CONAE

La Agencia Espacial Argentina

SABIA-Mar Calibration plan

IOCS meeting - 05 December 2025

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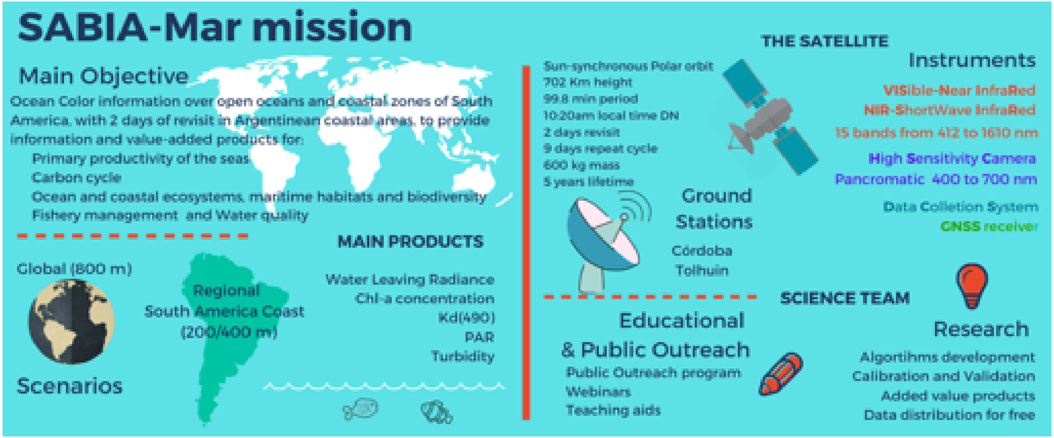
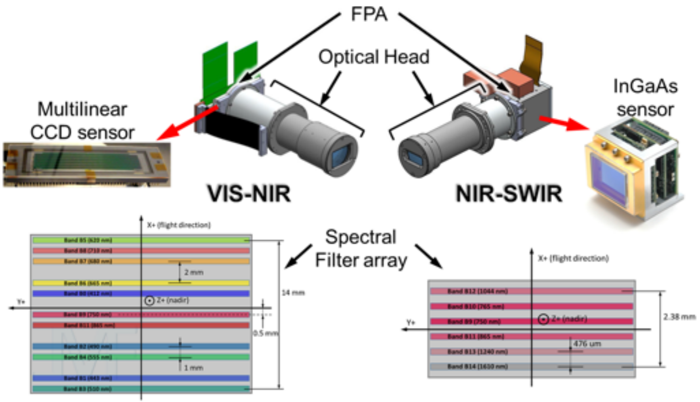
SABIA-Mar summary

Mission Summary



Main cameras

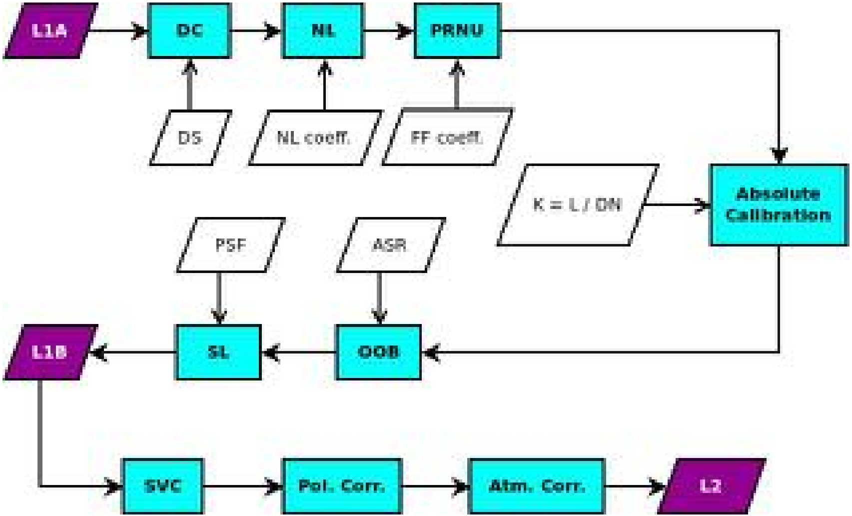


The design implies viewing geometry band-dependent, with a spread of 17.5 deg in zenith angle.

- Two multispectral pushbroom cameras, VIS-NIR and NIR-SWIR.
- 15 bands distributed in both cameras, 2 bands repeated for inter-calibration.
- Each camera has 3 identical electro-optical optical modules (EOM) in a fan shape configuration to meet field of view (FFOV) of 90 deg.
- Each camera: Optical Box (OB) and Calibrator.
- VIS-NIR: multi-linear sensor with 11 CCD linear array in parallel. 11 bands 412, 443, 490, 510, 555, 620, 665, 680, 710, 750, 865 [nm] with a spatial resolution (at nadir) of 200 [m] in coastal scenario and of 800 [m] in global scenario.
- NIR-SWIR: 2D InGaAs sensor array. 6 bands 750, 765, 865, 1044, 1240, 1610 [nm] with a spatial resolution (at nadir) of 400 [m].

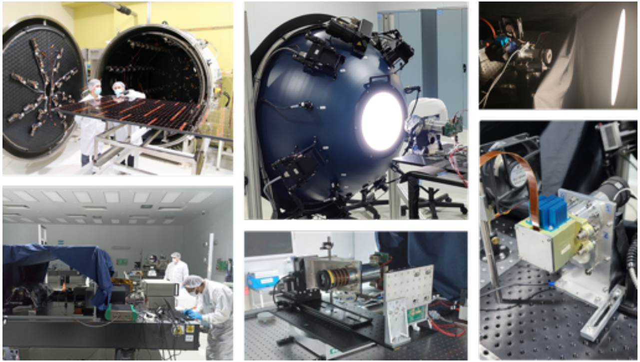
Pre-Launch calibration

Radiometric Corrections Flowchart



Pre-Launch characterization tests status

	Parameter	Status	
		VIS-NIR	NIR-SWIR
Radiometric	Offset/Dark current	Done	Done
	Linearity	Done	Done
	Absolute gain	Done	Done
	Inter-pixel response	Done	Done
	SNR	Done	Done
	Saturation level	Done	Done
	MTF	Done	Done
	Stray light	Done	Done
	Spectral response	Done	Done
	Polarization sensitivity	Done	Done
	Stability	Partially	Partially
	Diffuser(s) BRDF	Not yet	Not yet
Geometric	Pixel lines-of-sight	Done	Done
	Alignment matrix	Not yet	Not yet
	FFOV	Done	Done
	IFOV	Done	Done



SABIA-Mar integration and tests in CONAE and INVAP facilities, where all pre-launch tests are being developed.

Dark Signal subtraction

- Dark signal linear model by pixel is used
- Dark signal non-uniformity (DSNU) is subtracted
- Temperature dependence is considered by using data from optical black pixels for VN camera
- FPA temperature is controlled in NS camera

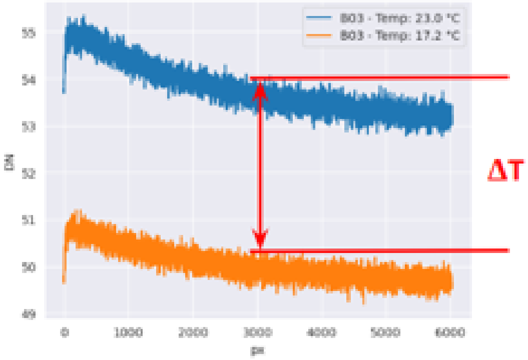


Figure: Dark signal obtained at different room temperatures and configuration of integration time in order to realize a linear model for to implement a correction.

Non-Linearity correction

Non-Linearity (NL)

- Non-linearity correction is performed in order to obtain a linear photo-response
- Fourth order function is preliminarily selected $f(DN) = a \cdot x^4 + b \cdot x^3 + c \cdot x^2 + d \cdot x + e$
- Implementation of mean coefficients for all the pixels or all the spectral bands (lines) will be analysed

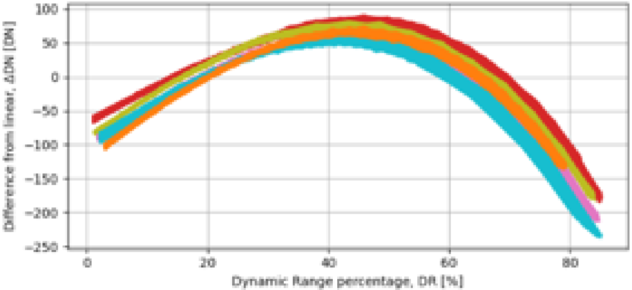


Figure: Different colours represents spectral bands, and overlapping lines are all of the pixels in line. A representative relative NL value is around 0.74% for VN and 0.64% for NS cameras.

Photo-Response Non-Uniformity correction

PRNU correction

- Integrating sphere is used to produce a flat field illumination with each EOM
- PRNU correction is performed in order to obtain an inter-pixel equalization
- The method assumes linear photo-response
- SL effects will be considered in order to avoid overcorrections

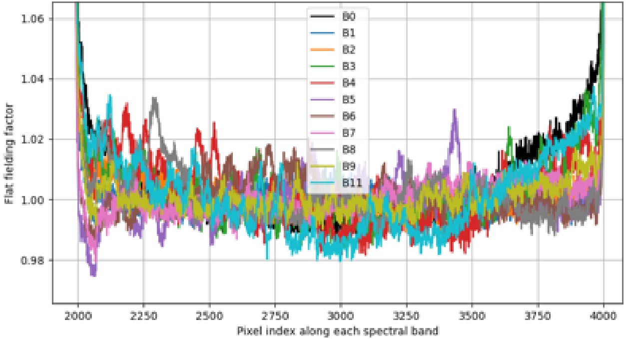


Figure: Factors around one by each spectral band for VN camera pixels in order to obtain a same digital signal for a unique value of input radiance.

Stray light (SL) tests

- Lab measurements were taken for all EOMs, cameras, and spectral bands.
- Spot images were acquired across multiple fields to sample the full FOV.
- Control images were collected to validate the correction.
- PSFs were constructed from the spot measurements.
- Core idea: generate a stray-light map from each PSF, convolve with the real image, and subtract to obtain the corrected image.

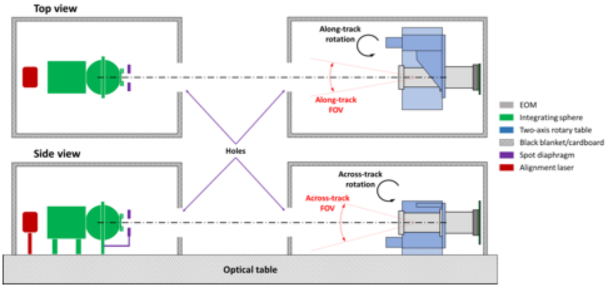
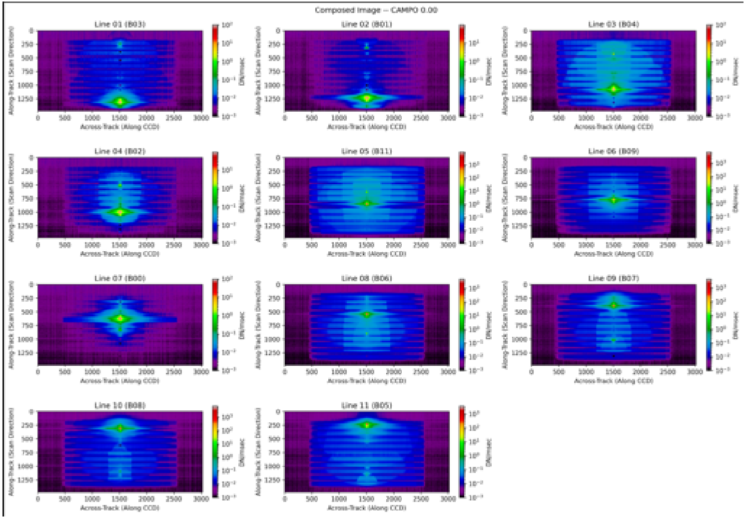


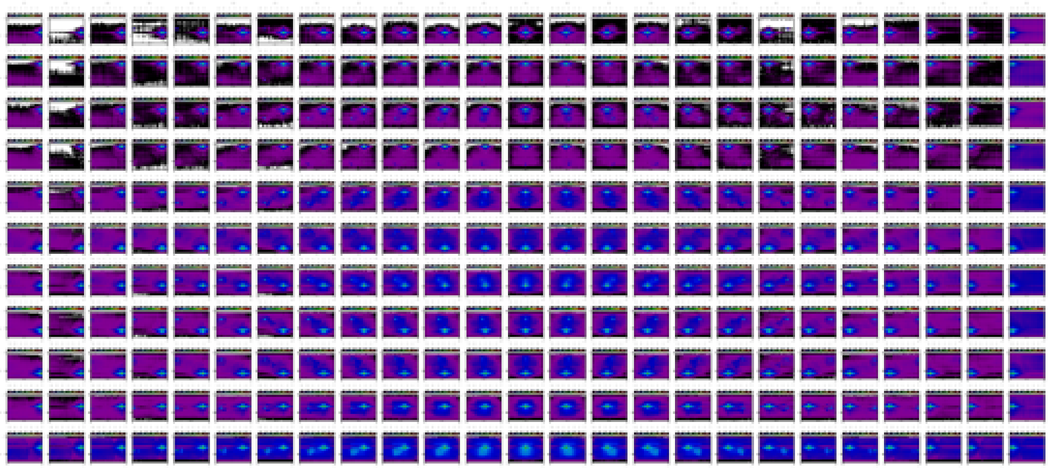
Figure: Stray Light characterization setup used to obtain PSF.

Example: Composed Image for VN3 field 0



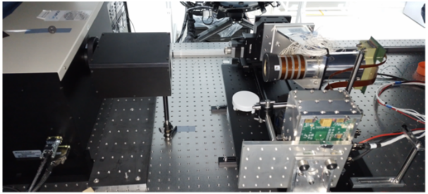
Each picture corresponds to one spectral band of one EOM of VIS-NIR camera, there are 11 pictures. The spot is located in the center of FOV across track (field zero) in the X axis. The Y axis corresponds to along track scan.

Example: PSFs obtained for VN1



PSF obtained for 11 bands $\times$ 25 fields for EOM VIS-NIR 1.

Spectral Response Function



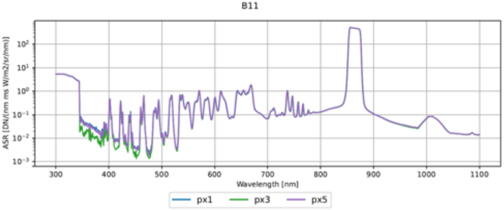


Figure: ASR: Setup (left). ASR for B11 band of VN3 (right).

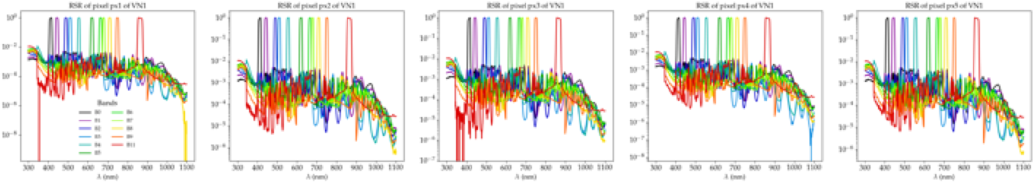


Figure: RSR functions for VN1 bands at different fields.

Out-Of-Band (OOB) correction

Based on Chen's paper (2013) $\longrightarrow$

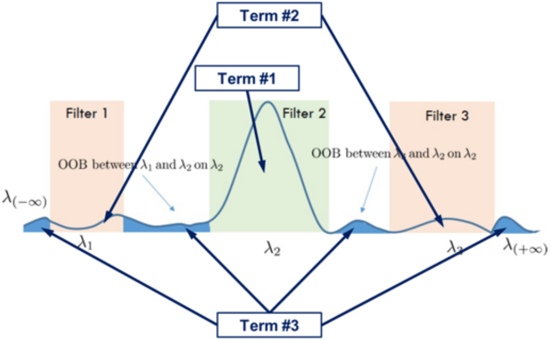
IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 51, NO. 4, APRIL 2013

Out-of-Band Correction for Multispectral Remote Sensing

Wei Chen and Robert Lucke

Measured signal, $\vec{S}_m$, is divided into three terms:

$$[\vec{S}_m]_k = \int_{\lambda \in \{\Delta\lambda_k\}} h_k(\lambda) S(\lambda)\, d\lambda + $$
$$+ \int_{\lambda \in \{\Delta\lambda_l : l \neq k\}} h_k(\lambda) S(\lambda)\, d\lambda + $$
$$+ \int_{\lambda \notin \{\Delta\lambda_k\}} h_k(\lambda) S(\lambda)\, d\lambda$$
$$(k = 1, \ldots, N_{bands})$$



Out-Of-Band (OOB) correction

- The system of N_{bands} equations is linearized and inverted to obtain the OOB-free measurements from the contaminated ones.
- The transformation coefficients depend only on the spectral response functions, $h_k(\lambda)$.
- Preliminary results:

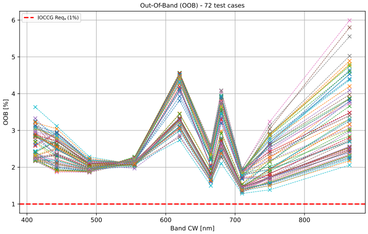


Figure: OOB level (before correction).

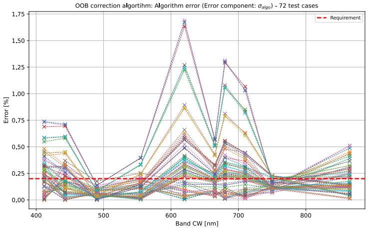


Figure: Algorithm error (after correction).

Polarization Tests

- Determines the parallel optical axes relative to the optical table.
- The polarizer is installed in a motorized rotating frame, allowing controlled and well-aligned variation of the polarization axis angle.
- The EOM is mounted on a rotating platform enabling selection of both the spectral band and the Field of View (FOV).

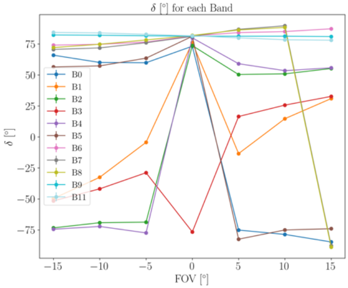
Figure: Polarization sensitivity experimental setup

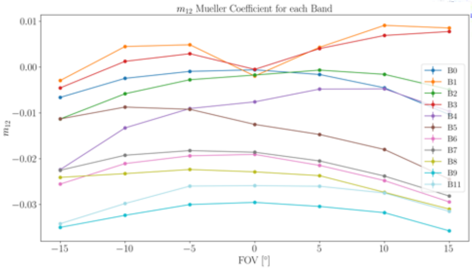
Polarization

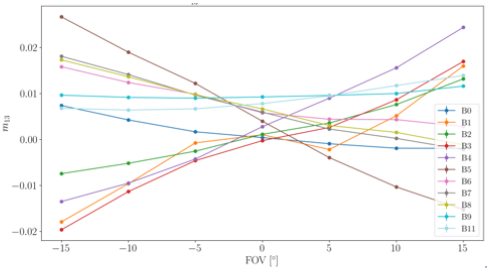
- We computed the Mueller coefficients m_{12} and m_{13} to perform AC by SP:

$$\begin{aligned} m_{12} &= \mathrm{DOLP}_2 \cos(2\delta), \\ m_{13} &= \mathrm{DOLP}_2 \sin(2\delta), \end{aligned} \tag{1}$$

where $\delta = \arctan(D_2/C_2)$ is the phase angle between the polarization axis of the incident light and the system fixed on the EOM.





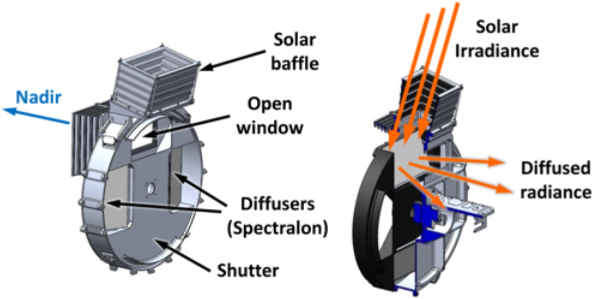


In-Orbit Calibration Plan

Solar Calibration

Objectives

- Absolute calibration.
- Inter-pixel relative calibration.
- Diffuser #1: instrument degradation.
- Diffuser #2: degradation of diffuser #1.
- Shutter: dark signal level correction.



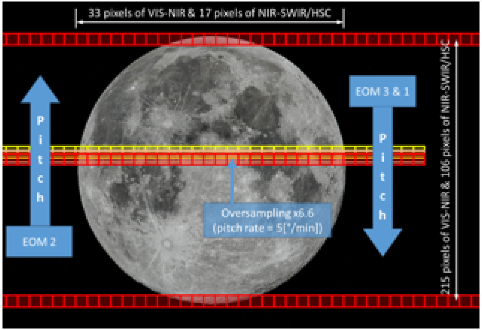
Collections

- Diffuser #1 every 7 days
- Diffuser #2 every 3 months

Lunar Calibration

Objectives

- Validation of Solar calibration and long-term radiometric changes of VIS-NIR and NIR-SWIR cameras.
- Absolute calibration and long-term radiometric changes of HSC response.
- MTF and pointing analysis.
- Assessment of stray-light performance.



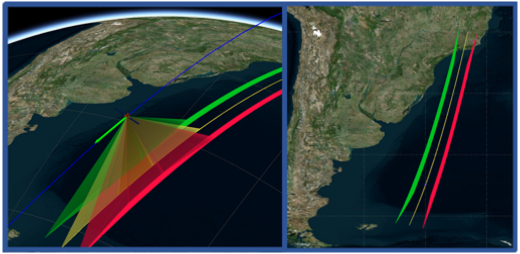
Collections

- 2 lunar disks per band every 29.5 days.
- Lunar phase angles: $\pm 7°$ (~ 1.1 days).
- VIS-NIR, NIR-SWIR and HSC.

Side-Slither & Deep Space

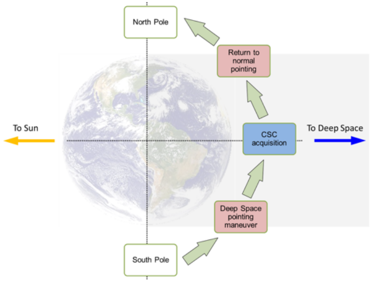
Side-slither

- Inter-pixel and inter-EOM equalization
- 90° rotation in YAW angle
- 5 min every 3 month

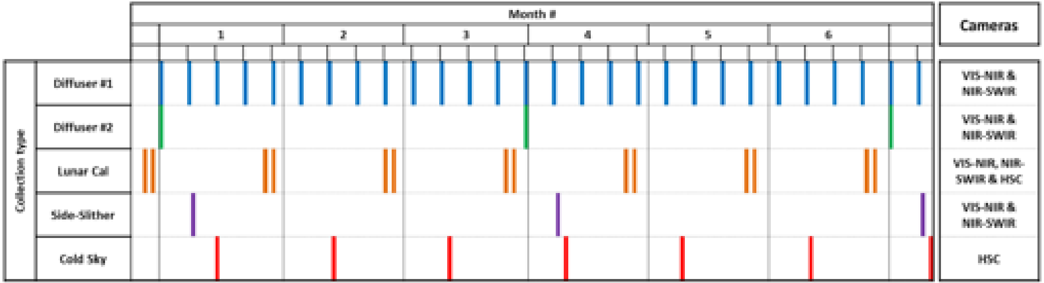


Deep space

- Dark current characterization of HSC camera.
- Pointing assessment using stars.
- 15 min every month.



On-board Collections Summary



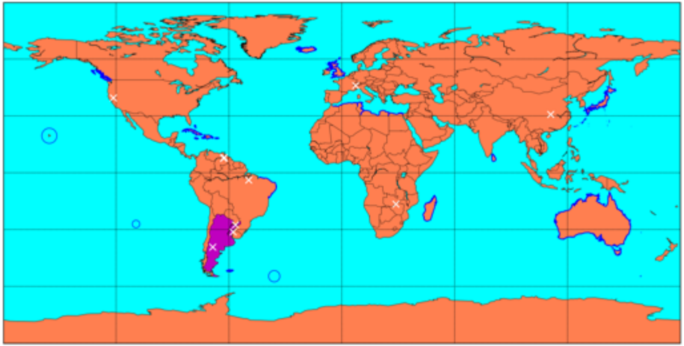
Geometric Calibration

Objectives

- Geolocation assessment and correction.
- Geometric calibration coefficients update: Line-of-sight, alignment matrices, time delay, etc.

Sites

- 17 coastlines and 10 dams structures



Vicarious Calibration

Objectives & Methods

- **Radiometric Vicarious Calibration:**
  - Absolute (Rayleigh scattering)
  - Relative (inter-band using Sun-glint)
  - Inter-camera cross calibration between VIS-NIR, NIR-SWIR and HSC.
- **System Vicarious Calibration:**
  - Fine-tuning of the combined instrument-atmospheric correction system.
  - Available external sites will be used (e.g.: MOBY, HyperNAV, AERONET)

¡Muchas Gracias!

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