Improvements to melting snow behavior in an NWP bulk microphysics scheme

Emilie C. Iversen[1], Dr. Greg Thompson[2], Dr. Bjørn Egil Nygaard[1], KVT[1], NCAR[2]

emilie.claussen.iversen@norconsult.com

Kjeller Vindteknikk

Owned by: Norconsult

- High expertise within meteorology, measurements and wind energy
- Established 1998
- 32 employees
- Turnover 2018: ~6.5 M EUR
- Offices: Lillestrøm, Stockholm, Espoo
- Main markets: Norway, Sweden and Finland

Wind energy

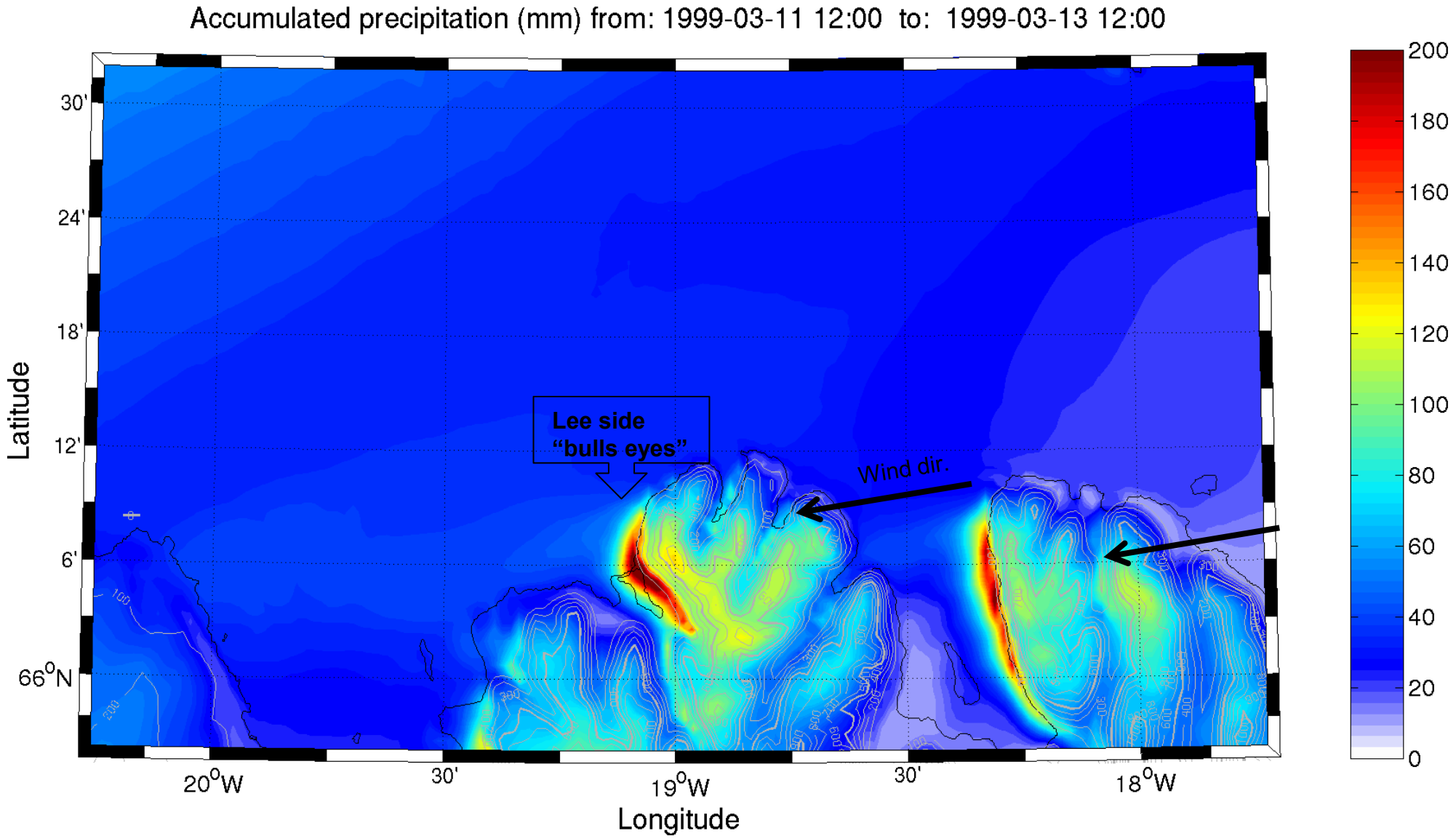
Power lines

Bridges

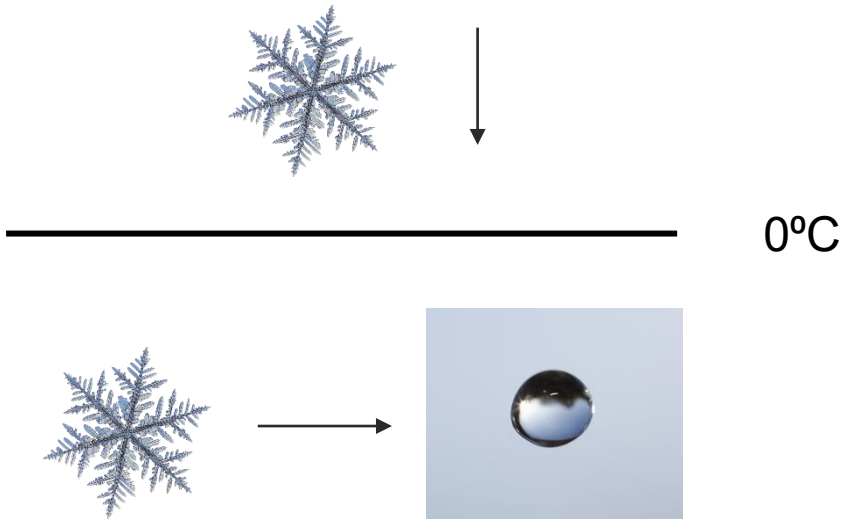
Backround

- Icebox project led by Statnett, the Norwegian TSO.
- Research on better modelling, prediction, surveilance and removal of atmospheric ice (AI) on power lines.
- Use the WRF (Weather Research & Forecast) regional model with Thompson-Eidhammer microphysics for modelling of AI.
- Both rime ice (supercooled liquid water droplets freezing) and wet snow icing (melting, sticky snow).
- Have seen limitations in the microphysics scheme to simulate melting snow.

Problem: Lee side precip. overprediction in melting zone

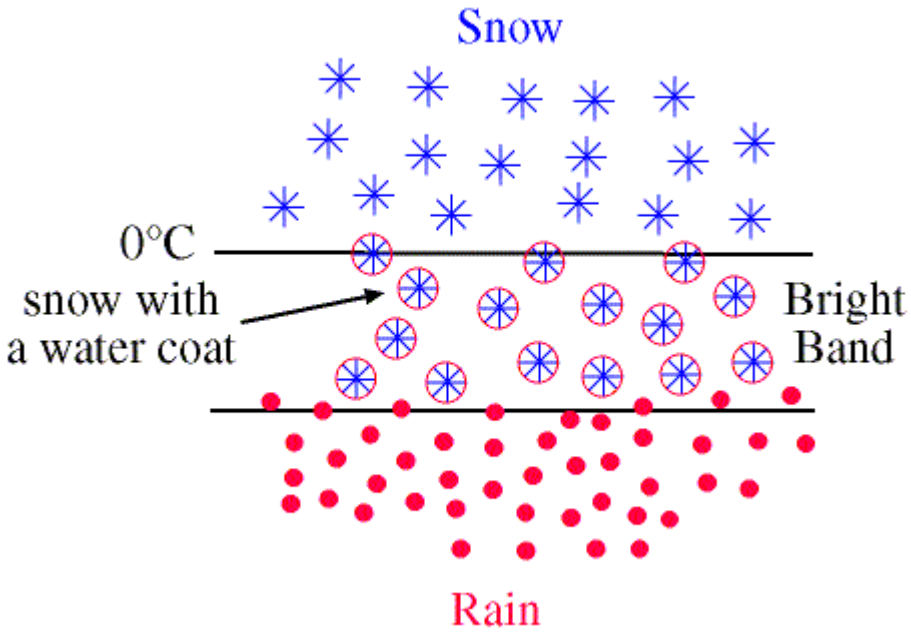


In the Thompson microphysics scheme:



Snow meltwater is shed into the scheme's rain category

"Reality":



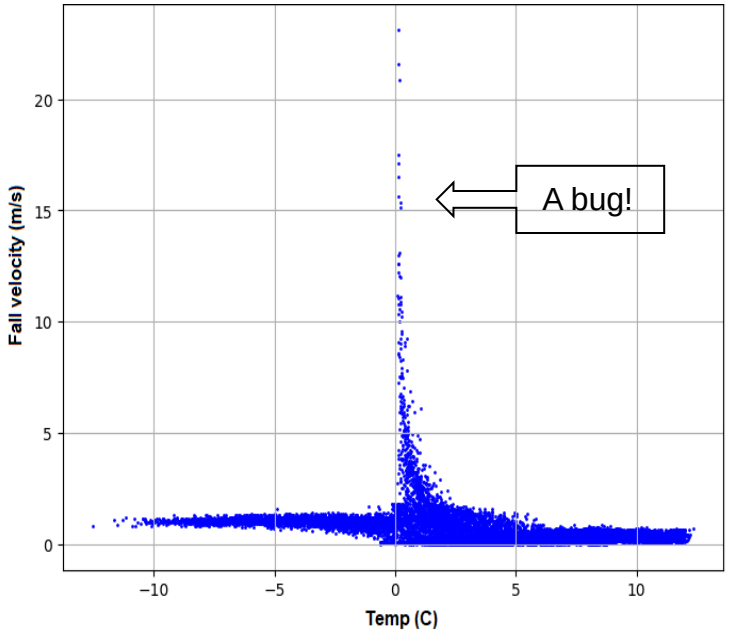
In the melting layer the melting snowflakes consist of a fraction of liquid water

In the Thompson microphysics scheme:

Melting level: $T > 0\,℃$

Code prior to WRF V3.8: $V_m = \max(V_s, V_r)$

Code preceding V3.8: $V_m = V_s \dfrac{V_r - V_s}{T - T_0}$

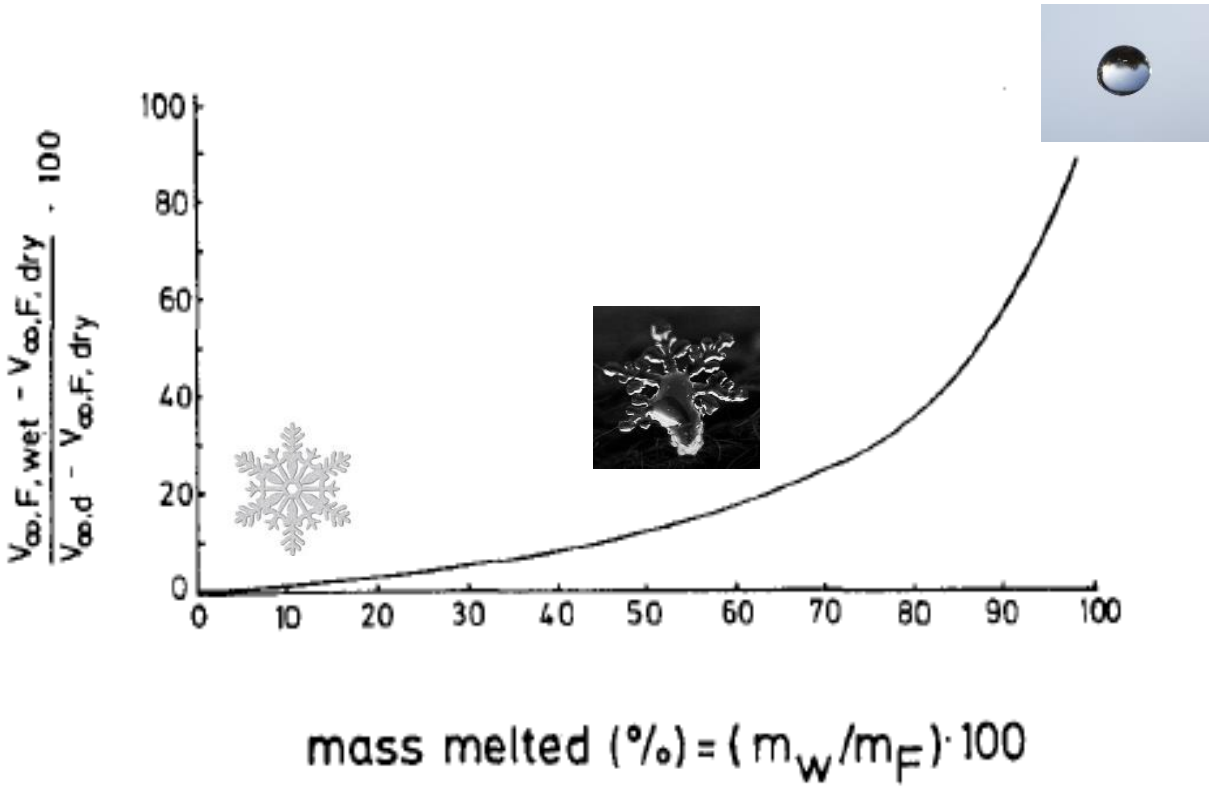


Due to this bug, the following references to the «old» scheme is wrt. WRF < V3.8

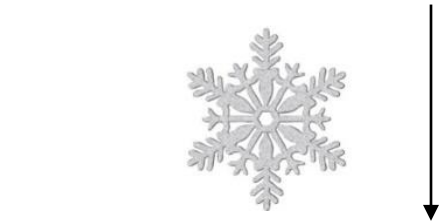
V_m= fall velocity of melting snow, V_r= fall velocity rain, V_s= fall velocity dry snow, T= air temp.

In “reality”: Melting snow fall speed is a function of its melted fraction

Mitra et al. (1990) (wind tunnel study)



….and melting level is determined by the wet bulb temp.



T = 0°C

RH < 100%

Evaporation

T > 0°C ,T_w < 0°C

T_w = 0°C

Melting

T_w > 0°C

T = air temp., T_w= wet bulb temp.

Therefore introduce new expression for melting snow fall speed:

Melted fraction ≈ liquid ratio, $LR = \frac{q_r}{q_r + q_s}$

$v(D) = \alpha D^{\beta} e^{-fD}$ *Thompson 04/08*

$V_m = f(V_r - V_s) + V_s$ *Mitra 90*

$V_m(D_w, f) \approx \frac{1}{g(f)} V_r(D_w)$ *Szyrmer & Zawadzki 99*

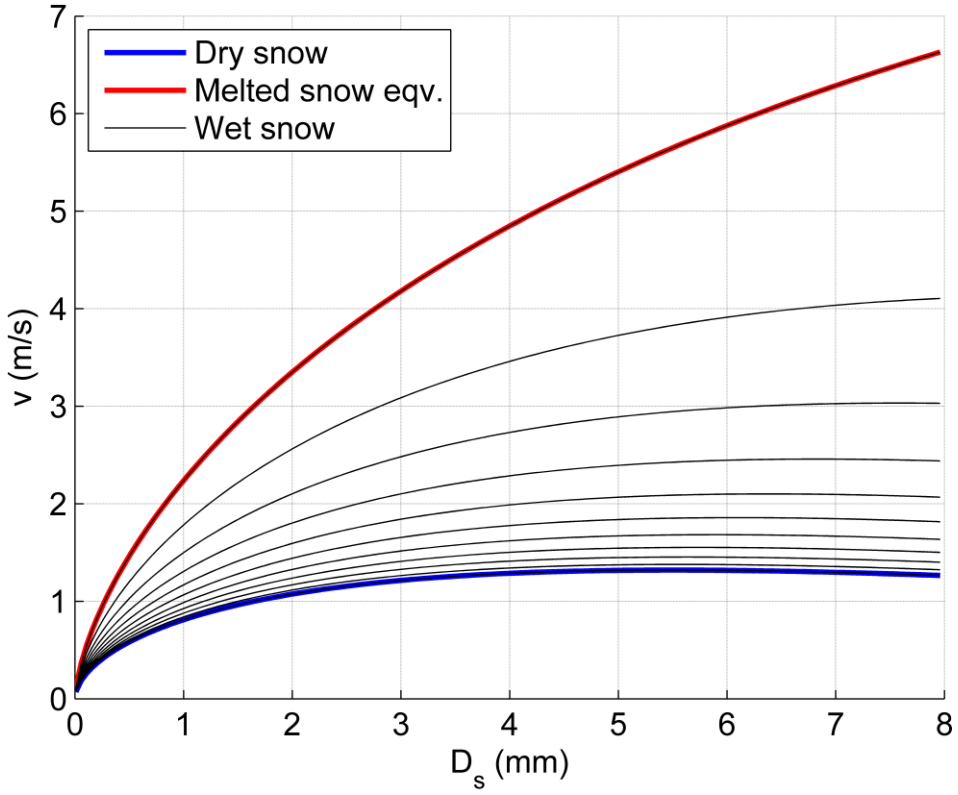
$g(f) \approx \frac{a}{\alpha} - c_g f - c_g f^2, \quad c_g = 0.5[\frac{a}{\alpha} - 1]$ *Szyrmer & Zawadzki 99*

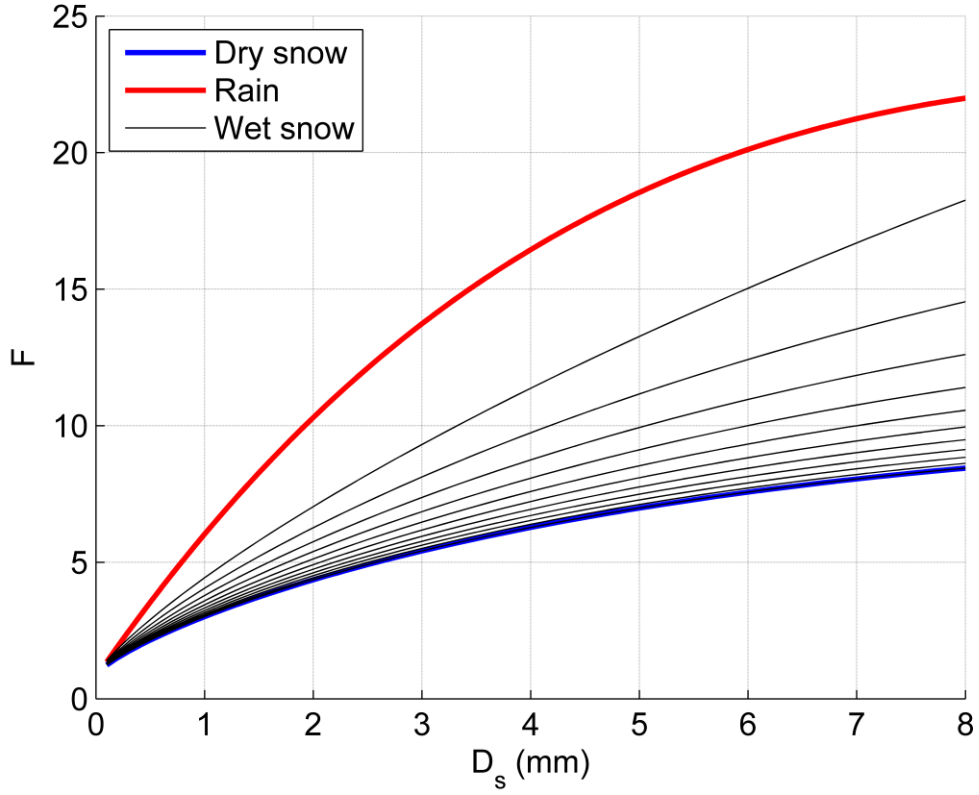
$$V_m(D_s, LR) = \frac{V_r(D_w)}{A - 0.5(A-1)LR - 0.5(A-1)LR^2}$$ *To fit Thompson*

$A = 6.176 D_s^{0.116} e^{(-9.925 D_s^{0.666} + 100 D_s)}$ *To fit Thompson*

- q – model mixing ratio
- α, β, f – fall speed constants from Thompson et al. (2008)
- D_w – melted snow eqv. diam.
- D_s – dry snow diam.
- α, a – fall speed constants from Langleben (1954) and Gunn & Kinzer (1949)

Result for fall speed and ventilation factor (F)





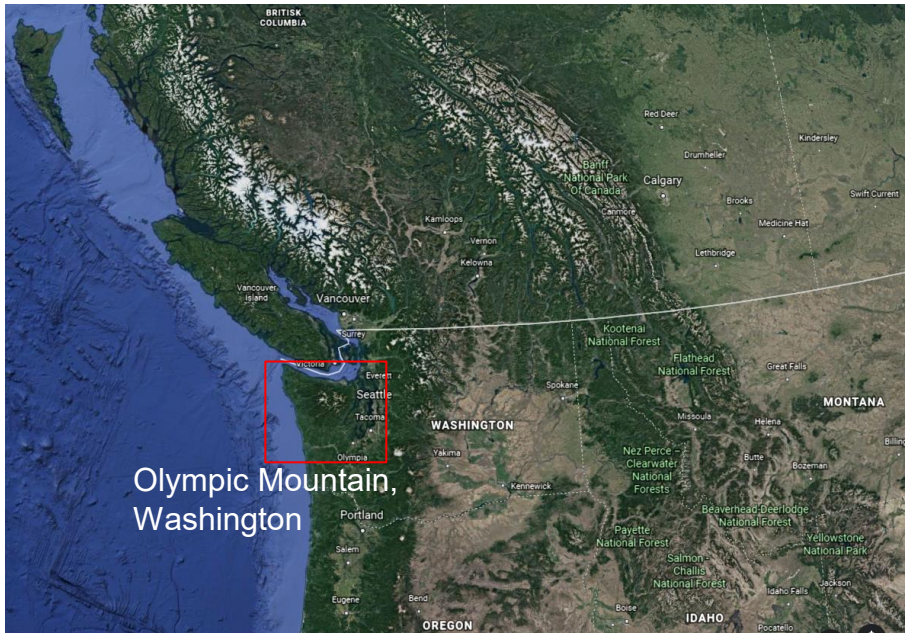
The different black lines are for LR increasing from 0 to 1 in intervals of 0.1

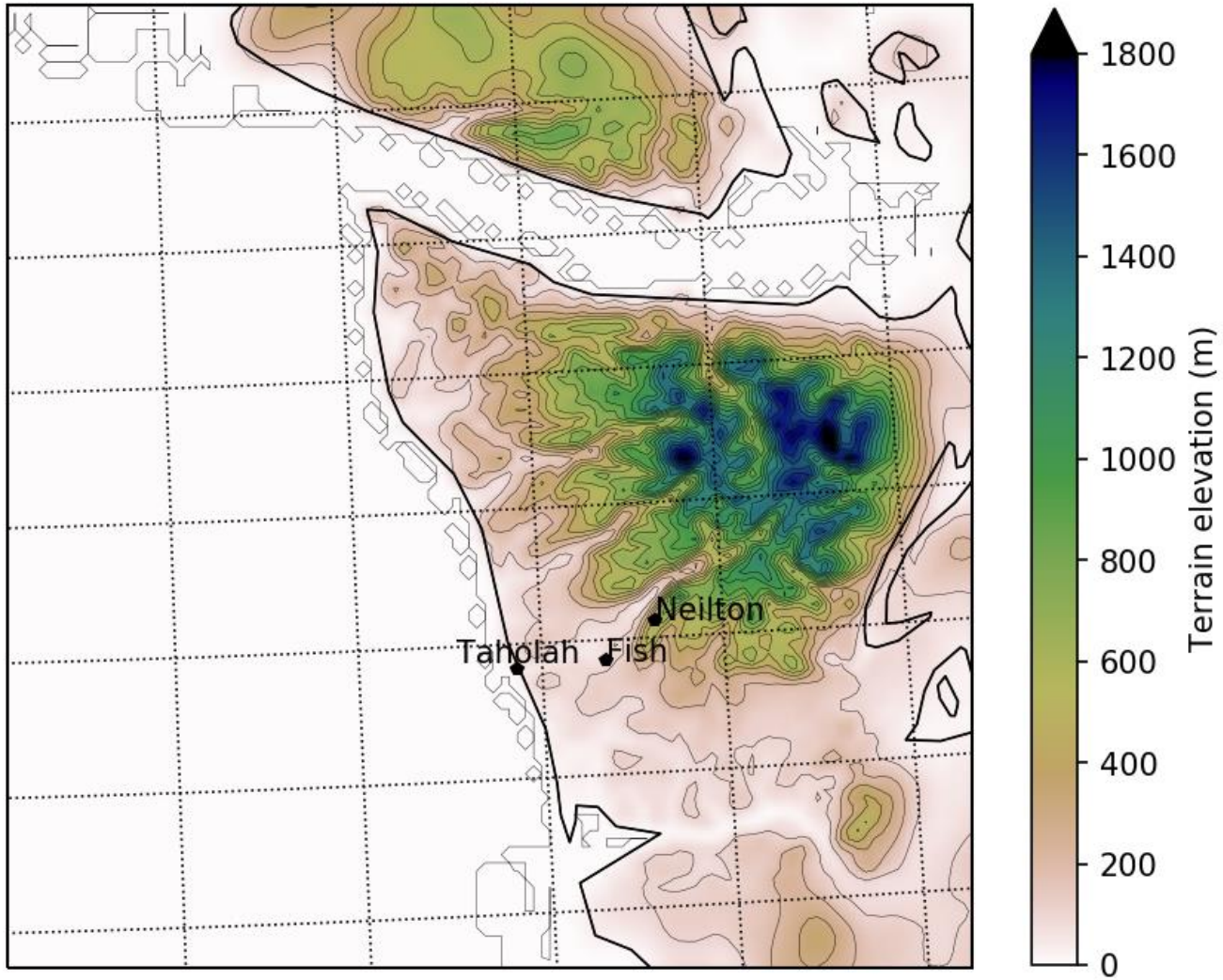
…and introduce new definition of melting level:

- $T_w > 0^o C$

Which was implemented in various process rates

3D real WRF run to validate introduced changes against obs.

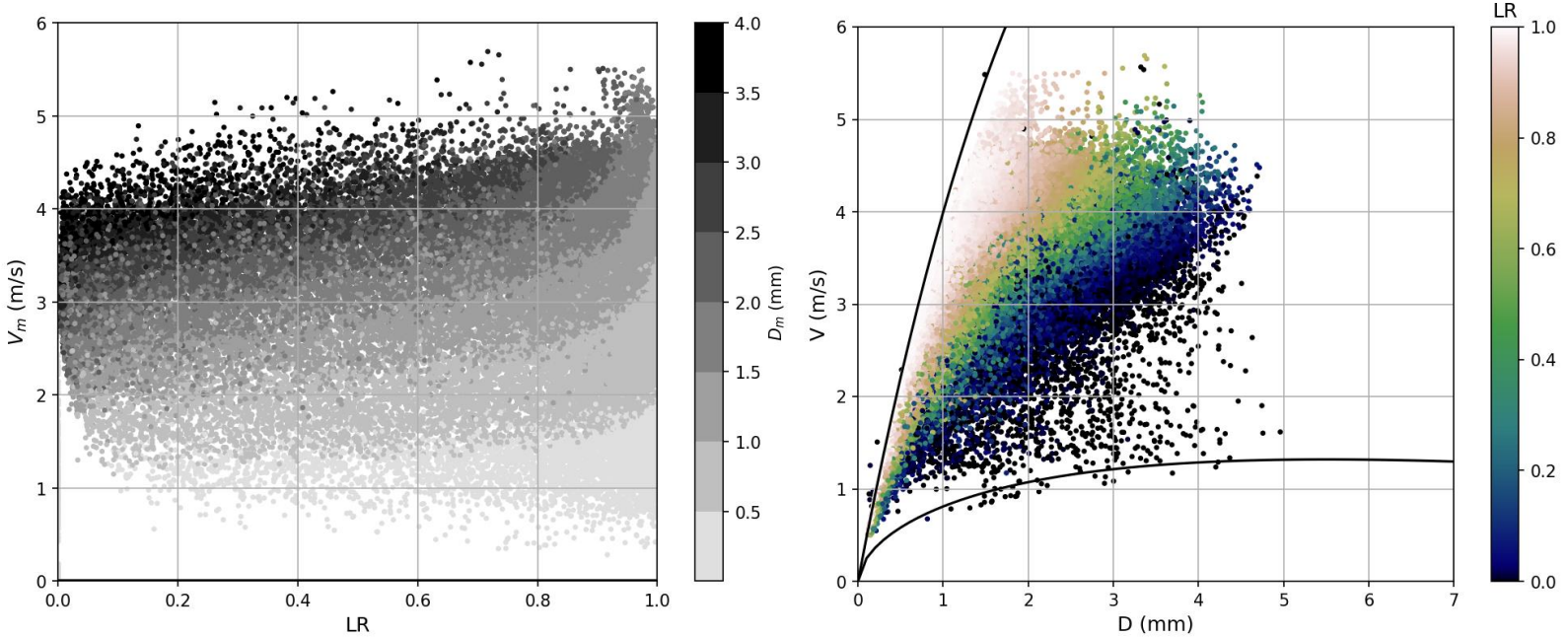




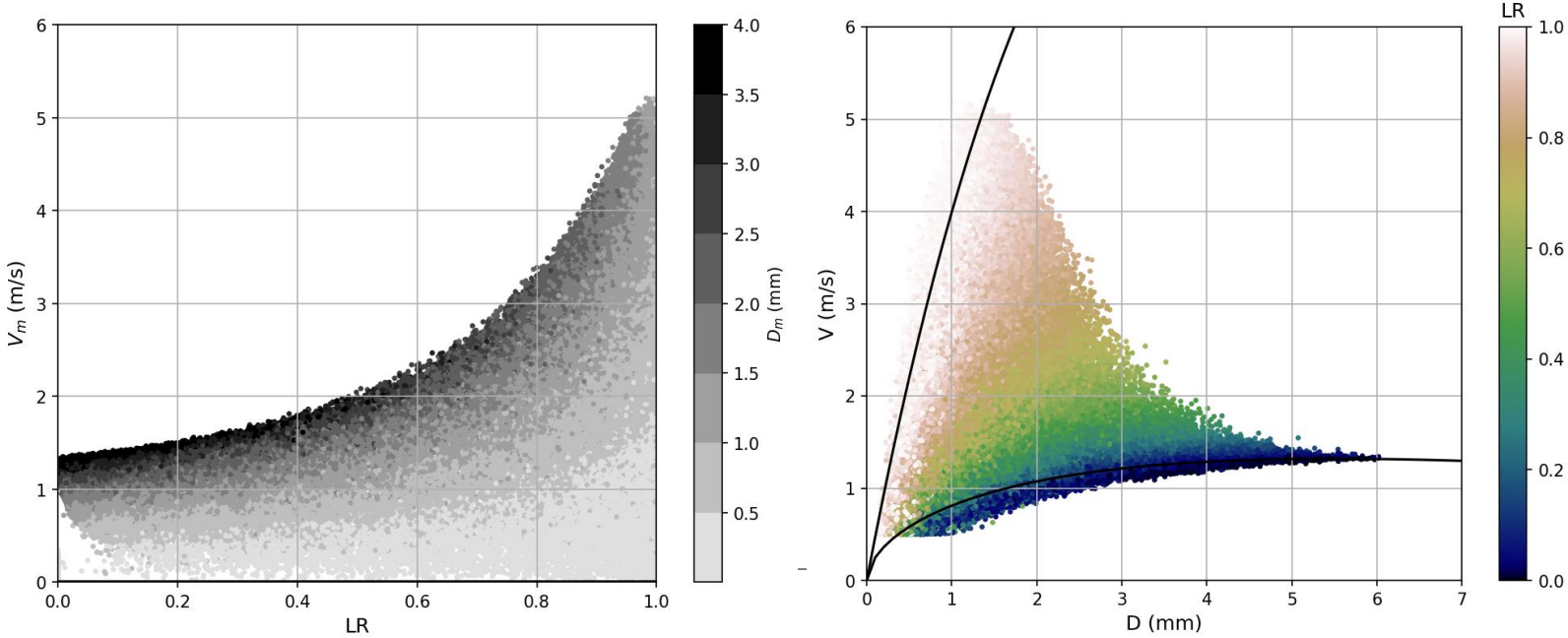
WRF Domain 3 x 3 km

KJELLER VINDTEKNIKK
En del av Norconsult

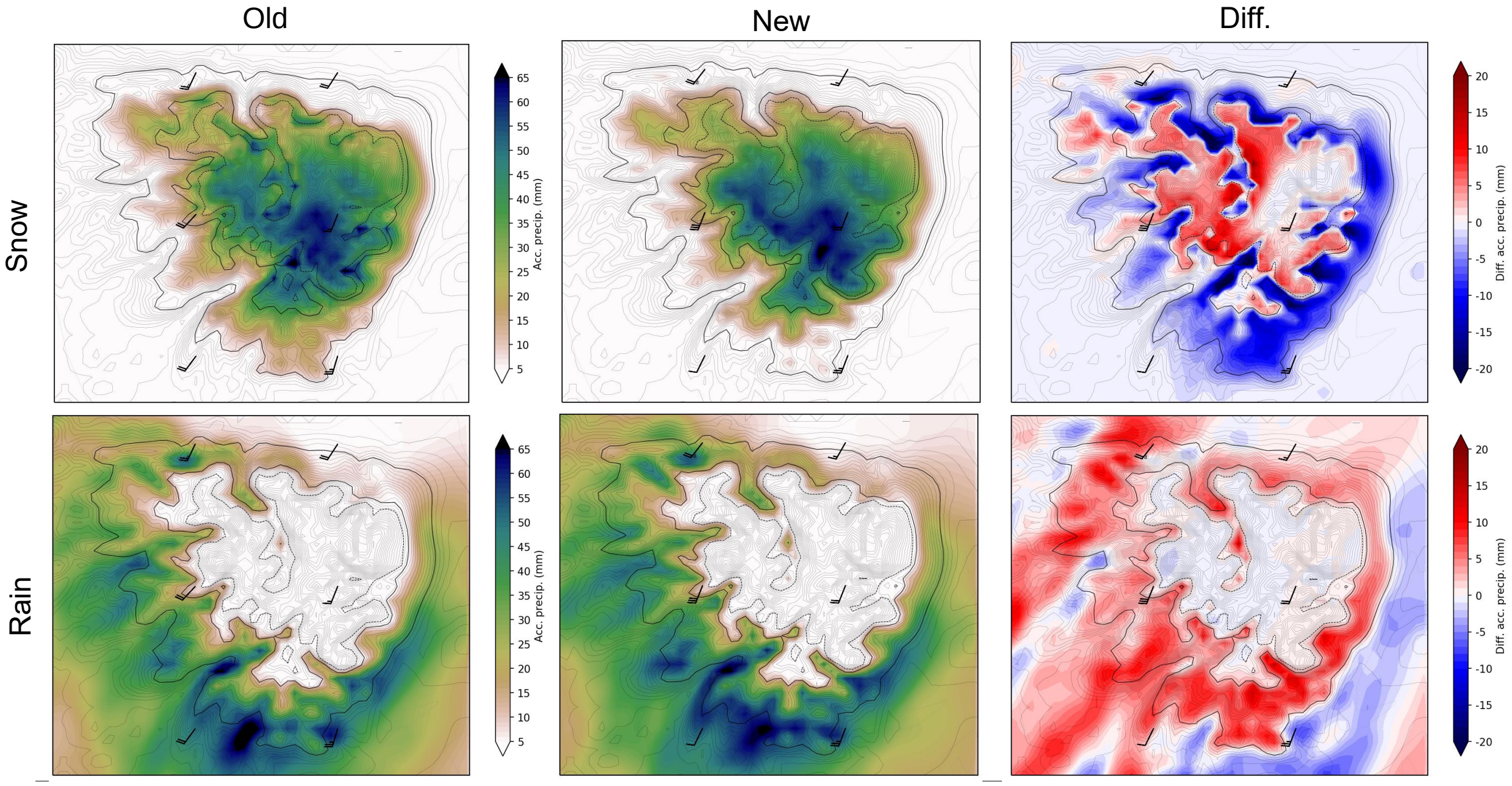
Old scheme



Modified scheme



Solid black lines are the velocity relations for dry snow and rain

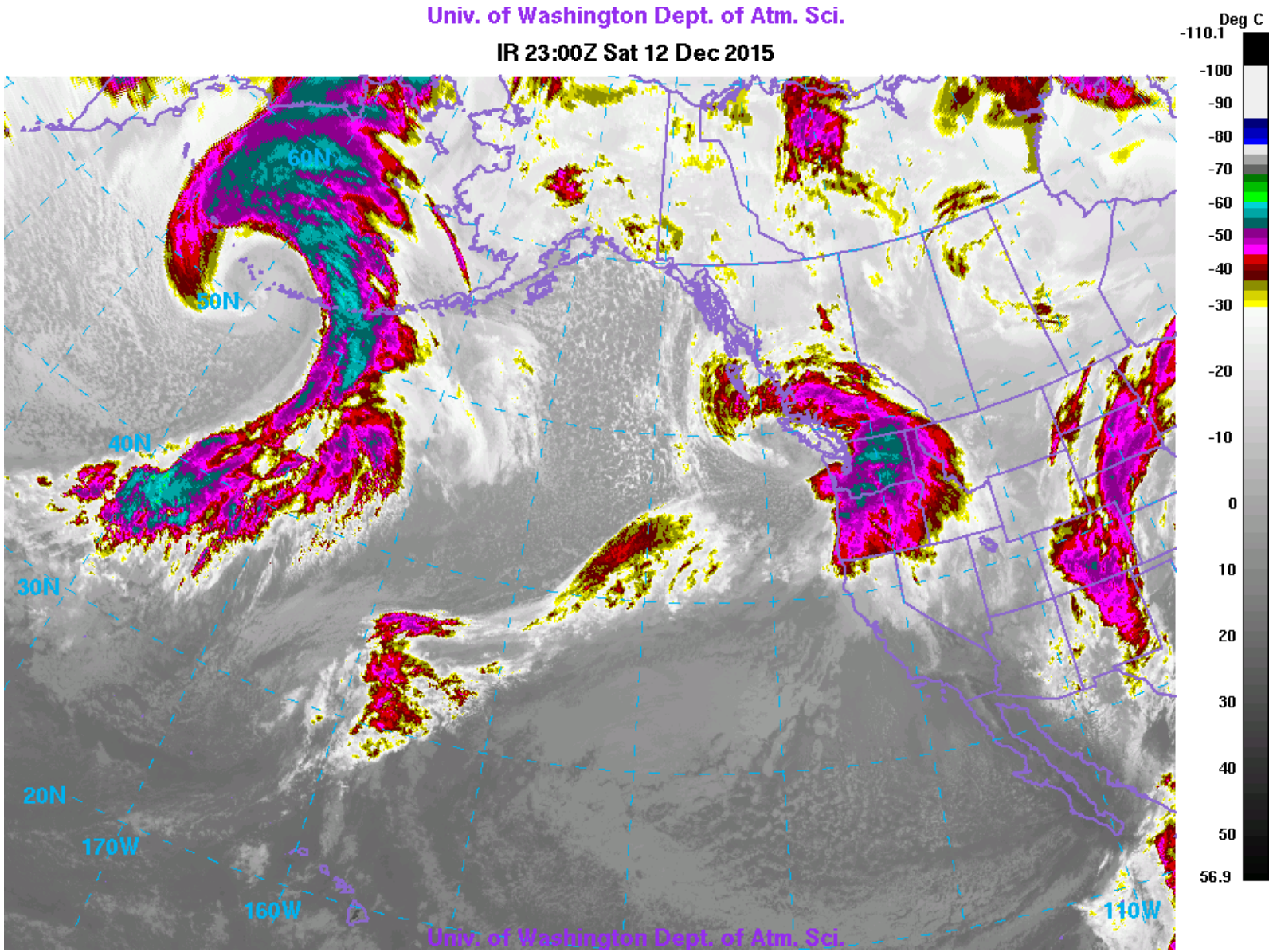


Notice the bulls-eyes of snow accumulation in lee-side melt zone in the old scheme

KJELLER VINDTEKNIKK
En del av Norconsult

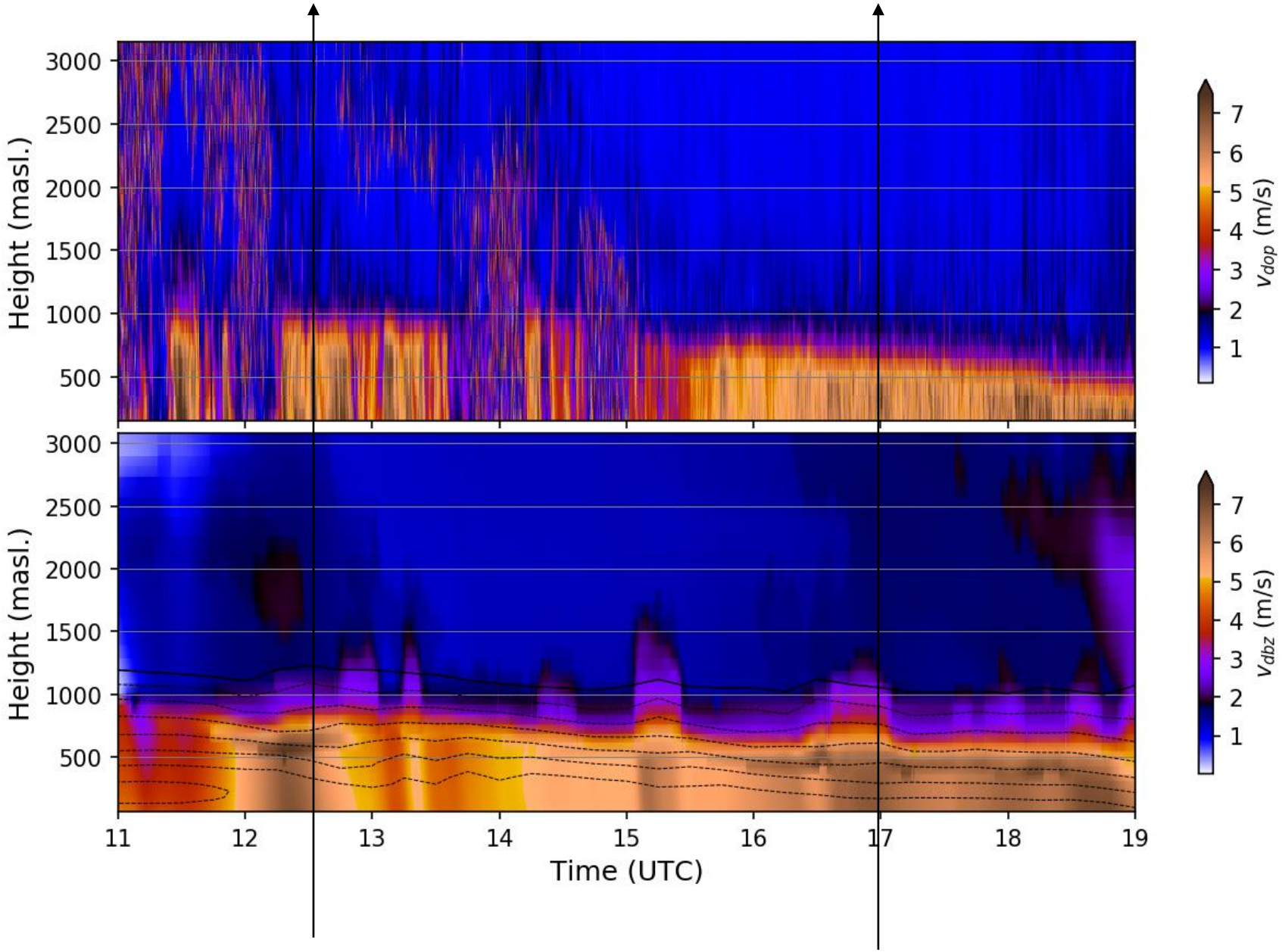
KJELLER VINDTEKNIKK
En del av Norconsult

Case:
Fishery, 12 Dec



MRR

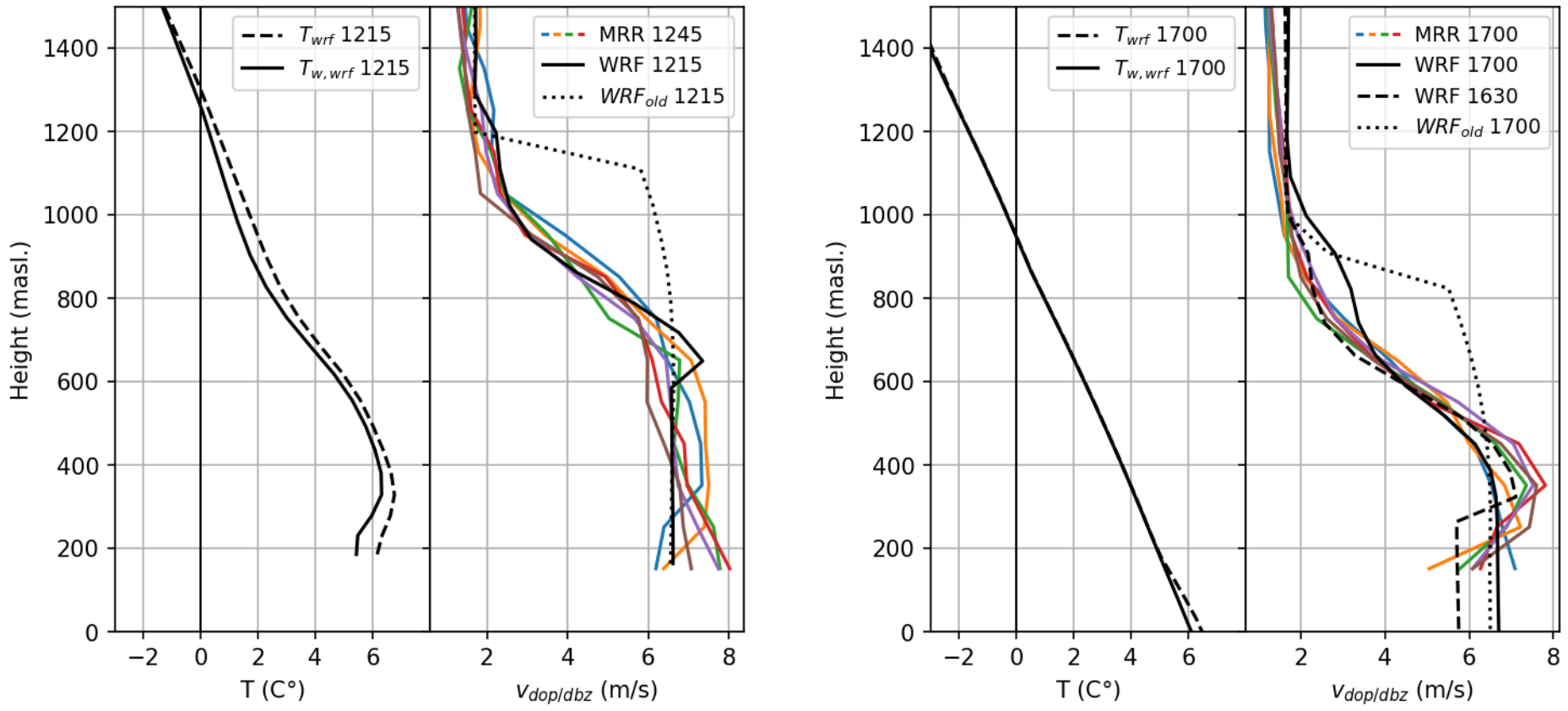
WRF



V_{dop}= doppler velocity, V_{dbz}= reflectivity weighted fall velocity. Solid black line: 0ºC, dotted: incr. of 1ºC

KJELLER VINDTEKNIKK
En del av Norconsult

Velocity profiles for timings indicated by arrows in previous slide



Right panels: Profile from modified scheme in black and from old scheme in dotted black

Conclusions:

- The new expression for melting snow fall velocity shows a good and improved comparison with observed fall velocities.
- The modified scheme shows a reduction in snow and an increase in rain accumulation in the melting zone around Olympic Mountain as a result of slower falling snow during melting. Snow accumulation is particularly decreased in lee side areas, where the old scheme showed significant and unphysical accumulation due to too high falling velocities.
- This should result in better predictions of precipitation phase and amount reaching the surface, but needs a validation against observed surface precip. accumulation.

Thank you!

emilie.claussen.iversen@norconsult.com