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DEFENSE, SPACE & SECURITY

Operational use of the Orfeo Tool Box for the Venµs Mission

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CONSULTING / DESIGN / BUILD / DEPLOYMENT / RUN

THE POWER OF INNOVATION

http://uk.c-s.fr/

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Outline

- Introduction of the Venμs mission
- Presentation of the Venμs L2&L3 ground segment, and using OTB
- OTB in a few words
- Assets of OTB for Venμs chains
- Conclusion

Venµs Mission

(**V**egetation and **E**nvironment monitoring on a **N**ew **Micro**-**S**atellite)

Presentation

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Venμs mission (1/2)

- Main specificity of Venμs
  - Venμs is a « research satellite », **Israeli** and **French mission**, launching in 2012
  - The satellite will serve as a demonstration satellite for the European **GMES** project.
- Actors:
  - CNES (with CESBIO)
    - is responsible for supplying the **superspectral camera**,
    - is in charge of launcher interface and of the **science mission center**,
  - ISA
    - is responsible for the spacecraft and for the **satellite control center**
  - CS-SI
    - is responsible for the development of the L2 and L3 chains, in accordance with the algorithms as defined by CNES/CESBIO

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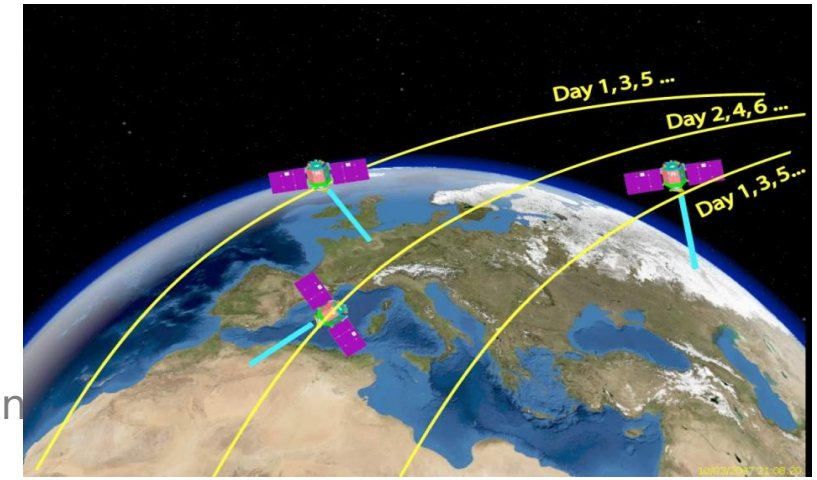
Venμs mission (2/2)

- Scientific objective
  - providing data for scientific studies dealing with the **monitoring**, **analysis**, and **modeling** of land surface functioning **under the influences of environmental factors** as well as human activities
  - Capacity of **multi-temporal observations** with **constant observation angles**

➔ Venμs will acquire high resolution and superspectral images of predefined sites of interest all around the world every two days

- Systematic acquisition: > 50 sites
- Revisit frequency: 2 days



➔ Sensors characteristics

- Resolution: **5m-10m**
- Field of View: **27 km**
- 12 spectral bands from **412 to 910 nm**,
- 2 stereoscopic bands with a low angle differen

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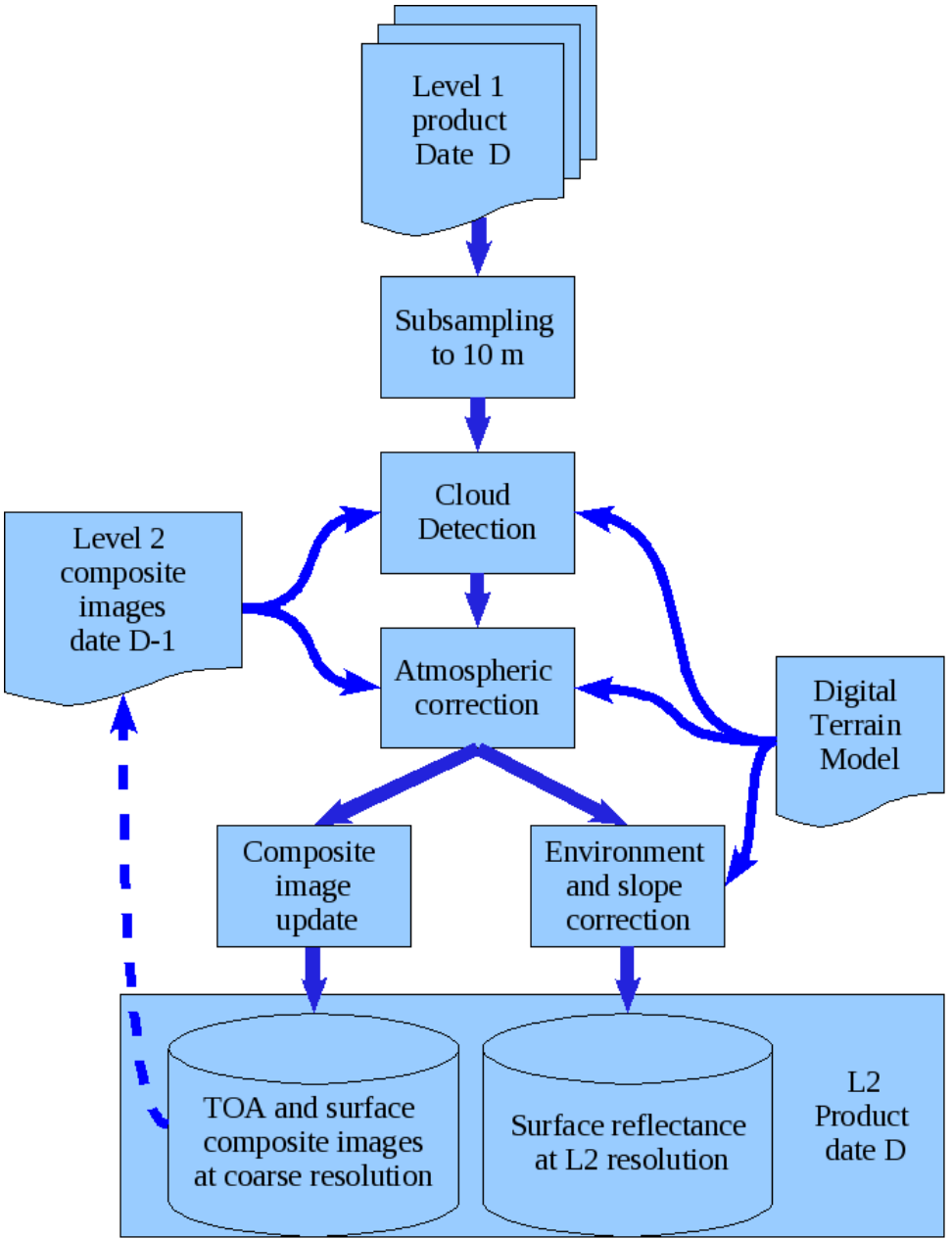
The Venµs L2&L3 ground segment

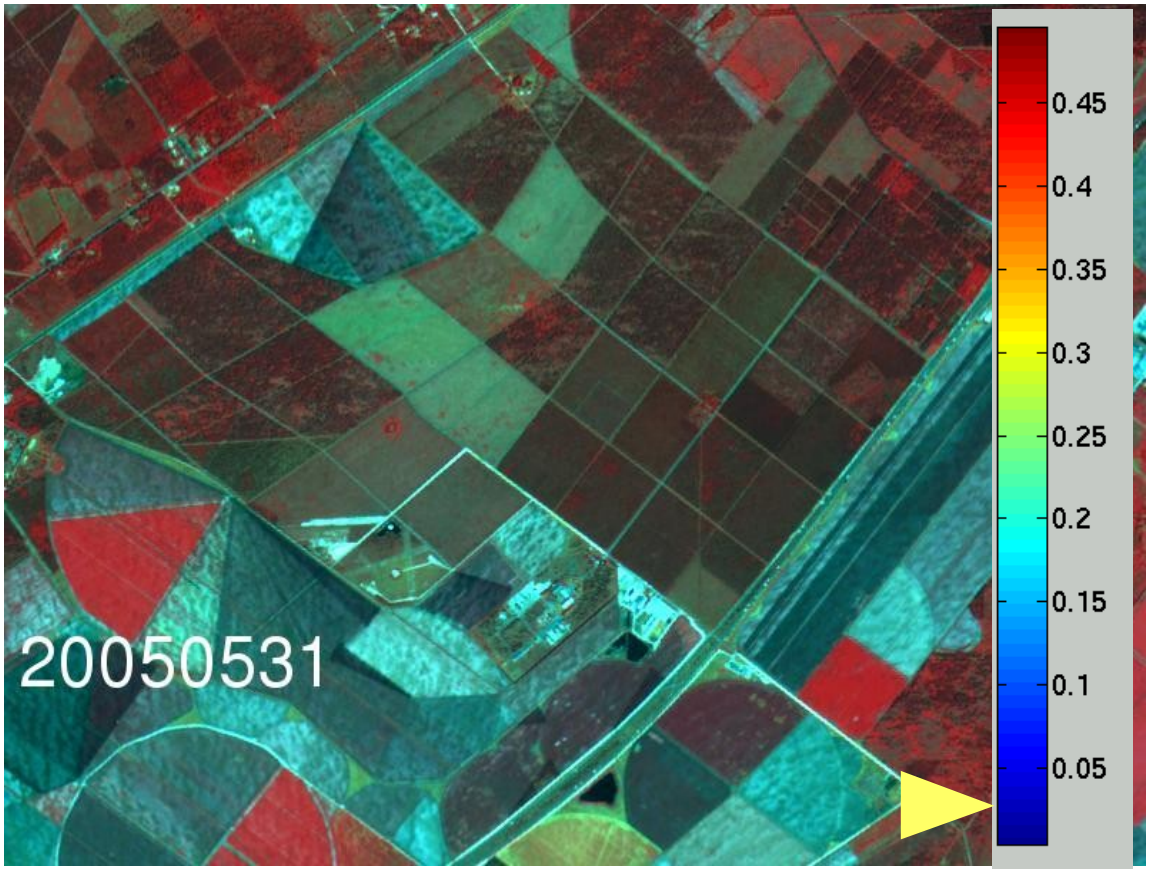
Presentation

Level 2 processing: algorithms (1/4)
The method: five main steps



Level 1 product
In a few words

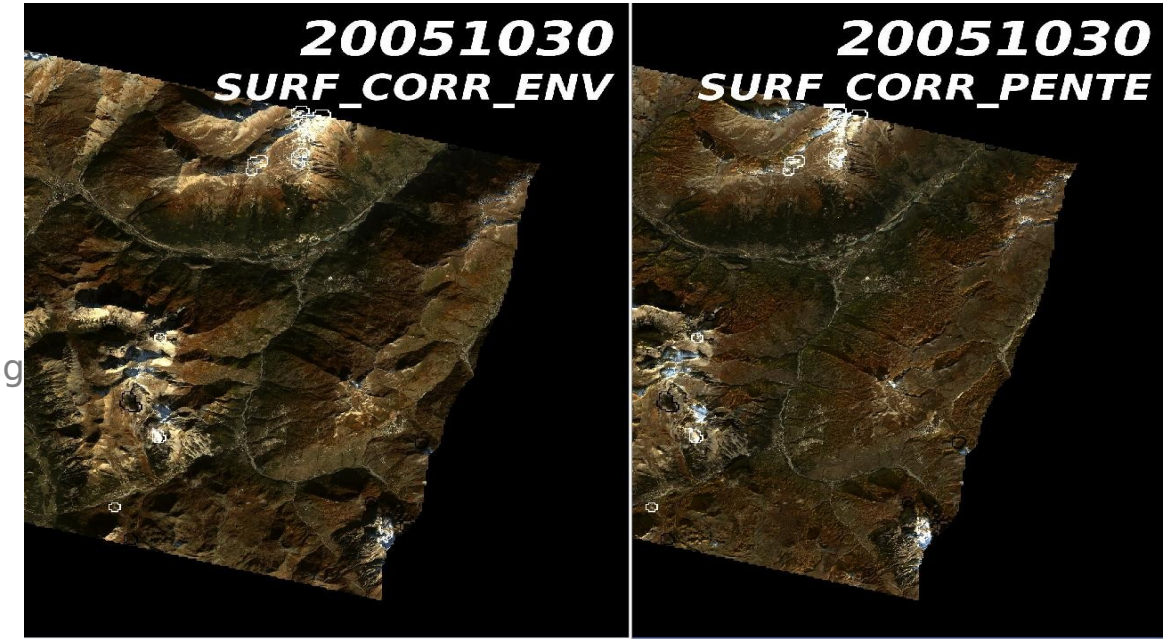
- The **Level 1** product contains several data:
  - *Top Of Atmosphere* (TOA) *reflectance* (12 bands)
  - *Saturated* pixels mask
  - *Aberrant* pixels mask
  - *Cloud* mask
  - *Cloud altitude*
  - *Solar angles* grid
  - *Viewing angles* grid
  - Quicklook



TOA reflectance

Levels 2 & 3 products
In a few words

- The **Level 2** product contains the following data bands (public data only):
  - *Surfaces reflectance* with and without *slope correction* (12 x 2 bands)
  - Atmospheric parameters
    - *Water vapor*,
    - *Aerosol optical thickness* (AOT),
  - Geophysical masks
    - *Cloud and cloud shadow* mask,
    - *Water* mask,
    - *Hidden surfaces*,
    - *Shadowed* by topography mask,
    - Sun too low flag, Tangent sun flag
  - Quality masks
    - *Saturation* mask,
    - *Aberrant* pixels mask,
    - *Edge* mask,
    - AOT pixel mask.



- The **Level 3** product contains the following data:
  - Composite images (cloud, ...) **every week** or **every decade**

Assets of OTB for Venµs chains

Presentation

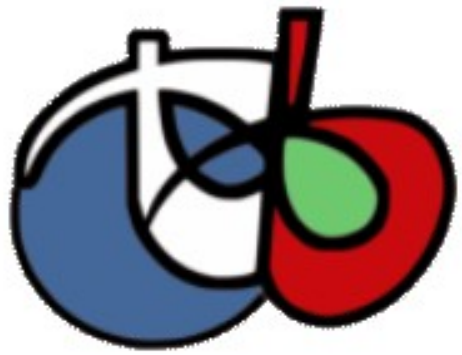
Callback of main Venµs chains requirements

- Operational systems requirements: 2 kinds of users/systems
  - CNES center with the VIP (Venµs Image Processing unit) **operational cluster system**
  - Scientifics users (with laptop/desktop/etc.) **stand-alone system**
- Architecture requirements: The Venµs chain must provide a L2 & L3 product
  - Execution time: **30 mn MAX** on reference platform and
  - By using **3 Gb RAM MAX**
- Data requirements and validation
  - Validate **interface** with **Venµs data** simulated
  - Validate **algorithms** with **Formosat-2 data** (used to prepare Venµs mission)
- Algorithms evolution : Venµs, a new dynamic ground segment
  - Scientific users can modify L2 and L3 processing
  - Architecture has to be able to **easily integrate improved algorithms**
- Venµs context: prepare future Sentinel-2 for GMES program
  - Architecture has to be able to easily **integrate new spectral camera for future sensors**

➔The solution: OTB …

Assets of OTB for Venµs chains

- Main decisive aspects for using OTB for the Venus ground segment:
  - Image processing algorithms available
  - System/architecture
  - Open source software



OTB

Orfeo ToolBox

In a few words

Orfeo Tool Box – OTB
In a few words

- What is OTB?
  - An Image processing toolbox
  - The **Monteverdi** (GUI) application for remote sensing images processing and information extraction
  - All Open source under CECILL license (close to GPL)
  - C++, + provide with Python, Java and IDL/Envi bindings
  - Support multiplatforms, multithreading ...
- OTB designed and funded by the CNES in the frame of the ORFEO Accompaniment Program
- It has been mainly developed by CS starting 2006 -> 2014
- For more information about OTB:
  - Official link: http://www.orfeo-toolbox.org
  - CS link: http://www.orfeo-toolbox.c-s.fr

Assets of OTB for Venµs chains

- Main decisive aspects for using OTB for the Venus ground segment:
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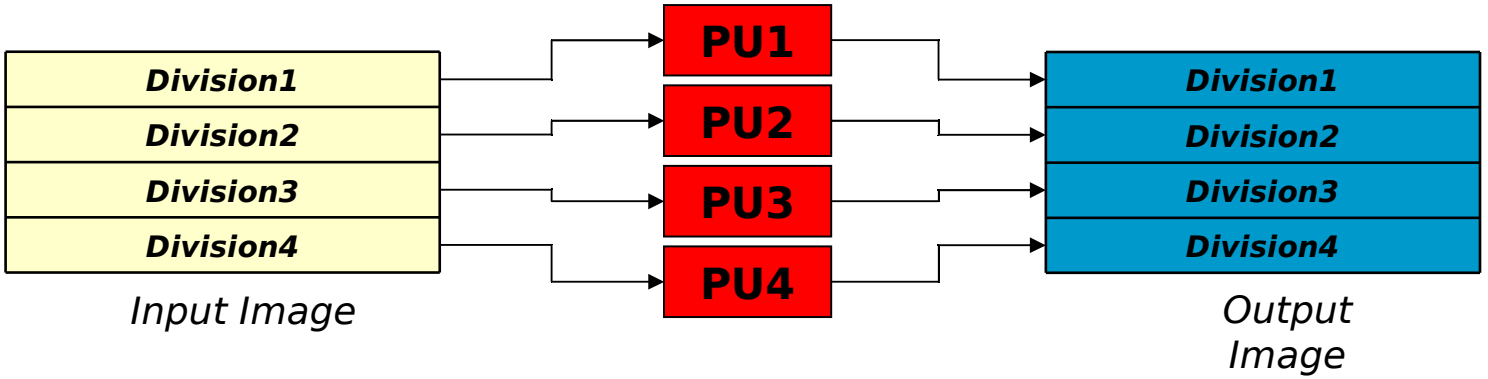
Assets of OTB for Venµs chains (1/3): Algorithms

- Algorithms **used**:
  - OTB filters: statistics, basics filters, resampling, interpolators, reading and writing TIF/JPG/HDF images data and XML data, DTM reading, ...
  - OTB framework: correlation, interpolation, composite filters, IO factories, ...
- Algorithms **adapted**:
  - Basics filters improved (ex: add pixel conditional (mask) for algorithm computation, ...)
- New algorithms **developed**:
  - Aerosol LUT and algorithms of extraction
  - Clouds detection,
  - Atmospheric correction,
  - Shadow detection,
  - Estimation of effect environment
- All algorithms are “threaded and streamed” ...

Assets of OTB for Venµs chains (2/3): System/architecture (1/3)

- System/architecture:
  - **Streaming**:
    - Combine the processing of several parts of a large image,
    - Make the output identical as what you would have obtained if the whole image was processed in one operation.
  - **Threading**
    - Ability to process simultaneously different parts of the image



Tiling: combination of threading and streaming capabilities

Assets of OTB for Venµs chains (2/3): System/architecture (2/3)

- System/architecture:
  - **Performances: constraints for operational running time (30')**
    - Multithreading

    ➔ select the **number of threads** used by the process
  - **Adapt execution parameters to execution platform resources (Max 3Gb)**
    - Streaming : the **streaming division** size (tiling)

    ➔ to **limit the memory size** (RAM) allocated by the processing
  - **Pioneer mission: Sentinel 2 adaptation requirement**
    - Generic implementation of multi spectral camera capability

    ➔*Factories* mechanism available in OTB (C++) are implemented to manage (read/write) products from several spectral cameras : **Formosat**, **Venµs** and others future spectral cameras as **Sentinel-2**, ...

Assets of OTB for Venμs chains (2/3): System/architecture (3/3)

- System/architecture:
  - Operational systems requirements: **stand-alone system** for scientific users (with laptop/desktop/etc.)
    - OTB is **multiplatform** which facilitate chains diffusion and execution on user favorite system

- **Perspectives: Venμs chain evolution by scientific users**
  - Adapt and run the Venμs chain easily with Python or Java languages thanks to binding OTB capabilities .
  - **Python bindings** improve algorithms run and check by not experiment developers
  - Access and generate to L2 & L3 product from QGIS by extending specific **QGIS plugin**

Assets of OTB for Venµs chains (3/3): Open source solution

- OTB **Open source software** use to provide the solution
- Main Assets:
  - ➘ Decrease the development cost of the Venµs chain:
    - Re-use existing code ➔ reduce development
    - Open code is free
  - Robustness and reliability of the OTB library,

    ➘ Decrease the risk of the development (CNES and CS teams),
  - Take advantage of **upgrade** of the OTB and new image processing algorithms
    - For **Scientifics users**, make easier to **improve** the Venµs chain, with **new algorithms** with future OTB releases
  - **Venµs contribution** to OTB open source project :
    - Provide to *OTB community* new algorithms and mechanisms developed

    ✂↗ Improve the reliability of the software:
      - "thematic" and "informatics" users validations

    ✂↗ Improve (reduce) the Venµs support project for CNES and CS (flexibility)

Conclusion

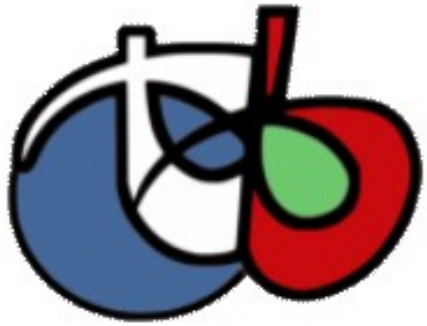
Conclusion

- CS has proposed an open source tool that has been selected for an operational spatial ground segment
  - First operational use: Venμs
  - Precursor of Sentinel-2
- Technical solution approved by the CNES responsible for the Venus ground segment
- Benefit of using OTB
  - Open source and multi-platform solution
  - Re-use of many image processing algorithms and IO data functionalities
  - Streaming and multithreading mechanisms to process huge data volume in reduced time
  - Maintain algorithms and make easier to improve the Venμs chain, with new algorithms (with future OTB release), etc.
  - Possibility to adapt the C++ Venμs chain in Python or Java languages easier with the binding capabilities by the scientific users no experts in computer science
  - Validation and improvement by the users community:
    - Operational users in CNES
    - Scientifics users involved in the Venμs project

    ➔ Interesting for Sentinel-2

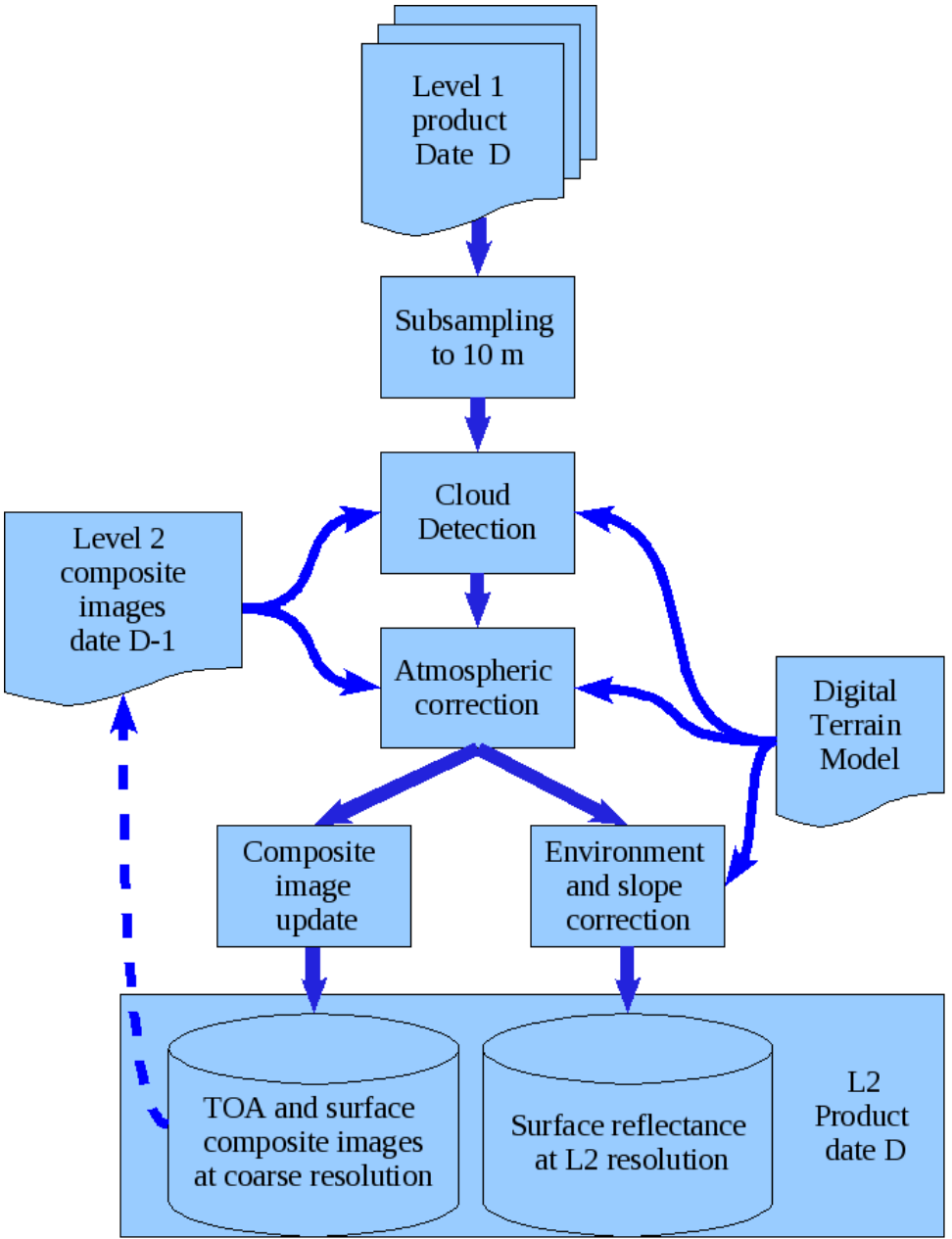
Thank you for your attention!!

— *thomas.feuvrier@c-s.fr* —



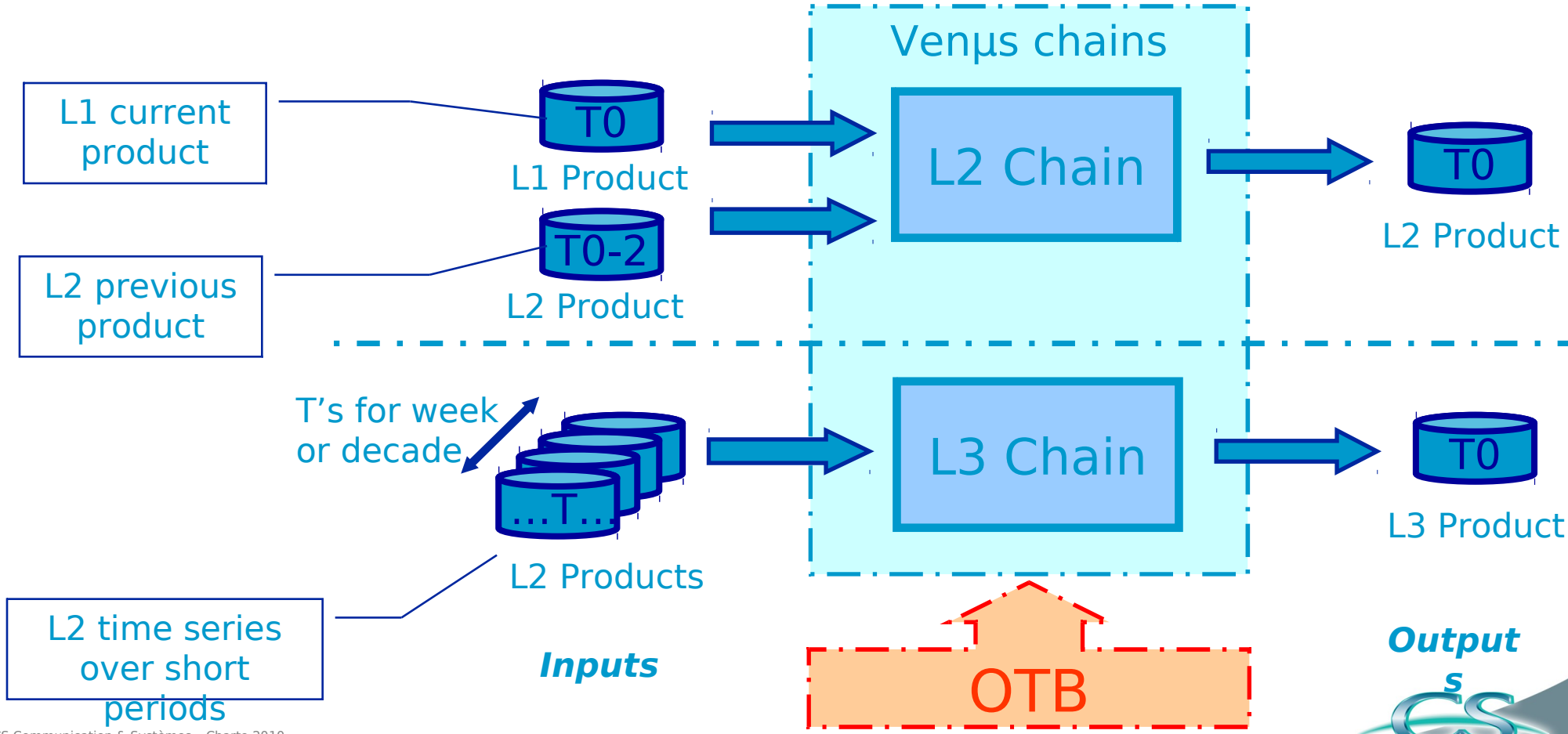
OTB Live DVD 3.4.0 available
… in this room !

Level 2 processing: algorithms (1/4)
The method: five main steps



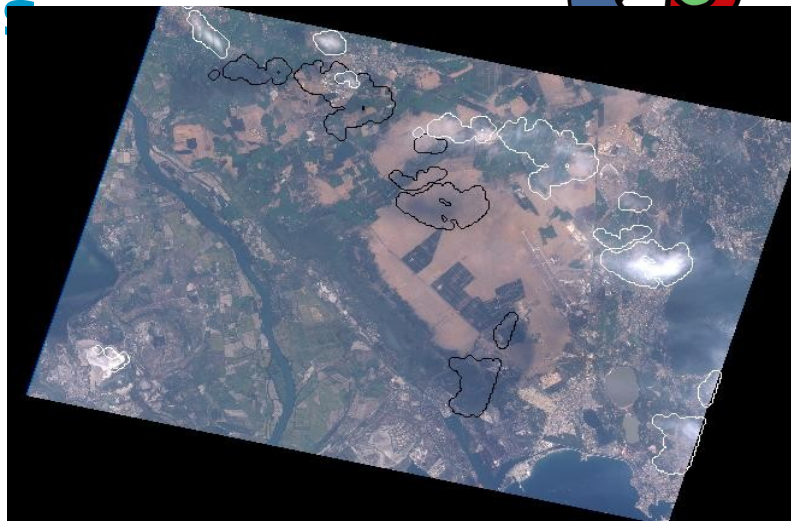
OTB in Venµs ground segment: L2 & L3 processing. In a few words

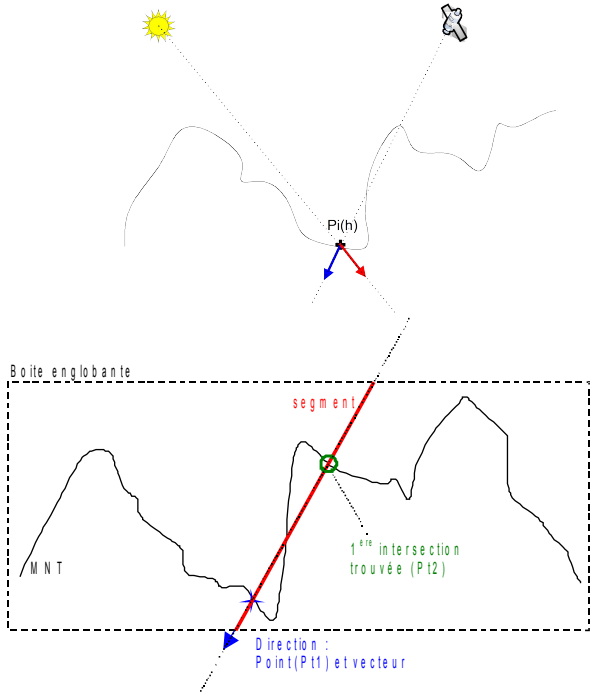
- 2 Venµs processor chains: L2 & L3
- Using Level 1, 2 & 3 image product
- Using OTB: algorithms, IO data services



Level 2 processing: algorithms (2/4)
Five main steps

- Subsampling
  - L1 resolution: 5 meters. The quality of Venμs data at this **resolution is not perfect**: the noise and registration requirements will only be met at 10m resolution
  - Development of BCO and linear filters to subsample images
- Cloud masking
  - Cloud detection:
    - Thresholds on spectral bands in the blue to detect high surface reflectances
    - Temporal variation of surface reflectances using products of previous dates avoiding false detection by detecting some characteristics effects (water bodies, rain events)
  - Shadow detection:
    - **Projection of clouds** on the ground using the **stereoscopic altitude of clouds**
    - Refinements are required to take into account the inaccuracy of cloud altitudes and to detect shadows due to clouds outside the image
    - Perform cloud projection taking into account the DTM (Digital Terrain Model)





Hidden surface

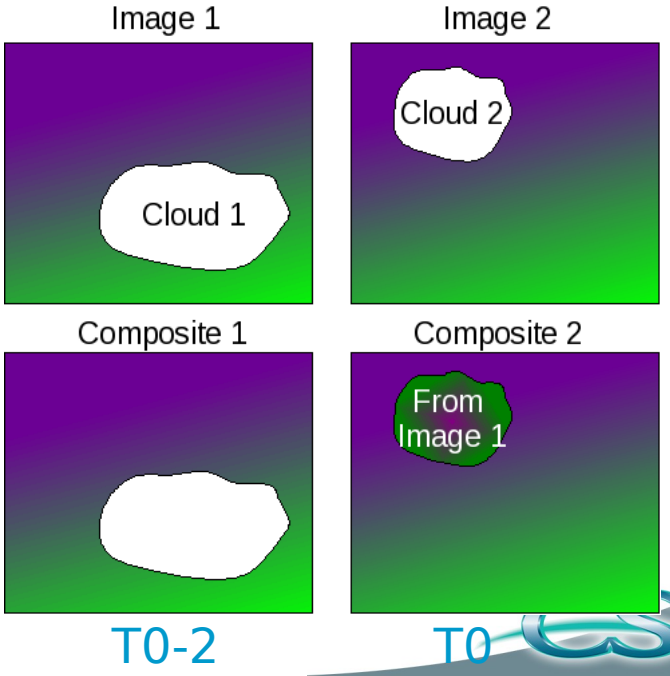
Level 2 processing: algorithms (3/4)
Five main steps

Atmospheric correction

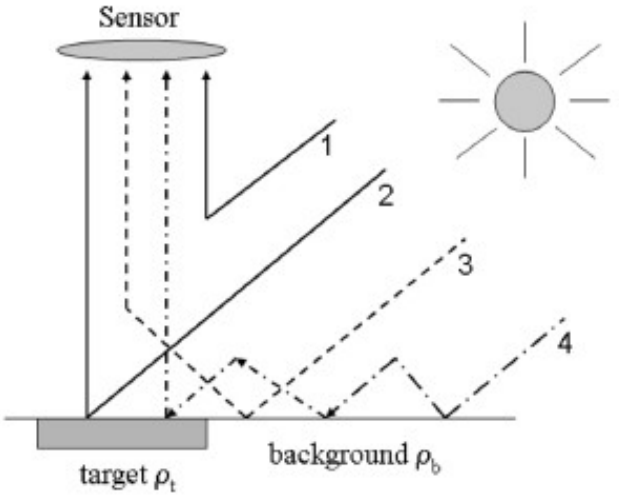
- Gaseous absorption correction:
  - Development of **SMAC model** (Simplified Method For Atmospheric Correction) to perform absorption corrections
  - Use of **ozone data** (from satellite TOMS), **pressure** (function of altitudes) to **correct oxygen absorption** and 910 nm spectral band to **correct water vapor absorption**
- Scattering correction:
  - **Rayleigh correction** to take into account the contribution of molecules
  - **Aerosol Optical Thickness** (AOT) estimation based on an **inversion method** (*Levenberg Marquardt Optimizer*). Use of multi-temporal criteria (stability of surface reflectances disturbed by aerosols)

Composite image update

- Synthesis of the most recent cloud free and good quality reflectances (tests to detect hotspot, cirrus, high AOT and rain)
- Composite product used by recurrent algorithms like cloud detection and aerosol correction



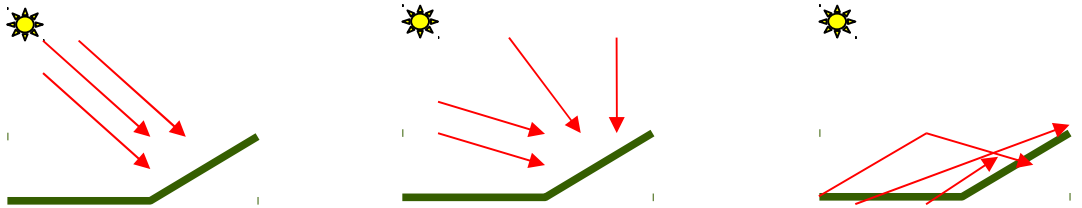
Level 2 & 3 processing: algorithms (4/4)
Five main steps



- Environment and slope correction
  - Environment effects : correction of the influence of neighboring pixels on the reflectance due to light scattering by the atmosphere
  - Slope correction : correction of topographic effects on the observed reflectances (direct irradiance changes with slopes, indirect irradiance from sky and solar and viewing angles are also modified by the topography)

1. Atmospheric Reflectance
2. Pixel reflectance

3+4. Adjacency effect



Slope correction

- ***L3 algorithms***
  - averaging the cloud free surface reflectances gathered during the compositing period

Main Venμs L2&L3 ground segment context

- Venμs chains is a demonstration mission whose aim is to show the benefit of
  - **superspectral**,
  - **high resolution**,
  - **high revisit frequency**, and
  - **high quality measurements**.
- One objective of Venμs is
  - to help define an operational mission with such characteristics and full global coverage
  - to develop pre-processing algorithms, methods, and applications that will use these data.

➔ Solution: developing **new multi-temporal algorithms** for

- Water detection
- Cloud and shadow detection
- Aerosol estimates