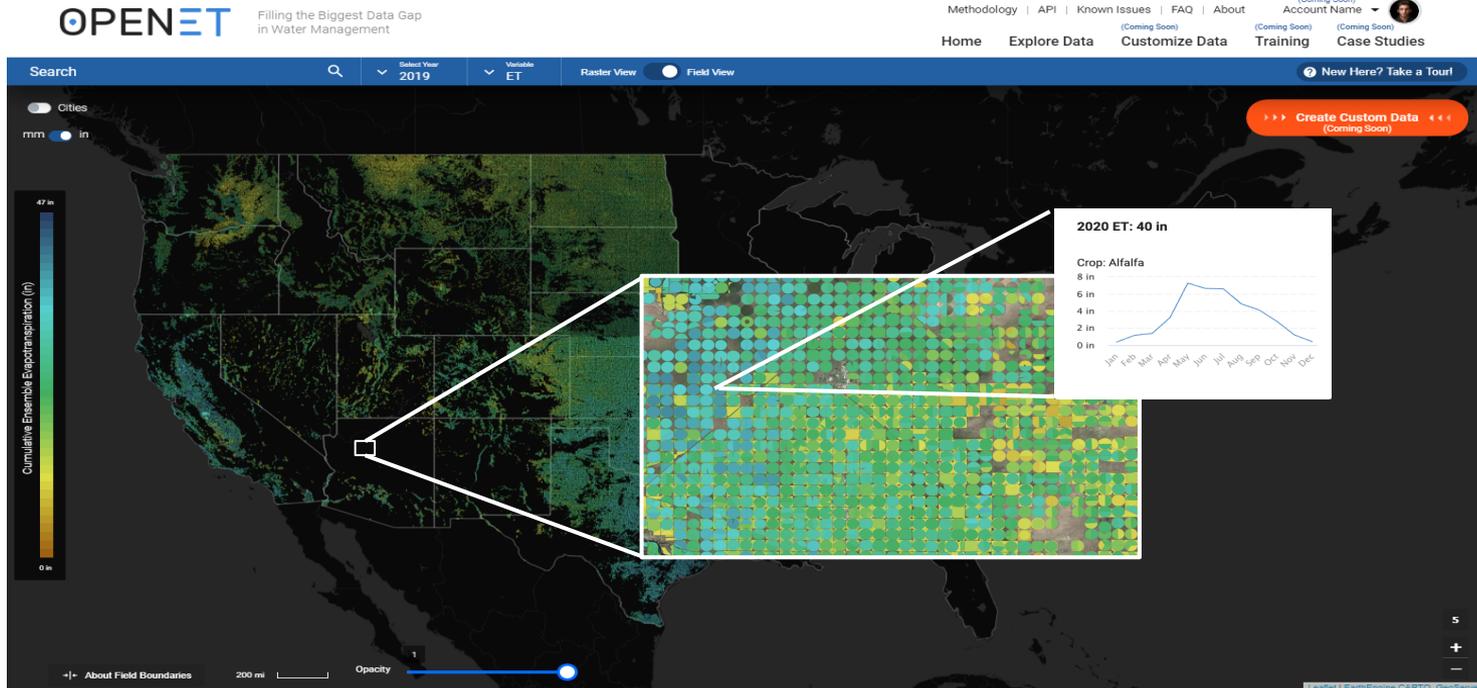


OPENET

Satellite-based ET Intercomparisons with Ground-based Measurements: Phase II Results



The OPENET Team

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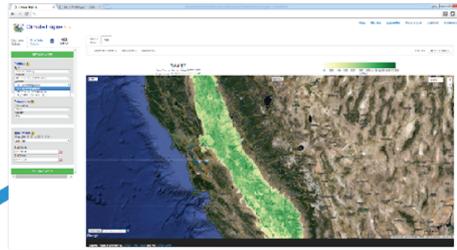
USGS (SSEBop) Gabriel Senay, MacKenzie Friedrichs, Gabriel Parrish

Universidade Federal do Rio Grande do Sul (SEBAL) Anderson Ruhoff

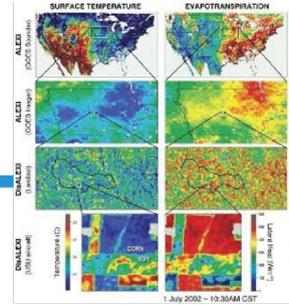
Google Earth Engine Tyler Erickson



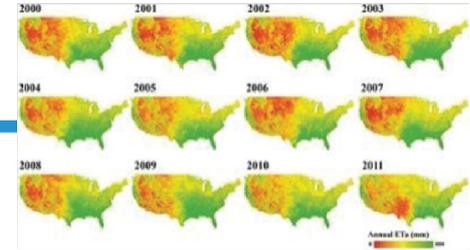
OpenET Uses Well-Established Methods



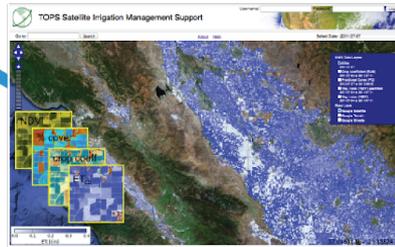
EE METRIC
University of Nebraska,
University of Idaho



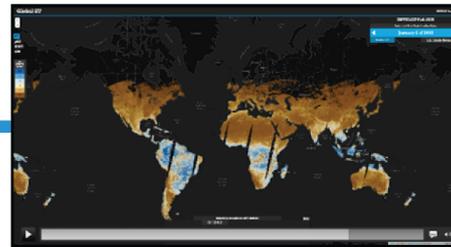
ALEXI/DisALEXI
USDA, NASA, University of Maryland,
University of Wisconsin



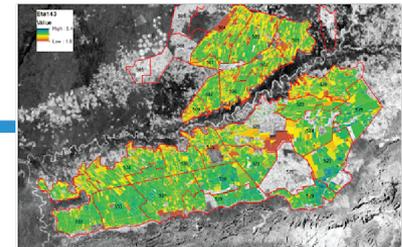
SSEBop
USGS



SIMS
NASA, CSUMB, Stanford University



PT-JPL
NASA

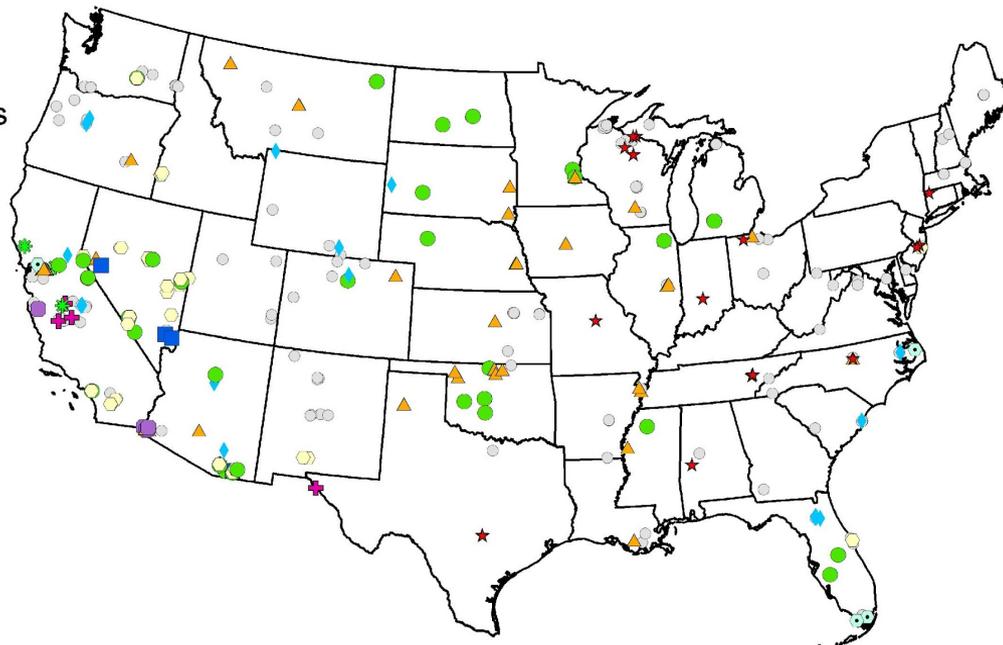


SEBAL

Developing a Benchmark ET Dataset From Eddy Flux Towers

Site Landcover

- ▲ Annual crops
- ◆ Evergreen Forests
- Grasslands
- ★ Mixed Forests
- ✚ Orchards
- Riparian
- Shrublands
- Vegetable crops
- ✱ Vineyards
- ⊙ Wetlands
- Filtered Sites



Phase I comparison 70 flux tower sites; 24 ag. sites
Phase II comparison for 142 flux tower sites; 70 ag.
33 sites held out for blind model evaluation

Flux Data Processing and Energy Balance Correction

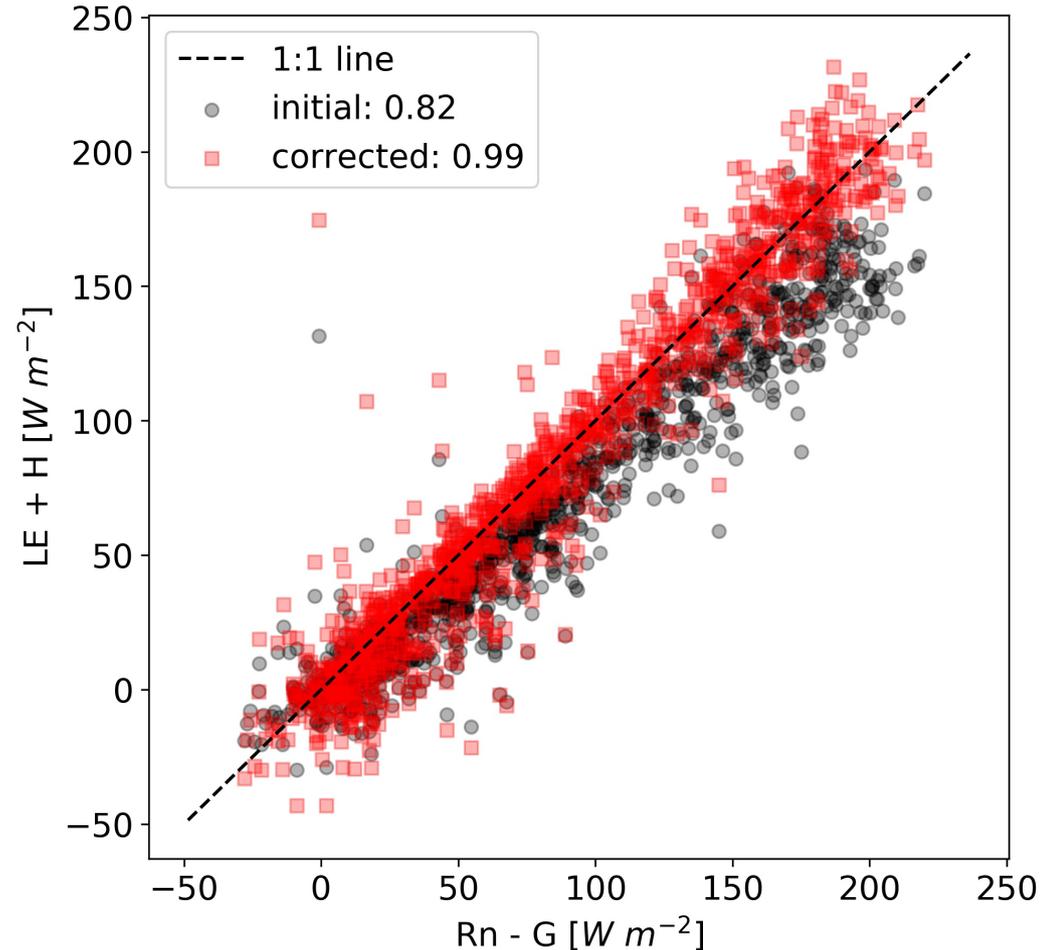
Gap-filling half-hourly energy balance components LE, H, Rn, and G, filling up to 2 hours during the daytime and 4 at night, then take daily average.

Energy balance closure correction that uses the median of daily energy balance ratios $(Rn-G)/(LE+H)$ over sliding windows to correct daily LE using the inverse of the ratio. Based from the FLUXNET2015 method (Pasterello et al., 2020).

Daily gap-filling ET with interpolated ET_{oF} x gridMET ET_o (Abatzoglou, 2013)

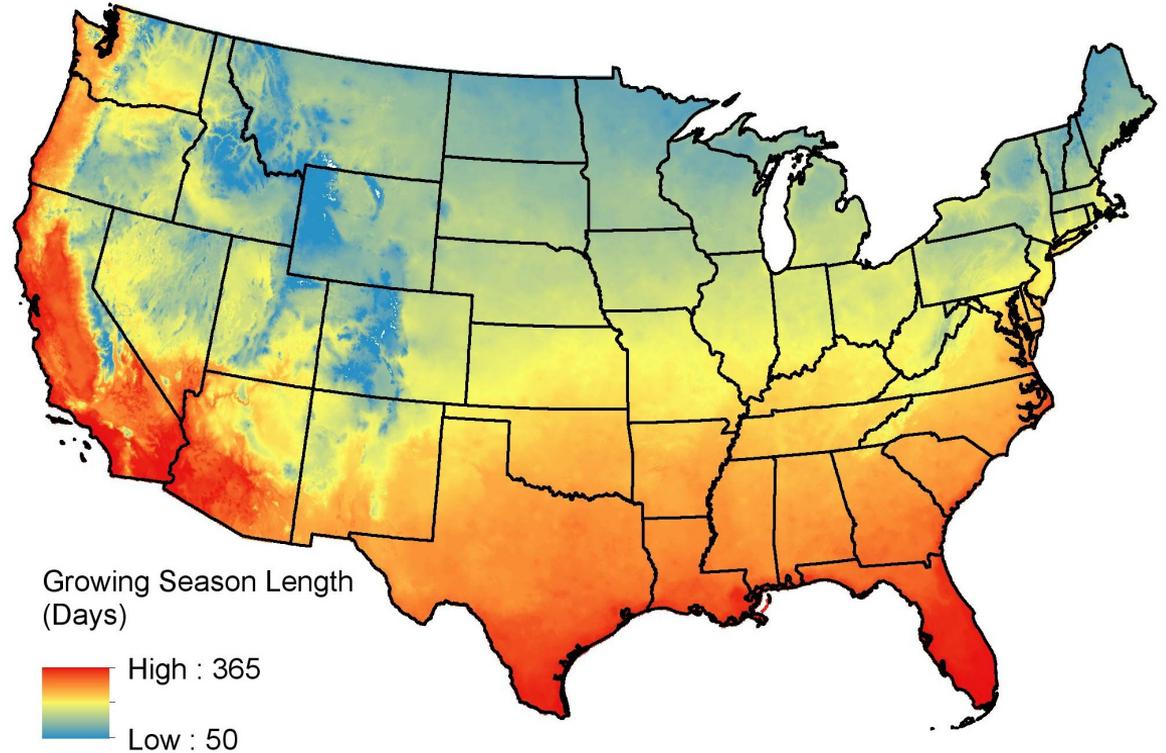
Reproducible methods using the “flux-data-qaqc” Python package (Volk et al., 2021)

Visual QA/QC and data filtering

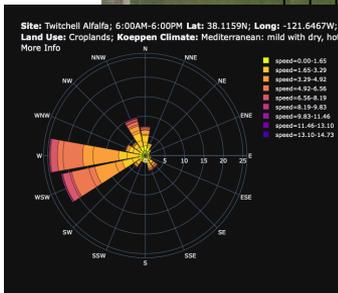
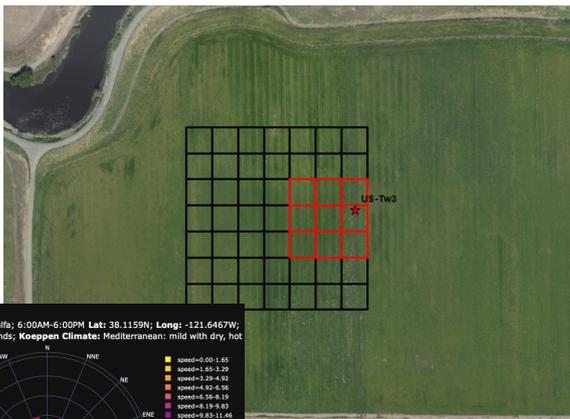


Benchmark ET Dataset Screening Criteria

- 300 deg. C cumulative growing degree day, -2 C killing frost temperatures using ~40 years of data to define growing seasons
- Growing season closure > 75%
- Cold season closure > 60%
- No gap filled daily ET or monthly ET with > 5 gap-filled days

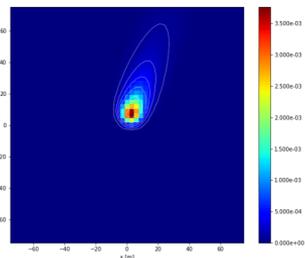


Flux Footprint Generation for Sampling of RSET Pixels

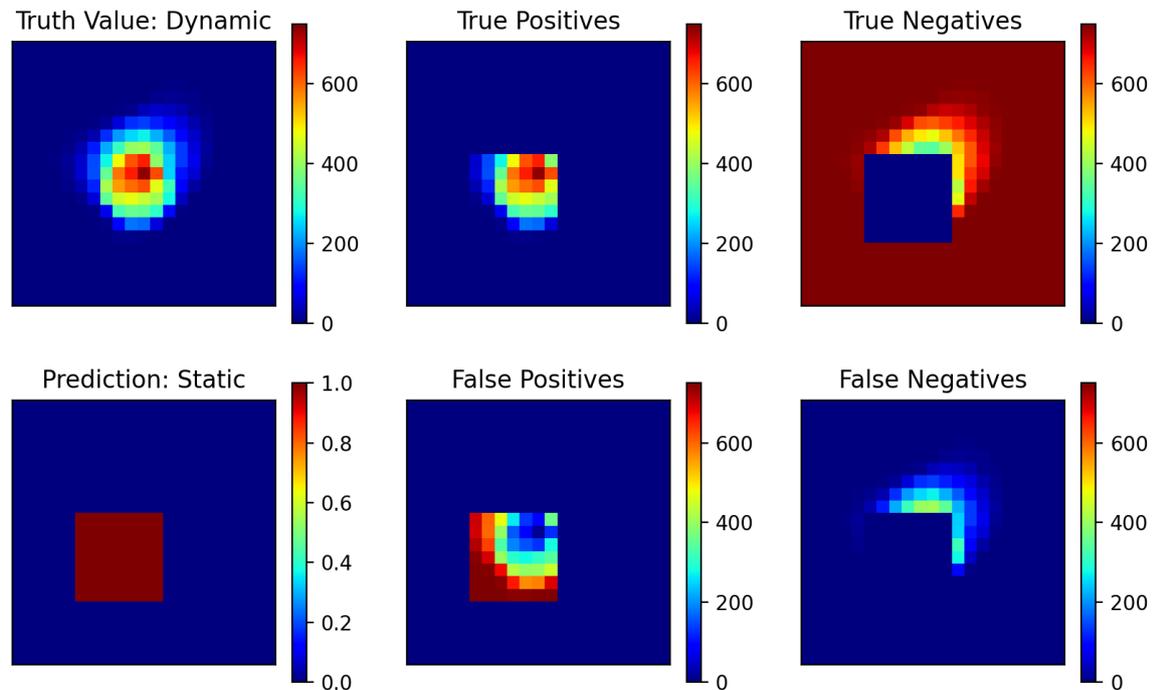


Review of sites and wind roses to ensure sufficient homogeneity and upwind fetch

Dynamic half-hourly footprint analysis following Kljun et al. (2015); example for celery field in Soledad, CA



US-GMF 7 x 7 Tower Footprint Confusion Matrix



Statistical Methods For Comparing Models to Ground Data

Grouped weighted mean statistics

$$STAT_{land} = \frac{\sum \sqrt{n_i} \cdot X_i}{\sum \sqrt{n_i}}$$

Where X_i is the statistic and n_i is the number of paired ET values for the i^{th} site.

Key summary statistics

Slope: of linear regression through origin

MBE: mean bias error

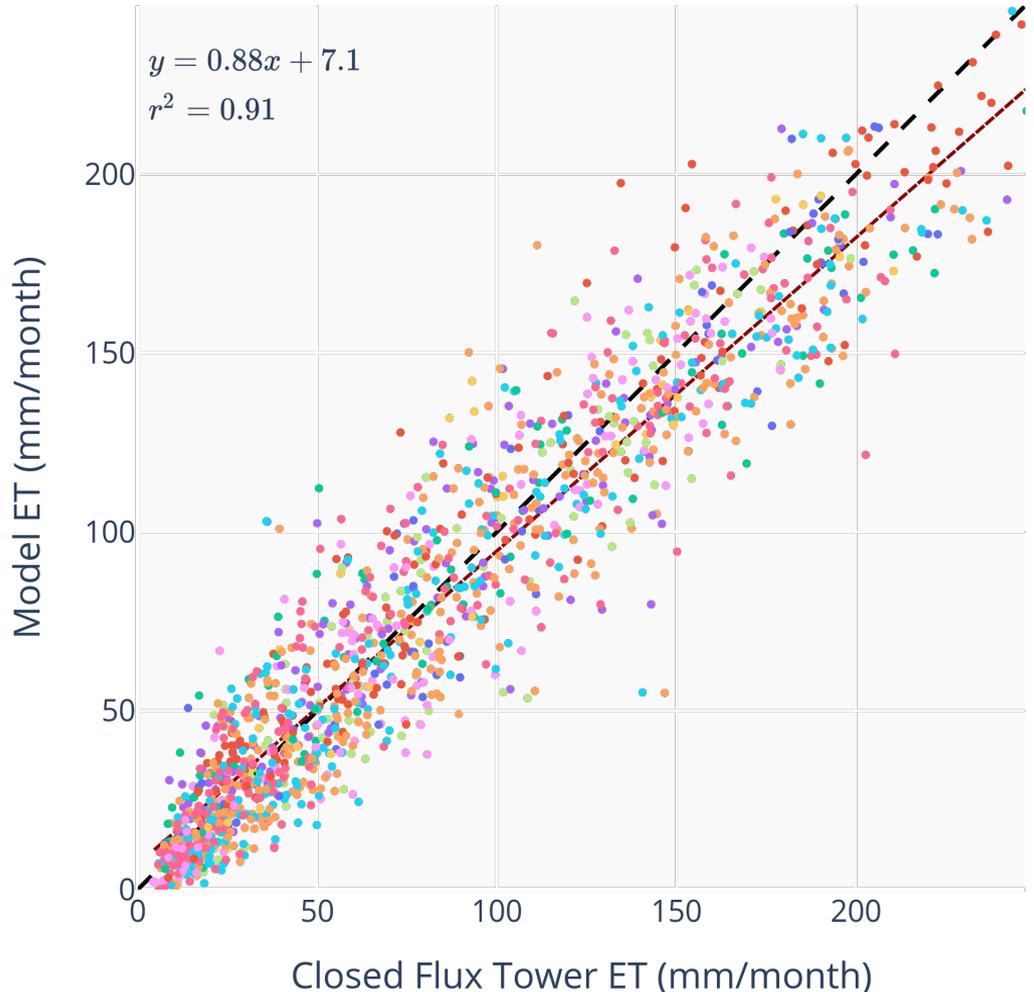
MAE: mean absolute error

RMSE: root mean square error

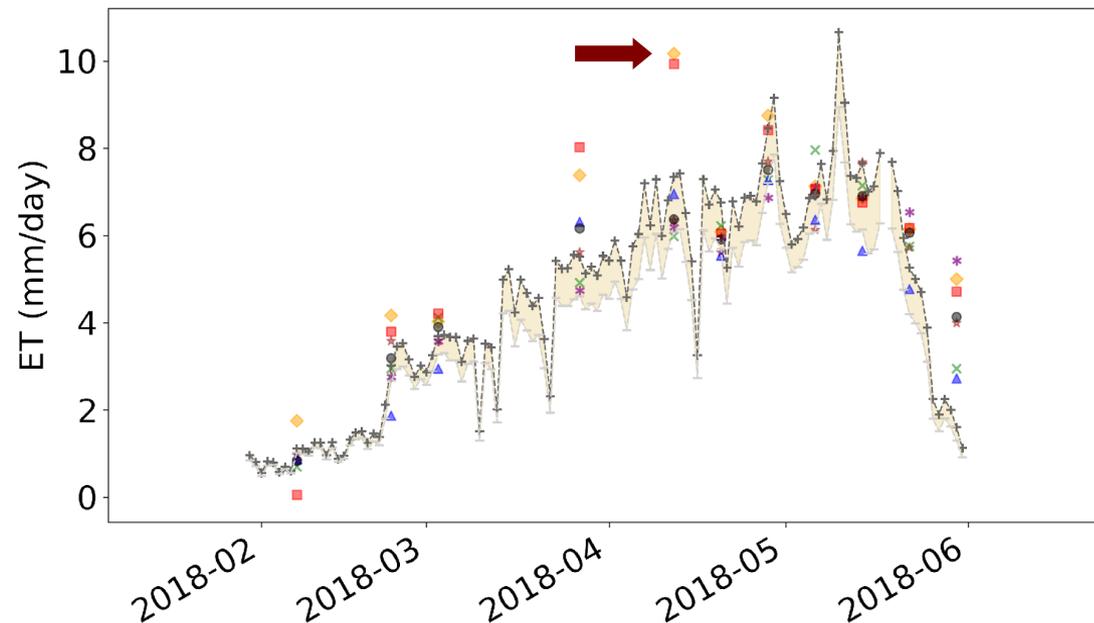
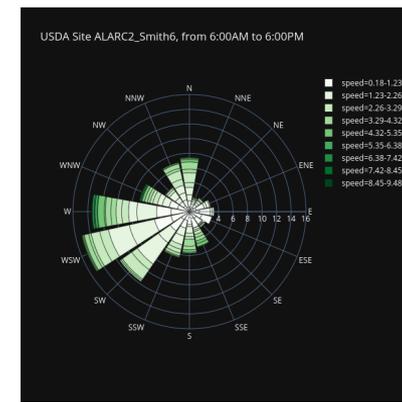
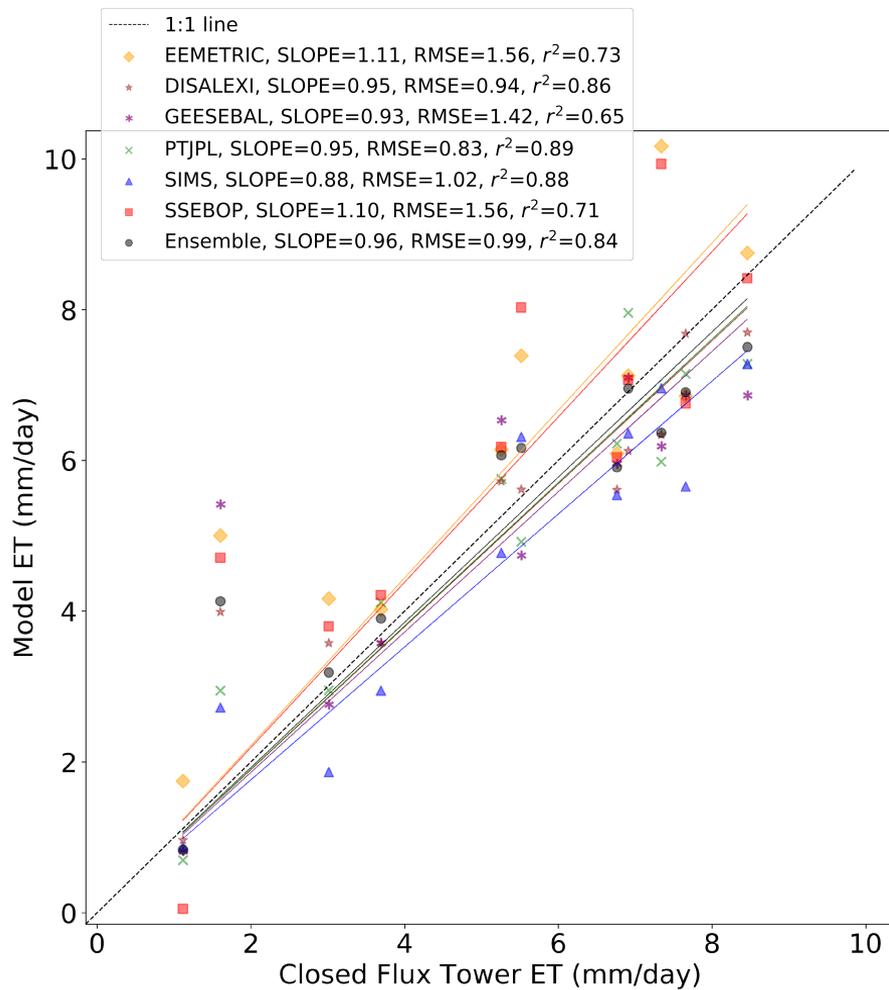
r^2 : coefficient of determination (not weighted)

Minimum of 6 days and 3 months of paired data per site for grouped statistics.

Ensemble, croplands sites



Example Comparison: Arizona Wheat



Model Ensemble: Median Absolute Deviation (MAD) Outlier Detection

$$MAD = 2 \cdot \text{median}(|X_i - \text{median}(X)|)$$

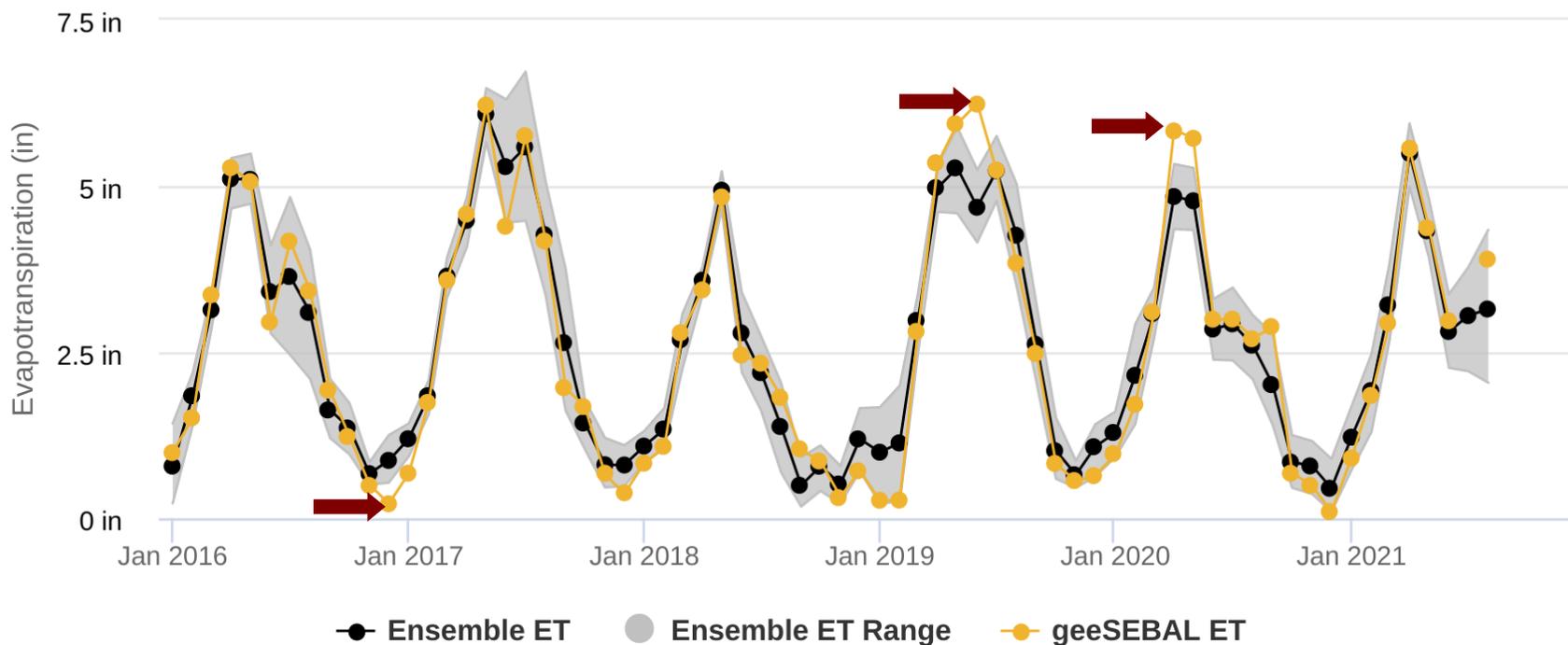
Ensemble ET range:

$$\text{median}(X) + MAD > ET > \text{median}(X) - MAD$$

Average ET within range
keeping at least 4 models.

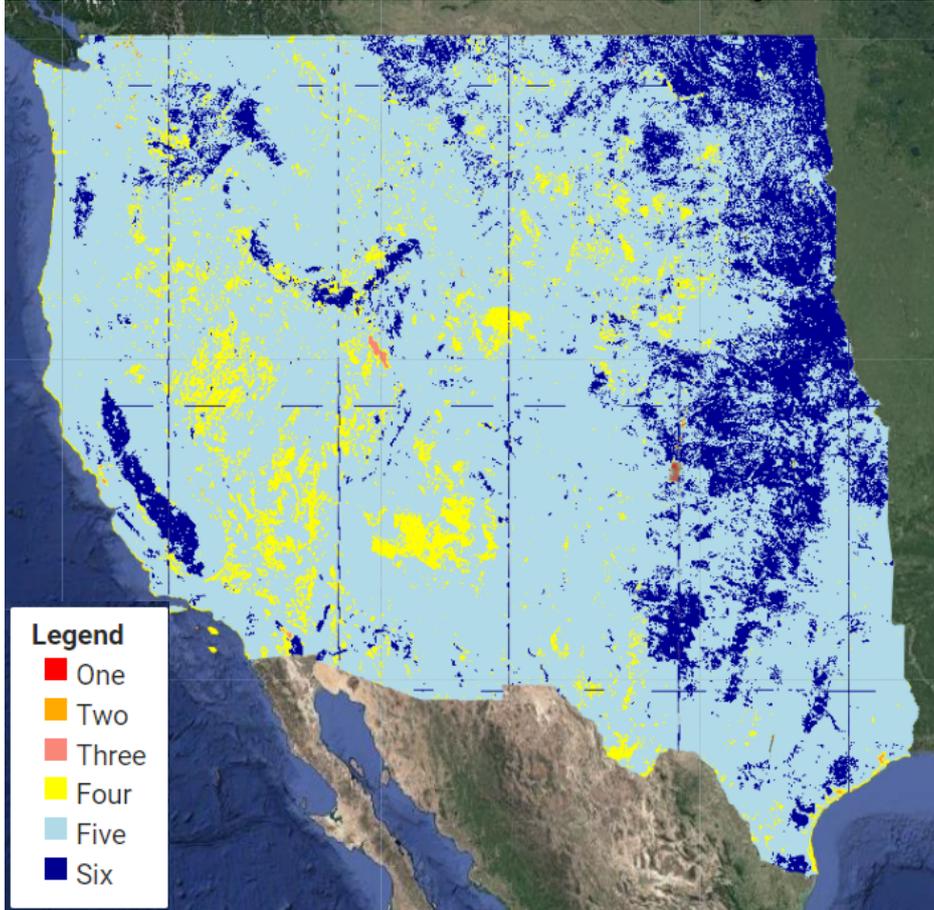
Evapotranspiration

 Download Data

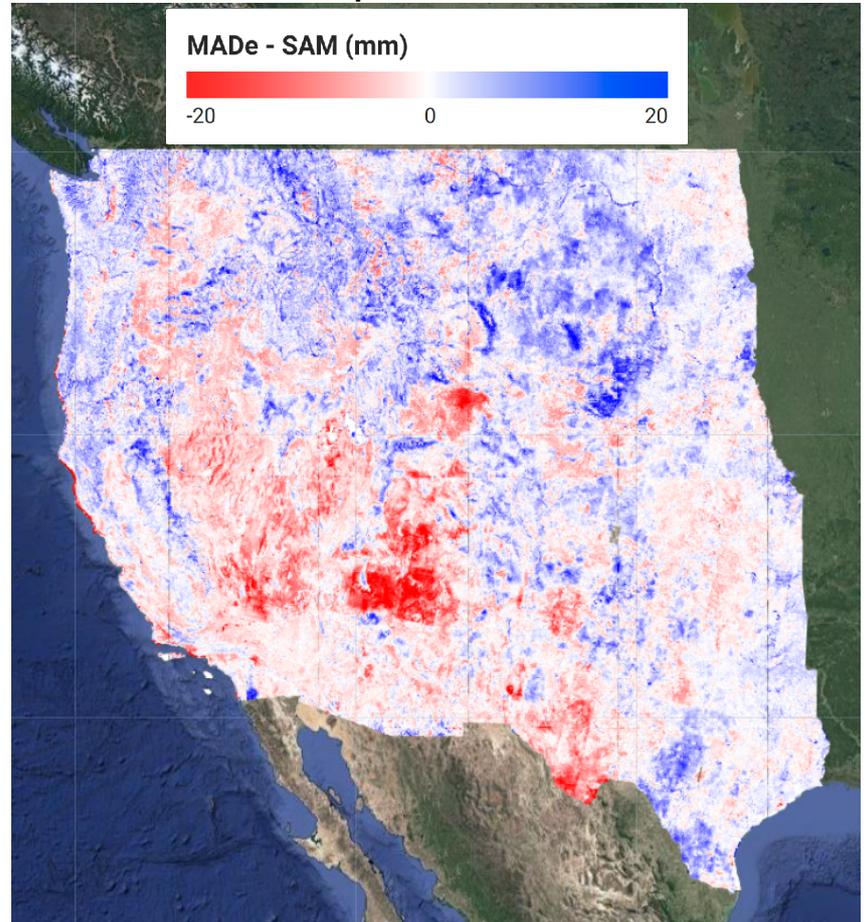


Mapping Ensemble Outliers and Deviation from Simple Mean

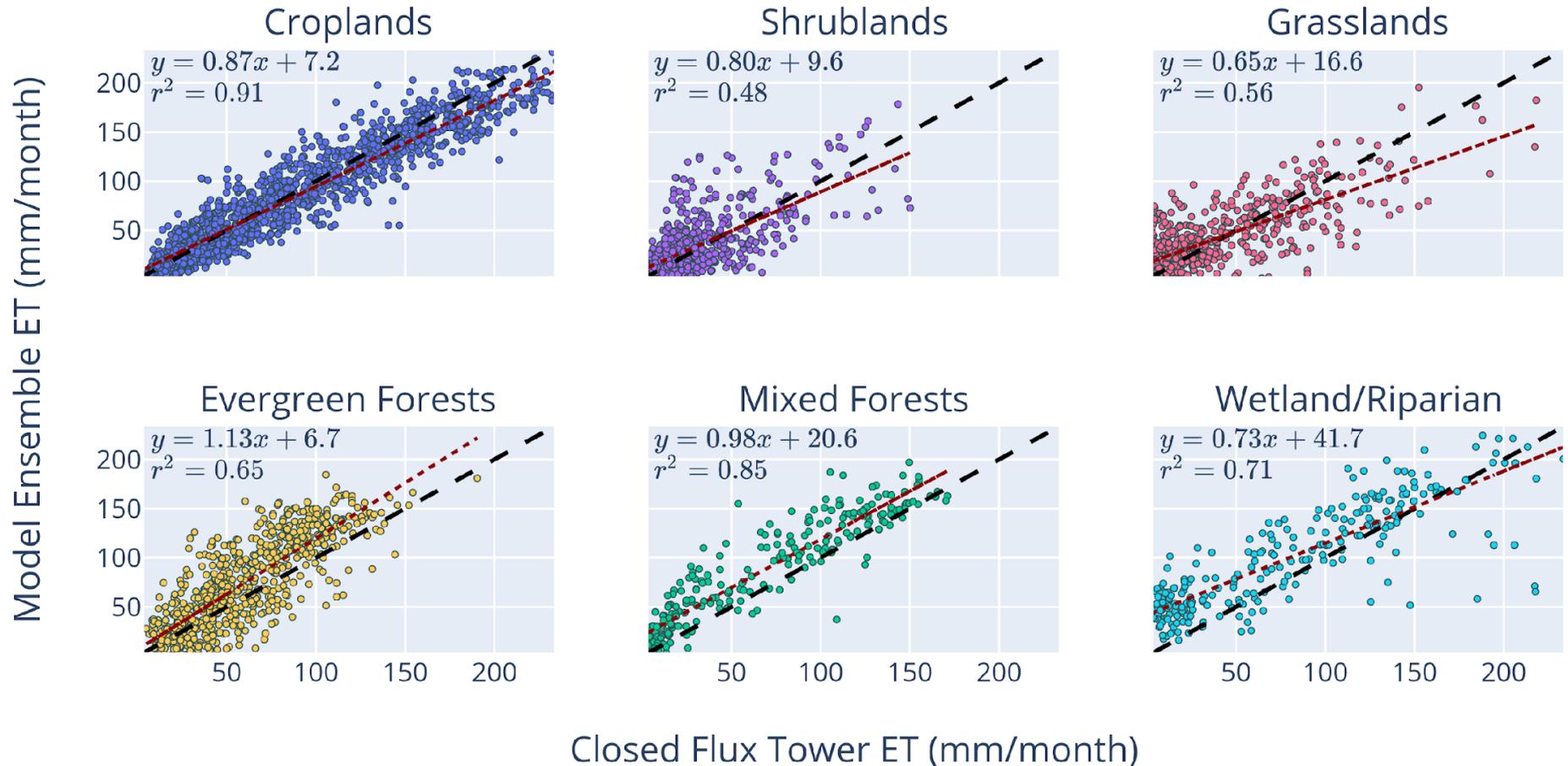
Model count in MAD ensemble, July 2020



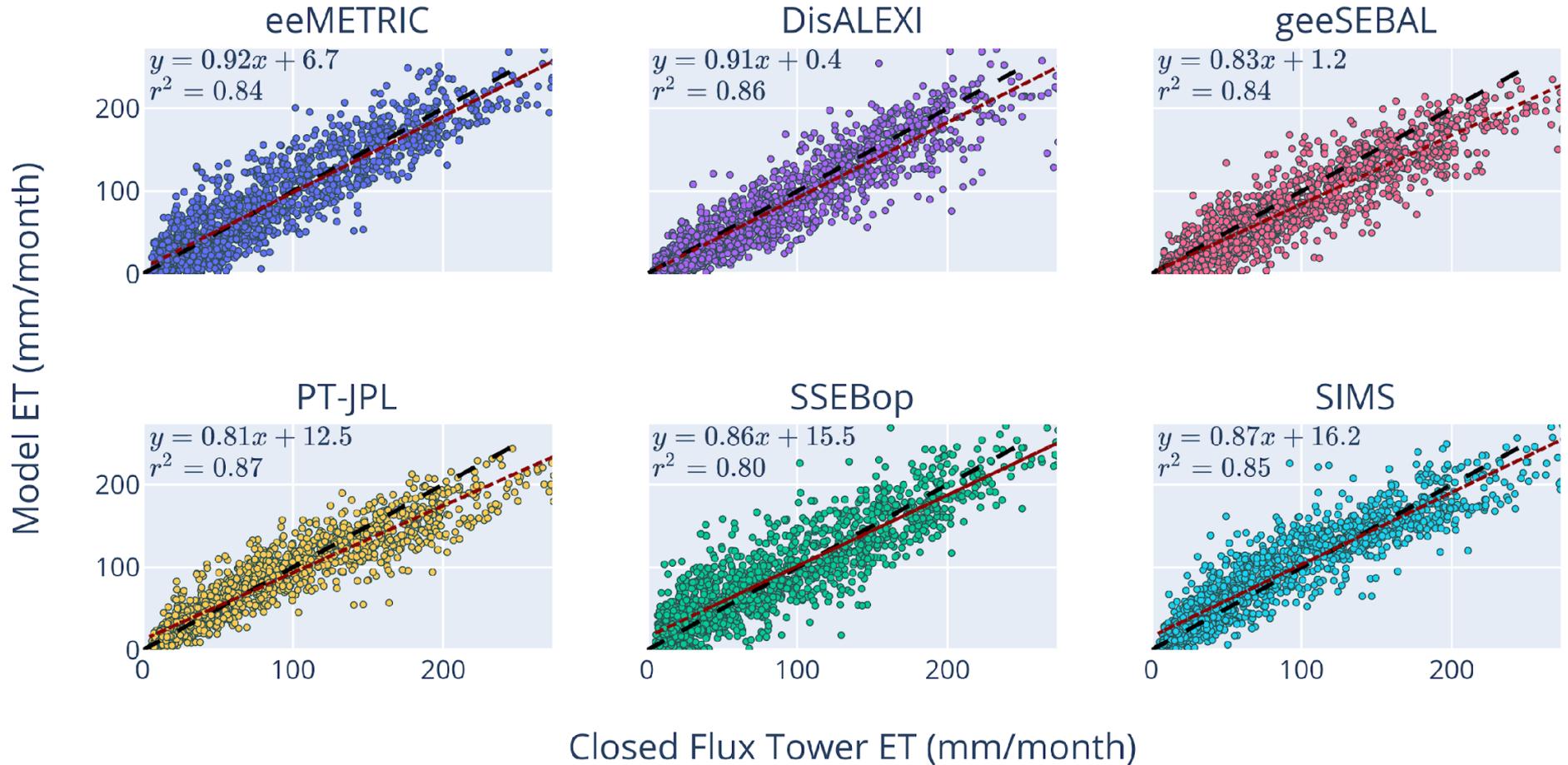
MAD minus simple mean ensemble



Ensemble ET based on Site Land Cover, Monthly ET



Model Comparison Across Cropland Sites, Monthly ET



Accuracy Results and Goals from the User Community

Croplands summary statistics for the phase II intercomparison.

Goals for error relative to closed flux ET, RMSE and MAE: 15-25% (daily); 15-20% (monthly); 10-15% (growing season)

Monthly	Statistic	Ensemble	Model Range
45 sites N = 1682 months Mean closed ET is 93.68 (mm)	Slope	0.95	0.86—1.04
	MBE (mm)	-3.64 (3.9%)	-13.77—5.16 (-14.7—5.5%)
	MAE (mm)	15.55 (16.6%)	17.96—22.92 (19.2—24.5%)
	RMSE (mm)	19.97 (21.3%)	23.43—28.72 (25.0—30.7%)
	r ²	0.91	0.8—0.87

Daily	Statistic	Ensemble	Model Range
49 sites N = 4913 days Mean closed ET is 3.64 (mm)	Slope	0.88	0.81—0.94
	MBE (mm)	-0.27 (7.4%)	-0.61—0.04 (-16.8—1.1%)
	MAE (mm)	0.83 (22.8%)	0.91—1.14 (25.0—31.3%)
	RMSE (mm)	1.08 (29.7%)	1.21—1.46 (33.2—40.1%)
	r ²	0.81	0.68—0.77

Growing Season	Statistic	Ensemble	Model Range
38 sites N = 151 seasons Mean closed ET is 609 (mm)	Slope	1	0.88—1.13
	MBE (mm)	-10.1 (1.7%)	-78.61—47.37 (-12.9—7.8%)
	MAE (mm)	80.25 (13.2%)	91.18—111.8 (15.0—18.4%)
	RMSE (mm)	92.72 (15.2%)	108.7—134.31 (17.8—22.1%)
	r ²	0.88	0.77—0.86

Conclusions

- Comparisons were made between ET estimates from about ~142 eddy covariance flux towers and OpenET remote sensing models
- Flux tower ET underwent thorough and reproducible QA/QC and energy balance closure corrections
- Grouped statistics show good model performance in agricultural settings from all models but there is room for improvement; the intercomparison has already led to model improvements
- Model agreement with ground measurements was poorest in arid regions of native shrublands and grasslands
- Future model evaluations will aim to increase ground-based data coverage