Past Observations and Future Challenges for Ocean Colou Remote Sensing

Charles R. McClain
Code 616, Ocean Ecology Laboratory
NASA Goddard Space Flight Center

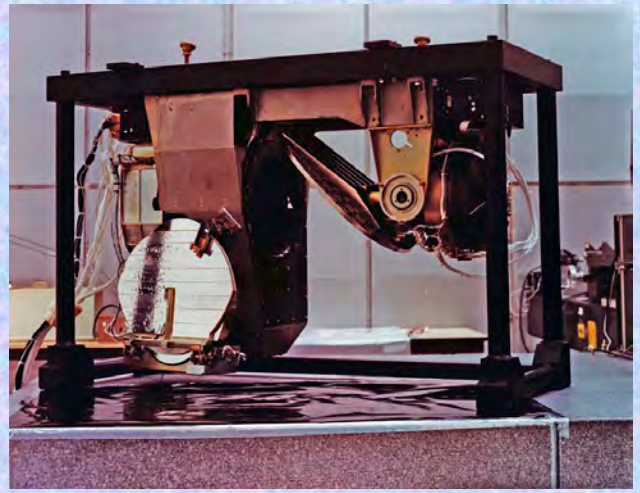
First International Ocean Colour Science Meeting
Darmstadt, Germany, May 6-8, 2013

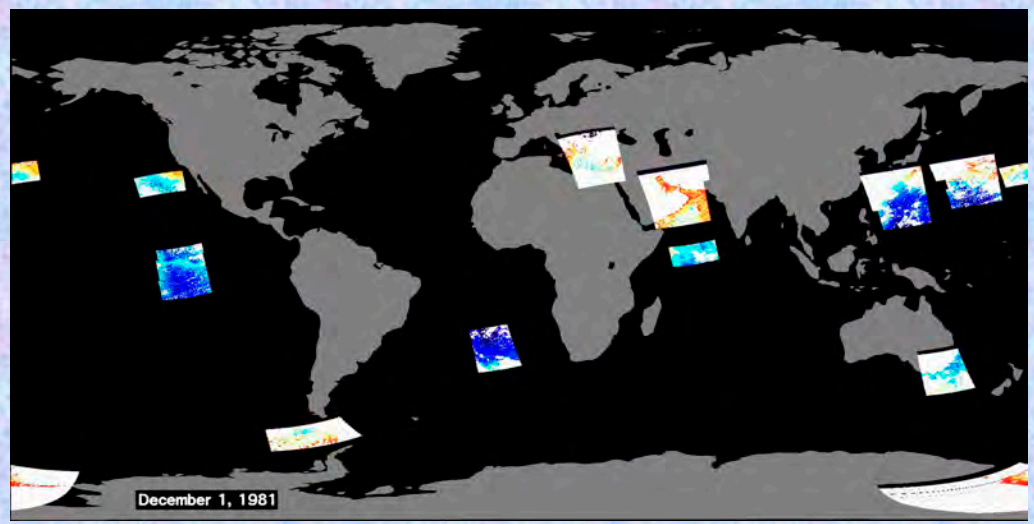
Ten Major Steps Forward for Satellite Ocean Biological-Biogeochemical Science

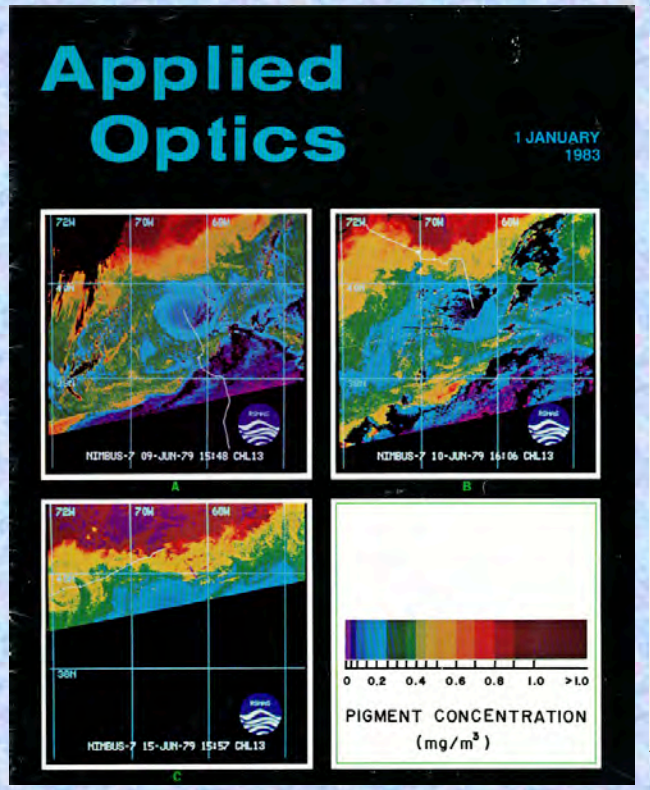
- Nimbus-7/CZCS demonstration & experiment team
- Global CZCS reprocessing
- SeaWiFS Project Office
- SeaDAS
- MOBY & vicarious calibration methodology
- Atlantic Meridional Transect
- International Ocean Colour Coordinating Group
- SIMBIOS Project
- Bio-optical algorithms: empirical to semi-analytic
- Chlorophyll-a multi-sensor Climate Data Record

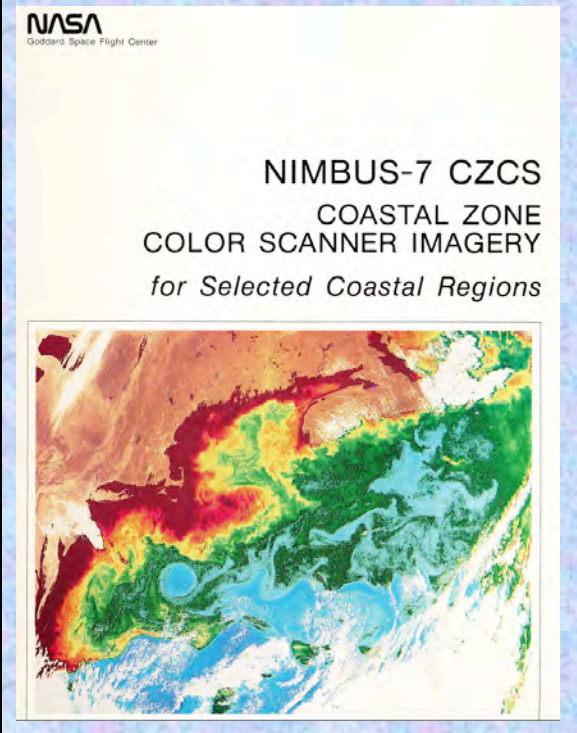
Coastal Zone Color Scanner Demonstration

(1978-1986)





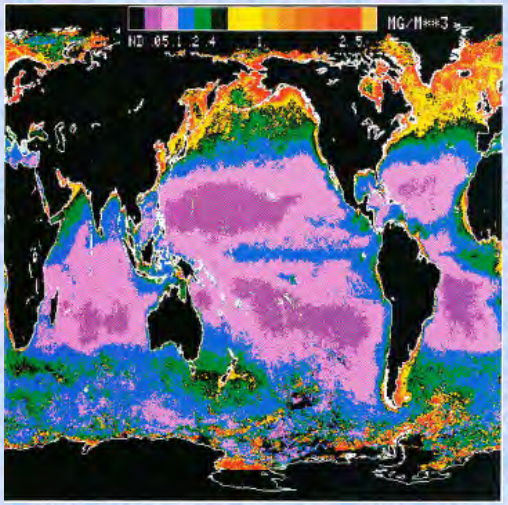


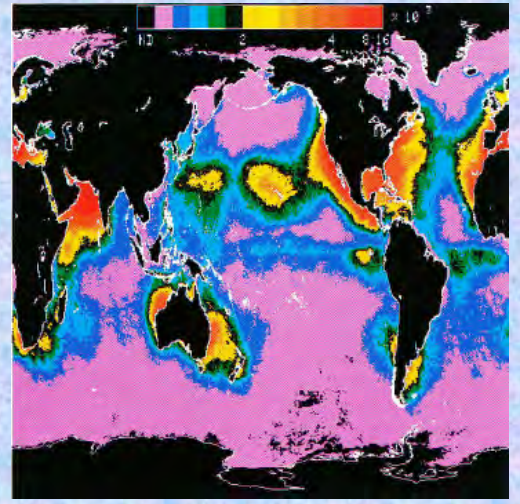


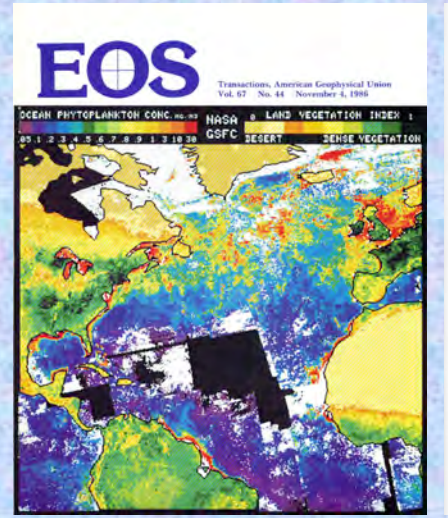
Nimbus-7 CZCS Experiment Team (NET)

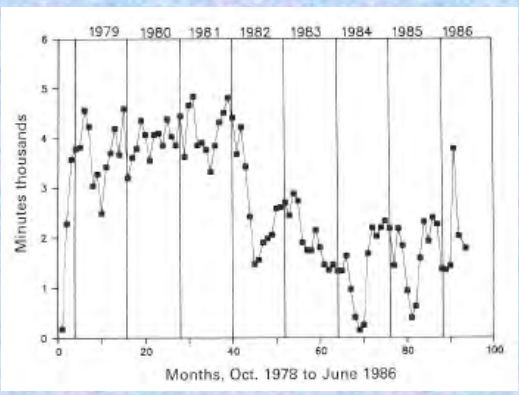
- **Warren Hovis (PI)**
- Howard Gordon
- Ross Austin
- Dennis Clark
- Charlie Yentsch
- Jim Mueller
- Boris Sturm
- Sayed El-Sayed
- Bob Wrigley
- Frank Anderson
- Ed Baker
- John Apel

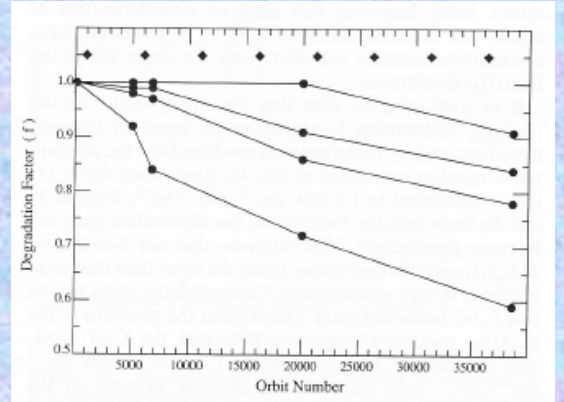
Coastal Zone Color Scanner Reprocessing (1985-1989)





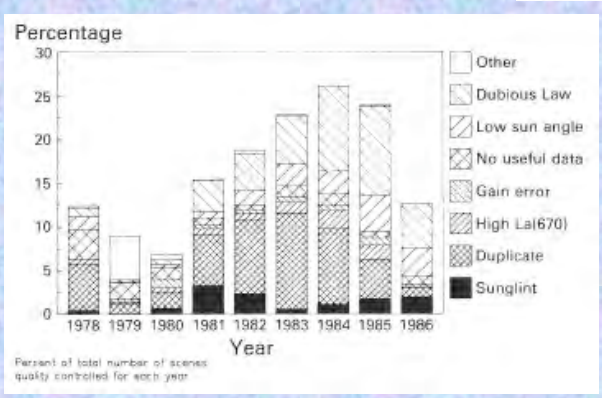


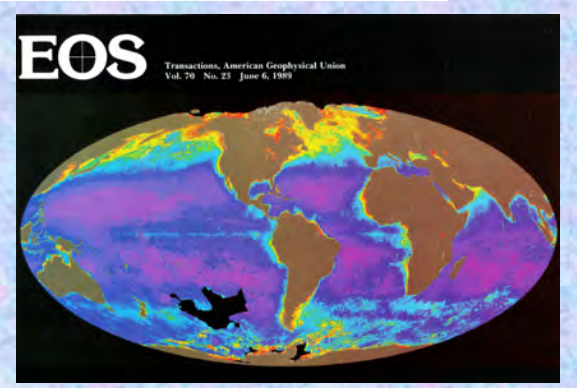




Reprocessing Team

- Wayne Esaias (PI)
- Chuck McClain (QC)
- Gene Feldman (Production)
- Bob Evans (Calibration)



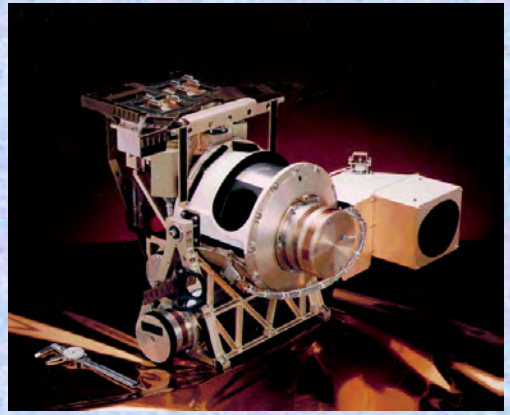


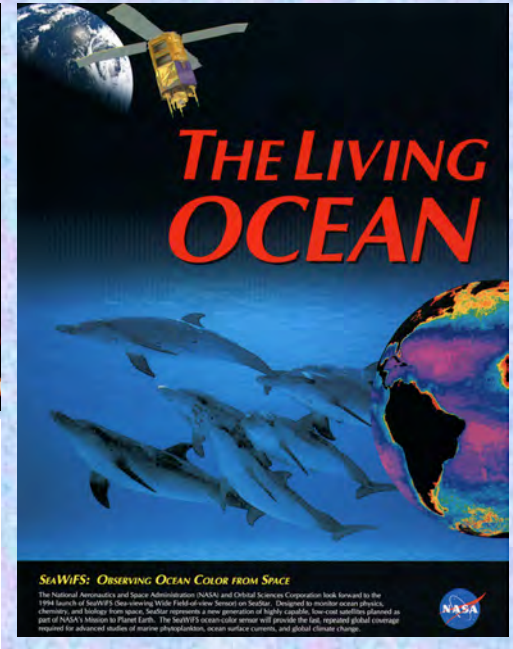
~ 5 years
~ 30,000
9-track tapes
~ 90,000 scenes

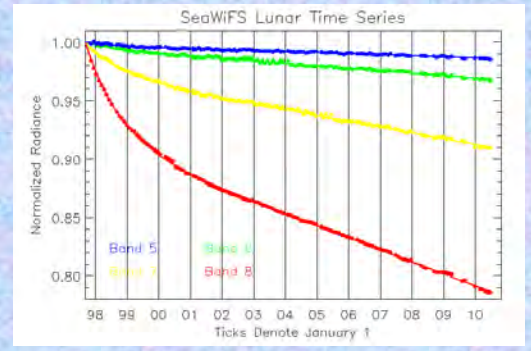
The SeaWiFS Project (1991-2010)

Notable Achievements

- Data-buy "insight, not oversight"
- "First-day" data access & graphical data ordering interface
- Lunar calibration method
- Technical Memorandum Series
- Open community participation
- SeaDAS
- SeaBASS
- In situ measurement protocols
- 1st OC climate quality data time series
- HRPT station support
- Calibration round-robins
- HPLC pigment analysis round-robins
- Data analysis round-robins
- NIR aerosol correction method (Gordon & Wang, 1993)
- Real-time field campaign support
- Community-based algorithms (e.g., chl-a, O'Reilly et al., 1999)
- Instrument development (e.g., SeaWiFS transfer radiometer)



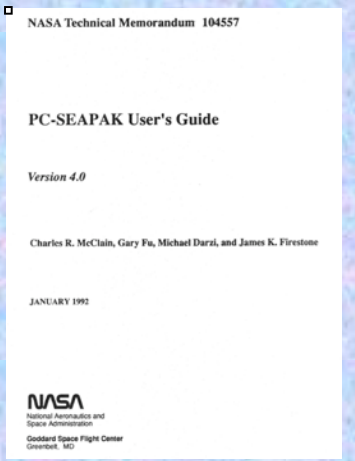




SeaDAS (1992-present)

Sensors Supported:

- CZCS (1978-1986)
- OCTS (1996-1997)
- SeaWiFS (1997-2010)
- MODIS/Terra (2001-present)
- MODIS/Aqua (2002- present)
- MERIS (2002-2012)
- Missions under evaluation/development
  - –ViiRS, OCM, HICO, and GOCI


NASA Technical Memorandum 104557

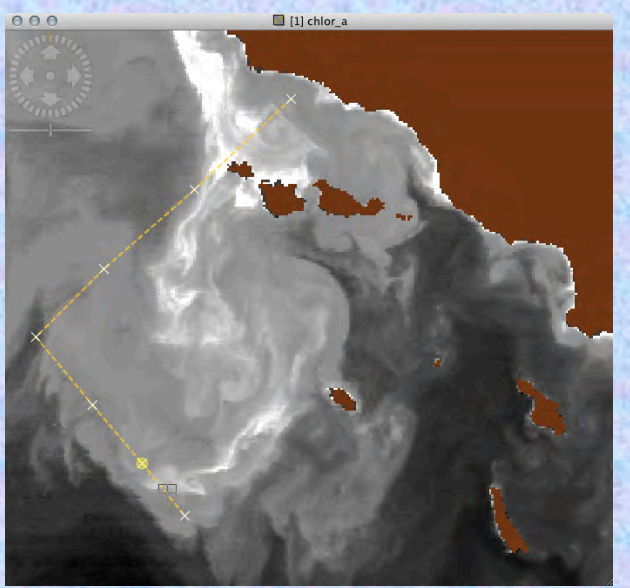
PC-SEAPAK User's Guide

Version 4.0

Charles R. McClain, Gary Fu, Michael Darzi, and James K. Firestone

JANUARY 1992

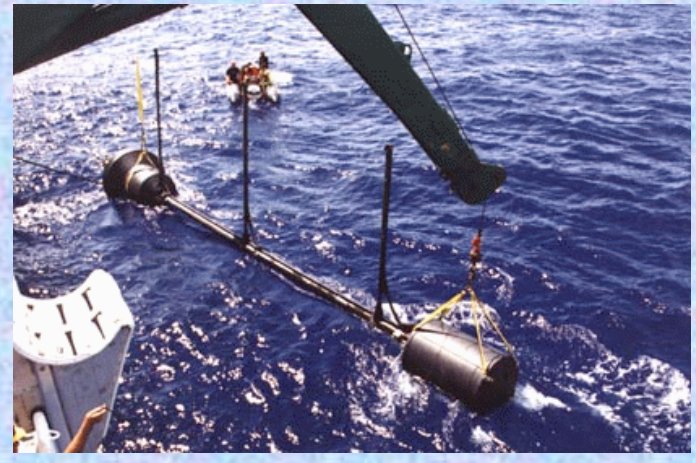
NASA
National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, MD

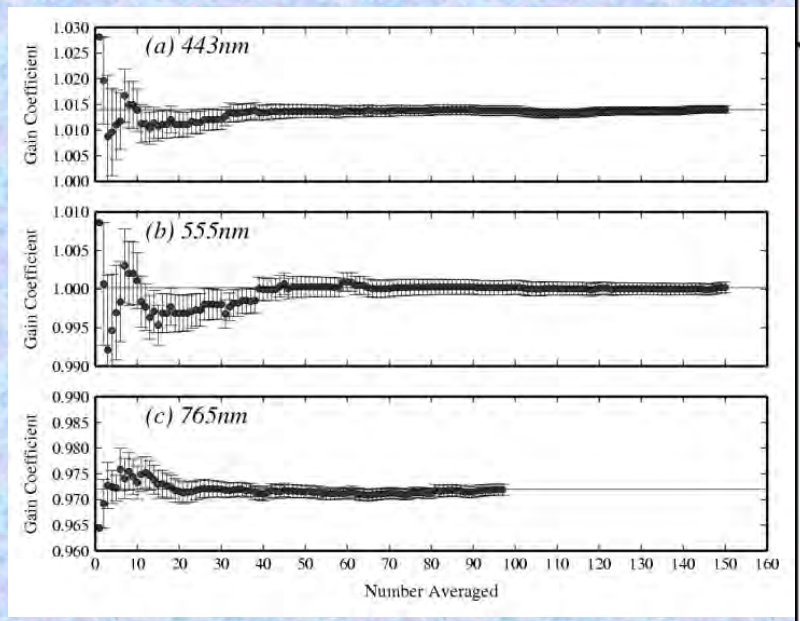


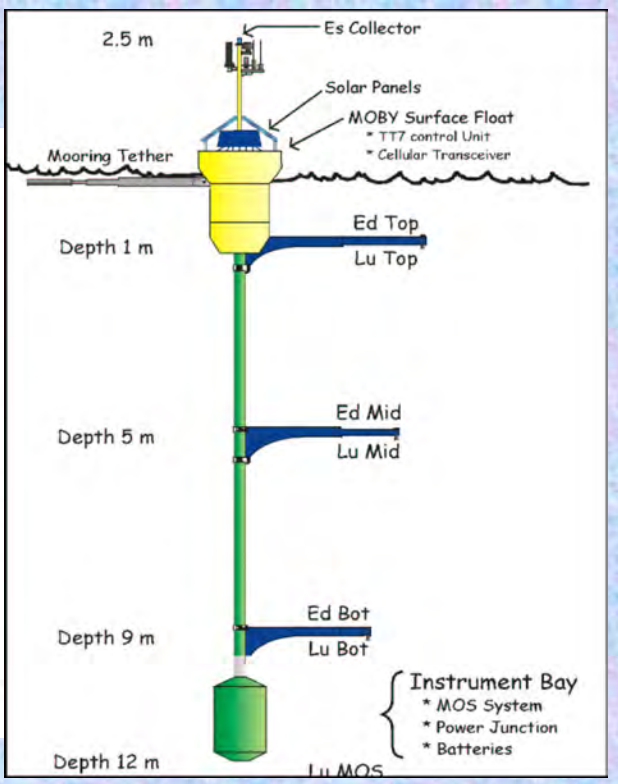
Marine Optical Buoy (MOBY)

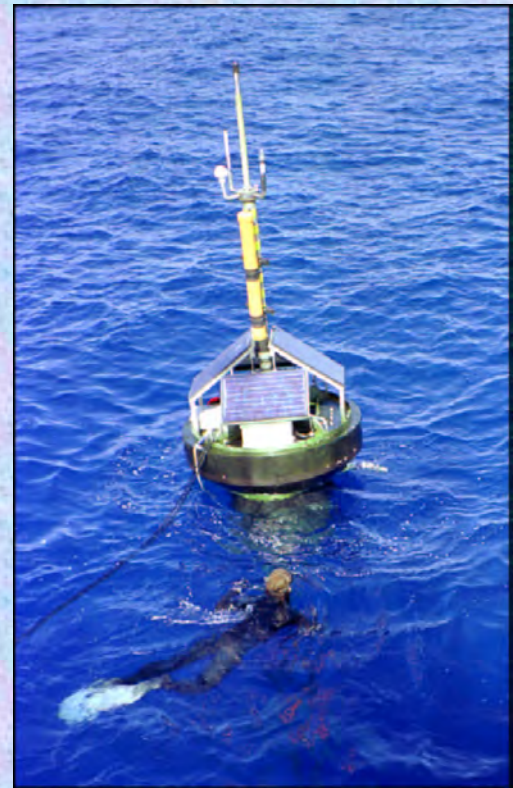
deployed 1996-present

Dennis Clark
Mark Yarbrough
Bill Broenkow
Carol Johnson
Mark Feinholz
Stephanie Flora
Chuck Trees
Ken Voss
Steve Brown

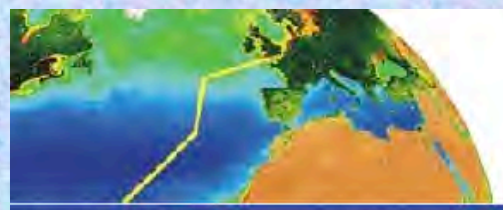








Atlantic Meridional Transect (1995-present)



Home | Contact Us | Site Map | Text Only Version

Atlantic Meridional Transect

Home | About AMT | Cruises | Data | Publications | AMT blog | Contact Us

Search

You are in : AMT - Atlantic Meridional Transect - Oceanographic research cruise

- Home
- About the AMT research
- Oceanographic research cruises
- AMT research data
- Publications
- AMT blog
- AMT - Contact us

The annual AMT voyage undertakes biological, chemical and physical oceanographic research in the Atlantic Ocean

The Atlantic Meridional Transect (AMT) is a multidisciplinary programme which undertakes biological, chemical and physical oceanographic research during an annual voyage between the UK and destinations in the South Atlantic - previously the Falkland Islands, South Africa and Chile, a distance of up to 13,500km. This transect crosses a range of ecosystems from sub-polar to tropical and from euphotic shelf seas and upwelling systems to oligotrophic mid-ocean gyres.

The programme was established in 1995 and since then has included 23 research cruises involving 223 scientists from 18 countries. AMT has proved to be a long-term multidisciplinary ocean observation programme, which is a platform for national and international scientific collaboration, a training arena for the next generation of oceanographers and an ideal facility for validation of novel technology.

The most recent AMT cruise departed from Southampton, UK on 10 October 2012 and arrived in Punta Arenas on 24 November 2012.

Expressions of interest are now invited for participation in AMT cruises in 2013 and beyond, please contact Andy Rees, apre@pml.ac.uk, for further details.

Latest news

- IMBER endorses AMT
  08 Nov 2012 | News
- AMT22 sails on 10 October
  28 Sep 2012 | News
- 05 Oct 2011 | Latest location
  Web news

Hosted at Plymouth Marine Laboratory in conjunction with the National Oceanography Centre.

PML | Plymouth Marine Laboratory

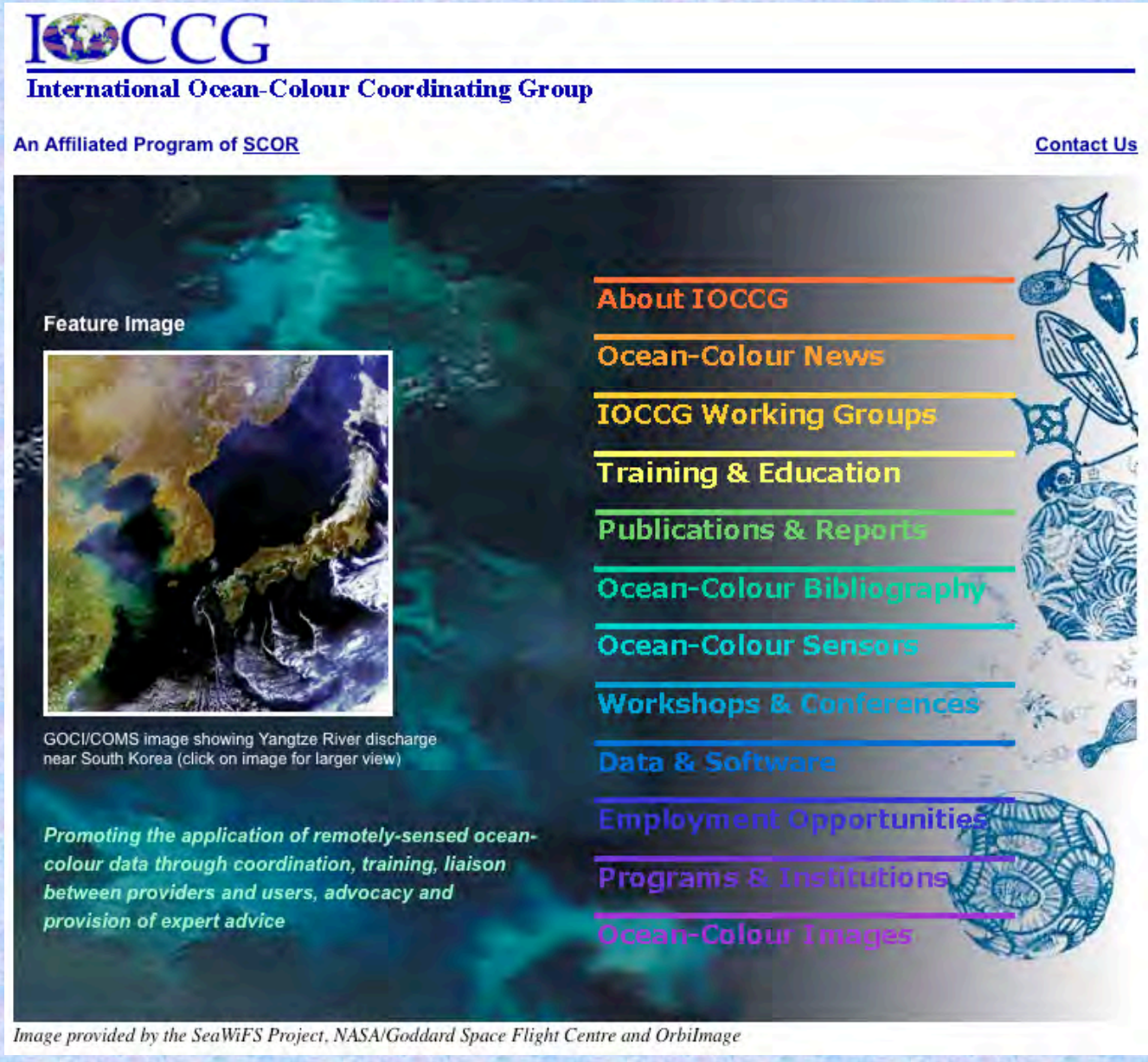
National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

International Ocean Colour Coordinating Group

1996-present

Chairs:
Trevor Platt
Jim Yoder
David Antoine
Project Coordinator:
Venetia Stuart

13 topical reports published to date.

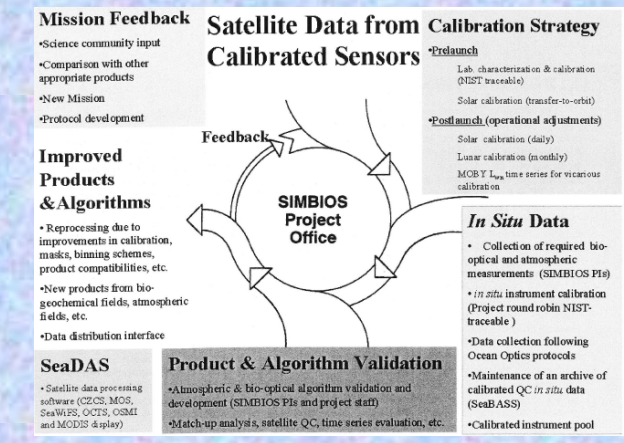


SIMBIOS (1997-2003)

(Sensor Intercalibration & Merger for Biological & Interdisciplinary Oceanic Studies)

Objectives:

- Ensure development of internally consistent research products & time series from multiple satellite ocean color data sources
- Develop methodologies for cross-calibration of satellite ocean color sensors
- Develop methodologies for merging data from multiple ocean color missions
- Promote cooperation between international ocean color projects



Organization

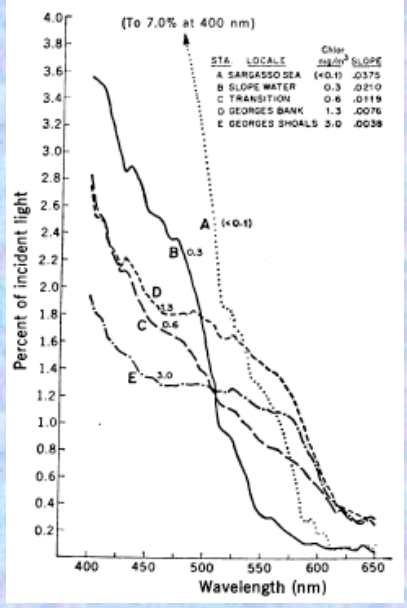
- SIMBIOS Project Office
- International Science Team

Activities

- Sensor evaluations (MOS, OCI, OSMI, OCTS, POLDER, MODIS)
- Calibration round robins (SIRREX)
- Coastal/Island AERONET sites (~12)
- Annual science team meetings
- In situ measurement protocols
- Annual project reports (Techical Memos)
- Instrument pool (Microtops, SIMBAD, etc.)
- SeaBASS support
- HPLC round robin
- Data merging methodologies

SIMBIOS International Science Team (#2)

Bio-optical Algorithms: Empirical to Semi-analytical



Clarke, Ewing, & Lorenzen, *Science*, 1970

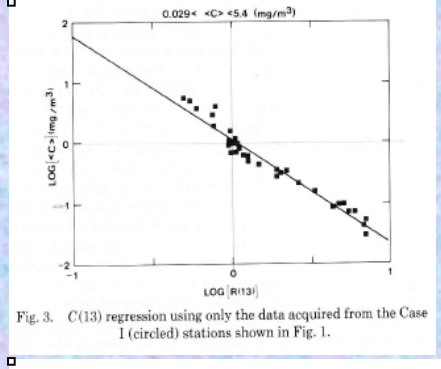


Fig. 3. C(13) regression using only the data acquired from the Case I (circled) stations shown in Fig. 1.

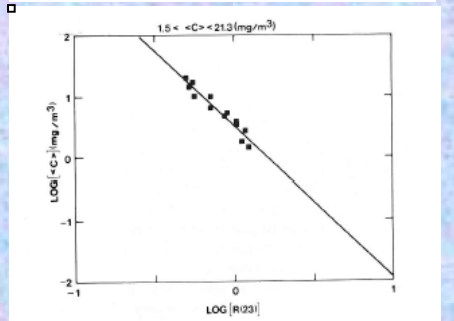
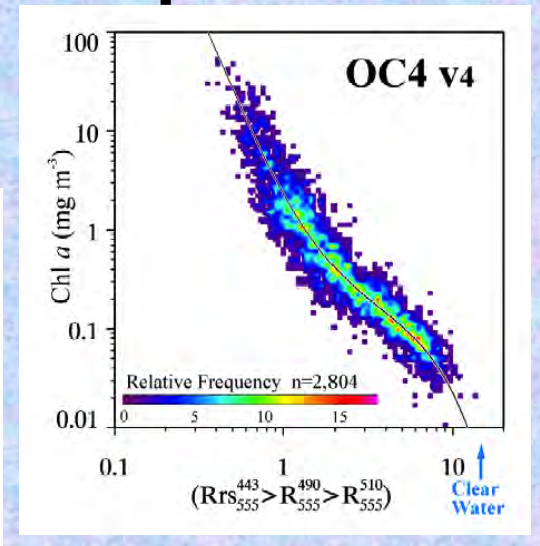
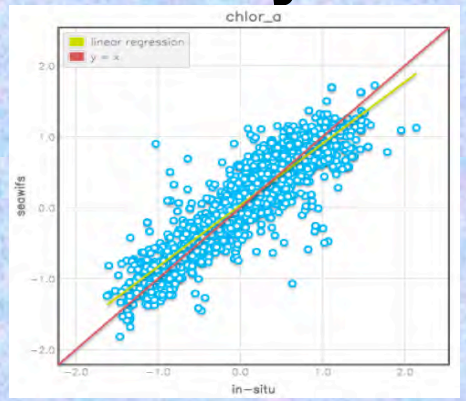


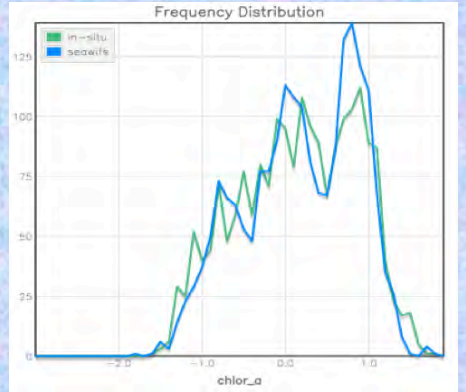
Fig. 5. C(23) regression using only the data from the stations in Fig. 1 for which ⟨C⟩ was in the 1.5–21.3-mg/m³ range.

Gordon et al., *Appl. Opt.* 1983



O' Reilly et al., *Appl. Opt.*, 1998





SeaWiFS chl-a retrievals

Present Validated Products

- Chlorophyll-a
- Diffuse attenuation coefficient (490 nm)

Current Unvalidated Research Products

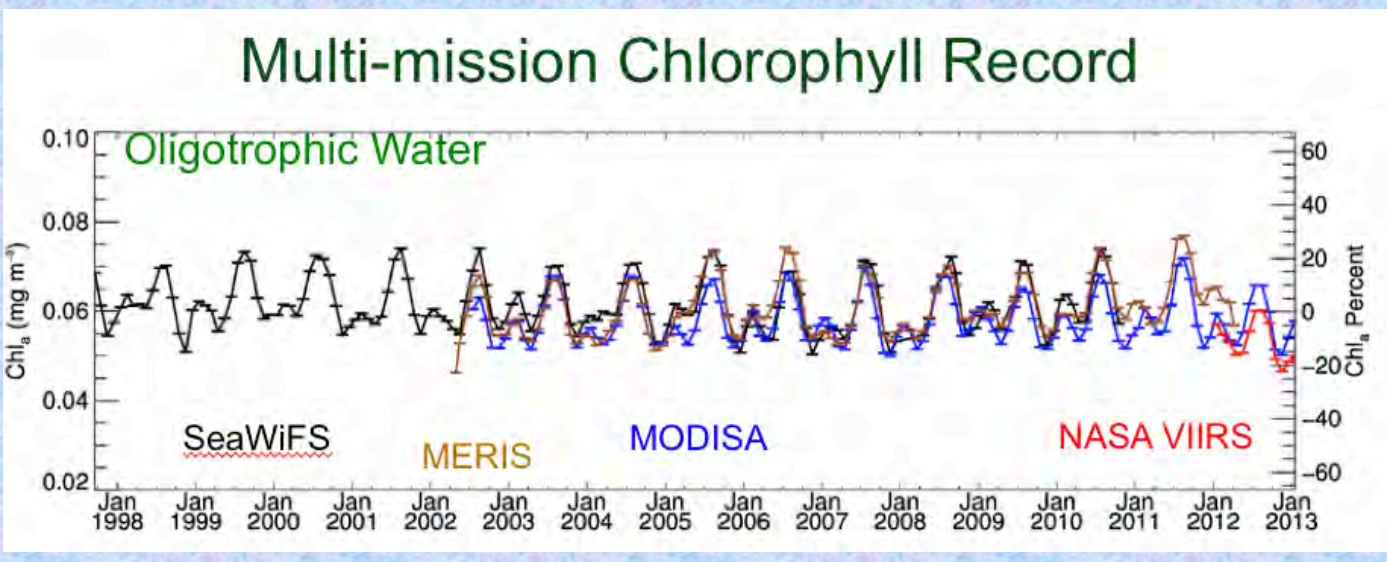
- Inherent optical properties
- Spectral diffuse attenuation
- Euphotic depth
- Spectral remote sensing reflectance
- Particulate organic carbon concentration
- Primary production
- Calcite concentration
- Colored dissolved organic matter
- Photosynthetically available radiation
- Fluorescence line height
- Total suspended matter
- Trichodesmium concentration

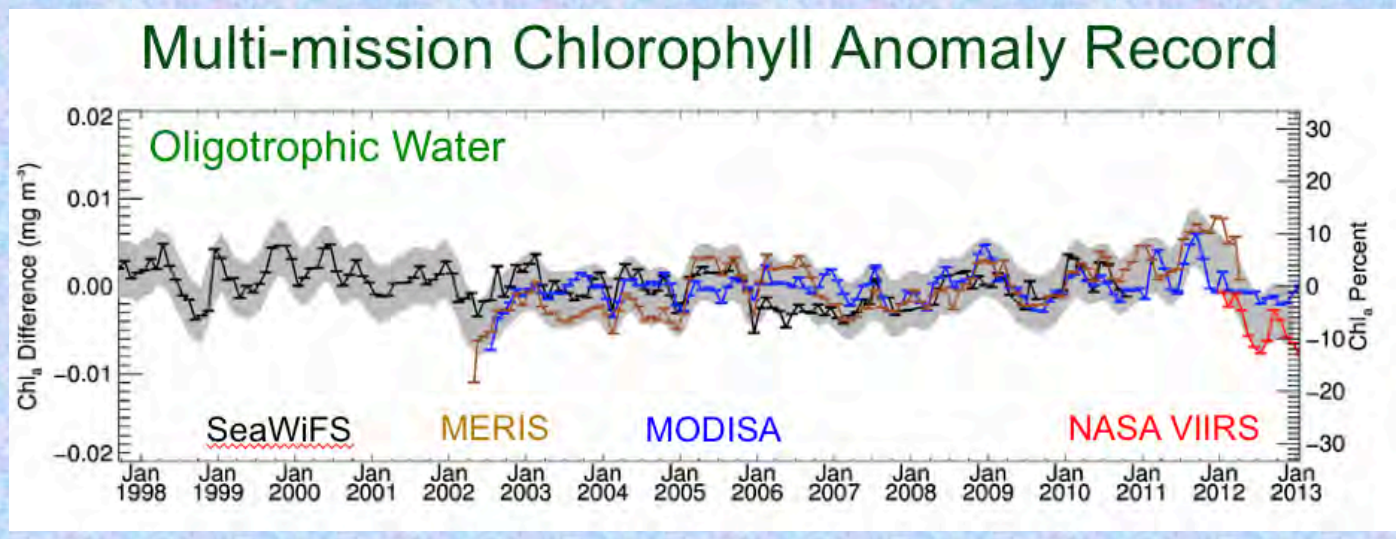
Future Research Products

- Particle size distributions & composition
- Phytoplankton carbon
- Dissolved organic matter/carbon
- Physiological properties (e.g., growth rates)
- Fluorescence quantum yield
- Phytoplankton pigment absorption spectra
- Export production
- Functional/Taxonomic groups

Chlorophyll-a Multi-sensor Climate Data Record

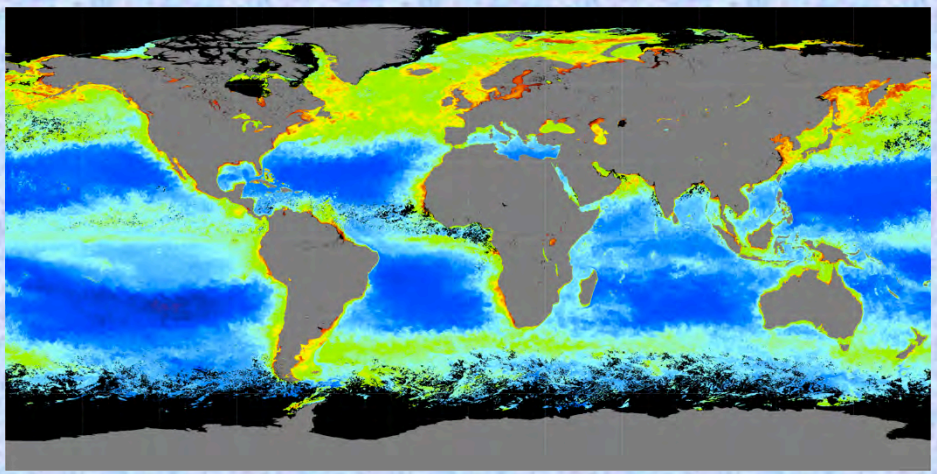
- Multiple sensors of different design
- Different degradation modes
- Common data processing algorithms & methodologies
  - Calibration*
  - Atmospheric correction
  - Bio-optical
  - Masks & Flags



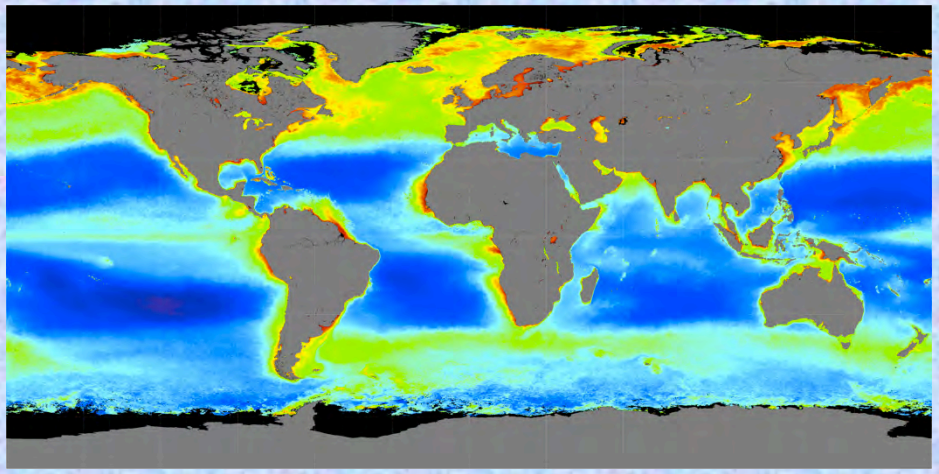


* MERIS on-orbit calibration is not lunar-based.

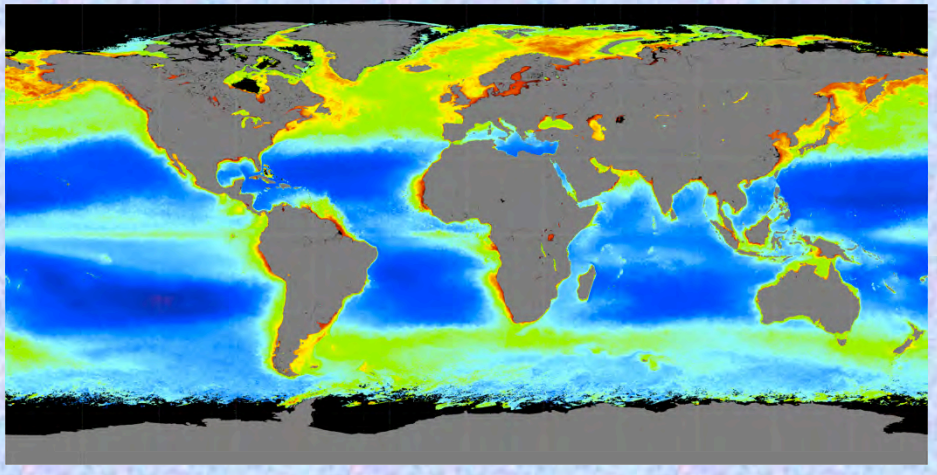
Data Product Consistency Across Global OC Sensors



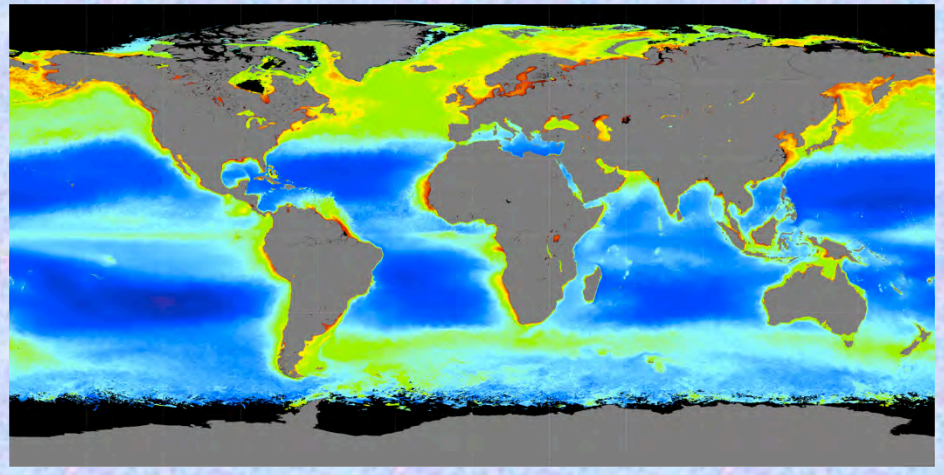
Spring 2012 - VIIRS



Spring Climatology - SeaWiFS



Spring Climatology - Aqua/MODIS



Spring Climatology - Terra/MODIS

Chlorophyll a concentration (mg / m^3)

0.01 0.03 0.1 0.3 1 3 10

Honorable Mention

(in no specific order)

- **Field programs**
  - Venice tower time series
  - BATS optical time series
  - AERONET-OC/SeaPRISM
  - Boussolle optical mooring time series
- **International cooperative activities**
  - Oceanography from Space conferences
  - Japan US Working group in Ocean Color (JUWOC)
  - NASDA-NASA OCTS reprocessing collaboration
  - HPLC Round-Robins (SeaHARRE)
- **Algorithms**
  - Gordon & Clark clear water radiance concept
  - Gordon-Wang atmospheric correction scheme
  - Behrenfeld-Falkowski primary production algorithm
- **OC Sensor Engineering**
  - LEO (Global): OCTS, POLDER, SeaWiFS, MODIS, MERIS, GLI
  - Geostationary: GOCI

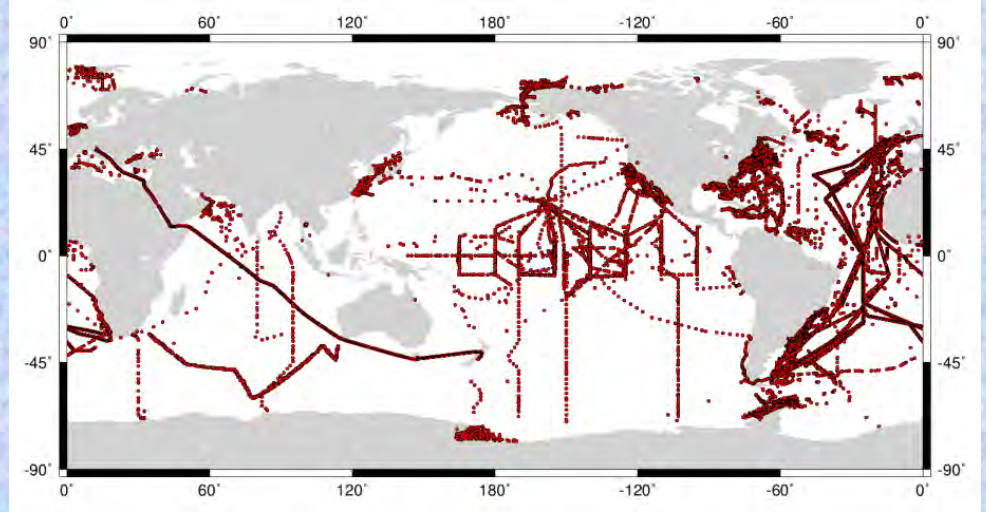
Future Science: How do we get there?

Present Validated Products
- Chlorophyll-a
- Diffuse attenuation coefficient (490 nm)

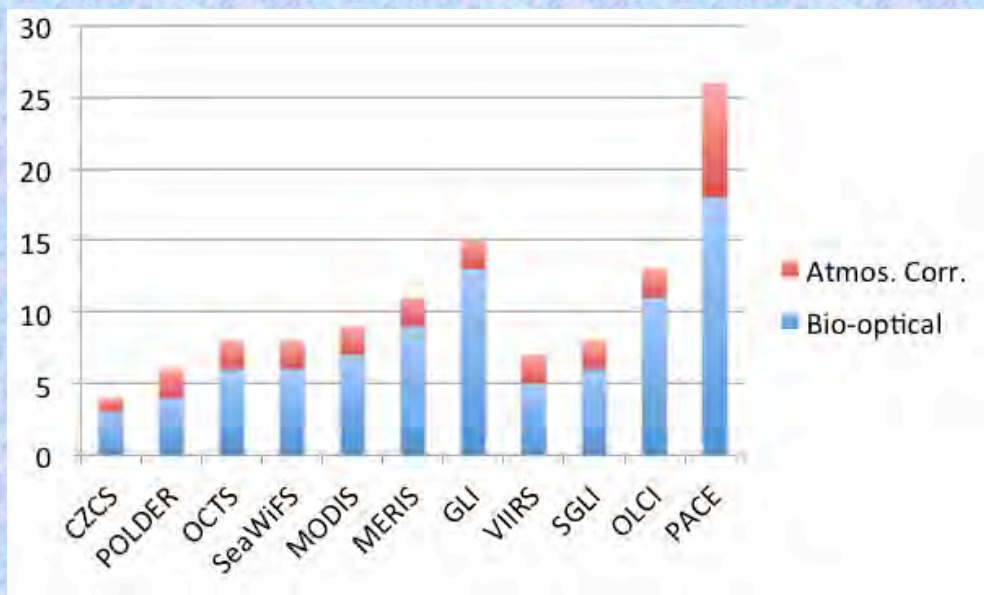
Current Unvalidated Research Products
- Inherent optical properties
- Spectral diffuse attenuation
- Euphotic depth
- Spectral remote sensing reflectance
- Particulate organic carbon concentration
- Primary production
- Calcite concentration
- Colored dissolved organic matter
- Photosynthetically available radiation
- Fluorescence line height
- Total suspended matter
- Trichodesmium concentration

Future Research Products
- Particle size distributions & composition
- Phytoplankton carbon
- Dissolved organic matter/carbon
- Physiological properties (e.g., growth rates)
- Fluorescence quantum yield
- Phytoplankton pigment absorption spectra
- Export production
- Functional/Taxonomic groups

SeaBASS Chl-a:
most sampled biogeochemical parameter



OC sensor spectral bands
Note: PACE/OES is hyperspectral (350-800nm)



Present & Future Challenges

- Mission opportunities & space agency budgets & priorities
  - Increasing requirements for more capable sensors
    - Technology not an issue, but cost & complexity can be
  - Competition for resources between science disciplines (Earth & space)
- Field measurements and related technology
  - In situ measurement requirements (increasing product suite/ diversity, consistent well-defined measurement protocols)
    - Need much more in situ data for most current & future derived products
  - Limited instrument development funding through present programs
- International cooperation
  - Coordination to minimize mission redundancies & optimize constellation to satisfy diverse science requirements
    - Global science vs. regional management
    - Combination of Low Earth Orbit (LEO) and Geostationary
  - Differing national policies on data and S/W sharing (field & satellite)
  - Collaboration on common infrastructure support (e.g., an international vicarious calibration strategy/system)
  - Joint Cal/Val cruise/field campaign program
  - Sponsorship of round-robin & protocol development activities

Some Suggestions

- International strategy on OC missions and science objectives
  - Low earth orbit: global, infrequent temporal
    - IOCCG Report #13
  - Geostationary: regional, high frequency temporal
  - Other ? (asynchronous, ocean-aerosol lidar, etc.)
- Pursue joint missions & partnerships
  - Defray launch, spacecraft, sensor, ground system, data processing, calibration/validation, science costs
- Coordinate joint international field campaigns for calibration/validation & algorithm development and mission science
  - Cruises of opportunity (significant science complement), e.g., AMT
  - Dedicated experiments
    - Sequence of targeted regions of interest
    - "Host nation" vessels, multiple nation vessels, etc. scenarios
  - Predefined measurement suite with internationally assigned &/or competed participation
  - Common in situ data archive with QC, e.g., SeaBASS
- Implement the International Network for Sensor InTercomparison & Uncertainty assessment for Ocean-colour Radiometry (INSITU-OCR)