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Tracing March 2004 and December 2005 Heavy Snowfall of South Korea Using NOAA AVHRR Images

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Abstract

This study is to grasp and analyse the temporal and spatial distribution of record-breaking heavy snowfall rarely occurred in the middle and southwest region of South Korea during March of 2004 and December of 2005 respectively. Snow cover area was extracted using the channels 1, 3 and 4 of NOAA AVHRR images and the snow depth distribution was spatially interpolated using snowfall data of meteorological stations. Using administration boundary and Digital Elevation Model from 1:5,000 NGIS digital map, the snowfall impact was assessed spatially and compared with the reports at that time. The damaged area by heavy snowfall over 15 cm snow depth could be identified successfully within the spatial extent of snowfall area extracted by NOAA AVHRR image.

Keywords : Heavy snowfall, NOAA AVHRR, Snow cover area, South Korea

I. Introduction

In recent decades, extreme weather events seem to be growing in frequency and risk due to water-related disasters. Among the natural disasters, heavy snow causes traffic jam, cutting electric wires, prevention of commercial transportation and disasters such as house and greenhouse collapsing, snow avalanche and snowmelt floods.

Ground monitoring of snow are normally based on point measurement, which is subjected to numerous problems especially in inaccessible mountainous regions. The characteristics of snow distribution have not been understood clearly because of difficulty of snow survey at high elevation region and difference of spatial amount of snowfall. Remote sensing technology is very effective to observe a wide area of snow extent. Although many researchers have used remote sensing for snow observation, there have been a few discussions on the characteristics of spatial and temporal variation of snow cover.

The available images from satellite-borne sensors, which can be presently considered as suitable candidates for snow cover monitoring on a cost-efficiency basis, are mainly those taken from the AVHRR(Advanced Very High Resolution Ra-

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diometer) sensor, placed on NOAA(National Oceanic and Atmospheric Administration) satellites. Snow cover extent has been globally monitored using the series from NOAA AVHRR since the early 1970s. Rango et al. (1983) state that the spatial resolution of 1.1 km is sufficient if large areas of more then 200-500 km^2 are targeted, however, an area 500-1000 km^2 and more seems to provide a more sound statistical data basis. Lucas et al. (1989) used unsupervised multispectral classification for separation of snow in AVHRR images by using channel 1, 3 and 4. Cracknel (1997) emphasized on using AVHRR images to determine snow cover extent. He recommended the threshold methods in snow and cloud separation. Simpson et al.(1998) used a multispectral-multistage method to separate snow and cloud in AVHRR images. They used channels 2, 3, 4 and 5 and proposed a three-stage algorithm. The method separates snow and cloud in the first stage and then, separate snow from clouds.

The aim of the study was to develop a method for monitoring the evolution of snow covered and snow free areas during the heavy snowfall period in South Korea.

II. Description of March 2004 and December 2005 of heavy snowfall in South Korea

1. March 2004

According to KMA (Korea Meteorological Administration), the city of Daejon in central South Korea received 49 cm of snow on March 5, than ever recorded for a single day in March since the KMA began keeping records in 1904. The storm moved away from the Korean peninsula on March 7(Fig. 1). The central provinces of South Korea were crippled when heavy snow closed roads throughout the region, including many in the country's capital, Seoul. The main damage was traffic jam for 27 hours in the Gyeongbu expressway. Others were collapse of the roof of cattle shed, factory and greenhouse.

2. December 2005

In December 2005, there was a climate extreme over the southwestern part of South Korea (Ho-Nam area), accompanied by significant amount of snowfall. Associated with such a heavy rainfall, a continental high-pressure system was stronger than normal and the oceanic low was deepened, leading to the intensification of the cold surges over the Korean peninsula. Under

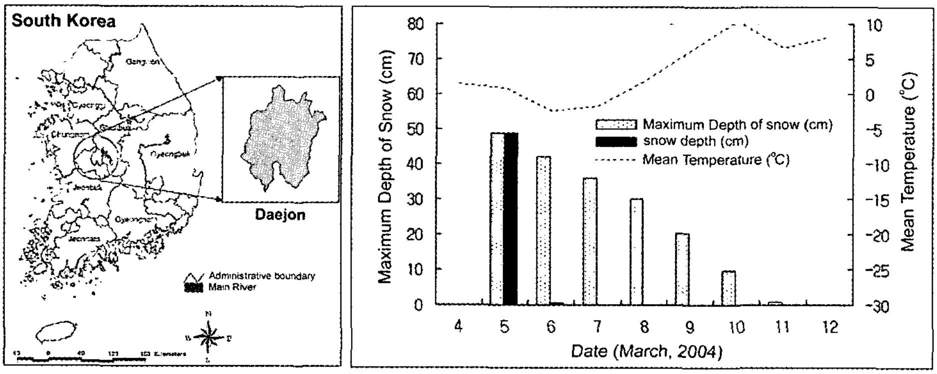

Fig. 1 March 2004 heavy snowfall data of central South Korea (Daejon station)

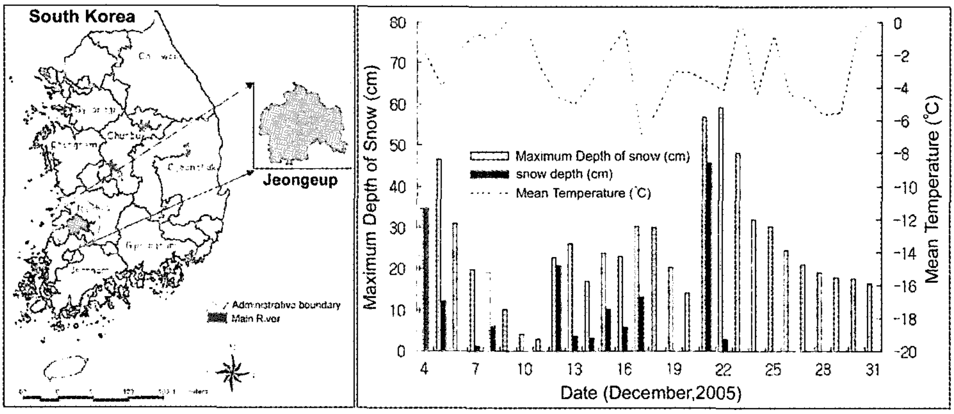

Fig. 2 December 2005 heavy snowfall data in the southwestern part of South Korea (Jeongeup station)

these synoptic situations, the central part of the peninsula experienced an extremely cold period, whereas the heavy snowy days lasted over the southwestern part (KMA, 2005). KMA (2005) reported that these unusual heavy snowfall events were induced by the warm sea surface temperature over the Yellow Sea that was 4-6 K higher than climatology. We can find several heavy snowfall days during December 2005, especially from 4 to 5, from 13 to 17 and from 21 to 23 December 2005 (Fig. 2). The main damage was isolation of local area by the long snowfall period. The next one was roofs and greenhouses collapsed in over 100 farming households in affected regions and destroy of house. A highway linking the southwestern provinces was blocked off on 21 December 2005 leaving thousands of people stranded in their cars for several hours. Most sections of the highway were reopened early 22 December 2005 after snow was cleared overnight.

III. Extraction of snow cover area and generation of snow depth distribution

1. Satellite data

The NOAA AVHRR sensor is well suited for snow cover monitoring. Its repetition cycle of less than one day allows to map the change of snow cover extent with a sufficiently high temporal resolution. With channels in the visible, near-infrared and thermal infrared part of the electromagnetic spectrum, this sensor allows semi-automatic discrimination of snow, cloud and snow-free areas.

In this study, we used NOAA/AVHRR data because recurrent time is short and ground resolution is adequate comparatively. The ground resolution of a pixel is about 1.1 km square and the recurrent time is about a half day. The definite strong point of AVHRR images is the daily nature of the data, covering all of Korean peninsula, and rapid processing of the images (delays of hours rather than day). Two clear-sky images of March 2004 were obtained. Five images of December 2005 and three images of January 2006 were obtained.

2. Extraction of snow cover area using NOAA AVHRR images

When we want to detect snow area in NOAA image, the important problem is how to discriminate snow area from cloud area. Since the 1980s, several algorithms have been developed for snow monitoring from optical sensors, including the multispectral thresholds classification method(Allen et al., 1990; Gesell, 1989; Harrison & Lucas, 1989; Liu et al., 1999; Romanov et al., 2000).

Kazama et al. (1995) showed how to differentiate between them. This method is schematically indicated in Fig. 3, where multispectral characteristics are used properly. Visual channel 1 can detect snow and cloud area, infrared channel 4 provides the temperature information with which we can detect high cloud, and middle infrared channel 3 can be used to detect low cloud because water particles in the air reflect ray of this channel.

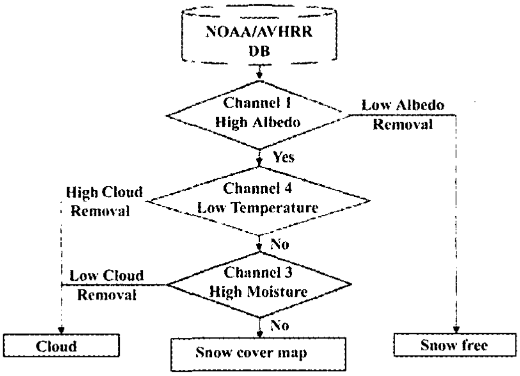

Fig. 3 Algorithm of snow cover area classification

Table 1 Threshold values of each channel of the selected NOAA AVHRR images

Date	Channel 1	Channel 3	Channel 4
March 7, 2004	22	10	-10
March 9, 2004	22	10	-10
December 19, 2005	15	10	-10
December 20, 2005	17	10	-10
December 24, 2005	14	10	-10
December 26, 2005	15	8	-10
December 27, 2005	15	10	-10
January 3, 2006	15	8	-10
January 7, 2006	20	10	-10
January 8, 2006	20	8	-10
Average	17.5	9.4	-10

Table 1 shows the threshold value of each channel to extract the snow cover area of the selected NOAA images by applying algorithm in Fig. 3 and Fig. 4 show the extracted snow covered area of March 2004 and December 2005.

3. Snow cover area in relation to elevation

To know the December 2005 snow cover distribution by elevation, the results from NOAA AVHRR images were summarized for Seomjin and Yeongsan river basin located in south-

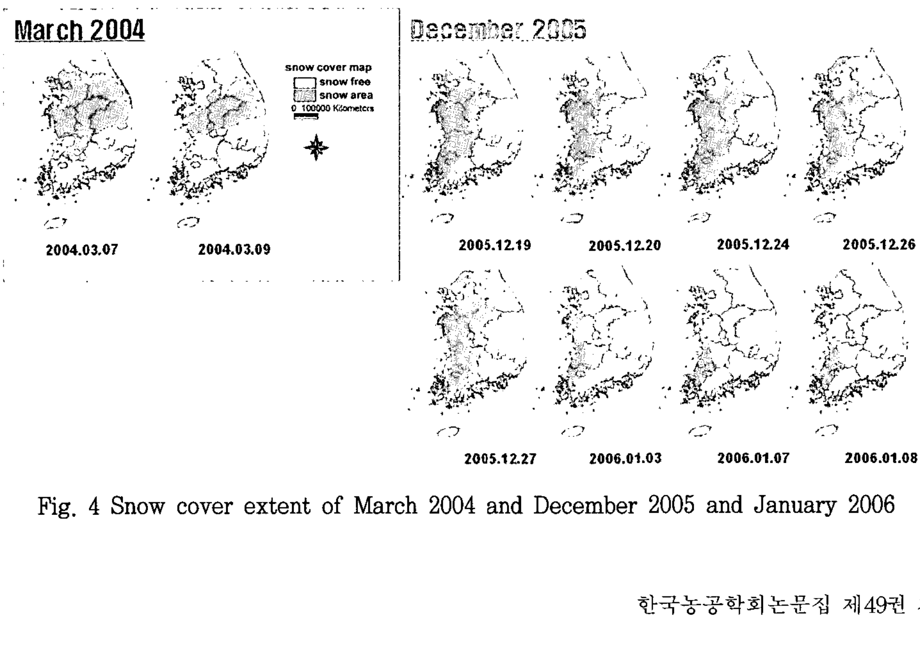

Fig. 4 Snow cover extent of March 2004 and December 2005 and January 2006

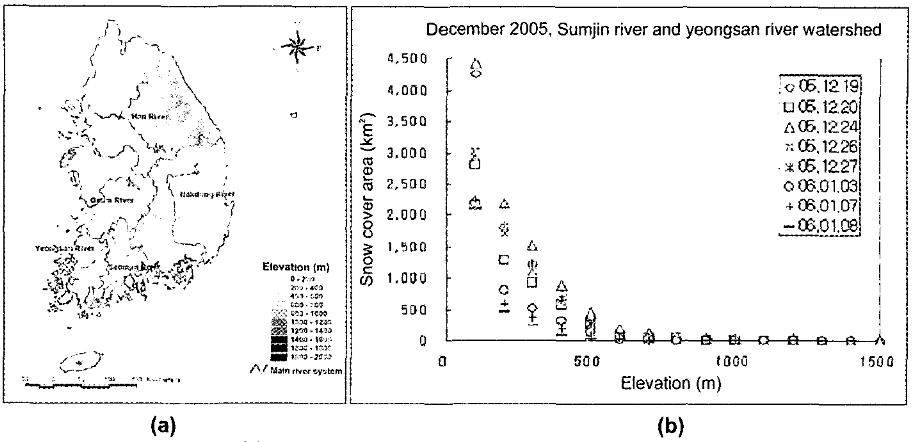

Fig. 5 (a) DEM of South Korea, (b) December 2005 snow cover area of Sumjin and Yeongsan river basin in relation to elevation

western area as in Fig. 5. Figure shows that the snow cover area exponentially decreased as elevation increases.

4. Snow depth generation by spatial interpolation using ground-observed snowfall data

Inverse Distance Weighting(IDW) method was applied to generate snow depth distribution. IDW directly implements the assumption that a value of an attribute at an unsampled location is a weighted average of known data points within a local neighborhood surrounding the unsampled location. The formula of this exact interpolator is (Burrough and McDonnell, 1998):

$$Z(x_0) = \frac{\sum_{i=1}^{n} Z(x_i) d_{ij}^{-m}}{\sum_{i-1}^{n} d_{ij}^{-m}} \qquad (1)$$

where x_0 is the estimation point and x_i are the data points within a chosen neighborhood. The weights(m) are related to distance by d_{ij}, which

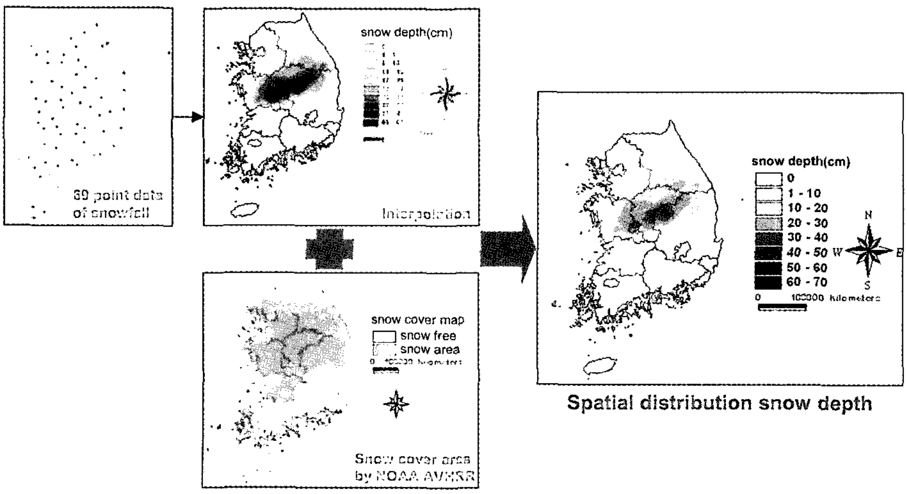

Fig. 6 Spatial distribution snow depth from GIS data and snow cover area

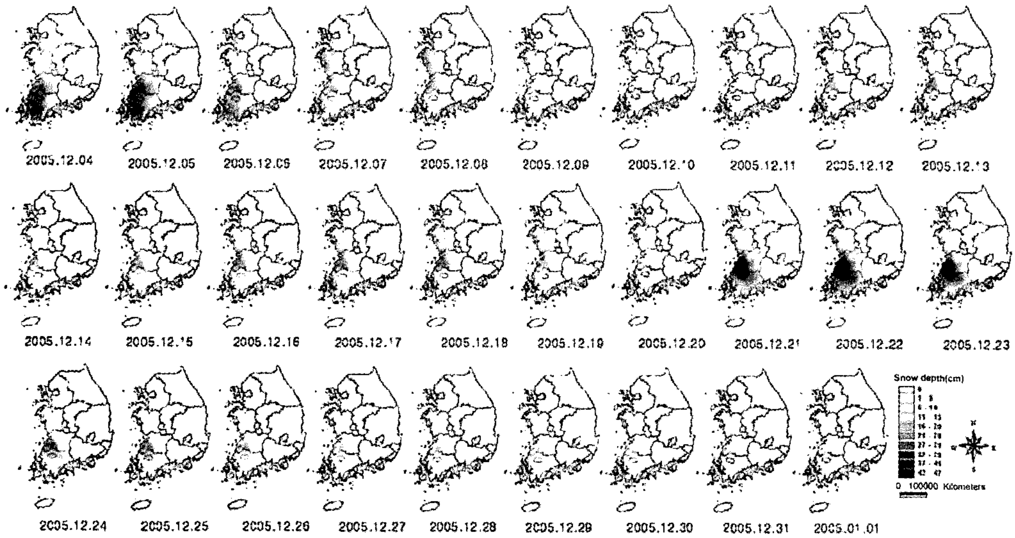

Fig. 7 The temporal and spatial distribution of snow depth for December 2005 heavy snowfall generated using 69 ground snowfall data

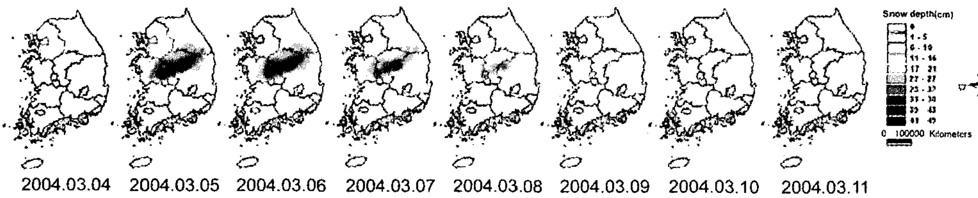

Fig. 8 The temporal and spatial distribution of snow depth for March 2004 heavy snowfall generated using 69 ground snowfall data

is the distance between the estimation point and the data points. The IDW formula has the effect of giving data points close to the interpolation point relatively large weights whilst those far away

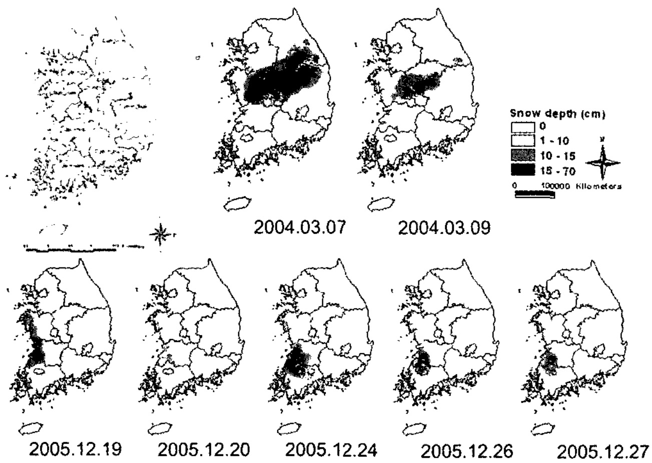

Fig. 9 Snow depth generation for snow cover area

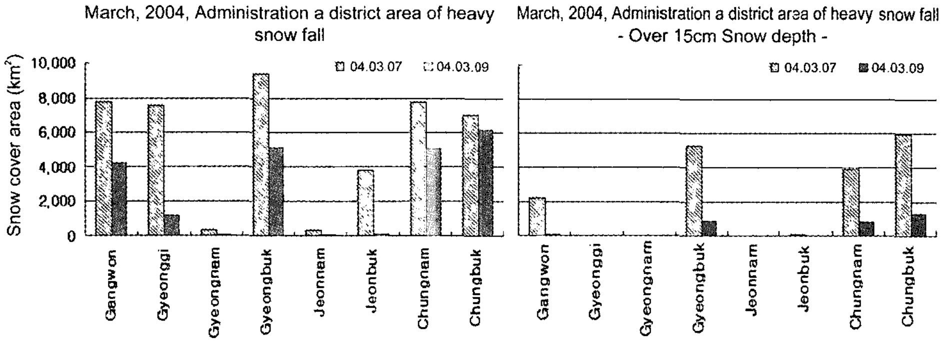

Fig. 10 Snow cover area by administration district for March 2004 heavy snowfall

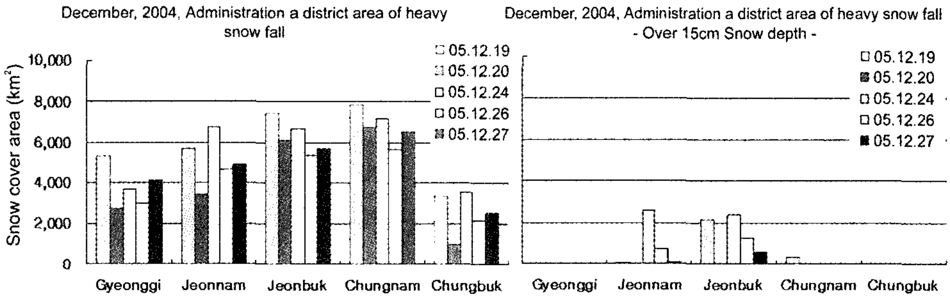

Fig. 11 Snow cover area by administration district for December 2005 heavy snowfall

exert little influence. The higher the weight used the more influence points close to x_0 are given.

The snowfall data of 69 meteorological ground stations were used, and spatially interpolated using GIS technique (Fig. 6). Fig. 7 and Fig. 8 show the temporal and spatial distribution of snow depth for March 2004 and December 2005 heavy snowfall generated using 69 ground snowfall data respectively. Finally Fig. 9 show the spatial distribution of snow depth for snow cover area.

5. Snow cover area by administration boundaries

By the March 2004 heavy snowfall, an estimated 670 billion won worth of property damage was reported. Especially, hard of a damage of this heavy snowfall was concentrated on Chungbuk province and Chungnam province. Fig. 10 shows the snow cover area by administration boundaries for March 2004 heavy snowfall.

For the December 2005 of heavy snowfall, the hardest did hit Jeonbuk province. Total damages estimated at 219.3 billion won. Fig. 11 shows the snow cover area by administration boundaries for December 2005 heavy snowfall.

Ⅳ. Conclusions

This study tried to trace the exceptional heavy snowfall occurred in March 2004 and December 2005 of South Korea using NOAA AVHRR satellite images. The extent of snow cover for the events were successfully extracted from NOAA images and the temporal variation of the snow cover area was also traced using the series of NOAA images. The damaged area by heavy snowfall over 15 cm snow depth could be identified within the spatial extent of snowfall area extracted by NOAA AVHRR image. By the recent phenomena of unpredictable heavy snowfall hitted for the whole South Korea, a need is urgently increasing to develop a real-time snowfall monitoring information system by NOAA AVHRR or Terra MODIS images.

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