

ENVIRONMENTAL FLUID DYNAMICS

ME EN 7710

Project #1

Due Feb 9, 23

Modeling the Urban Surface Energy Balance

Overview

The goal of this project is to obtain a working understanding of the Surface Energy Balance (SEB) for urban areas. For this project, you will model the urban SEB for a tower located in a suburban neighborhood in the Salt Lake Valley (Murray, UT) using the so-called LUMPS (Local-scale Urban Meteorological Parameterization Scheme) model. At the end of the project you will have a working simulation tool.

Part I: Radiation Modeling (due: Feb 9)

Familiarize yourself with the LUMPS model by reading Grimmond and Oke (2002). Write and validate a sub-module to determine the net radiation balance. Using the equations presented in class, in the hand-outs and in the textbook, write a computer program to do the following: calculate the incoming direct beam solar radiation at any point in the northern hemisphere, at any time of the day, at any latitude (ϕ), and for sloping terrain (slope angle $\hat{\beta}$ and slope azimuth $\hat{\Omega}$). In doing this, assume the atmosphere has a net transmissivity that can be modeled using the parameterization given in the provided handout for low, middle, and high cloud cover fractions or using a more advanced model that you might find in the literature. Please hand in your computer code as well as answering the questions below.

1. Determine the incoming solar radiation on a segment of horizontally homogeneous unobstructed flat terrain in Salt Lake City, UT on September 21, 2002 at 2 pm local time with no cloud cover (use the airport coordinates: $\phi = 40.788^\circ$ North and $\lambda_e = 111.978^\circ$ West).
2. For the same latitude, generate a contour plot of incoming solar radiation as a function of time of day and slope angle for (a) a north-facing slope ($\hat{\Omega} = 0$) on December 21 and (b) a south-facing ($\hat{\Omega} = 180$) slope on June 21.
3. Determine the incoming solar radiation for the same day and time as in problem 1, for a slope on the Oquirrh mountains (assume $\hat{\beta} = 5^\circ$ and $\hat{\Omega} = 90^\circ$)
4. Determine the incoming solar radiation for the same day and time as in problem 1, along the Wasatch front (assume $\hat{\beta} = 20^\circ$ and $\hat{\Omega} = 270^\circ$)
5. Compare to supplied incoming solar radiation data from the Dugway Proving Grounds ($\hat{\beta} = 0$; $\phi = 40.142^\circ$ North and $\lambda_e = 113.267^\circ$ West). Note that the time series is in UTC +6 hours. Please use July 19, 2001.
6. Compare to supplied incoming solar radiation data from the BLLAST experiment in Lannemezan, France ($\hat{\beta} = 0$; $\phi = 46^\circ 6' 32.9''$ North and $\lambda_e = 0^\circ 21' 32.1''$ East). Note that the time series given on the website for this is in UTC. Please use June 25, 2011.

Part II: LUMPS Model and Evaluation (due: Feb 23)

- Write the code for the LUMPS model and integrate the net radiation module from Part I into the LUMPS model.
- Utilize the provided surface cover and morphometry data as well as basic meteorological data from the flux tower in Murray to calculate the full SEB.
- Compare the calculated sensible and latent heat fluxes to those actually measured in the field. Note: you will get full diurnal solutions.
- Please present your results in the form of a well-written AMS conference paper that includes a brief introduction and methods section. Use the Grimmond and Oke (2002) paper as a model. Your paper should be limited to 7 pages

This project should be done individually, but cooperation amongst students is encouraged.

Part I of the project report is due by Tuesday February 7th and Part II of the project is due by Tuesday February 21st. Please contact me with any questions or problems.

Land Surface Cover Data

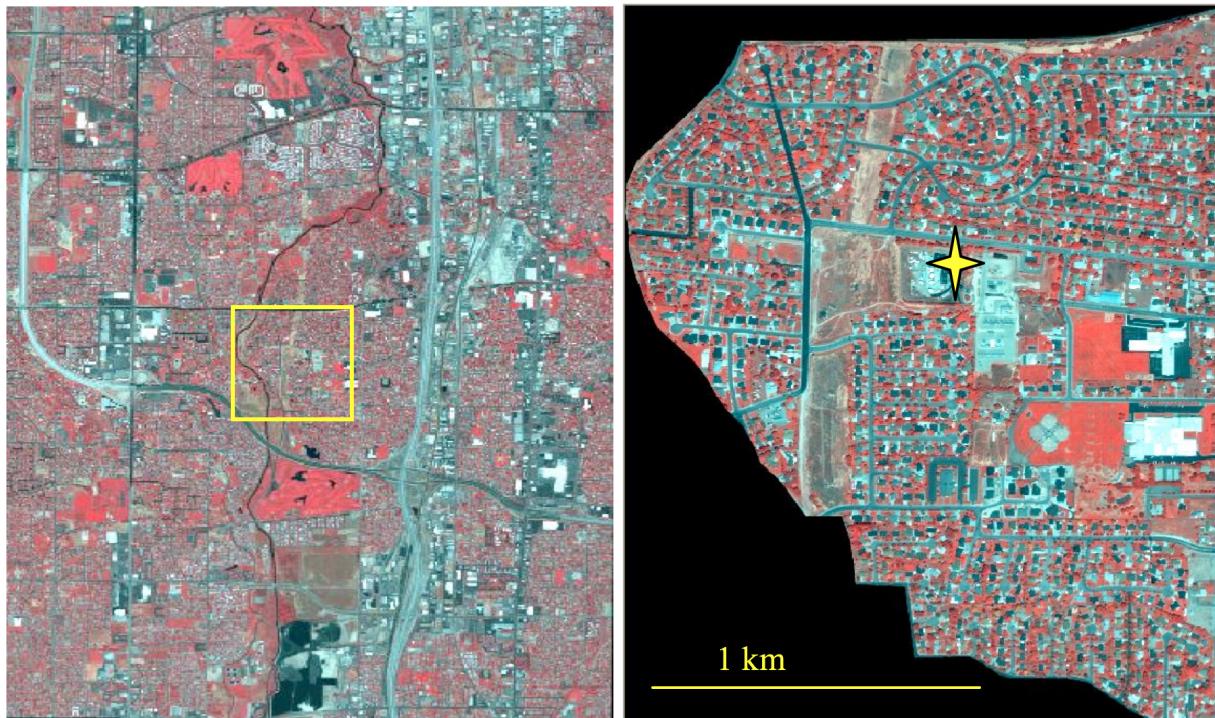


Figure. Satellite image of (*left panel*) the central portion of the SLV with a box (~1km x 1km) indicating the approximate region directly surrounding the tower and (*right panel*) the area surrounding the suburban flux tower.

Land Surface Cover Data, continued

Average Building Height	4.4 m
Average Tree Height	6.5 m

Table 1. Average heights for suburban site in Murray, UT.

Surface Type	Area (m ²)	Area (Acres)	fraction
Grass	373592.2	92.33	0.193159
Trees	200178.8	49.47	0.103494
Residential Rooftops	179834.7	141.8	0.296653
reflective rooftop	6430.262	1.58	0.003305
Parking Lot	15386.32	3.8	0.00795
Industrial Rooftops	34538.78	8.53	0.017845
Bare Soil	79901.81	19.74	0.041297
Asphalt Road	128578.3	31.78	0.066485
Other		128.97	0.269812
Total		478	

Table 2. Land cover fractions for suburban site in Murray, UT.

Murray Tower Met and Flux Data

See Canvas or the course website for datasets and handouts.

Site Info

Latitude: 40°39.11 N, Longitude: 111°55.19 W, Elevation: 1306 m, Average Site Albedo: 0.18

Slope of the saturation vapor pressure temperature curve

$$\frac{de_s}{dT} \simeq \frac{L_v}{R_v} \frac{e_s}{T^2}$$

The psychrometric constant (Brunt 1952)

$$\gamma = \frac{c_p}{L_v} \frac{P}{\epsilon}$$

Where the latent heat of vaporization can be calculated as function of air temperature as (Stull, 1988)

$$L_v \simeq [2.501 - 0.00237 \cdot T(\text{°C})] \times 10^6 \text{ J kg}^{-1}$$