Mapping Surface Albedo: Satellite Brightness and Ground Truth

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Modelling and empirical studies show that man's activities may result in large-scale global changes in climate in the coming years. These changes are expected to be most pronounced in areas that are presently snow- or ice-covered for a portion of the year. Ten years ago, George Kukla began studies at Lamont to improve our understanding of the global cryosphere (snow and ice), using data on snow and ice distribution newly available from satellites. Since then, Kukla and others in our Lamont climate studies group have continued this work and expanded it to look closely at the impact of the cryosphere on surface albedo.

Surface albedo, the percentage of incoming solar radiation that is reflected at the ground, is an important climatic parameter. Dark, low albedo surfaces are heated by absorbed solar radiation which, in turn, heats the atmosphere, creating and driving weather systems. High albedo surfaces are cooler, as they reflect most of the incoming energy directly back to space. Snow and ice are the largest variables in the climate system affecting surface albedo.

Surface albedo in snow covered areas is dependent on the condition of the snow as well as the height, density and type of vegetation. While the albedo of snow is high, it may vary from upwards of 90% when fresh and deep to 60% when old and wet. When vegetation masks the underlying snow the surface albedo of a snow-covered region may be much lower.

Fig. 1 is a mosaic of Defense Meteorological Satellite Program (DMSP) images depicting much of Eurasia under maximum snow cover conditions. DMSP imagery has a resolution of 2.8 km directly below the satellite, which flies in a polar orbit at an altitude of approximately 830 km. The entire earth is covered daily during daylight hours. The sensor spectral range is quite broad, .4 μm to 1.1 μm, covering much of the visible and near infrared. The mosaic was constructed using a number of cloud- and haze-free scenes from the winters of 1978 and 1979. Differences in image contrast account for the minor linear tonal breaks between adjacent sections of the mosaic (eg. a-a[1]). The remainder of the brightness contrasts are due to the masking effects of vegetation, with the exception of several areas (marked with F's) which are snow free or cloud covered (C). Several areas of snow-covered sea ice are also evident (I). Note the dark boreal forest stretching across central Asia surrounded by bright, sparsely vegetated tundra to the north and steppe to the south. Snow-covered portions of Europe are quite bright as a result of man's deforestation of the region.

The image brightness is measured by means of an image processing system. But several limitations do not permit the direct measurement of surface albedo from the imagery. These include the absorption and scattering of incoming and reflected solar radiation by the atmosphere lying between the ground and satellite, the spectral limitations of the sensor and the method by which the sensor scans the surface. Image brightness may be converted to estimated surface albedo by linear interpolation between brightnesses of selected surfaces with known albedos. Unfortunately, only limited ground-truth albedos over snow-covered surfaces have been available for this purpose.

During the 1982-83 winter the Lamont group began to improve this situation by gathering photo-documented albedos over a variety of snow-covered surfaces. A Cessna 172 aircraft was equipped with wingtip-mounted pyranometers to record albedo and an Olympus camera with a fisheye lens to record the entire scene measured by the pyranometers. Flight altitude was between 150 and 200 meters, low enough to preclude atmospheric attenuation of reflected signals.

Figs. 2-4 are examples of the variety of surfaces documented over southeastern New York and northern New Jersey. These photographs were taken on February 14, two days following the culmination of a blizzard that dropped close to .5 m of snow over the region. Albedos may be considered at or very close to maximum values. They range from a low 19% over a mixed coniferous-deciduous forest stand (Fig. 2) to 60% over a wasteland of scattered trees, shrubs, tall grass and herbs (Fig. 3) to 79% over flat, relatively vegetation-free

Mapping surface albedo: satellite brightness and ground truth. Lamont-Doherty Geological Observatory of Columbia University Yearbook 1982-1983, 9, 24-26, 1983.

onion fields (Fig. 4). It should be noted that the pyranometers have a cosine response and the fisheye photographs are distorted, resulting in 50% of the albedo signal coming from within a circle centered in the middle of the photo with a radius of .36 of the full photo radius, and 90% of the signal from a circle with .75 of the full radius.

In contrast, Fig. 5 shows the dark soiled onion fields on March 24, when they were partially flooded and at a minimum albedo of 7%. The 72% difference in albedo over the onion fields is the largest annual range yet documented over any land surface. In this case it was created by man, as this region was forested up to the latter half of the last century; it is estimated that its snow-covered albedo was close to that in Fig. 2 (19%) and its snow-free value was approximately 10%.

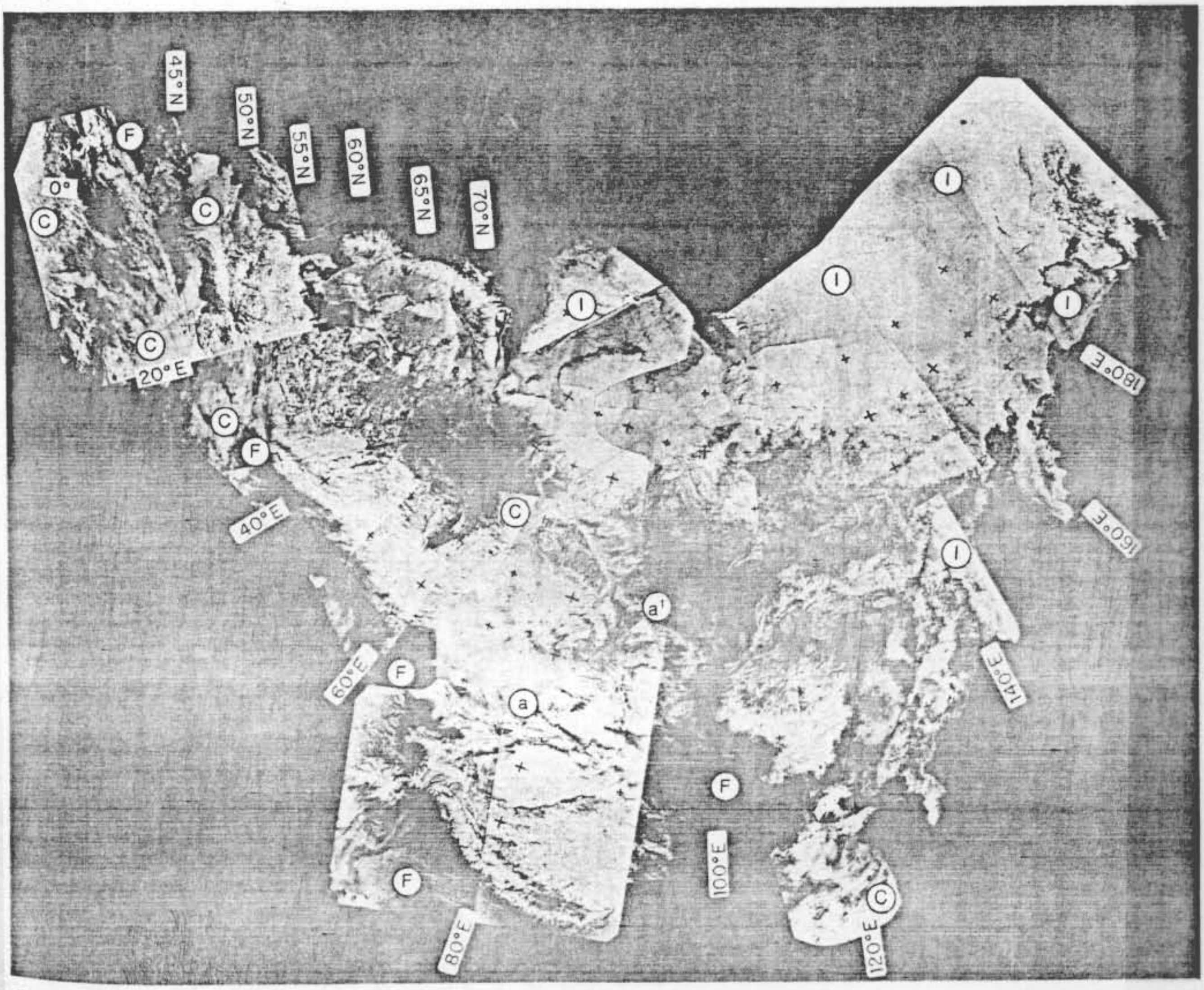


FIGURE 1: Mosaic of maximum snow-covered surface brightness over much of the Eurasian continent as depicted in Defense Meteorological Satellite Program imagery. Tonal breaks between different image scenes exemplified by a-a'. Snow free areas marked with F, cloud cover (C) and snow covered sea ice (I).

FIGURE 2: Hemlock and deciduous forest east of Greenwood Lake near Hewitt, N.J. on February 14, 1983. Albedo 19%. North is to the top on this and subsequent photos.

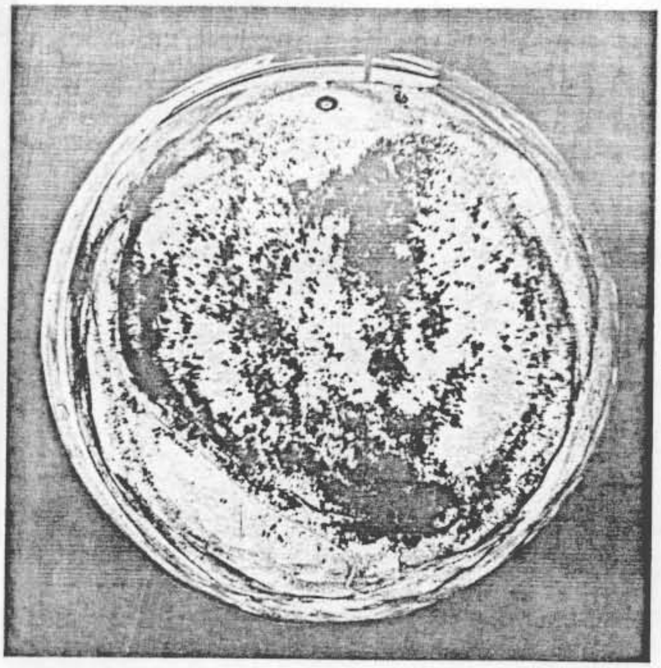
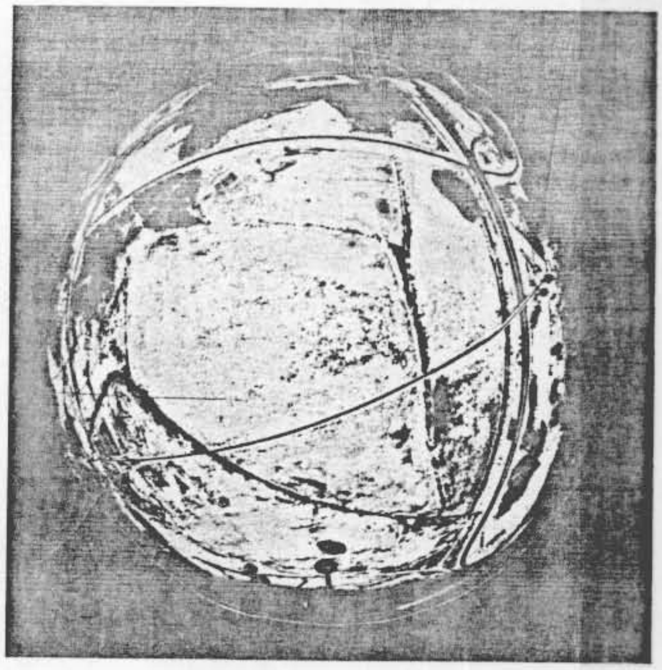


FIGURE 3: Wasteland of scattered trees, shrubs, tall grass and herbs southwest of N.Y. Thruway Harriman toll booths on February 14, 1983. Albedo 60%.



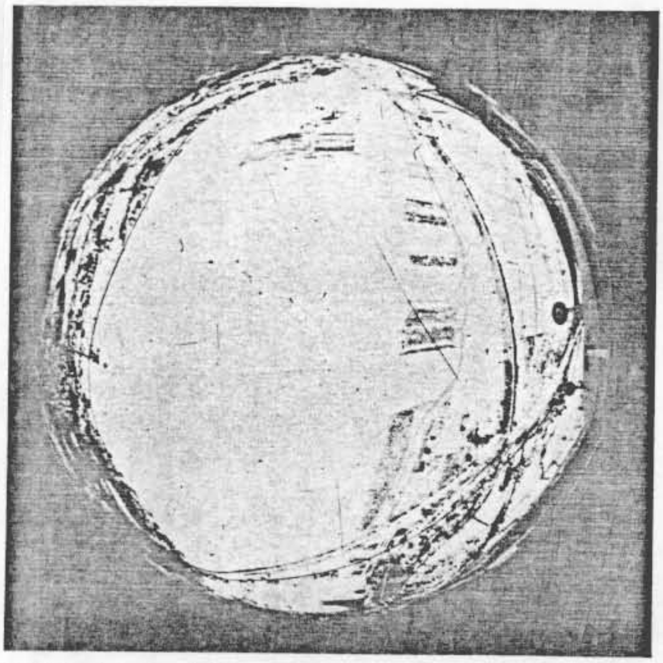


FIGURE 4: Onion fields near Chester, N.Y. on February 14, 1983, after a blizzard. Albedo 79%.

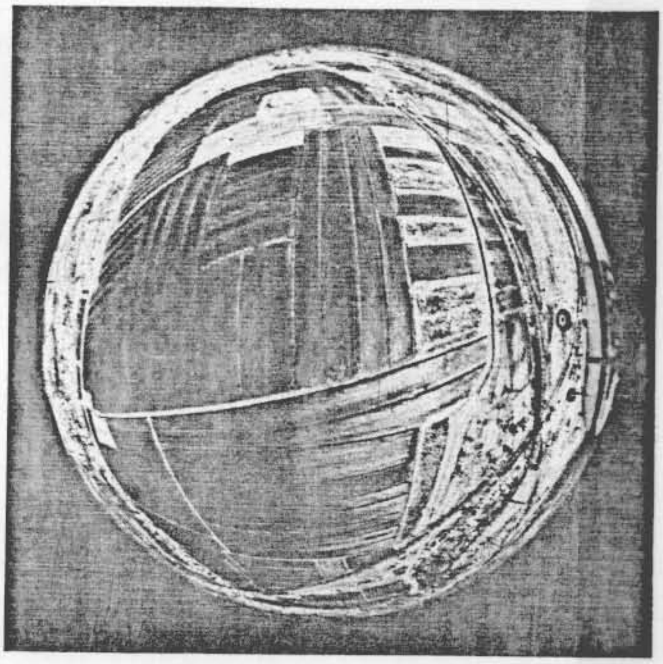


FIGURE 5: Onion fields as in Fig. 4 on March 24, 1983, partially flooded. Albedo 7%.