#### **Urban Water Systems: Regime** shifts in municipal water demand



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#### Adapting Urban Water Systems to a Changing Climate: Lessons from

#### the Millennium Drought in Southeast Australia

Stanley B. Grant,<sup>\*,†,‡</sup> Tim D. Fletcher,<sup> $\perp$ </sup> David Feldman,<sup>§</sup> Jean-Daniel Saphores,<sup>†,§</sup> Perran L. M. Cook,<sup>#</sup> Mike Stewardson,<sup>‡</sup> Kathleen Low,<sup>†</sup> Kristal Burry,<sup> $\nabla$ </sup> and Andrew J. Hamilton<sup>||</sup>

- <sup>†</sup>Department of Civil and Environmental Engineering, E4130 Engineering Gateway, University of California, Irvine, Irvine, California 92697-2175, United States
- <sup>‡</sup>Department of Infrastructure Engineering, Melbourne School of Engineering, Engineering Block D, The University of Melbourne, Parkville 3010, Victoria, Australia
- <sup>8</sup>Department of Planning, Policy, and Design, 300G Social Ecology I, University of California, Irvine, Irvine, California 92697-7075, United States
- Department of Agriculture and Food Systems, The University of Melbourne, 940 Dookie–Nalinga Road, Dookie College, Victoria 3647, Australia

<sup>1</sup>Melbourne School of Land and Environment, The University of Melbourne, Burnley Campus, 500 Yarra Boulevard, Richmond, Victoria 3121, Australia

"Water Studies Centre, School of Chemistry, Monash University, Victoria 3800, Australia

<sup>V</sup>Melbourne School of Land and Environment, The University of Melbourne, Parkville Campus, 207 Bouverie Street, Victoria 3052, Australia









Stanley Grant, UCI



Murray Peel, Univ Melb





Tim Peterson, Univ Melb

Jakin Ravalico, Melbourne Water

Kathleen Low, UCI



David Feldman, UCI

### Motivation

 Melbourne dramatically reduced per capita consumption during the Millennium Drought, through conservation and potable substitution—are there broader lessons?

Melbourne Per Capita Consumption during the Millennium Drought



### Approach

- With the help of Melbourne Water staff, retrieved monthly water consumption and reservoir storage data for the past 76 years
- Examined the unit (per capita) relationship between consumption and storage
- Identified feedback loops and regime shifts that influence per capita consumption, and used these to model (project) urban water demand and storage from inflow data

## Results

- Relationship between unit demand and unit storage:
  - Linear regime (negative feedback loop, maintaining "years of reservoir storage")
  - Constant regime (no feedback loop between consumption and storage)
  - Regime shifts caused by major events (large infrastructure upgrades and the Millennium Drought)
  - Regime-shift model captures >96% variance in historical reservoir storage





Historical Reservoir Storage in Melbourne Observed (data) vs model predicted (curve)



## Conclusions

- The Melbourne dataset reveals that ecological concepts of resilience and regime shifts can be applied to the longterm evolution of urban water demand
- Practically speaking, this provides a powerful new modeling approach for the long-term projection of urban water demand, and interpretation of demand data

### Products

- 1. Grant et al (2013) "Adapting urban water systems to a changing climate: Lessons from the Millennium Drought in Southeast Australia" *Environmental Science and Technology* **47**, 10727-10734.
- 2. Grant et al (20XX) "Cities react and adapt: A transition state model for the multi-decadal evolution of urban water demand", submitted to *Geophysical Research Letters*
- 3. Low et al (20XX) "Fighting drought with innovation: Melbourne's response to the Millennium Drought in Southeast Australia", submitted to WIRES Water
- 4. Grant et al (20XX) "Regime shifts and Urban Water Systems", in prep for WIRES Water

# Urban Water Systems: Coupling Climate and Demand Projections

- Given realistic water demand scenarios, what does the future hold for Melbourne's freshwater supply?
- What demand scenarios are sustainable in a changing climate?





Ali Mehran, UCI

Amir AghaKouchak, UCI



Murray Peel, Melb Uni



Jakin Ravalico, Melbourne Water







# Approach

- Downscale global circulation model predictions
- 2. Couple to Melbourne Water demand scenario anomalies (2020-35 compared to 1995 to 2010)



#### Simulation Result



#### **Publications Supported by PIRE**

AghaKouchak A., Feldman D., Stewardson M.J., Saphores J.-D., Grant S., Sanders B., 2014, Australia's Drought: Lessons for California, *Science*, **343** (6178), 1430-1431, doi:10.1126/science.343.6178.1430. 41-448.

Hao Z., AghaKouchak A., Nakhjiri N., Farahmand A., 2014, Global Integrated Drought Monitoring and Prediction System, *Scientific Data*, 1:140001, 1-10, doi: 10.1038/sdata.2014.1.

Liu Z., Mehran A., Phillips T.J., AghaKouchak A., 2014, Seasonal and Regional Biases in CMIP5 Precipitation Simulations, *Climate Research*, 60, 35-50

Hao Z., AghaKouchak A., Phillips T.J., 2013, Changes in Concurrent Monthly Precipitation and Temperature Extremes, *Environmental Research Letters*, 8(4), 034014

Mehran A., AghaKouchak A., Phillips T.J., 2014, Evaluation of CMIP5 Continental Precipitation Simulations Relative to Satellite-Based Gauge-Adjusted Observations, *Journal of Geophysical Research*, 119, 1695-1707

Mehran A., et al. 2015, Assessing Melbourne Water Availability in a Changing Climate, in Preparation.

#### **Publications Motivated by PIRE**

Tarroja B., AghaKouchak A., Samuelsen S., Sobhani R., Feldman D., Jiang S., 2014, Evaluating Options for Balancing the Water-Electricity Nexus in California: Part 1 - Securing Water Availability, Science of the Total Environment, 497-498, 697-710

Tarroja B., AghaKouchak A., Samuelsen S., Sobhani R., Feldman D., Jiang S., 2014, Evaluating Options for Balancing the Water-Electricity Nexus in California: Part 2 - Greenhouse Gas and Renewable Energy Utilization Impacts, Science of the Total Environment, 497-498.