NOAA ROSES Semi-Annual Report

Reporting Period: September 2020 – February 2021 (1st report)

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Project Title: Enhancing Evapotranspiration and Evaporative Stress Index Data Products from GOES-R Advance Baseline Imagers for NOAA NWP, NWM and Drought Monitoring Operations

Executive Summary (1 paragraph max)

In the first half of FY20 funding cycle, several major upgrades haven been implemented to the GET-D system to integrate GOES-16 and GOES-17 ABI observations. The upgrading includes the integration of ABI land surface temperature observations and solar insolation data products, which enables the enhancement of spatial resolution from 8 km to 2 km. Consistency of the upgraded system with the previous operational the GET-D system has been analyzed by visual and quantitative comparison. Moreover, the machine learning technique has been tested to couple AMSR2 Ka band observations under cloudy conditions when current GOES thermal based retrievals cannot be obtained because of cloud contamination. Detailed design of the upgraded GET-D system, analysis of product consistency and the evaluation of AMSR2 Ka-band LST Retrievals are documented in this semi-annual report.

Progress toward FY20 Milestones and Relevant Findings

The GET-D system has been successfully upgraded to generate GOES16/17 based ET products at 2km over CONUS domain. The processing outline of the upgraded GET-D system is shown in Figure 1. The major upgrading include: (1) redesign the spatial domain and the architecture of GET-D; (2) the integration of GOES16/17 ABI based land surface temperature (LST) data product and GSIP solar insolation data product; and (3) derivation of all-weather ET data product from the combination of the Ka-band microwave observations with the ABI thermal observations.

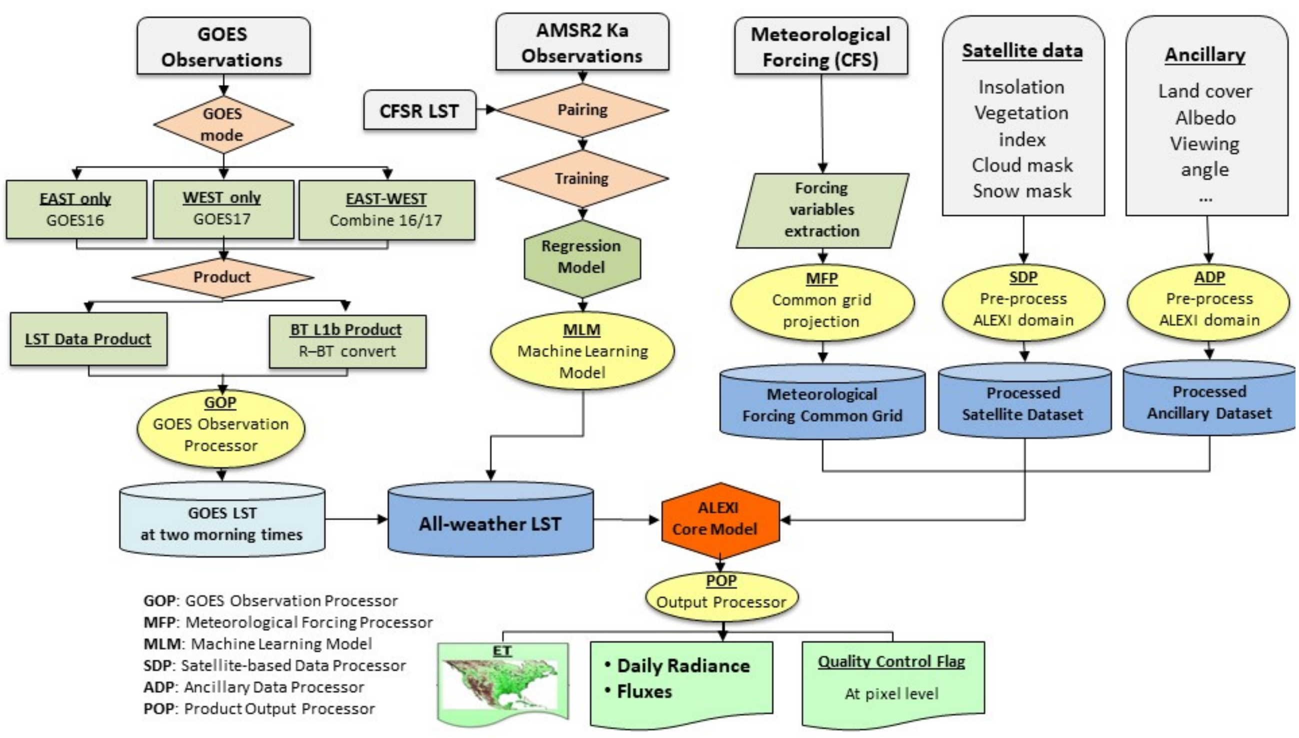

Figure 1 Data flow diagram of the upgraded GET-D system

1. Integration of GOES-16/17 ABI based LST and GSIP solar insolation data products

As shown in Figure 1, the GOES Observation Processor (GOP) module, which is responsible for the pre-processing of GOES-16/17 observations, involves the most revision during the system upgrading. The upgraded GET-D is able to proceed relying on either single GOES observation (GOES-16 or GOES-17) or GOES-16 and GOES-17 combined. The use of the combined GOES-16 and GOES-17 observations is expected to give the best performance since the satellite viewing angle over the CONUS domain is significantly reduced. The GET-D system is also capable of generating full spatial coverage products with GOES-East data only but with the compromise in accuracy over western areas due to relatively large viewing angles (larger than 45°). In addition, the GOP module can integrate either GOES LST data product or GOES L1b brightness temperature (BT) products based on the configuration.

Solar insolation (downward shortwave radiation) is another primary ABI based input to the ALEXI model of GET-D product system. Previously, the GET-D product system was using the daily solar insolation at 12.5km resolution from the GOES Surface and Insolation Products (GSIP) system based on GOES-13/15. The solar insolation data product is now upgraded to 2km resolution using GOES-16/17 ABIs. The SDP module has been revised to digest new GSIP solar insolation input at high resolution.

2. Analysis of Product Consistency

The new system has been successfully implemented with the major changes of the GOES ABI based inputs and is able to produce ET maps at designed spatial domain. The upgraded system has been tested from July to October 2017 when both GOES-16 and GOES-13 are available. The overlap period provides an opportunity to assess the consistency of the upgraded system with the previous operational the GET-D system. Figure 2 shows the comparison of the monthly ET composites (July 2017) between the GOES-13/15 based 8 km ET product and the new GOES-16/17 based one at 2 km resolution. Taking a closer look at regional maps over Oklahoma, the 2 km ET map (Figure 2e) agrees well with current operational product (Figure 2d), capturing low-to-high transition patterns from western to eastern Oklahoma, but provides much improved spatial details. In general, the upgraded system proves to be very consistent with the current operation with spatial correlation of 0.946 averaged over the whole CONUS domain. Notably, much better spatial heterogeneity can be captured in 2 km ET maps derived from the upgraded GET-D system.

-- Milestone 1 and 2 completed

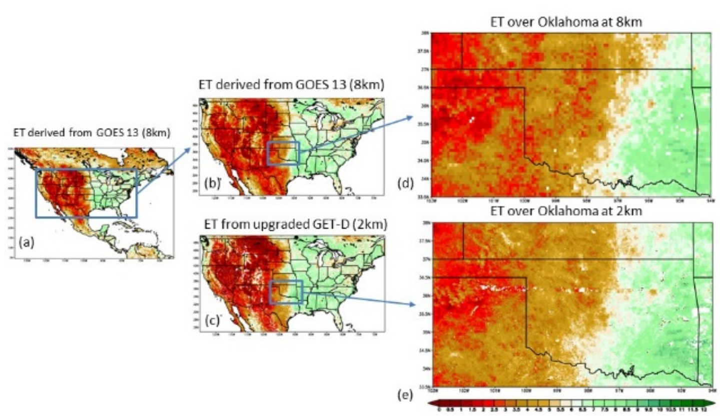

Figure 2 ET estimates comparison between operational GOES-13/15 based 8 km product (a: over North America domain and b: over CONUS domain) and upgraded GOES-16 based 2 km product (c), with regional comparison over Oklahoma at 8km (d) and 2km (e). Monthly composite of July 2017 (mm day^{-1})

3. Evaluation of AMSR2 Ka-band LST Retrievals on Cloudy Days

Given that current GET-D product is dependent on the availability of remotely sensed TIR observations, the ALEXI model can only be executed under clear-sky conditions. An important enhancement in the new system is to combine microwave (MW) observations with the TIR data to obtain all-weather LST that are then used to derive all-weather ET. The regression tree data mining technique is used to automatically search patterns and relationships between MW and TIR LST retrievals to allow the estimation of surface fluxes under cloud cover. We exploited the combination of AMSR2 Ka-band brightness temperature and GOES thermal LST to come up with a surface temperature map under all weather conditions.

Preliminary results demonstrated that the all-weather LST product increases data availability by more than 160%, which would be extremely beneficial to the end-users for a variety of applications. One example of clear-sky LST from GOES-16/17 compared with the all-weather LST from MW and TIR coupled LST over CONUS domain on July 3, 2018 is shown in Figure 3. Time series comparison between GOES-16/17 LST and MW-TIR coupled LST is shown in Figure 4, as along with in-situ LST observations at the SURFRAD-TBL station over the period from Jan. 1 to Dec. 31, 2018. It is very impressive to see that the all-weather LST retrievals with the cloudy days filled in can capture much better daily dynamic which agrees with the in-situ records very well.

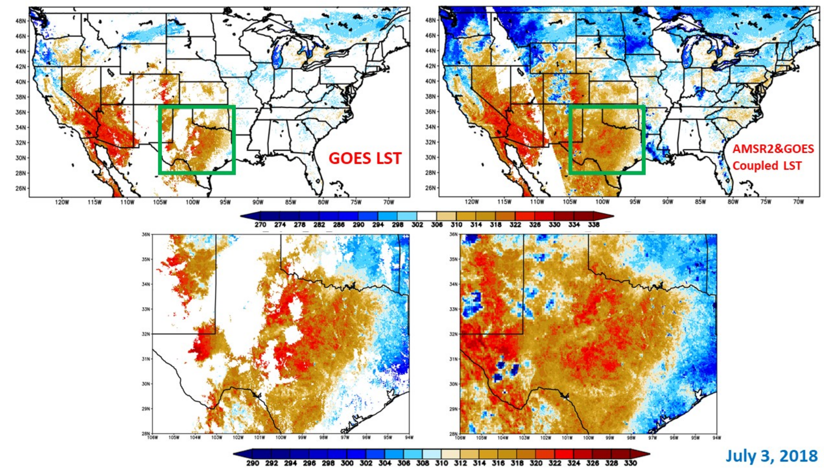

Figure 3 Visual comparison of GOES-16/17 LST and MW-TIR coupled LST over the CONUS domain (top panel) and the LMV region (bottom panel) on July 3, 2018

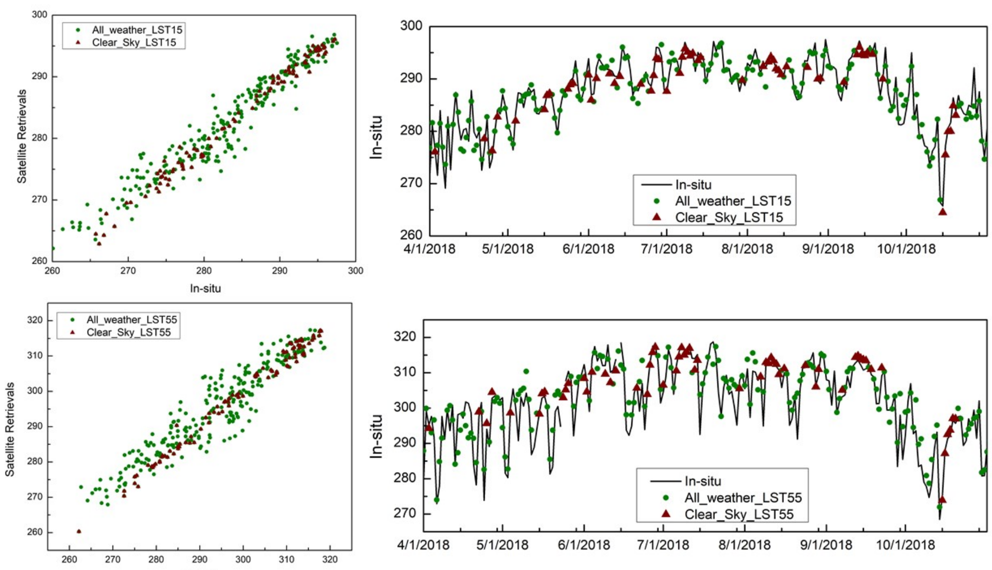

Figure 4 Time series comparison between GOES-16/17 LST and MW-TIR coupled LST, as along with in-situ LST observations at the SURFRAD-TBL station over the period from Jan. 1 to Dec. 31, 2018 (LST15: The first timestamp of ALEXI model at 1.5 hour before sunrise; LST55: The second timestamp of ALEXI model hour at 1.5 hour before noon)

The accuracy of all-weather LST retrievals is evaluated by comparing with in-situ measurements from 6 stations over CONUS. The error statistics of RMSE and correlation are shown in Table 1 and 2, respectively. The LST retrievals agree with the in-situ observations better on cloud-free days than cloudy days. It is understandable that clear-sky retrievals have lower RMSE and higher correlation because the uncertainties under cloudy conditions are higher and more complicated compared to clear sky situations. In general, the quality of all-weather LST retrievals is reasonable and acceptable as the mean correlation under all conditions could reach as high as 0.913.

-- Milestone 3 completed

Table 1 RMSE of MW-TIR coupled LST validated against in-situ observations (Jan. 26 – Dec.31 2018); statistics of clear sky pixels and cloudy pixels are separately

RMSE			**LST15**		**LST55**	
Site ID	LAT	LON	Clear Sky	Cloudy	Clear Sky	Cloudy
C1_LST15	36.6	-97.49	1.517	4.121	2.298	4.964
E12_LST15	36.84	-96.43	1.044	4.034	2.622	4.120
E33_LST15	36.93	-97.08	1.250	5.176	2.305	4.138
E41_LST15	36.88	-97.09	1.072	5.471	2.852	5.022
FPK_LST15	48.31	-105.1	0.888	5.137	2.386	5.494
TBL_LST15	40.13	-105.24	1.397	3.149	1.696	4.165
Average RMSE			**1.195**	**4.514**	**2.360**	**4.651**

Table 2 Correlation of MW-TIR coupled LST validated against in-situ observations (Jan. 26 – Dec.31 2018); statistics of clear sky pixels and cloudy pixels are separately

Correlation			**LST15**		**LST55**	
Site ID	LAT	LON	Clear Sky	Cloudy	Clear Sky	Cloudy
C1_LST15	36.6	-97.49	0.953	0.862	0.952	0.865
E12_LST15	36.84	-96.43	0.966	0.851	0.963	0.907
E33_LST15	36.93	-97.08	0.937	0.755	0.945	0.910
E41_LST15	36.88	-97.09	0.936	0.734	0.940	0.878
FPK_LST15	48.31	-105.1	0.973	0.907	0.979	0.947
TBL_LST15	40.13	-105.24	0.954	0.909	0.969	0.933
Average Correlation			**0.953**	**0.836**	**0.958**	**0.906**

4. Redesign the Spatial Domain and Architecture of GET-D to Meet User Needs

The previous operational GET-D based on GOES-13/15 imager data covers the North America domain at 8 km spatial resolution. To better meet users' needs, the upgraded GET-D system is designed to derive ET at 2km spatial resolution over CONUS domain (125W-66.75W, 24.83N-49.83N). Although some subroutines/functions of the GET-D software system remain unchanged in the upgraded GET-D system, several modules (e.g. GOP and SDP in Figure 1) have been heavily revised to adopt GOES-16/17 ABI based inputs and new algorithms (e.g. machine learning algorithm).

-- Milestone 4 and 5 completed

Plans for Next Reporting Period

1. Continue refining the code of all Modules/Functions of the upgraded GET-D system
2. Collect and process in situ ET measurements from AmeriFlux networks
3. Generate all-weather ET data product based on MW and TIR coupled LST
4. Evaluate all-weather ET using in situ ET observations from AmeriFlux networks