J6.14 LAND SURFACE WATER CYCLES OBSERVED WITH SATELLITE SENSORS

S. V. Nghiem[1]*, E. G. Njoku[1], G. R. Brakenridge[2], Y. Kim[1], and G. Neumann[1]
[1]Jet Propulsion Laboratory
California Institute of Technology, Pasadena, California
[2]Dartmouth Flood Observatory
Dartmouth College, Hanover, New Hampshire

1. INTRODUCTION

Acceleration of the global water cycle may lead to increased global precipitation, faster evaporation and a consequent exacerbation of hydrologic extremes. In the U.S. national assessment of the potential consequences of climate variability and change, two GCMs (CGCM1 and HadCM2) predict a large increase in precipitation over the southwestern U.S. particularly during winter (Felzer and Heard, 1999). Increased precipitation potentially has important impacts on agriculture and water use in the southeast U.S. (Hatch et al., 1999) and in the central Great Plains (Nielsen, 1997). A hurricane model predicts a 40% precipitation increase for severe hurricanes affecting southeastern Florida, which would provoke substantially greater flooding that could negate most of the benefits of present water-management practices in this basin (Gutowski et al., 1994). Thus, it is important to observe the hydroclimate on a continuous long-term basis to address the question of increased precipitation in the enhanced water cycle.

2. OBJECTIVE AND APPROACH

The objective is to assess changes in the occurrence frequency and spatial distribution of precipitation at continental scales using satellite remote sensing data and to detect consequent hydrologic extremes such as floods and droughts.

The approach is to determine the frequency of soil moisture events and the time scale of such events over the extent of the continental United States, where in-situ soil moisture and other meteorological data are available to calibrate and to validate remote sensing results. We use active SeaWinds/QuikSCAT (QSCAT) Ku-band scatterometer data in conjunction with concurrent passive radiometer data such as the Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI) and the Advanced Microwave Scanning Radiometer for the Earth Observation System (AMSR-E), and the Moderate Resolution Imaging Spectroradiometer (MODIS). Moreover, we use in-situ meteorological data and river gaging data.

3. RESULTS

QSCAT can detect precipitation water on land surfaces with nearly daily coverage over continental scales (Figure 1). QSCAT data compare well in timing and spatial patterns with surface measurements of precipitation. Figure 2 presents an example of the comparison over two years between wet surface events caused by precipitation, detected as strong impulse responses in the QSCAT signatures, with in-situ data from the NOAA National Climatic Data Center (NCDC) Global Summary of the Day (GSOD), at Great Falls, Montana (Nghiem et al., 2003).

Montana experienced a severe drought in the fall of 2000, and wildfires burned more than 2/3 million acres by September. The drought period in fall 2000 is evident in the QSCAT backscatter time-series plotted in the top panel of Figure 2. The drought period is characterized consistently by QSCAT backscatter signature with very little or no impulse. During this drought period, several heat waves are in seen in the temperature plots in the middle panel of Figure 2. The lack of precipitation during the drought period is observed in the in-situ precipitation data collected at Great Falls.

QSCAT measurements can also serve as an independent dataset for the inter-comparison of NLDAS (North American Land Data Assimilation System) and GLDAS (Global Land Data Assimilation System) results. Figure 3 shows a comparison between the QSCAT surface soil moisture increase pattern and the NLDAS daily integrated precipitation from Princeton University. Note that the QSCAT results represent surface

---

* *Corresponding author address:* Son V. Nghiem, Jet Propulsion Laboratory, California Institute of Technology, MS 300-235, 4800 Oak Grove Dr., Pasadena, California 91109, USA; e-mail: Son.V.Nghiem@jpl.nasa.gov.

water on land (soil moisture increase) while the precipitation data represent rain rate.

Precipitation frequency is measured by QSCAT in terms of percentage of wet days, defined as 100 times of the ratio of number of days when soil moisture increases by more than 5% over the total number of days in the period of interest. This is computed between mid-May and mid-September accounting for QSCAT missing data days. The QSCAT results (mid-May to mid-September) in the last half-decade (1999-2003) over the conterminous United States (CONUS) reveal a highly recurrent precipitation pattern over the Midwest with the wettest condition in year 2000 and a severe drought in 2003. QSCAT precipitation frequency Figure 4 shows a decrease by a factor of 2 over large regions in Iowa and other surrounding states. In the New England states, summer 2001 experienced the most frequent precipitation-induced surface wetness.

AMSR-E provides an improved soil moisture sensing capability (Njoku et al., 2003) over previous spaceborne radiometers. Patterns of surface soil moisture measured by AMSR-E and QSCAT wetness maps are consistent with surface weather analysis. Intense rainstorms occurred near San Antonio, Texas between 30 June and 10 July 2002. Precipitation data from the NCEP Climate Prediction Center indicated that ~16 inches of rain fell at San Antonio during that period. The AMSR-E data time series in Figure 5 from July through August 2002 shows interpolated surface soil moisture changes in response to the precipitation and subsequent drying. The 10.7 GHz frequency provides the clearest signal response. The response to the smaller amount of precipitation occurring during 15–17 July is also observed in the 10.7 GHz data. The AMSR-E gridded Level-3 land surface product includes measurements of surface soil moisture every 2-3 days (or better, depending on latitude). Figure 6 show an example of AMSR-E soil moisture map over U.S. Because of the different vegetation conditions, AMSR-E results are better over the western U.S. compared to the eastern U.S.

QSCAT results for wetland monitoring, using a polarization anomaly method (Nghiem et al., 2000), over the lower Mississippi floodplain in 2002, show a seasonal expansion of wet surface area in the winter months and a reduction in summer months (Figure 7). The water cycle over this region in 2002 exhibits a clear pattern with expanded surface water, probably coupled with wetter soils, leading river discharge increases by as much as 2 months (in Figure 7, shift discharge curves back ~2 months and they fit right on QSCAT anomaly area plot). Recently, multiple hurricanes have battered the U.S. Southwest and storms have dumped heavy rains causing floods in California. QSCAT wet surface maps can reveal the time and the areas where hurricanes and storms deposit most of the precipitation (Figure 8).

Finally, the combination of QSCAT, AMSR-E, and MODIS data collected over pre-selected river gaging reaches reveals the utility of satellite sensors to detect and monitor floods (see results at http://www.dartmouth.edu/~floods/). While much research is necessary, surface water mapping results from satellite data have found useful applications in flood and drought monitoring.

ACKNOWLEDGMENTS

The research carried out at the Jet Propulsion Laboratory (JPL), California Institute of Technology, was supported by the National Aeronautics and Space Administration (NASA). The research carried out at the Dartmouth Flood Observatory, Dartmouth College, was also supported by NASA. We thank E. Wood of the Princeton University for the LDAS data.

REFERENCES

Felzer, B., and P. Heard, 1999: Precipitation differences amongst GCMs used for the US national assessment, *J. Amer. Wat. Res. Assoc.*, **35**, 1327-1339.

Gutowski, W. J., G. F. McMahon, S. S. Schluchter, P. H. Kirshen, 1994: Effects of global warming on hurricane-induced flooding, *J. Water Res. Plan. Management-ASCE*, **120**, 176-185.

Hatch, U., S. Jagtap, J. Jones, and M. Lamb, 1999: Potential effects of climate change on agricultural, water use in the southeast U.S., *J. Amer. Wat. Res. Assoc.*, **35**, 1551-1561.

Nghiem, S. V., W. T. Liu, W.-Y. Tsai, and X. Xie, 2000: Monsoon winds and floods observed by SeaWinds Scatterometer on QuikSCAT, *Prog. Electromag. Res. Symp.*, Cambridge, MA.

Nghiem, S. V., E. G. Njoku, J. J. van Zyl, and Y. Kim, 2003: Soil moisture variability pattern over continental extent observed with active and passive satellite data, *Tech. Rep.,* **JPL D-26225**, 14 pp.

Nielsen, D. C., 1997: Water use and yield of canola under dryland conditions in the central Great Plains, *J. Produc. Agricul.*, **10**, 307-313.

Njoku, E. G., T. J. Jackson, V. Lakshmi, T. K. Chan, and S. V. Nghiem, 2003: Soil moisture retrieval from AMSR-E, *IEEE Trans. Geosci. Remote Sens.*, **41**, 215-229.

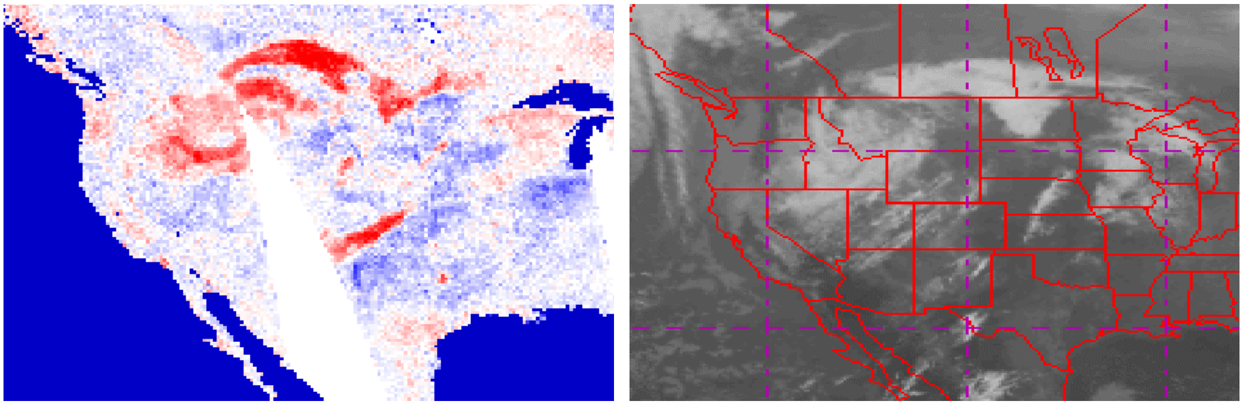

Figure 1: QSCAT map (left panel) of wet areas on land surface indicated by the red color on 13 December 2000 compared to the cyclonic pattern of cloud cover (right panel) over North America seen by GOES West satellite about half a day earlier.

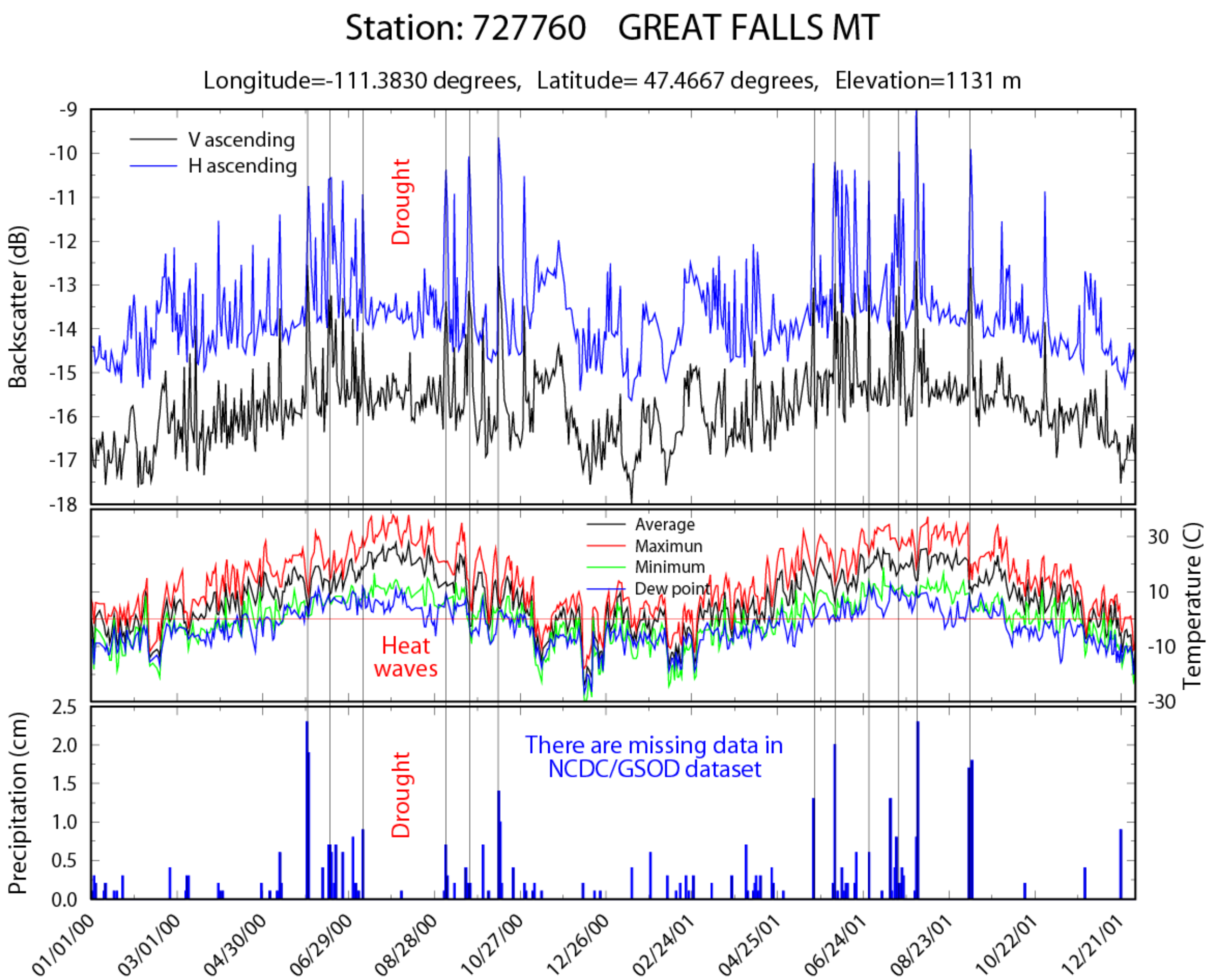

Figure 2: Comparison of two-year time-series QSCAT signature and NCDC/GSOD in-situ data around Great Falls, Montana, showing drought conditions in the fall of 2000.

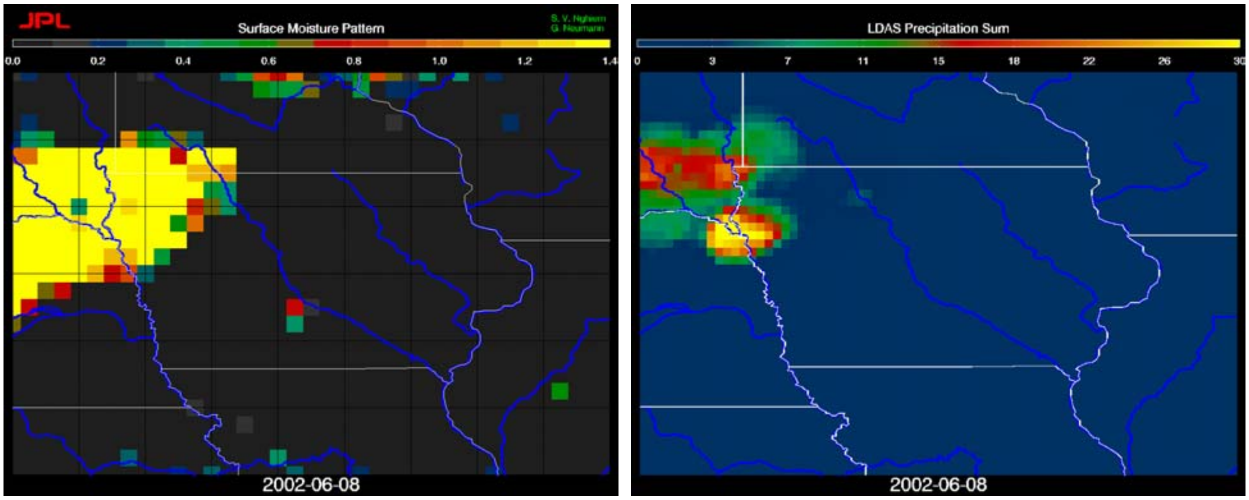

Figure 3: Comparison of QSCAT land surface pattern (left panel) with Princeton University's NLDAS daily integrated precipitation pattern (right panel).

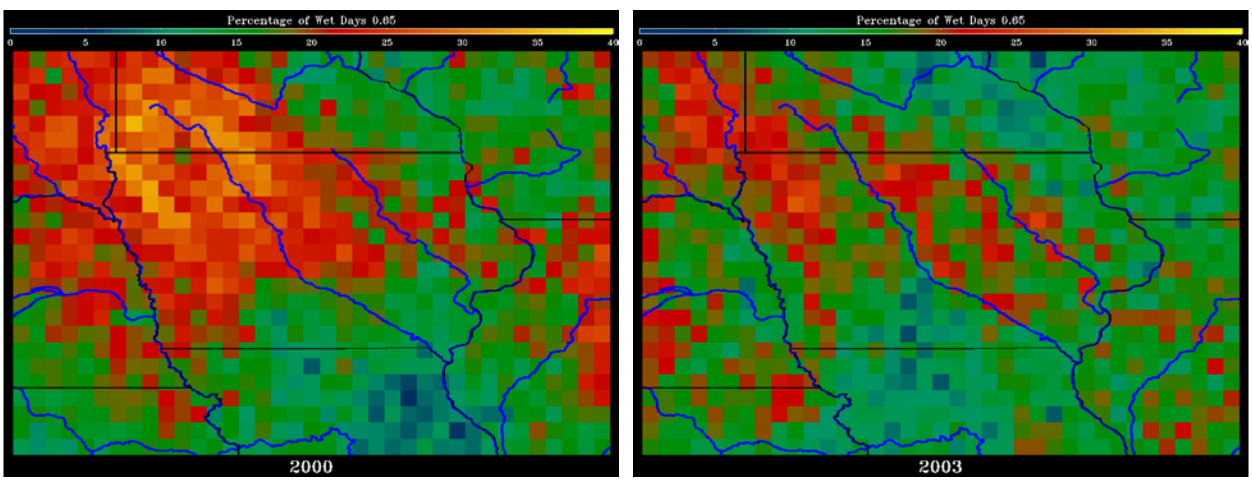

Figure 4: QSCAT precipitation frequency over the U.S. Midwest for the period of mid-May to mid-September in year 2000 (left panel) and year 2003 (right panel). Between 2000 and 2003 results, precipitation frequency decreased as much as a factor of 2 over some regions in the SMEX domain (NASA Soil Moisture EXperiment domain including Iowa and parts of surrounding states).

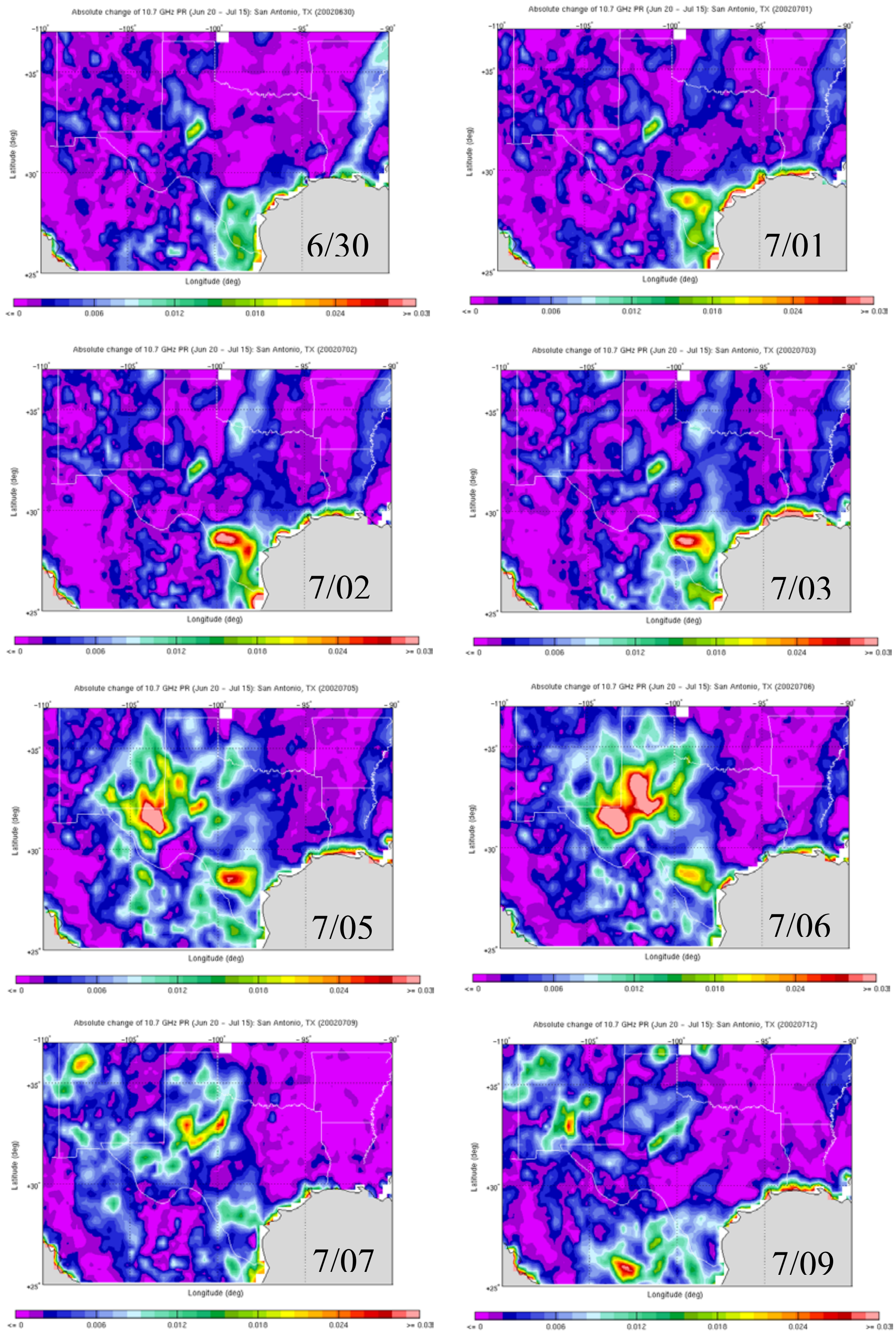

Figure 5: AMSR-E time-series images from July through August 2002 showing surface soil moisture changes in response to precipitation and subsequent drying.

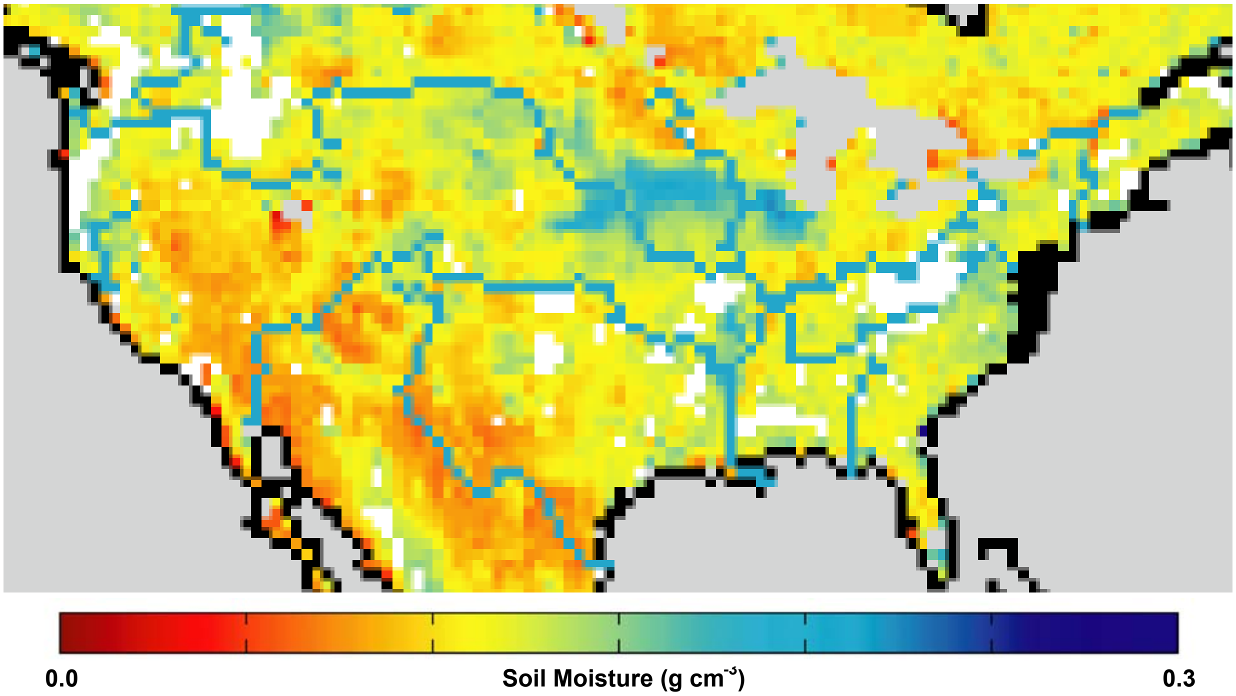

Figure 6: AMSR-E soil moisture over CONUS for the period 1-3 June 2003

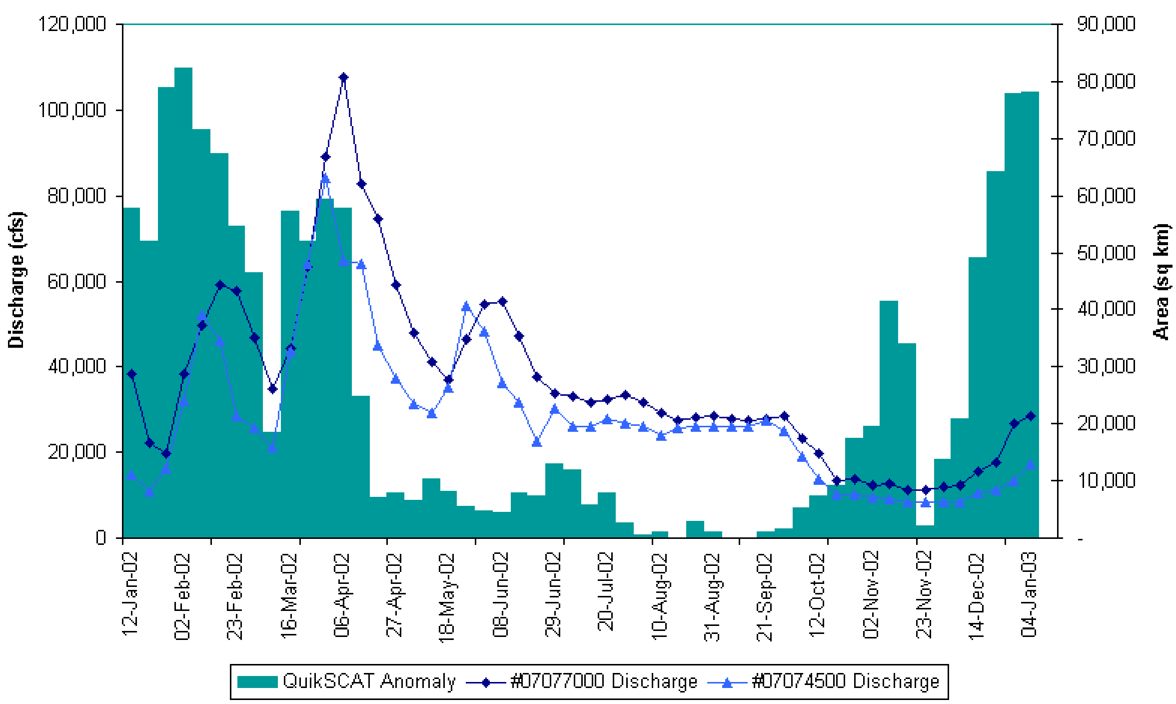

Figure 7: Seasonal evolution of wetland surface area over the lower Mississippi floodplain monitored by QSCAT on the weekly basis compared with U.S. Geological Survey (USGS) river discharge.

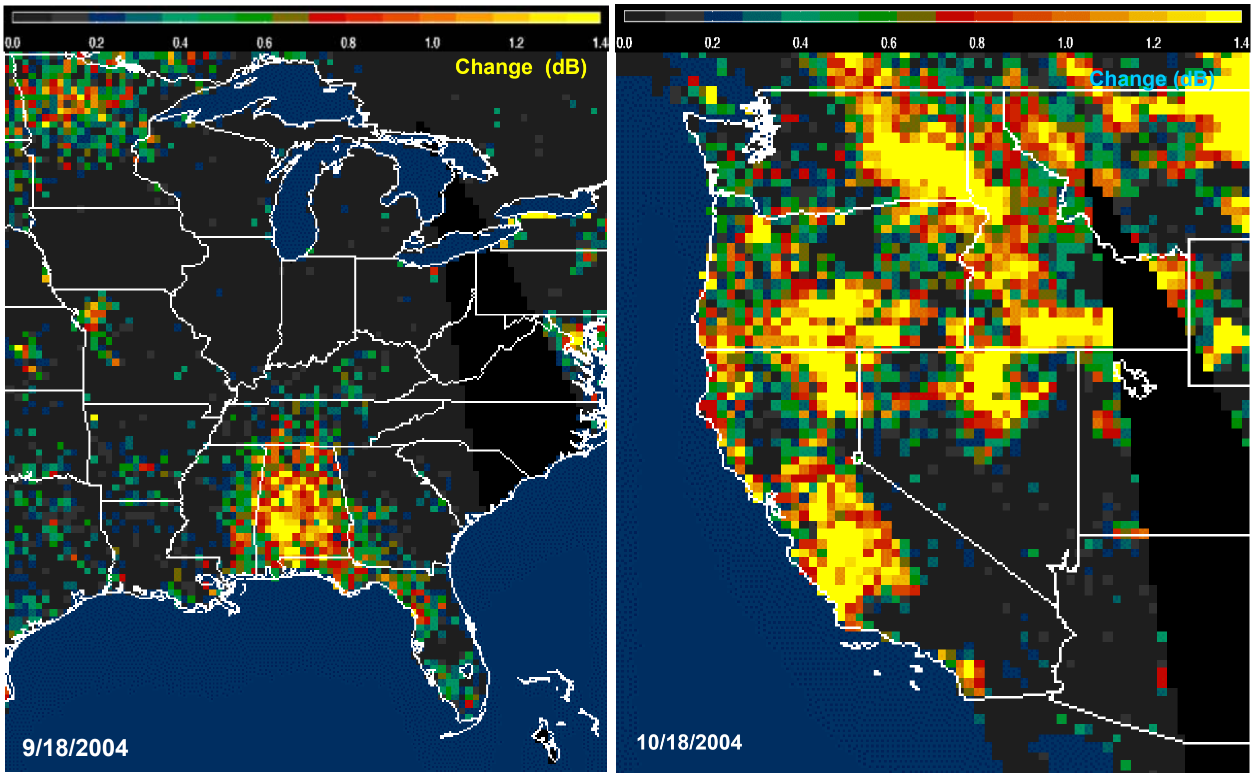

Figure 8: QSCAT map of wet surface areas caused by Hurricane Ivan (left panel) and storms over the western U.S. (right panel).