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:

- Precipitation
- Evapotranspiration
- Glaciers
- Snowpack
- Wildfire
- Streamflow
- Water Temperature
- Sea Level Rise
- Groundwater
- Floods
- Sediment

Dynamically-downscaled climate projections:
PNNL, UW, UCLA

Hydraulic/Hydrodynamic Modeling:
FloodFactor
SSM
PS-CoSMoS

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

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

Very little information

Miller et al. 2018
NOAA 2022
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)
- Management/Operations Model(s) e.g. WEAP, SWMM, Riverware
- Decision e.g. VIC, SAC

CO2 emissions for SSP baselines
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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

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?
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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

Connections between soil and aquifer

Hydrological Modeling Parameters

Vegetation, Soil type, …
Hydrologic Modeling Processes

Looking under the hood…

Clark et al. (WRR 2015)
Revealing Uncertainties

- Emissions Scenario(s)
- Global Climate Model(s)
- Model Initial Conditions
- Downscaling Method(s)
- Combined uncertainty
- Hydrologic Model Parameter(s)
- Hydrologic Model Structure(s)
Revealing Uncertainties

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- Hydrologic Model Parameter(s)
- Combined uncertainty
  - PDF for scenarios
  - PDF for models
  - PDF for calibration
  - PDF for ens. members
STRETCH BREAK

Ask your neighbor about downscaling...

or hydrologic modeling...

or your favorite type of bagel...
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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

Stochastic hydrology

Climate-informed vulnerability analysis

Paleoclimate studies

Source: J. Vano, Dos and Don’ts
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?

**FIT FOR PURPOSE**

Source: J. Vano, Dos and Don’ts
Do 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

- 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…**

Figure from Vano et al., BAMS, January 2014

Different: GCMs, emission scenarios, spatial resolution, hydrology, +
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
  o PUMA project examples
  o Leading Practices & other case studies
  o [www.wucaonline.org](http://www.wucaonline.org)

• Federal Agencies
  o Environmental Protection Agency
  o U.S. Climate Resilience Toolkit
  o Bureau of Reclamation
  o U.S. Army Corps of Engineers

• Dos and Don’ts Guidelines
  o Reviews other guidance
  o [https://global-change.github.io/dos_and_donts](https://global-change.github.io/dos_and_donts)

• Many others, including each other
Guide to Available Resources

Climate change portals and related resources

- Climate assessments
- Portals for visualizing climate change (comprehensive)
- Portals for visualizing climate change (targeted)
- Portals for downloading climate change data
- Portals for exploring historical data
- Adaptation guidance and climate service providers

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: www.agci.org/climate-portal-guide

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!

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
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