Precipitation downscaling using the Intermediate Complexity Atmospheric Research model (ICAR) in Western Canada

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Motivation

- Climate model outputs are still too coarse for hydrological applications.
- High resolution numerical weather prediction (NWP) models are too expensive to run for climate change impacts on the hydrological processes.
- The assumption of stationary relationships between atmospheric variables and local observations in both current and future climates restricts statistical downscaling application in impact studies.
- High spatial variability of meteorological variables (e.g., precipitation, temperature, and wind) in complex terrain has important hydrologic consequences.

Hypothesis:
If we can still obtain reasonably good simulation for precipitation in complex terrain in cold regions with reasonable reductions in the complexity of the climate and weather models?

Significance:
Reliable downscaling of orographic precipitation with non-linear characteristics and higher spatiotemporal variability improves the hydrometeorological prediction uncertainties.
Study Areas & Model Domains

- 13x13 RCM grids (WRFG-CGCM)
- 325x325 High resolution grids (2kmx2km ICAR)
Intermediate Complexity Atmospheric Research model (ICAR)

Identify the key physics and develop a simple model
GOAL: ~90% of the information for <1% of the cost
\[ \hat{u}(k, l) = \frac{-m(\sigma k - ilf)i\hat{\eta}}{k^2 + l^2} \]

\[ \hat{v}(k, l) = \frac{-m(\sigma l + ikf)i\hat{\eta}}{k^2 + l^2} , \]

\[ \hat{w}(k, l) = i\sigma \hat{\eta} \]

\[ \hat{\eta}(k, l) = \hat{\eta}e^{imz} , \]

\[ m^2 = \frac{N^2 - \sigma^2}{\sigma^2 - f^2(k^2 + l^2)} \]

\[ \sigma = Uk + Vl \]
Ideal ICAR Evaluation
Real World ICAR Evaluation

- Cool season (Oct-May) total precipitation in WRF and ICAR are in good agreement.

- Cool season precipitation is critical for mountain snowpack and water resources in the western United States.

- Differences between WRF and PRISM are comparable to differences between ICAR and PRISM.
Annual precipitation in the Yukon Territory

- Gridded Observation (ANUSPLIN) 10kmX10km
- ICAR driven by ERA-Interim 2kmX2km
- ICAR driven by WRFG-CGCM 2kmX2km
Seasonal precipitation in the Yukon Territory

ICAR-RCM/GCM

ANUSPLIN

ICAR-ERA-Interim
Seasonal precipitation in the Yukon Territory
Seasonal precipitation in the Yukon Territory
Seasonal precipitation in the Yukon Territory
Total precipitation in ICAR and observation are relatively in good agreement.

Lower resolution of forcing products causes ICAR to miss convection precipitation in the plains.
Seasonal precipitation in the Canadian Rockies
Seasonal precipitation in the Canadian Rockies
Seasonal precipitation in the Canadian Rockies
Seasonal precipitation in the Canadian Rockies
Conclusions

- For climate change impacts studies with multiple RCM/GCM forcing products, we need a model like the Intermediate Complexity Atmospheric Research model (ICAR) to:
  - overcome the high computation costs
  - Keep key physics with only losing ~10% of the information when compared with WRF model outputs.

- Uncertainties in gridded observation products make assessment of the model performance challenging.

- Initial ICAR test in Western Canada shows that with appropriate forcing data we can capture the orographic precipitation with high resolution for hydrological applications and with only 1% of the computation cost when compared with WRF.

- Annual and Jun-August downscaled precipitation is in good agreement with the observations in both the Yukon Territory and Canadian Rockies.

- Ongoing work will hopefully improve the convection precipitation parameterization in ICAR.
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