METR 104: Our Dynamic Weather (w/lab)	**Lab Exercise #2: Solar Radiation & Temperature Part VI: An Even More Complex Computer Model**	Dr. Dave Dempsey Dept. of Geosciences Dr. Oswaldo Garcia, & Denise Balukas SFSU, **Fall 2012**

(5 points)
(*Lab Section 1:* Wed., Oct. 31; *Lab Section 2:* Fri., Nov. 2)

Learning Objectives. After completing this activity, you should be able to:

A. Configure and run more experiments with a simple computer model (a STELLA model) of the daily temperature cycle.
B. Evaluate the model based on experience reading meteograms.
C. Solidify further a description of the role that computer models play in the way that science works in atmospheric science.

Materials Needed. To complete this activity, you will need:

- A computer in TH 604 or 607 with STELLA modeling software installed, plus either:
  - version III of a STELLA model of the daily temperature cycle ("DailyTempCycle.III.STM"), or
  - an internet connection with a Web browser, to access the Web-based version of the model at http://forio.com/simulate/dempsey2/dailytempcycle-iii/simulation/
- Two meteograms showing typical daily temperature cycles under cloud-free conditions at Hanford, CA (KHJO):
  - Ending at 09Z May 24, 1999
  - Ending at 07Z December 17, 1998

Prior Knowledge Required:

- Background needed for the previous lab exploration (Lab #2, Part V)
- Understanding of the Principle of Conservation of Energy, expressed in the form of the heat budget equation for an object, including the earth's surface
  - Some ways that the earth's surface can gain and lose heat:
    - absorption of solar radiation
    - emission of longwave infrared radiation
    - absorption of longwave infrared radiation emitted downward by greenhouse gases and clouds
    - conduction of heat from the surface into the atmosphere (or vice versa)
    - evaporation of water from the earth's surface
- Understanding of radiative absorption: when an object absorbs radiation, the energy is transformed into (an equal amount of) sensible heat in the object

II. An Even More Complex Computer Model

This is the last of six parts of Lab 2, where we have been analyzing and exploring ways in which we can explain the commonly observed daily temperature cycle. In Part I, we constructed graphs of solar radiation intensity data recorded at Hanford CA on two particular days. In Part II we described features of the solar radiation intensity observed at that location, and began looking for connections between the patterns of temperature and solar radiation observed there over the course of a day. In Part III we looked at the meteograms for two consecutive days at two locations in Colorado and saw examples of how “the weather complicates things”, in particular, how factors such as cloud cover can affect the daily temperature cycle.

In the next two parts we began using a computer model based on the Law of Conservation of Energy to try to simulate observed daily temperature cycles, and to evaluate how well the model performed. The model we used in Part IV (called "DailyTempCycle.I.STM") assumes that the surface temperature cycle is driven *exclusively* by the rate at which the surface *absorbs* solar radiation. We found that this model did not do a good enough job of explaining the temperature cycle. In Part V we modified the model (now called "DailyTempCycle.II.STM") to take into account the fact that, in addition to absorbing solar radiation, the surface also emits longwave infrared radiation.

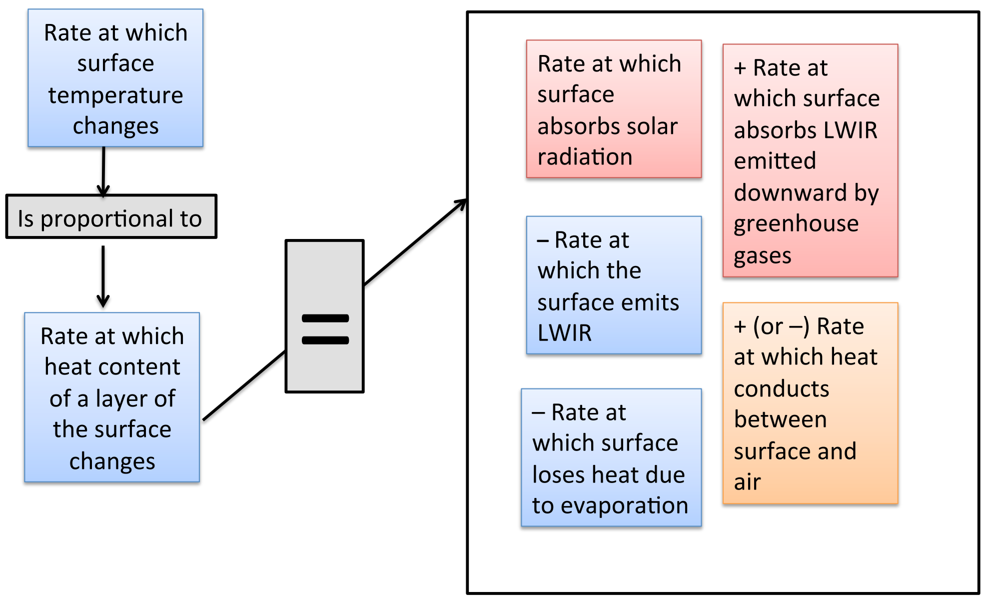
That last model produced a daily temperature pattern that was realistic in some ways but not in others. It produced a temperature maximum in the afternoon and cooling thereafter until near (just after) sunrise, as we commonly see in observations of the real atmosphere. The daily maximum temperature, although a little too high, wasn't too bad, but the minimum temperatures were much colder than we'd expect to see, and so the daily temperature range (the difference between the minimum and maximum temperature) was too large. We concluded that, although that model did much better than its predecessor did in Lab 2, Part IV, it is likely missing one or more physical mechanisms not accounted for yet. Let’s look at what those mechanisms might be:

We know that greenhouse gases and clouds absorb longwave infrared radiation emitted by the earth's surface. We also know that greenhouse gases and clouds emit longwave infrared radiation of their own, that they emit part of that radiation downward, and that the surface absorbs it. Hence, we'll include in the model this additional source of heat for the surface.

We also know that when two objects at different temperatures are in direct contact, heat will "flow" from the warmer one to the cooler one (so the warmer one cools off and the cooler one warms up). This is the process of ***conduction*** of heat. In particular, when air in contact with the earth's surface is warmer or colder than the surface, heat will conduct from one to the other, and the surface will gain or lose heat. We'll try to represent this process in the model.

Finally, we know that when water ***evaporates***, heat in the water transforms into latent heat in the water vapor, reducing the amount of heat in the remaining water. (We experience this directly when we overheat, produce sweat, and feel cooler when the sweat evaporates from our skin.) We'll try to represent evaporative cooling in the model (especially from the oceans, less so from land).

With these three new physical process added, the Law of Conservation of Energy applied to the earth's surface and written in a form that describes how the surface gains and loses heat and how its temperature responds as a result, can be written like this:



Using this relationship, we can calculate how fast the surface temperature changes and estimate temperature in the near future (at least, if the model is complete and accurate). We can run this more sophisticated model, compare the results to observed daily temperature cycles, and see how well the model performs. That is, we can evaluate, or *validate,* the model.

If the model does well, it could be useful for helping us to understand better how the atmosphere works and for making temperature forecasts. (We'd need further experience and validation of the model to be sure.) If the model doesn't do well, we have to question any assumptions that underlie the physical relationship as we've applied it above, or perhaps take into account physical processes that are important but that we have neglected.

III. Instructions

A. Access the model "Daily Temperature Cycle III.STM" on the computer desktop (or go to http://forio.com/simulate/dempsey2/dailytempcycle-iii/simulation/).

B. Your instructor will describe the model features and explain how to configure it, run it, and produce output graphs. The instructor will point out the default model configurations. Make sure you understand all the features of this model before proceeding. In this version of the daily temperature cycle model, you can specify:

1. *Where and when the model runs*:
   - latitude (in degrees)
   - day of the year (Julian day, expressed as a number from 1 to 365)

2. *Whether or not each of the following ways for the surface to gain or lose heat is turned on*:
   - emission of longwave infrared radiative energy
   - absorption of longwave infrared radiation emitted downward by greenhouse gases and clouds
   - conduction of heat between the surface and the atmosphere, and evaporation of water from the surface

3. *Several more model parameters*:
   - "Surface Type" (land or water)
   - "Cloud Cover" (expressed as a percentage of the sky covered by clouds)

By default, the latitude is set to 36°N (the approximate latitude of Hanford, CA); the day of the year is set at 142 (May 22); emission of longwave infrared (LWIR) radiation is turned on but the other two mechanisms listed above are not; the surface type is set to "land"; and the cloud cover is set to 0%. For this lab activity, start out with these default settings. Don't run the model yet. Note the ways in which this model differs from the version in Lab #2, Part IV.

C. Repeat a previous model simulation and confirm that is the same. (No written response required.)

You have been given a plot of sun angle (in degrees) and temperature (in °F) vs. time (in hours) for 2.5 days (60 hours) starting on May 22 at the latitude of Hanford, CA. (You generated this plot in Lab 2, Part V.) *Run* the latest version of the model with the default configuration described above, and *verify* that it reproduces this plot. (The plot is on the second graph, on Page 2 of the five pages of graphs available in this version of the model. Note one difference: the hours plotted along the bottom axis in this version of the model will be from 360 hours to 420 hours (15.0 to 17.5 days) instead of 0 to 60 hours (0 to 2.5 days). Both series of times start at midnight and end at noon, though. Note the maximum and minimum temperatures achieved over the course of each day, and the time of day when they occur.

D. In this section we will look at the effects of greenhouse gases and conduction and evaporation on the daily temperature cycle. Follow the steps outlined below in sequential order, *write answers to the questions in the space provided. Use the back of the sheet if you need more space.*

Step 1: *Reconfigur*e the model to run with greenhouse (GH) heating turned on. Do not run the model yet.

Question 1: Predict how you think this will change the temperature pattern.

Step 2: Now run the model without changing anything else.

Question 2:

a) Does the pattern of the daily temperature cycle change in any significant way from the initial run?

b) What about the actual temperatures (for example, the maximum and minimum values)—do they seem more realistic, less so, or no different? (For comparison, refer to the meteogram for Hanford, CA for the same day of the year.)

Step 3: Run the model again, with conduction/evaporation turned on.

Question 3:

a) Does the pattern of the daily temperature cycle change in any significant way from the initial run?

b) What about the actual temperatures (for example, the maximum and minimum values)—do they seem more realistic, less so, or no different? (For comparison, refer to the meteogram for Hanford, CA for the same day of the year.)

Step 4: *Print* a copy of the graph on Page 2 of your last model run. Remember to specify that only Page 2 should be printed (not all 5 pages!). When you are done, turn in your graph with your name written on it, along with your answers to the questions above and in Section E below.

E. In this part we examine what effect clouds have.

Step 5: *Reconfigure* the model to include significant cloud cover. Answer Question 4 before you run the model again.

Question 4: Predict what you expect to happen to the daytime maximum temperature and the nighttime minimum temperature due to the cloud cover.

Step 6: Run the model, and compare the model results to your prediction.

Question 5: How would you explain the results?