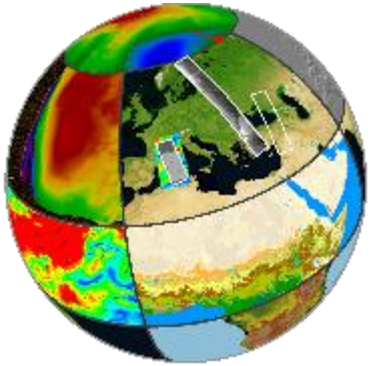

VH-RODA 2019

On-the-fly orthorectification, calibration, RCS equalization and terrain flattening of Sentinel-1 data

Serge RIAZANOFF
Director

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http://www-igm.univ-mlv.fr/~riazano/

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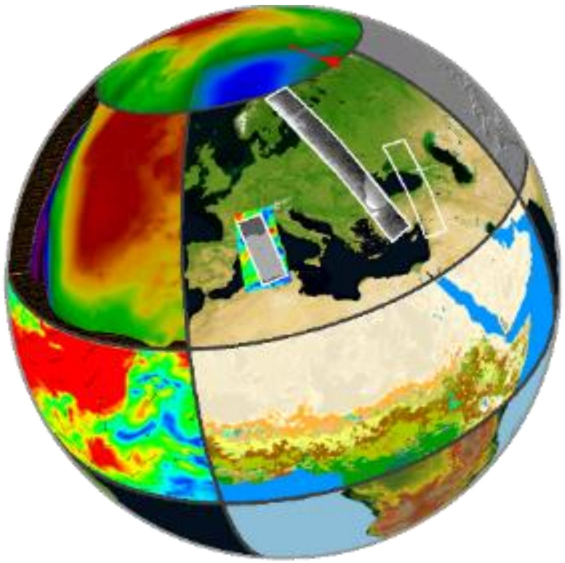
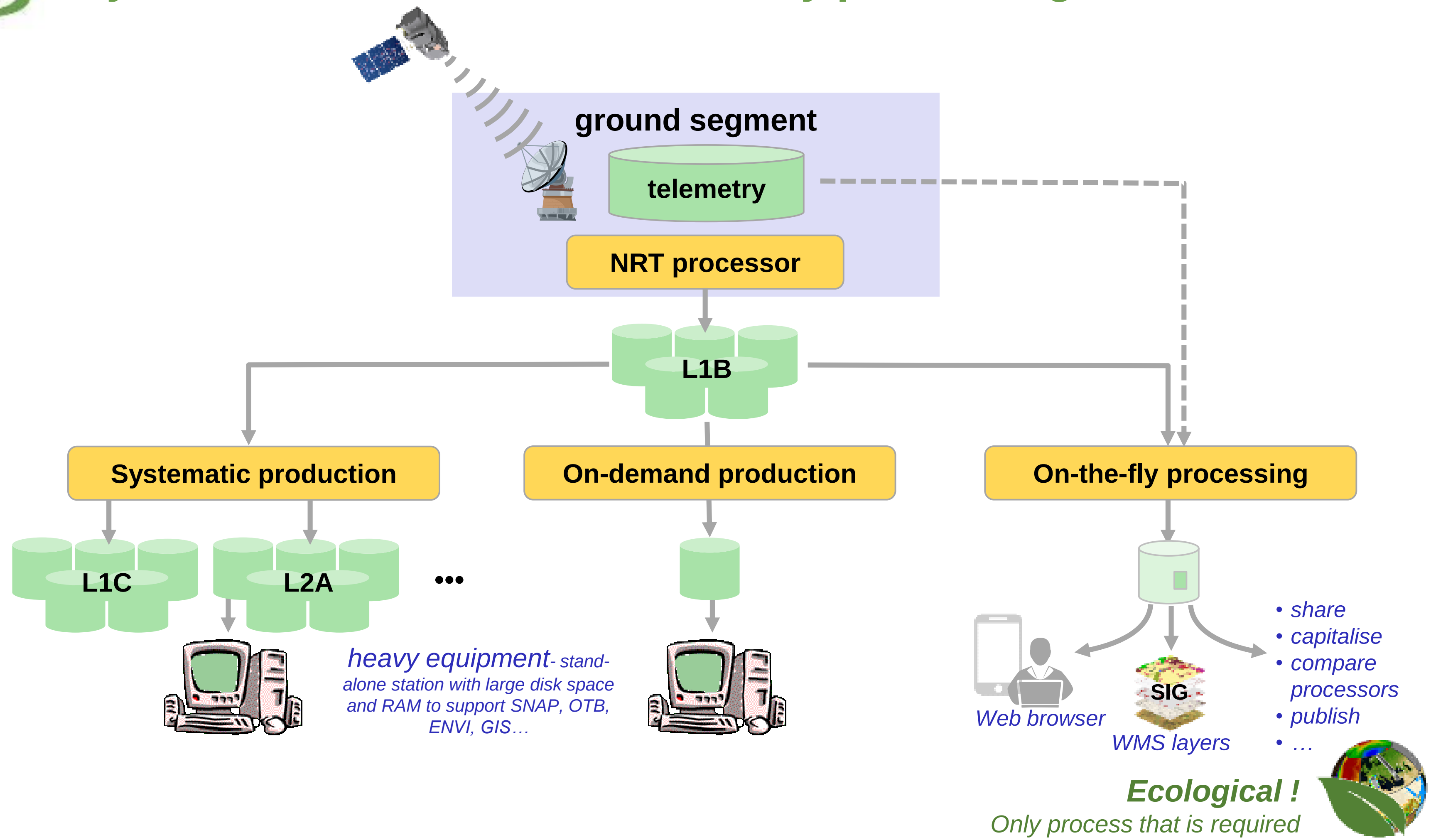
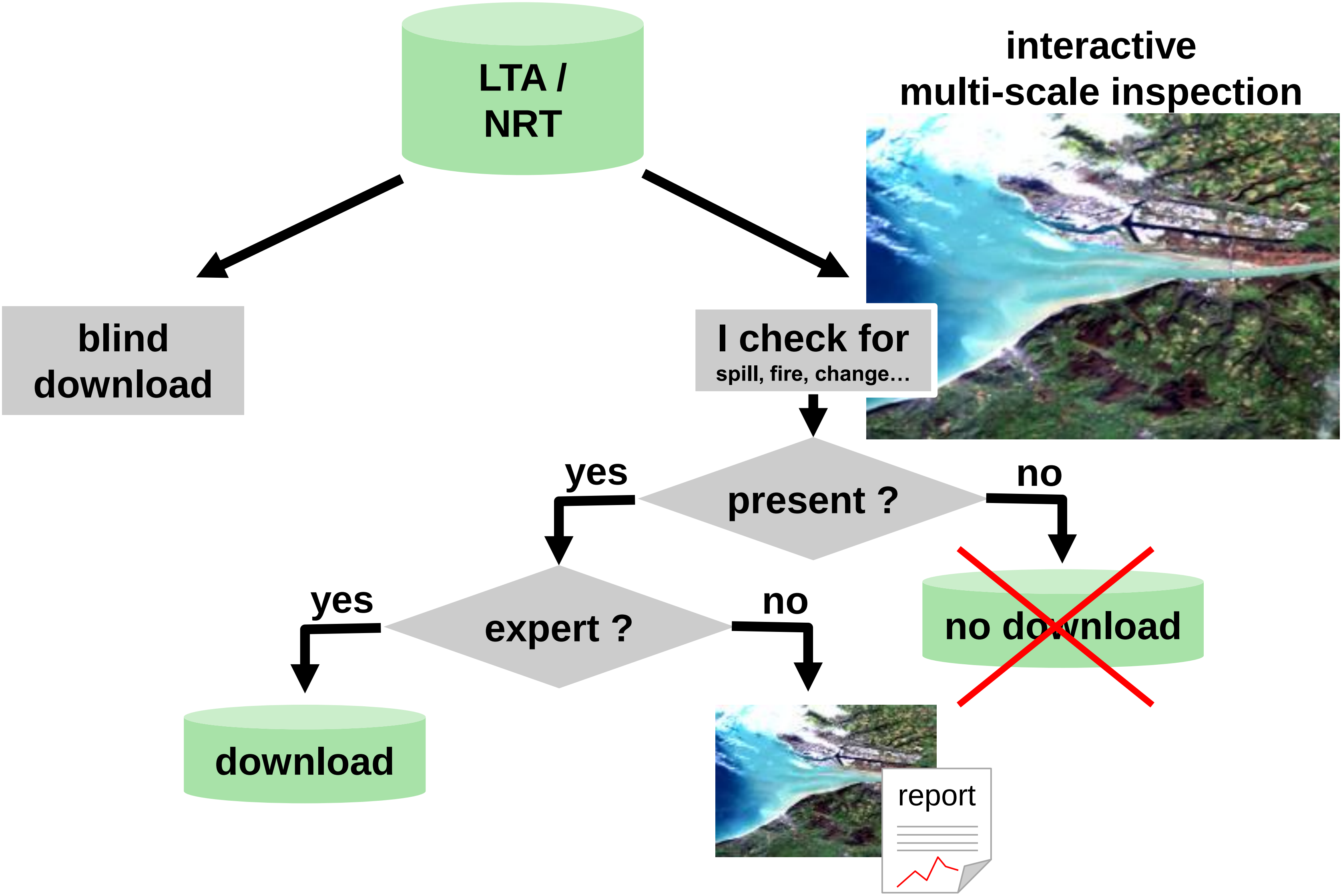


Systematic / on-demand / on-the-fly processing



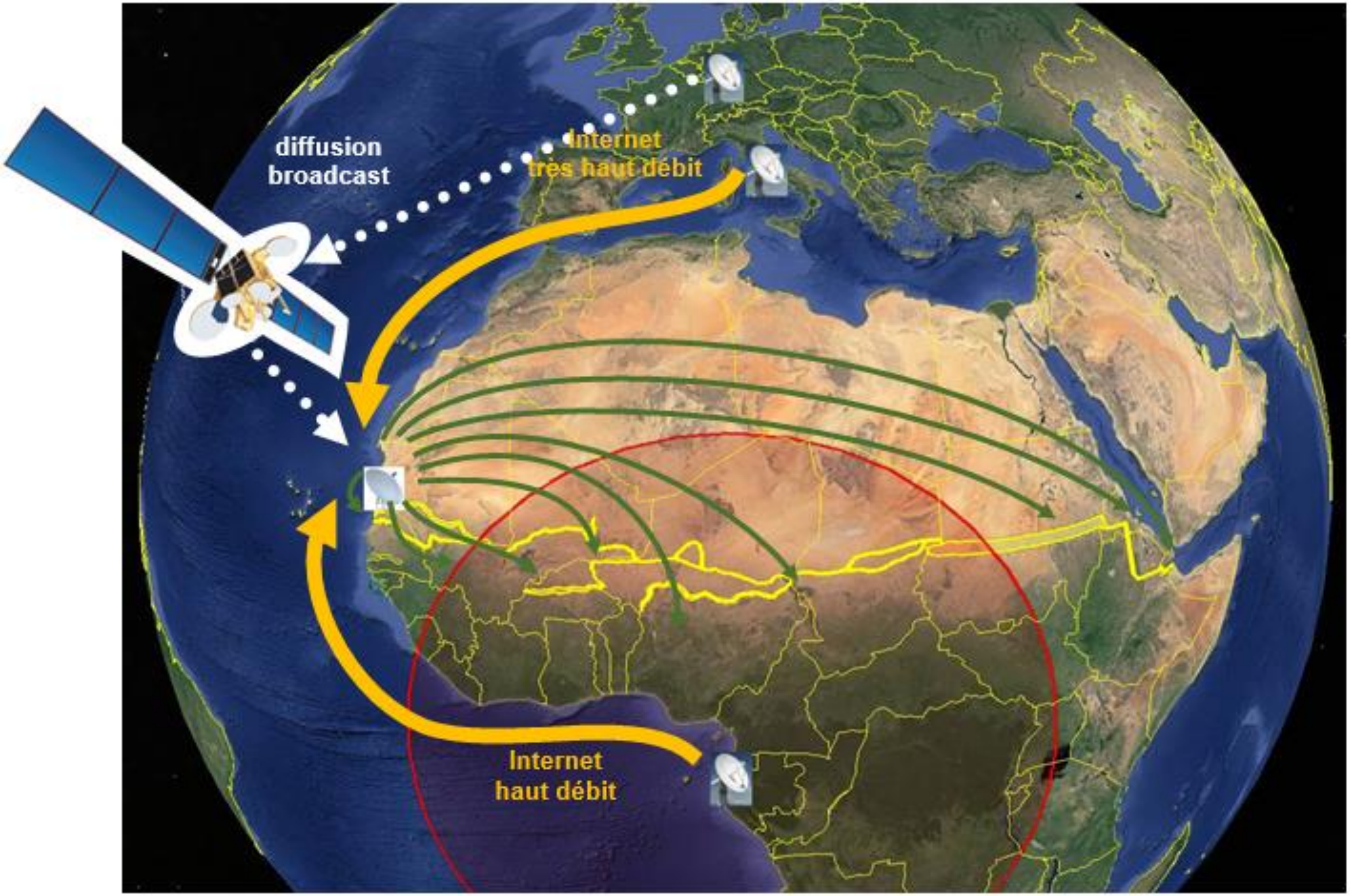
heavy production (peta-bytes)	light (one whole product)	very light (area at scale of interest)
new version of the processor ⇒ reprocess the whole archive	*no impact*	*no impact*
download with high bandwidth	download high large bandwidth	*very low bandwidth*

VtWeb - Paradigm change: More access for less downloads



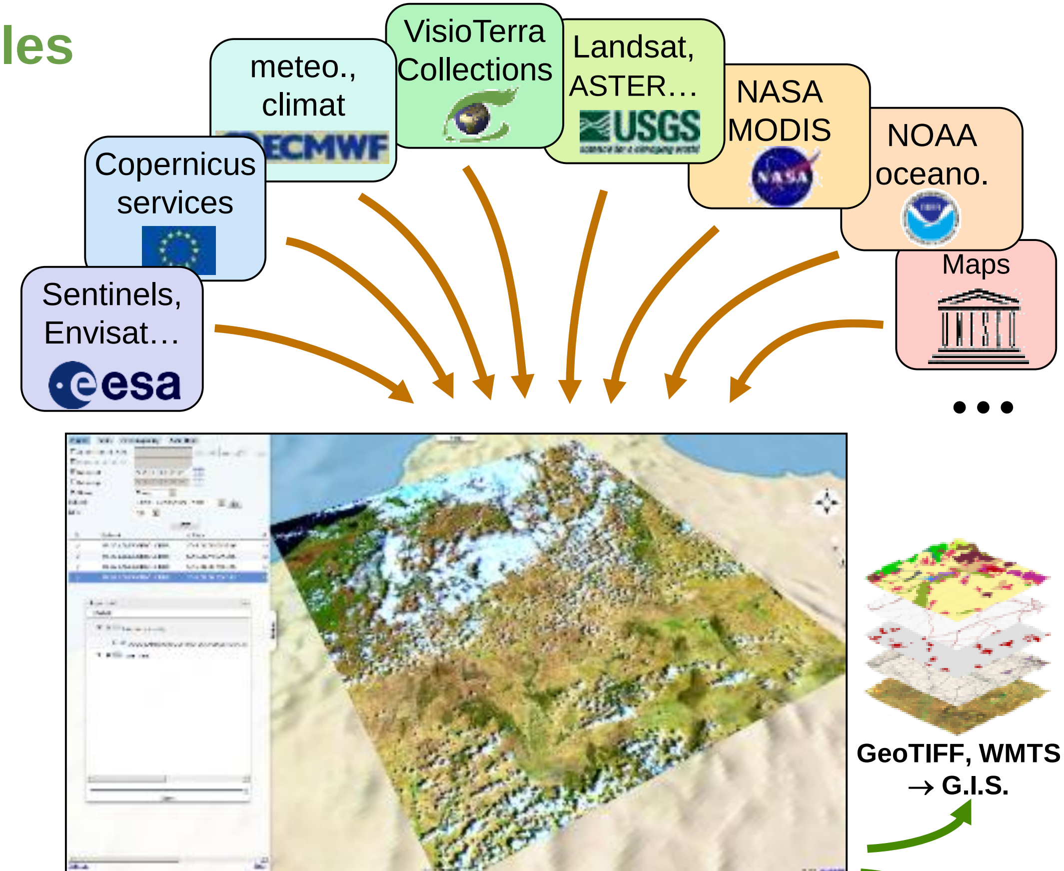
Data flows across the Great Green Wall infrastructures

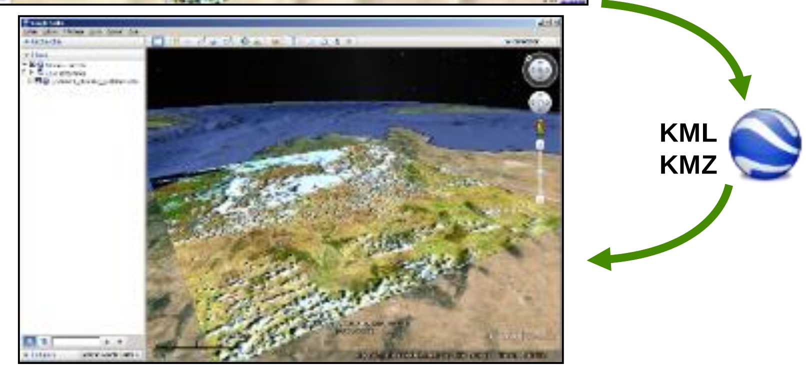
KMZ



VtWeb – Design principles

- www.visioterra.fr/?VtWeb
- global / free data
- data retrieval / data mining
- satellites / meteo / ECV / altimetry models / maps…
- Near Real-Time access
- automated processing
  - ❑ for citizen
    - default style
    - predefined styles
  - ❑ for scientists
    - parameter tuning
    - toward a P.O.F. toolbox
- collaborative infrastructure(s)
- 2D webmapping / 3D virtual globe
- on your area of interest
- archives to analyse changes
- value-added services, recurring monitoring, alarms…

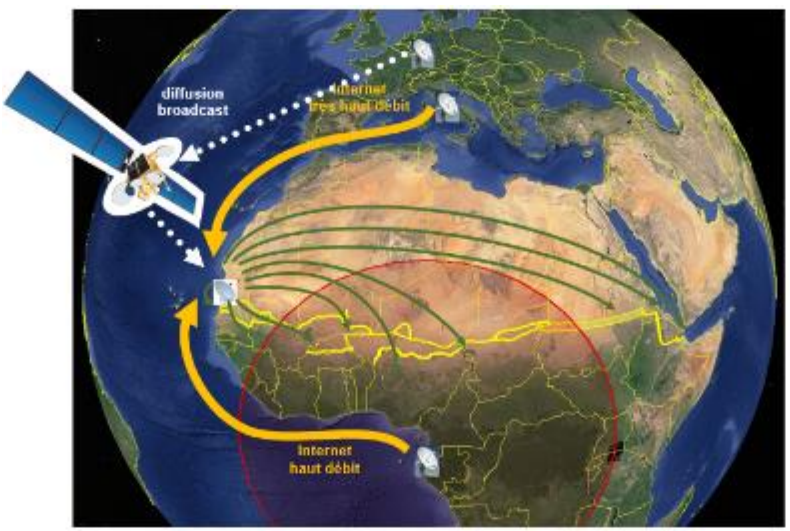


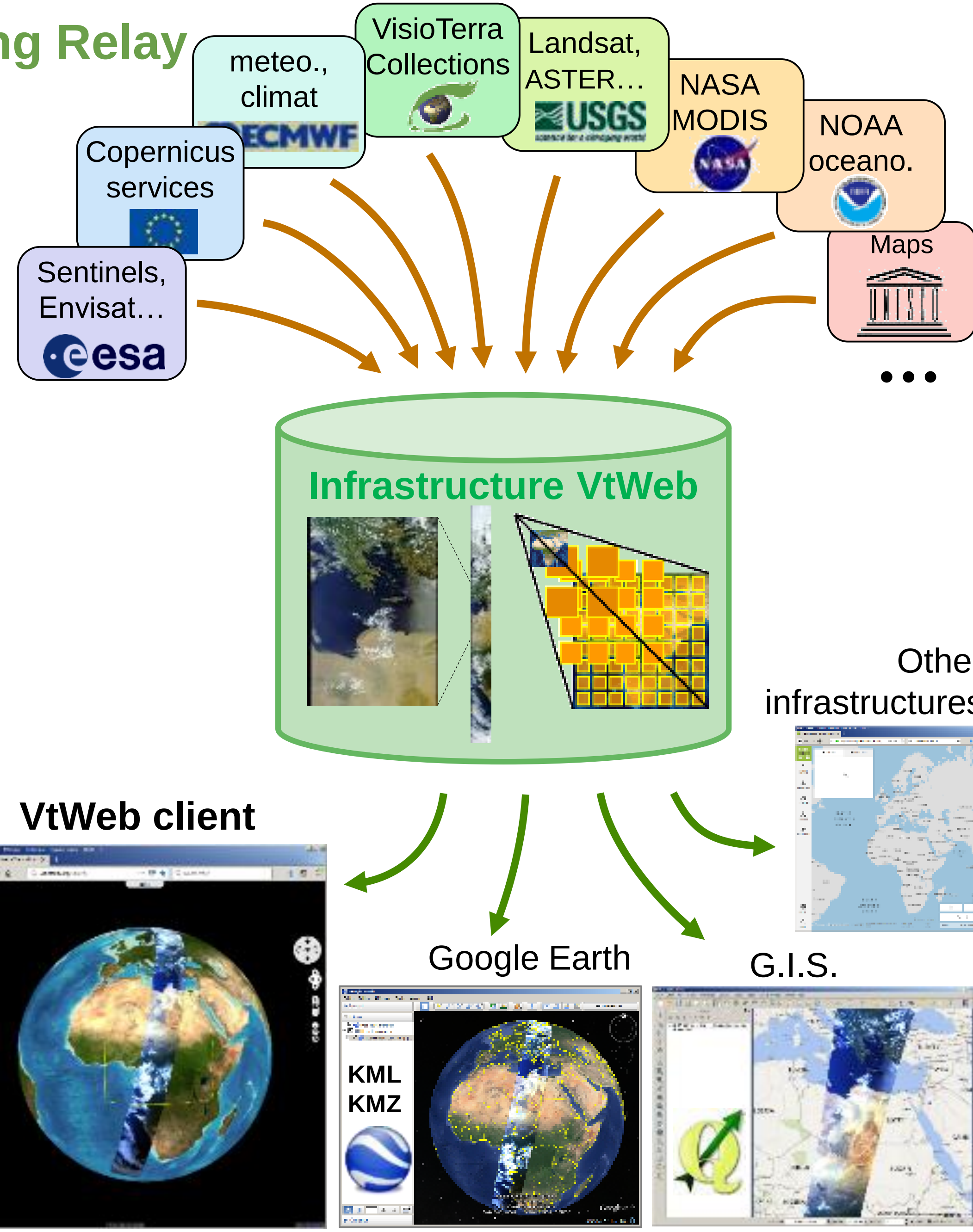


VtWeb – Data Processing Relay

- VtWeb infrastructure
  - 1 PB (1000 TB) available
    - 50 TB ASAR and ERS
    - 150 TB MERIS
  - 1 Gb/s symmetric fibre
  - 4 powerful servers

- DPR as a solution for Africa

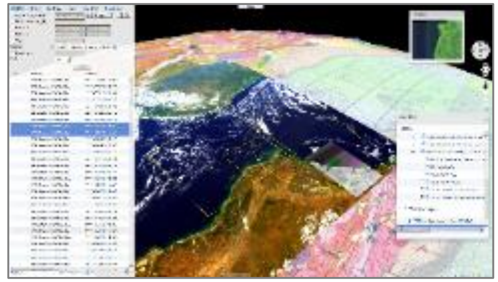




VtWeb – Generic platform for customized platforms

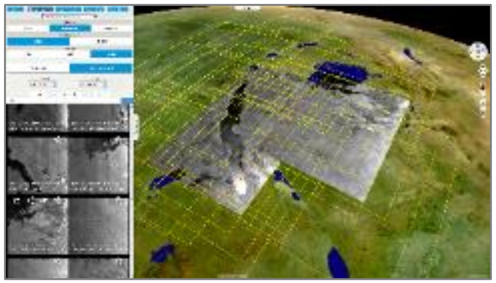
[visioterra.org/**VtWeb**](visioterra.org/VtWeb)

An advanced
one-stop-shop model

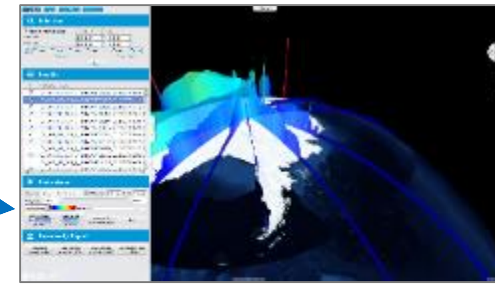


A showcase capitalising
VisioTerra know-how

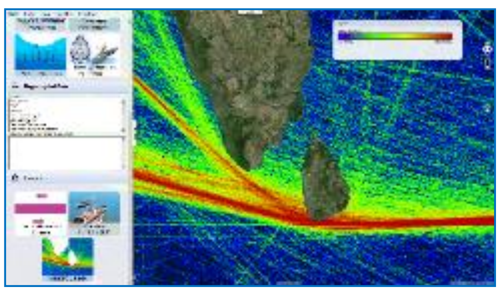
[**hedavi**.esa.int](hedavi.esa.int)



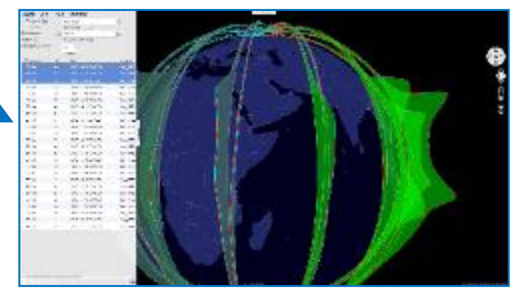
[visioterra.net/**VtCryoSat**](visioterra.net/VtCryoSat)



[visioterra.net/**VtPace**](visioterra.net/VtPace)

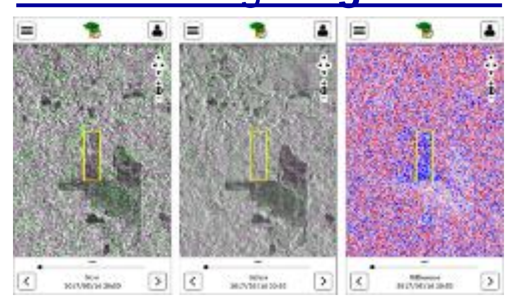


[visioterra.net/**VtGsep**](visioterra.net/VtGsep)



[www.**sentinelvision**.eu](www.sentinelvision.eu)

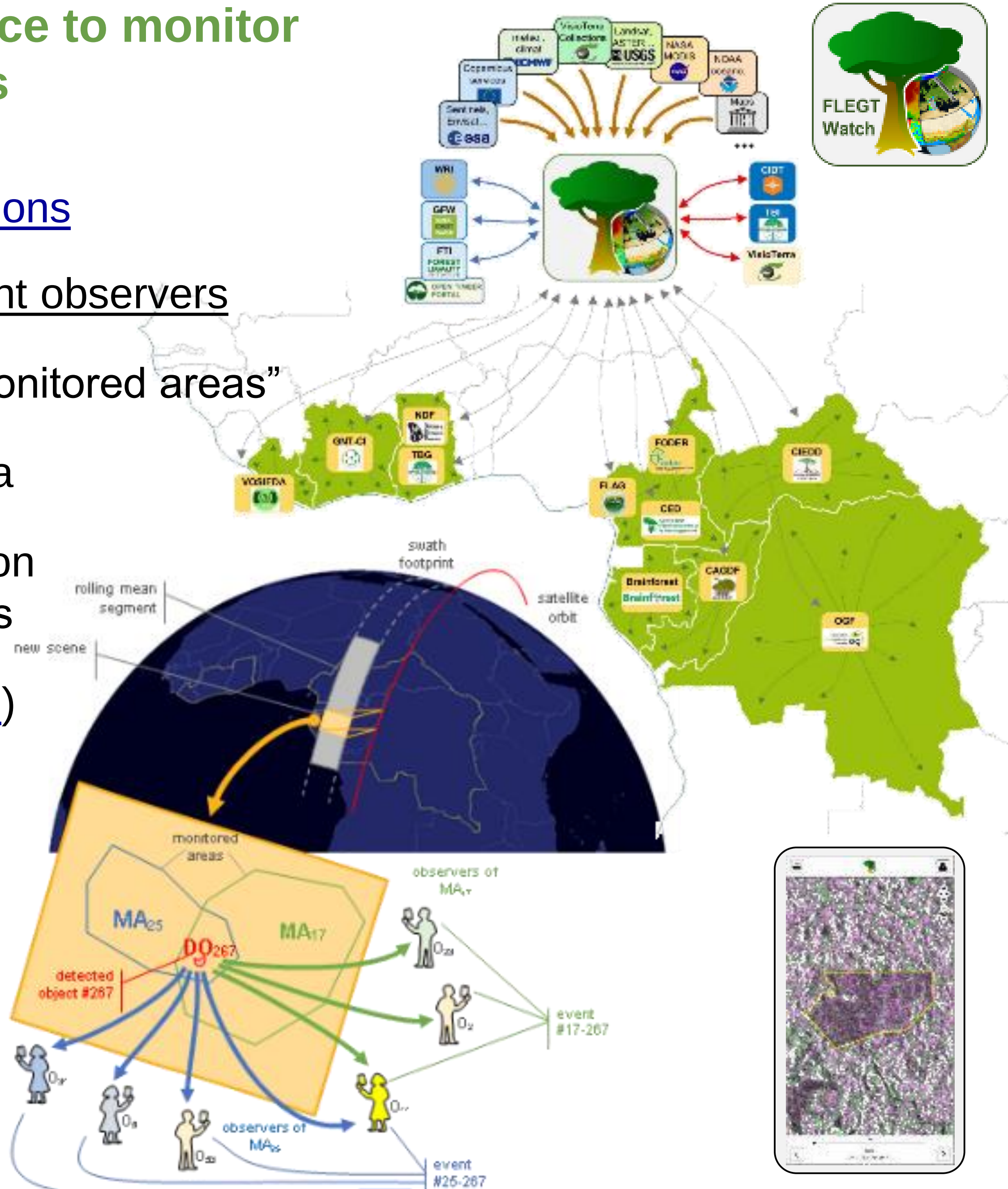
[visioterra.org/**FlegtWatch**](visioterra.org/FlegtWatch)



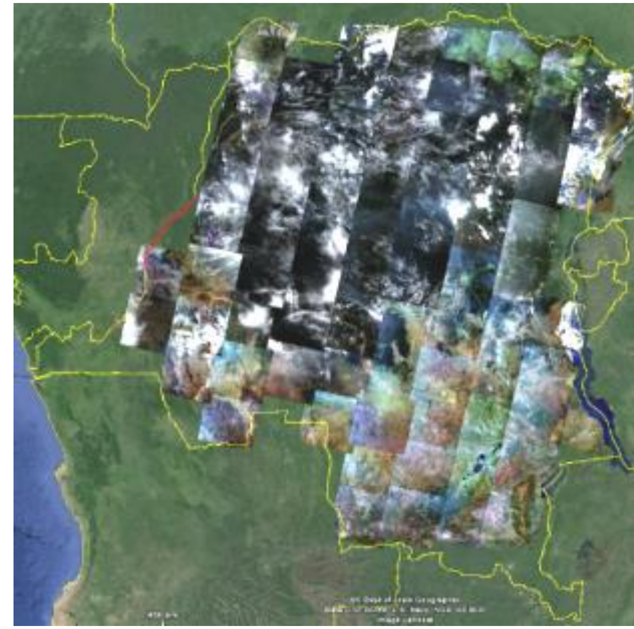
FLEGT Watch – Service to monitor Forest cover changes

Leaflets: 1. Presentation, 2. Operations

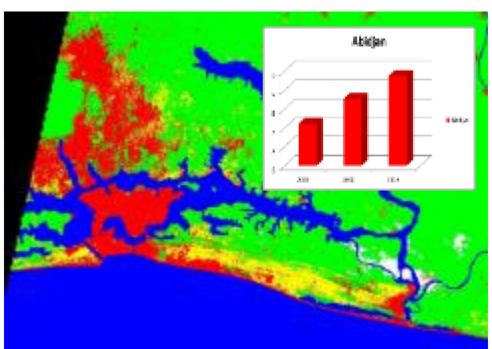
- Powerful tool to help independent observers
- Systematic observation over “monitored areas”
- Using free radar and optical data
- Fully automated change detection
  New “machine learning” technics
- Support for field missions (video)
- Collaborative assessment
- Forest cover indicators
- Dashboards on observations, events, activity of observers
- Observation reports (Tetrem)

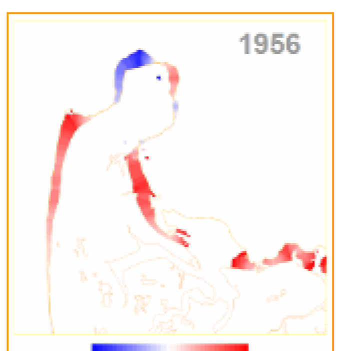


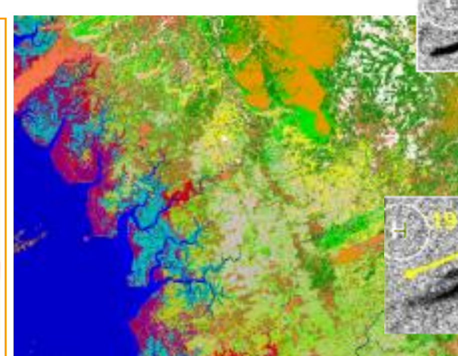
VisioTerra in Africa – Services, Spacemaps, Studies, Training

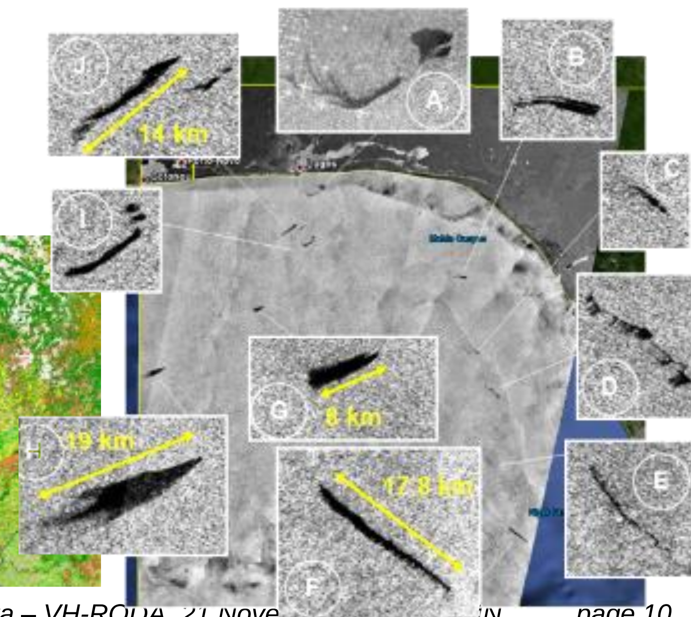


- **E.U. – FLEGT Watch – Monitoring the deforestation**
- APN – Changes in LU/LC in Park W (Benin)
- ESA – Automatic detection of fires / burnt areas (Sudan…)
- UNEP – Impact assessment of San-Pedro harbour (Ivory Coast)
- PAGGW – Support in geomatics for the Great Green Wall
- ERAIFT - Capacity building in Geomatics
- REMA - RBIS biodiversity information system (Rwanda)
- Rio Tinto - Land Use / Land Cover (LU/LC) maps in Guinea
- Dobbin International – LU/LC maps in Mozambique
- Universities and Institutes – Training and distance learning (*Gabon, Cameroon, DRC, Morocco, Algeria, Ghana...*)
- UNEP - Urban growth in Côte d'Ivoire
- TOTAL - Monitoring the coastline in Mandji (Gabon)
- TOTAL - Oil spills and oil seeps in Gulf of Guinea
- …







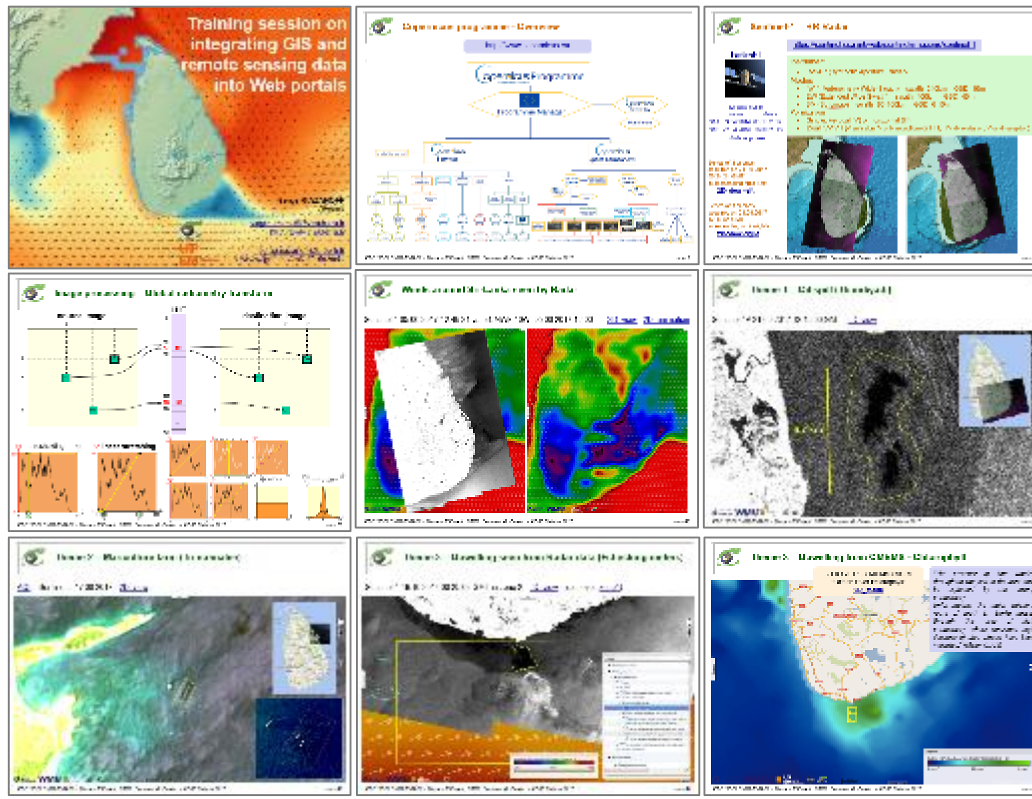


VtWeb for training – “hyperlooks” to teach EO image processing

- “Hyperlook” – rich URLs invented by VisioTerra
  http:// *serveur_id* *product_id* *processing_parameters* *viewing_parameters*

- Training VtPace in Sri-Lanka
  - Newsletter - video
  - Course support (PDF)
    - Session 1 – Available data
      - Copernicus services
      - Sentinel
      - Other data
    - Session 2 – VtPace
      - Presentation of PACe project
      - Presentation of the portal
      - Image processing technics
      - Functionalities
    - Session 3 – Themes of interest in Sri-Lanka

2D_view	-	Theme 1 – Oil spills
2D_view	-	Theme 2 – Mariculture farms
2D_stack	-	Theme 3 – Upwelling
3D_view	-	Theme 4 – Monitoring oil wells



VtWeb for sharing – “Stories” of “Sentinel Vision” Portal (SVP)

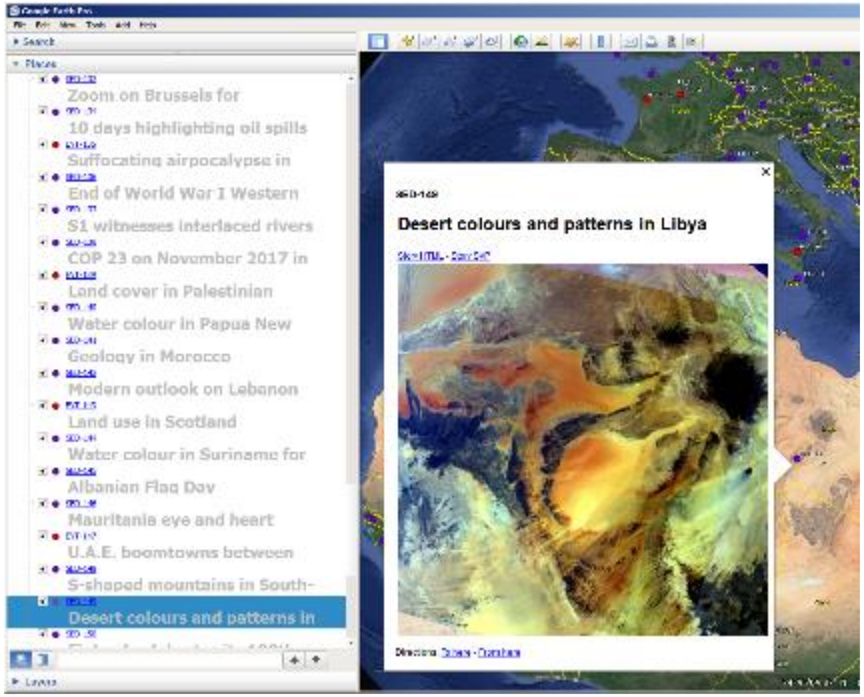
LIST-Thematic

LIST-All

Sentinel Vi… summary - storie…

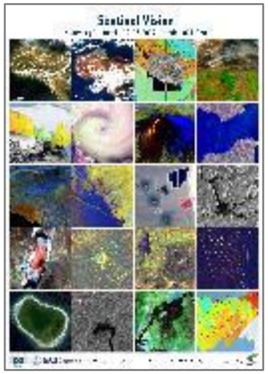
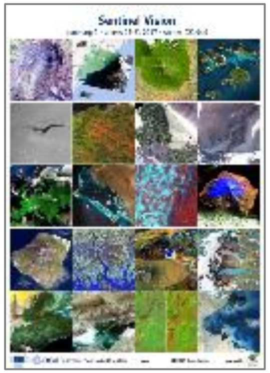
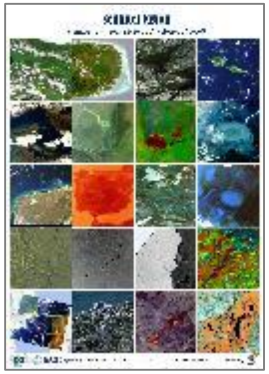
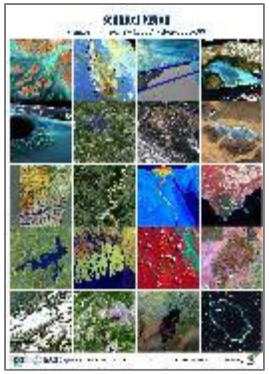
SED-001	S2	Sentinel-2 w…
SED-002	S3 OLCI	S3 OLCI wat…
EVT-003	S2	Geology in Za…
SED-004	S3 OLCI SLSTR	S-3 reveals f…
SED-005	S1 S3 SRAL	Discovering S…
SED-006	S3 OLCI	S3 tracking E…
EVT-007	S2	Etna, a giant…
SED-008	S1	Sentinel-1 w…
SED-009	S2	Sentinel-2A c…
SED-010	S1	Sentinel-1 w…
EVT-011	S1 S2	Las Vegas, s…
SED-012	S1	Risk of failur…
SED-013	S2	Sentinel-2 Re…
SED-014	S1	S1 images ce…
EVT-015	S1	Poiteuin mar…
SED-016	S1 S2	Wind farms i…
SED-017	S1 S2	Clipperton / F…
SED-018	S1	S1 detects oi…
…	…	…

KML-All - « Sentinel Vision » from Google Earth



Synthesis
of 20 stories
(5 weeks)

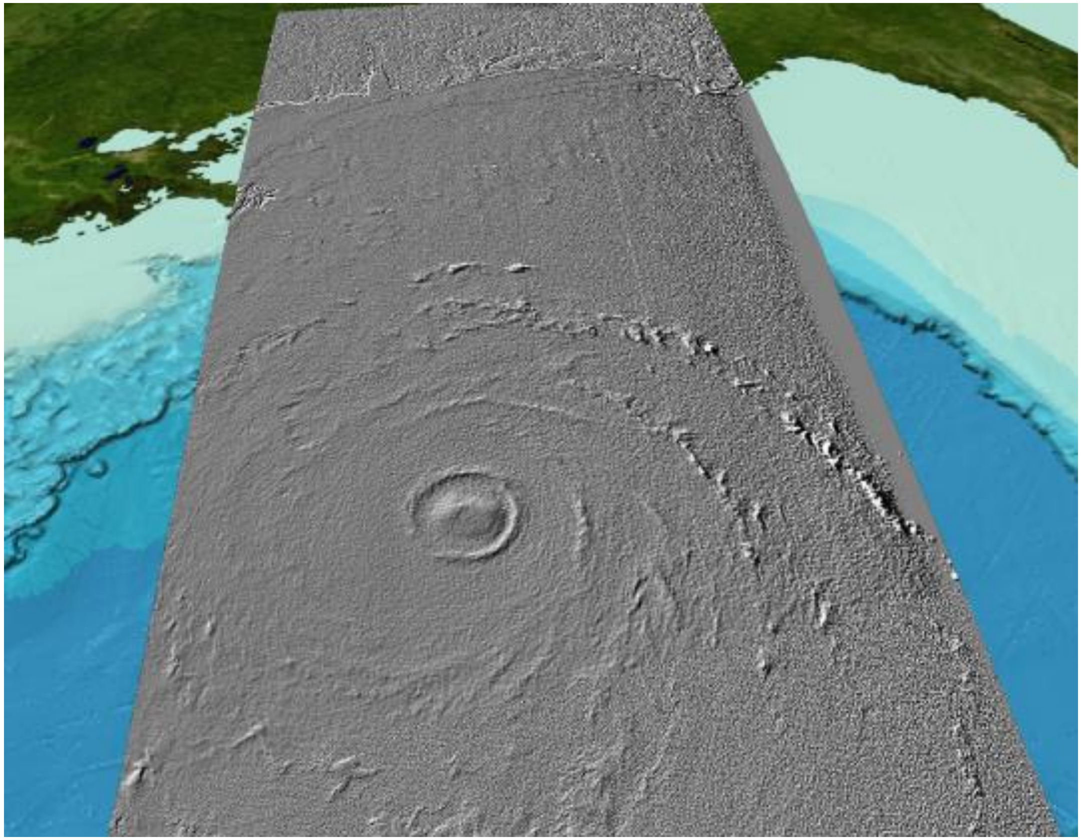
SYN-001 SYN-002 SYN-003 SYN-004
SYN-005 SYN-006 SYN-007 SYN-008
SYN-009 …

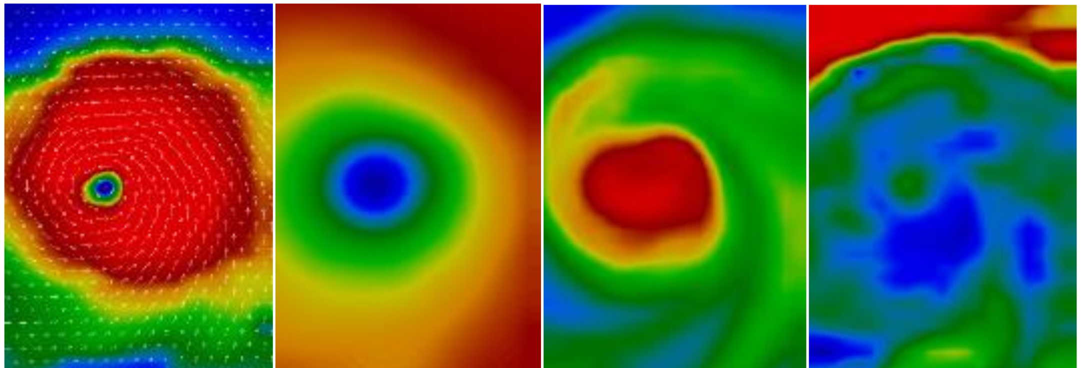





…

Correlations - Katrina (28.08.2005) – Early warning

- Envisat ASAR 28.08.2005
  Envisat MERIS 15:50:08
- Meteorology
  - winds <10m: 2D view
  - pressure (msl) 2D_view
  - water column 2D_view
  - temperature <2m 2D_view

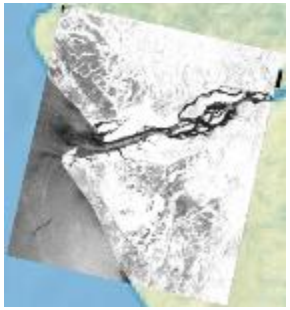


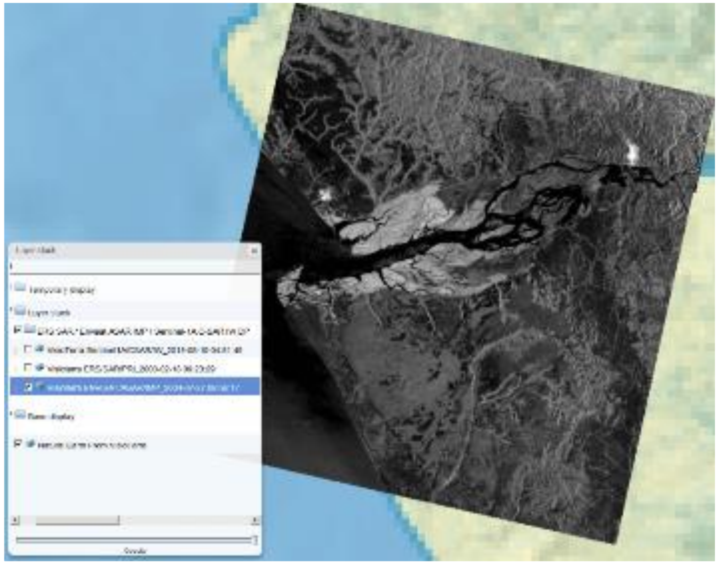


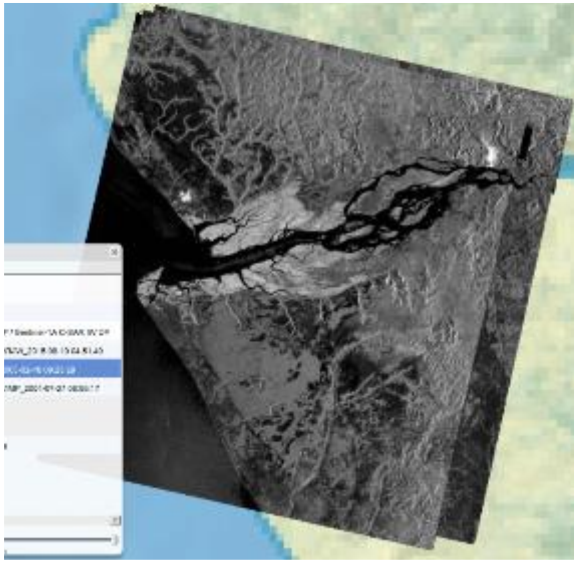
Heritage: ERS SAR → Envisat ASAR → Sentinel-1 C-SAR

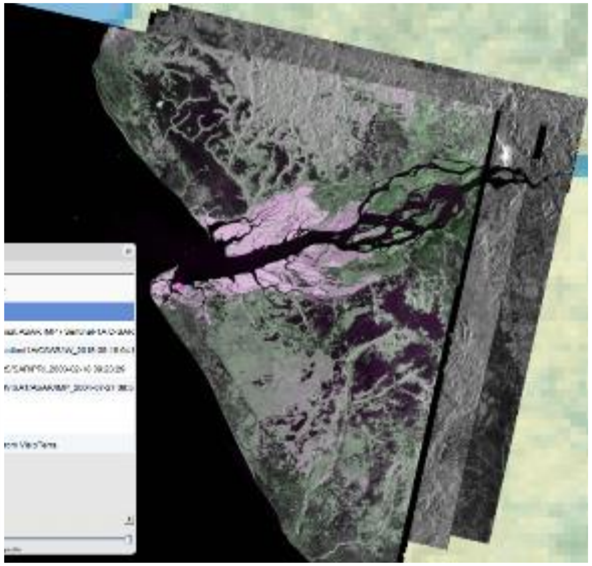
- ERS SAR PRI 27.07.2004 08:55
  Envisat ASAR IMP 18.02.2003 09:23
  Sentinel-1 C-SAR IW 19.08.2015 04:51

- Hyperlook:
  - Land processing animation 2D stack 2D_anim
  - Sea processing animation 2D stack 2D_anim

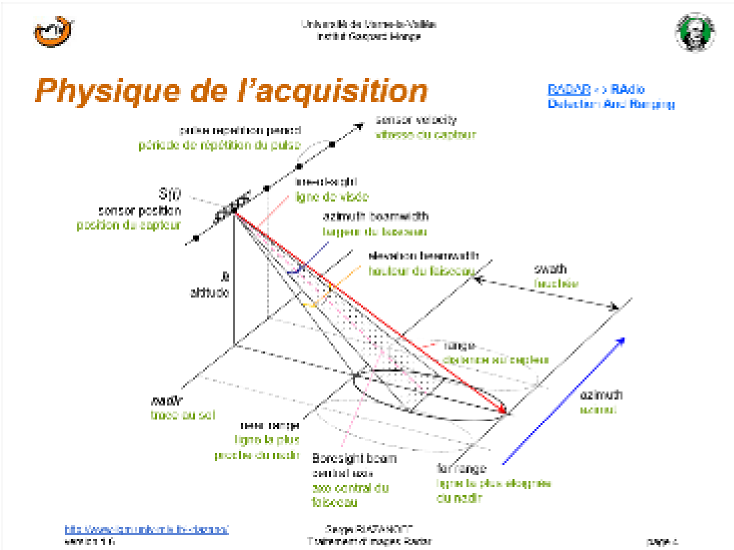


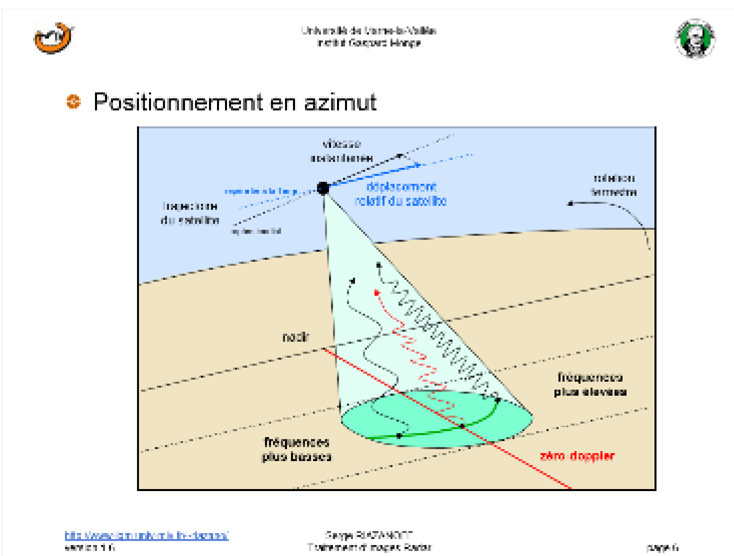


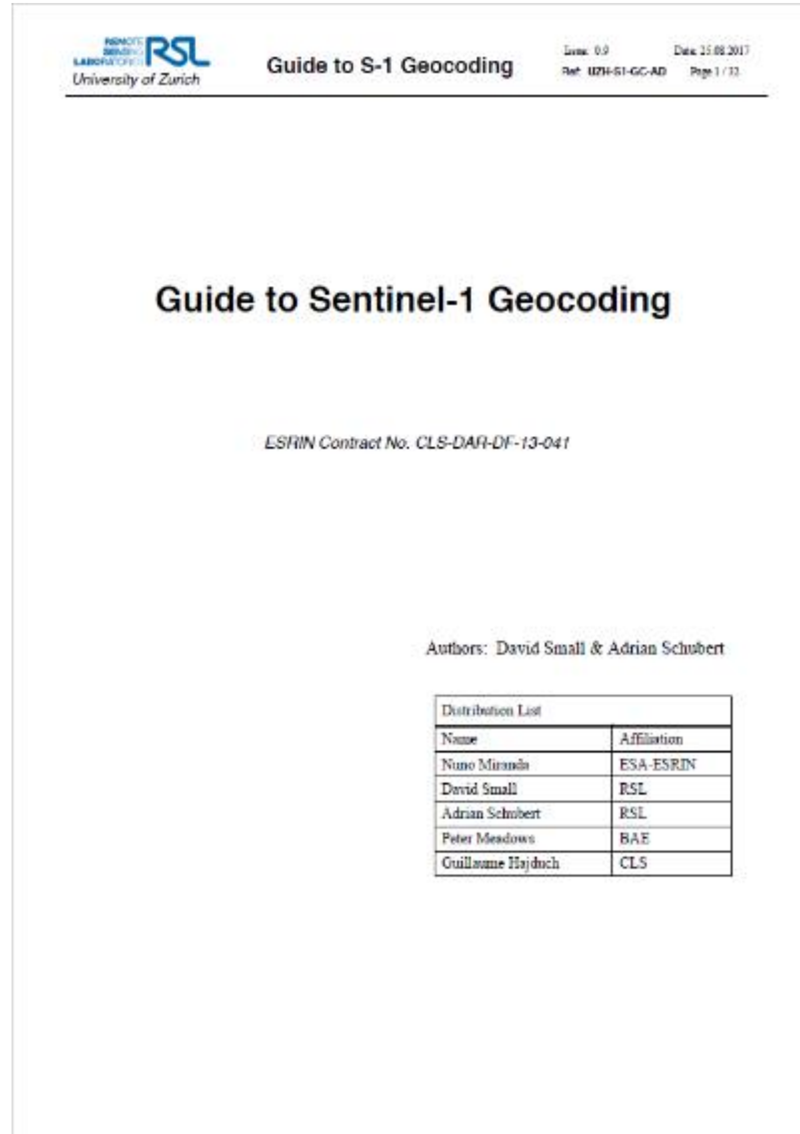




The physical “Zero Doppler” model







University of Zurich

Guide to S-1 Geocoding

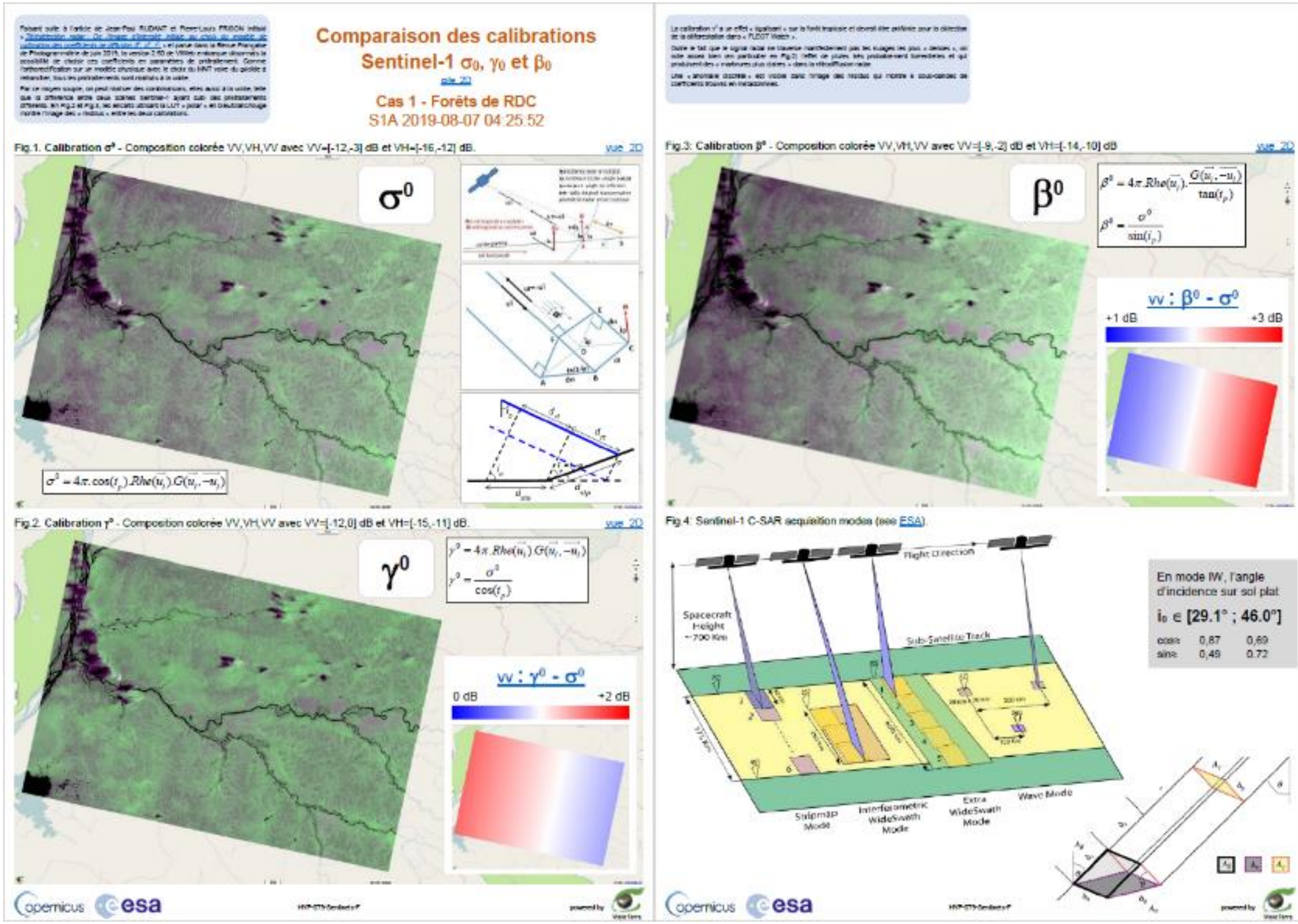
Guide to Sentinel-1 Geocoding

ESRIN Contract No. CLS-DAR-DF-13-041

Authors: David Small & Adrian Schubert

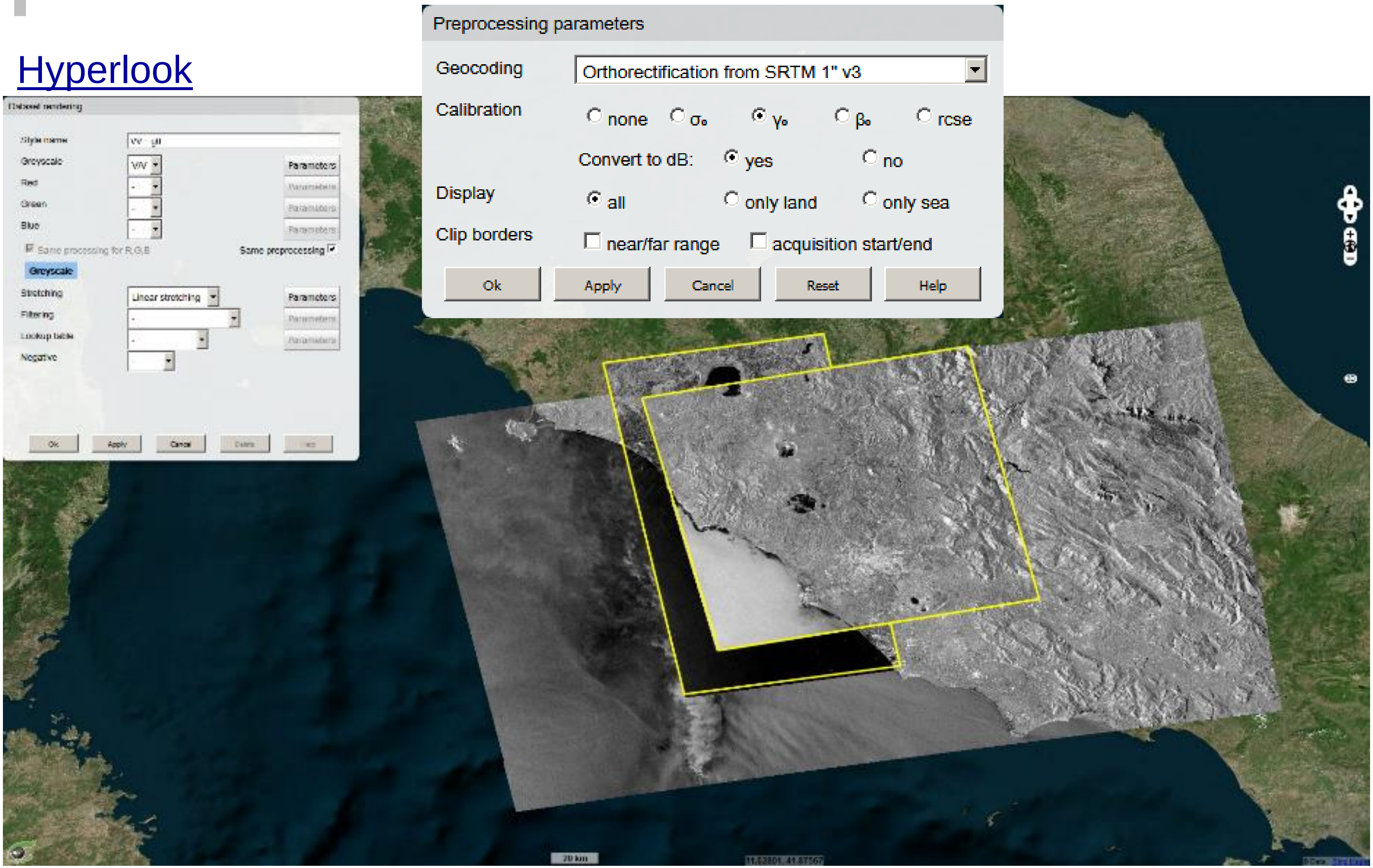
Distribution List	
Name	Affiliation
Nuno Miranda	ESA-ESRIN
David Small	RSL
Adrian Schubert	RSL
Peter Meadows	BAE
Guillaume Hajduch	CLS

Comparison σ^0, γ^0, β^0 – HYP-084-Sentinels

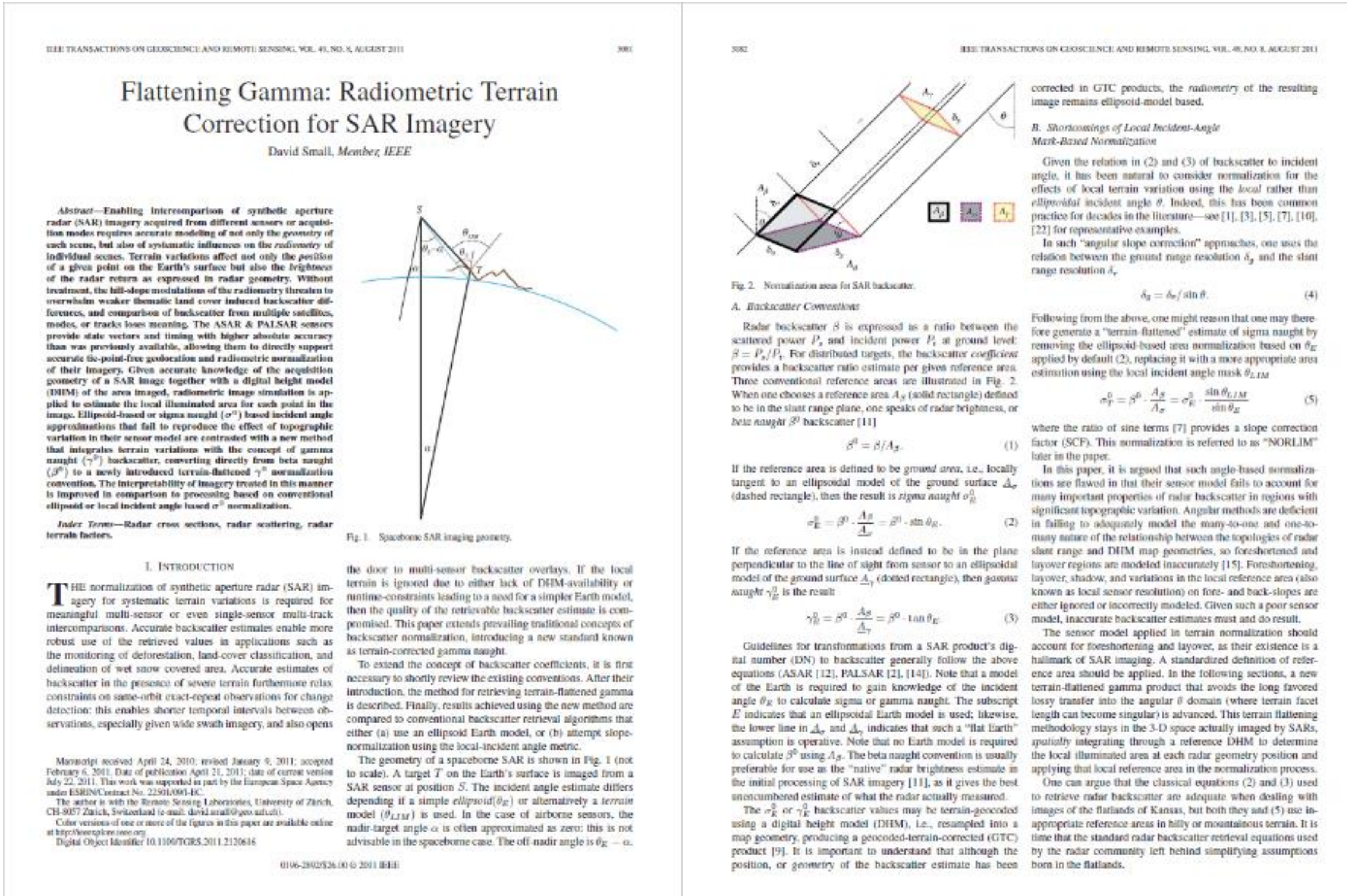


Orthorectification of Envisat/ASAR, ALOS PALSAR, S1/C-SAR

Hyperlook



RTC – Terrain flattening



IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 49, NO. 8, AUGUST 2011 3081

Flattening Gamma: Radiometric Terrain Correction for SAR Imagery

David Small, *Member, IEEE*

***Abstract*—Enabling intercomparison of synthetic aperture radar (SAR) imagery acquired from different sensors or acquisition modes requires accurate modeling of not only the *geometry* of each scene, but also of systematic influences on the *radiometry* of individual scenes. Terrain variations affect not only the *position* of a given point on the Earth's surface but also the *brightness* of the radar return as expressed in radar geometry. Without treatment, the hill-slope modulations of the radiometry threaten to overwhelm weaker thematic land cover induced backscatter differences, and comparison of backscatter from multiple satellites, modes, or tracks loses meaning. The ASAR & PALSAR sensors provide state vectors and timing with higher absolute accuracy than was previously available, allowing them to directly support accurate tie-point-free geolocation and radiometric normalization of their imagery. Given accurate knowledge of the acquisition geometry of a SAR image together with a digital height model (DHM) of the area imaged, radiometric image simulation is applied to estimate the local illuminated area for each point in the image. Ellipsoid-based or sigma naught (σ^0) based incident angle approximations that fail to reproduce the effect of topographic variation in their sensor model are contrasted with a new method that integrates terrain variations with the concept of gamma naught (γ^0) backscatter, converting directly from beta naught (β^0) to a newly introduced terrain-flattened γ^0 normalization convention. The interpretability of imagery treated in this manner is improved in comparison to processing based on conventional ellipsoid or local incident angle based σ^0 normalization.**

***Index Terms*—Radar cross sections, radar scattering, radar terrain factors.**

Fig. 1. Spaceborne SAR imaging geometry.

I. Introduction

THE normalization of synthetic aperture radar (SAR) imagery for systematic terrain variations is required for meaningful multi-sensor or even single-sensor multi-track intercomparisons. Accurate backscatter estimates enable more robust use of the retrieved values in applications such as the monitoring of deforestation, land-cover classification, and delineation of wet snow covered area. Accurate estimates of backscatter in the presence of severe terrain furthermore relax constraints on same-orbit exact-repeat observations for change detection: this enables shorter temporal intervals between observations, especially given wide swath imagery, and also opens the door to multi-sensor backscatter overlays. If the local terrain is ignored due to either lack of DHM-availability or runtime-constraints leading to a need for a simpler Earth model, then the quality of the retrievable backscatter estimate is compromised. This paper extends prevailing traditional concepts of backscatter normalization, introducing a new standard known as terrain-corrected gamma naught.

To extend the concept of backscatter coefficients, it is first necessary to shortly review the existing conventions. After their introduction, the method for retrieving terrain-flattened gamma is described. Finally, results achieved using the new method are compared to conventional backscatter retrieval algorithms that either (a) use an ellipsoid Earth model, or (b) attempt slope-normalization using the local-incident angle metric.

The geometry of a spaceborne SAR is shown in Fig. 1 (not to scale). A target T on the Earth's surface is imaged from a SAR sensor at position S. The incident angle estimate differs depending if a simple *ellipsoid*(θ_E) or alternatively a *terrain* model (θ_{LIM}) is used. In the case of airborne sensors, the nadir-target angle α is often approximated as zero: this is not advisable in the spaceborne case. The off-nadir angle is $\theta_E - \alpha$.

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The author is with the Remote Sensing Laboratories, University of Zurich, CH-8057 Zurich, Switzerland (e-mail: david.small@geo.uzh.ch).

Color versions of one or more of the figures in this paper are available online at http://ieeexplore.ieee.org.

Digital Object Identifier 10.1109/TGRS.2011.2120616

3082 IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 49, NO. 8, AUGUST 2011

Fig. 2. Normalization areas for SAR backscatter.

A. Backscatter Conventions

Radar backscatter β is expressed as a ratio between the scattered power P_s and incident power P_i at ground level: $\beta = P_s/P_i$. For distributed targets, the backscatter *coefficient* provides a backscatter ratio estimate per given reference area. Three conventional reference areas are illustrated in Fig. 2. When one chooses a reference area A_β (solid rectangle) defined to be in the slant range plane, one speaks of radar brightness, or *beta naught* β^0 backscatter [11]

$$\beta^0 = \beta / A_\beta. \quad (1)$$

If the reference area is defined to be *ground area*, i.e., locally tangent to an ellipsoidal model of the ground surface A_σ (dashed rectangle), then the result is *sigma naught* σ^0_E

$$\sigma^0_E = \beta^0 \cdot \frac{A_\beta}{A_\sigma} = \beta^0 \cdot \sin\theta_E. \quad (2)$$

If the reference area is instead defined to be in the plane perpendicular to the line of sight from sensor to an ellipsoidal model of the ground surface A_γ (dotted rectangle), then *gamma naught* γ^0_E is the result

$$\gamma^0_E = \beta^0 \cdot \frac{A_\beta}{A_\gamma} = \beta^0 \cdot \tan\theta_E. \quad (3)$$

Guidelines for transformations from a SAR product's digital number (DN) to backscatter generally follow the above equations (ASAR [12], PALSAR [2], [14]). Note that a model of the Earth is required to gain knowledge of the incident angle θ_E to calculate sigma or gamma naught. The subscript E indicates that an ellipsoidal Earth model is used; likewise, the lower line in A_σ and A_γ indicates that such a "flat Earth" assumption is operative. Note that no Earth model is required to calculate β^0 using A_β. The beta naught convention is usually preferable for use as the "native" radar brightness estimate in the initial processing of SAR imagery [11], as it gives the best unencumbered estimate of what the radar actually measured.

The σ^0_E or γ^0_E backscatter values may be terrain-geocoded using a digital height model (DHM), i.e., resampled into a map geometry, producing a geocoded-terrain-corrected (GTC) product [9]. It is important to understand that although the position, or *geometry* of the backscatter estimate has been corrected in GTC products, the *radiometry* of the resulting image remains ellipsoid-model based.

B. Shortcomings of Local Incident-Angle Mask-Based Normalization

Given the relation in (2) and (3) of backscatter to incident angle, it has been natural to consider normalization for the effects of local terrain variation using the *local* rather than *ellipsoidal* incident angle θ. Indeed, this has been common practice for decades in the literature—see [1], [3], [5], [7], [10], [22] for representative examples.

In such "angular slope correction" approaches, one uses the relation between the ground range resolution δ_g and the slant range resolution δ_r

$$\delta_g = \delta_r / \sin\theta. \quad (4)$$

Following from the above, one might reason that one may therefore generate a "terrain-flattened" estimate of sigma naught by removing the ellipsoid-based area normalization based on θ_E applied by default (2), replacing it with a more appropriate area estimation using the local incident angle mask θ_{LIM}

$$\sigma^0_T = \beta^0 \cdot \frac{A_\beta}{A_\sigma} = \sigma^0_E \cdot \frac{\sin\theta_{LIM}}{\sin\theta_E} \quad (5)$$

where the ratio of sine terms [7] provides a slope correction factor (SCF). This normalization is referred to as "NORLIM" later in the paper.

In this paper, it is argued that such angle-based normalizations are flawed in that their sensor model fails to account for many important properties of radar backscatter in regions with significant topographic variation. Angular methods are deficient in failing to adequately model the many-to-one and one-to-many nature of the relationship between the topologies of radar slant range and DHM map geometries, so foreshortened and layover regions are modeled inaccurately [15]. Foreshortening, layover, shadow, and variations in the local reference area (also known as local sensor resolution) on fore- and back-slopes are either ignored or incorrectly modeled. Given such a poor sensor model, inaccurate backscatter estimates must and do result.

The sensor model applied in terrain normalization should account for foreshortening and layover, as their existence is a hallmark of SAR imaging. A standardized definition of reference area should be applied. In the following sections, a new terrain-flattened gamma product that avoids the long favored lossy transfer into the angular θ domain (where terrain facet length can become singular) is advanced. This terrain flattening methodology stays in the 3-D space actually imaged by SARs, *spatially* integrating through a reference DHM to determine the local illuminated area at each radar geometry position and applying that local reference area in the normalization process.

One can argue that the classical equations (2) and (3) used to retrieve radar backscatter are adequate when dealing with images of the flatlands of Kansas, but both they and (5) use inappropriate reference areas in hilly or mountainous terrain. It is time that the standard radar backscatter retrieval equations used by the radar community left behind simplifying assumptions born in the flatlands.

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Merci de votre attention

Thank you for your attention

Questions ?

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