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INFLUENCE OF LAND USE ON THE REGIONAL CLIMATE OF SOUTHWEST AUSTRALIA

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Changes in land use such as deforestation for agricultural purposes can have a significant impact on the regional climate. This study focuses on the detection of cumulus clouds over Southwestern Australia where large tracts of land have been converted for agricultural purposes, to examine land use influences on cumulus cloud formation.

Once the preferential formation of cumulus cloud is observed, soil moisture availability and surface energy fluxes are investigated. Shortwave irradiance at the top of atmosphere is also determined. Results show that cumulus clouds form more frequently over native vegetation during summer and over agricultural areas during the winter months. Retrieved surface energy fluxes and moisture availability suggest that higher latent heat fluxes are responsible for the observed higher cumulus cloud occurrence over native vegetation in summer.

1. INTRODUCTION

Since the late 1800s, native perennial vegetation in Southwestern Australia has been replaced by a seasonal winter growing wheat crop. The boundary separating the two vegetation types is more than 700 km long, and it is called the vermin fence. The vermin fence marks the eastern-most limit of the agricultural areas (Lyons et al., 1993).

The vermin fence marks a sharp transition between large homogeneous tracts of differing vegetation types, agriculture to the east and native perennial vegetation to the west (Lyons et al., 1993). Such differences in land use are usually accompanied with differences in surface properties such as albedo, temperature, roughness length and soil moisture distribution (Segal et al., 1988; Meher-Homji, 1991; Shukla et al., 1990). This study investigates the differences in cumulus cloud formation, surface moisture availability and energy fluxes, and top of atmosphere (TOA) shortwave irradiance, between agricultural and native vegetation areas over Southwestern Australia.

2. DATA

Cumulus clouds are detected using the visible channel (0.5μm-0.75μm; 1.25 km spatial resolution) of GMS5 (Geostationary Meteorological Satellite). GMS5 provides daytime coverage of Southwest Australia roughly every hour from 0 UTC to 7 UTC. MODIS (Moderate Resolution Imaging Spectroradiometer) data and products are used in conjunction with a SVAT (Soil and Vegetation Atmospheric Transfer) model for the retrieval of surface energy fluxes and moisture. The TOA shortwave irradiance is derived from the CERES (Clouds and Earth's Radiant Energy System Satellite) observed shortwave irradiance (0.3μm-5μm).

3. METHODOLOGY

The area of study is Southwest Australia bounded by the latitude lines 26°S and 36°S to the north and south respectively, and longitude lines 114°E and 124°E to the west and east, respectively.

Cumulus clouds are detected from GMS5 visible imagery using the structural thresholding method (Nair et al., 1999), and then monthly maps of the frequency of occurrence of cumulus clouds at hourly intervals from 0 UTC to 7 UTC are created. The structural thresholding algorithm uses the spatial structure of the cloud elements in a scene to determine the location of cumulus cloud fields and to detect individual cumulus clouds within the scene. The monthly maps then are used to examine the differences in cloudiness over croplands and native vegetation.

The Triangle Method of Gillies et al. (1997) is used for retrieving the surface moisture and energy fluxes by inverting MODIS derived surface radiant temperatures and NDVI (Normalized Difference Vegetation Index) values. NDVI is defined as $(\alpha_{NIR}-\alpha_{RED})/(\alpha_{NIR}+\alpha_{RED})$, where α_{RED} and α_{NIR} are the near infrared and red surface albedos and is derived using MODIS channels 1 (0.63μm-0.69μm) and 2 (0.84μm-0.88μm), respectively. Surface radiant temperature is computed from the MODIS land surface temperature and MODIS channel 31 (10.78μm-11.28μm) emissivity products.

Scatterplots of surface radiant temperature versus NDVI show a triangular shape; this is due to the physical characteristics imposed by limits on the distribution of soil moisture and fractional vegetation cover (Gillies et. al. 1997). For a given set of atmospheric conditions derived from radiosonde observations, a SVAT model is used to predict the surface radiant temperature and energy fluxes for discrete values of surface moisture availability and vegetation fraction. Then nomograms are created of surface moisture availability as a function of fractional vegetation and surface radiant temperature. Finally, these nomograms are used to estimate surface moisture overlaid with SVAT derived nomograms. A high degree of fit between observed and model derived ranges of temperature at various vegetation fractions availability is observed. A similar

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procedure is used for estimating the surface energy fluxes. Three relatively cloud free MODIS scenes from December 2000 over Southwestern Australia were used to examine surface energy and moisture fluxes over agricultural and perennial vegetation areas.

Finally, monthly maps of CERES observed TOA shortwave flux are created by averaging the daily maps of CERES TOA shortwave fluxes over Southwest Australia using clear-scene CERES pixels.

4. RESULTS

In the summer months of December and January 2000, cumulus clouds occur with higher frequency over native vegetation. Cumulus clouds develop initially in the region close to the vermin fence in early morning (0 UTC to 2 UTC). From 3 UTC the region of cumulus cloud formation shifts over to native vegetation areas. A study of the months of June-September 2000 (winter months) seems to suggest a preferential formation of cumulus clouds over agricultural areas. This is consistent with previous observations done for 1999 (Ray et al., 2001).

Surface moisture availability and energy fluxes, derived from MODIS data for three relatively cloud free days in the dry season month of December, are different for agricultural and native vegetation areas. Moisture availability is higher over native vegetation areas compared to barren agricultural areas. The mean surface energy fluxes and moisture availability for areas of native vegetation and agriculture are shown in Table 1. The agricultural areas, which are barren during the dry season, are drier than native vegetation. Sensible heat is higher over barren agricultural areas, whereas latent heat is higher over perennial vegetation areas. This is consistent with surface moisture fraction and energy fluxes derived from an ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) image for January 16, 2001 (Ray et al., 2001).

TABLE 1

VEGETATION TYPE	Moisture fraction (0-1)		Sensible heat (W/m^2)		Latent heat (W/m^2)	
	Mean	σ	Mean	σ	Mean	σ
BARREN AGRICULTURE	0.20	0.16	239	63	264	91
PERENNIAL VEGETATION	0.24	0.17	216	54	299	82

Results of monthly shortwave irradiance created by using CERES clear scenes from August 2000 to December 2000 are shown in Table 2.

TABLE 2

VEGETATION TYPE	August, 2000 (W/m^2)		October, 2000 (W/m^2)		December, 2000 (W/m^2)	
	Mean	σ	Mean	σ	Mean	σ
BARREN AGRICULTURE	166	15	212	16	255	25
PERENNIAL VEGETATION	138	14	177	18	199	23

5. CONCLUSION

Results suggest local effects due to land use have a significant influence on the formation of cumulus clouds. Since the region has a very gentle slope, topographic effects are minimum.

Monthly maps of cumulus frequency for the year 2000 has shown preferential development of cumulus clouds over native vegetation areas in summer and over agricultural areas in winter. For the dry season, surface moisture and energy fluxes derived from remotely sensed data show native vegetation areas to be moister. Enhanced latent heat fluxes over native vegetation imply a moister boundary layer, which could be responsible for preferential cloud formation over native vegetation during the dry season.

Since during winter the agricultural areas come under the influence of frontal rainfall, soil moisture availability then is higher over agricultural areas than over the perennial vegetation areas. Cumulus clouds therefore form preferentially over agricultural areas at this time.

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