Building Resilience to a Changing Climate:
A Technical Workshop in Water Utility
Decision Support and Adaptation

A Practical Look at Using Climate Science, Locally

Julie Vano, Aspen Global Change Institute

Going Local

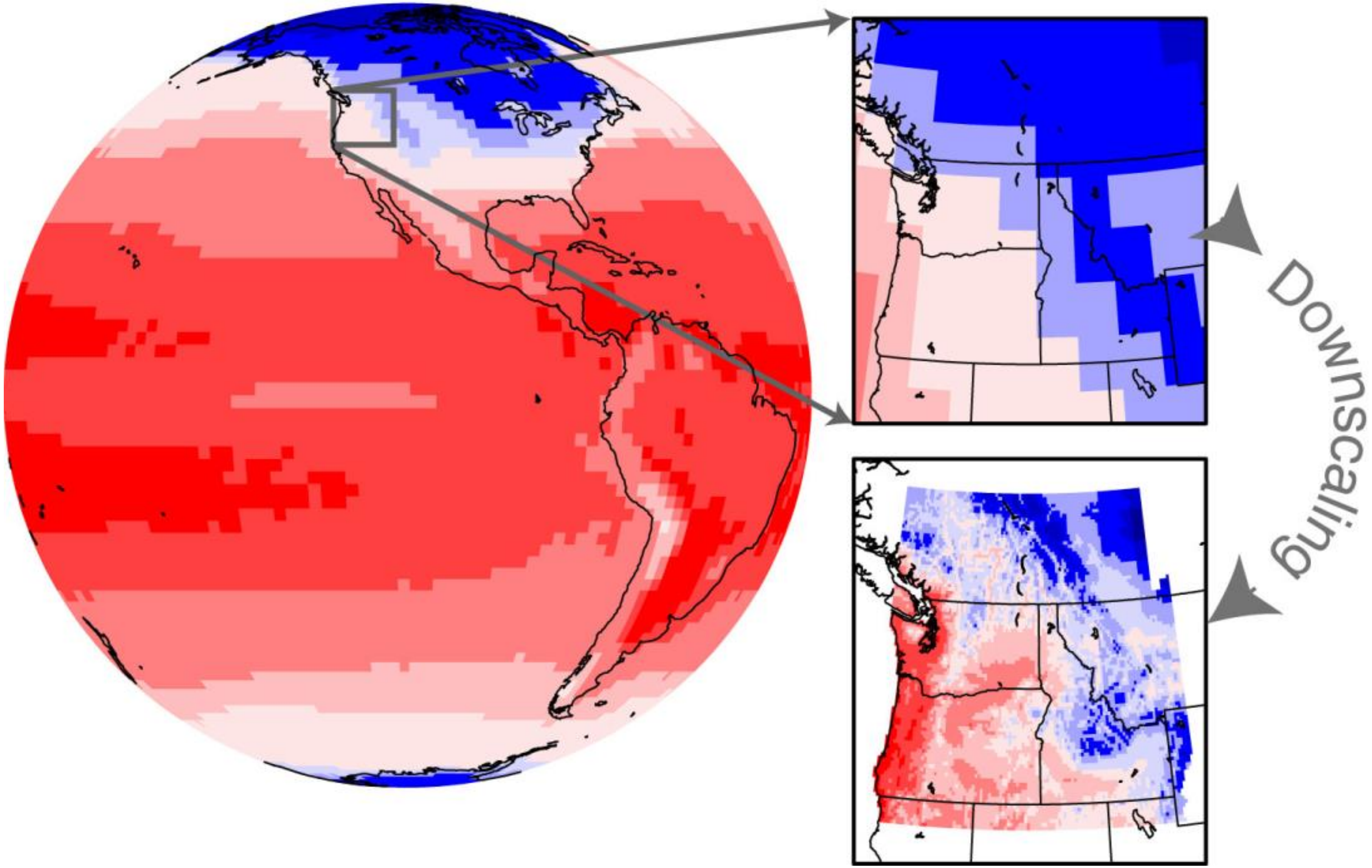


Figure courtesy of Climate Impacts Group

Many datasets, all different:

Dynamically-downscaled
climate projections:
PNNL, UW, UCLA

Precipitation

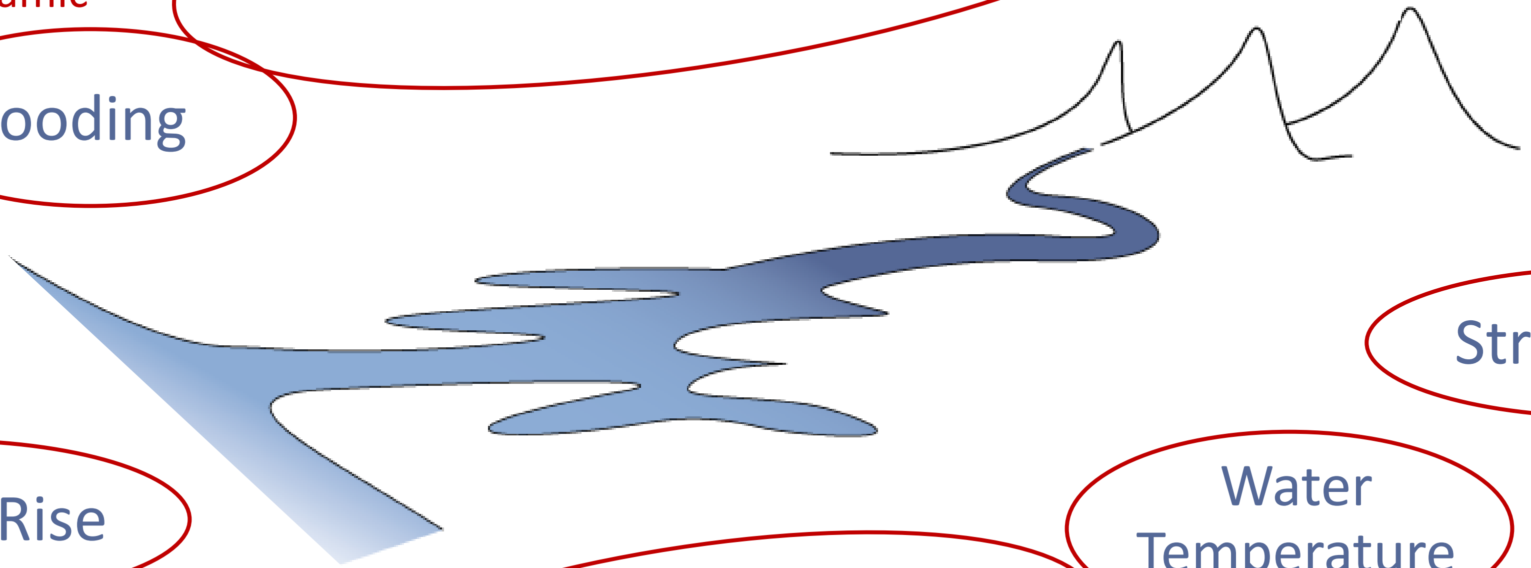
Evapotranspiration

Glaciers

Snowpack

Hydraulic/Hydrodynamic
Modeling:
FloodFactor
SSM
PS-CoSMoS

Flooding



Wildfire

Streamflow

Hydrologic model projections
RMJOC-II (coarse, comprehensive)
DHSVM, VELMA (fine, localized)

Water
Temperature

Sea Level Rise

Miller et al. 2018
NOAA 2022

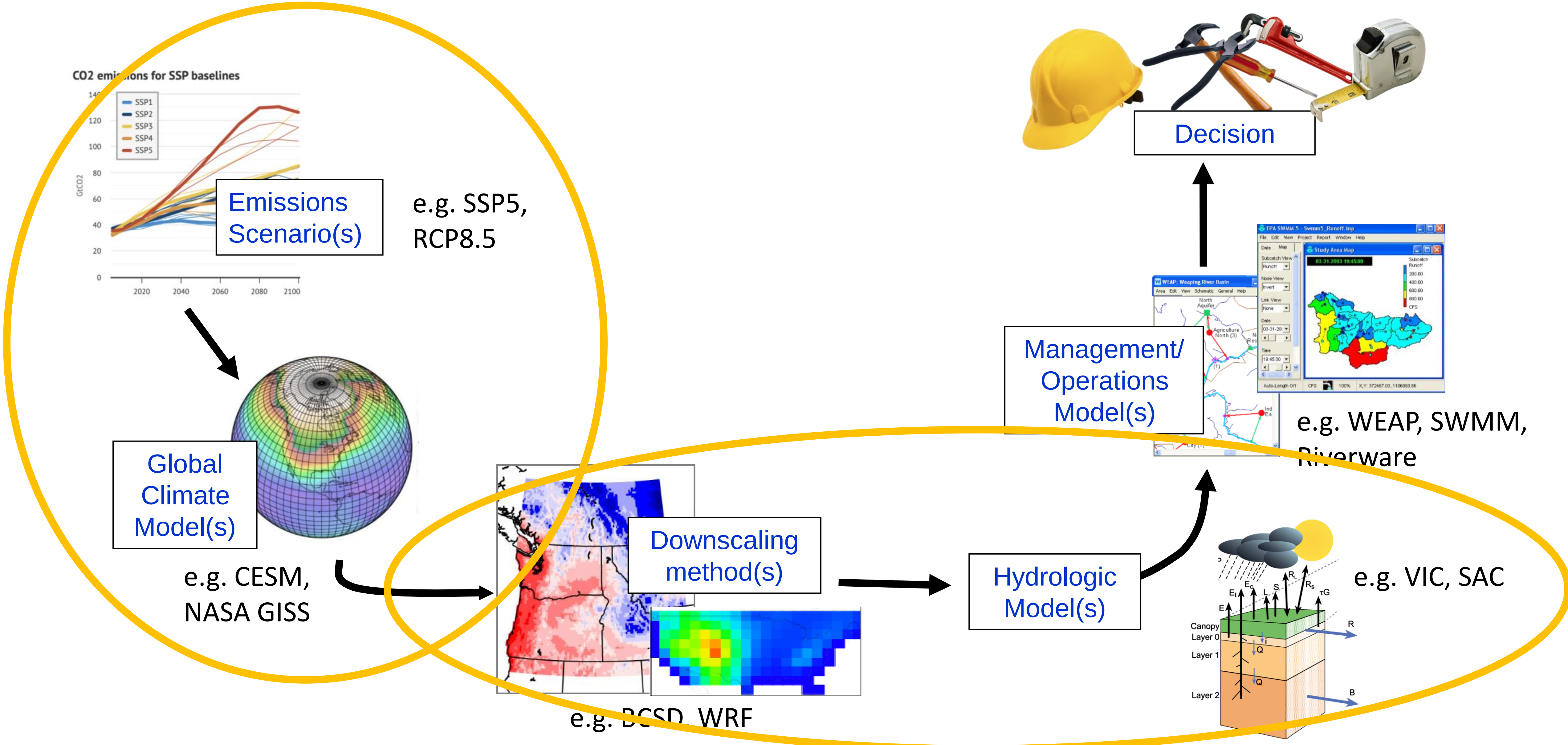
Sediment

Groundwater

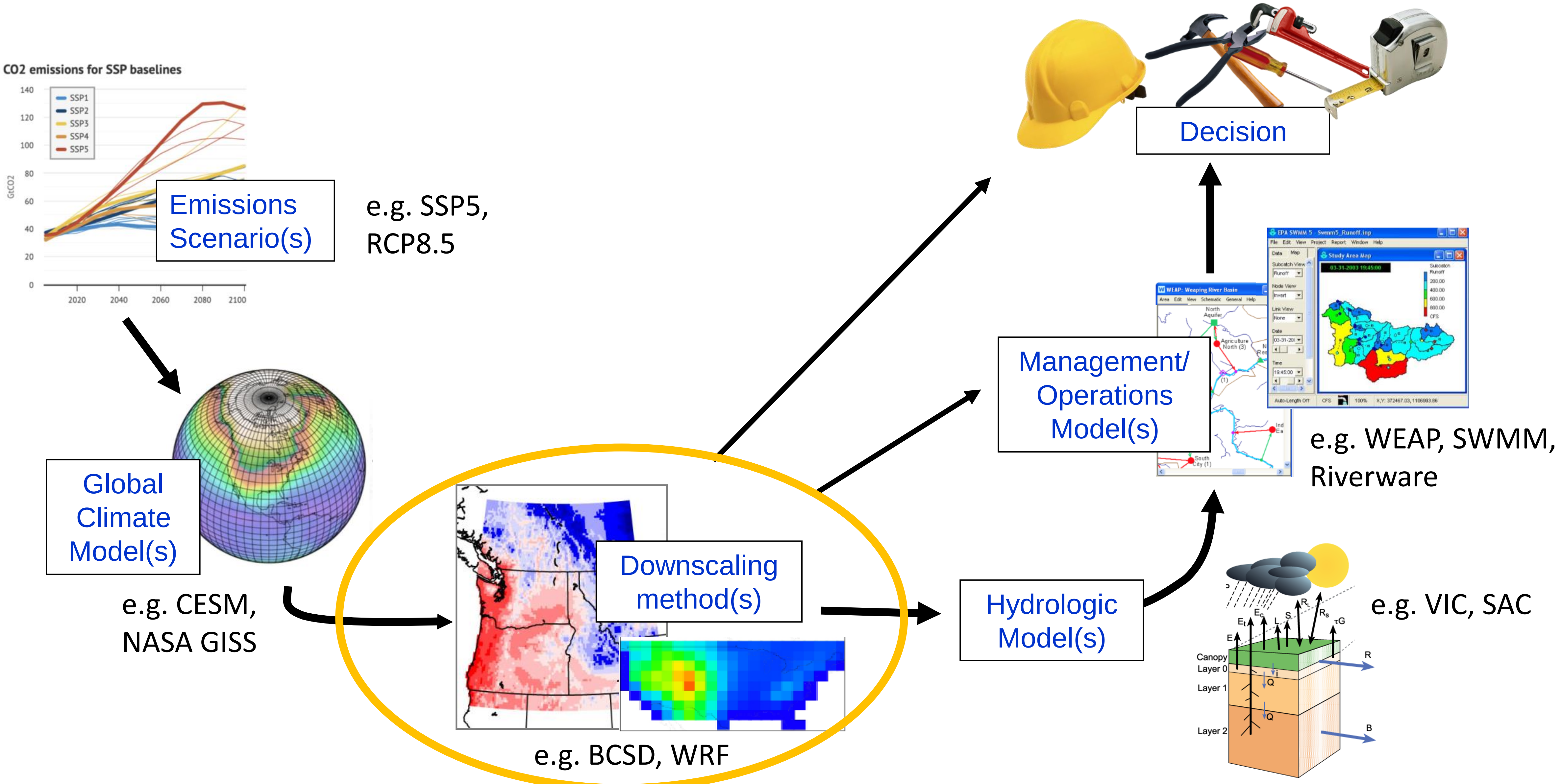
NoRWeST: August average
Siegel et al. (2023): Daily

Very little information

Classic Top-Down Modeling Approach



Classic Top-Down Modeling Approach



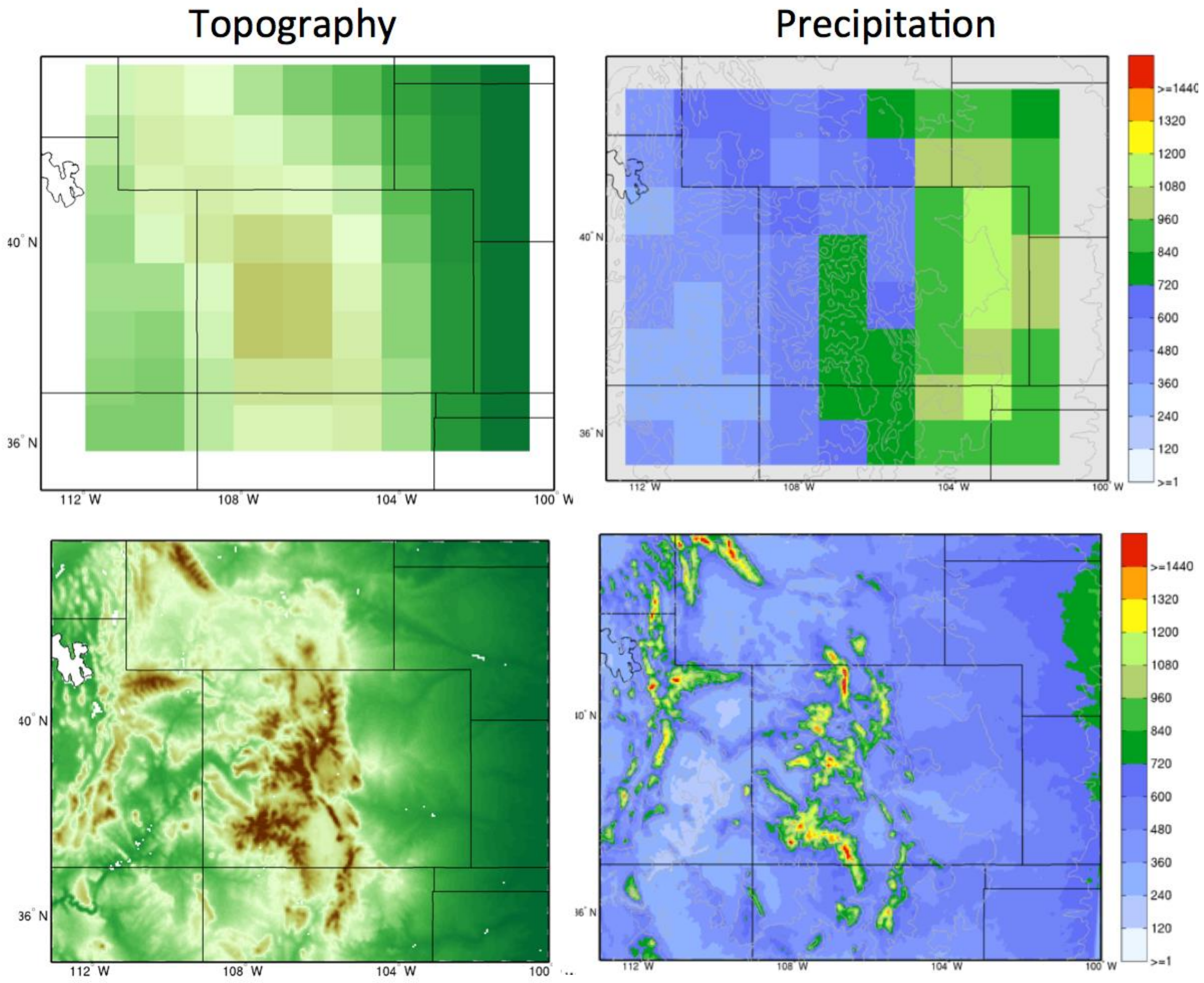
Why Downscale?

Global models

- Resolution does not capture topography
- Inaccurate in simulating orographic precipitation, temperature gradients, cloud, snow, etc.

Benefits of downscaling

- Local-scale insights
- Fine-scale, high-temporal inputs (e.g., precip, temp) for impacts models
- Can correct certain biases of global models

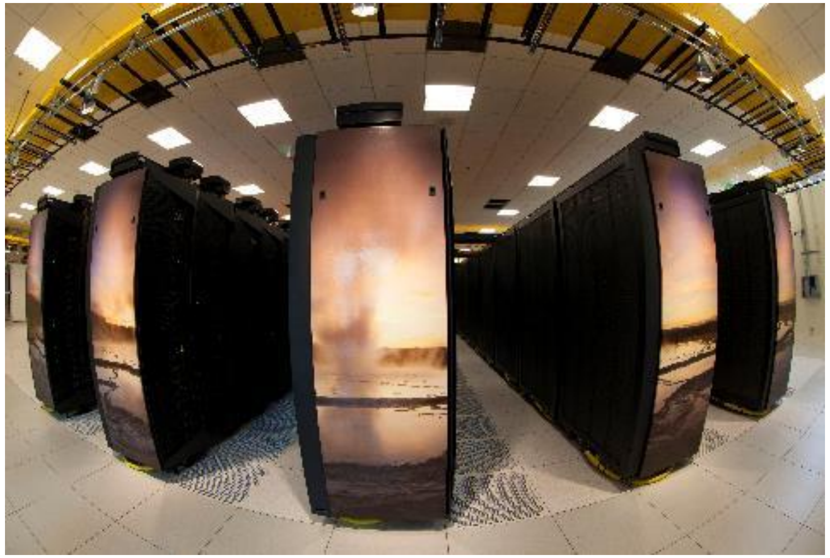


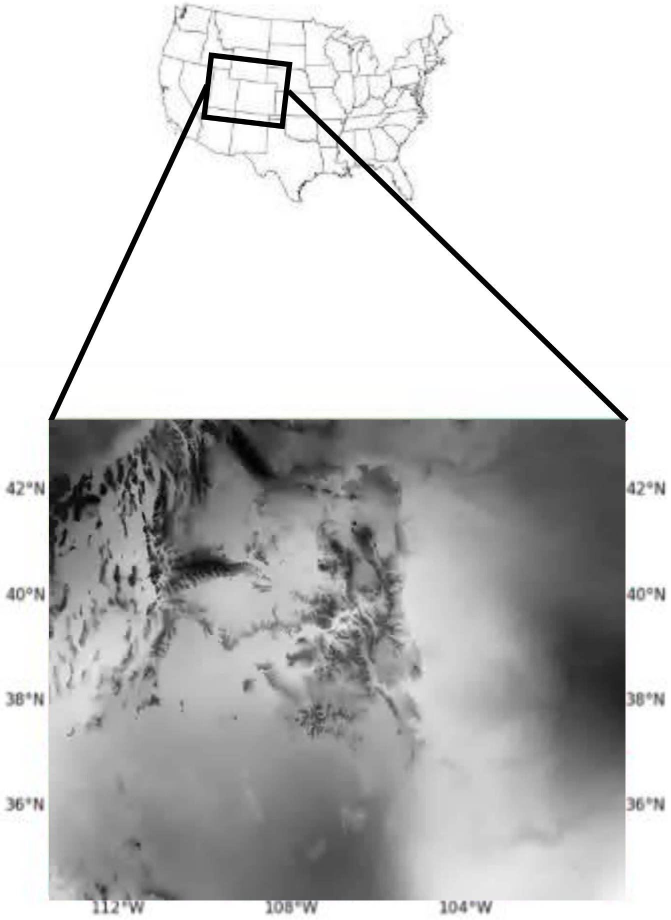
Types of Downscaling: Dynamical

Uses a high-resolution regional climate model to simulate local dynamics over the area of interest

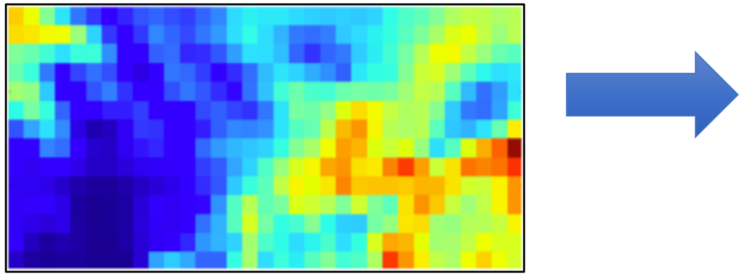
Global model output applied along boundaries and as initial conditions

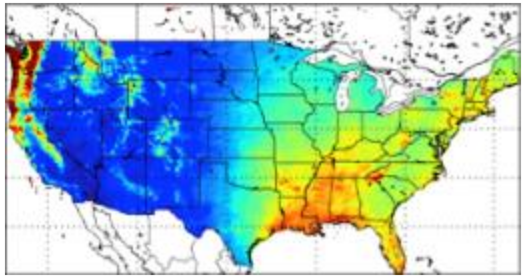
Computationally expensive, time and supercomputers (usually) required





Types of Downscaling: Statistical





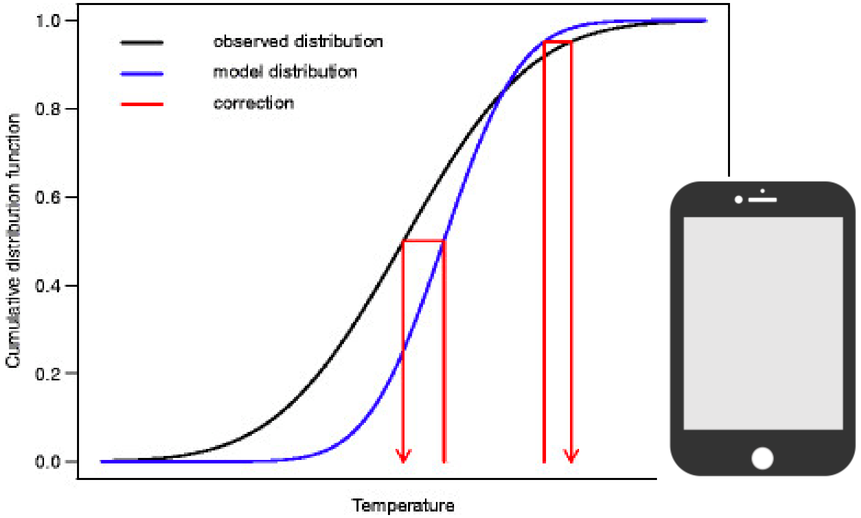
Uses statistical relationships that relate coarse to fine resolution from historical record

Stationary statistical relationships then applied to future global model output

Output usually for subset variables (precipitation, temperature)

Computationally cheap, quick and can be done anywhere

Reproduce historical data well



Example: Bias correction with spatial disaggregation (BCSD)

Tradeoffs Between Downscaling Approaches

Dynamical

Pros

- **Represents physical processes**
- No stationarity assumptions
- Physically consistent across variables

Cons

- **Computationally expensive**
- Limited datasets
- Introduces need for additional ensembles
- Produces signals that still must analyzed for credibility

Statistical

Pros

- **Computationally tractable for large global model ensembles**
- Large high-resolution data sets publicly available
- Consistent with observations

Cons

- **May not represent climate change signal correctly** (often is effectively just interpolated GCM signal)
- Statistical nature often introduces artifacts

A Continuum of Downscaling Options

increasing physical representation

Dynamical downscaling using state-of-the-art RCMs

e.g., RSM-ROMS, Water Research and Forecasting (WRF) model

- "Hybrid" (dynamical + statistical) downscaling
  e.g., build statistical emulator using limited set of dynamical runs
- Physically-based "quasi-dynamical" atmospheric models
  e.g., Intermediate Complexity Atmospheric Research model (ICAR)
- Statistical downscaling based on GCM dynamics (wind, humidity, stability, etc.) e.g., regression-based, analog, pattern scaling, En-GARD
- Methods to relate downscaled fields to synoptic scale atmospheric predictors e.g., self-organized maps, weather typing

Statistical downscaling based on rescaling GCM outputs

e.g., BCSD, BCSA, LOCA, BCCA, linear regression, and more

Questions to help determine most appropriate downscaling techniques

Where is it?

How large is the area of interest?

What is the impact of interest?

When in the future?

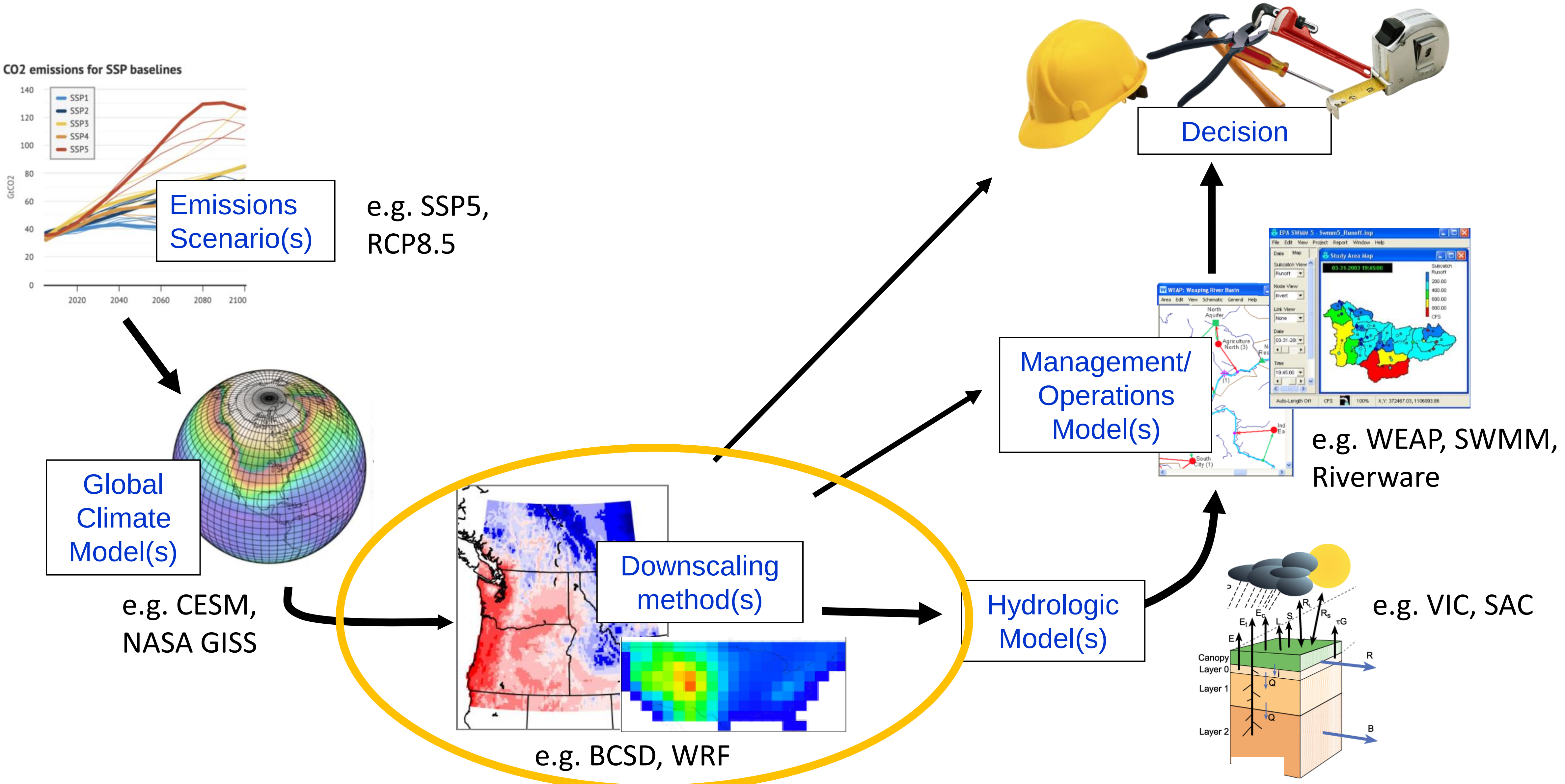
Does the sequencing of weather events matter?

What type of climate change uncertainty is important?

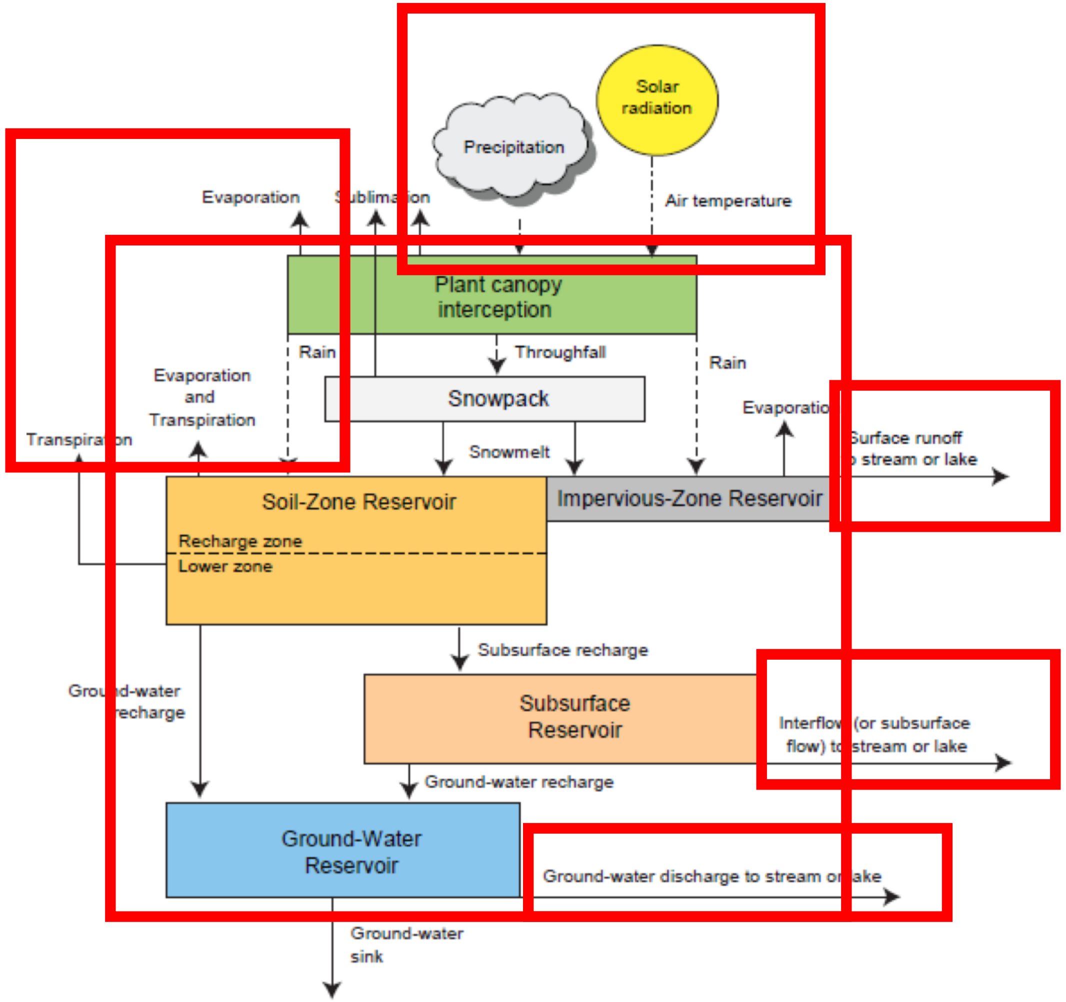
What is available?

Source: J. Vano, Dos and Don’ts

Classic Top-Down Modeling Approach



Why Use Hydrologic Models?



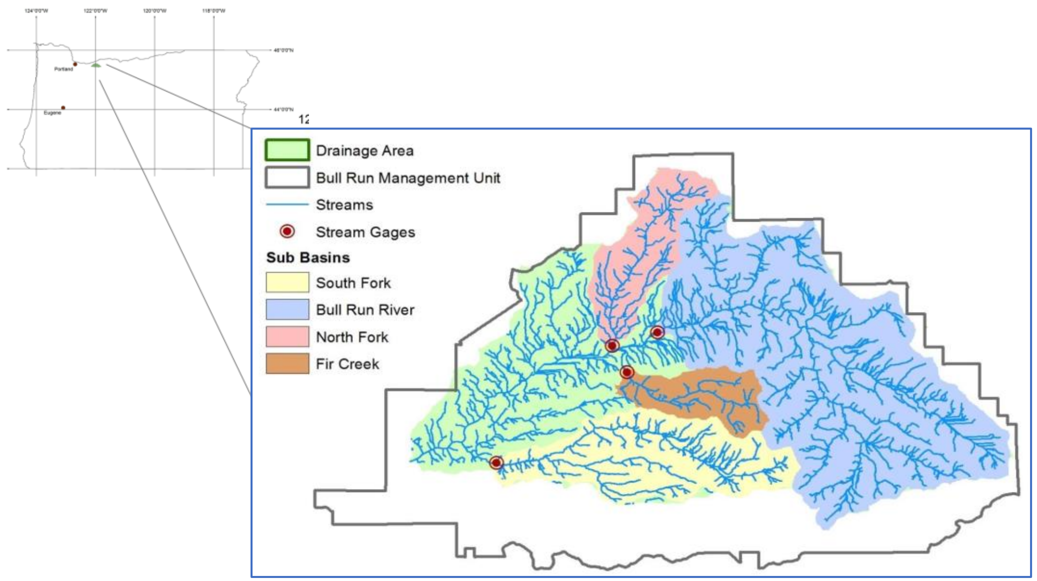
We have: precipitation, temperature, other atmospheric values

We want: streamflow (highs, lows), water demand from vegetation, water temperature

Hydrology models represent energy and water fluxes in watersheds, encapsulate our best understanding

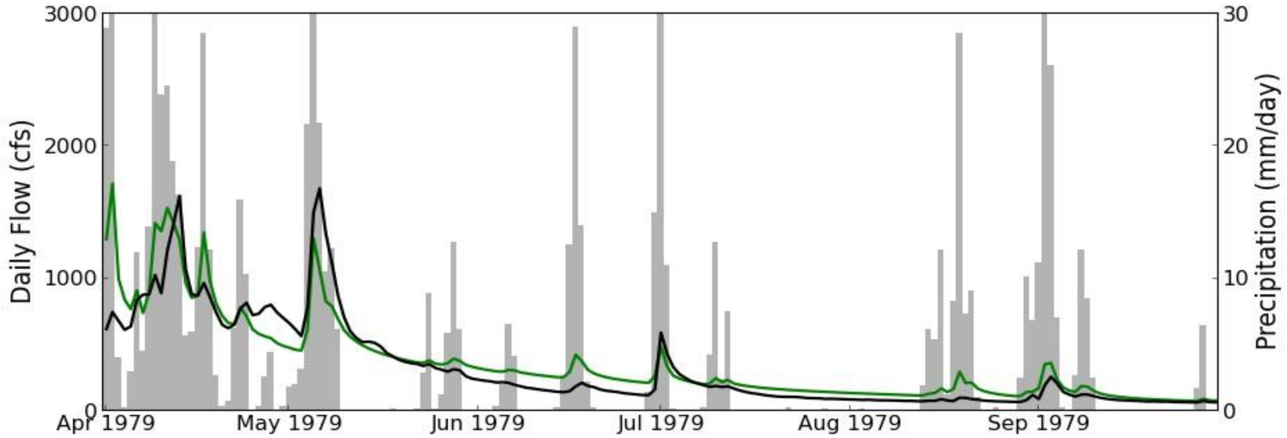
Fill gaps since measurements unavailable in most places

Benefits of Hydrologic Models



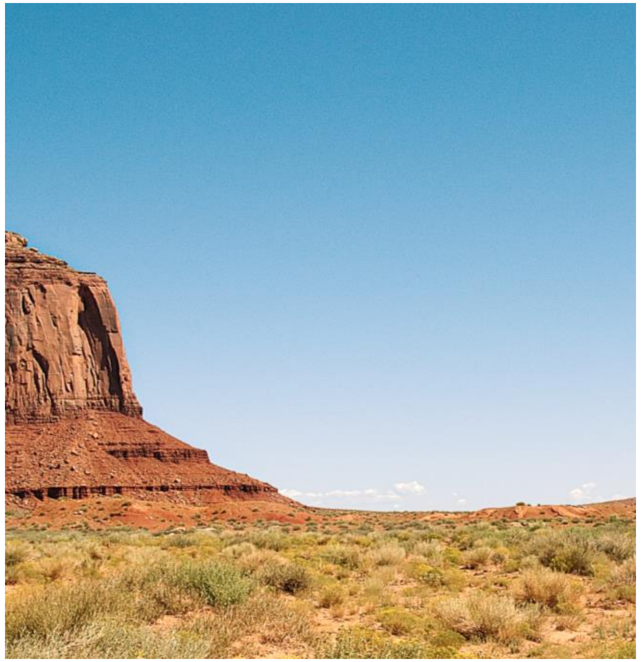
Example: Portland Water Bureau

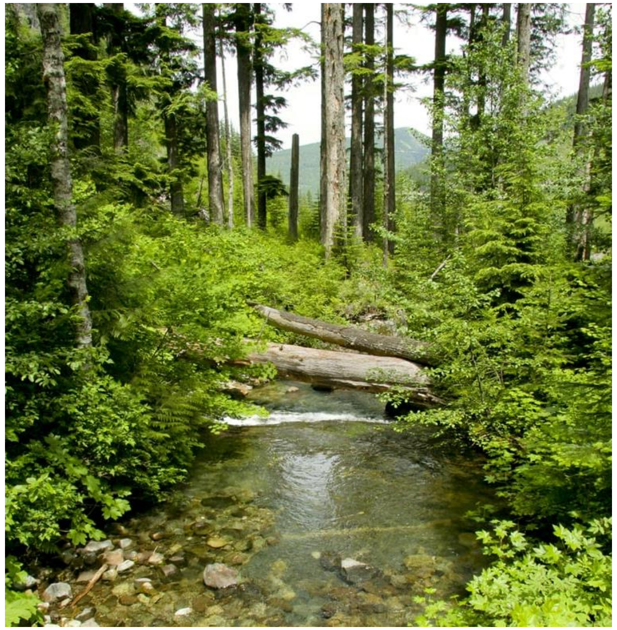
- Values from global models not helpful
- Worked with University of Washington to select and set up in-house hydrologic model
- Model helps understand how streamflow changes affect future supply conditions
- Included in Supply System Master Plan and more!



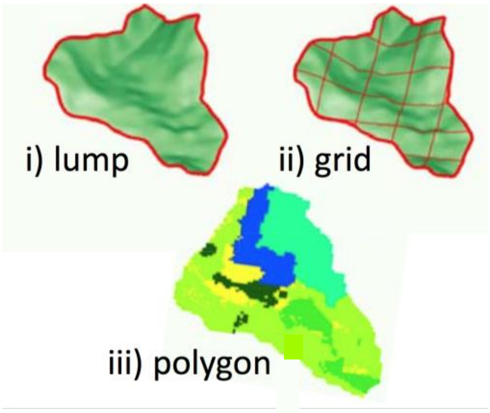
Cautions of Hydrologic Models

- Models built to represent many landscapes, processes, spatial configurations+
- May miss key elements
  - Groundwater interactions
  - Salt-water intrusion
- Important to be a savvy user



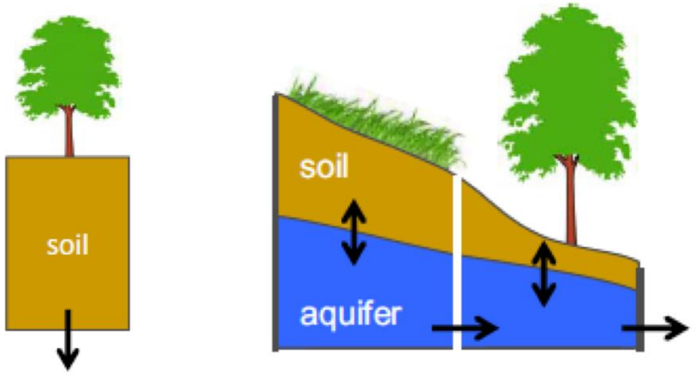


Hydrologic Modeling Spatial Structures



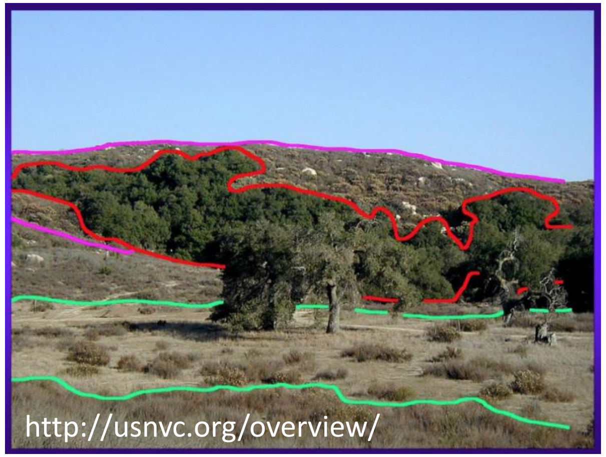
Lumped, gridded or hydrologically similar areas

Figures from Clark et al., WRR, 2015

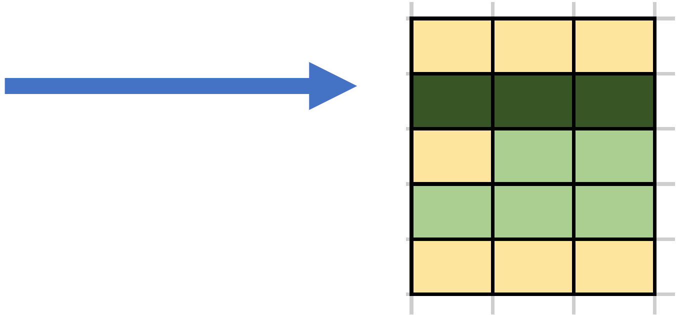


Connections between soil and aquifer

Hydrological Modeling Parameters

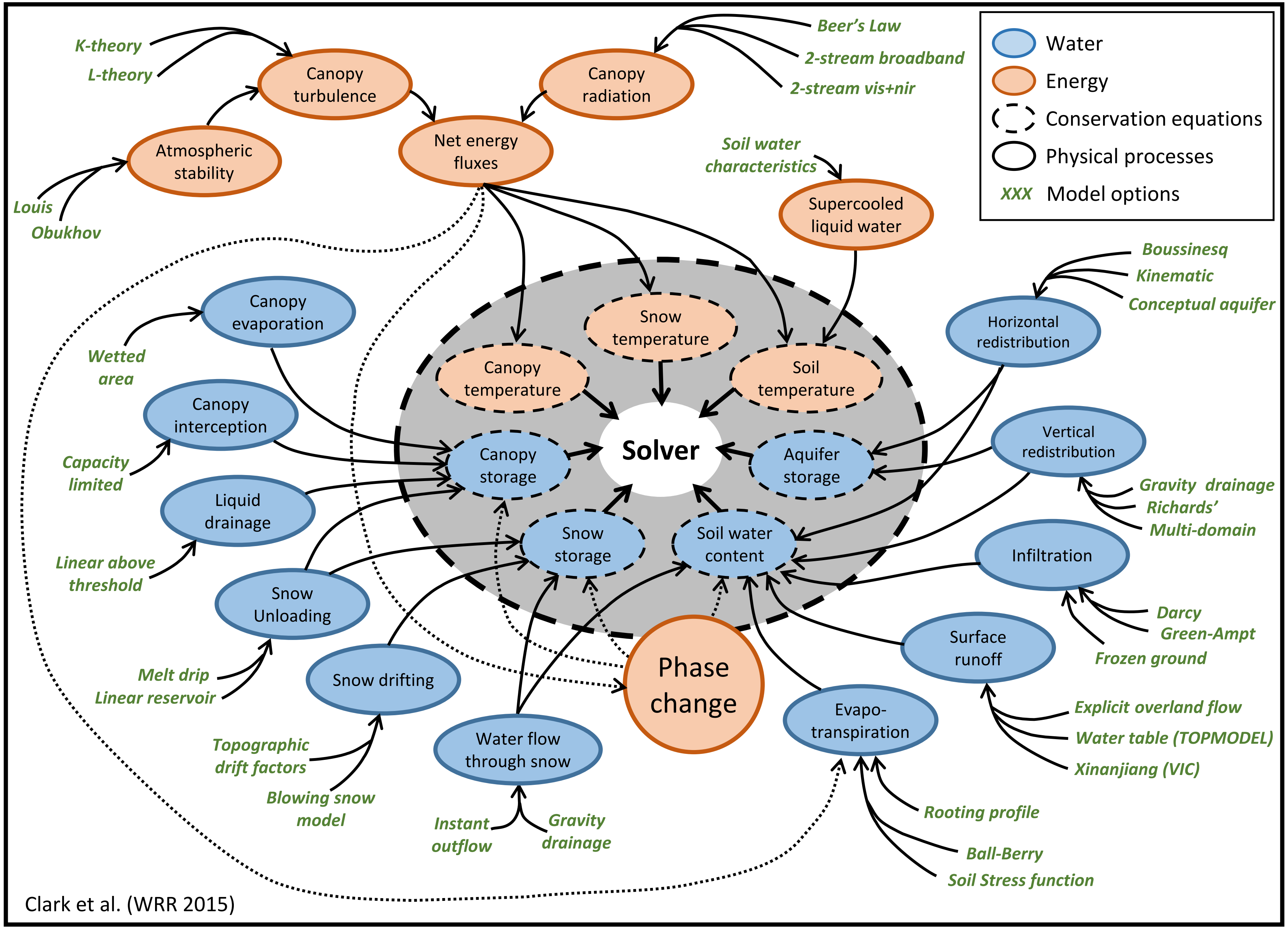


Vegetation, Soil type, …

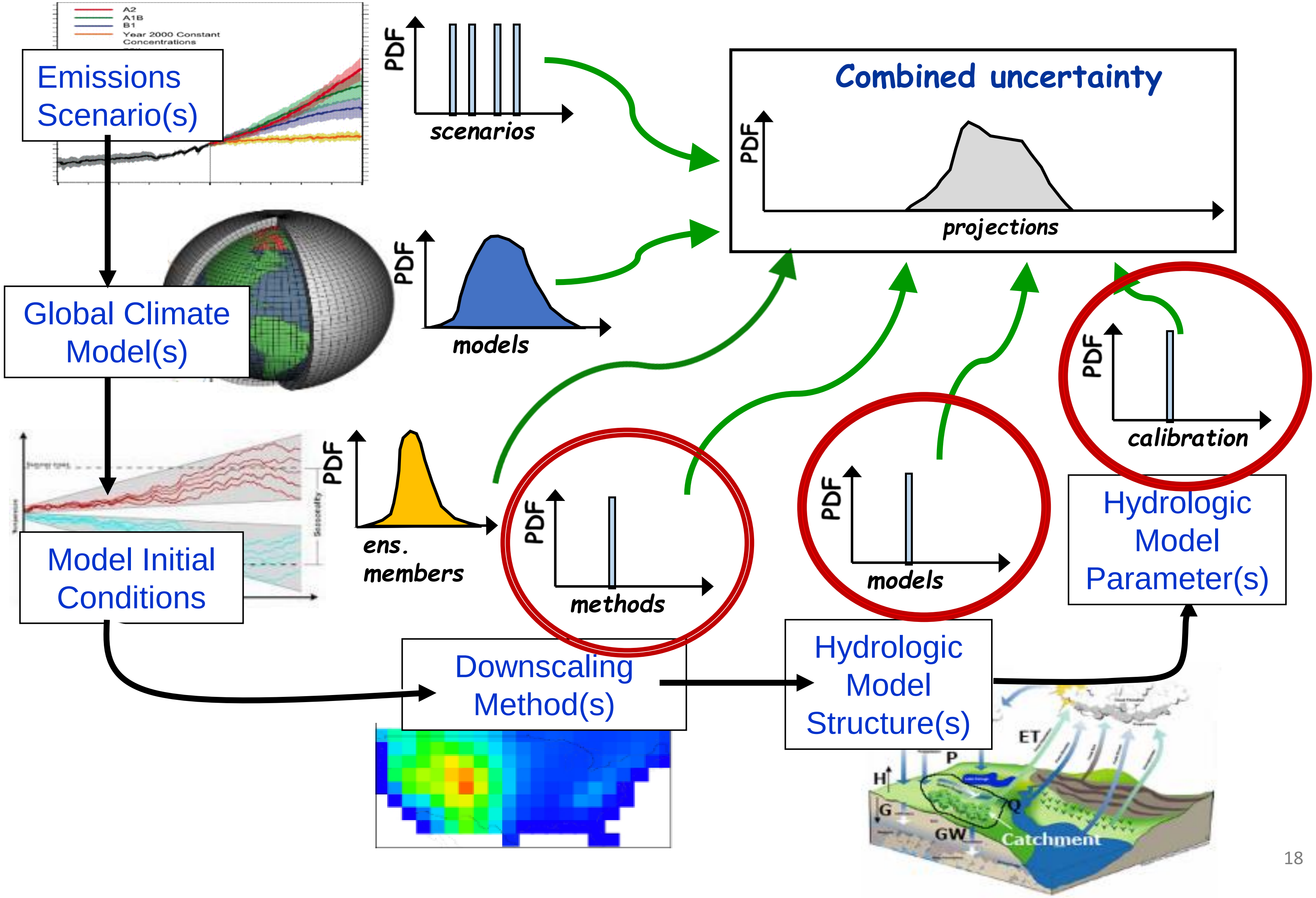


Hydrologic Modeling Processes

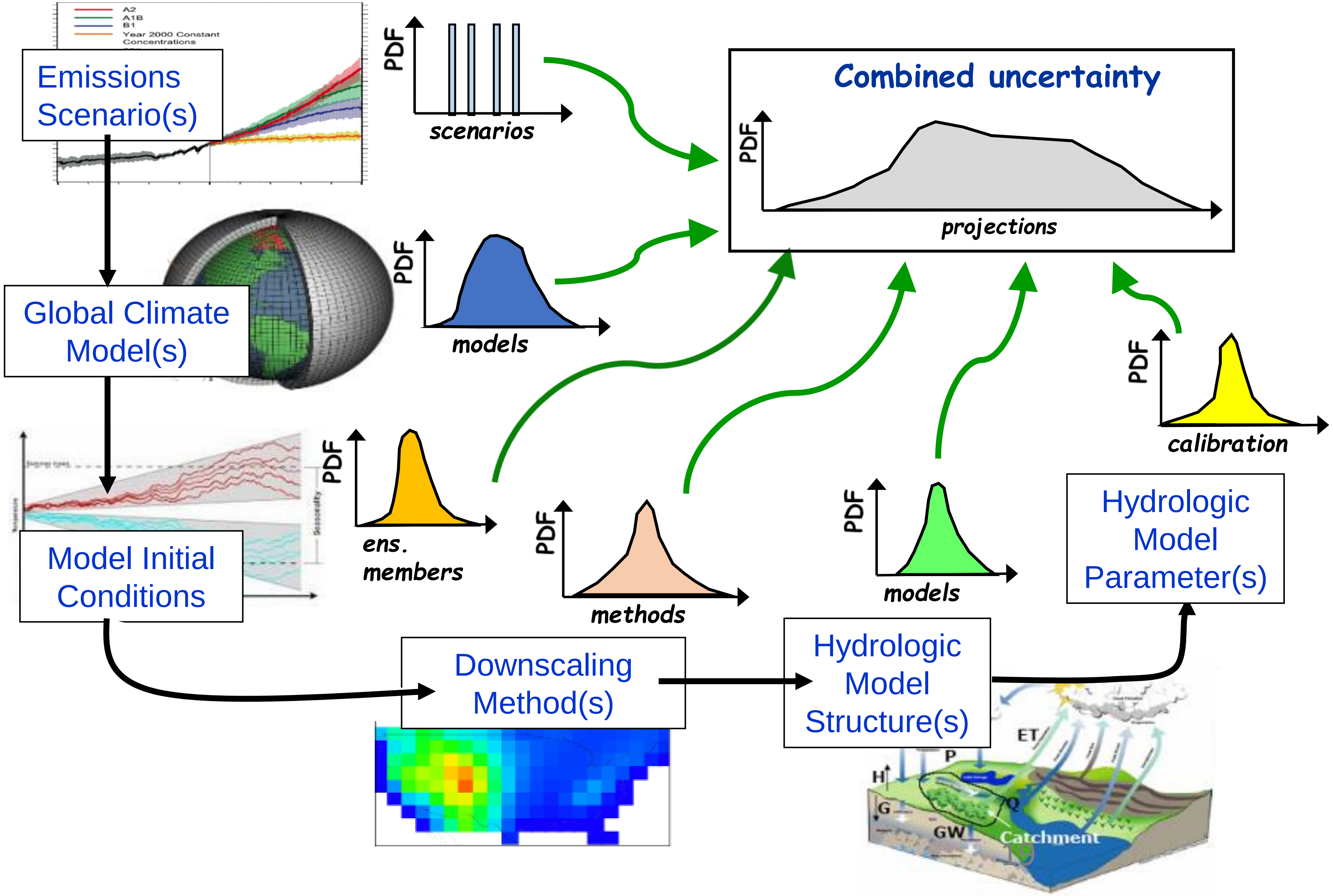
Looking under the hood…



Revealing Uncertainties



Revealing Uncertainties



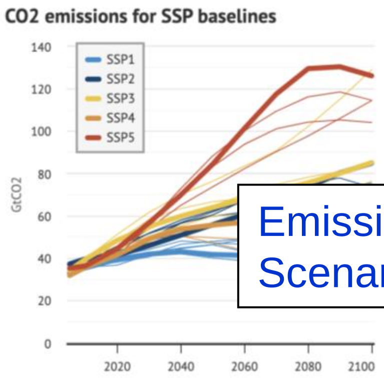
STRETCH BREAK

Ask your neighbor about downscaling…

or hydrologic modeling…

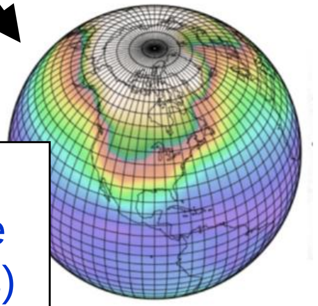
or your favorite type of bagel…

Classic Top-Down Modeling Approach



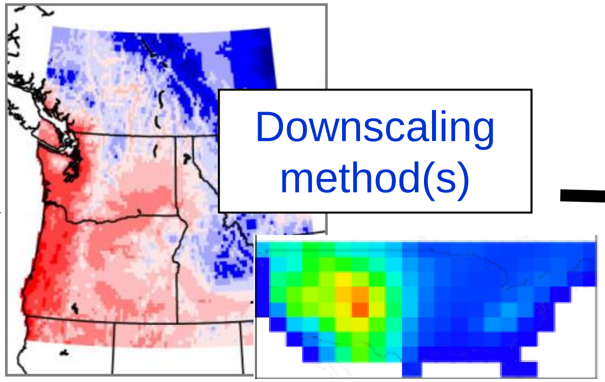
Emissions Scenario(s)

e.g. SSP5, RCP8.5



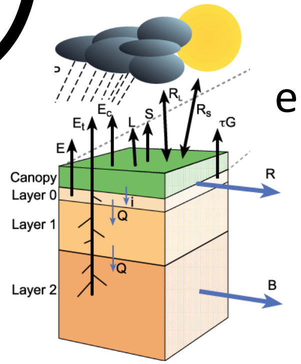
Global Climate Model(s)

e.g. CESM, NASA GISS



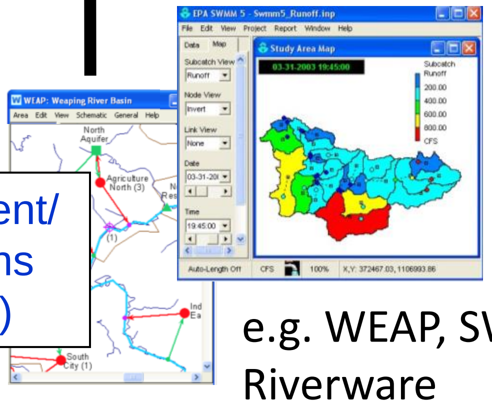
Downscaling method(s)

e.g. BCSD, WRF



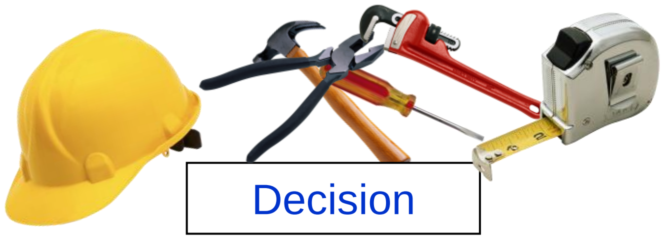
Hydrologic Model(s)

e.g. VIC, SAC



Management/ Operations Model(s)

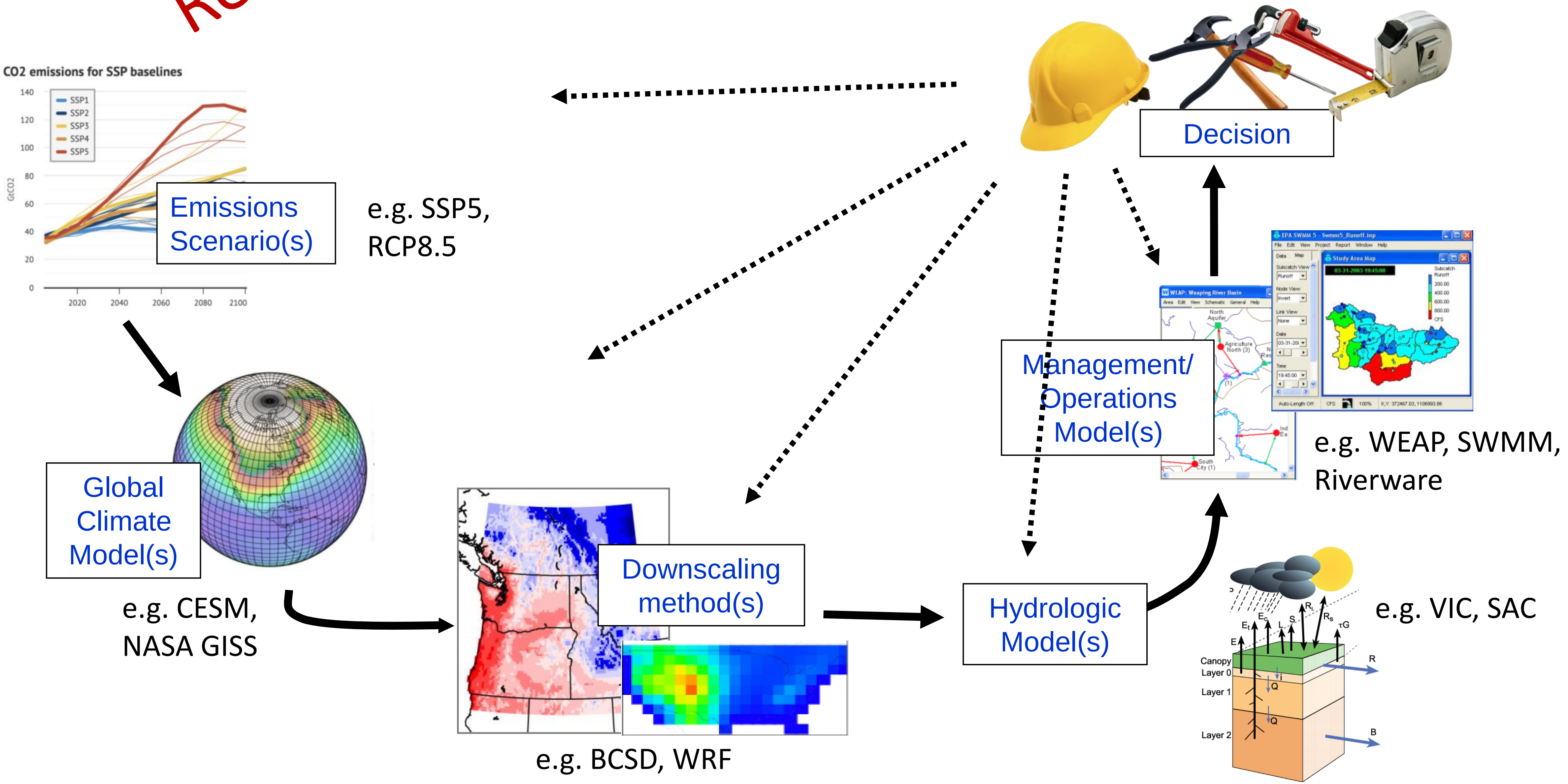
e.g. WEAP, SWMM, Riverware



Decision

Classic Top-Down Modeling Approach

Revised



Before you jump in.... clearly articulate

- What is your endgame? What question(s) do you want to answer? (e.g., what variables, levels of confidence)
- How will you get there
    - Method – simple or sophisticated
    - Data – type, scale, magnitude of change, level of uncertainty
    - Tools – current or new
- How it be useful
- How you will integrate new science
- Messaging – internal, external

Source: L. Kaatz, Denver Water

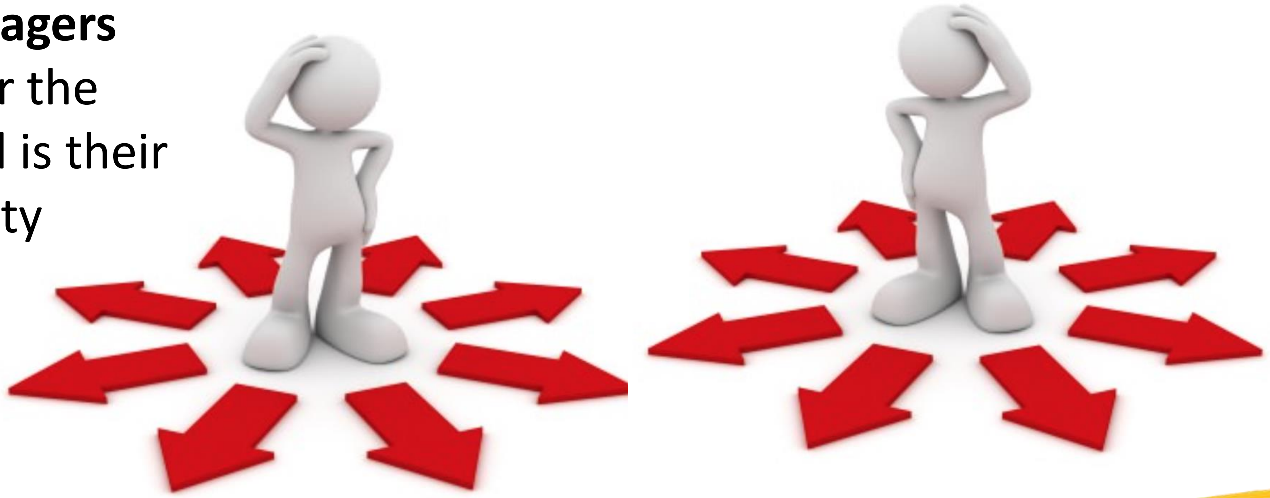
Guiding Principles

I. **It is important to evaluate climate risk**

II. **Models can be helpful tools, if used appropriately**

III. **Uncertainty is everyone's responsibility**

Water managers planning for the unexpected is their responsibility

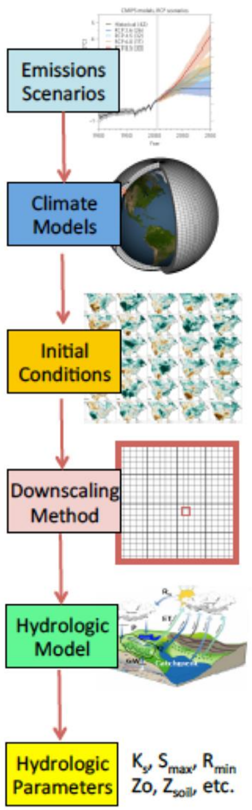


Scientists being clear about uncertainties and placing them in context is their responsibility

Source: J. Vano, Dos and Don'ts

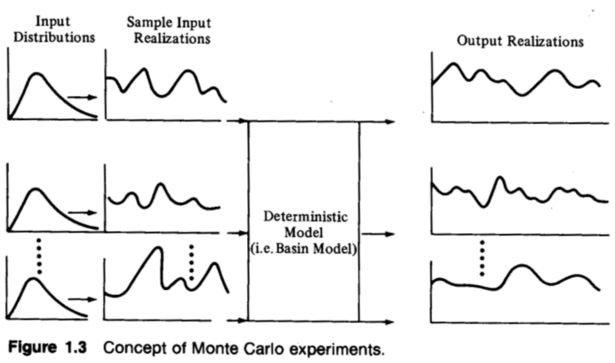
Do Be Aware of Multiple Ways to Evaluate Future Changes

Scenario studies



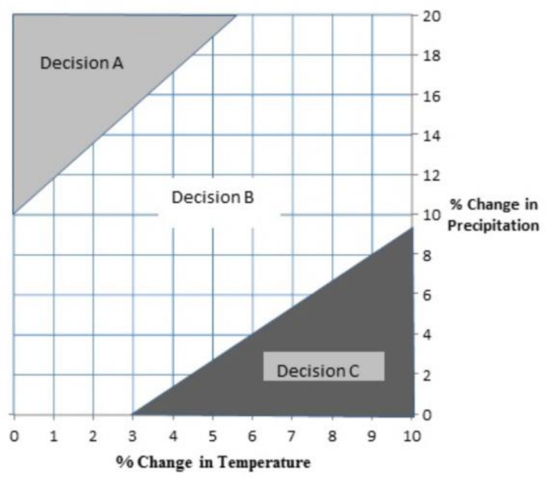
Clark et al. 2016; connect models in a chain

Stochastic hydrology



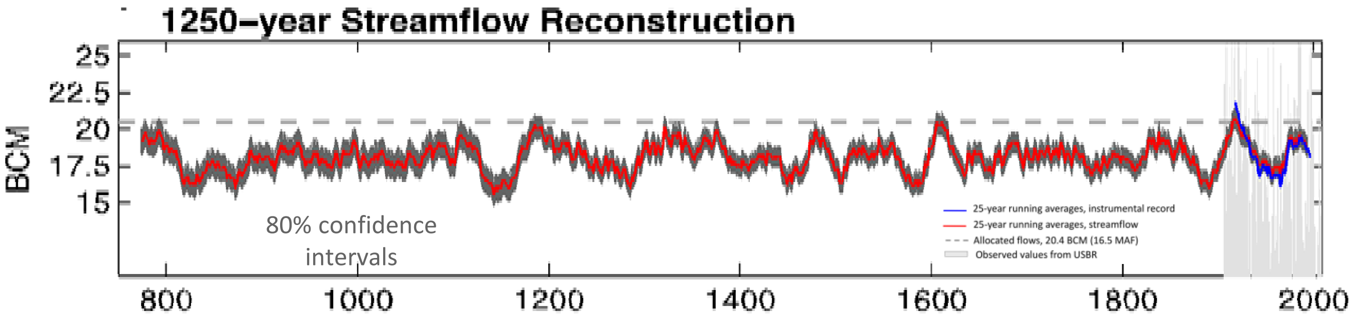
Bras and Rodriguez-Iturbe, 1985; generate synthetic timeseries using statics from the past

Climate-informed vulnerability analysis



Brown et al., WRR, 2016; explore system vulnerabilities with perturbations

Paleoclimate studies



Vano et al., BAMS, 2016; generate timeseries using reconstructions of the distant past

and others…

Source: J. Vano, Dos and Don’ts

Do Understand How the Decision Being Evaluated is Important to Model and Approach Selection

What are the questions we are trying to answer?

How will flows in April-September change in the future?

How should facilities be sized to prevent sewer overflows?

How will the magnitude, duration, and frequency of drought change?

How much warmer will streams be in 20 years?

water supply, streamflow timing, drought, stormwater, wastewater

FIT FOR PURPOSE

Source: J. Vano, Dos and Don'ts

<u>Do</u> Start by Determining the Level of Details that Fits Your Need and Resources

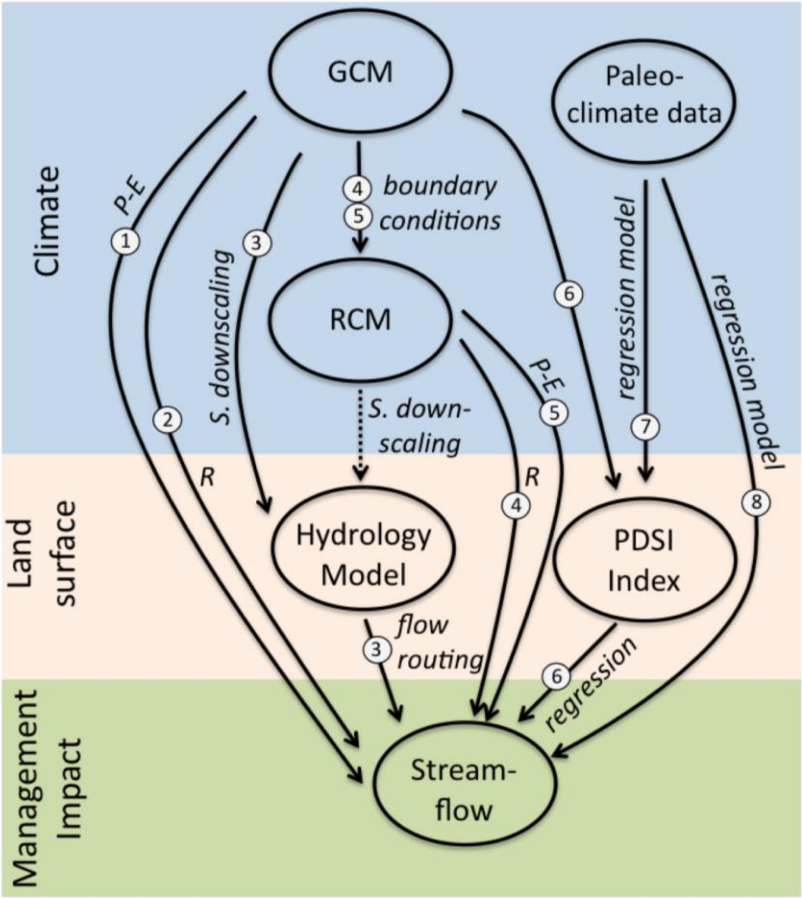
Additional Considerations:

- How much will it cost?
- How long will it take?
- To what extent will the analysis improve the decision?
- Can appropriate data and information be obtained?
- Who will undertake the analysis?
- How much information can you manage?




Source: J. Vano, Dos and Don'ts + one from WUCA

DON'T treat all future projections or methods equally



Different: GCMs, emission scenarios, spatial resolution, hydrology, +

Figure from Vano et al., BAMS, January 2014

- Certain models and methods are more appropriate
- Certain spatial and temporal scales are more appropriate for certain questions
- Realize some questions may not be possible to answer with current knowledge
- Finer resolution in space and time is not necessarily better
    - Higher Resolution ≠ Higher Accuracy
    - Most models do better on averages than on extremes

Be a savvy consumer and remember…

No Model is Perfect

“The accuracy of streamflow simulations in natural catchments will always be limited by simplified model representations of the real world as well as the availability and quality of hydrologic measurements.” (Clark et al., WRR, 2008)

Don’t expect perfect results,

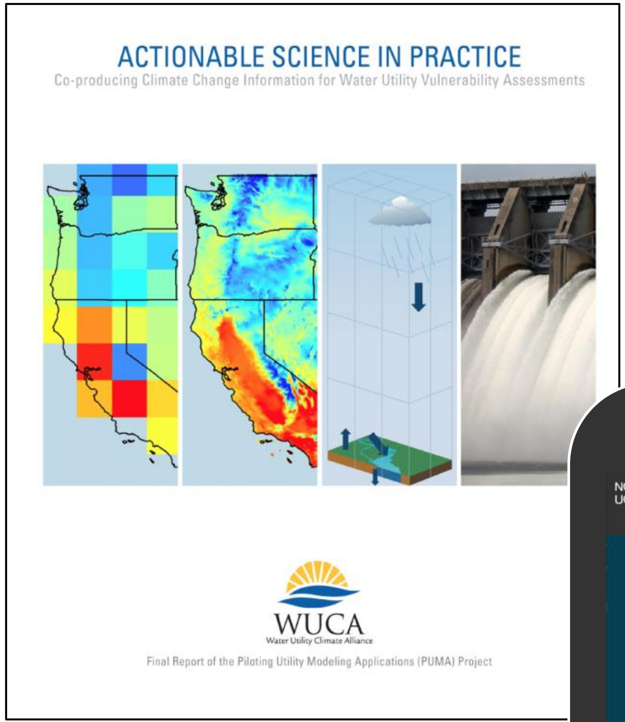
- Not prediction, but a tool to test how system responds (what if scenarios)

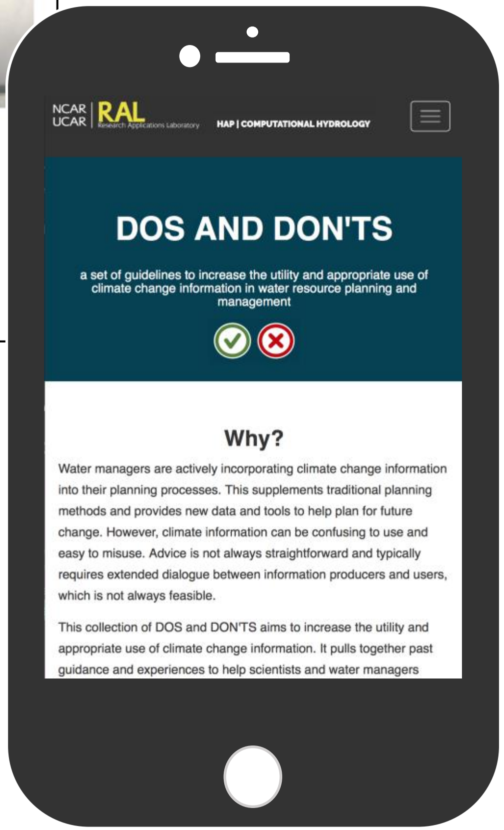
BUT we can make better choices…

- Seek simple yet defensible models (don’t need a Cadillac)
- Be aware of model shortcomings

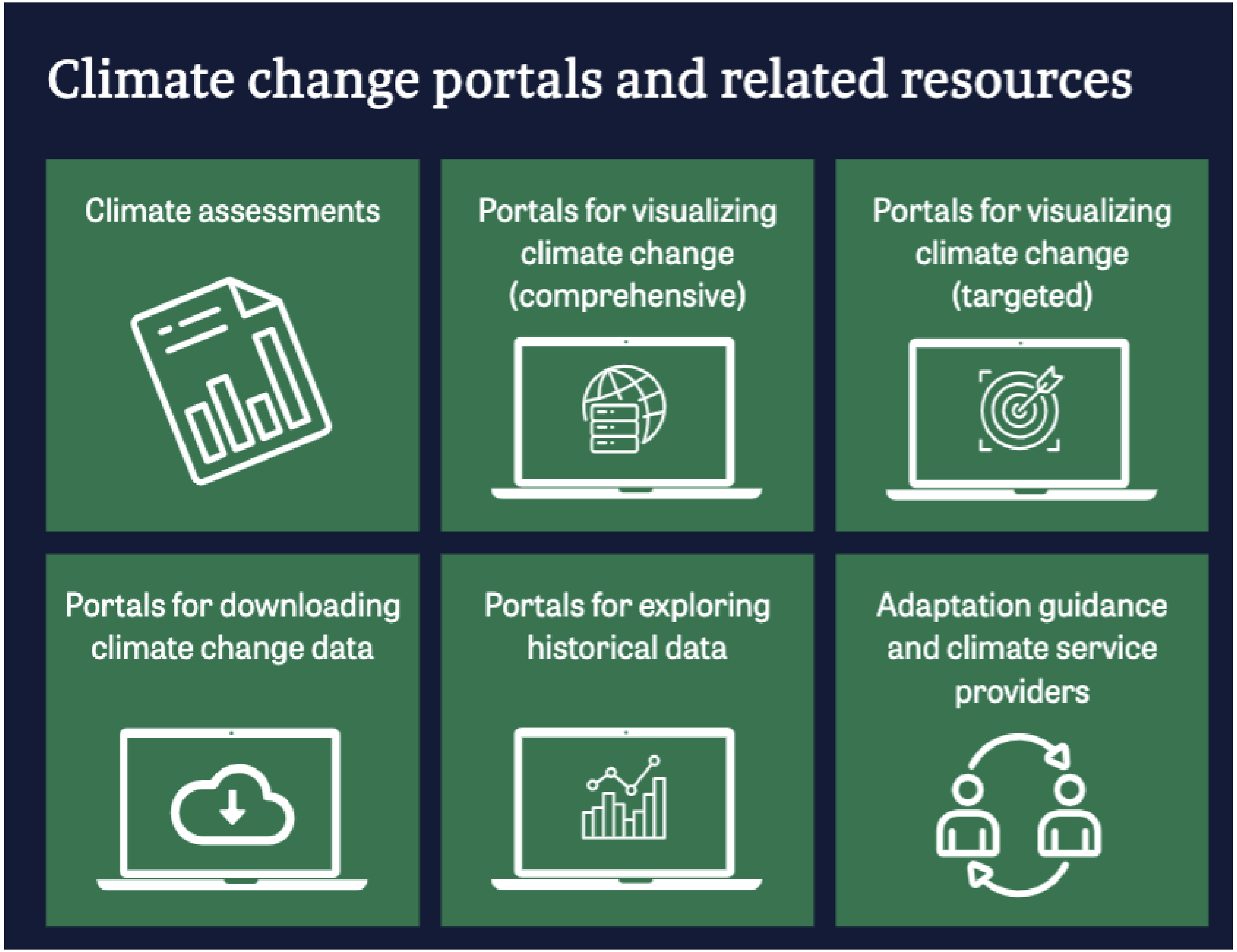
Resources

- WUCA products
  - PUMA project examples
  - Leading Practices & other case studies
  - www.wucaonline.org
- Federal Agencies
  - Environmental Protection Agency
  - U.S. Climate Resilience Toolkit
  - Bureau of Reclamation
  - U.S. Army Corps of Engineers
- Dos and Don'ts Guidelines
  - Reviews other guidance
  - https://global-change.github.io/dos_and_donts
- Many others, including each other





Guide to Available Resources

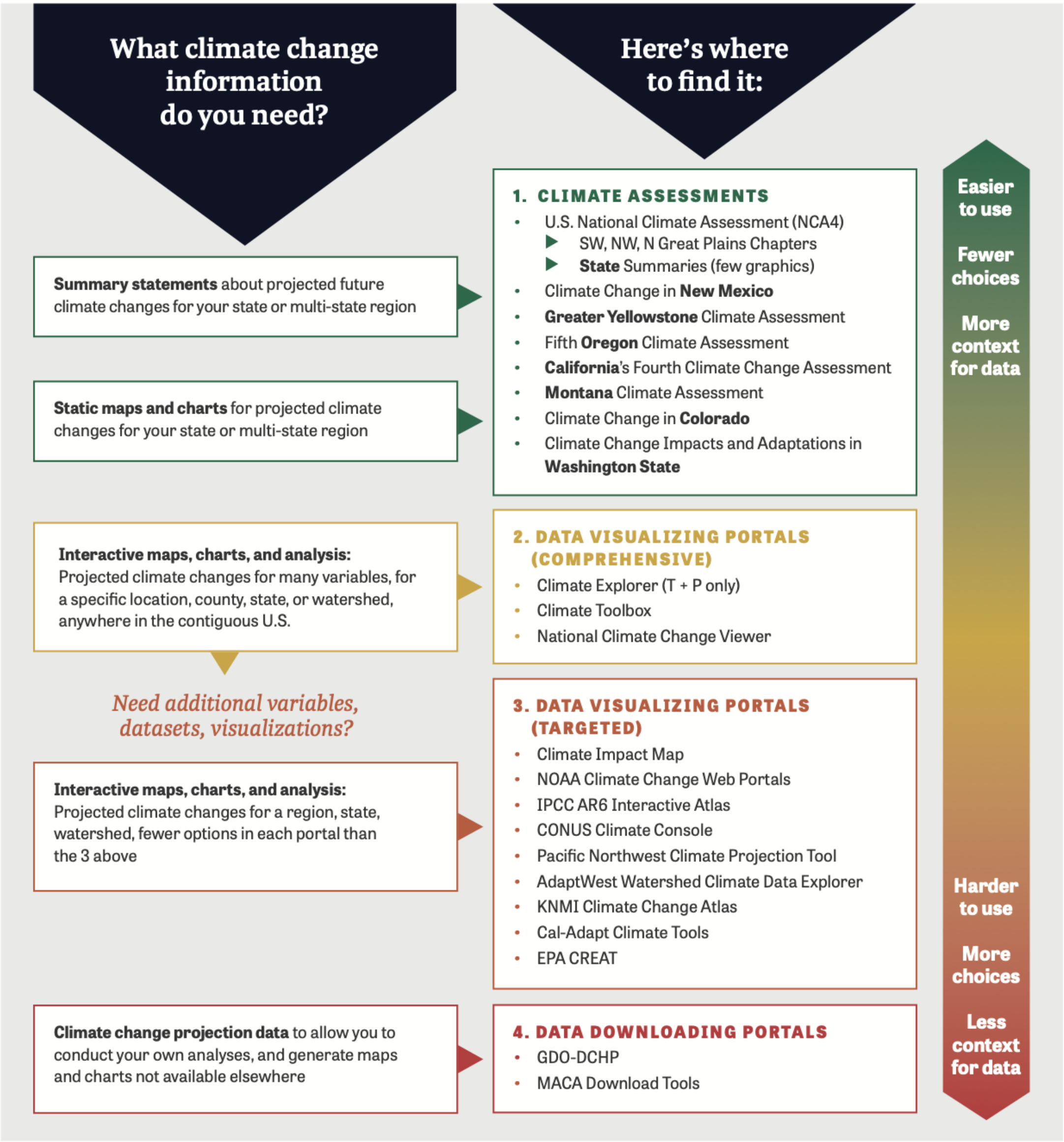


A User Guide to Climate Change Portals

and other resources that support planning and adaptation in the Mountain West

Places to go for climate change information

To match the need for climate change information (left) with the type of resources (right; Boxes 1–4).
All resources named in the numbered boxes are described in the guide, available online at: <web link>



www.agci.org/climate-portal-guide

contact jvano@agci.org

Upcoming FAQs about CMIP6

- What is CMIP6?
- How is CMIP6 different from CMIP5 (and CMIP3), and is CMIP6 better?
- What are the implications of the CMIP6 hot-model issue, and how can it be addressed?
- What are the emissions scenarios in CMIP6 and how do they differ from CMIP5 scenarios?
- What are the considerations in selecting the CMIP6 emissions scenarios (SSPs) to be used in an analysis?
- **and more!**

WUCA
Water Utility Climate Alliance

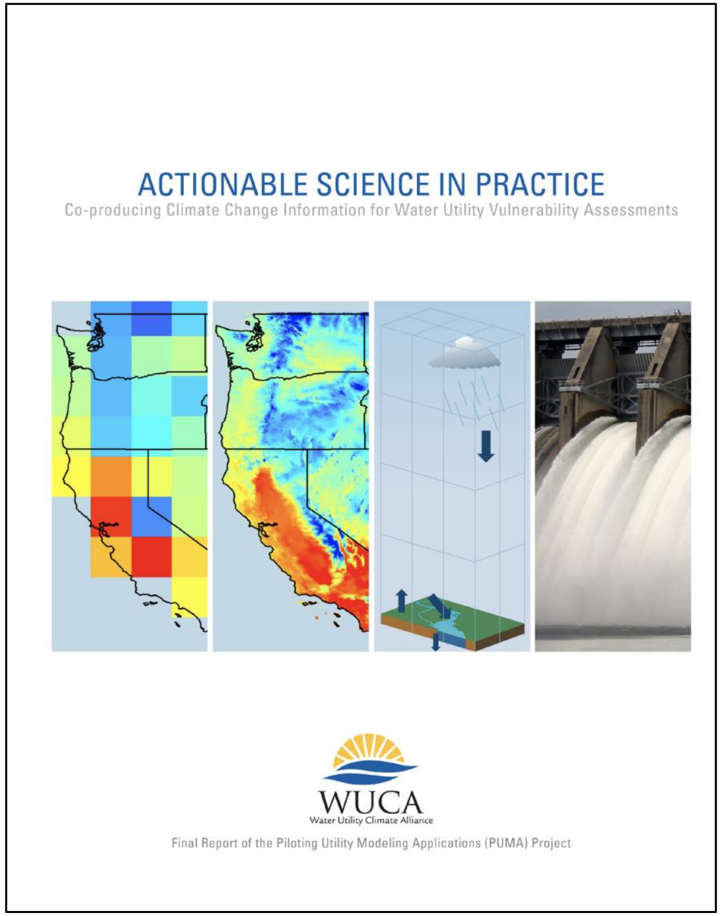
NEW WUCA product coming Fall of 2024!

Key Takeaways

- Downscaling and hydrology modeling provide local-scale insights of global-scale information.
- Downscaling exist on a continuum of tradeoffs between computational efficiency and method complexity.
- Model uncertainty is unavoidable and important to acknowledge.
- Models can be useful tools, if used appropriately. **Be a savvy consumer.**
- Consider your decisions before selecting data and tools.
- Lots of resources available. Consult local experts and national resources.

END

Past experiences at SPU with the PUMA project (2015)



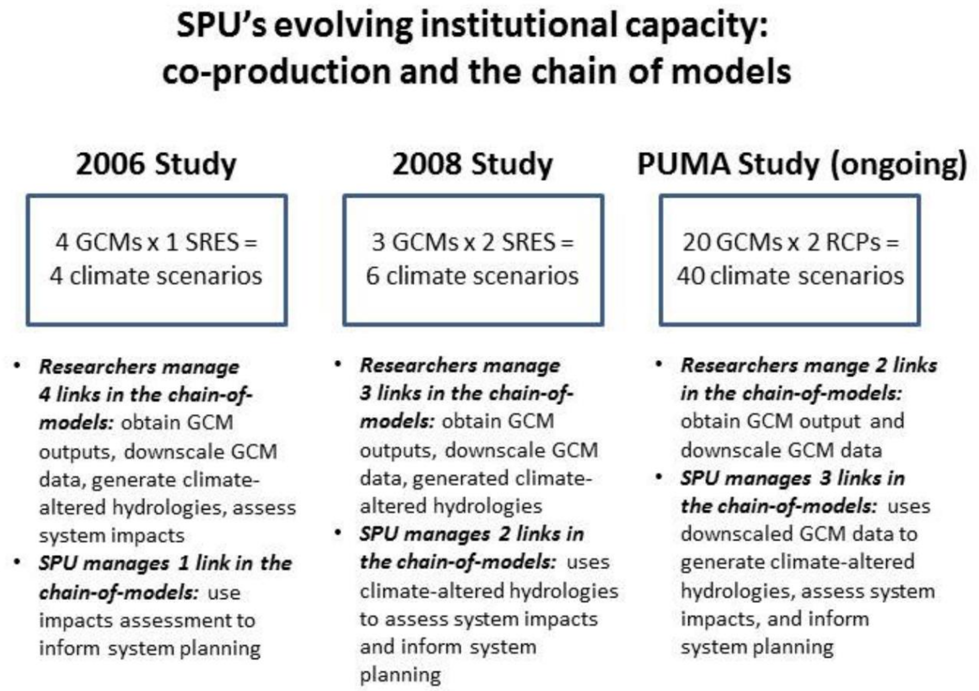


Figure 5. Representation of the increasing complexity of SPU climate studies and the increasing capacity of SPU staff to manage the chain of models required to do an assessment.

DON'T wait until new information is available, there will always be new research and models coming soon

- Research will continue to evolve (sustained assessment)
- Often the biggest challenge is the first time through
- Automate when possible

Common challenges the first time through:

- learning where and how to download the data
- using unfamiliar data formats (e.g., NetCDF)
- slicing data for a particular region or time period
- converting from one data format to another
- automating the process
- running new extremes through a reservoir model
- defining evaluation criteria
- displaying results in meaningful ways

Many datasets, all different: