Weighting Matrices applied in Image Reconstruction Algorithm in L1PP and their impact on Soil Moisture retrieval

Castro, R.(1), Barbosa, J.(1), Anterrieu, E.(2), Cabot, F.(3) and Richaume, P.(3)

Introduction

The single payload for the Soil Moisure and Ocean Salinity (SMOS) mission is the Microwave Imaging Radiometer by Aperture Synthesis (MIRAS). It is a Y-shaped interferometer formed by 69 equally spaced antennas operating in the L-band. Each pair of antennas forms a baseline that observes a specific a signal, i.e., a visibility.

The visibilities gathered by all baselines are transformed to brightness temperatures through the use of a linear operation system, $T = J^{+}V$, where J^{+} is the pseudo-inverse of the System Response Function.

The Level 1 Prototype Processor (L1PP) is a bridge between the data that MIRAS gathers and the Level 2 Algorithms to retrieve Soil Moisture from geolocated data of brightness temperatures.

It has been proposed to improve the radiometric accuracy of the retrieved maps by taking into account the variance-covariance matrix of the radiometric noise affecting the data.

This poster shows the results obtained during the SMOS Commissioning Phase using the Baseline Weights Algorithm implemented in L1PP and the Weighting Matrices derived with in-orbit data.

Computing the Weights

Estimation Over Open Ocean

It has been agreed that the weights to be applied should be derived from an Open Ocean Zone

Due do the number of overpassess it is possible to compute the radiometric noise levels affecting M-baselines[a] and L-baselines[b]

(a) Baselines formed by a NIR and a LICEF (b) Baselines formed by two LICEFs

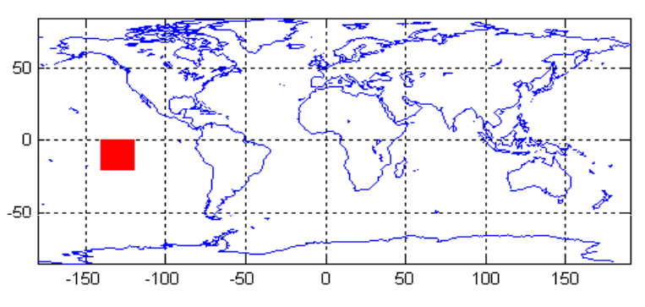


Figure 1 – Zone analysed on the Pacific

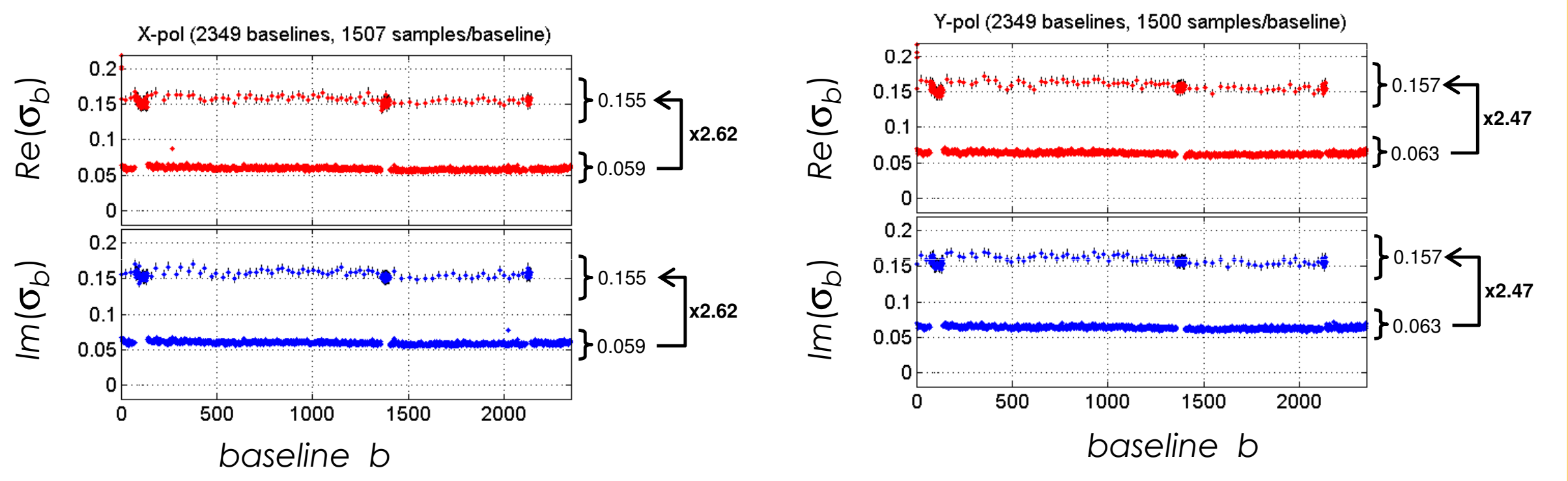


Figure 2 – Standard deviations σ_b of the real (red) and imaginary (blue) parts of the 2343 complex visibilities from the selected Pacific zone – Computed from data aquired in May 2010 (Left: H-pol, Right: V-pol)

M-Baselines have higher radiometric noise than the L-Baselines

Building the Weighting Matrices

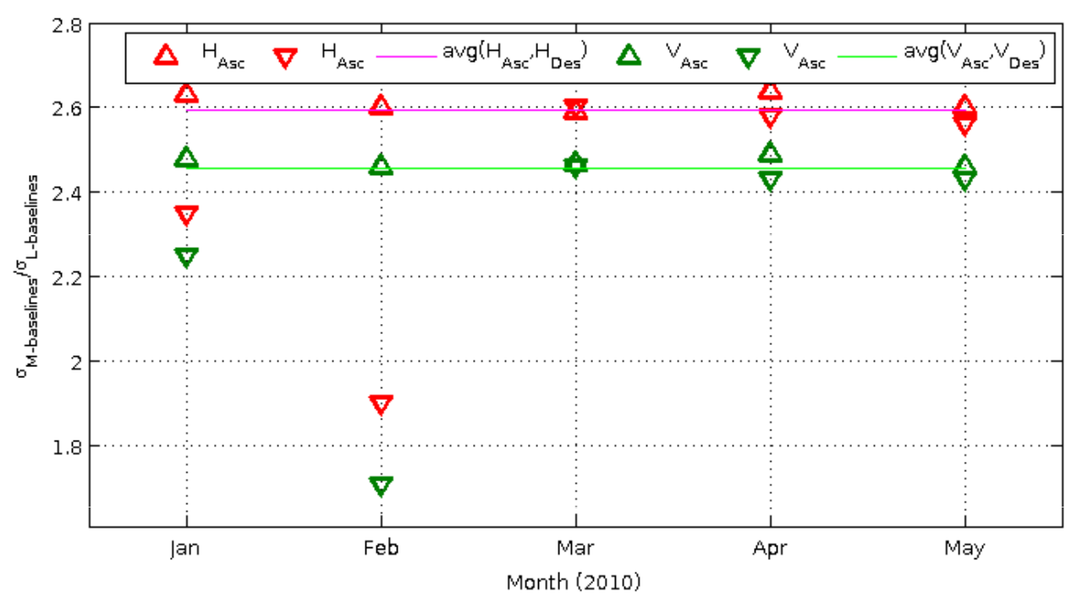


Figure 3 – Evolution of the ratio of Radiometric Noise levels between M- and L-Baselines

- ❑ Ratios are very stable for Ascending (Asc) Orbits (*)

(*) Jan and Feb values reflect the instability on Operational Processors in beggining of IOCP

- ❑ Averaging between Asc and Descending (Des) Orbits, the weighting matrices can be computed as $w_b = 1/R$

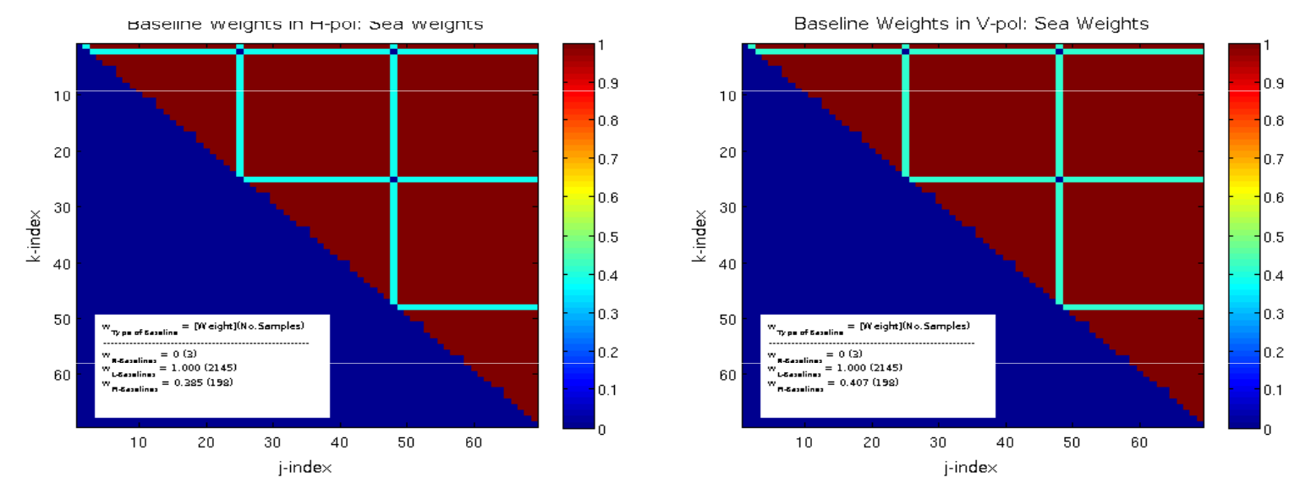


Figure 4 – Baseline Weight matrices to be applied to the visibilities (Left: H-pol, Right: V-pol)

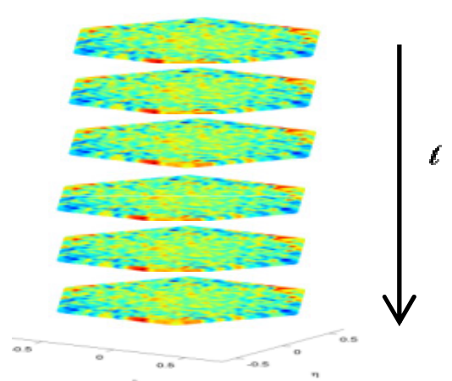
Radiometric Sensitivities computed with L1PP

The Radiometric Sensitivity is the best statistic that allows Level 1 to assess on the improvements brought by the *Baseline Weights Algorithm*. This assessment comprises several steps:

1. Generate J+ Matrices with different weighting matrices (**No Weights** applied and using **Sea Weights**) and use them to process the same orbit

2. Using L1b data, compute an average scene (using > 300 snapshots)(*) obtaining a Time Averaged Scene, $\bar{T}^{p}(\xi,\eta)^{2}$.

(*) For the results presented 512 snapshots per pol were used



3. Using the Time Averaged Scene, the empirical Radiometric Sensitivity is computed as shown in Eq. (1)

$$\bar{\sigma}^{p}(\xi,\eta)=\sqrt{\frac{1}{N}\left(\sum_{n=1}^{N}T_{n}^{p}(\xi,\eta)^{2}\right)-\bar{T}^{p}(\xi,\eta)^{2}} \quad \text{Eq.(1)}$$

4. Compare the Time Average Scene and Radiometric Sensitivities derived from the orbits processed

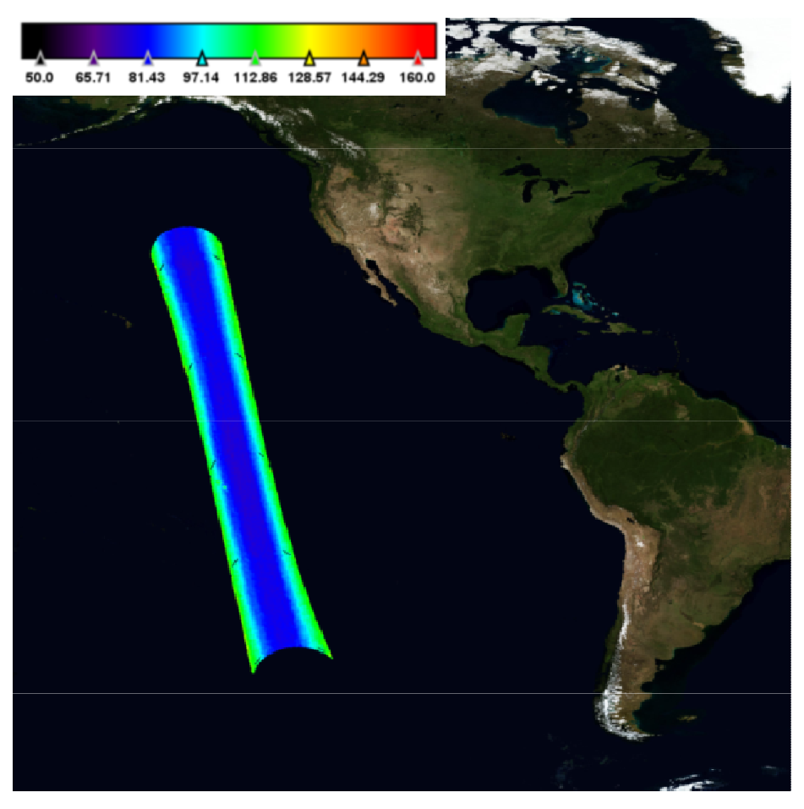


Figure 5 – Segment of Pacific orbit aquired on 10-Mar-2010, at 14:59:15 (H-pol image)

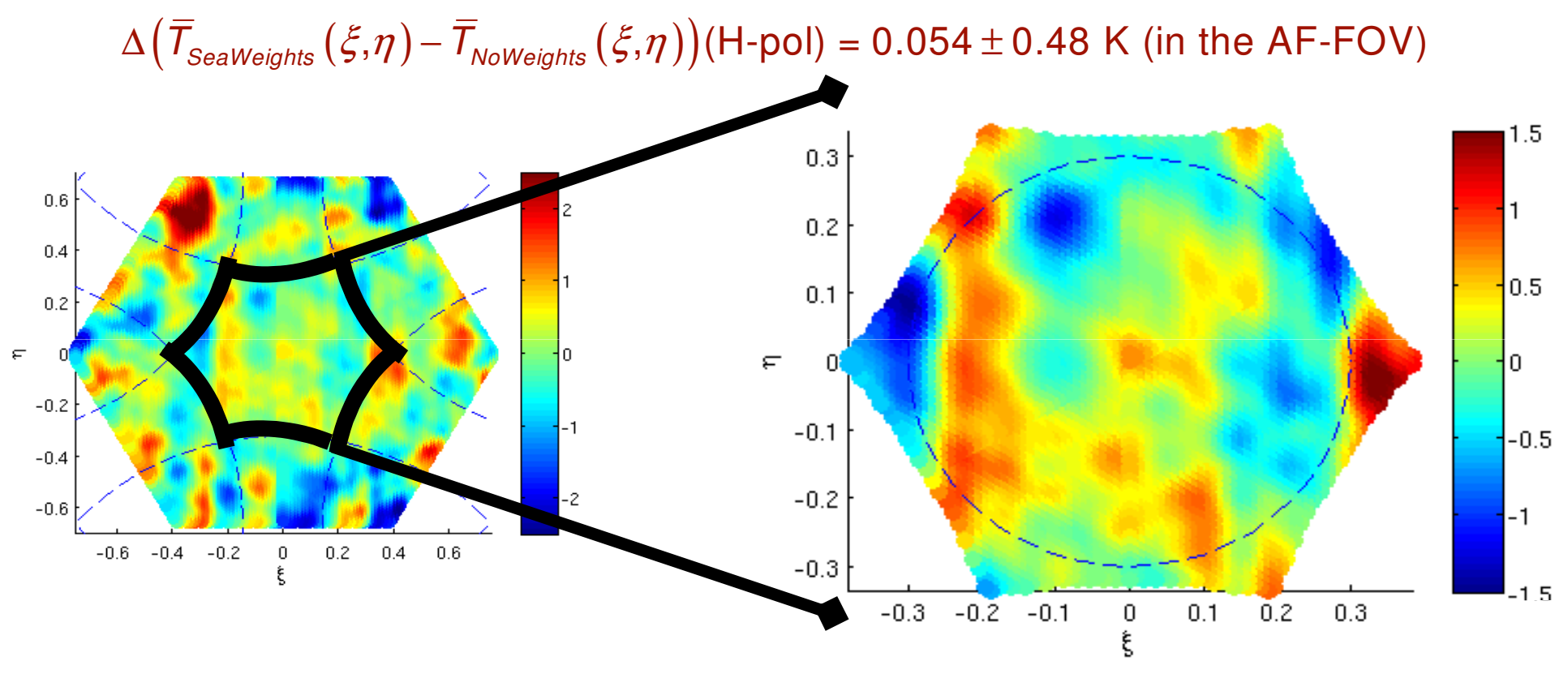


Figure 5 – Differences between Level 1b Time Average Temperature computed with 512 snapshots processed using Sea weights and with No Weights applied. (Left_ Hexagon, Right: Zoom in the Alias Free Field of View (AF-FOV). Images in H-pol)

Result #1

The Time Averaged Scene is <u>not affected</u> by weighting down some baselines in the image reconstruction. The standard deviation corresponds to a change of < 1% in the temperature of the scenes. This is also valid for V-pol

No Weights (H-pol)

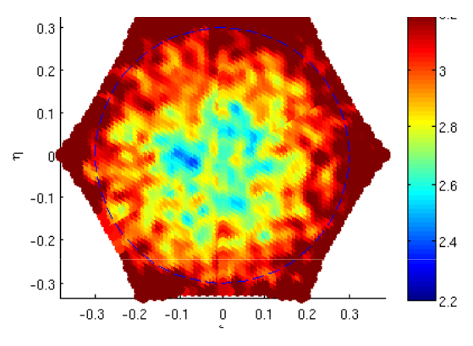


Figure 6 – Radiometric Sensitivity for 512 scenes processed with No Weights applied

Sea Weights (H-pol)

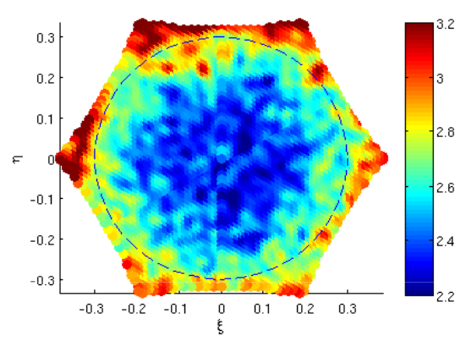


Figure 7 – Radiometric Sensitivity for 512 scenes processed with Sea Weights applied

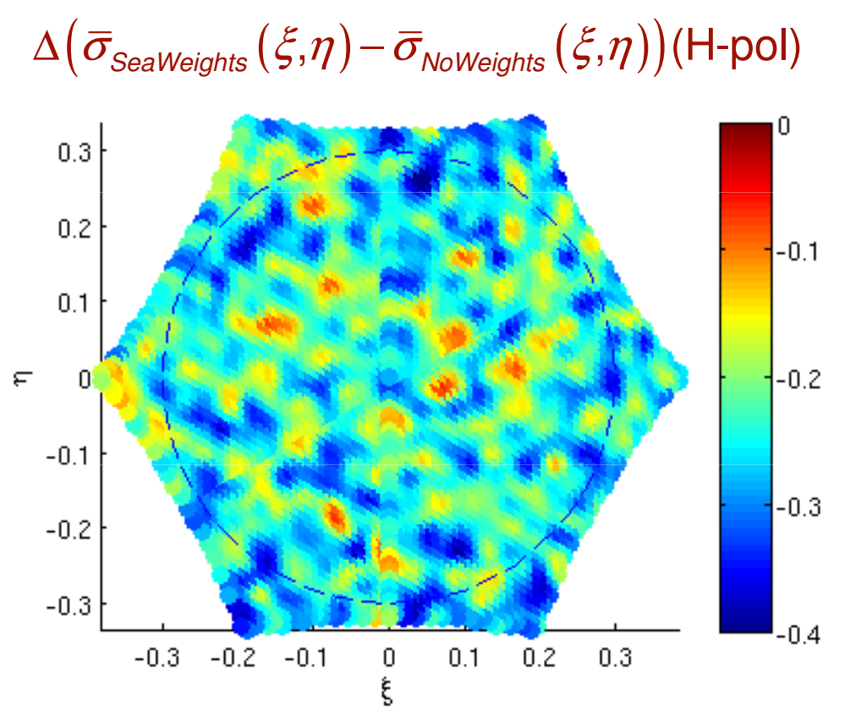


Figure 8 – Impact on the Radiometric Sensitivity when using Sea Weights.

Table I - Radiometric Sensitivity figures for two weighting options and their differences *(@ Circle r = 0.3)*	H-pol			V-pol			Re(HV)			Im(HV)		
	No Weights (1)	Sea Weights (2)	Δ [(2) -(1)]	No Weights (1)	Sea Weights (2)	Δ [(2) -(1)]	No Weights (1)	Sea Weights (2)	Δ [(2) -(1)]	No Weights (1)	Sea Weights (2)	Δ [(2) -(1)]
Boresight [K]	2.70	2.52	-	2.63	2.46	-	2.45	2.22	-	2.70	2.46	-
Average [K]	2.76	2.53	-0.24	2.93	2.72	-0.21	2.68	2.44	-0.24	2.68	2.44	-0.24
Std.Deviation [K]	-	-	0.05	-	-	0.05	-	-	0.05	-	-	0.05
Minimum [K]	2.29	2.09	-0.44	2.39	2.27	-0.39	2.35	2.12	-0.41	2.33	2.07	-0.41
Maximum [K]	3.37	3.14	-0.07	3.49	3.26	-0.03	3.14	2.85	-0.06	3.12	2.79	-0.03

Result #2

The Radiometric Sensitivity is <u>*improved*</u> by ~0.2 K in all polarisations.

Impact on Soil Moisture Retrieval

Detecting the impact of the above ~0.2 K radiometric sensitivity improvement on the Soil Moisture retrieval is a challenge

Challenging because:

1. The SMOS radiometric accuracy 2.5K to 5K allows to retrieve the absolute soil moisture with an error less than 0.04 [m³/m³]
   - ➥ *The 0.2 K of improved sensitivity is small in comparison.*
2. But retrieval errors are expected to be dominated by the errors on the surface knowledge
   - ➥ *Landcover classification: fractions, especially water bodies*
   - ➥ *Fixed parameters: sand, clay, vegetation or forecasted values*
3. The algorithms implemented in the L2 processor are still not completely calibrated and validated and still need to improve.

⇩ ⇩ ⇩ **but with a strict control** ⇩ ⇩ ⇩

Special SML2PP Setup *stabilize the retrieval*	**Focused DGG Analysis** *minimize the impact of surface errors*
• SML2PP V3.08 in ESL mode • No post analysis filtering • SM & Tau free parameters only • Hardened convergence criteria	• DT12 only ⇒ nominal model • FNO > 95% ⇒ uniform surface • Very low RFI ⇒ P < 0.01

Result #3

- No visible improvement for SM and Tau retrieval
- χ^2 is <u>*slightly improved*</u> for the Sea Weights option *by ~0.1 absolute ⇒ ~3.5% relative ⇒ ~0.35 K*

SM – Tau – χ^2 – Retrieval comparison Sea Weights versus No Weight

Australian rainy condition – Descending – Full Polarization – 20100212T072424 – L1PP L1C V330

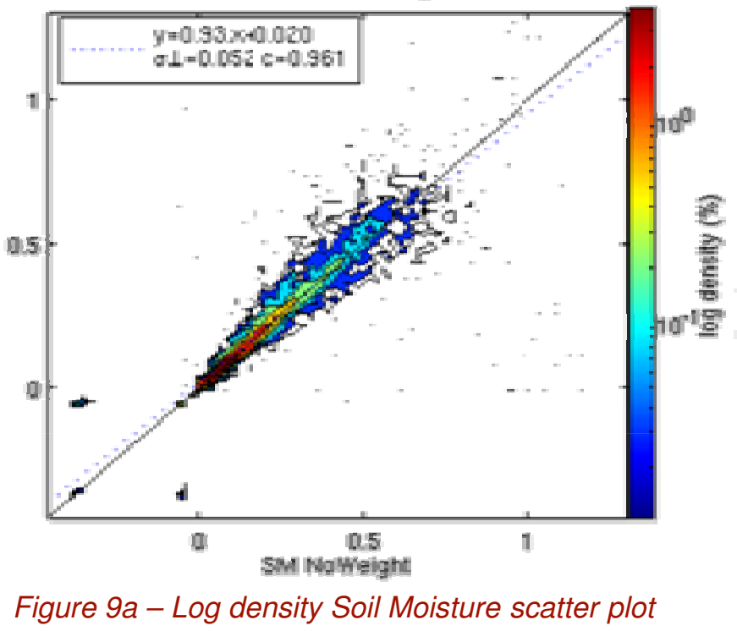


Figure 9a – Log density Soil Moisture scatter plot Sea Weights (y) vs. No Weights (x)

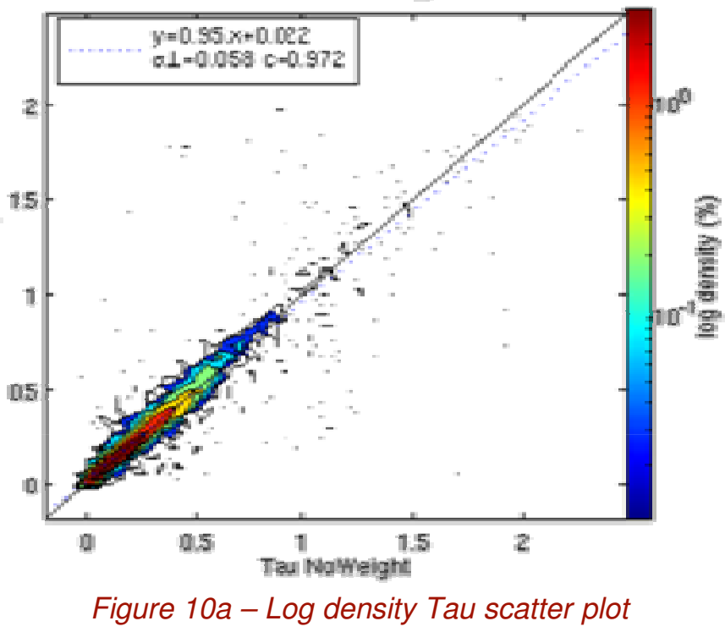


Figure 10a – Log density Tau scatter plot Sea Weights (y) vs. No Weights (x)

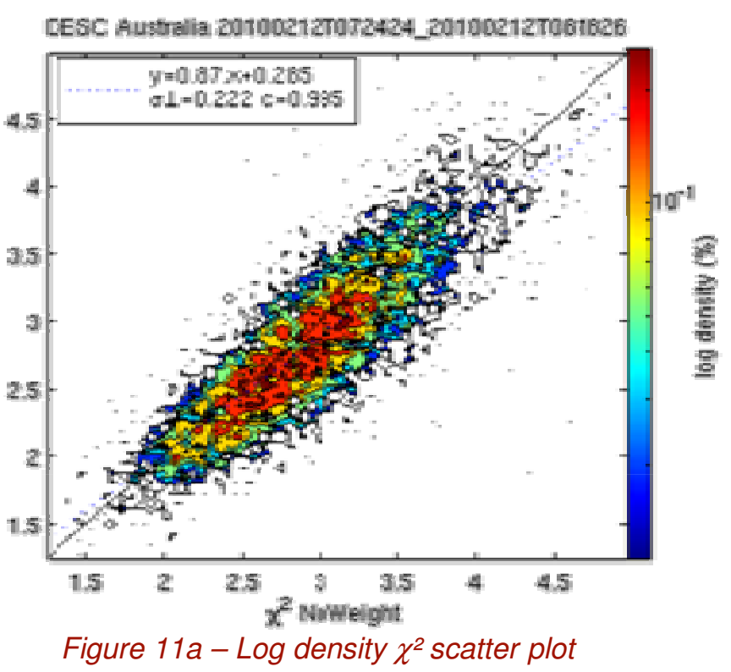


Figure 11a – Log density χ^2 scatter plot Sea Weights (y) vs. No Weights (x)

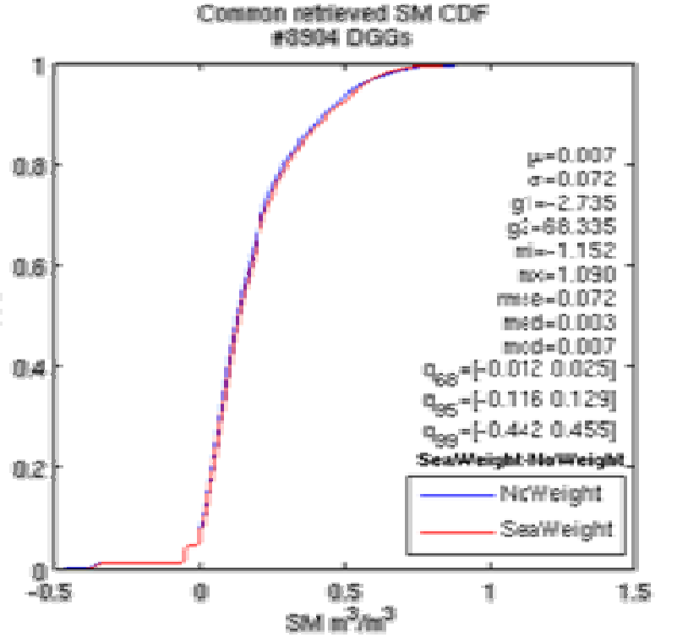


Figure 9b – CDF of Soil Moisture
Sea Weights vs. No Weights

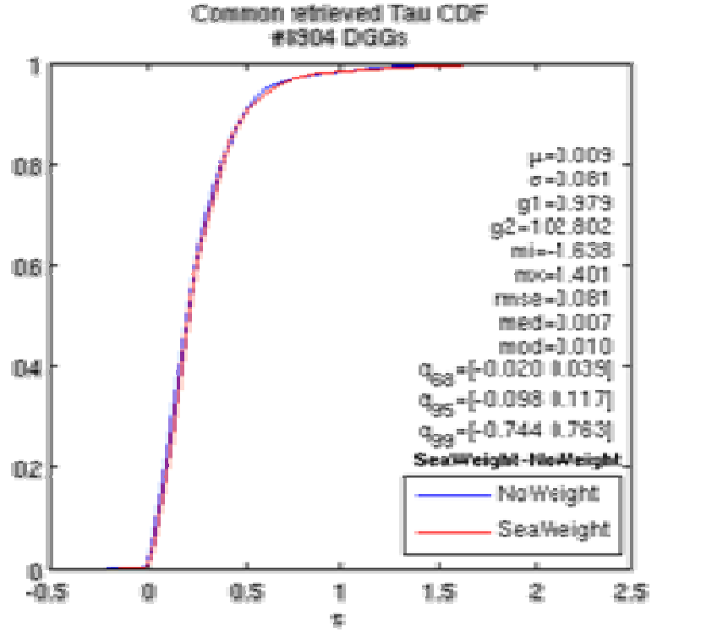


Figure 10b – CDF of Optical Thickness
Sea Weights vs. No Weights

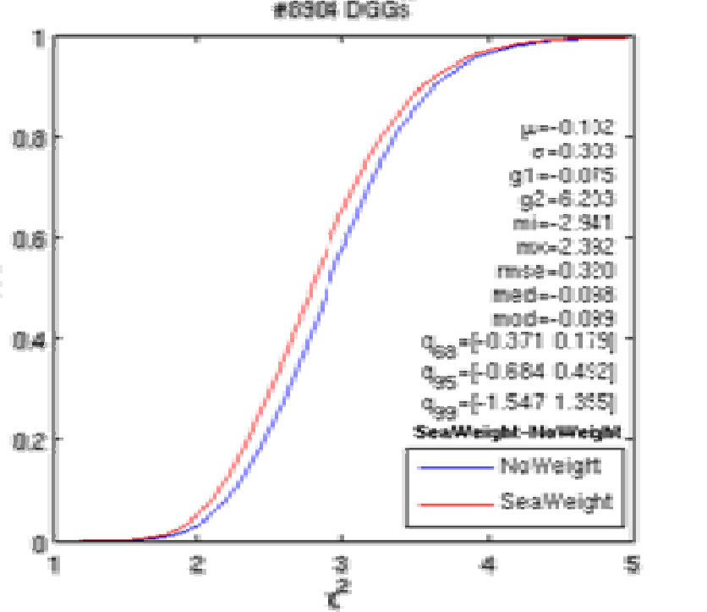


Figure 11b – CDF of χ^2
Sea Weights vs. No Weights

Conclusions:

The Baseline Weighting Algorithm has been designed to lower the noise levels in the reconstructed BTs of the L1 processing chain.

After an initial theoretical appraisal of the method, baseline weights were derived from in-orbit data and different weights are needed for baselines formed by NIR and LICEF receivers. The impact on the final BT has been accessed and, not only the final BT is not affected, the radiometric sensitivity is improved by 0.2K.

Performing the study at L2 processing level has proven that SM retrieved values are not affected but that the χ^2 of the retrieved values is reduced as much as 0.35K.

The Baselines Weights are being computed on a monthly basis and are periodically updated in the processing chain. It is expected that the final improvements will be even larger as the mission continues.

Contact details:
(1) Deimos Engenharia – Av. D. João II, Lote 1.17 Torre Zen, 10o, 1998-023, Lisboa, Portugal (Rita.Castro@deimos.com.pt and Jose.Barbosa@deimos.com.pt)
(2) Observatoire Midi-Pyrénées – Laboratoire d'Astrophysique - UMR5572, 14 av. Edouard Belin, 31400 Toulouse, France (Eric.Anterrieu@ast.obs-mip.fr)
(3) CESBIO – 18 Avenue E. Belin, 31401 Toulouse , Cedex 9, France (Francois.Cabot@cesbio.cnes.fr and Philippe.Richaume@cesbio.cnes.fr)