GEOS/MSL 695, Module 4: Ice optics measurements

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Aims

This module will introduce you to the optical properties of sea ice. It will provide an opportunity to measure spectral and allwave albedos and examine the spatial variability of albedo. In addition, spectral measurements of transmittance will be made for snow covered and bare ice.

Reading

- Thomas and Dieckmann: Chapter 2, Section 2.9.
- Perovich, D.K. *The Optical Properties of Sea Ice, CRREL Monograph*, *96-1*. 25 pp., May, 1996. This paper can be downloaded from http://www.crrel.usace.army.mil/personnel/perovich_donald/DKPpdf/M96_01.pdf

Equipment

Three optical instruments of varying complexity will be used to make the optical measurements. Instructions on operating these instruments are provided in the appendix to this document. In addition, you will have another opportunity to practice your ice coring and snow depth measuring skills.

- Kipp and Zonen albedometer (Kipp albedometer)
- Analytical Spectral Devices FieldSpec Pro spectroradiometer (ASD)
- Analytical Spectral Devices Dual Detector Underice spectroradiometer (Ice-2)
- Snow depth probe
- Core barrel
- Thickness tape
- Tripod
- Assorted rods

Checklists for operating the instruments are attached to each instrument.

Introduction

How the sunlight incident on a sea ice cover is partitioned between reflection, absorption in the ice, and transmission to the ocean is of key importance for the heat and mass balance of the ice cover. This partitioning of sunlight also has climate implications through the ice albedo feedback.

In this module we will examine the spatial variability of spectral and wavelength integrated albedo by measuring albedo every 5 m along a 100 m transect. We will also investigate spectral albedo and transmittance for snow covered ice and for bare ice. Extinction coefficients will be calculated for the snow and bare ice cases. The optical measurements will be complemented with a characterization of the snow, ice, and sky conditions.

These measurements will provide insights on the spatial variability of albedo in the spring. We will discuss changes in spatial variability as the melt season progresses. When making the measurements and analyzing the results always remember that two processes govern radiative transfer in snow and ice: scattering and absorption.

Field Methods

Three sets of optical measurements will be made using three different optical measurements. Allwave and spectral albedos will be measured every 5 m along a transect line. The all-wave albedos will be measured with the albedometer, which has upward and downward looking detectors. Spectral albedos will be determined using the ASD. This entails making a pair on measurements, one with the cosine collector pointing up (for incident) and one with the cosine collector looking down (for reflected). Remember the rules of albedo measurements: don't step on the site, face towards the sun, no shadows under the collector, and stay level.

Spectral albedo and transmission measurements will performed using the Ice-2 instrument at a single location for snow covered ice and for bare ice. One detector will be used to monitor the incident conditions, while the other detector is used to measure incident, reflected, and transmitted irradiance.

A basic characterization of the sky, snow, and ice conditions will also be made as outlined below. Instructions for operating the instruments are included in the Appendix and will be further explained during the field course. A step by step description of the measurements follows.

Albedo transects

- Set up a 100-m-long transect line.
    - Perpendicular to the orientation of the sun
    - Don't walk on the measurement area
- Measure wavelength-integrated albedo every 5 m using the Kipps
- Measure spectral albedo every 5 m using the ASD
- Measure snow depth every 5 m
- Describe surface state
- Take some photographs illustrating surface conditions

Transmission measurements

- Select a site
- Take an ice core
- Measure ice thickness
- Photograph the core and note distinctive features or layering
- Set up Ice-2 including reference sensor
- Measure albedo with Ice-2
- <u>Remember</u> to write down the integration times
- Measure transmitted with Ice-2
- Measure snow depth
- Shovel off snow in a circle of radius 1.5 times the ice thickness, centered on the underice sensor
- Photograph the site
- Measure albedo with Ice-2

- Measure transmitted with Ice-2

General

- Note the start and stop times of measurements
- Describe the sky conditions (e.g. sunny, partly cloudy, complete overcast, solar disk visible or not)

Data Analysis

The allwave data is the simplest to reduce. Enter the position, incident irradiance, and reflected irradiance. The incident (I) and reflected (R) Kipp radiometers were recently calibrated and no interdetector calibration factor is needed. Therefore the albedo is computed by dividing R by I. This is usually done in Microsoft Excel.

The ASD data is stored in a propriety format, so the first step of data reduction is translating the proprietary format into an ASCII file. This is explained in the Appendix on the ASD. Once an ASCII file with the data is generated, it can be imported into Excel and explanatory headers can be added to the columns. The first column of the ASCII file lists wavelengths and is followed by a column for each scan. Albedos are computed by taking the ratios of the appropriate pairs of scans.

The Ice-2 spectroradiometer also generates a proprietary datafile that needs to be translated into ASCII form. Again there are routines that will make this translation. The ASCII file can then be incorporated into Excel. The next step is to scale the observations by integration time and by incident irradiance. Use the spectra from the second detector to adjust for changing incident. Since ultimately we care about ratios there are several different ways to scale the observations. One scaling formula is:

$$I_{adj} = \frac{I \times T_{adj}}{I_{ref} \times T},$$

Where I_{adj} is the adjusted incident, I is the raw incident, I_{ref} is the reference, T is the integration time for the incident, and T_{ref} is the integration time for the reference. Just substitute to compute R_{adj}, and T_{adj}. After these adjustments, the albedo and transmittance are simply:

$$\alpha = \frac{R_{adj}}{I_{adj}} \quad \text{and} \quad \mathrm{T} = \frac{T_{adj}}{I_{adj}}.$$

For the bare ice case we can also calculate exponential decay spectral extinction coefficients. The well known Bouguer-Lambert (also known as Beer's) exponential decay law is:

$$I(z) = (1-\alpha) I_o e^{-\kappa z}$$

where z is depth in the ice, α is albedo, and κ is the extinction coefficient. With a little algebra this equation can be solved for κ in terms of the measured parameters as:

$$\kappa = \frac{\ln\left(\dfrac{T}{1-\alpha}\right)}{z}$$

where T is the transmittance and z is the ice thickness.

Differentiating between good data and bad data is critical. For example, the ASD outputs values at every nanometer from 350 nm to 2500 nm. However, there is no guaranty that these values are any good. The instrument sensitivity varies with wavelength, as does the incident solar spectrum. On cloudy days, there are portions of the spectrum where light levels are too low to accurately measure. This is particularly true of transmission measurements where absorption is quite large at longer wavelengths (beyond 850 nm) and light levels are small. You must examine the data and identify portions of the spectrum where the results are questionable. Criteria for rejection include: are the results noisy (rapid changes from point to point) and are the values much smaller than at other wavelengths?

Assignment

The assignment for this module entails reducing, analyzing, and plotting the optical data. Each group will produce one final report for this module. We will go through the data downloading as a group, then sub-groups can work on individual components of the assignment. Be sure to highlight (or delete) wavelength regions where uncertainties are great. The final report should include:

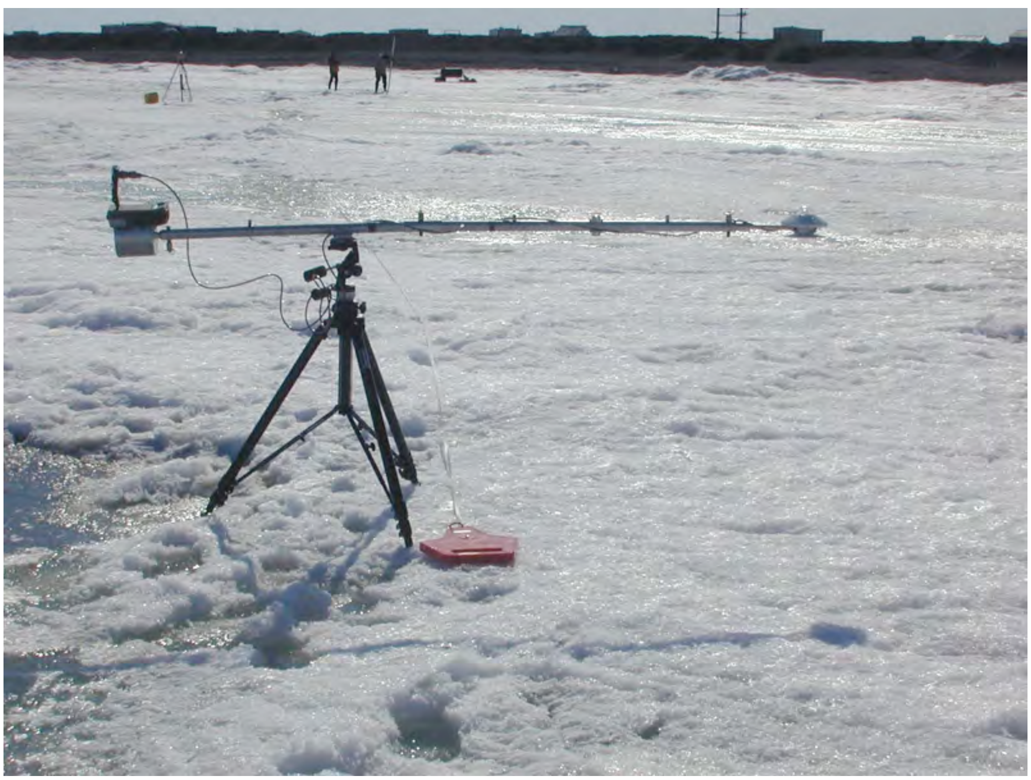
1. The mean and standard deviation of the allwave and spectral albedos along the 100 m line.
2. A plot of albedo vs. wavelength from 350 to 2500 nm for each of the 21 albedos (0, 5, 10,…100) measured along the line plus the average spectral albedo. Also, plot a point denoting the average allwave albedo along the line.
3. A plot of albedo vs position for the allwave albedo plus selected spectral albedos. Pick wavelengths that convey the most information about spectral changes.
4. Calculate and then plot spectral albedo, transmittance, and Beer's law extinction coefficient for the snowcovered ice and bare ice cases.
5. For these two cases comment on the partitioning of sunlight between reflection, absorption in the snow and ice, and transmission to the ocean. Make assumptions as needed.
6. Add photographs of the sites and the ice core to help illustrate the optical results.
7. As the melt season progresses, surface conditions will change and melt ponds will form as shown in Figure 2. Discuss your estimates of what will be the albedo and transmittance for these conditions. Comment on changes in allwave albedo, spectral albedo, and spectral transmittance. Will spatial variability increase or decrease? How does the solar partitioning change?
8. The report should also include the spreadsheet with the observations and analysis.

Appendix: Instruments

A. Kipp albedometer

This is the easiest of the instruments to setup and operate. Just follow the easy steps below and you will be ready to measure allwave albedos.

1. Set up the tripod by adjusting legs to the engraved mark.
2. Attach metal arm and counterweight to the tripod.
3. Insert Kipp albedometer into the arm and secure with metal pin.
4. Attach multimeter to velcro in counterweight.
5. Attach cable to switching box.
6. Plug switching box into ground and V ports of multimeter.
7. Turn out multimeter and set to Volts and 200 mV sensitivity.
8. Flick switch to measure incident and reflected light.
9. Remember to level the instrument.

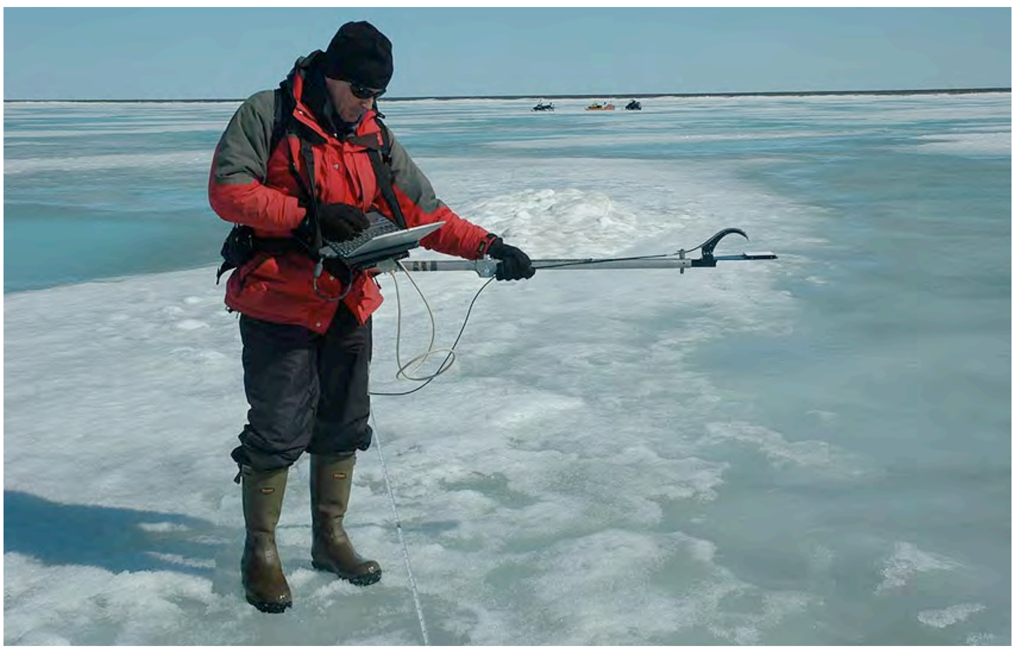


Kipp radiometer mounted on tripod.

B. Analytical Spectral Devices FieldSpec Pro (ASD)

This instrument is more than a spectroradiometer, it's a fashion statement. Not only do you operate this instrument, you wear it.

1. Put on computer table being careful to insert your arms through the straps.
2. Connect parallel cable to instrument.
3. Put on the backpack.
4. Plug port adapter into right side of computer.
5. Attach port adapter to velcro on bottom on computer.
6. Line up velcro and attach computer to computer table
7. Mount cosine collector into metal pipe securing with pin.
8. Carefully thread fiber optic probe into curved arm of cosine collector.
9. Turn on instrument (button on side) – ALWAYS turn instrument on first.
10. Turn on computer (little button on .
11. Wait and wait and wait until it boots up.
12. Double click on **High Contrast RS^3** (program in middle of screen).
13. When program has started there will be a display showing a scan. It is time to Optimize the instrument.
14. With the cosine level and pointed upward (white side up as in photo) hit click on **Opt** button. This process with take a minute or two. Progress can be monitored by watching the *Spectrum Avg bars* on the left hand portion of the screen.
15. To take a measurement just push the space bar. The instrument will beep when the scan has been taken and recorded.
16. Sequence is incident, reflected, new site, incident, reflected, etc. Wait 10-20 seconds between scans.
17. To quit the program just hit **Alt-q**.
18. Shut instrument off first

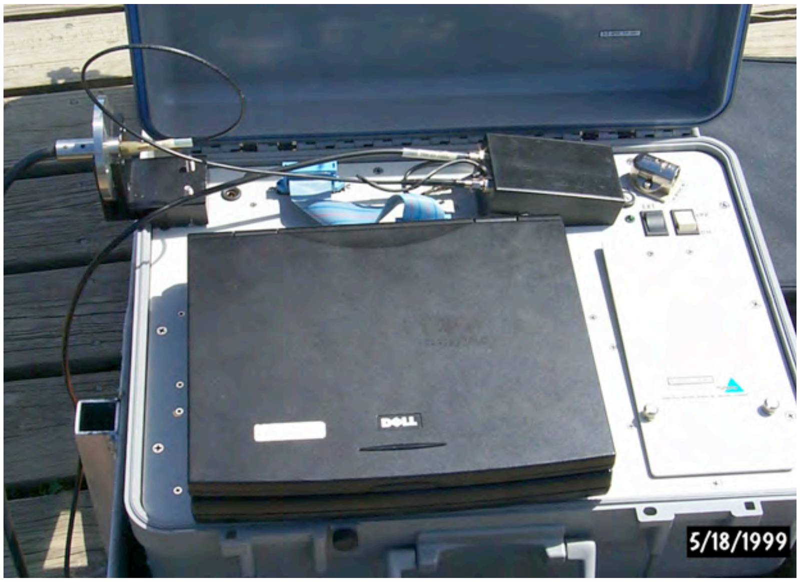


The ASD in action.

C. Ice -2 dual detector spectroradiometer.

This instrument has two fiber optics probes. They look like wires, but they are glass fibers and are quite fragile. Be nice to them.

1. Open gray box, turn on ASD box and allow it to start warming up
    a. Caution, the light on the ASD box will light up even if battery power is insufficient to run the device. Good idea to check bat volts before headed out with a voltage meter. The supply is 12V.
2. Remove protective wires/covers and attach fibers to box. A to A and B to B.
3. Fiber A is the incident reference detector (air/above ice one, on tripod)
4. Mount this detector on the small tripod, pointed upward.
5. Setup and level tripod in a place where it has an unobstructed view of the sky
6. Attach detector B to the underwater arm.
7. Take an ice core completely through the ice.
8. Mount computer on gray box.
9. Hook 25 pin connector to computer.
10. Turn on computer and wait and wait and wait.
11. Double click on DOS Dual icon, in the middle of the screen.
12. Measurement program opens and should automatically take a scan. The first scan it takes upon opening outputs files spectraR.000 and spectraT.000. There is an indicator in the lower left corner which tells you the name of the files which it is ABOUT to take. The file spectraR should be incident and spectraT transmitted.
13. Be sure to write down scan number and integration time, the program does not allow naming each file for the time/date/location etc.
14. There are three measurements to take at each site, and each measurement produces two files, one from the upward looking incident reference detector A, and one from B which will be in various configurations.
    a. Measurement one - A on tripod looking up, B above ice, in air, looking up
    b. Measurement two – A on tripod looking up, B above ice, in air, looking down for reflected
    c. Measurement three –A on tripod looking up, B mounted on rods, under ice, looking up for transmitted,
        i. Attach extension rods and handle to underwater arm.
        ii. Lower underwater arm through ice core hole.
        iii. Measure transmittance.
        iv. Pull underwater arm up through the hole.
        v. Shovel snow and repeat measurement for bare ice.
    d. Shovel snow off a circle of radius 3 X ice thickness and repeat a. through c.
15. Each of these measurements (actually 6 total) will produce a pair of spectra files. Note the names.
16. To quit turn off instrument
17. Then hit **Alt-Q** on computer
18. In DOS type **EXIT**
19. Shut down computer from windows.



Gray box with computer mounted and fiber optics probes connected. Underice arm with cosine collected installed.

Data reduction software

A. For Kipps

Just type in the numbers

B.For ASD

1. Double click on **ASD ViewSpecPro**
2. Click on **File, Open**.
3. Select files
4. Highlight files
5. Click on **Process, ASCII Export**
6. Set **Field Separator to Comma**
7. Click on **Output to single file box**
8. Click on **OK**
9. You're done, exit program

C. For Ice-2

Reduction

1. Data files automatically get dumped in the directory C:\crrel
2. Copy the raw data files into the subdirectory C:\crrel\ASDResults.
3. Right click and edit the file resamp.bat, so that it will write the resampled files to your target directory. It should look like:

   @echo off

   For %%f in (%1) do resample %%f GroupX\%%f

   Substitute your group number for X
4. Open a new DOS window, then enter **cd\crrel\asdresults**
5. Run the batch job to resample all the data files that are in that directory to 0.5 nm wavelength bins. **resample spectra*.*** where spectra is the first part of all the filenames, and the *.* is a wildcard which allows all filenames which start in spectra to be resampled.
6. The resampled data should end up in the directory C:\crrel\ASDResults\GroupX , and will all have the same file names as before, which is why you had to create a new directory in the first place. Otherwise all the original data would have been overwritten. Now you need to turn it into a CSV file.
7. Go to **cd\crrel\asdresults\groupX**
8. In DOS, run stable.exe as follows: **stable -x -f -cc spectra*.* > filename.csv,** where spectra*.* is the root name and wildcard for all the resampled data, and filename.csv is the name of the file the data is written to.
9. NOTE that the stable command outputs the CSV file with each scan file as a column. The order of the scan files (and hence columns) is the same as their order in the directory. You may have to rearrange the R and T files in the spreadsheet.
10. ALSO NOTE – an error comes up in relation to the –cc part of the DOS command above. Don't worry about it.