The impact of mineral dust deposition on the snow albedo

Anika Rohde, S. Werchner, G. Hoshyaripour, H. Vogel, B. Vogel

Karlsruhe Institute of Technology (KIT) - Institute of Meteorology and Climate Research

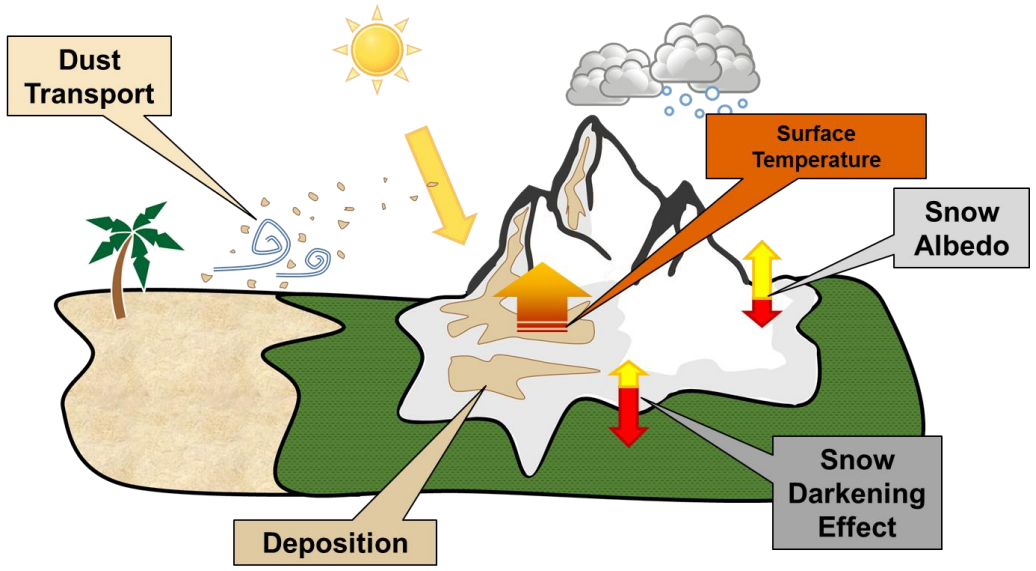
Objective and research questions

- implementation of the impact of aerosols on the snow albedo in

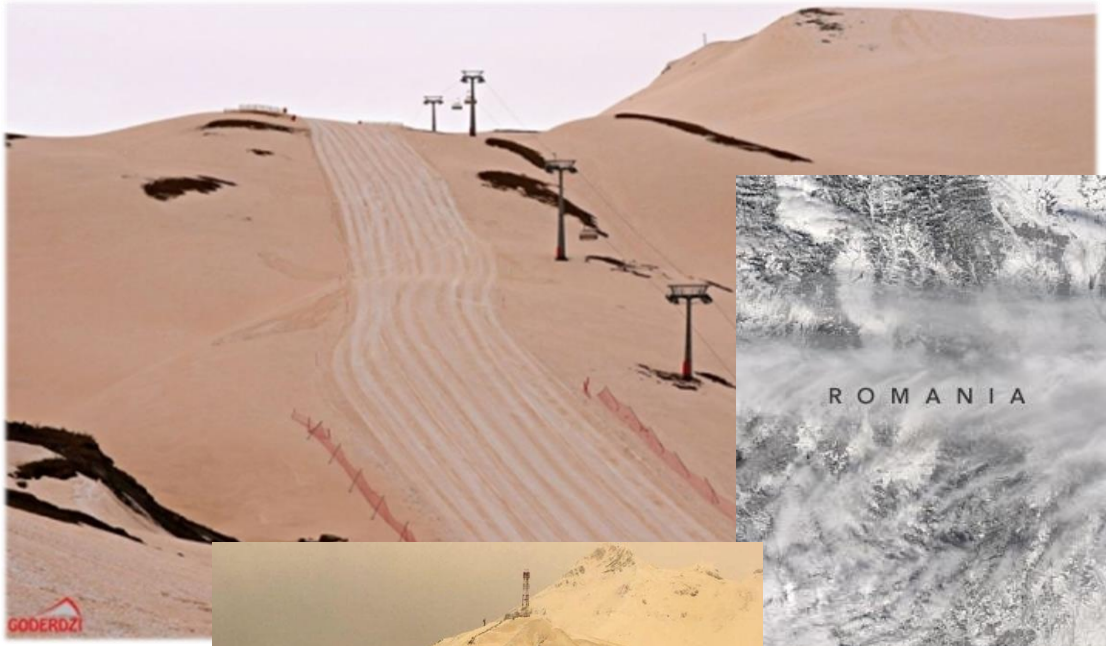
- quantification of the impact during major dust events

- feedbacks in the atmosphere
  - → shortwave radiation flux
  - → surface temperature
  - → air temperature

- high resolution simulations

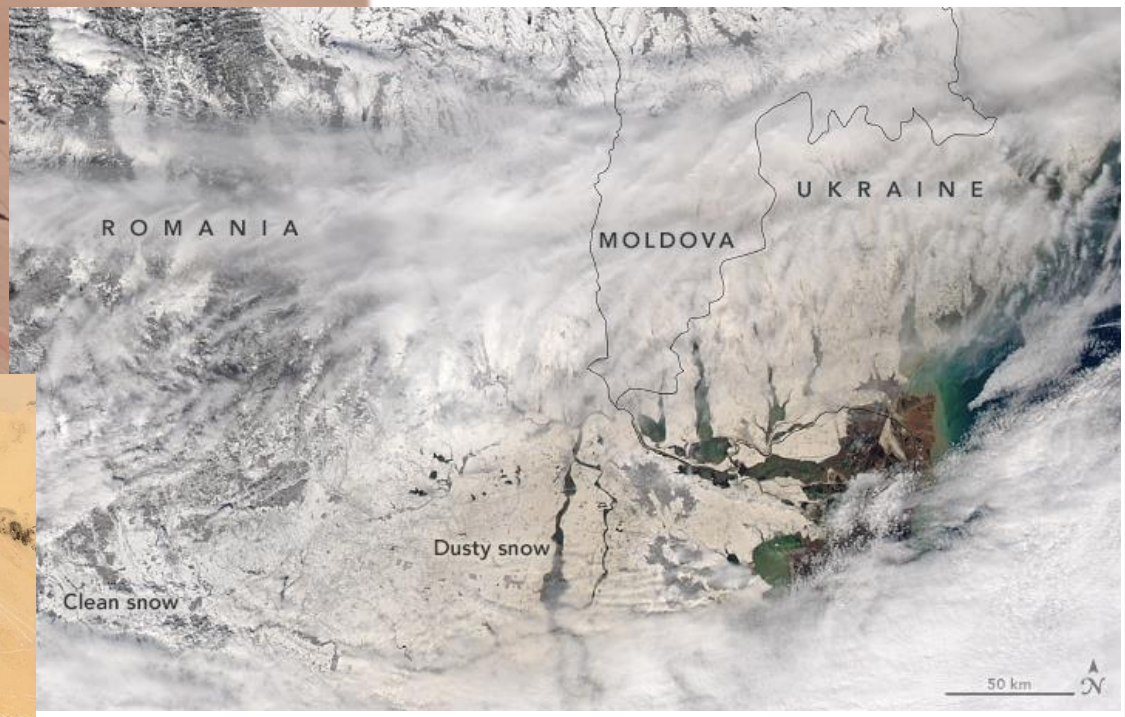


Aerosol Deposition on Snow (March 2018)



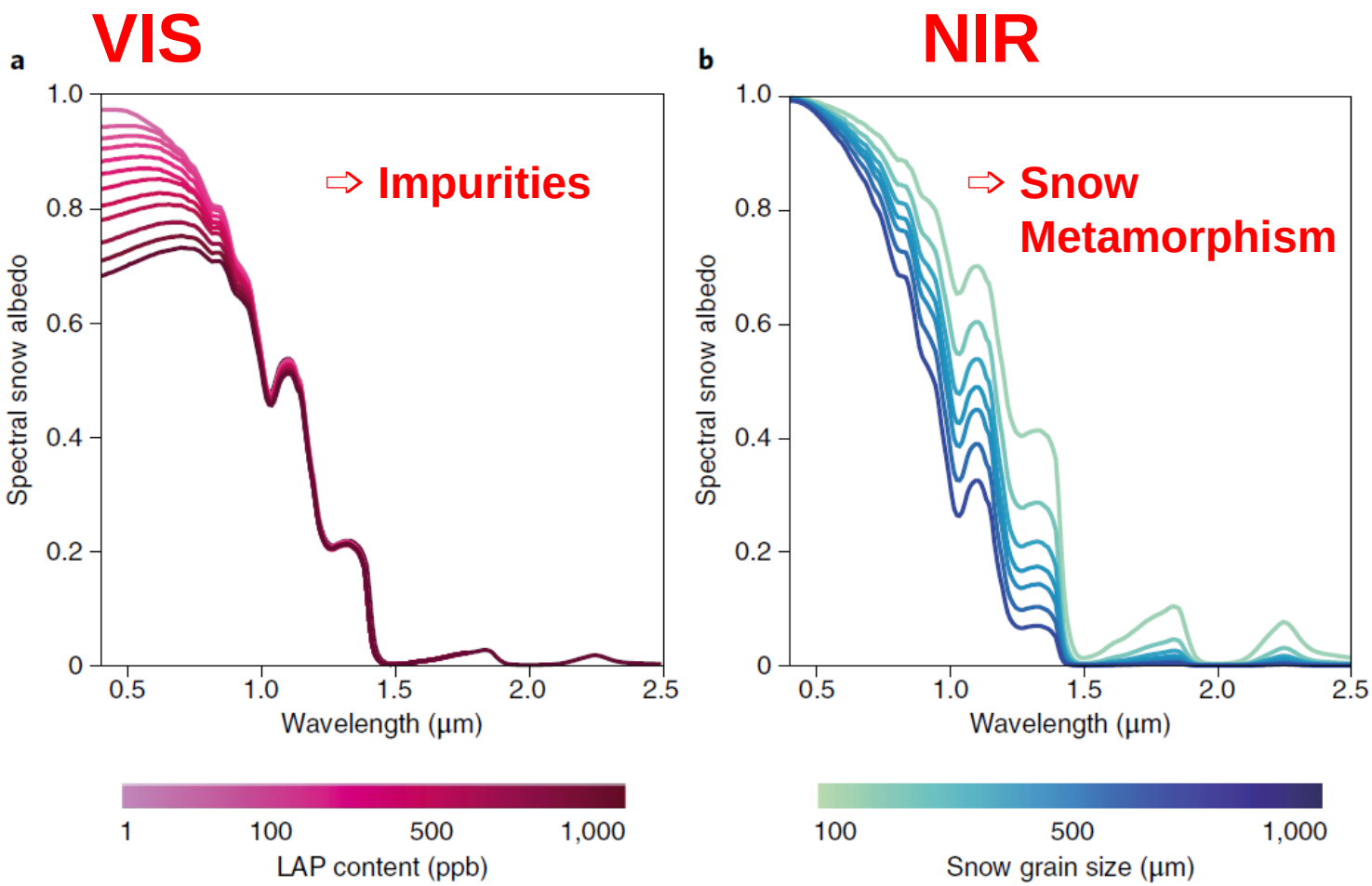
Credits: Goderdzi Resorts

Credits: BBC



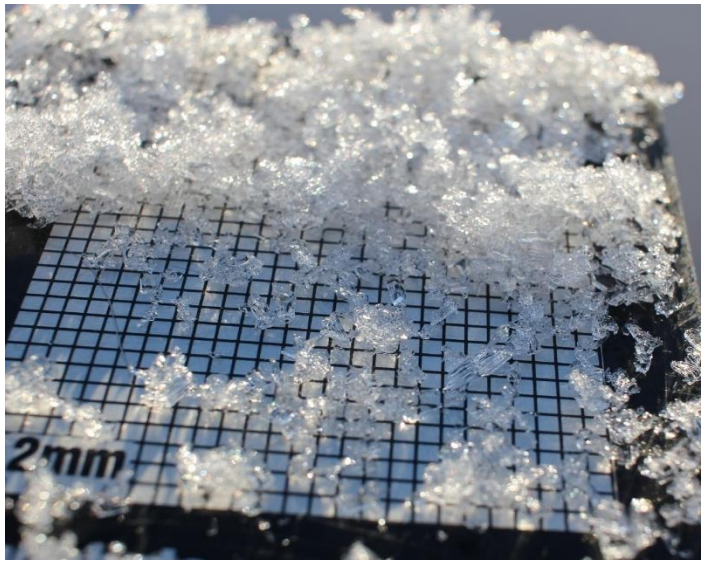
Credits: NASA

Snow Albedo: Skiles et al., 2018



New Implementation: Optical Grain Size

Snow Aging (Metamorphism)
= growth of ice crystals/snow



modified equation from MOSES 2.2
(Essery et al., 2001)

$$r(t+\Delta t) = \left[r(t)^2 + \frac{G_r}{\pi}\Delta t \right]^{1/2} - [r(t) - r_0]\frac{S_f \Delta t}{d_0} + [r_{max} - r(t)]\frac{z_{rain}\Delta t}{z_{rain,max}}$$

➡ growth factor

➡ snow fall

➡ rain fall

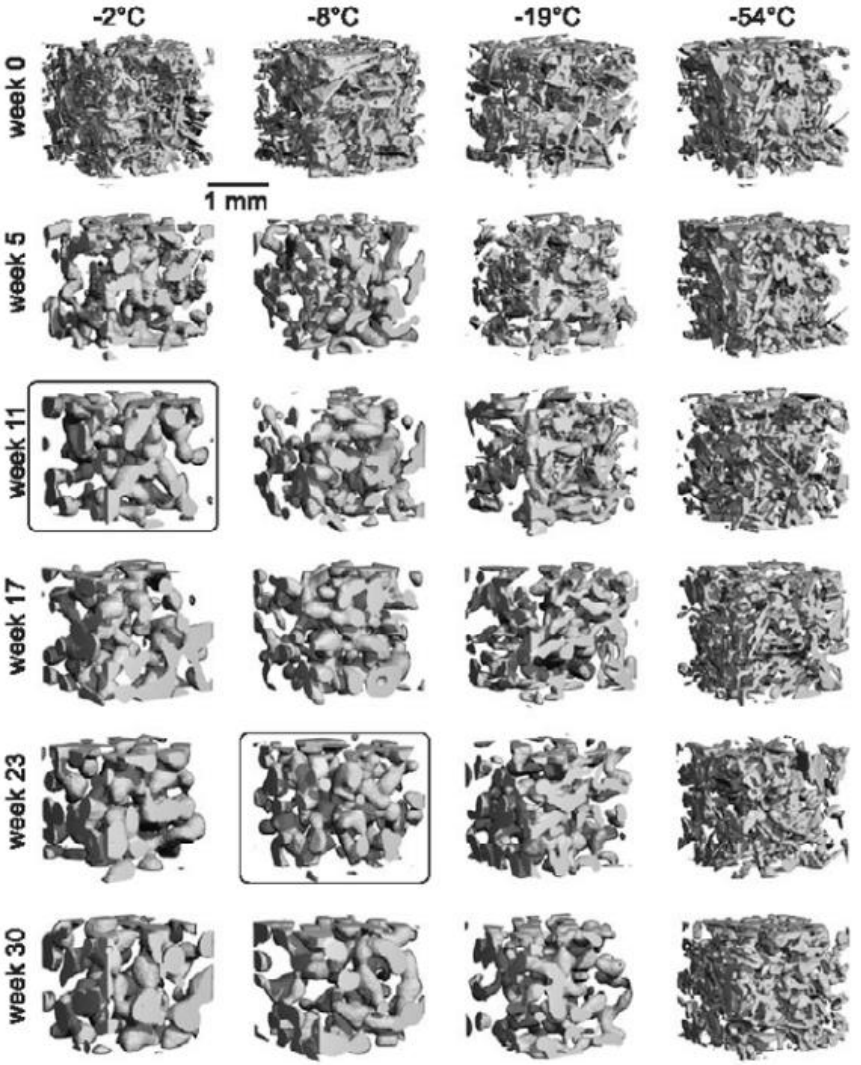
New Implementation: Optical Grain Size

comparison to a laboratory study by Kaempfer & Schneebeli, 2007

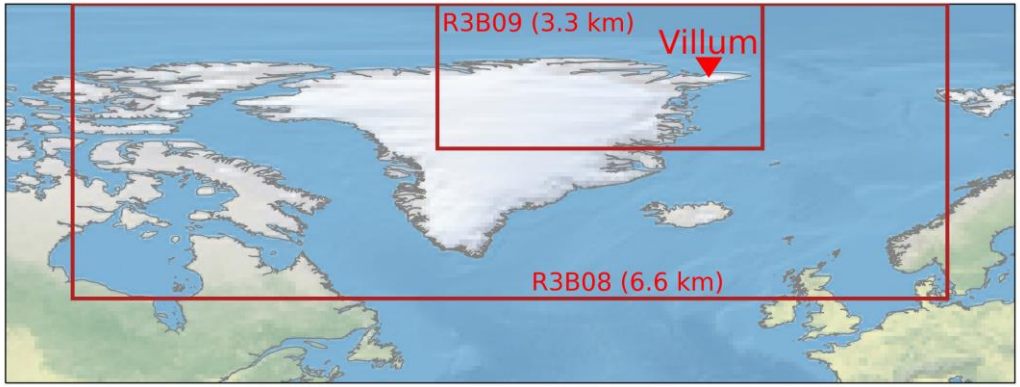
→ isothermal growth in cold room

→ temperature dependent growth

→ **but**: laboratory conditions differ from outdoor conditions (solar radiation, wind, …)



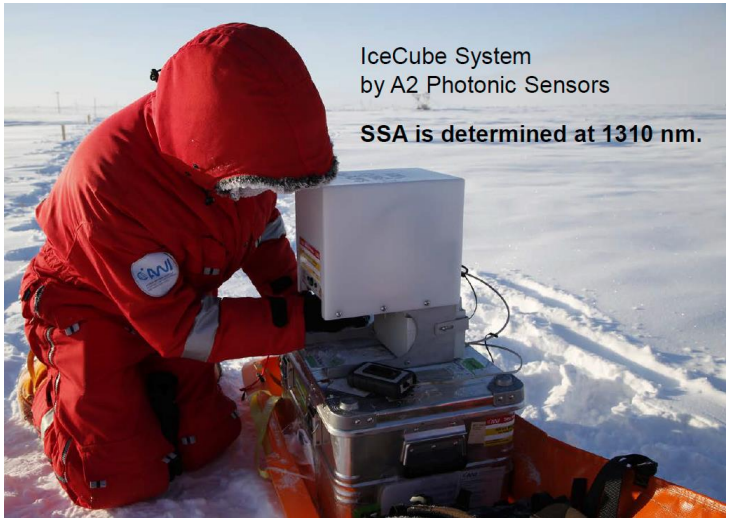
Case Study PAMARCMiP



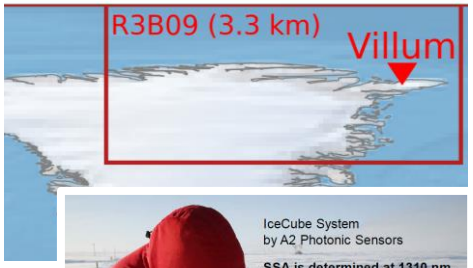
19.03.2018 – 05.04.2018

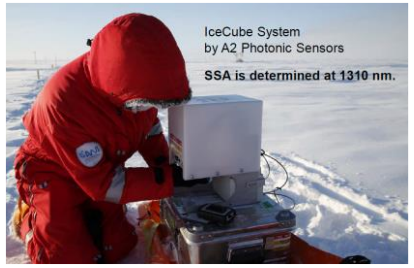
ICON-LAM

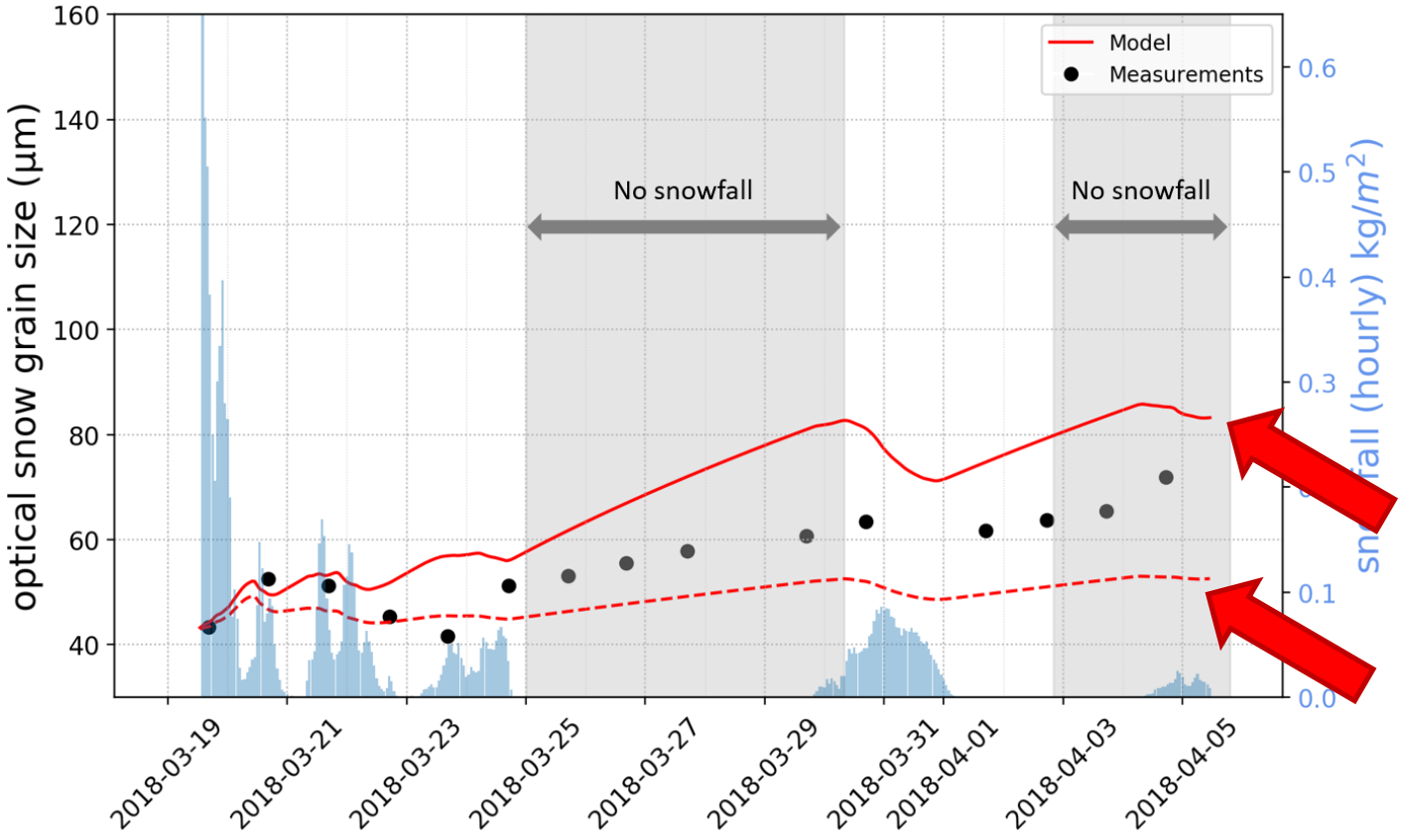
- no ART (albedo of clean but aging snow)
- boundary data: 6h IFS



PAMARCMiP







new parametrization

growth rate from laboratory measurements Kaempfer & Schneebeli, 2007

Special thanks to E. Jäkel, G. Birnbaum

New Implementation: Spectral Snow Albedo

Mie Calculations:

- extinction coefficient
- scatter coefficient
- asymmetry factor

→ New LUT in ICON (18 bands)

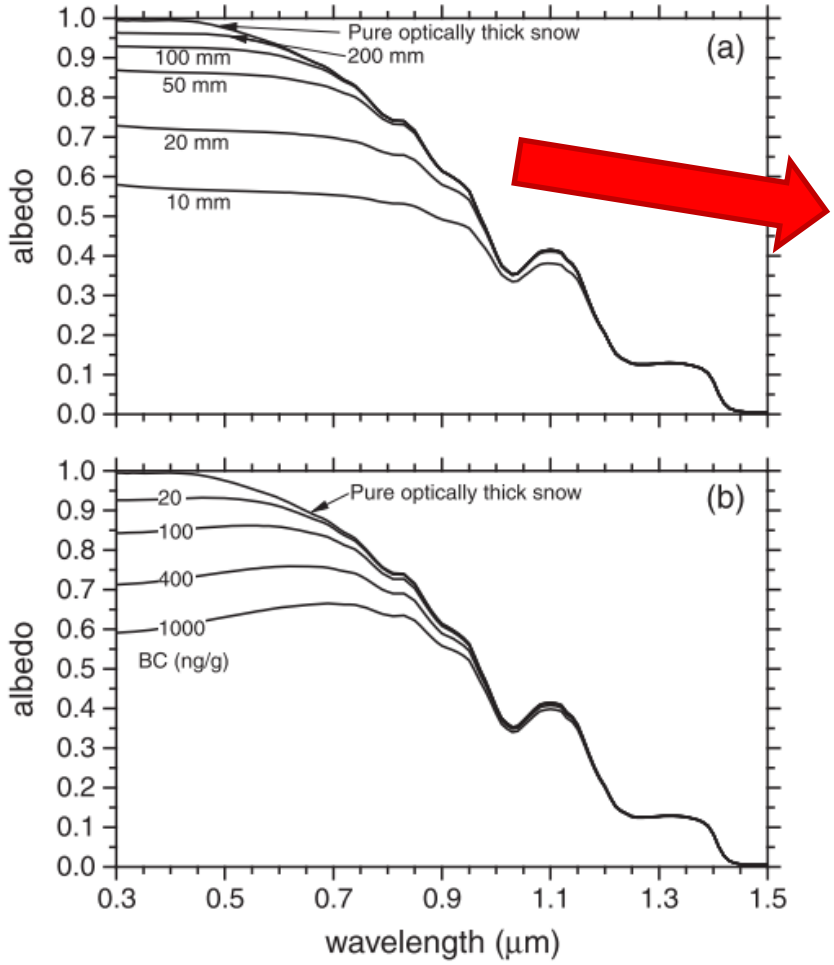
Spectral Snow Albedo according to Wiscombe & Warren, 1980:

$$a_d^{\infty} = \frac{2\,\tilde{\omega}^*}{1+P}\left\{\frac{1+b^*}{\xi^2}\left[\xi - \ln(1+\xi)\right] - {}^{b^*}/_{2}\right\}$$

Optically thin snow layer

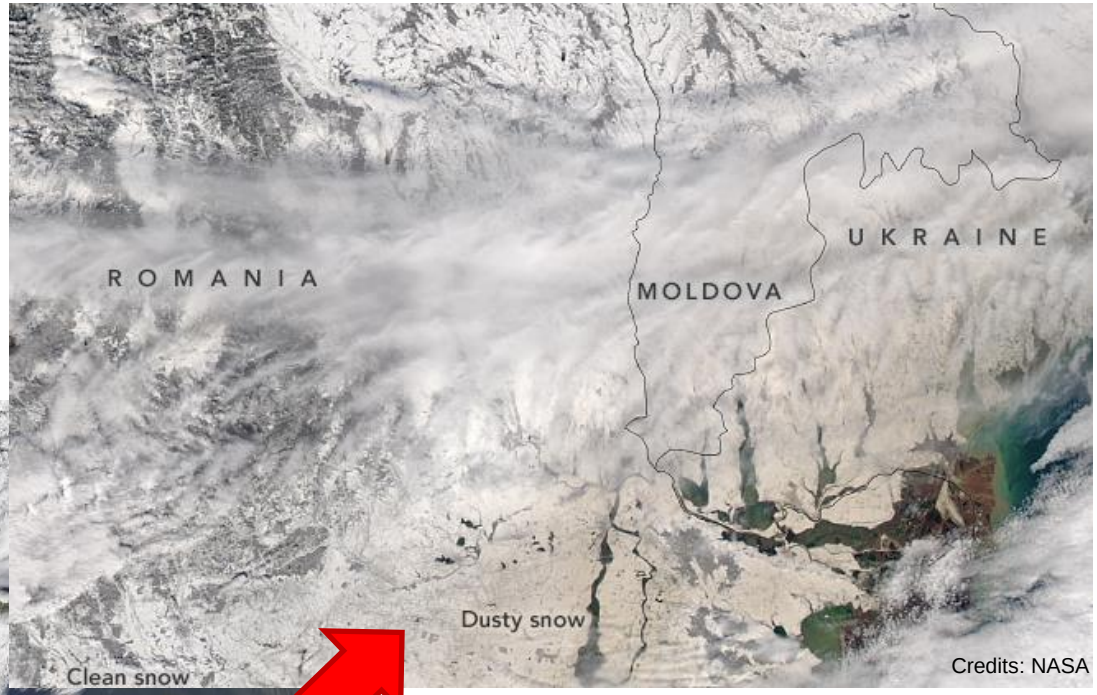
thin snow layer

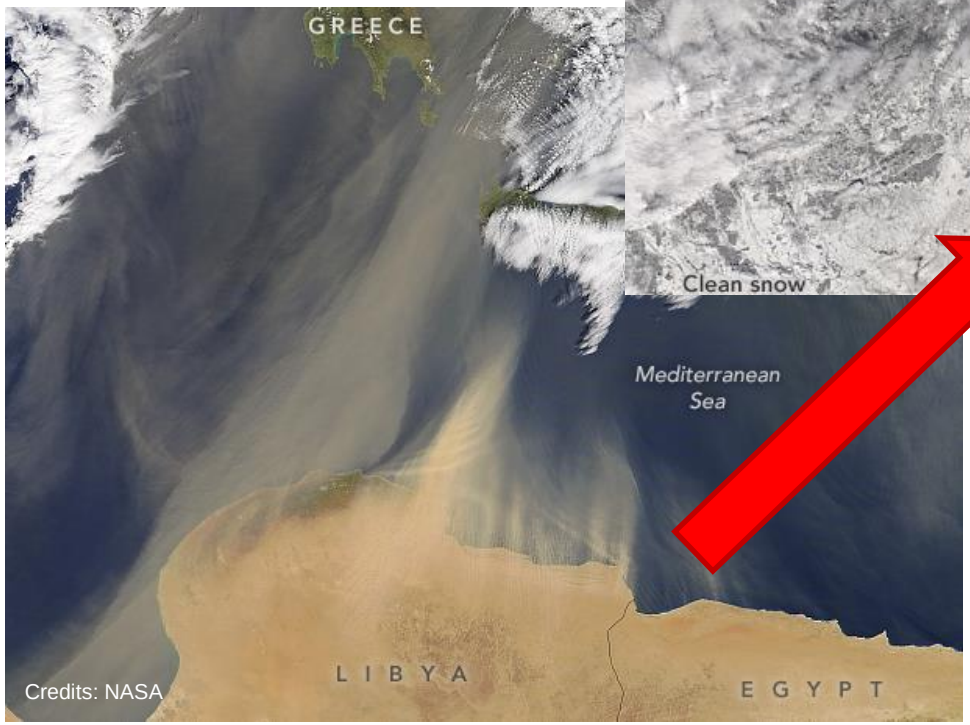
black carbon



Warren, 2013

Dust Event March 2018





Model set up:

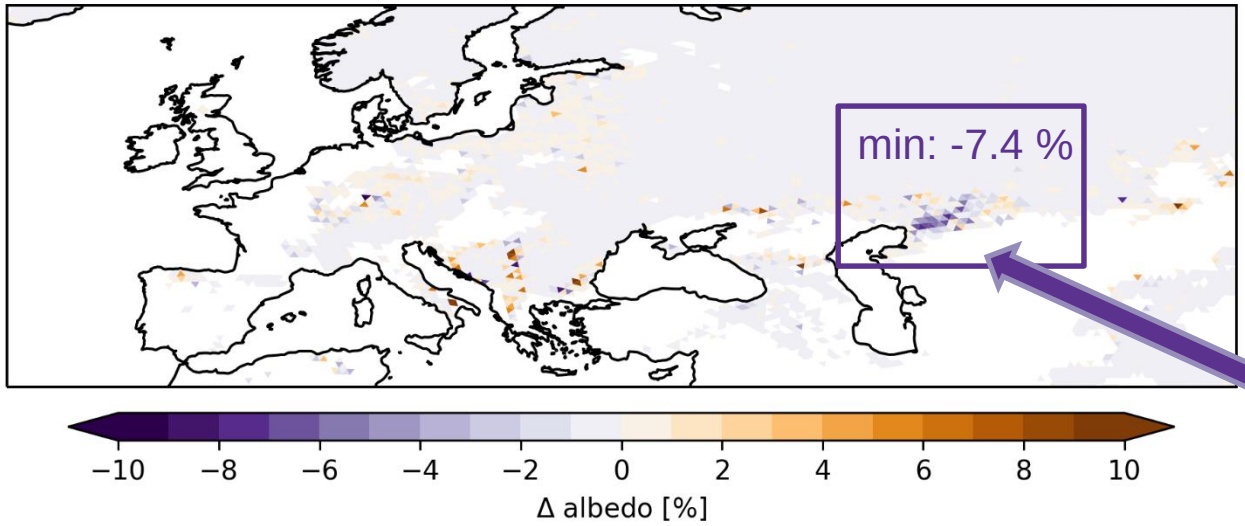
horizontal resolution: 40 km

simulation time: 3 days

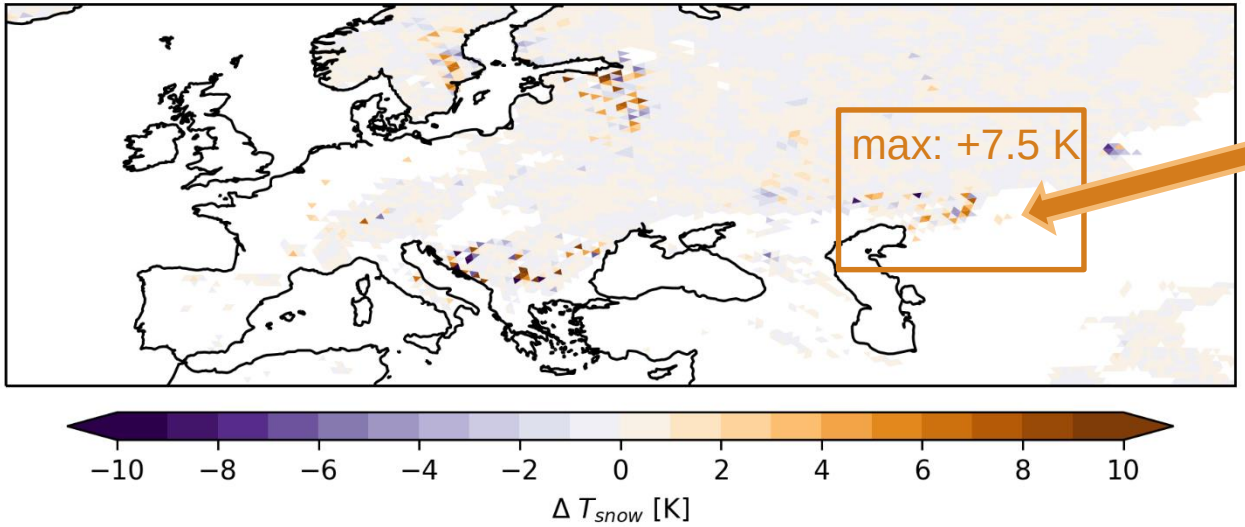
initial data: IFS & ICON-ART dust

Results

22-03-2018 00:00 + 29.0 h



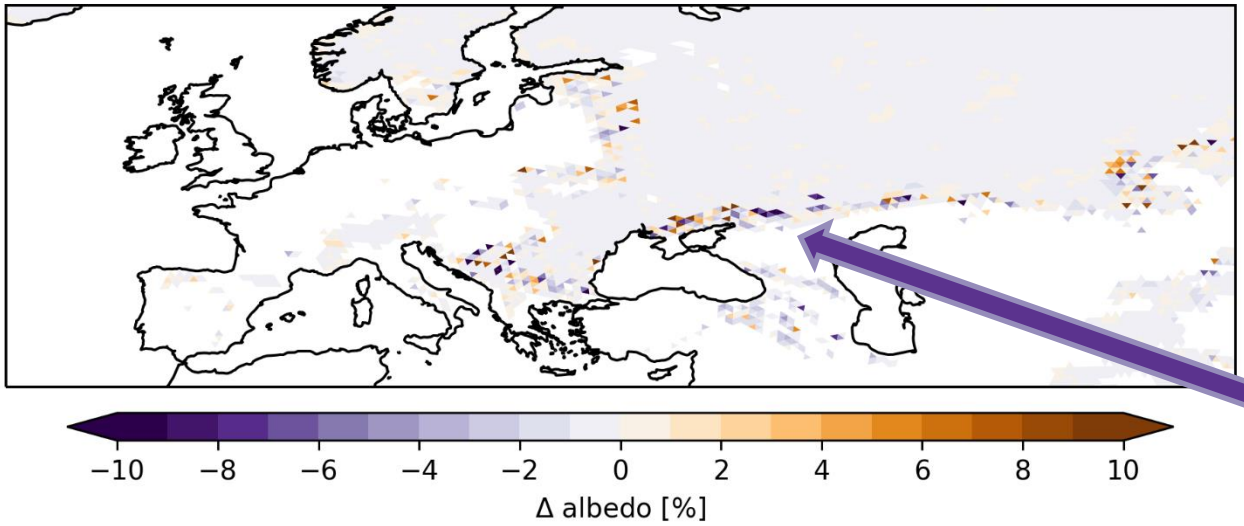
decrease of snow albedo



increase of snow temperature in top snow layer

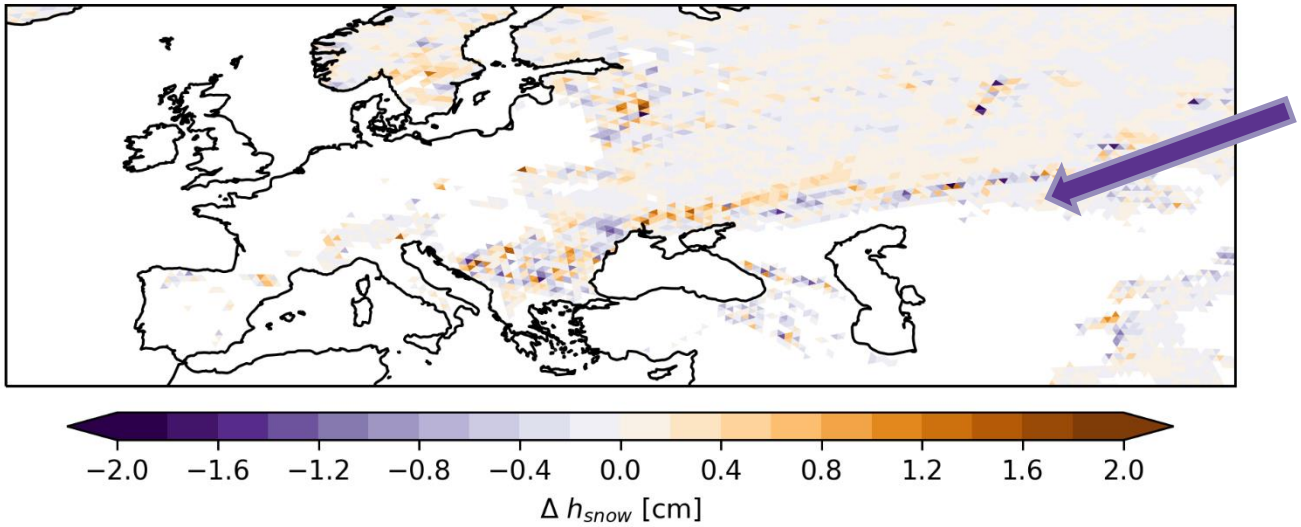
Results

22-03-2018 00:00 + 72.0 h



near snow line:

stronger decrease of snow albedo



decrease of snow height

Summary and Outlook

New implementations in ICON-ART

- new variable: optical equivalent snow grain size
- aging of snow grains
- spectral snow albedo
- mixing of optical properties of snow and dust

Case studies

- Greenland (PAMARCMiP)
- Dust Event 2018

Next steps

- layering of aerosol concentrations
- high resolution LAM-simulation

Senator Beck Basin,
San Juan Mountains, Colorado
Skiles et al., 2017

References

Essery, R., Best, M., & Cox, P. (2001). MOSES 2.2 technical documentation.

Kaempfer, T. U., & Schneebeli, M. (2007). Observation of isothermal metamorphism of new snow and interpretation as a sintering process. *Journal of Geophysical Research, 112*(D24). doi:10.1029/2007jd009047

Skiles, S. M. and T. Painter (2017). Daily evolution in dust and black carbon content, snow grain size, and snow albedo during snowmelt, Rocky Mountains, Colorado. *Journal of Glaciology* 63(237): 118-132.

Skiles, S. M., Flanner, M., Cook, J. M., Dumont, M., & Painter, T. H. (2018). Radiative forcing by light-absorbing particles in snow. *Nature Climate Change, 8*(11), 964-971. doi:10.1038/s41558-018-0296-5

Warren, S. G. (2013). Can black carbon in snow be detected by remote sensing? *Journal of Geophysical Research: Atmospheres, 118*(2), 779-786. doi:10.1029/2012jd018476

Warren, S. G., & Wiscombe, W. J. (1980). A model for the spectral albedo of snow. II: Snow containing atmospheric aerosols. *Journal of the Atmospheric Sciences*, *37*(12), 2734-2745.

Wiscombe, W. J., & Warren, S. G. (1980). A model for the spectral albedo of snow. I: Pure snow. *Journal of the Atmospheric Sciences*, *37*(12), 2712-2733.