Rudiger, Christoph; Hancock, Greg; Hemakumara, Herbert M.; Jacobs, Barry; Kalma, Jetse Daniel; Martinez, Cristina; Thyer, Mark Andrew; Walker, Jeffrey Phillip; Wells, Tony; Willgoose, Garry R.
Goulburn River experimental catchment data set
Water Resources Research, 2007; 43(10):1-10

Goulburn River experimental catchment data set

Christoph Rüdiger,[1,2] Greg Hancock,[3] Herbert M. Hemakumara,[4] Barry Jacobs,[4] Jetse D. Kalma,[4] Cristina Martinez,[3] Mark Thyer,[4] Jeffrey P. Walker,[1] Tony Wells,[4] and Garry R. Willgoose[4]

Received 20 December 2006; revised 13 June 2007; accepted 25 June 2007; published 2 October 2007.

[1] This paper describes the data set from the 6540-km^2 Goulburn River experimental catchment in New South Wales, Australia. Data have been archived from this experimental catchment since its inception in September 2002. Land use in the northern half of the catchment is predominantly cropping and grazing on basalt-derived soils, with the south being cattle and sheep grazing on sandstone-derived soils; only the floodplains are cleared of trees in the south. Monitoring sites are mainly concentrated in the nested Merriwa (651 km^2) and Krui (562 km^2) subcatchments in the northern half of this experimental catchment with a few monitoring sites located in the south. The data set comprises soil temperature and moisture profile measurements from 26 locations; meteorological data from two automated weather stations (data from a further three stations are available from other sources) including precipitation, atmospheric pressure, air temperature and relative humidity, wind speed and direction, soil heat flux, and up- and down-welling short- and long-wave radiation; streamflow observations at five nested locations (data from a further three locations are available from other sources); a total of three surface soil moisture maps across a 40 km $\times$ 50 km region in the north from $\sim$200 measurement locations during intensive field campaigns; and a high-resolution digital elevation model (DEM) of a 175-ha microcatchment in the Krui catchment. These data are available on the World Wide Web at http://www.sasmas.unimelb.edu.au.

Citation: Rüdiger, C., G. Hancock, H. M. Hemakumara, B. Jacobs, J. D. Kalma, C. Martinez, M. Thyer, J. P. Walker, T. Wells, and G. R. Willgoose (2007), Goulburn River experimental catchment data set, *Water Resour. Res.*, *43*, W10403, doi:10.1029/2006WR005837.

1. Introduction

[2] Information on surface and root-zone soil moisture is important for a wide range of environmental applications, including hydrology, meteorology, and climate studies. Surface soil moisture is known to be a governing variable in those fields by controlling land surface–atmosphere interactions through latent and sensible heat fluxes, water availability to plants, and the partitioning of rainfall between subsurface storage and runoff. However, our level of process understanding is not yet sufficient to rely on model predictions alone. Moreover, soil moisture remote sensing has not yet been developed to the point where it can provide reliable and routine soil moisture estimates. It is therefore imperative that experiments be undertaken to enable advances to be made in soil moisture remote sensing, hydrological prediction in ungauged basins, hydrological data assimilation, and the understanding of land surface feedback mechanisms to short-term meteorological and long-term climate events.

[3] While there have been several studies on the spatial and temporal variability of soil moisture, these have been either large-scale intensive experiments for short periods (weeks) of time, such as the Southern Great Plains (SGP) [e.g., *Famiglietti et al.*, 1999] and Soil Moisture Experiments (SMEX) series [e.g., *Jacobs et al.*, 2004a] experiments, or medium-term (years) detailed studies of small areas, such as the Tarrawarra [*Western et al.*, 1999], Nerrigundah [*Walker et al.*, 2001], and Mahurangi experiments [*Woods et al.*, 2001]. What has been missing to date is a long-term detailed experiment for a large area encapsulating a range of land cover, land use, and soil type conditions. Although monitoring programs such as the Oklahoma Mesonet [*Brock et al.*, 1995] provide long-term observations of soil moisture, they do not provide the nested high spatial resolution soil moisture, streamflow, meteorological, and supporting data necessary to make significant advances in these important areas of science.

[4] This paper describes data from the 6540-km^2 Goulburn River experimental catchment in New South Wales, Australia (Figure 1). This experimental catchment was designed specifically for soil moisture remote sensing, hydrological data assimilation, and prediction in ungauged basin studies. The novel aspect of this data set is the long-term nested monitoring of profile soil moisture, meteoro-

[1]Department of Civil and Environmental Engineering, University of Melbourne, Parkville, Victoria, Australia.
[2]Now at Centre National de Recherches Météorologiques/Groupe d'Etude de l'Atmosphère Météorologique, Météo-France/Centre National de la Recherche Scientifique, Toulouse, France.
[3]School of Environmental and Life Sciences, University of Newcastle, Callaghan, New South Wales, Australia.
[4]School of Engineering, University of Newcastle, Callaghan, New South Wales, Australia.

0043-1397/07/2006WR005837

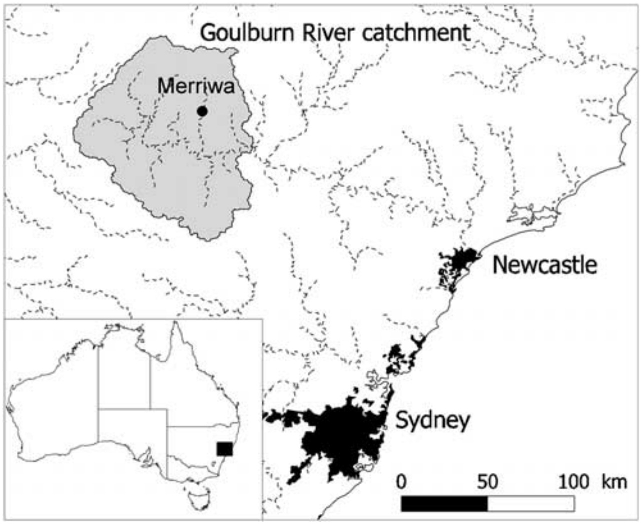

Figure 1. Regional map showing the location of the Goulburn River experimental catchment, shaded.

logical variables, and streamflow across a large catchment, with large scale campaign-based distributed surface soil moisture observations. Moreover, the catchment has a range of land use and soil conditions, ranging from cropping and grazing on heavy cracking basalt-derived soils in the north to predominantly forested land on mainly sandstone-derived soils in the south. These two distinct zones of land use and soil type in the catchment are each large enough to accommodate C-band (6.9-GHz) Advanced Microwave Scanning Radiometer for Earth Observing Systems (AMSR-E) passive microwave sensor footprints, allowing sensor validation and assimilation [*Rüdiger*, 2006]. Additionally, the field site has been used in 2005 for the joint Australian National Airborne Field Experiment (NAFE [*Walker et al.*, 2005]) and the European Space Agency's Campaign for validating the Operation of SMOS (CoSMOS), in preparation for the launch of the Soil Moisture and Ocean Salinity (SMOS) mission [*Kerr et al.*, 2001].

[5] The majority of instruments used for the data collection were installed in September 2002, with some additional instrumentation and associated upgrades during subsequent years (see Table 1). The collected data have a variety of potential uses additional to those listed above. Specific analyses the authors have conducted with the collected data include understanding the spatial and temporal variability of surface soil moisture (C. Rüdiger et al., manuscript in preparation, 2007); validation of the AMSR-E soil moisture product (C. Gruhier et al., manuscript in preparation, 2007), and downscaling low-resolution satellite observations of near-surface soil moisture using ancillary data (H. M. Hemakumara, Aggregation and disaggregation of soil moisture measurements, Ph.D. thesis, submitted to School of Engineering, University of Newcastle, Callaghan, Australia, 2007); assimilation of streamflow and near-surface soil moisture into a land-surface model for root zone soil moisture retrieval [*Rüdiger et al.*, 2005; *Rüdiger*, 2006]; understanding spatial and temporal patterns in soil organic carbon [*Jacobs et al.*, 2004b]; and simulation studies of catchment carbon budgets [*Jacobs et al.*, 2004b]. Furthermore, research is currently in progress that involves collecting information on soil organic carbon to determine the spatial variability and the displacement over time of soil organic carbon throughout the catchment [*Martinez et al.*, 2006]. Finally, the correlation between spatial soil moisture patterns with remotely sensed L-band data at different resolutions is being studied [*Saleh et al.*, 2007] using the in situ soil moisture observations and the ground- and air-based ancillary data collected during the NAFE campaign [*Walker et al.*, 2005, 2006].

[6] While the authors will continue to use this data set for modeling and analysis in a variety of projects, it is being made available to the broader research community so as to provide other researchers with the much needed long-term field data required for model and remote sensing evaluation studies.

2. Catchment Description

[7] The Goulburn River is a tributary to the Hunter River in New South Wales, Australia (Figure 1). This subhumid to temperate 6540-km^2 experimental catchment extends from 31°46′S to 32°51′S and 149°40′E to 150°36′E, with elevations ranging from around 100 m in the floodplains to around 1300 m in the northern and southern mountain ranges (Figure 2a). The terrain slope as derived from the national 250-m digital elevation model [*Australian Surveying and Land Information Group* (*AUSLIG*), 2001] (AUSLIG is now called Geoscience Australia) has a median of 8%, with a maximum of 71%. This catchment was chosen for (1) its relatively large area of predominantly low to moderate vegetation cover in the north of the catchment (Figure 2b) suitable for satellite soil moisture remote sensing studies; (2) its dense vegetation in the southern region for which no remotely sensed surface soil moisture information is available; (3) the lack of maritime effects in order to avoid mixed pixel responses when ocean and land surfaces fall within the same satellite footprint; (4) the distinct soil type distributions with basalt-derived soils in the north and sandstone-derived soils in the south; (5) the topographic variation including floodplains, undulating hills, and mountainous terrain; (6) the absence of

Table 1. Dates of the Instrument Installation (I), Site Update (U), and Major Field Campaigns (C)

Activity	Date	Description
I	Sep 2002	13 soil moisture monitoring sites (G6, K1-6, M2-5, M7, S2); two automated weather stations (K6, S2)
I	Nov 2002	seven soil moisture monitoring sites (G1-5, M1, S5); flume at Stanley (SF)
I	Jan–Feb 2003	five soil moisture monitoring sites (S1, S3, S4, S6, S7); one stream gauge (KM)
I	May 2003	three stream gauges (KU, ML, MU)
I	July 2003	one soil moisture monitoring site (M6); one stream gauge (KL)
C	7–9 Nov 2003	AMSR-E validation campaign
U	April 2004	four-way radiometer at S2
C	1–3 May 2004	AMSR-E validation campaign
U	Sep–Oct 2005	tipping bucket rain gauges and hydraprobes added to all the monitoring sites
C	7–9 Jul 2005	AMSR-E validation campaign
C	Oct–Nov–Dec 2005	NAFE/CoSMOS

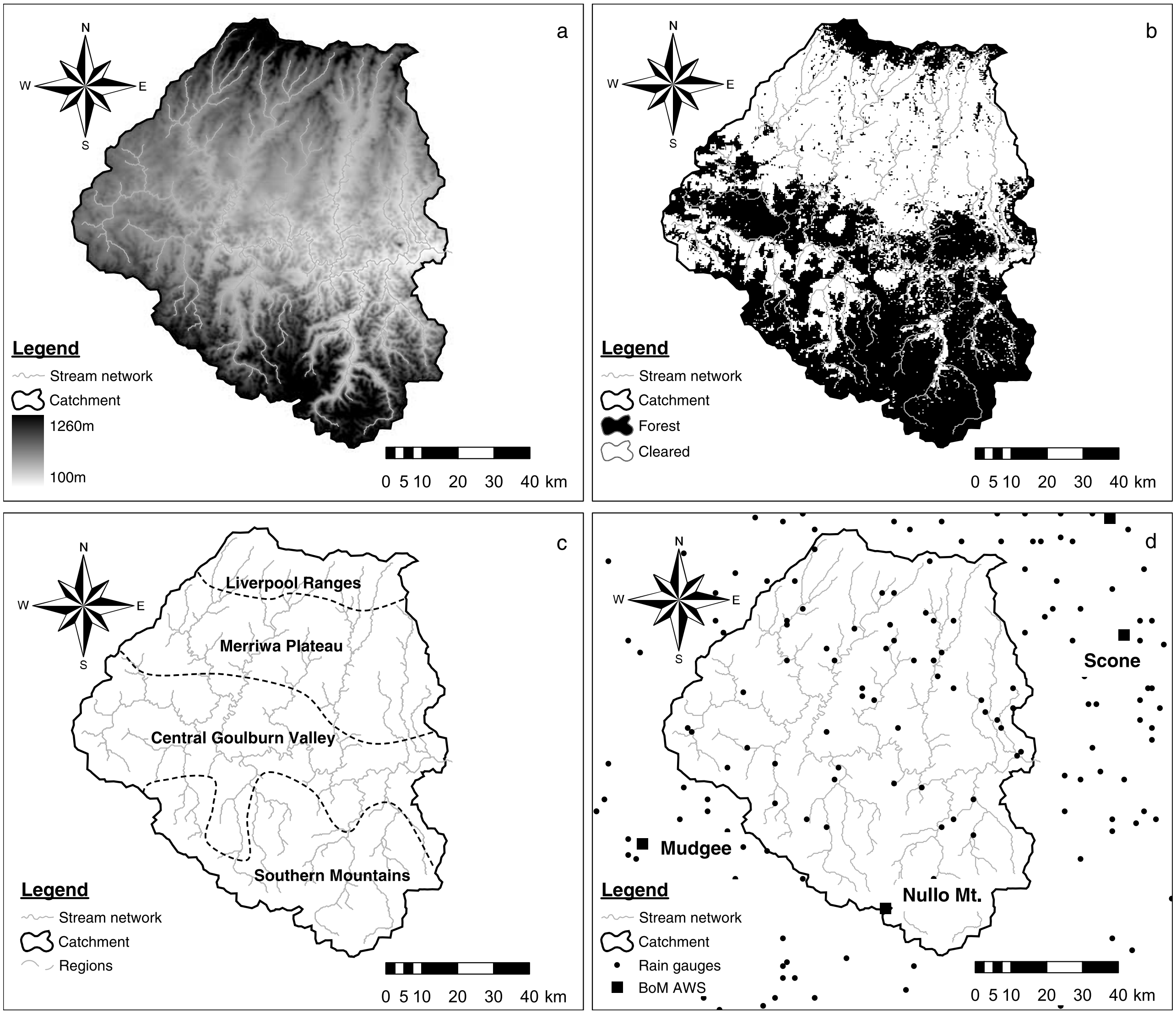

Figure 2. (a) Shaded relief plot of the published 250-m digital elevation model of the Goulburn River catchment, (b) areas of forested and cleared vegetation (derived from a Landsat image), (c) the four different geological regions within the Goulburn River catchment [after *Galloway*, 1963], and (d) location of collecting rain gauges and automated weather stations, operated by the Australian Bureau of Meteorology.

regulation in the river system; and (7) minimal soil moisture interactions with groundwater due to a deep aquifer.

[8] The geology of the Goulburn River catchment can be distinguished into two types: the north, which is predominantly Tertiary basalt [*Atkinson*, 1966; *Story et al.*, 1963], a product of Cainozoic volcanism that took place throughout much of eastern Australia [*Branagan and Packham*, 2000]; and the south, which is dominated by rocks of the Triassic age laid down as sediments in lagoons and consisting of sandstone, conglomerate, and shale [*Story et al.*, 1963]. The region's geomorphology is largely dependent on its geological and climatic history with four main types of country identified; the Liverpool Range and Merriwa Plateau in the north and the Central Goulburn Valley and Southern Mountains in the south (Figure 2c). A concise description of the vegetation and land systems is given in Table 2. A detailed description of the geological structure of the Goulburn River catchment is given by *Martinez* [2004].

[9] The Goulburn River runs generally from west to east, with tributaries from the north and south, meaning the catchment is dominated by easterly and westerly aspects. The main catchment has two more intensively monitored subcatchments, the Krui River (562 km^2) and Merriwa River (651 km^2) in the northern half of the catchment (Figure 3). Additionally, a densely monitored 175-ha microcatchment is located on a property called "Stanley," located in the lower reach of the Krui River catchment (Figure 3 insets).

[10] The general climate within the region can be described as subhumid or temperate [*Stern et al.*, 2000], with significant variation in the annual rainfall and evaporation during the year, and a high variability of rainfall throughout the catchment [*Bridgman*, 1984]. While the average annual rainfall in the Goulburn River catchment is approximately 650 mm, it varies from 500 to 1100 mm depending on altitude (Figure 4a). Major rainfall events generally occur from November to March with an average monthly precipitation

Table 2. Land Systems in the Goulburn River Catchment[a]

	Liverpool Range		Merriwa Plateau		Central Goulburn Valley	Southern Mountains		
Land System	Liverpool	Tubrabucca	Ant Hill	Bow	Ogilvie	Lees Pinch	Three Ways	Munghorn Gap
Geology	Tertiary basalt	Tertiary basalt	Tertiary basalt	Tertiary basalt	Permian conglomerates, sandstone, and shale	Triassic sandstone and minor shale	Triassic sandstone with subordinate shale beds	Triassic sandstone
Terrain	rugged	plateau	hilly	undulating	rugged	rugged	rugged	plateau
Soils	clayey humic skeletal soils, shallow cracking clays; small areas with alpine humus soils	leached kraznozems and transitional alpine humus soils with or without basalt floaters, skeletal soils, and sphagnum peats	dark, rather shallow, stony cracking clays	deep black and dark cracking clays, sometimes stony	skeletal soils, some shallow earths, solonetzic soils, and degraded black earths	bare rock and sandy, gritty, or gravelly skeletal soils, minor areas with podzolic soils and earths	sandy skeletal soils, sometimes humic, some earths	fairly deep sandy earths and some skeletal soils
Rainfall, mm	750–1000	750–1500	550–750	550	550–800	550–750	600–900	650–750
Vegetation	savannah woodland of box and gum, some thinned or cleared; 60% wooded	eucalypt subalpine woodland or wet sclerophyll forest; 90% wooded	savannah woodland of box and gum, some thinned or cleared; 10% wooded	eucalypt tree savannah, mostly thinned or cleared, with plains grass; 10% wooded	dense savannah woodland of box, gum, and ironbark in the west; wet or dry sclerophyll forest in the east; 100% wooded	shrub woodland of ironbark and gum; 100% wooded	dry sclerophyll forest; 100% wooded	dry sclerophyll forest or shrub woodland of ironbark and gum; 100% wooded

[a]Sources are *Atkinson* [1966] and *Story et al.* [1963].

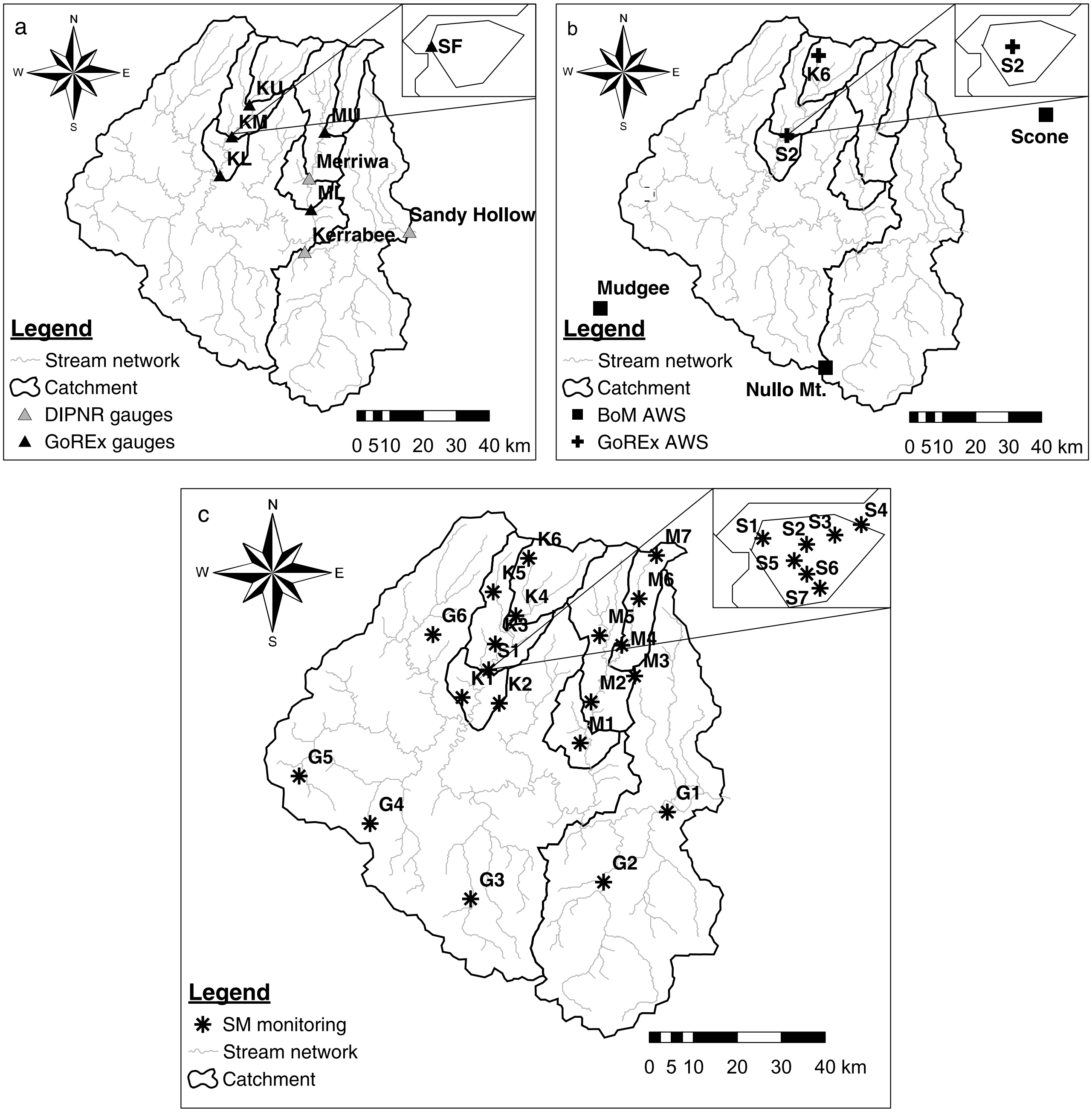

Figure 3. Catchment overview showing the location of (a) streamflow, (b) automated weather stations (AWS), and (c) soil moisture monitoring sites, with delineation of subcatchments used for monitoring and modeling. The numbering of the monitoring sites follows the location of the sites (G, Goulburn; K, Krui; M, Merriwa; S, Stanley); soil moisture monitoring sites received a number as index, while stream gauges in the Merriwa and Krui River catchments received a character designating lower (L), middle (M), or upper (U) according to the location of the stream gauge within the catchment, while the DIPNR sites maintained their names.

of 68 mm, while the monthly average precipitation in June is 32 mm. The average annual potential areal evaporation for the study region is about 1300 mm, with a maximum of 1360 mm and a minimum of 1240 mm (Figure 4b). The minimum monthly potential evaporation is reached in July with an average of 50 mm, and a maximum in January reaching 180 mm. Monthly mean maximum temperatures reach approximately 30°C in summer and 14°C in winter, with mean minimum values of 16°C and 2°C, respectively [*Australian Bureau of Meteorology*, 1988]. Except for elevated areas, frost is unlikely to occur during daytime in winter, but nighttime minimum temperatures in winter are frequently less than 0°C.

3. Data Summary

[11] The Goulburn River experimental catchment has been instrumented since September 2002 and will continue

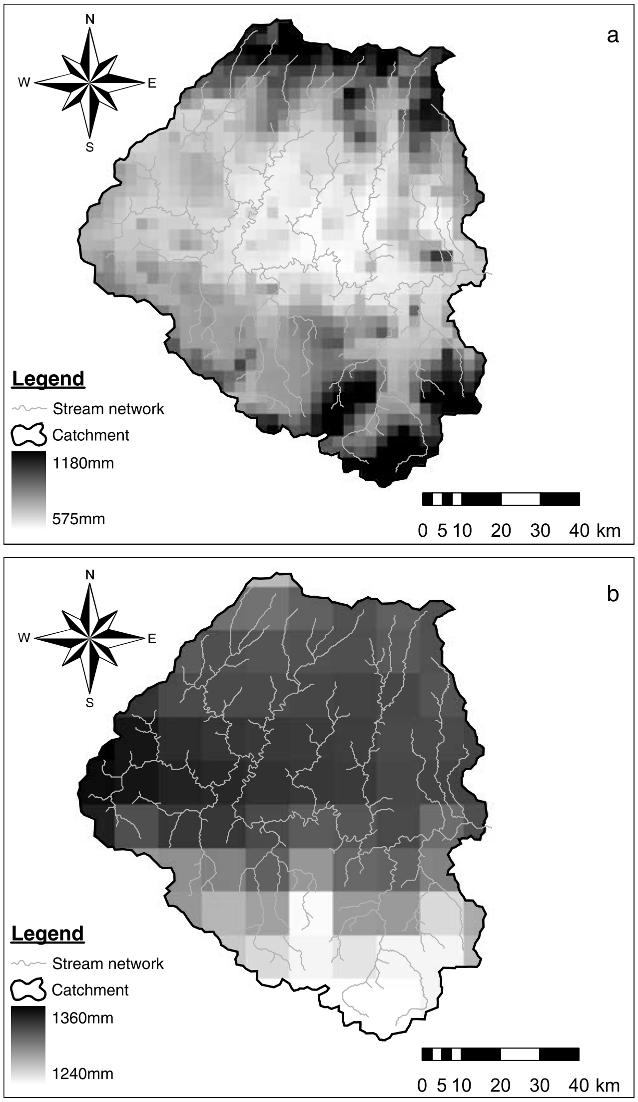

Figure 4. Spatial distribution of annual average (a) rainfall and (b) potential areal evapotranspiration (data from *Australian Bureau of Meteorology* [1988]).

through until at least January 2008. There have been several enhancements to the catchment instrumentation since its original installation (see Table 1). The catchment monitoring includes surface and root zone soil moisture, soil temperature, micrometeorology, and streamflow.

[12] A total of 26 soil moisture profile and temperature monitoring sites were chosen on the basis of (1) being a representative monitoring site, (2) spatial distribution across the experimental catchment, and (3) accessibility (Figure 3c). The representative monitoring site objective was addressed by choosing midslope locations with typical vegetation, soil, and aspect, so that they represented catchment average soil moisture locations [*Grayson and Western*, 1998]. The spatial distribution was chosen to give a concentration of measurements in the open cropping and grazing land to the north for application to remote sensing measurements, while achieving a good distribution for model verification within the chosen focus catchments and the broader Goulburn River experimental catchment.

[13] The automated weather stations were sited with regard to existing infrastructure and expected spatial variability, resulting in one at the center of the Goulburn River experimental catchment and a second in high terrain to the north of the catchment, supplementing existing sites to the south, east, and west (operated by the Australian Bureau of Meteorology). This also resulted in automated weather stations being located in both the upper and lower reaches of the Krui focus catchment, and in the center of the Stanley microcatchment. The siting of the weather stations also provides an increase in the density of meteorological observations within the Goulburn River catchment, and the addition of local short- and long-wave radiation observations. Figure 5 shows sample atmospheric data collected with the automated weather station at Stanley (S2) during 2004.

[14] Five stream gauges were installed in the two focus catchments, adding to the four existing stream gauges operated by the New South Wales Department of Infrastructure, Planning and Natural Resources (DIPNR) and allowing the Goulburn River experimental catchment to be subdivided into smaller modeling units. This included three subcatchments in the Krui River catchment, three subcatchments in the Merriwa River catchment, and a further two divisions in the broader Goulburn River experimental catchment. Catchment runoff observations were also made at the Stanley microcatchment.

[15] As continuous monitoring of spatially high resolution near-surface soil moisture was not feasible, detailed surface soil moisture data were collected during three intensive field campaigns between November 2003 and July 2004, with additional collection of soil temperature, vegetation biomass, and vegetation water content. An example of the soil moisture data is given in Figure 6.

3.1. Terrain Data

[16] The 9-s (approximately 250 m) digital elevation model (DEM) for all of Australia is available from Geosciences Australia and can be downloaded for free from their Web site. Moreover, an accurate 5-m DEM was created using a Differential Global Positioning System survey of the Stanley microcatchment. The approximately 16,000 data points collected at approximately 5-m spacing were gridded to a resolution of 5 m using kriging. In addition, detailed site surveys have been undertaken for each of the 26 soil moisture monitoring sites encompassing areas within a radius of approximately 250 m from each monitoring site.

3.2. Meteorological Data

[17] Two automated weather stations are being operated within the Goulburn River experimental catchment, located in the lower and upper reaches, respectively, of the Krui catchment. The northern weather station is at an elevation of 739 m and includes an air temperature and relative humidity sensor at 2 m, wind speed sensor at 3 m, tipping bucket rain gauge, and three soil temperature sensors at 150, 450, and 750 mm. The southern weather station located on "Stanley" includes a pyranometer and wind speed and direction sensors at 3 m, air temperature, relative humidity, and barometric pressure sensors at 2 m, a four-way radiometer at 1 m, tipping bucket rain gauge, two heat flux plates at 50 mm depth, and eight soil temperature sensors (at 25, 50, 100, 150, 300, 450, 600, and 750 mm). A schematic for the

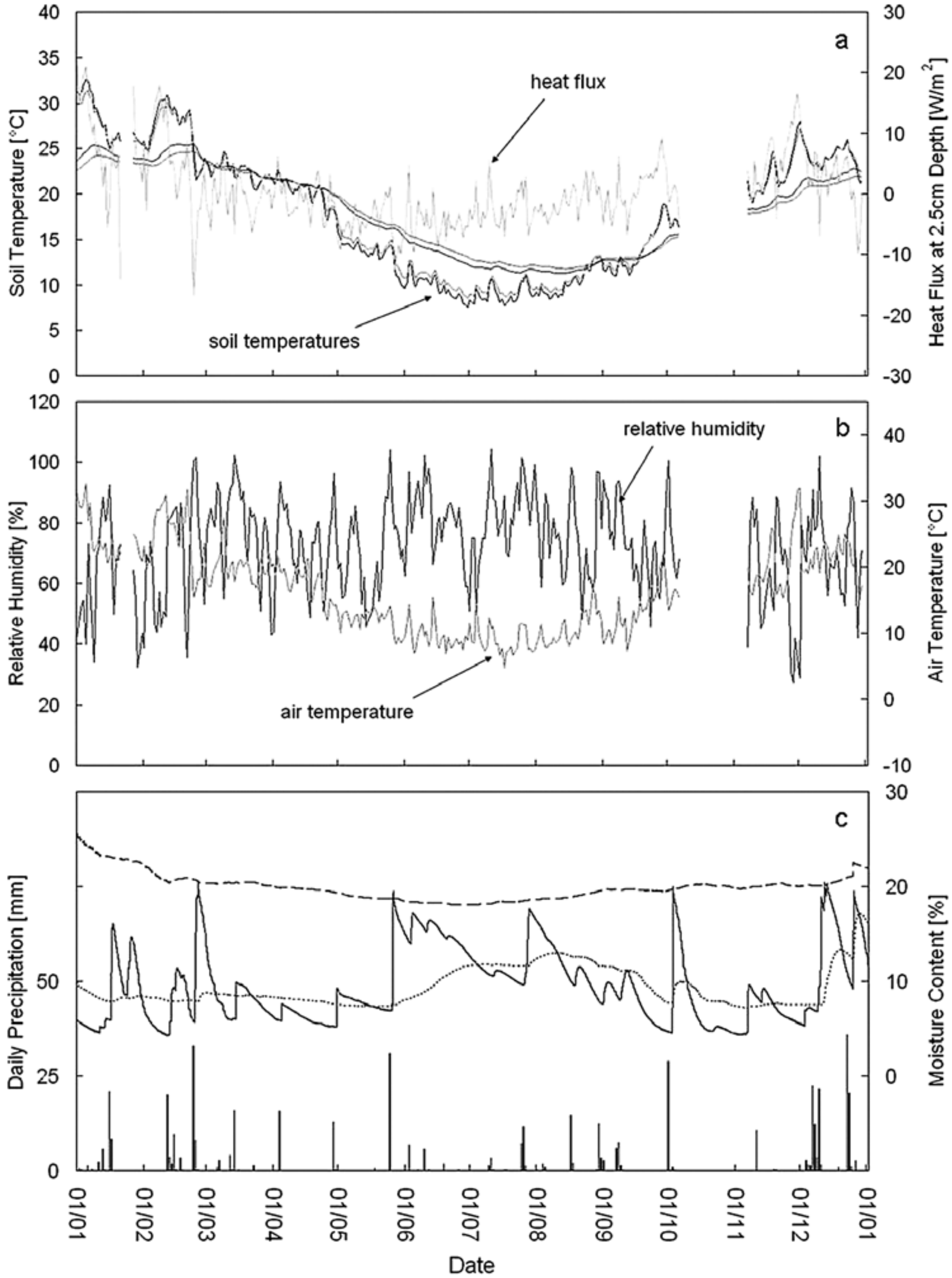

Figure 5. Sample data (from site S2) for daily averaged (a) soil heat flux (25 mm) and soil temperature (various depths), (b) relative humidity and air temperature, and (c) precipitation and soil moisture observed at K2 at depths of 0–300 mm (solid line), 300–600 mm (dotted line), and 600–900 mm (dashed line). Data gaps are due to instrument failures.

automated weather station setup is given in Figure 7. The meteorological measurements are taken every minute and averaged over 20 min. Rainfall data are logged for each tip of the 0.2-mm tipping bucket.

[18] Data from three further weather stations are available through the Australian Bureau of Meteorology. Those automated weather stations are located in the south, west, and east of the region, operated near Scone and Mudgee and at Nullo Mountain, respectively. The stations provide air temperature, wind speed, and rainfall data only. Numerous collecting rain gauges operated by the Australian Bureau of Meteorology are also located in and around the catchment and provide daily 9:00 A.M. rainfall observations (Figure 2d).

3.3. Soil Moisture Profile Data

[19] There are 26 soil moisture profile monitoring sites distributed throughout the Goulburn River experimental catchment, with each site having up to three vertically inserted Campbell Scientific CS616 water content reflectometers [*Campbell Scientific Inc.*, 2002] over depths of 0–300, 300–600, and 600–900 mm, respectively (see schematic in Figure 7). The exact number of soil moisture sensors installed at a site was determined by the depth to

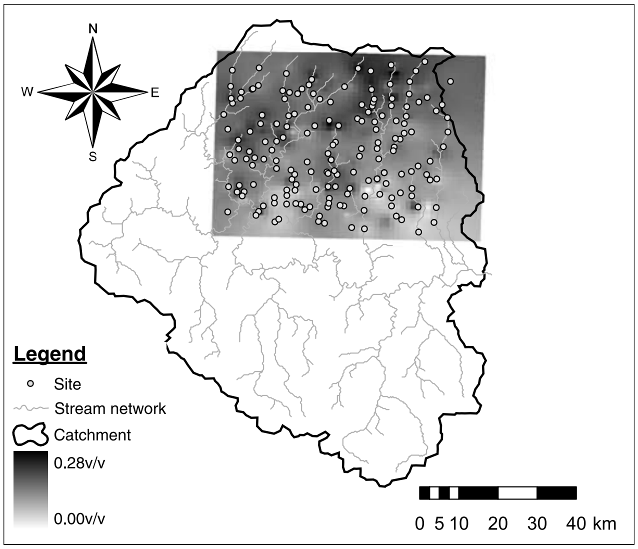

Figure 6. Interpolated surface (60 mm) soil moisture map and location of individual sampling sites within the focus area (from the 7–9 November 2003 field campaign).

the bedrock, being less than 900 mm in some cases. Sensors were installed by excavation to the top of the sensor installation level and backfilling. These sensors ensure a continuous observation of the soil moisture profile, with sensors read every minute and averages logged every 20 min.

[20] Sensor response to soil moisture varies with salinity, density, soil type, and temperature, requiring a detailed sensor calibration for each site using both laboratory and field measurements (C. Rüdiger et al., manuscript in preparation, 2007). As the CS616 sensors are particularly sensitive to soil temperature fluctuations, Campbell Scientific T107 temperature sensors were installed vertically with their midpoint at 150 mm below the soil surface, providing a continuous record of soil temperature at a midpoint of the 0–300 mm CS616 sensor for each monitoring site, enabling temperature corrections to be made. Deeper temperatures were found to have the same characteristics throughout the catchment and were therefore estimated from the detailed soil temperature profile measurements made at the automated weather station in the Stanley microcatchment, by using the same ratio between shallow and deep soil temperature at the different locations [*Rüdiger*, 2006]. A comparison between probe data using site-specific laboratory calibrations and independent gravimetric soil moisture samples indicated an overall root-mean-square error (RMSE) of 0.035 vol/vol.

[21] All soil moisture monitoring sites were recently upgraded with tipping bucket rain gauges and Stevens water HydraProbes, measuring the soil temperature at 25 mm and soil moisture in the 0–50 mm layer of soil. However, no additional tipping bucket rain gauges were added to the soil

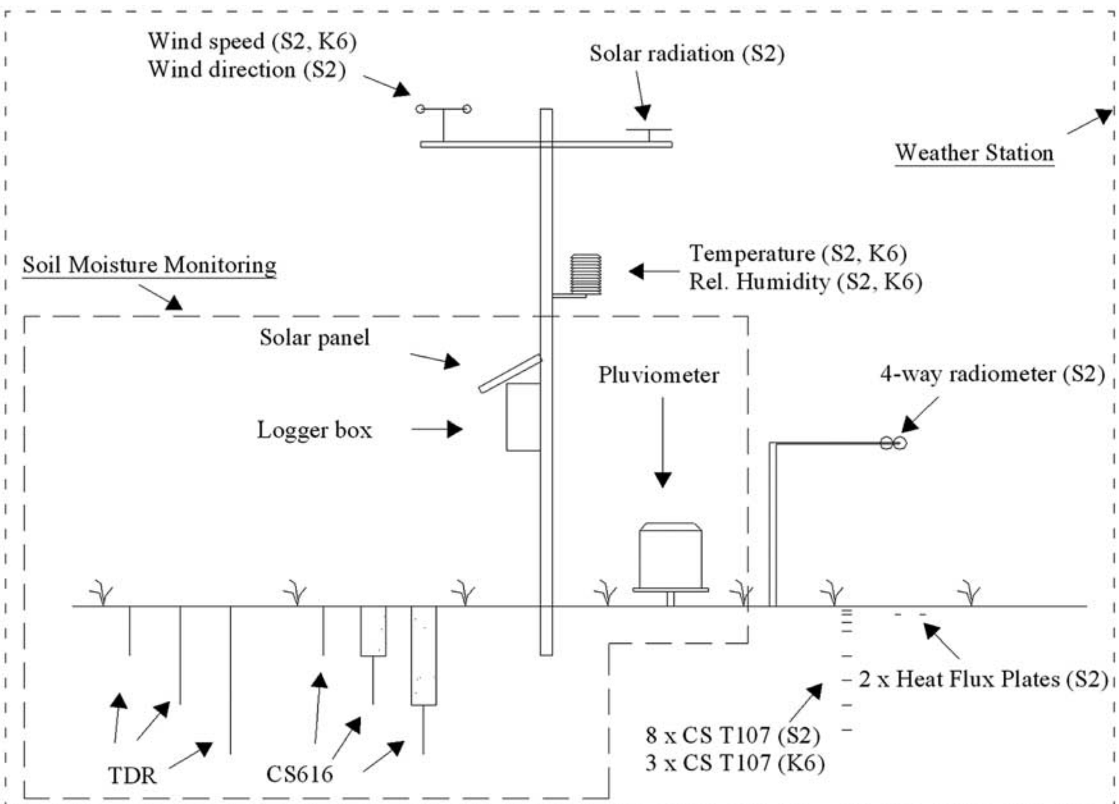

Figure 7. Schematic of the weather and soil moisture stations. The larger box includes the instrumentation typically installed at weather stations, while the smaller box includes the instruments typically installed at soil moisture monitoring sites. Instruments annotated with S2 are located at the AWS at Stanley, and those with K6 are located at the AWS at Spring Hill.

moisture monitoring sites at Stanley, as they were considered as being equivalent to a point within the larger catchment, with minimal rainfall variation across the site.

[22] Two focus catchments were created by establishing seven soil moisture monitoring sites in each of the major subcatchments (six individual sites in the Krui River catchment in addition to the Stanley microcatchment (with seven sites) and seven individual sites in the Merriwa Creek catchment), with a further six sites installed in the remaining Goulburn River experimental catchment (Figure 3c). The intensively monitored Stanley microcatchment was designed to explore the spatial variation of soil moisture across local scales. Moreover, the higher density of soil moisture monitoring sites in the Krui and Merriwa catchments allows for work on the spatial organization of soil moisture throughout the northern part of the catchment and supports work undertaken in the validation of models and validation and scaling of satellite measurements. Sample data measured at a site in the Krui subcatchment are shown in Figure 5c for 2004.

3.4. Near-Surface Soil Moisture Maps

[23] Three intensive field campaigns were conducted over an area of 40 km × 50 km in the northern part of the Goulburn River experimental catchment during 7–9 November 2003, 1–3 May 2004, and 7–9 July 2004. The objectives of these campaigns were to (1) carry out large-scale validation of passive microwave near-surface soil moisture data from AMSR-E and (2) evaluate approaches for downscaling of low-resolution AMSR-E data. The data collection took place over 3 days and generally coincided with several Aqua and Terra overpasses for each field campaign, with approximately 220 sites visited in each campaign at approximately 3 km spacings, to obtain near-surface soil moisture data using hand-held Theta probes (0–60 mm), volumetric soil samples for subsequent thermogravimetric soil moisture determination (0–10 mm), surface soil temperature data and vegetation samples for biomass and vegetation water content determination. Figure 6 shows the interpolated soil moisture data from one of the field campaigns.

3.5. Streamflow Data

[24] Streamflow is being measured at eight locations throughout the catchment, with three of these stream gauging stations (Sandy Hollow, Kerrabee, and Merriwa; see Figure 3) operated by the New South Wales Department of Infrastructure, Planning and Natural Resources (DIPNR). Three of the project's five stream gauging sites are located along the Krui River, and two are along the Merriwa River, complementing the DIPNR gauge near the town of Merriwa. Streamflow at the project-operated sites is measured with Solinst model 3001 leveloggers, which measure the local water pressure every 20 min. The instruments are not vented, and raw data are corrected for atmospheric pressure changes using measurements at the nearby Stanley microcatchment.

[25] Preliminary rating curves for the project's streamflow monitoring sites have been developed, using Manning's equation with measured cross-sectional information and estimated bed roughness from published values [*Barnes*, 1967] (see also http://wwwrcamnl.wr.usgs.gov/sws/fieldmethods/Indirects/nvalues/). However, because of the persistent drought conditions in recent years in the area, both the Krui and Merriwa rivers have provided only a few opportunities for calibration and validation of the rating curve with propeller meter data. Nevertheless, the observed flow depth is available for qualitative comparisons of observations and model output while the rating curves undergo further development. The runoff ratio for years 2003 and 2004 was calculated as 0.01 for the Sandy Hollow stream gauge, illustrating that the water balance in the catchment has been dominated by evapotranspiration in recent years.

[26] Runoff from the Stanley microcatchment is monitored with a 46 cm (1 foot, 6 inch) partial Parshall flume located at the outlet of the catchment. A stilling well at the side of the flume houses a Solinst levelogger (an Innovonics MD4W water level logger until March 2005), which measures the water level at 20-min intervals. The calibration of the flume is given by *Bos* [1976] and was confirmed by *Walker* [1999]. The laboratory calibrations of the water level sensors in place are available with the data set. No flow has been observed at this site since the flume installation.

4. Accessibility of the Data Set

[27] Apart from the additional streamflow and micrometeorology data collected by other organizations, the published DEMs, and satellite data, all other data described in this paper are available on the World Wide Web at http://www.sasmas.unimelb.edu.au. The Web site provides all the information needed for interpretation of these data, along with site overviews, photographs, data plots, and related publications. Due acknowledgement in any publication or presentation arising from use of these data is required.

[28] **Acknowledgments.** The authors wish to thank Robert and Maree Goodear for kindly providing accommodation during the installation of equipment and subsequent field campaigns, and Doc and Fiona Strahan for hosting the large amount of monitoring equipment located in the Stanley microcatchment. Further thanks are due all the property owners for kindly hosting soil moisture, streamflow, or climate monitoring sites and/or allowing access to their land. Field assistance by Riki Davidson, Ian Jeans, Patricia Saco, Emily Barbour, Simon Baker, and Makeena Kiugu is gratefully acknowledged. This data collection was funded over 2002–2005 by ARC Discovery Project DP 0209724 to J. D. Kalma, G. R. Willgoose, and J. P. Walker with considerable infrastructure support received from the Hydrological Science Branch at NASA Goddard Space Flight Center through the loan of monitoring equipment. Ongoing support for maintenance, upgrades, and data collection is currently provided from ARC Discovery Project DP0556941 to G. Hancock, J. D. Kalma, and J. J. McDonnell and ARC Discovery Project DP 0557543 to J. P. Walker, J. D. Kalma, and E. Kim.

References

Atkinson, W. (1966), A review of the land systems of the Hunter Valley, N. S. W., report, Hunter Valley Res. Found., Newcastle, N. S. W., Australia.

Australian Bureau of Meteorology (1988), Climatic atlas of Australia, 67 pp., Aust. Gov. Print. Serv., Canberra, A. C. T., Australia.

Australian Surveying and Land Information Group (AUSLIG) (2001), GEODATA 9 second digital elevation model, version 2, Belconnen, A. C. T., Australia.

Barnes, H. B. (1967), Roughness characteristics of natural channels, *U.S. Geol Surv. Water Supply Pap.*, *1849*, 219 pp.

Bos, M. G. (Ed.) (1976), *Discharge Measurement Structures*, *Publ. 20*, 464 pp., Work. Group on Small Hydraul. Struct., Int. Inst. for Land Reclam. and Impr., Wageningen, Netherlands.

Branagan, D. F., and G. H. Packham (Eds.) (2000), *Field Geology of New South Wales*, 3rd ed., N. S. W. Dep. of Miner. Resour., Sydney, Australia.

Bridgman, H. A. (1984), *Climatic Atlas of the Hunter Valley*, Dep. of Geogr., Univ. of Newcastle, Callaghan, N. S. W., Australia.

Brock, F. V., K. C. Crawford, R. L. Elliott, G. W. Cuperus, S. J. Stadler, H. L. Johnson, and M. D. Eilts (1995), The Oklahoma Mesonet: A technical overview, *J. Atmos. Oceanic Technol.*, *12*, 5–19.

Campbell Scientific Inc. (2002), CS616 water content reflectometer instruction manual, 33 pp., Logan, Utah.

Famiglietti, J. S., J. A. Devereaux, C. A. Laymon, T. Tsegaye, P. R. Houser, T. J. Jackson, S. T. Graham, M. Rodell, and P. J. van Oevelen (1999), Ground-based investigation of soil moisture variability within remote sensing footprints during the Southern Great Plains 1997 (SGP97) hydrology experiment, *Water Resour. Res.*, *35*(6), 1839–1851.

Galloway, R. W. (1963), Geomorphology of the Hunter Valley, in *General Report on the Lands of the Hunter Valley*, *Land Res. Ser.*, *8*, edited by R. Story et al., part V, pp. 90–102, Commonw. Sci. and Ind. Res. Organ., Australia, Melbourne, Victoria, Australia.

Grayson, R. B., and A. W. Western (1998), Towards areal estimation of soil water content from point measurements: Time and space stability of mean response, *J. Hydrol.*, *207*(1–2), 68–82.

Jacobs, J. M., B. P. Mohanty, E. C. Hsu, and D. Miller (2004a), SMEX02: Field scale variability, time stability and similarity of soil moisture, *Remote Sens. Environ.*, *92*(4), 436–446.

Jacobs, B., J. Kalma, G. Hancock, M. Hemakumara, J. Walker, and G. Willgoose (2004b), Towards understanding of the spatial and temporal distribution and dynamics of soil organic carbon within a large temperate agricultural catchment, in *International Workshop on the Terrestrial Water Cycle: Modelling and Data Assimilation Across Catchment Scales*, *Wageningen Univ. Rep. 122*, edited by R. Teuling et al., pp. 105–108, Wageningen, Netherlands.

Kerr, Y. H., P. Waldteufel, J. P. Wigneron, J. Font, and M. Berger (2001), Soil moisture retrieval from space: The Soil Moisture and Ocean Salinity (SMOS) mission, *Geosci. Remote Sens.*, *39*(8), 1729–1735.

Martinez, C. (2004), Geomorphic and hydrologic scaling properties of the Merriwa basalt catchments, B. S. honors thesis, School of Earth and Life Sci., Univ. of Newcastle, Callaghan, N. S. W., Australia.

Martinez, C., G. R. Hancock, D. Murphy, and J. D. Kalma (2006), An assessment of soil carbon at the hillslope scale: Australian examples, *Geophys. Res. Abstr.*, *8*, Abstract EGU06-A-05311.

Rüdiger, C. (2006), Streamflow data assimilation for soil moisture prediction, Ph.D. thesis, 407 pp., Dep. of Civ. and Environ. Eng., Univ. of Melbourne, Melbourne, Victoria, Australia.

Rüdiger, C., J. P. Walker, J. D. Kalma, G. R. Willgoose, and P. R. Houser (2005), Root zone soil moisture retrieval using streamflow and surface moisture data assimilation in nested catchments, in *MODSIM05: International Congress on Modelling and Simulation*, edited by A. Zerger and R. M. Argent, pp. 1458–1464, Modell. and Simulation Soc. of Aust. and N. Z., Canberra, A. C. T., Australia.

Saleh, K., et al. (2007), The CoSMOS L-Band Experiment in southeast Australia, in *Proceedings to IEEE International Geosciences and Remote Sensing Symposium (IGARSS) 2007*, IEEE Geosci. and Remote Sens. Soc., New York, in press.

Stern, H., G. de Hoedt, and J. Ernst (2000), Objective classification of Australian climates, report, Bur. of Meteorol., Melbourne, Victoria, Australia. (Available at http://www.bom.gov.au)

Story, R., R. W. Galloway, R. H. M. van de Graaff, and A. D. Tweedie (1963), General report on the lands of the Hunter Valley, *Land Res. Ser. 8*, Commonw. Sci. and Ind. Res. Organ., Melbourne, Victoria, Australia.

Walker, J. P. (1999), Estimating soil moisture profile dynamics from near-surface soil moisture measurements and standard meteorological data, Ph.D. thesis, Dep. of Civ., Surv., and Environ. Eng., Univ. of Newcastle, Callaghan, Australia.

Walker, J. P., G. R. Willgoose, and J. D. Kalma (2001), The Nerrigundah data set: Soil moisture patterns, soil characteristics, and hydrological flux measurements, *Water Resour. Res.*, *37*(11), 2653–2658.

Walker, J. P., J. M. Hacker, J. D. Kalma, E. J. Kim, and R. Panciera (2005), National airborne field experiments for prediction in ungauged basins, in *MODSIM05: International Congress on Modelling and Simulation*, edited by A. Zerger and R. M. Argent, pp. 2974–2980, Modell. and Simulation Soc. of Aust. and N. Z., Canberra, A. C. T., Australia.

Walker, J. P., O. Merlin, R. Panciera, and J. D. Kalma (2006), National airborne field experiments for soil moisture remote sensing, in *30th Hydrology and Water Resources Symposium* [CD ROM], 6 pp., Inst. of Eng., Launceston, Tasmania, Australia.

Western, A. W., R. B. Grayson, G. Blöschl, G. R. Willgoose, and T. A. McMahon (1999), Observed spatial organization of soil moisture and its relation to terrain indices, *Water Resour. Res.*, *35*(3), 797–810.

Woods, R. A., R. B. Grayson, A. W. Western, M. Duncan, D. J. Wilson, R. I. Young, R. Ibbitt, R. Henderson, and T. A. McMahon (2001), Experimental design and initial results from the Mahurangi river variability experiment: MARVEX, in *Land Surface Hydrology, Meteorology, and Climate: Observations and Modeling*, *Water Sci. Appl. Ser.*, vol. 3, edited by V. Lakshmi et al., pp. 201–213, AGU, Washington, D. C.

G. Hancock and C. Martinez, Faculty of Science and Information Technology, School of Environmental and Life Sciences, University of Newcastle, Callaghan NSW 2308, Australia.

H. M. Hemakumara, B. Jacobs, J. D. Kalma, M. Thyer, T. Wells, and G. R. Willgoose, Faculty of Engineering and the Built Environment, School of Engineering, University of Newcastle, Callaghan NSW 2308, Australia.

C. Rüdiger, Centre National de Recherches Météorologiques/Groupe d'Etude de l'Atmosphère Météorologique, Météo-France/Centre National de la Recherche Scientifique, 31057 Toulouse Cedex 1, France.

J. P. Walker, Department of Civil and Environmental Engineering, University of Melbourne, Parkville VIC 3010, Australia. (j.walker@unimelb.edu.au)