The Validity of Snow Density and Snow Water Equivalent Measurements in Serbia

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Definitions of SD/SWE

Snow water equivalent (SWE) is a total amount of water contained in snow cover

(Bulk) Snow density (SD) is an amount of water in snow cover averaged by 1 cm of snow height (Hs)

Relation between SD and SWE

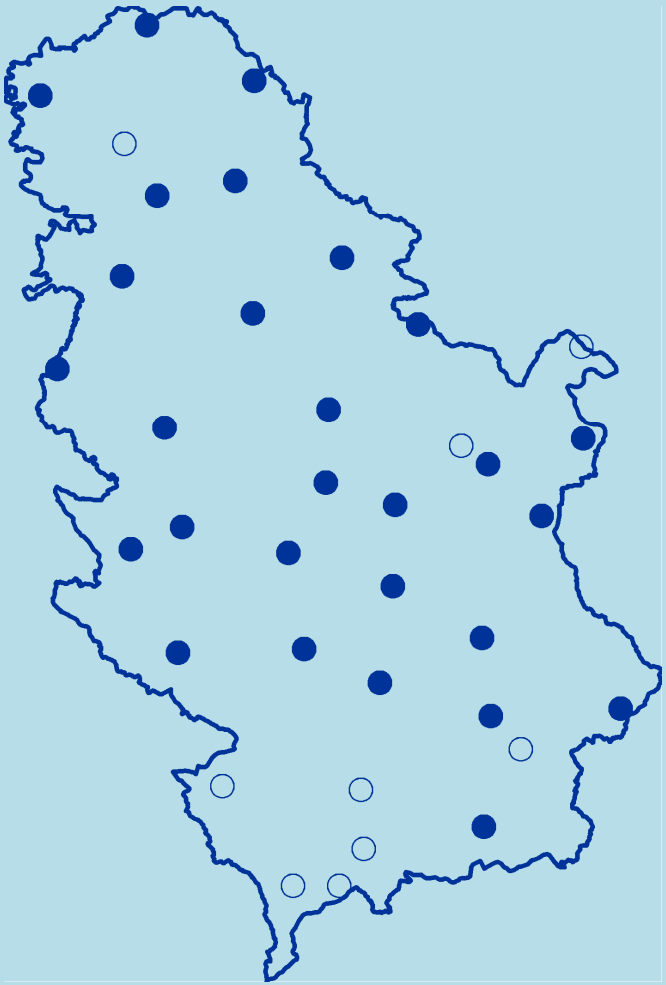
$$SD = \frac{SWE}{Hs}$$

Measurements od SD/SWE

✓ Weighing samples

✓ Remote sensing

Measurement of SD/SWE in Serbia



- ✓ 28 active stations
- ✓ Total of 37 stations
- ✓ Total of 11810 observations
- ✓ Period 1962-2016

Measurements are taken…

- ✓ on 5th, 10th, 15th, 20th, 25th and last day of month when Hs is at least 5 cm
- ✓ in days with new snowfall of at least 10 cm
- ✓ in days with snow melt of at least 10 cm

Purpose of SD/SWE data

- ✓ civil engineering (maximum snow loads)
- ✓ hydrological cycle models (water capacity)
- ✓ water management (water capacity)
- ✓ avalanche warnings
- ✓ scientific (climatology, WMO SPICE experiment, COST Action ES1404 - HARMOSNOW…)

Quality control of SD/SWE data

SD/SWE might be calculated from precipitation and snow amount

$$SWE_{calc} = \sum RR_{*} \qquad SD_{calc} = \frac{SWE_{calc}}{Hs}$$

Two quality control criteria

- ✓ SWE should not exceed precipitation sum since the snow cover formation (**calculated maximum**)
- ✓ SD can be smaller only if new snow precipitation is added (**calculated minimum**)

All values outside this range are considered as errors

Errors of SD/SWE data

21% of data with <u>too low values</u>!

Possible causes:

- ✓ mistaken measurements and/or calculation of SD/SWE
- ✓ common errors (typos, poor handwriting…)

Errors of SD/SWE data

46% of all data with <u>too high values</u>!

- ✓ low altitude stations error rate is 37%
- ✓ mountain stations error rate is 54%
- ✓ poor skilled staff stations error rate is 62%

Errors of SD/SWE data

Possible causes:

- ✓ samples might be mistaken from non-representative snow layer (wind driven snow layers of higher density)

$$SD = \frac{SWE}{Hs} \rightarrow SWE = SD \times Hs$$

- ✓ suspiciously high values of snow height
- ✓ common errors (typos, poor handwriting…) are diminished!

Wind driven snow layers and alternative criteria for upper QC range

Wind driven snow packs are being created by:

- ✓ snowfall
- ✓ wind gusts of at least 8 m/s
- ✓ temperature below -2°C
- ✓ obstacles and/or terrain slopes

Wind driven snow layers might be 2, 3 or more times higher than representative snow depth

Alternative upper limit multiplied:

- ✓ by 2 → from 46% to 10% error rate
- ✓ by 3 → from 46% to 3% error rate

How to deal with SD/SWE data?

Data within the criteria range are good for water capacity calculations involved

- ✓ hydrological cycle models
- ✓ water management

Data values up to alternative criteria are good for maximum snow load calculations involved (civil engineering)

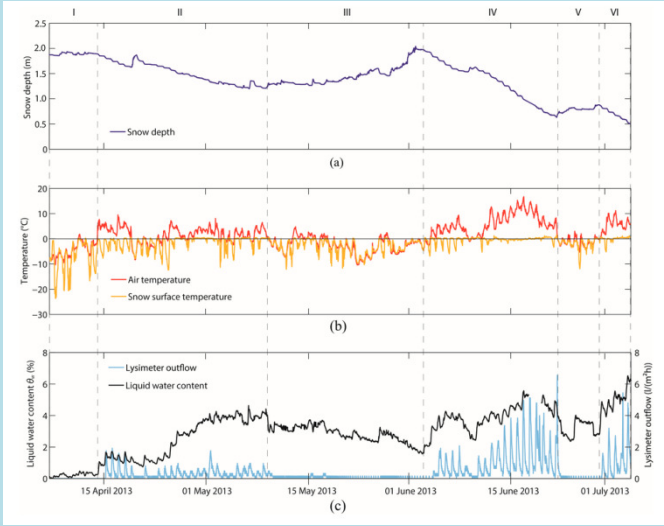
What is left to science?

Scientific use of SD/SWE data

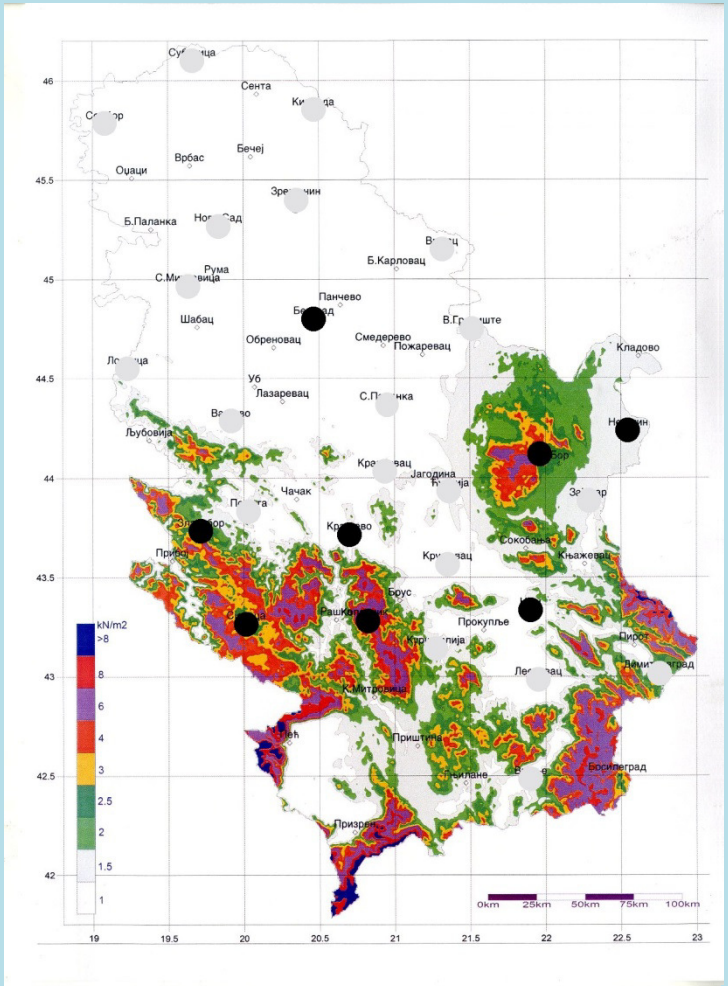
Not much use of present data

New measurement methods developed for science purposes

Snow profile observations



Suggested network optimization



- ✓ present network
- ✓ group of stations with similar results
- ✓ optimized network

Other benefits

Smaller number of errors → higher data quality

New measurements + trainings =

= more good results

= more valuable products

Questions?

Comments?

Thank you for your attention