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P1.1 A MULTI-SOURCE SNOW COVER DATABASE FOR NORTHERN HEMISPHERE LANDS

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1. INTRODUCTION

Snow cover is a sensitive indicator of climate dynamics and climate change, and an integrator of basic climate elements. Information on the extent and depth of snow cover is also critical in many applied studies. As such, it is important that accurate snow information be available to the research community. A multi-source database that includes visible and microwave satellite-derived snow estimates and *in situ* ground station observations has been developed for the analysis of continental snow cover at regional to hemispheric scales. Files of snow extent and snow depth have been developed at five-day intervals and at a 1 degree by 1 degree resolution from 1972 to present. Here, each of the data files is discussed briefly and an example for a pentad is presented to demonstrate the utility of a multi-source approach to monitoring hemispheric snow cover.

2. VISIBLE SATELLITE OBSERVATIONS

Meteorologists at the National Oceanic and Atmospheric Administration produce weekly charts of snow extent across Northern hemisphere lands from a visual interpretation of photographic copies of visible-band satellite imagery. These charts are subsequently digitized to the National Meteorological Center Limited-Area Fine Mesh grid (cf. Matson et al. (1986) and Robinson (1993a) for further details on NOAA charts). For the new visible file, the weekly charts are converted to pentads and to a 1° x 1° grid using a geographic information system (GIS). For a given pentad, a cell is considered either snow covered or snow free. Charts produced since 1972 are considered useful for large-scale climate studies (Wiesnet et al., 1987), and are included in the file. The climate group at Rutgers is in the midst of a project to reanalyze visible imagery, supplemented with station observations, to generate improved weekly snow charts for fall 1966 through 1971. These charts will be completed some time in 1998. While visible imagery is recognized as a very useful means of assessing regional snow cover, it does have some shortcomings. These include: 1) the inability to detect snow cover when solar illumination is low or when skies are cloudy, 2) the underestimation of cover where dense forests mask the underlying snow, 3) difficulties in discriminating snow from clouds in mountainous regions and in uniform lightly-vegetated areas that have a high surface brightness when snow covered, and 4) the lack of all but the most general information on snow depth (Dewey & Heim, 1982).

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3. MICROWAVE SATELLITE OBSERVATIONS

Estimates of the spatial extent and the depth or water equivalent of a snowpack may be calculated using measurements in multiple microwave channels (e.g., Kunzi et al., 1982; McFarland et al., 1987). A file based on these analyses is another component of the new integrated dataset. This file includes: 1) Scanning Multi-channel Microwave Radiometer (SMMR) snow estimates, based on the algorithm of Chang et al. (1987), for 1979 through mid 1987; and 2) Special Sensor Microwave Imager (SSM/I) estimates, derived from the algorithm of Grody and Basist (1996), for most years since 1987. The discrimination of dry snow cover and depth using microwave data is possible mainly because of differences in emissivity between snow-covered and snow-free surfaces. Differences in microwave scattering between snowpacks are generally a function of snow mass (expressed as depth or water equivalent), although other factors, such as ice layers within the pack, or depth hoar at the base, also affect scattering. Scattering is reduced when snow is wet, and the surface may be misinterpreted as being snow free. Vegetation penetrating though the pack also influences microwave signals reaching the satellite sensor, making estimates of snow difficult in forested regions. As for the visible observations, SMMR and SSM/I products are converted to pentads and to a 1° x 1° grid using GIS.

4. *IN SITU* STATION OBSERVATIONS

A station observation file, another component of the integrated analysis effort, is currently being supplemented with Global Telecommunication System snow depth observations from across the Northern hemisphere (available during most of the 1980s) and data from western China. To date, the file contains data from the United States Historical Daily Climate Dataset (Robinson, 1993b), Canada, and the former Soviet Union. For the new dataset, observations from all stations within a 1° x 1° grid cell are averaged to obtain a pentad mean depth. Depths are calculated for all cells within which at least one station is located. While providing important information on snow depth at an observation site, *in-situ* data have two main drawbacks; 1) a station observation may not be fully representative of conditions over a broad region, and 2) observations are lacking in many areas where a seasonal snow cover is common.

5. SNOW COVER: MARCH 2-6, 1980

The importance of using multiple data sources to monitor snow cover is exemplified in figure 1, where estimates of coverage from each of the previously described files are shown for the 13th pentad of 1980. Where the visible and microwave products agree that snow is or is not present, and where station observations also verify the surface condition, confidence is high. This is the case over the vast majority of Northern hemisphere lands during this first week of March. Snow covers most of Eurasia and North America north of 45°. Some disagreement occurs farther south. The largest (and most frequently observed) area in question is over the Tibetan plateau and the arid lowlands of east Asia. Here, the microwave product shows more extensive snow cover than the visible product. This is due to surface and atmospheric conditions in these regions differing from those assumed in the development of the Chang et al. (1987) global microwave algorithm, thus the brightness temperatures measured by the satellite and incorporated in the algorithm do not provide an accurate assessment of snow cover (Robinson and Spies, 1995). This is further verified by the absence of snow cover at most stations in this region.

Other regions of disagreement are rather small in area (thus tend to be difficult to see in figure 1). For instance, over the eastern Great Plains and Midwestern United States, the microwave and station data suggest more extensive snow than the visible product. More than likely, snow is present but not reported in the visible data due to the presence of clouds that mask the analyst's view of the surface. In the upper Great Plains, snow is observed in the visible product, with a mixed report from the stations and no snow reported by the microwave data. This may be a case where snow cover is shallow and somewhat patchy, yet still recognized on visible imagery over this lightly vegetated area. During this pentad over the U.S. middle Atlantic region, stations report snow cover while the two satellite sources indicate snow free conditions. The number of station cells reporting snow indicates that snow must be present. Clouds and a wet snow cover might explain why neither satellite technique shows snow.

There is also the potential problem of the timing of observations influencing snow reports in the middle Atlantic and elsewhere. Individual pentads should not be over-analyzed for relatively small differences between the products, as the development effort required adjusting non-pentad satellite reports to the pentad level. This may explain why a satellite file "missed" the snow cover during a given pentad.

6. CONCLUSIONS

A new multi-source snow dataset has been developed for detailed analyses of continental snow cover at regional to hemispheric scales. Having three independent sources of data for snow extent, at least for those 1° x 1° cells in which stations are situated, permits estimation of the accuracy of the various products. This ultimately leads to an integrated, more accurate assessment of snow cover, where the strength of one source of data compensates for the weakness of another. For instance, according to visible and *in situ* data, microwave estimates of snow extent tend to be too high in arid, particularly high-altitude arid, regions. Also, while not discussed here, there is some indication that snow extent based on visible satellite data is underestimated in the fall over eastern Siberia.

This dataset will soon be available on CD ROM. The gridded products are created and archived individually from each source of data. This permits them to be used independently or combined in any manner. This database will be useful in efforts to create a linkage that is as seamless as possible between results from the traditional weekly NOAA snow charts and new ones soon to replace them, which will be produced daily using a multi-source approach (B. Ramsay, per. comm.).

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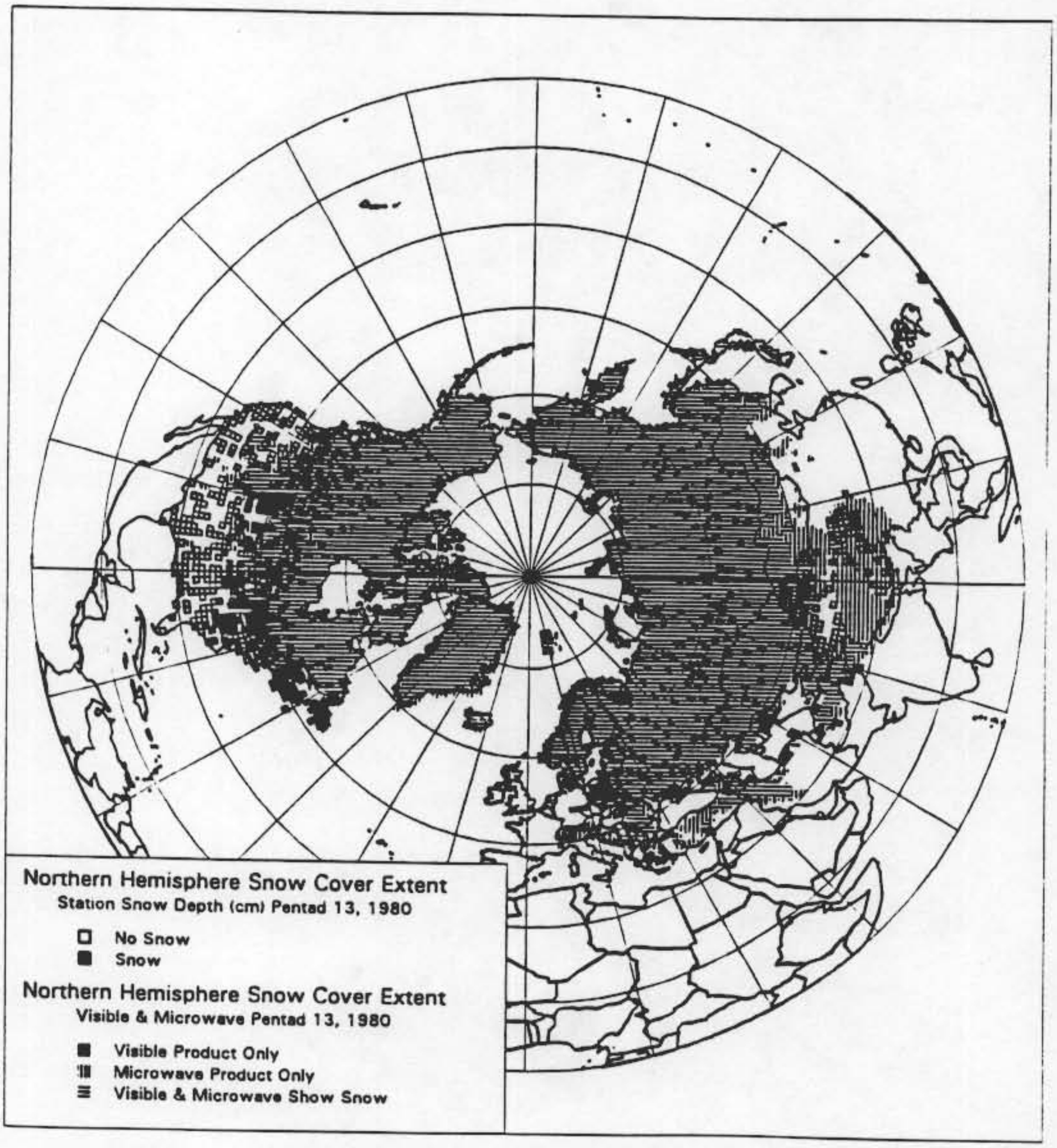

Figure 1. Snow extent over Eurasia and North America during the thirteenth pentad (March 2-8) of 1980. Included are estimates of coverage from: 1) NOAA snow charts, derived using visible satellite imagery, 2) from microwave satellite data, determined using the Chang et al. (1987) algorithm, and 3) from station observations.