

The video recording of this
presentation is available here :
<https://youtu.be/7EYI4mqTIUM>

The Importance of Spatial Heterogeneity of Snow to Climate Change Signals and Data Assimilation

*Ethan Gutmann, Jeffrey Arnold, Tom Painter,
Lindsey Bearup, Kostas Andreadis, Ken Nowak*

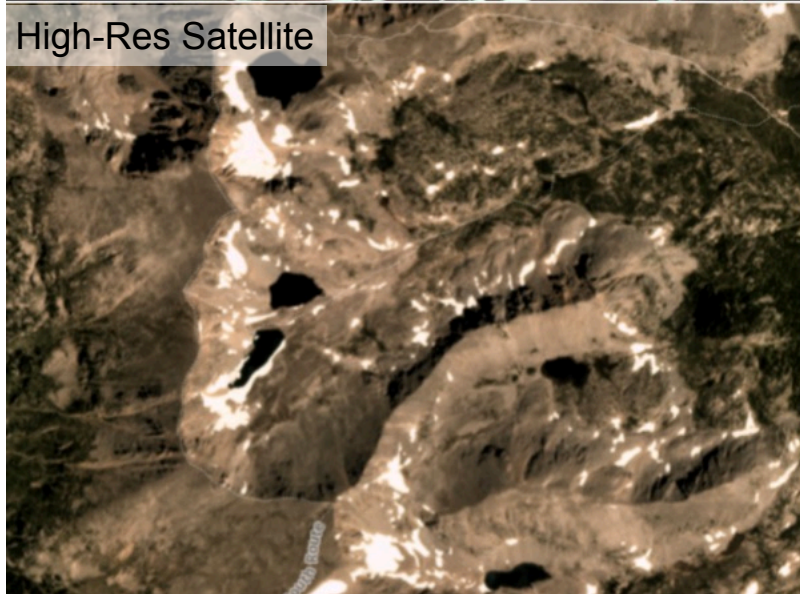
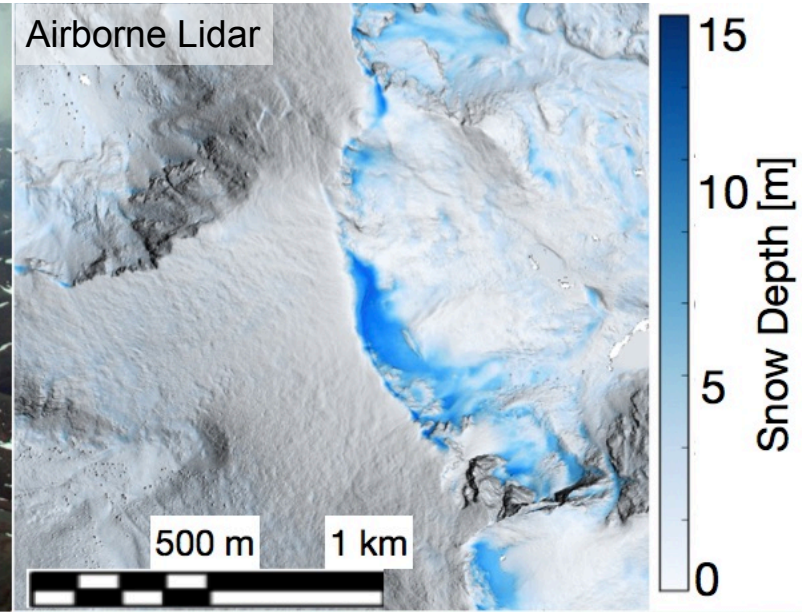
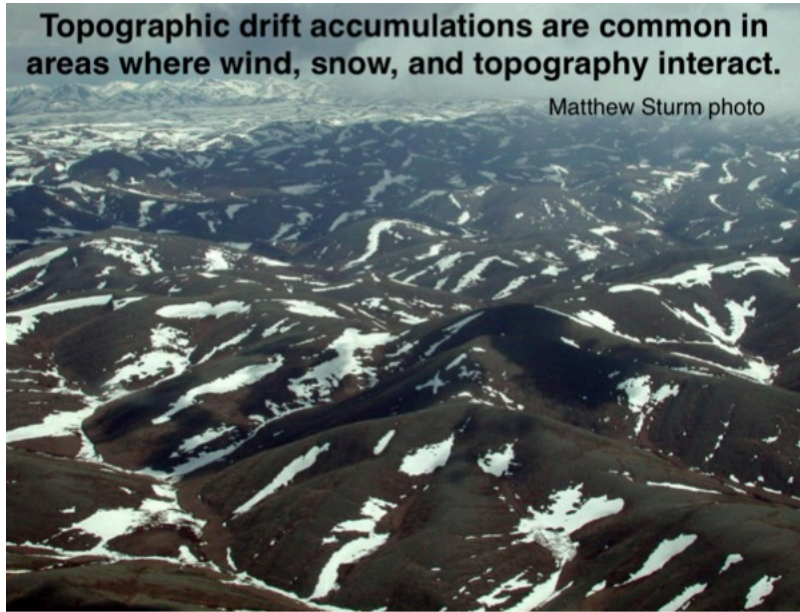
NCAR / RAL

January 15, 2020



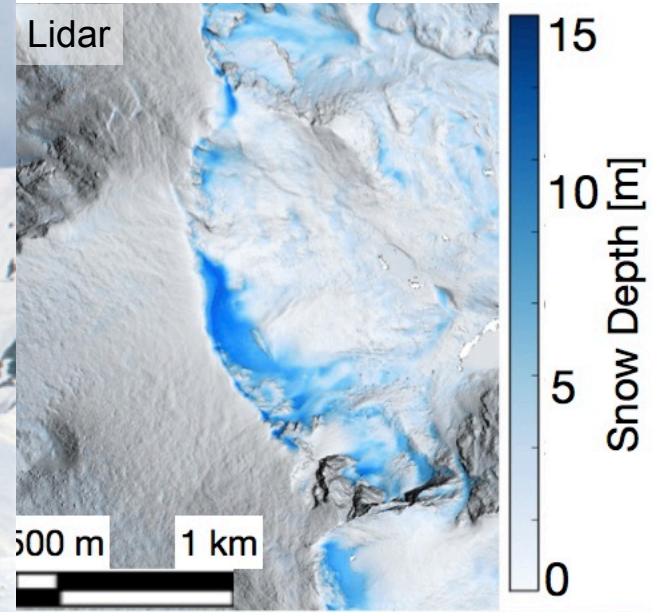
Spatial variability is everywhere

- Precipitation variations
- Preferential deposition
- Wind redistribution
- Topography
- Vegetation
- Differential Melt rates



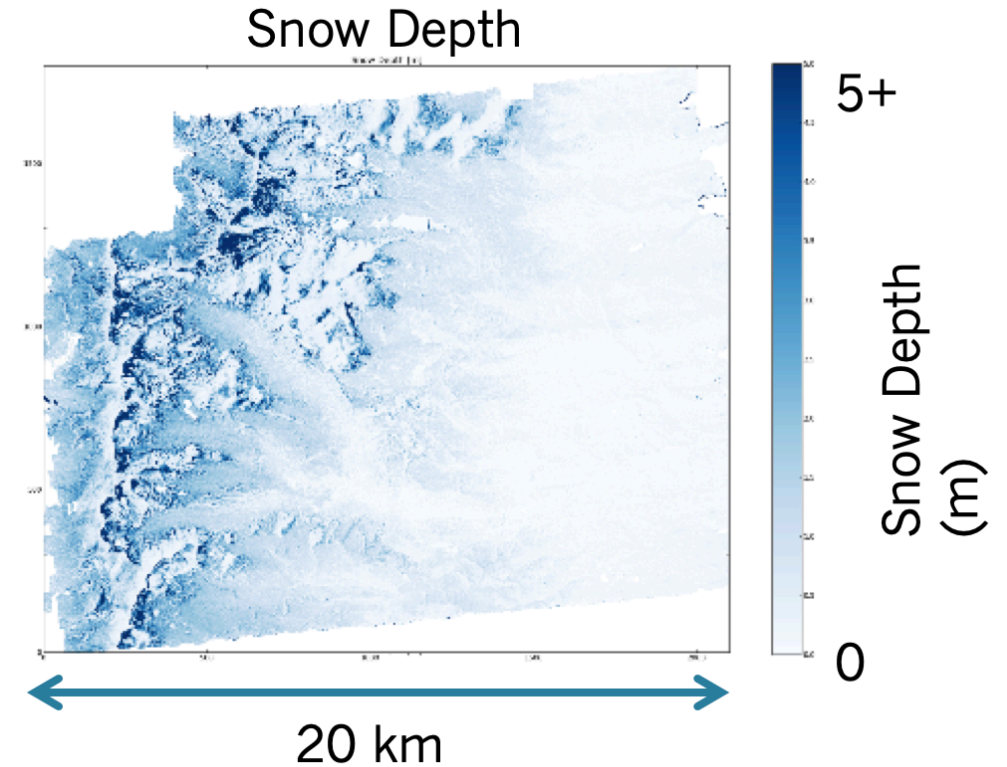
Spatial variability is everywhere

- Precipitation variations
- Preferential deposition
- Wind redistribution
- Topography
- Vegetation
- Differential Melt rates



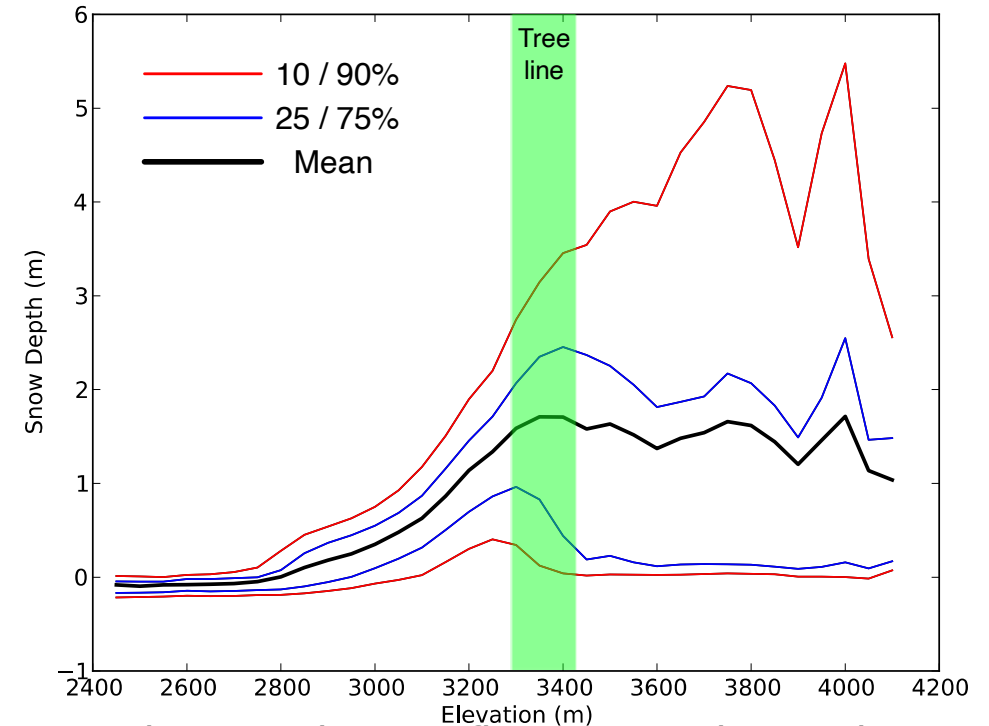
Large Potential Impacts

- Changes in areal average :
 - Albedo
 - Melt rate
 - Microwave emissions...?
 - Air temperature...?
- Implications for:
 - Snow-albedo feedback and climate change?
 - Changes in streamflow in a future climate?
 - Assimilation of snow data for streamflow forecasting?
 - Avalanche forecasting, boundary layer development, land atmosphere exchange, snow separation and sublimation rates... and on... and on?



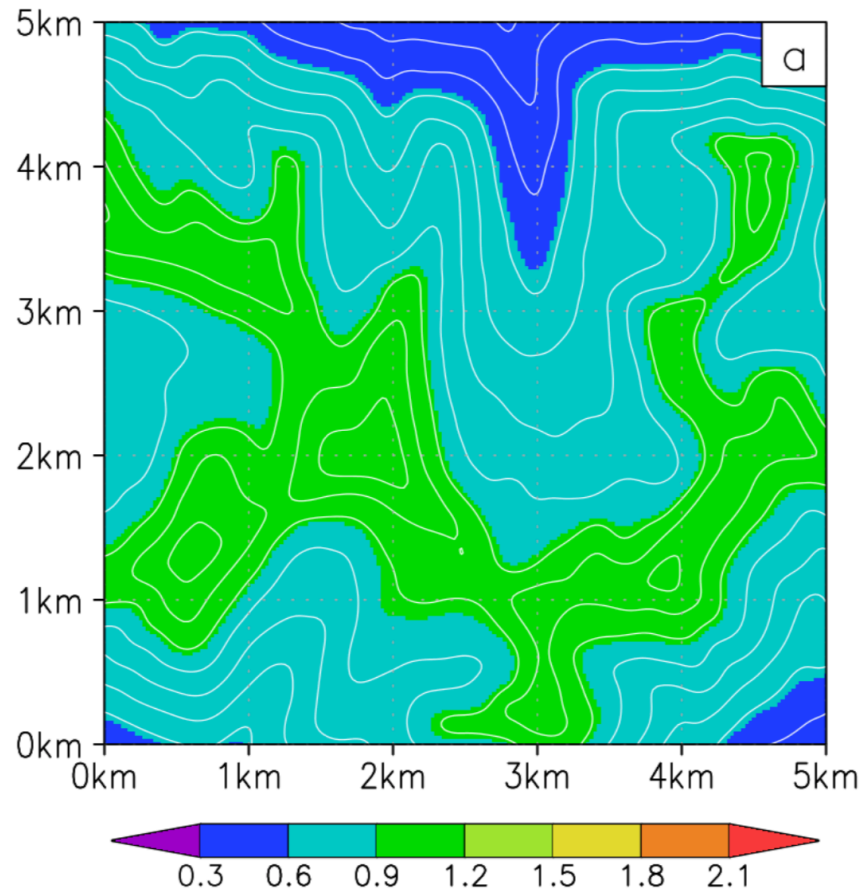
Large Potential Impacts

- Changes in areal average :
 - Albedo
 - Melt rate
 - Microwave emissions...?
 - Air temperature...?
- Implications for:
 - Snow-albedo feedback and climate change?
 - Changes in streamflow in a future climate?
 - Assimilation of snow data for streamflow forecasting?
 - Avalanche forecasting, boundary layer development, land-atmosphere exchange, flow separation and sublimation rates... and on... and on?



How do we treat snow variability in models

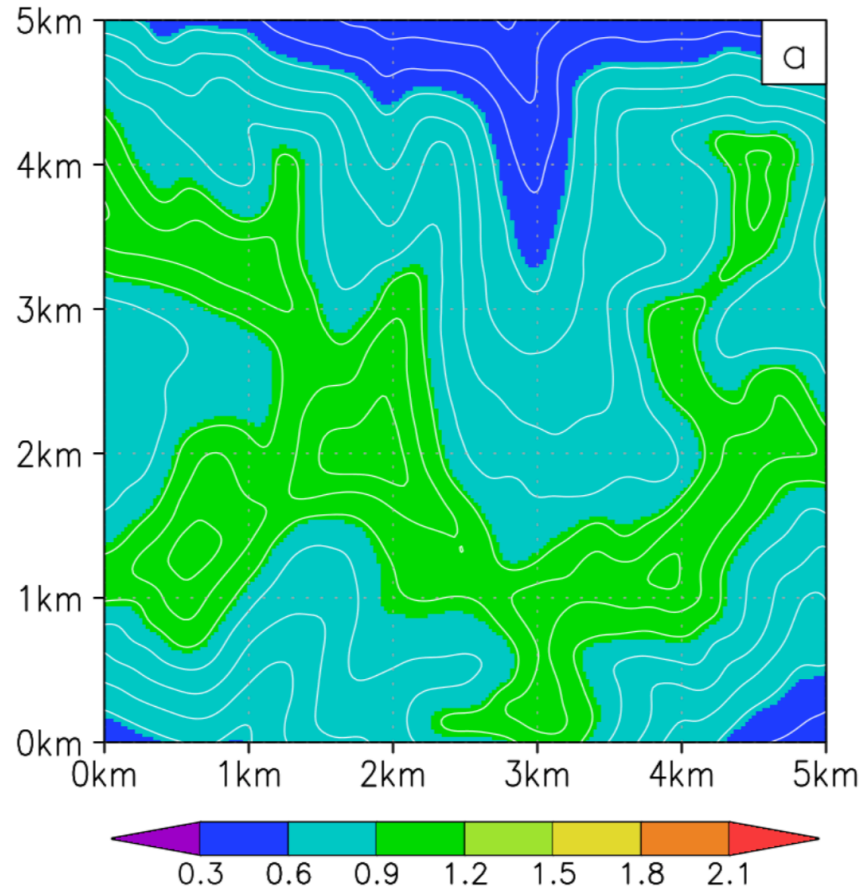
- Short answer, we usually don't really...



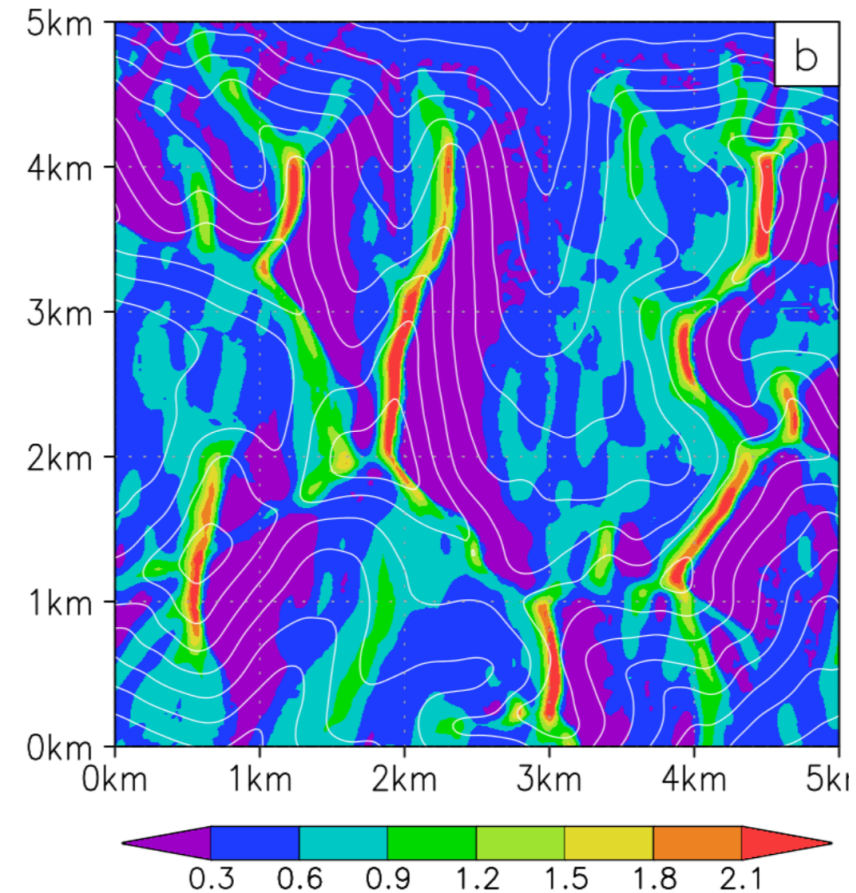
(figures courtesy Glen Liston)

How do we treat snow variability in models

- Short answer, we usually don't really...



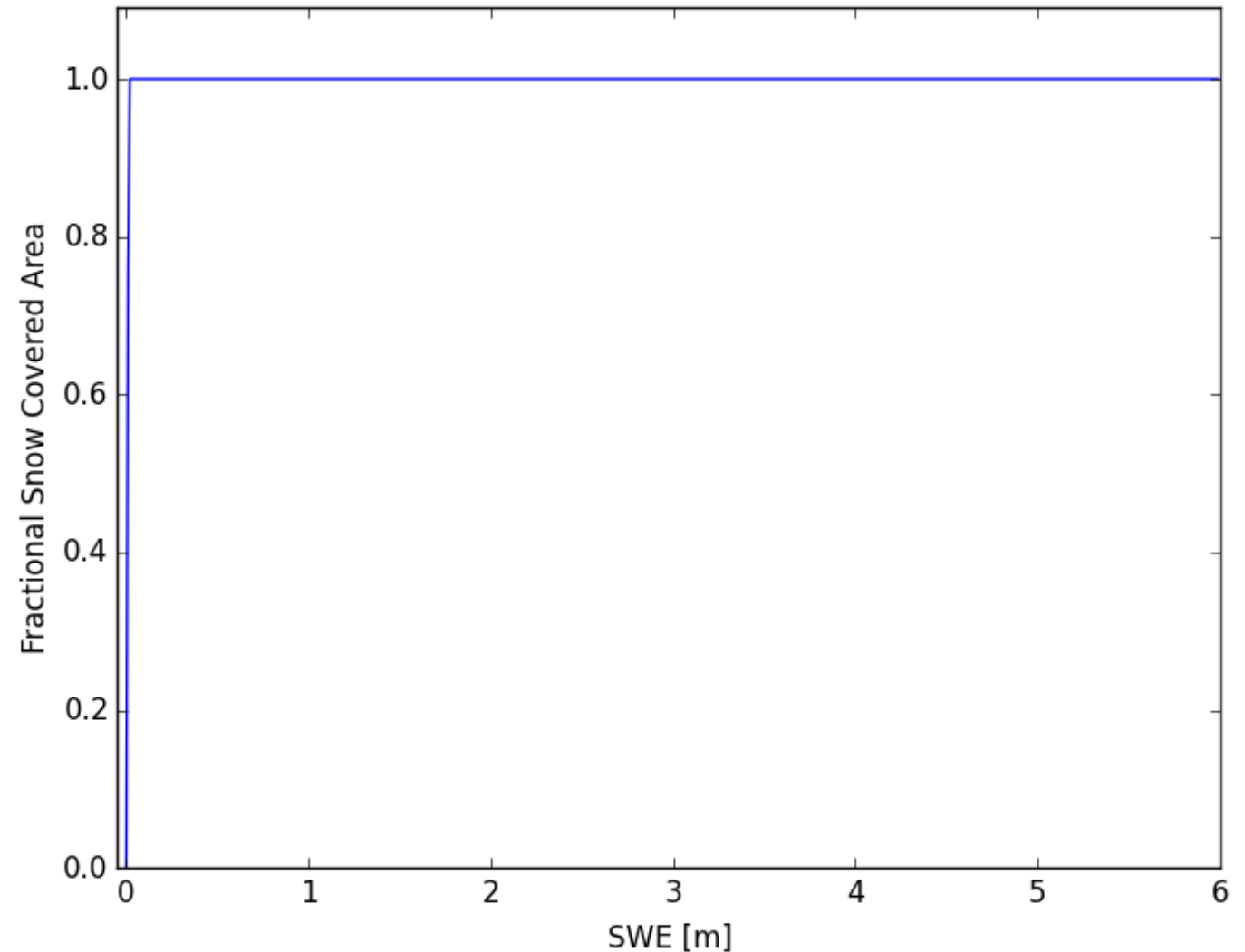
But we can...



(figures courtesy Glen Liston)

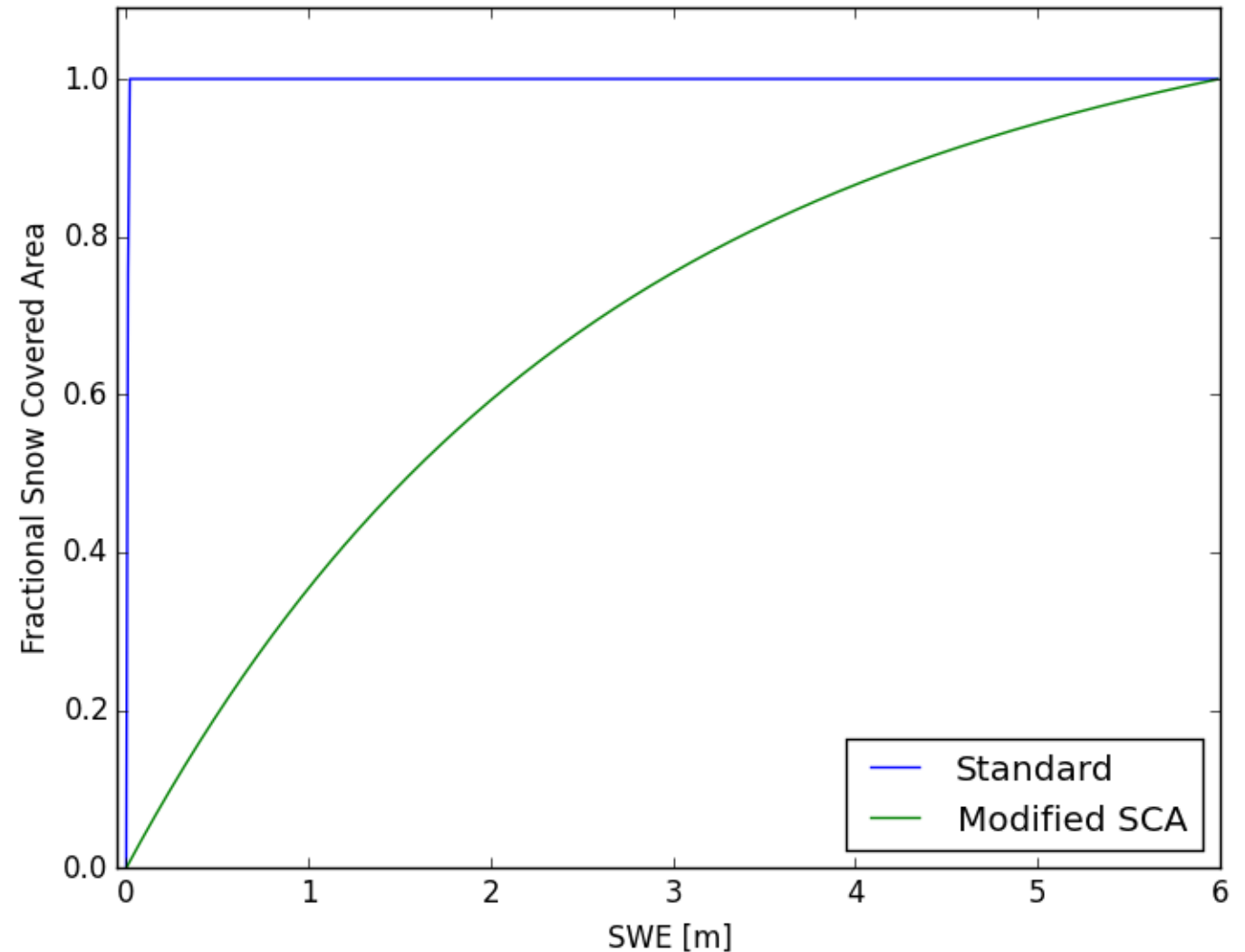
Snow Covered Area in Land Surface Models

- $SCA = f(swe, LC)$
- Above Treeline
 - SWE=2cm, SCA=1!
- Should be closer to
 - SWE=1m, SCA=0.5
- Do we need a better parameterization
- Can we model this explicitly...?

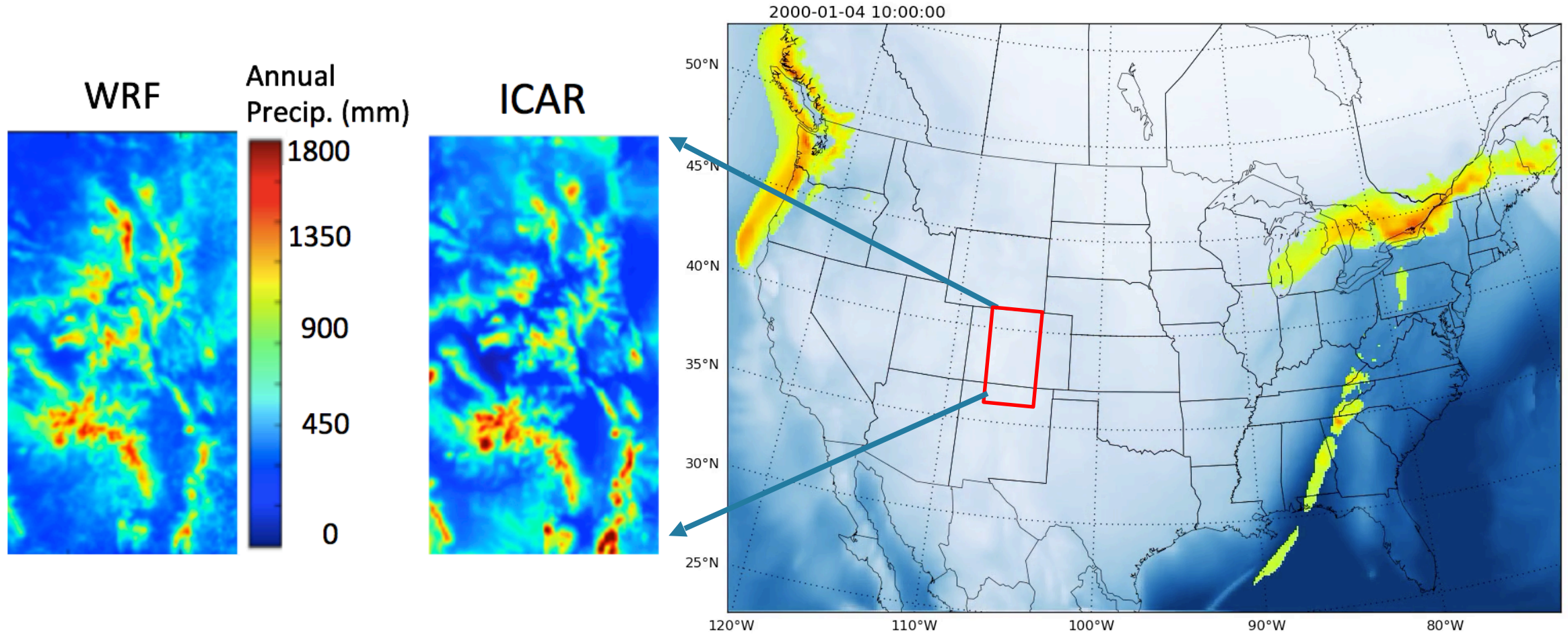


Snow Covered Area in Land Surface Models

- $SCA = f(swe, LC)$
- Above Treeline
 - SWE=2cm, SCA=1!
- Should be closer to
 - SWE=1m, SCA=0.5
- Do we need a better parameterization
- Can we model this explicitly...?

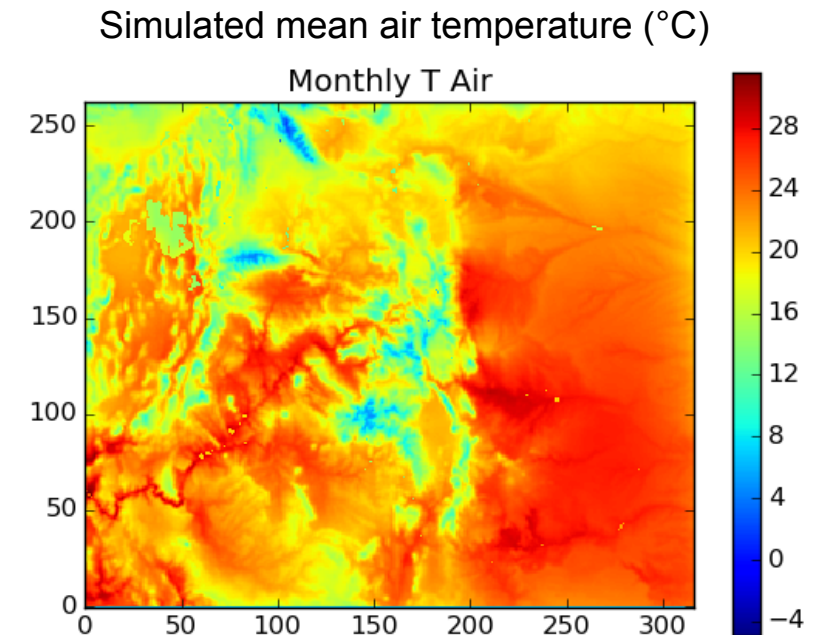
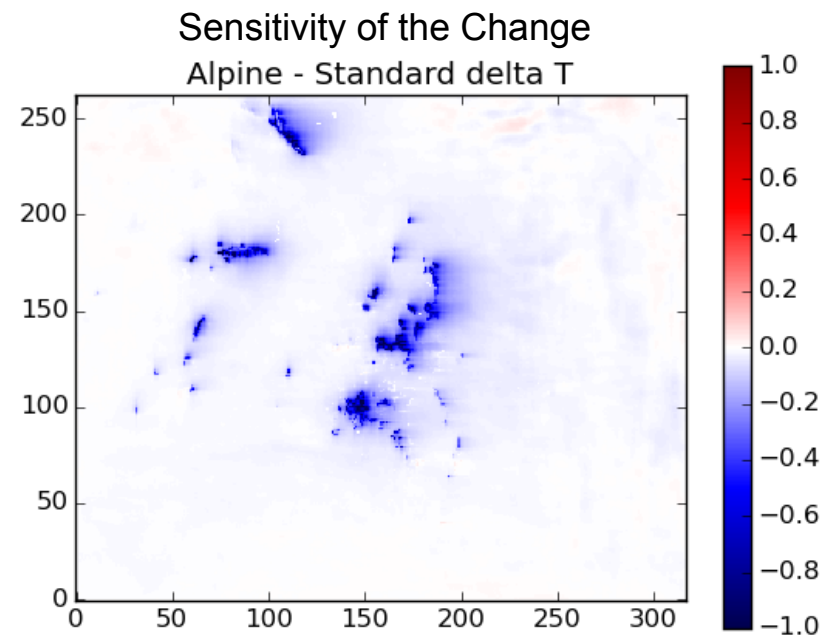
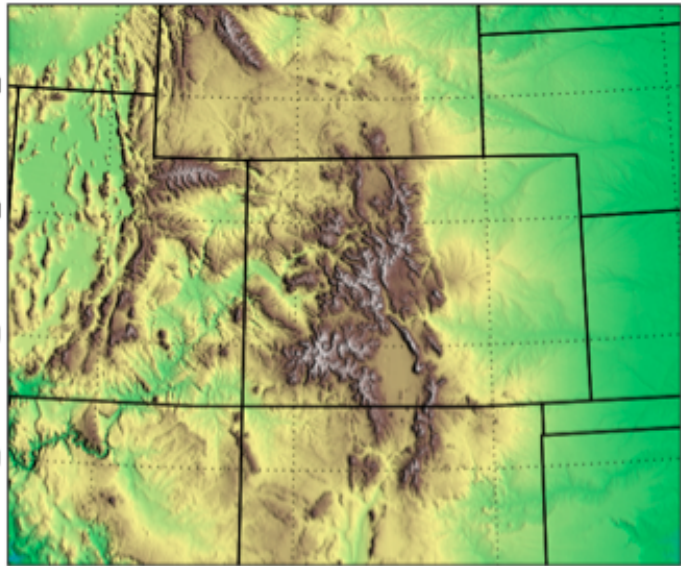
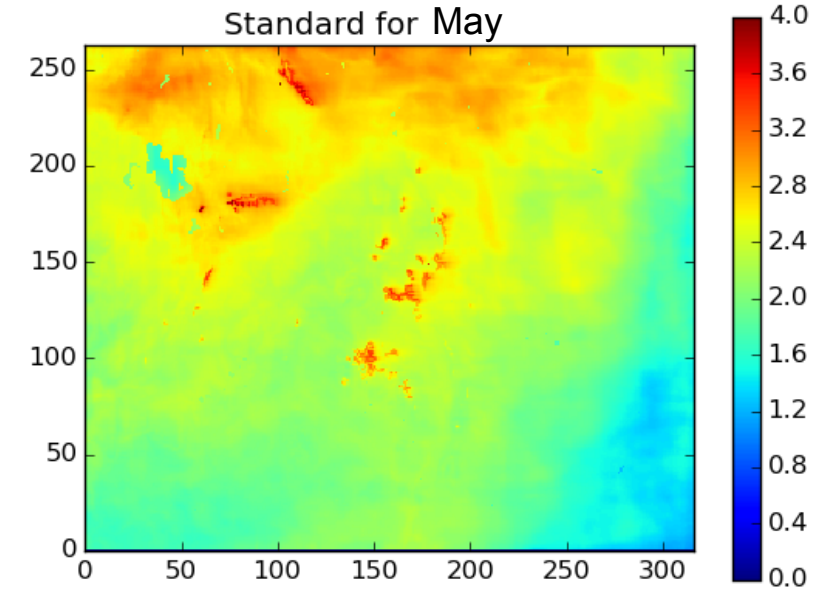
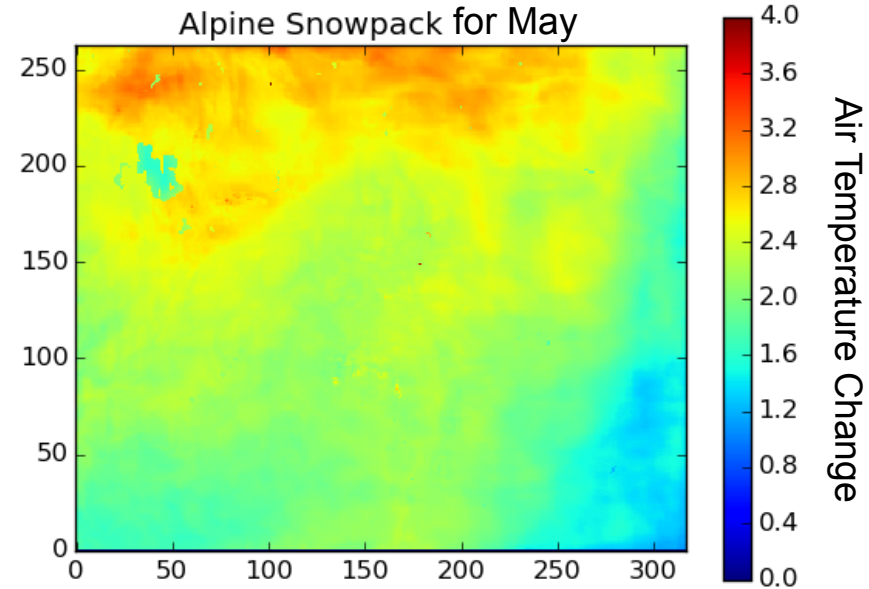


Evaluating regional climate effects with an Intermediate Complexity Atmospheric model (ICAR)



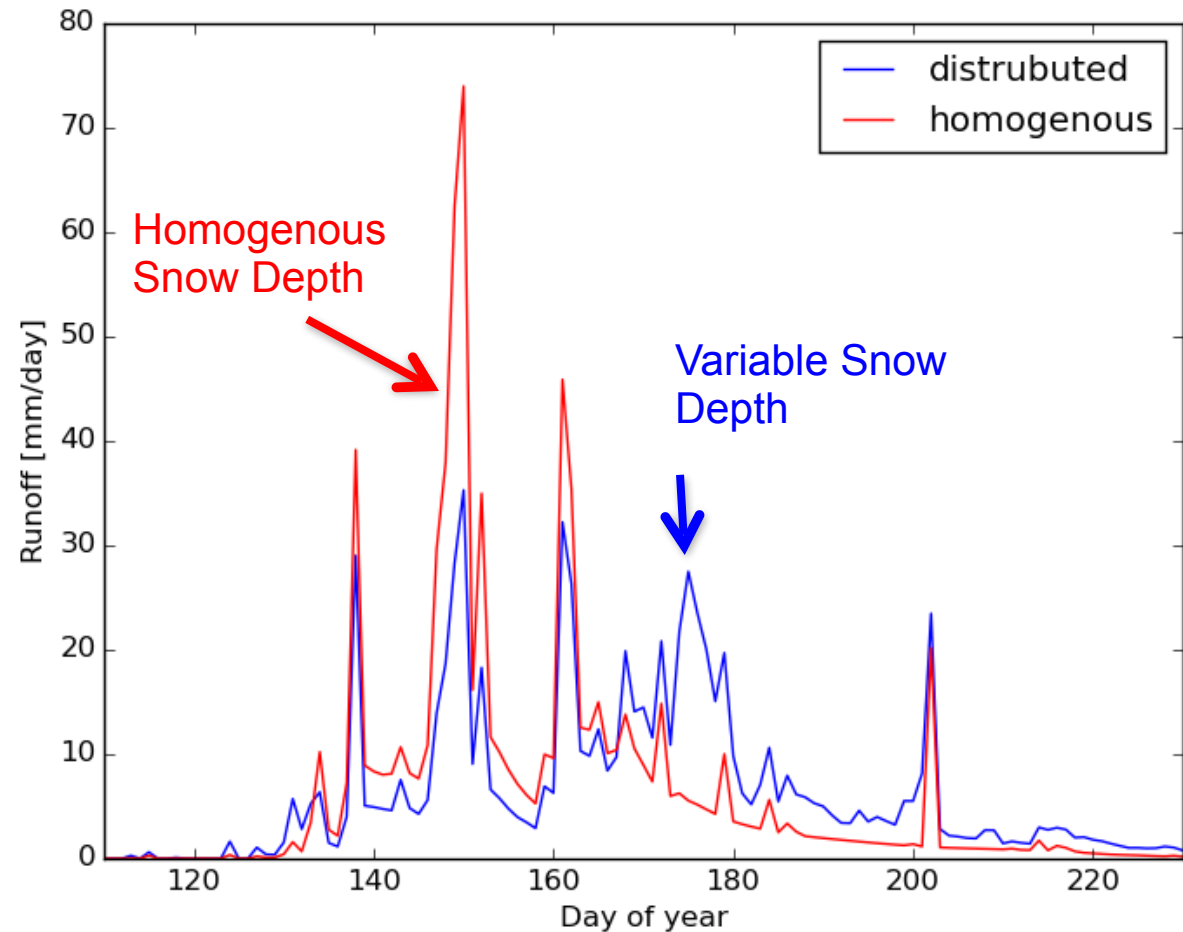
Implications for Changes in Air Temperature

- Simple regional climate model (ICAR: Gutmann et al 2016)
- Run in current and future climate
- Test the SCA curve



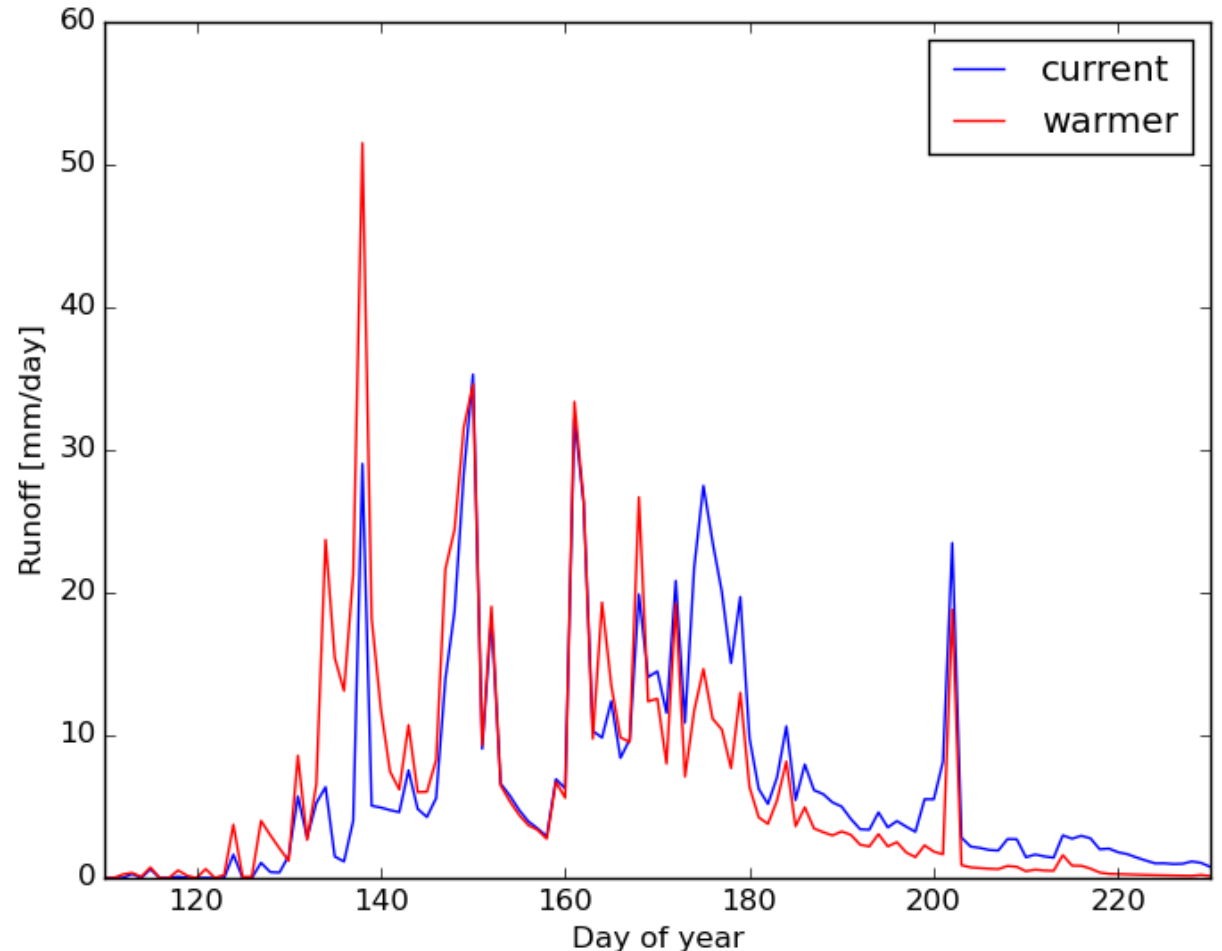
How does this variability effect streamflow?

- **More** late season snowmelt and runoff
- **Less** early spring runoff
 - Less surface area to melt
 - And less to evaporate/sublimate
- ~2% more runoff in total



How does variability affect changes in streamflow?

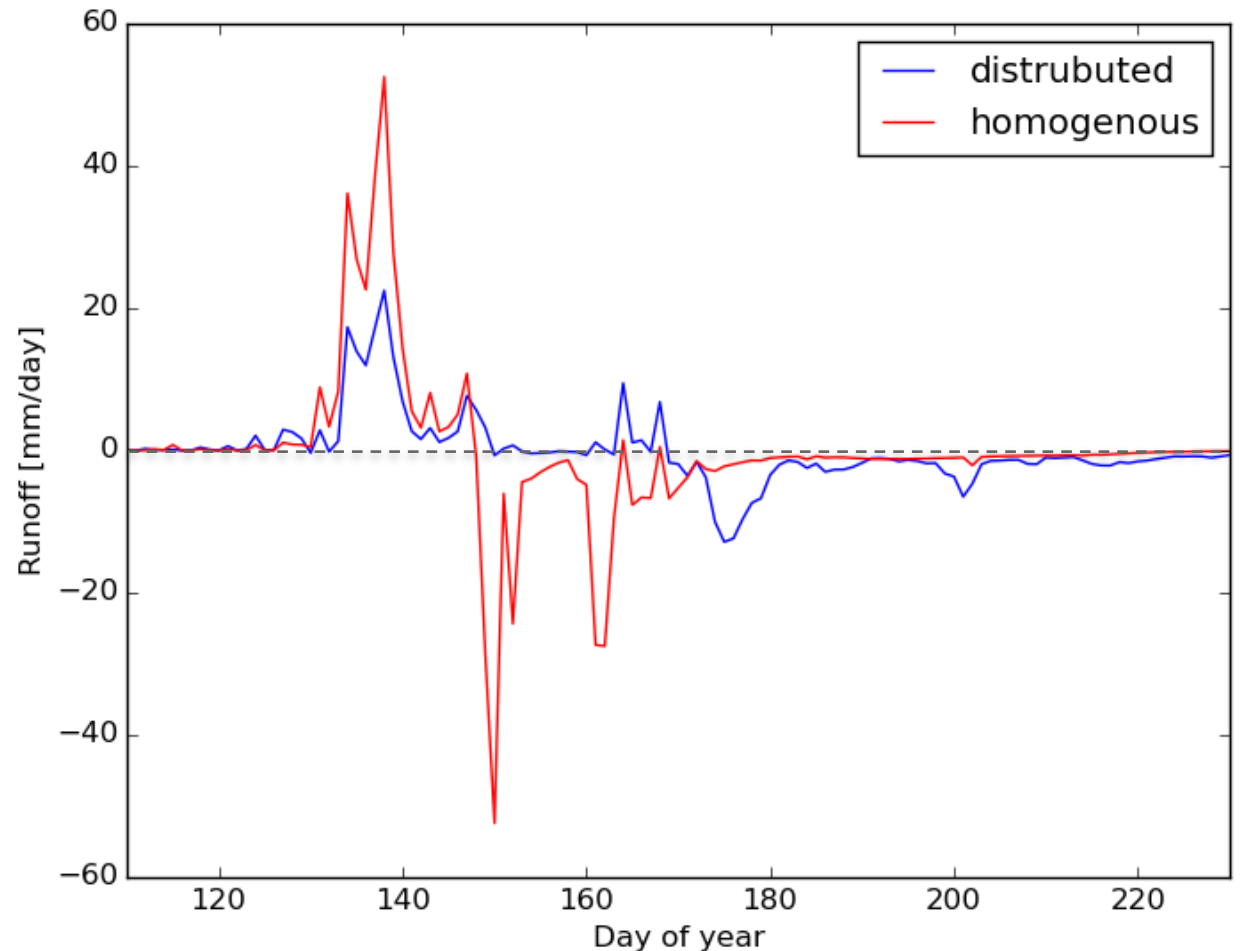
- **Less** increase in early spring runoff
- **Less** decrease in mid-season melt and runoff
- **More** decrease in late-season runoff
- Smaller, longer Change signal (might be easier to manage)
- Slightly smaller change in total runoff (−0.5mm vs −4mm)



How does variability affect changes in streamflow?

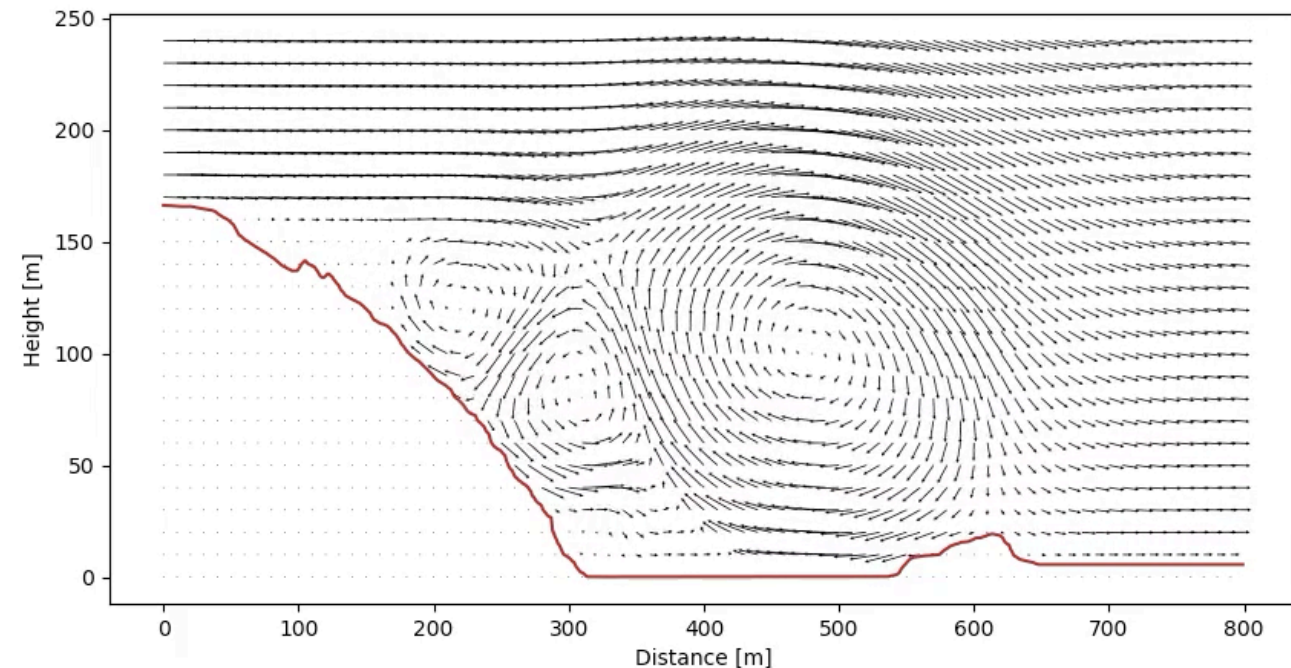
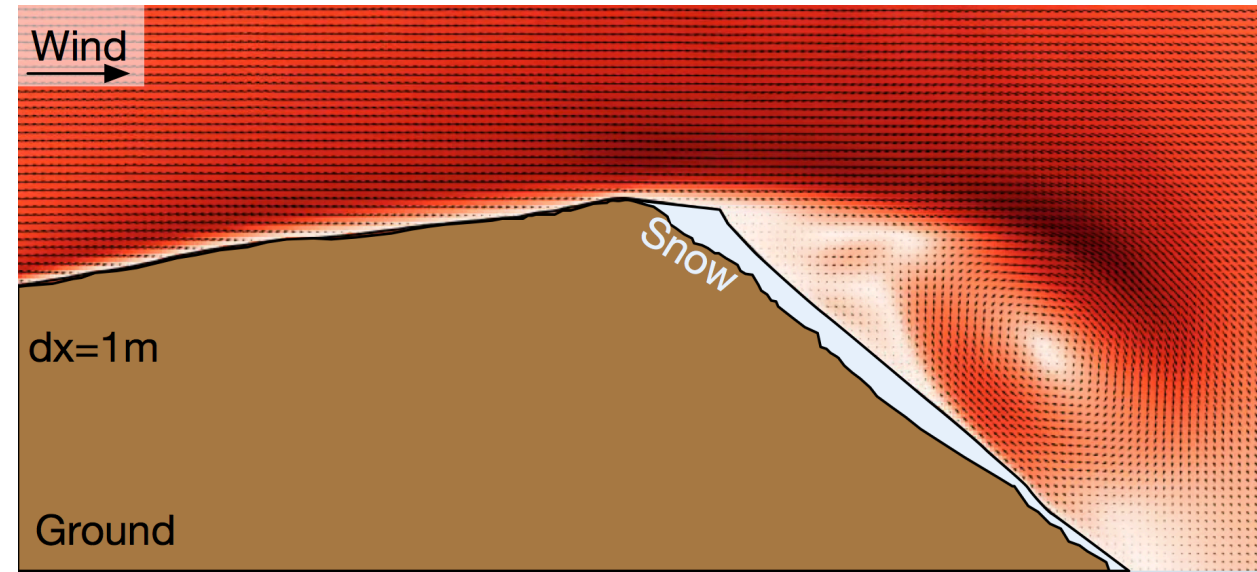
- **Less** increase in early spring runoff
- **Less** decrease in mid-season melt and runoff
- **More** decrease in late-season runoff
- Smaller, longer Change signal (might be easier to manage)
- Slightly smaller change in total runoff (−0.5mm vs −4mm)

Change in Runoff



The fundamental physics are hard

- Air flow over hills is complex
- Simulation requires sophisticated numerical models
 - High-res, immersed boundary...
- There are feedbacks between snow depth and air flow



Summary



Sponsors

- Spatial variability of snow can be enormous
- Heterogeneity greatly reduces snow albedo feedback and air temperature increases
- Heterogeneity affects changes in streamflow
- Inconsistency between homogeneous models and observations problematic for data assimilation

