USE OF GOES PROXY DATA FOR SNOWMELT MAPPING

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ABSTRACT

This study presents an application of the future GOES-R Advanced Baseline Imager (ABI) measurements for snowmelt detection. A snowmelt detection algorithm would be synergetic to the GOES-R Flood/Standing Water algorithm in providing valuable information to hydrologists and forecasters for snowpack-runoff prediction and flood monitoring all-year round. The methodology put forth is a technique that uses GOES-13 Land Surface Temperature (LST) as proxy to flag the melting snow sub-component of the GOES pixel using empirically-established thresholds. An investigation is also carried out using optical imagery from the Visible Infrared Imager Radiometer Suite (VIIRS) in concert with VIIRS-derived LST to examine the potential for improved day-time melt detection.

INTRODUCTION

The main goal of this project is development of a new application of the GOES-R LST product for snowmelt detection. A Snowmelt Detection (SD) application would be synergetic to the GOES-R Flood/Standing Water (FSW) product (Sun et al., 2011), which in concert *would provide valuable information to hydrologists and forecasters* for *snowpack-runoff prediction and flood monitoring all-year round*. Another goal is to enable the use of remotely sensed LST in surface energy balance modeling and land data assimilation schemes all-year round; At present, GOES-based land surface modeling applications are limited to snow-free landscapes, e.g., the Two-Source Energy Balance (TSEB) modeling scheme which is applied routinely over snow-free surfaces using GOES data over the continental U.S. for monitoring evapotranspiration (Anderson et al., 2007a) and drought (Anderson et al., 2007b, 2011). Recently, Kongoli et al. (2012) and Kustas et al. (2012) extended TSEB parameterizations over snow which would allow monitoring of surface fluxes (including evaporation/sublimation over snow) all-year round.

The methodology put forth is the development of a technique that uses GOES-derived LST to flag the melting snow component of the GOES pixel. GOES 13 data are used as proxy to derive LST. VIIRS data are also used as proxy to examine the potential of GOES-R optical spectral measurements for improved day-time snow melt detection. Specifically, VIIRS Normalized Snow Difference Index (NSDI) computed from comparable MODIS bands 4 and 6 was examined in concert with VIIRS derived LST.

LST was retrieved using the NOAA operational algorithm (Sun et al. (2012). The retrieval method relies on channels 2 and 4 of the current GOES-13 and -14 imager data (Table 1), using a dual window technique. Table 2 shows product evaluation statistics over snow and snow-free areas. Cloud and snow masks were derived from the GOES Surface and Insolation Product (GSIP).

Table 1. Channels used for LST Retrieval

Channels	Central Wavelength (μm)	Resolution (km²)
1 (visible)	0.65	1 km x 1km
2 (infrared)	3.9	4 km x 4km
3 (infrared)	6.75	4 km x 4km
4 (infrared)	10.7	4 km x 4km
6 (infrared)	13.3	4 km x 8 km (GOES-12/13) 4 km x 4km (GOES-14)

Table 2. GOES LST Retrieval Statistics

Date	Time	Ground Temperature	Sample size	Correlation coefficient	Accuracy	Precision
0401	Daytime	Surfrad	98	0.9554	1.6401	2.3280
0401	Nighttime	Surfrad	798	0.8614	2.8162	3.0006
0401	Daytime-snowfree	Surfrad	70	0.9448	1.7335	2.2032
0401	Nighttime snowfree	Surfrad	696	0.8614	2.5822	3.0233
0401	Daytime-snow	Surfrad	13	0.9534	1.4844	0.8024
0401	Nighttime-snow	Surfrad	32	0.9356	1.4157	0.8750

GOES-13 LST OVER SNOW SURFACES

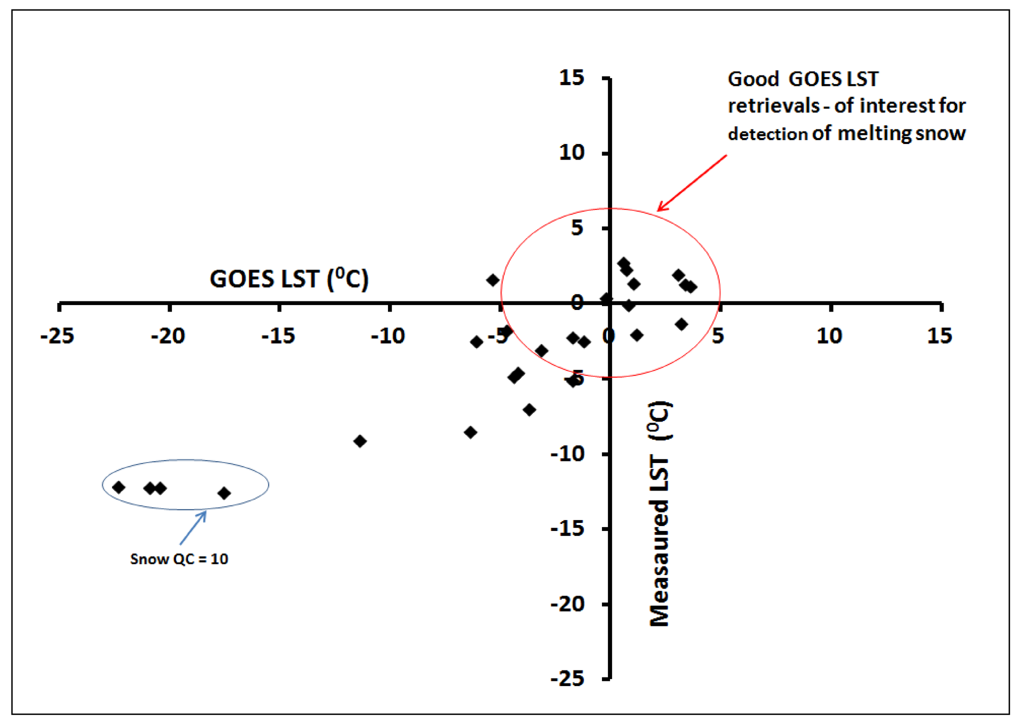

Figure 1. An example of GOES-13 retrieved LST and measured LST (computed from flux radiation data) at an AMERIFLUX site in Michigan during 2012 snow season. The surface type is deciduous broadleaf forest. Surface emissivity is assumed 0.98 for LST calculations. GOES LST performs reasonably well over the surface temperature range between -5 and +5 ^{0}C that is most relevant for wet snow detection.

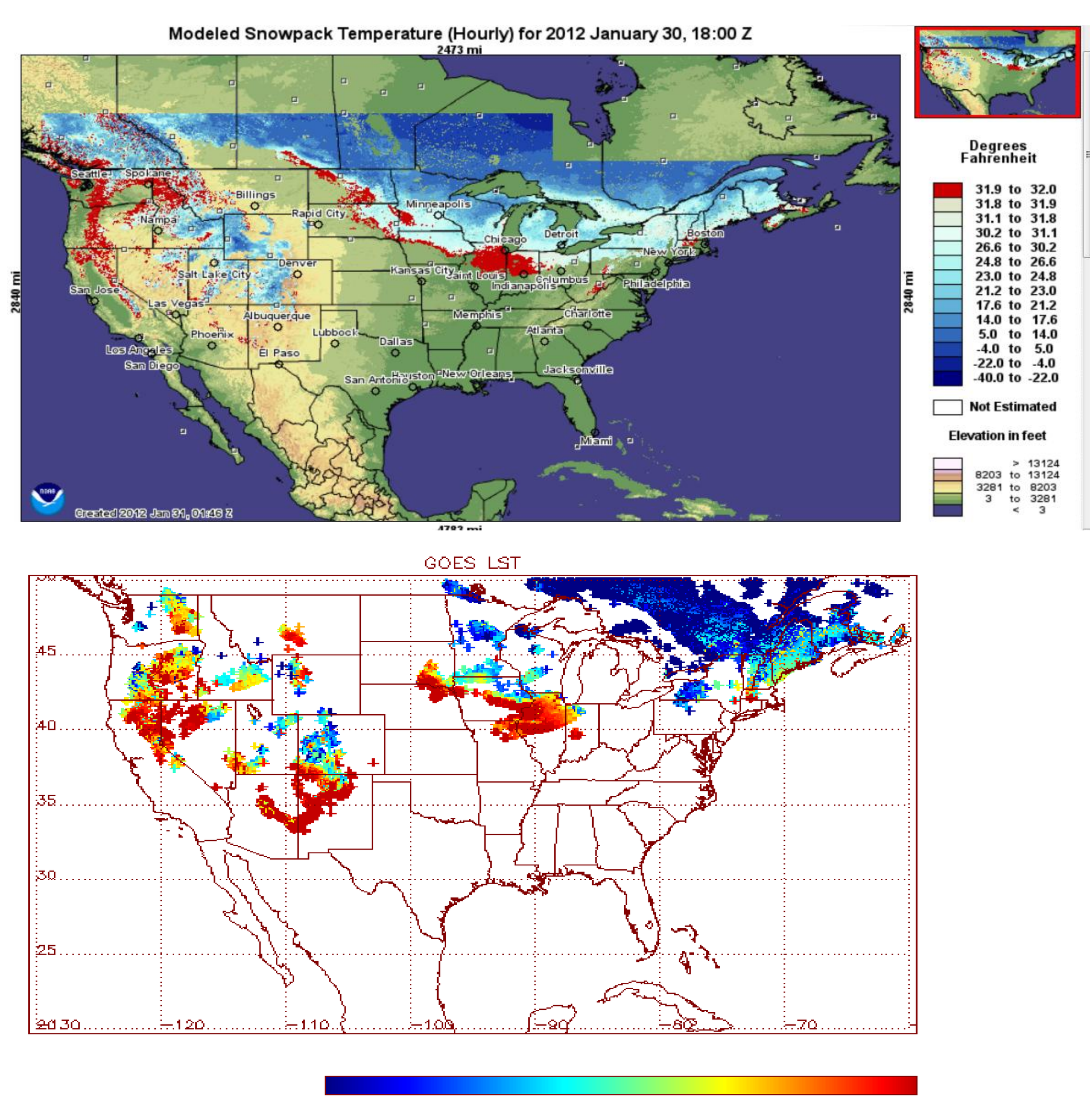

Figure 2. Modeled surface snowpack temperature in Fahrenheit over US on January 30, 2012, 16:00 Zulu time, obtained from the 1-km Snow Data Assimilation System (SNOWDAS) of NOAA's National Operational Hydrological Remote Sensing Center (NOHRSC) (top panel) and the closest-in-time (15 minute) GOES-13 LST in Kelvin over clear- and snow-identified scenes (bottom panel). Note that SNOWDAS reports the modeled snowpack temperature, which refers to the surface temperature of the snow component of the (mixed) surface, not the LST of that particular surface. On the other hand, GOES LST refers to the skin temperature of the (mixed) surface.. Inconsistencies between the dynamic snow mask applied by SNOWDAS (on an hourly basis) and the rather static snow mask applied to the GOES-13 LST (on a daily basis) can be seen, e.g., no-snow areas by SNOWDAS that are flagged as snow by GOES.

GOES/VIIRS LST-BASED WET SNOW DETECTION

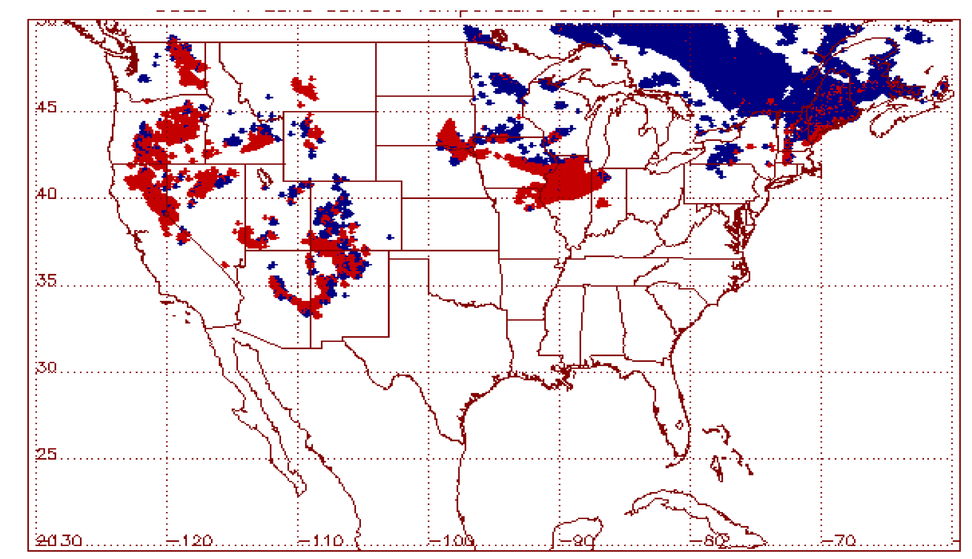

Figure 3. Wet snow areas (on January 30, 2012 18:00 Zulu time) depicted in red vs. dry snow areas depicted in blue as identified using the operational GOES-13LST product for an established LST threshold = 275 K over cloud-free and snow-flagged scenes. Visual inspection against the SNOWDAS-derived snowpack surface temperature (Figure 2, top panel) show reasonable large-scale correspondence although wet snow areas are overestimated. Possible explanations are a) inconsistent GOES snow mask with otherwise SNOWDAS snow-free areas that have above-freezing GOES LST values, and b) overestimation of retrieved LST.

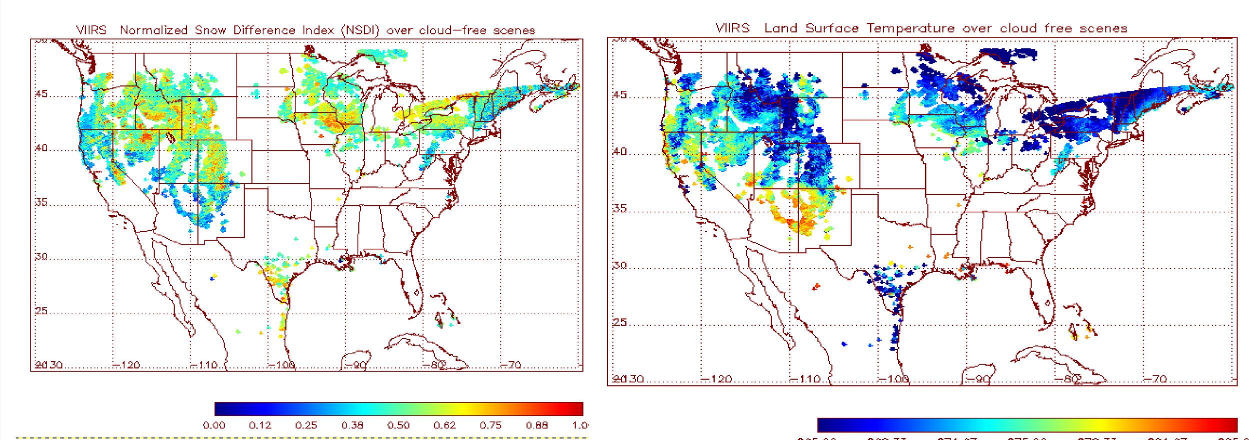

Figure 4. VIIRS NSDI (left) and VIIRS retrieved LST (right) over cloud free scenes over "snow and ice" surface type. VIRST LST uses a double window technique based on two thermal channels. Note the generally lower and more consistent LST values compared to those retrieved from the GOES-13 (Figure 2, bottom panel). Note also the anomalously low LST values over south Texas, probably caused by cloud contamination.

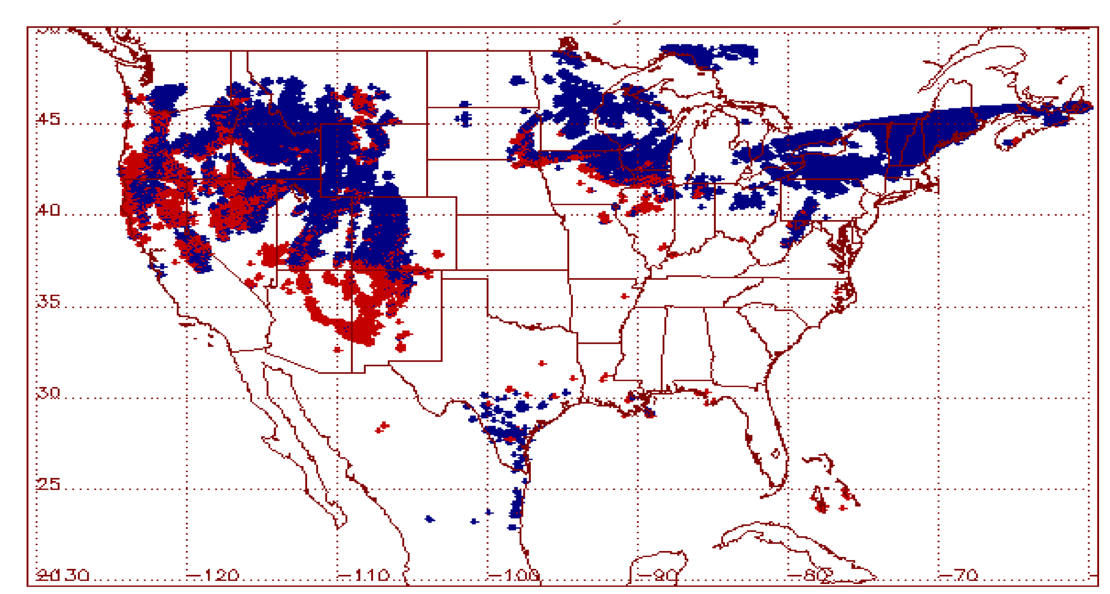

Figure 5. Wet snow areas depicted in red and dry snow areas depicted in blue as identified using the VIIRS LST product for an established LST threshold = 274 K over cloud-free scenes for the "snow and ice" surface type. Use of VIIRS NSDI did not appear to add substantial information in the wet vs. dry snow discrimination although high NDSI values correspond mostly with lower LST and thus would be indicative of dry snow. Visual inspection shows comparable large scale correspondence with SNOWDAS and GOES-LST based wet snow detection (Figure 3) although the wet snow areas appear to be less in extent and more comparable to SNOWDAS (Figure 2). Note that VIIRS "snow and ice" surfaces have a larger extent than the snow-identified areas by SNOWDAS and GOES, and thus they include snow-free areas especially over the Western US.

SUMMARY AND FUTURE WORK

This paper describes an application of the GOES-R Land Surface Temperature (LST) product for snowmelt detection. The methodology put forth is a technique that uses the NOAA's GOES-13 Land Surface Temperature (LST) as proxy to flag the melting snow sub-component of the GOES pixel with empirically-established thresholds. VIIRS data are also used as proxy to examine the potential of optical spectral measurements for improved day-time snow melt detection. Specifically, VIIRS Normalized Snow Difference Index (NSDI) computed from comparable MODIS bands 4 and 6 was examined in concert with VIIRS-derived LST. Comparison between GOES-derived LST and surface temperature computed from in-situ surface radiation station data over mixed surfaces showed reasonable retrievals over the near freezing temperature range that is most relevant for wet snow detection. Comparisons between GOES/VIIRS LST-based wet snow areas and those derived from the Snow Data Assimilation System (SNOWDAS) of NOAA's National Operational Hydrological Remote Sensing Center (NOHRSC) taken as ground truth showed large scale similarities and a real potential for capturing synoptic weather events. The technique is being refined using SNOWDAS as "ground truth" reference. Future work will also focus on testing an alternative physically-based approach: Applying the TSEB land surface model with GOES/VIIRS data for estimating surface energy fluxes and snowmelt.

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