Assimilation of S-NPP VIIRS Land Surface Temperature into NCEP RTMA AK Domain

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Objective and background

Over the CONUS, the 2DVar Real-Time Mesoscale Analysis (RTMA) and Unrestricted Mesoscale Analysis (URMA) system have access to a fairly dense network of conventional surface observations, especially in non-mountainous regions. However, outside of the CONUS domain, especially over Alaska (AK), the coverage of in-situ observations is relatively sparse. This complicates the creation of a high quality analysis. The assimilation of satellite observations is therefore an area that can be explored to improve the RTMA/URMA surface temperature analyses in regions of limited in-situ observations. This project is focused on the AK RTMA/URMA domain and explores the assimilation of Visible Infrared Imaging Radiometer Suite (VIIRS) satellite retrieved Land Surface Temperatures (LST) to improve the AK RTMA/URMA surface 2-meter temperature analysis (T2M). This 3-km resolution surface analysis is expected to contribute to improving forecasters' analysis of AK weather. Previously, Bosilovich et al. (2007) showed that LST assimilation improves estimates of 2-meter air temperature, both in the mean and variability. But their study was made with a coupled land surface model.

Methods

Previous investigations (Bosilovich et al. 2007; Reiche et al. 2010) on the assimilation of satellite retrieved LST have been mostly carried out within a pure soil model or within a coupled land surface model. Relationships between the LSTs and surface energy cycle are derived from these models. However, the RTMA/URMA is a 2DVar system; there is no coupled land surface model, or 3-D atmospheric profiles available in the analysis algorithm. It is therefore difficult to assimilate LST directly through the surface energy cycle. An alternative approach in assimilating LSTs into the RTMA/URMA system is to convert LST to T2M (also known as pseudo T2M), which can then be assimilated in the same manner as other conventional T2M observations, such as those observed from METARs. The Monin-Obukhov similarity theory, which is based on the Dyer and Hicks (1970) formula, is adopted to convert the LST to pseudo T2M in this work. The similarity theory and conversion from LST to T2M are described below in detail.

Temperature at the 2-meter height can be obtained using the similarity theory as follows:

$$T_z=\left[\theta_g + \left(\theta_s - \theta_g\right) \times \frac{\Psi_{T_z}}{\Psi_T}\right]\left(\frac{P_{sfc}}{1000}\right)^{\frac{R}{C_p}}$$

θ_s is potential temperature at the model lowest sigma level and θ_g is potential temperature on the ground, which is converted from LST. P_{sfc} is surface pressure. The stability functions are given by:

$$\Psi_T=\log\left(\frac{h_s}{z_0}\right) - \Psi_h;\ \Psi_{T_z}=\log\left(\frac{z}{z_0}\right) - \Psi_{hz}$$

where h_s is the height of at the lowest model level, and z=2m is the height at which the temperature will be computed. z_0 is the roughness length prescribed in the model. The ideal gas constant (R) is 287.04 $JK^{-1}kg^{-1}$, and the specific heat at constant pressure (Cp) is 1004.0 $JK^{-1}kg^{-1}$. ψ_h *and* ψ_{hz} are the stability function for heat but are calculated at the lowest model level and at the 2-m height above the ground, respectively. This stability function is determined according to atmospheric stability based on the Bulk Richardson number (Lee et al. 2005).

Preliminary Results

Two single analysis experiments were performed. The control run (CTRL) only assimilates conventional observations, as in the operational RTMA. The experiment assimilates VIIRS LST and conventional observations (EXPLST). Both experiments use the same downscaled 13-km Rapid Refresh model 1-hour forecast as the first guess. Due to its high resolution (750m), VIIRS LST was thinned to a 20-km mesh using the existing thinning scheme in GSI. All other conventional observations are kept at their original resolution. The observation error of LST is set to 1.2 Kelvin. The VIIRS LST high quality flagged pixels are used as the quality control. A gross error/outlier check is also employed in the 2DVar algorithm.

The departures of observations (pseudo T2M) from the background (OMB) and from the analysis (OMA) are shown in Fig. 1. For the cases examined here all histograms of OMA are more Gaussian than OMB. This indicates that the analysis algorithm is functioning as expected by fitting VIIRS pseudo T2M. The T2M analysis differences between EXPLST and CTRL (Fig. 2a) show mostly negative values, indicating that assimilating LST made the T2M colder than only assimilating the conventionally available in-situ observations. Consistent with the colder T2M, the 2-m dew-point temperature is also lower (Fig. 2b). Case studies beyond those described in this report have been carried out. It is confirmed that the analysis algorithm developed for the assimilation of VIIRS LST is able to fit the observations reasonably well. The standard deviation of analysis departures are reduced as expected.

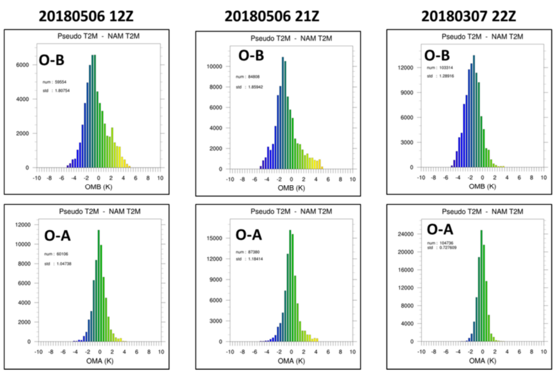

Figure 1. The histogram plots for departure of VIIRS LST pseudo T2M and model first-guess T2M (OMB) and analysis (OMA).

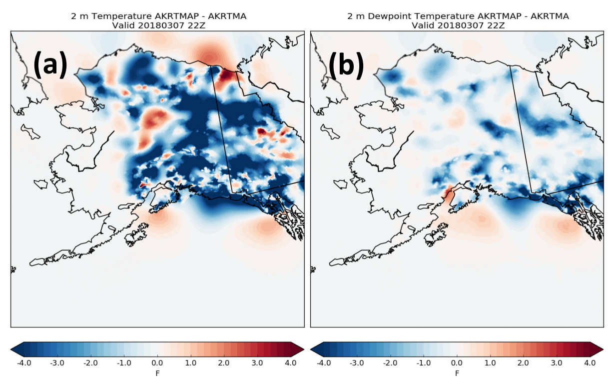

Figure 2. RTMA analysis difference between experiment EXPLST and CTRL for T2M (a), and 2- meter dew-point temperature (b).

References

Dyer, A. J., and B. B. Hicks, 1970: Flux-gradient relationships in the constant flux layer. *Quart. J. Roy. Meteor. Soc.*, **96**, 715-721.

Bosilovich, M., J. Radakovich, A. da Silva, R. Todling, and F. Verter, 2007: Skin temperature analysis and bias correction in a coupled land–atmosphere data assimilation system. *J. Meteor. Soc. Japan*, **85A**, 205–228.

Lee, S. J., D. F. Parrish, and W.-S. Wu, 2005: Near-surface data assimilation in the NCEP Gridpoint statistical-interpolation system: Use of land temperature data and a comprehensive forward model. NCEP office Note #446.

Reichle, R.H., S.V. Kumar, S.P. Mahanama, R.D. Koster, and Q. Liu, 2010: Assimilation of Satellite-Derived Skin Temperature Observations into Land Surface Models. *J. Hydrometeor.*, **11**, 1103–1122.

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