Using satellite-derived snow cover data to implement a snow analysis in the Met Office global NWP model

Samantha Pullen, Gabriel Rooney, Clive Jones

Workshop on Cold Regions Hydrology, Innsbruck, 28-30 April 2010
Contents

• Motivation
• Satellite data
• Snow analysis scheme – 2 phase approach
  • Basic scheme
  • Upgraded scheme
• Assimilation experiments
• Summary
Motivation

Met Office NWP model contained freely evolving snow amounts

- Not enough
- Too much variability
- Early snowmelt

- Improve snow analysis
- Improve forecasts of screen level variables
- Enable use of more satellite soundings over land – potential large impacts for atmospheric forecasts
Satellite data

NESDIS Interactive Multisensor Snow and Ice Mapping System (IMS)

- GEO, LEO (GOES, Meteosat, MTSAT, AVHRR, MODIS, SSM/I, AMSU)
- Derived products (e.g. USAF Snow and Ice Analysis Product)
- In situ data
- Analyst

- Daily, 4km resolution, NH
- Polar stereographic 6144 X 6144
- Snow cover (0 or 100), ice (0 or 1)
- Received in Met Office since Nov 2006
The snow analysis scheme
Phase 1

- IMS snow cover is binary but model variable is snow amount, or areal density, (kgm$^{-2}$)
- Average IMS snow cover onto UM grid to create fractional cover
- Use short f/c from previous cycle as background
- Compare presence of snow in fractional cover and background and update the model where they disagree
- To add snow, relate fractional cover to areal density using:

\[
S = \frac{-\log_e (1 - f_c)}{D}
\]

up to max of 10.0 kgm$^{-2}$

- Carried out at 0600 UTC daily
- Implemented operationally in November 2008

*S* = snow areal density  
*D* = masking depth of vegetation (0.2m$^2$kg$^{-1}$)  
*f*c = fractional snow cover

Used successfully by Romonov et al. (2003)
The snow analysis scheme
Phase 1

Observations

Frac cover = 0

Background

UM snow > 0

Analysis

Analysed snow = 0

Analysed snow = UM snow

Frac cover > 0

UM snow = 0
Two improvements made to basic snow analysis:

1. Correct a bug that prevented snow being added to all relevant model points

2. Mitigate effects of time delay in IMS data
   - IMS snow product comprises data up to 36 hours old
   - Genuine snowfall events may be removed by the snow analysis as the IMS data has not yet recorded the snowfall.
   - Use previous day’s background snow as additional constraint in cases of snow removal. Where the model forecasts a snowfall event well, IMS data may compare better with the previous day's background than the current one, in which case we can assume the model evolution is correct and make no change in the analysis.
IMS data time lag

29-11-06

30-11-06

01-12-06

02-12-06
The snow analysis scheme
Phase 2

Observations

Frac cover = 0

Frac cover > 0

Background

(UM snow)_{day-1} > 0

(UM snow)_{day-1} = 0

Analysis

Analysed snow = 0

Analysed snow = UM snow

UM snow > 0

UM snow = 0

© Crown copyright   Met Office
Assimilation experiments

Phase 1: Implementing the snow analysis

• NH winter season, 1 month, Dec 2006
• NH spring season, 3 months, March-May 2007
• Control contains no snow analysis

Neutral impact on f/c RMSE scores

Phase 2: Upgrading the snow analysis

• NH winter season, 1 month, Dec/Jan 2009/10
• NH spring season, 1 month, April 2009
• Control contains basic (phase 1) snow analysis

Neutral impact on f/c RMSE scores
(-0.2% winter)
Behaviour of the snow analysis

Snow removed

Frequency of snow removals in December 2006

Snow added

Frequency of snow additions in December 2006

Winter

Spring

Frequency of snow removals in April 2007

Frequency of snow additions in April 2007
Winter season trial (Dec06)

15-12-06

Sierra Nevadas

Great Lakes

© Crown copyright   Met Office
Spring season trial (MAM07)

20-04-07

Removal over Central Asia

Large-scale additions of snow over US, Canada and Eastern Europe

Analysis replaces snow that has been melted too early
Spring season trial (Apr 09)
(snow analysis upgrade)

Much more snow addition in upgraded analysis

Model snow line extended by large-scale additions of snow over N America and Russia
Snow analysis 30/11/06

30th T+3

29th T+3

Old

New

Background (unmodified) snow amount

Observed fractional snow cover

Snow Depth
3000-11-06 00
Presence of snow verified against SYNOP obs

Snow analysis vs no snow analysis

Upgraded snow analysis vs basic snow analysis
Surface field verification

• Most changes small, especially for spring trial
• Surface or low level T generally improved
• Winter trial surface RH improved for Europe (mainly snow removal) and above surface improved for N America (mainly snow addition)
• Most consistent improvements in winter trial for Europe
• Small improvement in snow amount forecasts in winter trial for Europe
• Where snow is mainly added results are less positive
Summary

• The Northern Hemisphere snow analysis has been operational in the Met Office’s global NWP model since November 2008.

• There is clear evidence that the snow analysis improves the analysed snow field, in terms of presence/non-presence of snow

• There is some evidence of improvements in surface/low level T and RH, especially where snow is predominantly removed by the analysis.

• Little of the information introduced by the analysis is retained in subsequent forecasts, especially where snow has been added.

• An upgrade to the snow analysis, to mitigate the effects of time delays in the IMS data, is due to be implemented operationally in July.

• A new multilayer snow physics scheme will soon be implemented, which may help with snow retention
Questions and answers