Numerical Weather Prediction of Supercooled Low Stratus Clouds Over Heterogeneous Surfaces Using the MUSC One-Dimensional Model: First Results

Erik Janzon,

Heiner Körnich, Johan Arnqvist, & Anna Rutgersson

UPPSALA UNIVERSITET

SMHI
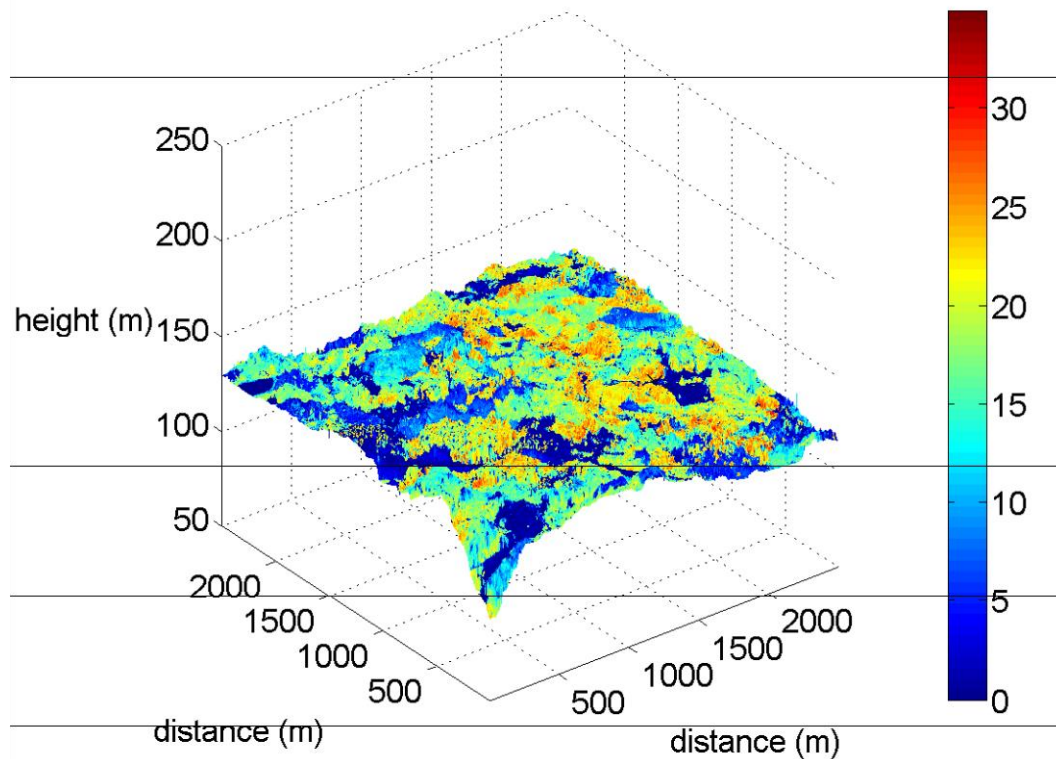
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Motivation

- Properties of the vegetation can have significant effects on boundary layer variables
  - Surface radiation budget (albedo changes, etc)
  - Turbulence (surface roughness)
  - Moisture fluxes (evapotranspiration)

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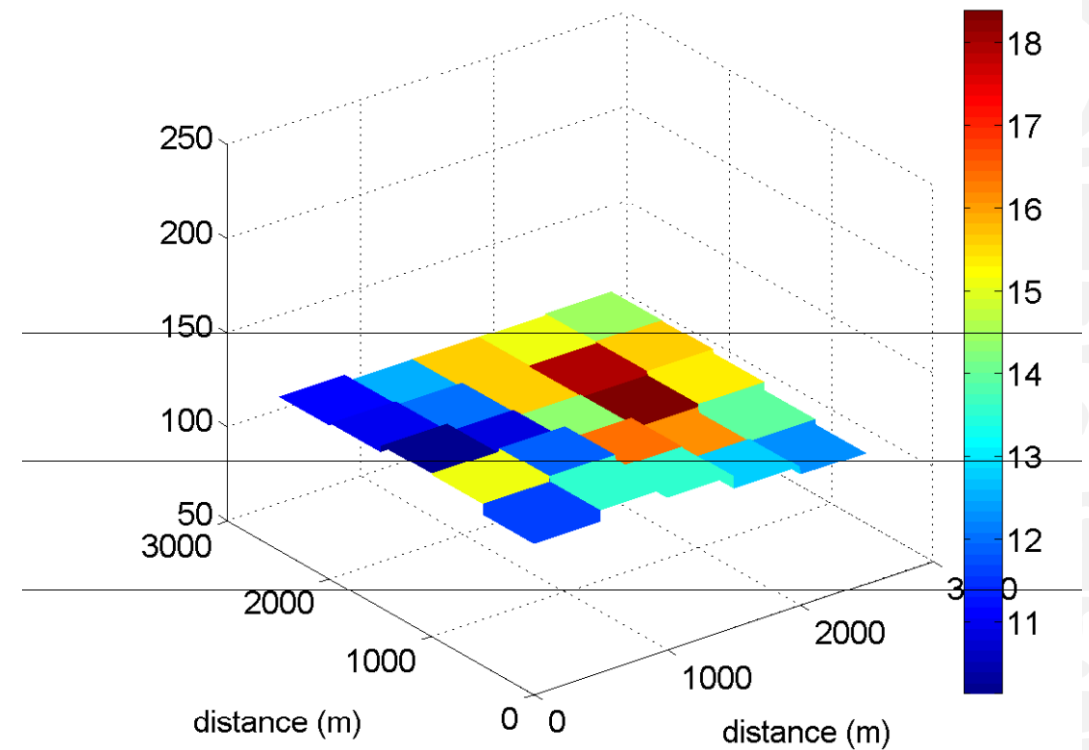
Land Surface Representation

REALITY

NWP MODEL

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

Question?

What is the sensitivity of the model forecast of low level clouds to changes in land use?
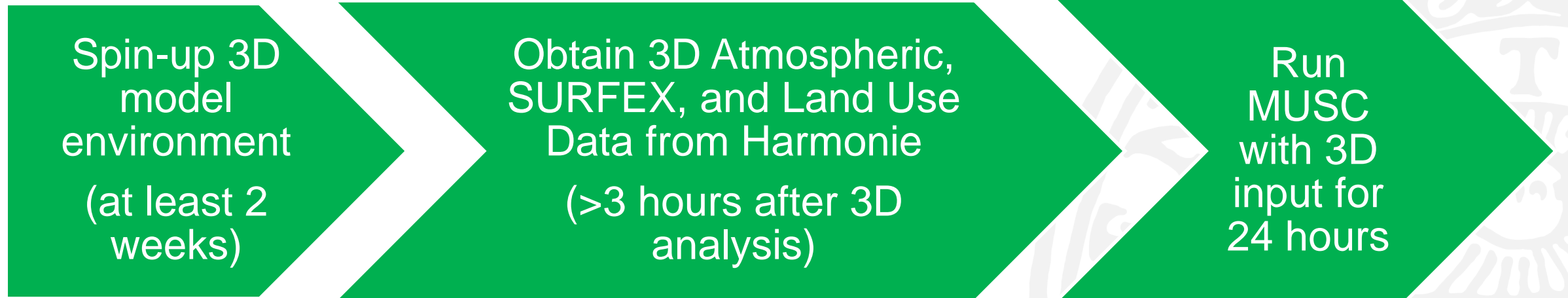
MUSC Single-Column Model

- Simplified version of HARMONIE 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

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

Sources: Räisänen and Rontu (2013) / Bryant (1997)
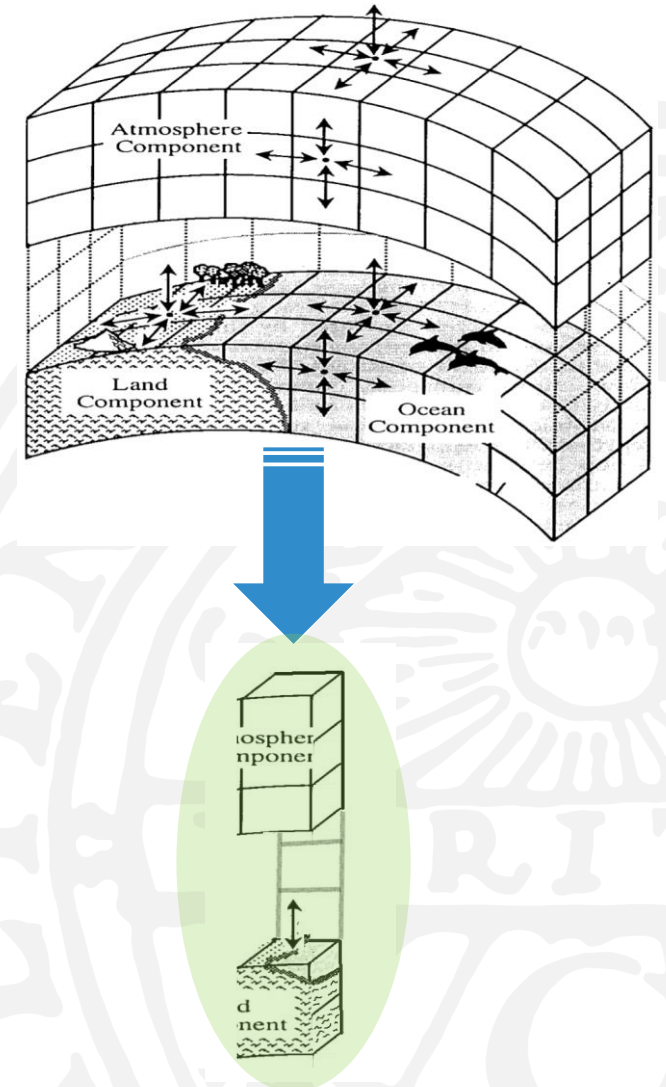
MUSC Single-Column Model

❑ *Not ideal for operational forecasting but:*

 ❑ *Omission of large scale forcing ideal for testing model sensitivity to parameterizations*

 ❑ *Low computational cost allows for many experiments to be quickly performed*

Source: Räisänen and Rontu (2013)

MUSC Model Run Procedure

Spin-up 3D model environment (at least 2 weeks) → Obtain 3D Atmospheric, SURFEX, and Land Use Data from Harmonie (>3 hours after 3D analysis) → Run MUSC with 3D input for 24 hours

Surface model SURFEX

- SURFEX version 7.3

- Calculates energy and mass exchanges between surface and atmosphere

- Surface characteristics from ECOCLIMAP-II database

- Fluxes in each gridbox are computed over each surface type (nature, town, sea/ocean, lake), averaged over the grid box, and weighted by fraction

Source: Le Moigne et al (2012)

Surface Model SURFEX

A T M O S P H E R E

radiative properties:
- albedo
- emissivity
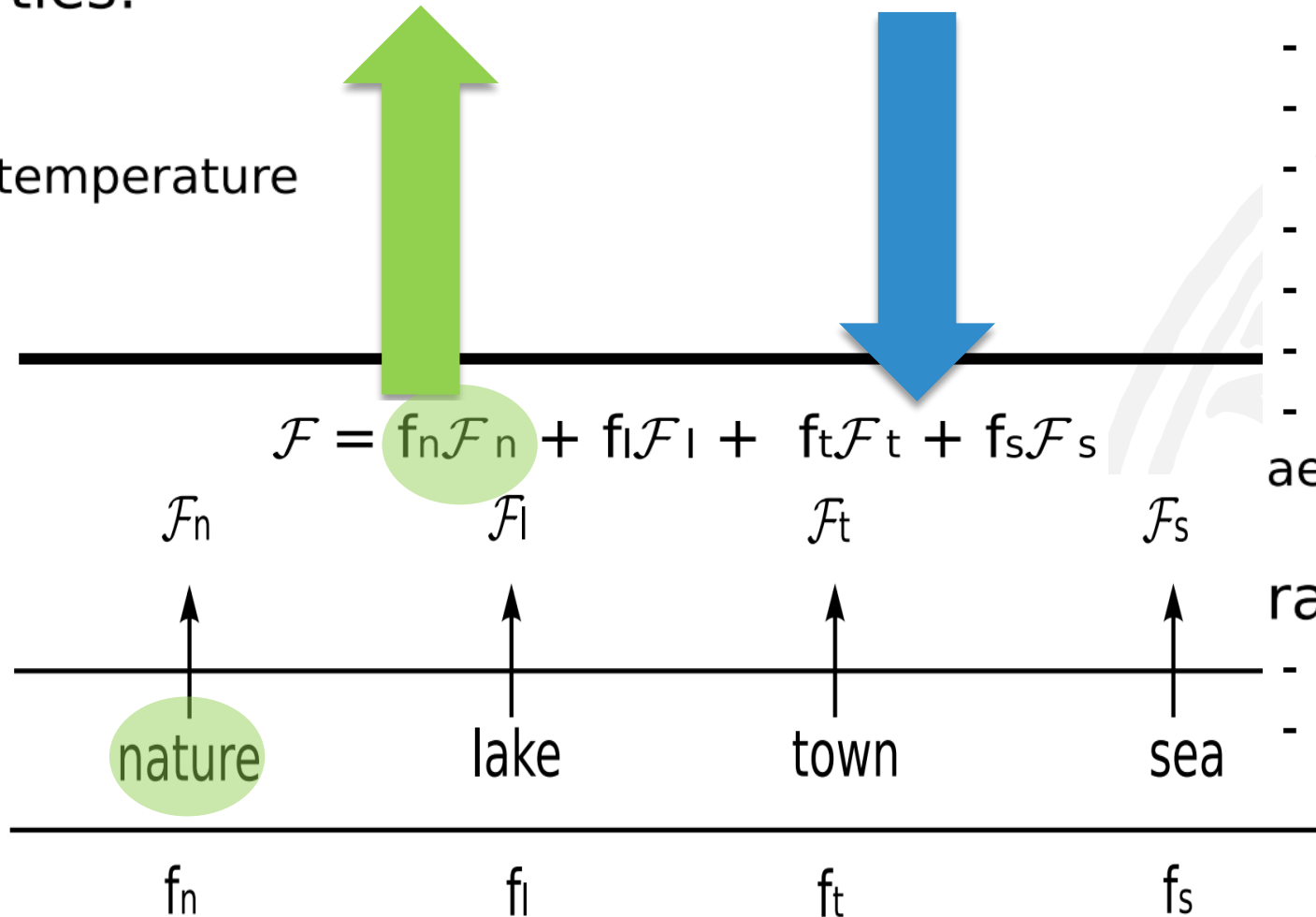- surface radiative temperature

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

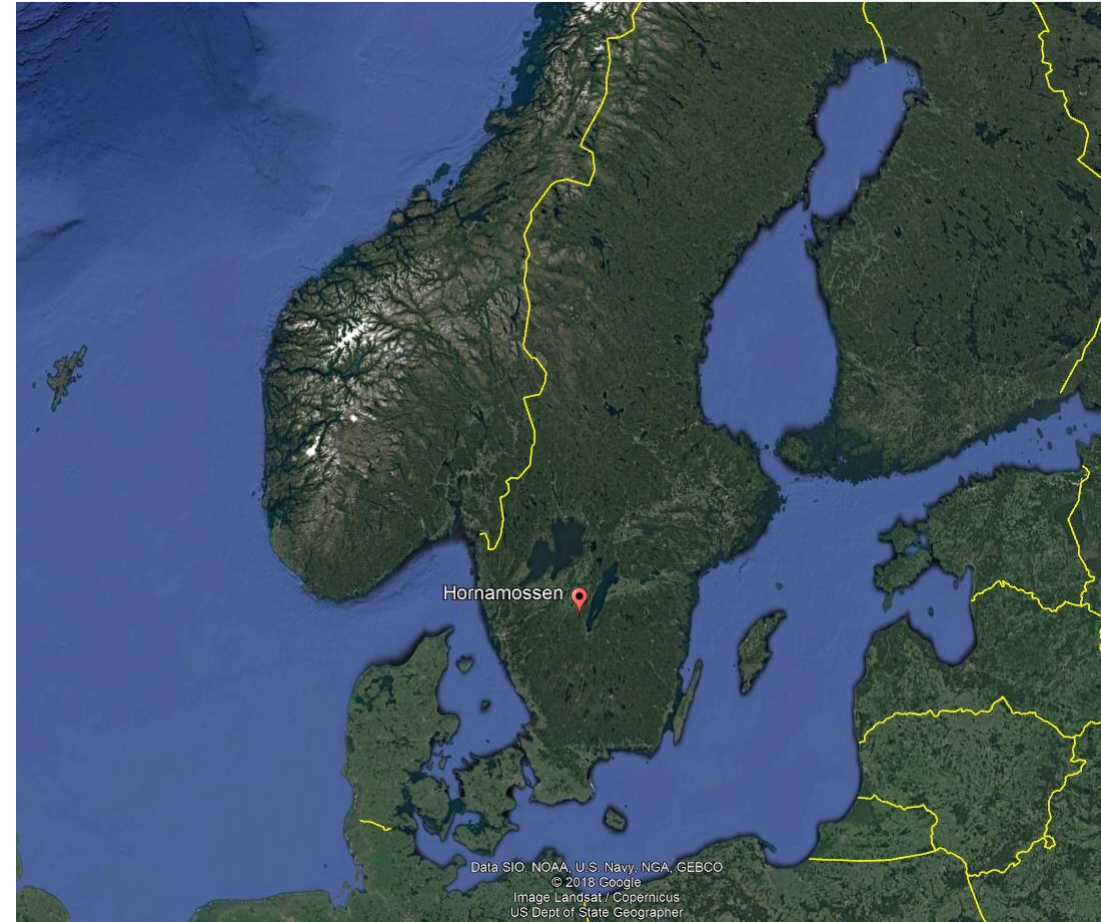radiative forcing:
- solar radiation
- infrared radiation

$$\mathcal{F} = f_n \mathcal{F}_n + f_l \mathcal{F}_l + f_t \mathcal{F}_t + f_s \mathcal{F}_s$$

$\mathcal{F}_n$ $\mathcal{F}_l$ $\mathcal{F}_t$ $\mathcal{F}_s$

nature   lake   town   sea

f_n f_l f_t f_s

Source: Le Moigne et al (2012)

Experiment

- MUSC is initialized from location of the Hornamossen met tower

- Test case initialized to capture a low cloud event from April 24, 2016

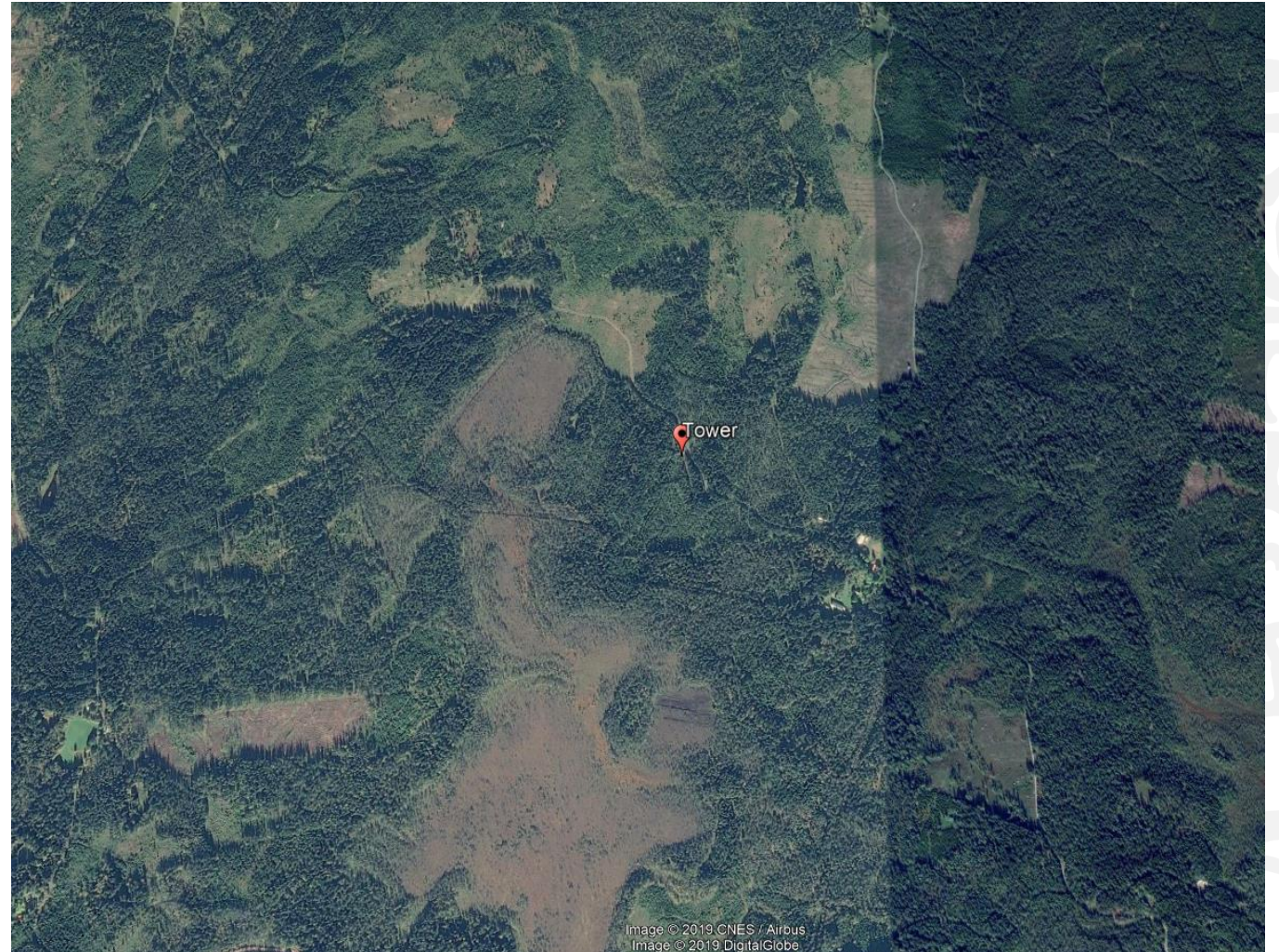- Coincident with measurement campaign

Experiment

- ECOCLIMAP-II surface cover for land around Hornamossen met mast is 100% forest (SFX.COVER319 and 321, South Sweden Mixed Forest and Mountain Boreal Forest)
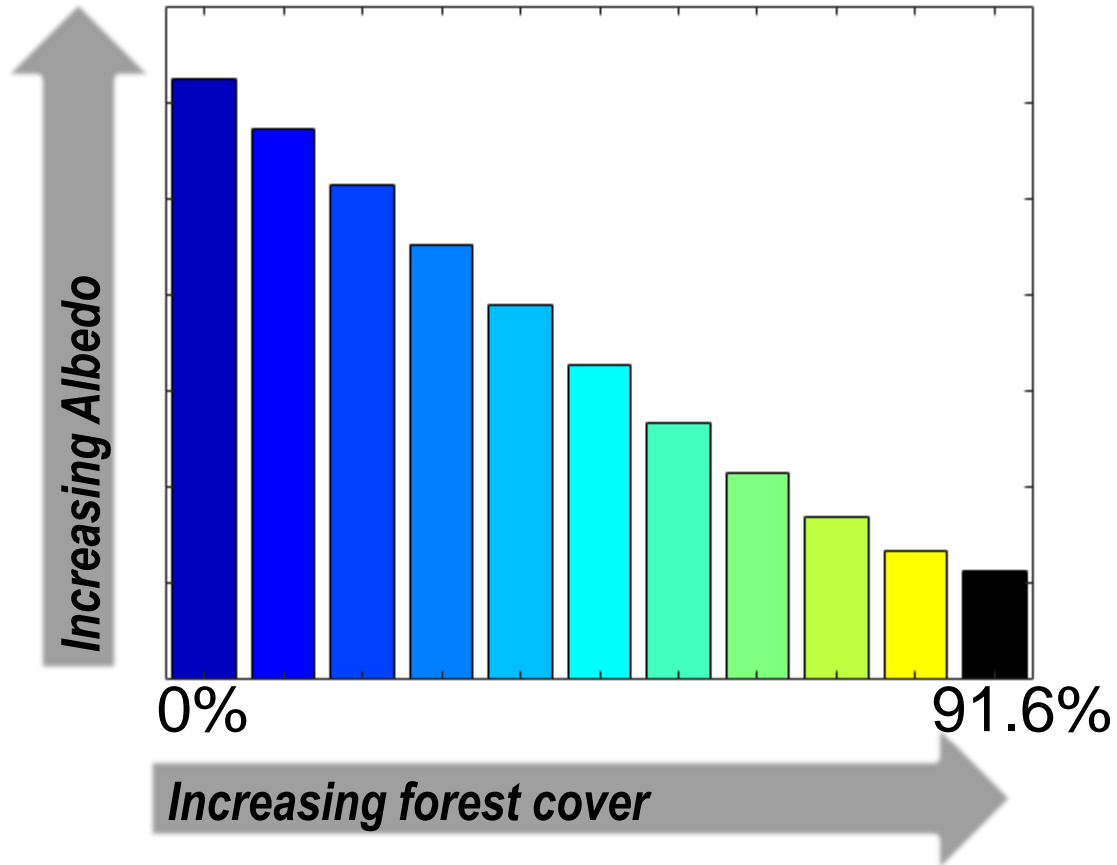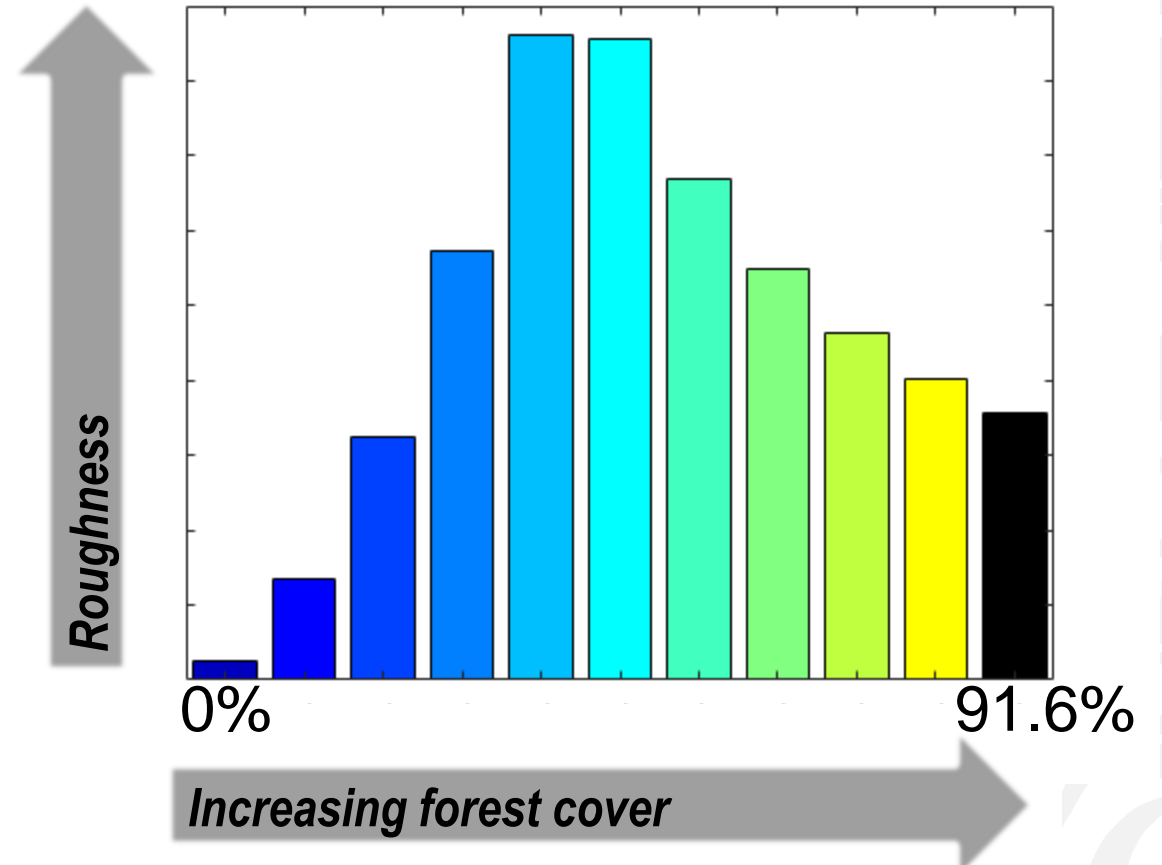
Experiment

- CNTRL: Baseline model run with prescribed land use from ECOCLIMAP

- 10 experimental model runs with 10% bare ground added in each case (SFX.COVER 538)
  - Example: Vegetation 91.6%, Bare ground 8.4%

    Vegetation 82.4%, Bare ground 17.6%

    And so on…

Change in Surface Parameters

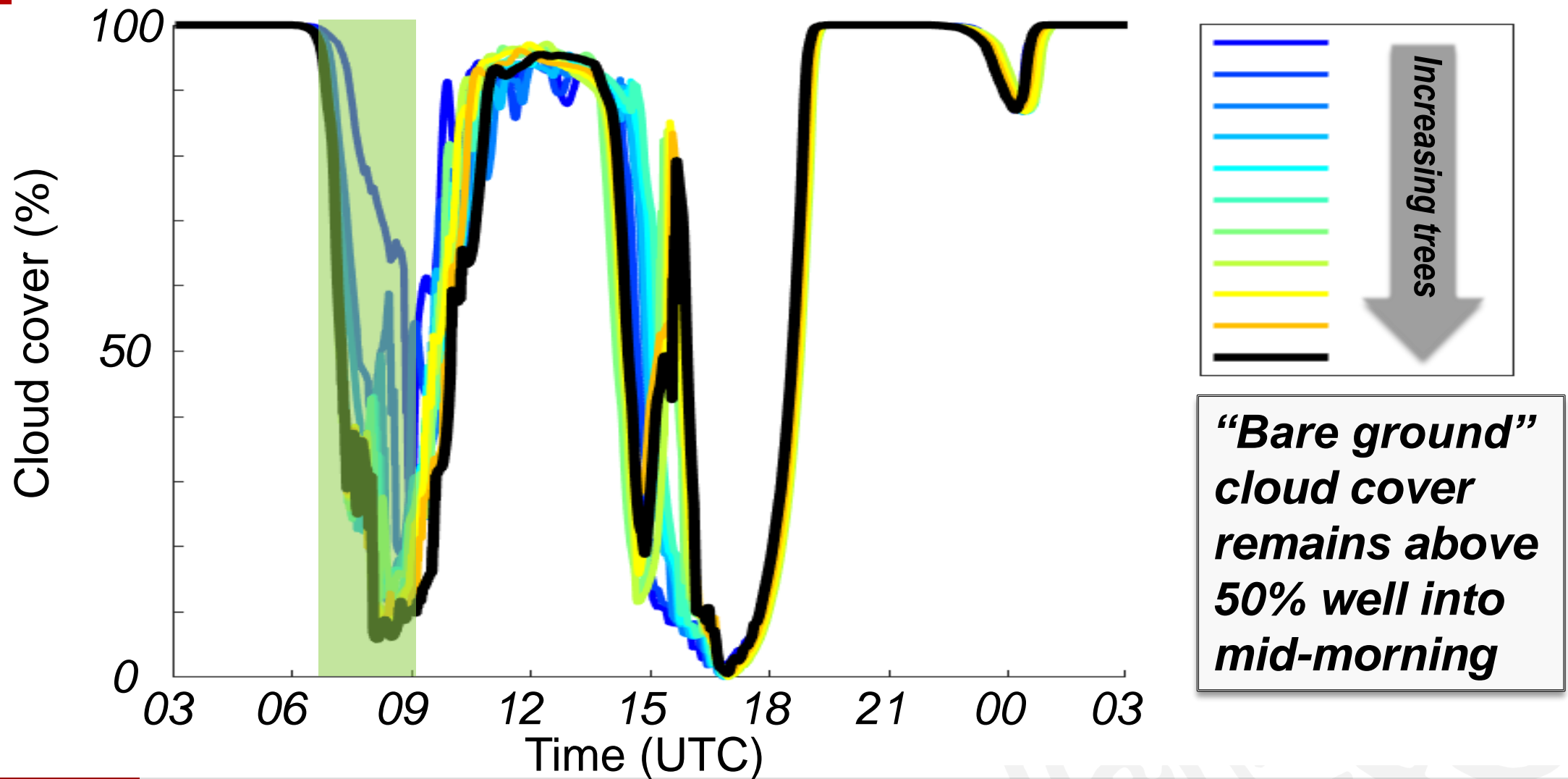Albedo (Visible Wavelength)

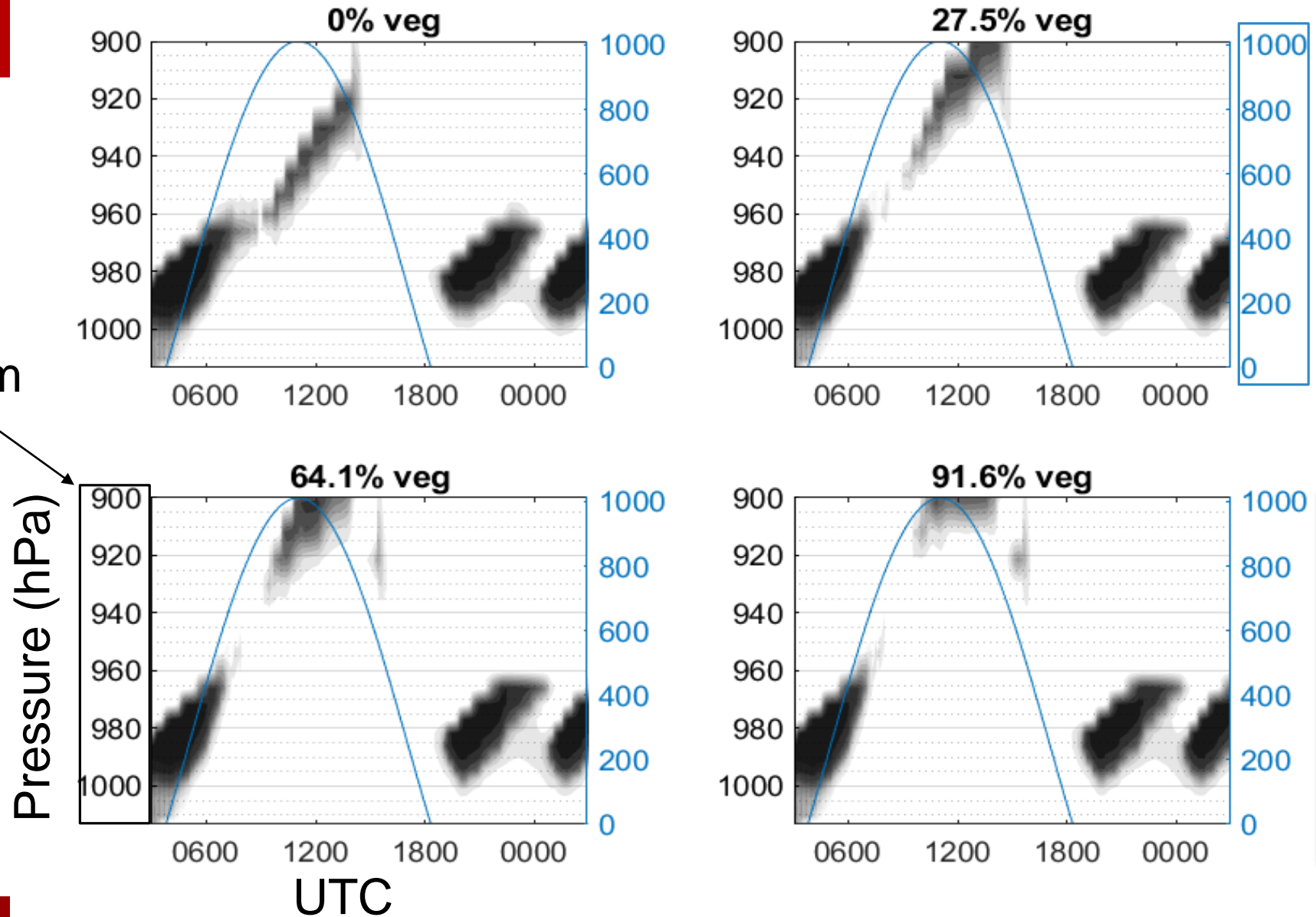Roughness Length (z0)

(From SURFEX output)

Low Level Cloud Response

Low Level Cloud Profile
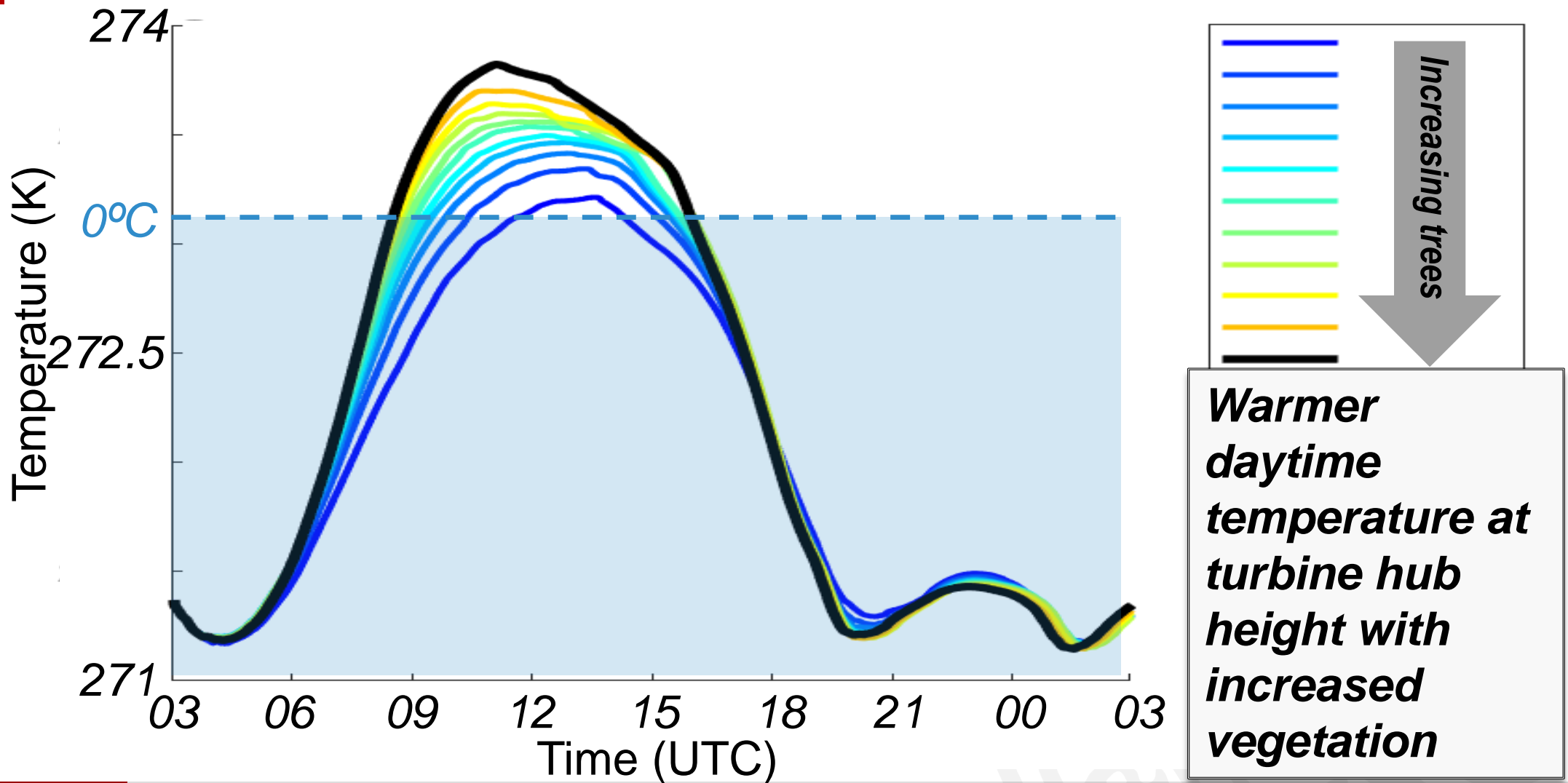

~940 m

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

Temperature at Hub Height

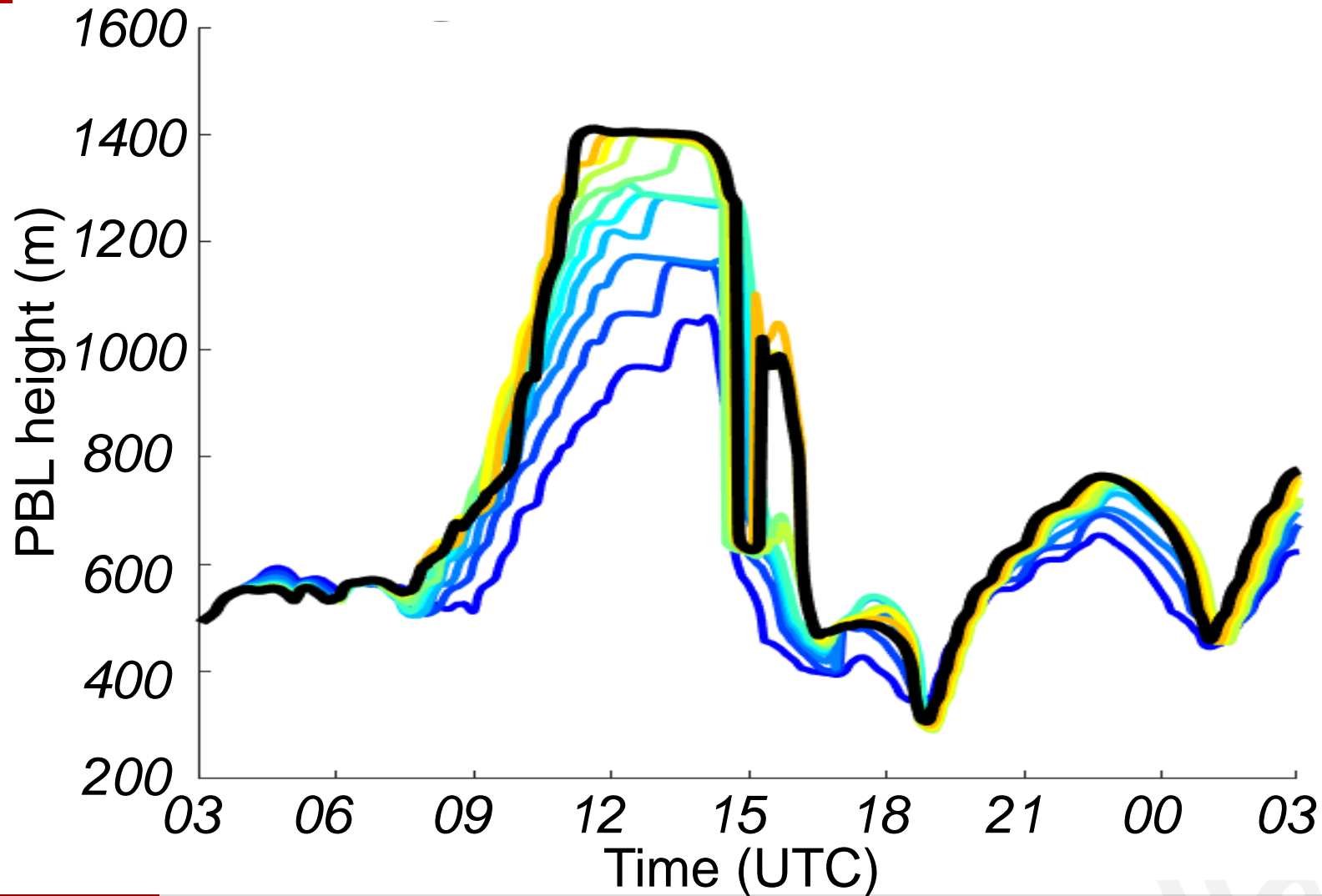*Warmer daytime temperature at turbine hub height with increased vegetation*

Boundary Layer Height

Increasing trees

Boundary layer is deeper with increase trees…changes appear to correlate with albedo differences

Concluding Remarks

- Results are preliminary!

- The model shows that changing surface cover has some effect on temperature, moisture and clouds at hub height

- Albedo changes appear to be more important than roughness length in this case

- More cold weather cases need to be tested against observations
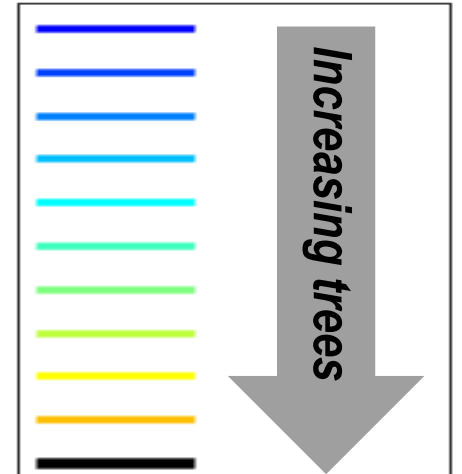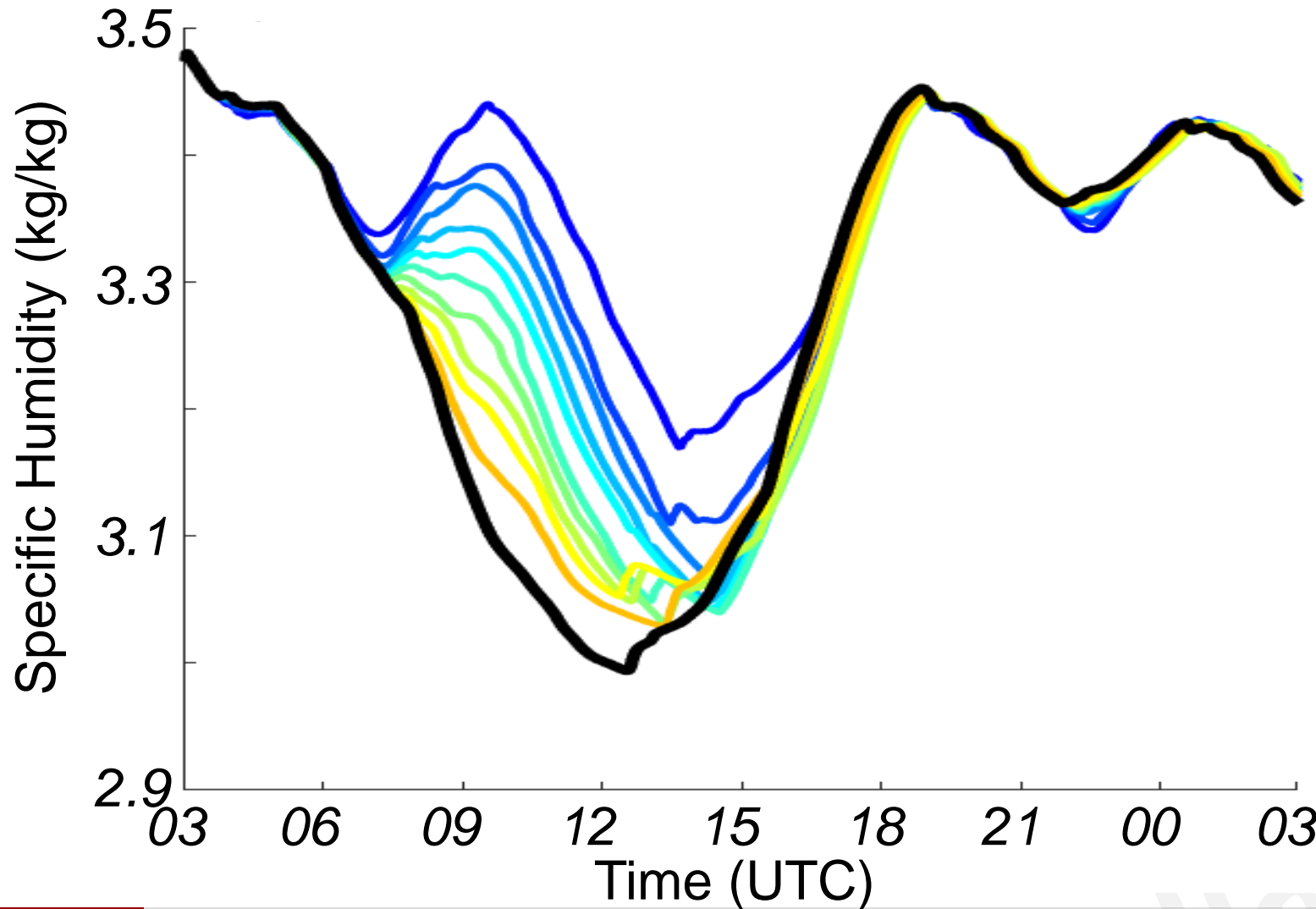
Thank you!

3D Model

- HARMONIE cy40h1.1.1 deterministic run used as 3D input for MUSC

- 24 hr forecast

- 2.5 km resolution

- Initial conditions using blending from ECMWF analysis (no data assimilation)

- 65 vertical levels
  - 21 levels below 900 hPa

Source: Bengtsson et al (2017)

Specific Humidity at Hub Height