# CONUS-Scale Testing of 4km Gridded Physically-Based Soil Moisture and Soil Temperature Fields

*By Michael Smith*

Victor Koren's modified Sacramento model has been integrated into the Hydrology Laboratory's Research Modeling System (HL-RMS) distributed model. His new Sacramento model combines the principles of heat transfer and physical soil properties to compute physically-based estimates of soil moisture and soil temperature (see Appendix).

In another development, HL-RMS has been modified to run over the entire continental US (CONUS). Victor, Fekadu Moreda, and Zhengtao Cui recently ran the new versions of the SAC model and HL-RMS over CONUS using seven days of hourly NEXRAD (NEXt generation RADar) Stage IV data as shown in Figure 1. Figures 2, 3, and 4 show actual computed soil moisture content in three different layers at the end of the seven day run of HL-RMS. Figure 5 shows computed surface runoff. In all these figures, the modeling resolution is 4km by 4km.

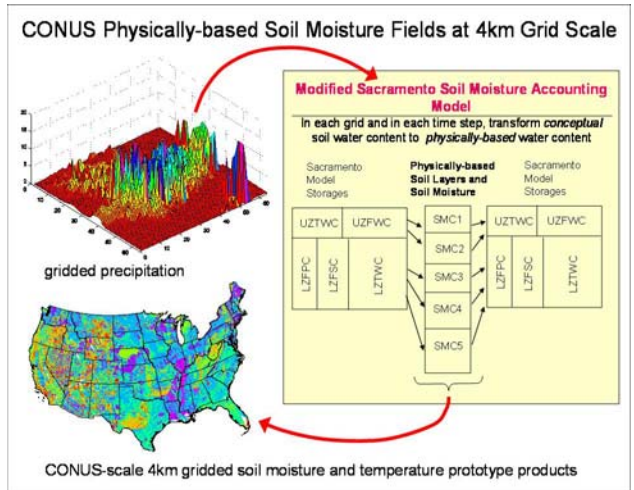


**Figure 1** Computation of nationwide 4km gridded soil moisture and soil temperature fields using the distributed model in HL-RMS and Victor Koren's modified Sacramento model.

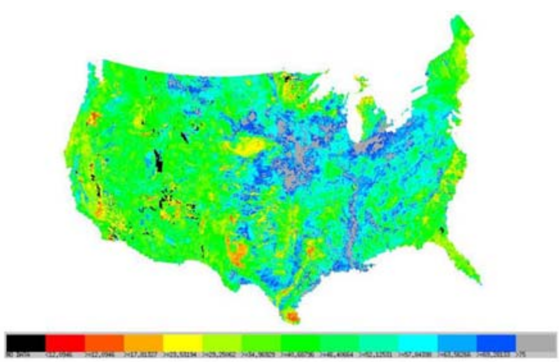

**Figure 2** 4km Computed Soil Moisture in 0-25cm layer at hour 0, June 17, 2004.

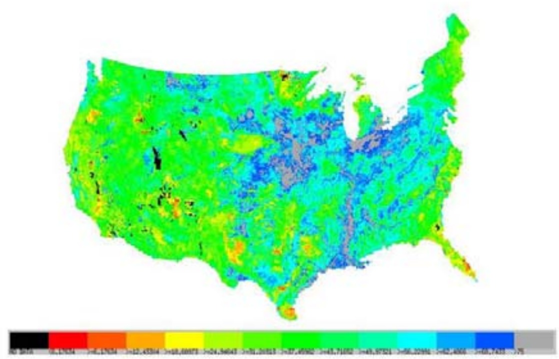

**Figure 3** 4km Computed Soil Moisture in 0-5 cm Layer at hour 0 on June 17, 2004.

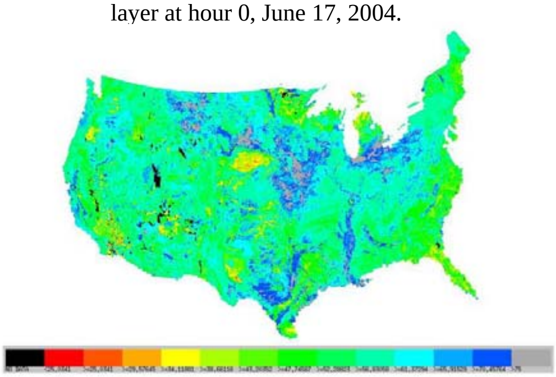

**Figure 4** 4km Computed Soil Moisture in 25-100cm Layer at hour 0 on June 17, 2004.

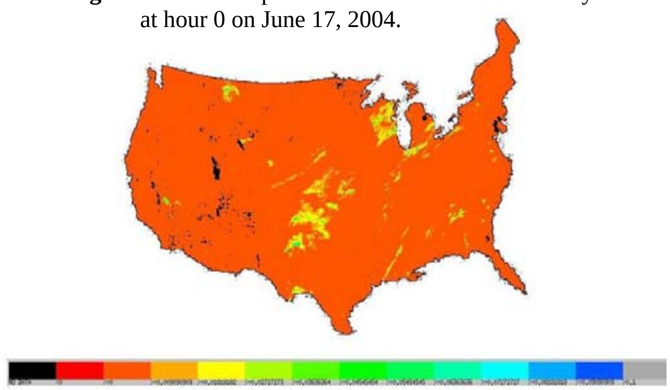

**Figure 5** 4km Computed Surface Runoff at hour 0 on June 17, 2004. Units are in mm/hour.

We see such large scale, high resolution tests as an exciting opportunity to develop new tools and prototype products for future RFC forecast operations:

1. Prototype versions of new water resources products can be tested. These include soil moisture and soil temperature for agricultural users. Such products are foundational to the NOAA Water Resources program as shown in Figure 6.


**Figure 6** Gridded Products Proposed for NOAA Water Resources Program. (Source: Gary Carter, 2005: Working Together to Live with a Limited Water Suply. Presented at 2005 AMS conference, January 10)

2. Gridded values of physically-based soil moisture can potentially be used to evaluate Flash Flood Guidance (FFG).
3. CONUS-scale runs will allow us to more effectively identify where our modeling efforts work and where they need improvement. This results in an accelerated research-to-operations pathway.
4. Research collaborators such as the University of Arizona can more effectively test their modeling improvements and calibration strategies. The University of Arizona is currently working with a version of HL-RMS running on their system.
5. New distributed model calibration strategies can be tested.
6. CONUS runs of HL-RMS can expedite the evaluation of new precipitation products such as National Severe Storms Laboratory's NMQ (National Mosaic and multi-sensor Quantitative precipitation estimation) and Q2 (next generation Quantitative Precipitation Estimation).
7. Such testing supports NOAA mission goals listed in the NOAA 2005-2010 Strategic Plan:
    a. Performance objectives for Weather and Water Mission Goal:
    Increase development, application, and transition of advanced science and technology to operations and services.
    b. Cross Cutting Priorities:
    Ensuring sound, state-of-art research.
8. CONUS runs of HL-RMS can contribute to the development of the National Integrated Drought Information System (NIDIS).

## <u>Appendix:</u> Victor Koren's Modification of the Sacramento Model to Generate Physically-Based Soil Moisture and Soil Temperature Fields

A. Introduction

The ability to generate lumped and distributed physically-based soil moisture estimates is a by-product of the pioneering frozen ground algorithm developed by Koren *et al.* (1999). Following the implementation of this work into the ETA weather model, Mitchell et al. (2002) reported reduced biases in weather model predictions, confirming the validity and utility of this frozen ground algorithm.

Later, the conceptual Sacramento rainfall-runoff model was modified to include this algorithm for advanced modeling of the effects of frozen soil on the runoff generation process (Koren, 2004; 2003). Rigorous testing in HL proved that this approach well reproduces observed soil temperatures and runoff hydrographs. This approach generates simulations that are as good as or better than the conceptual approach developed by Anderson and Neuman (1984) without calibration of the frozen ground model parameters. This version of the Sacramento model has been implemented in the HL distributed model HL-RMS (Smith *et al.*, 2004). Also, the lumped version of this Sacramento model was delivered for prototype field testing to OHRFC in March, 2004. This field testing was limited to the use of the frozen ground model in the calibration mode of NWSRFS.

B. R&D Time Line

a. April- May 2005. <u>Analysis of computed and observed soil moisture fields</u>. Here, HL-RMS will be used to compute gridded soil moisture estimates at each of the Oklahoma Mesonet sites. Computed and observed soil moisture estimates at these points will be analyzed to asses the ability of HL-RMS to reproduce the moisture dynamics of this system. These results were presented in Koren *et al.* (2005).

b. May-September, 2005. <u>Continued testing of HL-RMS soil moisture component against additional observations of soil moisture</u>. In addition to the Oklahoma Mesonet observations, manually-gathered soil moisture measurements will be used for evaluation of the HL-RMS soil moisture model. Data from selected NRCS SCAN sites will also be used.

c. October, 2005 – September, 2006. <u>Comparison to other distributed/soil moisture models via DMIP 2.</u> A significant DMIP 2 component calls for the testing of participants models over the Oklahoma Mesonet domain, similar to the tests described in paragraph ‘a’ above. This will provide a multi-institutional evaluation of many distributed model approaches to computing soil moisture.

C. References

Anderson, E.A., and Neuman, P.J., 1984. Inclusion of frozen ground effects in a flood forecasting model. Fifth Northern Research Basins Symposium and Workshop, March 19-23, Vierumaki, Finland.

Koren, V., Reed, S., Moreda, F., Smith, M., Zhang, Z., Cui, Z., 2005. Evaluation of a grid-based distributed hydrological model over a large area: model uncertainties at different scales. Presented at VIIth IAHS Scientific Assembly, Foz do Iguaçu – Brazil from April 03 to 09, 2005.

Koren, V., 2004. Physically-based parameterization of frozen ground processes in watershed modeling. Presented at Spring AGU, Montreal, Canada, May 15-22.

Koren, V., 2003. Parameterization of soil moisture-heat transfer processes for conceptual hydrological models. Proceedings of AGU/EGS Joint Meeting, Nice, France, April, Paper: EAE03-A-06486; HS18-1TU1P-0390

Koren, V., Schaake, J., Mitchell, K., Duan, Q.-Y, Chen, F., and Baker, J.M., 1999. A parameterization of snowpack and frozen ground intended for NCEP weather and climate models. *Journal of Geophysical Research*, Vol. 104 No. D16, 19, 569-19,585, August.

Mitchell, K., Ek, M., Lohmann,D., Koren, V., Schaake, J., Duan, Q., Grunmann, P., Gayno, G., Lin, Y., Rogers, E., Tarplay, D., and Peters-Lidard, C., 2002. Reducing near-surface cool/moist biases over snowpack and early spring wet soils in NCEP ETA model forecasts via land surface model upgrades. AMS proceedings, paper J1.1

Smith, M., Koren, V., Reed, S., Zhang, Z, Seo, D.-J., Moreda, F., Cui, Z. 2005. Distributed Model Intercomparison Project Phase 2 Draft Science Plan.

Smith, M., Koren, V., Zhang, Z., Reed, S., Seo, D.-J., Moreda, F, Kuzmin, V., Cui, Z., and Anderson, R., 2004. NOAA/NWS Distributed Hydrologic Modeling Research and Development. NOAA Technical Report NWS 45, April.

Correspondence to: Dr. Michael Smith, NOAA/NWS/Hydrology Laboratory
E-mail: michael.smith@noaa.gov