Assimilation of Satellite-derived Skin Temperature Observations into Land Surface Models

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Project Goal: The goal of this project is to investigate the potential for assimilating satellite retrievals of land surface temperature (LST) within the Goddard Earth Observing System (GEOS) land data assimilation system. Such a system will improve the characterization of LST background estimates for the assimilation of atmospheric radiances that are sensitive to the land surface.

Project Description: Land surface conditions are intimately connected with the global climate system and have been associated, through different pathways, with atmospheric predictability. Land surface (or "skin") temperature (LST) lies at the heart of the surface energy balance and is therefore a key variable in weather and climate models. LST influences the latent and sensible heat fluxes to the atmosphere through which it affects the planetary boundary layer and atmospheric convection. LST also plays an important role in the assimilation of atmospheric remote sensing observations. Because forward radiative transfer modeling for surface-sensitive (window) channels requires accurate information about land surface conditions, radiance observations from window channels are typically not assimilated. Accurate LST estimation is therefore critical to improving estimates of the surface water, energy, and radiation balance as well as atmospheric temperature and humidity profiles, which in turn are all critical to improving weather and climate forecast accuracy.

In this project we assimilated LST retrievals from the International Satellite Cloud Climatology Project (ISCCP) into the Noah and GEOS-5 Catchment (CLSM) land surface models using an ensemble-based, off-line land data assimilation system. LST is described very differently in the two models. CLSM describes LST as a prognostic variable that assigns a small heat capacity to the top 5 cm layer of the soil and the canopy. By contrast, Noah – used operationally at the National Centers for Environmental Prediction (NCEP) – determines skin temperature diagnostically from the surface energy balance. The different strategies for LST modeling in the two land surface models necessitate different approaches to data assimilation. For GEOS-5 development, it is critical to understand how CLSM can be used for LST assimilation and whether there are any advantages or disadvantages between the two LST modeling approaches.

Moreover, we pay particular attention to bias between observed and modeled LST. Because satellite and model LST typically exhibit different mean values and variability we have developed customized *a priori* scaling and dynamic bias estimation approaches for LST assimilation. For each of the two land models, we conducted one open loop (no assimilation) ensemble integration and four different experiments in which ISCCP LST retrievals were assimilated. Two of the four assimilation integrations (per model) were performed with the (unscaled) LST retrievals ("s0"), the other two utilized ISCCP retrievals that were scaled to each model's LST climatology prior to assimilation ("s1"). In each set of two assimilation integrations, one was done without bias correction ("b0"), and the other used the dynamic bias algorithms ("b8"). For each model, we thus compare four assimilation integrations: "s0b0", "s0b8", "s1b0", and "s1b8". Performance is measured against 27 months of *in situ* measurements from the Coordinated Energy and Water Cycle Observations Project at 48 stations.

Results: Figure 1 shows that LST estimates from Noah and CLSM without data assimilation ("open loop") are comparable to each other and superior to ISCCP retrievals. For LST, RMSE values are 4.9 K (CLSM), 5.5 K (Noah), and 7.6 K (ISCCP). Similarly, anomaly correlation coefficients (R) are 0.61 (CLSM), 0.63 (Noah), and 0.52 (ISCCP) (not shown). Obviously, the superior skill of the model LST estimates relative to the skill of the ISCCP retrievals limits the improvements that can be expected from assimilating the ISCCP data. Nevertheless, assimilation of ISCCP retrievals provides modest yet statistically significant improvements (over open loop; as indicated by non-overlapping 95% confidence intervals) of up to 0.7 K in RMSE (Figure 1) and 0.05 in anomaly R (not shown). The skill of latent and sensible heat flux estimates from the assimilation integrations is essentially identical to the corresponding open loop skill. Noah assimilation estimates of ground heat flux, however, can be significantly worse than open loop estimates (not shown). Provided the assimilation system is properly adapted to each land model, the benefits from the assimilation of LST retrievals are comparable for both models.

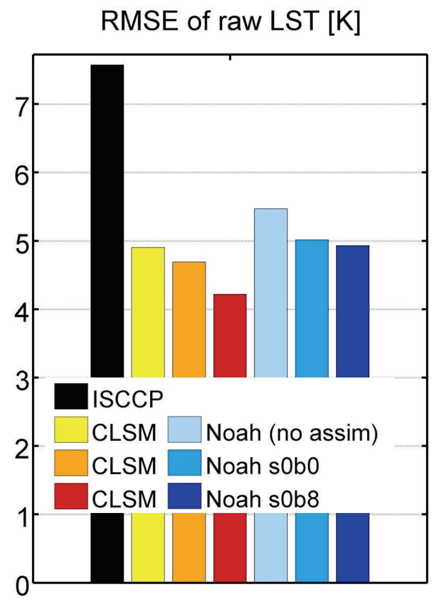

Figure 1: RMSE versus CEOP in situ observations for LST from ISCCP retrievals, model integrations, and select assimilation integrations without a priori scaling and (b0) without and (b8) with dynamic bias correction.

The main conclusions from the experiments are as follows:

(1) There are strong biases between LST estimates from *in situ* observations, land modeling, and satellite retrievals that vary with season and time-of-day. Biases of a few Kelvin are typical, with larger values exceeding 10 K.

(2) The skill of LST estimates from the CLSM and Noah land model integrations is superior to that of the ISCCP satellite retrievals.

(3) Assimilation of ISCCP LST retrievals into the land surface models can improve LST estimates by up to 0.7 K for RMSE and by up to 0.05 for anomaly R, while not making surface turbulent fluxes worse.

(4) Gross errors in surface flux estimates can result if biases are not taken into account properly, with a combination of *a priori* scaling and dynamic bias estimation methods yielding the best overall results.

(5) Assimilation diagnostics for integrations without *a priori* scaling strongly reflect the underlying biases, indicating that without *a priori* scaling the assimilation system is far from operating in accordance with its underlying assumptions.

(6) Provided the assimilation system is properly configured for each land model, the benefits from the assimilation of LST retrievals are comparable for both land models.

Publication

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