Copernicus FICE 2025

Training on
In situ Ocean Colour Above-Water Radiometry towards Satellite Validation

HyperCP Introduction

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PROGRAMME OF THE EUROPEAN UNION
Copernicus Europe's eyes on Earth
IMPLEMENTED BY EUMETSAT
FRM4SOC Phase-2
fiducial reference measurements for satellite ocean colour
CNR ISMAR
ISTITUTO DI SCIENZE MARINE

July 7-19, 2025
Venice, Italy

NASA

HyperCP Introduction

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NASA Goddard Space Flight Center
GESTAR-II Morgan State University

Instructors

HyperCP

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Funding is provided by the NASA PACE Mission and the Copernicus Programme

HyperCP Project Team

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Funding from NASA PACE Mission and Copernicus FRM4SOC Initiative

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[10] NOAA NMFS
[3] EUMETSAT
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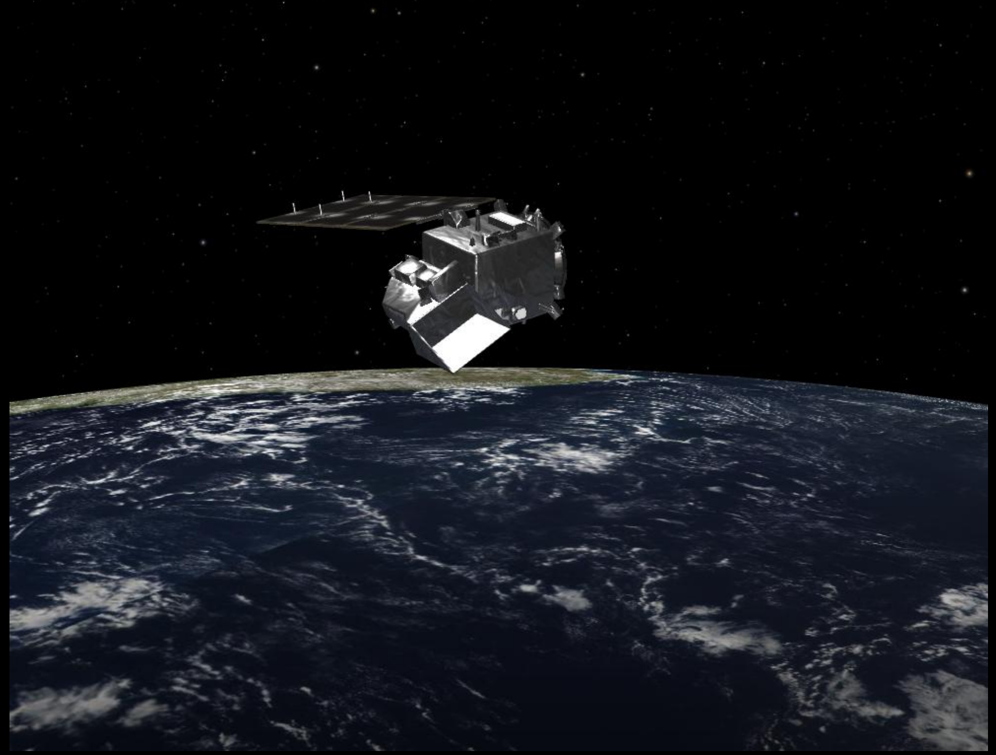
[9] Gybe Inc.

Background

Mission instruments are meticulously characterized prior to launch: stray light, thermal response, SNR, etc. to quantify and correct for anomalies.



On orbit, they require validation and system vicarious calibration to account for radiometric drift and atmospheric correction error.

SVC is traditionally at fixed, dedicated platforms in blue waters, but validation can come from portable platforms in all optical water types.

Rigorous validation requires high-quality, hyperspectral in situ radiometry from many locations and water types.

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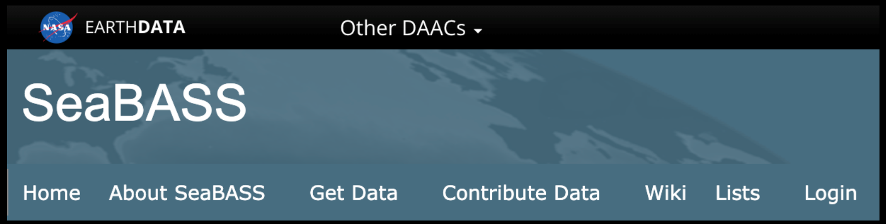
What is HyperCP?

Open-source processor for Above Water Radiometry (AWR) that facilitates **protocol-driven** data correction and reduction yielding high-quality surface reflectance measurements with end-to-end **uncertainty propagation** for submission to NASA's SeaBASS and Copernicus' OCDB archives for use in satellite validation and ocean color algorithm development



HyperCP

What's in a name?

A shameless compound acronym:

HyperCP = HyperInSPACE Community Processor
HyperInSPACE = Hyperspectral In situ Support for PACE
PACE = Plankton, Aerosol, Cloud, ocean Ecosystem [mission]

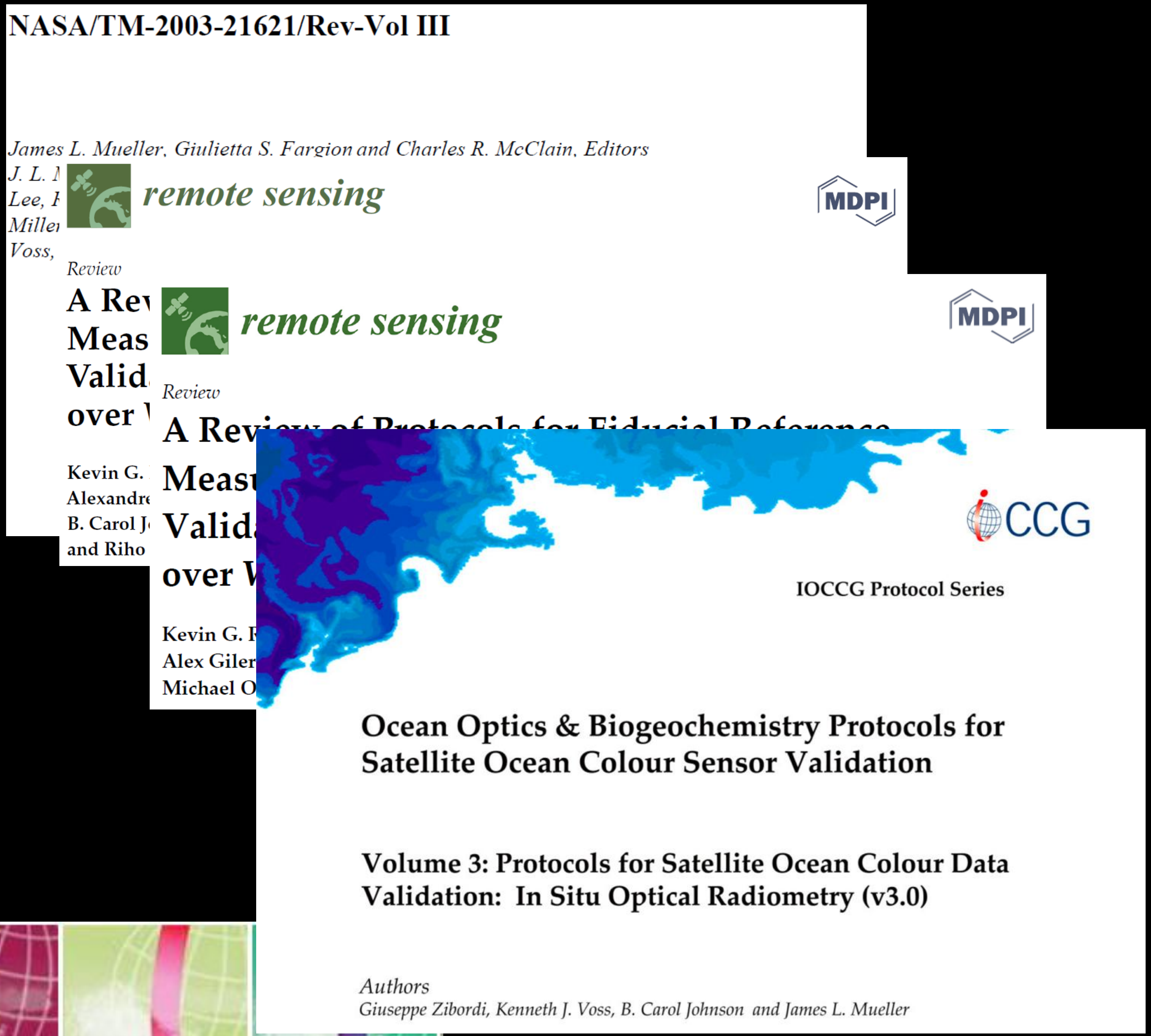
Hyperspectral In situ Support for Plankton, Aerosol, Cloud, ocean Ecosystem Community Processor

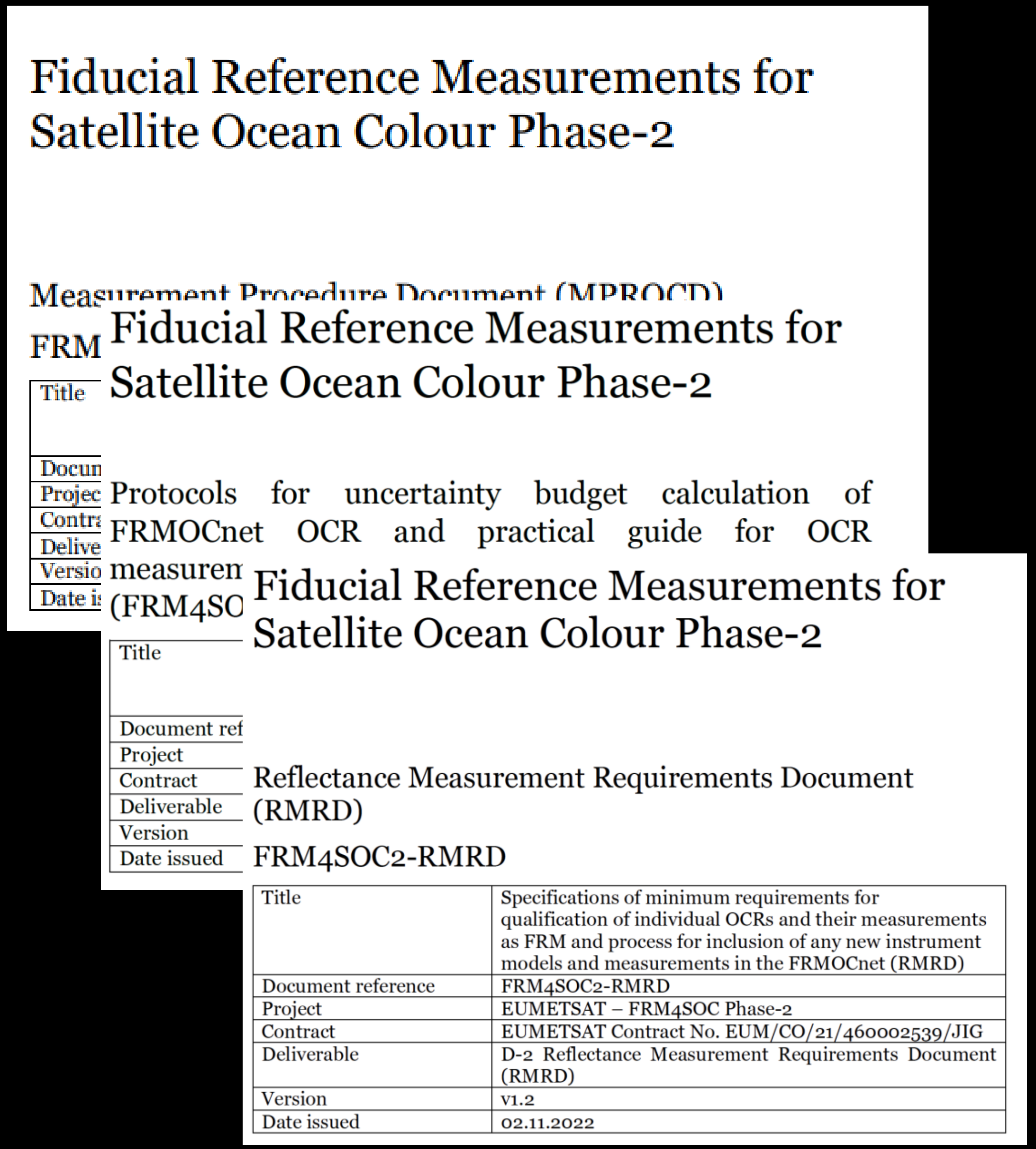
Sure to tax any title or abstract word limit.
We also sometimes call it **HCP**, for short.

HyperCP History

AWR protocols were updated by IOCCG and the community ~2017 - 2019 for the first time since the SeaWiFS era.

HyperInSPACE began at Goddard Space Flight Center toward the end of this period to process NASA's own radiometry and help the community process AWR following these protocols.





HyperCP History

2017

University of Victoria

PySciDon

Vandenberg Masters Thesis w/ M. Costa U. Victoria

1

2018

2

Initiated at NASA Goddard to incorporate IOCCG draft protocols and other advancements in AWR

3

α release

Internal alpha version shared at NASA

OSM2020

4

β release

Transition from internal NASA testing to invited external release

5

NASA GitHub

Official NASA public release v1.0.x

https://github.com/nasa/HyperInSPACE

6

NASA/FRM4SOC Meeting

GODDARD EARTH SCIENCES · EUMETSAT · NPL National Physical Laboratory · fiducial reference measurements for satellite ocean colour · ACRI ST

Discussed collaboration on HyperInSPACE to form a community processor compliant with FRM framework

7

v1.1.x release

Structural overhaul to accommodate incoming updates from FRM4SOC:

To add TriOS
To add full instrument characterization and uncertainties

8

HyperCP for FICE-2022

Identified for use in Field Intercomparison Experiment at AAOT

9

HyperCP Project Team Formed

Official collaboration guidelines adopted

10

HyperCP

v1.2.x release

FRM4SOC2 Updates incorporated:

TriOS
Full instrument characterization and uncertainties

4

FICE-2024

Training event for ocean colour above-water radiometry at AAOT

2019: Q1 Q2 Q3 Q4 | 2020: Q1 Q2 Q3 Q4 | 2021: Q1 Q2 Q3 Q4 | 2022: Q1 Q2 Q3 Q4 | 2023: Q1 Q2 Q3 Q4 | 2024: Q1 Q2 Q3 Q4

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HyperCP

HyperCP Guiding Principles

1. Informed by Scientific Consensus : Protocol Driven

2. Open Source: Transparent

3. Open Science: Free and Accessible

4. Collaborative & Adaptive: State of the Science

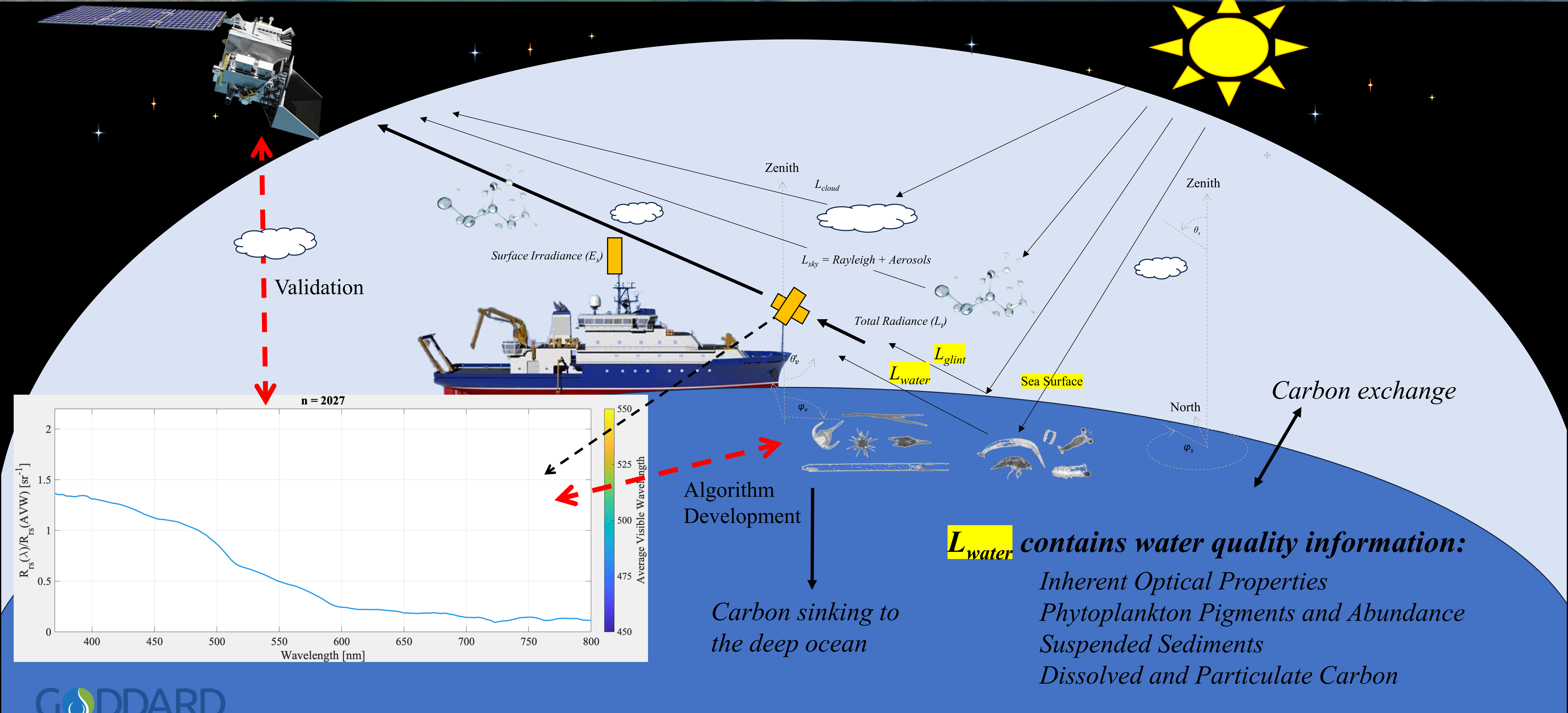
5. Community Resource

By the community for the community

Above Water Radiometry (AWR)

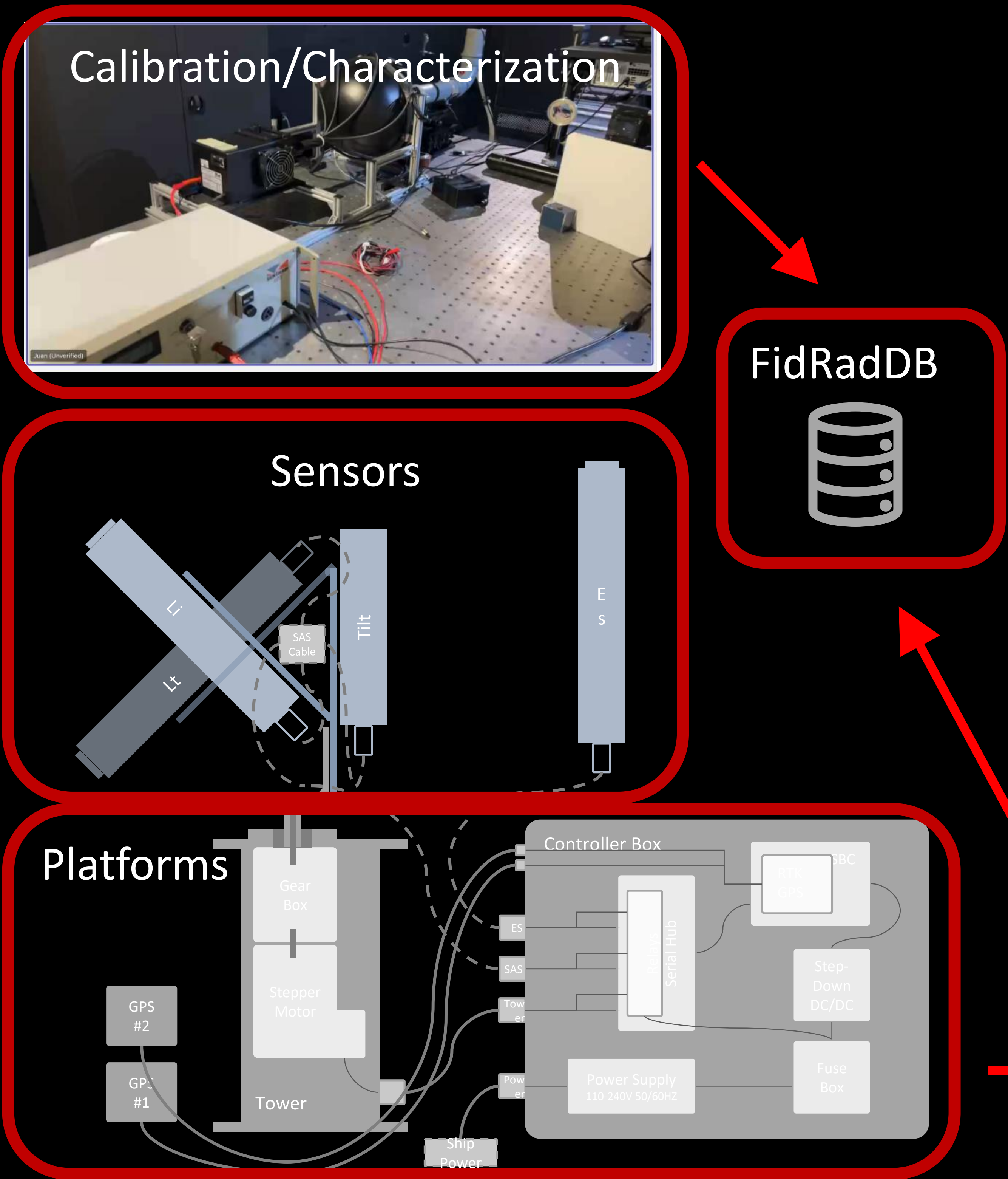
Principles and Theory

In Situ Above Water Radiometry (AWR)



(Cytometry images from Karlusich et al., Front. Mar. Sci., 2002)

HyperCP Ecosystem



Supported Sensors:

- Sea-Bird Scientific HyperOCR
- TriOS RAMSES
- IMO DALEC

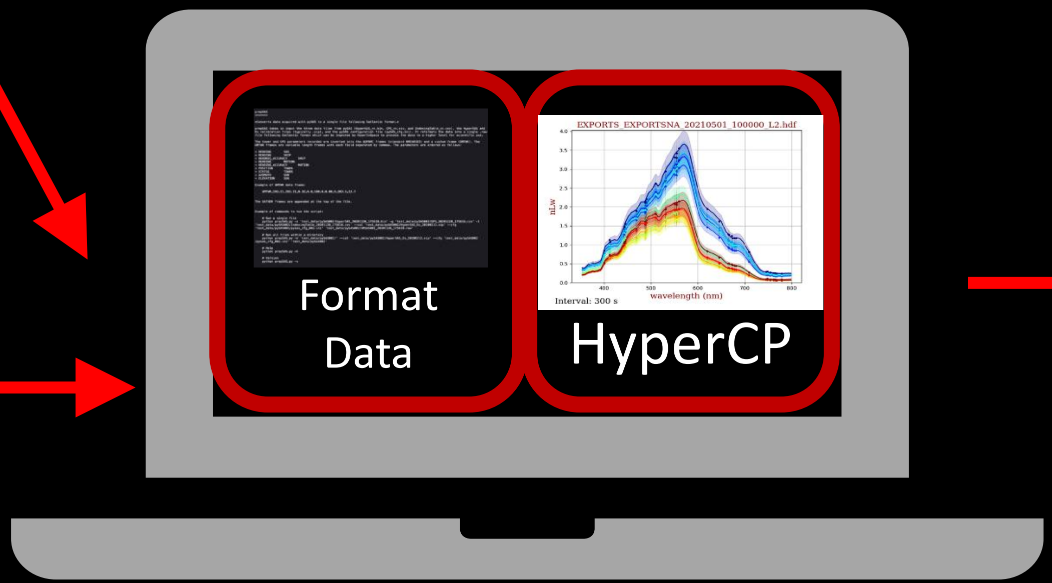
Platforms:

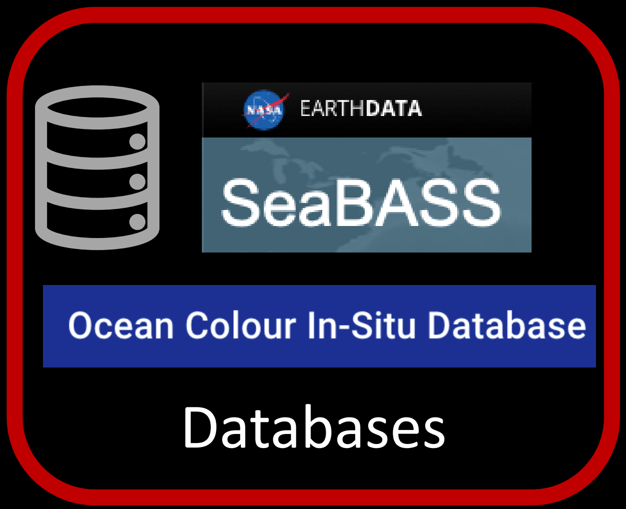
- Robotic: pySAS, Sea-Bird SolarTracker, DALEC, So-Rad, …
- Manual

Data Formatters: prepSAS, prepDALEC, …

Community Processor: HyperCP

Databases: FidRadDB, SeaBASS, OCDB






Manual Systems
pySAS
PANTHYR*
SoRad*
Manual Systems
PML
RRS Discovery met platform with AMT4 instruments.
HyperSAS radiometers
Sonic anemometer
C-band radar
Bow view
DALEC
pySAS
SolarTracker
*not currently adapted within HyperCP
SolarTracker

Water Leaving Radiance

Sea surface reflectance factor   Skylight radiance

$$L_w(\theta_v, \varphi_v, \lambda) = L_t(\theta_v, \varphi_v, \lambda) - \rho(\theta_s, \varphi_s, \theta_v, \varphi_v, \lambda, \mathrm{W}, \tau, \mathrm{T}, \mathrm{S}) * L_i(\theta_v, \varphi_v, \lambda)$$

Total upwelling radiance

$$= L_t(\theta_v, \varphi_v, \lambda) - L_r(\theta_s, \varphi_s, \theta_v, \varphi_v, \lambda, \mathrm{W}, \tau, \mathrm{T}, \mathrm{S})$$

Remote Sensing Reflectance

$$R_{rs} = \frac{L_w(\theta_v, \varphi_v, \lambda)}{E_s(\lambda)}$$

Sea surface irradiance

Normalized Water Leaving Radiance

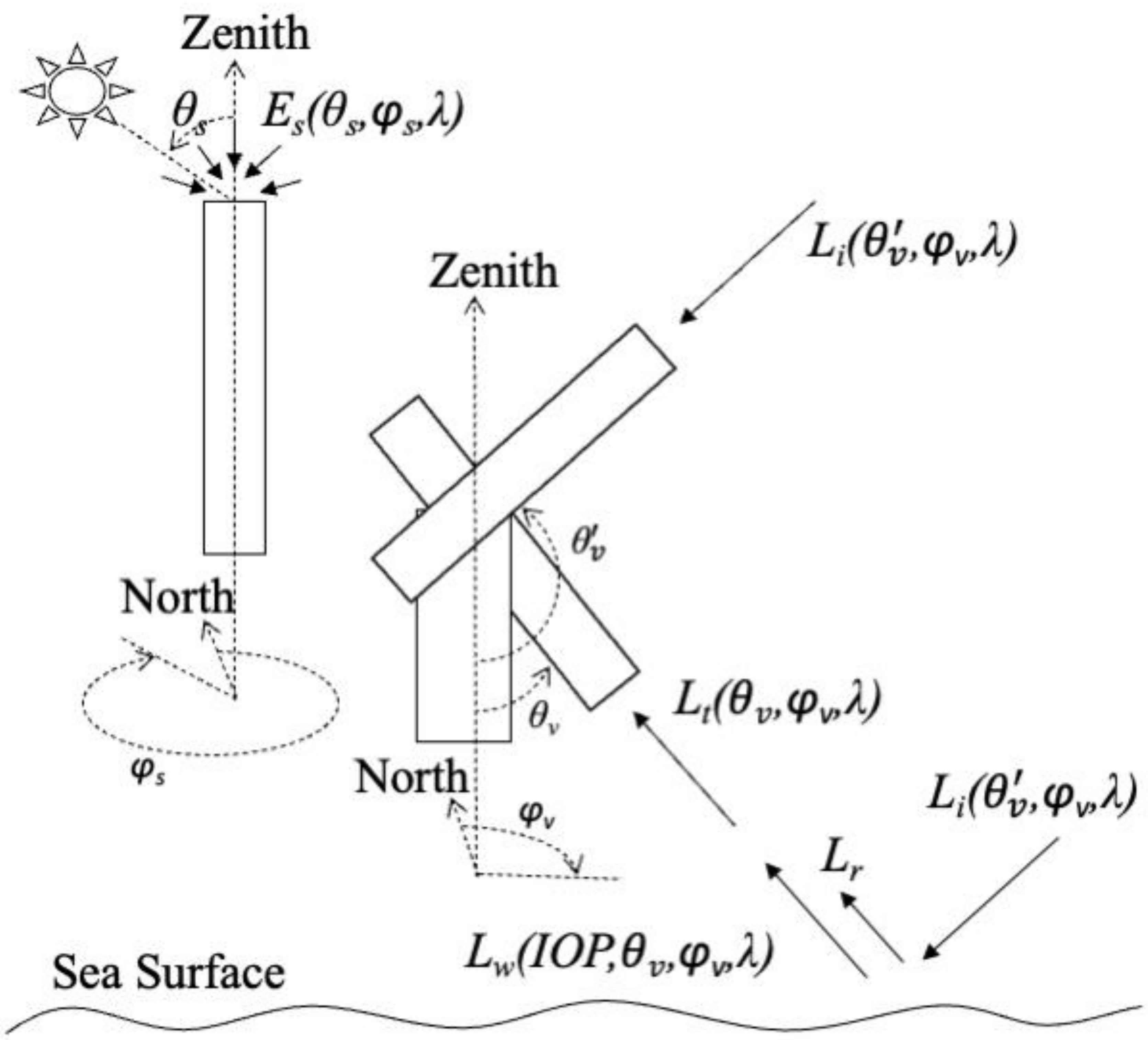
$$nL_w = R_{rs} * F0,$$

TOA irradiance

Exact Normalized Water Leaving Radiance

Corrected for BRDF nL_w^{ex}.

(adjusted to $\boldsymbol{\theta}_s = 0$, $\boldsymbol{\theta}_v = 0$)



Primary Challenges

Sea surface glint, platform perturbations, solar/sensor geometries, the environment, metrology, and traceability

Sun/Sky Glint Subtraction

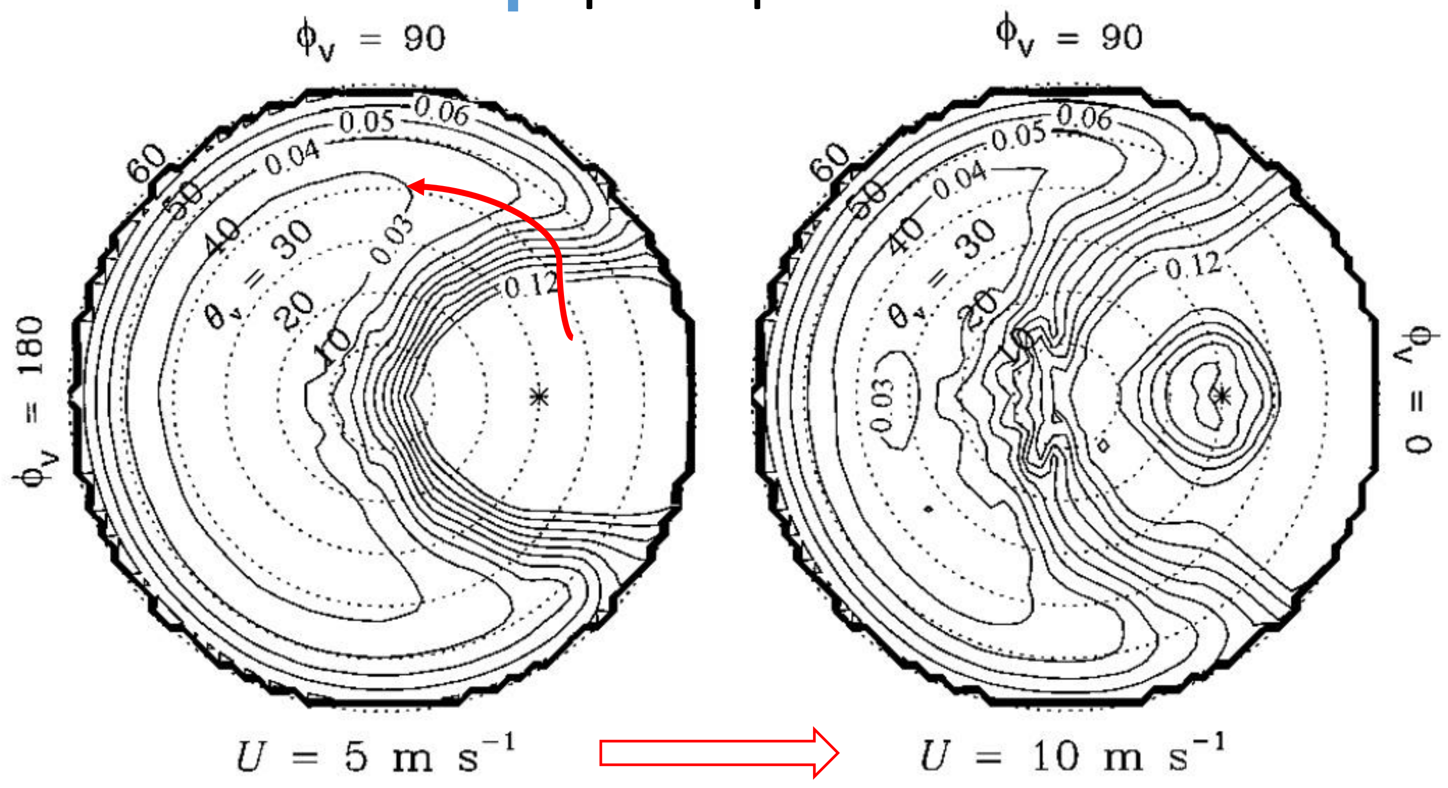
$$L_w(\theta_v, \varphi_v, \lambda) = L_t(\theta_v, \varphi_v, \lambda) - \rho(\theta_s, \varphi_s, \theta_v, \varphi_v, \lambda, \mathrm{W}, \tau, \mathrm{T}, \mathrm{S}) * L_i(\theta_v, \varphi_v, \lambda)$$

ρ: Sea surface reflectance factor

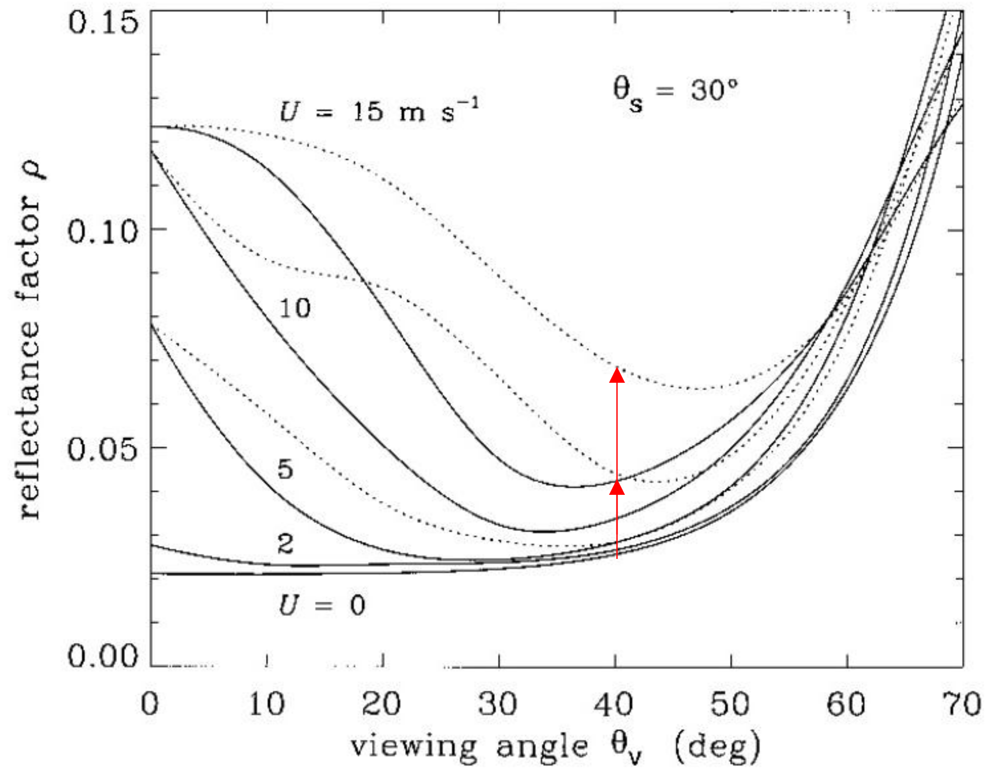
- $\boldsymbol{\theta_s}$: Solar Zenith Angle
- $\boldsymbol{\varphi_s}$: Relative Azimuth Angle
- **W**: Wind speed (Cox & Munk 1954)
- $\boldsymbol{\tau}$: Aerosol optical thickness
- **T**: Temperature
- **S**: Salinity

ρ is also slightly dependent on skylight polarization.
ρ is most dominated by $\boldsymbol{\varphi_s}$, peaking at the specular point of the sun.
ρ is optimal (low) at $\boldsymbol{\varphi_s}$ in 90° – 135°.
However at $\boldsymbol{\varphi_s}$ **=** 135° superstructure perturbation is typically increased.

ρ: polar plots



High values of **ρ** affecting more viewing geometries as surface becomes rougher



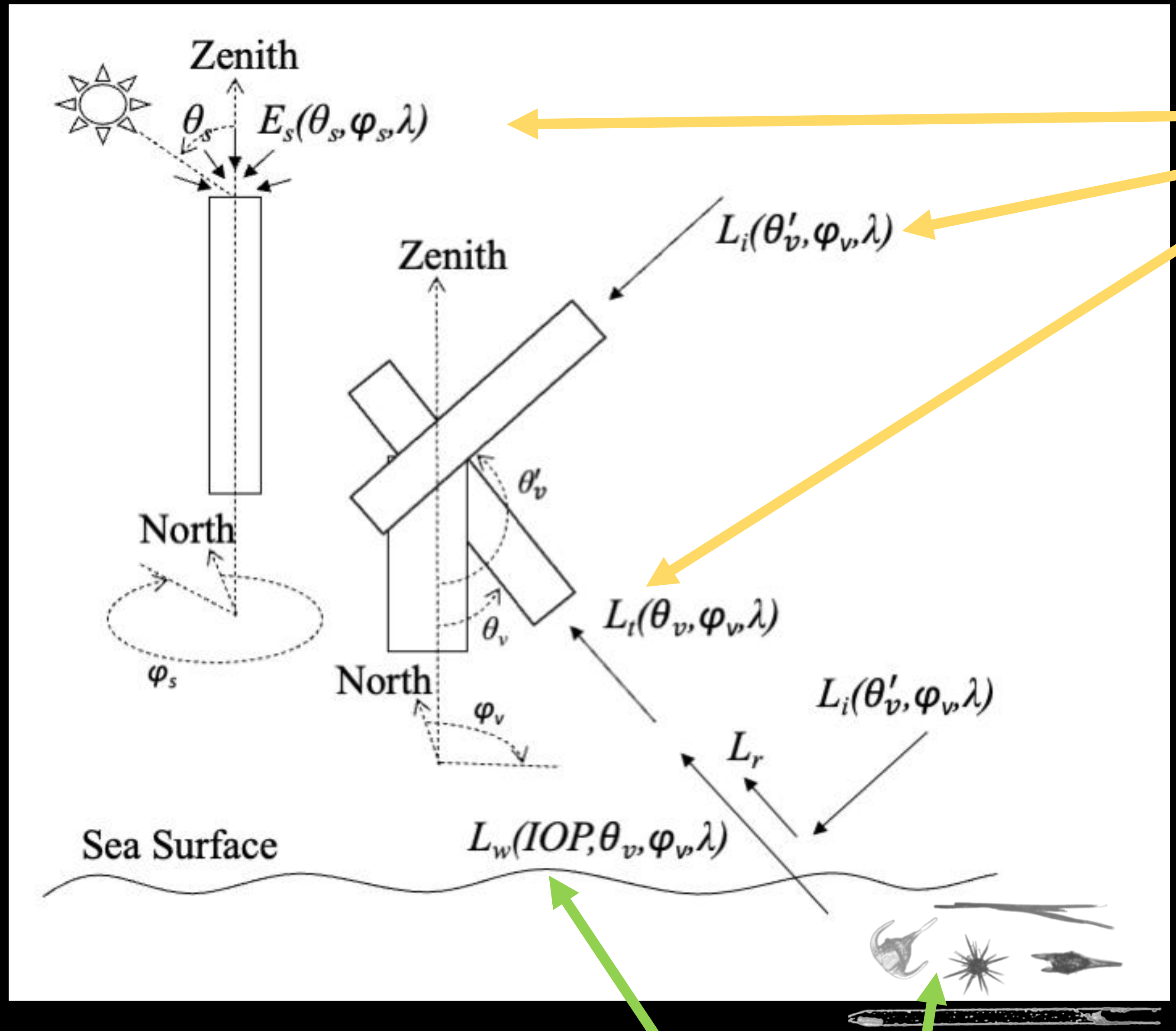
Solid lines are φ_s for 135°, dashed for 90°.

Figures adapted from Mobley 1999, Applied Optics

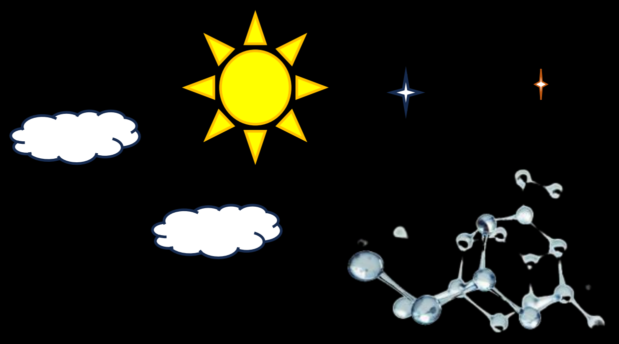
ρ: revisited by Mobley on 2015
Zibordi et al. 2016: Old (1999) values are still preferable

Azimuth and zenith/tilt must be carefully tracked in the field for **ρ**, but also because cosine collectors for downwelling irradiance are very sensitive to tilt.

Above Water Radiometry (AWR)



What we measure



Validation quality AWR requires good conditions (wind, sky, sea-surface, *tilt*, etc., refer to IOCCG Protocols)

Correcting AWR for surface reflectance of sun/sky (glint) is a challenge even in the best conditions. HyperCP can adjust the glint correction for solar/sensor geometries and optical water types. It has multiple options for glint, glitter and NIR residual corrections, and a long list of QC filters.

Sea surface reflectance factor

Skylight radiance

$$L_W(\theta_v,\varphi_v,\lambda) = L_t(\theta_v,\varphi_v,\lambda) - \rho(\theta_s,\varphi_s,\theta_v,\varphi_v,\lambda,\mathrm{W},\tau,\mathrm{T},\mathrm{S}) * L_i(\theta_v,\varphi_v,\lambda)$$

Total upwelling radiance

What we're after

$$R_{rs} = \frac{L_W(\theta_v,\varphi_v,\lambda)}{E_s(\lambda)}$$

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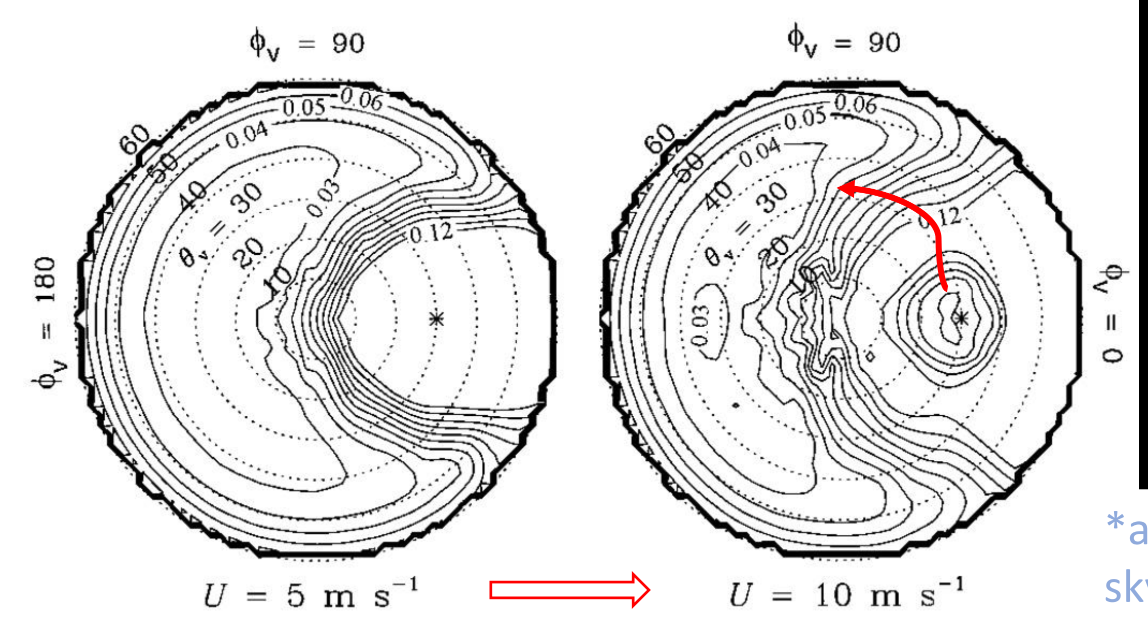
Above Water Radiometry (AWR)

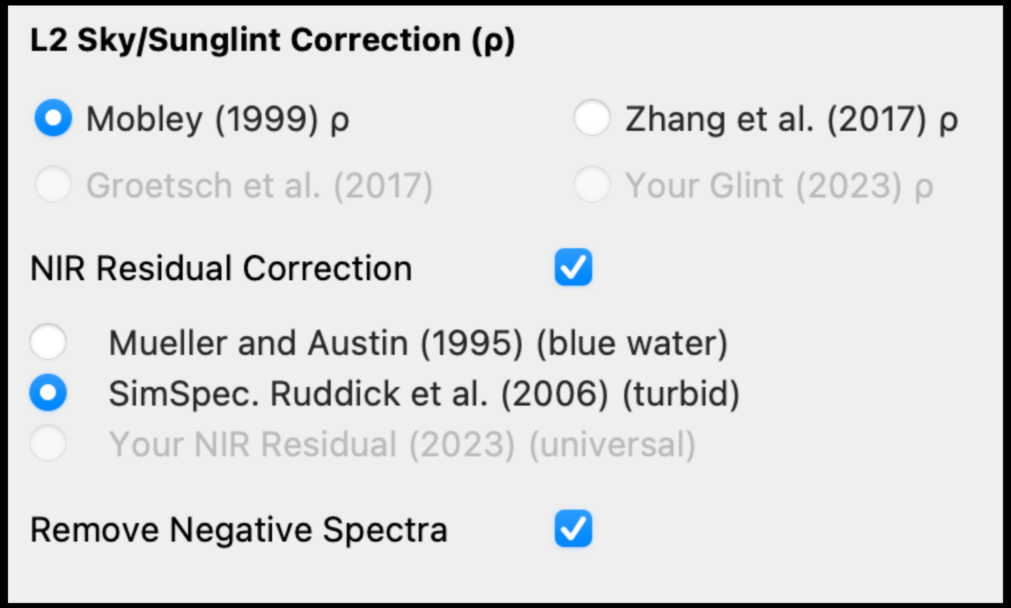
Sea surface "reflectance" factor*



*aka "glint", "surface-to-sky radiance ratio", etc.

High values of ρ (contours above) affecting more viewing geometries as surface becomes rougher

HyperCP



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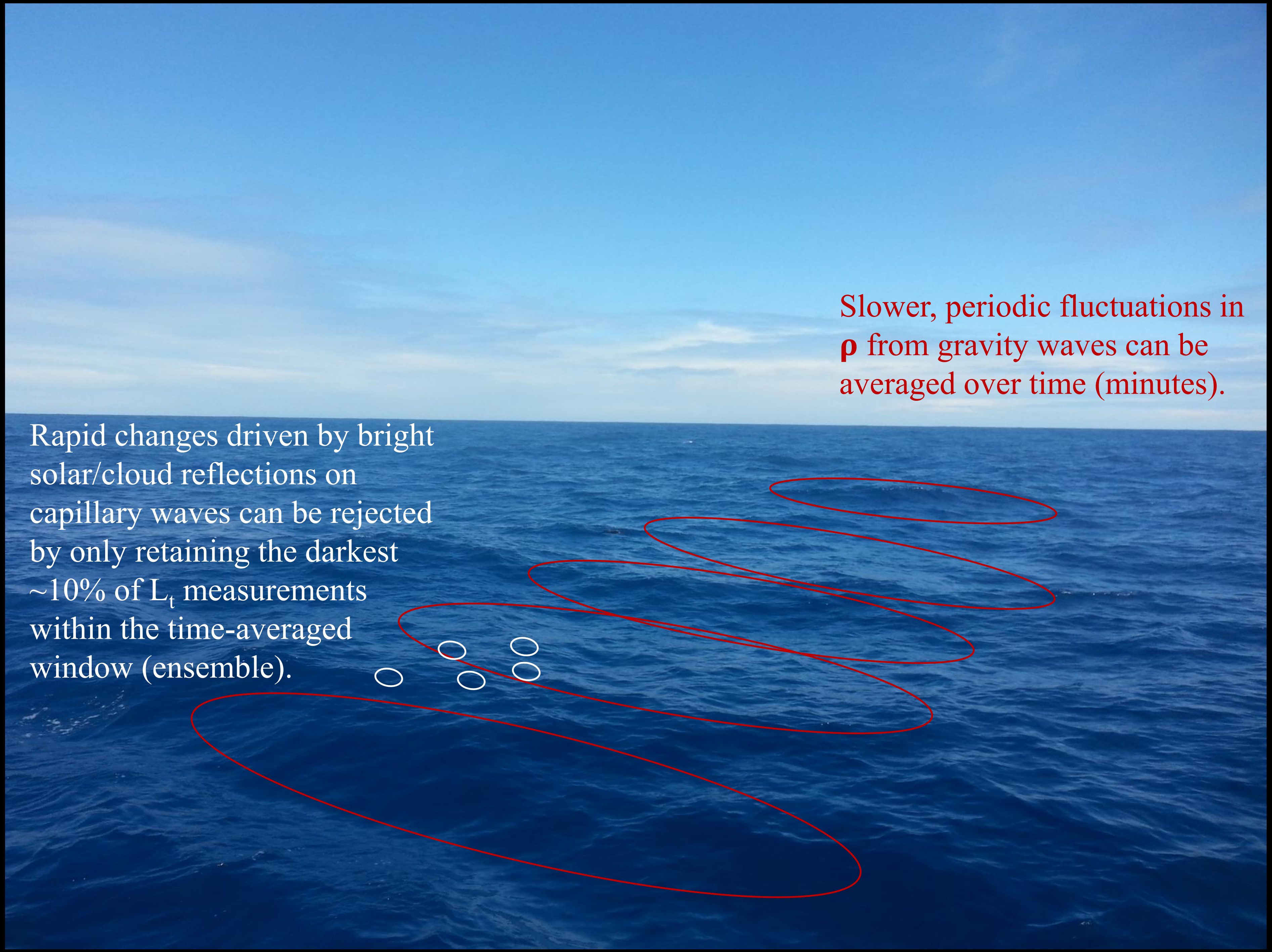
The Challenge of Surface Reflection (Glint)



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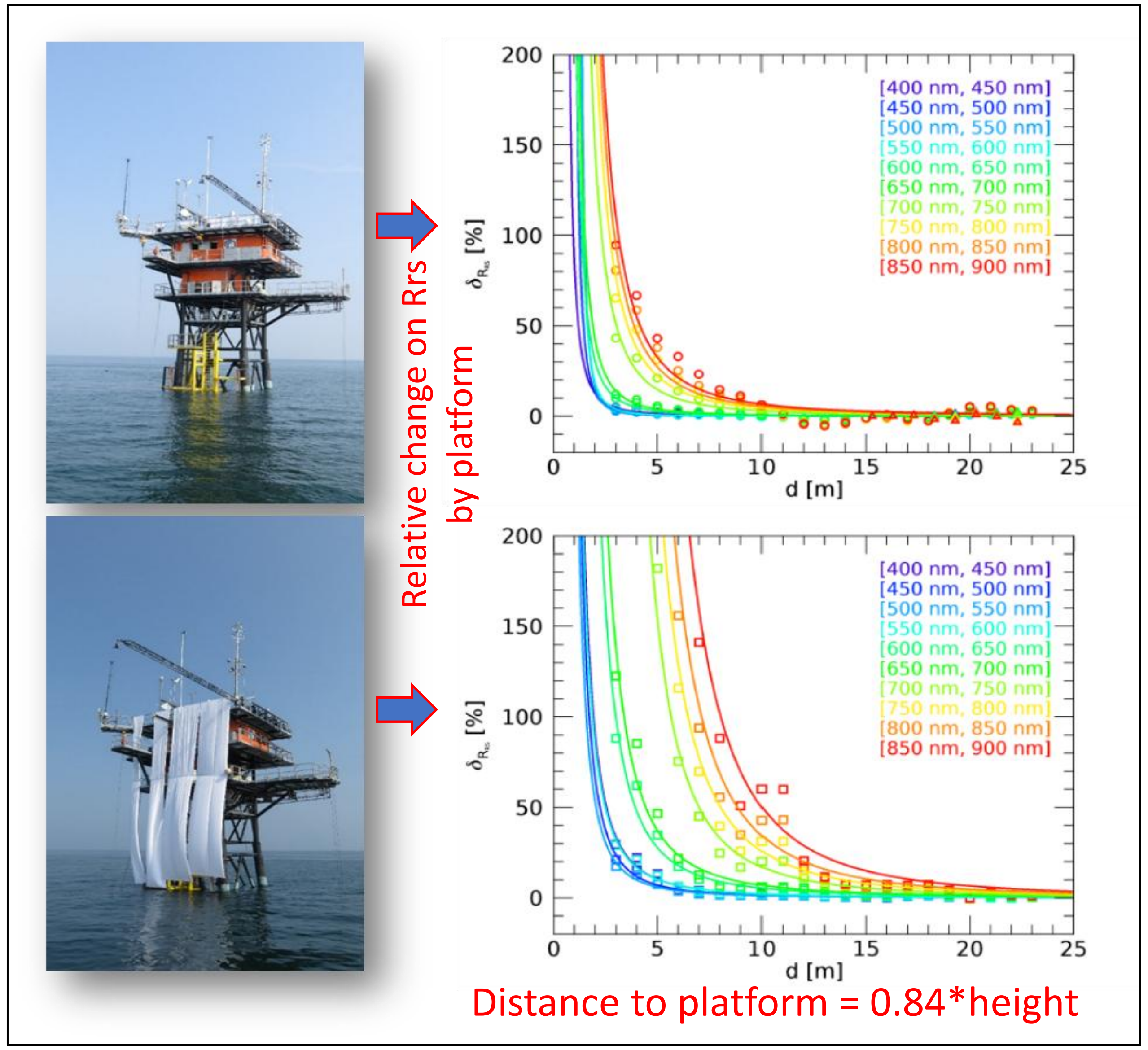
Platform Perturbations

Shadows and platform reflectance

- ρ is minimum at φ_s =180° away from Sun.
- However, φ_s =180° is generally affected by platform shadow
- φ_s=135° is generally outside of the platform shadow.
- However, φ_s =135° still typically affected by platform reflectance (especially if highly reflective)

∴ **The compromise φ_s should be between 90° and 135°.**

<u>If appropriate φ_s are not maintained and recorded, AWR is effectively useless due to the lack of an accurate glint correction.</u>



Talone, Zibordi, "Spectral assessment of deployment platform perturbations in above-water radiometry," Opt. Express 27, A878-A889 (2019)

ρ: Sea surface reflectance factor
φ_s: Sun-sensor (Li, Lt) relative azimuth

Calibration/Characterization Uncertainty

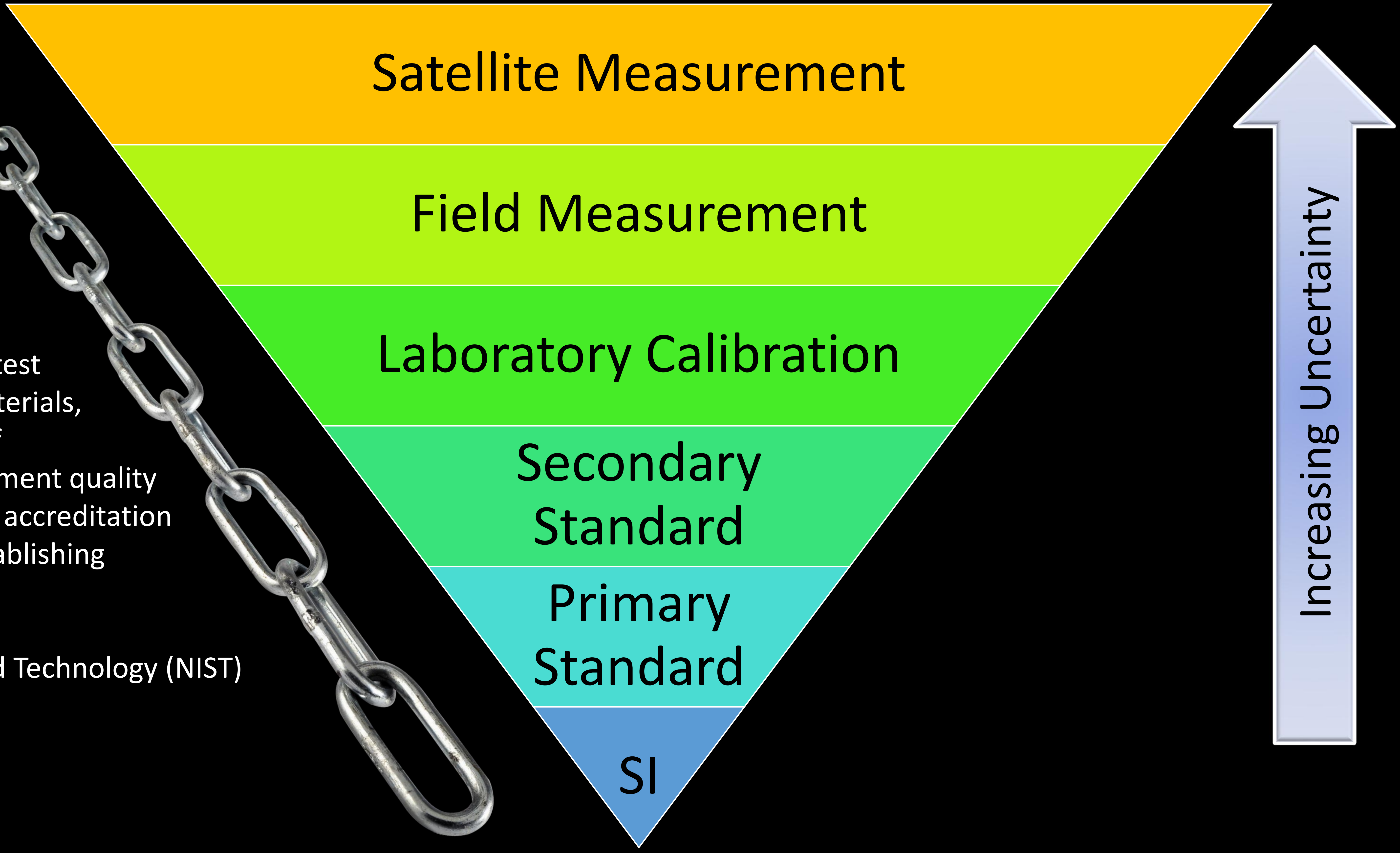
Overview

Metrology

“The science of measurement and its applications …

…calibrations, standard reference materials, standard reference data, test methods, proficiency evaluation materials, tools that facilitate the evaluation of measurement uncertainty, measurement quality assurance programs, and laboratory accreditation services that assist customers in establishing traceability of measurement results.

– National Institute of Standards and Technology (NIST)



Calibration

Laboratory calibration is one link in the chain

Absolute calibration

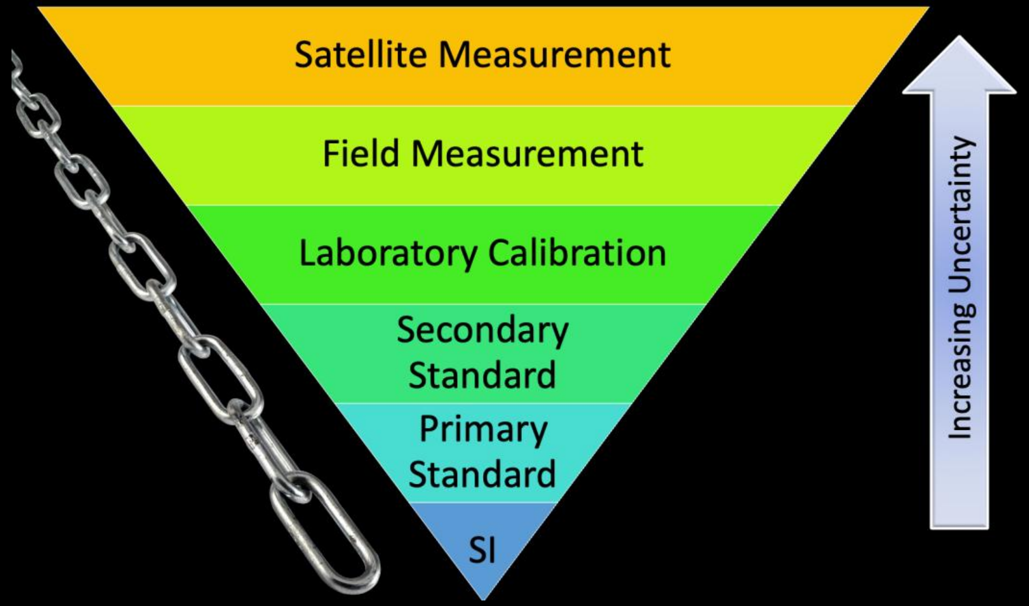
Calibration coefficient

$$\Im(\lambda) = C_{\Im}(\lambda)\,\aleph(\lambda)\,DN(\Im(\lambda))$$

Digital numbers

(Ir)radiance in physical units

Deviations from instrument's expected ideal performance



Calibration of irradiance

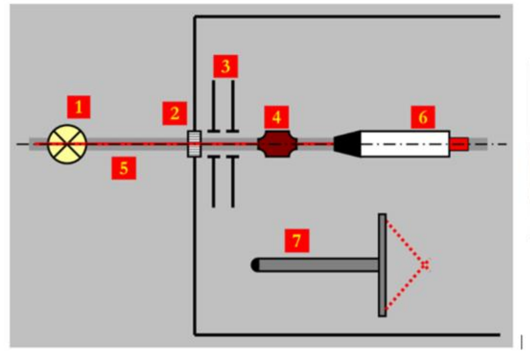


Figure 1.Pilot's (UT) irradiance calibration setup. 1 -FEL lamp; 2 – shutter; 3 – baffles; 4- -alignment laser; 5- optical rail; 6 – radiometer; 7 – contactless distance probe.

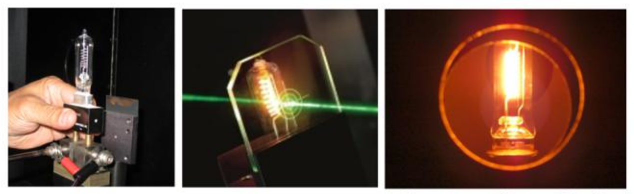


Photo courtesy of Gamma Scientific

Calibration of radiance

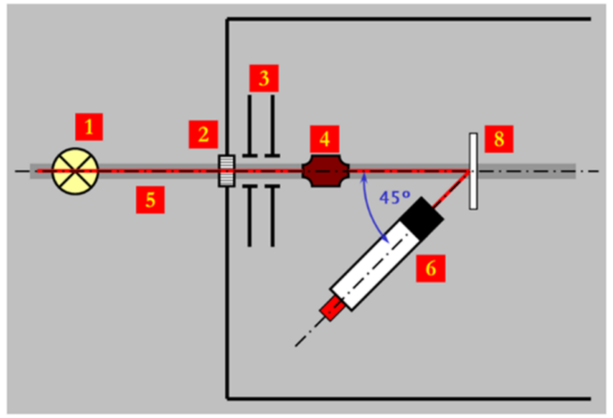
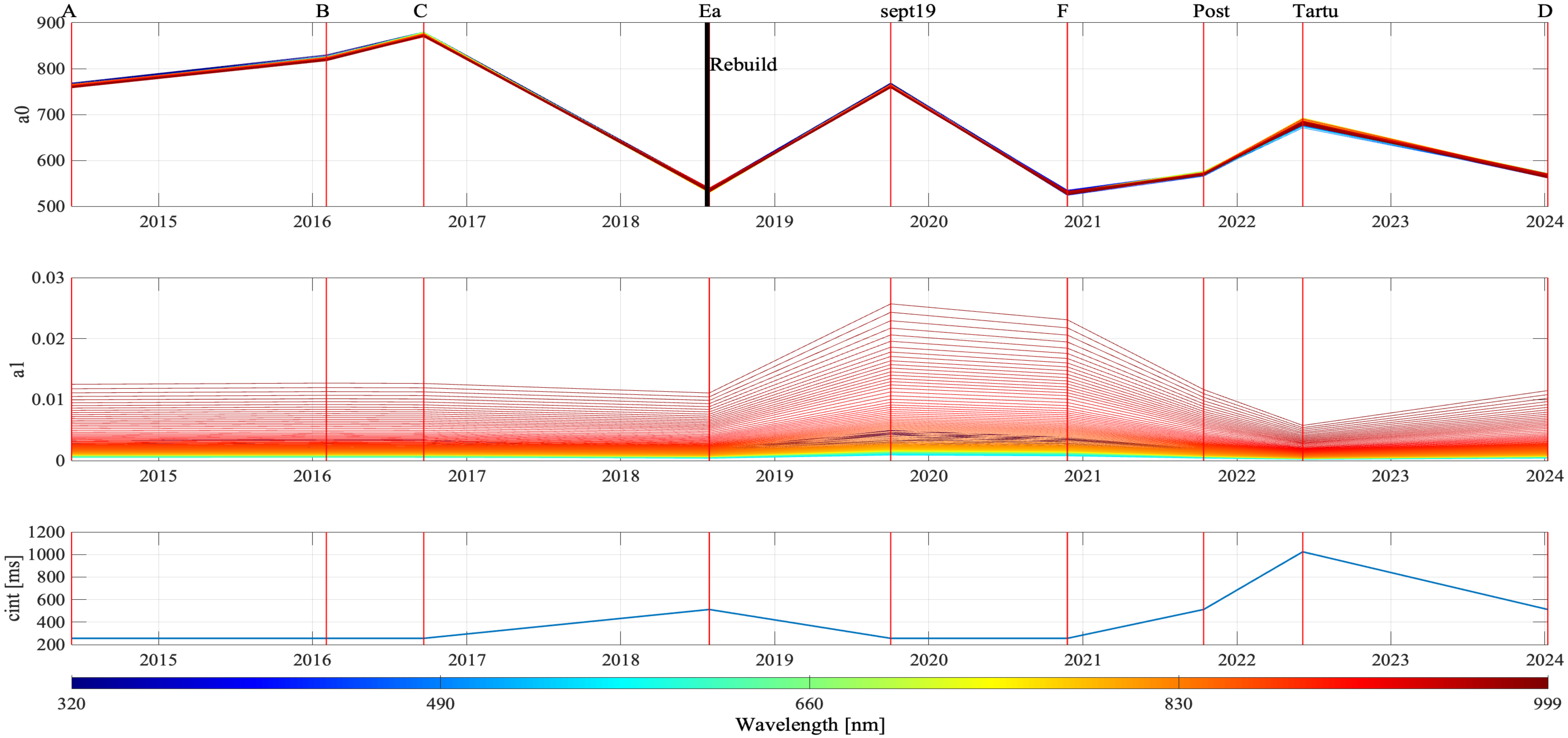


Figure 2. Pilot's (UT) radiance calibration setup. 1 -FEL lamp; 2 – shutter; 3 – baffles; 4- alignment laser; 5- optical rail; 6 – radiometer; 8 – reflectance panel.

Calibration Uncertainty

Additional factors impacting quality and



Characterization and Uncertainty

Absolute calibration

(Ir)radiance in physical units

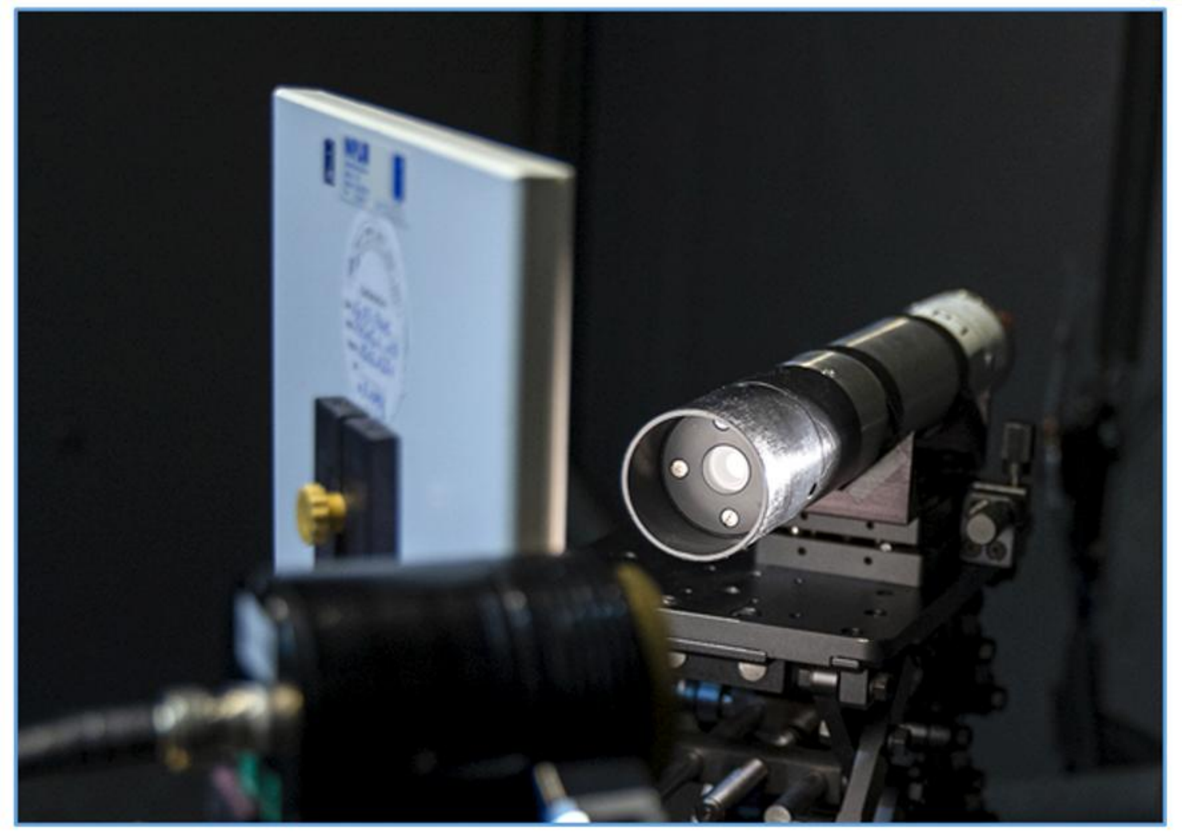
Calibration coefficient

$$\Im(\lambda) = C_{\Im}(\lambda)\, \aleph(\lambda)\, DN(\Im(\lambda))$$

Digital numbers

deviations from instrument's expected ideal performance

- Dark current noise
- Linearity of response
- Calibration/stability
- Straylight response
- Angularity of response
- Thermal response
- Polarization response



Characterization, complementary to absolute radiometric calibration, is the determination of the distinctive features of an instrument allowing us to account for these deviations....

Calibration/Characterization Uncertainty

Regimes Applied in HyperCP v1.2+

Instrument Characterization

Some factors impacting quality and uncertainty of the AWR collected in situ

Cloud cover (record it, at least on station)
Instrument fouling/obstruction (avoid it)
Instrument response/characterization

*
- Dark current noise
- Linearity of response
- Calibration/stability
- Straylight response
- Angularity of response
- Thermal response
- Polarization response

Dark frame subtraction/ correction
Deglitching (L1AQC)

Linearity correction
Calibration correction
Straylight correction
Cosine correction (Es)
Thermal correction

Uncertainty associated with these characterizations can be modeled using Monte Carlo simulations, and added to the reported products

Laboratory measurements can characterize these for **specific instruments** and **classes of instruments**.

Corrections further reduce uncertainty

* Requirements of the Ocean Optics & Biogeochemical Protocols for Satellite Ocean Colour Sensor Validation (IOCCG, 2019)

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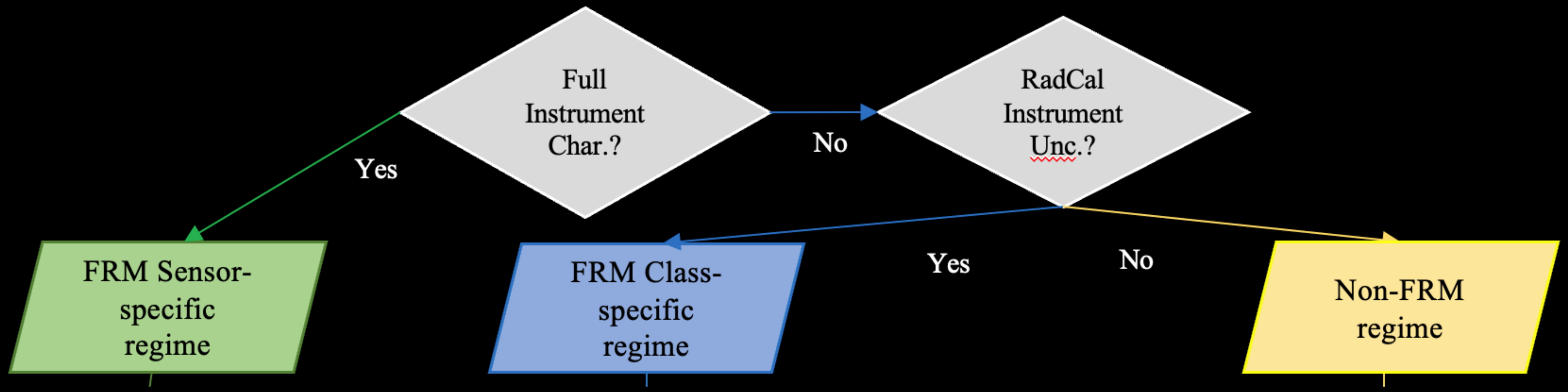
FRM Uncertainty Regimes v1.2

Instrument Characterization:

- Dark current noise
- Linearity of response
- Calibration/stability
- Straylight response
- Angularity of response
- Thermal response
- Polarization response

Instrument Classes:

Classes = Instruments:
- Sea-Bird HyperOCR
- TriOS RAMSES
- IMO DALEC



FRM-compliant with small uncertainties

FRM-compliant with bigger uncertainties

Non-FRM-compliant with large uncertainties

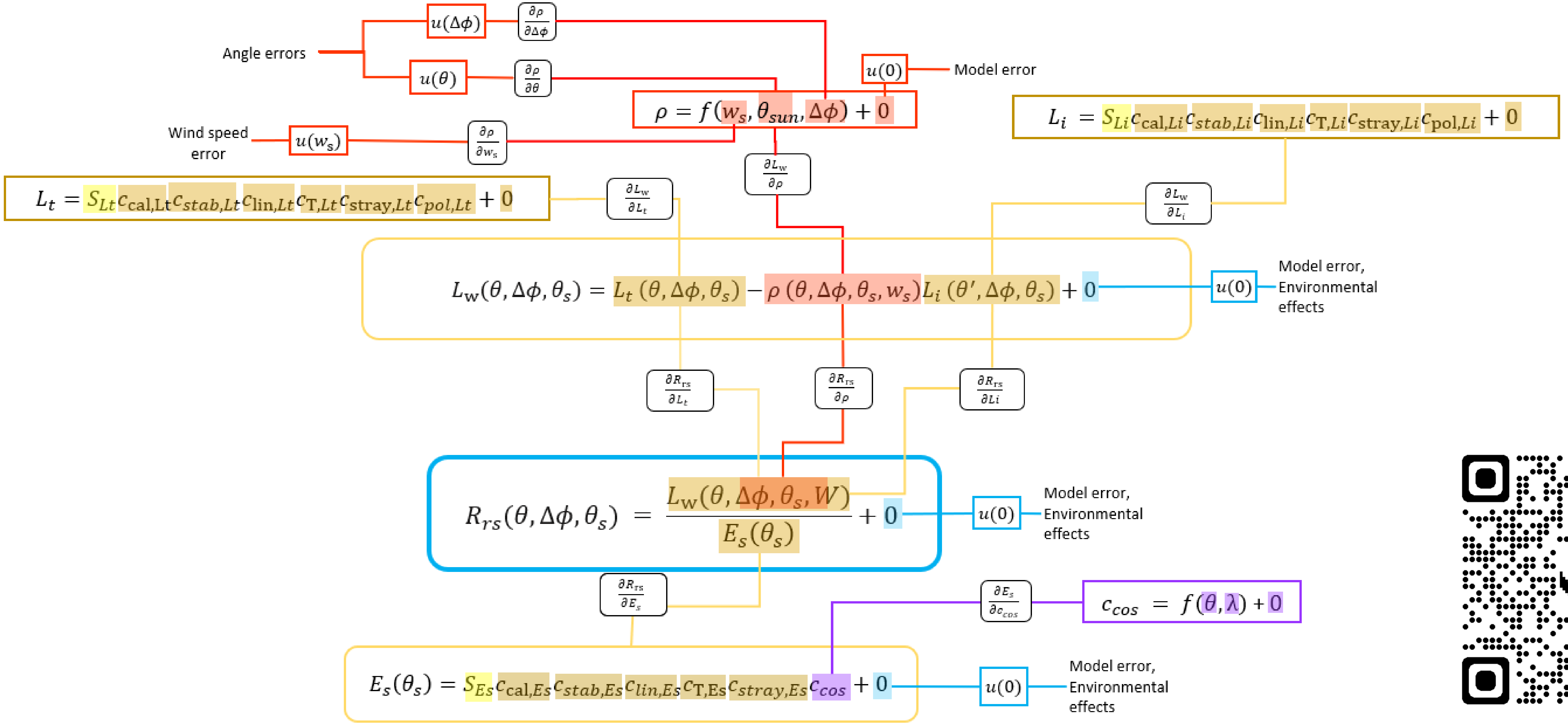
Full characterisation

FRM Class based

Non-FRM Class based (SeaBird only)

Guide to the expression of Uncertainty in Measurement (GUM)

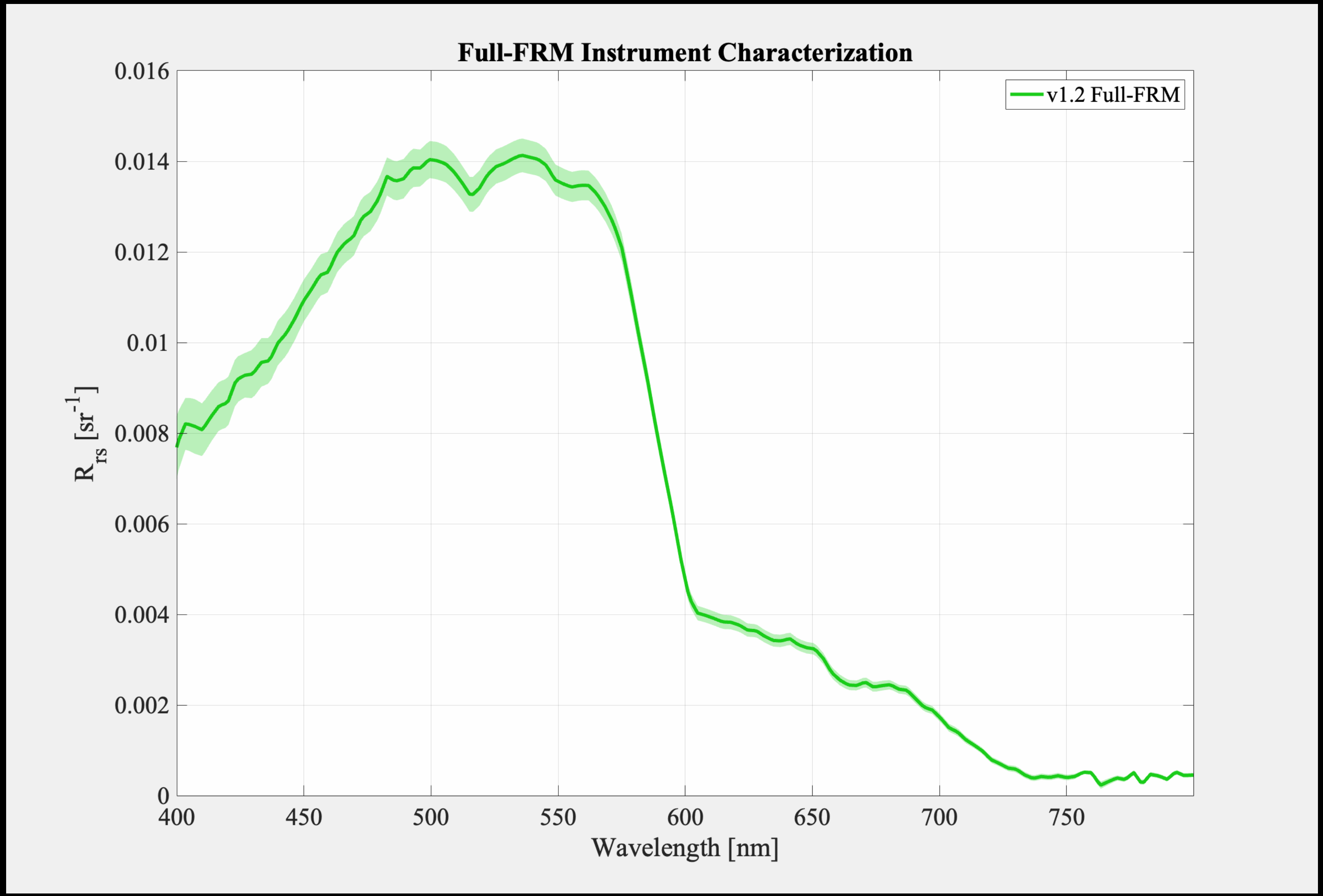
- *Applied in HyperCP using the CoMET tool: www.comet-toolkit.org*



Aga Bialek, National Physical Laboratory, UK, et al.

Remote Sens. 2020, 12, 780; doi:10.3390/rs12050780

Improved Precision and Uncertainty Estimation



v1.1:

- ✓ No instrument-specific characterizations, corrections, or uncertainty
- ✓ Only environmental variability and uncertainty course estimate for the glint correction (Mobley 1999).

v1.2 Class-based:

- ✓ Class-based (Sea-Bird, TriOS) characterizations and uncertainties (no corrections) in addition to environmental variability.
- ✓ Monte Carlo estimates of uncertainty for glint correction.

v1.2 Full-FRM:

- ✓ Instrument-specific characterizations, corrections, and uncertainties applied in addition to environmental variability.
- ✓ Monte Carlo estimates of uncertainty for glint correction.

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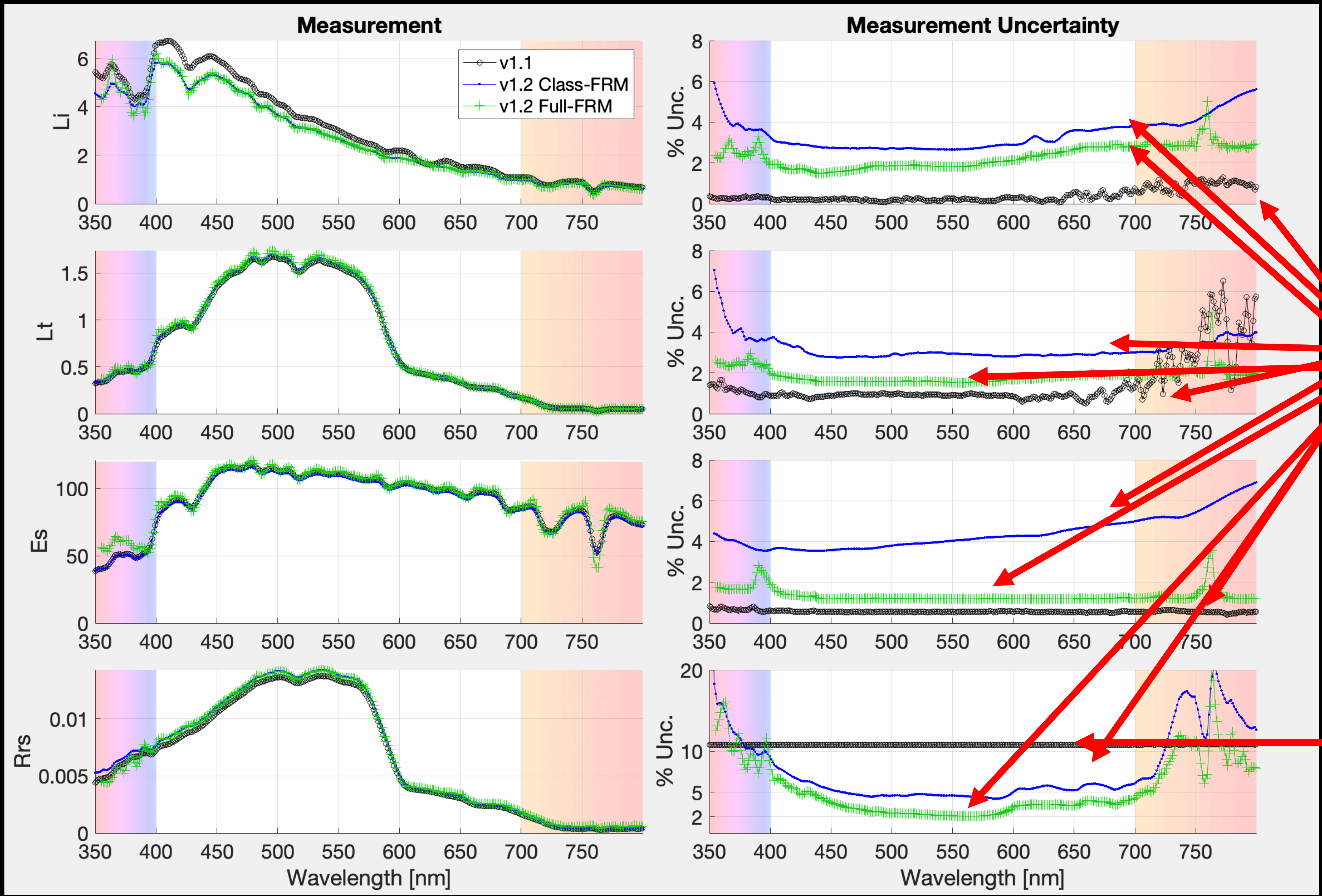
Improved Precision and Uncertainty Estimation



v1.1 underestimates; lack instrument characterization

Full-FRM with instrument characterization and correction; most accurate (and precise)

v1.1 overestimates; glint uncertainty poorly parameterized

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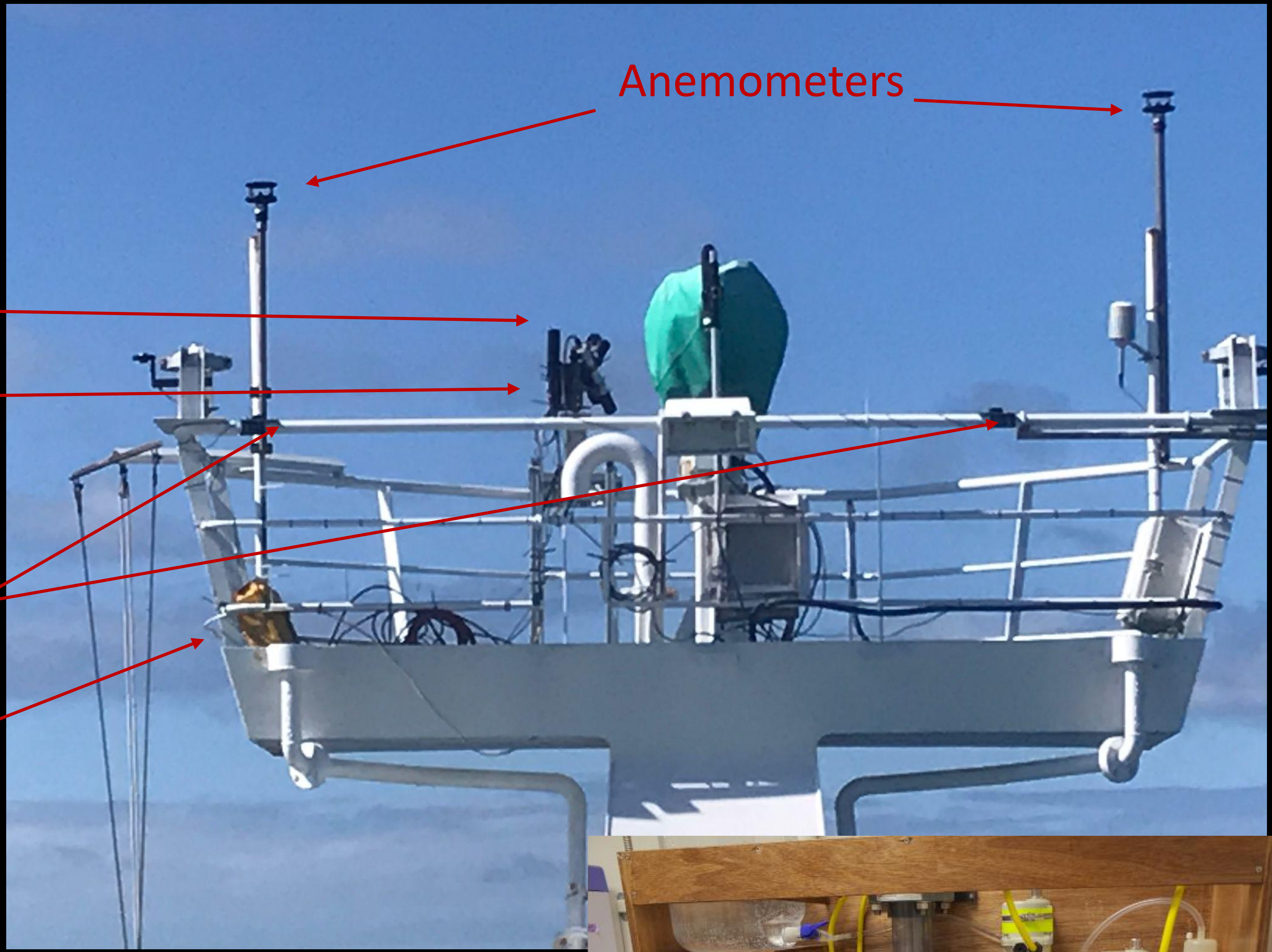
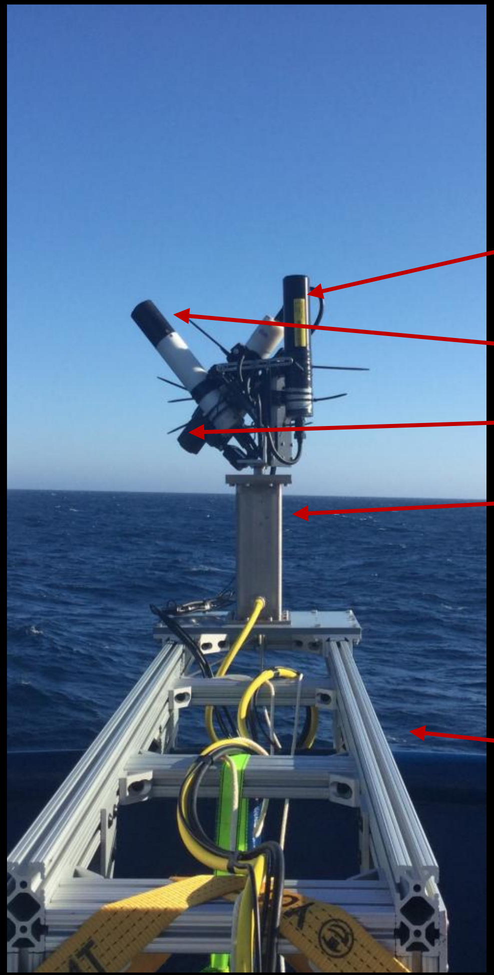
AWR In the Field

Critical ancillary datasets

On a Ship


Anemometers
Es
HyperSAS
Directional GPS Antennas
Controller Box


Tilt Sensor
Li (sky)
Lt
pySAS
Autonomous azimuth adjustment
Tower Support


Flow-through system (SST, Salinity, chl_fl, IOPs, etc.)

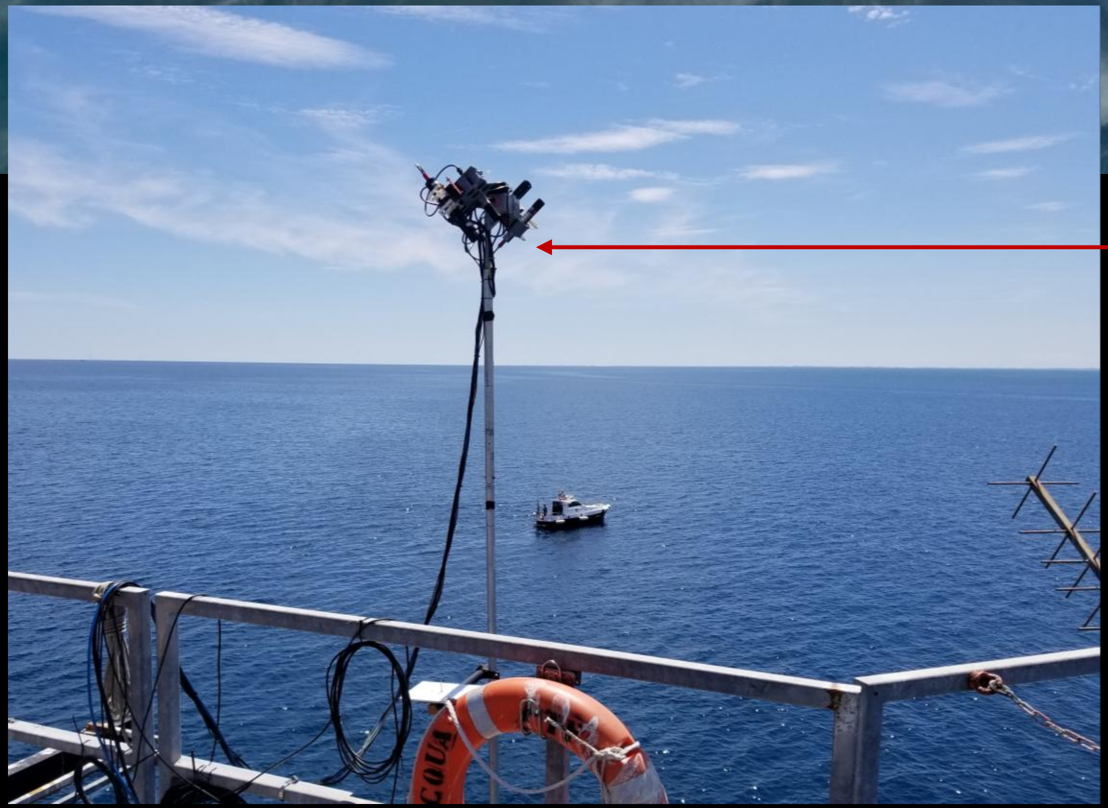
AAOT

Anemometers

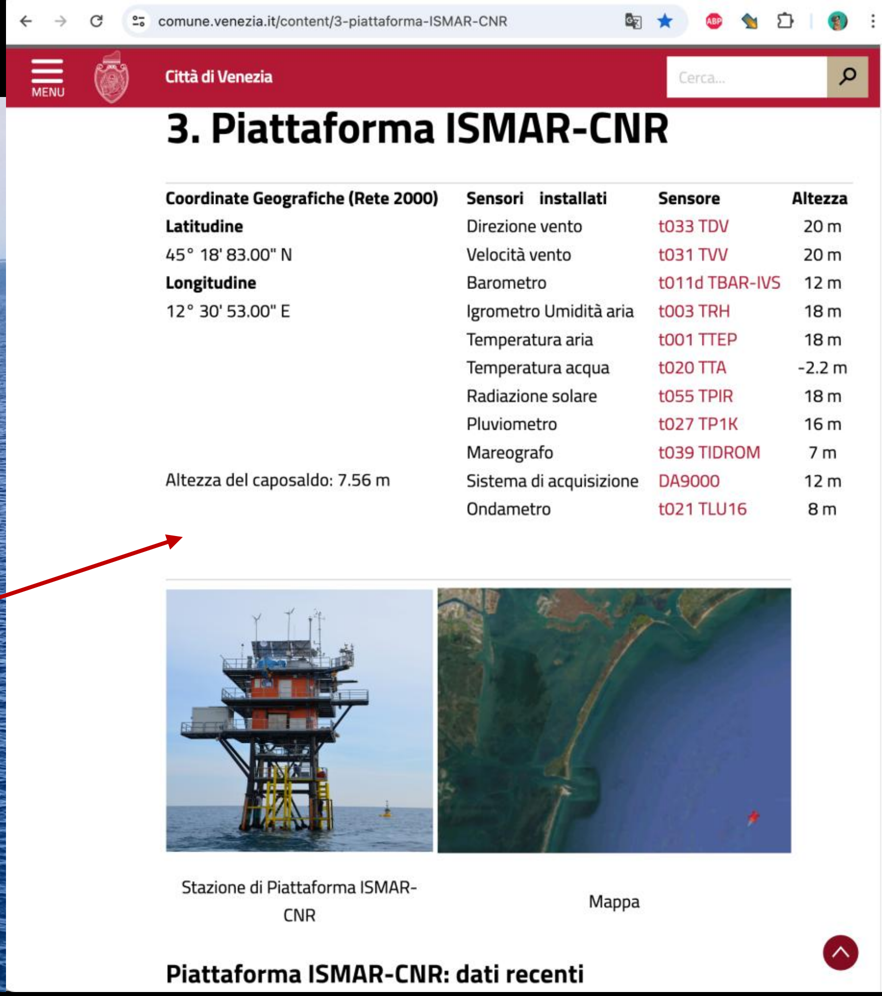
Es

pySAS

Manually operated radiometers



Buoy data



3. Piattaforma ISMAR-CNR

Coordinate Geografiche (Rete 2000)	Sensori installati	Sensore	Altezza
Latitudine	Direzione vento	t033 TDV	20 m
45° 18' 83.00" N	Velocità vento	t031 TVV	20 m
Longitudine	Barometro	t011d TBAR-IVS	12 m
12° 30' 53.00" E	Igrometro Umidità aria	t003 TRH	18 m
	Temperatura aria	t001 TTEP	18 m
	Temperatura acqua	t020 TTA	-2.2 m
	Radiazione solare	t055 TPIR	18 m
	Pluviometro	t027 TP1K	16 m
	Mareografo	t039 TIDROM	7 m
Altezza del caposaldo: 7.56 m	Sistema di acquisizione	DA9000	12 m
	Ondametro	t021 TLU16	8 m

Stazione di Piattaforma ISMAR-CNR

Mappa

Piattaforma ISMAR-CNR: dati recenti

https://www.comune.venezia.it/content/3-piattaforma-ISMAR-CNR

What is required from the field?

Primary Requirements:

1. Sensor geometries (and how maintained)
   a. Sensor azimuth and/or relative azimuth (to sun)
   b. Sensor zenith angles
   c. Tilt (particularly for E_s)
2. Wind speed
3. Sky conditions (%cloud, fog, rain)

(See the complete requirements at SeaBASS at QR Code above (https://seabass.gsfc.nasa.gov/wiki/data_submission_special_requirements) and refer to IOCCG Protocols)

$$L_W(\theta_v, \varphi_v, \lambda) = L_t(\theta_v, \varphi_v, \lambda) - \rho(\theta_s, \varphi_s, \theta_v, \varphi_v, \lambda, \mathrm{W}, \tau, \mathrm{T}, \mathrm{S}) * L_i(\theta_v, \varphi_v, \lambda)$$

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What is required from the field?

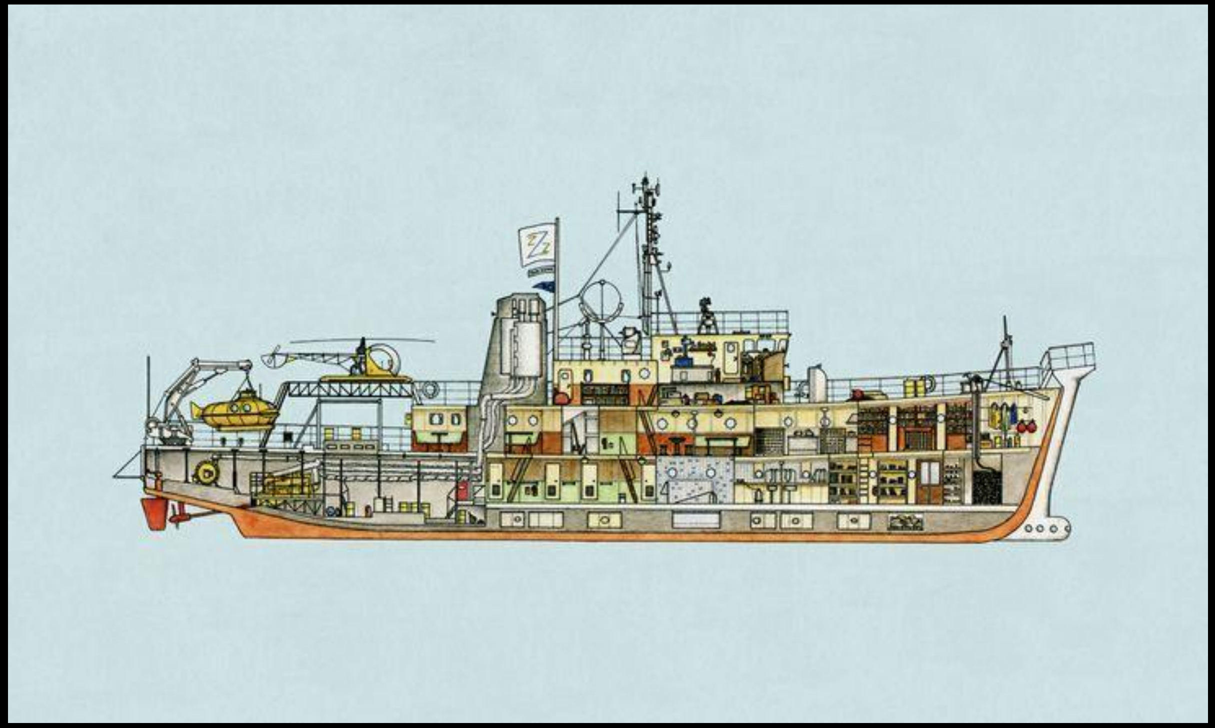
Secondary Requirements:

1. Aerosol Optical Depth
2. SST
3. Salinity
4. Air Temperature

$$L_w(\theta_v, \varphi_v, \lambda) = L_t(\theta_v, \varphi_v, \lambda) - \rho(\theta_s, \varphi_s, \theta_v, \varphi_v, \lambda, W, \tau, T, S) * L_i(\theta_v, \varphi_v, \lambda)$$

Wind, AOD, SST, and Sal fall back on models in HyperCP (MERRA-2, ECMWF)

What else helps identify validation-quality data?



Recommended Metadata:

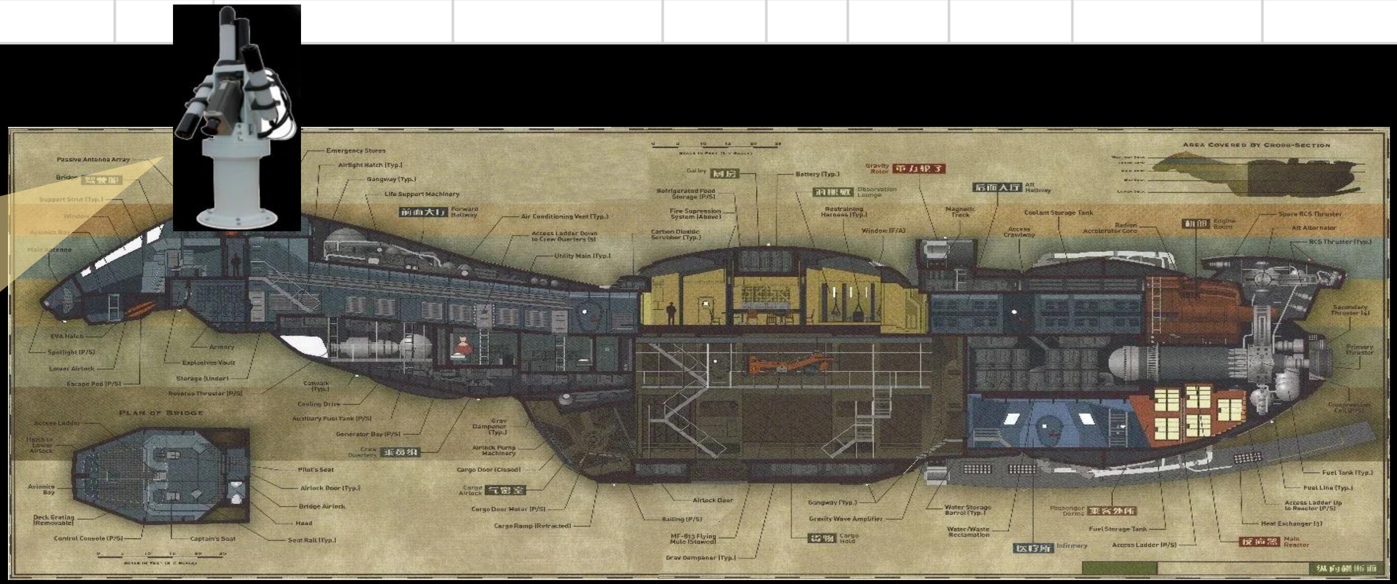
1. Bottom depth
2. Ship speed (through the water)
3. Station ID (get your whole cruise team to agree if you can)
4. Wave height
5. Field note comments (e.g., heavy spray - lenses wiped @0800, bloom slick, crossing turbidity front @1210, etc.)

Field Log

IOCCG_IOCS2023_pySAS_Radiometry_Field_Log

Experiment: FIREFLY02, Cruise: SEASON1, Platform: SERENITY, Operator: Hoban Waskburne. Home angle: 0, Min/Max Az: -20/+140, Height: 7m, Ship hull color: Silver.

station	raw filename	station start date/time	station end date/tim	lat	lon	ship heading	ship speed	relative azimuth (ship-sensor)	relative azimuth (solar-sensor)	wind speed	wind dir	waves	salinity	sea surface temperature	cloud	bottom depth	comments
(name agreed across sampling platforms)	(not for pySAS when working properly, or if station number is in the name)	(UTC. Confirm all systms set to UTC)	(UTC)	(deg; 3-4 decimals)	(deg)	(deg)	(kts)	(above-water; only if set manually)	(above-water; only if set manually)	(m/s)	(deg)	(m)	(psu)	(deg C)	(% or x/8)	(m)	(haze, fog, rain, optically shallow/bottom reflection, other issues)
checkout	pySAS/prepSAS defaults hourly files	2023-11-12-T-1400	2023-11-12-T-1410	27.764	-82.636	N/A	0	N/A	N/A	5	45	0.5	32	25	25	8	System checked out without incident
1	"	2023-11-12-T-1430	2023-11-12-T-1500	27.764	-82.636		0	"	"	5	50	0.5	33	24	50	35	IOP cast and Hyperpro multicast
2		2023-11-12-T-1600	2023-11-12-T-1645	27.764	-82.636		0			7	55	0.8	32	25	50	10	Clean lenses, IOP and AOP casts



Submission of Field Log in supporting documents is *strongly* encouraged.
Download a template from HyperCP repository
https://github.com/nasa/HyperCP:

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HyperCP

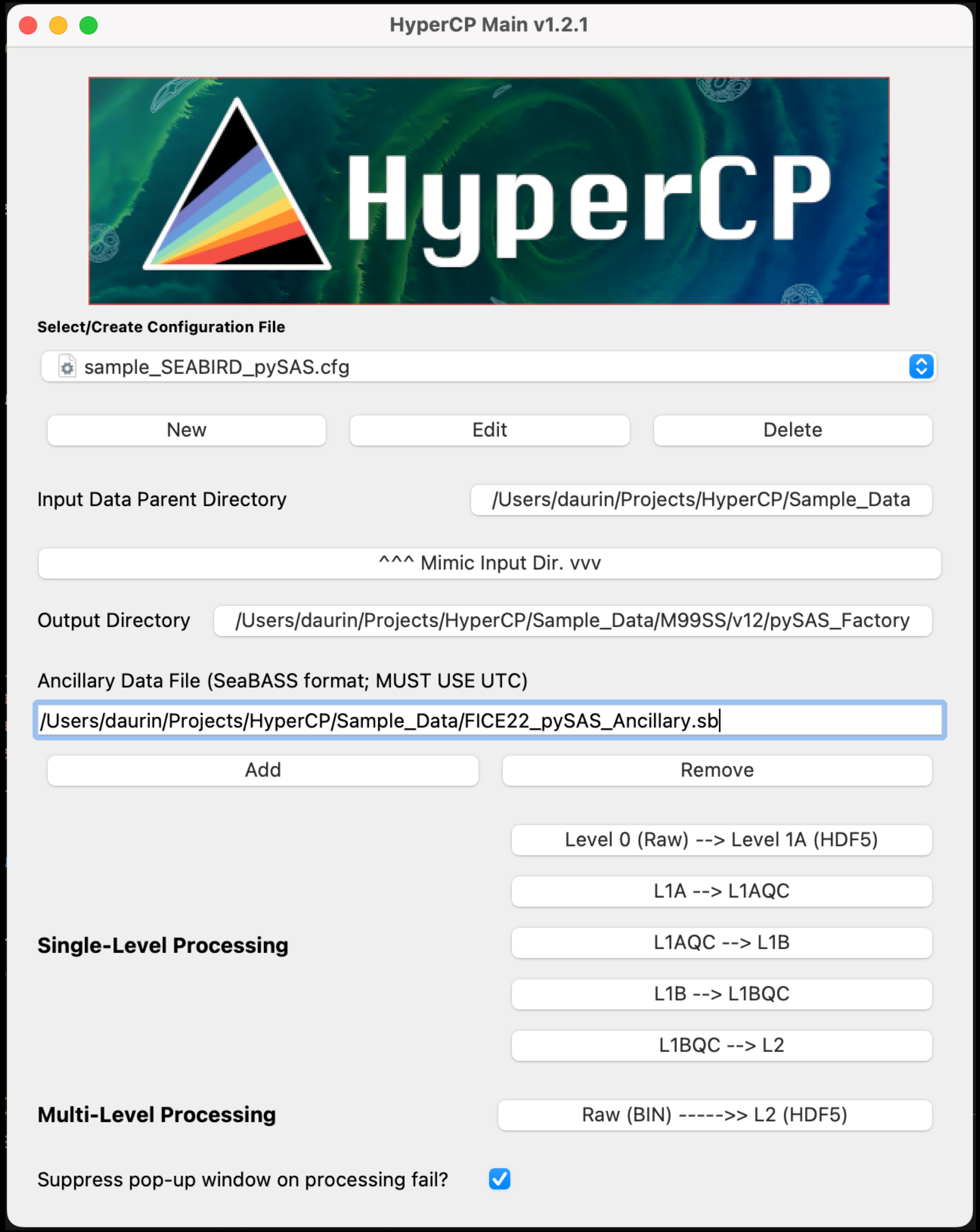
Intermission

Caffè

HyperCP

Overview

Overview



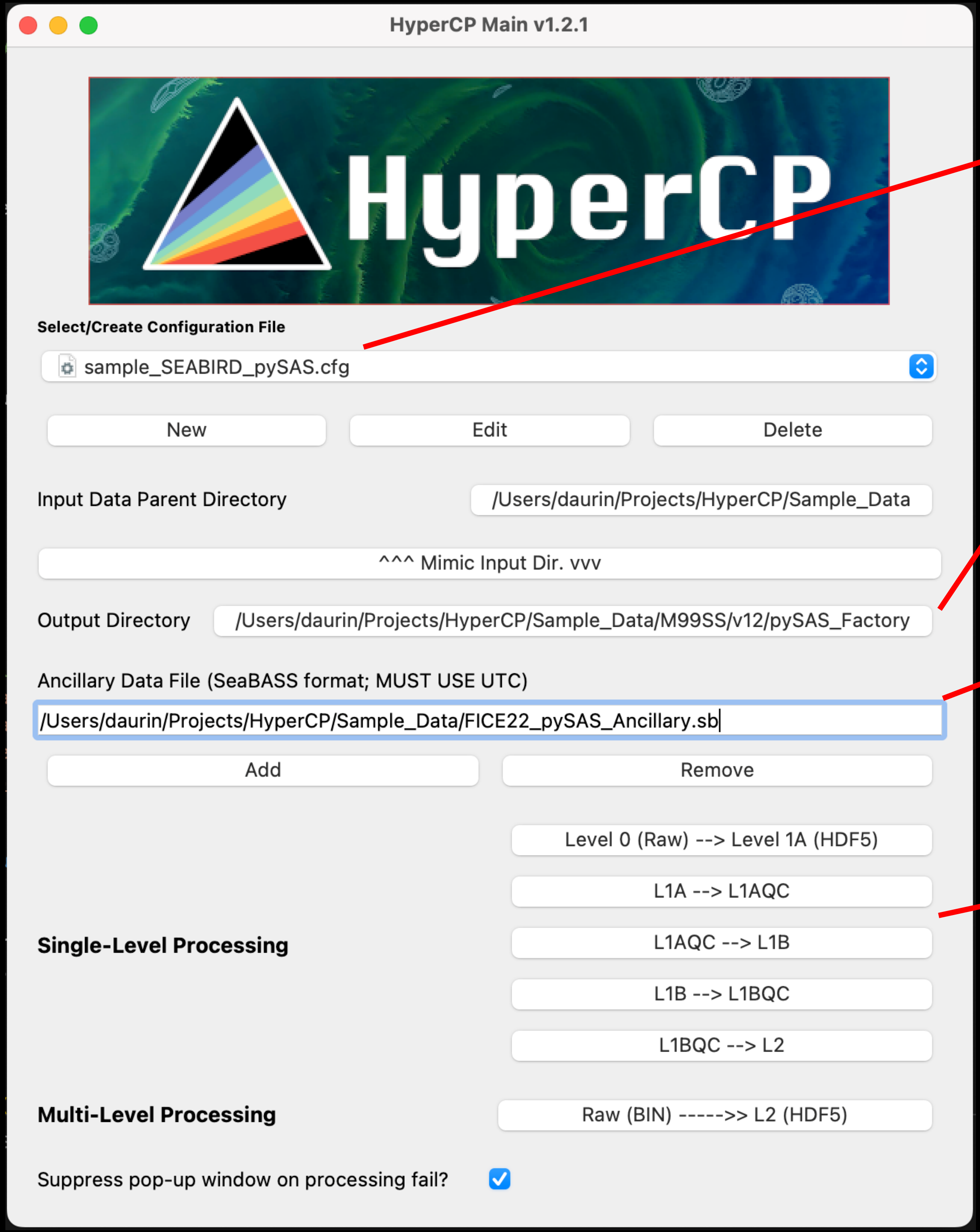
If you are having a difficulty reading this from your seat, I encourage you to launch HyperCP and follow along.

https://github.com/nasa/HyperCP

- See README for instruction/description
- See Discussion for support
- See Issues for reporting

Overview

GUI, or with configuration file on command line. Batch-able either way.

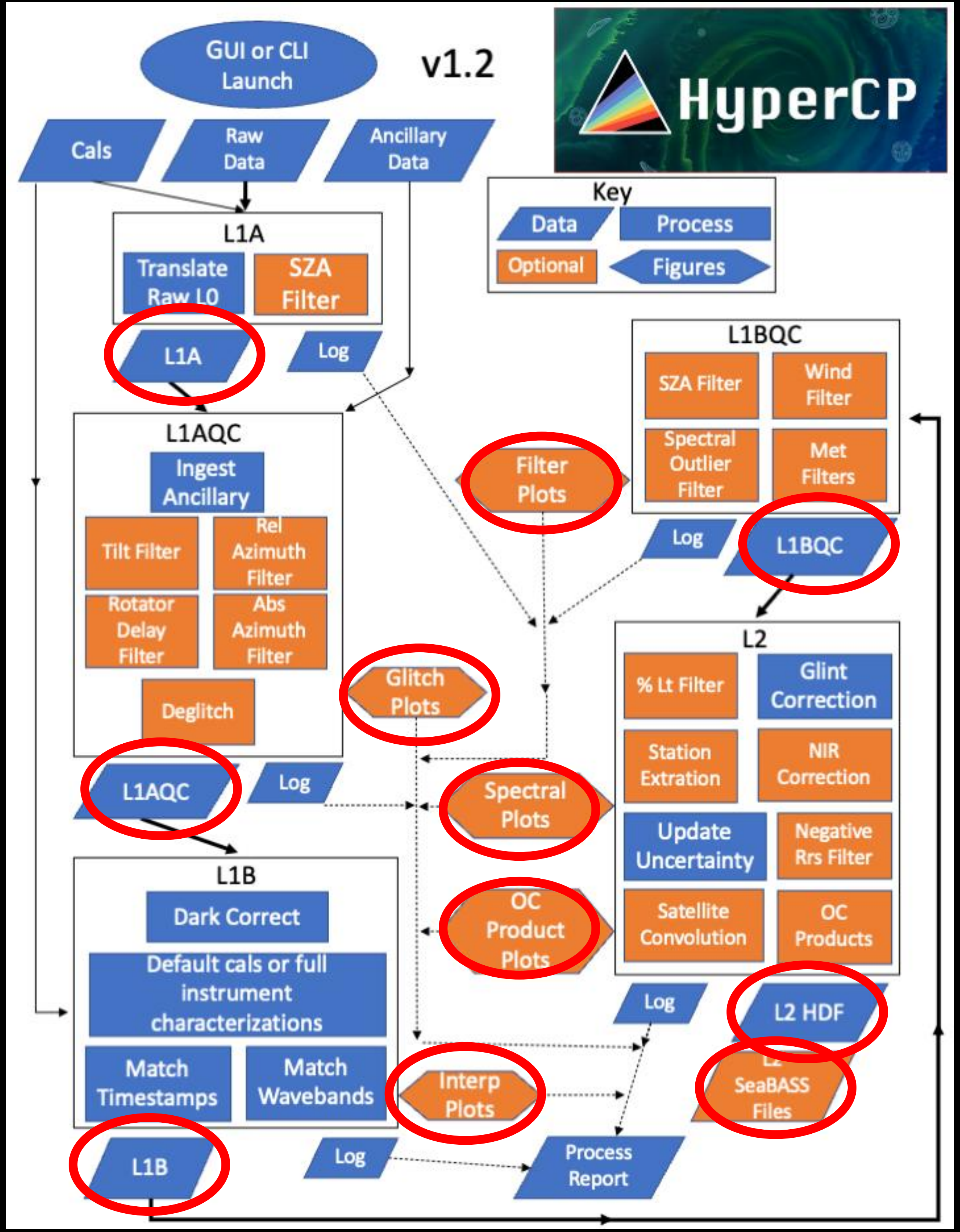


Each instrument deployment or cruise gets a unique **Configuration**

Output directories are automatically created for each level of processing, as well as for Plots, Reports, and SeaBASS files

The **Ancillary file** for the entire deployment/cruise is provided here

Processing can be run on one file or many files together, and can be run on one level or all levels together



https://github.com/nasa/HyperCP

- See README for instruction/description
- See Discussion for support
- See Issues for reporting

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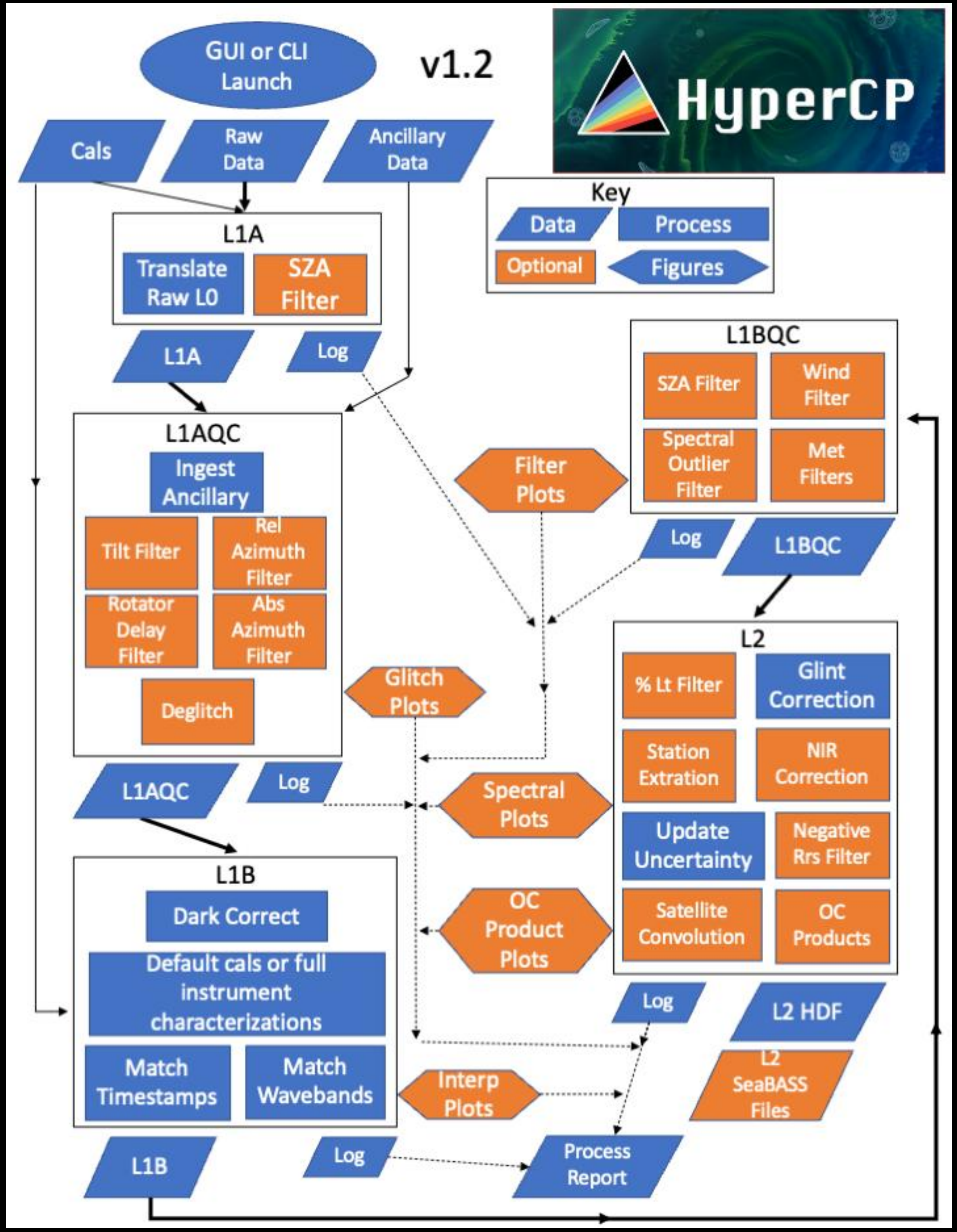
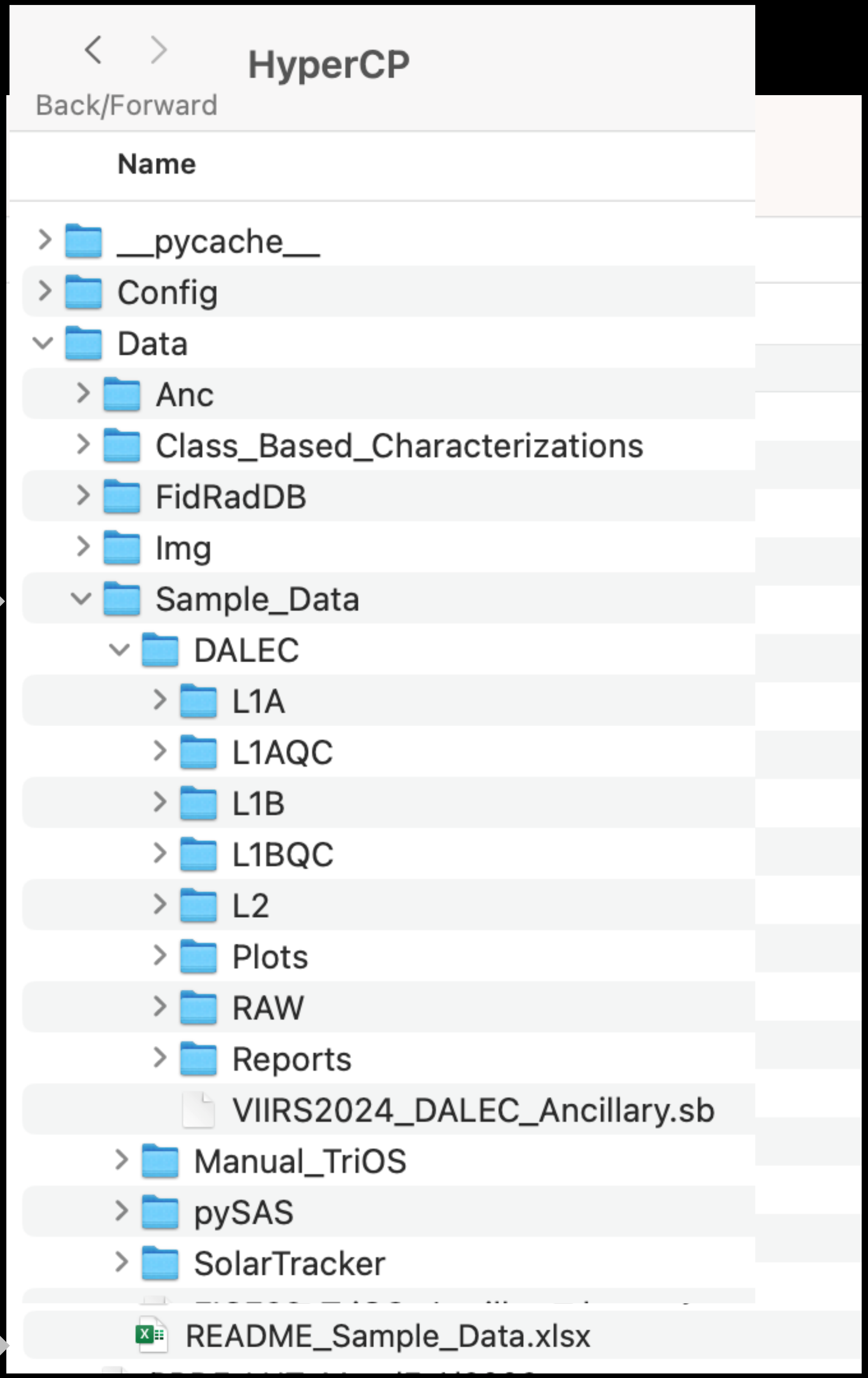
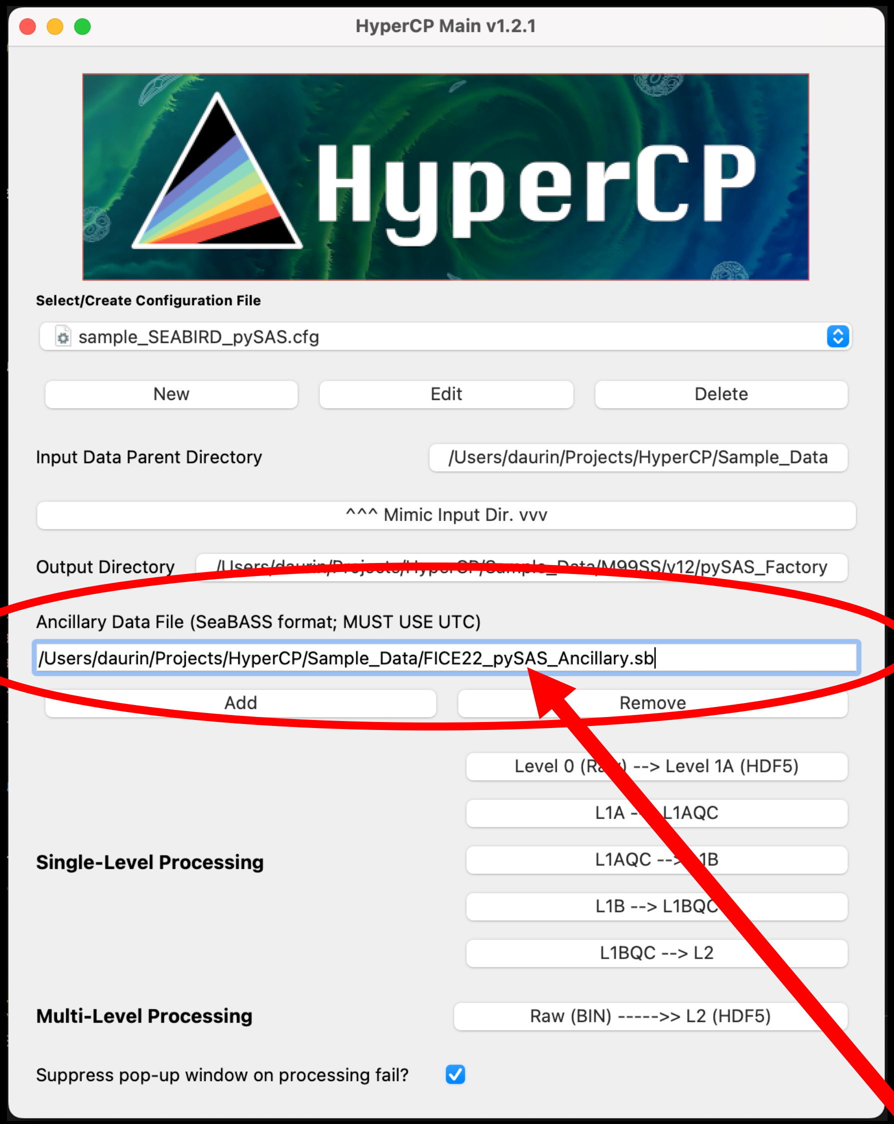
Directory Structure





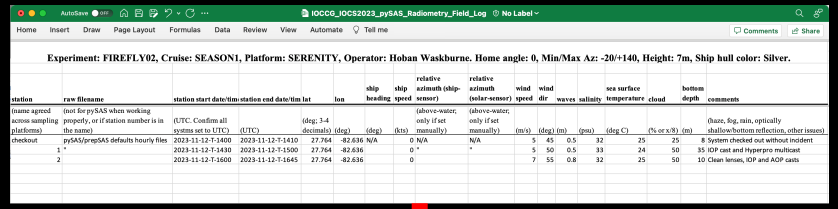
Guide to Sample Data:

Ancillary Data Inclusion/Submission

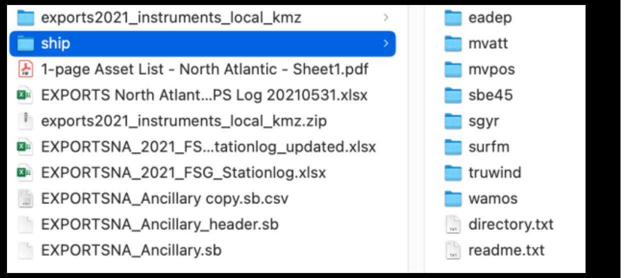


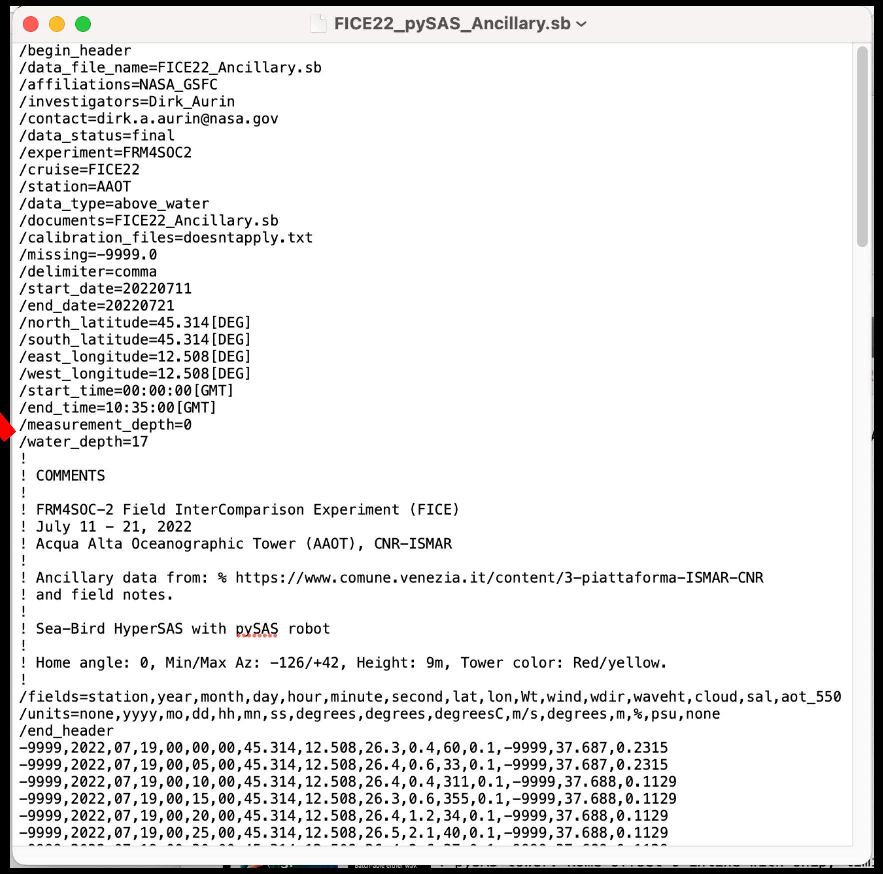
<u>PIs are responsible for tracking and assimilating ancillary datasets</u>.

Field notes:



Ship data (meteorological, flow-through):




FICE22_pySAS_Ancillary.sb

```
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/investigators=Dirk_Aurin
/contact=dirk.a.aurin@nasa.gov
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/cruise=FICE22
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/documents=FICE22_Ancillary.sb
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/end_date=20220721
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/south_latitude=45.314[DEG]
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!
! COMMENTS
!
! FRM4SOC-2 Field InterComparison Experiment (FICE)
! July 11 - 21, 2022
! Acqua Alta Oceanographic Tower (AAOT), CNR-ISMAR
!
! Ancillary data from: % https://www.comune.venezia.it/content/3-piattaforma-ISMAR-CNR
! and field notes.
!
! Sea-Bird HyperSAS with pySAS robot
!
! Home angle: 0, Min/Max Az: -126/+42, Height: 9m, Tower color: Red/yellow.
!
/fields=station,year,month,day,hour,minute,second,lat,lon,Wt,wind,wdir,waveht,cloud,sal,aot_550
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/end_header
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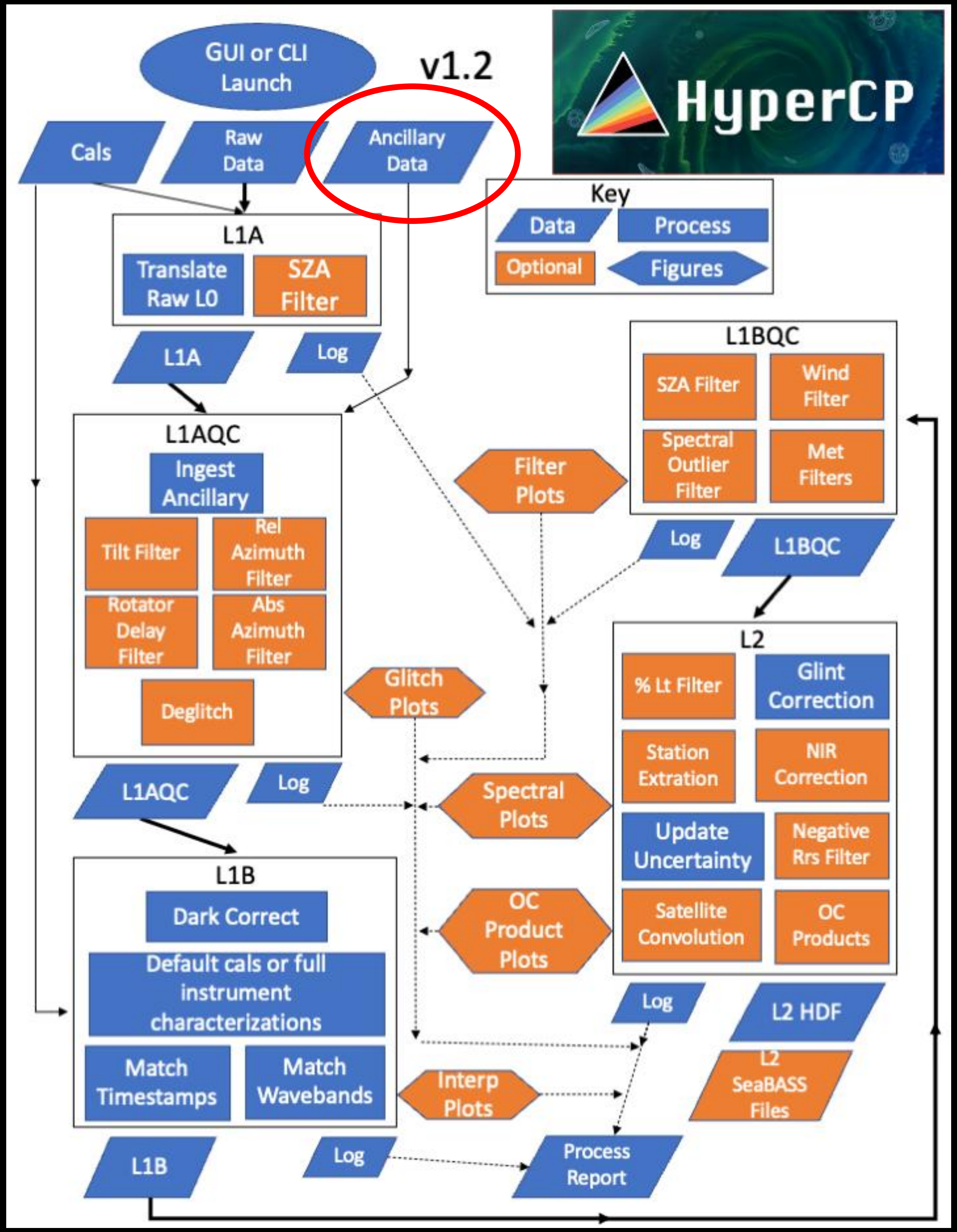
-9999,2022,07,19,00,25,00,45.314,12.508,26.5,2.1,40,0.1,-9999,37.688,0.1129
```

I recommend preparing these early and submitting them to SeaBASS supporting docs. *When you reach out to the team for support on running HyperCP, we will likely ask for this file.*



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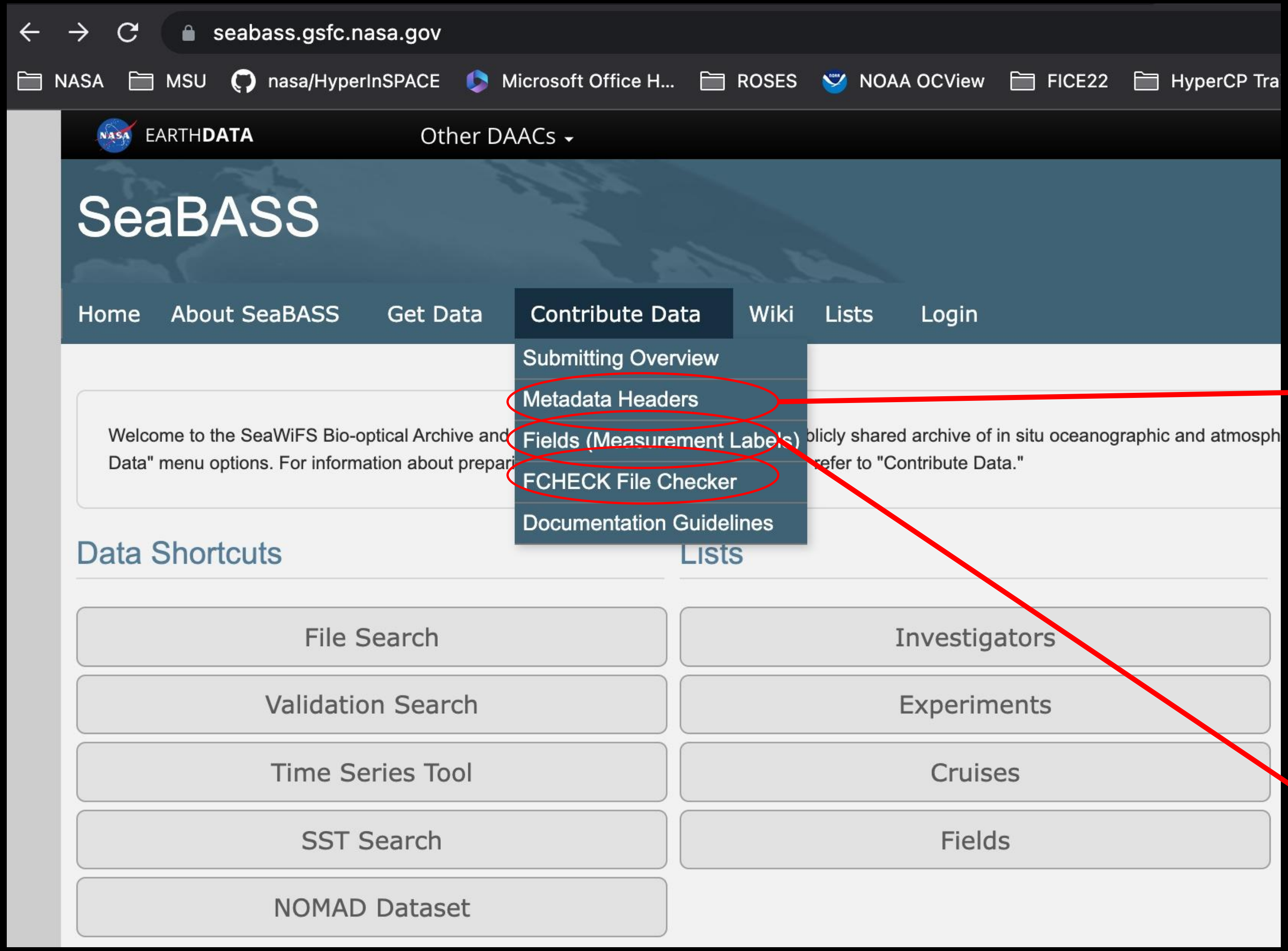
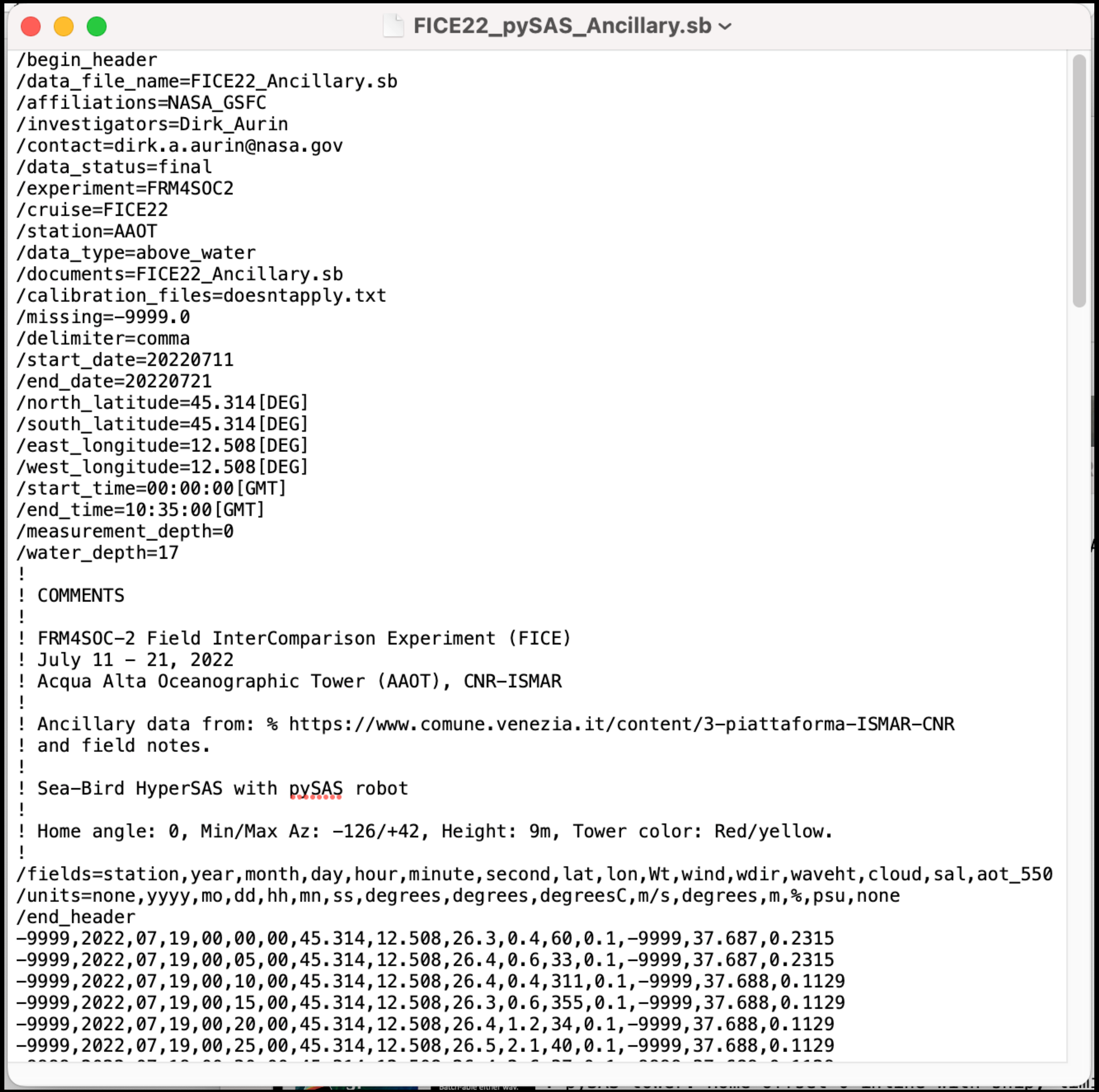
SeaBASS Format (Ancillary Data)

(More information about SeaBASS will be provided on Day 7.)

seabass.gsfc.nasa.gov





FICE22_pySAS_Ancillary.sb

```
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/affiliations=NASA_GSFC
/investigators=Dirk_Aurin
/contact=dirk.a.aurin@nasa.gov
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/cruise=FICE22
/station=AAOT
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/end_date=20220721
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/end_time=10:35:00[GMT]
/measurement_depth=0
/water_depth=17
!
! COMMENTS
!
! FRM4SOC-2 Field InterComparison Experiment (FICE)
! July 11 - 21, 2022
! Acqua Alta Oceanographic Tower (AAOT), CNR-ISMAR
!
! Ancillary data from: % https://www.comune.venezia.it/content/3-piattaforma-ISMAR-CNR
! and field notes.
!
! Sea-Bird HyperSAS with pySAS robot
!
! Home angle: 0, Min/Max Az: -126/+42, Height: 9m, Tower color: Red/yellow.
!
/fields=station,year,month,day,hour,minute,second,lat,lon,Wt,wind,wdir,waveht,cloud,sal,aot_550
/units=none,yyyy,mo,dd,hh,mn,ss,degrees,degrees,degreesC,m/s,degrees,m,%,psu,none
/end_header
-9999,2022,07,19,00,00,00,45.314,12.508,26.3,0.4,60,0.1,-9999,37.687,0.2315
-9999,2022,07,19,00,05,00,45.314,12.508,26.4,0.6,33,0.1,-9999,37.687,0.2315
-9999,2022,07,19,00,10,00,45.314,12.508,26.4,0.4,311,0.1,-9999,37.688,0.1129
-9999,2022,07,19,00,15,00,45.314,12.508,26.3,0.6,355,0.1,-9999,37.688,0.1129
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-9999,2022,07,19,00,25,00,45.314,12.508,26.5,2.1,40,0.1,-9999,37.688,0.1129
```

The SeaBASS FCHECK utility is accessible via email, sftp, or with a downloadable script

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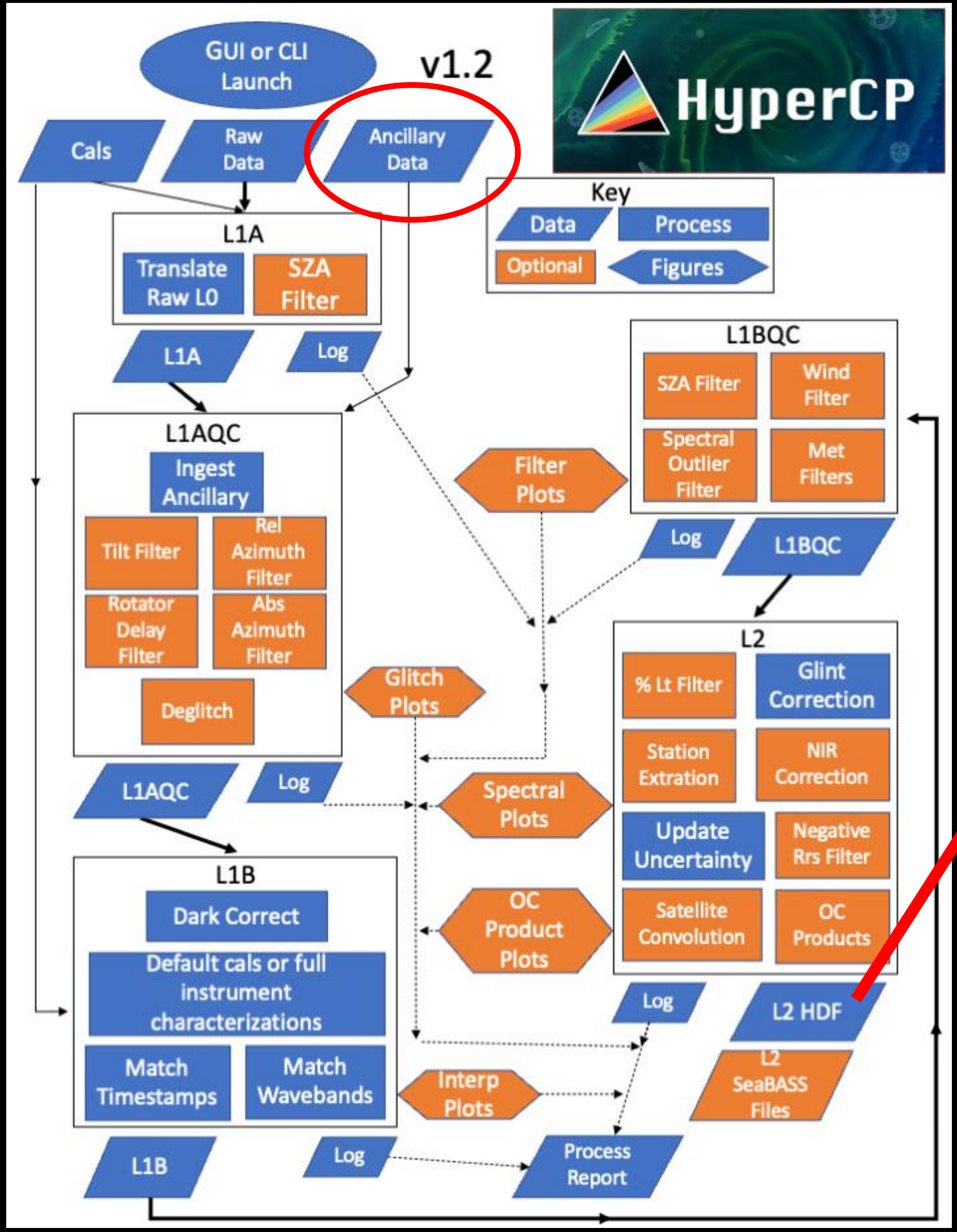
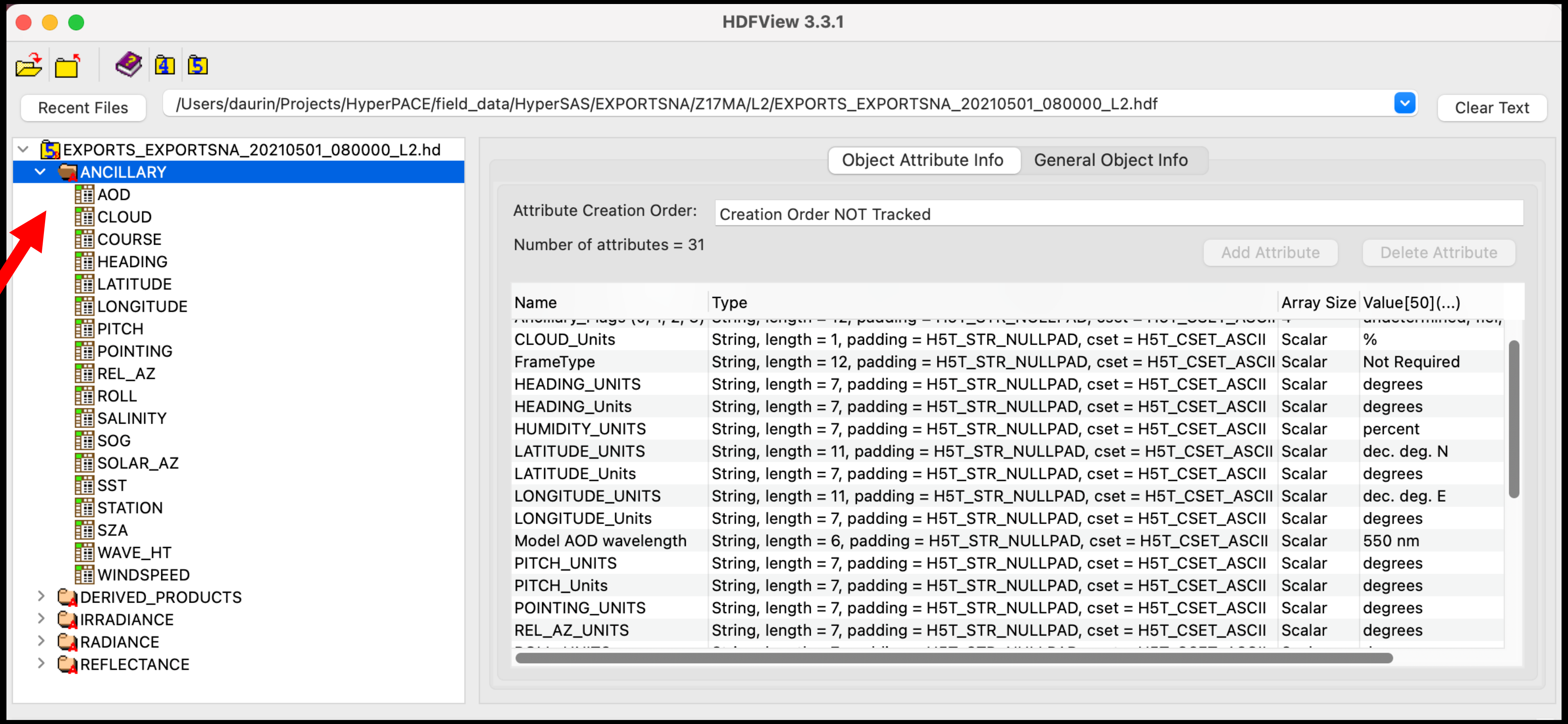
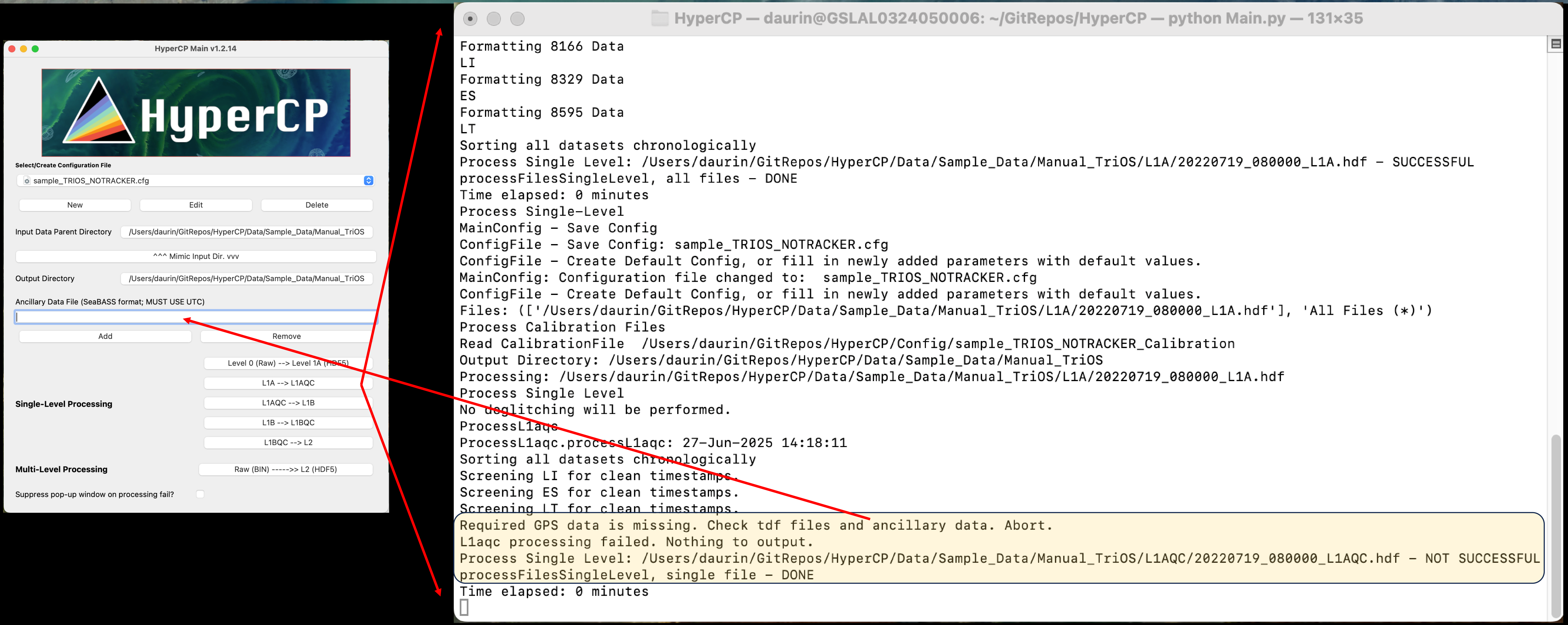
Ancillary Data at L2





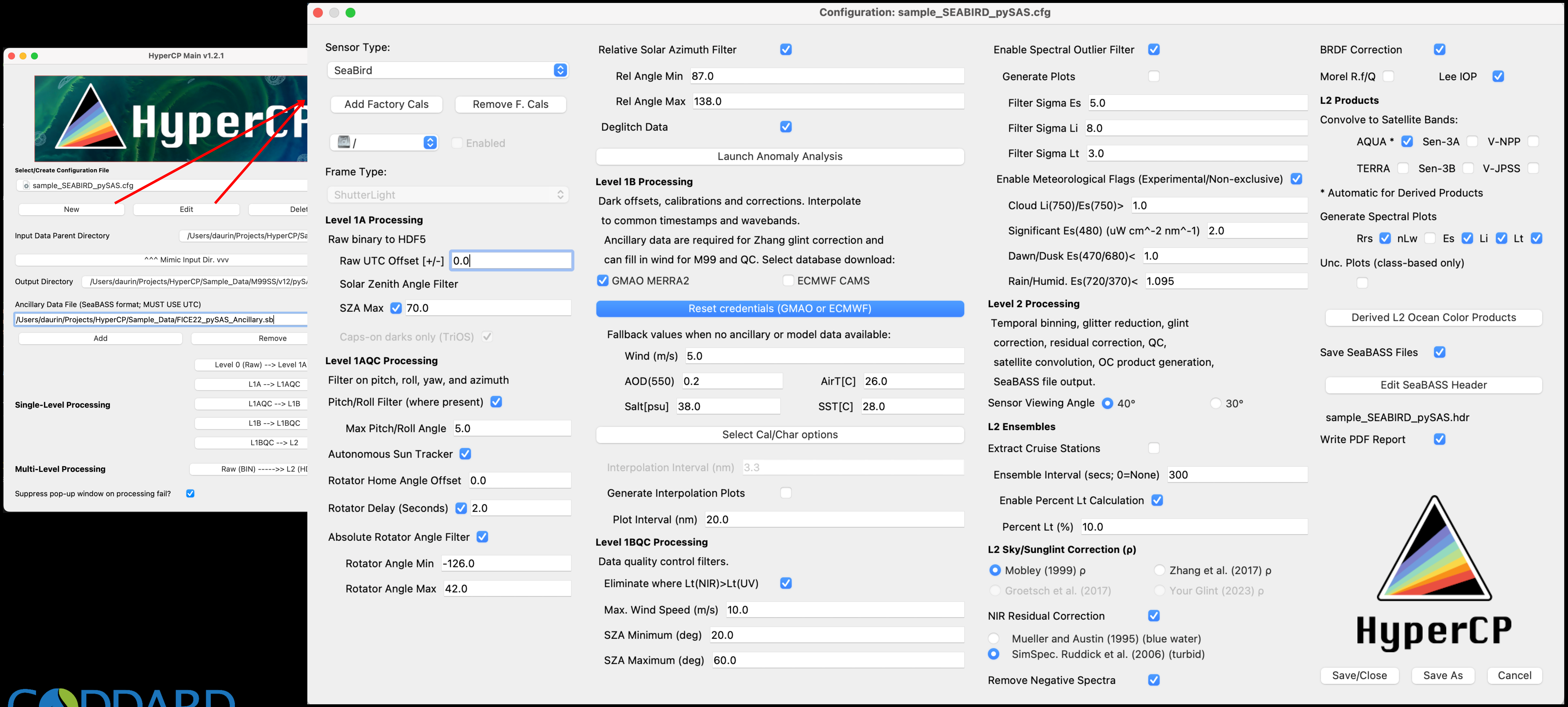
- Some of these are used for processing the data in HyperCP and some are used later in selecting data for mission validation.
- Much of this (not all) is captured automatically in the SeaBASS file metadata.
- We ask that you submit your L2 HDF files (and raw files) with your SeaBASS files.

The Terminal



Keep an eye on the terminal for important feedback.

The Configuration Window



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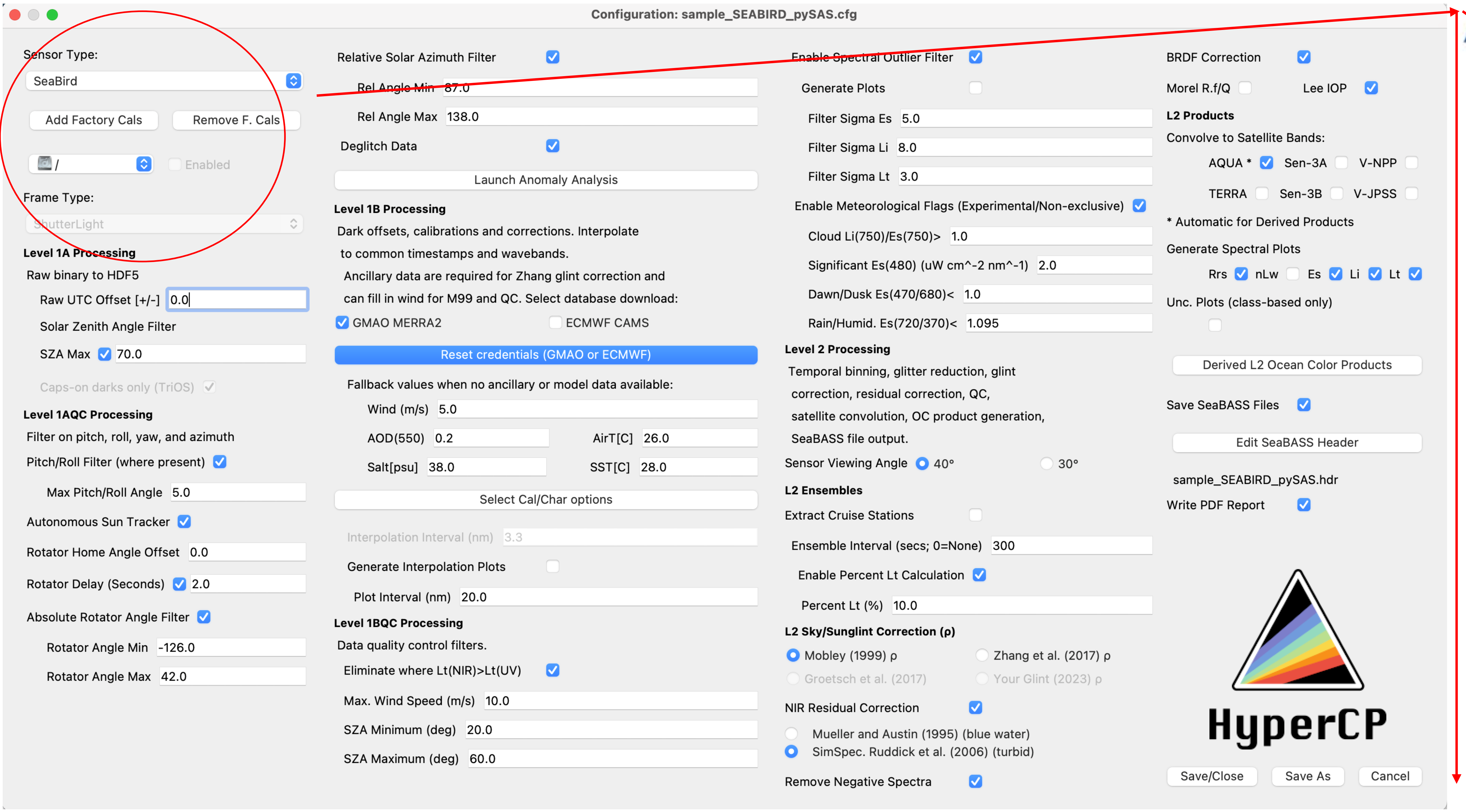
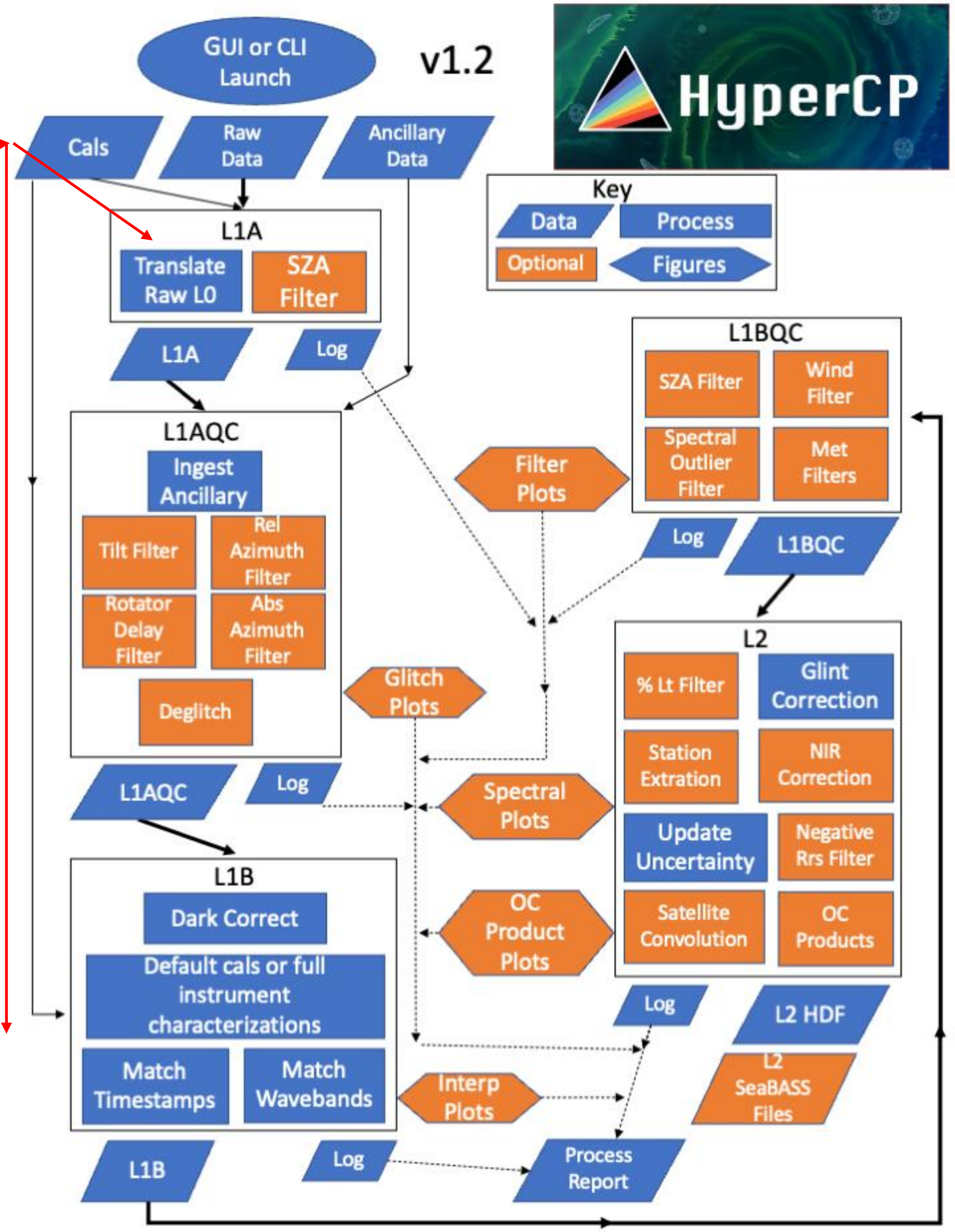
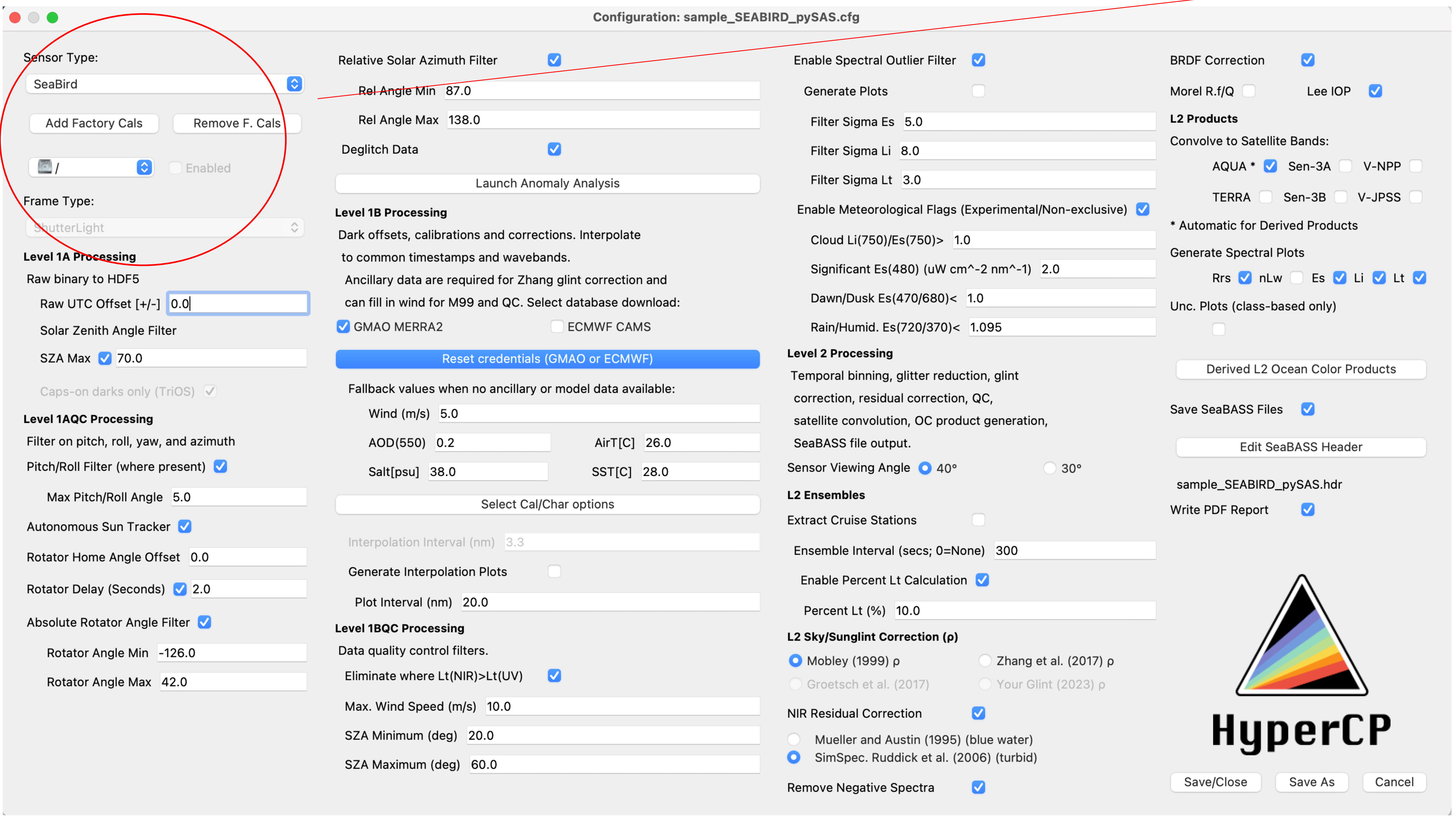
HyperCP: Loading Instrument Calibration





HyperCP: Loading Instrument Calibration



Sea-Bird HyperOCRs, pySAS

- GPRMC_NMEA0183v3.01.tdf ← GPS
- HED0187p.cal ← Es
- HLD0250h.cal ← Li
- HLD0251h.cal ← Lt
- HSE0187p.cal ← Es
- HSL0250h.cal ← Li
- HSL0251h.cal ← Lt
- HyperSAS.20230203.sip ← Zip of all .cal & .tdf files
- SATMSG.tdf
- SATTHS0009.tdf ← Tilt-Heading sensor
- UMTWR_v0.tdf ← Azimuth control robot

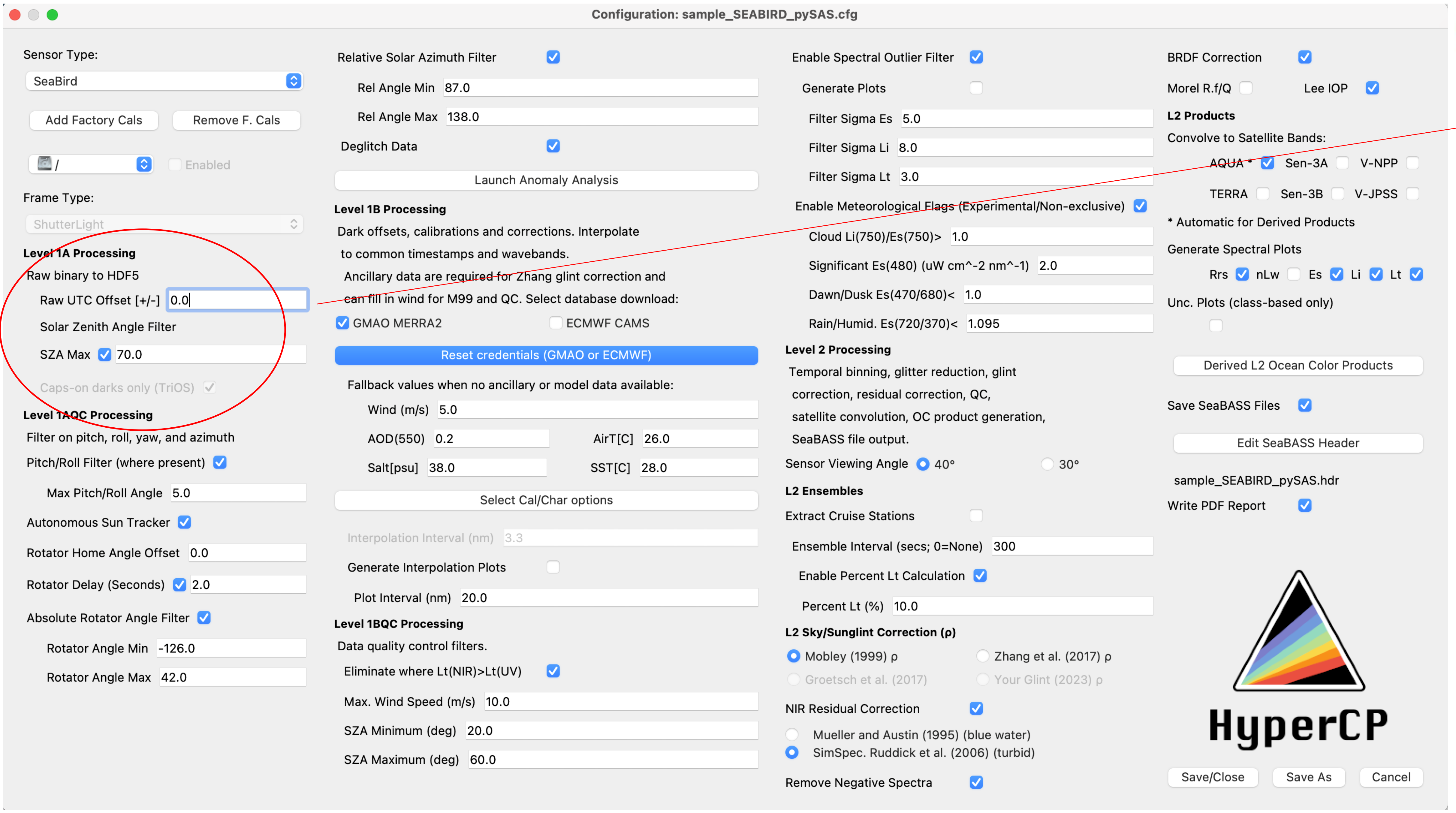
HED and HLD are **Dark** cals
HSE and HSL are **Light** cals

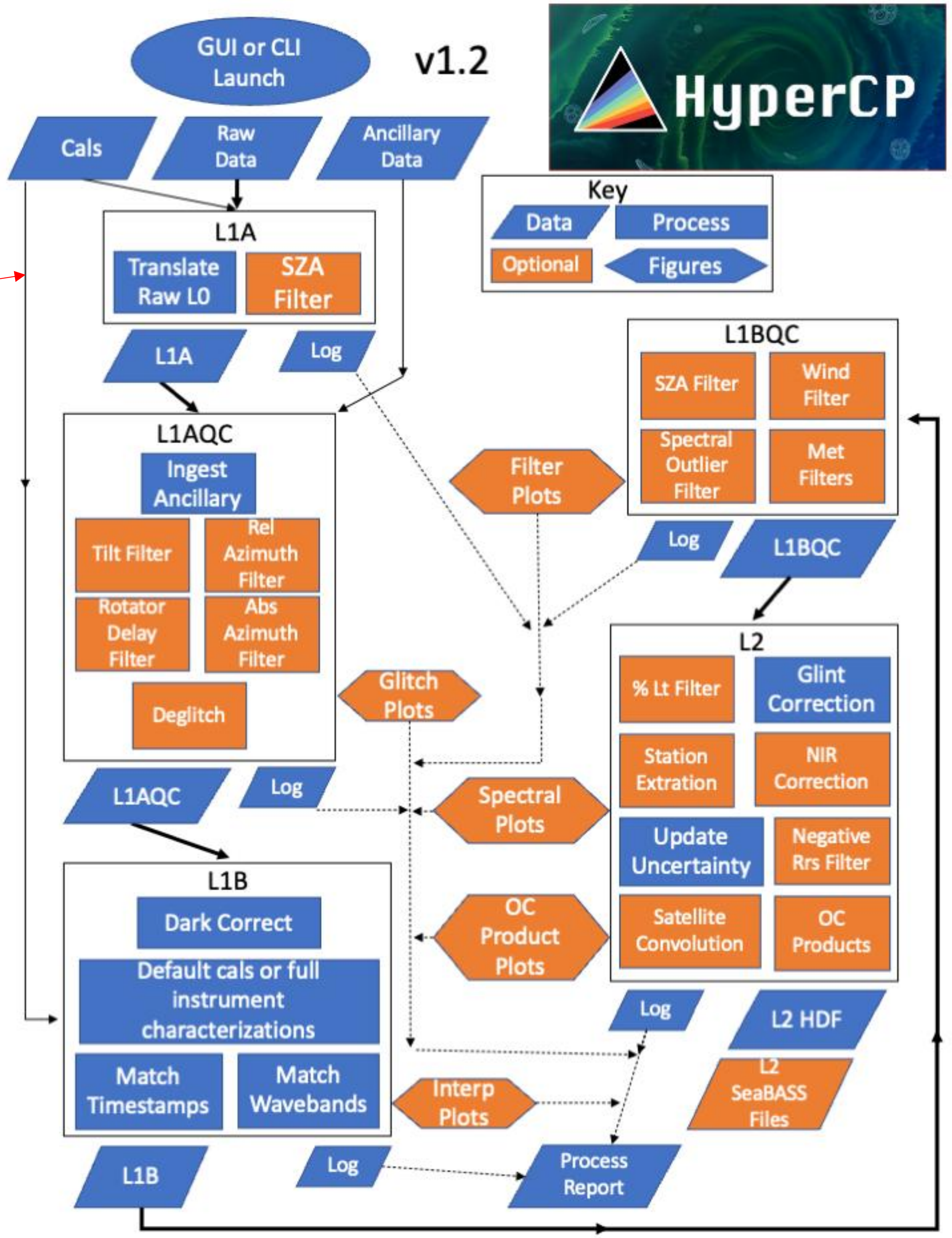
[HyperCP now automatically recognizes .cal files as Light/Dark and enables them by default on import.]

Demo:
Loading in Calibration and Telemetry Files

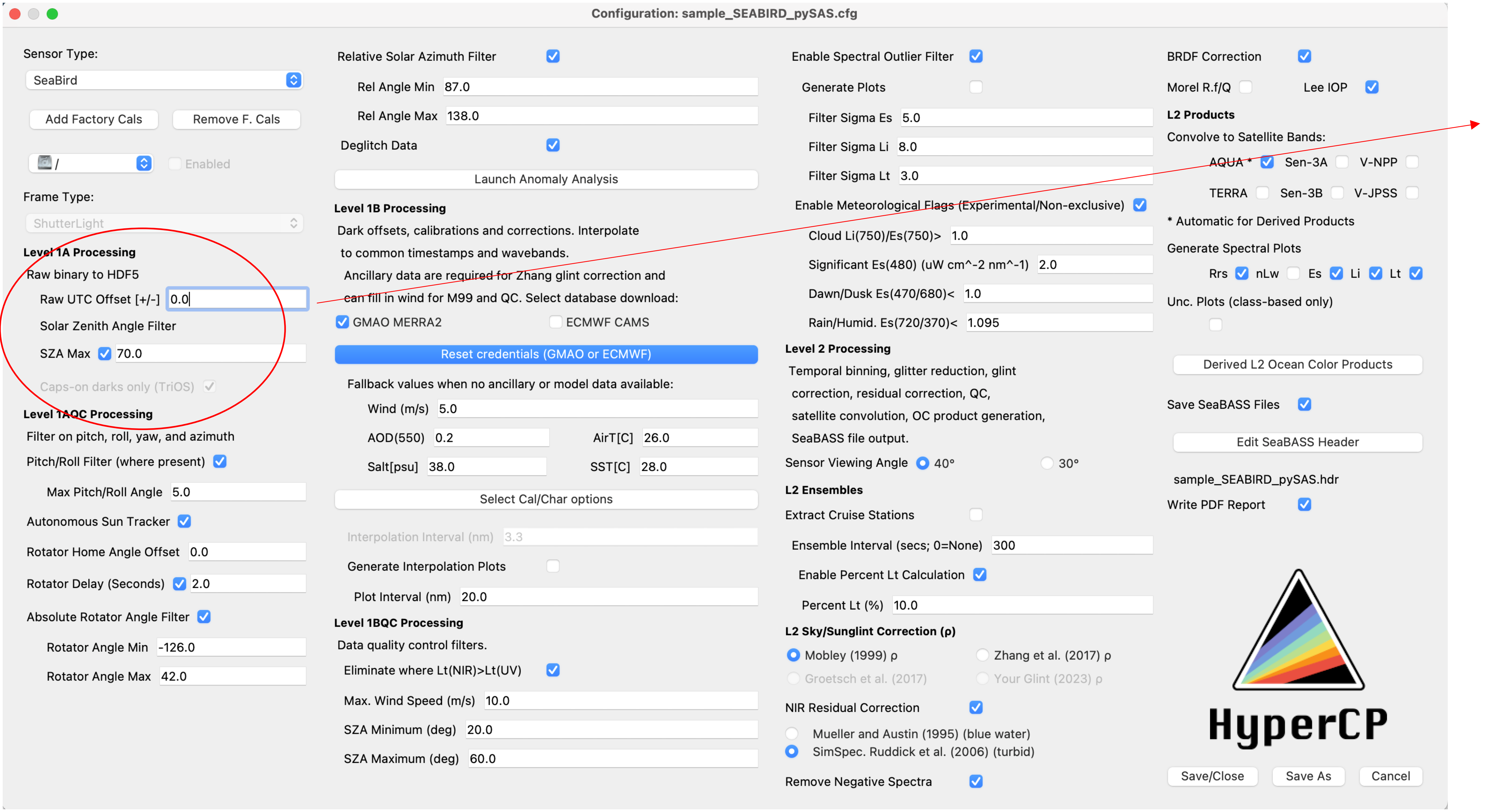
(Demo TBD based on timing)

HyperCP Level 1A: Read Data





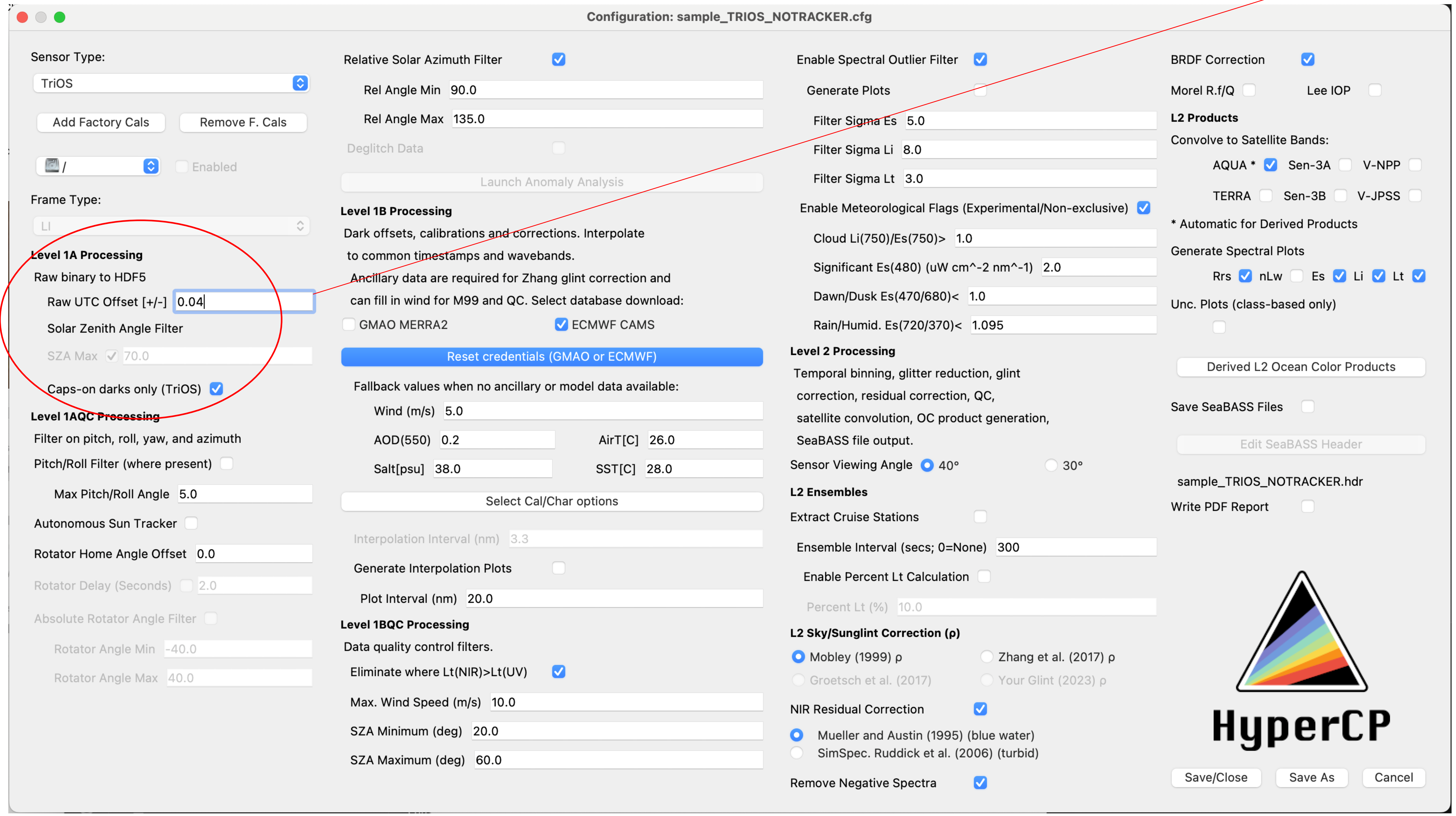
HyperCP Level 1A: Read Data



One should almost always set all computers, instruments, cameras, etc. to UTC when collecting data in the field. (Ancillary file must be UTC, currently. Data and photos can be accommodated for local but not recommended.)

SZA used here for data reduction of autonomous collections running into the morning/evening/overnight. SZA thresholds are fine-tuned in L1BQC.

HyperCP Level 1A: Read Data

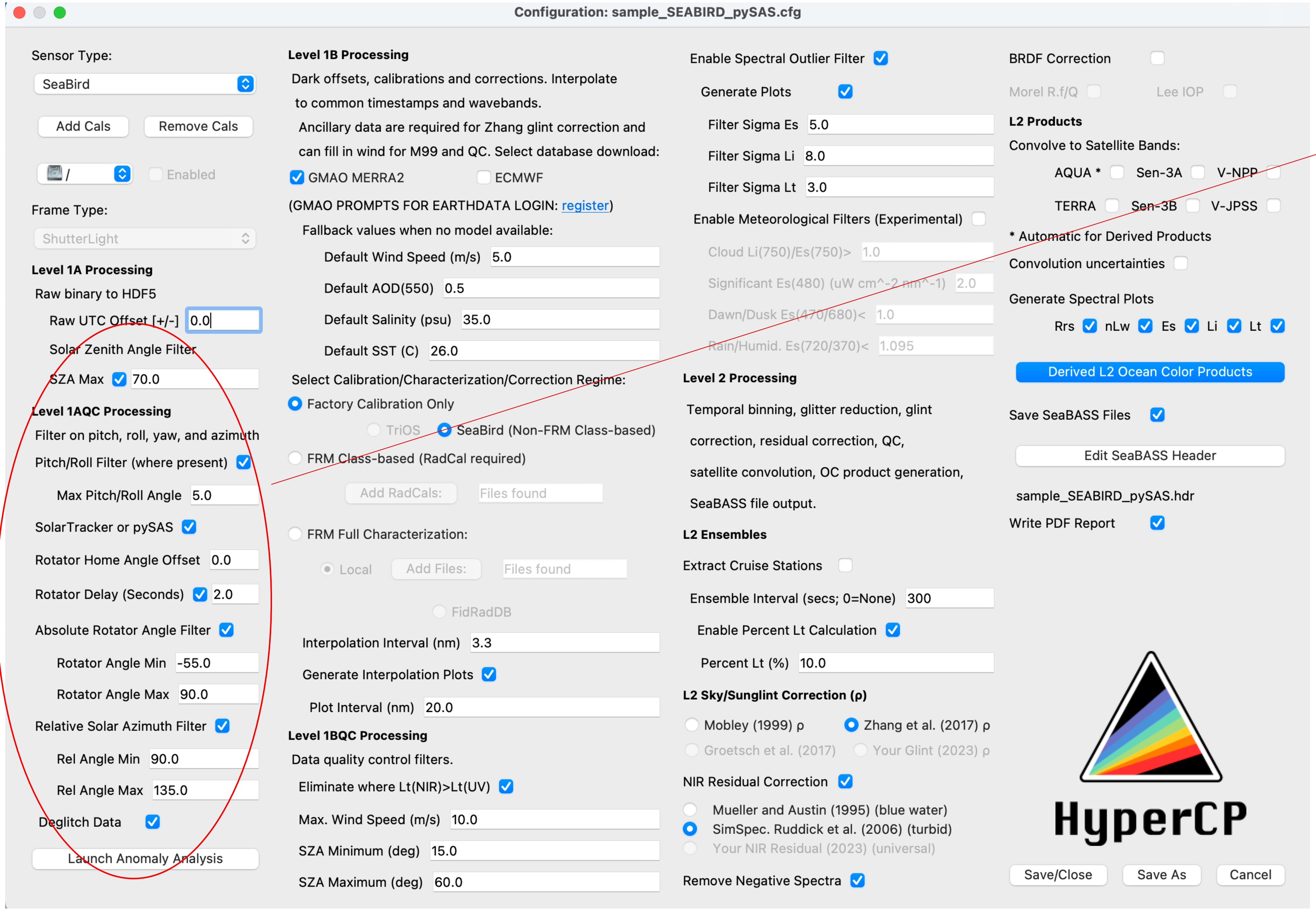


"Caps-on-darks" is a very special circumstance particular (currently) to TriOS configurations for estimating the internal working temperature of the radiometers, particularly the older "G1" models that have no internal thermistor.

Typically applied in conjunction with normal (no caps) measurements, temperatures estimated from instrument noise with the lens caps covering the fore optics can be applied to normal measurements taken shortly before or after for use in the thermal correction and uncertainty budget.

Caps-on-darks need only be run to L1A and require special file naming conventions.

HyperCP Level 1AQC: Quality Control Data



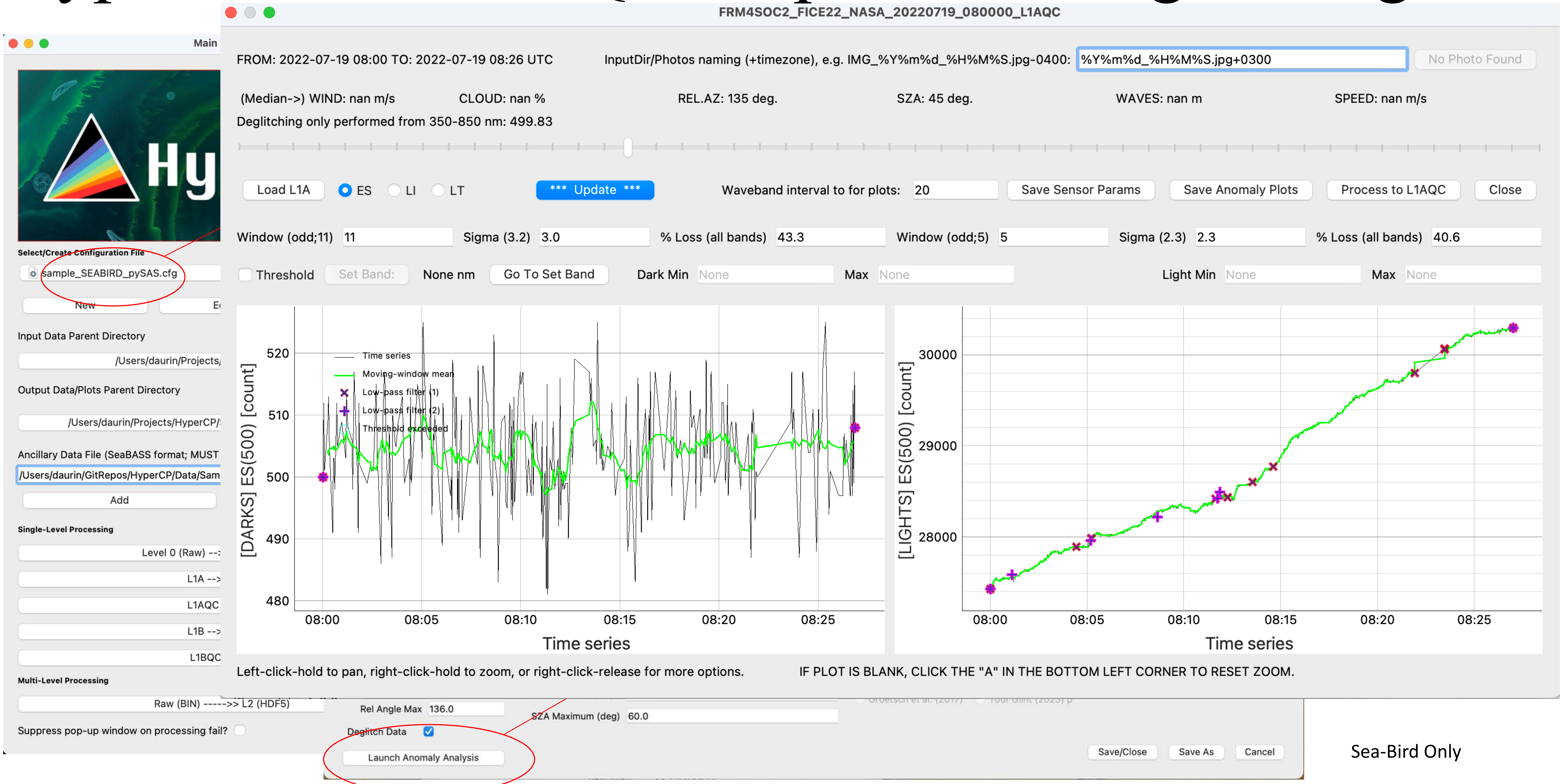
(See README documentation for explanation/sources of all default and recommended values throughout configuration.)

Tilt of Es should not exceed 5 degrees.

Identify whether an azimuth robot (e.g., SolarTracker or pySAS) was used. If not, the Ancillary file must include Sensor Azimuth or Relative Azimuth. If GPS is also missing in the instrumentation above, Latitude and Longitude must be included in the Ancillary file.

Use field logs/notes to identify min/max sensor azimuth (rotator angle to avoid obstruction) and home offset (latest values can also be recovered from pySAS file pysas_cfg.ini)

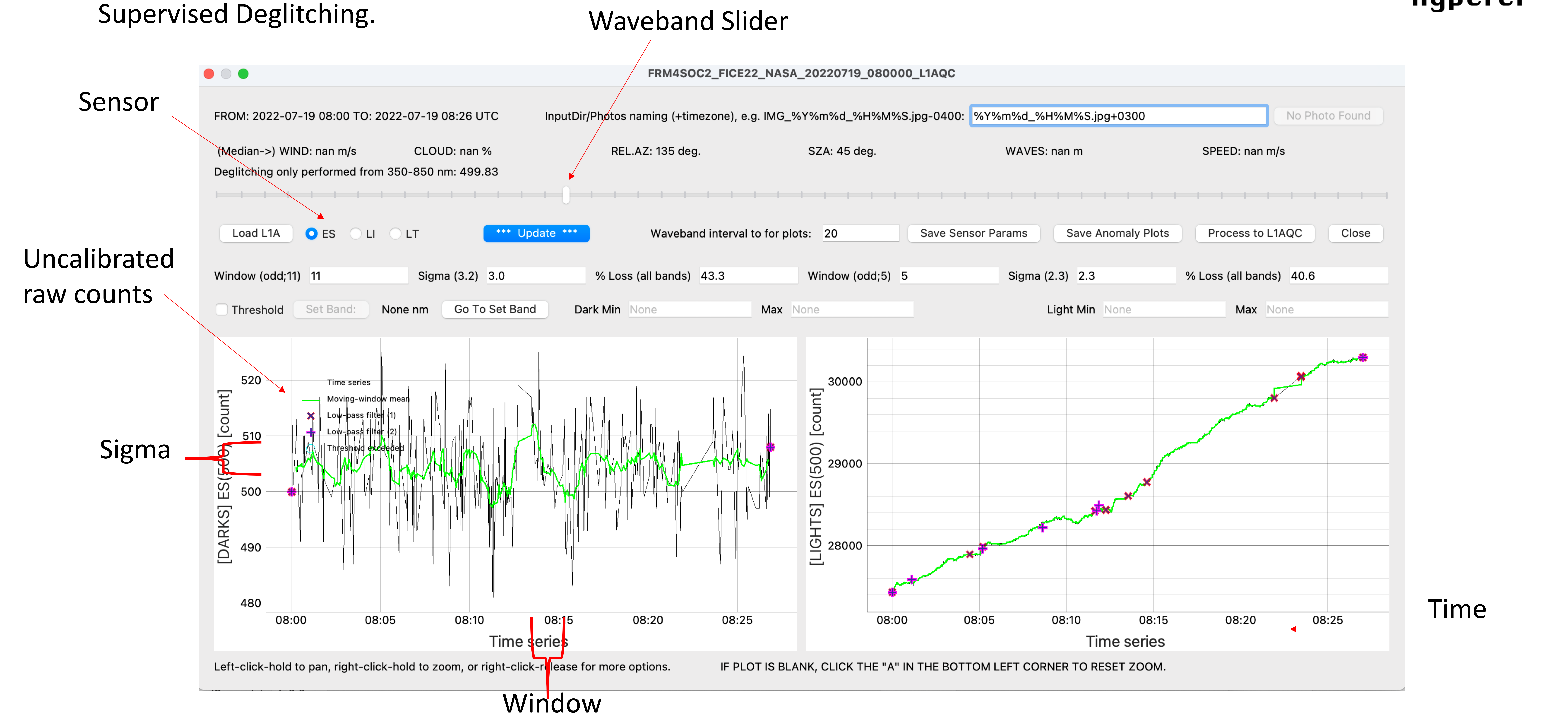
HyperCP Level 1AQC: Supervised Deglitching



Sea-Bird Only

HyperCP Level 1AQC: Supervised Deglitching

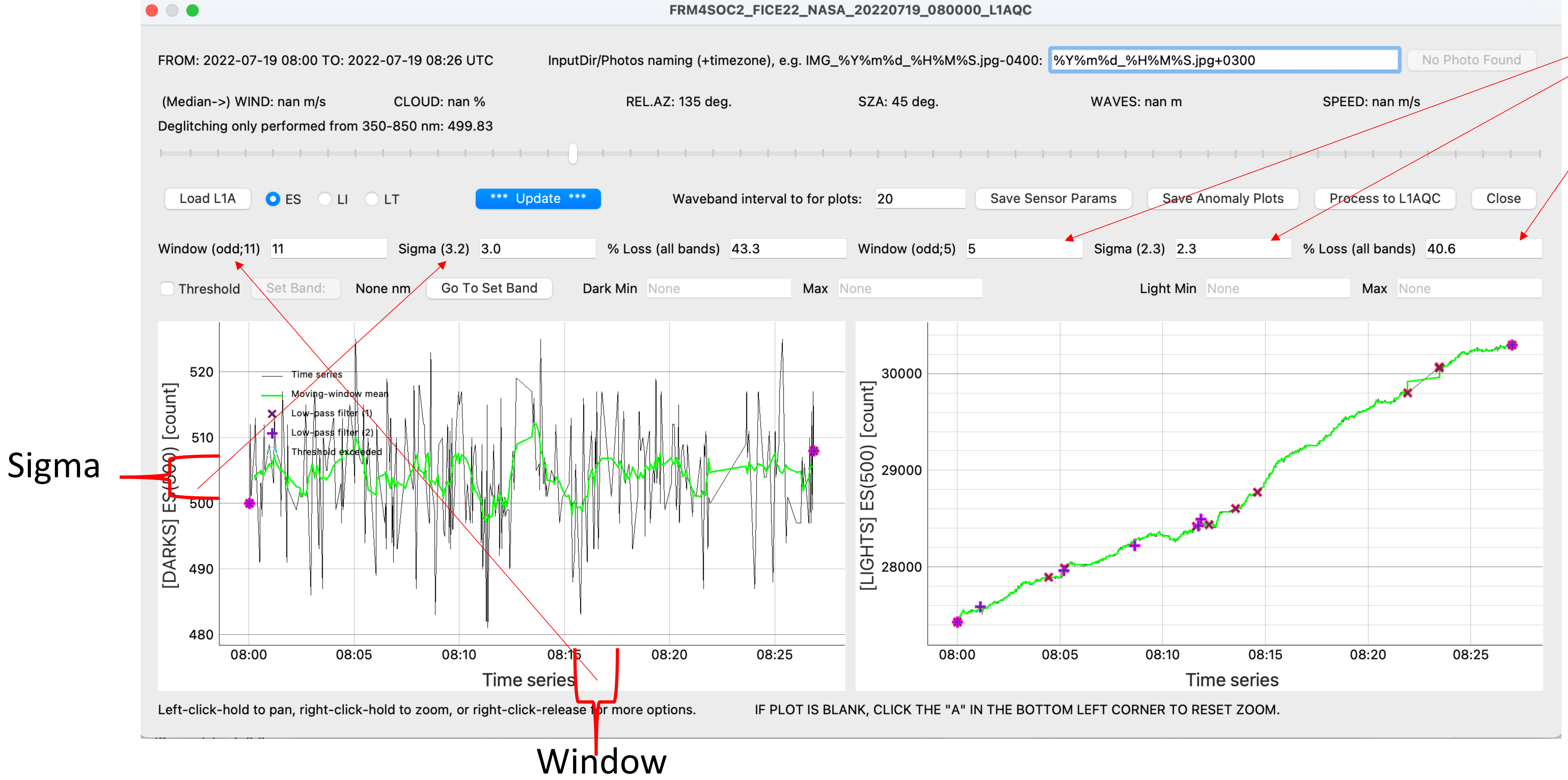
Supervised Deglitching.



HyperCP Level 1AQC: Supervised Deglitching

HyperCP

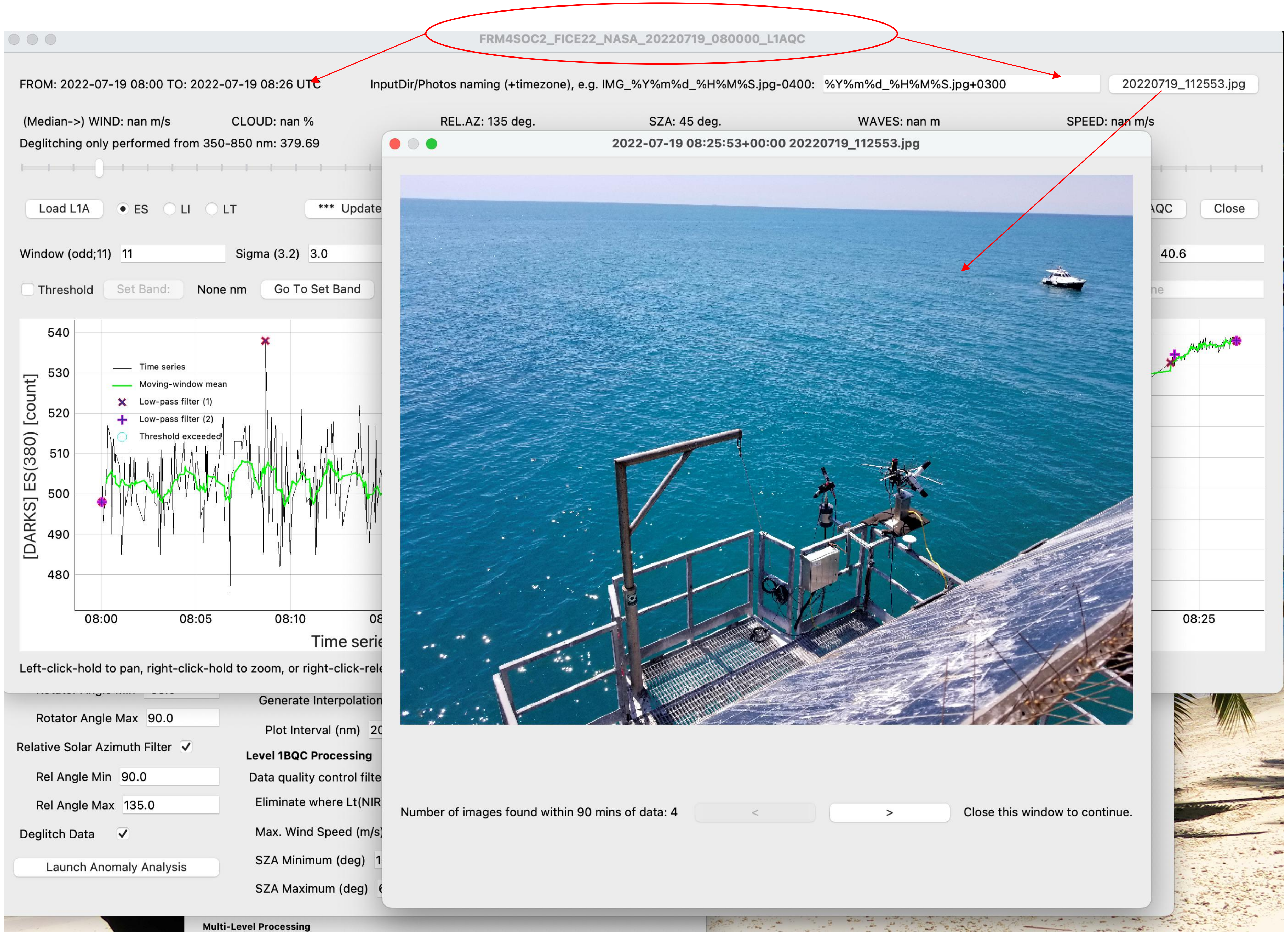
Supervised Deglitching.



Balance these while visually evaluating signal variability throughout the file. More aggressive deglitching yields lower uncertainty traded off against less data.

(Note: This file could be 5 mins or 5 hours, but default pySAS collections are 1 hr autonomous.)

HyperCP Level 1AQC: Supervised Deglitching

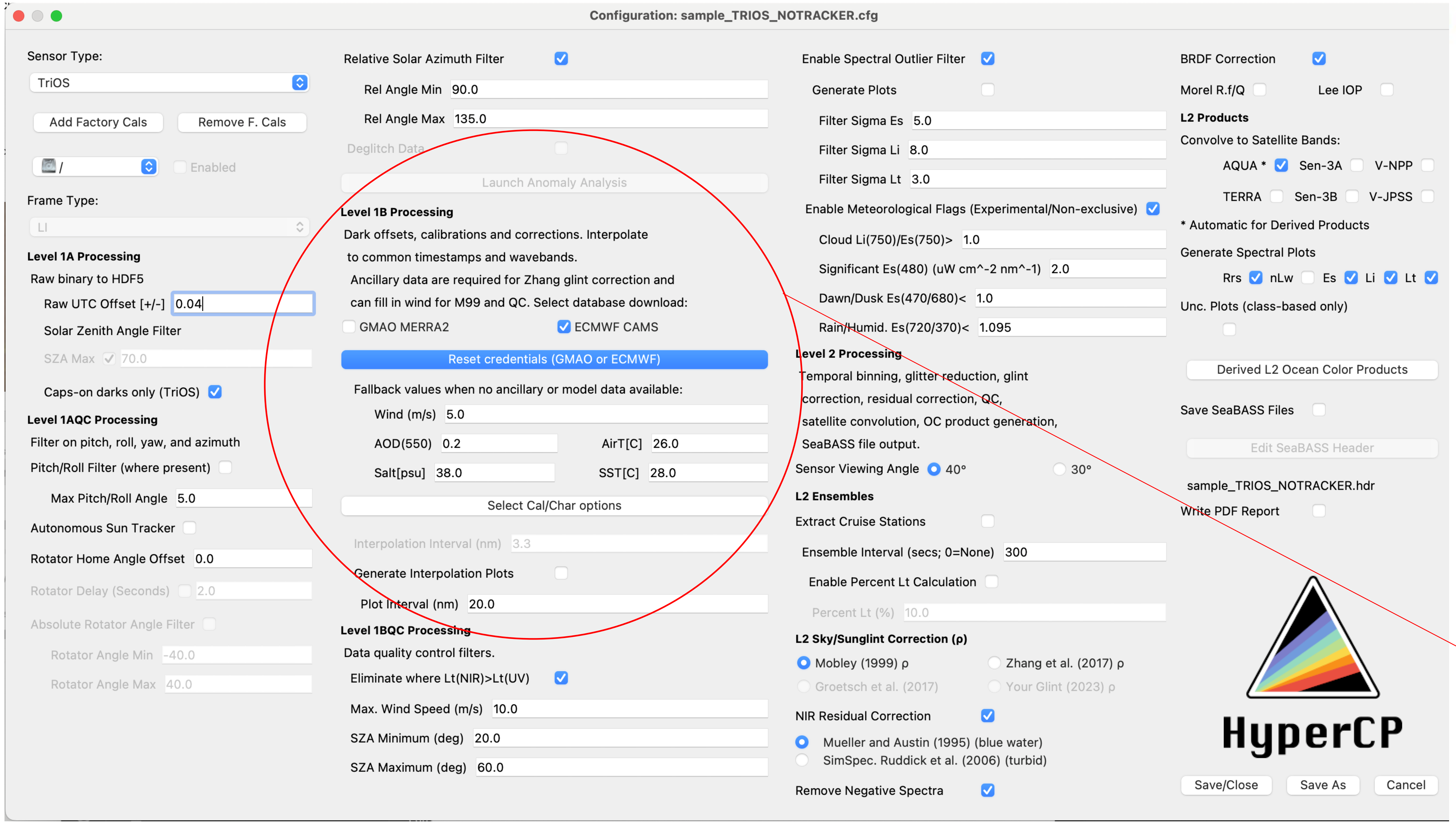


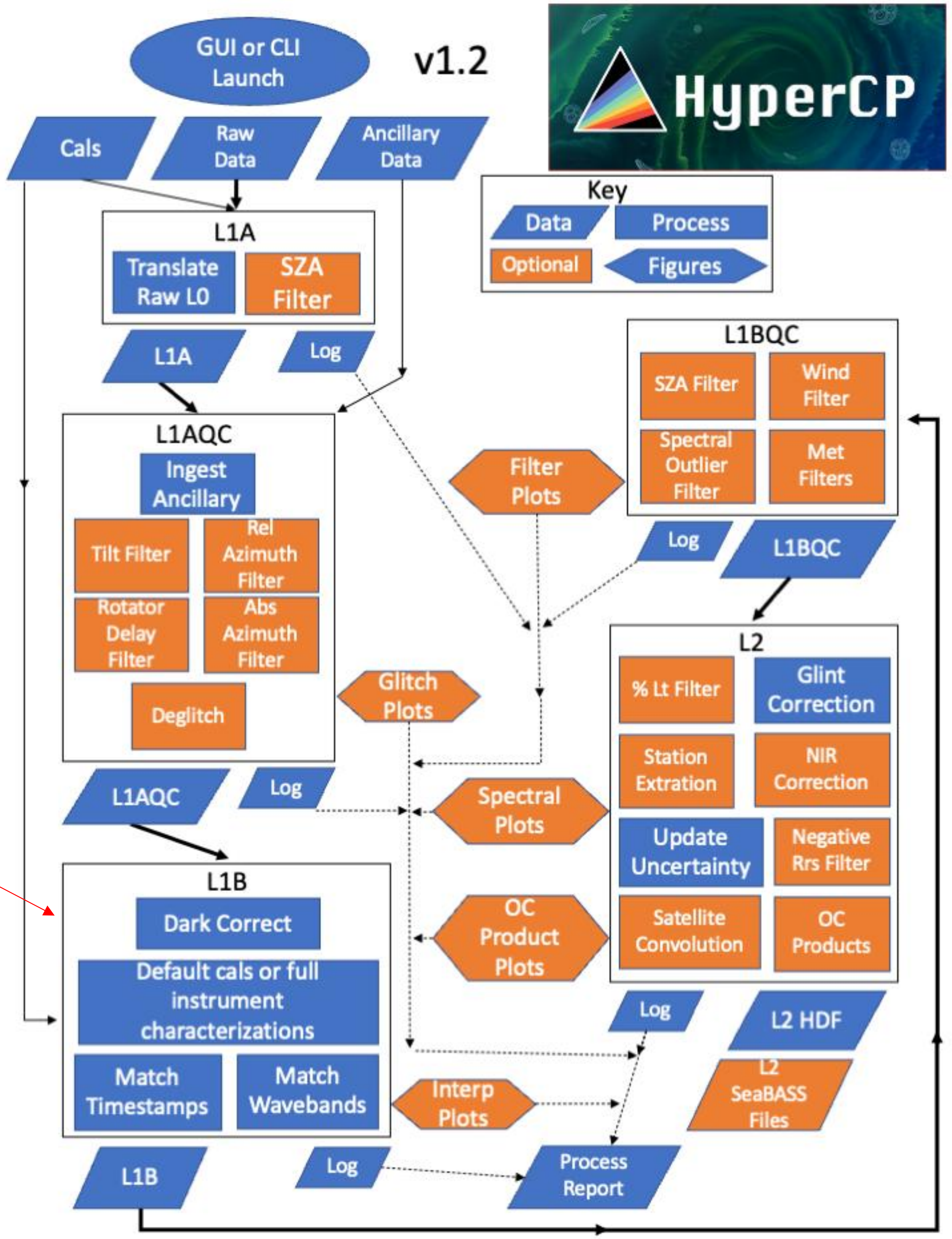
HyperCP

Demo:
Supervised Deglitching

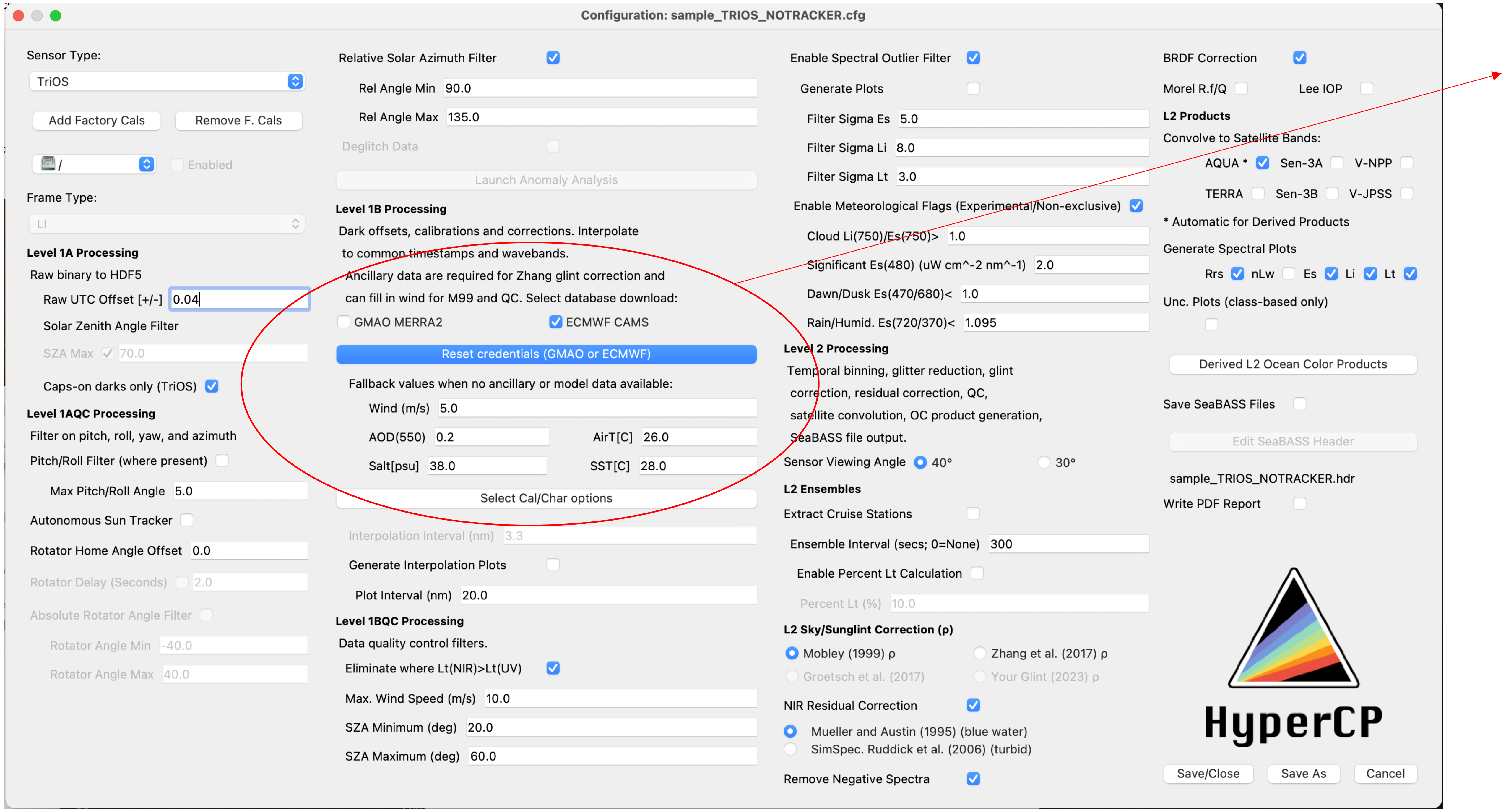
(Demo TBD depending on timing)

HyperCP Level 1B: Overview





HyperCP Level 1B: Load Ancillaries

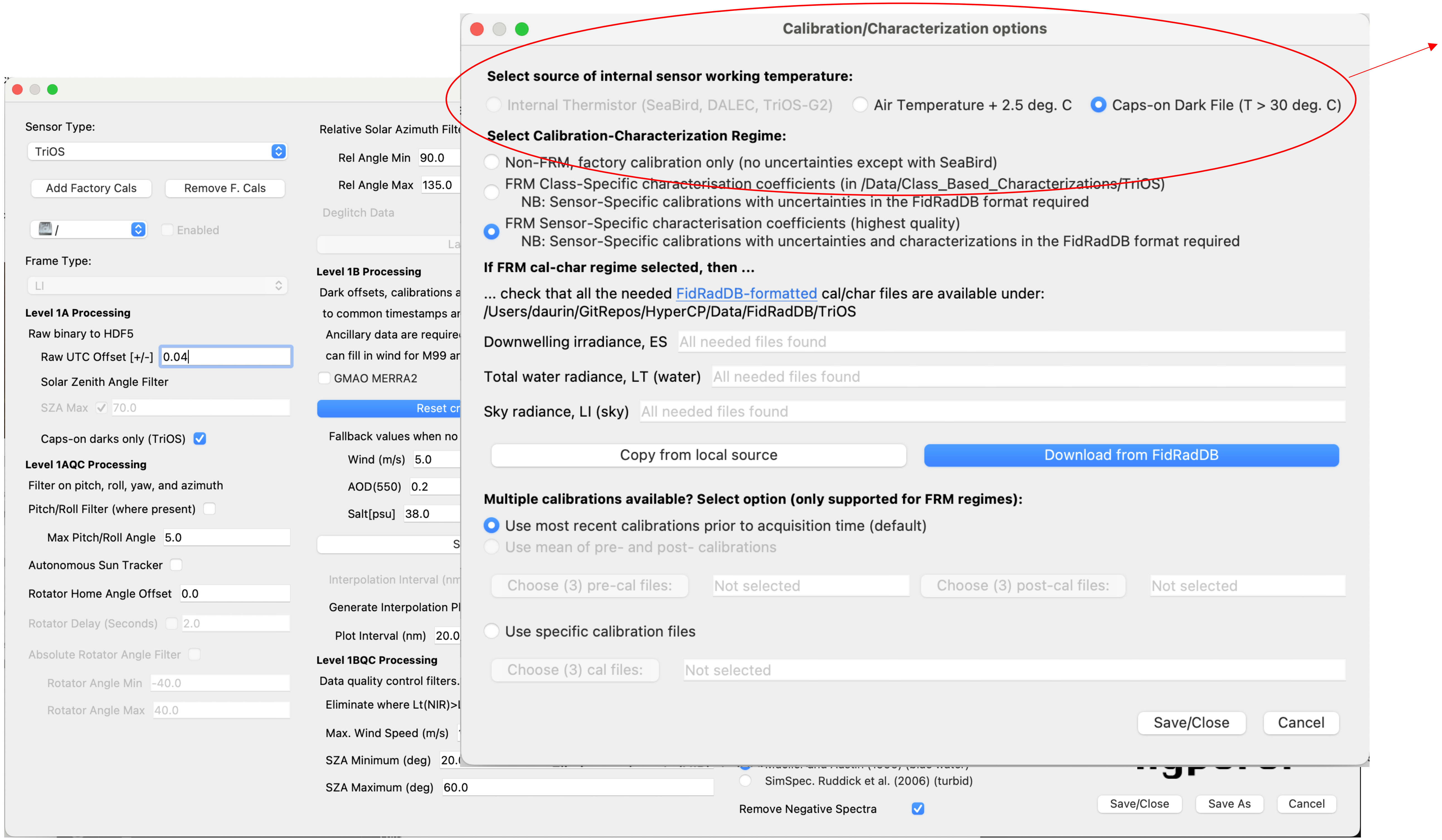


Wind speed is a requirement of L2 glint correction. AOD is a requirement of cosine correction, uncertainty budgets, and the Zhang et al. 2017 glint correction (along with SST and Sal). Air temp. may be used in thermal corrections.

Gaps in the Ancillary file can be filled using course model data -- either NASA GMAO or European ECMWF.

These fallback values are used if neither Ancillary nor model data are found. (*Not recommended for final process, but often needed for use in preliminary processing and data checks before model data are available, e.g., in the field*)

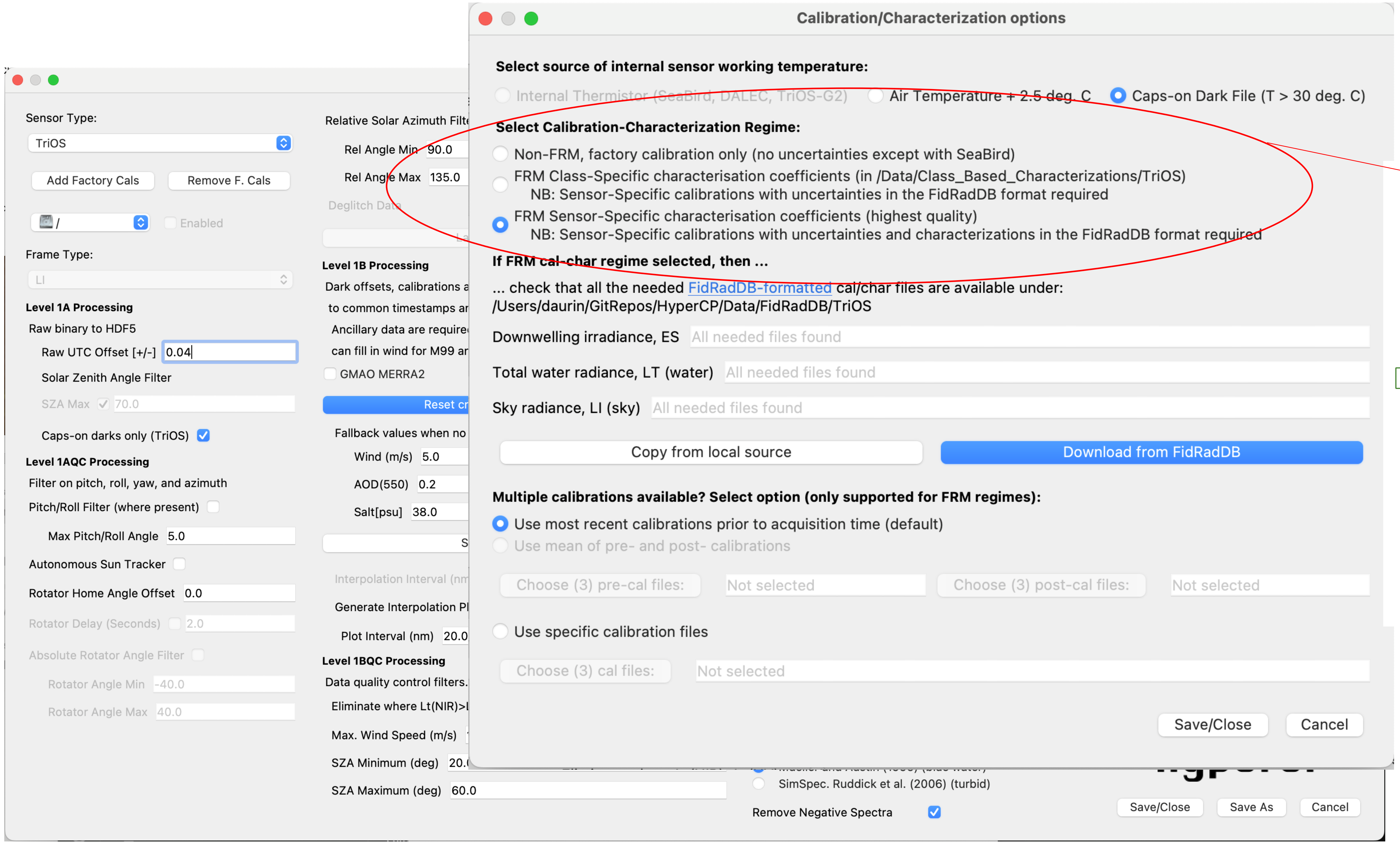
HyperCP Level 1B: Sensor Temperature

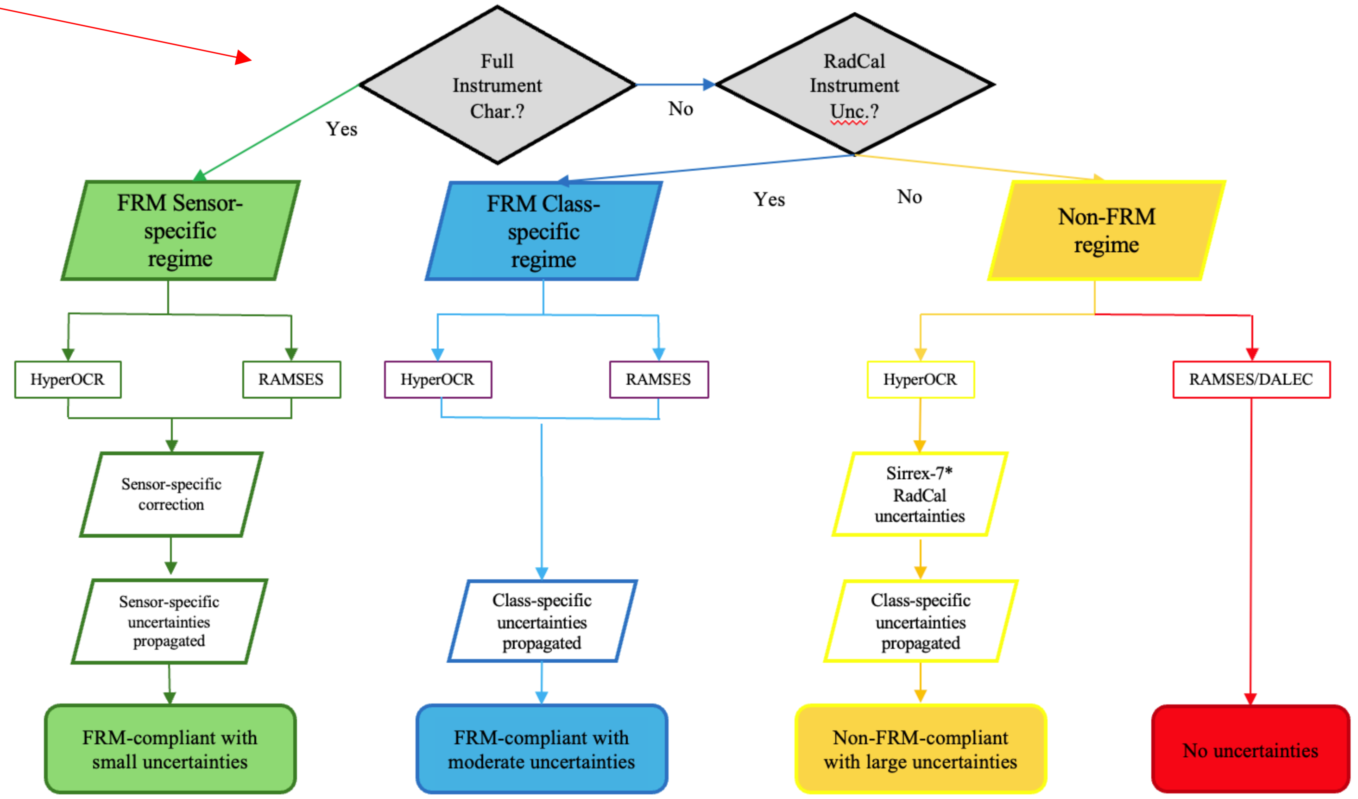


To calculate the thermal response correction and/or uncertainty, the source of the temperature must be identified. For instruments with a built-in internal thermistor (Sea-Bird, DALEC, TriOS G2), this is automatically selected.

For sensors without a thermistor, the working temperature is estimated from either air temperature + 2.5 C or data collected with the foreoptics occluded, when available. The latter approach is more accurate in high temperature settings (> 30 C).

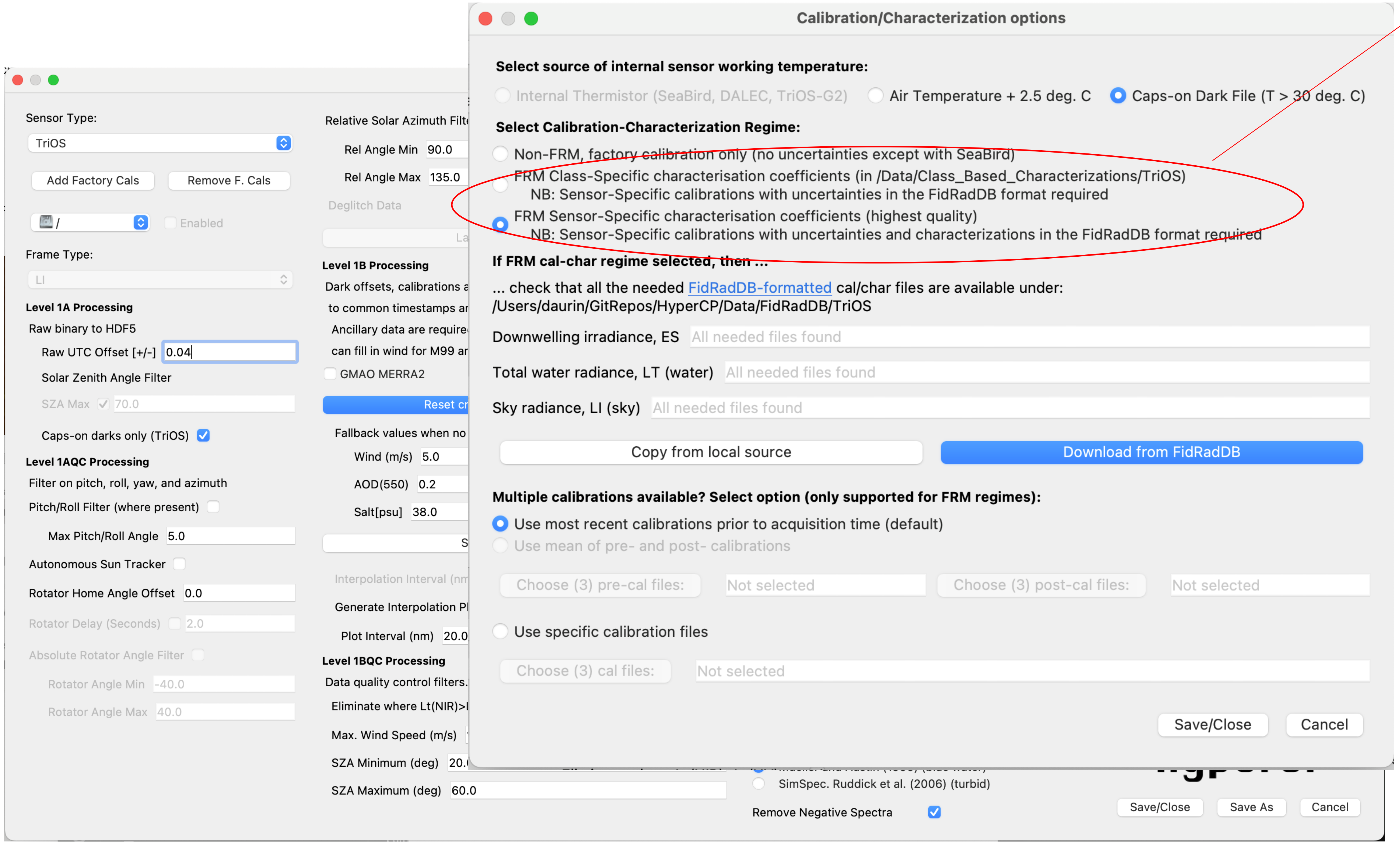
HyperCP Level 1B: FRM Cal/Char Regimes





NOTE that absolute radiometric calibrations *with uncertainty and in FidRadDB format* are required for FRM Class-based processing. Manufacturer cals do not (yet) include this… but we're working on it.

HyperCP Level 1B: FRM Regimes



FRM Class-specific (e.g., Sea-Bird or TriOS) and sensor-specific characterizations help accurately estimate uncertainties associated with instrument response using Monte Carlo modeling for:

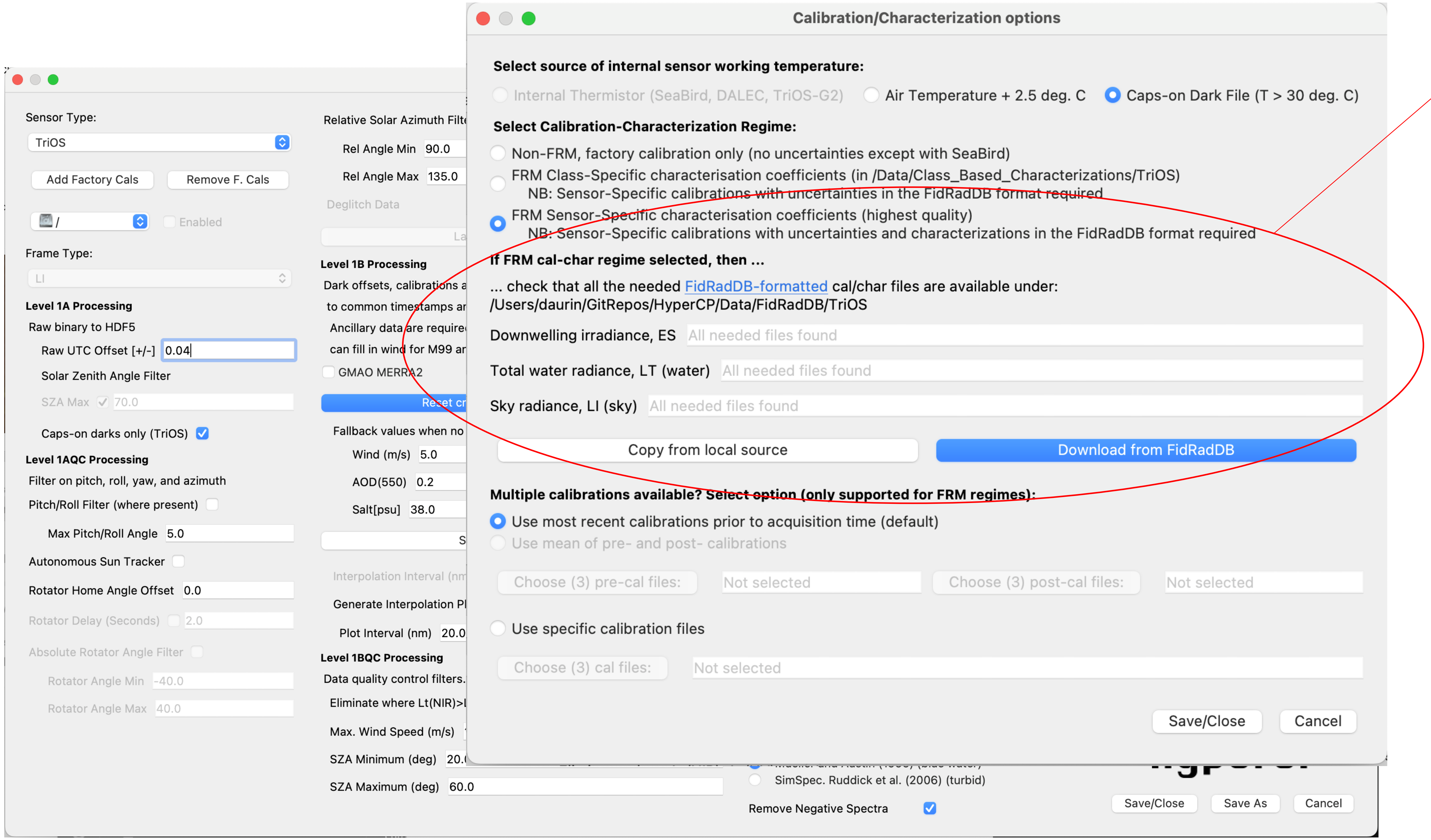
- Linearity of response
- Calibration/stability
- Straylight response
- Angularity of response
- Polarization response
- Thermal response

Sensor-specific characterizations also allow for corrections to be applied for linearity, calibration, straylight, cosine, and thermal response, thereby reducing uncertainty further.

Białek, A., et al.. Example of Monte Carlo Method Uncertainty Evaluation for Above-Water Ocean Colour Radiometry. *Remote Sens*. **2020**, *12*, 780. https://doi.org/10.3390/rs12050780

NOTE that absolute radiometric calibrations *with uncertainty and in FidRadDB format* are required for FRM Class-based processing. Manufacturer cals do not (yet) include this… but we’re working on it.

HyperCP Level 1B: Factory/Class/Full

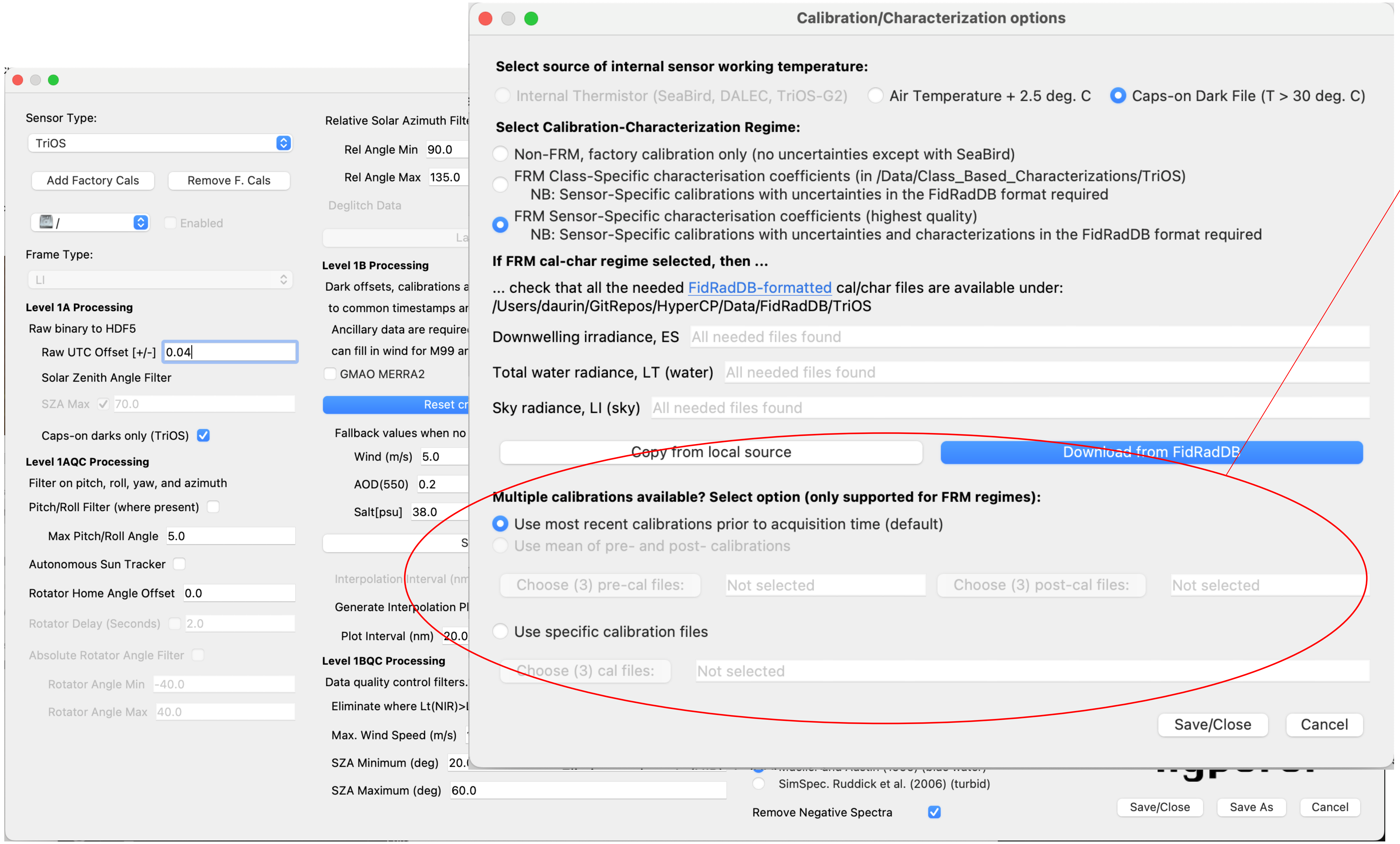


This interface will allow you to add the required calibration and characterization files (FidRadDB), depending on which regime you select.

The Fiducial Radiometer Database (FidRadDB) hosts the Cal/Char files for specific instruments evaluated in the lab at Tartu Observatory.

To import these Cal/Char files into HyperCP, either use the interface to copy them from a local source or allow HyperCP to download your files from FidRadDB directly.

HyperCP Level 1B: Factory/Class/Full



Because calibrations (and some characterizations) change over time, this interface allows you to choose which Cal/Char files to apply.

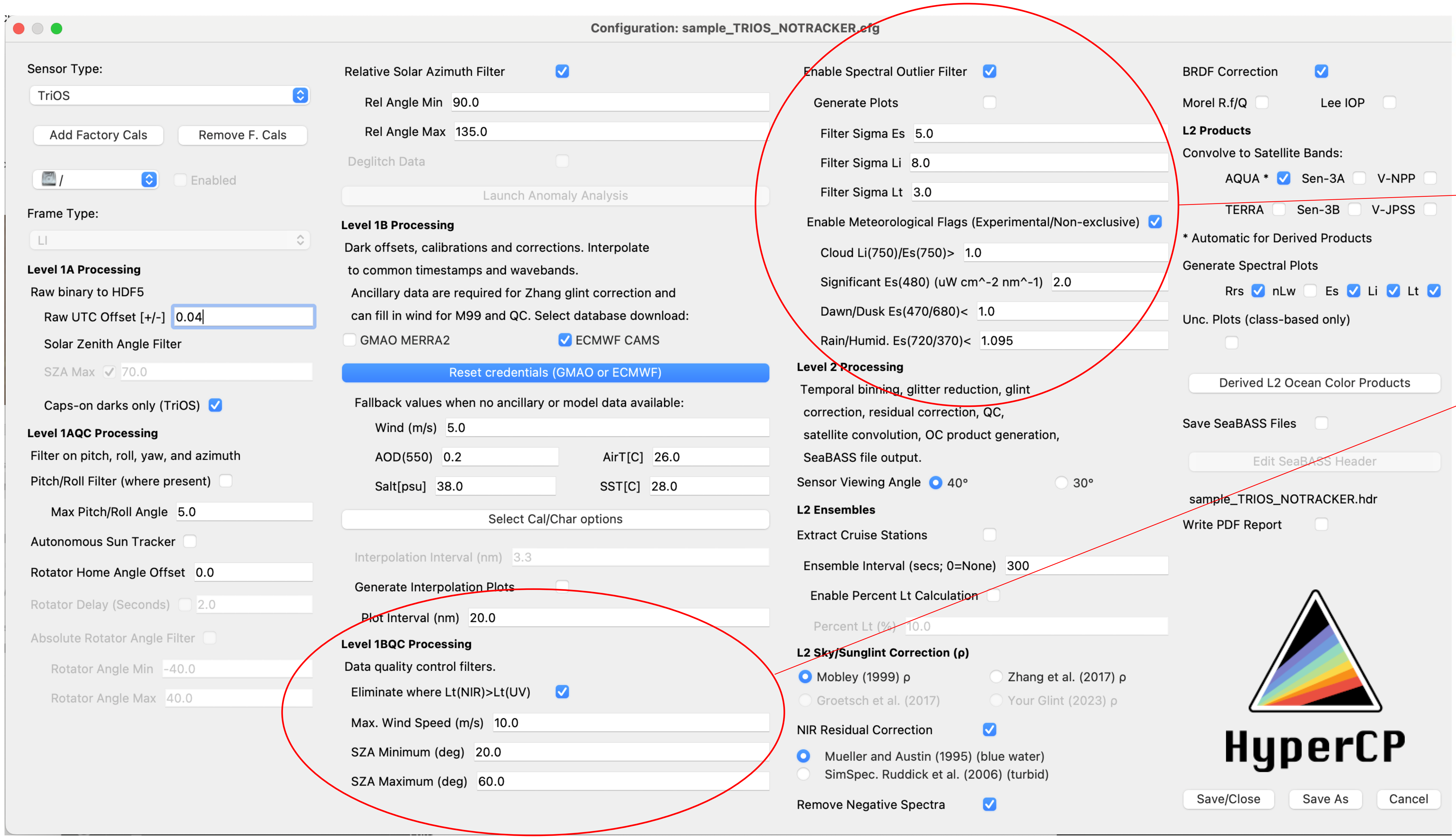
(Pre- and post-calibration averaging is still under development.)

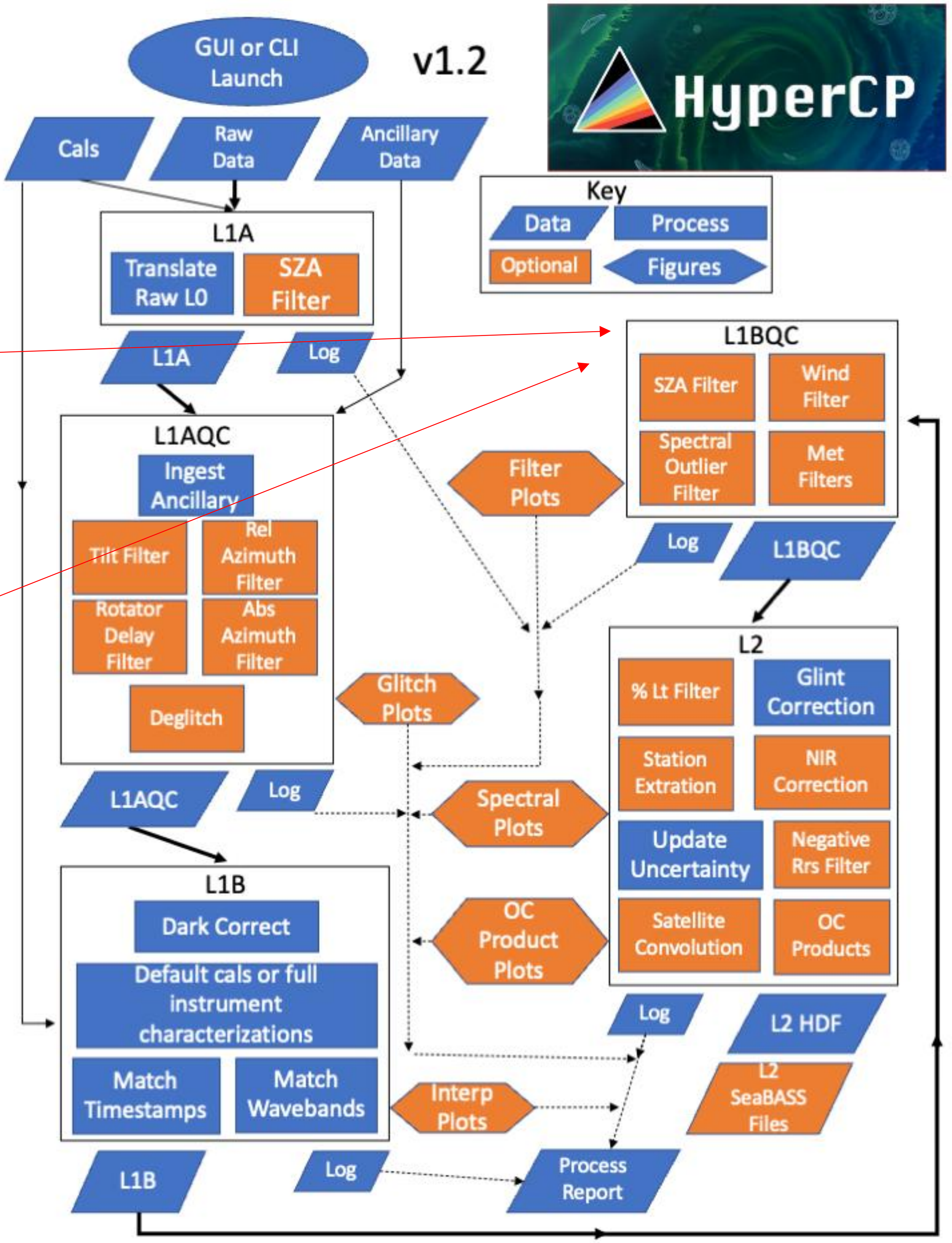
HyperCP

Demo:
Loading RadCal or Full Characterization Files

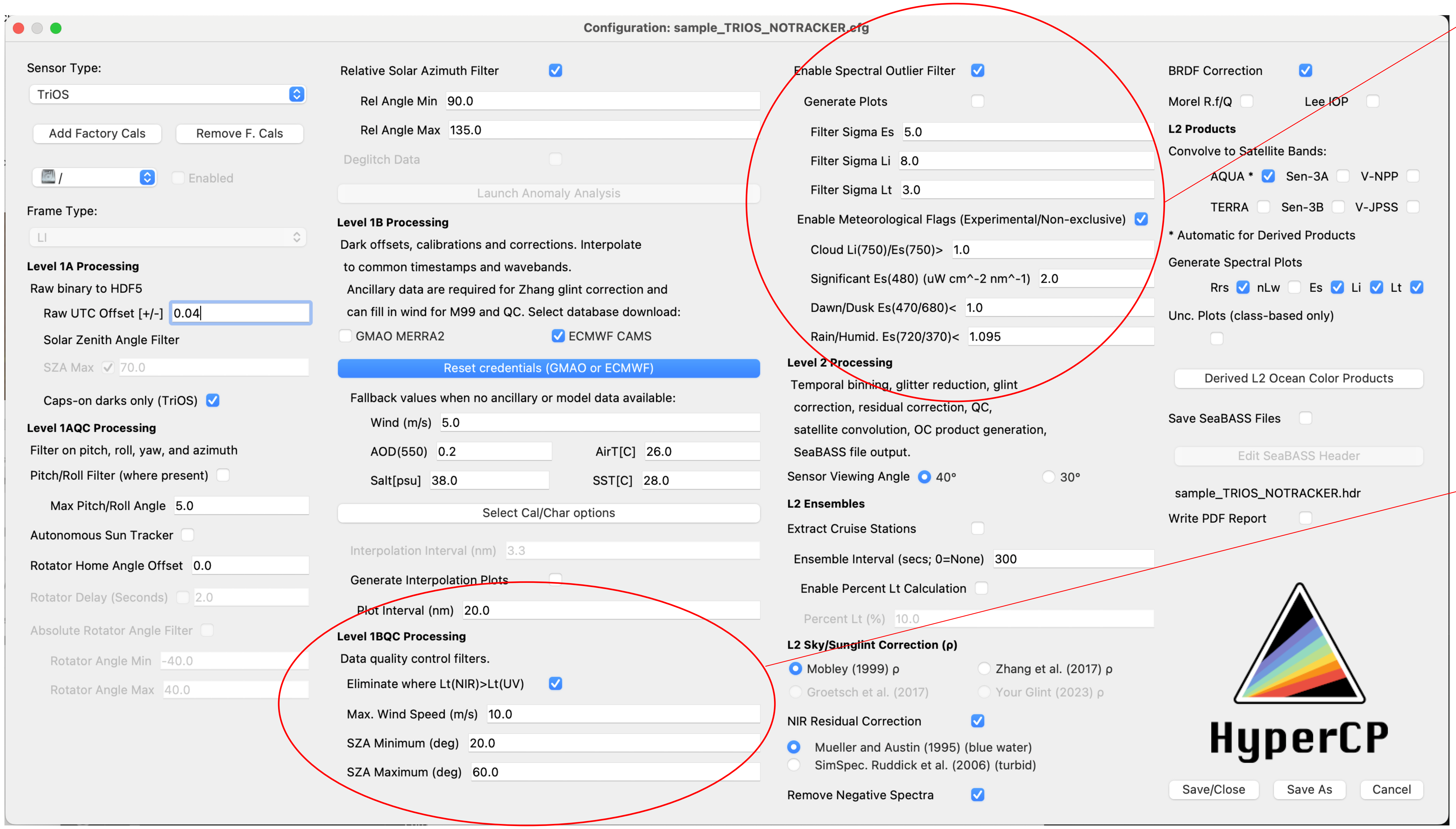
(Demo TBD depending on timing)

HyperCP Level 1BQC: Quality Control with Ancillaries & Stats





HyperCP Level 1BQC: Quality Control with Ancillaries



Reducing spectral filter sigma factors discards more of the spectra as outliers (see plots in later slides). For HyperSAS/pySAS platforms, one hour of raw data may contain as many as many as ~3,000 spectra, depending on light conditions and integration time.

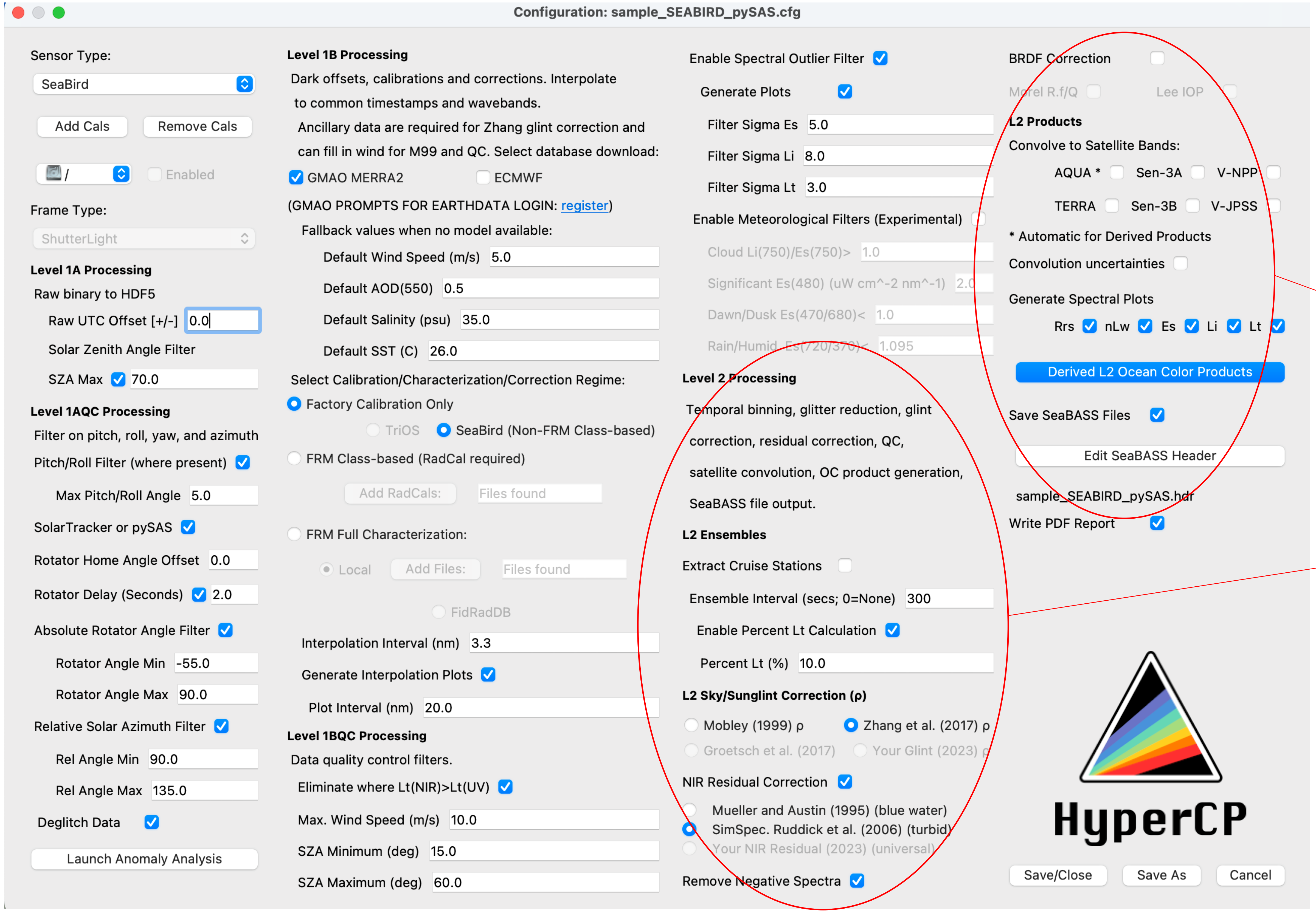
Met filters are optional and considered experimental.

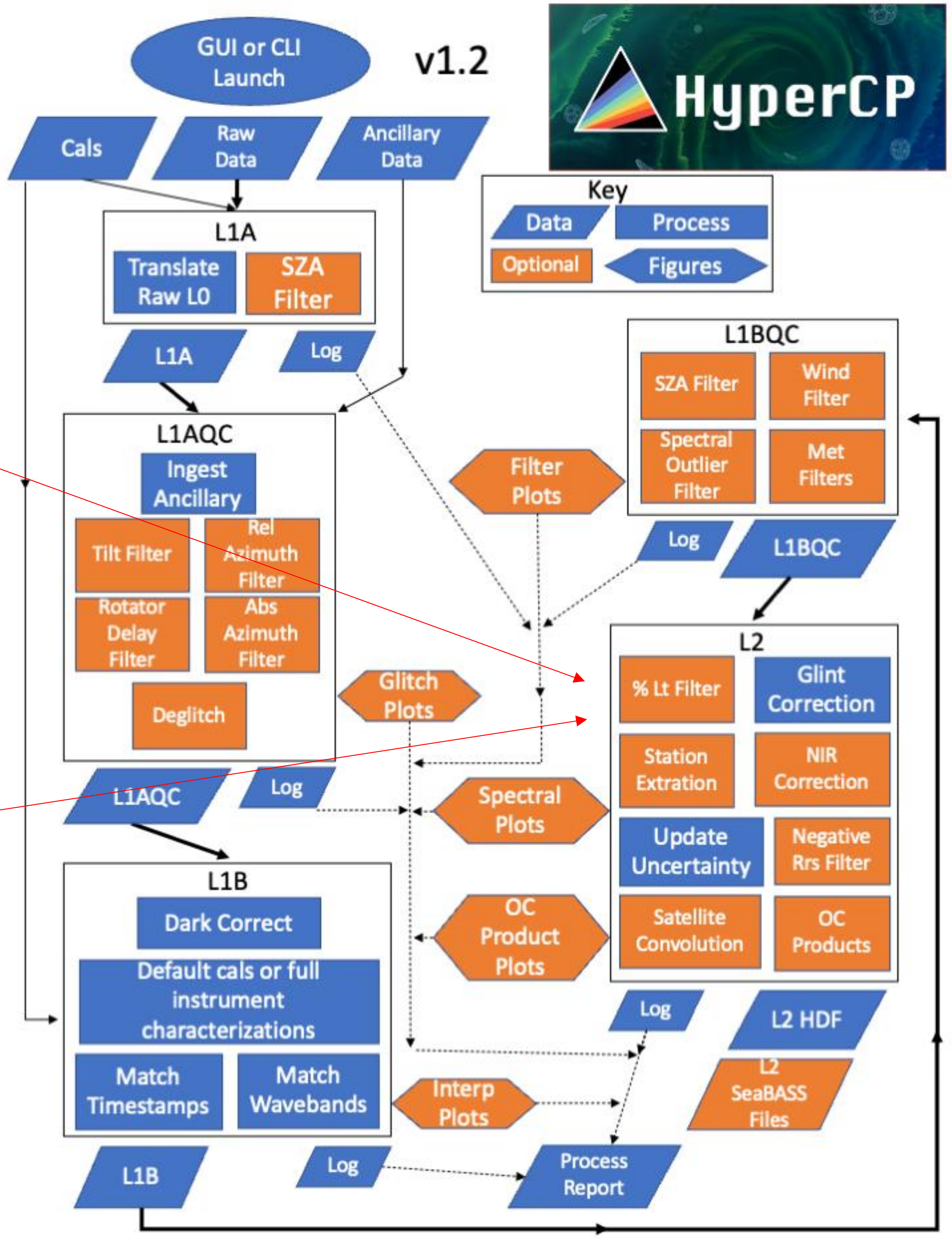
Basic quality controls for spectral shape and environmental conditions.

Demo:
Screening Spectral Filters

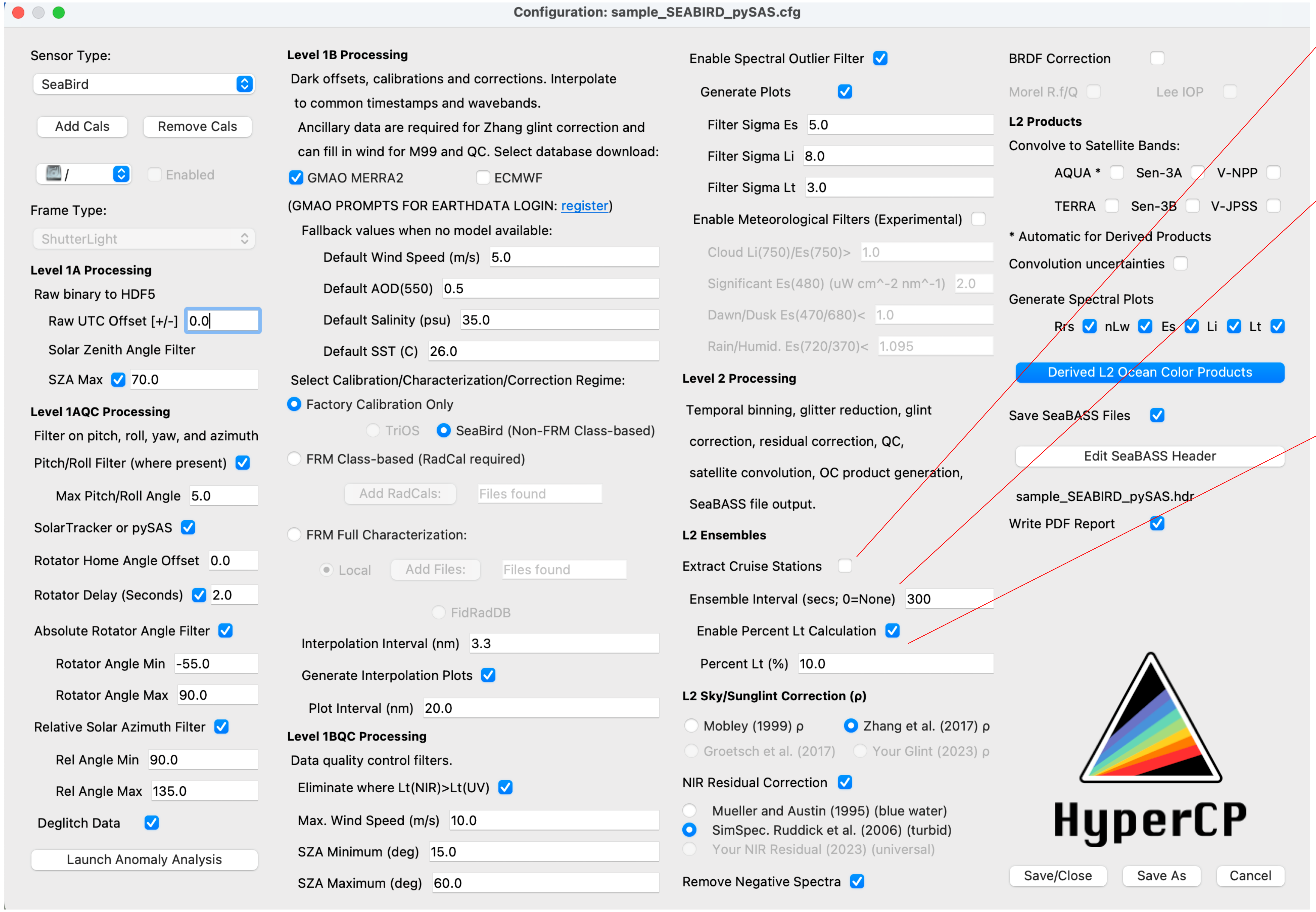
(Demo TBD)

HyperCP Level 2: Overview





HyperCP Level 2: Binning

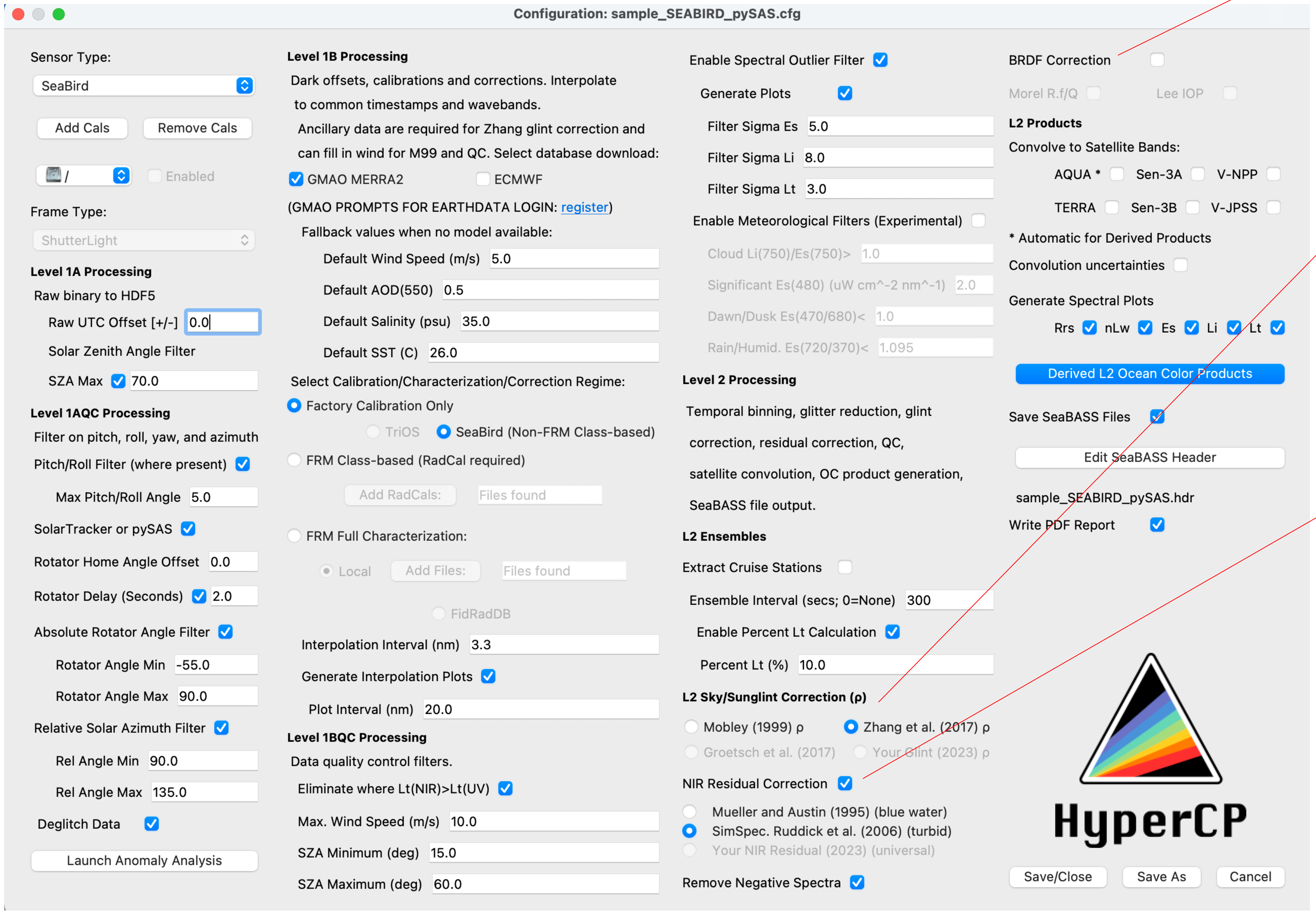


Stations from Ancillary file

Time bin average for smoothing gravity wave effects, to capture variability statistics for uncertainty, and for data reduction

Removes brightest 90% of upwelling radiance to reduce capillary wave reflection

HyperCP Level 2: Corrections…



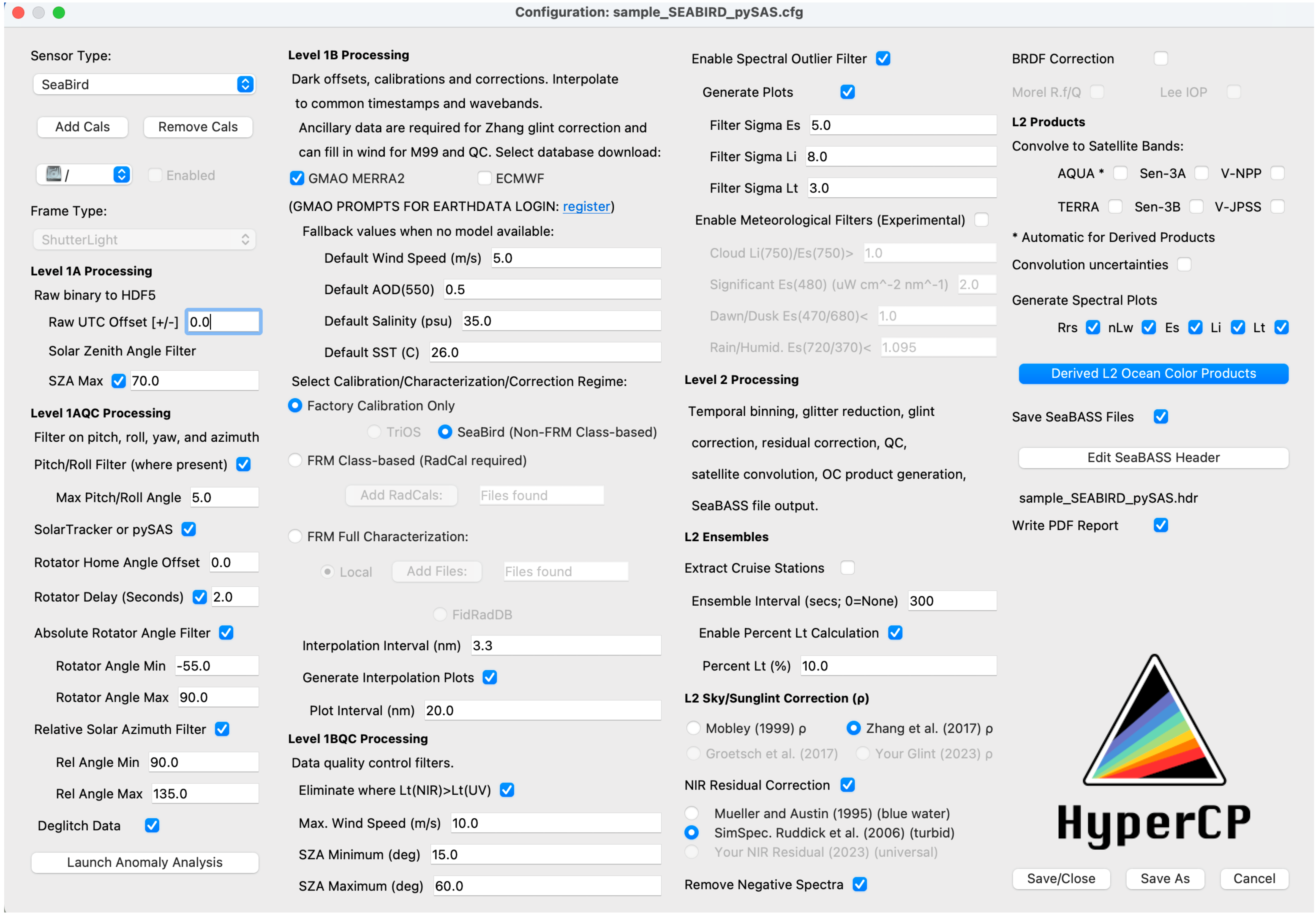
BRDF Correction [optional]
Apply BRDF correction to adjust reflectance for zenith sensor and sun in a non-absorbing atmosphere (e.g., for satellite comparison/validation)

Glint Correction
Most critically, correct total upwelling radiance for the Fresnel reflection of sun and sky (glint) yielding Lw from which reflectance is calculated.

NIR Residual Correction
Remove residual glint identified from reflectances in the NIR, followed by removing any ensemble reflectances that have negative values (VIS).

HyperCP is always under development to stay abreast of emerging science!

HyperCP Level 2: Corrections…



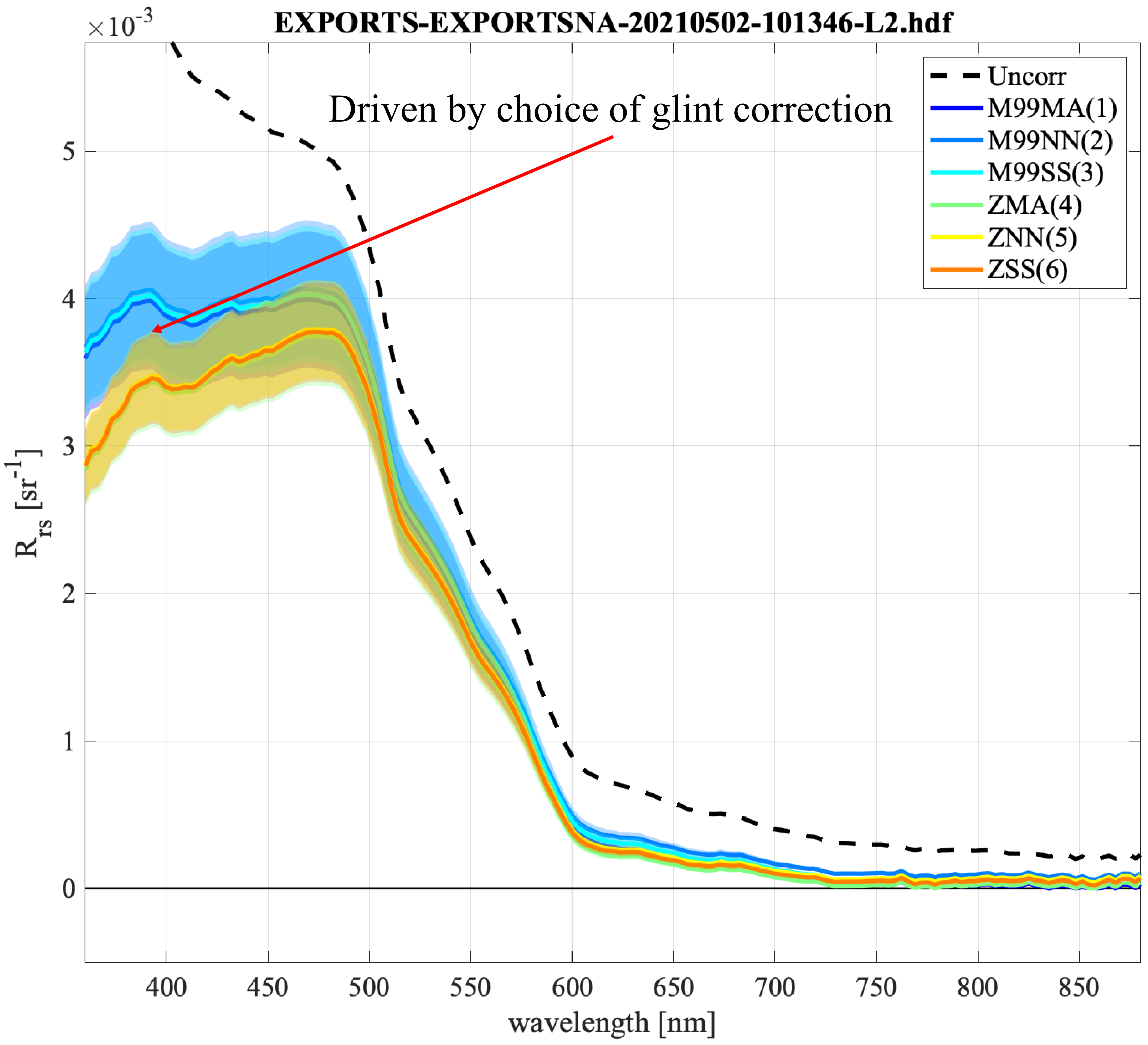
Broadly speaking, the best practices are:

In clear offshore waters

- ρ glint factor: Mobley 1999
- NIR residual correction: Mueller and Austin 1995
- f/Q BRDF correction: Morel 2002

More turbid, optically complex waters

- ρ glint factor: Zhang et al. 2017 (hyperspectral with polarization)
- NIR residual correction: the Similarity Spectrum approach of Ruddick et al. 2006
- BRDF correction: Lee et al. 2010 IOP-based BRDF correction (pending)



DASHBOARD

Ancillary

τ 0.09

Wind 1.4 m/s

RelAz 135º

SZA 43º

RH NaN%

Cloud NaN%

Glint: ZSS

HyperCP

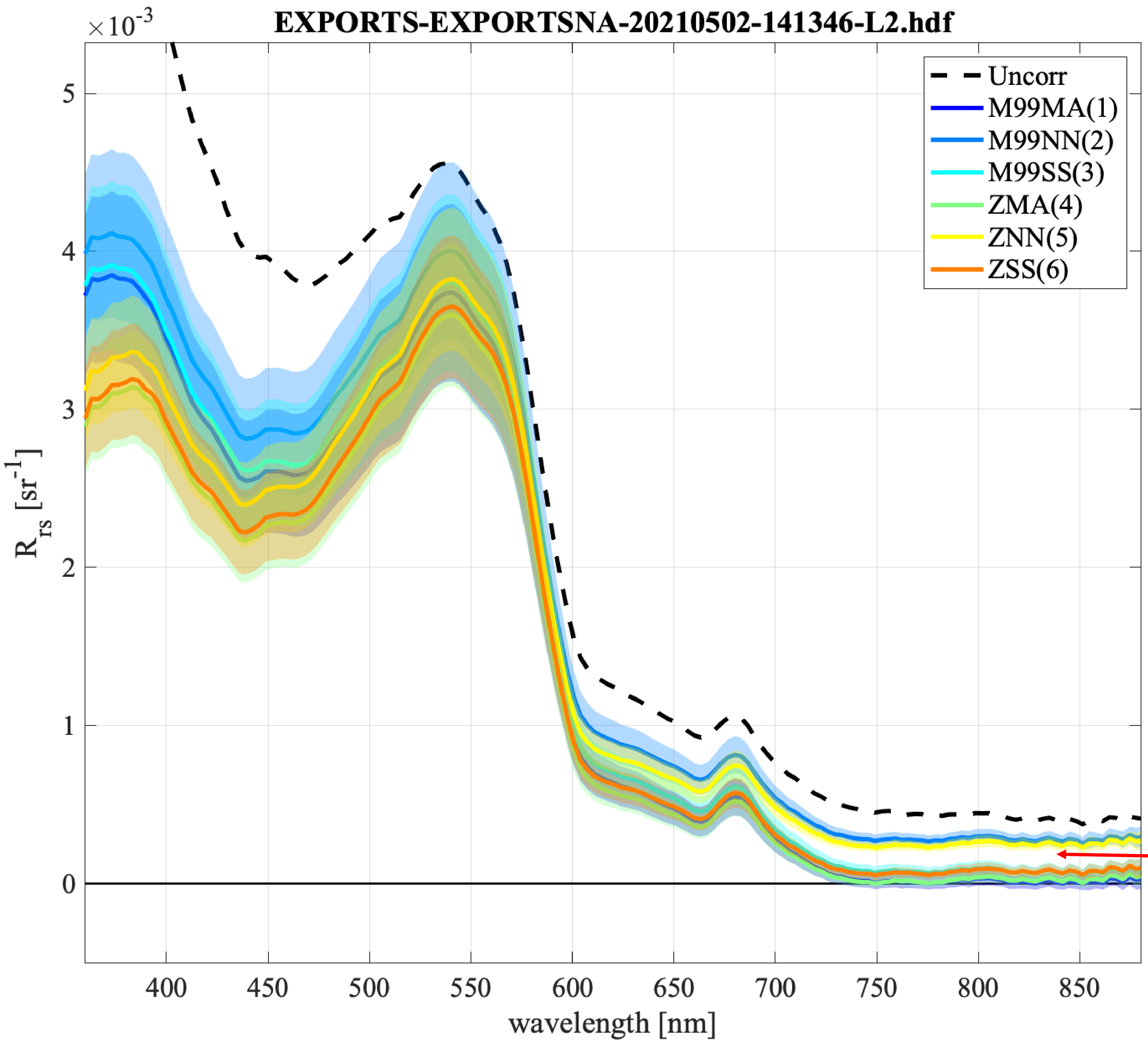
Comparison between various glint and NIR residual corrections of the same L2 ensemble reflectance spectrum where

Glint Correction:

- **M99**: Mobley 1999
- **Z**: Zhang et al. 2017

NIR Residual Glint Correction:

- **NN**: No NIR correction
- **MA**: Mueller and Austin 1995
- **SS**: SimSpec (Ruddick et al. 2006)



DASHBOARD

Ancillary

τ 0.08

Wind 2.6 m/s

RelAz 135º

SZA 40º

RH NaN%

Cloud NaN%

Glint: ZSS

HyperCP

Comparison between various glint and NIR residual corrections of the same L2 ensemble reflectance spectrum where

Glint Correction:

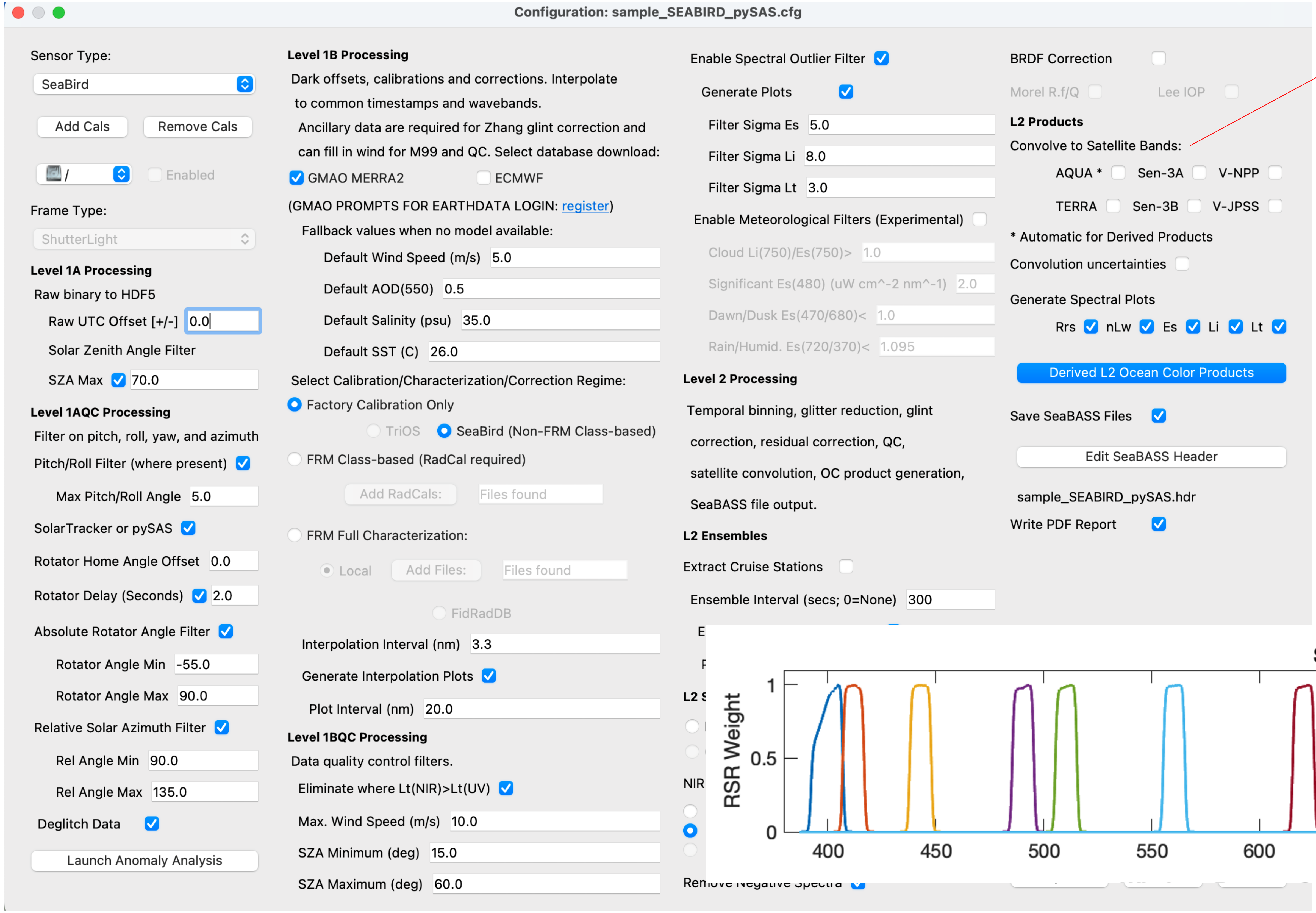
- **M99**: Mobley 1999
- **Z**: Zhang et al. 2017

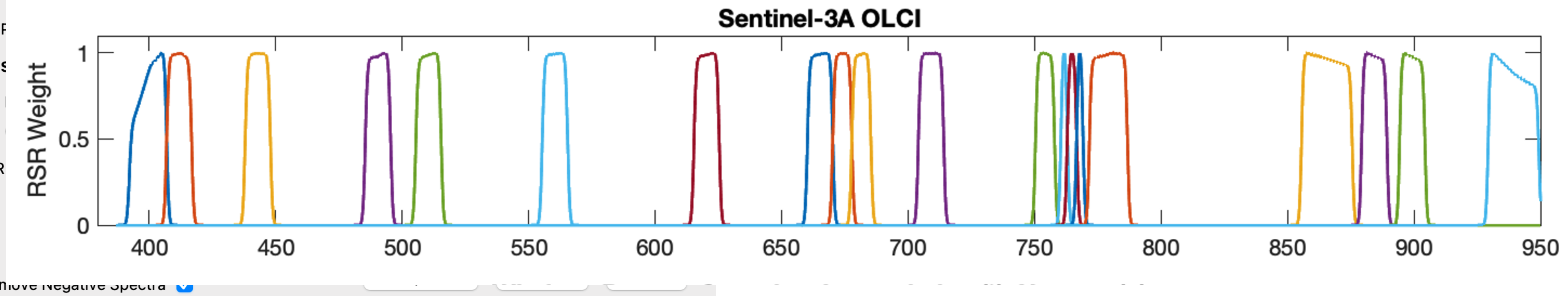
NIR Residual Glint Correction:

- **NN**: No NIR correction
- **MA**: Mueller and Austin 1995
- **SS**: SimSpec (Ruddick et al. 2006)

Driven by choice of NIR correction

HyperCP Level 2: Spectral Response Weighting for Satellite Band Convolution

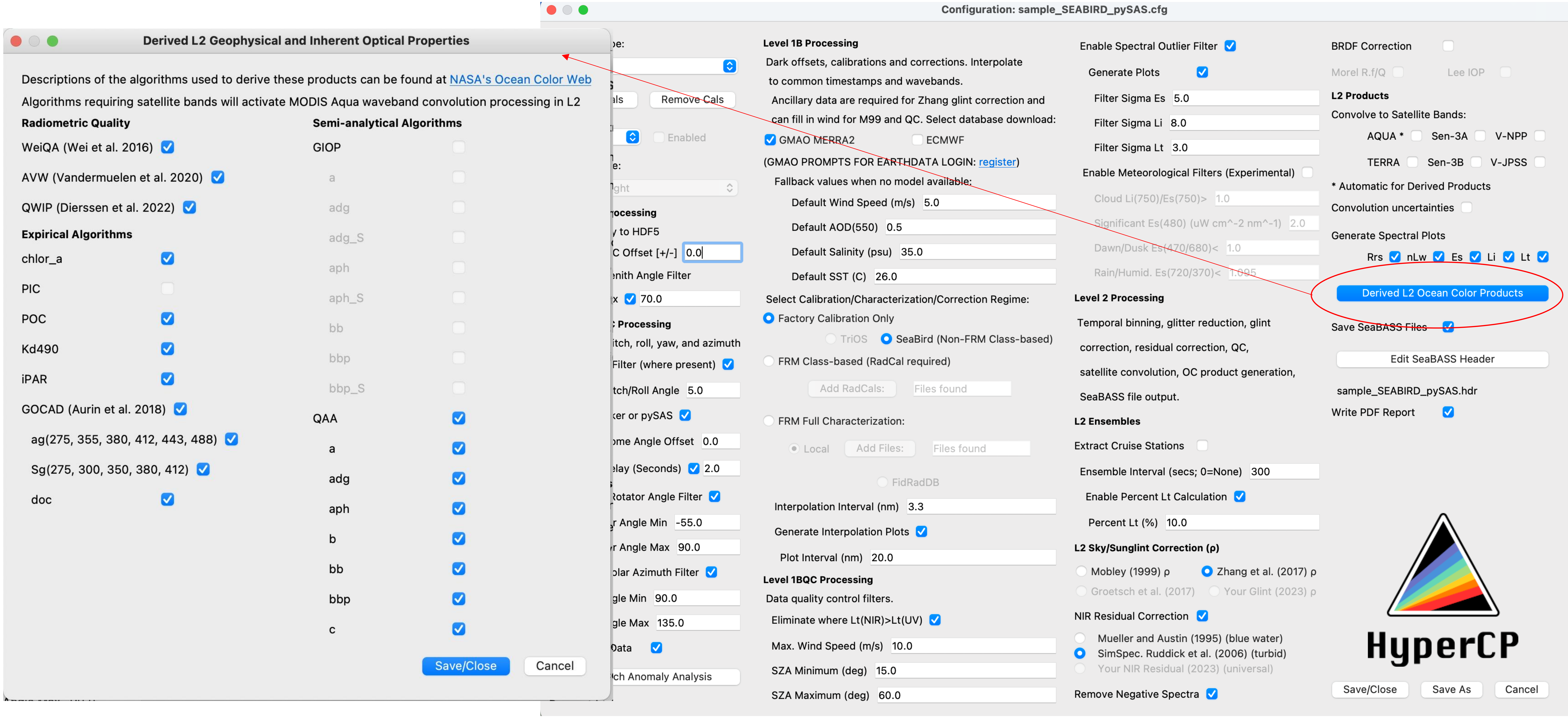




Relative Spectral Response (RSR) weighting functions for various multi-spectral satellite sensors are included in order to accurately convolve the hyperspectral L2 (ir)radiances to satellite bands for comparison/validation. (Ir)radiances are convolved prior to reflectance calculations.

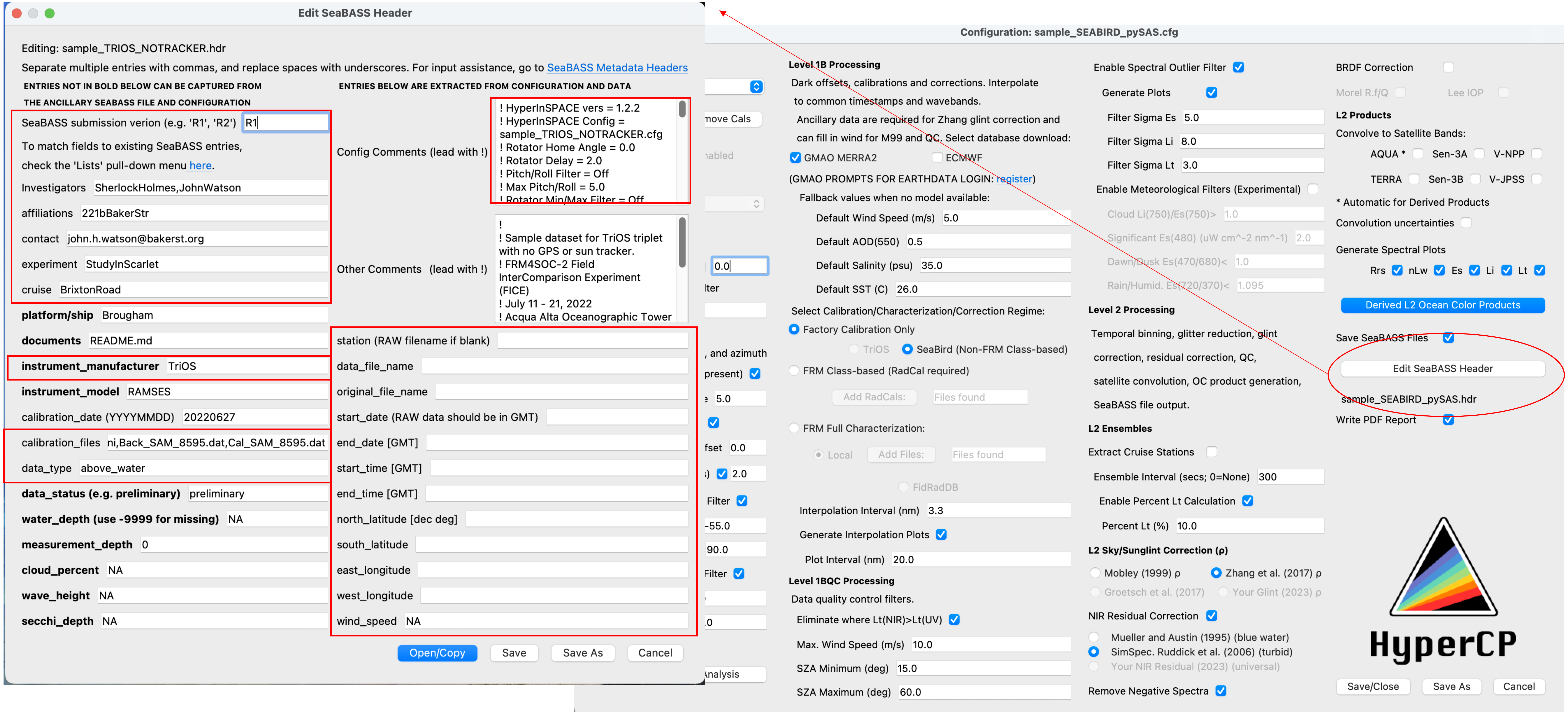
HyperCP Level 2: Derived Products

Several ocean color algorithms for deriving geophysical and inherent optical properties are provided (see README for sources). More are anticipated. Uses spectra convolved to MODIS Aqua bands.



HyperCP Output: SeaBASS & HDF5

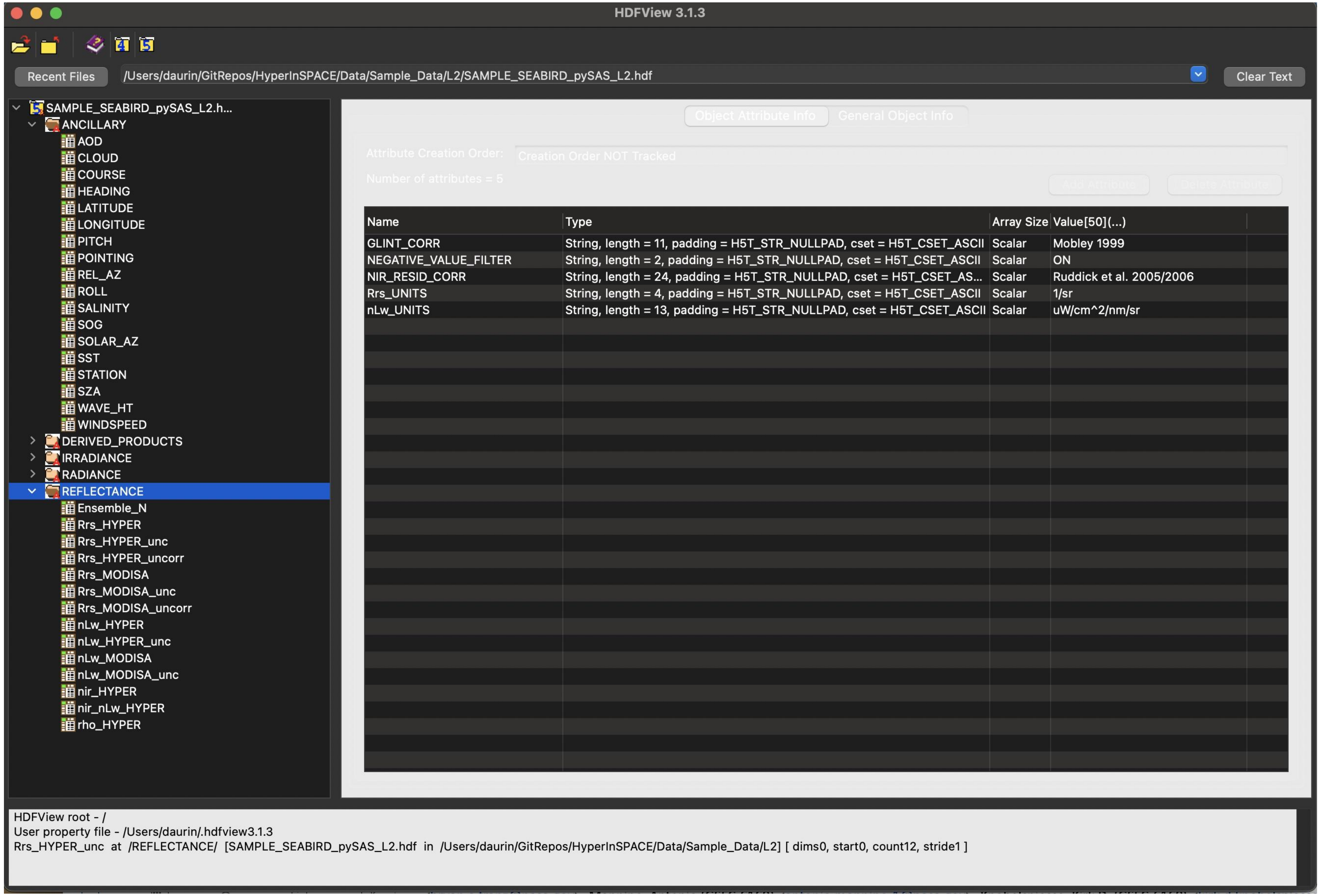
Red boxed can be autofilled. Fill in the rest as appropriate.



L2 Output

Data and Reports

HyperCP HDF5 Files



HyperCP L2 SeaBASS Files

HyperCP

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BogieAndBacall_TheBigSleep_WarnerBros_HyperSAS_20160520_0

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! HyperSAS with Sea-Bird SolarTracker
! Collected around Korean peninsula on RV Onnuri in association with KORUS-OC campaig
KR_2016
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BogieAndBacall_TheBigSleep_WarnerBros_HyperSAS_20160520_070223_L2_Rrs_R0.sb

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,0.000106,0.000109,0.000106,0.000107,0.000105,0.000106,0.000106,0.000104,0.000105,0.000106,0.000104,0.000105,0
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66,0.003417,0.003355,0.003279,0.003182,0.003056,0.002877,0.002703,0.002569,0.002486,0.002436,0.002394,0.00234
```

HyperCP Processing Report (PDF)

Processing Reports

File: SAMPLE_SEABIRD_pySAS Col

L1BQC : Process L1B to L1BQC

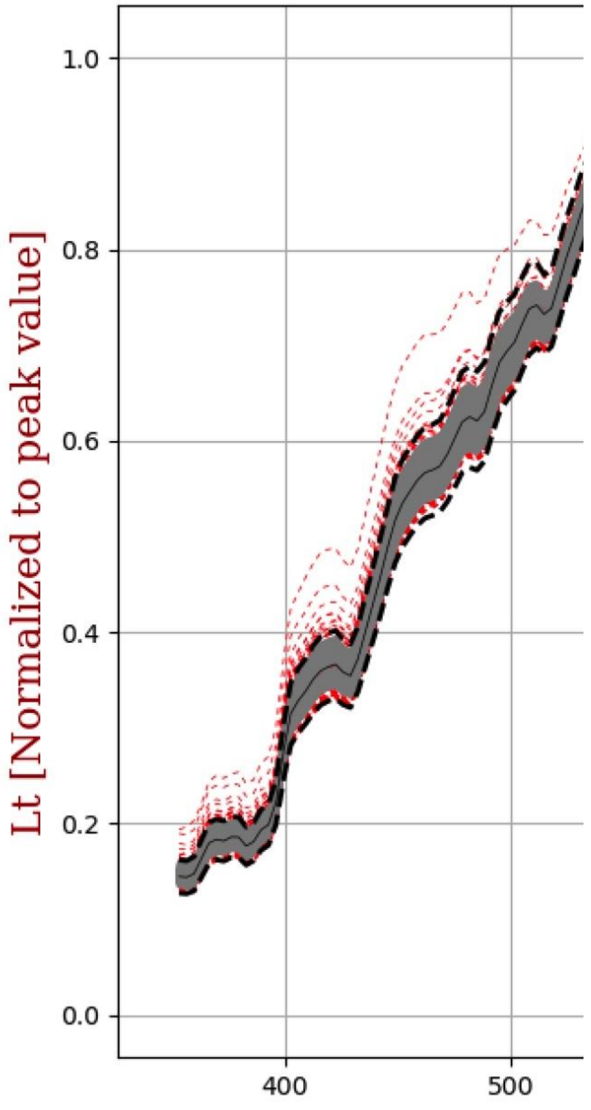
Apply more quality control filters.

Processing Parameters:
Max Wind: 10.0
Min SZA: 15.0
Max SZA: 60.0
Filter Sigma Es: 5.0
Filter Sigma Li: 8.0
Filter Sigma Lt: 3.0

Process log:

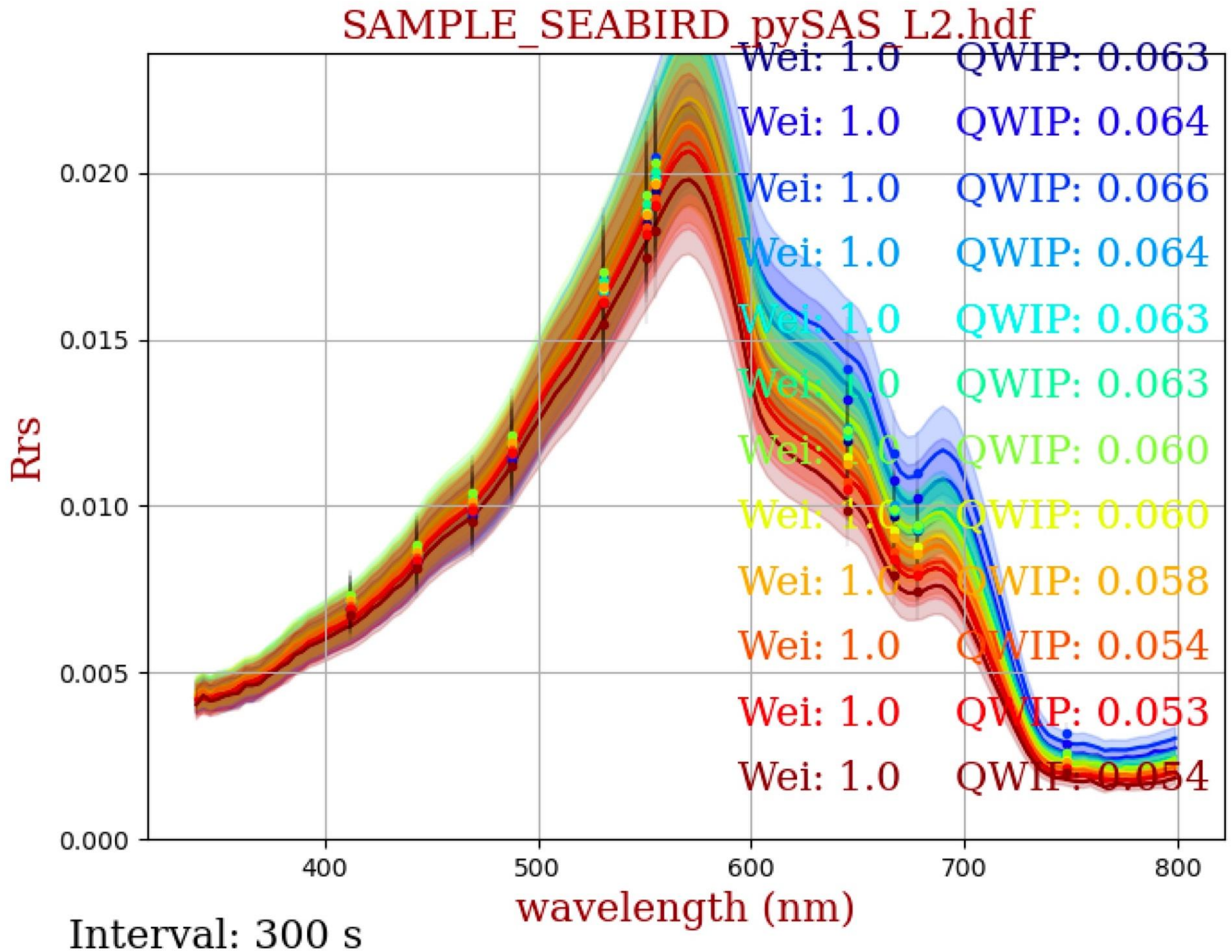
Process Single Level
Applying Lt(NIR)>Lt(UV) quality filtering to elin
0.0% of spectra flagged
Percentage of data out of Wind limits: 0 %
Percentage of data out of SZA limits: 0 %
Applying spectral filtering to eliminate noisy spect
0.4% of Es data flagged
0.0% of Li data flagged
4.6% of Lt data flagged
Remove IRRADIANCE Data
  Length of dataset prior to removal 1076 long
  Length of dataset after removal 1022 long: 5% removed
Remove RADIANCE Data
  Length of dataset prior to removal 1076 long
  Length of dataset after removal 1022 long: 5% removed
Remove ANCILLARY Data
  Length of dataset prior to removal 1076 long
  Length of dataset after removal 1022 long: 5% removed

L1BQC Spectral Filter

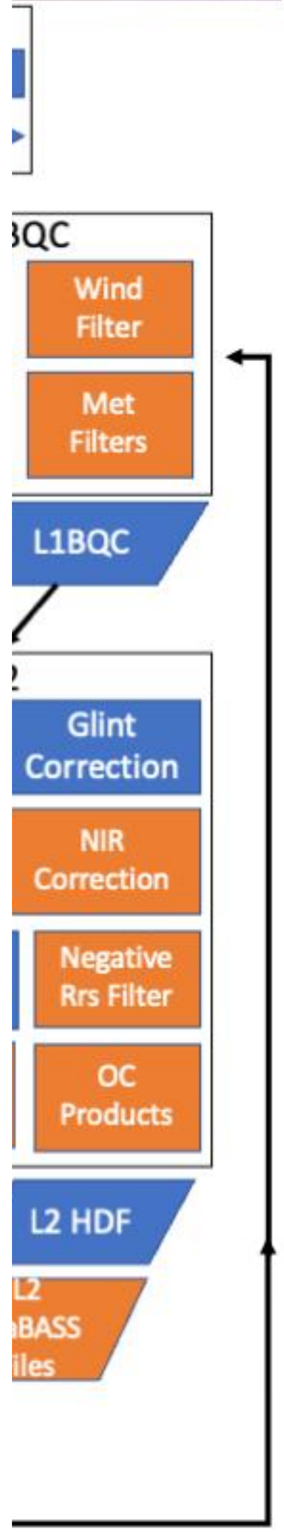


File: SAMPLE_SEABIRD_pySAS Collected: Sat May 01 05:54:30 2021

L2 Ensembles Rrs with uncert., convolutions, scores…

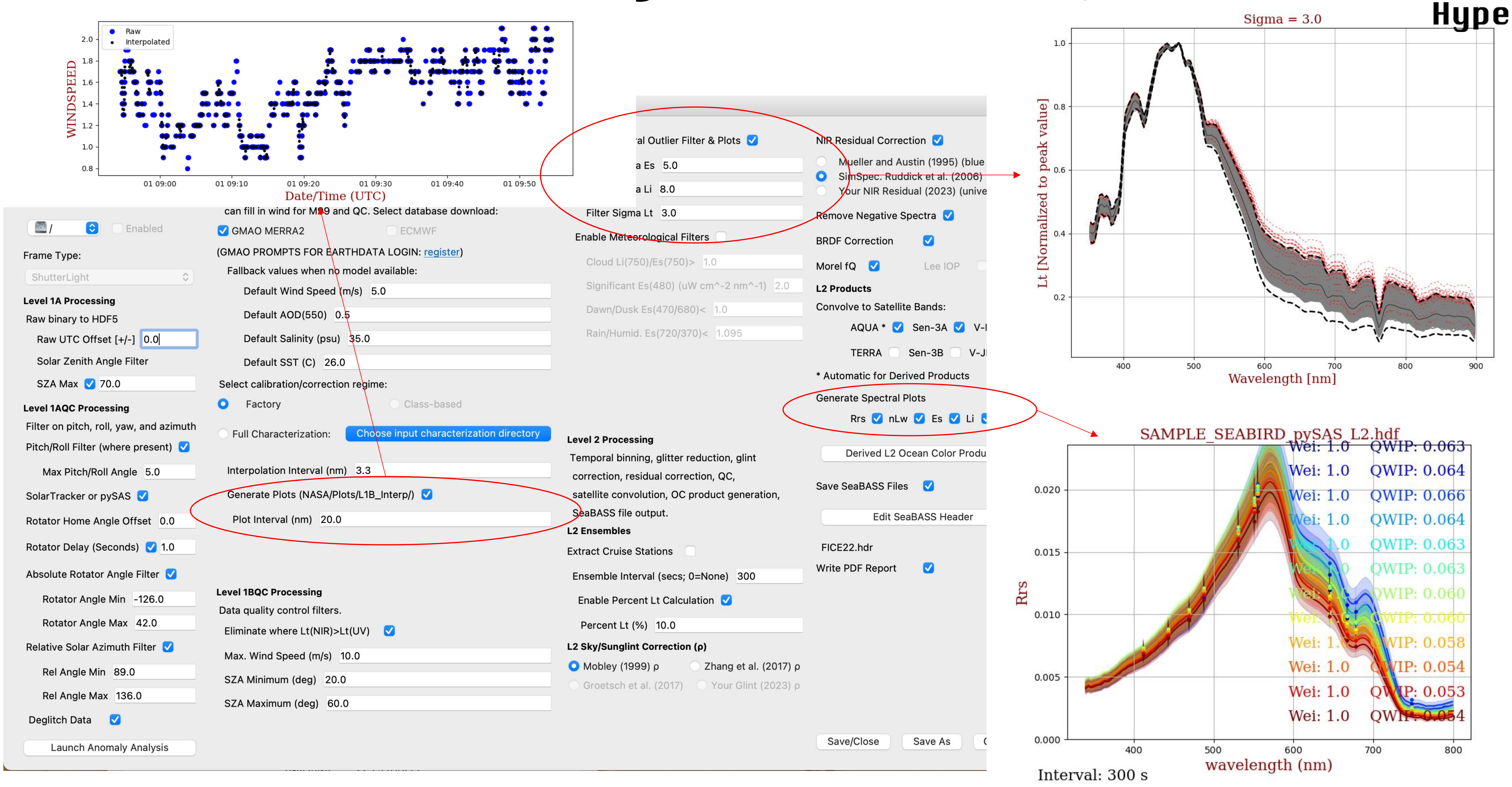


Interval: 300 s



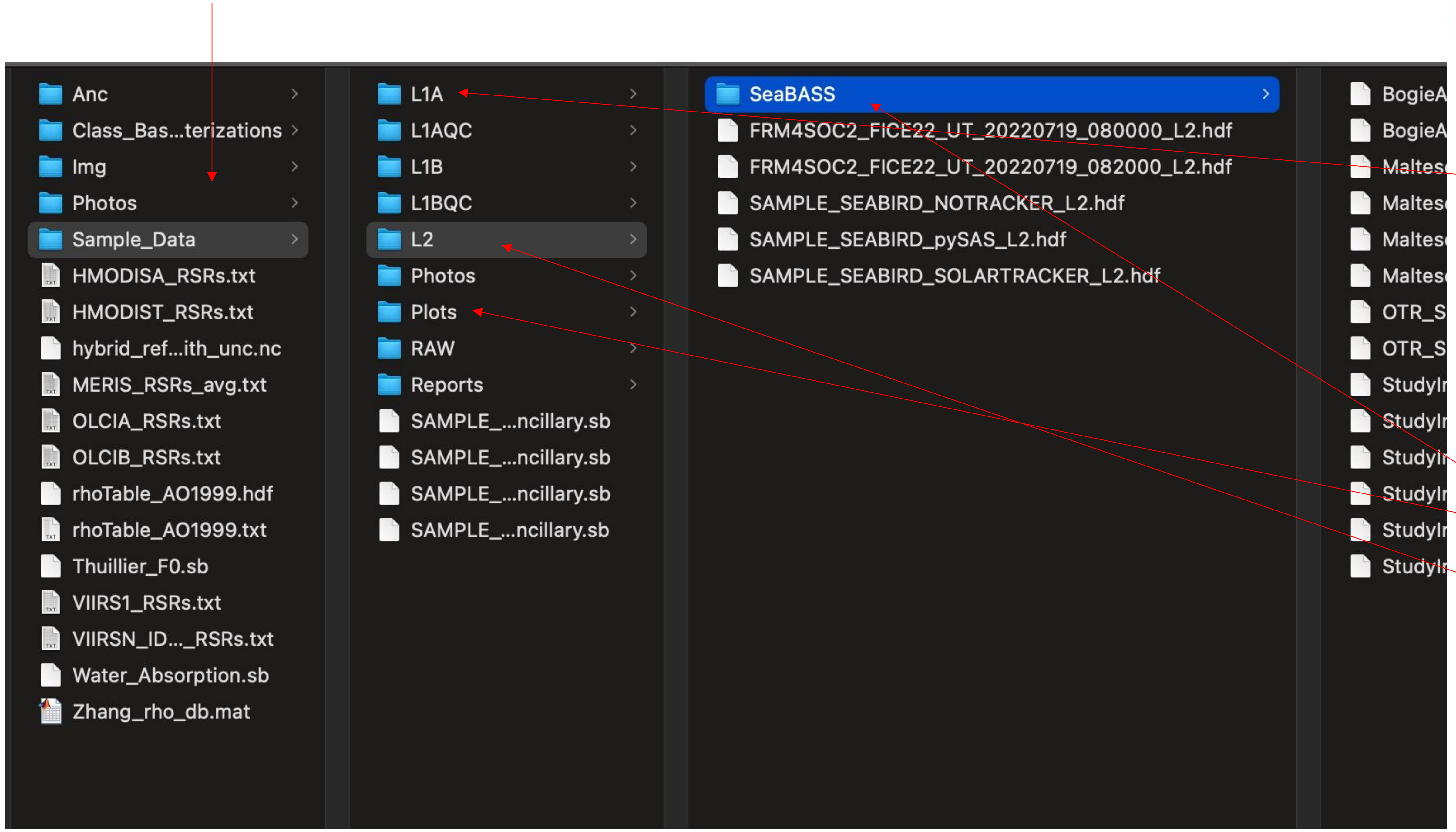
HyperCP Plots for Diagnostics and QC

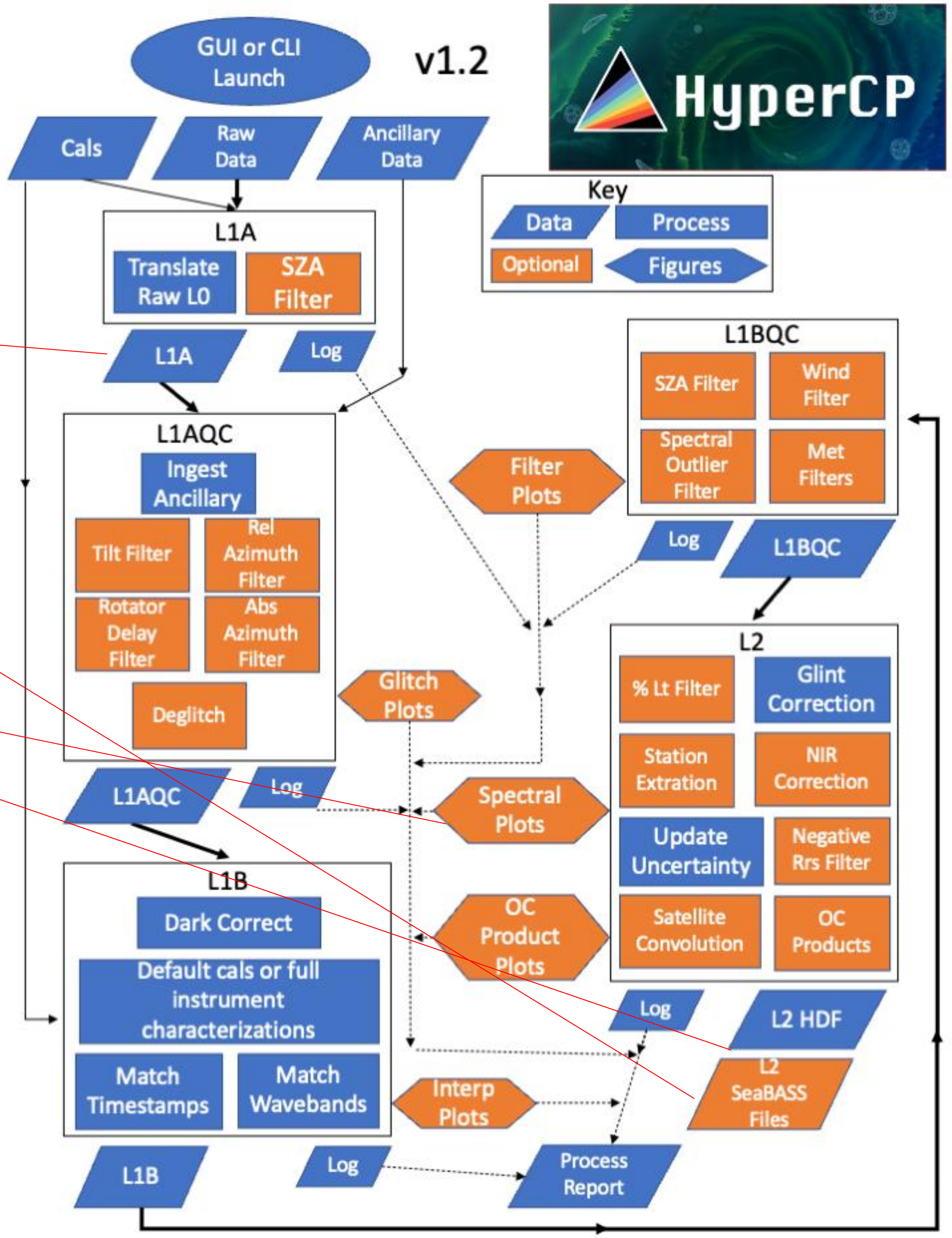
HyperCP



HyperCP Data Directory Overview

Chosen Data Output Folder (Main Window)





Conclusion

Above all, don't be discouraged if it doesn't run seamlessly the first time.

Stay up-to-date with latest version before you process

```
git pull
```

Don't forget to activate the environment before you run:

```
conda activate hypercp
python Main.py
```

We encourage you to report Issues or start Discussions on GitHub!