Radiometry lab:

We have the following instrumentation:

1) C-Ops, profiling radiometer system (upwelling radiance, downwelling irradiance, *Es*, shadowband).
2) Above water radiometer (sort of), hold *Lu* sensor by hand to get *Ltotal (Lt)* and *Lsky (Li),* then have *Es*.
3) Floating radiometer HTSRB (hyperspectral tethered radiometer buoy)
4) PAR sensor
5) Microtops hand held radiometers
6) Phone app….Hydrocolor.

Group 1. In-water Radiometry measurements off the dock (C-OPS)

The object is to get familiar with operating the C-OPS radiometer, and looking at the data.

A) Profile with the C-OPS on the sunny side of the dock, collect data (*Ed* and *Lu*) as you lower and raise the radiometer 5 times to a depth of 3 m (if there is enough water depth by the dock, keep the instrument out of the mud). This will allow you to calculate the upwelling radiance attenuation.
B) Flip the irradiance sensor over (pointed down) at the same depth the Lu sensor. This allows you to calculate the "Q" = *Eu/Lu*. Profile as deep as you can, without hitting the bottom.
C) While using the C-OPS, collect some of the shadowband version of *Es* (option on data collection window).

Group 2. In-water floating radiometer (HTSRB)

A) Down on the dock deploy the radiometer buoy placing the buoy between sun and dock (if possible).
B) Collect measurements with the buoy in full sunlight and in various positions around the dock (shadowed and non-shadowed). End with a collection of measurements in the best possible location.

Group 3. PAR sensor

A) This sensor displays the data on a hand held device, so measurements must be recorded manually with a notebook.
B) Determine how to make a profile with the PAR sensor, recording data every 20 cm. Try to do it in a period when the light field is stable.
C) Try to make some measurements along side the C-Ops at the same depth (need to make good notes to correlate the two measurements).

Computations for in-water data:

a. Accumulate the cast (depth profile) data and calculate the diffuse radiance attenuation coefficient (*KLu*).
b. How do the irradiance spectra change when the buoy is in full sun light, in the shadow of dock?
c. How does the upwelling radiance spectra change when in the various situations?
d. You need to determine how to calculate *KLu* for the buoy to propagate it to the surface. What could you try?
e. Calculate *Rrs* from both systems, how does the Rrs vary for the various situations.
f. Compute the *Rrs* and *nLw* for the SeaWIFS spectral bands.
g. Compute *Ed*(PAR) from hyperspectral data (400 to 700 nm) and SeaWIFS bands (extrapolate if needed) and compare these to each other.
h. Compare the PAR measurement with the simultaneous measurements with the PAR sensor.
i. Compare the *Es* measured with that calculated with Greg and Carder (script provided by Emmanuel).

While doing these measurements listed above, make measurements of the direct solar irradiance using the Microtops sunphotometer. A current protocol for using a Microtops is given by Knobelspiesse (2003). During the sky measurement period, try to make a set of Microtops measurements every 10 minutes. NOTE THESE MEASUREMENTS ONLY MAKE SENSE IF THERE IS A CLEAR UNOBSTRUCTED (no cloud) VIEW OF THE SUN, IF THIS IS NOT THE CASE SKIP IT.

Instructions

A) (in general) enter location of site…it will already be done in this case (it is 43.79 deg N, 69.96 degrees W

B) (in general) make sure time is accurate …it will be already done in this case.

C) turn on Microtops. Leave cover closed.

D) after instrument has done initialization and returned to "RDY Manual…." Open cover and point towards sun. Hint…eliminate shadow on your hands holding the sunphotometer and on the sunphotometer face…this will get you in the ball park to get the sun in the Sun target window…center sun in this bulls eye.

E) press scan and keep instrument pointed at sun. Jiggle around a little while holding it targeted on sun….one advantage of being old and shaky. This is in case the sun target is not aligned perfectly with the detector telescope.

F) Instrument will automatically collect 25 measurements, keeping the top value. Repeat this process 5 times, turn off instrument and turn it back on (to reset dark), then repeat another 5 times.

G) Turn off instrument and put in shaded spot until the next measurement.

NOTES (MOSTLY FOR ME): Use a terminal window, IGOR VDT-64 works, 19200 baud, 8 bits, 2 stop bits, no handshaking or parity

Computations for Microtops data:

a) Gather the data from all of the groups and plot the irradiance measured (in instrument counts) vs air mass (1/cos (solar zenith angle)) for each channel. The solar zenith angle can be calculated from a solar ephemeris program when one knows the measurement location and time (it is also calculated by the instrument internally and is in the data file).

b) plot the optical depth vs time through the measurement period.

Group 2. Above water radiometry.

We don’t have the normal instrumentation for this, so will have to improvise with what we have. We will use an Es sensor along with an Lu sensor. The Lu sensor will be used to get Lt and Li.

A) Mobley’s (1999) recommended values are 40 degrees for Li and Lt and at 135 degrees azimuth angle away from the sun. Remember that this system also logs a reference irradiance measurement. Note changes in the sky and water during the measurements.
B) Have all the group try to make measurements in this orientation. Each person should collect several sets of Lt and Li, so they can look at the variability by person and in the group as a whole.
C) IF possible arrange for a simultaneous measurement with the above water system and one or both of the in-water measurements.
D) Collect reference irradiance data with and without occulting the direct sun from the sensor (when the direct solar beam is blocked it is the diffuse downwelling irradiance).
E) Along side measurements with the SAS have someone use the Hydrocolor app on an iphone to make measurements of the same surface for comparison to the SAS.

For Hydrocolor: basically follow instructions listed on phone: Take picture of photographers grey card while card is placed on a level unshaded surface. Move phone around to match inclinometer green line between green arrows and compass rose match up with green arrow. (press capture). Then do the same with the sky and water images. Log the value of RRS by hand in your notebook.

COMPUTATIONS:

a) From the data collected with the SAS system, compute the above-water remote-sensing reflectances for the different people making those measurements. How variable are they? Use Mobley's (1999) equation to compute remote-sensing reflectance: Rrs=(Lt-0.028Li)/Ed.

b) Obtain the simultaneous data from all the groups and compute the remote sensing reflectance obtained with each technique. How do they compare? Are there regions of the spectrum, or locations where one method might be advantageous over another?

c) From the total and diffuse irradiance measurements, calculate the direct solar irradiance. Compare the spectra and magnitude of the direct and diffuse irradiance. Calculate the spectral direct/total spectral irradiance. Note that the C-OPS system can do this directly using their shadowband…..see how well that works

d) How do hydrocolor reflectance's compare with the SAS derived reflectance's?

Appendix A, information for calculations

Calculating remote sensing reflectance: (Rrs = Lw/Es)

Above water method:

Here one is measuring the light coming out of the water by using instruments above the surface. The corrections that must be applied need to correct for sky glint coming from the surface.

Rrs = (Lt-Lg)/Es

Lg= Lsky *Reflectivity of surface

In water method (floating device):

Here one measures the upwelling light below the surface of the water, and must correct for the attenuation of the light from the measurement depth to the surface and then for the transmission through the air-sea interface. A measurement of Es, above the surface is used to form Rrs.

Rrs = (Lu(z) T(z) Taw /Es

Where Taw is the transmission of the air-water interface = 0.54

T(z) is the radiance transmission from the measurement depth to the water surface:

T(z) = exp(KLu * z) assuming constant KLu

Klu(z) = -(1/Lu(z)) dLu(z)/dz….in other words negative the slope of ln(Lu(z)) vs z.

Not sure this will work, but in this case we don't have *KLu* with HTSRB so try this:

Go to a wavelength where you still have signal, but it is as far to the red as possible. Assume *KLu* =a_w.

Eu/Ed = 0.33 b_b/a; 3.5 *Lu=Eu* (from *Q note Q is probably bigger than this here, you actually measured it with the C-OPS*); so 0.094 b_b/a = *Lu(-)/Ed* = RRS

*Lu(-) = Lu(z) exp(KLu*z)* assume *Lu(-) = Lu(z)* exp(a_w*z) (in red).

Invert all of this to get b_b. Assume some sort of spectral relationship for bb.

Go to another wavelength and assume that *KLu* = a_w+b_b,

Using *Lu(-)* = *Lu(z)* exp(*KLu*z*) and 0.094 b_b/a = *Lu(-)/Ed* solve for *a*.

Update your approximation for *KLu*, and solve for *a* again…does this converge? You can compare the final *KLu* you come up with with the one you got with the C-OPS.

Calculating PAR

PAR = $\sum_{400nm}^{700nm}$ E Δλ Note need E in Watt m^{-2} nm^{-1}..

One can also state PAR in terms of quanta where :

PAR = $\sum_{400nm}^{700nm} \frac{E}{hc}$ λ Δλ Note need E in Watt m^{-2} nm^{-1}..

Where *h* is Planks constant (6.63 x 10^{-34} m^2 kg/s), and c is the speed of light (3 x 10^8 m/s).

Calculate SeaWIFS band

$$Rrs(\lambda) = \frac{\sum_{lower\lambda}^{upper\lambda} Rrs(\lambda')(\Delta\lambda')}{\sum_{lower\lambda}^{upper\lambda} (\Delta\lambda')}$$

SeaWIFS bands: assume the following square spectral bands:

1) Centered at 412 nm, 20 nm wide

2) Centered at 443 nm, 20 nm wide

3) Centered at 490 nm, 20 nm wide

4) Centered at 510 nm, 20 nm wide

5) Centered at 555 nm, 20 nm wide