

# Improved Surface Water Storage Monitoring through Multi-Sensor Harmonization

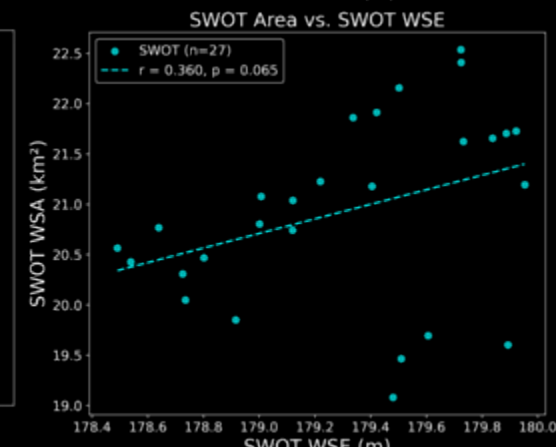
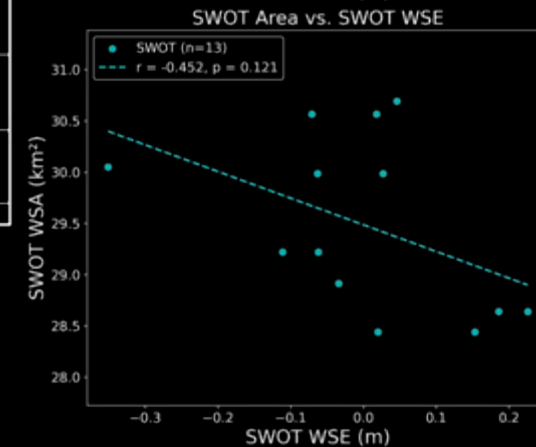
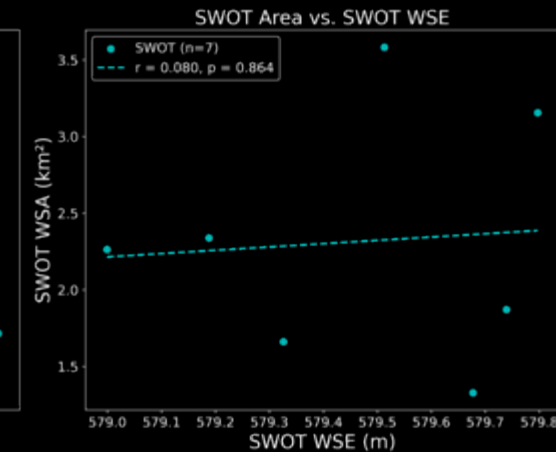
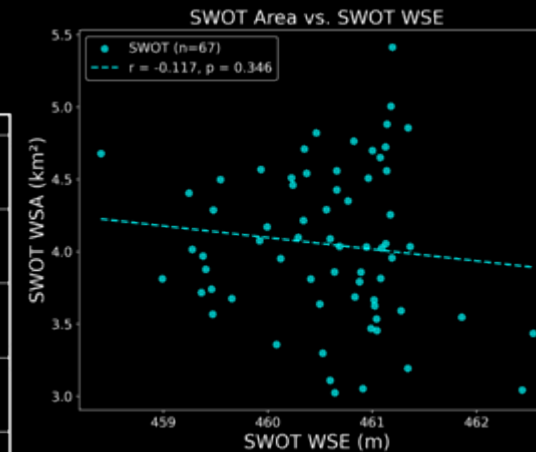
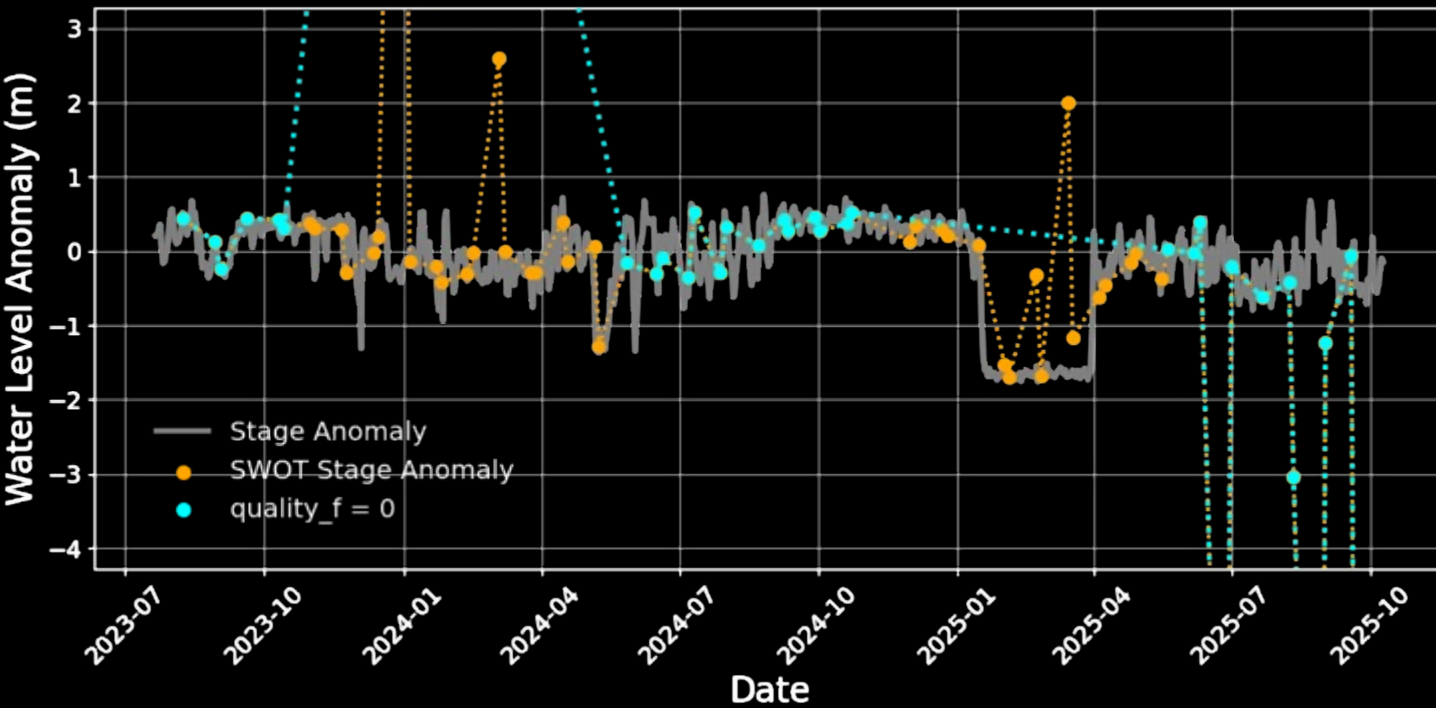
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<sup>1</sup>University of Oregon, Oregon USA

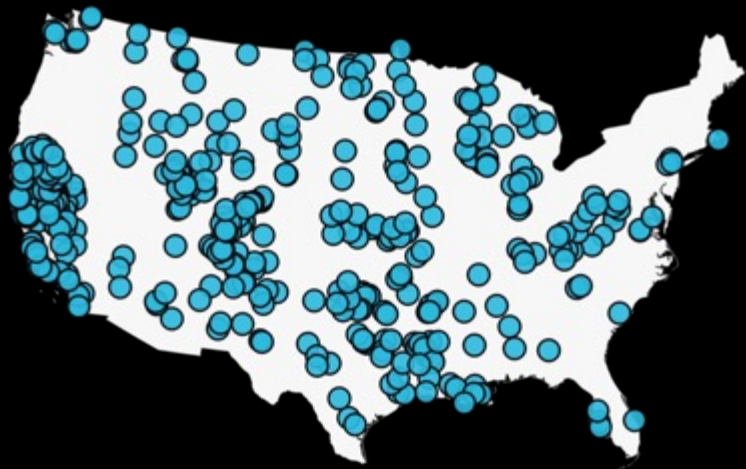
<sup>2</sup>Duke University, North Carolina, USA

# Key barriers to SWOT adoption by hydrologists

1. Noisy and sparse time series
2. Uncertain or unreasonable area – stage relationships
3. Lack of information on temporal resolution and measurement uncertainty



# Lake and Reservoir Benchmark Dataset: Harmonized Gage, SWOT, and Sentinel-2 Timeseries



411 Benchmark Lakes and Reservoirs

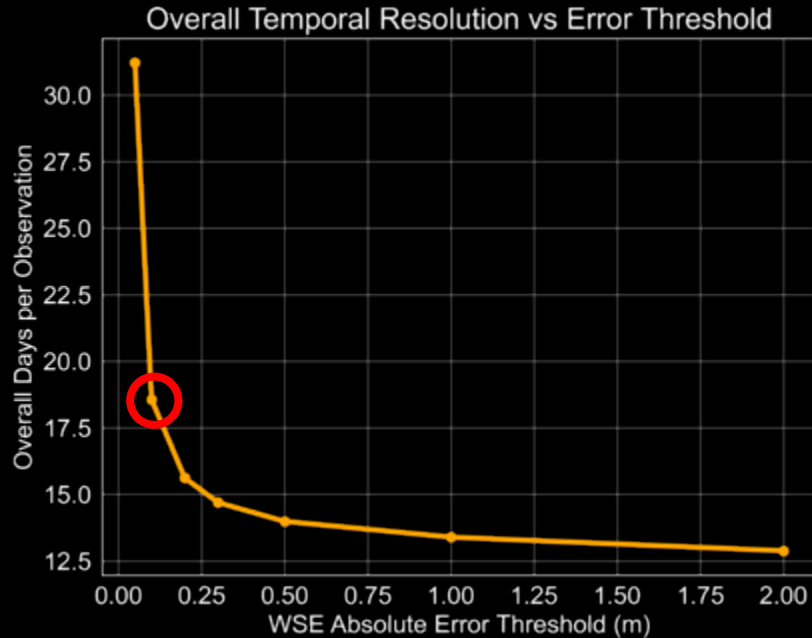
Breakdown of coincident SWOT + gage observations

In-Situ Variable	# Coincident Observations	# Lakes
Stage	20,964	332
Water Surface Area	11,891*	187
Storage	16,547	266

\*31,359 coincident Sentinel-2 and gage WSA observations

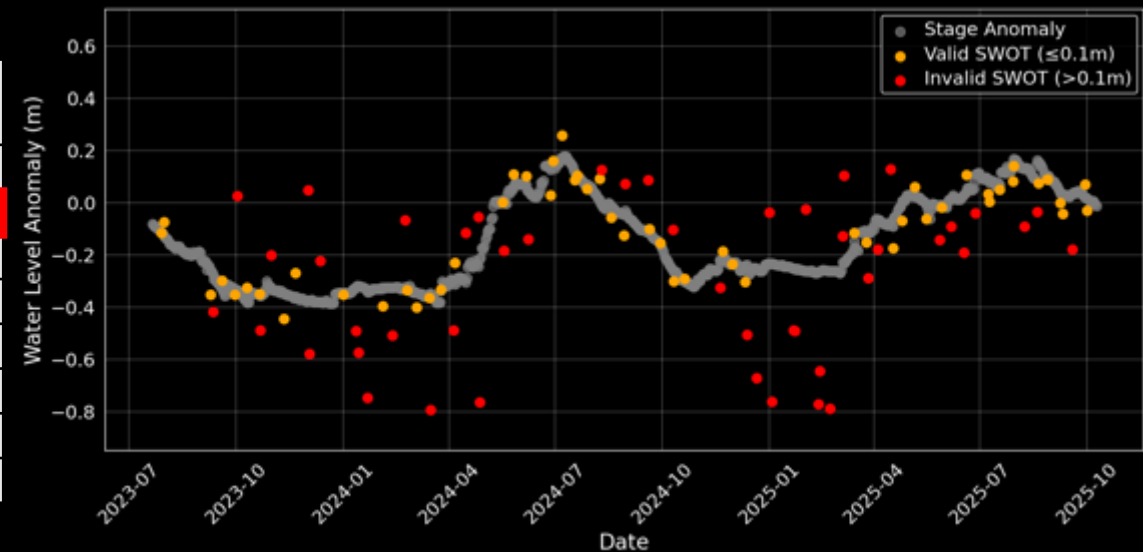
- Automated pipeline to update gage, SWOT, and Sentinel-2 data
- Daily 'truth' water surface area derived from gage stage-storage curve
- Bias corrected LakeSP WSE anomalies (i.e., stage) to track gage stage anomalies

# SWOT Temporal Resolution Determined by Error Tolerance and Filters

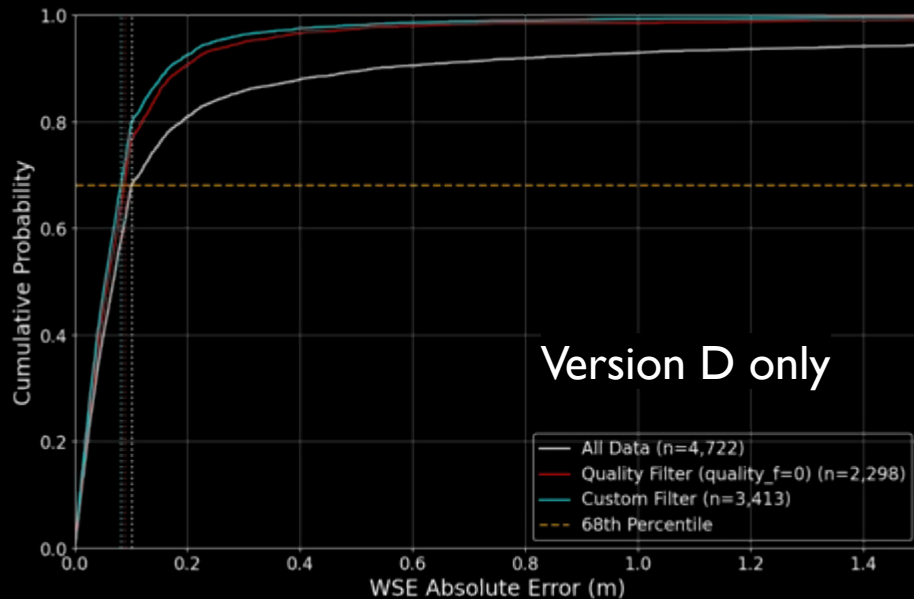
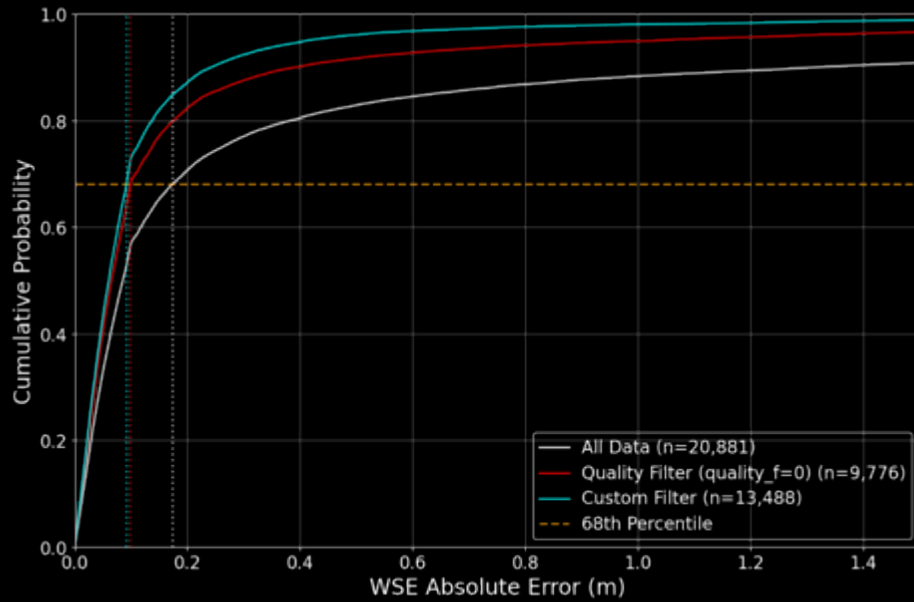


- SWOT science goal of 10 cm vertical accuracy yields a temporal resolution of **18.56 days per observation** (after bias correction)
- Filtering strategy must account for both the accuracy and temporal resolution required to address our science questions

Error Tolerance (m)	# Lakes	Total SWOT Observations	Mean Days per Observation	Median Days per Observation	Overall Days per Observation
0.05	328	5615	47.15	34.01	31.22
<b>0.1*</b>	<b>322</b>	<b>9624</b>	<b>26.32</b>	<b>19.74</b>	<b>18.56*</b>
0.2	322	11443	21.98	16.01	15.61
0.3	323	12216	20.57	14.58	14.69
0.5	324	12874	19.40	14.13	13.98
1	327	13581	18.67	13.43	13.39
2	327	14122	17.37	12.85	12.88
All data	327	15173	15.62	12.14	<b>12.09</b>



# Filter Evaluation: Regression vs. Classification Frameworks

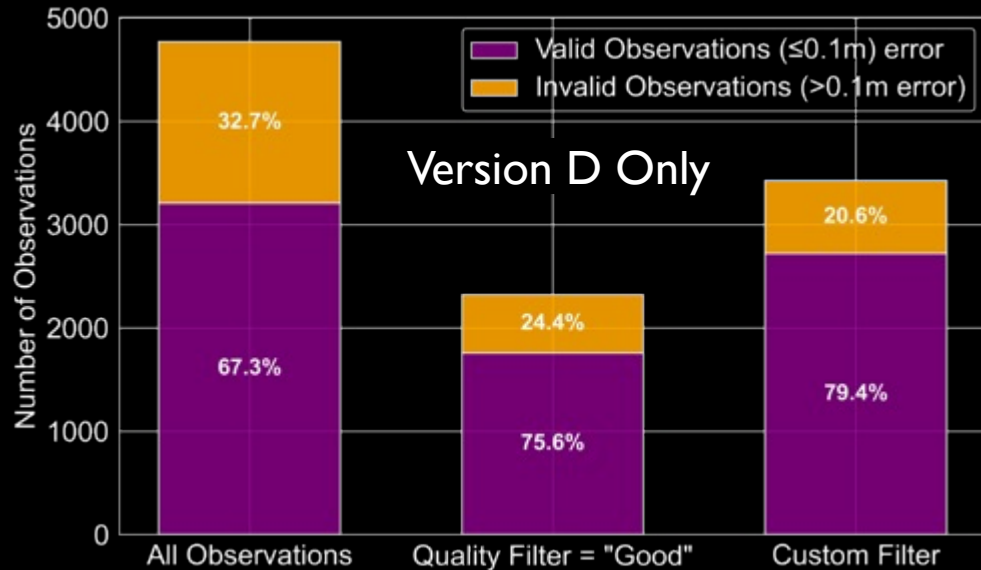
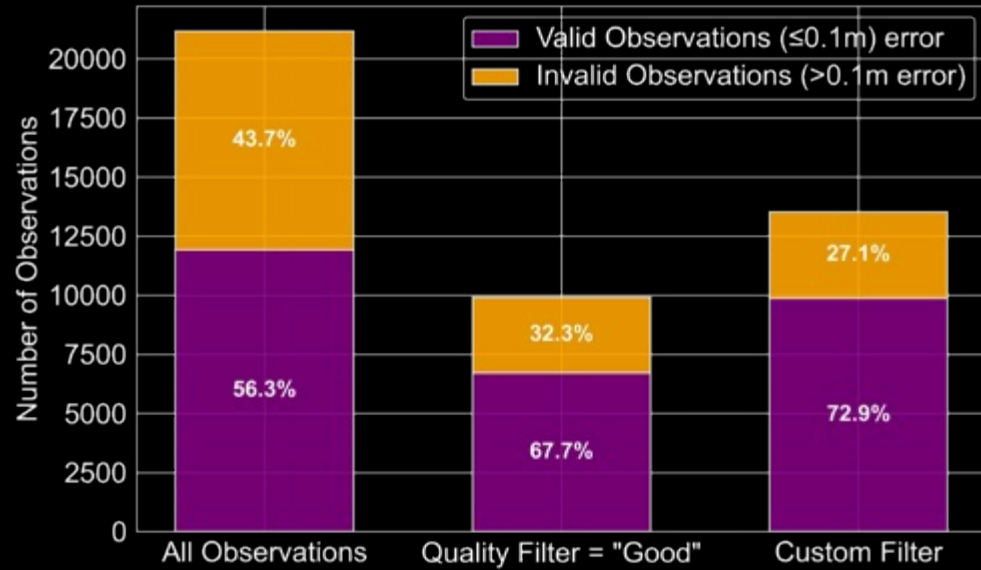


Custom Filter Example

Ancillary Variable	Threshold	LakeSP column
WSE Uncertainty	$\leq 0.1$	wse_u
WSE Standard Deviation	$\leq 0.35$	wse_std
Crossover calibration quality	$< 2$	xovr_cal_q
Absolute WSE anomaly (from median)	$< 50$	Based on 'wse'
Partial Observation (for area only)	$== 0$	partial_f

Filter	68 <sup>th</sup> Percentile	MAE	RMSE
<b>quality_f = 0</b>	0.096 m	0.40 m	3.74 m
<b>custom filter</b>	0.092 m	0.18 m	0.97 m
<b>total</b>	0.17 m	2.11 m	19.46 m

# Filter Evaluation with a Classification Framework



Custom Filter Example

Ancillary Variable	Threshold	LakeSP column
WSE Uncertainty	$\leq 0.1$	wse_u
WSE Standard Deviation	$\leq 0.35$	wse_std
Crossover calibration quality	$< 2$	xovr_cal_q
Absolute WSE anomaly (from median)	$< 50$	Based on 'wse'
Partial Observation (for area only)	$== 0$	partial_f

Filter	Temporal Resolution*	Precision**	Recall **
quality_f = 0	25.2	67.7 %	56.3 %
custom filter	18.3	72.9 %	82.7 %
total	11.7	56.3 %	100 %

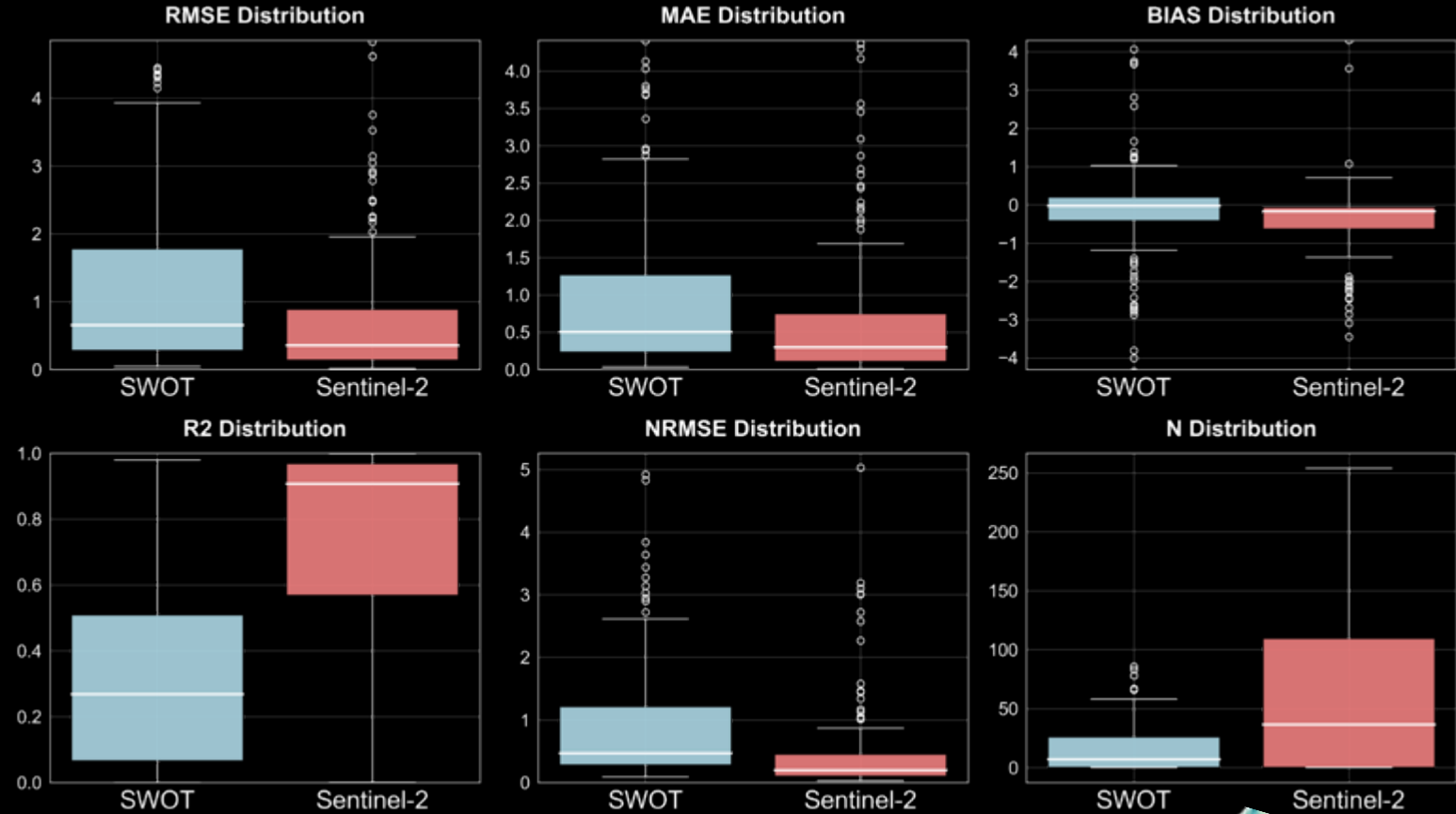
\*Temporal resolution in days per observation

\*\*Classifying observations under 10 cm threshold

# Sentinel-2 provides more accurate and frequent water surface area measurements

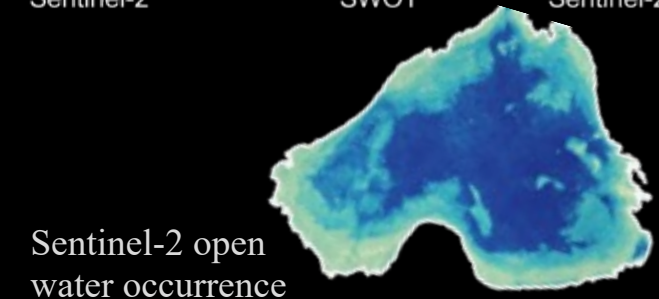
Can Sentinel-2 observations:

- (a) Reduce uncertainty in water storage estimates?
- (b) Enable historical reconstruction, reduced latency, and improved temporal resolution of water storage time series?

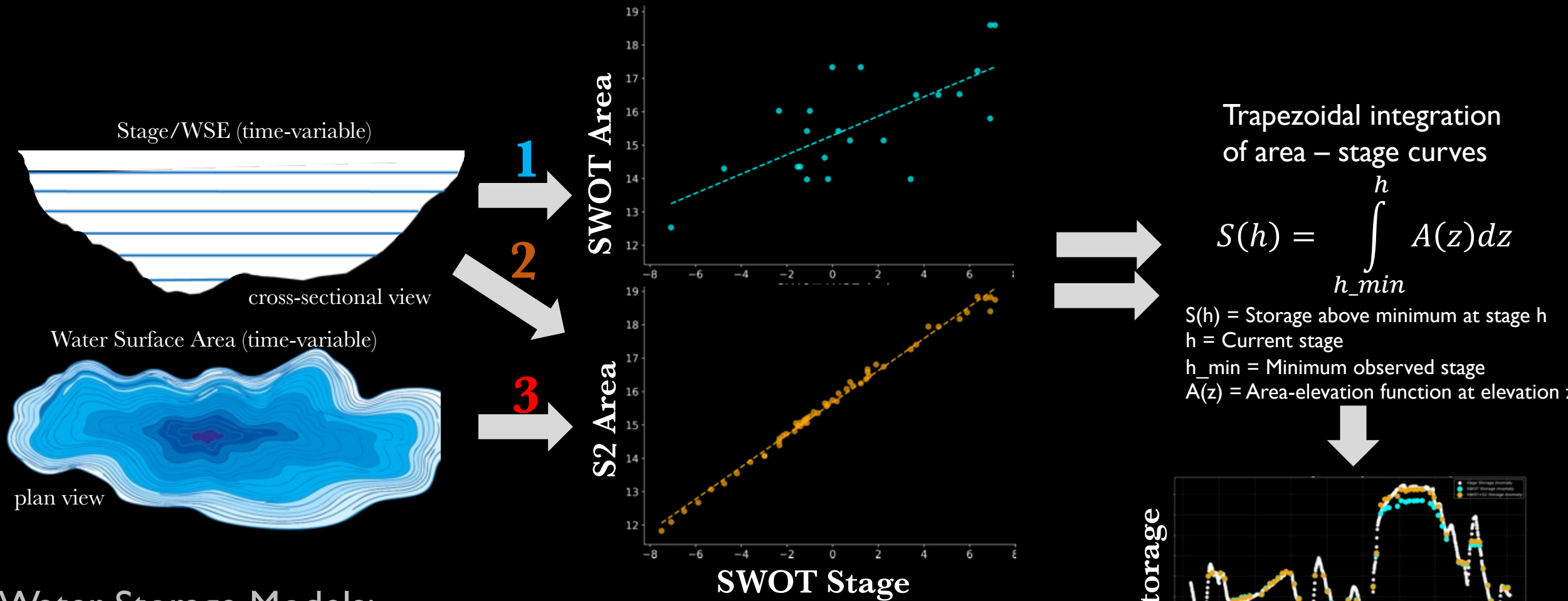


SWOT vs. S2 Area – Stage relationships

WSE-Area Sensors	r	r <sup>2</sup>	% Significant (p<0.05)
SWOT—SWOT	0.39 (0.46)	0.32 (0.25)	54.8 %
SWOT – S2	0.56 (0.73)	0.51 (0.55)	76.9 %



# Active water storage time series production



## Water Storage Models:

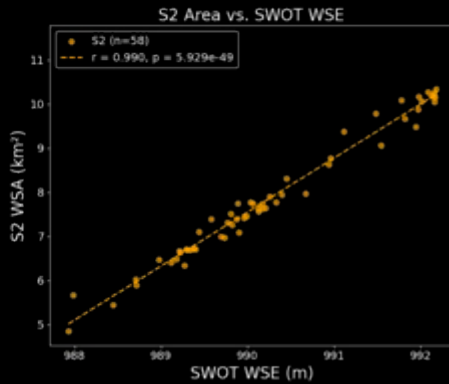
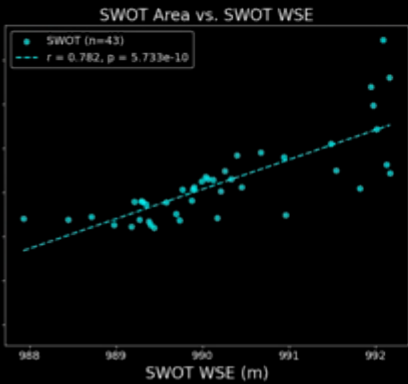
1. **SWOT** (SWOT WSE time-varying inputs SWOT Area-Stage curve)
2. **SWOT – S2** (SWOT WSE time-varying inputs, SWOT-S2 Area-Stage curve)
3. **S2 – SWOT\*** (S2 Area time-varying inputs, SWOT-S2 Area-Stage curve)

\*Where this model works, we can increase temporal resolution and historically reconstruct water storage

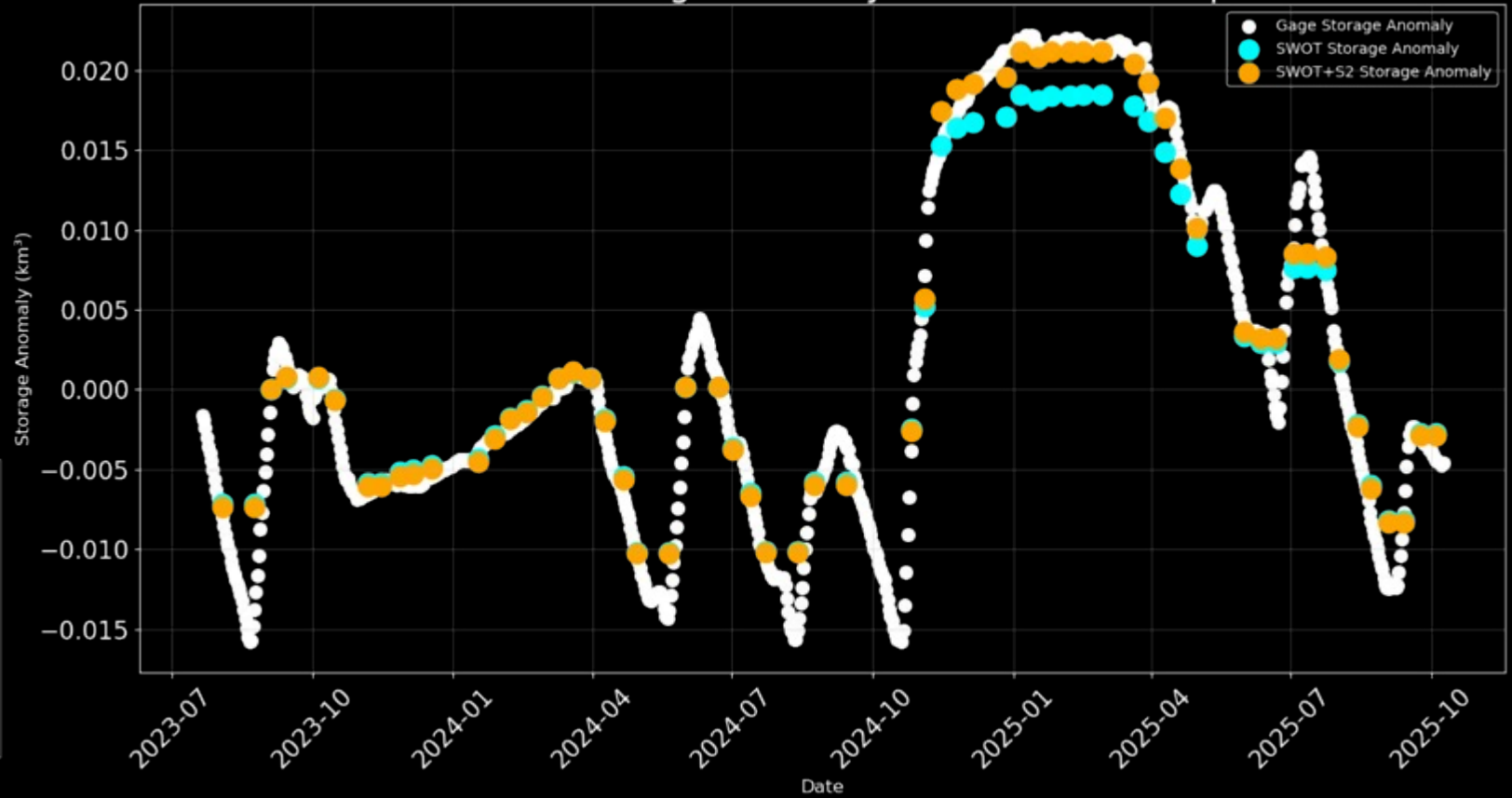
# Water Storage Monitoring Case Study, Brantley Reservoir, New Mexico



Area-Elevation Relationships for Gage 7520005453



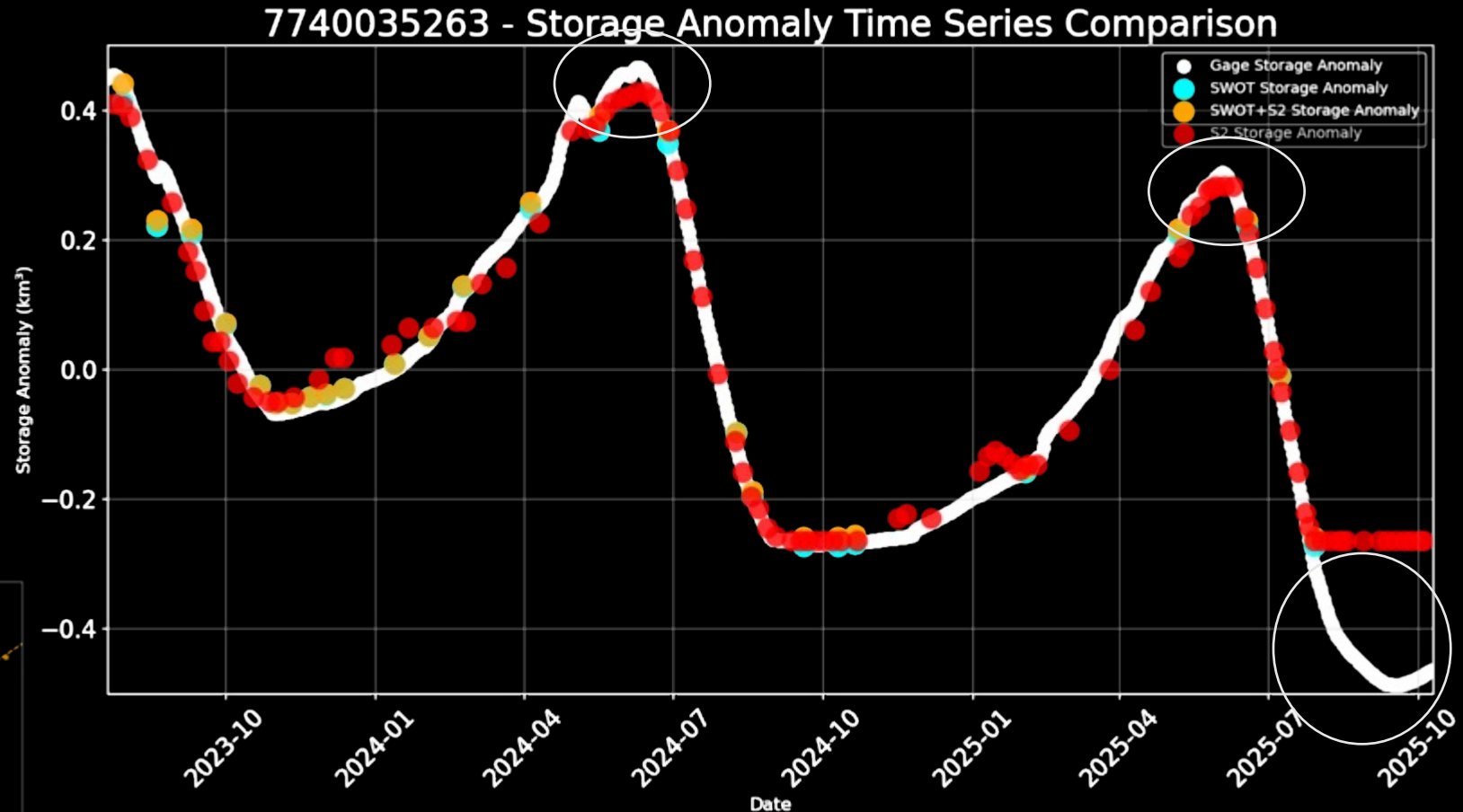
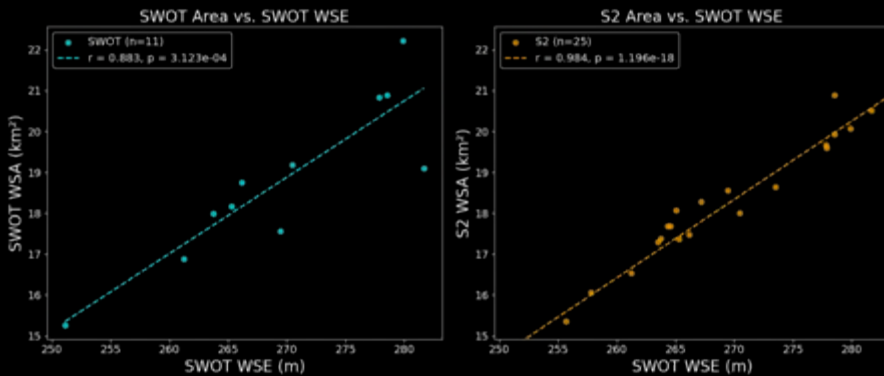
### 7520005453 - Storage Anomaly Time Series Comparison



# Water Storage Change Case Study: Pine Flat Reservoir, California



Area-Elevation Relationships for Gage 7740035263



- Sentinel-2 water surface area as temporal resolution helps capture local maximums.
- Potential to reduce latency between estimates, but there is a danger in extrapolating beyond the range of observed WSE

# Questions for the SWOT community

- We use complementary sensors to produce prior lake and river datasets. Why not go further and establish stage – area/width relationships for water storage and discharge estimates?
- Which functions provide the best mathematical relationship of stage – area/width relationships?
- How can we improve interpolations of SWOT observations to work towards daily time series?



**Thank You!**

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