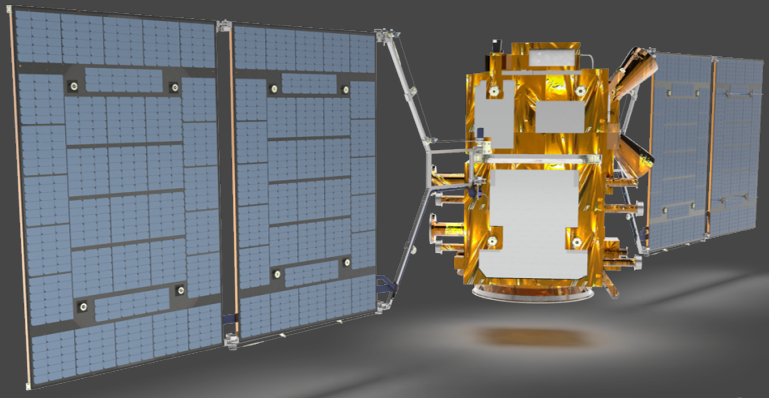
Mission Critical Design Review



SABIA-Mar Project

SECTION: 07E

In-orbit Cal/Val Strategy

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April 24-28, 2023
Centro Espacial Teófilo Tabanera, Córdoba, Argentina

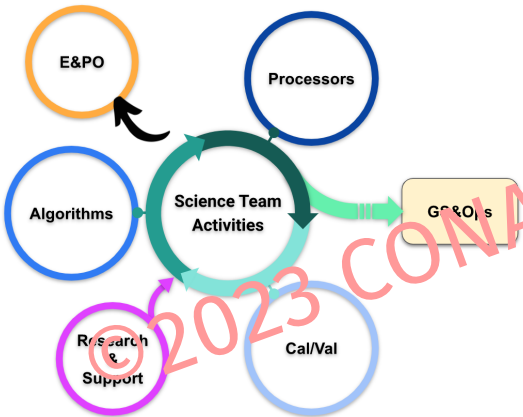
Ministerio de Ciencia, Tecnología e Innovación
Argentina

Contents

Related documentation

- SB-04050000000000-PL-00001-A - Mission Cal/Val Plan
- SB-04050502000000-PL-00001-B - Validation plan for science products
- SB-04050202000000-NT-00002-A - Solar Calibration
- SB-04050202000000-NT-00003-A - Lunar Calibration
- SB-04050202000000-NT-00001-A - Side-Slither Calibration
- SB-04050202000000-PL-00001-A - On-board Calibration Acquisitions
- SB-04050403000000-NT-00001-A - Geolocation On-Orbit Calibration and Validation Plan
- SB-04050301000000-PL-00001-A - Radiometric Vicarious Calibration
- SB-04050303000000-NT-00001-A - System Vicarious Calibration
- SB-08040200000000-IC-00012-A - Auxillary Data Sources Specifications
- SB-04050302000000-SP-00001-A - Especificaciones de Boya Oceánica

Science Team: Cal/Val area overview



- Cameras characterization and calibration requirements.
- Support during pre-launch characterization tests.
- Define and execute the post-launch calibration plan
- Validation plan for L2 and L3 (and higher) products.
- Define and update the imagery scenario: Global coverage, Regional coverage and Cal/Val ROIs.

Contents

On-board calibration

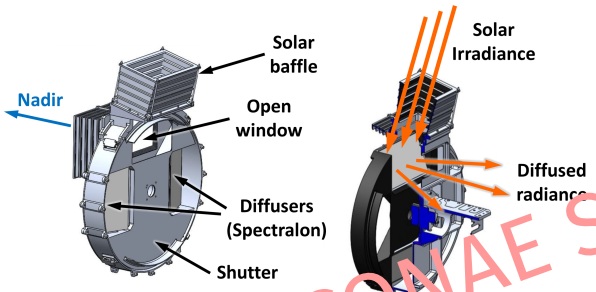
Objectives

- Commissioning phase: to prepare the cameras for normal operation.
  - Adjustment of the instrument's working parameters.
  - Adjustment of the calibration plan.
  - Transfer-to-orbit (on-ground vs on-orbit performance).
  - Testing radiometric performance.
  - Establishing radiometric trending baseline.
  - Update the calibration equation coefficients.
- Routine Cal/Val phase: to maintain cameras calibration throughout the mission life.
  - Correcting for cameras contamination and aging component.

On-board calibration

Methods

- Solar calibration collections: Short- and long-term radiometric changes in VIS-NIR and NIR-SWIR response.
- Shutter calibration collections: Dark signal characterization of VIS-NIR and NIR-SWIR.
- Deep Space/Cold Sky: Dark signal characterization of HSC.
- Lunar calibration collections: Validation of Solar calibration (VIS-NIR and NIR-SWIR). Long-term radiometric changes in HSC.
- Side-slither collections: Inter-pixel equalization.



$$L_{Cal}(B,p) = \frac{\cos(\theta_i)}{d_{Sun-SD}^2} \int E_0(\lambda) f_r^{SD}(\theta_i, p, \lambda, t) RSR_B(\lambda)\, d\lambda$$

- f_r^{SD} →Diffuser BRDF, B →spectral band.
- p →pixel viewing at diffuser with θ_r, ϕ_r.
- t →diffuser degradation over time.

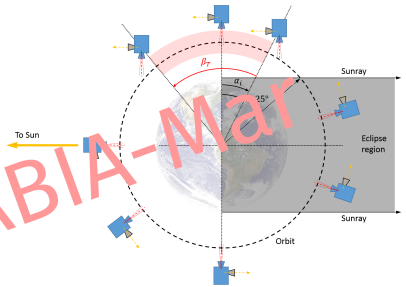
Objectives

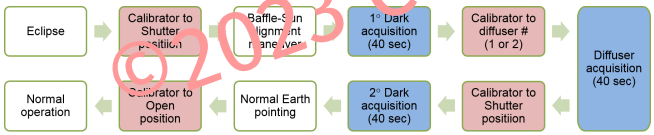
- Absolute calibration.
- Inter-pixel relative calibration.
- Diffuser #1: instrument degradation.
- Diffuser #2: degradation of diffuser #1.
- Shutter: dark signal level correction.

Solar calibration

Collections

- Diffuser #1 every 7 days
- Diffuser #2 every 3 months
- Inertial pointing (constant illumination angle & reduced BRDF characterization).
- 2 T_{int} on consecutive orbits.





Diffuser degradation

- Diffuser #1 < 5% (7hs)
- Diffuser #2 < 0.5% (1hs)
- If t_{SDi} < 15hs:

$$f_r^{SDi}(t_{SDi}) = [1 - D_{SDi} t_{SDi}] f_r^{SDi}(0)$$

Lunar calibration

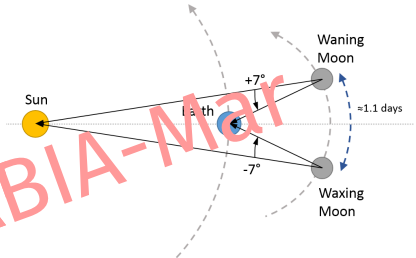
Objectives

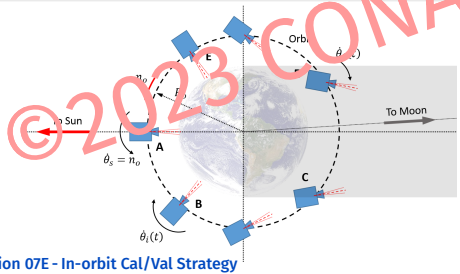
- Validation of Solar calibration and long-term radiometric changes of VIS-NIR and NIR-SWIR cameras.
- Absolute calibration and long-term radiometric changes of HSC response.
- MTF and pointing analysis.
- Assessment of stray-light performance.

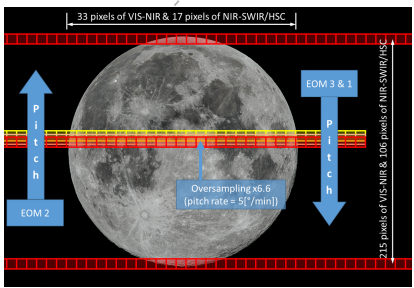
- Disadvantages:
  - Complex maneuver is required.
  - Lunar disk covered by only 33 pixels (VIS-NIR) and 17 pixels (NIR-SWIR and HSC).
  - Non-nominal conditions during acquisitions.

Collections

- 2 lunar disks every 29.5 days.
- Lunar phase angles: ± 7 [deg] (~ 1.1 days).
- VIS-NIR, NIR-SWIR and HSC.
- Pitch maneuver: ~6x oversampling along-track (pitch rate ~5[°/min])







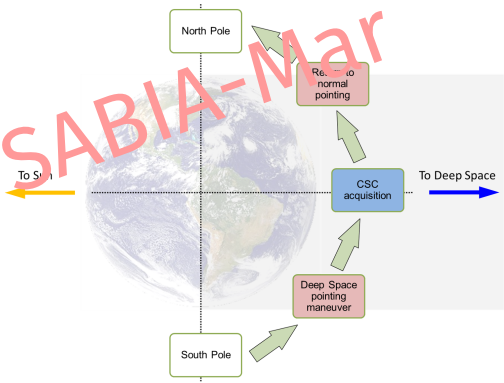
Deep Space/Cold Sky calibration collections

Objectives

- Dark current characterization of HSC camera.
- Pointing assessment using stars.

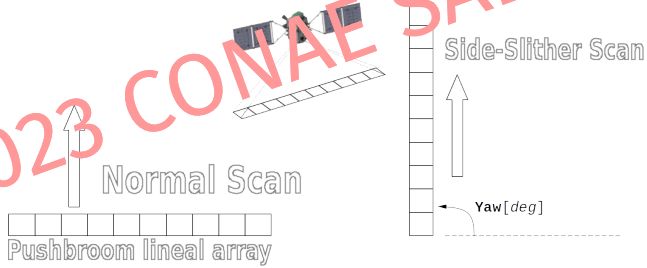
Collections details

- 15 minutes per month.
- Near new moon to avoid contamination.
- Avoid regional scenario.



Main characteristics

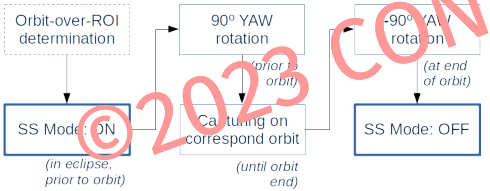
- It allows *flat-fielding* effect.
- Nominal conditions during acquisitions.
- A Yaw 90° satellite platform rotation is required.



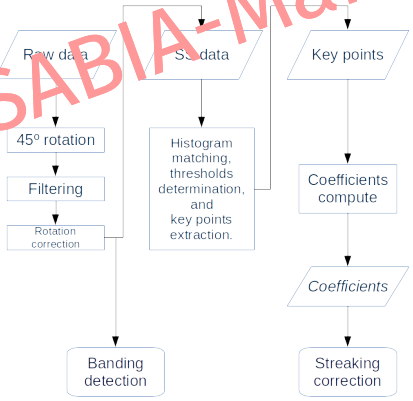
Side-slither collections

- Relative calibration considering *streaking* and *banding*
- In order to align to Nadir direction both spectral bands and EOM's pointing additional Pitch and Roll satellite platform rotations are considered
- Main method constrains
  - Inter band coregistration
  - Large inter spectral band pointing angle along-track
  - Large inter EOM pointing angle across-track
  - Enough large usable on-ground area
  - Achievable dynamic range (*ground and ocean radiance levels*)
  - Pointing accuracy and stability
  - Optical alignment uncertainty
  - Spatial and temporal on-ground stability

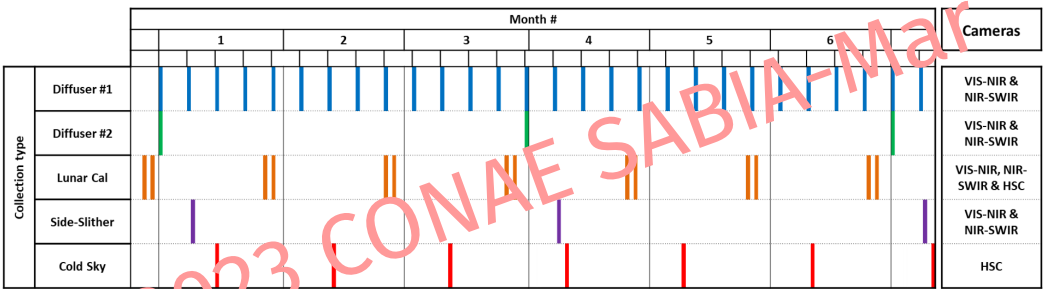
- Collections plan every 3 months
- Minimum time for a complete collection: 4 to 7 [min]
- Main stages during maneuver:



- Correction coefficients generation flowchart proposed (under review):



On-board collections plan



Geometric calibration

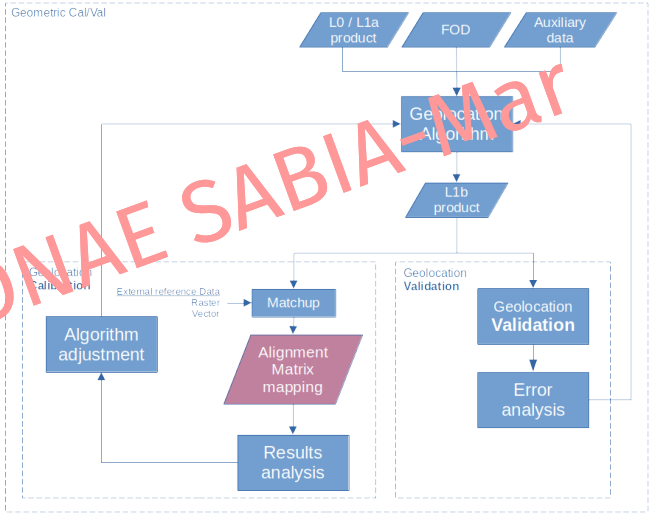
Objectives

- Accurate geometric correction and calibration based on sensor line-of-sight model
- Geometric calibration coefficients generation by using L1b products
- To verify thermal expansions and contractions long-term effects

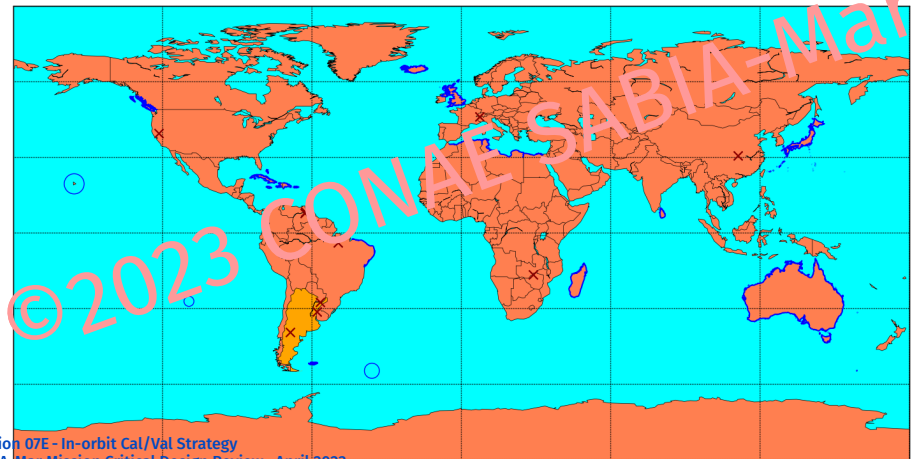
Methods

- Calibration coefficients update algorithm (*geolocation algorithm adjustment*)
- Geolocation validation (*satellite images and auxiliary data correlation method*)
  - Validation process based mainly on an satellite images correlation technique

- Geolocation Cal/Val flowchart

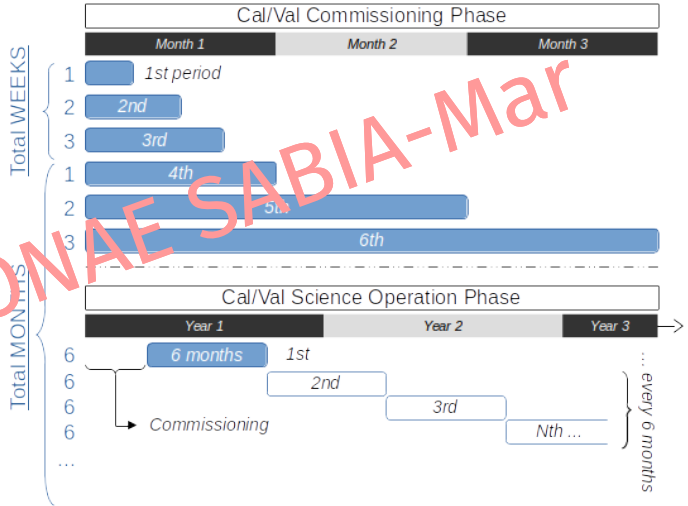


- Proposed sites for geometric calibration (*17 coastlines and 10 dams structures*)



Geometric calibration

- Phases: **intensive** phase and **operational** phase.
  - Intensive phase: calibration periods are incremental over the first 3 months in Commissioning mission phase. This first stage is carried out in conjunction with the **Engineering Team**.
  - Operational phase: every 6 months. This second stage is carried out for **Science Team**.



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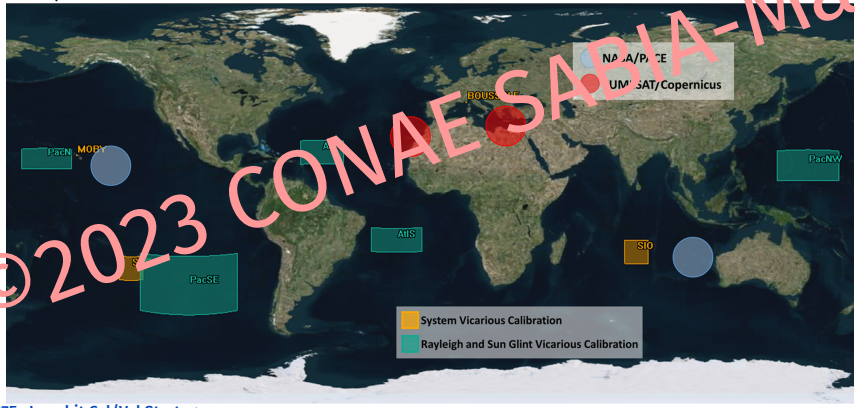
Vicarious calibration methods

- Radiometric Vicarious Calibration:
  - Absolute (*Rayleigh scattering*)
  - Relative (*inter-band considering 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)

Vicarious Calibration Sites

- Radiometric **absolute** calibration based on Rayleigh and Relative inter-band calibration using Sun-glint characteristics (*black ocean* and *clear atmosphere* regions).
- **System** vicarious calibration (buoys and measurement systems for calibration of OC products)



Contents

In-situ data sources I

For Products validation and coefficients adjustment (sometimes called *Products Calibration*) we will uses the following data sources:

- *In-situ* data bases for Global scenario: NOMAD, SeaBASS, MOBY, AERONET-OC, HyperNet, GLORIA, AODN, CFOO, NDBC.
- *In-situ* permanent stations for Regional scenario in Argentina:
  - AERONET-OC Bahía Blanca.
  - *Estación Permanente de Estudios Ambientales (EPEA)*
  - Marine Observations Network from Argentina (ROMA).
  - Red de Investigación de Estresores Marinos-Costeros de América Latina y El Caribe (REMARCO)
  - Estaciones de Monitoreo Ambiental Costero (EMAC)
- Field campaigns for Regional scenario:
  - Pampa Azul campaigns of opportunity
  - Institutional agreements: with INIDEP for exchange campaigns and EPEA data, with IAFE for Turbidity data, with CENPAT for coastal Chl-a data in Norht Patagonian Gulfs, whit INA for in-land waters, with PNA for night boats detection, with UNS for Mareographic Tower validation site.
  - Institutional agreements for in-land waters: INA and PROSAT II.

In-situ data sources II

- *In-situ* data for Regional scenario in South America:
  - *Projeto Sistema de Monitoramento da Costa Brasileira (SIMCosta)*
  - *Instituto del Mar de Perú (IMARPE)*
  - *Servicio Hidrográfico y Oceanográfico de la Armada de Chile (SHOA)*
  - *Centro de Estudios Avanzados en Zonas Áridas (CEAZA)* de Chile
  - *Centro de Investigación en Ecosistemas de la Patagonia (CIEP)* de Chile
  - *Centro de Datos Oceanograficos y Metereologicos (CDOM)* de Chile.
- CONAE's Future plans:
  - CONAE's Program for Argentinian Sea Bouy's.
  - Network for In Situ and Satellite Monitoring of Argentinian Waters (MISS-Arg).
  - Strengthen CONAE's capabilities acquiring additional instruments for in-situ campaigns.
  - Complement with additional equipment the Bahía Blanca Mareographic Tower in order to become a *SABIA-Mar* validation site.

In-land waters actual monitoring (INA and PROSAT):

- Embalse Salto Grande,
- Embalse Río Tercero,
- Embalse San Roque,
- Lago Moreno,
- Embalse Ramos Mexía,
- Embalse El Carrizal,
- Embalse Los Molinos,
- Lago Nahuel Huapi,
- Lago Gutiérrez,
- Río de La Plata.
- Laguna Mar Chiquita.

ROMA stations

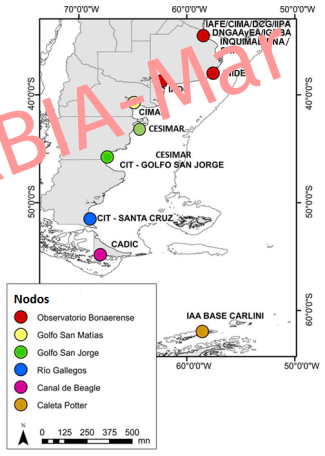
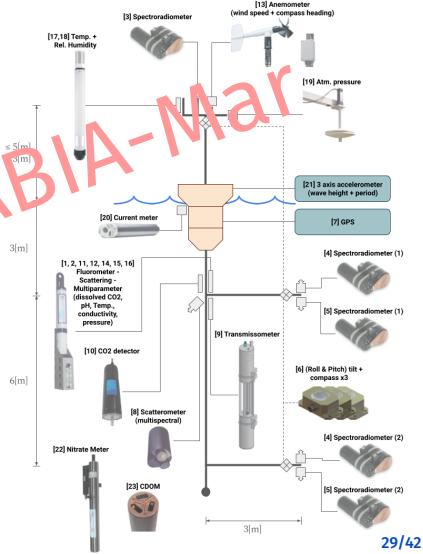


Image courtesy of ROMA Project.

CONAE capabilities for field campaigns

- Photometer: Microtops II Model 521 sun photometer manufactured by Solar Light (305.5; 312.5; 320.0; 936 ; 1020nm).
- Field Spectroradiometer: ASD FieldEspec FR spectrometer, with 3 nm from 350 to 700 nm and 10 nm spectral resolution from 1400 to 2100 nm.
- GPS: Marine hand help high sensitivity GARMIN GPSMAp 78s with hotfix.
- Sonda AlgaeTorch (de bbe molddaenke):Real time fluorescence measurements. Blue-green algae [μg chl –a/l], total chlorophyll [μg chl –a/l], turbidity, GPS coordinates. Measurement range 0 - 500 μg Chlorophyll-a/l; Resolution 0.1 μg Chlorophyll-a/l. Sample temperature 0 - 40 C. Turbidity correction 0 - 200 turbidity units.
- Aquared probe for disolved oxygen.
- Aquared probe for conductivity and suspended solid.
- Spectrophotometer UV-Vis doble real beam Peaks Instruments, model C 7200 S (190 a 1100 nm).
- To be acquired: Nano-Hyperspec VNIR Imaging Sensor.

- A program for the development of buoys in the Argentinian Sea is being carried out by CONAE and IADO (Argentinian Institution of Oceanography).
- The current project is planned as follows:
  - Perform environmental and feasibility studies.
  - Evaluate *in-situ* data acquisition effectiveness vs. time periods.
  - Develop, at least, an operative prototype prototype buoy suitable to SABIA-Mar Cal/Val system.
  - Elaborate buoy specifications and an affordable Maintenance Plan according to Cal/Val System Requirements
- The requirements for products validation and algorithms calibration were identified.



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Variables of interest

1. Chlorophyll-a (Chl-a)
2. Turbidity (T)
3. Downwelling solar irradiance (Es)
4. Downwelling irradiance (Ed) at two depths
5. Upwelling radiance (Lu) at two depths (10 degree FOV)
6. Orientation Angles (two-axis tilt)
7. Geolocation (latitude, longitude and time)
8. Multi-spectral backscattering coefficient (Bb)
9. Beam attenuation coefficient (c)
10. Partial pressure of CO2 gas dissolved in water (pCO2)
11. Dissolved O2
12. pH
13. Wind Speed and compass heading
14. Temperature (below water)
15. Conductivity
16. Pressure
17. Air Temperature
18. Air Relative Humidity
19. Atmospheric pressure
20. Current
21. Wave height and period
22. Nitrate
23. fDOM

SABIA-Mar, SM Complementary, SAOCOM, General

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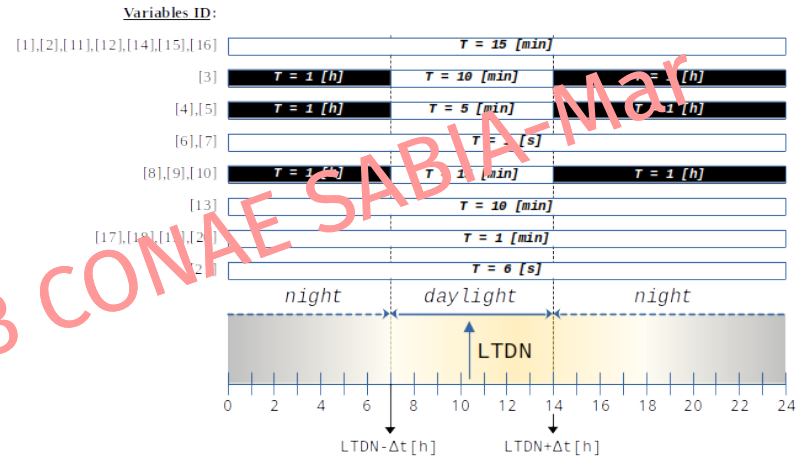
Daily collections plan

- *T*: collections period
- *LTDN* = 10:20 [*h*]
- $\Delta t \approx 3$ [*h*]



Future Monitoring Network MISS-Arg

Main idea and objectives:

- Inter-institutional network for sustained monitoring of some fixed points in coastal zone and in-land water bodies.
- Develop common methodologies for modeling, validating and calibrating coastal and inland water quality indicators, based on remotely sensed information from satellites in addition to in situ measurements.
- Establish the capabilities (human and equipment resources) to acquire calibration and validation qualified data in inland and coastal waters for SABIA-Mar mission products.
- Develop unified protocols in concordance with standard Ocean Color community protocols for *in situ* measurements.

Future Monitoring Network MISS-Arg

Initial areas of study and monitoring frequency (expandable):

- Node Coastal zone: Bahía Nueva and Las Grutas. In coordination with CENPAT.
- Node In-land waters: Embalse de Río Tercero, Laguna Mar Chiquita, Lago San Roque. In coordination with IG and UNRC.
- Pre-launch (2024-up to launch): monthly and seasonal coincident with actual satellite passes.
- Post-launch: weekly (TBD) coincident with SABIA-Mar pass.

Equipment needed for each network node:

- Air/underwater radiometers (TRIOS) (350-950 nm).
- Air radiometer (ASD) in the range (350 -2500 nm).
- Nefelometer (Hach turbidimeter).
- Fluorometer / multiparametric proud
- HPLC equipment for Chl-a lab determination.

In-situ data sources summary

	Regional Scenario	Global Scenario
CONAE resources	Radiometer	
	Photometer	
	GPS	
	Turbidimeter	
Existing data available free	Aeronet -OC BB	SeaBass
	GLORIA	GLORIA
		AERONET-OC
External under agreement	Pampa Azul campaigns of opportunity	IAFE(T)
	PICT Golfo San Matias (Lw, Chl-a)	Scrippts Institution (PAR)
	EPEA	HYPERNET
	AERONET-OC BB (Lw)	HYPERNAV
	HYPERNET	Vicarius calibration sites (other missions)
	IAFE (T)	
	ROMA	
	EMAC	
	REMARCO	
CONAE's Future infrastructure	Bahia Blanca Mareographic Tower	
	CONAE's Buoys system	
	New equipment to be acquire	

Contents

L2 SABIA-Mar Products Validation Plan is based on Bailey and Werdell protocol [1].

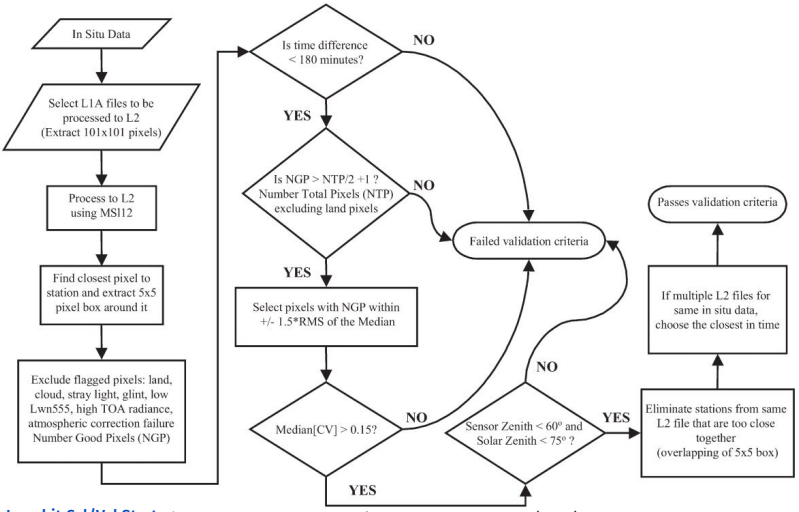
This protocol will be applied for Ocean Color variables: normalized Water Leaving Radiance L_W, Chlorophyll-a concentration $Chl-a$, Diffuse Attenuation coefficient $K_d(490)$, Photosynthetically Available Radiation PAR and turbidity T.

1. Bailey, S. W., Werdell, P. J. (2006). A multi-sensor approach for the on-orbit validation of ocean color satellite data products. Remote Sensing of Environment, 102(1–2), 12–23. https://doi.org/10.1016/j.rse.2006.01.015

Pixel selection criteria

- Criteria for *in situ* data set selection
  - Field instrument
  - Measurements during campaigns
  - Data processing
  - Ancillary information
  - Optically shallow water
  - Normalized water-leaving radiance **BRDF** to normalize $L_W(\lambda)$
- Criteria for Satellite data set selection
  - Spatial Considerations
  - Coincidence determination
  - Satellite data set processing
  - Satellite data set screening
- Statistics parameters stored for each satellite record

Products Validation: flowchart



Extracted from: Bailey, S. W., Werdell, P. J. (2006).

Metrics

- Metrics
  - Error metrics
  - Decision graphics

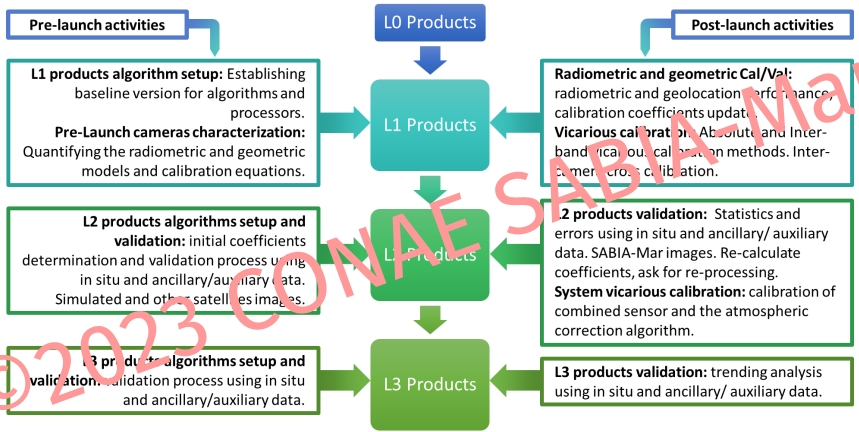
Product	Error Metrics	Graphics
Lw	Mean Slope Intercept r^2 RMSE BIAS	Scatterplots Residual plots Star plots
Chl-a		
Turbidity		
PAR		
Kd(490)		

Summary of metrics and graphics for SABIA-Mar products. Core performance metrics for algorithm evaluation include bias (systematic error), variability (random error, precision), and accuracy that combines bias and variability. Generally, systematic bias and accuracy metrics are calculated, and random error is inferred.

L3 validation methods

- Level-3 Temporal Trending
  - Level-3 trend analysis looks at long-term trends on global and regional spatial scales.
- Temporal Anomaly Analysis
  - The mean annual cycle for each parameter is subtracted from time series
- Trend Comparisons and Common Bins
  - Refers to compare Level-3 trends between missions.

Summary of Cal/Val Activities



QUESTIONS?