

## ▶ Improvements to WRF microphysics

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# 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



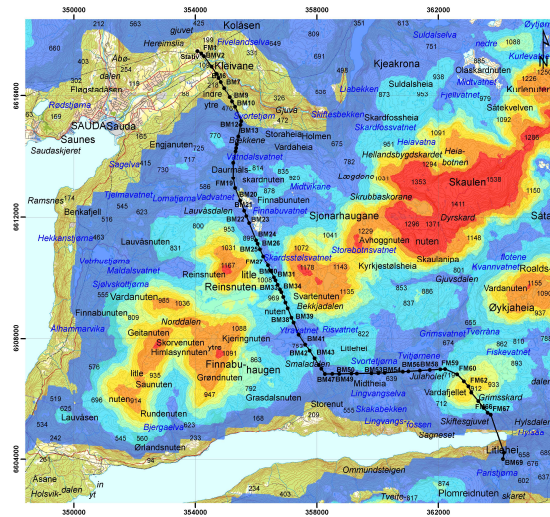
Power lines



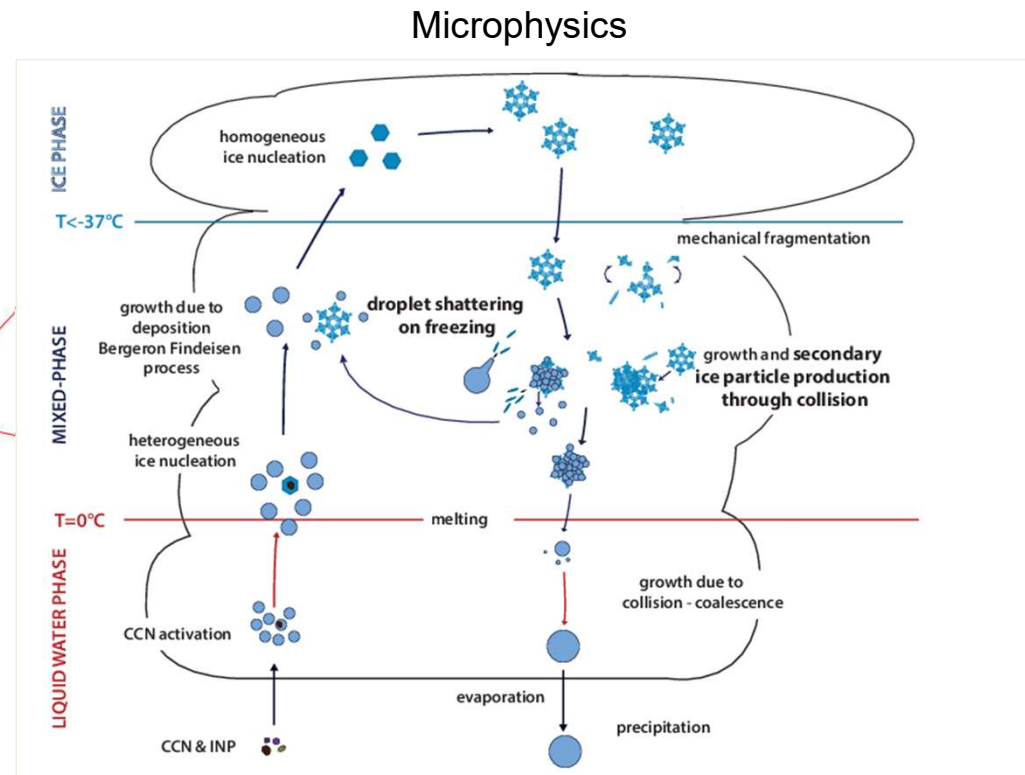
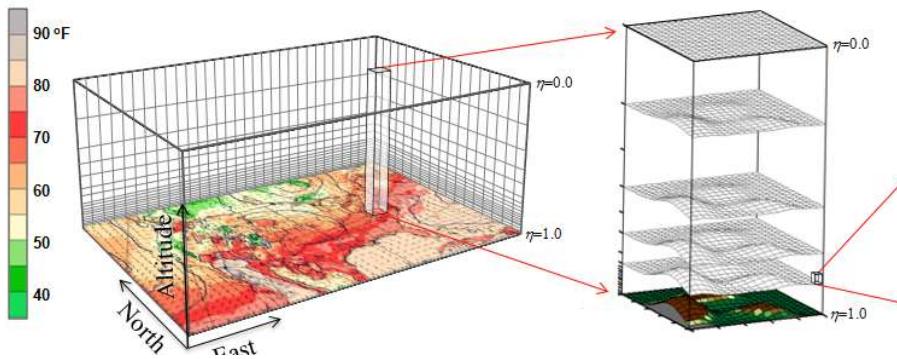
Bridges



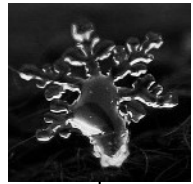
- H1 – Measuring stations and instrumentation
- H2 – Surveillance system
- H3 – Ice modeling for current and future climate
- H4 – Icing maps
- H5 – Anti-icing techniques
- H6 – De-icing techniques



# WRF is a numerical weather prediction model



# Microphysics important for icing prediction!



$0 < T < 2^{\circ}\text{C}$



Wet snow icing



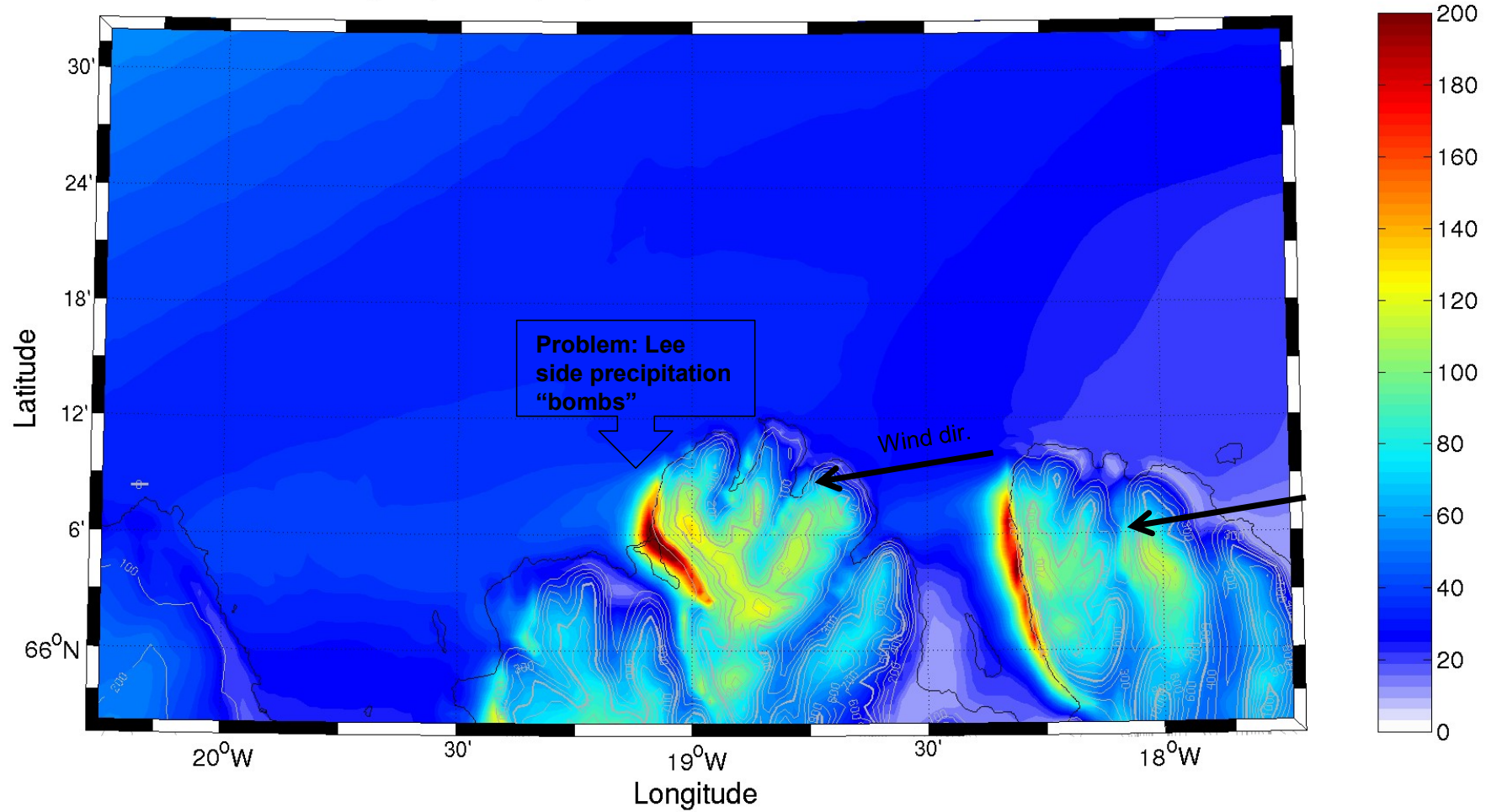
$T < 0^{\circ}\text{C}$



Rime icing

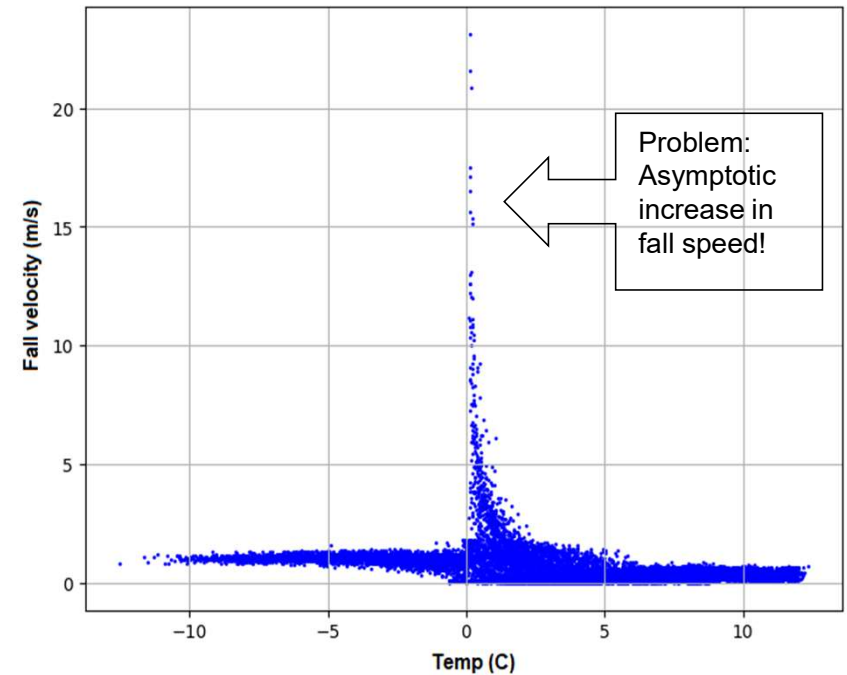
# WRF run

Accumulated precipitation (mm) from: 1999-03-11 12:00 to: 1999-03-13 12:00



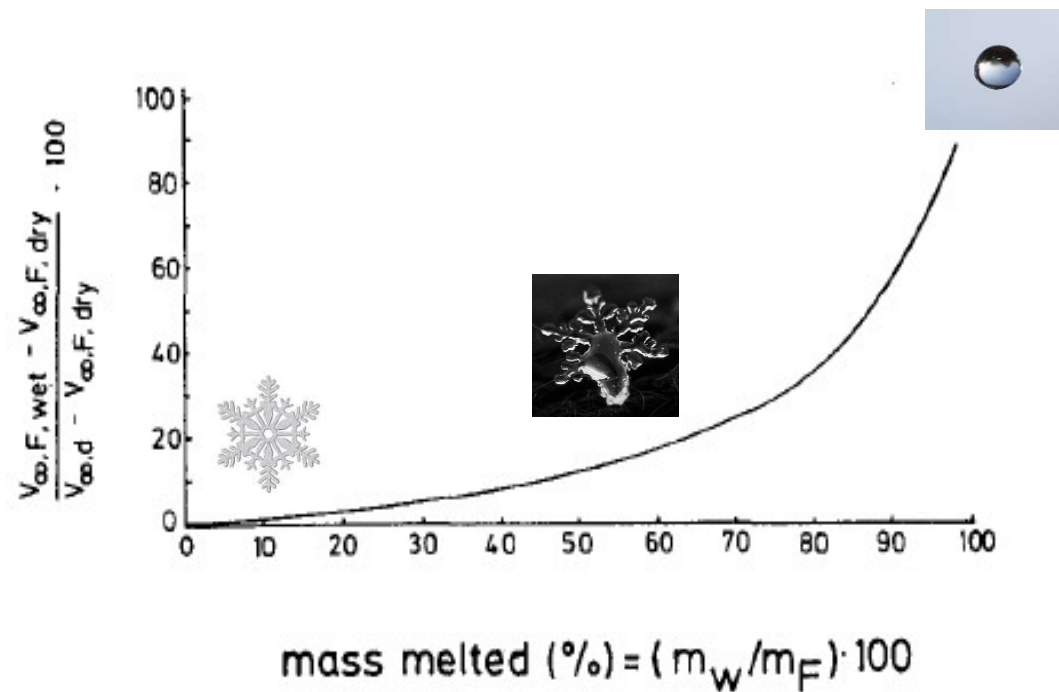
# Bug in fall speed expression in the microphysics!

Fall speed of melting snow: 
$$V_m = V_s \frac{V_r - V_s}{T - T_0}$$



# Wet snow fall speed is a function of its melted fraction

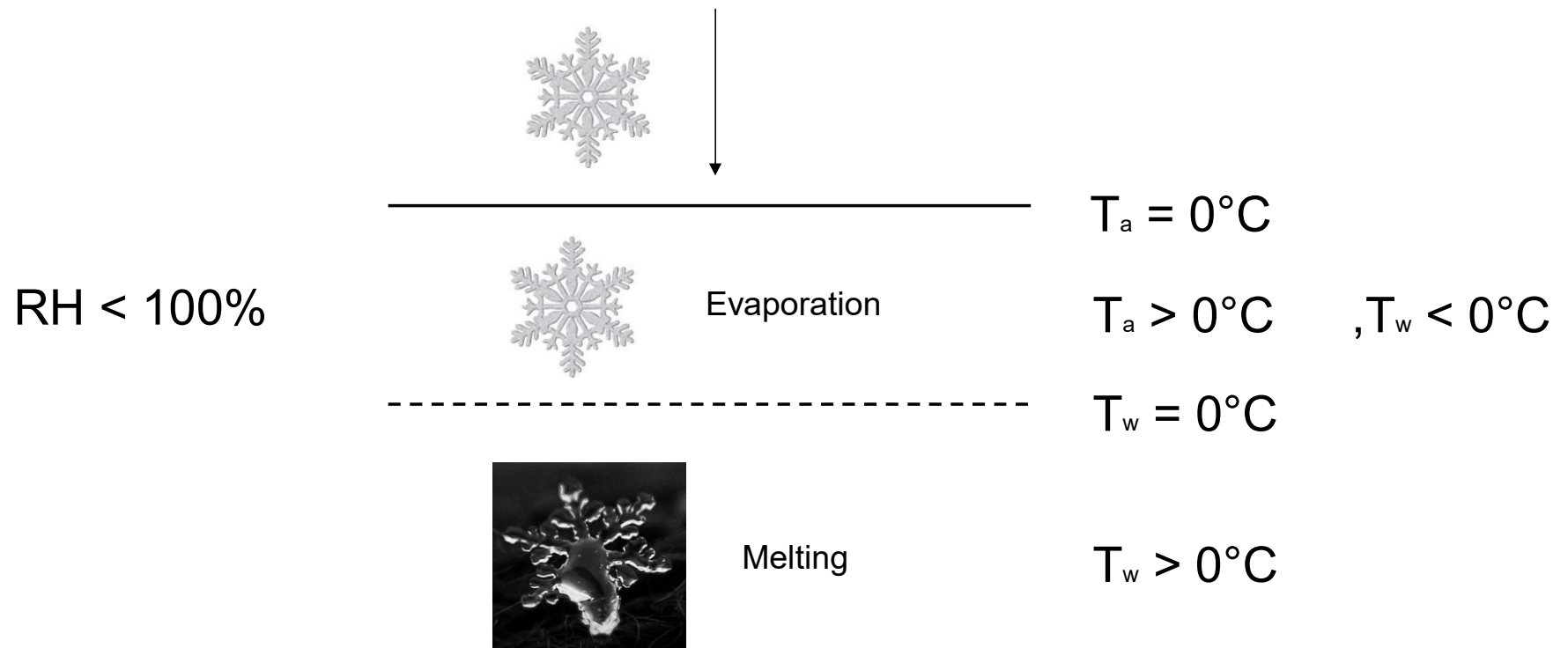
Mitra et al. (1990) (wind tunnel study)



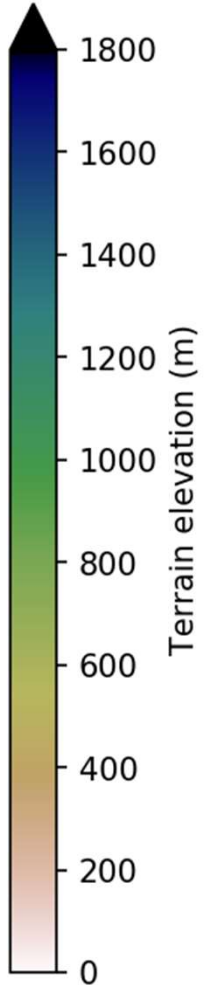
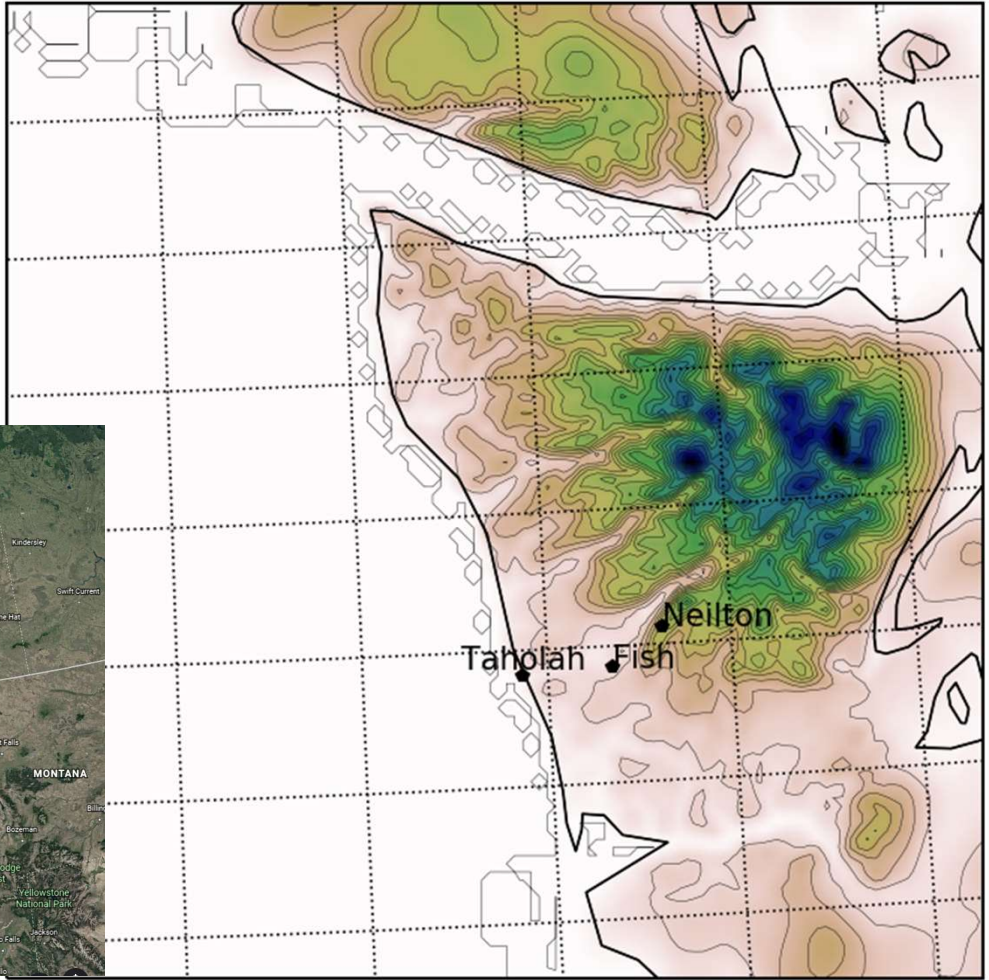
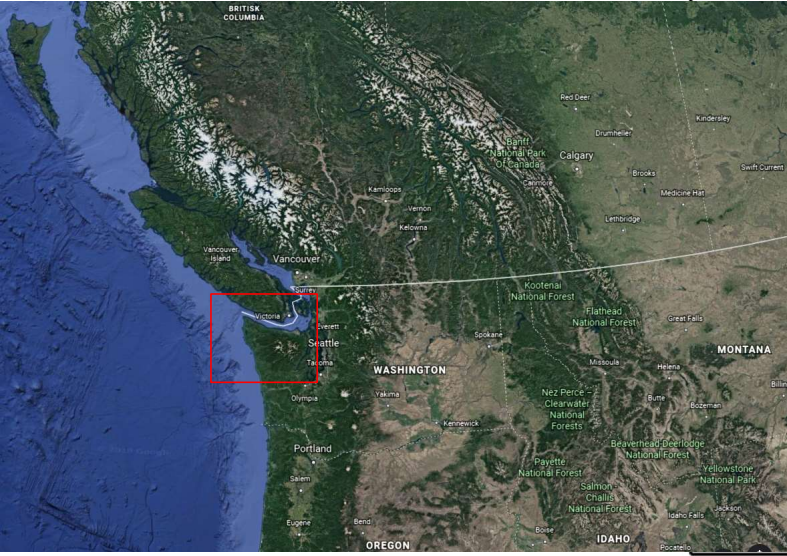


Before: Melting level:  $T_a > 0^\circ\text{C}$

**But, the use of  $T_w$  is better for determining melting level:**

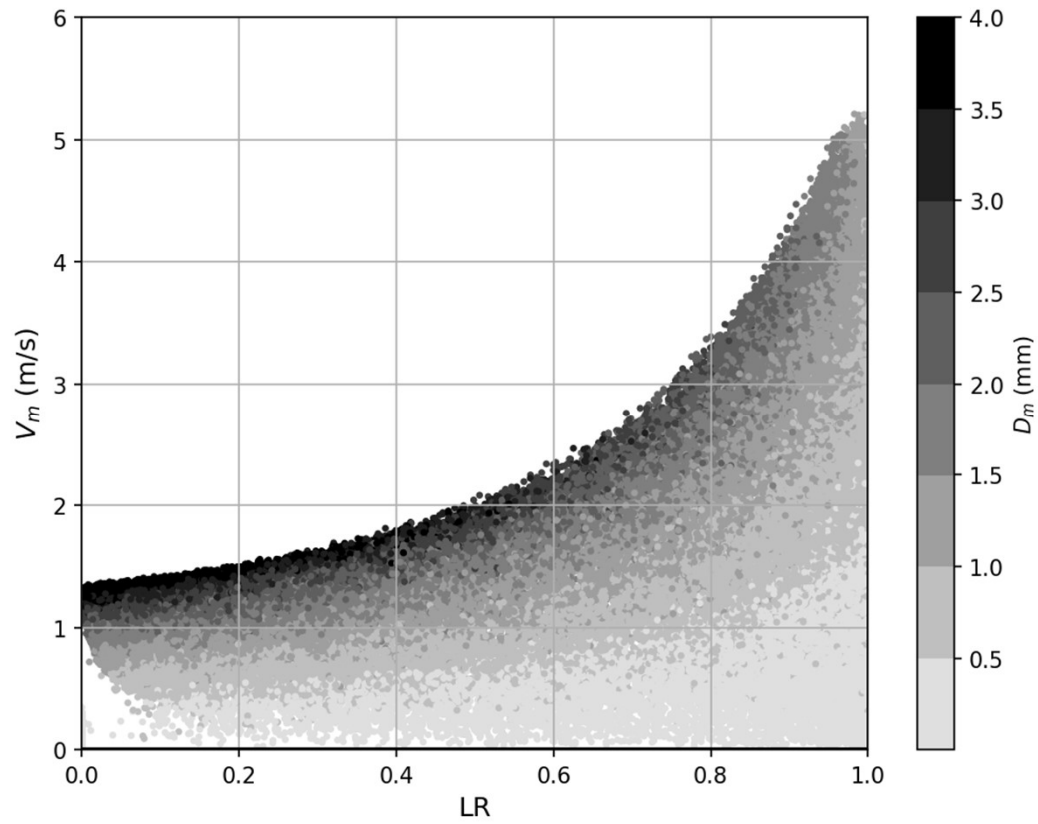


# Olympic Mountains, Washington state

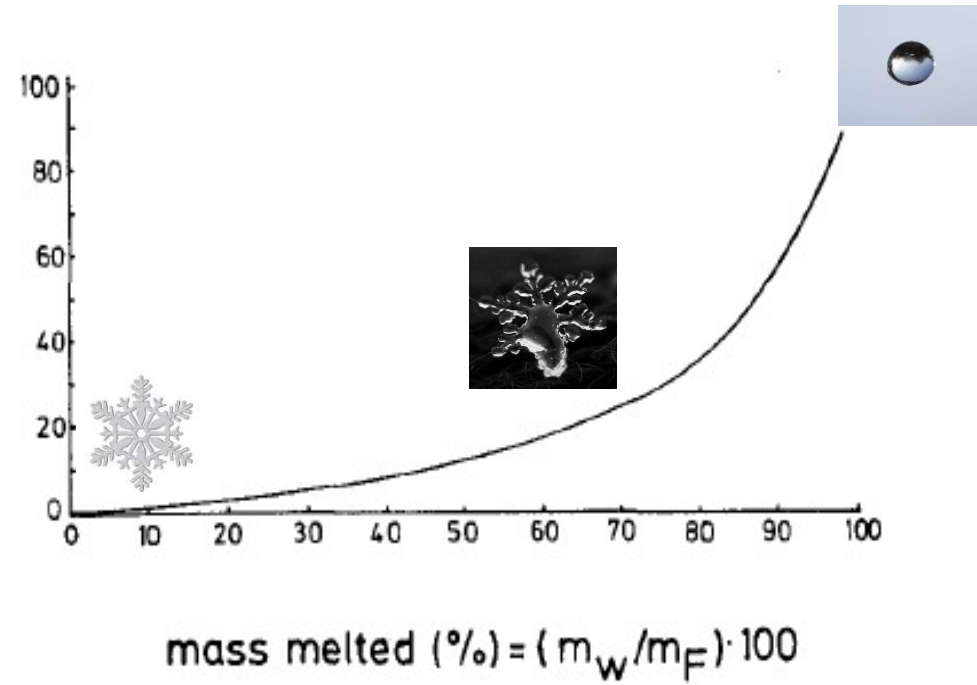


WRF domain

## Model output



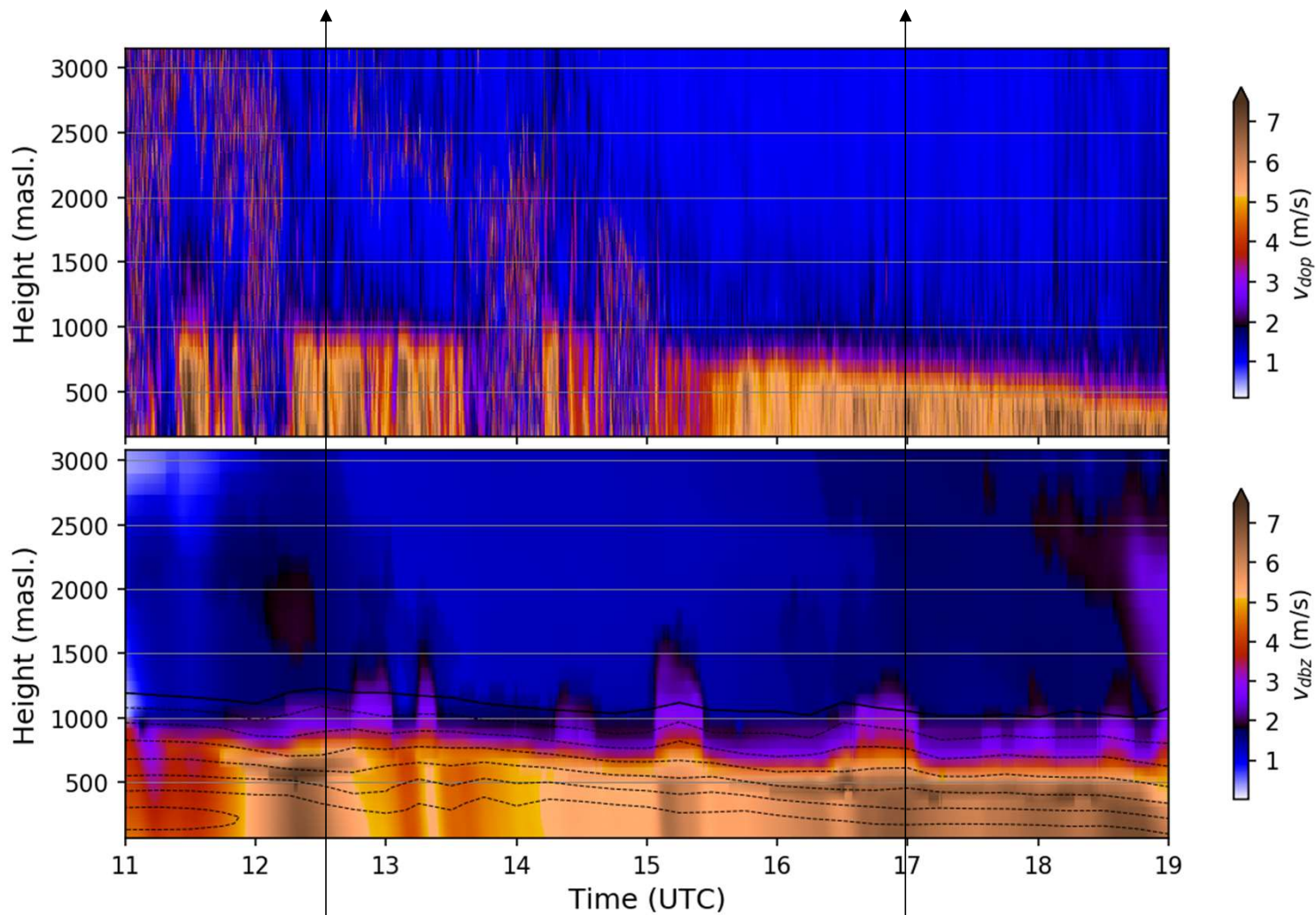
## Observations



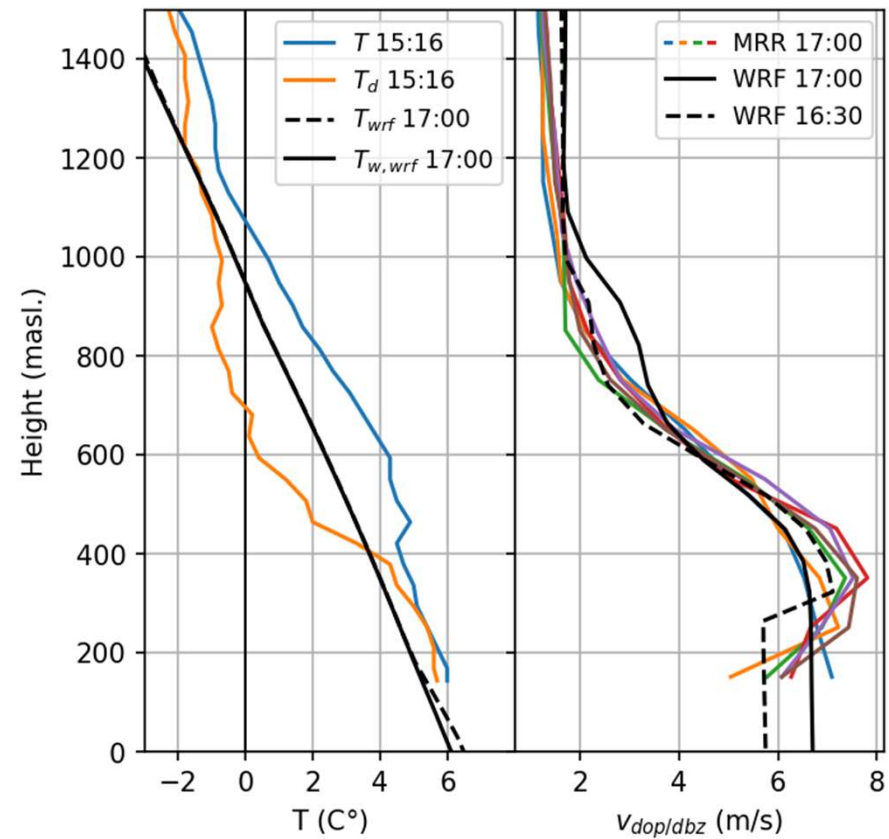
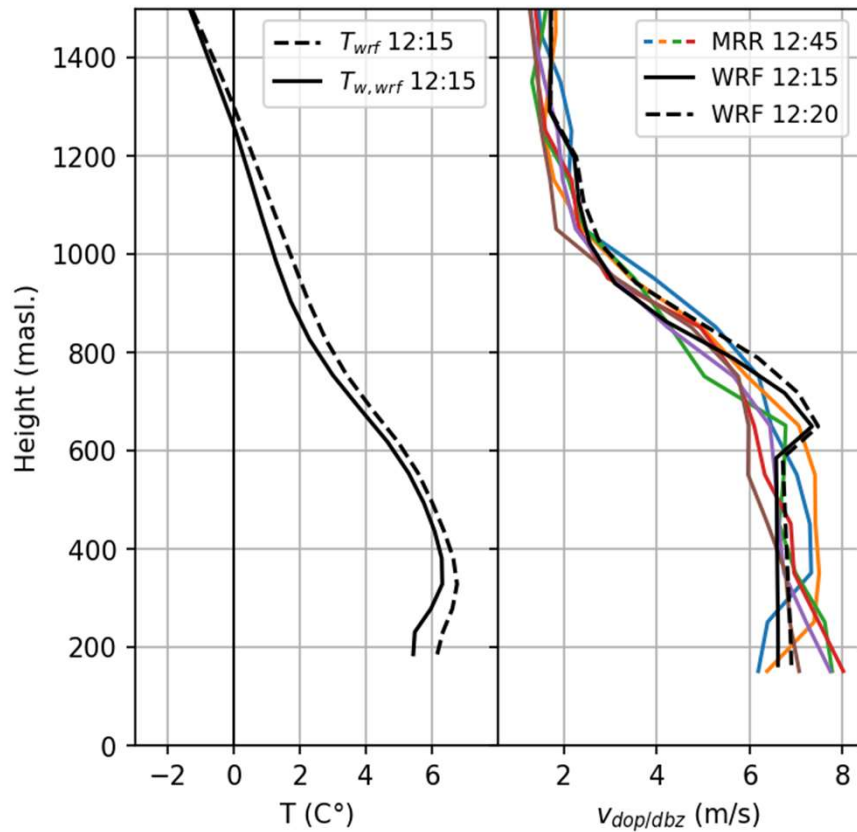


MRR

WRF

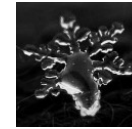


# Very good match of fall velocity profiles!

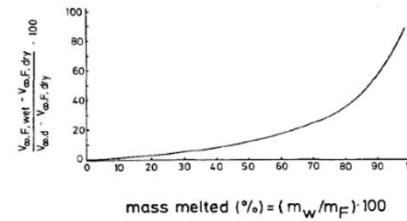


# Summary:

- Improved melting level def. ( $T_w$ ) →



- Improved melting snow fall speed



- Improved wet snow icing prediction (hopefully)



# Are wind turbines affected by wet snow icing?





**Thank you!**

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