A literature review of Snow DA

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Outlines:

- Introduction
- Snow physics ...
- Snow models / snow parameterisations
- Observations in situ
  space-born: raw data, products
- Snow analysis algorithms
- Snow analysis in different forecasting systems: IFS, HIRLAM, COSMO
- Plans, projects
Introduction

Snow cover … for meteorology:
• Snow Water Equivalent (SWE) and Snow Extent are key parameters for earth’s energy balance
• Snow cover affects the surface albedo
• Snow cover affects the heat flux between the ground and the atmosphere
• Snow cover has a strong effects on the lower part of the atmosphere

Snow cover … for hydrology:
• Maximum SWE is typically the most important characteristic for operational run-off and flooding forecasts in spring snowmelt.
• Snow is the main source for spring water supply important for agriculture, especially for semi-arid regions
• In mountains: avalanche warnings
• In some regions the run-off from mountain snow is the only source of water

Snow cover parameters are crucial for performance of environmental applications
Snow physics ...

## Snow models / snow parameterisations

- **SWE**
- **Snow Depth (SD)**
- **Temperature**
- **Liquid water content**
- **Snow density**
- **Albedo**
- **Grain size**
- **Snow Extent (SE)**

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<th>Model</th>
<th>Affiliation</th>
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<tr>
<td>2LM</td>
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<td>ACA</td>
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Ref: [http://xweb.geos.ed.ac.uk/~ressery/SnowMIP2.html](http://xweb.geos.ed.ac.uk/~ressery/SnowMIP2.html)
Observations: in situ

- Operational
  SYNOP: snow depth

- Non-operational
  snow courses: snow depth, SWE => snow density

+) reliability

-) low coverage
  no information about gaps in data
  the absence of report about snow depth does not mean that there is actually no snow!
  no plans to develop this type of measurements in future
Observations: space-born. Raw data

Visible and near-infrared channels – AVHRR, etc.
  Resolution: 500 m (highest), no data at night and under cloudy conditions
  High reflectivity in 0.54– 0.56 micrometers and high absorption in 1.63 – 1.65 micrometers.

Microwave radiometry – SSM/I, AMSR-E
  Resolution: (after preliminary processing) gridded - 0.25 degree, data present at night time and do not depend of cloudiness

Satellites
  Geostationary: GOES, Meteosat
  Polar-orbiting satellites: POES, Aqua, Terra

+) high coverage
   high resolution
   methods are developing intensively!

-) reliability is lower in comparison with in-situ measurements
Observations: space-born. Main products.

- **IMS (NOAA)**
  Intractive Multisensor Snow and Ice Mapping System
  uses many types of data, combine data from various sensor sources
  daily snow and ice information
  currently 2 resolutions: 25 km (1024x1024 grid) and 4 km (6144x6144)
  algorithm: subjectively analysis!
  output: SE, 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)**
  Satellite Application Facilities
  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

Ref:
- http://modis.gsfc.nasa.gov/about/specifications.php
Snow analysis algorithms

- Successive corrections
- Optimum Interpolation
- Kalman Filter – in hydrology

Quality control:

- Inhomogenous field => use ancillary information: precipitation, screen level temperature

- Observations are more often give larger values (not smaller) than analysis (Brasnett B., 1999)

Ref:
SA in different systems:
IFS (ECMWF)

- obs – SYNOP
- F.g. field: 6-hour forecast
- Main prognostic variable: SWE
- Assimilation algorithm: successive corrections
- IMS products used to correct snow boundary
  no snow in f.g., but snow in IMS: SD=10cm
  pseudo-observations of 0 cm of SD

Ref:
- Hyvärinen O., K. Eerola, N. Siljamo and J. Koskinen, 2009: Comparison of snow cover from satellite and numerical weather prediction models in Northern Hemisphere and northern Europe. Journal of Applied Meteorology and Climatology, in print
In different systems:

**HIRLAM**

- obs – SYNOP
- F.g. field: 6-hour forecast
- Prognostic variable: SWE (SD)
- Assimilation algorithm: OI
- No space-born products are used at the moment

Ref:

- Hyvärinen O., K. Eerola, N. Siljamo and J. Koskinen, 2009: Comparison of snow cover from satellite and numerical weather prediction models in Northern Hemisphere and northern Europe. *Journal of Applied Meteorology and Climatology*, in print
In different systems:

COSMO

- obs – SYNOP
- F.g. field: snow analysis form IFS and DWD
- Prognostic variable: SWE (SD)
- Assimilation algorithm: Cressmann analysis
- Snow Mapping Using Multi-Temporal METEOSAT-8 Data

Ref: Philippe A.J. Steiner1, Francis Schubiger1, 2007, Numerical Weather Prediction at MeteoSwiss,
Plans, projects:

- **GlobSnow**
  - start at 2009
  - funding by European Space Agency (ESA)
  - coordination by FMI

- Planned products:
  - SE, SWE

- **SWE**:
  - method: the inversion of brightness temperatures in different channels from semi-empirical snow emission model (Helsinki University of Technology, HUT) (Pulliainen J., 2006)
  - SYNOP observations will be used for calibration the HUT model.
  - The intended spatial resolution for **SWE**: 10 km

- [http://snow.fmi.fi](http://snow.fmi.fi)

Ref:
Plans and possible problems:

• Plans: to assimilate SWE products into HIRLAM

But:

• Methods applicable for dry snow only
• Double-counting of SYNOP observations

• Probably others …?

Thank you for attention!