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

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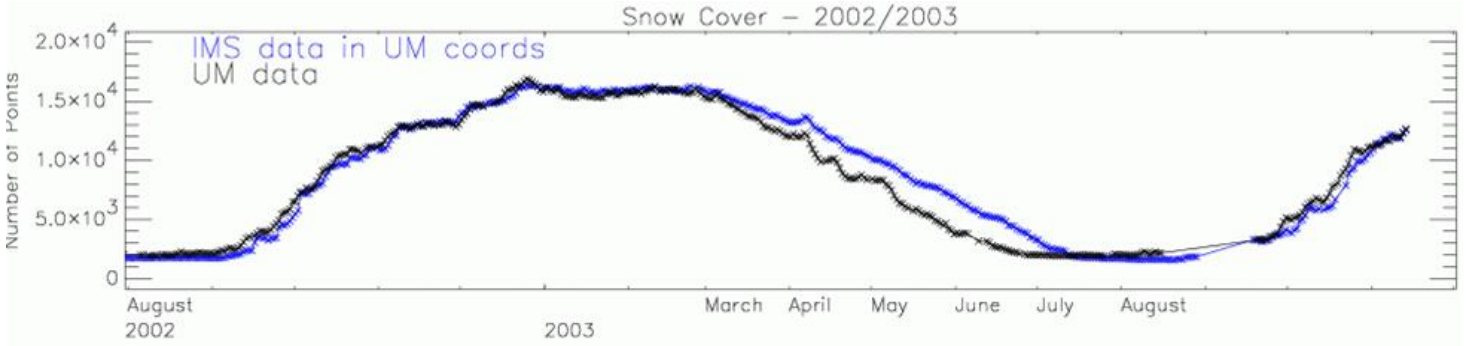
Motivation

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

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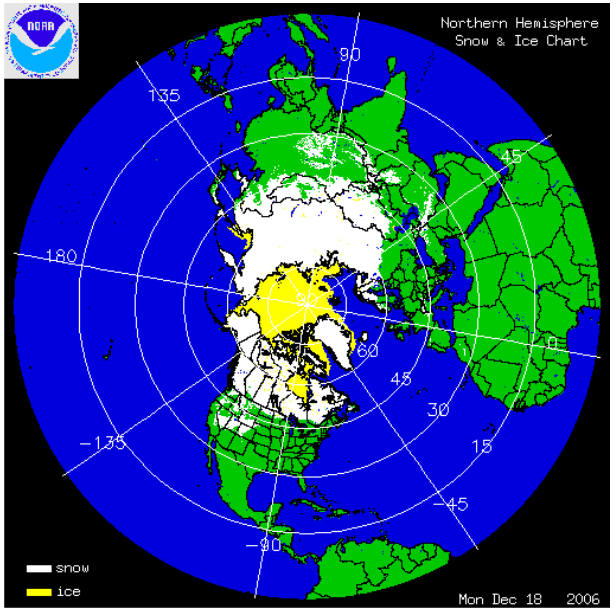
Satellite data

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

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

Used successfully by Romonov et al. (2003)

$$S = (- log_e (1 - f_c)) / D$$

up to max of 10.0 kgm^{-2}

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

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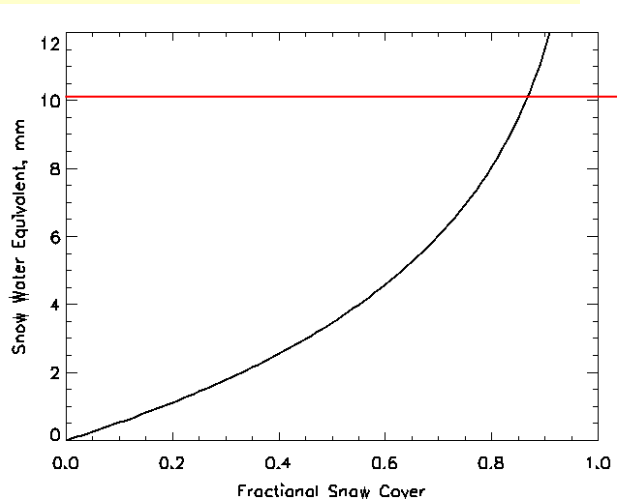
The snow analysis scheme

Phase 1

Observations	Background	Analysis
Frac cover = 0		Analysed snow = 0
Frac cover > 0	UM snow > 0	Analysed snow = UM snow
	UM snow = 0	



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Upgrade to the snow analysis
Phase 2

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.

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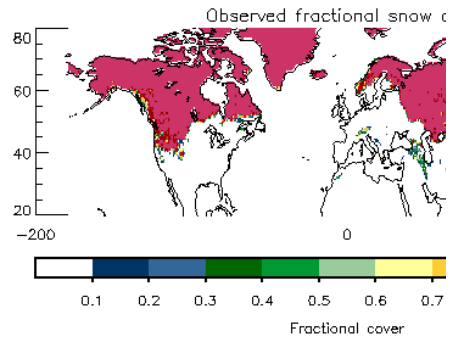
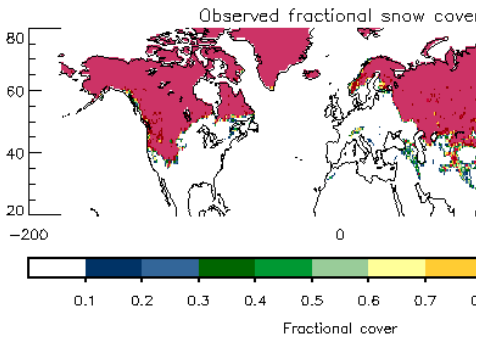
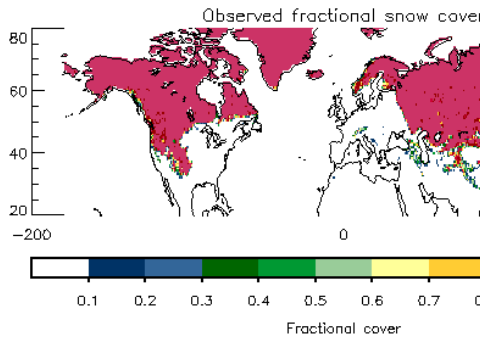
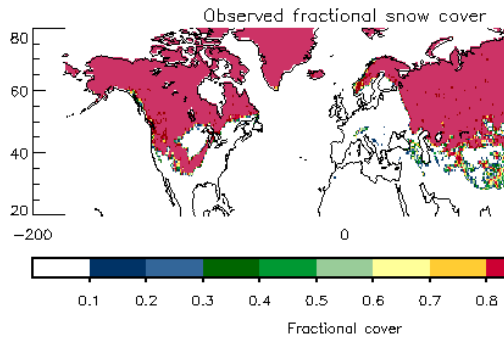
IMS data time lag

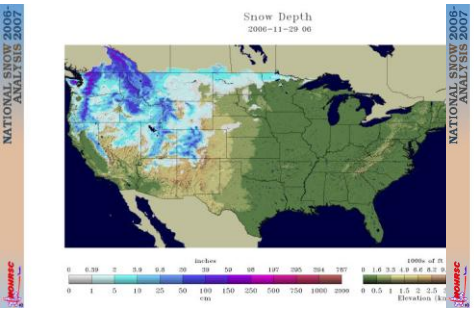


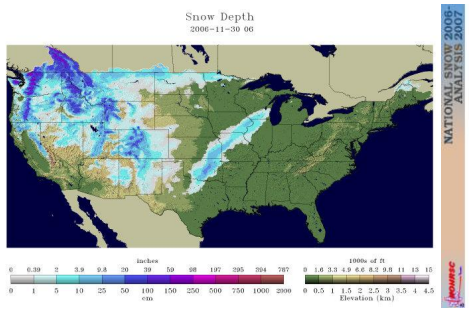


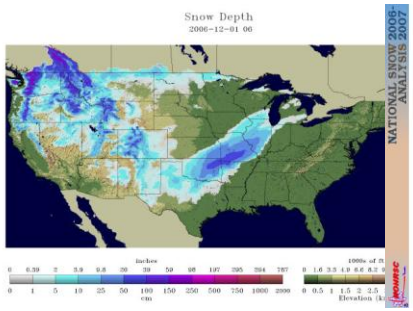


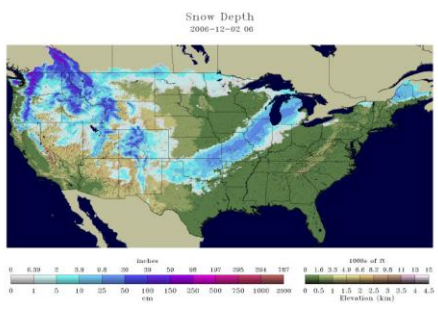


29-11-06 30-11-06 01-12-06 02-12-06









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The snow analysis scheme
Phase 2

Observations | Background | Analysis

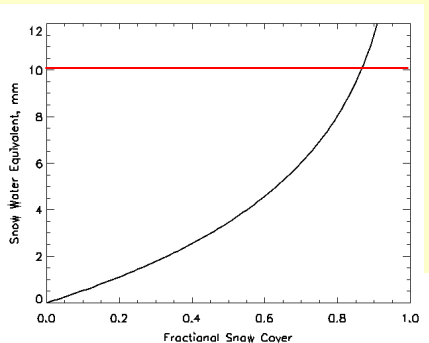
Frac cover = 0

(UM snow)$^{day-1}$ > 0 → Analysed snow = 0

(UM snow)$^{day-1}$ = 0 → Analysed snow = UM snow

Frac cover > 0

UM snow > 0 → Analysed snow = UM snow

UM snow = 0 → 

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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)

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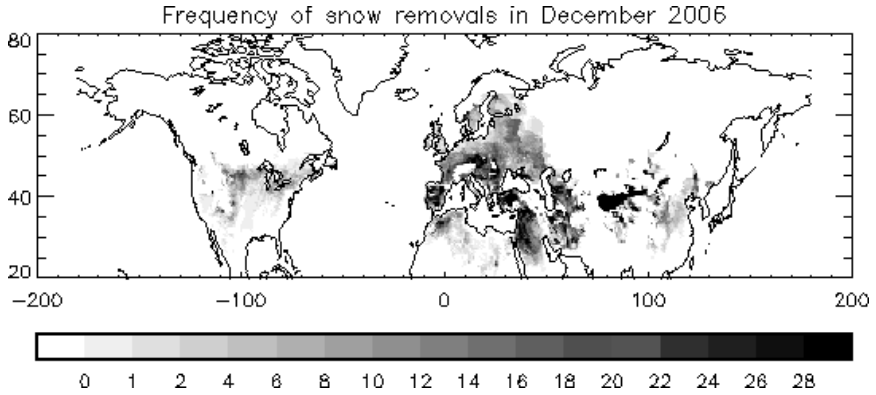
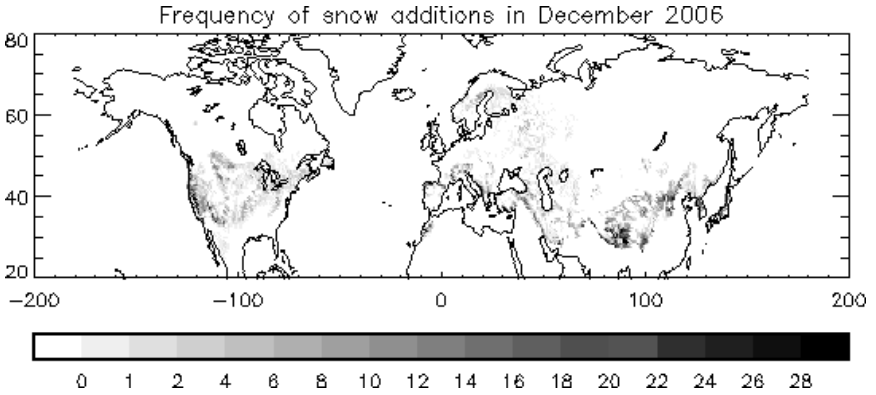
Behaviour of the snow analysis

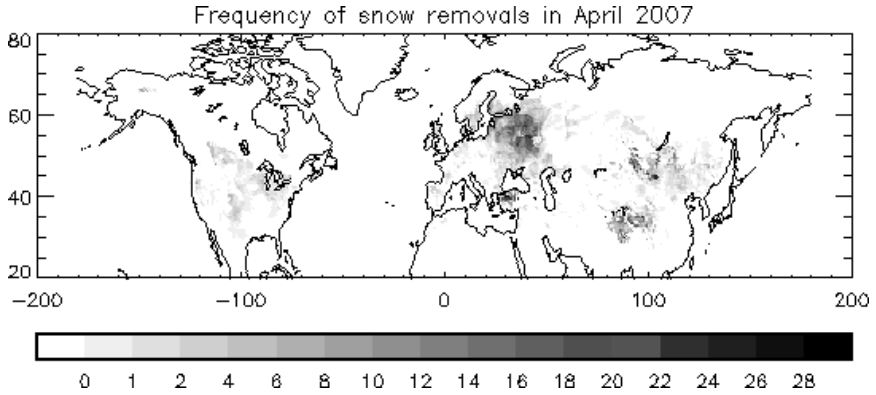
Snow removed

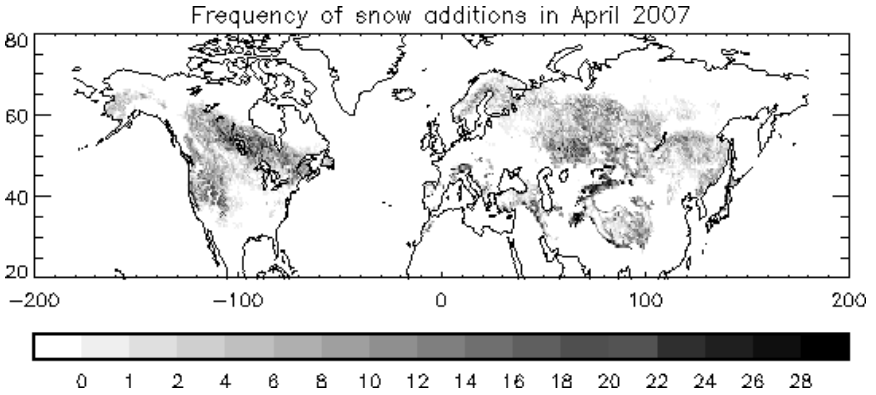


Snow added



Winter





Spring

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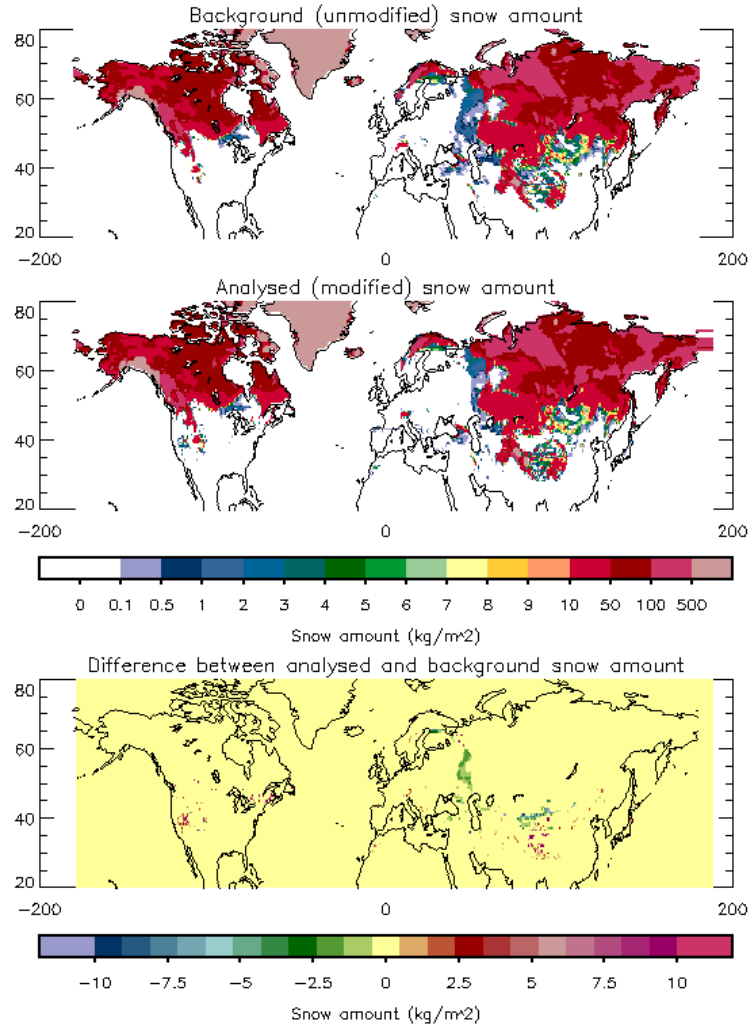
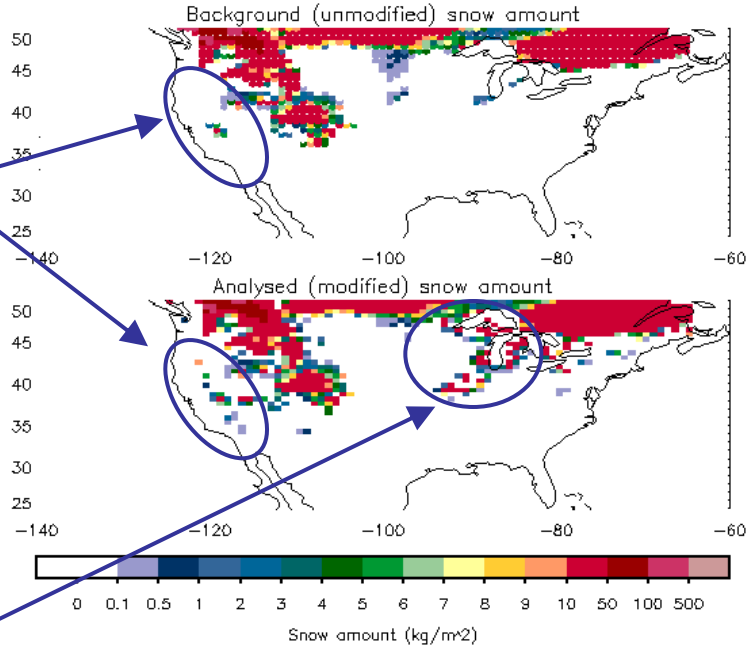
Winter season trial (Dec06)

15-12-06

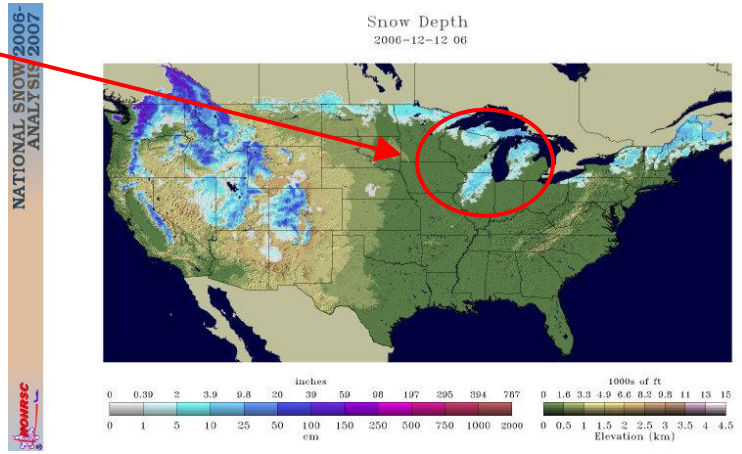


12-12-06

Sierra Nevadas



Great Lakes



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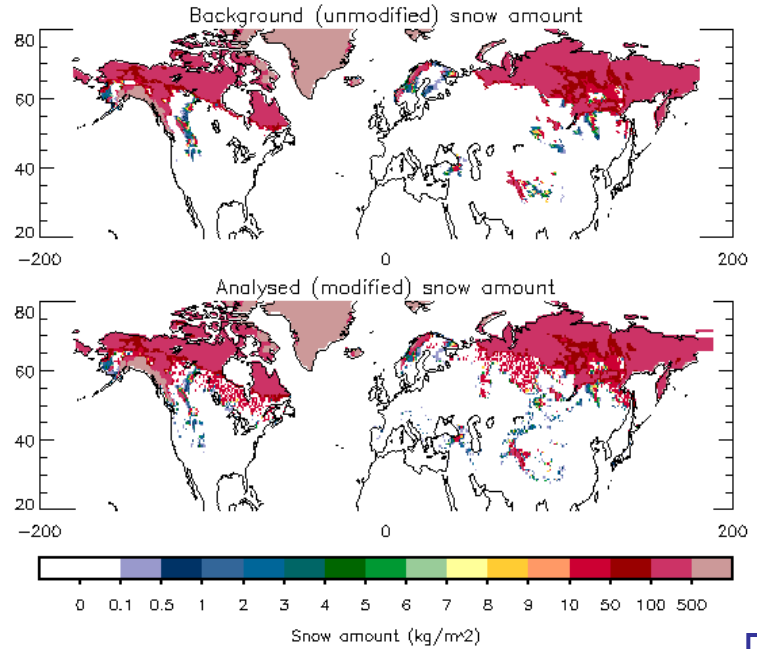
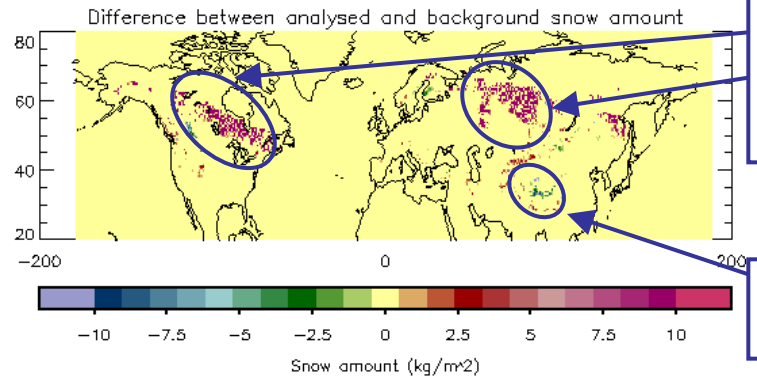
Spring season trial (MAM07)

Met Office

20-04-07



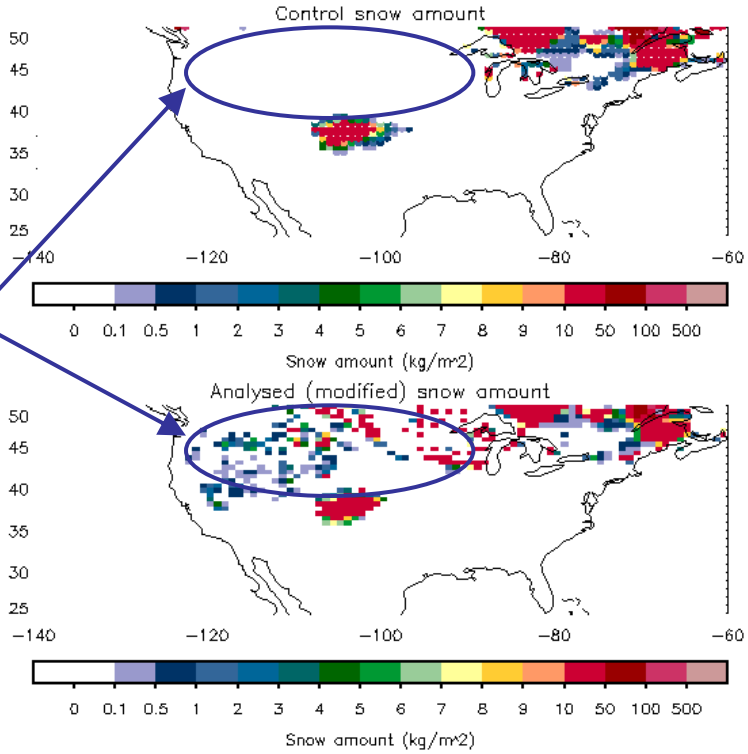


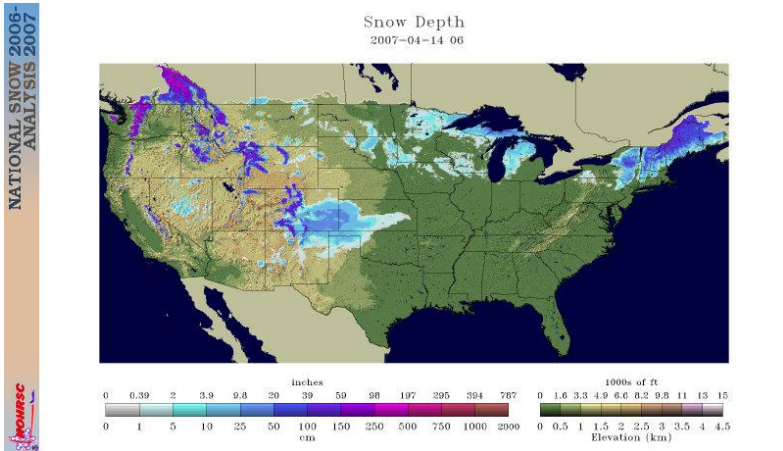
Analysis replaces snow that has been melted too early

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

Removal over Central Asia

14-04-07





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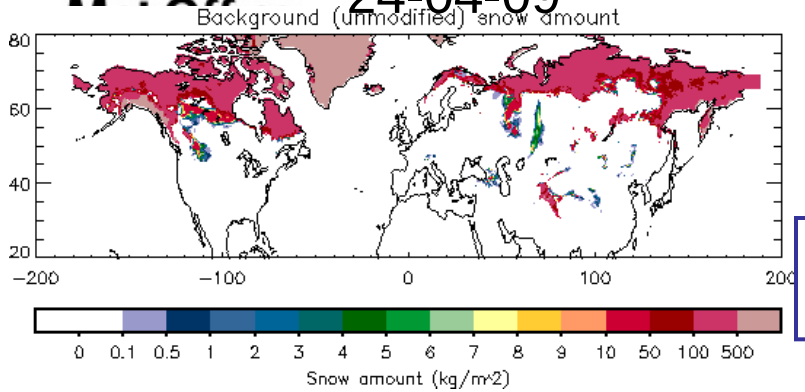
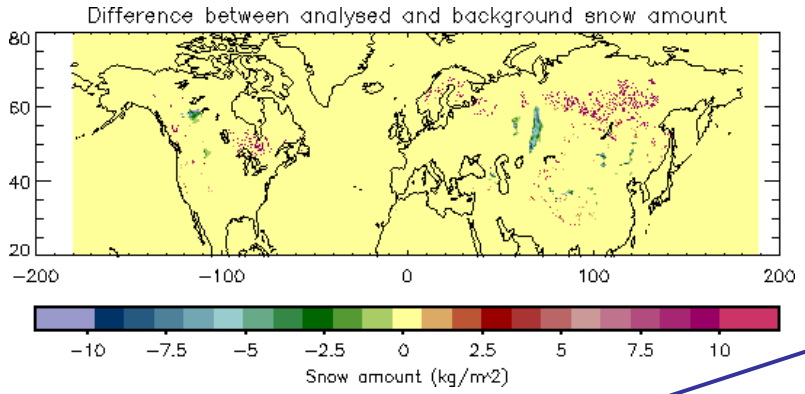
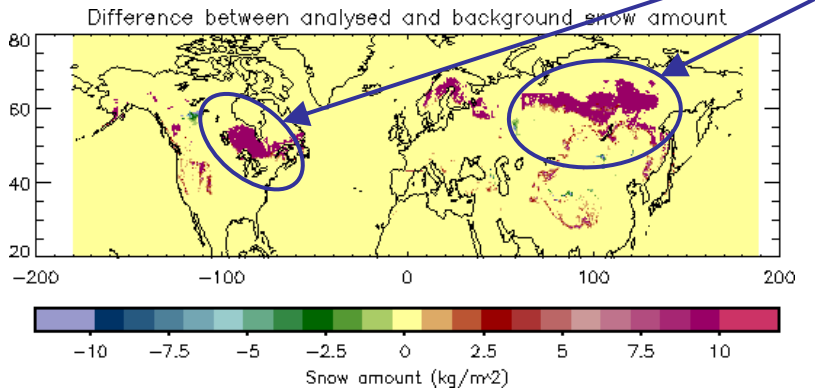
Spring season trial (Apr 09)
(snow analysis upgrade)

24-04-09



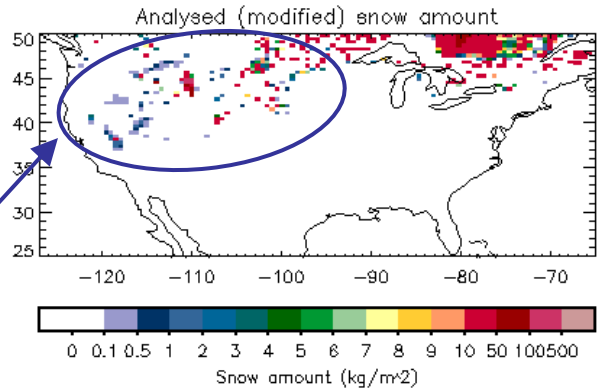


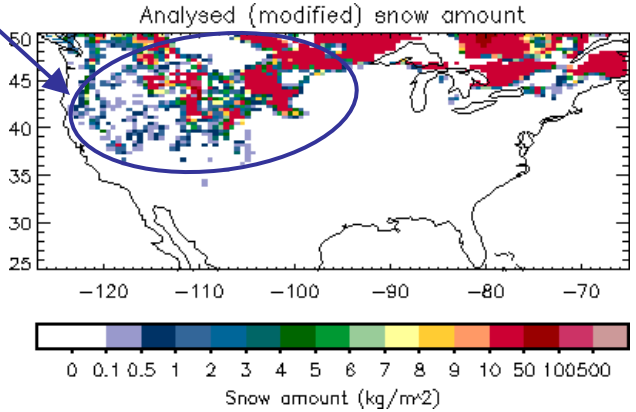


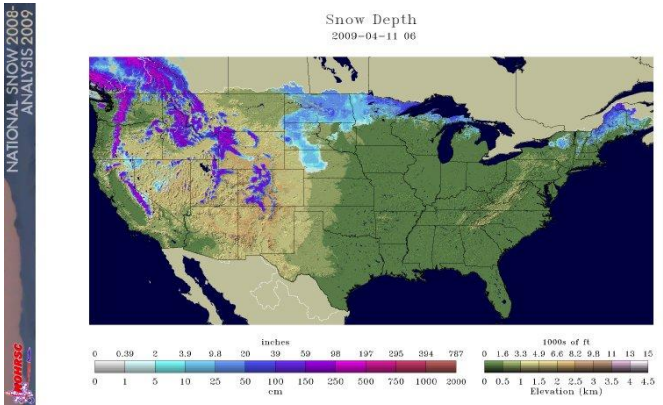
Much more snow addition in upgraded analysis

Model snow line extended by large-scale additions of snow over N America and Russia

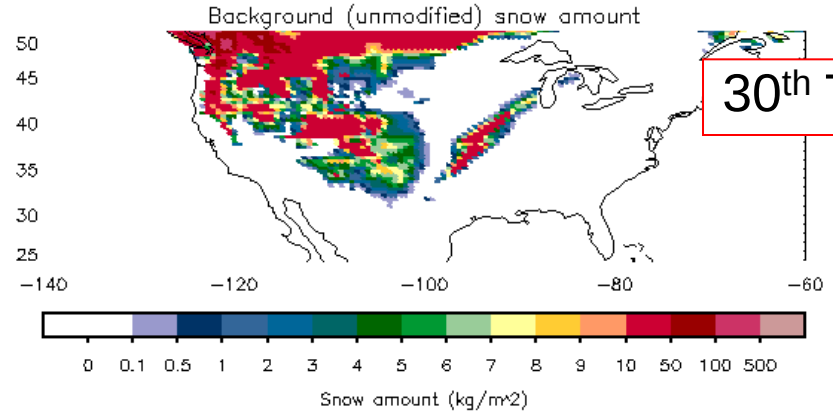
11-04-09



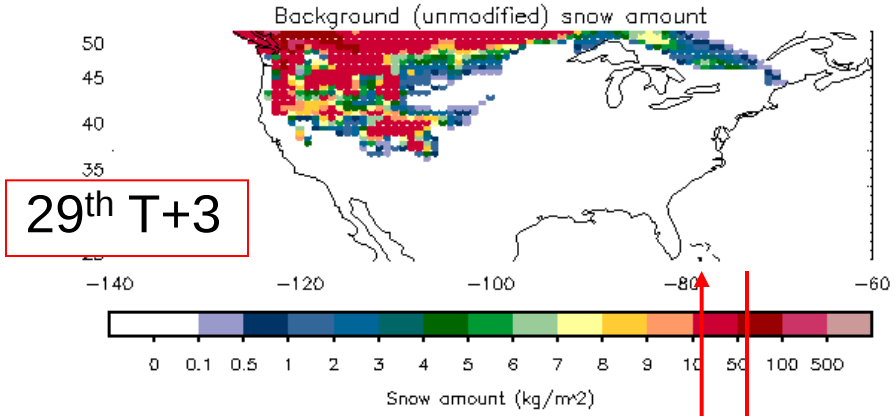




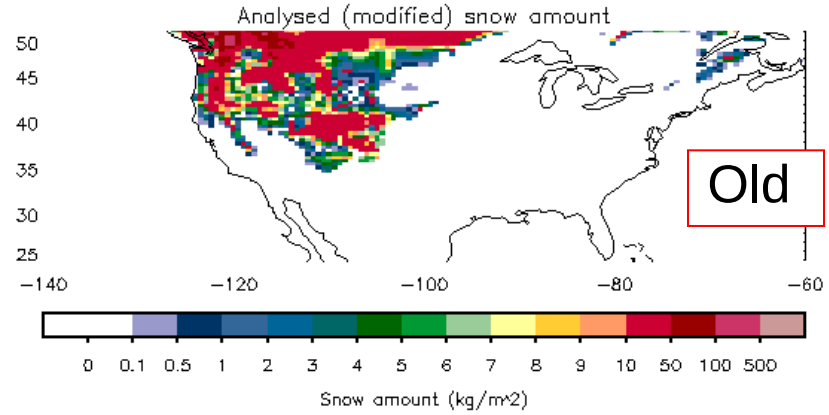
Snow analysis 30/11/06



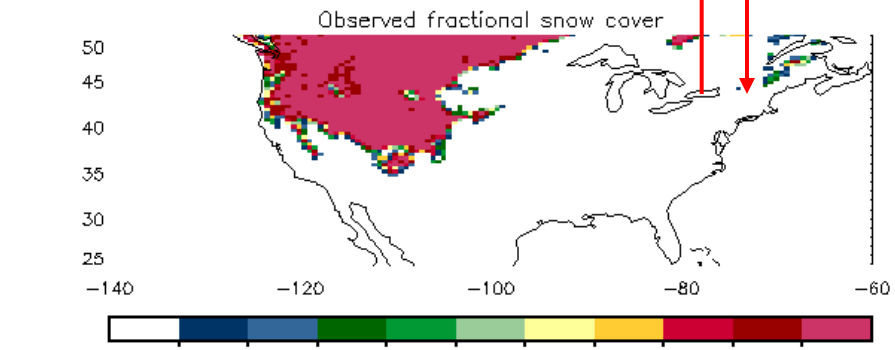
30th T+3

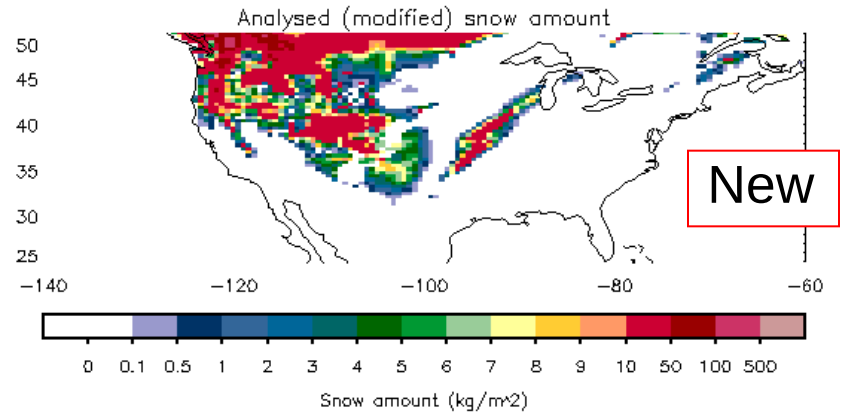


29th T+3

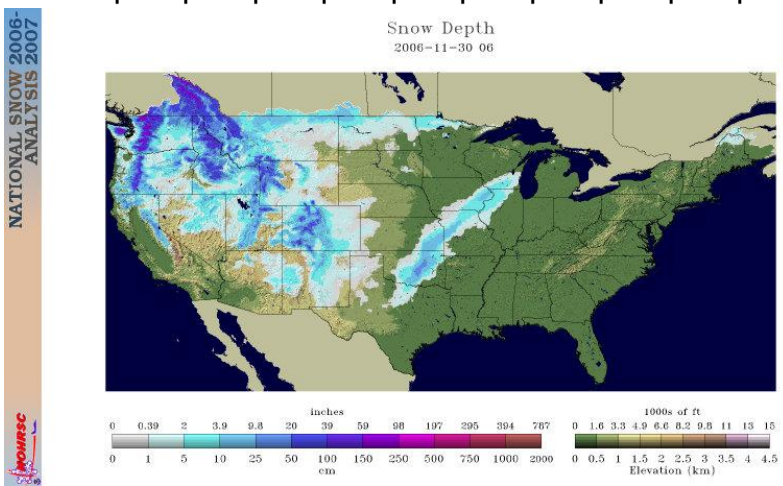


Old



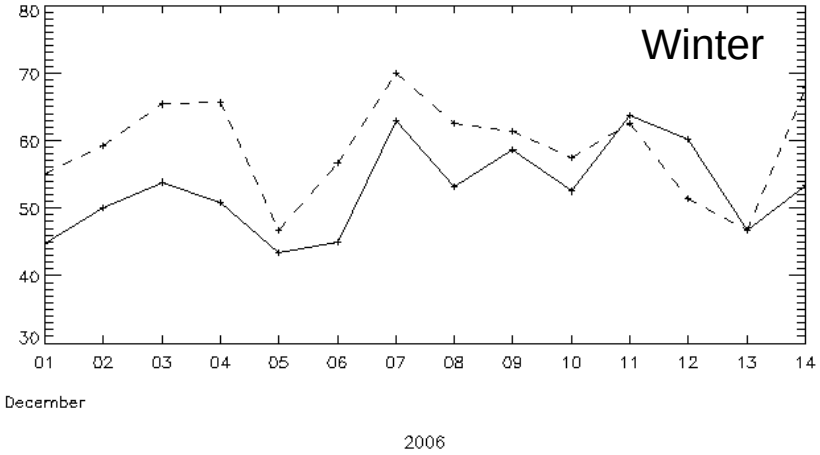


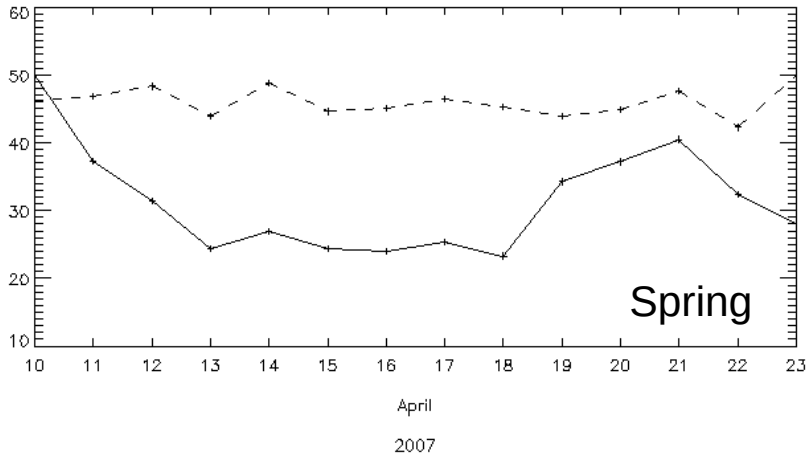
New



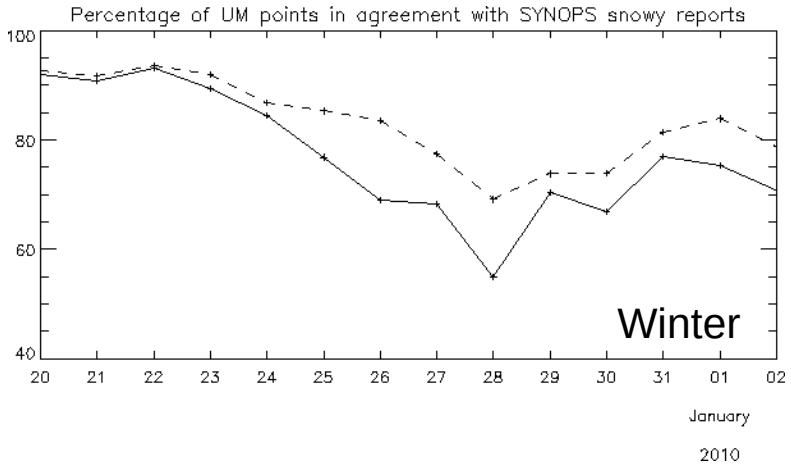
Presence of snow verified against SYNOP obs

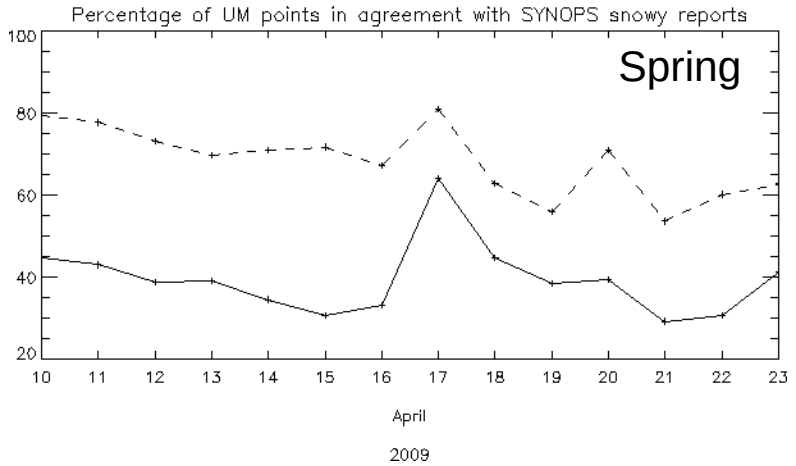
Snow analysis vs no snow analysis





Upgraded snow analysis vs basic snow analysis





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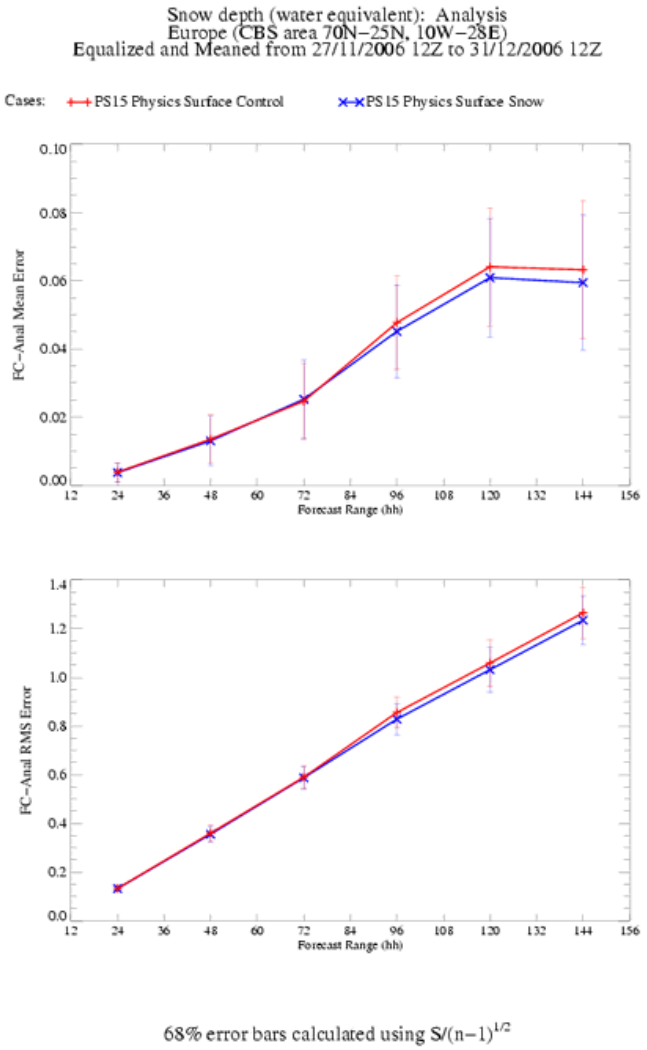
Surface field verification

- 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



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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

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Questions and answers

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