NOAA ROSES Semi-Annual Report

Reporting Period: September 2021 – February 2022 (3rd 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

In the first half of FY22, we have conducted comprehensive validation of GET-D ET estimated using in situ ET observations from AmeriFlux network which were collected and pre-processed from last funding cycle. In addition, reprocess of GET-D ET product has been carried out using all available GOES-16/17 TIR data set to generate long-term ET climatology. Lastly, an ABI-based Evaporative Stress Index (ESI) product has been generated for drought monitoring over the CONUS domain. Two applications of the GET-D ESI product are given in this report to demonstrate the unique advantages of ABI-based drought product. A manuscript for a Frontiers journal has been submitted and is currently on the second round of review.

Progress toward FY21 Milestones and Relevant Findings (with any Figs)

1. Comprehensive validation of the GET-D ET product using in situ ET observations from AmeriFlux networks – **Milestone 7 completed**

The GET-D clear-sky and all-weather ET retrievals are evaluated by comparing with in-situ ET measurements over the validation period from July 2017 to July 2019. Time series of comparison between the clear-sky and cloud-filled ET data sets over two sample sites (Fig. 1 and 2) are given first followed by an analysis (Table 1) on the overall error statistics (RMSE and r) averaged from all validation sites over the CONUS domain. It is encouraging to see that the accuracy of the cloudy pixel retrievals is at the same level as that on clear days. The overall statistics of the correlation and RMSE indicate that the machine learning approach is feasible to combine thermal, microwave, and model based LSTs to generate an ET product under all-weather conditions.

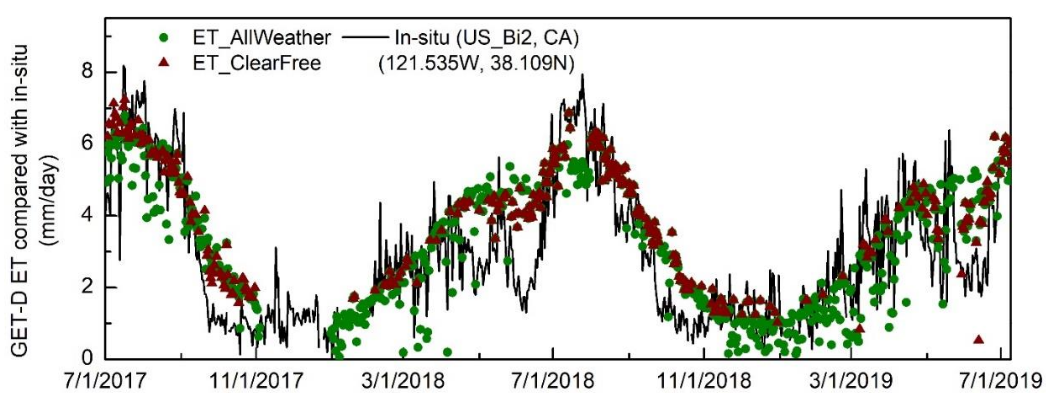

Fig 1. Time series comparison between clear-sky ET and all-weather ET, as well as in-situ ET observations at the AmeriFlux station (US-Bi2) in CA over the period from July 1, 2017 to July 1, 2019

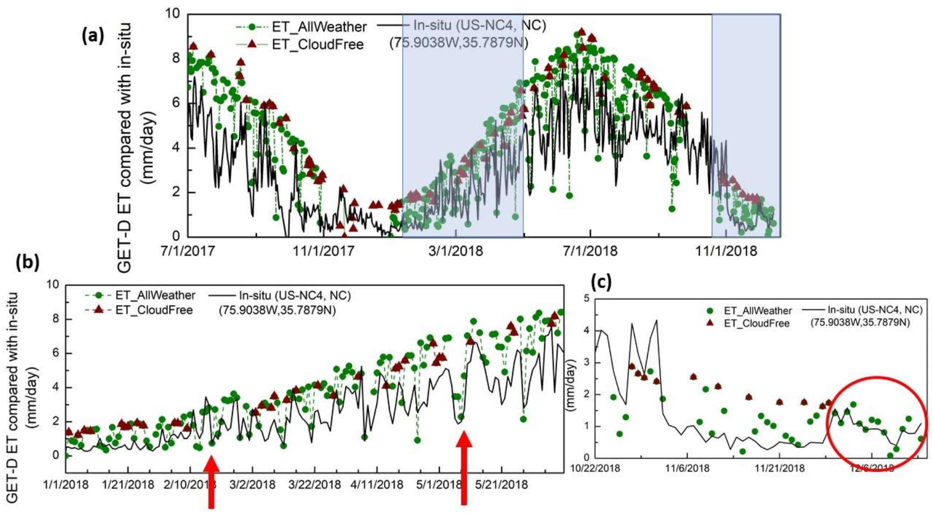

Fig. 2 Same as Figure 1, but at the station in North Carolina

Table 1 Validation statistics of GET-D ET estimates against in-situ measurements over a period from July 2017 to July 2019

			RMSE (mm/day)		Correlation		ubRMSE (mm/day)	
Site ID	LAT	LON	clear-sky	cloudy	clear-sky	cloudy	clear-sky	cloudy
US-ARM	36.606	-97.489	1.090	1.276	0.836	0.703	0.994	1.234
US-Bi1	38.099	-121.499	1.611	1.384	0.599	0.739	1.518	1.332
US-Bi2	38.109	-121.535	1.178	1.205	0.828	0.792	1.095	1.179
US-Hn2	46.689	-119.464	1.745	1.097	0.432	0.565	1.002	0.820
US-IB1	41.859	-88.223	0.559	0.994	0.921	0.813	0.487	0.902
US-IB2	41.841	-88.241	0.544	0.834	0.972	0.856	0.497	0.826
US-KFS	39.056	-95.191	1.884	1.671	0.518	0.396	1.726	1.544
US-KLS	38.775	-97.568	1.690	1.630	0.091	0.486	1.065	1.261
US-MOz	38.744	-92.200	1.721	1.516	0.880	0.870	0.847	0.928
US-NC2	35.803	-76.669	1.944	2.104	0.919	0.808	0.931	1.299
US-NC3	35.799	-76.656	1.449	1.674	0.813	0.767	1.392	1.547
US-NC4	35.788	-75.904	1.803	2.142	0.844	0.786	1.031	1.340
US-NR1	40.033	-105.546	0.945	1.218	0.889	0.624	0.420	0.959
US-Rms	43.065	-116.749	1.343	1.273	0.682	0.611	1.173	1.272
US-Ro4	44.678	-93.072	1.788	1.580	0.732	0.723	1.117	1.171
US-Ro5	44.691	-93.058	0.915	1.143	0.824	0.737	0.903	1.143
US-Ro6	44.695	-93.058	1.403	1.088	0.544	0.752	1.401	1.077
US-Rws	43.168	-116.713	1.335	1.259	0.686	0.589	0.505	0.724
US-Sne	38.037	-121.755	0.832	1.322	0.897	0.895	0.684	0.955
US-SRG	31.789	-110.828	0.924	1.108	0.819	0.706	0.770	1.025
US-SRM	31.821	-110.866	0.711	0.933	0.796	0.701	0.695	0.920
US-Tw3	38.116	-121.647	1.378	1.274	0.541	0.664	1.163	1.115
US-Var	38.413	-120.951	2.288	2.265	0.353	0.568	2.185	2.035
US-WCr	45.806	-90.080	1.481	1.554	0.827	0.770	1.121	1.286
US-Whs	31.744	-110.052	1.244	1.242	0.705	0.605	0.527	0.887
US-Wkg	31.737	-109.942	1.600	1.475	0.757	0.593	0.636	1.112
Average			**1.362**	**1.395**	**0.719**	**0.697**	**0.996**	**1.150**

2. Deliver GET-D ET and ESI Data to NCEP Users – **Milestone 8 completed**

Enhanced GET-D daily products have been delivered to NCEP EMC land group for their evaluation. We'll collect feedbacks from NCEP EMC about daily products from the upgraded GET-D for the Noah land surface model and other NWP model validation. In addition, research on assimilating either ESI or ET data for improvement of NWP models will be explored.

3. Generate GET-D ESI data based on the long-term climatology – **Milestone 9 completed**

In current reporting cycle, we have re-run the upgraded GET-D system with all available GOES-16/17 TIR data that are available from NOAA CLASS. The Evaporative Stress Index (ESI), which indicates how the current rate of ET compares to normal conditions, can then be generated based on the long-term ET climatology for drought monitoring purpose. The GET-D ESI drought product has been compared with the U.S. Drought Monitor (USDM). Drought maps of July, Aug. and Sept. from 2019 to 2021 compared with USDM have been presented in Fig. 3. The GET-D drought maps presented high agreement with USDM briefing in terms of drought patterns and intensity.

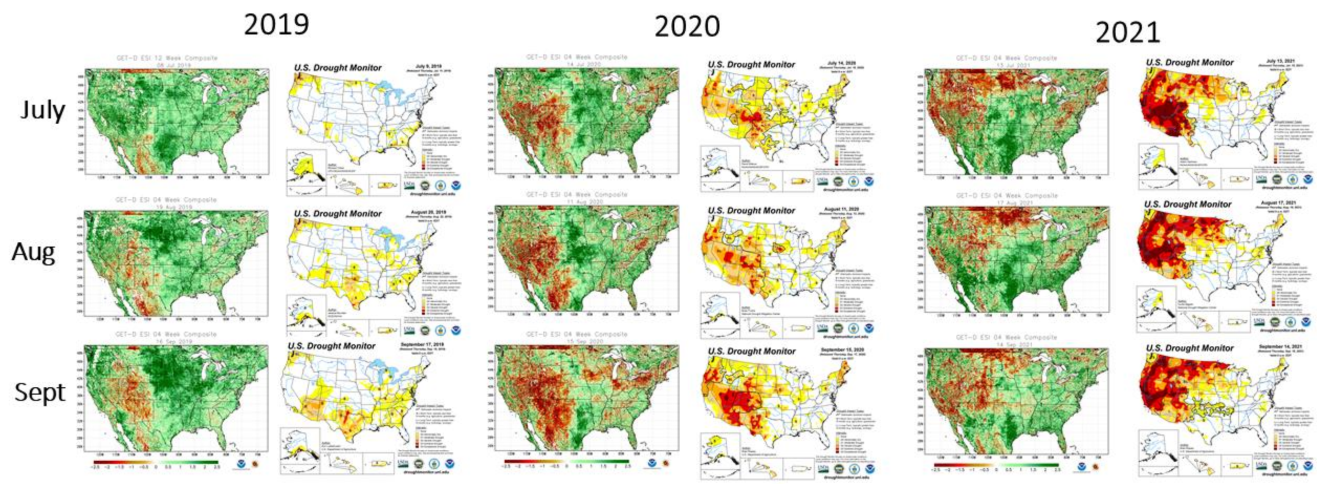

Fig. 3 GET-D ESI drought maps compared with the U.S. Drought Monitor on July, Aug. and Sept. from 2019 to 2021

4. Two application cases of GET-D ESI drought product – **Milestone 10 completed**

GET-D ET is derived directly from remotely sensed land surface temperature. The corresponding ESI can provide the estimation of surface soil moisture without using any rainfall data as inputs. Therefore, GET-D drought monitoring product has its unique advantages. Two cases will be presented in this section to demonstrate two unique characteristics of the ESI drought product.

<u>Case 1: Capability of capturing irrigation activities</u>

Fig. 4 shows a cropland area in the Columbia Basin in Washington, where the irrigation fields showed no shortage of water resources while the surrounding regions were developing a severe drought in July 2021. The animation in Fig. 5 presents the changes in ESI on daily basis over the irrigation areas from mid-June to the end of July, 2021. It clearly showed that irrigated cropland remained shaded green indicating an adequate surface soil moisture status as the adjacent areas started turning red from the late June due to lack of water. On the other hand, the precipitation based meteorological drought index, Standardized Precipitation Index (SPI), is shown in Fig. 5 on the right as a reference. The monthly composite of the SPI map didn't show the sufficient supply of water over the crop fields in July 2021 because of a lack of irrigation information to the model. The GET-D ESI inherently includes non-precipitation related surface water signals such as irrigation activities, groundwater supplied vegetation, etc.

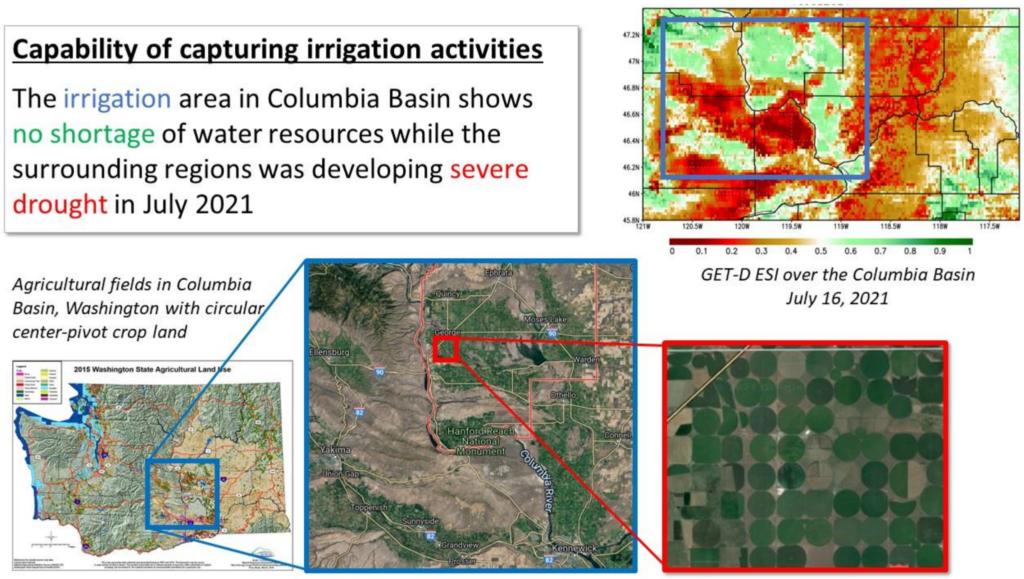

Fig. 4 Study area of crop fields in the Columbia Basin in Washington and GET-D ESI estimate on July 16, 2021 over that region.

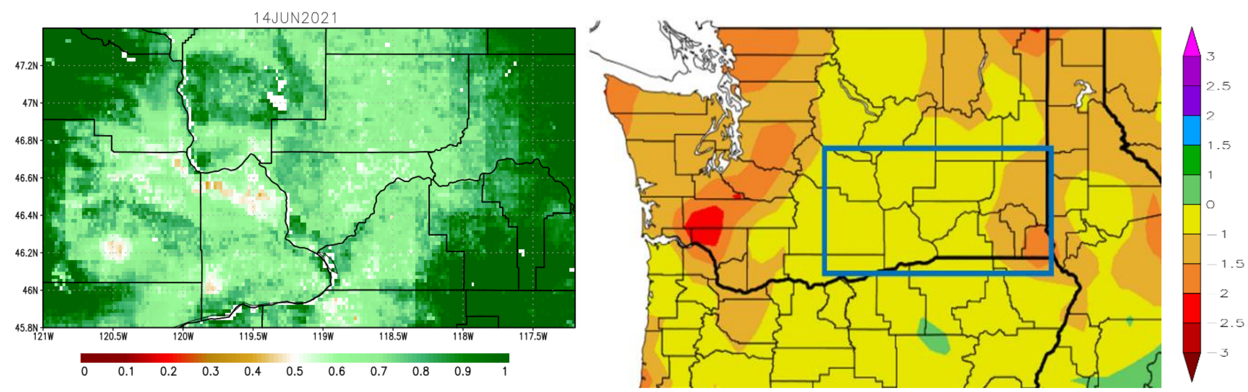

Fig. 5 Daily changes of GET-D ESI over the irrigation areas from Mid-June to the end of July in 2021 (left), compared with the monthly Standardized Precipitation Index (SPI) in July 2021 (right)

<u>Case 2: Capability of capturing early signals of "flash drought" or timely prediction of drought retreat</u>

Signatures of vegetation stress are manifested in the land surface temperature (LST) signal before any deterioration of vegetation cover occurs. Therefore, LST-based drought indices such as ESI can provide a timely or even effective early warning signal of agricultural drought than vegetation-index-based drought such as Vegetation Health based Drought Index (VHD).

Fig. 6 presents an example of the comparison between the LST-based ESI product and NDVI-based VHD product for the 2020 Western Drought. Both products captured the extreme drought over most of the western areas and Midwest, especially in Iowa, for the week ending September 8, 2020. In the following week, however, the conditions took a quick turn as heavy rainfall soaked interior north-eastern Texas, in a swath from Oklahoma to Kansas, across Iowa, and to the border between Wisconsin and Illinois. The multi-day rain event brought significant drought relief in Iowa and the north-western Texas. The ESI map on Sept. 15 clearly revealed the change of drought conditions. However, the VHD product didn't respond promptly because it usually took days for vegetation to recover from water stress.

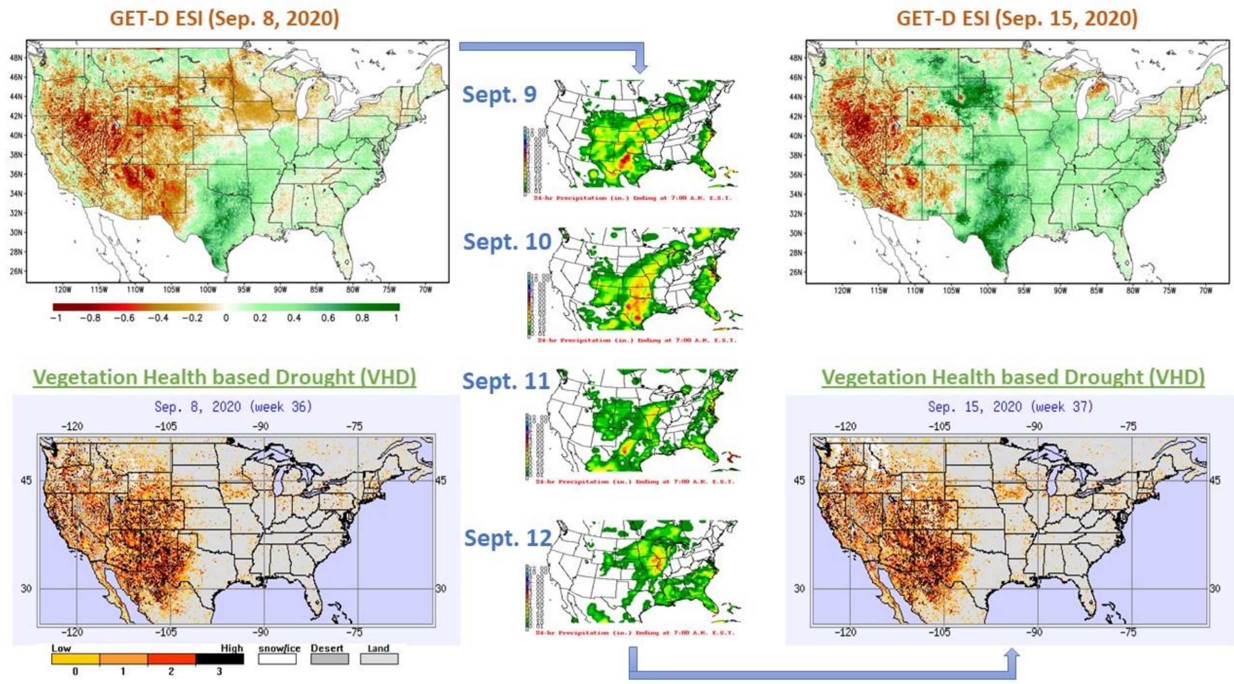

Fig. 6 GET-D Evaporative Stress Index (ESI) compared with Vegetation Health based Drought Index (VHD) for the Western Drought case on Sept. 8 and Sept. 15 in 2020

Plans for Next Reporting Period

1. Deliver GET-D Drought Maps to USDA and NIDIS and Collect their Feedbacks
2. Identify a plan for implementing the upgraded GET-D in OSPO systems
3. Submit end of project reports and publish research results

Task Schedule, Milestones and Status

Task and ***milestone (underlined and in italic)***	Y1	Y2	Y3	Progress Status
1. Evaluation of ABI Land Surface Temperature Data Products for GET-D (*LST input for GET-D defined*)	√			Completed
2. Evaluation of ABI-based GSIP Solar Insolation Data Products for GET-D (*Solar insolation input for GET-D defined*)	√			Completed
3. Evaluation of AMSR2 Ka-band LST Retrievals for GET-D Use on Cloudy Days (*Cloudy day LST input for GET-D decided*)	√			Completed
4. Redesign the Spatial Domain and Architecture of GET-D to Meet User Needs (*GET-D domain and architecture meeting user requirements defined*)	√			Completed
5. Code and Assemble All Modules/Functions of the Redesigned GET-D Product System (*GET-D code developed and ready for testing*)	√	√		Completed

6. Collect and Process in situ ET Measurements from AmeriFlux Networks (*GET-D ET validation data collected and processed*)	√	√		Completed
7. Calibrate and Validate ET and ESI Output (*GET-D ET and ESI output calibrated and validated*)		√		Completed
8. Deliver GET-D ET and ESI Data to NCEP and NWC Users and Collect their Feedbacks (NCEP and NWC *feedbacks on GET-D ET and ESI output collected and addressed with GET-D refinement*)		√	√	Completed
9. Reprocess GET-D with all available GOES TIR Data (*GET-D rerun for all available and collected GOES TIR data)*		√	√	Completed
10. Map Drought Occurrence with GET-D ESI (*GET-D drought product generated with the long term GET-D ET climatology*)		√	√	Completed
11. Deliver GET-D Drought Maps to USDA and NIDIS and Collect their Feedbacks (*USDA and NIDIS feedbacks collected on GET-D drought products*)			√	On track
12. Identify a plan for implementing the upgraded GET-D in OSPO systems (*Implementation plan of GET-D in NESDIS or Cloud operational environment planned*)			√	On track
13. Submit Semi-Annual and End of Project Reports and Publish Research Results (*Reports, presentations and refereed journal papers submitted or prepared*)	√	√	√	On track