

On the need to evaluate physical mechanisms associated with downscaled future climate change patterns

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Impact Relevance and Usability of High-Resolution Climate

Modeling and Data Sets

Aspen Global Change Institute

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Meeting questions I'll be addressing

1. **What are the most important climate phenomena to improve impacts modeling or risk management applications?** (From Q. 1)
2. **How well do the different potential sources of high resolution information represent those?** (From Q. 2)
3. **Can high-resolution simulations be paired with lower-resolution simulations to explore multiple scenarios and more fully characterize uncertainty?** (From Q. 4)

To address these questions, I'll discuss some examples from our recent work at UCLA.

Though some information on the technical aspect of the work is necessary to understand our methods, I'll avoid the details.

Instead, I'll focus on the most important aspects for the questions we're concerned with here in Aspen.

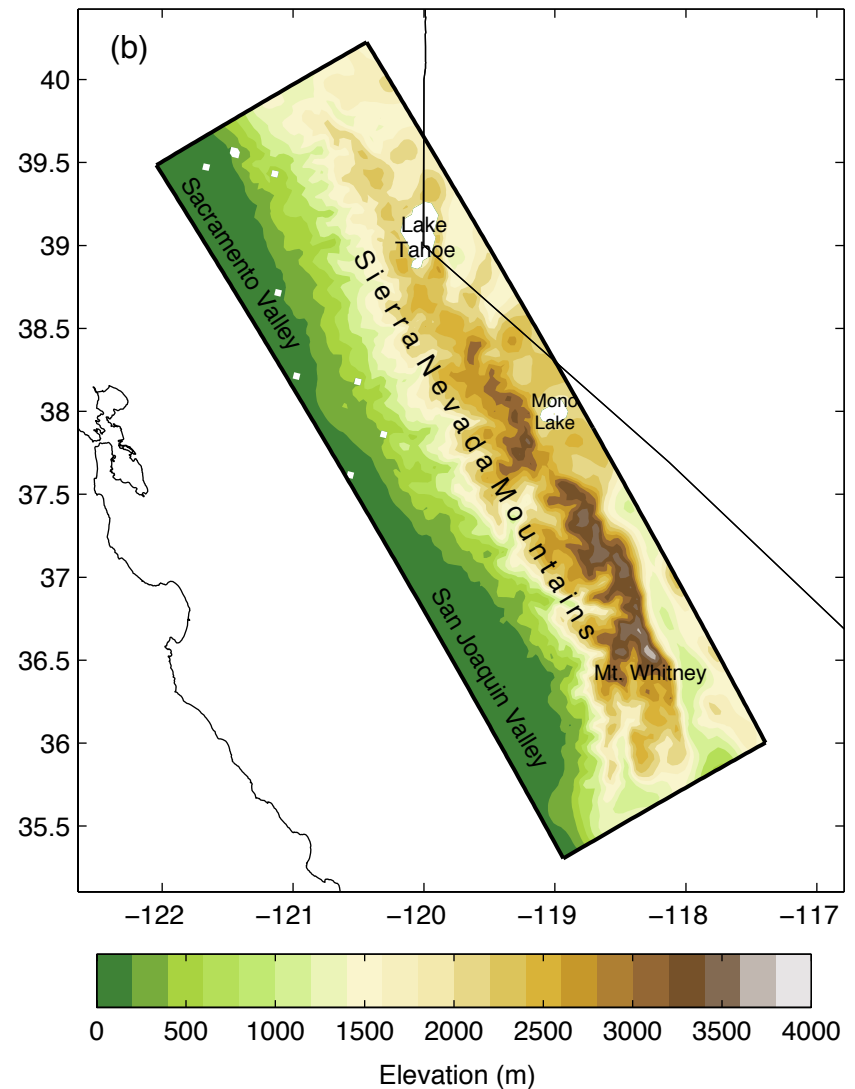
A brief overview of hybrid downscaling

- We have been doing regional climate projections with a technique we call hybrid dynamical-statistical downscaling.
- The essence of hybrid downscaling is to do limited dynamical downscaling for a particular region, and then develop simple mathematical (or statistical) models to mimic the dynamical model behavior.
- The statistical models can then be used to produce regional data corresponding to any GCM, for any time slice or forcing scenario.
- As we'll see, hybrid downscaling forces the practitioner to diagnose and understand the climate change patterns produced by dynamical downscaling.
- It avoids the stationary assumption.
- It allows for characterization of the full uncertainty associated with GCM spread and forcing scenario.

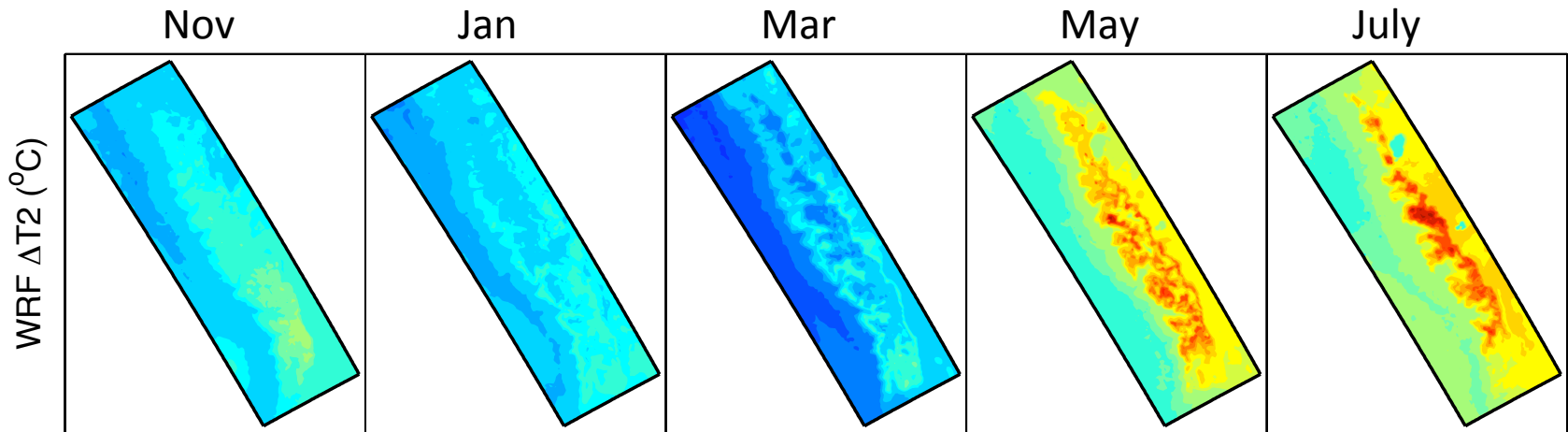
Application: California's Sierra Nevada

Step 1: Dynamical downscaling

- Dynamical downscaling, 3-km resolution over the Sierra Nevada
- Baseline (1981–2000) and Future (2081–2100) runs driven by 5 CMIP5 GCMs under RCP 8.5



Dynamically downscaled warming



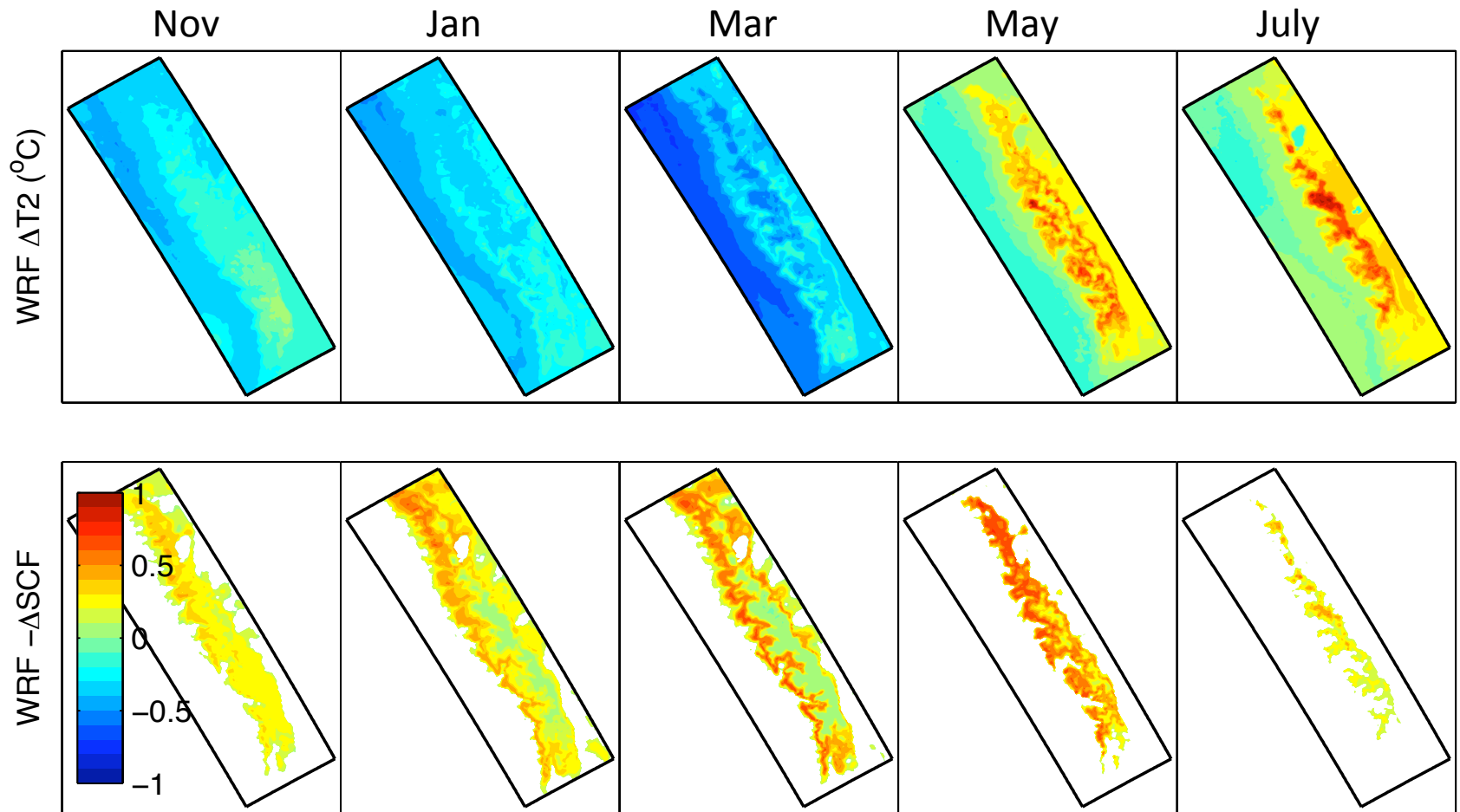
These are example warming patterns for 5 selected months, which span the most important phase of the annual cycle for water resources.

This is the average over all five dynamically downscaled futures.
(Warming patterns are very similar for individual simulations, even if the magnitudes vary.)

Two features are evident:

1. Warming is greater on the continental side of the Sierra Nevada.
2. The imprint of snow albedo feedback is clear in every month.

Dynamically downscaled warming

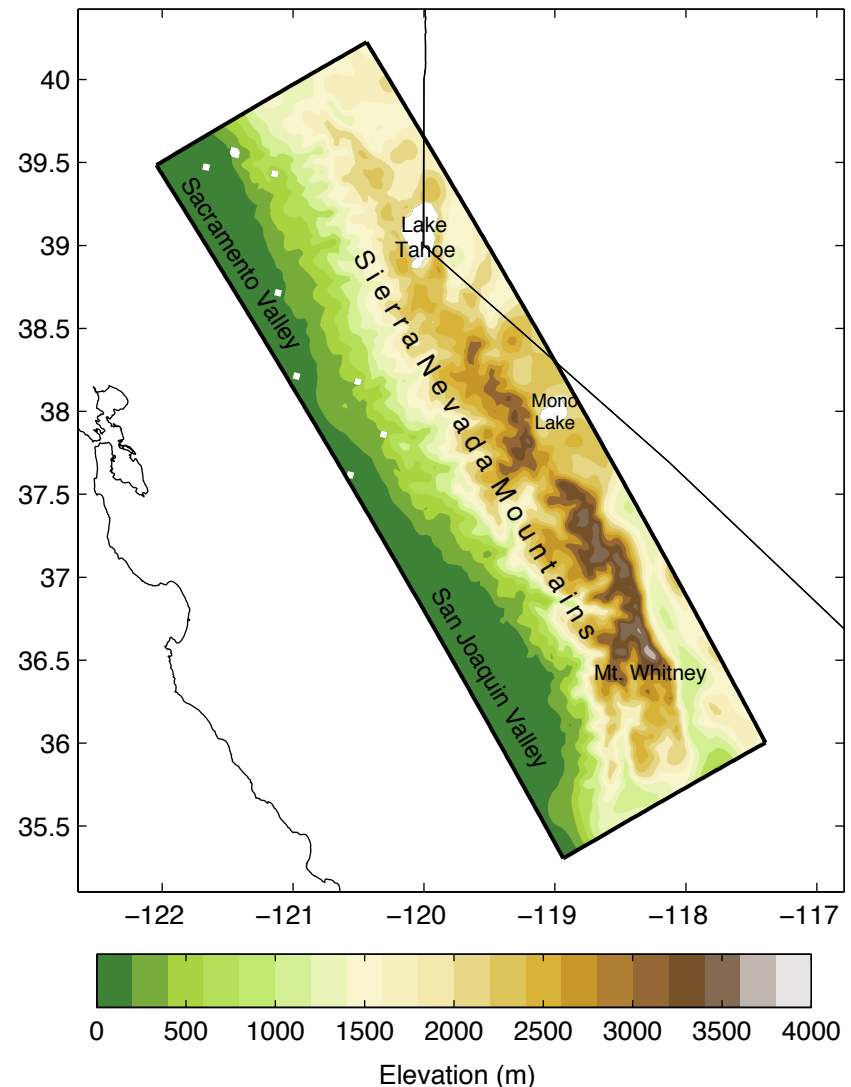


The impact of snow albedo feedback is especially evident if one compares the warming patterns to the change in fractional area covered by snow.

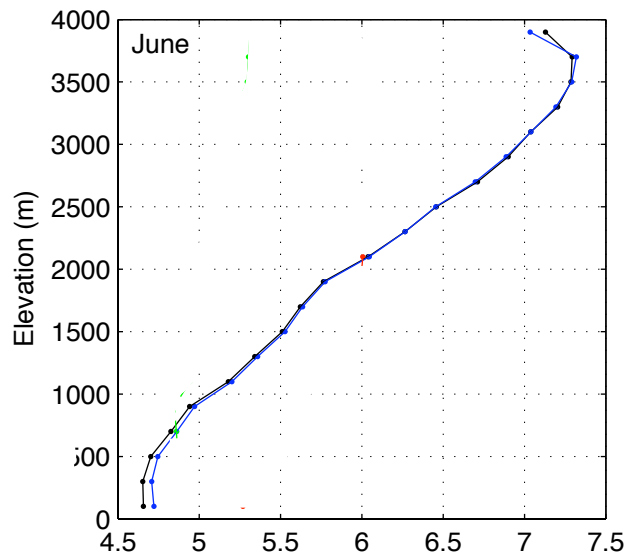
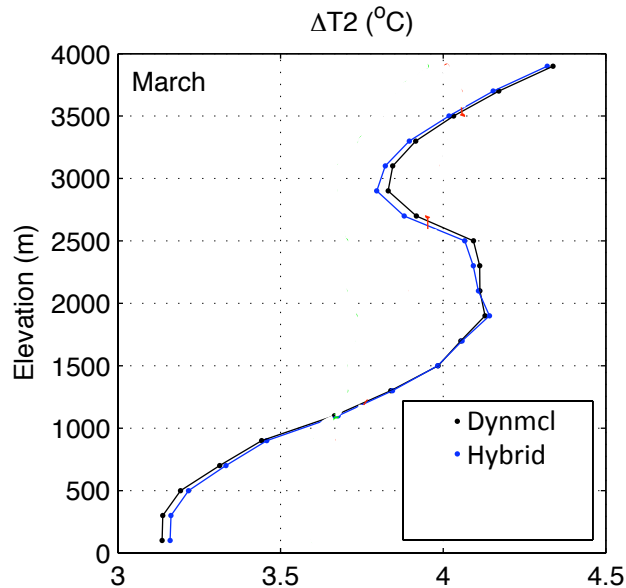
Application: California's Sierra Nevada

Step 2: Construction and application of statistical models

- Based on these results, we construct a simple mathematical model that takes as inputs the main drivers of regional warming.
- Through careful diagnostics, we have determined that those drivers are:
 1. Overall GCM warming in this region
 2. GCM warming contrast between N America and the adjacent Pacific Ocean
 3. Snow albedo feedback
- With these inputs, the statistical model then produces warming patterns that mimic those of WRF.

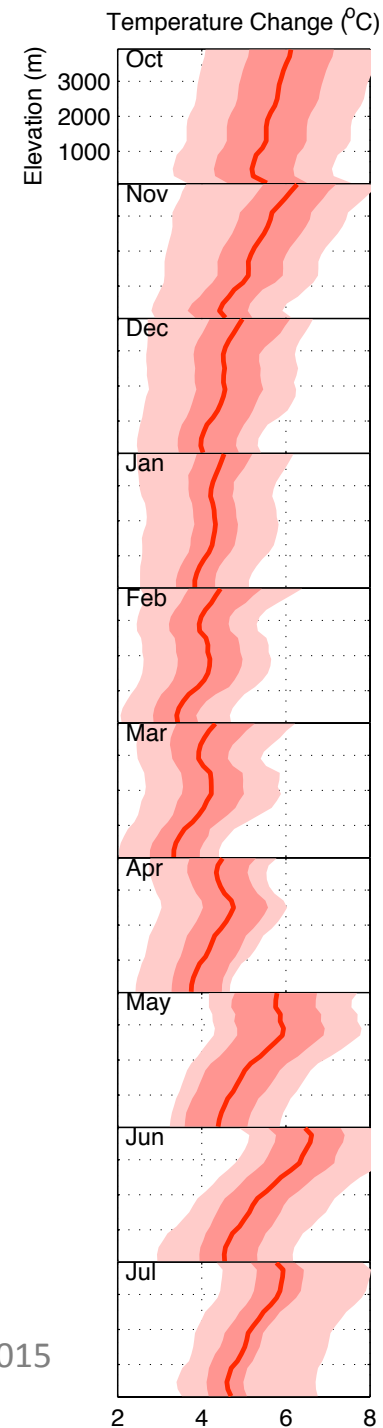


Application: California's Sierra Nevada

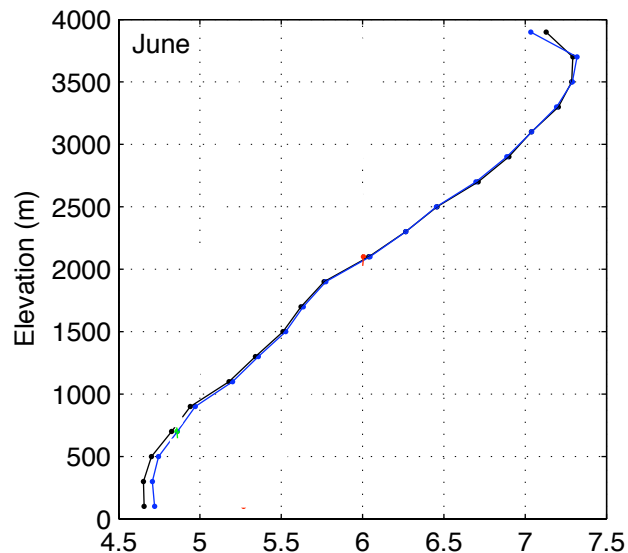
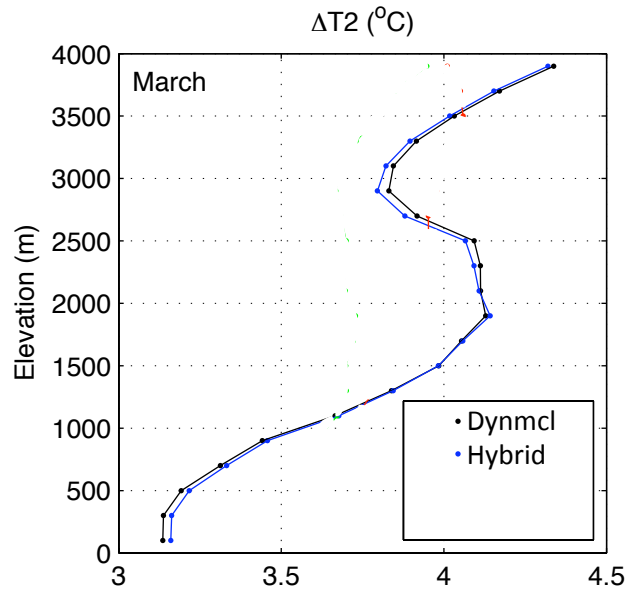


- This is the warming as a function of elevation, for March and June.
- Both the dynamical results and results from the statistical model are shown.
- The agreement is nearly perfect, indicating we can model WRF's warming patterns if we know:
 - 1) how much warming a GCM gives
 - 2) how much land-sea contrast that GCM has
 - 3) how much snow albedo feedback WRF produces

- The simple model can now be used to produce warming patterns that we would have produced *had we downscaled all available GCMs dynamically*.
- This is the warming as a function of elevation, from October through July.
- The solid red line is the ensemble-mean, and the red shading is an indication of uncertainty associated with GCM spread.
- Note the “warming bulge” associated with snow albedo feedback. It moves to higher elevations with the seasonal retreat of the snowline.

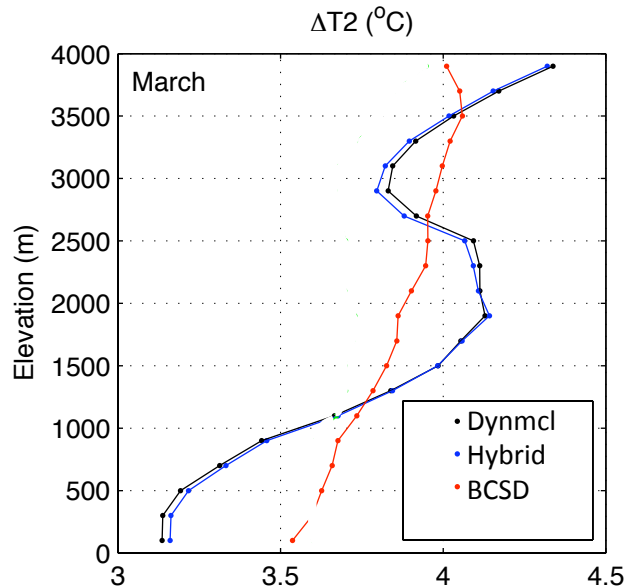


Other downscaling techniques

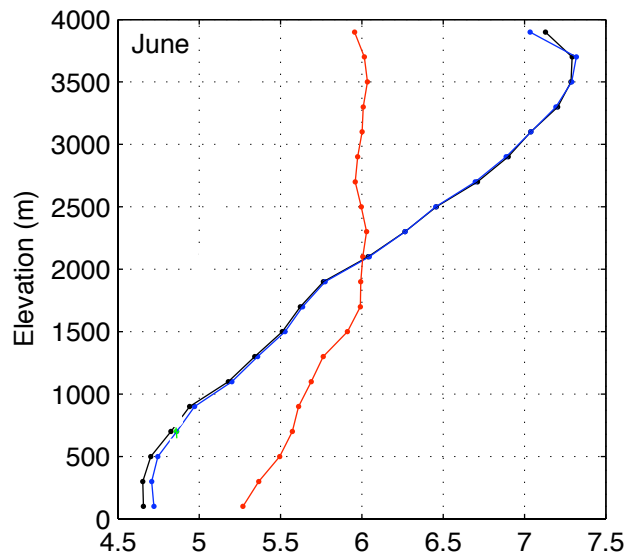


- How do these projections stack up against other downscaled data products?
- Here again is the warming produced by the hybrid approach as a function of elevation, for March and June.
- Let's now overlay the warming produced by two commonly used downscaling techniques.

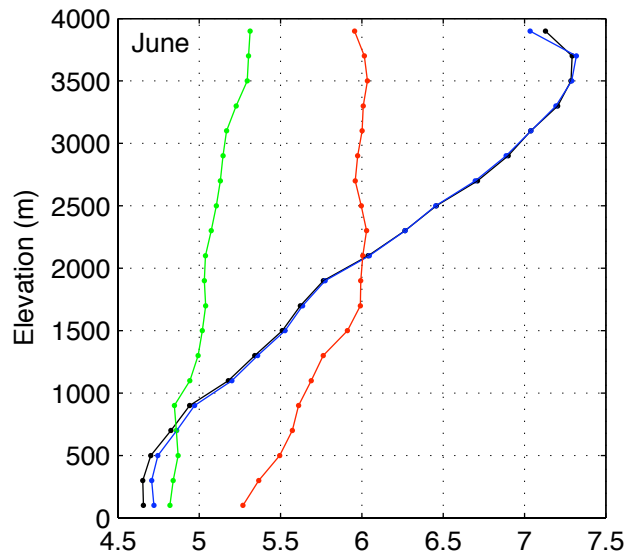
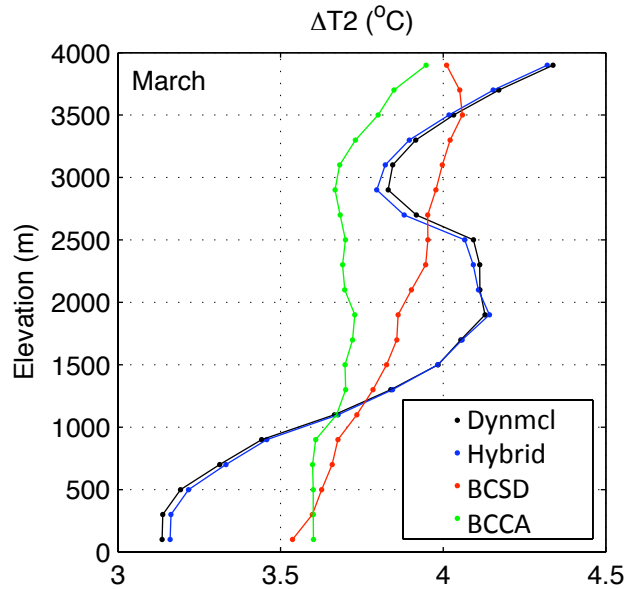
Other downscaling techniques



- Here's the warming given by BCSD, which may be one of the most commonly applied downscaling techniques.



Other downscaling techniques

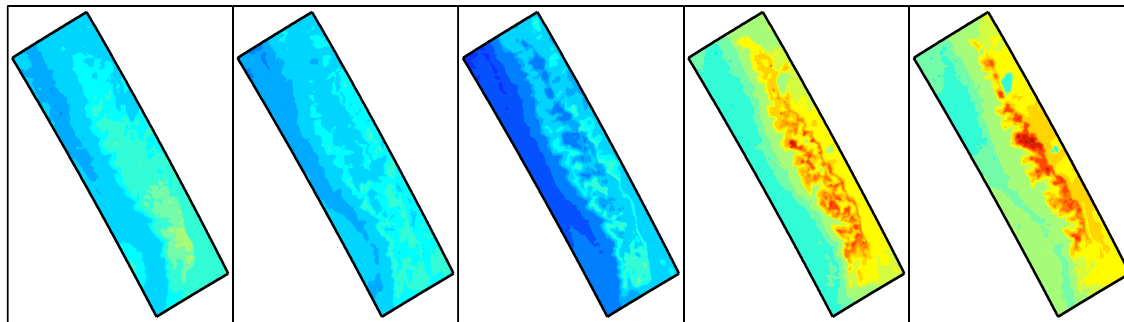


- And **here's** the warming given by BCCA, another common technique.
- Neither BCSD nor BCCA captures the large variations in warming with elevation.
- In fact, both BCSD and BCCA produce “flat” warming projections in the Sierra Nevada, with little spatial structure.

Comparison of warming patterns

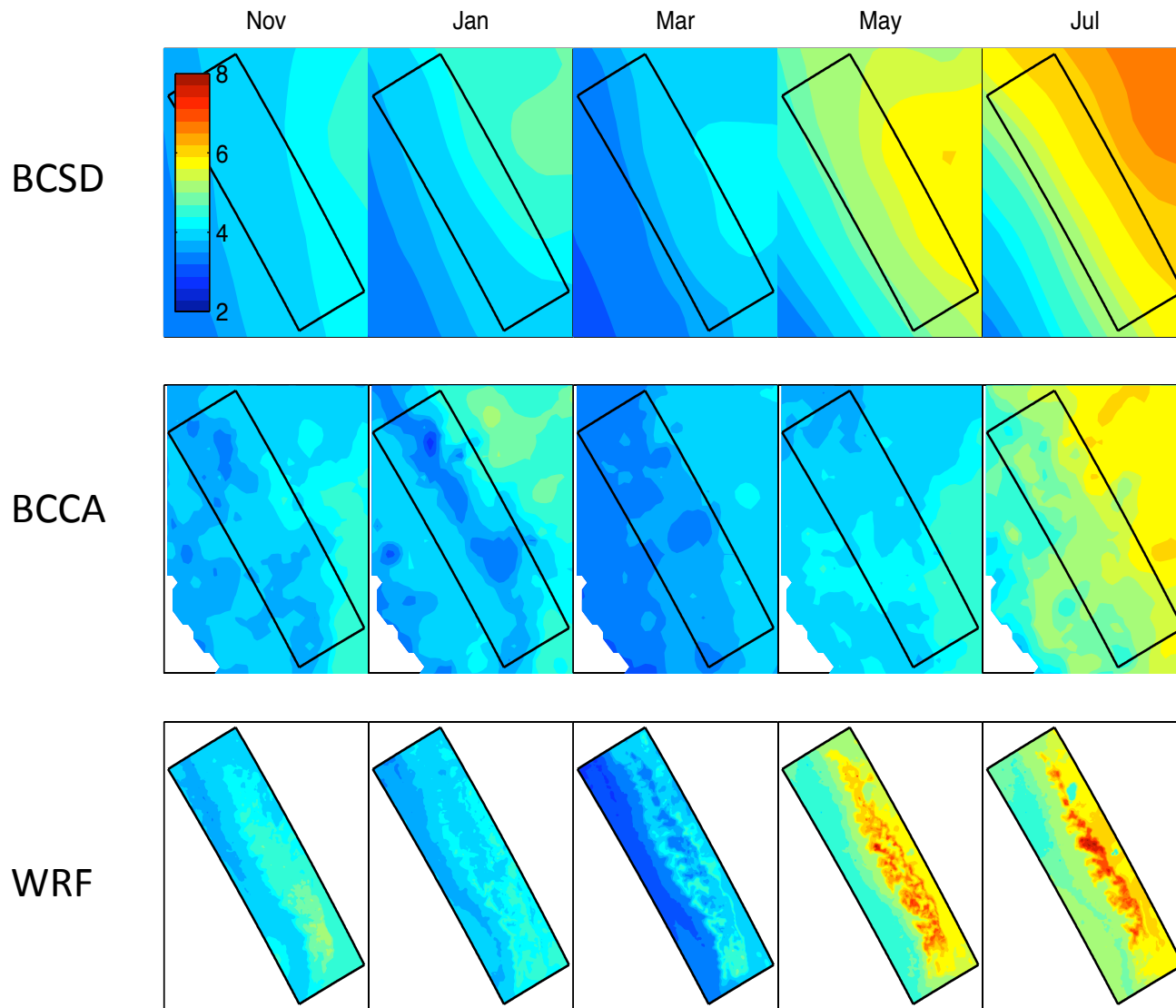
Here again are dynamically downscaled warming patterns for 5 months: Nov, Jan, Mar, May, July

WRF

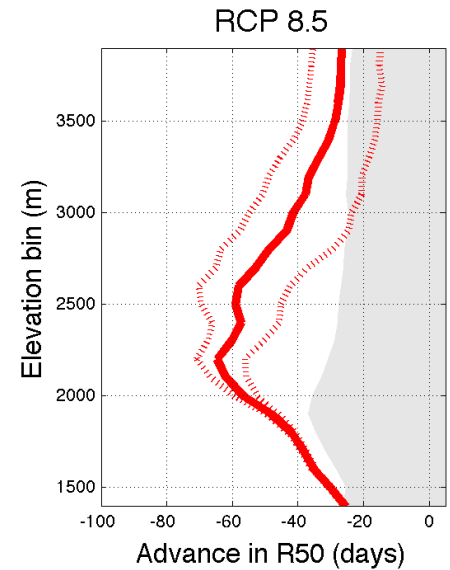


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Comparison of warming patterns

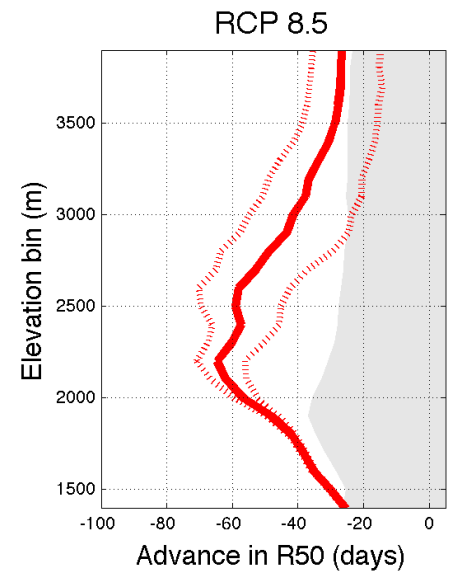


Does it matter?



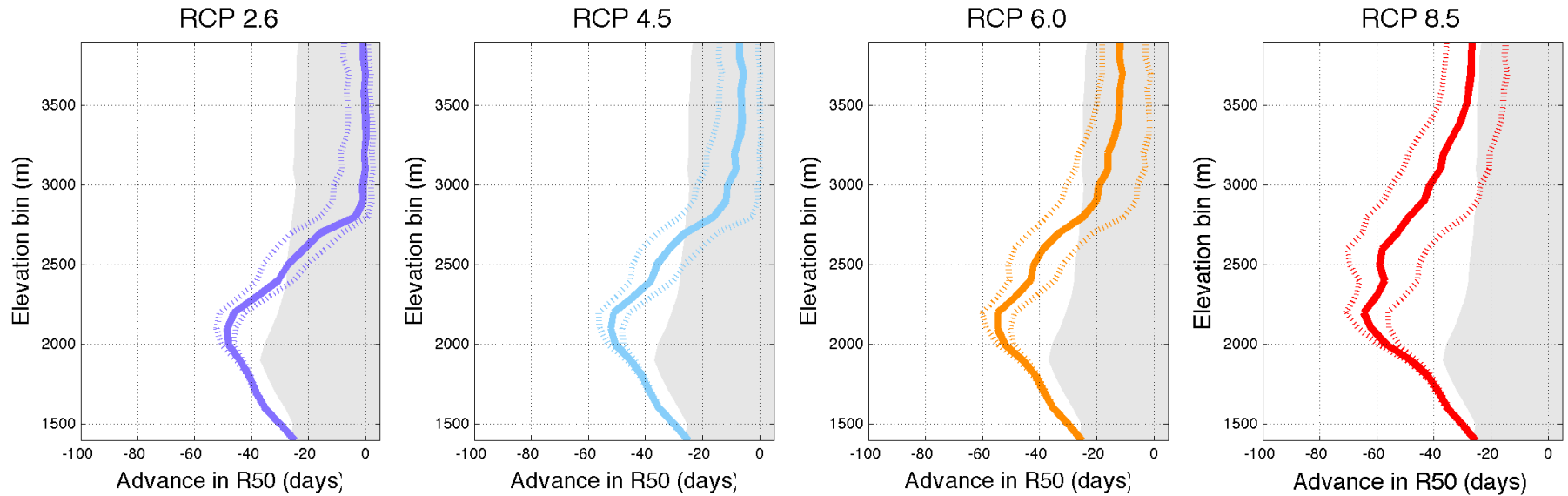
- We've used the hybrid approach to produce projections for other variables.
- Here is the end-of-century RCP8.5 advance in runoff timing as a function of elevation.
- This is measured runoff centroid date (R50), a key metric for water resource management and planning in California and elsewhere.

Does it matter?



- The solid line is the ensemble mean, while the dashed lines indicate uncertainty due to GCM spread. The gray shaded area shows the magnitude of baseline natural variability in R50.
- Clearly there is a dramatic change in runoff timing, with certain elevations affected more than others.

Does it matter?



- Here are the results for the other forcing scenarios.
- A significant change in runoff is apparent in all scenarios at precisely the elevations where snow albedo feedback most amplifies warming.
- This is true even for RCP2.6, which now seems an increasingly unlikely scenario.
- Thus, a significant change in runoff timing for watersheds draining certain elevations is **inevitable**. Hybrid downscaling has allowed us to reach a rather strong conclusion about future water resources.

Conclusions

- To have confidence in high-resolution climate projections used for decision making, it is critical to evaluate the physical mechanisms that underpin regional change patterns.
- If one formalizes this evaluation process through hybrid downscaling, one also has the benefit of a statistical model that can downscale an arbitrarily large GCM ensemble, providing ensemble-mean and uncertainty estimates associated with GCM spread.
- Understanding key physical processes and ensuring their inclusion in downscaled climate projections can affect policy-relevant conclusions about regional climate change.
- Application of downscaled data generally requires the involvement of a particular type of climate scientist – someone with expertise in climate data analysis, e.g. a climate model diagnostician.

End

