Chapter 7

CONTROLS ON PATTERNS OF SOIL MOISTURE IN ARID AND SEMI-ARID SYSTEMS

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1. Introduction

Soil moisture is a major control on ecohydrological processes at both the storm event and seasonal scales. It influences the partitioning of precipitation into infiltration and runoff (Chapter 3), is a control on biogeochemical processes (Chapter 11) and is a control on evapotranspiration by limiting water availability to plants (Chapter 3), and so also affecting the partitioning of energy into latent and sensible heat (Chapter 5). In this way soil moisture is a link between the surface energy, water and biogeochemical cycles. In water limited systems such as the arid and semi-arid zones, soil moisture plays a major role in vegetation patterns and type of vegetation cover, and is consequently of primary importance to the ecosystems of these areas (Chapters 1, 15; Hupet and Vanclooster, 2002; Kim and Eltahir, 2004).

Figure 1a illustrates a typical one-dimensional conceptualisation of the soil profile and the fluxes that influence the soil moisture stored in the profile. The exchanges between the atmosphere and the soil (precipitation and evapotranspiration) dominate changes in soil moisture (eg. Wilson et al., 2004), with moisture being replenished by infiltration and depleted by soil evaporation and plant transpiration. The relative contribution of evaporation and transpiration depends on the vegetation cover, with transpiration dominating in well vegetated landscapes. Fluxes between the soil profile and groundwater (or deeper parts of the regolith) can be important in some contexts. Drainage from the soil profile is the primary source of recharge for many groundwater systems and capillary rise from shallow groundwater tables can be an important source of water replenishing the profile soil water store during drier periods. In arid and semi-arid environments, interaction with shallow groundwater systems is generally limited to floodplains (Chapter 10) and regionally low areas around lakes. It rarely occurs at the hillslope scale for any significant period of time.

Included on Figure 1a is a series of soil moisture profiles measured for a clay-loam soil on a hillslope in Victoria, Australia. Both the amount of soil moisture and its dynamics change with depth. In the upper 50 cm, soil moisture is strongly influenced by the fluxes between the active root zone and the atmosphere, and the moisture here is more variable than the moisture at depth. Surface soil moisture also responds more quickly and so has both short and long time-scale variability, while the moisture at depth is less responsive to short term variations in the fluxes across the soil–atmosphere interface. In arid systems, hillslope soil moisture at depth is typically very low, except following unusually large rain events during which episodic recharge may briefly occur.

Figure 1b illustrates a standard conceptualisation of a hillslope. The key difference between Figure 1a and 1b is that lateral flow may now act to redistribute water via both surface and subsurface flow pathways. For significant subsurface lateral drainage to occur the following conditions are necessary:

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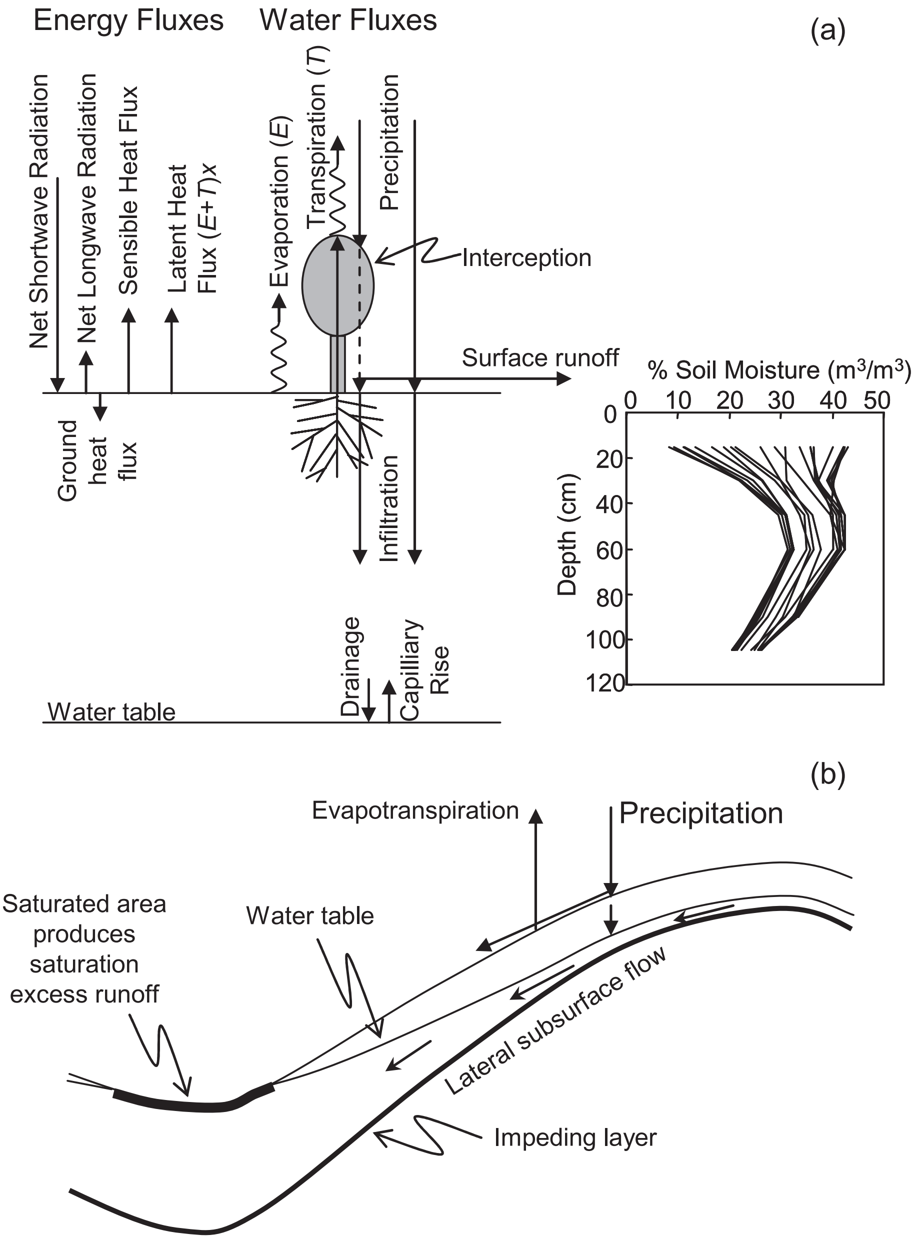

Figure1. a) A one-dimensional soil water balance. This is applicable where lateral flows are insignificant. The surface energy balance fluxes are also shown along with a time series of observed soil moisture profiles from the Tarrawarra Catchment. b) A two-dimensional conceptualisation of a hillslope where both subsurface and surface flow can redistribute precipitation and affect the local soil water balance. Source Western et al. (2002).

- Topographic relief with surface slopes greater than a few percent.
- An impeding layer in the soil profile limiting vertical drainage or anisotropy between vertical and horizontal hydraulic conductivities (Zavlasky and Sinai 1981).
- Sufficiently high moisture contents for periods long enough for flow to occur over significant distances.

In arid and semi-arid areas, the high moisture content conditions are present for only short periods following rainfall. Because there is a rapid decline in hydraulic conductivity or increase in resistance to flow as the soil dries (eg. Zaslavsky and Sinai, 1981), the distance over which lateral subsurface flow is important is very short, compared with wetter environments. However, high intensity rainfall can produce infiltration excess runoff, particularly from patches of (often unvegetated) soil (or rock) with low infiltration capacity, leading to wetter conditions down-slope due to run-on infiltration in patches of soil with higher infiltration capacity. Overland flow paths are also important over large scales because surface runoff is concentrated in topographic depressions and flood-flows overtopping river banks wet the floodplains (Figure 2). Thus the redistribution of water by surface flow paths is important over a range of scales from metres to thousands of kilometres.

These patterns of water movement can have important impacts on vegetation patterns. Water moving to areas of higher infiltration capacity or to small depressions on the hillslope encourages the growth of vegetation. This in turn enhances infiltration and hence increases soil water storage in these areas, thus supporting vegetation between rainfall events, thereby leading to a positive feedback between the vegetation, surface soil condition and hydrology (Chapter 5, this volume). In many arid areas, major streamflows are generated from many 100s or 1000s of km away, with the river acting as a conduit through the arid areas (see Chapter 10), replenishing soil moisture storages on the floodplains and river banks, supporting dense vigorous growth on the floodplain following flood events and supporting perennial riparian vegetation.

Topography is not the only influence on soil moisture in arid areas. Soil properties also affect soil moisture under both wet and dry conditions. The range in soil moisture is bounded at the upper end by the soil porosity and at the lower end by the wilting point (the value at which plants can no longer extract water and transpiration ceases) or residual soil moisture (the value at which the sun can no longer evaporate soil moisture; see Chapter 3). Soil properties also affect the amount of water held in the soil immediately following drainage after rainfall, commonly called the field capacity. These properties vary with soil type (texture and structure). Under extremely dry conditions, soil moisture patterns will be closely related to the pattern of wilting point, and hence be dominated by soil characteristics. Similarly, following rainfall and in the absence of lateral redistribution, soil moisture patterns will be dominated by the precipitation pattern, or if the soil becomes saturated, by the pattern of porosity or field capacity.

The notion of local and non-local controls on hillslope soil moisture patterns was introduced by Grayson et al. (1998). Non-local control occurs under wet conditions and is dominated by lateral water movement through both surface and subsurface paths, with catchment terrain leading to organisation of wet areas along drainage lines. Local control occurs under dry conditions and is dominated by vertical fluxes, with soil properties and only very local terrain (areas of high local convergence) influencing spatial patterns. The switch between these two was described in terms of the dominance of lateral over vertical water fluxes and vice versa. When evapotranspiration exceeds rainfall, the soil dries to the point where hydraulic conductivity is low and any rainfall essentially wets up the soil ‘uniformly’ and is subsequently evapotranspired before any significant lateral redistribution takes place. As evapotranspiration reduces and/or rainfall increases, areas of high local convergence become wet and runoff that is generated moves downslope, rapidly wetting up the drainage lines. In the wet to dry transitional period, a rapid increase in potential evapotranspiration causes drying of the soil and “shutting down” of lateral flow. Vertical fluxes dominate and the “dry” pattern is established. In arid and semi-arid regions, the local control exists during the vast majority of time, with non-local control occurring only immediately following rainfall at the hillslope scale. At the landscape and regional scale, the persistence of flows in rivers and across floodplains represents non-local control, but there is a sharp transition to local control outside the floodplains.

So in summary, soil moisture at a point is controlled by the balance between precipitation, evapotranspiration and lateral redistribution by surface and subsurface flow. These in turn are influenced by topography, soil properties and the patterns of vegetation. This chapter explores these various controls and influences through a series of examples from field and modelling studies in Australia. First we briefly introduce these studies and then separately discuss each of the controls and influences.

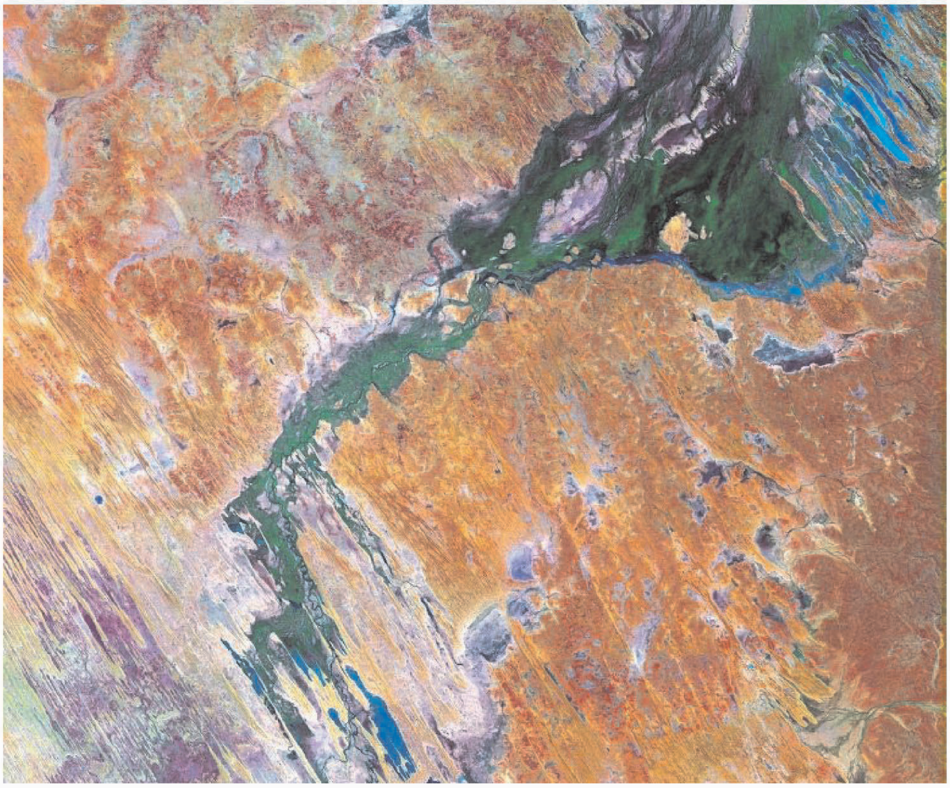

Figure 2. False colour Landsat image of the Goyder Lagoon region of the Diamantina/Warburton Rivers in the arid Lake Eyre basin (see Figure 3) showing a green flush in the floodplain and areas of local convergence following rainfall. Blue areas are a combination of flowing river water, floodwaters ponded in lakes and interdunal corridors and damp saline playas. Purple areas are dry floodplains and playas.

2. Overview of the field and modelling studies

Four studies will be used in the following discussion: i) several small temperate climate experimental catchments that experience summertime semi-arid conditions, ii) a large experimental catchment with climate ranging from humid to semi-arid and a range of landuses, iii) several catchments from the Lake Eyre Basin located in the Australian arid zone, and iv)

Australia-wide model simulated and satellite observed patterns of soil moisture in response to soils and vegetation.

The first is a series of field experiments on the temporal and spatial distribution of surface and shallow sub-surface soil moisture at hillslope to small catchment scale. These include the Tarrawarra (Western and Grayson, 1998) and Point Nepean (Wilson et al., 2004) catchments in South Eastern Australia (Figure 3). While these two Australian sites are located close to Melbourne, they have contrasting soil properties; Tarrawarra on silty clay loam and Point Nepean on sandy soil. Rainfall is quite uniform through the year but potential evapotranspiration (PET) rates change by almost an order of magnitude between summer and winter, leading to a monthly aridity index (PET/rainfall) varying between 0.2 in June and 2.9 in February (Western et al., 2004). The terrain is undulating with mean slopes of 8% at both sites. There is a difference in the geomorphology of these sites in that Tarrawarra is a fluvial landscape while the Point Nepean site is a dune field that retains its Aeolian morphology. In both these studies, soil moisture was measured using TDR instruments either in-situ or mounted on a small all-terrain vehicle, enabling spatial patterns to be measured over areas up to a square kilometre. These catchments are both in a temperate climatic zone, but the strong seasonal signal means that there are times of year when soil moisture controls are similar to those in semi-arid areas. These data will be used to indicate the relative importance of different sources of temporal and spatial variability in soil moisture.

The second study is at a much larger scale over the 80,000 km^2 Murrumbidgee River Basin (Figure 3). Although the headwaters of the basin lies within about 100 km of Australia's east coast, the basin lies to the west of the coastal divide and drains generally westward, discharging into the Murray-Darling River system. Most of the catchment is mixed rangeland and forest, with mean annual precipitation ranging from 1900 mm/yr in the east reducing to 320 mm/yr in the far west. There is a transect of ten soil moisture monitoring "sites" across the whole Murrumbidgee, measuring soil moisture profile and meteorological variables (Figure 3) (Western et al., 2002). On several occasions, mobile TDR equipment has been used to measure soil moisture in the top 30 cm over 10 km long transects near some of the ten Murrumbidgee sites. The data from this study will be used to highlight the effects of soil properties and changes in soil moisture behaviour over the large rainfall gradient.

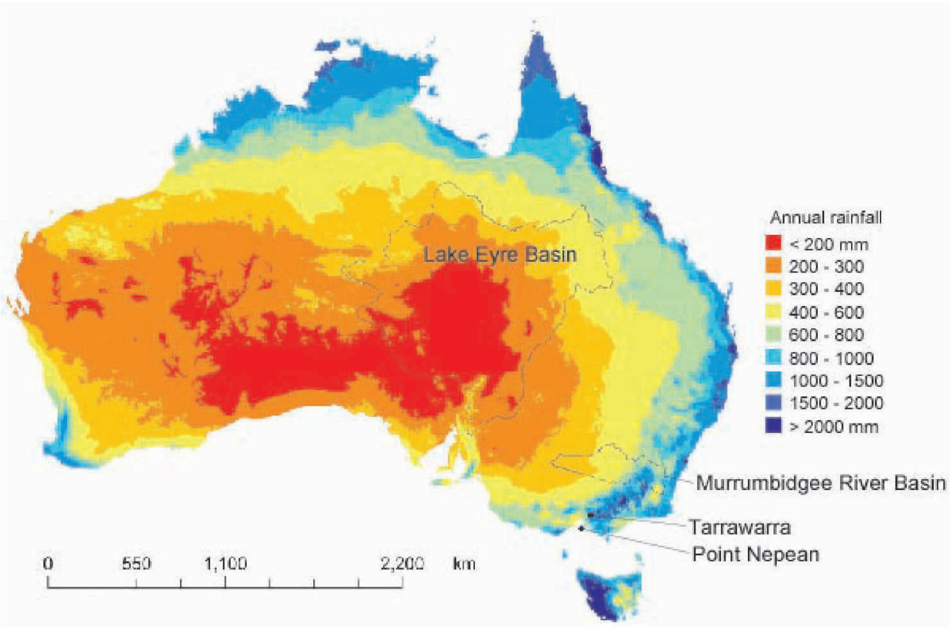

Figure 3. Location of Tarrawarra, Point Nepean, Murrumbidgee and Lake Eyre sites within Australia. The shading shows average annual precipitation across Australia, highlighting the Australian arid and semi-arid zones.

The third study focuses on the rivers and floodplains of the Lake Eyre Basin in the arid heart of Australia (Figure 3). Here we are working on the hydrological behaviour of sub-catchments ranging in size from 10,000 km^2 (in the Peake and Neales Rivers) to 160,000 km^2 (Diamantina River). Data from here are a combination of streamflow and groundwater monitoring along with observations of vegetation response to floods from satellite imagery (Figure 2). Rainfall-runoff modelling has also been undertaken on these catchments (Costelloe et al., in press) to provide key hydrological indicators to assist in ecological studies of the region. These data and model results are used to illustrate the dominance of large scale topography (river courses and floodplains) and the relative insignificance of hillslope scale topography on the soil moisture patterns in the arid zone.

The final study consists of a series of simulated and observed soil moisture patterns across the whole of Australia. The simulated patterns are based on results from a land-surface model (Koster et al., 2000) that incorporates topographic control as well as enabling soil and vegetation characteristics to be varied spatially. These simulations are all driven by the same forcing data (Walker et al., 2003), but vary in the level of detail provided on soil and vegetation properties. Comparison between the simulations provides some indication of the likely influence of soil and vegetation variability on soil moisture at the continental scale. In addition, the dominance of precipitation and effects of soil characteristics following rain can be observed. The observed soil moisture patterns are from the Scanning Multichannel Microwave Radiometer (SMMR) satellite (Owe et al., 2001).

3. Control by precipitation and climate

Soil moisture patterns are generally dominated by precipitation over a range of temporal scales and at larger spatial scales. We illustrate this at two very different scales using the data from the detailed field studies (Tarrawarra and Point Nepean) and the Australia-wide modelling.

Figure 4a shows the components of total temporal variance at each monitoring station at Tarrawarra (total variance 30-55% $(m^3/m^3)^2$) and Point Nepean (total variance 10-15% $(m^3/m^3)^2$) based on high resolution (30min) time series of root-zone soil moisture. The seasonal signal was identified in the time series, leaving a residual (representative of event scale variability), a component due to measurement error and a remaining "unexplained" component (see also Wilson et al., 2004).

Between 71 and 81 per cent of the temporal variance is explained by seasonal variance at Tarrawarra. In contrast, on the sandy soils of Point Nepean, seasonal variance explains only between 18 and 53 per cent of the overall temporal variance (Figure 4a). Variance in moisture content at the storm event-scale is more important to overall variance on the sandy soil. At Point Nepean, the average residual variance accounts for between 33 and 59 per cent of the temporal variance, while the highest was 24 per cent at Tarrawarra. This difference reflects differences in soil water storage capacity due to the soil texture differences. Very little of the temporal variance in soil moisture could not be explained by a combination of variance in the seasonal series, variance in the average residual series or by measurement error.

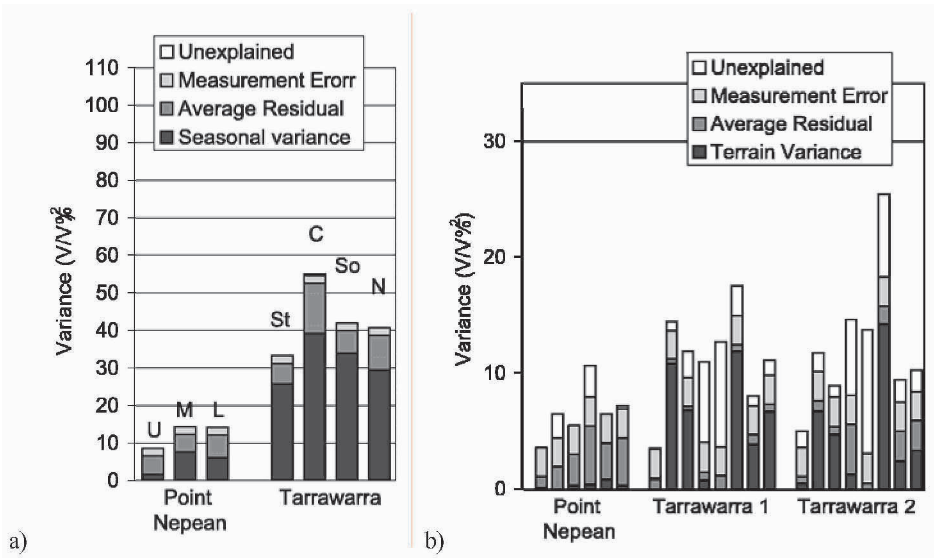

Figure 4. Classified a) temporal and b) spatial variance in soil moisture for Point Nepean and Tarrawarra field sites.

Compared to temporal variability, spatial variability, is relatively small (total variance <10-20%$(m^3/m^3)^2$ at Tarrawarra and <5-10%$(m^3/m^3)^2$ at Point Nepean). Measurements of the spatial distribution of soil moisture indicate that landscape related processes operating at a variety of scales control the distribution (see below) but that overall variance is much lower than temporal variance. The total spatial variance at each monitoring location is shown as the total column height in Figure 4b (sites are assessed individually whereas they are grouped in 4a). Using a similar approach as in 4a, a "terrain signal" was identified from the data via a multiple linear regression against static terrain parameters, the average spatial residual (as an analogue for static soils and vegetation effects) was also identified, as was a measurement error, leaving a small "unexplained variance" (Wilson et al., 2004).

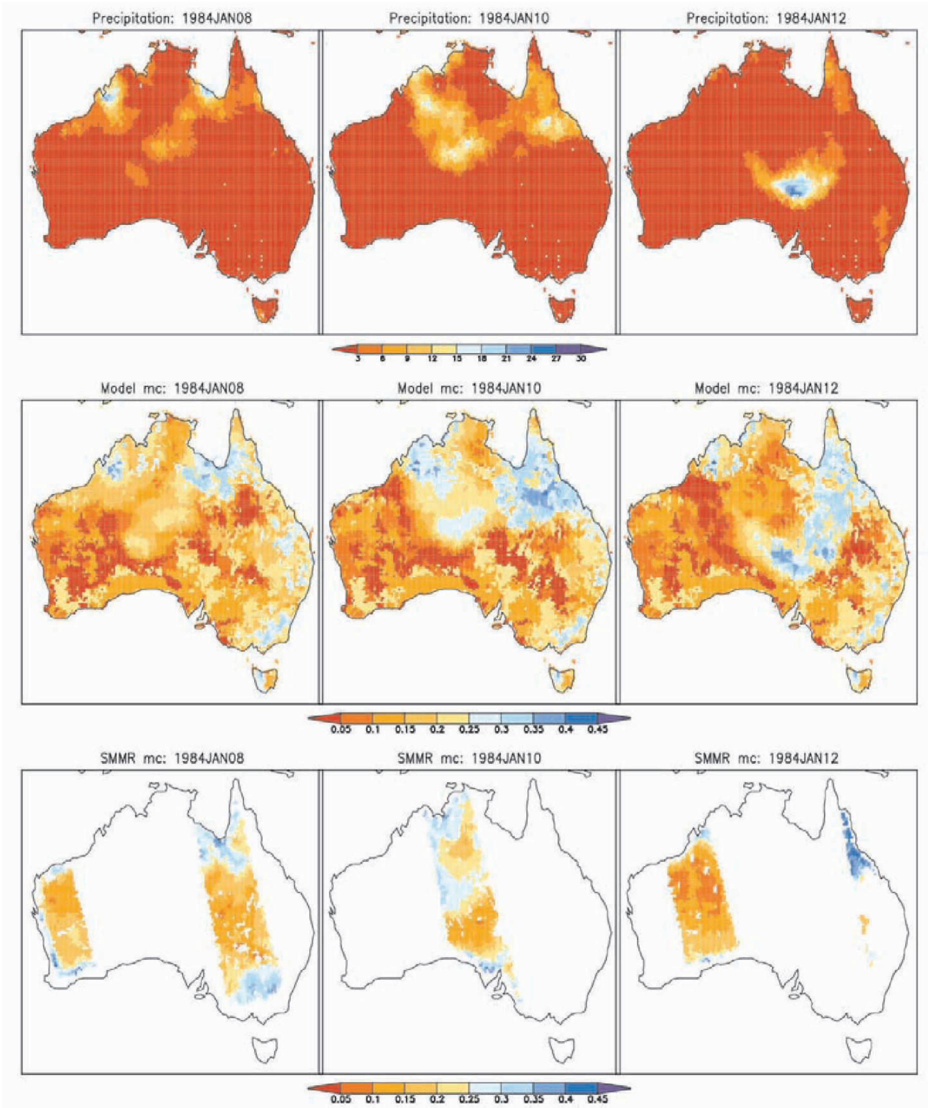

Figure 5. Pattern of near-surface soil moisture in response to precipitation: a synoptic front passing across Australia (columns 1 to 3) showing the rainfall field (top row), model derived near-surface soil moisture content (middle row) and remotely sensed surface soil moisture content by the Scanning Multichannel Microwave Radiometer (bottom row).

The clear message from Figure 4 is that at the small catchment scale, total variance in the temporal pattern of moisture content dominates over that in the spatial pattern, with temporal variance up to 10 times greater than spatial variance. Whether seasonal or event scale temporal effects are dominant depends on the storage characteristics of the soils and meteorological forcing pattern. Precipitation is also the dominant control on patterns in near-surface soil moisture content at much larger spatial scales. This is demonstrated in Figure 5 where a synoptic precipitation event can be seen passing across Australia, resulting in a closely matching pattern in surface soil moisture.

Both climatic and soil property variations are major controls on the spatial distribution of soil moisture at large scales. Figure 6 shows the soil moisture behaviour at the monitoring sites over the Murrumbidgee River Catchment. Figure 6a shows 10th, 25th, 50th, 75th and 90th percentiles of 0-30cm soil moisture. Clearly there are sites in the dry western half of the catchment that have low soil moisture (e.g. Balranald) and other sites that have consistently higher soil moisture (eg Hay). While there is some indication of a reduction in soil moisture in the semi-arid parts of the basin (west) compared with the humid (east) of the basin, this is disguised by soil type effects to a large degree. Figure 6b shows the same percentiles for reduced soil moisture, P, where $P = \frac{\theta - \theta_w}{\theta_f - \sigma_w}$ and θ is soil moisture, θ_w is the soil moisture at wilting point and θ_f is the soil moisture at field capacity. The wilting point and field capacity were inferred from the soil moisture time series. This normalisation removes the soil effect and shows the impact of climate on the spatial distribution more clearly.

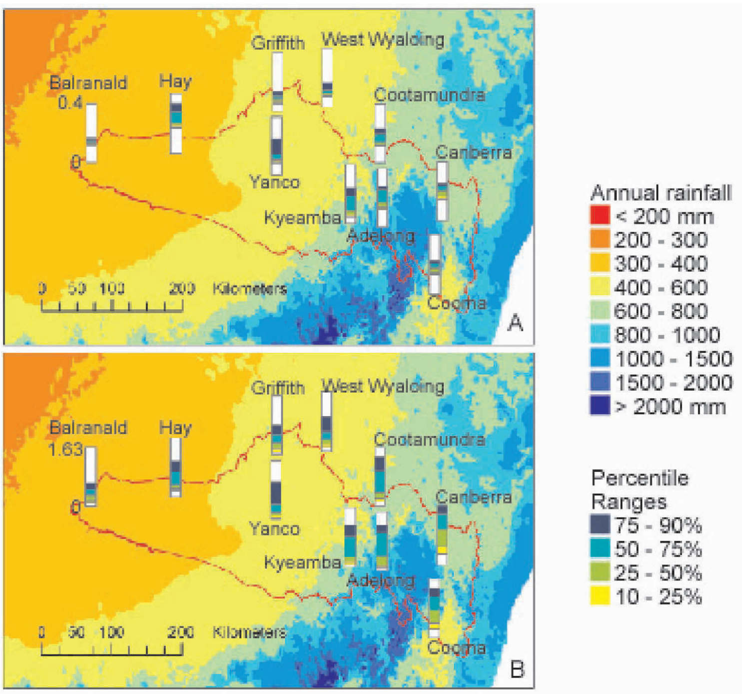

Figure 6. a) The temporal distribution of soil moisture. b) The temporal distribution of normalized soil moisture, P. In both maps, the columns are all drawn to the same scale (0 to 0.4 m^3/m^3) and the coloured bands represent the moisture contents corresponding to the percentile ranges given in the legend. The sites are located at the centre of the base of each column. The average annual precipitation is shown as the background pattern and the Murrumbidgee River Basin is outlined.

The typically low values of soil moisture in arid and semi-arid areas also influence the soil moisture profile behaviour. There is typically a large soil moisture deficit and thus a substantial amount of storage available in the upper part of the soil column that needs to be filled before drainage to the deeper soil layers occurs. This means that the deeper layers are typically dry and they respond episodically when rainfall events are sufficiently large to fill the storage available in the upper layer. Figure 7 shows the response of soil moisture in the 0-7cm, 0-30cm, 30-60cm and 60-90cm layers, along with rainfall for the period October 2001 to May 2004. This effect is clear here. In contrast in Adelong Creek, which is in the higher rainfall part of the Murrumbidgee basin, the soil moisture at depths responds seasonally and it is typically at or above field capacity during the wet part of the year. These results reinforce the point made earlier that where soil water storage is large (due to either more precipitation and in soils with higher storage capacity), seasonal timescales dominate temporal behaviour while where storage is limited or precipitation is low, the event scale is more important.

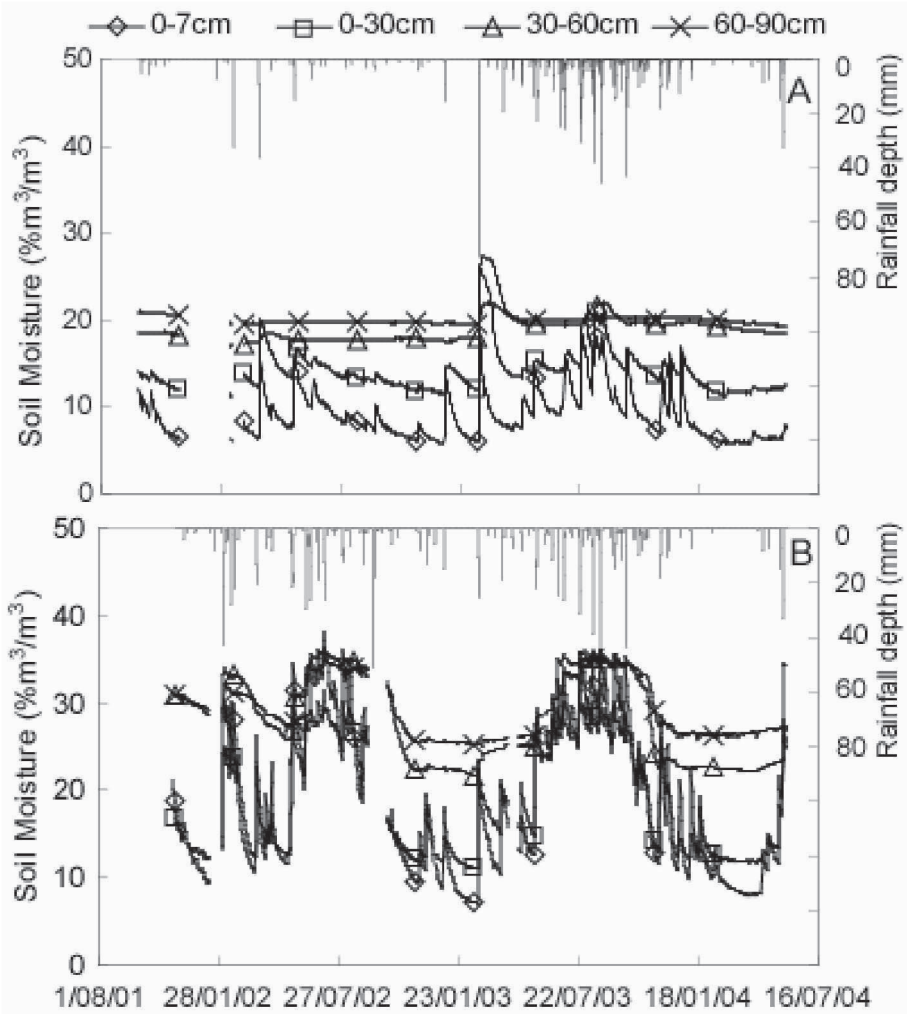

Figure 7. Observed soil moisture for four depths at a) Balarnald and b) Adelong (see Figure6).

4. Control due to topographic convergence and lateral movement

A number of empirical studies have examined the correlation between terrain properties and a measure of soil water storage status. Rarely has the percentage of variance explained exceeded 50% and at no sites has it consistently exceeded 50% (eg. Familglietti et al., 1998; Nyberg, 1996; Zaslavsky and Sinai, 1981; Moore et al., 1988; Ladson et al., 1992; Burt and Butcher, 1985; Moore and Thomson, 1996 and Jordan, 1994). At Tarrawarra we found that the explained variance ranged between 0 and 50% for individual terrain parameters and up to 61% under moderately wet conditions where lateral flow was active but saturated areas were confined to the drainage lines (see also Figure 4b).

At Tarrawarra the proportion of variance explained by topography is strongly related to the catchment wetness status. Figure 8 shows the proportion of spatial variation in 0-30 cm soil moisture explained by topography. Dry conditions at Tarrawarra are an analogue of the conditions found in arid and semi-arid landscapes for the vast majority of time in that soil moisture is close to wilting point. In these conditions there is essentially no relationship to terrain at the hillslope scale because there is no lateral redistribution of soil moisture. The results at Tarrawarra also show how it takes time for topographic redistribution to occur. The measurements on 14 February 1996 (mid summer) follow approximately 60 mm of rain in the preceding four days yet no topographic effects are evident and soil moisture is still low. As the catchment wets in autumn, the strength of the relationship with topography is much less than during the drying period the following spring, which follows an extended wet period.

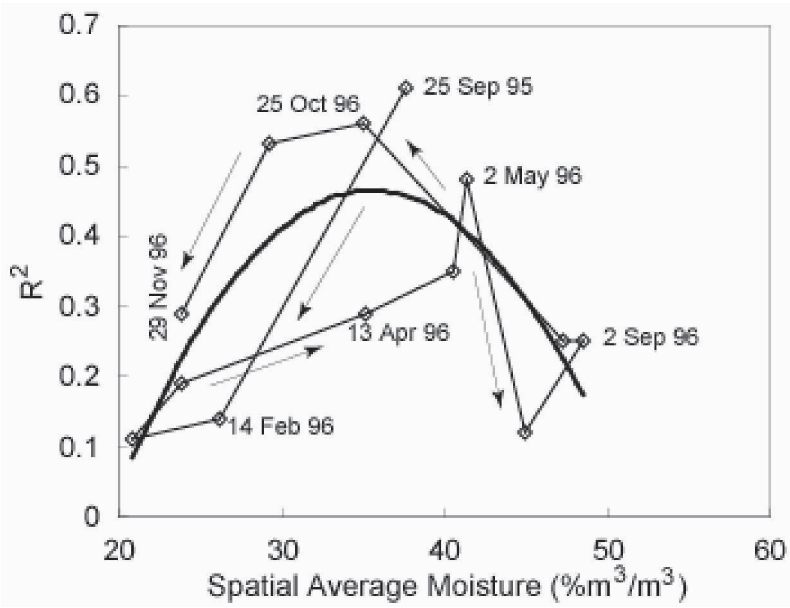

Figure 8. The proportion of spatial variance explained by multiple regression of soil moisture against the topographic wetness index and a potential solar radiation index and its relationship to catchment wetness (Western et al., 1999). The curved line shows a quadratic fit to the data and the arrows indicate the progression through time. Key dates of samples are shown.

In summary, at the hillslope scale, the topographic control on moisture content depends on overall wetness, being greatest when there is sufficient water for significant lateral redistribution, but not so much that everything is saturated (because porosity controls the moisture content then). In arid and semi-arid conditions, it is rare for lateral redistribution to be significant (i.e. the landscape is typically in the "dry" or "local control" state, Grayson et al., 1998). As illustrated in Figure 2, at very large scales, topographic control is represented by river and floodplain networks, but outside the immediate vicinity of the network, lateral redistribution is restricted to very short periods following heavy precipitation, where surface runoff processes dominate.

5. Control due to soils and vegetation

In the preceding examples, soils effects have been mentioned in relation to soil water storage and subsequent effects on temporal and spatial patterns. Soil texture, the amount of organic matter present and soil structure are all recognised to affect the moisture storage capacity of a soil. Soil texture, for example, influences moisture holding capacity, as fine textured soils retain water more effectively than sandy soils. The vegetation characteristics also have the potential to affect effective storage due to different rooting depths and effects on total evaporation.

In this section, we illustrate the relative importance of soil and vegetation effects, largely through the example of soil moisture simulations across Australia. The land surface model used for simulating soil moisture content across Australia uses spatially varying information on topography, soil properties, soil depth and vegetation type (Figure 9), and both spatially and temporally varying information on vegetation dynamics (Figure 10) through the leaf area index and fraction of vegetation that is actively transpiring or "green". In this application soil properties were defined by a set of characteristic soil properties for each soil texture type, and mapped according to the distribution in soil texture. Likewise the vegetation albedo and momentum parameters for evapotranspiration calculations were derived from a characteristic set of values for each vegetation type. Moreover, some of the soil moisture distribution timescale parameters used by the model are derived from the soil properties, soil depth and topographic data. Hence, specifying a uniform set of soil parameters for Australia additionally implies a uniform soil depth and topographic characteristics.

For a single day with minimal precipitation across the continent, Figure 11 shows the effect of spatially varying soil and vegetation parameters on root zone soil moisture compared with spatially uniform soil with spatially varying vegetation, spatially uniform vegetation with spatially varying soil, and soil and vegetation both spatially uniform. Figure 12 shows a summary of these three scenarios through the seasonally averaged root zone soil moisture residual from the spatially varying soil and vegetation parameter case for a single year.

Comparing Figures 11 and 12 to the patterns of 9 and 10 clearly show that, when precipitation effects are either minimal or averaged out, the soil parameters have the greatest impact on spatial soil moisture pattern, with the pattern in soil moisture residual closely matching the pattern in assumed soil texture. Vegetation makes only a minor contribution to the pattern of root zone soil moisture content. The importance of soil properties on observed soil moisture was also shown in Figure 6 for the Murrumbidgee River Basin sites. The dominance of soil properties over vegetation effects is consistent with modeling results from these sites (Richter et al., in press) and with the modeling results of Shao et al (1997). Apart from some minor influence of broadleaf evergreen trees, there is a poor match in the vegetation effect residual (Figures 11 and 12) with the vegetation type (Figures 9 and 10).

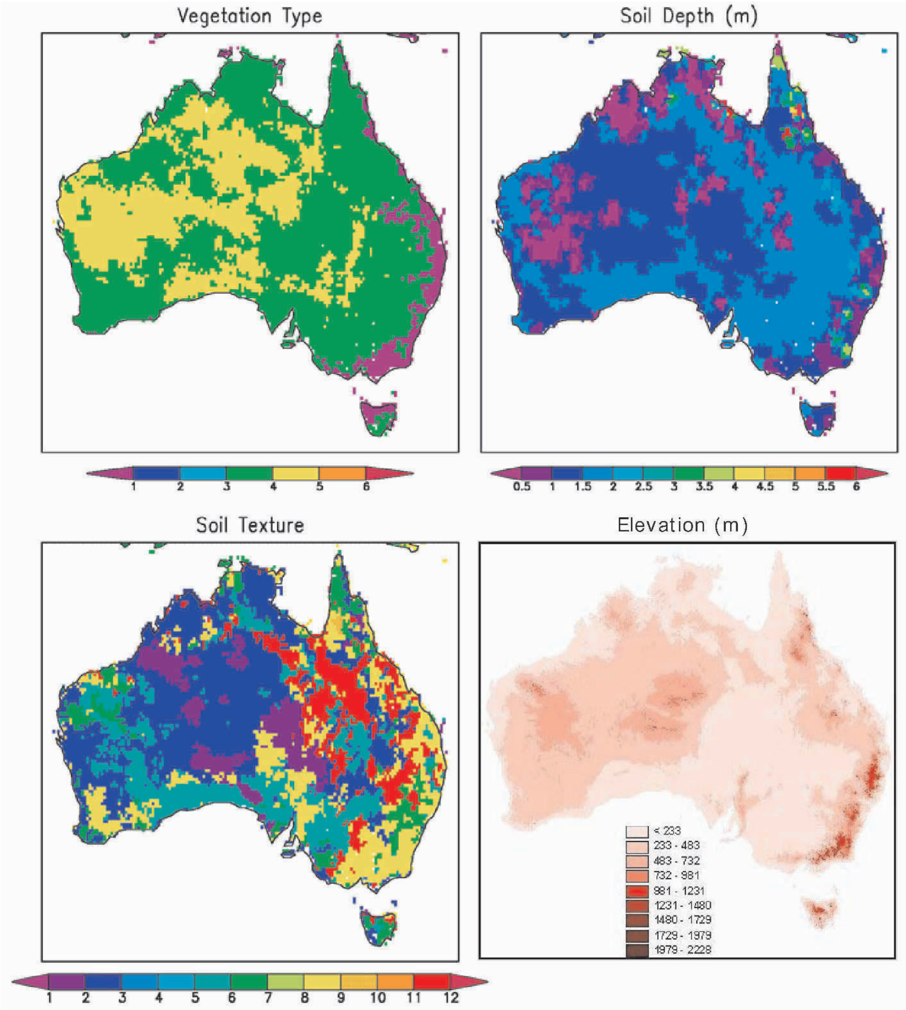

Figure 9. Static patterns underlying topographic, soils and vegetation parameters used by the land surface model. Vegetation albedo and momentum parameters were defined by vegetation type[1] while soil hydraulic parameters were defined by soil texture[2].

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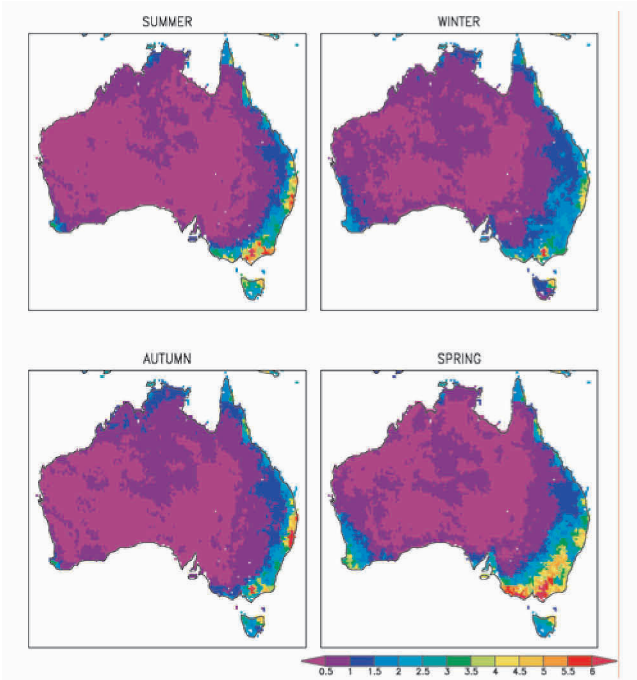
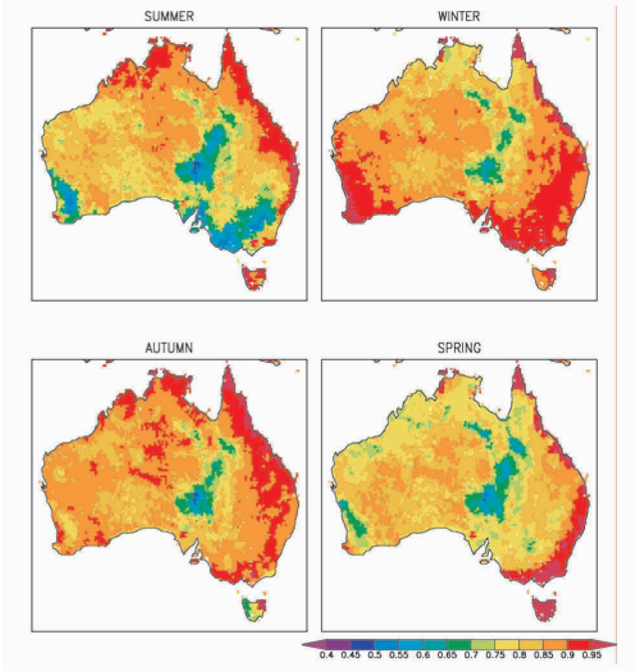
1 **Vegetation/Land use type** 1. Broadleaf evergreen trees; 2. Broadleaf deciduous trees; 3. Needle-leaf trees; 4. Grass land; 5. Broadleaf shrubs; 6. Dwarf trees; 7. Bare soil

2 . **Soil texture class**:1. Sand; 2. Loamy sand; 3. Sandy loam; 4. Silt loam; 5. Silt; 6. Loam; 7. Sandy clay loam; 8. Silt clay loam; 9. Clay loam; 10. Sandy clay; 11. Silty clay; 12. Clay.



a)



b)

Fig 10: Dynamic patterns underlying the vegetation parameters used by the land surface model. Remotely sensed spatial and temporal variation in vegetation a) leaf area index and b) greenness. The seasonal data has been derived from monthly observations.

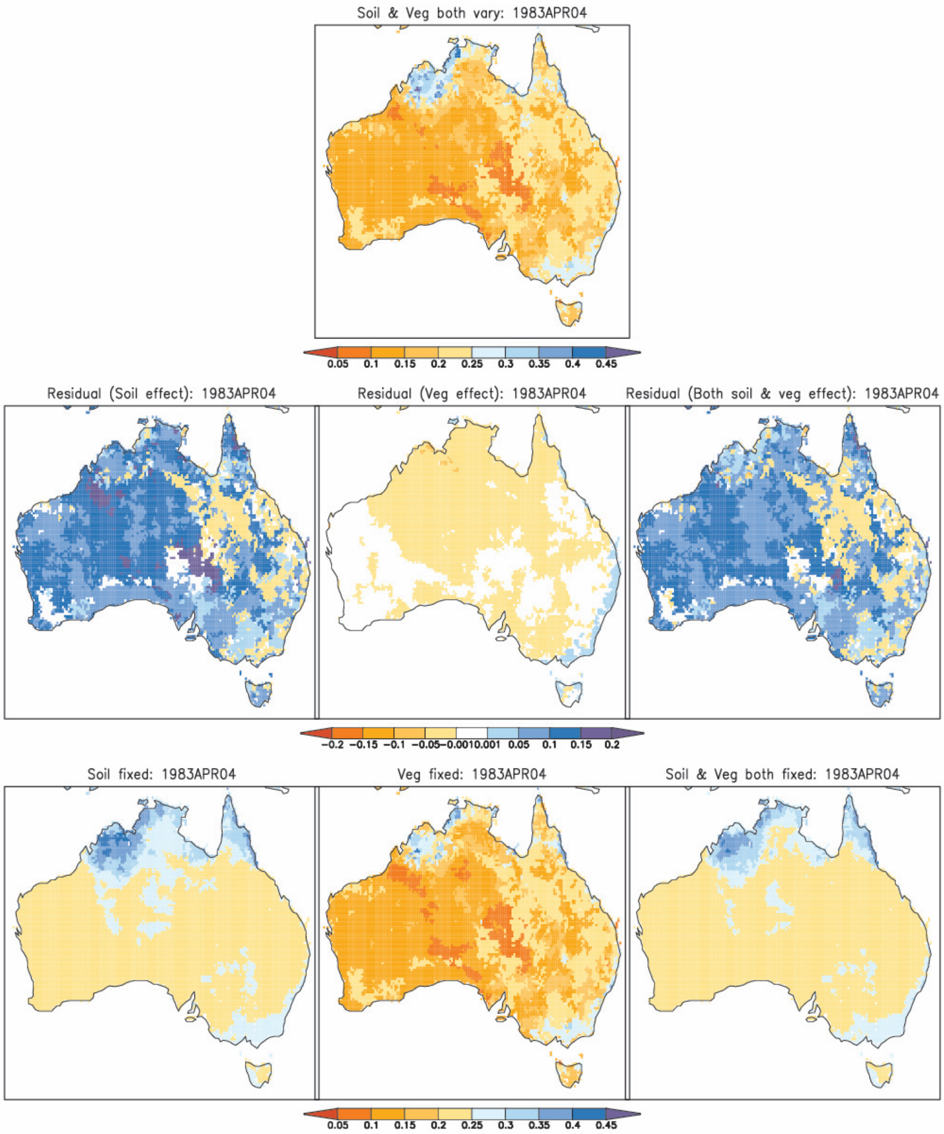


Figure 11. Patterns in root zone soil moisture resulting from patterns in vegetation, soils and topographic parameters used by the land surface model. The top row is model derived soil moisture with spatially varying parameters and bottom row is with one or more parameters fixed. The middle row is the residual when subtracting the bottom row from the top row. Results are for a single day where there is no rainfall.

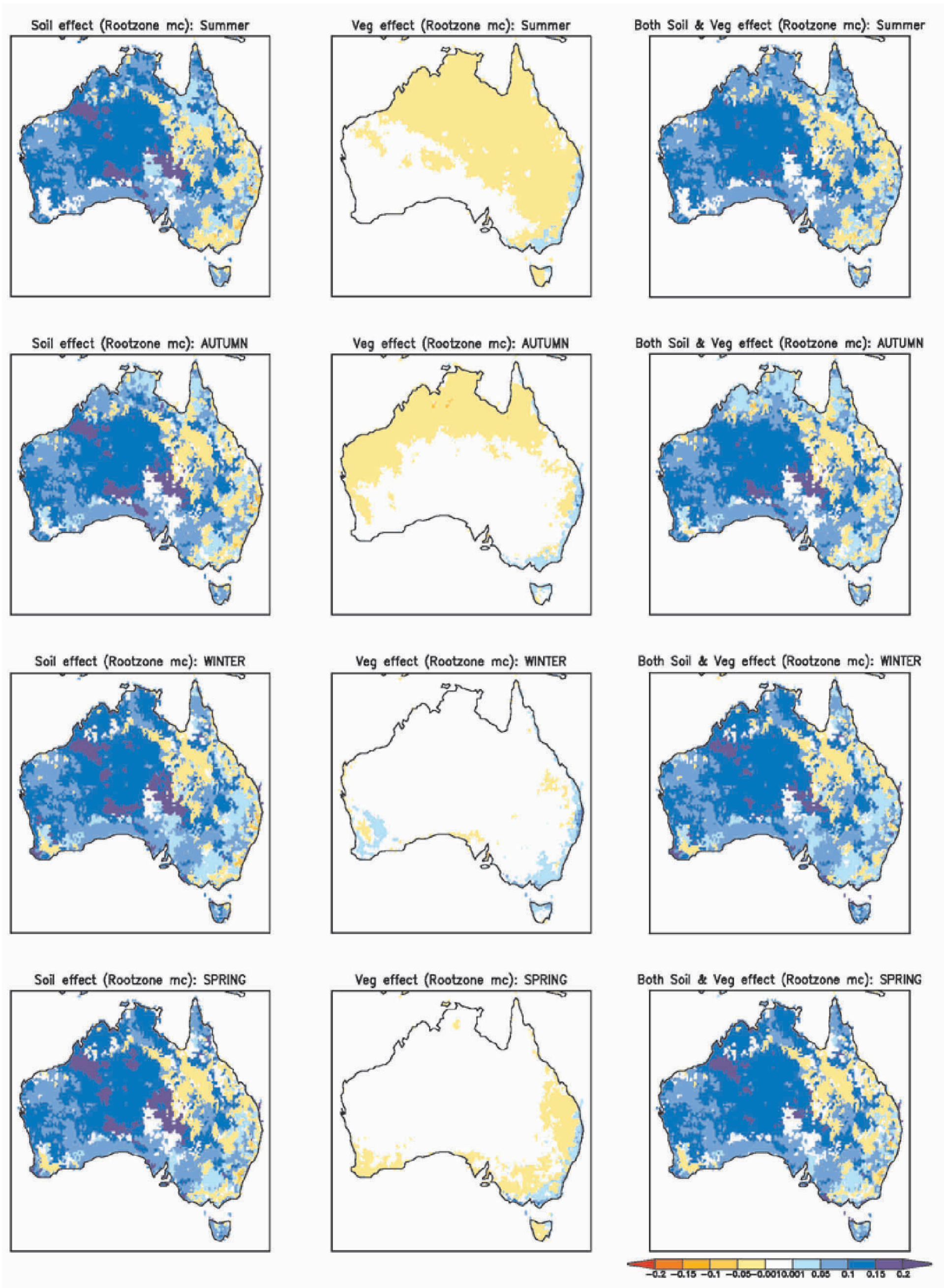


Figure 12. Seasonally averaged residuals of root zone soil moisture resulting from patterns in vegetation, soils and topographic parameters used by the land surface model.

Whether the simulations in Figures 11 and 12 represent reality is dependent on how well the maps of soil texture/type reflect differences in hydraulic characteristics, the maps of vegetation reflect spatio-temporal variation in important vegetation characteristics including canopy characteristics and rooting depth, and how well the model captures the functioning of the vegetation and soils. Wilson et al. (2004) show that over small areas such as Pt Nepean and Tarrawarra, there are static characteristics of the landscape that strongly affect soil moisture patterns (see "average residual" in Figure 4b), but are not well reflected in standard "soil type" maps. Houser et al. (2000) show a similar result for small catchments in the arid Walnut Gulch area.

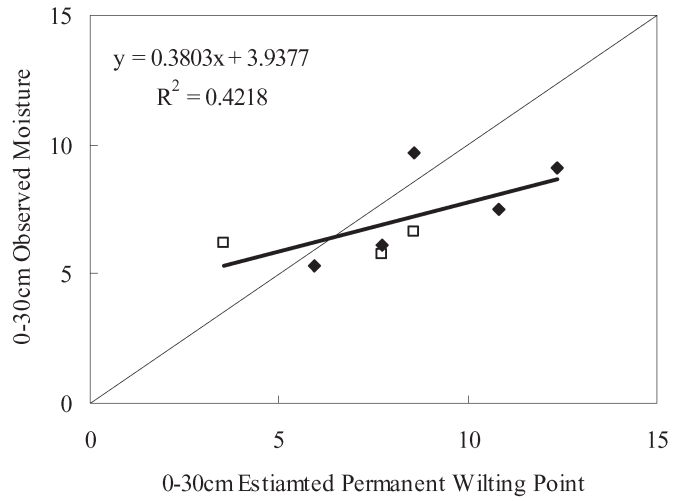


Figure 13. Estimated wilting point from soils mapping compared to observed moisture content during an extended drought period.

Nevertheless, at larger scales or where mapping has been particularly detailed, maps of soil texture/type can provide some indication of real controls on soil hydraulic behaviour. Figure 13 shows the relationship between wilting point as estimated from detailed soil mapping and as measured using TDR for five 1ha patches and for the soil types encountered along a 4 km transect across Kyeamba Creek (Murrumbidgee catchment). The observed data are averages of between 11 and 43 individual measurements within the one mapped soil unit. The measurements were taken after an extended period of drought. It can be seen here that the wilting point is related to the observed "dry-end" soil moisture where bare soil evaporation is likely to have reduced moisture contents at the surface to close to residual values due to the extended drought period.

These results (and other similar results across large areas) indicate that the general patterns reflected in Figures 11 and 12 are realistic, and while the absolute values may not be correct, the conclusions regarding the general influence of soils versus vegetation appear sound, at least in terms of soil moisture content. It is likely that if total water availability was considered, the importance of vegetation would increase.

6. Summary

In this chapter we have explored the various controls on soil moisture variability in time and space, using examples from field and modelling studies from small catchments to continental scales. It is shown that precipitation events are the dominant control on soil moisture in the semi-arid and arid zones. Where rainfall is higher and soil water storage capacity is greater, the seasonal signal of precipitation dominates temporal variability. As the environment becomes more arid and/or soil water storage is lower, event-scale variability becomes an increasing component of overall soil moisture variability.

Topographic effects are significant at the small catchment scale under wetter conditions, where there is opportunity for lateral subsurface flow, but under arid conditions, this effect occurs only at the very local scale. In arid areas, the dominant lateral redistribution process is surface runoff, where long-term wet regions are restricted to the major river and floodplain networks and thus affected by large-scale topography. At these scales, topography is a dominant control on moisture patterns, with floodplain inundation creating persistent wet areas throughout the arid zone (eg. Figure 2).

Soil effects are shown to be important because they affect the total storage capacity and the wet and dry limits of soil water content. Particularly under dry conditions where the residual water content is closely related to soil texture, patterns of soil moisture reflect patterns of soil texture. At the scales studied here, vegetation is shown to have a limited influence on soil moisture patterns. This is partly because of the interrelationship between climate, soils and vegetation distribution and partly because we are looking at soil moisture content rather than total water availability (where rooting depth becomes important).

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