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MAN INDUCED WINTER SURFACE ALBEDO CHANGES IN THE MIDDLE LATITUDES

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1. INTRODUCTION

Winter temperatures in the middle latitudes may have been influenced by changes of surface albedo induced by man. Man's use of land, primarily for agriculture, has resulted in extensive deforestation and loss of natural grasslands. This has resulted in significant alterations of seasonal and annual surface albedos, particularly when snow is present.

We report here the results of a study in which the anthropogenic impact on winter surface albedo is calculated in a portion of the U.S.A., between 71°-105°W and 38°-43°N. Our study applies aerial and satellite albedo measurements of present ecosystems to the past distribution of vegetation to reconstruct winter albedo prior to major disturbance by man.

The anthropogenic impact on surface albedo in the middle latitudes needs to be studied in order to assess the potential impact of man on historic changes in climate. In addition, the major climatic impacts of increasing CO_2 and the "nuclear winter" are expected to take place in seasonally snow covered regions, primarily due to the snow-ice/albedo feedback (Ramanathan, 1979; Robock, 1984).

2. AERIAL ALBEDO MEASUREMENTS

Present day hemispheric albedo (.28-2.80µm) was measured over surfaces representative of past undisturbed cover. Our study zone was in New York and New Jersey. We collected the data in a series of flights at an average altitude of 200m, at which 90% of the reflected signal came from an area of approximately 0.50km^2. The confidence limits of the gathered data is $\pm$4% of the calculated albedo value. Photographs taken with a fisheye (180°) lens documented the measurements. Instrumentation and methodology are described in more detail elsewhere (Robinson, 1984; Robinson and Kukla, in press, a).

Representative albedos of fully snow covered surfaces were derived by averaging flight measurements from February 14 and 18, 1983. The ground was covered with close to 50cm of 2 day old dry snow on the 14th and approximately 25cm of 6 day old wet snow on the 18th. The average albedo of uninterupted snow surfaces on these two days was .83 and .75, respectively. Measurements over 3 to 5 sites along the flight route were used to calculate the daily value for each surface.

Resultant values ranged from .24 over a deciduous forest with 25% evergreens to .76 over open grassland (table 1). Intermediate values varied as a function of the height and density of vegetation.

3. SATELLITE ALBEDO MEASUREMENTS

Present day clear sky surface albedo over snow covered middle and high latitudes of the Northern Hemisphere was measured from satellite imagery in 1°x1° lat/long cells. Data were obtained by image processor analyses of Defense Meteorological Satellite Program transparencies from 1978 and 1979. Scene brightness was converted to surface albedo by linear interpolation between bright and dark snow covered surfaces with known albedo. Brightness was measured if a region was interpreted as having at least 15cm deep snow in a relatively fresh state. Albedos so calculated may be up to .10 too low or .05 too high. Satellite imagery and methodology are described in more detail elsewhere (Robinson, 1984; Robinson and Kukla, in press, b).

Snow covered albedo averaged over the 1°x1° cells in the U.S. study zone ranges from .35 over a heavily forested cell in New England to .78 over several cells of field and pasture in Nebraska and Kansas. Values are generally higher than .70 west of the Mississippi River, decreasing below .50 over the Appalachian Mountains and most areas further east.

4. ECOSYSTEMS

Past and present land ecosystems were charted in 1°x1° lat/long cells from published sources by Matthews (1983). Past ecosystems reflect the vegetational landscape prior to modifications by agricultural activities. At present, 125 of the 155 cells in the study zone have at least 20% agricultural land. Only 17 can be considered fully forested and 13 are composed of grassland.

The distribution of past ecosystems is shown in table 1. Forests covered 82 cells east of the Mississippi. The Midwest was covered with tall grass with 10-40% tree cover interspersed with forest. West of 95°W grasslands became progressively shorter. In general, these conditions lasted in the east until the arrival of white settlers in the 17th century. In the west, the influence of settlers was first felt in the 19th century, at which time the east was approaching peak deforestation, which has since reversed (Siccama, 1971; Lawson, 1974).

5. HISTORIC ALBEDO CHANGES

Present snow covered albedo in all cells was compared to the albedo when in a naturally vegetated state, as derived from aerial measurements of present land types which most closely resemble the past conditions (table 1). Present albedos are higher than in the past over all cells, except over former short grassland (figure 1, table 1).

Present albedo in previously forested cells is approximately twice as large as in the past. The difference ranges from .09 to .48. The lower value comes from forested or reforested zones with less dense and shorter woodlands than in the past. Changes over past grasslands are much smaller than in forested regions, particularly where natural vegetation was short. The lower albedo at present over short grassland is due to windbreaks, towns, farm buildings and roads protruding through the snow.

An extreme case of man induced albedo change was found within our flight study region. Here, the snow covered albedo of a vegetated swamp increased by .51 when the area was cleared and drained for use as farmland. The present value of .79 was measured from the aircraft while the former albedo of .28 was taken from historic descriptions of swamp vegetation and present measurements of equivalent vegetative cover.

6. CONCLUSION

The changes of albedo found in the study zone may be considered representative of those in other populated regions where seasonal snow cover occurs, such as Europe and portions of east Asia (Robinson, 1984). As a result of these changes, winter surface albedo and, consequently, the local microclimates have become considerably more sensitive to the presence and duration of snow cover. It would be interesting to find out whether the conversion of woodlands and grasslands to farmland resulted in a measurable change in regional weather patterns. Since adequate observational records are not available, modeling will be needed to examine this question and assess what climatic impact future deforestation might bring.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

Lawson, M.P., 1974: The Climate of the Great American Desert (Reconstruction of the climate of western interior United States, 1800-1850). Univ. of Nebraska Press, 135pp.

Matthews, E., 1983: Global vegetation and land use: new high-resolution data bases for climate studies. J. Cli. and Appl. Met. 22, 474-487.

Ramanathan, V., M.S. Lian and R.D. Cess, 1979: Increased atmospheric CO_2: Zonal and seasonal estimates of the effect on the radiation energy balance and surface temperature. J. Geophys. Res. 84, 4949-4958.

Robinson, D.A., 1984: Anthropogenic impact on winter surface albedo. Doctoral thesis, Columbia University, 384pp.

Robinson, D.A. and G. Kukla, in press, a: Albedo of a dissipating snow cover. J. Cli. and Appl. Met..

Robinson, D.A. and G. Kukla, in press, b: Maximum surface albedo of seasonally snow covered lands in the Northern Hemisphere. J. Cli. and Appl. Met..

Robock, A., 1984: Snow and ice feedbacks prolong effects of nuclear winter. Nature 310, 667-670.

Siccama, T.G., 1971: Presettlement and present vegetation in northern Vermont with special reference to Chittenden County. Am. Midl. Nat. 85, 153-172.

Table 1. Present and past albedos over ecosystems in the U.S. study zone (71°-105°W, 38°-43°N). Values listed for each ecosystem include the number of $1^{\circ}x1^{\circ}$ lat/long cells it covered when vegetation was considered to be in a natural state (#cells), its albedo when snow covered (A_{pa}), the present average albedo of these cells when snow covered (A_{pr}), the average albedo change from past to present conditions (ΔA) and the range of change for all cells (ΔA_r).

Ecosystem	#cells	A_{pa}	A_{pr}	ΔA	ΔA_r
cold-deciduous forest with evergreens	18	.24	.45	+.21	+.11-+.36
cold-deciduous forest without evergreens	64	.28	.57	+.29	+.09-+.48
tall/medium/short grassland with 10-40% woody tree cover	24	.54	.70	+.16	+.07-+.22
tall grassland, no woody cover	13	.64	.75	+.11	+.08-+.14
medium grassland, no woody cover	22	.70	.76	+.06	-.01-+.08
short grassland, meadow, no woody cover	14	.76	.73	-.03	-.14-+.01

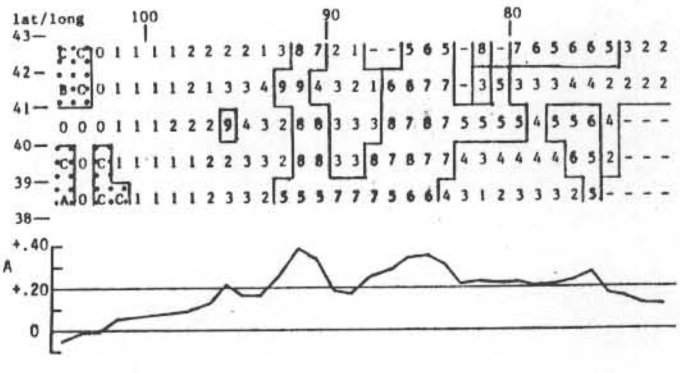

Figure 1. Change in land surface albedo of fully snow covered $1^{\circ}x1^{\circ}$ lat/long cells in the U.S. study zone from past natural vegetation to present conditions. At the top, albedo change is shown in .05 increments with A=-.15--.11, B=-.10--.06, C=-.05--.01, 0=.00-+.04.....9=+.45-+.49. The bottom curve shows albedo change (ΔA) averaged by longitude.