P162 EXPANSION OF THE REAL-TIME SPORT-LAND INFORMATION SYSTEM FOR NOAA / NATIONAL WEATHER SERVICE SITUATIONAL AWARENESS AND LOCAL MODELING APPLICATIONS

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1. INTRODUCTION

The NASA Short-term Prediction Research and Transition (SPoRT) Center in Huntsville, AL (Jedlovec 2013; Ralph et al. 2013; Merceret et al. 2013) is running a real-time configuration of the Noah land surface model (LSM) within the NASA Land Information System (LIS) framework (hereafter referred to as the "SPoRT-LIS"). Output from the real-time SPoRT-LIS is used for (1) initializing land surface variables for local modeling applications, and (2) displaying in decision support systems for situational awareness and drought monitoring at select NOAA/National Weather Service (NWS) partner offices. The SPoRT-LIS is currently run over a domain covering the southeastern half of the Continental United States (CONUS), with an additional experimental real-time run over the entire CONUS and surrounding portions of southern Canada and northern Mexico. The experimental CONUS run incorporates hourly quantitative precipitation estimation (QPE) from the National Severe Storms Laboratory Multi-Radar Multi-Sensor (MRMS) product (Zhang et al. 2011, 2014), which will be transitioned into operations at the National Centers for Environmental Prediction (NCEP) in Fall 2014.

This paper describes the current and experimental SPoRT-LIS configurations, and documents some of the limitations still remaining through the advent of MRMS precipitation analyses in the SPoRT-LIS land surface model (LSM) simulations. Section 2 gives background information on the NASA LIS and describes the real-time SPoRT-LIS configurations being compared. Section 3 presents recent work done to develop a training module on situational awareness applications of real-time SPoRT-LIS output. Comparisons between output from the two SPoRT-LIS runs are shown in Section 4, including a documentation of issues encountered in using the MRMS precipitation dataset. A summary and future work is given in Section 5, followed by acknowledgements and references.

2. NASA LIS AND SPORT-LIS CONFIGURATIONS

2.1 LIS framework

The NASA LIS is a high performance land surface modeling and data assimilation system that integrates satellite-derived datasets, ground-based observations and model reanalyses to force a variety of LSMs (Kumar et al. 2006; Peters-Lidard et al. 2007). By using scalable, high-performance computing and data management technologies, LIS can run LSMs offline globally with a grid spacing as fine as 1 km to characterize land surface states and fluxes. LIS has also been coupled to the Advanced Research Weather Research and Forecasting (WRF) dynamical core (Kumar et al. 2007) for numerical weather prediction (NWP) applications using the NASA Unified-WRF modeling framework.

2.2 SPoRT-LIS Description

In the SPoRT-LIS, version 3.2 of the Noah LSM (Ek et al. 2003; Chen and Dudhia 2001) is run in analysis mode (i.e., uncoupled from an NWP model) in separate runs over the southeastern CONUS and full CONUS domains at 0.03-degree grid spacing for continuous long simulations. The soil temperature and volumetric soil moisture fields were initialized at constant values of 290 K and 20 % in all four Noah soil layers (0-10, 10-40, 40-100, and 100-200 cm) on 1 June 2010, followed by an integration using a 30-minute timestep to near real-time.

2.2.1 **Static input fields**

The SPoRT-LIS uses the International Geosphere-Biosphere Programme (IGBP) land-use classification (Loveland et al. 2000) as applied to the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument (Friedl et al. 2010). All static and dynamic land surface fields are masked based on the IGBP/MODIS land-use classes. The soil properties are represented by the State Soil Geographic (STATSGO; Miller and White 1998) database.

Additional parameters include a 0.05° resolution maximum snow surface albedo derived from MODIS (Barlage et al. 2005) and a deep soil temperature climatology (serving as a lower boundary condition for the soil layers) at 3 meters below ground, derived from 6 years of Global Data Assimilation System (GDAS) 3-hourly averaged 2-m air temperatures using the method described in Chen and Dudhia (2001). In addition, real-time green vegetation fraction (GVF) data derived from MODIS normalized difference vegetation index (NDVI) data (Case et al. 2014) are incorporated into the LIS runs in place of the default monthly climatology GVF dataset (Gutman and Ignatov 1998) as used in the community WRF NWP model. The real-time MODIS GVF are produced by SPoRT on a CONUS domain with 0.01° (~1 km) grid spacing, and updated daily with new MODIS NDVI swath data from the University of Wisconsin Direct Broadcast feed that the SPoRT Center receives in near real-time.

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2.2.2 Simulations and atmospheric forcing

The Noah LSM simulation in both LIS runs was initialized at 0000 UTC 1 June 2010, coinciding with the first day of availability of the real-time SPoRT-MODIS GVF. The simulations were run for over two years prior to use for real-time applications in order to remove memory of the unrealistic uniform soil initial conditions. The atmospheric forcing variables required to drive the LIS/Noah integration consist of surface pressure, 2-m temperature and specific humidity, 10-m winds, downward-directed shortwave and longwave radiation, and precipitation rate. In the long-term simulation, all atmospheric forcing variables are provided by hourly analyses from the North American Land Data Assimilation System-phase 2 (NLDAS-2; Xia et al. 2012), except for precipitation, where hourly precipitation analyses from the NCEP Stage IV precipitation product (Lin and Mitchell 2005; Lin et al. 2005) are used for the Southeastern CONUS run, and hourly MRMS QPE for the full CONUS run (Stage IV and MRMS domains shown in Figure 1). The grid spacing of the NLDAS-2 analyses is one-eighth degree (~14 km), the Stage IV analyses have 4.8 km grid spacing, and the MRMS QPE is on a 0.01-degree grid (~1 km). The Noah LSM solution ultimately converges to a modeled state based on the NLDAS-2 and Stage IV/MRMS precipitation input.

The Stage IV precipitation analyses are typically available within an hour or two of the current time with the MRMS precipitation available ~4-5 hours of real time. Meanwhile, the NLDAS-2 analyses have ~3-4 day lag in real time, warranting the use of alternative datasets in order to provide timely SPoRT-LIS output each day. To integrate LIS/Noah from the time availability of NLDAS-2 to approximately the current time, the LIS is re-started using atmospheric forcing files from the NCEP GDAS (Parrish and Derber 1992; NCEP EMC 2004), along with a continuation of the Stage IV or MRMS hourly precipitation. The GDAS contains 0–9 hour short-range forecasts of the required atmospheric forcing variables at 3-hourly intervals, derived from the data assimilation cycle of the NCEP Global Forecast System (GFS) NWP model. The GDAS files are available about 6–7 hours after the valid GFS forecast cycle. Finally, to ensure continuous availability of SPoRT-LIS output for initializing LSM fields in local NWP modeling applications, an additional LIS re-start is made, driven by atmospheric forcing from the NCEP GFS model 3–15 hour forecasts.

The SPoRT-LIS cycle is initiated four times daily at 0400, 1000, 1600, and 2200 UTC with the history re-starts of the simulations as described above. In each cycle, the first re-start simulation begins 5 days before the current time, over-writing previous output files to ensure a model convergence towards NLDAS-2 + Stage IV or MRMS precipitation forcing. Table 1 provides a summary and comparison between the Southeastern U.S. and CONUS real-time LIS-Noah runs at SPoRT.

Table 1. Configuration details for the real-time SPoRT-LIS runs over the Southeastern U.S. and CONUS domains.

Configuration Detail	**Common to Both Domains**	**Southeastern U.S. Domain**	**CONUS Domain**
Land surface model	Noah version 3.2		
Horizontal grid spacing	0.03 degree		
Grid dimensions		1064 x 672	2200 x 934
Atmospheric forcing	NLDAS-2/GDAS/GFS SW/LW Rad, sfc P, 2-m T, 2-m q, 10-m wind	Stage IV hourly Precipitation[1]	NSSL MRMS hourly gauge-adjusted radar QPE[2]
Soil database	STATSGO		
Land use database	MODIS/IGBP		
Green Vegetation Fraction	Daily SPoRT-MODIS[3]		
Cold start initialization	1 June 2010		
History restart interval	6 hours		

[1]Lin and Mitchell (2005), Lin et al. (2005); [2]Zhang et al. (2011, 2014, this meeting, *28th Conf. Hydrology*); [3]Case et al. (2014)

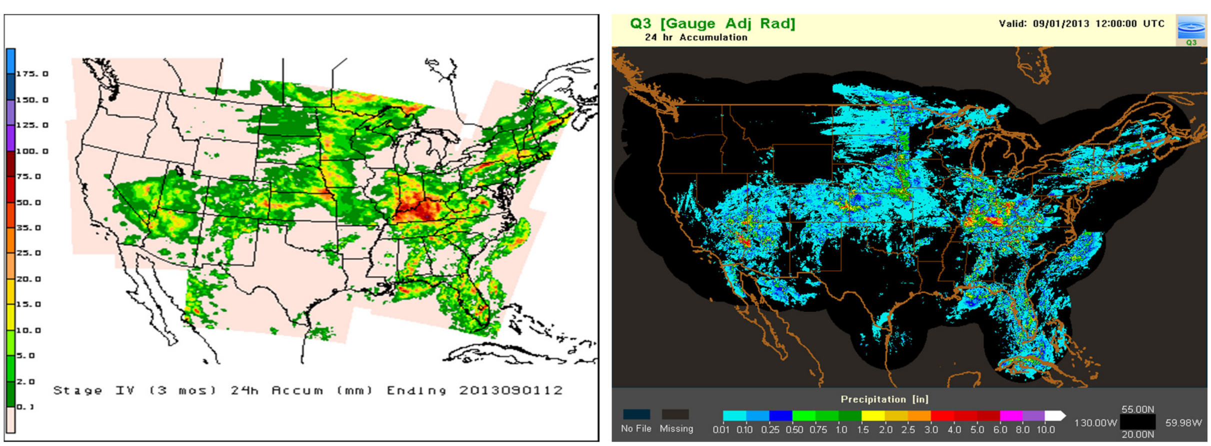

Figure 1. Twenty-four-h precipitation valid 1200 UTC 1 Sep 2013 from the Stage IV (left) and MRMS QPE (right).

3. LIS TRAINING FOR SITUATIONAL AWARENESS

SPoRT is developing training for NWS forecasters on using LIS LSM output in applications of situational awareness, particularly for drought monitoring, and assessing flood potential based on antecedent soil moisture conditions. The training module includes background material on the LIS, how it is configured and run in the real-time SPoRT configuration, and a full audio script with quiz questions. An example case study is presented in the module for two contrasting heavy rainfall cases: One event with moderate rainfall and high antecedent soil moisture, and another event with heavy rainfall and very dry antecedent soil moisture (Figure 2). The moderate rainfall/high soil moisture case resulted in the most flood reports around northern Alabama compared to the heavy rainfall/low soil moisture event. SPoRT plans to conduct real-time assessments of the SPoRT-LIS with select NWS partner forecast offices during 2014 to determine its utility and areas for improvement.

The SPoRT-LIS output has also been transitioned for use in the next-generation Advanced Weather Interactive Processing System (AWIPS II) at the NWS Huntsville, AL forecast office (Figure 3). The LIS output is written to GRIB2 files, which are then ingested into AWIPS II using baseline GRIB2 model data decoders. A set of instructions was developed to document the steps needed to modify AWIPS II configuration table files (i.e., "xml" files) in order to define the LIS variable attributes. Once these tables are in place, AWIPS II can easily display the data as any other modeling dataset, overlaid alongside with other datasets such as radar and satellite images. Additionally, unique color enhancement curves were developed for each variable to produce a desired display for situational awareness. For example, in the skin temperature plot overlaid with radar reflectivity (bottom panel of Figure 3), the 0°C is denoted by the transition from light blue to dark blue and could be helpful in assessing the threat for frozen precipitation impacting the surface. The NWS partners conducting the assessment of SPoRT-LIS in 2014 are already upgraded to AWIPS II, and will be able to provide valuable feedback on overlaying LIS data with other pertinent datasets. This capability should greatly enhance the potential utility of real-time SPoRT-LIS data for situational awareness applications.

4. SEUS AND CONUS LIS RESULTS

4.1 Comparison between SEUS and CONUS LIS

By comparing the integrated relative soil moisture between the current Southeastern U.S. SPoRT-LIS using Stage IV precipitation, and the full CONUS SPoRT-LIS using MRMS precipitation, we see that the MRMS-driven soil moisture tends to be drier. The difference snapshots on 17 September and 17 December indicate that the CONUS SPoRT-LIS is drier by 2–8 % or more across much of the eastern U.S., especially in December (Figure 4), indicating that the MRMS QPE is drier overall than the Stage IV precipitation over a long integration time period. In addition, radar beam blockage patterns in the MRMS product stand out as negative differences, particularly in eastern Mississippi and western Alabama associated with the Columbus, MS radar, and over northern portions of South Carolina associated with the Columbia, SC radar. Detailed local to regional differences of both a positive and negative sense are evident in other regions (e.g., Southern Plains), likely due to the resolution differences between the MRMS product (~1 km) and the Stage IV product (~ 5 km).

4.2 CONUS SPoRT-LIS Limitations with MRMS QPE

Throughout this evaluation and previous comparisons (e.g., Case et al. 2013), the LIS has proven to be a valuable tool in assessing the quality and limitations of QPE products being used as precipitation forcing for the Noah LSM. In this experiment, the long-term integration revealed numerous limitations with using the MRMS QPE product to drive a land surface model integration.

The primary limitations are related to the overly-strong dependence of the MRMS hourly product on radar estimates of QPE, which resulted in numerous artificial soil moisture patterns. The comparison between the 0-10 cm soil moisture and U.S. radar coverage map in Figure 5 shows a strong spatial pattern similarity between the gaps in radar coverage and areas of relatively dry soil moisture, particularly in the U.S. Intermountain West. The resulting soil moisture pattern is most likely caused by the MRMS product's inability to estimate precipitation outside of radar coverage in these areas, as rain gauge observations are also limited in the Intermountain West. Additionally, artificial gradients and circular patterns in soil moisture occur in southeastern Canada and northern Mexico related to the edges of contributing radars and poor QPE estimation at farther distances from radar sites. During Fall 2013, regional tile drop-outs occurred in the MRMS CONUS QPE product that resulted in discontinuities in the precipitation pattern (right panel of Figure 1 depicts a tile drop-out in the northeast quarter of the MRMS domain) and resulting soil moisture. This problem was corrected, however, in the MRMS product in early October.

Another problem that manifested itself is severe radar beam blockage issues due to physical impediments. Such beam blockage is prevalent not only in the Intermountain West, but also at specific radar sites in the eastern U.S., as highlighted in Figure 6. In particular, the Columbus, MS radar has experienced problems with rapidly-growing evergreen pines that have caused beam blockage at certain azimuths. The Columbia, SC radar appears to have a similar type of problem in the eastern portion of Figure 6. Meanwhile, the Stage IV precipitation product does not experience problems of this magnitude because the NWS River Forecast Centers conduct manual quality-control prior to finalizing the QPE (K. White, personal communication). Based on these LIS integration results using MRMS QPE forcing, additional measures of quality-control are required before considering the use of the MRMS product in driving land surface model integrations for real-time NWP and situational awareness applications.

5. SUMMARY AND FUTURE WORK

This paper described the SPoRT real-time configurations of LIS and how these data can be used for initializing local NWP models and for enhancing situational awareness at NWS weather forecast offices. A training module is being developed to give background information on the LIS and how it can be applied to drought monitoring and flood forecasting. Comparisons between the current real-time configuration using Stage IV precipitation forcing and an experimental CONUS domain using MRMS precipitation forcing showed that numerous limitations still exist in the MRMS dataset that preclude its routine use in land surface model integrations. Among those include an overly strong dependence on radar-estimated QPE in areas with insufficient radar coverage in the western U.S., radar beam blockage, and circular QPE patterns. Each of these problems contributed to artificial patterns of soil moisture in the long-term LIS integration.

Future efforts to improve the CONUS LIS integration shall involve using only NLDAS-2 atmospheric forcing to drive the long-term LIS integration, which applies a topographical adjustment to precipitation in areas of complex terrain (Daly et al. 1994). SPoRT is recognized as an early adopter for the upcoming NASA Soil Moisture Active-Passive (SMAP) mission, which will offer L-band radiometer retrievals of soil moisture in conjunction with high-resolution radar soil moisture estimates. The SMAP mission will provide unprecedented global estimation of soil moisture, which will be assimilated in LIS simulations at SPoRT (e.g., Kumar et al. 2008, 2009) once near real-time data become available sometime in 2015. The enhanced LIS output using assimilated SMAP data will have the potential to further improve the initialization of soil variables in local and regional real-time NWP modeling applications, and enhance situational awareness. In preparation for the SMAP mission, SPoRT is currently developing a module to assimilate retrievals of Soil Moisture Ocean Salinity L-band retrievals into LIS as a demonstration of likely future SMAP capabilities (Blankenship et al. 2014). SPoRT will also update its real-time GVF dataset from the current SPoRT-MODIS product (Case et al. 2014) to the new VIIRS-based GVF being developed at NESDIS (Vargas et al. 2013).

ACKNOWLEDGEMENTS/DISCLAIMERS

This research was funded by Dr. Tsengdar Lee of the NASA Science Mission Directorate's Earth Science Division in support of the SPoRT program at the NASA MSFC. Mention of a copyrighted, trademarked or proprietary product, service, or document does not constitute endorsement thereof by the authors, ENSCO Inc., the SPoRT Center, the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, or the United States Government. Any such mention is solely for the purpose of fully informing the reader of the resources used to conduct the work reported herein.

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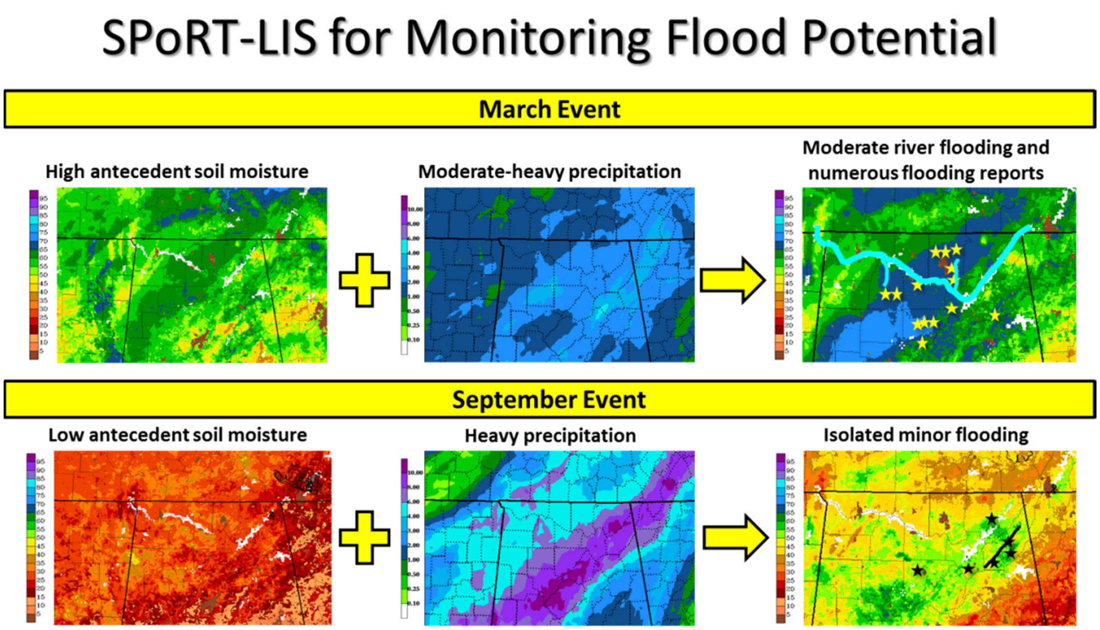

Figure 2. Comparison of two different substantial precipitation events over North Alabama with greatly contrasting antecedent soil moisture conditions as depicted by the SPoRT-LIS. The March 2011 event (top) had lower accumulated precipitation totals than the Tropical Storm Lee event (bottom), but resulted in many more flooding reports, likely due to the higher antecedent soil moisture.

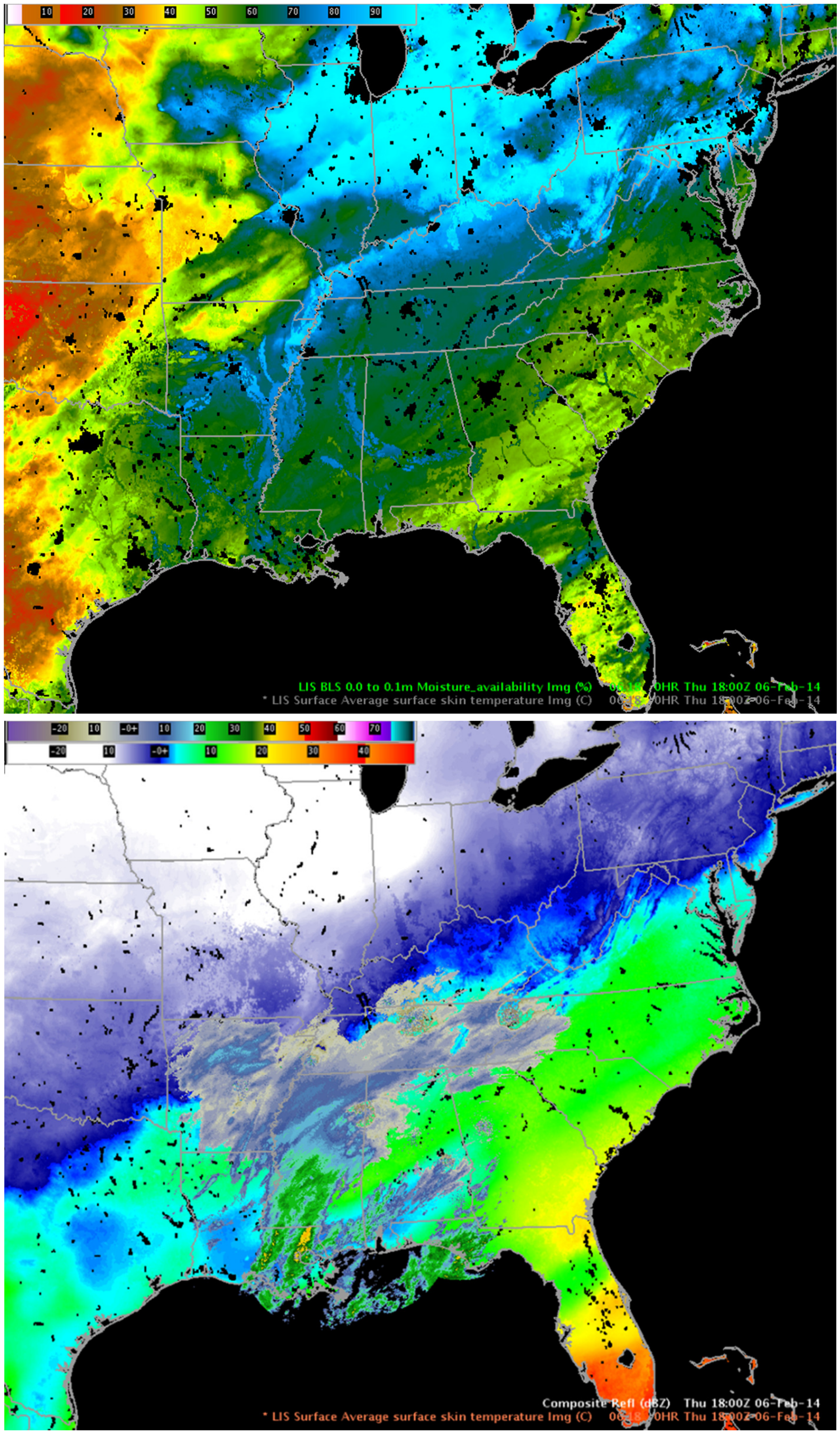

Figure 3. Screen captures of SPoRT-LIS output as displayed in the AWIPS II decision support system at the NWS Huntsville, AL weather forecast office: Top-layer 0-10 cm relative soil moisture (i.e., available water in %; top), and Skin surface temperature (°C) with radar reflectivity overlaid (bottom).

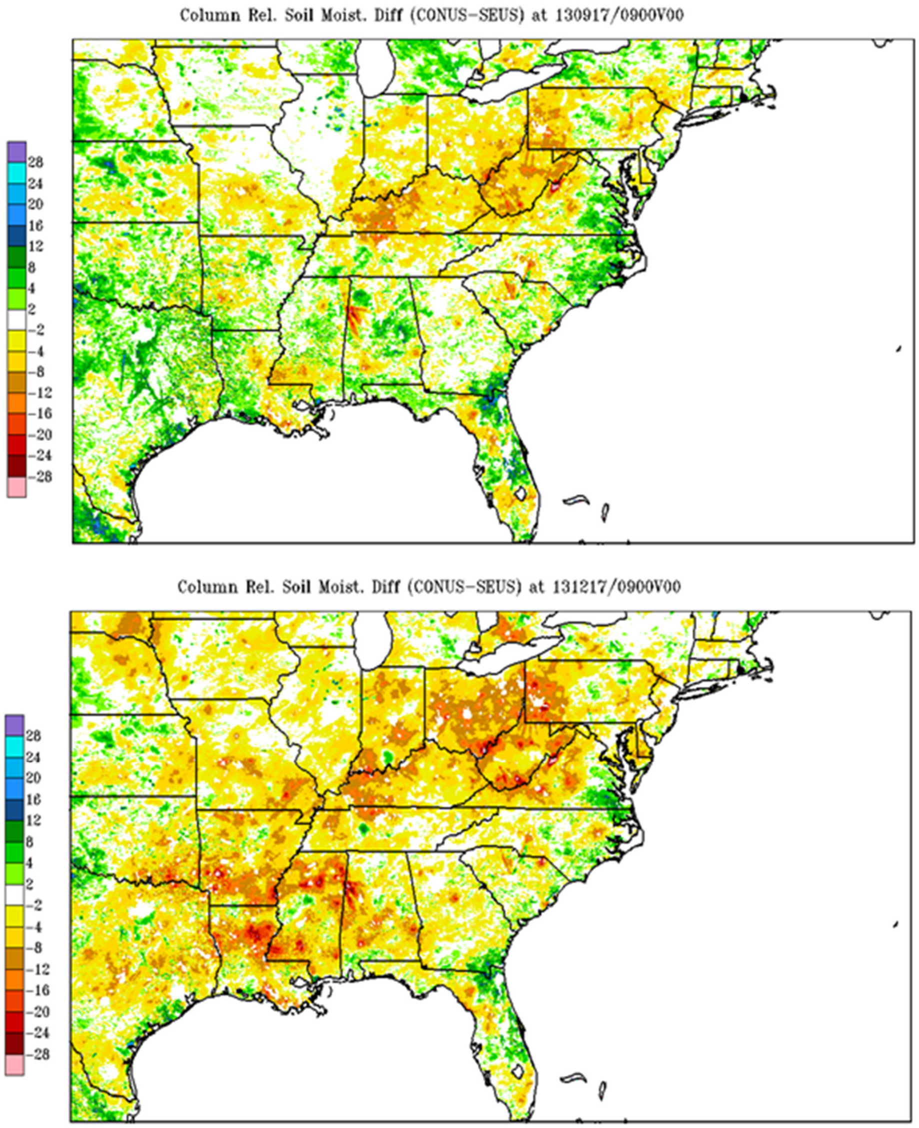

Figure 4. Difference in column-integrated relative soil moisture (%) between the CONUS LIS using MRMS precipitation and the current Southeastern U.S. LIS using Stage IV precipitation, valid at 0900 UTC 17 September (top) and 0900 UTC 17 December 2013 (bottom).

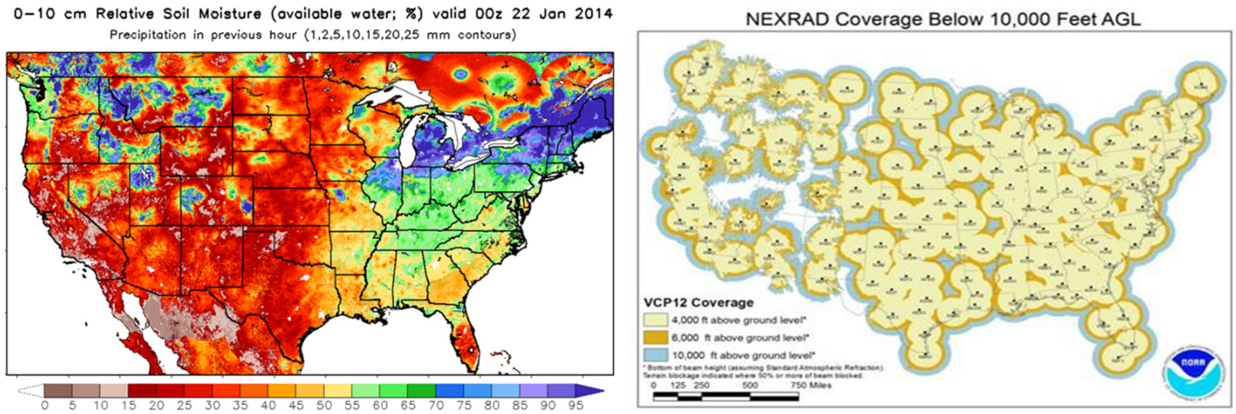

Figure 5. Depiction of 0-10 cm relative soil moisture in the CONUS SPoRT-LIS using MRMS precipitation (left), and the coverage map of the U.S. Doppler Radar network (right).

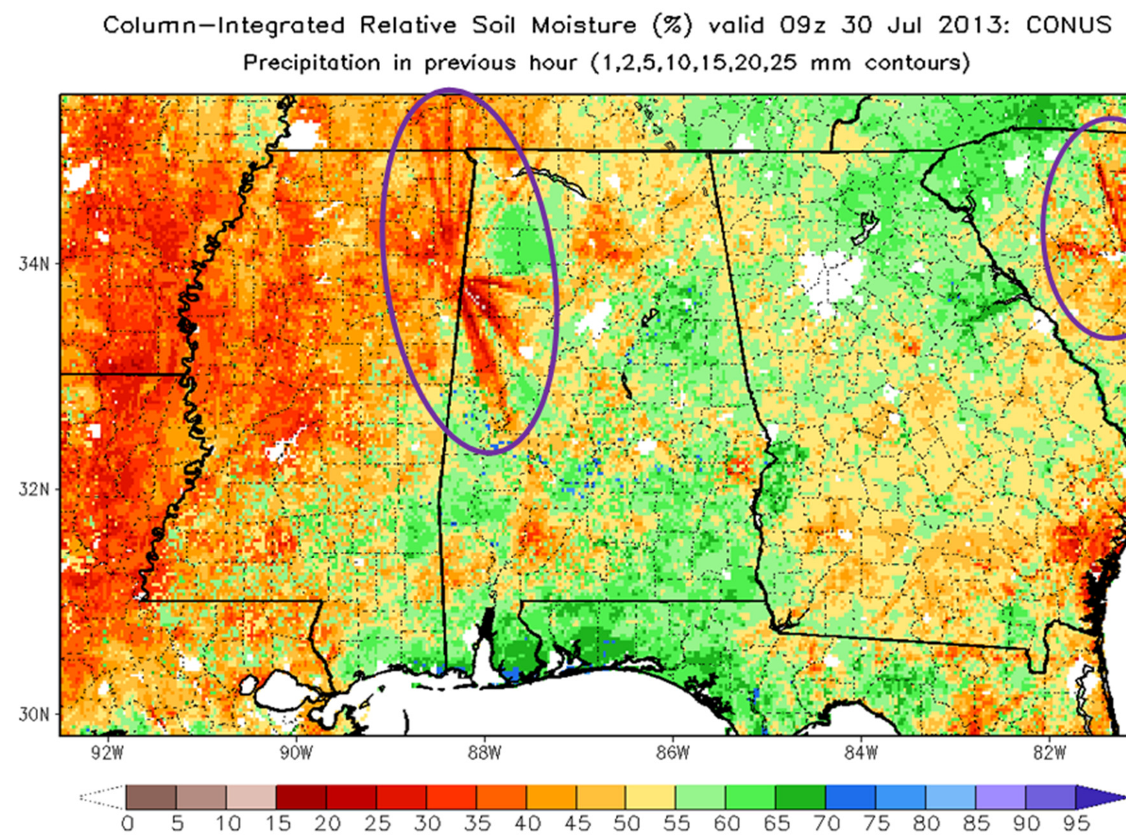

Figure 6. Column-integrated relative soil moisture from the CONUS SPoRT-LIS using MRMS precipitation forcing. Circled areas highlight the spurious dry soil moisture patterns resulting from radar beam-blockage problems in the MRMS QPE product.