Remote Sensing of Snow Cover for Climate Monitoring in the Canadian Subarctic: A Comparison Between SMMR–SSM/I and NOAA–AVHRR Sensors

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ABSTRACT:

By considering the advantages and disadvantages of each remote sensing observation method, the most favourable solution for studying snow cover currently remains the synergistic use of multi-sensor satellite data. Using Principal Component Analysis (PCA) applied to SMMR and SSM/I time series over a 23-year period (1978–2001), we were able to evaluate the sensitivity of passive microwave sensor data in identifying the seasonal cycles and the interannual variability of snow cover conditions in the Canadian Subarctic (northern Manitoba). We also demonstrated that the Nimbus-7 SMMR Pathfinder Daily EASE-Grid Brightness Temperatures are biased, especially in vertical polarisation. Dates characterising the beginning of snow accumulation on the ground and snow cover disappearance were obtained from the PCA and then compared to both snow cover information derived from optical satellite imagery (NOAA/NESDIS weekly snow charts) and conventional snow cover measurements recorded at the Churchill and Gillam airport weather stations. It appears that passive microwave radiometers meet some difficulties in estimating accurately the date of the first snow on the ground, especially under warm and dry winter conditions. Indeed, the difference can sometime exceed 4 weeks (*e.g.* winters 92–93 and 98–99) between passive microwave estimates and *in situ* observations. Consequently, the results clearly indicate the need to improve snow cover duration estimates derived from passive microwave data by adding information from optical sensors. However, SMMR and SSM/I data efficiently compensate for the deficiencies of optical imagery, especially when cloud cover remains over a study area for long periods due to the presence of large atmospheric disturbances. In addition, passive microwave data also allow to monitor intra- and inter-annual variations in snow depth.

Keywords: snow cover, remote sensing, multi-sensor approach, passive microwave data, SSM/I, SMMR, NOAA-NESDIS weekly snow charts, daily data and pentads.

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INTRODUCTION

For the climatologists and the meteorologists studying atmospheric and climatic variability on a global scale, the monitoring of the snow cover component undeniably remains a challenge. Through its inherent physical properties, snow cover significantly influences the evolution of weather on a daily basis as well as climate variability on a much longer time scale. First snow modifies the radiative balance and energy exchanges between the surface and the atmosphere, and thus indirectly acting on the atmospheric dynamics. In addition, this component of the cryosphere is extremely sensitive to climate fluctuations. Consequently, the accurate observation of the spatial and temporal variability of snow cover could contribute, in a foreseeable future, to the monitoring of Global Change.

To study the effects of the extent and variability of seasonal snow cover on the climate system and for data assimilation or for the validation of GCMs, climatologists need to acquire snow cover information both on a fine temporal scale and large areas. Compared to the conventional snow measurements sporadically taken *in situ*, satellite remote sensing data are particularly well-adapted to the monitoring of snow-covered surfaces over continuous space-time scales. Nowadays, a wide range of instruments is available for measuring and observing snow cover; especially, a variety of spaceborne sensors with various spectral, spatial and temporal resolutions that purposely meets the needs both required by climatologists and hydrologists. However, each type of sensor is has some specific technical constraints and limits. Visible-band and near-infrared (NIR) imagery, for example, only offers the possibility to map the evolution and extent of snow cover. Furthermore, the accuracy of the snow extent maps inferred from shortwave data remains largely dependent of cloud cover and illumination conditions, especially in the higher latitudes which are strongly affected by darkness throughout the long polar nights. The use of thermal infrared images allows surface temperature monitoring and also complements the snow cover extent mapping. At these wavelengths, nocturnal observations can be collected Nevertheless, the thermal infrared signal remains sensitive to the presence of cloud cover. As they are completely independent of illumination conditions and nearly unaffected by cloudiness, a great deal is expected from spaceborne passive and active microwave data. Indeed, most clouds are transparent in this portion of the electromagnetic spectrum (Hall and Martinec, 1985). In homogeneous areas, snow cover parameters such as snow cover extent and snow water equivalent can be inferred on a daily basis using passive microwave data. The all-weather investigation of the spatio-temporal variability of snow packs thus represents the major application of passive microwave radiometry (Gloersen *et al.*, 1984). However, because of their coarse spatial resolution, the use of current passive microwave sensors is restricted to the climatological and hydrological studies conducted at regional to global scales. In contrast, the fine spatial resolution of Synthetic Aperture Radars (SAR) makes active microwave data a viable tool for studying snow cover, on a fine scale, in the context of hydrological investigations. However, the complex interactions between the radar signal and snow pack properties strongly limits the processing and interpretation of radar images. In addition, the 5.3 GHz frequency (C-band) at which current SAR sensors operate is not optimised for dry snow cover studies, especially for a quantitative determination of snow cover parameters such as snow water equivalent (Rango, 1993).

Presently, because of the advantages and disadvantages inherent to each data type employed to monitor snow cover from space, the most favourable solution probably consists of using jointly multi-sensor satellite data (visible-band and near-infrared, thermal infrared and microwave). This strategy is increasingly highlighted in a growing number of publications. Jin and Zhang (1999), for example, simultaneously used passive and active microwave data to significantly expand the temporal monitoring of the complex snow covers encountered in Siberia and Greenland. By merging the data issued by the SSM/I passive microwave radiometer with the information inferred from the OLS thermal infrared sensor mounted on the same spacecraft, Standley and Barret (1999) attempted to reduce the confusion between the slightly snow-covered surfaces and clouds containing a strong amount of microwave scatterers. Others have combined traditional snow cover information with optical (NOAA–AVHRR imagery) and radar (ERS-2) data in order to periodically update hydrological models inputs, thus substantially improving streamflow forecasting during the snowmelt period (Koskinen *et al.*, 1999).

In this paper, we present preliminary results of a study related to the monitoring of climate variability in the Canadian Subarctic (Northern Manitoba) which was recently undertaken in order to assess the complementarity of snow cover information derived from passive microwave imagery (SMMR and SSM/I data) and those resulting from the visual interpretation of satellite images gathered in the visible and near-IR portion of the electromagnetic spectrum (NOAA–NESDIS weekly snow charts). Snow water equivalent variability observed during the period of peak snow accumulation, snowmelt dates, annual snow cover duration, and dates of snow cover appearance and disappearance are as many parameters whose fluctuations should be monitored to develop a valuable index of climatic variability and climate change (Goodison and Walker, 1993; Barry *et al.*, 1995). We precisely focused here on estimating the dates of snow cover appearance and disappearance.

STUDY AREA

The study area is located in north Manitoba (Canada), on the western side of Hudson Bay, between latitudes 56°N and 59°N, in an area dominated by wetlands and where terrain elevation does not exceed 200 m (Hudson Bay Lowlands) (Figure 1).

One particular characteristic of this area is that it encompasses both the southern limit of the continuous permafrost zone and northern limit of treeline and the continuous forest (Rouse, 1991). The study area falls within the Subarctic ecoclimatic zone, a very contrasted geographical environment that successively juxtaposes low density boreal forest, boreal forest–tundra transition zone then shrubby tundra. Approximately 54.47% of the surface area is covered by evergreen needleleaf forest, 26.08% by open areas (shrub/lichens, treeless and burns) and 10.30% by a transition treed shrubland where the tree cover represents less than 10% of the vegetation community (Figure1). These values were derived using the land cover map of Canada produced from the NOAA–AVHRR imagery (Cihlar and Beaubien, 1998). This complex mosaic of cover types is characterised by extremely different degrees of roughness and aerodynamic properties influencing snow accumulation patterns, blowing snow and, overall, the satellite remotely sensed signals.

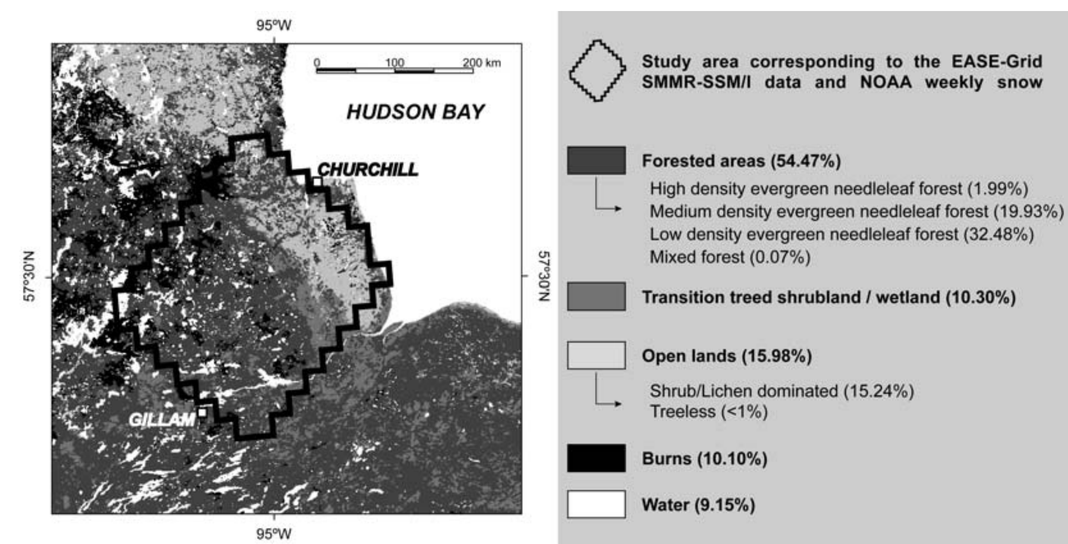

Figure 1: Location of the study area and land cover.

MATERIAL AND METHODS

SMMR and SSM/I passive microwave data time series: data description, spectral signature of snow and Principal Component Analysis

Passive microwave data from the Scanning Multichannel Microwave Radiometer (SMMR) and the Special Sensor Microwave Imager (SSM/I), projected on an Equal-Area Scalable Earth Grid (EASE-Grid) and corresponding to the 18 (19) and 37 GHz brightness temperatures, respectively, recorded twice daily at the time of the Nimbus-7 and DMSP satellites repeated ascending and descending overpasses (*Nimbus-7 SMMR and DMSP SSM/I Pathfinder Daily EASE-Grid Brightness Temperatures*), were used in the current study (Armstrong *et al.*, 1994 ; Knowles *et al.*, 1999). The SMMR and SSM/I radiometers provide, on a daily basis, digital charts of brightness temperatures with a resampled spatial resolution of 25 km for the 18 (19) and 37 GHz channels. Specific information on the EASE-Grid data product can be found in Armstrong and Brodzik (1995).

A dual-frequency algorithm derived from the spectral gradient method of Künzi *et al.* (1982) was developed and applied to the SMMR and SSM/I data. This algorithm was used twice: 1) for computing the spectral difference between the daily brightness temperatures measured at 18 (19) and 37 GHz, both in horizontal and vertical polarisation and 2) for averaging, on a five-day basis (pentads), these spectral differences. Indeed, pentads are commonly applied to long time series of passive microwave data, mainly in order to reduce the volume and computing time of the data to process and, if required, to deal with the problem of orbital gaps recurrent below 56°N (Basist *et al.*, 1996) and occasional missing swath data (*e.g.* substantial SSM/I data gaps observed during the 1994–1995 period, especially for Alaska, Canadian Prairies and the surroundings areas).

The dual-frequency algorithm allows to determine the presence or absence of snow on the ground and constitutes a valuable snow water equivalent index when applied to dry snow-covered surfaces, in homogeneous and non-complex areas such as the Canadian Great Plains and the Russian Steppes (Walker and Goodison, 1993). However, in the particularly heterogeneous landscape encountered in the Subarctic ecoclimatic zone, passive microwave remote sensing of snow cover comes up against the complexity of the interactions between microwave radiation and the internal structure of snow cover, as well as the variability of the microwave signal with the various cover types. This is the main reason why the experiment carried out by Boudreau and Rouse (1994) in the vicinity of the northern village of Churchill (see figure 1), and which object was to evaluate the potential of SSM/I passive microwave data to estimate snow physical parameters, was not conclusive. Nevertheless, we demonstrated, in a previous study undertaken around the same site (Pivot *et al.*, 2002), that the SSM/I radiometer remains a very valuable tool for monitoring the temporal evolution of snow cover in Subarctic environments. Thus, the fluctuations of the multi-frequency algorithm described above could be regarded as a proxy of snow cover conditions. Consequently, by interpreting these fluctuations, one is likely to obtain accurate estimates of the dates of beginning, melting and disappearance of snow.

The passive microwave signature of dry snow strongly differs from the signature of snow-free surfaces. For dry snow conditions, emissivities decrease with increasing frequency. Indeed, an important microwave scattering commonly occurs above 30 GHz that jointly increases with the amount of snow on the ground (Mätzler, 1987). Consequently, in the presence of dry snow, the spectral difference is positive and increases gradually and concurrently with snow accumulation. In opposition, for snow-free conditions, emissivities increase with increasing frequency (Mätzler, 1987). Consequently, when the ground is free of snow, the difference between the brightness temperatures measured at frequencies 18 (19) and 37 GHz is negative. The microwave signature of wet snow is similar to that of a snow-free surface and opposite to that of a dry snow cover; emissivities increase with increasing frequency and reach, beyond 10 GHz, a maximum around 0.9 (Mätzler, 1987). This results in a generalised increase of brightness temperatures while the difference between 18 (19) and 37 GHz frequencies tends to be considerably smaller. Therefore, the multi-frequency algorithm remains positive during snowmelt, but tending towards values close to 0 K.

A subset window (78750 km^2) corresponding to the study area (Subarctic ecoclimatic zone for Northern Manitoba) was extracted from the available SMMR and SSM/I Northern Hemisphere images acquired over a 23-year period, from October 1978 to March 2001 (see the black box on Figure 1). Sea-ice/water and coastal mixed pixels contaminated by the Hudson Bay were carefully removed. A Principal Component Analysis (PCA), a well-known statistical technique to process such voluminous time series, was performed to efficiently extract the snow cover information contained in this extended image data set. PCA proceeds by a linear transformation of a series of numeric variables in order to create a new series of orthogonal factors (principal components or PCs) which, unlike the input variables, are uncorrelated between them. The PCs are ordered in terms of the percentage of the explained variance contained in the original data set (Eastman and Fulk, 1993).

In order to emphasise the temporal patterns contained in such time series of subset images, a column-standardised principal component analysis with an orthogonal Varimax rotation was performed. Indeed, column-standardisation was applied in order to obtain a variance of one for each variable (*i.e.* spatial dimension), thus reducing the impact of the spatial variations induced by the variety of landscapes and inversely highlighting the information related to the temporal changes (Fung and LeDrew, 1987).

Extraction of the dates of snow cover appearance and disappearance from the NOAA–NESDIS weekly Northern Hemisphere snow charts

The amount of solar radiation reflected over snow-covered surfaces considerably contrasts with that of snow-free surfaces (Rango, 1993). As a result, visible-band/NIR spaceborne sensors contributed early-on to the mapping snow cover extent. Since 1972, a series of meteorological satellites was launched by the U.S. National Oceanic and Atmospheric Administration (NOAA), that successively carried the VHRR (*Very High Resolution Radiometer*) and the AVHRR (*Advanced Very High Resolution Radiometer*) sensors (Hall et Martinec,1985 ; Robinson, 1993). The snow extent maps derived from these sensors and produced by the NOAA–NESDIS (NOAA Environmental Satellite, Data and Information Service) were so accurate that they were soon recognised as an operational and suitable product for hemispheric and regional-scale snow cover studies. These charts are derived from the visual interpretation of the shortwave imagery by trained analysts and are initially digitised on a weekly basis from a set of 89×89 cells projected onto a polar stereographic grid. A cell is considered to be completely covered if it is interpreted to be at least fifty percent snow-covered, otherwise it is considered to be snow free. A complete description of the procedure can be found in Robinson (1993). Recently, the digital NOAA–NESDIS Weekly Northern Hemisphere Snow Charts were regridded to the Northern Hemisphere 25-km EASE-Grid format (Armstrong and Brodzik, 2002), hence facilitating direct comparison with other EASE-Grid products.

Thus, the matching subset window corresponding to that previously selected for the SMMR–SSM/I EASE-Grid data was extracted over the same observation period. However, this EASE-Grid subset window initially corresponded to four original cells with a poorer spatial resolution of 1×1 degree latitude/longitude. As a result, the effective subset area largely exceeded the boundaries of the SMMR–SSM/I study area, especially in the southern part of the Subarctic zone, where it encompasses a substantial part of the High-Boreal evergreen needleleaf forest.

Each year, the dates of snow cover appearance and disappearance were derived according to the following principles: 1) the date of onset of snow corresponds to the first week where at least one EASE-Grid cell is identified as snow-covered and 2) the date of snow disappearance matches the week where all the cells of the subset area are concurrently interpreted as snow-free.

Conventional snow depth measurements and surface meteorological data

The dates of snow cover onset and disappearance derived from the NOAA–NESDIS weekly snow charts and obtained from the SMMR–SSM/I passive microwave time series using PCA were empirically compared to conventional snow cover and meteorological ground-based measurements recorded at both the Churchill (58°44 N, 94°04 W) and Gillam (56°21 N, 94°42 W) airport weather stations. These data are archived and distributed in digital format by the

Meteorological Service of Canada. Two major problems are related to traditional ground measurements: the accuracy and the representativeness of these point data. As an example, the Churchill site is located in the vicinity of the Hudson Bay, in an open area strongly exposed to wind. The redistribution of snow by wind remains a key factor for explaining the spatial variability of snow accumulation and the difficulty in estimating consistent and averaged snow cover conditions using point measurements. Indeed, wind-effect is usually responsible for an underestimation of snowfall catches by precipitation gauges; inversely, abnormal values can be measured in the field during snow depth surveys, when snow has been significantly blown and redistributed by wind. In addition, the Churchill weather station is located in a coastal area where the snow cover conditions strongly differ from those prevailing in the close environment situated farther inland. In fact, several vegetation types follow one another along a distance which does not exceed 50 km and where one promptly passes from open forest, to partially treed transition zone and then to tundra. This diversity definitely influences snow cover parameters and their evolution. At the local scale, snow measurements made at the Churchill weather station are not representative of the surroundings. Therefore, according to the heterogeneity of our study area on a regional scale (see figure 1), conventional point measurements of snow cover should be considered with caution when used as absolute values for validating the snow information derived from remote sensing techniques.

RESULTS AND DISCUSSION

PC2 scores of the PCA applied on 23 years of daily passive microwave data (SMMR–SSM/I times series)

The sensitivity of passive microwave sensors (SMMR and SMM/I) data in identifying the seasonal cycle and the interannual variability of snow cover in the Canadian Subarctic was assessed by applying a PCA on the spectral differences computed as described previously, over a 23-year period (1978–2001). PC2 appears to be the most interesting component and explains 45.1% of the variance. The formation of this component is mainly attributed to the snow-covered periods corresponding to spectral differences above 0K. Thus, annual snow-cover duration can be estimated through this component since the reversal of the scores sign closely agrees with the dates of appearance and disappearance of snow (Figure 2). Positive scores are commonly interpreted as snow-free days or pentads (spectral differences below 0K), while negative scores as periods where snow is present. However, negative scores are also noticeable in the early and middle part of the snow cover season. There, they are associated with sudden changes affecting the spectral-difference values (close to 0K), usually due to an episodic snowmelt event. Furthermore, PC2 also depicts the interannual variability of snow cover, the strength of the scores closely matching snow depth fluctuations. Identical results have previously been obtained with the SSM/I times series alone (Pivot *et al.*, 2002). However, unlike the SSM/I scores, those from SMMR do not reflect the interannual variability of snow depth recorded at the Churchill airport weather station. As an example, winter 1982–1983 has been the snowiest of the 1980s, but its scores are almost at the same intensity as the scores recorded in 1984–1985, when snow depth measured at the Churchill airport was approximately 50% lower. Preliminary observations assume that the estimation of the dates of snow cover onset and disappearance is apparently not affected by this bias if the scores at horizontal polarisation are employed. Nevertheless, there is a perceivable sizeable shift at the vertical polarisation between the SMMR and SSM/I mean scores intensity. For the moment, we are not able to provide some explanations and this problem is currently under investigation. However, its consequence on snow cover studies can be clearly established.

Obviously, this bias is likely to affect the estimation of the dates of snow cover periods from PC2 scores insofar as the principle of the reversal of the scores sign should be maintained. Moreover, considering the superiority of the vertical polarisation for retrieving snow cover parameters, as demonstrated by research groups in Finland (Hallikainen and Jolma, 1992) and in

Canada (Goodison and Walker, 1993), this apparent bias could strongly affect snow water equivalent retrieval algorithms which include vertical polarisation.

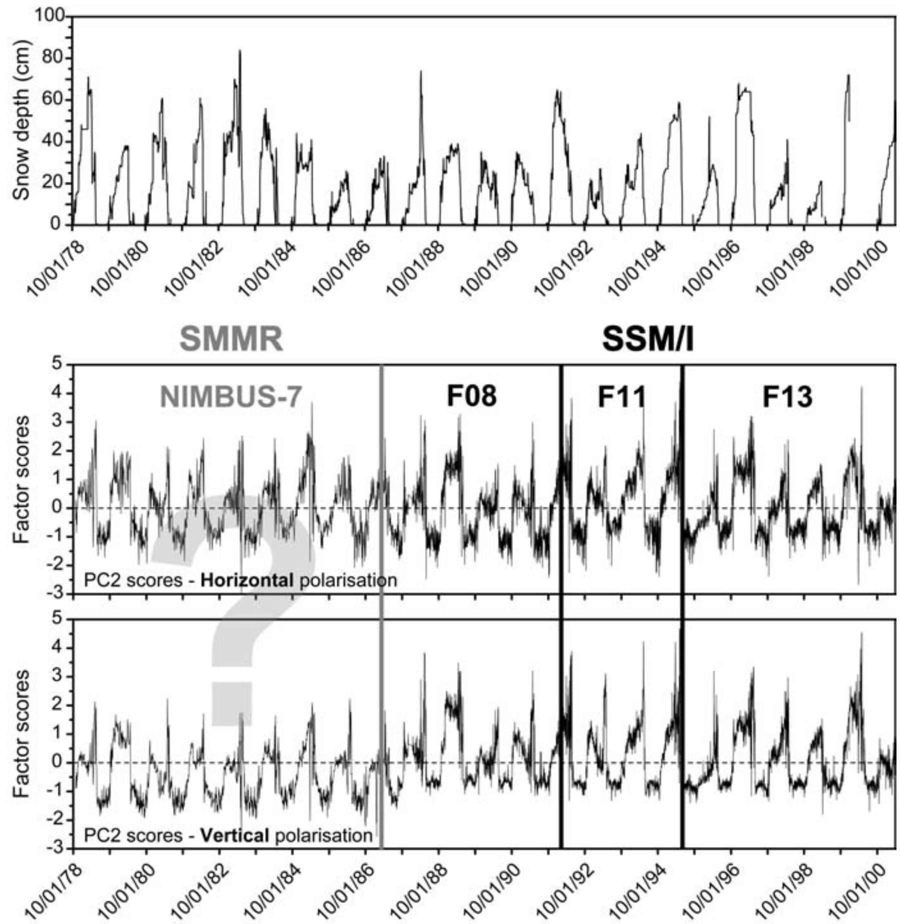

Figure 2: Interpretation of the PCA second axe based on snow depth measurements at the Churchill airport weather station and comparison between the SMMR and SSM/I PC2 daily scores, for both horizontal and vertical polarisation.

Seasonal and interannual evolution of snow cover as detected by SMMR–SSM/I (horizontal polarisation) and NOAA–AHVRR, and observed at the Churchill and Gillam airports weather stations

The dates characterising the first snow accumulation and snow cover disappearance, obtained by applying a PCA to SMMR and SSM/I daily and 5-day averaged spectral differences in horizontal polarisation (for preventing the effects related to the SMMR data bias identified above), were compared to both snow cover information derived from optical satellite imagery (NOAA–NESDIS weekly snow charts) and conventional snow cover and meteorological measurements recorded at the Churchill and Gillam airport weather stations.

In Figure 3, it appears that the passive microwave radiometers have some difficulties in estimating accurately the date of the first snow on the ground when pentads are used instead of daily observations, especially under warm and dry winter conditions, such as those that occurred during fall 1992–1993 (Figure 3a) and fall 1998–1999 (Figure 3b). Indeed, snow fall recorded during October 1992 and 1998 were 10 to 12 cm lower than the 1961–1990 normal, and snow depth never exceeded 10 cm throughout several weeks. The difference between the dates of snow cover onset, derived from daily data or pentads by the way of PCA, is considerable and exceeds 4 weeks (see shadow boxes in Figures 3a and 3b).

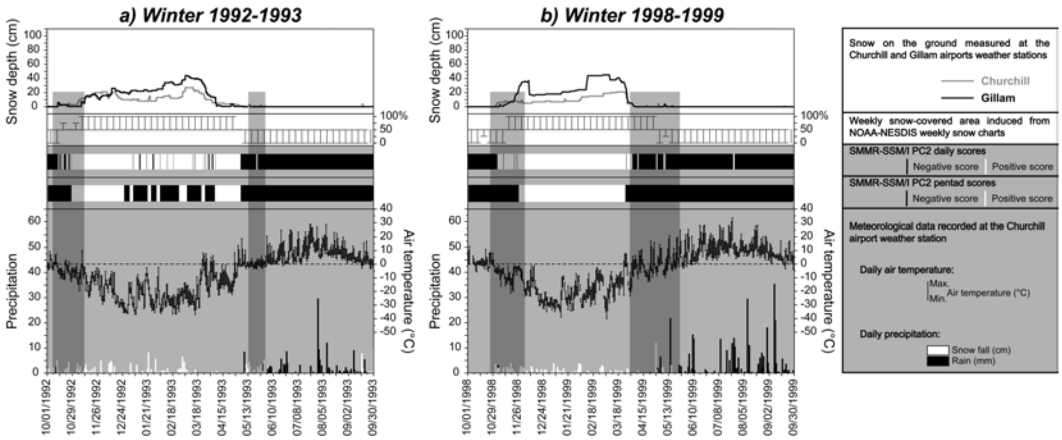

Figure 3: Comparison between multi-source data acquired for two warm and dry winters (a – 1992–1993 and b – 1998–1999) illustrating the loss of information related to the use of pentad instead of daily passive microwave data in PCA.

This temporal shift can be explained as follows. Microwaves naturally penetrate shallow dry snow covers and thus are practically not scattered by the snow particles. At that time, the presence of snow is difficult to detect as the signal recorded by the spacecraft sensors mainly comes from the underlying ground that radiometrically appears “warmer” than dry snow (Bernier, 1987; Rango, 1993). Therefore, in the dry and shallow snow cover situation prevailing in October 1992 and 1998, the passive microwave signature of each cell contained in our study area was almost identical to the signature of snow-free surfaces so that the spectral differences values closely reached 0K. Furthermore, during the early part of the 1992–1993 snow-cover period, strong fluctuations of air temperature were observed so that the diurnal air temperature rose above 0°C on several occasions (Figure 3a). The daily fluctuations of the PC2 scores, either positive else negative, are associated with variations in air temperature and the state of snow cover (*i.e.* succession of thawing–freezing events). By computing the mean spectral differences over pentads, a significant part of the information related to the daily variability of the state of snow cover is definitely smoothed and lost. For each pentad, the averaged spectral difference values thus closely reach 0K and are inferred on the PCA output as continuous snow-free periods. For the same reasons, this problem can also occur in spring, especially when snow decay is well underway and snow cover remains thin and wet. Snow depth recorded as a trace over a more or less long period and late snowfall succeeding the whole disappearance of winter snow cover (see the shadow box on Figure 3b) can be misinterpreted as snow-free periods as well.

As they were more consistent, we only retained, in Figure 4, the dates of the first appearance of snow and its definitive disappearance inferred from the daily PC2 scores, in order to compare them with the dates derived from the NOAA–NESDIS weekly snow charts and snow information obtained from ground weather stations. Note that for the Churchill and Gillam snow information, we reported in Figure 4 both the dates of onset and ending of snow covers, established through much of the winter season over a continuous period and the time period characterised by snow traces or non-persistent snow accumulations.

The preliminary results show that SMMR and SMM/I data can efficiently compensate for the deficiencies of visible-NIR imagery in estimating the dates of snow cover appearance or disappearance, especially when cloud cover remains over the study area for long periods due to the presence of large atmospheric disturbances which prevents the detection of snow cover for extended periods. This characteristic situation is usually observed in autumn, during the first snow fall events (*e.g.* 1987–1988, 1990–1991, 1993–1994 and 1994–1995). As an example, the estimation of the date of snow cover appearance in October 1993 can be improved by 15 days when retaining the date given by passive microwave data, which moreover perfectly agrees with ground observations.

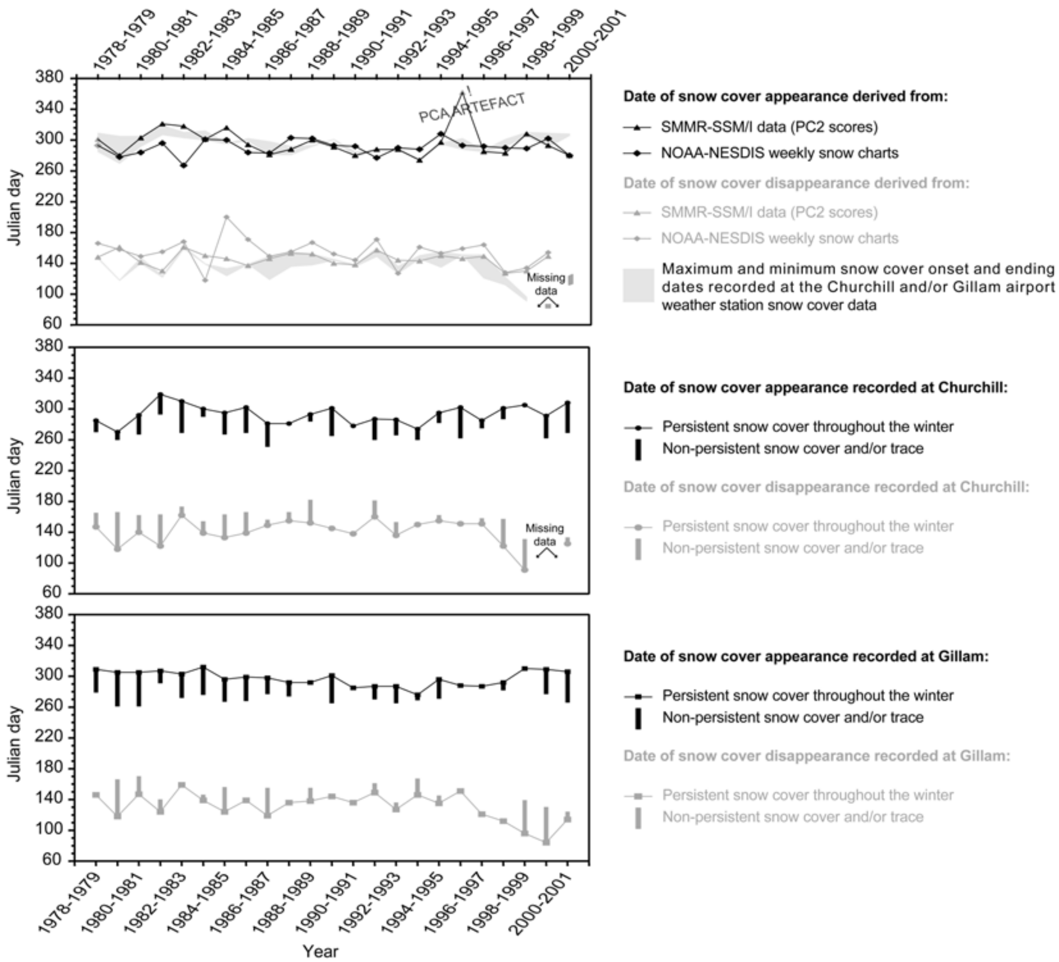

Figure 4: Comparison between the dates of onset and disappearance of snow cover derived from the SMMR–SMM/I data and NOAA–NESDIS weekly snow charts and observed at the Churchill and Gillam airport weather stations.

The results inversely demonstrate the need to improve snow cover duration estimates derived from passive microwave data by adding information from optical sensors, if one is interested in identifying the occurrence of trace of snow on the ground (small amount of snow usually below 1 cm) and periods characterised by non-persistent snow accumulations during the transition seasons, such as autumn and spring. The moisture, radiative, and heat fluxes between the atmosphere and the ground can be strongly affected by small amounts of snow or intermittent snow-covered periods so that it is highly recommended to accurately identify the occurrence of such events. As and example, NOAA–NESDIS weekly snow charts appeared to be very suitable in assessing the presence of a discontinuous snow cover during the 1982, 1989 and 1992 springs, at last improving the snow cover duration estimations for these snow season periods.

Finally, two biased situations can be highlighted in Figure 4. The first contributes in strongly underestimating the date of snow cover onset in autumn 1995 (around 8–10 weeks later) and was clearly identified as a mathematical artefact generated by the PCA which origin is currently under investigation. The second tends to overestimate by about 5–6 weeks the date of snow disappearance during the summer 1985 and was probably produced by a misidentification of the presence of snow on the ground on date of 07/19 that might have inadvertently been confused with that of clouds.

CONCLUSION

Since 1995, the NOAA–NESDIS supports the development and implementation of prototypes for daily automated snow mapping systems based on a wide variety of satellite and surface observations, such as the Interactive Multisensor snow and ice mapping System (IMS), which should definitely replace the current weekly snow charts product (Ramsay, 1998). More recently, Romanov *et al.* (2000) developed a similar interactive application enabling the computerised extraction of snow information on a global scale using both the SSM/I passive microwave imagery and optical and thermal sensors onboard Geostationary Operational Environmental Satellite (GOES). The improvement of these applications is essential for an accurate and operational snow cover monitoring. However, the success of such systems largely depends on the way the multi-sensor satellite data are precisely translated into snow information.

Using a Principal Component Analysis applied to SMMR and SSM/I time series (daily and pentads) over a 23-year period (1978–2001), we were able to evaluate the sensitivity of passive microwave data in describing the seasonal cycle and the interannual variability of snow cover conditions in the Canadian Subarctic (northern Manitoba). The PC2 scores derived from the passive microwave data set captured well the beginning and ending of the snow season, merely when daily data were used as input. Indeed, we demonstrated that although pentads are commonly used in the processing of passive microwave time series, there can be a loss of information as opposed to daily data, especially under warm and dry winter conditions.

It has been clearly demonstrated that the Nimbus-7 SMMR Pathfinder Daily EASE-Grid Brightness Temperatures are biased, especially in vertical polarisation. The long time series of passive microwave data collected since the end of 70s provide an unprecedented opportunity for monitoring the seasonal and the interannual variability of snow-cover parameters of relevance to climate change in northern Canada. Consequently, this bias needs to be studied thoroughly in further investigations because of its immediate repercussion on snow water equivalent retrieval algorithms applied to SMMR data.

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