Ocean Biology Processing Group
Evaluations of CZCS & OCTS

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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**
  - Gregg et al. (2002)
  - Laboratoire d’Oceanographie de Villefranche-U. Miami (2005)
Previous CZCS & OCTS Processings cont.

- **OCTS**
  - NASDA
  - Gregg (1999)
  - NASA-NASDA (2000; SIMBIOS Project)
“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: Significant polarization residuals remain
  - 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 & ±10° mirror tilt (corresponds to ±20° 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


SeaWiFS 2005

SeaWiFS 2006

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

Solid lines are EG94
* 670nm includes Antione 2005 adjustment
Circles are an exponential fit derived from model-based calibration
Model-based CZCS Calibration*: BATS
Comparisons with SeaWiFS

*Time dependence & vicarious gains

Level 2 Time Series @ BATS
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


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 $L_e(I) < 0.3$ and 1.0 mW cm$^{-2}$ μm$^{-1}$ sr$^{-1}$, respectively.

Spring 1981

Fall 1979

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 tropospheric layer only vs. El Chichon (King) stratospheric layer only.
CZCS: Comparison of CZCS & SeaWiFS Global Oligotrophic Lwn’s

SeaWiFS- solid  CZCS-dashed

443 nm
510 nm
520 nm
550 nm
555 nm
670 nm
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

SeaWiFS- Solid  CZCS-Dashed

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

• 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 ±20°, 0°
    • 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: 4th line, 5th pixel subsampling (only data available to OBPG)

• 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)
OBPG line: $L_{\text{wn}}(412)$ without NASDA nadir tilt calibration adjustment
$L_{\text{wn}}(412)$ analyses based on NIR atmospheric corrections w/o trends removed.

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

Global average

Hawaii

SeaWiFS-solid OCTS-dashed

Dual NIR trend analysis
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)