SMOS Level 1 Processor Prototype

Activities led by Critical Software

José Freitas
Marco Ventura
Ivo Carola
José Carlos Correia

Outline

- Tools
  - L1PP Visualization Tool
  - BinXML Evolution
- Technical Notes
  - Sun BT self estimation study
  - Impact of solar flares in the L1PP
  - Hardware/Software Performance Assessment

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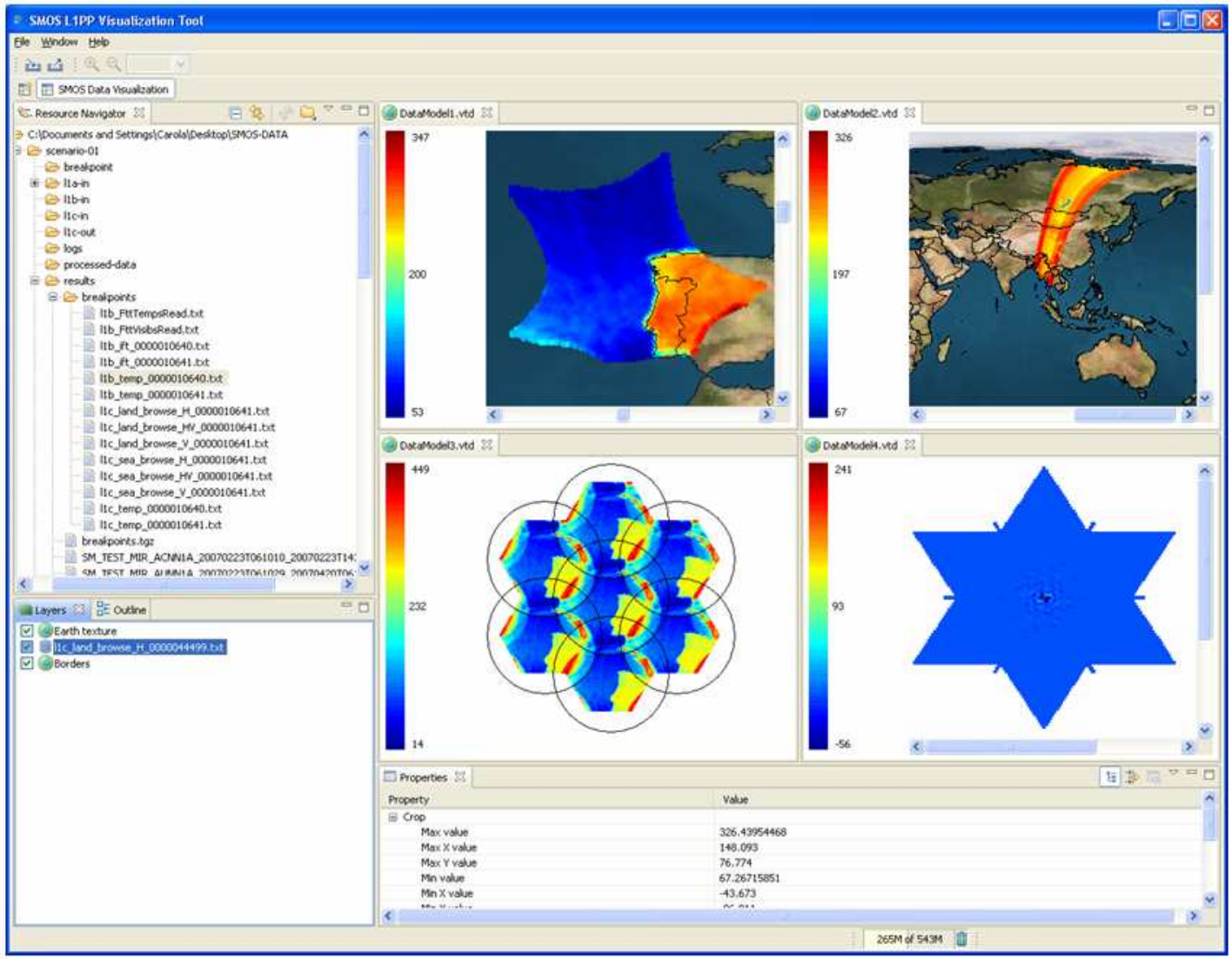
L1PP Visualization Tool - Features

- Multi-platform stand-alone tool
  - Linux 32/64
  - Mac OS X PPC/Intel
  - Windows
- Support for L1PP L1b and L1c Products/breakpoints
  - L1b
    - Visualization of the Fourier components (star domain)
    - Visualization of the BT on the FOV of the instrument (Inverse DFT)
    - Layered view of unit circles and aliases
  - L1c
    - Visualization of georeferenced snapshots and browses
    - Possibility to select a snapshot within a product
    - Layered view of Background and coastline
- Export functionality to JPEG/GIF
- Zoom, filter/crop data, adjust graphics scale
- Installer downloads automatically needed ADFs from project's website

L1PP Visualization Tool - Snapshots



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BinXML Evolution – nested variable arrays

- Variable array is a structure that uses information read from the binary file to define the actual size of the array.
- Objectives
  - Describe a product using a single XML BinX Schema, without knowing a priori the dimensions of the data structures to be read/write
  - Read/Write "linked lists" based data structures (in particular L1c)
- Output from this activity
  - Adaptation of BinX library (from Edikt) to support nested variable arrays
  - Update of Binary XML library with new variable arrays functionality

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Sun BT Self-estimation study

- Objectives
- The approach
- Results
- Conclusions

Objectives

- One of the main effects that needs to be taken into account in the Image Reconstruction process is the contamination of the images due to the Sun appearing in the FOV

- UPC has defined and implemented in SEPS a new algorithm to estimate the Sun BT and then remove the direct Sun effect on the MIRAS brightness temperatures maps

- The objective of this study was to assess the accuracy of the Sun self-estimation and correction algorithm implemented in L1PP

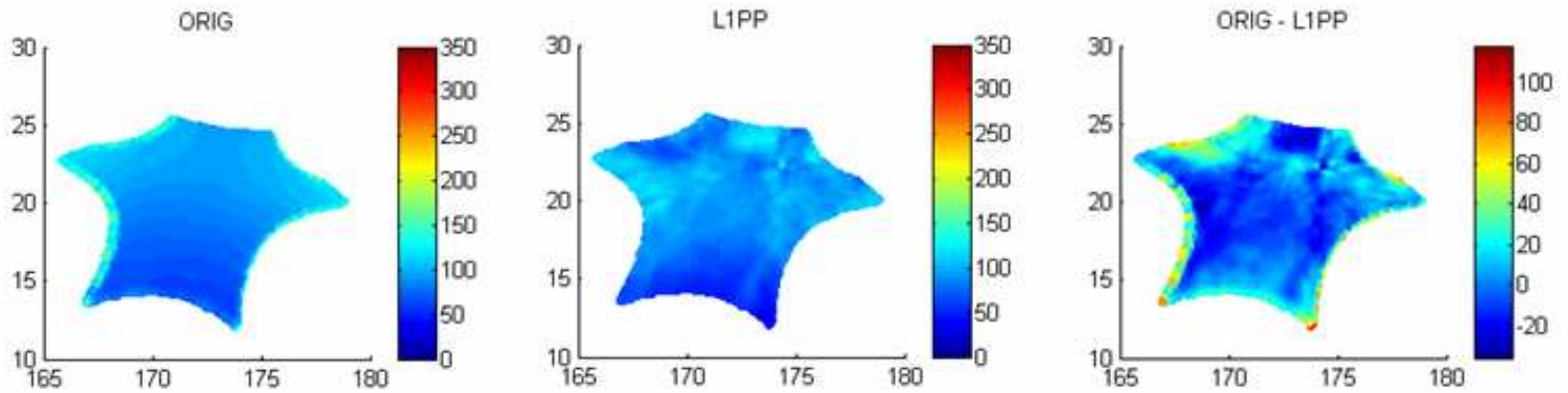
The approach

- The study was carried out by taking the following steps:
  - Definition of different scenarios simulating different test cases:
    - 1 – Nominal sun effects simulated
    - 2 – "Solar Flares" simulated
    - 3 – No Sun effects simulated
- Analysis of the output images and errors
- Assessment of the Sun correction algorithm efficiency

Results

- Scenario 01 ("Nominal Sun effects")

H Pol

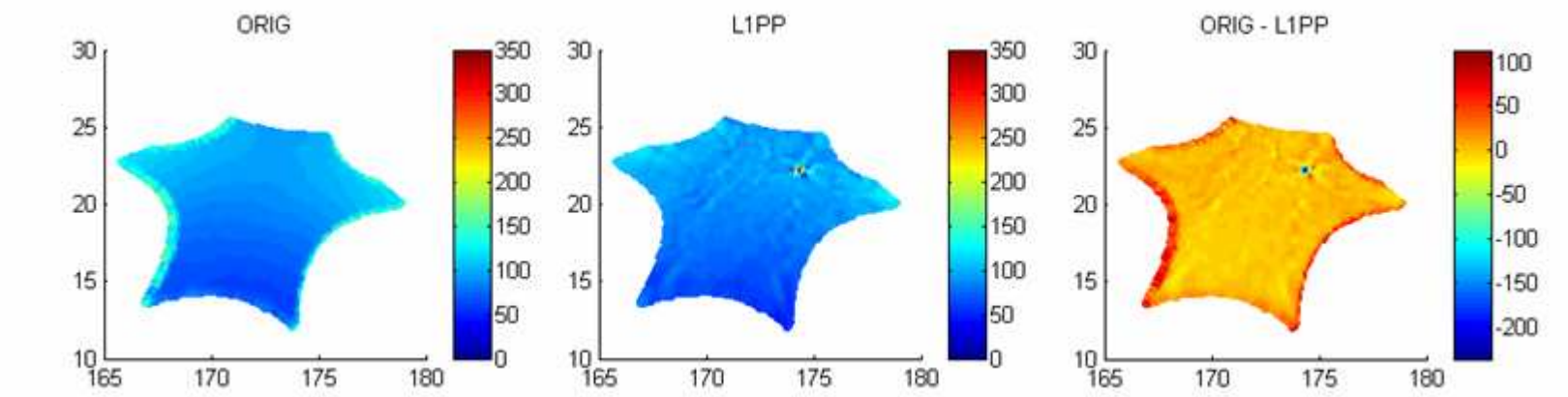


Scene	SEPS BT Simulated	L1PP BT Estimated	BT Error (%)
1 (H Pol)	96 792 K	87 606 K	-9.5 %
2 (V Pol)	96 792 K	91 190 K	-5.8%

Results

- Scenario 02 ("Solar Flares")

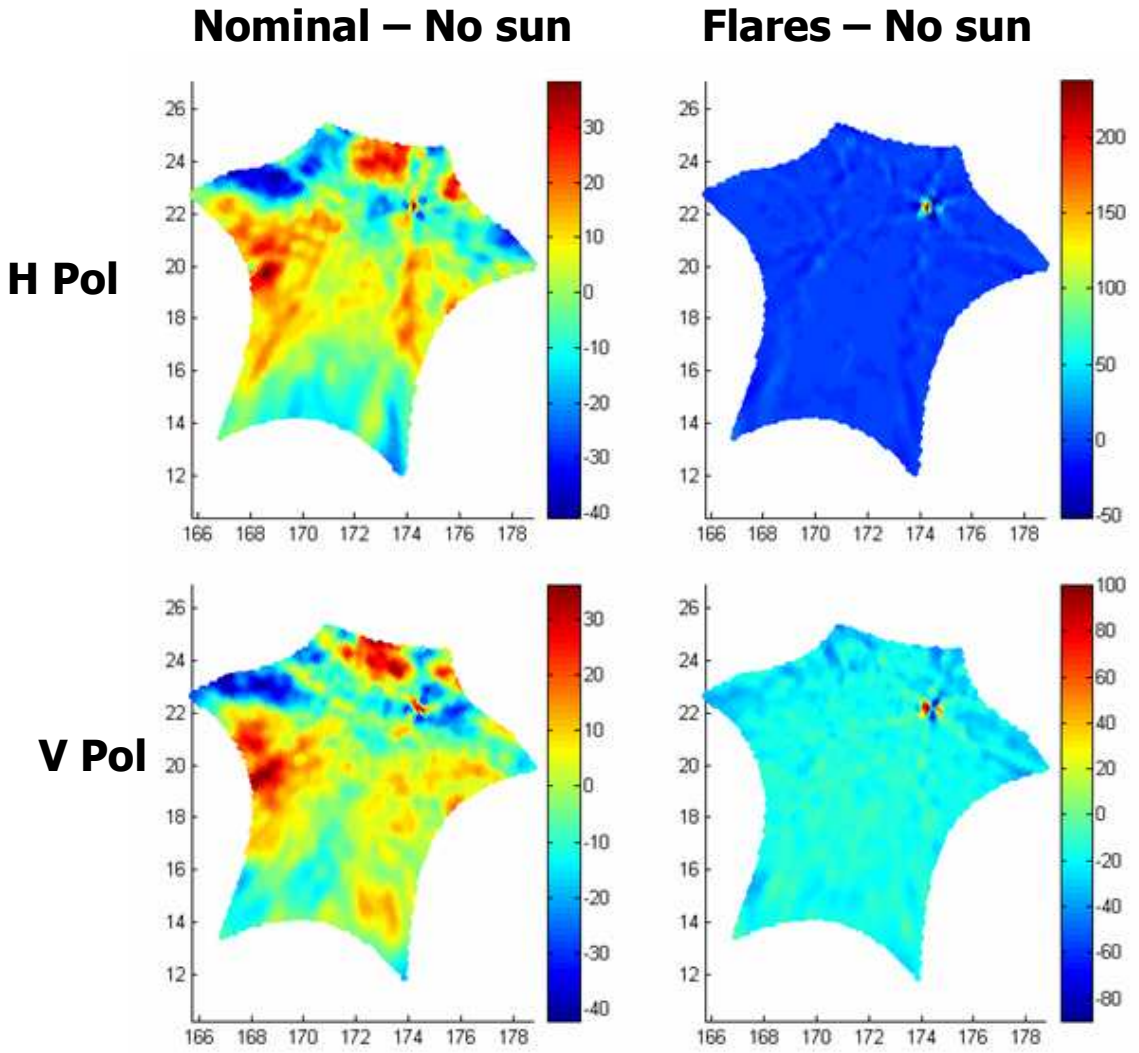
H Pol



Scene	SEPS BT Simulated	L1PP BT Estimated	BT Error (%)
1 (H Pol)	967 918	859 565 K	-11.2 %
2 (V Pol)	967 918	909 992 K	-6.0%

Results

- Sun effects that are not properly removed:
  - Scenarios 01 - 03
  - Scenarios 02 - 03



Conclusions

- Images are much more affected when a flare occurs => these scenes should be flagged
- Accuracy of Sun BT estimation worst than the one reported by UPC in SEPS simulations => further investigation and cross validation is needed

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Impact of solar flares in the L1PP

- Objectives
- Radio emission from the Sun in the L-Band
- Frequency of Solar Flares occurrence
- Conclusions and Recommendations

Objectives

- The objective of the study was to describe the impact of solar flares occurrence in satellite missions such as SMOS and to describe the approach taken to deal with this phenomenon in the SMOS L1PP Data Processing.

- The study was based on literature data and conclusions reported on:
  - "Impact of the Sun on Remote Sensing of Sea Surface Salinity from Space", Le Vine et al. 2005
  - National Geophysical Data Center http://www.ngdc.noaa.gov/stp/SOLAR/ftpsolarradio.html

Radio emission from the Sun (I)

- The Sun is a strong source of radiation at L-band
- The solar activity varies with a 11-year cycle
  - near solar minimum, solar contamination is not a problem
  - near solar maximum, a significant contamination from the Sun can occur
- The solar flux at a given wavelength, F_λ , can be expressed in solar flux units, sfu
  - Values at different wavelengths are available daily from different ground stations around the world
- At L band (1.4 GHz), the relationship between the equivalent temperature, T_{Sun} , expressed in kelvin, and the solar flux F_L , can be written as:
  - $T_{Sun} \sim 2000\ F_L$

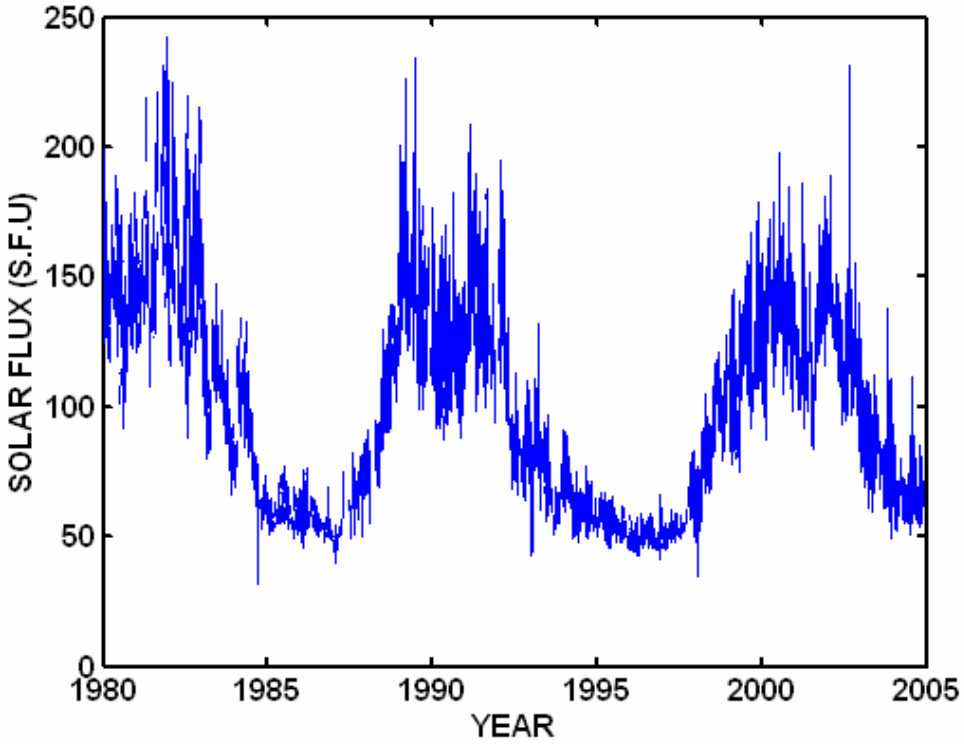
Radio emission from the Sun (II)

- The radio emission from the Sun can be divided into two categories according to their characteristic scale of temporal variation:
  - $T_{Sun}(t) = T_S(t) + T_R(t)$

T_S – a slowly varying component (timescale of hours to days). Mean value follows the 11 year solar cycle
T_R – a rapidly varying component (timescale of seconds to minutes) associated with solar flares

The correlation with the **11 year solar cycle** can be clearly noticed;
It is also noted that **the flux does not exceed 250 sfu**, even at the periods of high activity

T_S component of solar flux at 1.4 GHz at noon from Sagamore Hill



Frequency and duration of solar flares (I)

- A Solar flare is a violent explosion occurring on the atmosphere of the Sun that can eject particles and emit radiation in all parts of the spectrum into space. Their frequency varies with the 11 year solar cycle.

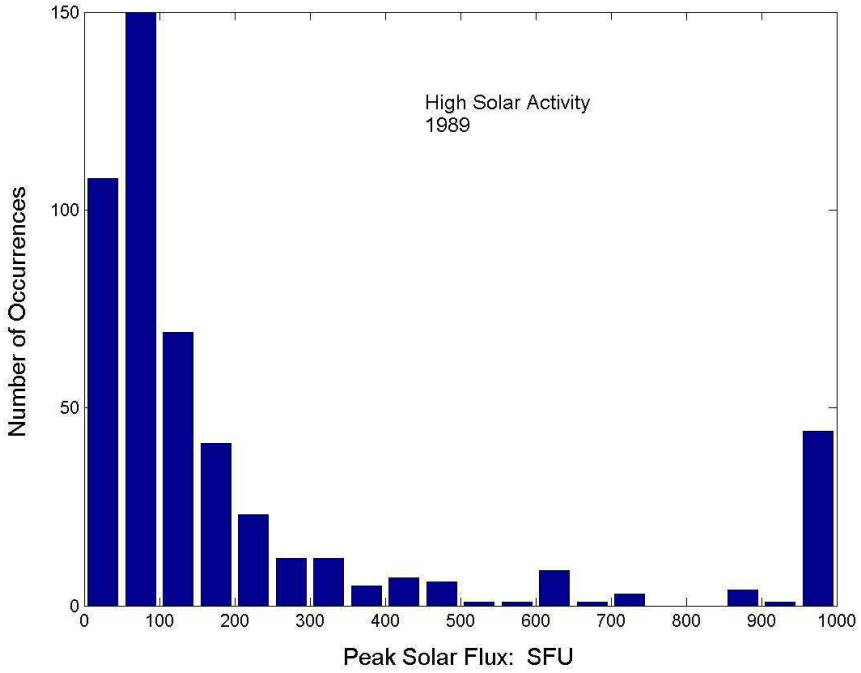
- These solar storms begin in a few seconds and can last up to a few hours. A typical flare lifetime is 20 minutes

- The frequency of occurrence of solar flares can vary from several per day when the Sun is particularly "active" to less than one each week when the Sun is "quiet"

- Not all solar flares are associated with an increase of microwave radiation. When these increases occur, they are designated Solar Microwave Bursts (SMB)

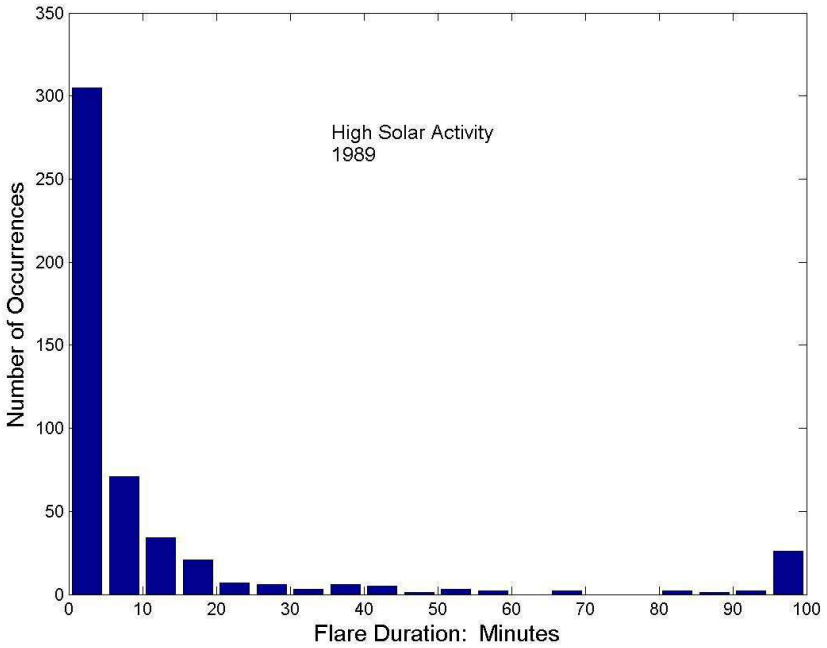
Frequency and duration of solar flares (II)

Distribution of peak amplitude for SMB at 1.4 GHz during high solar activity [RD.6].



- The **maximum number of occurrences** happen for peaks of solar flux with less than 100 sfu.

Distribution of duration of SMB at 1.4 GHz during high solar activity [RD.6].



- However, **the duration of all of these intense emissions is relatively brief**

Conclusions and recommendations

- The combined analysis of the previous figures lead us to say that the occurrence of strong flares lasting long periods should be very low
- It is proposed to use a limiting solar flare threshold of tolerance set to 250 sfu for the purpose of the L1PP Data Processing
- The limiting solar flare threshold temperature should be

$$T_{Sun} = 500\,000\ K$$

- Any Sun brightness temperatures above 500 000 K should be indicative of a possible solar flare occurrence and the corresponding snapshot flagged as such

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Hardware/Software Performance

- Objectives
- Overall processing performance
- Geolocation Analysis
- G and J+ computation – Single vs Multi-thread
- Conclusions

Objectives

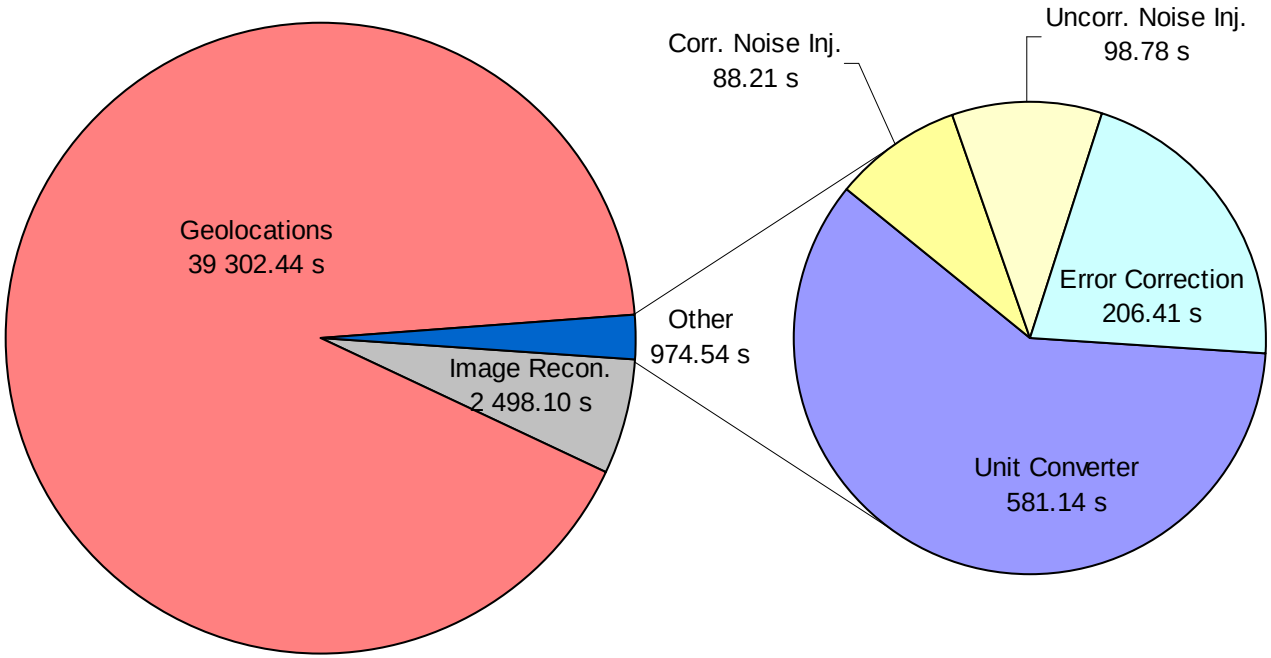
- To assess the overall performance of the L1PP
- To identify Software processing bottlenecks
- To identify possible optimisation strategies

Overall processing performance

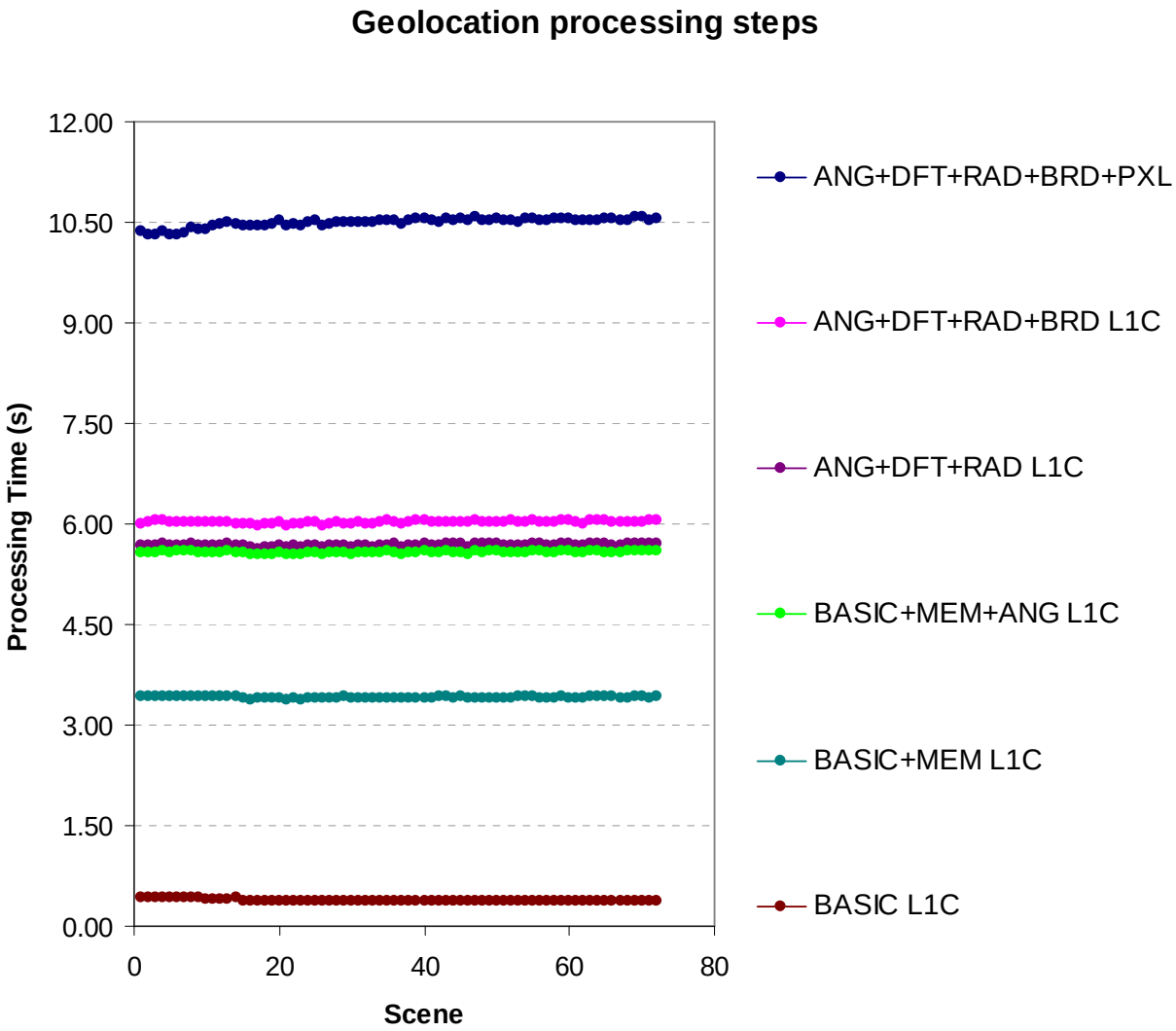
- Data Set: Half orbit (2500 scenes)

Processing Unit	Time	time/scene
Unit Converter	581.14 s	0.23 s
Correlated. Noise Injection	88.21 s	3.68 s
Uncorrelated Noise Injection	98.78 s	9.88 s
Error Correction	206.41 s	0.08 s
Image Reconstruction	2 498.10 s	1.01 s
Geolocation	39 302.44 s	**15.96 s**

Real Reconstruction



Geolocation Analysis



- Blue - the **complete L1c processing**, and the quantitative jump in processing time is due to the computation of the **pixel footprint**.
- Pink - the computation of **pixel flags**, including the flagging of pixels too close to the border of the EAF-FOV;
- Red - the **Discrete Fourier Transform** of the L1b data plus the **radiometric accuracy** computation;
- Green - the first level of computations needed for each pixel processing, namely the computation of all **pixel angles** and the unit circle coordinates;
- Teal - the **memory allocations**;
- Brown - the "unavoidable" computations;

G and J+ computation

- Comparison between Single vs Multi-thread matrices computation:
  - Multi-thread – compiled FFTW threaded library and Automatically Tuned Linear Software (ATLAS), which provides a parallelized implementation of LAPACK and BLAS libraries

Description		Single thread	Multi thread	Gain
UPC Unit Circle	Load Data	0:04:21	0:04:00	
	generation	0:05:11	0:03:18	
	Overall	0:09:31	0:07:18	23%
UPC Hexagon	Load Data	0:04:20	0:04:02	
	generation	0:05:10	0:03:13	
	Overall	0:09:30	0:07:14	24%
J Matrix	FFT preparation	0:00:11	0:00:11	
	H part	0:15:08	0:17:43	
	Invert H part	0:57:02	0:23:06	
	write to file	0:00:02	0:00:02	
	V part	0:14:58	0:17:11	
	Invert V part	0:54:45	0:24:10	
	write to file	0:00:02	0:00:02	
	FFT preparation	0:00:23	0:00:21	
	HV part	1:42:43	1:37:35	
	Invert HV part	6:39:54	3:33:39	
	write to file	0:00:22	0:00:12	
	Overall	**10:45:29**	**6:34:13**	39%

Conclusions

- Geolocation module represents around 80% of L1PP processing time, therefore, it is a good candidate for additional optimization efforts
- The usage of multi-threaded libraries speeds up the generation of G and J+ matrices around 25% and 40% respectively
- Current average processing time per scene is around 17s

Contacts

José Freitas
jfreitas@criticalsoftware.com

Marco Ventura
mventura@criticalsoftware.com

Ivo Carola
icarola@criticalsoftware.com

José Carlos Correia
jccorreia@criticalsoftware.com

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www.criticalsoftware.com

Critical Software SA	**Critical Software SA**	**Critical Software SA**	**Critical Software, Limited**	**Critical Software Technologies Ltd**
Parque Industrial de Taveiro, Lote 48 3045-504 **Coimbra**, PORTUGAL Tel: +351 239 989 100 Fax: +351 239 989 119	Campus do INETI no Lumiar, Edifício M8 Estrada do Paço do Lumiar 1649-038 **Lisboa** PORTUGAL Tel: +351 217 145 430 Fax: +351 217 145 432	Tecmaia - Rua Eng.º Frederico Ulrich, nº 2650 4470-605 Moreira da Maia, **Porto**, PORTUGAL Tel.: +351 229446927 Fax: +351 229446929	111 North Market Street, Suite 670 **San Jose, California**, USA, 95113 Tel: +1(408) 9711231 Fax: +1(408) 3513330	Suite 19-21 - 2 Venture Road Southampton Science Park Chilworth - Southampton SO16 7NP - **United Kingdom** Tel: +44 (0)23 8076 3853