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Abstract

The NOAA/STAR Ocean Color team is focused on “end-to-end” production of ocean color satellite products. In situ validation of satellite data is essential to producing the high-quality products required and expected by the international ocean color remote-sensing community. In November 2014, a 10-day cruise was conducted aboard the NOAA Ship *Nancy Foster* in the western Atlantic along the US mid-east coast with the primary aim of in situ calibration and validation of the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument onboard the Suomi National Polar-orbiting Partnership (SNPP) satellite. This was the first NOAA dedicated VIIRS ocean color validation cruise supported through the NOAA Office of Marine and Air Operations. Collaborating groups included: Naval Research Laboratory; University of Southern Mississippi; City College of New York; University of Massachusetts at Boston; University of South Florida; University of Miami; Lamont-Doherty Earth Observatory at Columbia University; the National Institute of Standards and Technology, NASA/Goddard Space Flight Center and the Joint Research Centre of the European Commission. We present the scope of the observations of inherent and apparent optical properties made in support of the three primary objectives: 1) VIIRS ocean color validation; 2) uncertainty characterization of in situ ocean color measurements and 3) optical characterization of ocean variability. Cruise data will be reposit at NOAA CoastWatch/OceanWatch for convenient public access and will be archived as required by NOAA. A second dedicated VIIRS ocean color cruise is planned for late 2015 and additional NOAA ocean color cruises are anticipated for different regions in the future.



Fig. 1 NOAA Ship *Nancy Foster*.

Cruise Objectives

- Observe in situ properties for VIIRS ocean color satellite validation
- Determine uncertainties associated with in situ ocean color measurements
 - among identical instruments and protocols
 - from different instrumentation
 - from different sampling protocols
 - from different post-processing methods
 - from spatial and temporal variability
- Validate ocean processes

Cruise Track and Stations

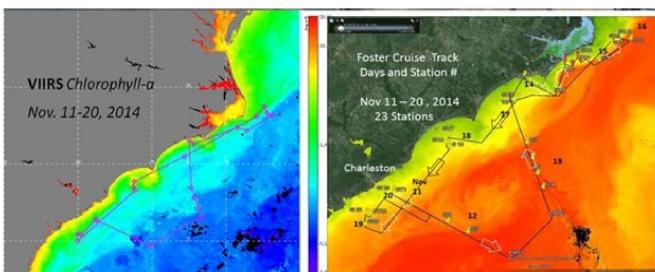


Fig. 2. Cruise track overlaid onto NOAA MSL12 VIIRS composite image of chlorophyll-a concentration [mg m^{-3}] (left); cruise track overlaid onto VIIRS Naval Research Laboratory (NRL) composite image of sea surface temperature (right). Both satellite images are time-binned 11-20 November 2014, the time period of the cruise.

On Station Measurements

In water profiling of ocean radiometry - AOPs

Four instruments deployed simultaneously (HyperPro x2; MicroPro; C-OPS)

In water profiling of IOPs

- Multiple optical packages deployed to measure
- Total absorption
 - CDOM absorption
 - Scatter, Backscatter
 - Fluorometry (chlorophyll, CDOM, phycoerythrin)

In water profiling of other parameters

- Conductivity (salinity)
- Temperature
- Dissolved O_2

Surface floating radiometry

- HyperTSRB (Satlantic)
- Sky-Blocking Apparatus (SBA)
- Upwelling Radiance Distribution Camera System (NURADS)

Above water observations of ocean radiometry

Five instruments (ASD x3; GER; SR1900) with three gray cards and one blue glass tile developed by NIST

Sun Photometry - 5 instruments - Microtops



Fig. 3. Four profiling radiometers deployed simultaneously.



Fig. 4. Skylight-blocked approach (SBA).

Continuous Underway Measurements

Flow-through continuous measurements

- Absorption
- Beam attenuation/scattering
- Backscattering
- Dynamic imaging particle analysis (FlowCam)
- CDOM fluorescence, phytoplankton functional groups, chlorophyll and phycobilipigments, major phytoplankton groups (ALF, bbe AlgaeOnlineAnalyser)
- Phytoplankton photosynthetic competency (Mini FIRE)
- SST, salinity, chlorophyll fluorescence (from ship's system)

On deck continuous measurements

Several above water hyperspectral radiometry optical systems:

- HyperSAS, HyperSAS-POL, TRIoS, Bow-mounted HyperPro

Other continuous measurements (from ship's onboard systems)

- Acoustic Doppler Current Profiler (ADCP)
- Meteorology and environmental data (i.e., wind speed and direction, sea state, air temperature)
- Radiance integrated from 400 to 700 nm (PAR)

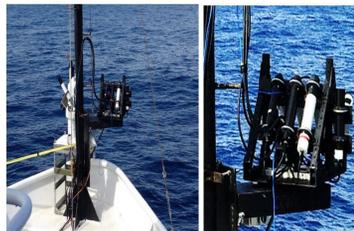
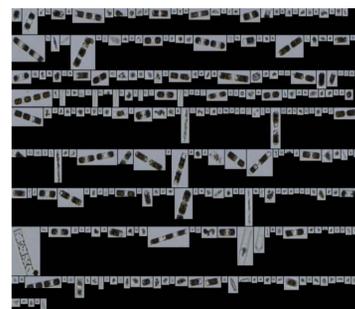


Fig. 6. HyperSAS-POL on the mast at the bow of the ship.

Fig. 7. Collage showing the diversity of phytoplankton communities imaged by the FlowCam.



Water Sampling and Analyses

Samples collected from Rosette bottles (discrete depths) and from underway flow-through system

- HPLC phytoplankton pigment analyses
- CDOM absorption
- Dissolved organic carbon
- Particulate organic carbon and particulate nitrogen
- Fluorometric extracted chlorophyll
 - acidification method
 - non-acidification narrow-band method
- Total suspended matter
- Particle fluorescence and digital imaging (FlowCam)
- Variable fluorescence – Mini-FIRE
- Advanced Laser Fluorometer - ALF
- Phycobilipigment concentration
- Filter pad spectral absorption

Instrument Calibrations

Pre- and post-cruise inter-calibrations of radiometers were conducted at the NOAA Optical Characterization Experiment Laboratory in College Park, Maryland using National Institute of Standards and Technology (NIST) traceable FEL-1000 Watts lamp #667 for irradiance, and an Optronic Laboratories OL-455 integrating sphere for radiance.

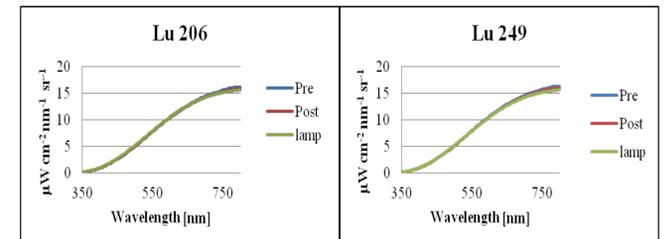


Fig. 8. Example of the pre- and post-cruise inter-calibration of the NOAA/STAR (*Lu 206*) and USF (*Lu 249*) radiance sensors used in the Nov. 2014 Cal/Val cruise. The lamp radiances are the expected calibration source radiances. The pre- and post calibration measurements are the measured values of the lamps using each specific instruments original calibration.

Participating Institutions

International:
 • Joint Research Centre of the European Commission

Universities:
 • U. Southern Mississippi
 • U. Miami
 • U. South Florida
 • U. Massachusetts – Boston
 • City College of NY
 • LDEO at Columbia

US Agencies:
 • NOAA/STAR
 • NASA/GSFC
 • National Institute of Standards and Technology (NIST)
 • Naval Research Lab (Stennis)



Fig. 9. Cruise participants (15 scientists) aboard the NOAA Ship *Nancy Foster*.

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