Summary of MODIS Terra Ocean Observations.

Ocean web site: http://modis-ocean.gsfc.nasa.gov

January 24, 2001

Seas are Calming and the Ship is Answering the Helm

- Tremendous Progress has been made during Year 1.
  - Crossing Time (Inclination) adjustment to avoid more glint was successfully implemented.
  - On-orbit characterization of ocean bands has resulted in identification of key issues, and solutions to most are in progress with MCST.
  - Fluorescence and 4 μm band observations herald significant new scientific insights to key ocean processes.
  - Modified Aqua gains will maximize SST accuracy from MODIS.
  - All ocean data parameters, through L-4, are in production, and are nearing scientific quality, with near daily, global 1 km coverage.
  - MOBY time series continues at ±3%, 2 mini initialization cruises have been very successful in getting clear matchups for validation.
  - Coastal oceanographers are truly excited with the high resolution bands.

Seas are Calming and the Ship is Answering the Helm (2)

  - Dedicated work on the part of Ocean code developers, SDST and the Goddard DAAC has enabled significantly better performance for ocean processing and archiving over the baseline limits. All data is being ingested at nearly 1x production.
  - Significant improvement in ordering, over ECS baseline, has evolved from in-house efforts, despite the extremely cumbersome ESDT and management structure.

- The ocean group is now in position to implement a full initialization of data products over the next few months.
- We are increasingly confident that the ocean community will perceive that MODIS observations offer a significant improvement in quality over precursor missions.

SCIENCE QUESTIONS (Ocean NPP)

This Product Derives Ocean Net Primary Production and Annual Export Production from Chlorophyll, Light, SST, and Mixed Layer Depth

Carbon fixed/m2/day - Needed to understand:

Magnitude and Variability of ONPP

Ecosystem dynamics (coupling with physical forcings)

Food chain efficiency (fisheries resources)

Carbon cycle (carbon export, pCO_2 and hence air sea C flux)

(ocean NPP is 40-50% of global total production)

RELEVANT SCIENCE QUESTIONS

Variability - How are global ecosystems changing?

Response - How do ecosystems respond to and affect global environmental change and the carbon cycle?

Consequences - What are the consequences of climate and sea level changes and increased human activities in the coastal regions?

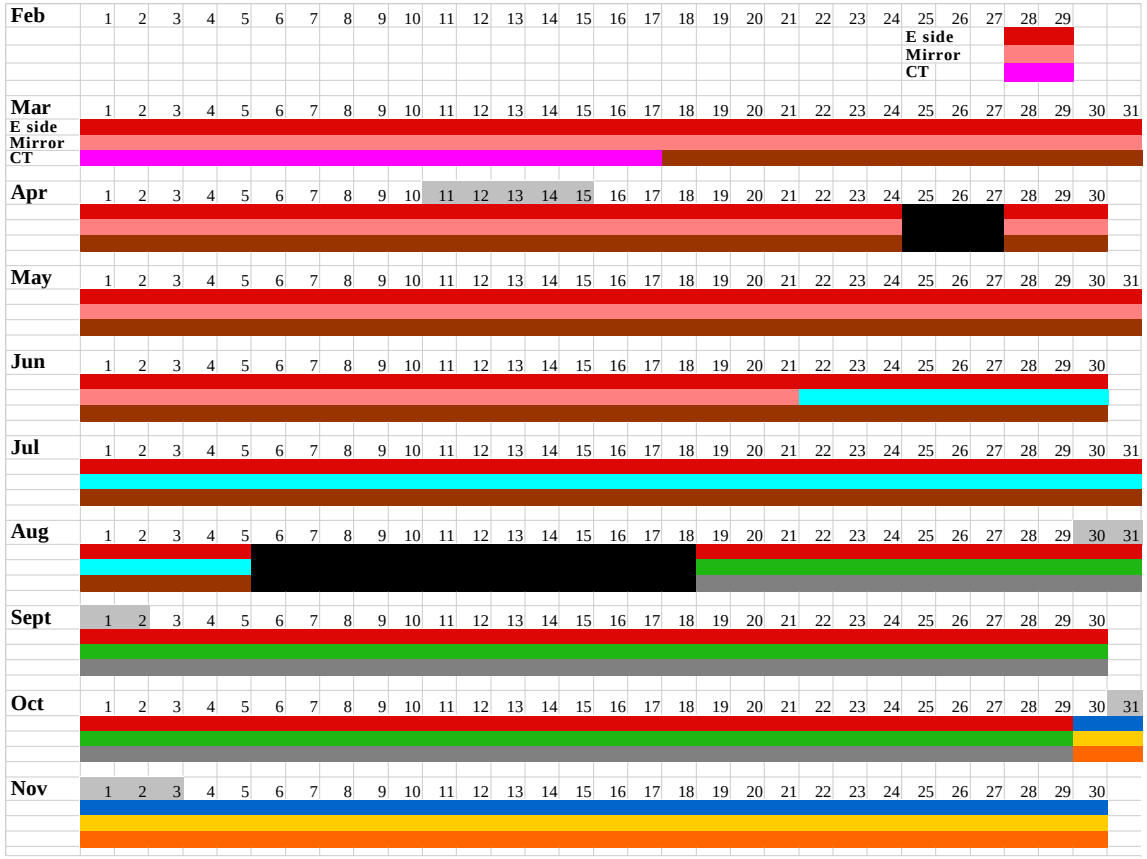
Prediction - How well can cycling of carbon through the Earth system be modeled, and how reliable are predictions...

OCEAN COLOR BAND ACTIVATION

- Significant Changes in instrument performance (and radiometry) occurred in March, June, August, October.
- Unique solutions to instrument effects in ocean data are required in response to each one. In effect >3 initializations are needed, where we expected only one.
- Initializations are based on April and December MOCE cruises, SeaWiFS, and MOBY. Initialization must be repeated for each epoch.
- Software problems (L2-3 bugs) are being identified and corrected.
  - –Binner and averaging issues, quality flags and thresholds
  - –Confounded by lack of sensor stability through Oct 30, 2000, lags in production, and lack of reprocessing.
  - –Delays in band-band gain adjustment have impacted bio-optical algorithm refinements.

Ocean Calibration Adjustments must occur retrospectively in a reprocessing mode

Time courses of sensor "state" for 3 parameters are shown. Grey dates show periods for which ocean de-striping was developed. These tables can only be applied within stable periods.



Improved stability, less noise since Oct 30 switch to “B side” electronics, finally!

- Sensor digitization noise was reduced by a factor of 2.
- Second generation corrections greatly decrease striping due to detector differences and polarization.
- Improved glint correction and cloud masking was implemented in November.
- Significant binner bugs have been identified and corrected.
  - Level 3 36 km and 1 degree maps made prior to Jan 23 have been removed. Earlier data at 4.6 km has some (not major) errors.
- Mirror sidedness and scan effects remain, at reduced levels, but with a complexity that will require months to analyse before corrections can be implemented.
- Sensitivity decrease with time has been identified by MCST, must be assessed for ocean observations.

Other Examples

- Many examples of ocean applications are detailed in Posters.
- Some highlights.
  - BRDF effects defined by Voss, are 20% level for clear waters for MODIS, and must be treated differently than for SeaWiFS.
    - Cruise data confirmation, being implemented in new corrections.
  - Red Tides visible in 250 m LSR products.
    - Examined by Carder group.
    - Confirms associations between Trichdesmium and red tide of Walsh.
  - Merging Studies to improve algo. performance and daily coverage have been conducted (Campbell & Dowell, and W. Gregg).
  - Use of ocean color time series to evaluate river-coastal interactions
    - Campbell and Salisbury

Harmful Algal Blooms

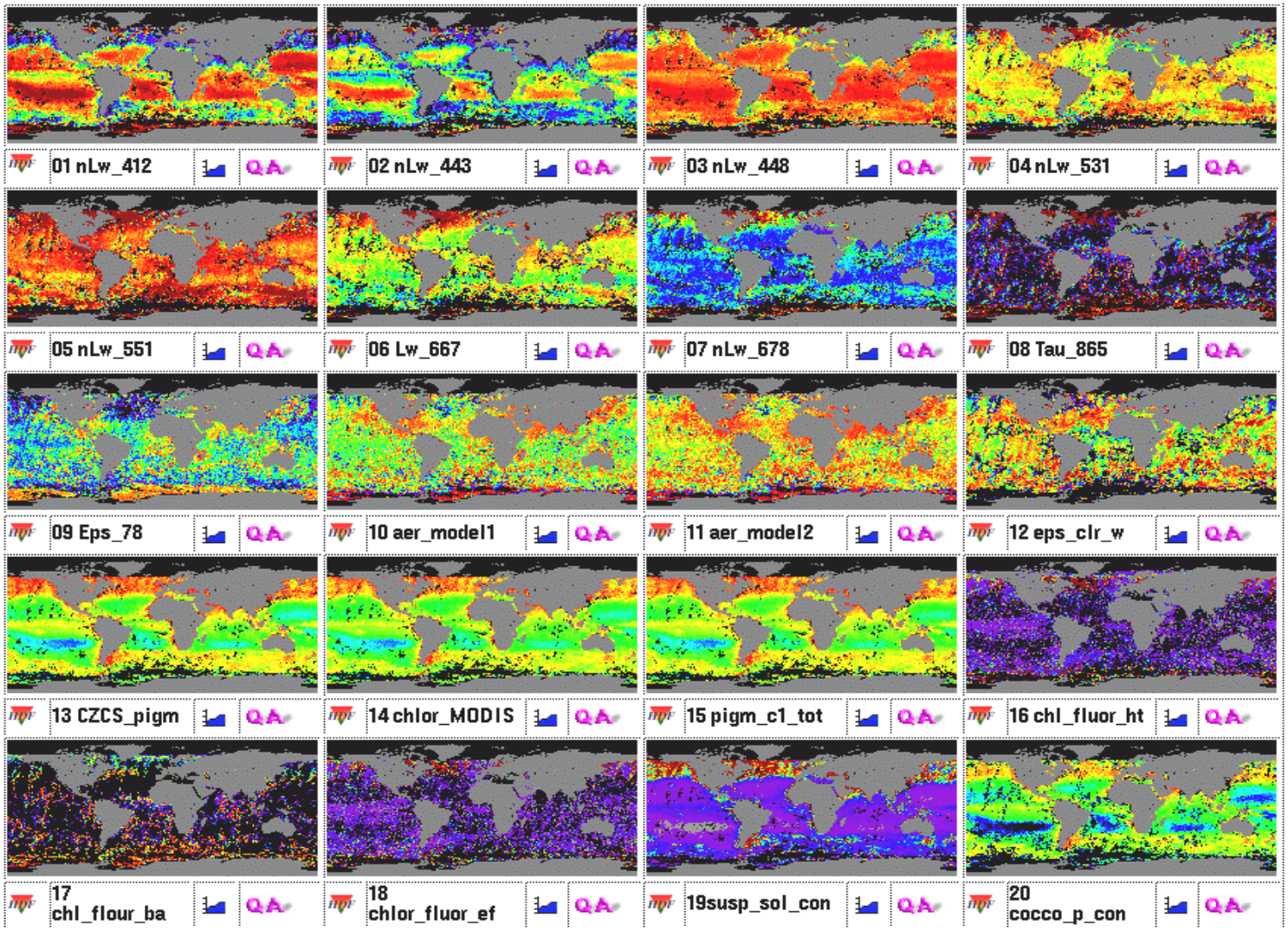
- Major HAB ***G. breve*** bloom seen near Galveston downstream from a bloom of nitrogen-fixing ***Trichodesmium*** using high-resolution bands.
- ***G. breve:*** low backscattering per unit chlorophyll.
- ***Trichodesmium:*** high back-scattering per unit chlorophyll.
- ***Trichodesmium*** requires iron input to make nitrogenase for N fixation.
- ***Saharan dust*** provided the iron to the western Gulf of Mexico during May – August.
- Runoff not indicated as iron source as there was no evidence of high colored dissolved organic matter on the outer continental shelf.
- Excess N from fixation stimulates HAB species.
- For the first time satellite imagery has captured the essence of the Walsh and Steidinger (submitted) and Lenes (in press) theories regarding major HABs in the Gulf of Mexico.
  - Fe ⟶ Trichodesmium N fixation ⟶ HAB

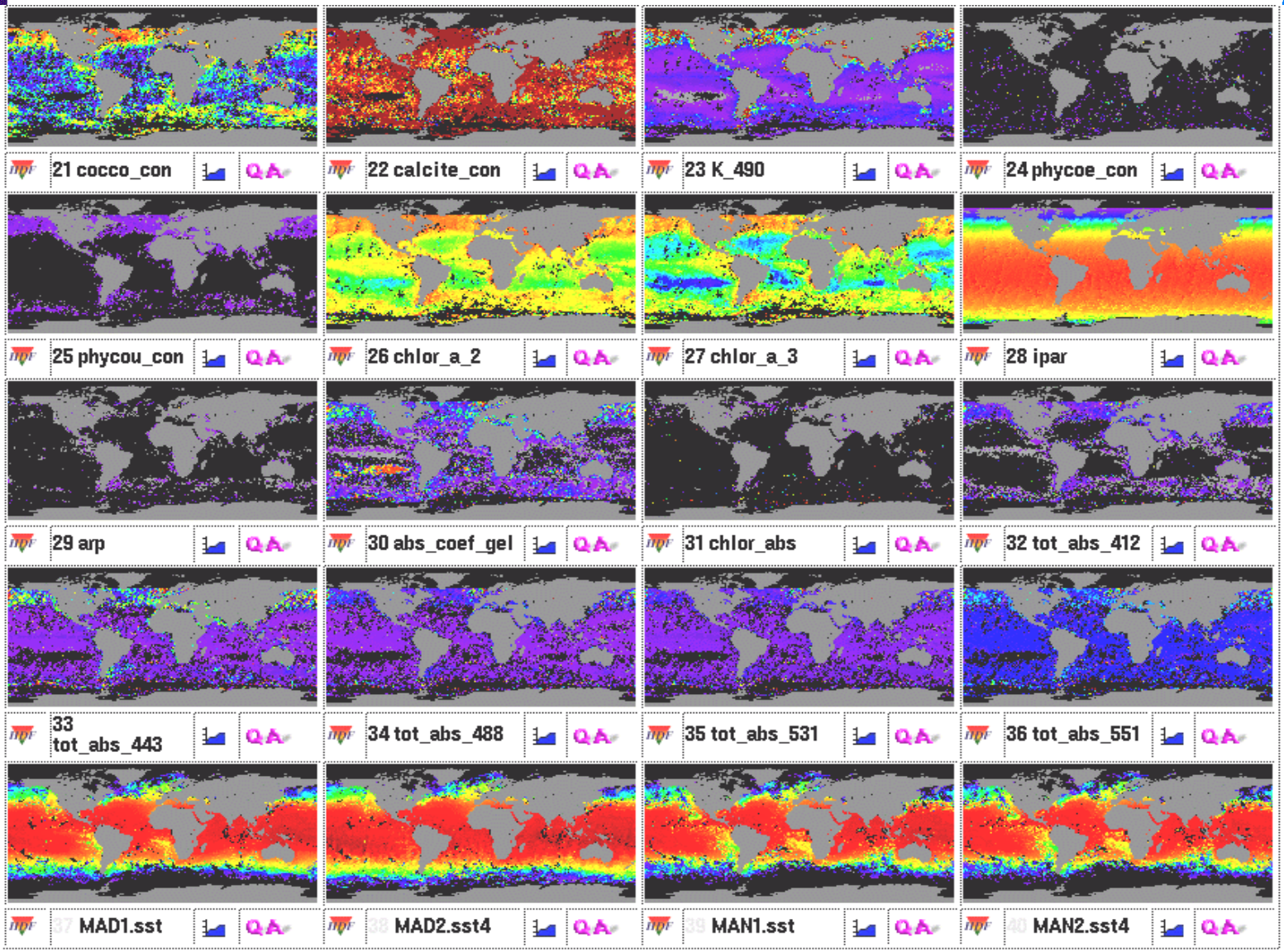
MODIS Ocean

Home Data Products Quality Assurance Validation Data Processing References Links

Weekly declouded
36Km maps

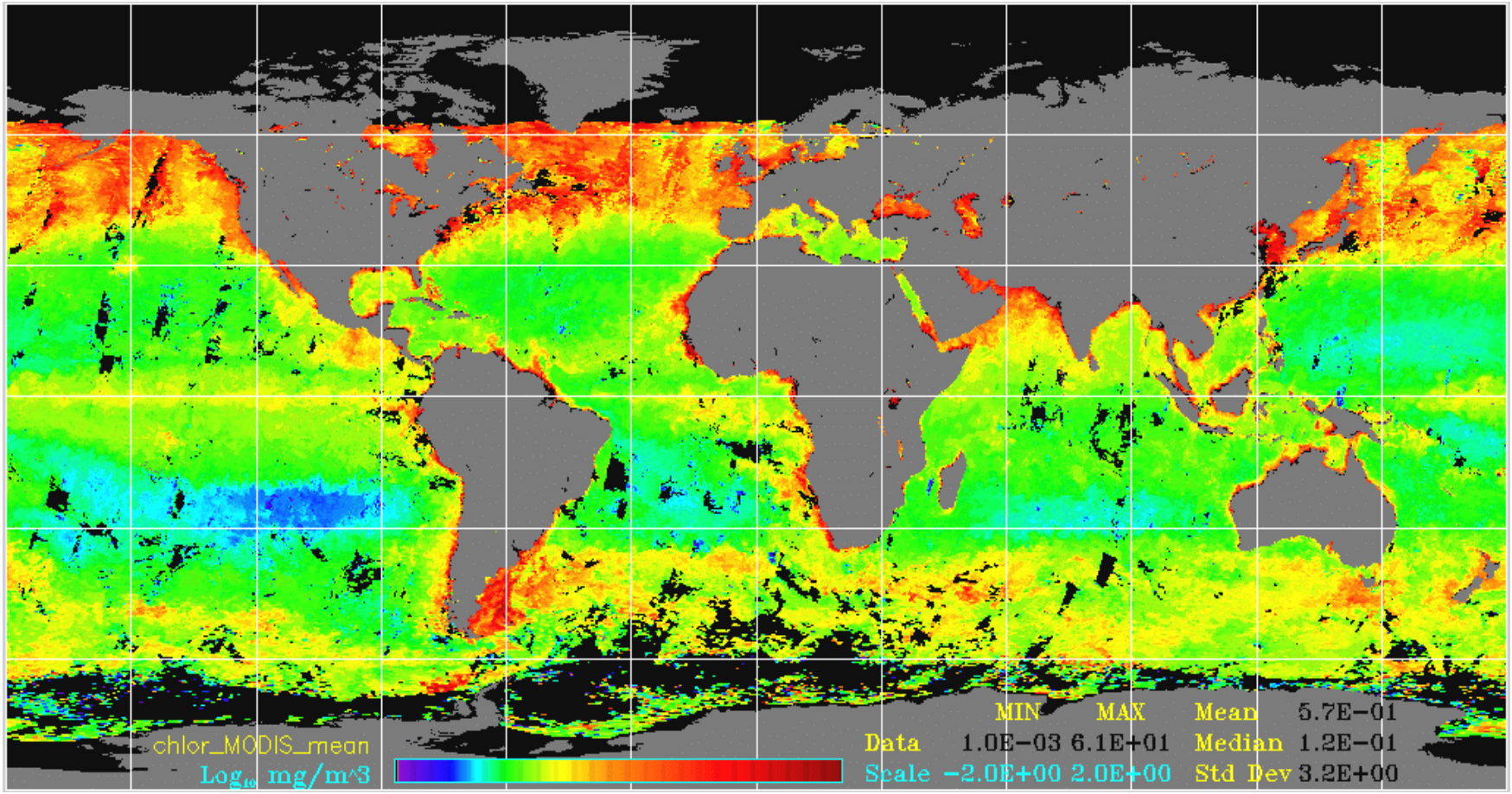
Week starting Day 313 (November 8, 2000)

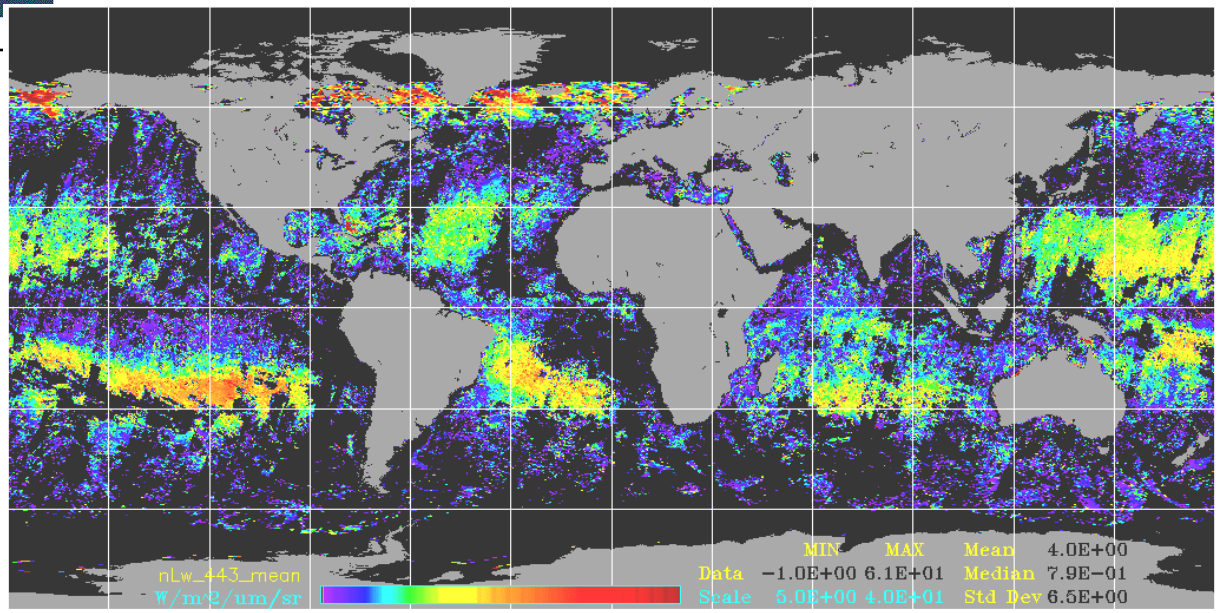




Designed and Developed by: Marius Necsoiu, Futuretech (marius@puffin.gsfc.nasa.gov) and Kevin Turpie, GSC (turpie@osprey.gsfc.nasa.gov)
Authorized by: Wayne E. Esaias, Code 971, NASA Goddard Space Flight Center

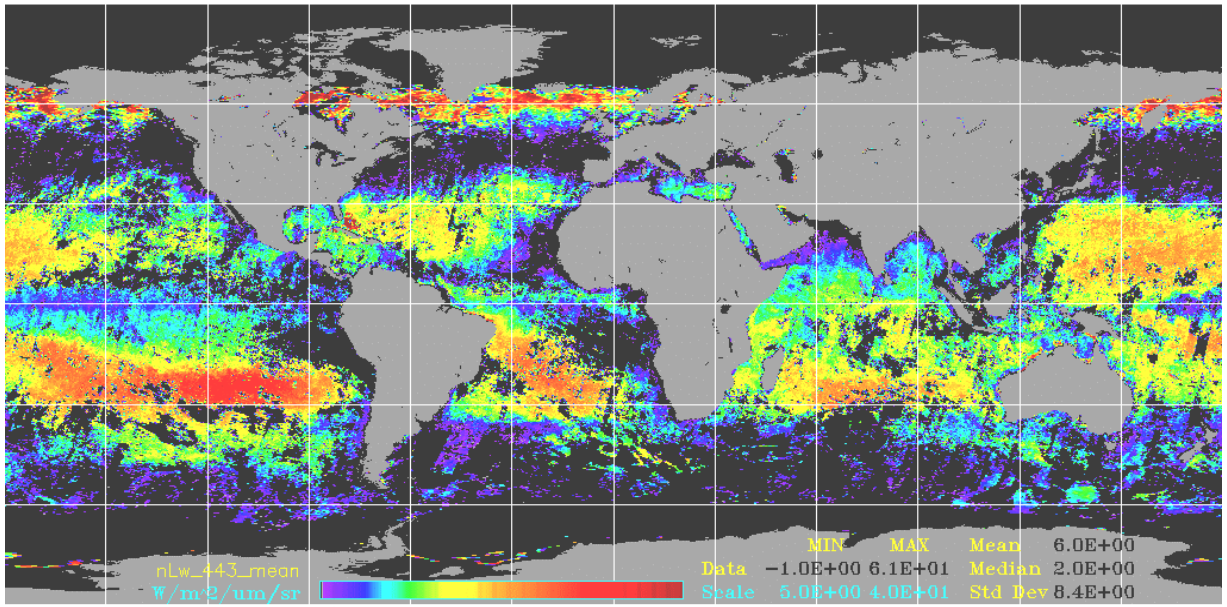
chlor_MODIS weekly, 2000.313-320





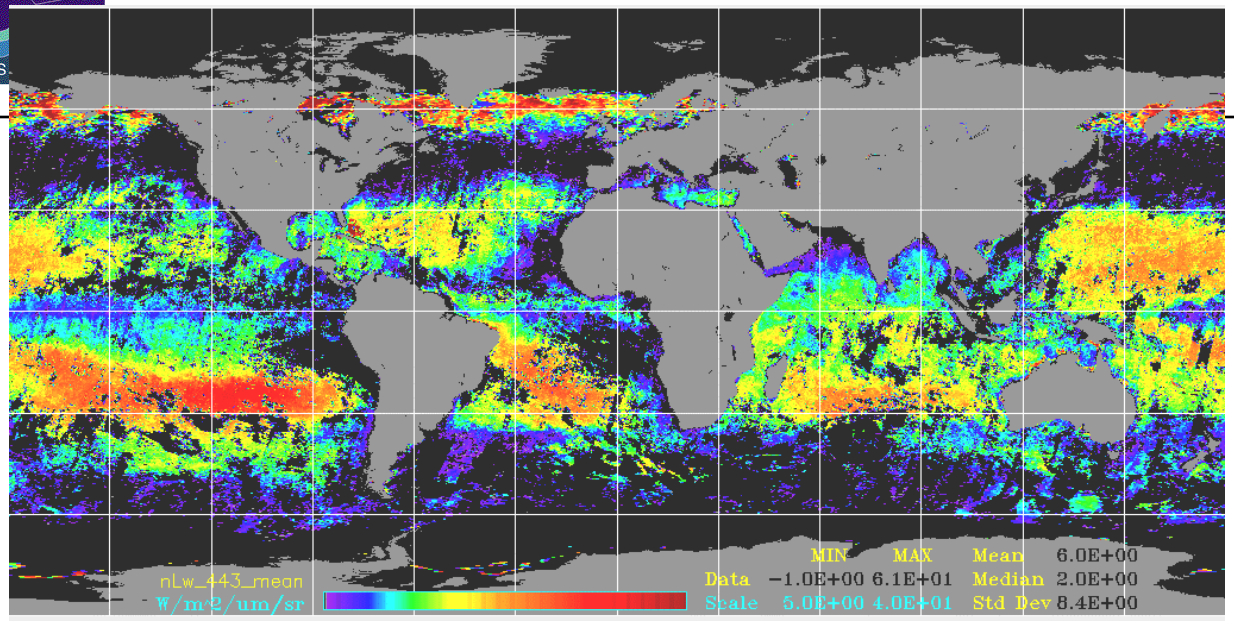
nLw_443 weekly
2000.297-304

A-side with corrections



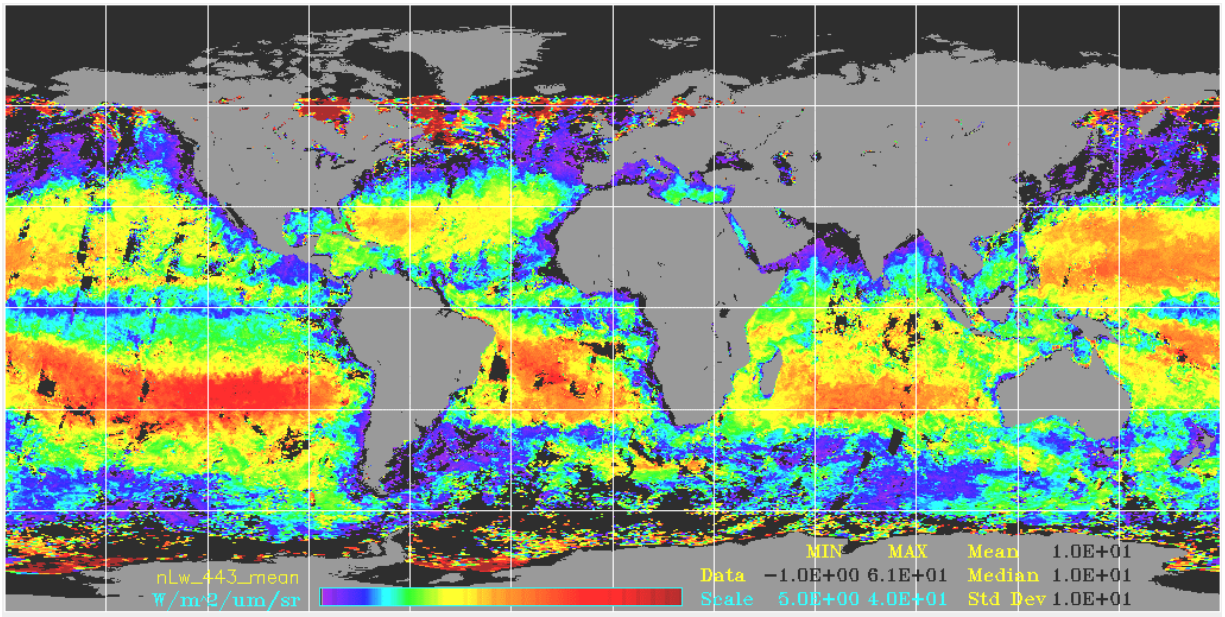
nLw_443 weekly
2000.305-312

B-side,no corrections



nLw_443 weekly
2000.305-312

B side no corrections
36-km "early" binning

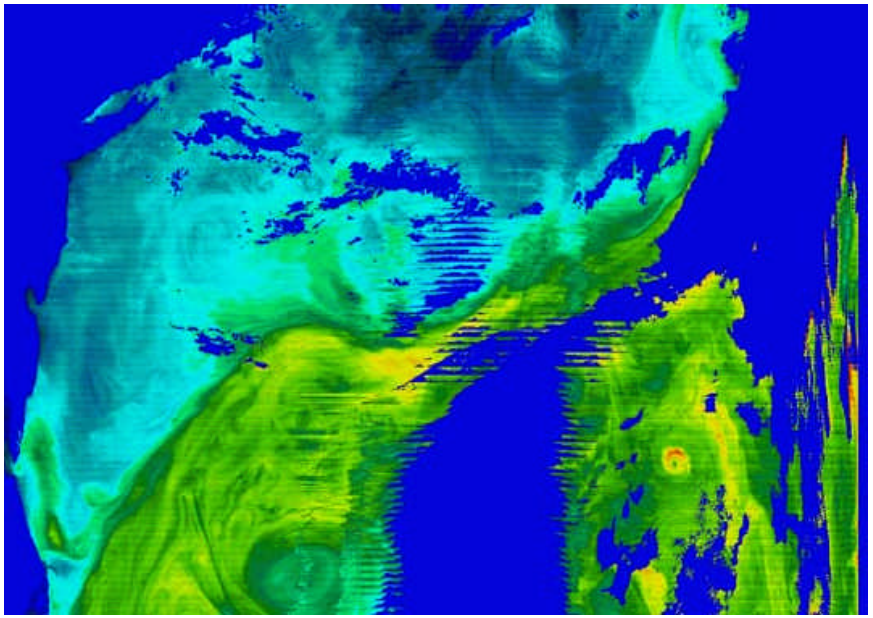


nLw_443 weekly
2000.313-320
(latest MODAPS version)

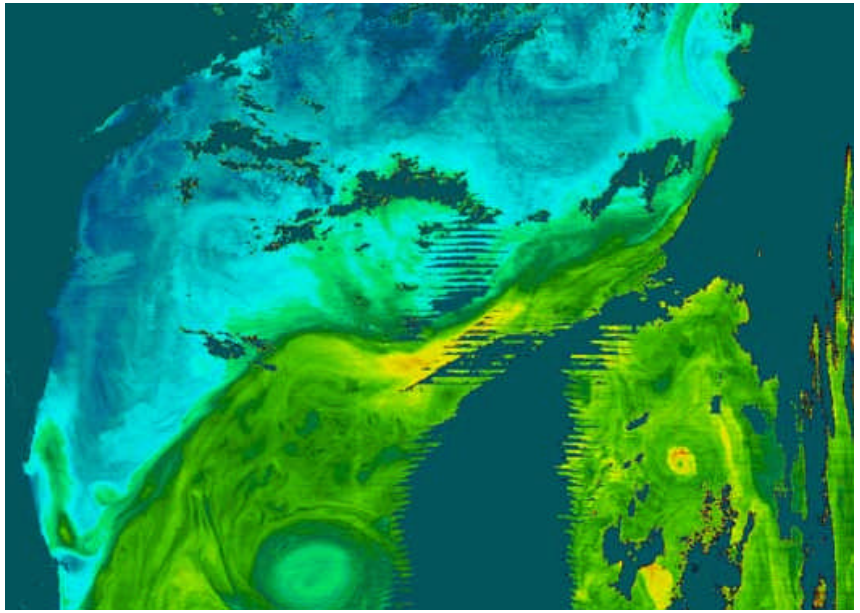
B side, partial corrections
36-km corrected binning

Mirror Side, Detector Destriping

May 8, 2000, Band 9 (443) Water Radiance
East Coast U.S. Gulf Stream Region

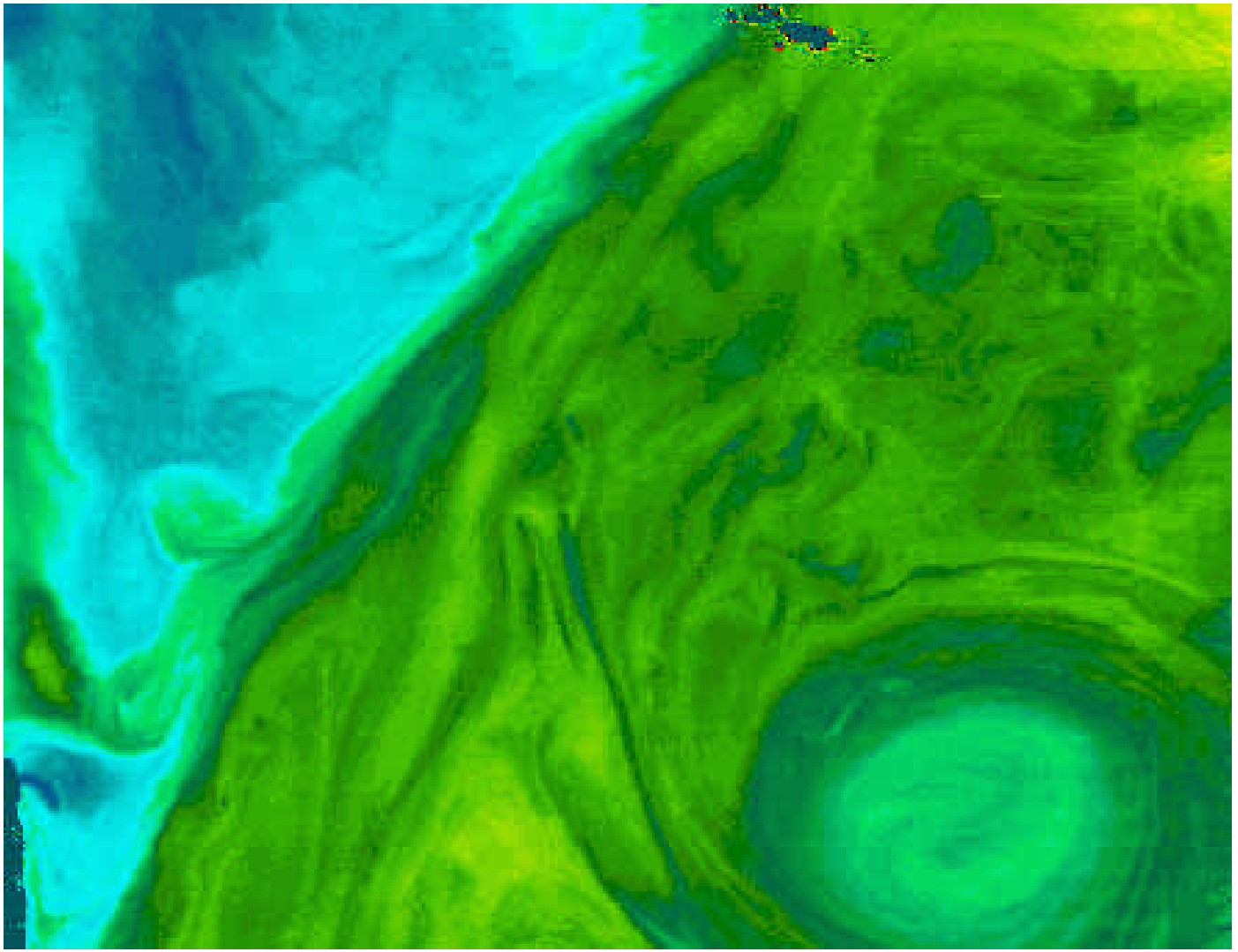


No Correction

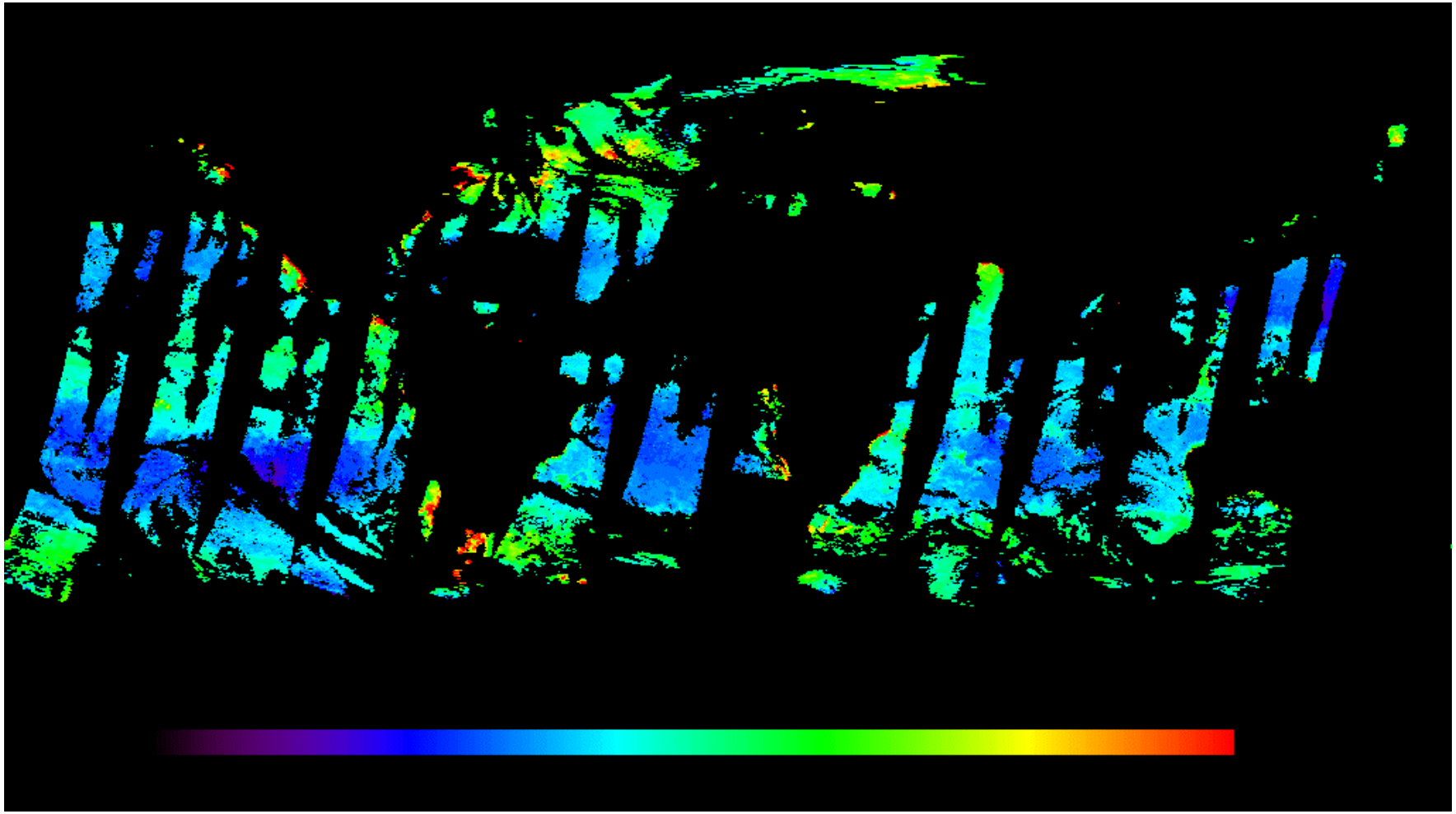


With L-2 Correction

Gulf Stream 443 nm water leaving radiance
1 km resolution May 8, 2000

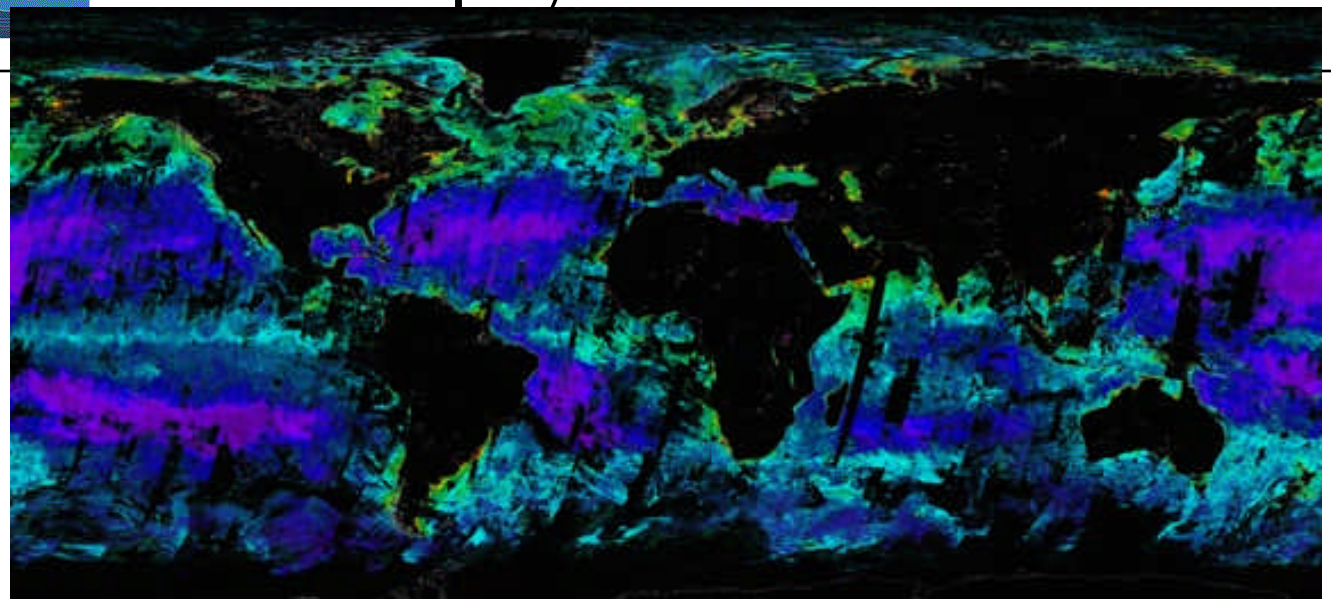


Second generation ocean calibration and polarization -initial results look promising



Clark 3-band Chlorophyll a for 11 April 2000, produced on 1/17/01 with “A” side calibration and improved sensor polarization correction - Evans, Gordon, et al. Mirror side correlation noise effects are still present as biases at this resolution.

Chlorophyll - MODIS and SeaWiFS

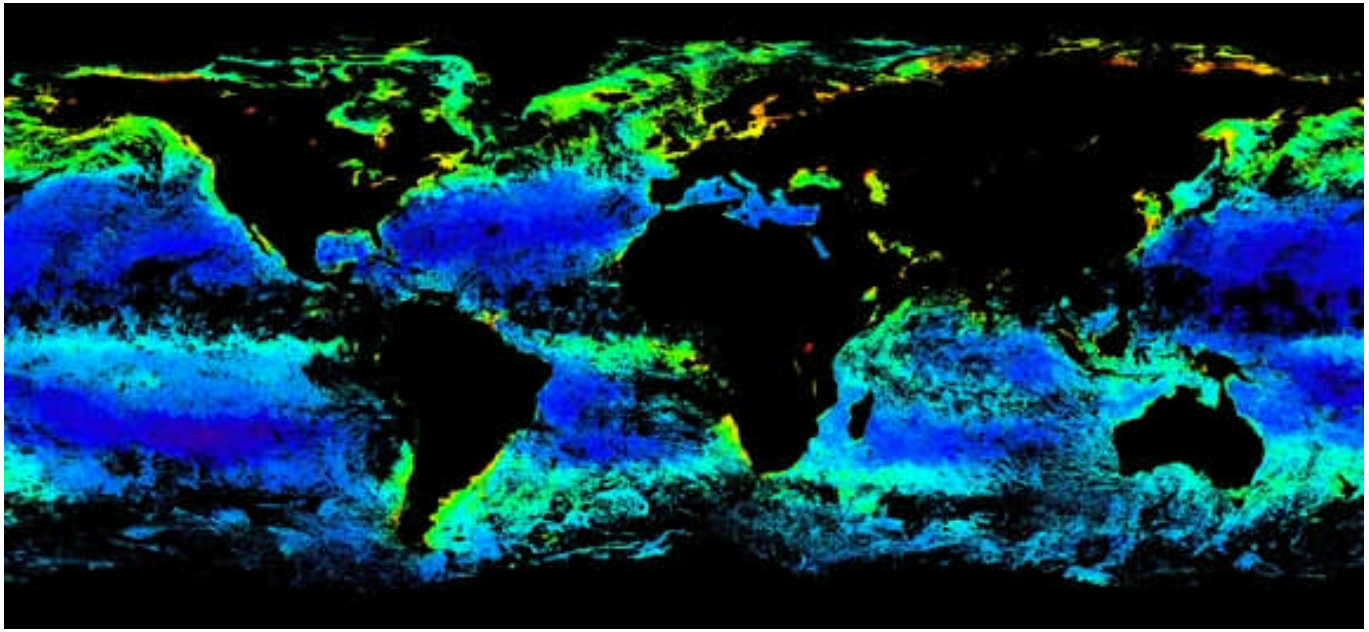


MODIS Chlorophyll
243-250, 2000
U. Miami

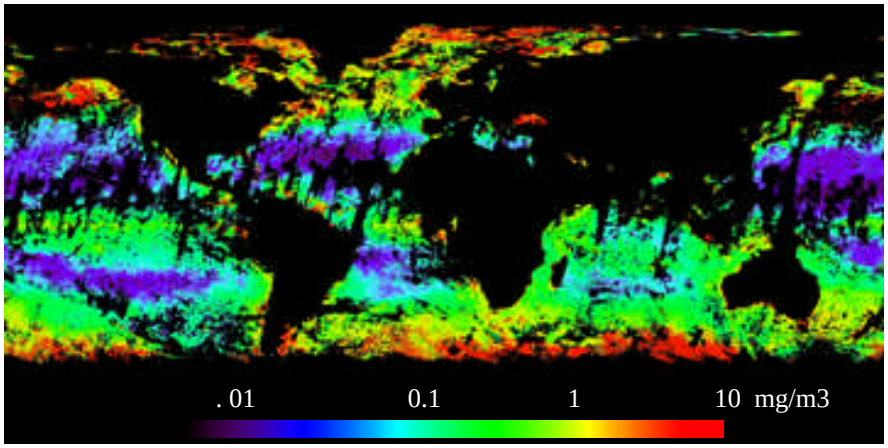
Coverage in tropics is greater for MODIS (time of day +no loss due to tilt). MODIS reveals fine structure globally. Color scales are not identical, cal.not final.

SeaWiFS
Chlorophyll
241-248, 2000

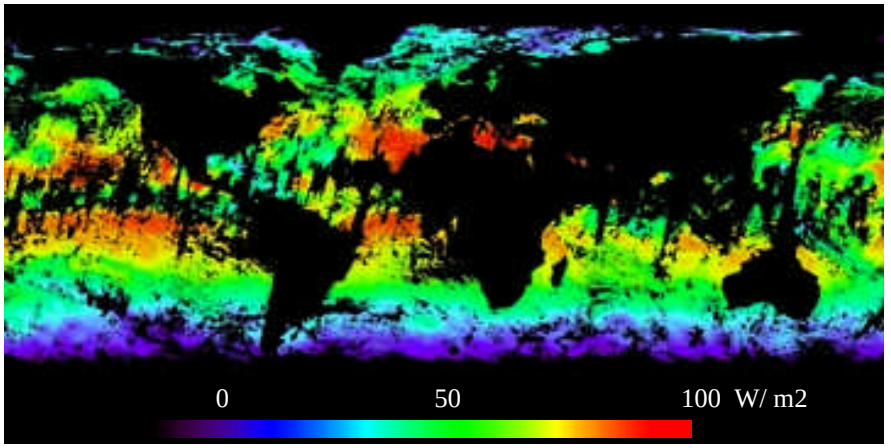
SeaWiFS
Project



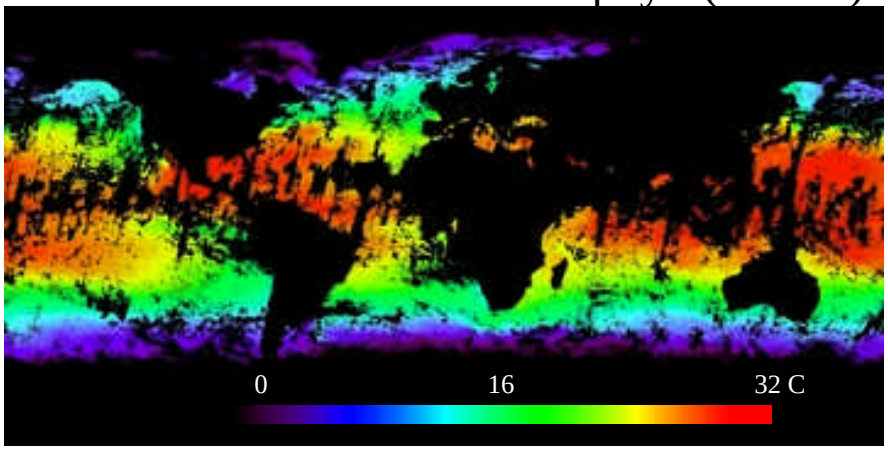
Ocean Weekly Production Inputs, Week 233



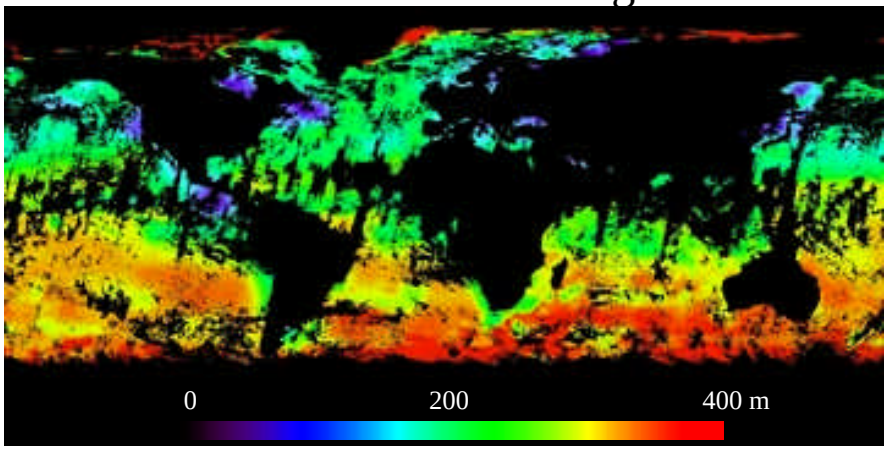
MODIS Chlorophyll (Carder)



DAO PAR radswg



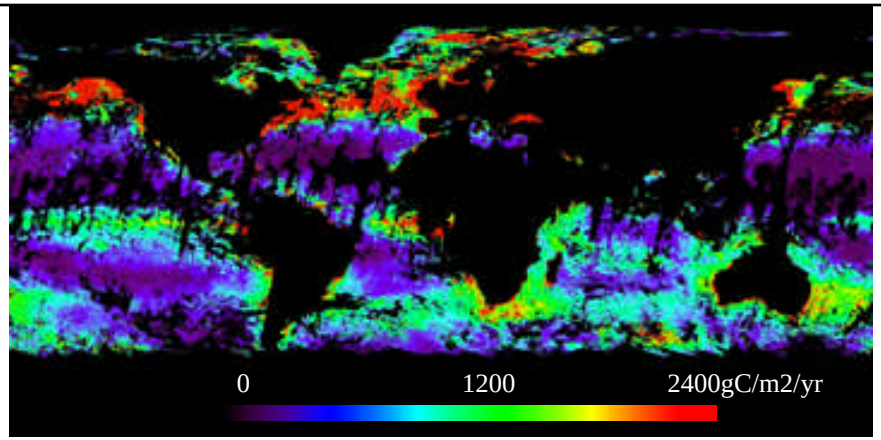
MODIS SST 11-12 µm Day



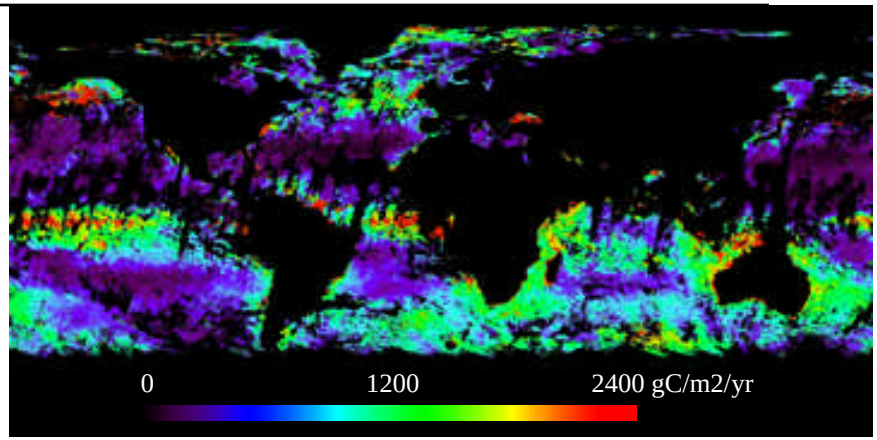
FNMOC Mixed Layer Depth

Esaias, Iverson, Turpie

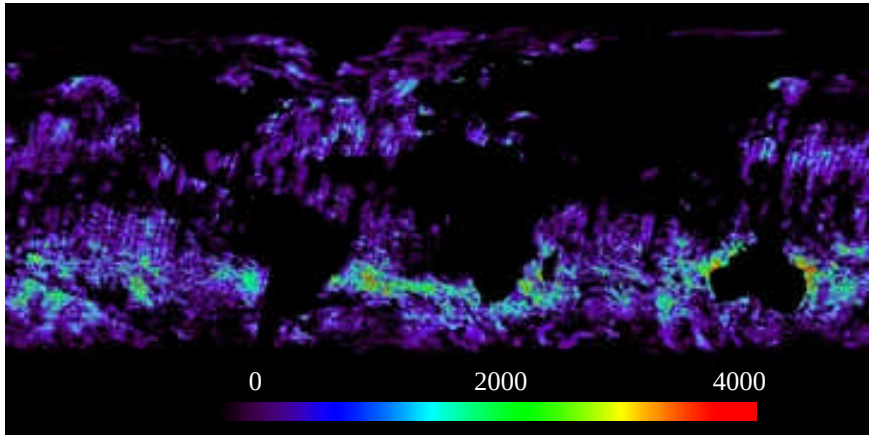
L-4 Weekly Ocean Production Indexes



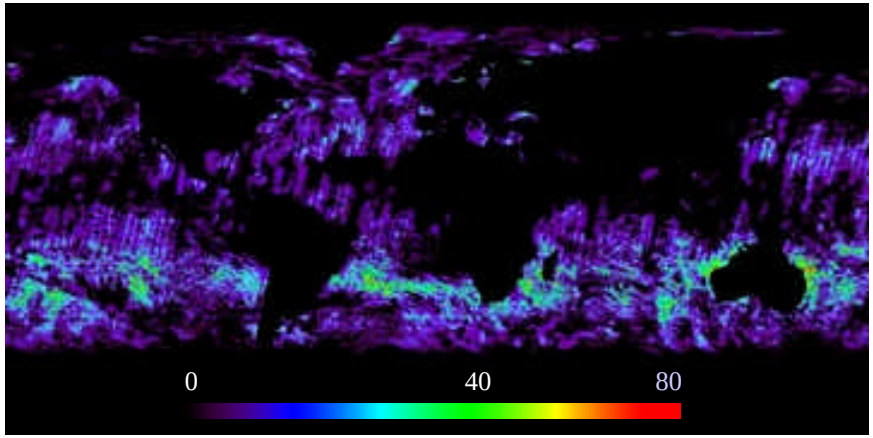
Ocean Productivity P1 (B/F)



Ocean Productivity P2 (H/Y/R)



Number of pixels



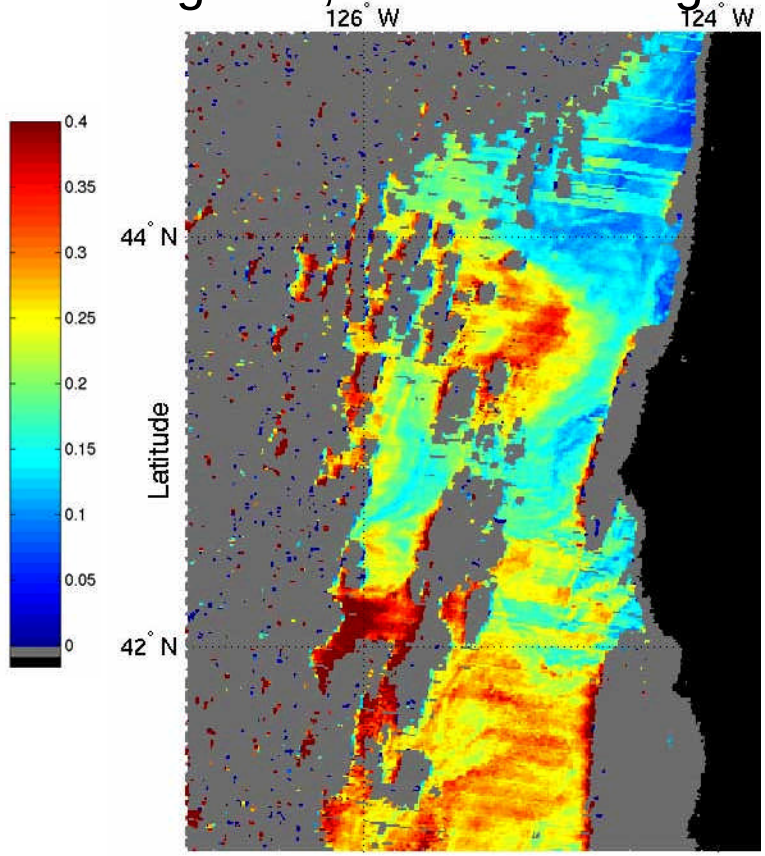
Number of granules

Test - Unvalidated, for Week 233, 2000, 36 km

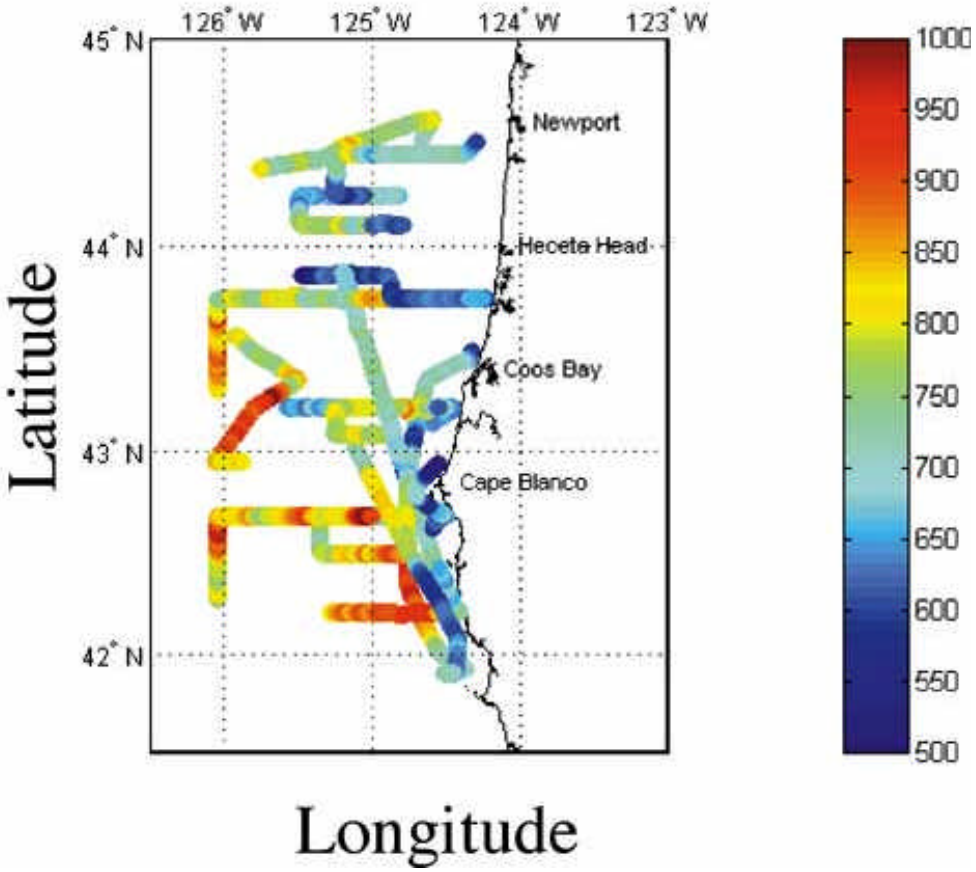
Esaias, Iverson, Turpie

Fluorescence/Chlorophyll

MODIS (FLH+.02)/Chl
August 1, 2000 Off Oregon



In situ est. of photosynthetic absorption cross-section



Preliminary version, band calibration adjustment in progress

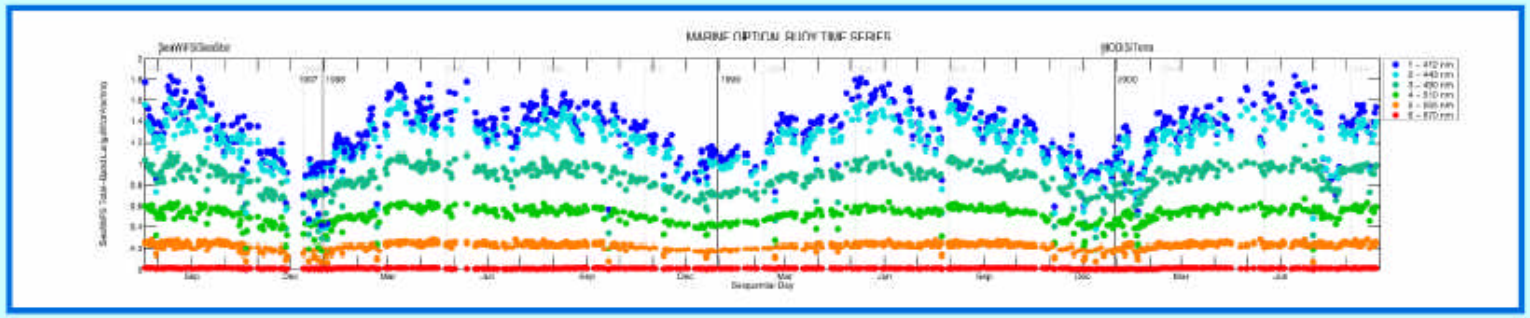
Abbott, et al.

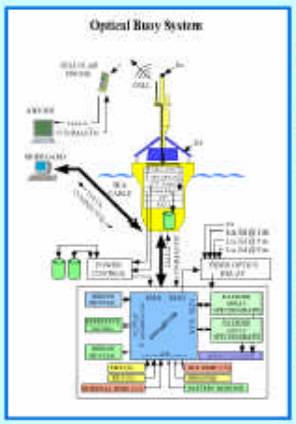
Visible Ocean Validation

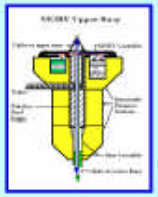
MOBY Time Series with “NIST” accuracy of ~ 3%!

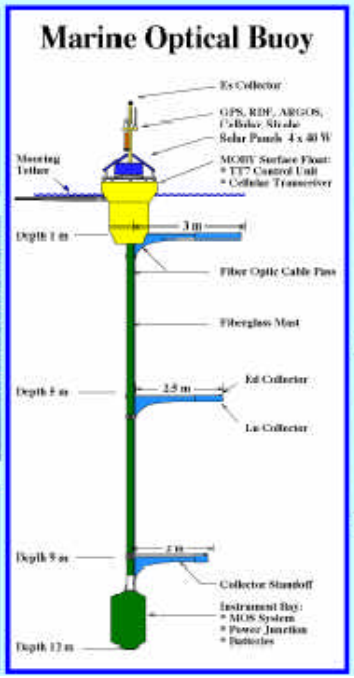
Marine Optical Buoy (MOBY) Ocean Color Calibration/Validation Time Series (1997 - 2000)

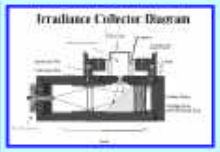
Dennis K Clark,[1] Mark A. Yarbrough,[2] Michael E. Feinholz,[2] Stephanie J. Flora,[2]
William A. Broenkow,[2] and Yong Sung Kim[3]

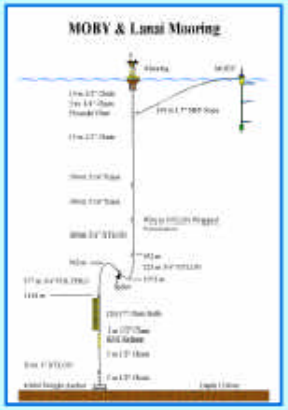




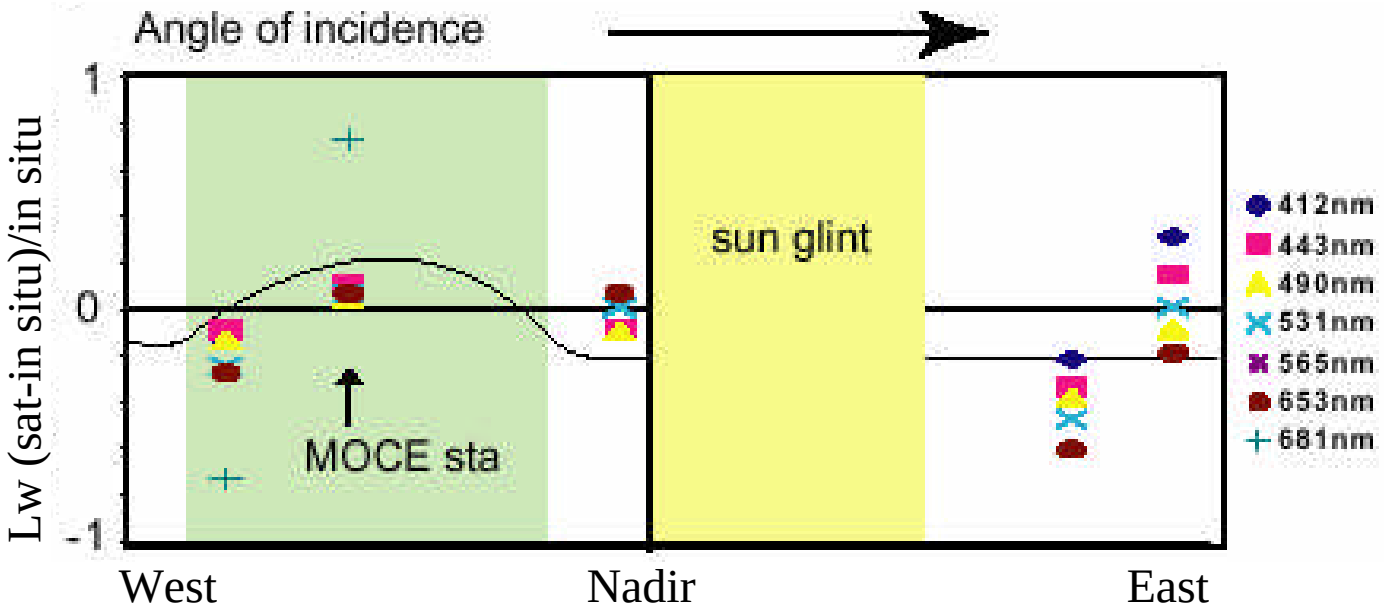








Water Leaving Radiance Validation



5 coincident stations were obtained April 2-9 by Clark. The differences between the “destriped” MODIS and in-situ data are plotted as a function of the MODIS scan angle geometry by Evans. The indicated station is given priority for vicarious calibration based on its favorable geometry. Comparisons are within 5-10% except for the 681nm band, where radiance is near zero. This is very encouraging for the first iteration.

Validation of Coccolith Calcite using Chalk

23 tons of chalk were dispersed in the Gulf of Maine.

August 7 SeaWiFS image $b_b(550)$

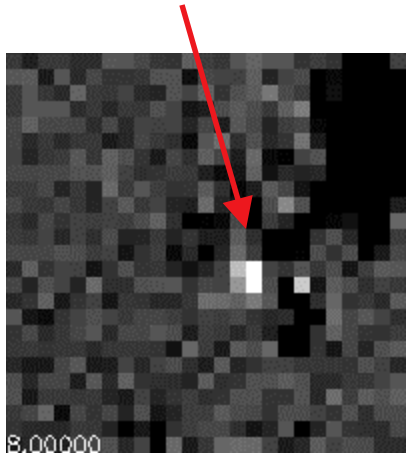
(MODIS was off due to formatter)

Comparison of b_b (optical backscatter) in two 1.1km pixels

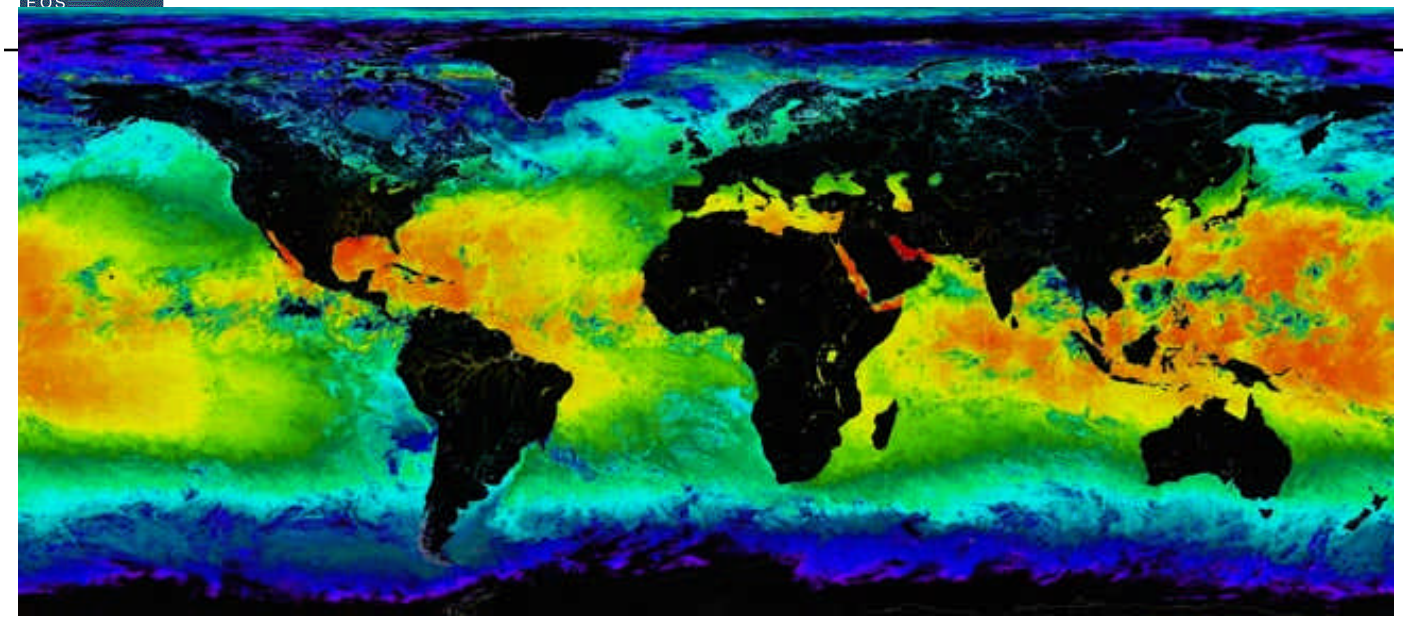
In situ $b_b(550) = 0.017 \pm .01$

Satellite derived $b_b(550) = 0.013, 0.016$ m^{-1}

Balch, Gordon, et al.



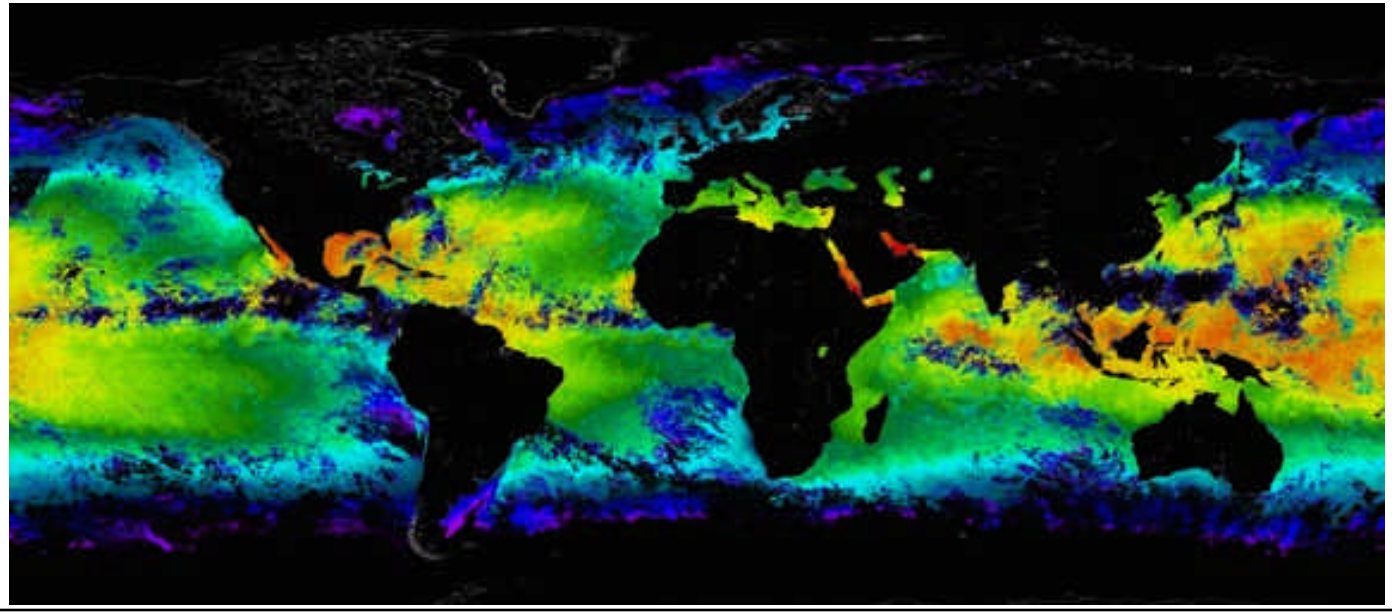
SST - MODIS and AVHRR



MODIS 4 micron Night SST

Improved coverage in tropical regions. Color scales are not identical, cloud mask is not applied.

AVHRR Night SST



Ocean Validation - SST

Weekly route of the Royal Caribbean Cruise ship *Explorer of the Seas* A fully automated M-AERI is serviced on Saturdays in port, and then spends 5.5 of the remaining days of the week at sea. Data will be sent back enroute. This data will be used to validate the MODIS SST time series in this hurricane nursery area.

Data Quality Improvement Schedule

- L-2, 3 Products are now useful for comment - Beta quality.
- All products are available from the Goddard DAAC.
- Latest improvements will be in production by Jan 30.
- Future software changes should be in operations by:
  - 1 April - version 3.0 will include:
    - fixes to flags and thresholds in quality fields
    - Preliminary band-band gain adjustments
    - Fixes to some algorithm bugs, time dependent LUTs
  - 1 June - version 3.1 will transition from Beta to Provisional for 39 params
    - April, December initialization results
    - Band-band gain adjustments,
    - Many more algorithm adjustments
    - Improved Fluorescence band calibrations
- Other corrections deferred to later versions (12/01 and >)
  - Mirror correlated noise, response decays, optimal polarizations, etc.

Degree of Validation, Documentation

- Algorithms have all been documented in Peer Reviewed Literature.
- Product validation is incomplete at this point - not global or continuous
- Visible
    - Image context (striping).
    - MOBY time series, MOCE 6 (April 2-9), buoy servicing minicruises.
    - Other team member cruises, drifters, AOL flights
    - SeaWiFS comparisons.
  - SST
    - Image context (striping).
    - 4 micron vs 12 micron retrievals
    - AVHRR comparisons.
    - M-ARIE along-track results.
- Presentations and Posters given at IGARSS, EUROPTO, Oceans from Space, Ocean Optics, PORSEC. Documents available via web site.
- Visible and SST papers in preparation for spring submission.

Challenges for Year 2

- Characterization of SST bands will remain incomplete until the Deep Space Manuever is performed, as promised, by the Project. Lack of DSM will limit solution to ocean RVS issues, and SST accuracy. Availability of MODIS science quality SST will be delayed by several years. Also affects visible.
- Scan and band-band correlated noise must be aggressively characterized, and development of V-3 L1b must proceed.
  - Is Aqua free from these effects, and can we find out?
- Data system throughput, notably lack of adequate reprocessing resources, poses significant hardship to use of MODIS data.
- Delayed launch of Aqua means more resources (esp. PI time and processing capacity) are available for Terra issues, but defers getting improved data and will limit funds.
- Recompetition approach is of great interest.

Producing of a Science Quality Time Series

- L1 backlogs have been virtually eliminated, but L2 lags ~24 days behind and the backlog will continue for several months.
- All ocean parameters, levels are available from Goddard DAAC.
  - Beta quality implies significant problems which are listed on the web site, caution is urged for scientific use.
  - See modis-ocean page for recommended ordering process.
- Quality of products improves with time - quality is not yet consistent.
- First reprocessing is expected to begin in June or July as new computers are installed.
- Unless the reprocessing rate is increased significantly, production of a first consistent quality annual time series will occur considerably after 2 years from launch.
- We need to speed this up as much as possible.
- We cannot validate a time series until it is produced.

Other Items

- Second generation MODIS calibration and science algorithms are targeted to become available in Dec, 2001.
- Launch of Aqua MODIS will not be before July 12, may slip until Dec or later due to spacecraft issues.
- MODIS will begin production of merged Terra and Aqua daily products 6-9 months following Aqua launch. Release date goal is L+12 months.
- Aqua MODIS SST gains were successfully changed to enable much better SST performance.
- A deep-space calibration maneuver for IR calibration is critical for both Terra and Aqua SST products. We hope that this is done in March for Terra, despite objections from MITI and unwarranted fears.

Data & Software Distribution

- EOS has set an upper limit of distribution of 2x the Terra mission data volume, in total. Thus, there is very limited capability to distribute entire data sets, compared to SeaWiFS.
- Code distribution and support needs some attention from ESDIS. Resources need to be made available somewhere.
- SeaDAS software supports analysis of MODIS ocean color products, thanks to support from SeaWiFS and SIMBIOS.