Estimation of Surface Air Temperature from MODIS 1km Resolution Land Surface Temperature over Northern China

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http://disc.gsfc.nasa.gov/mairs/

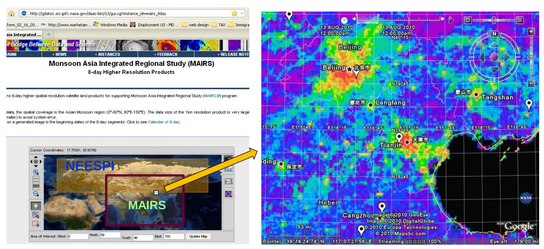
Abstract:

Surface air temperature is a critical variable to describe the energy and water cycle of the Earth-atmosphere system and is a key input element for hydrology and land surface models. It is a very important variable in agricultural applications and climate change studies. This is a preliminary study to examine statistical relationships between ground meteorological station measured surface daily maximum/minimum air temperature and satellite remotely sensed land surface temperature from MODIS over the dry and semiarid regions of northern China. Studies were conducted for both MODIS-Terra and MODIS-Aqua by using year 2009 data. Results indicate that the relationships between surface air temperature and remotely sensed land surface temperature are statistically significant. The relationships between the maximum air temperature and daytime land surface temperature depends significantly on land surface types and vegetation index, but the minimum air temperature and nighttime land surface temperature has little dependence on the surface conditions. Based on linear regression relationship between surface air temperature and MODIS land surface temperature, surface maximum and minimum air temperatures are estimated from 1km MODIS land surface temperature under clear sky conditions. The statistical errors (sigma) of the estimated daily maximum (minimum) air temperature is about 3.8°C (3.7°C).

I. Motivation:

Traditionally, surface air temperatures (T_{min} and T_{max}) are obtained from meteorological stations at 2 meters above the ground. In general, meteorological stations are distributed sparsely that is not enough for higher resolution regional model. Recent studies [1-3] have shown that estimated minimum air temperatures (T_{e_min}) from MODIS Land Surface Temperature (T_s) are statistical meaningful over Africa, US Mississippi, and in Alpine areas, but the estimated maximum air temperature (T_{e_max}) has large errors at some regions. In supporting research of Monsoon Asia Integrated Regional Study (MAIRS) project, NASA GES DISC has processed standard 8-day 1km MODIS land surface temperature by mosaic-ing and re-projecting 10x10 degree tiled data files (MOD11A2.005 and MYD11A2.005) over the entire monsoon Asia region (60°E-150°E, 0°-60°N) and made the data accessible easily for any region through the online visualization and analysis system, Giovanni. The question is how accurate T_{e_min} and T_{e_max} are over the Monsoon Asia region. This work is to examine that over the dry and semiarid regions of northern China.

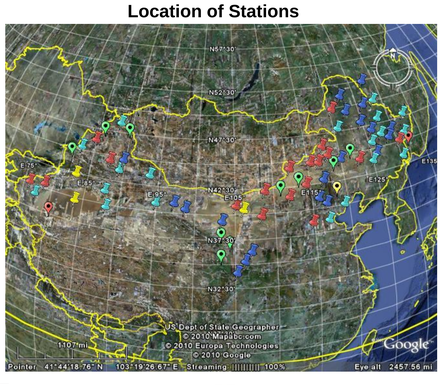
http://disc.gsfc.nasa.gov/mairs/visualization/



Daytime 1km Land Surface Temperature from MODIS-Terra for Aug13-20 2010 near Beijing-Tianjing, China. Only six WMO stations in the shown area (marked as). Image is created from the Giovanni portal mairs_8day (http://disc.gsfc.nasa.gov/giovanni)

II. Data and Processing:

Location of Stations



- Urban-1 (17 stations)
- Urban-2 (21 stations)
- Cropland (20 stations)
- Grassland (10 stations)
- Barren sparse vegetated (3 stations)
- Shrubland (2 stations)
- Woody- savannas (1 station)
- Evergreen needle leaf (1 stations)

Four datasets of year 2009 are used in this study. MODIS data are downloaded from USGS Land Processes Distributed Active Archive Center (https://lpdaac.usgs.gov/) :

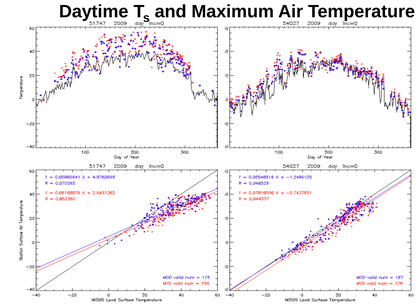
1) MODIS daily land surface temperatures (T_s) at 1km resolution of Collection-5 from Terra (MOD11A1.005) and Aqua (MYD11A1.005);
2) Daily surface air maximum and minimum temperatures from 75 meteorology stations over northern China are downloaded from China Meteorological Data Sharing Service System (http://cdc.cma.gov.cn/) ;
3) MODIS yearly land cover type at 500m resolution (MCD12Q1.005) of 2008;
4) MODIS monthly vegetation index at 1km resolution from Terra (MOD13A2.005) and Aqua (MYD13A2.005).

Each station,

1) Daily MODIS T_s and monthly MODIS NDVI from Terra and Aqua are extracted at the nearest points to the station location for daytime and nighttime, respectively
2) MODIS yearly land cover type are extracted from 9 points centered by the station for identifying the environment of a station. Land cover type is classified as the one that appears most within the 9 points. Most stations are located in the suburban areas. Since no year 2009 data are available yet, the data from 2008 are used by assuming that the environment has no significant change from year 2008 to 2009.

III. Statistical Relations between T_s and T_{min} / T_{max} :

Daytime T_s and Maximum Air Temperature



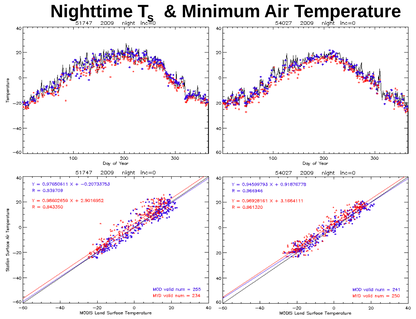
Time series show surface air temperatures (black solid line) and MODIS T_s from Terra (blue dots) and Aqua (red dots).

Scatter plots show that a) correlations are high, passing 0.001 significance level; b) the linear regression coefficients (slope and offset) varies significantly from one station to another for daytime (left), but much less for nighttime (right). The slope varies from 0.61 to 1.01 for daytime.

It is found that the linear regression slope of daytime T_s and T_{max} is associated with land surface type of the station location and vegetation index (NDVI).

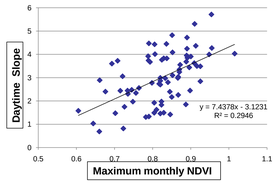
Stations are grouped into 5: urban-1 (NDVI<0.4), urban-2 (NDVI >=0.4), grassland, cropland, barren sparse vegetated. Other land types have only one or two stations.

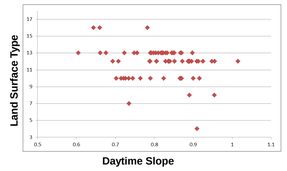
Nighttime T_s & Minimum Air Temperature



$T_{max} - T_{sday}$	r_mod	Mean_mod	Sigma_mod	r_myd	Mean_myd	Sigma_myd
barren	0.9327	-6.0503	5.7060	0.9274	-10.052	5.8880
grassland	0.9345	-4.900	5.2733	0.9309	-7.4280	5.6345
cropland	0.9672	-0.5128	4.6506	0.9611	-3.204	5.0623
urban-1	0.9544	-4.7396	5.0828	0.9460	-7.9916	5.1426
urban-2	0.9661	-1.3790	0.8333	0.9512	-3.7687	4.9433

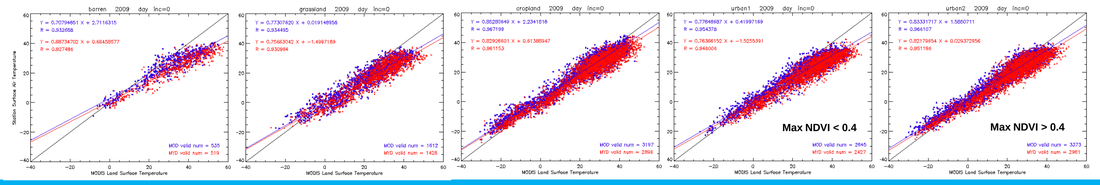
$T_{min} - T_{snight}$	r_mod	Mean_mod	Sigma_mod	r_myd	Mean_myd	Sigma_myd
barren	0.9432	-0.0805	4.2127	0.9425	2.3495	4.1494
grassland	0.9517	0.4218	3.9739	0.9532	2.4821	3.7861
cropland	0.9640	0.1168	3.9961	0.9611	1.9855	4.0575
urban-1	0.9647	-0.971	3.7380	0.9619	1.2017	3.8286
urban-2	0.96627	-0.586	3.8152	0.9663	1.4882	3.7594





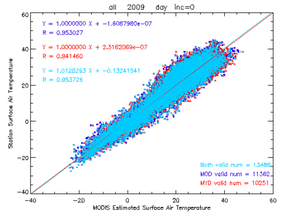
16 = Barren sparse vegetated
13 = urban
12 = cropland
10 = grassland
8 = woody savana
7 = open shurbland
4 = deciduous broadleaf

Note: Correlations for types 4, 7, 8 are not performed due to too small number of stations



IV. Estimation of T_{min} and T_{max} from MODIS T_s:

Maximum Temperature



MOD MYD
MCD = mean (MOD, MYD)

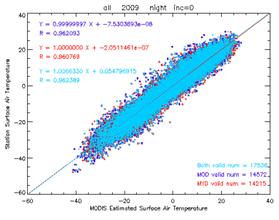
For each station, calculate estimated air temperature by applying linear regression Equation: $T_e = a * T_s + b$ Where, a and b depend on surface types:

Surface Type	a (day) MOD/MYD	b (day) MOD/MYD	a (night) MOD/MYD	b (night) MOD/MYD
Barren	0.7079/0.6873	2.7116/0.6646	0.9103/0.9252	0.2362/2.4246
grassland	0.7731/0.7566	0.0191/-1.4997	0.9021/0.9401	0.2493/2.2665
cropland	0.8528/0.8293	2.2342/0.6139	0.9151/0.9193	0.2094/1.9383
urban 1	0.7785/ 0.7637	0.4199/-1.525	0.9419/0.9637	-0.9175/1.1737
urban 2	0.8333/ 0.8218	1.5851/0.0294	0.9377/0.9584	-0.5876/1.3954

$T_{max} - T_{e_max}$	r	mean	sigma
MOD	0.9605	0.0	3.828
MYD	0.9515	0.0	4.069
All	0.9614	0.0997	3.825

$T_{min} - T_{e_min}$	r	mean	sigma
MOD	0.9629	0.0	3.740
MYD	0.9615	0.0	3.797
All	0.9362	0.056	3.735

Minimum Temperature



MOD MYD
MCD = mean (MOD, MYD)

V. Summary:

Statistical relationships are investigated between MODIS T_s and surface air maximum (T_{max}) and minimum (T_{min}) by using 2009 data for 75 stations over dry and semiarid region of northern China. Results are summarized as follows:

- MODIS land surface temperature of daytime (T_{sday}) and nightime (T_{snight}) from both Terra and Aqua are correlated significantly (p=0.001) with air temperatures T_{min} and T_{max} ;
- The correlation between T_{snight} and T_{min} is slightly higher than that between T_{sday} and T_{max};
- The slope of the linear regression equation of T_{sday} and T_{max} depends on land surface type and vegetation index;
- Combining estimated temperatures from Terra and Aqua reduces the estimation error;
- Estimated air temperatures have errors of about 3.7 °C for T_{min} and 3.8°C for T_{max}.

References:

[1] Christelle Vancutsem, Pietro Ceccato ,Tufa Dinku, Stephen J. Connor (2010), Evaluation of MODIS land surface temperature data to estimate air temperature in different ecosystems over Africa, Remote Sensing of Environment 114 (2010) 449–465
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[3] Mostovoy, G. V., King, R. L., Reddy, K. R., Kakani, V. G., & Filippova, M. G. (2006). Statistical estimation of daily maximum and minimum air temperatures from MODIS LST data over the state of Mississippi. GIScience and Remote Sensing, 43(1), 78–110.

Acknowledgments:

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GES DISC MAIRS portal: http://disc.gsfc.nasa.gov/mairs/