P

Enhancing Numerical Weather Prediction Initial Conditions with MODIS

Jordan J. Gerth

Cooperative Institute for Meteorological Satellite Studies (CIMSS)

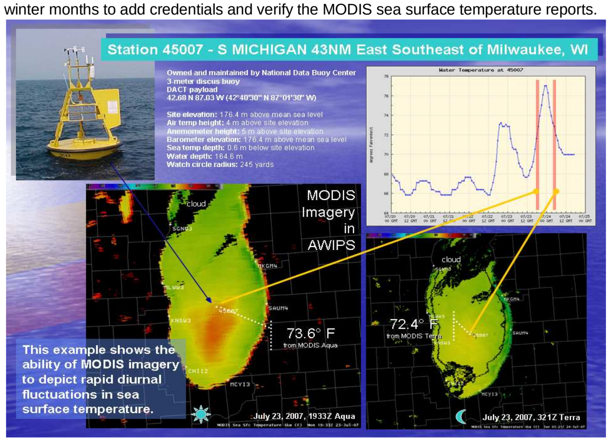
University of Wisconsin at Madison

In the spring of 2007, the Wisconsin Space Grant Consortium (WSGC) awarded a grant to pursue research in utilizing imagery and products from two NASA space satellites, Aqua and Terra, equipped with MODerate-resolution Imaging Spectroradiometers (MODIS) for enhancing the initial conditions of local numerical weather prediction models, particularly with respect to marine influences. The initial grant was intended to focus on the production of a sea surface temperature analysis using data from the two MODIS satellites influenced with in-situ reports.

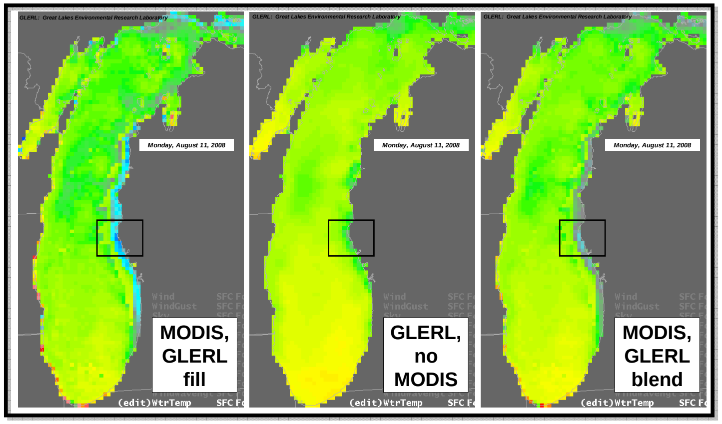
In the summer of 2007, the Weather Research and Forecasting (WRF) Model was installed and run daily without the use of satellite data from MODIS. The model was initialized with data from the Global Forecast System (GFS). The simulation domain was the southern half of Wisconsin, including much of Lake Michigan. The purpose of this exercise was to determine the response of the WRF to changes in the physical and dynamical schemes, as well as the impact of boundary conditions and spatial resolution.

MODIS sea surface temperature data was also interrogated. Consecutive MODIS sea surface temperature images over the Great Lakes showed warming of southern Lake Michigan to reach one degree Fahrenheit per hour during the day at the height of the summer, under full sun and light winds. Significant diurnal changes in sea surface temperature were not found during the winter and early spring months, due to the low sun angle.

Changes to the MODIS cloud mask were made to increase the usability of data, but the results of this change have been mixed. While data is more prevalent and tight contrasts in water temperature are no longer filtered out of the final sea surface temperature images, some sea surface temperature images suggest that areas of sea fog are not being correctly filtered, producing spurious sea surface temperature readings over cool lakes. Furthermore, there are no data buoys in the Great Lakes during the winter months to add credentials and verify the MODIS sea surface temperature reports.



This research has been made possible by the continuous financial and resource contributions from leading state and federal government agencies supporting earth systems science, including:



Lake/Sea Breeze Science

Fundamental to the problem of understanding how Lake Michigan influences the weather in Wisconsin's coastal communities is conceptualizing the dynamical and physical processes behind the sea breeze, a feature most notable during daylight in the summer months. It is important to realize that the sea breeze is a mesoscale meteorological feature, and as such, larger synoptic features may, and likely will, alter the land-sea interaction, particularly in the presence of strong advective winds and frontal passages. The figures from Tripoli (2008) require the weather pattern to be initially uniform between land and sea, as well as settled for the genesis period of the sea breeze.

When the sun rises, both the land and the sea are heated at the same rate. The ground, however, does not absorb the incoming solar radiation and the land emits strong radiation and warms the air directly above it. When air is heated, it decreases in density, making it lighter than the air above it. This causes the air to rise and the pressure near the land surface to fall in the creation of a very slight thermal low. Approximately 1000 meters above this low, the rising air cools and creates an equally weak area of high pressure above.

In an attempt to remedy the difference in pressure in and above the planetary boundary layer (PBL), there is the initiation of an offshore flow aloft coupled with an onshore flow near the surface. This onshore flow produces a convergence boundary known as a sea breeze. The air behind the sea breeze boundary is typically cooler and drier than the air prior to its passage. If the gradient between the two air masses is sufficiently large, thunderstorms are a possibility.

$\alpha \equiv$ angle of horizontal wind with any fixed reference (increases counter clockwise)

$|\vec{U}| \equiv$ horizontal wind vector; $\vec{U} = u\hat{i} + v\hat{j}$

u,v $\equiv$ x an y components of wind

$u_g, v_g \equiv$ x an y components of geostrophic wind

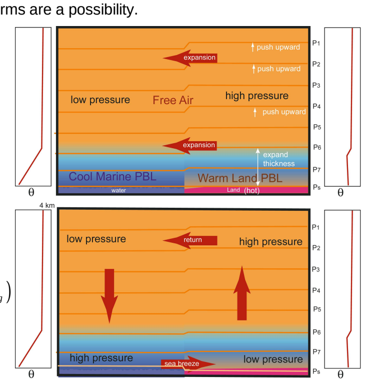
f $\equiv$ Coriolis parameter

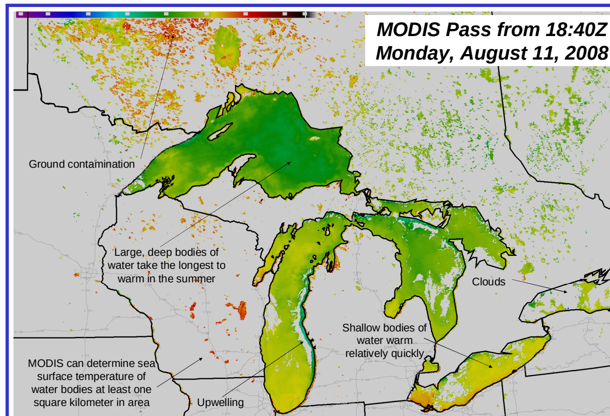
$p \equiv$ pressure; $p_m \equiv$ mesoscale pressure;

$p_g \equiv$ synoptic pressure; $p = p_m + p_g$

$F_x, F_y =$ frictional acceleration of u,v

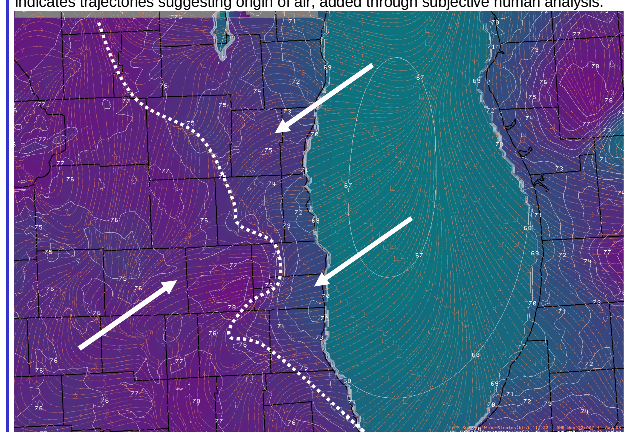
$$\frac{\partial \alpha}{\partial t} = -f - \frac{1}{\rho |U|^2}\left(u\frac{\partial p_m}{\partial y} - v\frac{\partial p_m}{\partial x}\right) + \frac{f}{|U|^2}\left(uu_g + vv_g\right) + \frac{1}{|U|^2}\left(uF_y - vF_x\right) - \left(u\frac{\partial \alpha}{\partial x} + v\frac{\partial \alpha}{\partial y} + w\frac{\partial \alpha}{\partial z}\right)$$





Local Analysis and Prediction System (LAPS)

LAPS combines surface observations, limited satellite imagery information from GOES, radar reflectivity, and upper air observations, when available, with a one-hour forecast from the most recent run of the 13-kilometer resolution Rapid Update Cycle (RUC) Model to produce an analysis over a predefined forecast area at twenty minutes after the hour, every hour. Below, the Local Analysis and Prediction System (LAPS) at two kilometers spatial resolution provides an analysis of surface winds (streamlines in orange) and temperature (white, in degrees Fahrenheit) at 22:00 UTC Monday, August 11, 2008. The dotted line indicates the position of the lake breeze over southern Wisconsin. Arrows indicates trajectories suggesting origin of air, added through subjective human analysis.



References

Aune, Robert. Personal Interview. 1 February 2007.
Bachmeier, Scott. Personal Interview. 26 January 2007.
Craven, Jeffrey. Personal Interview. 30 January 2007.
Licitar, Kim. Personal Interview. 31 January 2007.
The Realtime CIMSS Regional Assimilation System Forecast. http://cimss.ssec.wisc.edu/model/realtime/. 25 January 2007.
NCEP/NOAA Real-time, global, sea surface temperature analyses. http://polar.ncep.noaa.gov/sst/. 30 January 2007.
The Weather Research and Forecasting Model Web Site. http://www.wrf-model.org/index.php. 28 January 2007.
Strabala, Kathy. Personal Interview. 29 January 2007.
Tripoli, Gregory. Lecture. http://www.aos.wisc.edu/~aos453/lectures/lecture_08.seabreez.ppt. 14 March 2008.