Regional Climate Change Impacts of the Snow Albedo Feedback in the Colorado Rockies

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- If you see me around the conference, please stop me and ask me any questions!
- For further information, scan the ***QR code*** to check out our recent paper in the Journal of Climate!

The Snow Albedo Feedback (SAF) is a dominant climate feedback in Mid-latitude mountain regions. The SAF enhances warming in mountain regions, where seasonal snow cover is decreasing in response to long-term warming trends, by reducing the surface albedo and altering the surface energy budget. However, the regional scale effects of the SAF and its interactions with surface and terrain driven weather patterns are unstudied. In this study, high resolution regional atmospheric climate model simulations are used to investigate the SAF on the mesoscale in a region with complex terrain.

Key Questions

- How does the SAF modify the regional climate response in the Colorado Rockies
- What is the seasonal cycle of the SAF?
- How does the SAF interact with terrain driven weather

Acronym key

- **LSM:** Land surface model
- **SAF:** Snow albedo feedback
- **pgw:** pseudo global warming
- **CCSM:** Community Climate System Model
- **NARR:** North American Regional Reanalysis
- **WRF:**Weather Research and Forecast model

Conclusions

- SAF is the dominant feature driving warming patterns during spring
- Adds significant variability to regional climate response
  - Inter-seasonal/inter-annual
  - Spatial/Diurnal
- Atmospheric circulations redistribute warming from snow loss regions throughout the domain
  - Enhances warming where snow cover does not change
- Influences regional scale mountain breeze circulations (not shown)

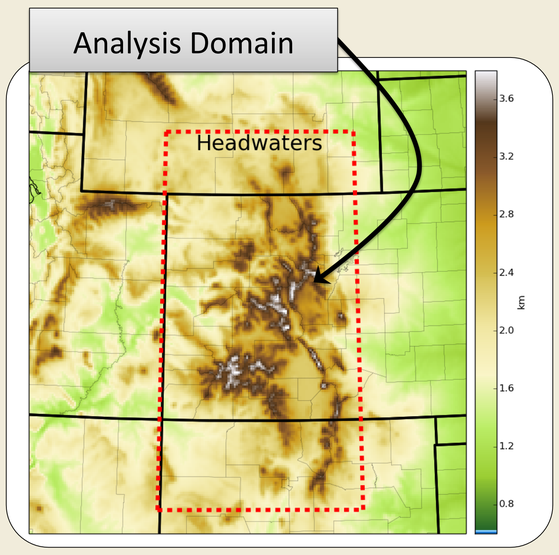
WRF Regional Climate Experiment

Model Details

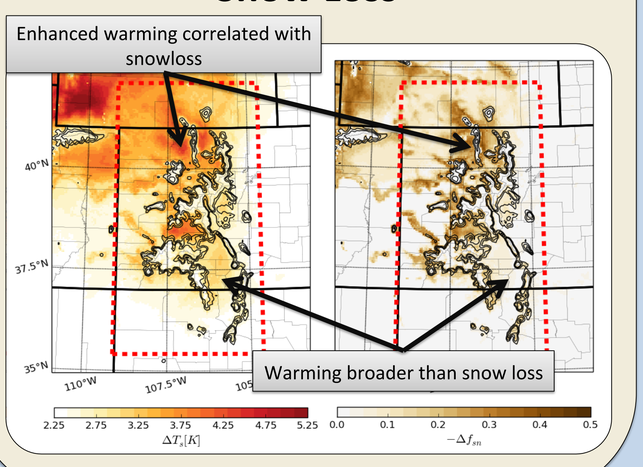
- Rasmussen et al (2014)
- 4km grid-spacing
- NARR Forcing
- 8-year simulation
  - 2000-2008
- Noah LSM
  - Snow model adjustments Barlage (2010)
- Convection Permitting

Pseudo Global Warming Experiment

- **Two** simulations
  - Control (ctrl), perturbed (pgw)
- Mean perturbation added to boundary forcing
  - Same "weather" simulated under warmed climate
- 10-year mean CCSM3 ensemble mean output centered on 2055
- CO_2 = 533 ppm

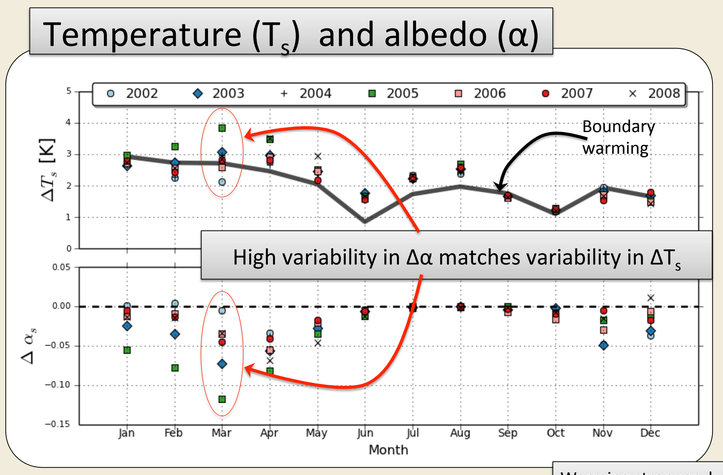


Example: April Warming and Snow Loss

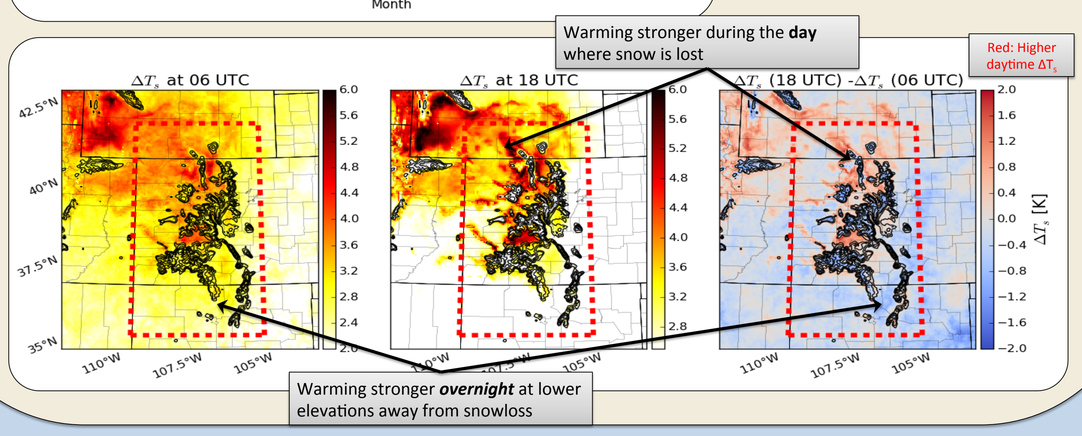


Inter-annual and Diurnal Variability

Temperature (T_s) and albedo (α)



- Adds regional variability to global climate forcing
- Warming is diminished but more widespread overnight
- Redistribution of SAF warming overnight by regional scale mountain wind regimes?



Linear Feedback Analysis

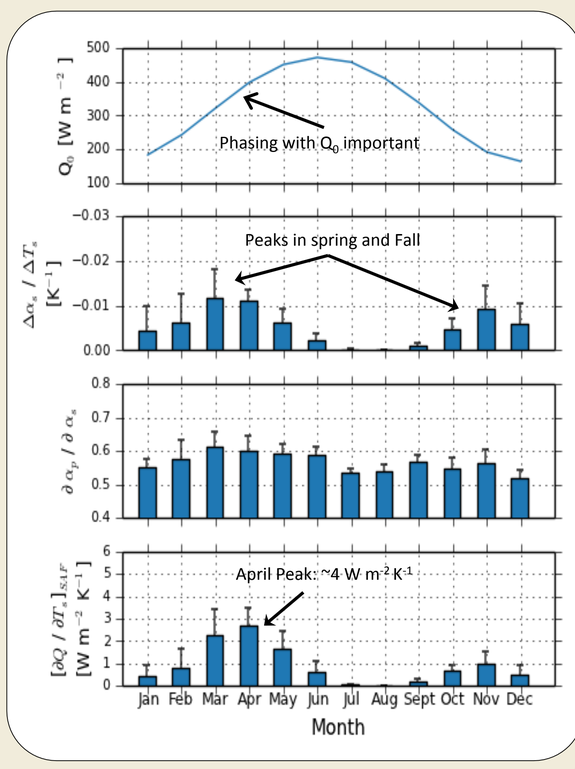
Goal

- Compute energy fed back into climate system by the SAF per degree of surface warming
- W m^{-2} K^{-1}

$$\left(\frac{\partial Q}{\partial T_s}\right)_{\mathrm{SAF}} = -Q_0 \frac{\Delta\alpha_s}{\Delta T_s} \frac{\partial\alpha_p}{\partial\alpha_s}$$

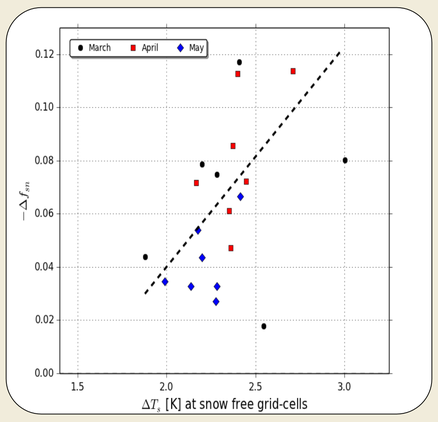
Solar Radiation
Surface Albedo and Warming (pgw-ctrl)
Effect of surface albedo on planetary Albedo

- SAF is strongest during the spring transition season
  - High year-to-year variability
- Variability driven by $\Delta\alpha/\Delta T_s$ not $\partial\alpha_p/\partial\alpha_s$
  - Fall: Delayed onset of accumulation season
  - Spring: Earlier onset of snowmelt season
- High sun angle during springtime important for timing of maximum SAF strength



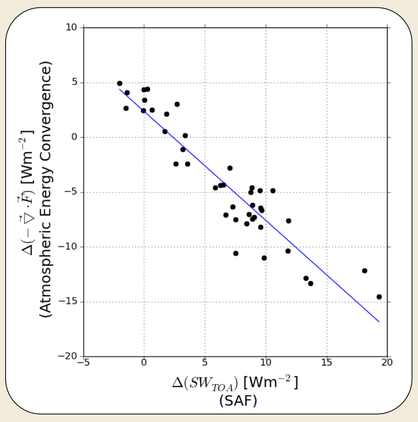
Non-local Warming

- Warming at "snow free" grid points is enhanced by the SAF.
- Enhanced remote warming associated with transport of SAF warming by circulation
- Most important during the spring months



Energy Transport

- As SAF strength increases, ***more*** energy is ***exported*** from the region via atmospheric circulation
  - Negative change in energy *convergence*
- Energy transport is a regional "***negative feedback***" to the SAF
  - Reduces enhanced warming where SAF is active
  - Extends the effects of the SAF beyond snowloss areas



References

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- Barlage, M., et al (2010), Noah land surface model modifications to improve snowpack prediction in the Colorado Rocky Mountains, J. Geophys. Res., 115
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