Hydrologic and Climatologic Conditions That Shape Groundwater Resources in the West

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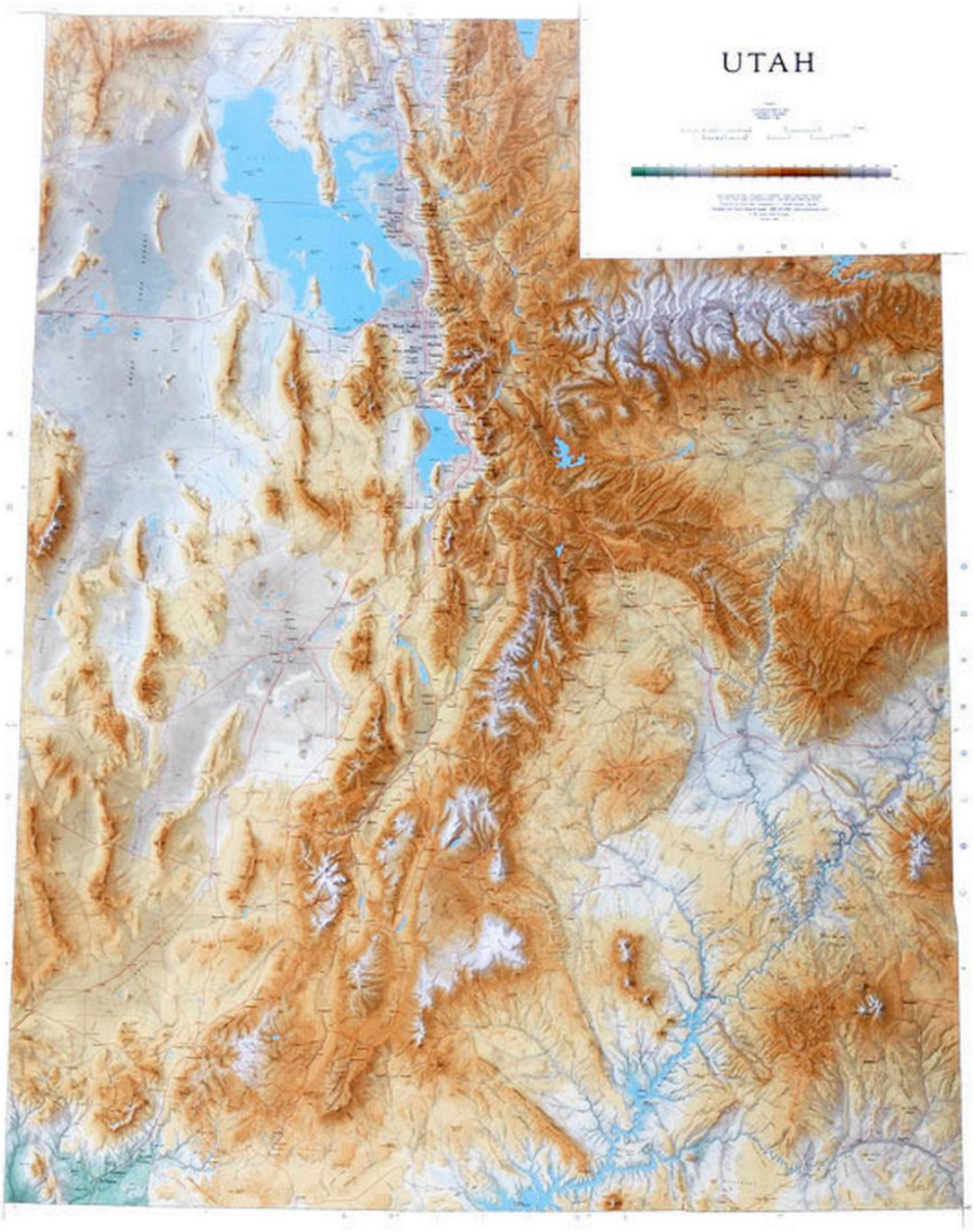
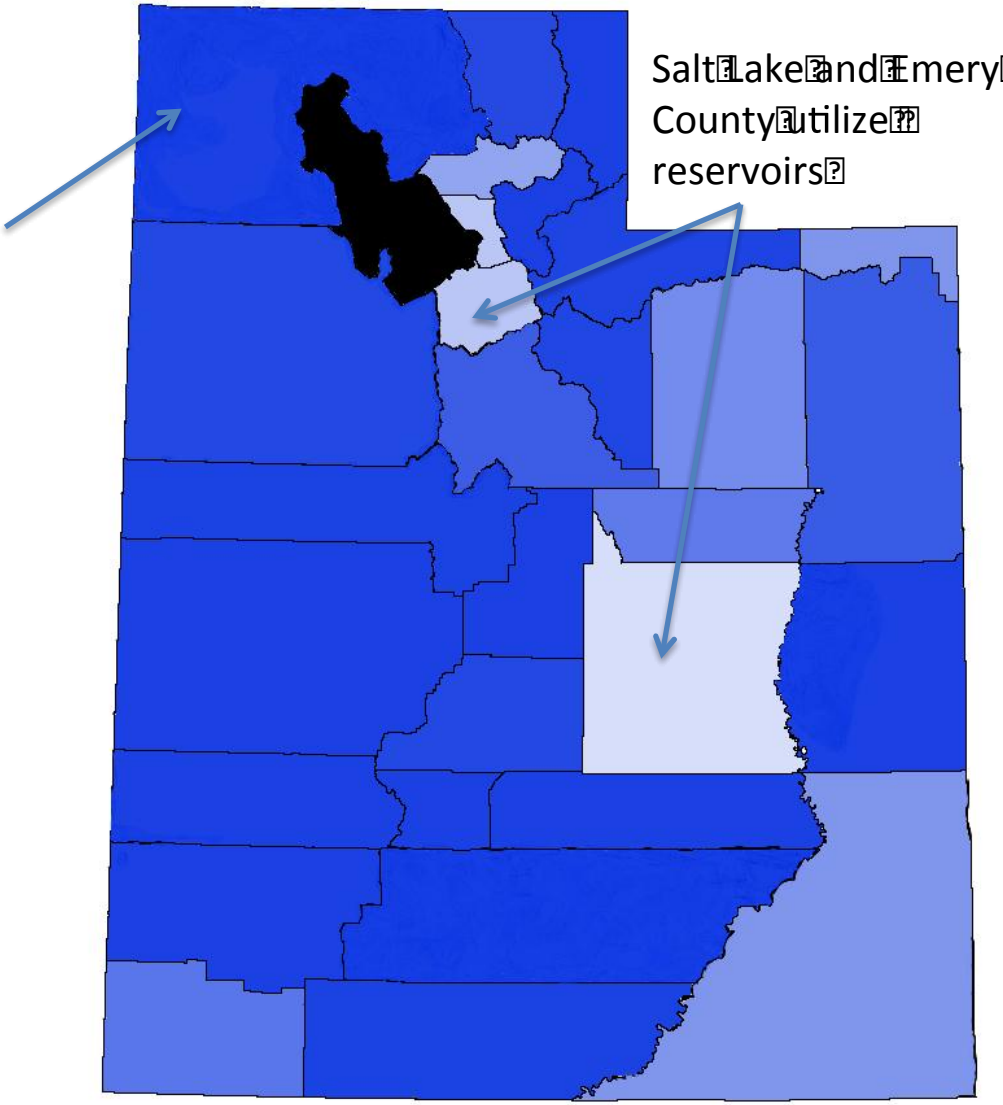
W h?



Utah Groundwater Dependence

(color = % dependence on groundwater for public supply for 2005)

County	% Dependence
Beaver	100.00%
Box Elder	100.00%
Cache	98.92%
Carbon	69.07%
Daggett	53.85%
Davis	36.42%
Duchesne	57.17%
Emery	22.83%
Garfield	100.00%
Grand	100.00%
Iron	100.00%
Juab	100.00%
Kane	100.00%
Millard	100.00%
Morgan	100.00%
Piute	100.00%
Rich	100.00%
Salt Lake	29.03%
San Juan	54.75%
Sanpete	100.00%
Sevier	98.83%
Summit	99.30%
Tooele	98.92%
Uintah	89.76%
Utah	82.83%
Wasatch	99.23%
Washington	75.50%
Wayne	100.00%
Weber	47.86%



Utah Groundwater Policy

Current as of 2013

Open

Restricted

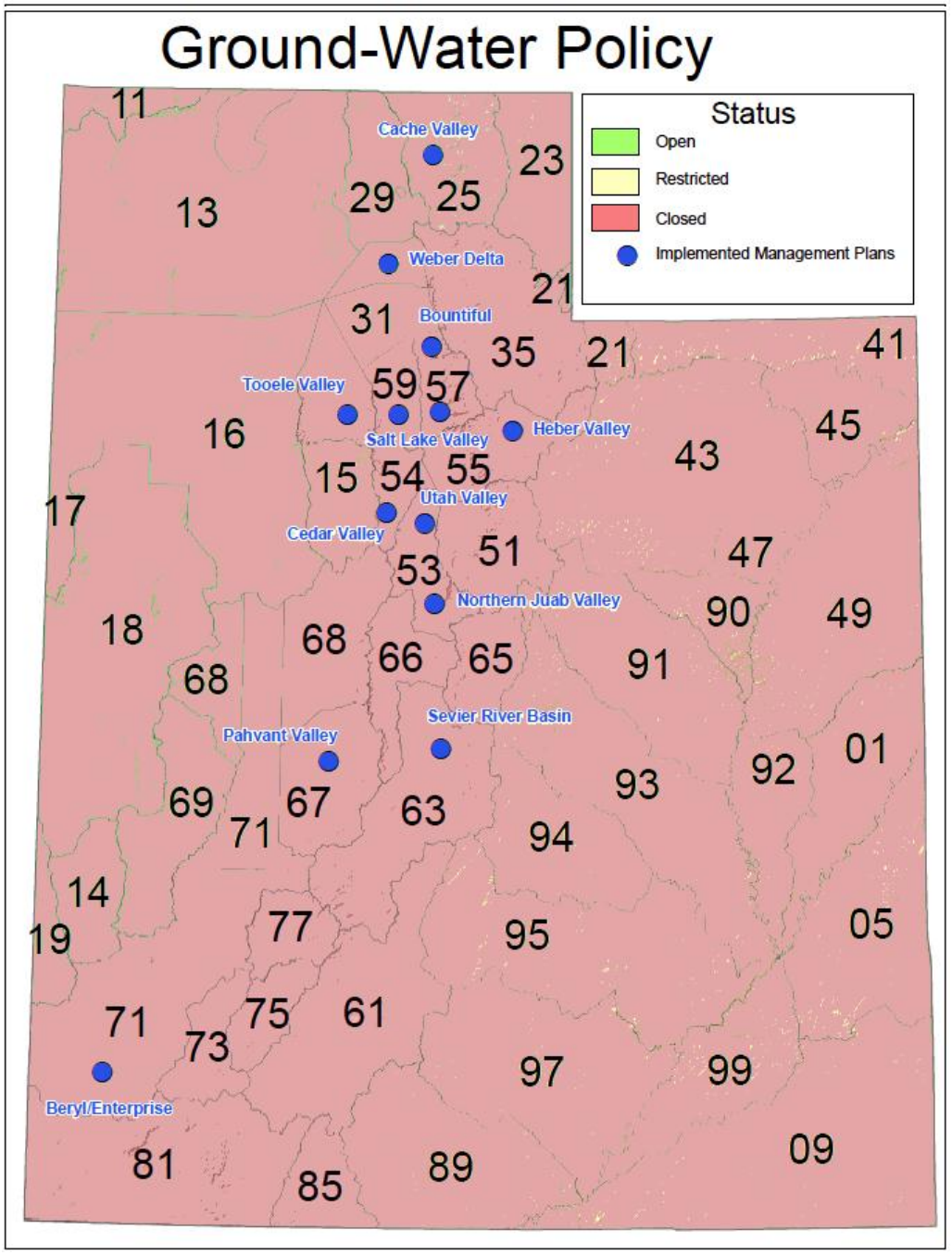
Closed

Implemented Management Plans

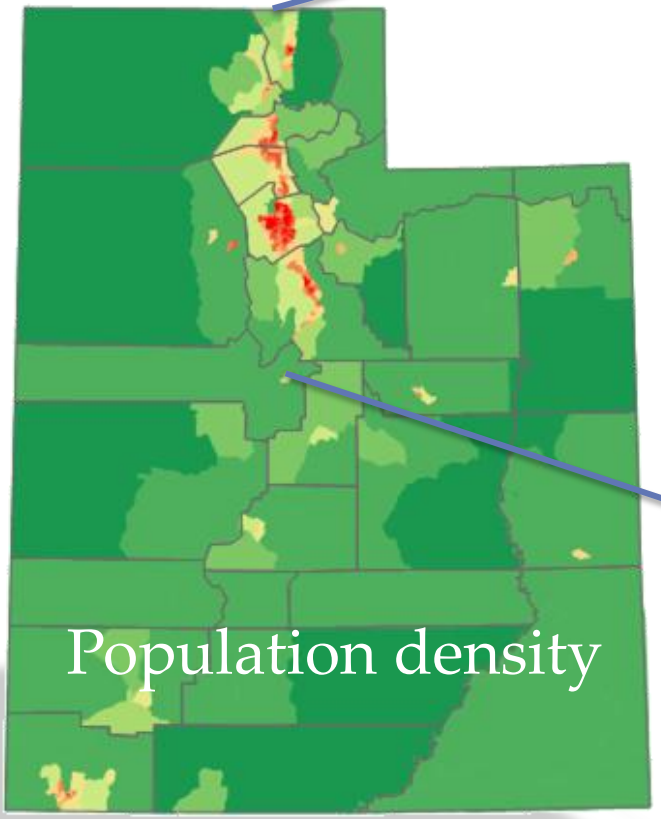
No guarantee you'll find water!

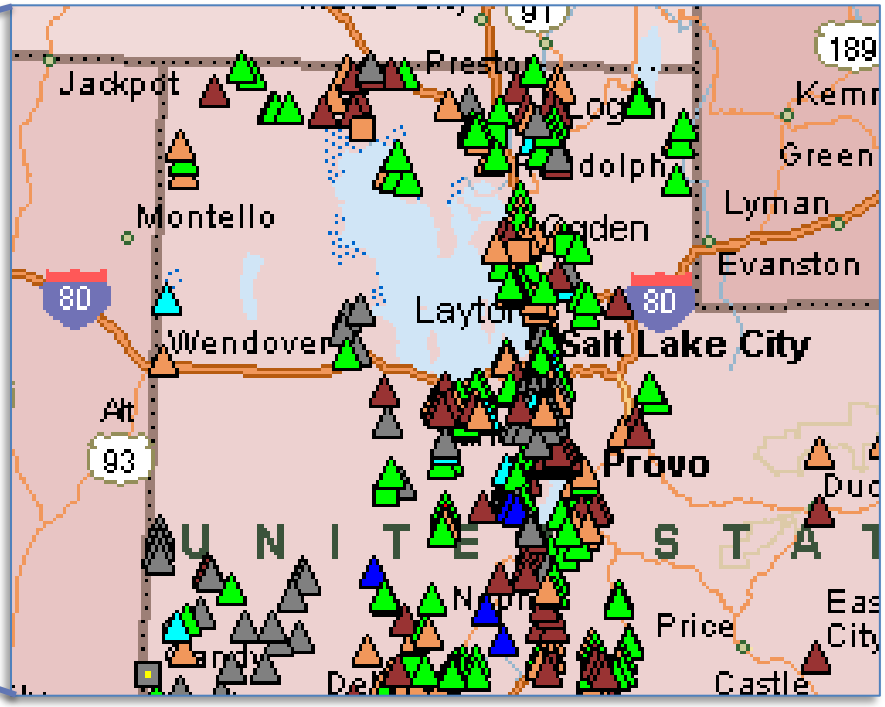
Mid 1900's

Early 1900's



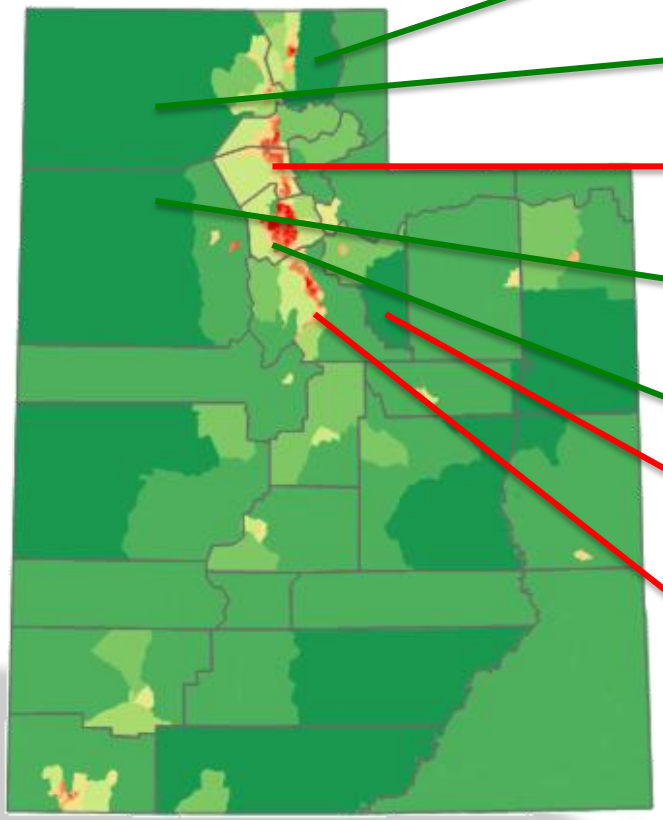
USGS Active Groundwater Level Network

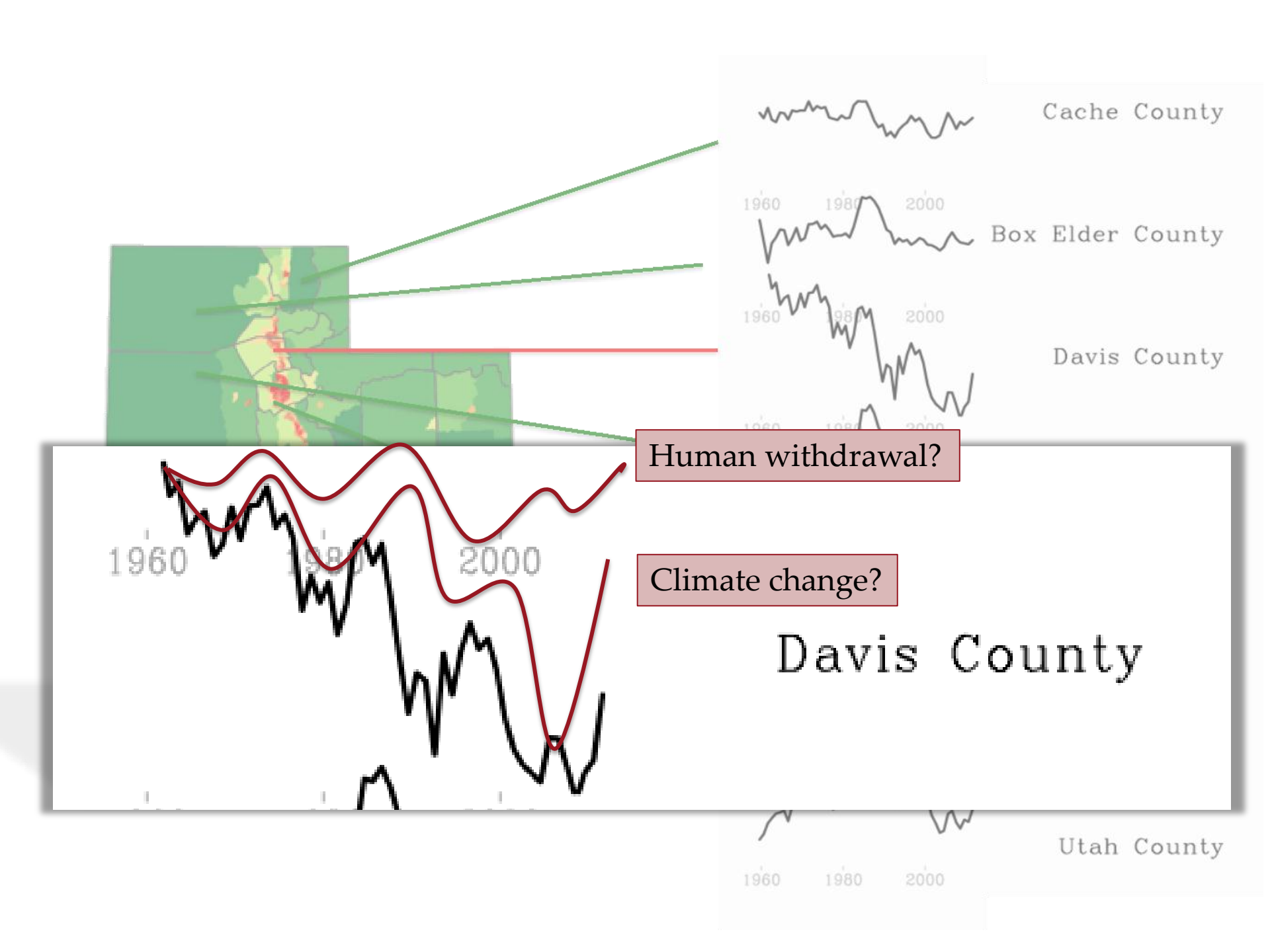


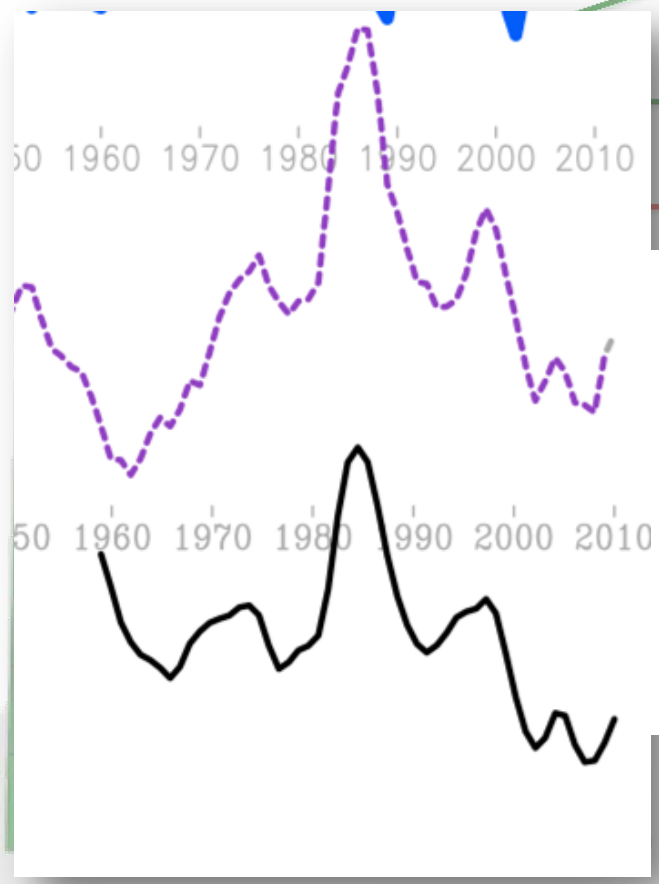


400 wells analyzed

Groundwater since 1960




Cache County
1960
1980
2000
Box Elder County
1960
2000
Davis County
Human withdrawal?
1960
2000
Climate change?
Davis County
Utah County
1960
1980
2000



Great Salt Lake E ation

Northern Utah Groundwater

Great Salt Lake (GSL)

Closed-basin lake

$S = P - E + R_o + R_u$

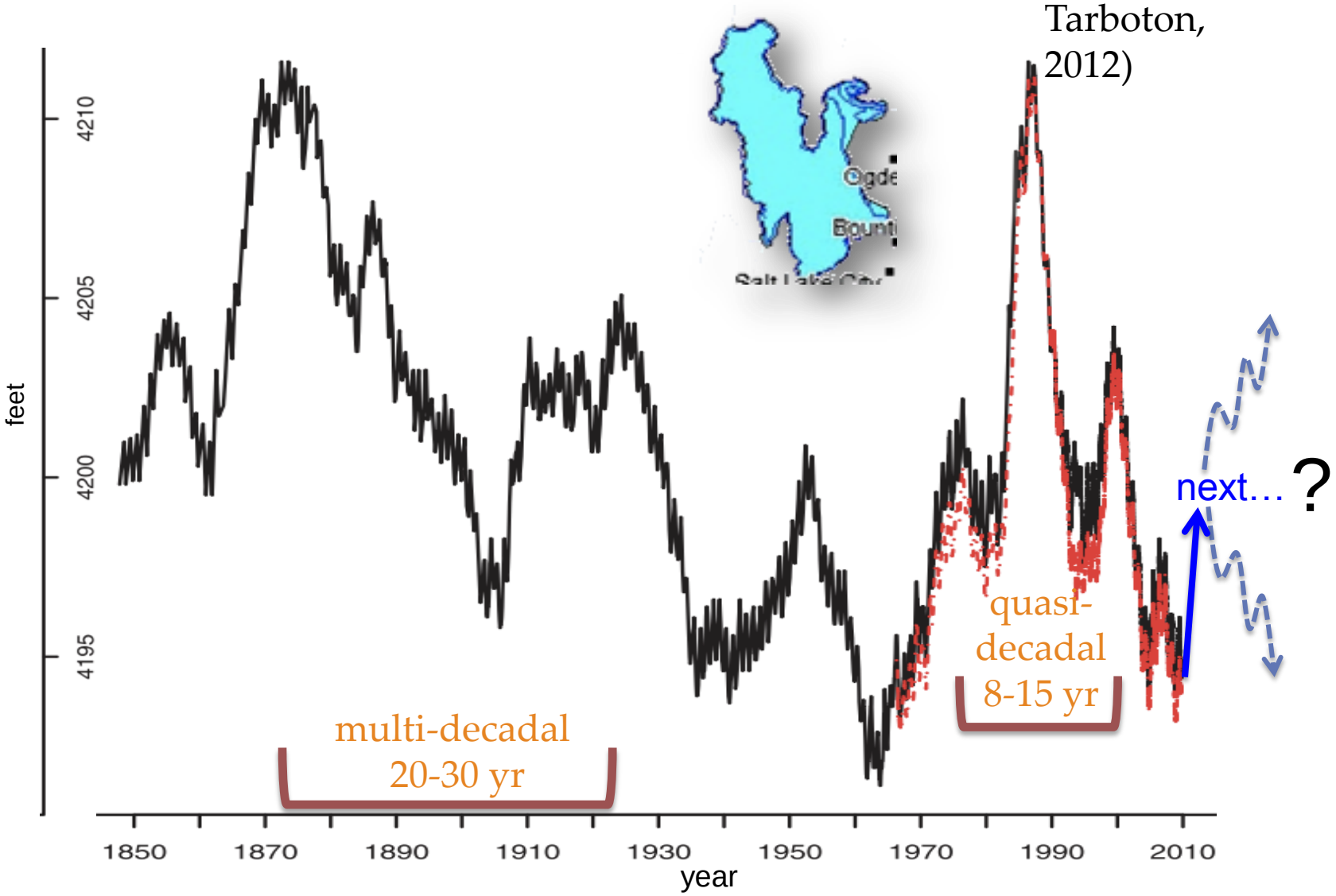
controlled by climate

S= rate of storage of water (dS/dt)
P= precipitation rate
E= evaporation rate
R_o= surface runoff
R_u= subterranean runoff

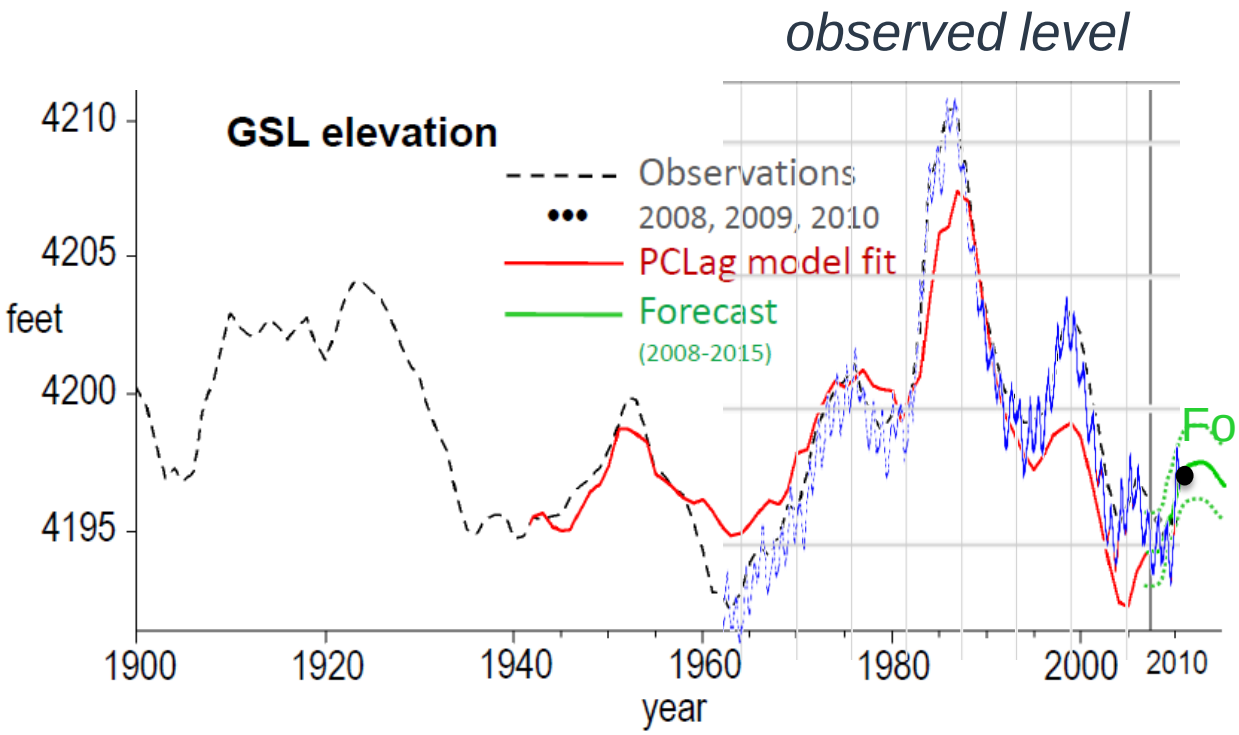
} also controlled by human

Great Salt Lake – Utah's barometer & rain gauge

(Mohammed, Tarboton, 2012)



Knowing the climate oscillations, one could forecast the GSL level up to 8 years

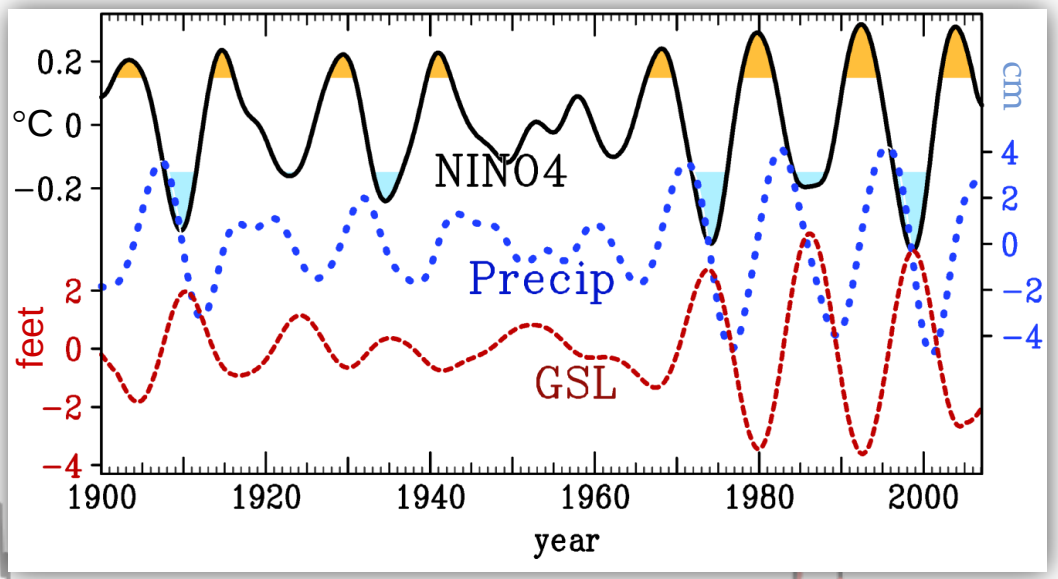


Forecast out to 8 years

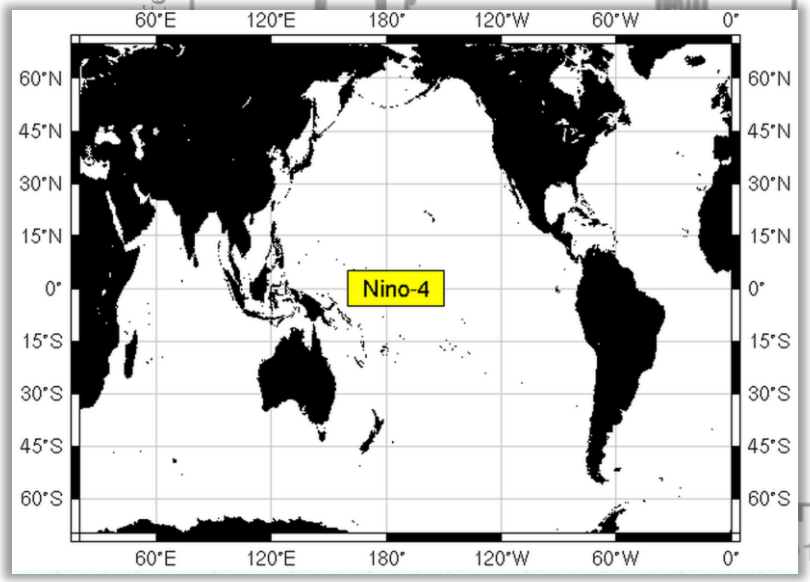
(Gillies et al. 2011; JHM)

Pacific Q.D.O →

(central tropical Pacific)

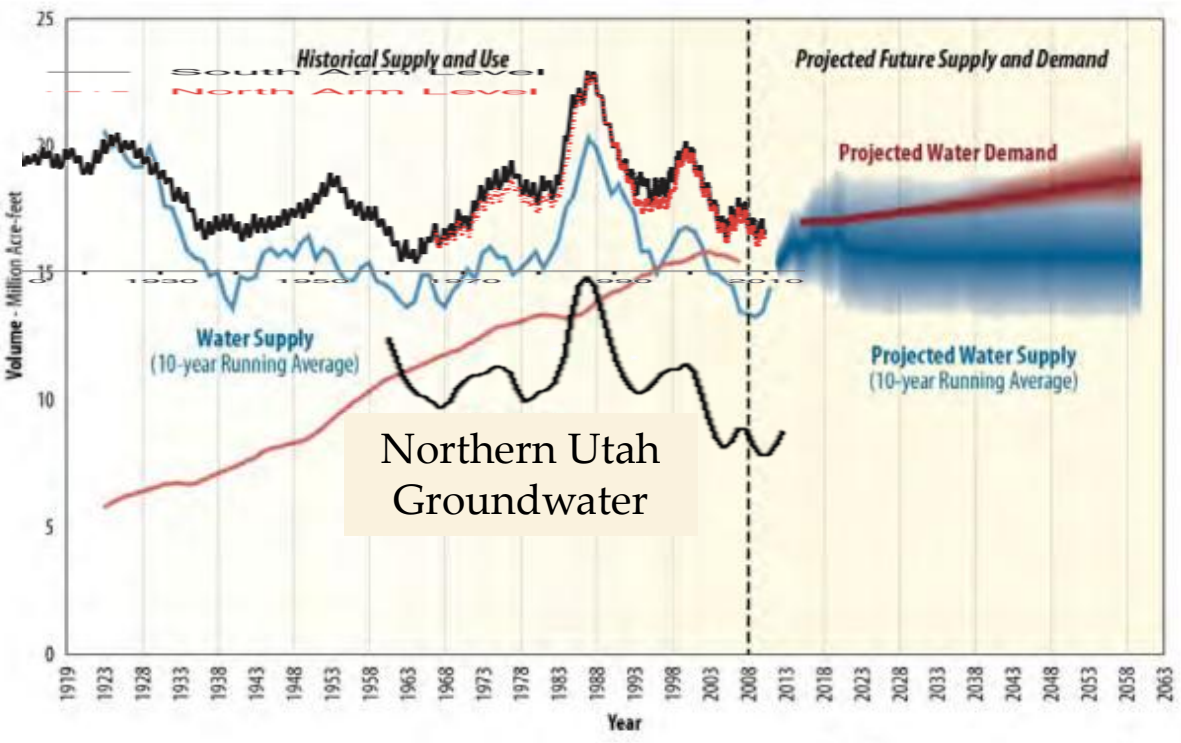


(Wang et al. 2010; JCLI)



Colorado River Basin- Historical Water Supply and Demand

USBR 2012



Northern Utah Groundwater

22 models in the CMIP5 project (UN IPCC 5th Assessment Report)

Community Earth System Model (CESM)

Groundwater output not in CMIP5

CESM water balance:

$$\Delta W_{can} + \Delta W_{sno} + \sum_{i=1}^{N_{levsoi}} \left(\Delta w_{liq,i} + \Delta w_{ice,i} \right) + \Delta W_a = \left(\begin{matrix} q_{rain} + q_{sno} - E_v - E_g - q_{over} \\ -q_{drai} - q_{rgwl} - q_{snwcp,ice} \end{matrix} \right) \Delta t$$

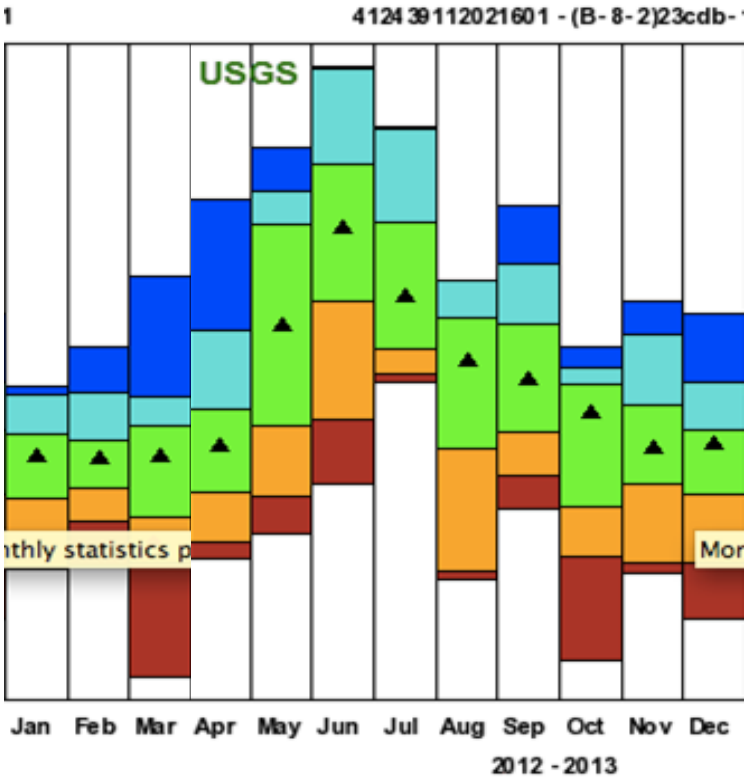
Depth to water table = Z_{∇}

$$S = P - E + R_u + R_o$$

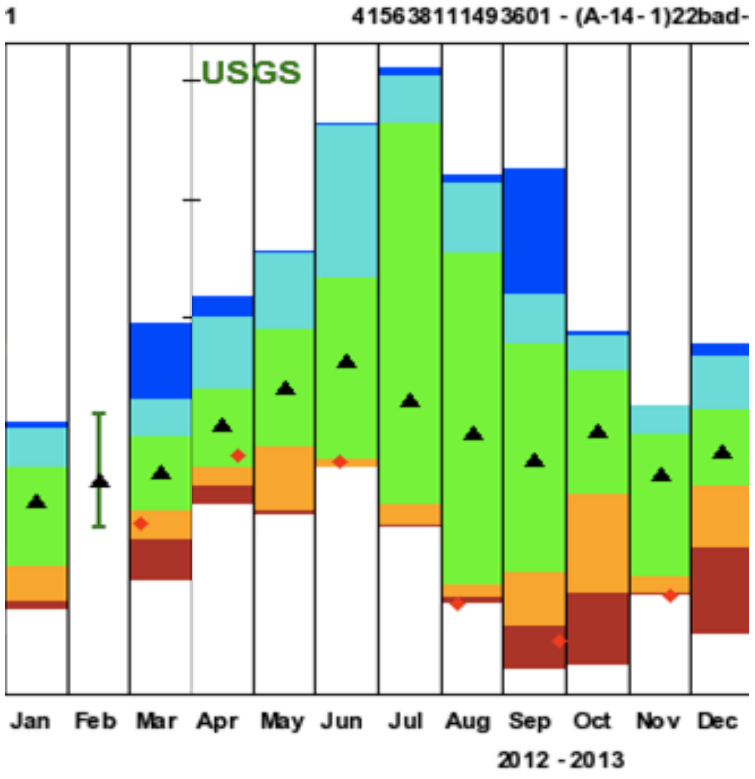
S= storage term
P= precipitation
R_u= subsurface runoff
R_o= surface runoff

Can CESM simulate GW?

Box Elder Well: 412439112021601(B-8-2)23cdb-1
Overlaid with ZWT CESM Runs

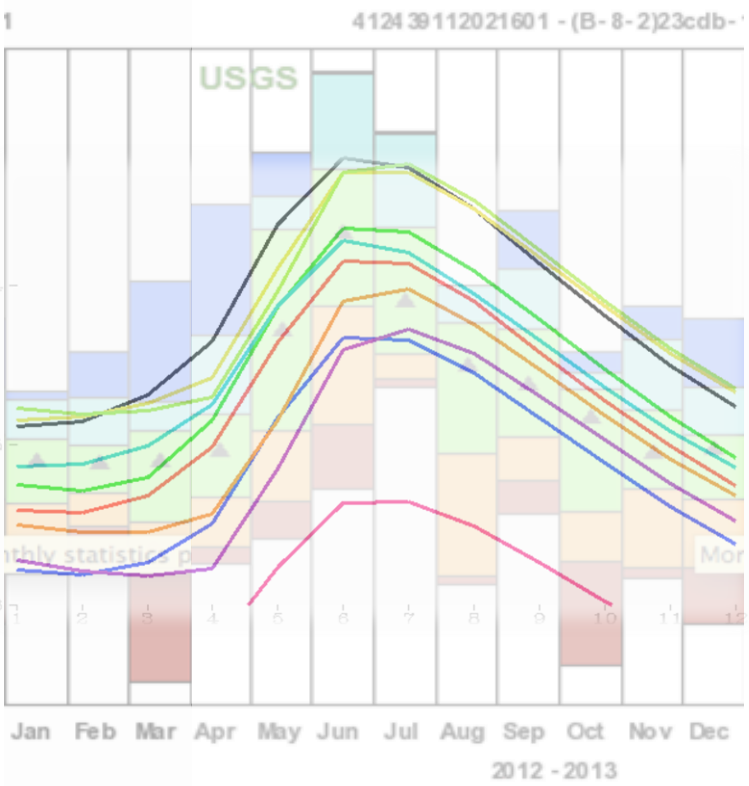


Cache County Well: 415638111493601(A-14-1)22bad-1
Overlaid with ZWT CESM Runs



Monthly Observed vs. Modeled Groundwater

Box Elder Well: 412439112021601(B-8-2)23cdb-1
Overlaid with ZWT CESM Runs



Cache County Well: 415638111493601(A-14-1)22bad-1
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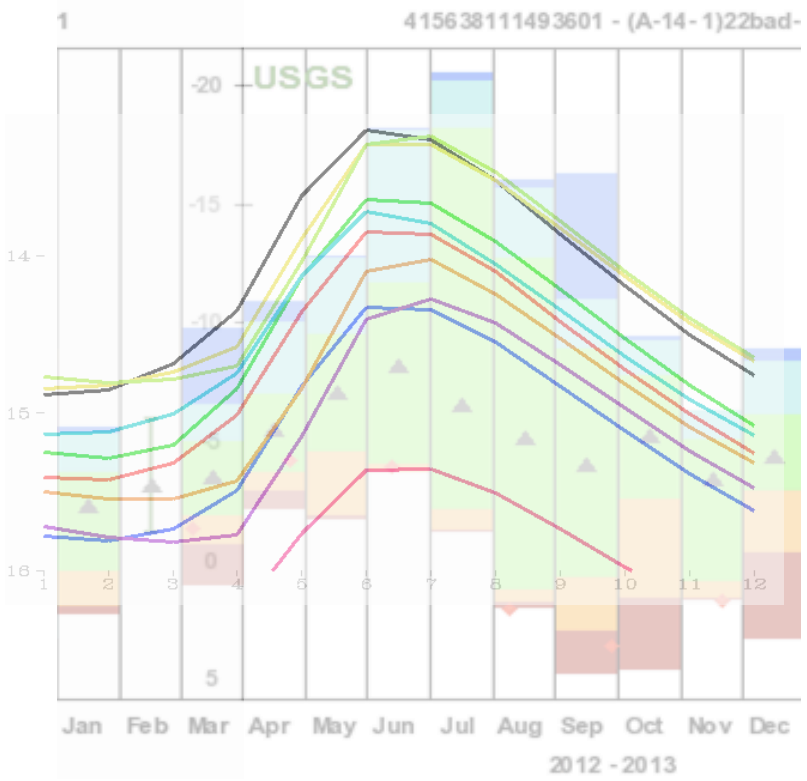
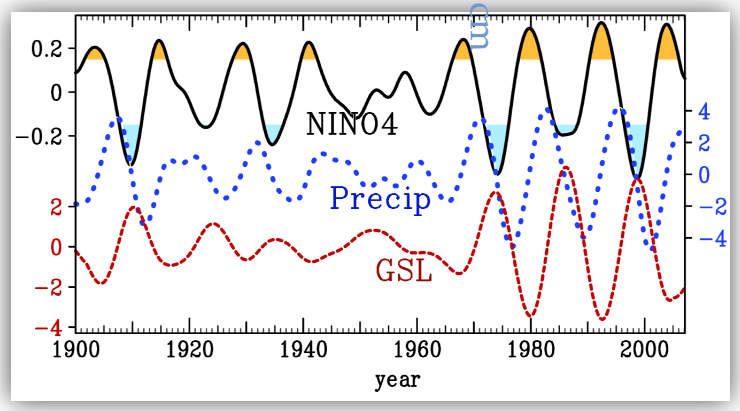
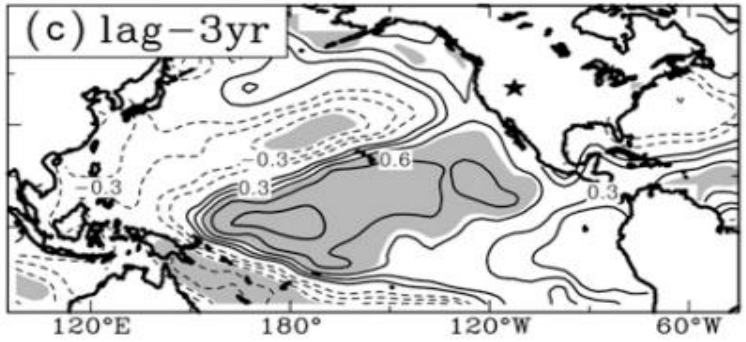


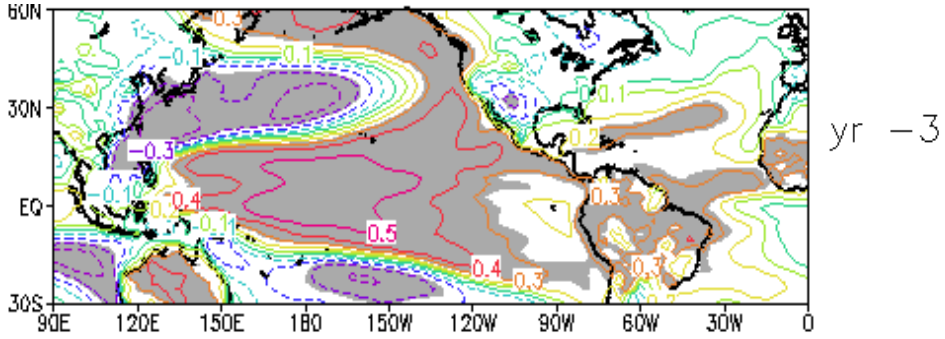
Large-scale climate forcing



Observed (108years)



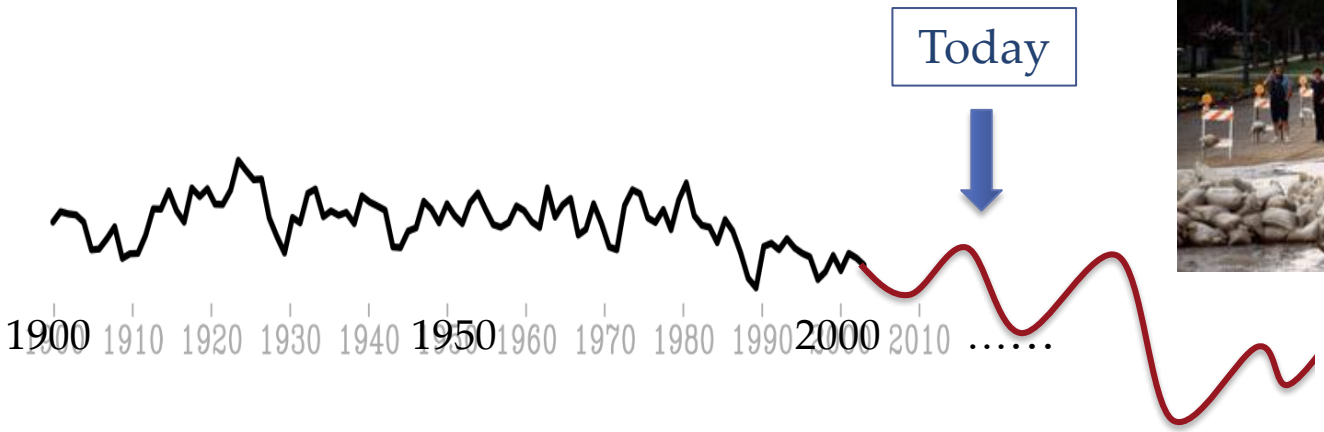
Modeled (156 years)



Wang et al. (2010; JCLI)

Correlation map between northern UT's PRECT and Pacific SST

Historical Experiments

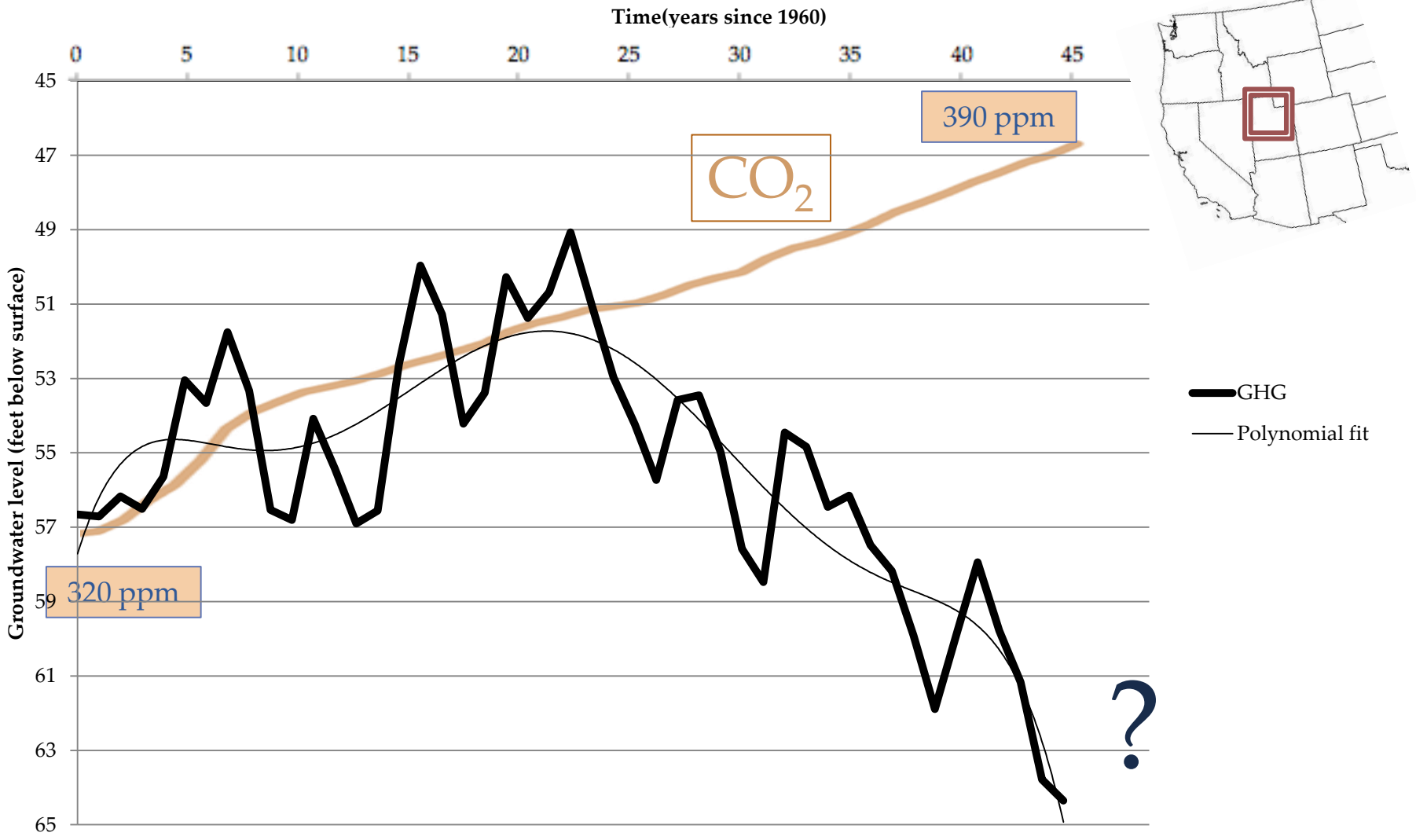


Experiments

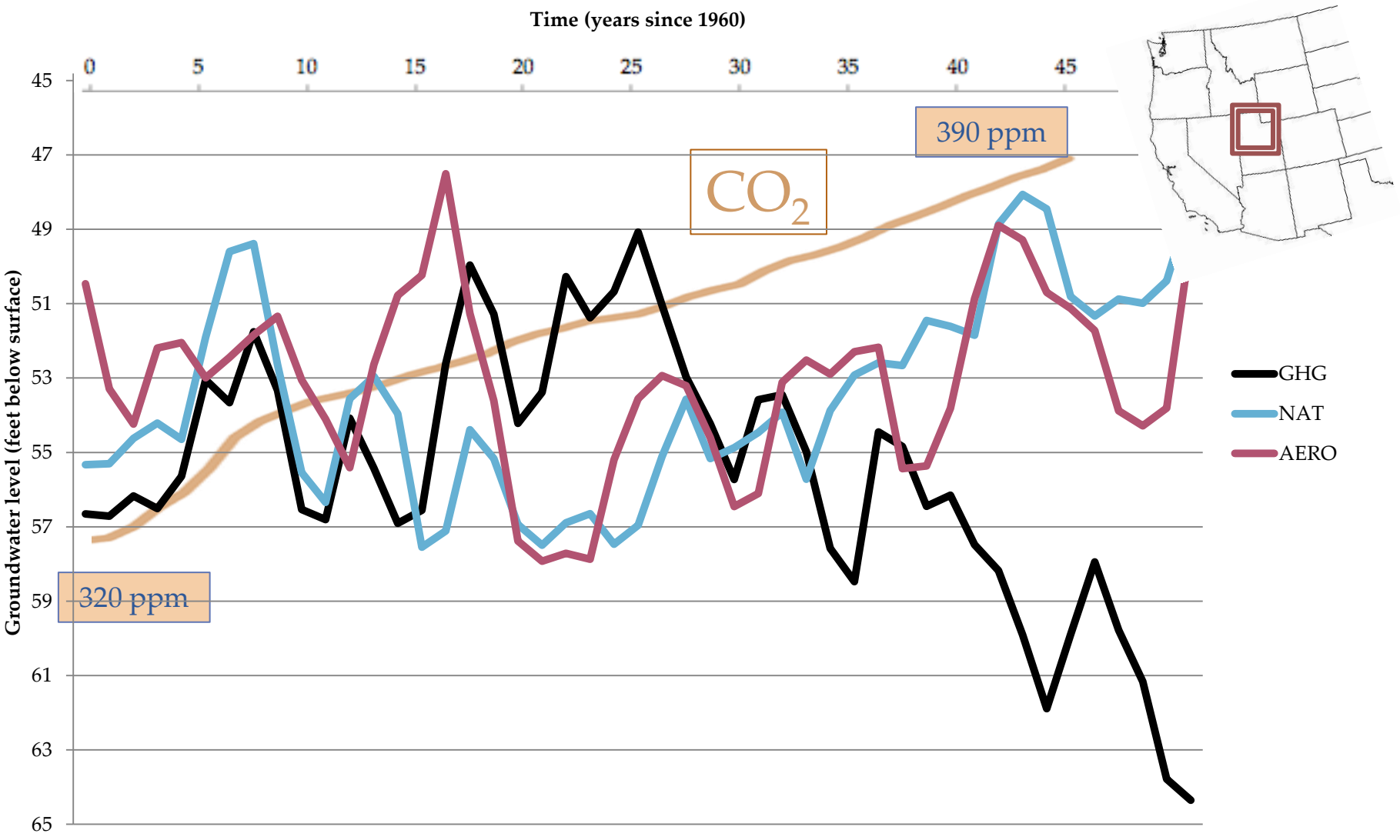
- **GHG**- greenhouse gas forcing (simulates increased CO2 emissions)
- **NAT**- natural forcing (simulates natural volcanic and solar activity)
- **AERO**- aerosol forcing (simulates increased aerosol emissions)

CESM Groundwater

Calendar year



CESM Groundwater



Groundwater (units:m)

Trend: Annual

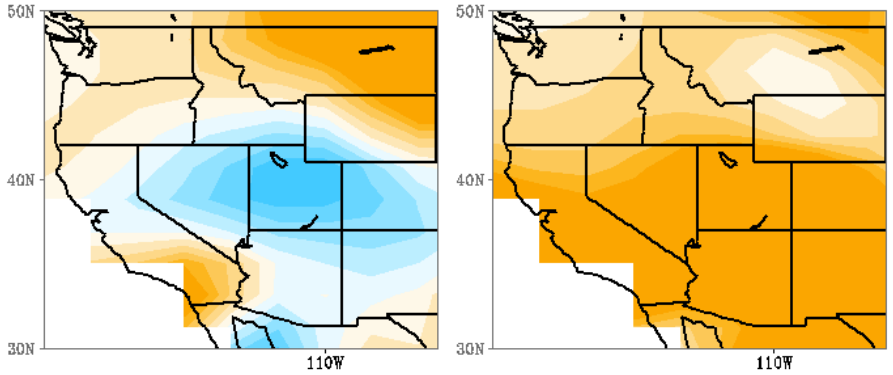
NAT

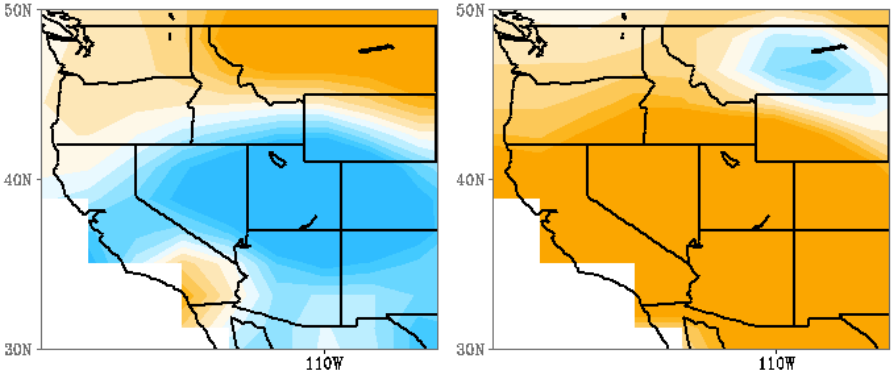
GHG

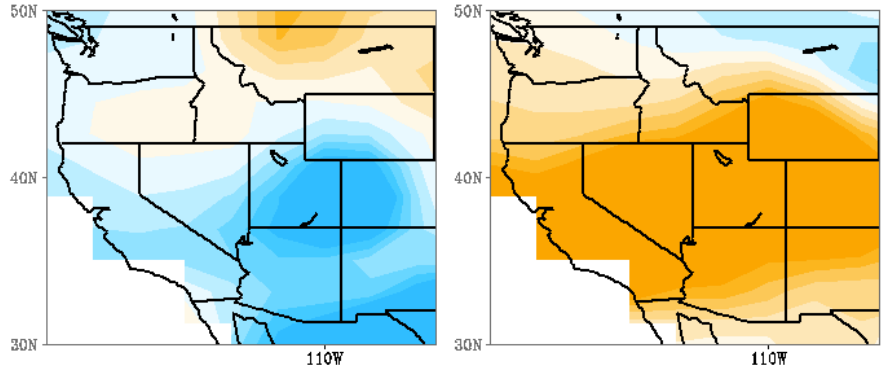
1960-2005

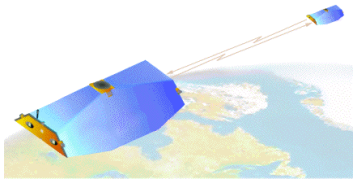
1974-2005

1995-2005

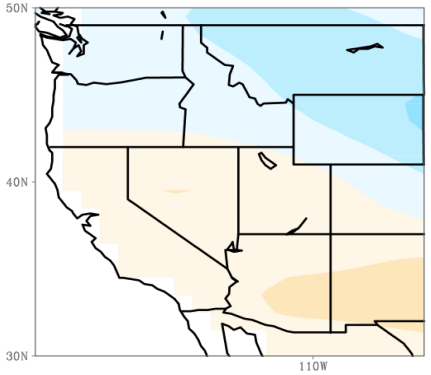


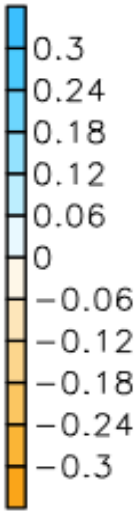






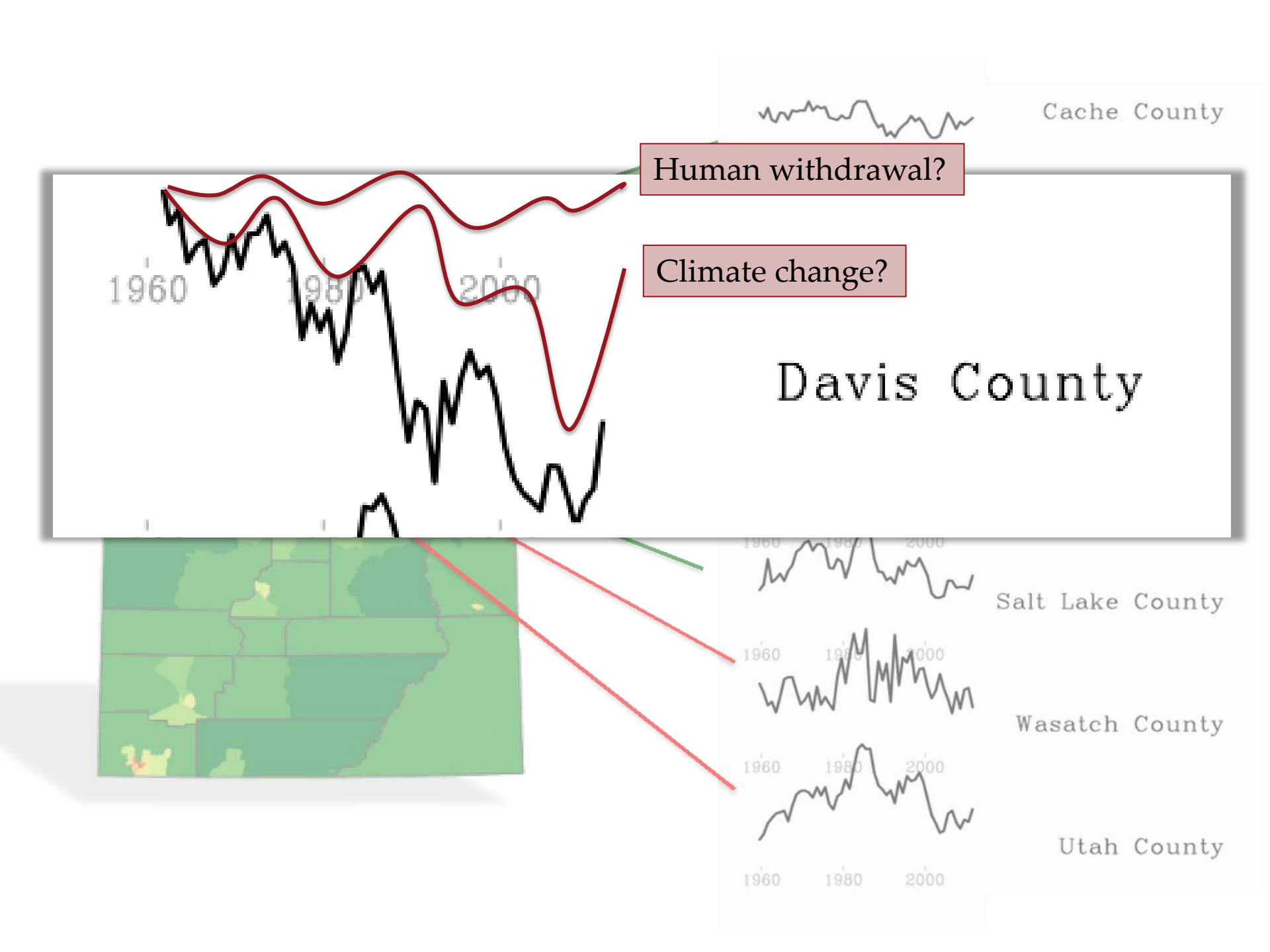
Observed / GRACE 2002-2011



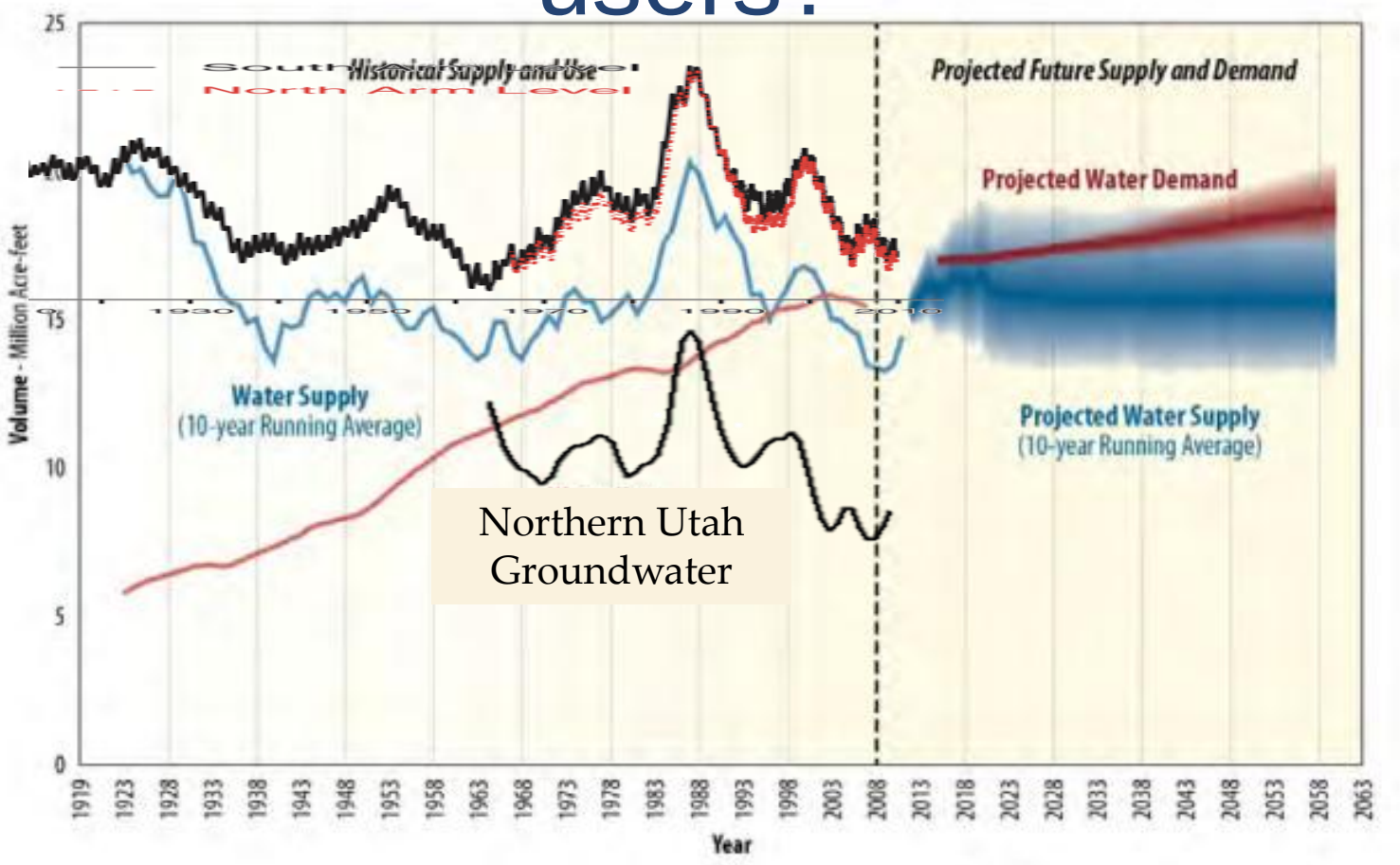


Future of water in Utah?

- Can Utah withstand increased withdrawal?
- For how long?
- While CO2 continues to rise


Cache County
Human withdrawal?
Climate change?
1960
1980
2000
Davis County
Salt Lake County
Wasatch County
Utah County

Working to get information to users?



Northern Utah Groundwater

Thank you!

References:

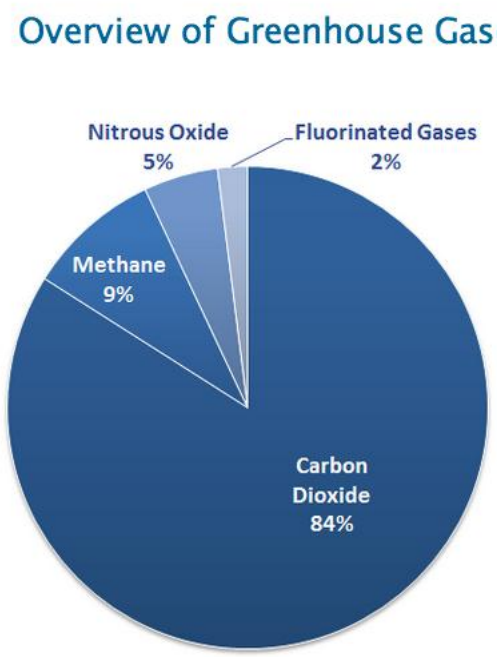
- Wang, S.-Y., and R. R. Gillies, 2013: Influence of the Pacific quasi-decadal oscillation on the monsoon precipitation in Nepal. *Climate Dynamics*, 40, 95-107.
- Wang, S.-Y., R. R. Gillies, and T. Reichler, 2012: Multi-decadal drought cycles in the Great Basin recorded by the Great Salt Lake: Modulation from a transition-phase teleconnection. *J. Climate*, 25, 1711-1721.
- Wang, S.-Y., and A. J. Clark, 2011: Quasi-decadal spectral peaks of tropical Western Pacific SSTs as a precursor for tropical cyclone threat. *Geophys. Res. Lett*., 37, L21810.
- Gillies, R. R., O.-Y. Chung, S.-Y. Wang, and P. Kokoszka, 2011: Incorporation of Pacific SSTs in a time series model towards a longer-term forecast for the Great Salt Lake. *J. Hydrometeorology*, 12, 474-480.
- Wang, S.-Y., R. R. Gillies, L. E. Hipps, and J. Jin, 2011: A transition-phase teleconnection of the Pacific quasi-decadal oscillation, *Clim Dynamics*, 36, 681-693.
- Wang, S.-Y.,R. R. Gillies, J. Jin, and L. E. Hipps, 2010: Coherence between the Great Salt Lake level and the Pacific quasi-decadal oscillation, *J. Climate*, 23, 2161–2177.
- Wang, S.-Y., R. R. Gillies, J. Jin, and L. E. Hipps, 2009: Recent rainfall cycle in the Intermountain Region as a quadrature amplitude modulation from the Pacific Decadal Oscillation, *Geophys. Res. Lett*., 36, L02705.

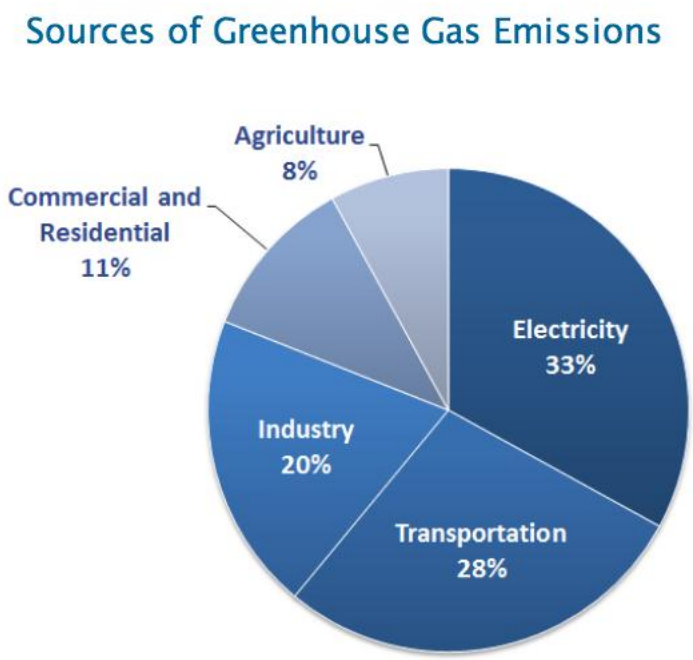
[I]f wells are driven into a subterranean body of water, and a spring is dried up, the owner of the wells will be enjoined from permitting them to flow; if a tunnel is driven into a mountain and percolating waters are gathered with the result that the water of a surface stream is affected, the water cannot be claimed by the person who drove the tunnel; if a man digs a trench across his lands and thereby intercepts the ground water percolating through his lands to lower levels with the result that a prior user is injured, the prior user can enjoin the injury. . . . It ought to make no difference as to the kind of a channel through which water reaches the sunlight . . . . Once the water bubbles forth to be used by man in the reclamation of our desert areas, whether from a pipe driven into the earth by man or as the result of an earthquake or some other force of nature, the first to apply to a beneficial use should be protected.[1]

Justesen v. Olsen, 40 P.2d 802, 807–08 (Utah 1935).

The Office of the State Engineer was created in 1897. The State Engineer is the chief water rights administrative officer. A complete "water code" was enacted in 1903 and was revised and reenacted in 1919. This law, with succeeding complete reenactments and amendments is presently in force mostly as *Utah Code*, Title 73. In 1967 the name of the Office of the State Engineer was changed to the Division of Water Rights with the State Engineer designated as the Director, but the public sometimes still refers to the Division as the State Engineer's Office.

GHG Emissions as of 2011





Global greenhouse gas emissions have grown markedly since pre-industrial times, with a 70% increase from 1970 to 2004 alone. Over this period, emissions from the transport and energy sectors have more than doubled. Policies put in place in some countries have been effective in reducing emissions in those countries to a certain degree, but not sufficiently to counteract the global growth in emissions.