



— BUREAU OF —
RECLAMATION

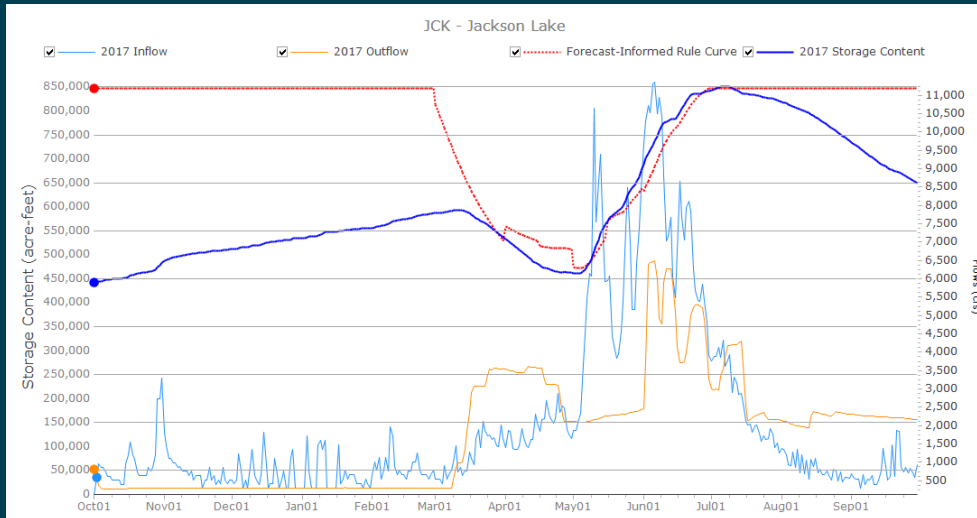
Reclamations Forecast Update Phase 1

December 1, 2021

Technical Management Team

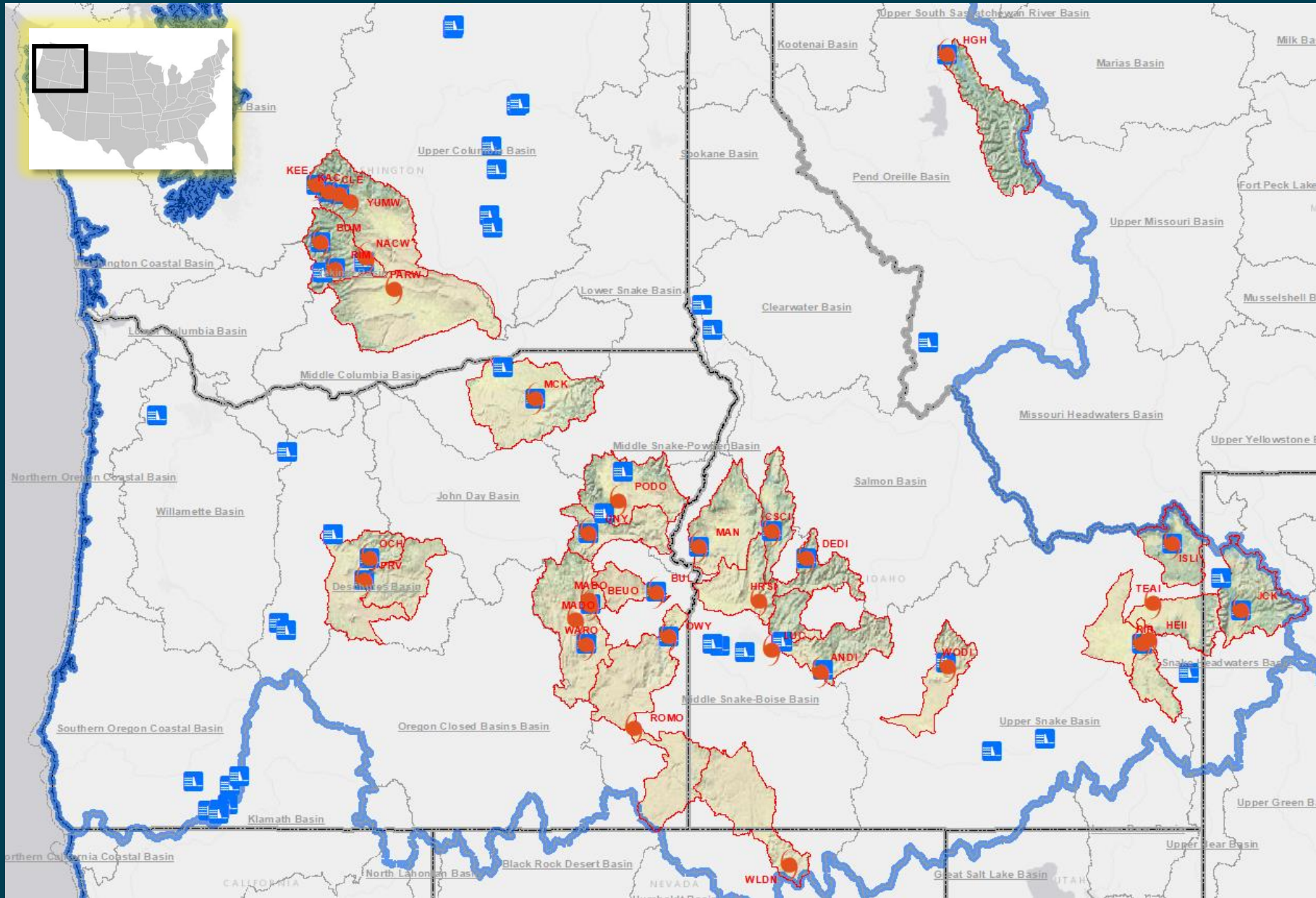
Forecast Use

- Flood control
- BiOp Operations
- Refill projections
- Water supply allocation planning
- Facilities O&M planning



November 1	Stipulated Augmentation Rental Dist 01					
Carryover	April 1 - Sept 30 Heise Forecast 1000s AF					
1000s AF	< 2,450	< 2,920	< 3,450	< 4,208	< 5,042	> 5,670
0	0	0	0	0	150000	185000
100	0	0	0	0	150000	185000
200	0	0	0	0	150000	185000
300	0	0	0	0	150000	185000
400	0	0	0	0	150000	185000
500	0	0	0	0	150000	185000
600	0	0	0	60000	150000	185000
700	0	0	0	60000	150000	185000
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3,300	100000	100000	185000	185000	205000	205000
3,400	100000	100000	185000	185000	205000	205000
3,500	100000	100000	185000	185000	205000	205000
3,600	100000	100000	185000	185000	205000	205000

Forecast Points and Basins



MLR Forecast Equations

- Equations of the form:

$$Y = X1 + X2 + X3 + X4$$

Where:

$X1 = f(\text{Antecedent Runoff for a defined period for select stations})$

$X2 = f(\text{Precipitation for a defined period for select stations})$

$X3 = f(\text{Snowpack for a defined period for select stations})$

$X4 = f(\text{Precipitation for a defined period for select stations})$

– Ex: Boise River at Anderson Ranch May Forecast:

- $X1 = f(\text{AND Inflow})_{\text{Oct to Dec}}$
- $X2 = f(\text{AND, ARK, CVAI, IDHI Precipitation})_{\text{Oct to Mar}}$
- $X3 = f(\text{ATAI, JKPI, MRKI, TRMI, VNNI Snowpack})_{\text{Apr}}$
- $X4 = f(\text{AND, ARK, CVAI, IDHI Precipitation})_{\text{Apr to Jun}}$

– Ex: Owyhee River at Owyhee Dam April Forecast:

- $X1 = f(\text{ROMO Inflow})_{\text{Oct to Nov}}$
- $X2 = f(\text{DANO, MCDO, MOCN, OWY, OWYN, ROMO Precipitation})_{\text{Oct to Dec}}$
- $X3 = f(\text{BERN, BIGN, SMTI, TACN, JCUN Snowpack})_{\text{Mar}}$
- $X4 = f(\text{DANO, MCDO, MOCN, OWY, OWYN, ROMO Precipitation})_{\text{Feb to Jun}}$



Phase 1

- Develop software – Pyforecast (2018-2020)
- Develop new forecasts
- Do the new forecasts do better



PyForecast

- <https://github.com/usbr/PyForecast/>
- Wiki: <https://github.com/usbr/PyForecast/wiki>



Traditional Water Supply Forecasting Workflow

- Data inventory
- Data QA/QC
- Train/run forecast models
- Issue forecasts



Development Process

- Potential Predictor Inventory
 - All sites within forecast area
 - Used SE (no SU), PM (no co-op), antecedent QU, Climatic
- Data cleanup
 - Minor cleanup/extension/etc. as needed
- Potential Predictor Culling
 - Predictor analyzer tool (correlation)
 - Toss out unreliable/poor quality/poor correlator
- Initial PyCast Runs
 - Predictor Usage Count
 - Top PyCast Model
- Forced Predictor PyCast Runs
 - Ensure coverage/consistency month to month/etc.
 - Forced PyCast Model
- Summary Statistics



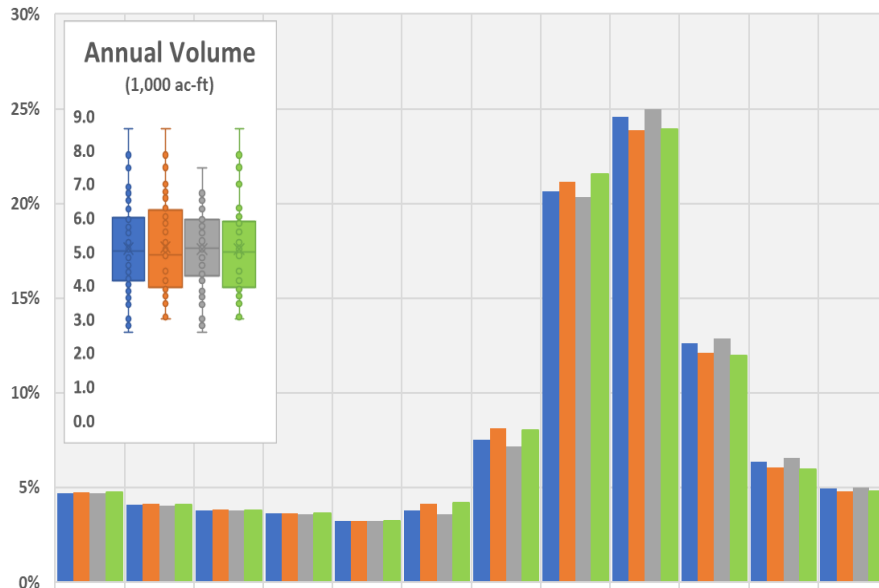
Heise Forecast Development



Period of Record Determination

Average Annual Volume Monthly Distribution

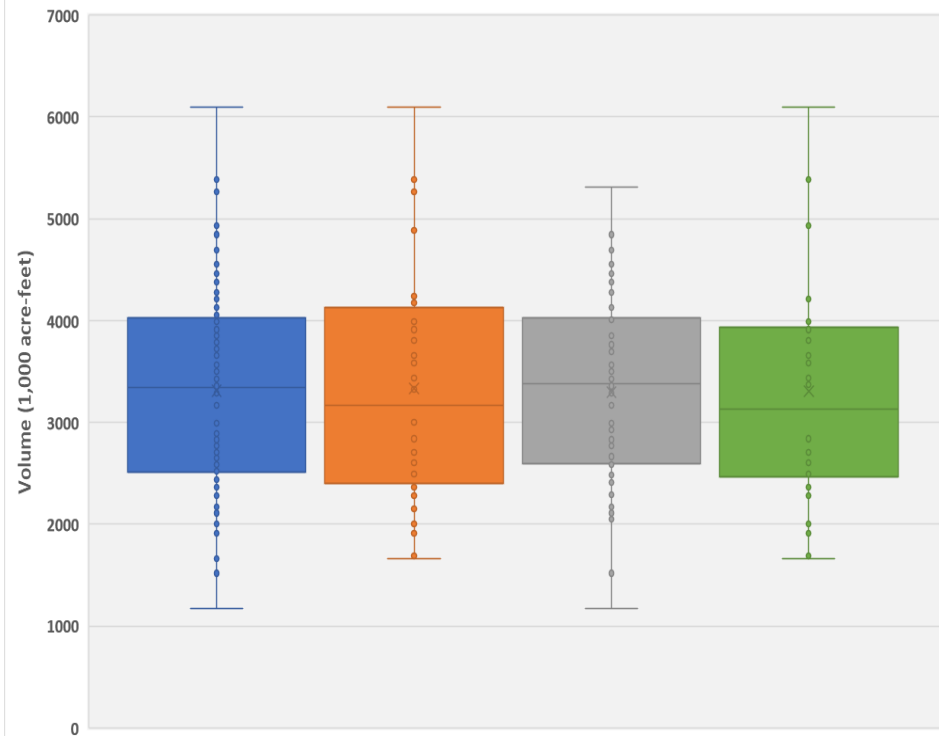
■ 1911-2020 ■ 1981-2020 ■ 1911-1980 ■ 1991-2020



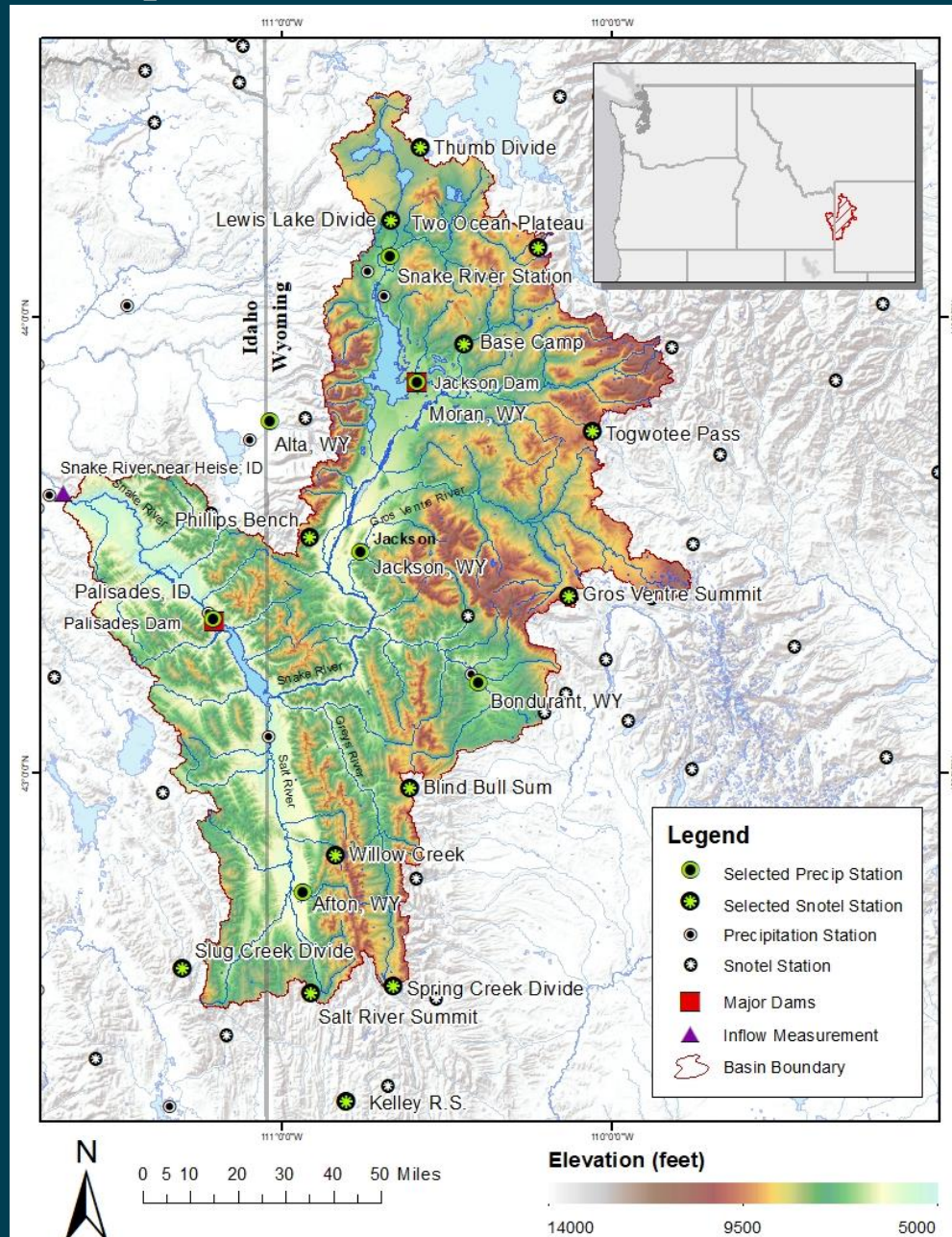
Period	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1911-2020	4.7%	4.1%	3.8%	3.6%	3.3%	3.8%	7.5%	20.6%	24.6%	12.6%	6.4%	4.9%
1981-2020	4.8%	4.2%	3.8%	3.7%	3.3%	4.2%	8.2%	21.2%	23.8%	12.1%	6.0%	4.8%
1911-1980	4.7%	4.1%	3.8%	3.6%	3.2%	3.6%	7.2%	20.3%	25.0%	12.9%	6.6%	5.0%
1991-2020	4.7%	4.1%	3.8%	3.7%	3.3%	4.2%	8.0%	21.5%	23.9%	12.0%	6.0%	4.8%

Period Volume Comparison (Apr-Jul)

■ POR ■ 1981-2020 ■ 1911-1980 ■ 1991-2020



Culled Precip and Snotel



Culled Potential Predictors

Snotel Predictors for PyCast Consideration - Snake nr Heise (HEI QU)																			
HUC	HUC Location	Site	SU/SE	Hydromet Pcode	Period of Record	Elevation	Jan-Jul		Feb-Jul		Mar-Jul		Apr-Jul		May-Jul		Jun-Jul		NOTES
							Data Date	r2	Data Date	r2	Data Date	r2	Data Date	r2	Data Date	r2	Data Date	r2	
17040105	1	Salt River Summit	SE	SLTY SE	Oct-80	7640	1-Jan	0.39	1-Feb	0.62	1-Mar	0.72	1-Apr	0.78	1-May	0.77	1-May	0.79	Earliest Melt Out (EMO) April 22, Median Melt Out (MMO) May 19
14040107	3	Kelley R.S.	SE		Oct-80	8180	1-Jan	0.42	1-Feb	0.64	1-Mar	0.73	1-Apr	0.78	1-May	0.77	1-May	0.76	EMO April 29, MMO May 25
17040102	1	Gros Ventre Summit	SE	GRVY SE	Oct-80	8750	1-Jan	0.46	1-Feb	0.65	1-Mar	0.78	1-Apr	0.78	1-May	0.75	1-May	0.73	EMO May 7, MMO May 29
14040101	2	Blind Bull Sum	SE	BBSY SE	Oct-80	8650	1-Jan	0.51	1-Feb	0.68	1-Mar	0.71	1-Apr	0.77	1-May	0.80	1-Jun	0.89	EMO May 16, MMO June 16
10080001	2	Togwotee Pass	SE	TOGY SE	Oct-80	9580	1-Jan	0.59	1-Feb	0.68	1-Mar	0.76	1-Apr	0.77	1-May	0.82	1-Jun	0.78	EMO June 1, MMO June 28
17040103	1	Phillips Bench	SE	PHBY SE	Oct-80	8200	1-Jan	0.40	1-Feb	0.55	1-Mar	0.71	1-Apr	0.76	1-May	0.81	1-Jun	0.86	EMO May 11, MMO June 12
14040101	2	Spring Creek Divide	SE	SCDY SE	Oct-80	9000	1-Jan	0.45	1-Feb	0.64	1-Mar	0.71	1-Apr	0.75	1-May	0.74	1-Jun	0.74	EMO May 13, MMO June 14
17040207	2	Slug Creek Divide	SE	SLGI SE	Oct-80	7225	1-Jan	0.36	1-Feb	0.65	1-Mar	0.72	1-Apr	0.74	1-May	0.76	1-May	0.80	EMO April 14, MMO May 14
10070001	2	Thumb Divide	SE	THMY SE	Feb-38	7980	1-Jan	0.38	1-Feb	0.53	1-Mar	0.69	1-Apr	0.74	1-May	0.83	1-May	0.83	EMO April 23, MMO May 24
17040101	1	Lewis Lake Divide	SE	LWSY SE	Oct-80	7850	1-Jan	0.35	1-Feb	0.44	1-Mar	0.62	1-Apr	0.71	1-May	0.77	1-Jun	0.88	EMO May 8, MMO June 11
17040105	1	Willow Creek	SE	WILY SE	Oct-80	8080	1-Jan	0.37	1-Feb	0.61	1-Mar	0.70	1-Apr	0.71	1-May	0.80	1-May	0.75	EMO May 6, MMO June 6
17040101	1	Two Ocean Plateau	SE	TOPY SE	Oct-80	9240	1-Jan	0.56	1-Feb	0.56	1-Mar	0.68	1-Apr	0.68	1-May	0.70	1-Jun	0.80	EMO June 6, MMO June 30
17040101	1	Base Camp	SE	BSCY SE	Oct-80	7060	1-Jan	0.39	1-Feb	0.47	1-Mar	0.60	1-Apr	0.66	1-May	0.85	1-May	0.82	EMO April 22, MMO May 16

Precip Predictors for PyCast Consideration - Snake nr Heise (HEI QU)																			
HUC	HUC Location	Site	PM	Hydromet Pcode	Period of Record	Elevation	Jan-Jul		Feb-Jul		Mar-Jul		Apr-Jul		May-Jul		Jun-Jul		NOTES
							Data Date	r2	Data Date	r2	Data Date	r2	Data Date	r2	Data Date	r2	Data Date	r2	
17040105	1	Afton, WY	PM	AFTY PM	Mar-1903	6200	Oct-Dec	0.39	Oct-Jan	0.54	Oct-Feb	0.60	Oct-Mar	0.58	Oct-Apr	0.55	Oct-May	0.58	
17040204	2	Alta, WY	PM	ALTY PM	Aug-1909	6450	Oct-Dec	0.37	Oct-Jan	0.45	Oct-Feb	0.61	Oct-Mar	0.61	Oct-Apr	0.71	Oct-May	0.77	
17040103	1	Bondurant, WY	PM	BONY PM	May-1946	6645	Oct-Dec	0.43	Oct-Jan	0.56	Oct-Feb	0.61	Oct-Mar	0.63	Oct-Apr	0.62	Oct-May	0.56	
17040101	1	Moran, WY	PM	JCKY PM	Jan-1915	6800	Oct-Dec	0.46	Oct-Jan	0.51	Oct-Feb	0.70	Oct-Mar	0.71	Oct-Apr	0.74	Oct-May	0.73	
17040103	1	Jackson, WY	PM	JKNY PM	Sep-1916	6230	Oct-Dec	0.52	Oct-Jan	0.60	Oct-Feb	0.67	Oct-Mar	0.67	Oct-Apr	0.62	Oct-May	0.58	
17040104	1	Palisades, ID	PM	PAL PM	Oct-1939	5450	Oct-Dec	0.31	Oct-Jan	0.44	Oct-Feb	0.53	Oct-Mar	0.57	Oct-Apr	0.58	Oct-May	0.57	
17040101	1	Snake River Station, WY	PM	SKRY PM	Jan-1931	6900	Oct-Dec	0.46	Oct-Jan	0.51	Oct-Feb	0.61	Oct-Mar	0.64	Oct-Apr	0.63	Oct-May	0.58	

Antecedent Runoff Predictors for PyCast Consideration - Snake nr Heise (HEI QU)																			
HUC	HUC Location	Site	PM	Hydromet Pcode	Period of Record	Elevation	Jan-Jul		Feb-Jul		Mar-Jul		Apr-Jul		May-Jul		Jun-Jul		NOTES
							Data Date	r2	Data Date	r2	Data Date	r2	Data Date	r2	Data Date	r2	Data Date	r2	
		HEI QU			1911		Oct-Dec	0.21	Oct-Dec	0.20	Oct-Dec	0.19	Oct-Dec	0.17	Oct-Dec	0.15	Oct-Dec	0.10	

Climatic Predictors for PyCast Consideration - Snake nr Heise (HEI QU)																			
HUC	HUC Location	Site	PM	Hydromet Pcode	Period of Record	Elevation	Jan-Jul		Feb-Jul		Mar-Jul		Apr-Jul		May-Jul		Jun-Jul		NOTES
							Data Date	r2	Data Date	r2	Data Date	r2	Data Date	r2	Data Date	r2	Data Date	r2	
		ONI			Jan-1950		Prev Aug	0.13	Prev OND	0.13	Prev OND	0.13	Prev OND	0.14	Prev OND	0.13	Prev OND	0.13	
		SOI			Jan-1951		Prev Aug	0.20	Prev Aug	0.20	Prev Aug	0.21	Prev Aug	0.21	Prev Aug	0.21	Prev Aug	0.19	

13 Snotel
7 Precip (Monthly PM)

1 ant. Runoff
2 Climatic



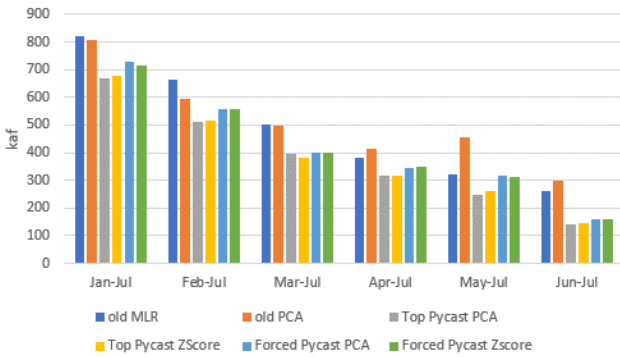
Equations

- Used Z-Score and PCA
 - MLR resulted in negative coefficients – collinearity
- Top Pycast and Forced
 - Jan-Jul
 - Feb-Jul
 - Mar-Jul
 - Apr-Jul
 - May-Jul
 - Jun-Jul

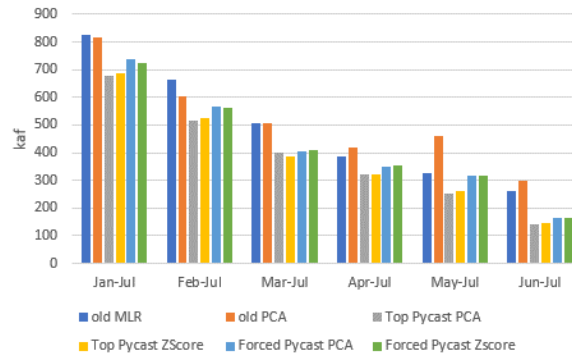


Summary Statistics

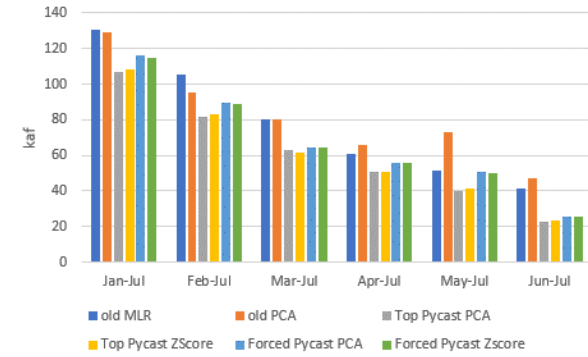
RMSE



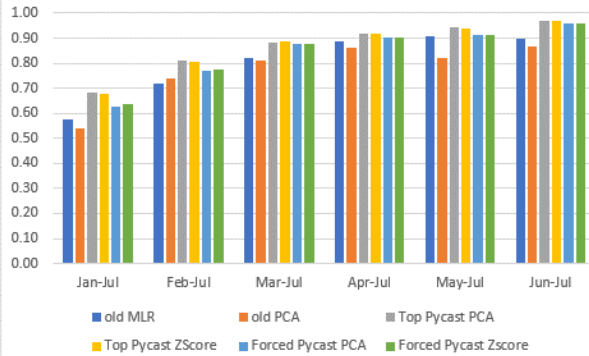
Standard Deviation of the Error



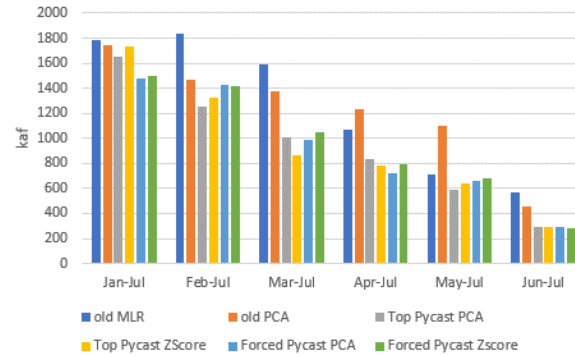
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r2

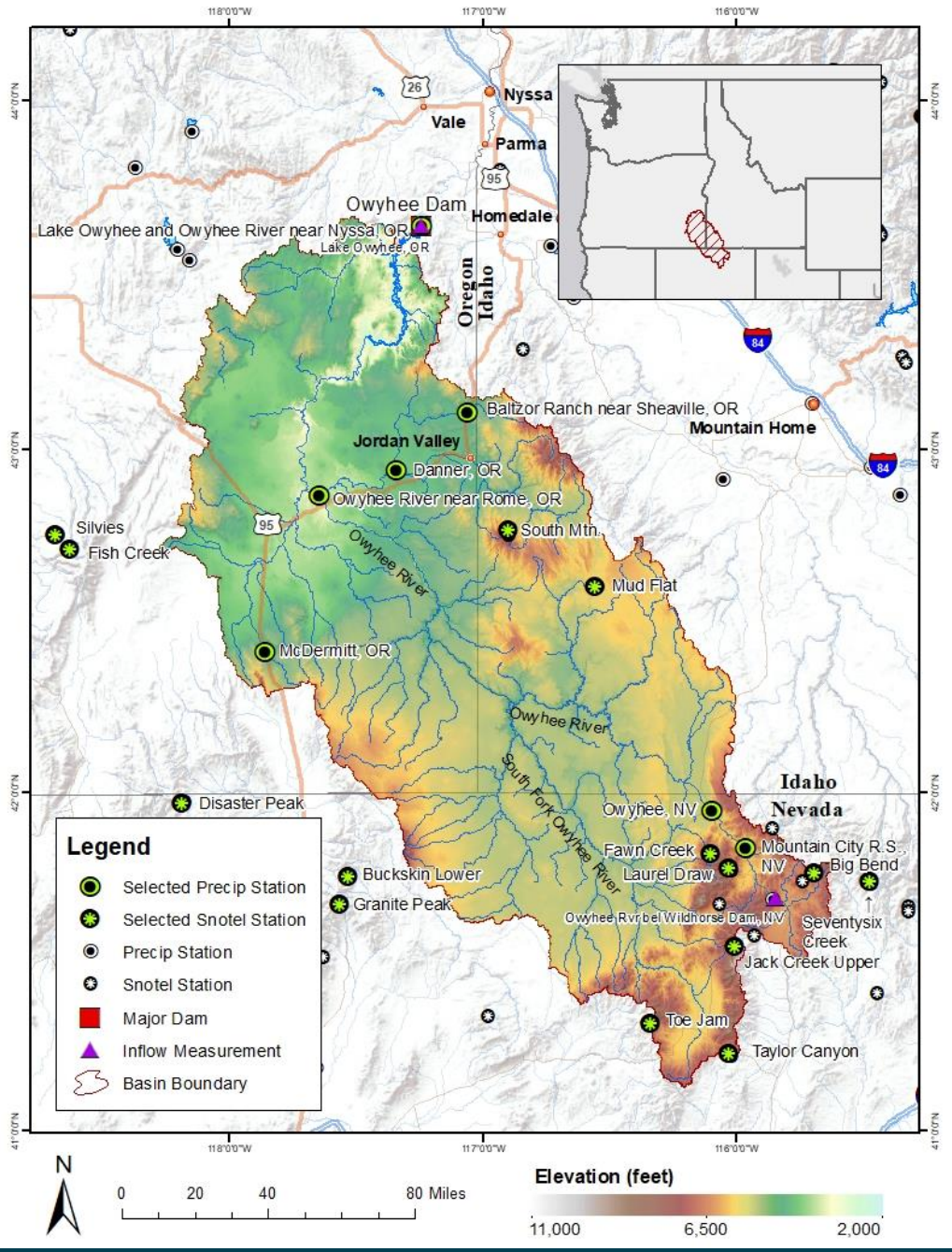


Max Error



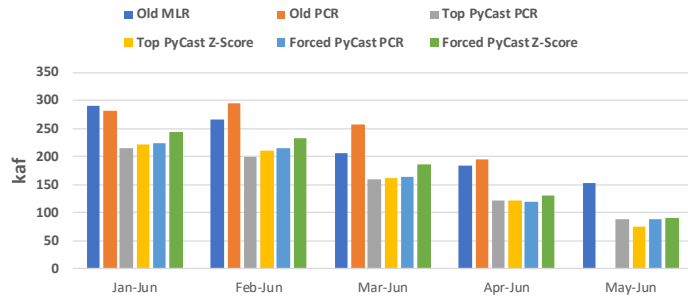
Owyhee Basin



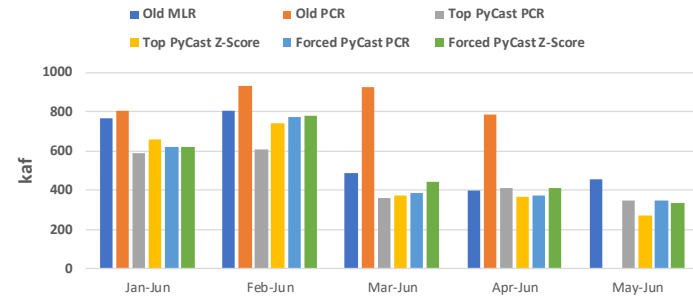


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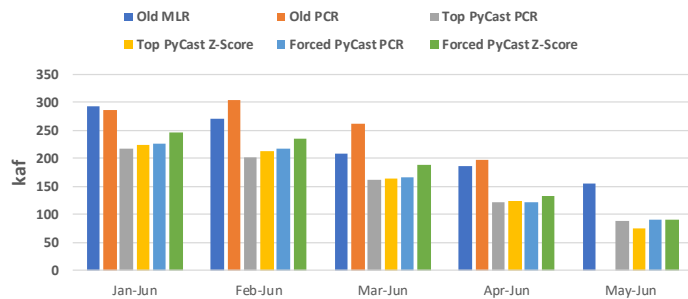
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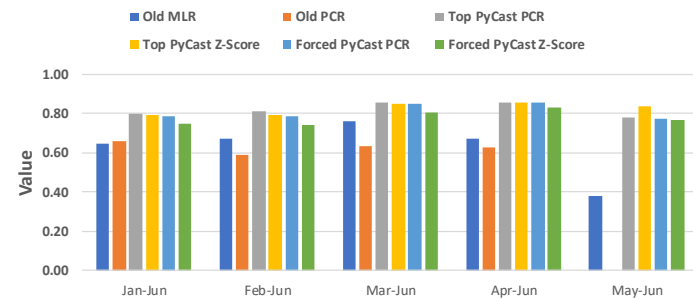
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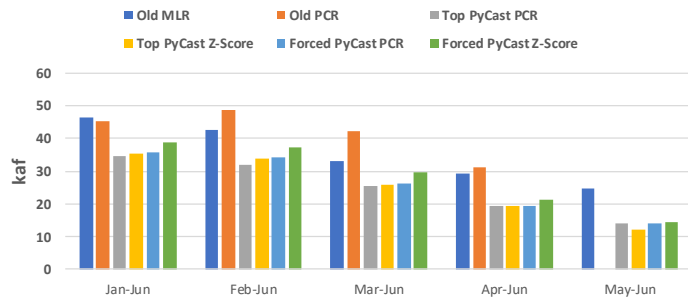
Error Standard Deviation



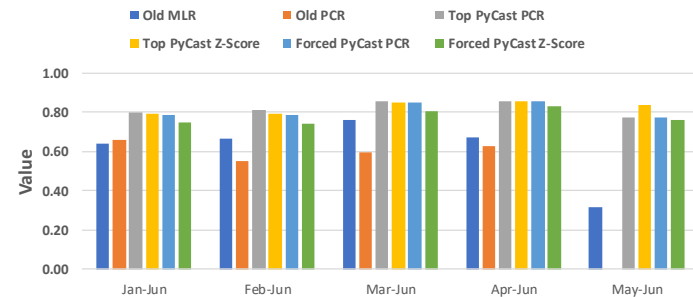
Coefficient of Determination (R-Squared)



Standard Error

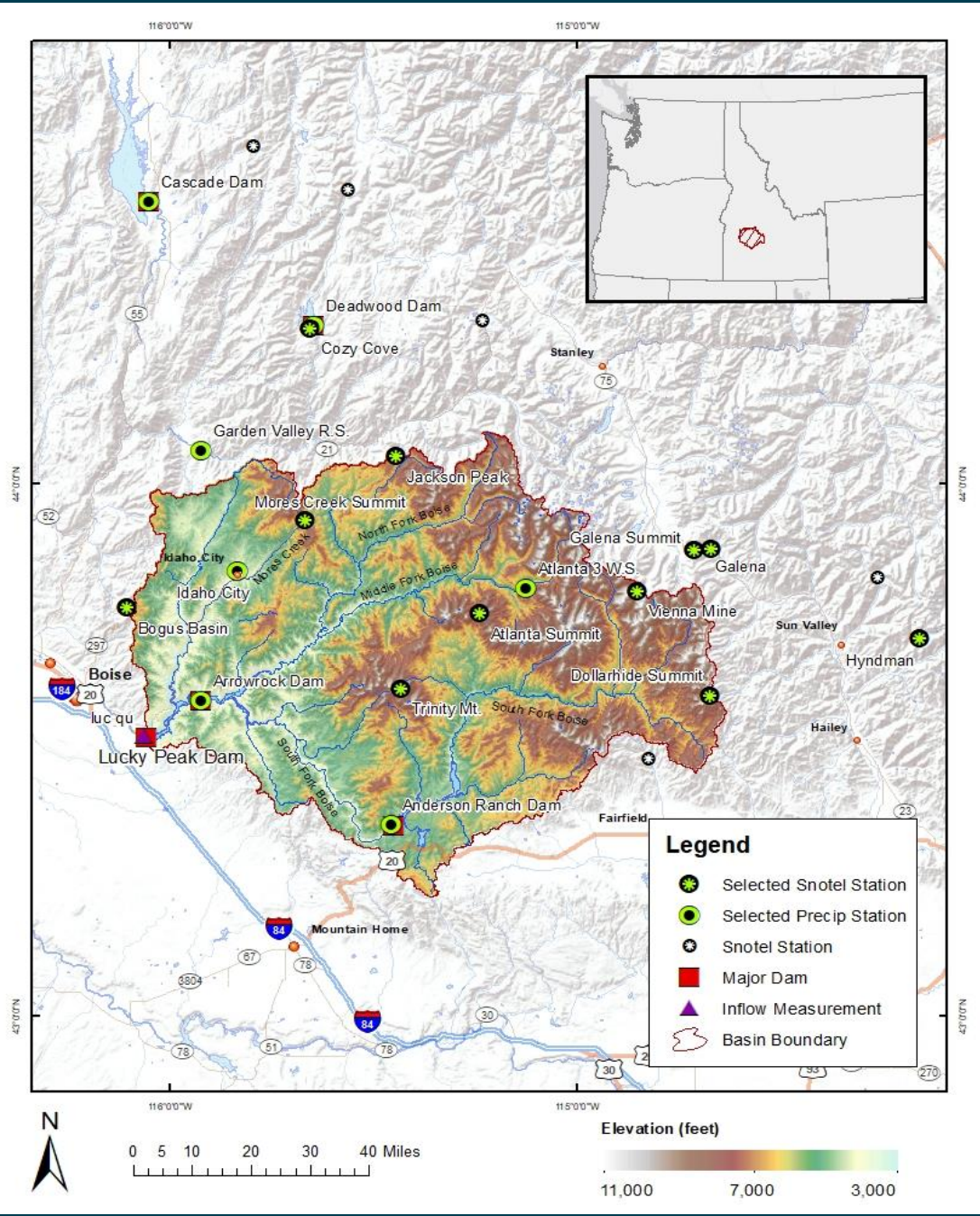


Nash-Sutcliffe Efficiency



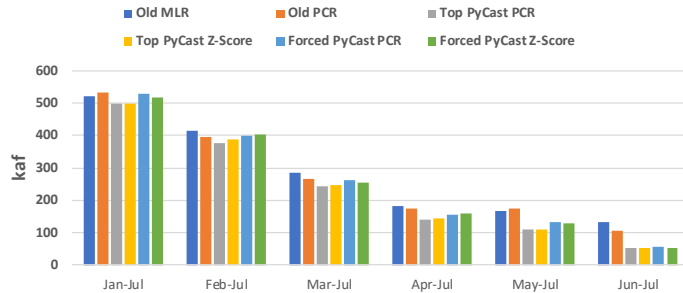
Boise Basin



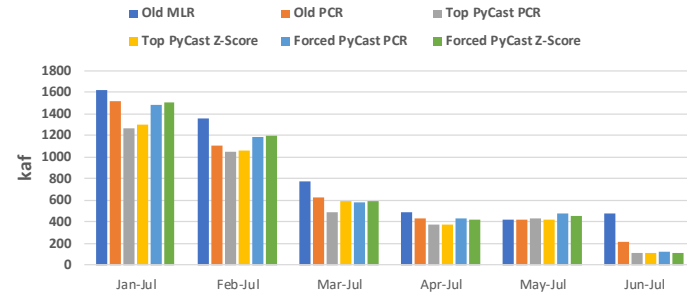


Summary Statistics

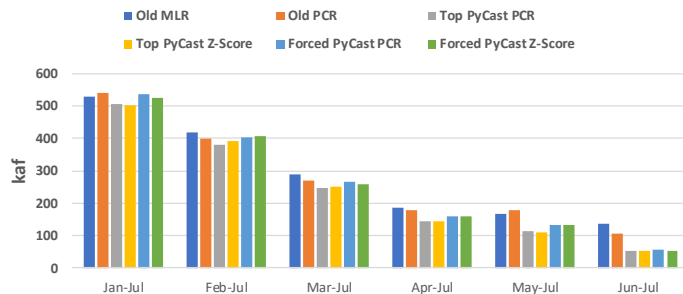
RMSE



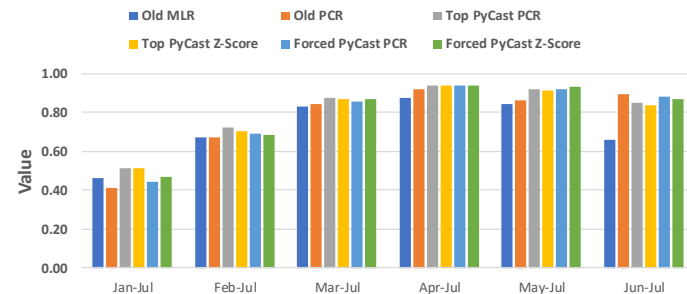
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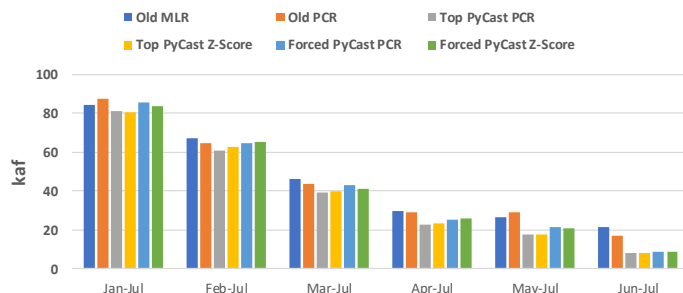
Error Standard Deviation



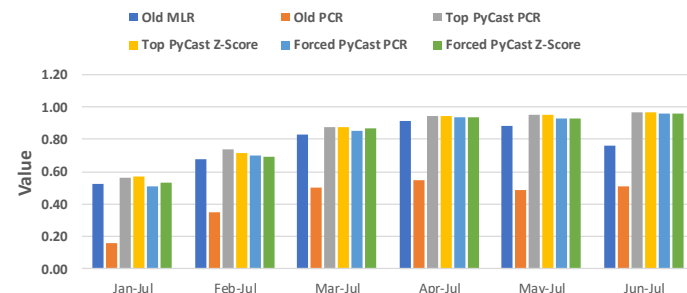
Coefficient of Determination (R-Squared)



Standard Error



Nash-Sutcliffe Efficiency



Next Steps

- Peer Review – Finishing up in December
- Phase 2: Establish new equations for other 30 sites – Fall 2021
- Phase 3: Look at different equations using:
 - SNODAS data
 - PRISM data
 - Soil moisture
 - 6 week precip forecasts
 - etc



Questions?

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