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Lamont Climatic Snow Cover Charts

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A climatic series of snow cover charts is produced at the Lamont-Doherty Geological Observatory of Columbia University. The objective of the work is to increase the accuracy and homogeneity of the NOAA snow cover series from 1966 through 1973. For that interval, the NOAA weekly charts are considerably less accurate and less detailed than the more recent products (Kukla and Robinson, 1979; Kukla and Robinson, p.103 this volume). Most seriously affected is the information on the relative reflectivity and the position of snow cover in the zone of poor illumination in autumn. The early inaccuracy is due to the inferior quality of early satellite imagery and the relative inexperience of the NOAA interpreters at that time.

Lamont charts (see figure 1) are designed to:

1. present the information in a manner compatible with the current NOAA series (Smigielski, p.59 this volume; Matson and Wiesnet, 1981). To that end, they indicate separately all snow cover visible on clear days;
2. be compatible with the recent U.S. Air Force charts (Woronicz, p.63 this volume). Therefore they indicate separately the snow cover under persistent clouds;
3. identify the charted information with a time resolution of two days or less. A numerical code is used which includes symbols specifying the date of the observation;
4. improve the information on the relative snow cover reflectivity.

Table 1 specifies the different features distinguished in the Lamont charts.

Snow Area Density (SAD) Index

The three grades of relative snow reflectivity in the NOAA charts are replaced by the six classes of the SAD index in the Lamont set. SAD approximates the areal proportion of snow covered ground visible from the nadir view in satellite imagery. The remainder is either a vegetation canopy or snow-free ground. SAD is expressed in percent. It should be nearly independent of the solar angle and the state of the atmosphere, therefore almost independent of the time of the satellite overpass. The proportion of the snow covered area in the analyzed scene explains most of the local variance of the winter surface albedo.

There are a few disadvantages to the SAD. The index depends on the spatial resolution of the satellite sensor because the SAD is based on the assumption of a bimodal distribution of fields fully covered by snow and those snow free. The size of the fields is expected to conform with the grid resolution of the analyzed satellite imagery. The subgrid features, which in reality break the continuity of any land-based snow cover, can't be distinguished. For instance, snow covered farmland with abundant small forest patches or remainders of standing crops will have apparent high brightnesses similar to homogeneous snow cover on top of lake ice. However, the albedo of the farmland will be lower than that of the frozen snow-covered lake. The reverse holds true for the subgrid snow patches located in predominantly snow-free fields.

In addition, SAD does not differentiate between fresh and aging snow surfaces. Albedo of the latter may be considerably lower due to changes in grain size, reduced thickness of the cover, surface dirt contamination, increased proportion of protruding dark objects, etc.

Empirical adjustments were made for the impact of differenct underlying surface types on the surface albedo of snow fields. The highest SAD class, 6, is assigned only to the areas where snow is deposited on top of glaciers, sea ice, lake ice, or arctic tundra.

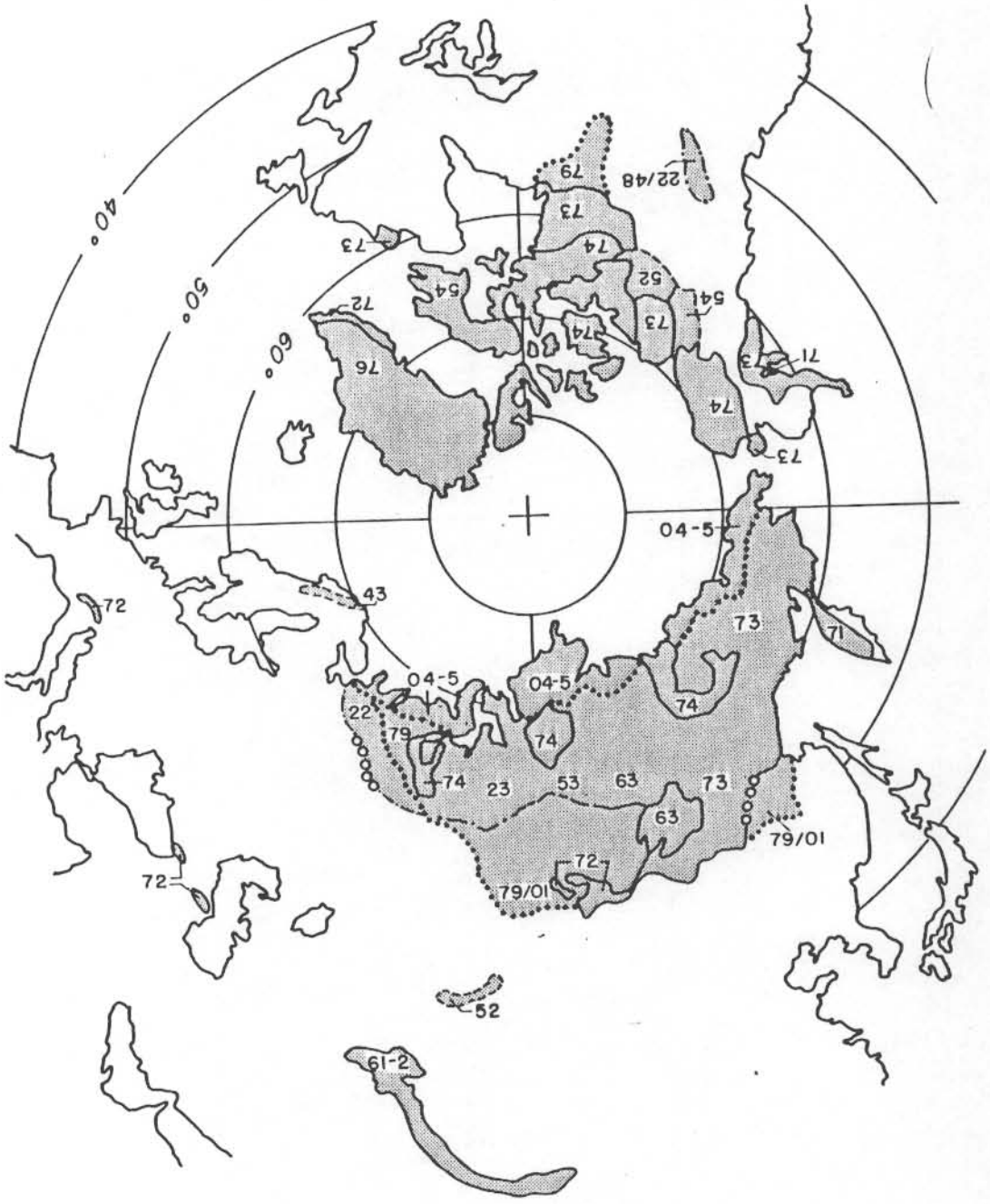

Figure 1. A sample of a Lamont climatic snow cover chart for the second week of October 1972. The symbols are explained in table 1.

A typical example of the large scale brightness differences between fully snow covered surfaces in winter is shown in Kukla p. 135 this volume. Correlation of the NOAA relative brightness classes with the SAD system is in table 2, with corresponding approximate mean values of surface albedo. Note that the average albedo of a stabilized compact snow cover on land is considered to be 70 percent; on sea ice 80 percent.

Table 1. Lamont Snow Charting Code

Satellite Observation

Day of Observation			1	2	3	4	5	6	7
Boundaries			Dash-Dot			Dashed		Full	
SAD (Snow area density) Class	Snow Limit %	Snow Mean %	Charted Symbol						
0	0	0	10	20	30	40	50	60	70
1	≤ 20	10	11	21	31	41	51	61	71
2	≤ 40	30	12	22	32	42	52	62	72
3	≤ 60	50	13	23	33	43	53	63	73
4	≤ 80	70	14	24	34	44	54	64	74
5	≤ 100	90	15	25	35	45	55	65	75
6	100	100	16	26	36	46	56	66	76

Climatology

No Observation
Dotted
Charted Symbol
00
01
02
03
04
05
06

Ground Meteorology: Persistent Cloud or Poor Visibility (Dotted Boundary)

7	Meteorological conditions favor snowfall	17	27	37	47	57	67	77
8	Reported snowfall	18	28	38	48	58	68	78
9	Reported snow on ground	19	29	39	49	59	69	79

ooo Area where satellite observation of snowfield is obscured by clouds.

Table 2. Comparison of the NOAA relative brightness classes with the snow area density (SAD) and the approximate clear skies mean surface albedos.

NOAA Class	Approximate Mean Surface Albedo %	Lamont SAD Class	Approximate % of Snow Cover
Scattered Mountain Snow	15	0	No Snow
	21	1	10
1	30		
	32	2	30
2	45	43	3	50
	54	4	70
	65	5	90
3			
	60		
	80*	6	100

*75 percent over arctic tundra with a high proportion of water bodies.

Note: The approximate albedo of NOAA classes after Batten (1977). Albedo of Lamont SAD classes computed by assuming the average albedo of 100-percent snow-covered land to be 70 percent, of snow-covered ice 80 percent.

The Time Scale

The weekly chart is meant to show, when possible, the snow extent and the snow area density (SAD) on the last day of the seven-day-long interval, but this is not always possible because of the presence of clouds. For that reason the days are numbered 1 through 7, with 7 corresponding to the last day of the week (table 1). For instance, a charted set, starting with the 14th of February and ending with the 20th of February will recognize February 14th as day 1, and February 20th as day 7. The information obtained on days 6 and 7 is of the highest value.

Sources

The following sources are used in the Lamont recharting of the 1966-1972 set:

1. visual imagery of Tiros N and NOAA polar orbiting satellites (on loan from Sea Ice Consultants);

2. United Kingdom Meteorological Office snow cover data published semi-monthly from 1966-70 and every 5 days in 1971-72;

3. WMO daily synoptic weather charts of the middle and high latitudes of the Northern Hemisphere;

4. Weather and Crop Bulletin snow charts of the United States published weekly from December 1 through March;

5. reports of snow on the ground in Climatological Data, monthly NOAA publications of climate data from individual states or regions of the U.S.

Additional satellite information, such as visible and infrared NOAA-VHRR and AVHRR images and geostationary satellite imagery, is available for the analysis of post-1972 data.

Charting Procedure

The compilation of the charts proceeds in several steps.

Step 1. Satellite imagery of day 7 is examined and the obvious clouds are delimited.

Step 2. The snow on ground is charted where confidently recognized by its surface signature (see Barnes and Bowley, 1974; Barnes et al., 1974). This includes:

   a. snow/water interfaces along the coastline, lake banks, and rivers,

   b. treelines in the mountains, characteristic outlines, and brightness patterns of forested areas,

   c. swampy river beds (snow free and dark against lighter background in autumn, reverse in spring),

   d. characteristic relief texture in mountains and hills.

   The SAD of the charted snowfields is estimated by visual or machine-assisted (image processor) comparisons with standard grey scales (table 1, SAD classes 0-6).

Step 3. Bright areas without characteristic local textures of land surface or clouds are compared with the maximum SAD chart (Kukla and Robinson, p. 135 this volume). If high maximum SAD is indicated, the image is compared with satellite imagery of earlier days. Repetitive boundaries are interpreted as boundaries of a snow field.

Step 4. The procedure in steps 1, 2, and 3 is repeated for days 6. Only the areas covered by clouds or with unclear textures the previous day are analyzed.

Step 5. Imagery of day 5 is analyzed and comparisons made with earlier days. This is only done for areas with no useful data from previous analysis. The same is then repeated for days 4, 3, 2 and 1, if necessary. Boundaries are drawn in solid lines for day 7 and 6, dashed for days 5 and 4, and dash-dot for the remainder.

Step 6. Ground station reports of the WMO network for days 7 and 6 are incorporated in order to:

a. delimit the snow extent in the areas of persistent cloudiness; and

b. show the snow boundary on day 7 or 6 in the areas where the surface was only seen on the earlier days (table 1. SAD class 9).

Step 7. Where no information is obtained in the previous steps, the ground station reports on the occurrence of snowfall are used (table 1 SAD class 8).

Step 8. Where no reports on snowfall or on snow on the ground are available, stations reporting precipitation at subzero (Celsius) temperatures are shown and such are separately marked (table 1 SAD class 7).

Step 9. Where no data are obtained in steps 1-8, the average extent of snow for day 7 isplotted from climatology or the snow boundary is interpolated through the blank zone (table 1, Climatology).

Compatibility of the Lamont Charts with the NOAA and U.S. Air Force Charts

Area S_{NOAA} compatible with the methodology of the NOAA snow charts is defined as:

$$S_{NOAA} = [(11,12...16) + (21,22...26) + (31,32...36) + (41,42...46) + (51,52...56) + (61,62...66) + (71,72...76)]$$

Reflectivity grade 1 of the NOAA chart corresponds approximately to SAD classes 1 and 2, grade 2 to SAD class 3, grade 3 to SAD classes 4, 5, and 6 (See table 1). Scattered mountain snow corresponds either to SAD 0 or rarely, to SAD 1.

The area S_{AF} compatible with the methodology of the U.S. Air Force snow charts for day 7 is definded as:

$$S_{AF} = [(71,72...76) + 79 + (01,02...06)]$$

Final Remarks

Work on the climatic snow cover charts is still in progress. Though time consuming, this work is thought worth the effort since the resulting product is the most complete weekly compilation of snow cover data and it could serve as a reliable base for climate modeling.

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