Land surface air temperature monitoring using a combination of satellite and in situ measurements

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Abstract

Land surface air temperatures are sparsely observed in situ over much of the globe. Even in areas that are considered to be well observed, the density of instruments is usually not high enough to provide the spatial information that may be required for some applications (e.g. detailed characterisation of urban heat islands or heat stress during heat wave events). We present a new, high-resolution monitoring product for Europe that will provide estimates of daily maximum and minimum near-surface land air temperatures in near-real-time based on a combination of remotely-sensed and in situ data. A simple linear model is constructed that predicts air temperature from elevation and latitude, together with satellite-observed Land Surface 'skin' Temperature (LST) and vegetation fraction. The model is trained using collocated satellite and in situ observations at ground stations, and validated using an independent subset of in situ observations. The accuracy of the data set is approximately 1-3 degrees C. Although less accurate than conventional in situ-based air temperature data sets, our data set should provide timely and detailed spatial information that may be used to inform decision makers to more effectively target resources during heat wave events, for example. We present examples of this product during recent heat wave events over Europe. We also discuss future plans to extend the data set into data-sparse regions, such as parts of Africa, where observations of this type should be very valuable.

1. Introduction

In this study we use infrared (IR) satellite data to map minimum and maximum near-surface air temperatures (NSAT) over Europe. IR satellite data have several advantages over station data. They are capable of providing near spatially-complete fields that are representative of areas ('pixels') up to a few km in size, while station data are sometimes sparse and highly localised 'point' observations that may not be representative of the surrounding area. Sensors in geostationary orbit can also provide diurnal coverage with observations as frequent as every 15 minutes. Disadvantages include the fact that IR observations are restricted to cloud-free conditions, and that the sensors cannot measure surface temperature directly. This latter disadvantage means that surface temperatures must be derived from the radiance observations, which can introduce significant errors into the data sets. Finally, the satellite record is short (up to 30 years or so) compared with many station records, which may be a limiting factor for some applications.

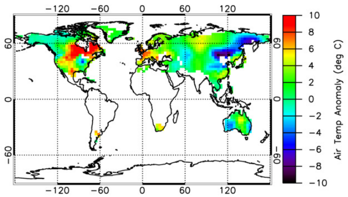

Fig. 1.1 – HadGHCND maximum daily temperature anomaly on 28 September 2011. HadGHCND is a gridded station data set (Caesar et al., 2006). There are significant gaps in the data over Africa, South America, India and the Middle East.

2. Method

It is not possible to estimate NSAT directly from satellite radiances. Current methods enable the land surface 'skin' temperature (LST) to be estimated from IR satellite radiances with an accuracy of about 1-3 ºC. Although related to the NSAT, the LST may differ by several degrees. The approach adopted here is to estimate minimum and maximum NSAT from minimum and maximum daily LST and other parameters using an empirical multiple linear regression (Fig 2.1).

The satellite data used here are from the SEVIRI; the pixel LST, FVC, elevation and latitude data are sourced from the EUMETSAT Land Surface Analysis Satellite Applications Facility (LSA SAF). The station data are SYNOP observations that have undergone the single-station quality control checks described by Durre et al. (2010). Before the regression, the predictor variables (x) are standardised by subtracting the mean then dividing by the standard deviation.

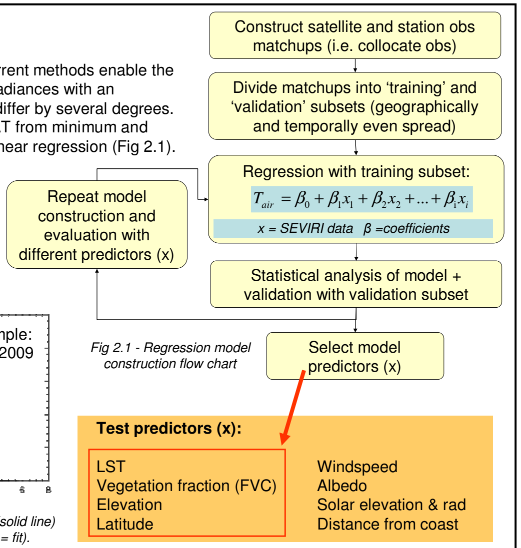

Fig 2.1 - Regression model construction flow chart

SEVIRI

- Spinning Enhanced Visible and Infrared Imager (SEVIRI)
- Geostationary orbit above 0º lat, 0º long (Platform: Meteosat)
- 12 channels (visible, near IR and IR)
- Observations every 15 minutes
- Spatial resolution 3 km at sub-satellite point.

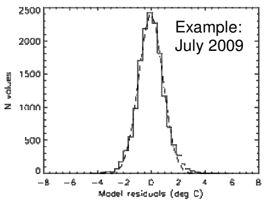

Fig 2.2 – The model residuals (solid line) are Gaussian (dashed line = fit).

3. Results

Model parameters are derived on a monthly basis (e.g. Tab. 3.1). LST is always the dominant predictor. Evaluation with the independent subset of validation stations indicates an accuracy of ~1-3ºC (Fig. 3.1). However, there is some indication the accuracy has some geographical dependence (Figs. 3.1 & 3.2); separate models may be required for different land types or regions (future work). Accuracies over mountainous regions are lower (e.g. Alps).

Tab. 3.1 – Regression parameters and statistics for July 2009. The multiple linear correlation coefficient is 0.86.

	Param	Error	T value	P value	$R(T_{air})$
Constant	27.22	-	-	-	-
Height	-1.24	0.01	-146.02	0.00	-0.20
Latitude	-0.87	0.01	-68.98	0.00	-0.62
FVC	0.87	0.01	78.50	0.00	-0.50
LST	4.67	0.01	350.24	0.00	0.83

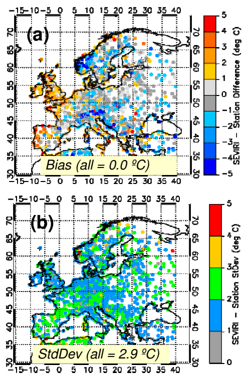

Fig. 3.1 – Station validation results for July 2009 Tmax showing (a) mean bias and (b) standard deviation.

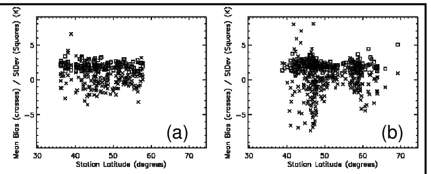

Fig 3.2 – Fig 3.1 validation results vs latitude for GlobCover land types (a) Mosaic cropland (50-70%) and vegetation (grassland/ shrubland / forest) (20-50%) and (b) Closed (>40%) broadleaved deciduous forest (The Alps at ~ 47º have lower accuracy).

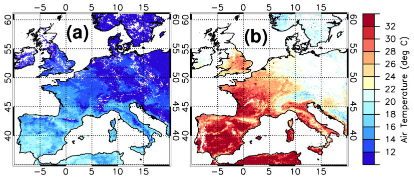

Fig. 3.3 – (a)Tmin and (b) Tmax for 26 June 2011 (heat wave)

4.Conclusions and Next Steps

- Land near-surface air temperatures are generally obtained from in situ stations. Problem: point observations & geographically sparse.
- An empirical model has been developed to estimate NSATs from satellite LSTs, vegetation fraction, latitude and elevation over Europe. Independent in situ validation indicates the accuracy of the satellite NSATs is ~1-3ºC (comparable to satellite LSTs).
- The satellite air temperatures can be used to supplement existing station observations, providing extra coverage and fine spatial detail that will be useful for many applications.
- The SEVIRI field of view includes Africa, which is not well represented by existing data sets (e.g. Fig 1.1). In the near future, we plan to extend this analysis to Africa. If successful, other geostationary sensors, such as GOES and MTSAT will then be used to extend this data set to other data-sparse regions such as South America and parts of Asia.

REFERENCES

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