Climate Change Impacts on Santa Margarita Sustainable Groundwater

Dr. Bruce Daniels

Ph.D. Hydroclimatology, UC Santa Cruz (Science of Climate Impacts on Water)

Hydroclimatology.com



Climate & Water Relation

Weather ==> (Climate)

Surface ==> Water

Groundwater

==>



Recharge is not Constant 20 years ago \neq today \neq 20 years future

Climate is Changing

=> Precipitation is Changing

=> Recharge is Changing



Recharge Not Directly Connected to Precipitation

Connected by Complex

Hydrologic Partitioning





Partitioning Is Not Constant

Dependent on temperature, radiation, wind, humidity, plant types and coverage, animals, soil profiles, timing, etc. (all climate dependent)



What is Interception? Important?



What is Interception? Important?

Rain Caught by Plants and Evaporates Without Ever Reaching the Ground!

MidCounty Basin is 16.7% of Precipitation



How much Precipitation is Recharge?

MidCounty Basin is 9.8%

(also climate dependent)



All Partition Fractions?

Interception Sublimation Imperv Evap Surface Runoff Infiltration Soil ET

16.7% 0.0% 1.7% 13.8% 67.8% 47.3%

Exfiltration0.0%Interflow10.6%Recharge9.8%Baseflow4.4%Lake Evap0.0%Stream Outflow28.8%

What are yours?

Total Evaporation = 65.7%



Is Recharge:Precipitation Relationship Linear?

i.e. 10% more Precipitation means 10% more Recharge?

NO

The Relationship is Curved with the Larger Storms Producing the Largest Recharge



Recharge vs. Precipitation



Recharge Just Depend on Annual Precipitation Amount?

NO

Also Depends on Seasonal Precipitation



Seasonal Precipitation

• *"less precipitation in the fall (November–December) and spring (March–April)"* [Flint 2012, USGS]



[Snyder et al. 2004, UCSC]

<u>Rain Season</u>

4 months \rightarrow

Dec - Mar

 \rightarrow 2 months \rightarrow Jan & Feb

Flooding

Dry Season

Recharge Just Depend on Annual & Seasonal Precipitation?

NO

Also Depends on Daily Timing and Patterns



Precipitation Daily Timings

- Precipitation Daily Observations
- Precipitation Events Changes
 - Intensity = -2.9% per decade
 - Duration = +2.2% per decade
- Pauses between Events
 - Lull = +1.7% per decade

"get weaker" "last longer"

"gap bigger"

[Daniels 2014, UCSC]

Real Timings Hydrology Impact

- Trends Continue for 30 Years
- Apply Trends to MidCounty Basin
- Same Precipitation Amount

- Evaporation +4.4%
- Recharge -6.7%
- Baseflow -5.7%
- Streamflow -3.0%

Recharge Also Depends on Temperature



Temperature -> Evaporation

<u>Physics</u>: +1 °F Temperature \rightarrow +4% Evaporation



Evaporation Impact

- <u>MidCounty Groundwater Basin</u>
 - Rain = 32.3" & Temp = 70°F
 - Evaporation/Transpiration (ET) = 21.2"
 - •66% Lost
 - <u>34% Usable</u>

domestic usage commerce & business streamflow & fish seawater intrusion outflow



Evaporation Impact

- Groundwater Basin
 - Rain = 32.3" & Temp = 70°F
 - Evaporation = 21.2"
 - 66% Lost
 - <u>34% Usable</u>
- FUTURE?
- Rain = 32.3" & Temp = 77°F
- Evaporation = 130% * 21.2" = 27.6"
- 85% Lost
- <u>15% Usable</u>

Evaporation Impact

- Groundwater Basin (PRMS model)
 - Rain = 32.3" & Temp = 70°F
 - Evaporation = 21.2"
 - 66% Lost
 - <u>34% Usable</u>
- FUTURE?
 - Rain = 32.3" & Temp = 77°F
 - Evaporation = 130% * 21.2" = 27.6"
 - 85% Lost
 - <u>15% Usable</u>

Calif Winter Temps



"8–27% of the observed drought anomaly in 2012–2014" Copyright ©Bruce Daniels 3/8/19 [Williams et al. 2015]

Other Changes Predicted

- Average precipitation increases small amount
- Annual variability increases substantially
 - Dry years → Drier, Wet years → Wetter
 (wetter by up to 35 percent) [Swain et al. 2018]
- Extreme atmospheric river events and severe flooding increases [Dettinger 2011]



Future Drought Extremes

Greater than "80% chance of a MULTI-DECADAL drought during 2050–2099"

"Exceptionally high risk of a multi-decadal MEGADROUGHT occurring over the {Southwest} during the late 21st century"



Changing Climate is Water Change

Lewis Carroll Alice in Wonderland



"It takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!"

Sustainable Water Planning

- Reliable Climate Forecast Need
 - 50 year Water Plans SGMA
- "Reliable" Critically Important
 - Basis for huge efforts and investment
 - Failure not acceptable
- Consider Forecasting
 - What Does NOT Work?
 - What Does Work?



BACKUP SLIDES

- Climate Forecasting
 - What does not work
 - What does work
- 2015 Drought Data



Standard Climate Forecast

Climate Models



Hydrology Model



Temperature & Precipitation Forecast Spreads



Precipitation Indecisive





+25%

Global Climate Models (GCMs)

- 56 GCMs used 2009-10 (CMIP5)
- Globe sliced into avg 14,000 Areas
 - 144 horizontal by 96 vertical
 - each about 140 by 130 miles
- Area gives single number for:
 - Temperature
 - Precipitation
 - Snowpack
 - Etc.





GCM "Drizzle Problem"





Trust of GCMs

- Future Forecasts Testing?
 - NO, nothing to compare with
- Past Forecasts Testing?
 - YES, compare against historical records
 - Necessary Minimum for Model Trust!



GCMs No Trust in California

 Map Count of GCMs that match historical Precipitation





[Hay USGS, AGU Dec 2016]

What Does Work?

- Don't Use Models
- Use Observations
 - Instant Match with Past
- Ignore Precipitation Forecasts
 - Chaotic & Average is Zero Anyway
- Consider Temperature Forecasts
 - All Models Confirm Warming & Range Narrower



#1 – Precipitation Data for Past Years



#2 - Categorize Years by Temp



#3 - Choose Years Weighted by Temp



Current vs. Past Droughts

Statewide average of annual precipitation 1890-2000

1890-1999 (110 yrs) 9 Droughts 33 years dry = <u>30%</u>

2000-2015 Last 15 years 11 years dry = <u>73%</u>

Winter 2015 Snow 5% Normal

New Low Record – Beats 1977 & 2014

Zero January Rain

New Record - Beats 2014

San Francisco Rainfall Nov 2014 - Feb 2015

Drought Cause

High Pressure Ridge in NE Pacific
 Blocked Storms 2 years

Drought Prediction?

Declining Arctic Sea Ice [Sewall & Sloan 2005, UCSC]

Drought Again?

Random Natural Variability? – Gone, Never to Return

Or

Consequence of Changing Climate? – More of the Same

