BUREAU OF RECLAMATION

First Order Delta Salinity Estimation
for Climate Change Scenario Analysis

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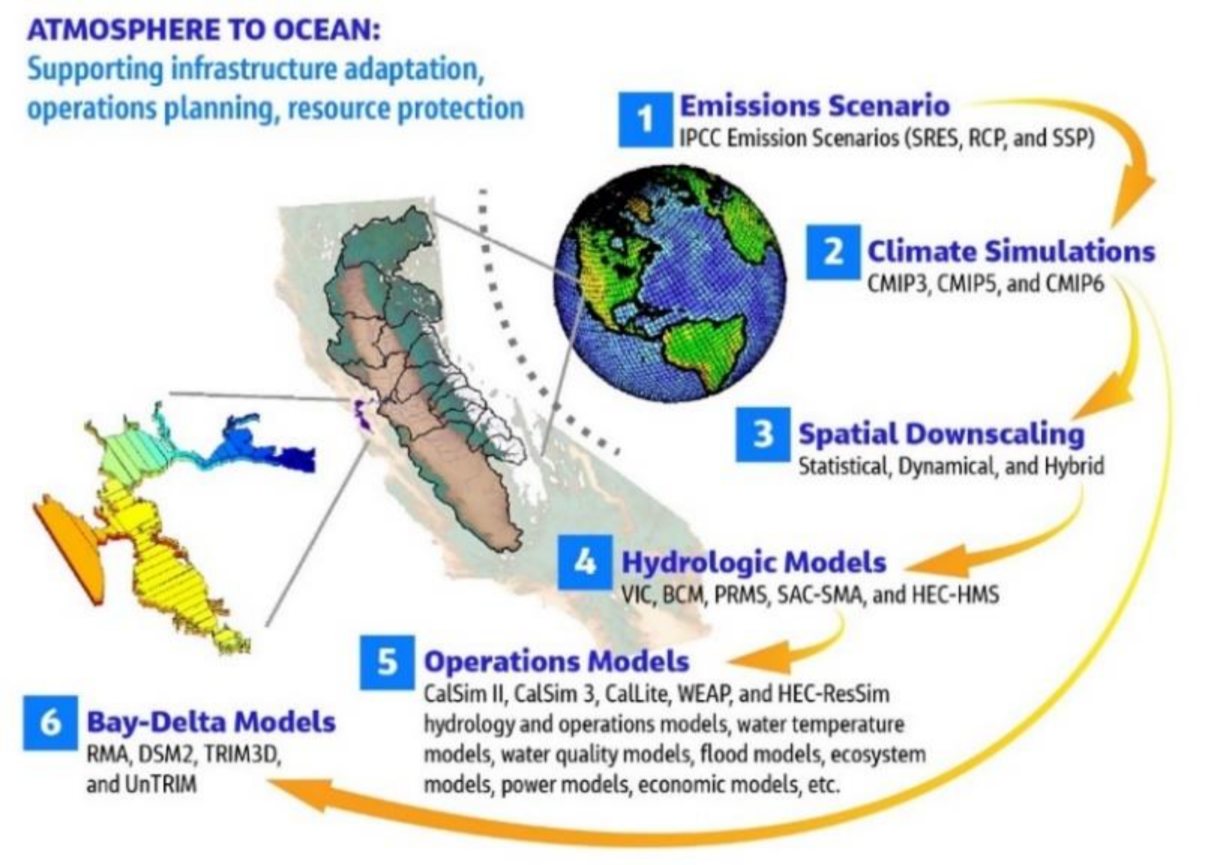
Collaborators: Jacobs Engineering
CWEMF 2023 Annual Meeting
Apr 18th, 2023

How will sea level rise affect CVP operations?



Bureau of Reclamation. "2021 LTO Climate Change Dataset Development." Bureau of Reclamation. May 2022

CVP operations:

- Strongly influenced by Delta outflow requirement
- Set by salinity targets

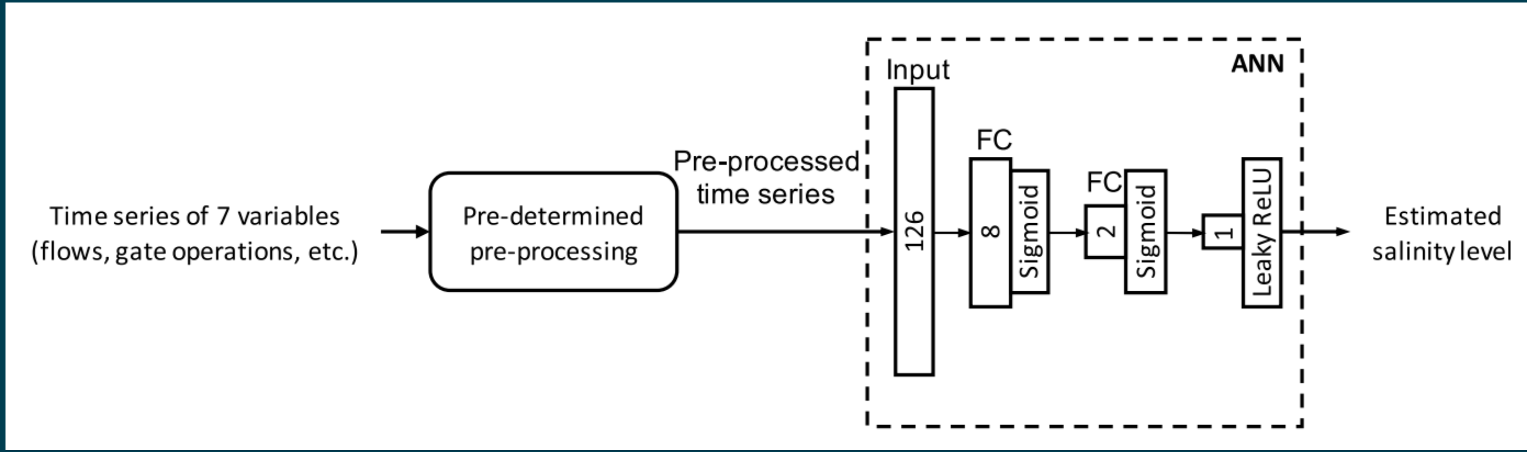
Estimating impacts from sea level rise:

- Sensitivity analysis
- Climate change analysis

Current Workflow Limitations

Salinity modeled with ANN

- Trained for stationary climate with single SLR scenario
- Based on computationally expensive DSM2 and SCHISM simulations



Qi, Siyu, et al. "Enhanced Artificial Neural Networks for Salinity Estimation and Forecasting in the Sacramento-San Joaquin Delta of California." Journal of Water Resources Planning and Management 147.10 (2021): 04021069.

ANN is not suited for full exploration of potential future climate conditions

Other Existing Works

- G-model
  - Linear regression model
  - Based on limited data
  - Demonstrates feasibility for our proposed work
- Advances since the G-model can lead to increase in skill
  - Data science
  - Modeling: DSM2, SCHISM
  - Data availability and duration: 1921-2012

Project Goals

- Develop a first order model for estimating Delta salinity under climate change
  - Less accuracy compared to ANN
  - Broader range of SLR scenarios
- Couple model with CalSim to explore how salinity affects CVP operations and infrastructure
- Develop workflow to continuously improve model with newly available data

Methodology

Compile Data

- DSM2 & SCHISM model output
- Historical data

Build Model

- Linear regression
- Non-linear regression
- Gaussian Mixture model
- Bayesian Regression

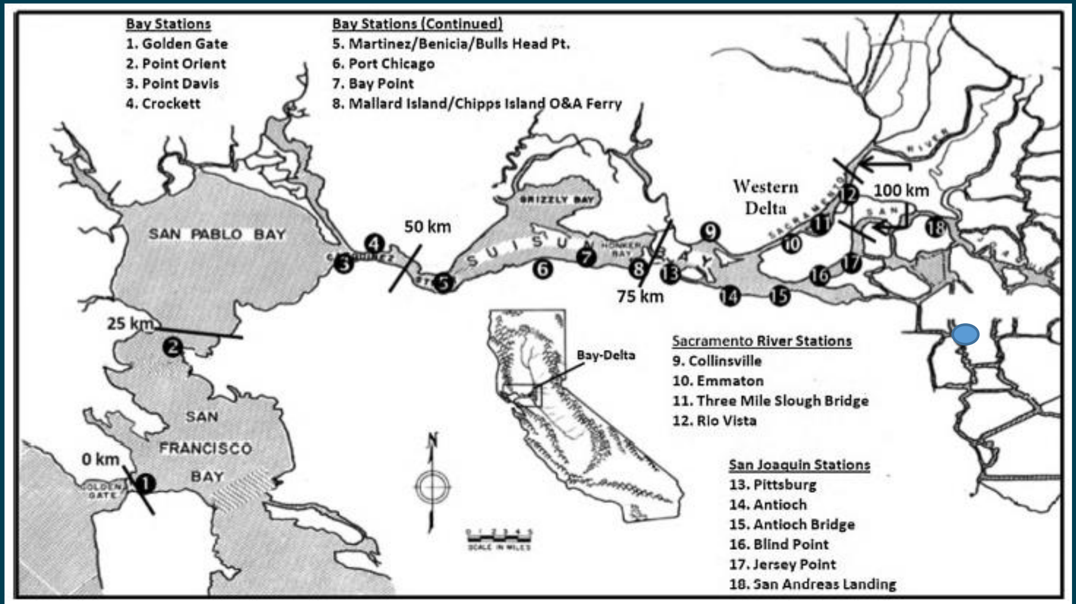
Incorporate into CalSim

- Explore SLR effects
- Identify refinement needs

Update Data & Improve Model

Salinity Data

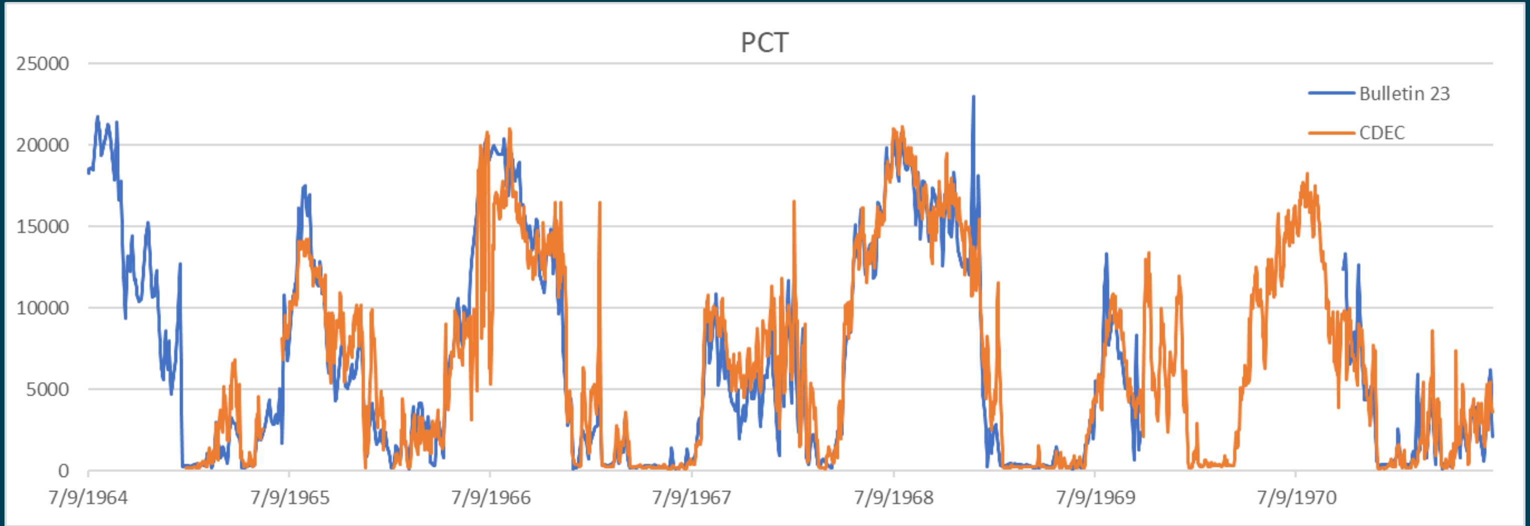
- Salinity dataset (1921-2012) [Hutton et al., 2016]
  - Bulletin 23 (Approx 1921-1971)
    - Grab sample data, converted to daily average with DSM2 simulation
  - CDEC (Approx 1964 – 2012)
    - Contains data from various sources, mostly CDEC

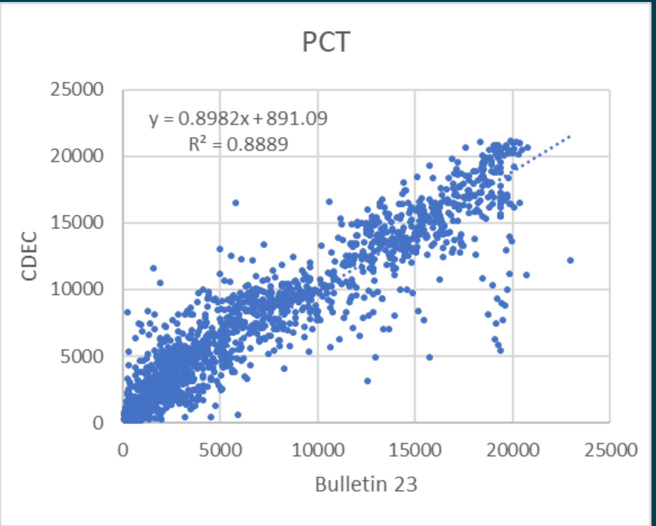


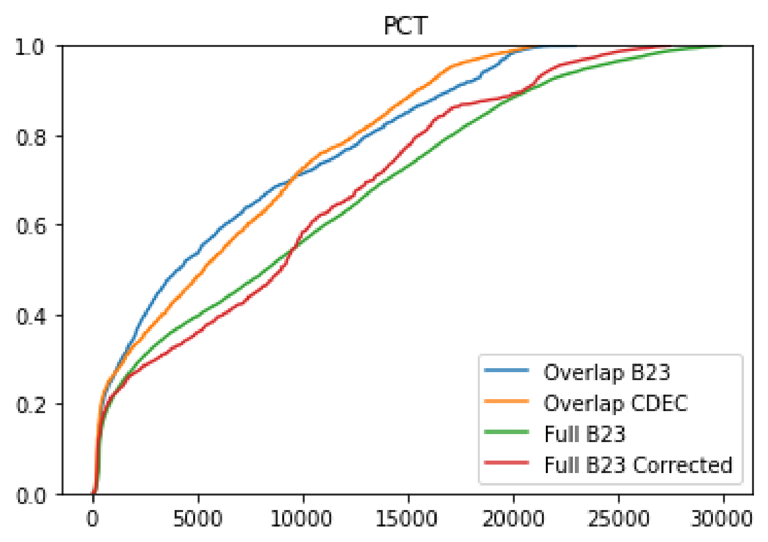
[Hutton et al., 2016]

- Rock Slough Salinity (2000-2010) from CDEC
  - Bacon Island at Old River (BAC)
- X2 [Hutton et al., 2016]

Join Salinity Datasets



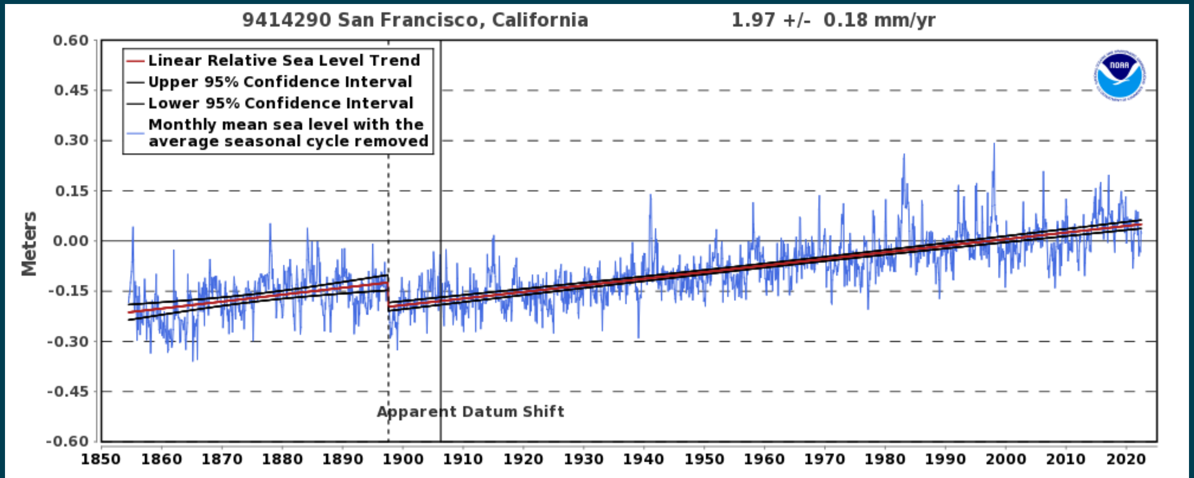




- ~7 years of overlap show bias between dataset
- Correct bias using quantile mapping based on the overlap years

Sea Level Data

- Data sources
  - NOAA at Golden Gate Bridge
    - 9414290 San Francisco, CA
  - Planning tide from DSM2 inputs
- Variables used
  - Daily Mean Sea Level
  - Total Tidal Energy
    - daily maximum – minimum hourly astronomical tide
    - From ANN



NOAA, "Relative Sea Level Trend." NOAA Tides and Currents, https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?id=9414290. Accessed 13 Sep 2022

Flow Data

- DWR Dayflow Model [Dayflow, 2023]
- Variables used

QOUT = QTOT + QPREC
- QGCD - QEXPORTS - QMISDV
QTOT = QSAC + QEAST + QYOLO
QEAST = QSJR + QCSMR + QMOKE + QMISC
QXGEO

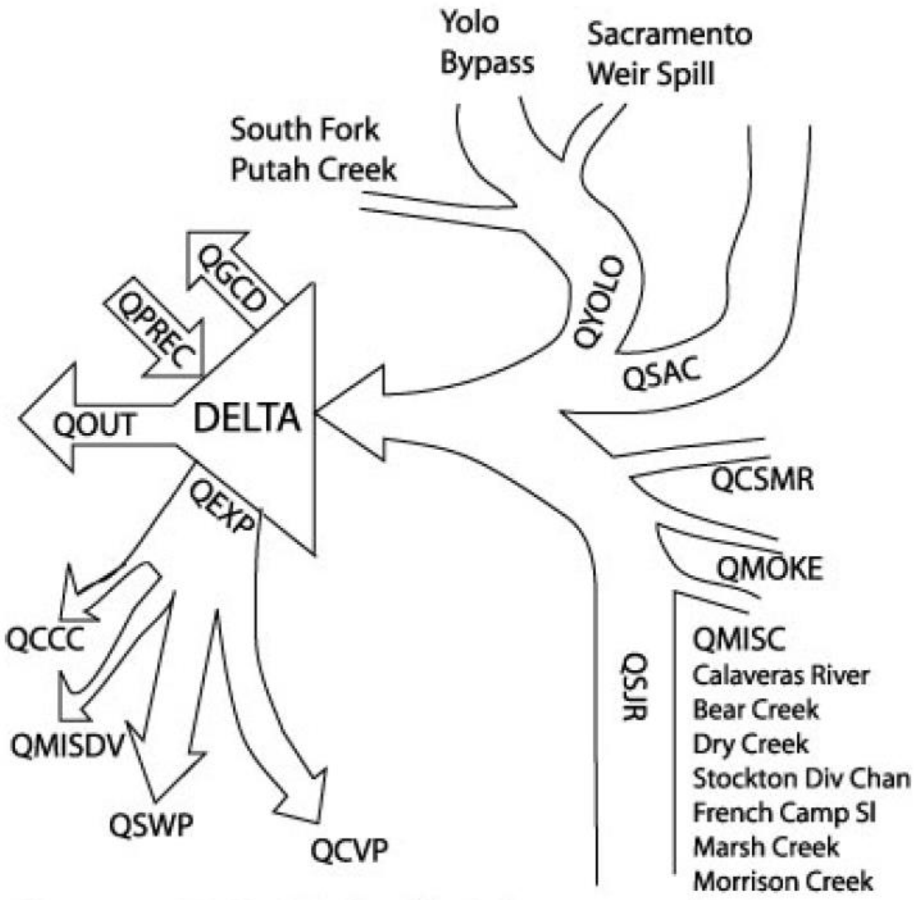


Figure 2: Delta Hydraulic Scheme used in Dayflow

[Dayflow, 2023]

Data Correlation

		Salinity											Flow											Sea Level (SL)			
		MRZ	PCT	MAL	CLL	EMM	TSL	RVB	ANH	JER	RSL	X2	QOUT	QTOT	QPREC	QGCD	QEXPORTS	QMISDV	QSAC	QEAST	QYOLO	QSJR	QXGEO	Mean	Min	Max	TTE
Salinity	MRZ	1.00	0.92	0.78	0.69	0.52	0.45	0.14	0.58	0.40	0.56	0.93	-0.67	-0.65	-0.23	0.37	0.28	-0.01	-0.76	-0.63	-0.31	-0.61	-0.45	0.13	-0.05	0.17	0.15
	PCT	0.92	1.00	0.92	0.85	0.73	0.66	0.30	0.77	0.57	0.62	0.95	-0.56	-0.56	-0.19	0.31	0.11	0.00	-0.70	-0.56	-0.25	-0.54	-0.46	0.03	-0.10	0.10	0.14
	MAL	0.78	0.92	1.00	0.96	0.88	0.82	0.51	0.91	0.75	0.66	0.87	-0.42	-0.42	-0.16	0.28	0.08	0.00	-0.54	-0.42	-0.17	-0.41	-0.38	0.03	-0.06	0.07	0.09
	CLL	0.69	0.85	0.96	1.00	0.93	0.88	0.62	0.96	0.84	0.66	0.80	-0.36	-0.36	-0.15	0.25	-0.03	0.00	-0.48	-0.36	-0.14	-0.35	-0.38	-0.01	-0.07	0.03	0.07
	EMM	0.52	0.73	0.88	0.93	1.00	0.91	0.70	0.93	0.85	0.61	0.68	-0.26	-0.27	-0.10	0.16	-0.12	0.00	-0.37	-0.26	-0.10	-0.25	-0.33	-0.02	-0.06	0.01	0.05
	TSL	0.45	0.66	0.82	0.88	0.91	1.00	0.79	0.93	0.91	0.77	0.62	-0.23	-0.24	-0.08	0.11	-0.07	0.00	-0.32	-0.24	-0.09	-0.24	-0.30	-0.03	-0.06	0.00	0.04
	RVB	0.14	0.30	0.51	0.62	0.70	0.79	1.00	0.74	0.89	0.44	0.33	-0.09	-0.10	-0.04	0.02	-0.15	0.00	-0.14	-0.09	-0.03	-0.09	-0.20	-0.07	-0.05	-0.04	0.01
	ANH	0.58	0.77	0.91	0.96	0.93	0.93	0.74	1.00	0.93	0.71	0.71	-0.29	-0.30	-0.10	0.18	-0.04	0.00	-0.40	-0.30	-0.11	-0.29	-0.34	-0.03	-0.06	0.01	0.05
	JER	0.40	0.57	0.75	0.84	0.85	0.91	0.89	0.93	1.00	0.78	0.54	-0.19	-0.20	-0.07	0.10	-0.08	0.00	-0.26	-0.19	-0.07	-0.19	-0.27	-0.05	-0.05	-0.02	0.02
	RSL	0.56	0.62	0.66	0.66	0.61	0.77	0.44	0.71	0.78	1.00	0.55	-0.24	-0.27	0.11	-0.16	-0.09	-0.04	-0.31	-0.32	-0.12	-0.31	-0.18	0.11	0.02	0.01	0.00
	X2	0.93	0.95	0.87	0.80	0.68	0.62	0.33	0.71	0.54	0.55	1.00	-0.71	-0.71	-0.21	0.34	0.17	0.00	-0.79	-0.68	-0.36	-0.65	-0.48	0.03	-0.11	0.10	0.14
Flow	QOUT	-0.67	-0.56	-0.42	-0.36	-0.26	-0.23	-0.09	-0.29	-0.19	-0.24	-0.71	1.00	0.99	0.51	-0.34	-0.11	0.08	0.89	0.82	0.86	0.71	0.60	0.20	0.24	0.03	-0.14
	QTOT	-0.65	-0.56	-0.42	-0.36	-0.27	-0.24	-0.10	-0.30	-0.20	-0.27	-0.71	0.99	1.00	0.46	-0.29	-0.02	0.10	0.89	0.82	0.86	0.72	0.64	0.23	0.26	0.05	-0.14
	QPREC	-0.23	-0.19	-0.16	-0.15	-0.10	-0.08	-0.04	-0.10	-0.07	0.11	-0.21	0.51	0.46	1.00	-0.31	-0.01	0.05	0.43	0.29	0.40	0.17	0.28	0.20	0.14	0.09	-0.03
	QGCD	0.37	0.31	0.28	0.25	0.16	0.11	0.02	0.18	0.10	-0.16	0.34	-0.34	-0.29	-0.31	1.00	0.18	0.00	-0.33	-0.20	-0.19	-0.16	-0.05	0.21	0.02	0.26	0.16
	QEXPORTS	0.28	0.11	0.08	-0.03	-0.12	-0.07	-0.15	-0.04	-0.08	-0.09	0.17	-0.11	-0.02	-0.01	0.18	1.00	-0.01	0.02	-0.08	-0.03	-0.08	0.32	0.36	0.20	0.25	0.03
	QMISDV	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	0.00	0.08	0.10	0.05	0.00	-0.01	1.00	0.04	0.04	0.15	0.00	0.03	0.03	0.02	0.02	0.00
	QSAC	-0.76	-0.70	-0.54	-0.48	-0.37	-0.32	-0.14	-0.40	-0.26	-0.31	-0.79	0.89	0.89	0.43	-0.33	0.02	0.04	1.00	0.75	0.57	0.67	0.74	0.19	0.24	0.03	-0.14
	QEAST	-0.63	-0.56	-0.42	-0.36	-0.26	-0.24	-0.09	-0.30	-0.19	-0.32	-0.68	0.82	0.82	0.29	-0.20	-0.08	0.04	0.75	1.00	0.56	0.97	0.49	0.20	0.23	0.05	-0.12
	QYOLO	-0.31	-0.25	-0.17	-0.14	-0.10	-0.09	-0.03	-0.11	-0.07	-0.12	-0.36	0.86	0.86	0.40	-0.19	-0.03	0.15	0.57	0.56	1.00	0.44	0.41	0.21	0.21	0.06	-0.10
	QSJR	-0.61	-0.54	-0.41	-0.35	-0.25	-0.24	-0.09	-0.29	-0.19	-0.31	-0.65	0.71	0.72	0.17	-0.16	-0.08	0.00	0.67	0.97	0.44	1.00	0.43	0.16	0.20	0.03	-0.11
	QXGEO	-0.45	-0.46	-0.38	-0.38	-0.33	-0.30	-0.20	-0.34	-0.27	-0.18	-0.48	0.60	0.64	0.28	-0.05	0.32	0.03	0.74	0.49	0.41	0.43	1.00	0.27	0.25	0.12	-0.08
SL	Mean	0.13	0.03	0.03	-0.01	-0.02	-0.03	-0.07	-0.03	-0.05	0.11	0.03	0.20	0.23	0.20	0.21	0.36	0.03	0.19	0.20	0.21	0.16	0.27	1.00	0.47	0.68	0.15
	Min	-0.05	-0.10	-0.06	-0.07	-0.06	-0.06	-0.05	-0.06	-0.05	0.02	-0.11	0.24	0.26	0.14	0.02	0.20	0.02	0.24	0.23	0.21	0.20	0.25	0.47	1.00	-0.08	-0.73
	Max	0.17	0.10	0.07	0.03	0.01	0.00	-0.04	0.01	-0.02	0.01	0.10	0.03	0.05	0.09	0.26	0.25	0.02	0.03	0.05	0.06	0.03	0.12	0.68	-0.08	1.00	0.74
	TTE	0.15	0.14	0.09	0.07	0.05	0.04	0.01	0.05	0.02	0.00	0.14	-0.14	-0.14	-0.03	0.16	0.03	0.00	-0.14	-0.12	-0.10	-0.11	-0.08	0.15	-0.73	0.74	1.00

Proposed Methods and Results

- Model development
  - Selection, training, and testing processes
- Quantify model skill
  - Comparison with ANN
- Replace ANN DLL with new model in CalSim
  - Uses a SLR parameter and real time flow from CalSim
- Exploration of SLR effects and CVP sensitivity to SLR
  - Identify DSM2/SCHISM models refinements
- Continuously refine model from additional DSM2/SCHISM simulations

ANN Development

- Reclamation received Applied Science award to help develop ANN training workflow
- DWR open-sourced their ANN tools
  - Upgrade workflow to TensorFlow

- Reclamation is building capacity towards joint development
  - Build hyper parameter tuning into scripting
  - Construct HPC training workflow
  - Evaluate cross validation approaches

References

- Hutton, Paul H., et al. "Nine decades of salinity observations in the San Francisco Bay and Delta: Modeling and trend evaluations." Journal of Water Resources Planning and Management 142.3 (2016): 04015069.
- Dayflow. *California Natural Resources Agency Open Data*, 19 Jan. 2023, https://data.cnra.ca.gov/dataset/dayflow.

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