520 ASSESSMENT OF THE 3-KM SPoRT LAND INFORMATION SYSTEM FOR DROUGHT MONITORING AND HYDRYLOGIC FORECASTING

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1. Introduction and Background Information

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.

The NASA Short-term Prediction Research and Transition (SPoRT) Center is running a real-time configuration of the Noah land surface model (LSM; Ek et al. 2003; Chen and Dudhia 2001) 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. This extended abstract summarizes the summer/autumn 2014 assessment of several soil moisture variables output by the SPoRT-LIS. The assessment was conducted from 1 August through 31 October 2014 and included participation from NWS forecast offices in Houston, TX, Huntsville, AL and Raleigh, NC.

Although the SPoRT-LIS output includes numerous variables available for ingest, only four soil moisture variables were included as part of this assessment:

- 0-10 cm Volumetric Soil Moisture (m^3 m^{-3}, or %),
- 0-10 cm Relative Soil Moisture (RSOIM; %),
- 0-200 cm RSOIM (%), and
- One-week change in 0-200 cm RSOIM (%)

Justification for LIS Assessment

The LIS has been run in real time for a few years now at NASA/SPoRT over a southeastern Continental U.S. (CONUS) domain. The SPoRT-LIS runs the version 3.2 of the Noah LSM in an offline mode (separate from a numerical weather prediction model), driven by operational analyses and gridded precipitation. The SPoRT-LIS has been run primarily to support enhanced soil initialization for local modeling applications at NWS Weather Forecast Offices (WFOs). However, the SPoRT-LIS has not yet been formally assessed for situational awareness applications.

Since 2011, the Huntsville WFO has examined web-based LIS graphics in a testbed mode and used this information to offer feedback for delineation of drought classification boundaries within the U.S. Drought Monitor (USDM). Additionally, forecasters have examined LIS antecedent soil moisture fields in a qualitative manner to develop conceptual models or thresholds of soil moisture that correspond to elevated risks for areal/river flooding across northern Alabama and southern Tennessee. Given the successful testbed use of real-time SPoRT-LIS data for drought and areal flooding applications, the SPoRT-LIS was ready for a wider WFO assessment. Therefore, for this assessment, we examined the potential utility of the SPoRT-LIS soil moisture products for enhancing operational decisions in the areas of drought monitoring and assessing areal/river flooding risk. This assessment supports the SPoRT research to operations strategy since soil and hydrology applications will have increased visibility with NASA missions such as the Soil Moisture Active Passive (SMAP), which launched in January 2015, and the Global Precipitation Mission (GPM), which launched in early 2014.

Since 2010, the SPoRT-LIS has been run primarily to support enhanced soil initialization for local modeling applications at WFOs in Houston, Huntsville and Mobile, and as supplemental guidance for a summer convective initiation forecast experiment conducted by the Birmingham WFO (Goggins et al. 2010; Unger et al. 2011). From spring 2011 to 2014, the Applications Integration Meteorologist (AIM) at the Huntsville WFO examined SPoRT-LIS variables in a testbed mode via web graphics, and used the information to suggest delineation of drought classifications for the U.S. Drought Monitor (White and Case 2013). Additionally, the AIM and other forecasters examined several soil moisture fields to develop conceptual models or thresholds of soil moisture that corresponded to elevated risks for areal/river flooding. Given the successful use of these near real-time soil moisture variables for drought and areal flooding applications in the initial testbed mode, SPoRT decided to conduct a broader dissemination and more formal assessment of the SPoRT-LIS.

Initially, technical challenges prevented the transition of the SPoRT-LIS data into the Advanced Weather Interactive Processing System I (AWIPS I) platform at NWS offices due to the inability of the software to ingest and display sub-surface data fields appropriately. However, the data-ingest mechanisms within the next generation AWIPS II are more self-describing, thereby enabling the ingest and display of sub-surface data. The Houston, Huntsville and Raleigh WFOs were chosen to participate in this assessment partly because of the presence of the AWIPS II platform in their operations. The inclusion of experimental data sets (such as SPoRT-LIS) outside the Satellite Broadcast Network (SBN) was made possible after initial testing of AWIPS II at the Tier-1 AWIPS II testing offices (Houston and Huntsville included) beginning in spring 2013. For the Raleigh NWS WFO, the AWIPS II upgrade and install was completed in November 2013, with the testing phase completed by late February 2014. SPoRT-LIS ingest and the development of initial data color curves was completed in January 2014 at the Huntsville WFO, although several iterations of color curves followed, mainly for the one-week change in total column (0-200 cm) RSOIM.

In addition to AWIPS II considerations, the Houston, Huntsville and Raleigh NWS WFOs were also chosen to participate in the assessment for the following reasons:

- Close, existing collaborations with their respective state climate offices,
- Robust drought/hydrology programs,
- County warning forecast area boundaries lay within the SPoRT-LIS domain, and
- Expressed interest in participation.

The remainder of this paper includes more detailed, specific information regarding the SPoRT-LIS and the assessment conducted from August through October 2014.

2. SPoRT-LIS Product Description

The soil moisture variables/products used during this assessment were derived from the SPoRT-LIS running the Noah LSM in an offline mode, driven by operational analyses and gridded precipitation. The SPoRT-LIS is a continuous integration of the Noah LSM within LIS beginning 1 June 2010 through the present time, continuously restarted as new model analyses and precipitation datasets become available in real time. Below is a brief description of the LIS configuration as run in real-time to support this assessment, including the input data sets, domain, product latency, and variables output to the NWS forecast offices participating in the assessment.

Domain and Resolution

The SPoRT-LIS is run in real-time on a grid with 0.03° spacing over the southern and eastern half of the Continental U.S. (CONUS; Figure 1). In the SPoRT-LIS, the Noah LSM is run offline or in analysis mode (i.e., uncoupled from an NWP model) for a continuous long simulation. 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.

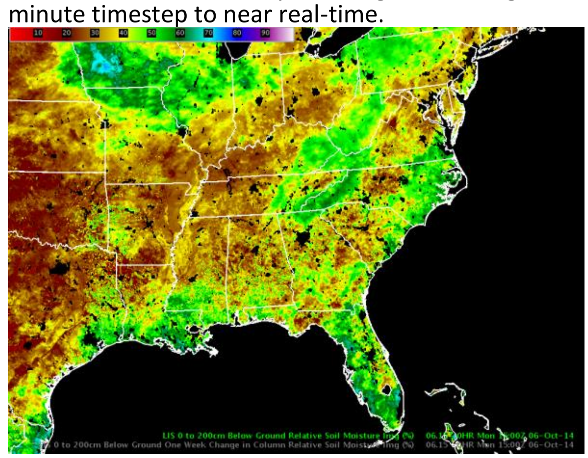

Figure 1. Depiction of the 0-200 cm total column relative soil moisture on the full SPoRT-LIS domain, as displayed in the AWIPS II at NWS Huntsville, AL.

Input Parameter Data Sets

The SPoRT-LIS uses the International Geosphere-Biosphere Programme (IGBP) land-use classification (Loveland et al. 2000) applied to the Moderate Resolution Imaging Spectroradiometer (MODIS) (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.

Simulation and Atmospheric Forcing

The Noah LSM simulation 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 radar and gauge blended precipitation product (Lin and Mitchell 2005; Lin et al. 2005) are used. The grid spacing of the NLDAS-2 analyses is one-eighth degree (~14 km) and the Stage IV analyses have 4.8 km grid spacing. The Noah LSM solution ultimately converges to a modeled state based on the NLDAS-2 and Stage IV 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 (Wu et al. 2002; NCEP EMC 2004), along with a continuation of the Stage IV 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; however, the SPoRT-LIS output using GFS forecasts is not disseminated to the NWS WFOs for this assessment.

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 precipitation forcing.

Data format and dissemination

SPoRT-LIS data are output in the gridded binary (GRIB) format and then converted to GRIB-2 format prior to sending the data to NWS Southern Region Headquarters via the local data manager (LDM) software. Gridded output in three-hourly intervals are sent to the LDM server for ingest into AWIPS II.

Real-time latency

The SPoRT-LIS output latency depends on the timeliness of the available NCEP/EMC operational analyses driving the LIS/Noah integration. The SPoRT-LIS output through the portion of the integration cycle using the GDAS and Stage IV precipitation analyses results in a data latency of ~2-8 hours from the time that files are sent to LDM to the time that the data are displayed within AWIPS II at a local WFO. Thus, the most recent SPoRT-LIS output valid time is anywhere from 2-8 hours old relative to the wall-clock time. For the purposes of situational awareness of soil moisture for drought monitoring and assessing areal flood potential, however, this latency was deemed acceptable (see Assessment Results section).

Output variables for assessment

0-10 cm Volumetric Soil Moisture: volumetric soil moisture is the volume of water content per total volume of soil, and is expressed as a unitless percentage (%, or $m^3\ m^{-3}$). Volumetric soil moisture can be measured directly and are thus better suited for comparison to in-situ networks that measure soil at similar depths. This variable has been used for drought monitoring purposes by NWS Huntsville, mostly for comparison with the regional Soil Climate Analysis Network.

0-10 cm Relative Soil Moisture (RSOIM): RSOIM is the ratio of volumetric soil moisture between the wilting and saturation points for a given soil type, and is expressed as a percentage. Relative soil moisture values, thus, offer more information about the soil saturation state and the availability of water for evapotranspiration by vegetation. Values at 0% indicate vegetation can no longer extract any moisture from the soil, while values at 100% indicate complete saturation with respect to soil type. This variable has been useful mainly for drought monitoring purposes, especially when determining impacts from dry conditions on short time scales.

0-200 cm Relative Soil Moisture (RSOIM): Similar to the variable above, the 0-200 cm RSOIM is the ratio of volumetric soil moisture between the wilting and saturation points for a given soil type (expressed as a percentage), but valid over the entire 0-200 cm column of the Noah LSM. This layer represents the total column soil moisture in the SPoRT-LIS and has demonstrated operational utility for both drought monitoring and assessing flood threat. The total column layer is also generally used for comparison to other soil moisture model analyses, including those from NCEP (Noah LSM and NLDAS-2), the Climate Prediction Center, and the NWS (Sacramento Soil Moisture Accounting Model [SACSMA]). Due to the deeper layer, soil moisture evolves more slowly than in the 0-10 cm layer. However, this variable has demonstrated greater utility overall for drought monitoring purposes since drought evolves typically on longer timescales. This variable has also proven to be operationally useful for assessing the threat for areal/river flooding, particularly in several river basins in the Huntsville County Warning and Forecast Area (CWFA). Subjective analysis of several events in the Huntsville CWFA have shown that the threat for flooding increases substantially when a standard synoptic-scale rainfall event of two to three or more inches of rain occurs over 0-200 cm RSOIM values in excess of 55-60%. Although a more rigorous, objective analysis is preferred, Huntsville WFO forecasters have still used these thresholds to increase situational awareness of the flooding risk in recent years.

One Week Change in 0-200 cm (ROIM): This variable is a simple difference between the current 0-200 cm RSOIM and the value from one week ago at the same UTC hour. These data offer a quick, effective evaluation of soil moisture changes during the previous week, which can be especially useful for the drought monitoring process. These data were created by the SPoRT modeling team specifically due to a request from the AIM.

It is important to note that in the display of RSOIM variables within AWIPS II (and on the SPoRT web page), urban pixels are masked due to the inherent handling of urban points by the Noah LSM. The Noah LSM "hard-wires" the wilting and saturation points of volumetric soil moisture to a very narrow range for urban land-use points. This introduces an artifact of the RSOIM quickly saturating during rain events, and rapidly drying during precipitation-free episodes (especially for the shallow, top-layer 0-10 cm RSOIM). Consequently, SPoRT opted to mask out urban points in the RSOIM variables to prevent these artifacts from being manifested in the display.

3. Transition and Training

In the months leading up to the assessment, SPoRT personnel developed two Articulate© training modules specific to the SPoRT-LIS data. The first of these, "*NASA Land Information System: A Primer*", was created as an introductory course on the NASA LIS and the SPoRT-LIS for the operational forecaster. The module includes information about the NASA LIS framework and SPoRT's real-time configuration of the Noah land surface model within LIS. Input static fields and atmospheric forcing datasets are described, including the use of real-time MODIS GVF in place of climatological GVF. The second module, "*NASA Land Information System: Applications Training*" provides operational examples and potential benefits of the SPoRT-LIS for NWS forecast/analysis operations. Specifically, the module covers the applications of SPoRT-LIS soil moisture variables for determining areal/river flood risk and enhancing drought analysis. Only soil moisture variables transitioned for the summer LIS assessment are covered in the training module. The "primer" module is designated as a prerequisite to taking the second, operationally-relevant module. These modules were made available to the Houston and Raleigh NWS offices for viewing/download on 16 July 2014, and are available at the following URL: http://weather.msfc.nasa.gov/sport/training/.

In addition to the Articulate© training modules, a two-sided, one-page SPoRT "Quick-Guide" was created and delivered to participating NWS offices via email on 21 July 2014. A hard copy was also mailed to each office. Digital copies of these Quick Guides are also available at the URL linked above. These Quick Guides are a highly condensed version of the modules contained on a one page document for easy access at forecast workstations. They are meant to serve as a quick reference with pertinent information about each of the soil moisture variables, including strengths, weaknesses and proper operational usage.

4. Assessment Feedback Methodology

Survey questionnaires

To create a proper balance between the needs of the assessment and the often busy operational forecast environment, SPoRT developed the 2-minute feedback form, which can be accessed at any time on the SPoRT website. The feedback form and corresponding questionnaire use a Likert-type scale to determine the level of perceived utility of the product on the forecaster's decision-making process for the given forecast challenge. For this assessment, questions were designed to evaluate how soil moisture products were utilized to assess drought conditions and/or flood risk. Accordingly, since this assessment involved the use of the data for two distinct purposes (i.e., evaluation of drought conditions and/or flood risk), two separate surveys were created pertaining to the specific application of the data. Forecaster respondents answered questions using clickable radio buttons corresponding to their choice of 3-6 predetermined answers. Comment boxes were also provided to allow for follow-up clarification and further description to certain questions. At the end of each survey, a comment box was provided for any additional information the forecaster respondent felt pertinent to the survey. All of the answers were tallied at the end of the assessment and analyzed to gain a better understanding of the utility of the soil moisture products. Survey questions and predetermined answers are contained in Appendix A.

Wide World of SPoRT blog posts

In addition to the evaluation form, SPoRT also hosts The Wide World of SPoRT, a blog on the Wordpress website at URL: https://nasasport.wordpress.com/. Forecasters and developers were encouraged to highlight examples of specific product use. These examples work to educate not only SPoRT staff and assessment participants, but those in the broader collaborative community, from developers to end-users, by providing operational use-case examples and lessons learned. There were a total of 10 to the Wide World of SPoRT blog posts pertaining to the use of the SPoRT-LIS data during the assessment period.

NWS Chat and Email Communication

The SPoRT NWS chat room was also provided for participants at each NWS office as a forum for communication and feedback during the assessment. The chat room was created to enable more efficient communication between SPoRT and assessment participants in an open forum setting. In addition, the chat room has proven to be valuable for communicating information about specific products and any related technical issues. For example, information pertaining to a temporary outage of the SPoRT-LIS data during the 16-17 August weekend was shared with the assessment participants. SPoRT provided an estimated time for the return of product availability along with confirmation of receipt of the data in AWIPS on 18 August.

Communication was also conducted via email with survey respondents during the process. Comments and other aspects of feedback by respondents were addressed during the assessment. These conversations led to improved understanding of the SPoRT-LIS soil moisture products and their uses at the respective WFOs.

5. Assessment Results

The overall results of the August to October assessment indicate that participating forecasters were able to understand the SPoRT-LIS soil moisture product and incorporate the data into operations, especially pertaining to drought monitoring. The SPoRT-LIS data proved reliable, and timeliness was not a concern during the assessment (survey responses unanimously indicated that SPoRT-LIS output were timely). Forecasters had a high degree of confidence in applying the LIS soil moisture data, as the soil moisture output corroborated with other datasets typically utilized by forecasters. Forecasters found the most utility in the total column relative soil moisture (0-200 cm RSOIM) and weekly change in 0-200 RSOIM variables.

Due to the typical prevailing climatological conditions of the Southern U.S. during the late summer and early fall, the vast majority of surveys involved application of drought monitoring rather than assessing areal flood potential (89% of completed surveys pertained to drought applications). Very few opportunities occurred that enabled forecasters to establish critical thresholds of soil moisture that correlated with a flooding event. Therefore, most of the survey results reflect the application of SPoRT-LIS soil moisture to drought monitoring. Additionally, no strongly prevalent drought conditions occurred during the August to October 2014 timeframe in the three CWFAs. Selected survey assessments results are highlighted in the sub-sections below; all survey questions are listed in Appendix A for reference purposes.

Summary of completed surveys

Twenty eight surveys were completed during the assessment. Of these, twenty-four detailed the use of the data for drought monitoring application, while three surveys were submitted pertaining to the use of the data for areal/river flood risk analysis. One survey submitted by the HGX WFO involved the use of the data for high temperature forecasting. While a potentially useful and inventive application of the soil moisture data, this survey response fell outside the scope of the assessment and was not included in the final report statistics.

The survey question on training indicated that the vast majority of participants were able to interpret the SPoRT-LIS data based on the training already received from the modules produced by SPoRT (26 of 27 responses). This result suggests that the two SPoRT-LIS training modules successfully conveyed information about the product and operational applications to drought and areal flooding at an appropriate level for the forecast environment.

Survey Responses Specific to Drought Assessment

The confidence level in the SPoRT-LIS soil moisture was largely “High” (80% of responses, Figure 2a), with no forecaster having rated his/her confidence less than “Medium”. The SPoRT-LIS soil moisture data were usually compared to other available data sources for corroboration, with the SPoRT-LIS soil moisture trends typically similar or only slightly different than the comparison observations (92% of responses, Figure 2b). The similar data trends likely contributed to the overall high confidence expressed in the product. It is worth mentioning that comparing the SPoRT-LIS output with other model analyses can be problematic. Other soil moisture analyses commonly referenced during the assessment, such as those from the Climate Prediction Center or the Noah or Sacramento Soil Moisture Accounting (SACSMA) models, output values in terms of anomalies or percentages of normal, while the SPoRT-LIS output contains soil moisture magnitudes only. Thus, participants had to compare areas of relative dryness in the SPoRT-LIS output with other soil moisture analyses. Other significant differences between the SPoRT-LIS and other models, such as data latency and spatial resolution, lead to other complications when attempting to make direct comparisons. For example, data latency with the previously mentioned Noah and SACSMA models are about four days, while latency with the SPoRT-LIS is just two to eight hours (data latency in AWIPS II). Changes in shallow layer soil moisture can be particularly large during heavy precipitation events and would be reflected in the near real-time output of the SPoRT-LIS, but would not in the other analyses if they fell within the most recent four day period.

For assessing the USDM classification, the vast majority of responses (96%, Figure 2c) indicated "Large" or "Some" contribution to decisions regarding the drought classification. This result and the number of responses during the assessment indicates that forecasters were actively engaged in the weekly USDM conference calls. Feedback via the survey through question 9 (Appendix A) and through other means of communication (blog posts and email) also noted the contribution of SPoRT-LIS soil moisture products to the drought decision-making process. Participants identified the weekly change in 0-200 cm RSOIM as the most valuable field for assessing drought (54% of responses, Figure 2d), followed by the 0-200 cm RSOIM (25%) and 0-10 cm RSOIM (13%).

Survey Responses Specific to Areal/River Flooding

The application of the data to assessing the risk for areal or river flooding proved to be more challenging, partly due to the lack of synoptic scale systems during the assessment period (August through October). Nevertheless, three surveys were received pertaining to the use of the data for this application. In one of these surveys, the respondent noted that the data were not applied operationally, but for post-analysis. Survey questions and predetermined answers are contained in Appendix A, under "*Questions specific to Areal/River flooding Assessment*".

Similar to the use of the data for drought analysis, no survey respondents expressed a lack of confidence in the application of the data for forecasting areal/river flooding. Two respondents indicated medium confidence, while one expressed high confidence. Meanwhile, in the question regarding the impact of the SPoRT-LIS soil moisture for help in assessing the threat for areal/river flooding, one response indicated some impact, while the other stated a large impact. For the survey expressing a *large* impact, however, it should be noted that the data application may have been improper. The forecaster wrote that the "LIS was favored over the FFG (Flash Flood Guidance)" when responding to the list of complimentary products used to assess the flooding threat. This issue stresses the need for close collaborations between product developers and end users to ensure that forecasters understand product/data limitations and utilize them appropriately for specific operational challenges.

For the survey where *some* impact was noted, a more appropriate and exciting application of the data was demonstrated. After a relatively heavy rainfall event in the Houston CWFA (rainfall amounts exceeding four inches were noted), the forecaster used the 0-200 cm RSOIM data to show an emergency manager why flooding was likely not occurring in Grimes County, TX. The survey respondent also indicated that this county is "fairly data-free in real time", depending largely on radar-derived data for precipitation analysis. The fact that the SPoRT-LIS soil moisture data helped to demonstrate why flooding was likely not occurring in an area of concern and that the forecaster had sufficient confidence to share the data with the county emergency manager speaks to its operational utility and reliability.

Considering the use of the 0-200 cm RSOIM data, this layer was cited in two surveys as the most valuable for assessing the flood threat. This was most appropriate as the training highlighted the use of this layer alone for assessing the threat for longer-term areal/river flooding.

Survey respondents were provided a section for relating further comments regarding the application of the data for instance(s) of flooding.

6. Conclusions and Recommendations

Summary and Conclusions

This final report presented highlights and key results of a three-month assessment of the SPoRT real-time configuration of the NASA LIS, held from August to September 2014. The focus of the assessment was on applications of select SPoRT-LIS soil moisture products to assist in drought monitoring and assessing longer-term areal/river flooding potential, with participation from NWS WFOs at Huntsville, Houston, and Raleigh. SPoRT personnel developed two training modules and a Quick Guide in conjunction with NWS forecasters to ensure that the training was at an appropriate level and that personnel involved in the assessment were adequately trained and familiar with the SPoRT-LIS soil moisture products.

Twenty seven survey questionnaires and ten blog posts were completed during the assessment that highlighted drought monitoring applications primarily, since the prevailing weather conditions during the period were not conducive to many flooding events. Survey results indicated that forecasters had high confidence in applying the SPoRT-LIS soil moisture to drought monitoring. Participants noted that they were comfortable in using the SPoRT-LIS data based on the training, indicating the success of the modules developed in advance of the assessment. Forecasters identified the total column relative soil moisture and especially the weekly change in this variable as the most helpful fields in making decisions regarding drought classification.

Recommendations and Future Work

Based on the results presented and various comments received from the surveys, the following recommendations are gleaned:

- While able to provide sub-county scale details of soil moisture variability, the SPoRT-LIS soil moisture needs an historical context to better quantify the relative dryness or moistness of the soils. SPoRT should develop a soil moisture climatology and accompanying soil moisture anomalies to promote more quantitative measures of soil moisture conditions,

- The SPoRT-LIS domain should be expanded to full CONUS since many NWS WFOs in the western U.S. could benefit from real-time LIS soil moisture output, and
- SPoRT should consider further enhancing the soil moisture accuracy through assimilation of satellite remote sensing of soil moisture, in preparation for using data from the Soil Moisture Active Passive (SMAP) mission.

To help address these recommendations in a preliminary fashion, SPoRT is already undertaking the development of a CONUS-scale soil moisture climatology on a 0.03-deg (~3 km) grid spanning 1981 – 2010 (Case et al. 2015). A daily soil moisture climatology is being developed for every county in the CONUS based on daily output of 0-200 cm RSOIM. From the daily county-by-county climatologies, soil moisture gridded anomalies are being developed, with the option of examining histograms of soil moisture distributions relative to the daily average in a given county. SPoRT is also collaborating with personnel from the NCEP Environmental Modeling Center in order to complement (and not merely duplicate at higher resolution) current operational products already being generated by the NLDAS-2 and Climate Prediction Center.

Additionally, this climatological run will serve as a backdrop for a future expanded near real-time SPoRT-LIS over a CONUS domain. SPoRT currently runs an experimental CONUS version of LIS in real-time (Case and White 2014) driven by the Multi Radar Multi Sensor (MRMS; Zhang et al. 2011, 2014) quantitative precipitation estimates in place of Stage IV; however, limitations with the current MRMS QPE deem it inadequate for use in long-term LSM simulations (Case et al. 2013; Case and White 2014). In preparation for using data from the upcoming SMAP mission, SPoRT personnel are conducting soil moisture data assimilation experiments within LIS using the European Space Agency's Soil Moisture Ocean Salinity soil moisture retrievals (Blankenship et al. 2015). Finally, SPoRT plans to incorporate into the CONUS LIS runs the real-time daily global GVF data being produced by the National Environmental Satellite Data and Information Service, derived from the Visible Infrared Imaging Radiometer Suite (Vargas et al. 2013). A final report detailing more information from this assessment will be made available on the SPoRT website at http://weather.msfc.nasa.gov/sport/evaluations/.

7. References

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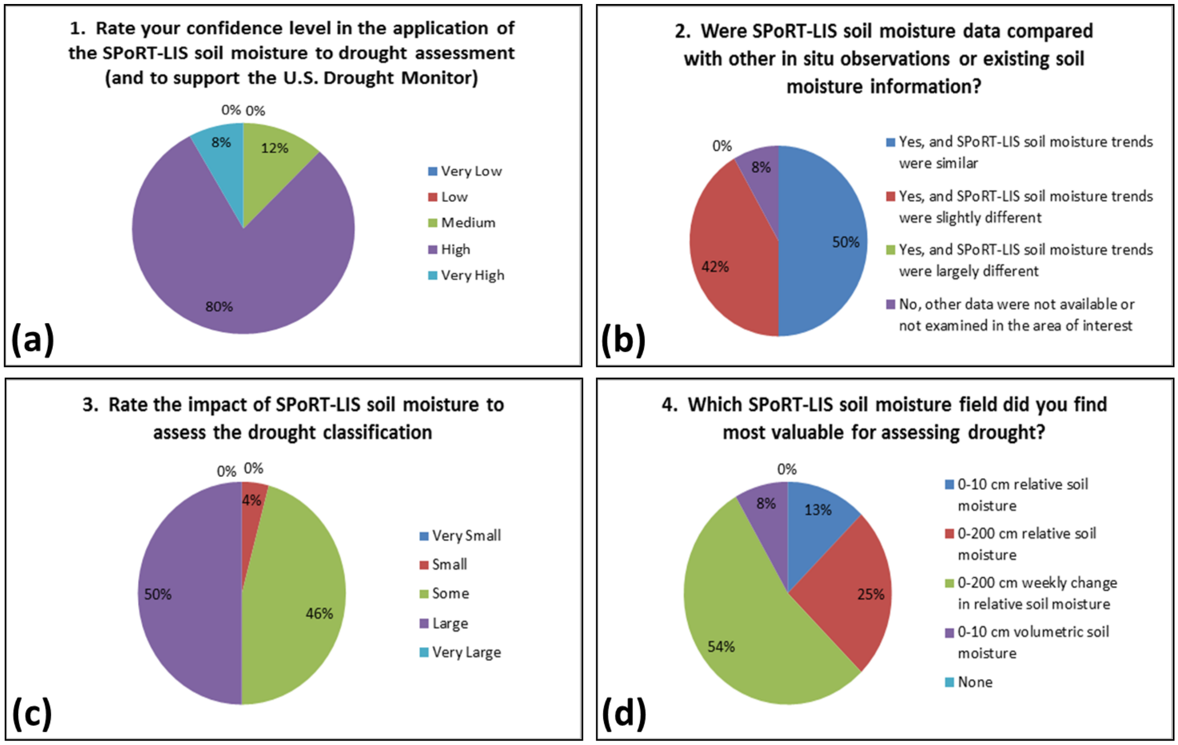

Figure 2. Summary of select SPoRT-LIS assessment survey results pertaining to drought monitoring, including (a) Forecaster confidence in applying soil moisture to drought assessment; (b) How SPoRT-LIS soil moisture were compared to other observations; (c) Perceived impact of soil moisture to assess the USDM classification; and (d) Soil moisture variables found to be most valuable for assessing drought conditions.

Appendix A: Survey Questions for drought monitoring and assessing areal flood potential

The following three questions were asked for both drought and flood surveys:

Have you completed training materials regarding LIS soil moisture prior to the assessment period? Check all that apply

- *Yes, I have completed the LIS Primer module by SPoRT*
- *Yes, I have completed the LIS Applications training module by SPoRT*
- *Yes, I have participated in or seen a teletraining session (live or recorded)*
- *No, I have not previously completed the training items listed above*

Regarding the training used with products being evaluated?
Check all that apply for this particular event

- *I used/referenced one of the Quick Guide sheets in the operations area*
- *I used/referenced the recorded module*
- *I consulted with a fellow forecaster for help*
- *I was able to interpret the product(s) based on previous training or experience*
- *I was NOT able to interpret the product(s) based on current training/knowledge, and need additional help*

Was the LIS soil moisture output timely for application to the forecast issue?

- *Yes, it was timely*
- *No, it was not timely*
- *No, it was not available at the time*

Questions specific to Drought Assessment:

1. Rate your confidence level in the application of the LIS soil moisture to drought assessment (in particular to support the U.S. Drought Monitor) [*Very low, Low, Medium, High, Very High*]

2. Were LIS soil moisture data compared with other in situ observations or existing soil moisture information?

- *Yes, and LIS soil moisture trends were similar*
- *Yes, but LIS soil moisture trends were slightly different*
- *Yes, but LIS soil moisture trends were largely different*
- *No, other data were not available or not examined in the area of interest*

3. Rate the impact of LIS soil moisture output to assess the drought classification: [Very small, Small, Some, Large, Very Large]

4. Which LIS soil moisture field did you find most valuable for assessing drought?

- *0-10 cm relative soil moisture*
- *0-200 cm relative soil moisture*
- *0-200 weekly change in relative soil moisture*
- *0-10 cm volumetric soil moisture*
- *None*

5. Would you like a change in the LIS soil moisture product display or additional output fields/layers?

- *No, I like the product as is - product displays are good and output fields/layers are easy to interpret and use*
- *Yes, I would like a change - state a sentence or two with suggestions and/or requests*

6. Did you use a product which provided more confidence and/or better utility than the NASA/LIS soil moisture for estimating the drought classification? (*Yes or No*)

7. For both "Yes" or "No" in the previous question, please list either the product(s) that were complemented by LIS or that was/were preferred over LIS. (*e.g., AHPS/Stage IV Precipitation, CPC soil moisture products, agricultural reports, in situ soil moisture observations*)

8. How was NASA/LIS soil moisture applied to assessing the drought classification? Check all that apply

- *To more efficiently estimate drought compared to traditional methods*
- *To more accurately estimate drought compared to traditional methods*
- *To examine sub-county areas for input to the U.S. Drought Monitor*
- *To influence an operational product related to drought information for the public*
- *Other: (explain)*

9. Please provide a brief event description and any additional comments regarding the application of NASA/LIS for this instance of drought monitoring.

Questions specific to Areal/River flooding Assessment:

1. Rate your confidence level in the application of the LIS soil moisture as applied to forecasting the potential for areal/river flooding (excluding flash flood events): [*Very Low, Low, Medium, High, Very High*]

2. Where LIS soil moisture data compared with other in situ observations or existing soil moisture information?

- *Yes, and LIS soil moisture trends were similar*
- *Yes, but LIS soil moisture trends were slightly different*
- *Yes, but LIS soil moisture trends were largely different*
- *No, other data were not available or not examined in the area of interest*

3. Rate the impact of LIS soil moisture output to assist in the process of assessing the threat of areal/river flooding: [*Very Small, Small, Some, Large, Very Large*]

4. Which LIS soil moisture field did you find most valuable for assessing the flood threat?

- *0-10 cm relative soil moisture*
- *0-200 cm relative soil moisture*
- *0-200 weekly change in relative soil moisture*
- *0-10 cm volumetric soil moisture*
- *None*

5. Would you like a change in the LIS soil moisture product display or additional output fields/layers?

- *No, I like the product as is - product displays are good and output fields/layers are easy to interpret and use*
- *Yes, I would like a change - state a sentence or two with suggestions and/or requests*

6. In addition to model/WPC QPE, did you use a product which provided more confidence and/or better utility than the NASA/LIS soil moisture for estimating the flooding threat potential?

- *No - the NASA/LIS was used to complement model and/or WPC QPE products*
- *Yes - there was another product outside of QPF that I preferred for this event (See next question to list product)*

7. For both "*Yes*" or "*No*" in the previous question, please list either the product(s) that were complemented by LIS or that was/were preferred over LIS. (*e.g., RFC river stage guidance, AHPS/Stage IV Precipitation, CPC soil moisture products, in situ soil moisture observations*)

8. How was NASA/LIS soil moisture applied to this potential flooding event?
Excluding flash flood events; Check all that apply

- *To more efficiently estimate flood threat compared to traditional methods*
- *To more accurately estimate flood threat compared to traditional methods*
- *To examine flood risk for sub-county areas*
- *To influence an operational product or the forecast for flood risk for NWS customers*
- *Other: (explain)*

9. Please provide a brief event description and any additional comments regarding the application of NASA/LIS for this instance of flooding. (*why/how; impacts on forecasts; etc.*)