A simple variography based metric to indicate spatial similarity in simulated rainfall fields

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To capture spatial characteristics, but avoid dependence on co-location, a metric based on the semi-variogram parameters 'sill' and 'range' is applied and tested. The distance metric was found to summarise similarity in spatial variability and dependence.

Background, data and methods

Capacity to simulate rainfall fields with similar spatial characteristics to observed is a desirable criteria for water resource impact studies, as this translates to improved catchment rainfall climatologies and subsequent runoff simulation. As part of the Victorian Climate Initiative (VicCI), 6 different model configurations were assessed with the aim to select a configuration to be used for further longer experiments with a water resource context.

Model structure, experiment design and assessment

The simulations assessed are generated using the Weather and Research Forecasting (WRF) model (version 3.6.1)[1] with lateral and lower boundary conditions from the re-analysis data set ERA-Interim[2]. A telescopic nest of 3 spatial domains hone in on a 2 km resolution model window, which includes the Victorian Alps and its western slopes (Figure 1). Six different physics configurations are tested with regard to skill in simulating daily rainfall (Table 1, Box 1). The ensemble is used to simulate three two week windows of major rainfall events occurring in 2010-2011. Here characteristics of the variography metric is demonstrated for 11th August 2010 (see right hand panel).

Simulated daily rainfall totals are assessed against gridded observed data from the Australian Water Availability Project (AWAP)[3]. Prior to assessment simulated data were re-gridded to AWAP resolution, a regular 0.05° (~5 km) latitude longitude grid.

Variography metric

The experimental variogram describes the dissimilarity between data points as a function of distance[4]. Specifically, the semi-variogram (γ) is half that of the expected squared difference of the intrinsic random function $Z(x)$ at separation distance (or lag) h:

$$2\gamma(h)=E\{[Z(x)-Z(x+h)]^2\}$$

This formulation holds true if $Z(x)$ is intrinsically stationary – a requirement if using the variogram in regionalisation. This assumptions may be violated here, as dissimilarity may depend on geographical location in addition to distance (sample data is not de-trended). Here however, parameters (sill and range) of the variogram models (theoretical structures fitted to the experimental variogram) are merely used to provide a 'spatial signature' of the rainfall fields (the sill representing the zero-correlation semi-variance and the latter the spatial distance associated with the sill).

The variography metric is simply the inverse Euclidean distance between the location given by the observed (AWAP) parameters and those of the WRF simulations in a sill-range parameter space (normalised), so that simulations further away has a smaller metric; a variation of this metric was previously used to weigh projections of extreme rainfall fields for the UK[5].

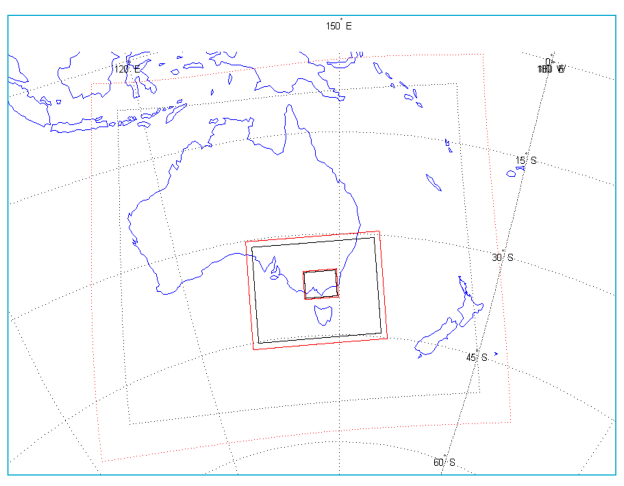

Figure 1: Spatial dimensions of the three domains, the outer domain at 50 km resolution, the intermediate domain at 10 km resolution and the innermost convective permitting resolution domain (at 2 km resolution). The red markers denote the native model domain and the black markers indicate the model domain after the relaxation zone of 10 grid cells is removed

Table 1: List of micro physics and planetary boundary layer (PBL) options for ensemble members N1-N6. Acronyms are spelled out in Box 1.

SCHEME	N1	N2	N3	N4	N5	N6
Micro-physics	WDM6	Thompson	Milbrandt	WDM6	Thompson	Milbrandt
PBL	MYNN	MYNN	MYNN	YSU	YSU	YSU

Example, comparing simulated rainfall fields with observed rainfall:

Rainfall totals for observed and simulated fields are displayed in Figure 2. The experimental variograms and best model fit is shown in Figure 3. The normalised variogram parameters (sill and range) of best model fit are shown in Figure 4 and the resulting variography metric is given in Table 2.

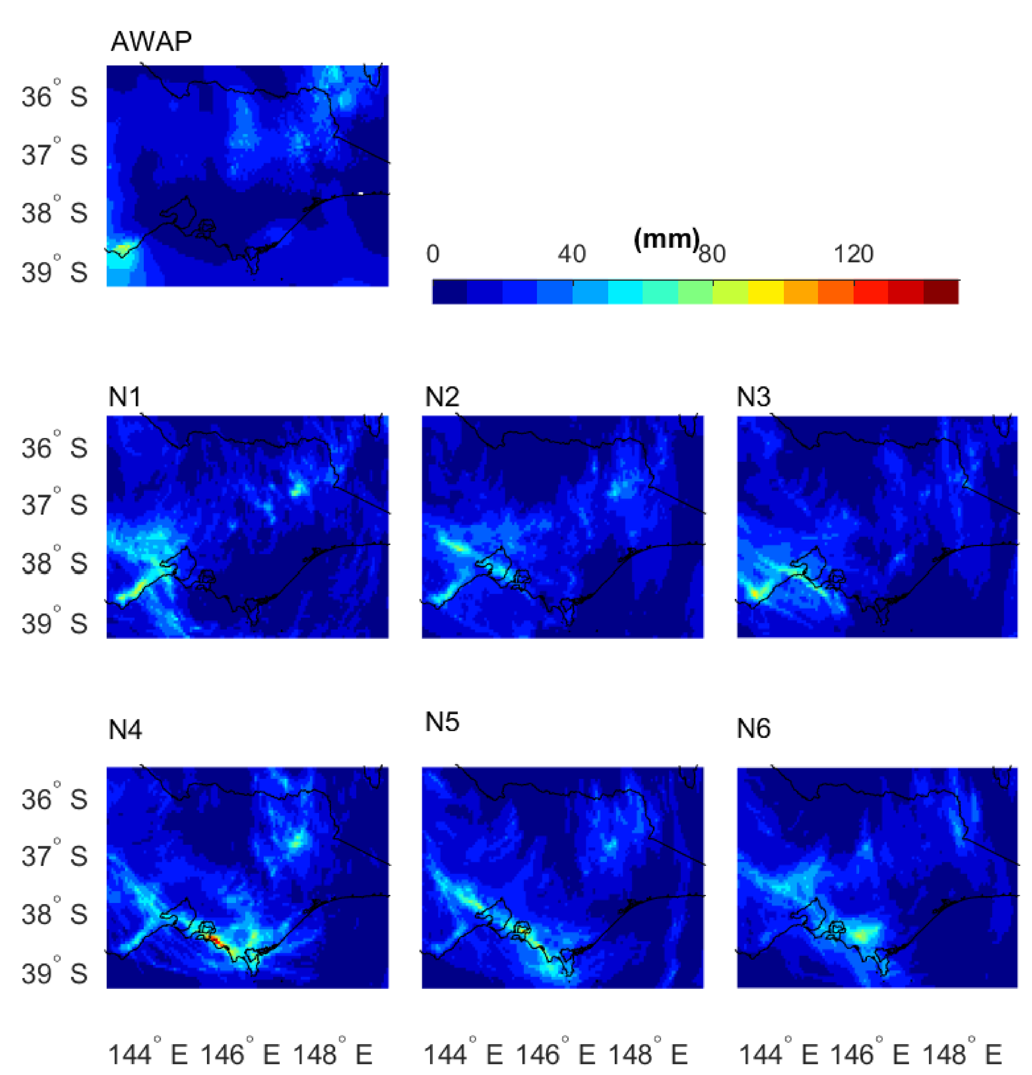

Figure 2: Observed (AWAP) and WRF simulation (N1-N6) rainfall totals for the 11th of August 2010 on the 2km resolution model domain. WRF simulations are re-gridded to AWAP resolution, i.e. 0.05°.

Observation: Simulations show location errors relative to observed, though somewhat less so overall for N1. N4 shows larger intensities than other simulations (larger spatial variance).

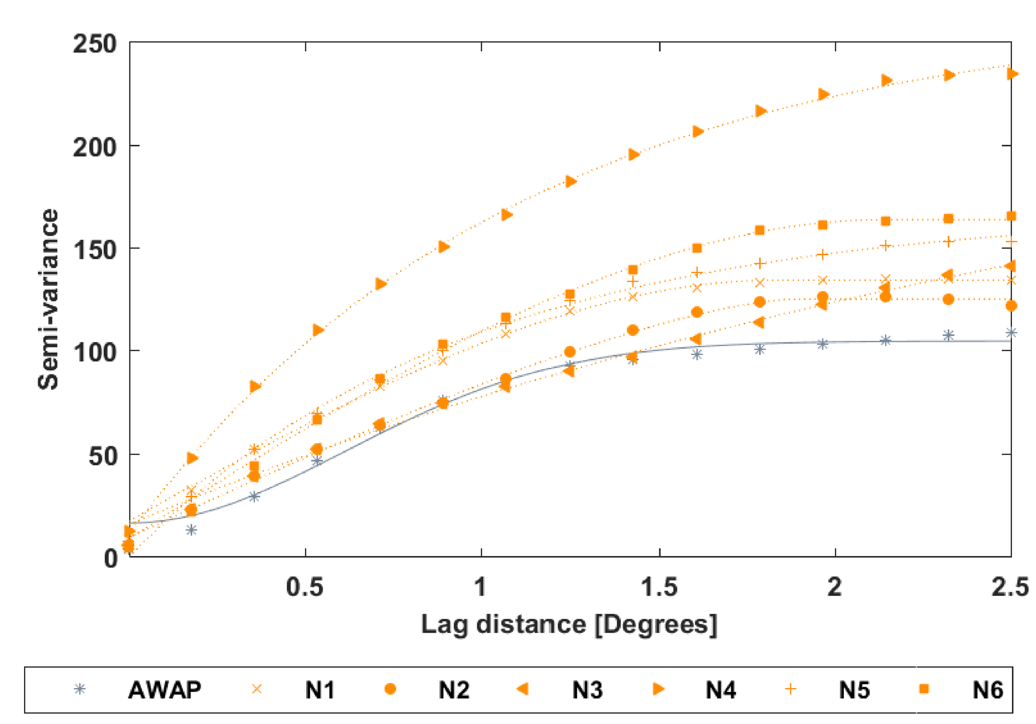

Figure 3: Isotropic empirical variogram (symbols) and fitted variogram models (lines) for observed (AWAP, in grey) and simulated rainfall totals (orange) shown in Figure 2.

Observation: All models more or less overestimate spatial variance (sill), less so for N1 and N2 and clearly more so for N4 (as seen in Figure 2). A more varied result is shown for range, where N1, N2 and N6 show reasonable agreement with observed.

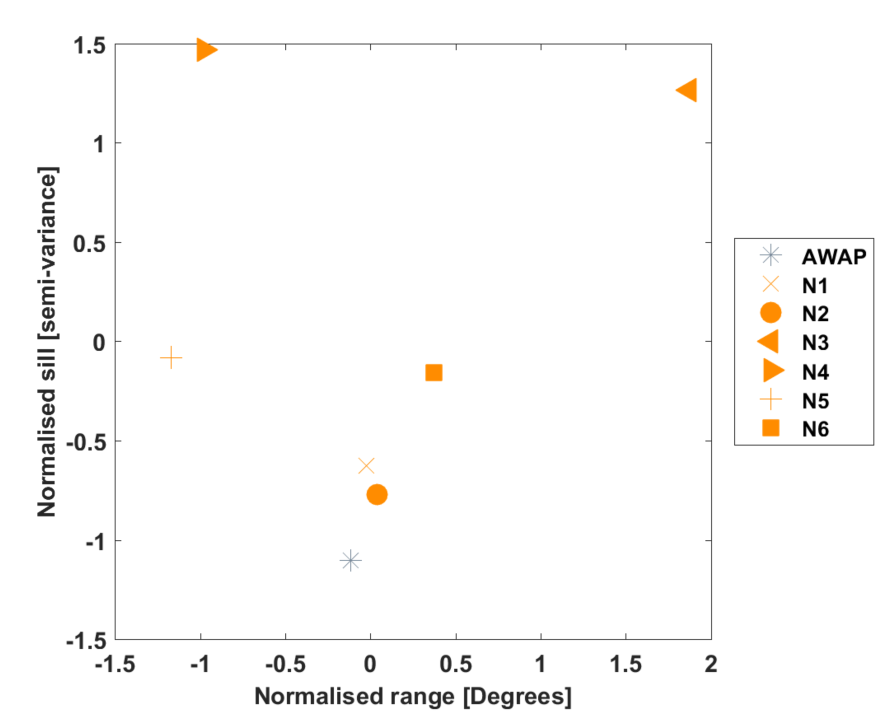

Figure 4: Variogram model parameters (sill and range, normalised respectively) for observed (AWAP, in grey) and simulated rainfall totals (orange) as shown in Figure 2.

Observation: Two markers (N1 and N2) are clearly closer to the observed (grey) than other simulations (orange). N1 and N2 have the smallest overestimation of sill (spatial variance) and have a reasonable range. Thus, these are given the higher scores in Table 2.

Table 2: Variography metrics, calculated as the inverse Euclidean distance between observed (AWAP in grey) and WRF simulations (in orange) displayed in Figure 4 (greater score indicate less difference to observed parameters).

N1	N2	N3	N4	N5	N6
2.05	2.72	0.32	0.37	0.68	0.94

Box 1: Physics ensemble details

Selecting physics schemes for WRF was made with the requirements for the fine-resolution innermost domain at focus. Guidance was sought from WRF support material and peer-review literature relevant for the VicCI case study in terms of it s geographical location and application. The following schemes are common to all ensemble members: ***short and long wave radiation schemes***: the rapid radiative transfer model for GCMs for long and short wave radiation (RRTMG); ***land surface model scheme***: Noah Land surface model; ***cumulus scheme*** (d01 and d02): Betts-Miller-Janjic (BMJ); ***surface physics scheme***: fifth generation Penn State/NCAR Mesoscale Model (MM5); ***microphysics scheme*** (allowing 5 hydrometeors, some estimated using double moment schemes): the WRF double moment 6-class (WDM6) scheme, the Thompson scheme, and the Milbrandt scheme; ***planetary boundary layer (PBL) scheme***: local closure scheme Mellor-Yamada Nakanishi and Niino Level 2.5 scheme (MYNN) and the non-local closure scheme Yonsei University scheme (YSU). References for each parameter scheme are given at: http://www2.mmm.ucar.edu/wrf/users/wrfv3.5/phys_references.html

FOR FURTHER INFORMATION

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