Supplementary Material

Part A. Derivation of catchment attributes and correlation lengths

A GIS coverage with the outline of each of the catchments were produced by supervised terrain analysis of the 9-second Australian digital elevation model (ASLIG *et al.*, 1996). The catchment polygons were used to calculate catchment average values and time series for the data sets described below.

Categorical geology information was derived from the 1:2,500,000 Geology National Geoscience Dataset (Shaw et al., 1998). To allow a meaningful number of samples for at least some classes, the lithology was lumped by age (Caenozoic, Precambrian to Mesozoic and Archean) and for the first two classes by origin (sedimentary vs. volcanic, igneous or metamorphic).

The 3-second SRTM v.2 (USGS, 2006) was used to derive slope (in degrees) and the multi-resolution valley bottom flatness index (MrVBF; Gallant and Dowling, 2003). Soil mapping and soil property data were retrieved from the Australian Soil Resources Information System (Johnston et al., 2003). They include dominant soil class and texture class value (in five categories), estimates of saturated hydraulic conductivity (K_{sat}, mm h^{-1}), plant available water content (PAWC, mm), clay content (%) and solum thickness (m).

Woody vegetation cover fraction was mapped at 30 m resolution from Landsat TM mapping (NFI, 1997). Non-agricultural land, grazing land, horticulture, and broad acre cropping were derived from 1:2,500,000 land use mapping at national scale (BRS, 2006). Time series of vegetation greenness (Enhanced Vegetation Index, EVI) were calculated from MODIS satellite reflectance observations (MOD43B4, 16-day composites, 1-km resolution, 2001-2006) with nadir bidirectional reflectance distribution function adjusted reflectance (Schaaf et al., 2002). From the EVI time series, average, minimum, and maximum EVI were calculated, as well as and two indicators of vegetation seasonality; $VSI_1=EVI_{max} / EVI_{min}$ and $VSI_2=EVI_{max} / EVI_{avg,}$.

Daily gridded climate data available included precipitation (P) produced by interpolation of station data (Jeffrey *et al.*, 2001) and Priestley-Taylor potential evapotranspiration (E_0) produced by combining interpolated climate station data with a long-term albedo climatology (Bureau of Meteorology, 2009) (both 1980-2006 and 0.05° resolution). Actual evapotranspiration (E_{RS}; 1990–2006, 1 km resolution) was estimated from MODIS and

AVHRR satellite observations and the mentioned E_0 (Guerschman *et al.*, 2008). From the gridded data catchment-average time series and average values for the period of analysis were calculated. From these in turn the following climate indicators were calculated: humidity index (H):

$$H = \overline{P} / \overline{E}_0 \tag{S1}$$

Average evaporative fraction (EF):

$$EF = \overline{E}_{RS} / \overline{E}_0 \tag{S2}$$

Precipitation-weighted monthly humidity index (PWMH; subscript m refers to monthly totals):

$$PWMH = \sum \left(P \frac{P}{E_0} \right)_m \Big/ \sum P_m \tag{S3}$$

Average monthly excess precipitation (AMEP; n_m refers to the number of months):

$$AMEP = \frac{1}{n_m} \sum \max\left\{0, P_m - E_{0,m}\right\} \tag{S4}$$

Depth-weighted average event precipitation (DWAEP; p denotes event precipitation):

$$DWAEP = \frac{\sum p^2}{\sum p} \tag{S5}$$

Mean event precipitation (MEP; n_p denotes the number of days with rainfall):

$$MEP = \frac{\sum p}{n_p} \tag{S6}$$

Coefficient of variation in monthly precipitation (CVMP):

$$CVMP = \frac{\sum \left(P - \overline{P}\right)_m^2}{\sum P_m} \tag{S7}$$

Spatial correlation lengths of all attributes listed above were estimated by visually fitting a spherical model to the semi-variogram. The resulting ranges are listed in Table S1. Attributes related to soils, topography, major land uses and vegetation cover generally have correlation lengths of 100 to 300 km, whereas climate and potential evaporation have correlation lengths of 300 to 750 km. The semi-variograms for rainfall and AMEP suggested two superimposed

models, with a smaller part of variation being correlated over ca. 200 km (attributed to orographic and coastal effects) and a larger part correlated over greater lengths (attributed to broad climate zones). Catchment size and area with different crops did not show any spatial correlation.

Table S1. The range of the semi-variogram models fitted to the calculated catchment attributes in order of increasing magnitude.

Catchment attribute	*Range of semi-variogram (km)*
Size	none
Horticulture	none
Broad acre cropping	none
EVI seasonality	100
Solum thickness	150
Slope	200
K_{sat}	200
Woody vegetation	200
Grazing	200
EVI_{avg}	200
Soil texture class	250
PWMH	250
EVI_{min}	250
MrVBF	300
PAWC	300
non-agricultural use	300
CVMP	300
EVI_{max}	300
E_{RS}	300
E_0	400
DWEAP	400
HI	550
Clay content	600
P	600 (200)
MEP	700
AMEP	750 (200)

Part B. Semi-variograms fitted to the analysis results

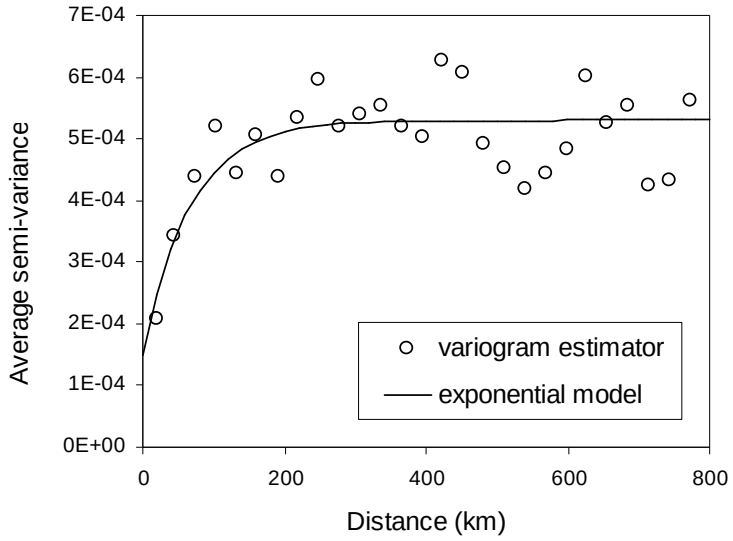

Figure 1. Semi-variogram for the remaining residual variance in k_{BF} with a visually fitted exponential model (nugget=$1.5 \cdot 10^{-4}$, sill=$3.8 \cdot 10^{-4}$, range=200 km)

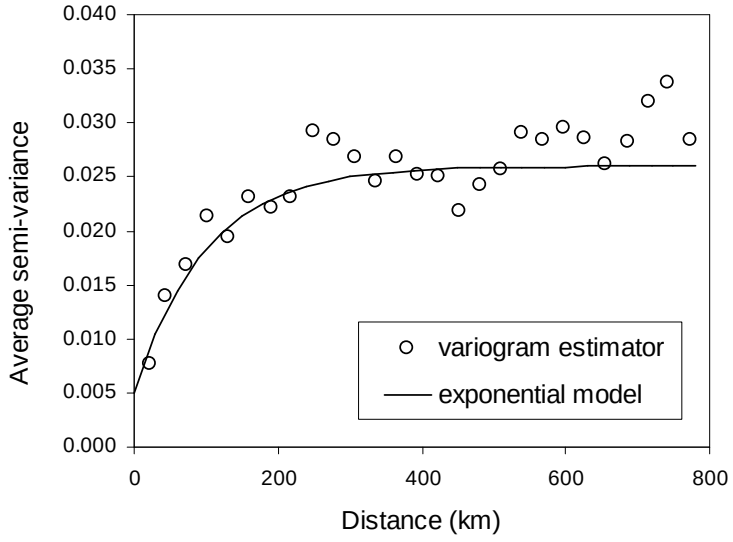

Figure 2. Semi-variogram for the remaining residual variance in BFI with a visually fitted exponential model (nugget=0.005, sill=0.0021, range=300 km).

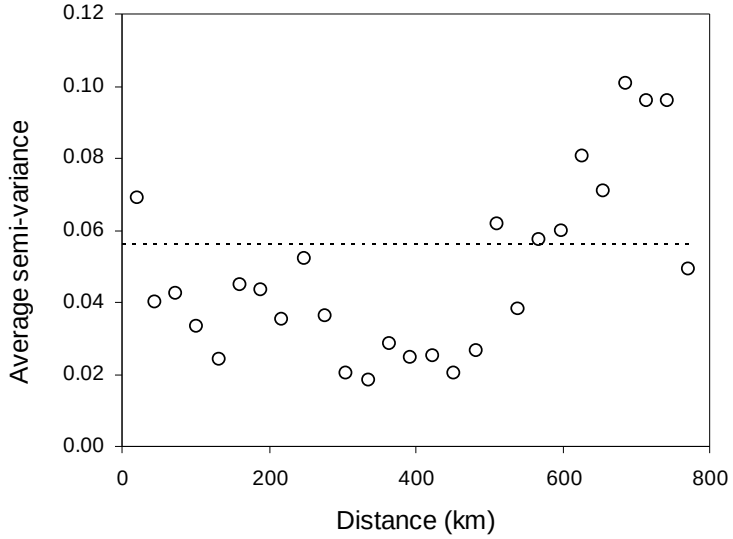

Figure 3. Semi-variogram for the remaining residual variance in baseflow (BF), showing no evidence for spatial correlation.

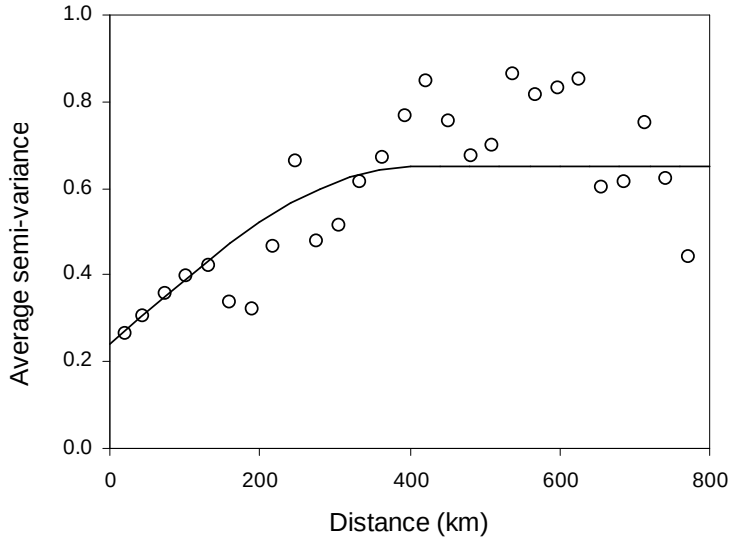

Figure 4.The semi-variogram for the remaining *relative* residual variance period average quick flow (QF in mm d^{-1}) (i.e. the residual variance normalised by the actual QF) with a visually fitted spherical model (nugget=0.24, sill=0.65, range=400).

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