Forecasting of wet snow and freezing rain accretion on power lines

André Simon[1], Oldřich Španiel[1], Mária Derková[1], Katalin Somfalvi-Tóth[2]

[1]SHMÚ, [2]University of Kaposvár

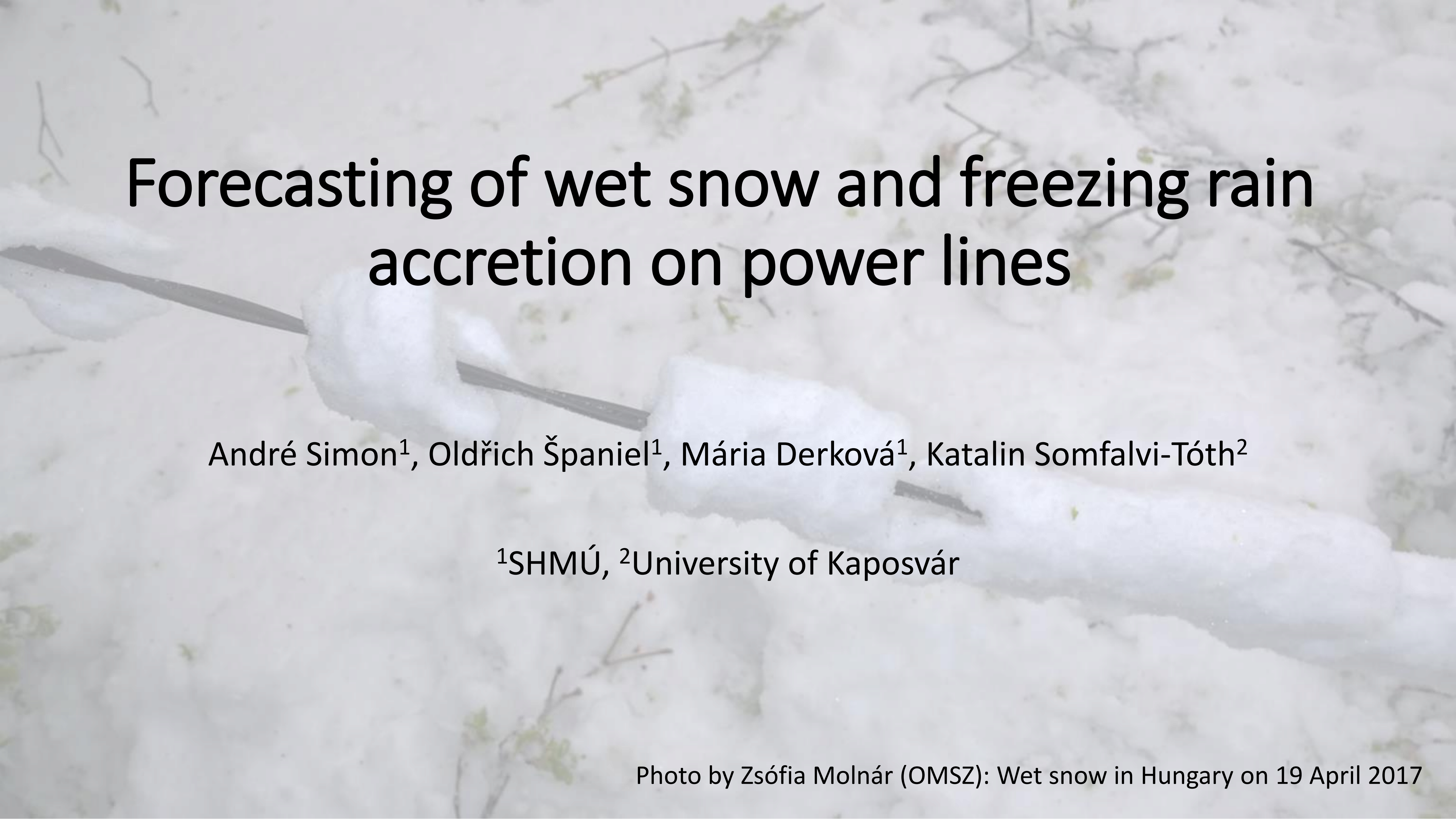


Photo by Zsófia Molnár (OMSZ): Wet snow in Hungary on 19 April 2017

Parameters determining accretion of snow and icing on structures

- Precipitation (high precipitation needed for direct impact if strong wind is absent)
- Wind (increases the precipitation flux toward the object and the density of accreted snow, decreases the accretion efficiency, induces wire rotation and cylindrical accumulation)
- Wet-bulb temperature (determines the precipitation type and its properties, e.g. the stickiness of the snow)
- Microphysics (important for fall velocity of snow and rain – modifying the precipitation flux, water content of the snow is crucial for its stickiness)

A simple accretion model

(Admirat 2008, Ducloux and Nygaard 2014, Somfalvi-Tóth et al., 2015, ...)

Diameter flux:

$$\left(\frac{d\,\Phi}{d\,t}\right) = \frac{2\,K}{\pi\,\rho}$$

Snow/ice load flux:

$$\left(\frac{d\,M}{d\,t}\right) = K\,\Phi$$

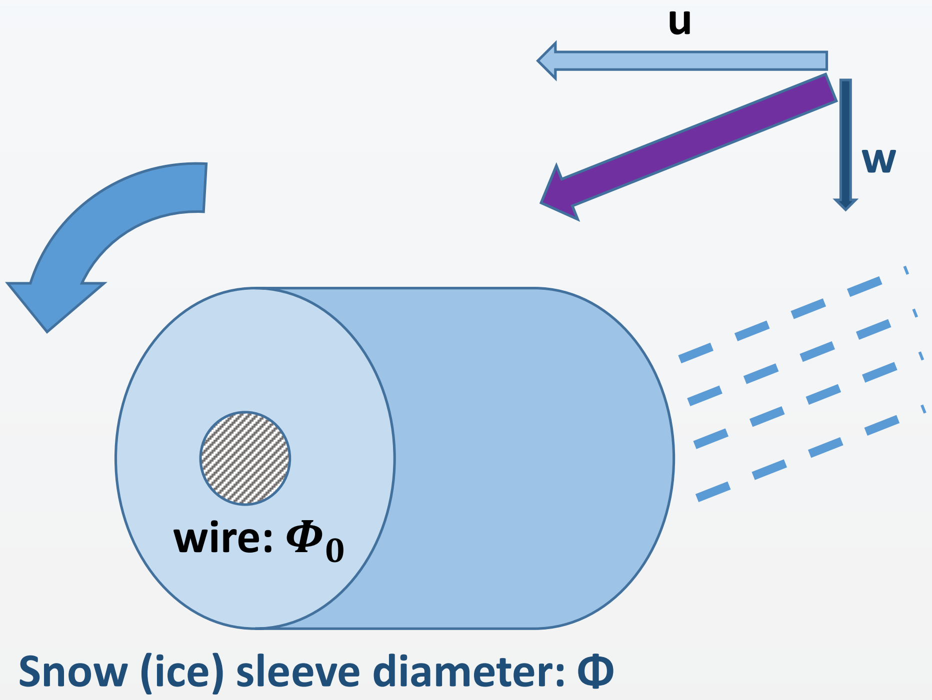
Sleeve diameter changing in time

$$K = \beta\,P_f\,\sqrt{1 + \frac{u^2}{w^2}}$$

Accretion efficiency

Precipitation flux

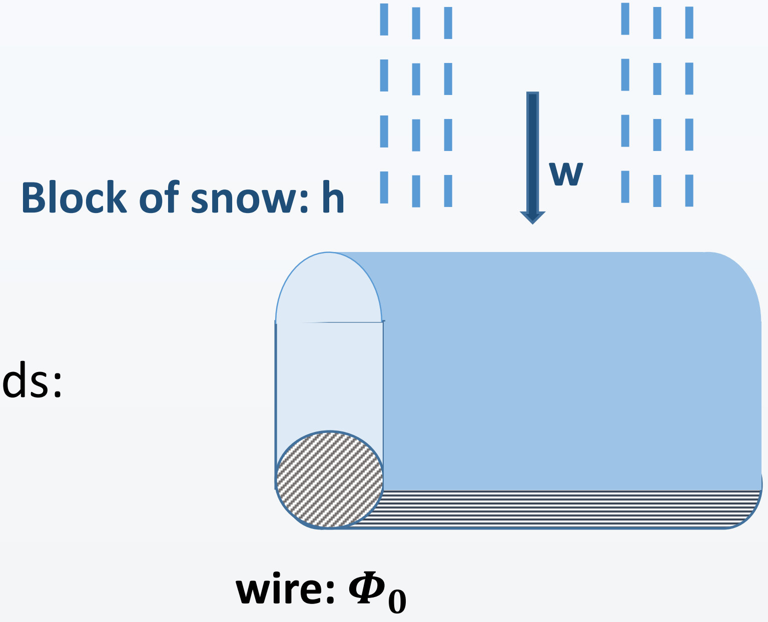
Flux term



Snow (ice) sleeve diameter: Φ

- Basically a cylindrical accretion expected, which is mainly caused by rotation of the wire by moderate-to-strong wind (> 5 m/s)
- No shedding or thawing included yet (planned)

Block accretion



Snow/ice load flux:

$$\left(\frac{d\,M}{d\,t}\right) = K\,\Phi_0$$

Diameter fixed in time

Diameter flux emulated from loads:

$$\left(\frac{d\,\Phi_e}{d\,t}\right) = \frac{2\left(\frac{d\,M}{d\,t}\right)}{\rho\,\pi\,\Phi_e}$$

- Case of weak wind: usually < 5 m/s – after Sakakibara et al. (2007)
- Significantly lower loads, because of small flux
- Dry snow accretion also possible (-2 °C ≤ Tw < -0.2 °C, u ≤ 2 m/s)
- Fictive cylindrical diameter flux is emulated from snow load
- Weighting between block- and cylindrical accretion to enable change of the accretion form in time

Another important parameterizations

- Definition of wet snow (snowfall by -0.2 °C ≤ Tw ≤ 1.2 °C, T ≤ 2 °C) Makkonen and Wichura (2010), Makkonen (1989)
- Definition of freezing rain (rain by -10 °C ≤ Tw ≤ 0 °C)
- Accretion efficiency: -1 (Admirat) ≤ n ≤ - 0.5 (Nygaard et al., 2013), currently set to -0.6

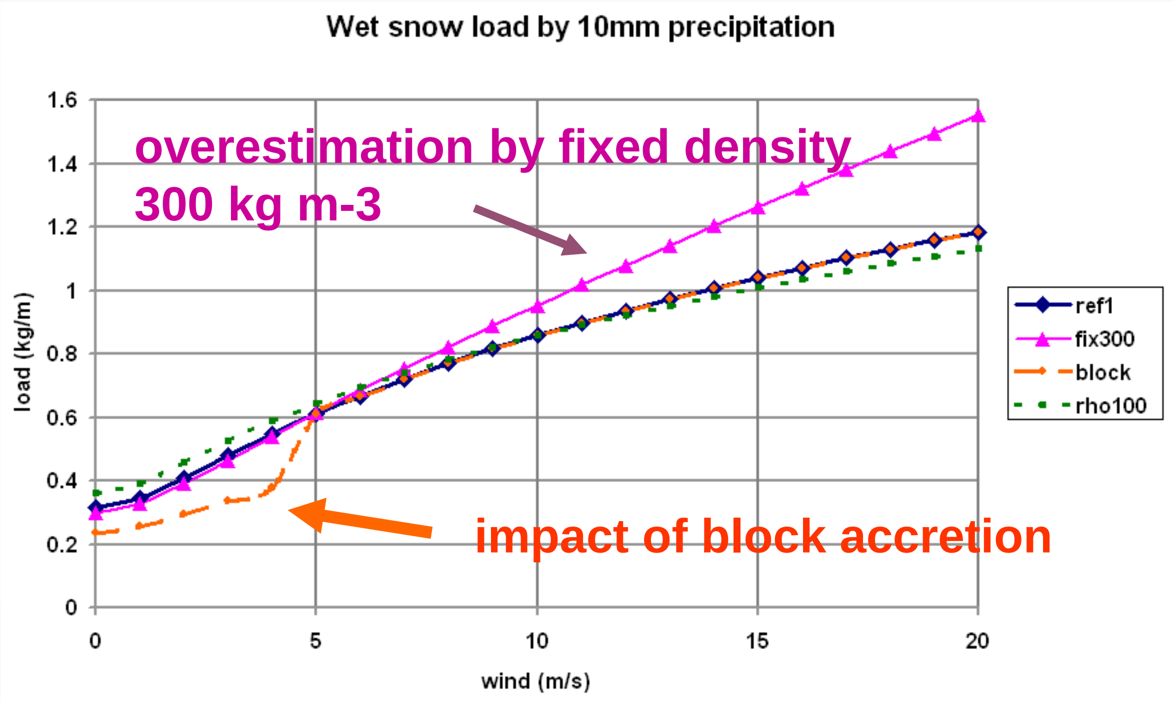
$$\beta = v^n \qquad v = \sqrt{u^2 + w^2}$$

- Wet snow density: is high by strong wind (elimination of air-bubbles in the sleeve), can be from 100 up to 800 kgm^{-3} in extreme cases, nearly linear function expected

$$\rho = \rho_{min} + b\,v$$

Tests in idealised conditions, setup

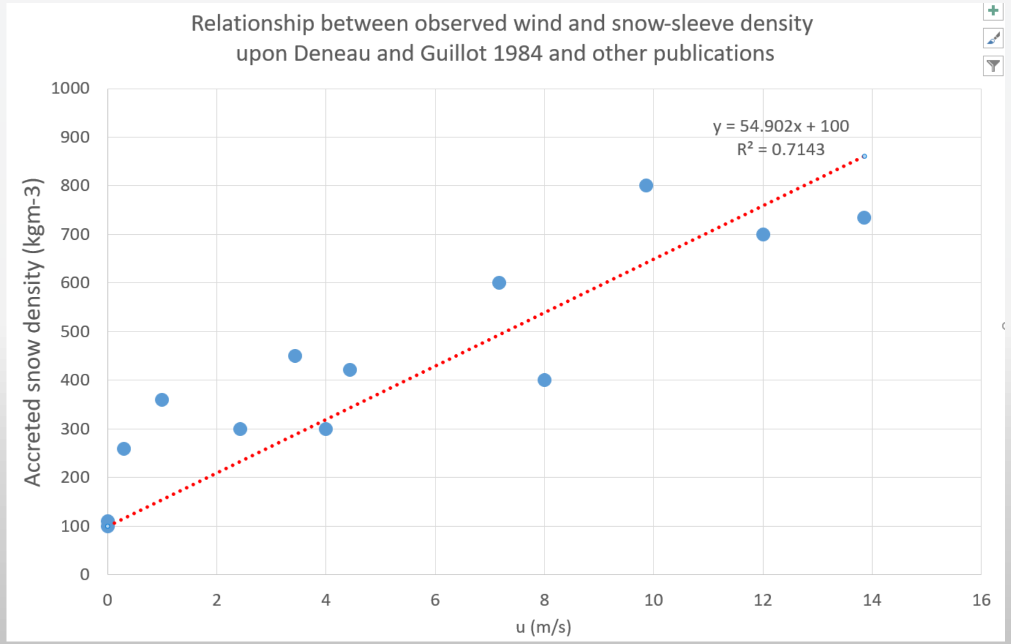
- Relationship between load/diameter and wind (precipitation flux assumed constant in time)
- Use of 13 published cases (Japan, Italy, France, Iceland, Hungary) with known wet snow loads and meteorological conditions to specify the setup for wet snow density function (ρ_{min}, b) and for accretion/sticking efficiency (β)



Wet snow load by 10mm precipitation

overestimation by fixed density 300 kg m-3

impact of block accretion



Relationship between observed wind and snow-sleeve density upon Deneau and Guillot 1984 and other publications

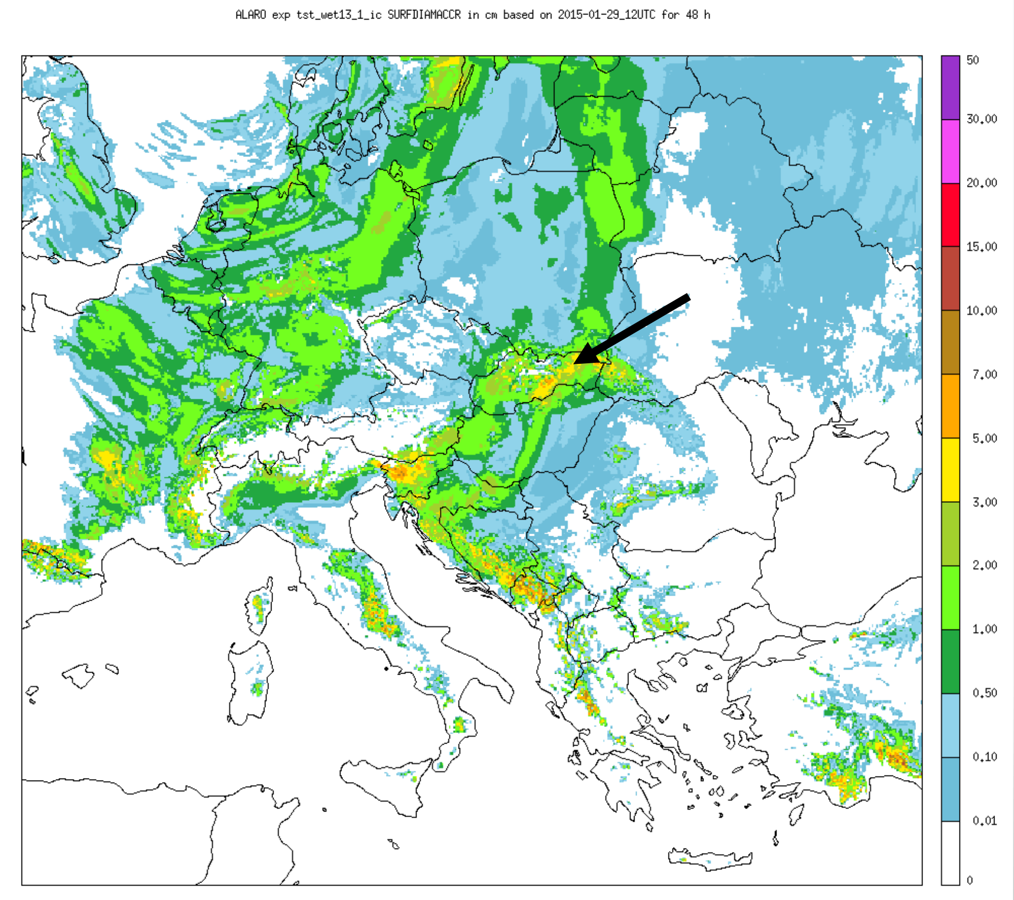
Model implementation

- Coded for cy43 t2 bf10 v01, tested with ALARO 1 /SHMÚ 4.5 km resolution
- ACWSNOW – new routine within APLPAR (model physics)
- Physics is needed (accumulation each time step, availability of some parameters, diameter flux is called from the previous time step, etc.)
- Consistent with model precipitation fluxes but not with recent diagnostic precipitation type (to be optional in future)
- Output parameters: cumulated fluxes (via CPCFU):
  SURFLOADSNOW, SURFLOADICE - loads of accreted wet snow and FZRA
  SURFDIAMACCR – increase in snow sleeve diameter (wet snow+ice)
  SURFPCPWSNOW, SURFPCPICE – precipitation as wet snow or freezing rain
- Namelist parameters: LWSNOW=.T. (NAMCFU)
  WDIAMWIRE – wire diameter (NAMPHY2)
  HWET – height of the calculation, etc.

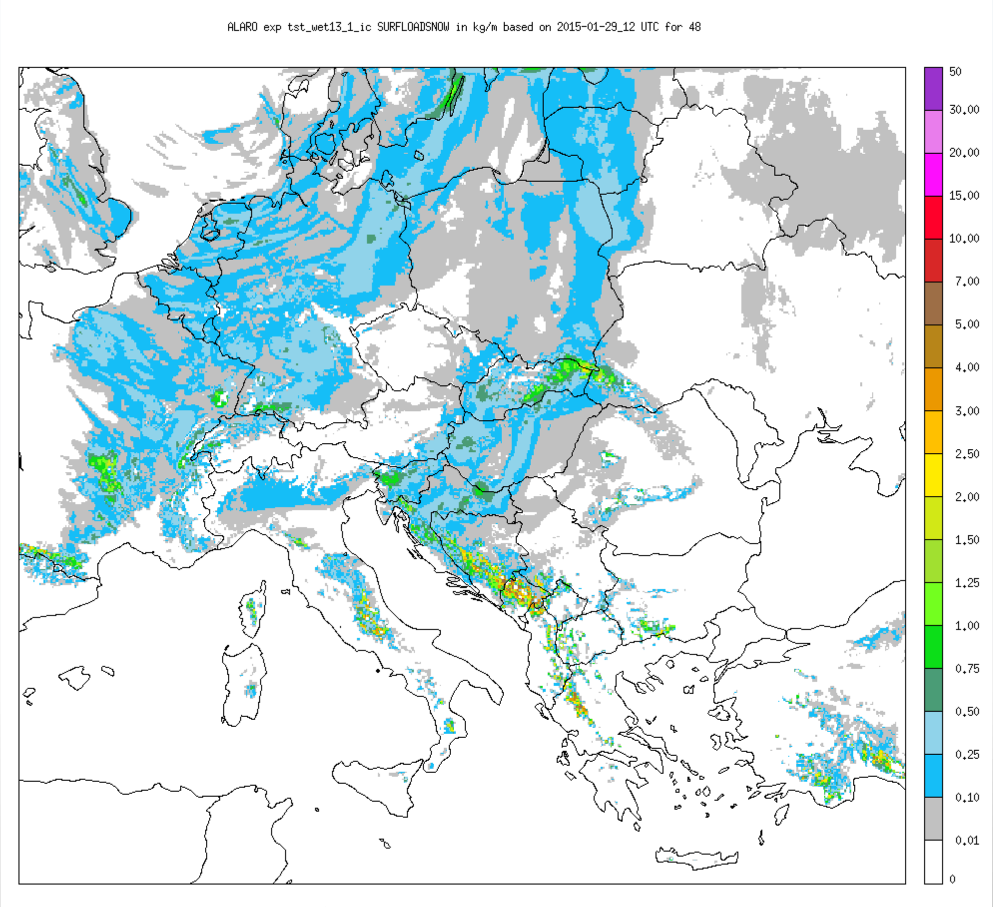
Example: wet snow event in Slovakia

- 29-31 January 2015 (1 casualty)

Diameter (cm)



Wet snow load (kg/m)

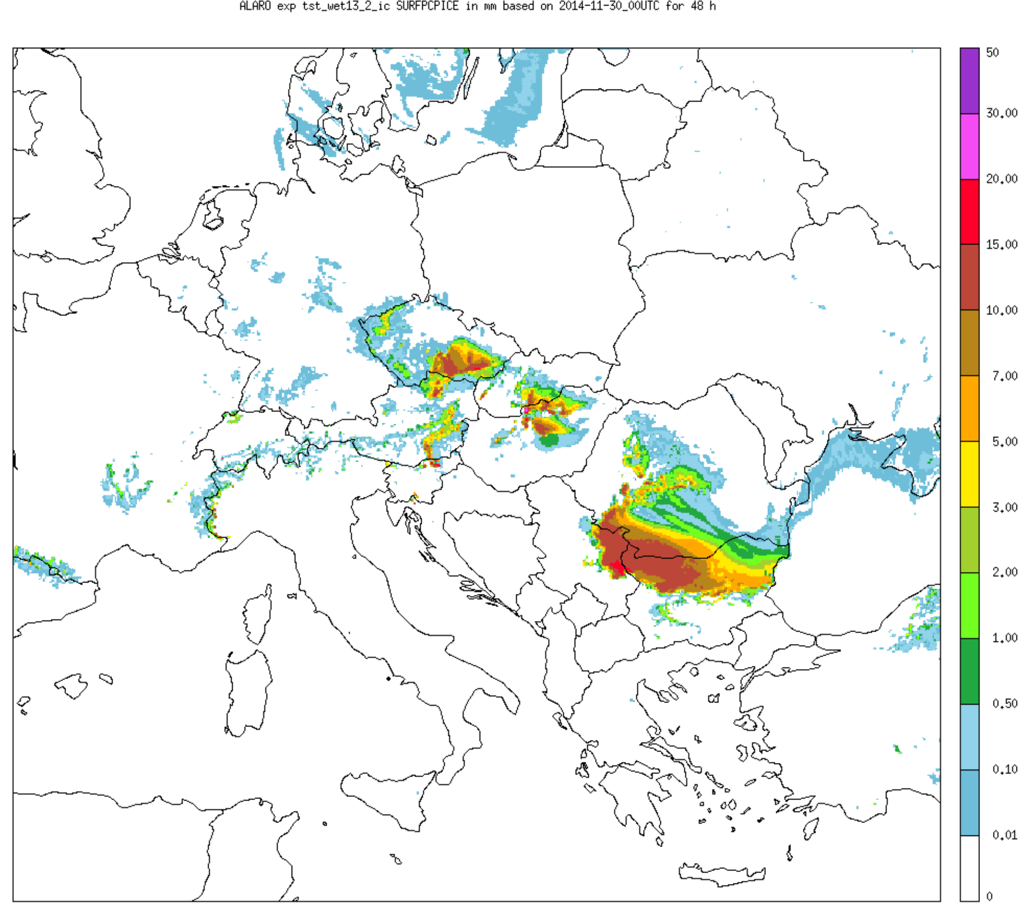


ALARO/SHMÚ, 4.5 km horizontal resolution

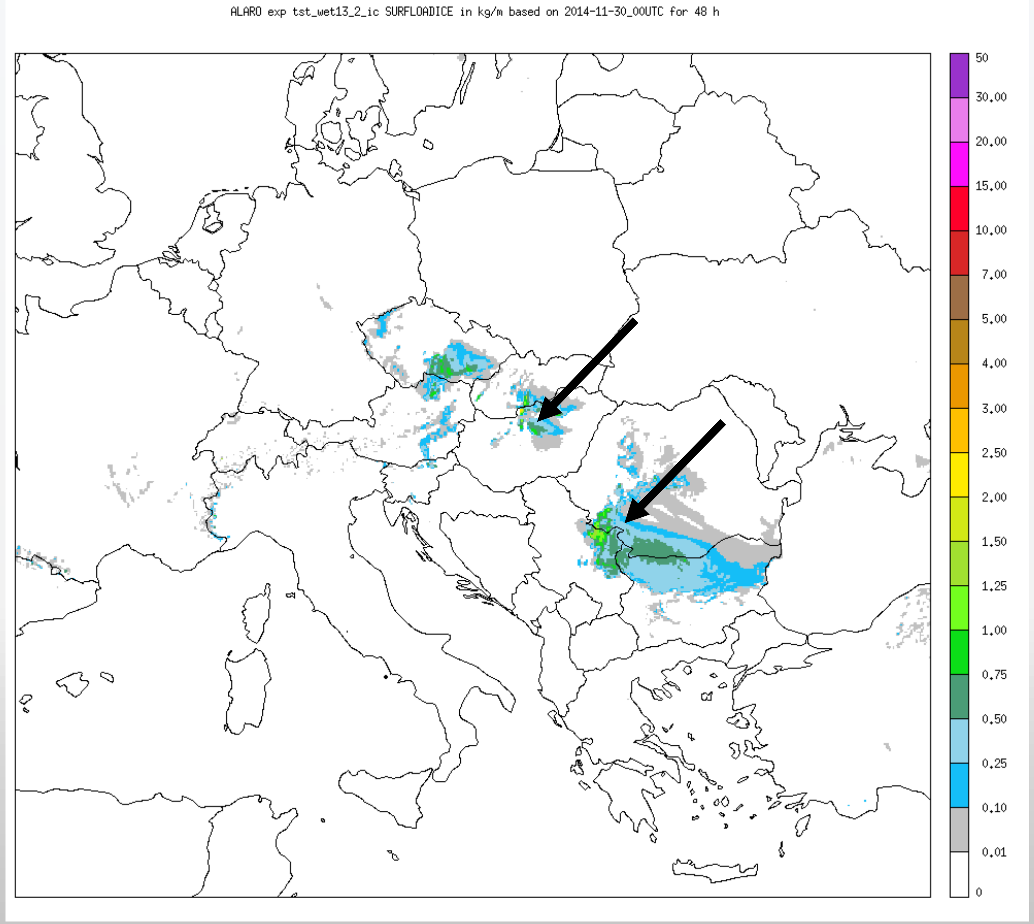
Ice storm in central Hungary

- 30 November – 1 December 2014 (~50 mm freezing rain)
- severe FZRA event also in SE Europe?

Freezing rain precipitation



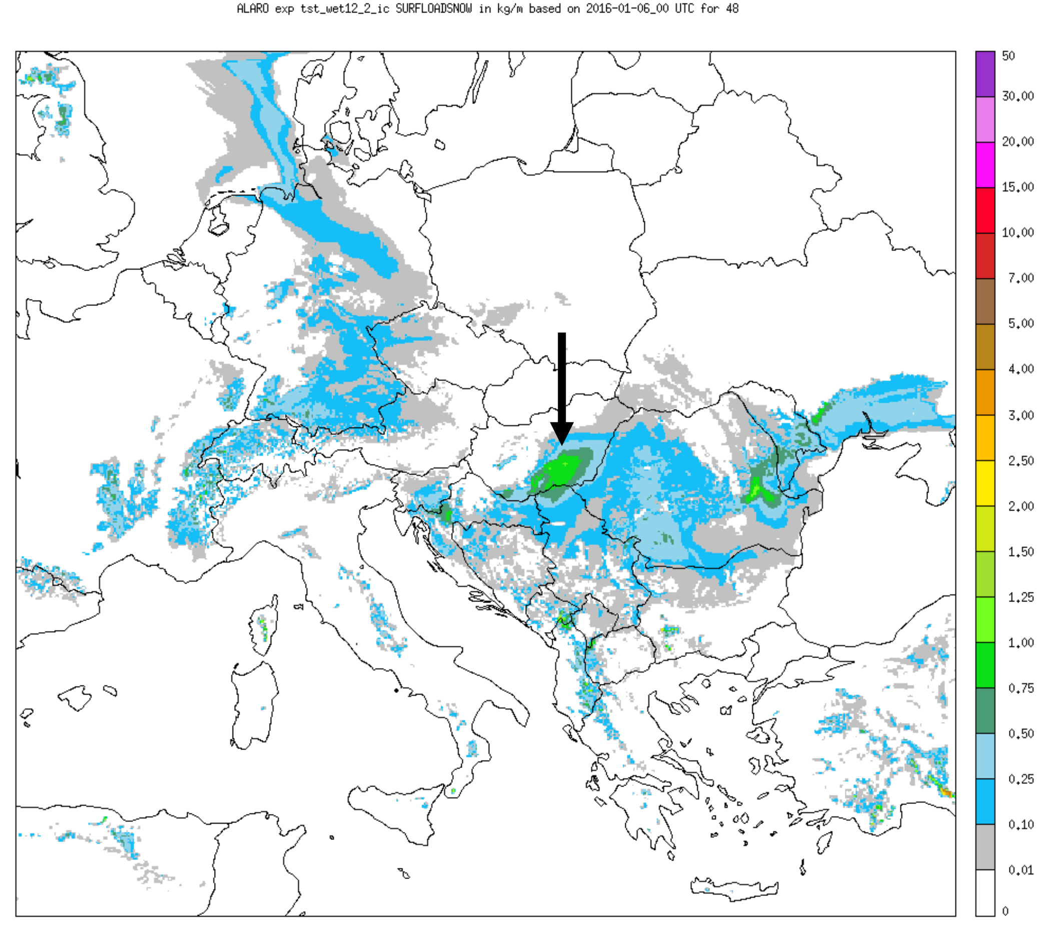
Ice load



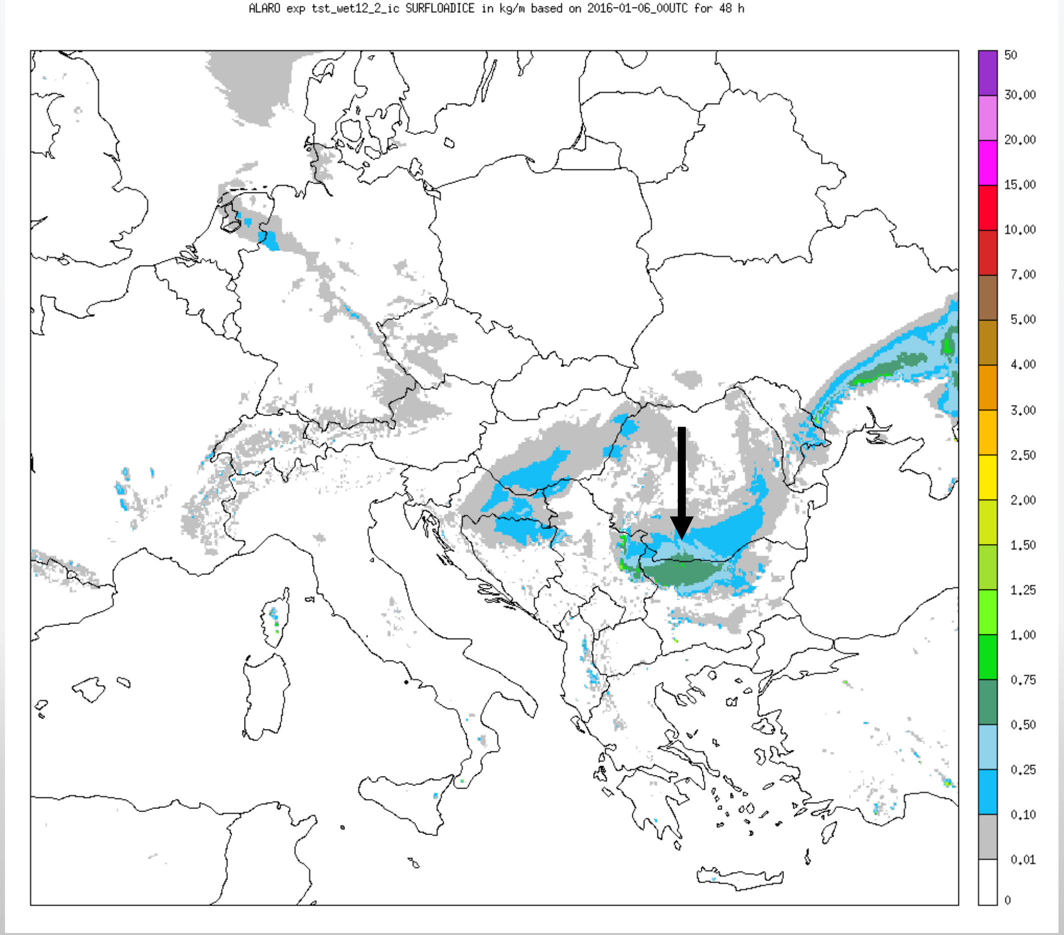
Mixed wet snow/ice events

- Wet snow and freezing rain on 6 January 2016 (Hungary and Bulgaria)

Wet snow load

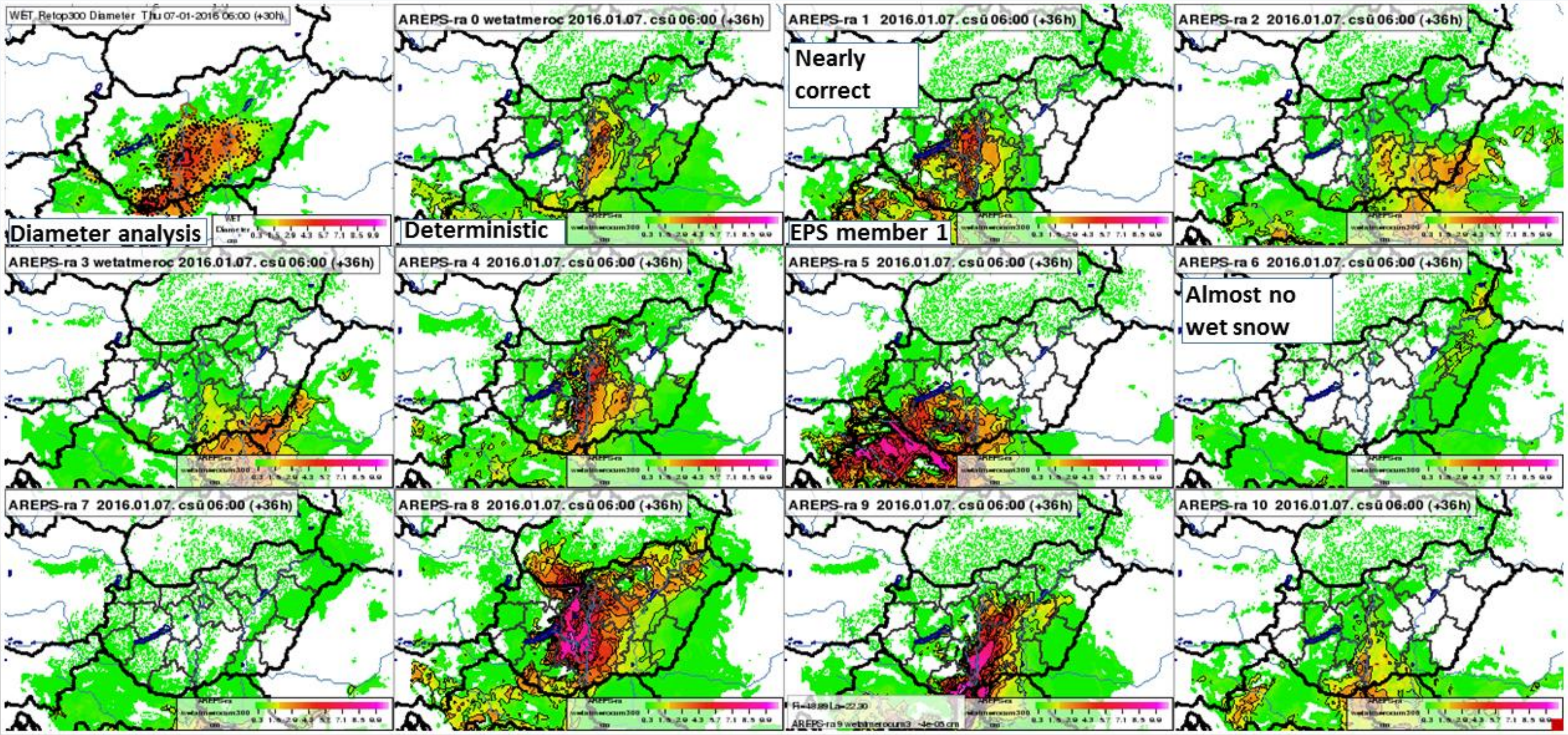


Ice load



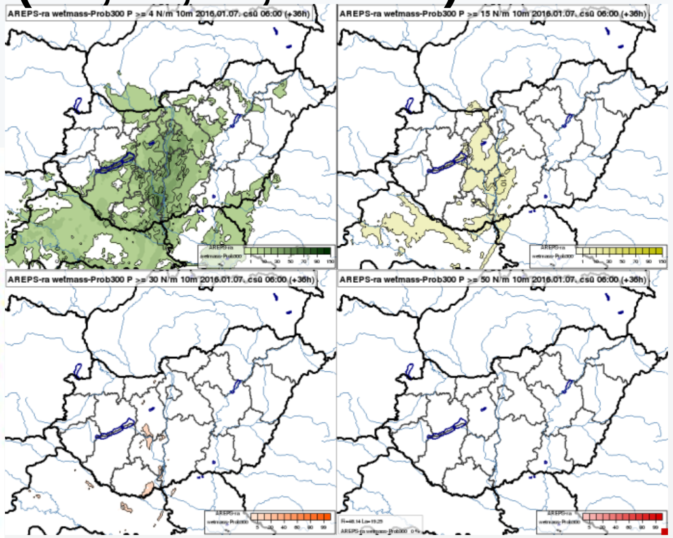
Forecast uncertainty (OMSZ)

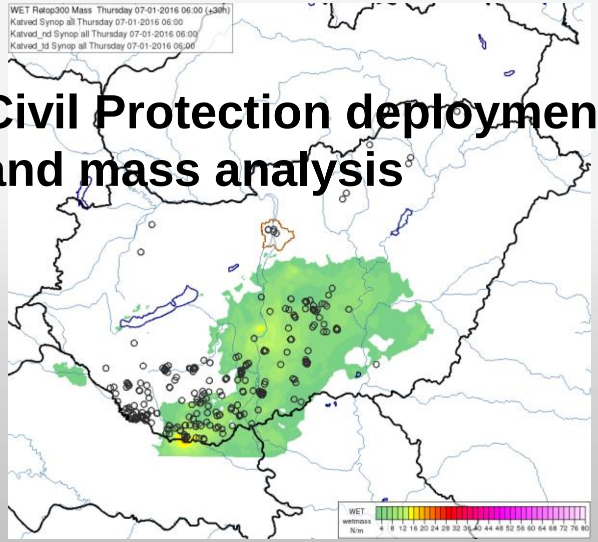
- EPS – first tests with AROME (from Simon et al., 2018, Somfalvi-Tóth et al., 2018)
- High sensitivity on forecast 2m temperature



Wet snow diameter diagram for 11 members + analysis

Probability of wet snow mass (> 4, 15, 30, 50 N/m)





Civil Protection deployments and mass analysis

Conclusion

- The parameterization focuses on forecast of direct impact of winter precipitation on high voltage power lines. Significant events start from 3 kg/m loads and are rare (usually wind is important). For other power lines, substantial (often indirect) damage is already observed by ~1 kg/m loads or even less.
- Unfortunately, there is very little (published) load observation
- There are many ways to improve, e.g. to specify the fall speed velocity of snowflakes and rain droplets, LWC of the snow sleeve, etc.
- Loads were probably often underestimated with respect to OBS and known damage, sometimes due to problems with precipitation type. It can be important to use high (2 km) resolution (mountain areas, etc.)

Acknowledgements

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