ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

FMI’s road weather model and shadowing algorithm

High Latitudes Event Week 2023

31.1.2023 **Virve Karsisto**

Contents

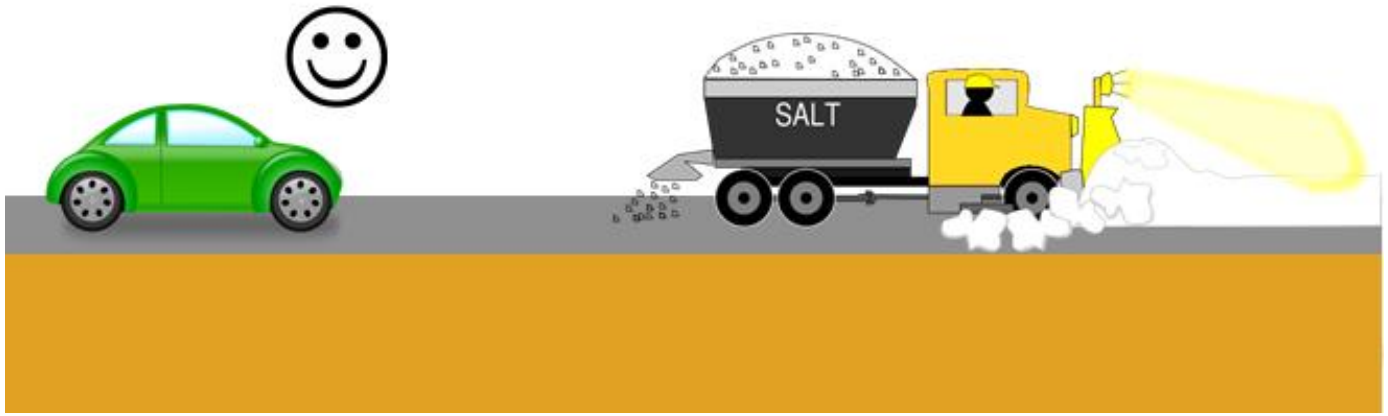
Image by Pexels from Pixabay

1. Introduction

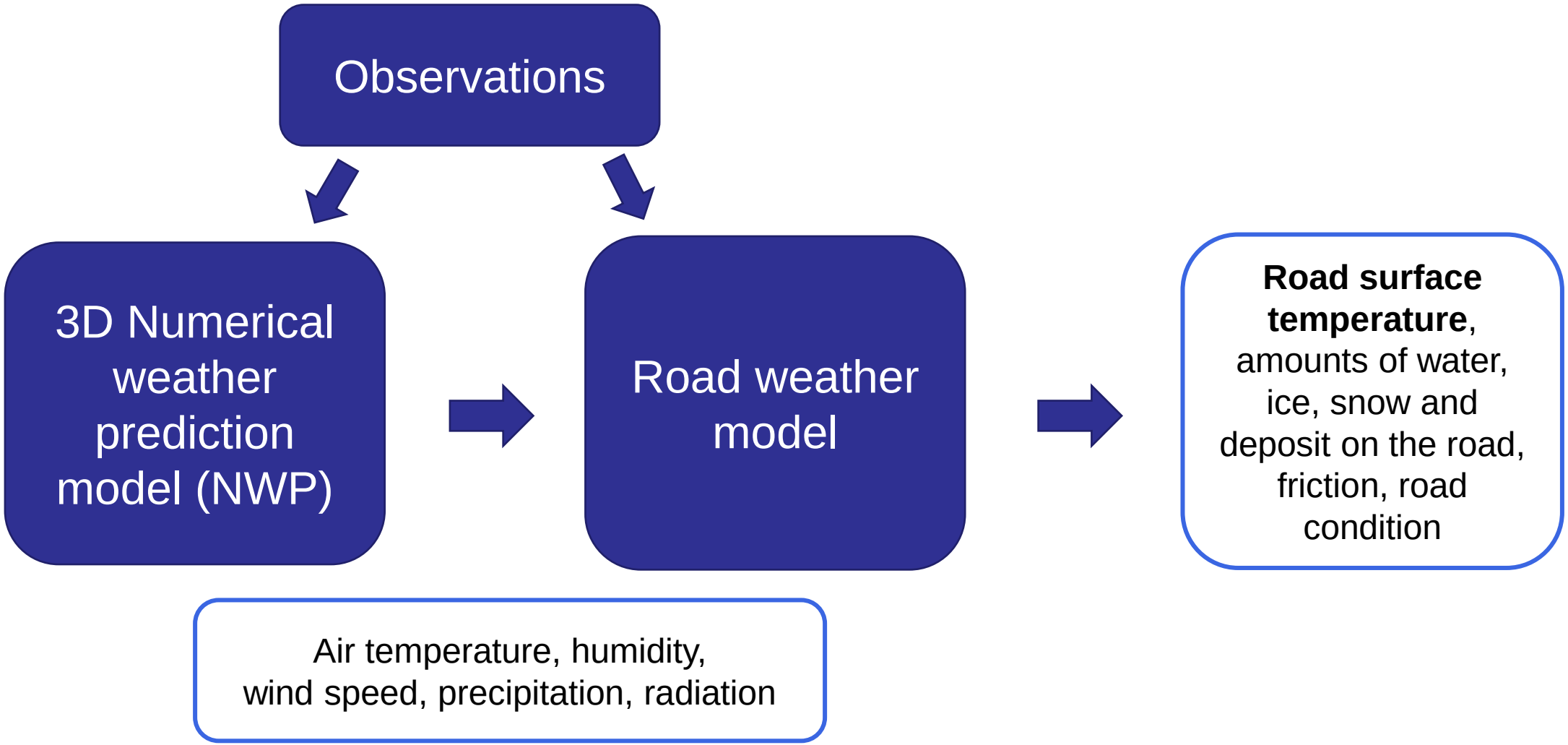
- Road surface temperature modeling activities initiated already in 1979 in FMI
- Road weather model (RWM) of that time was in operational use during the early 1980s
  - Later discontinued
- The current operational RWM in FMI developed in the late 1990s
  - Operational since 2000
- Continuous development
  - Pedestrian model
  - Friction
  - Probability forecasts

Benefits of road weather forecasts

- With accurate forecasts, plowing & salting can be done at the right time
    - The roads remain safe
    - Savings are made when roads are not salted unnecessarily
- Road users know how to prepare and adapt their driving style to the conditions
    - Especially important for autonomous cars

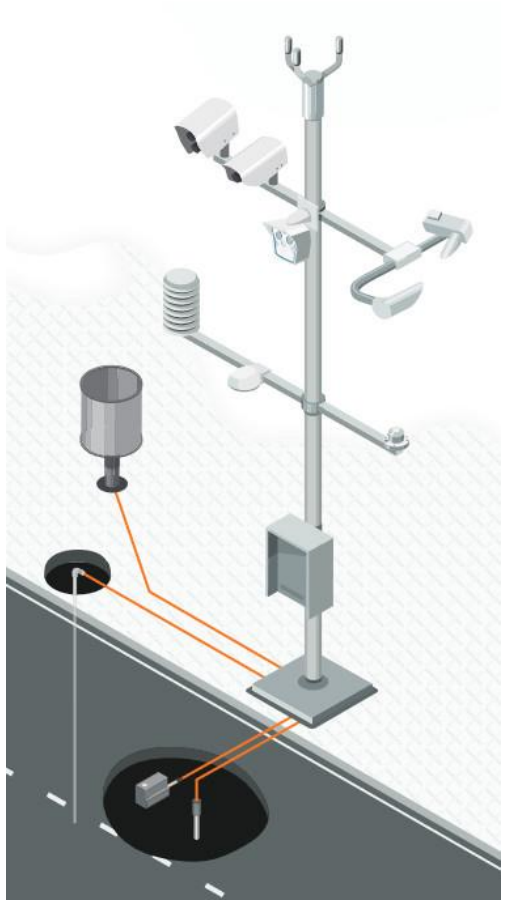


2. Key elements of road weather forecast

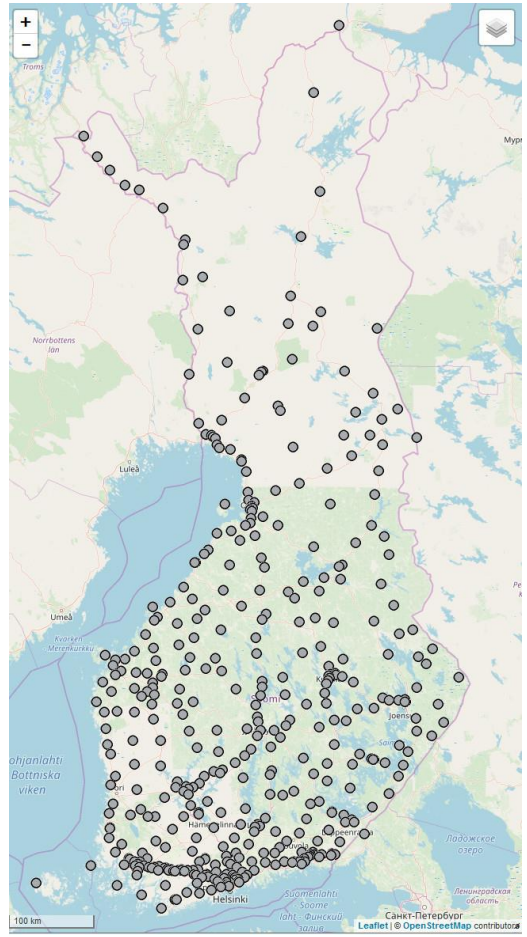


Observing road weather

- Road weather stations
  - Located at the side of the road
- There are about 400 RWS in Finland
- Road weather cameras
- Observations done by cars
    - Car’s own sensors and additional equipment



Road weather station
www.vaisala.com



Road surface temperature observations

Sensor embedded to asphalt

www.vaisala.com

Optical sensors

www.teconer.fi

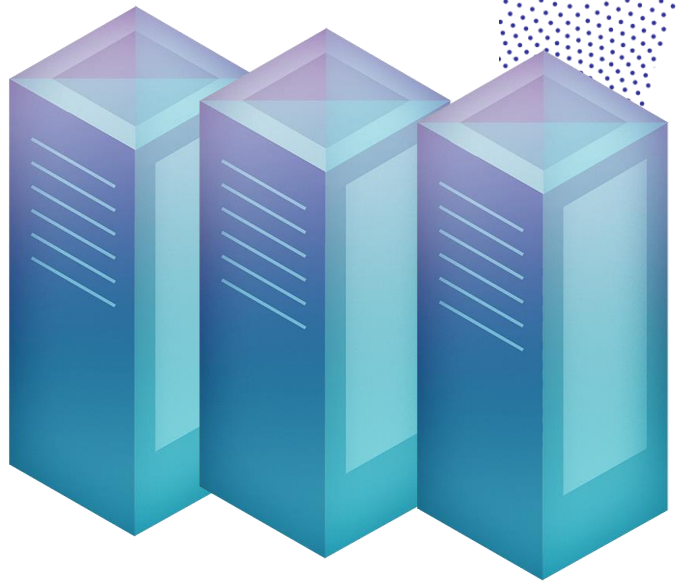
www.vaisala.com

NWP model data

- RWM is very senstive to NWP model data
- Official FMI road weather forecasts use data edited by duty meteorologist
  - SmartMet editing tool
  - Possible to use GFS, ECMWF, MEPS (MetCoOp Ensemble Prediction System) or post processed data as background
  - MetCoOp nowcast used at the first hours
- Probability forecasts are done by running the RWM with MEPS data

MetCoOp Ensemble Prediction System (MEPS)

- Run in co-operation with Finland's Sweden's, Norway's and Estonian's national weather institutes
- Horizontal resolution 2.5 km
- 5 members are launched every hour
- Forecast length of each member is 66 h
- 15-member ensemble can be formed from the member executions of the past 3 hours



How is satellite data utilized in NWP models?

Some examples:

- Microwave Soundings are used to determine temperature and humidity profiles
- GPS satellites can be used to obtain temperature and humidity information
- Estimation of winds by tracking the motion of clouds

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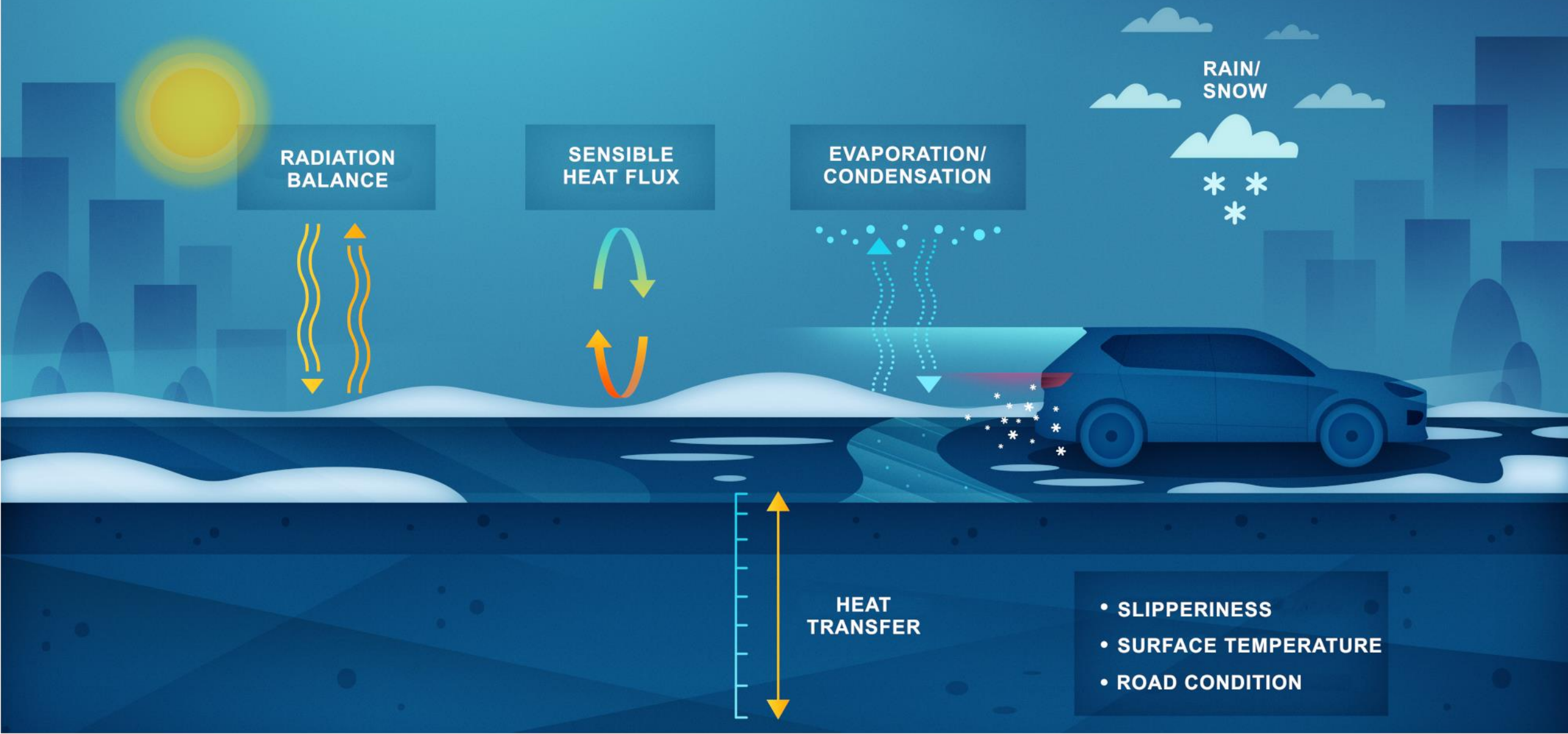
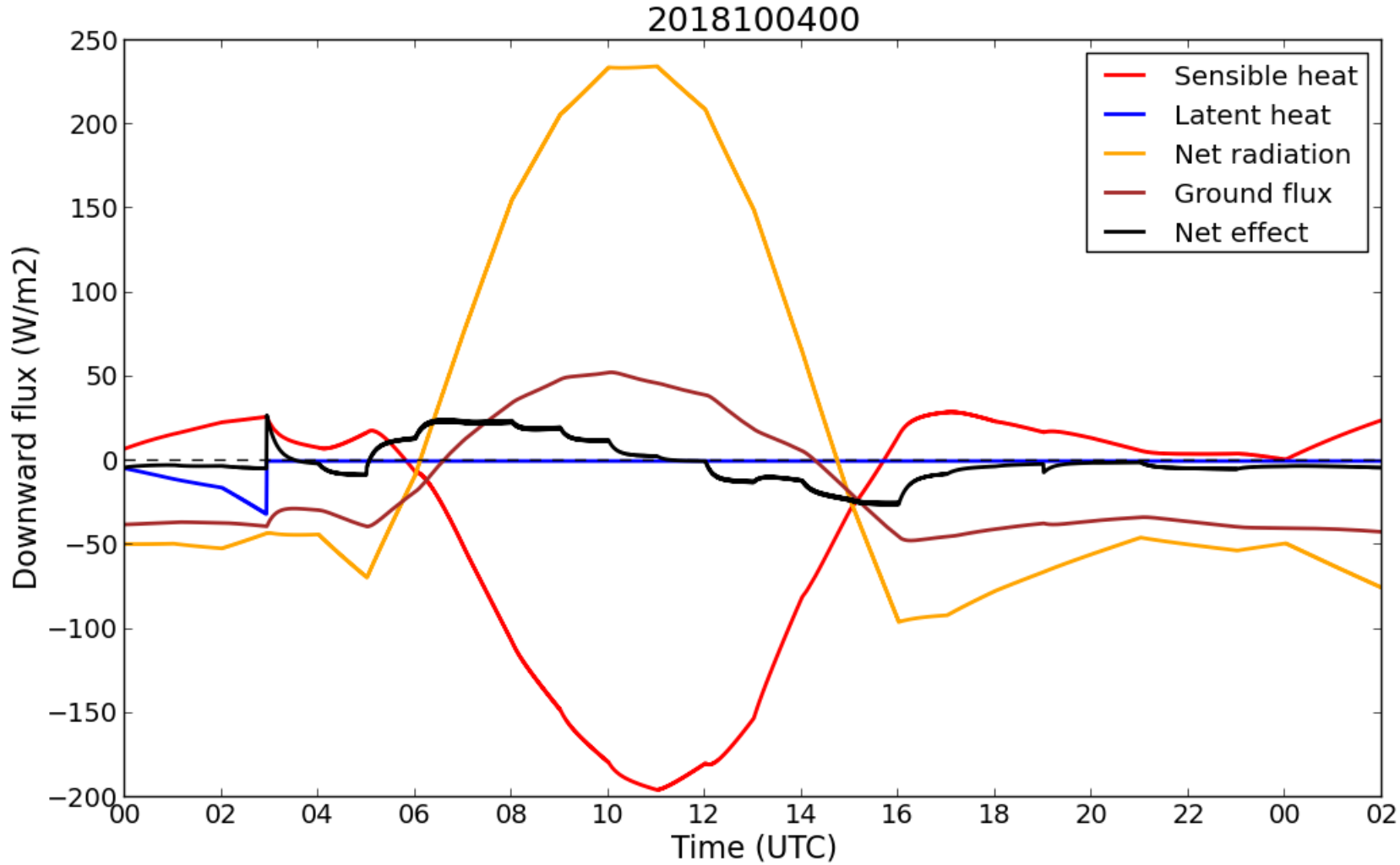
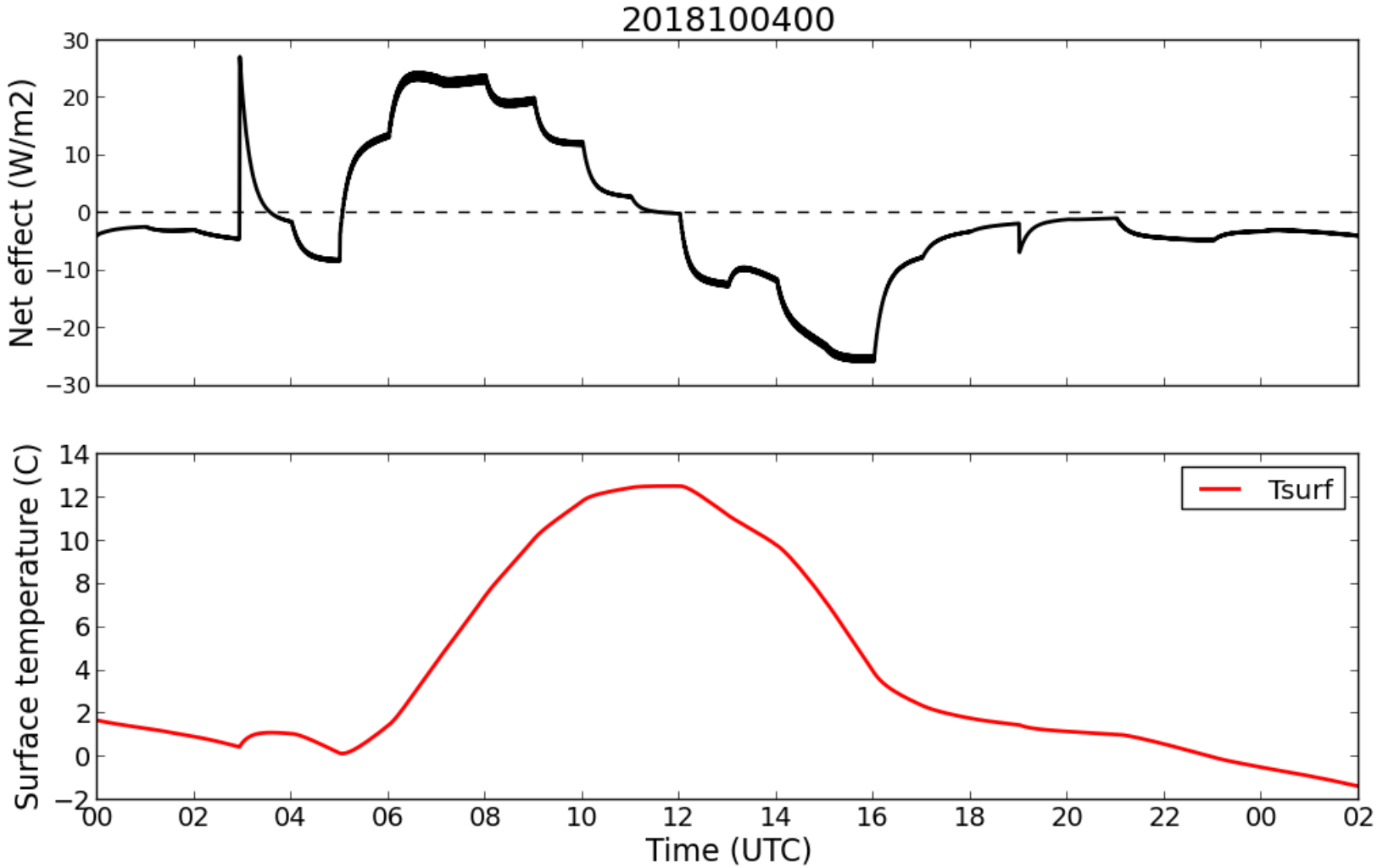
Road weather model

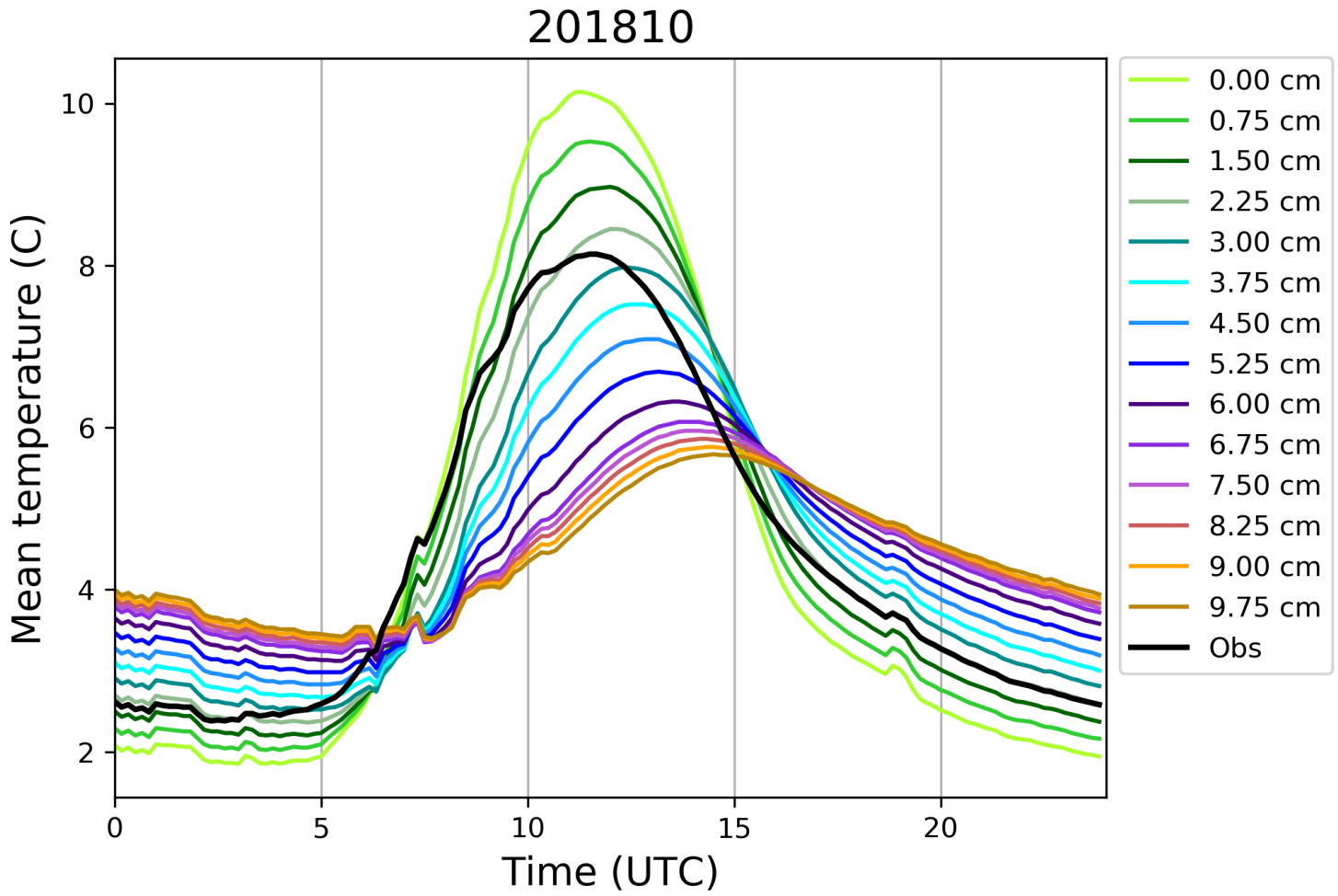
- One-dimensional heat balance model




2018100400
Sensible heat
Latent heat
Net radiation
Ground flux
Net effect
Downward flux (W/m2)
Time (UTC)
250
200
150
100
50
0
−50
−100
−150
−200
00
02
04
06
08
10
12
14
16
18
20
22
00
02

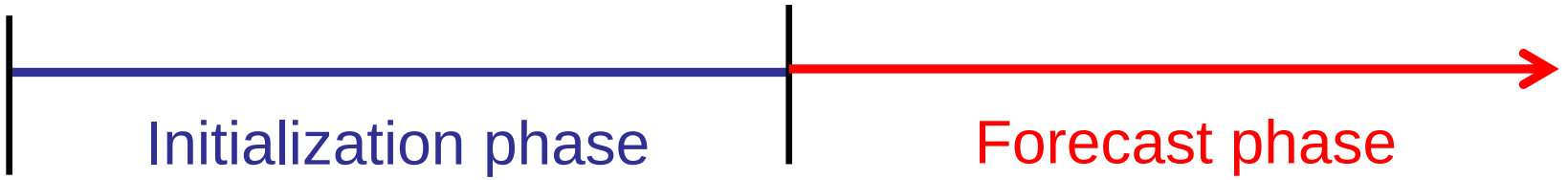

2018100400
Net effect (W/m2)
30
20
10
0
−10
−20
−30
Surface temperature (C)
14
12
10
8
6
4
2
0
−2
Tsurf
00
02
04
06
08
10
12
14
16
18
20
22
00
02
Time (UTC)

Temparature interpolated at different depths
First four model layers 0 -1.5 cm, 1.5 - 4.75 cm, 4.75 - 8.48 cm 8.48 - 12.9 cm



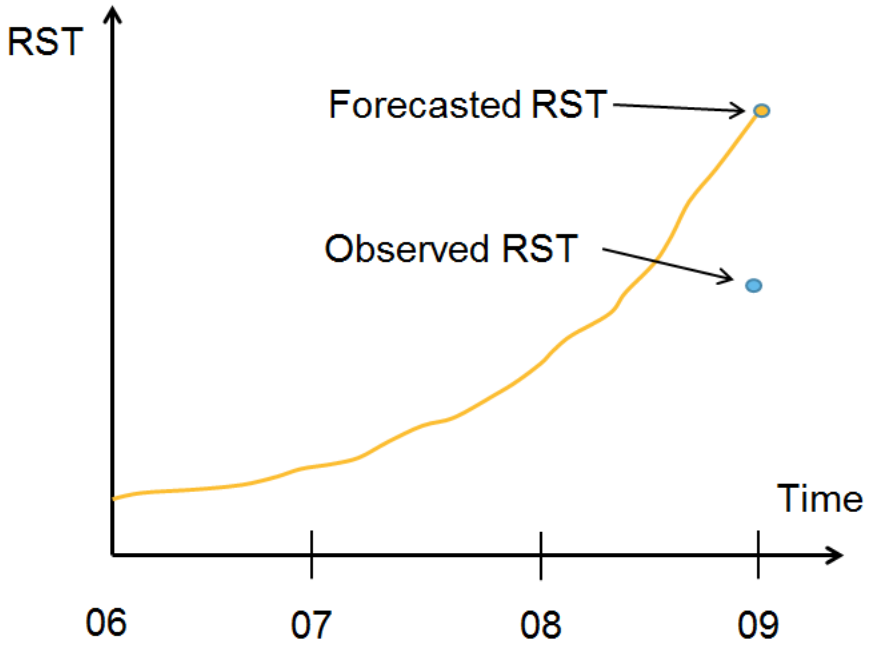
Model phases

- Initialization phase
  - Atmospheric forcing from observations
- Forecast phase
  - Atmospheric forcing from numerical weather prediction model

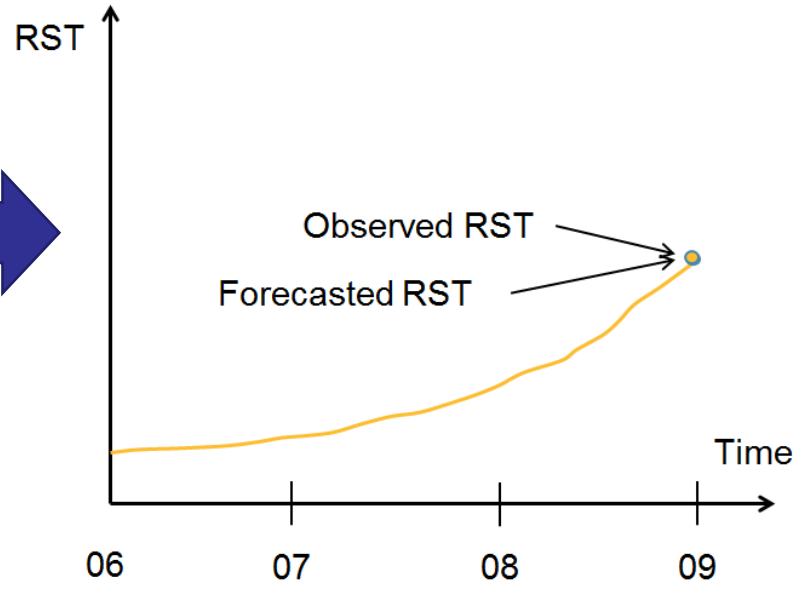


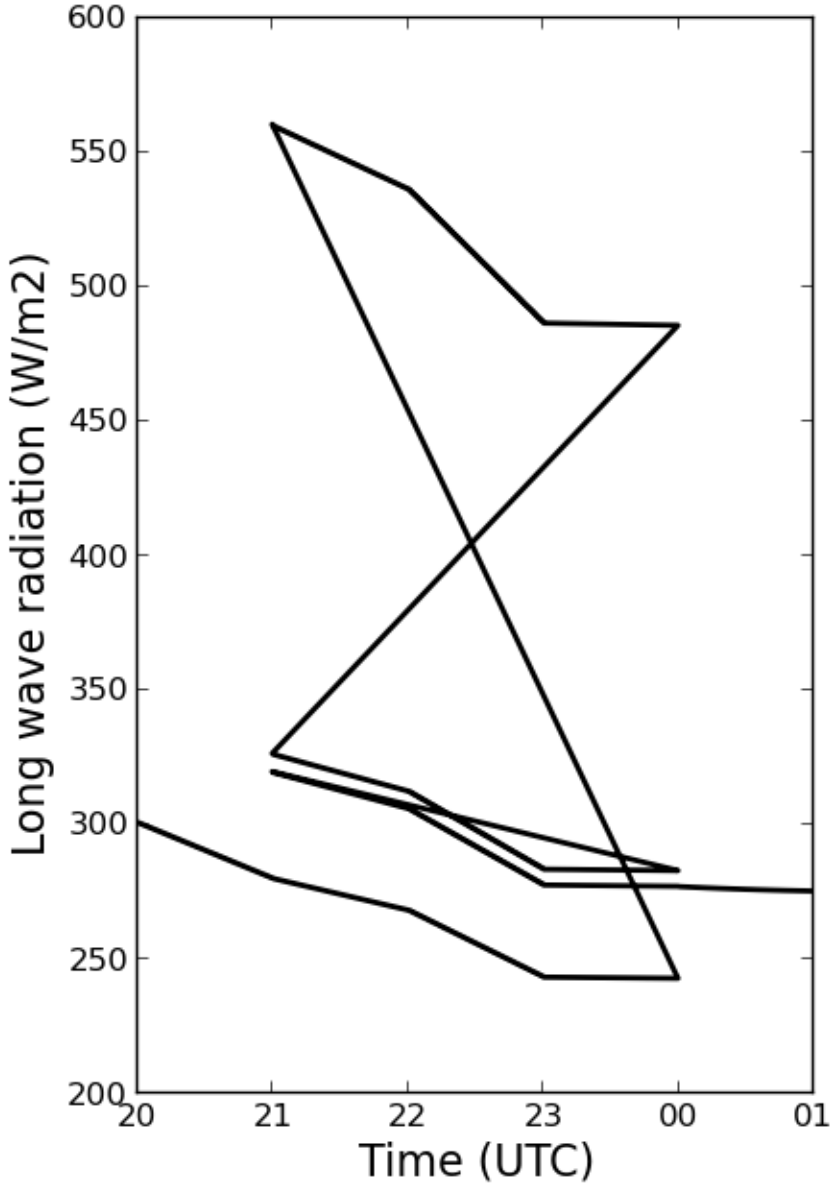
Coupling method

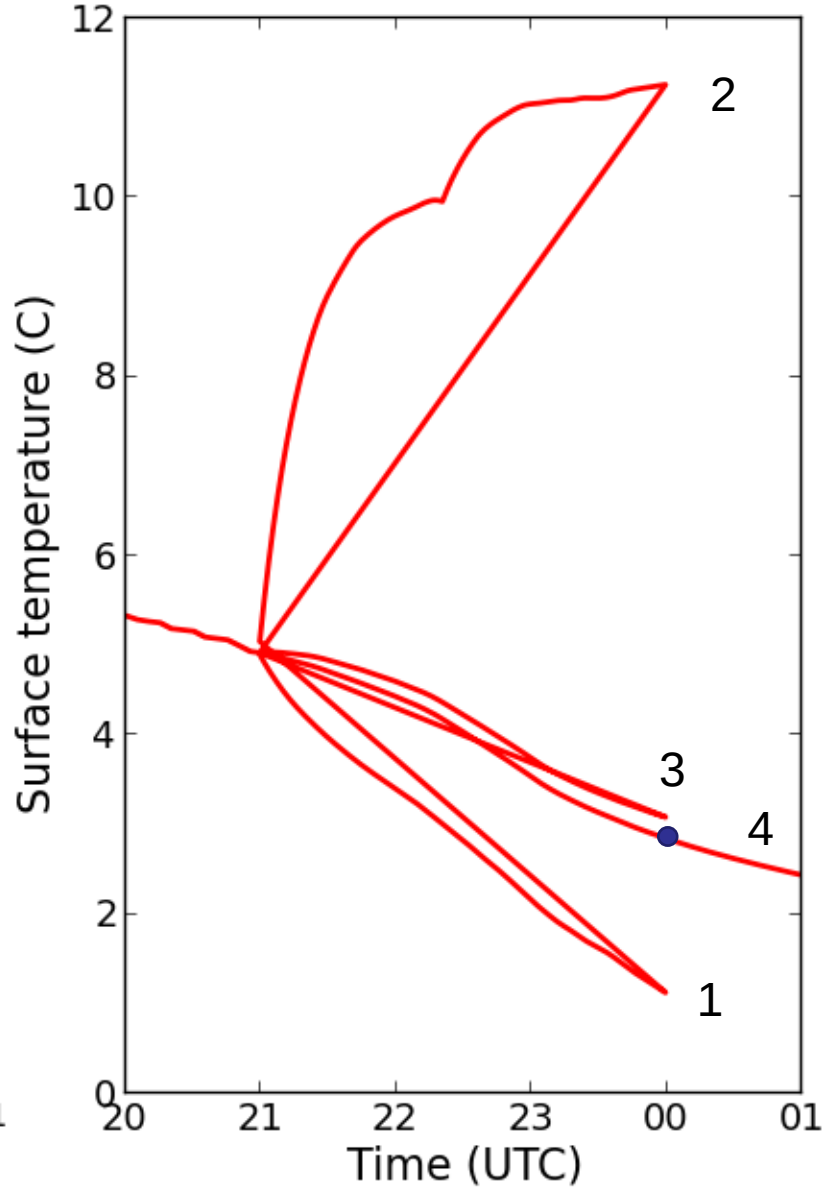
- Incoming long wave/short wave radiation flux in the model is adjusted so that forecasted road surface temperature (RST) fits to the last observed value



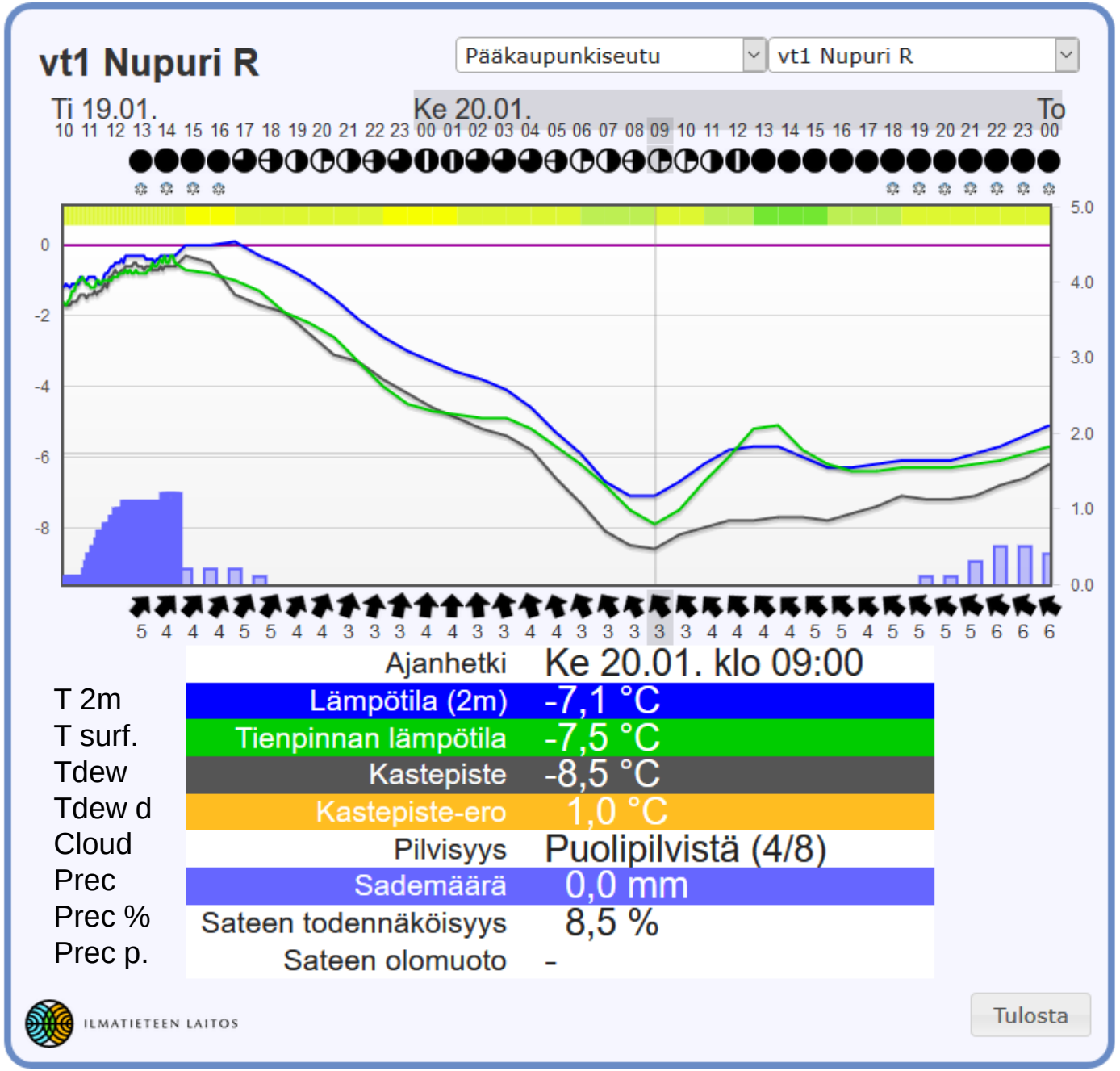
- Radiation correction coefficient is determined in an iterative process
- Coefficient is used in actual forecast phase
  - Approaches exponentially 1 as the forecast advances



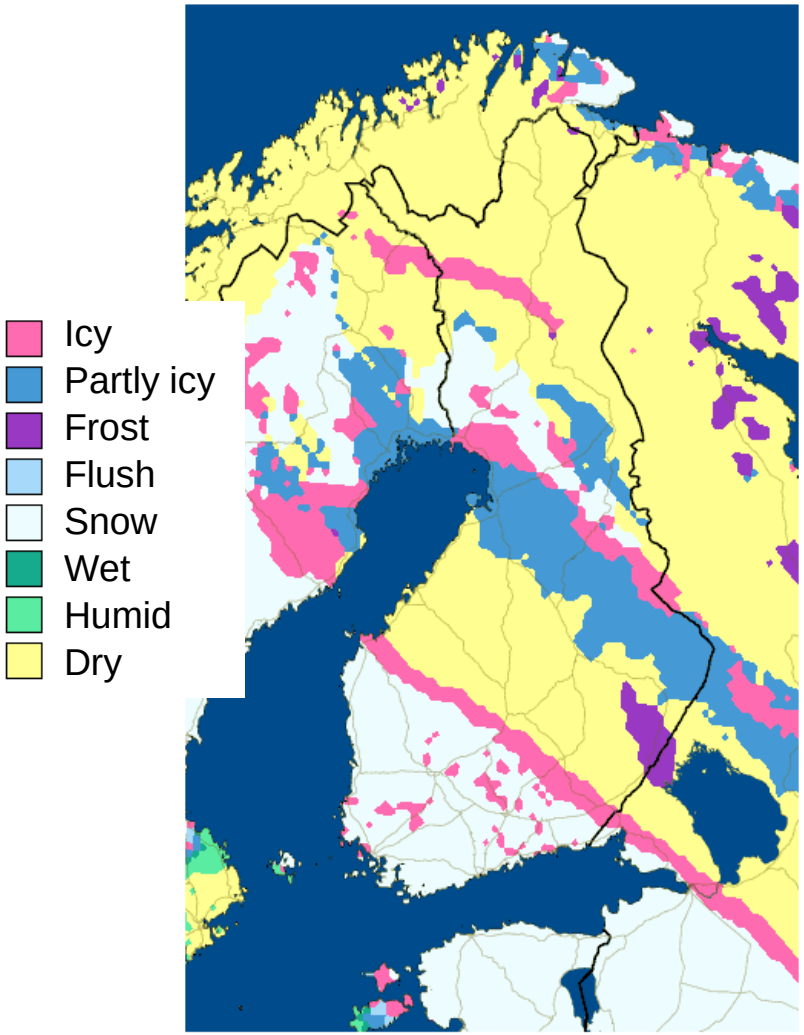

Long wave radiation (W/m2)
600
550
500
450
400
350
300
250
200
20
21
22
23
00
01
Time (UTC)


Surface temperature (C)
12
10
8
6
4
2
0
20
21
22
23
00
01
Time (UTC)
1
2
3
4

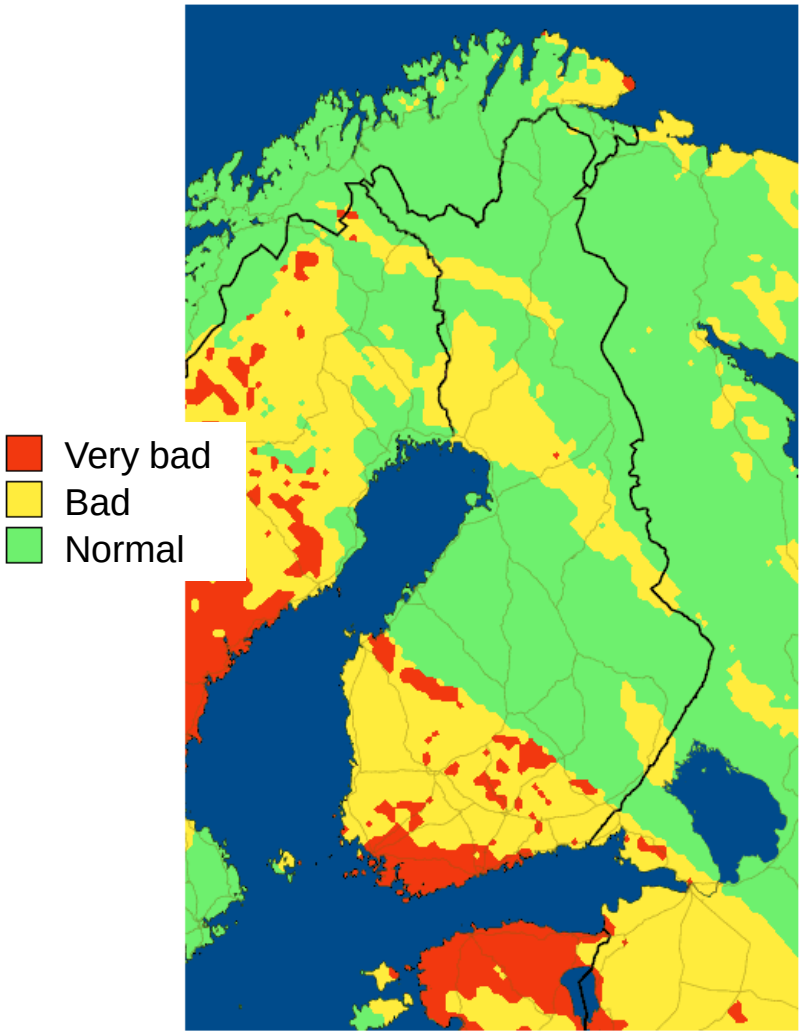
Example forecast



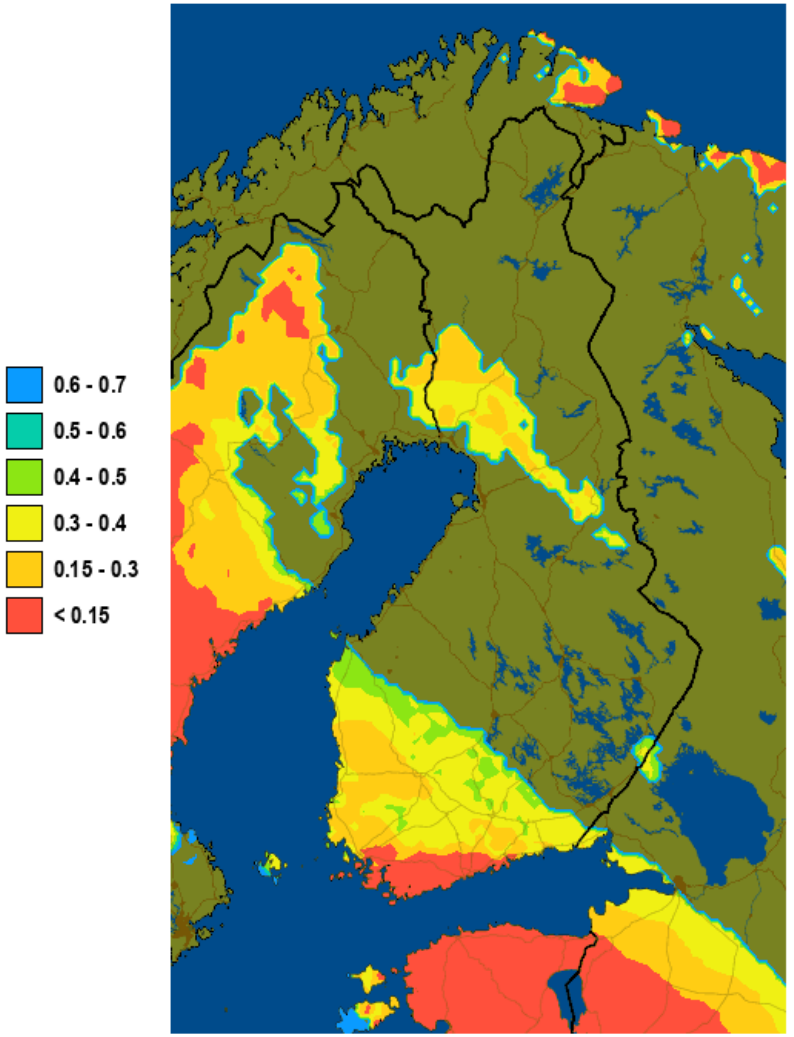
Road Condition



Traffic index

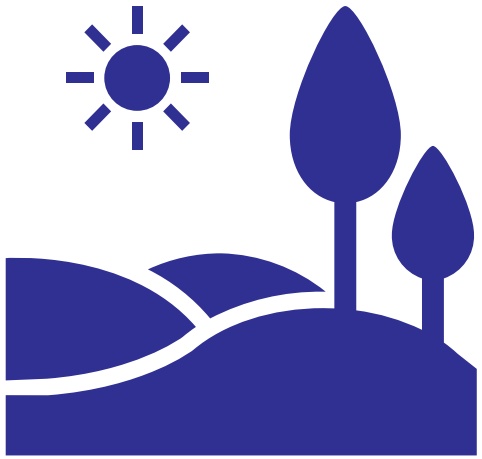


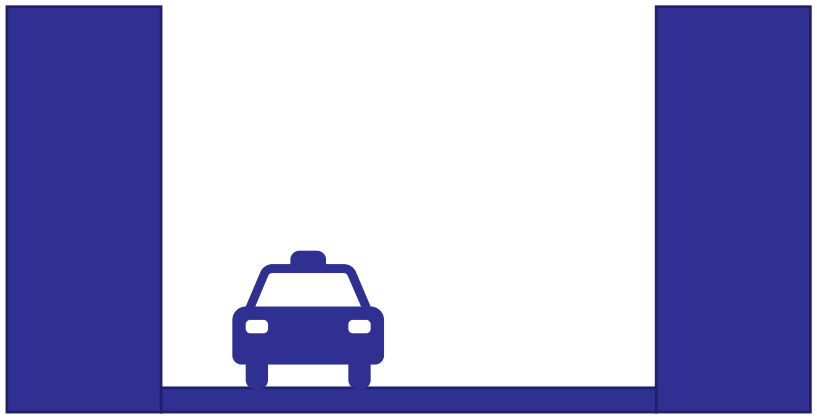
Friction



3. Sky view factor and shadowing

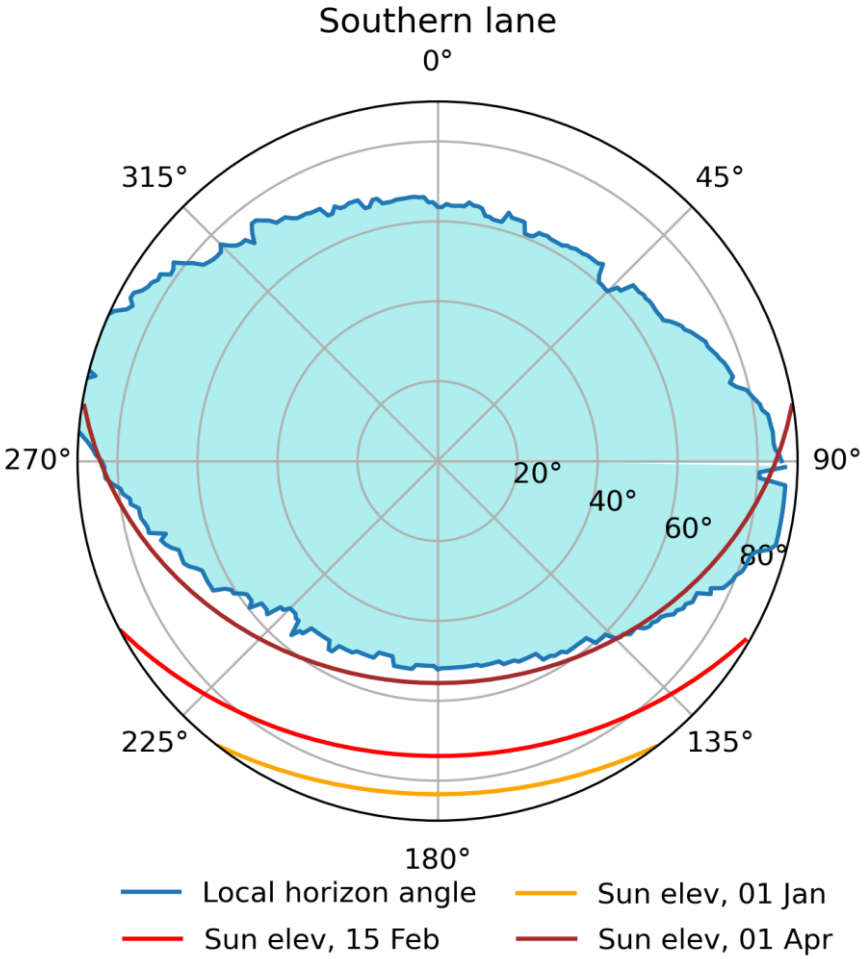
- Road surroundings affect road surface temperature
- Shadowed locations can be several degrees colder than locations exposed to the sun
- Obscured locations can remain warmer on clear nights





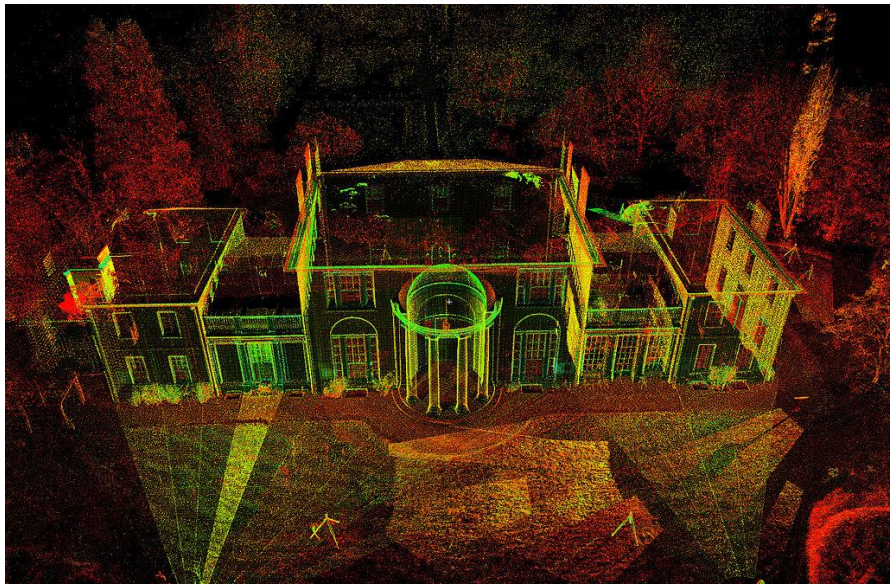
Sky view factor and shading added to the FMI Road weather model

- Sky view factor (SVF) means the ratio of sky hemisphere visible from the ground
  - Affects to the incoming radiation
- Shading is determined using local horizon angles
  - Point is in shadow if the sun elevation is lower than the horizon angle in the sun direction
  - Direct solar radiation is set to zero when the point is in shadow



Laser scanning

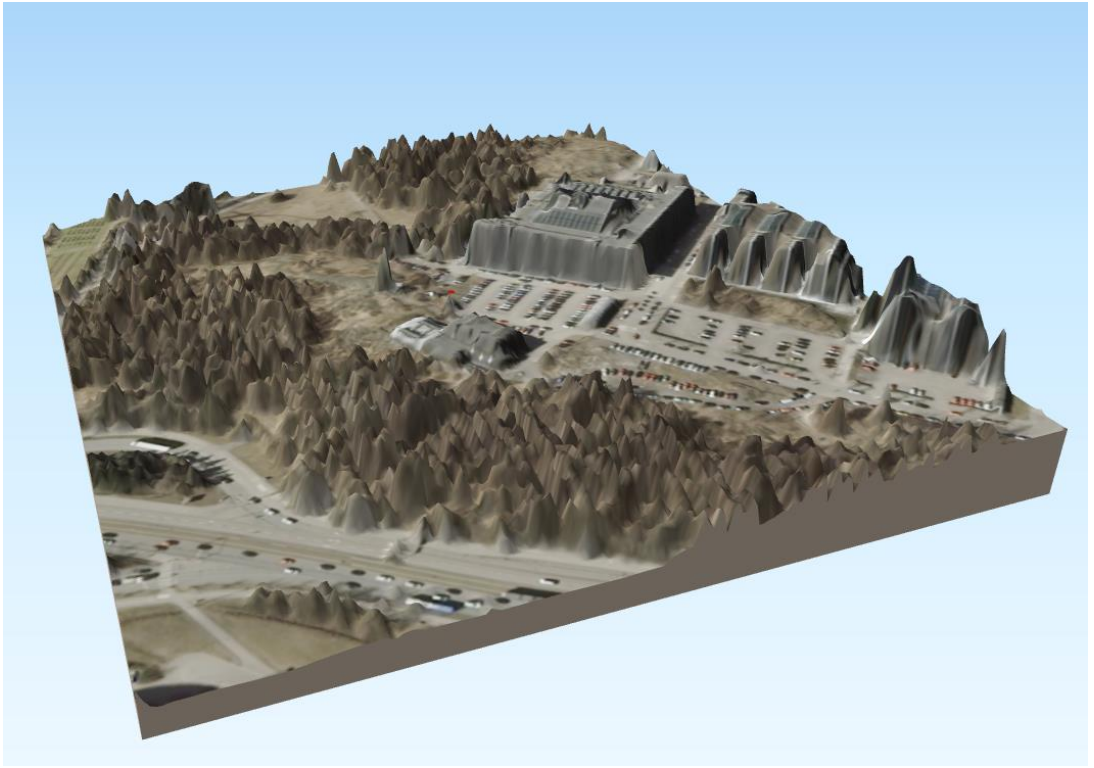
- Laser scanner emits laser beams in dense raster
  - Coordinates of the surrounding objects can be calculated from the back-scattered beams
  - When done in several directions, a point cloud can be formed
- National land survey of Finland provides laser scanning data for the whole Finland area
  - Open data resolution 0.5 points per square meter
  - 5 points per square meter available with permission



www.cyark.org CC-BY-SA-3.0

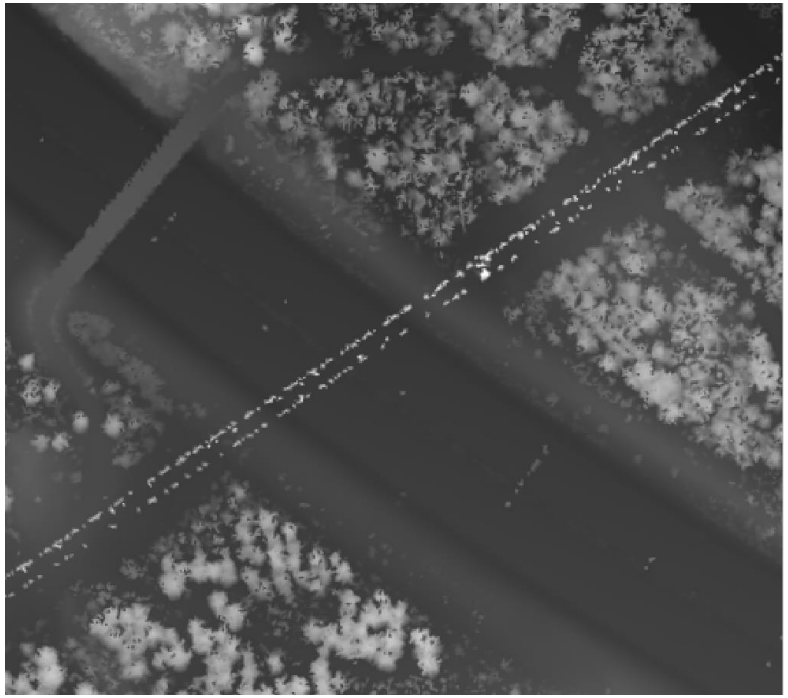
Determination of SVF

1. Digital surface model was generated from the laser scanning data
2. Local horizon angles at the selected point were calculated by using digital surface model
3. SVF was calculated from the local horizon angles

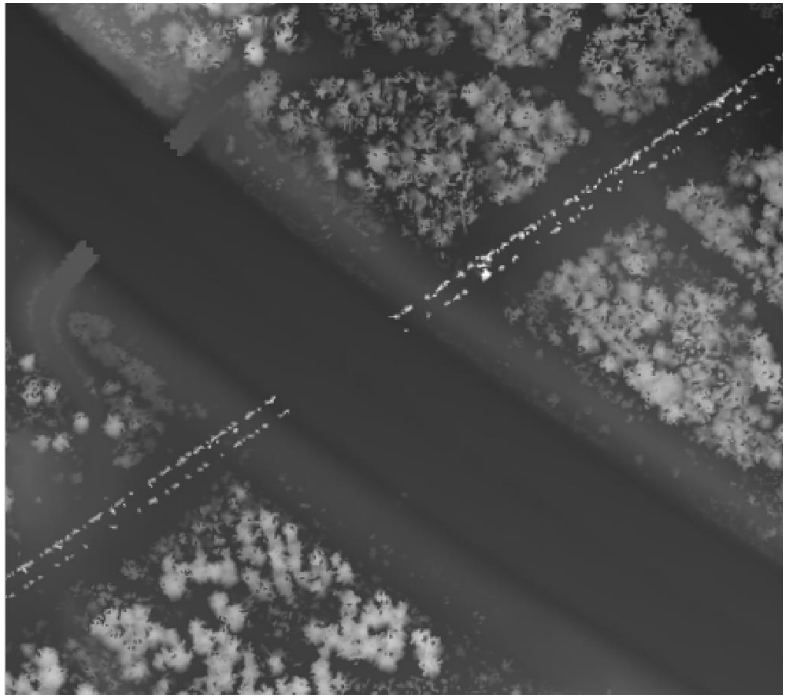


Digital surface model for Kumpula, Helsinki

- Powerlines, electricity poles etc. cause problems
- We used 10 m wide overlay extracted from a 2 m digital elevation model to get rid of some of these
- Points in tunnels and close to overpassing bridges were removed

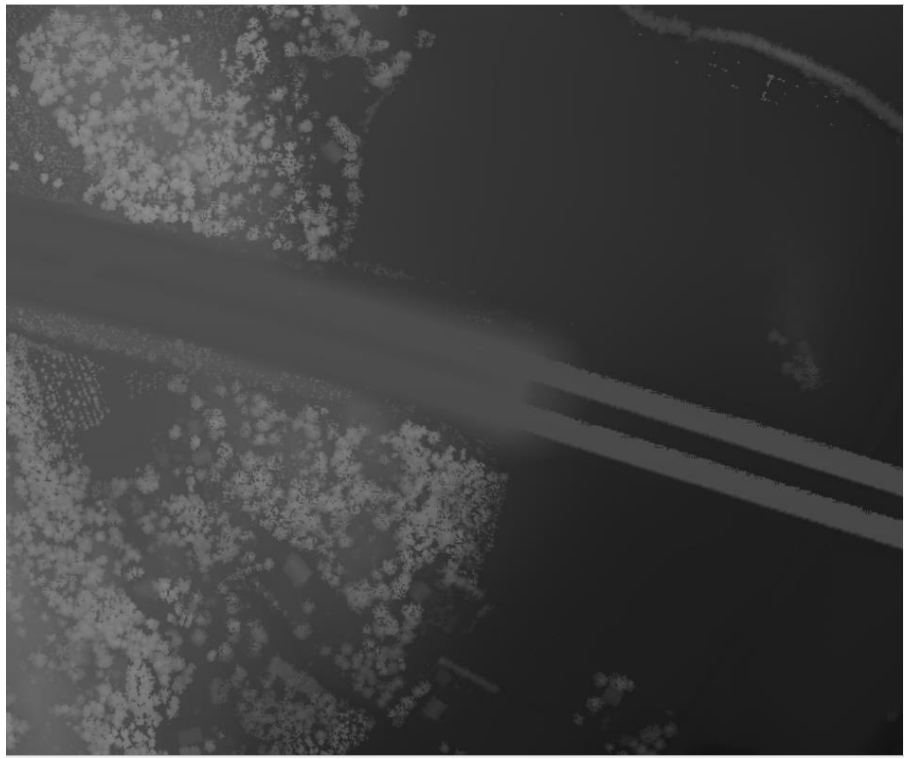


Original

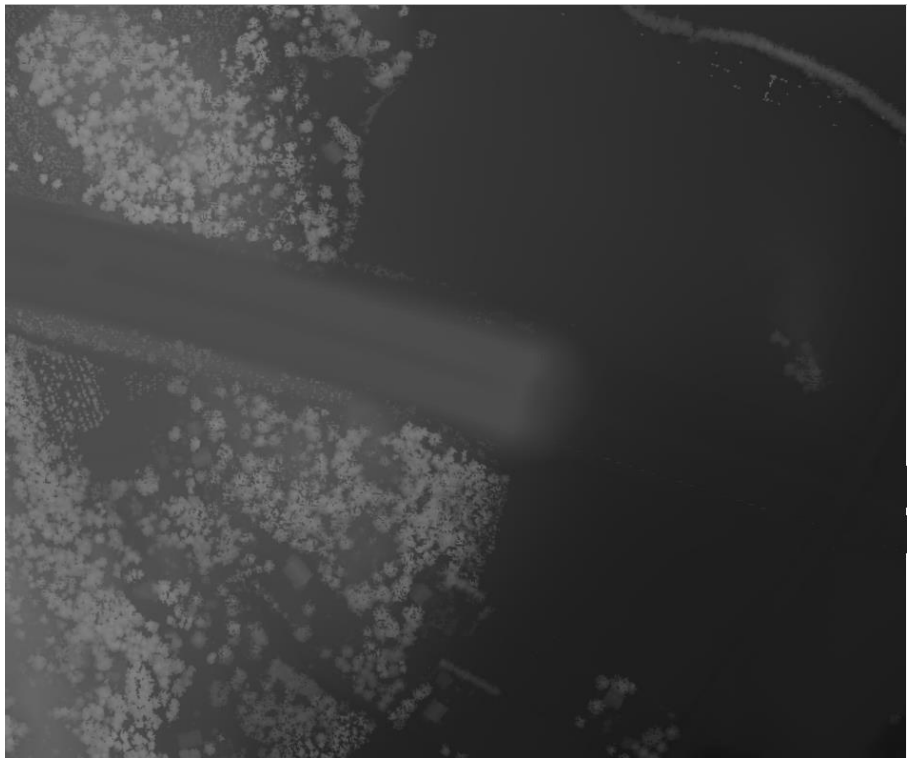


With 2 m DEM road layer

- However, 2m DEM should not be used when road is on bridge
- Too spiky or bulky features were removed by an algorithm from calculated local horizon angles

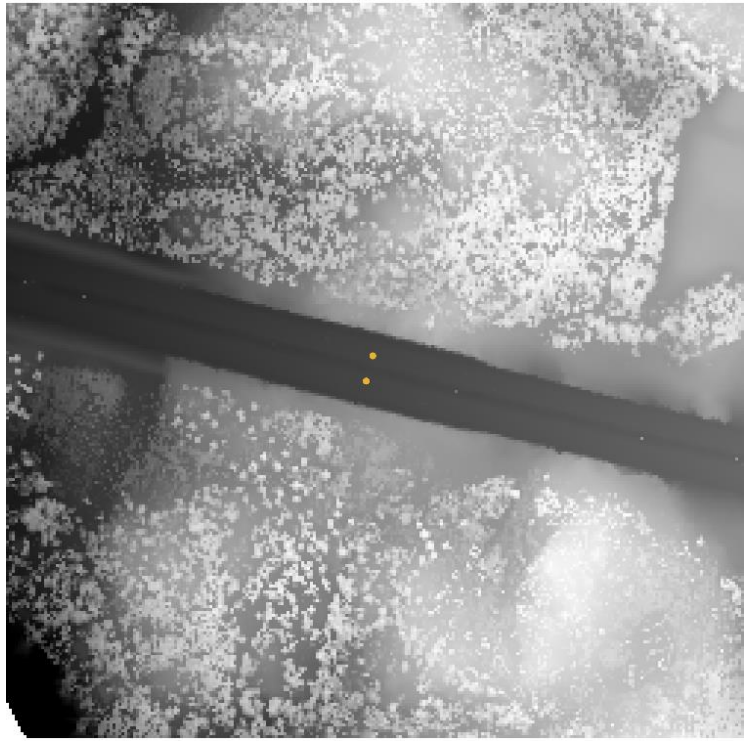


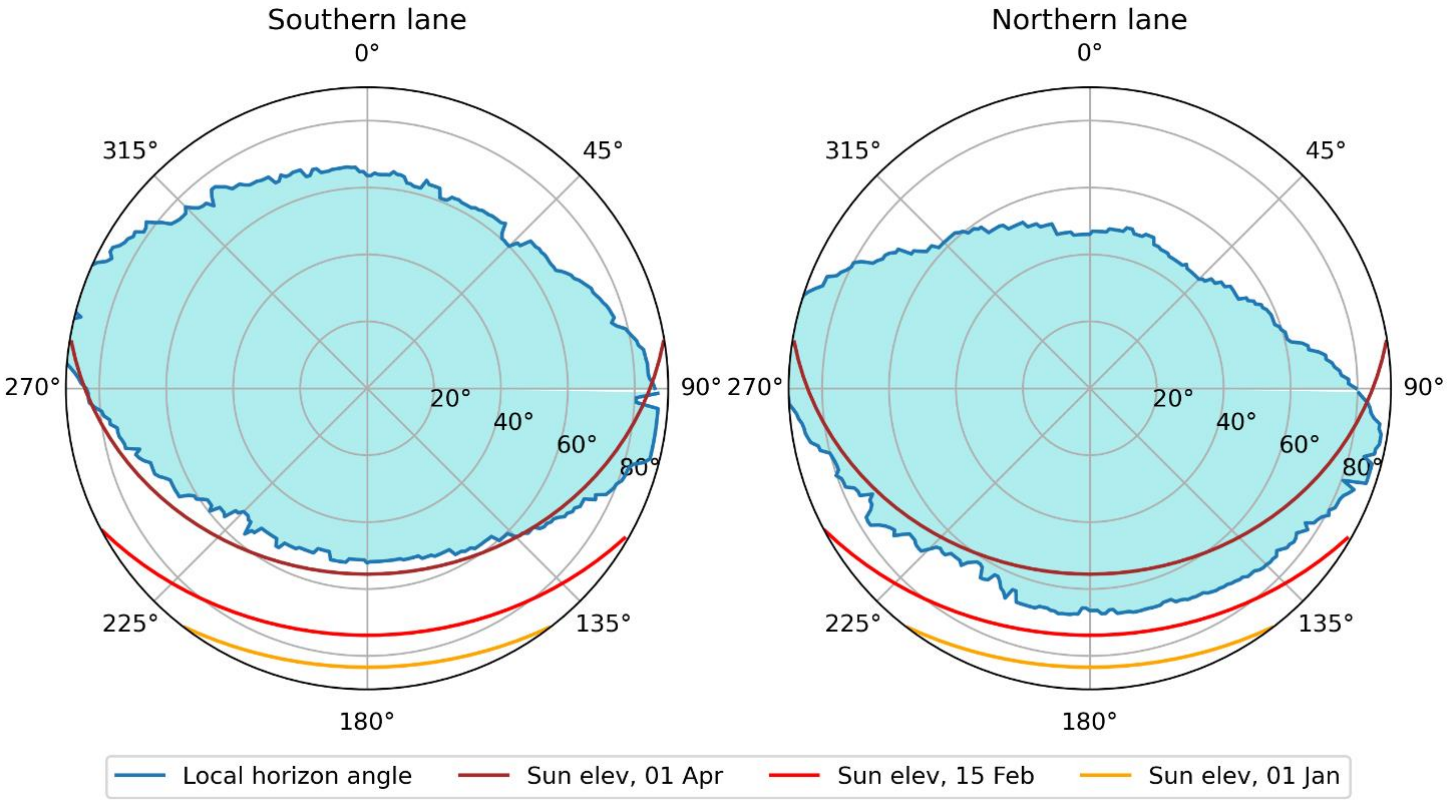
Original



With 2 m DEM road layer

- Differences between roadways, Salo Lakiamäki, Helsinki-Turku motorway

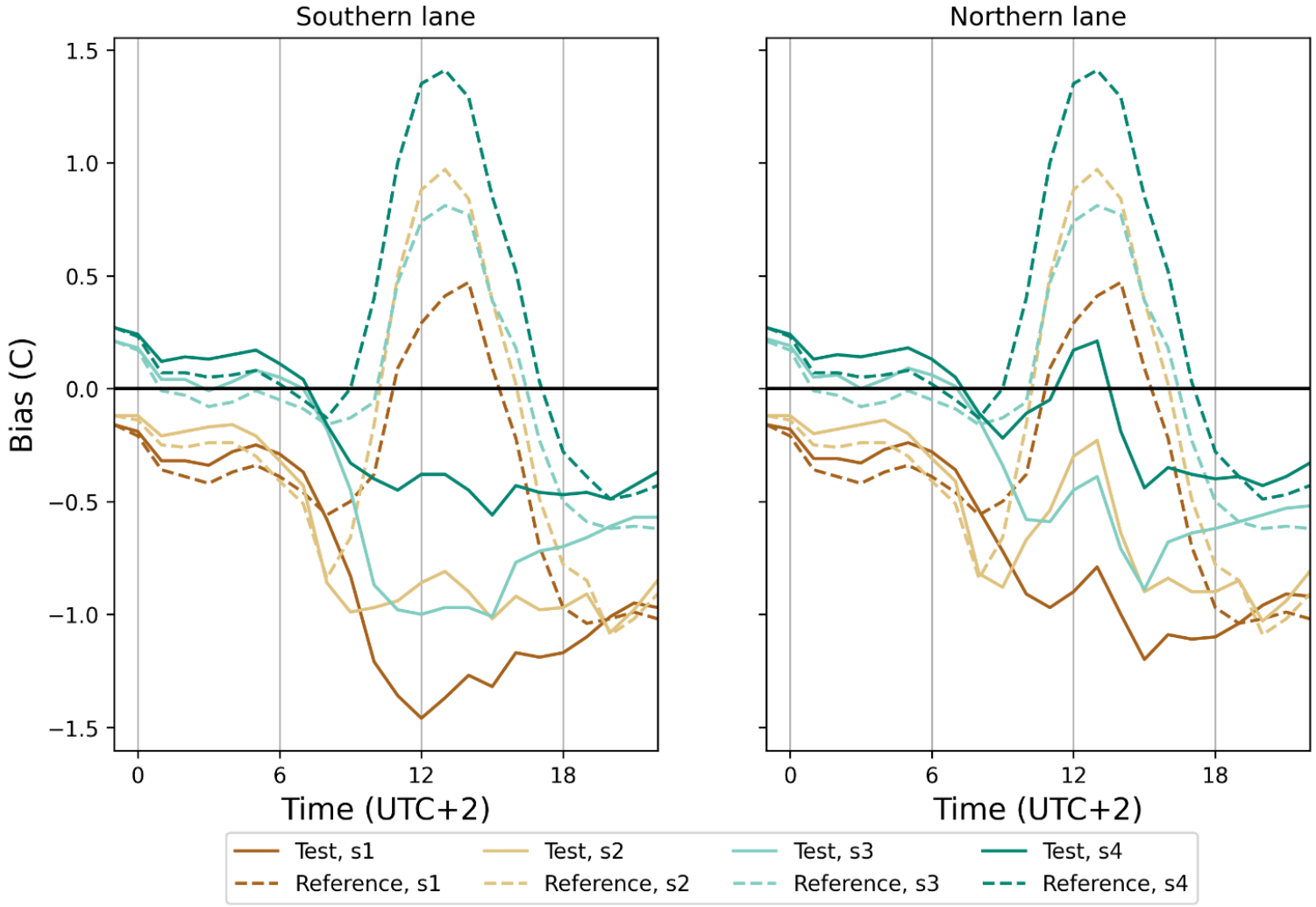




Results

- **Test**: SVFs and shading included
- **Reference**: no SVFs and shading
- Verification is done using the same sensor's data as used in initialization
- Results dependent on both the roadway and the sensor
- Reference simulations have warm bias during the day

Surface temperature bias, Salo Lakiamäki, Octobers 2018, 2019, 2020, forecast start time 21 UTC



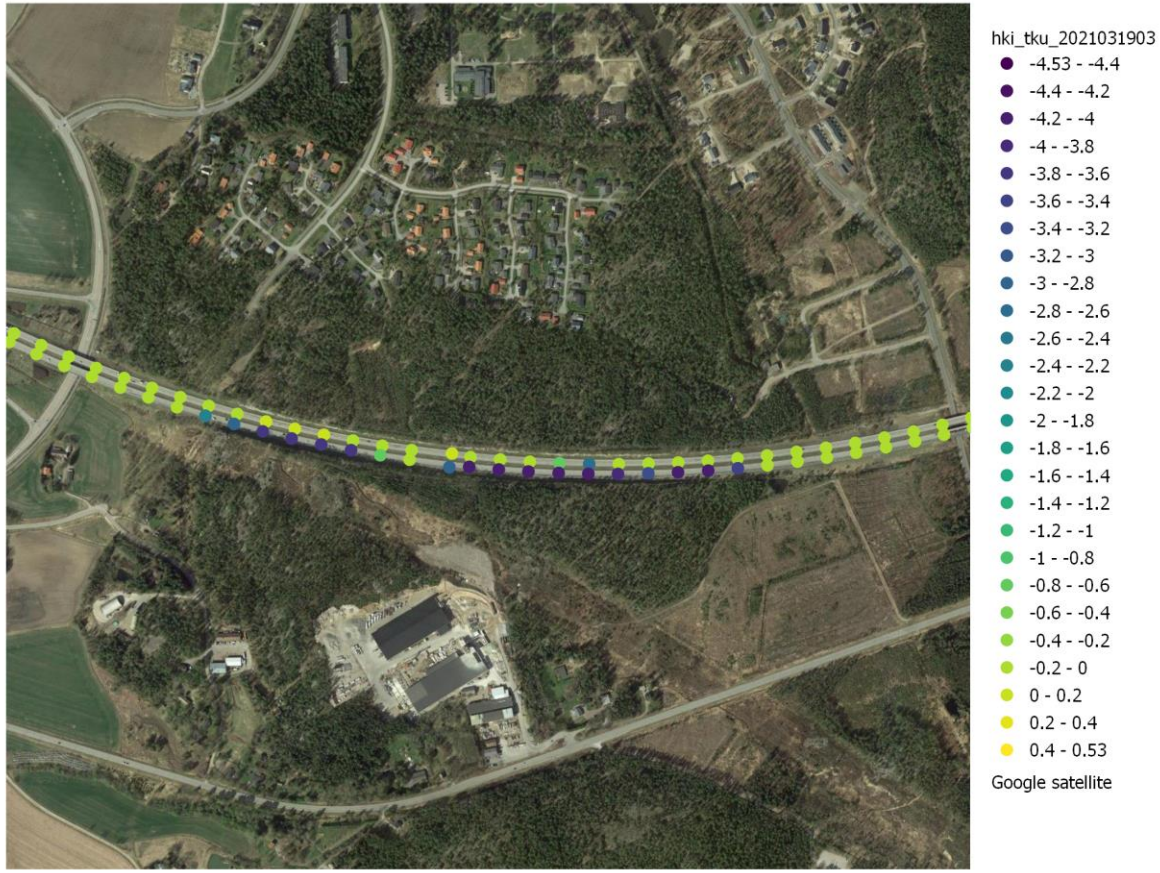
- At best shading considerably decreases the RMSE during the day
- In many cases, shading increases the already negative bias
- The effects of shading and SVFs vary greatly depending on the studied location, even between roadways

More information:

Karsisto, V., and Horttanainen, M. (2022). Sky View Factor and Screening Impacts on the Forecast Accuracy of Road Surface Temperatures in Finland. *Journal of Applied Meteorology and Climatology* (published online ahead of print 2022), available from: https://doi.org/10.1175/JAMC-D-22-0026.1

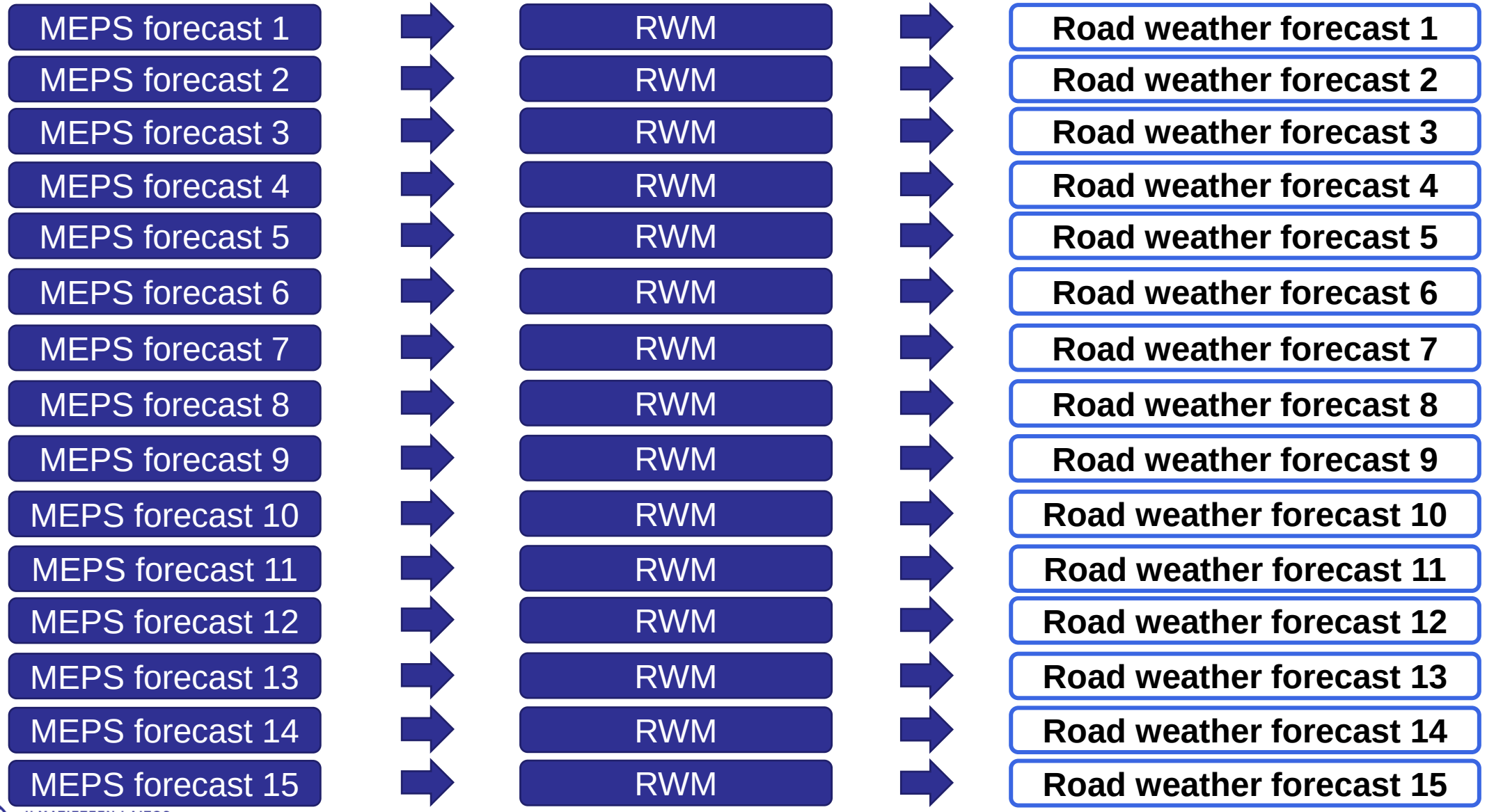
Test ongoing on Helsinki-Turku motorway (~150 km)

- Forecast points located every 50 meters on both roadways
- Forecast updated every hour
- Input forecast from MEPS model
- Figure shows example road surface temperature forecast for 19th March 2021
  - The southern roadway is shadowed by forest, causing lower temperatures in the morning



4. Probability forecasts

- Information about forecast uncertainty is useful for decision makers
  - Better risk management
  - Unnecessary salting can be avoided
- Common way to produce probability forecasts is ensemble forecasting
- Finnish Meteorological Institute (FMI) is producing ensemble road weather forecasts with MEPS data


MEPS forecast 1
MEPS forecast 2
MEPS forecast 3
MEPS forecast 4
MEPS forecast 5
MEPS forecast 6
MEPS forecast 7
MEPS forecast 8
MEPS forecast 9
MEPS forecast 10
MEPS forecast 11
MEPS forecast 12
MEPS forecast 13
MEPS forecast 14
MEPS forecast 15
RWM
RWM
RWM
RWM
RWM
RWM
RWM
RWM
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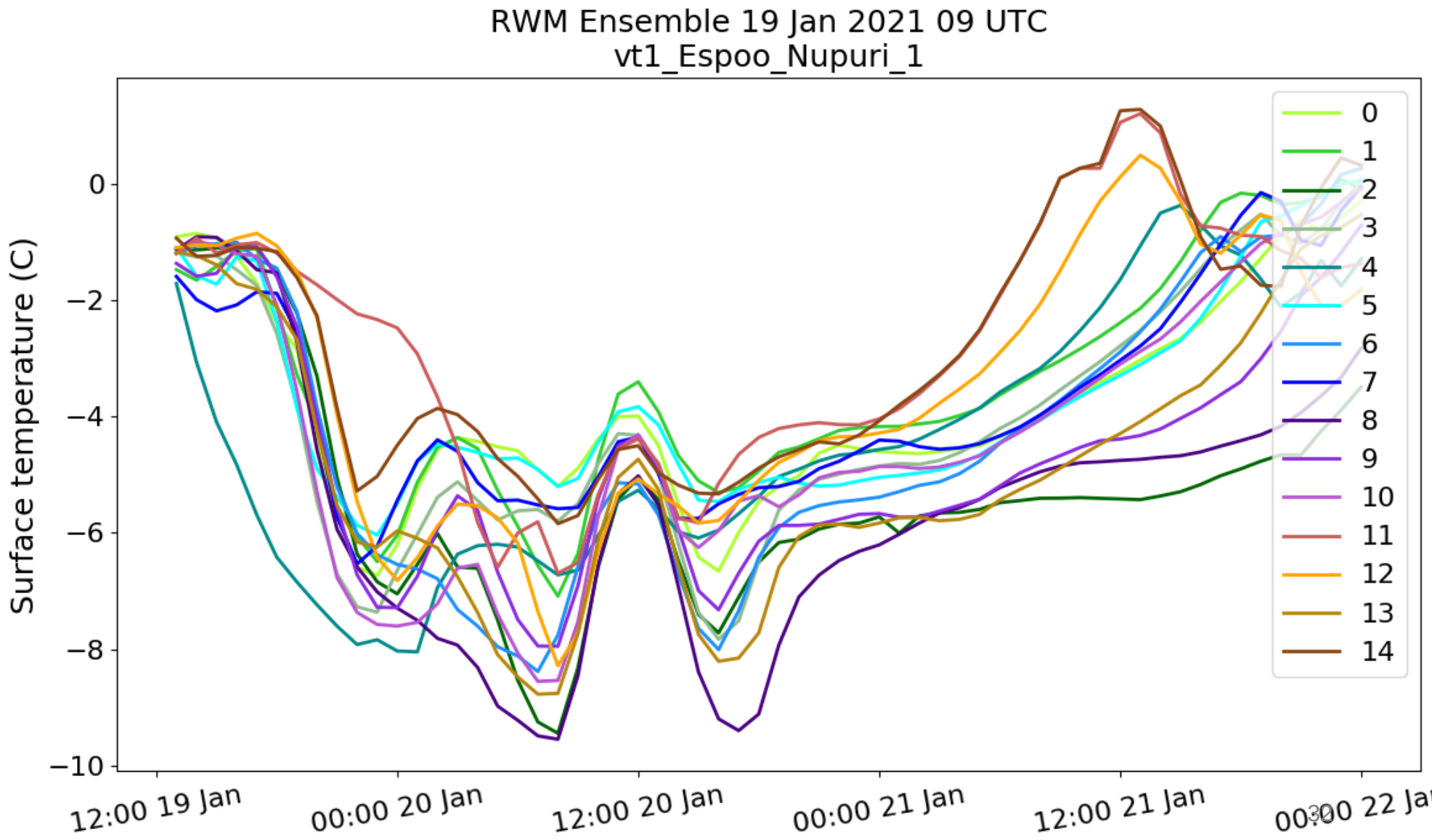
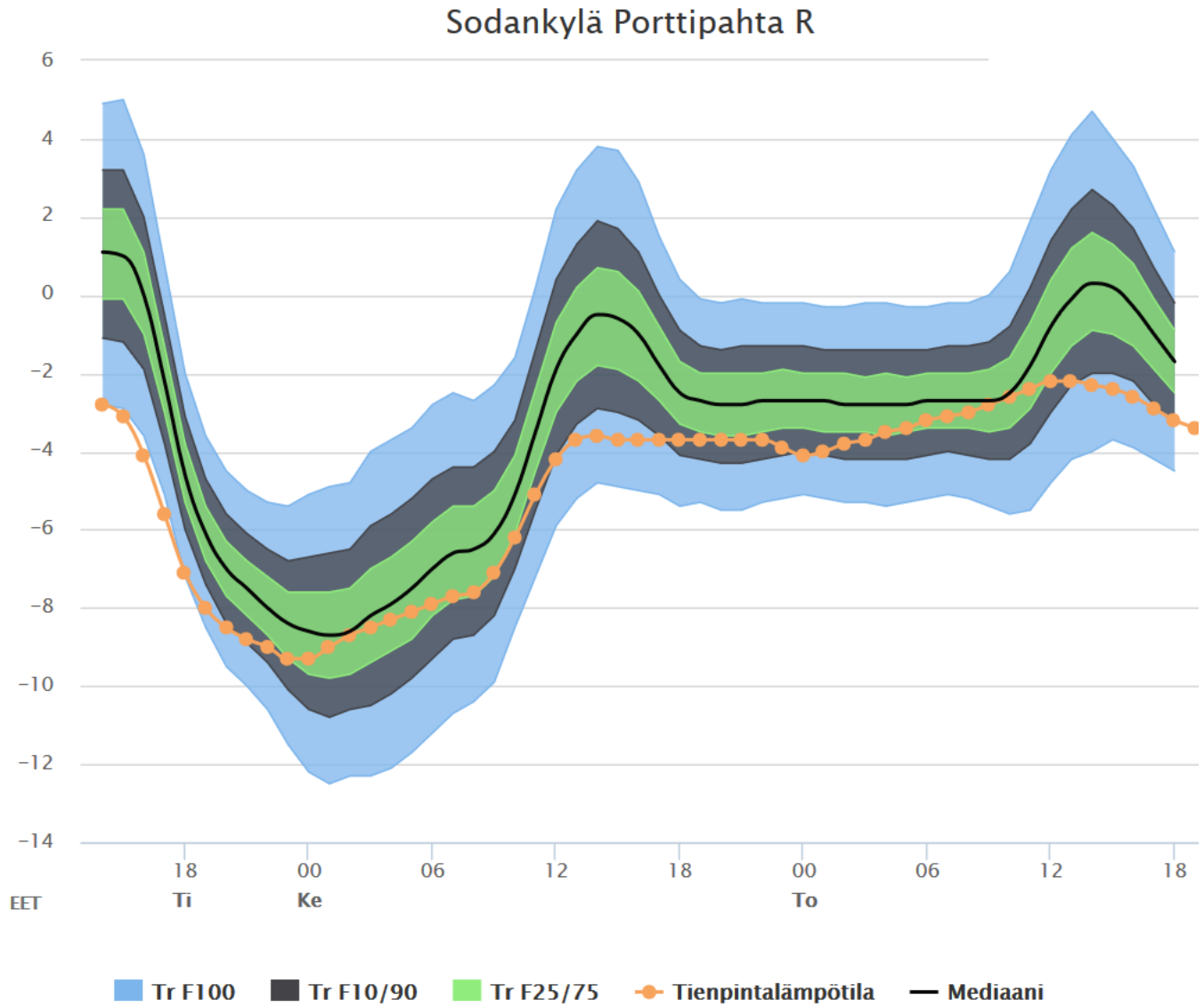
Road weather forecast 1
Road weather forecast 2
Road weather forecast 3
Road weather forecast 4
Road weather forecast 5
Road weather forecast 6
Road weather forecast 7
Road weather forecast 8
Road weather forecast 9
Road weather forecast 10
Road weather forecast 11
Road weather forecast 12
Road weather forecast 13
Road weather forecast 14
Road weather forecast 15

Example


RWM Ensemble 19 Jan 2021 09 UTC
vt1_Espoo_Nupuri_1
Surface temperature (C)
0
−2
−4
−6
−8
−10
12:00 19 Jan
00:00 20 Jan
12:00 20 Jan
00:00 21 Jan
12:00 21 Jan
00:00 22 Jan
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14


Sodankylä Porttipahta R
6
4
2
0
−2
−4
−6
−8
−10
−12
−14
18
00
06
12
18
00
06
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18
EET
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Ke
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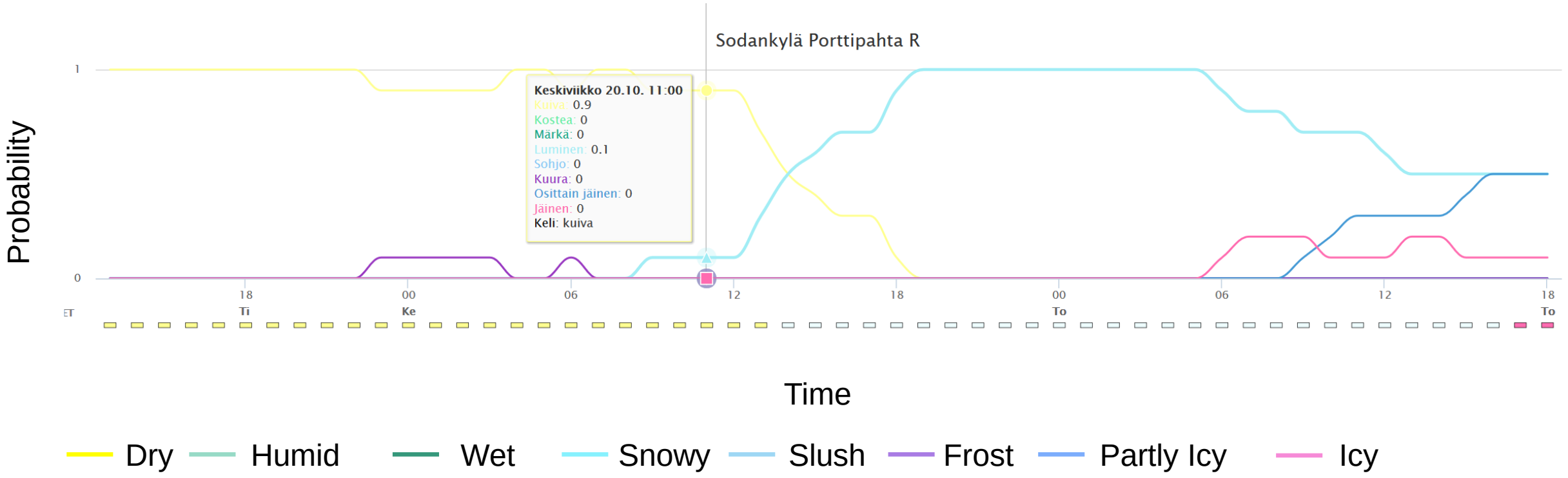
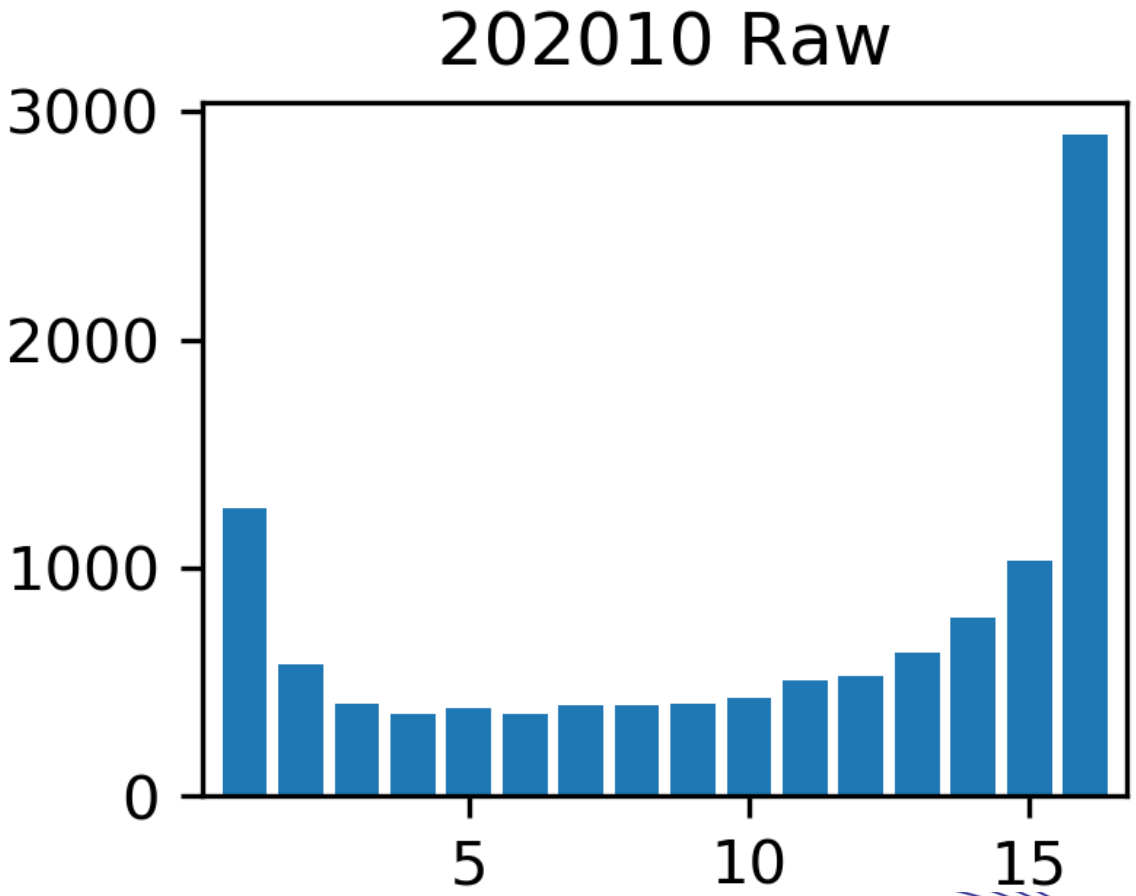
Tr F100
Tr F10/90
Tr F25/75
Tienpintalämpötila
Mediaani

Road condition

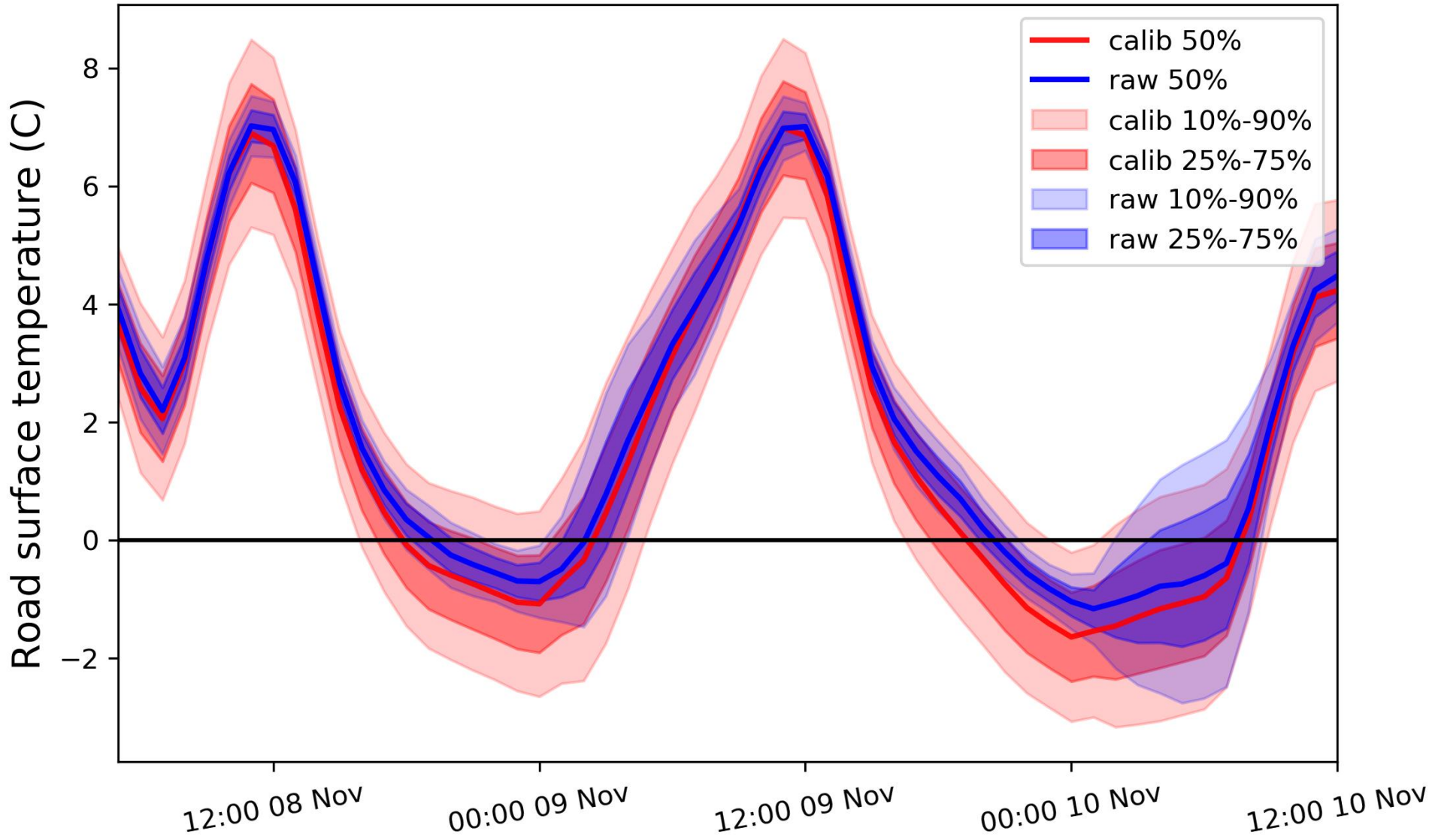


Verification

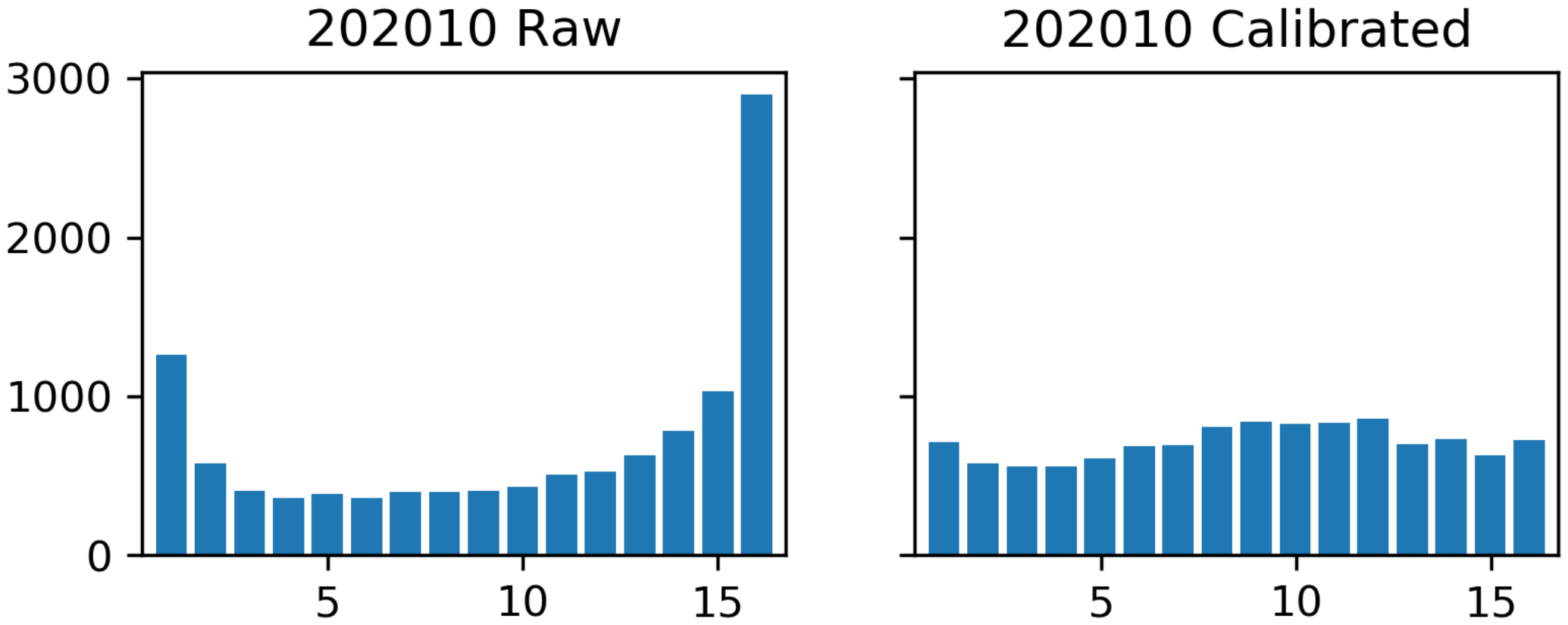
- Surface temperature probability forecasts are too self confident
- Spread is too low
- Observed value is often lower or higher than forecasted
- Calibration needed



Rank histogram
Forecast length: 24 h


Road surface temperature (C)
8
6
4
2
0
−2
12:00 08 Nov
00:00 09 Nov
12:00 09 Nov
00:00 10 Nov
12:00 10 Nov
calib 50%
raw 50%
calib 10%-90%
calib 25%-75%
raw 10%-90%
raw 25%-75%

Results



5. Research projects

- 5G-Safe-Plus
  - Advanced road safety services enabled by hybrid 5G and ITS-G5 communications
- SafeTrucks
  - Advanced road safety by dynamics and road weather services tailored for individual heavy vehicles
- Winter Premium
  - Utilization of arctic conditions to increase transport capacity in heavy transport