Evaluation of Evapotranspiration Simulations from the U.S. National Agroecosystems Model using OpenET Data

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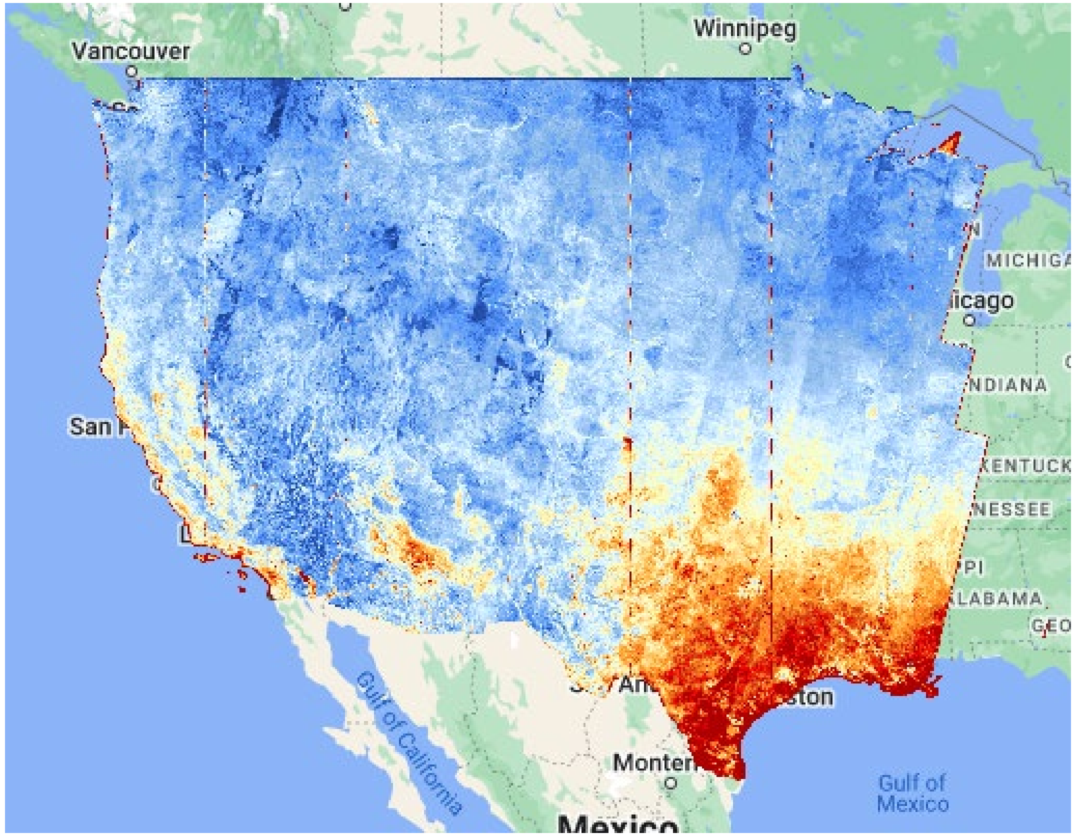
Introduction

- OpenET (https://etdata.org)
  - State-of-art satellite ET estimates for western CONUS
  - Ensemble of six ET estimation approaches
  - Monthly and annual data from 2016 to 2023
  - 30 m spatial resolution
  - Resolved to field scale
  - Access via Google Earth Engine
- National Agroecosystems Model (NAM)
  - National implementation of SWAT+ model
  - Resolved to field scale
    - 217,712 fields resolved in Texas
    - 1,760,166 fields in western CONUS
- Objectives
  - Use OpenET data to evaluate NAM ET simulations in Texas and the western CONUS
  - Use NAM to evaluate strategies for addressing regional water availability issues in western CONUS



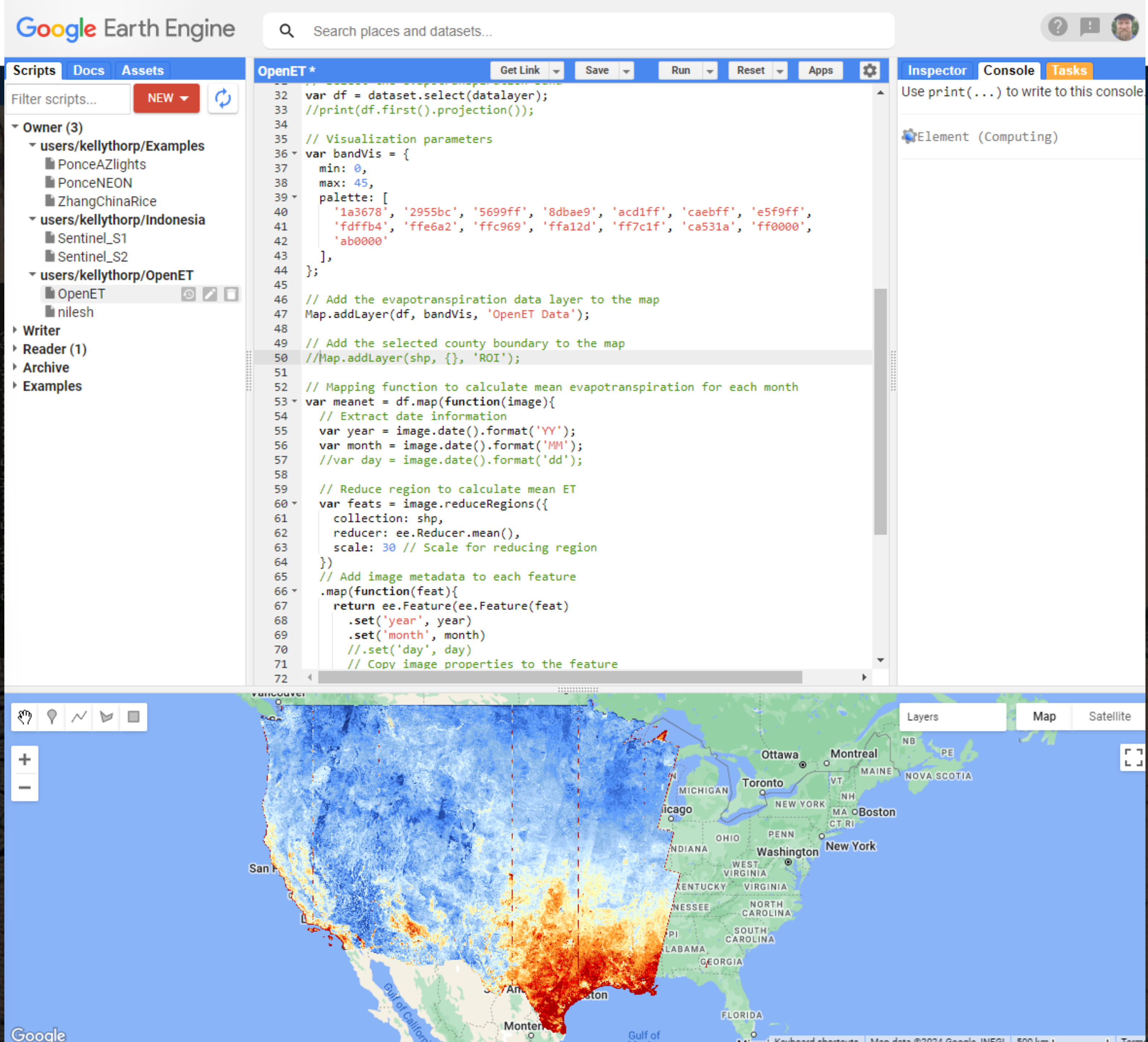
OpenET

- Source: https://etdata.org
- Goal is “transformative, timely ET data”
  - ET-based irrigation practices
  - Water trading programs
  - Surface and groundwater accounting
- Satellite and ground-based data sources
  - Landsat, Sentinel-2, GOES, etc.
  - Weather station network data
  - Field boundary and crop type datasets
  - Gridded data corrected for bias using 800 weather stations in ag area
- Six surface energy balance models
  - ALEXI/DisALEXI (M. Anderson, ARS)
  - eeMetric (Rick Allen)
  - geeSEBAL (W. Bastiaansen)
  - PT-JPL (NASA JPL)
  - SIMS (F. Melton, NASA)
  - SSEBop (G. Senay, USGS)
- Ensemble: Mean of all 6 models after outlier removal

Model Acronym	Model Name	Primary References
ALEXI/DisALEXI v 0.0.32	**At**mosphere-**L**and **Ex**change **I**nverse / **Dis**aggregation of the **A**tmosphere-**L**and **Ex**change **I**nverse	Anderson et al., 2007; Anderson et al., 2018;
eeMETRIC v 0.20.26	Google **E**arth **E**ngine implementation of the **M**apping **E**vapo**t**ranspiration at high **R**esolution with **I**nternalized **C**alibration model	Allen et al., 2007; Kilic et al., 2011; Allen et al., 2011
geeSEBAL v 0.2.2	**G**oogle **E**arth **E**ngine implementation of the **S**urface **E**nergy **B**alance **A**lgorithm for **L**and	Bastiaanssen et al., 1998; Laipelt et al., 2021
PT-JPL v 0.2.1	**P**riestley-**T**aylor **J**et **P**ropulsion **L**aboratory	Fisher et al., 2008
SIMS v 0.1.0	**S**atellite **I**rrigation **M**anagement **S**upport	Melton et al., 2012; Pereira et al., 2020
SSEBop v 0.2.6	**Op**erational **S**implified **S**urface **E**nergy **B**alance	Senay et al., 2013; Senay et al., 2018

OpenET Data

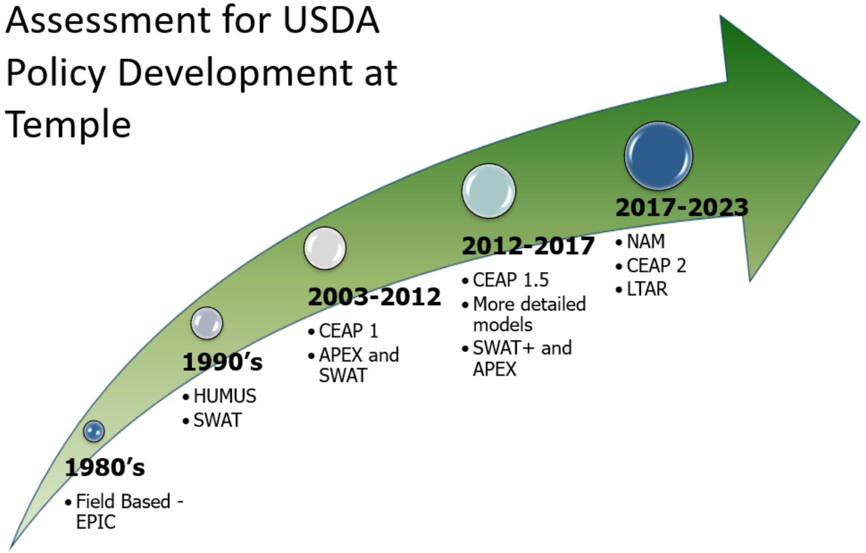
- Data Explorer
  - 30 m resolution ET data
  - Field-scale
  - Arizona example
- Google Earth Engine
  - Python code editor
  - Automate data retrieval
  - Load shapefiles with features of interest as “assets” in GEE
  - Write script to retrieve ET data to Google Drive



National Agroecosystems Model (NAM)

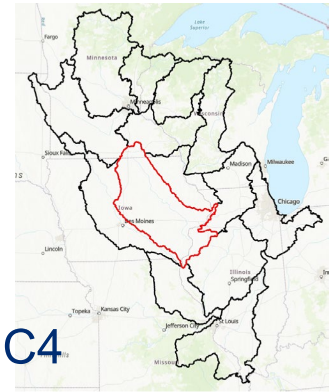
- SWAT+ modeling framework for CONUS
  - Assessment of conservation practices (CEAP)
  - Environmental impact from agriculture
  - Evaluation of land use change
  - Management of water resources
  - Studying impacts of climate uncertainty
- Incorporates field-scale and stream processes
- Based on USGS Hydrologic Unit Code (HUC) system
  - Individual SWAT+ models for each HUC8 (2121 basins)
  - Subbasins at HUC12 scale (65,000 basins)
  - Individual fields incorporated as hydrologic response units (HRU)

History of Conservation Assessment for USDA Policy Development at Temple

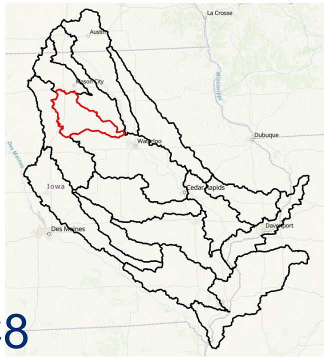


HUC2

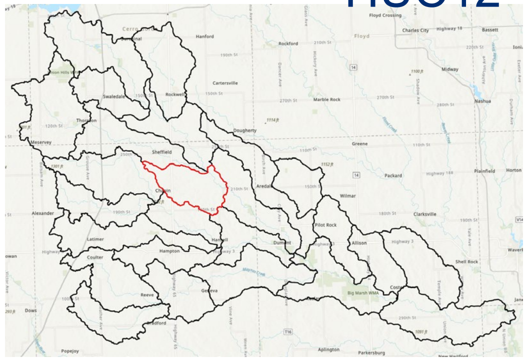
HUC4



HUC8



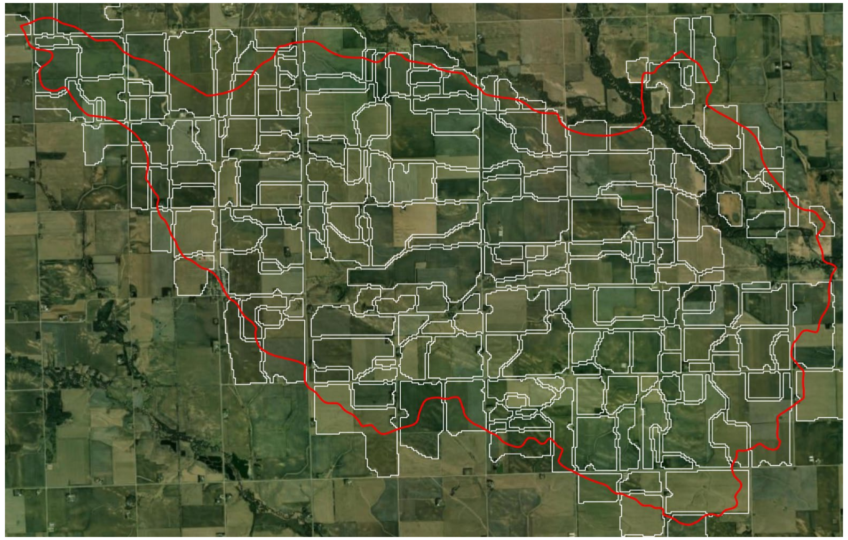
HUC12



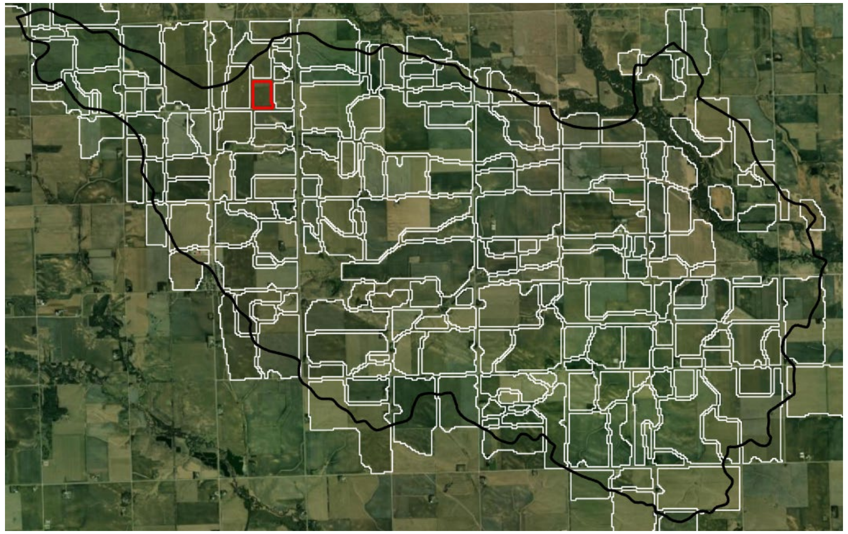
National Agroecosystems Model (NAM)

- National field boundary maps
  - Yan and Roy (2016) Landsat approach
  - Provides unique IDs (FUID) and field geometries
  - 4.5 million fields in CONUS
  - Simulation of upland processes begin at field scale

HUC12: 070802040401



FUID: 1277645001



HRU_ID = 1484863
FUID = 1277645001
1% Slope
Soil = Dinsdale
Corn-Soybean rotation
Tiled
Not Irrigated

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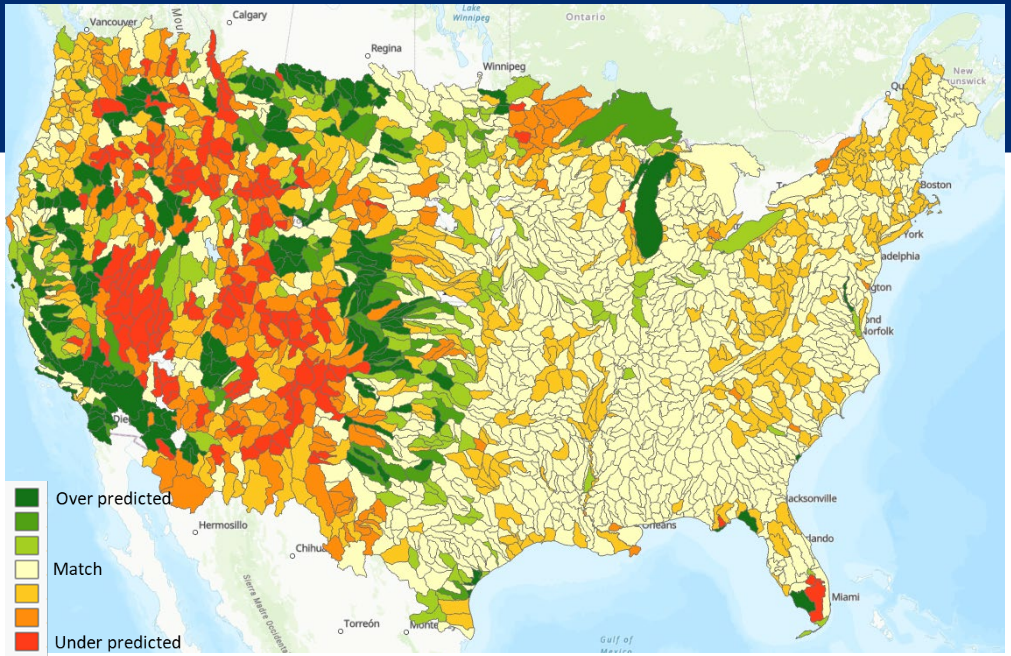
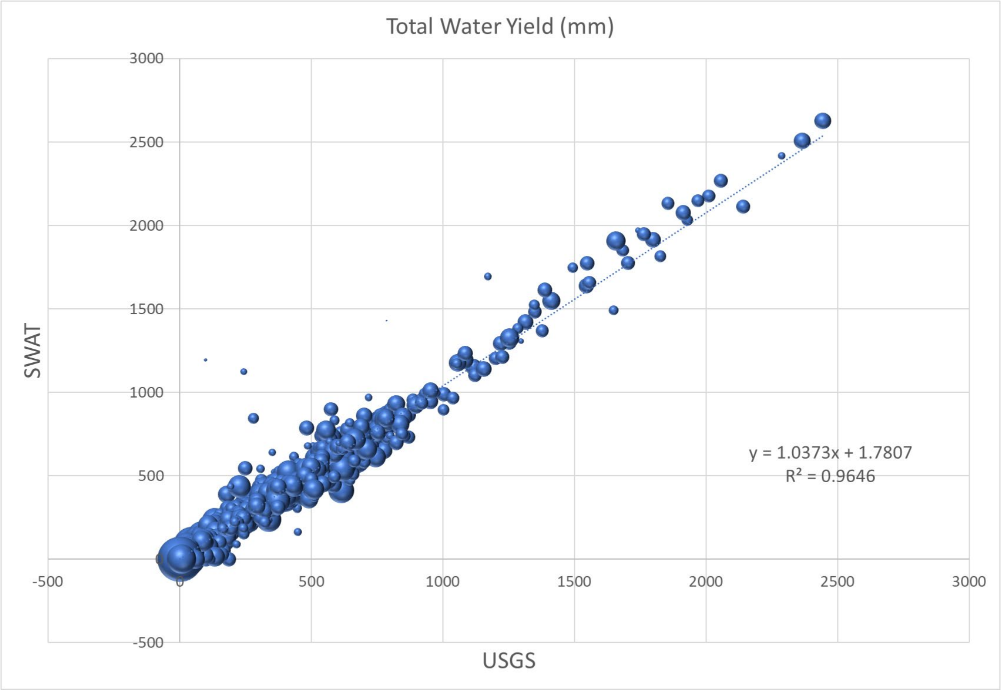
NAM Runs and Calibration

- Running the model
  - ~8 wall-clock hours on HPC
  - Break runs into 2121 HUC8 basins
  - Some basins run asynchronously
  - Others require synchronous execution
  - No routing required for upland processes
- Ongoing, long-term calibration effort
  - Water yield and stream flow
  - Nutrient and sediment loads
  - Corn and soybean yield
  - ET with limited USGS data (Rietz et al 2017)
    - Poor water yield in western CONUS
    - OpenET data can help improve model



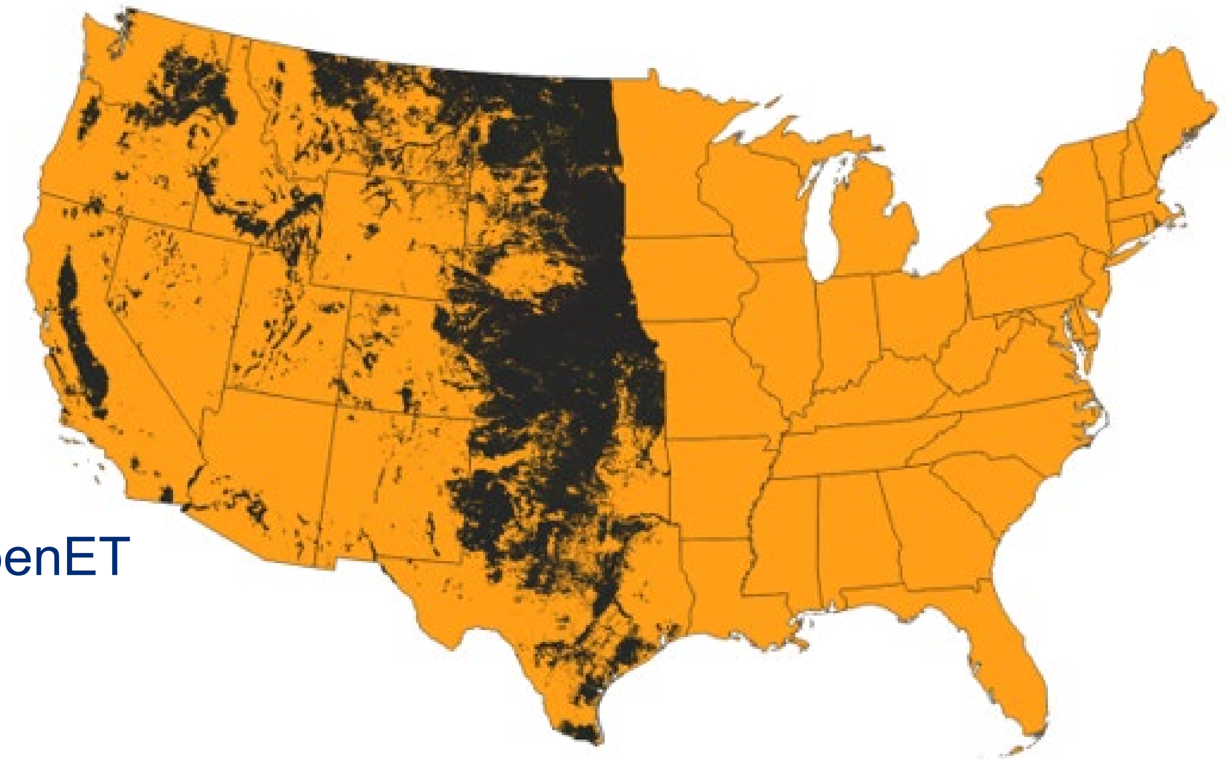


SWAT+ Evapotranspiration

- 3 potential (i.e., maximum) ET methods
  - Priestley-Taylor
  - Penman-Montieth (resistance terms for 40 cm alfalfa)
  - Hargreaves and Samani (1985)
    - $ET_{max} = 0.0023 \times ra \times (T_{avg} + 17.8) \times SQRT(T_{max}-T_{min})$
    - NAM simulations use this equation.
- NAM weather inputs
  - Eastern US
    - Weather station data at HUC12 scale
    - Interpolation for HUC12's with no station
  - Western US
    - Limited weather stations
    - Nexrad data for precipitation
    - Prism data for temperature
    - At centroid of HUC12

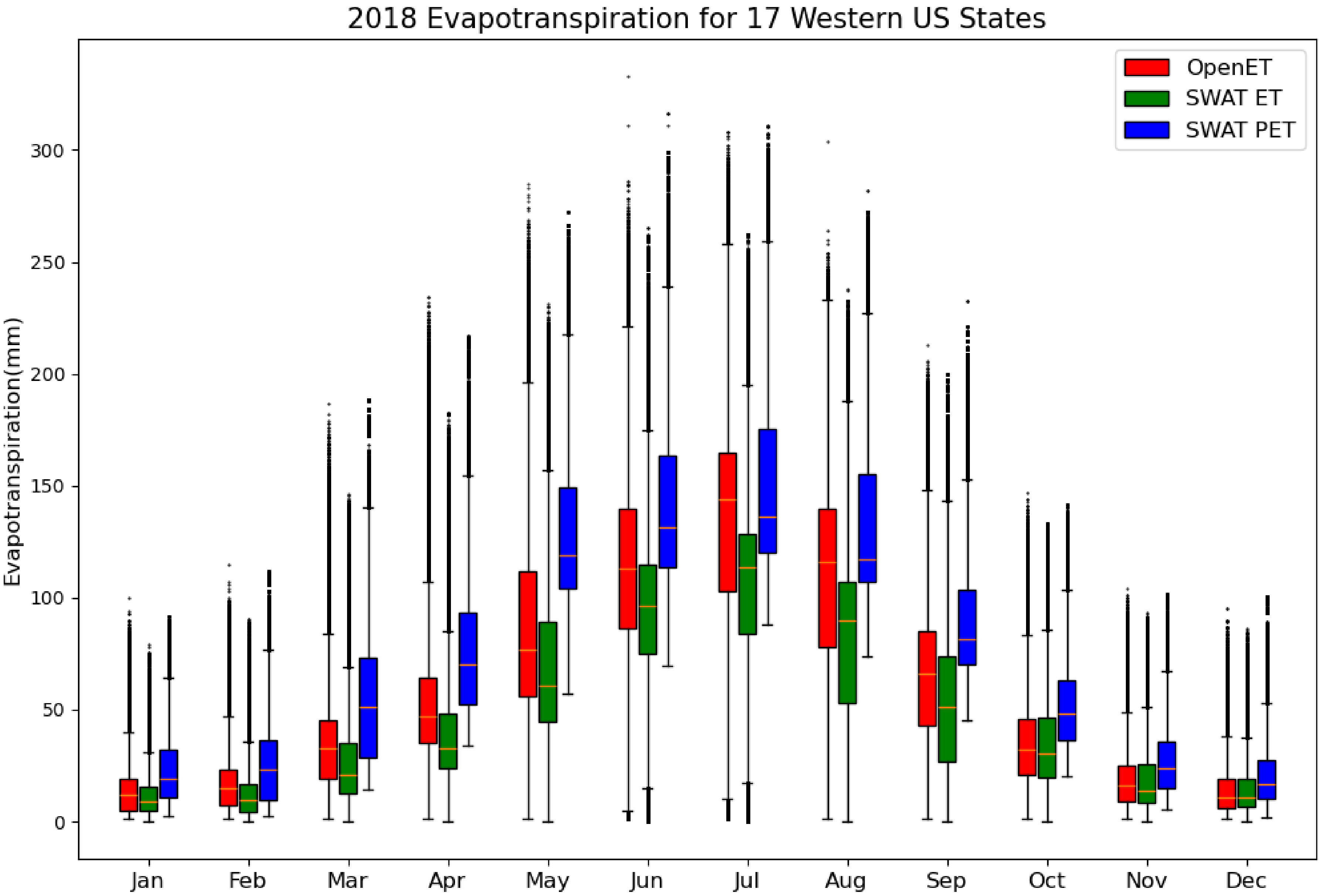
Methodology

- Use NAM field boundary shapefiles
  - Yan and Roy (2016) Landsat method
  - Partition data by 17 western US states
  - Compute centroid of each field
  - Load shapefiles to Google Earth Engine
  - Obtain monthly ensemble ET data from OpenET
- Use latest calibrated NAM model
  - Pull monthly water balance output
  - Extract potential (maximum) simulated ET
  - Extract actual simulated ET
- Focus on years 2016 through 2018



Results

- 2016, 2017, 2018
- Field scale ET
- 17 western states
- Underestimated actual ET
- Potential (maximum) ET is sufficient
- Suggests a supply side issue
    - Inadequate irrigation
    - Inadequate precip



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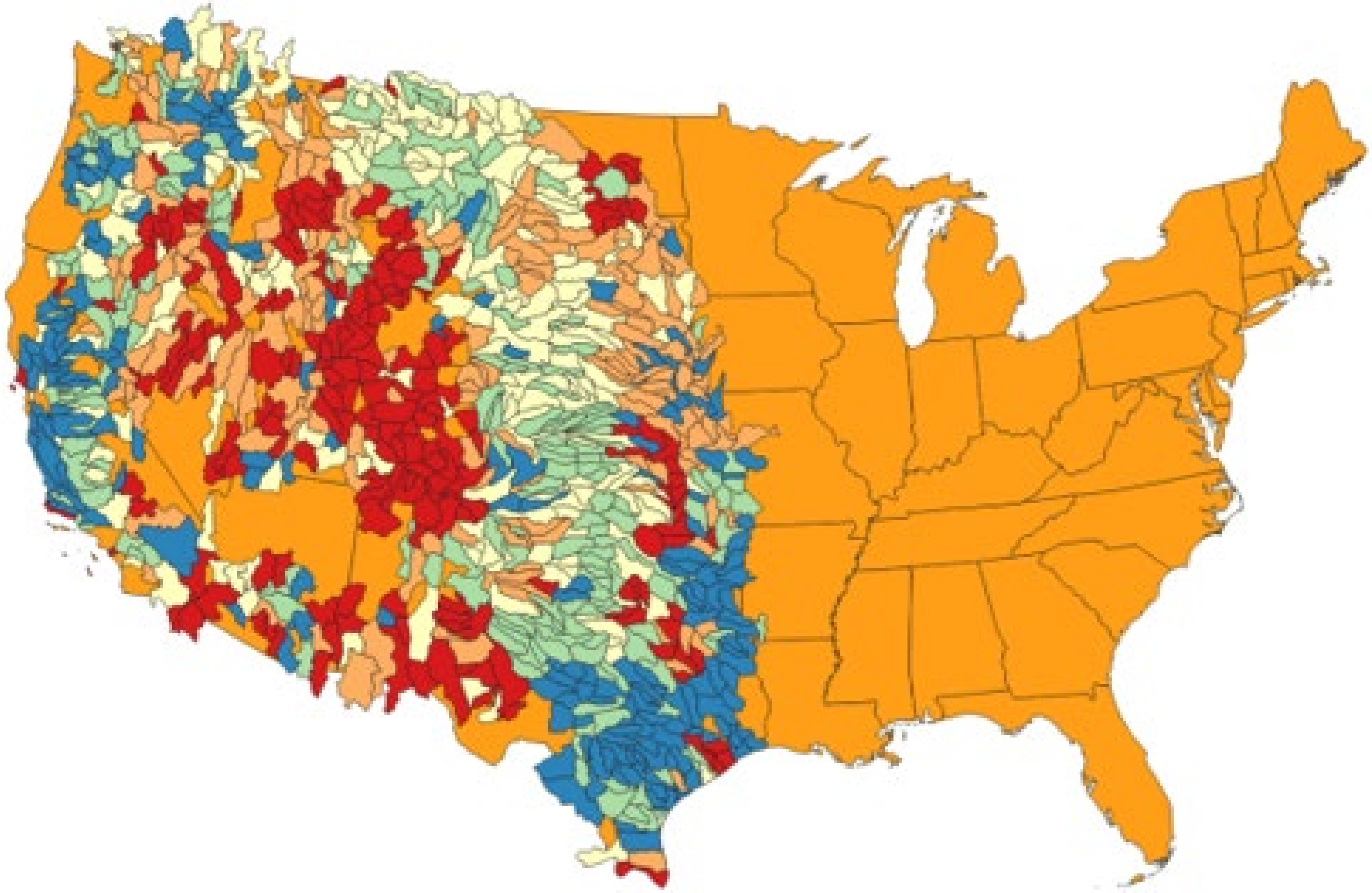
Spatial Error

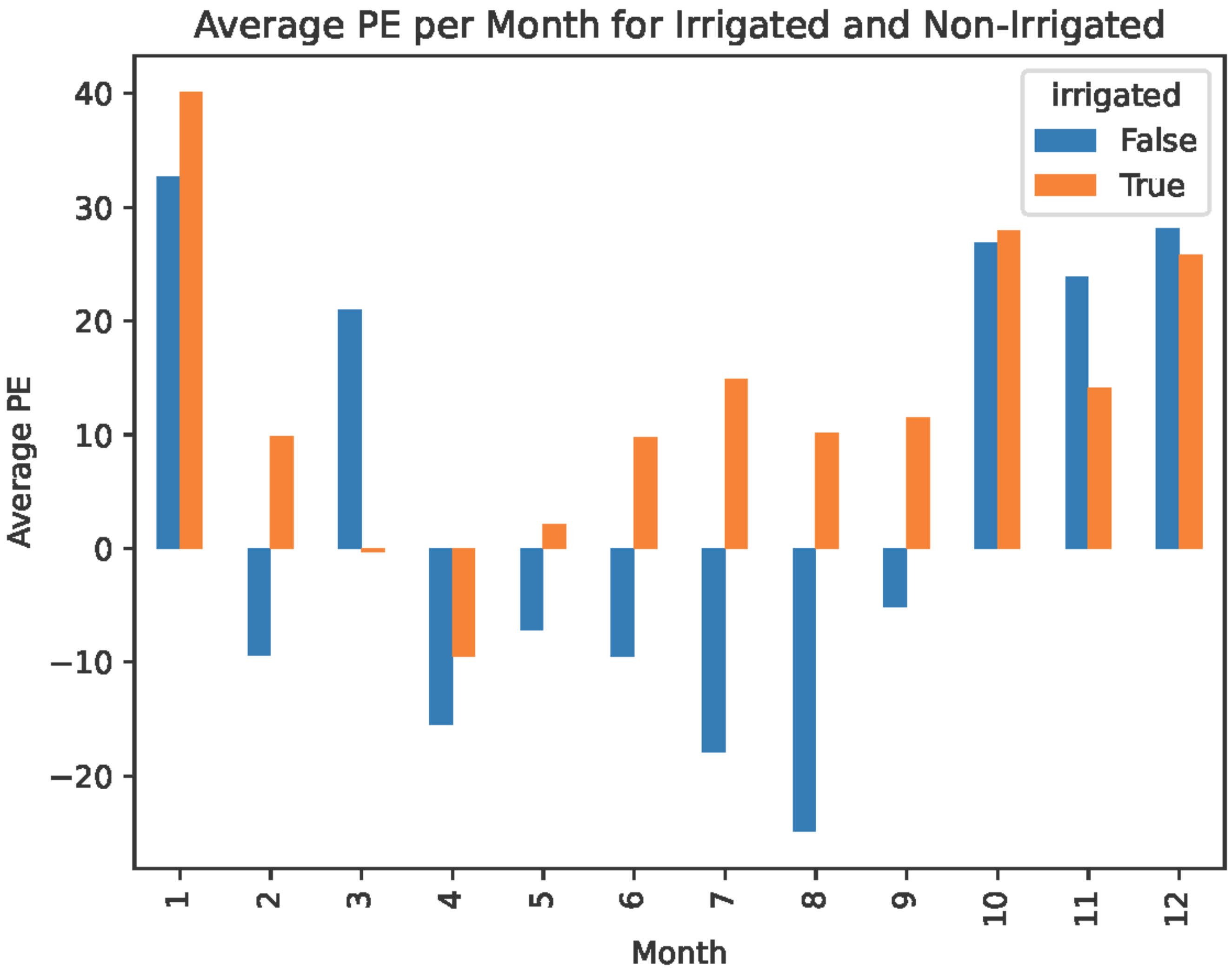
- Median percent error for ET at HUC8 and HUC12 scale
- Red: Underestimated ET
- Green: Reasonable ET
- Blue: Overestimated ET
- There are spatial patterns.
- Can use to improve model.



Symbol	Values	Legend
	-84.04 - -31.83	-84 - -32
	-31.83 - -21.89	-32 - -22
	-21.89 - -9.70	-22 - -10
	-9.70 - 2.90	-10 - 3
	2.90 - 107.74	3 - 108

Rainfed vs Irrigated

- Percent error for monthly ET
  - Orange: Irrigated
  - Blue: Rainfed
  - 2016, 2017, 2018
- Irrigated: Overestimated ET
- Rainfed: Underestimated ET
- Can look at improvements to rainfall data and irrigation decision criteria.



Future Work

- Lots of opportunity for building on
  - QA/QC of weather data
    - Assess deviation from reference conditions using FAO56 guidelines
    - Consider alternative weather data sources
  - Incorporation of ASCE standardized reference ET algorithm into SWAT+
    - Include adjustment from reference ET to maximum ET based on simulated LAI
    - Obtain standardized reference ET estimates from OpenET for comparison
  - Retrieve OpenET data at difference scales
    - Within field boundaries versus at field centroids
    - Within HUC12 boundaries versus at HUC12 centroids
    - OpenET data HUC12 scale allows assessment for non-ag area
    - Patiently wait for OpenET to expand to eastern CONUS
  - Improve parameterization for irrigation in the western US
- Post-doc opportunities on SWAT+ and NAM at Temple
  - Implementation of SWAT+ NAM on SCINet HPC infrastructure (ARS computing cluster)
  - Evaluating upland management practices on crop production vs environmental impact

Thank you for your attention!

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