CZCS Calibration: Methods and Historical Overview

1. Prelaunch Calibration

Before the Coastal Zone Color Scanner (CZCS) was launched, rigorous laboratory testing was required to ensure the instrument could accurately measure light and temperature.

Laboratory Setup:

- **Visible Channels (Bands 1–5):** These were calibrated using a custom-built, 76-centimeter diameter integrating sphere as a diffuse radiance source. The integrating sphere was calibrated using a standard lamp from the National Bureau of Standards. A spectrometer and a second integrating sphere were used to transfer the calibration from the standard lamp to the primary integrating sphere.
- **Thermal Channel (Band 6):** This channel was calibrated using a blackbody source.
- **Vacuum Testing:** A collimator was used to calibrate the CZCS under vacuum conditions.

The instrument's manufacturer, Ball Aerospace, provided the initial calibration coefficients (slope and intercept) to convert the raw digital counts of the sensor into meaningful radiance values for each band and gain setting.

Intended On-Orbit Calibration:
Originally, the CZCS was designed to calibrate its first five bands while in orbit using built-in, redundant incandescent light sources. However, this built-in lighting system had two major flaws:

1. The light from the incandescent lamps did not pass through the entire optical train, meaning they could not provide a "true" full-system calibration.
2. The lamps were not bright enough to provide a meaningful signal for Band 1.

Result: The built-in lamps were ultimately only used to verify the instrument's stability over time.

(Note on Band 6: The thermal channel was meant to be calibrated on-orbit by viewing deep space and the instrument's own blackened, temperature-monitored housing. However, because Band 6 failed early in the mission, its calibration requires no further discussion.)

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2. Temporal Degradation

In 1981, the Nimbus Experiment Team (NET) discovered that the sensitivity of the CZCS visible bands—particularly the 443 nm band—was degrading over time.

The EG94 Solution:
To address this degradation, Evans and Gordon (1994, "EG94") derived a long-term degradation correction. The EG94 correction is a time-varying, band-dependent multiplicative factor applied on top of the original Ball Aerospace calibration.

The OBPG Re-evaluation:
Later, the Ocean Biology Processing Group (OBPG) re-evaluated the sensor's degradation using a clear-water radiance model (Werdell et al., 2006).

- By using an exponential fit to the derived gain coefficients, the OBPG successfully replicated the EG94 results.
- Because their exponential fit and the piecewise linear fit of EG94 produced comparable results, the OBPG decided to continue using the EG94 temporal calibration for current data processing.

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3. Vicarious Calibration

Vicarious calibration involves adjusting an instrument's calibration using indirect, independent measurements.

The EG94 Adjustments:
Evans and Gordon made initial vicarious adjustments to the original Ball Aerospace pre-launch calibration:

- **Bands 2 and 3 (520 nm & 550 nm):** These were calibrated by forcing the peak frequency of 10-day average global radiance values to match known clear-water radiance values.
- **Band 1:** This band was calibrated by forcing agreement with simultaneous *in situ* (on-site) data collected during post-launch validation cruises conducted by the NET.

The OBPG Adjustments:
When the OBPG took over data processing, they retained the EG94 coefficients but added their own vicarious calibration coefficients on top of them.

- **The Method:** The OBPG used a clear-water radiance model based on a climatological *in situ* chlorophyll time-series from the Bermuda Atlantic Time Series (BATS) site.

- Unlike the EG94 calibration, the OBPG applied this clear-water radiance model approach to Band 1 as well.
- **Purpose:** The additional OBPG calibration accounts for differences in the atmospheric correction approaches used by EG94 versus the OBPG.

User Flexibility (Backward Compatibility):
The OBPG could have removed the EG94 coefficients before applying their newer coefficients. However, because the EG94 coefficients are simply multiplicative factors, they were left in the calibration. Leaving the EG94 vicarious coefficients in the data provides a great advantage: **if users want to revert the data to the original EG94 results, they simply set the OBPG vicarious coefficients to 1 (unity).**

References

1. **Ball Aerospace Division (1979).** *"Development of the coastal zone color scanner for Nimbus-7, vol 2: Test and performance data, Final report."*

2. **Evans, R.H., and Gordon, H.R. (1994).** *"Coastal zone color scanner 'system calibration': A retrospective examination"*, Journal of Geophysical Research (JGR), Vol 99, No. C4, pp 7293–7307. doi: 10.1029/93JC02151

3. **Werdell, P.J., Antoine, D., Bailey, S.W., Feldman, G.C., Hooker, S.B., McClain, C.R., and Zibordi, G. (2006).** *"Alternate on-orbit vicarious calibration schemes for ocean color satellites"*, NASA Ocean Color Research Team Meeting, Newport, RI, 11-13 April 2006.