Impact of model resolution on rainfall for Arizona using WRF model

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Introduction

- This study performs regional climate simulations for the winter season in Arizona, a region with dramatic contrasts in topography and local rainfall patterns.
- The dependence of the simulated rainfall on the model resolution and the switching on/off of cumulus parameterization scheme is evaluated.
- Winter is chosen for simulating precipitation because the model generally simulates the climatology of the cold season more accurately than the warm season.
- Using the WRF 3.1 model, we perform a series of seasonal simulations with multiple nesting centered in Arizona for seven 92-day runs for each winter season (November-January) from 2003-2009.

Model Setup

- Time-varying large-scale boundary condition is constructed from 6-hourly NCEP Global Analysis (FNL) data on 1 deg x 1 deg grid.
- The model has 28 levels in the vertical for all runs with the model top pressure as 50 hPa.
- Liquid-form precipitation (RAINC and RAINNC) and its associated vertical velocity is analyzed.

Nesting	Resolution			Cumulus convective parameterization (Kain-Frisch scheme)
	Outermost domain	Intermediate domain	Innermost domain	
2 layer	36 km	-	12 km	ON
3 layer	54 km	18 km	6 km	ON
				OFF
3 layer	48 km	12 km	3 km	OFF

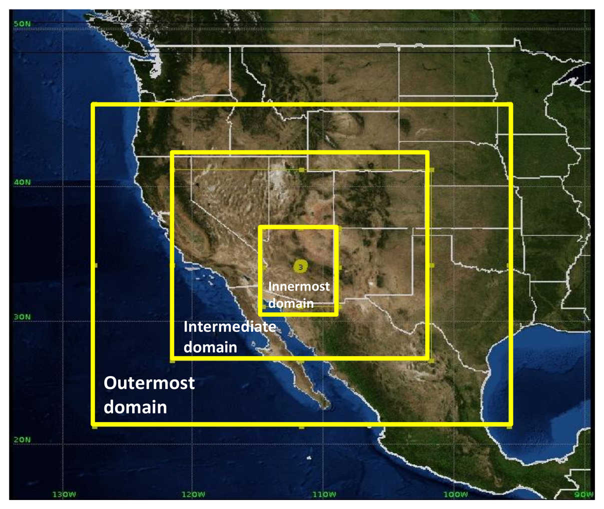

Fig 1. Nested domains

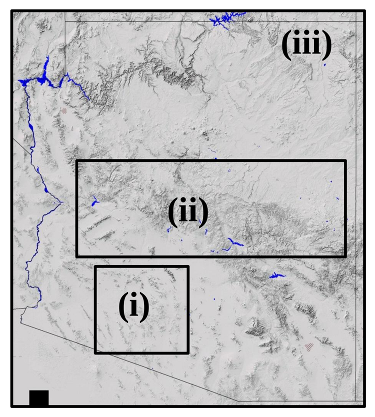

Fig 2. Innermost domain (AZ)

Results

Seasonal cumulative rainfall

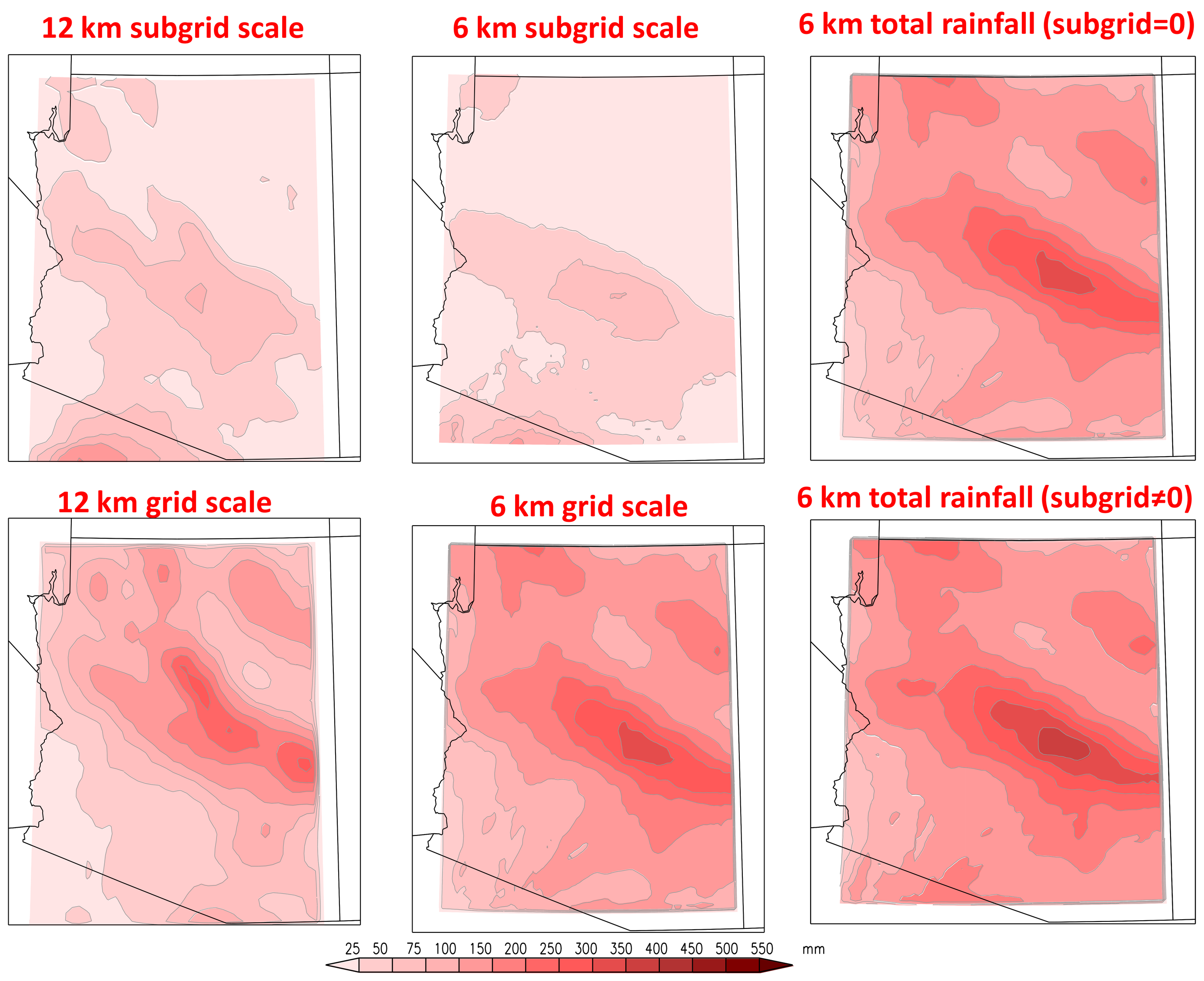

Fig. 3. Cumulative rainfall for winter season averaged over 7 winters from 2003 to 2009 for different set of runs.

- At 6 km resolution, two sets of runs with convective scheme turned on and off produced approximately equal amount of total rainfall, because in the latter grid-scale rainfall increases to compensate for the absence of subgrid-scale contribution.

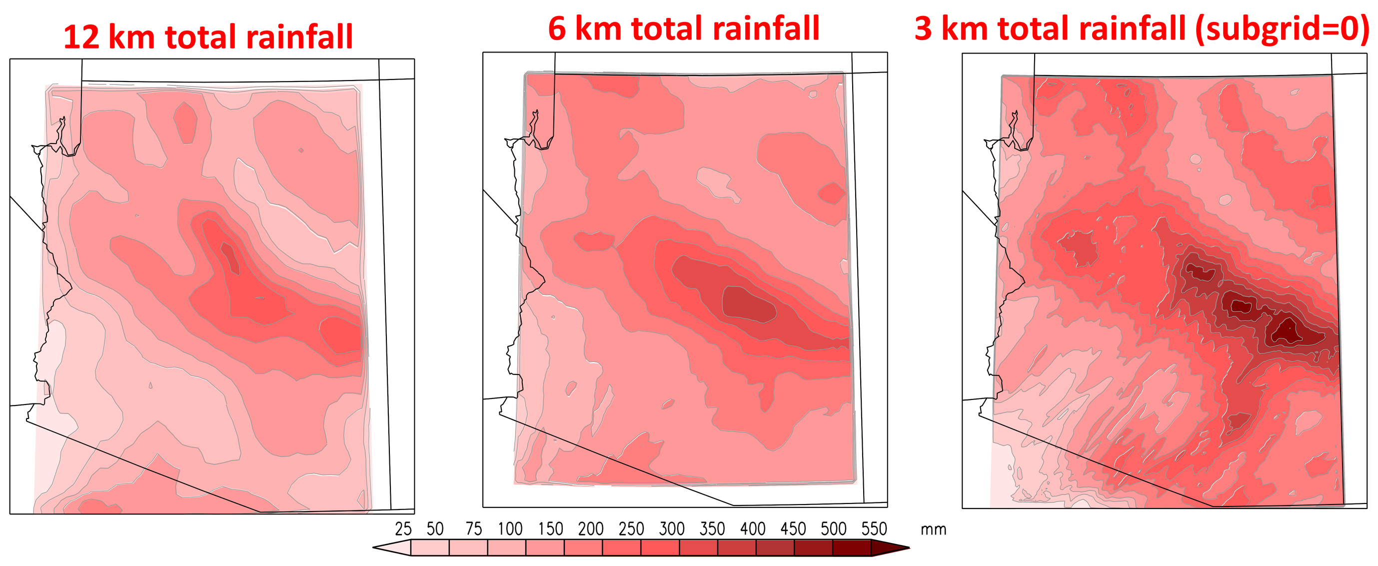

Fig. 4. Cumulative total average rainfall for winter season averaged over 7 winters from 2003 to 2009 for different set of resolutions.

- Total rainfall increases with resolution.
- Enhanced rainfall over the mountains in central Arizona.
- At 3 km resolution, footprints of "streaks" of convective storms moving across the relatively flat southern Arizona.

Temporal characteristics of rainfall and extreme events

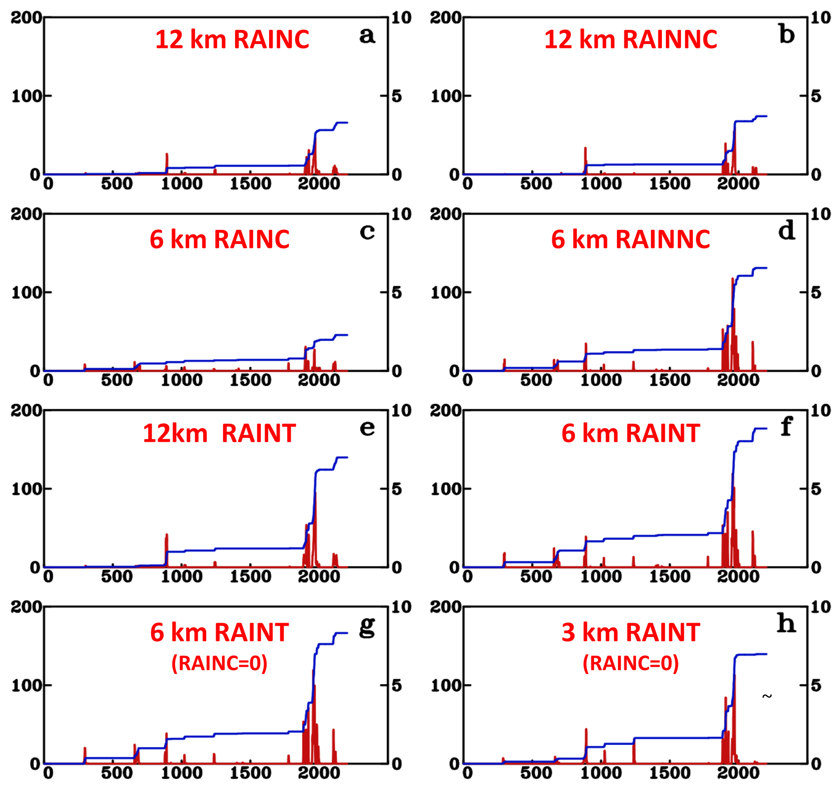

Fig. 5. Time series of hourly averaged rainfall (mm) over box (i) in Fig. 2 from 1 Nov 2009 - 31 Jan 2010.

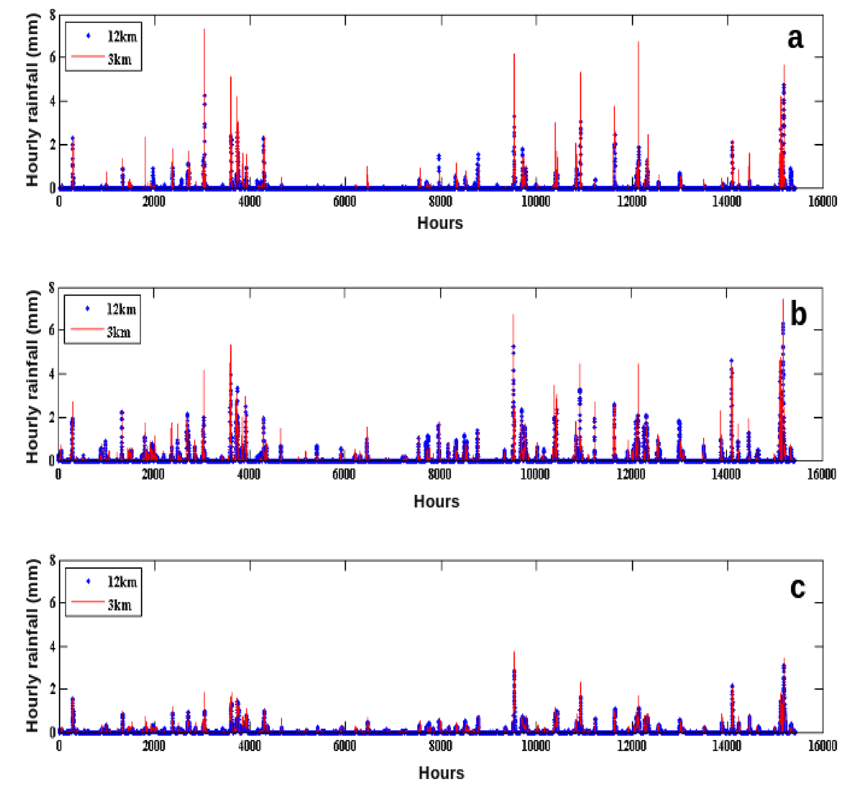

Fig. 6. Time series of hourly averaged rainfall (mm) over (a) box (i), (b) box (ii), and (c) innermost domain (AZ) box (iii) in Fig. 2 for 7 winter seasons.

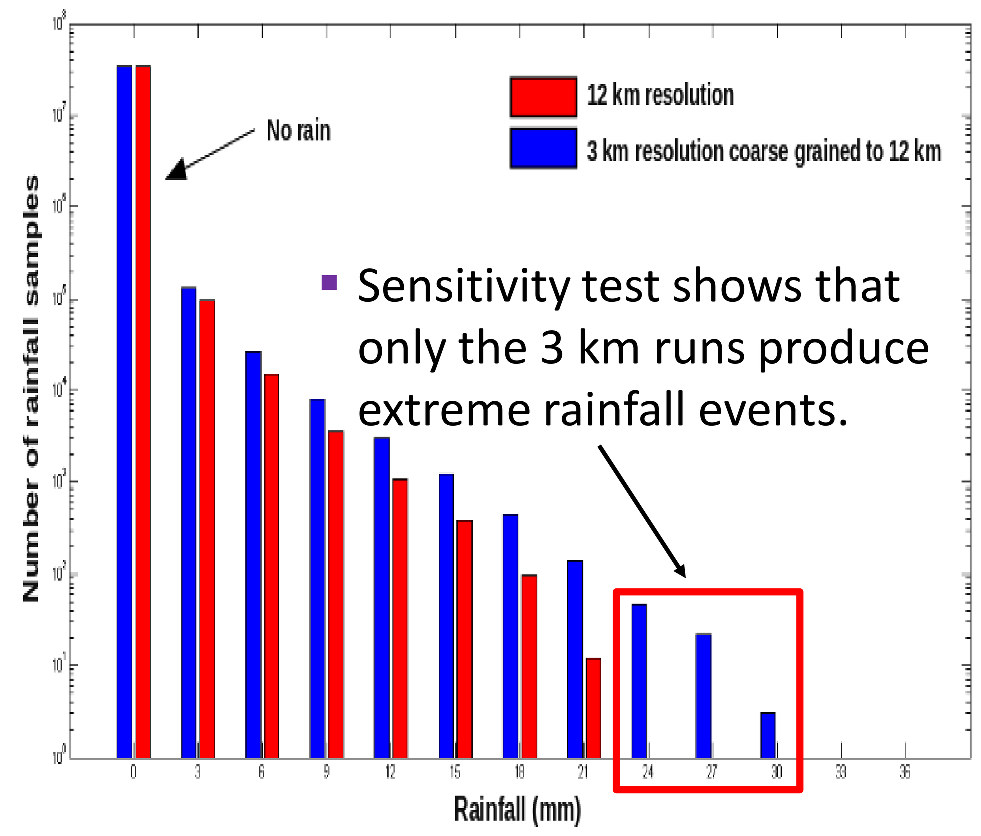

Fig. 7. Comparative histogram for rainfall with 3 mm bin size for 12 km and 3 km resolution (coarse grained to 12 km).

- Sub-grid scale parameterized and grid-scale rainfall generally has a similar pattern in their temporal evolution.
- A rainfall event is picked up by both 12 km and 3 km runs.
- The rainfall for 12 km run is less intense than the 3 km run for the same event.

Vertical Velocity

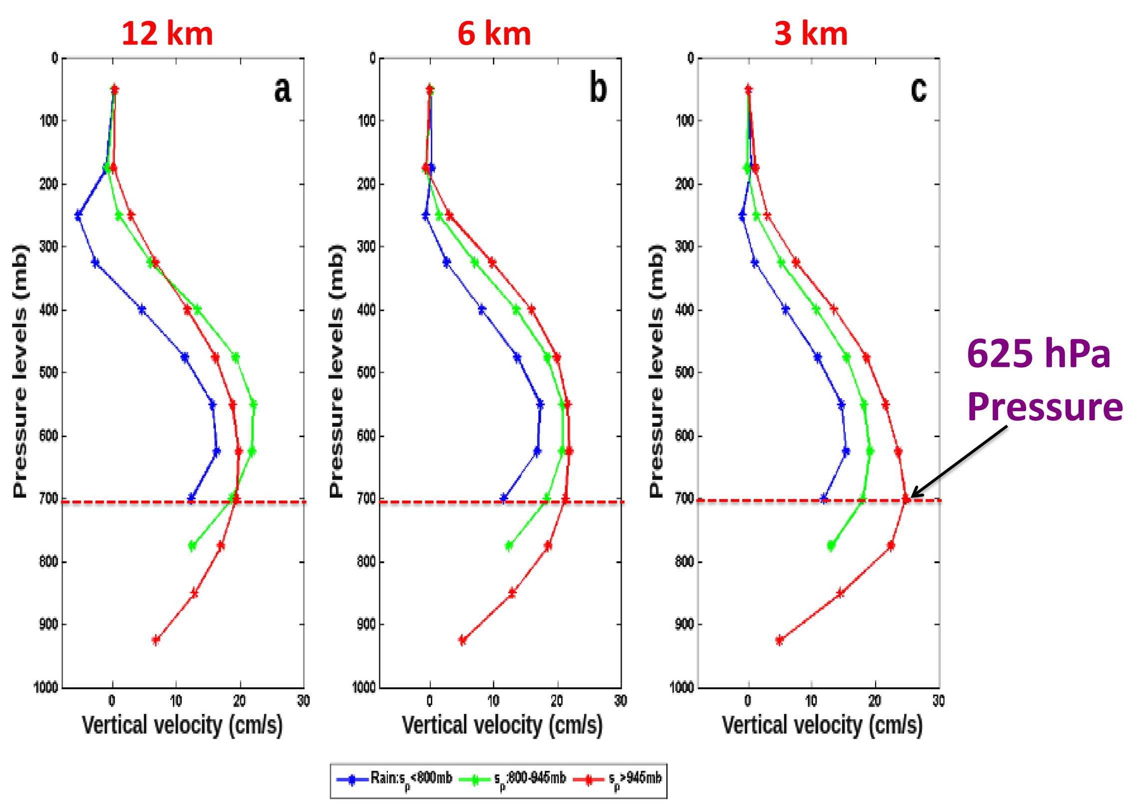

Fig. 8. Average vertical wind velocity profile (cm/s) for different grid resolutions.

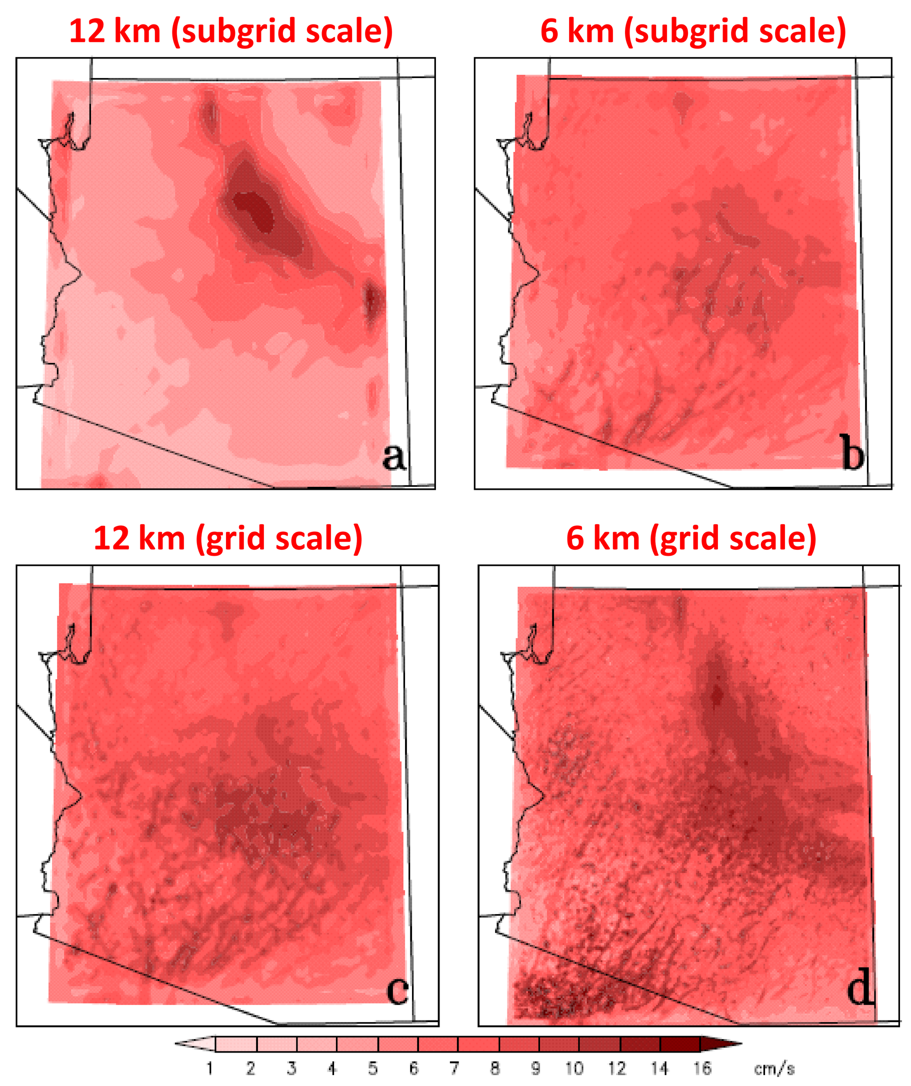

Fig. 9. The standard deviation of vertical velocity at 625 hPa level for different cases.

- The changes in rainfall are accompanied by changes in the characteristics of vertical motion over different parts of Arizona.
- At 12 km maximum vertical velocity is mostly associated with large-scale topographic lifting over northern Arizona.
- At 6 km north-south oriented "stripes" in southern Arizona reflect the movement of rain-producing storms.
- They become even more prominent in 3 km run showing organized convection over the relatively flat southern Arizona.

Conclusions

- Substantial changes in the intensity and characteristics of rainfall and vertical motion as the model resolution approaches the cloud-resolving scales.
- Climate downscaling should not stop at the 30 km or 15 km resolution commonly adopted in practice today.
- Use high-resolution model (~ 3 km) for extreme events analysis of semi-arid regions.

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