Atmospheric radiation measurements for aerosol and cloud characterization

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Measurements to Perform:

- Linearity of the photometer (Malus curve)
- Spectrum of the photometer
- Measurement of the sky radiances

Other potential measurements throughout the day:

- Characterization of the phone's camera
- Polarization of the Sky
- Langley plot calibration

General hints:

- Always make plots while acquiring data. You needs these plots in real time in order to determine if your measurements are being performed correctly and if anything needs to be changed.
- Try to interpret your partial observations and think if they agree with your expectations. Use your observations to learn more about the phenomenon under study.

The use of the SmartPhone as a tool to practice atmospheric radiation (and other) measurements

In order to use the phone for the measurement of atmospheric properties, we first need to understand the capabilities of the SmartPhone as a radiation measurement device. In most smartphones There are at least two sensors that can be used for radiative measurements:

1- light photometer

- Broad band photodiode sensor
- Usually the peak of light sensitive lies in the VIS, and in some devices it extend the sensitivity in the Near InfraRed (NIR).
- Usually the phone photometer has very large dynamic range and allow for the direct measurement of the sun as well as for the measurement of the sky in geometries where the sky is substantially dark. The high dynamic range of the sensor is a great advantage but it also indicates that this sensor is likely non-linear and must be calibrated for quantitative measurements.

2- imaging camera

- Usually a detector array with either CCD or a CMOS technology
- Each pixels is covered with a color filter centered at the Red, Green, or Blue wavelengths (RGB).
- Due to limitations coming from the small size of the detector on the smartphone cameras, the phone pictures have very short dynamic range and require constant/automatic/proprietary corrections in order to produce nice pictures. This corrections make it hard to use the Cell Phone camera for any quantitative measurements.
- In this experiment, the camera will be used only for illustration of the spectral measurements of the RGB filters, and for the spatial distribution and characteristics of the clouds in the sky.

5

Installing and aligning the collimators on the top of the smartphone.

This is the first activity for Groups measuring on the roof and the second activity for teams measuring in the Lab (before Malus curves):

Procedure:

- Start with the installation of the collimator base (without the black tubing on top) and line it up on top of the photometer's photodiode.
- Use black electric tape to fix the collimator on top of the phone.
- Install the black collimator tubing
- Add a piece of white tape on top of the collimator's base
- Point the phone to the sun and find the geometry that maximizes the signal arriving at the phone's photometer.
- When the maximum signal is located, make a small mark that corresponds to the projection of the target (whole) on the white tape determining the exact geometry of the collimator's pointing

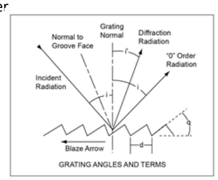
- For people measuring on the roof: Start experiment #3

6

Experiment 1: Spectrum of the Phone's photometer 1/2

- Objective:
  - Determine the spectral response of the phone's photometer and use this knowledge to interpret the atmospheric results observed by the phone.
- Materials
  - Optical spectrometer with diffraction grading
  - Continuous incandescent light source
- Procedure
  - Mount your phone on the appropriate support on the optical spectrometer and align the photometer with the focused spot of the spectrometer
  - Locate the zero order of scattering (region with white light) and use it as reference for other angular measurements. The wavelength of the light is determined by the equation of the diffraction grating, which consists in:

$$n\lambda = d(\sin i + \sin i')$$



https://www.dynasil.com/knowledge-base/diffraction-gratings/

7

Experiment 1: Spectrum of the Phone's photometer 2/2

where:

- ***n*** is the order of scattering (which in our case will be 1) and
- ***d*** is the grating constant (distance between lines in the grating).
  Our grading is 600 lines/mm. Determine the distance "d" between lines.
- ***lambda*** = diffracted wavelength of the light
- θ = angle of diffraction
- ***i*** and ***i'*** are respectively the angles of incidence, and angle of diffraction

- Scan the base of the spectrometer to different angles.
- Notice when the visible spectrum starts to be detected and take notes of the intensity as function of the diffraction angle.
- Plot the spectrum (in real time) and determine the number of points needed to have a good understanding of your measuring system.

8

Experiment 2 – Measurement of the linearity of the Phone's photometer

- Objective:
  - Verify the non-linear response of the Phone's photometer in order to allow a quantitative (yet not absolutely calibrated) measurement of the sky radiance.
- Procedure:
  - Follow instructions on how to add a collimator to the smartphone
  - Add a pointer on the phone's collimator to provide reading for the rotating polarizer
  - Mount a fix polarizer on top of the phone's collimator
  - Add a rotating polarizing (with protractor) on top of the fixed one
  - Rotate the top polarizer every 10degs and take notes of the intensity on the photometer.
  - Plot your results in real time as function of angle.
  - Determine the angular position for the minimum intensity of the polarizer and use it as reference for the other angles. This is needed to fix the phase of the next measurements
  - After correcting the phase, plot the experimental results for intensity versus angle, the analytical equation for the Malus Law ($Intensity \propto \cos^2(\Theta)$).
  - Fit an equation to the experimental data and use it to correct he If the plot is not
  - Any non-linear behavior should be obvious from this plot. Apply corrections as needed.

Note: the liner polarizer that we are using only work in the visible range. If the phone's sensor has sensitivity beyond the visible, the Malus law may not be the best representation for the measurements.

9

Experiment 5 – Measurement of the solar and sky radiances as function of the scattering angle

- Objective
  - Explore the distribution of solar light scattered by aerosol particles and gas molecules in the atmosphere as function of the scattering geometry.
- Procedure
  - Follow previous instructions on how to add and align the collimator on top of the phone's photometer
  - Mount the phone in the rotating base
  - Align the phone's collimator to the sun and measure light intensity as a reference.
  - Rotate the system to different azimuth angles following an almucantar scan. Take notes and plot the intensity as function of angle (in real time). Take as many points as needed to have a good characterization of the scattering in the sky. Take into account the solar and viewing geometry in order to calculate scattering angle.
  - Make plots of intensity versus azimuth angle, and intensity versus scattering angle.
  - Compare your results with AERONET almucantars performed today or even this week.

10

Qualitative observation on the scattering of solar light by aerosol and gas molecules

SPSAS on Atmospheric Aerosols

11

Experiment 6 – the effects of Rayleigh and aerosol scattering on the polarization of the sky

- Objective:
  - Observe (qualitatively) the polarization of the sky and compare your results with the predicted behavior from Rayleigh scattering.
- Materials:
  - Two pieces of linear polarizing sheet.
- Procedure:
  - Consider and study the theoretical curve for the Polarized phase function of Rayleigh scattering as function of the scattering geometry
  - Looking at the position of the sun try to predict the behavior of the polarized Rayleigh scattering in the sky
  - Use the linear polarizing sheet in front of your eyes and try to validate your understanding of the Rayleigh scattering behavior.

12

7 – Use of AERONET data

- During the Aerosol school there is an AERONET sunphotometer mounted on the top of the MAC museum. The station is called Ibirapuera
- Go to the AERONET webpage and locate the Ibirapuera station. Download level 1 (raw radiances) and level 2 data (aerosol optical depth, and microphysical parameters)
- Plot the sky radiances as function of the scattering geometry and compare with the expected behavior for the scattering of solar light by aerosol and gas molecules.

13

Other Potential Experiments throughout the day

SPSAS on Atmospheric Aerosols

14

Experiment 8: Spectral characterization of the Phone's camera

15

Experiment 9: Spectral characterization of the LED's from the LED sunphotometer

Experiment 10: Use of the LED sunphotometer for optical thickness measurements

16