HyperInSPACE

HyperCP Tutorial

Above Water Radiometry Processing

Ocean Optics Class 2023 – June 28-29, 2023

Nils Haëntjens, Instructor – Dirk Aurin, Main Author

HyperCP contributors: N. Vandenberg, M. Costa, A. Deru, A. Ramsey, A. Bialek, M. Bretagnon, G. Bai, J.I. Gossn

What is HyperCP?

PACE
Plankton, Aerosol, Cloud, ocean Ecosystem
Advanced Measurements of Sea & Sky
NASA/GSFC • UMBC • SRON/Airbus NL

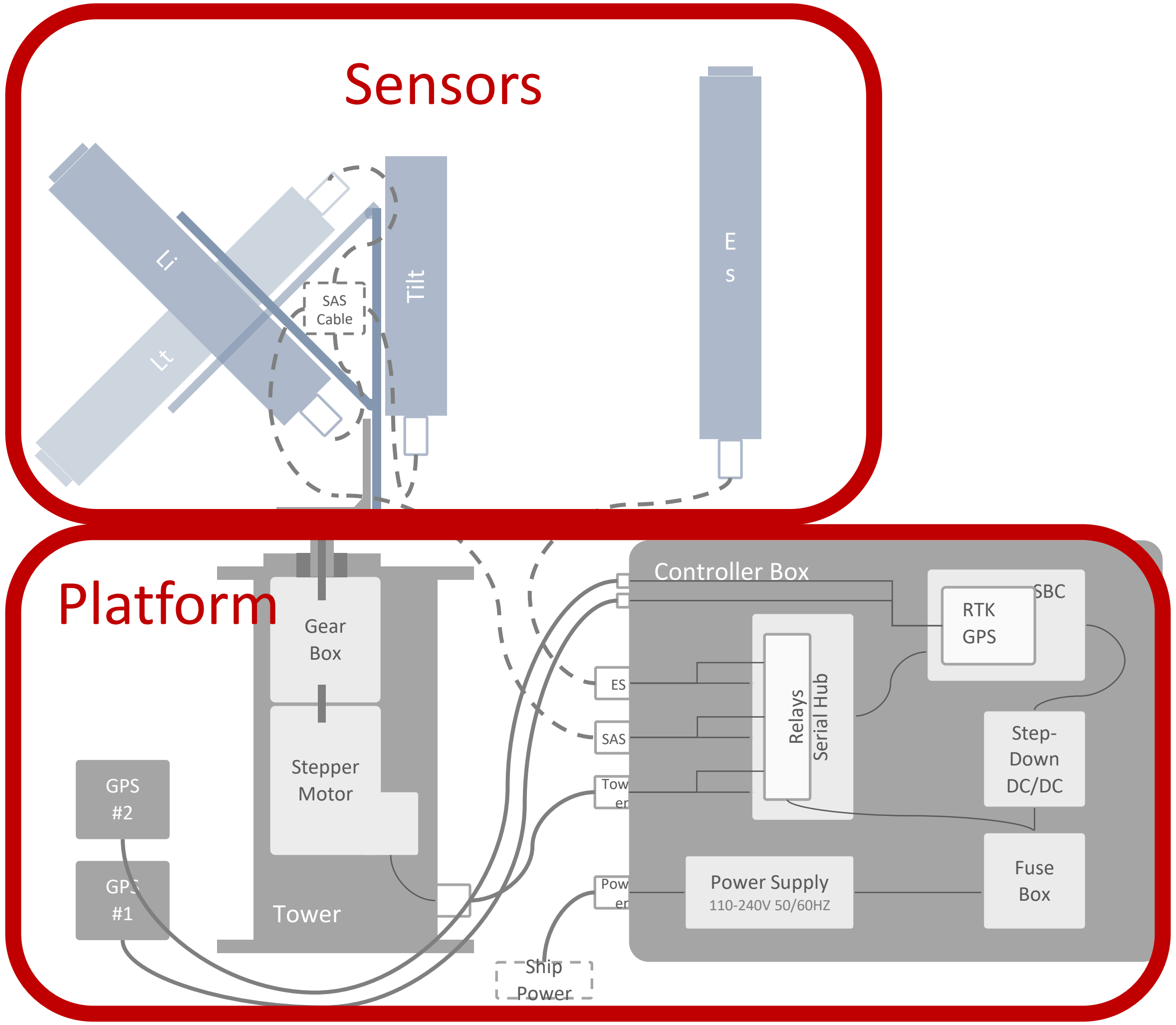
- HyperInSPACE (Hyperspectral In-situ Support for PACE) Community Processor

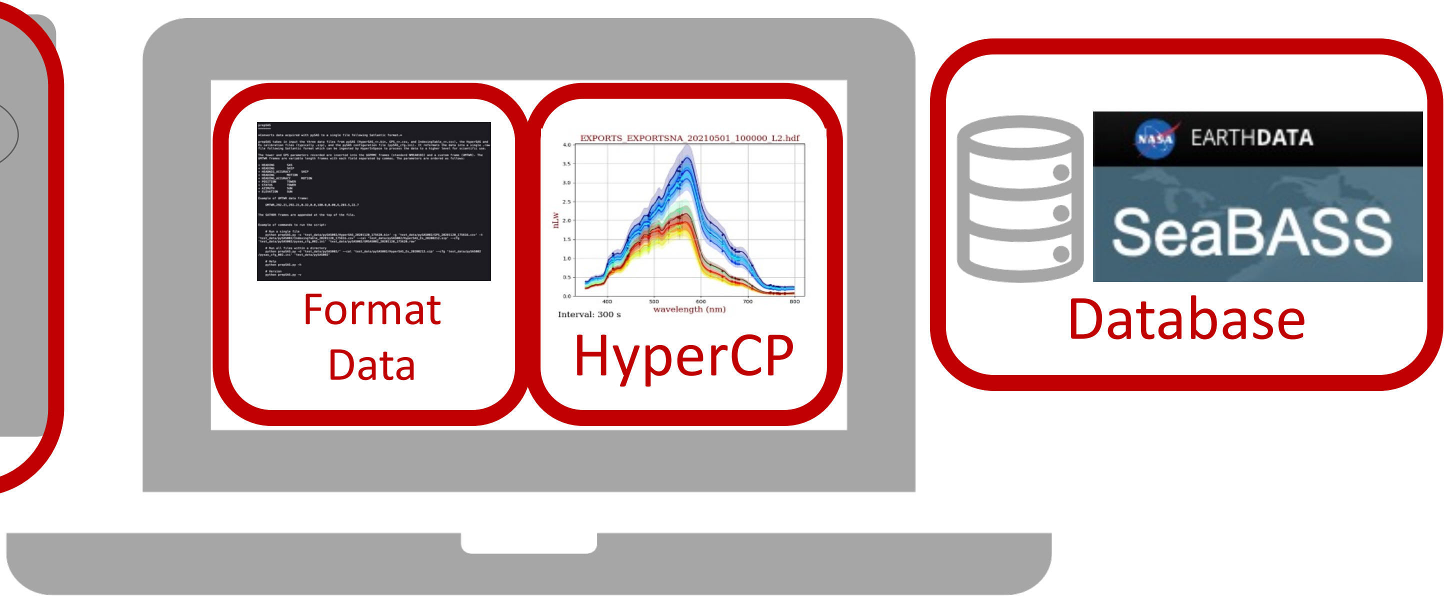
- An open-source processor for above water radiometry (AWR) that facilitates protocol-driven data correction and reduction yielding high-quality surface reflectance measurements from autonomous or manually operated platforms. Results flow back from the community to archives such as NASA's SeaBASS database for use in satellite validation and ocean color algorithm development.

June 1, 2023

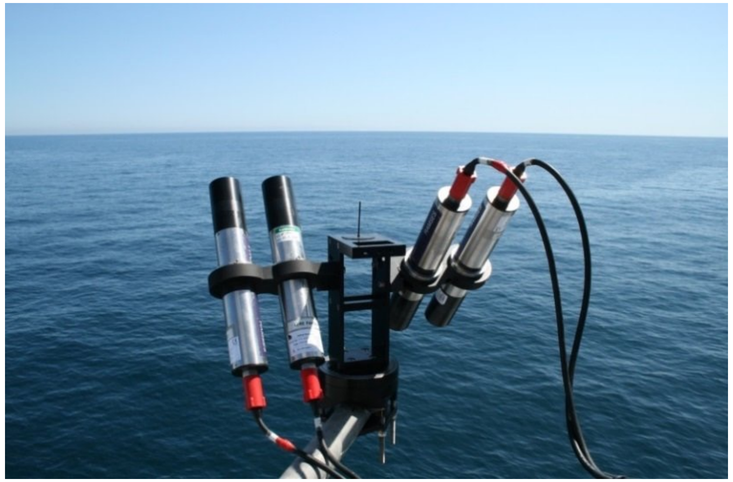
HyperCP Ecosystem

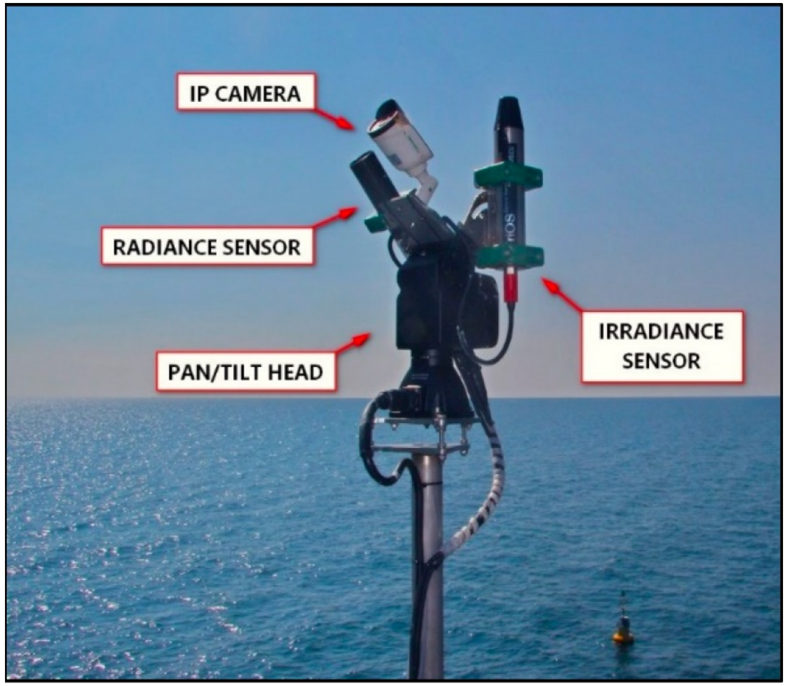
1. Sensors:
   - Sea-Bird Scientific HyperOCR
   - TriOS RAMSES
2. Platform:
   - Robotic: pySAS, Sea-Bird Scientific, Panthyr
   - Manual
3. Data Formatters: prepSAS, TriOS specific
4. Community Processor: HyperCP
5. Databases: SeaBASS

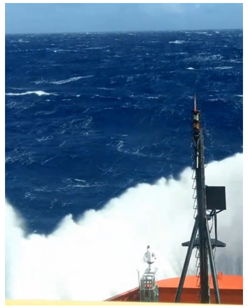




Supported (v1.2.0):
Sea-Bird HyperOCRs and TriOS RAMSES in either manual collection or autonomous, underway modes

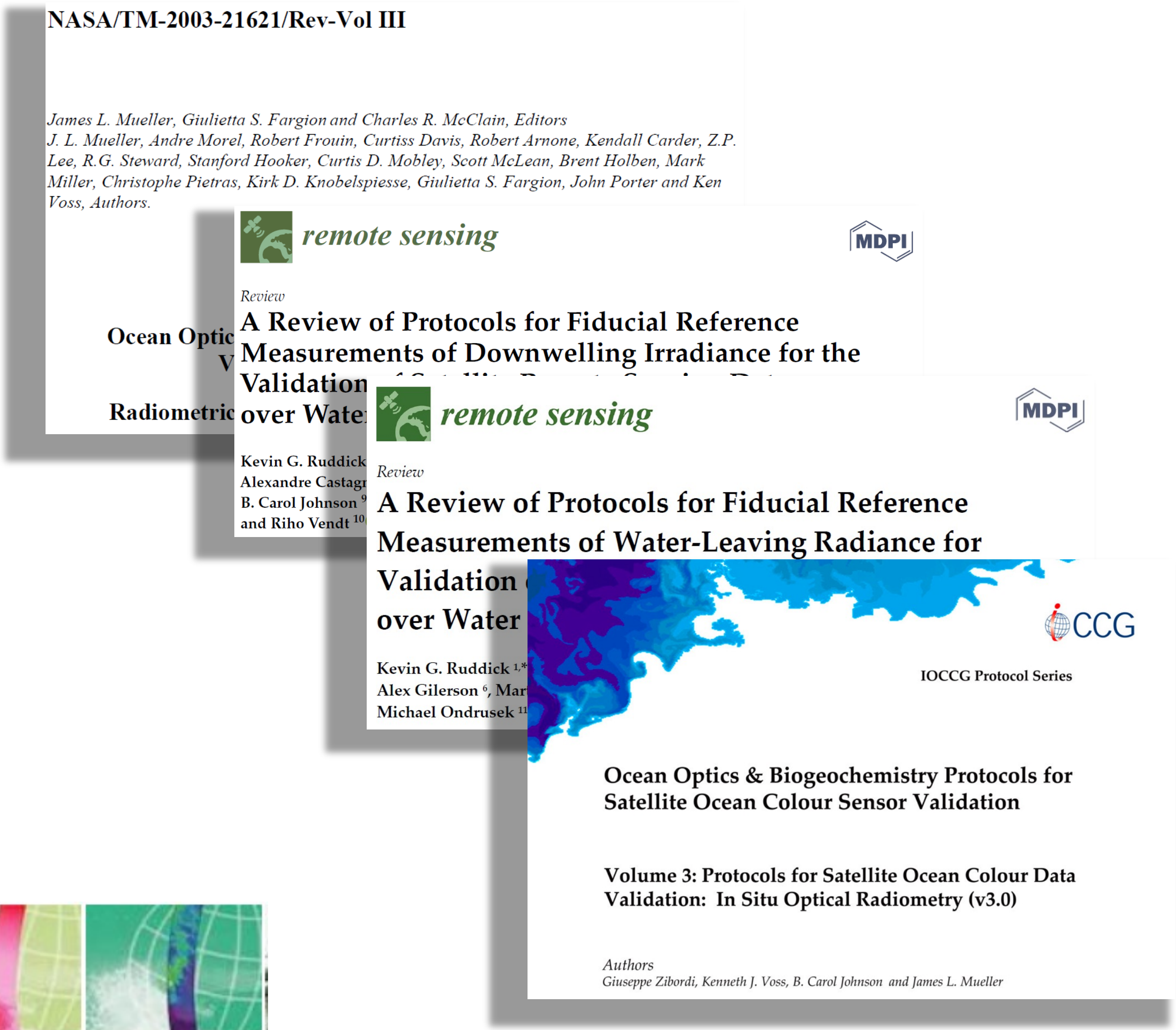


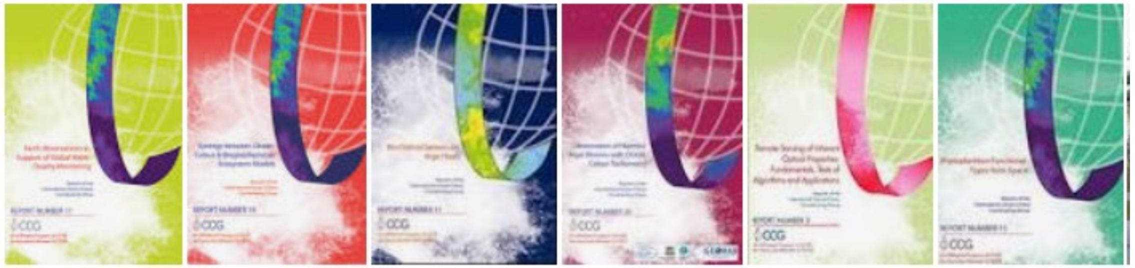




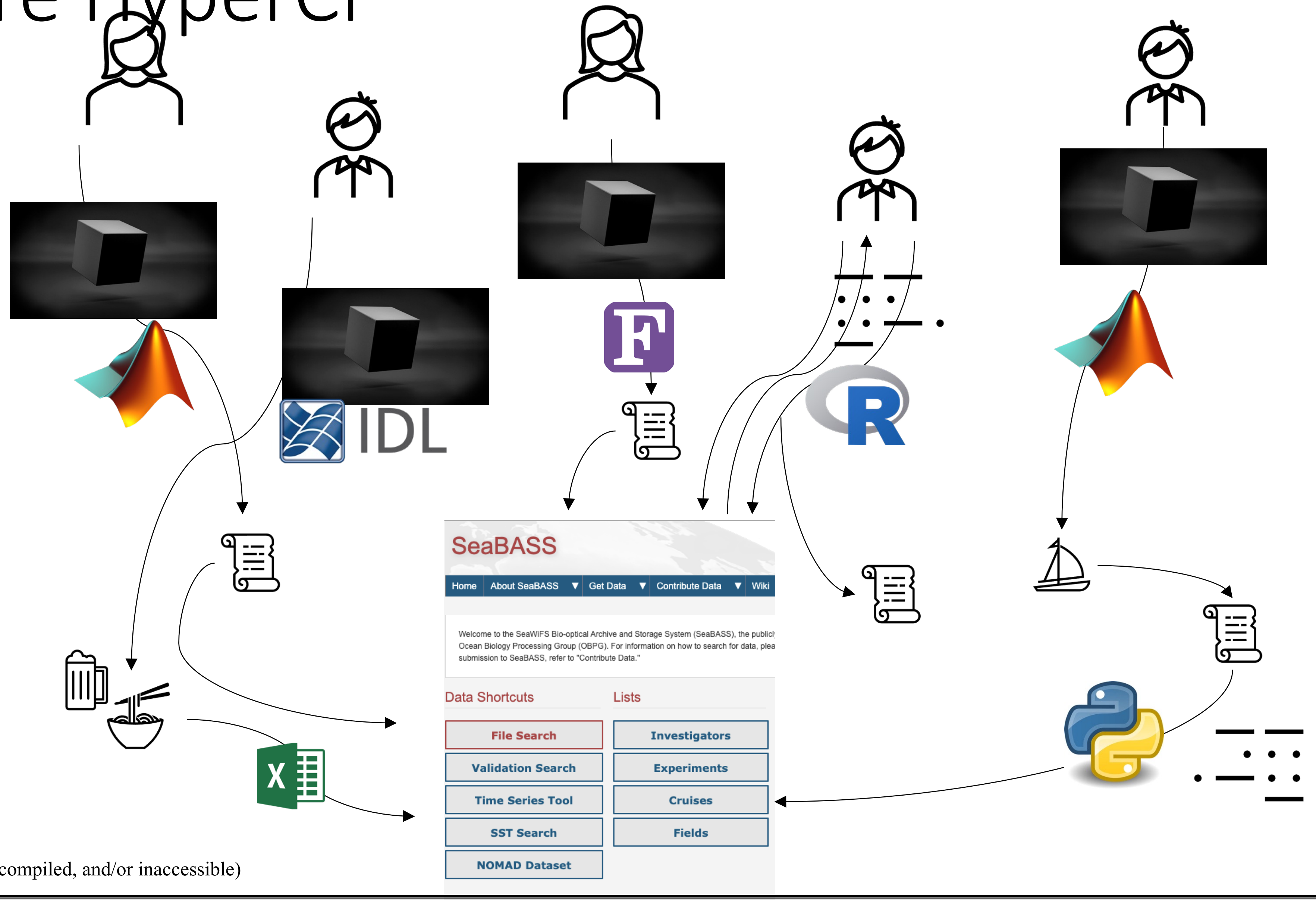
In situ radiometry protocols and methods were updated by the community ~2017 - 2019 for the first time since the SeaWiFS era

HyperInSPACE began at Goddard Space Flight Center toward the end of this period to process NASA radiometry and help the community follow these protocols, particularly when submitting data to NASA.



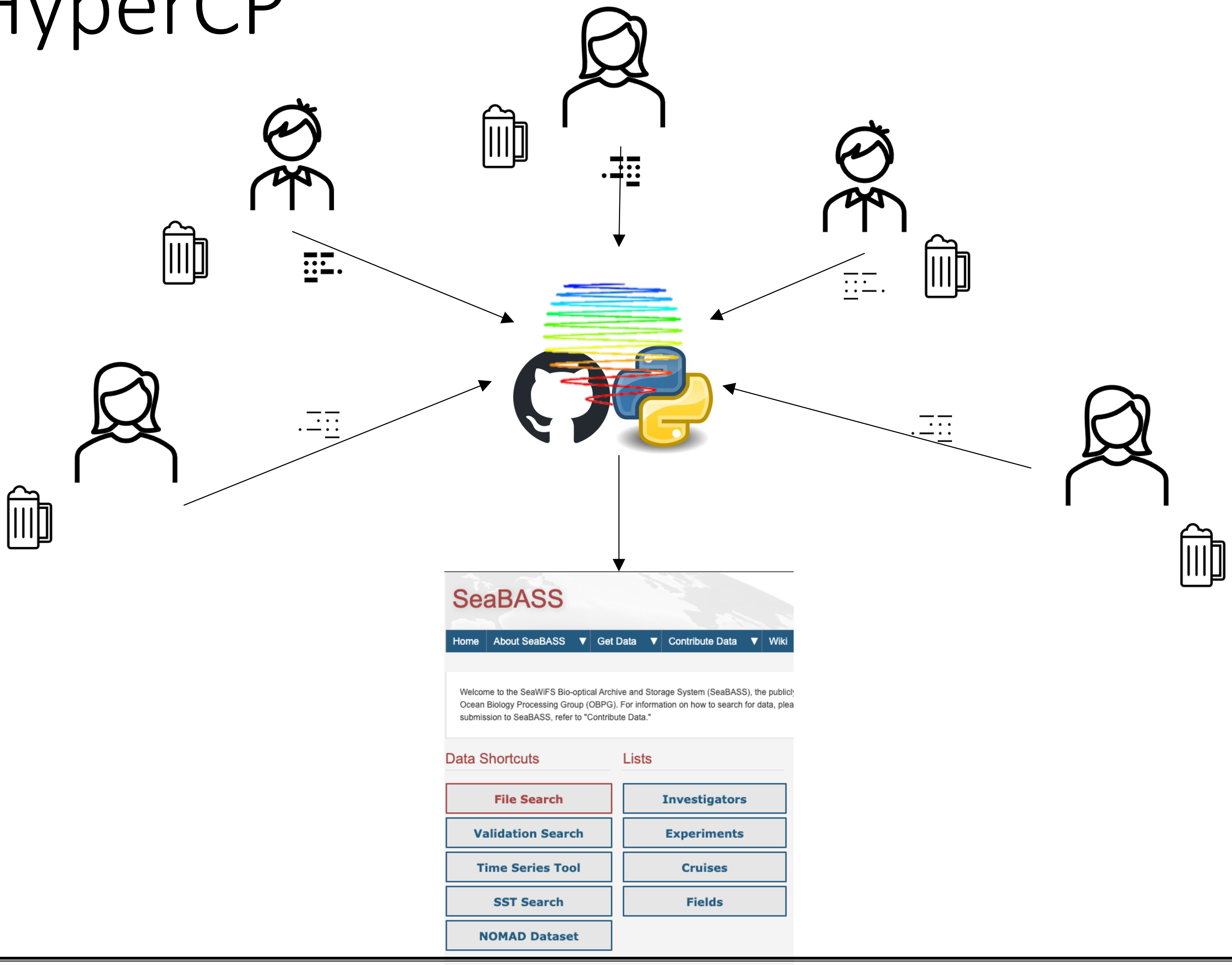


Before HyperCP

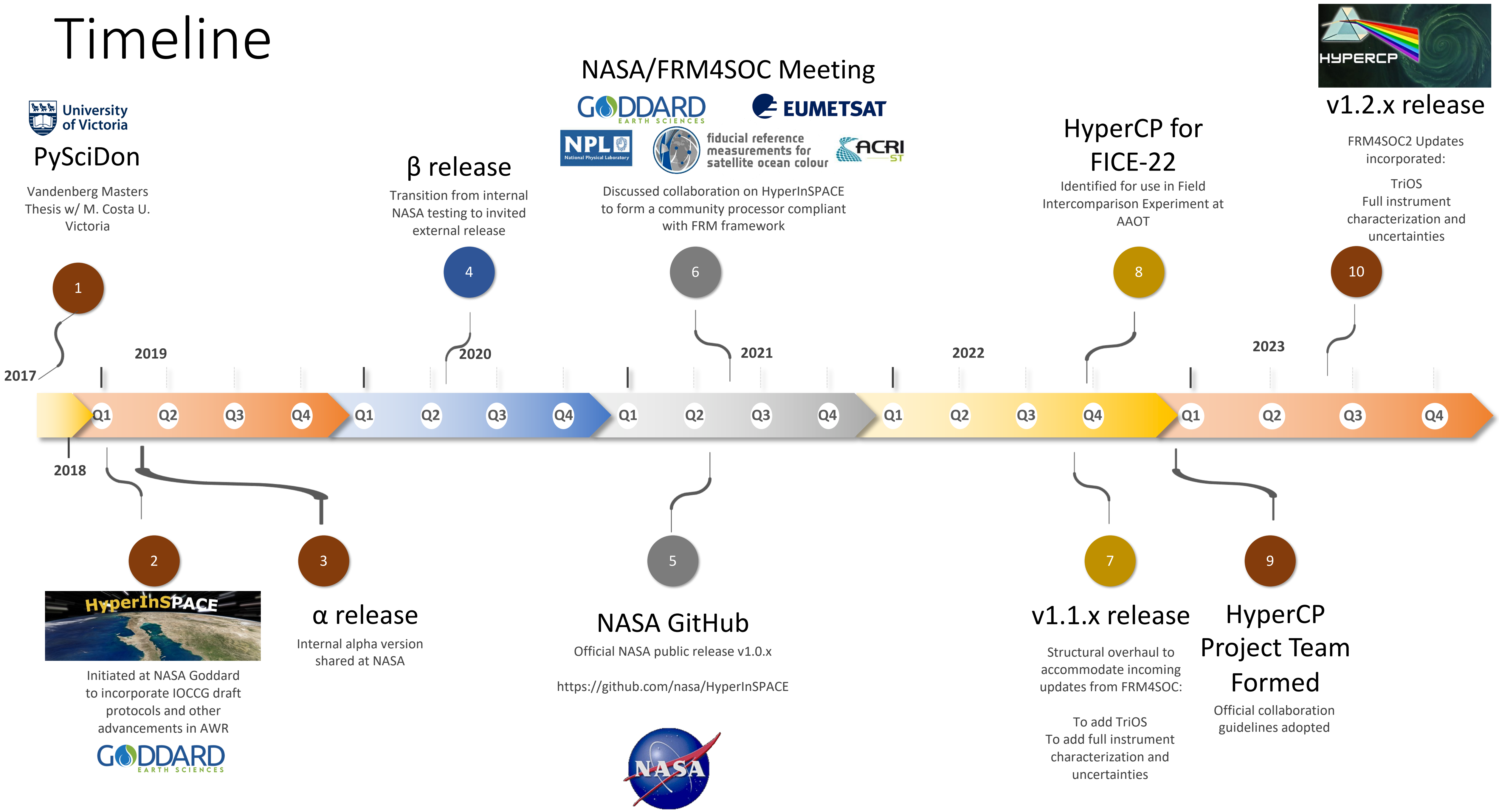


 =Black box (proprietary, compiled, and/or inaccessible)

With HyperCP



Timeline



University of Victoria
PySciDon
Vandenberg Masters Thesis w/ M. Costa U. Victoria
1
2017
2018
2019
2
HyperInSPACE
Initiated at NASA Goddard to incorporate IOCCG draft protocols and other advancements in AWR
GODDARD EARTH SCIENCES
3
α release
Internal alpha version shared at NASA
4
β release
Transition from internal NASA testing to invited external release
2020
5
NASA GitHub
Official NASA public release v1.0.x
https://github.com/nasa/HyperInSPACE
NASA
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
2021
2022
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-22
Identified for use in Field Intercomparison Experiment at AAOT
2023
9
HyperCP Project Team Formed
Official collaboration guidelines adopted
10
HYPERCP
v1.2.x release
FRM4SOC2 Updates incorporated:
TriOS
Full instrument characterization and uncertainties
Q1
Q2
Q3
Q4

Water Leaving Radiance

Glint/Fresnel factor

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

Total upwelling radiance

Skylight radiance

Remote Sensing Reflectance

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

Sea surface irradiance

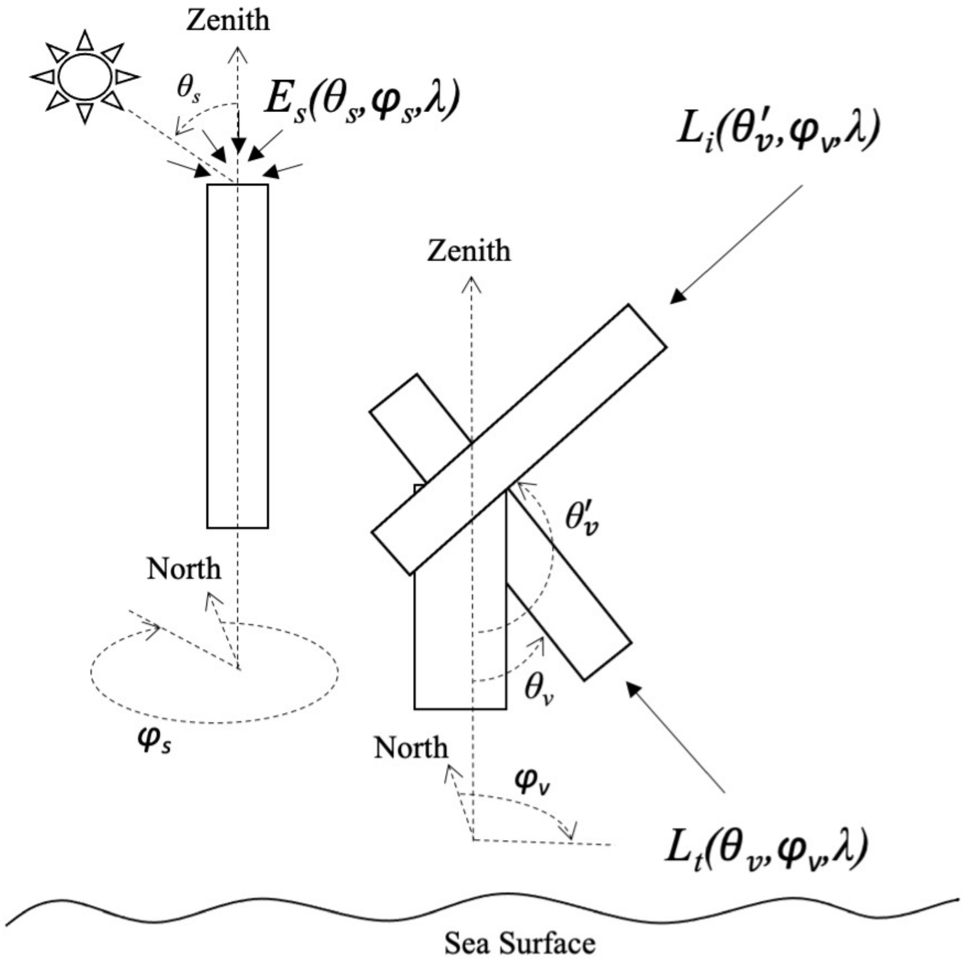
Normalized Water Leaving Radiance

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

TOA irradiance

Exact Normalized Water Leaving Radiance

nL_W^{ex}. Corrected for BRDF
(adjusted to $\boldsymbol{\theta}_s = 0$, $\boldsymbol{\theta}_v = 0$)



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

ρ(λ) is a function of the sensor zenith (***θ***)$^{+}$, solar-sensor relative azimuth (***φ***)$^{+}$, wind speed/surface roughness (**W**), and to a lesser extent aerosols (***τ***), water temperature (**T**) and salinity (**S**). Skylight polarization also plays a small role. As a viewer at the origin of these polar plots, the magnitude of **ρ** is most dominated by the azimuth angle, peaking at the specular point of the sun (* in Figure 7). Optimal (low **ρ**) angles are 90 – 135 degrees from the sun.

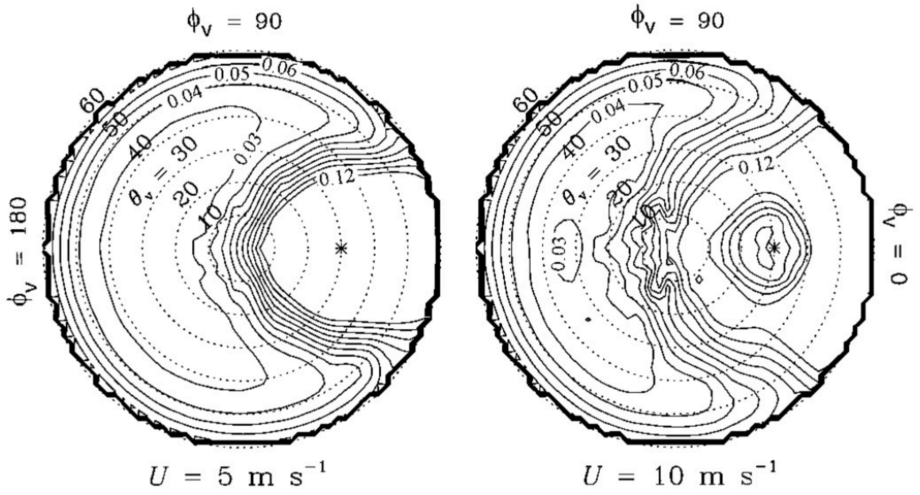


Fig. 7. Contour plots of ρ (solid lines) as a function of viewing direction (θ_v, ϕ_v) for θ_s = 30 deg and two wind speeds. Contour values are 0.03 to 0.12 by 0.01. The ✶ symbols show the specular direction of the Sun, and the θ_v contours (dotted lines) are labeled along the ϕ_v = 135-deg direction.

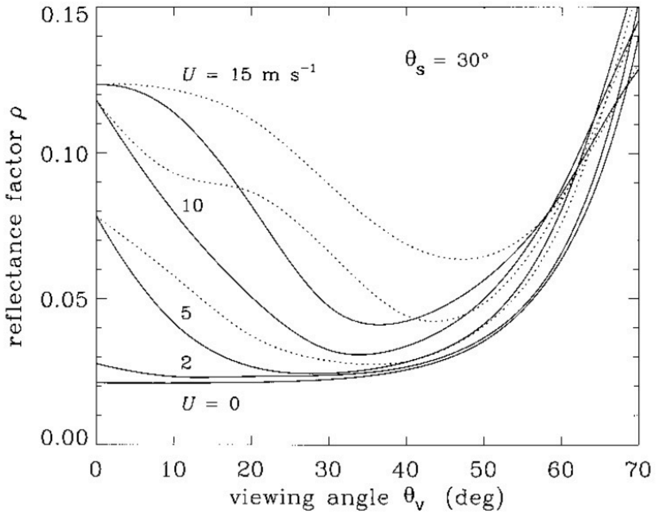


Fig. 8. Effect of wind speed and viewing direction on ρ for a Sun zenith angle of θ_s = 30 deg and a clear-sky radiance distribution. The solid curves are for an azimuthal viewing direction of ϕ_v = 135 deg, and the dotted curves are for ϕ_v = 90 deg.

20 December 1999 / Vol. 38, No. 36 / APPLIED OPTICS 7449

$^{+}$ 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.

Mobley 1999, Applied Optics

Mobley 1999, Applied Optics

Bear in mind that light from multiple angles above and below the water can scatter into the field of view of Lt, depending on wind conditions and the volume scattering function of the water column.

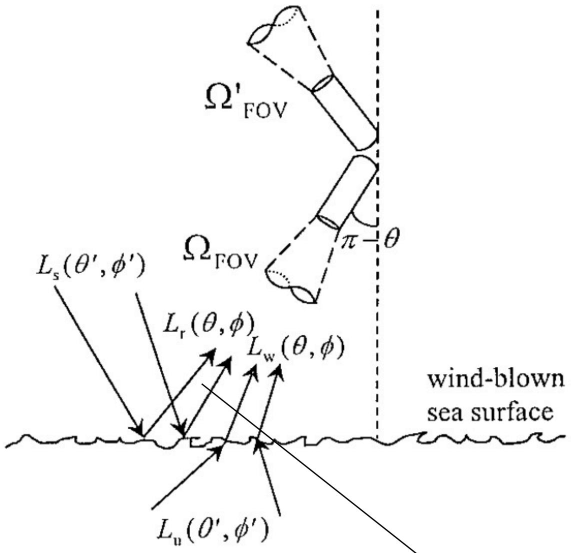
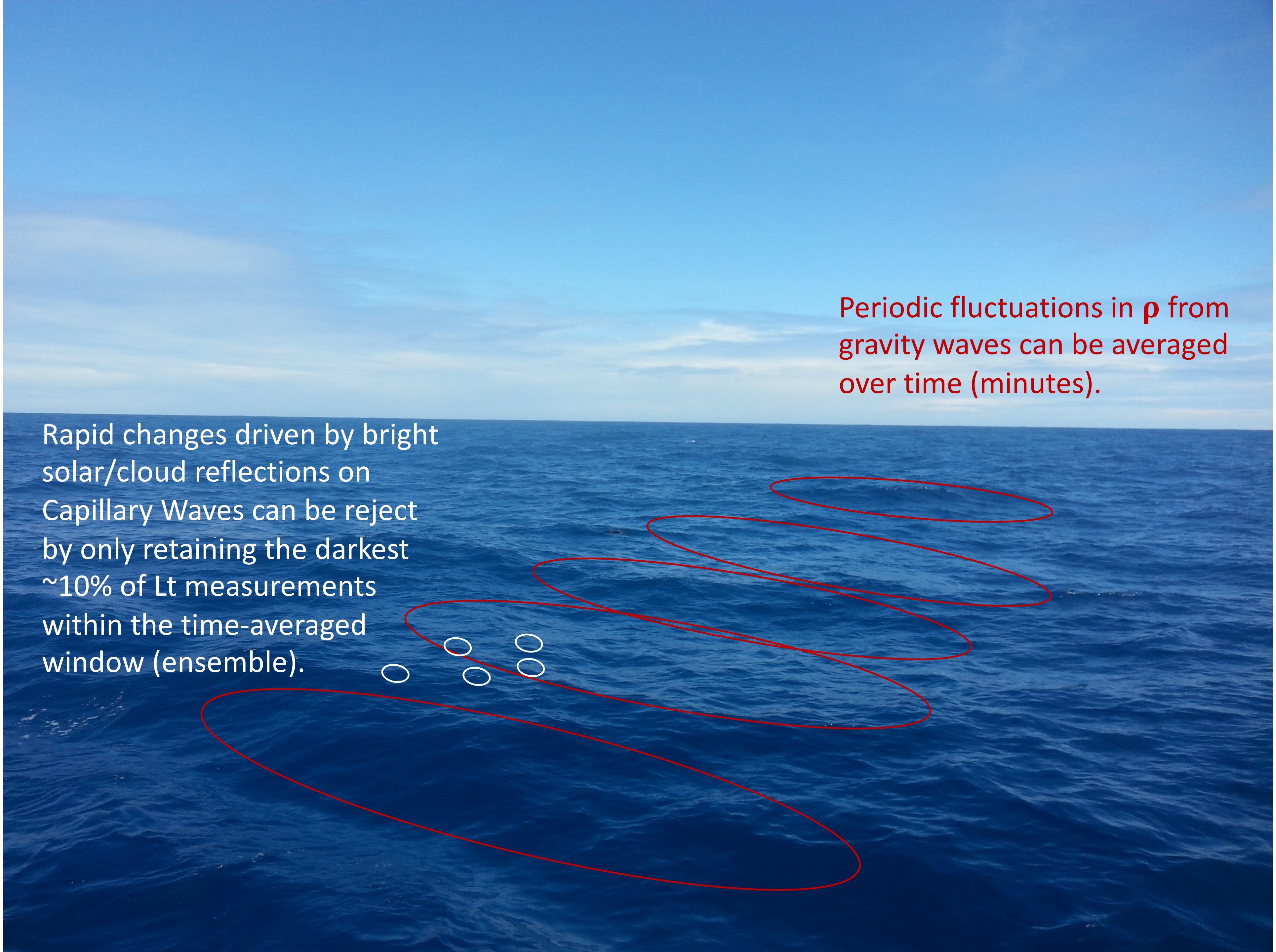


Fig. 1. Illustration of concepts for a wind-blown sea surface. L_r is the surface-reflected part of the incident sky radiance L_s. L_w is the transmitted part of the upwelling underwater radiance L_u. The downward-looking radiometer has a FOV with solid angle Ω_{FOV}.

directions, yields E_d), and let L_r denote that part of L_s that is reflected by the sea surface into the direction of the sensor. The total radiance reaching the detector is then

$$L_t(\theta, \phi) = L_r(\theta, \phi) + L_w(\theta, \phi). \quad (2)$$

$= \boldsymbol{\rho} * Li$


Periodic fluctuations in **ρ** from gravity waves can be averaged over time (minutes).
Rapid changes driven by bright solar/cloud reflections on Capillary Waves can be reject by only retaining the darkest ~10% of Lt measurements within the time-averaged window (ensemble).

Platform perturbations

While 180° relative azimuth has the lowest $\boldsymbol{\rho}$, it is usually in the platform shadow. 135° is generally outside of the platform shadow, but may be close enough to the platform to pick up reflectance from the platform itself, if it is highly reflective. The compromise relative azimuth angles used are between 90° and 135°.

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

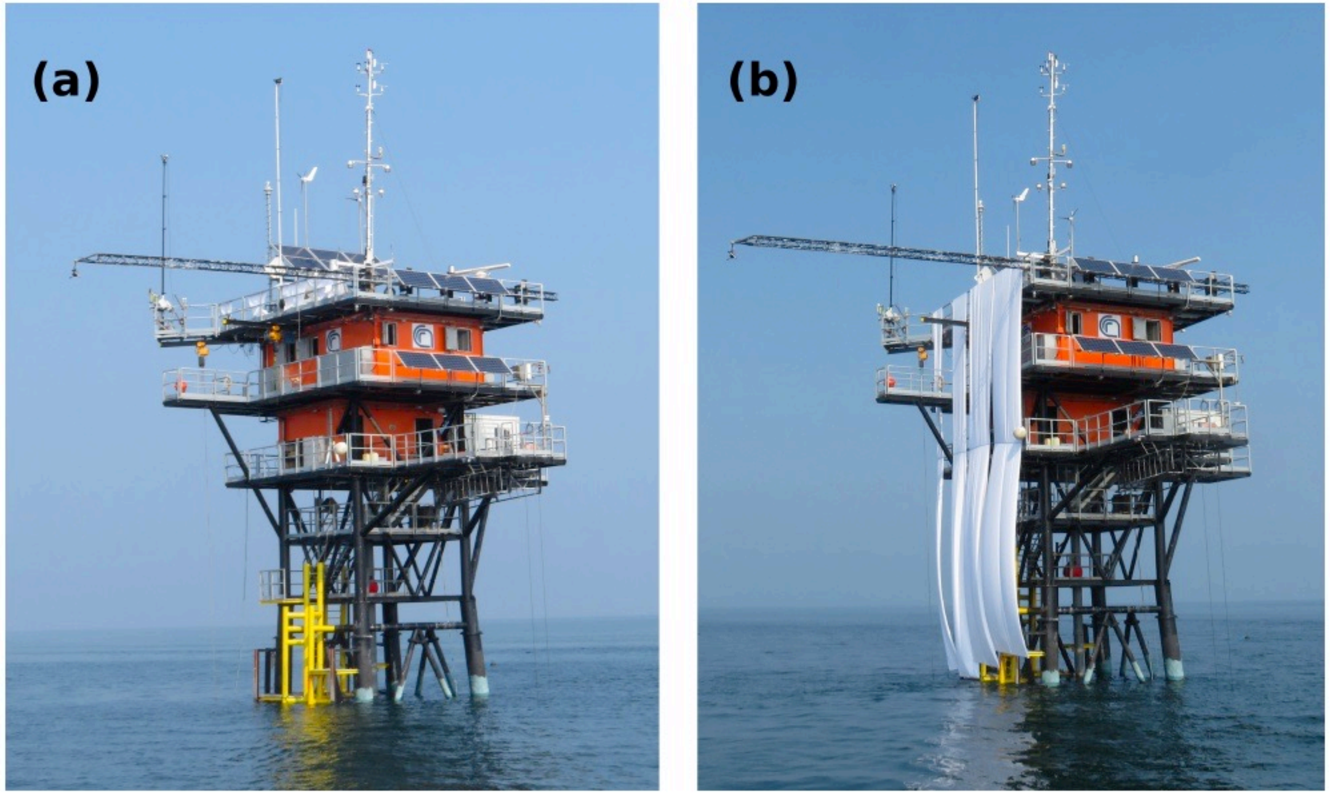


Fig. 7. AAOT platform (a) without and (b) with the white cover used for the assessment of spectral perturbations in above-water radiometric data.

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

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

Cloud cover (record it)
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
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 can be applied to these to reduce measurement uncertainty

In the Field

At a minimum, field logs should include comments on station or when anything noteworthy happens (e.g, system malfunction, birds landing on the pySAS, OC frontal boundary crossed, etc.) Teams should agree upon common names for Experiment, Cruise, and Stations.

Experiment_Cruise_Instrument_Radiometry_Field_Log_example.xlsx

Radiometry log for pySAS. Experiment: FIREFLY02. Cruise: SEASON1. Platform: SERENITY. Operator: Hoban Washburne. pySAS setup: Home angle: 0. Min/Max azimuth: -20/+145, Height: 7 m, Ship hull color: Blue.

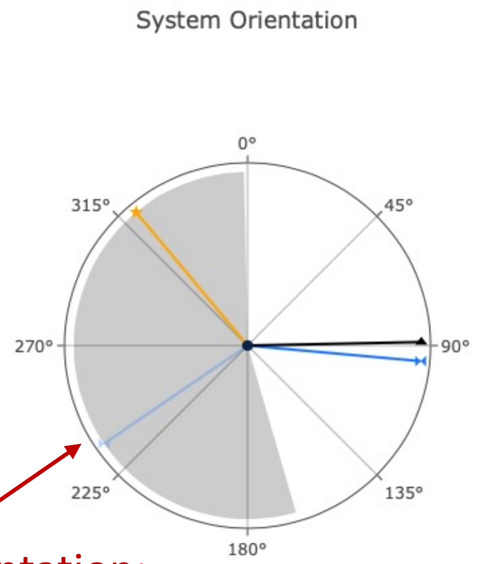
Station	Raw Filename	Start Station Date/T	End Station Date/Ti	lat	lon	relative azimuth	wind speed	wind dir	waves	Cloud	Comments
(name agreed across sampling platforms)	(not for pySAS when working properly, or if station number is in the name)	(UTC. Confirm all systms set to UTC)	(UTC)	(deg N; 3-4 decimals)	(deg E)	(above-water; only if set manually)	(m/s)	(deg)	(m)	(% or x/8)	(haze, fog, rain, optically shallow/bottom reflection, other issues)
checkout	pySAS autonomous defaults	2023-05-23-T-1500	2023-05-23-T-1530	43.1234	-20.4321	pySAS logger	5	45	0.5	30	pySAS system tested and data offloaded for processing
1		2023-05-23-T-1600	2023-05-23-T-1630	43.2345	-20.321		5	60	0.5	45	IOPs on rosette and Hyperpro multicast
2		2023-05-23-T-1700	2023-05-23-T-1730	43.3456	-20.2109		2	90	0.5	50	Dolphins reported around bow of ship
3		2023-05-23-T-1800	2023-05-23-T-1830	43.5678	-20.1098		7	90	1	75	Minor whitecaps starting to form
-		2023-05-23-T-1945		43.789	-19.4567		8	90	1.33	50	Clean Li/Lt lenses

If possible, capture streaming ancillary data from the ship/platform: Wind, Speed, Heading, SST, SSS, RH, flow-through IOPs, etc. If data are being collected underway with no autonomous platform (e.g., SolarTracker, pySAS) field notes must include relative azimuth (or sensor azimuth)

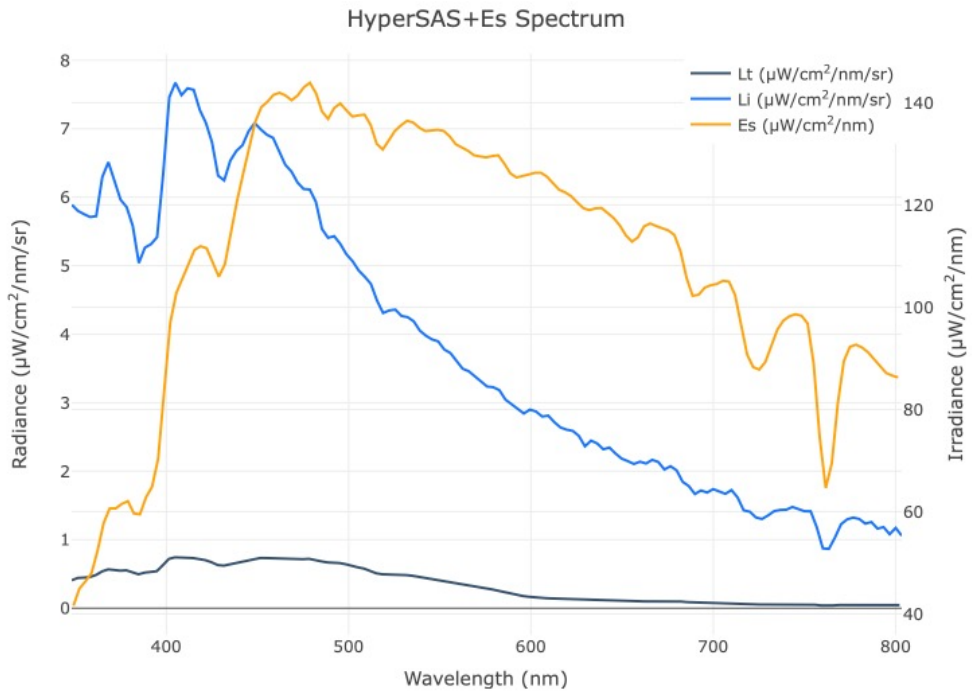
pySAS Setup

Es
HyperSAS
GPS Antennas
Controller Box
Tilt Sensor
Li (sky)
Lt
Tower
Autonomous azimuth adjustment
Tower Support

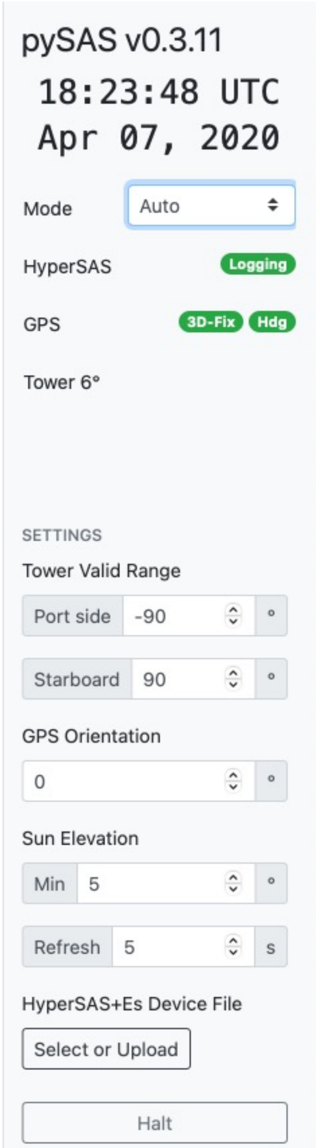
pySAS User Interface



System Orientation:
Radiometers
Sun
Ship
Blind Zone



Radiance (Lt, Li) and Irradiance (Es) Spectrum



Connect to pySAS interface via Wi-Fi with a computer
Download data over SFTP for processing
Documentation at: https://github.com/OceanOptics/pySAS/

pySAS output

- Design for autonomous operation over extended periods of time
- Data is automatically saved in hourly files
- pySAS Output:
    - HyperSAS_<date>_<time>.bin:
        - Data: Lt, Li, Es, Tilt from Sea-Bird Scientific HyperOCR and THS sensors
        - Format: Satlantic Log File Standard
    - GPS_<date>_<time>.csv
        - Data: Latitude, Longitude, Elevation, Ship Heading, Accuracy
        - Format: csv
    - IndexingTable_<date>_<time>.csv
        - Data: Radiometer Orientation with respect to the ship
        - Format: csv

prepSAS convert

- Parameters:
  - Satlantic Calibration File (.sip)
  - pySAS Configuration File (.ini)
  - Output frequency mode:
    - day: if low variability in day (station)
    - hour: if higher variability encountered
  - Path to directory containing files to process
    - Recommended name: L0A
  - Path to output directory
    - Recommended name: L0B
  - Prefix: can set prefix of output files with an experiment and cruise name to comply with SeaBASS naming convention.
  - Parallel: use all cpu available on host computer

- Download at

```
wget https://github.com/OceanOptics/pySAS/tree/master/prepSAS
```

- Install in HyperInSPACE conda environment using:

```
pip install –r requirements.txt
```

- Execute:

```
# Setup parameters in setup.py
python run.py
# Set arguments directly in shell
python prepSAS.py –h …
```

HyperCP Input

- pySAS data in a single ".raw" file:
  - Format: Satlantic Log File Standard
  - Radiometric data (Lt, Li, Es)
  - True Headings (SAS, Ship, Motion)
  - GPS Position
  - Sun Azimuth and Sun Elevation
- Auxiliary data:
  - Format: SeaBASS
  - [ship heading, relative sensor azimuth]: if standalone SAS (no pySAS tower)
  - Environmental conditions: aerosol optical depth, cloud cover, salinity, water temperature, and **wind speed**
  - station number

HyperCP Installation

To install and launch the program:
https://github.com/nasa/HyperInSPACE

Use "dev" branch for the class

Requirements and Installation

Clone this repository (branch: "master") to a convenient directory on your computer. When HyperCP/Main.py is launched for the first time, sub-directories will be created and databases downloaded and moved into them as described below. No system files will be changed.

HyperCP requires Python 3.X installed on a Linux, MacOS, or Windows computer. The Anaconda distribution (or Miniconda) is encouraged. (If you are unfamiliar with Anaconda, a nice walkthrough can be found here.)

All of the package dependencies are listed in the environment.yml file included with the package. To make sure you have all of the necessary dependencies, navigate to the HyperCP directory on command line and type

```
prompt$ conda env create -f environment.yml
```

and follow the prompts to install the additional package dependencies on your machine within the new virtual environment. When completed you should be in the virtual environment (hypercp) and ready to run the package. To return to the environment later before launching the program, type

```
prompt$ conda activate hypercp
```

To stay up to date with the latest commits to the master branch, it is strongly recommended that you pull them prior to using the software. From the HyperCP directory, type:

```
(hypercp) prompt$ git pull
```

To report an issue, please submit here: https://github.com/nasa/HyperInSPACE/issues

Launching

HyperCP is a Main-View-Controller Python package with a GUI that can be launched in several ways, such as by navigating to the project folder on the command line and typing

```
(hypercp) prompt$ python Main.py
```

However you launch the GUI, *watch for important feedback at the command line terminal* in addition to informational GUI windows.

There is a command line option for batching a single level which can be triggered by adding the `-cmd` argument to the above command followed by: `-c config -i inputFile -o outputDirectory -l processingLevel`, where config is the configuration file, and the other arguments are self-explanatory (processingLevel should be in all caps, e.g., `L1AQC`). An example script has been provided (run_sample.py) for batching files using the command line option.

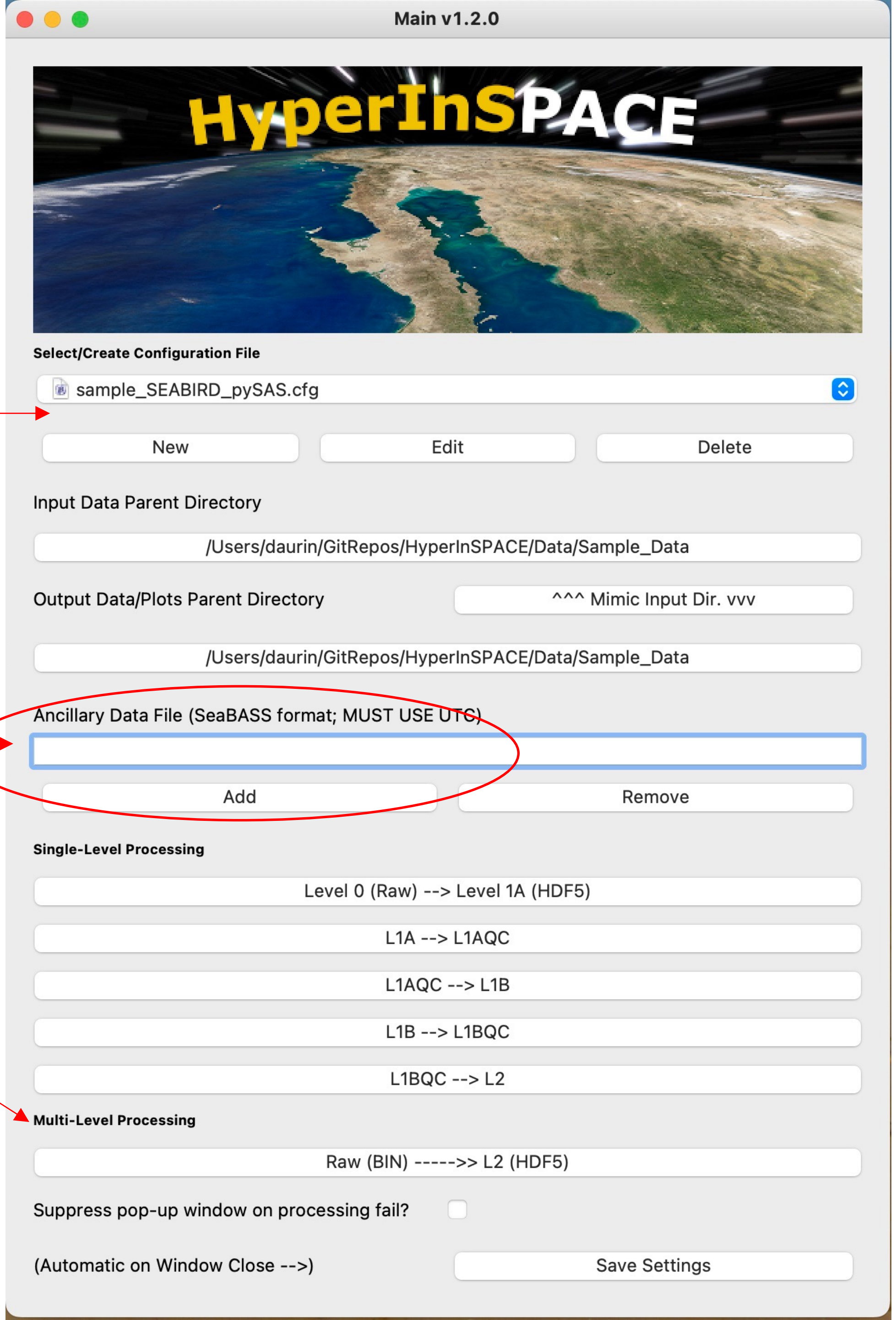
Batching multiple files across single or multiple processing levels is also possible as described below under Processing Overview.

HyperCP Overview

Every deployment gets a unique configuration

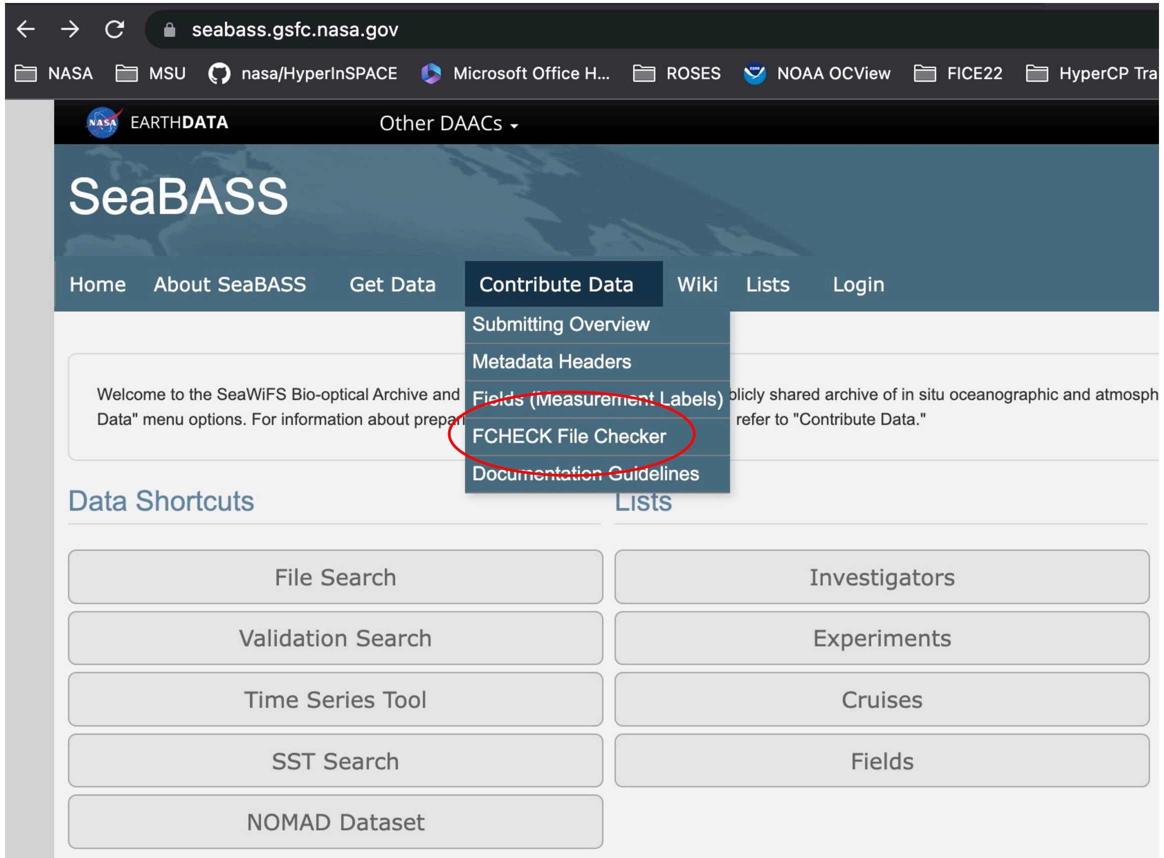
Ancillary data from field notes and external (e.g. ship) data should be provided. Simple text file in SeaBASS format (next slide).

Data can be processed one file at a time or many files at a time, and can be processed for a single level, or L0 (Raw) -> L2.

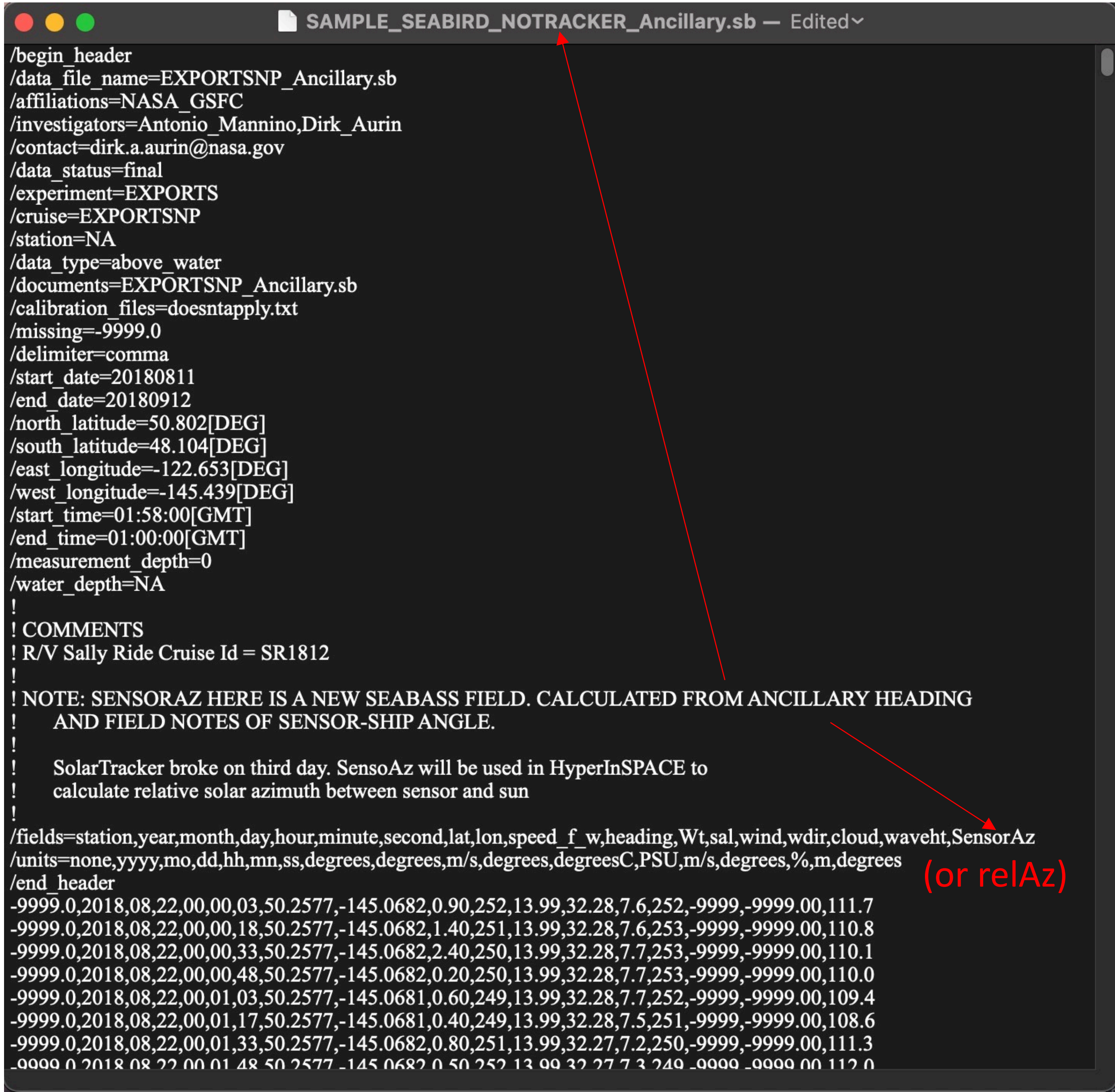


HyperCP Ancillary Data

These should be as detailed and high-frequency as possible, particularly when using non-autonomous platforms (i.e., “NOTRACKER”; ~10 s for a moving ship).



SeaBASS format description. Confirm correctly formatted using FCHECK

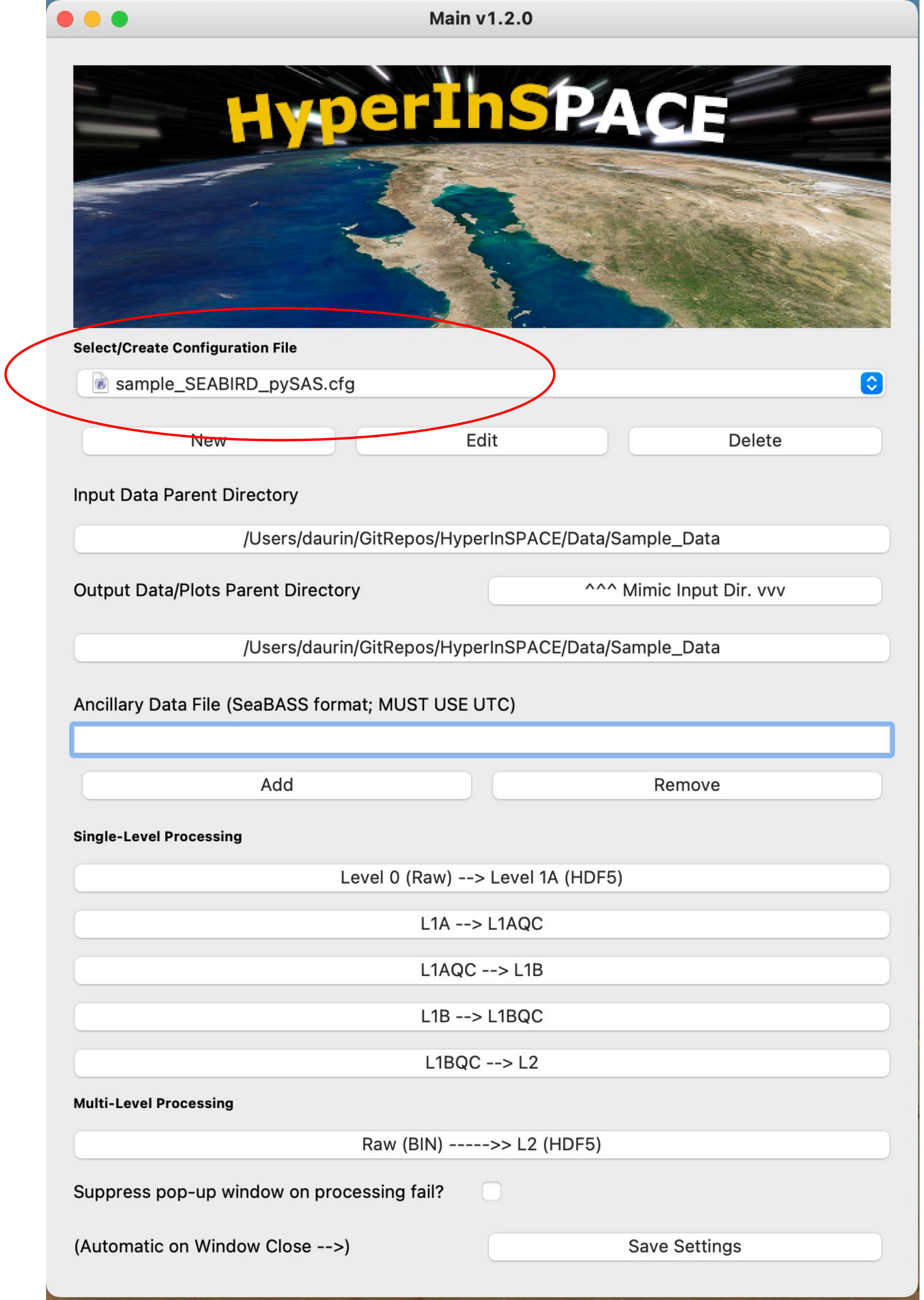



```
/begin_header
/data_file_name=EXPORTSNP_Ancillary.sb
/affiliations=NASA_GSFC
/investigators=Antonio_Mannino,Dirk_Aurin
/contact=dirk.a.aurin@nasa.gov
/data_status=final
/experiment=EXPORTS
/cruise=EXPORTSNP
/station=NA
/data_type=above_water
/documents=EXPORTSNP_Ancillary.sb
/calibration_files=doesntapply.txt
/missing=-9999.0
/delimiter=comma
/start_date=20180811
/end_date=20180912
/north_latitude=50.802[DEG]
/south_latitude=48.104[DEG]
/east_longitude=-122.653[DEG]
/west_longitude=-145.439[DEG]
/start_time=01:58:00[GMT]
/end_time=01:00:00[GMT]
/measurement_depth=0
/water_depth=NA
!
! COMMENTS
! R/V Sally Ride Cruise Id = SR1812
!
! NOTE: SENSORAZ HERE IS A NEW SEABASS FIELD. CALCULATED FROM ANCILLARY HEADING
!      AND FIELD NOTES OF SENSOR-SHIP ANGLE.
!
!      SolarTracker broke on third day. SensoAz will be used in HyperInSPACE to
!      calculate relative solar azimuth between sensor and sun
!
/fields=station,year,month,day,hour,minute,second,lat,lon,speed_f_w,heading,Wt,sal,wind,wdir,cloud,waveht,SensorAz
/units=none,yyyy,mo,dd,hh,mn,ss,degrees,degrees,m/s,degrees,degreesC,PSU,m/s,degrees,%,m,degrees
/end_header
-9999.0,2018,08,22,00,00,03,50.2577,-145.0682,0.90,252,13.99,32.28,7.6,252,-9999,-9999.00,111.7
-9999.0,2018,08,22,00,00,18,50.2577,-145.0682,1.40,251,13.99,32.28,7.6,253,-9999,-9999.00,110.8
-9999.0,2018,08,22,00,00,33,50.2577,-145.0682,2.40,250,13.99,32.28,7.7,253,-9999,-9999.00,110.1
-9999.0,2018,08,22,00,00,48,50.2577,-145.0682,0.20,250,13.99,32.28,7.7,253,-9999,-9999.00,110.0
-9999.0,2018,08,22,00,01,03,50.2577,-145.0681,0.60,249,13.99,32.28,7.7,252,-9999,-9999.00,109.4
-9999.0,2018,08,22,00,01,17,50.2577,-145.0681,0.40,249,13.99,32.28,7.5,251,-9999,-9999.00,108.6
-9999.0,2018,08,22,00,01,33,50.2577,-145.0682,0.80,251,13.99,32.27,7.2,250,-9999,-9999.00,111.3
-9999.0,2018,08,22,00,01,48,50.2577,-145.0682,0.50,252,13.99,32.27,7.3,249,-9999,-9999.00,112.0
```

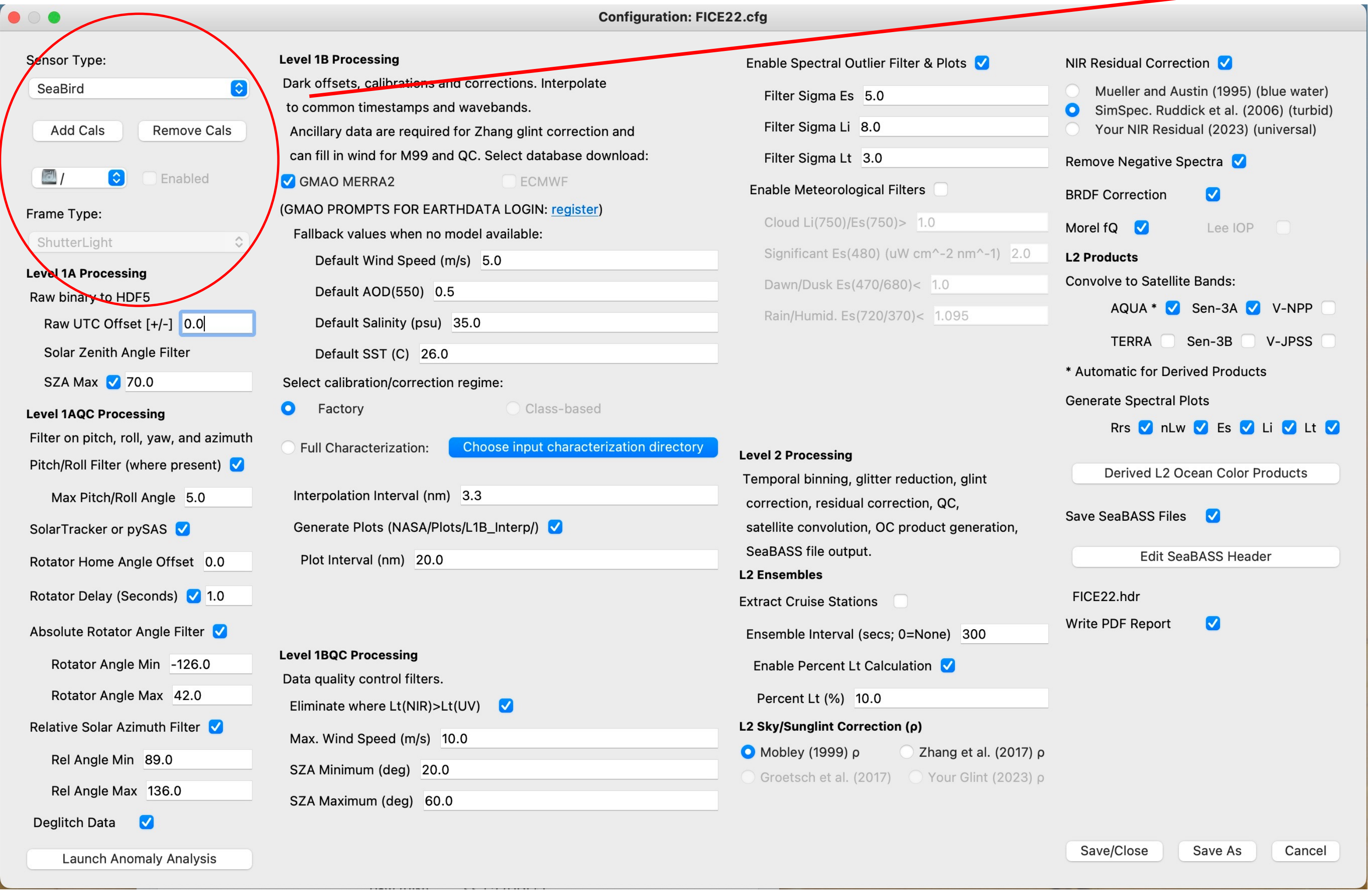
HyperCP Overview

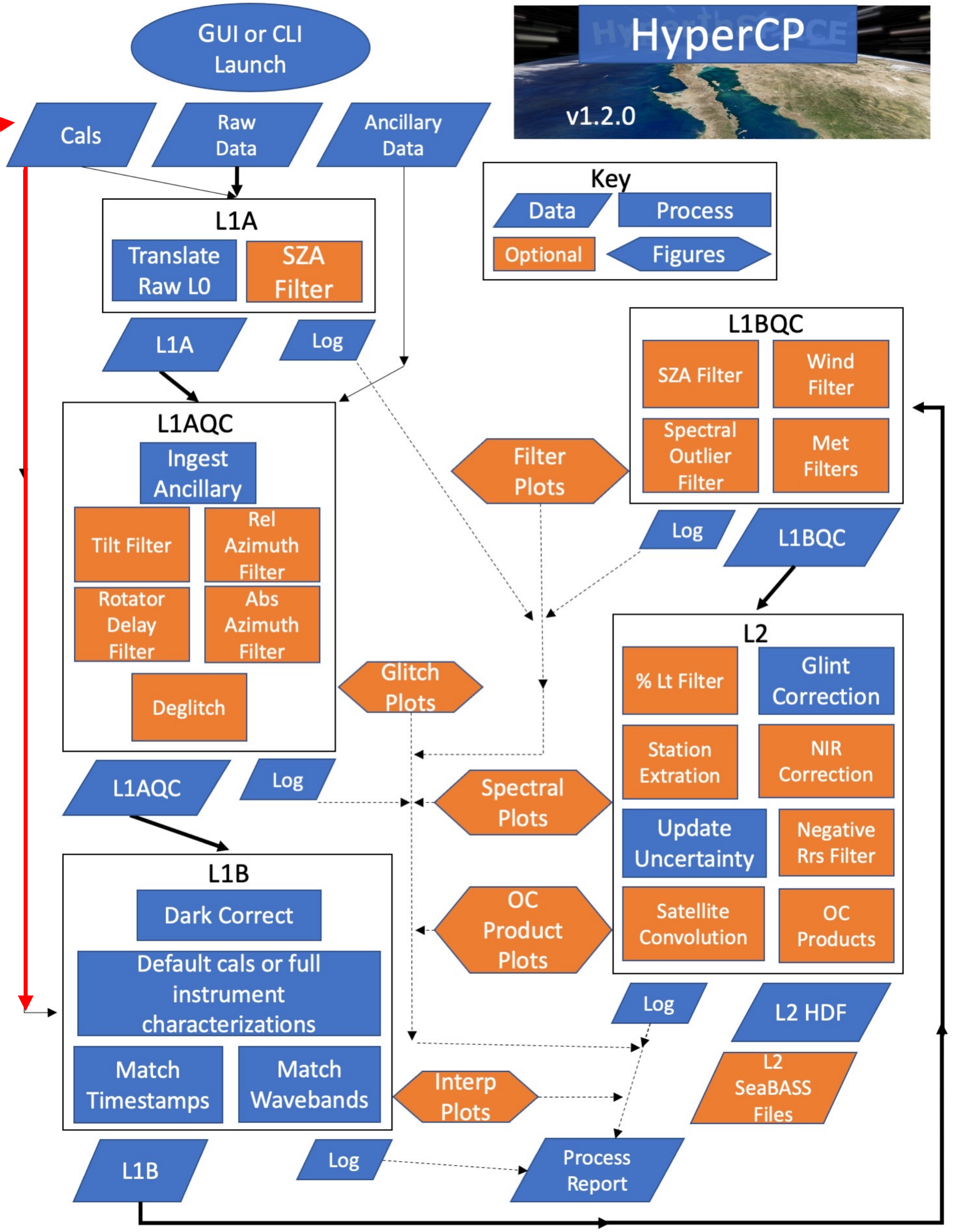
Main GUI screen > Select Configuration

The configuration is for parameterization of data processing specific to the platform (e.g., most recent calibrations) and the sampling environment (e.g., optical water type).

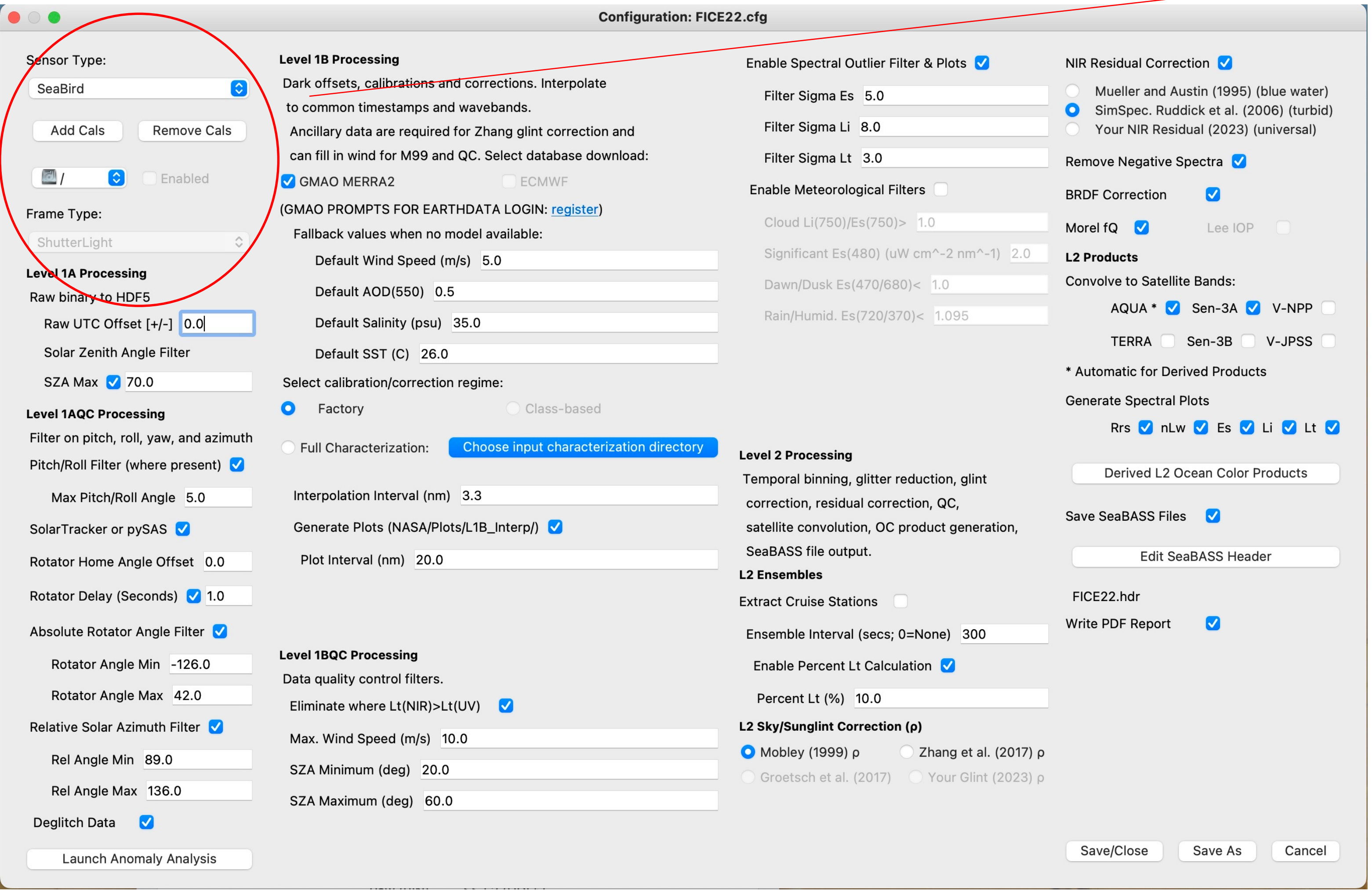


HyperCP: Loading Instrument Calibration

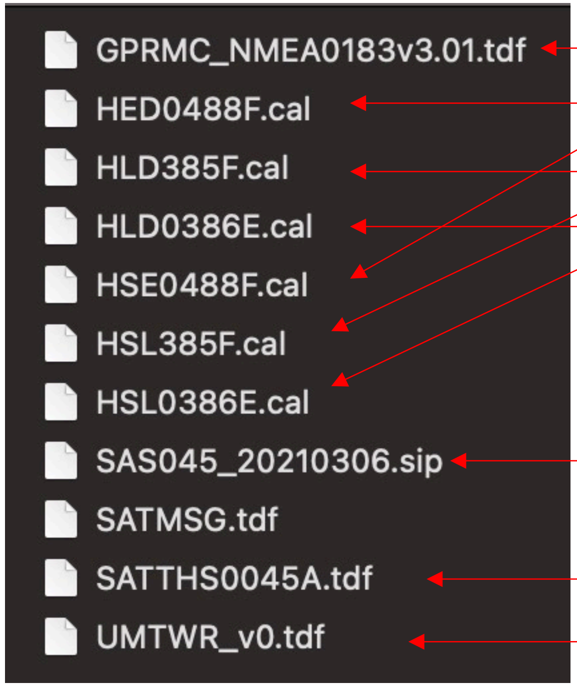




HyperCP: Loading Instrument Calibration



Sea-Bird HyperOCRs, pySAS



GPS

Es

Li

Lt

Zip of all .cal & .tdf files

Tilt-Heading sensor

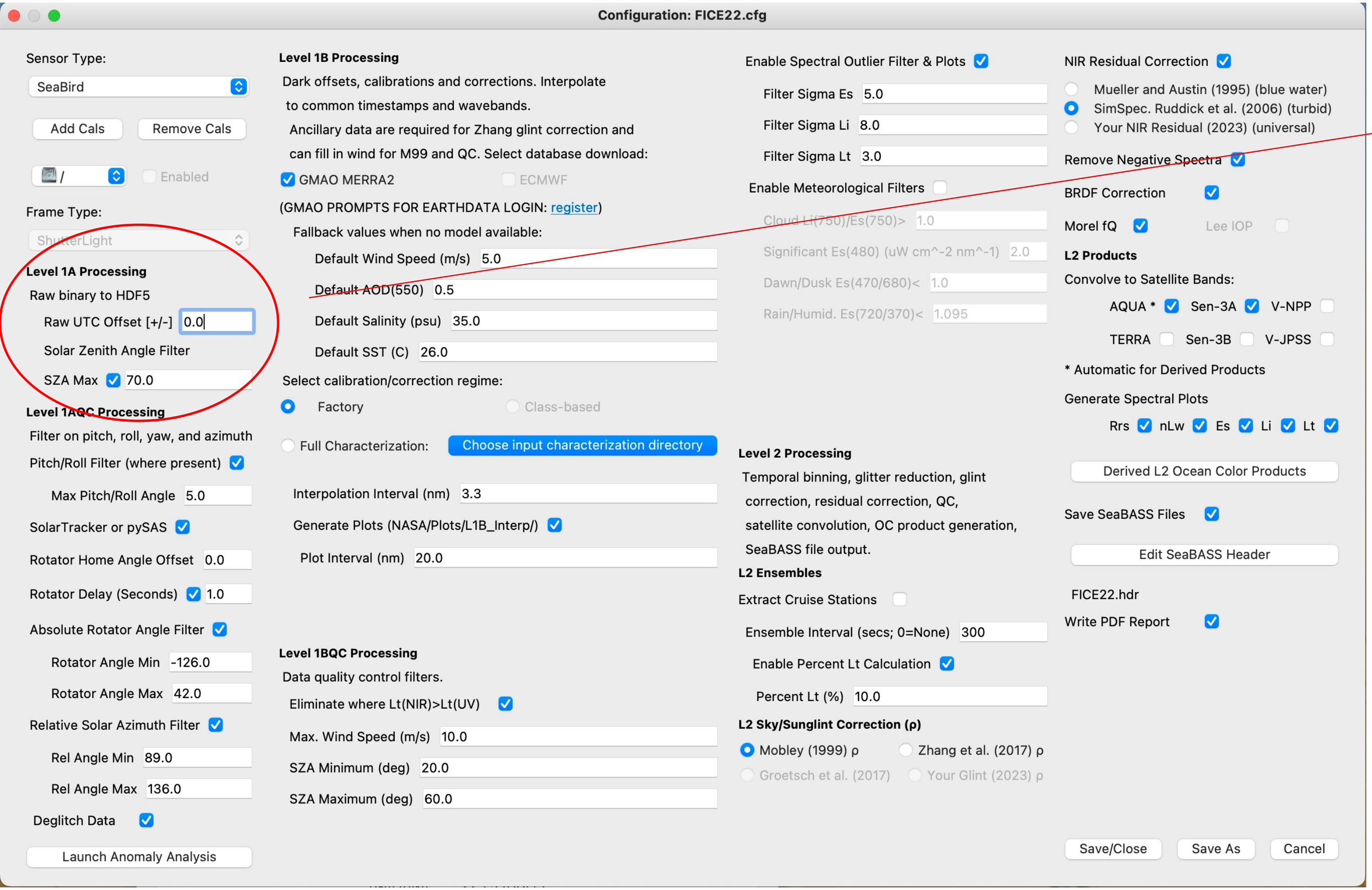
Azimuth control robot

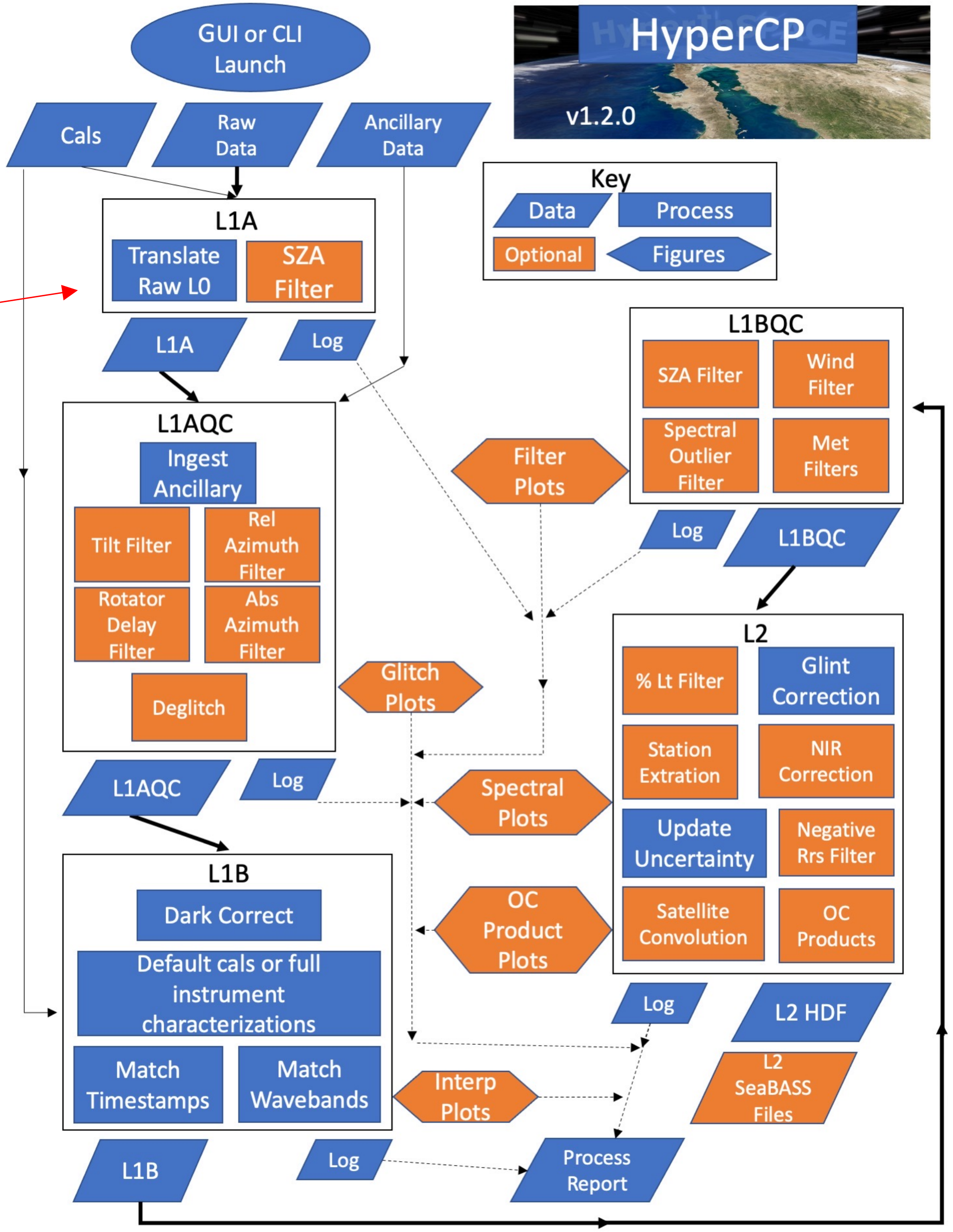
HED and HLD are **Dark** cals

HSE and HSL are **Light** cals

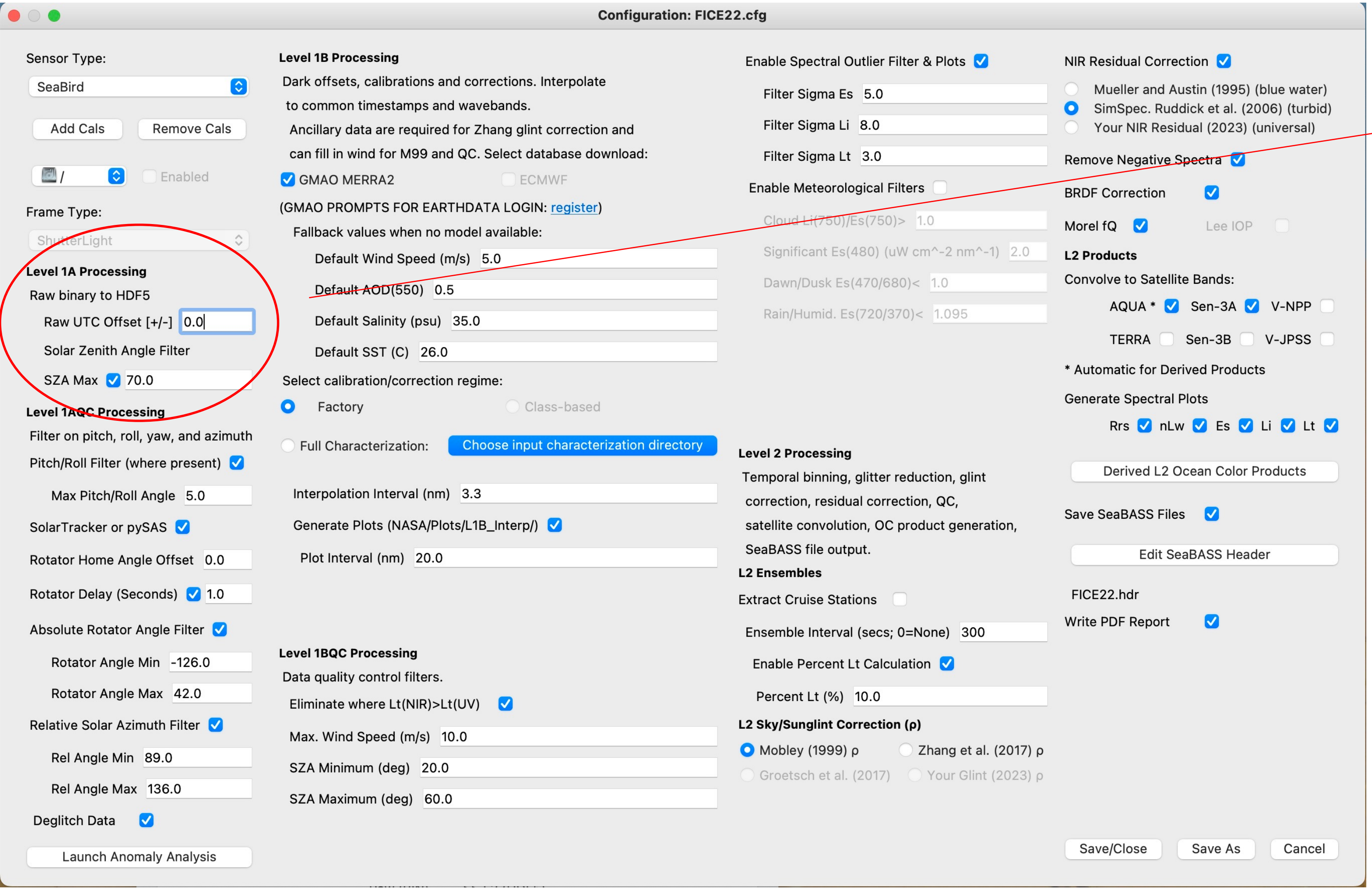
[*Plan to automate interpretations and enabling in the future, but for now, need to select Type and Enable each*]

HyperCP Level 1A: Read Data





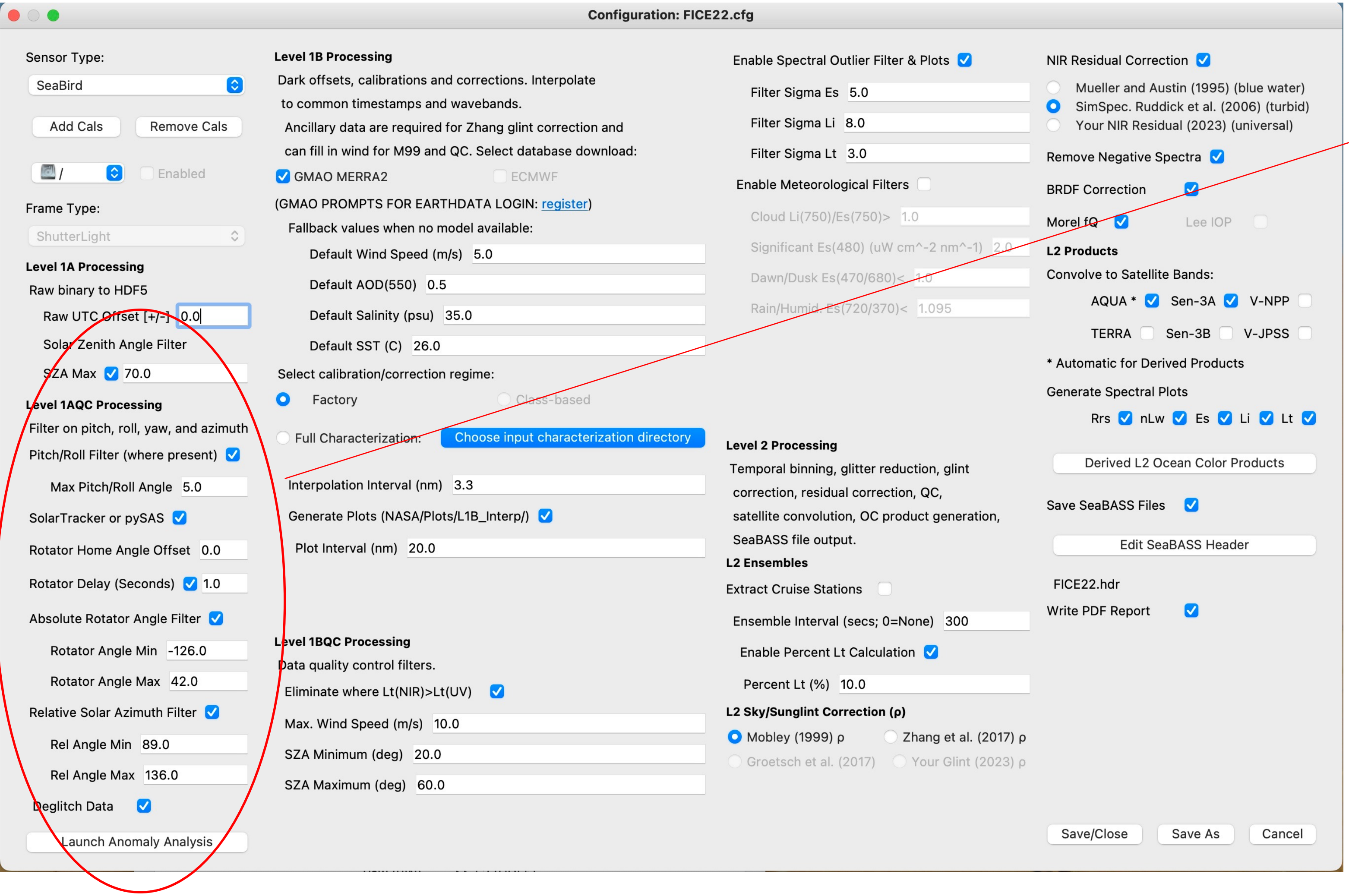
HyperCP Level 1A: Read Data



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. SZA fine tuned in L1BQC.

HyperCP Level 1AQC: Quality Control Data

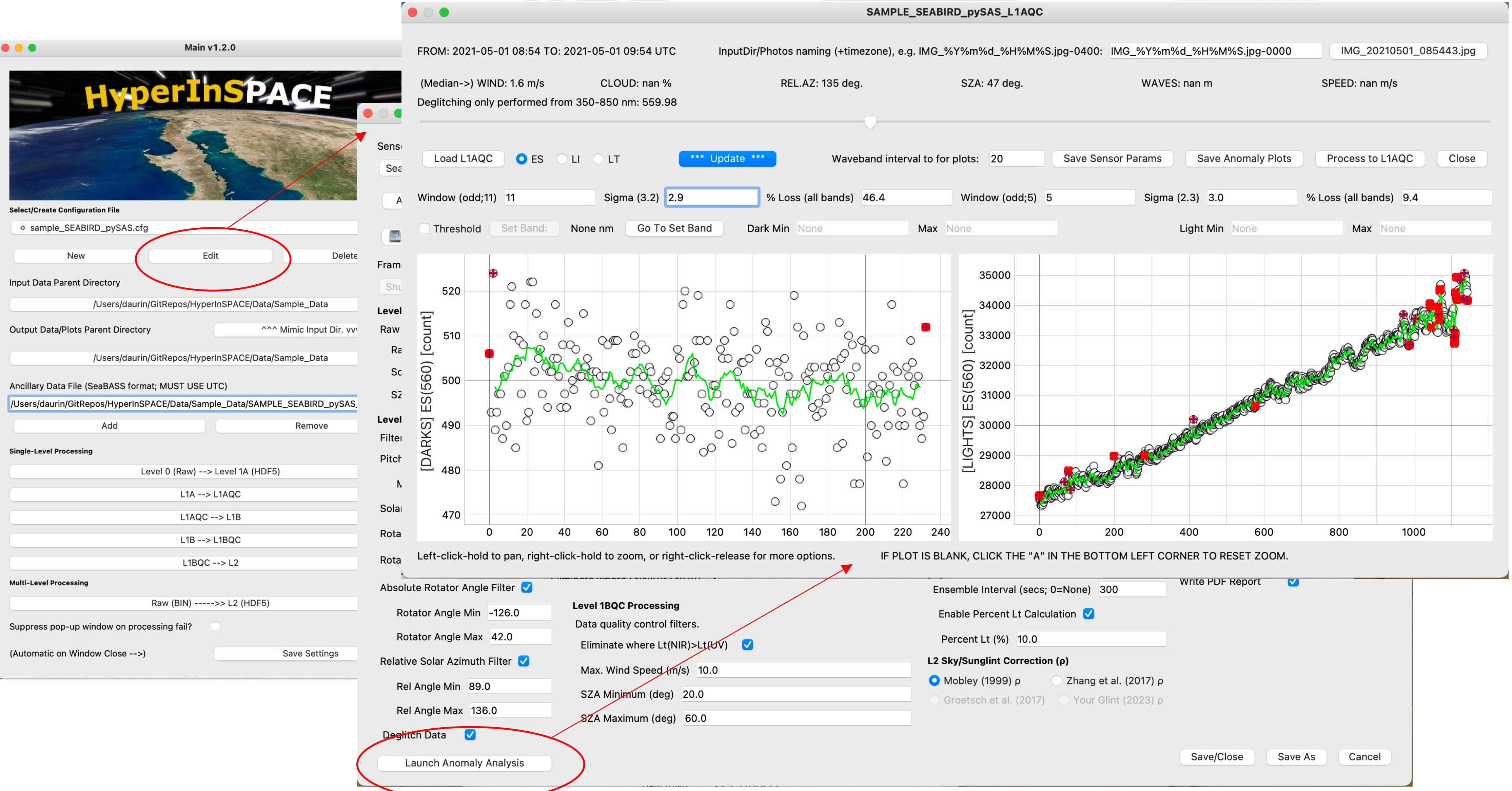


Tilt of Es should not exceed 5 degrees. (See README for explanation/sources of all default and recommended values throughout configuration.)

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.

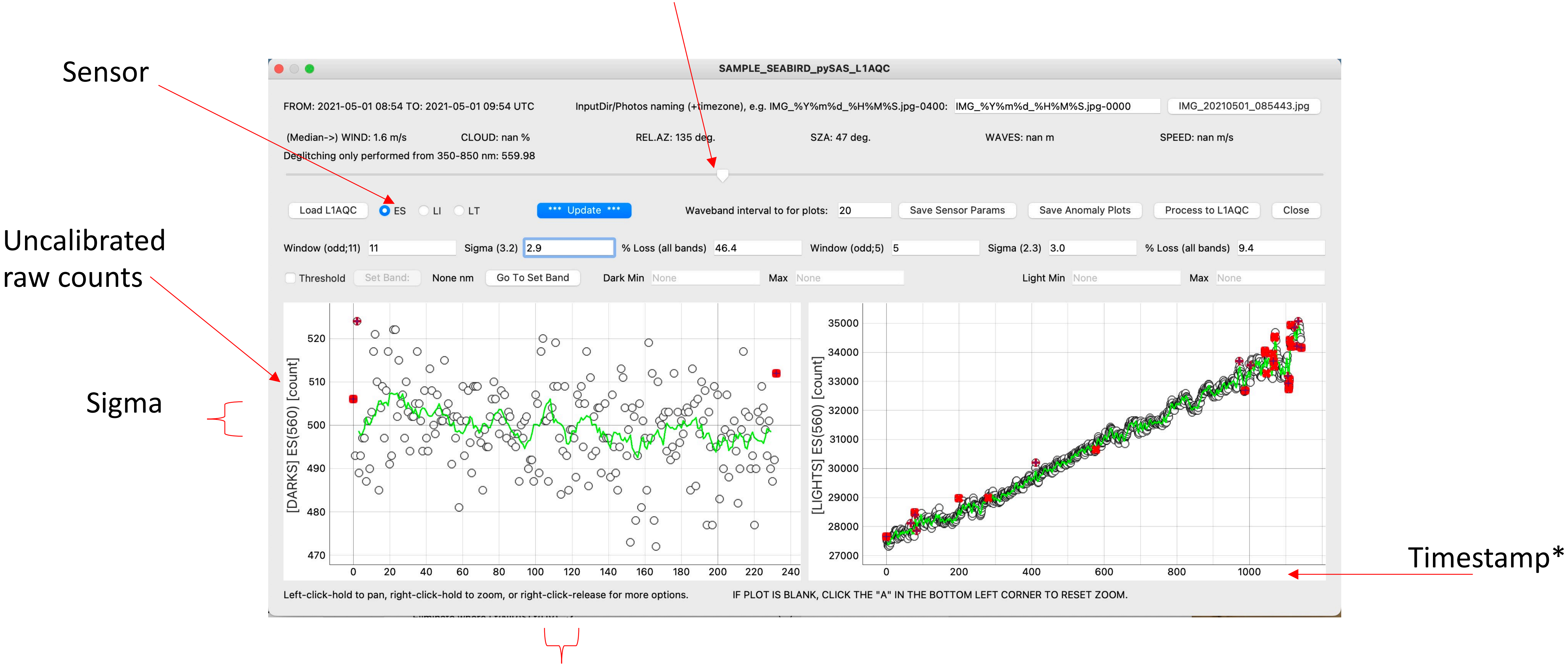
Use field logs/notes to identify min/max sensor azimuth (rotator angle to avoid obstruction) and home offset (latest values can also be recovered from pySAS file pysas_cfg.ini)

HyperCP Level 1AQC: Supervised Deglitching



HyperCP Level 1AQC: Supervised Deglitching

Supervised Deglitching.

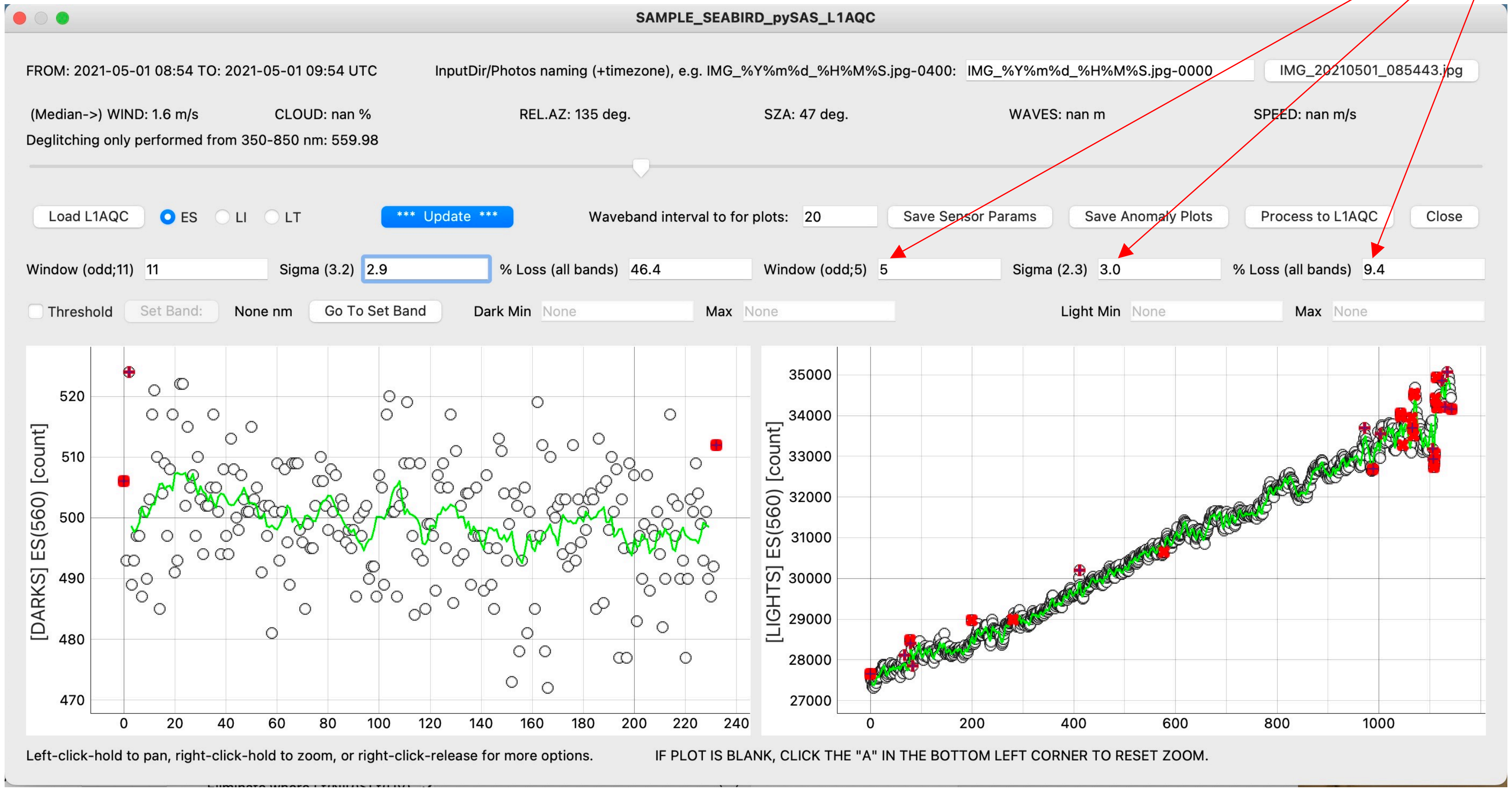


*bug: serial number in latest version

HyperCP Level 1AQC: Supervised Deglitching

Supervised Deglitching.

Sigma

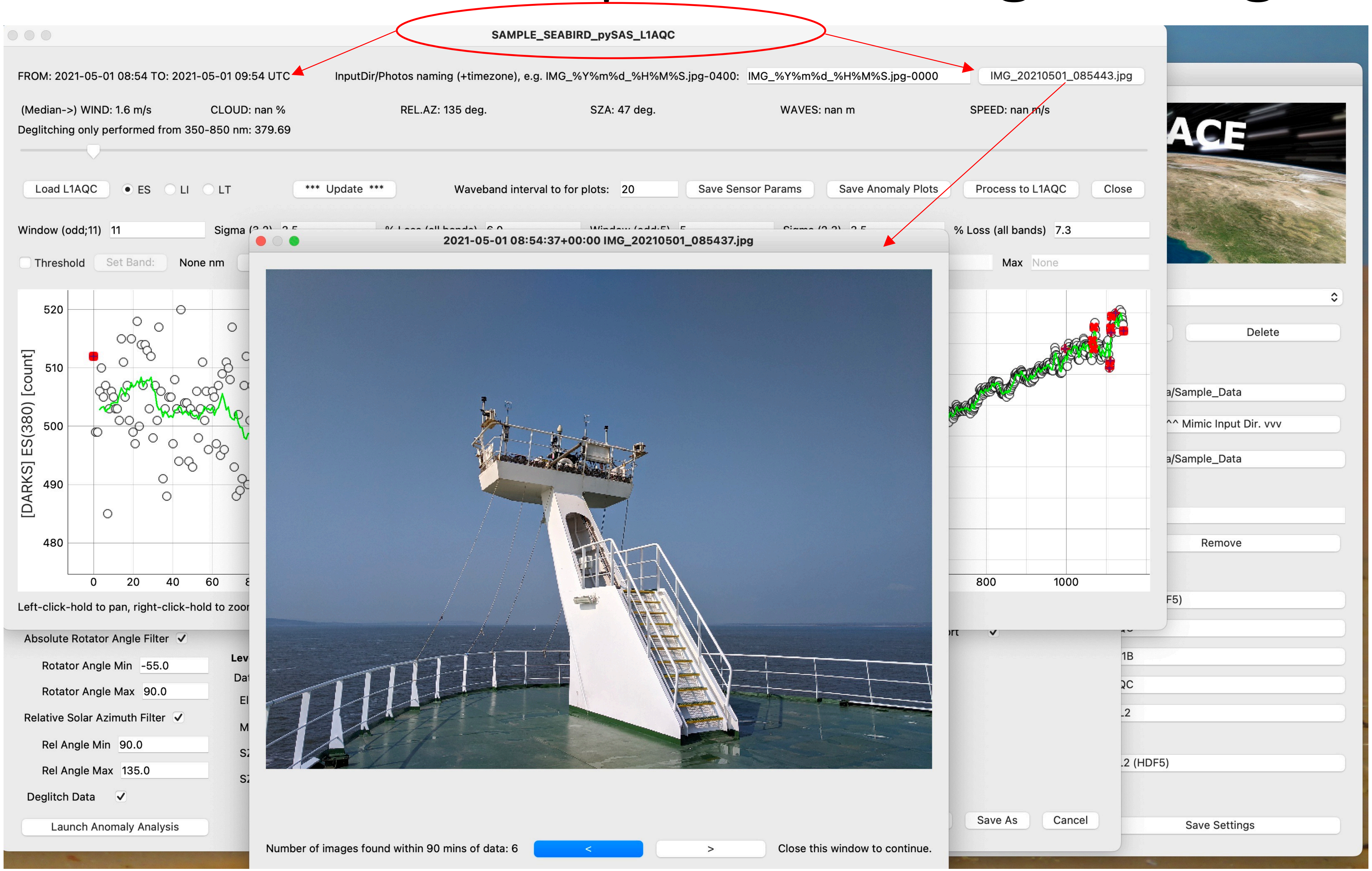


Window

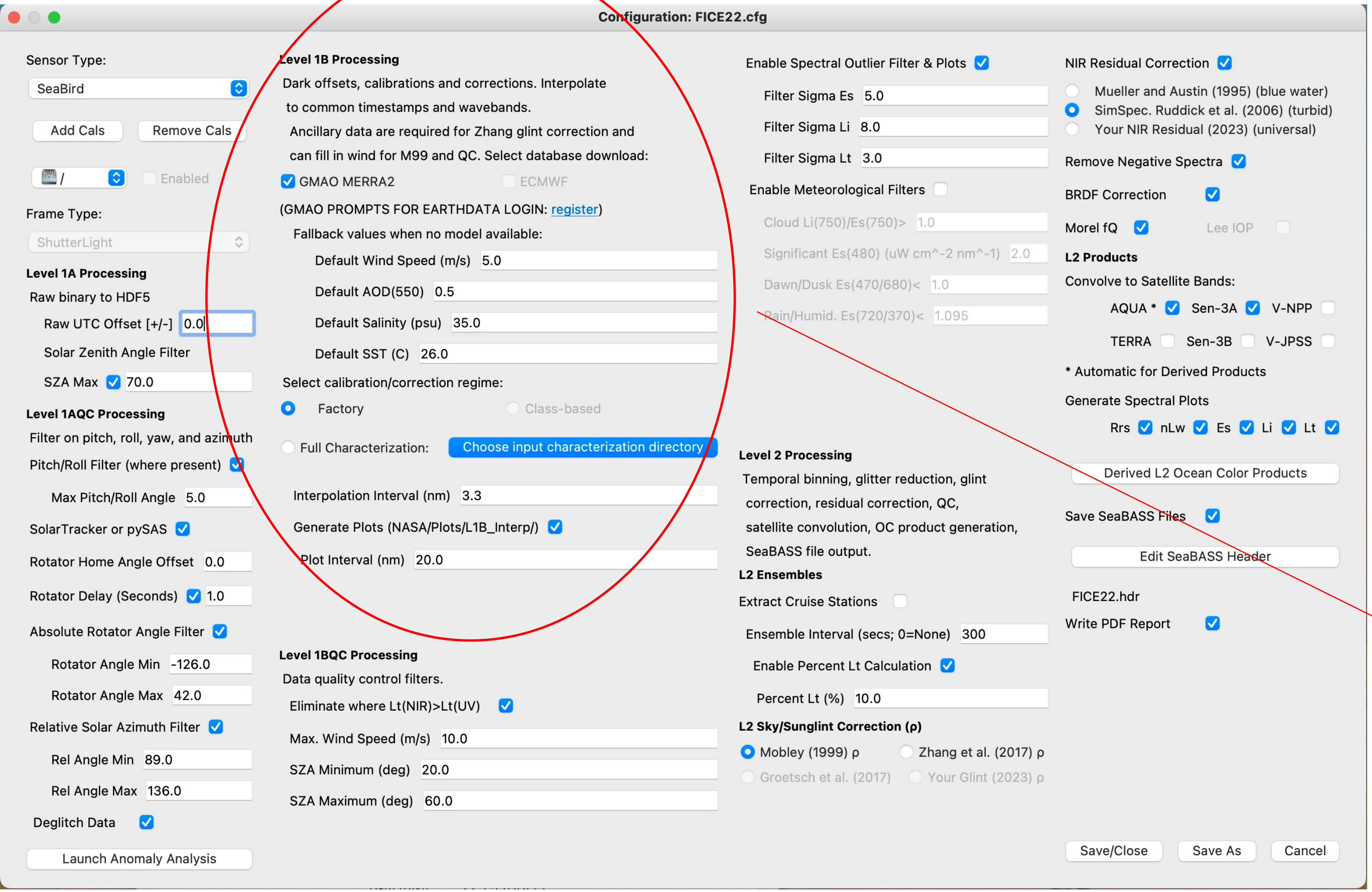
Balance these while visually evaluating signal variability throughout the file. More aggressive deglitching yields lower instrument uncertainty traded off with less data.

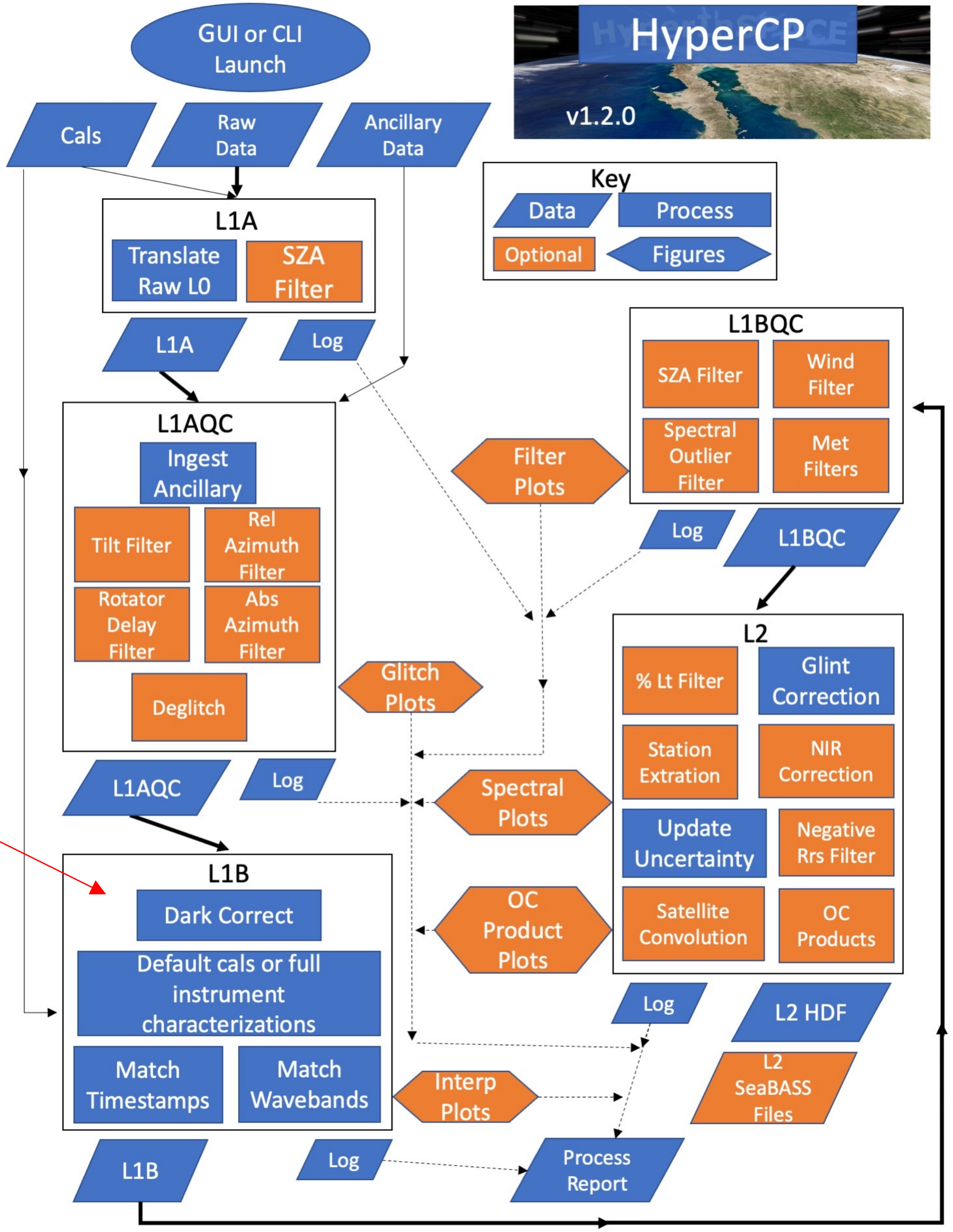
Note: This file could be 5 mins or 5 hours, but default pySAS collections are 1 hr autonomous.

HyperCP Level 1AQC: Supervised Deglitching



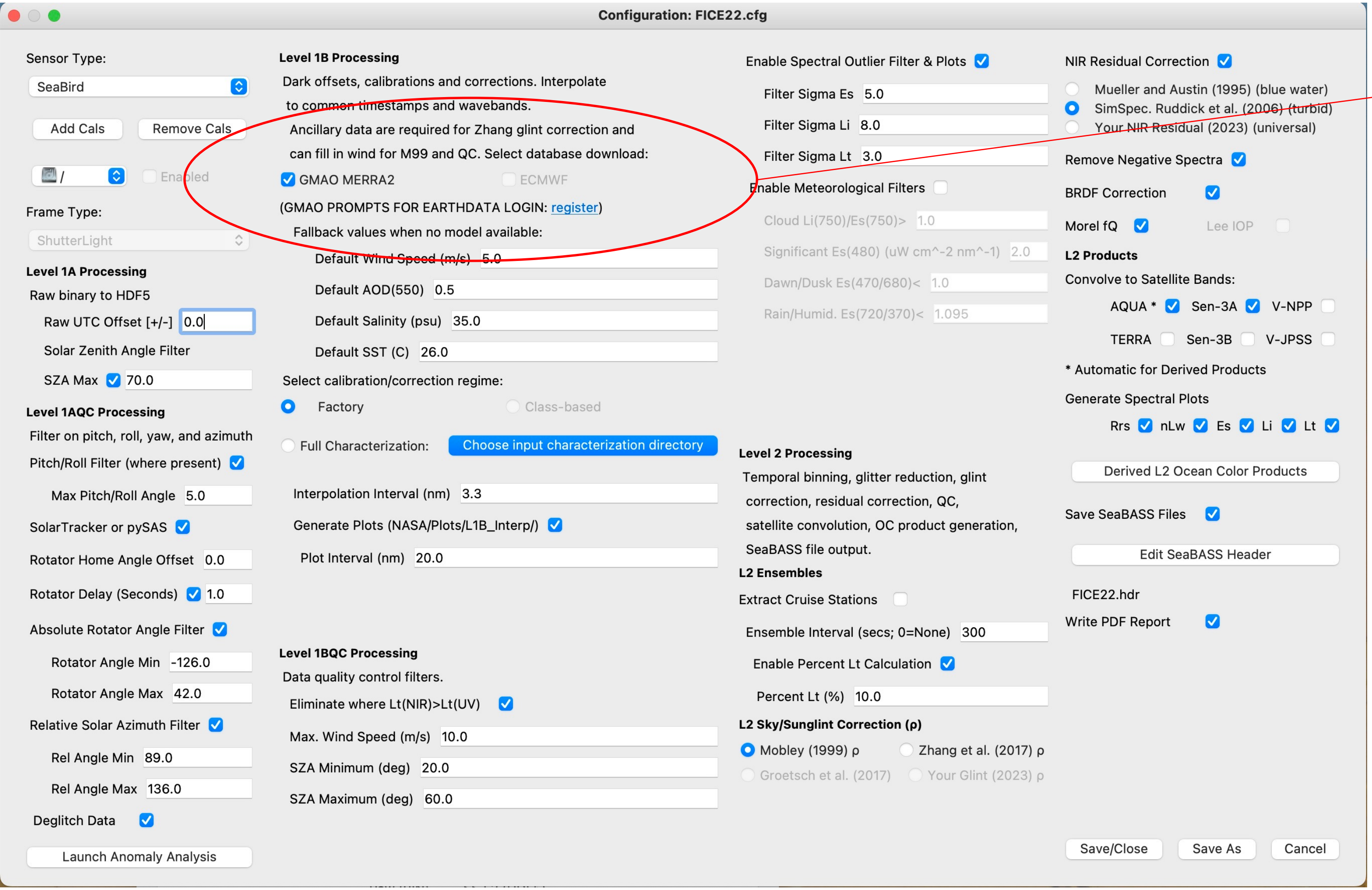
HyperCP Level 1B: Overview





HyperCP Level 1B: Load Ancillaries

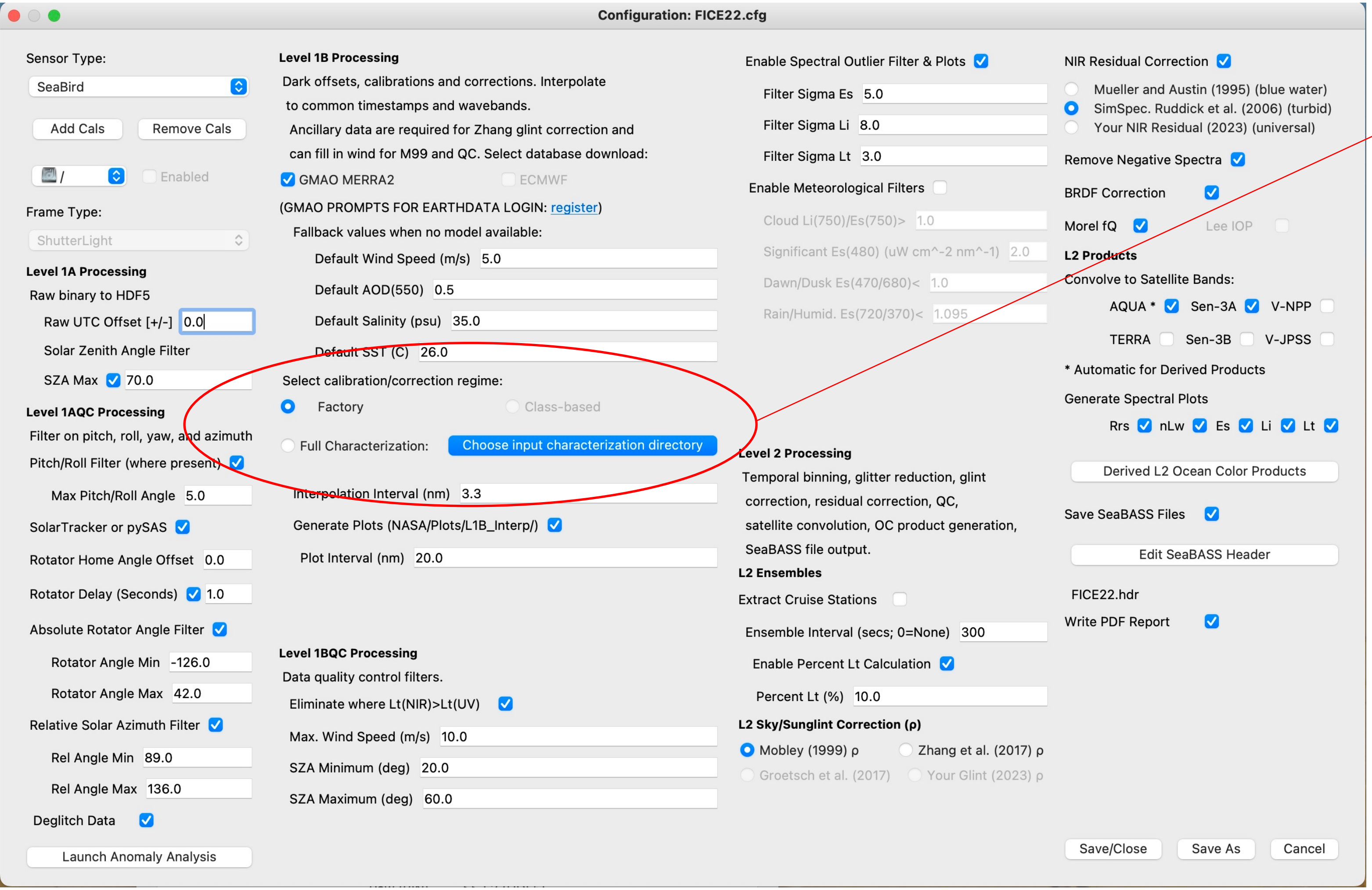
Configuration and data flow.



Wind speed is a requirement of L2 glint correction and AOT is a requirement of cosine correction, uncertainty budgets, and the Zhang et al. 2017 glint correction. Any gaps in the Ancillary file provided can be filled using model data -- either NASA GMAO or European ECMWF. GMAO requires a NASA EarthData account (free & easy).

The Default values below models are last-resort fallback values if neither Ancillary nor model data are found. (*Fallback is not recommended for final process, but often needed for use in preliminary processing and data checks before model data are available, which can take some weeks.*)

HyperCP Level 1B: Load Calibration

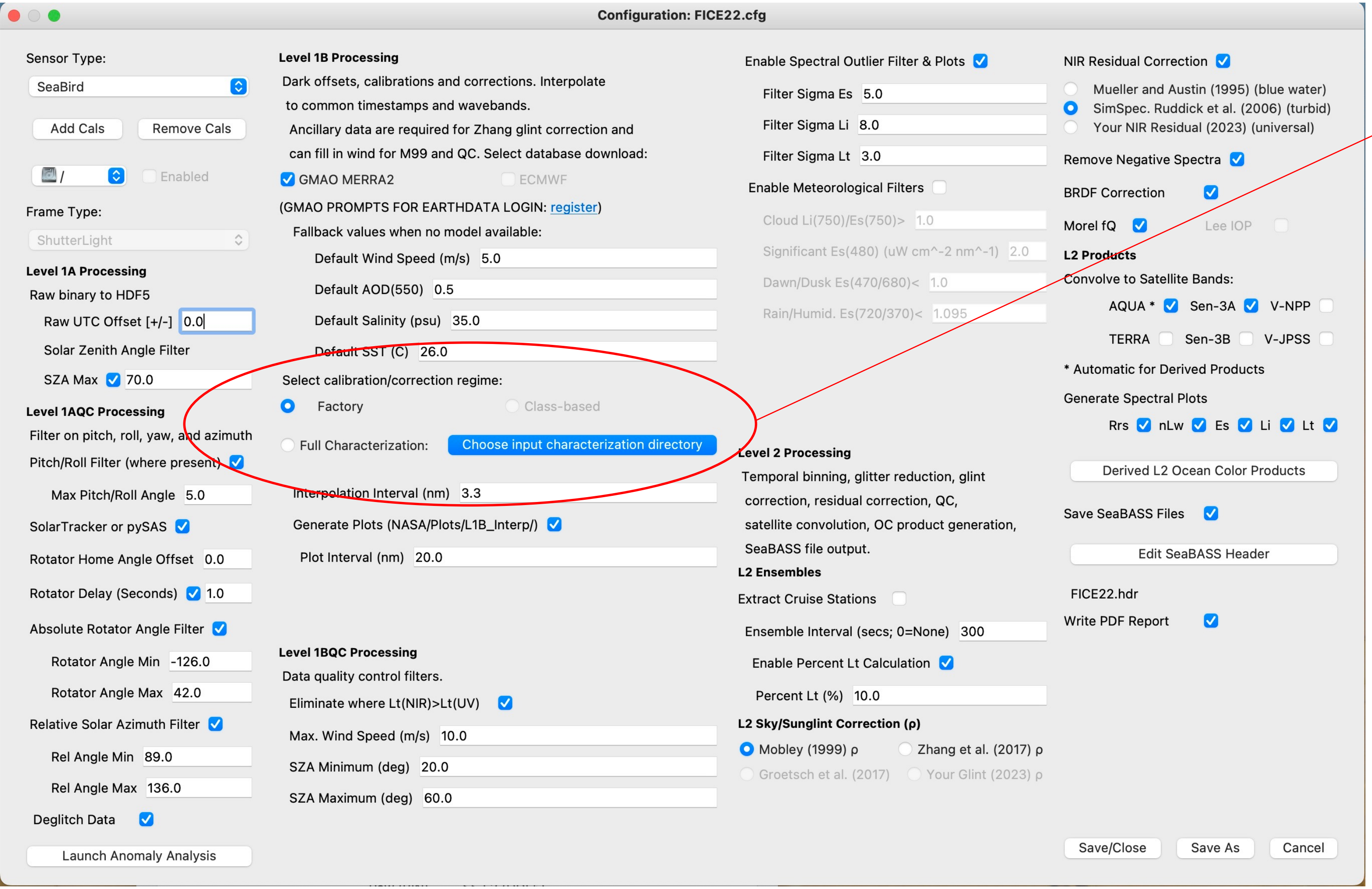


Class-based and Full Characterization calibrations/corrections are still under development and expected to go public this summer. For now, use standard Factory calibration.

In Factory mode, uncertainties in L2 products are still calculated using L2 ensemble variability and rough glint correction uncertainty estimates.

HyperCP Level 1B: Load Full Characterization

Coming soon



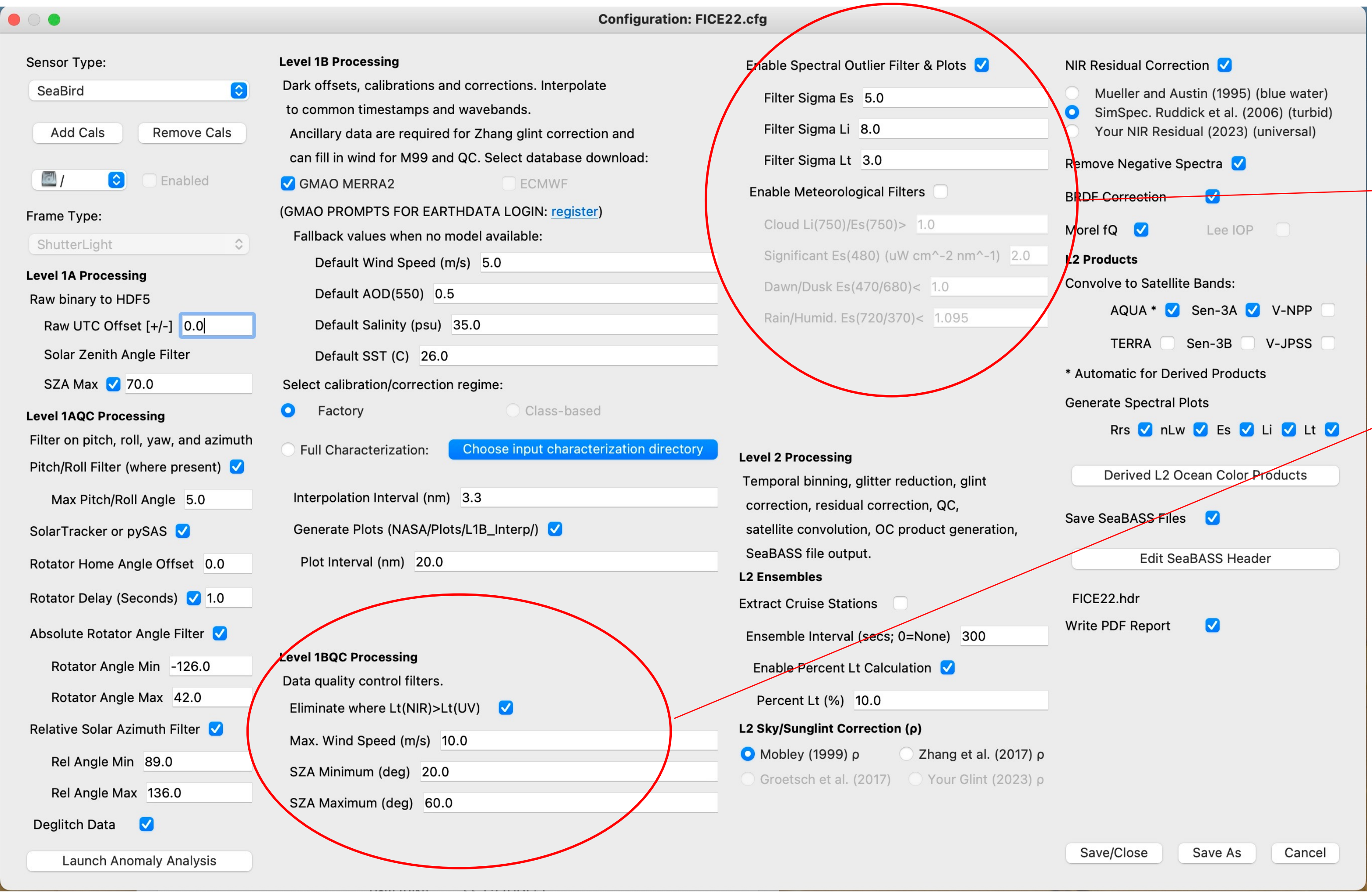
Class-based (e.g., Sea-Bird or TriOS) and Instrument-specific (Full, FRM-compliant) characterizations can accurately estimate uncertainties associated with instrument response:

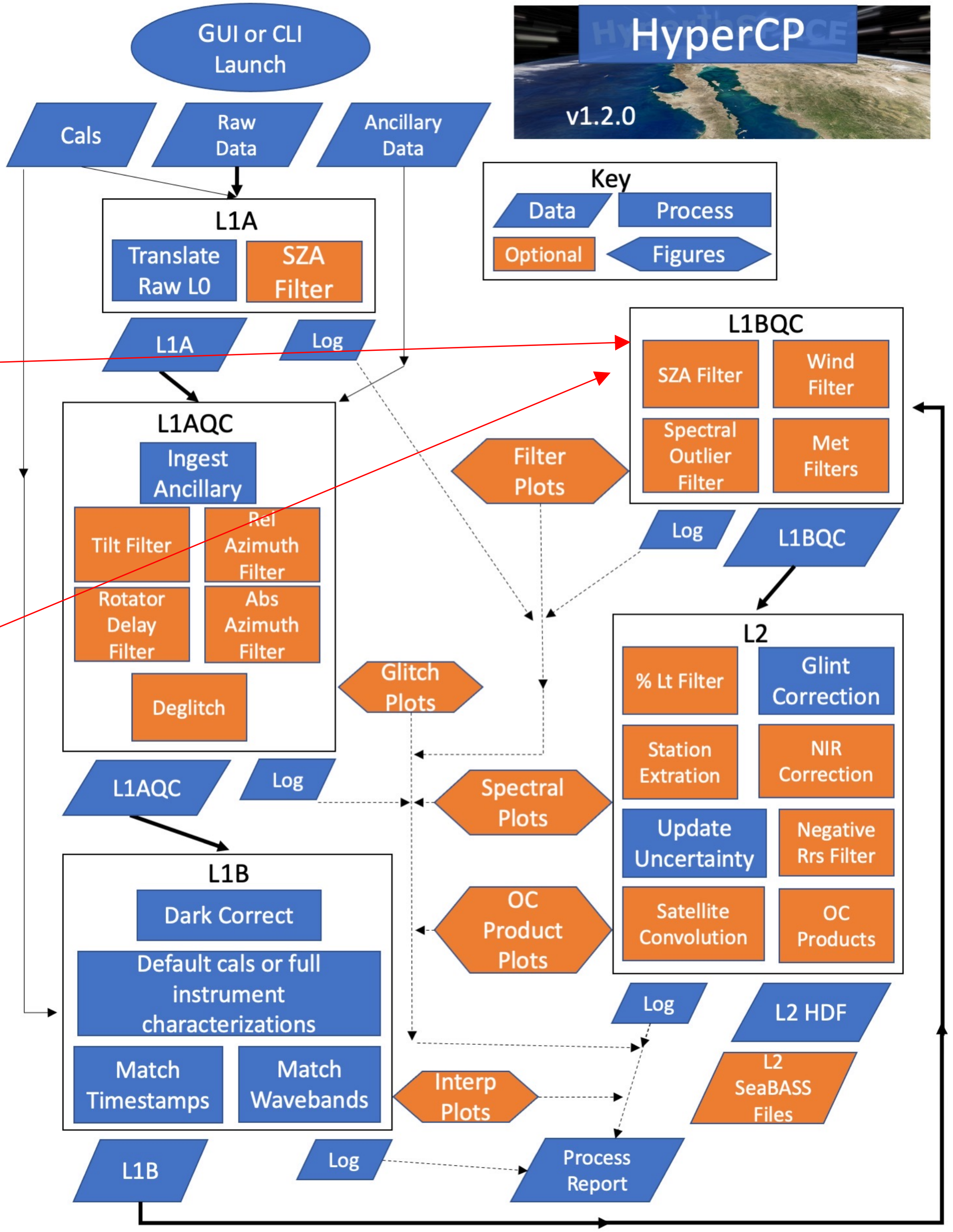
- Linearity of response
- Calibration/stability
- Straylight response
- Angularity of response
- Polarization response
- Thermal response

Using these pathways will also trigger use of Monte Carlo models estimating the uncertainties introduced by processing steps (e.g., glint correction).

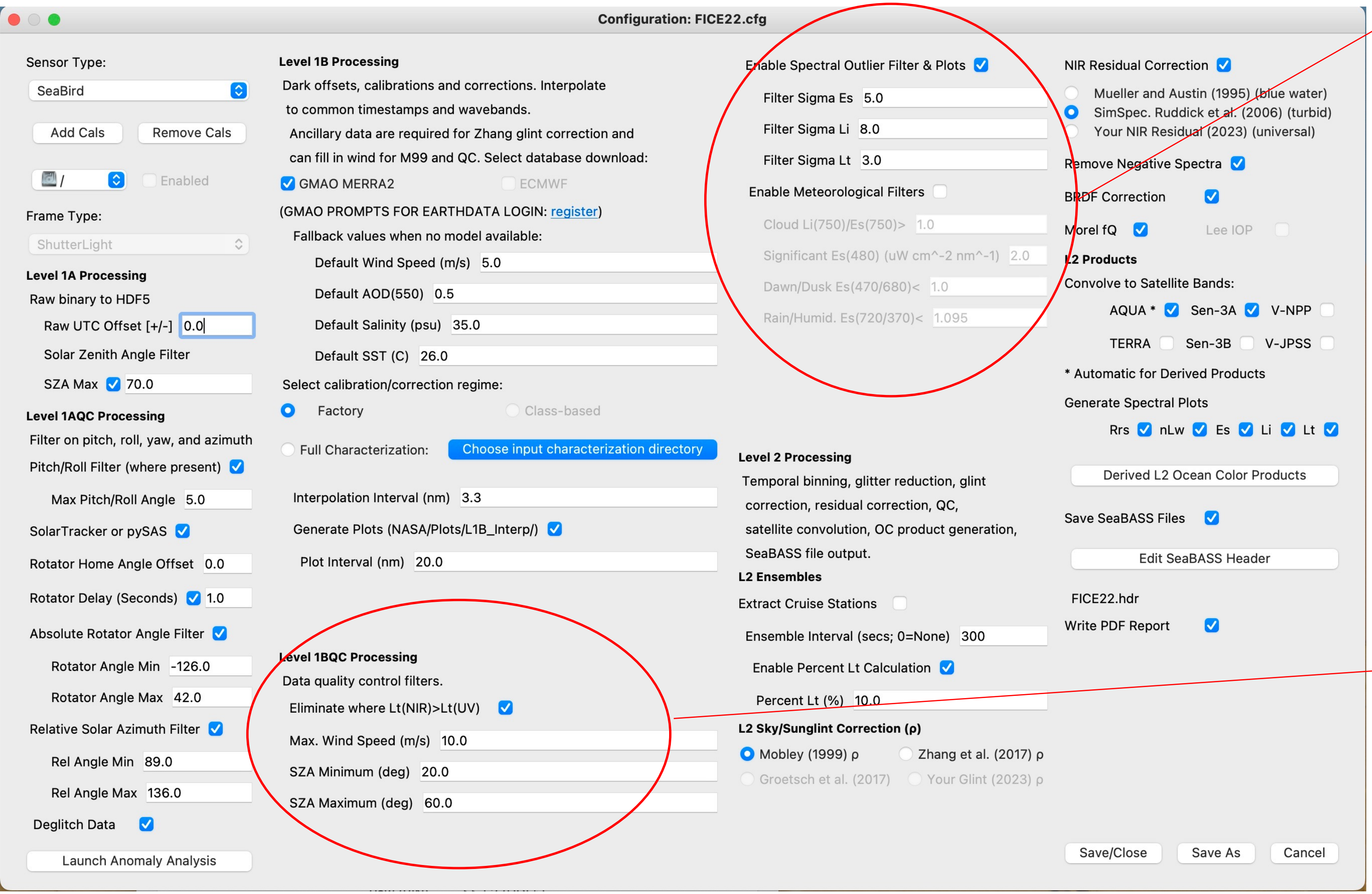
Białek, A., et al.. Example of Monte Carlo Method Uncertainty Evaluation for Above-Water Ocean Colour Radiometry. *Remote Sens.* **2020**, *12*, 780. https://doi.org/10.3390/rs12050780

HyperCP Level 1BQC: Quality Control with Ancillaries





HyperCP Level 1BQC: Quality Control with Ancillaries

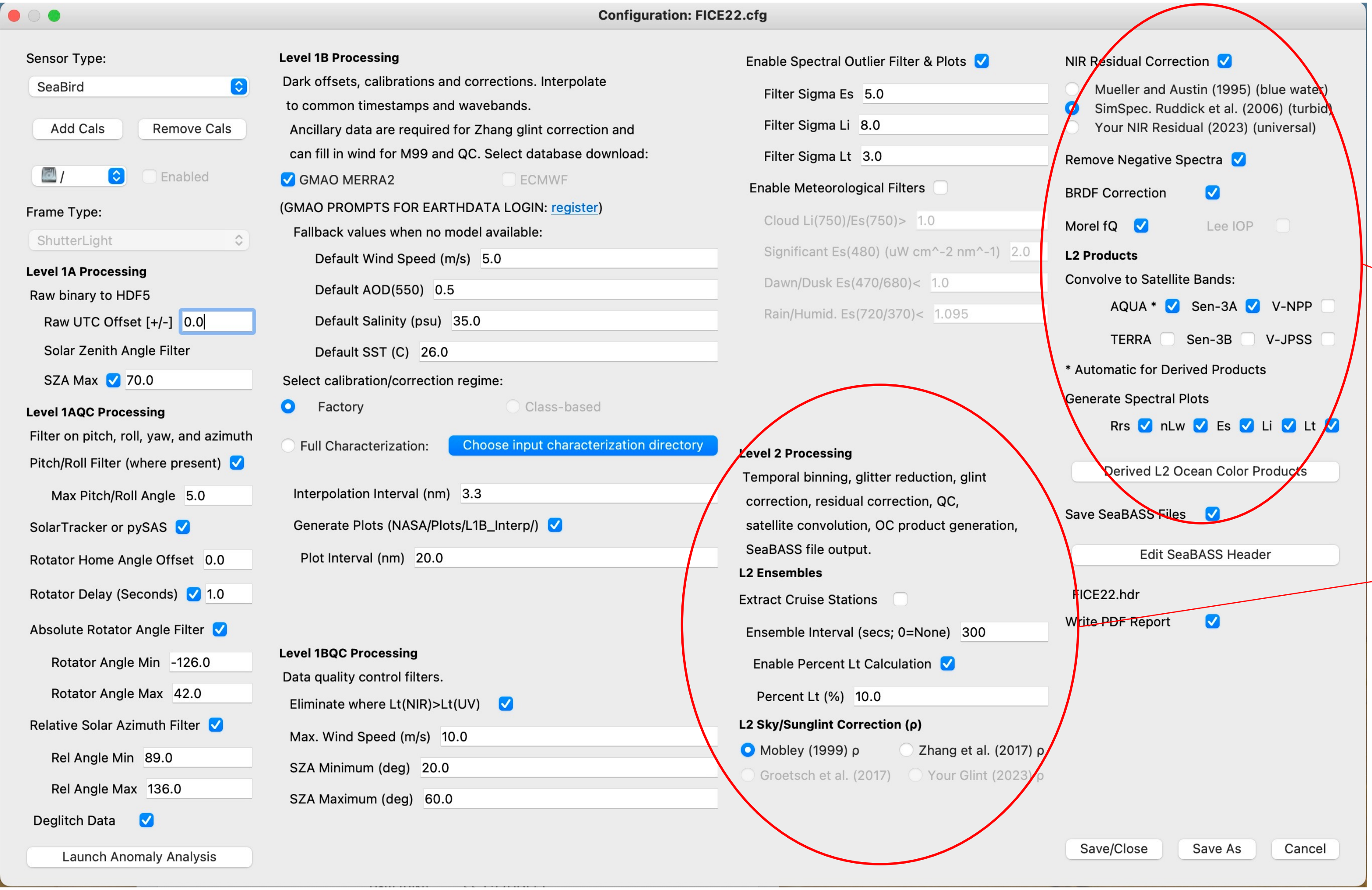


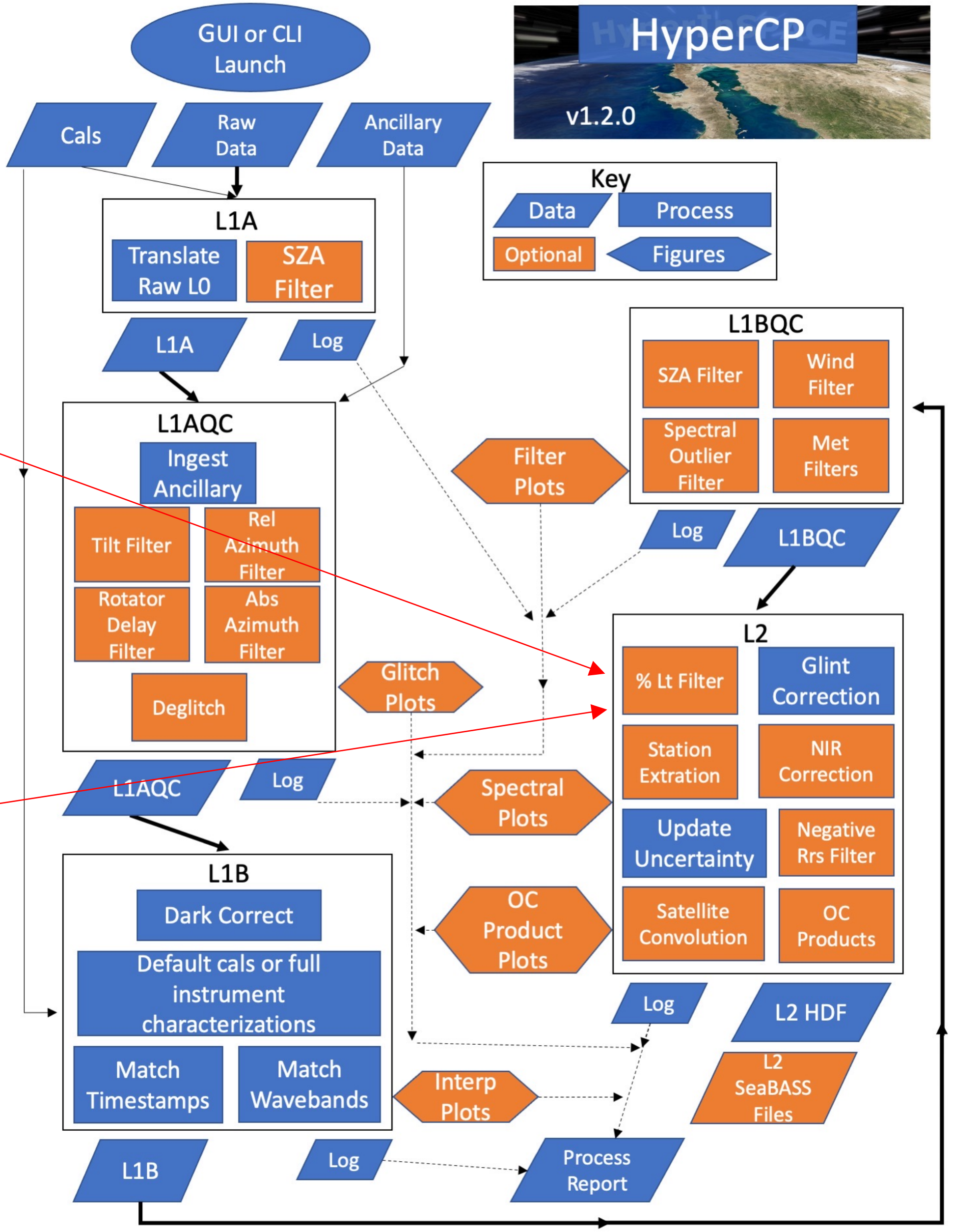
Reducing spectral filter sigma factors discards more of the spectra as outliers (see plots in later slides). For HyperSAS/pySAS platforms, one hour of raw data may contain as many as many as ~3,000 spectra, depending on light conditions and integration time.

Met filters are optional and considered experimental.

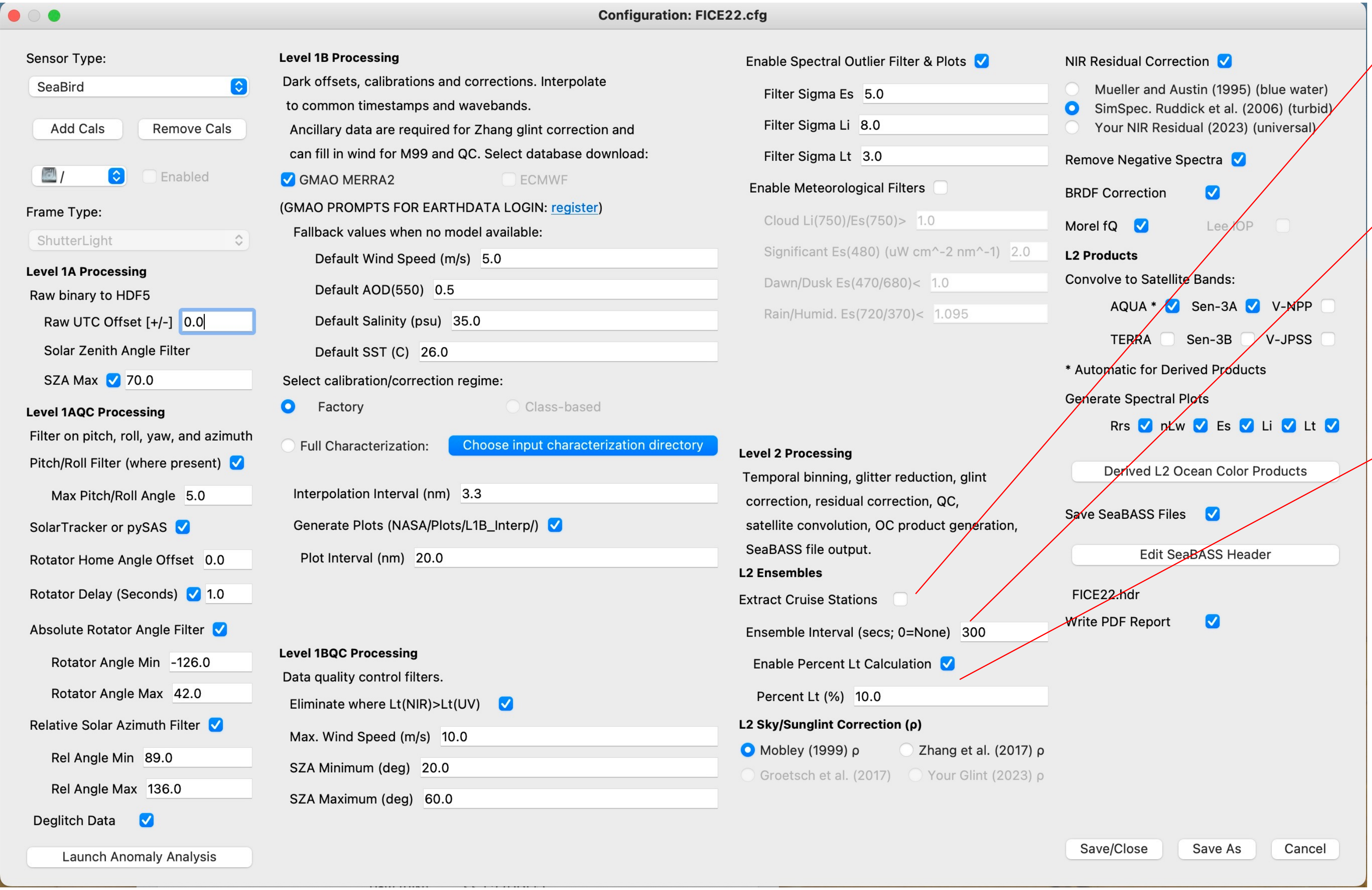
Basic quality controls for spectral shape and environmental conditions.

HyperCP Level 2: Overview





HyperCP Level 2: Binning

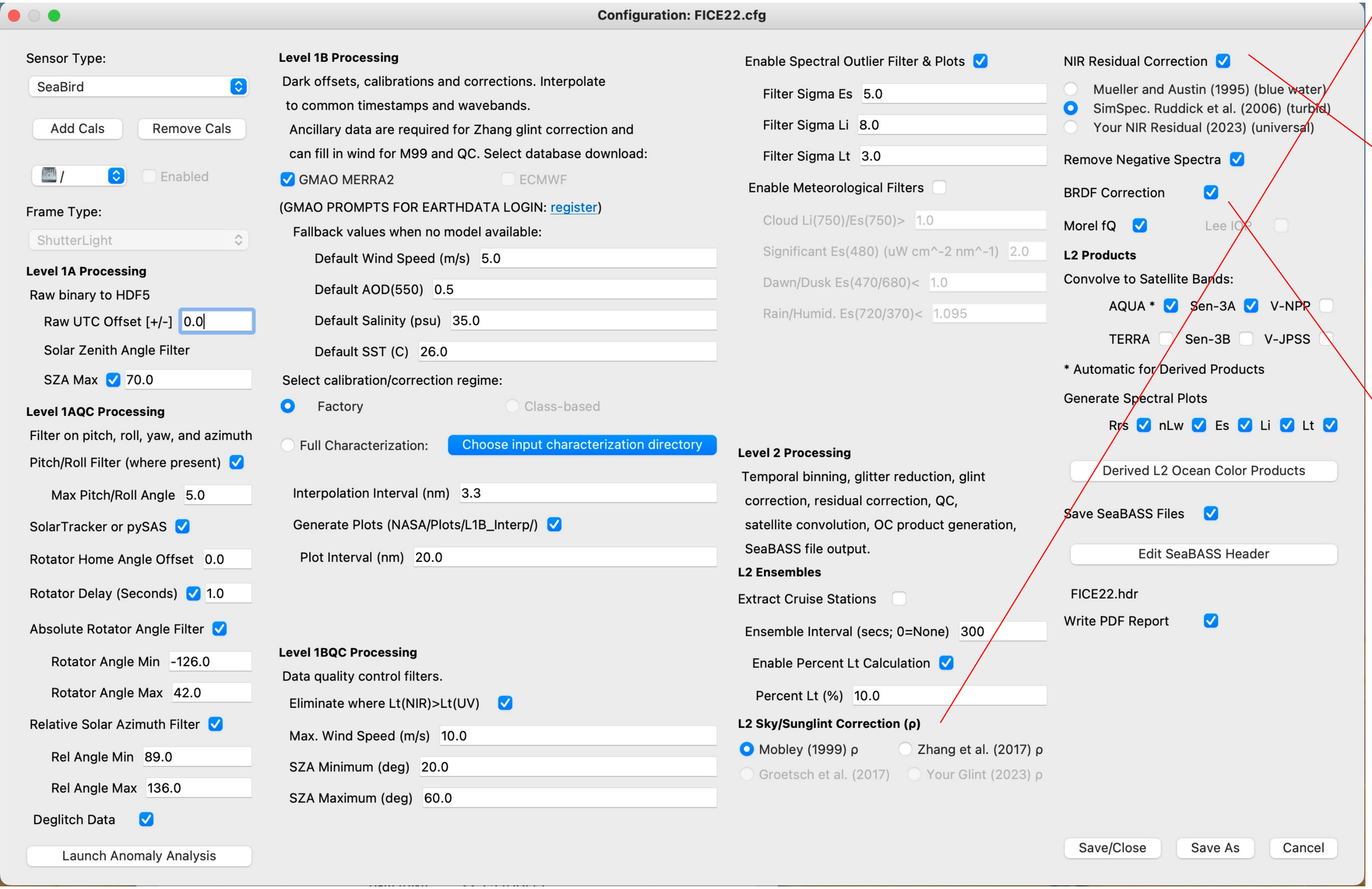


Stations from Ancillary file

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…



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

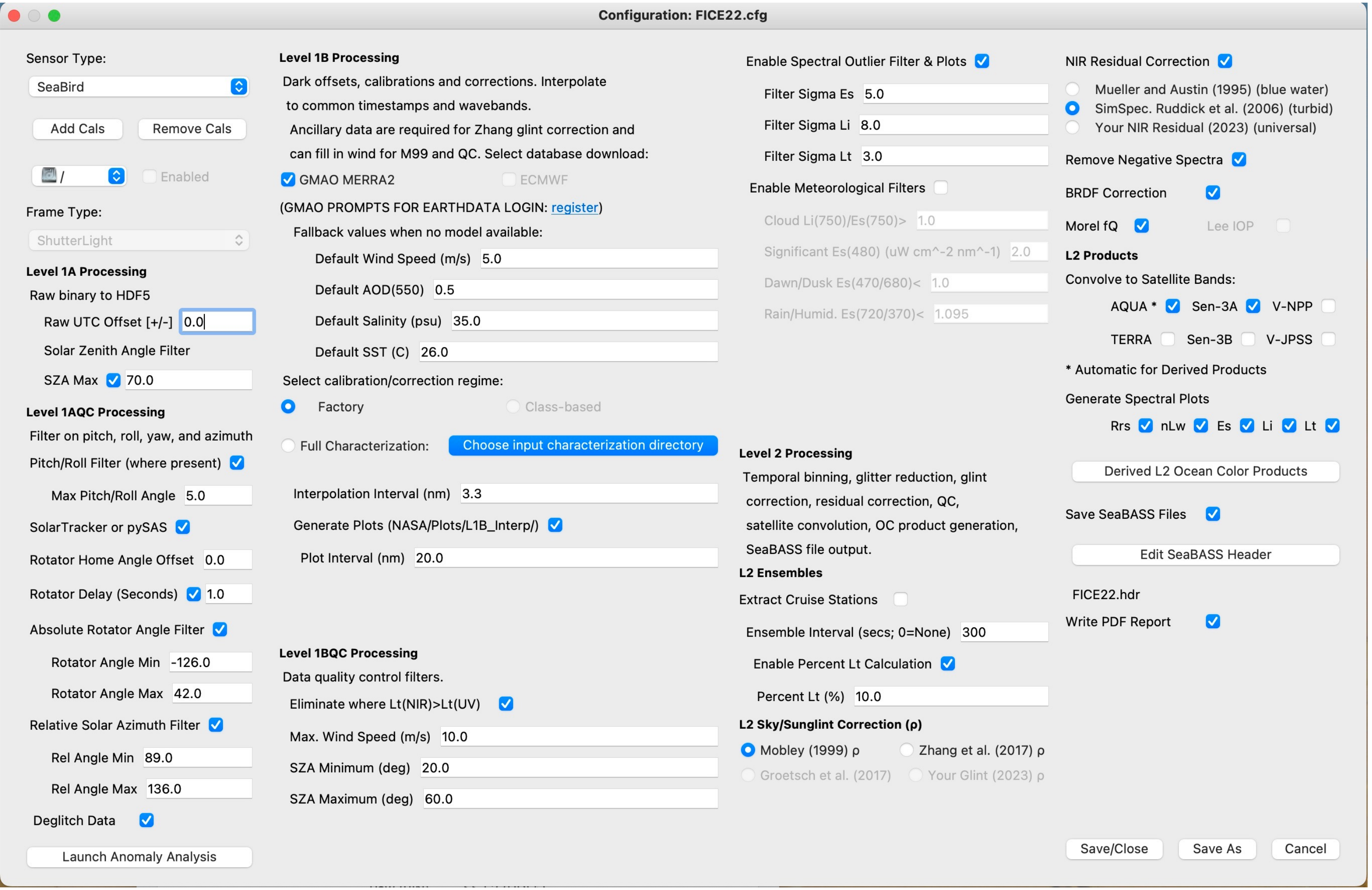
NIR Residual Correction
Remove residual glint identified from reflectances in the NIR, followed by removing any ensemble reflectances that have negative values (VIS).

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)

HyperCP is constantly under development to stay abreast of emerging science

HyperCP Level 2: Corrections…

Configuration and data flow.



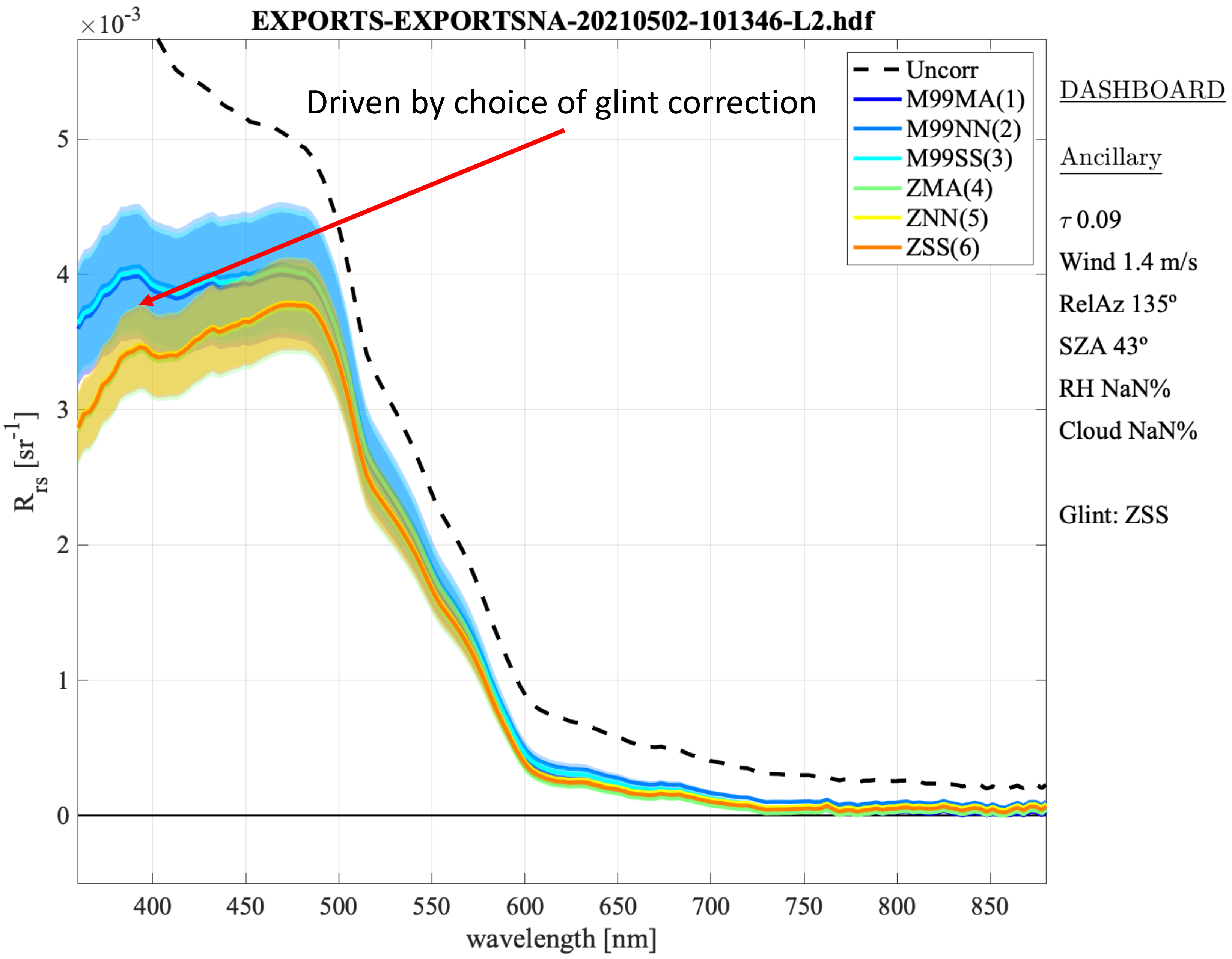
Broadly speaking, the best practice are

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

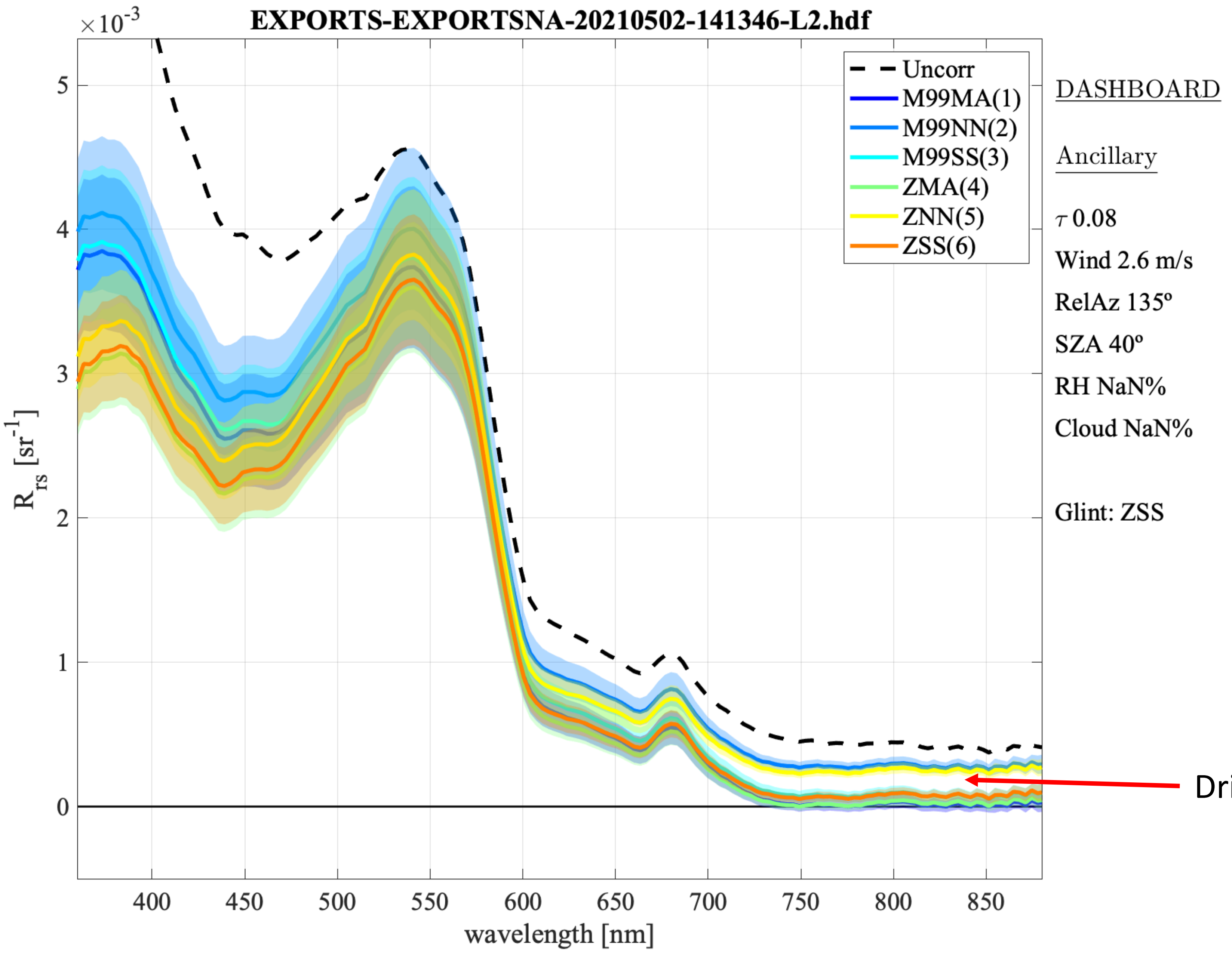
- **ρ** glint factor: Zhang et al. 2019 (hyperspectral with polarization)
- NIR residual correction: the Similarity Spectrum approach of Ruddick et al. 2006
- BRDF correction: Lee et al. 2010 IOP-based BRDF correction (pending)



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)



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

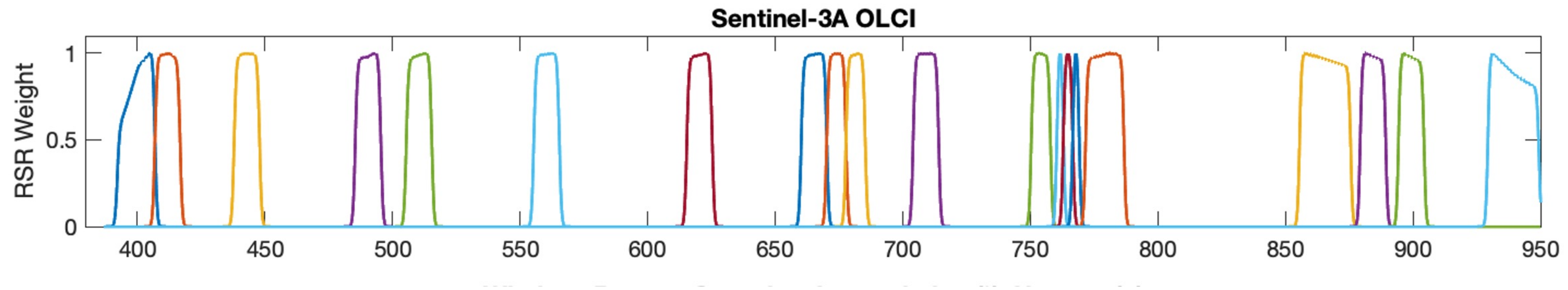
NIR Residual Glint Correction:

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

Driven by choice of NIR correction

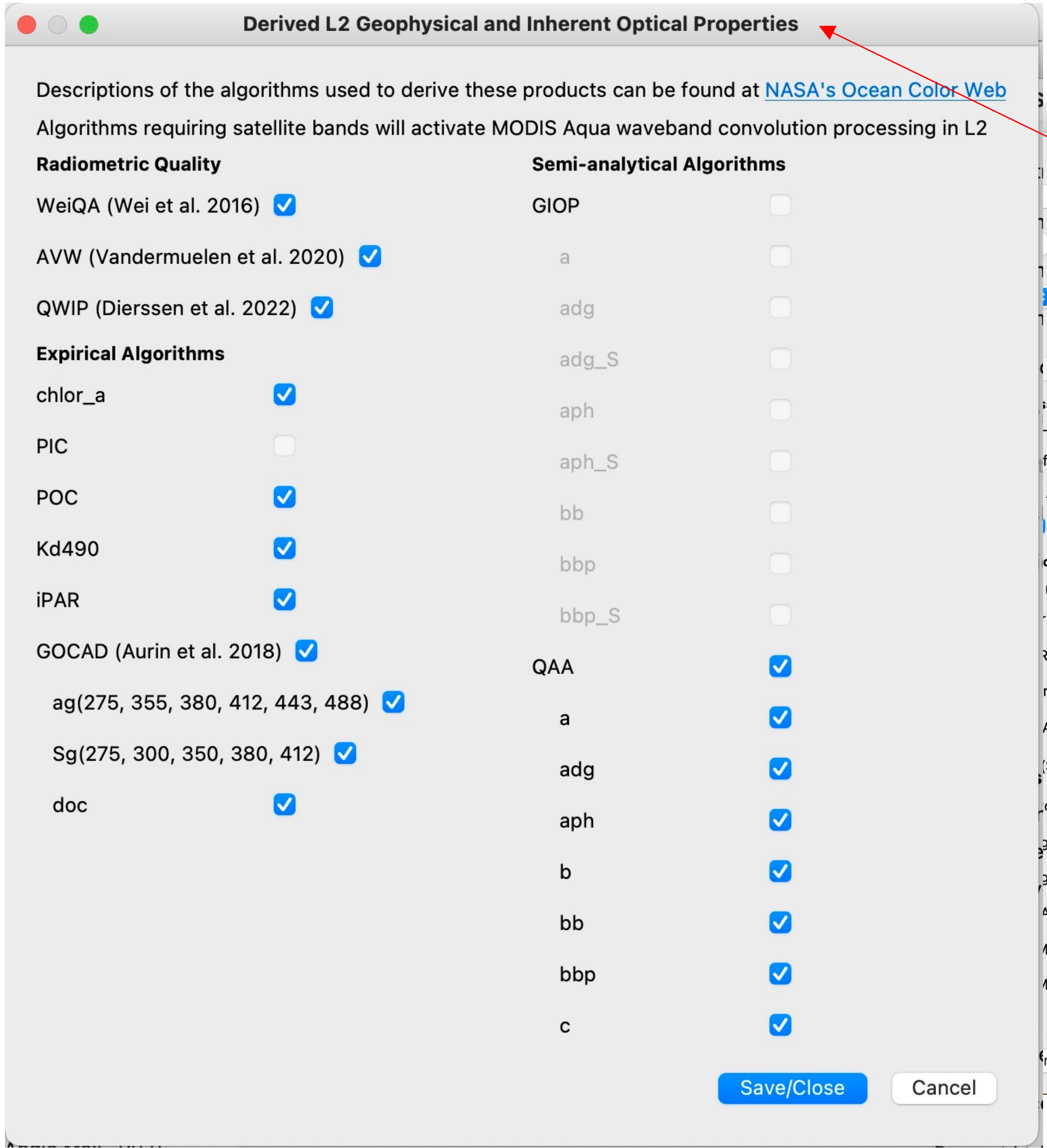
HyperCP Level 2: Spectral Response Weighting Fun.

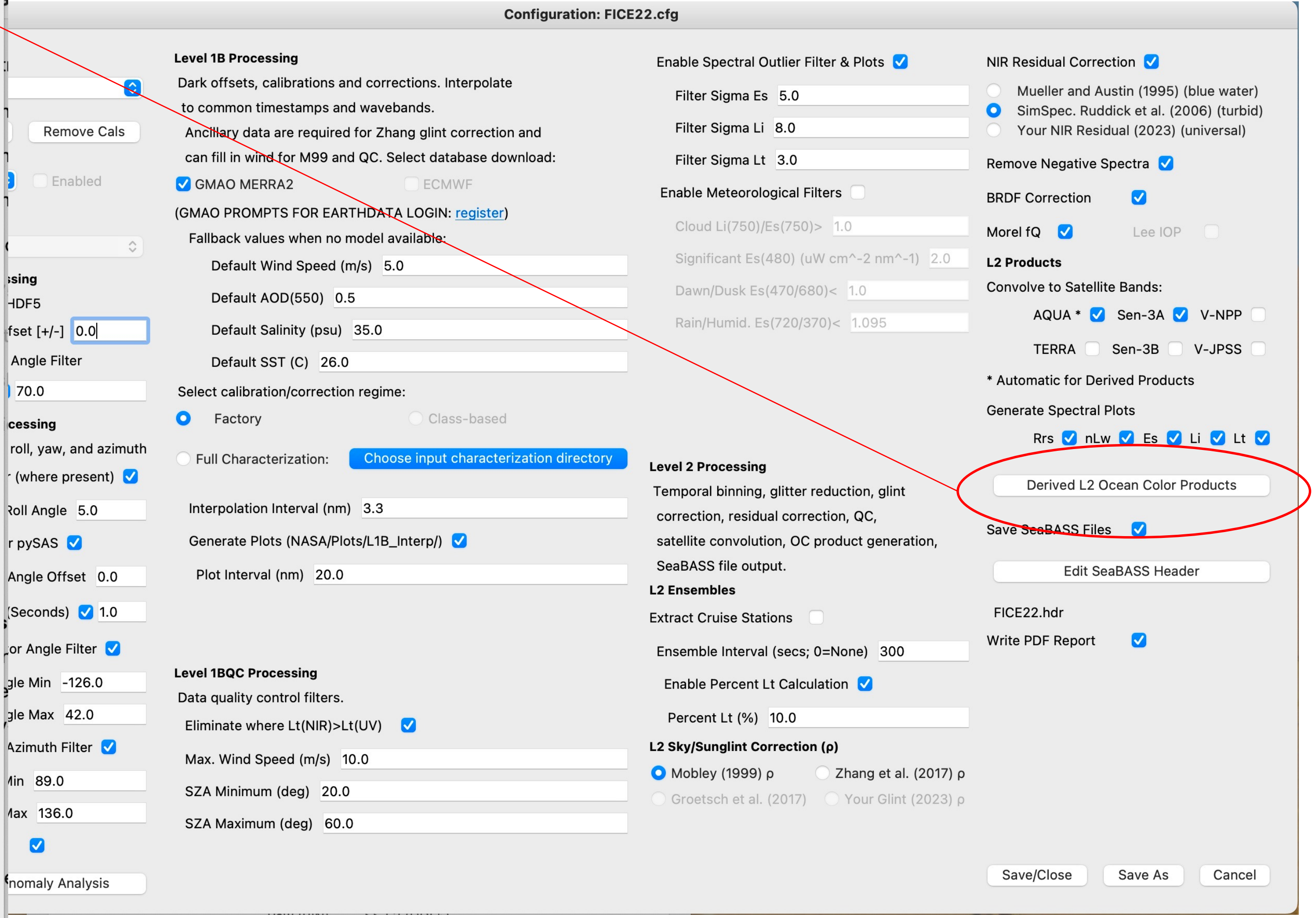
Relative Spectral Response (RSR) weighting functions for various multi-spectral satellite sensors are included in order to accurately convolve the hyperspectral L2 (ir)radiances to satellite bands for comparison/validation. (Ir)radiances are convolved prior to reflectance calculations.



HyperCP Level 2: Derive Products

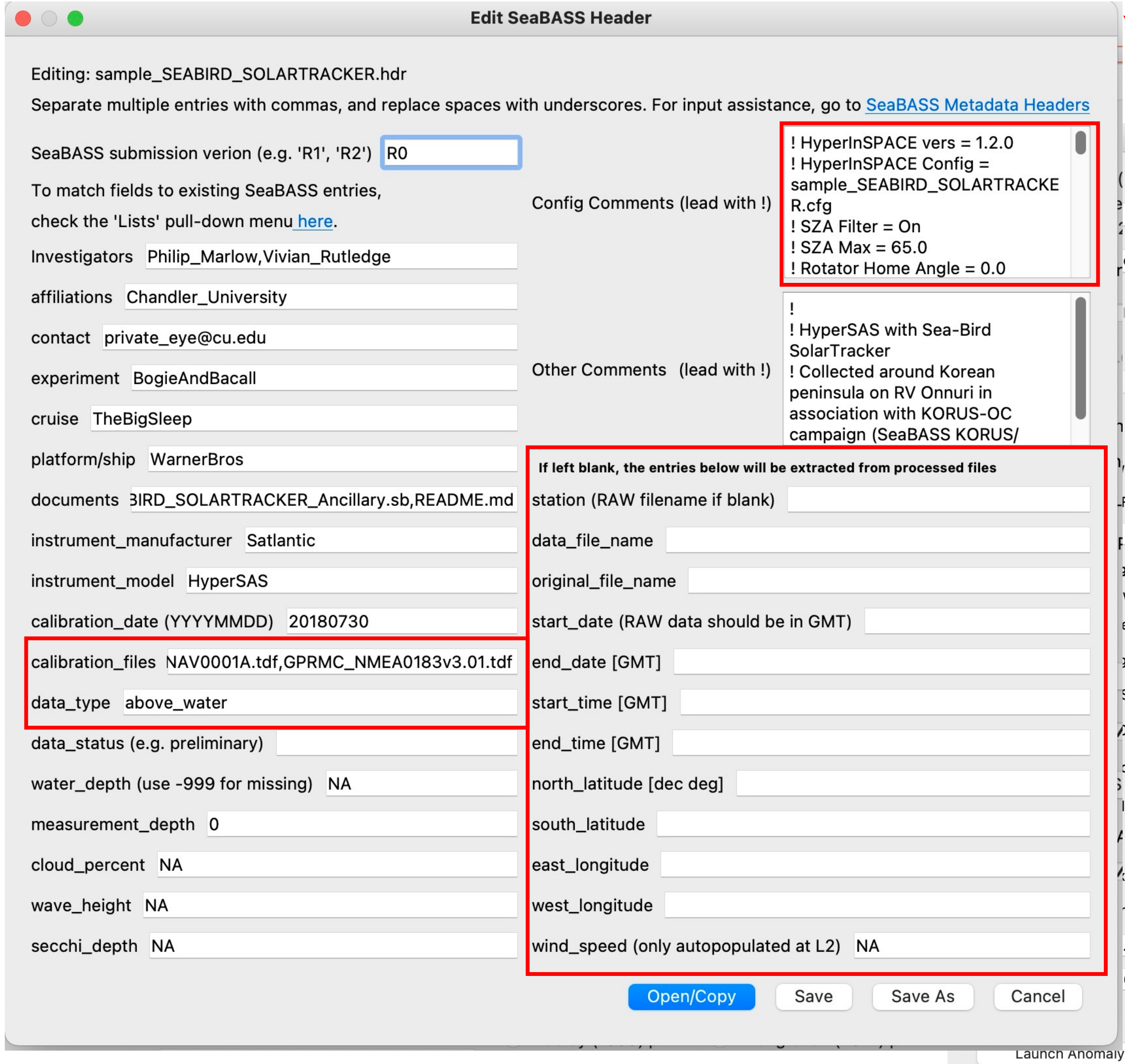
Several ocean color algorithms for deriving geophysical and inherent optical properties are provided (see README for sources). More are anticipated.

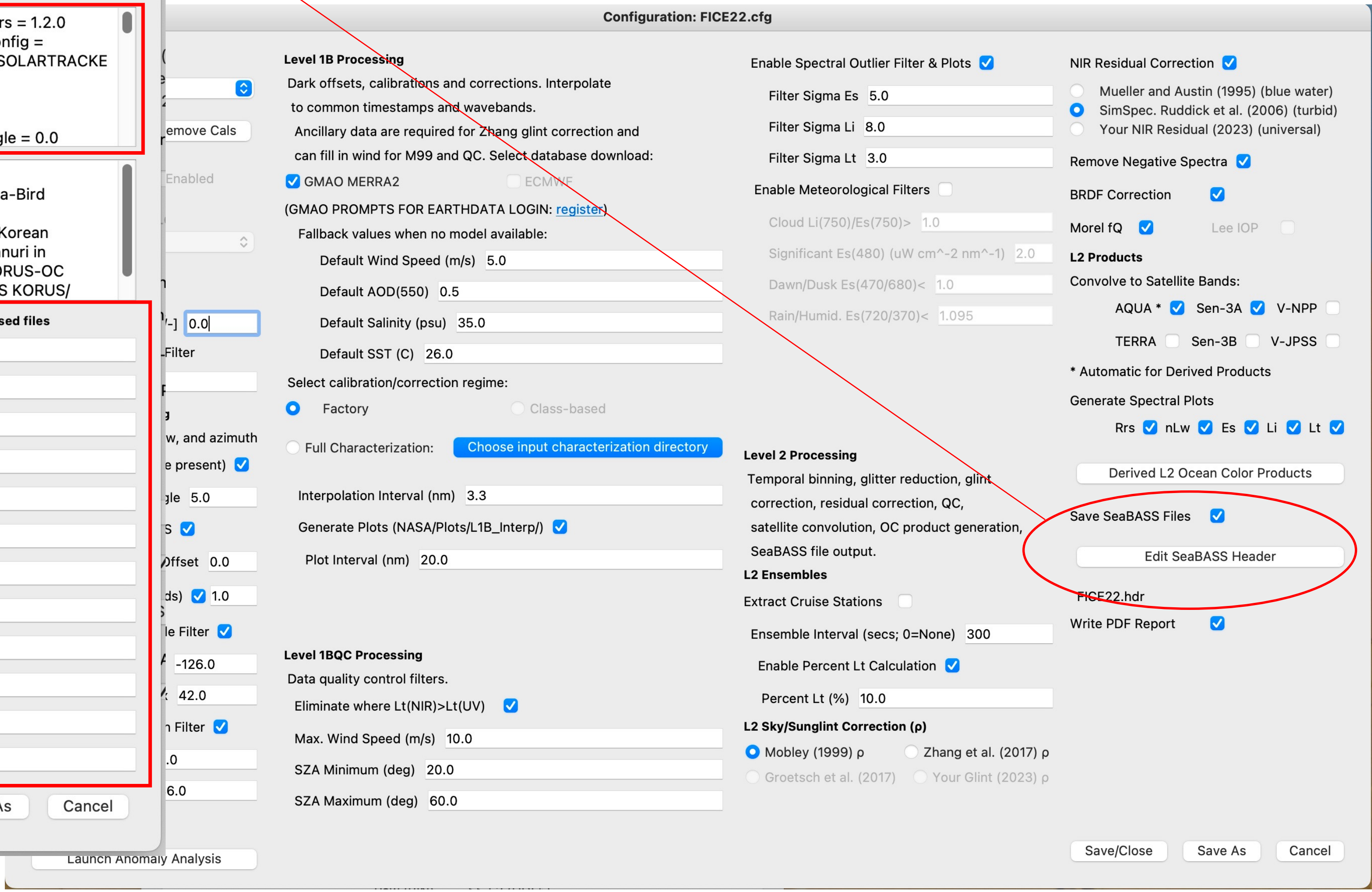




HyperCP Output: SeaBASS & HDF5

Autofilled. Fill in the rest as appropriate.





HyperCP SeaBASS Files

BogieAndBacall_TheBigSleep_WarnerBros_HyperSAS_201605

```
/begin_header
/investigators=Philip_Marlow,Vivian_Rutledge
/affiliations=Chandler_University
/contact=private_eye@cu.edu
/experiment=BogieAndBacall
/cruise=TheBigSleep
/documents=SAMPLE_SEABIRD_SOLARTRACKER_Ancillary.sb,README.md
/instrument_manufacturer=Satlantic
/instrument_model=HyperSAS
/calibration_date=20180730
/
calibration_files=SAS045_20160203.sip,HSE488B.cal,HSL386B.cal,SATPYR.tdf,HLI
B.cal,IRP3397A.cal,SATTHS0045A.tdf,HLD385B.cal,HSL385B.cal,SATNAV0001A.t
/data_type=above_water
/data_status=
/water_depth=NA
/measurement_depth=0
/cloud_percent=NA
/wave_height=NA
/secchi_depth=NA
/station=SAMPLE_SEABIRD_SOLARTRACKER
/data_file_name=BogieAndBacall_TheBigSleep_WarnerBros_HyperSAS_20160520_0
/original_file_name=SAMPLE_SEABIRD_SOLARTRACKER.raw
/start_date=20160520
/end_date=20160520
/start_time=07:02:23[GMT]
/end_time=07:46:23[GMT]
/north_latitude=34.9733[DEG]
/south_latitude=34.9701[DEG]
/east_longitude=129.1175[DEG]
/west_longitude=129.0981[DEG]
/wind_speed=3.021344052939816
/missing=-999
/delimiter=comma
!/platform=WarnerBros
! HyperInSPACE vers = 1.2.0
! HyperInSPACE Config = sample_SEABIRD_SOLARTRACKER.cfg
! SZA Filter = On
! SZA Max = 65.0
! Rotator Home Angle = 0.0
! Rotator Delay = 5.0
! Pitch/Roll Filter = On
! Max Pitch/Roll = 5.0
! Rotator Min/Max Filter = On
! Rotator Min = -20.0
! Rotator Max = 45.0
! Rel Azimuth Filter = On
! Rel Azimuth Min = 90.0
! Rel Azimuth Max = 135.0
! Deglitch Filter = On
! ES Dark Window = 11
```

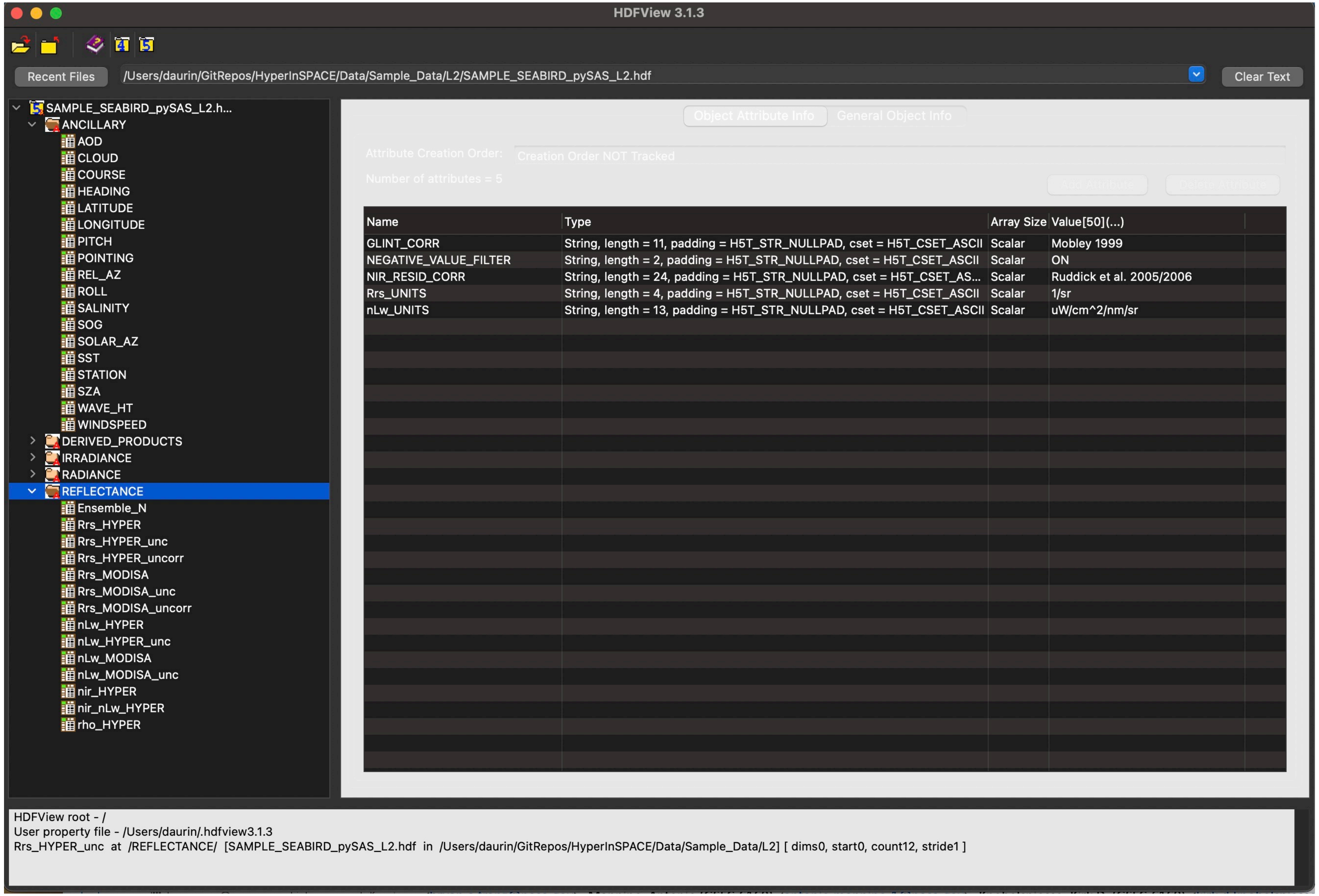
BogieAndBacall_TheBigSleep_WarnerBros_HyperSAS_20160520_0

```
! ES Light Window = 5
! ES Dark Sigma = 3.2
! ES Light Sigma = 3.5
! LI Dark Window = 11
! LI Light Window = 5
! LI Dark Sigma = 3.4
! LI Light Sigma = 3.0
! LT Dark Window = 11
! LT Light Window = 5
! LT Dark Sigma = 3.5
! LT Light Sigma = 3.2
! Wavelength Interp Int = 3.3
! Default Wind = 5.0
! Default AOD = 0.5
! Default Salt = 35.0
! Default SST = 26.0
! Max Wind = 10.0
! Min SZA = 20.0
! Max SZA = 60.0
! Spectral Filter = On
! Filter Sigma Es = 5.0
! Filter Sigma Li = 8.0
! Filter Sigma Lt = 3.0
! Meteorological Filter = Off
! Cloud Flag = 1.0
! Es Flag = 2.0
! Dawn/Dusk Flag = 1.0
! Rain/Humidity Flag = 1.095
! Ensemble Interval = 300
! Percent Lt Filter = On
! Percent Light = 10.0
! Glint_Correction = Mobley 1999
! NIR Correction = Mueller and Austin 1995
! Remove Negatives = On
! DateTime Processed = Fri Jun  2 11:28:12 2023
!
! HyperSAS with Sea-Bird SolarTracker
! Collected around Korean peninsula on RV Onnuri in association with KORUS-OC campaig
KR_2016
/
fields=date,time,lat,lon,RelAz,SZA,AOT,cloud,wind,Rrs353.2,Rrs356.5,Rrs359.8,Rrs363.1,
Rrs376.3,Rrs379.6,Rrs382.9,Rrs386.2,Rrs389.5,Rrs392.8,Rrs396.1,Rrs399.4,Rrs402.7,Rrs4
15.9,Rrs419.2,Rrs422.5,Rrs425.8,Rrs429.1,Rrs432.4,Rrs435.7,Rrs439.0,Rrs442.3,Rrs445.6,
Rrs458.8,Rrs462.1,Rrs465.4,Rrs468.7,Rrs472.0,Rrs475.3,Rrs478.6,Rrs481.9,Rrs485.2,Rrs4
98.4,Rrs501.7,Rrs505.0,Rrs508.3,Rrs511.6,Rrs514.9,Rrs518.2,Rrs521.5,Rrs524.8,Rrs528.1,
Rrs541.3,Rrs544.6,Rrs547.9,Rrs551.2,Rrs554.5,Rrs557.8,Rrs561.1,Rrs564.4,Rrs567.7,Rrs5
80.9,Rrs584.2,Rrs587.5,Rrs590.8,Rrs594.1,Rrs597.4,Rrs600.7,Rrs604.0,Rrs607.3,Rrs610.6,
Rrs623.8,Rrs627.1,Rrs630.4,Rrs633.7,Rrs637.0,Rrs640.3,Rrs643.6,Rrs646.9,Rrs650.2,Rrs6
63.4,Rrs666.7,Rrs670.0,Rrs673.3,Rrs676.6,Rrs679.9,Rrs683.2,Rrs686.5,Rrs689.8,Rrs693.1,
Rrs706.3,Rrs709.6,Rrs712.9,Rrs716.2,Rrs719.5,Rrs722.8,Rrs726.1,Rrs729.4,Rrs732.7,Rrs7
45.9,Rrs749.2,Rrs353.2_unc,Rrs356.5_unc,Rrs359.8_unc,Rrs363.1_unc,Rrs366.4_unc,Rrs3
```

BogieAndBacall_TheBigSleep_WarnerBros_HyperSAS_20160520_070223_L2_Rrs_R0.sb

```
76.3_unc,Rrs379.6_unc,Rrs382.9_unc,Rrs386.2_unc,Rrs389.5_unc,Rrs392.8_unc,Rrs396.1_unc,Rrs399.4_unc,Rrs402.7
_unc,Rrs406.0_unc,Rrs409.3_unc,Rrs412.6_unc,Rrs415.9_unc,Rrs419.2_unc,Rrs422.5_unc,Rrs425.8_unc,Rrs429.1_unc
,Rrs432.4_unc,Rrs435.7_unc,Rrs439.0_unc,Rrs442.3_unc,Rrs445.6_unc,Rrs448.9_unc,Rrs452.2_unc,Rrs455.5_unc,Rrs
458.8_unc,Rrs462.1_unc,Rrs465.4_unc,Rrs468.7_unc,Rrs472.0_unc,Rrs475.3_unc,Rrs478.6_unc,Rrs481.9_unc,Rrs485.
2_unc,Rrs488.5_unc,Rrs491.8_unc,Rrs495.1_unc,Rrs498.4_unc,Rrs501.7_unc,Rrs505.0_unc,Rrs508.3_unc,Rrs511.6_un
c,Rrs514.9_unc,Rrs518.2_unc,Rrs521.5_unc,Rrs524.8_unc,Rrs528.1_unc,Rrs531.4_unc,Rrs534.7_unc,Rrs538.0_unc,Rrs
541.3_unc,Rrs544.6_unc,Rrs547.9_unc,Rrs551.2_unc,Rrs554.5_unc,Rrs557.8_unc,Rrs561.1_unc,Rrs564.4_unc,Rrs567.
7_unc,Rrs571.0_unc,Rrs574.3_unc,Rrs577.6_unc,Rrs580.9_unc,Rrs584.2_unc,Rrs587.5_unc,Rrs590.8_unc,Rrs594.1_un
c,Rrs597.4_unc,Rrs600.7_unc,Rrs604.0_unc,Rrs607.3_unc,Rrs610.6_unc,Rrs613.9_unc,Rrs617.2_unc,Rrs620.5_unc,Rrs
623.8_unc,Rrs627.1_unc,Rrs630.4_unc,Rrs633.7_unc,Rrs637.0_unc,Rrs640.3_unc,Rrs643.6_unc,Rrs646.9_unc,Rrs650.
2_unc,Rrs653.5_unc,Rrs656.8_unc,Rrs660.1_unc,Rrs663.4_unc,Rrs666.7_unc,Rrs670.0_unc,Rrs673.3_unc,Rrs676.6_un
c,Rrs679.9_unc,Rrs683.2_unc,Rrs686.5_unc,Rrs689.8_unc,Rrs693.1_unc,Rrs696.4_unc,Rrs699.7_unc,Rrs703.0_unc,Rrs
706.3_unc,Rrs709.6_unc,Rrs712.9_unc,Rrs716.2_unc,Rrs719.5_unc,Rrs722.8_unc,Rrs726.1_unc,Rrs729.4_unc,Rrs732.
7_unc,Rrs736.0_unc,Rrs739.3_unc,Rrs742.6_unc,Rrs745.9_unc,Rrs749.2_unc
/units=yyyymmdd,hh:mm:ss,degrees,degrees,degrees,degrees,unitless,%,m/s,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/
sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/
sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/
sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/
sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/
sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/
sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/
sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/
sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/
sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr,1/sr
/end_header
20160520,07:02:23,34.9701,129.1175,112.7,50.7,0.1902,-9999,3.1,0.002160,0.002202,0.002294,0.002408,0.002357,0.0
02415,0.002480,0.002517,0.002515,0.002605,0.002672,0.002672,0.002760,0.002787,0.002798,0.002821,0.002853,0.00
2923,0.002933,0.002970,0.003013,0.003050,0.003072,0.003096,0.003116,0.003102,0.003104,0.003123,0.003139,0.003
158,0.003177,0.003219,0.003243,0.003285,0.003315,0.003350,0.003378,0.003390,0.003404,0.003426,0.003415,0.0033
90,0.003339,0.003288,0.003206,0.003119,0.002990,0.002826,0.002654,0.002524,0.002444,0.002401,0.002362,0.00231
7,0.002273,0.002212,0.002144,0.002069,0.001985,0.001889,0.001799,0.001727,0.001669,0.001613,0.001546,0.001467,
0.001377,0.001264,0.001137,0.000994,0.000859,0.000733,0.000611,0.000507,0.000410,0.000327,0.000276,0.000247,0.
000222,0.000211,0.000207,0.000194,0.000185,0.000192,0.000186,0.000179,0.000164,0.000159,0.000147,0.000141,0.0
00133,0.000124,0.000102,0.000086,0.000084,0.000080,0.000080,0.000090,0.000096,0.000100,0.000098,0.000087,0.00
0055,0.000039,0.000047,0.000040,0.000038,0.000030,0.000033,0.000026,0.000010,0.000005,0.000008,0.000000,0.000
003,0.000011,0.000025,0.000031,0.000035,0.000052,0.000060,0.000325,0.000330,0.000340,0.000355,0.000349,0.0003
55,0.000363,0.000368,0.000368,0.000378,0.000386,0.000387,0.000397,0.000401,0.000403,0.000405,0.000409,0.00041
8,0.000419,0.000424,0.000430,0.000435,0.000438,0.000441,0.000444,0.000443,0.000443,0.000447,0.000449,0.000452,
0.000455,0.000461,0.000464,0.000470,0.000474,0.000479,0.000482,0.000485,0.000488,0.000491,0.000491,0.000489,0.
000484,0.000478,0.000469,0.000460,0.000445,0.000427,0.000407,0.000393,0.000384,0.000379,0.000375,0.000371,0.0
00366,0.000360,0.000351,0.000343,0.000334,0.000322,0.000312,0.000304,0.000297,0.000291,0.000283,0.000274,0.00
0263,0.000251,0.000236,0.000218,0.000202,0.000187,0.000172,0.000159,0.000147,0.000136,0.000130,0.000127,0.000
123,0.000122,0.000122,0.000121,0.000120,0.000121,0.000121,0.000121,0.000119,0.000119,0.000117,0.000115,0.0001
15,0.000115,0.000114,0.000112,0.000111,0.000112,0.000112,0.000113,0.000113,0.000114,0.000115,0.000114,0.000108
,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
.000106,0.000111,0.000110,0.000112,0.000112,0.000115
20160520,07:07:41,34.9702,129.1148,117.8,51.9,0.1902,-9999,3.1,0.002126,0.002159,0.002253,0.002342,0.002293,0.0
02350,0.002432,0.002468,0.002478,0.002567,0.002629,0.002639,0.002734,0.002786,0.002796,0.002836,0.002894,0.00
2974,0.002996,0.003040,0.003089,0.003126,0.003154,0.003185,0.003207,0.003189,0.003189,0.003210,0.003230,0.003
247,0.003264,0.003307,0.003334,0.003379,0.003408,0.003436,0.003460,0.003474,0.003487,0.003503,0.003497,0.0034
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 HDF5 Files



HyperCP Processing Report

GUI or CLI Launch

Processing Reports

File: SAMPLE_SEABIRD_pySAS Col

L1BQC : Process L1B to L1BQC

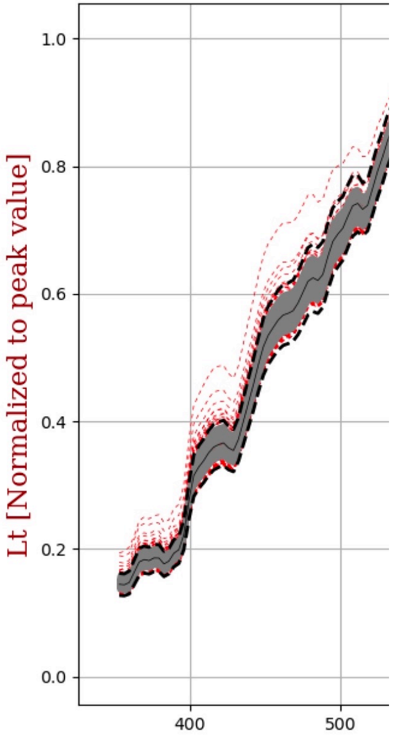
Apply more quality control filters.

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:

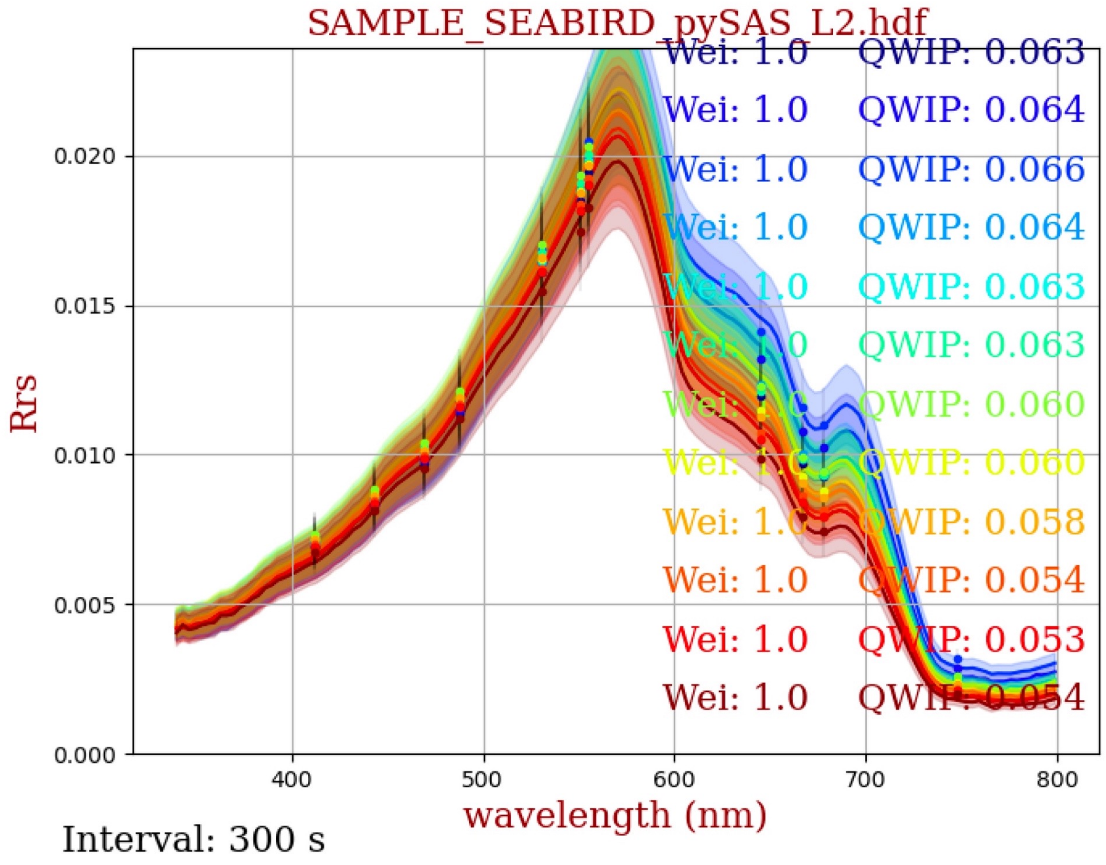
Process Single Level
Applying Lt(NIR)>Lt(UV) quality filtering to elin
0.0% of spectra flagged
Percentage of data out of Wind limits: 0 %
Percentage of data out of SZA limits: 0 %
Applying spectral filtering to eliminate noisy spect
0.4% of Es data flagged
0.0% of Li data flagged
4.6% of Lt data flagged
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

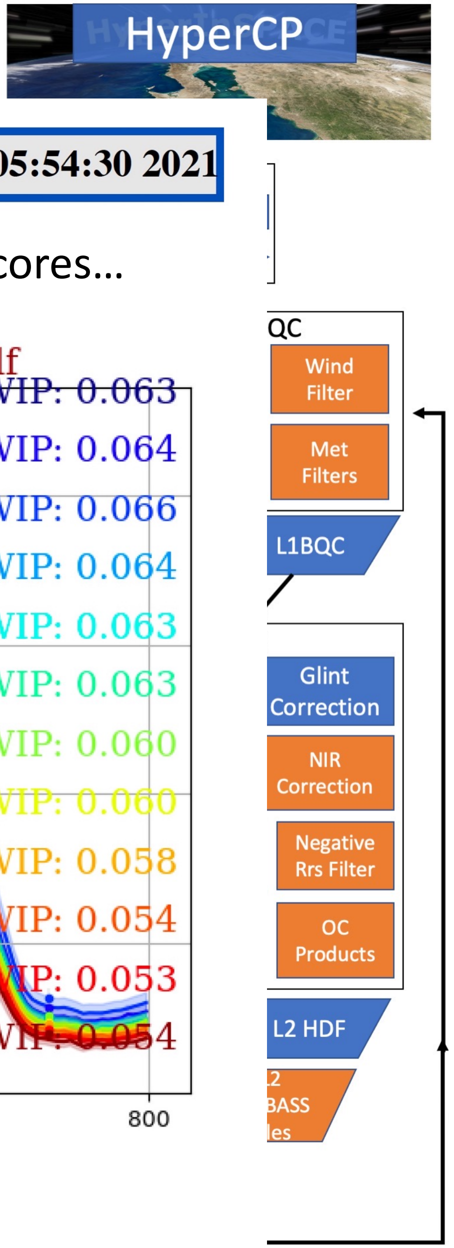
L1BQC Spectral Filter



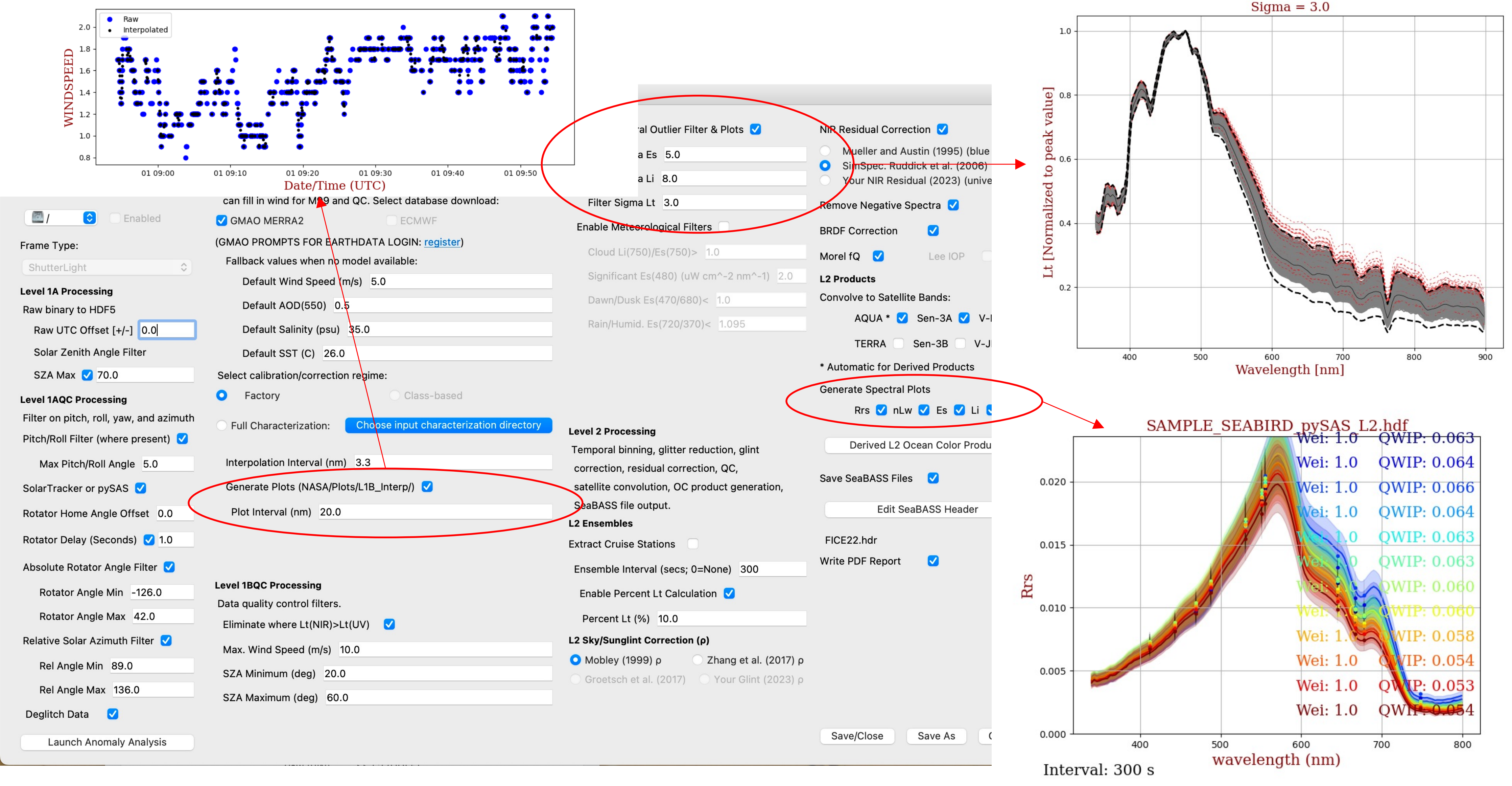
File: SAMPLE_SEABIRD_pySAS Collected: Sat May 01 05:54:30 2021

L2 Ensembles Rrs with uncert., convolutions, scores…





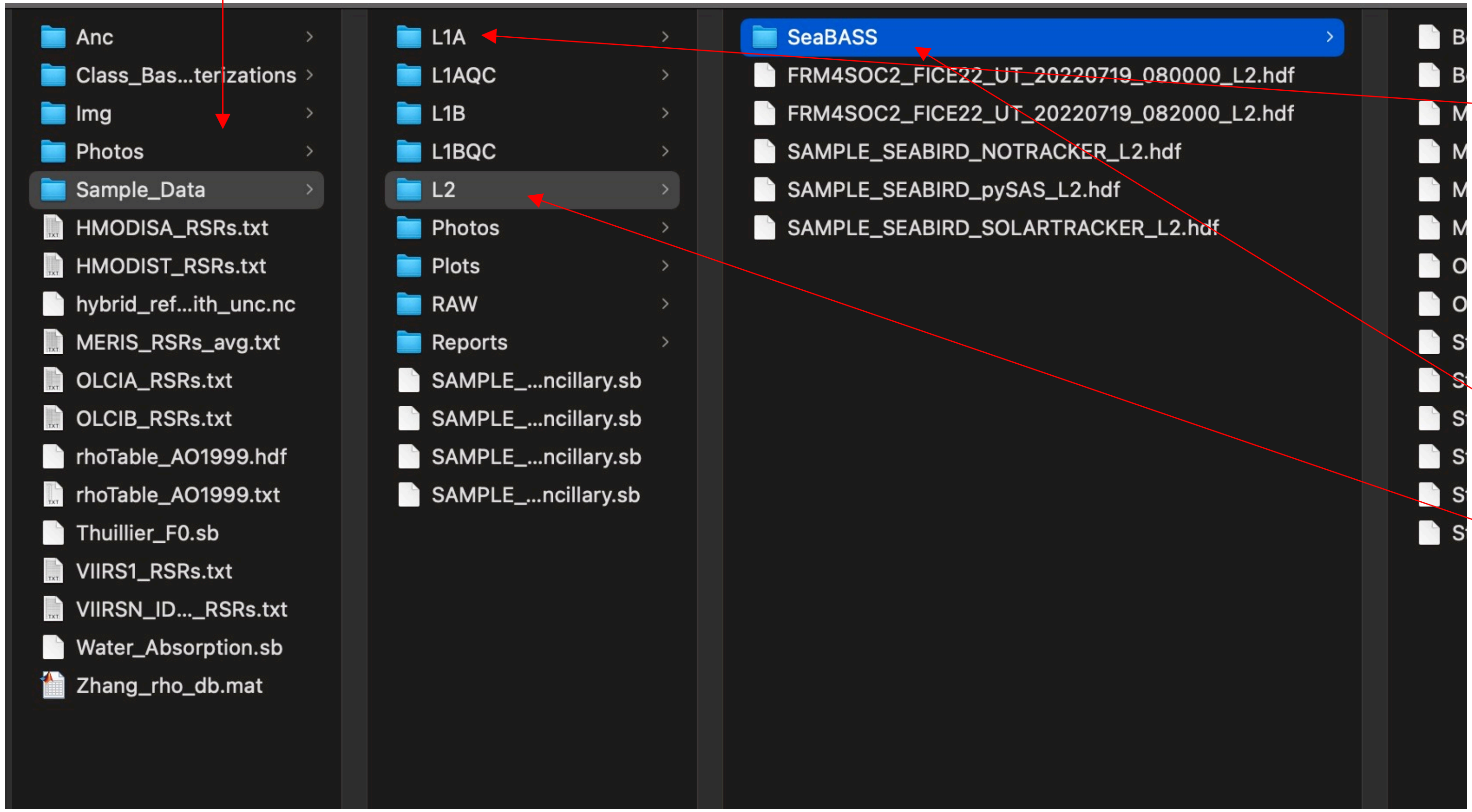
HyperCP Plots for Diagnostics and QC

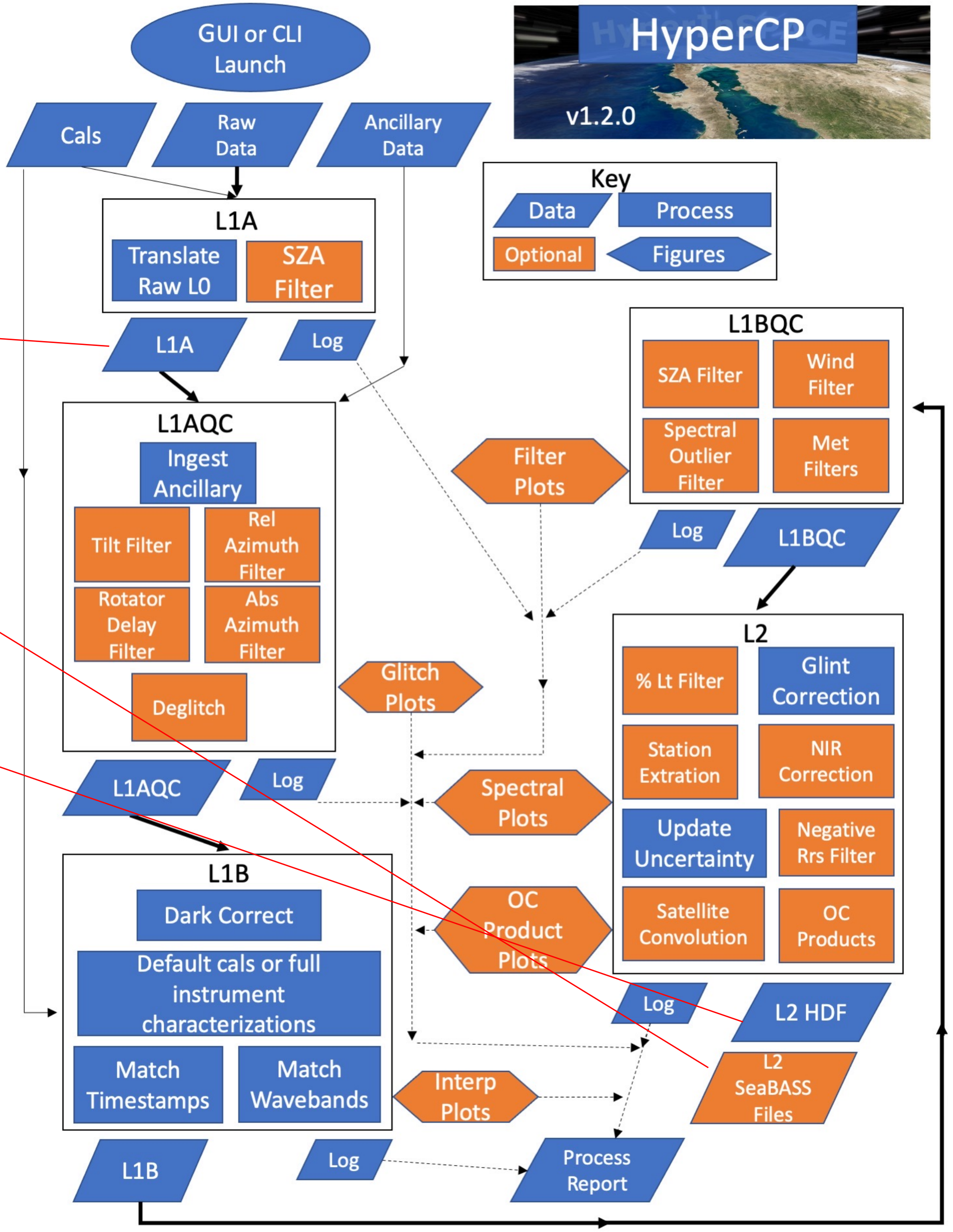


HyperCP Overview

Data Output

Chosen Data Output Folder (Main Window)

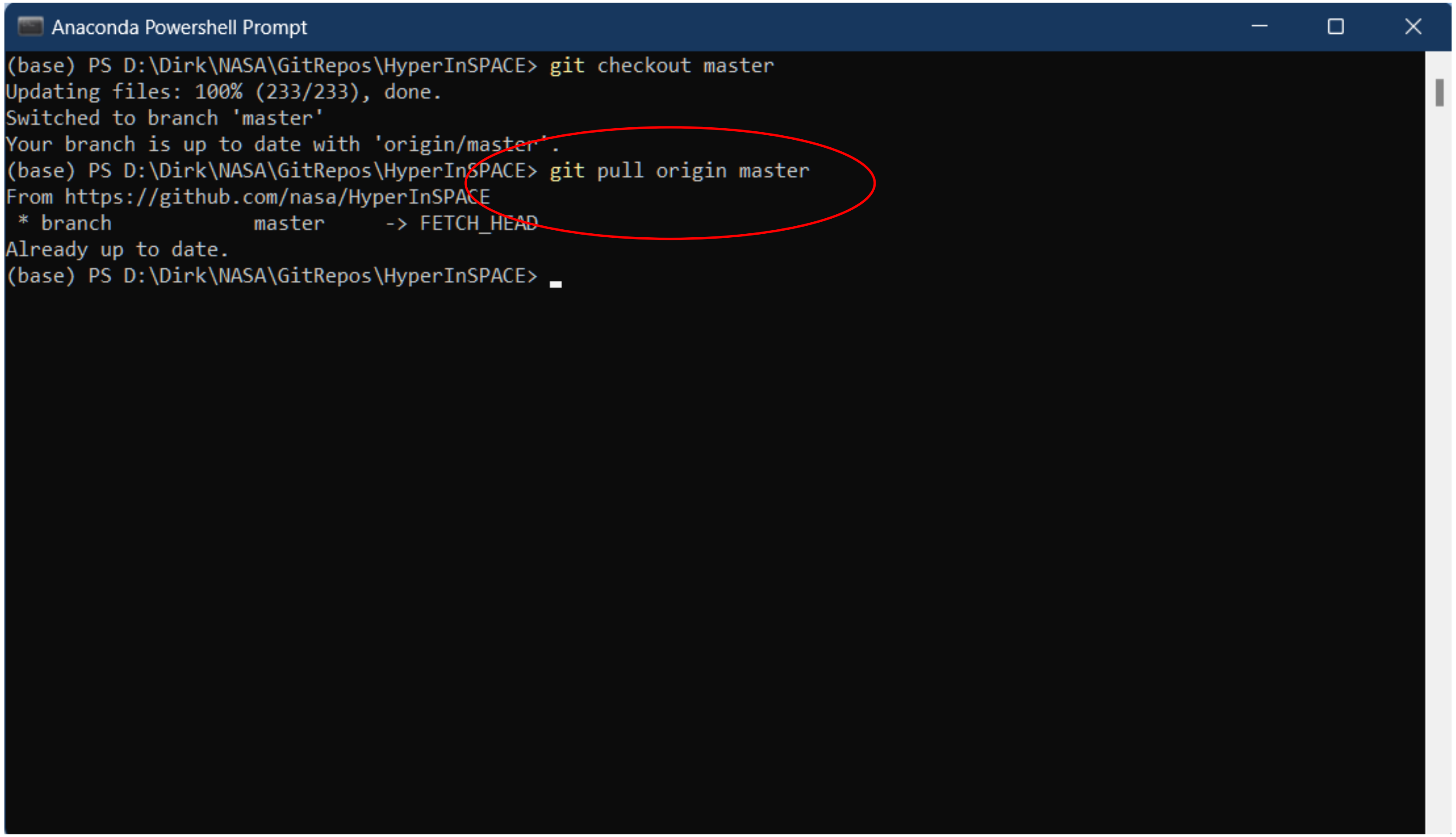




Processing the AWR in HyperCP

Follow the instructions in the readme at https://github.com/nasa/HyperInSPACE to install and launch the program

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



Above all, don’t be discouraged if it doesn’t work seamlessly the first time.

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

```
❯ git pull origin master
```

A recent major overhaul to v1.2.0 may not have all bugs worked out.

Feel free to report issues.

“Live long and process!”

@oceancolorcoder

Hands On

1) Open HyperCP GUI and process one of the sample data files provided
    a) Select a Configuration
    b) Choose Input/Output Data directories (i.e., HyperInSPACE/Data/Sample_Data)
    c) Select Ancillary File
    d) Choose Factory mode in L1B, and for speed, choose the M99 glint correction
    e) Process data Raw > L2
2) Assemble ancillary field notes and data into a SeaBASS file format
3) Offload pySAS (L0a) data (probably done for you)
4) Process L0a pySAS data to L0b(Raw) using the prepSAS.py module
5) In HyperCP, start a new Configuration and check/adjust all parameters for all levels
6) Try experimenting with the Anomaly Analysis tool for deglitching
    a) Run L1AQC first with no deglitching, then run the tool on this unaltered file)
7) Process a file from Raw > L2, one level at a time
    a) Watch for command line feedback/error messages
8) Try experimenting with more/less aggressive spectral filtering (L1BQC)
    a) See results in the Output/Plots/L1BQC_Spectral_Filter folder
9) Batch process an entire directory of Raw data to L2 in the GUI
10) Bonus: Adapt the run_sample.py script call to CLI with multiprocessing to re-batch your data with Z17 glint correction (change output directory) and compare your L2 results