Large Eddy Simulation of Icing Conditions Impacting Wind Farms

Winterwind
Åre 2020

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SMHI

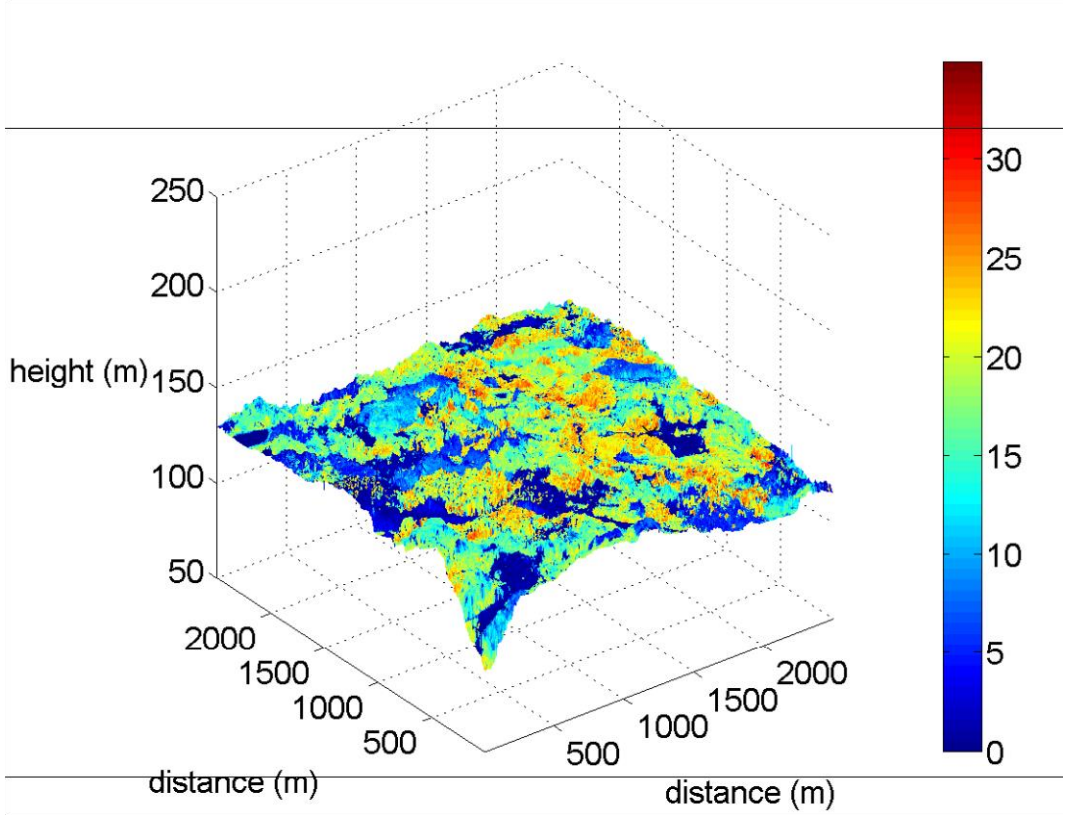
Motivation

- Properties of the vegetation can have significant effects on boundary layer variables
  - Surface radiation budget (albedo differences, etc)
  - Turbulence (surface roughness)
  - Moisture fluxes (evapotranspiration, removal of cloud water through deposition)

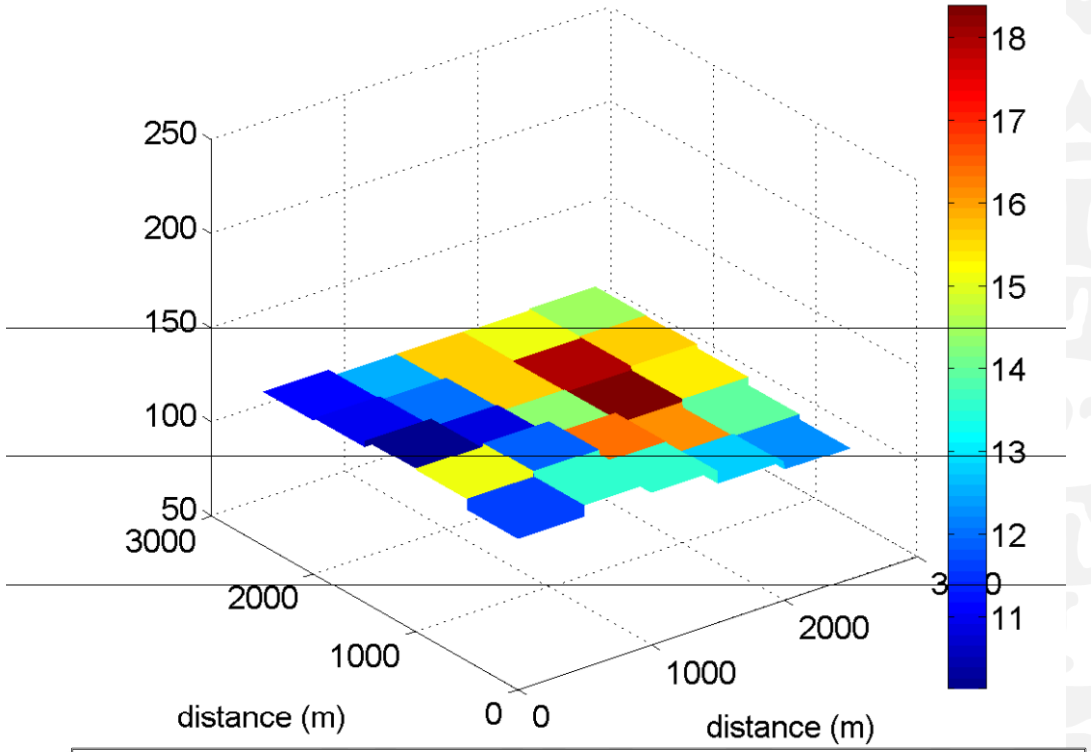
❑ ***All variables that may affect the forecast of in-cloud icing conditions***

Land Surface Representation

REALITY



NWP MODEL



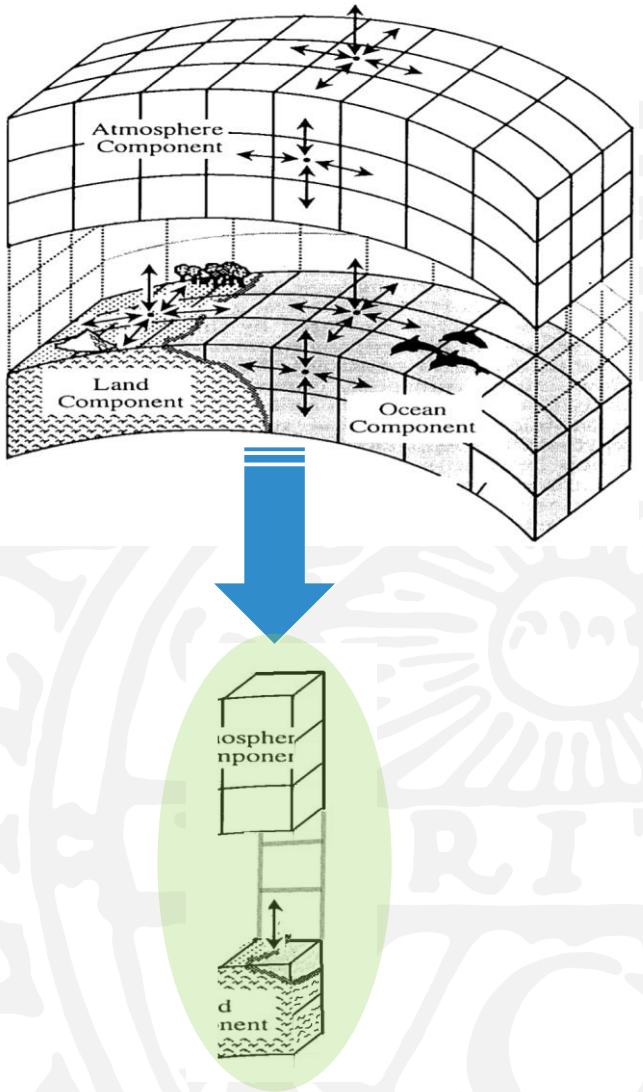
Note: the model in this example has relatively high resolution…

Source: Johan Arnqvist

MUSC Single-Column Model

- Simplified version of HARMONIE-AROME 3D model- *Modèle Unifie Simple Colonne (MUSC)*
  - Initial atmospheric state and surface-related properties from 3D model provided as input
  - Time integration of simulation performed in single column
  - No horizontal advection
  - SURFEX surface model

❑ ***Simplified framework allows for idealized experiments to be performed with minimal computational cost***



Sources: Räisänen and Rontu (2013) / Bryant (1997)

Surface Model SURFEX

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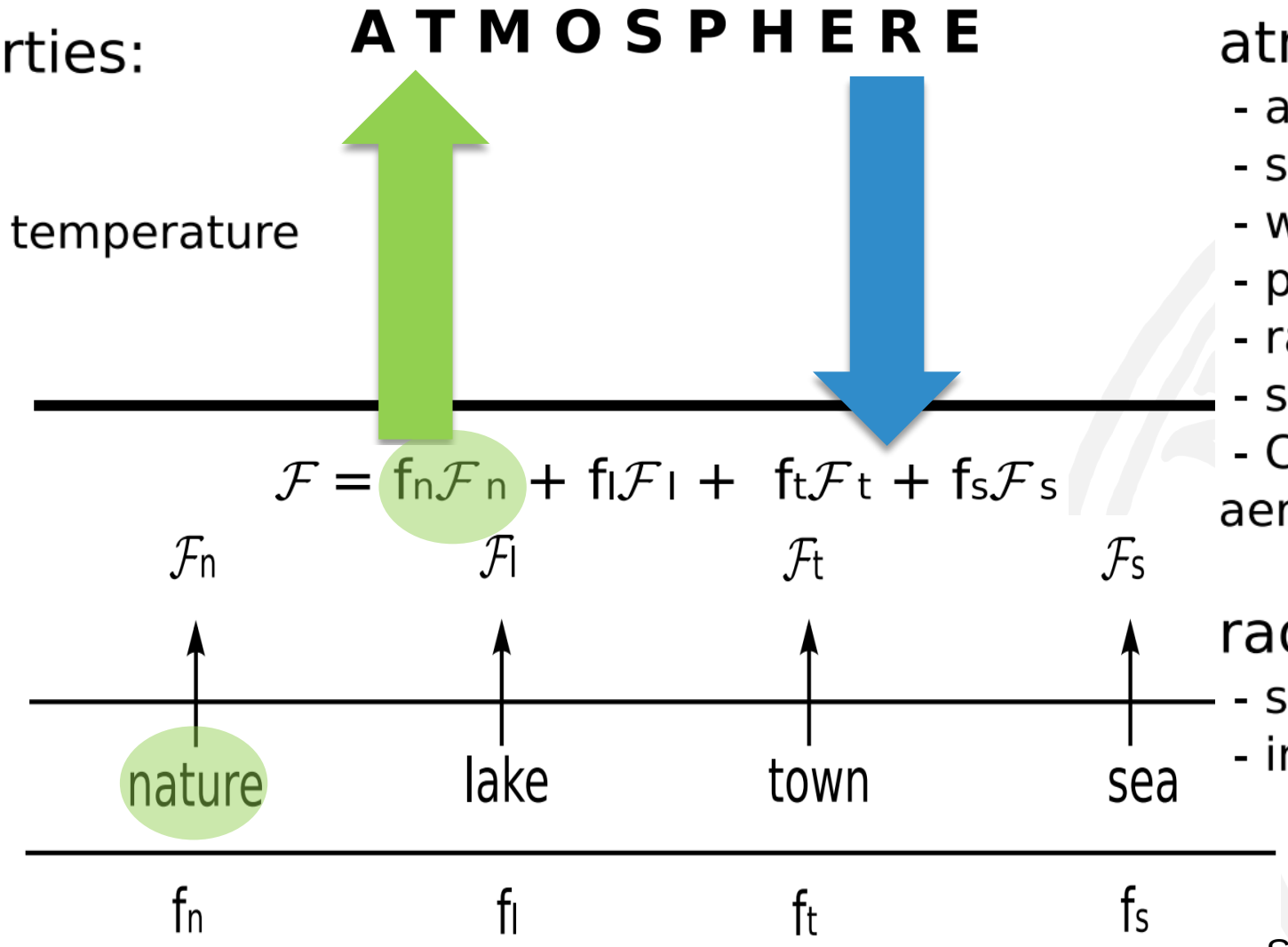
radiative properties:
- albedo
- emissivity
- surface radiative temperature

surface fluxes:
- momentum
- sensible heat
- latent heat
- CO2
- chemical species
- aerosols



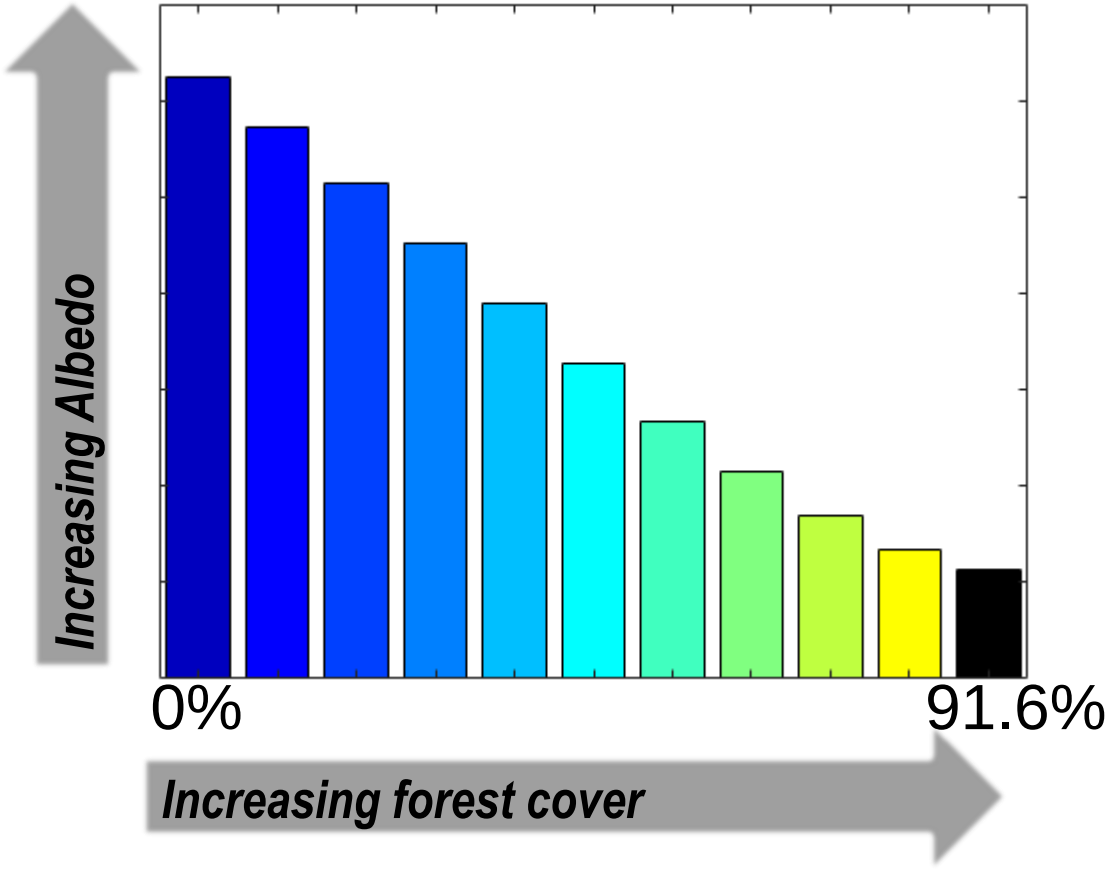
atmospheric forcing:
- air temperature
- specific humidity
- wind components
- pressure
- rain rate
- snow rate
- CO2, chemical species, aerosols concentration

radiative forcing:
- solar radiation
- infrared radiation

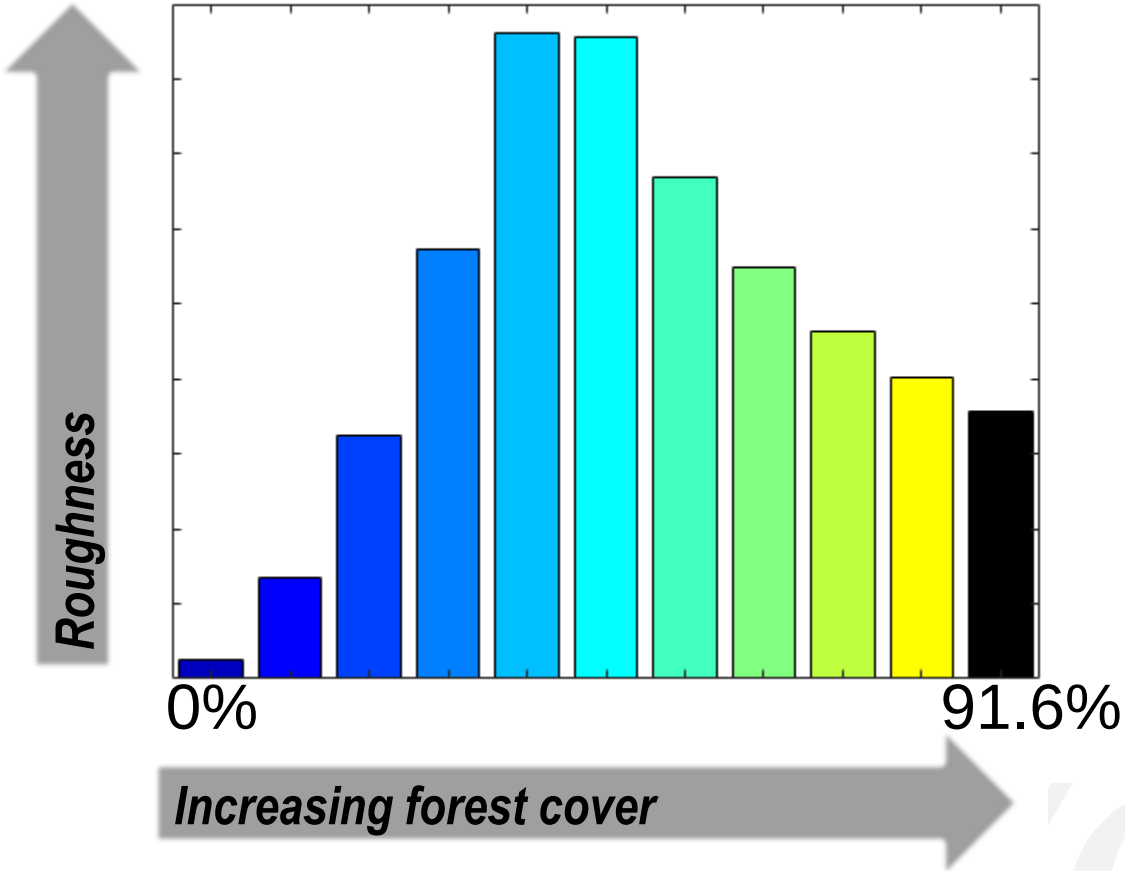
Source: Le Moigne et al (2012)

Change in Surface Parameters

Albedo (Visible Wavelength)

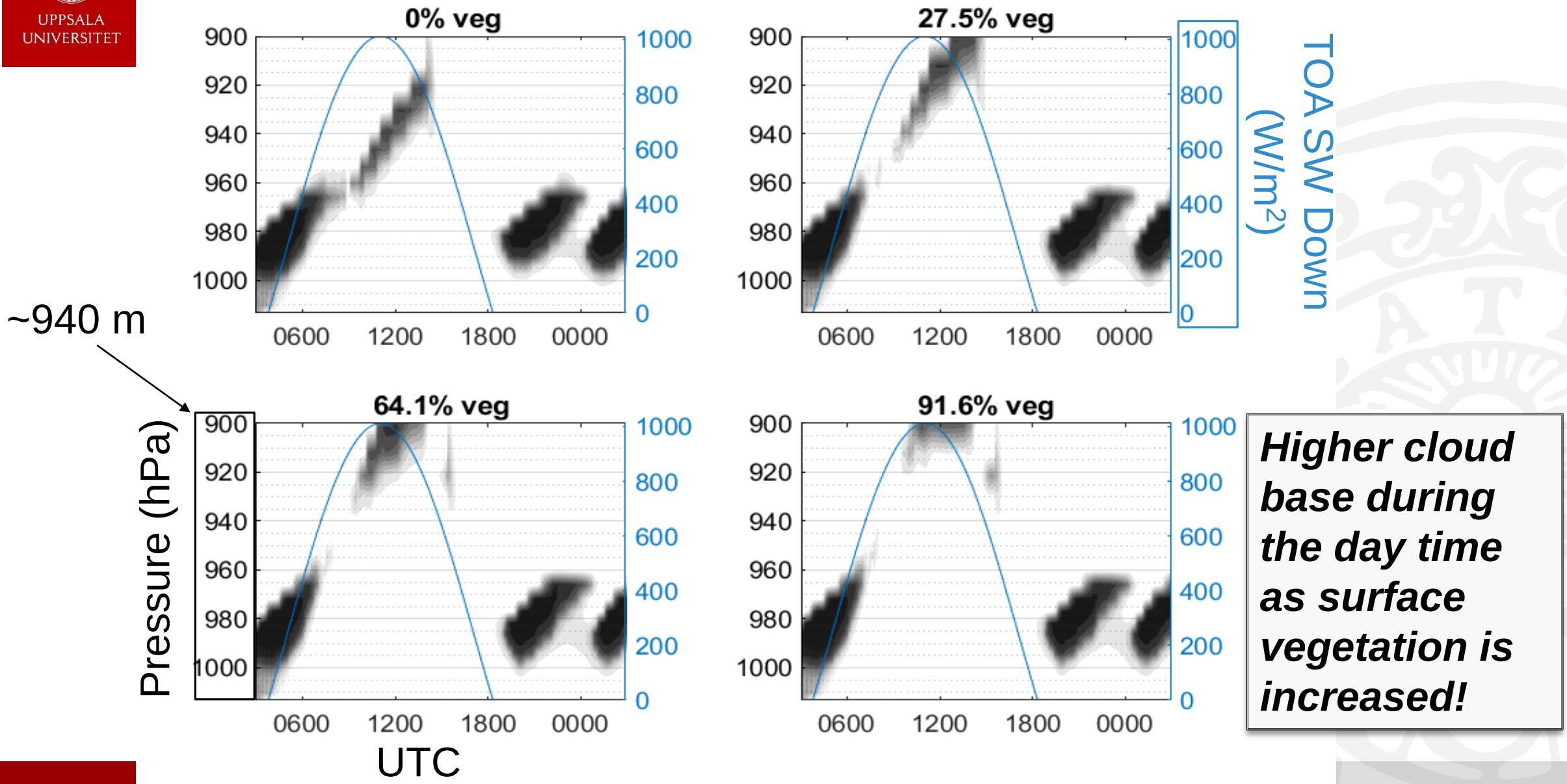


Roughness Length (z0)



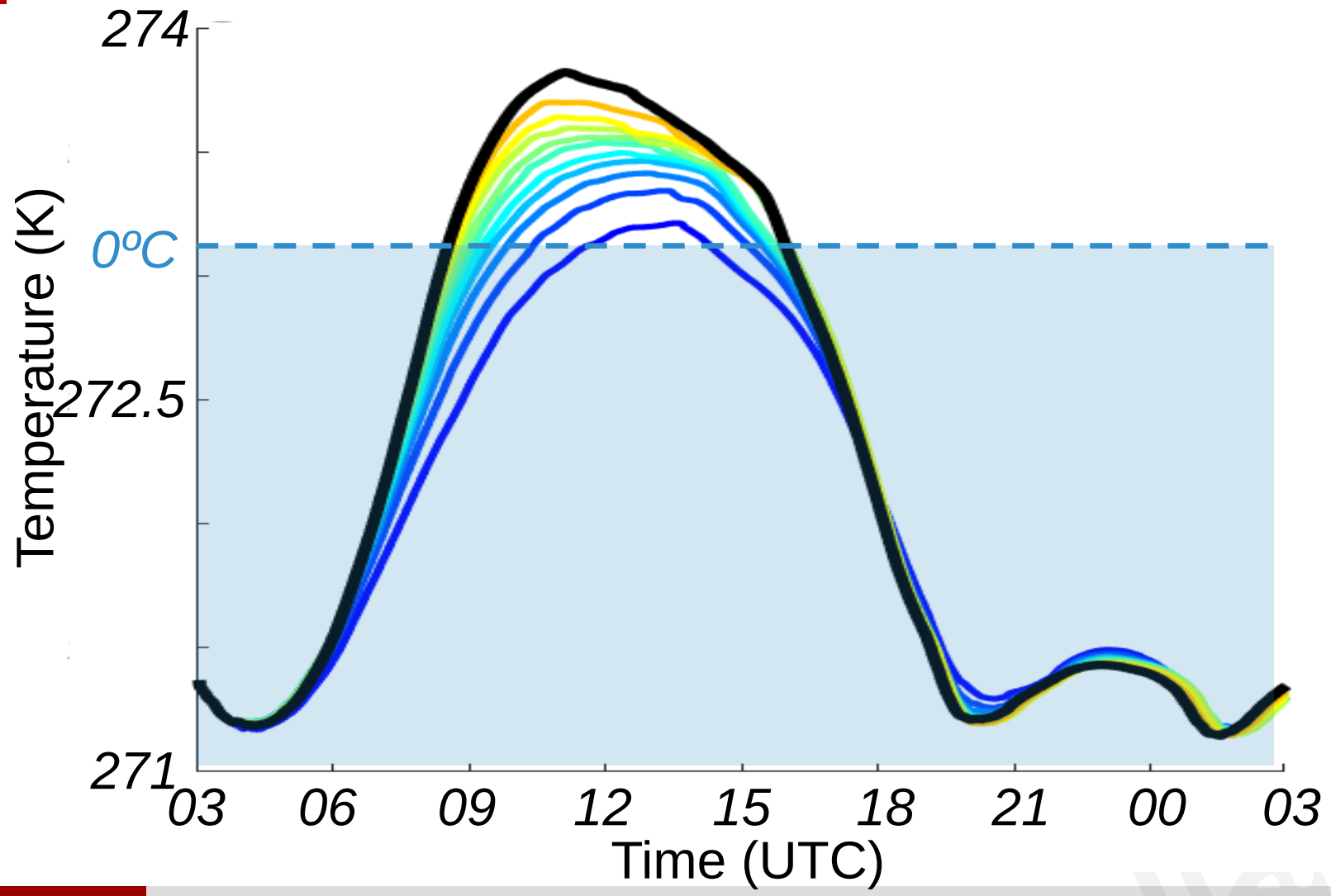
(From SURFEX output)

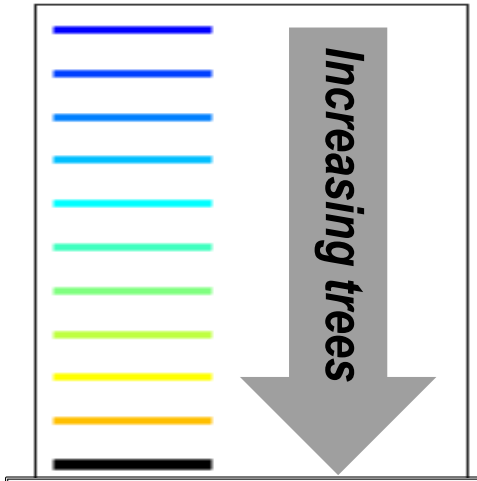
Low Level Cloud Profile



Higher cloud base during the day time as surface vegetation is increased!

Temperature at Hub Height





Warmer daytime temperature at turbine hub height with increased vegetation

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Meso-NH

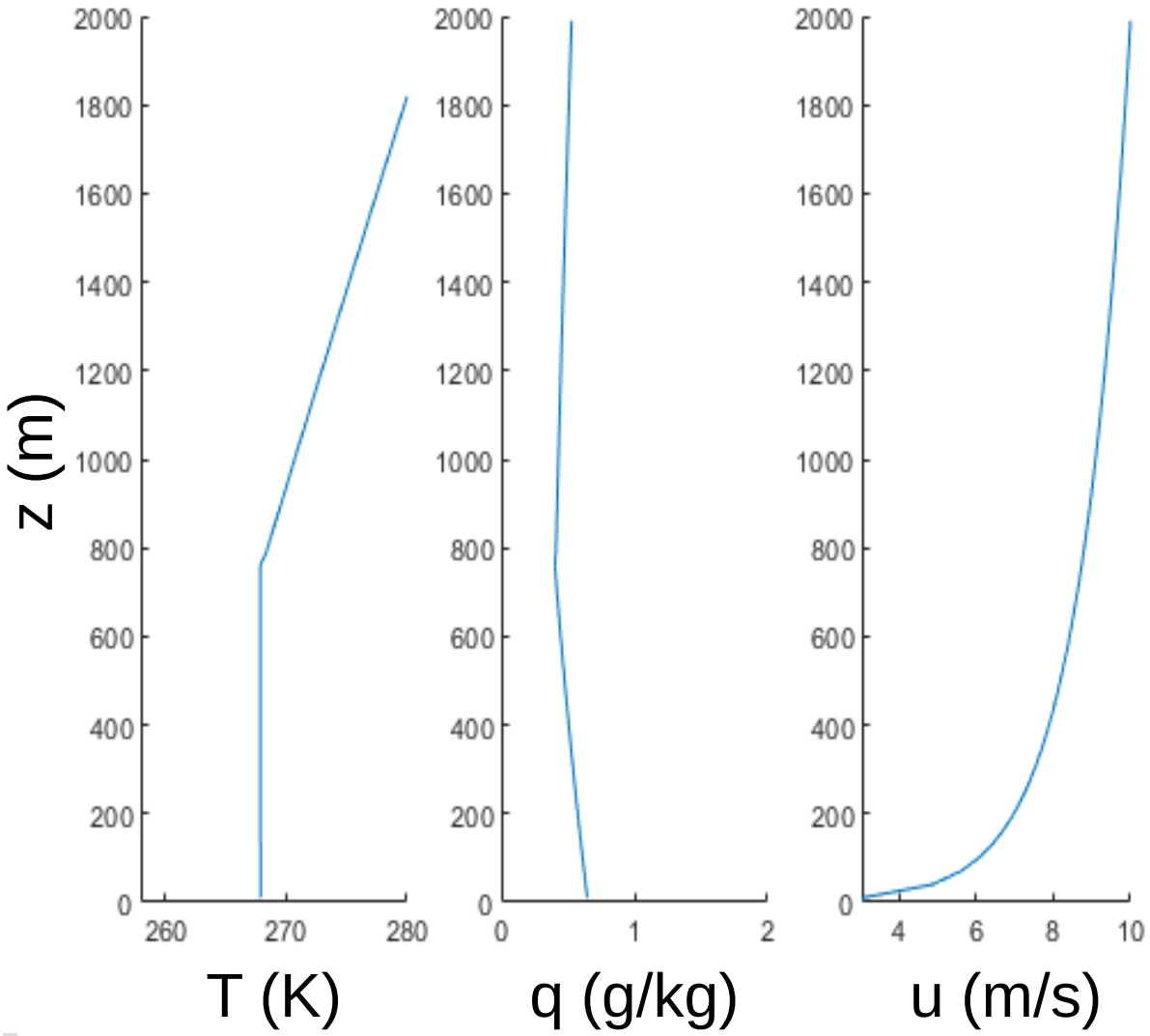
- Large Eddy Simulation (LES) to examine fluxes in more detail, including horizontal fluxes

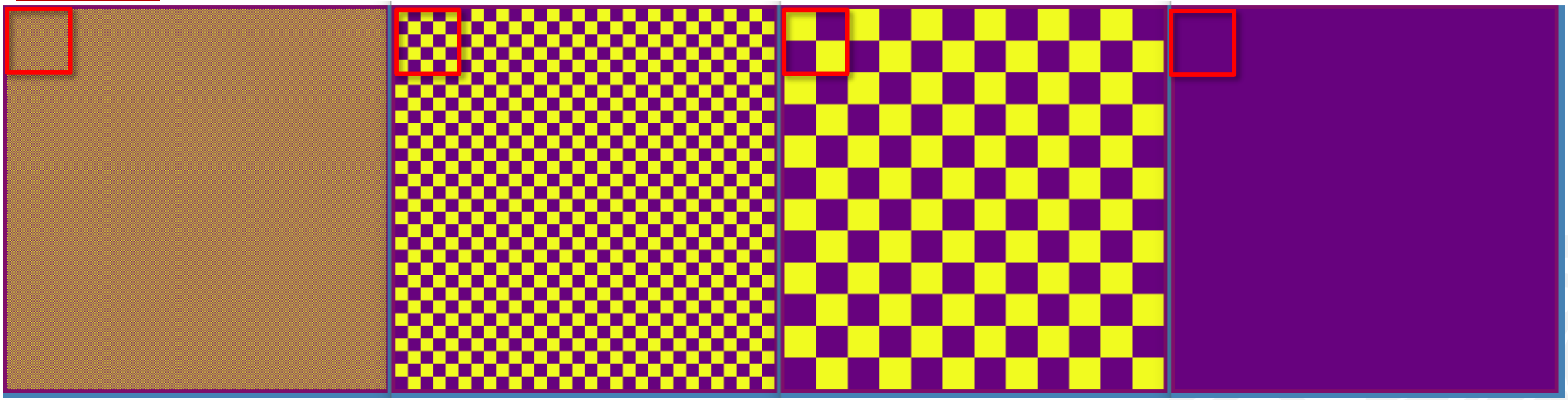
- Meso-NH contains code and parameterization schemes common to HARMONIE-AROME and MUSC
  - Turbulence scheme described in Cuxart et al. (2000)-adaptable for both mesoscale and LES scales

- What is the sensitivity of the surface model to land surface heterogeneity?

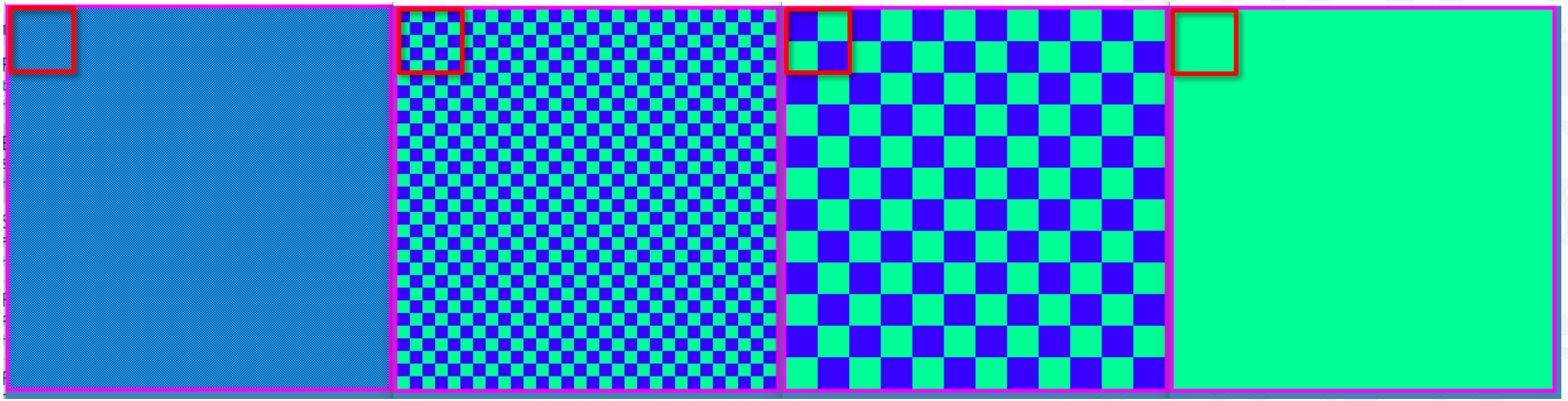
Initial Test

- Dry neutral case *(25% RH)*
- Inversion height: $0.15\frac{u_*}{f}$
- Log initial u profile (assuming $z_o = 1\ \mathrm{m}$)
- 1.5 order 3D Turbulence *(Cuxart et al. 2000)*
- LS forcing assuming u_g=10 m/s
- Cyclic LBC
- 23-24 March 2016 23:00-11:00 solar profile
- Flat terrain, 300x300 grid points, $dx = 50\ \mathrm{m}$





z_o (meters)



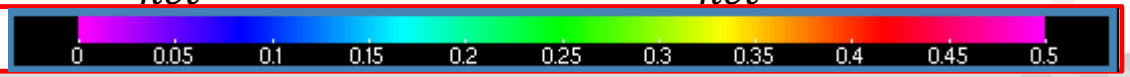
l_{het}=50 m

l_{het}=500 m

l_{het}=1250 m

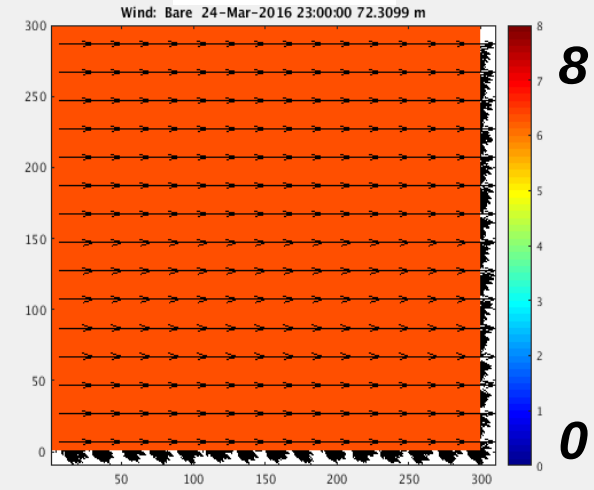
BARE

Albedo

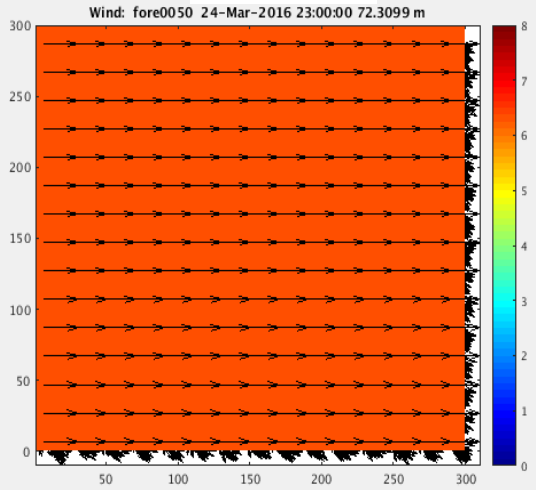


Wind Speed (ms^{-1}) @ 72 meters

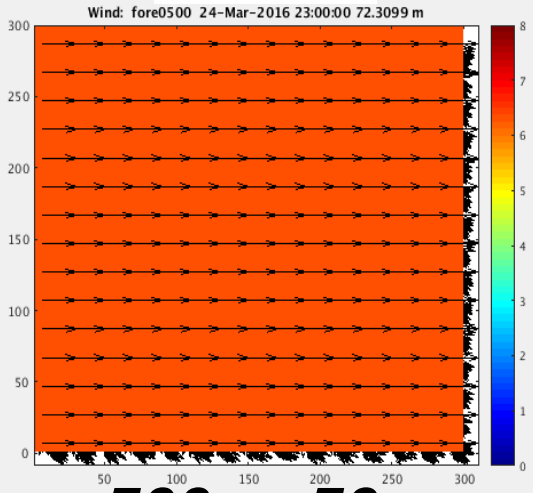
BARE



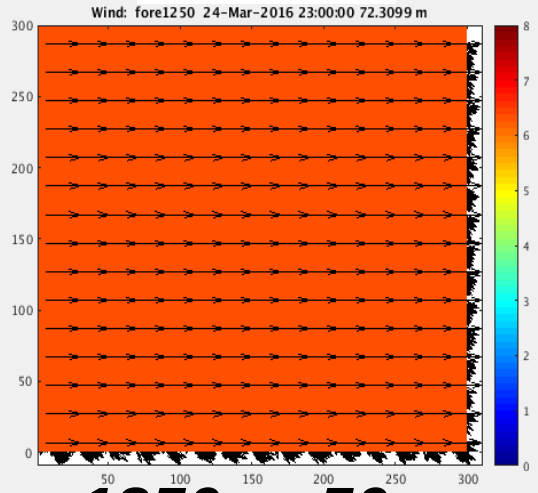
50 m



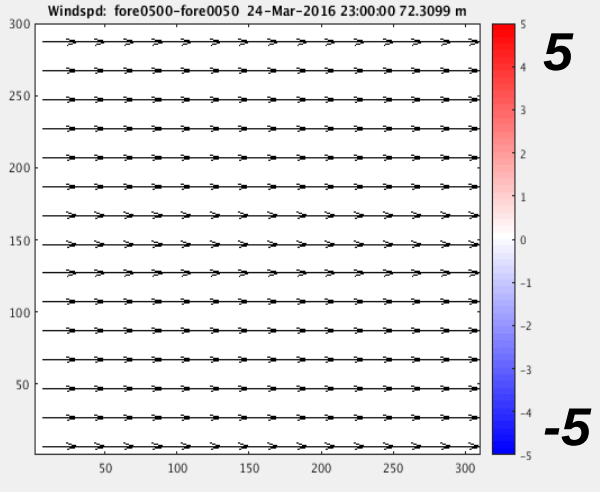
500 m



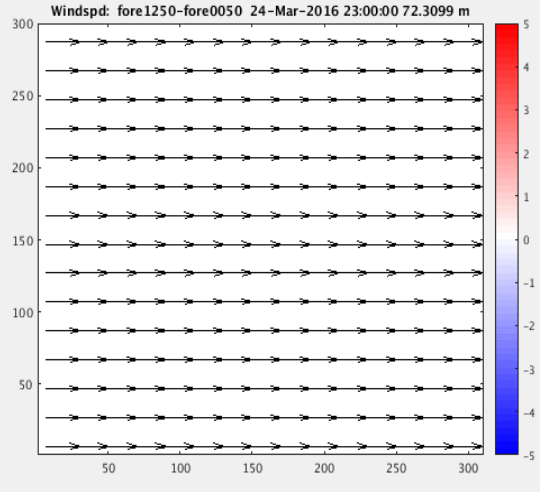
1250 m



500 m-50 m



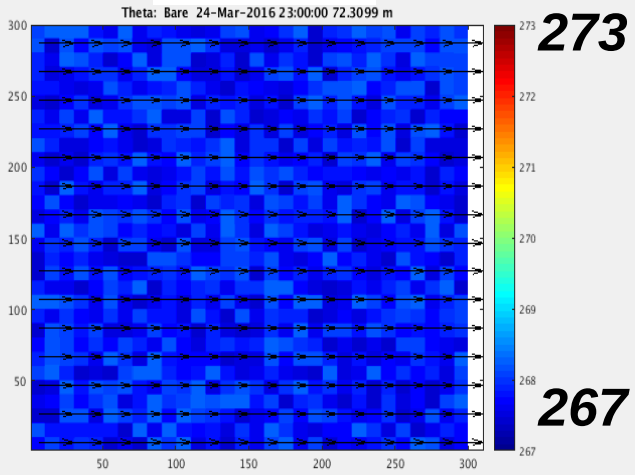
1250 m-50 m



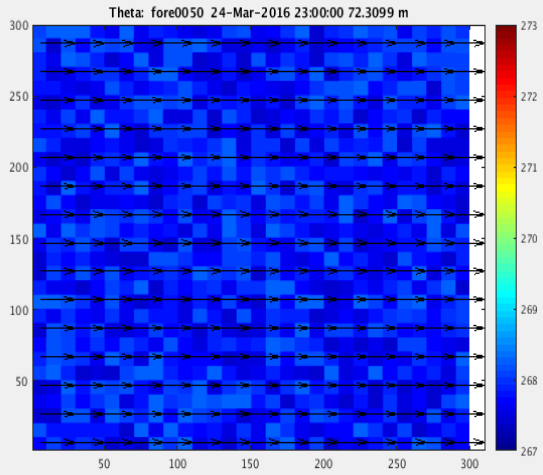
Blue: exp greater than l_{het}=50 m

Theta (K) @ 72 meters

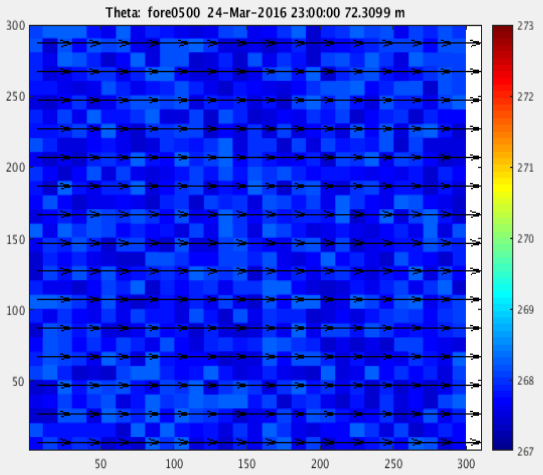
BARE



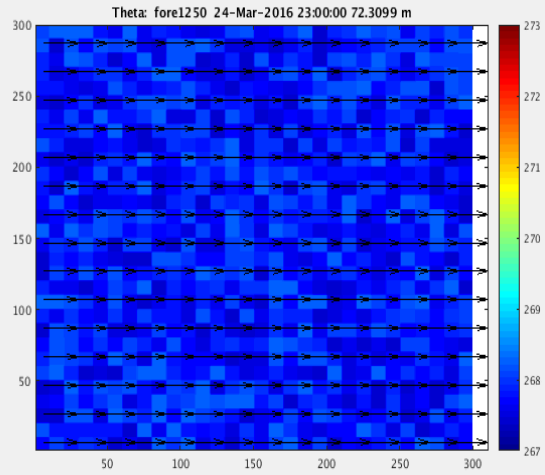
50 m



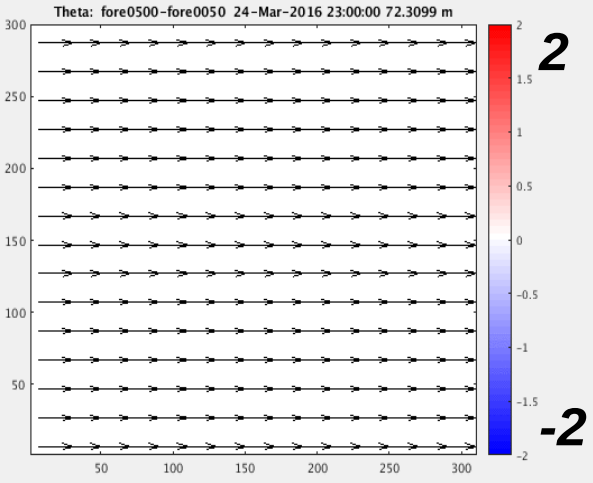
500 m



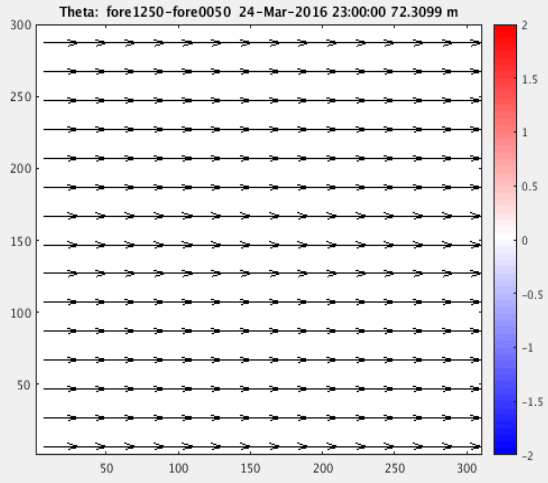
1250 m



500 m-50 m



1250 m-50 m



Blue: exp greater than l_{het}=50 m

LES Experiment

- Comparison of Meso-NH results to MUSC
  - “Moist” case with cloud cover
  - Full diurnal cycle, different solar input (December versus March), different stability
- Opportunity to examine TKE budget and temperature impact for different length scales of land cover heterogeneity
- Develop more realistic parameterizations of fluxes including these heterogeneity impacts

Concluding Remarks

- Single column model shows some sensitivity of the low level cloud forecast to the surface cover
- Albedo changes appear to be more important than roughness length in the single column model
  - *Closer analysis needed for different stabilities including horizontal advection*
- LES study to explore impacts of land surface cover heterogeneity to horizontal and vertical fluxes

- ***More comparison to observations (i.e. cloud radar, tall tower at i.e. Svartberget and Hornamossen)***