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

Generating Harmonised Fundamental Climate Data Records

Sam Hunt[1], Peter Harris[1], Ralf Quast[2],
Jon Mittaz[1,3], Ralf Giering[2] & Emma Woolliams[1]

[1]National Physical Laboratory, [2]FastOpt GmbH, [3]University of Reading

Contents

Historical Satellite Records

FIDUCEO Project Approach

Harmonisation

NPL National Physical Laboratory

Fiduceo

TIROS-N

NOAA-6

NOAA-7

NOAA-8

NOAA-9

NOAA-10

NOAA-11

ERS-1

Oct-78

Jul-81

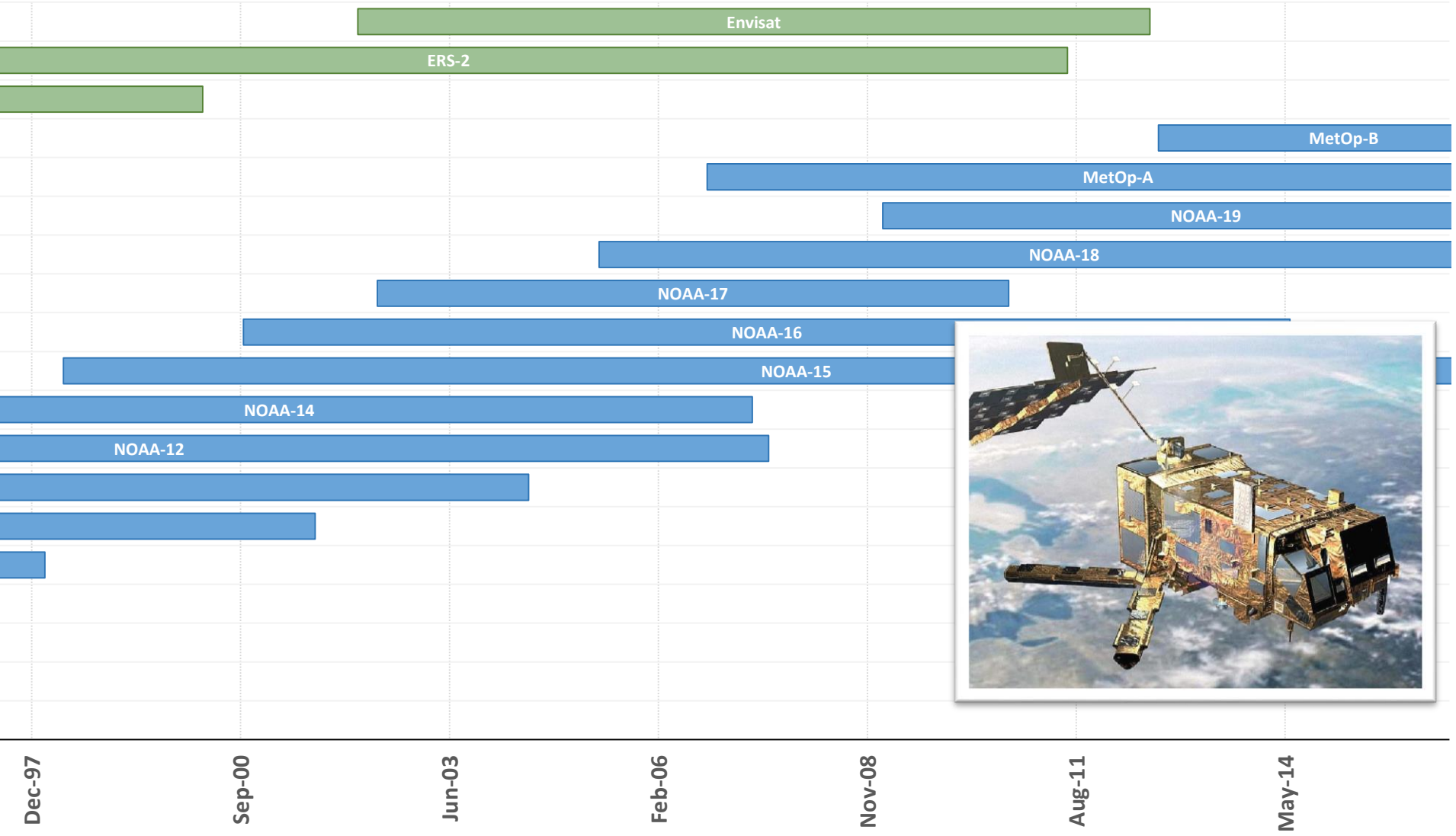
Apr-84

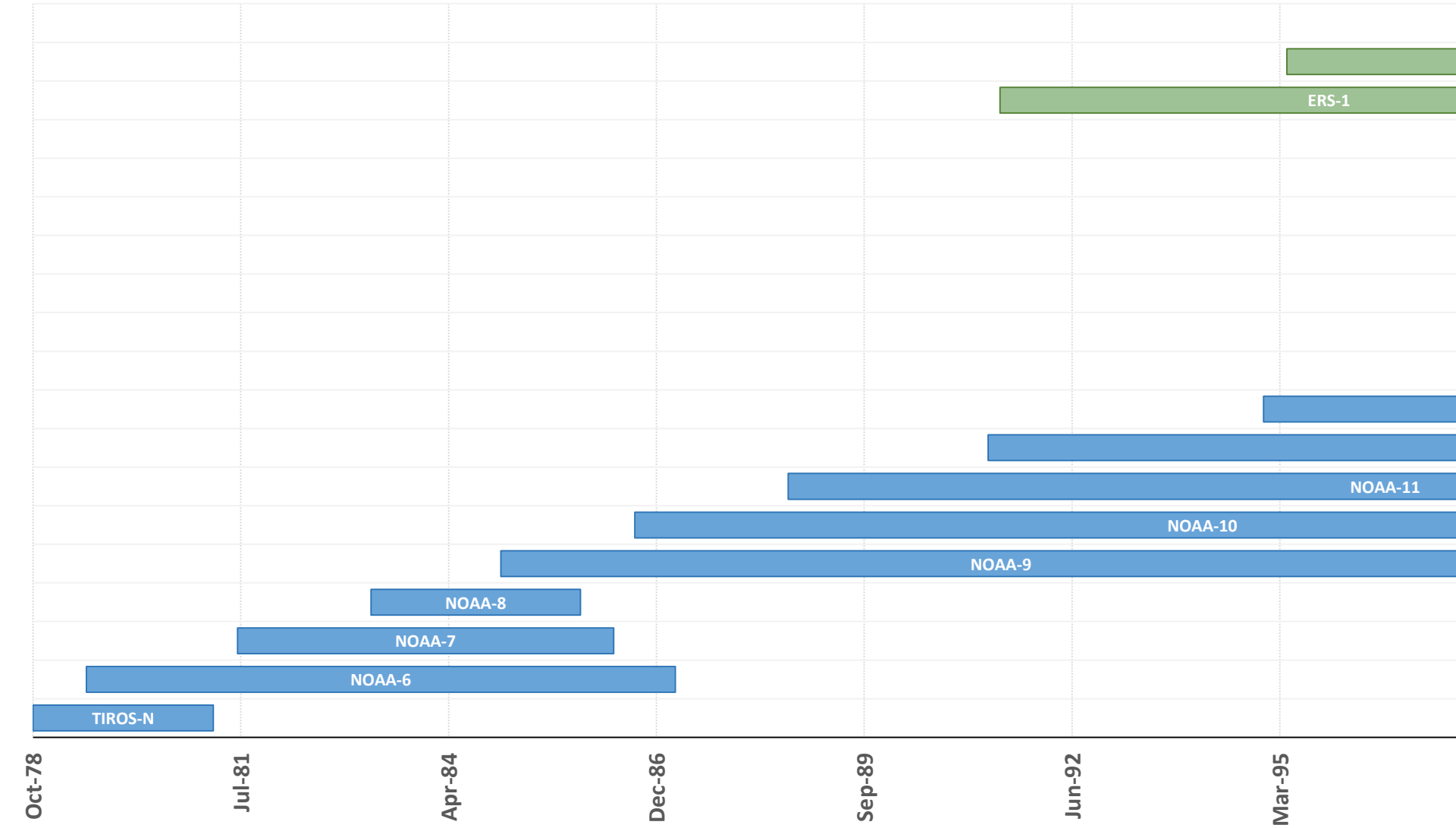
Dec-86

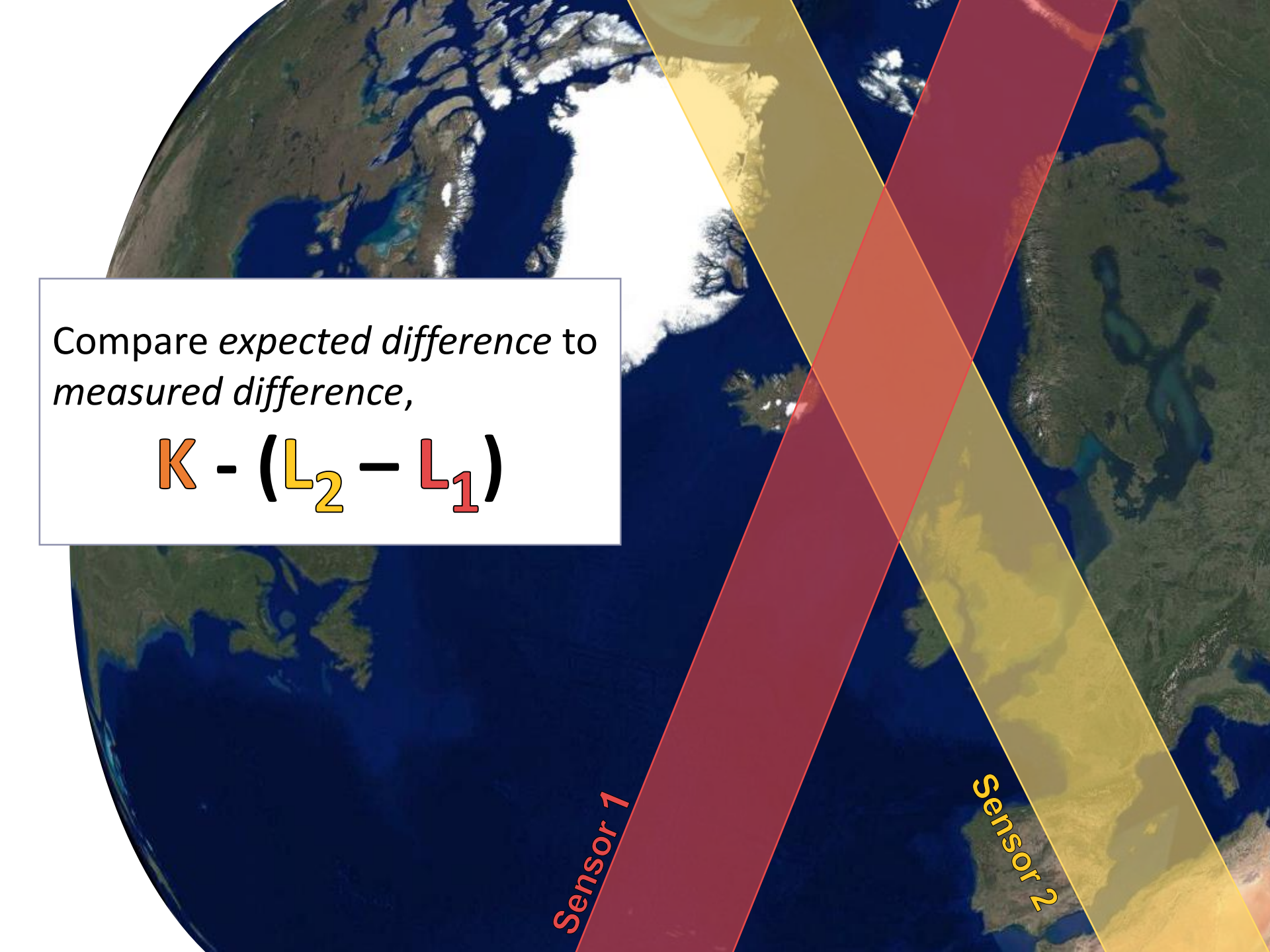
Sep-89

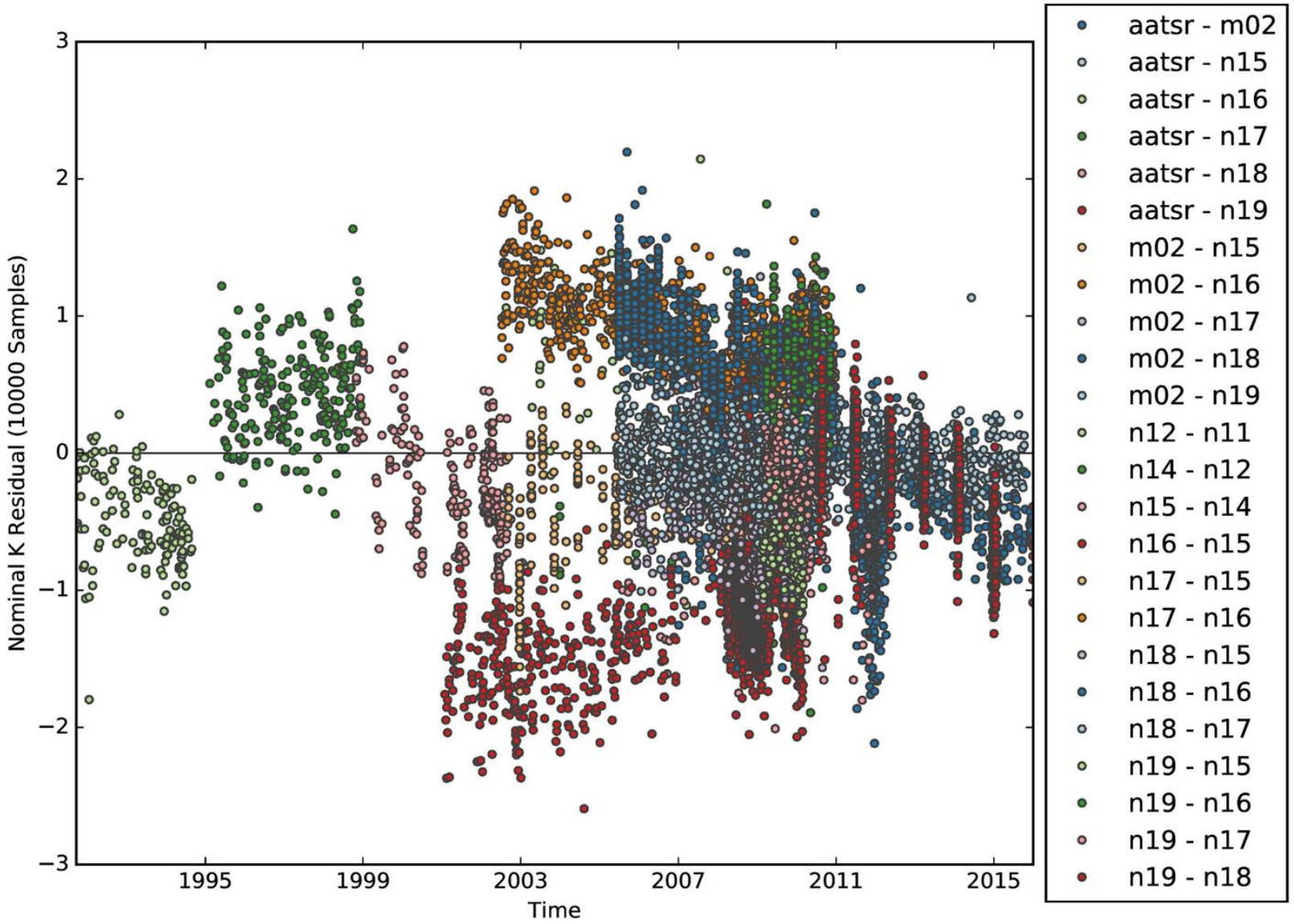
Jun-92

Mar-95


Envisat
ERS-2
MetOp-B
MetOp-A
NOAA-19
NOAA-18
NOAA-17
NOAA-16
NOAA-15
NOAA-14
NOAA-12
Dec-97
Sep-00
Jun-03
Feb-06
Nov-08
Aug-11
May-14


ERS-1
NOAA-11
NOAA-10
NOAA-9
NOAA-8
NOAA-7
NOAA-6
TIROS-N
Oct-78
Jul-81
Apr-84
Dec-86
Sep-89
Jun-92
Mar-95


Compare *expected difference* to *measured difference*,
$K - (L_2 - L_1)$
Sensor 1
Sensor 2


Nominal K Residual (10000 Samples)
3
2
1
0
−1
−2
−3
1995
1999
2003
2007
2011
2015
Time
aatsr - m02
aatsr - n15
aatsr - n16
aatsr - n17
aatsr - n18
aatsr - n19
m02 - n15
m02 - n16
m02 - n17
m02 - n18
m02 - n19
n12 - n11
n14 - n12
n15 - n14
n16 - n15
n17 - n15
n17 - n16
n18 - n15
n18 - n16
n18 - n17
n19 - n15
n19 - n16
n19 - n17
n19 - n18

Contents

Historical Satellite Records

FIDUCEO Project Methodology

Harmonisation

NPL National Physical Laboratory

Fiduceo

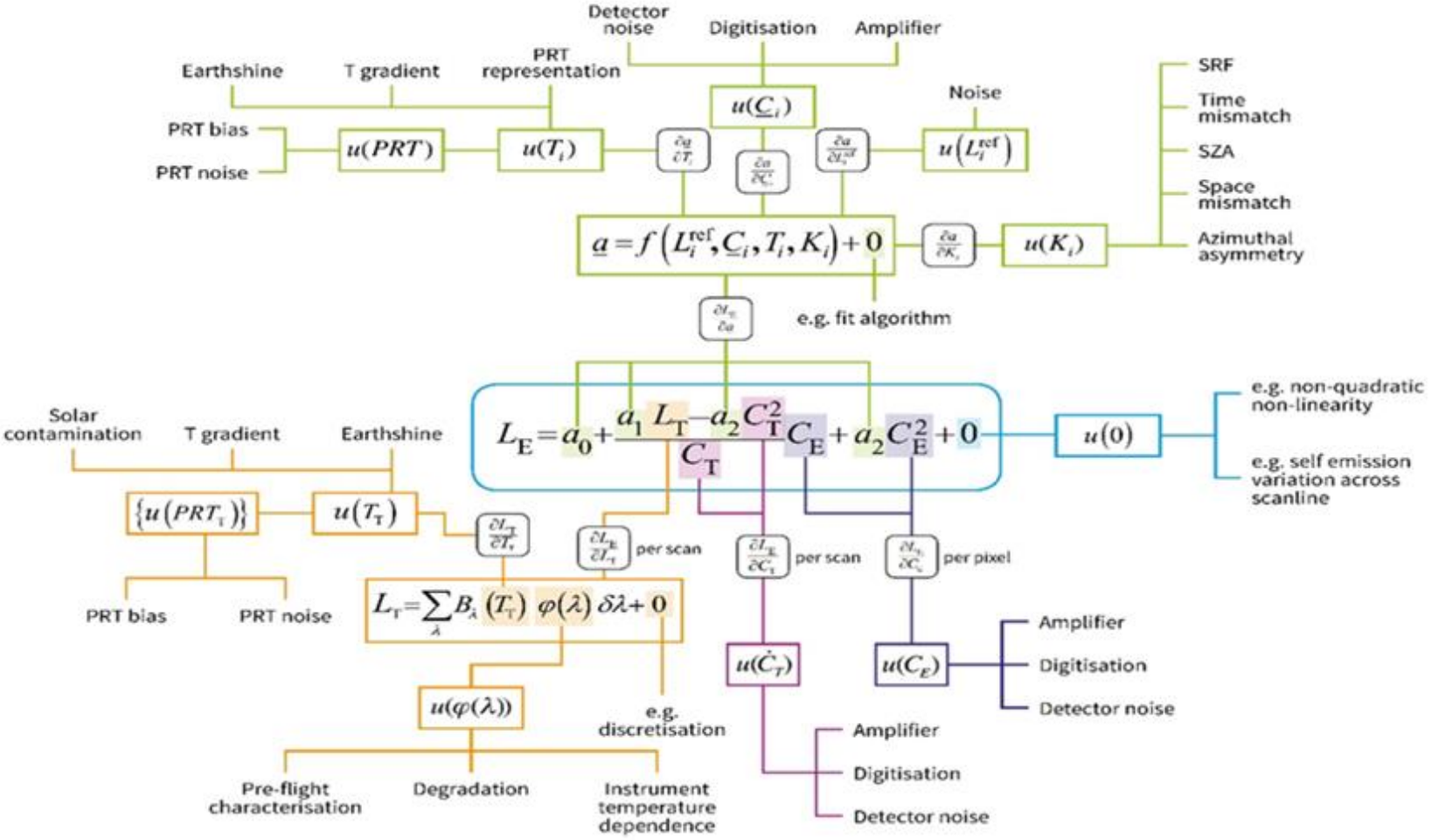
Project Sensor Series

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,…

NPL National Physical Laboratory

Fiduceo

FIDUCEO Approach – Measurement Tree



NPL National Physical Laboratory

Fiduceo

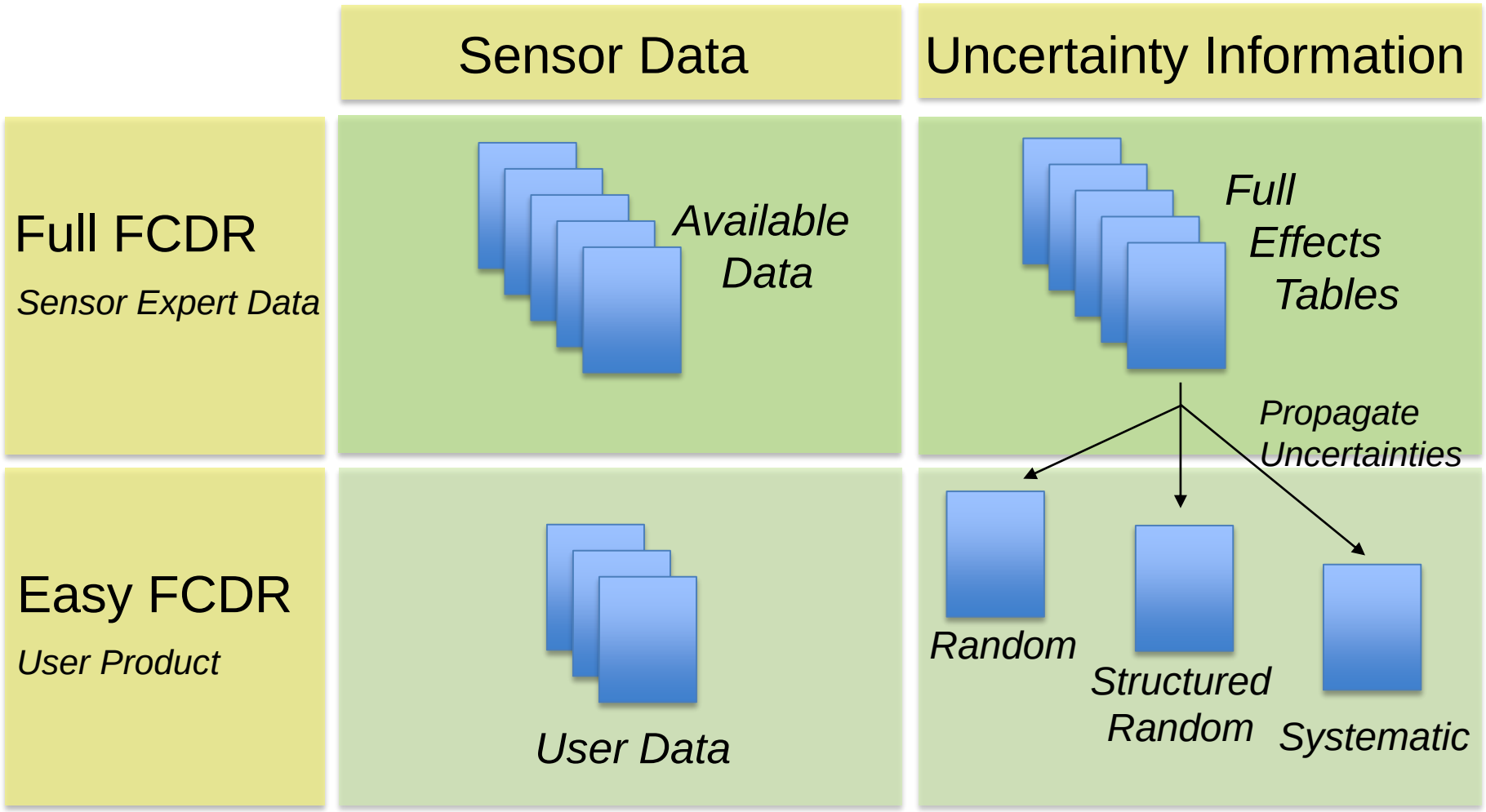
FIDUCEO Approach – Effects Tables

Table descriptor		Value / Expression
Name of effect		
Affected term in measurement function		
Correlation type and form	within scanline [pixels]	
	from scanline to scanline [scanlines]	
	between orbits [orbits]	
	Across time [e.g. days, months, years]	
Correlation scale	within scanline [pixels]	
	from scanline to scanline [scanlines]	
	between orbits [orbits]	
	Across time	
Channels / bands	List channels and bands affected	
	Correlation matrix	
Uncertainty	PDF shape	
	Uncertainty units	
	Uncertainty magnitude	
Sensitivity Coefficient		

NPL National Physical Laboratory

Fiduceo

FIDUCEO Approach – File Format



NPL National Physical Laboratory

Fiduceo

Contents

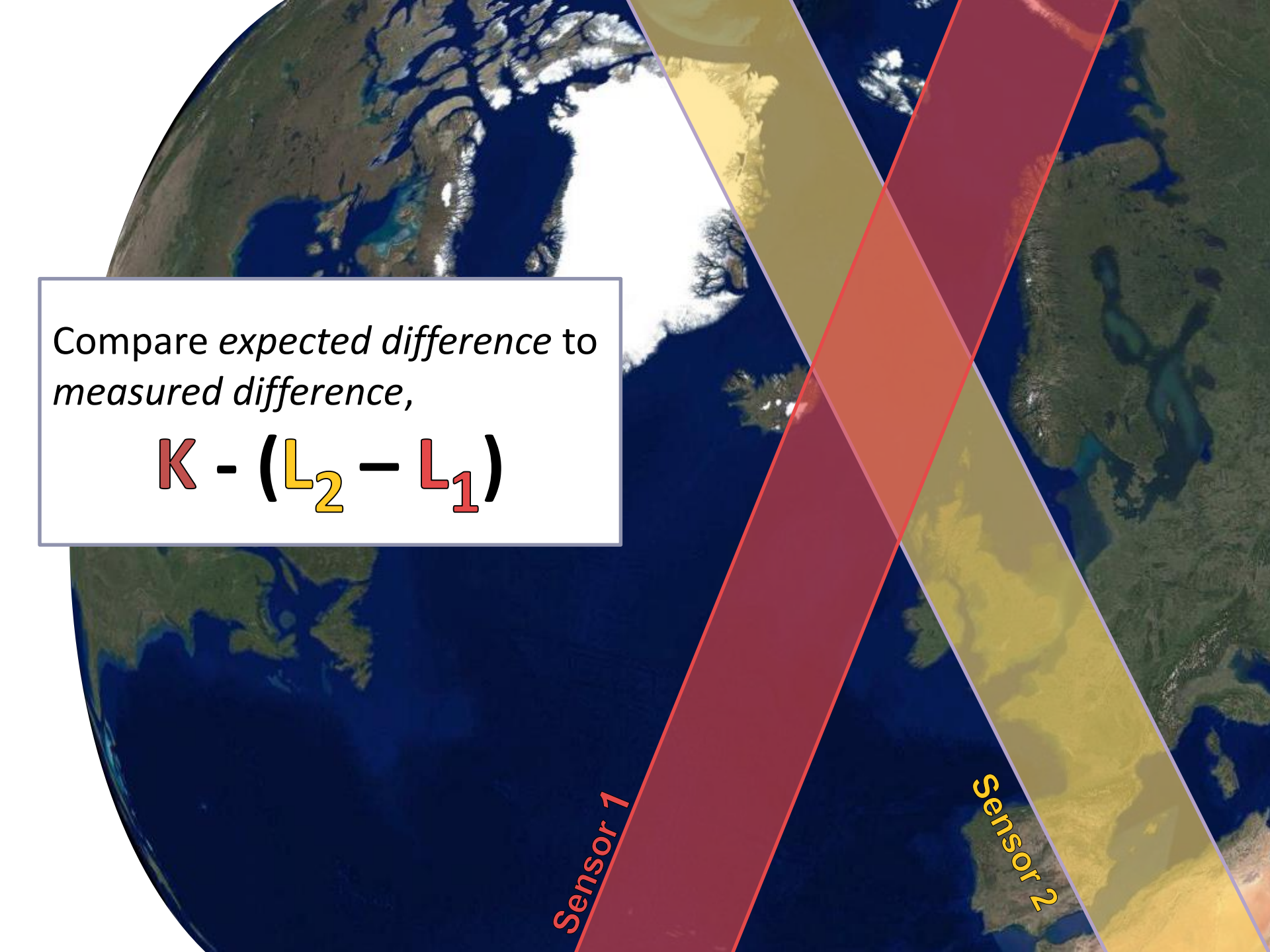
Historical Satellite Records

FIDUCEO Project Methodology

Harmonisation

NPL National Physical Laboratory

Fiduceo


Compare *expected difference* to *measured difference*,
$K - (L_2 - L_1)$
Sensor 1
Sensor 2

Harmonisation Problem

For match up dataset for full sensor series optimise for,

$$K = L_2 - L_1$$

where,

$$L_1 = f_1(X_{1,1} \ldots X_{1,N};\ \boldsymbol{a_1})$$

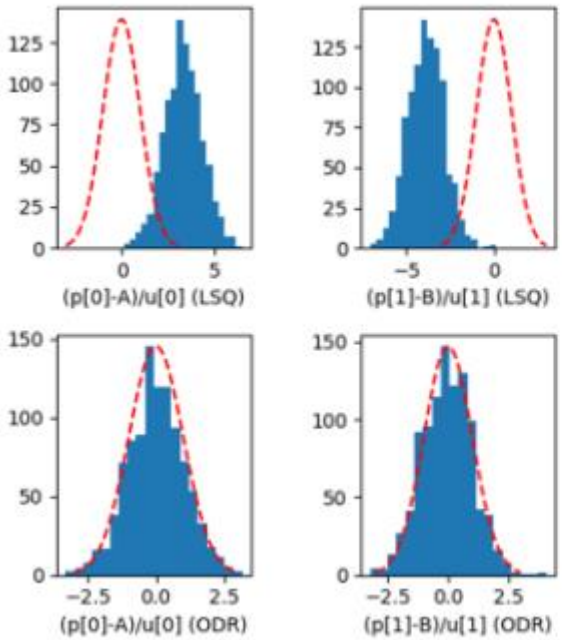
$$L_2 = \begin{cases} L_{\text{ref}} \\ f_2(X_{2,1} \ldots X_{2,N};\ \boldsymbol{a_2}) \end{cases}$$

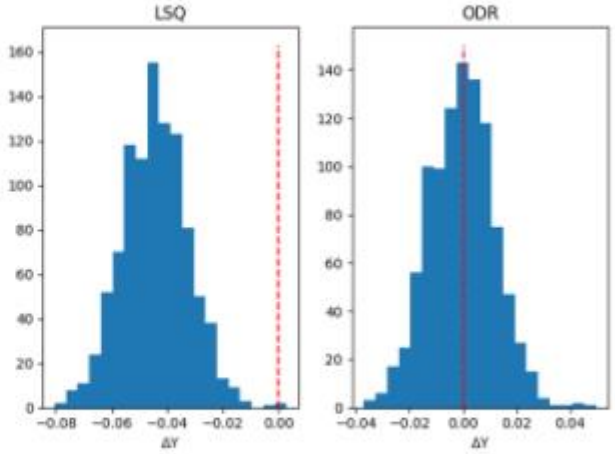
- Harmonisation Parameters
- Sensor State Variables (i.e. Level 0)

NPL National Physical Laboratory

Fiduceo

Least-Squares vs. Errors-in-Variables





See blog:
[Beyond least squares analysis: Regression considering correlation]

NPL National Physical Laboratory

Fiduceo

Considering Match-Up Correlation

		Random Error Effects	
		Independent	Structured
Systematic Error Effects	No Common Error	1 – Random Representation: $u_r(\underline{X})$	3 – Structured Random Representation: $\widehat{W}, u_r(\underline{\tilde{X}})$
	Common Error	2 – Random + Systematic Representation: $u_r(\underline{X})$, $u_s(\underline{X})$	4 – Structured Random + Systematic Representation: $\widehat{W}, u_r(\underline{\tilde{X}}), u_s(\underline{\tilde{X}})$

NPL National Physical Laboratory

Fiduceo

‘Errors-in-variables’ problem

Challenging due to:

- Size of data set (>10^8 matches)
- Highly correlated errors

→ Develop Novel Methods

First transform into data $\boldsymbol{X}$ to independent variables $\widetilde{\boldsymbol{X}}$, so have problem

Data

$\tilde{\boldsymbol{L}}_{\mathrm{ref}}^{\mathrm{data}}, \widetilde{\boldsymbol{X}}^{\mathrm{data}}, \widetilde{\boldsymbol{K}}^{\mathrm{data}}$

Objective function

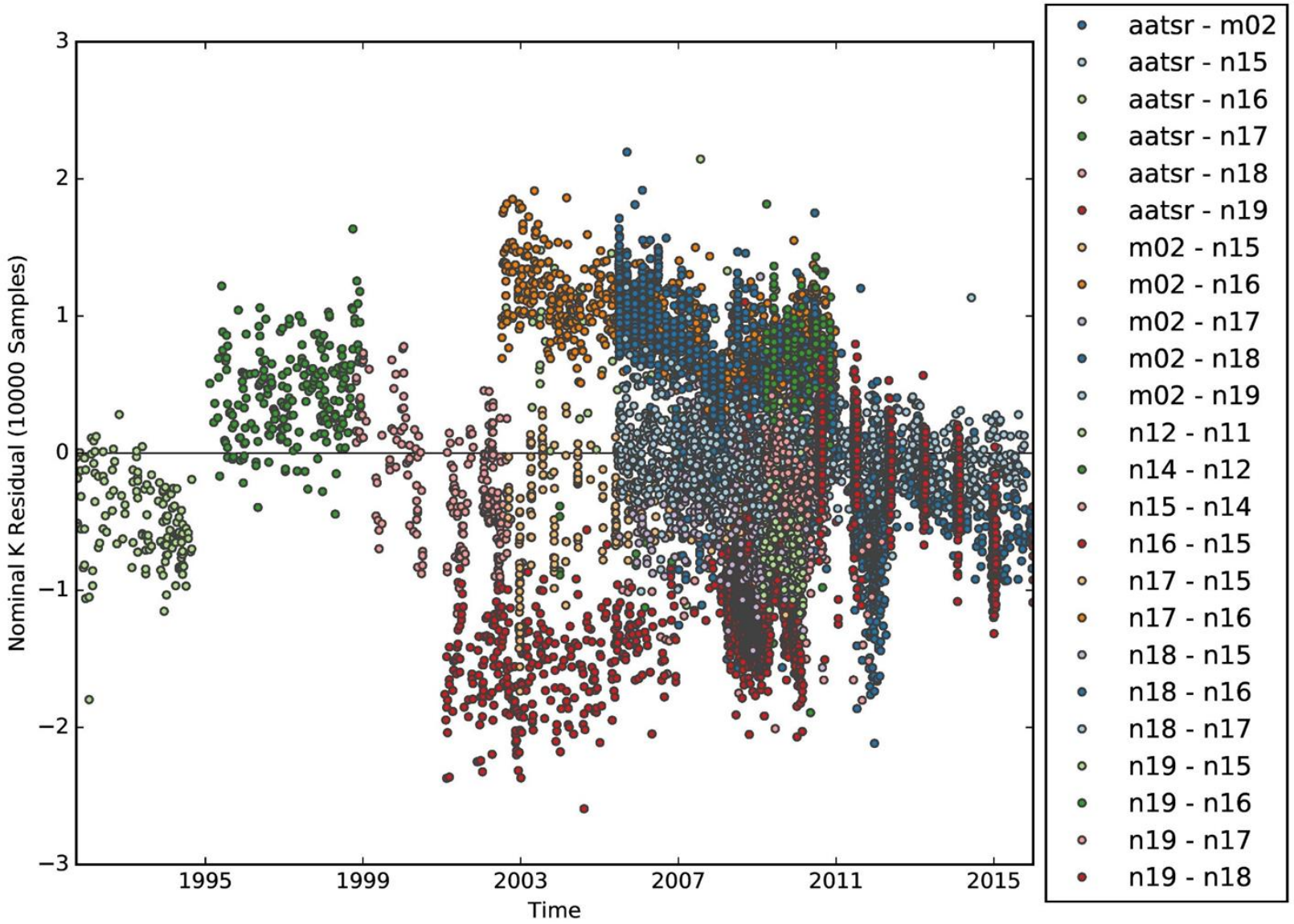
Parameters

$\tilde{\boldsymbol{L}}_{\mathrm{ref}}, \widetilde{\boldsymbol{X}}, \widetilde{\boldsymbol{K}}, \boldsymbol{a}_t, \ldots$

$$F \equiv \left(\tilde{\boldsymbol{L}}_{\mathrm{ref}}^{\mathrm{data}} - \tilde{\boldsymbol{L}}_{\mathrm{ref}}\right)^{\mathrm{T}}\left(\tilde{\boldsymbol{L}}_{\mathrm{ref}}^{\mathrm{data}} - \tilde{\boldsymbol{L}}_{\mathrm{ref}}\right) + \left(\widetilde{\boldsymbol{X}}^{\mathrm{data}} - \widetilde{\boldsymbol{X}}\right)^{\mathrm{T}}\left(\widetilde{\boldsymbol{X}}^{\mathrm{data}} - \widetilde{\boldsymbol{X}}\right) + \left(\widetilde{\boldsymbol{K}}^{\mathrm{data}} - \widetilde{\boldsymbol{K}}\right)^{\mathrm{T}}\left(\widetilde{\boldsymbol{K}}^{\mathrm{data}} - \widetilde{\boldsymbol{K}}\right)$$

NPL National Physical Laboratory

Fiduceo


Nominal K Residual (10000 Samples)
3
2
1
0
−1
−2
−3
1995
1999
2003
2007
2011
2015
Time
aatsr - m02
aatsr - n15
aatsr - n16
aatsr - n17
aatsr - n18
aatsr - n19
m02 - n15
m02 - n16
m02 - n17
m02 - n18
m02 - n19
n12 - n11
n14 - n12
n15 - n14
n16 - n15
n17 - n15
n17 - n16
n18 - n15
n18 - n16
n18 - n17
n19 - n15
n19 - n16
n19 - n17
n19 - n18

Example: AVHRR

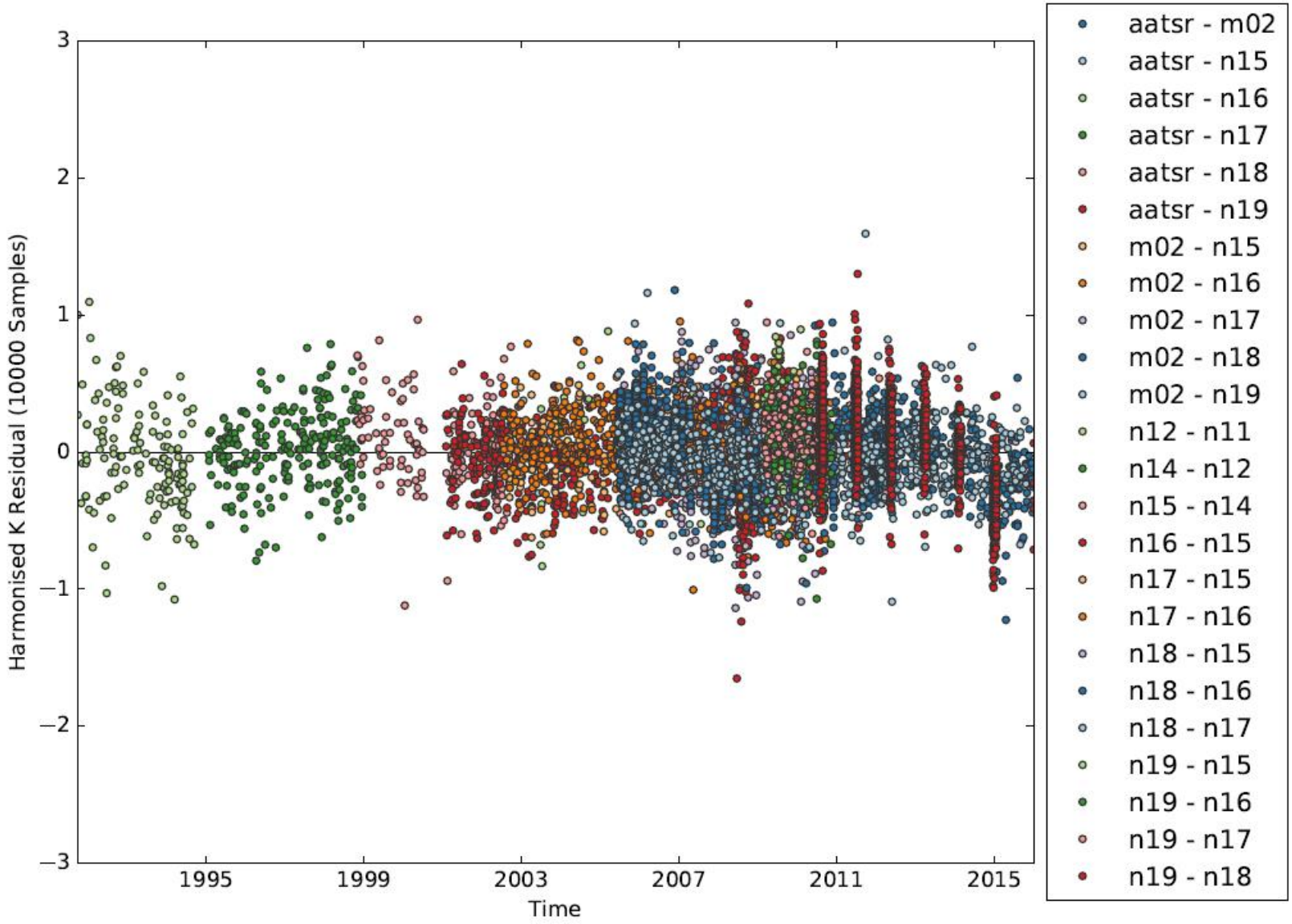
- Sensor Measurement Function (Simplified),

$$L_{\mathrm{E}} = a_0 + \frac{(\epsilon + a_1)L_{\mathrm{ICT}}}{\bar{C}_{\mathrm{S}} - \bar{C}_{\mathrm{ICT}}}(\bar{C}_{\mathrm{S}} - C_{\mathrm{E}}) + a_2(\bar{C}_{\mathrm{ICT}} - C_{\mathrm{E}})(\bar{C}_{\mathrm{S}} - C_{\mathrm{E}})$$

  - Harmonisation Parameters
  - Sensor State Data
  - Sensor Constant

NPL National Physical Laboratory

Fiduceo


Harmonised K Residual (10000 Samples)
3
2
1
0
−1
−2
−3
1995
1999
2003
2007
2011
2015
Time
aatsr - m02
aatsr - n15
aatsr - n16
aatsr - n17
aatsr - n18
aatsr - n19
m02 - n15
m02 - n16
m02 - n17
m02 - n18
m02 - n19
n12 - n11
n14 - n12
n15 - n14
n16 - n15
n17 - n15
n17 - n16
n18 - n15
n18 - n16
n18 - n17
n19 - n15
n19 - n16
n19 - n17
n19 - n18

Example: AVHRR

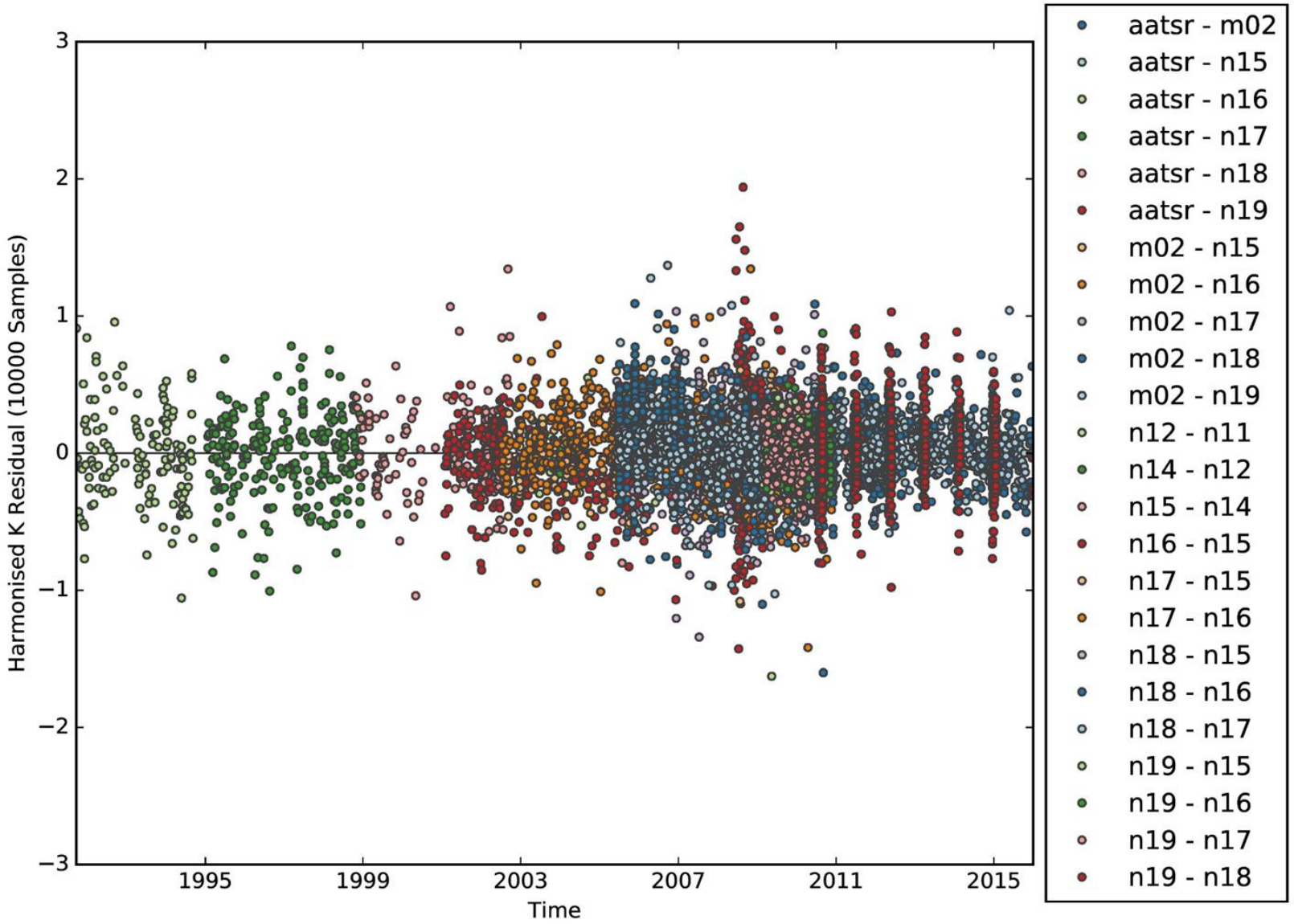
- Sensor Measurement Function (more complex),

$$L_E = a_0 + \frac{(\epsilon + a_1)L_{ICT}}{\bar{C}_S - \bar{C}_{ICT}}(\bar{C}_S - C_E) + a_2(\bar{C}_{ICT} - C_E)(\bar{C}_S - C_E) + a_3 T_O$$

  - Harmonisation Parameters
  - Sensor State Data
  - Sensor Constant

NPL National Physical Laboratory

Fiduceo


Harmonised K Residual (10000 Samples)
3
2
1
0
−1
−2
−3
1995
1999
2003
2007
2011
2015
Time
aatsr - m02
aatsr - n15
aatsr - n16
aatsr - n17
aatsr - n18
aatsr - n19
m02 - n15
m02 - n16
m02 - n17
m02 - n18
m02 - n19
n12 - n11
n14 - n12
n15 - n14
n16 - n15
n17 - n15
n17 - n16
n18 - n15
n18 - n16
n18 - n17
n19 - n15
n19 - n16
n19 - n17
n19 - n18

Thank you!

https://www.fiduceo.eu

NPL National Physical Laboratory

Fiduceo