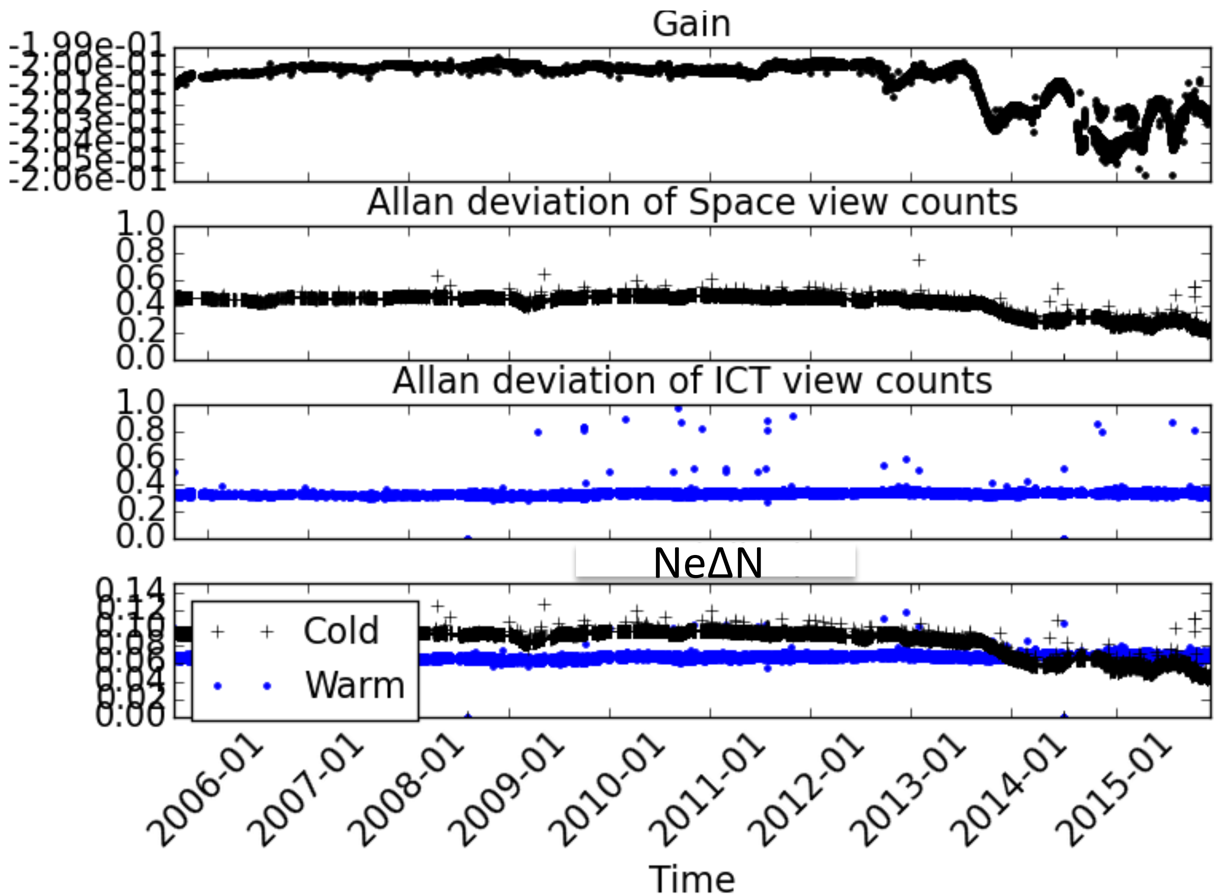
AVHRR-06,
ch @ 11µm,
Orbital means



➡ What to expect when looking at the Earth

Temporal variability of the noise

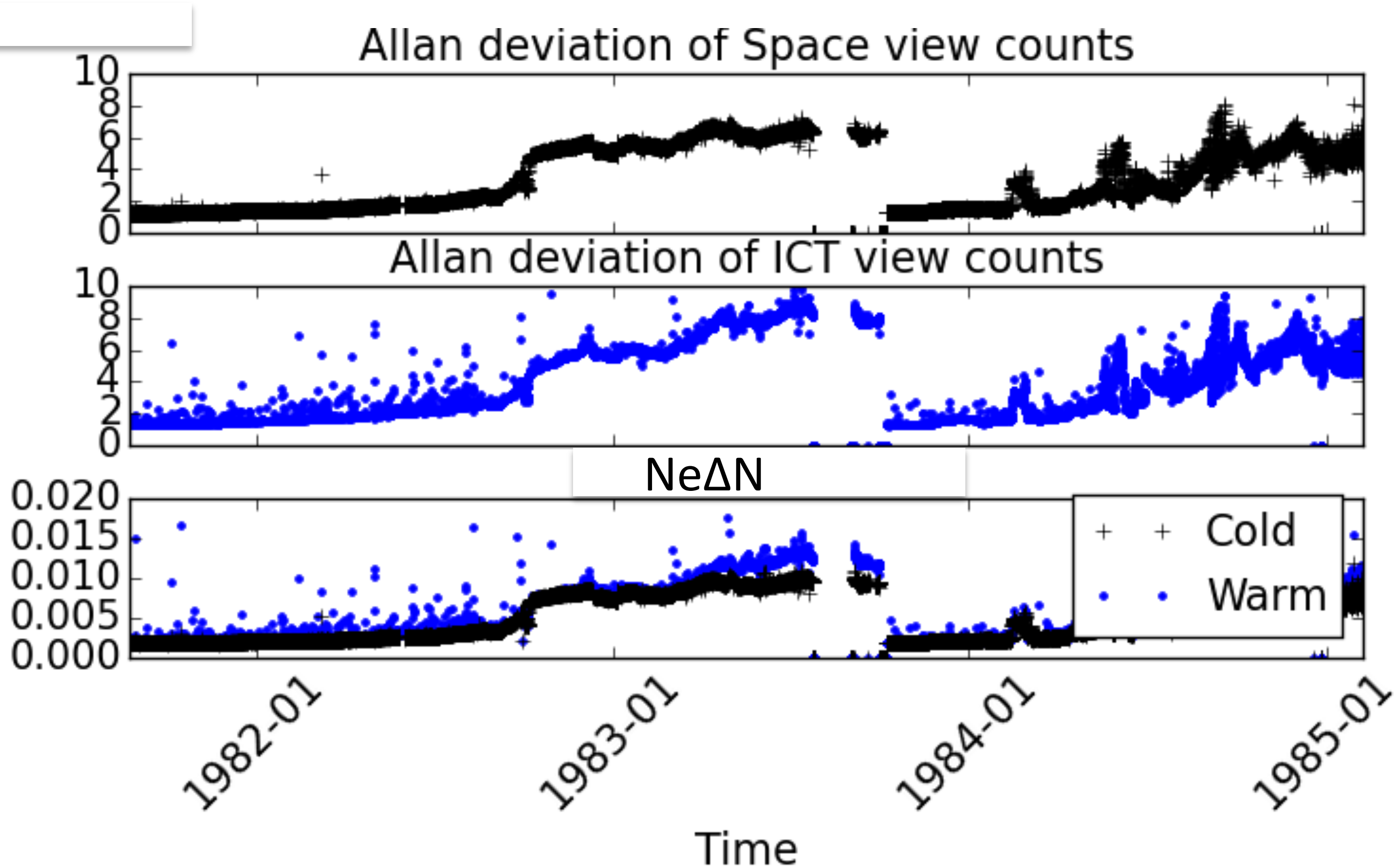
AVHRR18_G, Ch. @ 11μm



Due to degradation over time (but not for the ICT)

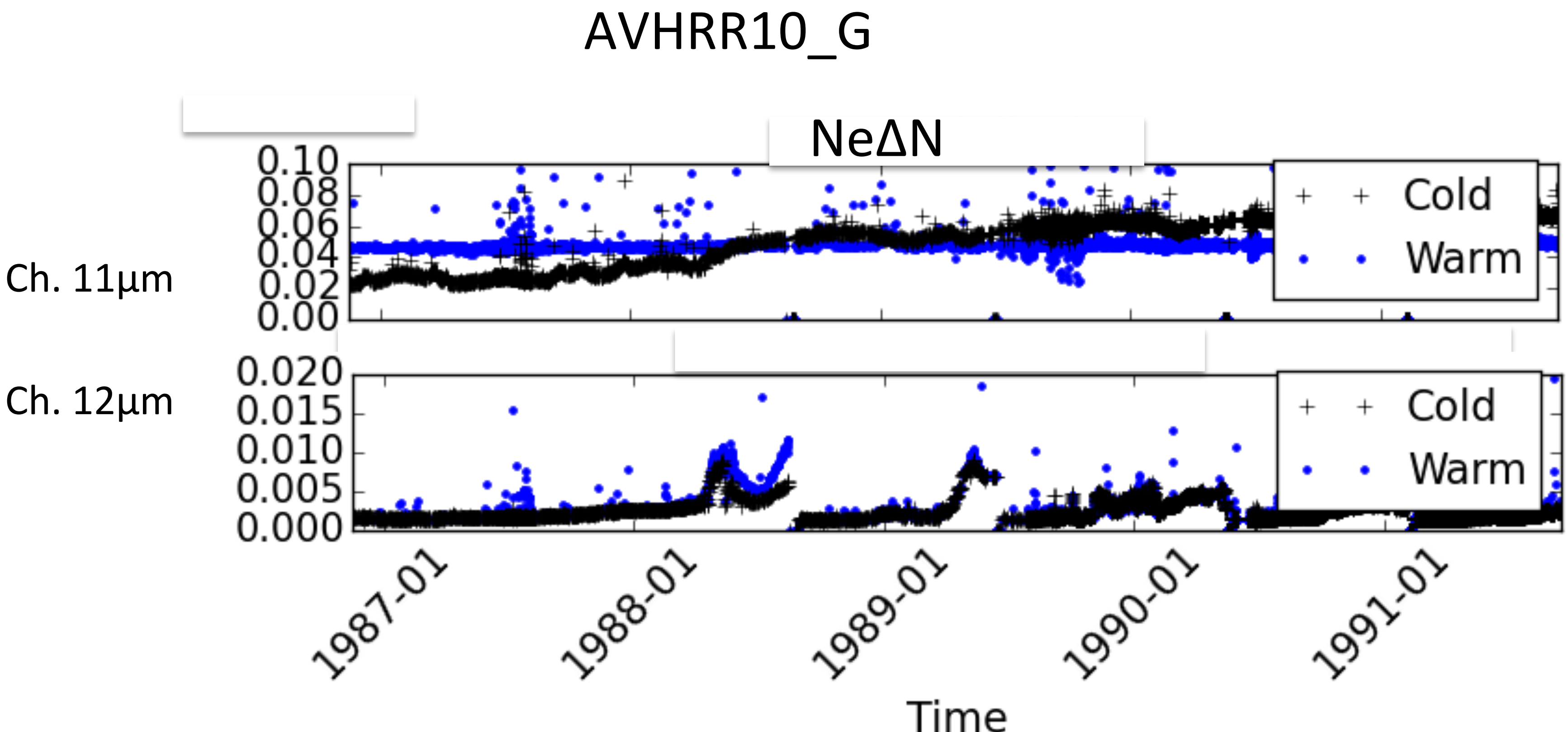
Temporal variability of the noise

AVHRR-07,
ch@3.7µm



➡ Jumps linked to events that touched the instrument

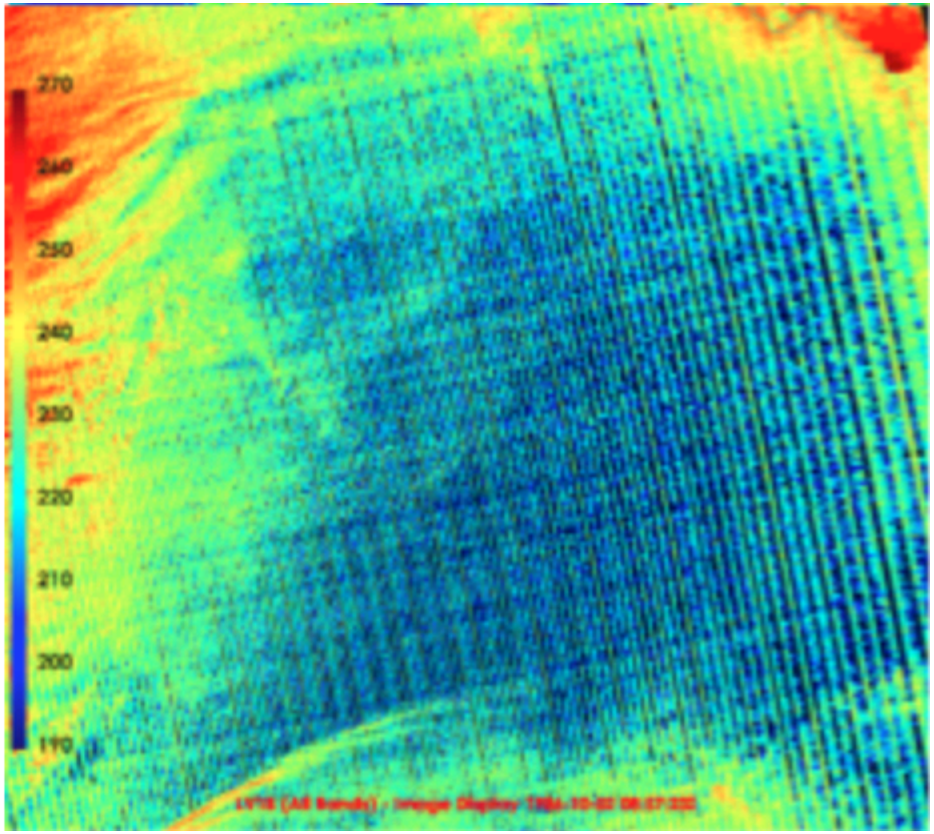
Spectral variability of the noise



➡ Noise is much more complex than a unique value for all the channels and sensors. Need to take this variability into account.

Consequence of the noise

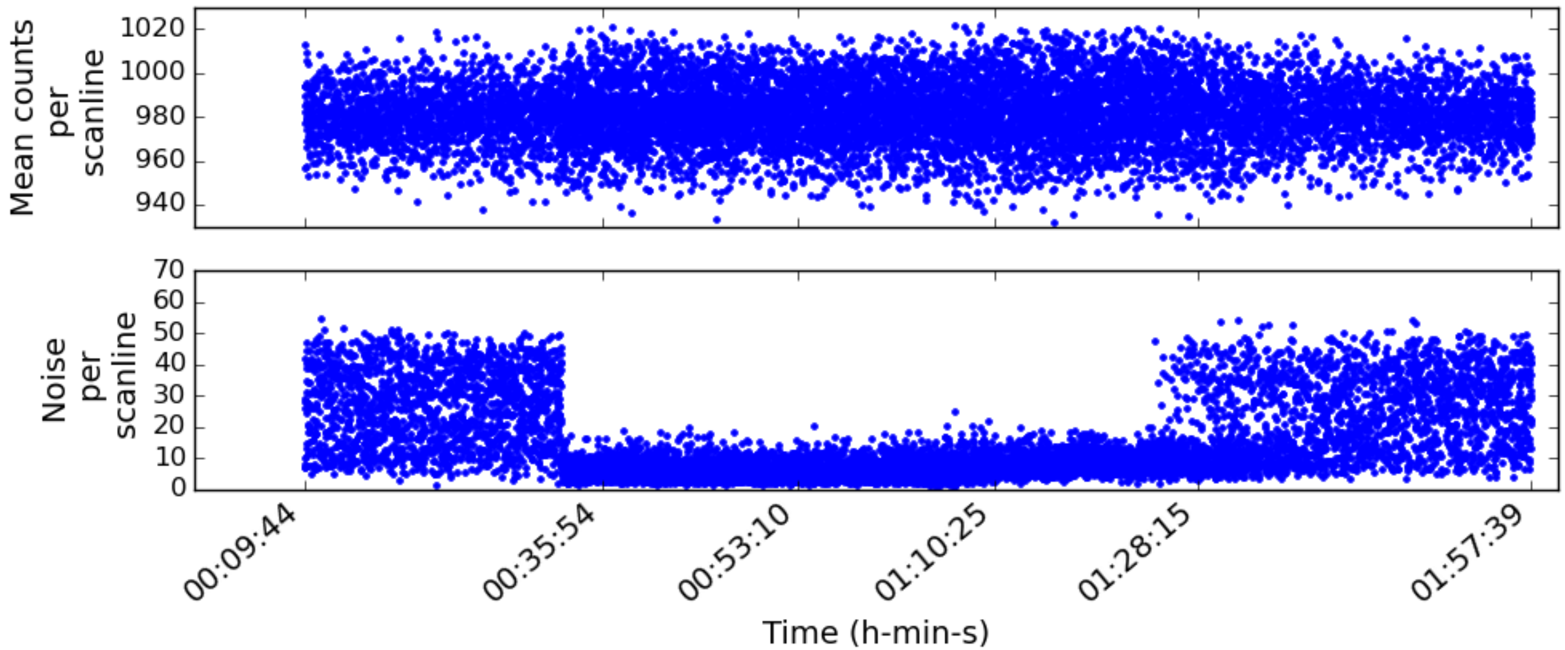
AVHHR-09, channel at 3.7 μm



➡ Stripping effect due to high noise

Temporal variability of the noise

TIROS-N, channel at 3.7 µm



➡ Important variability, also at short scale (only for TIROS-N)

Propagation of the Level 1B uncertainty into the SST equation

- SST equation for nighttime applications :

$$\mathbf{SST = (a + b\, S\theta)\, T37 + (c + d\, S\theta)\, (T11 - T12) + e + fS\theta + corr}$$

OSI SAF, François et al., 2002

  - T37, T11, T12 are the brightness temperatures at 3.7, 11 and 12 microns, respectively;
  - corr is the correction term resulting from preliminary adjustment on the match-up database;
  - Sθ= sec(θ) –1, with θ the satellite zenith angle
  - The coefficients of the algorithms have been derived from a simulated brightness temperatures

Propagation of the Level 1B uncertainty into the SST equation

- SST equation for nighttime applications :

  $$\mathbf{SST = (a + b\,S\theta)\,T37 + (c + d\,S\theta)\,(T11 - T12) + e + fS\theta + corr}$$

- Uncertainty ≈0.49 *Merchant and Le Borgne, 2004*

- Different sources of uncertainty:
  - Radiometric noise
  - Retrieval algorithm
  - Calibration and forward model
  - Skin and diurnal effects.

Propagation of the Level 1B uncertainty into the SST equation

- SST equation for nighttime applications :

  SST = (a + b Sθ) T37 + (c + d Sθ) (T11 - T12) + e + fSθ + corr

- Different sources of uncertainty:
  - Radiometric noise

$$\Delta SST = \sqrt{\left(\frac{\partial SST}{\partial T_{37}}\right)^2 (\Delta T_{37})^2 + \left(\frac{\partial SST}{\partial T_{11}}\right)^2 (\Delta T_{11})^2 + \left(\frac{\partial SST}{\partial T_{12}}\right)^2 (\Delta T_{12})^2}$$

Uncertainty on the SST due to radiometric noise

Brightness Temperature

Radiance

$BT \rightarrow N$

$Ne\Delta N$

Calculated orbit by orbit

$N_{1,2} = N \pm Ne\Delta N$

$BT_{1,2}$

$\Delta T_{1,2} = BT_{1,2} - BT$

$\Delta T = (\Delta T_1 + \Delta T_2)/2$

BT

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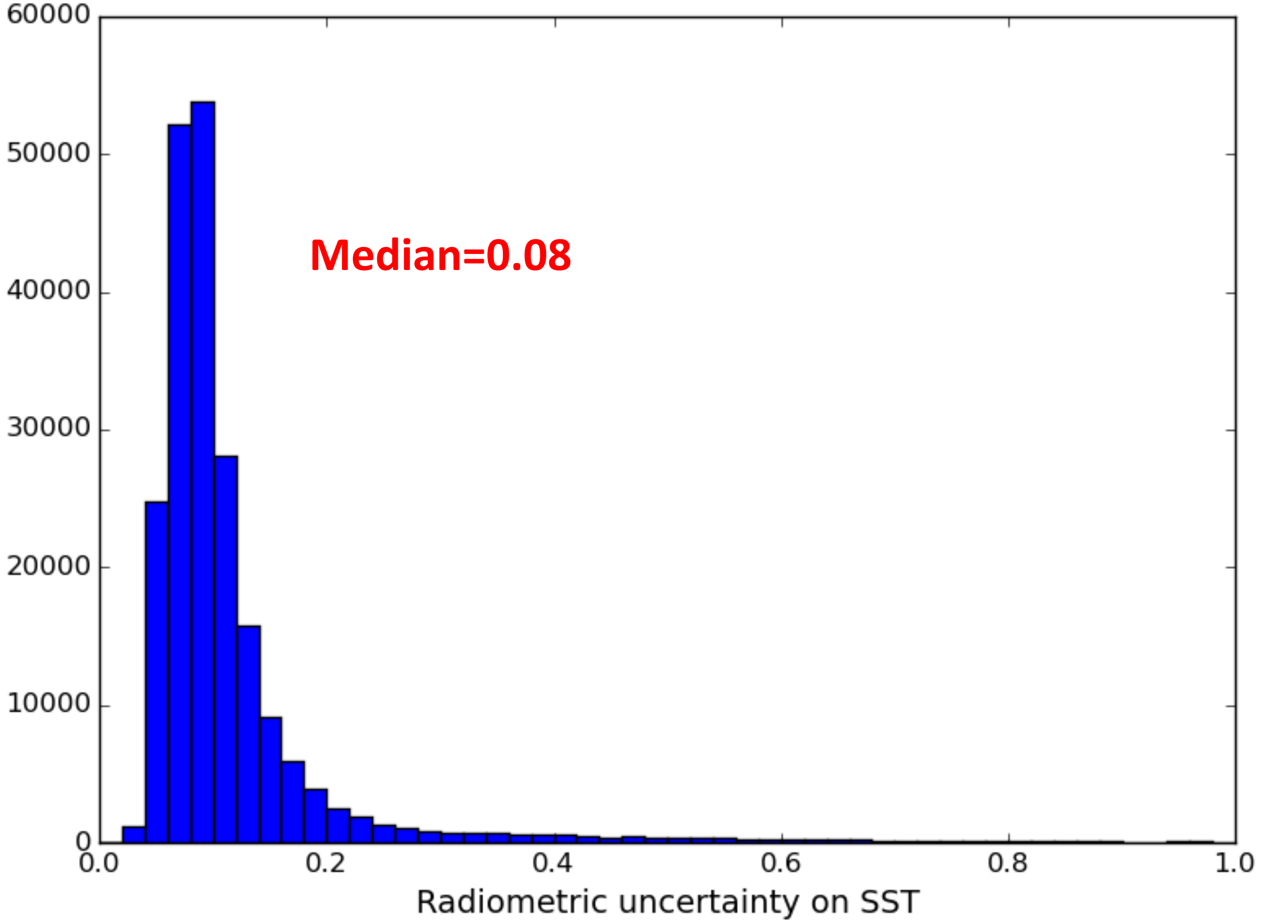
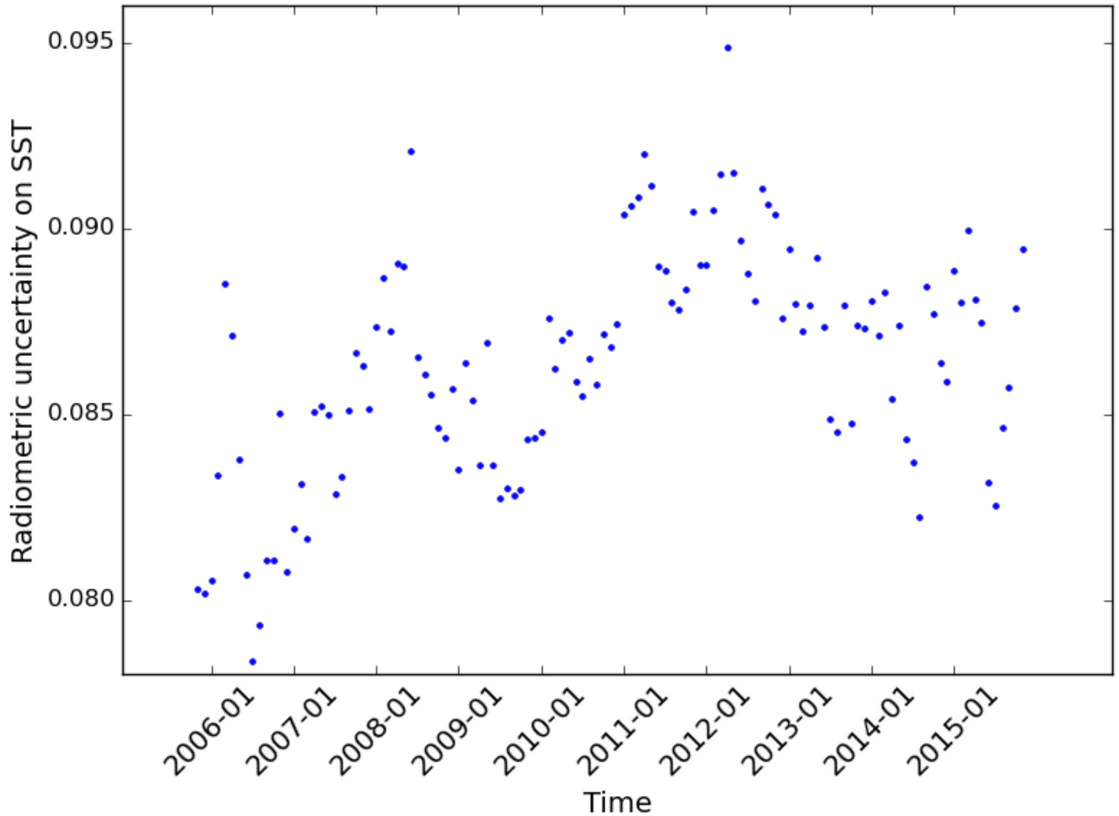
Instrumental ΔT for AVHRR18_G

Uncertainty ≈0.49
(Merchant & Le Borgne)



Radiometric uncertainty on SST

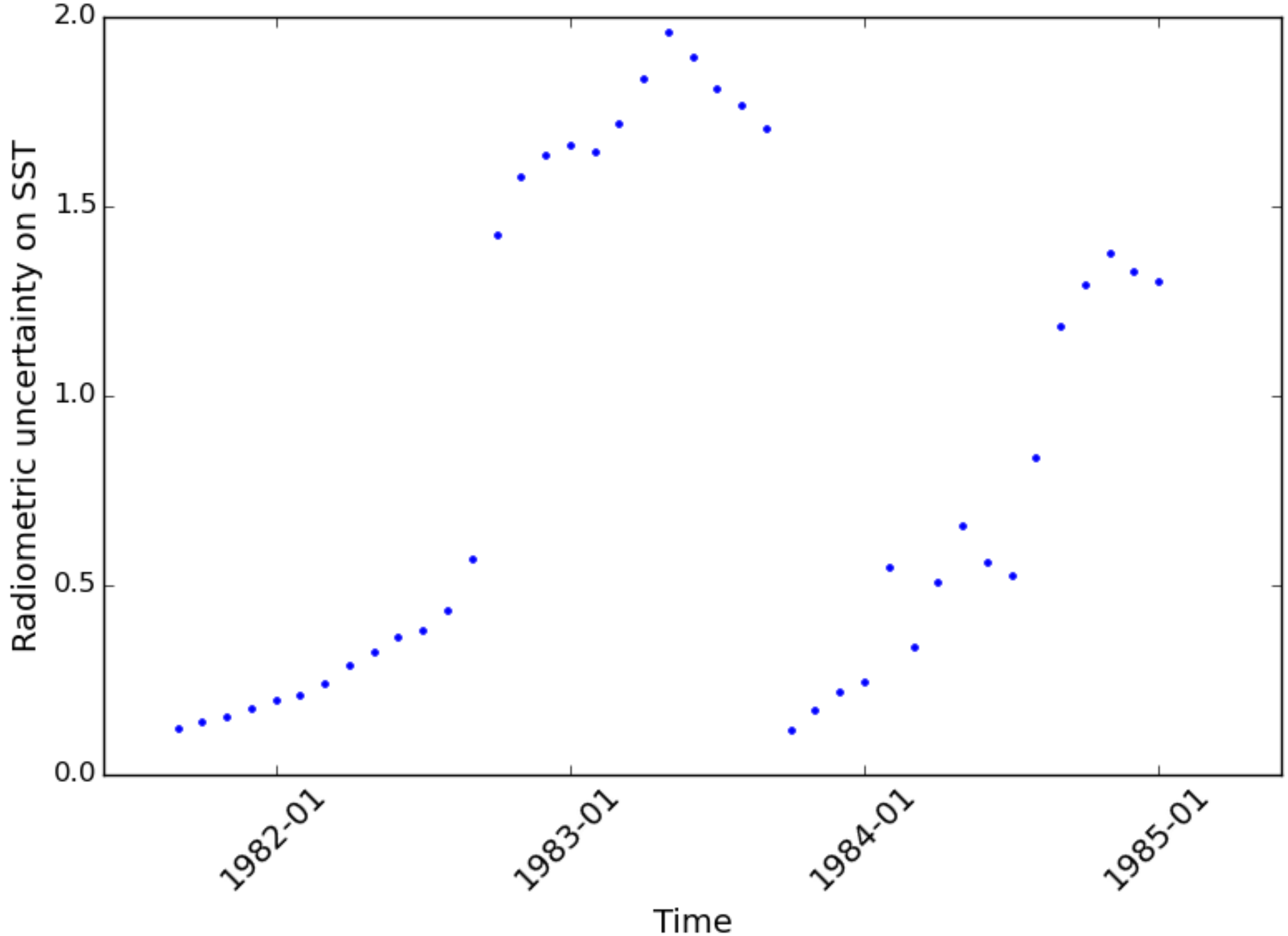
Monthly median of ΔT for AVHRR18_G



➡ **Dominant source of uncertainty in SST is due to the retrieval process and not to the measurements.**

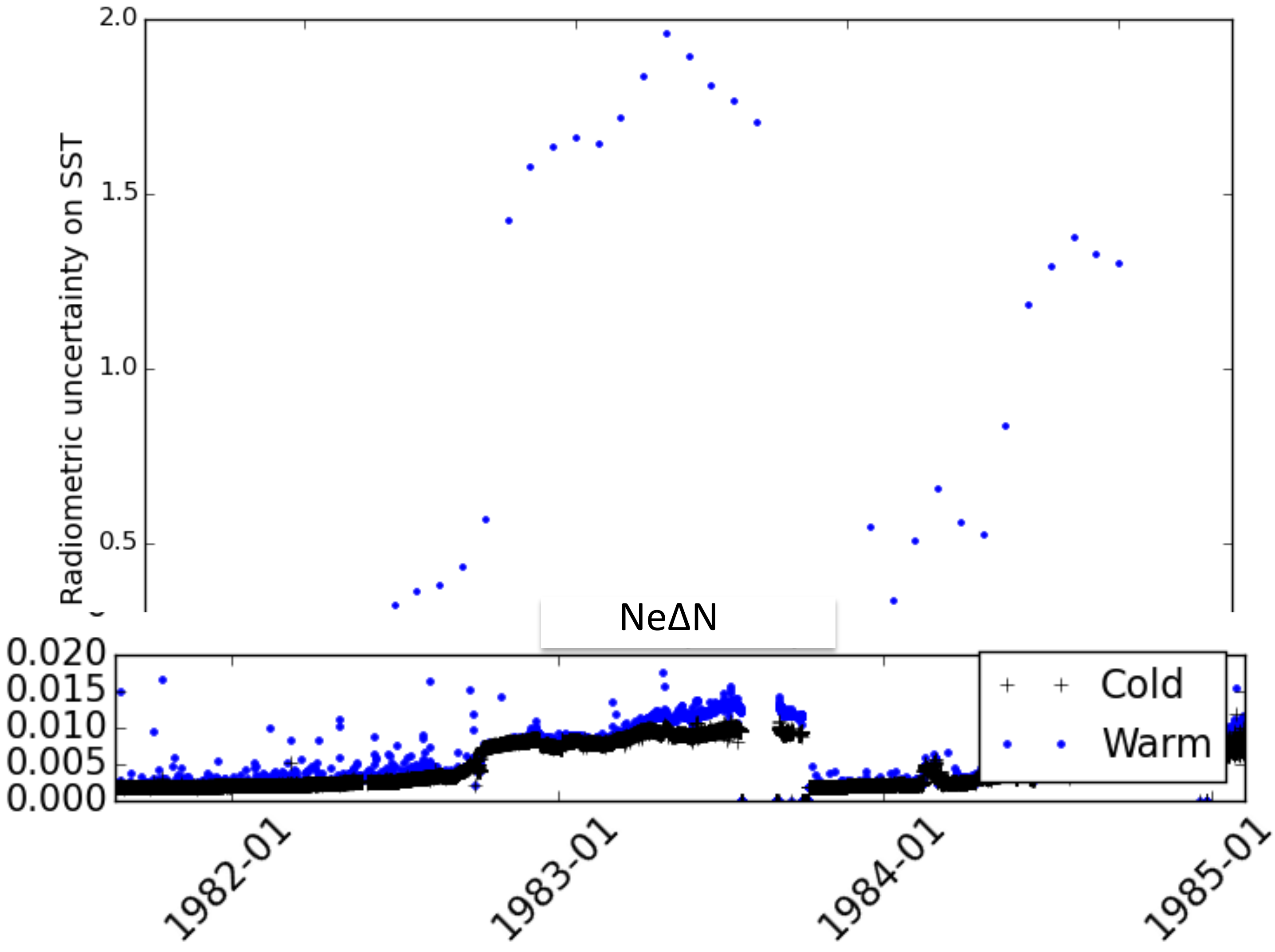
Radiometric uncertainty on SST

Monthly median of ΔT for AVHRR07_G



Radiometric uncertainty on SST

Monthly median of ΔT for AVHRR07_G



Summary

- Important variability of the noise at Level 1B:
  - ➢ Spectrally
  - ➢ Temporally

  ➡ Necessity to take this variability into account to estimate SST uncertainties

- Radiometric uncertainty of SST ranges from 0.08 to much larger

  ➡ Instrument noise may not be the main source of uncertainty

Thank you!