SNOW DAYS DETERMINATION, USING PASSIVE MICROWAVE SATELLITE DATA

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ABSTRACT

This paper reports the results of an initial investigation of the potential for remote sensing application with special reference to passive microwave satellite imagery. It is based on SSM/I data. The study area is of the whole of Iran, with one or two satellite passes being used per day. For the purpose of identifying snow from variable surface conditions, the snow maps presented in this study were generated using the Grody&Basist algorithm which is based on separating scatterers from emitters in the 19, 22, 37 and 85.5 GHz frequencies of the passive microwave region of the electromagnetic spectrum.

Comparisons with surface observations from 136 synoptic stations obtained from the Iranian Meteorological Organisation are also provided. Conclusions are drawn as to the potential of combined satellite/surface methods for monitoring and understanding longer-term temporal variations in snow cover over Iran.

Keywords: SSM/I, Snow Days, Iran.

INTRODUCTION

Patterns and changes in snow cover distribution are important features of Iran's climates for the following practical reasons:

1. Unusually heavy snow accumulation in late winter or early spring may delay the arrival of the expected increase in air temperature, and, in addition, late season heavy snow can cause extensive flooding. Conversely, the absence of normal snow can cause acute water deficits in the many regions that rely on snow melt as a water source (Hall, 1988).
2. In snow covered areas, melt water is stored in dams, barriers and or reservoirs for agriculture and electricity production during periods of high demand (winter and early spring). A change in the amount and the temporal distribution of snow affects run-off considerably. This means that hydro-power and agriculture authorities need to change the operation scheme of the reservoirs or dams and/or an increase the price for electricity or crop production.

In Iran, snow is one of the most important sources of power generation, irrigation and drinking water supply (Ghobadian. 1990; Water Resource Research Organization, 1992). For its accurate estimate and forecasting, one would like to have data regarding snow cover extent, snow depth and snow water equivalent etc. Such data are scarce and not always continuous, especially in respect to the large mountainous basins in the Zagros and Alborz. Therefore, there is an essential need to apply remote sensing to snow monitoring in Iran. The analysis of satellite data is beginning to provide information in relation to both the spatial and temporal distributions of snow cover. With the advent of satellite remote sensing technology (Chang *et al.,* 1991), especially the availability of SSM/I data (Basist *et al.,* 1996), it seems to be possible to investigate snow cover and its related parameters (snow days, snow depth, snow water equivalent etc) in Iran.

DATA SOURCES

This paper reports the results of an initial investigation of the potential for a remote sensing application with special reference to passive microwave satellite imagery. It is based on SSM/I

(Special Sensor Microwave/Imager) data for the 12 calendar months of 1992. In this respect, an improved decision tree algorithm (Grody and Basist, 1994) is used to separate the scattering signature of snow cover from other scattering signatures and emitters. The snow cover product derived from SSM/I is compared with data on the different types of falling precipitation drawn from 136 synoptic stations. These data were obtained from the Iranian Meteorological Organization.

ALGORITHM IN USE

Several algorithms are available to identify and retrieve snow areal extent and therefore the number of snow days, for different regions and under different seasonal conditions. For the purpose of distinguishing snow from variable surface conditions with sometimes similar radiation characteristics, the snow maps presented in this paper were generated using the Grody/Basist algorithm which is based on separating "scatterers" (rain, dry snow, cold desert and frozen ground) from "emitters" (water, wet soil and vegetation) in the 19, 22, 37 and 85.5 GHz frequencies of the passive microwave region of the electromagnetic spectrum.

SNOW AREAL EXTENT

Changes in snow covered area can be assessed by comparing results from the SSM/I snow classification for 12 successive monthly images. As seen from the SSM/I satellite images (Figures 1 (a)-(l)), the snow cover began to emerge first in the highest points of the Zagros and Alborz Mountains during September and October. In December, the snow cover increased in extent parallel to the mountainous areas in the west, north-west and north, as well as some parts of the north-east and south-west towards the north. By this time, the Siberian High Pressure had become well developed as the result of the extreme surface cooling and the constant feeding of fresh Arctic air into Central Asia. This high pressure extends across Iran through the north-west and north-east, and is generally large enough to effectively prevent the invasion of air from other regional source into the interior Iran.

By January, the snow covered area had expanded well in all the mountainous regions. From January through March, the snow cover increase may have been accompanied by increases in depth and thickness also. In March, with increasing solar insulation, the snow lines gradually began to retreat upward to hilltops so that during the months of April and May, snow lines receded rapidly towards the summits. Summer is seen to be snow-free everywhere.

According to the passive microwave satellite images, shown in Figures 1 (a)-(l), elevation is one of the main terrestrial controls of snow cover distribution in Iran, while snow-free areas are mainly located at lower altitudes.

It is not unusual for the snow cover not to be seen over the two great deserts, Dasht-e-Kavir and Dasht-e-Lut, in the plateau. These areas are covered by sparse vegetation and frozen ground, and are mostly snow-free during the cold season.

The lack of the observation of snow by the SSM/I along the southern Caspian narrow plain and southern coastal areas may be because of the effect of the Caspian Sea, Persian Gulf and Oman Sea for the large bodies of water have a thermal inertia that might be influential upon the sub-regional climate. Dense forest cover may have an additional influence in some localities.

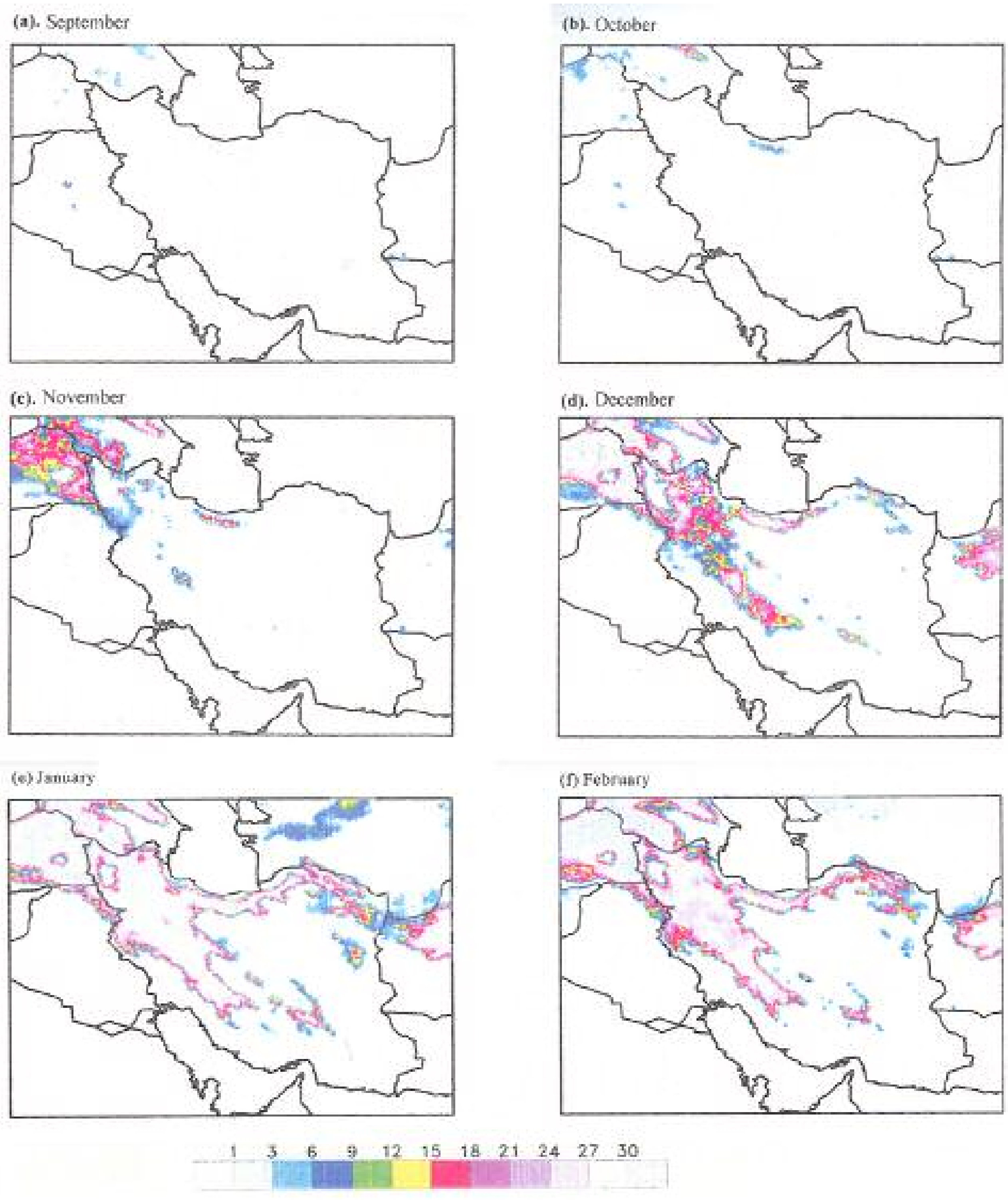

Figure 1 (a)-(l): 12 monthly SSM/I snow days in Iran for January through December 1992 using Grody and Basist algorithm.

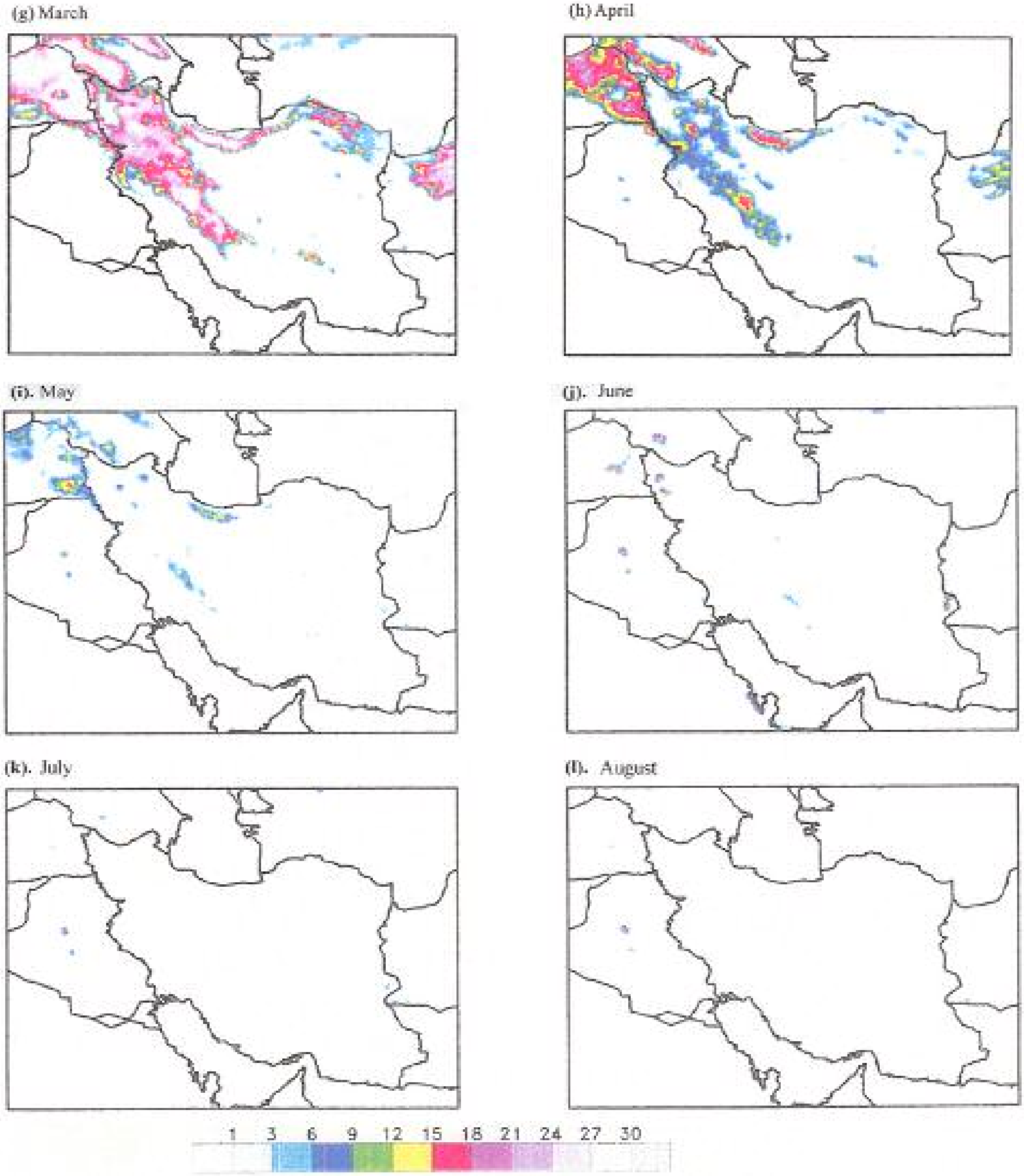

Figure 1 (a)-(l): (continued).

IN SITU/SATELLITE DATA INTER-COMPARISON

The near real-time in situ data available at present relate to the falling precipitation, and these observations have a variable relationship with satellite-derived statistics for snow on the ground. To explore the relationships between these two types of observations, annual totals of falling sleet or snow can be compared with annual totals of SSM/I snow days for the locations of the 136 surface meteorological stations. The following categories and types of categories were identified:

1. Locations where synoptic station observations of falling sleet or snow exceeded the SSM/I snow on the ground days by more than 10 (Group I) (see Figure 2 (a)), or by 1-10 (Group II) (Figure 2 (b)).
2. Locations where synoptic station observations of falling sleet or snow exactly equalled the SSM/I snow on the ground days (Group III) (Figure 2 (c)).
3. Locations where SSM/I snow on the ground days exceeded the synoptic station observations of falling sleet or snow by increasing amounts, namely 1-20 (Group IV) (Figure 2 (d)), 21-40 (Group V) (Figure 2 (e)), 41-60 (Group VI) (Figure 2 (f)), 61-80 (Group VII) (Figure 2 (g)), and 81-100 (Group VIII) (Figure 2 (h)).

Figures 2 (a)-(h) illustrate the results. In Figures 2 (a) & (b) stations occupy the central plateau of Iran, and the northern coastal regions of the Caspian Sea. In these areas, the numbers of snow days identified by both sources are generally very low, and sleet is more likely than snow. Thus, numbers of SSM/I-identified snow days are lower than those from the synoptic station reports, which relate to falling sleet or snow.

Figure 2 (c) shows areas of equal surface and satellite snow days that are virtually all in the southern part of Iran, near to the Persian Gulf, where winters are warm: In these cases, both sources of information reveal zero snow days. An interesting outlier is Gharakhil-e Ghaemshr, where both sources indicated three snow days: this station is on the Caspian Sea coast, where most stations fall into Groups I or II

Figures 2 (d)-(h), in which SSM/I snow days are progressively more and more in excess to the synoptic station reports of sleet and snow, involve hilly and mountainous regions of Iran. These are the colder regions, for which there is relatively small number of days on which sleet or snow are observed to fall, but there are a relatively large number of days on which snow is observed by the satellite as lying on the ground. In the more extreme cases (Figures 2 g & h), the days with snow on the ground exceed those with sleet or snow falling by more than two months in aggregate. The highest values of all are at Yasouj, near one of the highest points in the Zagros Mountains (88 days) and in the far north-west of Iran, where they exceed three months in total at Piranshahr (by 93 days) and at Makoo (by 99 days).

These results, and the relative spatial coherence of the distribution patterns of both the SSM/I-derived snow cover areas, and their relationships with the surface stations involved, give promise to SSM/I snow cover mapping, and suggest that the *in situ* and satellite observations are not very different from each other, but also could be complementary to each other, in a future operational system involving DMSP satellite data.

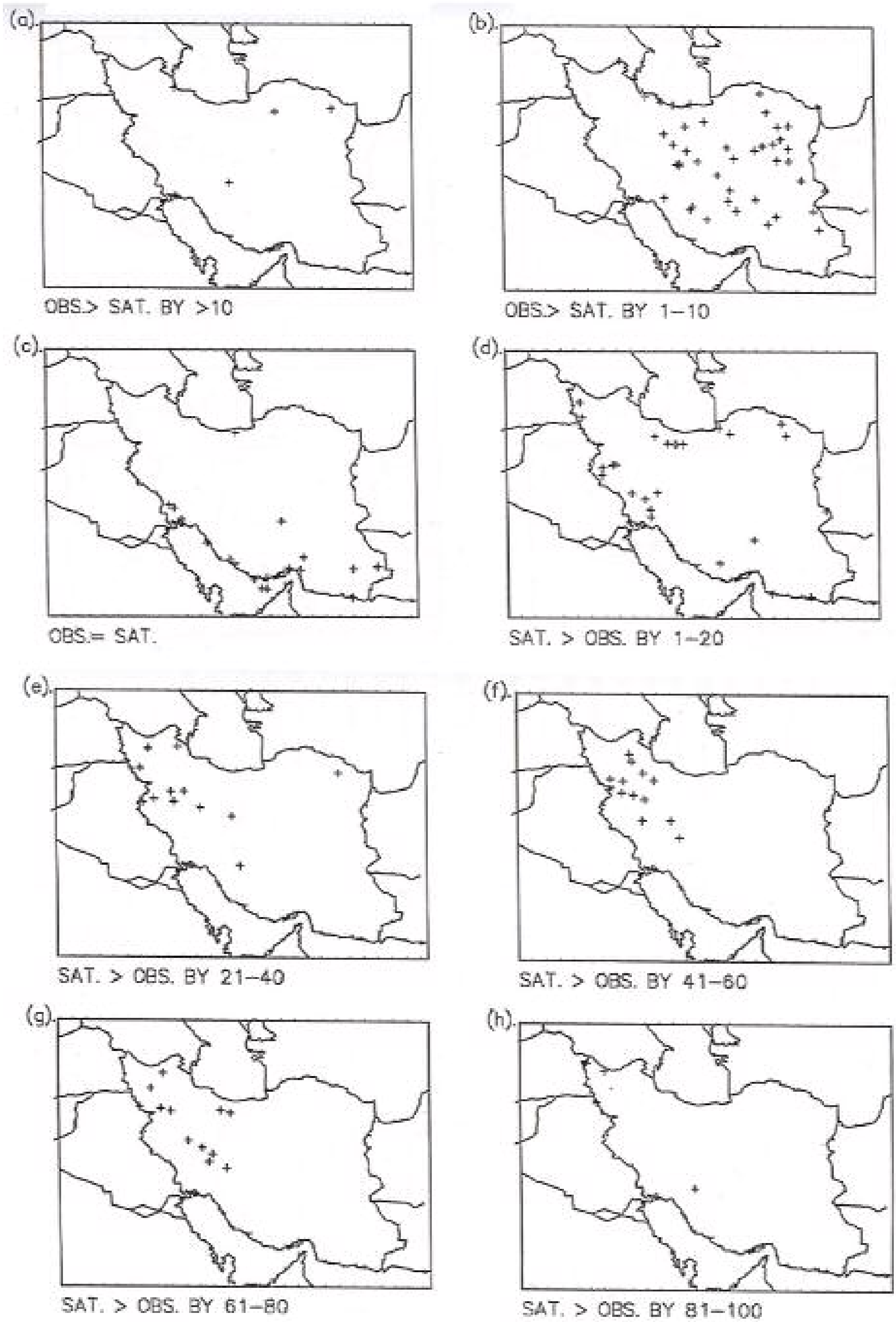

Figure 2 (a)-(h): comparison of annual totals of falling sleet or snow with annual totals of SSM/I snow days for the locations of the 136 surface meteorological stations in different categories.

DISCUSSIONS AND CONCLUSIONS

In this paper, satellite passive microwave data have been analyzed to establish and demonstrate the utility of one remote sensing application in relation to conventional snow monitoring over Iran. Data from two different sources were obtained: surface data from Iranian Meteorological Organization (IMO) and SSM/I data from the Centre for Remote Sensing (CRS), Bristol University. The surface meteorological data only relate to the type of precipitation falling, and the relationship between this parameter and satellite-derived snow lying on the ground is regionally very variable. This situation limits the known accuracy of the SSM/I satellite data. However, the initial results showed that microwave data have the potential to provide useful information related to snow cover area. For example, they can provide spatially-continuous maps of snow cover over the country as a whole. In addition, the results from them indicated a good coherency with snowy areas especially in high elevated mountains, where both data sets display high number of days with snow.

One objective of the present study was to investigate how the Iranian distribution of areas under snow cover and snow days can be monitored from space by passive microwave emission. In this respect, an appropriate algorithm was used to separate the snow cover signature from all other atmospheric and surface parameters observed by SSM/I satellite.

Since most parts of Iran are underlain cold desert and frozen ground, especially at high elevations, initial results from this technique provides a very promising way of retrieving passive microwave data on snow cover which cannot be provided from any other near real-time sources. The result of present research showed that SSM/I data has a great potential to explore other aspects of snow on the ground which SSM/I may be able to evidence, especially snow depth. This will be very useful for studies of climatic change, for the passive microwave archive is already nearly 20 years long.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Basist, A., Garrett, D., Ferraro, R., Grody, N. and Mitchell, K. 1996: A comparison between snow products derived from visible and microwave satellite observations. *Journal of Applied Meteorology*, **35**, 163-177.

[2] Ghobadian, A. 1990: Iranian *Natural Resources in Relation to Agricultural Utilzation*; *Reconstruction and Reclamation*. Kerman University Press, Kerman, Iran.

[3] Grody N.C. 1991. Classification of snow cover and precipitation using the Special Sensor microwave Imager. *Journal of Geophysical Research*, .**96**, No. D4, 7423-7435.

[4] Grody N.C. and Basist A. 1994. Identification of Snow Cover Using SSM/I Measurements. Submitted to *Remote Sensing of Environment*.

[5] Hall, D.K. 1988: Assessment of Polar climatic change using satellite technology. *Review of Geophysics* **6**(21), 26-39.

[6] *Meteorological Year Books. 1992*. Iranian Metorolgical Organization (IMO). Publication section of I.M.O, Tehran, Iran.

[7] *Snow Depth Report.* 1992: Water Resource Research Organization (WRRO). Ministry of Energy, Tehran, Iran.