**Using supplemental vegetation data to analyze ARM surface flux measurements**

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Introduction

Information on vegetation and crop types near flux towers is a critical supplement for the interpretation of surface flux measurements. This repository presents vegetation data created from records collected by site-operations staff as part of Preventive Maintenance (PM) reports. These data are then used to supplement surface flux measurements collected by the [ARM Eddy Correlation Flux Measurement System (ECOR)](https://www.arm.gov/capabilities/instruments/ecor) at the Southern Great Plains (SGP) extended and supplemental facilities.

The instrument webpage describes the ECOR system as follows: “The eddy correlation (ECOR) flux measurement system provides half-hour measurements of the surface turbulent fluxes of momentum, sensible heat, latent heat, and carbon dioxide. The ECOR uses the eddy covariance technique, which involves correlation of the vertical wind component with the horizontal wind component, air temperature, water vapor density, and CO2 density.” Vertical fluxes of sensible and latent heat at the surface are also available from the Energy Balance Bowen Ratio station ([EBBR](https://www.arm.gov/capabilities/instruments/ebbr)), the bulk aerodynamic EBBR value-added product ([BAEBBR](https://www.arm.gov/data/science-data-products/vaps/baebbr)), and the Carbon Dioxide Flux Measurement Systems ([CO2FLX](https://www.arm.gov/data/data-sources/co2flx)).

Vegetation information is collected within ARM PM reports and associated with flux data from three data streams (30ECOR/QCECOR and ECORSF) at 30-min resolution. PM reports observations were made user-friendly, especially for long-term measurements and multiple sites. Python scripts (Jupyter notebooks) were developed for users to analyze surface fluxes as a function of the vegetation types to support land-atmosphere interactions research (e.g., Fig. 1).

“Uncorrected turbulent fluxes are available in the 30ECOR datastream. It is recommended that routine ECOR corrections are applied to the data prior to use, and corrected fluxes are available in the [30QCECOR VAP](https://www.arm.gov/news/data/post/102284). In October 2019, the ECOR systems at SGP were upgraded with newer-model instruments, including the addition of a microprocessor allowing both uncorrected and corrected fluxes in a single datastream, ECORSF, and eliminating the need for the ECOR VAP at these sites.” Jupyter notebooks have been uploaded to the [ARM Github repository](https://github.com/ARM-DOE/ARM-FLUX-VEG) to support the analysis of these datasets. There are multiple Jupyter notebooks corresponding to different ECOR data streams and PM report formats.

Jupyter notebooks

* SGP\_30ECOR\_Surface\_Conditions.ipynb
* SGP\_30QCECOR\_Surface\_Conditions.ipynb
* SGP\_ECORSF\_Surface\_Conditions.ipynb
* SGP\_30QCECOR\_Surface\_Conditions\_cropwise.ipynb

The first three notebooks provide python scripts to correlate the three different ECOR data streams with surface and vegetation conditions in the PM reports. These scripts help classify the data into observations from individual SGP facility locations. These scripts have the functionality to plot the seasonal trends in surface flux measurements (averaged at various temporal resolutions) whenever a specific crop was reported at a facility (Fig. 2). The final script provides similar analyses, but the data are classified as a function of a specific crop reported across all facilities to analyze the same data sets from a crop wise perspective (Fig. 3). Each notebook has extensive comments to describe the components. Questions regarding the use of these notebooks can be directed to the corresponding author.

Input data

* Old PM report observations (1999 – 2019) uploaded as an excel spreadsheet named SGP\_Surface\_Conditions.xlsx.

This file contains the variables listed in Table 1. The table contains descriptions of the variables along with the most reported technician responses.

* New PM report observations (2019 – present) uploaded as a .csv file named “sfccond\_reports\_YYYYMMDD.csv” where YYYYMMDD is the date of last update.

New PM reports are uploaded biweekly. This file will be updated every 6 months to keep it updated with the latest PM report responses. The variables included in these data files are listed in Table 2. An example of a PM report is provided in the Github repository as “PM\_Report\_Example.pdf” with the response choices for each variable.

* ARM ECOR datastreams – please see the linked ARM instrument/VAP webpages.

Tables and Figures

Table 1: Variables within the old PM report observations file with most reported responses.

|  |  |  |
| --- | --- | --- |
| **Variable name** | **Description** | **Most reported responses** |
| All sites | | |
| Name | Technician name |  |
| tvlA | Type of vegetation | Mostly clumped grass, Mostly uniform grass |
| tvlB | Type of vegetation | Derived from grazed grasslands, Native prairie |
| tvlC | Vegetation condition | 'Brown due to freezing conditions', 'Lush green, unwilted', 'Green w/brown patches because of hot, dry weather', 'Mostly brown due to hot, dry weather','Fully green but noticeably wilted' |
| tvlD | Surface soil conditions | 'Dry and dusty', 'Moist but not muddy', 'Muddy or standing water' |
| tvlE | Moisture on vegetation (or soil if no vegetation) | 'Dry', 'Slightly wet because of rain or dew', 'Mostly wet because of rain or dew' |
| hinside | Approximate height of vegetation inside fence |  |
| houtside | Approximate height of vegetation outside but near fence |  |
| Sites with Eddy Correlation (EC) Stations: | | |
| ecunan | Unanticipated vegetation condition | Yes, No |
| pasrg | Pasture or rangeland | Yes, No |
| ecvt2 | Type of vegetation | 'Derived from grazed grasslands', 'Native prairie', 'Forest Covered' |
| ecvt1 | Type of vegetation | 'Mostly clumped grass', 'Mostly uniform grass', 'Forest Covered', 'Woods' |
| mbs | Mostly bare soil | Yes, No |
| wwh | Winter wheat | Yes, No |
| wwhlst | Winter wheat condition | 'Green, ground covered','Partial soil coverage because plants are small','Stubble after harvest','Stubble mostly covered with green weeds after harvest','Yellow but unharvested' |
| rcrp | Row crops | Yes, No |
| rctyp | Row crop type | 'Alfalfa', 'Soybeans', 'Corn', 'Other Row Crop (see comments)','Sorghum', 'Milo' |
| rctyp1 | Row crop type | 'Green, ground covered', 'Only debris left after harvest','Yellow but unharvested', 'Partial soil coverage because plants small' |
| ecvcon | Vegetation condition | 'Lush green, unwilted', 'Brown due to freezing conditions','All or mostly bare soil', 'Mostly brown due to hot, dry weather','Green with brown patches because of hot, dry weather','Fully green but noticeably wilted' |
| ecsoil | Surface soil conditions | 'Dry and dusty', 'Moist but not muddy', 'Muddy or standing water' |
| ecmoist | Moisture on vegetation or soil | 'Dry', 'Slightly wet because of rain or dew', 'Mostly wet because of rain or dew', '0-25% snow covered' |
| echt | Approximate height of vegetation |  |
| Only at extended sites with EBBR stations | | |
| vhifmos | Vegetation inside fence is mostly | Grassy, Broadleaf |
| vhofmos | Vegetation outside fence is mostly | Grassy, Broadleaf |

Table 2: Variables within the new PM report observations file. The response choices for each variable are in the PM report example uploaded to the Github repository.

|  |  |
| --- | --- |
| **Variable Name** | **Description** |
| 'time' | Date and time |
| 'operators' | Technician name |
| 'instrumentClass' | Datastream name (“sfccond”) |
| 'siteFacilityCode' | Facility Code |
| 'reportId' | Report number |
| 'reportSiteCode' | Site Code (“sgp”) |
| 'reportFacilityCode' | Facility Code (e.g., E3) |
| 'reportInstrumentClass' | Datastream name (“sfccond”) |
| 'reportedOn' | Report date and time |
| 'reporterId' | Technician ID |
| 'reportStateCode' | State of report (New or Completed) |
| 'reportDataType' | “PMR” |
| 'reportFrequencyCode' | “BIWEEKLY” |
| 'reportKey' | Report key in “PM-YYYY-SS-FF-NN” where YYYY is year, SS is the site code, FF is facility code, NN is the report number |
| 'comments' | Additional comments |
| 'notifySiteOps' | Notify site operations (True or False) |
| 'notifyInstrumentMentor' | Notify instrument mentor (True or False) |
| For fenced areas containing SIROS, SMOS, and/or EBBR | |
| 'typeOfAreaSse' | Type of Area |
| ‘typeOfVegetationSse' | Type of Vegetation |
| 'vegetationConditionSse' | Vegetation Condition |
| 'moistureOnVegetationSse' | Moisture on Vegetation |
| ‘surfaceSoilConditionsSse' | Surface Soil Conditions |
| 'vegetationHeightInsideFenceSse' | Vegetation height inside fenced area |
| 'vegetationHeightOutsideFenceSse' | Vegetation height outside fenced area |
| Only for sites with Eddy Correlation (EC) stations | |
| 'unanticipatedVegetationConditionEc' | Unanticipated vegetation condition (Yes or No) |
| 'rowCropsEc' | Row Crops (Yes or No) |
| 'rowCropsTypeEc' | Row crop type |
| 'rowCropsConditionEc' | Row crop condition |
| 'winterWheatEc' | Winter Wheat (Yes or No) |
| 'winterWheatConditionEc' | Winter Wheat Condition |
| 'mostlyBareSoilEc' | Mostly Bare Soil (Yes or No) |
| 'vegetationHeightEc' | Approximate height of vegetation |
| 'pastureOrRangelandEc' | Pasture/Rangeland (Yes or No) |
| 'pastureOrRangelandGrassEc' | Condition of pasture/rangeland grass |
| 'pastureOrRangelandTypeEc' | Pasture/Rangeland type |
| 'vegetationConditionEc' | Vegetation Condition |
| 'surfaceSoilConditionsEc' | Surface soil condition |
| 'moistureOnVegetationSoilEc' | Moisture on Vegetation or soil |
| Only at extended sites with EBBR stations | |
| 'vegetationInsideFenceEbbr' | Vegetation type inside fenced area (EBBR) |
| 'vegetationOutsideFenceEbbr' | Vegetation type outside fenced area (EBBR) |

A graph with lines and dots

AI-generated content may be incorrect.

Figure 1: Latent heat flux and CO2 flux measurements at the SGP E37 facility as a function of the condition of winter wheat.

A graph showing different colored lines

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A graph showing different colored lines

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A graph showing the growth of a graph

AI-generated content may be incorrect.

Figure 2: Average latent heat flux at E3 (Leroy, OK) when Soybean was reported.

A graph showing a number of different colored lines

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Figure 3: Daily average latent heat flux across different years at all sites with Alfalfa.