

ESTIMATING SENSIBLE HEAT FLUX IN THE HAMPTON ROADS AREA

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Abstract

For my research project, my objective is to estimate sensible heat flux amounts in the Hampton Roads area. My research will demonstrate the basic concepts of Sensible Heat Flux, the amount of heat transferred into the atmosphere, per unit of time through a unit area. Heat Flux - is the process by which the air gets warmer every day. In order to estimate the heat flux amounts in the area, I have been using data from the Modis Aqua and Terra satellites. The atmospheric data that I am using to make estimates are Surface Temperature, Solar Radiation, Wind Speed, Air Temperature, and Leaf Area Index. For this particular research project, I will show results for sensible heat flux patterns in the Hampton Roads Area. The study that I am conducting is for the summer of 2003, thus I will make a plot that represents the sensible heat flux patterns for each month of the summer. Once required data have been gathered, the Analytical Land-Atmosphere Radiometric Model (ALARM) will be used to convert radiometric land surface temperature to isothermal surface temperature to successfully evaluate heat flux in each particular area.

My research demonstrates the basic concepts of Sensible Heat Flux, the amount of heat, transferred in a liquid, in particular in the atmosphere, per unit of time through a unit area. Heat Flux occurs through precipitation and causes the temperature in the soil to differentiate from the temperature in the air. Heat flux can be estimated by detecting the radiometric surface temperature. Determining sensible heat flux is very beneficial to the environment and helps in working with the heat budget. For my research project, I will create program to plot heat flux data, which will lead to the creation of a graph showing heat flux in the Hampton area, paying special attention to critical amounts of heat flux. My research topic was assigned and supervised by Dr. Ayman Suleiman. The heat budget is the relation between fluxes of heat into and out of a given

region or body and the heat stored by the system. In general, this budget includes advective, evaporative, and other terms as well as a radiation term. There are several quantities which describe the sensible heat flux from the plant-soil-atmosphere system. Sensible heat flux is always positive when heat is being transported *upwards* (as opposed to soil heat conduction, where heat flux down into the soil is positive). While designing my program to plot heat flux data, I had to create variables corresponding to the data. Using radiometric surface temperature directly in estimating sensible heat flux may lead to a significant error with some estimates of heat flux. The correct radiometric surface temperature for use in estimating heat flux has not been clearly defined. The best way to estimate heat flux is by converting radiometric land surface temperature into aerodynamic surface temperature. Once field data has been gathered, the radiometer model can be used to convert radiometric land surface temperature to isothermal surface temperature to successfully evaluate heat flux in each particular area.

Heat Flux is the amount of heat, transferred in a liquid, in particular in the atmosphere, per unit of time through a unit area. Heat Flux occurs through precipitation and causes the temperature in the soil to differentiate from the temperature in the air. Heat flux can be estimated by detecting the radiometric surface temperature. Determining sensible heat flux is very beneficial to the environment and helps in working with the heat budget. The heat budget isn't a standard budget as you would expect, rather it is a term that scientists use to describe how much energy is being used to warm the atmosphere. The heat budget is the relation between fluxes of heat into and out of a given region or body and the heat stored by the system. In general, this budget includes advective, evaporative, and other terms as well as a radiation term. Sensible heat flux deals with the heat difference in the soil temperature and the temperature in the air. Knowing the difference in temperature in the

surface and in the air can be very beneficial because it helps balance the land surface energy budget.

The sensible and latent heat fluxes can be calculated from the basic measurements of precipitation and soil temperature by solving the preceding set of equations for the both of them. There are several quantities which describe the sensible heat flux from the plant-soil-atmosphere system. Sensible heat flux is always positive when heat is being transported *upwards* (as opposed to soil heat conduction, where heat flux down into the soil is positive). While designing my program to plot heat flux data I included several variable names to display data. Hflux is an output variable name - it is assigned the quantity Econd when it is written to file. ECOND is computed in the subroutine prof12 as such: $qcond(jz)=akh(jz)*(Ttemp(ihr,jz+1)-Ttemp(ihr,jz))$. Ttemp is the temperature profile through all the layers. This quantity describes the heat flux from the combined soil and canopy systems into the atmosphere. I designed my program to plot heat flux data with the programming language IDL.

Conversion of radiometric land surface temperature (θ_r) to an equivalent isothermal (aerodynamic) surface temperature (θ_i) is important in balancing the land surface energy budget with satellite – based radiometric land - surface temperature measurements. Using radiometric surface temperature directly in estimating sensible heat flux may lead to a significant error with some estimates of heat flux. The correct radiometric surface temperature for use in estimating heat flux has not been clearly defined. The best way to estimate heat flux is by converting radiometric land surface temperature into aerodynamic surface temperature. In Order to Convert Radiometric Land Surface Temperature to an Equivalent Isothermal Temperature, I have viewed data from Analytical Land – Atmosphere Radiometer Model (ALARM) findings in other areas.

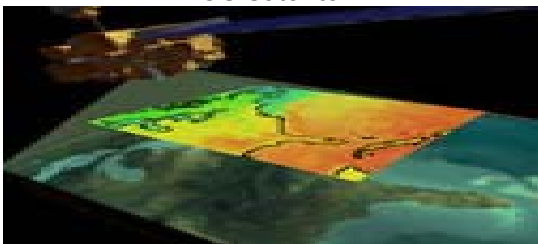
The estimation of surface latent and sensible heat fluxes can be accomplished with many different methods. Most of these methods usually require key input parameters

such as surface air temperature, specific humidity and wind speeds. It is appropriate at this point to ask how accurate the satellite-derived surface fluxes are when compared to other widely available data sets. One such dataset is the NCEP/NCAR reanalysis fields, a major community effort to consistently derive and archive global fields of several atmospheric parameters using state-of-the-art global model and data assimilation systems. Another important issue to address is how sensitive the computations of surface latent and sensible heat fluxes are to the accuracy of the input parameters. “To examine in more detail the sensitivity of latent and sensible heat fluxes to the accuracy of the input parameters, we first calculated surface heat fluxes using the similarity theory method developed by Liu et al. (1979) with surface observations from the in-situ data. The necessary input parameters are SST, T_a , Q_a , surface wind speeds (W) and surface pressure. We focus here on the sensitivity to SST, T_a , W and Q_a , since these parameters can be retrieved from satellite data. The sample size includes 139,548 observations. Next, we exchanged some of the input parameters by the corresponding satellite-derived parameter (or NCEP/NCAR value) and computed statistics (correlation coefficient, rms error and mean bias) relative to the surface heat fluxes calculation using all in-situ parameters.” (1)

“Modelling of the sensible heat flux incorporates the source area concept, which estimates the area most likely contributing to the heat flux measurement. With source area estimates calculated, we can then assess the microscale variability of surface temperature contributing to the measurement.” (2) The source area concept is used to create models of sensible heat flux in particular areas. The source area concept is also a tool for estimating the area that is most likely contributing to the heat flux measurements. Another important feature in dealing with sensible heat flux is the Source Area Concept. The source area concept is a layout that is used to create models of sensible heat flux in a particular area. The source area concept helps estimate the area that is most likely contributing to heat flux measurements while creating models of sensible heat flux.

While conducting my research, I viewed many amounts of data from the Modis website. The Modis sensor is where I obtained all of my Surface Temperature, Leaf Area Index, and Solar Radiation results. The Modis Terra and Modis Aqua spectrometers are the two imagers that most of my data was recovered from. The Modis Terra spectrometer has a 2,330-km-wide viewing swath, MODIS sees every point on our world every 1-2 days in 36 discrete spectral bands. "MODIS is ideal for monitoring large-scale changes in the biosphere that will yield new insights into the workings of the global carbon cycle. While no current satellite sensor can directly measure carbon dioxide concentrations in the atmosphere, MODIS can measure the photosynthetic activity of land and marine plants (phytoplankton) to yield better estimates of how much of the greenhouse gas is being absorbed and used in plant productivity. Coupled with the sensor's surface temperature measurements, MODIS' measurements of the biosphere are helping scientists track the sources and sinks of carbon dioxide in response to climate changes." (3)

EOS Satellite:



(www.terra.nasa.gov/About/MODIS/modis_sci_tn.jpg)

The Modis Aqua sensor is the sister sensor for the Modis Terra spectrometer. The Modis Aqua sensor also contains similar data and is an Earth Observing System (EOS) Aqua will help to provide answers. Flying in an orbit that covers the globe every 16 days, Aqua will provide a six year chronology of the planet and its processes. Comprehensive measurements taken by its onboard instruments will allow scientists to assess long-term change, identify its human and natural causes and advance the development of models for long-term forecasting." (4) The Aqua sensor has advanced capabilities and

collect data in many spectral ranges. Using data from Aqua, I was able to collect the much needed 8 day Leaf Area Index data. Here is an example of the spectral range of the Modis Aqua instrument.

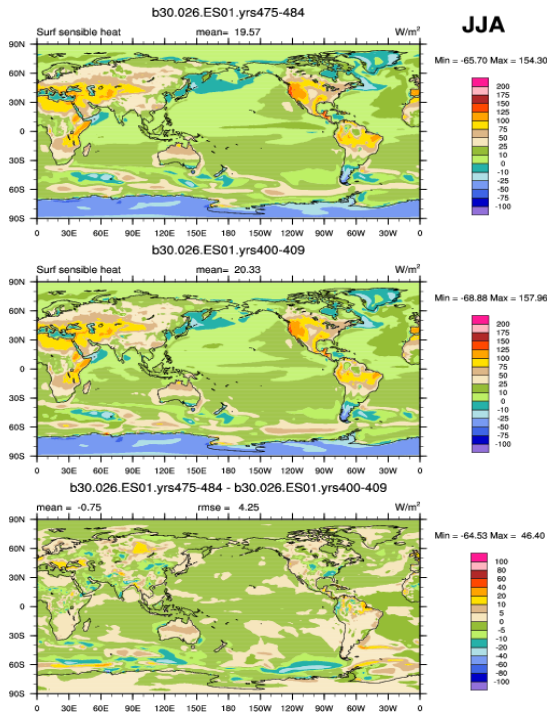
Sensor Characteristics

Primary Use	Band	Bandwidth ¹	Spectral Radiance ²
Surface/Cloud Temperature	20	3.660 - 3.840	0.45 (300K)
	21	3.929 - 3.989	2.38 (335K)
	22	3.929 - 3.989	0.67 (300K)
	23	4.020 - 4.080	0.79 (300K)
Atmospheric Temperature	24	4.433 - 4.498	0.17 (250K)
	25	4.482 - 4.549	0.59 (275K)
Surface/Cloud Temperature	31	10.780 - 11.280	9.55 (300K)
	32	11.770 - 12.270	8.94 (300K)

(5)

As I stated earlier, Sensible Heat Flux is the amount of heat, transferred in a liquid, in particular in the atmosphere, per unit of time through a unit area. Heat Flux is responsible for heat rising from the soil to heat the air and vice versa. "Sensible heat is heat energy transferred between the surface and air when there is a difference in temperature between them. A change in temperature over distance is called a "temperature gradient". In this case, it is a vertical temperature gradient, i.e., between the surface and the air above. We feel the transfer of sensible heat as a rise or fall in the temperature of the air. Heat is initially transferred into the air by conduction as air molecules collide with those of the surface. As the air warms it circulates upwards via convection. Thus the transfer of sensible heat is accomplished in a two-step process. Because air is such a poor conductor of heat, it is convection that is the most efficient way of transferring sensible heat into the air." (6)

In the Hampton Roads area, the energy balance is usually positive because heat is usually transferred upwards from the ground to heat the air. The total amount of energy from heat in the atmosphere is equal to Latent Heat + Sensible Heat + Surface Heat Flux. "When the surface is warmer than the air above, heat will be transferred upwards into the air as a positive sensible heat transfer. The transfer of heat raises the air's temperature but cools the surface. If the air is warmer than the surface, heat transferred from the air to the surface creating a negative sensible heat transfer. If heat is transferred out of the air, the air cools and the surface warms. This situation may take place at night when the sun goes down and there is no input of solar radiation. At this time, the ground cools due to longwave emission and the air directly above the surface is warmer." In Hampton, also with most of Virginia, the drier ground conditions provide for the growth of crops such as tobacco and potatoes. As shown from these charts the average Sensible heat Flux mounts are slightly positive near the Virginia area.



(7) For mathematical computations of Sensible Heat Flux density estimates, the

saturation mixing ratio, density, and evaporation rate

must be taken into account. For example,

$$H = -\frac{\rho C_p}{r_H} (T - T_o)$$

where T is the air temperature, T_o is the surface temperature, and r_H is the resistance to sensible heat transfer. The negative sign makes H positive away from the surface." (8) The process by which sensible heat flux occurs provides for seasons to occur and for different areas to have the seasonal cycles that they have. "Sensible heat flux is the process where heat energy is transferred from the Earth's surface to the atmosphere by conduction and convection. This energy is then moved from the tropics to the poles by advection, creating atmospheric circulation. As a result, atmospheric circulation moves warm tropical air to the polar regions and cold air from the poles to the equator." (9)

In conclusion, I have gathered much field data, and am in the process of using the radiometer model to convert radiometric land surface temperature to isothermal surface temperature to successfully evaluate heat flux in each particular area. Sensible heat flux deals with the heat difference in the soil temperature and the temperature in the air. Knowing the difference in temperature in the surface and in the air can be very beneficial because it helps balance the land surface energy budget. Scientists may use knowledge of heat flux and sensible heat flux to study balances of heat transfer in the atmosphere for many years to come.

Acknowledgements:

I would like to thank my advisor, Dr. Ayman Suleiman of the Center for Atmospheric Sciences at Hampton University for his tremendous support and advice that he gave me for the duration of this project. I learned a lot from Dr. Suleiman and from his guidance I was able to see how learning about sensible heat flux was beneficial and the affect that it has on the environment. I would also like to thank Mr. Mike Hill of the Center for Atmospheric Sciences at Hampton University, as well for his support and assistance ship with all of the programming

questions that I had during the completion of this research project.

Works Cited

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