The Canadian Meteorological Centre Global Daily Snow Depth Analysis, 1998-2011: Overview, Experience and Applications

ROSS BROWN[1] AND BRUCE BRASNETT[2]

EXTENDED ABSTRACT OF POSTER

Keywords: snow depth, global, analysis, optimal interpolation

DESCRIPTION

The Canadian Meteorological Centre (CMC) global daily snow depth analysis has been produced in a more-or-less consistent fashion since March 1998. The analysis uses all available real-time snow depth reports (i.e. synoptic reports, meteorological aviation reports and special aviation reports on the WMO information system) and is updated every 6 hours using the method of optimum interpolation following Brasnett (1999). The error correlations used in analysis have e-folding distances of about 120 km horizontally and 800 m vertically; and the vertical correlation is taken into account in the interpolation of screen-temperatures to the 1/3º grid used in the analysis.

The initial guess field is provided by a simple snow accumulation and melt model using analyzed temperatures and forecast (6 hour) precipitation from the CMC global forecast model GEM. The precipitation is assumed to be snow if the analyzed screen-level temperature is < 0°C. A degree-day melting algorithm removes mass from the snowpack at the rate of 0.15 mm.h^{-1}°.K^{-1}. A flowchart of the production process is provided in Figure 1.

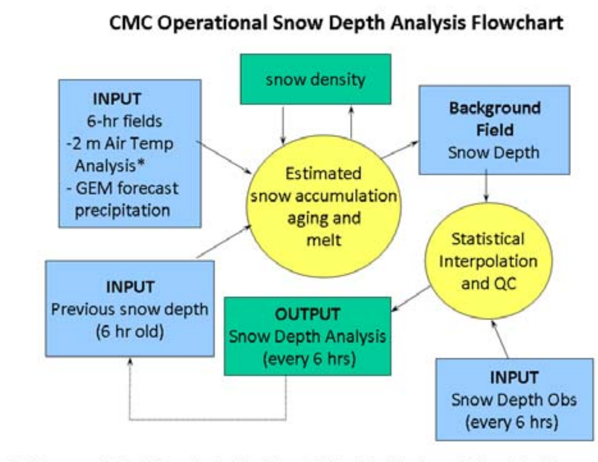

Figure 1. Flowchart of CMC operational daily snow depth analysis process.

[1]Climate Research Division, Environment Canada (ross.brown@ec.gc.ca)
[2] National Prediction Development Division, Environment Canada (bruce.brasnett@ec.gc.ca)

The analysis also includes an estimate of the density of the snowpack. The density of new snow is assumed to be 100 $kg.m^{-3}$ and the snowpack gradually increases in density as it ages. The increase in density with aging stops when the density reaches 300 $kg.m^{-3}$ (except 210 $kg.m^{-3}$ if the vegetation is needleleaf forest, since in these regions the canopy shelters the snowpack from wind and sunlight and densities are less). New snow causes the density to decrease by an amount related to the mass of the new snow and the mass of the existing snowpack. During melting, the density is allowed to increase up to a maximum value of 550 $kg.m^{-3}$.

In data sparse regions the snow depth analysis is generated entirely by the background field with consequently more potential to be affected by changes in the forecast model. There are two known changes that may affect the homogeneity of the background field particularly in high accumulation environments such as Greenland and some locations in the Rocky Mountains: (1) the resolution of the GEM forecast model changed from ~100 km to ~35 km in October 2006; (2) the maximum snow depth limit was changed from 600 cm to 1200 cm in October 2008 to provide more realistic spring and summer snow cover in mountain regions. The analysis is not considered reliable in these regions. In Arctic regions the analysis has been shown to melt snow too quickly in the spring (Brown et al., 2010). Part of this problem is attributed to unrepresentative snow depth observations made at open areas where snow melts out earlier than the surrounding terrain.

Offline runs of the analysis have been made since October 2006 to maintain data homogeneity (a bug was introduced in the operational implementation of the analysis at that time). A Northern Hemisphere subset of the analysis interpolated to a 24-km polar stereographic grid (the same grid as the NOAA IMS 24-km product) is archived at NSIDC and updated annually (http://nsidc.org/data/nsidc-0447.html). The NSIDC dataset includes monthly SWE values estimated from mean snow depth using a density look-up table derived from snow course observations for Sturm et al. (1995) snow-climate classes (Brown and Mote, 2009). An 18-year historical analysis of daily snow depth and estimated SWE over North America for the AMIP2 period (1979-1997) was generated following the same analysis methodology (Brown et al., 2003).

ISSUES

Some of the issues that need to be taken into consideration when using the analysis are the variable distribution of surface observations in space and time (Fig. 2), unrepresentative point snow depth observations (Fig. 3) and increasing automation of in situ snow depth observations.

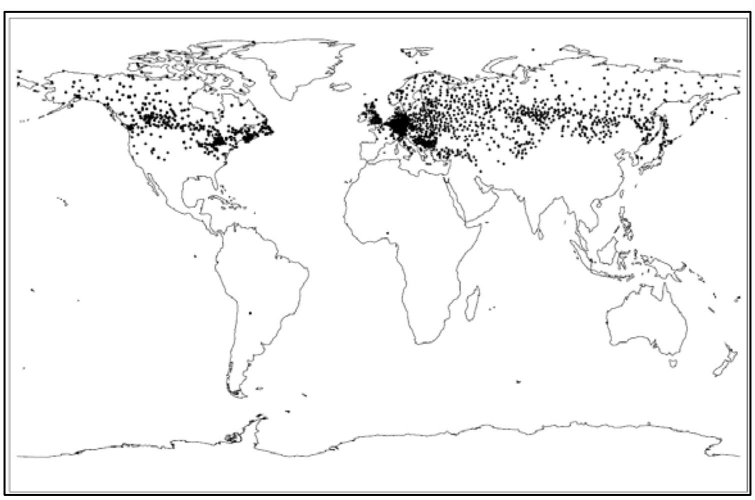

Figure 2: Example of the spatial distribution of real-time snow depth observations for Feb. 7, 2007. China does not report snow depth observations in real-time. Note sparse data coverage over northern Canada and Russia.

In Canada, more than half the snow depth observations reported in real-time are made from autostations equipped with ultrasonic depth sensors. Experience has shown that a number of autostations consistently fail the QC checks applied as part of the analysis process (consistency with neighboring station and consistency with changes in the background field from the previous analysis). A particularly noticeable problem at some prairie and northern locations is almost unvarying snow depths over the snow season that creates large anomalies if these observations are left in the analysis (Fig. 4). Subsequent verification of conditions at some of these sites revealed that the sensors were reporting snow depths correctly but were located in exposed areas where most of the new snowfall was removed by wind action.

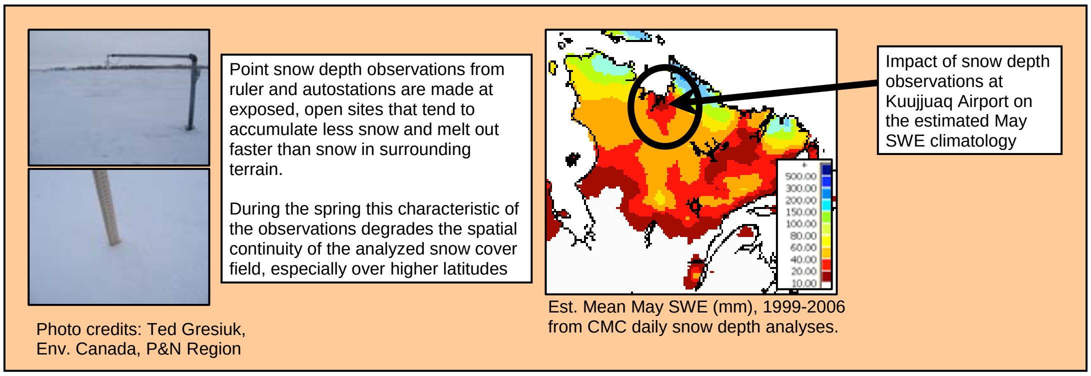

Figure 3. Impact of point snow depth observations made at open sites on the spatial continuity of analysed snow cover.

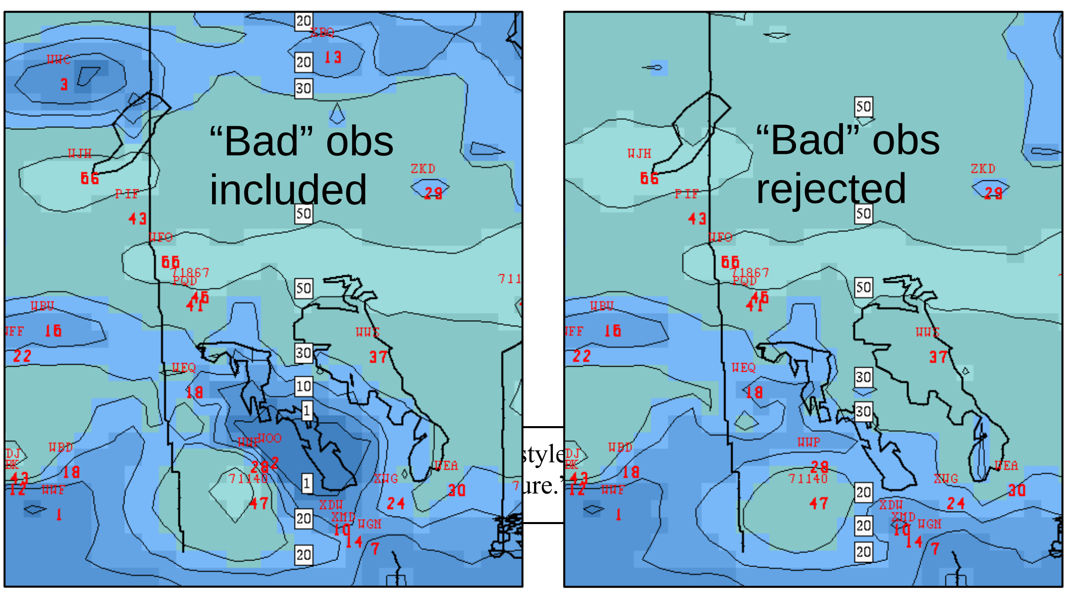

Figure 4. Impact of removing “suspect” autostation observations from the snow depth analysis of Feb. 17, 2007. The autostations were consistently reporting low snow depth values that contributed to large anomalies over the northern domain and south central areas in the left panel.

EXAMPLES OF APPLICATIONS

The historical archive of CMC daily analyses has been used in a number of applications including multi-dataset estimates of Arctic and NH snow cover change (e.g. Brown et al., 2010; Brown and Robinson, 2011; Derksen et al., 2010), the evaluation of climate models (e.g. Brown and Mote, 2009), and verification of satellite-derived snow cover products (e.g. Luojus et al., 2010).

REFERENCES

Brasnett B. 1999. A global analysis of snow depth for numerical weather prediction, *J. Appl. Meteorol.* **38**: 726−740.

Brown RD, Brasnett B, and Robinson D. 2003. Gridded North American monthly snow depth and snow water equivalent for GCM evaluation. *Atmosphere-Ocean* **41**: 1−14.

Brown RD, and Mote P. 2009. The response of Northern Hemisphere snow cover to a changing climate. *J. Climate* **22**: 2124–2145.

Brown R, Derksen C, and Wang L. 2010. A multi-data set analysis of variability and change in Arctic spring snow cover extent, 1967–2008. *J. Geophys. Res*. **115**: D16111, doi:10.1029/2010JD013975.

Brown RD, and Robinson DA. 2011. Northern Hemisphere spring snow cover variability and change over 1922–2010 including an assessment of uncertainty. *The Cryosphere* **5**: 219−229, doi:10.5194/tc-5-219-2011.

Derksen C, Brown R, and Wang L. 2010. Arctic—Terrestrial Snow [in *State of the Climate in 2009*]. *Bull. Amer. Meteor. Soc*. **91**: s1–s222. doi: 10.1175/BAMS-91-7-StateoftheClimate.

Luojus K, Pulliainen J, Takala M, Lemmetyinen J, Derksen C, and Wang L. 2010. GLOBSNOW: Global Snow Monitoring for Climate Research—Snow Water Equivalent (SWE) product guide. http://www.globsnow.info/swe/GlobSnow_SWE_product_readme_v1.0a.pdf.

Sturm M, Holmgren J, and Liston GE. 1995. A seasonal snow cover classification system for local to global applications. *J. Climate* **8**: 1261−1283.