Improving the representation of supercooled liquid water in the HARMONIE-AROME model

Photo: Einar Egeland

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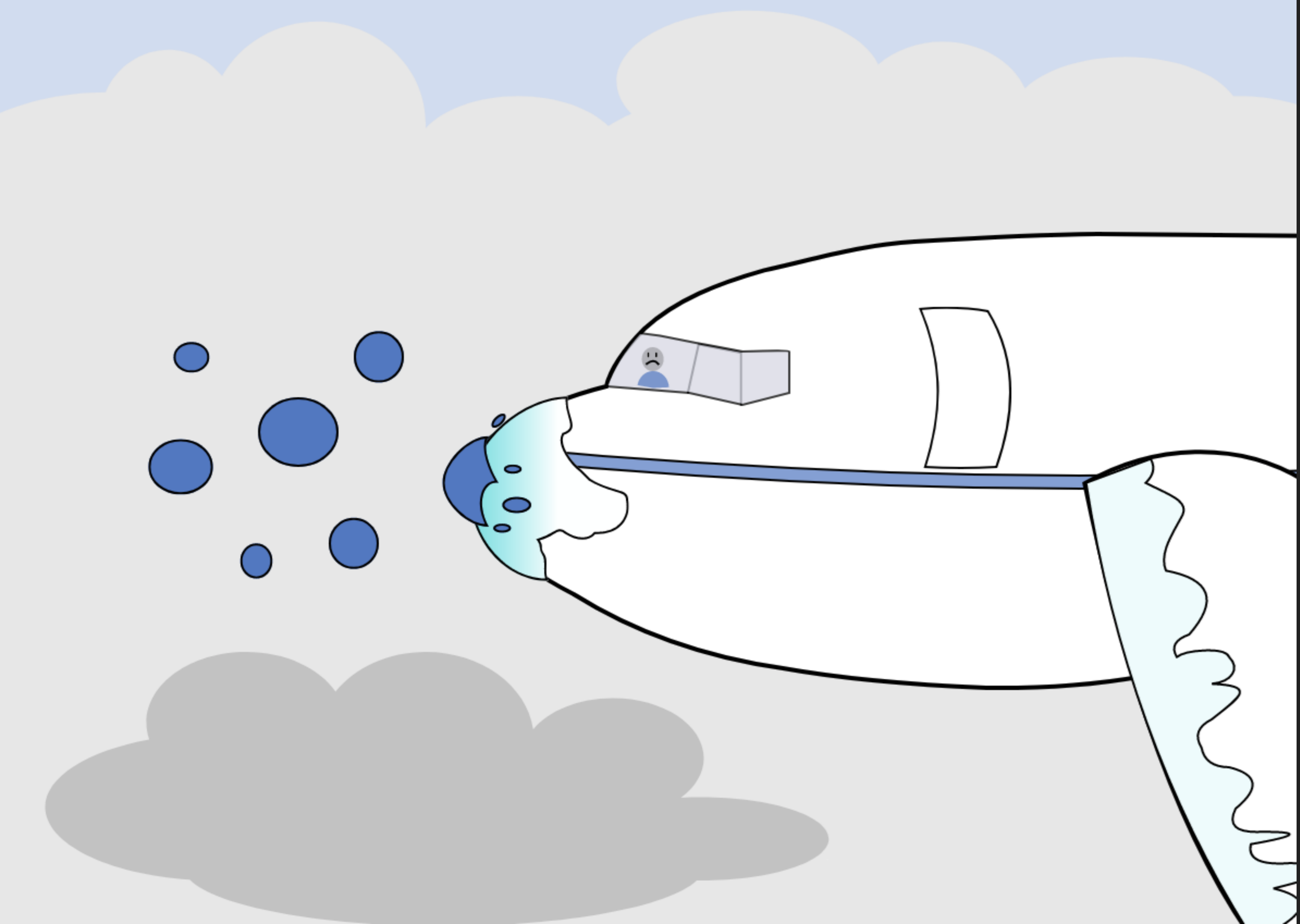
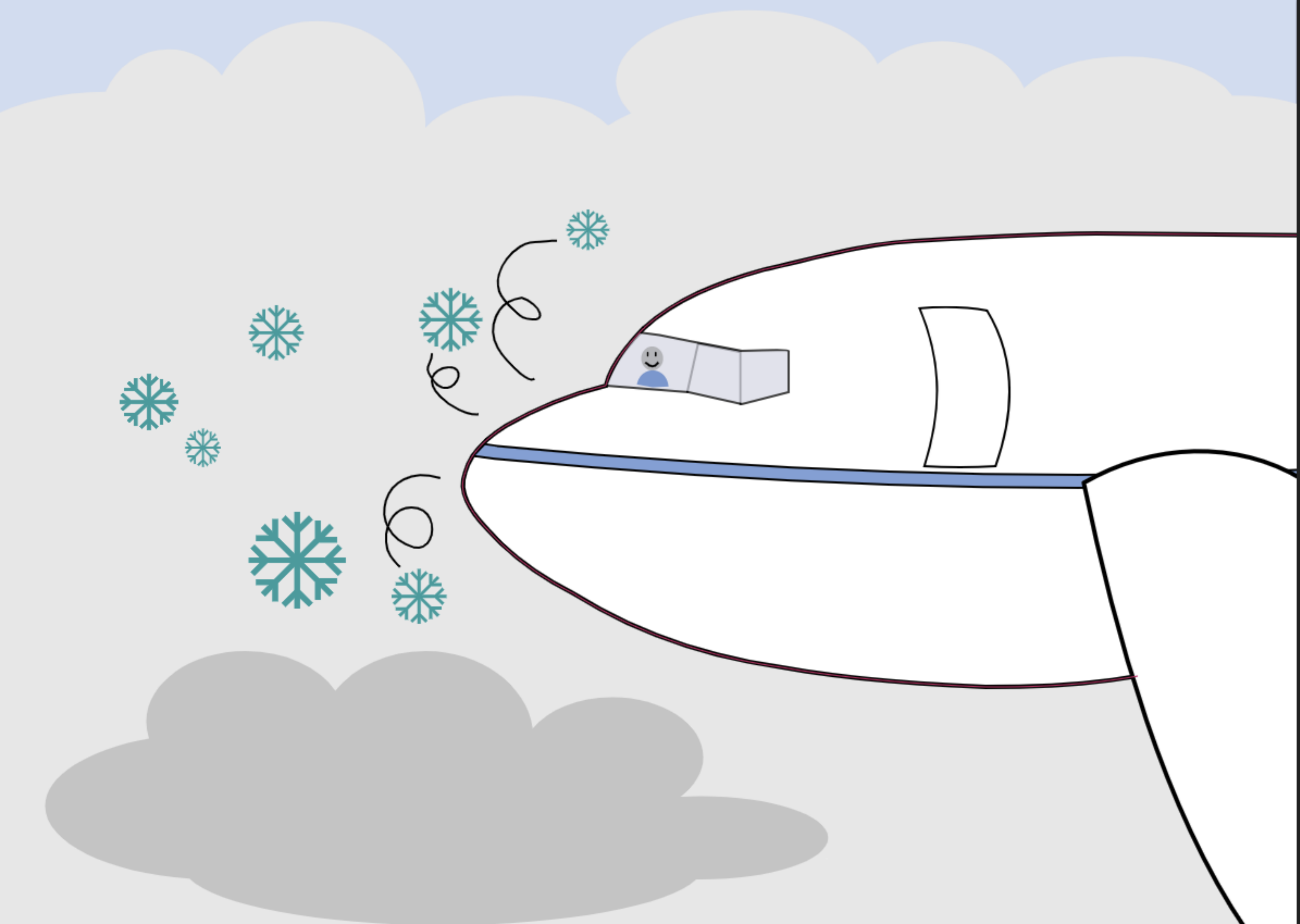
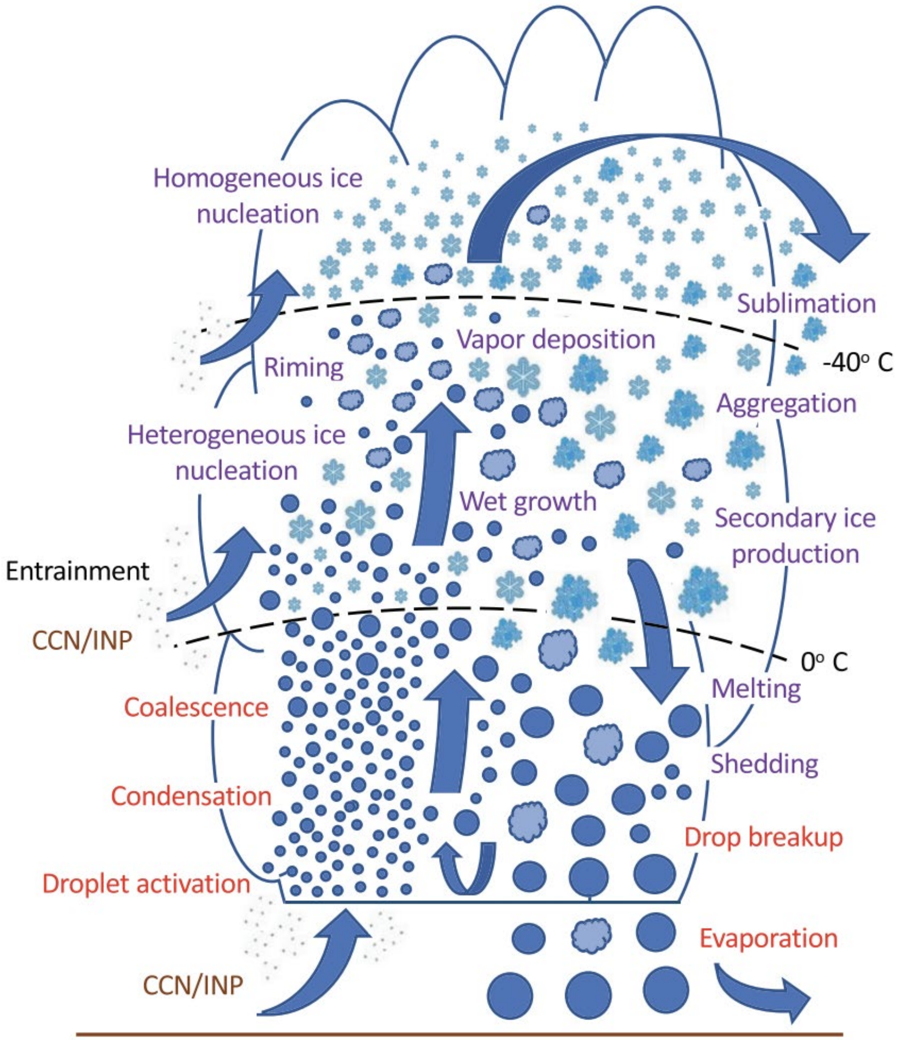
Photo: Ole Gustav Berg

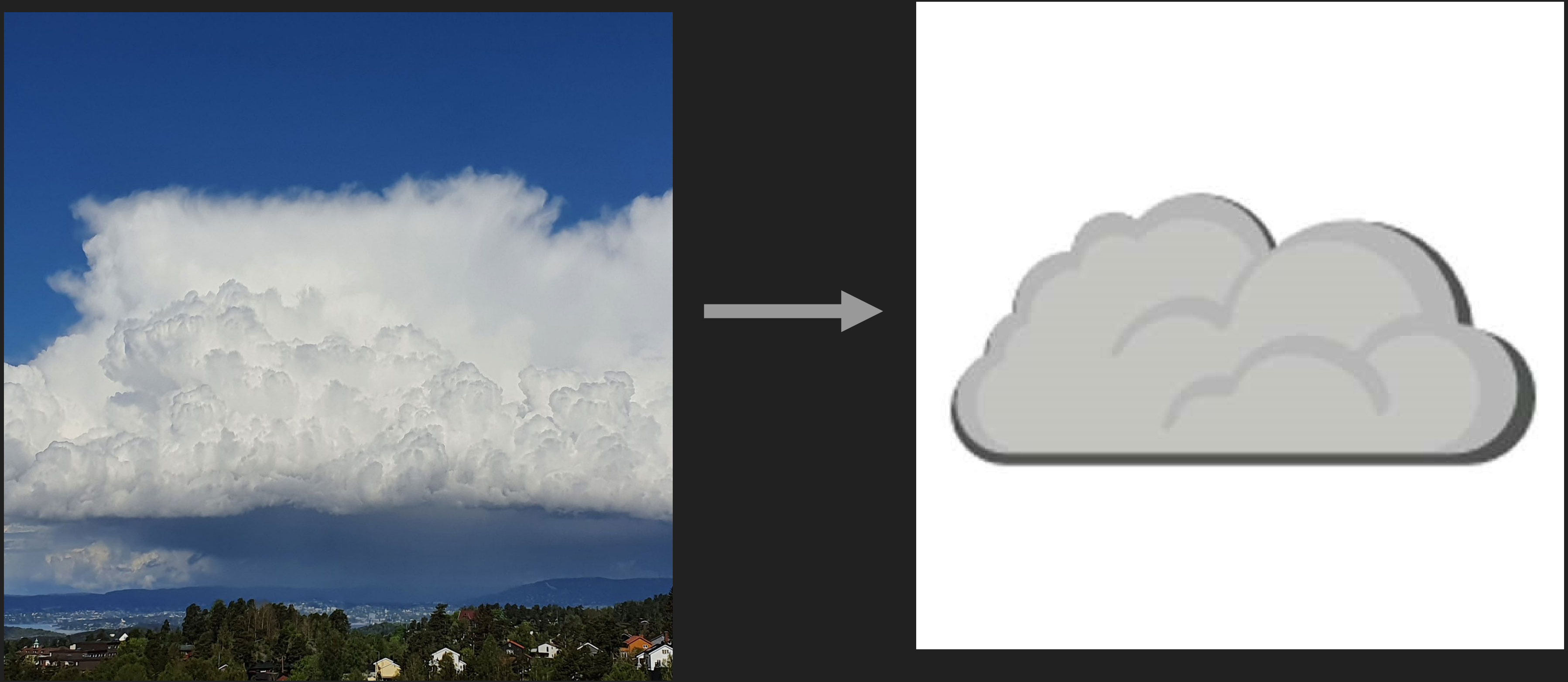






From Morrison et al. 2020

Clouds in numerical weather prediction models



ICE3 microphysics scheme

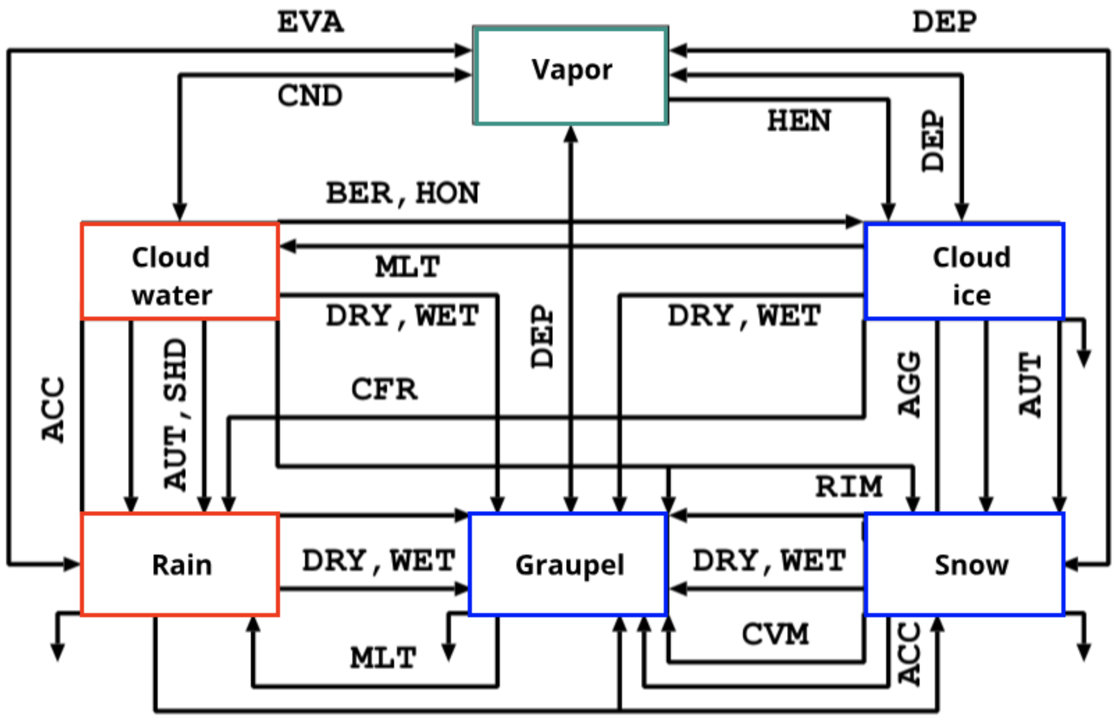


Figure 6.2: Diagram of the microphysical processes for mixed phase cloud in the present scheme.

From Mascart and Bougeault, 2011

Illustration: Tanja Tomasevic

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Goal:

Improve the representation of supercooled liquid water in the HARMONIE-AROME weather forecast model, and downstream forecasts of atmospheric icing

Part I: Down the rabbit hole

Illustration: Vivian Peng

Objective

WRF
Thompson

AROME
ICE3

Objective

WRF
Thompson

AROME
ICE3

= ICE-T

Important processes

Important processes

Ice initiation: Stricter criteria for heterogeneous ice nucleation

Important cloud processes

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Accretion of liquid water (cloud water/rain) by solid species (snow/graupel): less efficient accretion

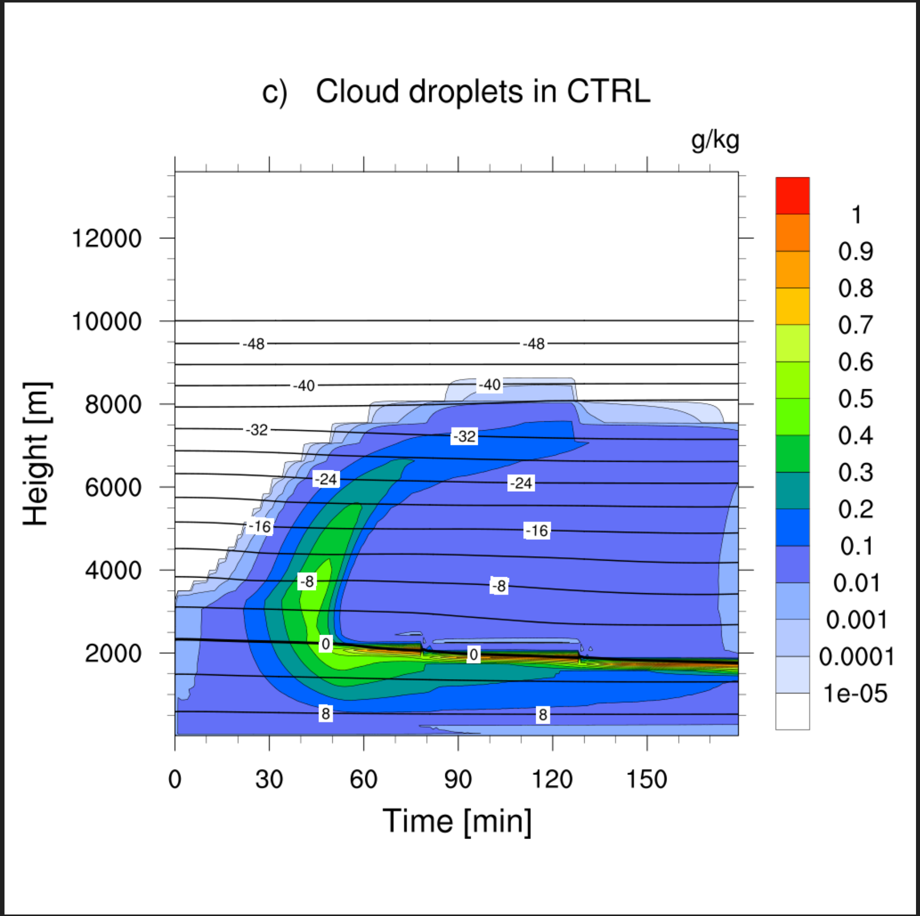
Important cloud processes

Ice initiation: Stricter criteria for heterogeneous ice nucleation

Accretion of liquid water (cloud water/rain) by solid species (snow/graupel): less efficient accretion

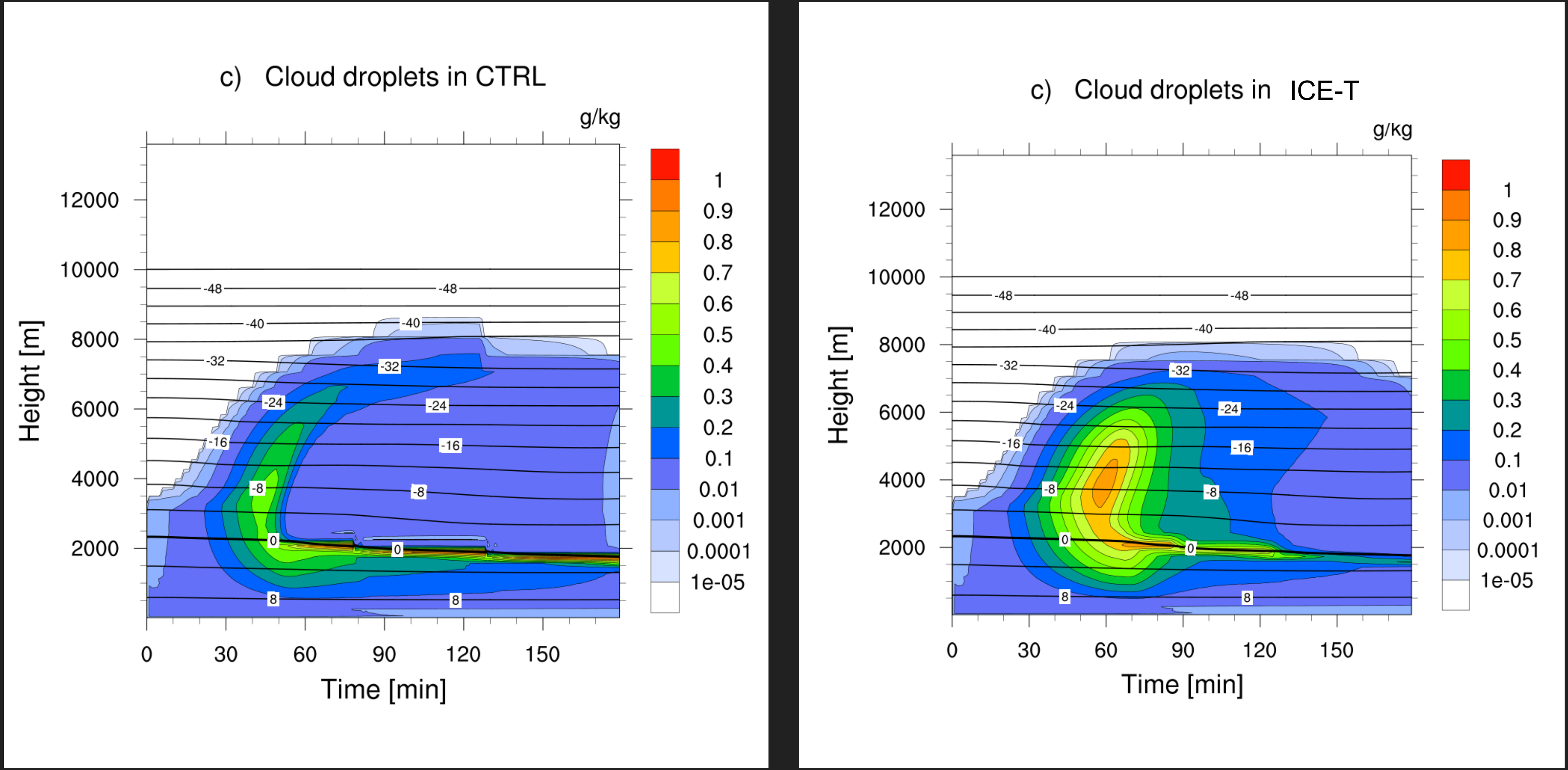
Rain size distribution

Change in supercooled liquid water



ICE-T

Change in supercooled liquid water



Part II: Back to the surface

Real case simulations

Dec 1 2016 - Feb 28 2017

CTRL and ICE-T

2.5km grid spacing, 65 vertical levels, domain covering Norway, Sweden and parts of Finland

Observations of ice loads from Ålvikfjellet and Hardingnuten

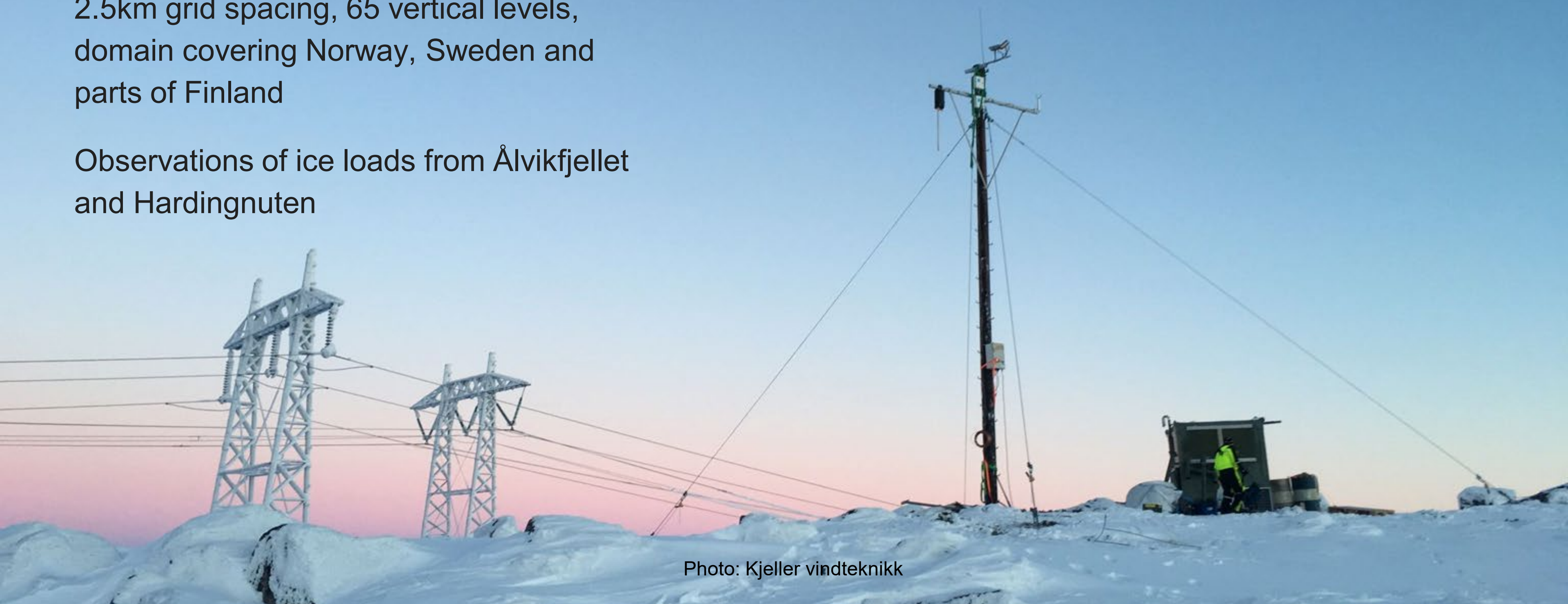
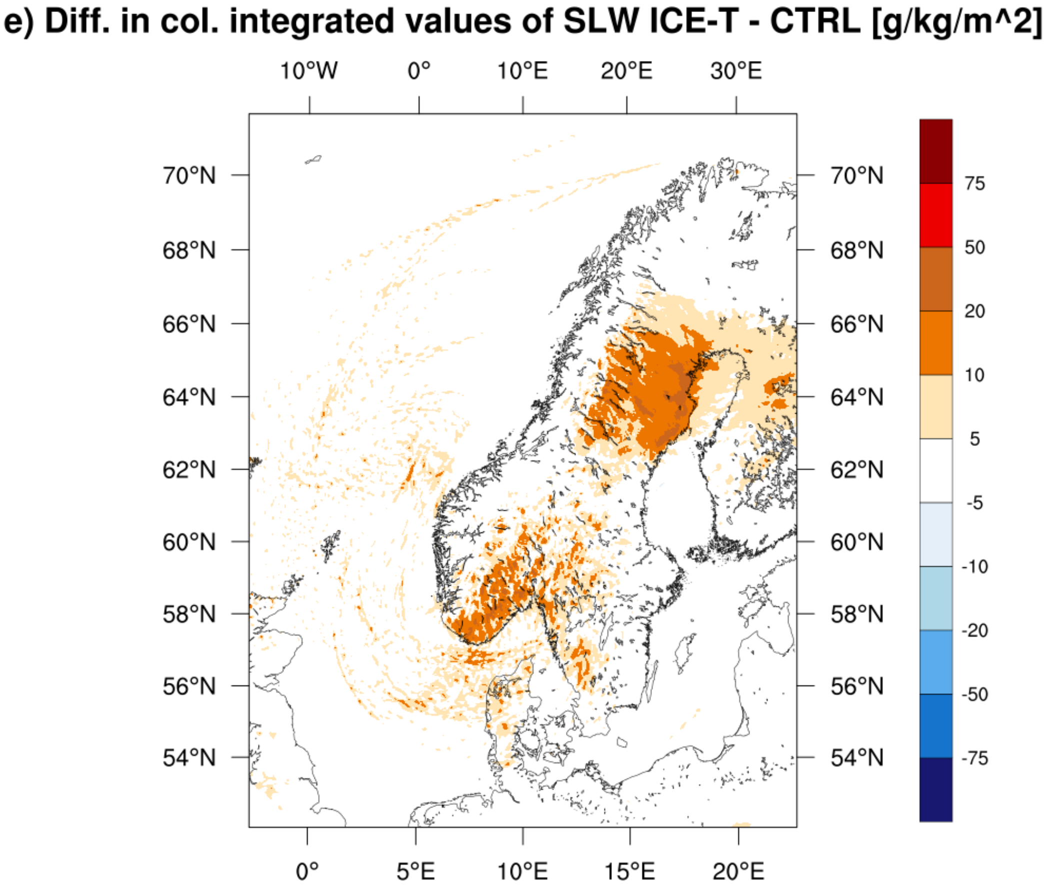


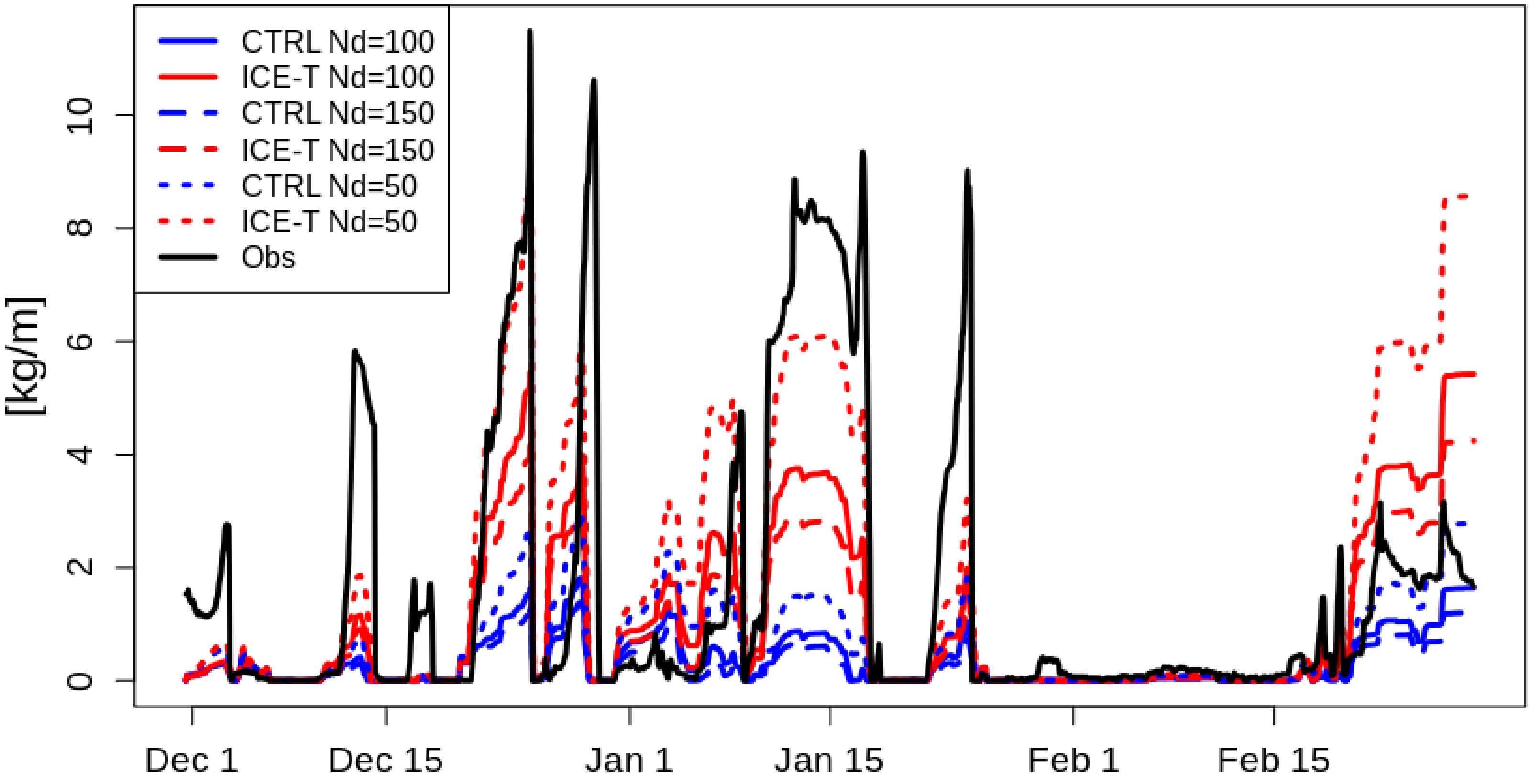
Photo: Kjeller vindteknikk

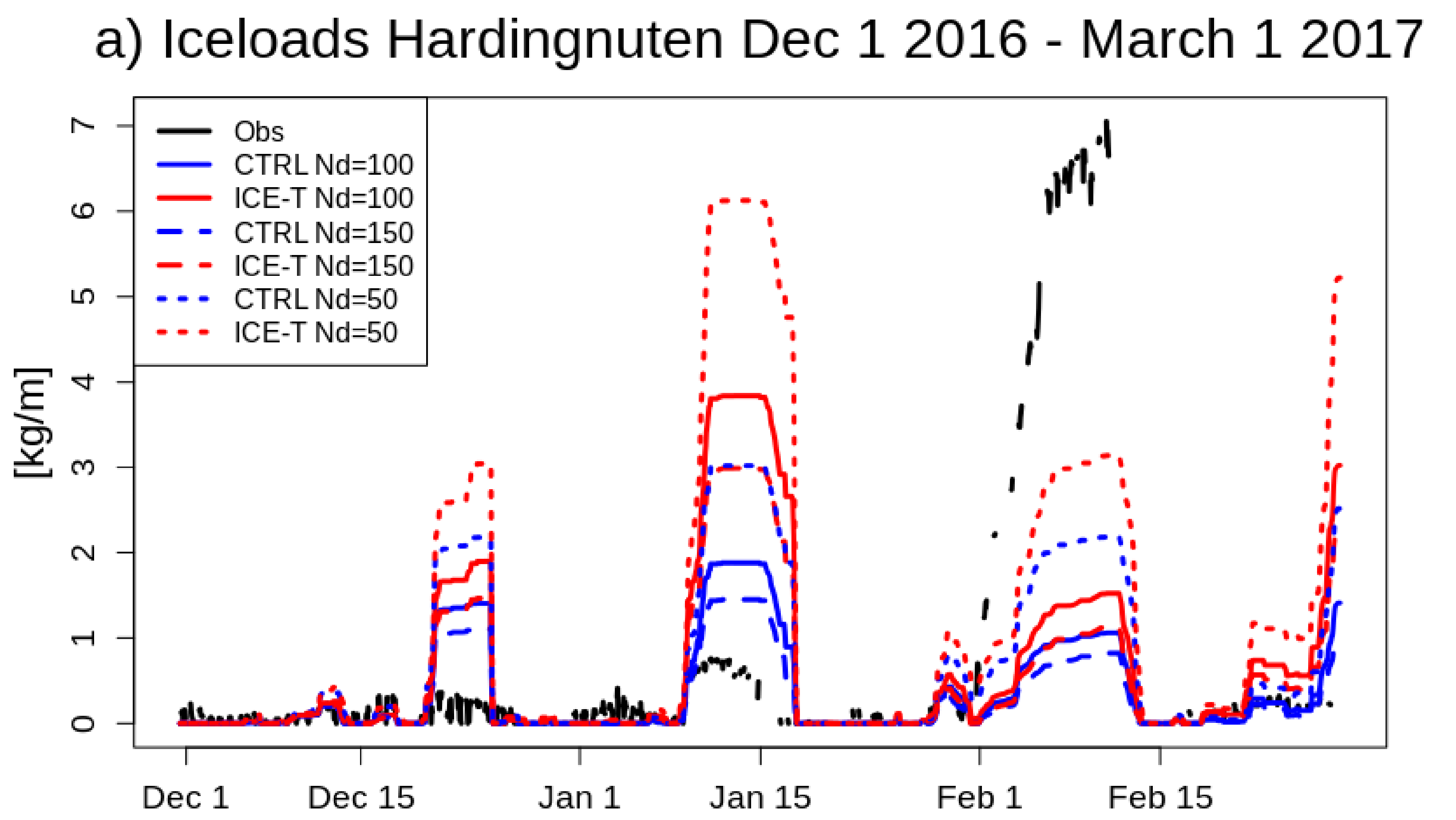
More supercooled liquid water

Difference in supercooled liquid water between ICE-T and CTRL



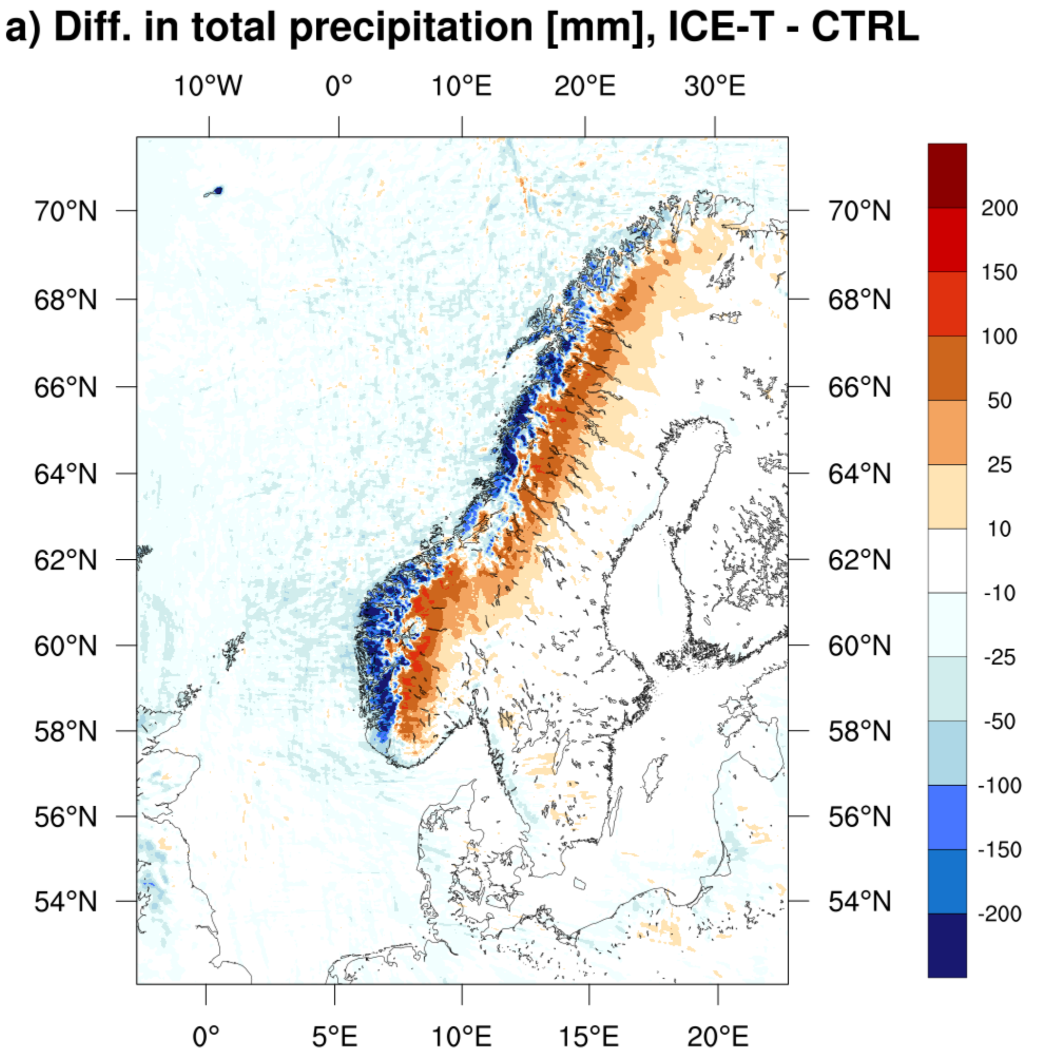
a) Iceloads Ålvikfjellet Dec 1 2016 - March 1 2017




a) Iceloads Hardingnuten Dec 1 2016 - March 1 2017
Obs
CTRL Nd=100
ICE-T Nd=100
CTRL Nd=150
ICE-T Nd=150
CTRL Nd=50
ICE-T Nd=50
[kg/m]
0
1
2
3
4
5
6
7
Dec 1
Dec 15
Jan 1
Jan 15
Feb 1
Feb 15

Changed precipitation pattern

Difference in precipitation between ICE-T and CTRL



Part III: Take-off!

Photo: shutterstock

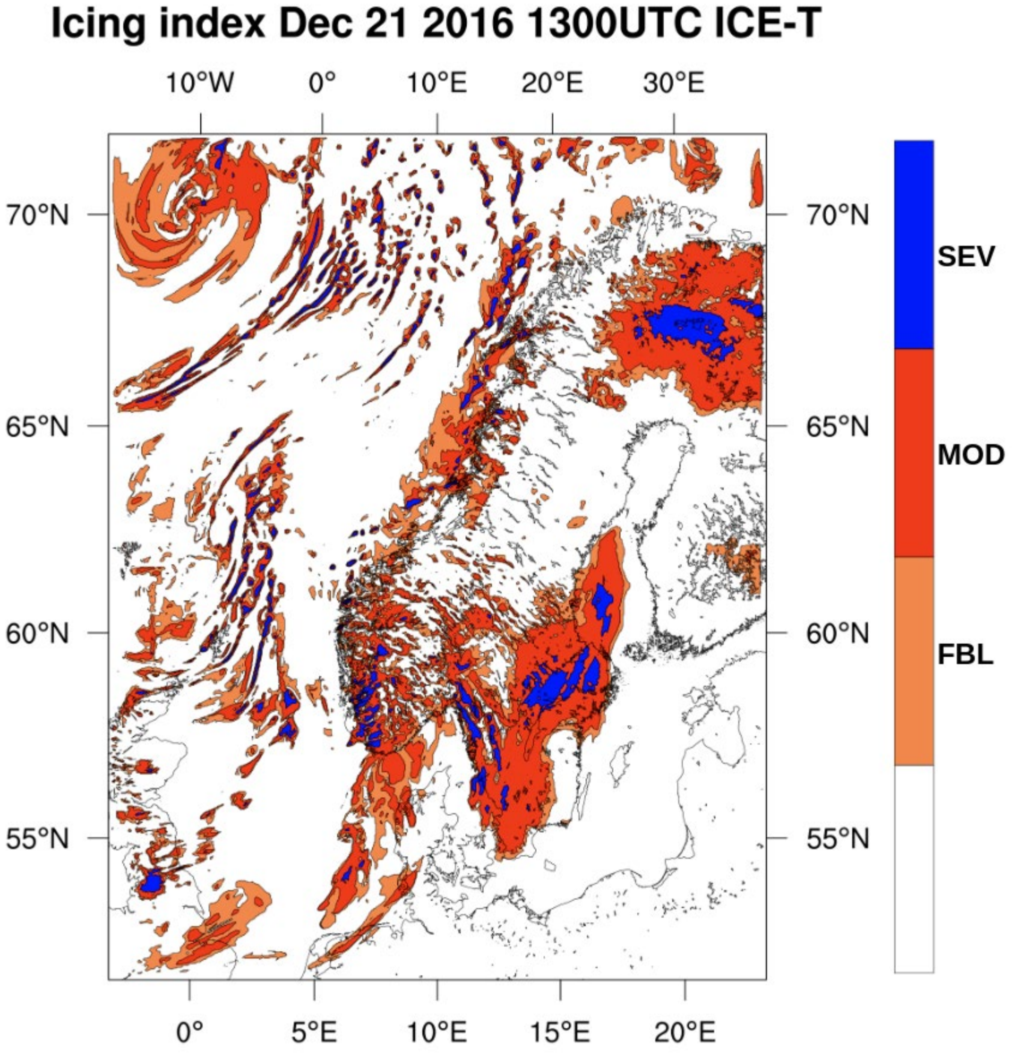
Aircraft icing

Investigate the ICE-T's ability to predict aircraft icing

Compare modelled icing indices with pilot reports

Compare simulated atmospheric profiles of LWC and IWC with derived profiles from CloudSat-CALIPSO

Compare modelled LWP with similar values derived from AMSR-2



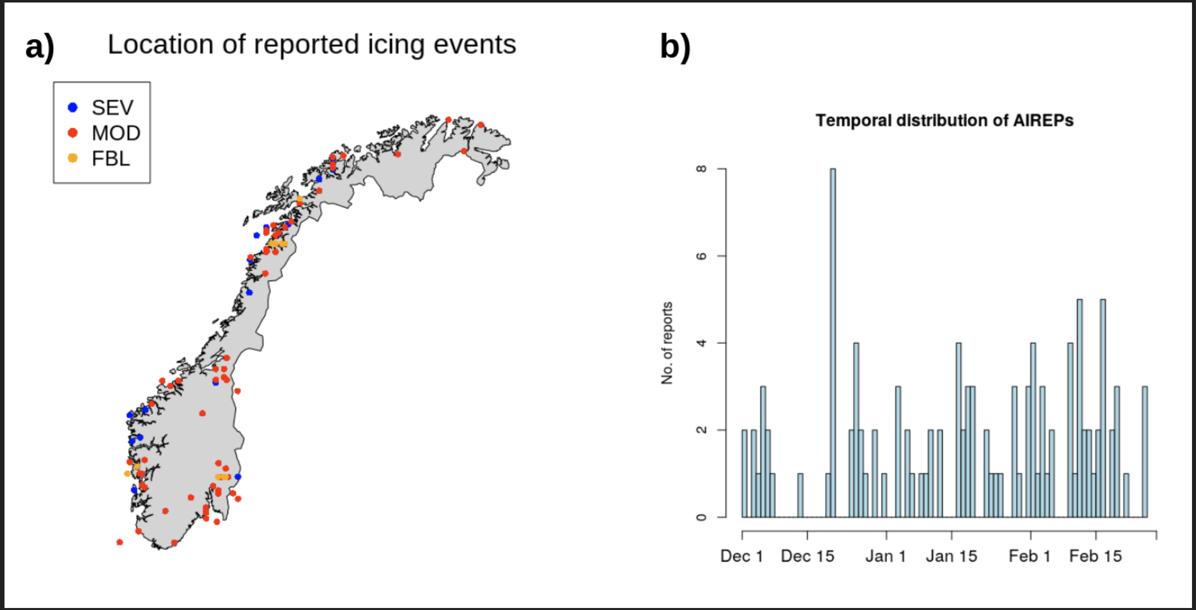
Pilot reports

111 total

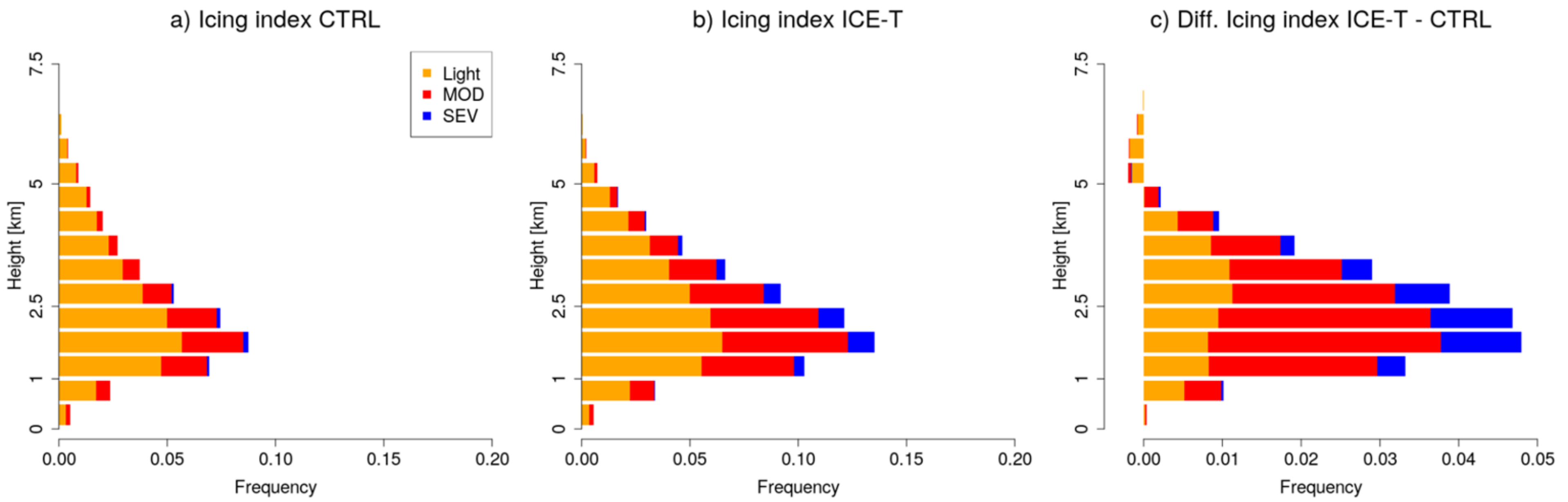
12 FBL (light), 78 MOD (moderate), 21 SEV (severe)

Time, location, height interval, severity

Problem: Biased and subjective, no reports of no icing



Increased frequency of icing forecasts and severity



Higher detection rate

Icing cases detected: CTRL: 73 (66%), ICE-T: 83 (75%)

Moderate and severe events: CTRL: 48% ICE-T: 62%

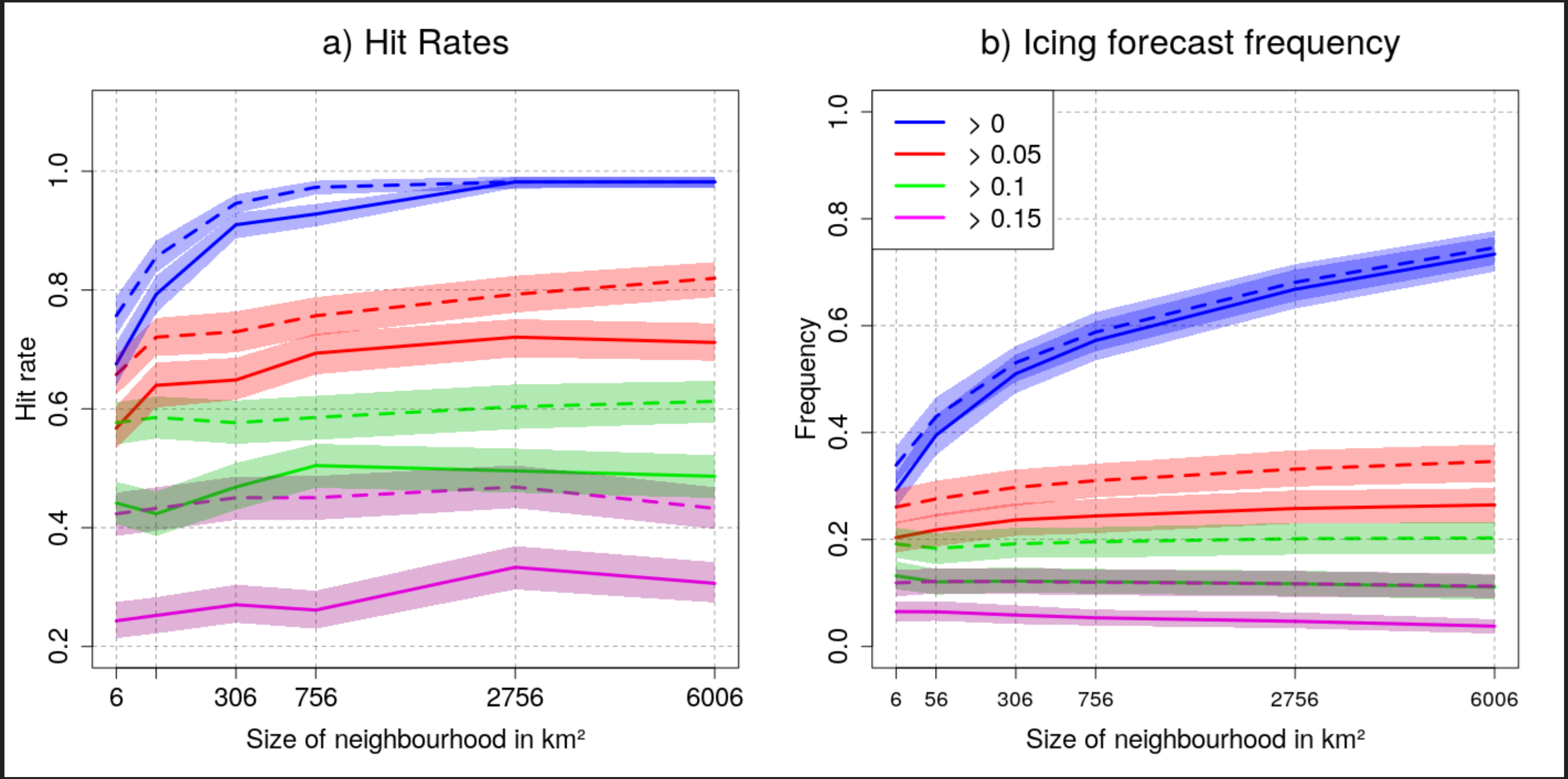
Neighbourhood

neighbourhood areas: 6, 56, 306, 756, 2756, and 6006km²

Thresholds: > 0% (any icing), 5%, 10% , 15%

Hit rate and icing forecast frequency

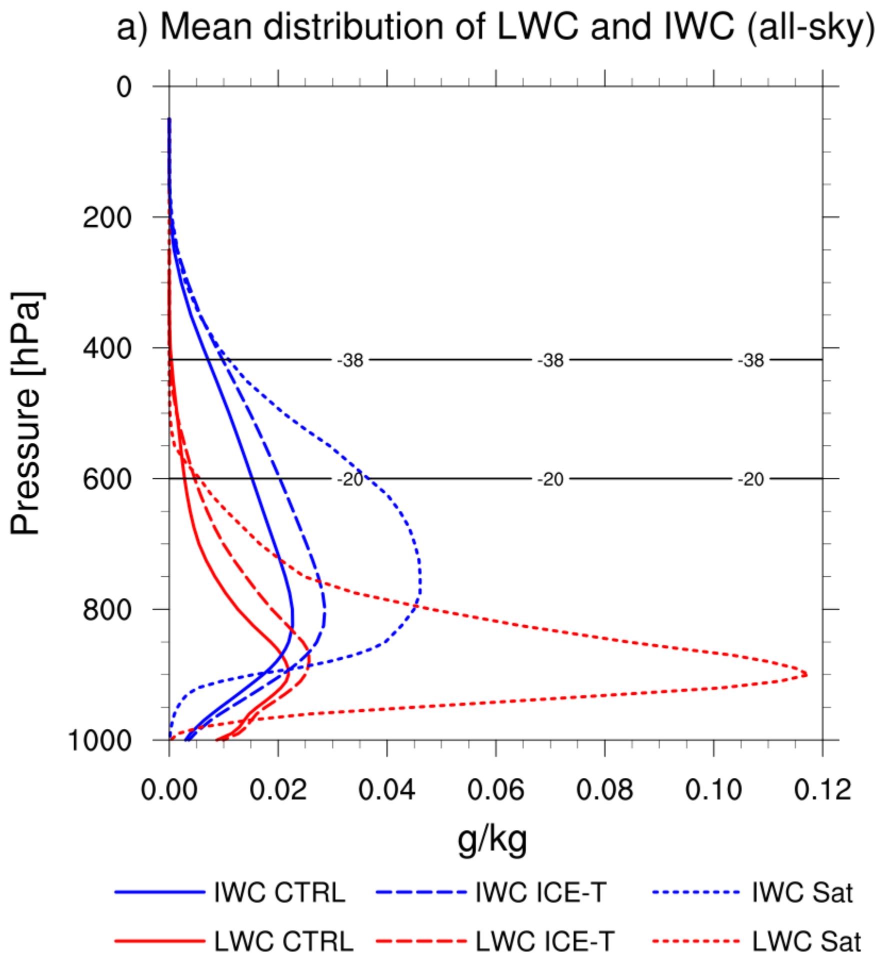
Increased hit rates and Icing forecast frequencies with ICE-T (dashed lines) compared with CTRL (solid lines)



Atmospheric profiles of liquid and ice

Vertical profiles of liquid (red lines) and ice (blue lines)

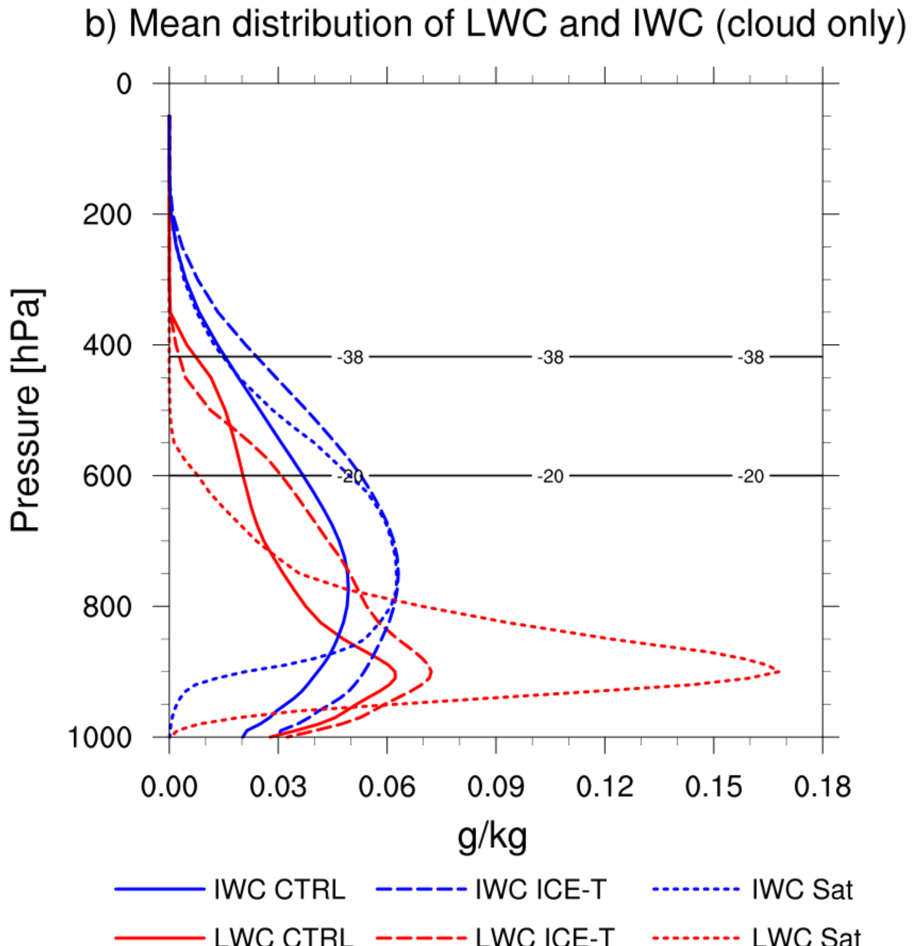
Satellite profiles from CloudSat-CALIPSO

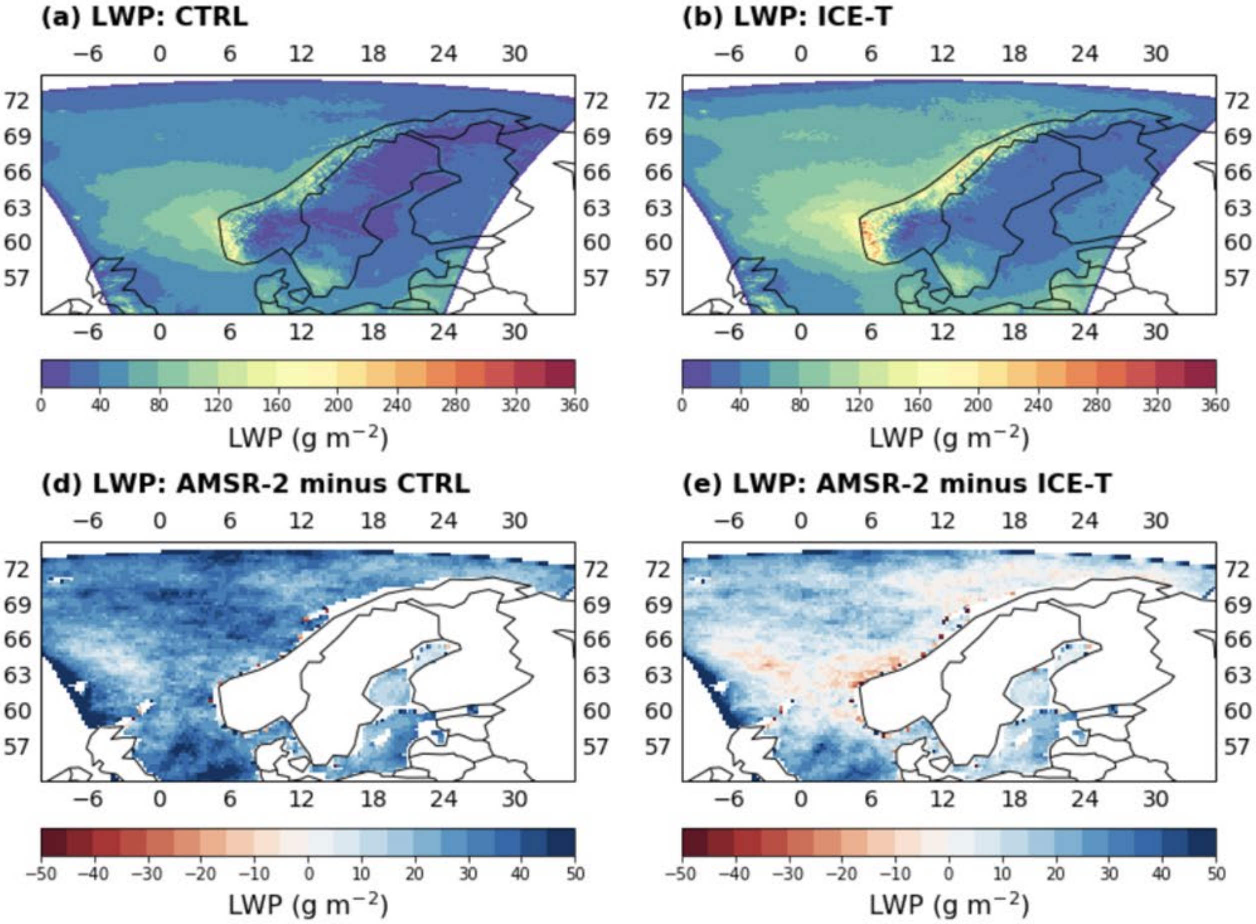


Atmospheric profiles of liquid and ice (cloud only)

Vertical profiles of liquid (red lines) and ice (blue lines)

Satellite profiles from CloudSat-CALIPSO





Mean values (ocean only):
CTRL: 52 g/m²
ICE-T: 69 g/m²
AMSR-2: 78 g/m²

Average liquid water paths for the entire 3 month period for both simulations and satellite retrieved data from AMSR-2

Conclusions

Modified important processes

Leads to increased

- supercooled liquid water
- ice loads
- forecasts of icing

Better match

- ice loads
- hit rates
- satellite

Supercooled liquid water could still be underestimated

Shift in precipitation pattern


Photo: Greg Thompson


Thank you for your attention!
Photo: Ole Gustav Berg