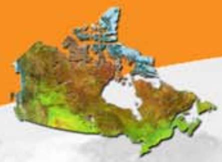

Impact of Drought on Land Surface Albedo

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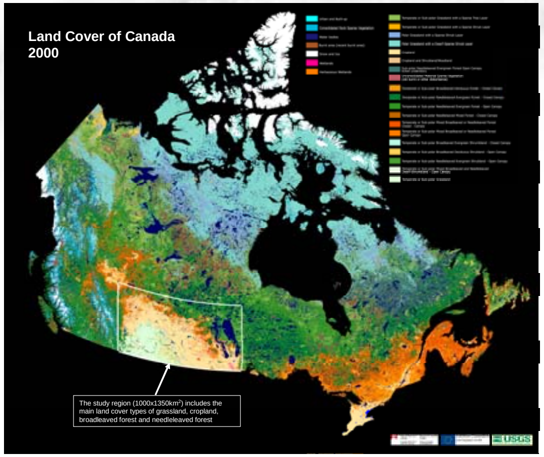
Reducing Canada's vulnerability to climate change

Introduction

Albedo is the fraction of incident solar radiation (shortwave) reflected by a surface . It is one of the key parameters in climate models. It directly controls the radiative energy partitioning of the surface and affects its physical, physiological, and biogeochemical processes including surface temperature, energy balance, evapo-transpiration, photosynthesis, and respiration. Several recent studies (e.g., Betts, 2000) have indicated that climate change induced by the land surface albedo change due to land cover and land use changes can have similar or even greater magnitude than that induced by doubling atmospheric CO_2 concentration. At the global scale, a simulation with extreme cases of unvegetated and vegetated land surfaces generated a two-fold difference in land precipitation and 8ºC differences in mean seasonal temperature (Kleidon et al. 2000). Hansen et al. (1995) estimated that land cover changes from 1850 to the present have led to cooling of approximately 0.2°C owing to increased albedo associated with clearing and Govindasamy et al. (2001) reported that land use change may explain the observed cooling of prior centuries.



Land surface albedo can be changed by anthropogenic as well as natural factors. While anthropogenic changes involving changes in land use tend to be very persistent, albedo changes caused by natural factors can be very dynamic and difficult to quantify. For example, it is well known that albedo of water-stressed leaves (and dry surfaces) tends to be higher than well-tugored leaves (and wet surfaces). However, how ecosystem drought can affect land surface albedo at large scale has rarely been investigated. Albedo changes caused by the changes of ecosystem function have not been adequately addressed in the current climate simulations. This knowledge gap may cause great uncertainties in the projected climate change results simulated by climate models.

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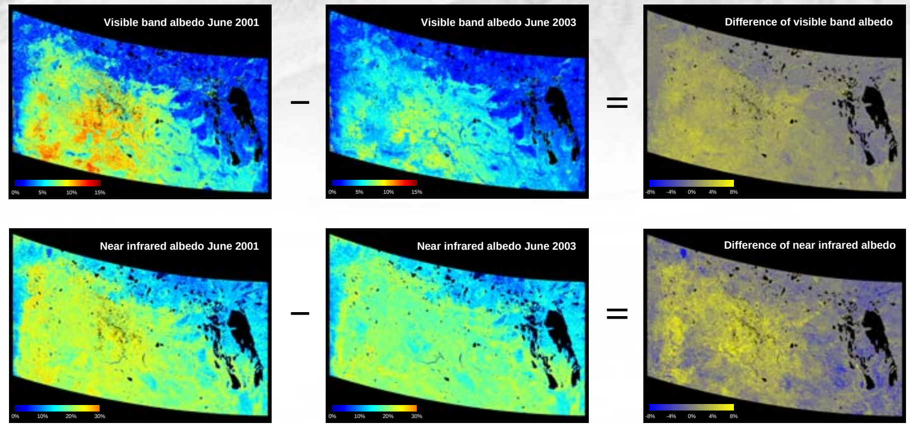
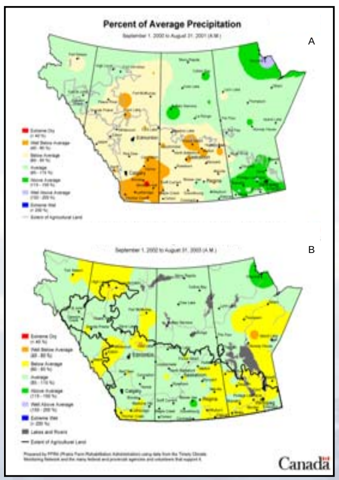


Study Region

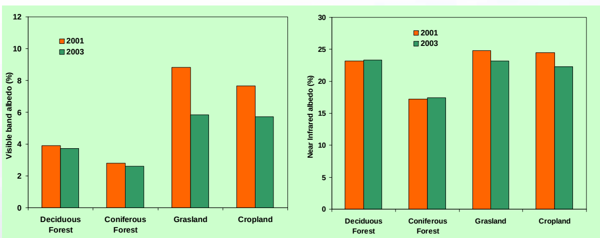
The region selected for this study includes the whole prairies and the boreal forests close to its north border. We investigated the impact of drought on land surface albedo for four typical Canadian ecosystems: temperate grassland, cropland, boreal deciduous forest, and boreal conifer forest. The study area contains significant amount of pixels for all of these four ecosystems. In 2001, precipitation was below historical average for most of the region (see Fig. A). In some areas such as southern Alberta, precipitation felled below 50% of their normals. As a result, extensive drought conditions occurred across the region which caused crop production well below its average. In 2003, precipitation was close to its normal for most of the region (see Fig. B) and the crop water conditions were significantly improved. The very different precipitation conditions over this region in these two years provides us the opportunity to investigate how drought and climate variations can affect land surface albedo for different ecosystems.



Results

The 1km resolution land surface albedo product obtained from MODIS sensor onboard satellite *terra* was used to investigate the albedo variations between the two years (Strahler et al., 1999; Davidson and Wang, 2004). Albedo in June was used in the analysis because spring and early summer water conditions mainly affects the crop growing conditions and determines the productivity of the agriculture year. The upper three images in the above figure illustrate visible band albedo (VIS) distributions over the study region in 2001, 2003 and their differences. In 2001, VIS albedo in some of the grassland and cropland areas reached as high as 15%, indicating low biomass and vegetation cover caused by drought. In 2003, most of the VIS albedo in the prairie area remained below 10% mainly because of the better crop growing conditions in this year. For the forest areas, there were no significant differences in VIS albedo between the two years and they were mostly under 5%. The difference of VIS albedo between the dry and normal years shows that it can exceed 5% for grassland and cropland, but close to zero for forest land covers. The lower three images in the above figure illustrate the corresponding albedo distributions in the near infrared band (NIR). Water stress in 2001 led to the NIR albedo higher than 25% for most of the prairie regions. On the contrary, area with NIR albedo greater than 25% was significantly reduced in 2003. Albedo in the forested areas showed similar values also in NIR. Difference of NIR albedo between the two years was significant for grassland and cropland and it exceeded 6% in large areas.

It was found that albedo changes between the dry and normal years can exceed well above 5% in both VIS and NIR. Although this difference seems small, it may be large enough to influence the surface energy balance, and ultimately climate. Chapin et al. (1999) indicated that the net climate-forcing due to about 5% difference in albedo between forest tundra and shrub tundra of northern Alaska are in the order of 5.5 W m^{-2}, which is comparable to the effect of a doubling of global atmospheric CO2 concentration (4.4 W m^{-2}, Wuebbles 1995). Therefore, albedo changes caused by ecosystem drought over the arid and semiarid grassland and cropland regions could significantly feed back to climate on the local, and possibly global, scale.



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