GRS processor: Glint removal for Sentinel-2 scheme and application to Sentinel -2 and Landsat-5, 7, 8

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GRS PROCESSOR:
GLINT REMOVAL FOR SENTINEL-2

SCHEME AND APPLICATION TO SENTINEL-2 AND LANDSAT-5, 7, 8

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GRS PROCESSOR: GLINT REMOVAL FOR SENTINEL-2

Content

GRS birth

Theoretical principles

Technical algorithm

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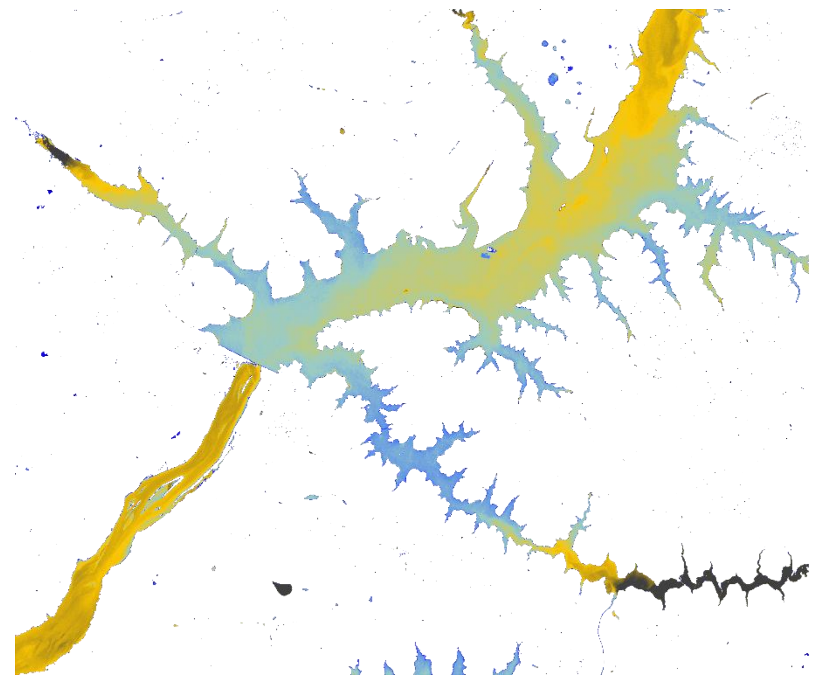
Perspectives



[Image S2A, Amazonian dam and re-suspension]

OBJECTIVES

Observe

Small to great lakes (French reservoirs, ponds, alpine lakes…)

Main rivers and estuaries on watershed scale (Amazonia, Nile, Mekong)

Characterize

Dissolved and particulate matter

Biological activity, micro-algae (e.g., cyanobacteria)

Water quality

Sedimentary mass

Understand and forecast

Coupling observation data with ecological and thermo-dynamic models

Assess anthropological local and global impacts

Sedimentary fluxes

OBJECTIVES

Observe

Characterize

Understand and forecast

Pre-requisite decametric satellite observation:

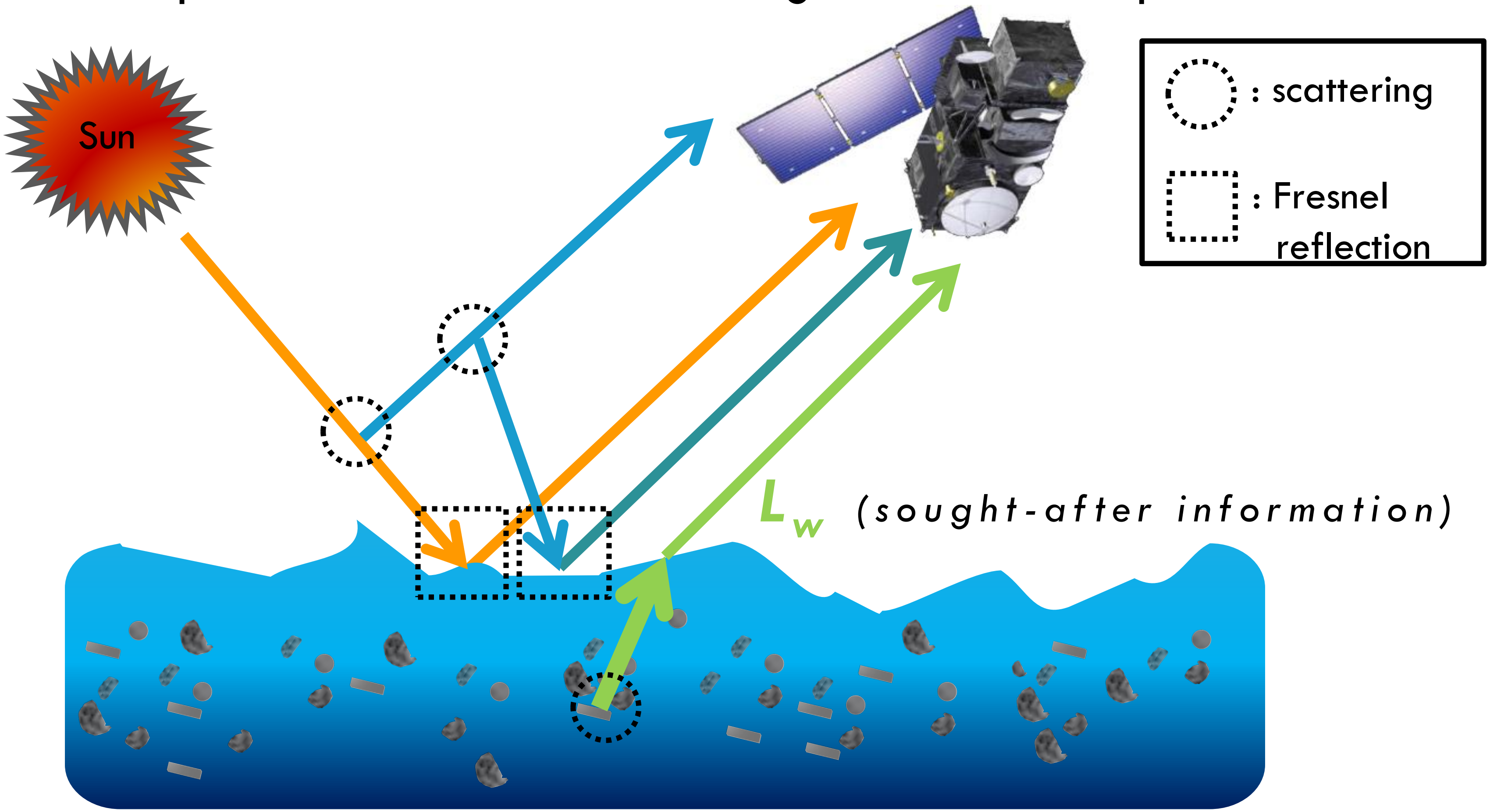
Sentinel-2 and Landsat-8 best suited to achieve these goals.

But, we encountered big issues with atmospheric correction and **the "stochastic" presence of sunglint.**

Birth of the GRS-algorithm

PRINCIPLES

Simplified picture of the TOA signal over aquatic scene

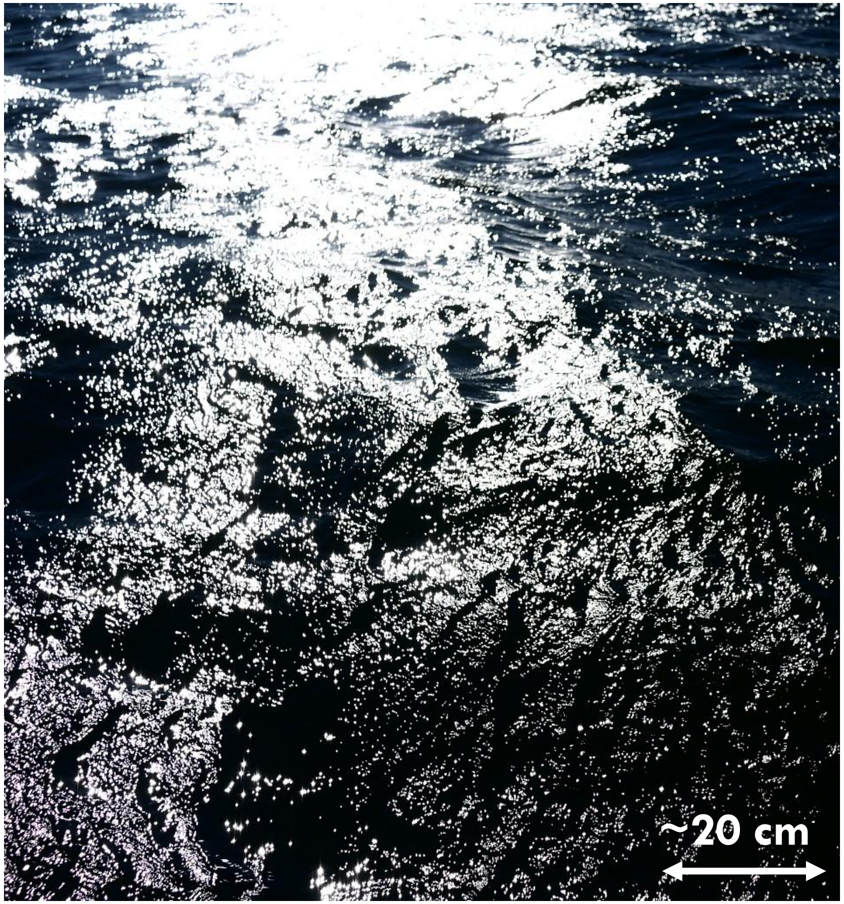


Diffuse light: skylight, reflected skylight and water-leaving radiance

Direct light: sunglint

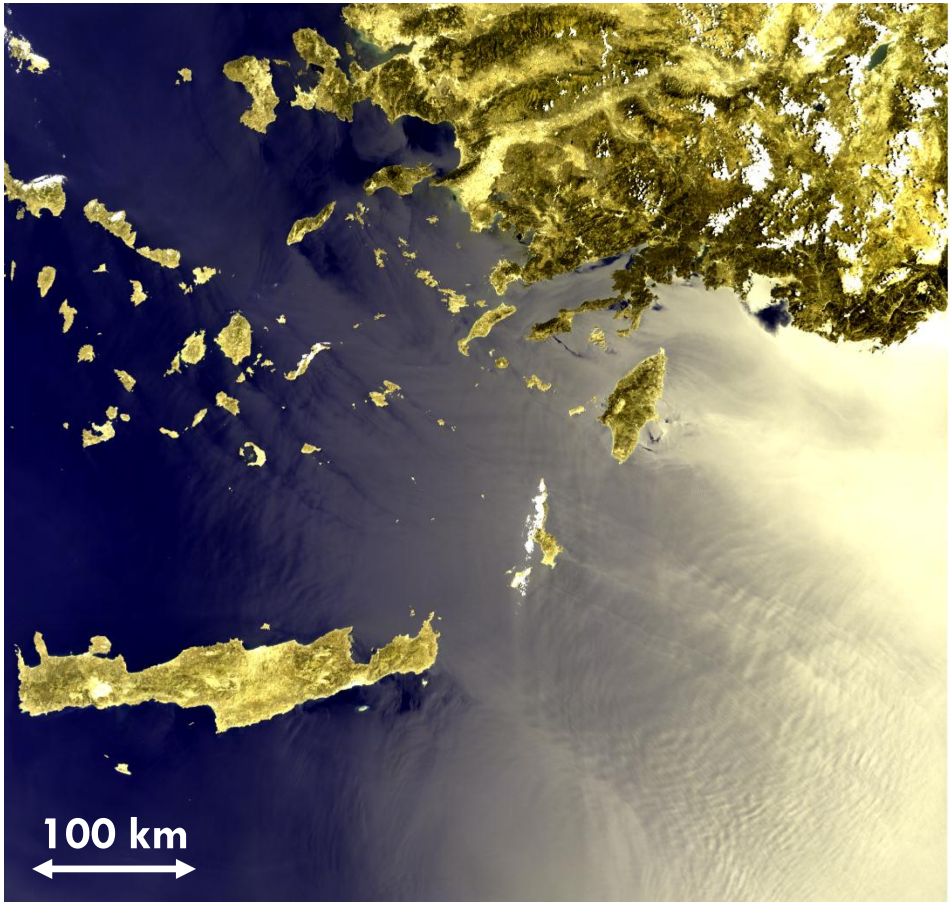
SUNGLINT EXAMPLES

…from a ship



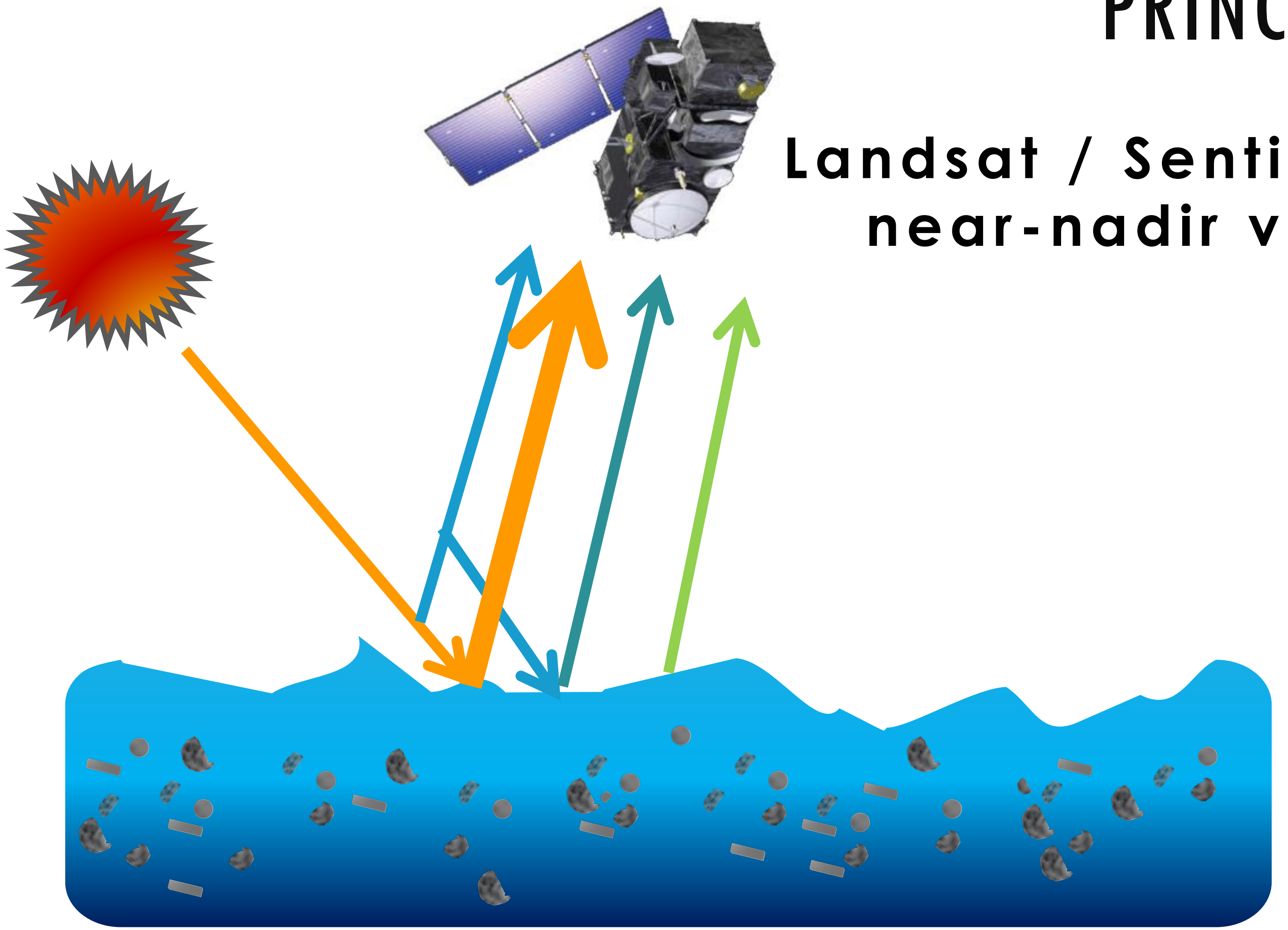
(standard digital camera)

…from a satellite



(image Sentinel-3/OLCI, May 10, 2016)

PRINCIPLES

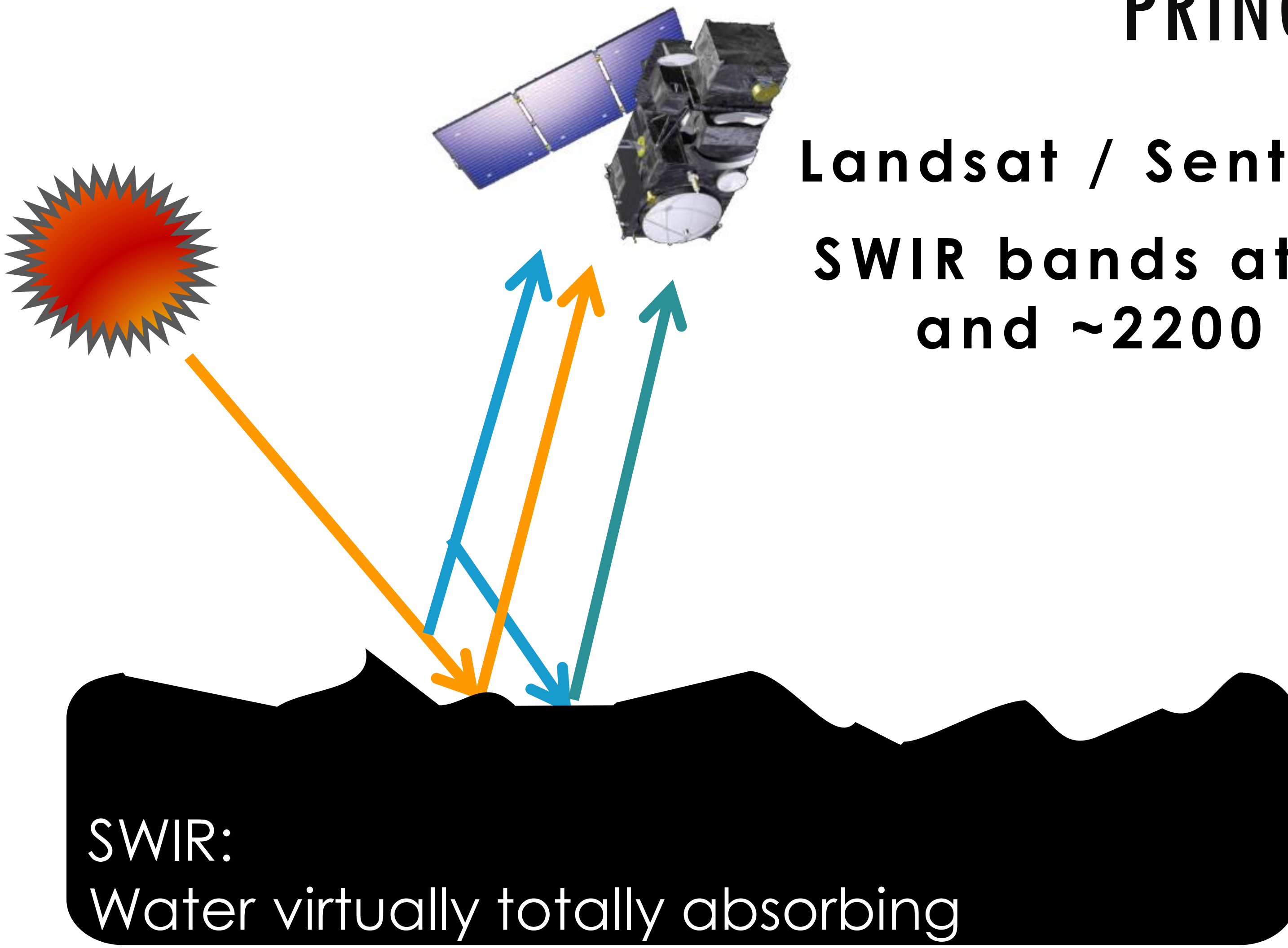


→ Increase probability/intensity of sunglint

PRINCIPLES

Landsat / Sentinel-2:

SWIR bands at ~1600 and ~2200 nm



Diffuse light: **skylight**, **reflected skylight**

Direct light: **sunglint**

SUNGLINT IN S2 AND LANDSAT IMAGERY

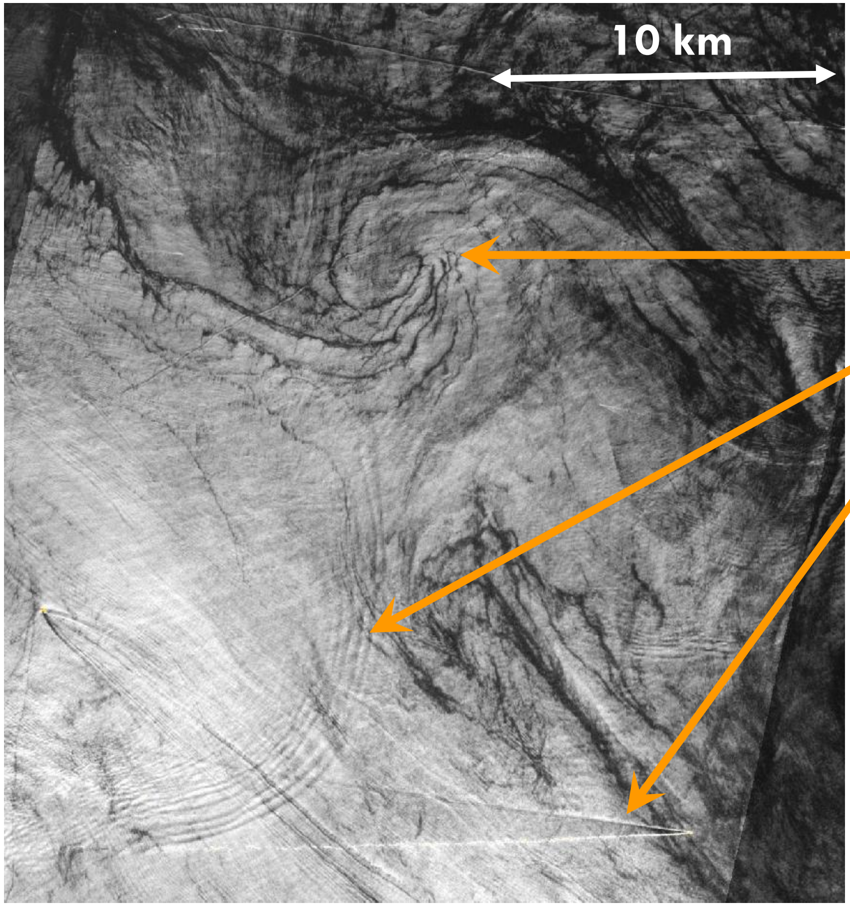


Image Sentinel-2, SWIR-band (~2200nm)

Patterns:

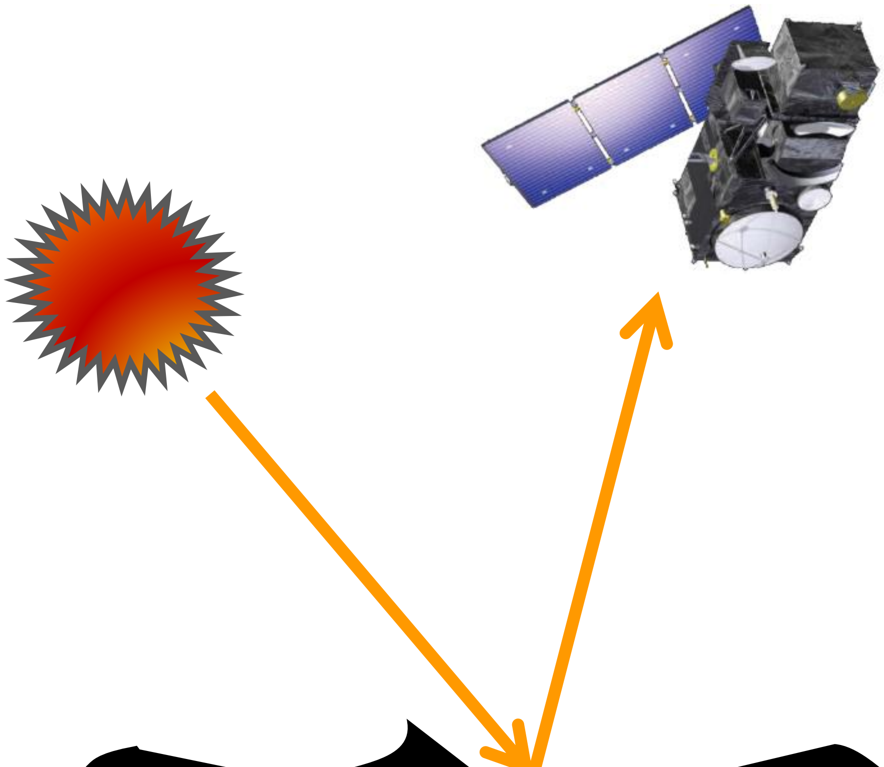
Eddy with surfactant

Wave packet (internals)

Ship wake

…

PRINCIPLES



If aerosol known

+

dedicated radiative transfer code

=

Radiance for skylight and skylight reflection

SWIR → sunglint (direct light) → BRDF of water surface

sunglint (direct light) radiance

Known →

Sun radiance

$$L_g^{TOA}(\theta_s,\theta_v,\Delta\varphi) = T_u(\theta_v)\,T_d(\theta_s)\,L_{sun}^{\downarrow}(\theta_s)\,BRDF_{surf}(\theta_s,\theta_v,\Delta\varphi)$$

Unknown →

Upward/downward direct transmittances

Bidirectional reflectance distribution function

$$T(\theta) = \exp\left(-\frac{\tau_{mol}+\tau_a}{\cos\theta}\right)$$

θ_s : Sun zenith angle
θ_v : Viewing zenith angle
$\Delta\varphi$: Relative azimuth (view-Sun)
τ : optical thickness (molecules / aerosols)

PRINCIPLES

SWIR → sunglint (direct light) → BRDF of water surface

Independent of wavelength →

Geometrical consideration

Wave slopes statistics and shadowing

$$BRDF_{surf} = \underbrace{R_f(\omega)}_{\text{Fresnel coefficient}} \overbrace{\frac{\pi}{4\cos\theta_v \cos^4\theta_N}}^{\text{Geometrical consideration}} \overbrace{q(\zeta_x, \zeta_y, h)}^{\text{Wave slopes statistics and shadowing}}$$

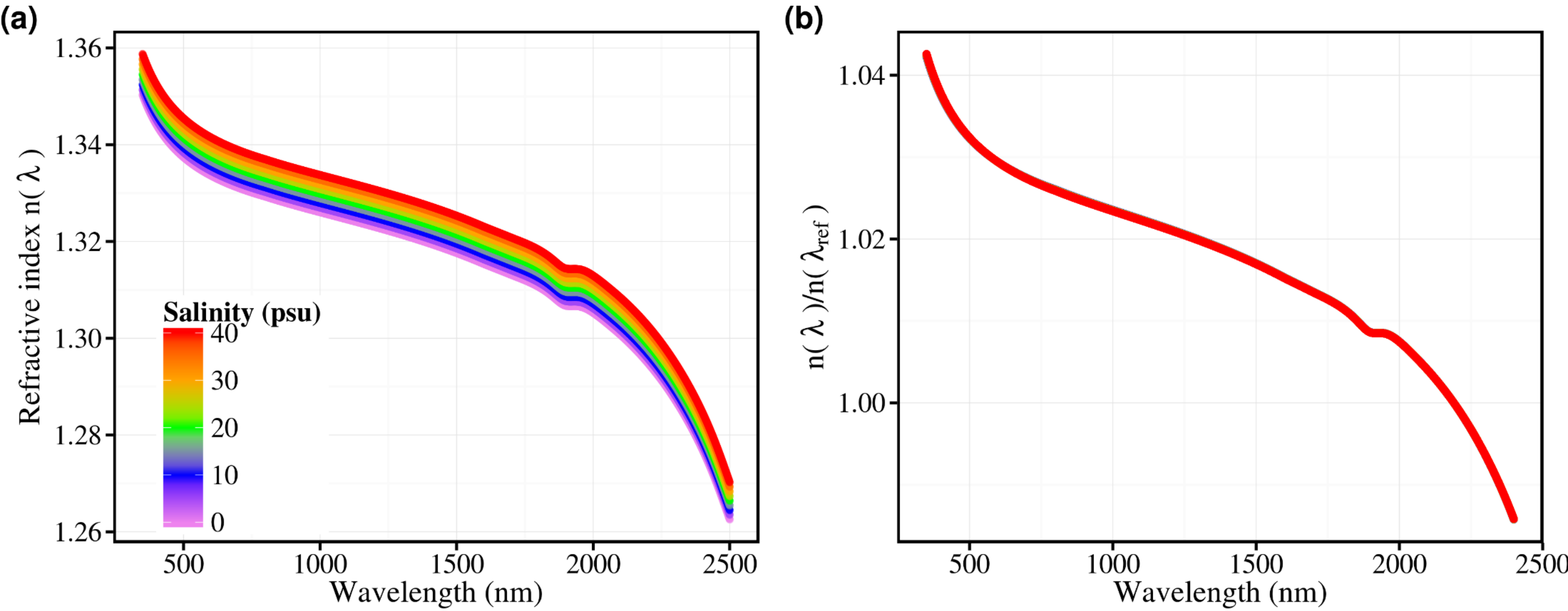
Fresnel coefficient

↓

dependent on refractive index of water, $n(\lambda)$

← Wavelength dependent

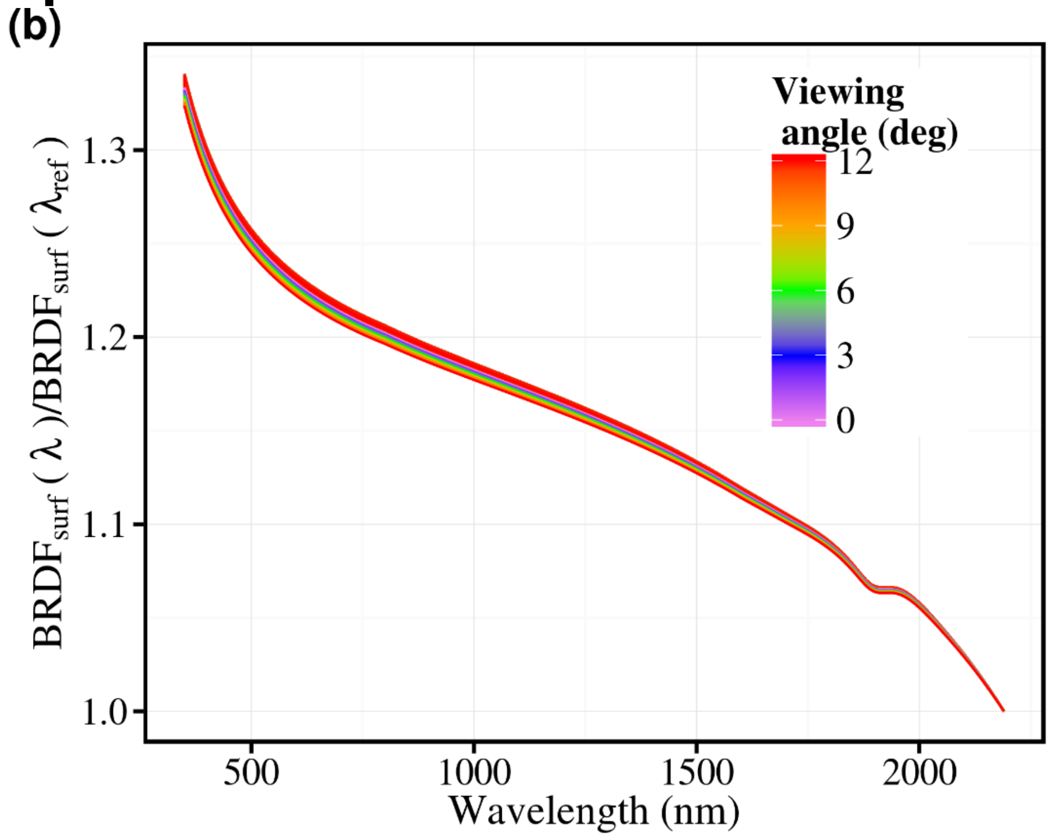
Spectral dependence of refractive index, *n*, over visible-SWIR region



→ **Spectral variation of a few percent**

PRINCIPLES

$n(\lambda)$ → spectral variation of $BRDF$ of water surface



→ **Spectral variation of more than 30% from SWIR to blue**

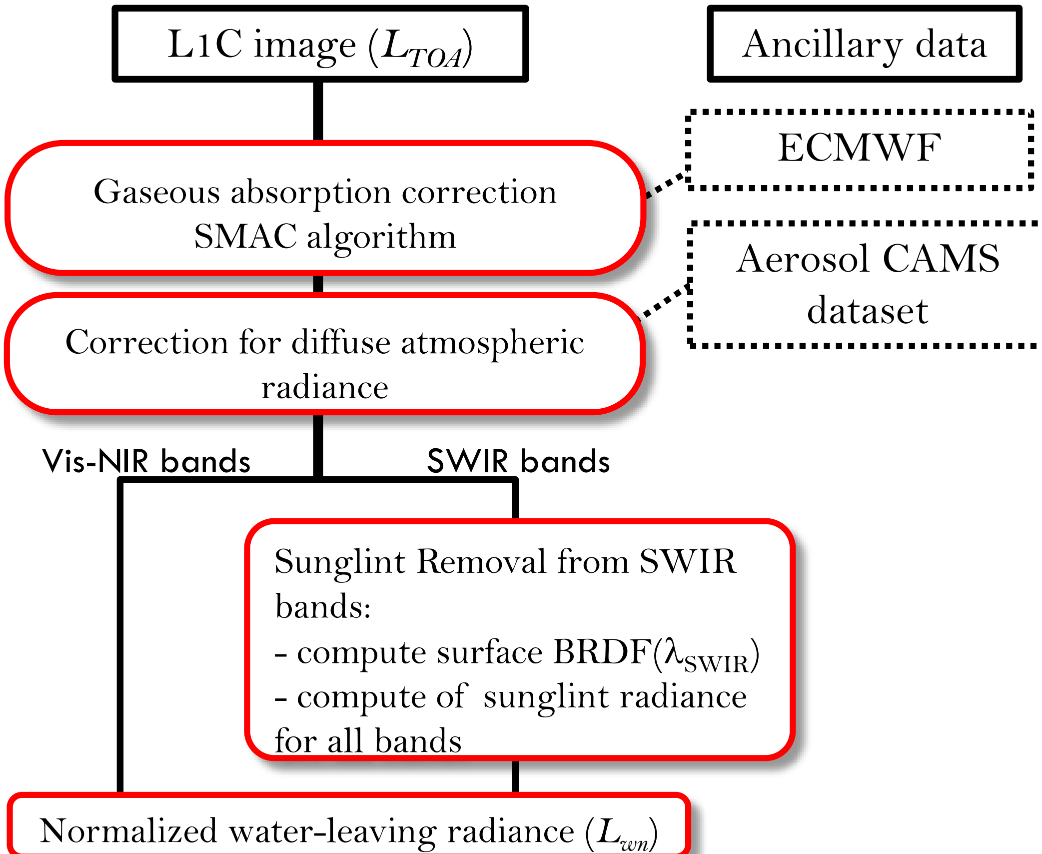
→ **must be accounted for to extrapolate BRDF retrieved in the SWIR**

GRS ALGORITHM

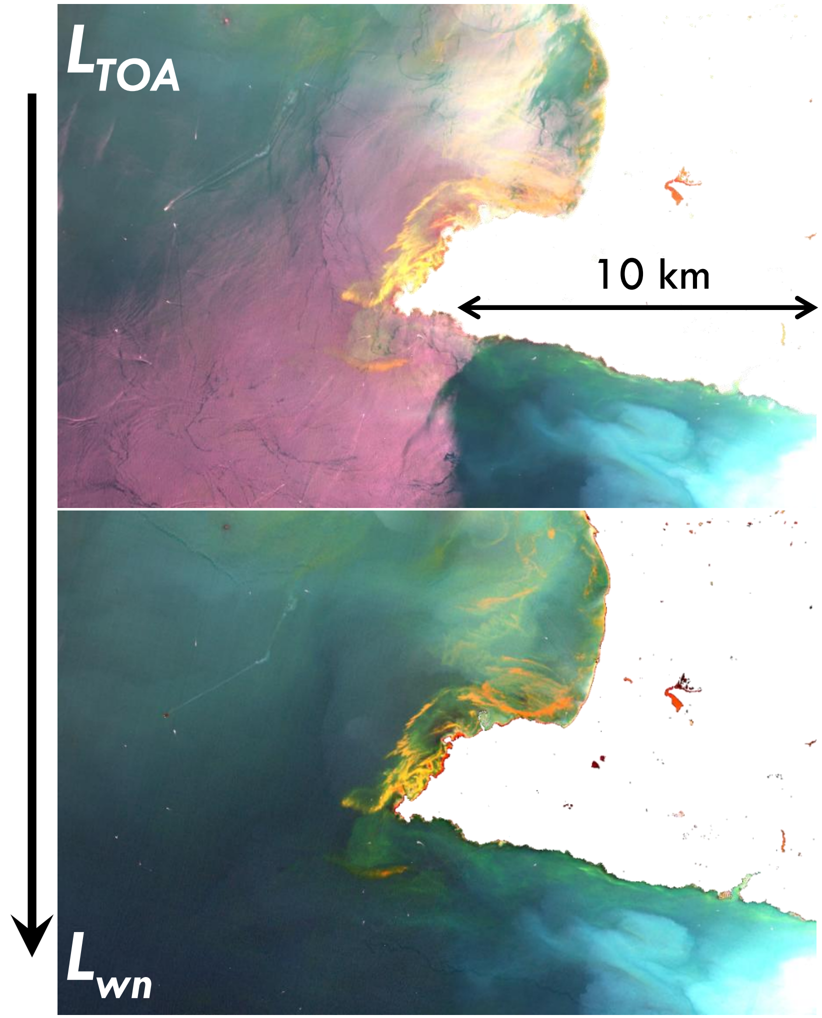
(GLINT REMOVAL FOR SENTINEL-2-LIKE DATA)

GRS: coded in python and fortran, main lib: snappy (ESA)

Can process: Sentinel-2 A & B, Landsat 5, 7 & 8

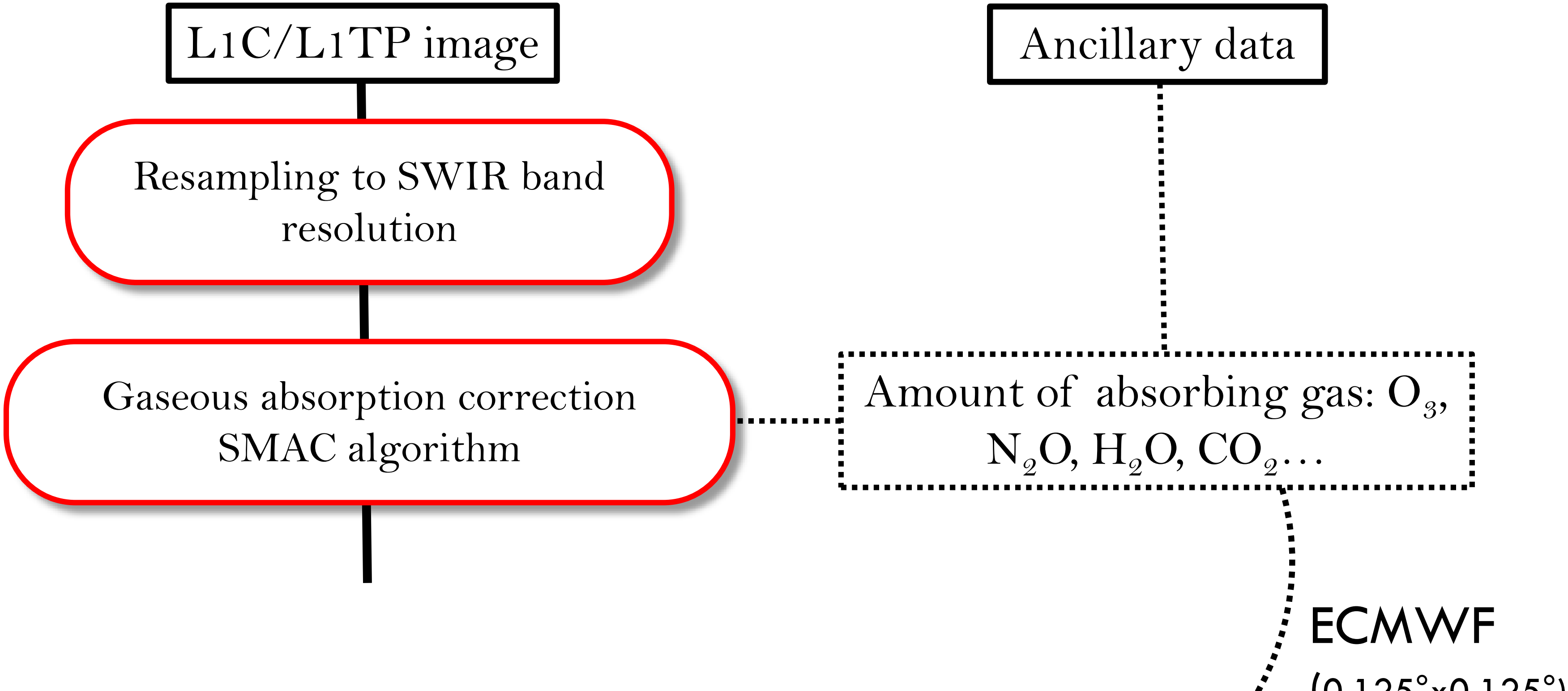


[Harmel et al., 2018]



Sentinel-2 image of 5 Aug. 2018, [2°W, 47°N]

GRS ALGORITHM



Compute transmittances from 6S pre-computations for:

- A given atmospheric profile
- absorbing gas concentrations
- satellite bands characteristics

GRS ALGORITHM

Ancillary data

Aerosol optical thickness

Correction for diffuse atmospheric radiance

$$\log(\tau_a(\lambda)) = a_0 + a_1 \log(\lambda) + a_2 \log(\lambda)^2$$ ← Ancillary (CAMS)

$$\tau_{a\_sim}(\lambda) = \gamma \tau_{a\_sim}^{fine}(\lambda) + (1-\gamma)\tau_{a\_sim}^{coarse}(\lambda)$$ ← LUT

Optimal fit to obtain γ and compute the sky + reflected sky radiance:

$$L_{sky}(\lambda, \tau_a) = \gamma L_{sky}^{fine}(\lambda, \tau_a) + (1-\gamma) L_{sky}^{coarse}(\lambda, \tau_a)$$

Interpolated within LUT

GRS ALGORITHM

Ancillary data

Aerosol optical thickness

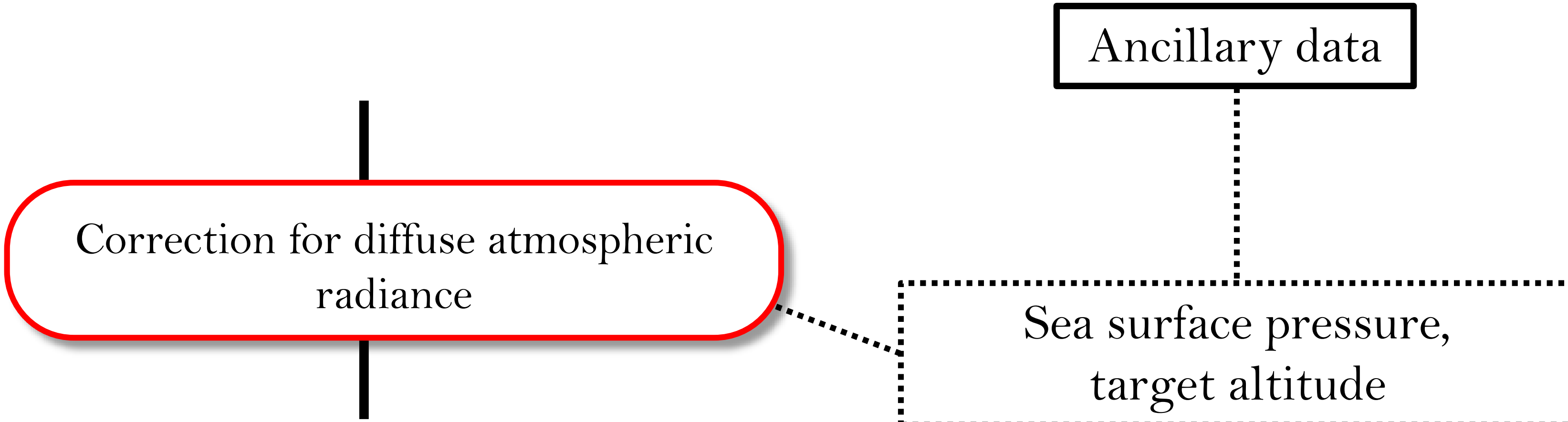
Correction for diffuse atmospheric radiance

LUT: simulations from OSOAA code [Chami et al., 2015]
Atmosphere/rough interface/water coupled system.
Polarization accounted for.
Aerosol models (size lognormal, Mie calculations):

	r_g (µm)	σ	r_{eff} (µm)	n_r	n_i
fine	0.10	0.60	0.25	1.40	0.002
coarse	0.80	0.60	1.98	1.35	0.001

$$L_{sky}(\lambda,\tau_a) = \gamma L_{sky}^{fine}(\lambda,\tau_a) + (1-\gamma) L_{sky}^{coarse}(\lambda,\tau_a)$$

Interpolated within LUT



Effect of atmosphere thickness (e.g., elevated target):

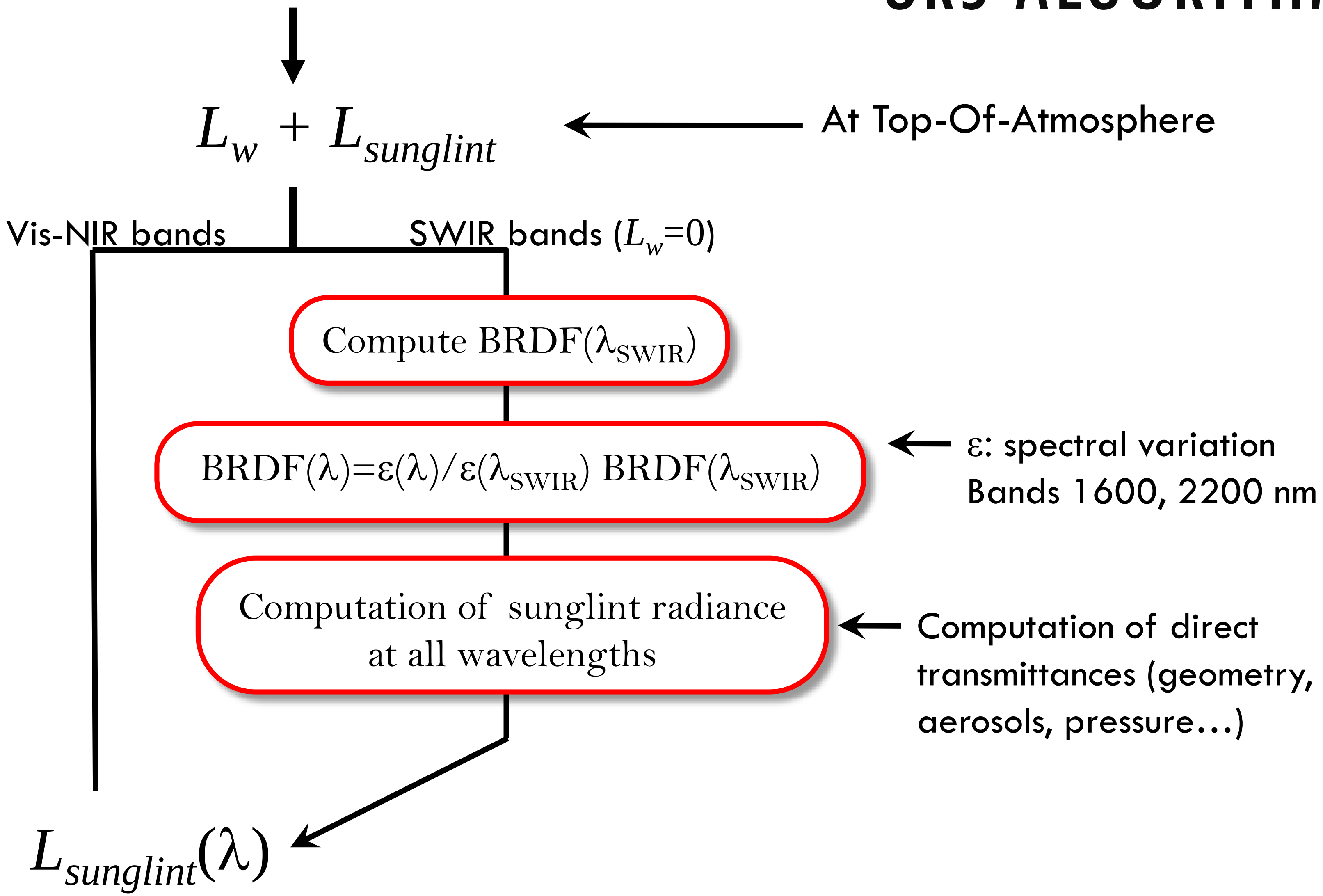
Sea level pressure (ECMWF)

Target altitude (m)

$$P(h) = P(0)\left[1 - \frac{0.0065h}{288.15}\right]^{5.255}$$

Rayleigh optical thickness and radiance from LUT recalibrated on *P(h)*

GRS ALGORITHM



GRS ALGORITHM

Correction for sunglint radiance

↓

L_w ← At Top-Of-Atmosphere

Normalized water-leaving radiance L_{WN}

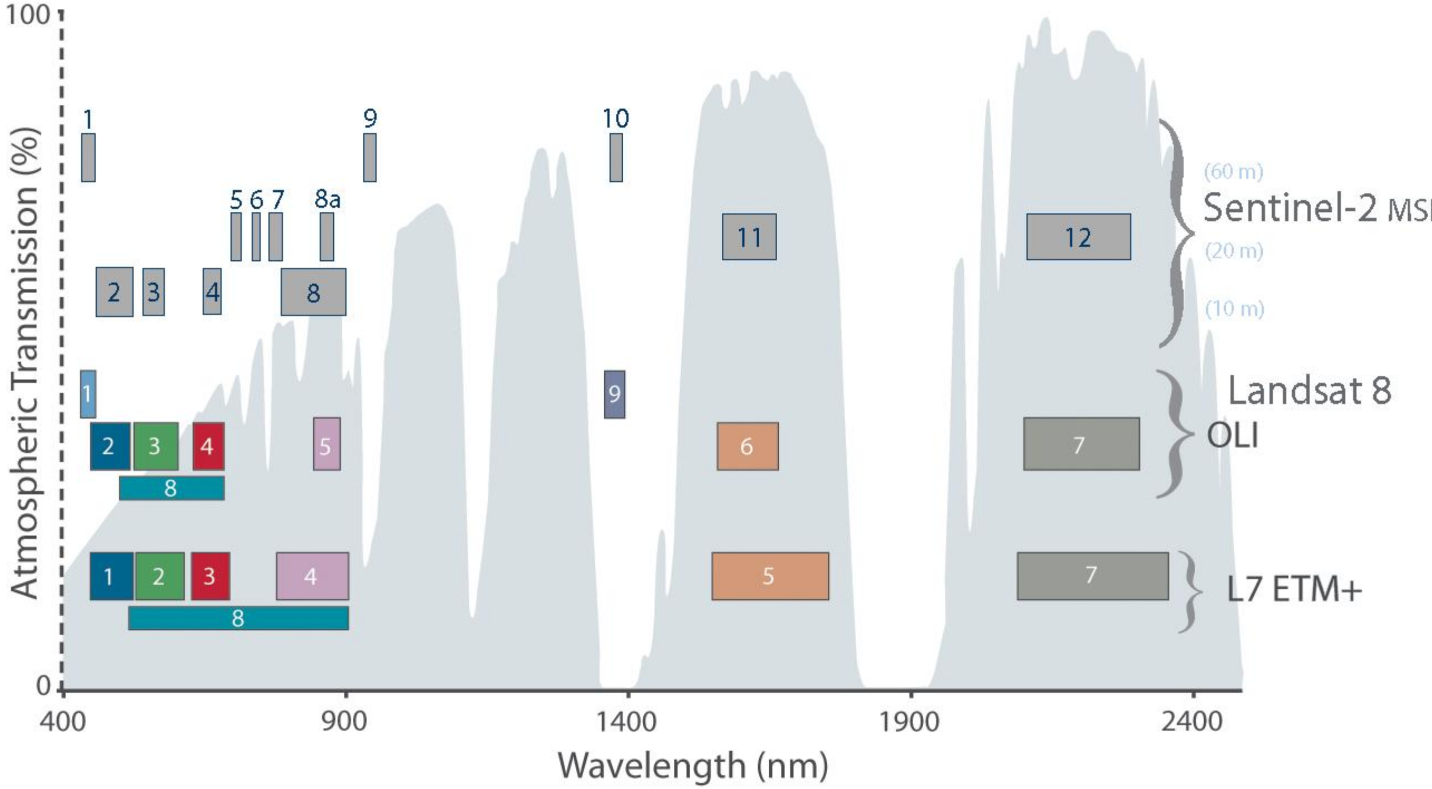
Correction for Sun-Earth distance

$$L_{WN}(\theta_v, \Delta\varphi) = \left(\frac{R}{R_0}\right)^2 \frac{L_w^{TOA}(\theta_s, \theta_v, \Delta\varphi)}{t_d(\theta_s)\cos\theta_s}$$

Upwelling diffuse + direct transmittance

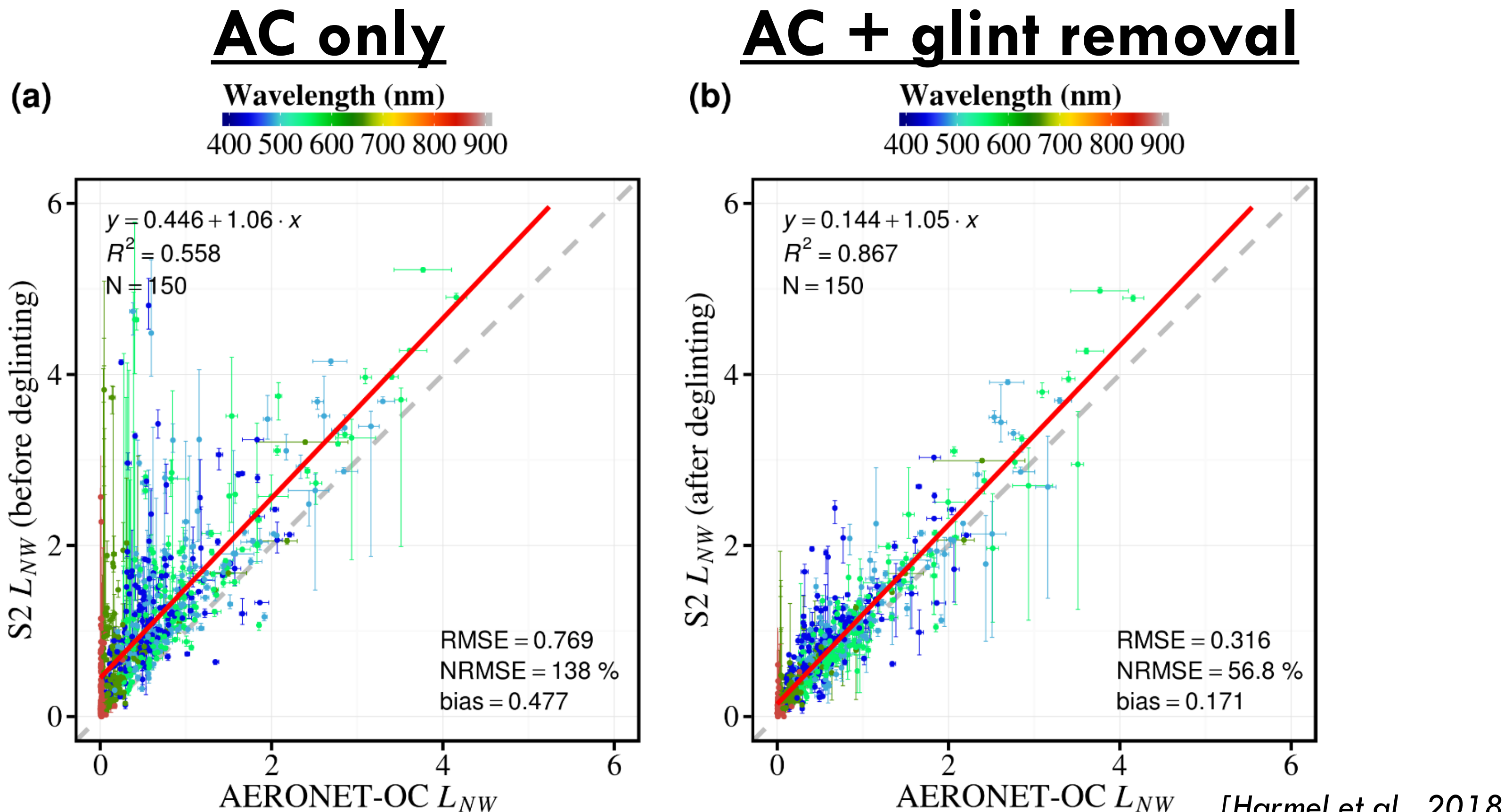
No bidirectional correction for L_{WN}

GRS ALGORITHM IMPLEMENTED FOR S2 AND LANDSAT SERIES



- All parameters calculated for the RSR of the sensors (Landsat-5, 7, 8 and Seninel-2 A/B)
- Time range limited by CAMS data availability (2003-present)

VALIDATION WITH AERONET-OC DATA



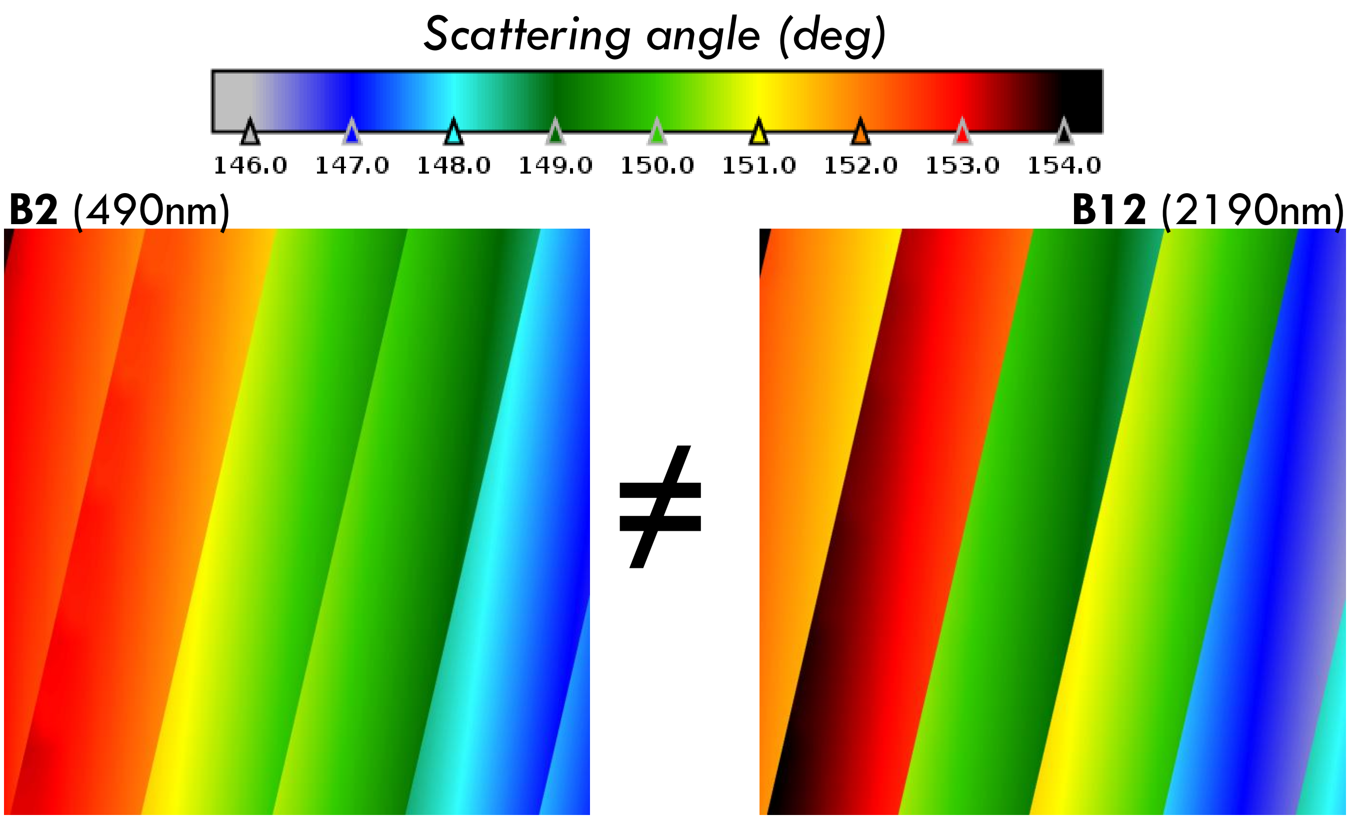
[Harmel et al., 2018]

150 satellite images (S2)

16 AERONET-OC (14 coastal, 2 lake sites)

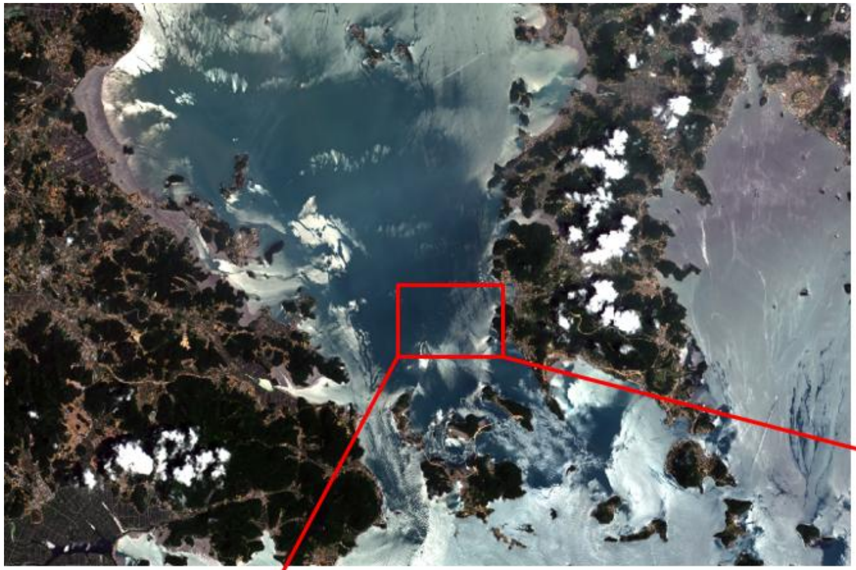
CURRENT LIMITATIONS

- Not coupled yet with masking procedure: “water”, “clouds”, “cloud shadow”, “cliff shadow”…
- Need of exogenous data for aerosols (e.g., spectral optical thickness)
- Differences in viewing angles between spectral bands are not accounted for at the pixel level

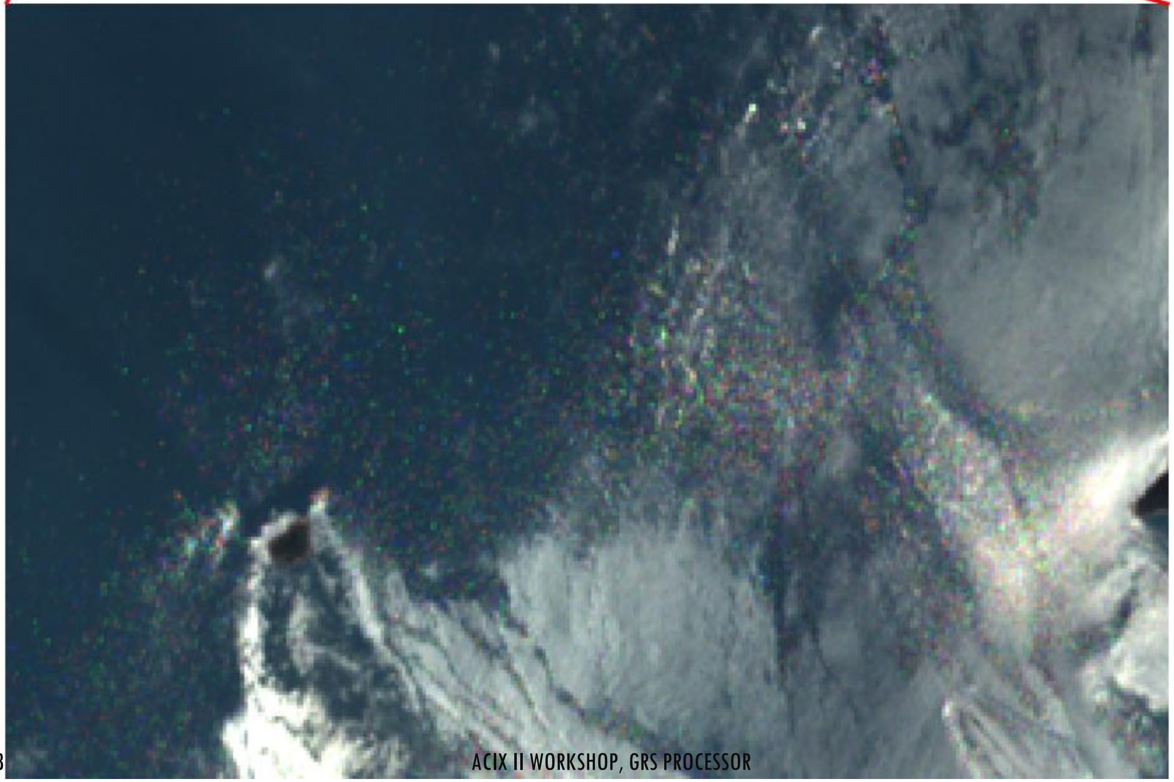


[Image S2A, tile 32TQR, 2016-07-18]

CURRENT LIMITATIONS

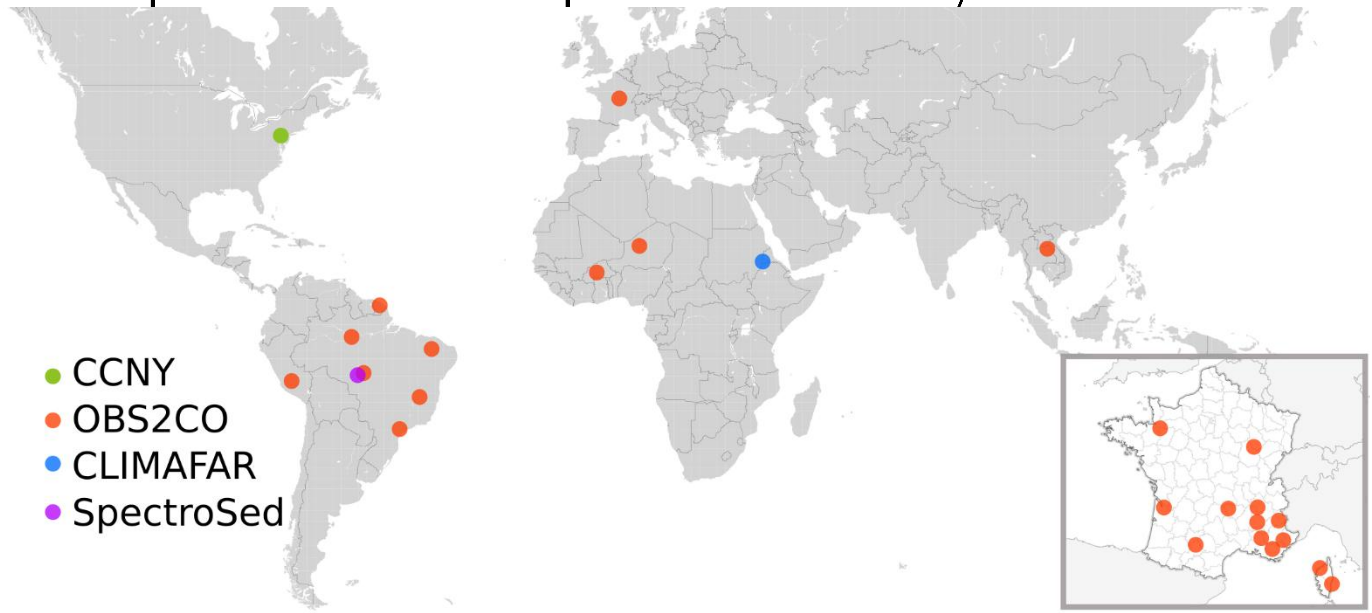


Example of RGB S2A image where glinted pixels appear red, green and blue due to potential mis-coregitration, **time lag between band acquisition or changes in viewing angles between bands.**



PERSPECTIVES

- Coupling with detection chain for “water” and “mixed” pixels
- Exploitation of directional information from each spectral band and “multi-view” pixels (**need of L1B data**)
- Development of a coupled estimation of sunglint and aerosol (retrieval from direct and diffuse light)
- Coupling with SWOT data (→ sedimentary fluxes over 150 pre-defined sites)
- Evaluation of performances from public and our Cal/Val in situ data



Contact: tristan.harmel@ntymail.fr

THANK YOU