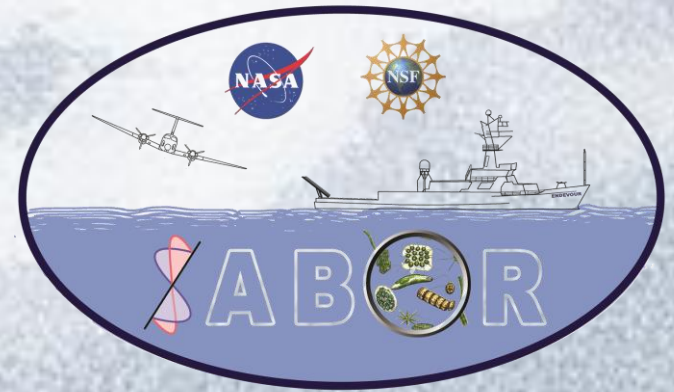


SABOR: Ship-Aircraft Bio-Optical Research Campaign



Outline

▶ SABOR

▶ Genesis & objectives

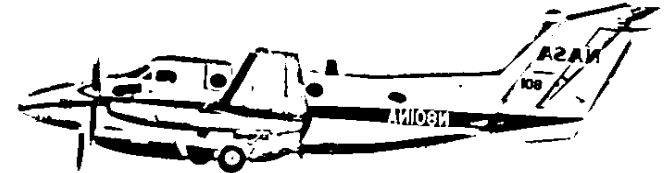
▶ Components

▶ Ship based measurements

▶ Aircraft based measurements

▶ Deployment concept

▶ Where, when & how



SABOR: Genesis

- ▶ Three independent proposals funded under the OBB A.3 had related objectives and complementary methodologies
 - ▶ Cetinić et al.: Multi-sensor, ecosystem-based approaches for estimation of particulate organic carbon
 - ▶ Gilerson et al.: Development of a Methodology for the Retrieval of Characteristics of Water Constituents from Satellite Polarimetric Observations
 - ▶ Hostetler et al.: Advanced Ocean Retrievals Using Lidar and Polarimeter Measurements
- ▶ With Paula's encouragement, the teams joined forces for a combined effort
- ▶ Collaboration between NRL and NASA LaRC led to ONR funding for NRL's participation

SABOR: Objectives

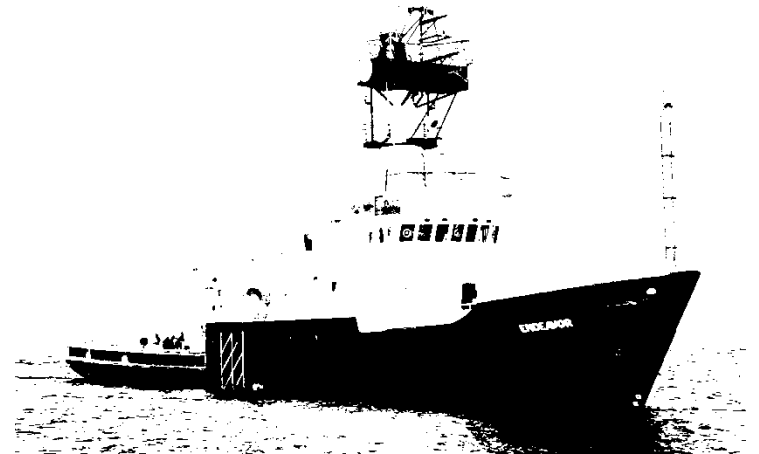
Can we use polarization measurements to do biogeochemistry?

Synergistic approach:

- ▶ In situ IOPs and biogeochemical measurements
- ▶ In situ polarimetric (above and in water) observation for retrieval of IOPs
- ▶ Airborne lidar + polarimeter objectives

VALIDATION + REDUNDANCY

Ship based measurements



Ecosystem based POC retrieval

Cetinić, Perry, Poulton & Slade

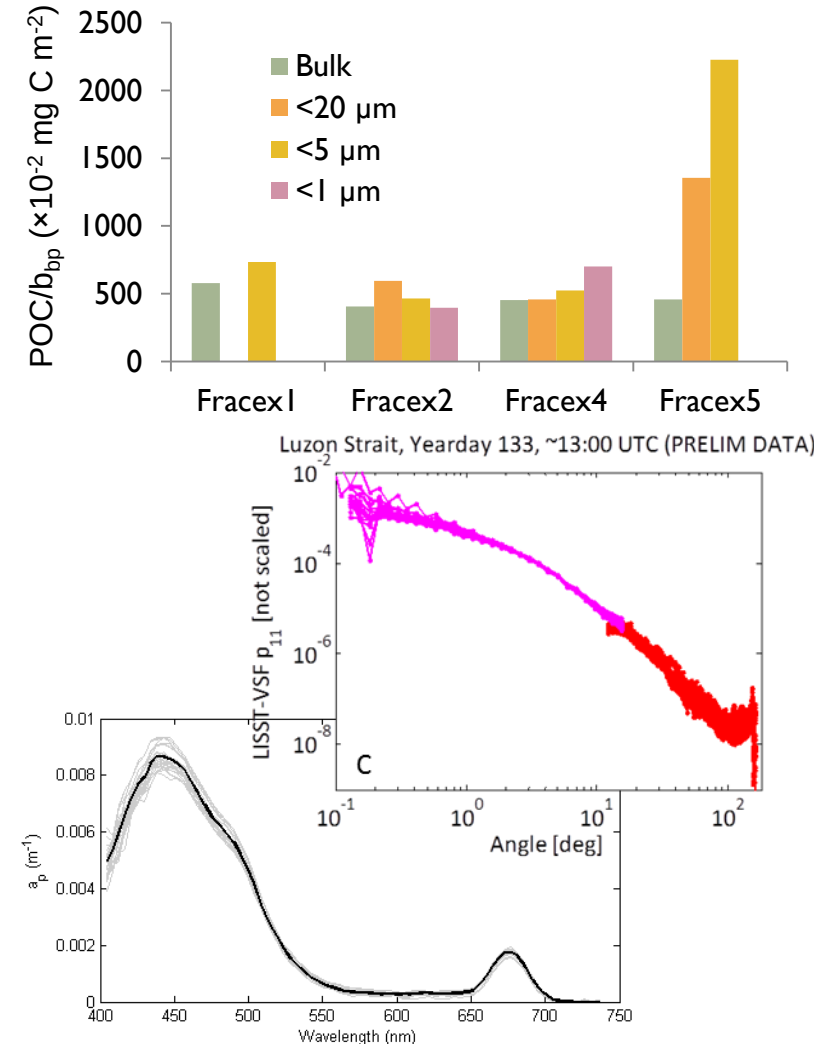
Flow-through, size fractionated IOPs

sensor	measurement
Flow control	(0.2, 1/5 and 20 μm @ hourly)
LISST-vsf	$\beta(515 \text{ nm}, \psi)$, $\psi = 0.08\text{--}150^\circ$ and $DoP = S12/S11$, $\psi = 10\text{--}150^\circ$
BB3	$\beta(\lambda, 117^\circ)$, $\lambda = 400, 532, 660 \text{ nm}$
ac-s	$a_v, c_v, a_{pg}, c_{pg}, a_g, a_p, c_p$ (multi λ)
C-star	$c_{pg}(657)$ closed path
Wetstar	chl fluorescence

& discrete samples (size fractionated)

POC, SPM, HPLC pigments,

C_{phyto} Phytoplankton composition + PSD

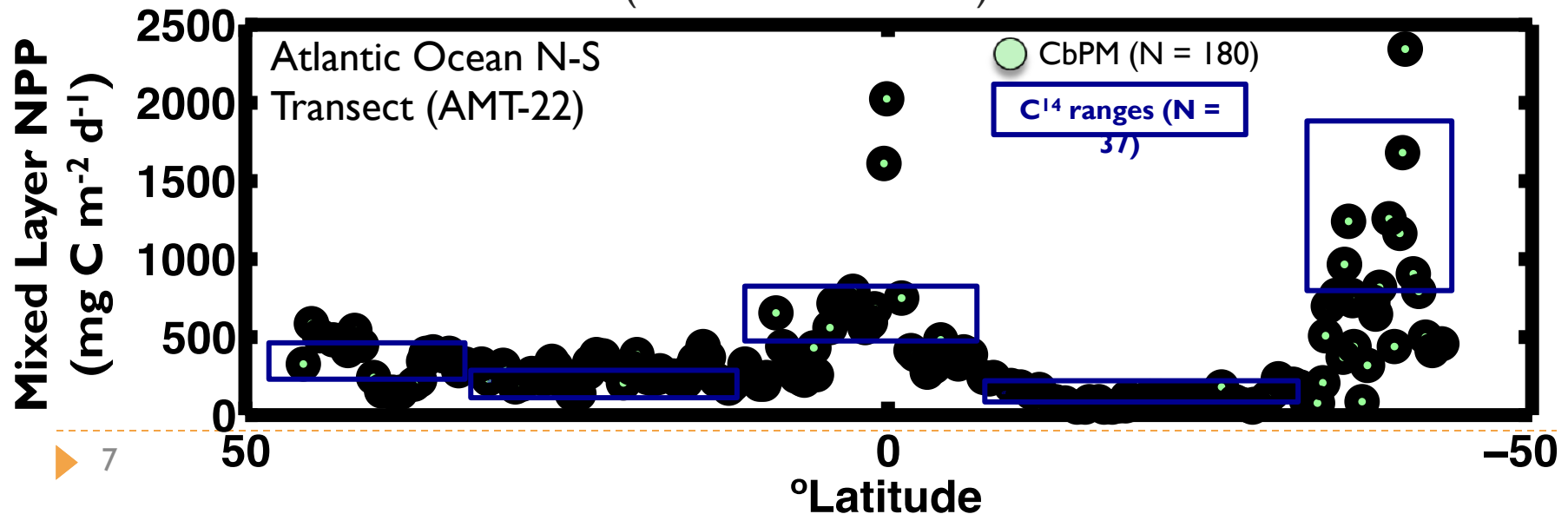


Phytoplankton Carbon, Growth Rates, and Primary Production

1) Behrenfeld, Graff, Westberry & Milligan
2) Halsey & Fisher

Phytoplankton Carbon	Growth Rate (μ)	Primary Production ($C \times \mu$)	Supporting Measurements
Direct measurement	Carbon-based Productivity Model (CbPM)	C^{14} – multiple incubation durations (Gross & Net PP)	HPLC Pigments
$b_{bp} - C_{phyto}$ proxy	Dilution Experiments	CbPM (Net PP)	Total POC
Flow-cytometry	Species-specific μ (sequence-based)		Community Composition

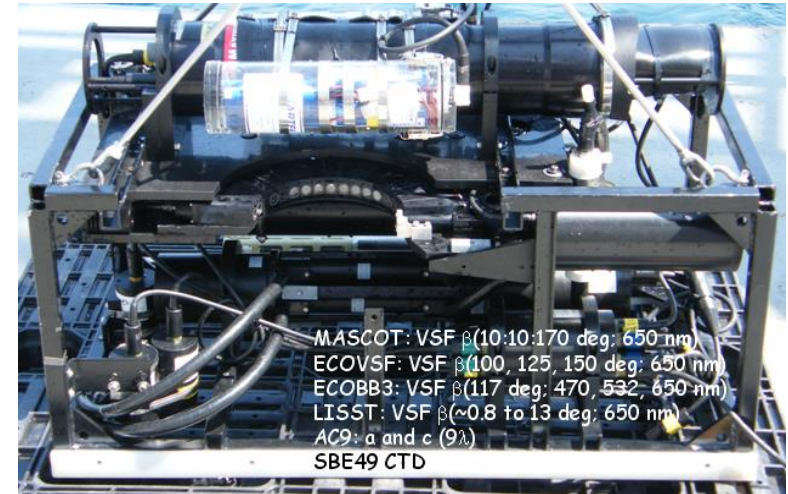
Example of the CbPM applied in-situ vs ranges in depth integrated C^{14} NPP
(Graff et al. in review)



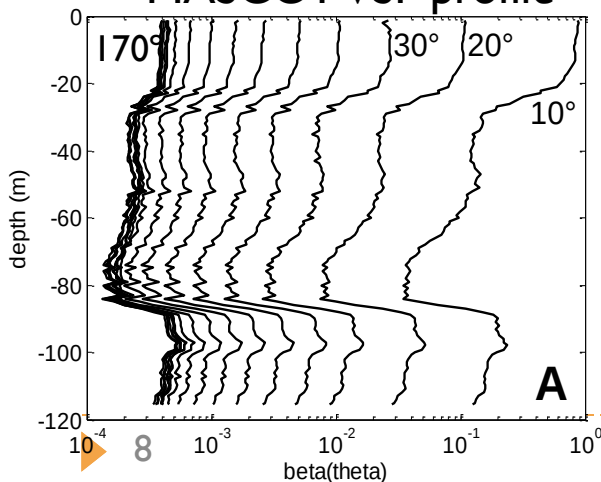
In situ polarized VSF and other IOPs

Twardowski & Stockley

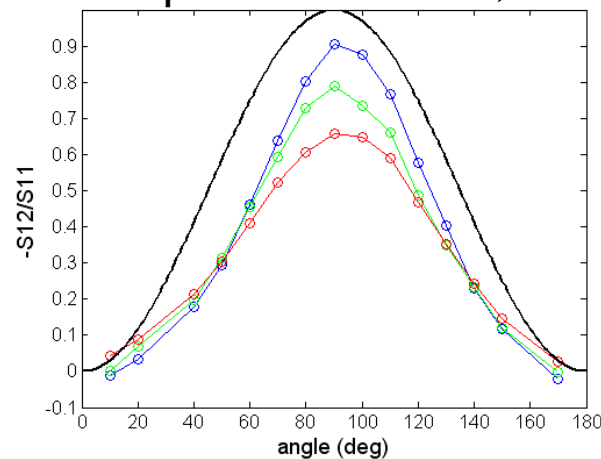
sensor	measurement
MASCOT + POLMOD	$\beta(10:10:170^\circ), i_\perp(10:10:170^\circ), i_\parallel(10:10:170^\circ)$ at 658 nm
LISST-B	$\beta(0.8 - 13^\circ)$ at 650 nm
ac-9s	$a_b, c_b, a_{pg}, c_{pg}, a_g, a_p, c_p$ (9 λ)
ECOs	$\beta(412 - 700 \text{ nm}, 104 - 151^\circ)$
C-star	$c_{pg}(657)$ open path
CTD	z, T, S



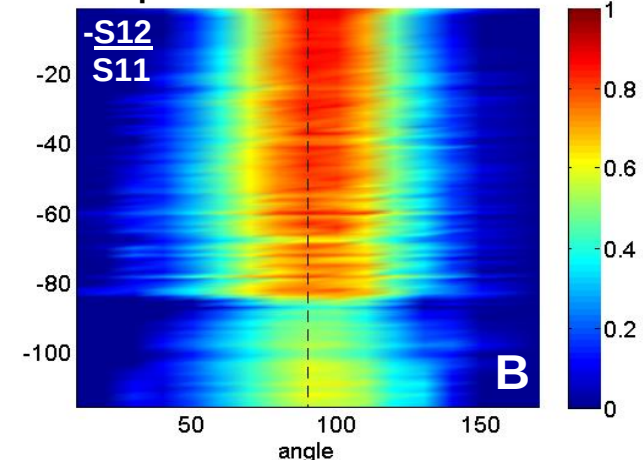
MASCOT VSF profile



depolarization ratio, θ

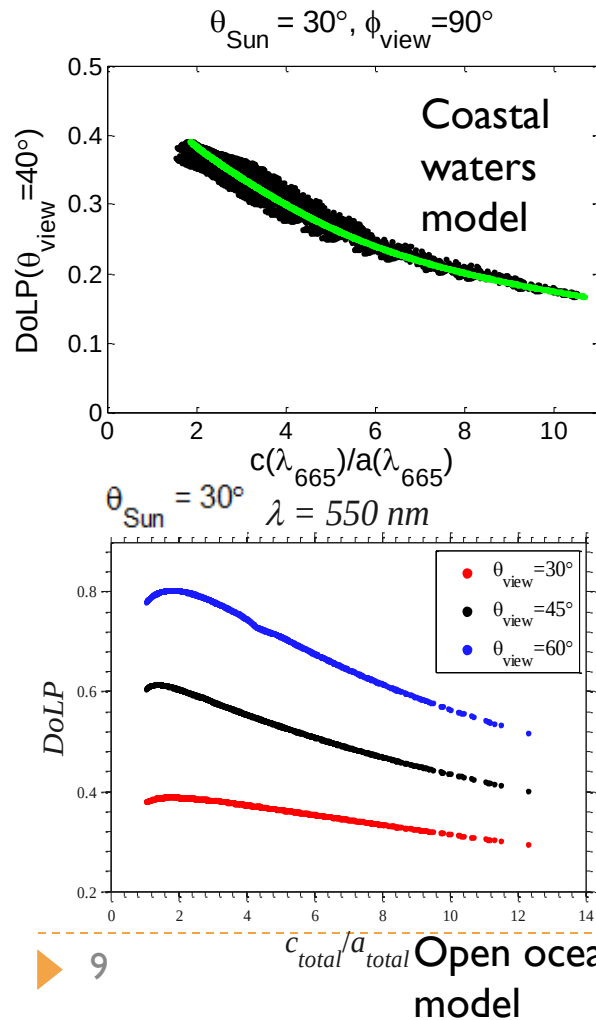


depolarization ratio, z



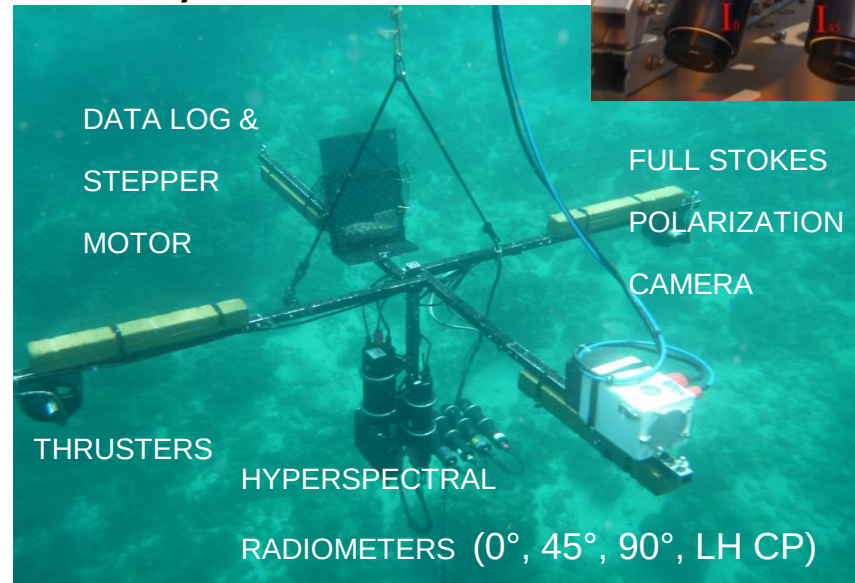
Polarization light fields

Expected DoLP vs c/a relationships
based on extensive RT simulations



HyperSAS-POL for
underway measurements

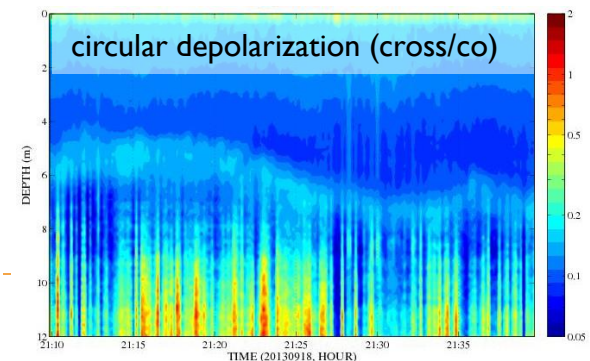
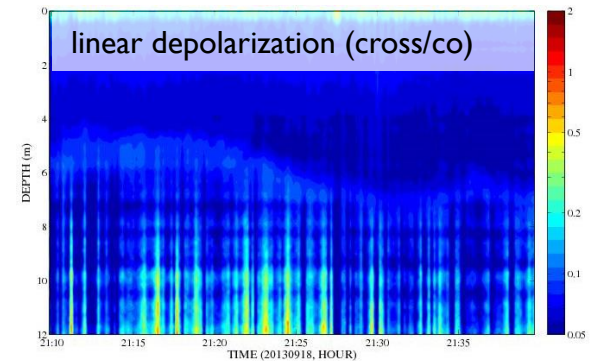
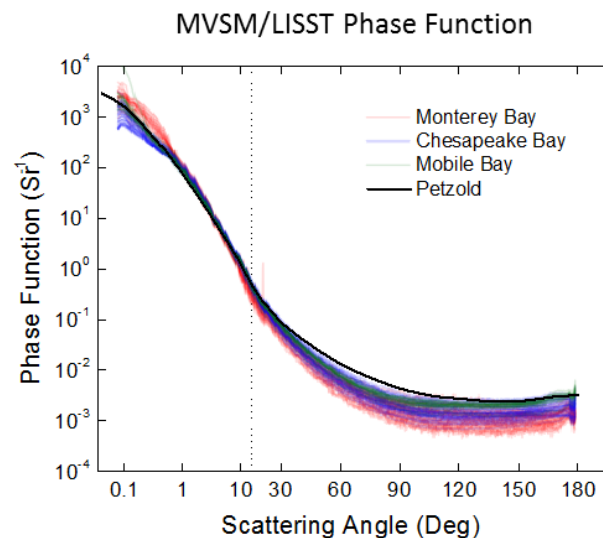
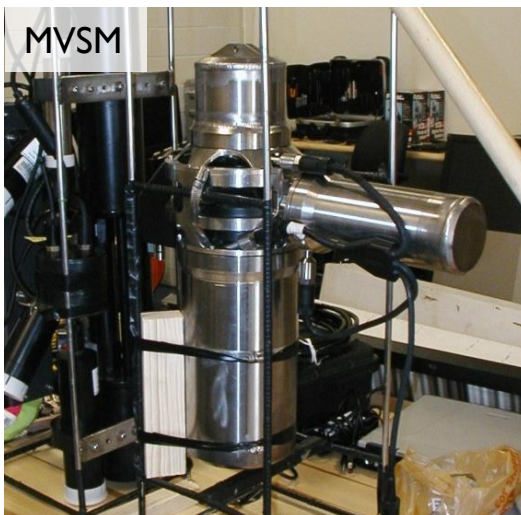
Underwater polarimeter-
camera system

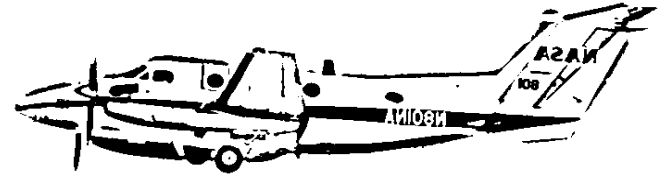


In situ VSF & ship-based Polarimetric Lidar

Gray, Kearney & Gould

Sensor	Measurement
MVSM	β (0.5 - 179°) at 443, 490, 510, 532, 555, 565, 590, 620 nm
LISST-100X	β (0.08 - 13°) at 532 nm
Polarimetric lidar	532 nm laser and four receiver channels





Aircraft based measurements

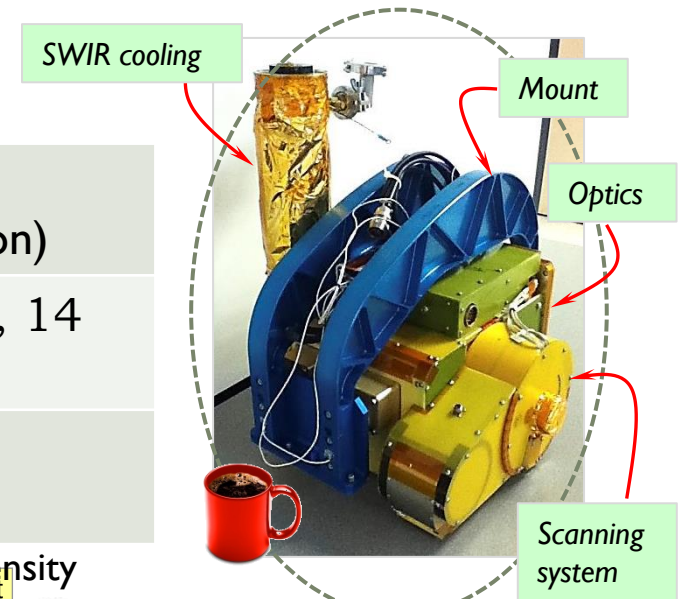


Airborne Research Scanning Polarimeter

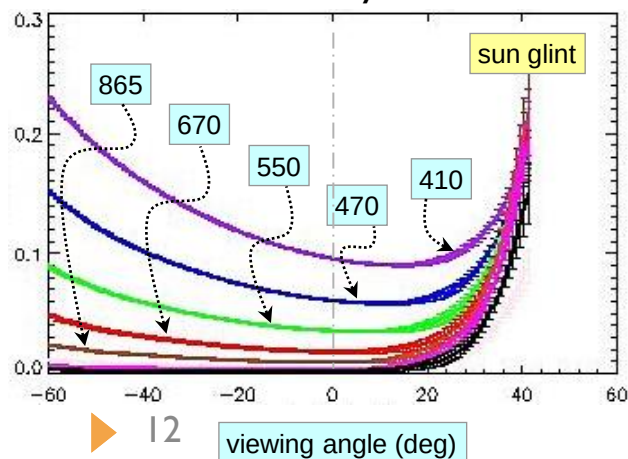
Chowdhary and Cairns

RSP obtains multiangle and multispectral measurements of intensity and of linear polarization for each pixel along the ground track

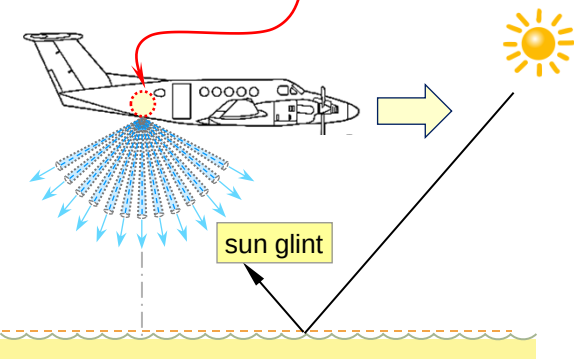
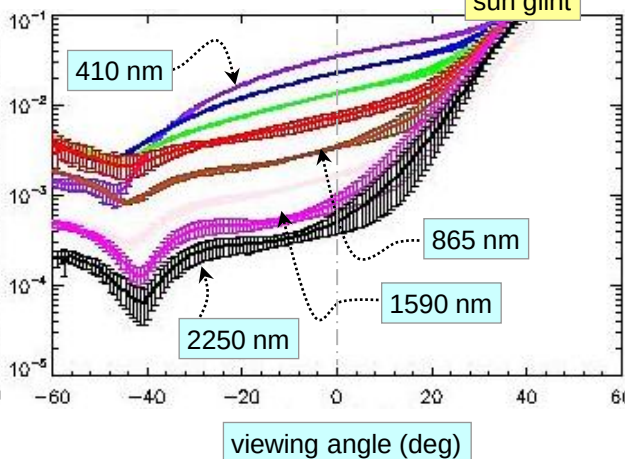
Radiances	Stokes parameter I (Intensity) Stokes parameters Q & U (Linear Polarization)
views	152 viewing angles, $\pm 60^\circ$ from nadir, 14 mrad IFOV
wavelengths	9 bands, 410 – 2250 nm, 20 nm bandwidth in VIS



Normalized Intensity



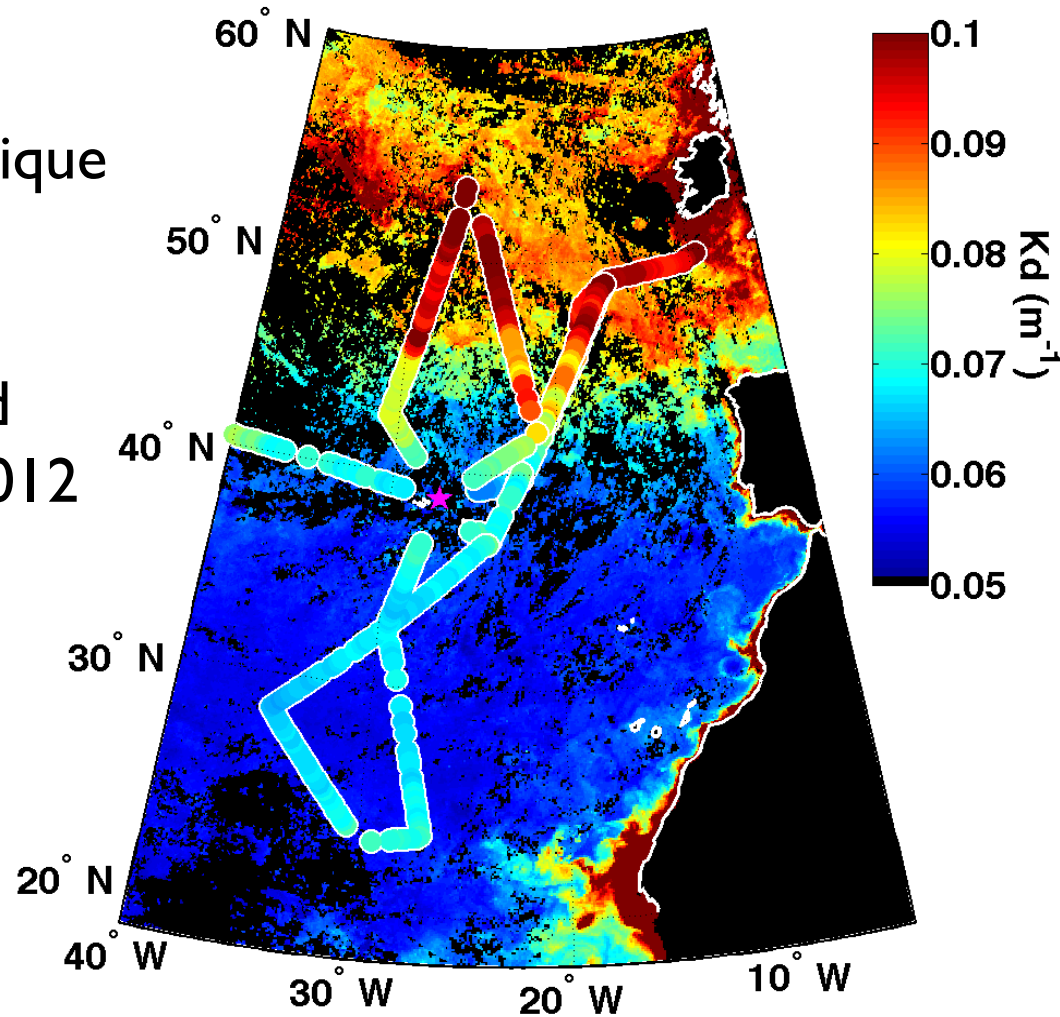
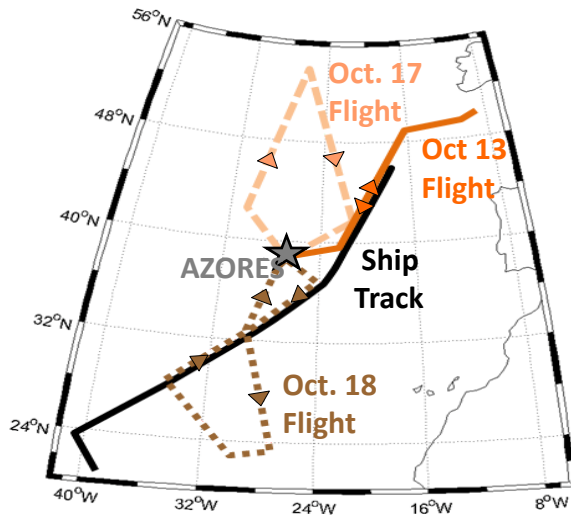
Normalized Linear Polarized Intensity



Improving and validating lidar retrievals

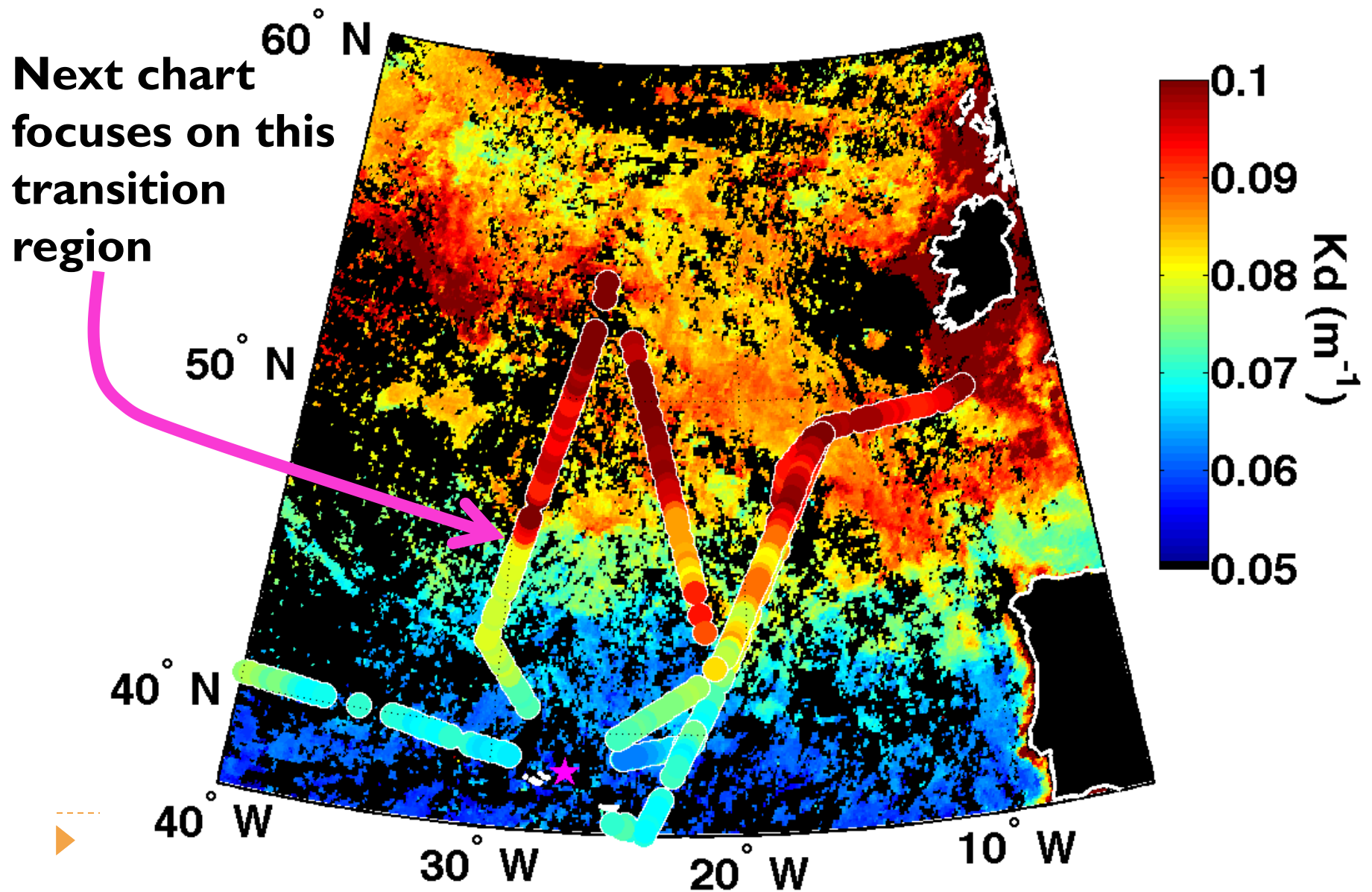
Hostetler, Hu, Hair, & Behrenfeld

- Employing the High Spectral Resolution Lidar (HSRL) technique to make quantitative profile retrievals of b_{bp} and K_d
- Preliminary data were acquired from the Azores in October 2012



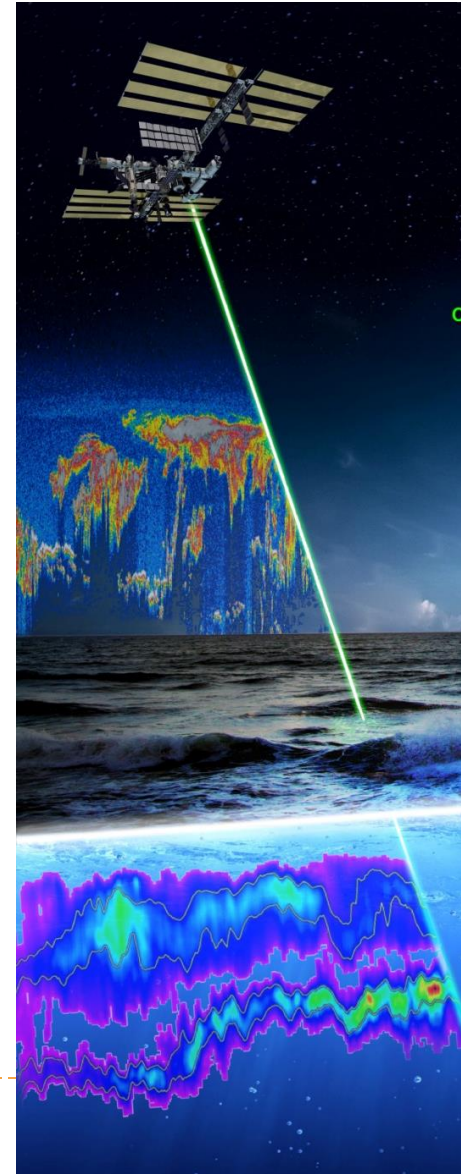
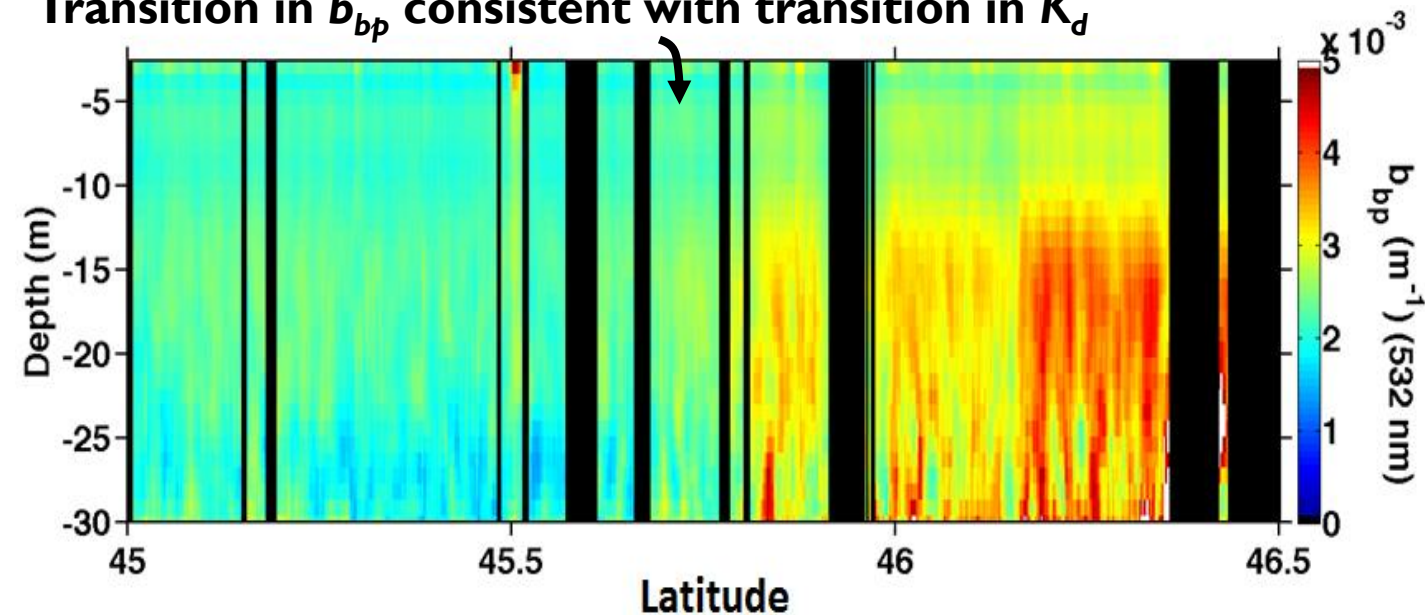
HSRL-I retrieval of K_d (532 nm) along flight tracks.
Background is MODIS K_d scaled to 532 nm

Lidar Kd Retrieval at 532 nm



b_{bp} retrieved from HSRL-1 lidar in the transition region

Transition in b_{bp} consistent with transition in K_d



- ▶ Azores mission provided first-ever independent profiles of K_d and b_{bp} from lidar
- ▶ The HSRL-I has since been modified to improve the technique
- ▶ SABOR will vet the techniques planned a space version of the lidar: OPAL – Ocean Profiling and Atmospheric Lidar

SABOR Deployment



SABOR Deployment: 19 July – 5 Aug

20-day cruise

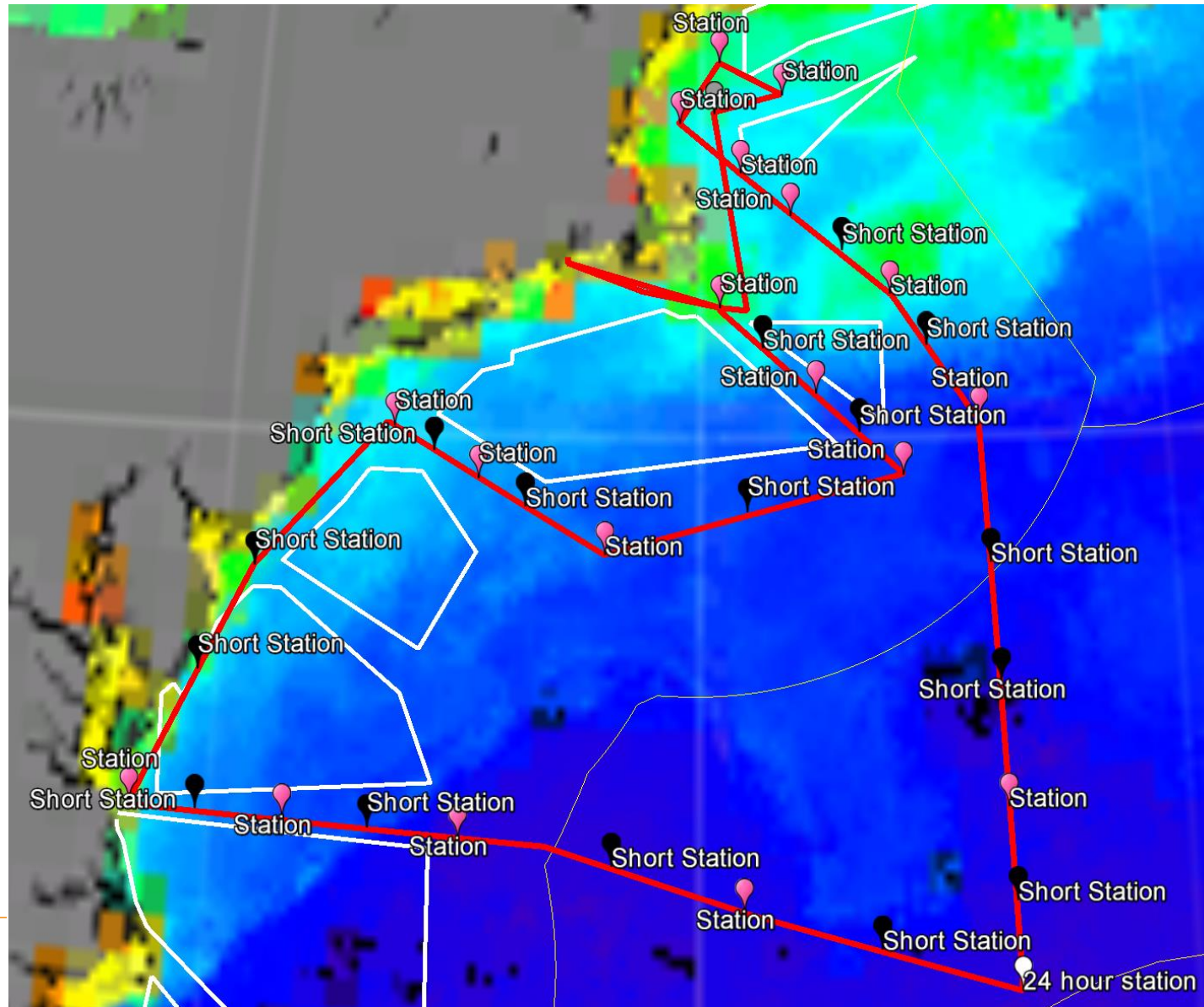
**Ship outfitted with
optical and
constituent
measurements**

**Aircraft deploying
lidar and
polarimeter**

**NASA B200
Aircraft**



**UNOLS Research
Vessel**



SABOR: Summary

- ▶ Ship + Airplane experiment
- ▶ Across-fields collaboration = Synergistic results
- ▶ showcase for future of polarization measurements in field of oceanic biogeochemistry?
- ▶ Look for our posters/talks on Ocean Optics and 2015 OCRT

Thank you

