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Evolving the GSICS Approach to Inter-Satellite Calibration

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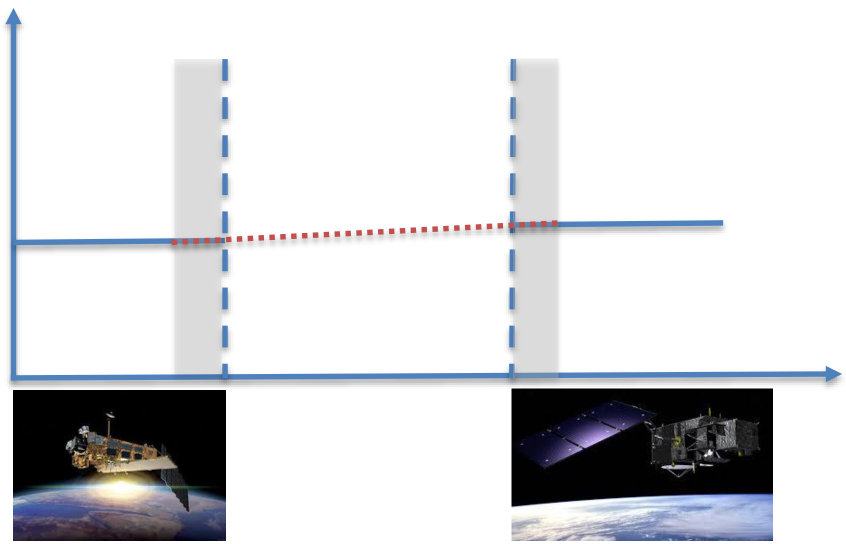
Aims

- Discuss framework for inter-comparisons during (A)ATSR-SLSTR gap.



Collocation of target instrument

↓

Intercomparison and analysis

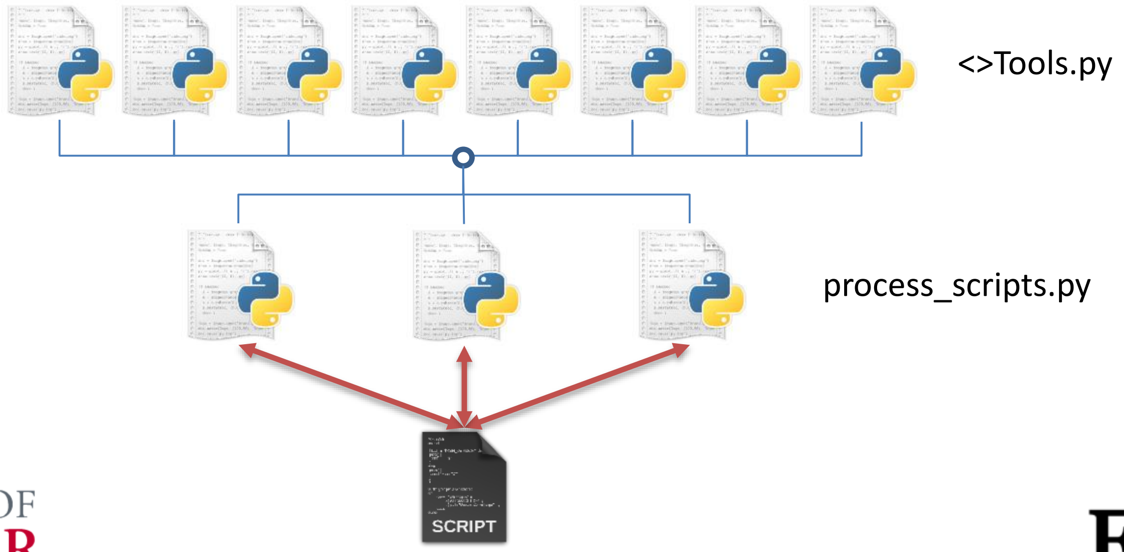
↓

Output

- Goal is to build a generic framework that can handle different intercomparison types: (i) satellite-to-satellite and (ii) satellite-to-in situ

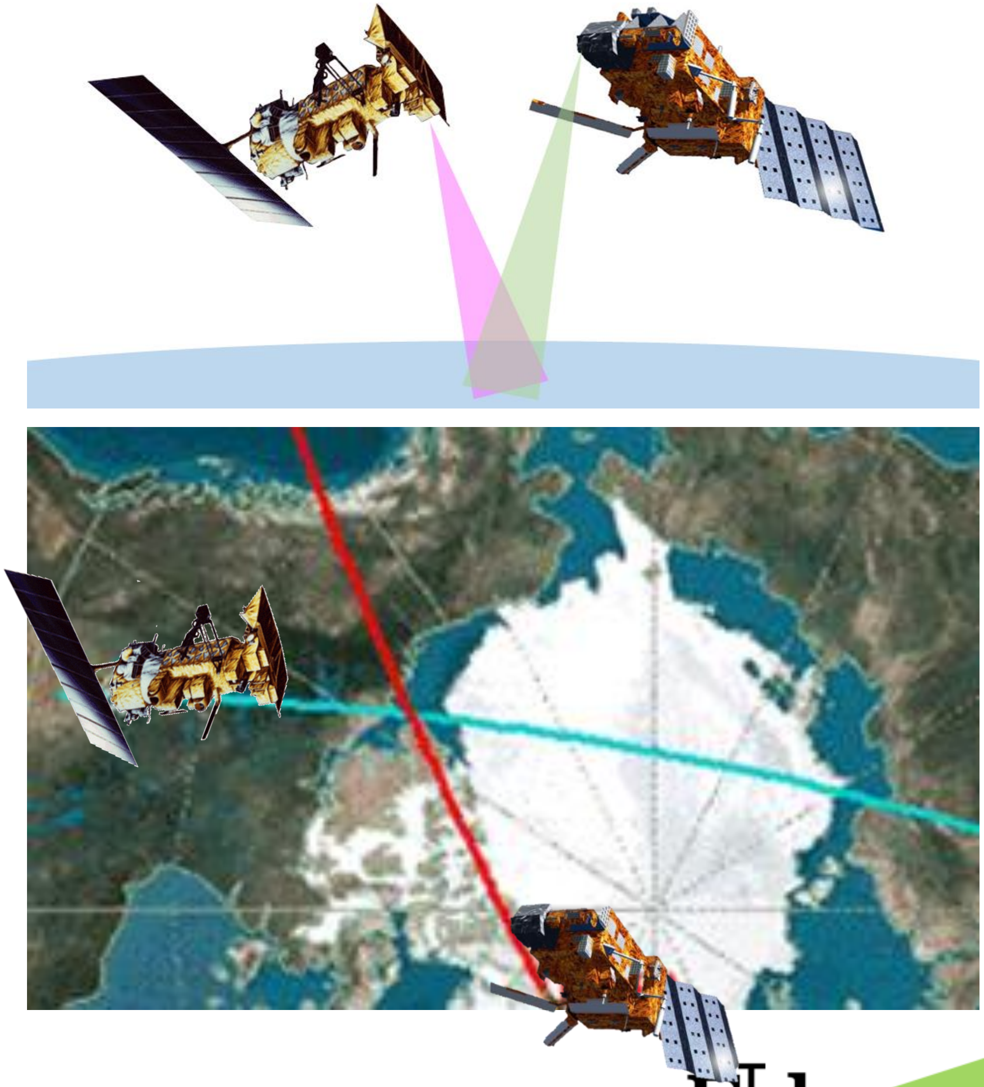
Aims

- Introduce current GSICS approach to inter-satellite calibration through simultaneous nadir overpasses (SNOs)
- Discuss briefly some of the issues of using this approach within FIDUCEO
- Present an evolved approach within the GSICS framework
  - Software tools: flat pack approach, “some assembly required”



Simultaneous Nadir Overpasses

- A simultaneous nadir overpass is a common technique used to compare observations from 2 satellites.
- Global Space-Based Inter-Calibration System (GSICS) conduct routine calibration of NWP satellites using SNOs.
- The idea is to use a reference standard satellite observation (e.g. IASI) to calibrate a target instrument (e.g. HIRS).



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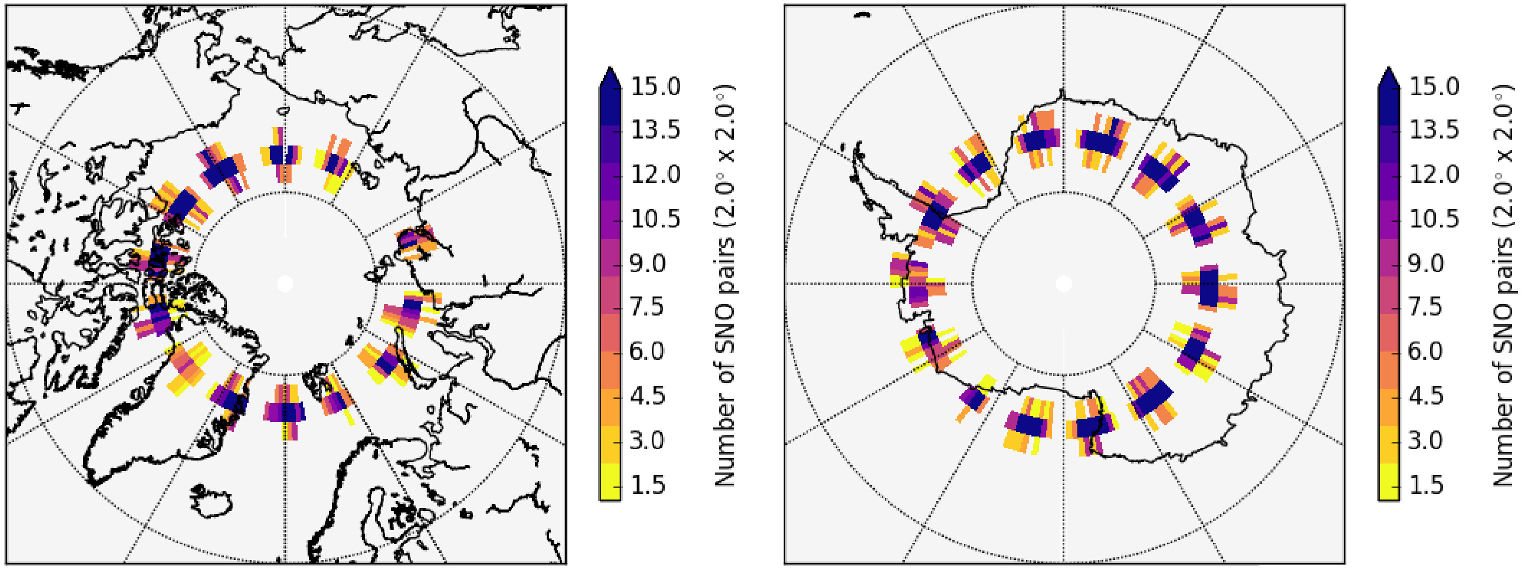
Simultaneous Nadir Overpasses

- Due to time criteria most SNOs occur at the poles.
- SNOs collect in clusters (x,y,t)
  - basis for processing multiple years/platforms
  - can use same definition for radiosonde comparisons.

HIRS-N18 IASI-MA SNOS between 2011-04-15 to 2011-04-21



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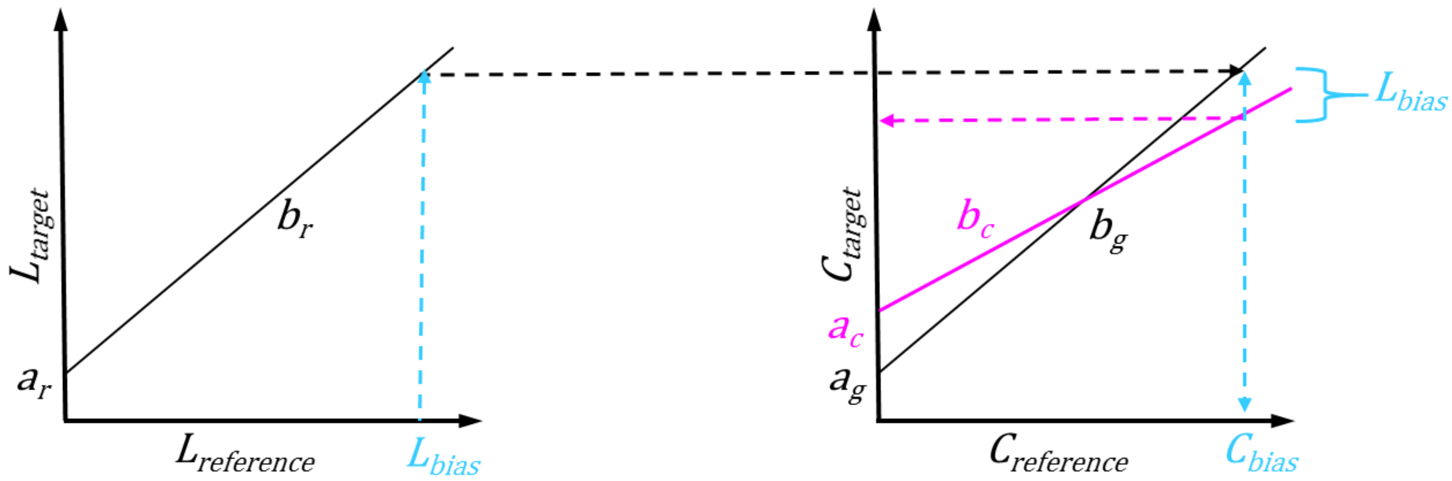
GSICS Inter-Calibration Method

- The GSICS inter-calibration process (Hewison et al, 2013a) uses thousands of SNO pairs from a 14 day window in order to allow comparison of the target and reference instruments via ordinary linear regression (OLS):
  - $L_{target} = a_r + b_r L_{reference}$
- Where a_r and b_r are the correction coefficients and L_{target} is the target instrument radiance. The target radiance is then converted to a consistent reference radiance ($\hat{L}_{target}$) by inverting the linear relationship
  - $\hat{L}_{target} = \left(\frac{1}{b_r}\right) L_{target} - \left(\frac{a_r}{b_r}\right)$



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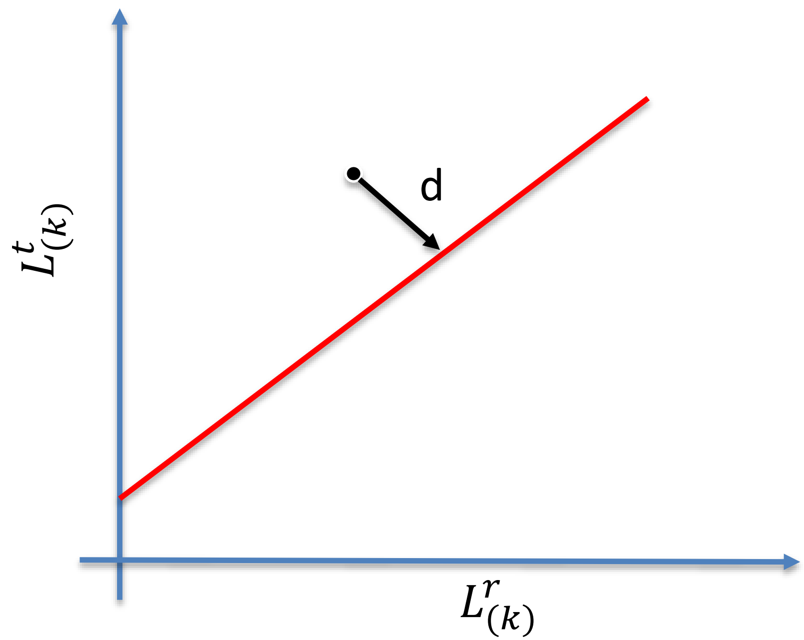
Evolution of the Inter-Calibration Method

- GSICS approach assumes no uncertainty in either measurement or account of the uncertainty in the collocation.
- Need a system that can account for heterogeneity and measurement uncertainties and their correlations.
- 1st we need to repose the problem so we consider uncertainties in both observations.
  - *"What is the distance between a measurement pair* $\left(L^r_{i(k)}, L^t_{i(k)}\right)$ *and the straight line* $L^t_{(k)} = a^r_{(k)} + b^r_{(k)} L^r_{(k)}$ *where the distance is specified in multiples of the error standard deviations of each measurement?"*



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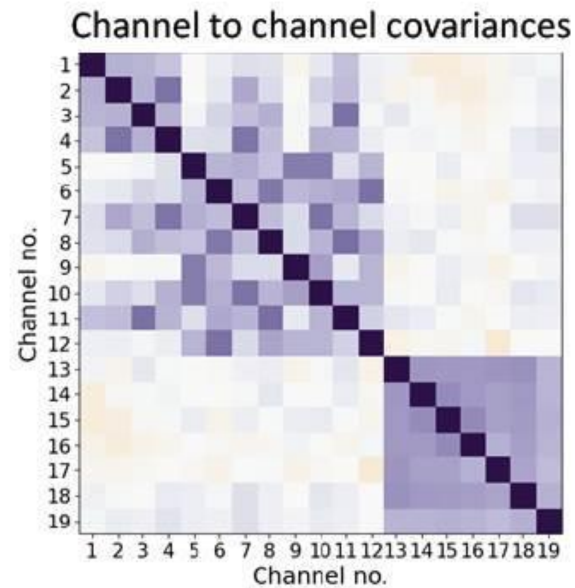
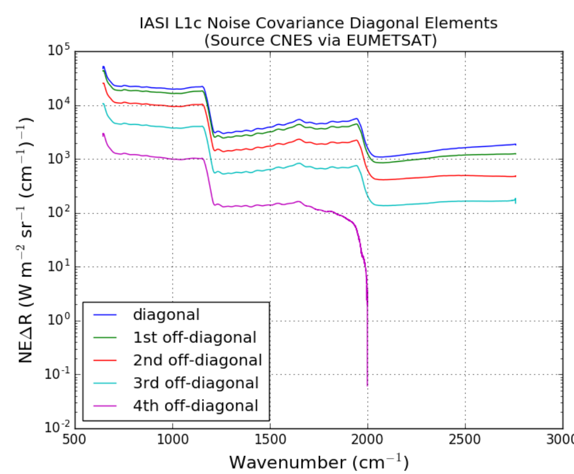
Evolution of the Inter-Calibration Method





- As FCDR products provide detailed covariances which account for correlations between channels
  - we need to solve for all channels (k) at once (observational packet = 1 spectra).
- For each MMS file there will be m observational packets (i = obs. packet index).
- Therefore we can define the following objects:

  (i) l^r - observation packet for the reference instrument.

  (ii) l^t - observation packet for the target instrument

  (iii) a - a k element vector of $a^r_{(k)}$ values.

  (iv) $\boldsymbol{B}$ – a k x k matrix whose diagonal values are a vector (b) made up of $b^r_{(k)}$ values.

  (v) $\boldsymbol{R}^r, \boldsymbol{R}^t$ - k x k observation error covarinces
- The regression model relating the 2 obs. packets:
  - $l^t = a + \boldsymbol{B} l^r$ **[8]**

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Evolution of the Inter-Calibration Method

- After substitution and factorisation the cost function which a and b minimises is expressed as:
  - $J[a,b] = \frac{1}{2}\sum_i d_i^2 = \frac{1}{2}\sum_{i=0}^{m}\left[l_i^t - a - \boldsymbol{B}l_i^r\right]^T(\boldsymbol{R}^t + \boldsymbol{B}\boldsymbol{R}^r\boldsymbol{B})^{-1}\left[l_i^t - a - \boldsymbol{B}l_i^r\right]$
- Still some issues to consider …

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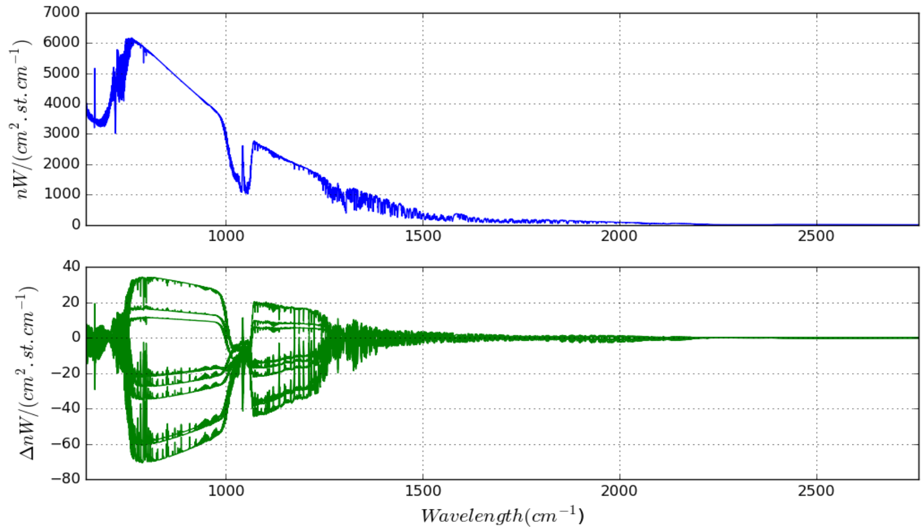
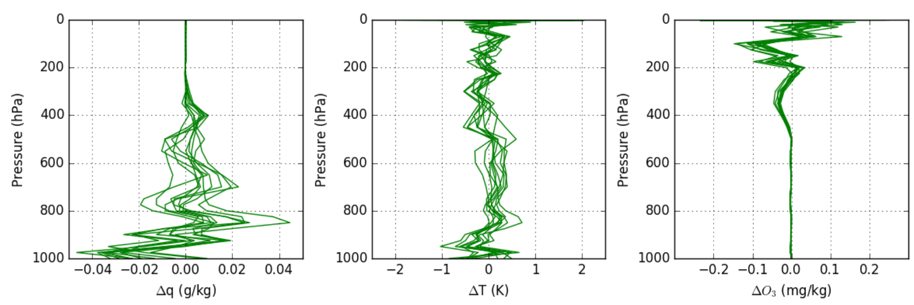
Evolution of the Inter-Calibration Method

- Approach still needs allow for non-coincidental scenes.
- Therefore we apply the following assumptions:
  1. Clear skies (for now)
  2. Access to additional information about the scene from (a) accurate model geophysical variables, and (b) a RTM capable of simulating both instruments.
  3. Both instruments share the same RTM
- Assumption 1: Employ the IASI L1c cloud flag
- Assumption 2: ERA 5 analysis + 10 member ensemble fields
- Assumption 3: Reference Forward Model (RFM), line-by-line RTM, can vary all inputs including spectroscopy





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Evolution of the Inter-Calibration Method

- Using these assumptions we can continue to adapt the method to account for non-coincidence.
- Expand the list of defined variables to include terms base don new assumptions.

Variable	Description	Variable	Description
x^r	Atmospheric state vector for the reference instrument	x^t	Atmospheric state vector for the target instrument
δx^r	Uncertainty on the reference instrument state vector	δx^t	Uncertainty on the target instrument state vector
θ^r	Viewing angle of the reference instrument	θ^t	Viewing angle of the target instrument
x^r_{true}	True version of x^r	x^t_{true}	True version of x^t
l^r	Observation packet from the reference instrument	l^t	Observation packet from the target instrument
δl^r	Uncertainty on reference observational packet	δl^t	Uncertainty on target observational packet
l^r_{true}	Noise-free observation packet that a perfect reference instrument would observe	l^t_{true}	Noise-free observation packet that a perfect target instrument would observe
$h(x,\theta)$	The RTM output	ϵ^h	Uncertainty of RTM output
δx^{rt}	Difference in reference and target state vectors	$\delta\theta^{rt}$	Difference in viewing angles of reference and target instruments.

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Evolution of the Inter-Calibration Method

$$\left\langle \delta \mathbf{l}^{\mathrm{r}} \delta \mathbf{l}^{\mathrm{r}\,\mathrm{T}} \right\rangle$$

$$J[\mathbf{a},\mathbf{b}] = \frac{1}{2}\sum_i d_i^2 = \frac{1}{2}\sum_{i=1}^{m} \left[\mathbf{l}_i^{\mathrm{t}} - \mathbf{a} - \mathbf{B}\mathbf{l}_i^{\mathrm{r}}\right]^{\mathrm{T}} \left(\mathbf{R}^{\mathrm{t}} + \mathbf{B}\mathbf{R}^{\mathrm{r}}\mathbf{B}\right)^{-1} \left[\mathbf{l}_i^{\mathrm{t}} - \mathbf{a} - \mathbf{B}\mathbf{l}_i^{\mathrm{r}}\right]$$

$$\mathbf{l}^{\mathrm{t}}_{\mathrm{true}} = \underbrace{\mathbf{l}^{\mathrm{r}} + \mathbf{H}_{\mathbf{x}^{\mathrm{r}},\theta^{\mathrm{r}}}\delta\mathbf{x}^{\mathrm{rt}} + \mathbf{H}_{\theta^{\mathrm{r}},\mathbf{x}^{\mathrm{r}}}\delta\theta^{\mathrm{rt}}}_{\text{known/calculable}} + \underbrace{-\delta\mathbf{l}^{\mathrm{r}} + \mathbf{H}_{\mathbf{x}^{\mathrm{r}},\theta^{\mathrm{r}}}\delta\mathbf{x}^{\mathrm{r}} - \mathbf{H}_{\mathbf{x}^{\mathrm{t}},\theta^{\mathrm{t}}}\delta\mathbf{x}^{\mathrm{t}}}_{\text{statistics known}} + \underbrace{\epsilon_1^{\mathrm{h}} - \epsilon_2^{\mathrm{h}}}_{?}$$

Reference measurement (l_i^r)

Reference Error covariance ($\boldsymbol{R}^r$)

$$\begin{aligned}\mathbf{R}^{\mathrm{r}} &= \left\langle \delta\mathbf{l}^{\mathrm{r}}\delta\mathbf{l}^{\mathrm{r}\,\mathrm{T}}\right\rangle + \left\langle \left(\mathbf{H}_{\mathbf{x}^{\mathrm{r}},\theta^{\mathrm{r}}}\delta\mathbf{x}^{\mathrm{r}}\right)\left(\mathbf{H}_{\mathbf{x}^{\mathrm{r}},\theta^{\mathrm{r}}}\delta\mathbf{x}^{\mathrm{r}}\right)^{\mathrm{T}}\right\rangle + \left\langle \left(\mathbf{H}_{\mathbf{x}^{\mathrm{t}},\theta^{\mathrm{t}}}\delta\mathbf{x}^{\mathrm{t}}\right)\left(\mathbf{H}_{\mathbf{x}^{\mathrm{t}},\theta^{\mathrm{t}}}\delta\mathbf{x}^{\mathrm{t}}\right)^{\mathrm{T}}\right\rangle \\ &\quad + \left\langle \left(\mathbf{H}_{\mathbf{x}^{\mathrm{r}},\theta^{\mathrm{r}}}\delta\mathbf{x}^{\mathrm{r}}\right)\left(\mathbf{H}_{\mathbf{x}^{\mathrm{t}},\theta^{\mathrm{t}}}\delta\mathbf{x}^{\mathrm{t}}\right)^{\mathrm{T}}\right\rangle + \left\langle \left(\mathbf{H}_{\mathbf{x}^{\mathrm{t}},\theta^{\mathrm{t}}}\delta\mathbf{x}^{\mathrm{t}}\right)\left(\mathbf{H}_{\mathbf{x}^{\mathrm{r}},\theta^{\mathrm{r}}}\delta\mathbf{x}^{\mathrm{r}}\right)^{\mathrm{T}}\right\rangle\end{aligned}$$

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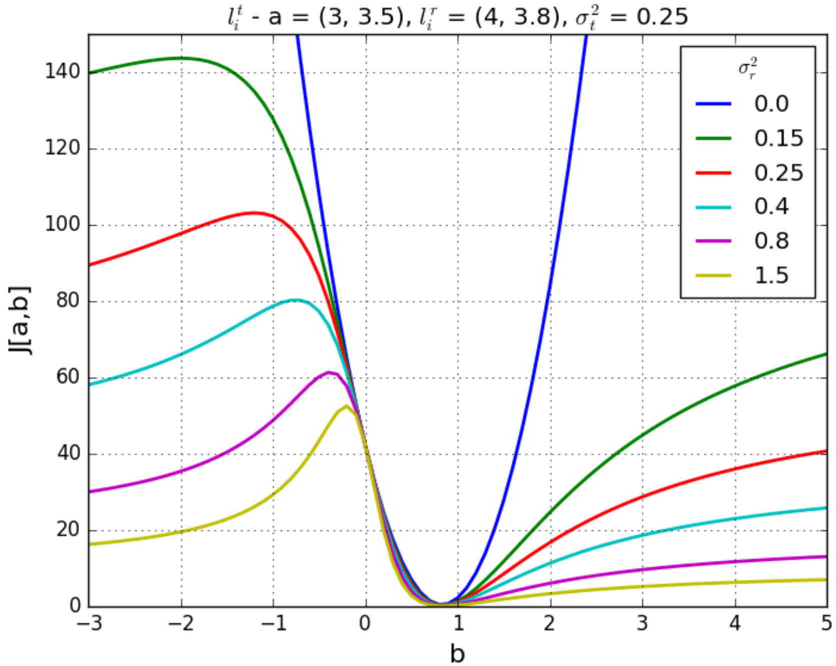
Evolution of the Inter-Calibration Method

- Final thing to consider is how to minimise the cost function.

$$J[\mathbf{a},\mathbf{b}] = \frac{1}{2}\sum_i d_i^2 = \frac{1}{2}\sum_{i=1}^{m}\left[\mathbf{l}_i^{\mathrm{t}} - \mathbf{a} - \mathbf{B}\mathbf{l}_i^{\mathrm{r}}\right]^{\mathrm{T}}\left(\mathbf{R}^{\mathrm{t}} + \mathbf{B}\mathbf{R}^{\mathrm{r}}\mathbf{B}\right)^{-1}\left[\mathbf{l}_i^{\mathrm{t}} - \mathbf{a} - \mathbf{B}\mathbf{l}_i^{\mathrm{r}}\right]$$

- The problem is not quadratic. Example: for a case of 2 pairs, single channel and Rr diagonal elements of possible values range from 0-1.5. This results in non-quadratic cost function with a less well-defined minimum, an asymmetric profile around the minimum, and a nearby maximum.
- Currently looking at methods to solve this, potential to use block gradient descent approach.



Thank you for listening