# 15.10 USING FINE SCALE VEGETATION, SOIL AND SATELLITE MAPPING TO INVESTIGATE THE IMPACT OF HETEROGENEOUS LAND SURFACES IN CSIRO CLIMATE MODELS

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## 1. INTRODUCTION

The importance of land surface processes on atmospheric boundary layer development and larger scale weather has been widely studied for over 30 years. Reviews by Betts et al. (1996) and Pielke et al. (1998) detail how exchanges of energy, moisture and momentum between the atmospheric boundary layer and the land surface are strongly influenced by vegetation and soil moisture. Changes in the land surface and the atmospheric boundary layer impact larger scale weather through entrainment with the troposphere and convective cloud formation (Avissar 1995 and Garrat 1993).

Dynamic, heterogeneous landscapes are difficult to describe in climate models as the scale at which human and natural processes alter the landscape are often several orders of magnitude finer than the horizontal resolution of the models (Raupach and Finnigan 1995, and Baidya Roy and Avissar 2000).

The scale mismatch between landscape processes and climate models is a major barrier to investigating the impacts on climate of landscape heterogeneity and land cover change. Long term remote sensing and international data integration projects have started to address these issues of scale by making global land surface data available at resolutions of the order of 1km (Loveland et al. 2000, and Buermann et al. 2001).

This research investigates the impact of including dynamic heterogeneous land surface parameters in CSIRO climate models at a range of horizontal resolutions. A land surface model has been developed incorporating the Simple Biosphere Model (SiB) of Sellers et al. (1986) with global fine scale vegetation, soil and satellite mapping.

The role of the land surface on climate is examined at various resolutions to identify the scales at which land surface heterogeneity influences boundary layer development and larger scale weather over the Australian continent.

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## 2. DATA AND METHODS

The CSIRO Global Circulation Model (GCM) and the CSIRO limited area model (DARLAM) are used as the basis of the land surface and climate modelling experiments. The models are run globally at the T63 (180 km) resolution for the GCM, and over the Australian continent at the 45 km and 15 km resolutions for the limited area model.

The experimental framework is set up as a series of sensitivity experiments, simulating the climate over the Australian continent for the 1969 – 2000 period. Sources of climate variability unrelated to the land surface are removed through prescribing sea surface temperatures and sea ice distributions from the Hadley Centre global record (Rayner et al. 1996). Solar variability and enhanced $C0_2$ greenhouse warming are also removed from the experimental framework through setting these values as constant.

The land surface is described through linear averaged aggregation of fine scale parameters to the resolution of the climate model experiments. As a result of this, the landscape heterogeneity included in each modelling experiment is a product of the horizontal resolution of the climate model.

### 2.1 *CSIRO Land Surface Model*

The land surface models of both the CSIRO GCM and DARLAM are based on the land surface parameterisation of Noilan and Planton (1989). The land surface is specified for each grid cell of the model by the series of parameter files listed in Table 1.

The model represents the land surface as a single layer of vegetation over bare soil. The total surface reflectivity to incoming solar radiation is described through monthly average surface albedo. The surface albedo value specifies the average fraction of incoming radiation reflected from both soil and vegetation for all sun angles through the day, over all wavelengths. January albedo values for Australia are shown in Fig 1 at various model resolutions.

TABLE 1. Land Surface Parameter Files.

| Filename | Parameter Description |
|---|---|
| Veg Type | Dominant SiB Vegetation Type |
| Albedo | Monthly Average Surface Albedo |
| SigmaF | Monthly Vegetation Fraction |
| LAI | Monthly Leaf Area Index |
| RSmin | Monthly Minimum Leaf Resistance |
| Z0 | Monthly Surface Roughness Length |
| Soil Type | Dominant CSIRO Soil Class |
| Sand | Fraction of sand in soil profile |
| Silt | Fraction of silt in soil profile |
| Clay | Fraction of silt in soil profile |

The division of absorbed solar radiation between the vegetation layer and the soil is provided through a monthly vegetation fraction. In addition to vegetation fraction, the leaf density of the vegetation layer is described through a monthly leaf area index value. Resistance to transpiration of the vegetation layer is described through a monthly, unrestrained leaf resistance value. Aerodynamic roughness due to surface elements is described using a surface roughness length value.

The model represents the soil as a six layer soil profile with surface and deep soil water runoff. The hydrological and thermal properties of the soil in all layers are determined by the soil texture in terms of sand, silt and clay composition. The vegetation is assumed to be deep rooted, drawing soil moisture from the top five soil layers for transpiration

## 2.2 *New Land Surface Data*

Describing the dynamic, heterogeneous nature of real landscapes requires fine scale temporal and spatial mapping of land surface conditions. The first component of this process involves describing current distributions of vegetation biomes and soil texture in broad classifications. The second component involves describing temporal and spatial variability within the broad classifications from observation.

For this study global vegetation biome mapping is derived from the Global Land Cover Characterisation (GLCC) data set developed as part of the International Geosphere Biosphere Program, Data and Information Systems (IGBP-DIS) initiative (Loveland et al. 2000). This data set is a 1 km resolution, SiB vegetation map derived from Advanced Very High Resolution Radiometer (AVHRR) satellite imagery for the 1992 – 1993 period.

The global soil mapping is derived from the soil texture interpretation of Reynolds et al. (1999). The soil texture mapping is developed from the United Nations, Food and Agriculture Organisation's (UN FAO) global soil map and global soil profile database. Soil texture is provided as fractional composition of silt, sand and clay at 10 km resolution.

The temporal and spatial variability within vegetation biomes are specified through leaf area index mapping. This data is provided from the average monthly green leaf area index mapping of Buermann et al. (2001). The leaf area index data is an 8 km resolution measure of green leaf area over bare soil. The leaf area measure is interpreted from AVHRR satellite imagery for the 1981 – 1991 period.

In areas of sparse vegetation soil reflectivity is derived from observed surface albedo. The global albedo data is specified from the Earth Radiation Budget Experiment's (ERBE) satellite observation. The ERBE data is sourced from the International Satellite Land-Surface Climatology Project (ISLSCP) as 1 degree average monthly albedo for the 1986 – 1990 period (Sellers et al. 1995).

The land surface data was integrated into a Geographical Information Systems (GIS) database with a common spatial resolution of 8 km.

## 2.3 *New Land Surface Model*

A new land surface model was required to incorporate the fine scale land surface data into the CSIRO climate models. Rather than redevelop the land surface models within both climate models, the new land surface model has been developed to process the fine scale land surface data to produce the parameter files of the existing land surface model.

The parameter files generated at the 8 km resolution of the GIS database are aggregated up to the resolution of climate model. The outcome of this process can be seen in Fig 1 for albedo.

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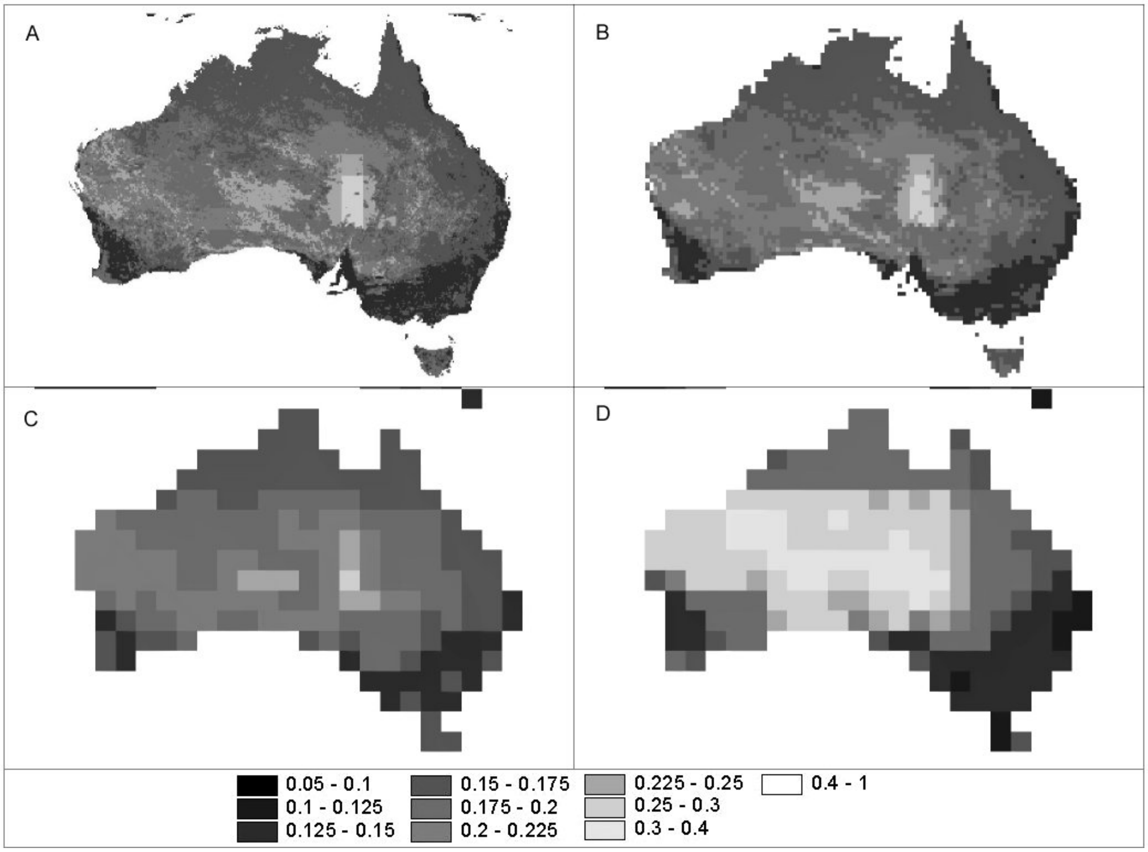


FIG. 1 January Surface Albedo: (A) New Surface Model at 15 km; (B) New Surface Model at 45 km; (C) New Surface Model at 180 km; and (D) Old CSIRO Surface Model at 180 km resolution.

The Veg Type parameter file is generated directly from the GLCC vegetation map. Radiation parameters of Albedo and SigmaF are generated using the two stream radiation transfer model of Sellers (1985). The average monthly values are calculated from hourly radiation weighted absorption and reflection values for vegetation and soil for the mid day of each month.

The vegetation and soil optical parameters are derived from the GLCC vegetation map and the time invariant vegetation values specified by Sellers et al. (1996). Leaf area index values and sparsely vegetated soil albedo are supplied from the averaged monthly satellite observation.

Unrestrained stomatal resistance values are generated from the GLCC vegetation map and the ISLSCP minimum unrestrained leaf resistance values supplied for SiB vegetation types. The unrestrained leaf resistance values are scaled to produce the correct transpiration rates for the Noilan and Planton (1989) parameterisation.

The surface roughness length is calculated using the simplified roughness model of Raupach (1994). The model uses the canopy height specified from the GLCC vegetation map and monthly leaf area index.

The global soil texture mapping is used to determine the CSIRO soil class by sand, silt and clay composition. From the CSIRO soil class all other soil parameters are prescribed.

### 2.4 *Model Performance with New Land Surface*

The performance of the CSIRO climate models with the new land surface parameters is being validated against observed climate records, and with climate simulation using the existing CSIRO land surface. Early precipitation and screen temperature analysis for the Australian continent are shown in Table 2. These results indicate that the CSIRO GCM performs as well with the new land surface parameterisation as it does with the old CSIRO land surface parameterisation.

TABLE 2. Australian Monthly Averages for the period 1970 - 1980.

| Variable | New Model | Old Model | Obs. |
|---|---|---|---|
| Precipitation | 46.4 mm | 41.0 mm | 42.5 mm |
| Precipitation Anomaly | 3.8 mm | -1.5 mm | |
| Spatial Prec Correlation | 0.44 | 0.44 | |
| Screen Temperature | 20.6$^{O}$ C | 20.3$^{O}$ C | 21.1$^{O}$ C |
| Temperature Anomaly | -0.5$^{O}$ C | -0.8$^{O}$ C | |
| Spatial Temp Correlation | 0.86 | 0.84 | |

This is an important result as the new land surface parameters are significantly different to the existing CSIRO land surface parameters. These differences can be clearly seen for the GCM surface albedo values of Fig 1.

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