Using FAIR principles to improve the usability of a food-energy-water system simulation model

Andrew Hamilton

2021 FAIR Workshop

June 2, 2021

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

PURDUE UNIVERSITY

CoFiRES CENTER ON FINANCIAL RISK IN ENVIRONMENTAL SYSTEMS

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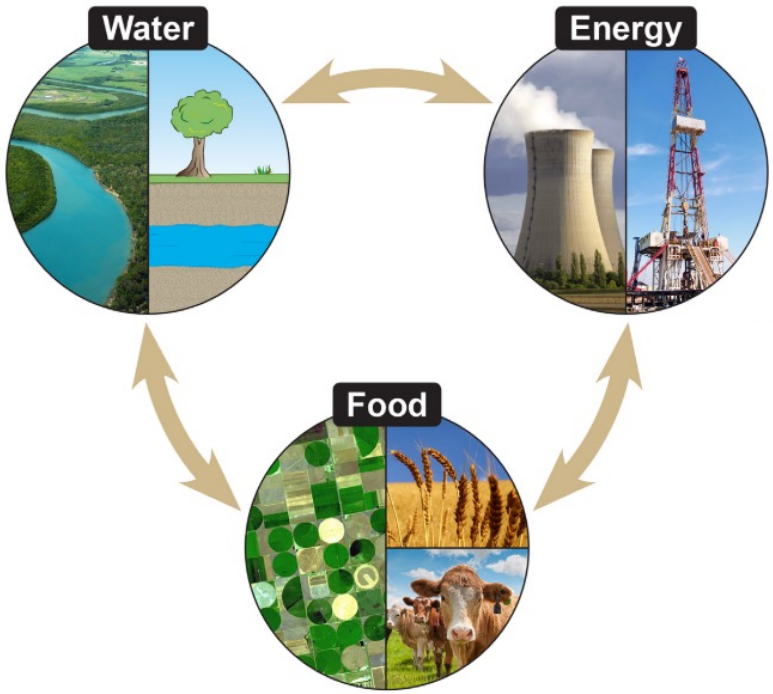
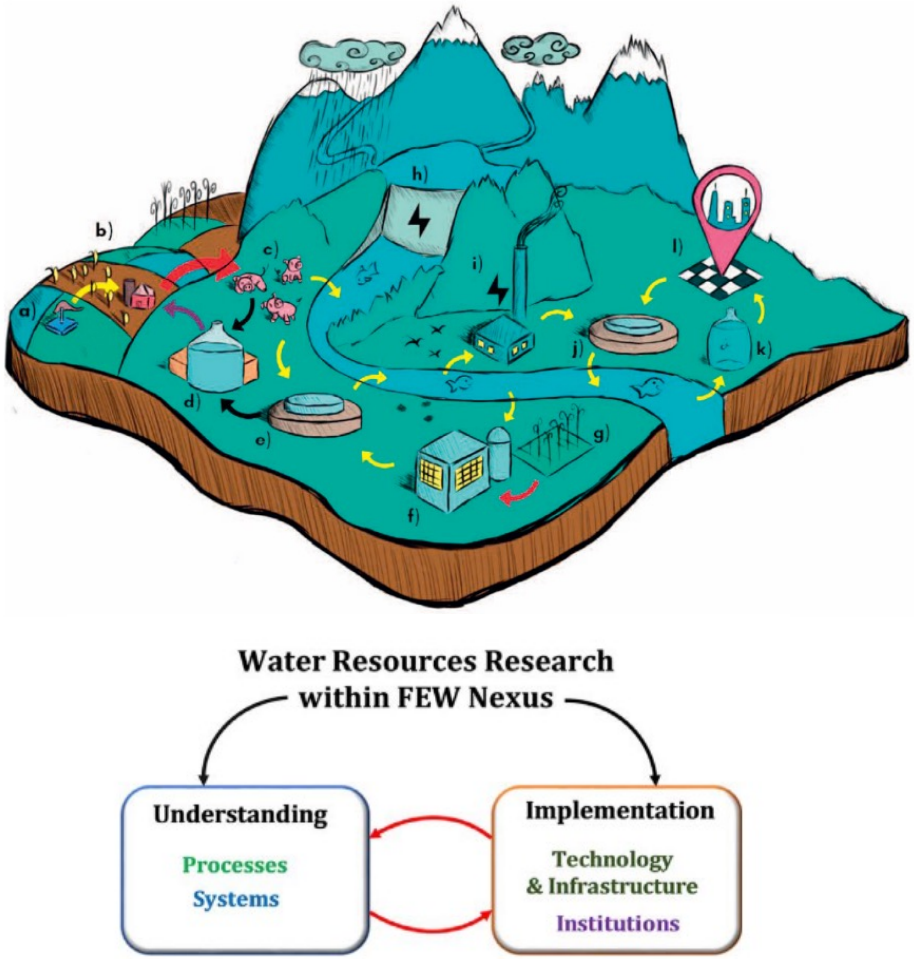
Food-Energy-Water Nexus



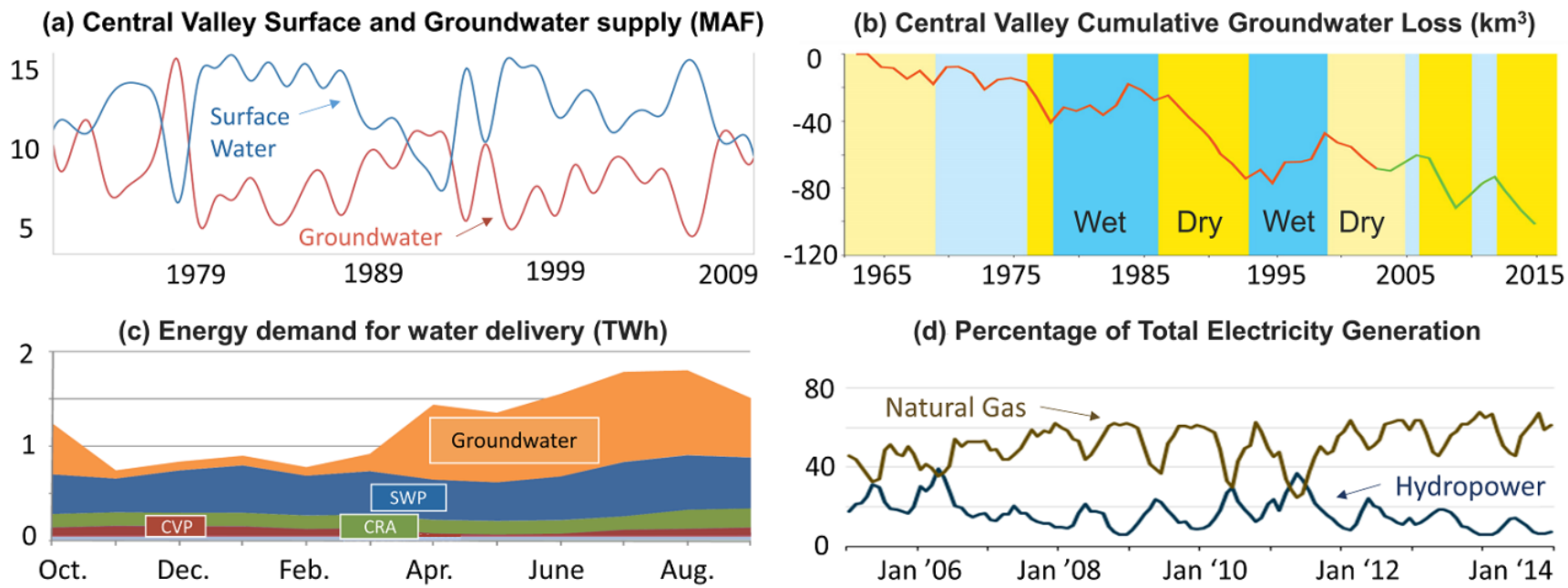
Scanlon et al. (2017). The food-energy-water nexus: Transforming science for society. *Water Resources Research, 53*(5): 3550-3556.



Cai et al. (2018). Understanding and managing the food-energy-water nexus – opportunities for water resources research. *Advances in Water Resources, 111*: 259-273.

Food-Energy-Water Nexus

California as "laboratory" for exploring connections & implications for management



Drought in California

Search The Guardian US edition

California is on the brink of drought – again. Is it ready?

Maanvi Singh
@maanvissingh
Tue 6 Apr 2021 06.00 EDT

Gavin Newsom
@GavinNewsom

5:01 PM · Apr 21, 2021

Where I'm standing I should be 40 ft under the water of Lake Mendocino.

Instead--I'm on dry, cracked earth. That's climate change.

Today I declared a drought conditions state of emergency in Mendocino & Sonoma to immediately increase drought resilience. kcra.com/article/gov-ne...

Los Angeles Times

By LOUIS SAHAGÚN

APRIL 26, 2021 UPDATED 10 AM PT

Wells dry up, crops imperiled, farm workers in limbo as California drought grips San Joaquin Valley

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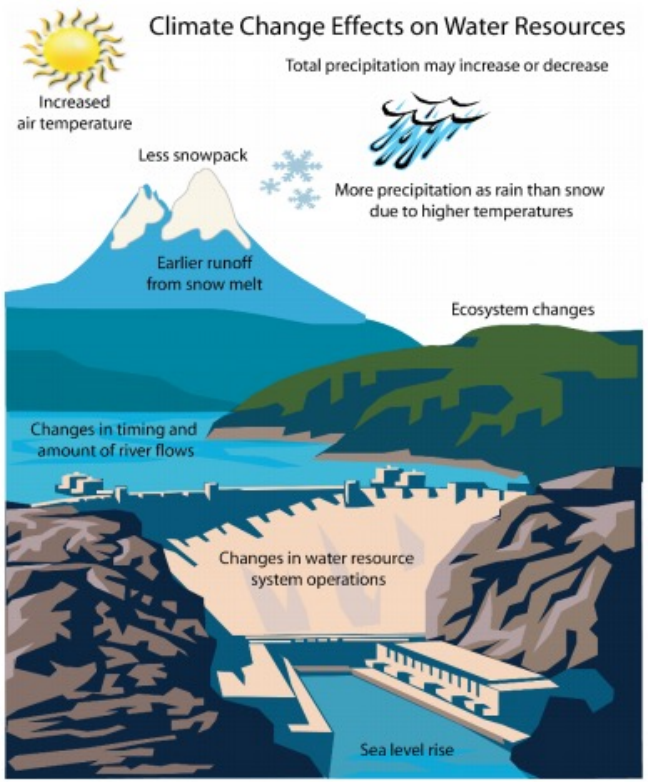
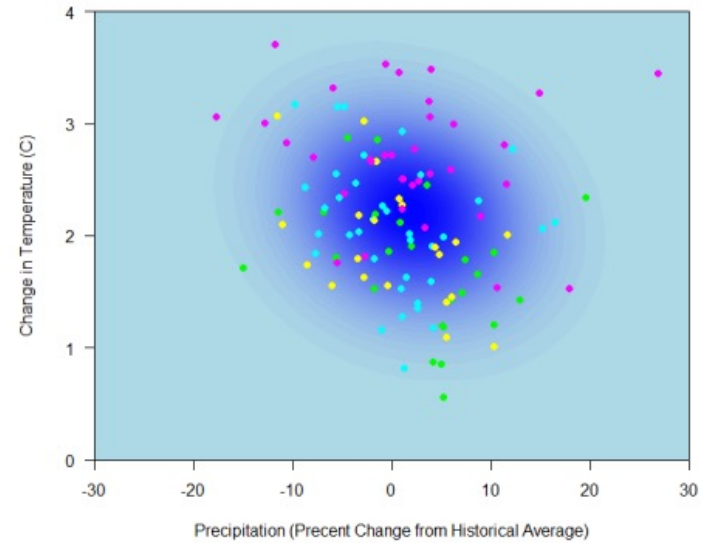
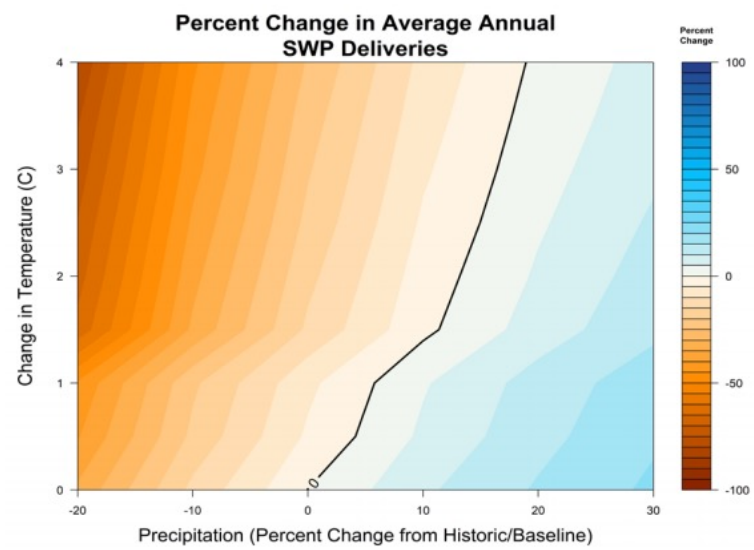
As drought hits California, long-term issues loom

BY DAN WALTERS
APRIL 25, 2021

Climate change and water resources

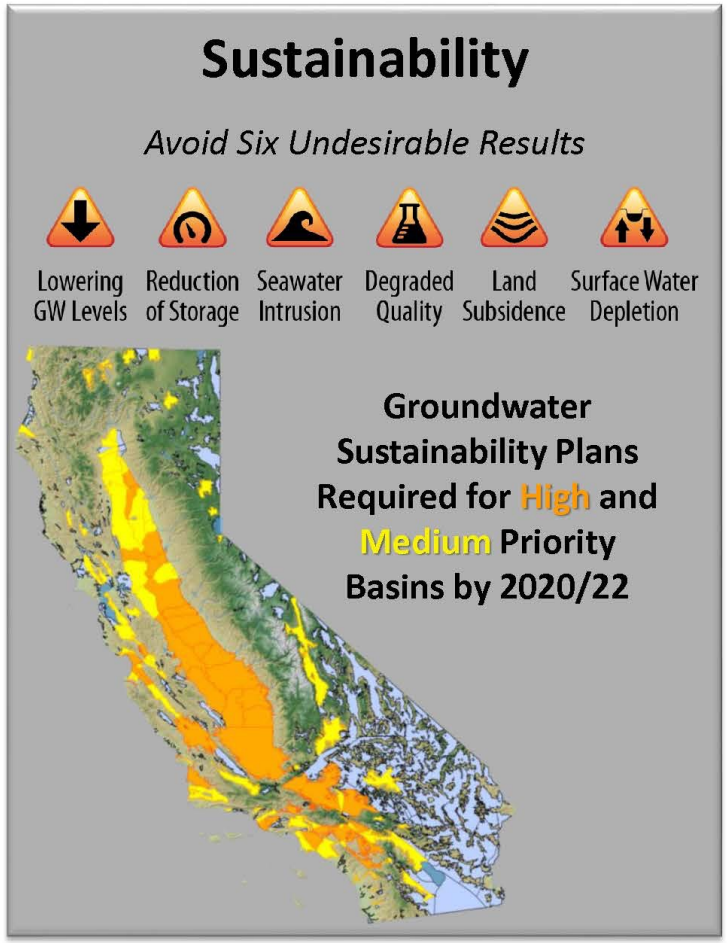




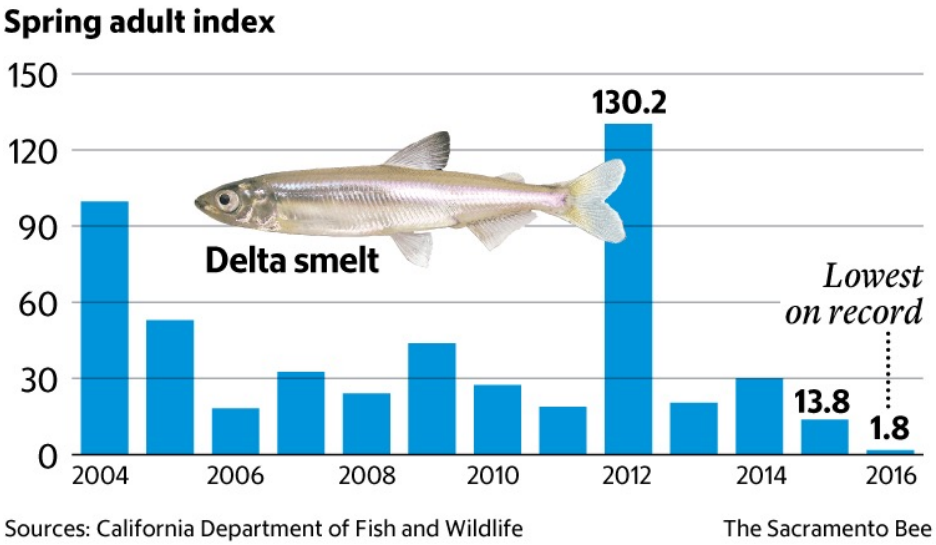


California Department of Water Resources. 2019. Climate Action Plan, Phase 3: Climate Change Vulnerability Assessment.

Environmental regulation

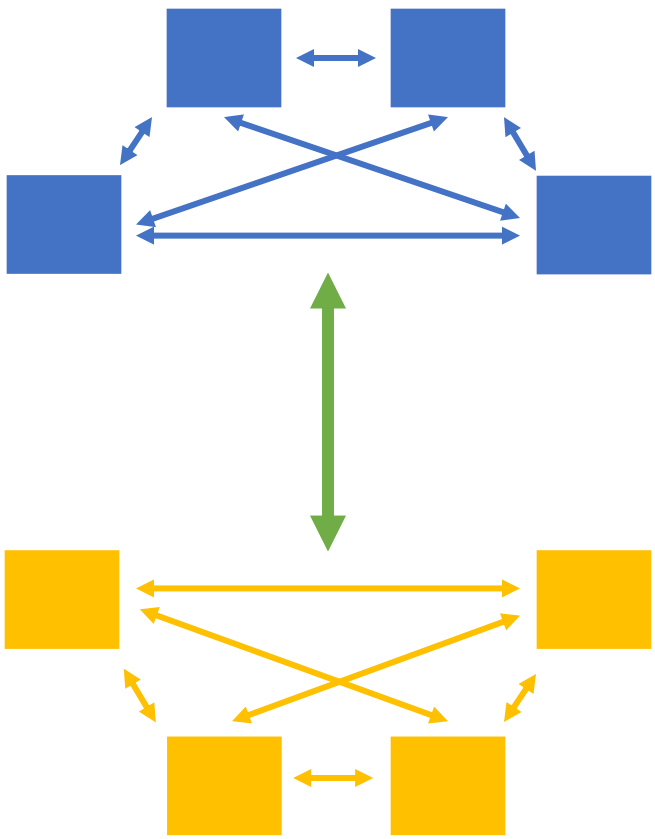


https://mavensnotebook.com/2017/08/31/state-water-board-update-on-sgma-implementation/



The Sacramento Bee.

Actions of other water users



California Food-Energy-Water System (CALFEWS)

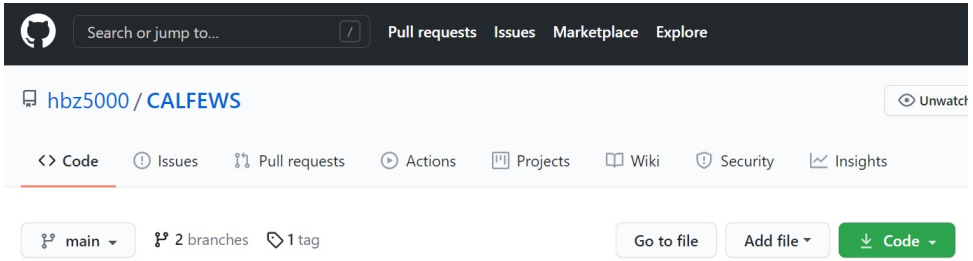
ELSEVIER

Environmental Modelling & Software

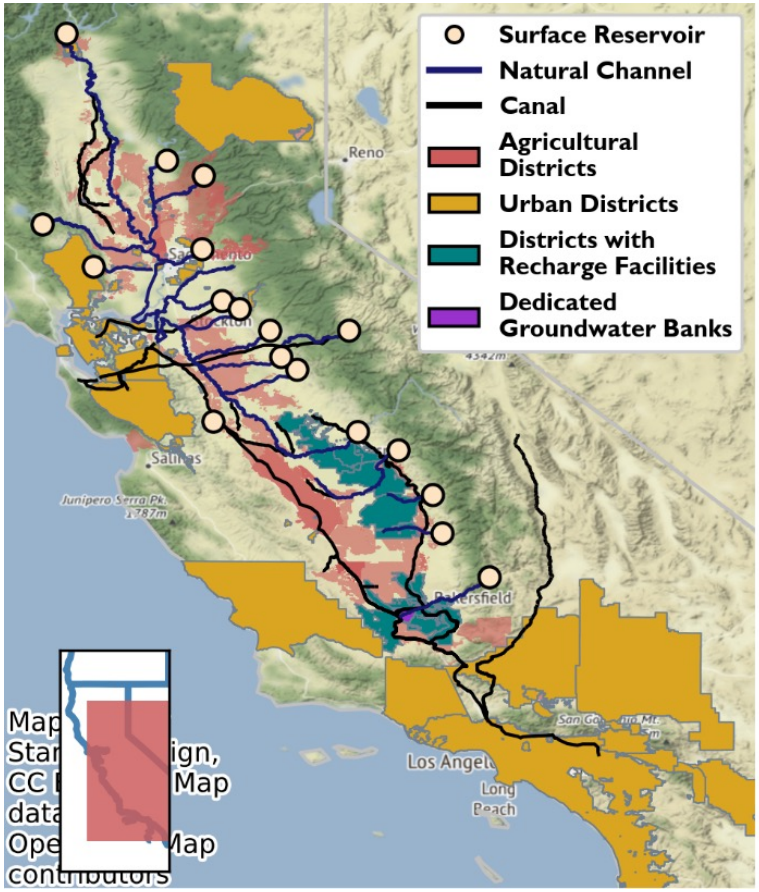
Volume 141, July 2021, 105052

California's food-energy-water system: An open source simulation model of adaptive surface and groundwater management in the Central Valley

Harrison B. Zeff [a], Andrew L. Hamilton [a], Keyvan Malek [b], Jonathan D. Herman [c], Jonathan S. Cohen [c], Josue Medellin-Azuara [d], Patrick M. Reed [b], Gregory W. Characklis [e]



https://github.com/hbz5000/CALFEWS



FACT Fellowship

Project pt. 1: Making CALFEWS model more FAIR

- Goal: Make it easier for other academics & government employees to adopt CALFEWS for research &/or planning purposes
- Improve README & documentation of code organization on GitHub
- Improve documentation of input data sources
- Create Jupyter notebooks to introduce user to running code and to reproduce paper figures
- Create code-free GUI on MyGeoHub for running scenarios & visualizing results

GUI for CALFEWS

MyGeoHub

RESEARCH RESOURCES COMMUNITY TEACHING SUPPORT ABOUT

Andrew L Hamilton

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Graphical User Interface for the California Food-Energy-Water System (CALFEWS) simulation model

Edit

By Andrew L Hamilton, Harrison Zeff, Keyvan Malek, Jonathan Herman, Jonathan Cohen, Josue Medellin-Azuara, Patrick M. Reed, Gregory W. Characklis

Graphical User Interface for the California Food-Energy-Water System (CALFEWS) simulation model

Launch Tool

Version 1.0 - published on 04 Feb 2021

doi:10.21981/AH5Y-G419 cite this

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Tools

Published on

04 Feb 2021

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When watching a resource, you will be notified of changes made. You may stop watching at any time.

Abstract

This tool provides a graphical user interface for the California Food-Energy-Water System (CALFEWS), an open-sourced, Python-based model for simulating the integrated, multi-sector dynamics of water supply in the Central Valley of California. CALFEWS captures system dynamics across multiple scales, from coordinated management of inter-basin water supply projects at the state and regional scale, to agent-based representation of conjunctive surface water and groundwater supplies at the scale of irrigation and water storage districts. This user interface can be used to simulate operations under different hydrologic conditions and visualize the results using the interactive plotting features.

Credits

A.L.H. is grateful for guidance from Venkatesh Merwade, Carol Song, Matthew Huber, Lan Zhao, and I Luk Kim. This graphical user interface was developed under the FAIR Cyber Training Fellowship program at Purdue University (NSF Award #1829764). Development of the CALFEWS simulation model is supported under an INFEWS/T2 grant (Award #1639268)

GUI for CALFEWS

MY GEO HUB jupyter Edit App Terminate Session

About | Run simulation | Plot data

Graphical User Interface for the California Food-Energy-Water System (CALFEWS) simulation model

This tool provides a user interface for the California Food-Energy-Water System (CALFEWS), an open-sourced, Python-based model for simulating the integrated, multi-sector dynamics of water supply in the Central Valley of California. CALFEWS captures system dynamics across multiple scales, from coordinated management of inter-basin water supply projects at the state and regional scale, to agent-based representation of conjunctive surface water and groundwater supplies at the scale of irrigation and water storage districts. This user interface can be used to simulate operations under different hydrologic conditions and visualize the results using the interactive plotting features.

More information on the CALFEWS model, and comparison of model output to historical data, can be found in the following manuscript:

Zeff, H.B., Hamilton, A.L., Malek, K., Herman, J.D., Cohen, J.S., Medellin-Azuara, J., Reed, P.M., and G.W. Characklis. (2020). "California's Food-Energy-Water System: An Open Source Simulation Model of Adaptive Surface and Groundwater Management in the Central Valley". (In review, preprint available here.)

GUI for CALFEWS

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About | Run simulation | Plot data

Select inflow scenario

Historical validaton 1997-2016
Historical reconstruction 1906-2016
2-year example
22-year synthetic
WRF 2007-2017

Folder name to save results (no spaces)

2-year_example

Click to begin

Start

Progress

Inflow scenario	Description	Est. runtime (mins.)
Historical validaton 1997-2016	20-year simulation using historical data and infrastructure (see Zeff et al., 2020, https://engrxiv.org/sqr7e)	11
Historical reconstruction 1906-2016	111-year simulation using statistically-reconstructed data and 2017 infrastructure (see Zeff et al., 2020, https://engrxiv.org/sqr7e)	56
2-year example	2-year example simulation, with wet year (1997) followed by dry year (2014)	2
22-year synthetic	22-year synthetic dataset using the CAPOW stochastic engine (see Su et al., 2020, https://doi.org/10.1016/j.envsoft.2020.104667)	12

GUI for CALFEWS

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About | Run simulation | Plot data

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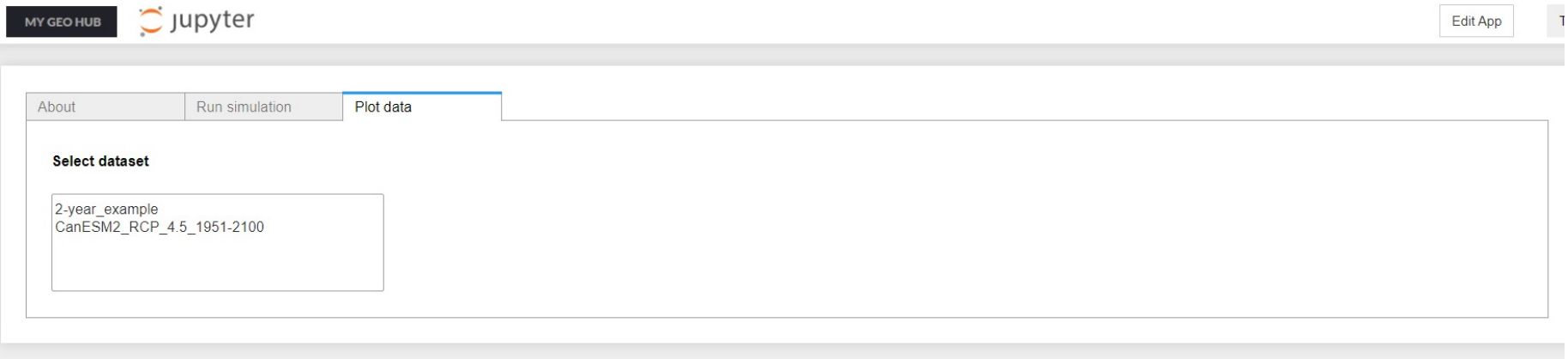
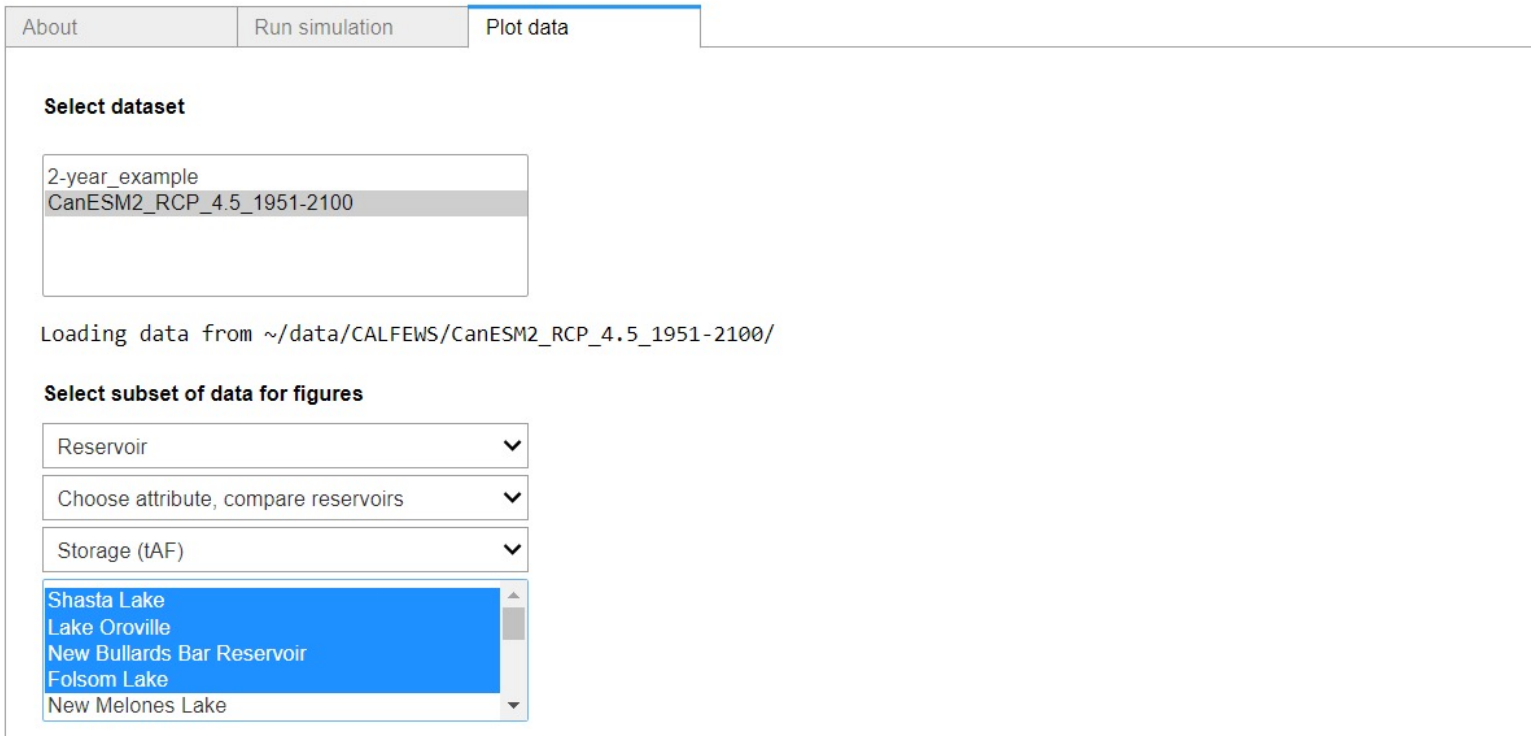
2-year example	2-year example simulation, with wet year (1997) followed by dry year (2014)	2
22-year synthetic	22-year synthetic dataset using the CAPOW stochastic engine (see Su et al., 2020,	12

```
#######################################################
Begin initialization...
Initialization complete,  0:00:52.893097
Begin simulation,  0:00:52.893791
temp/sim/2-year_example
Year  1.0 ,  0:01:28.627244
Year  2.0 ,  0:01:56.171116
Simulation complete, 0:01:58.904889
#######################################################
Copying data to ~/data/CALFEWS/2-year_example
Finished! Proceed to "Plot data" tab.
```

GUI for CALFEWS



GUI for CALFEWS



GUI for CALFEWS

Figure 1: Full time series (click and drag to select zoom region for Figure 2)

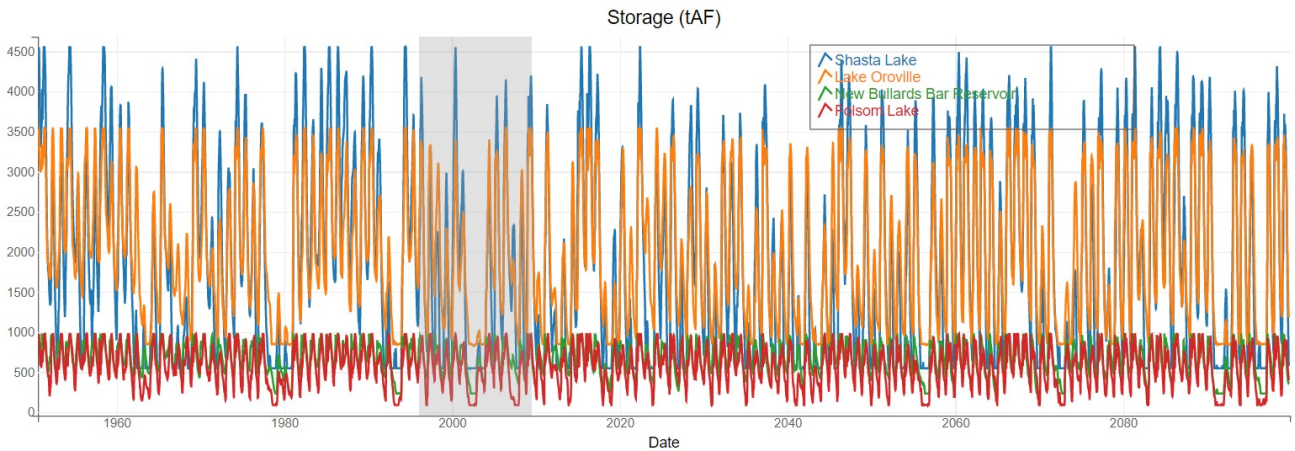
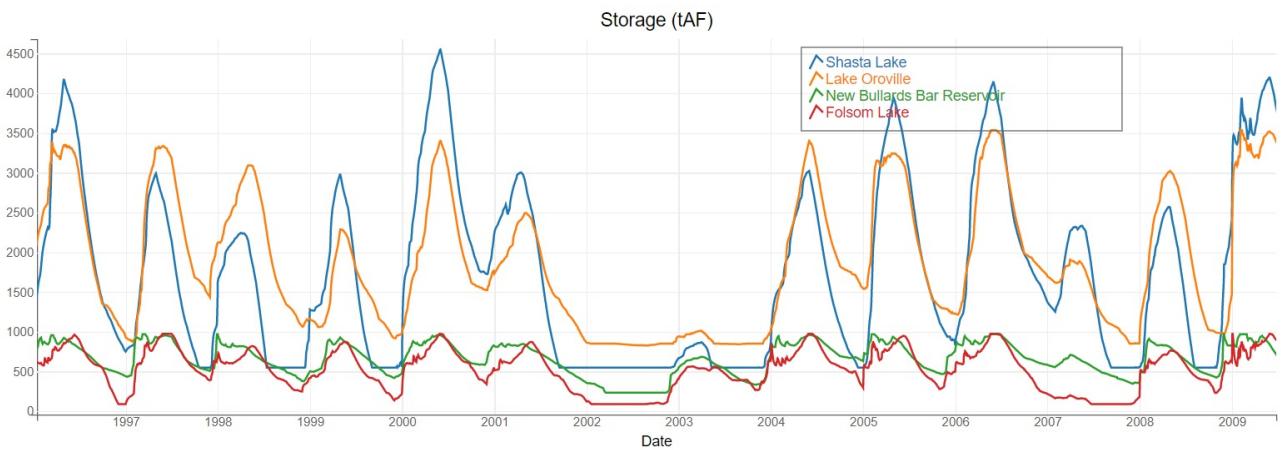


Figure 2: Zoomed in time series



Download full dataset or subset of data

(buttons will create link below plots)

Full dataset | Subsetted dataset

FACT Fellowship

Project pt. 2: Integrate FAIR principles into course

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ahamilton144 / Python-For-Environmental-Research

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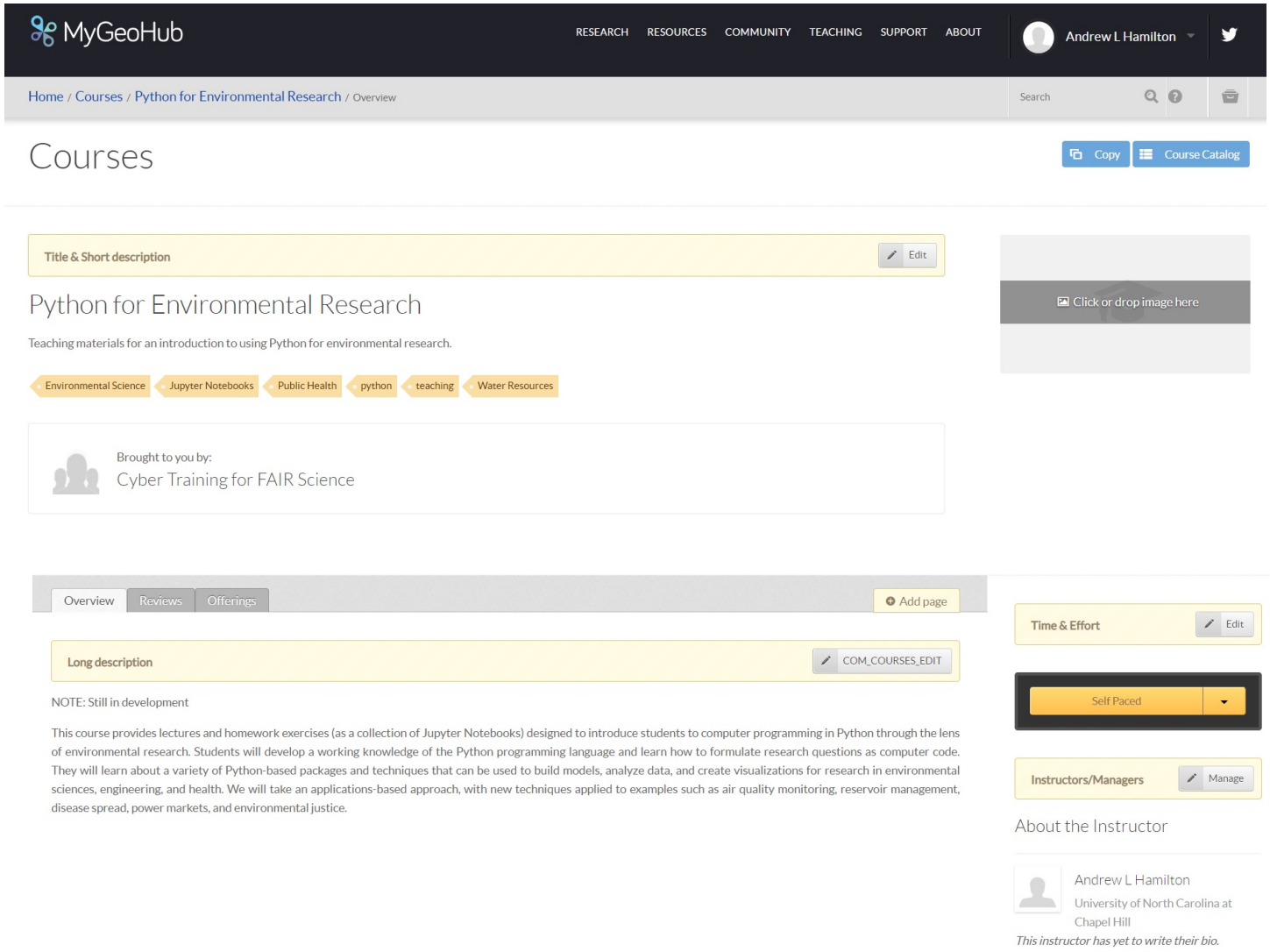
README.md

Python for Environmental Research

This repository contains all materials used for teaching *Python for Environmental Research* (ENVR 890-001), a 1-credit course in the Department of Environmental Sciences & Engineering, Gillings School of Global Public Health, at the University of North Carolina at Chapel Hill. This course was taught for the first time in Fall 2020. **See syllabus for more information.**

Not a GitHub user yet? Download files directly here: DOI 10.5281/zenodo.4495708

Python for Environmental Research course



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Python for Environmental Research course

- Progress
- Pages
- Announcements
- Dashboard
- Notes
- Discussions
- Getting Started

- Introduction to Jupyter & Python
- Basic data structures
- Conditions, functions, & loops
- Advanced data structures
- Systems of equations & optimization
- Data, visualization, & regression
- Simulation, Monte Carlo, & time series
- Geospatial analysis

Python for Environmental Research course

Systems of equations & optimization

Lectures	Notes: Systems of equations & optimization Notes: Systems of equations & optimization Lec5_SystemsEquations.ipynb
Activities	Homework: Systems of equations & optimization Homework: Systems of equations & optimization HW5_SystemsEquations.ipynb

Python for Environmental Research course

Slide Type Slide

Lecture 5: Systems of equations & optimization

ENVR 890-001: Python for Environmental Research, Fall 2020

September 18, 2020

By Andrew Hamilton, some material adapted from Greg Characklis, David Gorelick, and H.B. Zeff.

Slide Type Fragment

Summary

Now that we have covered the basics of Python programming (e.g., variable types, data structures, if statements, loops, functions), we can move on to **solving problems** in environmental science, engineering, and public health. The first type of problem we will solve will be **systems of equations and optimization**.

This will involve a bit of math, but we will try to focus on the programming elements.

Slide Type Slide

Linear system of equations

Systems of equations appear in many different fields of science and engineering research. The simplest and most common is the linear system of equations. For example, here is a linear system with two equations and two unknowns:

Slide Type Fragment

$$y + 3z = 16$$
$$4y - z = -1$$

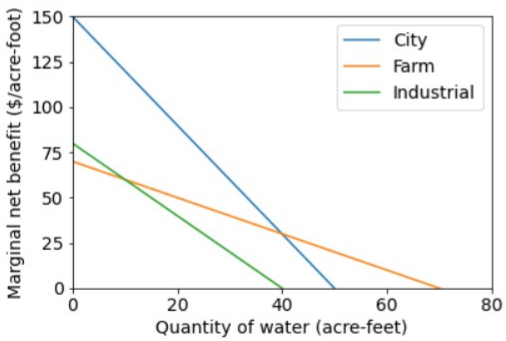
Python for Environmental Research course

In [5]:

Slide Type Fragment

```
### plot MNB curves
plt.plot(qs, city_q)
plt.plot(qs, farm_q)
plt.plot(qs, indus_q)
plt.xlim([0, 80])
plt.ylim([0, 150])
plt.xlabel('Quantity of water (acre-feet)')
plt.ylabel('Marginal net benefit (\$/acre-foot)')
plt.legend(['City','Farm','Industrial'])
```

Out[5]: <matplotlib.legend.Legend at 0x7f5c7d1487f0>



Slide Type Slide

What if there are only 100 acre-feet of water available? What is the efficient allocation to each sector?

Thank you!

INFEWS/T2: The sustainability-productivity tradeoff: Water supply vulnerabilities and adaptation opportunities in California's coupled agricultural and energy sectors, NSF Award #1639268

Greg Characklis, HB Zeff, Pat Reed, Jon Herman, Josué Medellín-Azuara, Jordan Kern, Tamlin Pavelsky, Keyvan Malek, Rohini Gupta

CyberTraining: CIU: Cross-disciplinary Training for Findable, Accessible, Interoperable, and Reusable (FAIR) Science, NSF Award #1829764

Venkatesh Merwade, Matthew Huber, Carol Song, Lan Zhao, Wan Ju Huang, I Luk Kim