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Assimilation of satellite snow observations in HIRLAM

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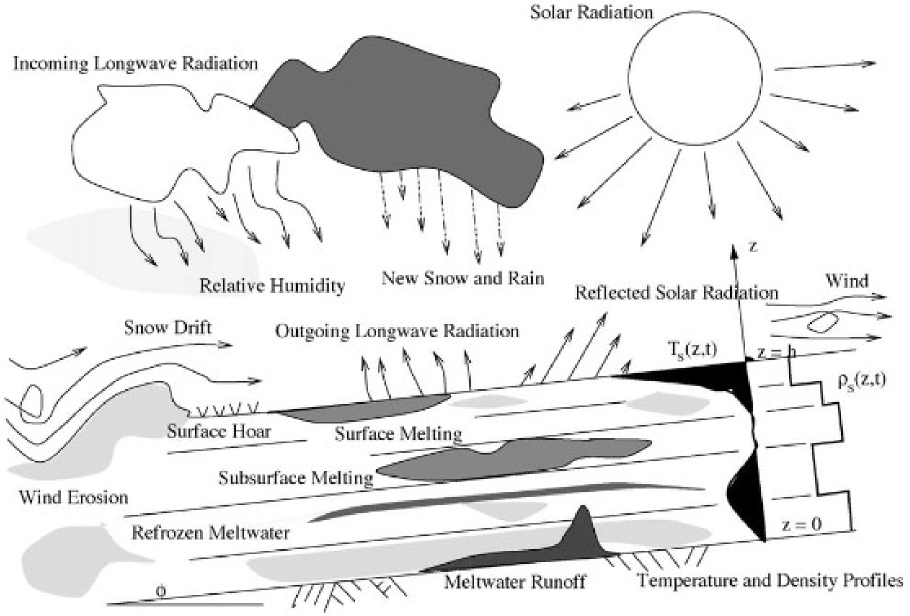
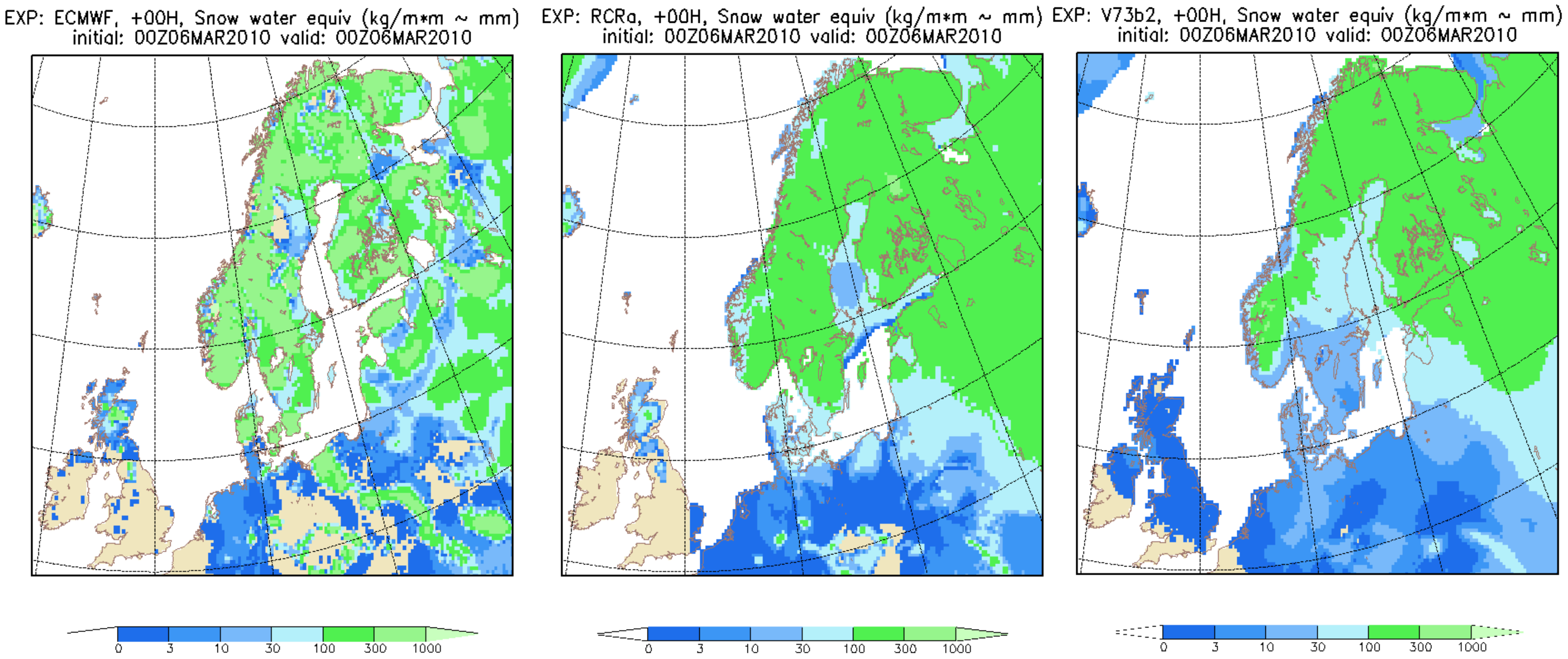
Introduction

- **Microphysics, optical and electrical properties, heat transport, stress etc.**
- **Snow is a complicated body**
  - water in solid phase
  - sometimes liquid water
  - and gaps filled with air.
- **Snow crystals**
  - snow flakes
  - even ice particles
  - break, stick together and undergo metamorphism to form snow grains
- **With time, grains transform to particles and finally may form permanent ice.**



Snow analysis is by no means a trivial task!



Current Hirlam snow analysis

- **Corrects the background field with available observations**
  - Background = short forecast
    - Snowfall and melting
    - Spin-up problem in snowfall in the first hours of the forecast
  - Optimal interpolation (OI)
  - Quality control
    - First guess check (against background field)
    - OI check (against other observations)

Current Hirlam snow analysis (cont.)

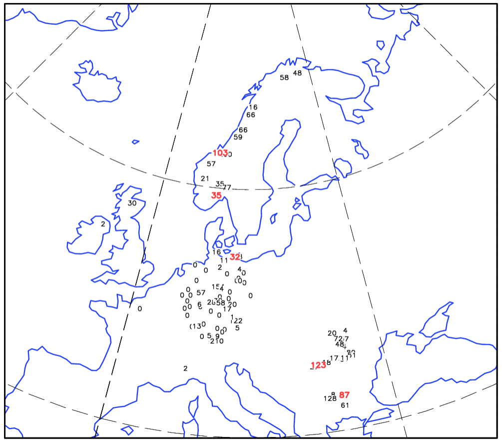
- **What is snow:**
  - In the forecast model: snow water equivalent
  - SYNOP observations: snow depth
  - ➔ density of the snow is needed in the data assimilation
- **In practice**
  - Convert first-guess snow SWE into snow depth
  - Do the analysis in snow-depth space
  - Convert the analysis back to SWE
  - Snow density is predicted by the model

Snow observations at the moment

- **Only conventional SYNOP snow depth observations are used**
- **Distribution of SYNOP observations**
- **”00 cm of snow problem”**

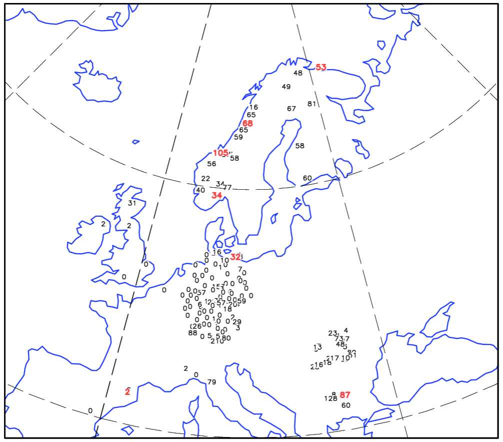
Distribution of SYNOP snow observations

EXP: snow obs. data at 20100303 00 UTC



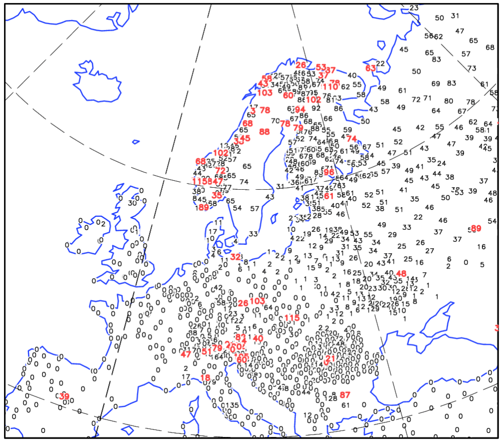
00UTC

EXP: snow obs. data at 20100303 12 UTC



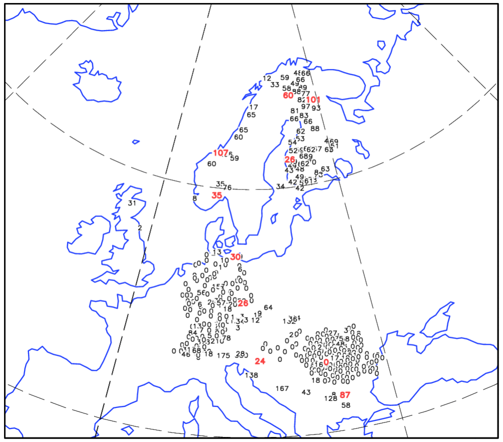
12UTC

EXP: snow obs. data at 20100303 06 UTC



06UTC

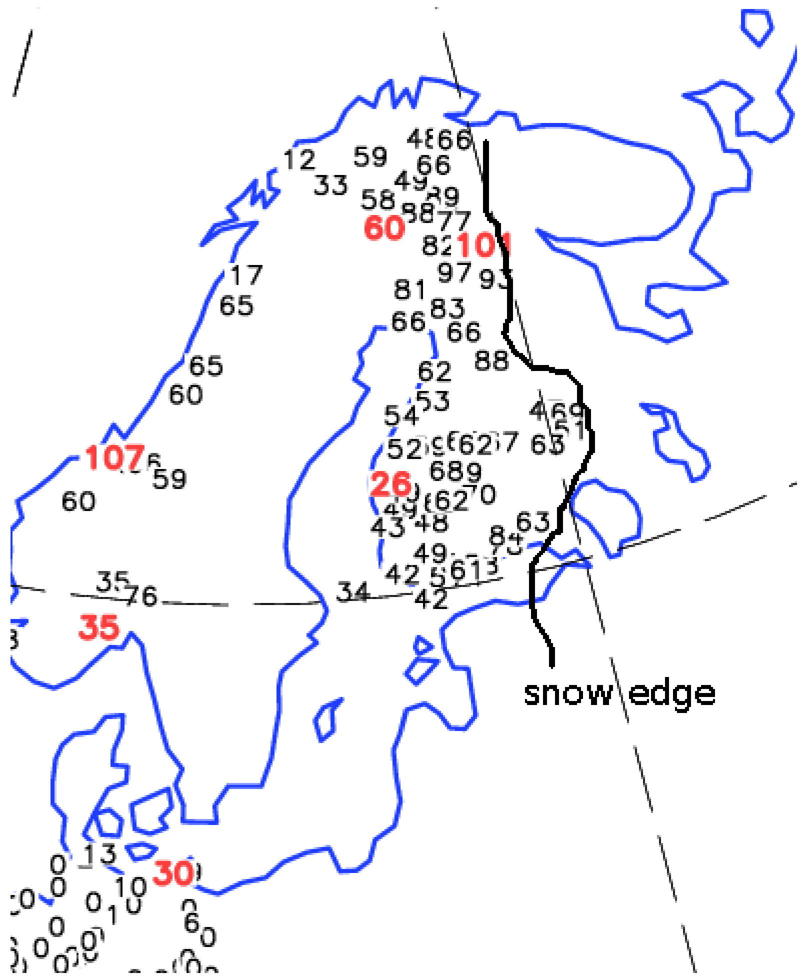
EXP: snow obs. data at 20100303 18 UTC



18UTC

”00 cm of snow problem”

- **Many stations do not report 00 cm snow**
- **Suppose the black line is the snow edge**
- **Information spreads from existing stations into the area of no observations**
- **➔Snow edge is difficult to analyze**

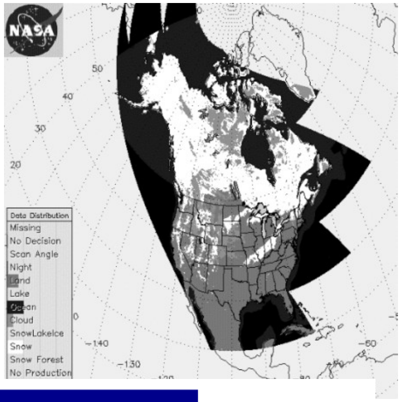


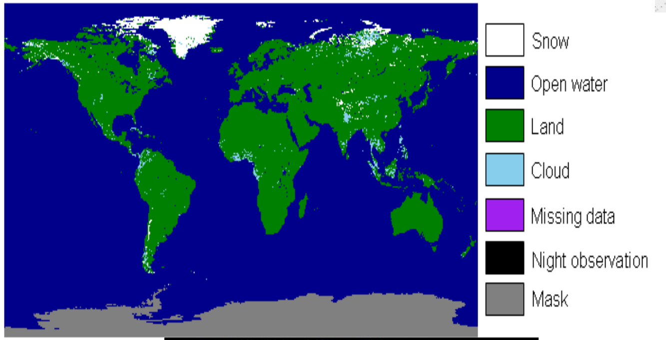
Examples of satellite data used in NWP

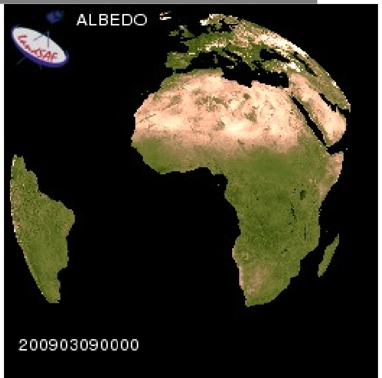
- **IMS (NOAA)**
- **Interactive Multisensor Snow and Ice Mapping System**
  - combine data from various sensor sources
  - daily snow and ice information
  - output: each pixel is classified as snow, snow-free land, clouds, water

- **MODIS (receiving apparatus with fully automatic system)**
  - Moderate Resolution Imaging Spectroradiometer
  - working with signals from Terra and Aqua
  - daily observation
  - up to 250 m resolution
  - output: raw data and calculated Normalized Difference Snow Index (NDSI) to classify each pixel as snow, snow-free land, clouds, water

- **SAF (EUMETSAT)**
  - uses Meteosat (MSG) and EUMETSAT Polar System daily snow cover map
  - resolution depends on region (from 1 up to 7 km)
  - algorithm based on cloud-mask: Derrien, M. et al, 2005
  - output: snow presence product, which classifies every land pixel as snow covered, partially covered or snow free if the clouds conditions allow the classification





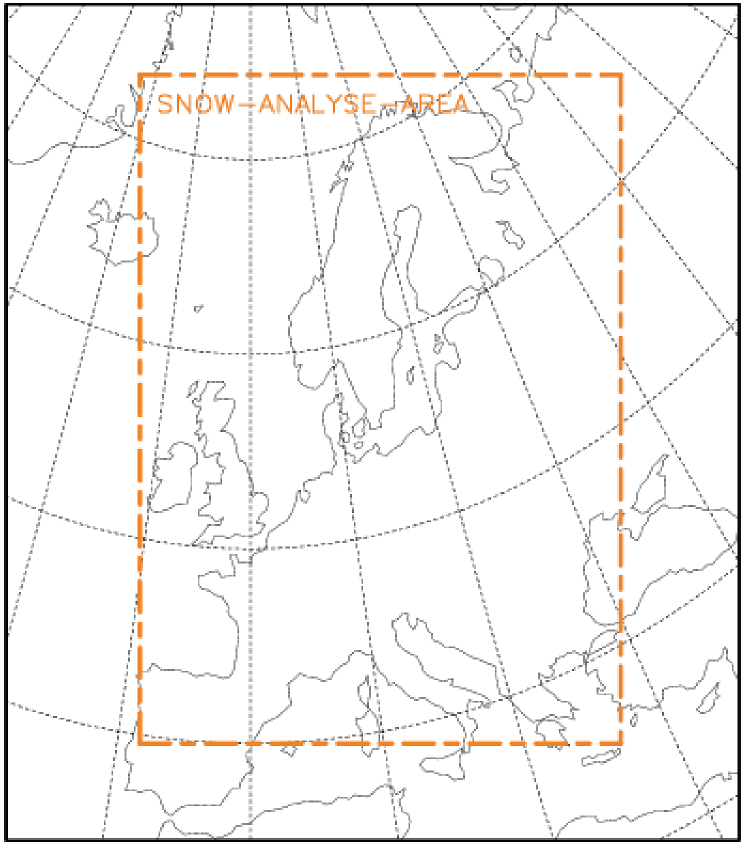


The current study

- **Pilot study**
- **Use of satellite data in HIRLAM data assimilation**
  - Globsnow (to improve data coverage)
  - Landsaf (snow/no snow – analysis of snow edge)
- **Start with HIRLAM, which we know better, later HARMONIE**
- **The effect in the HIRLAM new surface scheme?**
  - **More sensitive to snow analysis than the old scheme**
- **Option: are the in-situ observations needed at all (directly)?**
- **No independent snow observations to verify against**
  - Differences in the analysis
  - Changes in the forecast (t2m etc.)
  - Verify the forecasts

Design of the experiments

- **Hirlam version**
  - Latest 7.3 version
  - New surface scheme (”newsnow”)
  - Resolution 0.15 deg., 60 levels
  - 3DVAR
- **Time**
  - March 1st, 2009 …
- **Globsnow observations**
  - Available every 4th day: 1st March, 5th March, 9th March etc. …
  - Use them when available



Different data scenarios

- **Reference: only SYNOP observations**
- **Globsnow data in addition to the reference**
- **QC-issues related to globsnow data**
  1. Globsnow data ”at the sea level”
  2. Globsnow data, elevation from gtopo (high resolution)
  3. Globsnow data using HIRLAM orography
  4. Globsnow data using HIRLAM orography, Mariken’s corrections (relaxed quality control checks)
- **Resolution of the globsnow data: ~20km, compares to the grid definition in our tests**
  - **Results are shown from two experiments (**both with Mariken’s quality control check)
  - Reference: only Synop
  - Synop + Globsnow

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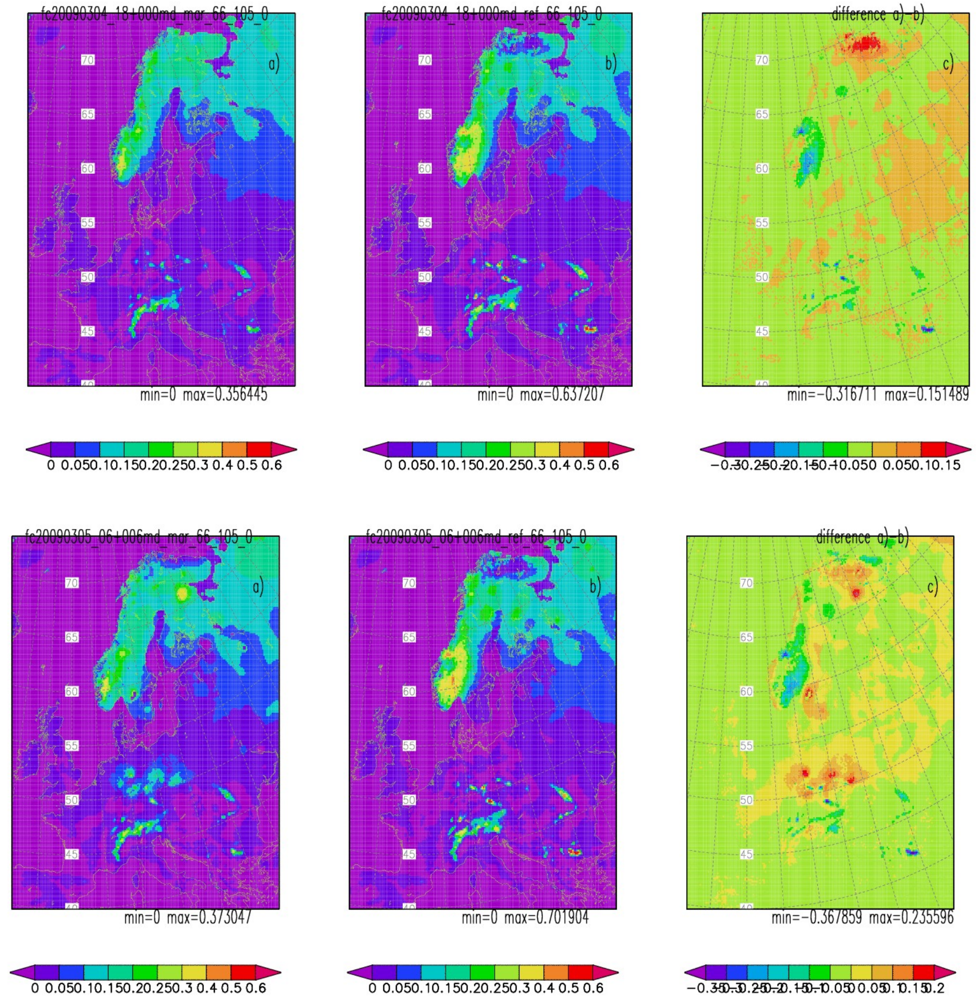
- **Snow analysis**
  - 4.3.2009 18UTC (upper)
  - 5.3.2009 06UTC (lower)

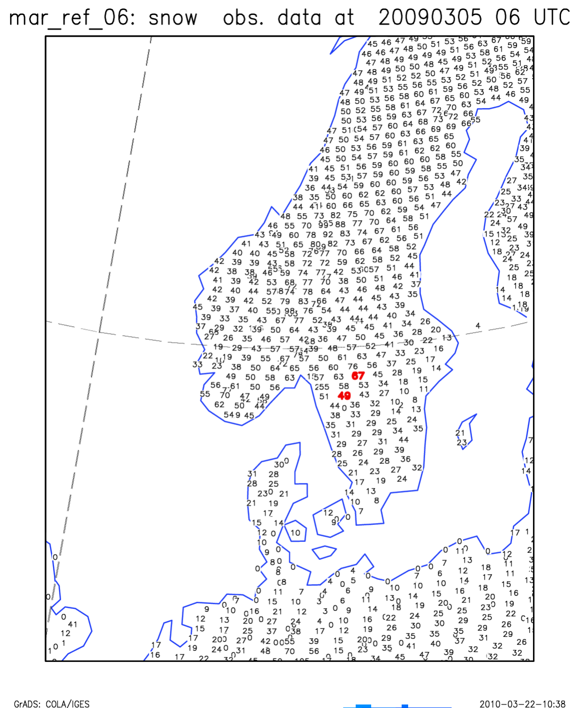
- **Second Globsnow dataset has been used in the lower figure**

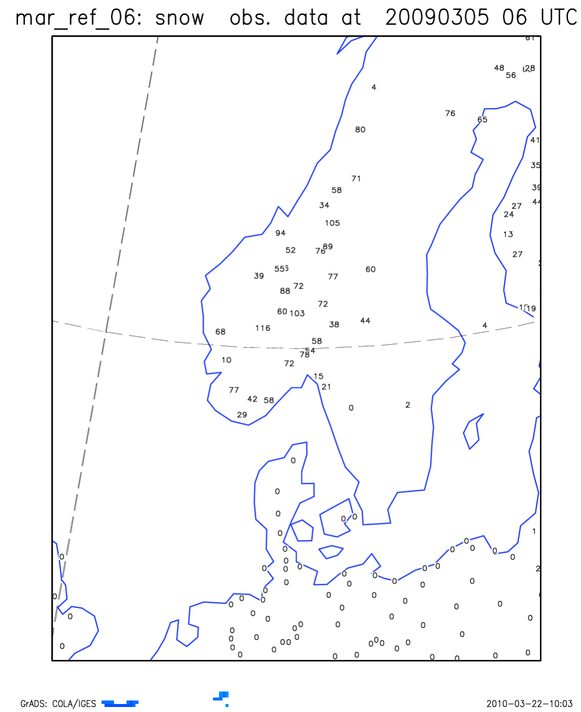
- **Differences**
  - Germany and Poland
  - Sweden and southern Norway
  - Lapland and Kola

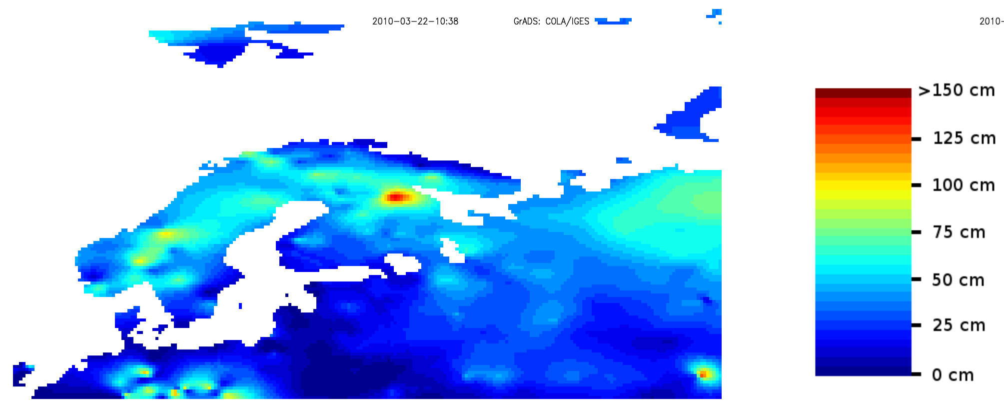
With Globsnow | **Only SYNOP** | **Difference**



- **Red: observations rejected in quality control**
- **In southern Sweden, two SYNOP observations available**
- **Close to observations, the SYNOP and Globsnow observations coincide**

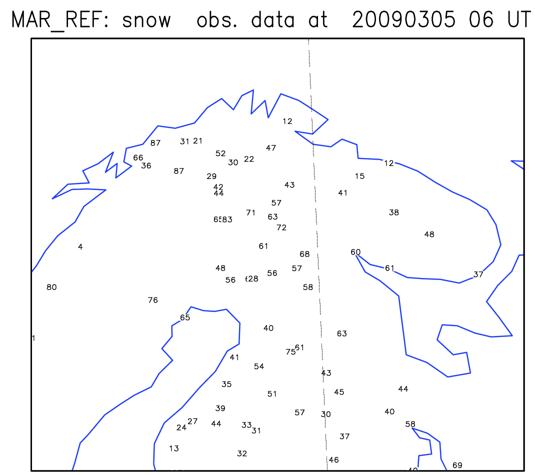


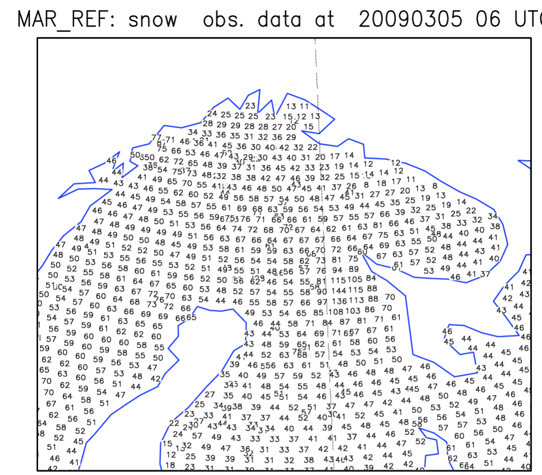


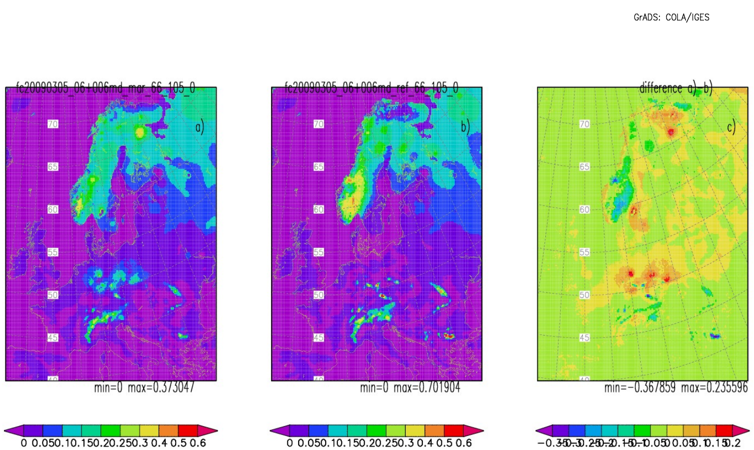


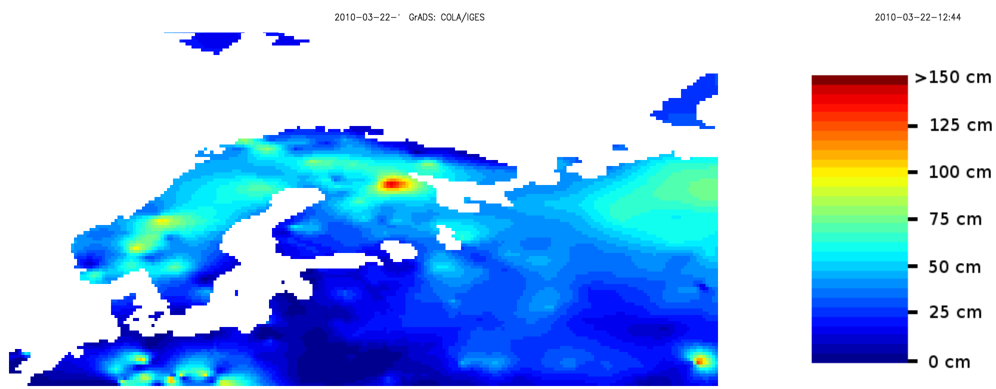
Northern area

- The snow depth maximum seen in Globsnow data west of the White Sea cannot be confirmed by the SYNOP observations
- Where there are SYNOP observations, the Globsnow follows them
- But where comes the minimum in the reference?
- A problem of HIRLAM snow analysis in the northernmost forest!



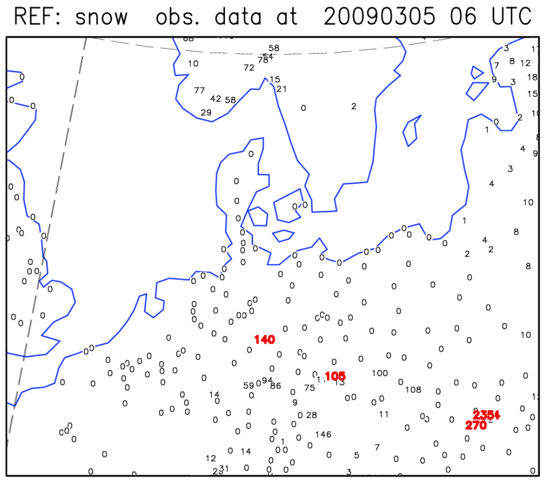


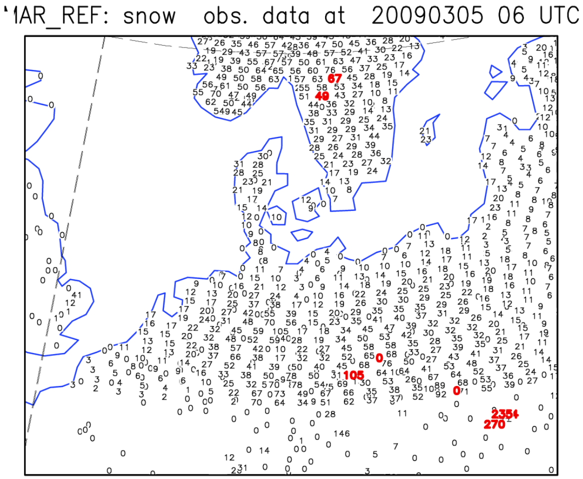


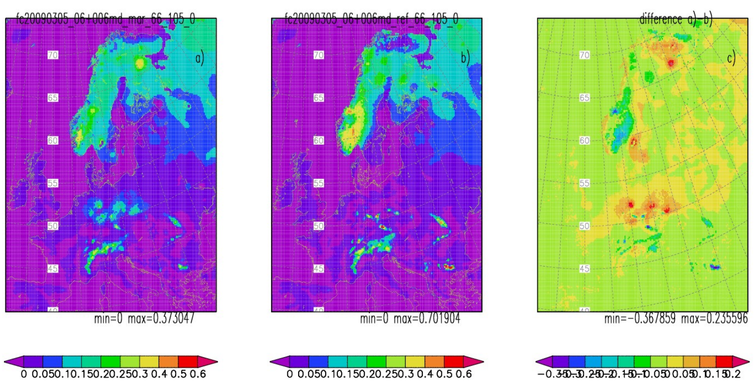


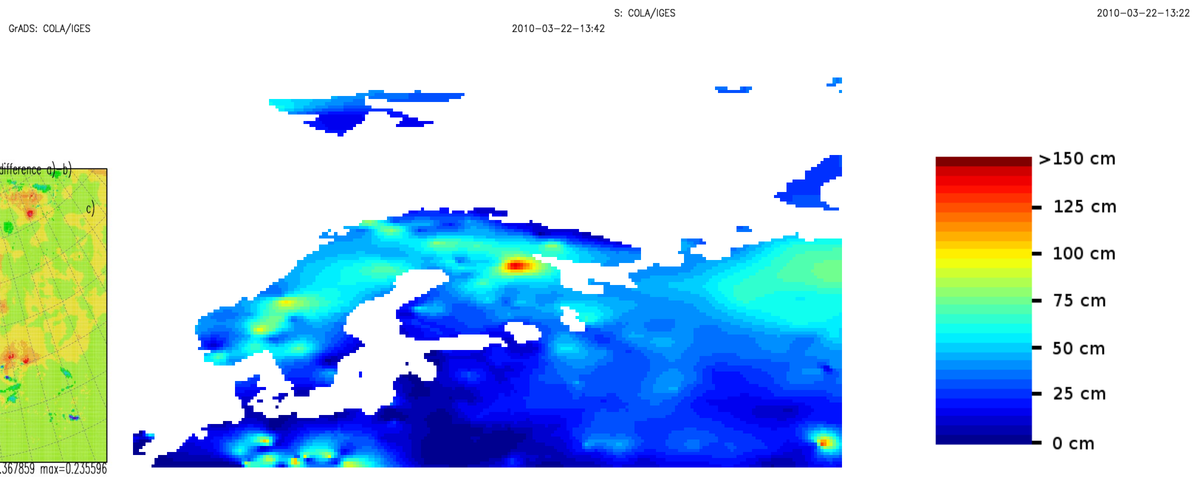
Germany and Poland

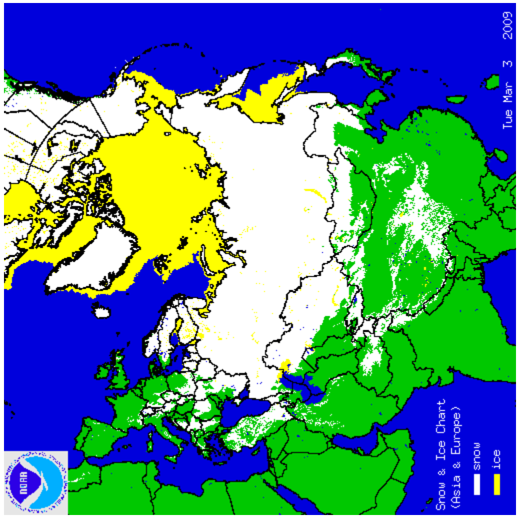
- The Globsnow observations do not fit the SYNOP observations in Germany, Poland and Denmark
- In Baltic countries the agreement is better



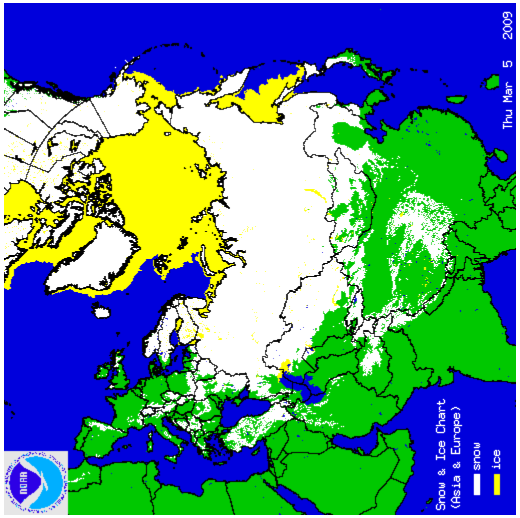








3 MARCH



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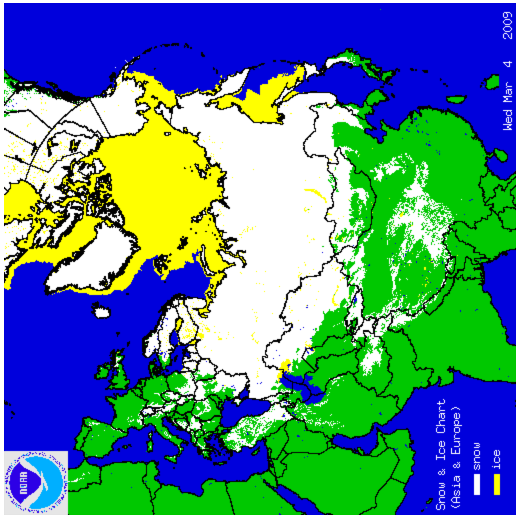

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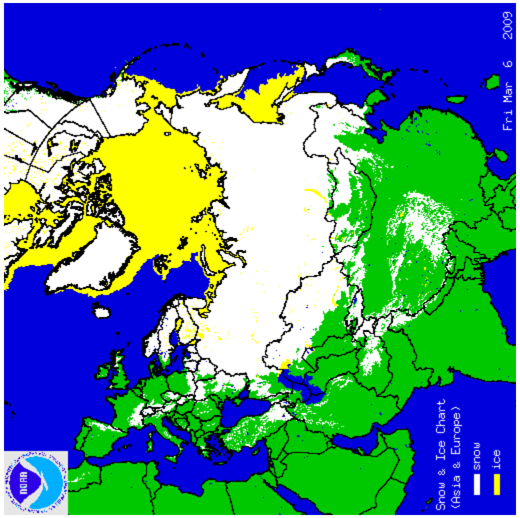

6 MARCH

Concluding remarks: to do in near future

- **Longer time periods, effect on forecasts**
- **LANDSAF data and the analysis of snow edge**
- **Improvement and tuning of HIRLAM optimal-interpolation based snow analysis**
- **Snow parametrizations in the forecast model: e.g. improvement of handling of snow on ice**

Another point of view?

- **Atmosperic data assimilation within NWP models**
  - Earlier
    - From satellite radiances of different channels → temperature profiles
    - Temperature profiles as input in the analysis together with soundings
  - Nowadays
    - Use the radiances directly
    - Forward model from model space to observation space needed (part of observation operator)
    - A forward model can use all model variables

NWP – customer or producer of snow data assimilation?

- **Globsnow can be thought as an observation operator**
- **Can we use modelled snow data instead of SYNOP observations?**
- **In addition, a NWP model contains much more useful information like:**
  - Fractions of open land, forest, lakes and sea
  - Specific features of snow on open area, forest (and ice)
  - Predicted snow density and albedo, many other surface characteristics
  - Observed and predicted three-dimensional atmospheric data
- **Dream or not?**
  - **Assimilate the raw satellite data in the NWP context using variational data assimilation techniques?**
  - **Or provide NWP information for the Globsnow stand-alone analysis?**