Ocean Biology Processing Group Evaluations of CZCS & OCTS

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MODIS Science Team Meeting
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OBPG Perspective & Objectives

- Apply vicarious calibration techniques & atmospheric correction & bio-optical algorithms used for SeaWiFS & MODIS, as possible.
  - Develop new approaches & algorithms, if necessary
  - New methods & algorithm must provide comparable results to operational versions
- Focus on Lwn’s as primary quantities of interest
- Evaluate data sets for climate research

OBPG Accomplishments under the REASoN-CAN

- **CZCS**
  - Generated a merged local area coverage (MLAC) data set
    - All duplicate scenes/subscenes eliminated using "best data" criteria
  - Renavigated entire mission using ephemeris from Nimbus-7/SMMR
  - MLAC data set placed on-line with browse and order capabilities similar to SeaWiFS & MODIS
  - Evaluated sensor degradation and vicarious calibration using current processing algorithms and models
  - Evaluated derived product data quality (Lwn's and chlorophyll-a)
- **OCTS**
  - Evaluated sensor degradation and vicarious calibration using current processing algorithms and models

Previous CZCS & OCTS Processings

- **CZCS**
  - GSFC-U. Miami (1989)
    - Feldman, G., & others, Ocean Color: Availability of the global data set, *EOS, Trans. Am. Geophys. Union*, 70(23), 634, 1989.
    - Evans, R. H., & H. R. Gordon, Coastal zone color scanner “system calibration”: A retrospective examination, *J. Geophys. Res.*, 99(C4), 7293-7307, 1994. Referred to as EG94.
  - Gregg et al. (2002)
    - Gregg, W. W., M. E. Conkright, J. E. O’Reilly, F. S. Patt, M. H. Wang, J. A. Yoder, and N. W. Casey, NOAA-NASA Coastal Zone Color Scanner reanalysis effort, *Appl. Opt.*, 41(9), 1651-1628, 2002.
  - Laboratoire d’Oceanographie de Villefranche-U. Miami (2005)
    - Antoine, D., A. Morel, H. R. Gordon, V. F. Banzon, & R. H. Evans, Bridging ocean color observations of the 1980s and 2000s in search of long-term trends, *J. Geophys. Res.*, 110, C06009, 22 pp., 2005.

Previous CZCS & OCTS Processings *cont.*

- **OCTS**
  - NASDA
    - Shimada, M., H. Oaku, Y. Mitomi, & H. Murakami, Calibration of the Ocean Color & Temperature Scanner, *IEEE Trans. Geosci. & Remote Sens*., 37(3), 1484-1495, 1999.
  - Gregg (1999)
    - Gregg, W. W., Initial analysis of ocean color data from the ocean color and temperature scanner. I. Imagery analysis, Appl. Opt., 38(3), 476-485, 1999.
    - Gregg W. W., F. S. Patt, & W. E. Esaias, Initial analysis of ocean color data from the ocean color and temperature scanner. II. Geometric and radiometric analysis, *Appl. Opt*., 38(27), 5692-5702, 1999.
  - NASA-NASDA (2000; SIMBIOS Project)
    - Wang, M., A. Isaacman, B. A. Franz, & C. R. McClain, Ocean-color property data derived from the Japanese Ocean Color and Temperature Scanner and the French Polarization and Directionality of Earth's Reflectances: a comparison study, *Appl. Opt*., 41(6), 974-990, 2002.

“Common” Processing Approach & Key Requirements

- **Prelaunch characterization & calibration**
  - Polarization sensitivity, response vs. scan, counts vs. radiance, relative spectral response, etc.
- **On-orbit performance**
  - Sensor loss of sensitivity vs. time
  - Vicarious calibration
    - CZCS: Clear-water radiances (very little concurrent radiometric data)
    - OCTS: MOBY &/or clear-water radiances (very little concurrent radiometric data)
    - SeaWiFS & MODIS: MOBY
- **Atmospheric corrections**
  - Standard multiple scattering Rayleigh, sun glint, & foam corrections
  - Aerosols
    - CZCS: 670 nm-based aerosol correction with turbid water reflectance correction
    - OCTS, SeaWiFS, MODIS: Gordon & Wang aerosol correction (2 NIR band scheme) with turbid water NIR correction, Morel bidirectional reflectance, TOMS ozone
- **Data quality masks and flags**
  - Clouds, sun glint, etc.
- **Chlorophyll-a**
  - Empirical maximum ratio algorithms, e.g., OC4v4
- **CZCS & OCTS product validation**
  - Clear-water radiance comparisons
  - Comparisons with SeaWiFS clear water Lwn’s, AOTs, etc.
  - Time series analyses
  - Comparisons with field data (generally sparse)

None of these sensors have the same set of bands for ocean color.

CZCS
(October,1978 - June,1986)

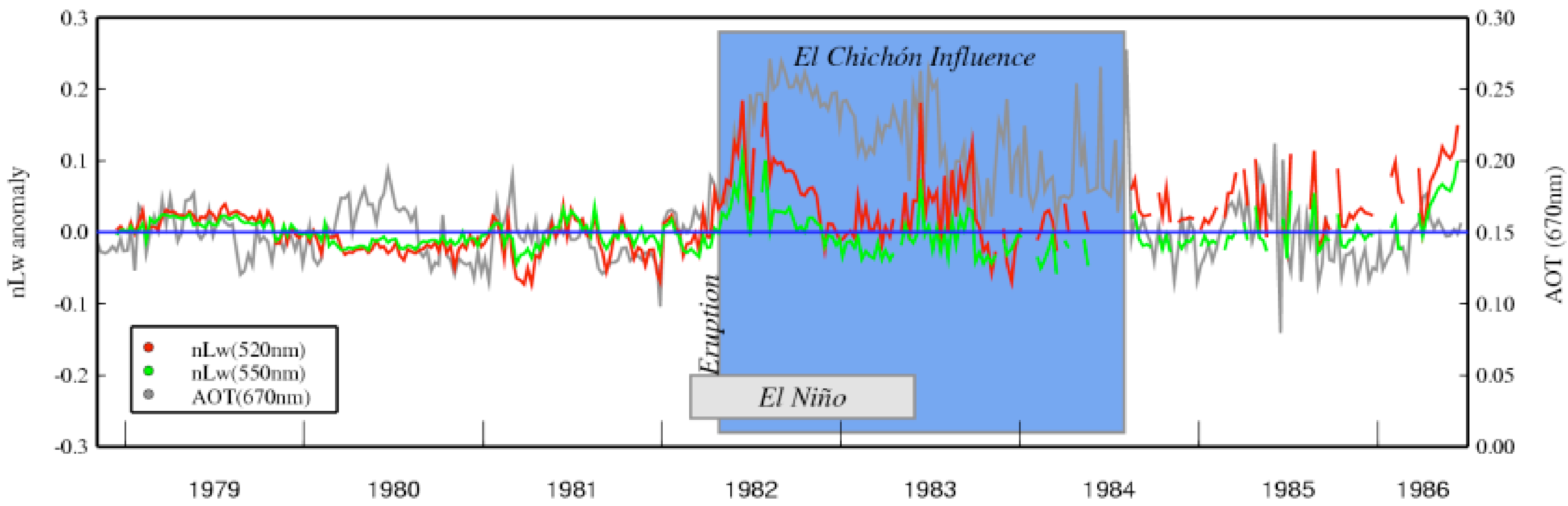
- Spectral coverage
  - Bio-optical: 443, 520, and 550 nm (20 nm bandwidths)
    - Small spectral difference between 520 & 550 limits chlorophyll-a algorithm accuracy at high concentrations
  - Aerosol correction: 670 nm (20 nm bandwidth)
    - Lack of additional NIR bands a major limitation for aerosol correction
  - Cloud flag: 750 nm (100 nm bandwidth)
- Special features
  - Polarization scrambler: <u>Significant polarization residuals remain</u>
  - 4 science gains (Gains 2-4 ratios relative to Gain 1: 0.7, 0.55, 0.25)
    - Most data collected with Gains 1 & 2
  - Tilting for sun glint avoidance up to ±20º in 2º increments (mirror tilt)
  - Internal calibration lamps
    - Proved useless on-orbit
  - Noon-time ascending orbit (~955 km altitude) with west to east scan
- Temporal & spatial coverage
  - 825 m resolution @ nadir; ~±39º scan range, 1636 km swath
  - Mission baseline of 10% global coverage
  - Coverage extremely uneven over time and space (e.g., N.H. vs. S.H.)
- Additional information
  - Limited prelaunch characterization
    - Available: radiance response, spectral response functions, SNR, polarization sensitivity (partial), modulation transfer function
    - Not available: response vs. scan, temperature dependence, point spread function, etc.
  - Substantial electronic “over-shoot” off bright targets
    - Bands saturate over clouds
  - 8-bit digitization
  - SNRs, Bands 1-4: 260, 260, 233, 143

CZCS Polarization Uncertainty

(Information from Ball Bros. final report)

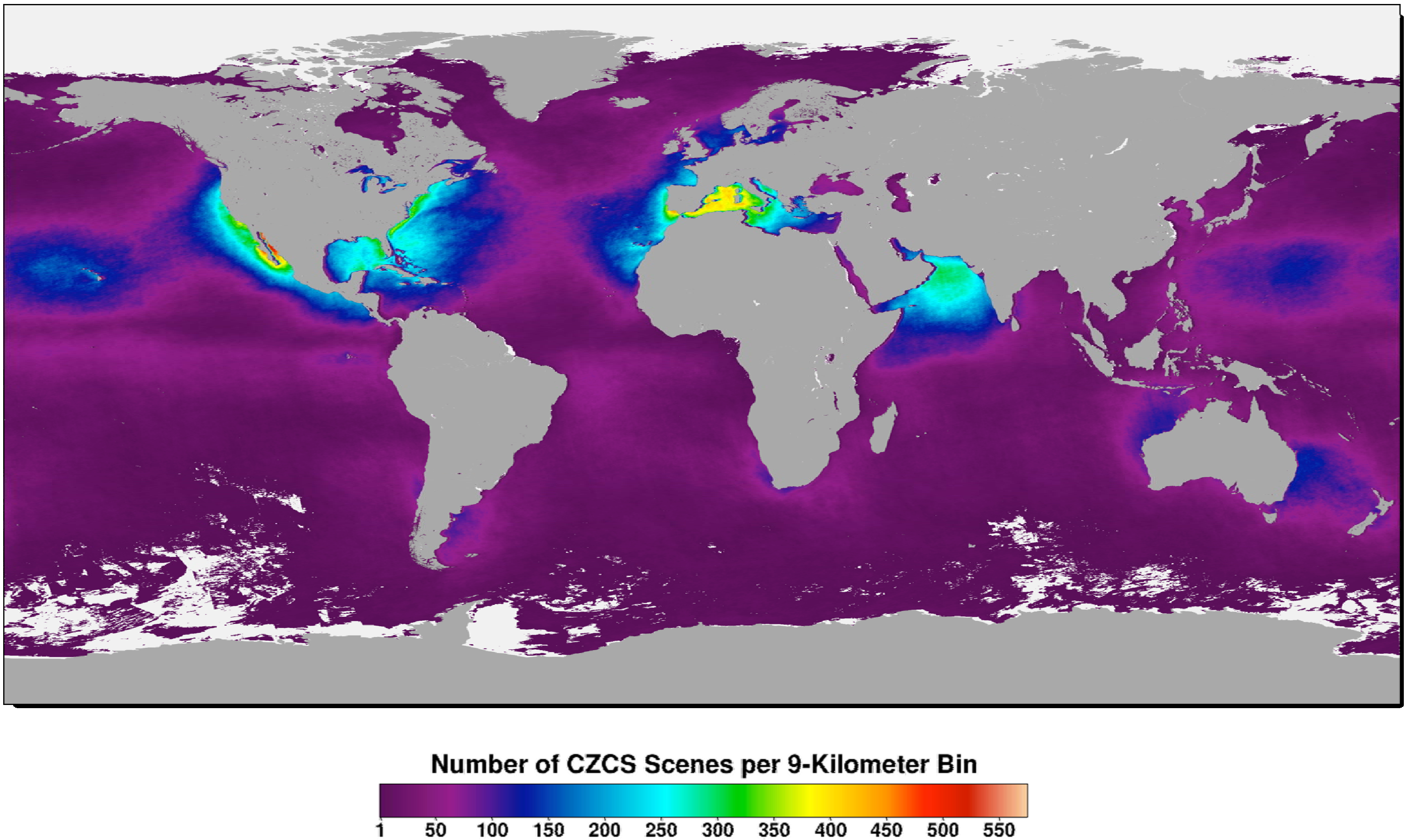
- Piece-part depolarization scrambler test indicates 0.5% sensitivity to monochromatic light (wavelength not provided).
- System-level tests show greatest polarization sensitivity at 443 nm, 2-3% for 0 & ±10º mirror tilt (corresponds to ±20º viewing angle change).
  - No information provided on polarization phase function.
  - Validity of system-level test uncertain due to problems with test set-up.

CZCS Mission History

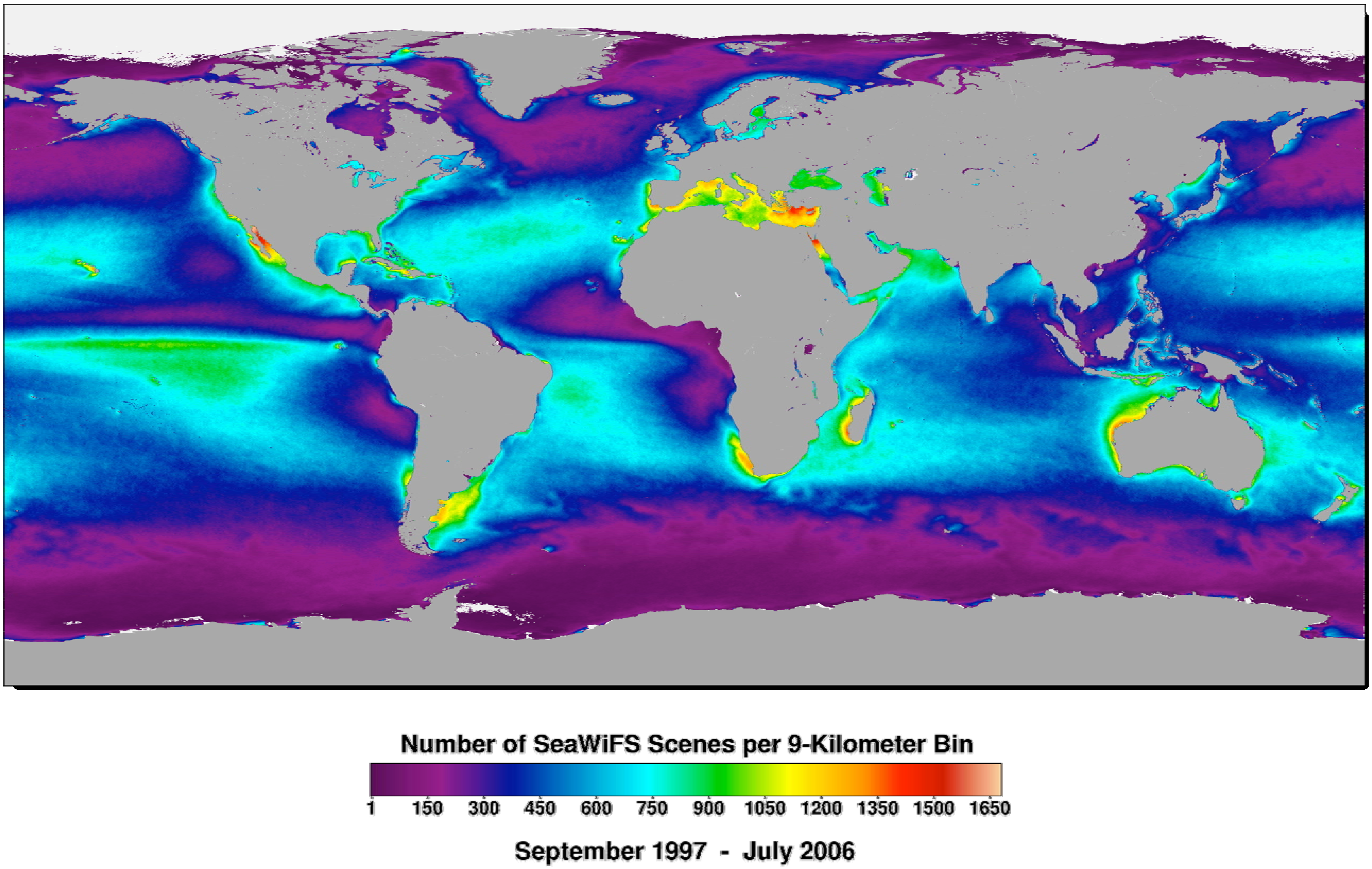


http://oceancolor.gsfc.nasa.gov/CZCS/czcs_processing/

CZCS Coverage: Total Mission



SeaWiFS Coverage: Total Mission

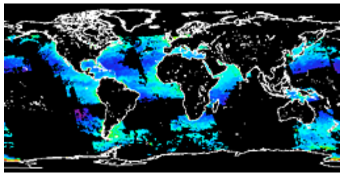


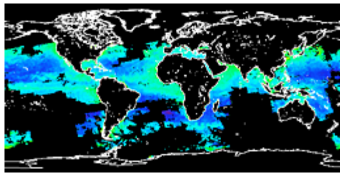
Note: Scale 3x CZCS coverage scale

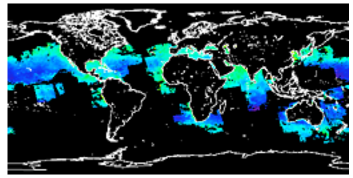
Monthly Coverage Comparisons for CZCS and SeaWiFS

Coastal Zone Color Scanner

December


1978


1979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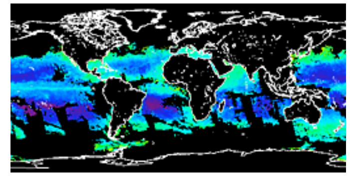
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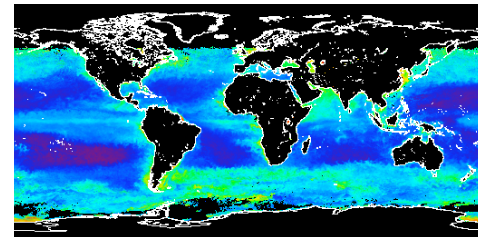
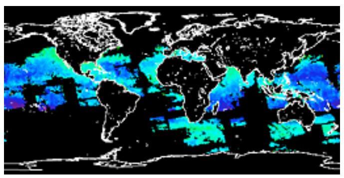

SeaWiFS 2005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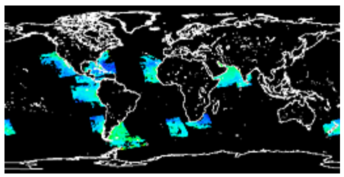
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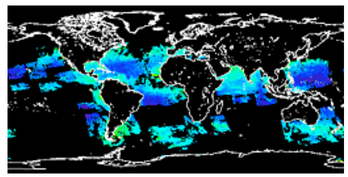
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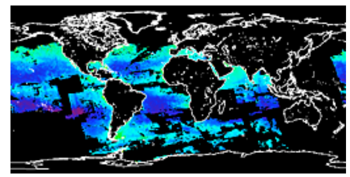
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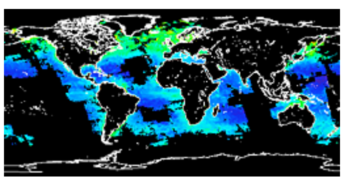
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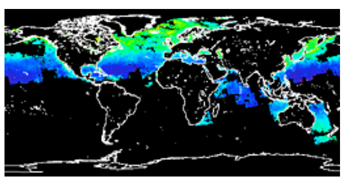
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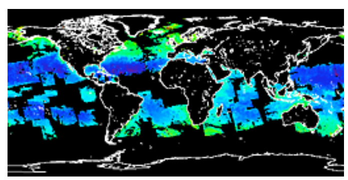
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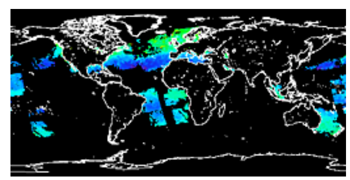
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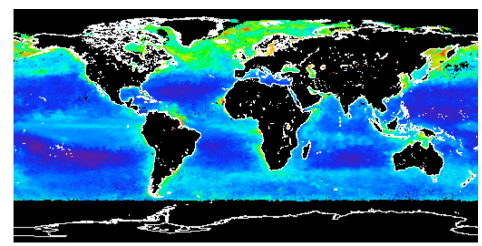
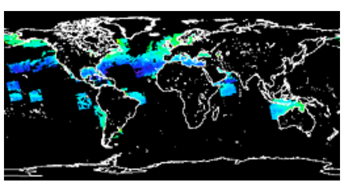

SeaWiFS 2006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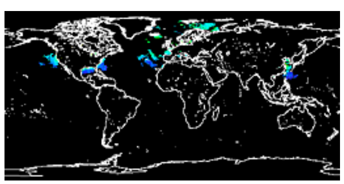
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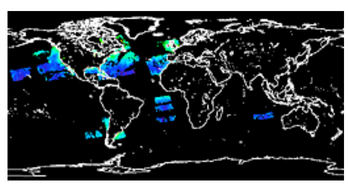
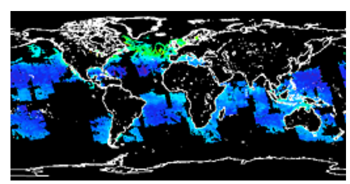
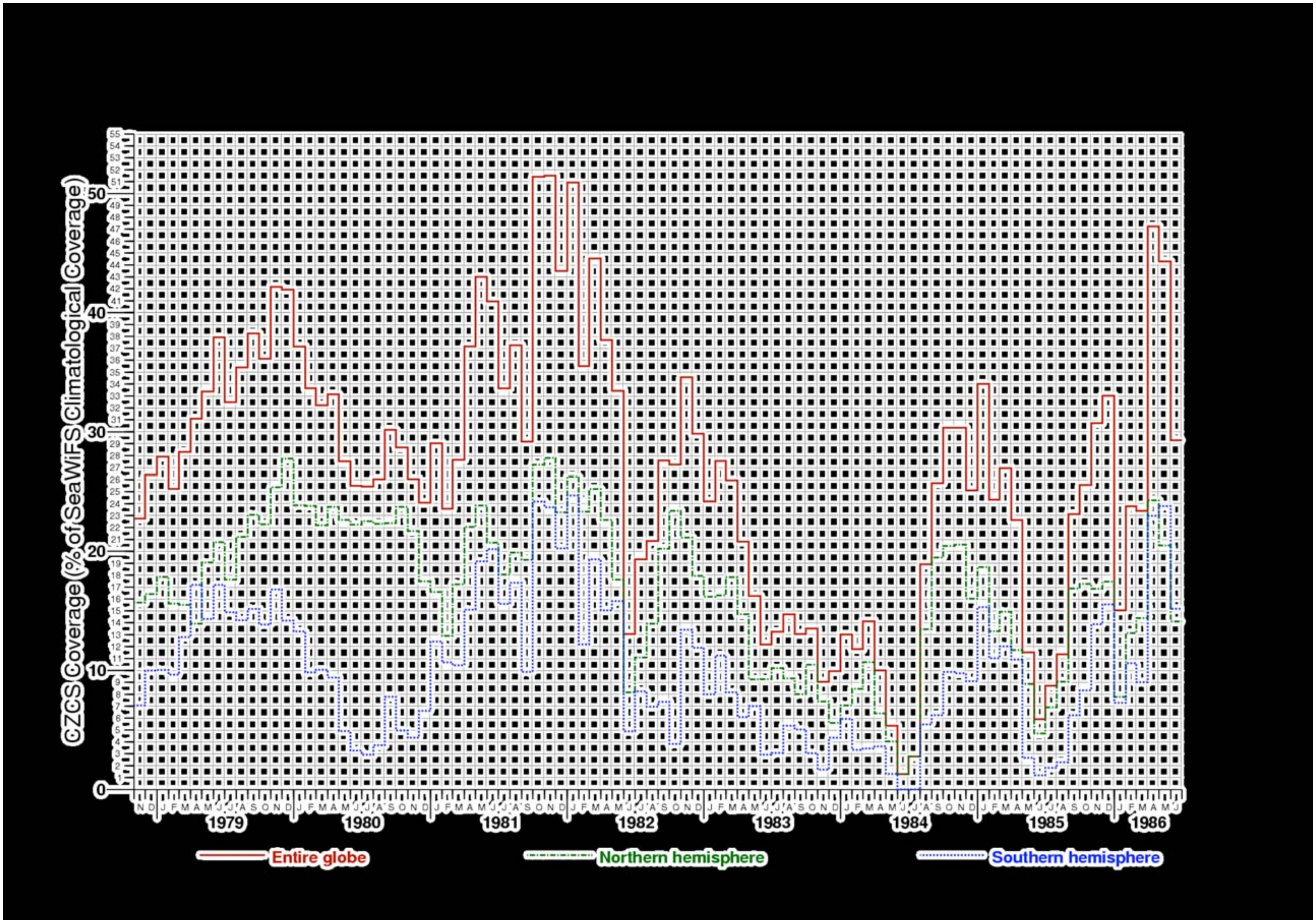

1985


1986

June

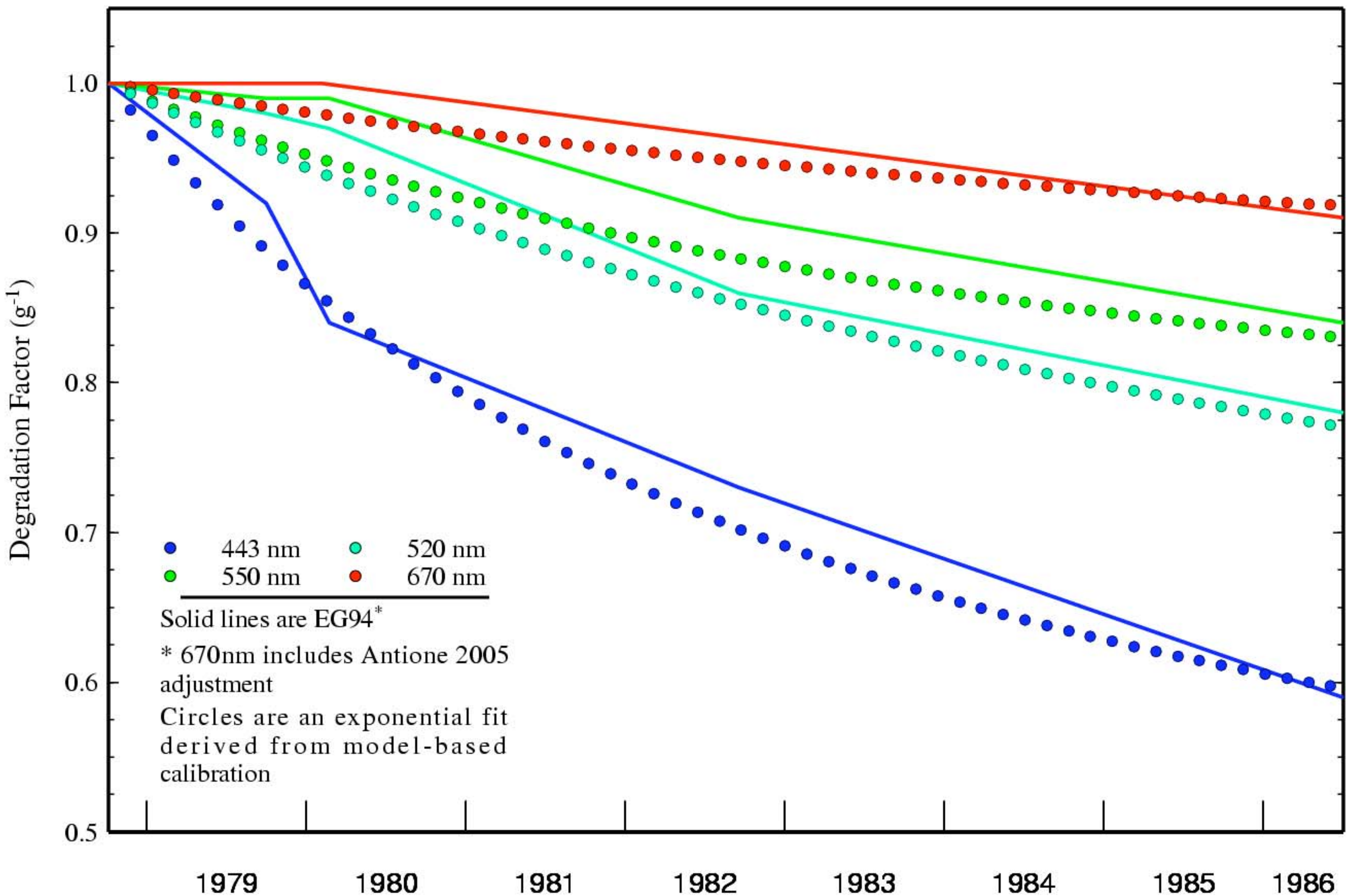
CZCS/SeaWiFS Coverage Time Series

Normalized to SeaWiFS Monthly Coverage (9 km bins)



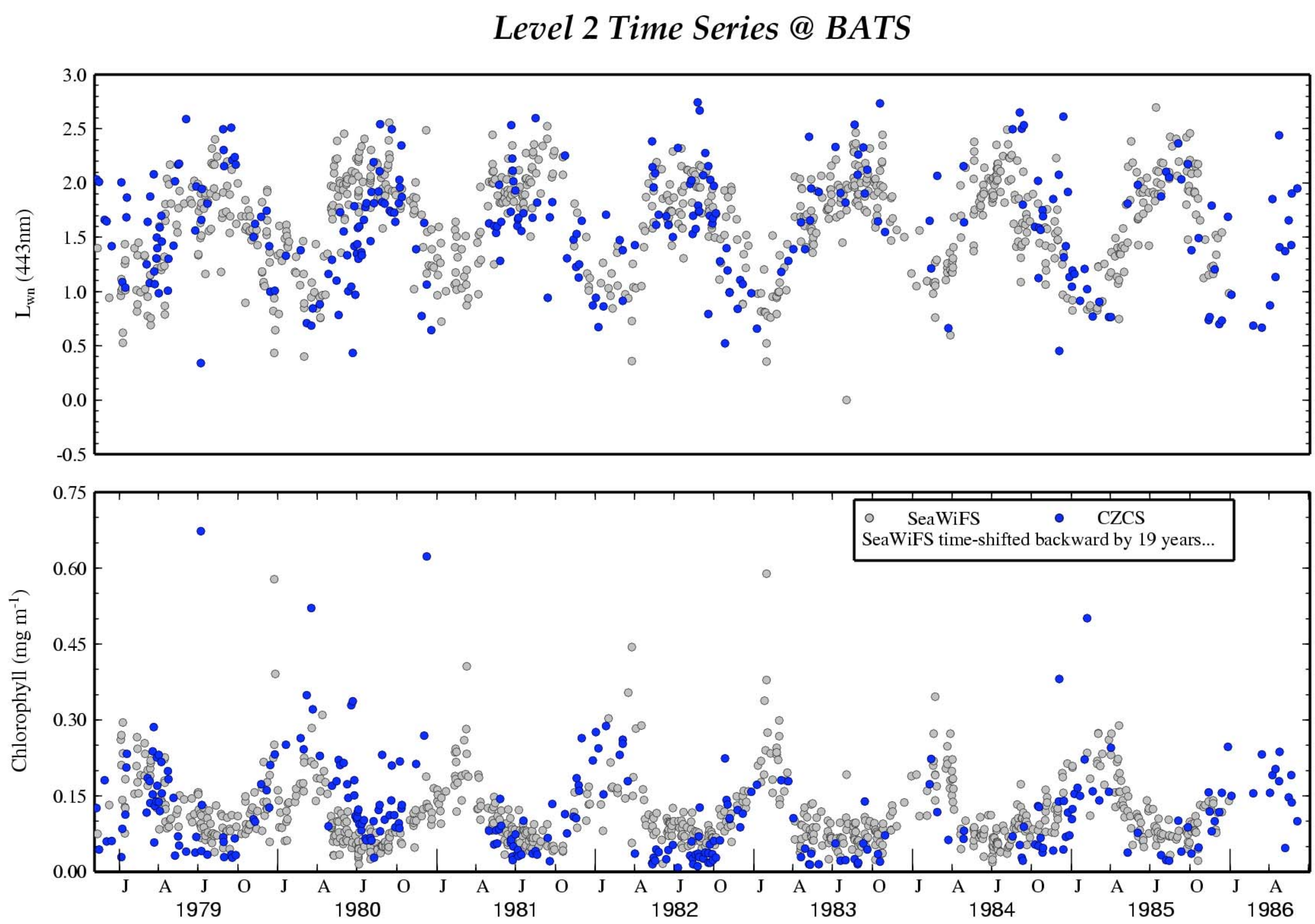
CZCS Degradation: EG94 & model-based estimates

Model-based degradation derived at BATS (Sargasso Sea) using in situ chlorophyll observations



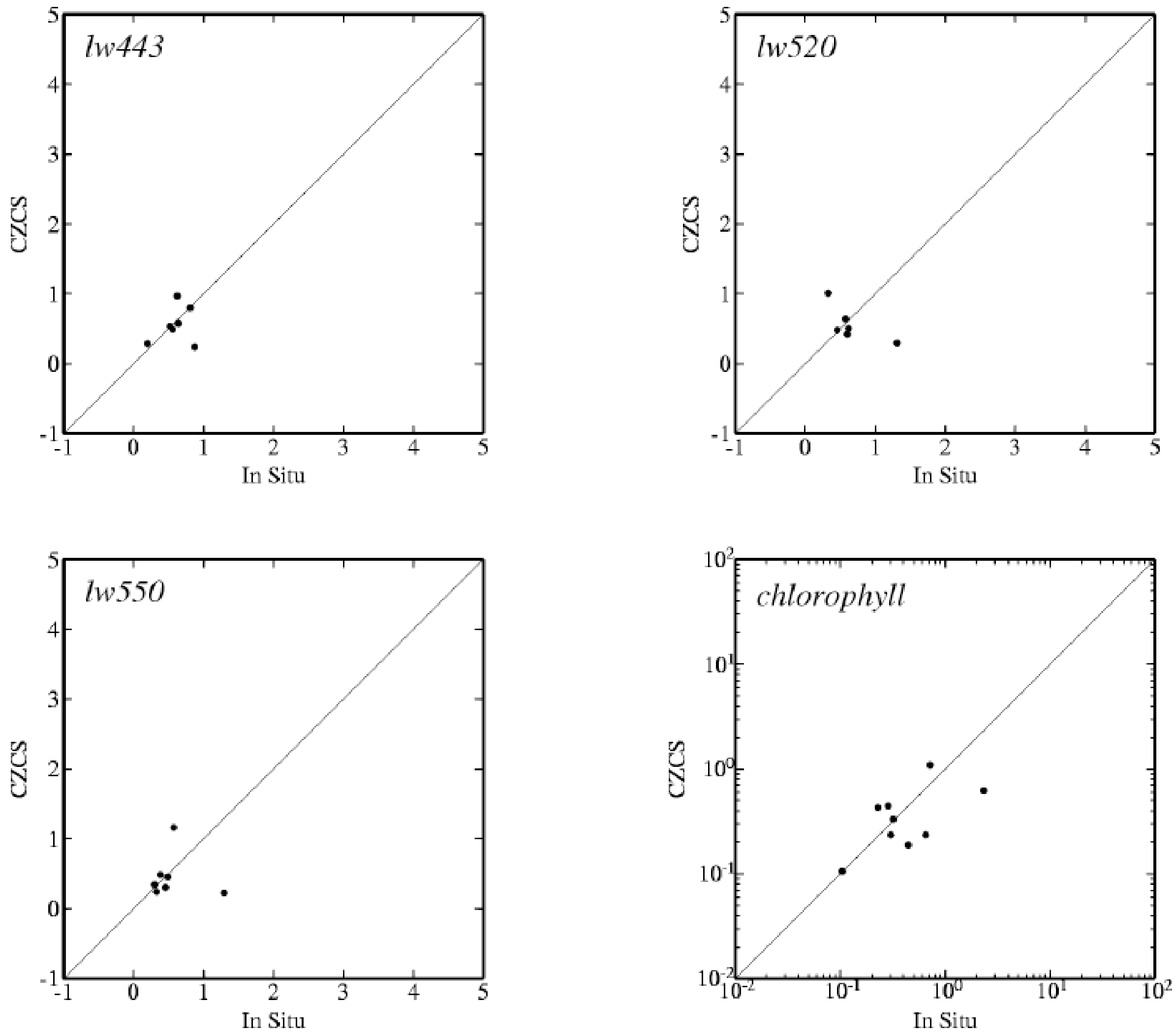
Model-based CZCS Calibration*: BATS Comparisons with SeaWiFS

*Time dependence & vicarious gains



CZCS NET Field Data Match-ups

- **Current radiometric QC & match-up selection criteria applied**
- **Roughly 10% of NET stations selected (% similar to that of recent data sets)**



Multiple Lwn Distribution Peaks & N.H. - S.H. Disparity

Lwn(520)

From EG94, June & Oct. 1981

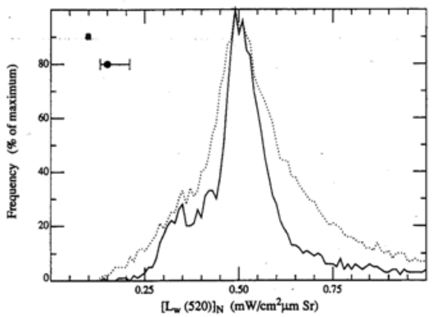


Figure 2a. Global frequency distribution of normalized water-leaving radiance at 520 nm for a 10-day period in mid-June 1981. Horizontal error bar represents the estimated error around the computed value (solid circle). Solid and dotted curves are for $L_a(4) < 0.3$ and 1.0 mW cm^{-2} μm^{-1} sr^{-1}, respectively.

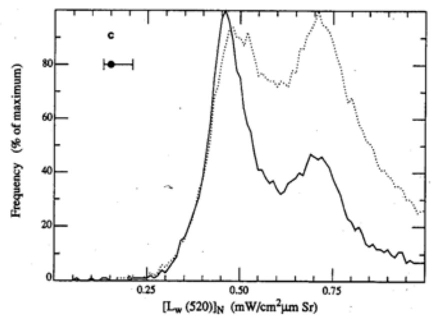
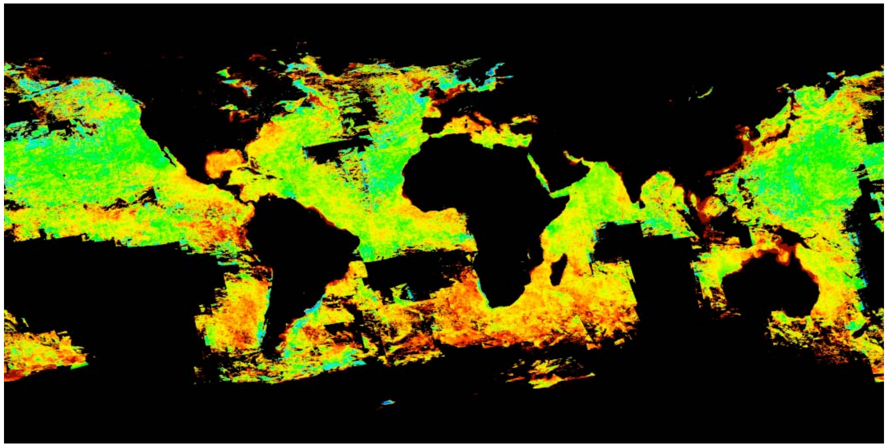
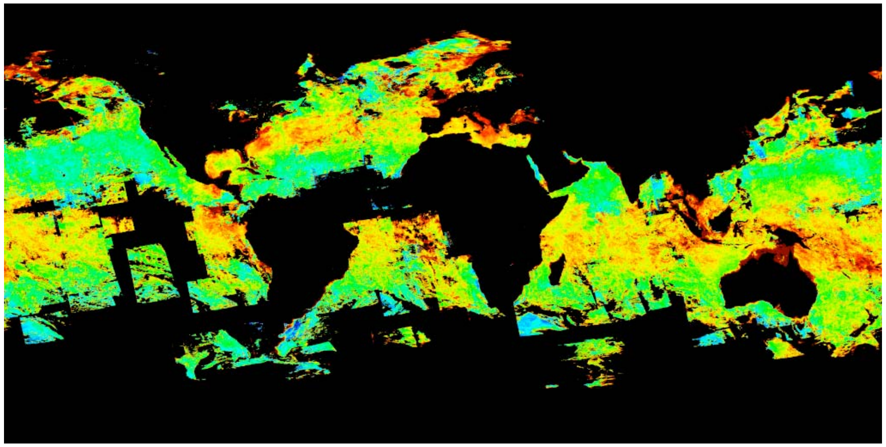


Figure 2c. Global frequency distribution of normalized water-leaving radiance at 520 nm for a 10-day period in early October 1981. Horizontal error bar represents the estimated error around the computed value (solid circle). Solid and dotted curves are for $L_a(4) < 0.3$ and 1.0 mW cm^{-2} μm^{-1} sr^{-1}, respectively.

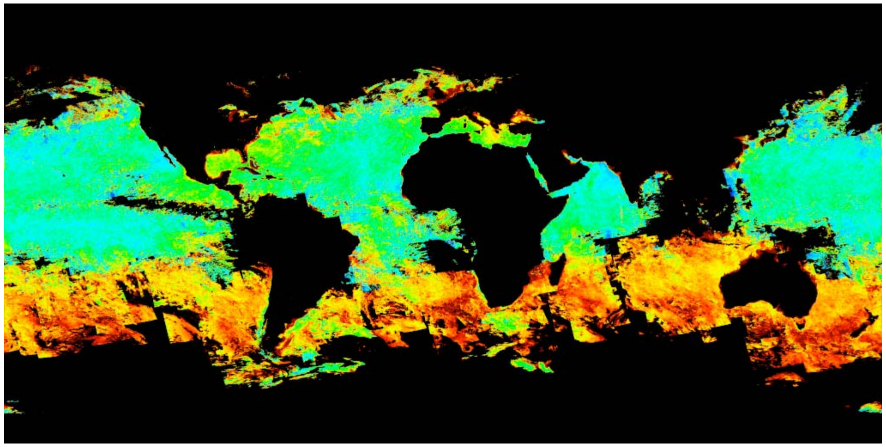
Fall 1979



Spring 1981

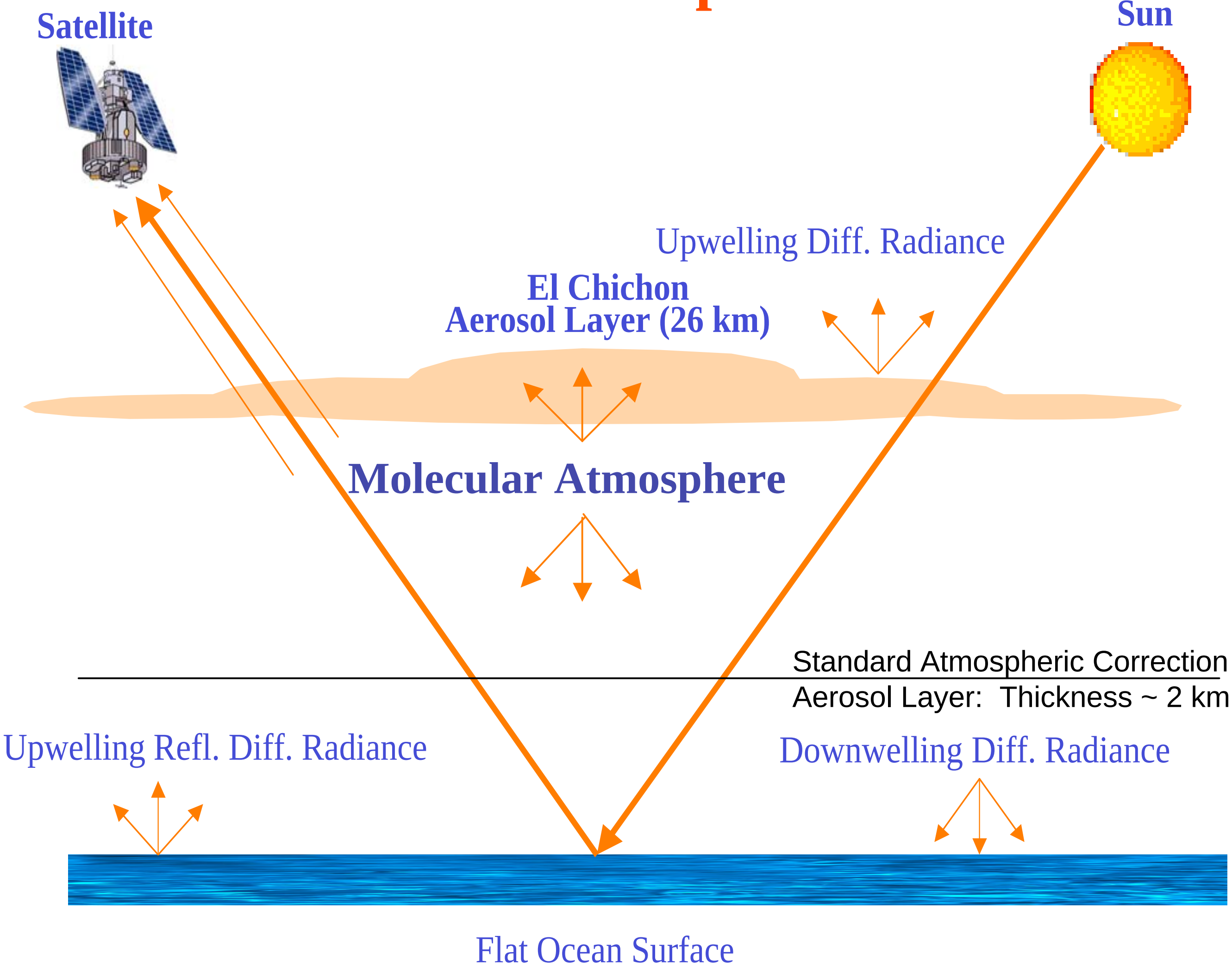


Fall 1981



El Chichon Stratospheric Aerosols: Non-negligible Effect

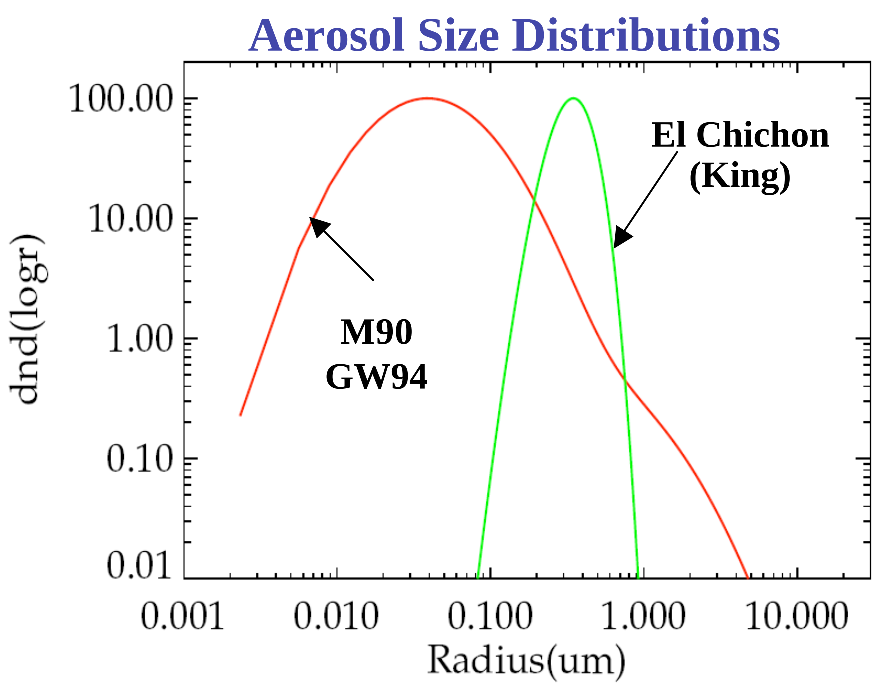
The Ocean-Atmosphere Model

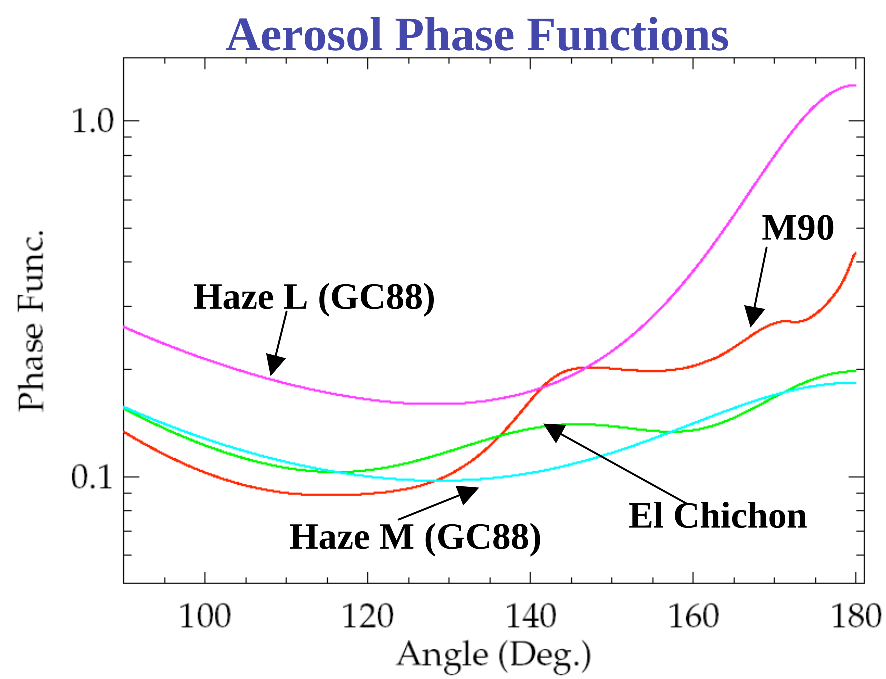


CZCS: El Chichon Aerosols

Aerosol Size Distributions & Phase Functions

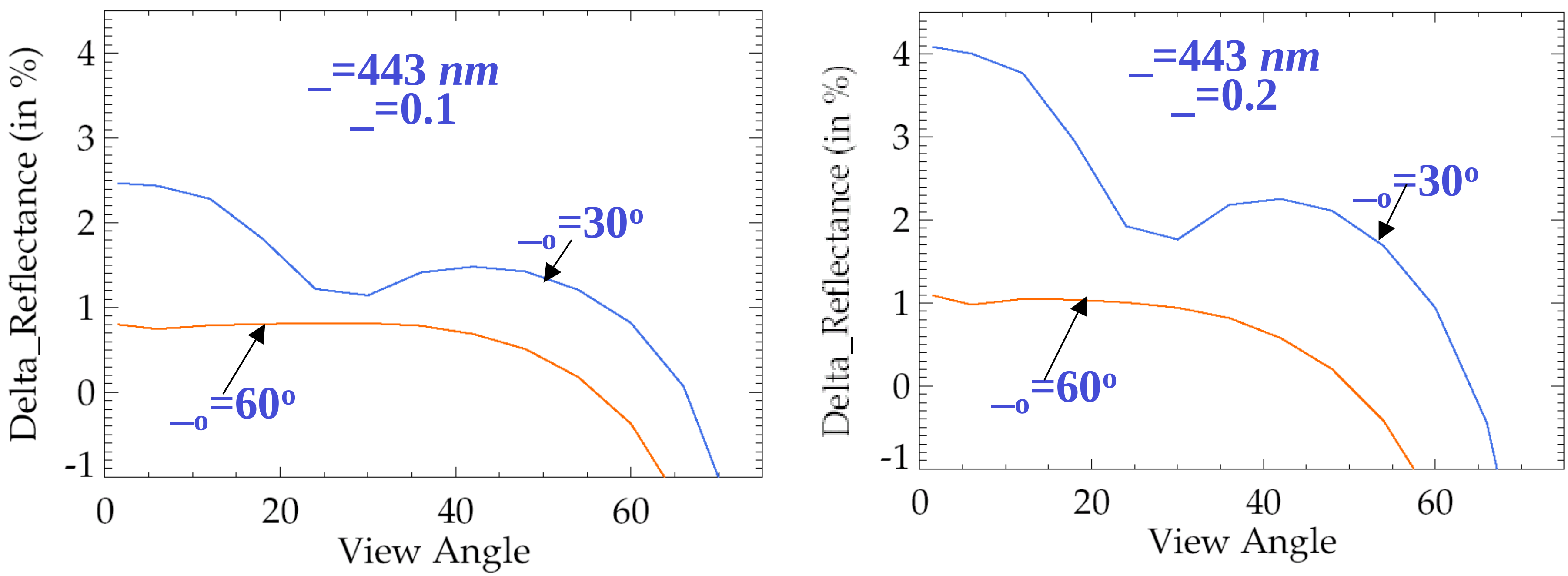
.





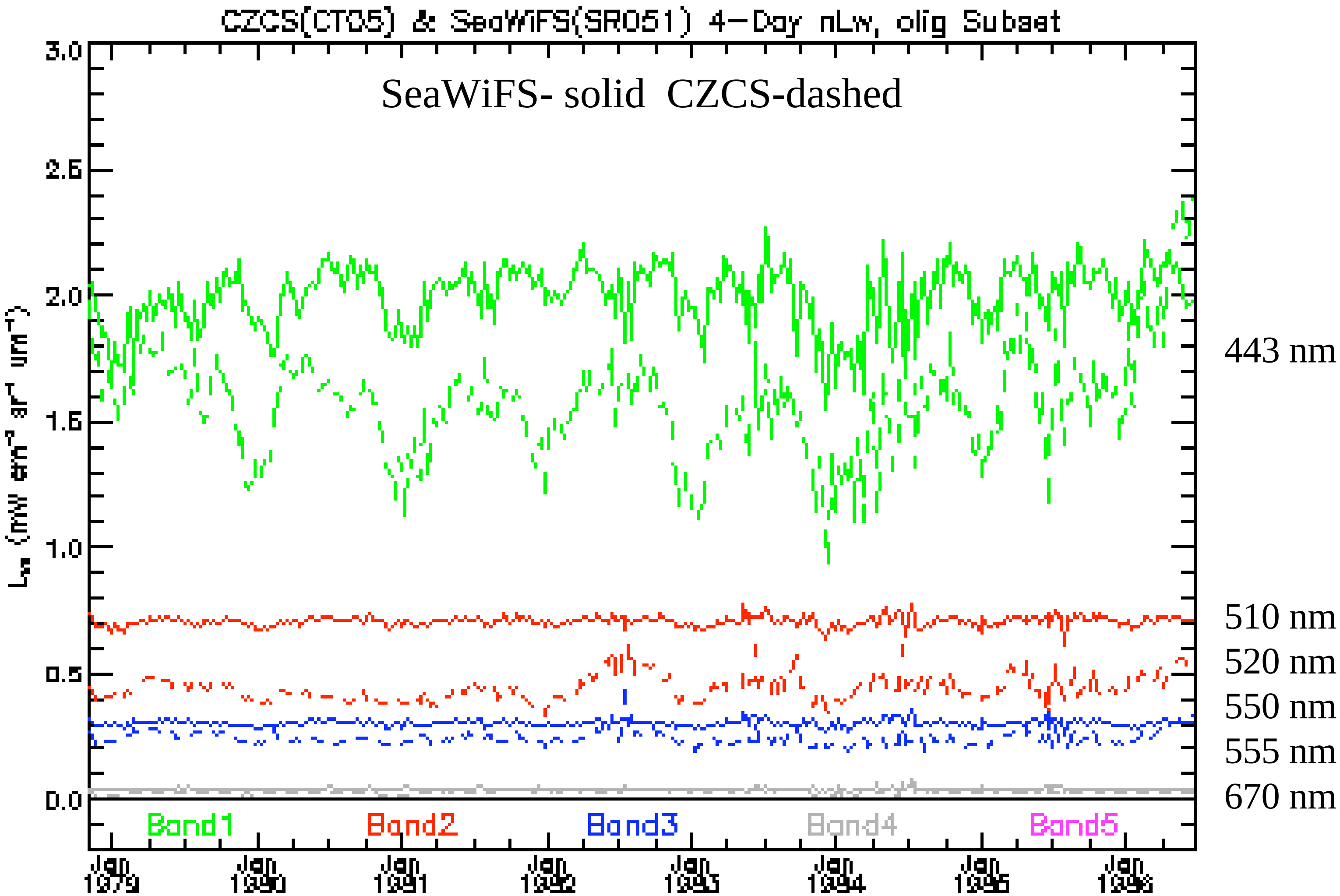
M90: Marine aerosol with 90% humidity
GW96: Gordon & Wang 1994
GC88: Gordon & Costaño, 1988

Change in the TOA Reflectance due to El Chichon Aerosols (CZCS, 443 *nm*)

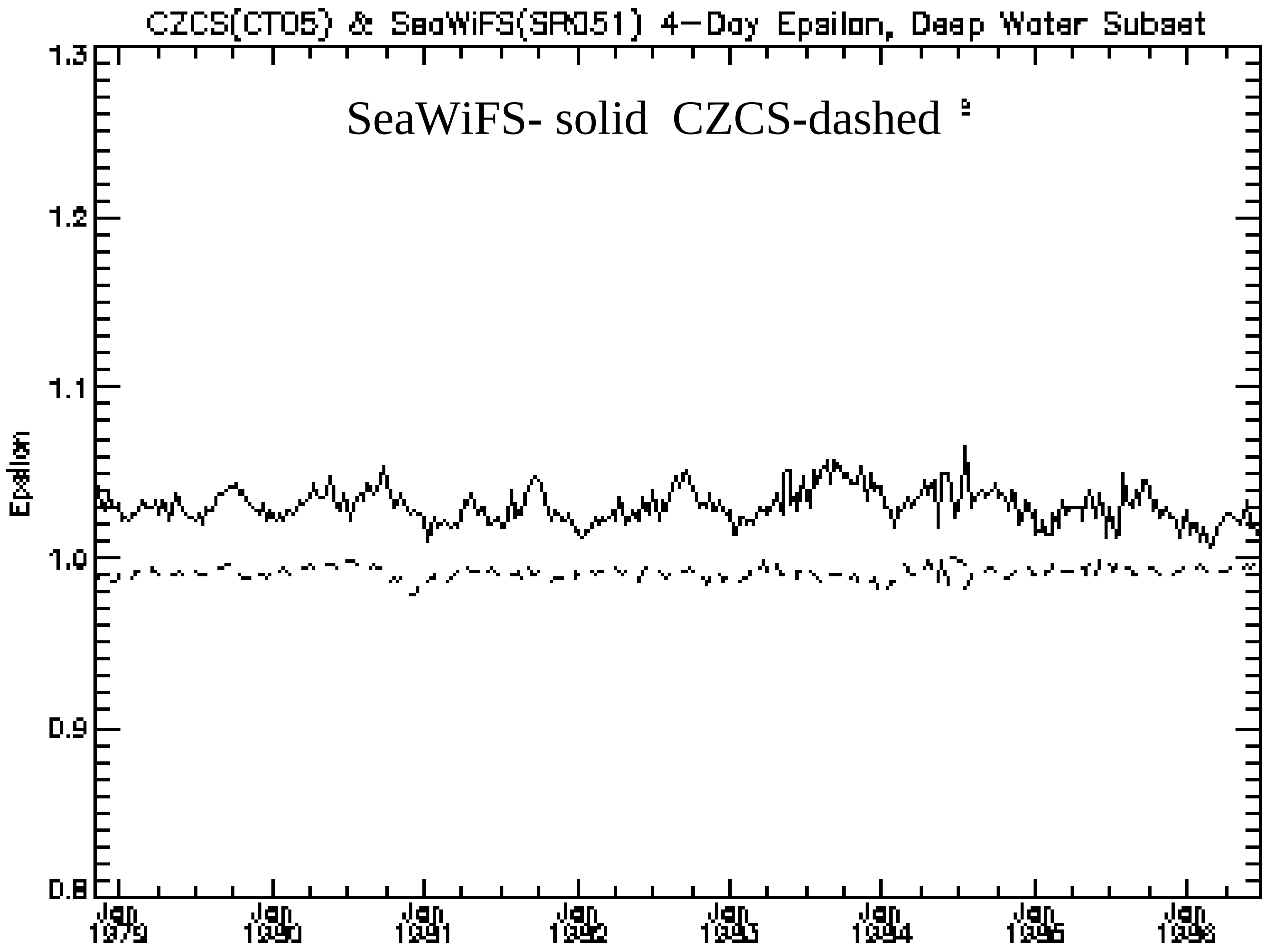


Delta reflectance computed between two cases:
M90 trophospheric layer only vs. El Chichon (King) stratospheric layer only.

CZCS: Comparison of CZCS & SeaWiFS Global Oligotrophic Lwn's



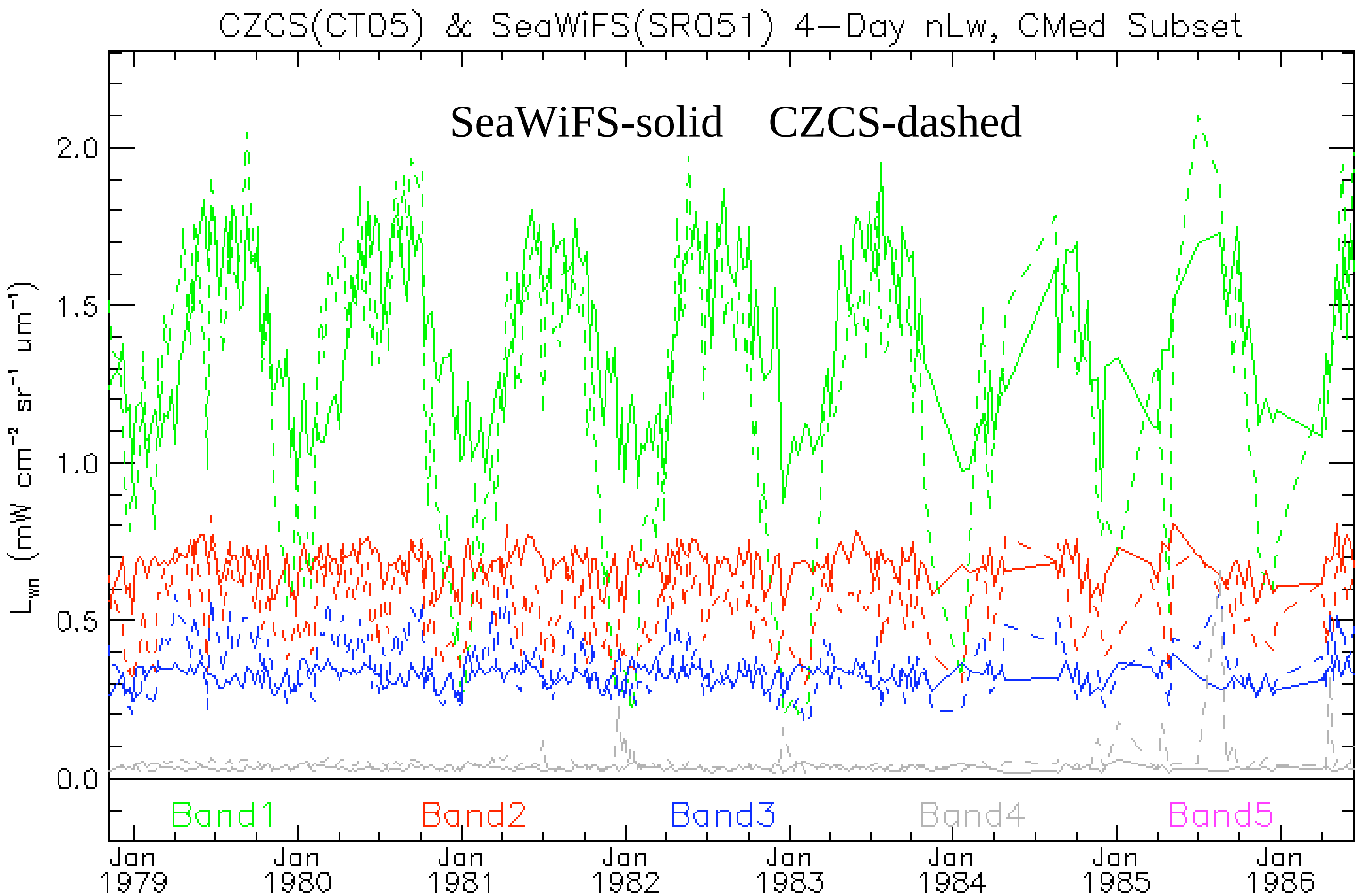
CZCS: Comparison of CZCS & SeaWiFS Global Oligotrophic Epsilons



CZCS epsilon values primarily determined by the fixed M90 model used in the processing.

CZCS: Extreme Seasonality at 443 nm

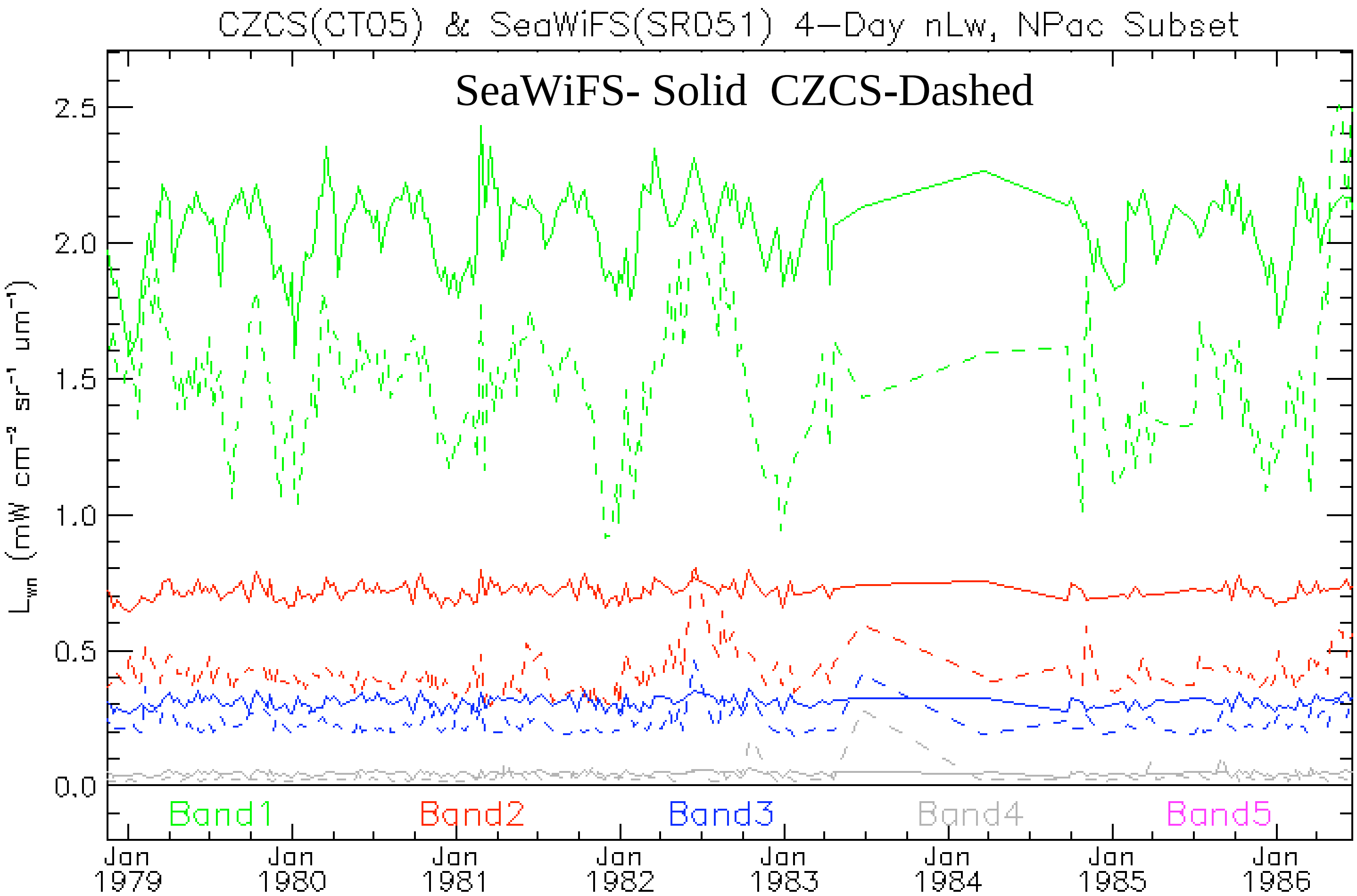
Model-based time dependence & vicarious calibration



Mediterranean Sea

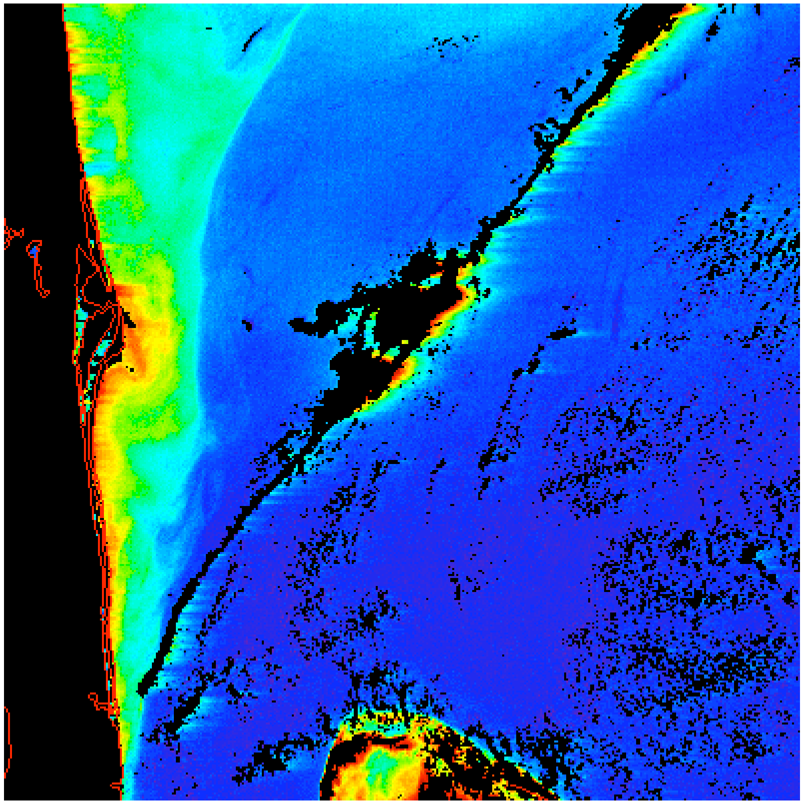
CZCS Lwn's: Large Biases

Model time dependence with model-based vicarious calibration

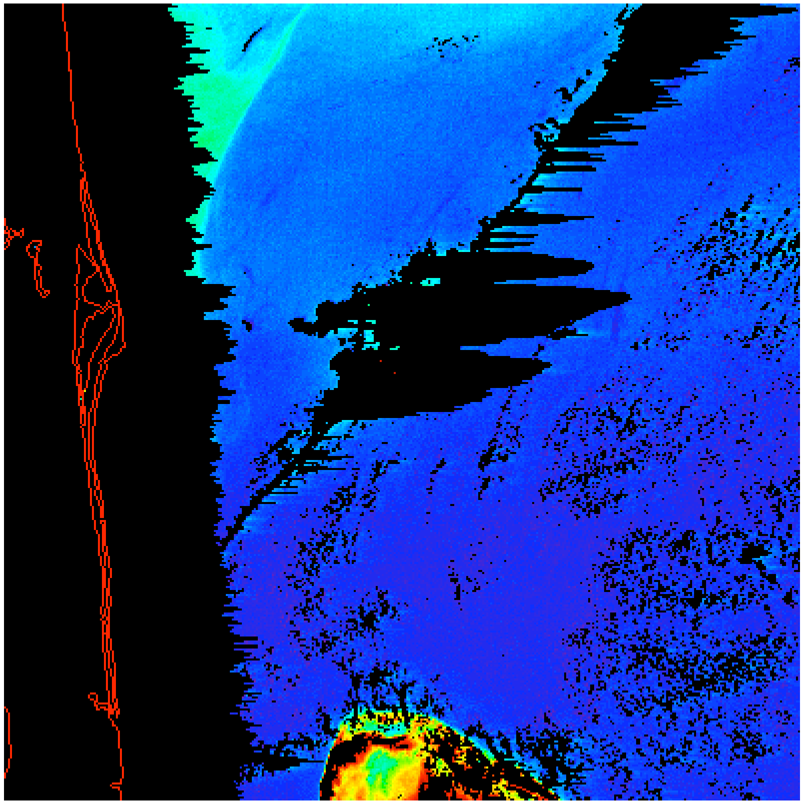


North Pacific

CZCS Electronic Overshoot (ringing): Revised Mueller (1988) algorithm



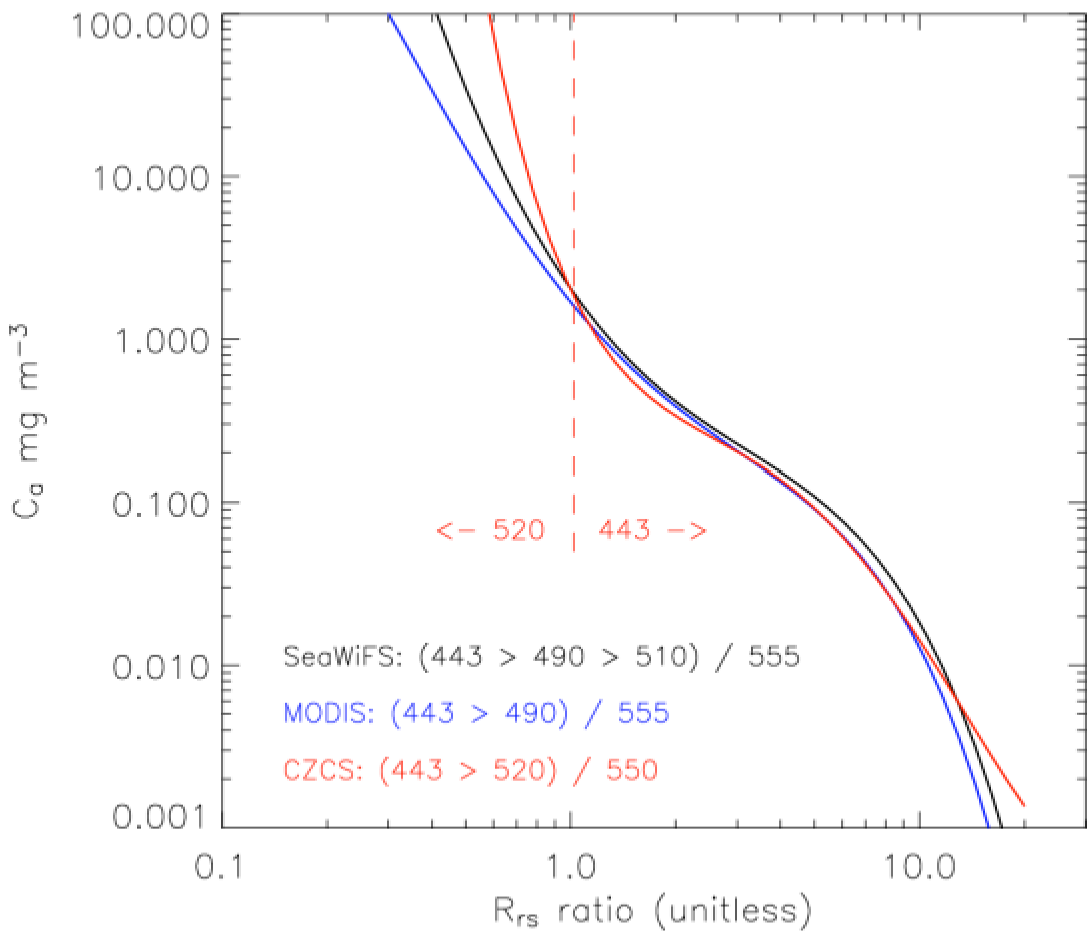
Lwn(520): no mask



Lwn(520): masked

CZCS Chlorophyll-a Algorithm: 520/550 band ratio problem

- The 520-550 band pair provides little spectral separation
- Ratio results in minimal algorithm sensitivity: small errors in ratio produces large errors in chlorophyll



Comparison of maximum band ratio algorithms

CZCS: OBPG Summary

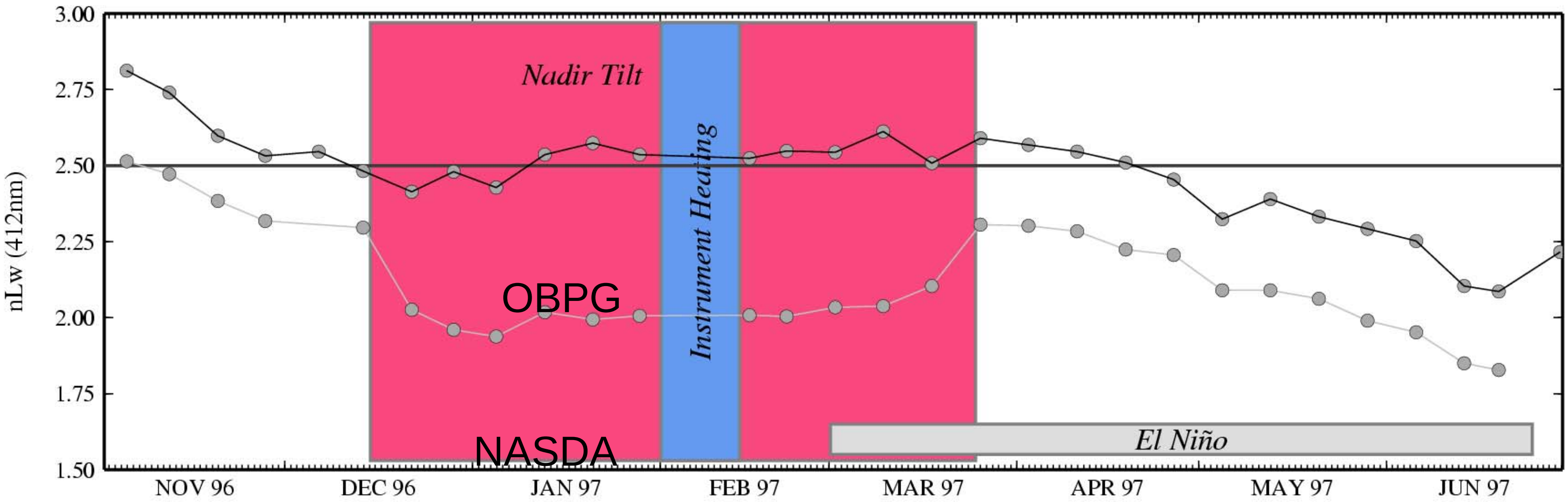
- Global coverage inadequate for global climate data record status
  - N. H. coverage may be suitable for certain hemispheric studies during early phase of mission
- Data quality varies with location based on comparisons with SeaWiFS
  - Comparisons quite good at validation site (Bermuda)
  - At other locations, large biases, either uniform or seasonal, observed
  - Implication: sensor characterization inadequate
- Sensor degradation and behavior difficult (or impossible) to explain
- El Chichon aerosols do impact CZCS retrievals contrary to Gordon & Costaño (1988)
- Lack of validation data prohibits accurate assessment of radiometry and data quality

OBPG assessment: CZCS global data cannot be brought up to a level of accuracy comparable to SeaWiFS and MODIS & should not be used for global climate research. A few regions for certain periods may be acceptable.

OCTS
November, 1996 – June, 1997

- Spectral coverage
  - Bio-optical: 412, 443, 490, 520, 565, and 670 nm (20 nm bandwidths)
  - Aerosol correction: 765 & 865 nm (40 nm bandwidth)
  - 10 detectors/band
- Special features
  - Gains: 4
  - Tilting for sun glint avoidance up to ±20º, 0º
    - Tilts the scan mirror, not the instrument
    - Creates spatial separation of spectral data as scan angle increases
      - Introduces noise in the retrievals due to resampling required to achieve approximate co-registration
  - Internal calibration lamps (not useful)
  - Solar diffuser (not useful)
  - 10:40 descending orbit
- Temporal & spatial coverage
  - 700 m resolution @ nadir; 1400 km swath
  - GAC data: 4^{th} line, 5^{th} pixel subsampling <u>(only data available to OBPG)</u>
- Additional information
  - Limited prelaunch characterization
    - Available: radiance vs. counts, spectral response functions
    - Not available: response vs. scan, temperature dependence, polarization sensitivity, point spread function, etc.
  - 10-bit digitization
  - SNRs, Bands 1-6: 779, 1373, 1453, 994, 988, 1603, 706, 637
  - Significant uncorrected straylight (ghosting)

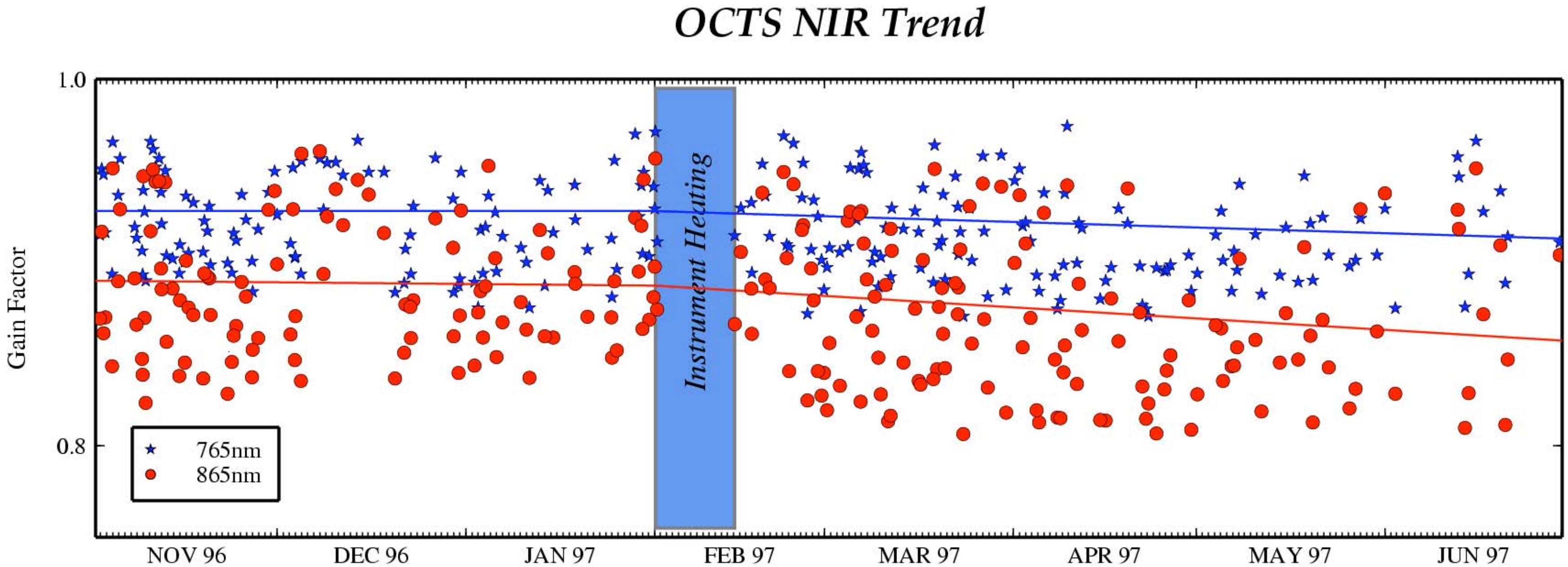
OCTS Mission Timeline



OBPG line: Lwn(412) without NASDA nadir tilt calibration adjustment
Lwn(412) analyses based on NIR atmospheric corrections w/o trends removed.

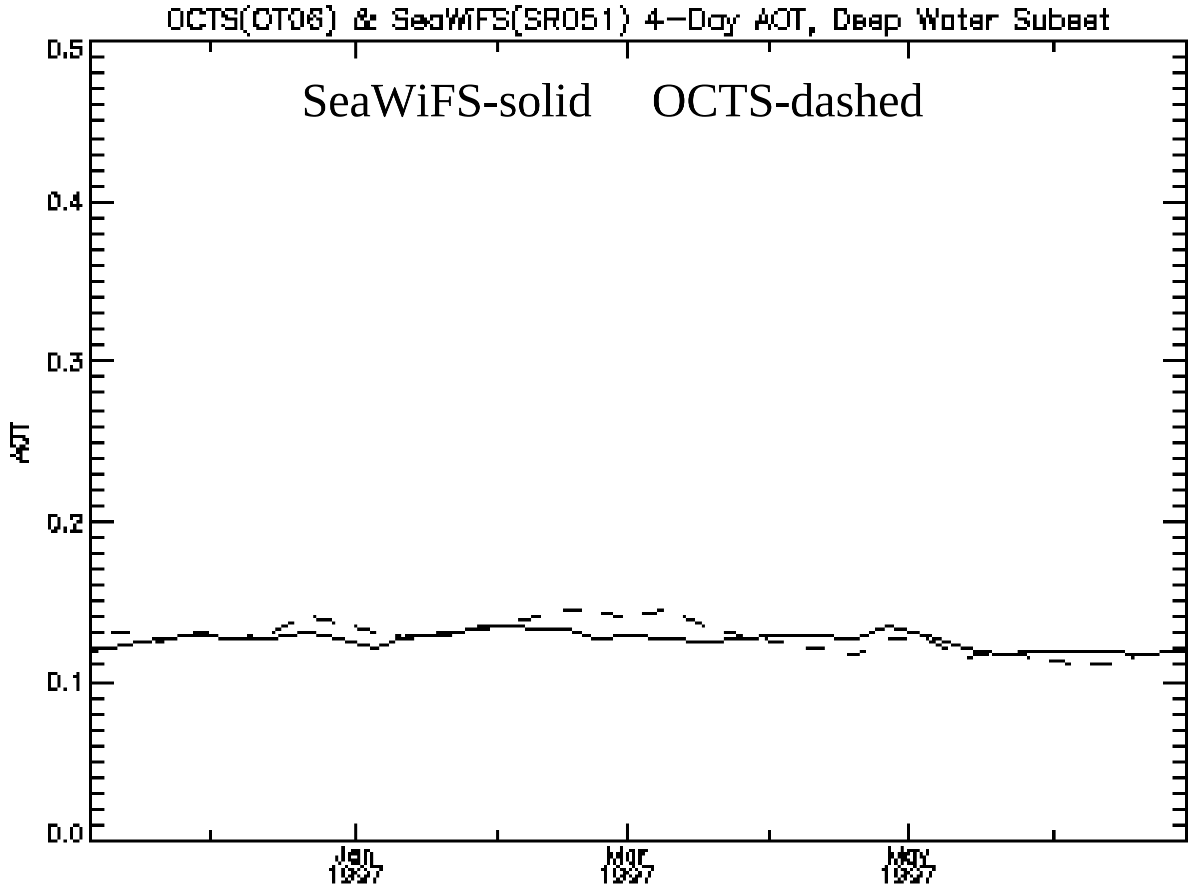
http://oceancolor.gsfc.nasa.gov/OCTS/octs_processing.html

OCTS NIR Trends



Analyses based on assuming zero ocean reflectance in open ocean.
Single trend characterizations of 765 and 865 time dependence inadequate.
Dual trend corrections (pre- & post-heating) required.

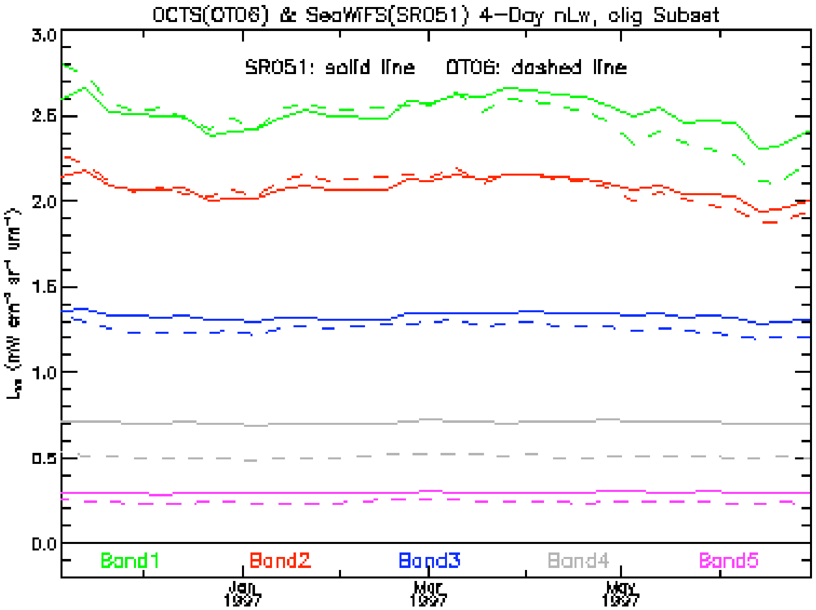
OCTS(1996-1997) & SeaWiFS (1999-2000) Aerosol Optical Thicknesses (865 nm): Deep-Water Averages



Aerosol optical thicknesses similar to SeaWiFS: No pronounced trend or discontinuity

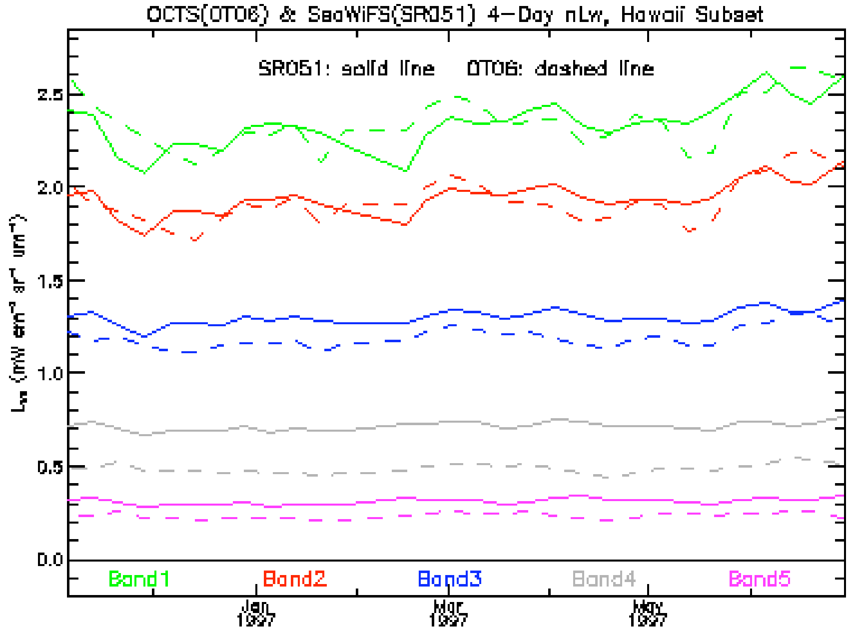
OCTS Lwn Time Series: Comparison with SeaWiFS (1999-2000) in Oligotrophic Waters

Dual NIR trend analysis



Global average

Hawaii

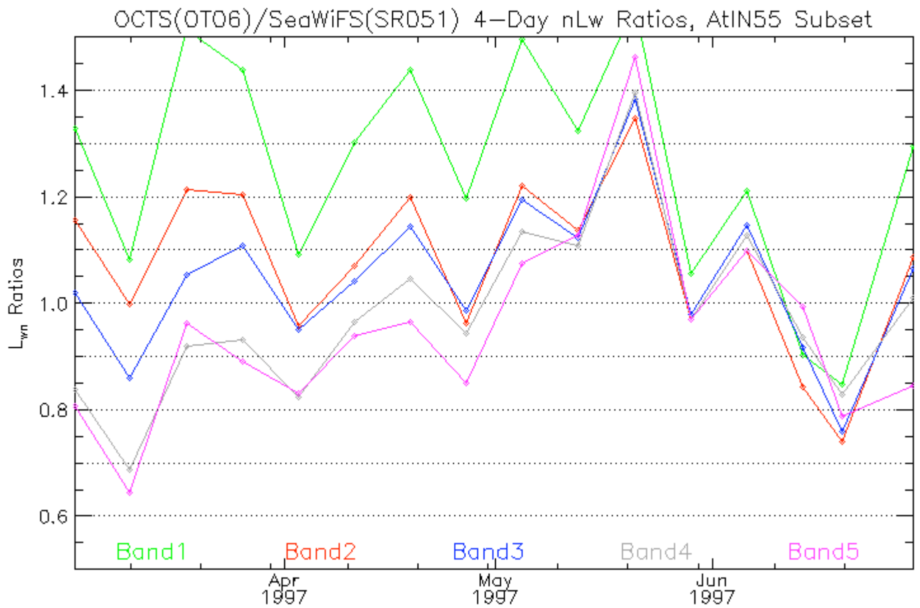


443 nm
490 nm
520 nm
555 nm
565 nm
670 nm

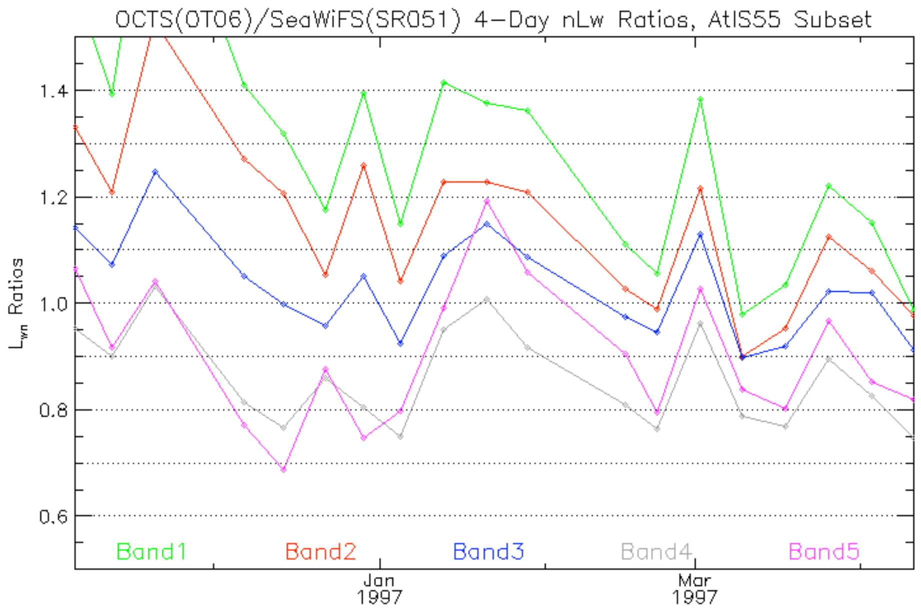
SeaWiFS-solid OCTS-dashed

OCTS Lwn Time Series: Comparison with SeaWiFS (1999-2000) in High Latitude Waters

Dual NIR trend analysis



North Atlantic: 55°N



South Atlantic: 55°S

OCTS/SeaWiFS Ratio

OCTS: OBPG Summary

- Lack of radiometric validation data makes quantification of data accuracy difficult to impossible
  - No overlap with SeaWiFS
  - Simultaneous global POLDER data
    - See Wang et al. (2002)
- Trends in water-leaving radiances coincide with El Niño onset: sensor & geophysical changes convolved.