UiO : Department of Geosciences
University of Oslo

Snowfall Regime Evaluation for MetCoOp Ensemble Prediction at a Norwegian Mountain Site

19th Conference on Mountain Meteorology

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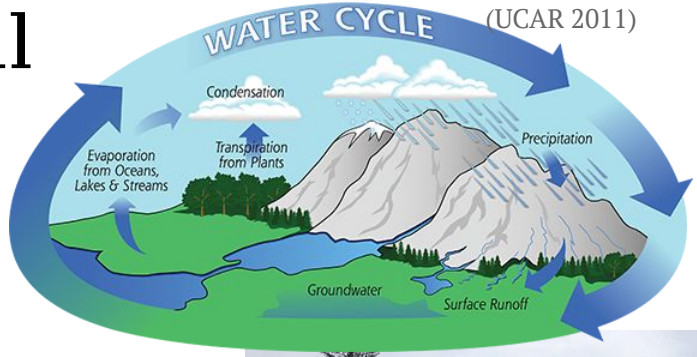
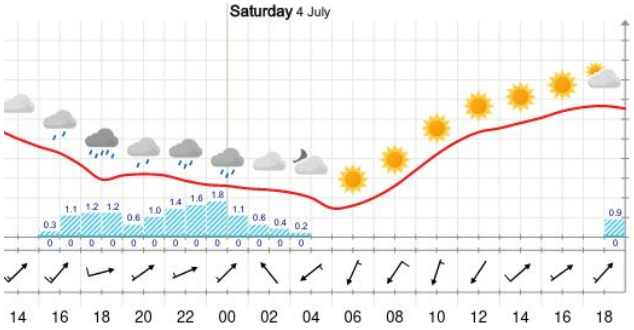
Importance of Snowfall

- Precipitation observations are important
  - Hydrology, climate, weather research
- Orographic precipitation: important source of drinking water and can cause
  - avalanches in winter
  - Floodings during melt season
- Forecast uncertainties are an important research topic



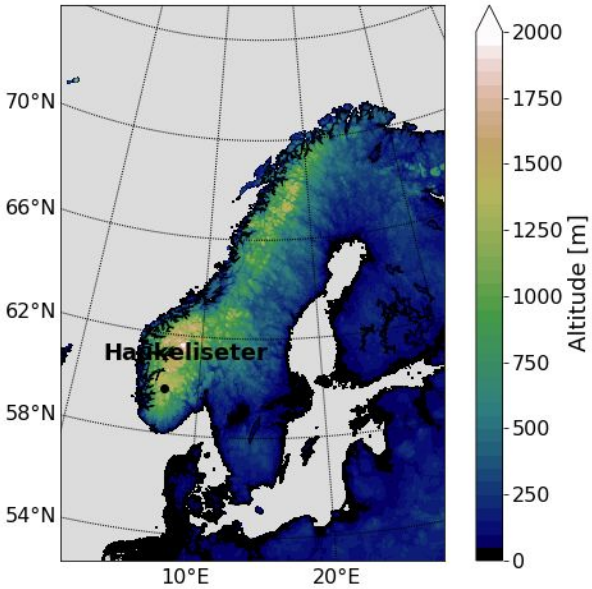
(UCAR 2011)

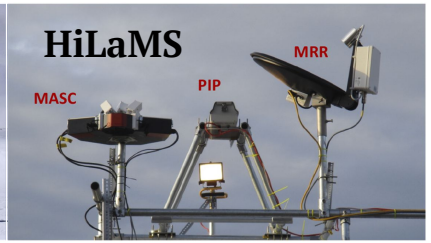
(Colleuille 2020)



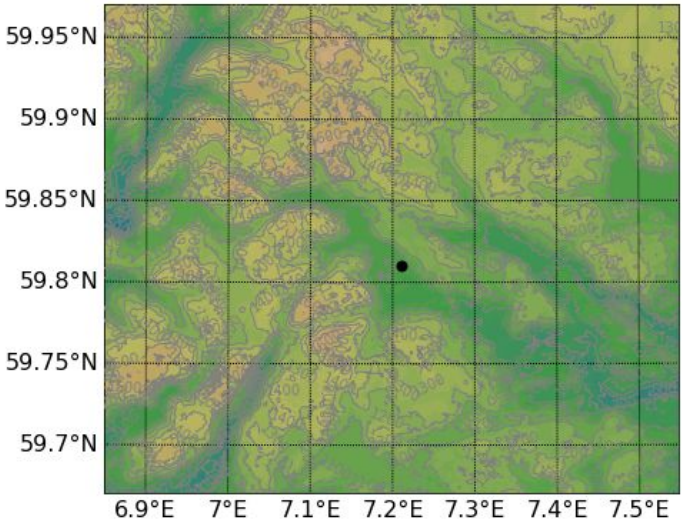
(Yr.no 2020)

Haukeliseter Site and Instrumentation



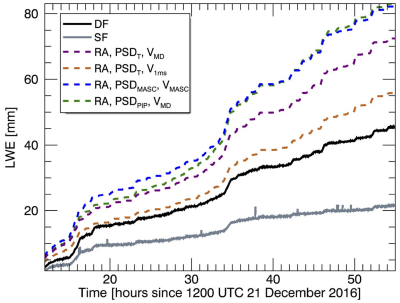


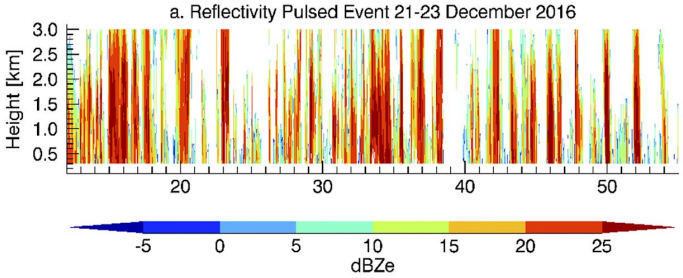
(Schirle et al. 2019)

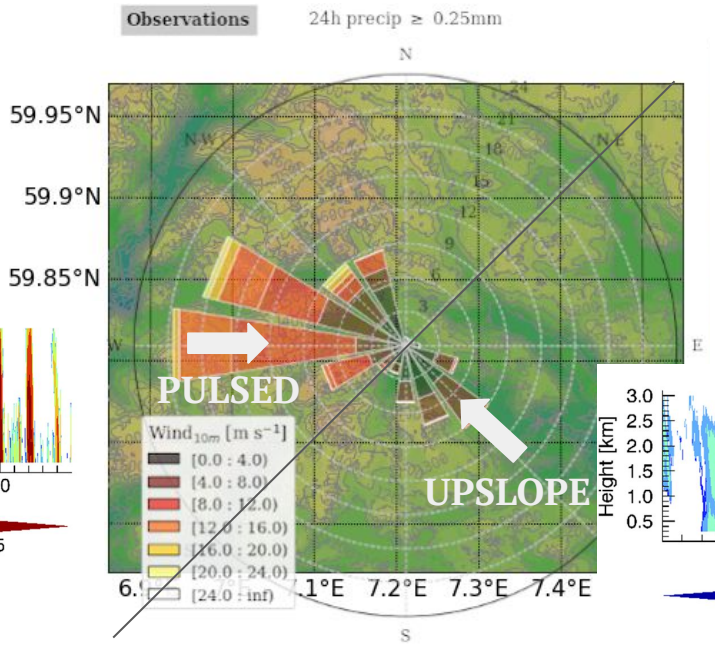


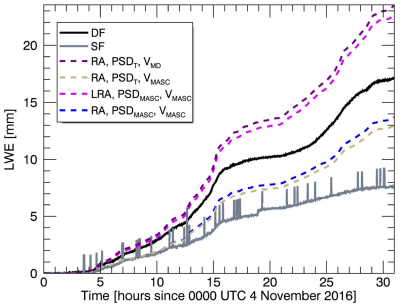
- Double fence snow gauge
- Wind
- Temperature
- Relative humidity
- MASC, PIP, MRR

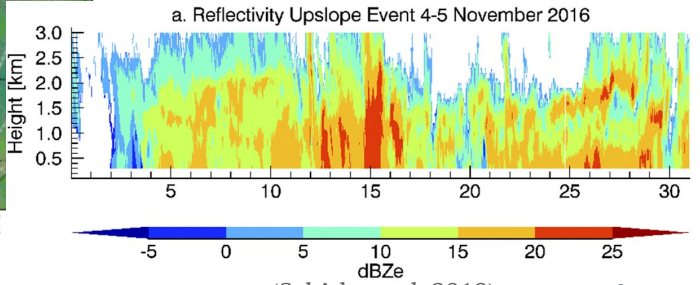
Haukeliseter Snowfall Regimes







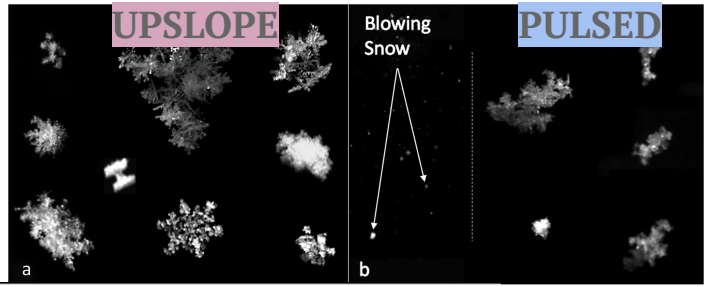




(Schirle et al. 2019)

Retrieval of Snowfall from Combined Radar and Microphysical Observations

- Optimal estimation snowfall retrieval



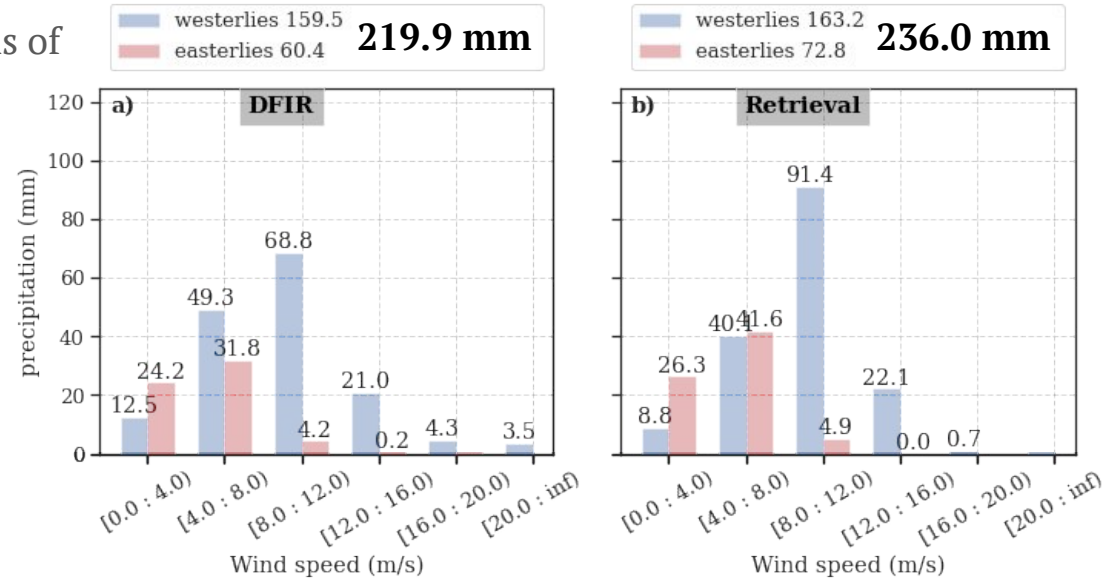
Particle model	PSD	Fall speed	% difference
Rimed aggregate	MASC	MASC	+9
Rimed aggregate	PIP	PIP	−0.4
Unrimed aggregate	MASC	MASC	+78.7
Unrimed aggregate	PIP	PIP	+59.4
Rimed aggregate	Temperature-based	Doppler velocity	+27.3

	PSD λ	Fall speed	% difference
Rimed aggregate	MASC	MASC	+48.9
Rimed aggregate	PIP	Doppler velocity	+58.7
Unrimed aggregate	MASC	MASC	+138.6
Rimed aggregate	Temperature-based	Doppler velocity	+15.8

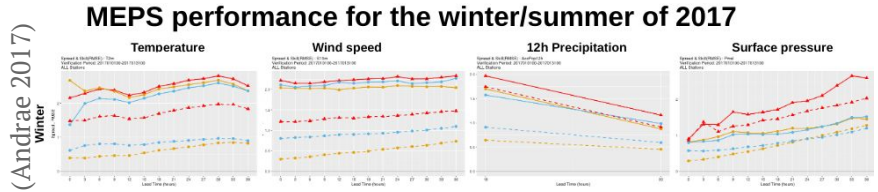
(Schirle et al. 2019)

Retrieval Validation - Winter 2016-2017

- Radar retrievals and DFIR observations of surface snowfall
  - Total difference: **+7.3%**
- Upslope (easterlies)
  - 27.5% of total precipitation
  - Difference: **+20.5%**
- Pulsed (westerlies)
  - **72.5%** of total precipitation
  - Difference: **+2.3%**



MEPS and microphysical adjustments



- Cooperation between Norway, Sweden, Finland
- EPS operational since Nov 2016, based on HARMONIE-AROME
- 2.5 km grid spacing
- 65 levels
- Consisted of 1+9 members
- Control and perturbed members runs up to 66h and 54h, respectively
- Microphysics is resolved in ICE3
  - Supercooled liquid depleted too quickly

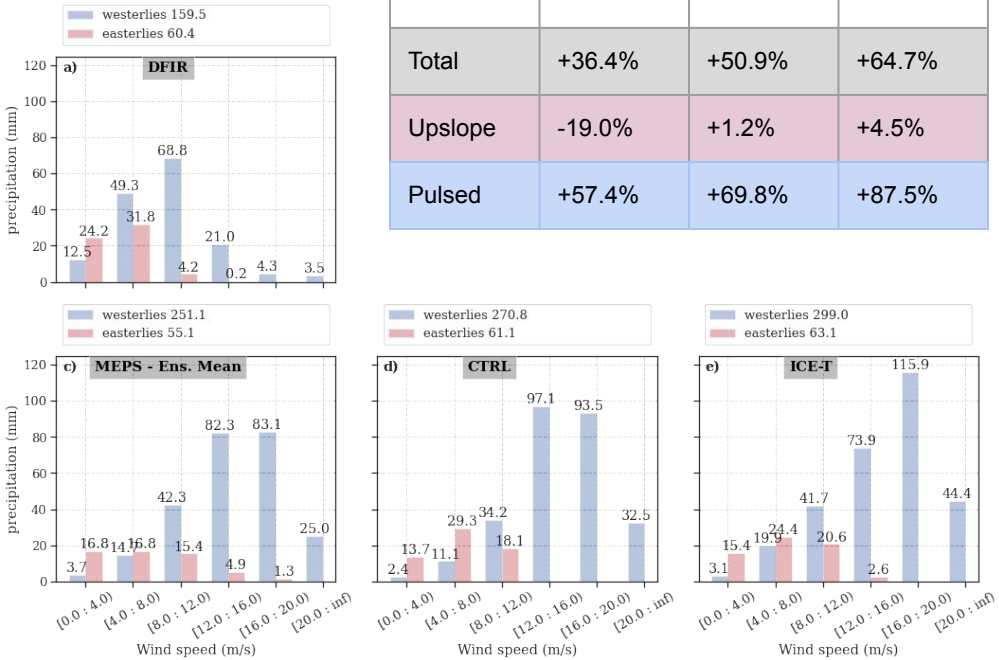
- Engdahl et al. 2020
  - Included different ice nucleation scheme
  - Autoconversion, rain accreting cloud water, ice initiation, snow/graupel collecting cloud droplets and rain, mass-diameter relation and fall speed, rain size distribution
- Engdahl et al. (in review)
  - 3 month simulations winter 2016-2017
  - CTRL, ICE-T

Norwegian Meteorological Institute SMHI FMI

MEPS Seasonal Snowfall Verification - Surface

- Overestimation of surface snowfall
- Increase from CTRL → ICE-T
  - Due to more graupel production and snow in Southern Norway in the model simulations
- Model bias
  - Small during upslope
  - Large during pulsed
- Pulsed
  - Too much snow at 10-m wind speeds > 12m/s)
  - Strong wind bias in model (Müller et al. 2017)
  - Undercatch by DFIR at high wind speeds (< 9m/s → 10%, up to 20m/s → 20%, Nitu et al. 2018)

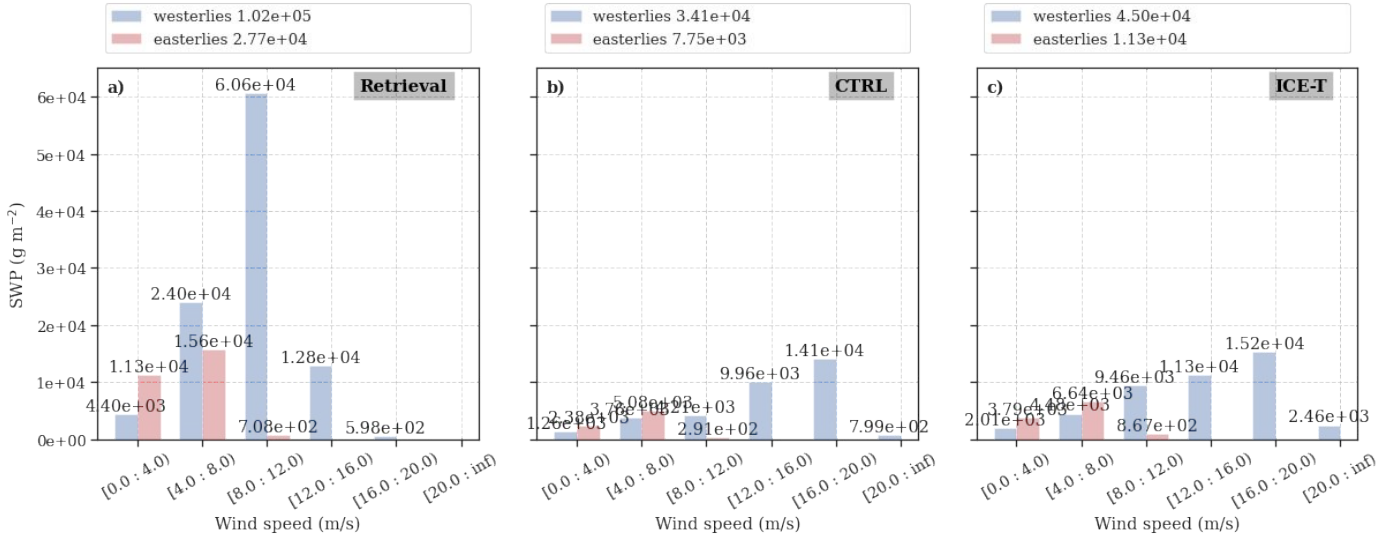
	MEPS	CTRL	ICE-T
Total	+36.4%	+50.9%	+64.7%
Upslope	-19.0%	+1.2%	+4.5%
Pulsed	+57.4%	+69.8%	+87.5%



MEPS Seasonal Snowfall Verification - Vertical

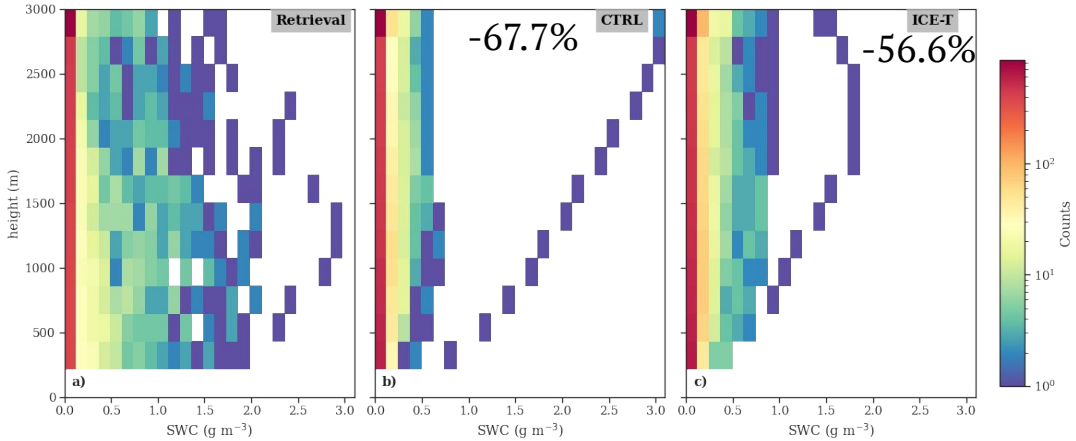
- Underestimation of SWP
- Decrease of bias from CTRL to ICE-T
- Model bias during pulsed
  - Too much snow at 10-m wind speed > 16m/s

SWP	CTRL	ICE-T
Total	-67.7%	-56.6%
Upslope	-72.0%	-59.2%
Pulsed	-66.6%	-55.9%



MEPS Seasonal Snowfall Verification - Vertical

- Microphysical adjustments improved SWC
  - Related to the increase in snow and decrease in graupel
  - → snow remains longer in the atmosphere
  - → smaller fall velocities
- Perhaps, still too much graupel
  - Particles fall out too fast in the model
  - → accumulate more at the surface → overestimation at the surface
- Underestimation of SWC by model
  - Timing of the 30-min pulses might be missed



Summary

- Estimated the vertical profile of snowfall using combined radar, in-situ microphysical, and fall speed observations
- Identified two primary storm regimes with distinct meteorological and microphysical characteristics
- Use to validate operational forecast model MEPS with different microphysical schemes
  - Overestimation at the surface
  - Underestimation in the vertical

Photo: Robert O. David

Surface	Retrieval	MEPS	CTRL	ICE-T
Total	+7.3%	+36.4%	+50.9%	+64.7%
Upslope	+20.5%	-19.0%	+1.2%	+4.5%
Pulsed	+2.3%	+57.4%	+69.8%	+87.5%
Vertical			CTRL	ICE-T
Total			-67.7%	-56.6%
Upslope			-72.0%	-59.2%
Pulsed			-66.6%	-55.9%