Hyperspectral radiometric device for accurate measurements of water leaving radiance from autonomous platforms for satellite vicarious calibrations (HYPERNAV)

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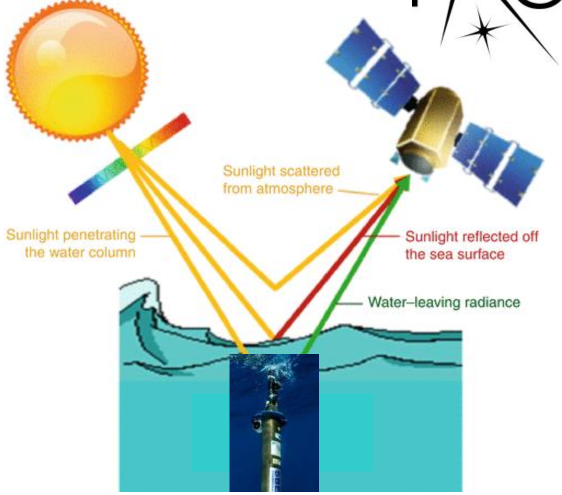
FRM4SOC, ESRIN 22 February 2017

Project overview and Background



OBJECTIVE

- Develop next generation hyperspectral radiometers,
- Implementation on an autonomous profiling platform
- Develop an end-to-end data management system

Support satellite vicarious calibration / product validation for next generation of hyper spectral ocean color satellites.

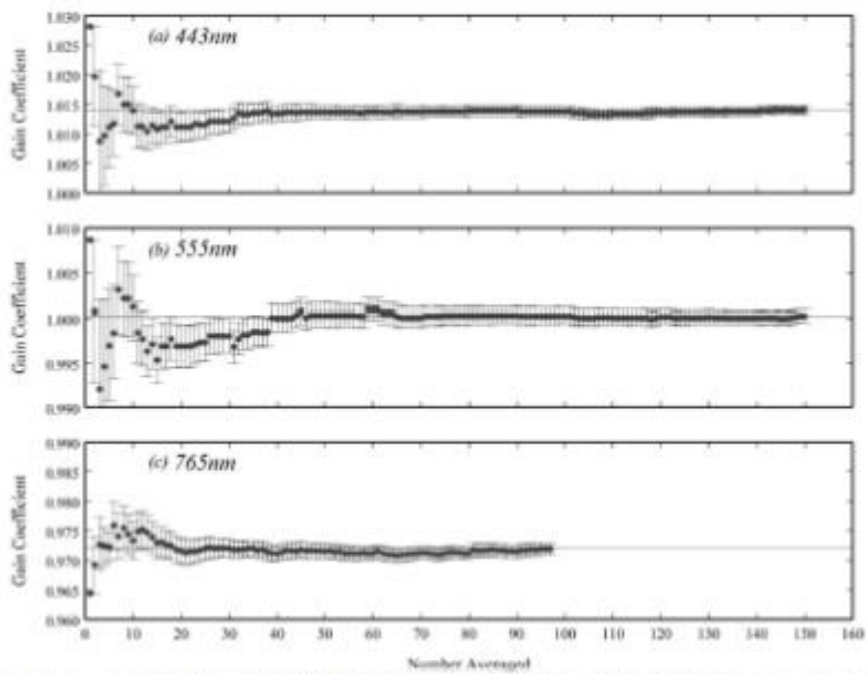


Fig. 6. Mean vicarious gains, $g(\lambda)$, derived for SeaWiFS bands at 443, 555, and 765 nm based on calibration samples spanning the mission lifetime from September 1997 to March 2006. Individual gains from the mission-long set of calibration match-ups were randomly sampled, growing the sample set one case at a time and averaging to show the effect of increasing sample size on $g(\lambda)$. Vertical error bars show the standard error on the mean at each sample size.

MOTIVATION:
Early in a satellite mission - > provide many high quality in situ data matchups as possible.

One of three projects funded by OBB/ ESTO response to NASA ROSES call.

Current strategies for Cal/Val of Ocean Color

Instrumented buoy or AERONET-C station ex. MOBY, BOUSSOLE	**Oceanographic Cruises**
Demonstrated high quality data	Demonstrated high quality data
Limited spatial coverage	Limited spatial coverage
Great temporal coverage	Limited temporal coverage
~ 15 matchup data points per year per site provided	Takes ~10 days at sea to get one matchup data point

Both are expensive and take significant time to gather sufficient data early in sensor's life

Fleet of Instrumented Profiling Floats

- Data quality unknown
- Great spatial and temporal coverage
- Relatively inexpensive
- Augments MOBY & Boussole data
- Augments Bio-Argo float capabilities

Requirements Matrix

REQUIREMENT	CAPABILITY
Spectral Range 350-900 nm	350 to >900 nm
Resolution < 3 nm	<=2.2nm (350-800nm), <=2.35nm (800-900nm)
Radiometric Uncertainty < 4% in blue-green	< 4% in the blue-green. TBD for red. Uncertainty due to extrapolation from L(z) to L(0).
Radiometric Stability O(1%) per Deployment	System will park at 1000 m depth, inhibiting biofouling.
Autonomous Field Operation	Excellent history of long-term float deployment. Float scheduling can be updated after deployment.
Fully Lab and Field Characterized	Radiometers will be fully characterized (stray light, temp, linearity, etc) Calibrated with NIST-calibrated lamps.
Fully Autonomous Data Delivery to Enable the NASA Mission Science.	A full end-to-end system with automated Prosoft processing scripts.

Design of Float System

1. Navis platform has a proven history with bio-optical measurements.
2. A modular design allows HyperNavs to be tested as freefall systems before being attached to Navis, simplifying development.

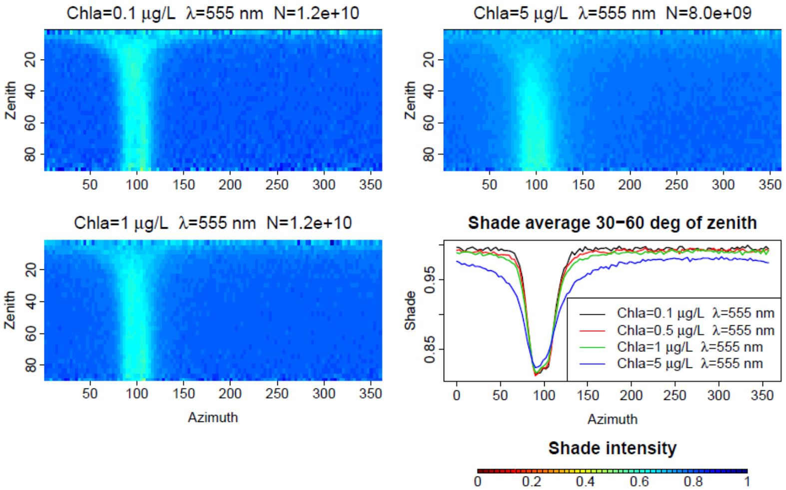
HyperPro

Radiometer
Freefall Profiler & TSRB

HyperNav
Radiometer on Navis Float

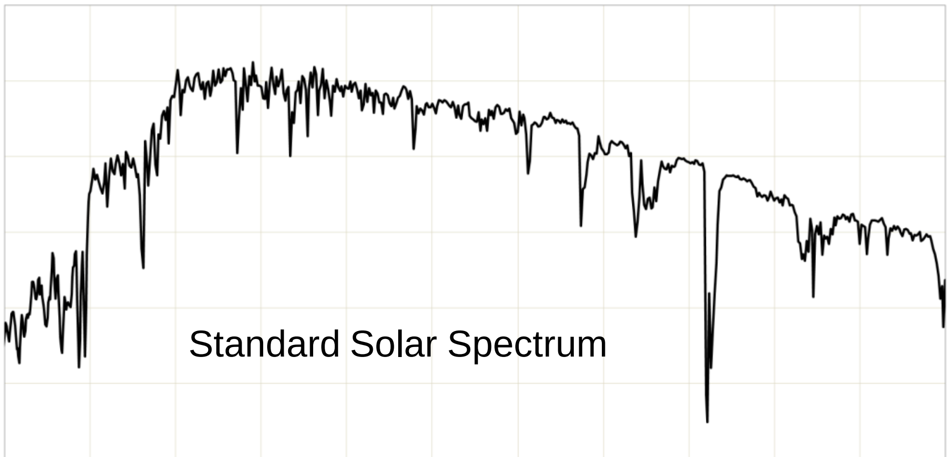
Design of Radiometric System

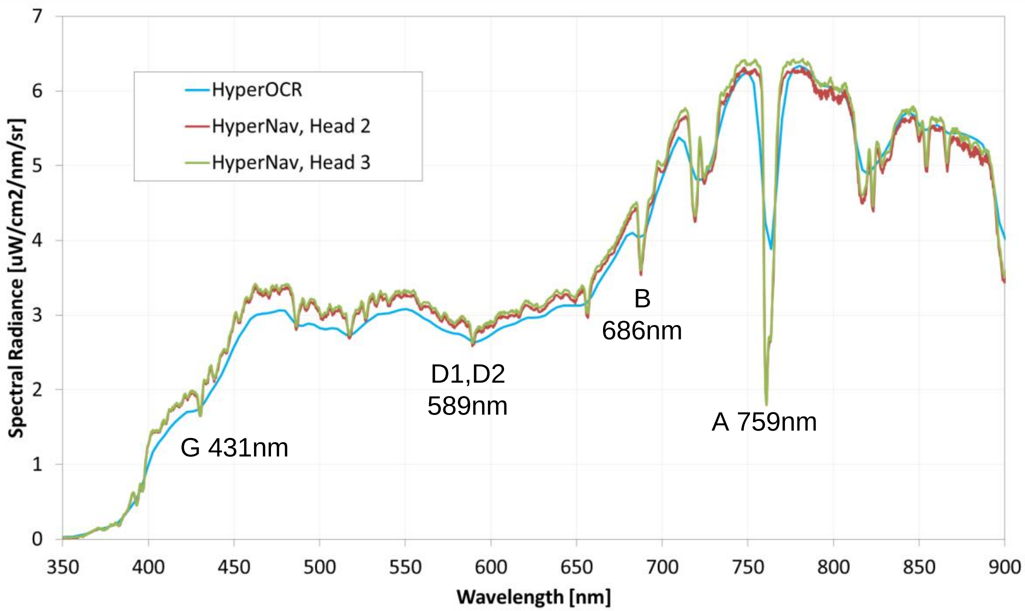
1. Dual heads -> sun-side radiometer & intercomparison.
2. Heads on arms reduce self-shading.
3. Right-angle design -> near surface.
4. Reduced errors in extrapolation to Lu(0-).
5. Tilt sensors for alignment and to monitor position.
6. Shutters for collecting darks.
7. Depolarizer to remove uncertainty in the fore optics.



Supercomputer simulations of shading vs zenith, azimuth, depth, wavelength, chl-a using SimulO software by Edouard Leymarie (LOV)

In-Air HyperNav-HyperOCR Comparison





HyperNav resolves Fraunhofer lines

- Registration
- Enables new science.

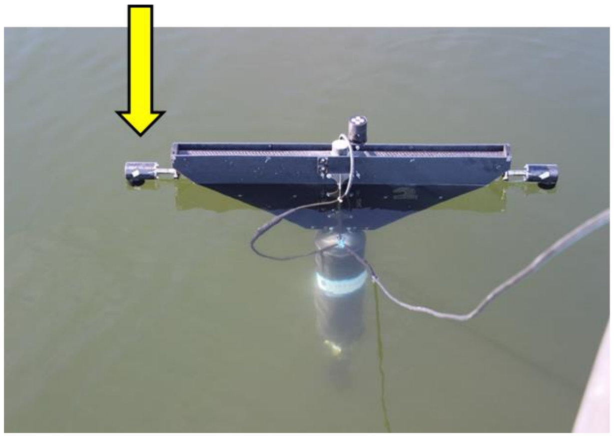
A neutral density filter was needed to prevent HyperNav from saturating. It distorted the observed spectrum (see below)

Difference between HyperNav heads – measurements not done at the same time – varying sky conditions.

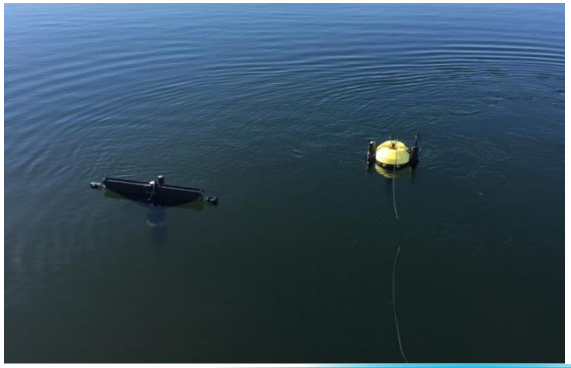
Field Test - Platform Stability

TSRB Radiometer Depth

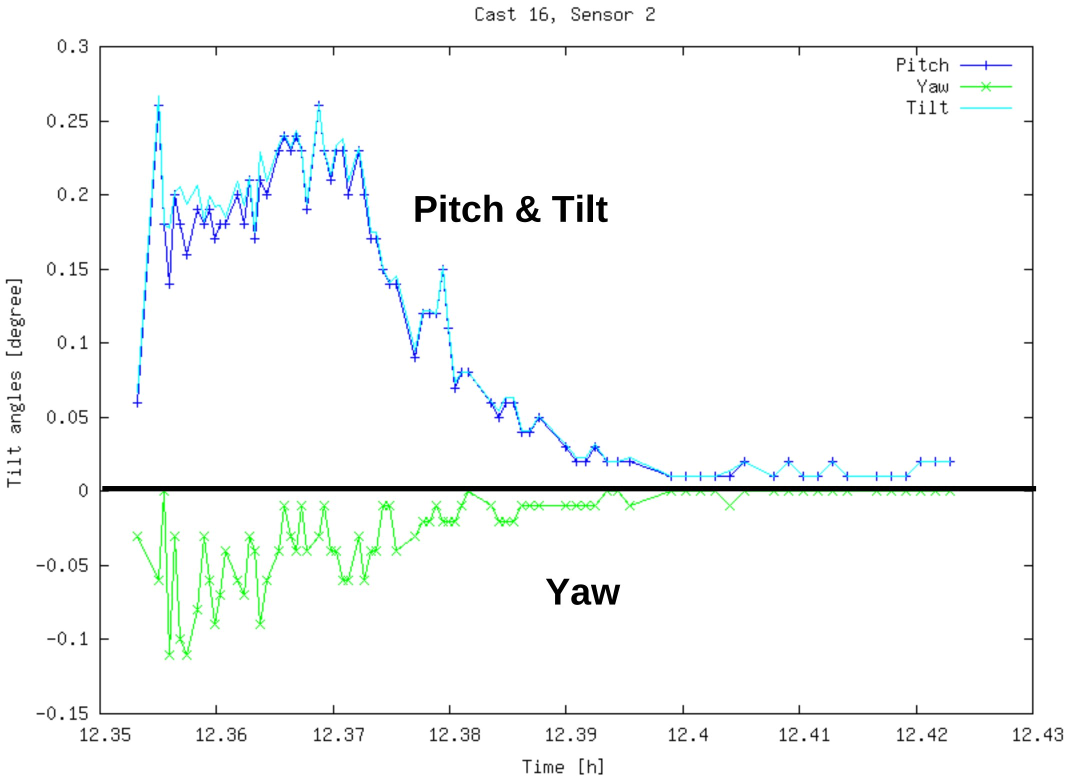
Heads ~2 cm below the surface



- Optics very close to surface.
- Reduces error in extrapolation to surface.

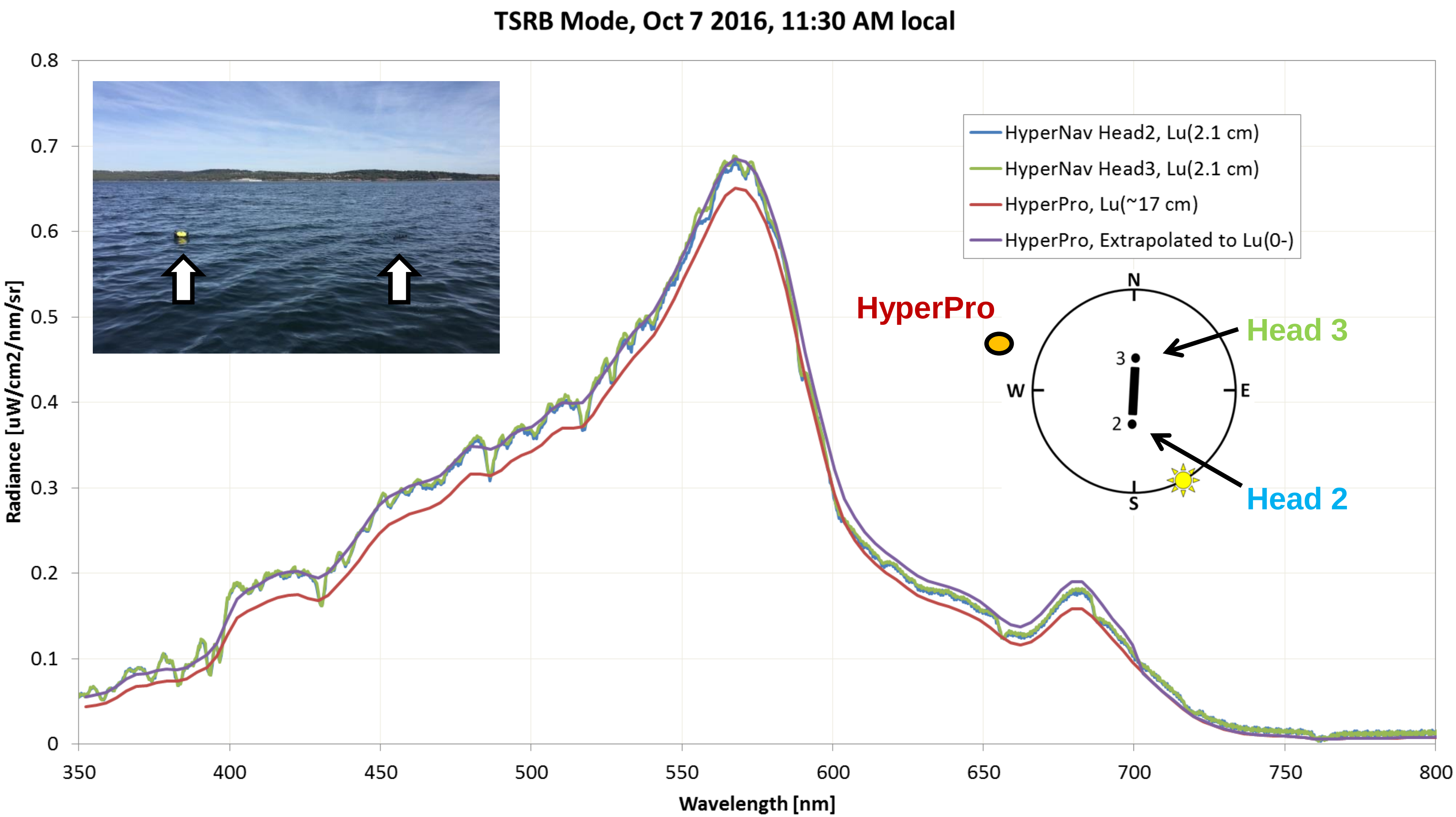


Freefall Tilt



- Decent rate was estimated to be 15 cm/s.
- Excellent descent behavior, calm water tilt <0.3 deg.

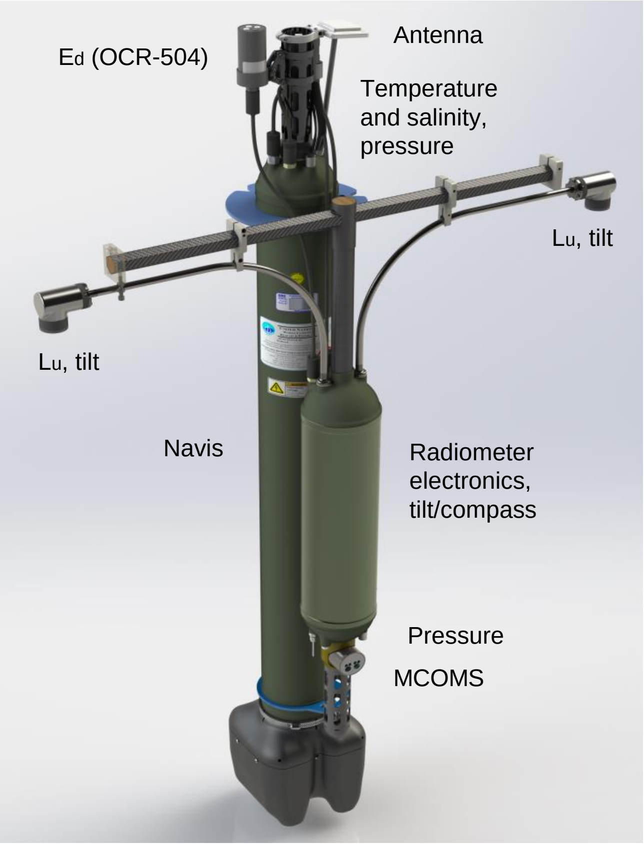
Radiometric Field Test - Bedford Basin



HyperPro extrapolation to Lu(0-) uses spectral k estimation (Austin Petzold 1981 & Morel 2001)

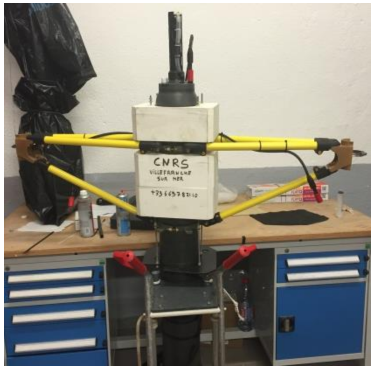
HYPERNAV System Overview

SENSOR	LOCATION	PURPOSE
OCR-504	Top of Navis mast	(380nm, 490nm, 590nm, PAR) Validation, sky conditions
MCOMS	Base of radiometer	(Chl, 700 BB, FDOM) Data validation
Pressure	Base of radiometer	High accuracy & resolution depth for surface extrapolations
Temperature and Salinity	Top of Navis mast	For use with pressure for depth calculation
Tilt/Compass	Radiometer body	Quality control, orientation to the sun
Tilt	Radiometer heads	Head alignment and monitoring



Key Aspects:

- Dual independent radiometers – relative drift
- Lu very close to surface
- Hyperspectral
- Improved pressure accuracy
- Minimization of self shading
- Ability to extend at surface acquisition time
- Tilt data utilization for power saving



Courtesy of LOV, E. Leymarie

Surface Extrapolation – Depth Uncertainty

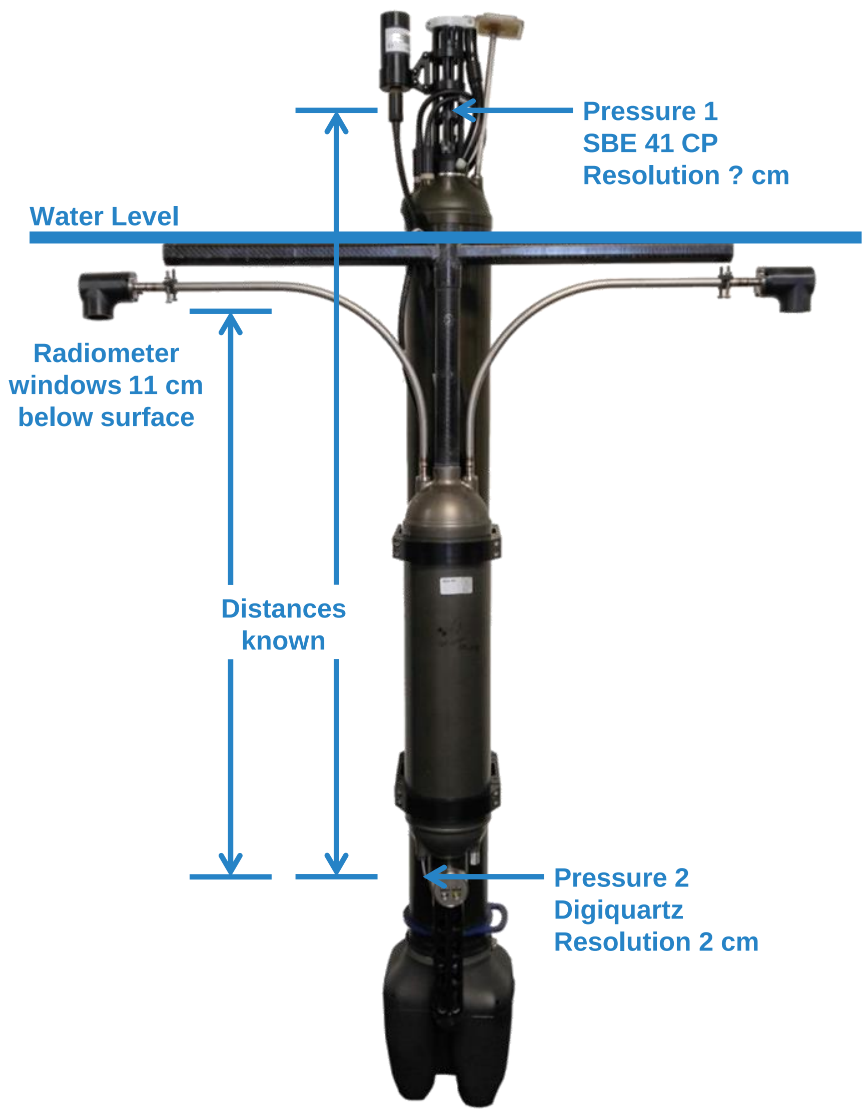
Atmospheric pressure known with variance < 3 hPa^2 = 1.7 cm H_2O

Ponte and Dorandeu (2003) Uncertainties in ECMWF Surface Pressure Fields over the Ocean in Relation to Sea Level Analysis and Modeling

At the surface we have both in-air and in-water pressure sensors.

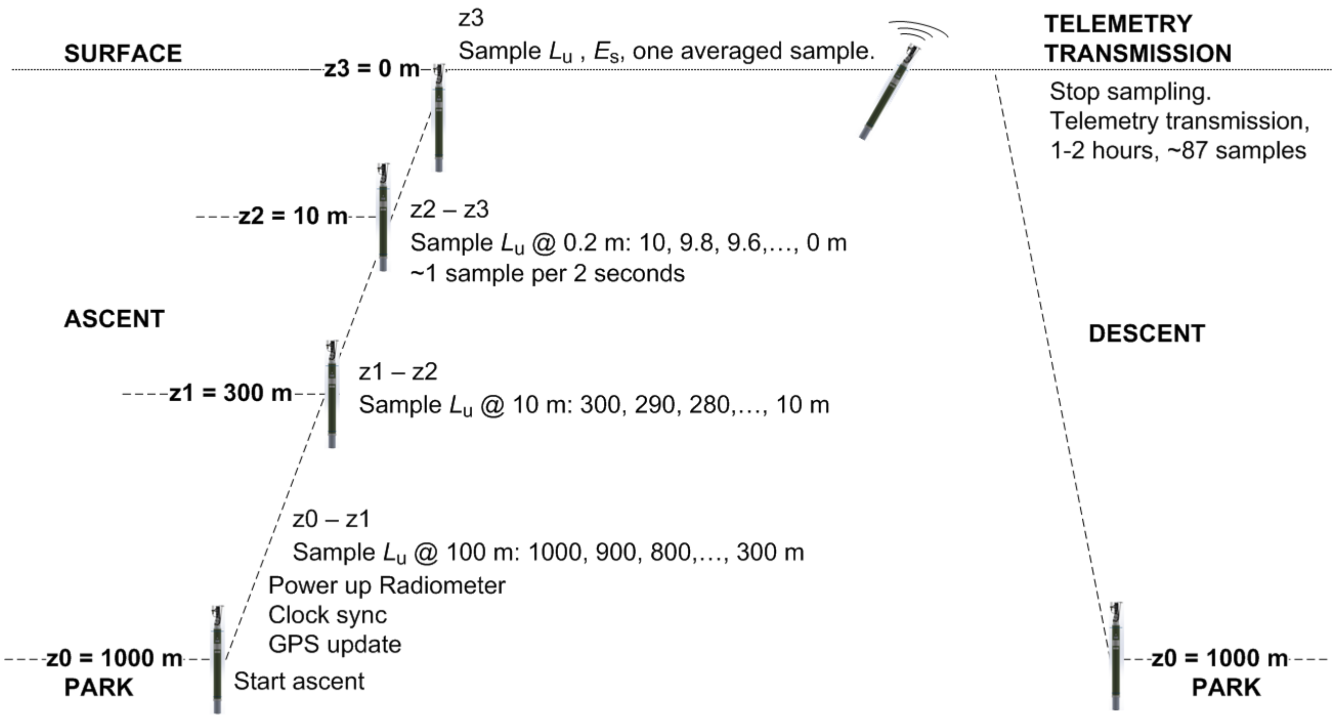
Tare the in-air sensor at the surface and use distance below the surface to correct the in-water sensor. Use NOAA¹s NCEP GFS and GDAS files.

During ascent, use the high resolution pressure sensor to correlate with radiometric readings.



Profile Definition

Considerations include data quality, power consumption, and data transmission volume. It is flexible and can be modified after we gain experience with field deployments.



1000 – 300 m	Baselines, darks, QC
300 – 10 m	Water properties, reduce uncertainty in Lu(0-)
10 – 0 m	Primary data for determining Lu(0-), pressure tare, clear sky determination

Uncertainties Matrix Development 550nm

SOURCE	TARGET % @550nm	METHOD OF VALIDATION	MITIGATION
Calibration			
Irradiance standard	0.78	Provided by NIST	Use NIST calibrated lamp
Reflectance target	1.8	Provided by manufacturer	Use corrections for 0-45 deg
Reproducibility	1.5	Repeated calibrations	Careful lab procedures
Instrument			
Immersion factor	0.3	Theory and experiment	Careful lab procedures
Linearity	TBD	NIST beam conjoiner	Characterization and correction
Stray light	0.04	NIST laser scanning	Characterization and correction
Thermal effects	0.02	At calibration station over 4-30 C	Characterization and correction
Polarization effects	TBD	Integrating sphere and polarizer	Depolarizer
Wavelength accuracy	0.4	Provided by mfr., verified with gas lamps	Quality control on spectrometers
Field			
Wave focusing	1.0	Field measurements	High frame rate near surface
Self-shading	0.5	Monte Carlo	Model corrections
Tilt effects	0.5	Tilt sensors in heads	Only collect data when tilts are good
Biofouling	2.0	Retrieval of floats, post calibration	Park in aphotic zone
Total	3.5		

Next Steps - Characterizations

Immersion Coefficients

Theory and experiment following procedure of Zibordi 2005

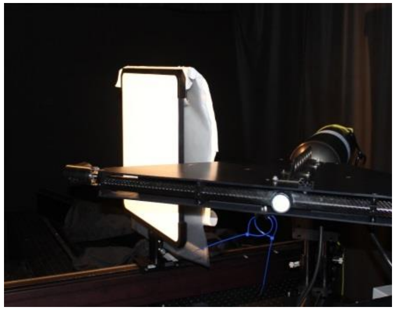
Calculate using T and S measured by Navis float

Spectral Stray Light

To be measured at NIST, tunable laser

Generate stray light correction matrix

Stray light correction measurements and processing algorithms already exist for HyperOCRs.



Linearity

To be measured at NIST, beam conjoiner

Generate correction function

Goal: accuracy to <0.1% (as per Mueller)

Thermal

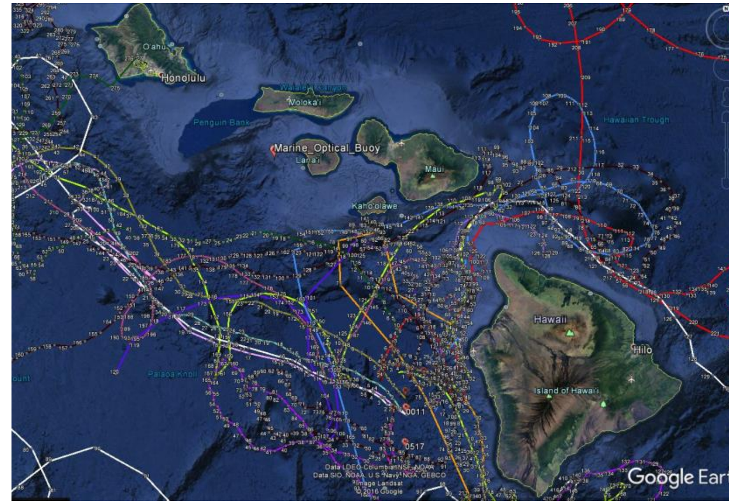
Measured using radiometric calibration setup

Generate correction function

Next Steps - Deployments

Complete HyperNav development
& attach to Navis float platform

Test freefall systems at MOBY
& float system also in Hawaii



Float Field Test

- Tilt and rotation
- Behavior at the surface before data transmission
- Behavior during transmission, when bladder is inflated
- Real data transfer (end-to-end system operation)
- Post calibration (recovery) to document stability
- Quantify uncertainty due to deployment biofouling, etc.

Thank You

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