Coupled energy and water use in the Phoenix Metro Area as influenced by drought and climate change; empirical observations and simulation analyses

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Objective: Examine electricity consumption and water availability and use in the Phoenix Metropolitan Area for climate projected by four GCMs and two emission scenarios.

Background

Energy:

GCMs project rising temperatures—for Phoenix a 1 C to 2 C increase in ambient air temperatures (T_A) by 2029 and a 3 C to 6 C by the year 2100.

Increased T_A ➡ increased energy consumption

Water:

General circulation models (GCMs) posit decreased, future surface water availability (IPCC 2007).

Runoff estimates vary—near future (mean) runoff may decrease by 10% (range: -60% to +120%) for the Colorado River (Christensen and Lettenmaier 2007, figure 1), and 33% (range: 50% to 127%) for the Salt-Verde River system (Ellis et al. 2008).

Decreased runoff ➡ decreased surface water

Increased T_A ➡ increased water use

Combined:

1) Synergistic effects:
   a) Decreased available water
   b) Increased use of that water
   c) Increased energy consumed

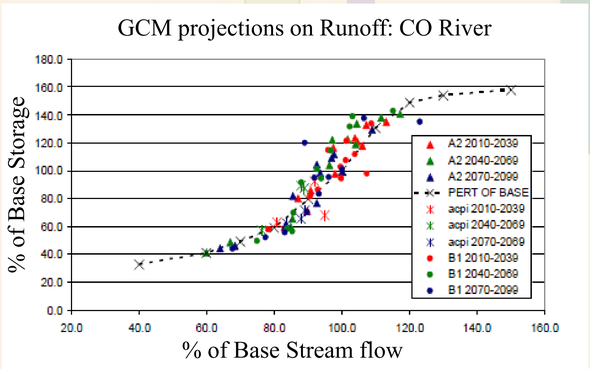


Figure 1. Christensen and Lettenmaier; 2007 .

Approach

Climate Change Scenarios:

1) Four GCMs (three time periods)
   a) GFDL
   b) CCSM3
   c) HadCM3
   d) PCM

2) Two emission scenarios
   a) A1B (balanced energy sources)
   b) A1Fi (fossil intensive)

Empirical Investigations:

1) Electricity sales data: Federal Energy Regulatory Commission (FERC Form 714; hourly data).

2) Hourly ambient air temperature data: Sky Harbor airport (National Climatic Data Center)-baseline.

3) Current climate baseline sensitivity of electricity consumption to variations in air temperatures.

Simulation Analyses:

1) Provider-level WaterSim 4.0 (Sampson et al., submitted). Monthly water supplies, demand, & use (Fig. 2).

2) Included algorithms to estimate electricity used to convey & treat potable water & waste water (monthly).

3) Assume a 25% reduction in GPCD by 2100.

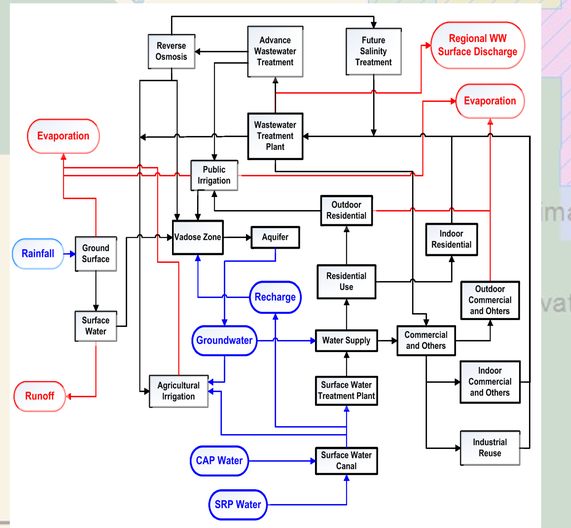
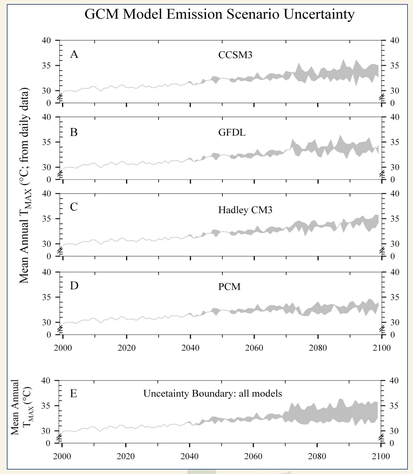


Figure 2. The "City Model" of WaterSim 4.0

Results

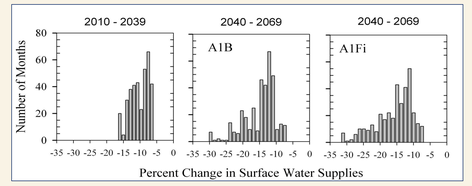
Climate System



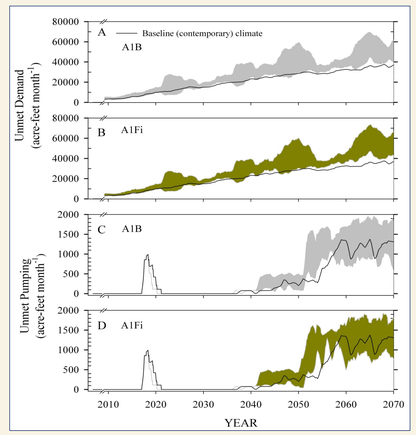
Increased temperatures: 2 °C to 6 °C

Water

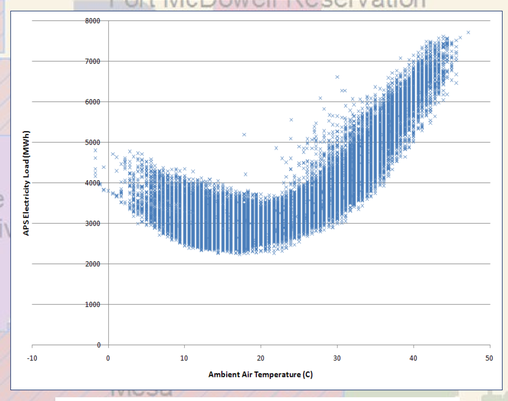
Decreased surface water



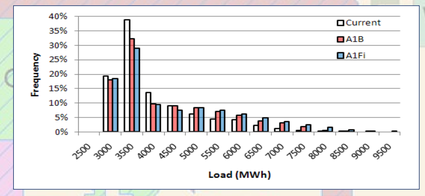
Increased unmet demand



Electricity

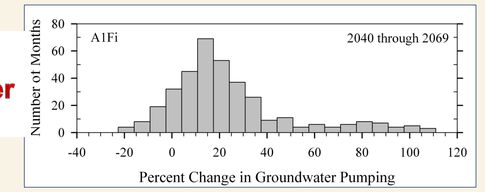


Load sensitivity: ~ 3% per °C

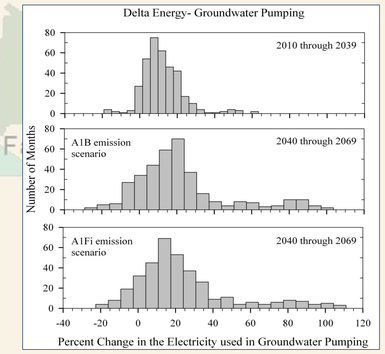


Increased frequency at higher loads

Increased groundwater pumping



Combined



More electricity used for groundwater pumping

Conclusions

1) 18% reduction in surface water availability by 2070.
2) Water demand will increase up to 20% by 2070 from increased temperatures alone (unmet demand results in increased groundwater pumping).
3) 7% increase in peak electric load (8% total system) from increased temperatures.
4) Electricity used in pumping groundwater will increase 12% (by 2039) to 24% (by 2070).

References

Christensen, N. S., Lettenmaier, D.P., 2007. A multimodel ensemble approach to assessment of climate change impacts on the hydrology and water resources of the Colorado River basin. Hydrol. Earth Syst. Sc. 11, 1417–1434.

Ellis, A.W., Hawkins, T.W., Balling, R.C., Gober, P., 2008. Estimating future runoff levels for a semi-arid fluvial system in central Arizona, USA. Climate Res. 35, 227-239.

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