



— BUREAU OF —
RECLAMATION

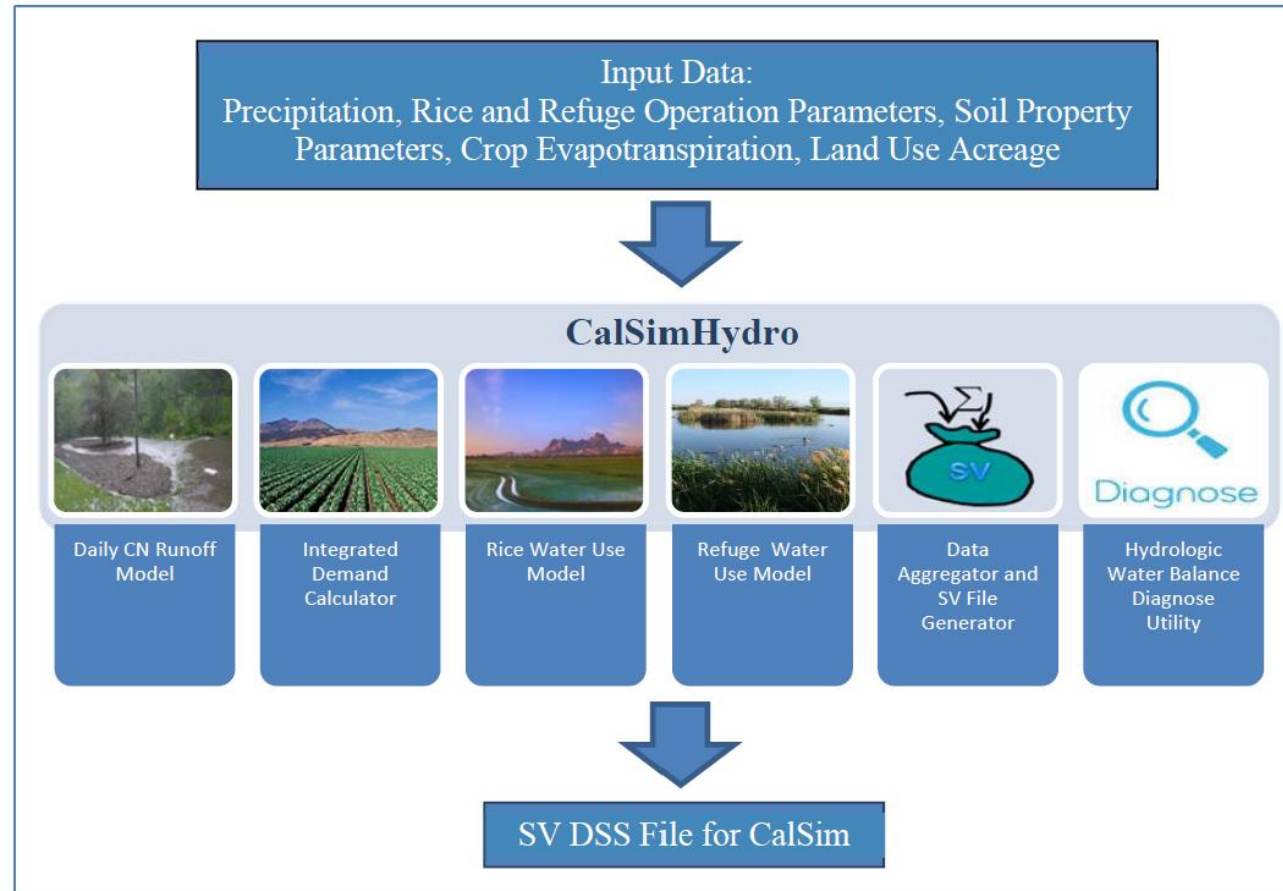
CalSimHydroV2 Ostrich Calibration

CWEMF Annual Meeting, April 2026

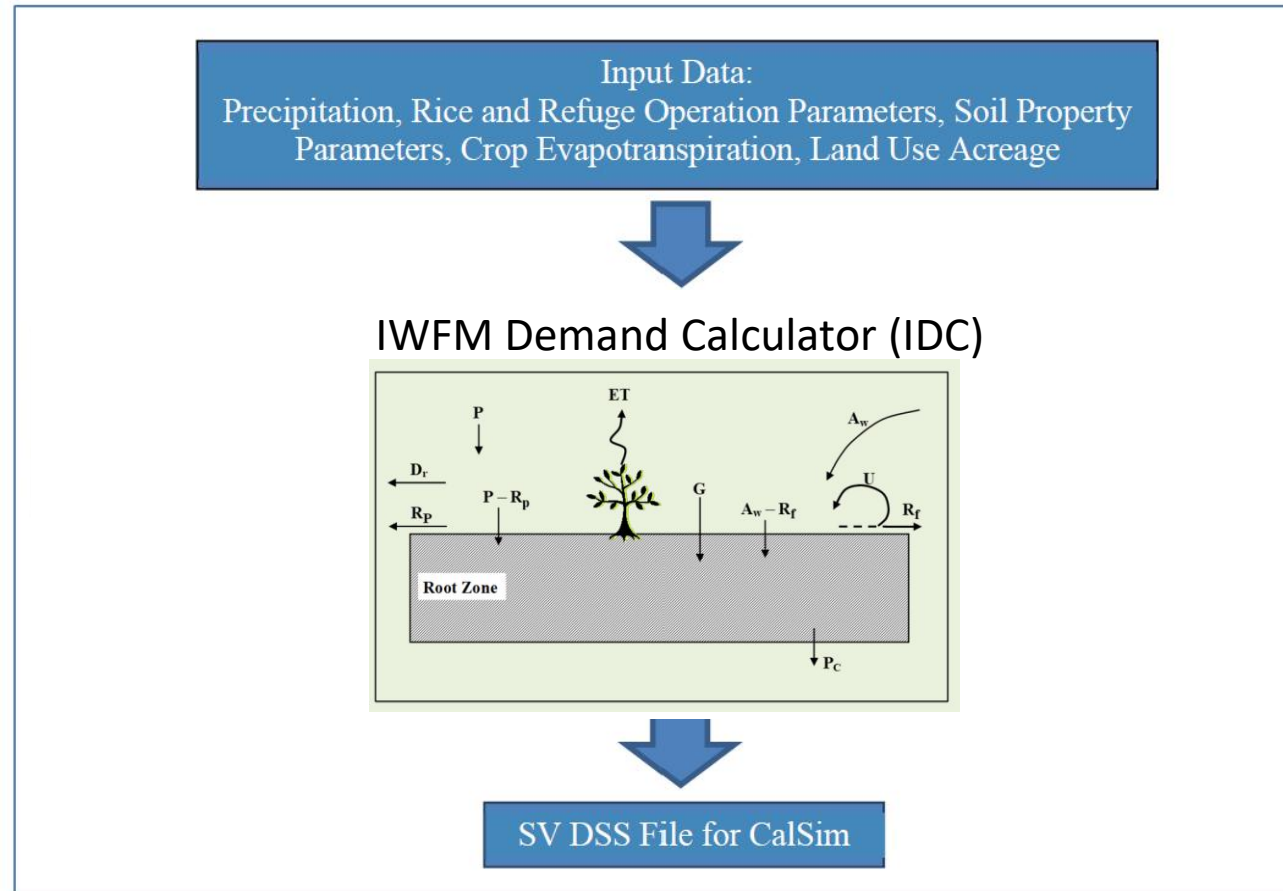
Lauren Thatch (Reclamation)

Collaborators: Drew Loney (Reclamation), Frankie
Nuffer-Rodriguez (Reclamation)

Overview of CalSimHydroV2 development



Overview of CalSimHydroV2 development



New IDC methods require new model parameters

$$P_C^{t+1} = P_{Crdc}^{t+1} + K_s \left(\frac{\theta^{t+1}}{\theta_T} \right)^{1/2} \left\{ 1 - \left[1 - \left(\frac{\theta^{t+1}}{\theta_T} \right)^{1/m} \right]^m \right\}^2$$

$$m = \frac{\lambda}{\lambda + 1}$$

$$P_{Crdc}^{t+1} = \begin{cases} \theta^t (Z^t - Z^{t+1}) & \text{if } Z^t > Z^{t+1} \\ 0 & \text{otherwise} \end{cases}$$

K_s saturated hydraulic conductivity (L/T)
 λ pore size distribution index (dimensionless)
 θ_T total porosity (L/L)

- Prev. CalSimHydro model estimated percolation as the amount of soil moisture above field capacity at the end of the timestep.
- New IDC, percolation is estimated using a 1-D physically based routing approach
 - Van Genuchten-Mualem equation



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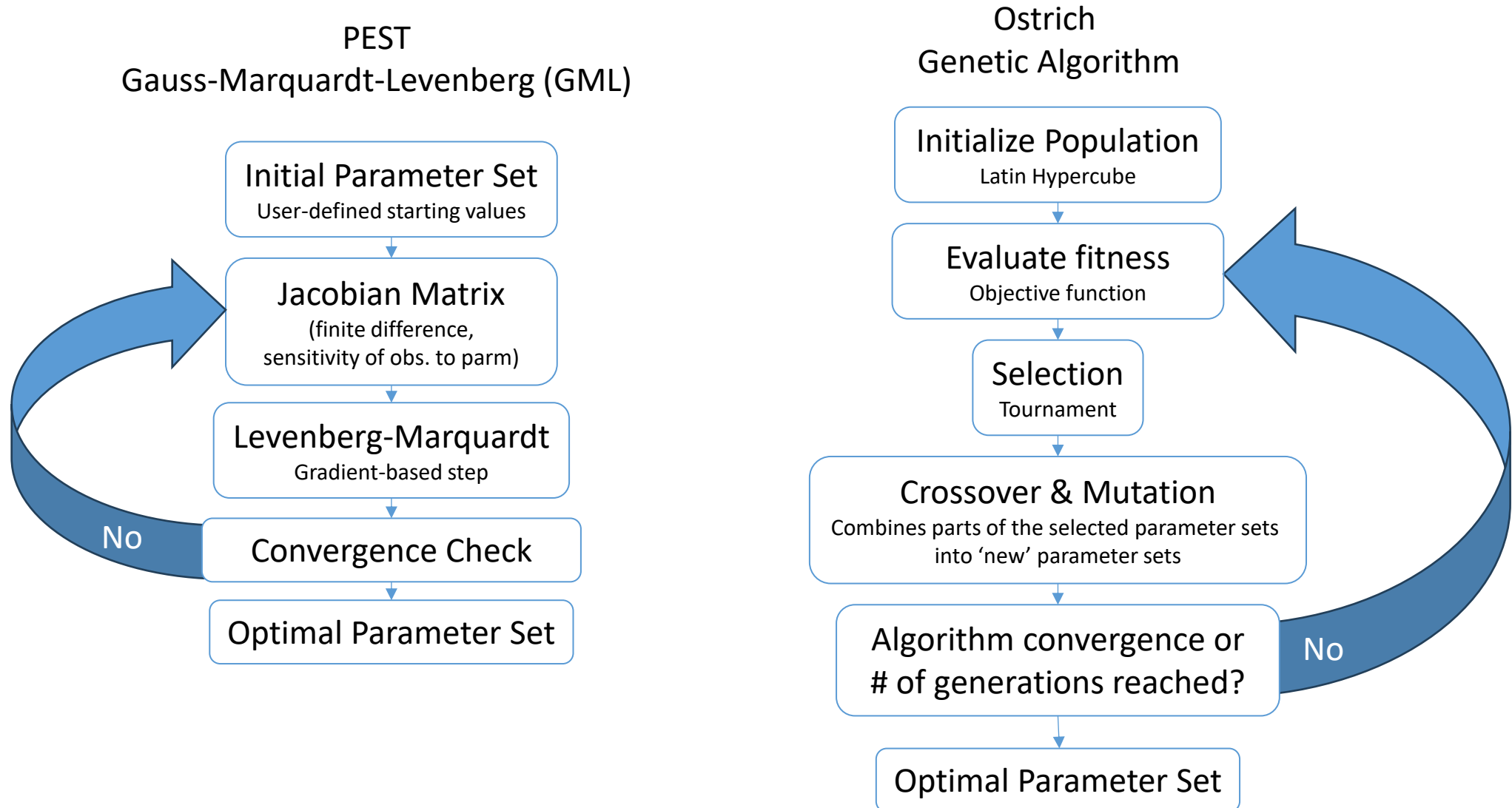


Study Objective

- Calibrate the CalSimHydro model to provide representative estimates of applied water demands, deep percolation, and surface runoff for CalSim 3 model inputs
 - Develop a workflow and toolset to calibrate the updated CalSimHydro model using the Ostrich calibration framework
 - Develop calibration objectives, including historical surface water diversion and actual ET estimates, for the updated model
 - Conduct a thorough analysis of model results compared to previous model results and observational datasets
 - Integrated calibration workflow into broader CalSim 3 Historical Model and GWDLL calibration

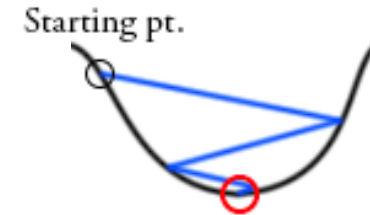
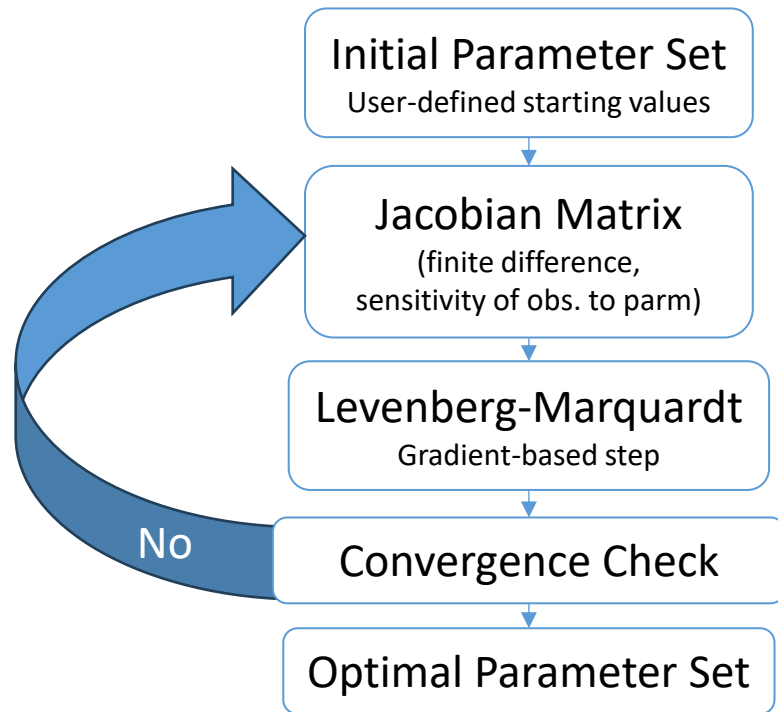


Calibration Tool Comparison

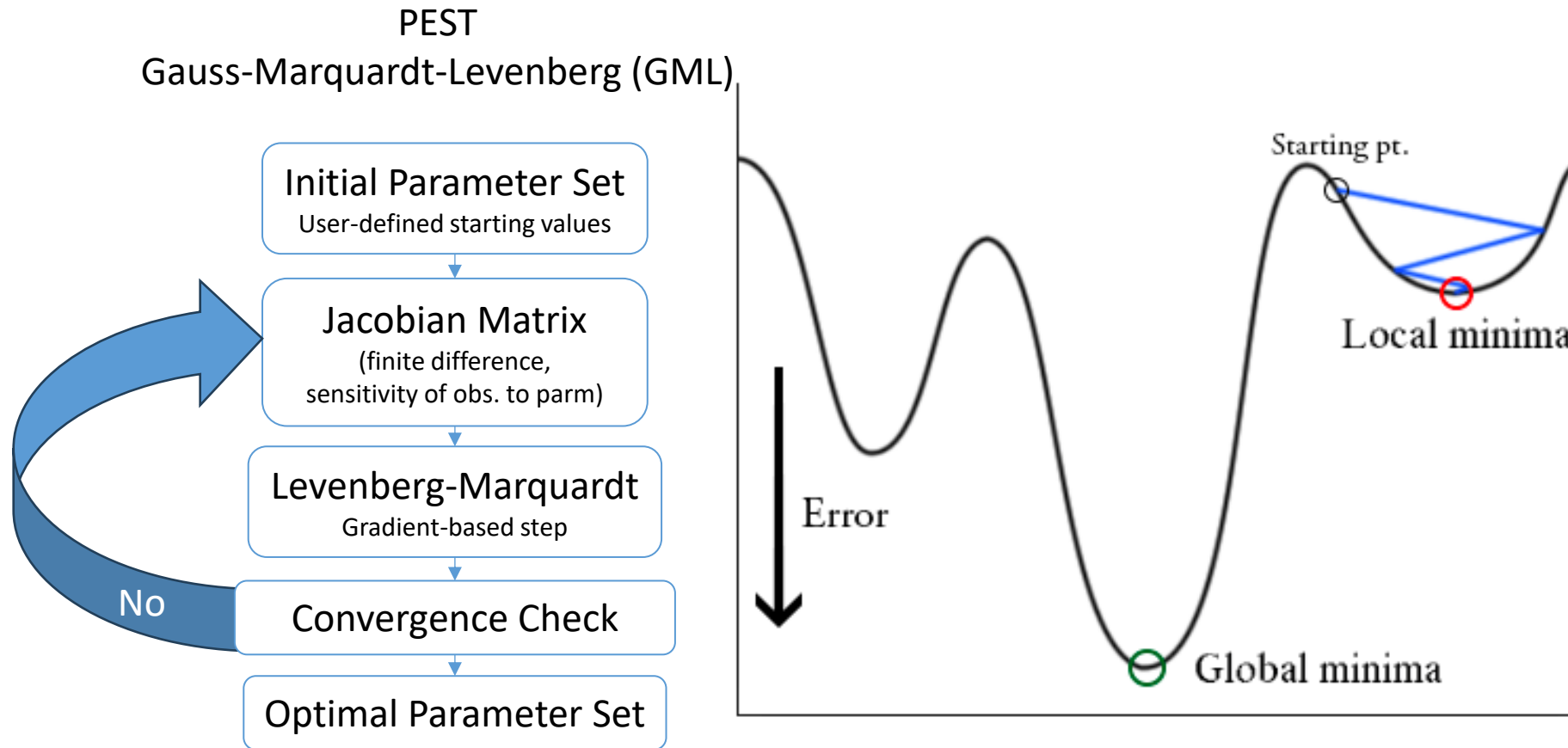


Gradient Solver Approach

PEST
Gauss-Marquardt-Levenberg (GML)



Gradient Solver Approach



Calibration Tool Comparison

- PEST - GML

- Benefits

- Fast if response surface is convex, or near global minima
 - Widely used
 - Built in sensitivity analysis (Jacobian)

- Drawbacks

- High risk of local minima
 - Not parallel by default (sequential)

- Ostrich – GA

- Benefits

- Global parameter search
 - Population diversity
 - MPI

- Drawbacks

- Genetic algorithm settings
 - Computational cost and number of generations required to find 'global' solution



Benefits of the OSTRICH approach

- Publicly available, open-source code:
 - <https://github.com/DOI-BOR/ostrich>
- Model-independent, multi-algorithm optimization and calibration tool

1 SEARCH ALGORITHMS

Each algorithm has its own configuration group, wherein the user can specify the values for various algorithm control variables. Additional optional configuration variables and groups (i.e. Warm Start, Pre-Emption, Parameter Correction, a List of Initial Parameters, Math and Stats, and Line Search) may also be available for a given algorithm, as indicated in Table 1.

BISECTION

GAUSS-MARQUARDT-LEVENBERG

GRIDDED EXHAUSTIVE SEARCH

STEEPEST DESCENT

ASYNCHRONOUS PARALLEL PARTICLE SWARM OPTIMIZATION

BALANCED EXPLORATION-EXPLOITATION RANDOM SEARCH

SIMULATED ANNEALING

VANDERBILT-LOUIE SIMULATED ANNEALING

ASYNCHRONOUS PARALLEL DYNAMICALLY DIMENSIONED SEARCH

SHUFFLED COMPLEX

FLETCHER-REEVES

MULTI-START GML WITH TRAJECTORY REPULSION

POWELL'S ALGORITHM

PARTICLE SWARM OPTIMIZATION (PSO)

PARTICLE SWARM OPTIMIZATION WITH GML POLISHING

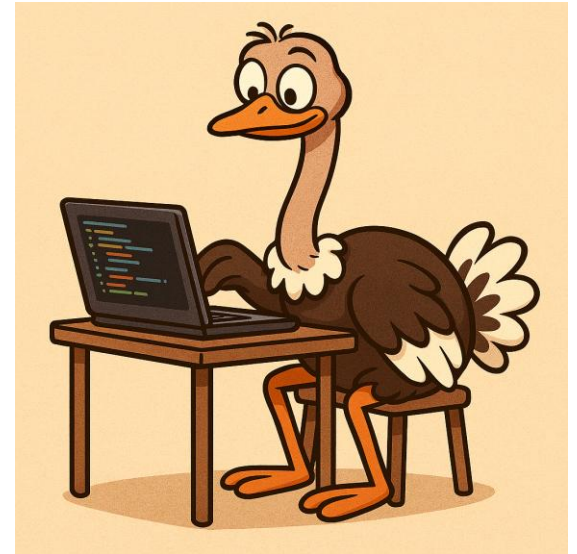
BINARY AND REAL CODED GENETIC ALGORITHMS

COMBINATORIAL (DISCRETE) SIMULATED ANNEALING

DYNAMICALLY DIMENSIONED SEARCH (DDS)

DISCRETE DYNAMICALLY DIMENSIONED SEARCH

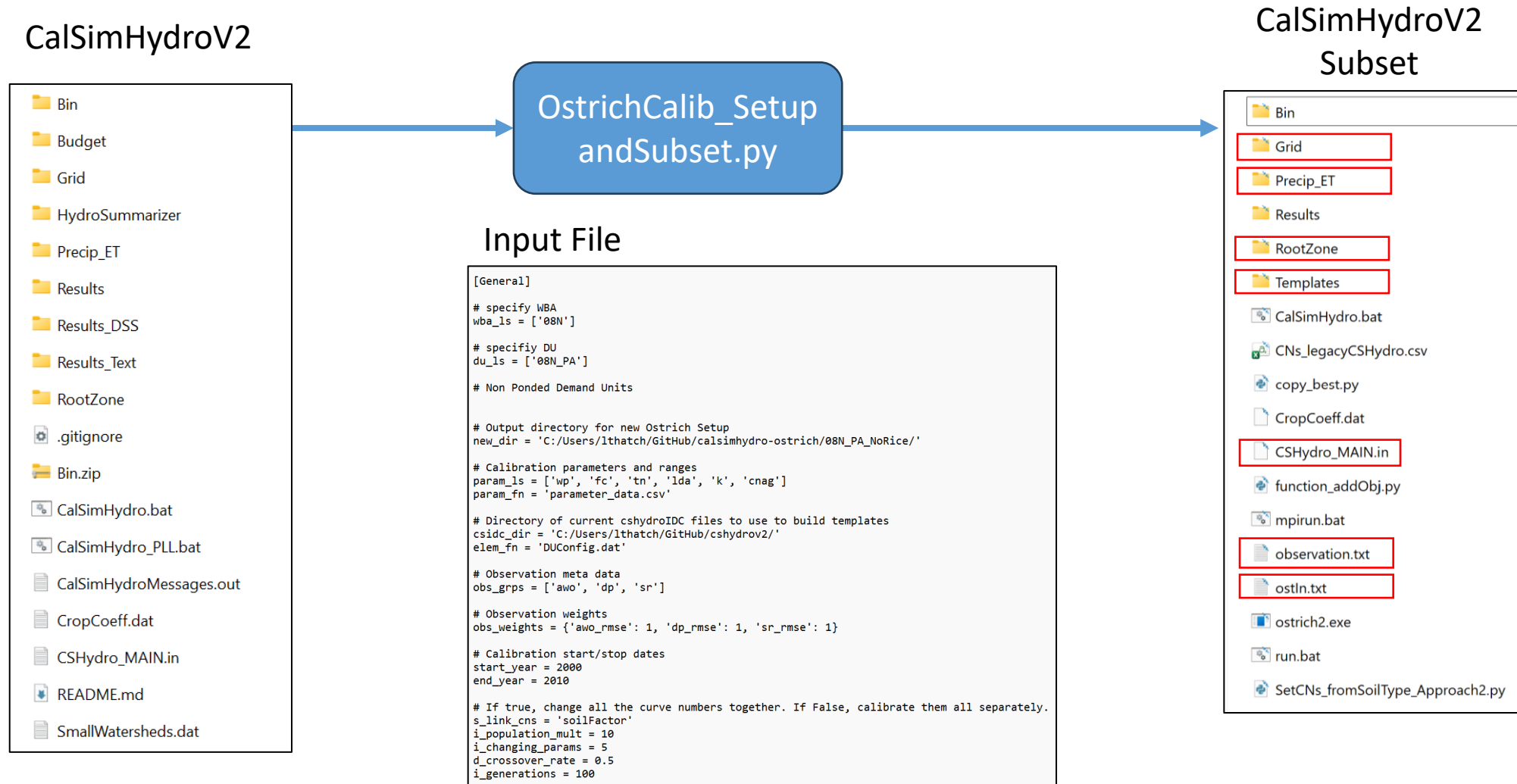
SAMPLING ALGORITHM (BIG BANG - BIG CRUNCH)



Copilot



Automated model subsetting and calibration setup



Ostrich Model Setup

- Subsets model to relevant grid only
 - Including input DSS files
- Minimizes run time, increases calibration speed

DUConfig.dat

C	-----									
C	-----									
C	Demand Unit	-----Corresponding Nodes-----								
C	IDU	IDE(1)	IDE(2)	IDE(3)	IDE(4)	IWBA				
C	-----									
	33	65	67	68	66	8	1.00000	08N_PA	/	1.00000

ROOTZONE_MAIN.tpl

C	to the appropriate data column in the Surface Flow Destination file (DESTFL)						
C							
C	-----						
C	IE	WP	FC	TN	LAMBDA	K	KPonded
C	-----						
	33	\$wp_08N_PA\$	\$fc_08N_PA\$	\$tn_08N_PA\$	\$lda_08N_PA\$	\$k_08N_PA\$	0.001250000

OstIn.txt

```
#Configuration File for Ostrich Program
ProgramType      GeneticAlgorithm
ModelExecutable  run.bat
ModelSubdir      core_
ObjectiveFunction WSSE

# Optional variables
PreserveModelOutput      no
PreserveBestModel        yes
OnObsError                1000000
SolveOnPrimary           yes
WarmStart                no

# Specify the files to be transferred to the working directories
BeginExtraFiles
function_addObj.py
run.bat
CSHydro_MAIN.in
observation.txt
SetCNS_fromSoilType_Approach2.py
CNS_legacyCSHydro.csv
CropCoeff.dat
EndExtraFiles

BeginExtraDirs
Bin
Templates
Grid
Precip_ET
Results
RootZone
EndExtraDirs

# Specify the file pairs for calibration
BeginFilePairs
Templates/ROOTZONE_MAIN.tpl      RootZone/ROOTZONE_MAIN.dat
Templates/NonPondedAg_MAIN.tpl    RootZone/NonPondedAg/NonPondedAg_MAIN.dat
Templates/SoilParam.tpl           SoilParam.dat
EndFilePairs

#Parameter Specification
BeginParams
$wp_03_NA$      0.1178  0.0      0.3      none      none      none      F10.6
$lda_03_NA$     0.2150627  0.001  2.0      none      none      none      F10.6
$k_03_NA$       12.28989  0.001  100.0    none      none      none      F10.6
$ratfc_03_NA$   0.5      0.0      1.0      none      none      none      F10.6
$rattn_03_NA$   0.5      0.0      1.0      none      none      none      F10.6
$soilFactor_03_NA$ 1.5      0.0      3.0      none      none      none      F10.6
EndParams

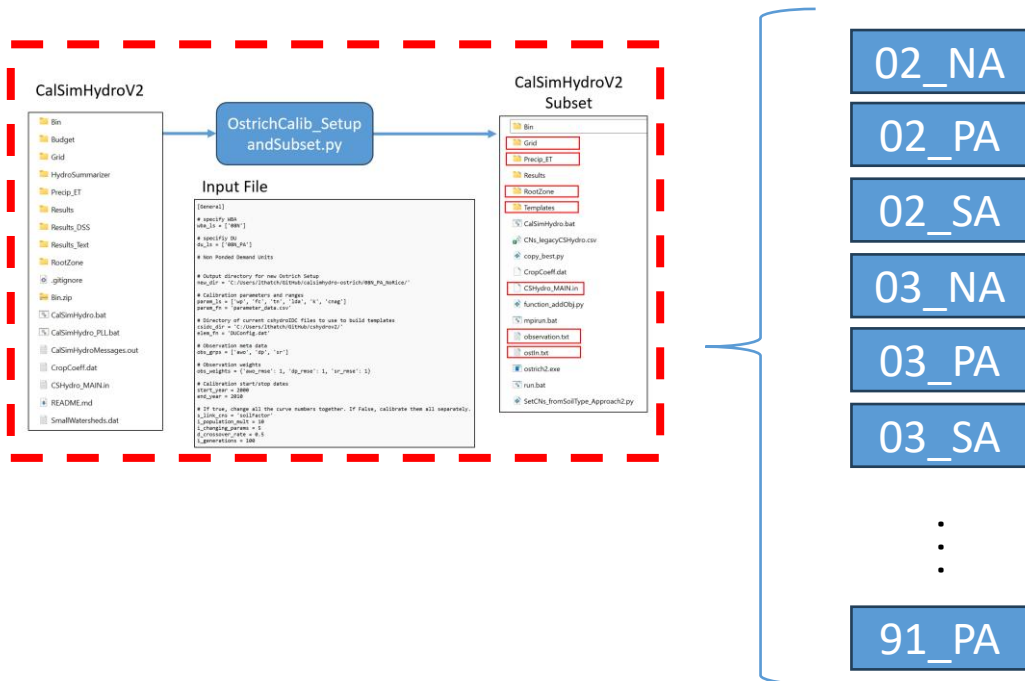
BeginTiedParams
$fc_03_NA$      2      $wp_03_NA$      $ratfc_03_NA$   linearmax      0      1      1      0      1      F10.6
$tn_03_NA$      2      $fc_03_NA$      $rattn_03_NA$  linearmax      0      1      1      0      1      F10.6
EndTiedParams

#Observation Configuration
BeginObservations
#observation value weight file keyword line column tok aug? group
awo_rmse 0 1 objective.txt awo_rmse 0 0 2 '\t' No awo_rmse
dp_rmse 0 1 objective.txt dp_rmse 0 2 '\t' No dp_rmse
sr_rmse 0 1 objective.txt sr_rmse 0 2 '\t' No sr_rmse
```



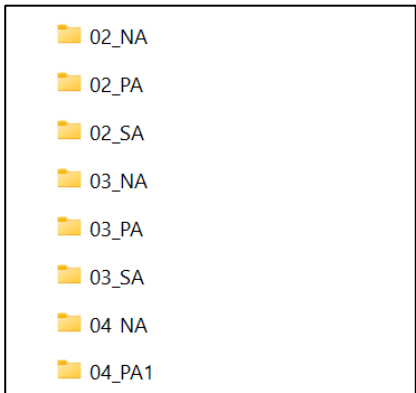
Multi DU Calibration Setup

1) Script runs provided list of DU calibrations



2 Archives model results

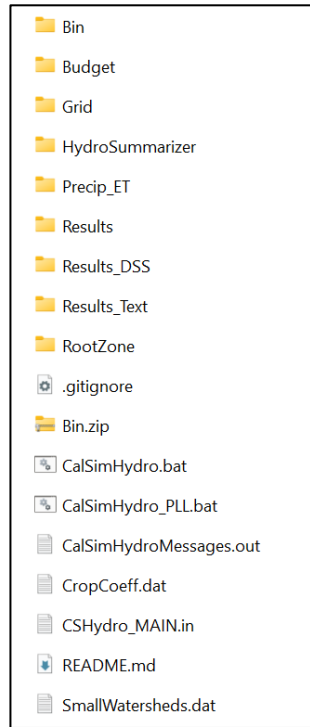
'best' model and results



Csv of final parameters

DU	WBA	Variable	Value	varType
02_NA	02	wp_02_NA	0.020506	wp
02_NA	02	lda_02_NA	0.927033	lda
02_NA	02	k_02_NA	70.0941	k
02_NA	02	ratfc_02_N	0.138112	ratfc
02_NA	02	rattn_02_N	0.418988	rattn
02_NA	02	soilFactor_	2.279173	soilFactor
02_NA	02	fc_02_NA	0.158617	fc
02_NA	02	tn_02_NA	0.577605	tn
02_PA	02	wp_02_PA	0.123678	wp
02_PA	02	lda_02_PA	0.379061	lda
02_PA	02	k_02_PA	60.81753	k
02_PA	02	ratfc_02_P	0.124771	ratfc
02_PA	02	rattn_02_P	0.24473	rattn

3 Reassembles full CalSimHydroV2 model with updated parameters



4 Rerun complete model, QA/QC of run results to ensure consistency with DU results

Tied Parameter Development and Exploration

- Curve numbers vary across soil types and land use.
 - Method varies CN by single variable representing soil group, instead of individually variable CNs
- Reduces calibrated parameters
- Ties CN estimation to physical soil parameters

```
#Parameter Specification
BeginParams
$wp_06_NA$ 0.1190261 0.0 0.3 none none none F10.6
$lida_06_NA$ 0.2598553 0.001 2.0 none none none F10.6
$k_06_NA$ 3.874518 0.001 100.0 none none none F10.6
$ratfc_06_NA$ 0.5 0.0 1.0 none none none F10.6
$rattn_06_NA$ 0.5 0.0 1.0 none none none F10.6
$soilFactor_06_NA$ 1.5 0.0 3.0 none none none F10.6
EndParams

BeginTiedParams
$fc_06_NA$ 2 $wp_06_NA$ $ratfc_06_NA$ linearmax 0 1 1 0 1 F10.6
$tn_06_NA$ 2 $fc_06_NA$ $rattn_06_NA$ linearmax 0 1 1 0 1 F10.6
EndTiedParams
```

SCS TR-55 Table 2-2b – Runoff curve numbers for cultivated agricultural lands¹

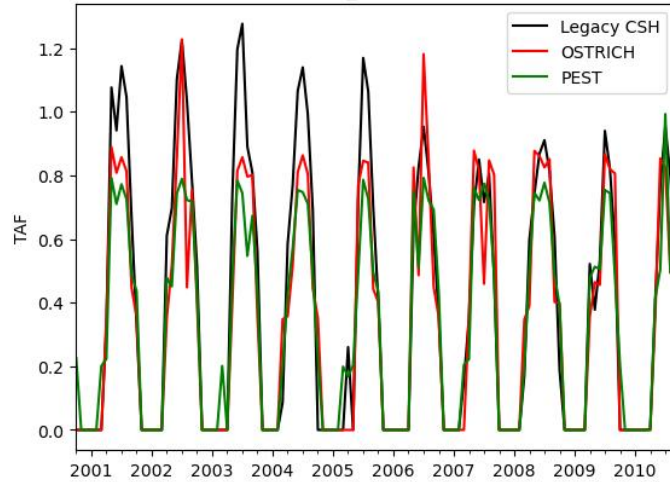
Cover description			Curve numbers for hydrologic soil group			
Cover type	Treatment ²	Hydrologic condition ³	A	B	C	D
Fallow	Bare soil	-	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89



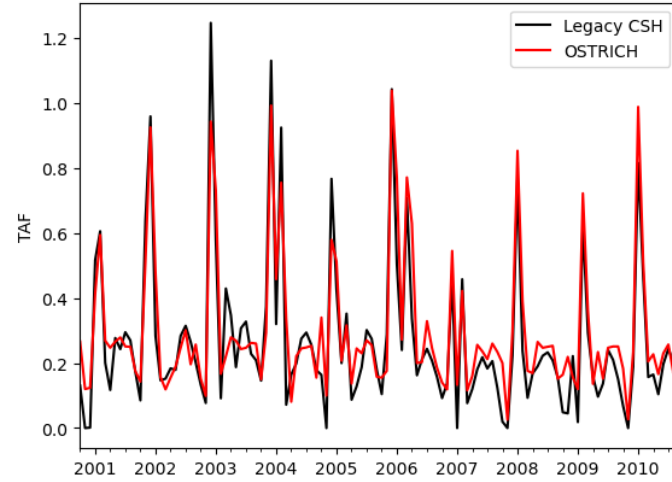
Initial evaluation of calibration setup

Applied Water

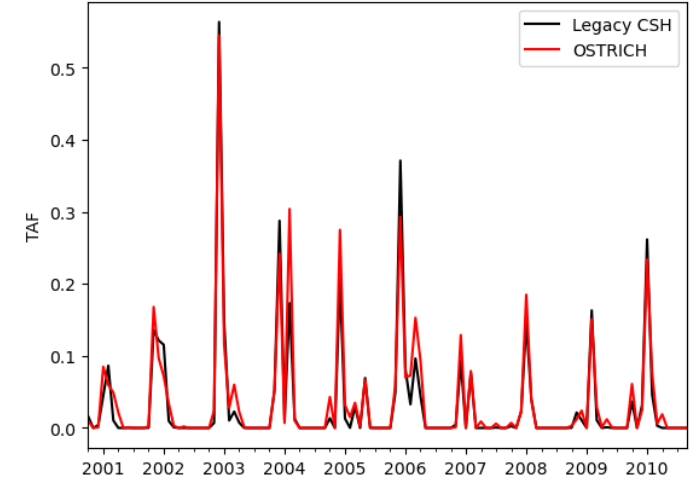
DU
03_SA



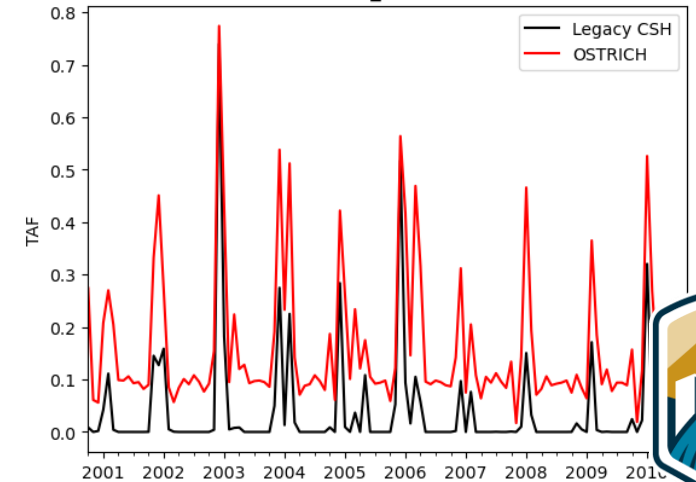
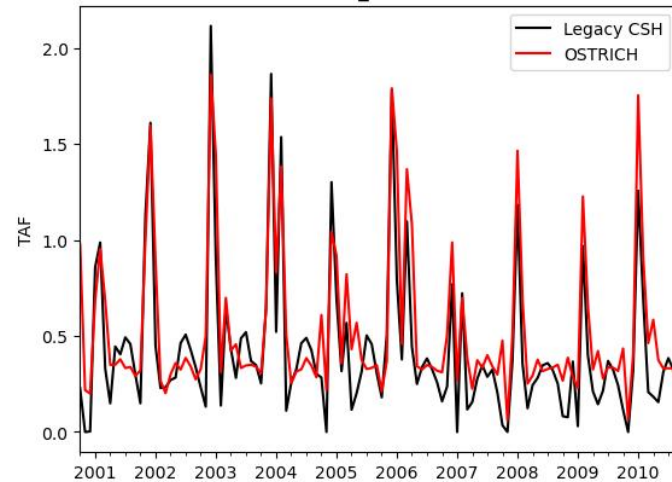
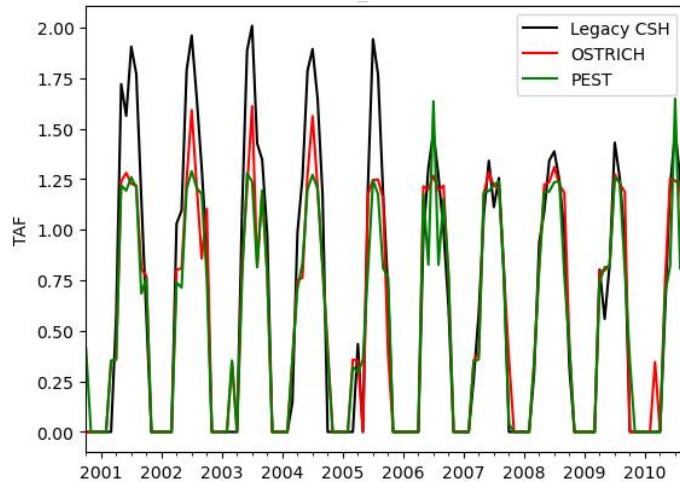
Deep Percolation



Surface Runoff



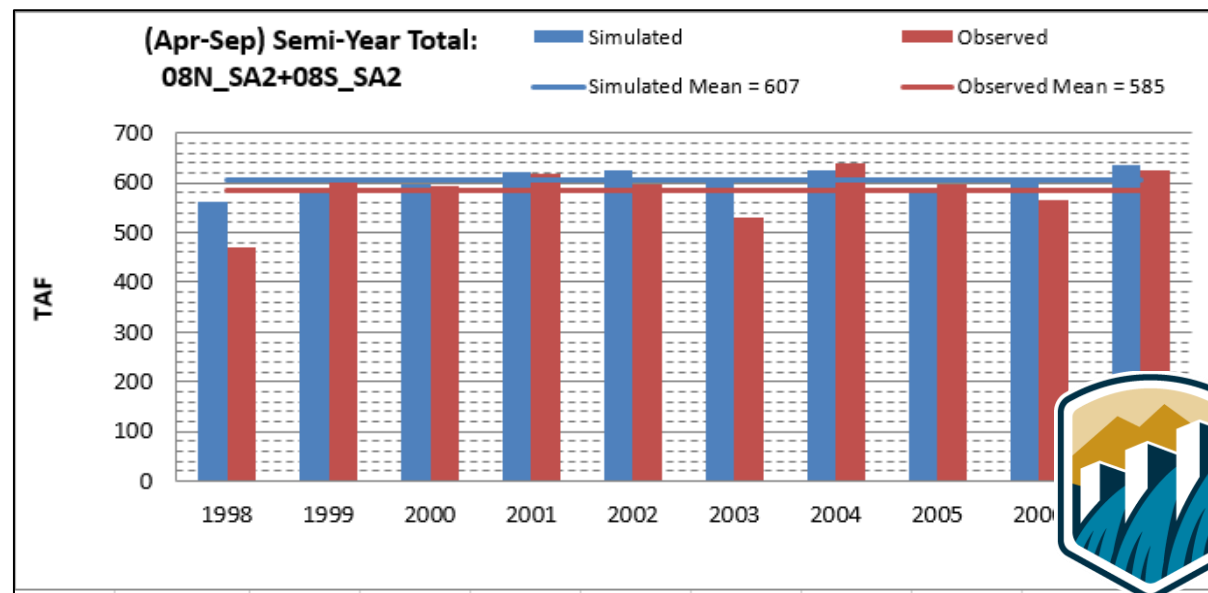
DU
03_PA



Previous CalSimHydro calibration

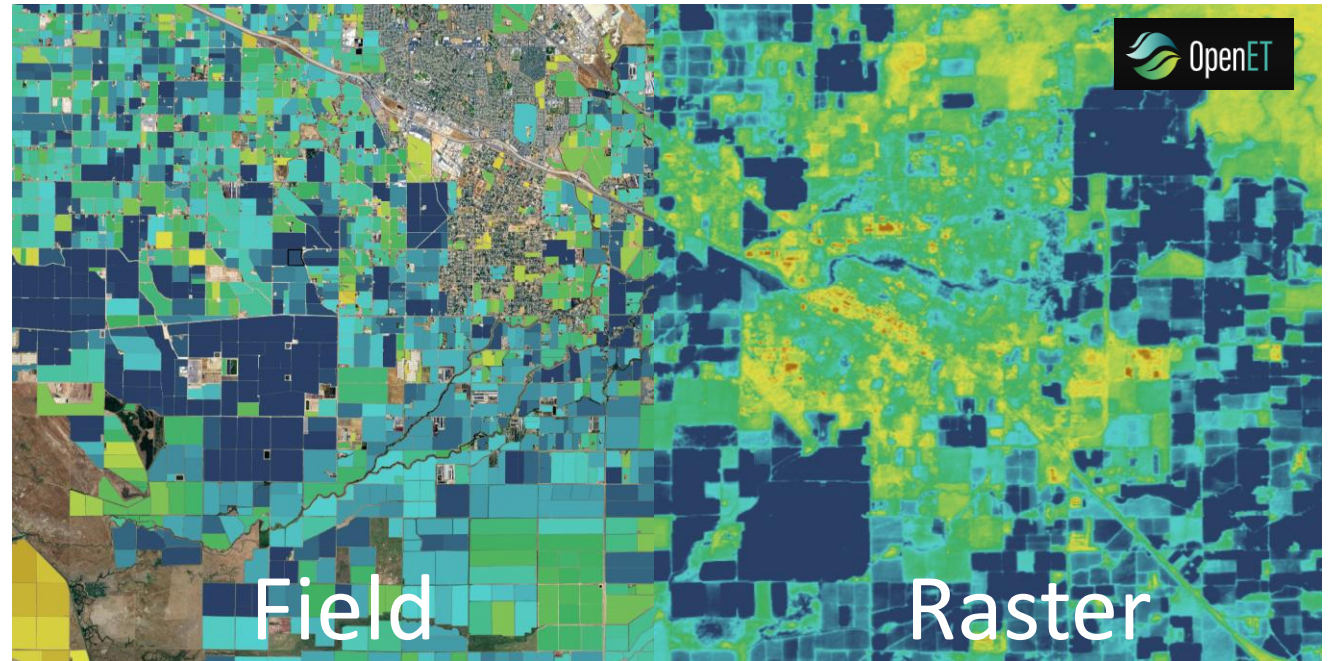
- Calibration Period: 1998-2007
- Calibrated Parameters
 - Minimum soil moisture requirements
 - Rice crop planting dates (fraction split between April and May)
 - Water Use Factors (CalSim3)
- Observations
 - Historical diversions

Semi-Annual Statistics for Summer (Apr-Sep) TAF							
	3285	3231	54	2%	380	441	
DUs	Simulated Mean (M)	Observed Mean (M)	Mean Error	% Mean Error	MAE	RMSE	Water District or Agency
08N_SA2+08S_SA2	607	585	22	4%	30	42	Glenn-Colusa ID
11_SA2+11_SA3+11_SA4	505	508	-4	-1%	23	27	Richvale ID; Biggs-West Gridley WD, Butte WD; Sutter Extension WD
19_SA	222	239	-18	-7%	36	40	Bardis et al., Pelger MWC, Sutter MWC (95%), mics. Settlement contractors
11_SA1	228	218	10	5%	17	20	Western Canal WD
20_NA1	200	185	15	8%	23	26	Yolo County FCWCD
08N_SA1	135	168	-33	-19%	35	36	Maxwell ID (95%), Princeton-codora Glenn ID, Provident ID, misc. settlement contractors
08S_SA3	197	166	32	19%	32	34	RD108, River Garden Farms, misc. settlement contractors
25_PA1+SIDSH	122	111	11	9%	11	15	Solano ID
07S_PA	159	108	51	47%	51	55	4M WD, Colusa County WD, Corina WD, Davis WD, Dunnigan WD, Glenn Valley WD, Holthouse WD (35%), etc
15N_NA2	109	106	3	3%	8	9	Cordua ID, Hallwood ID, Ramirez WD
23_NA	70	104	-34	-33%	36	39	Camp Far West ID, South Sutter WD, non-district



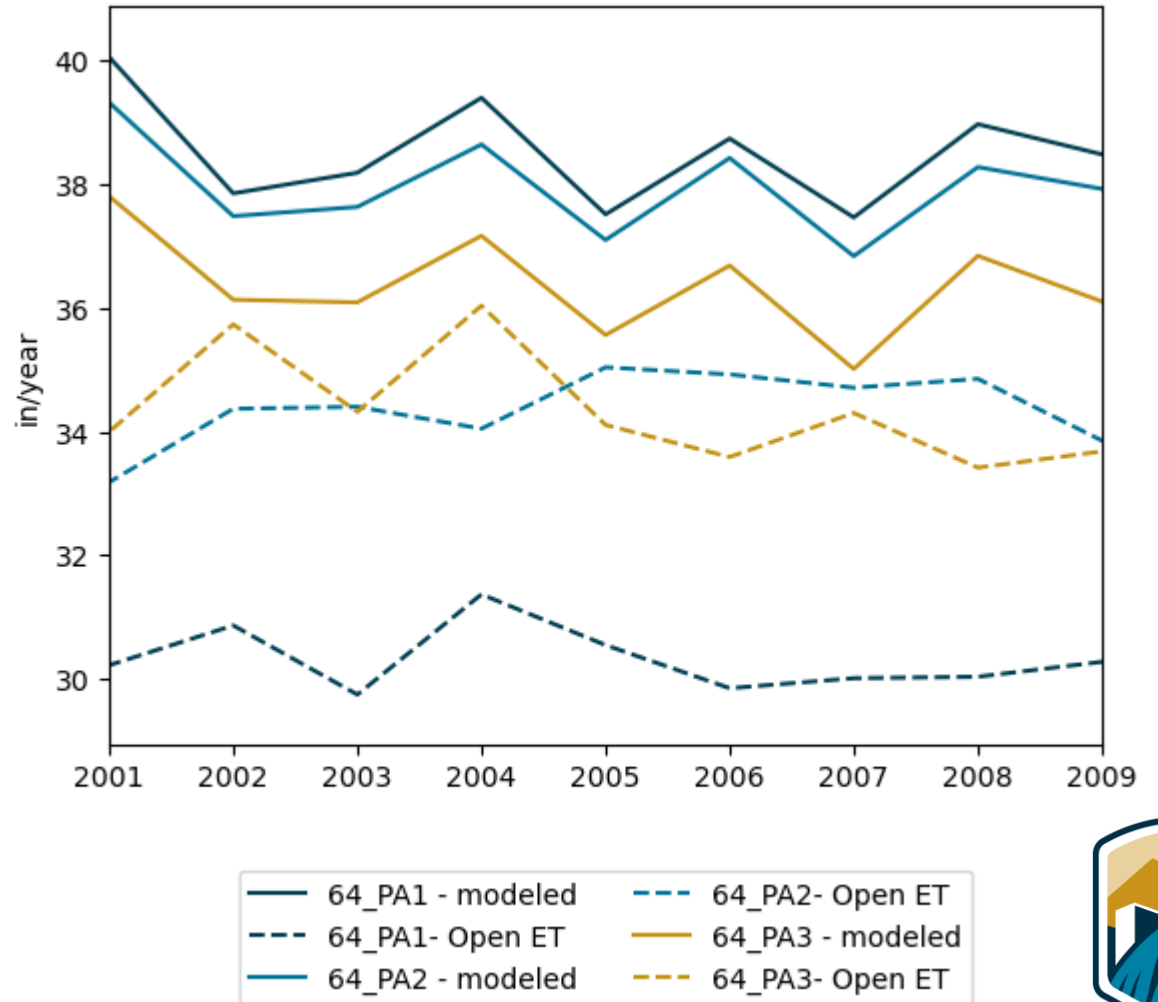
Updates to CalSimHydro calibration datasets

- Extend calibration period: 1990-2021 (30⁺-year period)
- Update observations
 - Historical diversions
 - Satellite based actual ET estimates
 - GSP Annual Reports
 - Groundwater pumping, diversion, and applied water estimates



Initial non-ponded crop ET comparison with OpenET

- Modeled crop ET represents ideal, well watered conditions
- Modeled ET > Satellite based estimates
- Provide insights on possible crop ET reduction factors



Surface and groundwater usage data from GSPs

**Table 2-2
WY2019 Total Water Use**

Component	Historic Condition Water Budget ***	Current Condition Water Budget
Hydrologic Period	WY 1989 - 2014	WY2019
Inflows		
Surface Water	12,200	12,833
Native Flows	1,900	907
Contract Water Class 2	6,600	11,926
MID Diversions	1,600	-
CVP supply by Cottonwood Cr.	2,100	-
Precipitation *	7,200	6,270
Groundwater Extraction - Ag ***	15,800	15,800
Subsurface Inflow	500	-
Groundwater Extraction - Residential	100	100
Outside Water Purchases		-
San Joaquin River Seepage		500
Total Inflows	35,800	35,503

* Value from CIMIS Station #7 Firebaugh/Telles

*** Average Values from Previous years 1989-2014

Gravelly Ford WD

Table 8. Groundwater Extraction in RCWDGSA from 2015 to 2019

Water Year	Water Demand (AF)			Surface Water Use (AF)			Groundwater Extraction (AF)		
	Crop Demand Estimate	Actual Municipal Demand	Total	Agricultural In-Lieu	Municipal	Total	Agricultural	Municipal	Total
2015	23,401	0	23,401	0	0	0	23,401	0	23,401
2016	23,423	0	23,423	0	0	0	23,423	0	23,423
2017	21,248	70	21,318	6,636	0	6,636	14,612	70	14,682
2018	23,841	186	24,027	1,361	0	1,361	22,480	186	22,666
2019	20,257	205	20,462	7,607	0	7,607	12,650	205	12,855

Root Creek WD



Available data can vary significantly between GSPs

Table 5. Total Crop Water Demand for the RCWDGSA from 2014 to 2019

	2014 (Critical year)			2015 (Critical year)			2016 (Dry year)			2017 (Wet year)			2018 (Below Normal year)			2019 (Wet year)		
Crop	Acres	ET (feet)	Estimated Demand (AF)	Acres	ET (feet)	Estimated Demand (AF)	Acres	ET (feet)	Estimated Demand (AF)	Acres	ET (feet)	Estimated Demand (AF)	Acres	ET (feet)	Estimated Demand (AF)	Acres	ET (feet)	Estimated Demand (AF)
Almond	1,740.2	3.06	5,325	2,133.2	3.06	6,528	2,143.2	3.06	6,558	2,133.7	2.72	5,804	2,394.9	3.07	7,352	2,334	2.72	6,349
Cherry	8.5	3.03	26	8.5	3.03	26	8.5	3.03	26	9.0	2.73	25	10.5	3.00	31	10	2.73	29
Citrus	2,959.1	2.85	8,433	2,959.1	2.85	8,433	2,959.5	2.85	8,435	2,959.1	2.48	7,339	2,938.4	3.02	8,874	2,887	2.48	7,160
Date	1.0	2.92	3	1.0	2.92	3	1.0	2.92	3	1.0	2.65	3	0.7	2.89	2	1	2.65	2
Grape	383.5	2.11	809	261.5	2.11	552	261.5	2.11	552	219.5	2.01	441	218.2	2.10	458	220	2.01	442
Nursery Plants	22.4	2.92	65	22.4	2.92	65	22.4	2.92	65	22.4	2.65	59	15.8	2.89	46	14	2.65	37
Olive	214.0	3.00	642	93.0	3.00	279	93.0	3.00	279	93.0	2.80	260	70.0	3.03	212	57	2.80	160
Persimmon	1.0	3.03	3	1.0	3.03	3	1.0	3.03	3	1.0	2.73	3	0.8	3.00	2	1	2.73	2
Pistachio	2,673.0	2.75	7,351	2,674.0	2.75	7,354	2,674.0	2.75	7,354	2,674.0	2.69	7,193	2,410.9	2.77	6,678	2,217	2.69	5,964
Plum	4.5	3.03	14	4.5	3.03	14	7.5	3.03	23	6.5	2.73	18	8.1	3.00	24	4	2.73	10
Pomegranate	6.5	2.92	19	6.5	2.92	19	6.5	2.92	19	7.0	2.65	19	6.9	2.89	20	7	2.65	18
Wheat	460.0	1.07	492	118.0	1.07	126	100.0	1.07	107	100.0	0.85	85	104.2	1.35	141	100	0.85	85
Totals	8,473.7		23,182	8,282.7		23,401	8,278.1		23,423	8,226.2		21,248	8,179.2		23,841	7,852		20,257



Next steps

- Assemble additional observation datasets
 - GSP annual reports
 - OpenET data
 - Diversion data (CalSim 3 historical model)
- Expand model comparisons with updated observation data
- Update objective functions to include additional datasets
- Expand calibration workflow to non-ponded crops and refuges
- Determine DU groupings for streamlined calibration and parameter reduction



Questions?
ltatch@usbr.gov



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