Quantifying Potential Changes in Recharge from Changes in Weather Patterns

SOUTHWEST RESEARCH INSTITUTE®

Nick Martin, PG, PH
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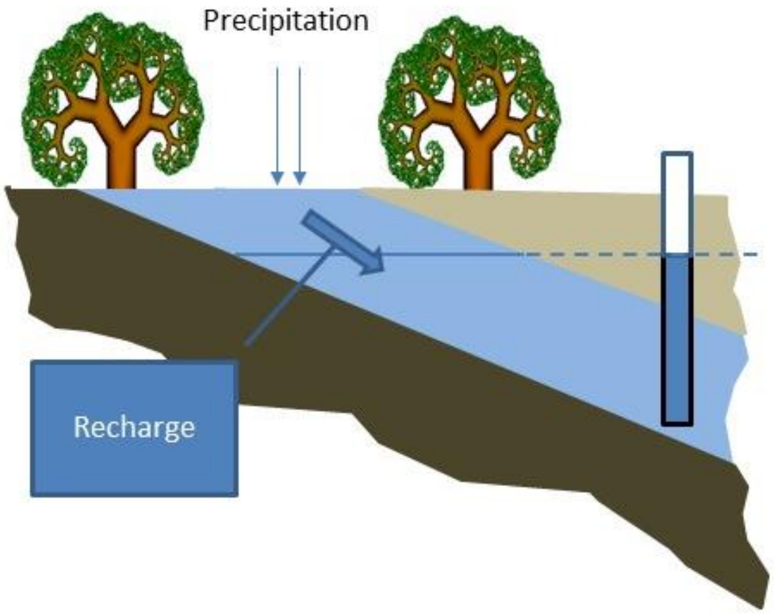
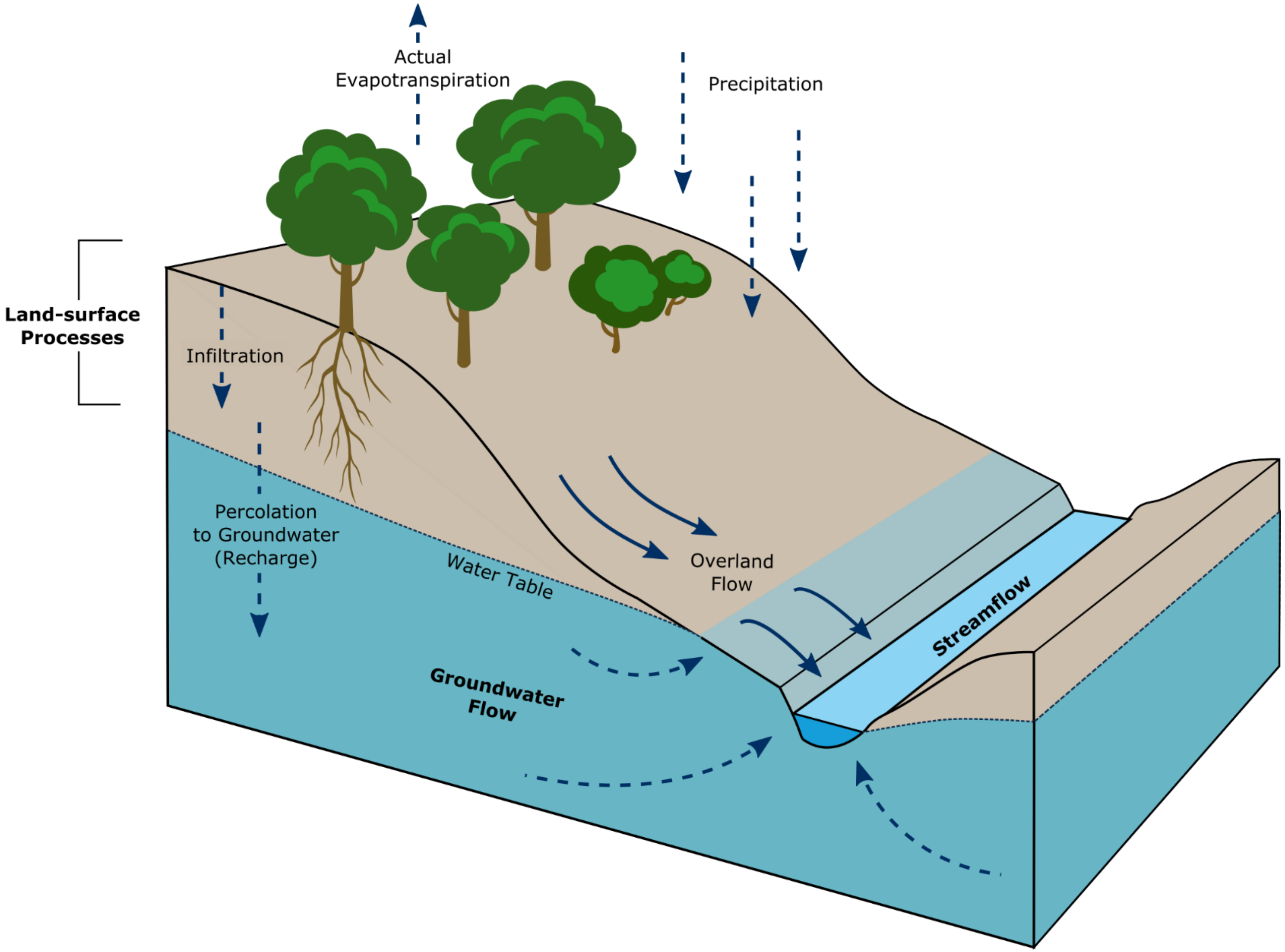
Recharge

- Precipitation that falls on the ground surface and infiltrates or percolates down to saturated groundwater
- Most likely to occur where aquifer rocks are exposed at the ground surface
- Concept of recharge is sometimes extended to include all “inflows” to an aquifer



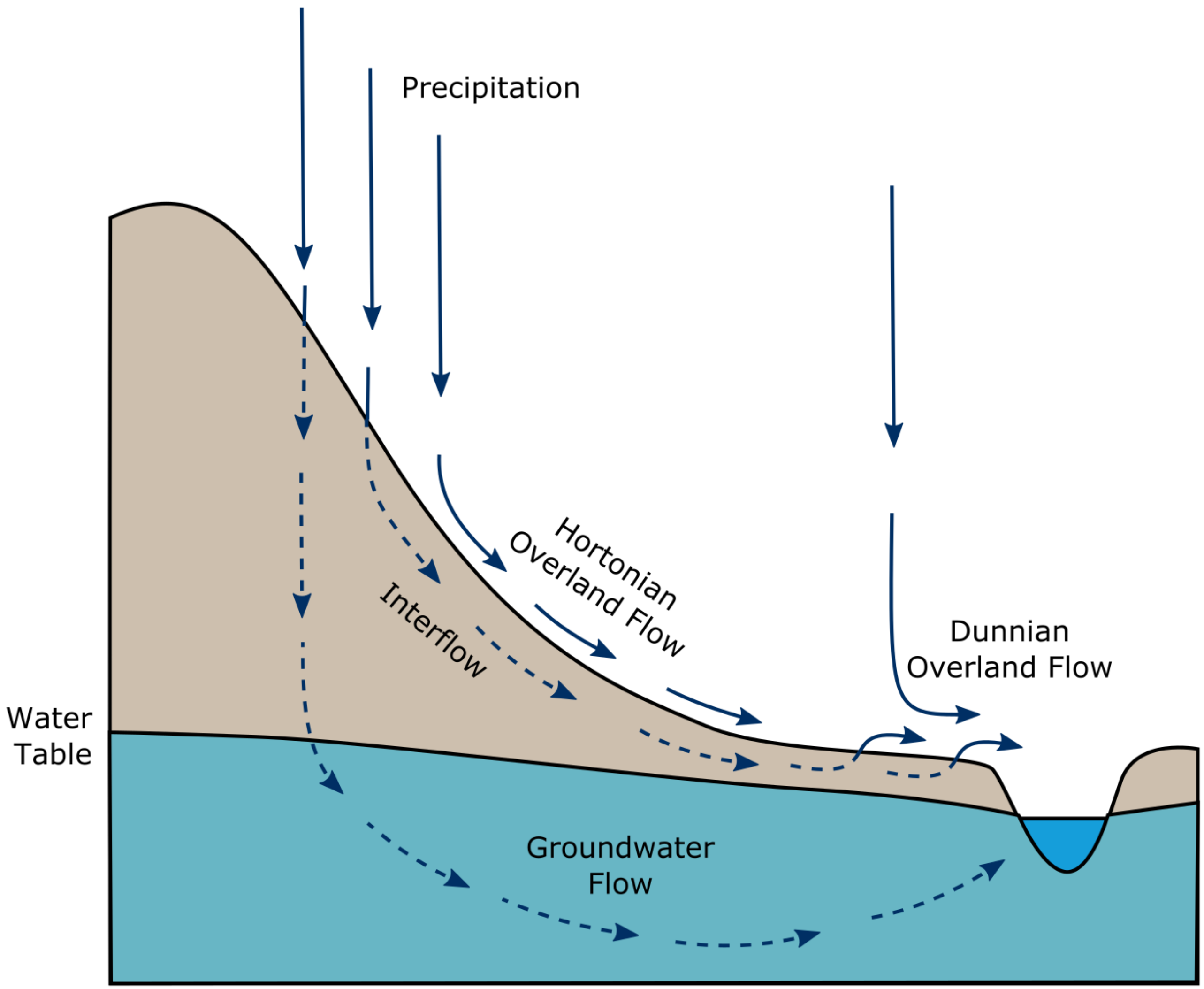
Recharge


Actual
Evapotranspiration
Precipitation
Land-surface
Processes
Infiltration
Percolation
to Groundwater
(Recharge)
Water Table
Overland
Flow
Streamflow
Groundwater
Flow

Recharge

- Characteristic time scales for precipitation considerations
  - 15-minute to 1-hour periods for "engineering" considerations like drainage and watershed runoff
  - Daily to monthly periods for "agricultural" considerations like water available to crops
  - Monthly to annual for regional "water resources" analysis
- Characteristic time scales for surface water movement and pipe or conduit flow
  - 0.1 to 1 meter per second (1/3 to 3 feet per second)
- Characteristic time scales for porous media groundwater movement
  - 1 to 10 meters per day (3 to 30 feet per day)
  - Approximately 90,000 seconds in a day and the characteristic time scale for watershed considerations is about 1 / 10,000 of that for porous media, groundwater considerations

Recharge


Precipitation
Hortonian Overland Flow
Interflow
Dunnian Overland Flow
Water Table
Groundwater Flow

Recharge

- In both karst and porous media aquifer systems, recharge needs to be determined or calculated using characteristic time scales of watershed and stream flow processes
  - In karst systems, recharge to the aquifer can occur at "surface water" movement rates because of conduits
  - In porous media systems, "recharge" is what is left over after precipitation is fractioned off into actual evapotranspiration and stream flow generation
  - Can average recharge over time to provide a monthly recharge rate to use in analyzing the water resources of an aquifer
  - Cannot, however, easily go from a monthly-average representation to a higher frequency representation like a daily value

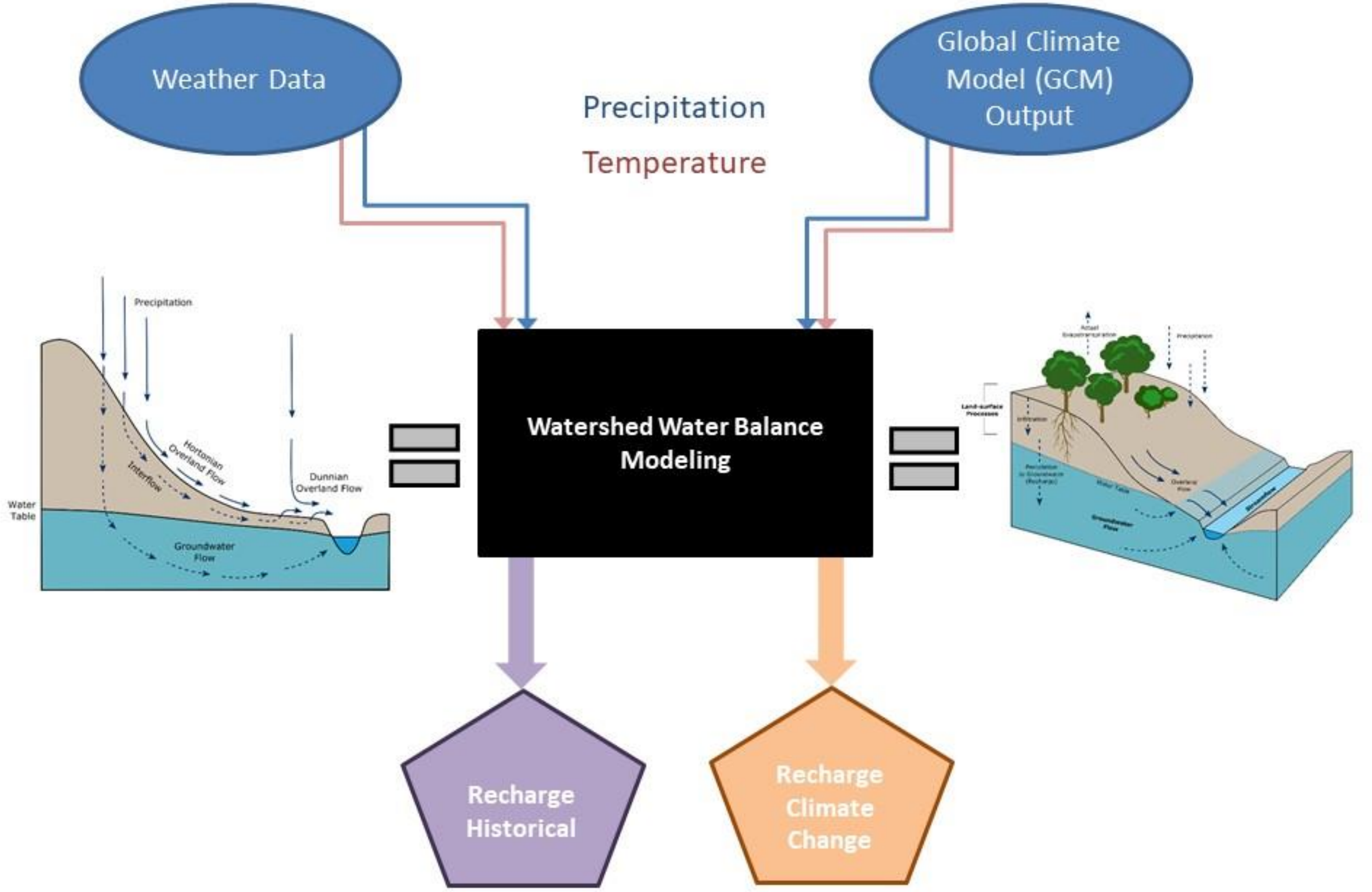
Weather and Climate

- **Weather** – "The state of the atmosphere at a given time and place, with respect to variables such as temperature, moisture, wind velocity, and barometric pressure [https://www.thefreedictionary.com/weather]."
- **Climate** – "The average of weather over at least a 30-year period. Note that the climate taken over different periods of time (30 years, 1000 years) may be different. The old saying is climate is what we expect and weather is what we get [National Weather Service (NWS), 2004]."
- "Climate is the weather of a place averaged over a period of time, often 30 years. Climate information includes the statistical weather information that tells us about the normal weather, as well as the range of weather extremes for a location [National Snow & Ice Data Center (NSIDC), 2018]."

Weather and Climate

- Weather – need daily or higher frequency
- Climate – shortest time period is 30-years
- Recharge is driven by weather and need to use "weather" to determine recharge
  - If are looking at evapotranspiration and stream flow generation as part of the recharge analysis, need to consider every day or every hour
- To quantify changes in recharge due to climate variations, need to simulate or calculate recharge over at least a 30-year period
  - Integration of the small, daily impacts over 30 years
  - What the daily impacts will be are unknown and so are uncertain about the total impacts

Quantifying Impacts to Recharge



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Black Box Water Balance Model

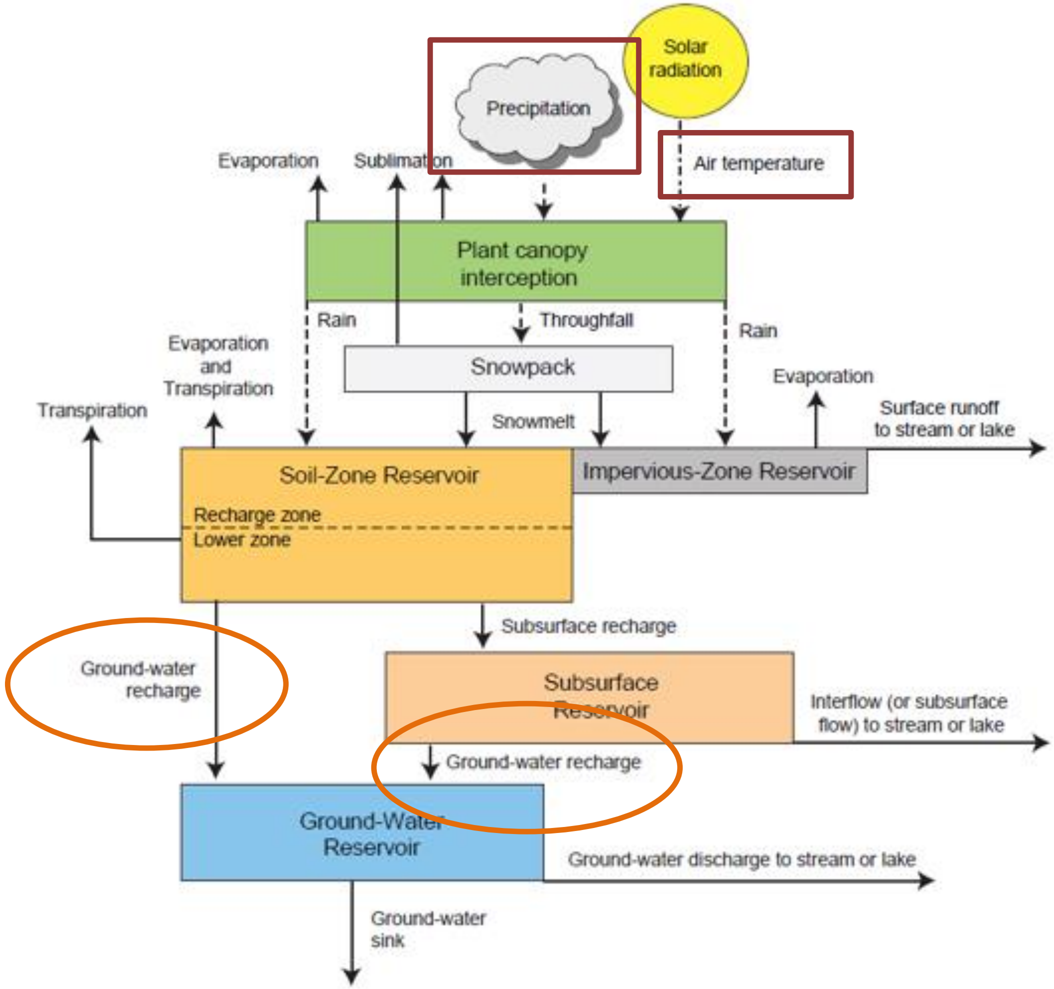
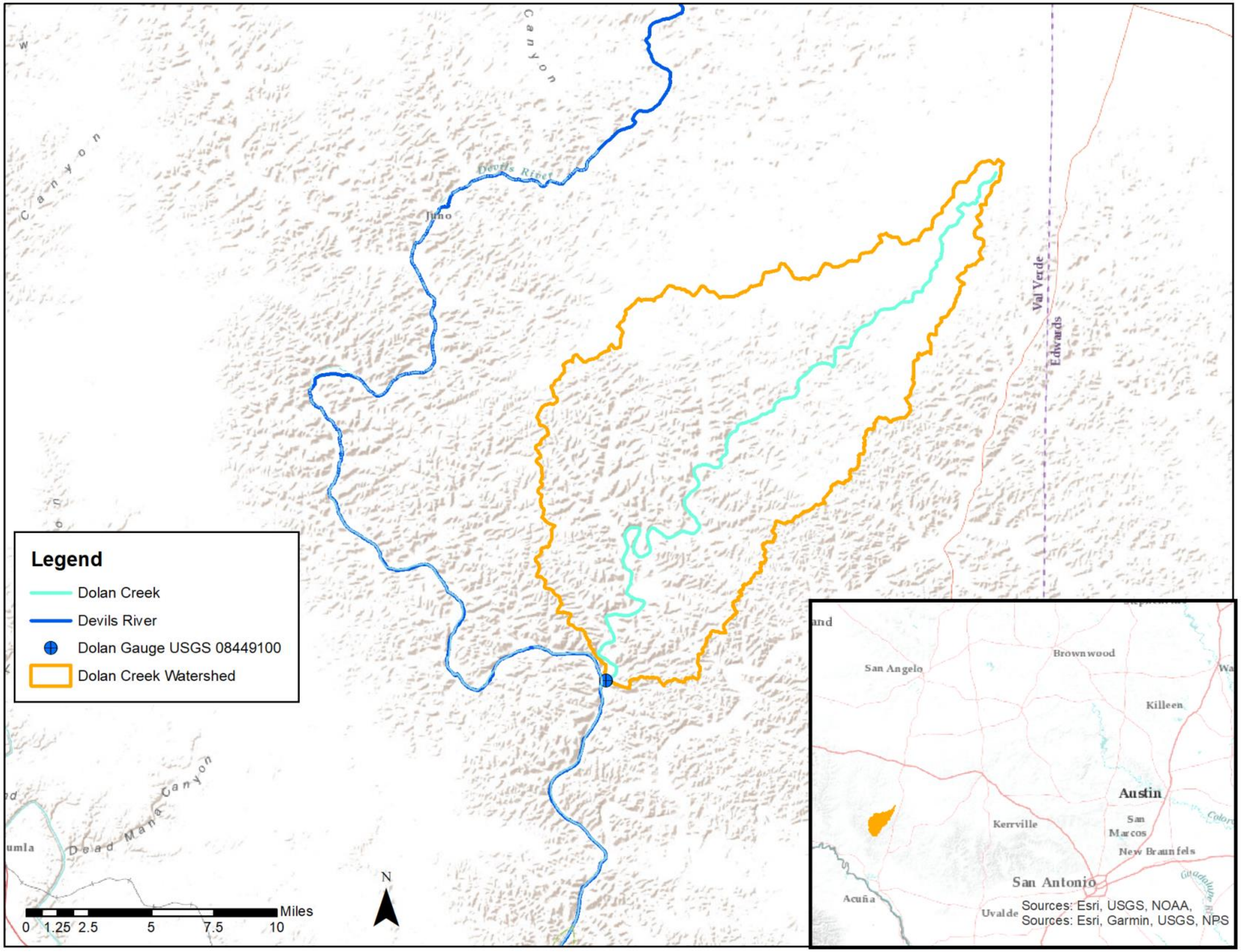


Figure 2. Schematic diagram of a watershed and its climate inputs (precipitation, air temperature, and solar radiation) simulated by PRMS (modified from Leavesley and others, 1983).

Quantifying Impacts to Recharge

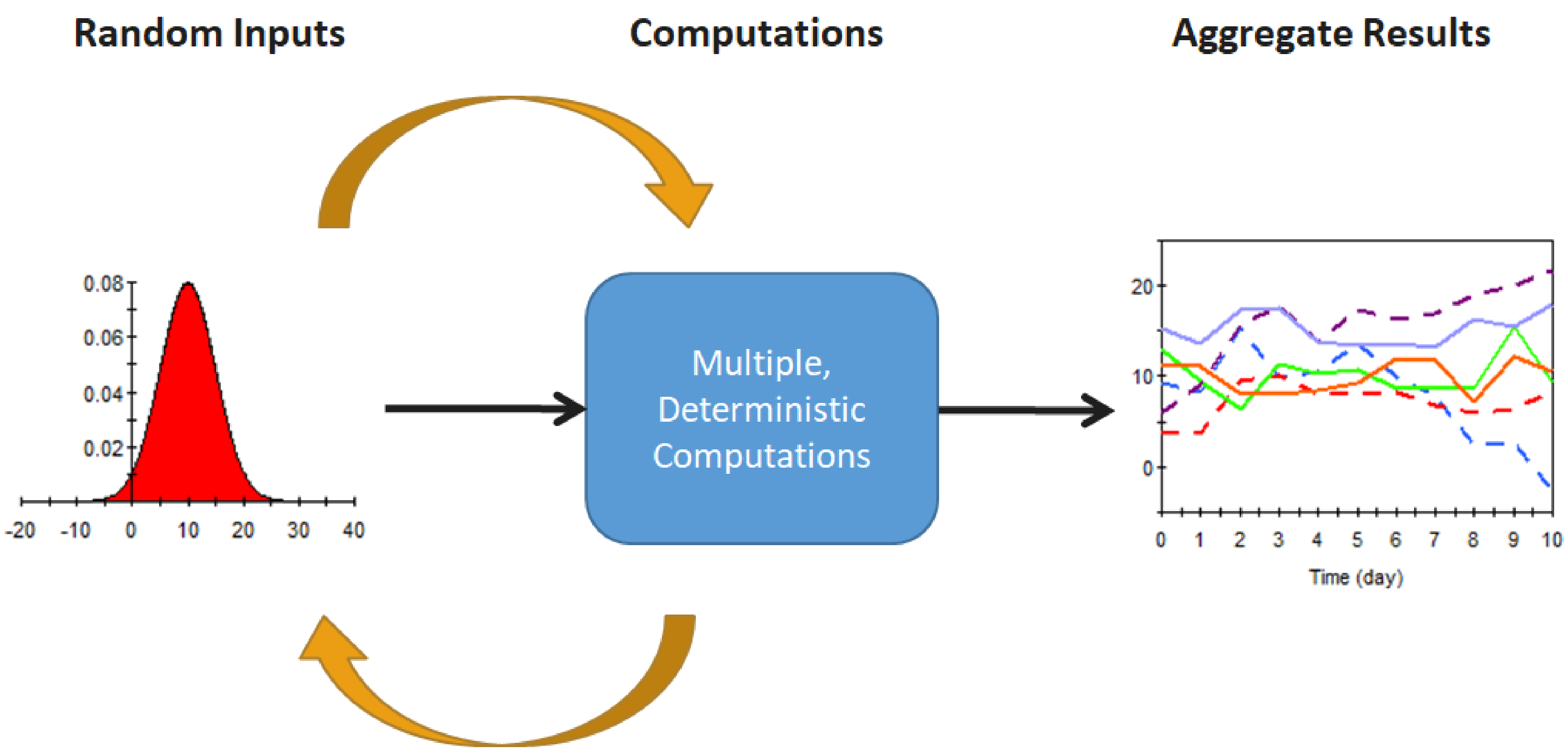
- An approach is presented to quantify impacts to recharge from possible future climate changes for any watershed in any aquifer recharge zone
- All that is needed is:
  - A model (could be an existing model) to simulate the watershed water balance in recharge and contributing zones
  - A way to produce daily time series of precipitation and air temperature that are statistically equivalent to observed/historic precipitation and temperature
  - A way to produce daily time series of precipitation and air temperature that are statistically equivalent to forecasts for change in average weather (i.e. climate change forecasts)

Dolan Creek Watershed



Stochastic Weather Generators (WGs)

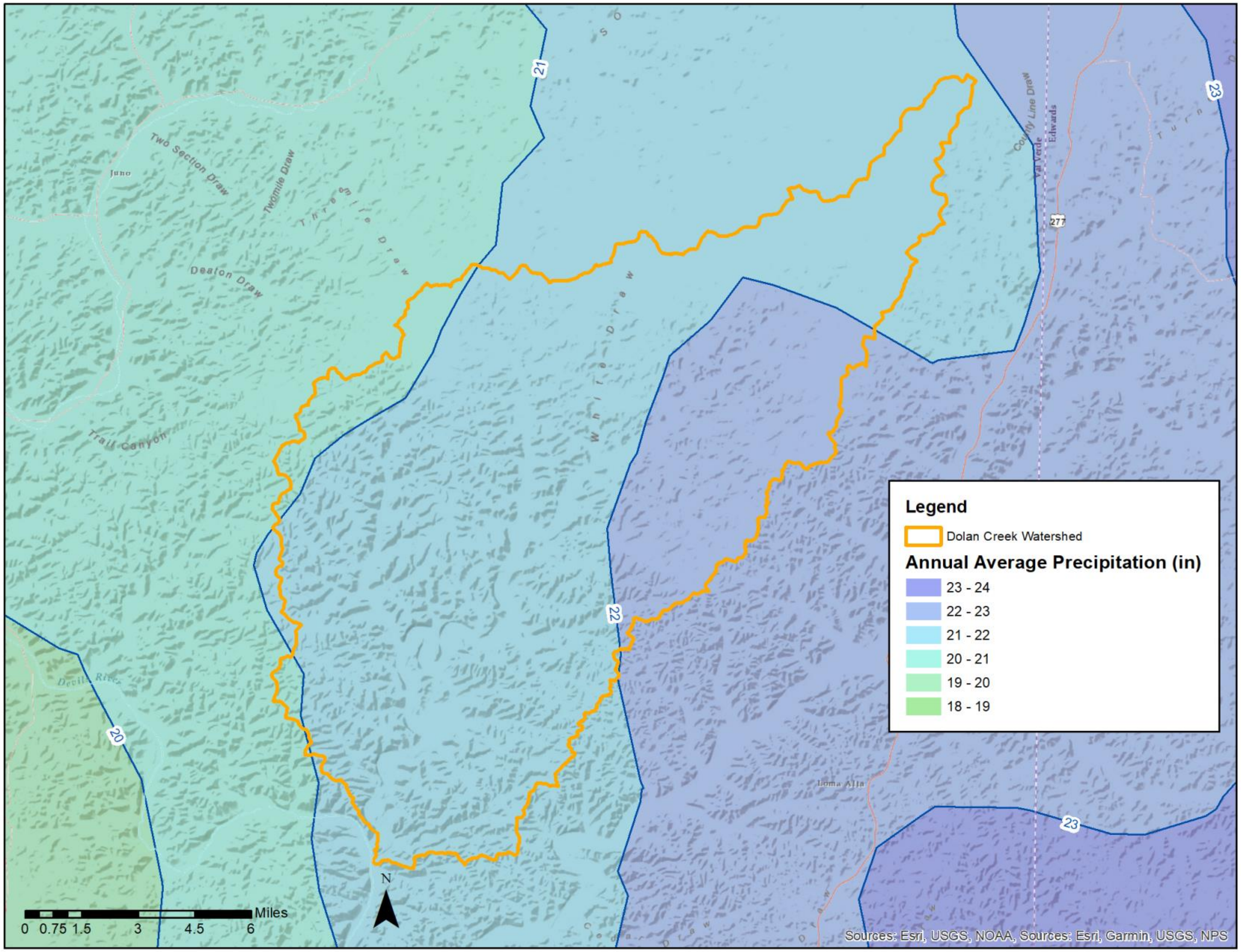
- WGs can provide precipitation and temperature time series



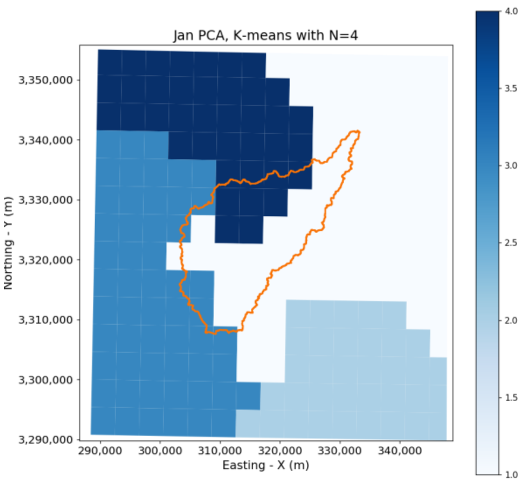
Weather Data

- One source is PRISM [http://prism.oregonstate.edu/]
- PRISM stands for Parameter-elevation Regressions on Independent Slopes Model
  - It uses meteorological station data and interpolates it to a 4 km grid that covers the continental United States
  - Technically is a modeled product and is not purely data but is extensively verified and validated against numerous data sets

Weather Data



Weather Data - Regions



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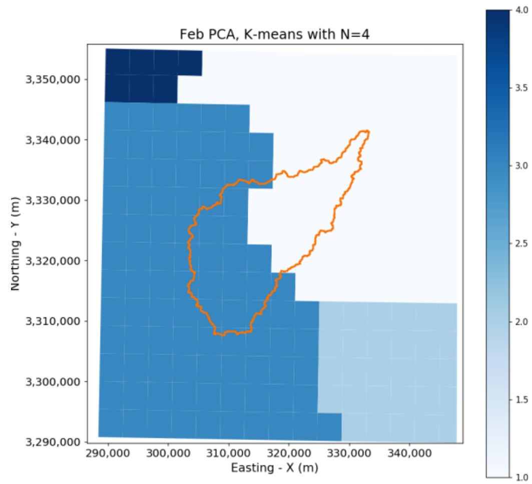

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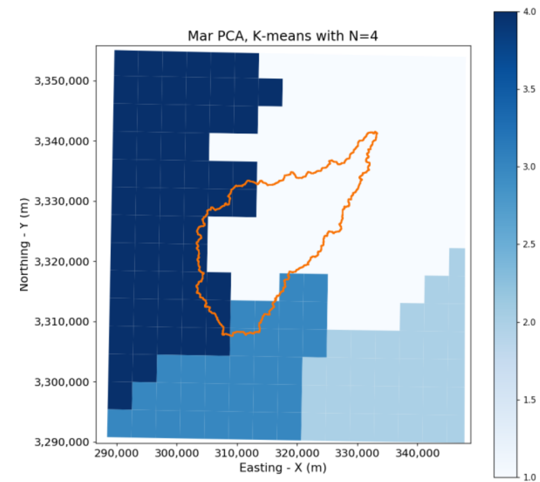

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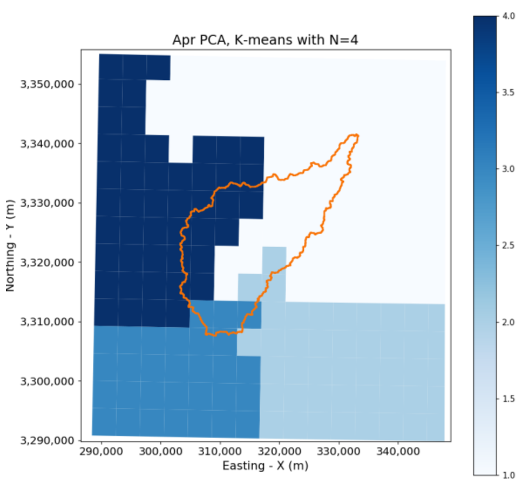

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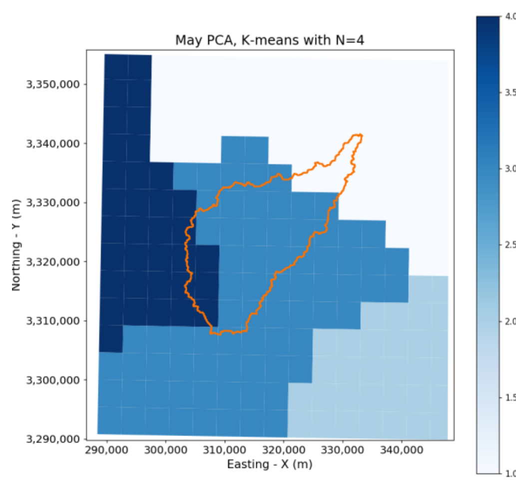

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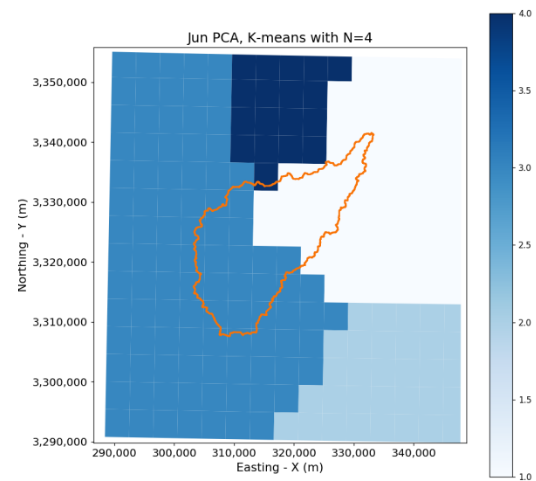

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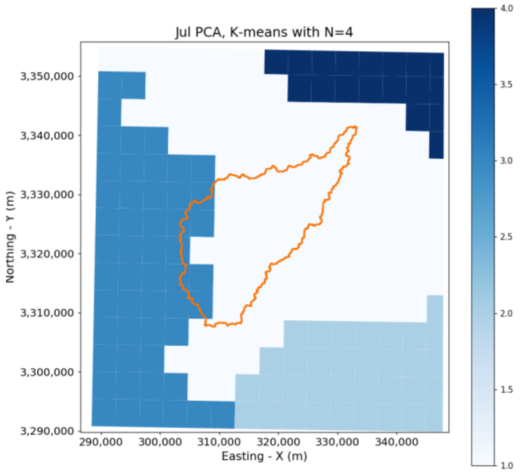
Weather Data - Regions



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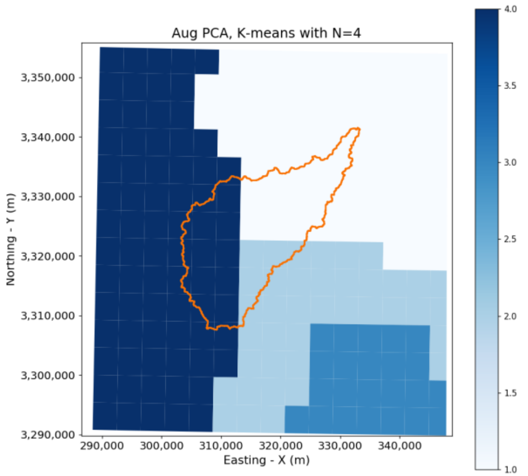

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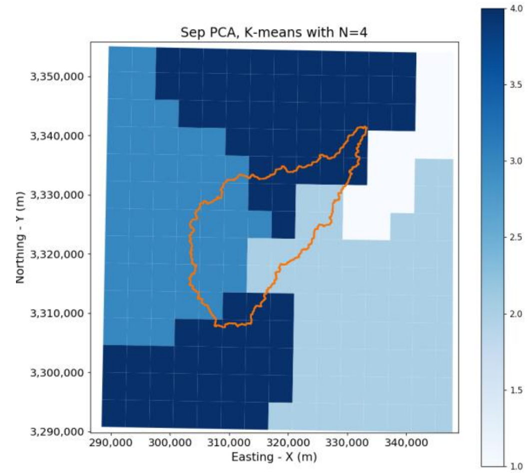

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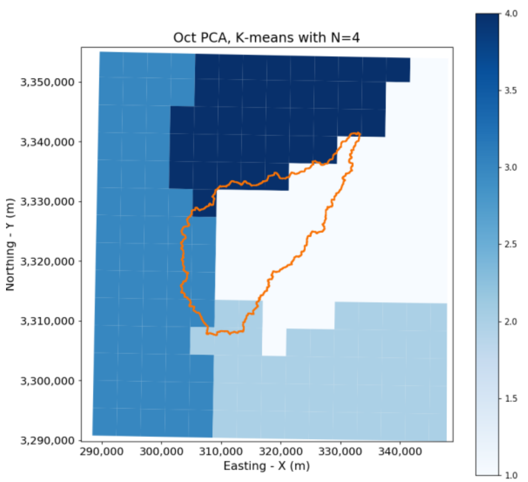

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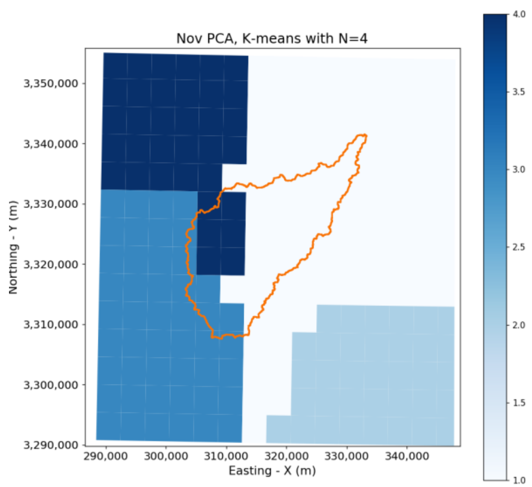

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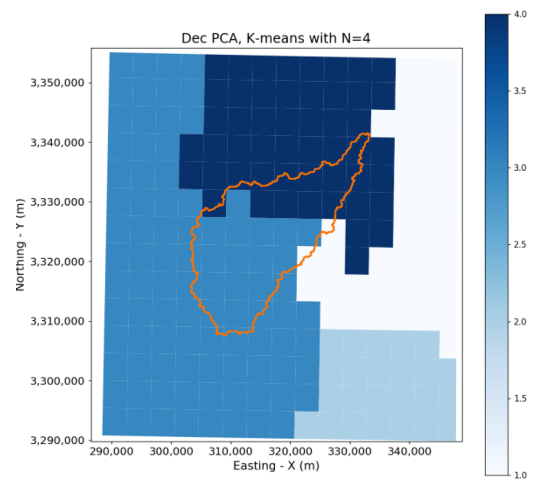

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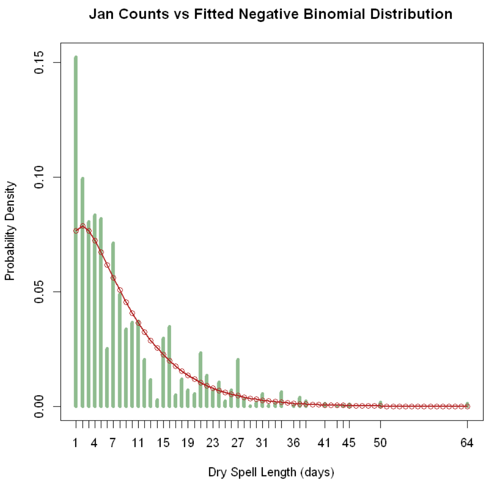
Weather Data – Consecutive Dry Days



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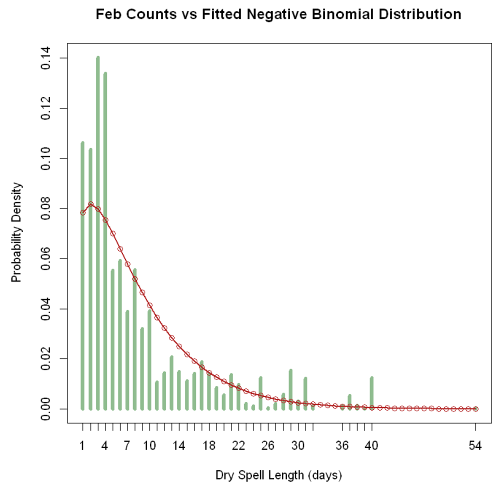

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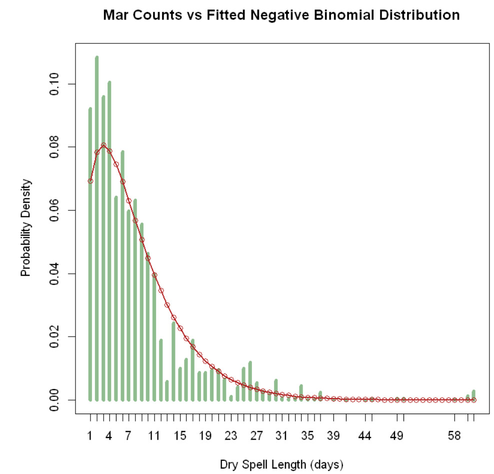

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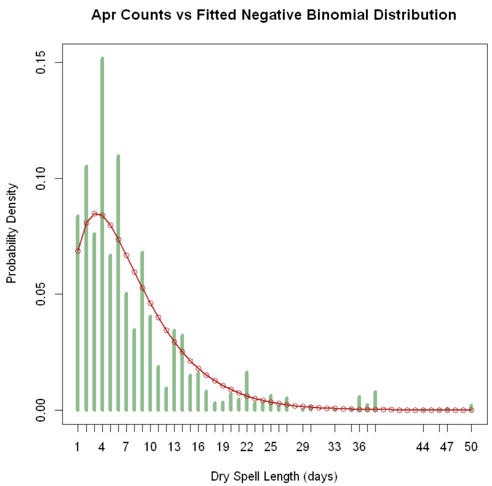

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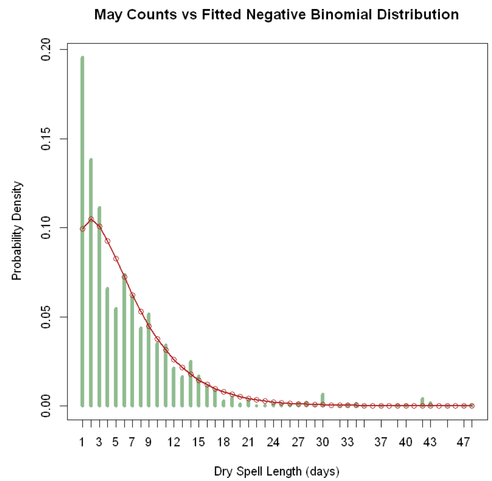

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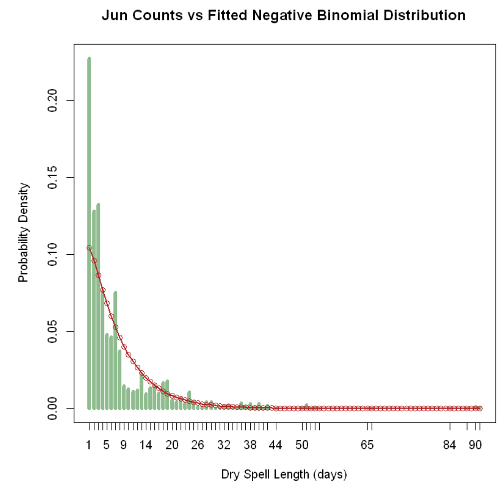

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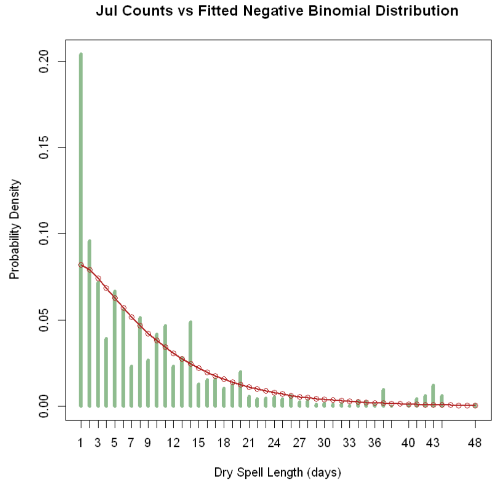

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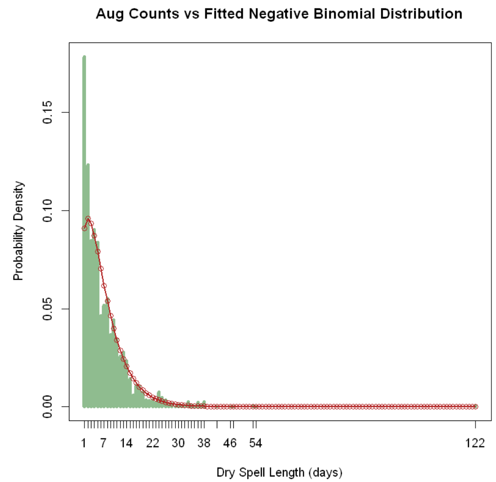

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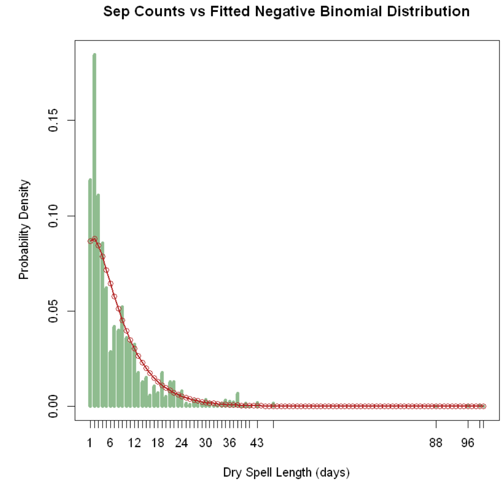

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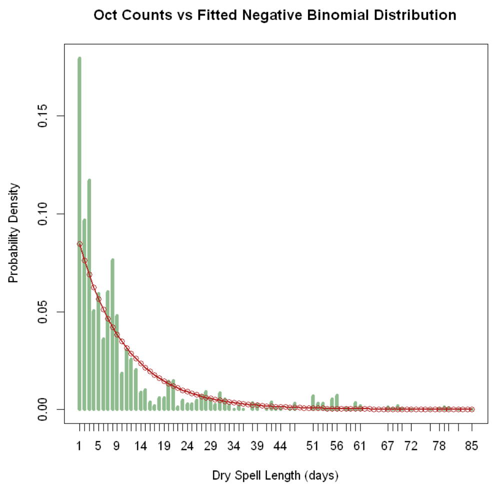

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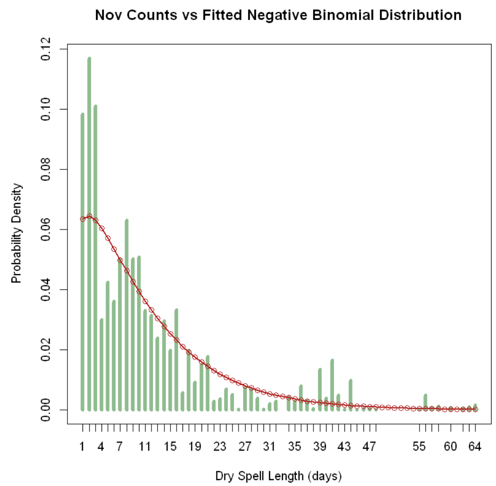

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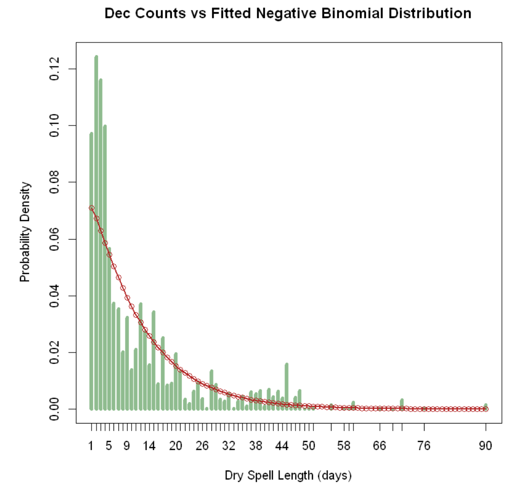

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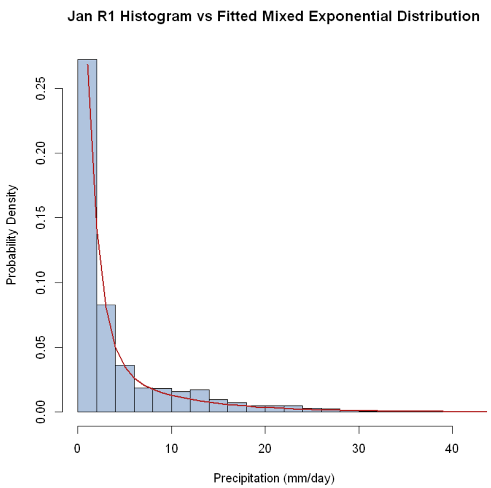
Weather Data – Daily Precipitation



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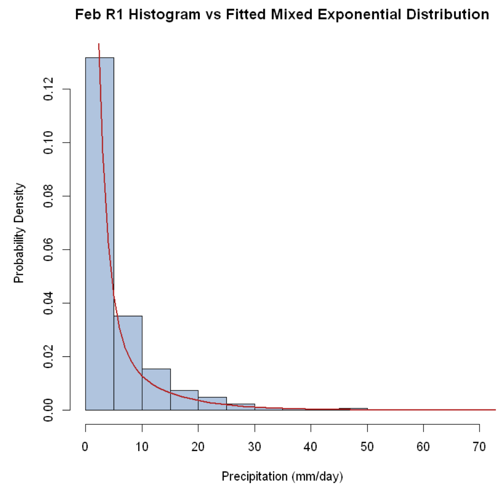

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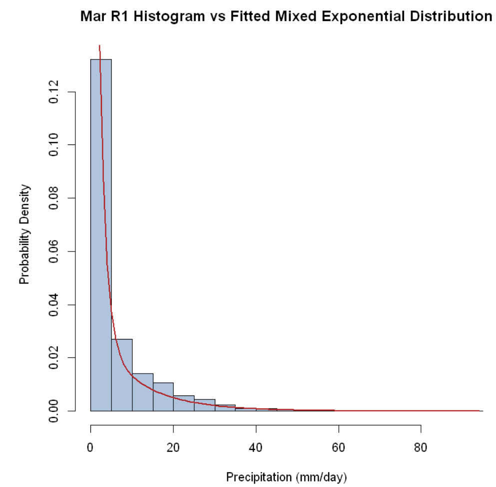

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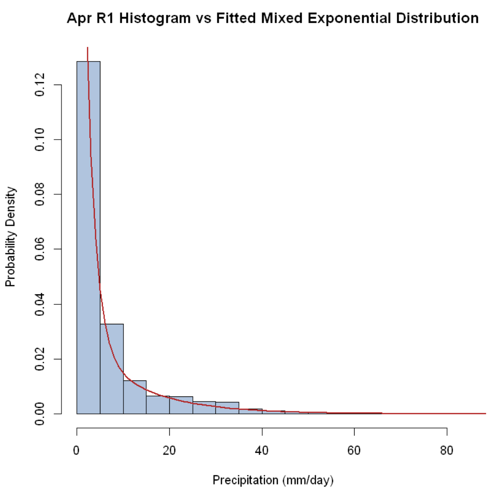

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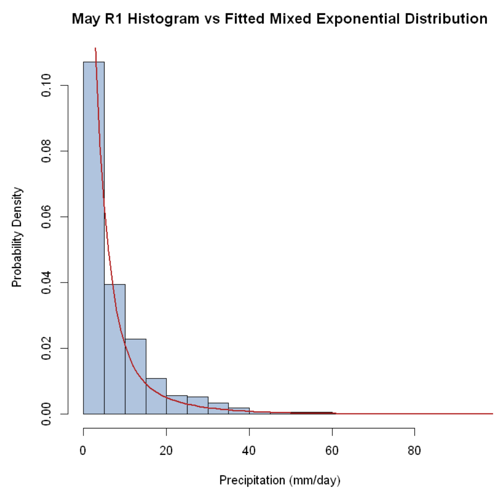

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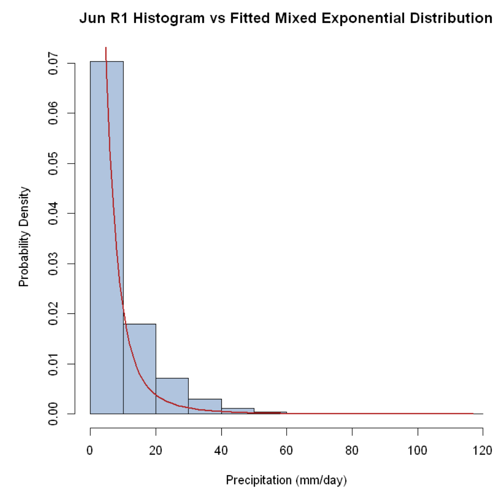

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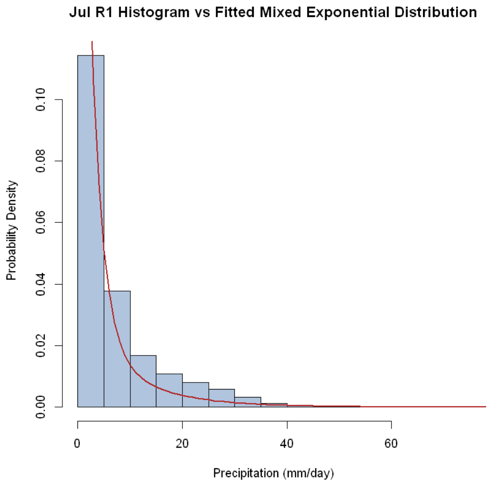

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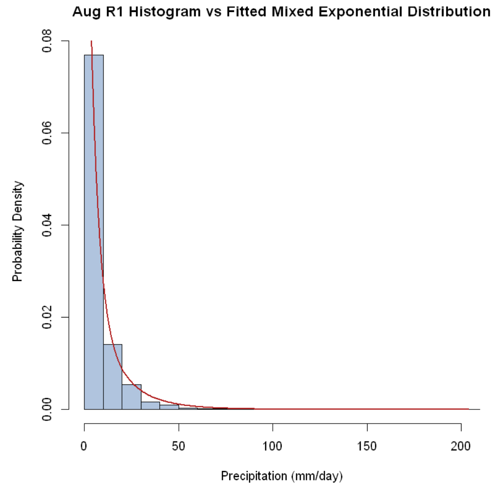

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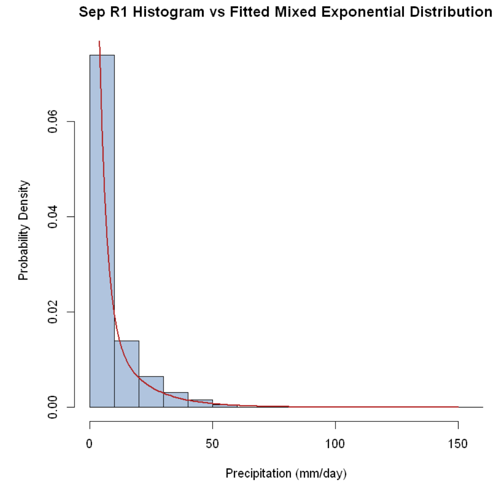

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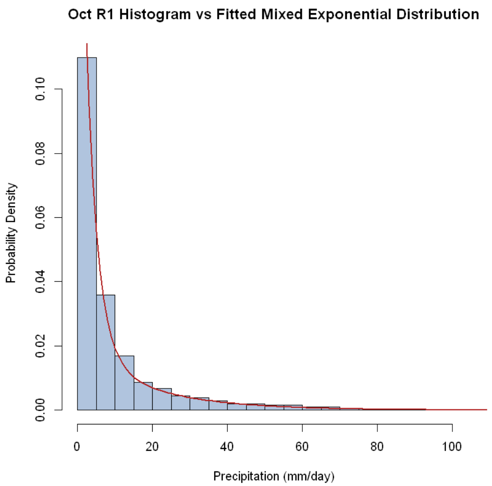

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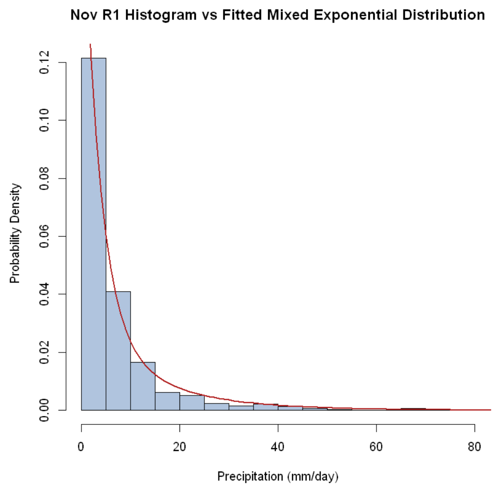

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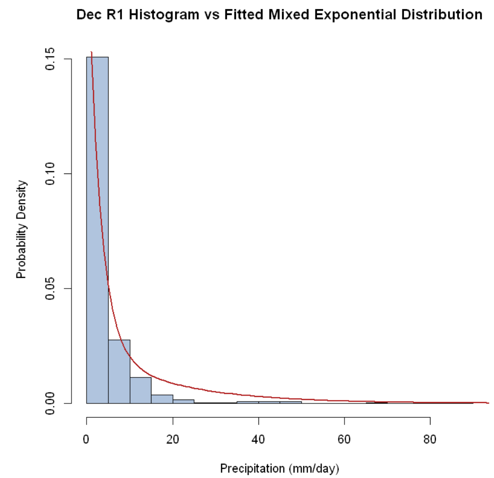

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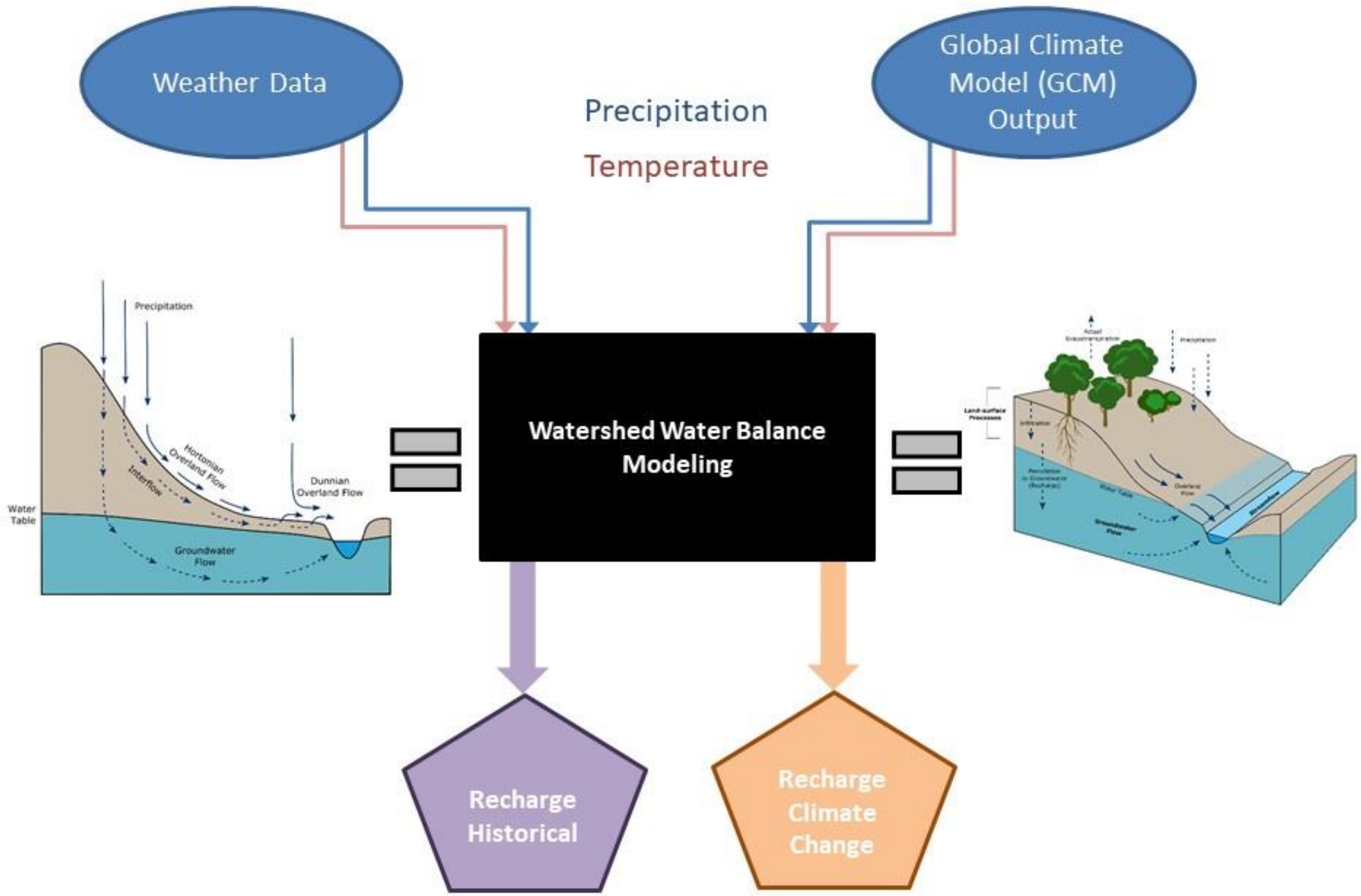
Quantifying Impacts to Recharge



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Climate Forecasts

- Coupled Model Intercomparison Project (CMIP) is a collaborative framework designed to improve knowledge of climate change. It was organized in 1995 by the World Climate Research Programme (WCRP).
  - CMIP is a standard experimental framework for studying the output of coupled atmosphere-ocean general circulation models (GCMs)

    [https://climatedataguide.ucar.edu/climate-model-evaluation/cmip-climate-model-intercomparison-project-overview]
- The current CMIP phase is Phase 6. Phase 5 is the most recently completed phase and so Phase 5 (CMIP5) has the most recent model results.
- Two goals of CMIP5 are:
  - evaluate how realistic the models are in simulating the recent past,
  - provide projections of future climate change in near term (out to about 2035) and long term (out to 2100 and beyond)

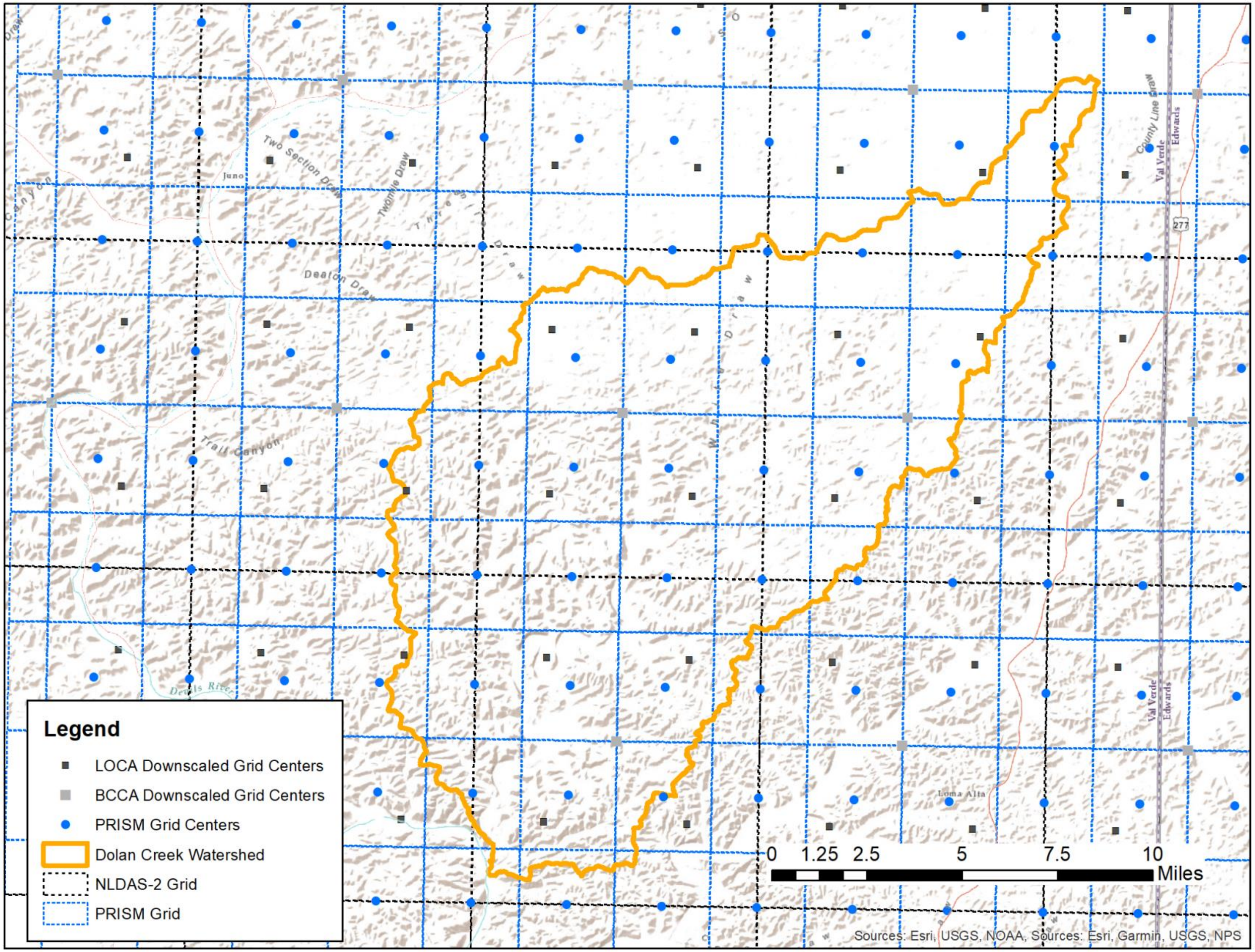
CMIP5

- The core projections involve simulation of climate using coupled atmosphere-ocean interaction models for a suite of Representative Concentration Pathways (RCPs). An RCP is a greenhouse gas concentration (not emissions) trajectory adopted by the IPCC for its fifth Assessment Report (AR5).
  - RCP 2.6: Radiative forcing stabilizes at ~2.6W/m^2 near 2100
  - RCP 4.5: Radiative forcing stabilizes at ~4.5W/m^2 after 2100
    - Considered the central or median scenario
  - RCP 6.5: Radiative forcing stabilizes at ~6.5W/m^2 after 2100
  - RCP 8.5: Radiative forcing reaches ~8.5W/m^2 near 2100

CMIP5 Downscaling

- Downscaled CMIP5 Climate and Hydrology Projections are available from the "Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections" archive at:
  - http://gdodcp.ucllnl.org/downscaled_cmip_projections
- Downscaling is required because the scale of global climate modeling is still too coarse to support local impacts assessment for many types of resources (e.g., hydrology in complex terrain, aquatic ecosystems, managed water resources, and other managed natural resource systems).
- Downscaled GCM output is available from more than 30 different models, 4 RCP scenarios, and 2 algorithms
  - 1) LOCA: Localized Constructed Analog
  - 2) BCCA: Bias Correction with Constructed Analogs

Downscaled Model Results



Work in Progress

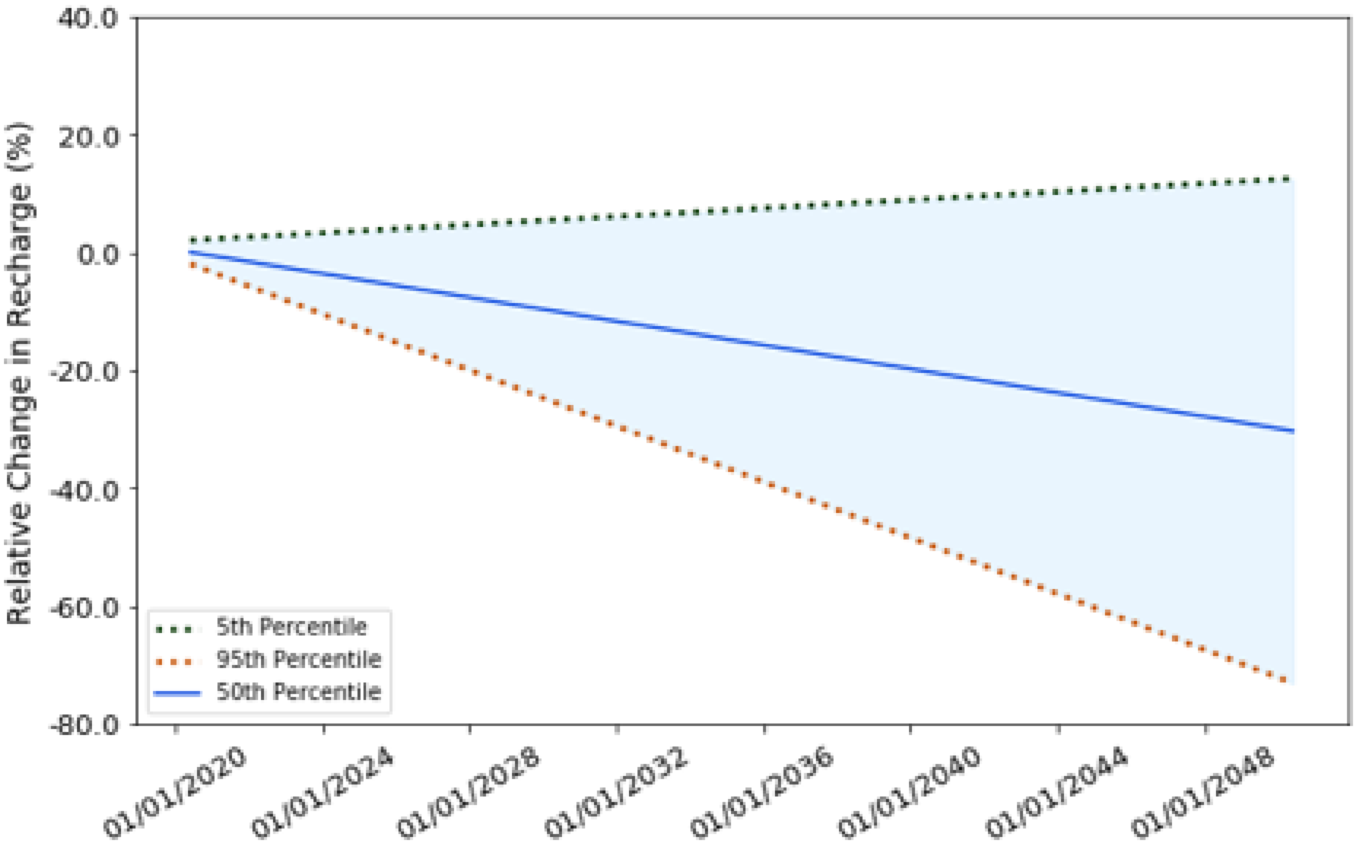
- Take downscaled GCM output and divide into 30-year comparison periods
  - 1980 – 2010: Base case or historical
  - 2011 – 2040: Forecast period 1
  - 2041 – 2070: Forecast period 2
  - 2071 – 2099: Forecast period 3
- For each climate period produce –
  - Monthly regionalization
  - Distributions of dry and wet spells by month
  - Distributions of daily precipitation depth by month
  - Seasonal regression relationships for temperatures versus wet or dry state by month

Next Steps

- Make WGs to use to run the "Black Box Model"
  - Historical data WG, created from PRISM data sets
  - WG for 2011 – 2040 which is the historical data WG with distributions modified with deltas, or relative changes, from GCM Forecast Period 1 relative to GCM Base Case
  - WG for 2041 – 2070 which is the historical data WG with distributions modified with deltas from GCM Forecast Period 2 relative to GCM Base Case
  - WG for 2071 – 2100 which is the historical data WG with distributions modified with deltas from GCM Forecast Period 3 relative to GCM Base Case

Parse Climate Change Impact

- Results: Probabilistic prediction for relative change in recharge given projected changes in average weather



Thank you

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