Lab 1 – The UBC Climatological Station

The UBC Climatological Station at Totem Field provides high-quality measurements of atmospheric variables such as temperature, humidity, wind, precipitation, snow, and radiation. Most variables have been continuously measured since 1957. Researchers, students, plant operations, UBC Botanical Garden and the UBC Farm are relying on these data to monitor local weather, growth conditions, climate statistics and climate change on UBC campus, for example, to support snow removal operations, to determine plant growth conditions, or in the evaluation of advanced energy conservation systems in new buildings.

1.1 History and Scope of the Station

The UBC Climatological Station was established in 1957 at UBC Point Grey Campus west of the Agronomy Barn on Agronomy Road. By 1961 the UBC Climatological Station had achieved the necessary standards to be classed as an Ordinary Climatological Station by the Environment Canada Climatological Network (Hare and Thomas, 1979), and at that time was one of the best-equipped stations in the nation-wide network. In the early 1970s, campus development forced its relocation further south, where it has remained for over 30 years (49° 15' 29" N, 123° 14' 58" W). The station is located 100 m a.s.l. with an open exposure to the majority of the climatic elements.

Historically, manual readings were made every morning. These included:

1. Daily minimum air temperature
2. Daily maximum air temperature
3. Daily total precipitation
4. Snow depth
5. Cloud cover

The climatological data from 1961 to 1995 were sent to Environment Canada each month for inspection and processing into climatological summary statistics including calculation of daily, monthly and annual means. The processed data set are available electronically through Environment Canada (http://climate.weatheroffice.ec.gc.ca/).

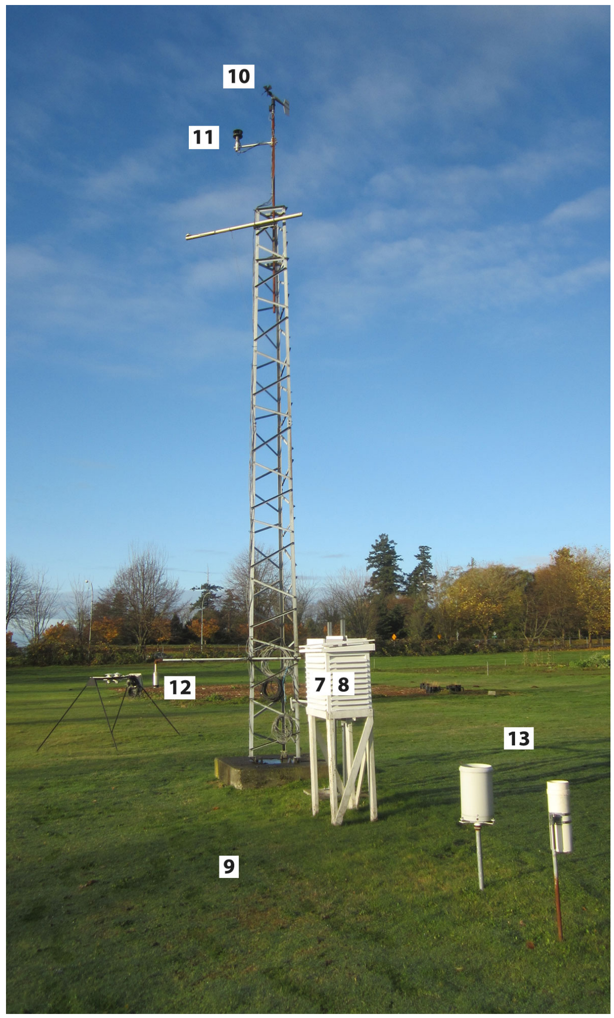

Figure 1.1: The UBC Climatological Station.

As the University has grown and attracted researchers from an extensive range of specializations so to has the UBC Climatological Station. The sta-

Table 1.1: Automatic measurements recorded every 10 seconds at the UBC Climatological Station

No.	Variable	Instrument	Height/Depth
1	Short-wave irradiance	Thermopile-based pyranometer	1 m height, A-frame
2	Short-wave reflectance	Thermopile-based pyranometer	1 m height, A-frame
3	Long-wave irradiance	Thermopile-based pyrgeometer	1 m height, A-frame
4	Long-wave emittance and reflectance	Thermopile-based pyrgeometer	1 m height, A-frame
5	Net all-wave radiation	Thermopile based net-radiometer	1 m height, A-frame
6	Irradiance of photosynthetically active radiation	Quantum sensor (silicon photovoltaic detector)	1 m height, A-frame
7	Air temperature	Thermistor	1.3 m height (Stevenson screen)
8	Humidity	Capacitive thin-film polymer sensor	1.3 m height (Stevenson screen)
9	Soil temperature	Thermocouples	10, 20 and 40 cm depths
10	Wind speed / direction	Propeller anemometer	10 m height
11	Wind speed / direction	Ultrasonic anemometer	10 m height
12	Snow depth	Sonic ranging sensor	1.3 m height
13	Precipitation	Tipping bucket rain gauges	ground level

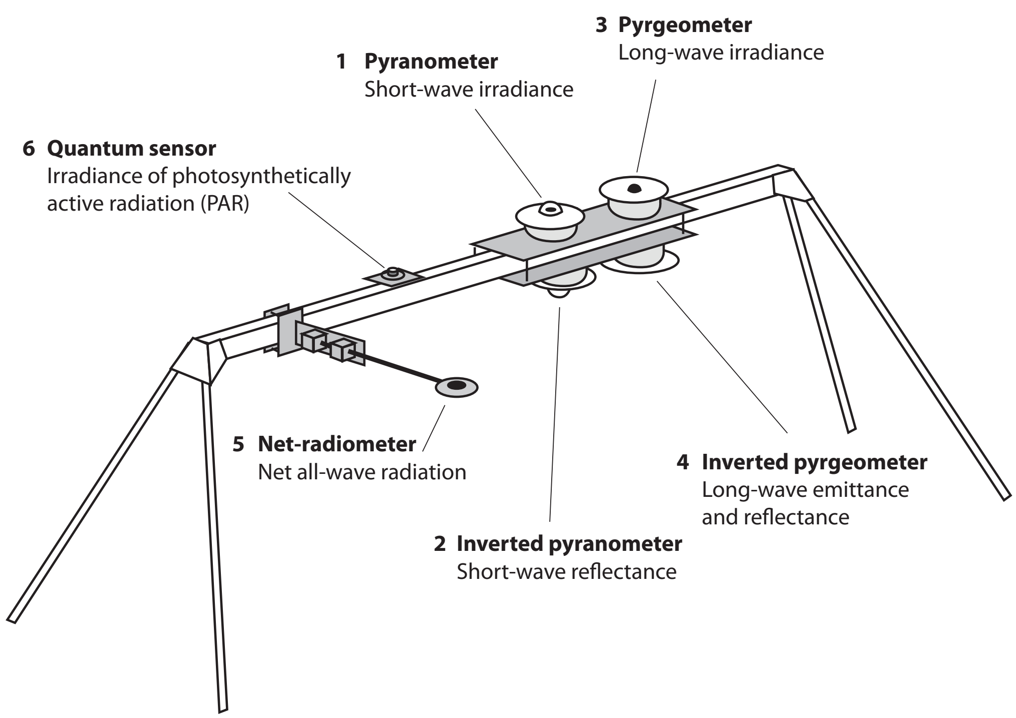

Figure 1.2: Radiation measurements on the A-frame

tion was equipped with an electronic data logger in the early 1990s. The automatic measurements, which presently the data record is reliant on, are made every ten seconds and half-hour average values are calculated and stored in the memory of the data-logger. Table 1.1 lists the automatic measurements currently being made at the climate station. Fig. 1.1 shows the meteorological tower, Stevenson screen, data logger housing and instruments and Fig. 1.3 the set-up of the radiometers.

Current projects ongoing at the site include the continuing efforts of the Faculty of Land and Food Systems in collaboration with the Department of Geography to maintain a long-term climate record for the UBC campus, for teaching purposes, research, campus operations and services, meteorological instrument testing and calibration.

In April 2008 a state-of-the-art mobile LIDAR (light detection and ranging) instrument was added to the station. The LIDAR is located 100 m north of the tower in a container. The instrument shoots a beam of laser light in the visible (532 nm) and near-infrared (1064 nm) wavelengths directly upward and captures the light that is backscattered from aerosols in a large telescope. The resulting images are used to monitor layers of aerosols (suspended particles) in the bottom 10-12 km of the atmosphere and are plotted in real-time on the Internet (http://www.coralnet.ca/). Of particular interest are layers of desert dust and pollution that travel across the Pacific mostly from Asia, but also from local air pollution and forest fires. The instrument was developed jointly by Environment Canada, the BC Ministry of Environment and the UBC Geography Department.

1.2 Standardization

Any site of a climatological station must meet certain basic criteria before its data will be accepted by Environment Canada. For example, the surroundings must be reasonably flat, there should be no major obstacles to airflow, no significant obstruction to the horizon, no extraneous sources of heat, vapour or dust and the surface should consist of short grass. Similarly, the instrumentation must conform to Environment Canada standards. The data gathered from a climatological station are to be related to large-scale air mass and regional characteristics not the microclimate of the site (e.g., the main wind measurements are made at 10 m above the surface so as to avoid the effects of local obstacles such as the instrument shelters etc.). Insistence on these points assures users of site and instrument standardization so that different stations can be compared within expectable limits of accuracy.

Air temperature and humidity are measured in a Stevenson screen (white louvred box, Fig. 3) designed to protect the instruments from liquid water (rain / snow), shade them from solar radiation, but permit free air circulation. Its base must be 1-2 m above ground.

In addition to the thermistor, which produces the temperature signal for the data logger, classic minimum and maximum thermometers are still present. The minimum thermometer uses an alcohol column which pulls an index marker as the temperature drops. When the temperature rises, the marker is left at the minimum temperature position. The maximum thermometer works just like a clinical thermometer in that it has a constriction in the column so it must be "shaken down".

Figure 1.3: The Stevenson Screen.

1.3 Sample climate data

Fig. 4 shows climate conditions at Totem Field over a seven-day period in spring.

The 10-m level wind speed and direction is measured with an R.M. Young combination propeller anemometer / wind vane. Fig. 4 panel A and B show wind speed and direction over the seven-day period.

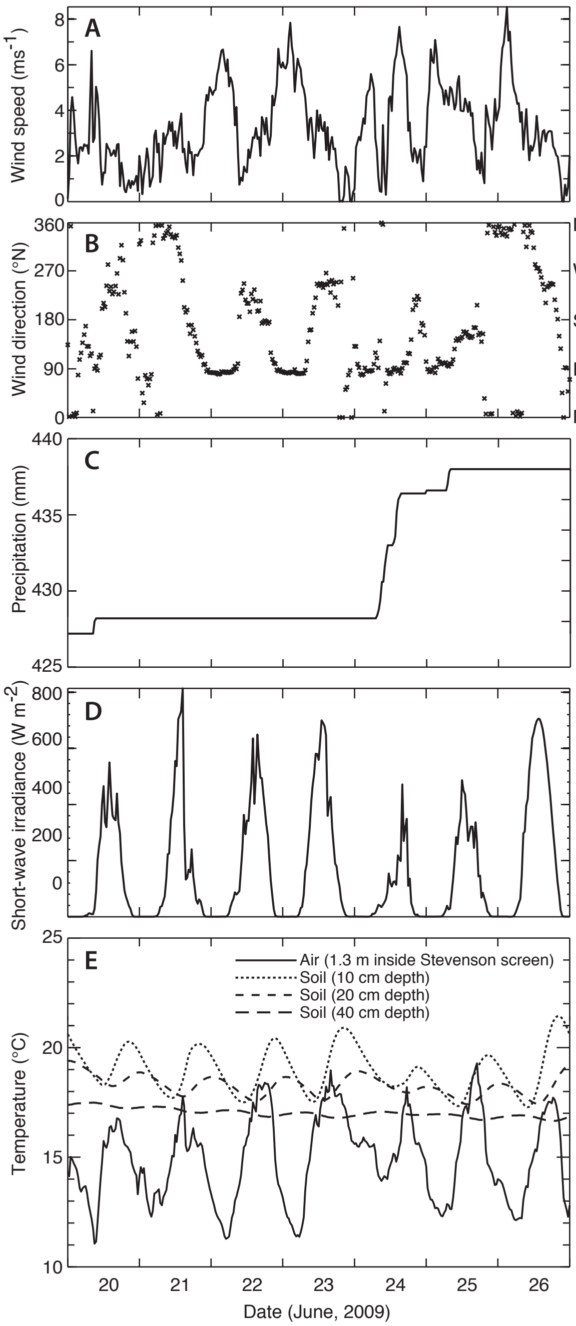

Figure 1.4: Time traces of (A) wind speed, (B) wind direction, (C) precipitation, (D) short-wave irradiance, and (E) soil and air temperature from June 20, to June 26, 2009.

Fig. 1.4 panel C shows rainfall as measured by the tipping-bucket rain gauge. This gauge has a small bucket beneath the funnel which tips after every 0.2 mm of catch and thereby trips an electrical circuit resulting in a count in the data logger. The number of 'counts' per period (e.g. per hour) gives the intensity (mm h^{-1}) as well as the cumulative amount of rain.

The depth of new snowfall and the total depth of snow lying on the ground was historically measured with a metre stick. Water equivalent of the snow (mm) is typically estimated as one tenth of the snow depth. It is now measured using an automated sonic snow depth sensor.

Fig. 1.4 panel D shows the short-wave (solar) irradiance $K_{\downarrow}$ at the station and is measured by a pyranometer (Figure , label 1). The pyranometer contains a small black absorber disk inside a glass dome whose radiative properties allow only radiation in the band from 0.3 to 3.0 μm to pass through. As radiation reaches the absorber disk, it will warm up and create a temperature difference to the rest of the body of the instrument whose temperature varies only slowly. The difference can be directly related to the short-wave receipt. Why do $K_{\downarrow}$ values reach zero during the night? Can you distinguish between clear and cloudy days in Fig. 1.4 panel D?

Figure also shows an inverted pyranometer that senses the shortwave radiation reflected from the underlying surface $K_{\uparrow}$. This can be used to calculate the surface albedo α as $\alpha = K_{\uparrow}/K_{\downarrow}$

Fig. 1.4 panel E shows air temperature and soil temperature at three depths (10, 20, 40 cm). From the meteorological conditions measured at the UBC Climatological Station during June 20th to 26th 2009 can you recognize any relationships (hourly or daily) between the variables?

1.4 Report and Questions

1. Why do you think a Stevenson screen is built with slatted walls and double roof, and painted white? [1]

2. Is the climatological station suitably located to provide climatic data representative of the UBC campus and Point Grey Areas? Discuss why or why not. [1]

Use the applet Climate Change at UBC[1] *to answer all of the following questions. All data displayed in the applet have been measured at the UBC climatological station.*

[1]accessible through http://www.geog.ubc.ca/courses/geob204/climate/

3. How do air temperatures, short-wave irradiance and precipitation measured this July compare to July values averaged over the last 30 years? [1]

4. Find the average air temperature measured during the month of February 2010 - when the Olympic Winter Games took place in Vancouver. Comment on the value. Have comparable temperatures ever been observed in any February since the start of the measurements? [0.5]

5. List the ten warmest years since the beginning of the air temperature measurements at UBC. Speculate on all causes that could explain their occurrence within the last 50 years. [1]

6. Separately analyze air temperatures in summer and winter during the last 50 years. Discuss if you can identify any trends in the average air temperatures in summer over the last 50 years. Is a similar observation also found in average air temperatures in winter? [1]

7. Plot your own climate diagram that shows average monthly precipitation (averaged over the last 30 years). Draw the twelve months on the x-axis, and the corresponding monthly total precipitation in mm/month on y-axis. Comment on the distribution of precipitation during the year. [2]

8. Comment on whether you can identify any trends in total annual precipitation over the last 50 years at UBC. You should explore the annual trends in precipitation, but also separately the four different seasons (spring, summer, fall, and winter) [1].

9. In climatology, we use the unit 'mm' to report the amount of precipitation fallen over a given time period. How do you interpret the physical meaning of 'mm'? [0.5]

10. Create a table that lists short-wave irradiance for each of the seasons in $\mathrm{MJ\,m^{-2}}$ averaged over the last 10 years. What are the main causes for the observed differences between the seasons? [1]

References

Hare, F.K. and M.K. Thomas. 1979. Climate Canada, John Wiley, Toronto, Ch. 14, 181-191.