DISTRIBUTION OF SNOW AND MAXIMUM SNOW WATER EQUIVALENT OBTAINED BY LANDSAT DATA AND DEGREE DAY METHOD

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ABSTRACT

This study attempts the estimation of maximum snow water equivalent map and snowcover distribution using several Landsat data taken in snowmelting season during latest four years. The test site is Okutadami-gawa Basin located in the central position of Tohoku-Kanto-Chubu District. The year-to-year normalization for snowmelt volume computation on the snow line is conducted by year-to-year correction of degree days using the snowcover percentage within the test basin obtained from Landsat data. The maximum snow water equivalent map in the test basin is generated based on the normalized snowmelt volume on the snow line extracted from four Landsat data taken in a different year. The snowcover distribution on an arbitrary day in snowmelting season of 1982 is estimated from the maximum snow water equivalent map. The estimated snowcover is compared with the snowcover area extracted from NOAA-AVHRR data taken on the same day, and the applicability of the snow estimation using Landsat data is discussed.

DATA ANALYSIS METHOD

The flow diagram of data analysis is shown in Fig. 1. The estimation of maximum snow water equivalent map in the test site is based upon the extraction of snow boundary mesh corresponding to the boundary region between snowcover and snow free area, and upon the computation of snowmelt volumes at each snow boundary mesh using accumulative temperature. The snow boundary mesh is extracted as a mesh in which the percent snowcover obtained from a Landsat snowcover extraction image is nearly 50 percent.

The maximum snow water equivalent at each snow boundary mesh is computed as a snowmelt volume obtained by a snowmelt model based on accumulative degree days at the elevation of each snow boundary mesh. The values of maximum snow water equivalent at snow boundary meshes obtained from Landsat data taken in different years are normalized by year-to-year correction of degree-days. The whole map of maximum snow water equivalent in the test site is generated using the above normalized maximum water equivalent values located in various spots in the test site.

The snowcover map on an arbitrary day in snowmelting season can be estimated by the computation of snowmelt volumes on the maximum snow water equivalent map. The snowcover extraction images obtained from NOAA-AVHRR data are used for the assessment of the above estimated snowcover map.

COMPUTATION AND YEAR-TO-YEAR CORRECTION OF SNOWMELT VOLUME USING DEGREE-DAY METHOD

The snowmelt volume on a certain snow line accumulated from the beginning of snowmelt until the appearance of the snow line, which is equivalent to the maximum snow water equivalent on the snow line, can be computed by the following equation based on the degree-day method.

$$M = K\Sigma\overline{Te} \tag{1}$$

where

M : Snowmelt volume (g/cm^2)
$\overline{Te}$: Effective daily average temperature on the snow line (°C)
$\Sigma\overline{Te}$: Degree-days on the snow line (°C•day)
k : Snowmelt coefficient (g/cm^2• °C•day)

$\overline{Te}$ is estimated from the average temperature at the standard weather station in the test basin using the relationship between temperature and elevation as follow,

$$\overline{Te} = \overline{Tb} - 0.6(he - hb)/100 \tag{2}$$

where

$\overline{Tb}$: Effective daily average temperature at the standard weather station
he : Elevation at the snow line
hb : Elevation at the standard weather station

In Eq. (1) a certain year-to-year correction for degree-days makes possible year-to-year normalization of snowmelt volume on the snow line, which makes it possible to use the snow line obtained from the Landsat data taken in a different year. The following two hypotheses are assumed for the year-to-year correction,

(a) snow distribution is equal, that is, the location of snow line is also equal if the snowcover percentage within the basin is equal between two days in a different year.

(b) The snowcover percentage in the basin decreases monotonously and regularly as degree-days increases.

The above hypothesis (a) is considered to be approximately approvable from the fact that the snowcover distribution between two different years Landsat data in which the snowcover percentage is nearly equal agrees very well. Under this hypothesis the correction of degree-days which equalizes the snowcover percentage between two different years' data leads to the year-to-year normalization of snowmelt volume.

Table 1 shows the snowcover percentage obtained from four Landsat data taken in a different year respectively. Photo 1 shows the superimposed image of the snowcover areas extracted from the four Landsat data.

Fig. 2 shows the relationship between snowcover percentage and degree-days in Okutadami-gawa Basin, which is used for year-to-year correction of degree-days. The solid line shows the relationship obtained by applying Eq. (1) to the maximum snow water equivalent map generated based on snow survey, in which the snowmelt coefficient K is assumed 0.45. The mark ⊗ in Fig. 2 shows the location of the snowcover percentage obtained from Landsat data in the snowcover percentage vs. degree-days plane. The dotted lines show the estimated curves for the relationship in 1981 and 1982 using the solid curves of 1978, 1979 and 1980. From Fig. 2, the correction values for degree-days in 1979 and 1981 which equalize the snowcover percentage to that of 1982 are estimated +70 ('79.5.4), +75 ('79.5.22) and −180 ('81.6.16) degree days respectively.

MAXIMUM SNOW WATER EQUIVALENT MAP AND SNOWCOVER DAILY VARIATION MAP

By the year-to-year correction described above, many point estimates of maximum snow water equivalent can be obtained using four Landsat data taken in a different year. Using these point estimates, the maximum snow water equivalent map is generated based on 500 meter mesh. Photo 2 shows the obtained maximum snow water equivalent map of Okutadami-gawa Basin in 1982. The total maximum snow water equivalent within Okutadami-gawa Basin in 1982 is estimated to be about 4.1×10^8 m^3.

The snowcover distribution on an arbitrary day can be estimated by subtracting the snowmelt volume calculated from Eq. (1) at each mesh. Photo 3 shows the estimated snowcover map from April 25 to May 30 in 1982 by seven days. The snowcover areas extracted from NOAA-AVHRR data taken on April 25 and May 23 in 1982 are shown in Photo 4, which can be compared with the estimated snowcover areas in Photo. 3. On April 25, the snowcover extracted from NOAA data is relatively smaller than that of estimated map, however, on May 23, both the snowcover areas are consistent with each other. The primary reason why the snowcover areas are not consistent on April 25 is considered to be unclearness of snow line in NOAA data due to rough resolution and as a result bad precision for snowcover extraction. The consistency of the snowcover areas on May 23, late in the snowmelting season, suggests that the estimation of maximum snow water equivalent and snowcover distribution conducted in this study can be applied practically in this test basin.

CONCLUDING REMARKS

The two hypotheses (a) and (b) assumed for the year-to-year correction of snowmelt volume are not based upon actual snow survey, but for the practical use of Landsat data taken in a different year, which are necessary to be assessed by some experimental snow studies. The satisfactory condition of Landsat data for the application of the estimation method in this study is to be able to compute snowcover percentage within a certain basin, which is rather severe condition for the routinized use of Landsat data considering the weather condition of Japan. It seems necessary to develop the year-to-year correction method using only the local information of snow line.

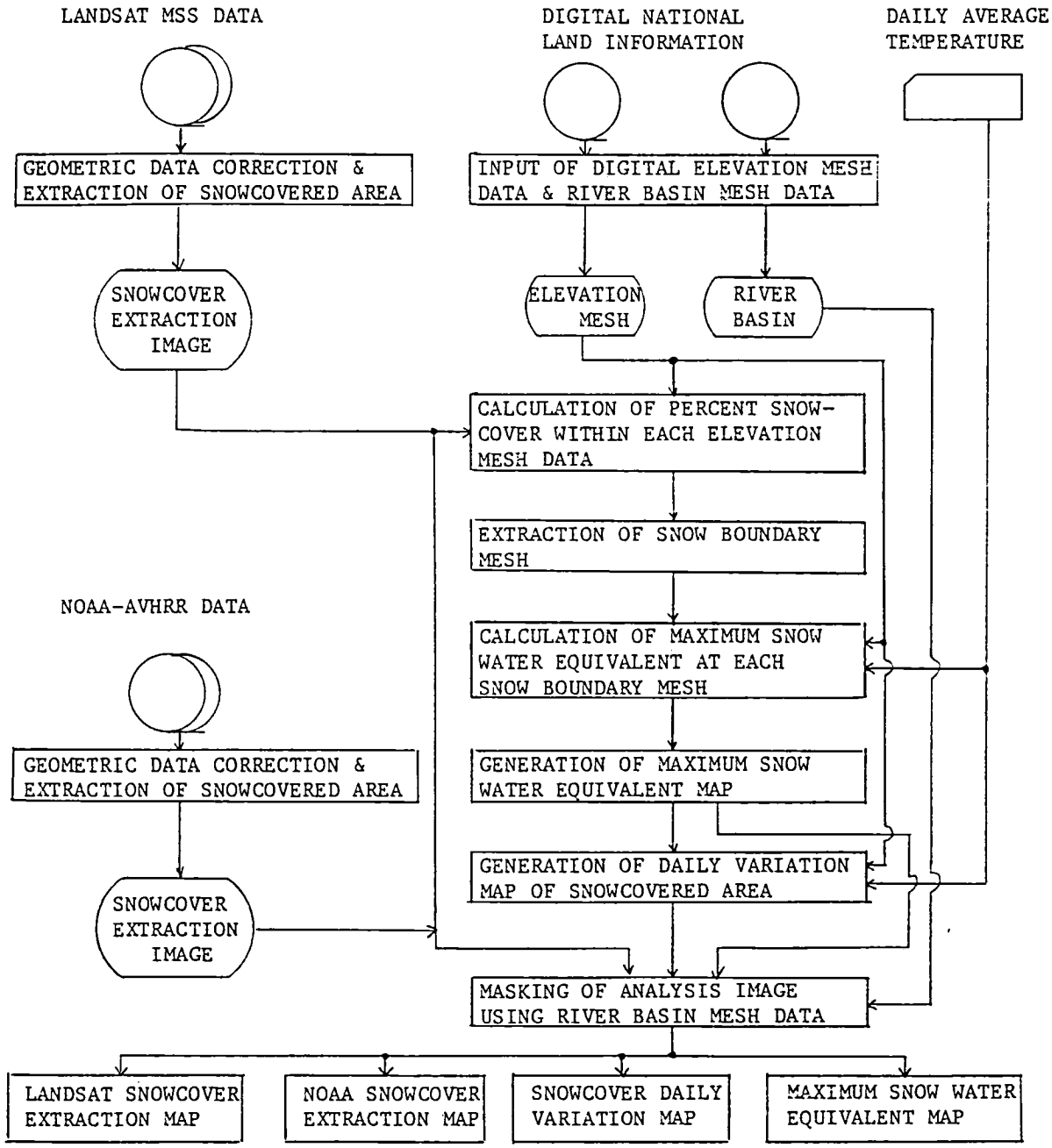

Figure 1. Flow Diagram of Data Analysis

Table 1
Snowcover Area and Snowcover Percentage within
Okutadami-gawa Basin Obtained from Landsat Data

OBSERVATION DATE	SNOWCOVER AREA (Km^2)	SNOWCOVER PERCENTAGE (%)
MAY 4 1979	274.7	63.0
MAY 22 1979	114.7	26.3
JUN 16 1981	70.2	16.1
MAY 15 1982	181.4	41.6

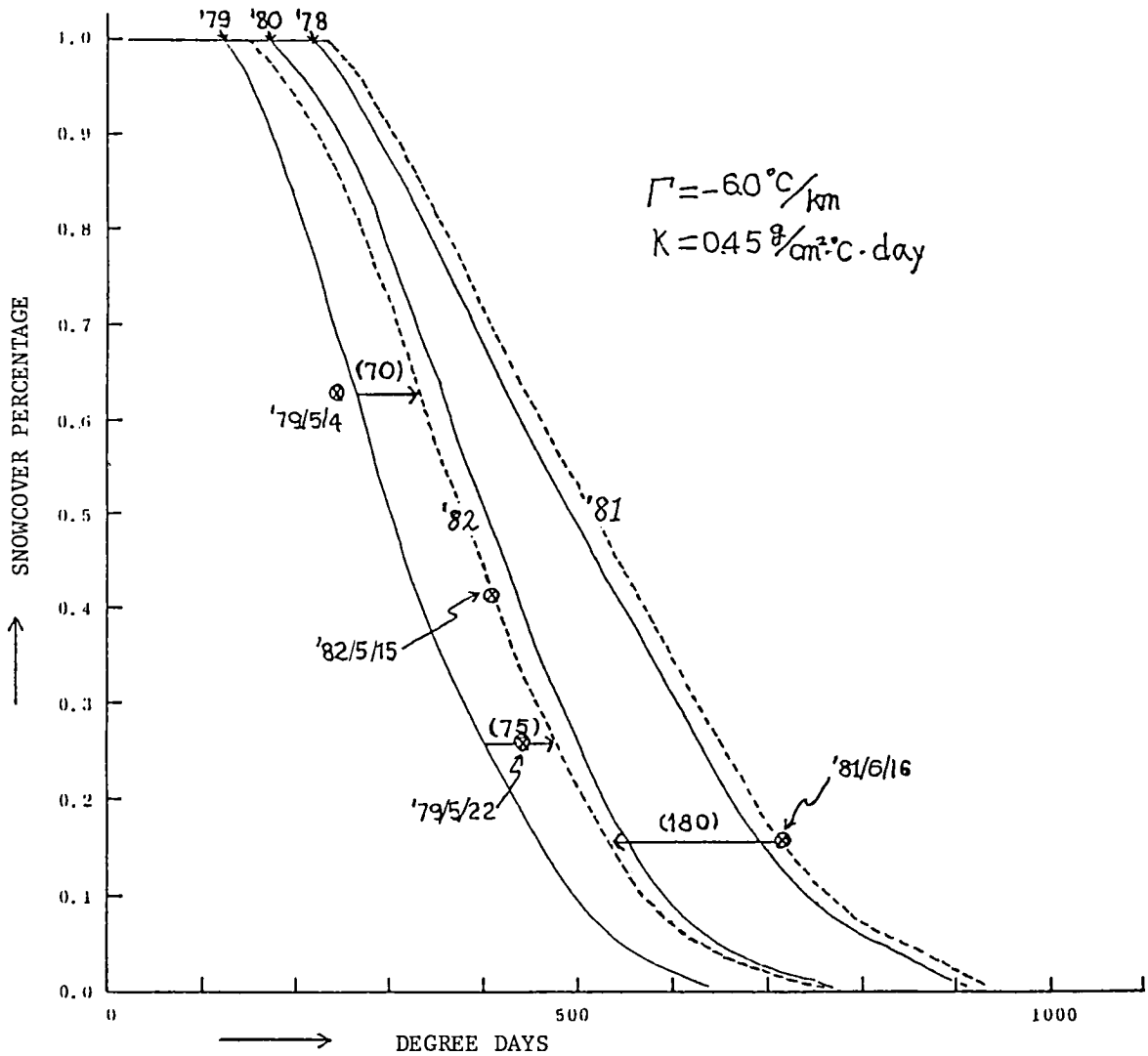

Figure 2. The Relationship Between Snowcover Percentage and Degree Days in Okutadami-gawa Basin