Improvements of Snow Simulations in the Weather Research and Forecasting Model

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Introduction

1. **70-80% of water resources are derived from snow melt in the western United States.**

2. **Accurate forecasts of snow are vital to the region's well being.**

3. **This study is focused on better understanding and improving snow simulations in an advanced regional climate model.**

The WRF Model

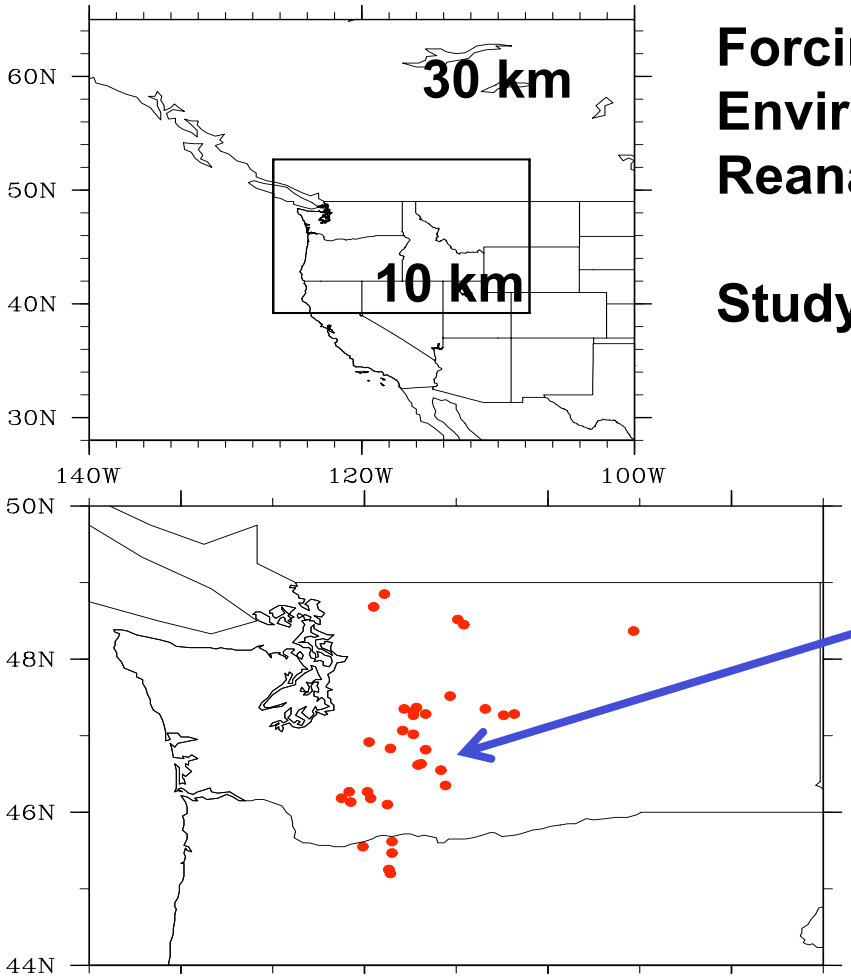
The Weather Research Forecasting Model (3.0) was recently coupled with Community Land Model version 3.5 (CLM3.5) to improve snow simulations (Jin et al 2010; Subin et al 2010).

Both WRF and CLM were developed by the National Center for Atmospheric Research.

Comparison of the Land Surface Models within WRF

	Vegetation	Soil	Snow
Noah	One vegetation type in one grid cell	4 layer temperatures and moistures and frozen soil	1 layer snow lumped with the top soil layer; No liquid water; Fixed snow density
RUC	One vegetation type in one grid cell	6 layer temperatures and moistures and frozen soil	2 layer snow; No liquid water; Fixed snow density
CLM	Up to 10 vegetation types in one grid cell	10-layer temperatures and moistures and frozen soil	5 layer snow with liquid water; Variable snow density

WRF Simulation Domains

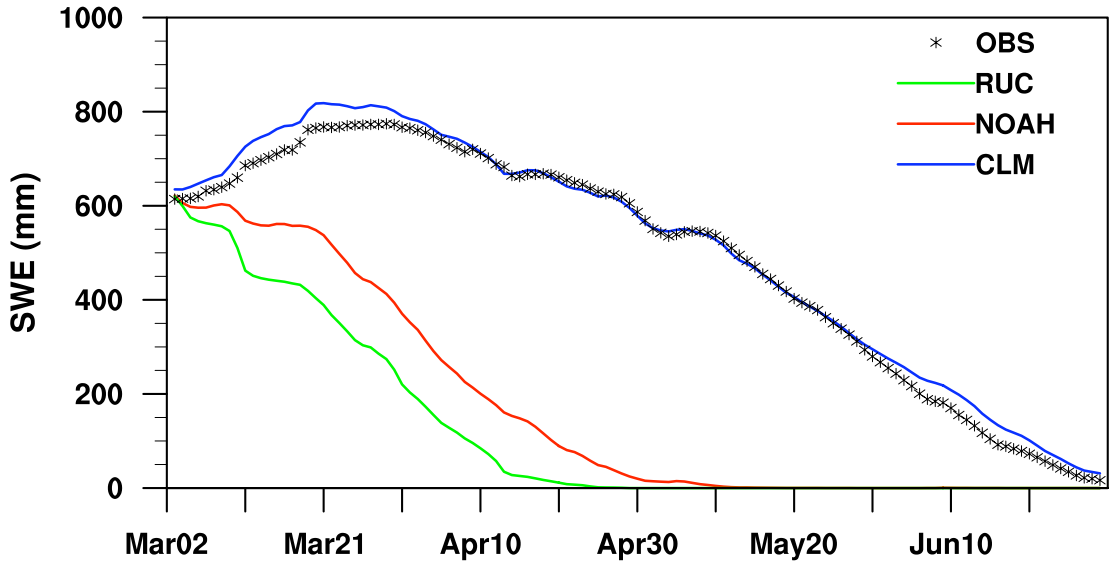


Forcing Data: National Centers for Environmental Prediction Reanalysis data

Study Period: 3/1/-6/30, 2002

35 Snow Telemetry (Snotel) Stations

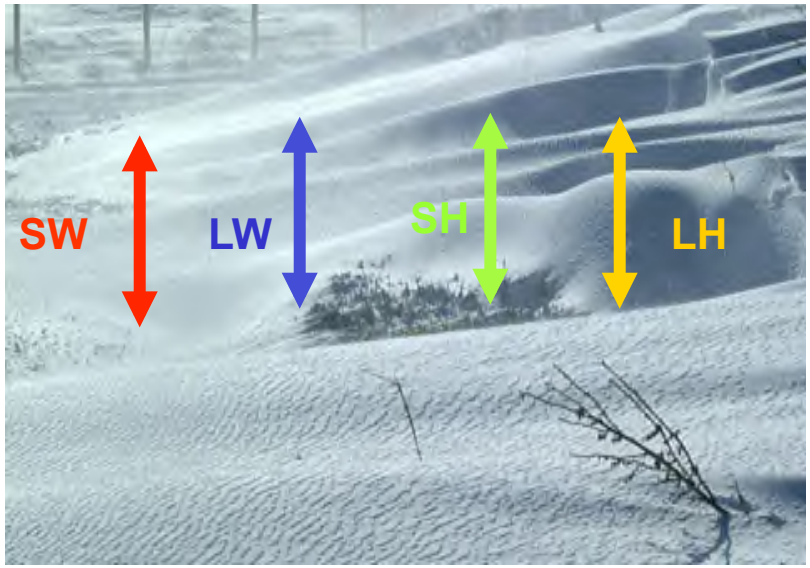
WRF Snow Simulations at 10 km Resolution

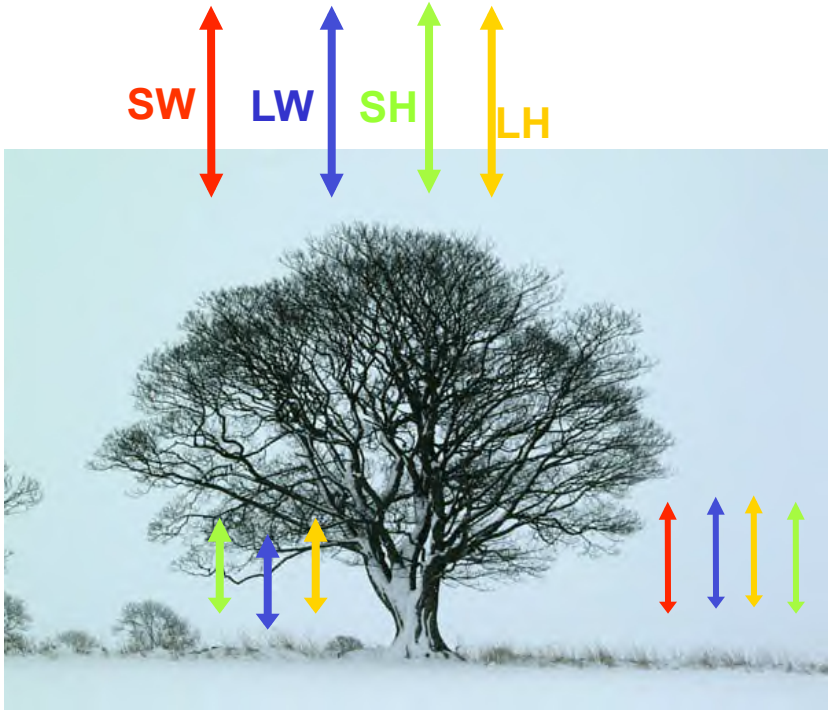


	OBS	CLM	NOAH	RUC
SWE (mm)	494	511	174	123

Surface Energy Balance Equation in the NOAH and RUC Models

(1- Alb) SWD + LWNET = SH + LH + G + SM

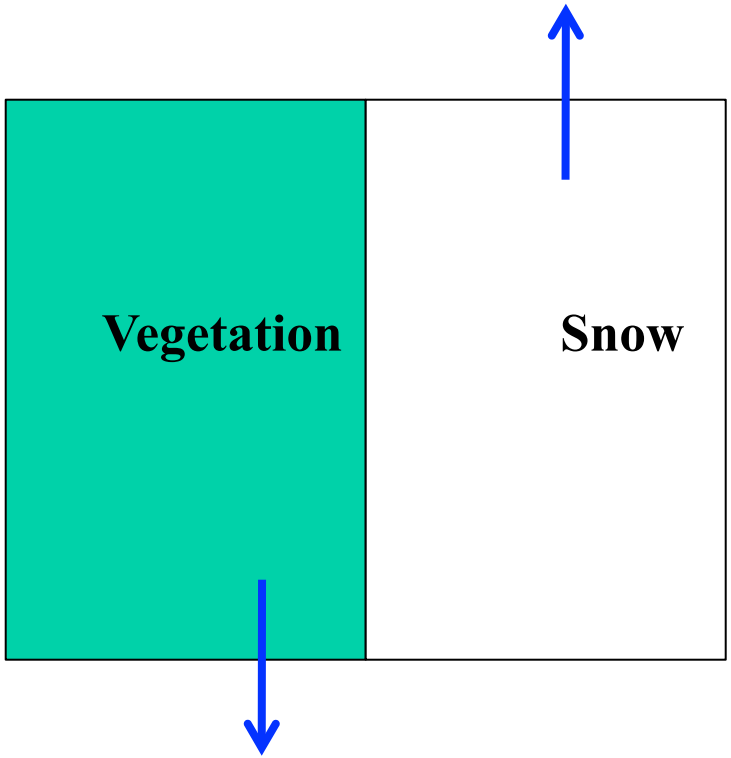




In the NOAH and RUC model, no vegetation fraction is formulated.

Surface Energy Balance Equations in CLM

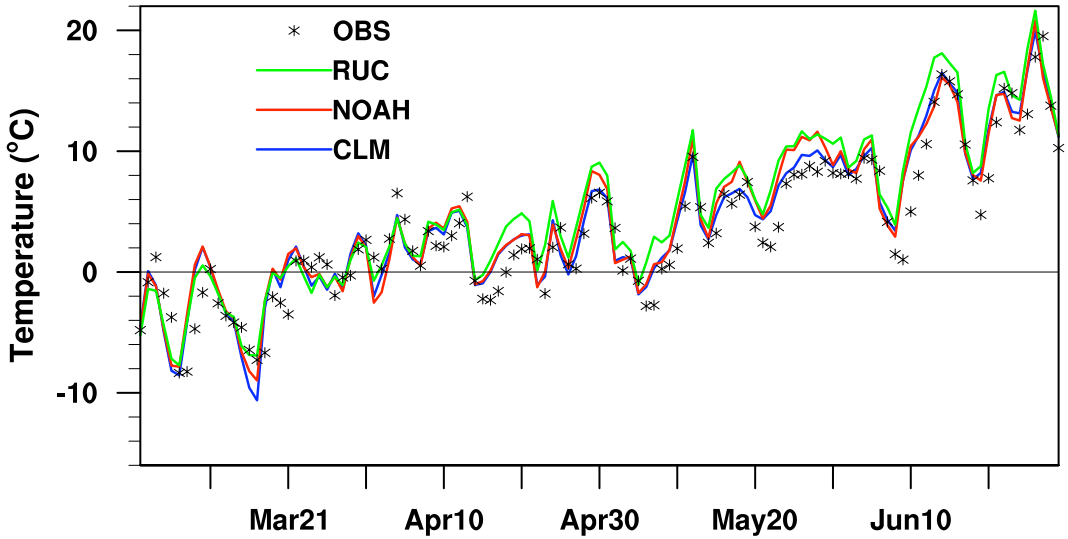
Snow: $(1- Alb_{snow})\ SWD_{snow} + LWNET = SH + LH + G + SM$



Canopy: $(1- Alb_{veg})\ SWD_{veg} + LWNET = SH + LH + G$

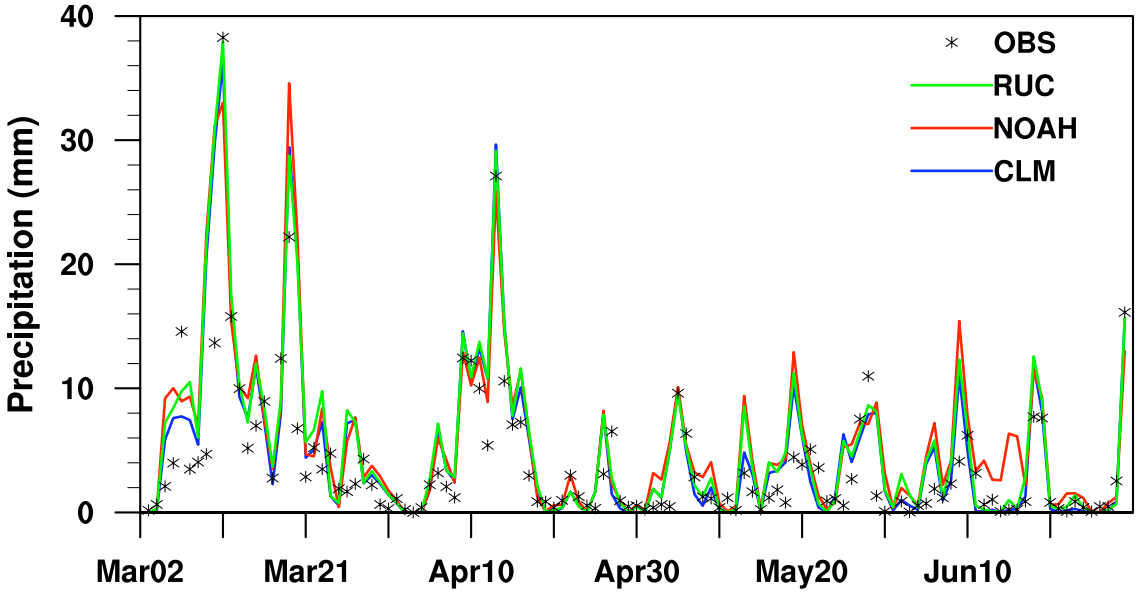
Snow under the canopy: $LWNET = SH + LH + G + SM$

WRF Snow Simulations at 10 km Resolution



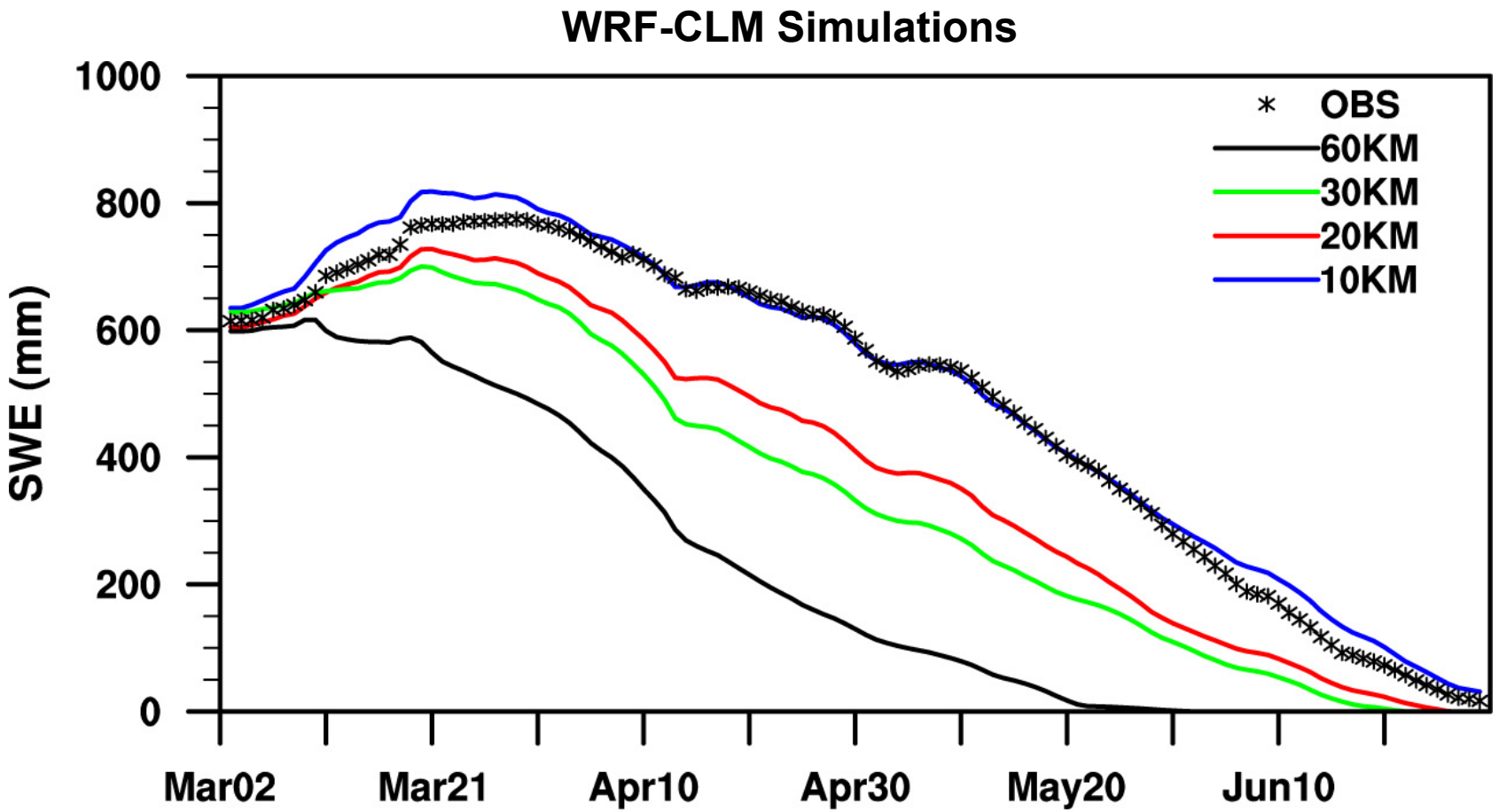
	OBS	CLM	NOAH	RUC
Temp (°C)	3.5	4.1	4.4	5.1

WRF Snow Simulations at 10 km Resolution

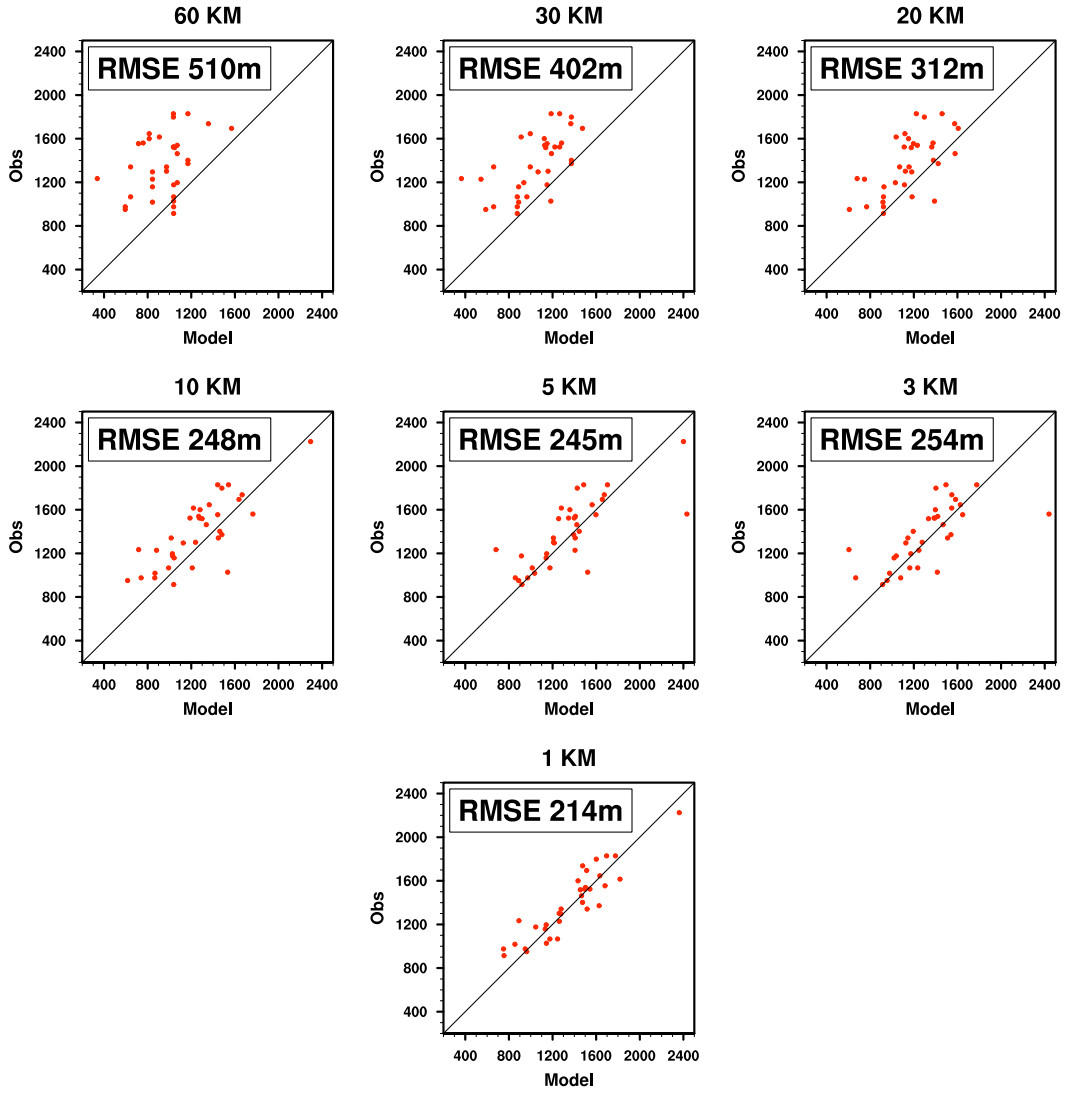


	OBS	CLM	NOAH	RUC
PCP (mm/day)	3.9	5.0	5.8	5.5
Latent Heat Flux (Wm^{-2})		30	63	49

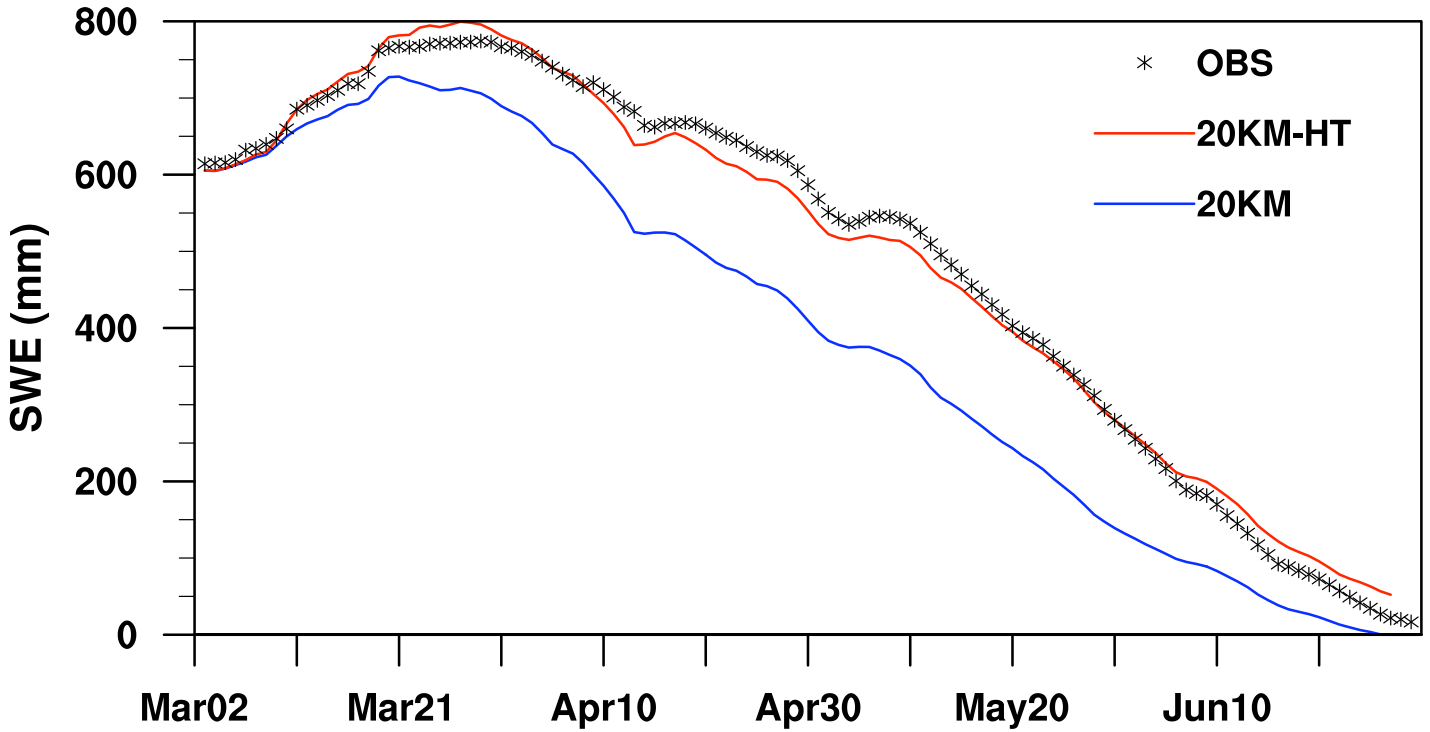
WRF-CLM Snow Simulations at Different Resolutions



WRF-CLM Snow Simulations at Different Resolutions



WRF-CLM Snow Simulations at 20 km Resolutions



Conclusions

1. **Coupling CLM into WRF significantly improves snow, temperature, and precipitation simulations when compared to those produced by WRF with the NOAH and RUC land surface schemes.**

2. **The improvements results from more realistic surface energy allocation in CLM.**

Conclusions

3. This study also shows that topography also have a significant impact on snow simulations

4. CLM produces most accurate SWE simulations at 10 km resolution over the Columbia River Basin.

Conclusions

5. However, realistic SWE simulations with WRF-CLM can still be achieved at a coarser resolution (20 km) when the model elevations at the Snotel stations were replaced with actual values, further indicating the importance of the topography to SWE simulations over this mountainous region.

The WRF Model settings

The settings within WRF:

1. **Microphysics : the Lin et al. scheme**
2. **Shortwave radiation: Goddard shortwave scheme**
3. **Longwave radiation: the RRTM scheme**
4. **Planetary boundary layer: the Mellor-Yamada-Janjic TKE scheme**
5. **Cumulus: the Grell-Devenyi ensemble scheme**

WRF Precipitation Simulations at 10 km Resolutions