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

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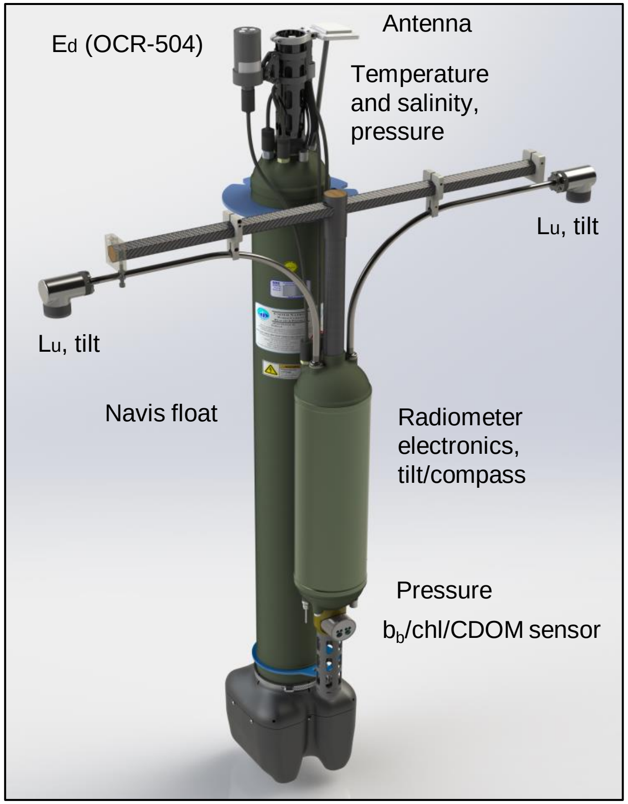
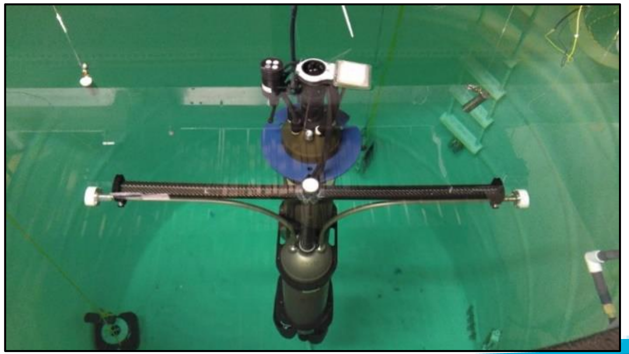
Project Overview

Goals

- Next-generation hyperspectral radiometric sensors for calibration/validation.
- Utilize autonomous floats as a platform to collect hyperspectral radiometric to minimize uncertainty.
- Develop an end-to-end system/strategy for new ocean-color satellite calibration – including float deployment, radiometric data quality assurance, data delivery and satellite inter-comparison.

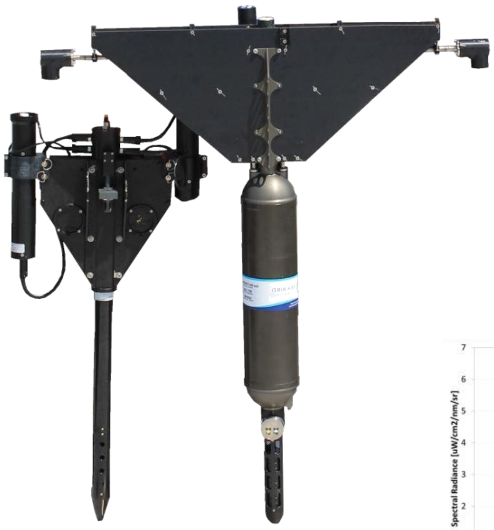




HyperNav autonomous float system advantages

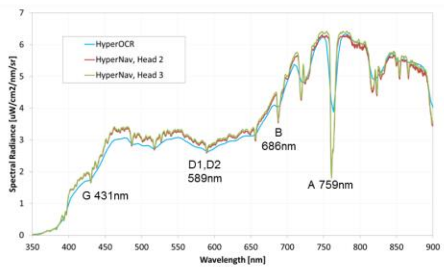
- Risk reduction approach to the vicarious calibration program for PACE and other missions.
- Deployment floats at the start of a satellite mission - Rapid characterization of in flight satellite radiometer.
- Provide radiometric measurements across a broader range of solar angles and geographic regions, to assess the satellite dependencies on out-of-band response, BDRF, etc.
- Augments other moored cal/val sites throughout satellite lifetimes, enables rapid collection of vicarious calibration data.

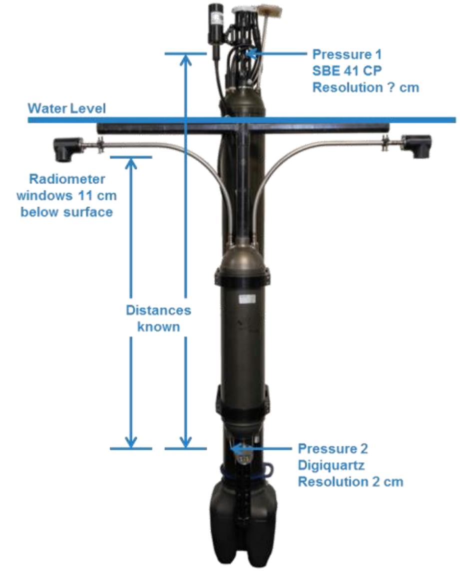
HyperNav Summary



HyperPro Freefall Profiler

- Free-fall radiometric profiling device – dual hyperspectral upwelling radiance.
- Extends capabilities of existing HyperPro product.
- 350nm – 900nm, ~2nm spectral resolution.
- Ability to resolve Fraunhofer lines.





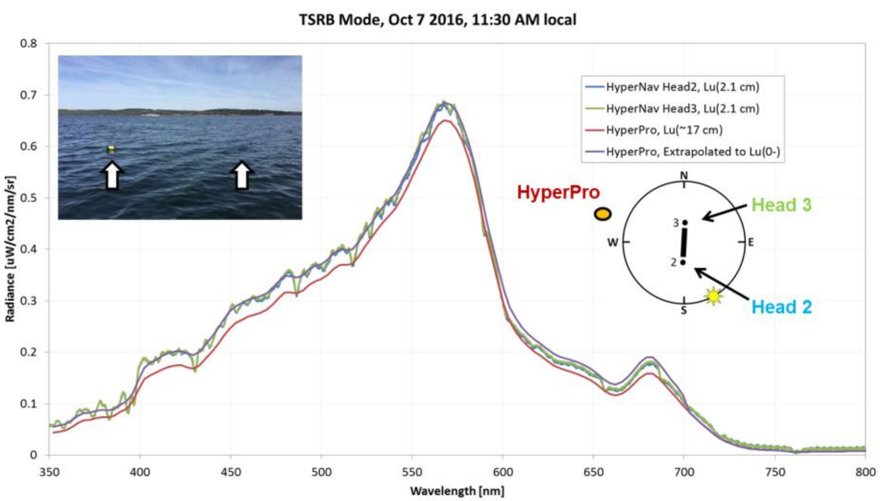
HyperNav system - Navis float, Hyperspectral L_u x2

- CTD, optics, tilt, roll, pitch, telemetry.
- Precise pressure sensors for accurate radiance determinations.
- Ability to measure upwelling radiance to just below the sea surface (~10-20cm).
- Park at depth to minimize fouling.

Sensor depth = 11.6 cm

		Chl *a* (mg/m^3)			
		0.1	0.5	1	5
Wavelength (nm)	412	0.9965	0.9916	0.9876	0.9691
	490	0.9969	0.9934	0.9908	0.9758
	555	0.9942	0.9918	0.9901	0.9795

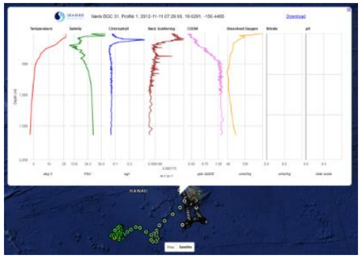
Self shading Modeling results



Surface spectra for Lu sensors

Upcoming schedule 2017

Data Delivery/Management System implementation
Radiometric Characterizations at NIST
Field Deployments
Final report and recommendations (Sept. 2017)



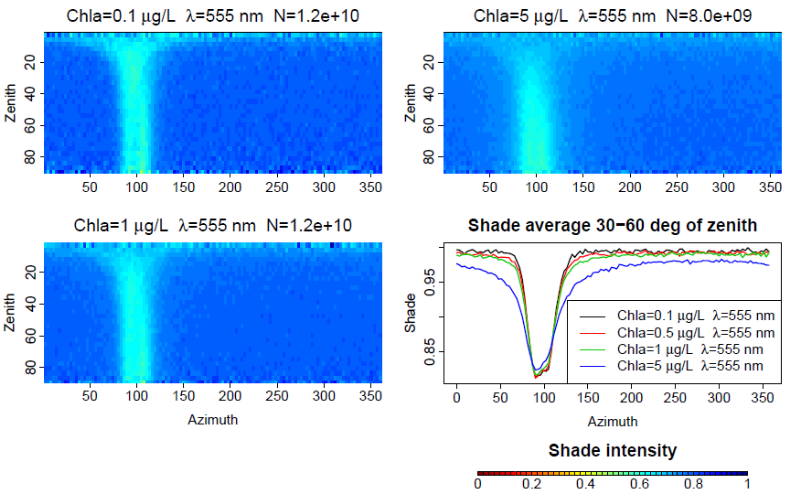
$TRL_{in} = 3$ $TRL_{current} = 6$ $TRL_{goal} = 7$

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.

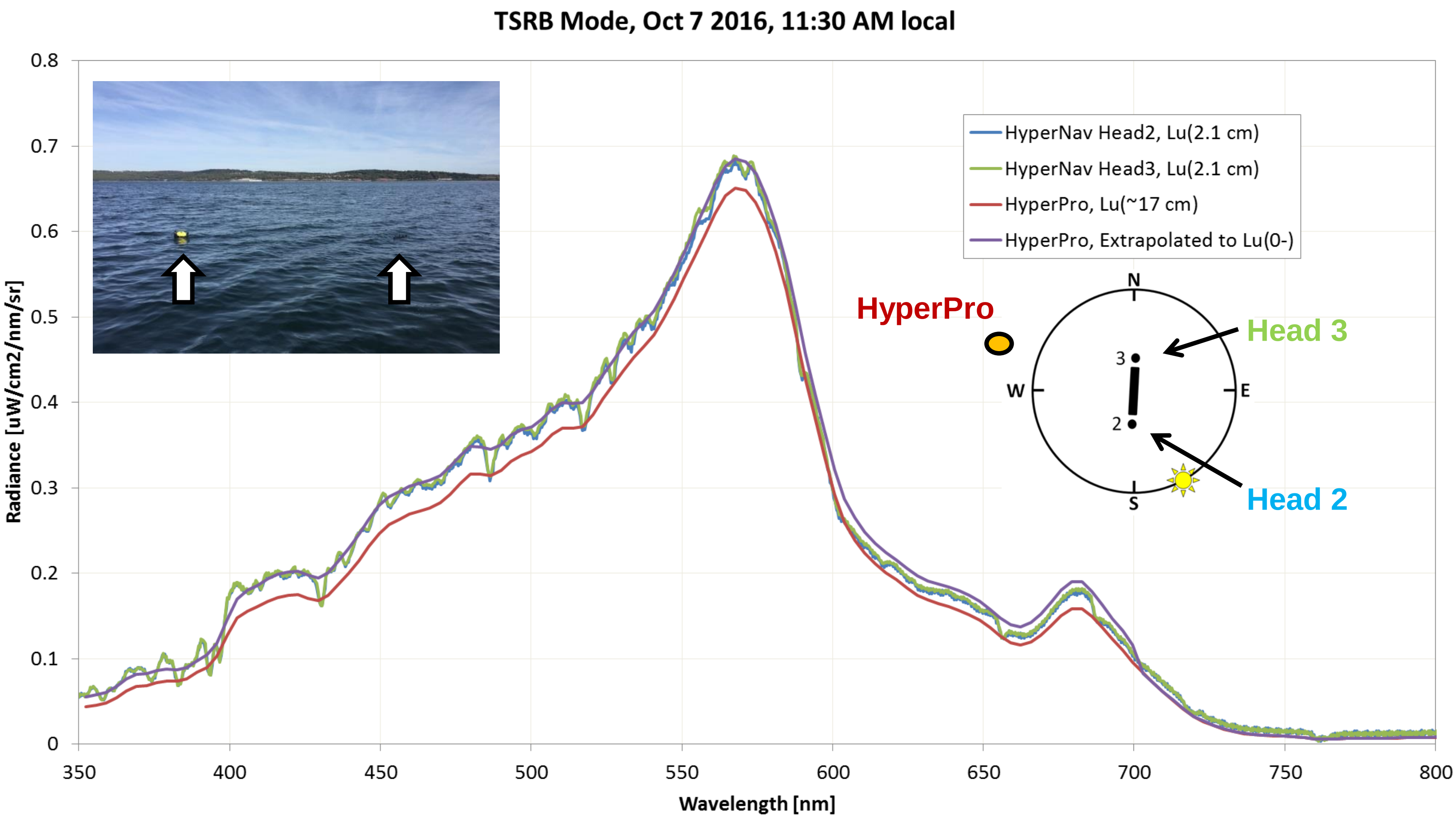
Design of Radiometric System

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.
8. 2.3 nm nominal resolution, 350-900 nm



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

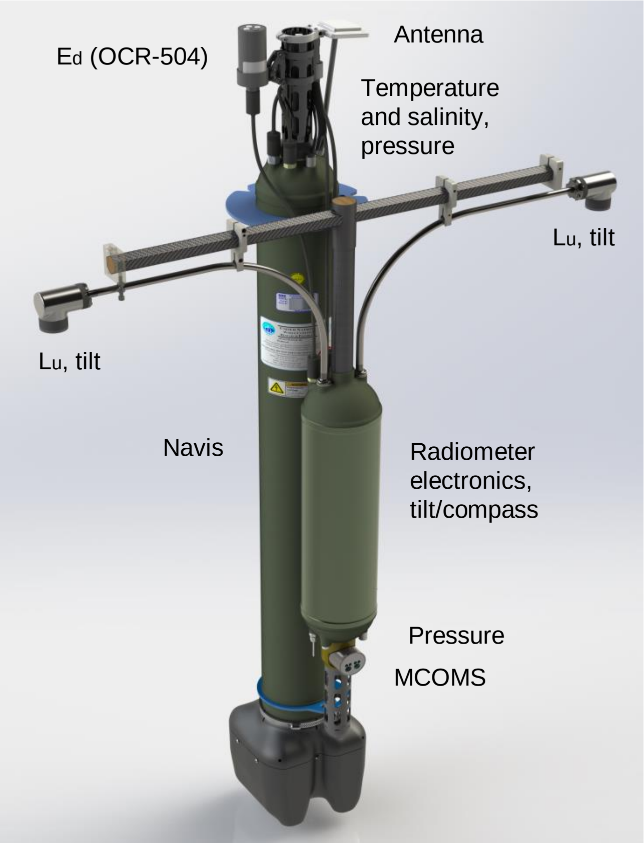
Radiometric Field Test



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

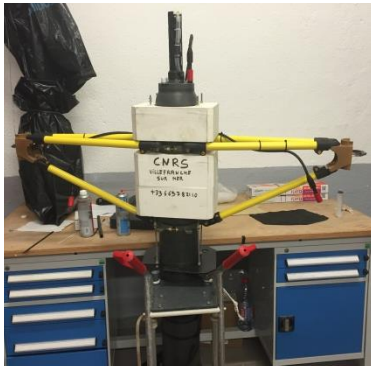
HYPERNAV System Overview

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

Uncertainties Matrix

SOURCE	TARGET %@412nm	TARGET %@443nm	TARGET %@500nm	TARGET %@550nm	TARGET %@665nm	METHOD OF VALIDATION	MITIGATION
Calibration							
Irradiance standard	1.04	0.94	0.84	0.78	0.68	Provided by NIST	Use NIST calibrated lamp
Reflectance target	1.8	1.8	1.8	1.8	1.8	Provided by manufacturer	Use corrections for 0-45deg
Reproducibility	1.6	1.6	1.6	1.6	1.5	Repeated calibrations	Careful lab procedures
Instrument							
Immersion factor	0.3	0.3	0.3	0.3	0.3	Theory and experiment	Careful lab procedures
Linearity	0.3	0.3	0.3	0.3	0.3	NIST beam conjoiner	Characterize and correct
Stray light	0.10	0.09	0.06	0.04	0.09	NIST laser scanning	Characterize and correct
Thermal effects	0.01	0.00	0.01	0.02	0.07	At cal station over 4-30 C	Characterize and correct
Polarization effects	0.5	0.4	0.1	0.1	0.5	Int. sphere and polarizer	Depolarizer
Wavelength accuracy	0.4	0.4	0.4	0.4	0.4	Provided by mfr., verified w/ Fraunhofer lines	Quality control on spectrometers
Field							
Wave focusing	1.0	1.0	1.0	1.0	1.0	Field measurements	High frame rate at surface
Self-shading	0.5	0.5	0.5	0.5	0.5	Monte Carlo	Model corrections
Tilt effects	0.5	0.5	0.5	0.5	0.5	Tilt sensors in heads	Only send data w/ good tilts
Surface extrapolation	0.65	0.65	0.65	1.13	4.84	Modelling	High accuracy pressure
Biofouling (6 mnths)	0.5	0.5	0.5	0.5	0.5	Retrieval of floats, post cal	Park in aphotic zone
Total	**3.1**	**3.1**	**3.0**	**3.1**	**5.6**		

Measured (green) **Rough estimate, need improved estimate** (tan) **Estimated, to be measured** (purple)

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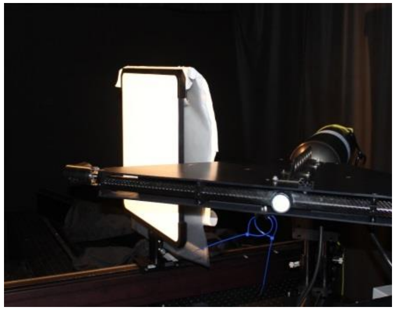
Next Steps



Continued Radiometric Characterizations

- **Immersion Coefficients** – Lab Experiments (Zibordi 2005)
  Calculate using T and S measured by Navis float
- **Thermal** – Lab Experiments (correction function)
- **Spectral Stray Light** – NIST (correction function)
- **Linearity** – Lab & NIST (Goal: accuracy to <0.1%)

Continued Float Field Testing

- Testing at MOBY, Hawaii
- Behavior at the surface - data transmission
- Behavior during transmission, bladder inflated
- Real data transfer (end-to-end system operation)
- Post calibration (recovery) to document stability
- Quantify uncertainty due to deployment biofouling, etc.

Thank You