PREFLIGHT SOLAR-RADIATION-BASED CALIBRATION OF SeaWiFS

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OUTLINE

Concept

Method

Advantages

Disadvantages

Error sources

Accuracy

Application to Aircraft Sensors

CONCEPT

Duplicate on the ground solar conditions in orbit
- Direct beam only
- Correct incidence angle on diffuser

Correct for atmospheric effect
- Transmittance of the atmosphere
- Diffuse light from scattering

WHY IS THE SOLAR DIFFUSER AND ITS CALIBRATION SO IMPORTANT?

The solar diffuser is important because it is the only on-board system that can provide a calibration that is:

- Full aperture
- Full field
- End-to-end
- Of appropriate radiance distribution and level

The preflight calibration of the sensor/diffuser is important because:

- It is often desirable to associate the in-flight calibration with an SI-based preflight calibration. The method described here, and minor variations, is the only way to do it.

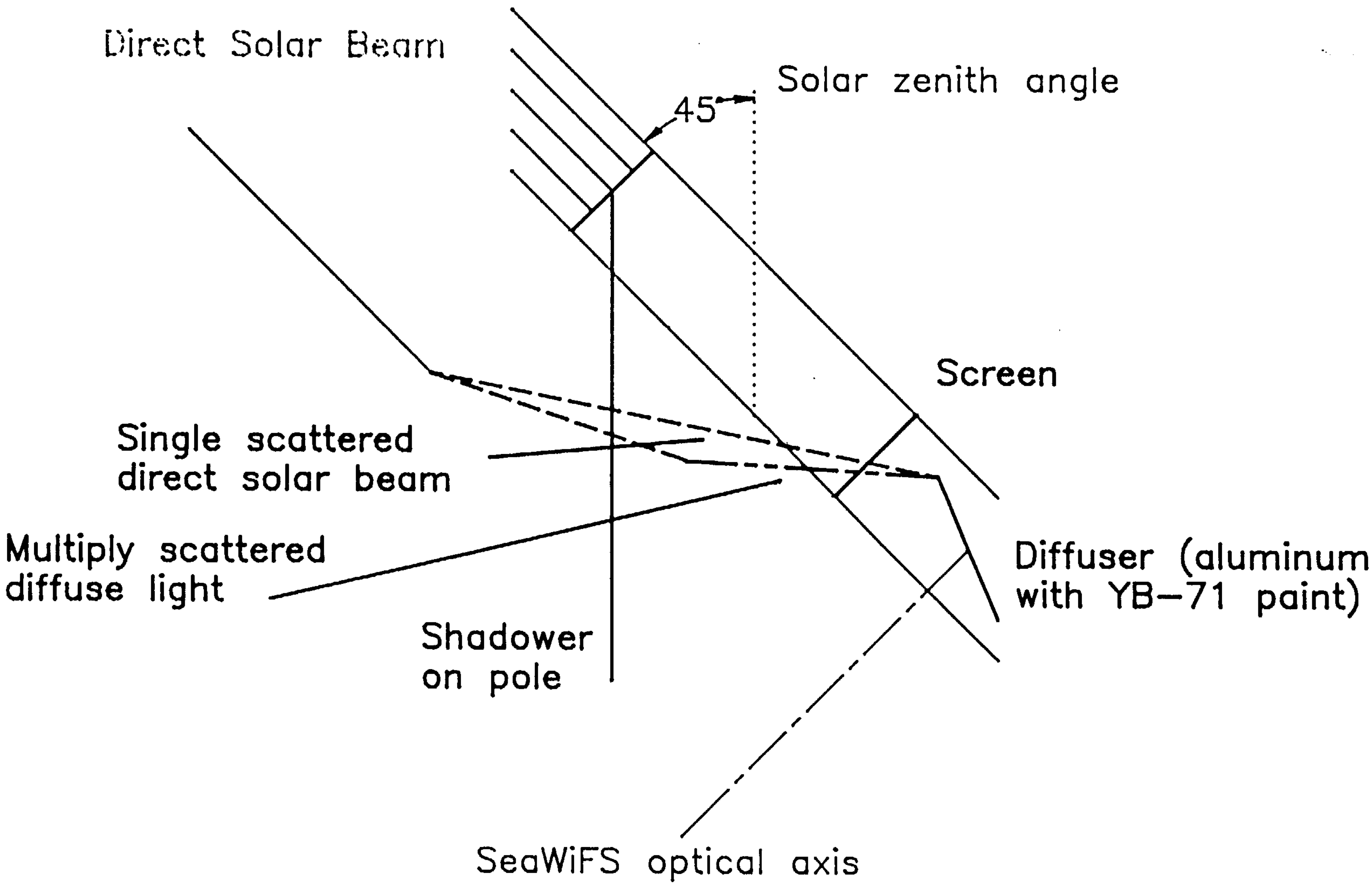
METHOD

Any sensor with a solar diffuser can be calibrated preflight using the sun as source.

The procedure is to situate the sensor such that the diffuser is illuminated in the same geometry as in orbit. The digital counts are recorded by the sensor in each band with the diffuser sunlit and shadowed. The difference, corrected for atmospheric transmittance, corresponds to the in-orbit illumination.

This calibration was proposed at the SeaWiFS Science Team meeting in January. The measurements were made on March 8 in the rock garden at SBRC.

Experiment Illumination Geometry



ACCURACY

- For nominal 23-km visibility US standard atmosphere, the uncertainty range is from ±2.8% to ±1.4%, depending on the wavelength, for a solar zenith angle of about 55°.
- Note that it is desirable to calibrate at small solar zenith angles, as the transmittance uncertainty is decreased.
- The SeaWiFS screen over the diffuser reduces the BRDF sensitivity. This may not be the case for other sensors, so the angle of incidence onto the diffuser has to be known to about 0.25°.
- The accuracy of the comparison with a SIS is limited by the uncertainty in the method as described above. It is also limited by the uncertainty in the calibration of the SIS and the uncertainty in our knowledge of the solar spectral exo-atmospheric irradiance.

MINIMIZING ERRORS

Reduce optical depth errors ($\Delta\delta$)
- Use a well-calibrated solar radiometer
- Use a Langley plot on a "good" day
  - Requires stable atmosphere over half a day
- Make measurements on an extremely clear day
  - Reduced aerosol scattering
- Make measurements at a high elevation site
  - Reduced aerosol scattering
  - Reduced Rayleigh scattering
  - Reduced absorption

Reduce transmittance errors
- Make measurements at a low solar zenith angle
- Know the solar angle well

Reduce diffuse correction error
- Use smallest possible shadower
  - Reduces the blocked diffuse component
- Make measurements on an extremely clear day
  - Reduced aerosol scattering
- Know precisely the shadower angular extent
  - Allows better correction computation

ERROR SOURCES

Transmittance ($T(\lambda)$)

$$T(\lambda) = e^{-\delta(\lambda)/\mu_s}$$

where:

$\delta(\lambda)$ = spectral optical depth

$\mu_s \approx \cos\theta_s$

θ_s = solar zenith angle

Fractional error in T

$$\frac{\Delta T(\lambda)}{T(\lambda)} \approx -\frac{\Delta\delta(\lambda)}{\mu_s} + \frac{\delta(\lambda)\sin\theta_s\,\Delta\theta_s}{\mu_s^2}$$

where

$\Delta\delta(\lambda)$ = absolute error in optical depth ($\delta(\lambda)$)

$\Delta\theta_s$ = error (in radians) in the knowledge of θ_s

Diffuse correction

- blocked aureole
- non-lambertian diffuser

DISADVANTAGES

- Risk associated with moving the sensor outside (contamination)
- Need clear weather conditions
- Need accurate spectral atmospheric transmittance measurements
- Requires diffuser illumination at the same angle as in-flight
- Need to obtain higher accuracy solar exo-atmospheric spectral data in order to provide an accurate comparison with national laboratory standards.

ADVANTAGES

- The same source (the sun) is used both preflight and in-flight. Thus any problem due to Fraunhofer lines is accounted for in both calibrations.
- There is no problem due to low radiance in the blue.
- Calibrates the complete sensor/solar-diffuser system.
- The calibration is easy and rapid -- the source does not have to warm up.
- The sun is stable, it does not need to be checked for change in output
- The source is inexpensive and can be duplicated anywhere on the earth or in orbit. Although there may be differences between national standards from different countries, there are no differences between a US, Japanese or UK sun.

CONVENTIONAL SPHERICAL INTEGRATING SOURCE (SIS) CALIBRATION

ADVANTAGES:

- Conducted in the laboratory
- Easy to repeat
- SIS can be checked by a calibrated detector

DISADVANTAGES

- Time consuming spectroradiometric calibration of the SIS
- Low radiance output of SIS in the blue
- SIS radiance does not contain Fraunhofer lines
- SIS cannot be used to calibrate the sensor/solar-diffuser system

AIRCRAFT METHOD TEST

This method was tested last month at the Boulder City airport in Nevada.

- Daedalus 1268 Scanner (DOE Remote Sensing Lab equipment, operated by EG&G Energy Measurements, Inc)
- MBB helicopter (as above)
- 0.5 nominal reflectance Spectralon reference panel

Data not yet reduced. We plan to compare the calibration from this method with an in-flight calibration done with four large reference panels earlier that day. Spectral optical depths were collected for both experiments along with meteorological data and reflectance measurements of the panels. Preliminary results from the in-flight calibration show an extremely clear atmosphere.

APPLICATION TO AIRCRAFT SENSORS

Requirements:

- Sensor can be operated with the aircraft on the ground
- Sensor can view a reference panel under the aircraft
- Panel can be illuminated directly by the sun
    - No shadows from aircraft
    - No specular reflections onto the panel
- Geometry such that panel can be shaded by parasol

Advantages:

- Sensor can be calibrated just before and/or after a data run
- Sensor is in actual aircraft environment rather than lab
- Procedure is quick and easy
- Reflectance of panel(s) can be selected to match that of target
- Very little equipment other than sensor/aircraft needed