A new snow melting scheme for COSMO

"new": explicit consideration of snow liquid water fraction

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Paper in preparation for submission to Geosci. Model Dev.

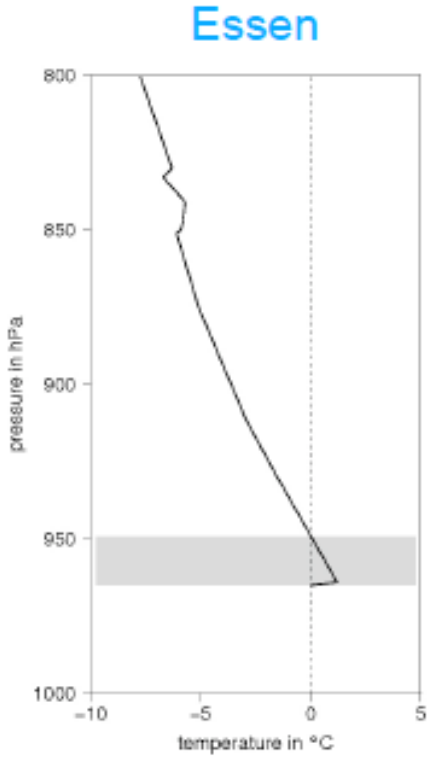
Motivation

Intense snowfall occurs
- often with T_s close to 0°C
- sometimes in situations with near-surface melting layer producing wet snow

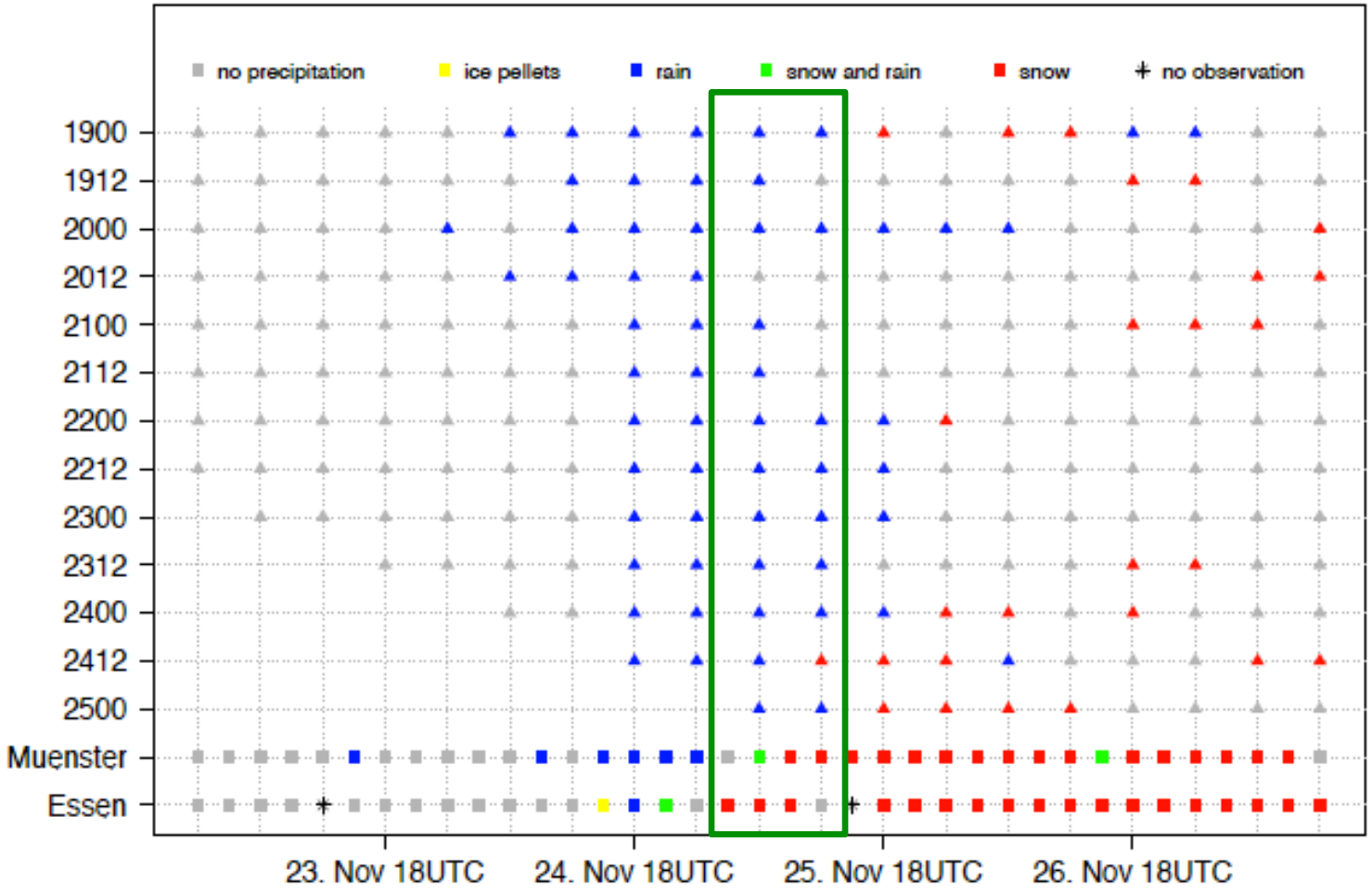
Damage to infrastructure is particularly large for wet snow

Forecasts often fail in these situations (critical transition rain – wet snow)

Part of this forecasting problem might be due to oversimplified treatment of snow melting



Motivation: ECMWF forecast performance



period of wet snowfall

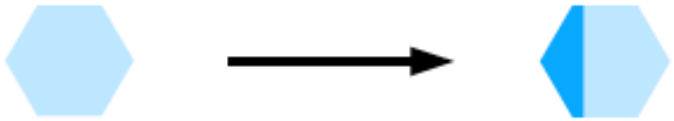
Melting Scheme

Current Melting Scheme of the COSMO Model

generated meltwater is instantaneously converted into rain
→ NO internal mixing of liquid and solid water

New Melting Scheme

generated meltwater is NOT instantaneously converted into rain
→ internal mixing of liquid and solid water



$$LWF = \frac{m_w}{m_s}$$

Liquid
Water
Fraction

Individual Snowflake

Mass change of the liquid water generated by melting following *Mitra et al. (1990)*

$$\left(\frac{dm_w}{dt}\right)_{melt} = G(T, e)\, C_s\, F_s$$

parameterize as functions of D_s and LWF

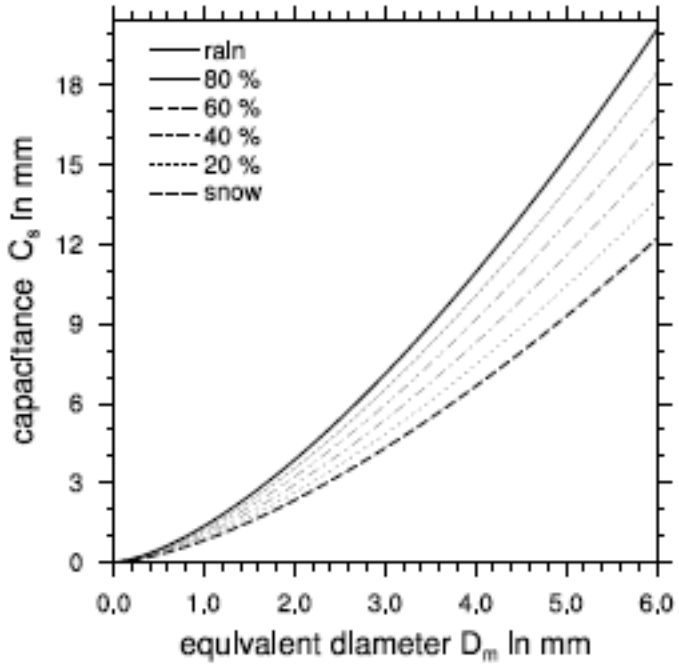
m_w	mass of the meltwater		
T	ambient air temperature	e	ambient vapor pressure
C_s	Capacitance of the snowflake	F_s	Ventilation coefficient

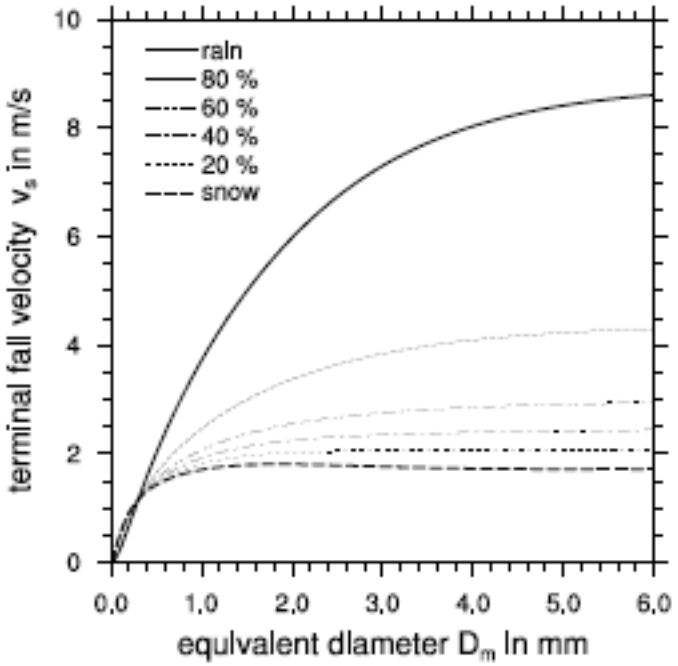
depends on the geometry of the snowflake

depends on the sedimentation velocity of the snowflake

Parameterization of $C(D_s, LWF)$ and $v(D_s, LWF)$

Use knowledge from wind tunnel experiments (Mitra et al. 1990)





Bulk scheme

old: L_s snow water content (ice)

new: $L_{s,i}$ snow water content (ice)
$L_{s,w}$ snow water content (liquid)

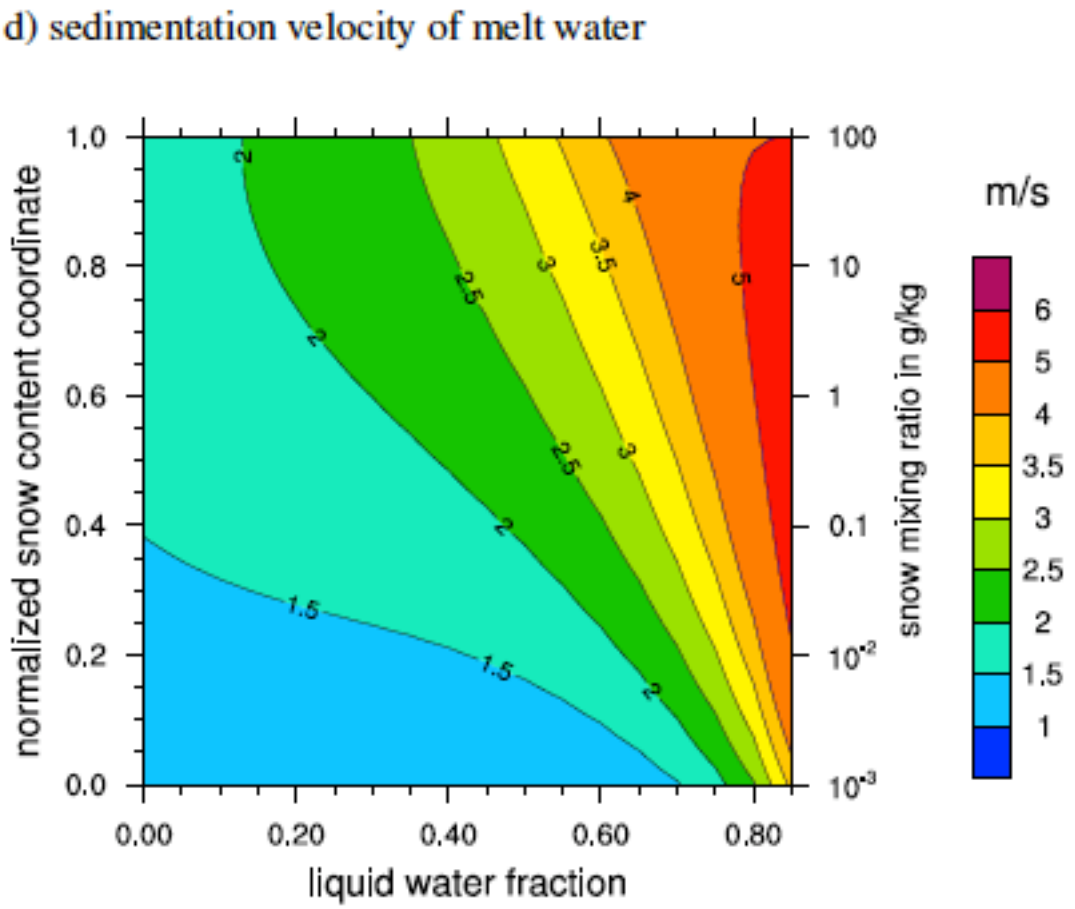
At every model time step: determine
- melting
- snow to rain conversion
- fall velocities of ice and liquid parts of snow

e.g., parameterization of melting:

$$\left.\frac{\partial L_{s,w}}{\partial t}\right|_{\text{melt}} = \int_{D^*}^{\infty} \left.\frac{dm_w}{dt}\right|_{\text{melt}} f_m(D_s,\ell)\,dD_s$$

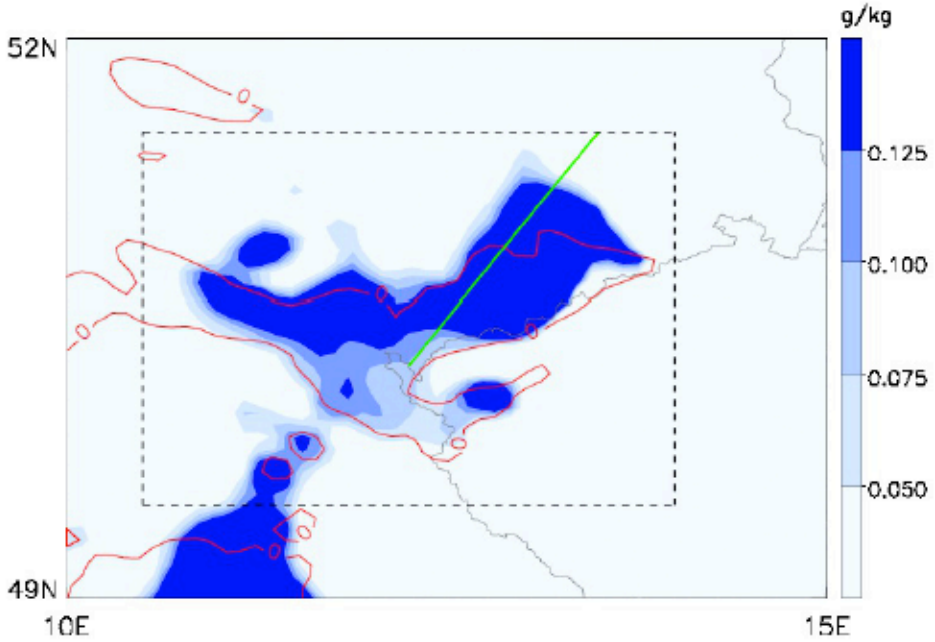
$$= G(T,e) \int_{D^*}^{\infty} C_m(D_s,\ell)\, f_v(D_s,\ell)\, f_m(D_s,\ell)\,dD_s$$

Approximation of integrals by polynomial functions

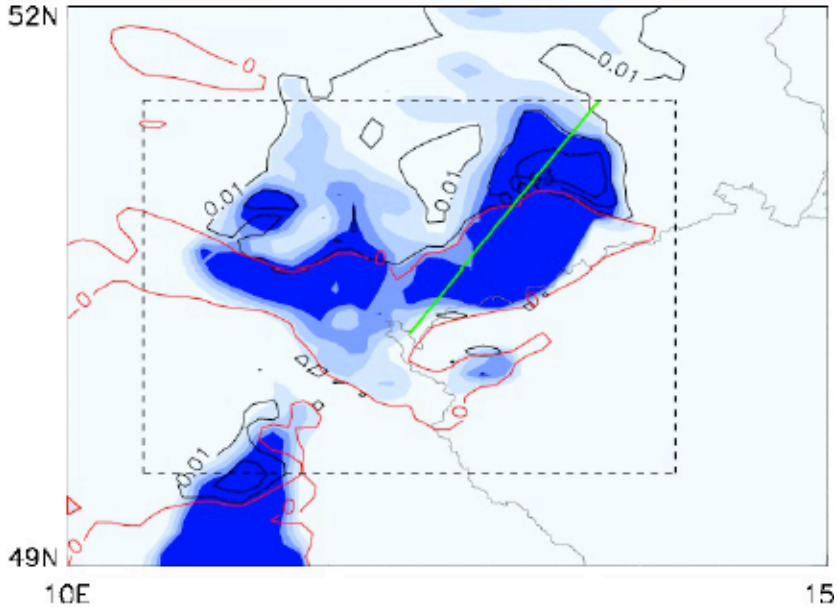


First case study: snowfall in E Germany on 16 Nov 2010

Consider on model level 8:
- snow mixing ratio
- meltwater mixing ratio (black contours)
- 0°C isoline (red)



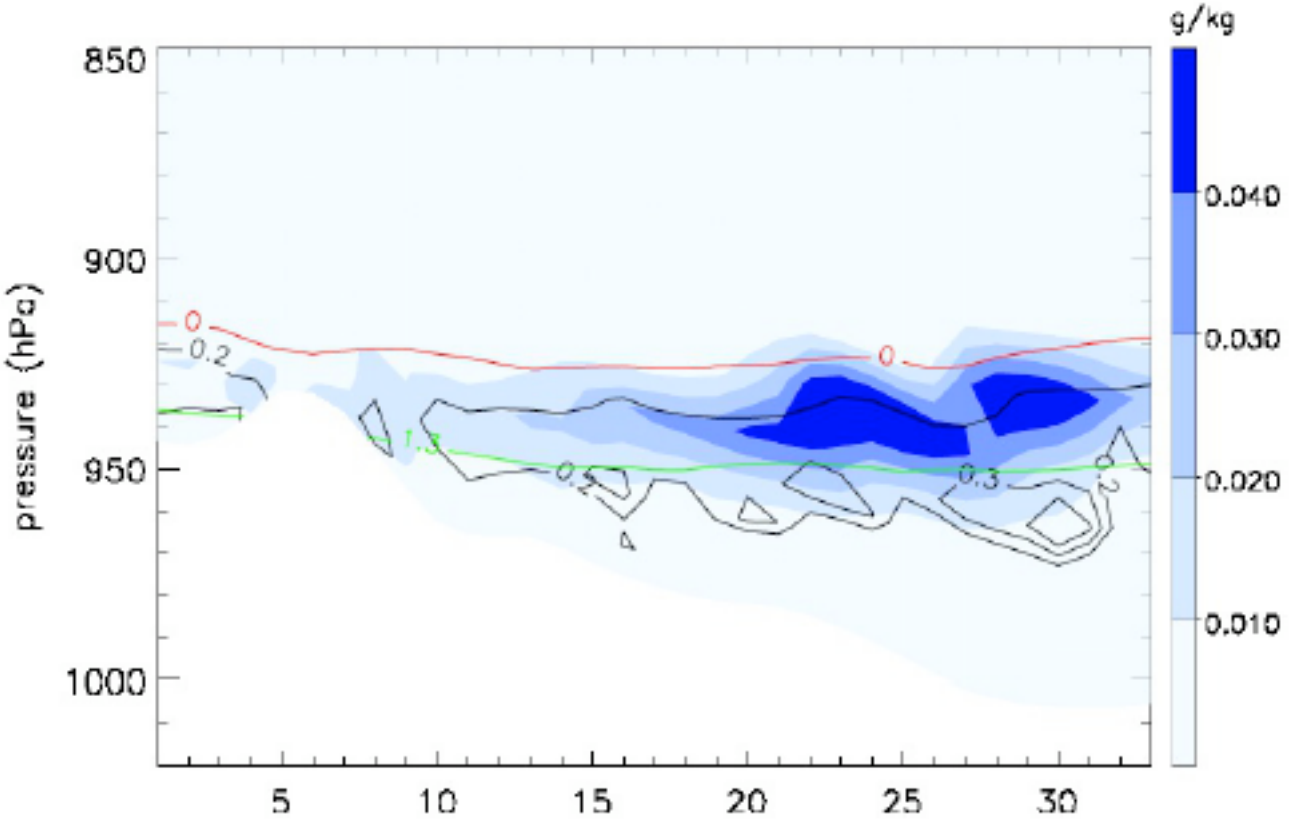
old scheme



new scheme

First case study: snowfall in E Germany on 16 Nov 2010

- meltwater mixing ratio (colors)
- liquid water fraction (black contours)
- red line: T=0°C; green line: T_w=1.3°C

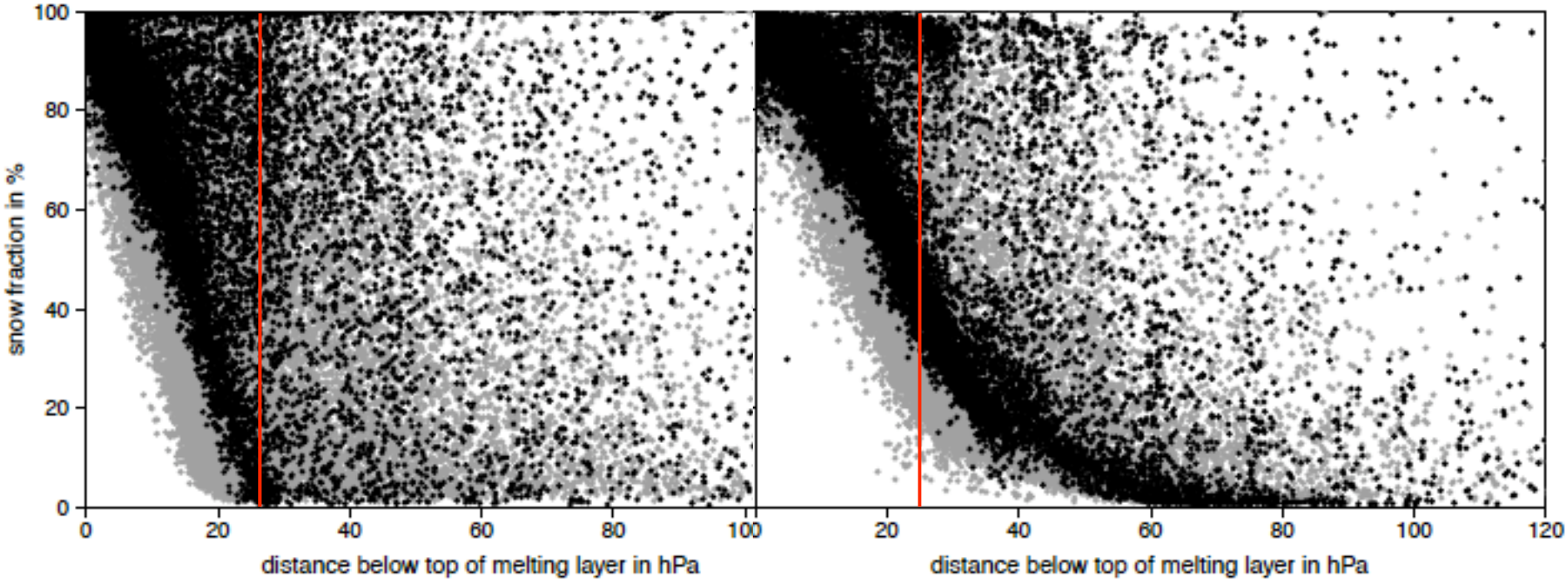


Comparison of old and new schemes

→ much slower melting of snow!

old scheme

new scheme



Summary and outlook

Snow melting with liquid water fraction of snow has been implemented in the COSMO 1-moment scheme

New scheme leads to slower melting process

New scheme allows simulation of „bright band“ due to melting

Open issues:

Is new scheme really better?
→ More case studies, QPF verification, comparison with radar

Is new scheme valuable for prediction of surface snow accumulation?

Can scheme be extended to capture freezing rain?