Monitoring Air and Land Surface Temperatures from Remotely Sensed Data for Climate-Human Health Applications

Ceccato, P.*, Vancutsem, C.*, Temimi, M.†

* *The International Research Institute for Climate and Society, The Earth Institute, Columbia University, Lamont Campus, 61 Route 9W, Monell Building, Palisades, NY, 10964-8000 USA*

† *NOAA-CREST, The City College/City University of New York, Steinman Hall, Rm T-109, 140th Street & Convent Ave, NY, NY 10031*

Abstract: Climate change affects air and land surface temperatures with implications for climate sensitive human and animal diseases (Patz *et al.*, 2008). In highland areas, East Africa and Latin America for example, changes in land surface and air temperatures will impact on the spatial distribution of risk for vector-borne disease. Heat waves in urban areas have already affected human health and their frequency might increase in the future (Meehl and Tebaldi, 2004). Monitoring changes in land surface temperature (Ts) and air temperature (Ta) is therefore important to assess and forecast risks in vector-borne disease distribution and heat stress in urban areas.

Air temperature is commonly obtained from synoptic measurements in weather stations, which are dependent on the regional infrastructure. These data are collected as point samples whose distribution is rarely designed to capture the range of climate variability within a region especially in developing countries. Dissemination periods of temperature data are also variable, therefore limiting their use for real-time applications. There is a need expressed by the scientific and user communities to access high spatial resolution and real-time temperature data for developing models and taking actions to mitigate impacts of temperature changes.

Satellite measurements from National Oceanographic and Atmospheric Administration (NOAA) –Advanced Very High Resolution Radiometer (AVHRR) and TERRA-Moderate Resolution Imaging Spectroradiometer (MODIS) provide measures of land surface temperature (Ts) on daily temporal resolution and high spatial resolution (1km). Specific methods (split-windows techniques) have been developed to derive Ts (Price, 1984, Wan *et al*., 2002) but only recently, Ts products derived from NOAA-AVHRR (Pinheiro *et al.*, 2006) and MODIS (Wan *et al.*, 2002) have been made available for operational monitoring.

The derivation of air temperature (Ta) from satellite information and its use for human health are however far from straightforward. Recent research carried at the International Research Institute for Climate and Society (IRI) showed that minimum Ts retrieved from MODIS night images provide accurate estimate of minimum Ta in different ecosystems in Africa (Vancutsem *et al.*, 2010). This research showed that it is possible to use minimum Ta derived form MODIS for monitoring risks of malaria transmission in

highlands regions including Eritrea and Ethiopia where a high proportion of the population live at risk of epidemic malaria. However, additional information on max Ta is also of importance for studying risks of malaria distribution and heat waves.

During daytime the retrieval of maximum Ta from Ts is more complex due to different factors which influence ΔTs-Ta: *i.e.* solar radiation, soil moisture and surface brightness. Analysis performed at IRI of different approaches to retrieve maximum Ta from satellite measurements has showed that methods based on Temperature Vegetation index method-Normalized Difference Vegetation Index and Solar Zenith Angle to correct ΔTs-Ta are not sufficiently accurate to retrieve maximum Ta in different ecosystems.

Methodology

A more promising approach consists in deriving maximum Ta from minimum Ta using diurnal cycle climatology model based on surface weather observations of Ta and cloud-cover information. Maximum Ta maps are created based on Aqua-MODIS LST night-time images and climatology data derived from WORDCLIM (Hijmans *et al*., 2005). WORDCLIM database provides invaluable information on the monthly average of maximum and minimum air temperature. These inputs along with other ancillary data allow us to characterize the diurnal cycle in the study area (amplitude and phase) and determine maximum Ta by extrapolating in time minimum Ta according to the determined diurnal cycle. Resulting maps are validated with max Ta measured in 28 stations located in Botswana (8 stations), Eritrea (4 stations), Ethiopia (8 stations) and Madagascar (8 stations) for the time period 2002 – 2008.

Results

Comparison between max Ta measured in stations and max Ta estimated from AQUA-MODIS night LST and WORDCLIM showed that although the two products follow the same temporal evolution (Figure 1 and Figure 2), some discrepancies between max Ta and max Ta estimates are still present (Table 1).

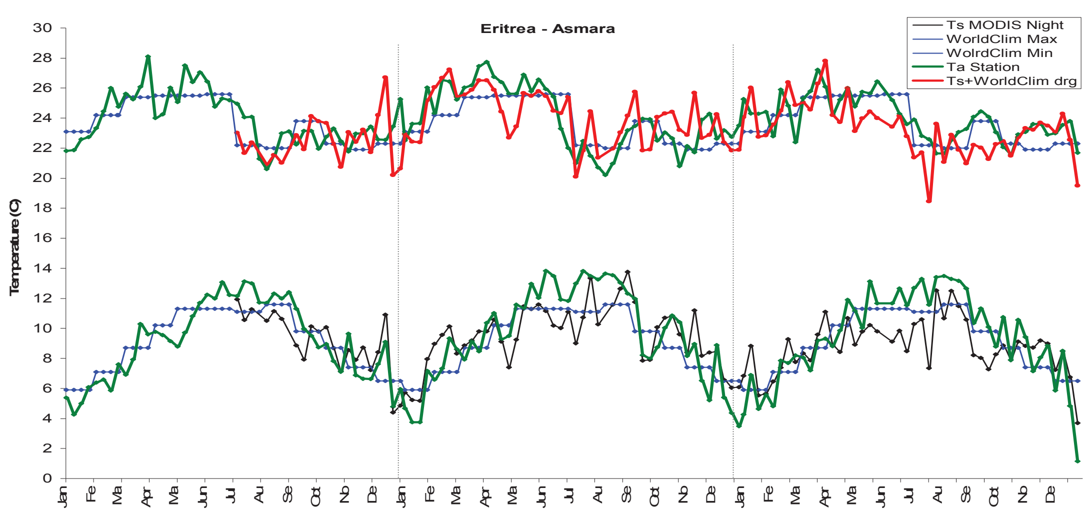

Figure 1: The minimum and maximum temperature profiles derived from stations (green), AQUA-MODIS LST night time measurements (black), min and max Ta climatology derived from WORLDCLIM data (blue) and max Ta estimated (red) for one station in Asmara, Eritrea

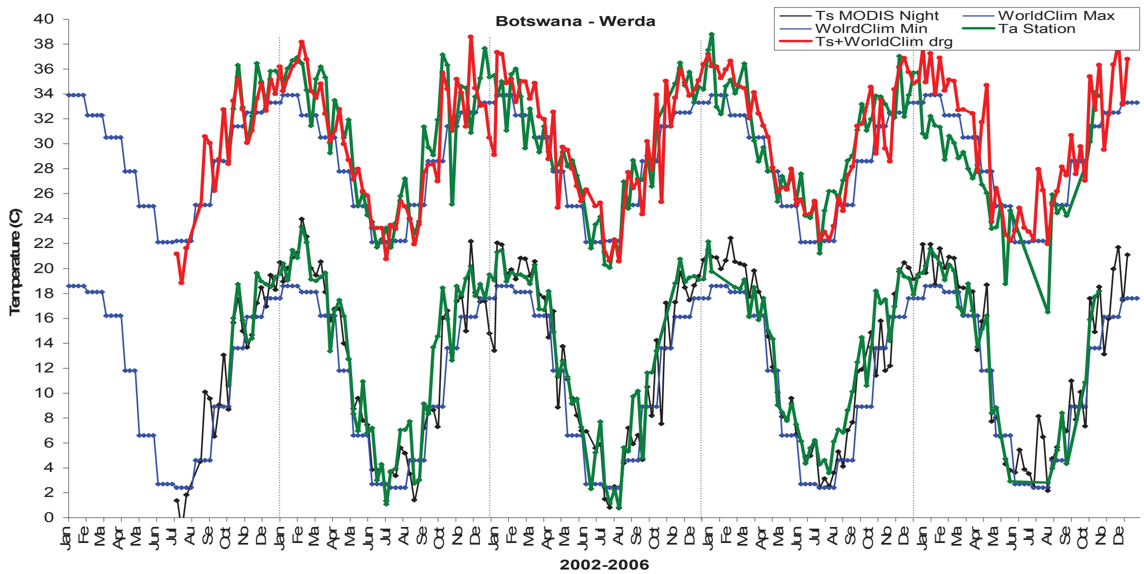

Figure 2: The minimum and maximum temperature profiles derived from stations (green), AQUA-MODIS LST night time measurements (black), min and max Ta climatology derived from WORLDCLIM data (blue) and max Ta estimated (red) for one station in Werda, Botswana

Country	MD	MED	MAE	SD	RMSE	SKEW	KURT
Ethiopia	-3.03	-2.73	4.17	4.37	5.31	-0.11	0.45
Botswana	-0.93	-0.85	2.40	2.84	2.99	-0.03	-0.31
Madagascar	0.20	0.18	1.62	2.07	2.08	0.04	0.28
Eritrea	-0.33	-0.25	1.71	2.08	2.11	0.01	-0.11
Tot 4 countries	-1.16	-0.75	2.63	3.40	3.60	-0.72	1.61

Table 1: Mean deviation (MD), median (MED), mean absolute error (MAE), standard deviation (SD), root mean square error (RMSE), skewness value (SKEW) and kurtosis value (KURT) of the difference between maximum air Temperature and maximum air Temperature estimated, by country, for all the weather stations. We are investigating the reasons for the discrepancies (current hypothesis are attributed to cloud cover, soil moisture and wind factors). Additional studies are underway to improve the retrieval of max Ta.

References

Hijmans, R., Cameron, SE., Parra, JL., Jones, PG., Jarvis, A. (2005). Very high resolution interpolated climate surfaces for global land areas. *Int. J. Climatol.* 25: 1965-1978

Meehl, G.A., Tebaldi, C. (2004) More Intense, More Frequent, and Longer Lasting Heat Wave in the 21st Century. Science 305 (5686): 994.

Patz, J.A., Olson, S.H., Uejio, C.K., Gibbs, H.K. (2008). Disease emergence from global climate and land use change. *Medical clinics of North America* 92(6): 1473

Price, J.C., (1984). Land surface temperature measurement from the split window channels of the NOAA 7 advanced very high resolution radiometer. *Journal of Geophysical research*, 89, pp7231-7237.

Pinheiro, A. C. T., R. Mahoney, J. L. Privette, and C. J. Tucker. 2006. Development of a daily long-term record of NOAA-14 AVHRR land surface temperature over Africa. *Remote Sensing of Environment* 103:153-164.

Price, J.C., (1984). Land surface temperature measurement from the split window channels of the NOAA 7advanced very high resolution radiometer. *Journal of Geophysical research*, 89, pp7231-7237.

Vancutsem, C., Ceccato, P., Dinku, T., Connor, S.J. (2010). Evaluation of MODIS Land-Surface Temperature data to estimate air temperature. *Remote Sensing of Environment,* 114: 449-465

Wan, Z.M., Zhang, Y.L., Zhang, Q.C., Li, Z.L. (2002). Validation of the land-surface temperature products retrieved from Terra Moderate Resolution Imaging Spectroradiometer data. *Remote Sensing of Environment*, 83 (1-2), pp 163-180.