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METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

Precipitation Type and Satellite Images for High Latitudes

High Latitudes Event Week 2023

2.2.2023

Johannes Häkkinen

- M.Sc. in meteorology
- Operational Aviation Forecaster, Weather and Safety Center
  - Forecaster since 2016
- Other tasks
  - Development of forecasting tools and methods
  - Verification of weather models regarding aviation

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Agenda

Wintry precipitation

Top-Down method

Services for EFHK (Helsinki-Vantaa airport)

Summary

Wintry precipitation

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Wintry precipitation

- Freezing drizzle
- Snow grains
- Freezing rain
- Ice pellets
- Snow
- Sleet
- Diamond dust

Hail, snow pellets/graupel not covered in this presentation.

Wintry precipitation

- Freezing drizzle (FZDZ)
  - Drizzle when the surface temperature is below zero.
  - Cloud's thickness is atleast 300 meters, typically 1000 meters.
  - Cloud base is lower than 300 meters.
  - None (or just some) ice formation in the cloud.
    - Temperature inside stratus is (0 … -12 °C)
- Snow grains (SG)
  - Freezing drizzle that freezes before falling to the ground
  - Similiar situations to FZDZ but
    - The cloudbase is too high
    - OR a very strong surface inversion

Wintry precipitation

- Freezing rain (FZRA)
  - Requires a snow producing layer (< -12 … -18 °C), a think enough warm layer and a cold layer near surface.
  - Typically surface temperature is -7 … +2 °C
    - In Finland temperature is often close to 0 °C with FZRA.
  - Typically observed with warm/moist low pressures from Atlantic collide with cold airmass.
    - Generally ahead of warm front
- Ice pellets (PE)
  - Similiar conditions to FZRA but
    - The maximum temperature of warm layer is lower than 3 °C, there's not enough heat/time for all the snow to melt.
    - OR cold layer near surface is too cold/thick.

Wintry precipitation

- Snow (SN)
  - Most common precipitation during the winter. Forms in various different circumstances.
  - Requires lift and moisture.
  - Dewpoint is often a better indicator:

Dewpoint	Probability of snow
- 2,6 °C	90 %
+ 0,1 °C	50 %
+ 1 °C	10%

- Sleet (SNRA)
  - Snow that partially melts in the warm layer near surface.
    - If the warm layer is thin or dry the precipitation is likely snow.

Wintry precipitation

- Diamond dust (ex-IC)
  - Requires very cold surface temperatures (-15 … -35 °C)
    - Strong inversion and some moisture
  - Might form without a visible cloud
  - Forecasting is challenging.
  - Observing for instruments is challenging.
    - Produces unrealistic values for visibility measurements.

Top-down Method

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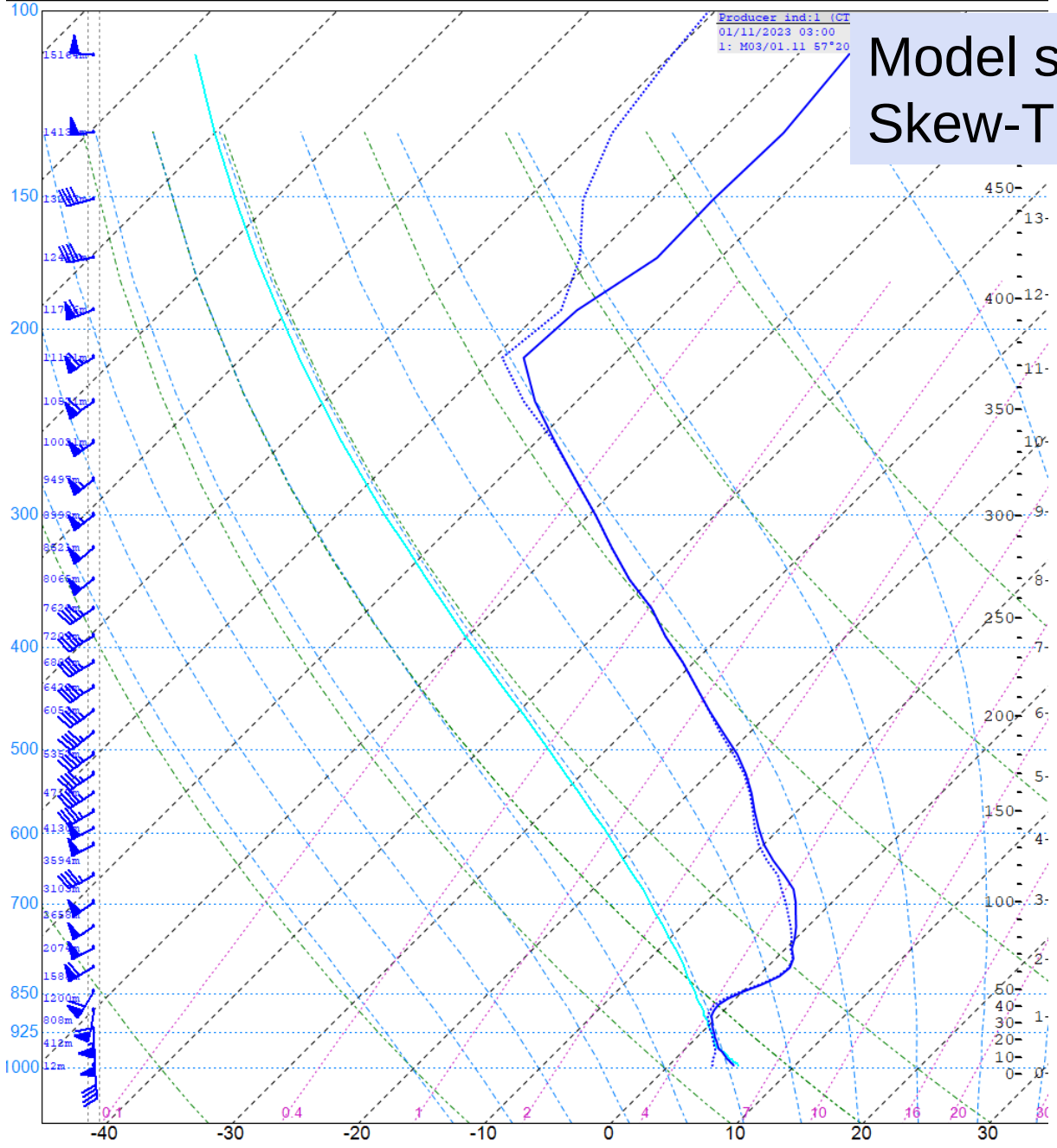
Top-down Method

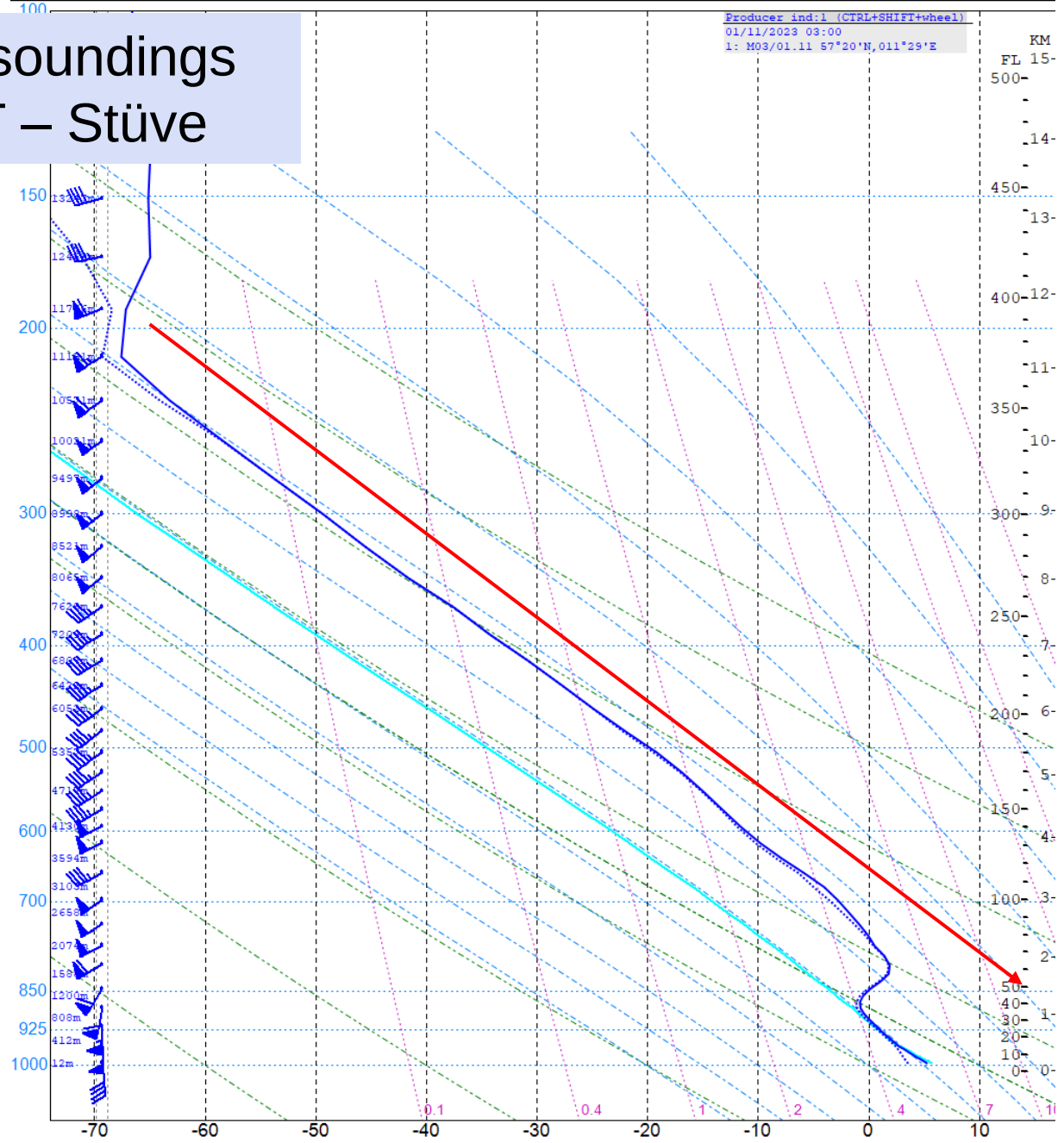
- Estimate the hydrometeors path in the model sounding.
- Ice formation in clouds is based on the cloud temperature:

Temperature	Ice formation
> - 4 °C	No ice formation in the cloud
- 10 °C	70 % chance of ice formation in the cloud
- 12 °C	Limit we typically use for ice formation
- 15 °C	90 % chance of ice formation in the cloud
< - 20 °C	Guaranteed ice formation in the cloud

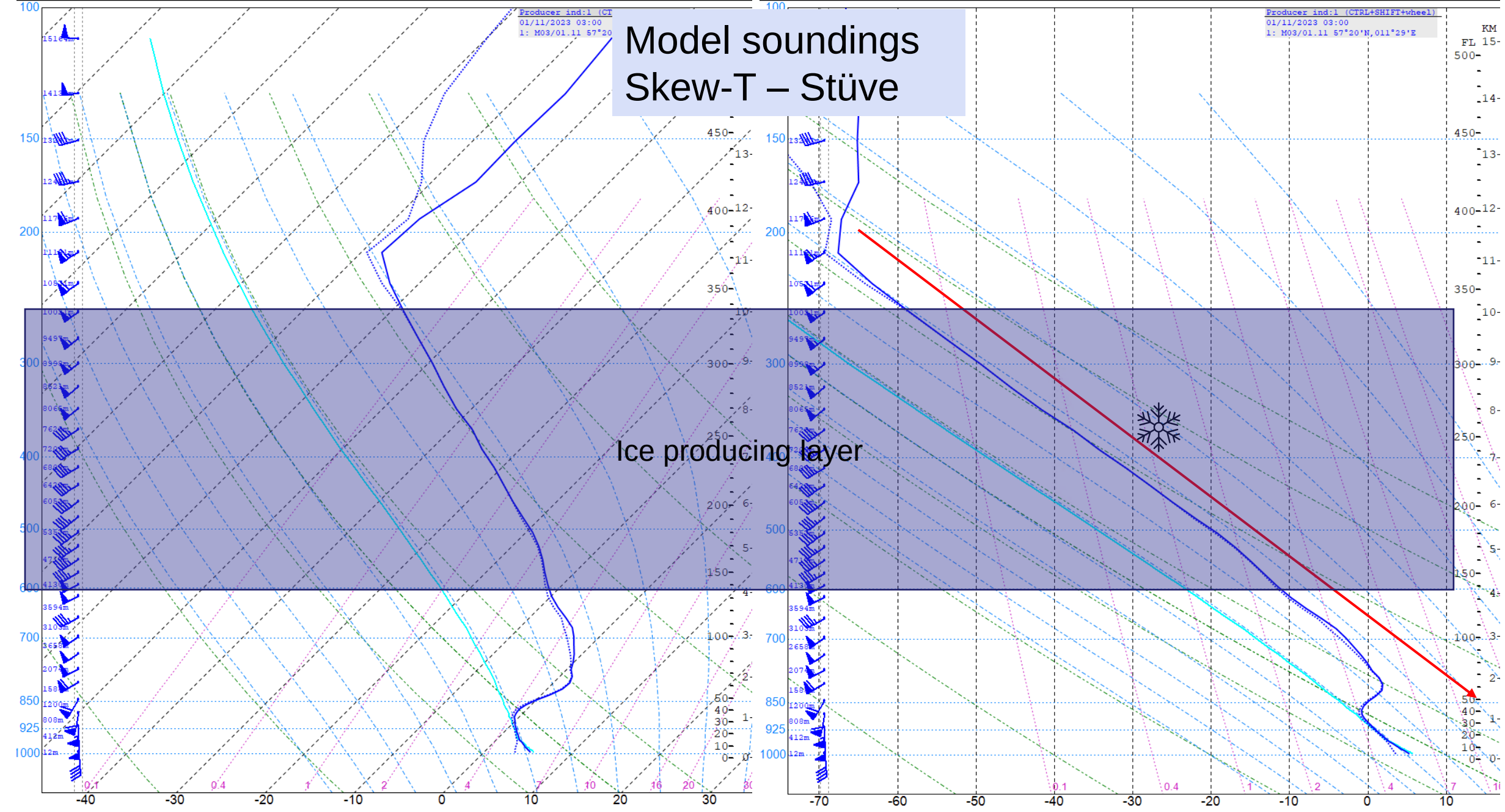
- Couple different layers in soundings:
  - Ice producing layer (ice crystal nucleation/growth)
  - Warm layer (warming/melting)
  - Cold layer (refreezing/contact freezing)

Model soundings
Skew-T – Stüve

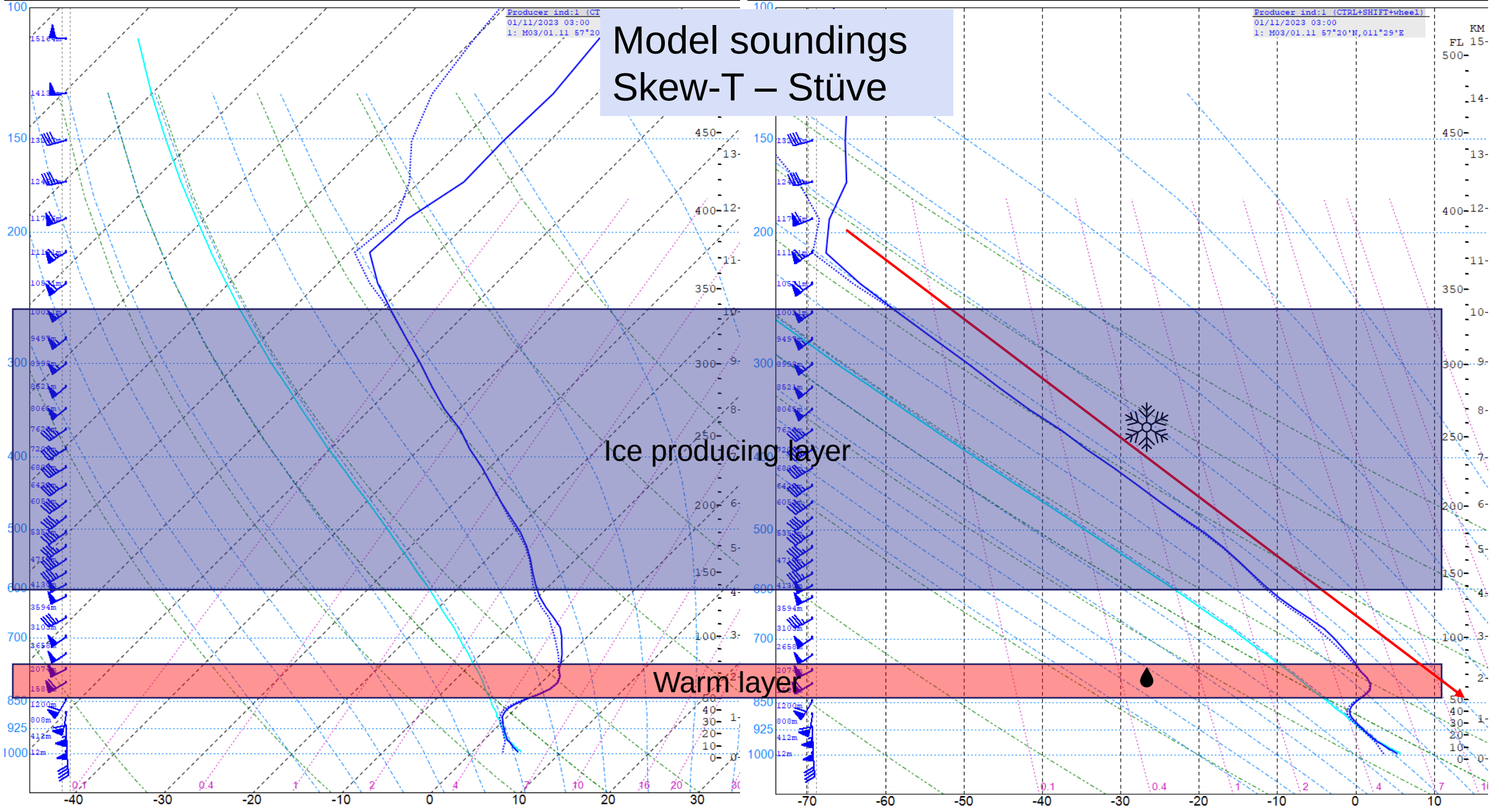




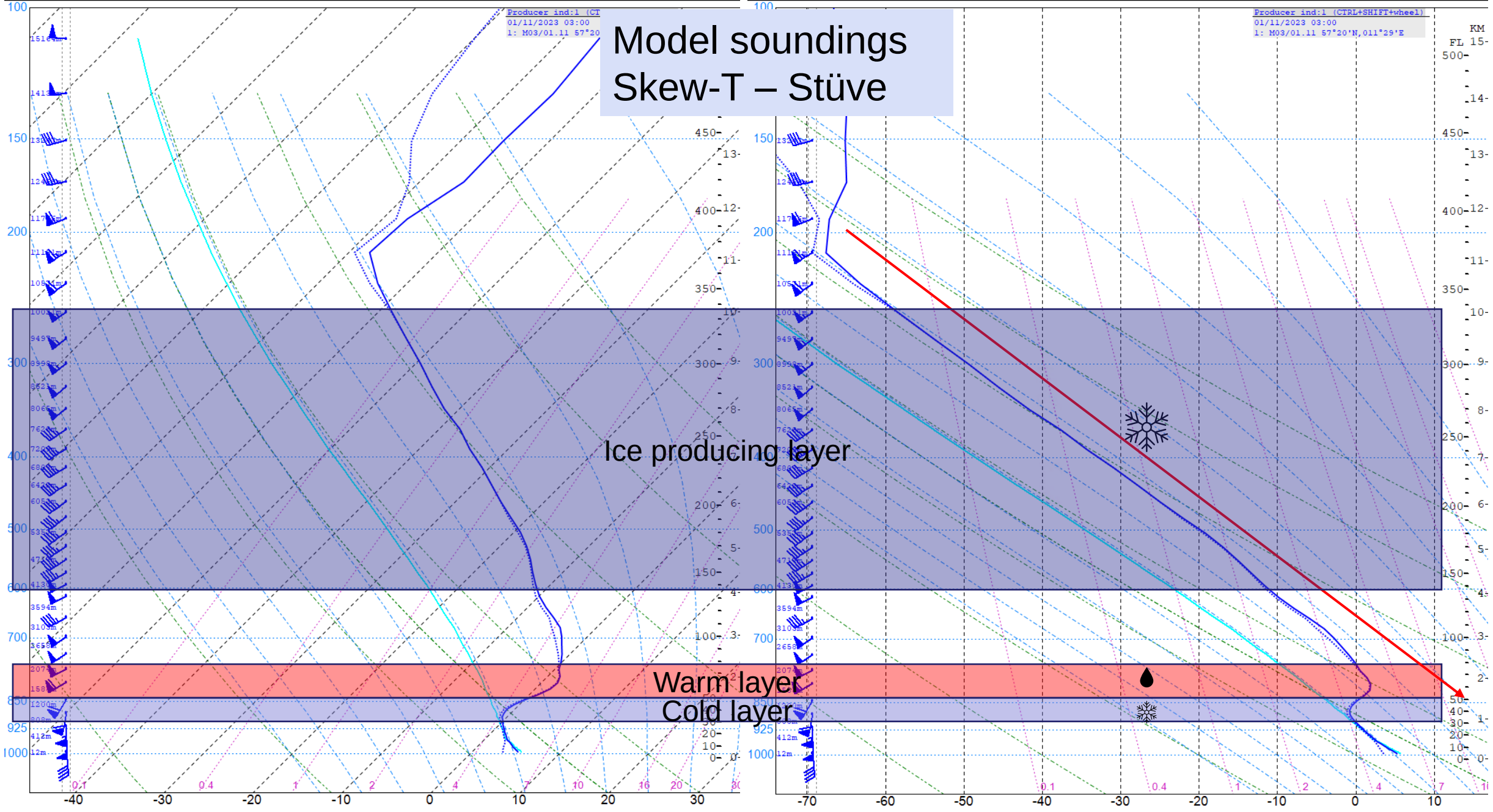
Model soundings
Skew-T – Stüve



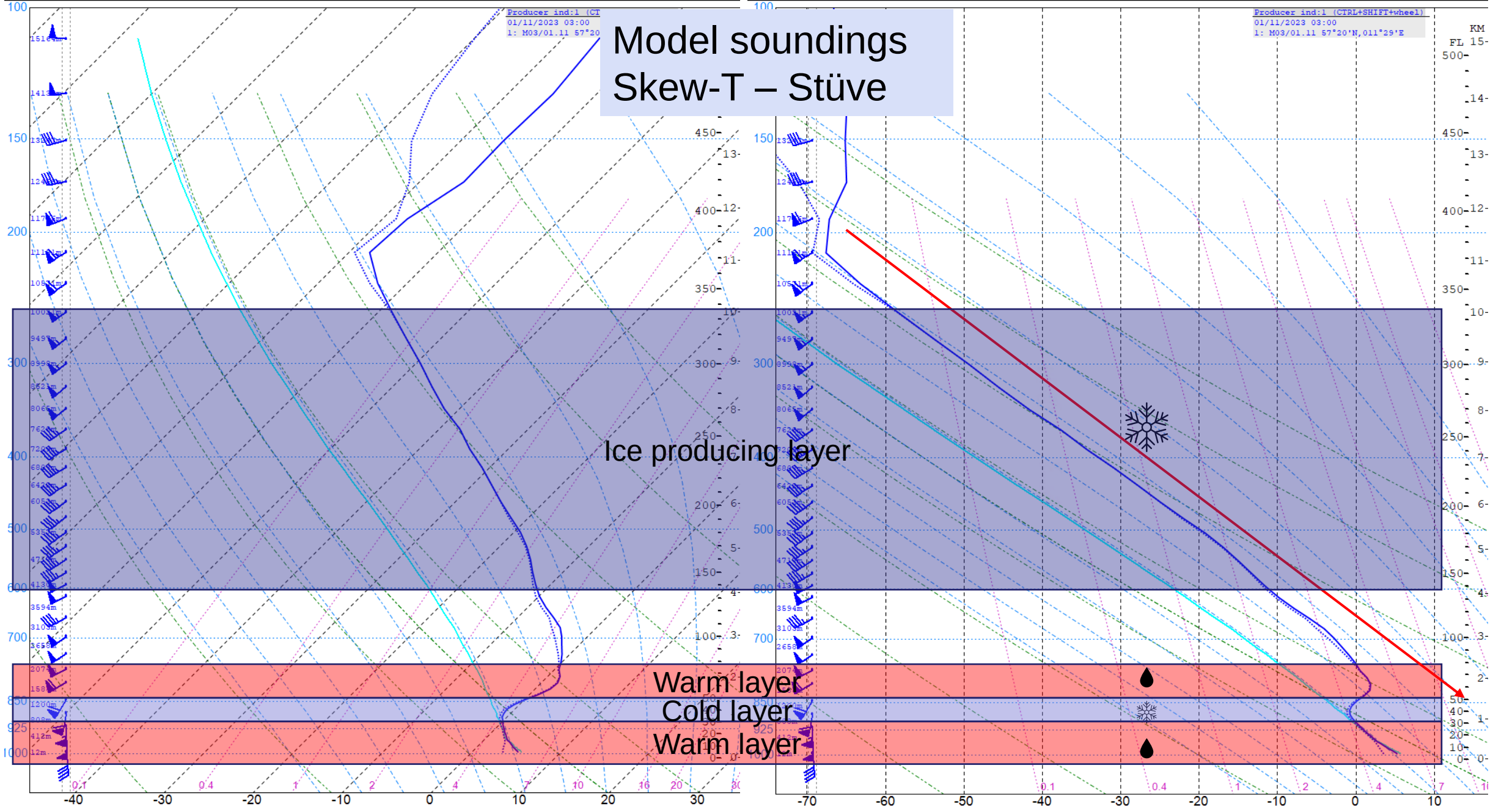
Model soundings
Skew-T – Stüve



Model soundings
Skew-T – Stüve



Model soundings
Skew-T – Stüve



Some ”guidelines” for top-down method

- No ice formation in cloud (T_{top} > ~-12 °C) and cloud is at least 300 m thick.
  - If $T_{surface}$ < 0 °C, freezing drizzle
    - If cloud is thicker than 2 km, freezing rain (rare)
  - If $T_{surface}$ > 0 °C, drizzle
    - If cloud is thicker than 2 km, rain (rare)
- Ice formation in the cloud (T_{top} <~-12 °C), no warm layerS
  - Thick cloud with upward motion, snow
  - Thin and stable cloud, snow grains
- Ice formation in the cloud (T_{top} <~-12 °C), warm layer and cold layer near surface
  - If warm layer’s T_{max} < 1 ˚C, snow
  - If warm layer’s T_{max} = 1…3 ˚C, snow or Ice pellets
  - If warm layer’s T_{max} > 3 ˚C, freezing rain
- Ice formation in the cloud (T_{top} <~-12 °C), warm layer and thick cold layer near surface.
  - If the cold layer near surface is thicker than 800 m and T_{min} < -6 °C, Ice pellets

MetEd has more material and training

- MetEd has good a training resource with a lot more details of the process. Highly recommended.
  - Free, registration required

https://www.meted.ucar.edu/norlat/snow/preciptype/index.htm

Examples of Top-down Method

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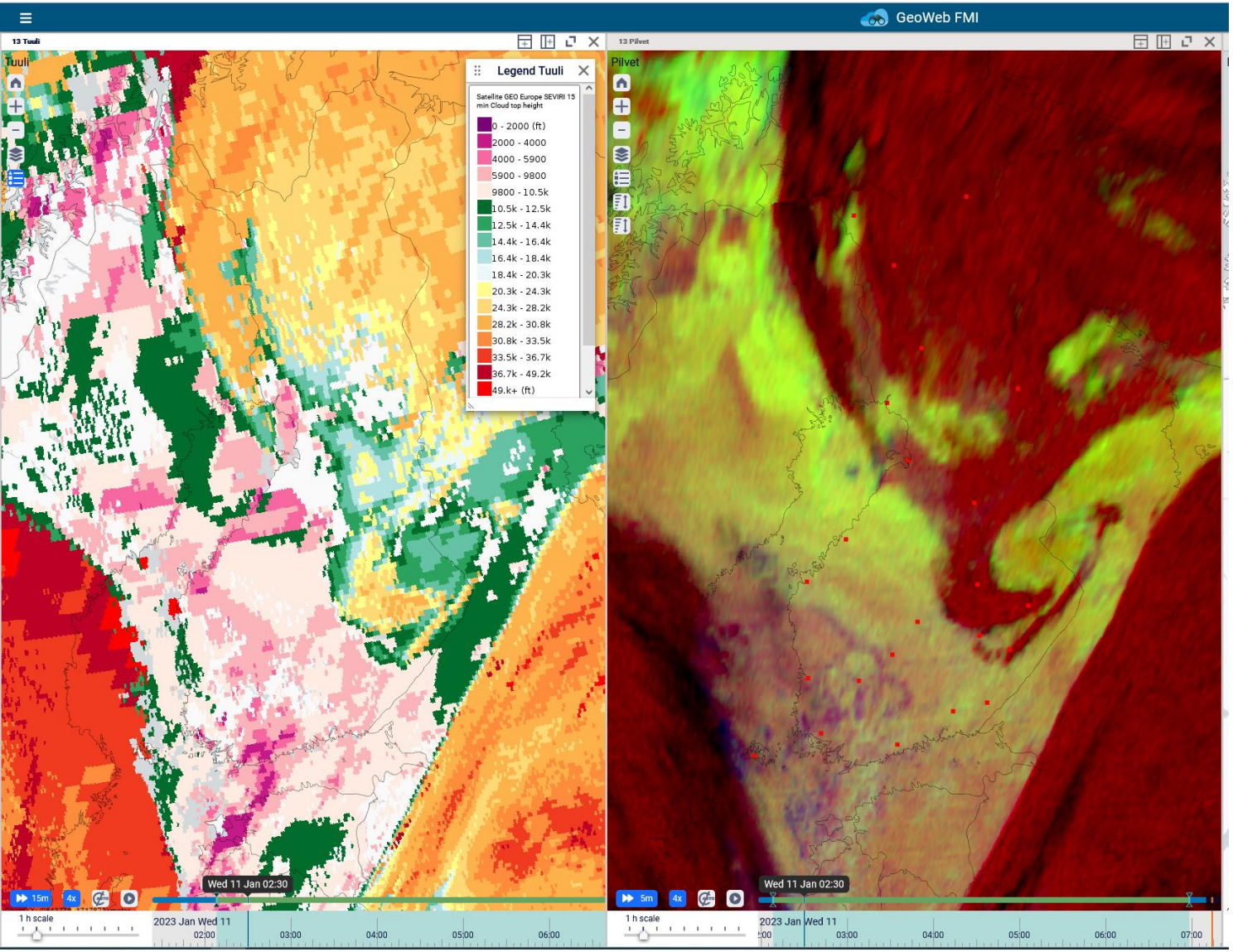

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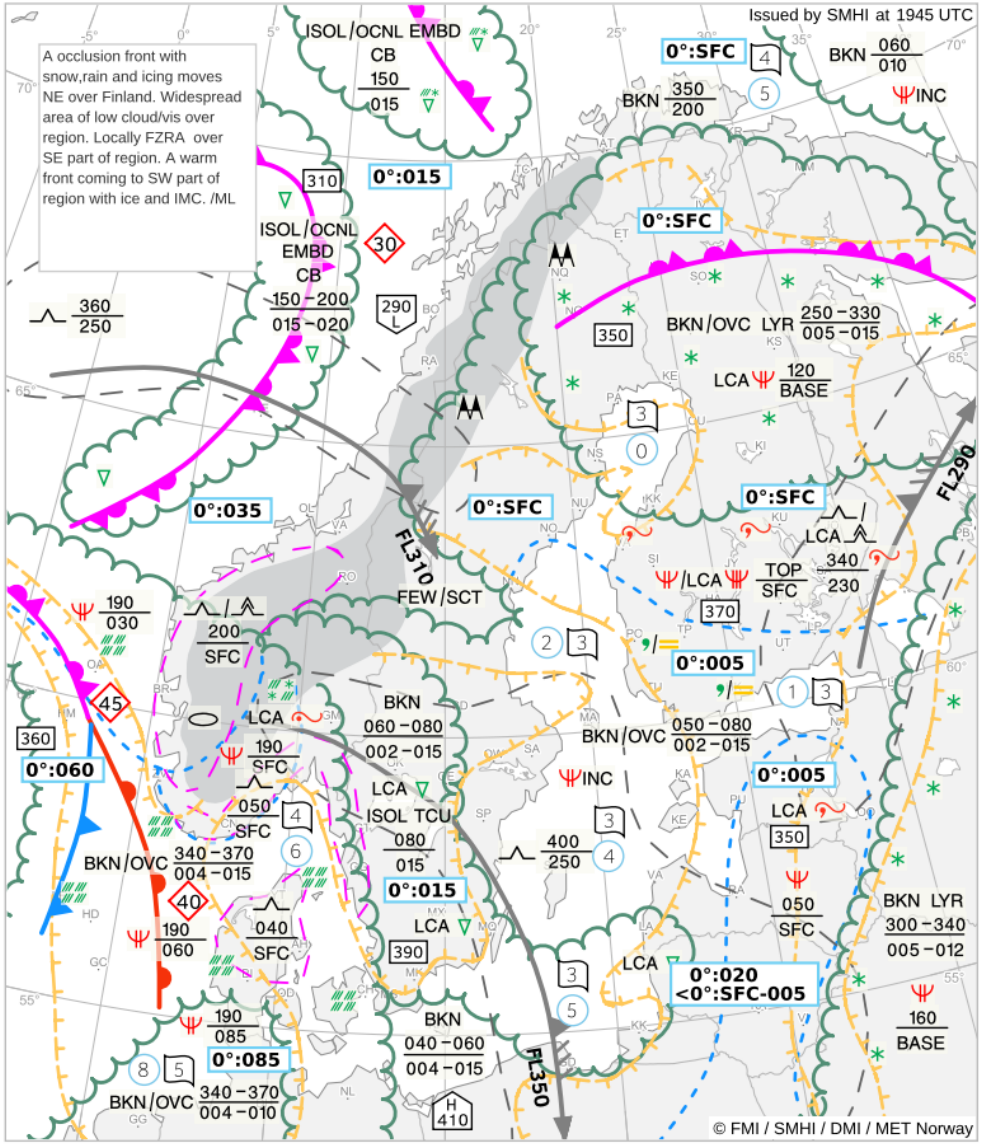


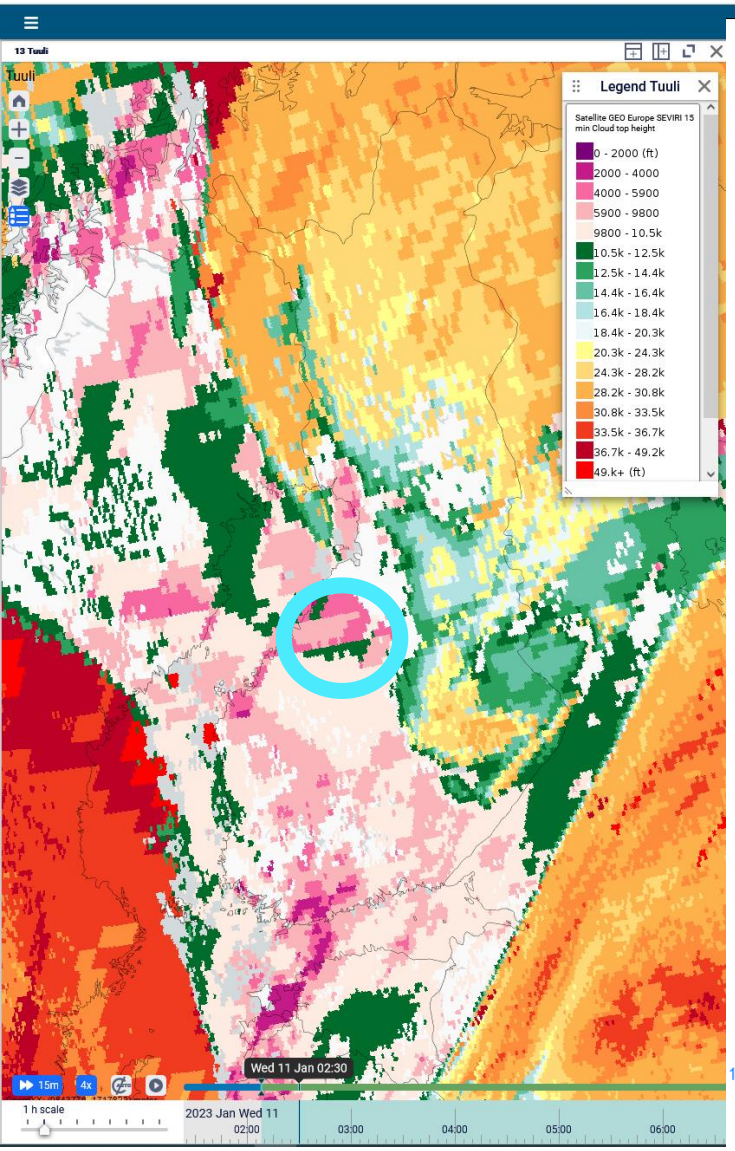
Fixed time prognostic chart

CB and TCU imply MOD or SEV ICE/TURB, CB also implies TS and/or GR. Units: speed in knots; pressure (QNH) in hPa; levels in hectofeet AGL below FL050, otherwise in flight levels. Low ceiling/visibility is not detailed in mountain areas (shown with grey shading).

Symbols and lines

- Significant weather (SIGWX)
- Ceiling<1000ft and/or visibility<5km
- High level turbulence
- Low level turbulence
- Change in icing
- Moderate/Severe turbulence
- Moderate/Severe icing
- Rain, Snow, Sleet
- Showers
- Freezing rain/drizzle
- Drizzle, Snow grains
- Thunderstorm, Hail
- Mist, Fog, Freezing fog
- Haze, Smoke, Blowing snow
- Mountain waves, Mountain obscuration
- 0°C level
- Sea surface temperature, Sea state (index)
- Surface wind >30kt
- Convergence line
- Severe squall line
- Position, speed, direction and level of max wind
- Tropopause level
- Tropopause high, Tropopause low

More information: https://www.northavimet.com/NSWC


13 Tuuli
Tuuli
Legend Tuuli
Satellite GEO Europe SEVIRI 15 min Cloud top height
0 - 2000 (ft)
2000 - 4000
4000 - 5900
5900 - 9800
9800 - 10.5k
10.5k - 12.5k
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28.2k - 30.8k
30.8k - 33.5k
33.5k - 36.7k
36.7k - 49.2k
49.k+ (ft)
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4x
1 h scale
2023 Jan Wed 11
02:00
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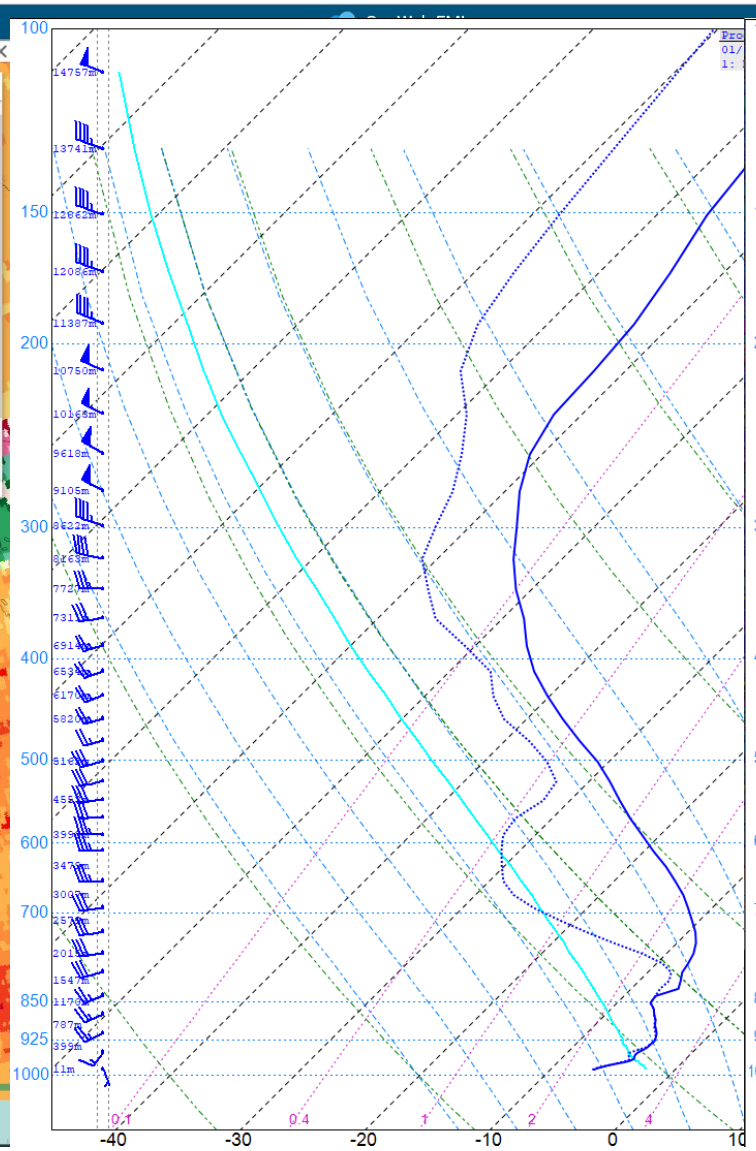
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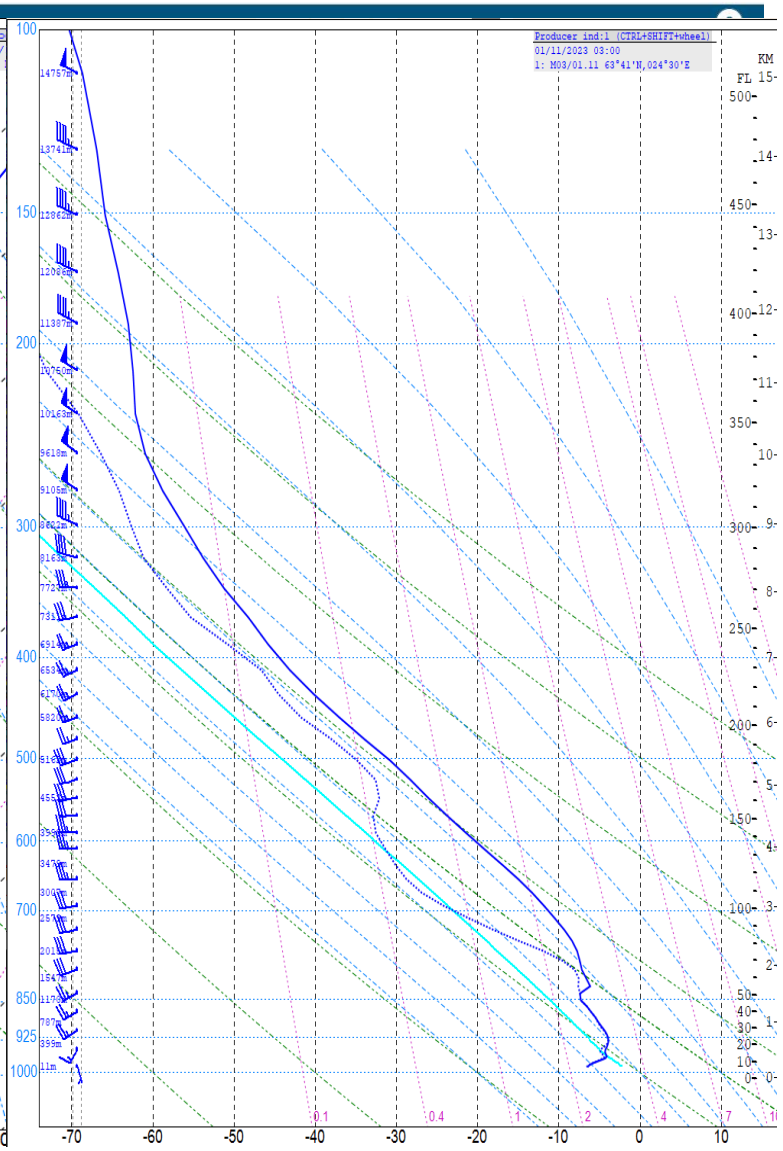
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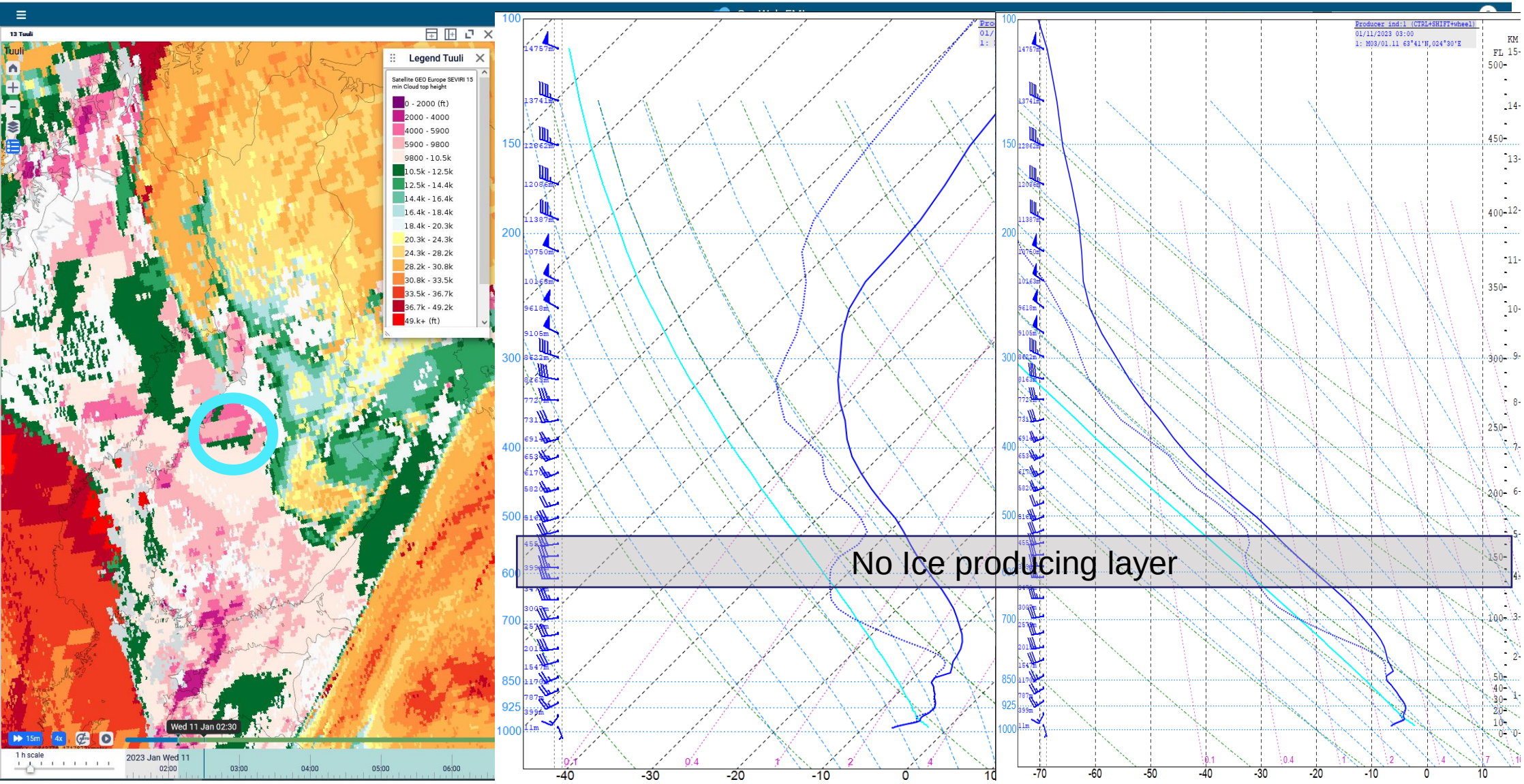
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Satellite GEO Europe SEVIRI 15 min Cloud top height
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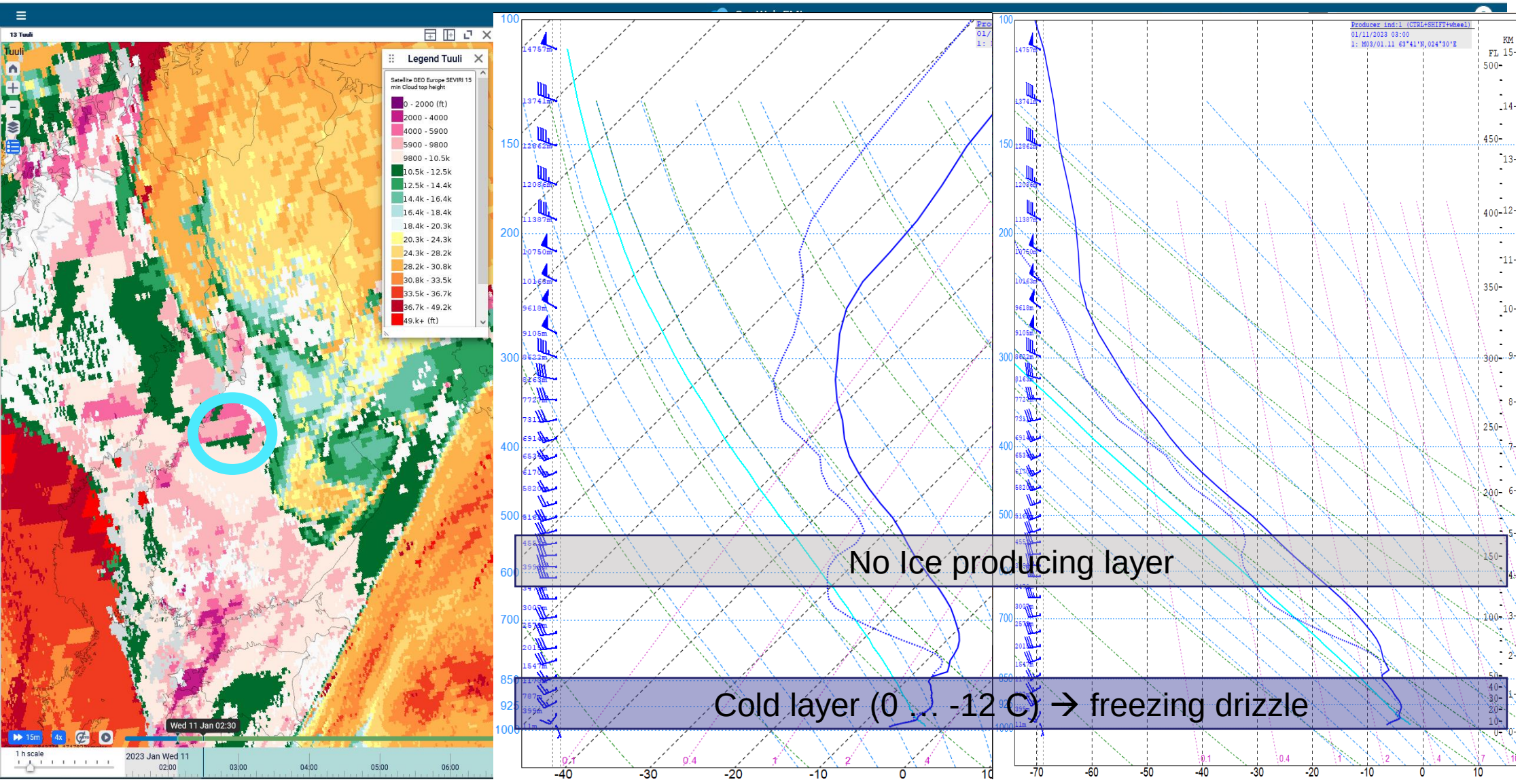
Wed 11 Jan 02:30
2023 Jan Wed 11
No Ice producing layer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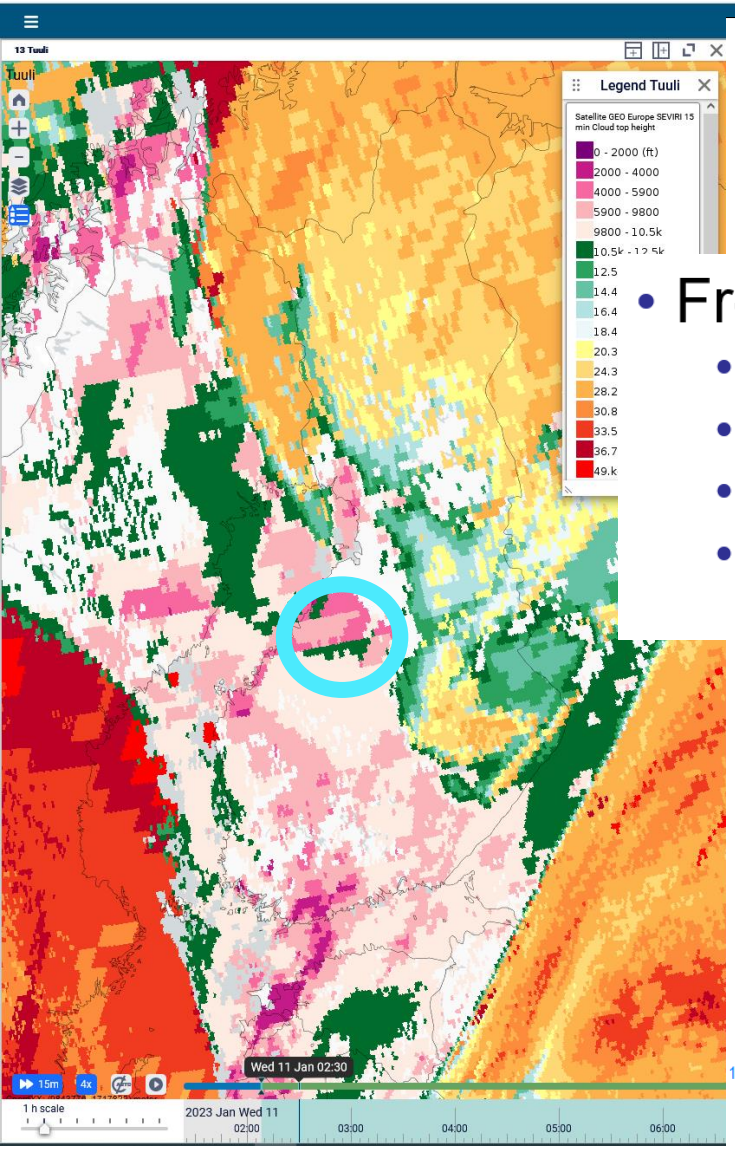
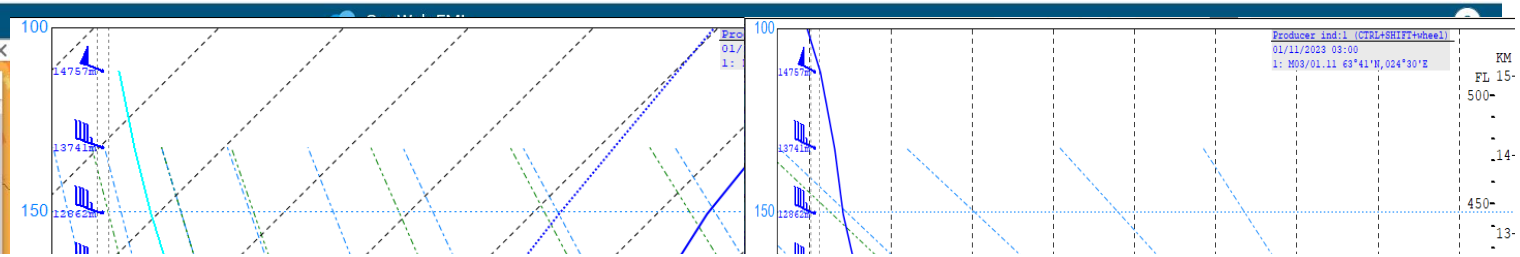
2023 Jan Wed 11
No Ice producing layer
Cold layer (0 … -12 C) → freezing drizzle





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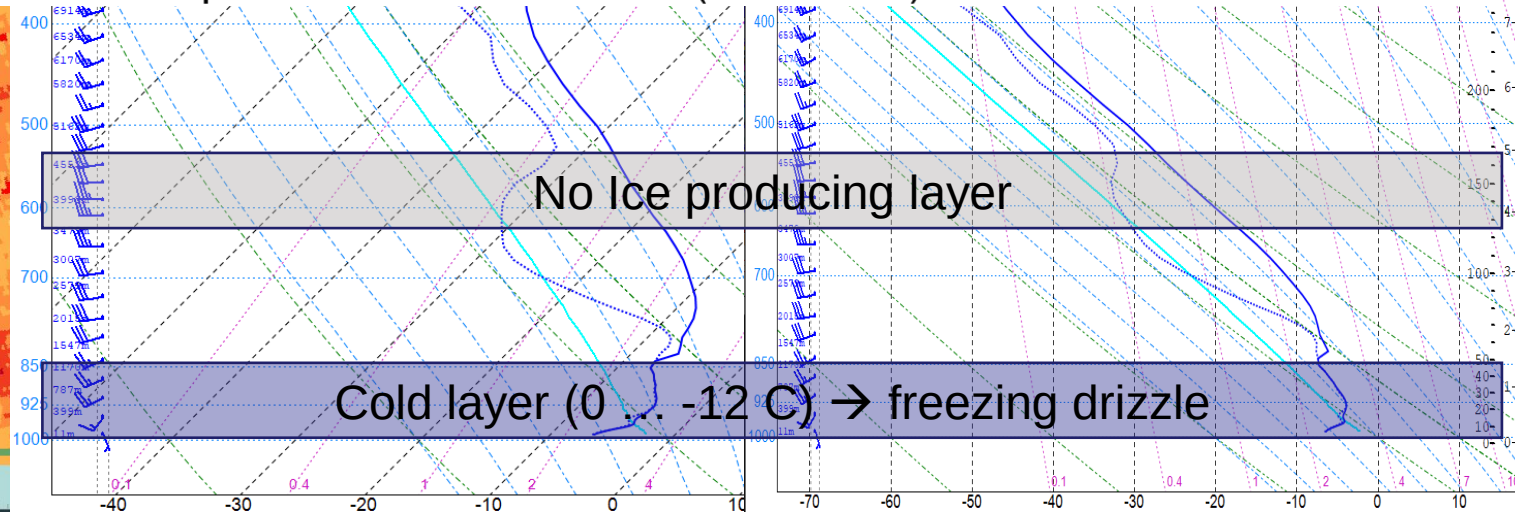

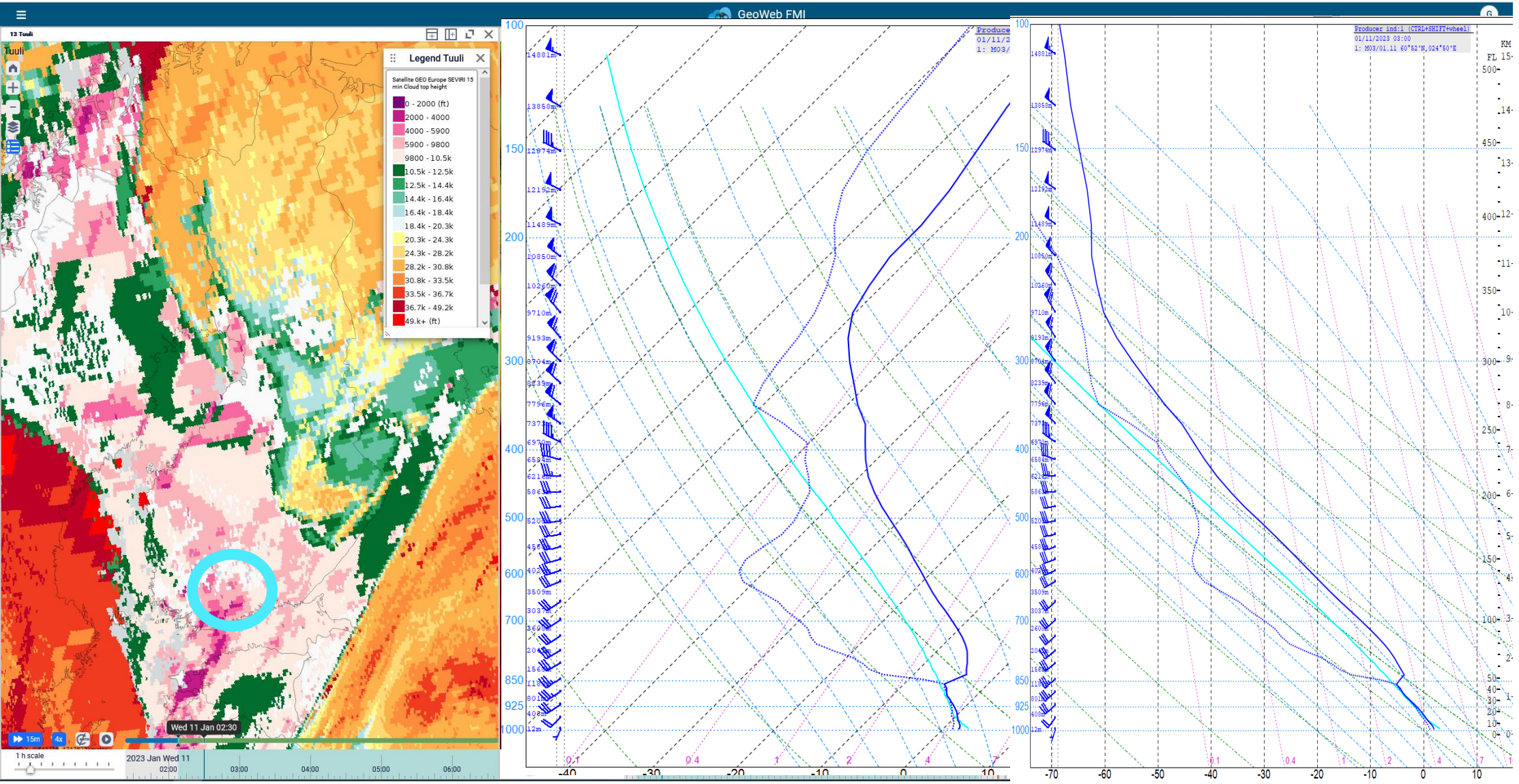
GeoWeb FMI
Tuuli
Legend Tuuli
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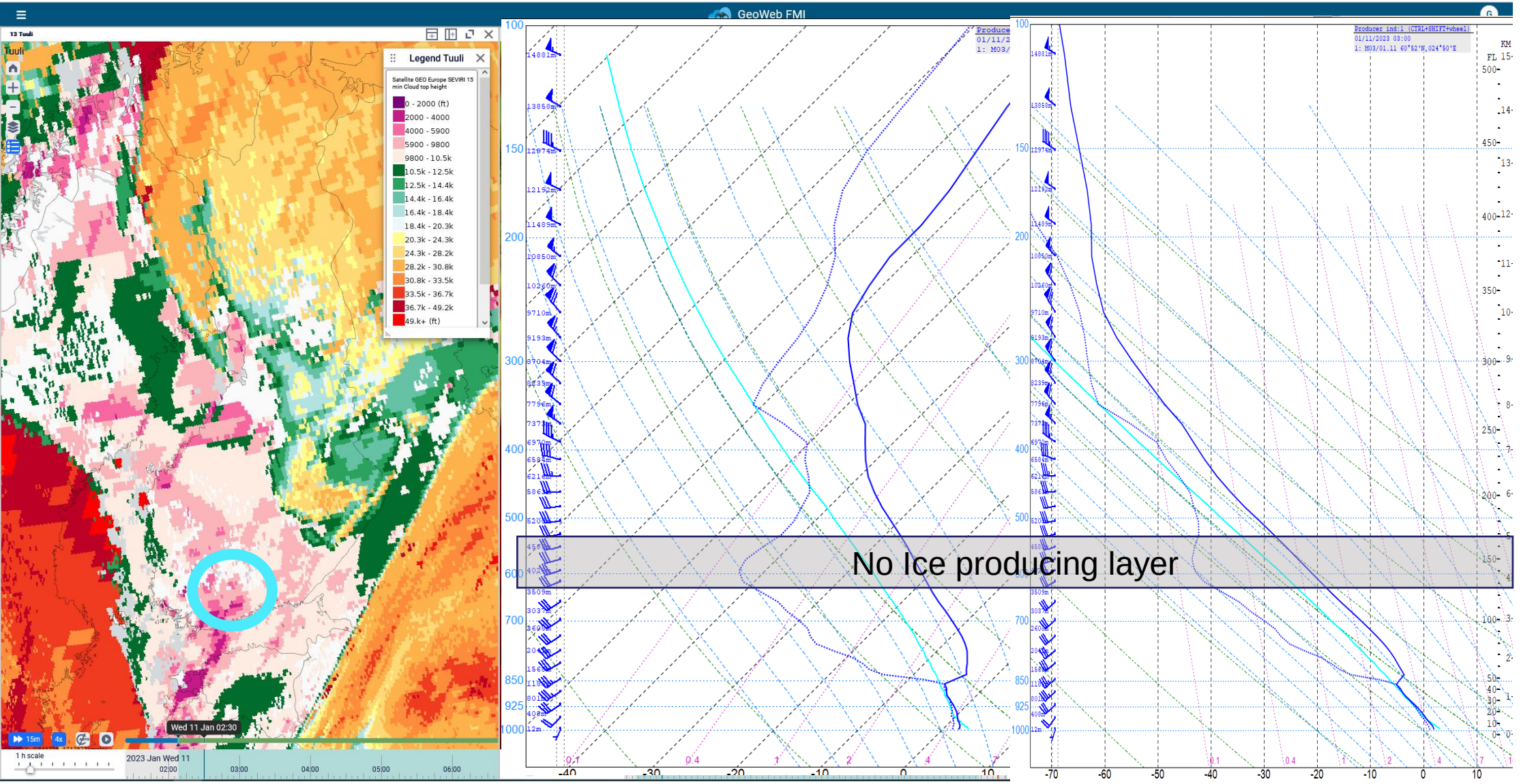
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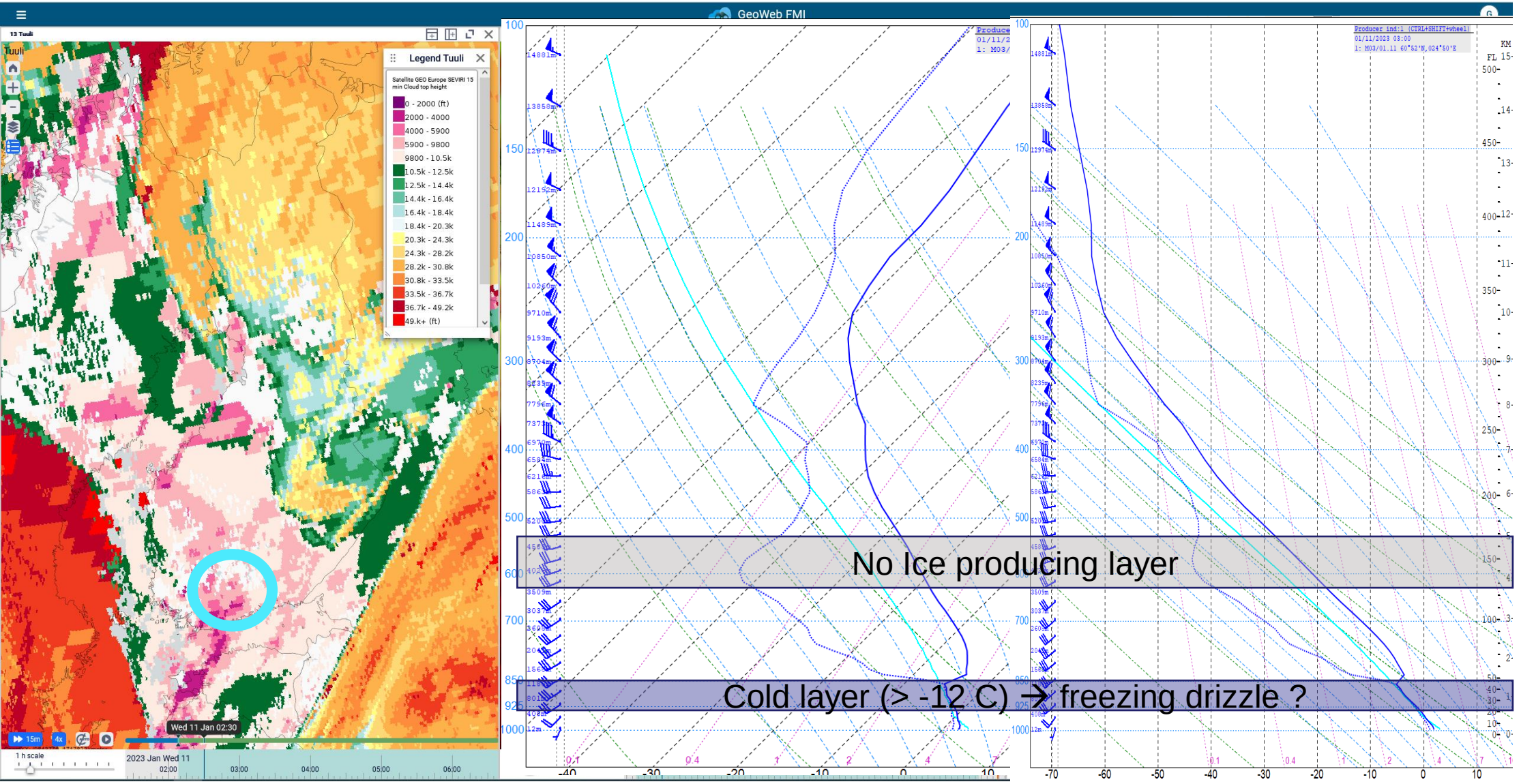
Wed 11 Jan 02:30
1 h scale
2023 Jan Wed 11
No Ice producing layer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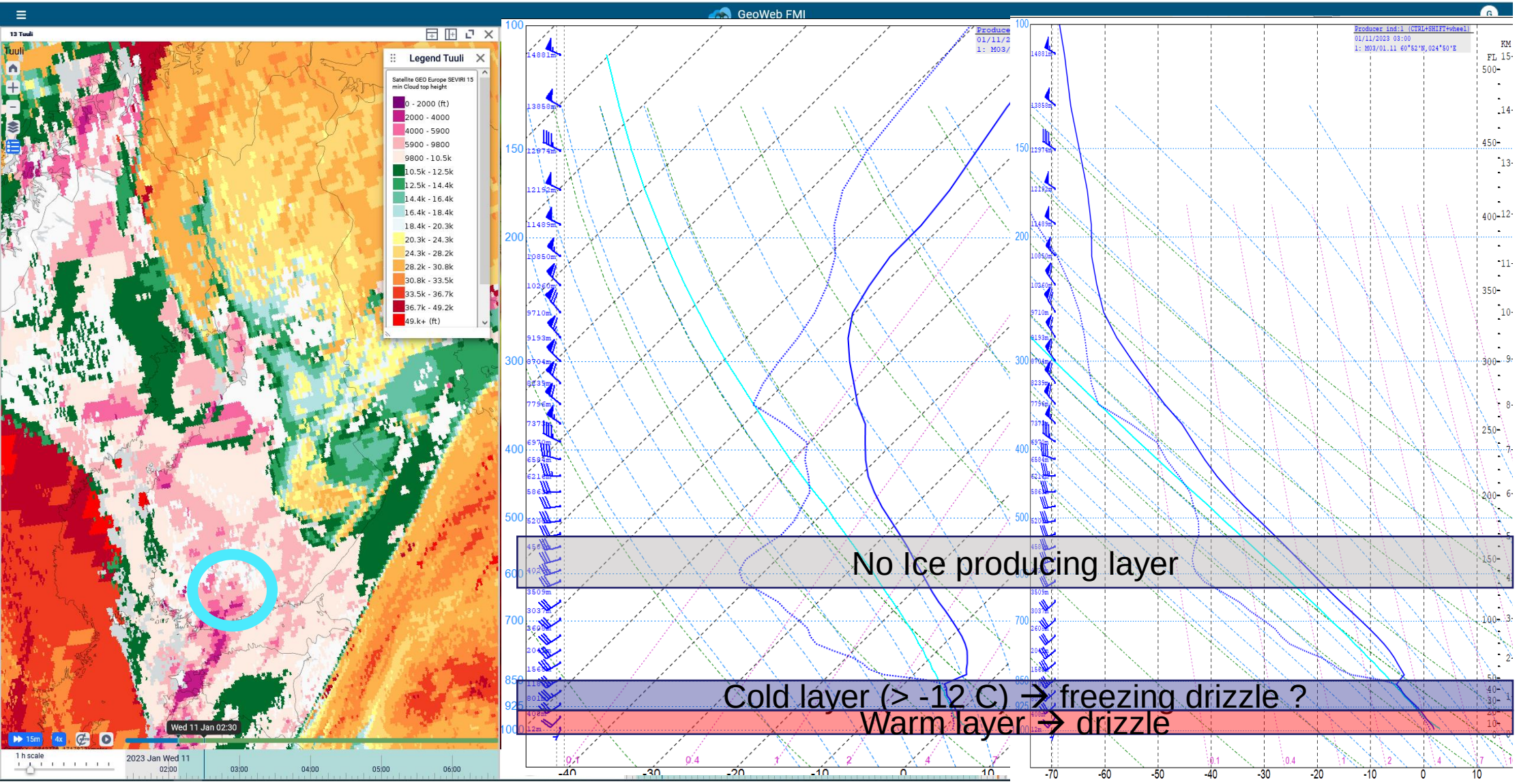
2023 Jan Wed 11
No Ice producing layer
Cold layer (> -12 C) → freezing drizzle ?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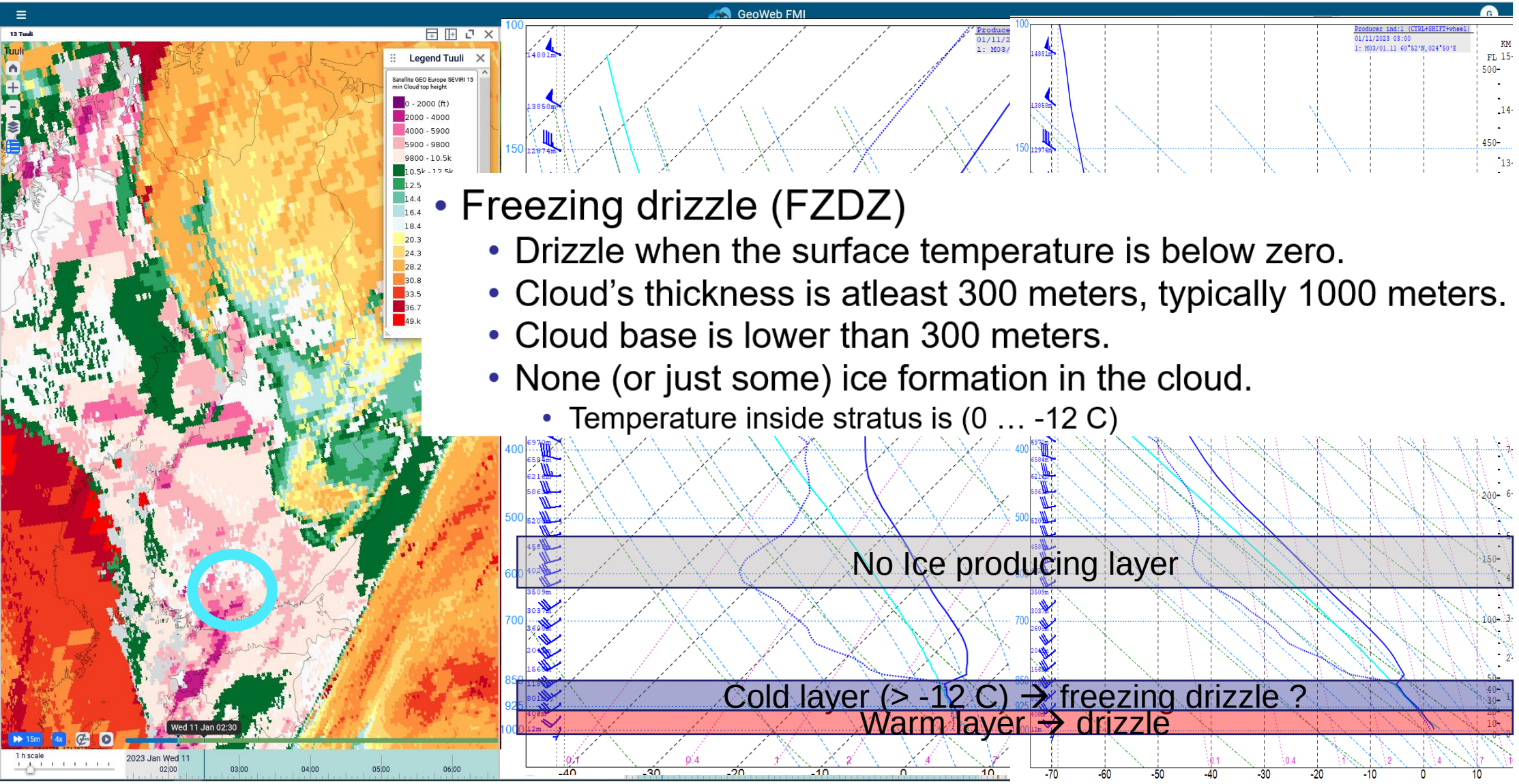
49.k+ (ft)
Wed 11 Jan 02:30
2023 Jan Wed 11
No Ice producing layer
Cold layer (> -12 C) → freezing drizzle ?
Warm layer → drizzle



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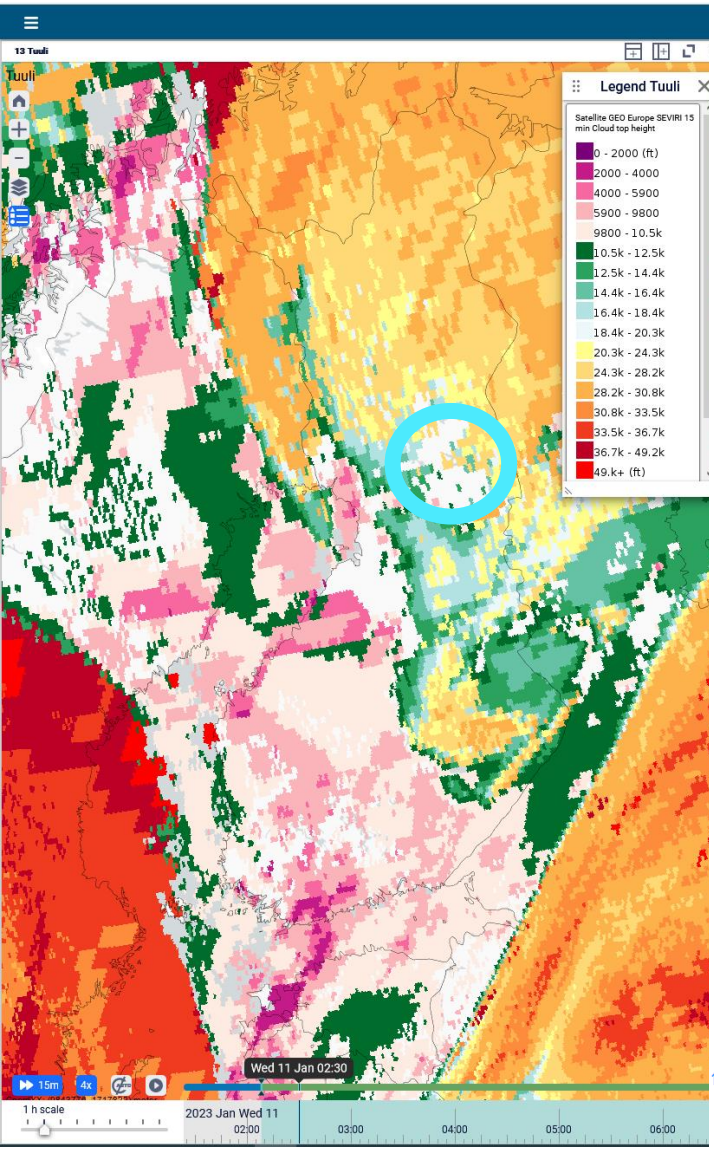
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2023 Jan Wed 11
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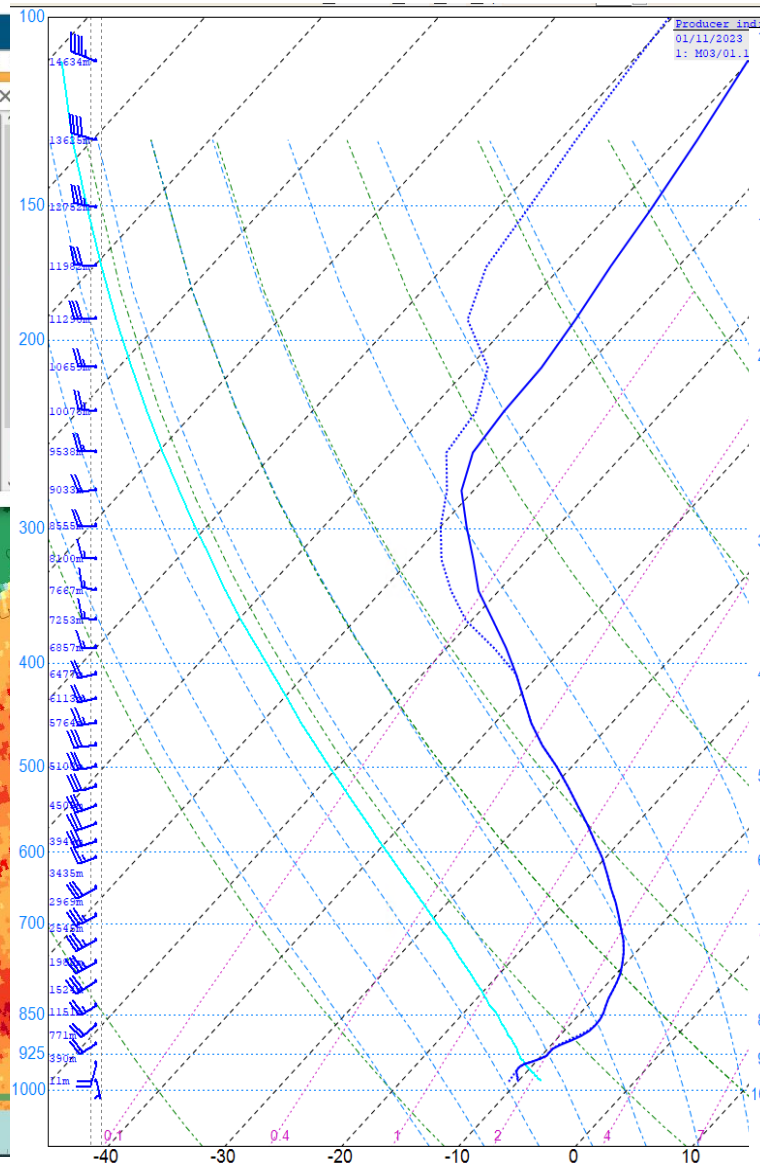
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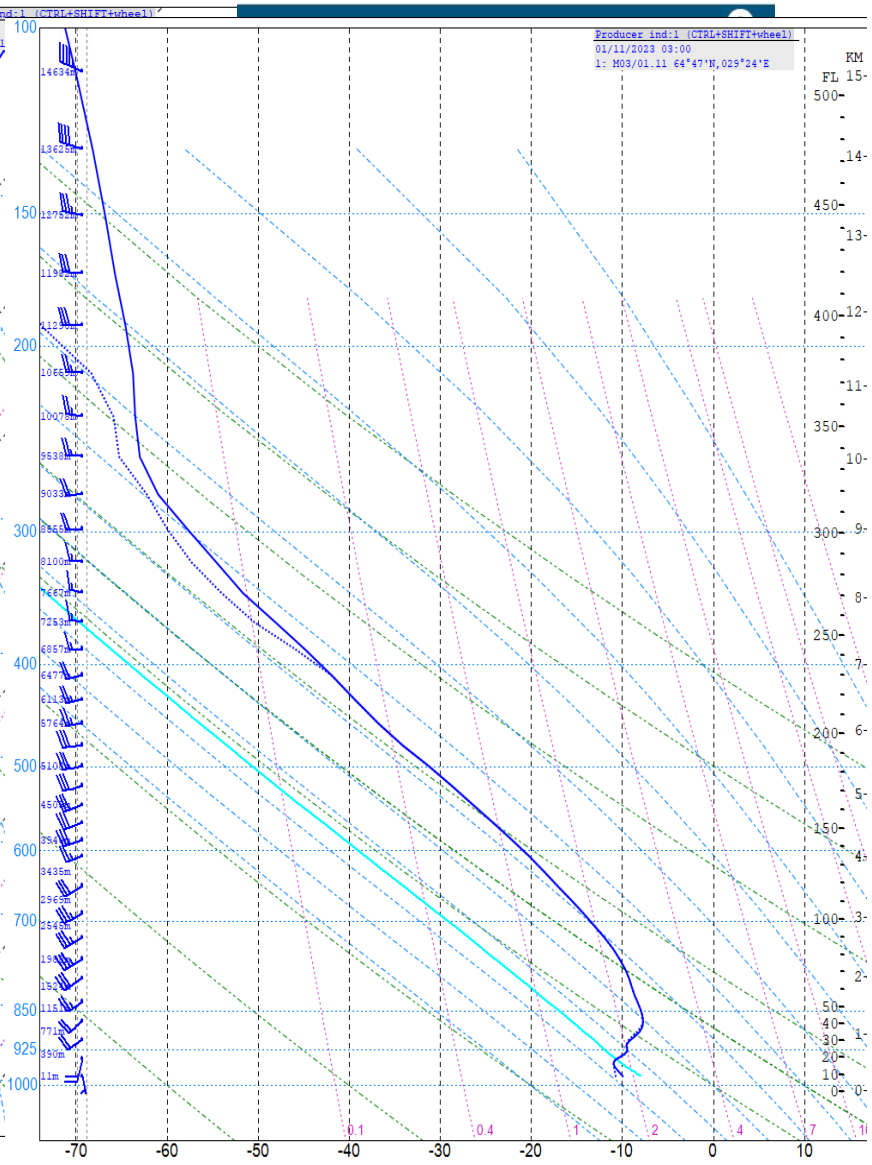
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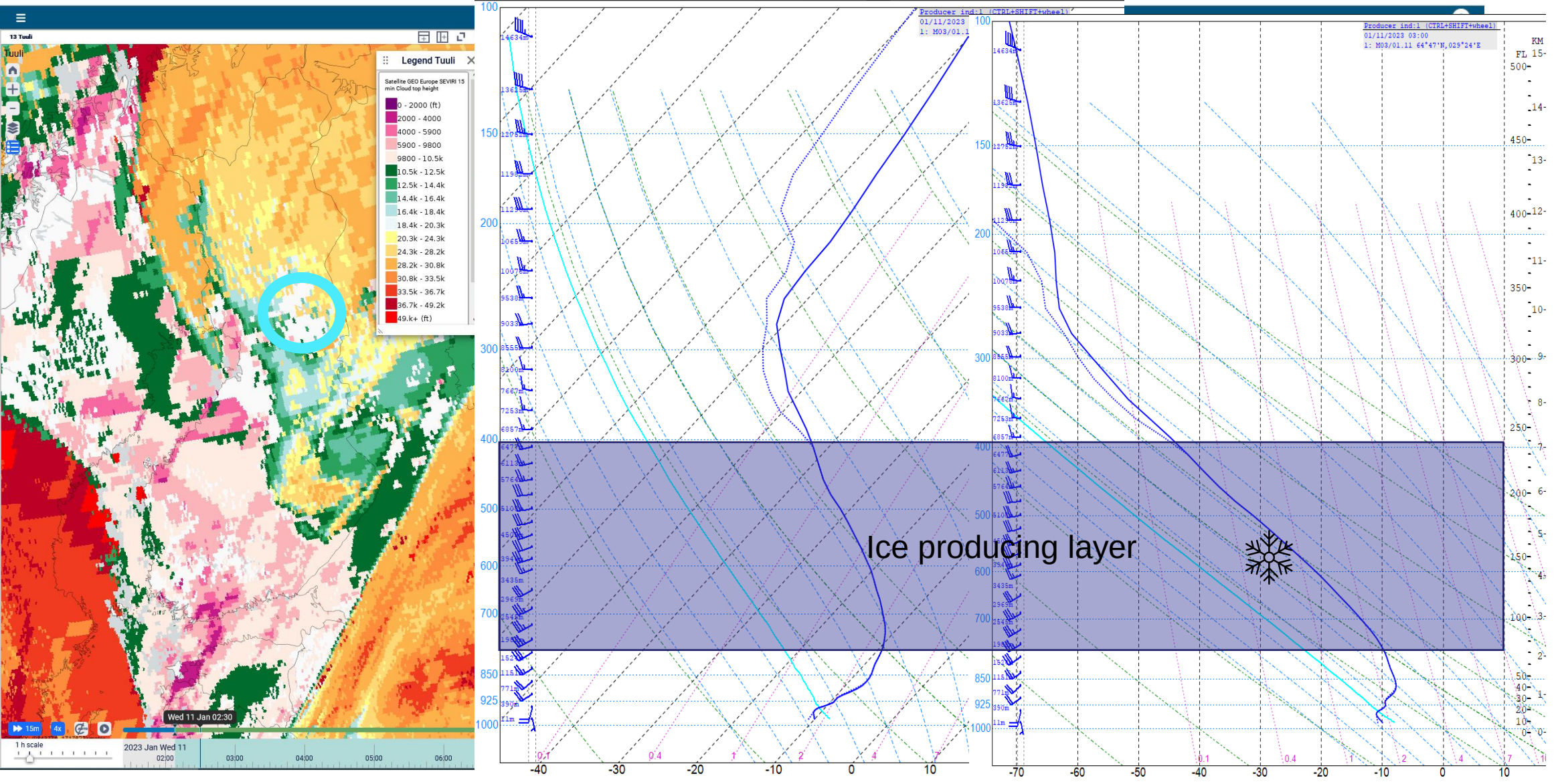
-10
0
10


Legend Tuuli
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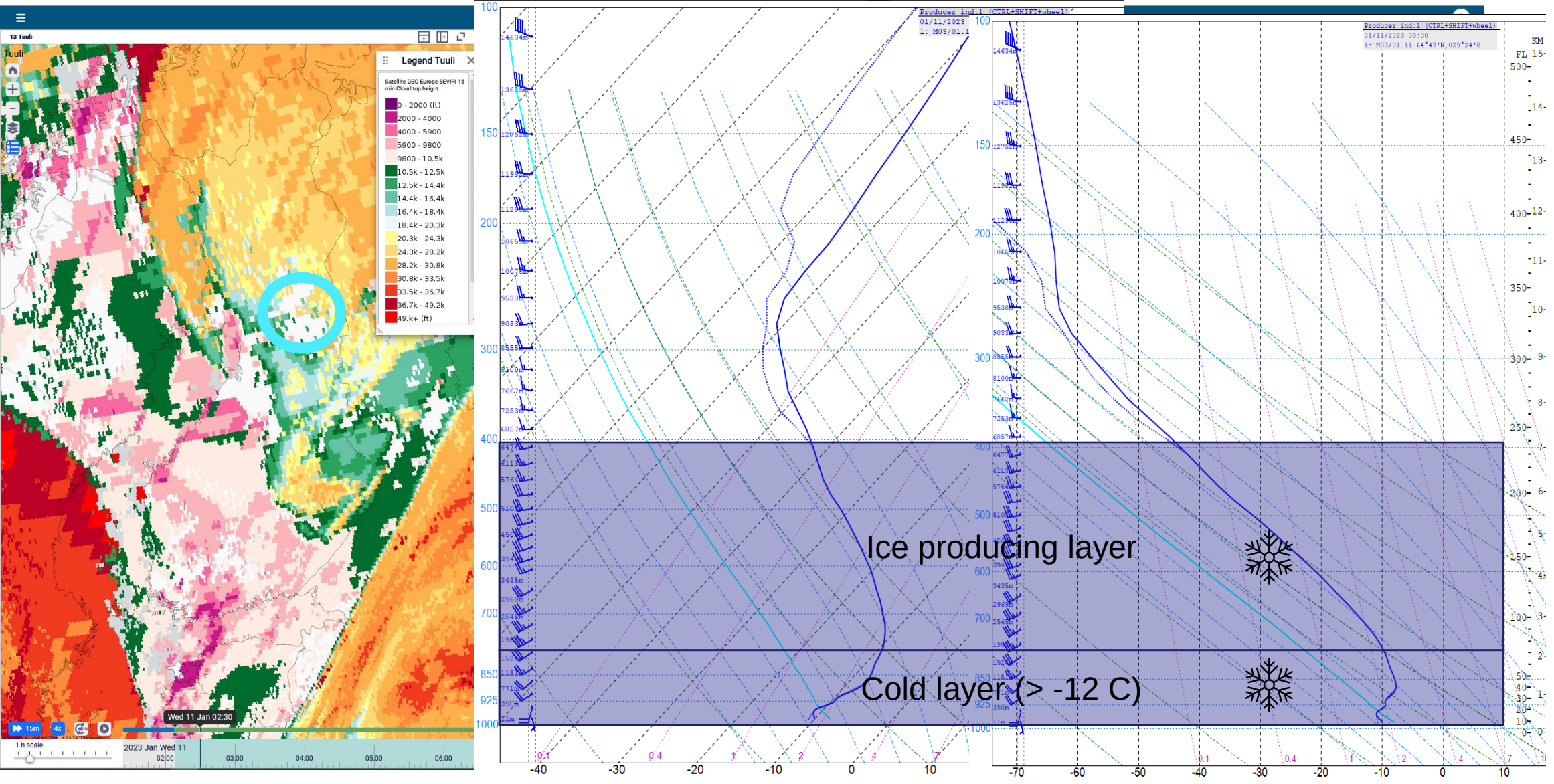
49.k+ (ft)
Wed 11 Jan 02:30
2023 Jan Wed 11
Ice producing layer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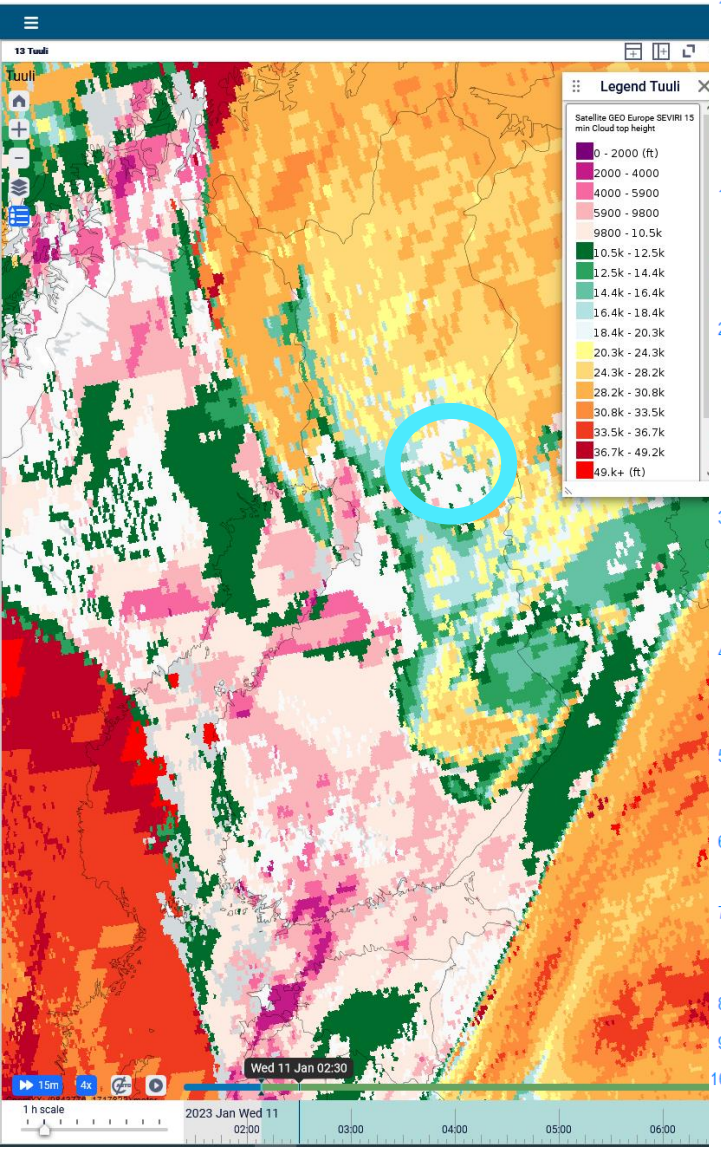
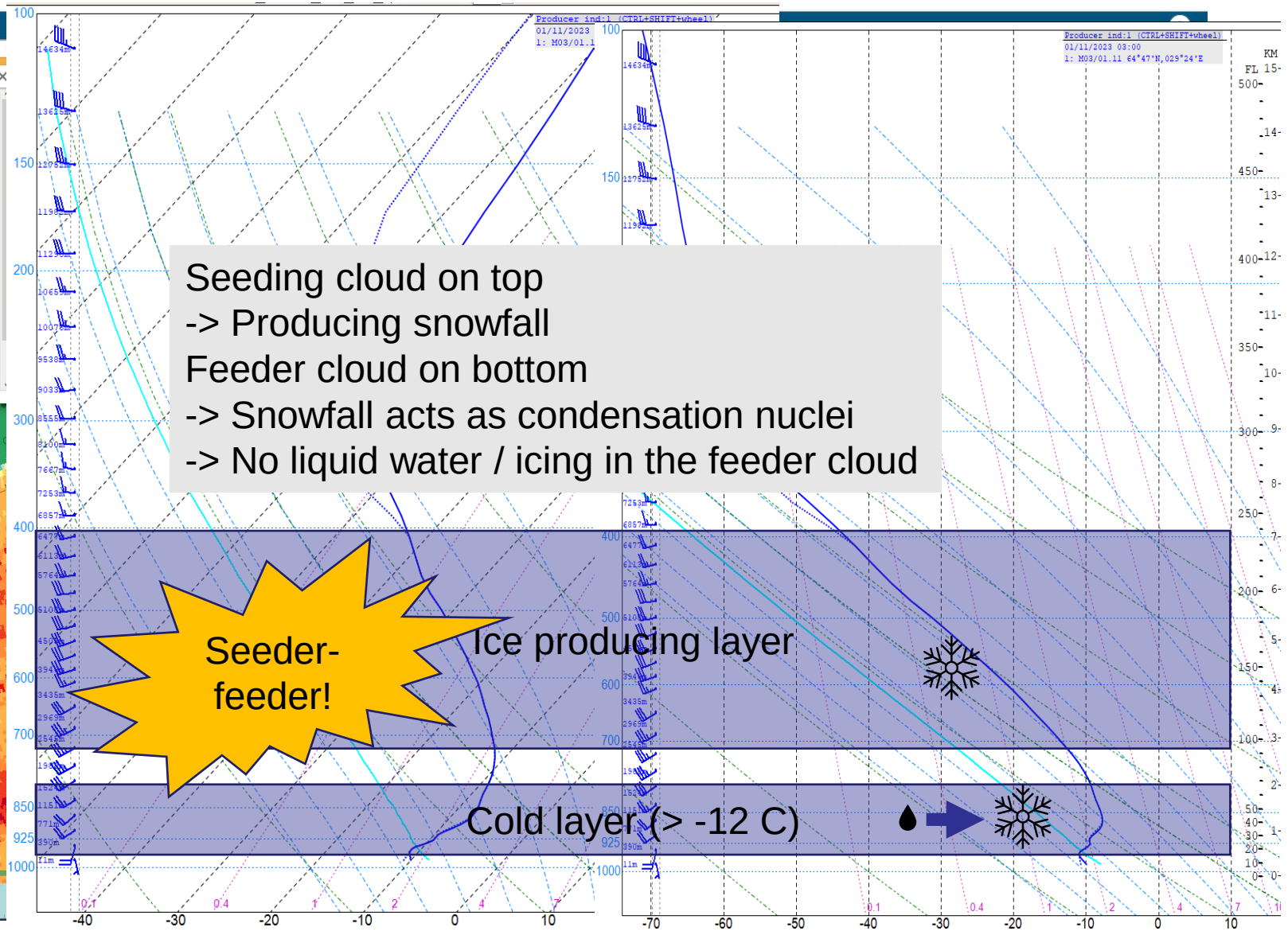
49.k+ (ft)
Wed 11 Jan 02:30
2023 Jan Wed 11
Ice producing layer
Cold layer (> -12 C)



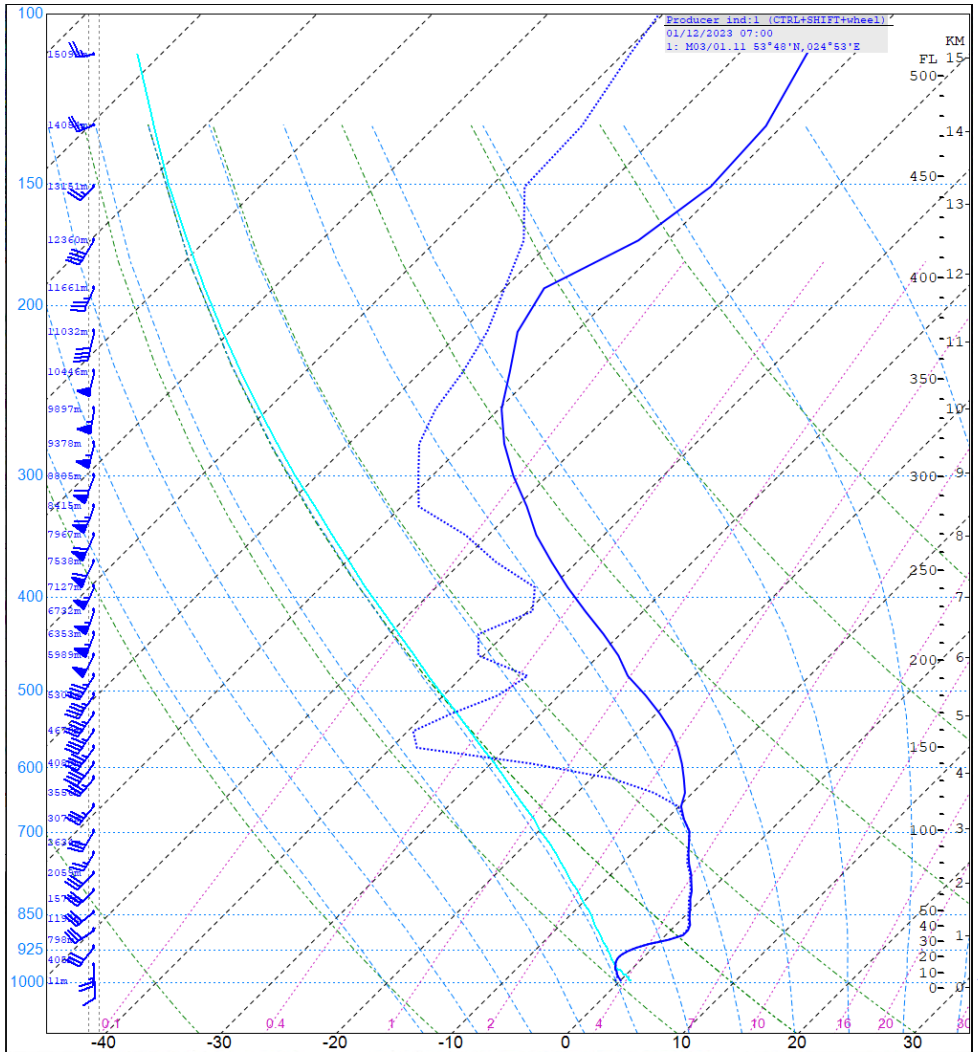


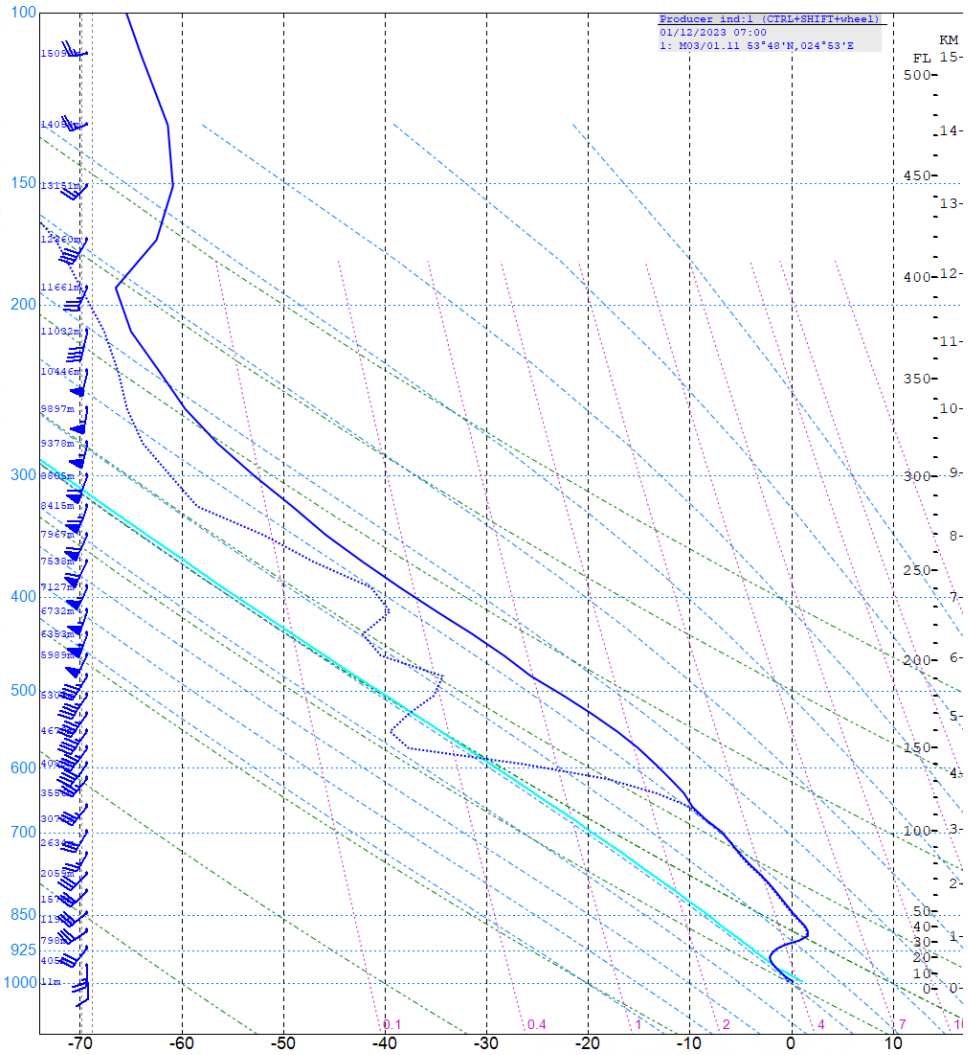
Seeding cloud on top
-> Producing snowfall
Feeder cloud on bottom
-> Snowfall acts as condensation nuclei
-> No liquid water / icing in the feeder cloud

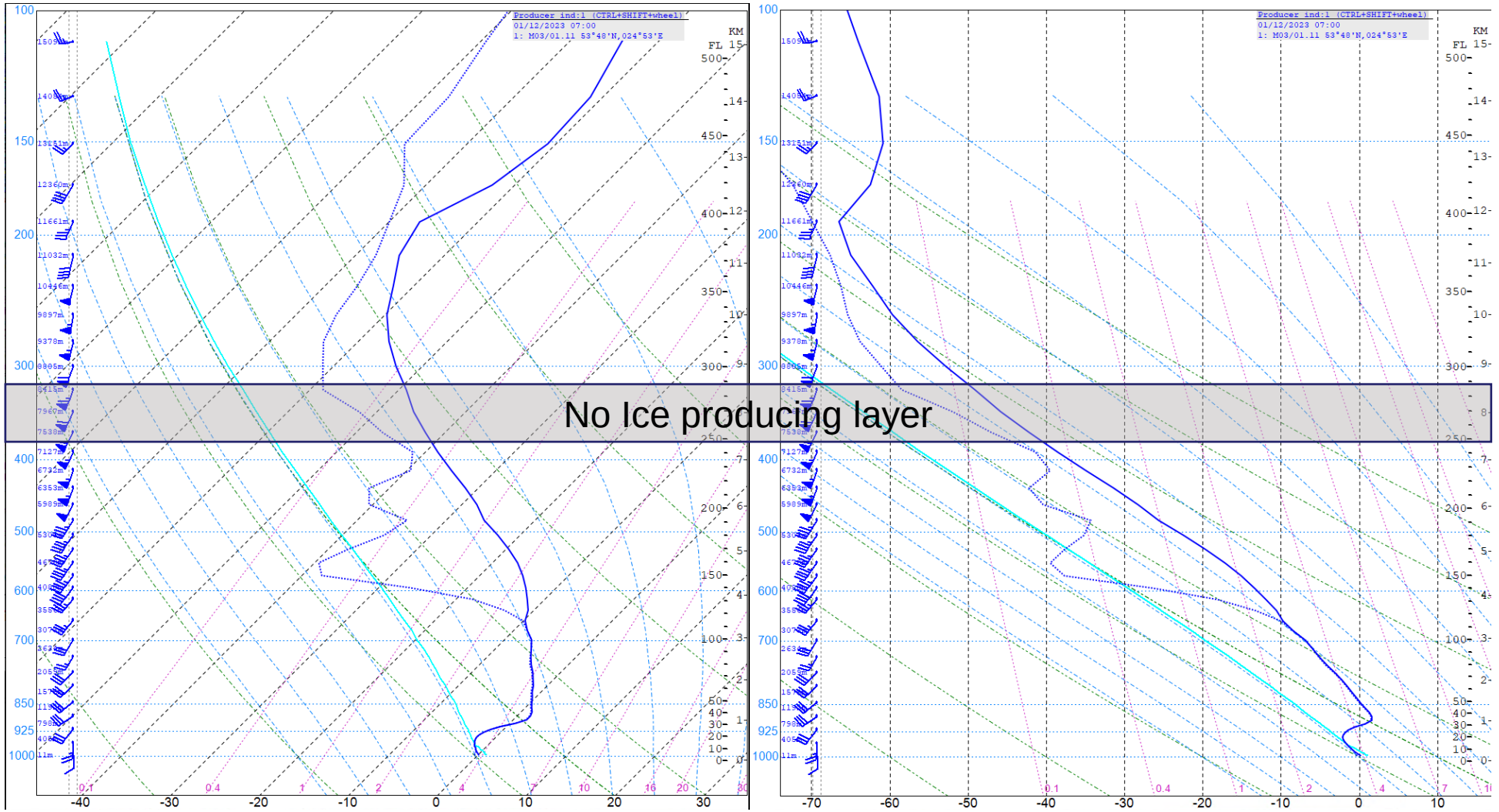
Seeder-feeder!

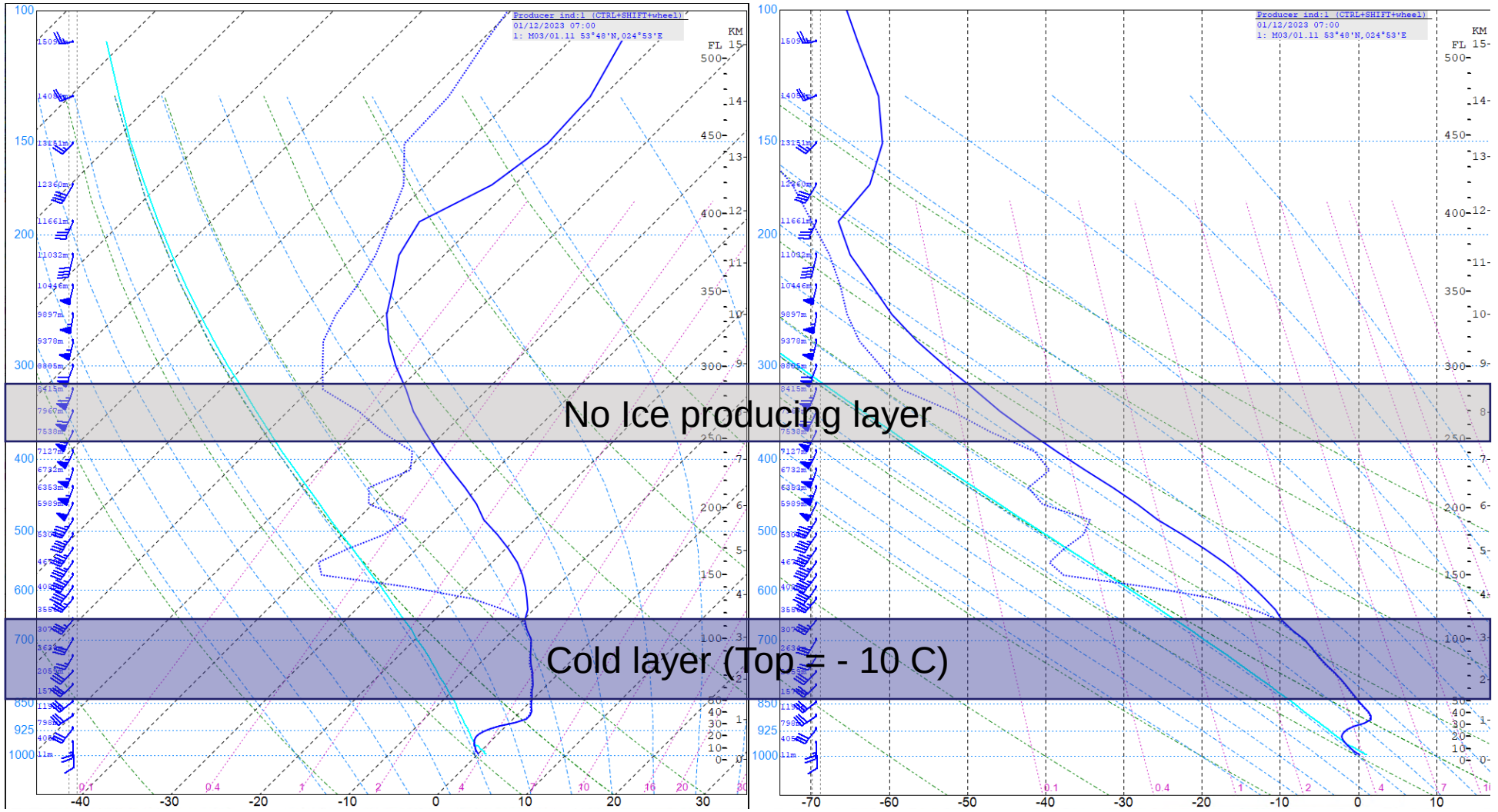
Ice producing layer

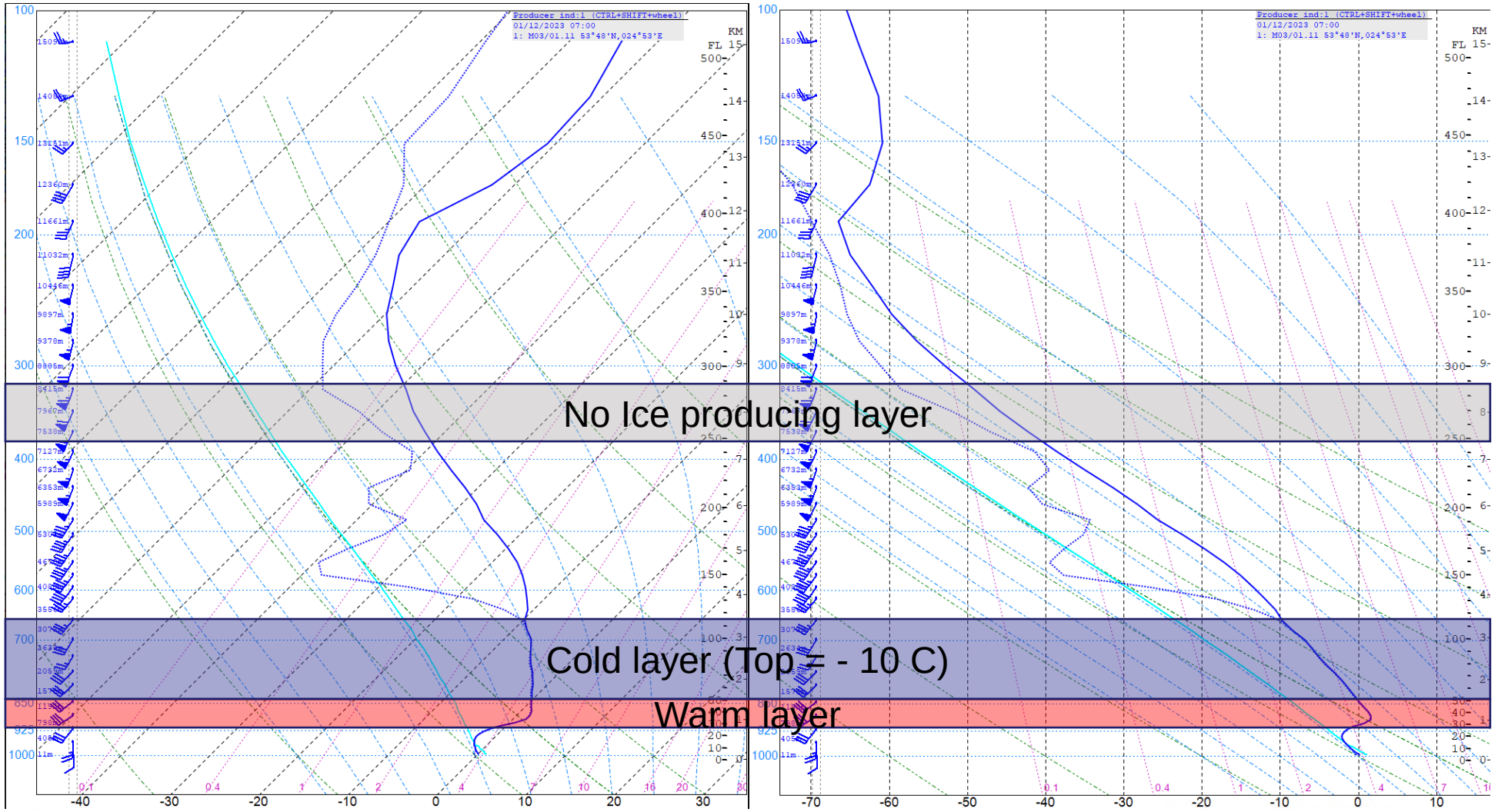
Cold layer (> -12 C)

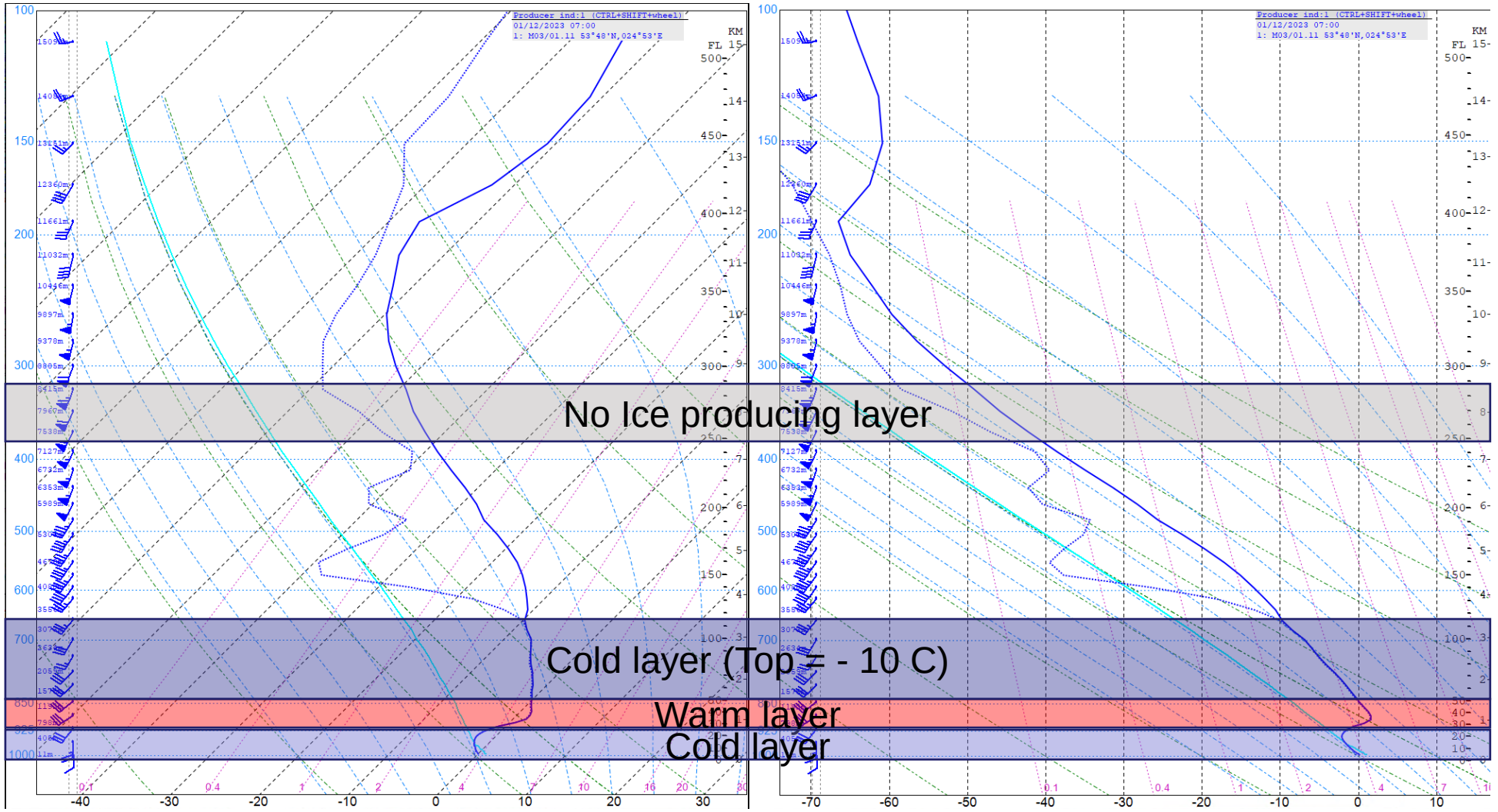

Producer ind:1 (CTRL+SHIFT+wheel)
01/12/2023 07:00
1: M03/01.11 53°48'N,024°53'E
KM
FL

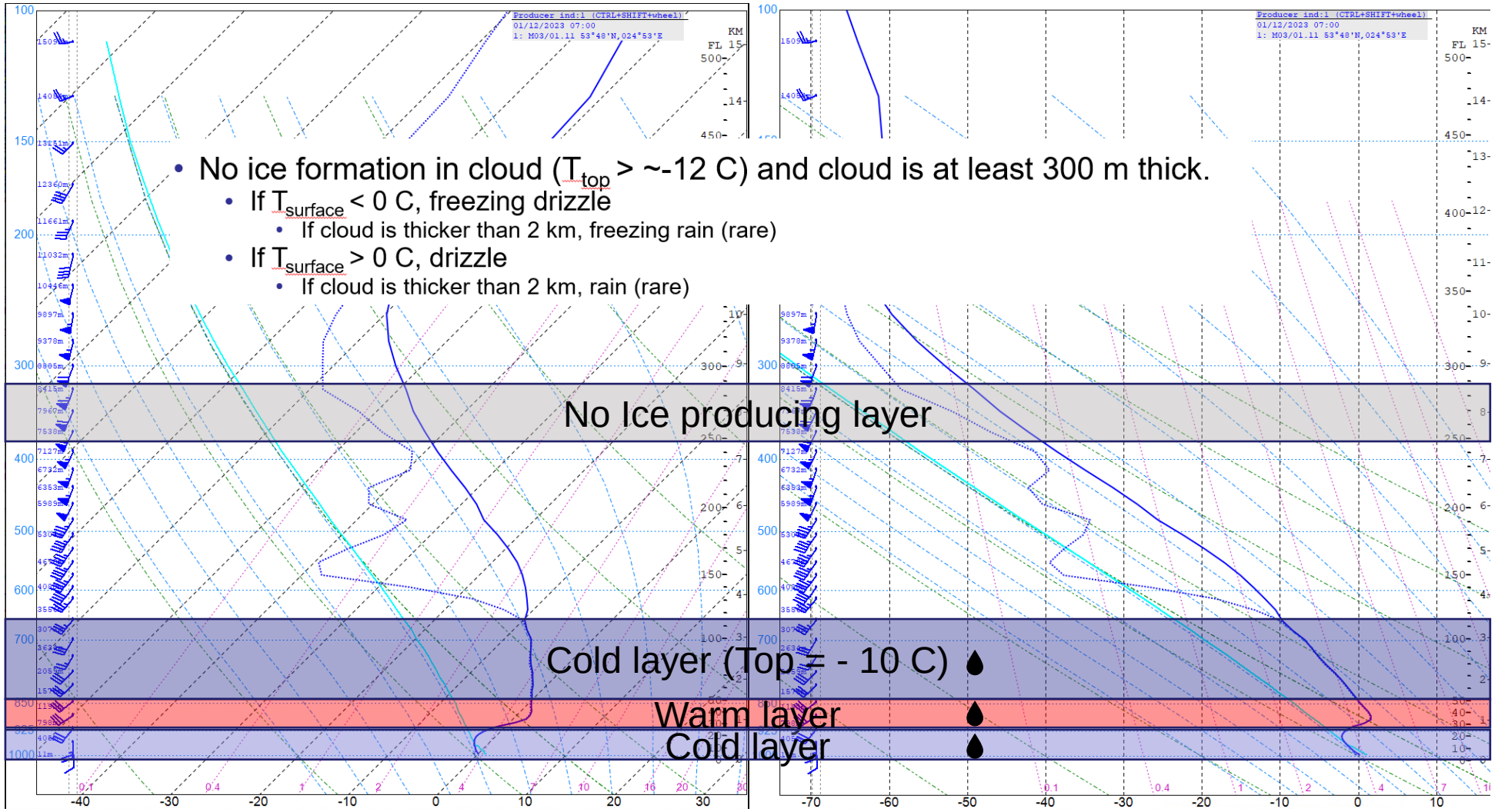

Producer ind:1 (CTRL+SHIFT+wheel)
01/12/2023 07:00
1: M03/01.11 53°48'N,024°53'E
KM
FL


Producer ind:1 (CTRL+SHIFT+wheel)
01/12/2023 07:00
1: M03/01.11 53°48'N,024°53'E
KM
FL
No Ice producing layer


No Ice producing layer
Cold layer (Top = - 10 C)

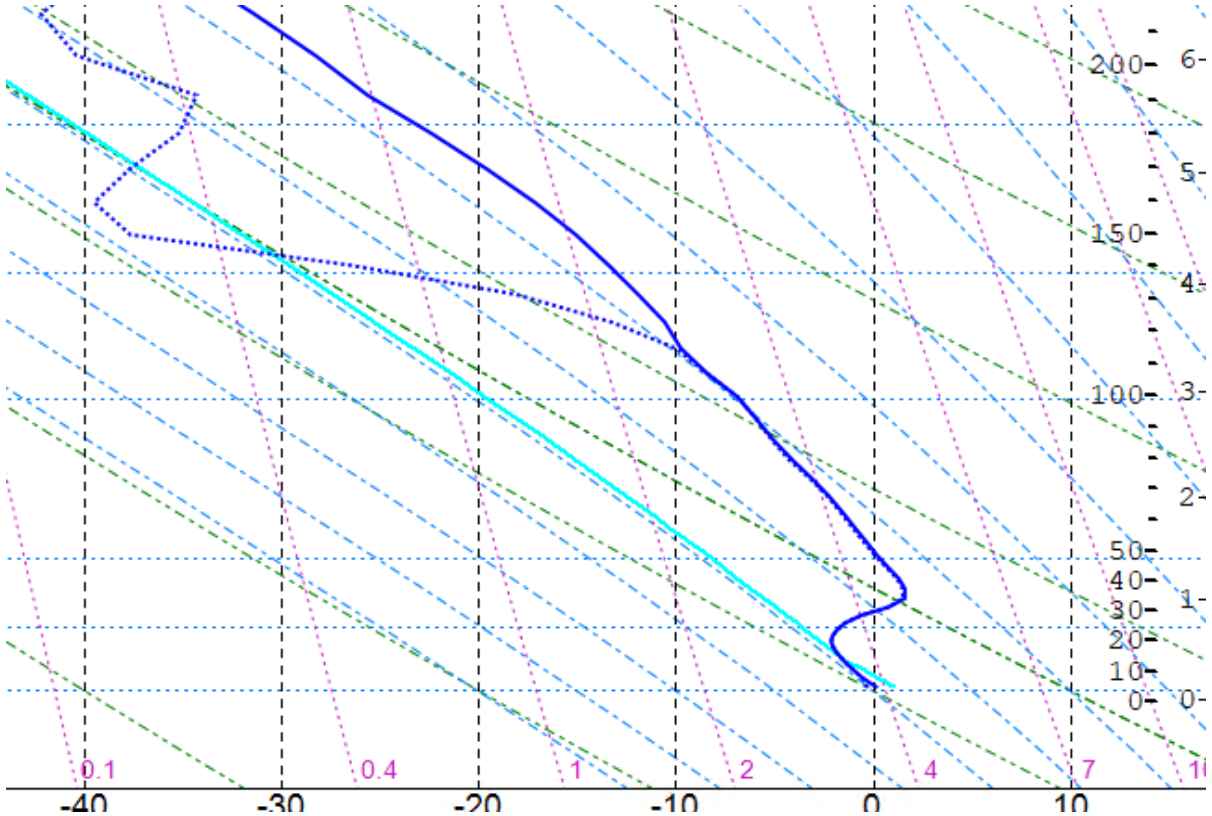

No Ice producing layer
Cold layer (Top = - 10 C)
Warm layer


No Ice producing layer
Cold layer (Top = - 10 C)
Warm layer
Cold layer



- No ice formation in cloud (T_{top} > ~-12 C) and cloud is at least 300 m thick.
  - If $T_{surface}$ < 0 C, freezing drizzle
    - If cloud is thicker than 2 km, freezing rain (rare)
  - If $T_{surface}$ > 0 C, drizzle
    - If cloud is thicker than 2 km, rain (rare)

Tips for nowcasting / correcting model

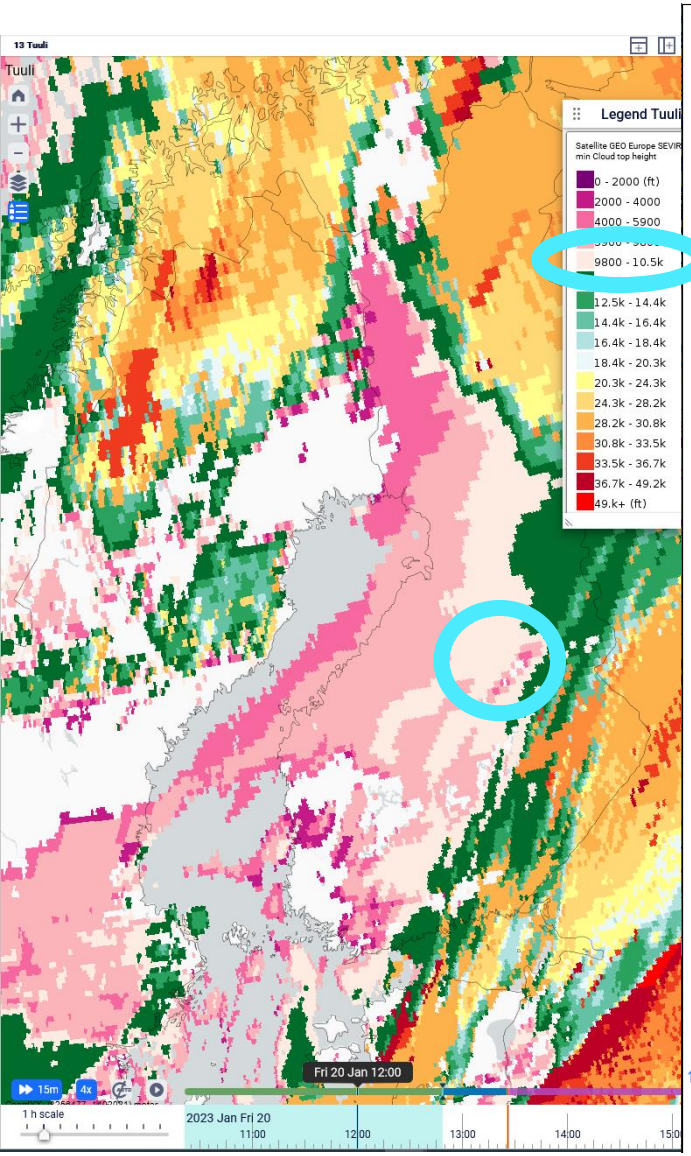


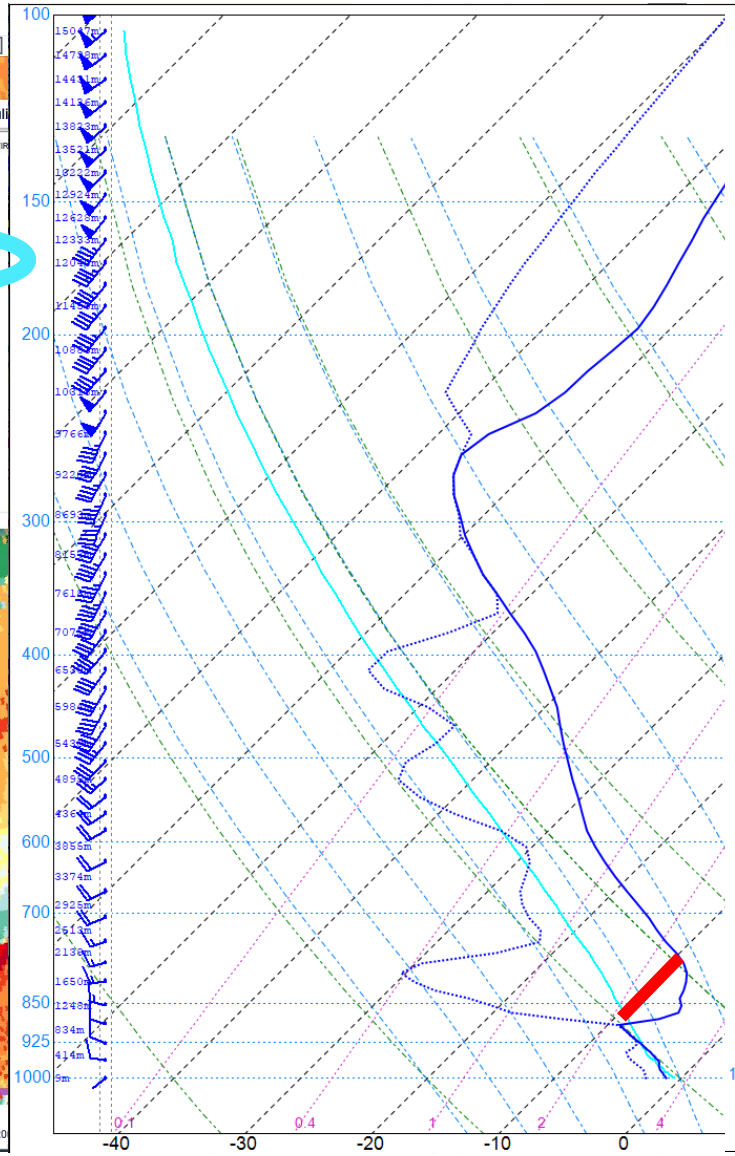
- Cloud top information
  - Satellites
- Ceiling information
  - Ceilometers
- In between
  - Radars and soundings
- Surface
  - Temperature and dew point

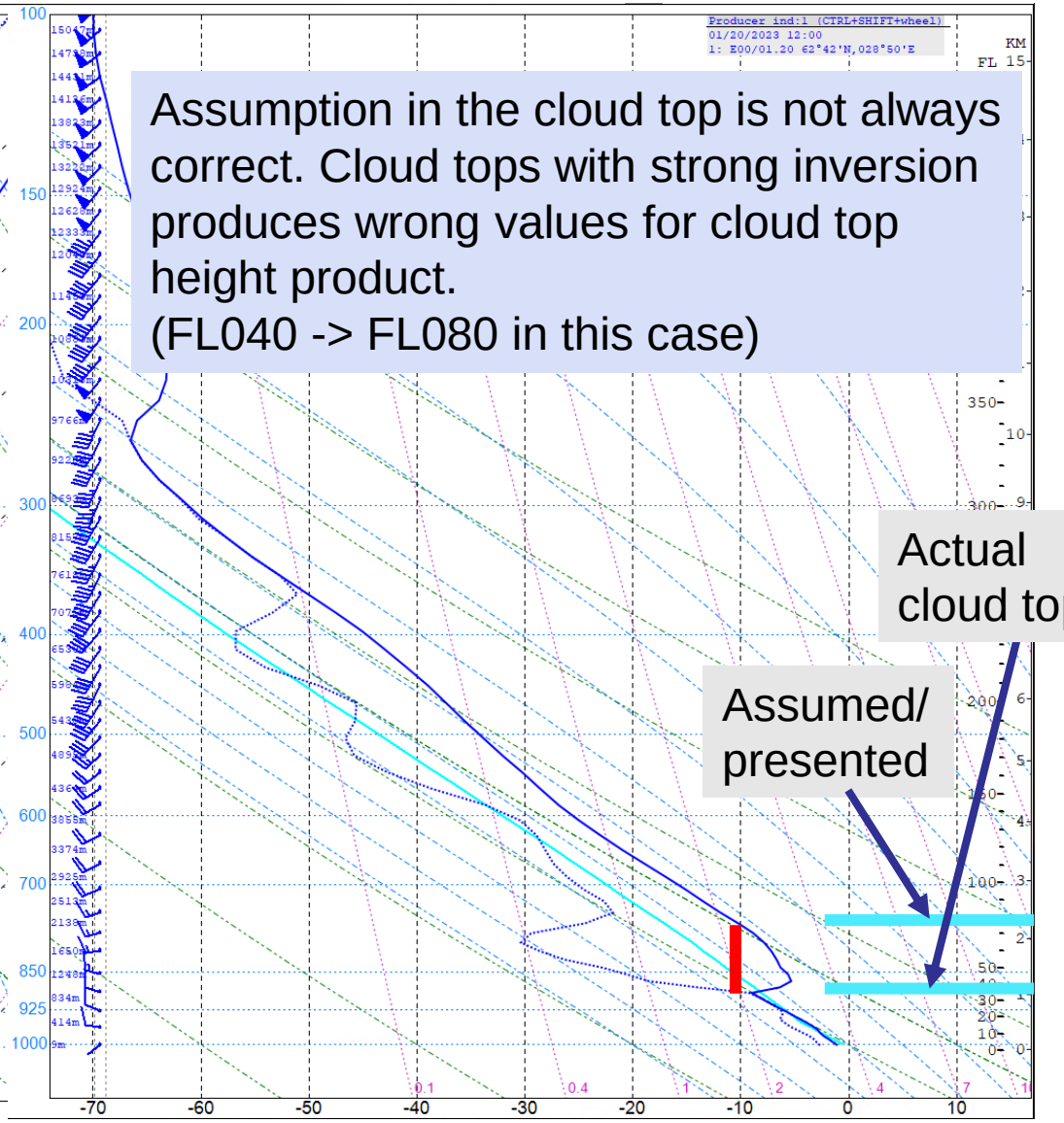
Tips for nowcasting / correcting model

- Follow dewpoint and temperature observations.
  - Compare to model data.
  - Typically, temperature drops slightly once the precipitation starts. (Also breaks inversion)
  - Mast-observations if available
- Check latest soundings and possibly AMDARs
  - Compare to model soundings
- Vertical information from radars and ceilometers
  - Precipitation forming layer
  - Melting layer/bright band (Hydro class)
  - Not all precipitation can be seen via radar.
    - Lowest elevation angle is typically at ~2 km altitude at 100 km from radar
- Satellite images
  - Check if cloud top matches model observations
  - Check if the timing matches the model
- Other ground observations for precipitation form (road weather, AWS-metars)
  - Take account the accuracy

Problem with Cloud top height in inversion





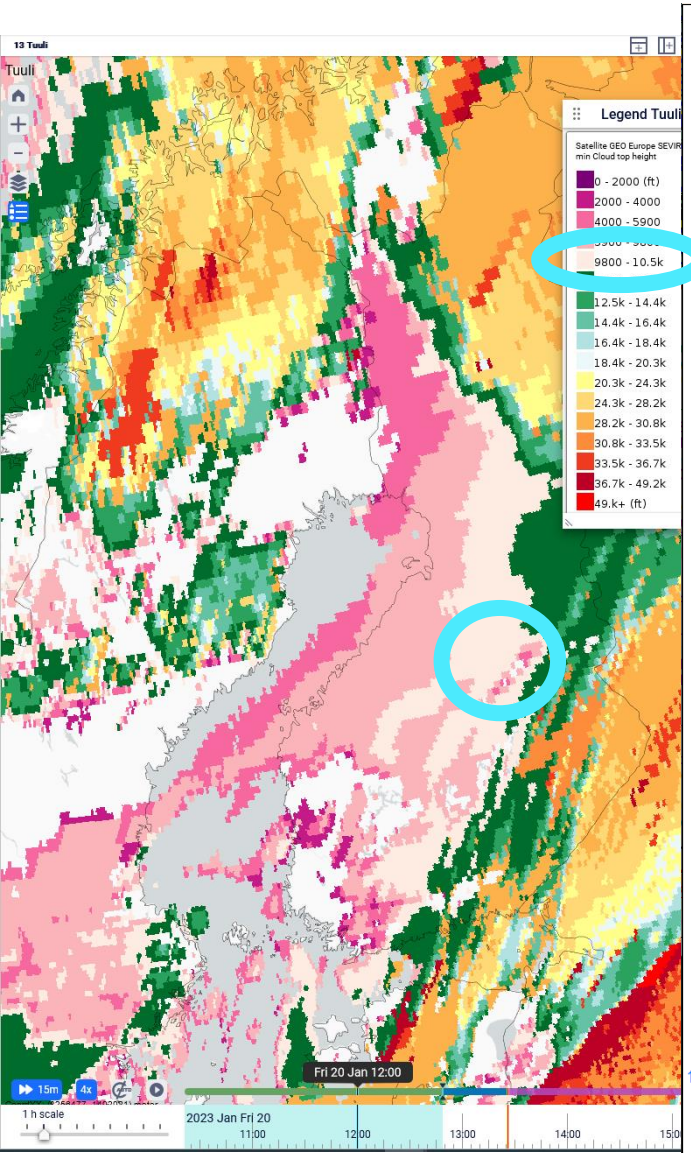


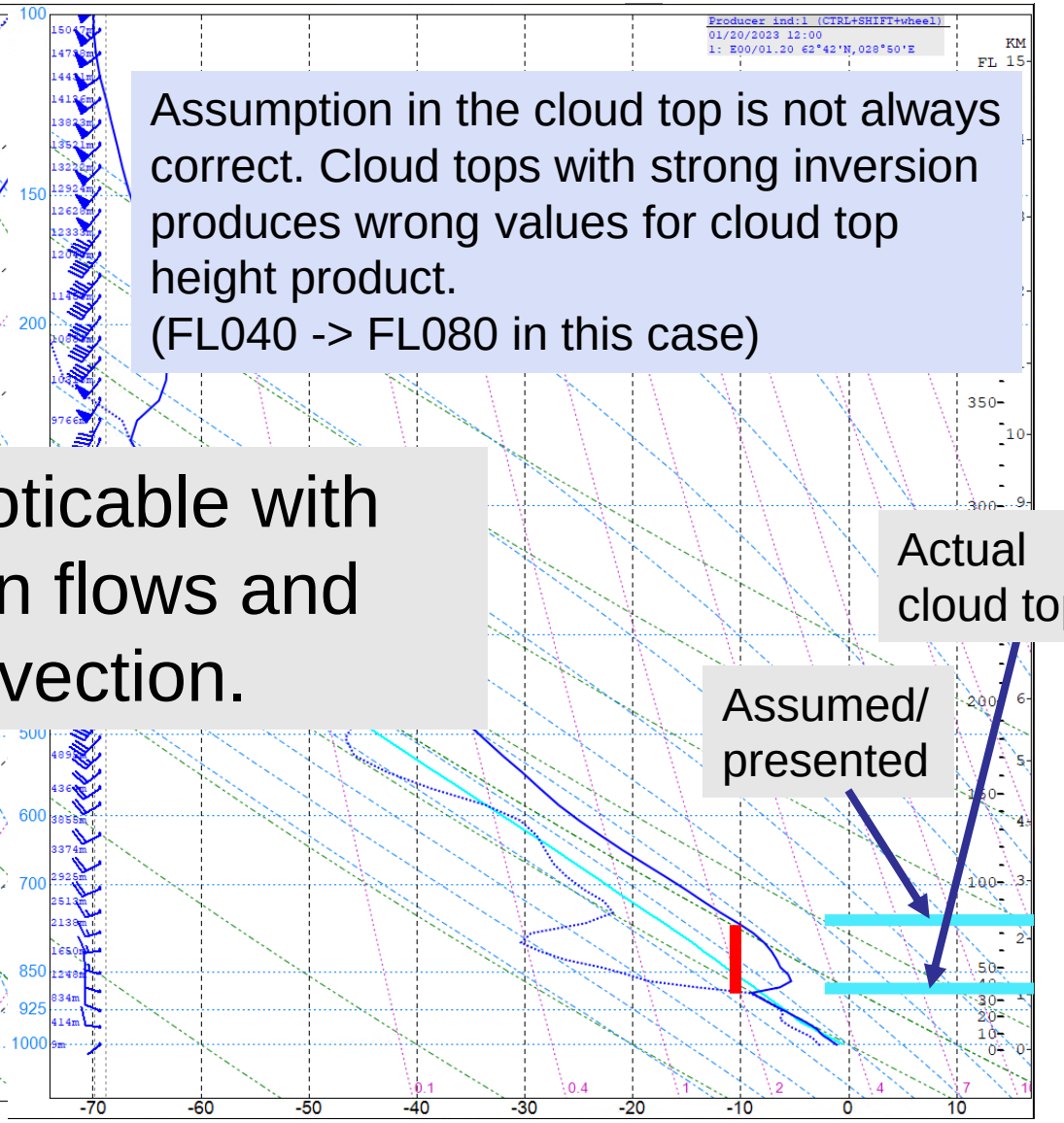
Assumption in the cloud top is not always correct. Cloud tops with strong inversion produces wrong values for cloud top height product.
(FL040 -> FL080 in this case)

Actual cloud top

Assumed/ presented

Problem with Cloud top height in inversion





Assumption in the cloud top is not always correct. Cloud tops with strong inversion produces wrong values for cloud top height product.
(FL040 -> FL080 in this case)

Most noticable with northern flows and cold advection.

Actual cloud top

Assumed/ presented

Services for EFHK

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Forecasting and briefing service for Helsinki Airport APOC

- Wintertime (Nov-Mar) decision support service for Helsinki Airport
- Early warning (~48 hrs ahead) of major snowfall events at Helsinki Airport is given by FMI aviation forecaster
- Airport Operational Center APOC then decides if a weather meeting takes place (~24 hrs ahead the event)
- All essential airport operators can participate: APOC, air traffic controls, airline companies, ground handling, runway maintenance, de-/anti-icing, apron personnel…)
- Direct interacting with Helsinki Airport personnel: the FMI forecaster participates, gives weather briefing and answers questions

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Our forecast in a nutshell

- Snow and freezing precipitation
  - Start and end time
  - Dry or wet snow
  - Accumulation
- Wind direction and speed
- Risk for low visibility procedures (LVP)
- Uncertainties

Snow type

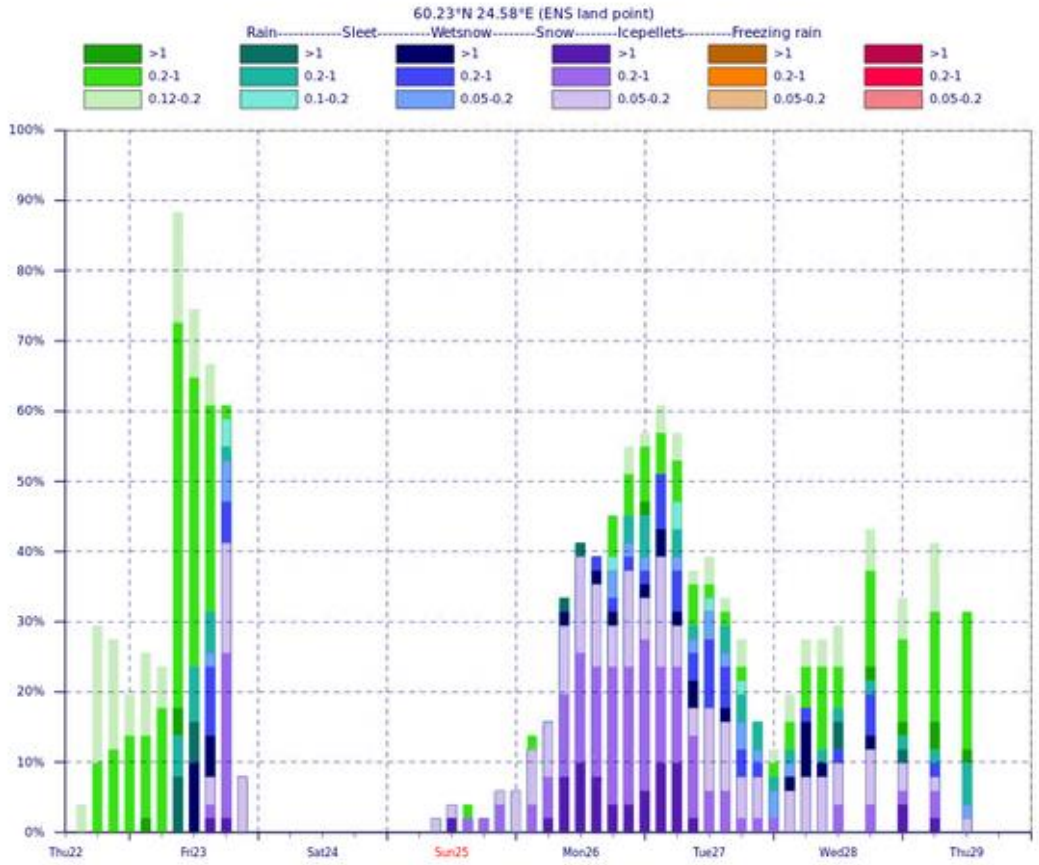
- Dry snow (< -2 °C)
  - Does not stick to runways or planes
    - Different preparations by airport
  - Risk of drifting / blowing snow

- Wet snow (2 – -2 °C)
  - Sticky snow
  - Sticks to runways and planes
    - Especially troublesome if plane's surface temperature is below zero

Snow type

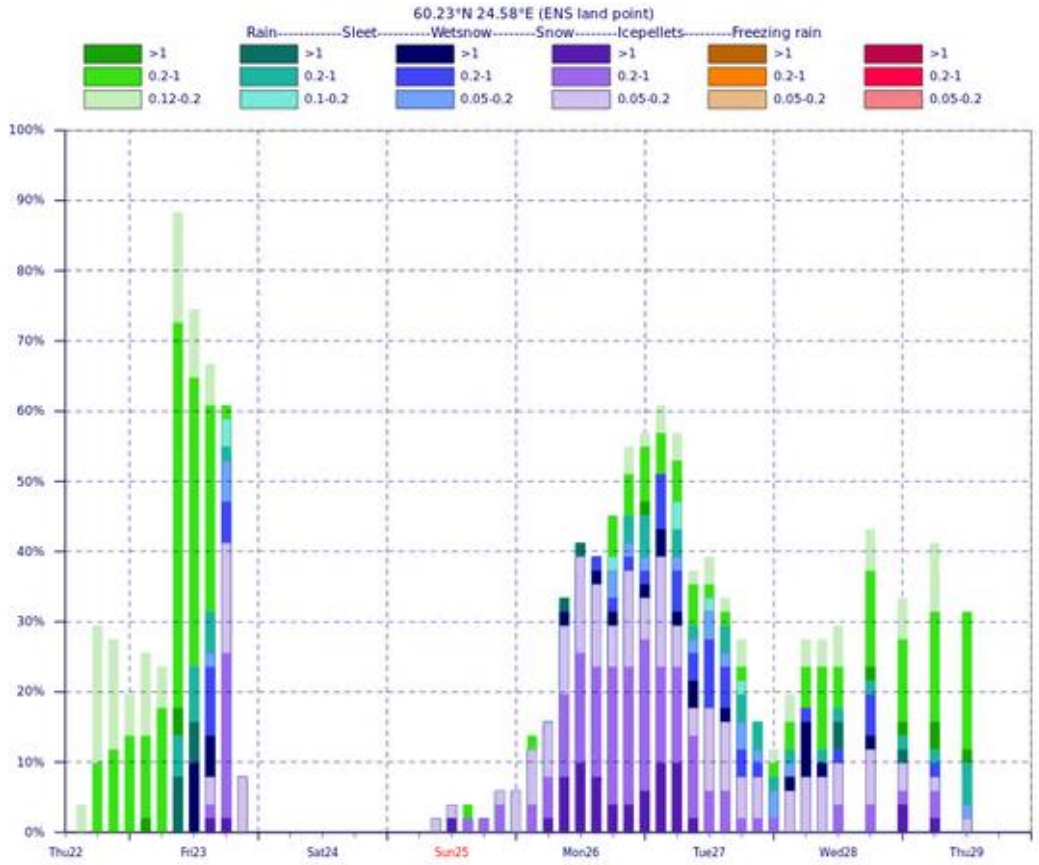
- Forecasting sources:
  - Precipitation type can be found in most weather models
    - Probability products are used often. Provides a critical source for model development and change in accuracy.
    - Becky Hemingway's presentation from Monday "Precipitation type products"
    - FMI has post processing parameter similar
      - Includes drizzle and freezing drizzle
      - Doesn't include difference between wet and dry snow
  - Crown snow-load model
    - Rime, dry snow, wet snow and frozen snow
    - Research article:
      - Modelling crown snow loads in Finland: a comparison of two methods
      - Lehtonen I., Hoppula P., Pirinen P., Gregow H. (2014).
      - https://doi.org/10.14214/sf.1120

Where does uncertainty come from? Timing or route?



- Is it 50 % chance for snow on Monday? As in 50 % of members forecast snow.

Where does uncertainty come from? Timing or route?



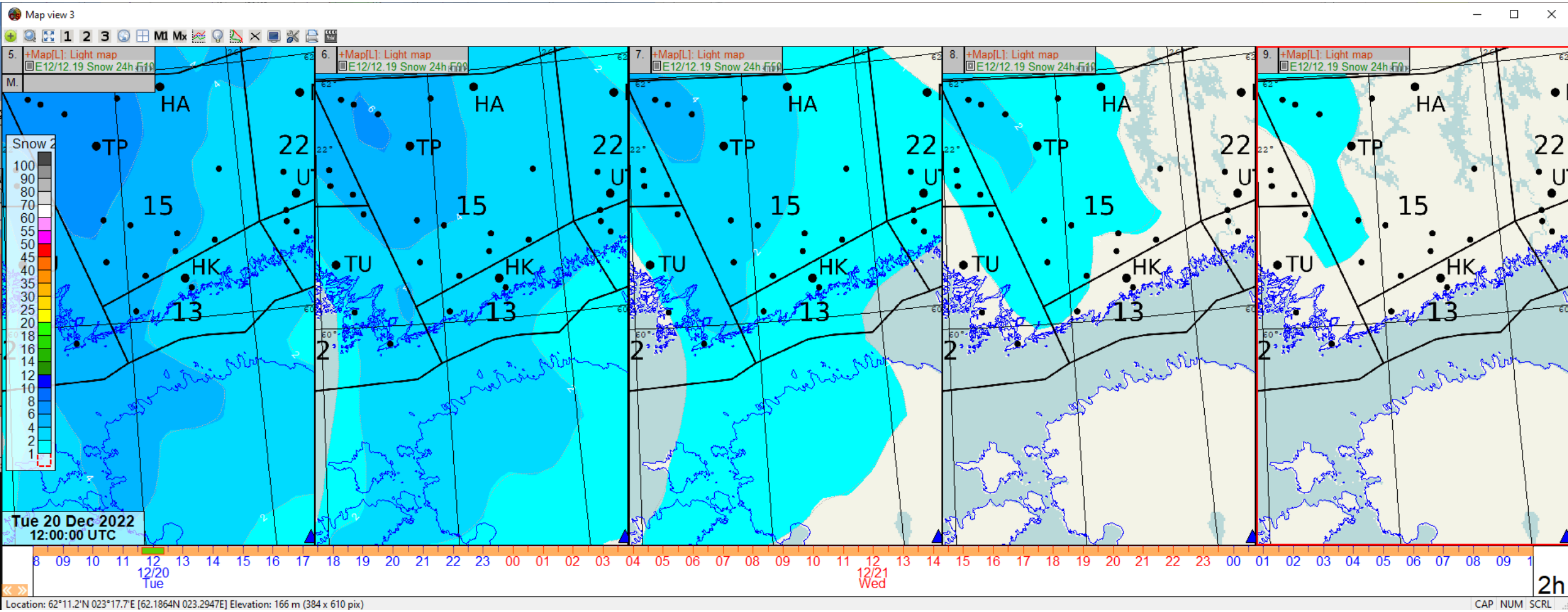
- Is it 50 % chance for snow on Monday? As in 50 % of members forecast snow.

Or

- Is it 100 % of members forecasting snow, but 50 % forecast snowfall in morning and 50 % forecast snowfall in the evening.
- Can’t say from this diagram alone.
- Answer can often be found in the accumulation forecasts.

Snow accumulation

- 6-48h accumulation fractiles. F100, F90, F50, F10, F0.



Snow accumulation

- ”Typical” snow
  - 1 mm = 1 cm
- Very dry snow (T_{sfc} = -10 – -20 °C)
  - 1 mm = 2 – 3 cm of snow
- Wet snow (T_{sfc} = 2 – -2 °C)
  - 1 mm = 0,5 – 1 cm of snow

- Snow compacting is not important for airports since the runways require constant brushing.

Example case 20.12.2022

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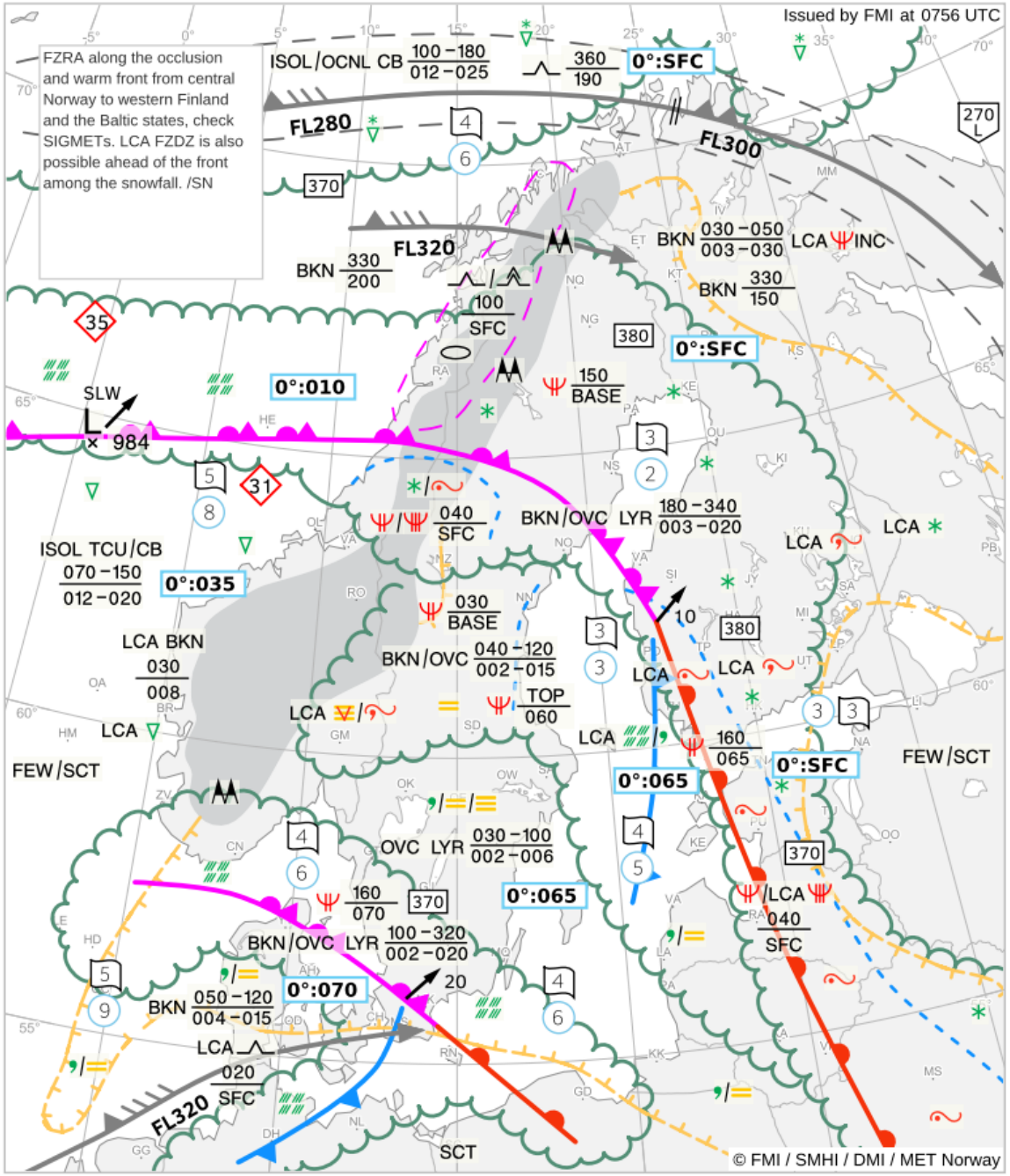
SWC SFC-FL450 valid time 12 UTC 20.12.2022



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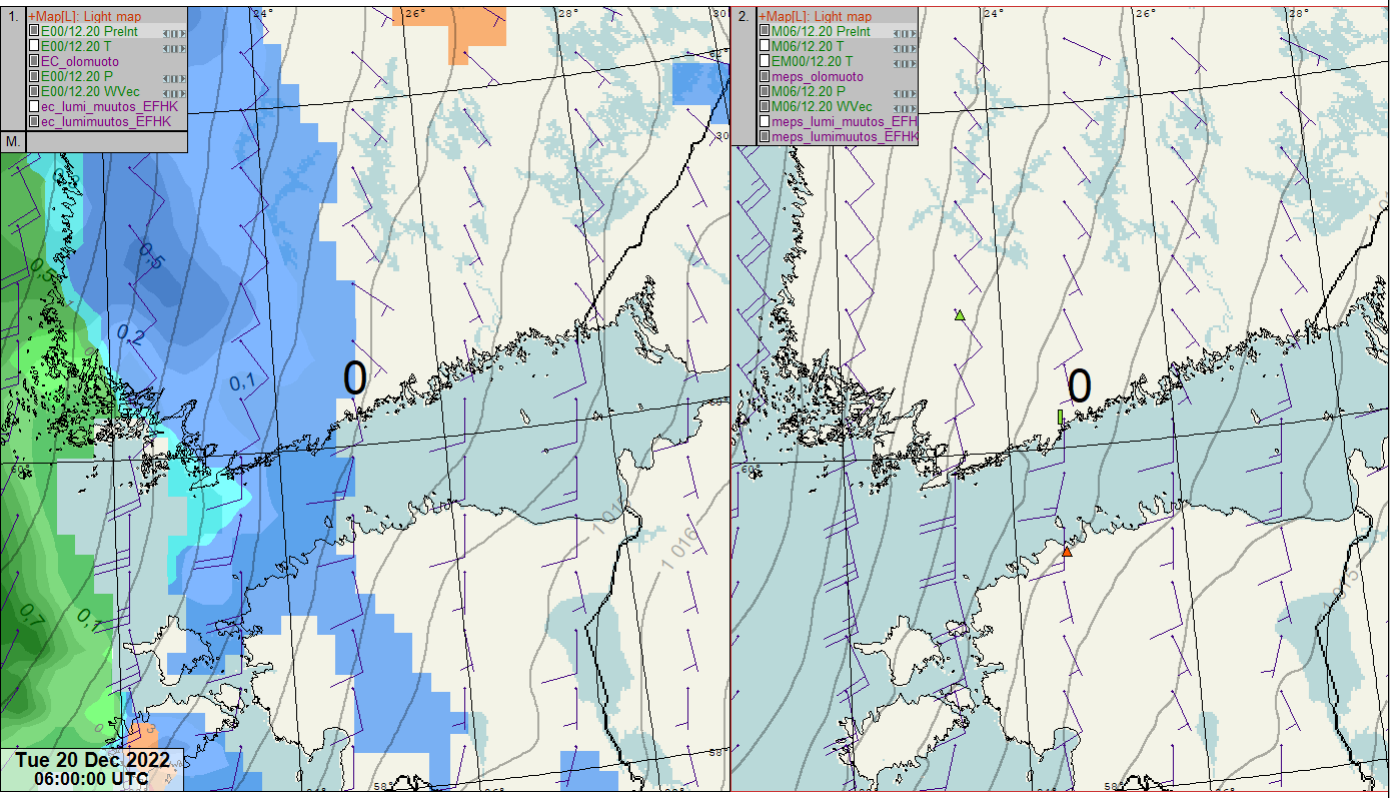

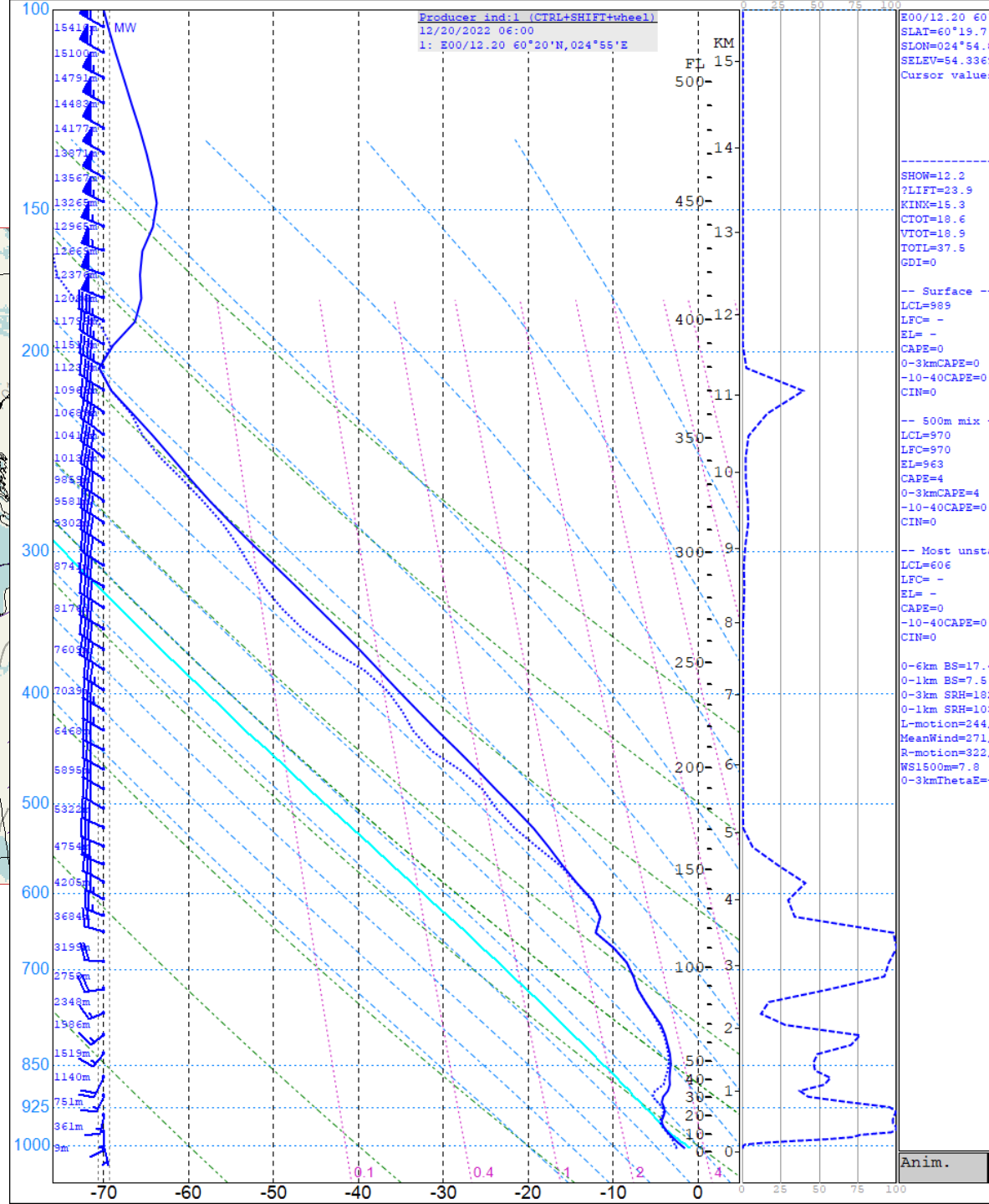

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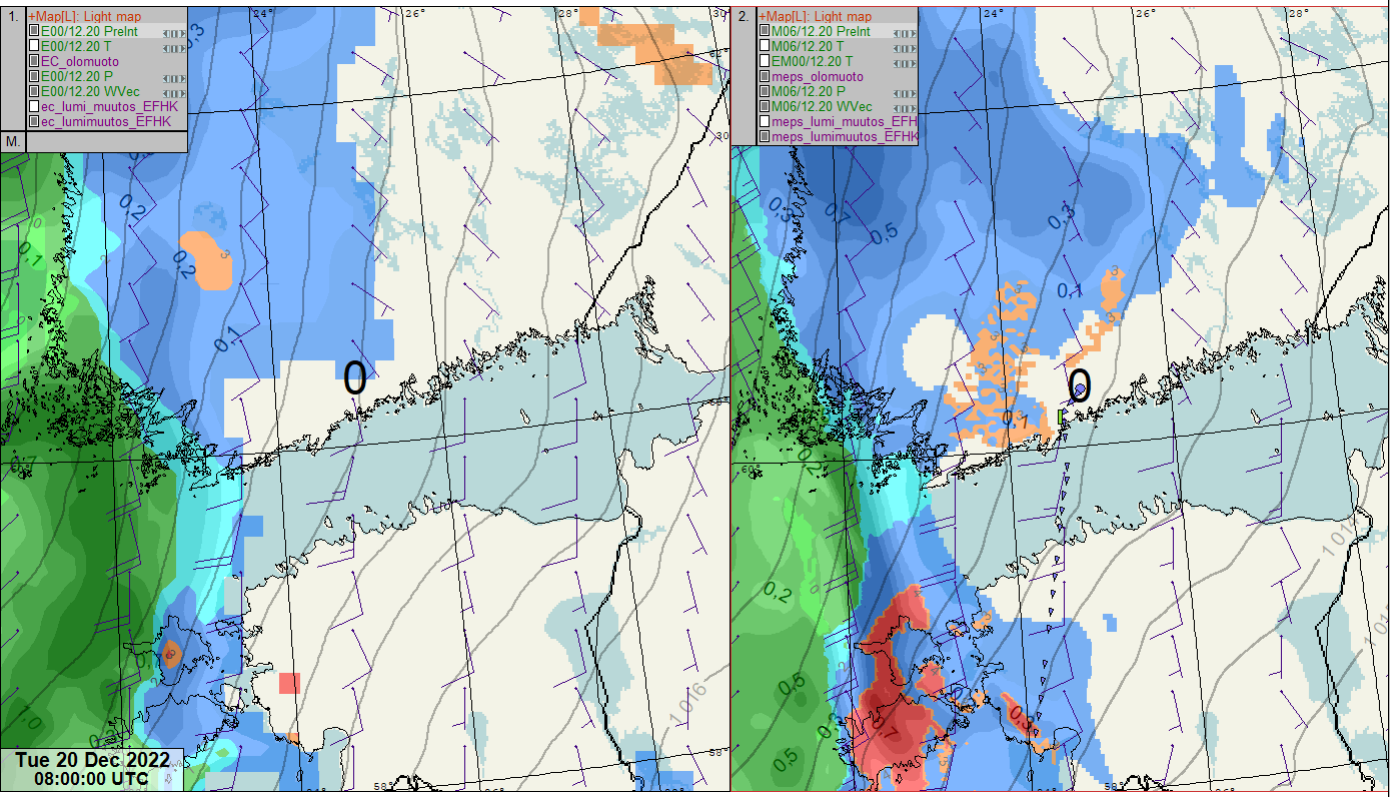

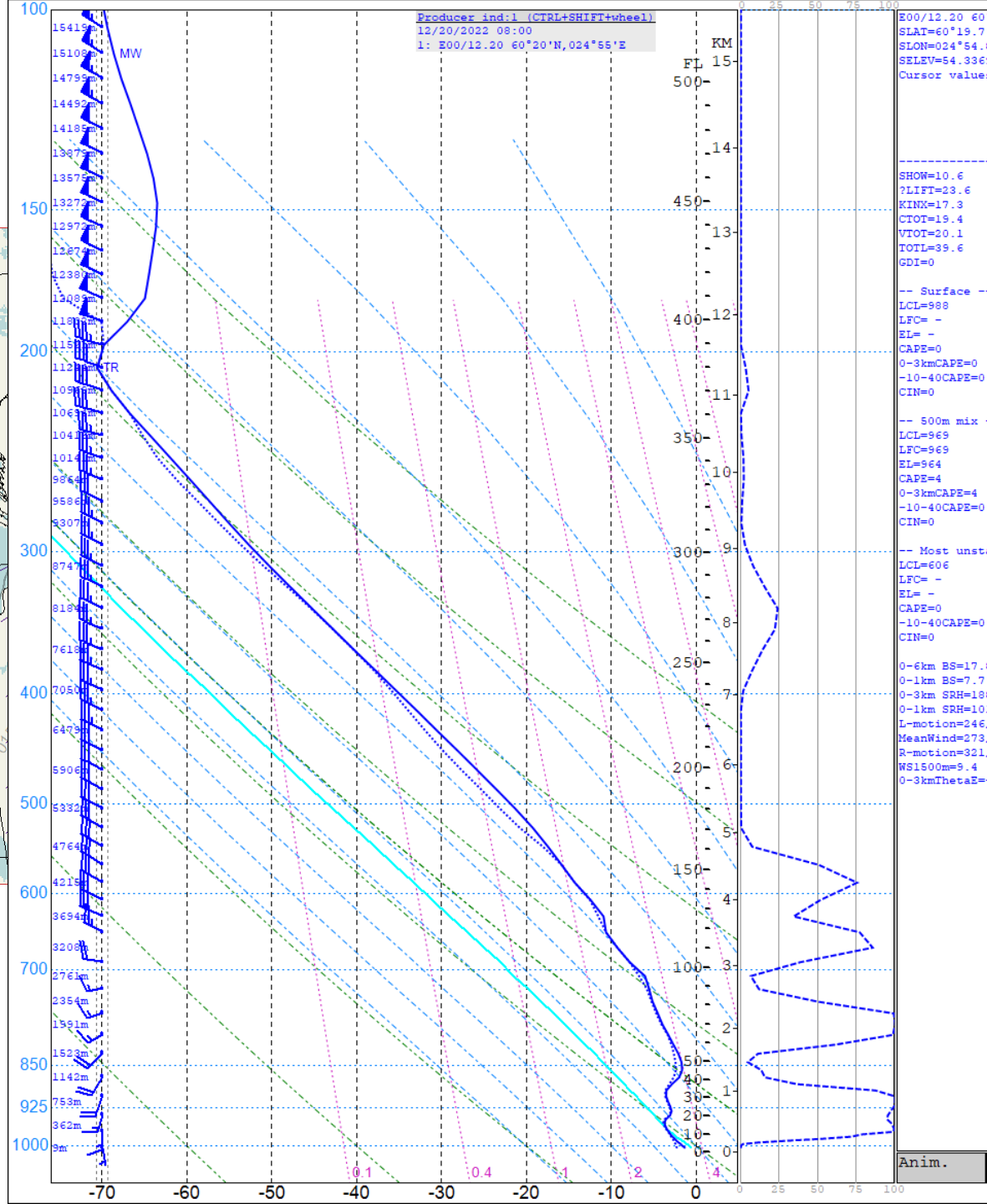

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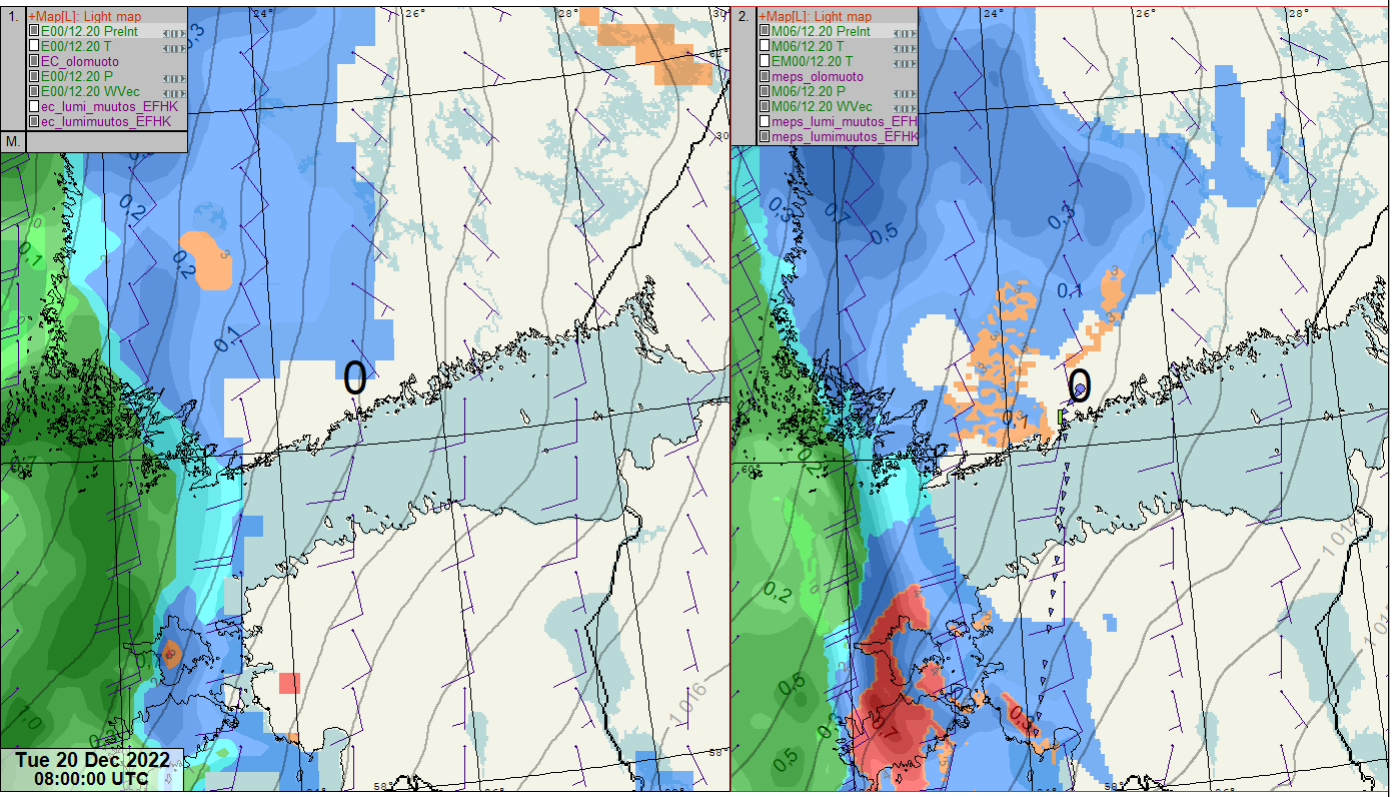

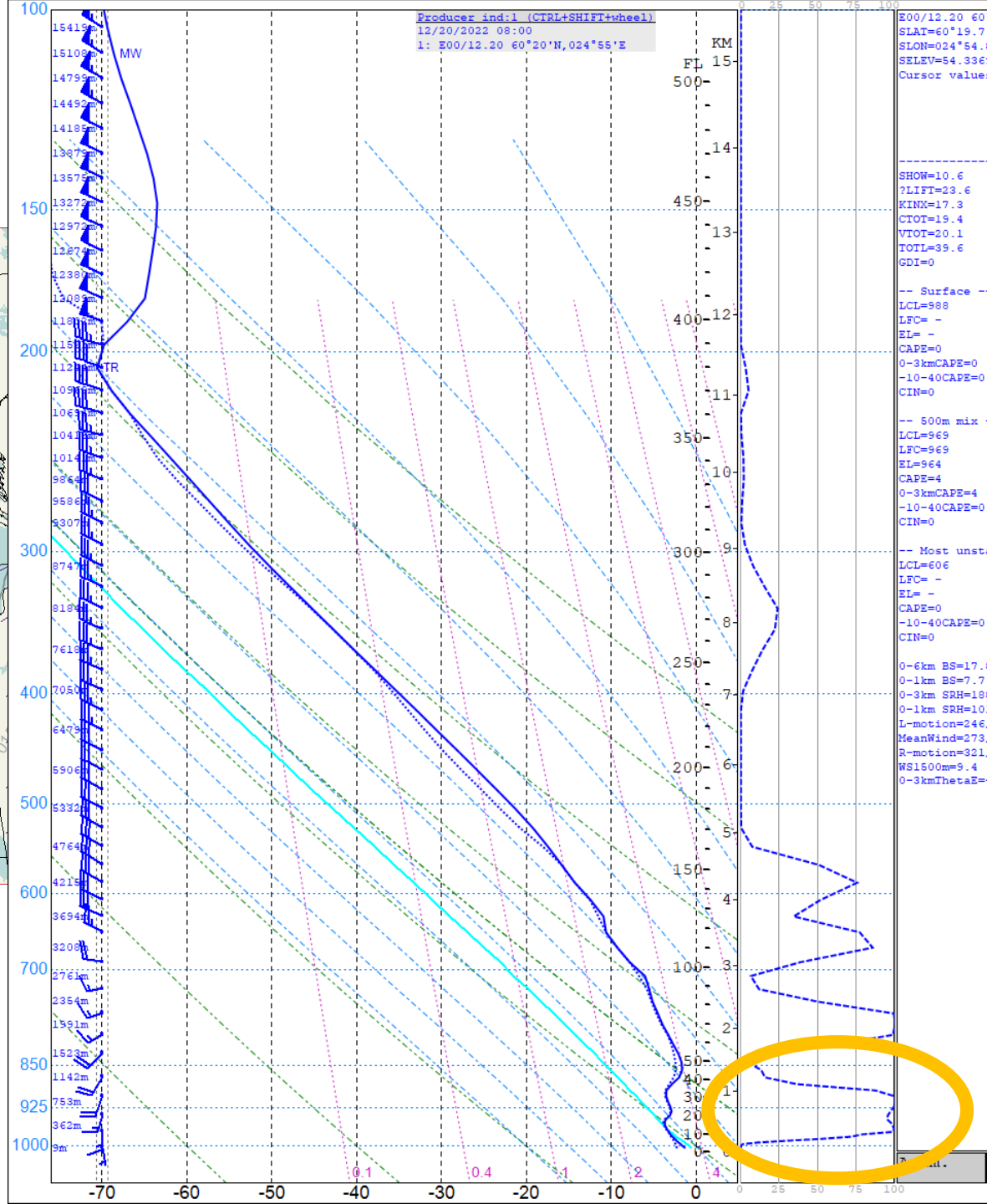

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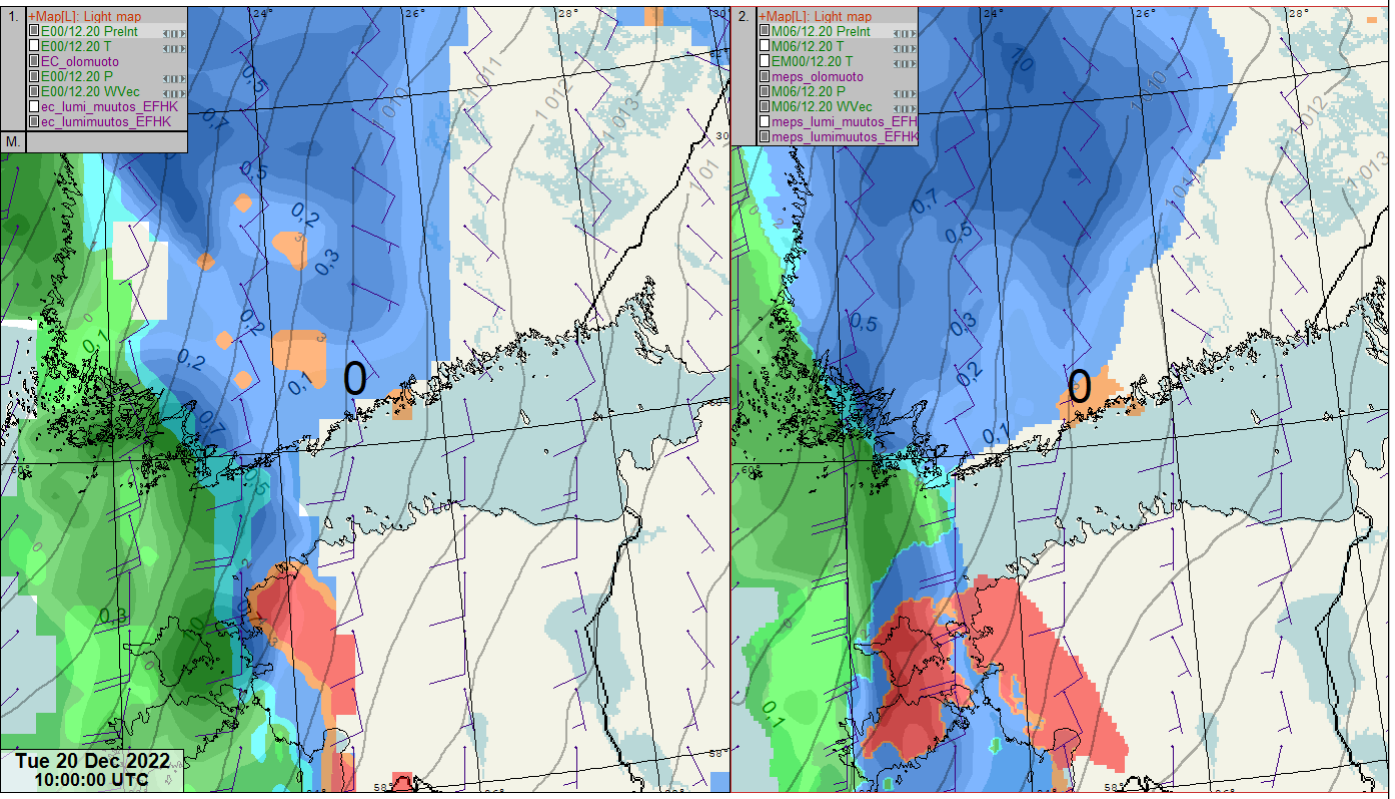

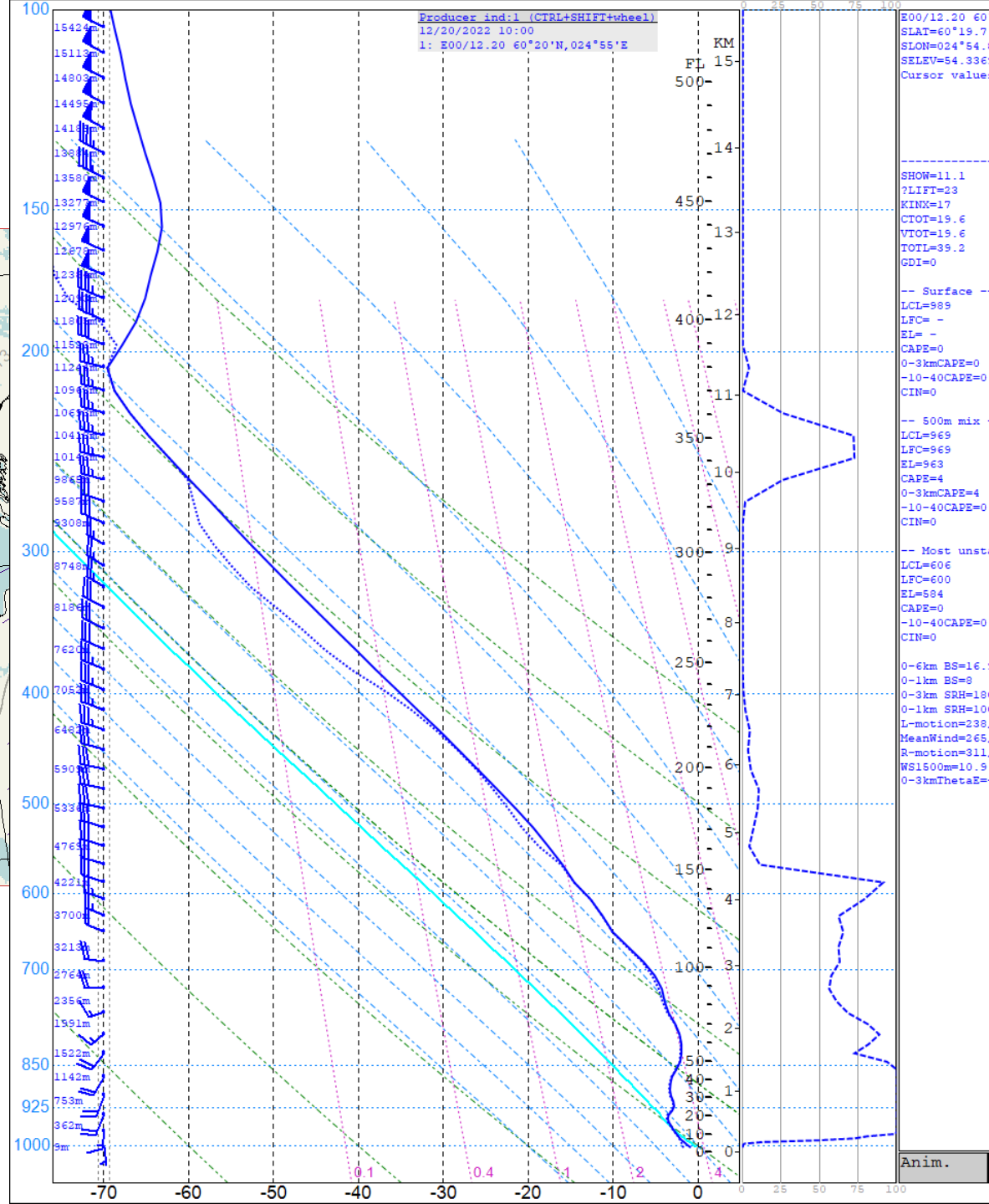

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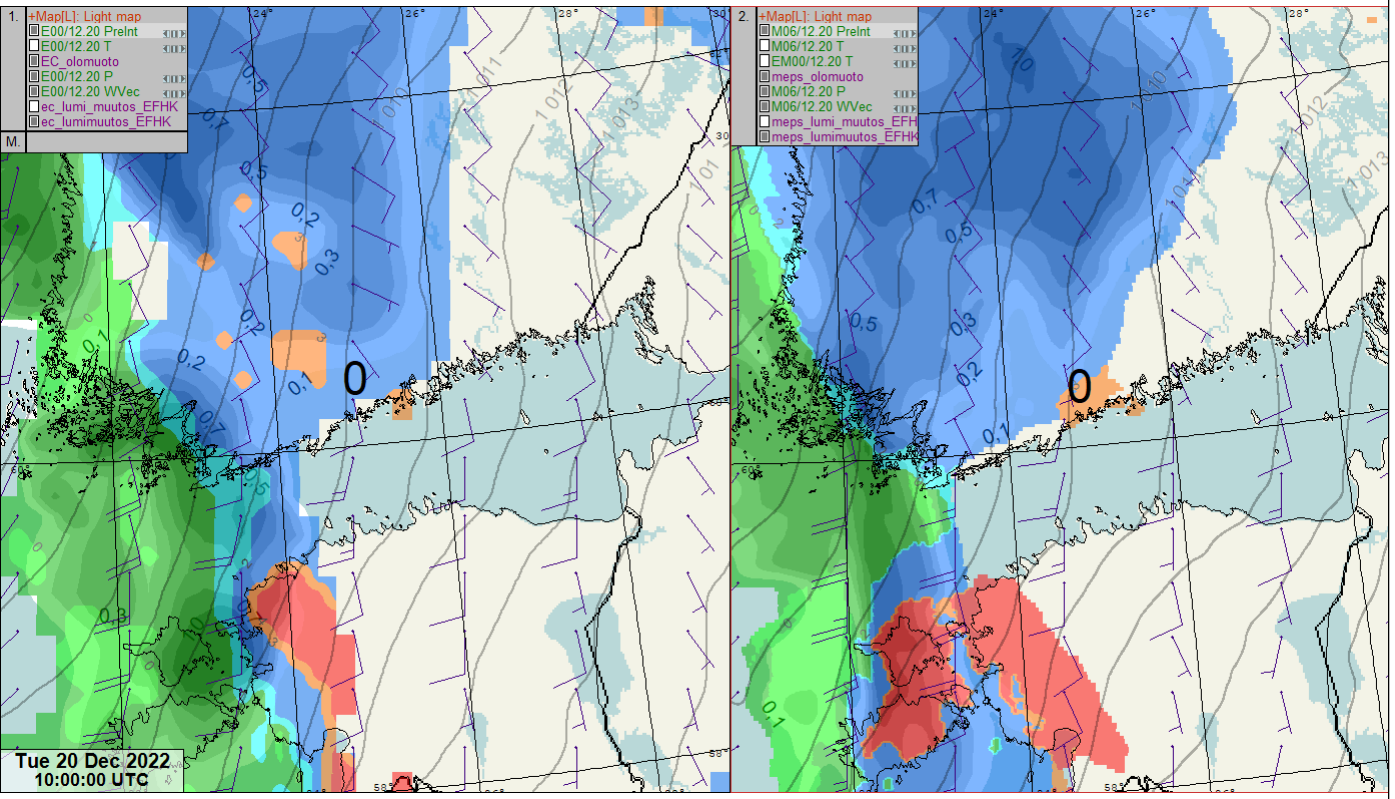

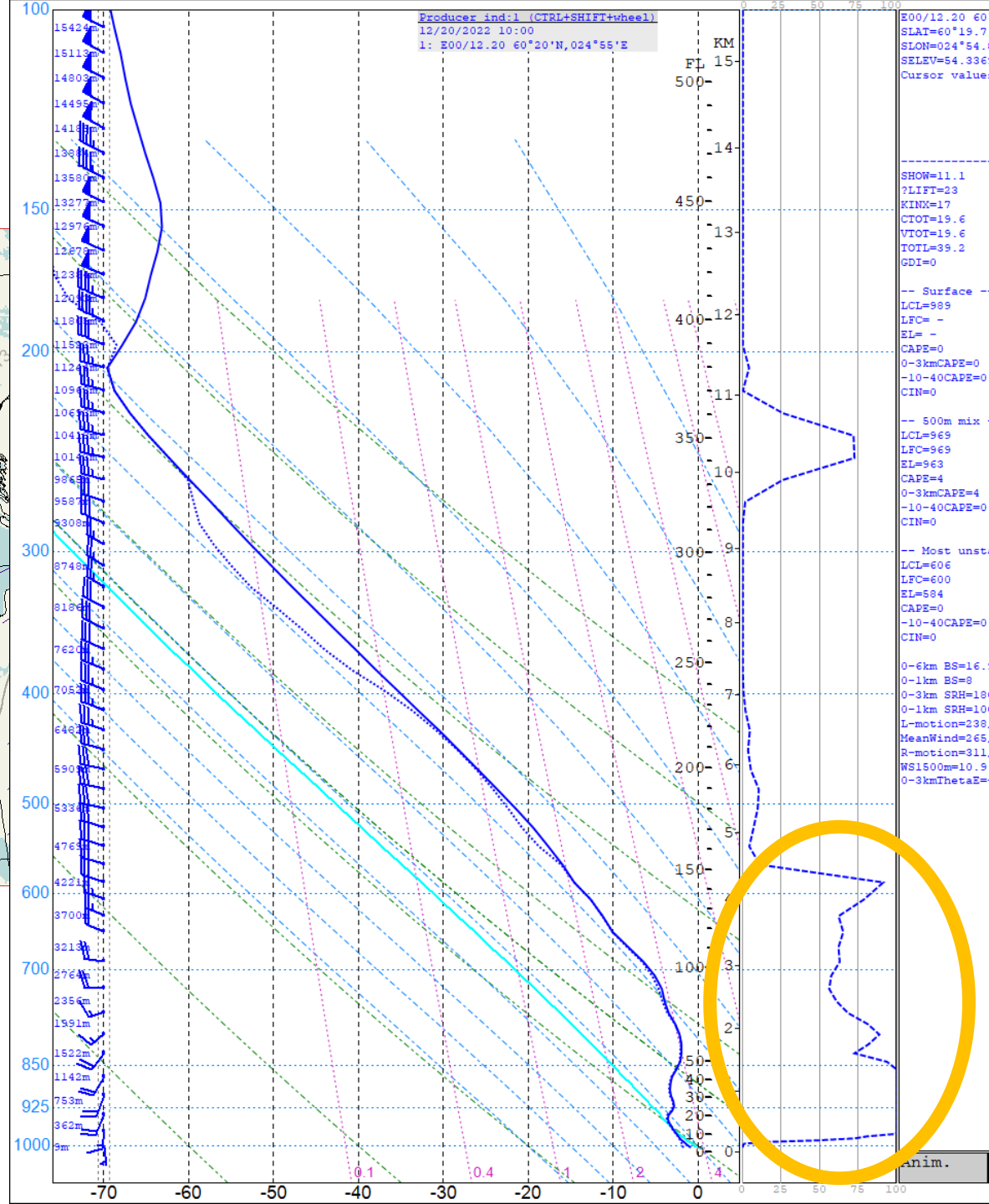

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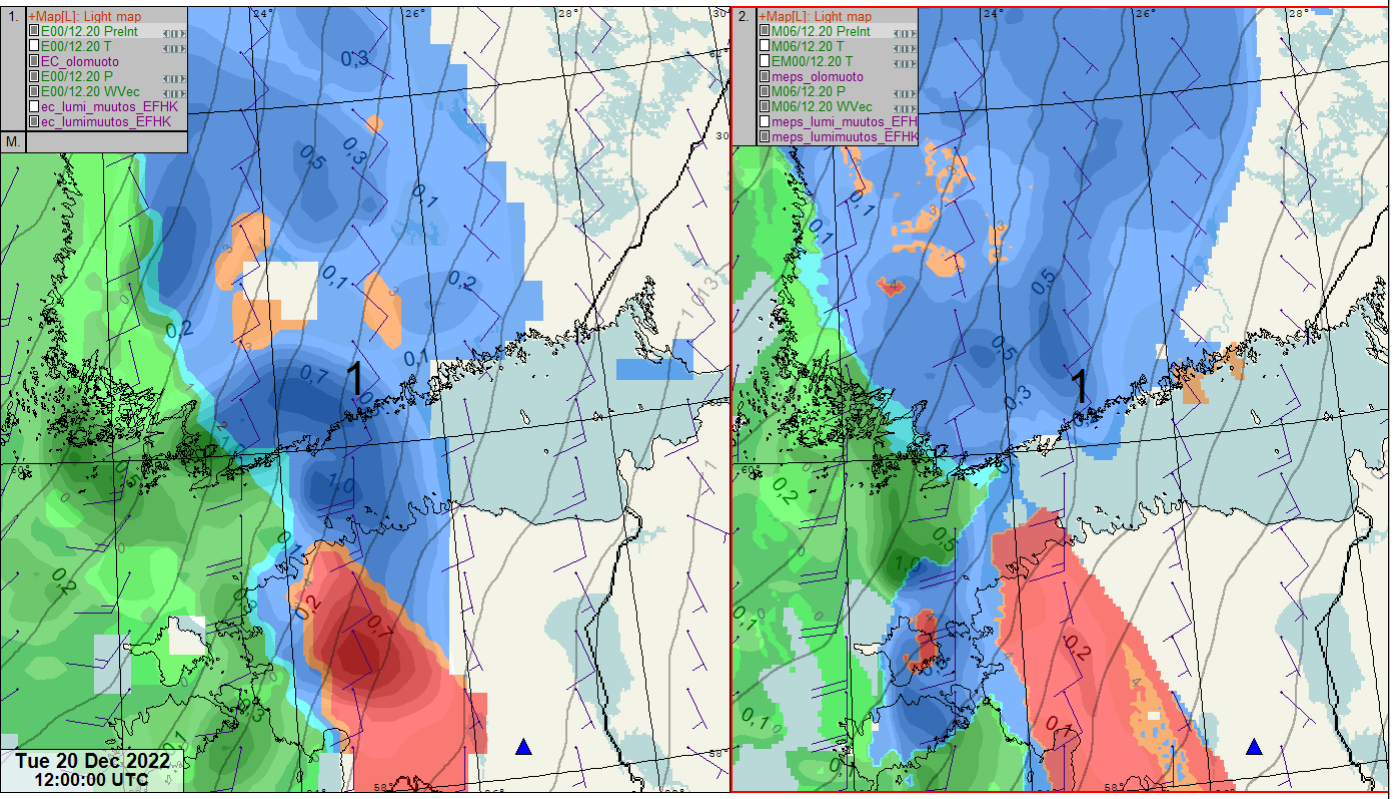

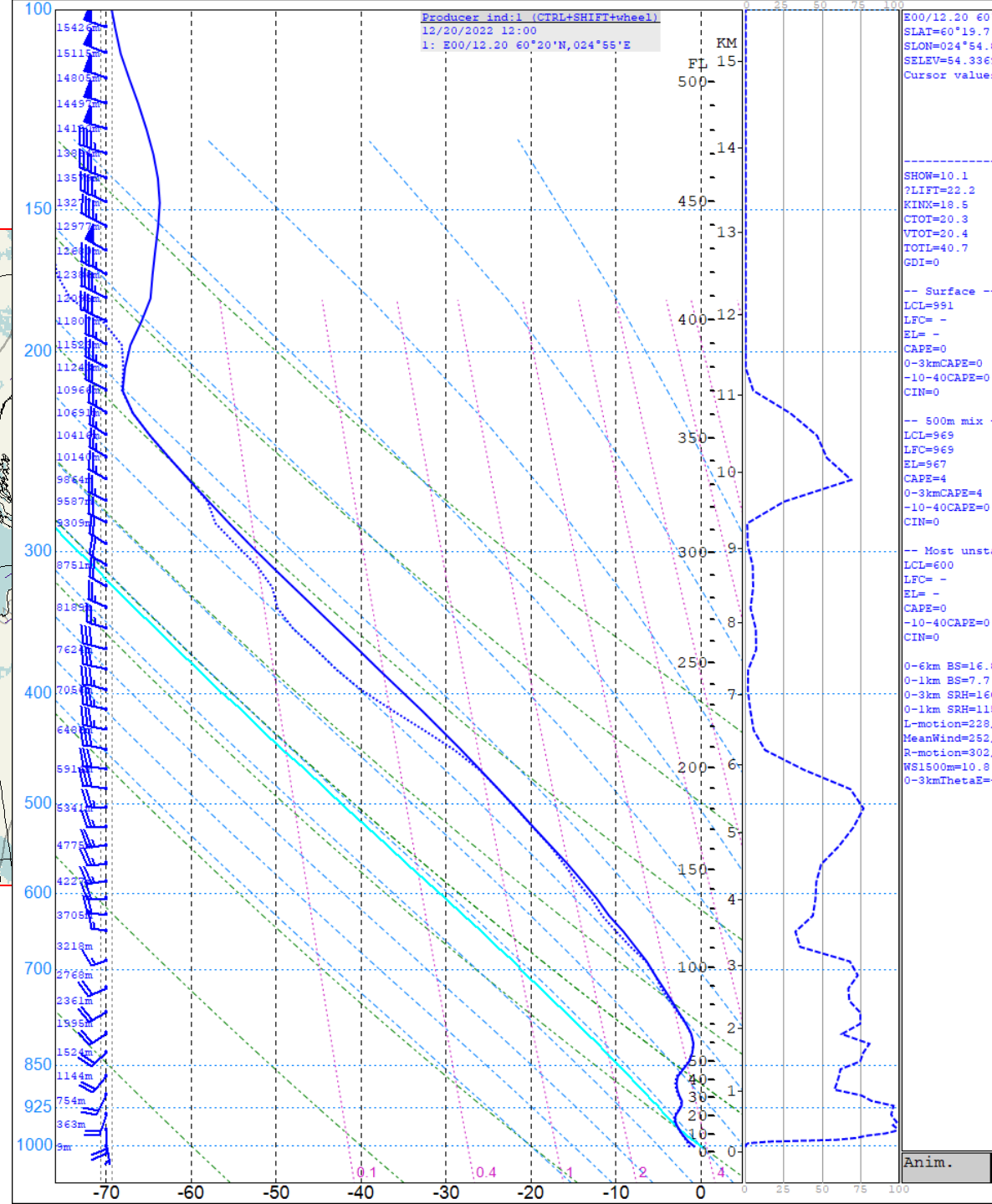

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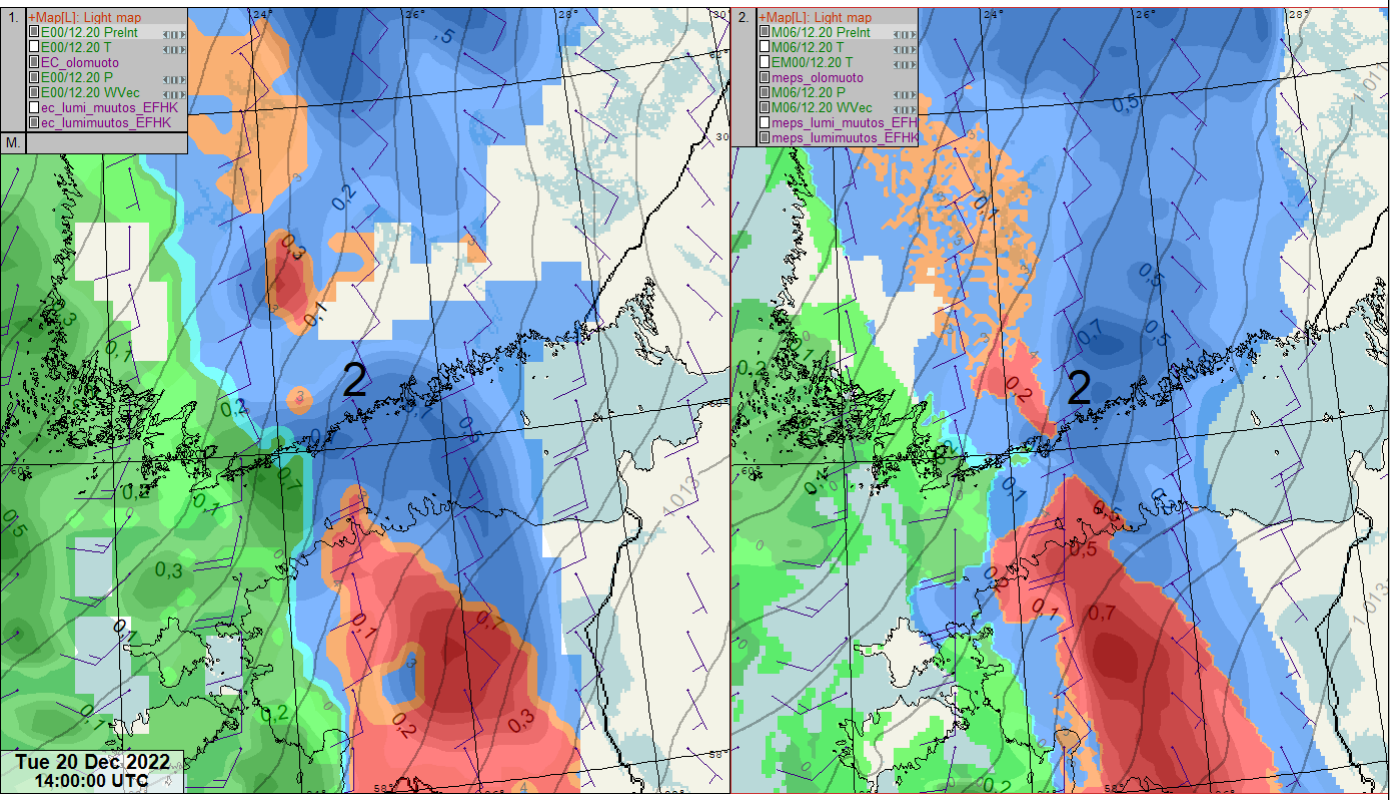

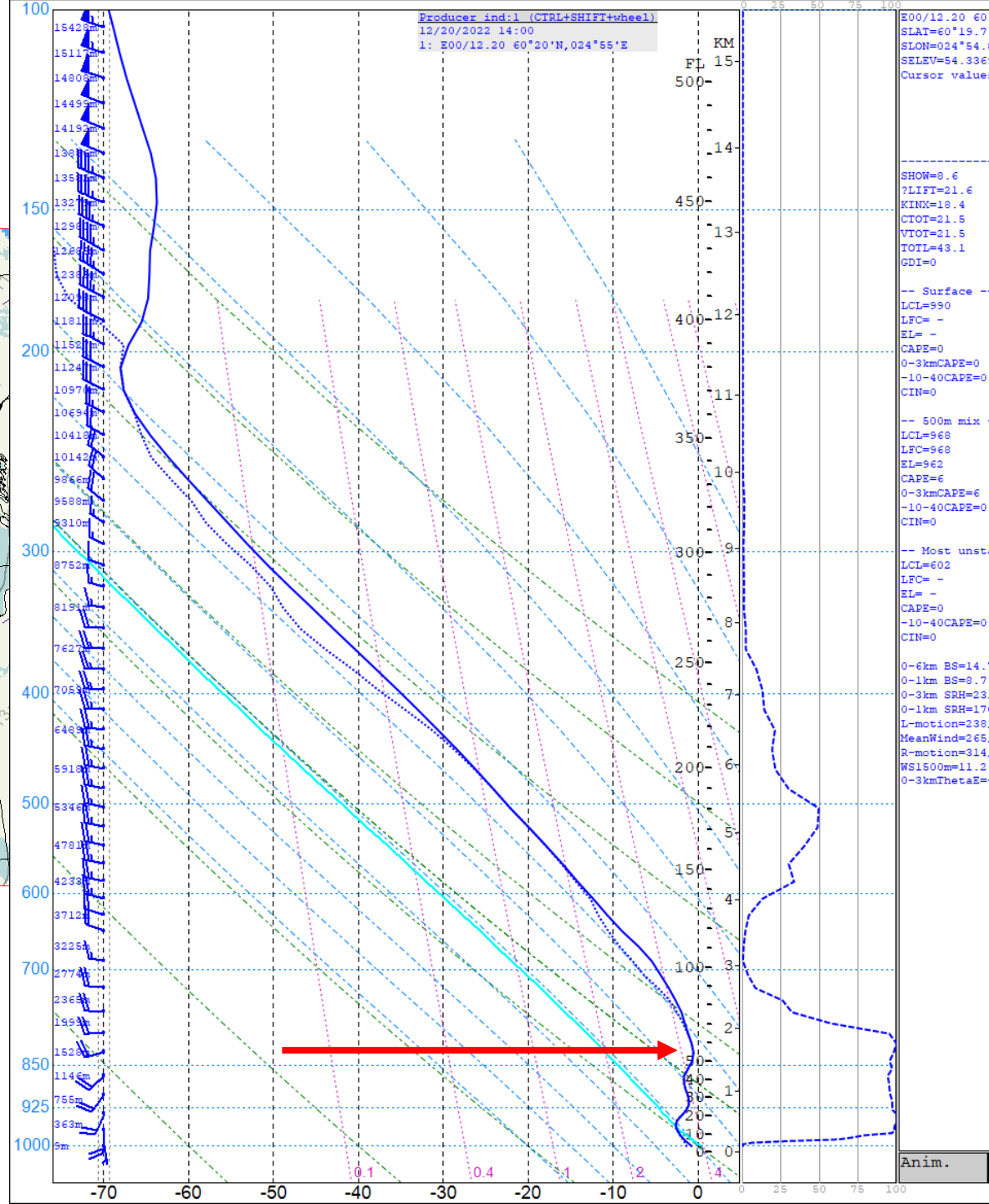

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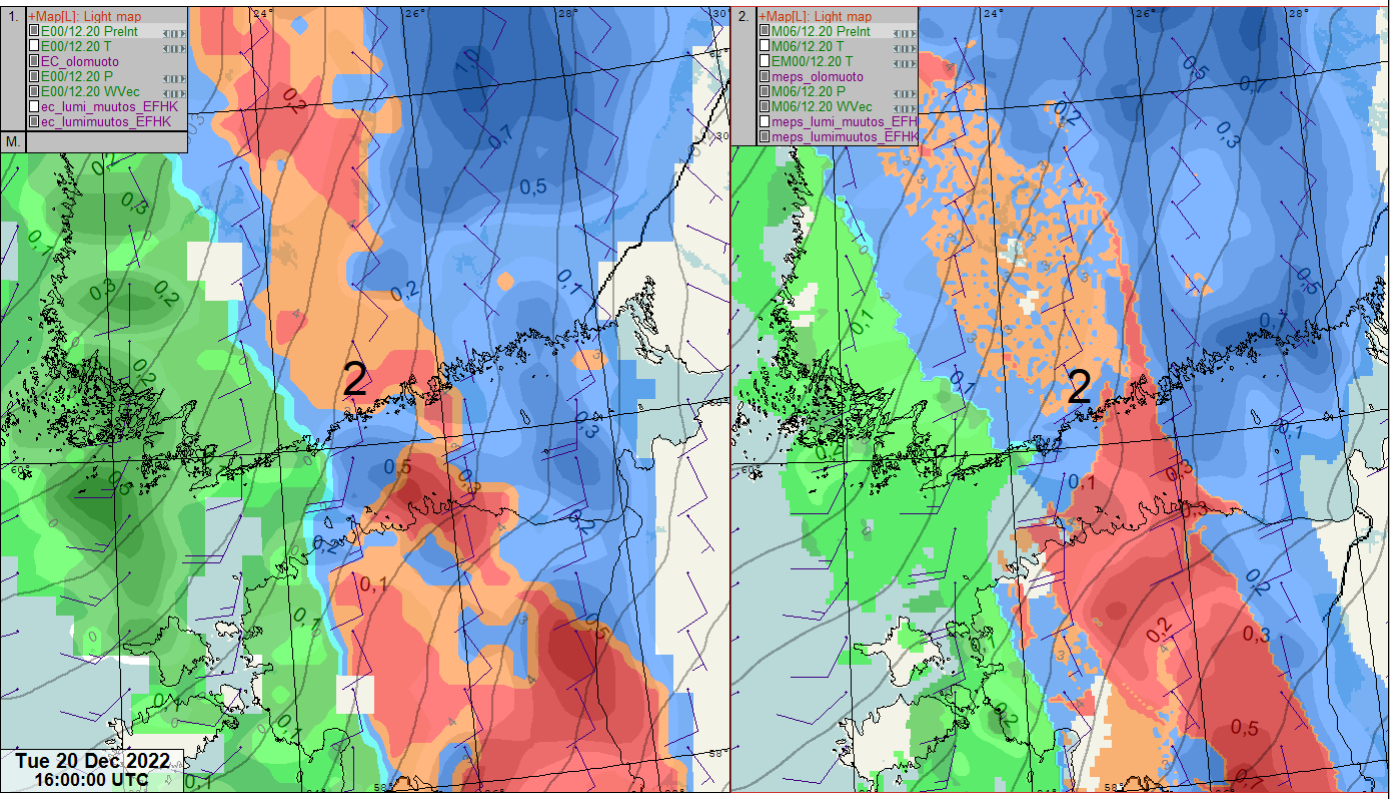

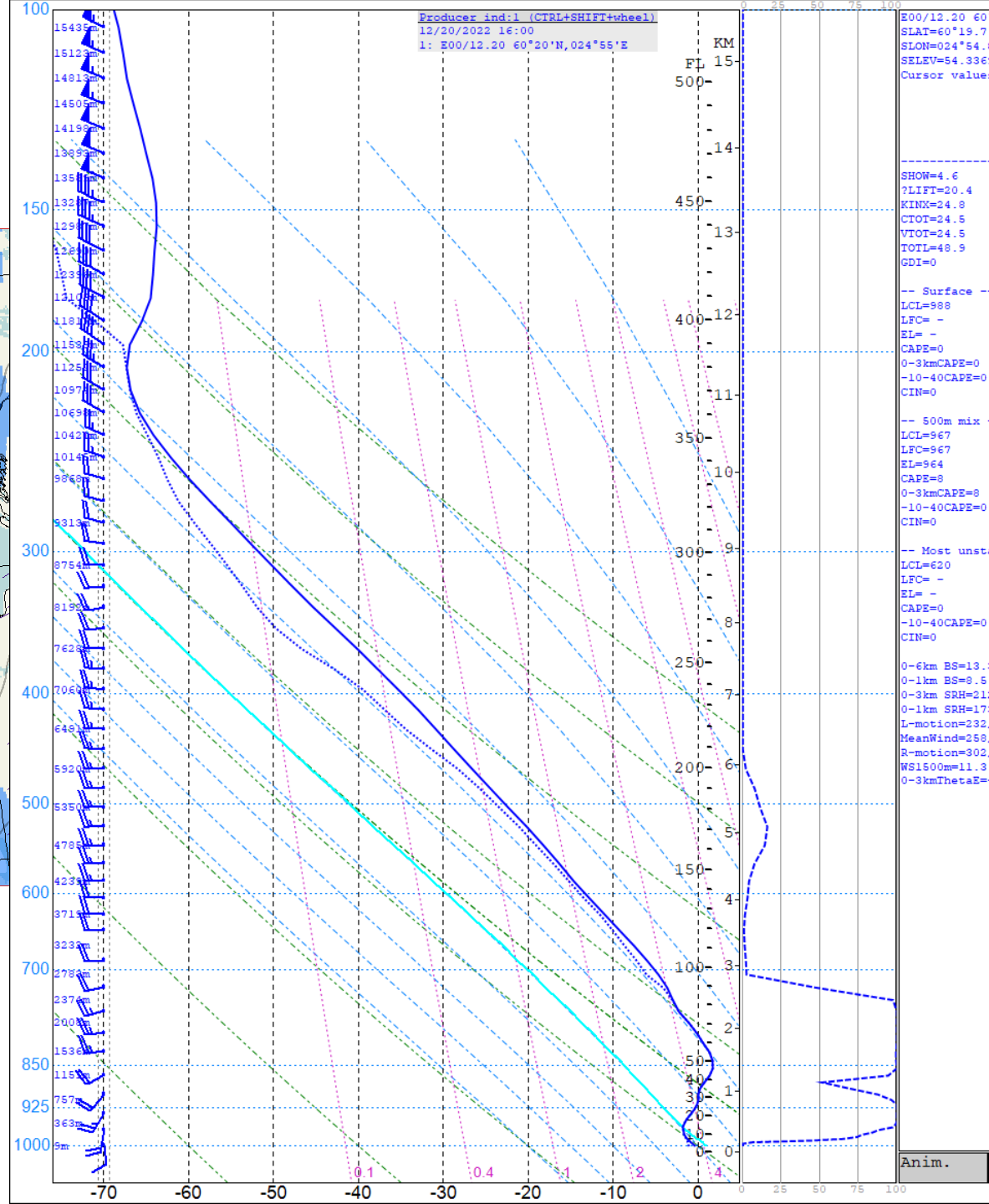

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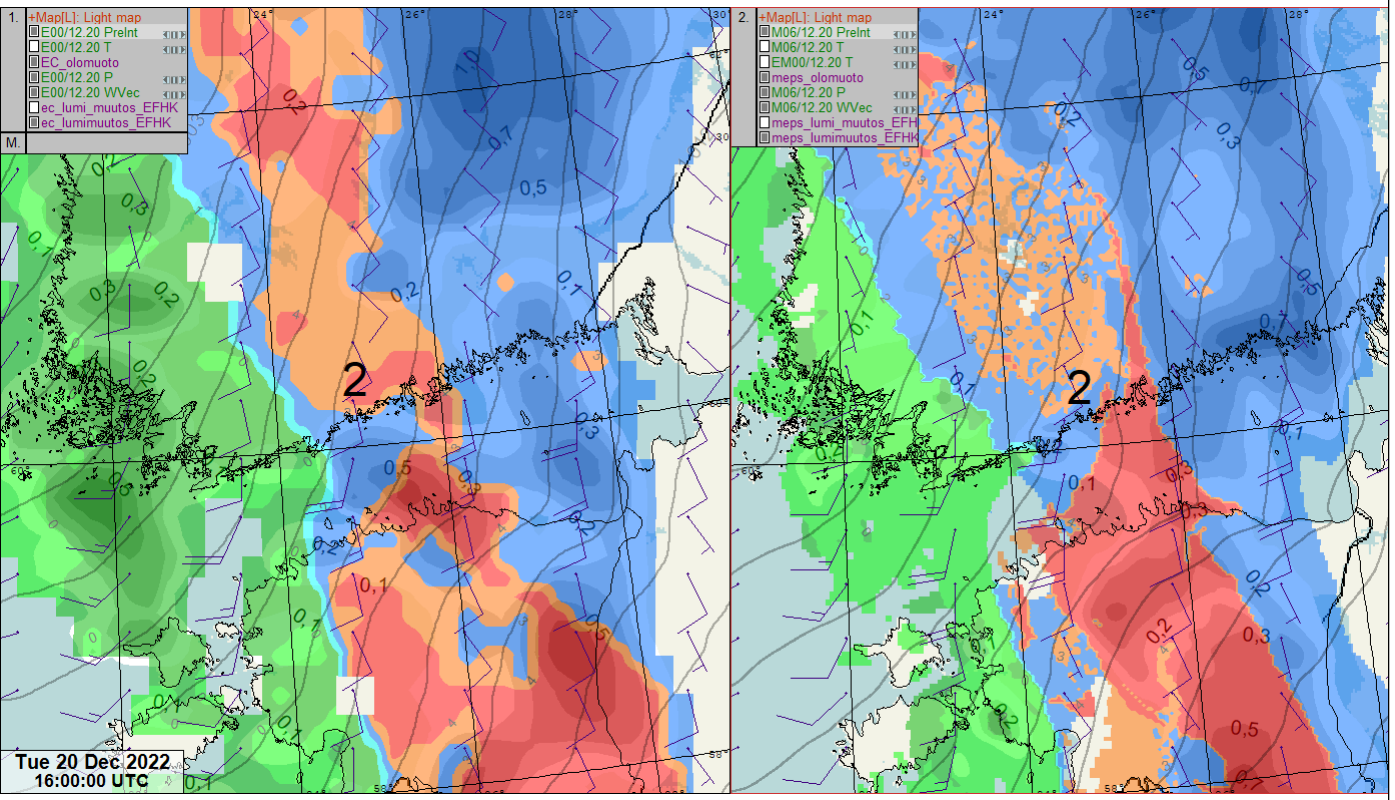

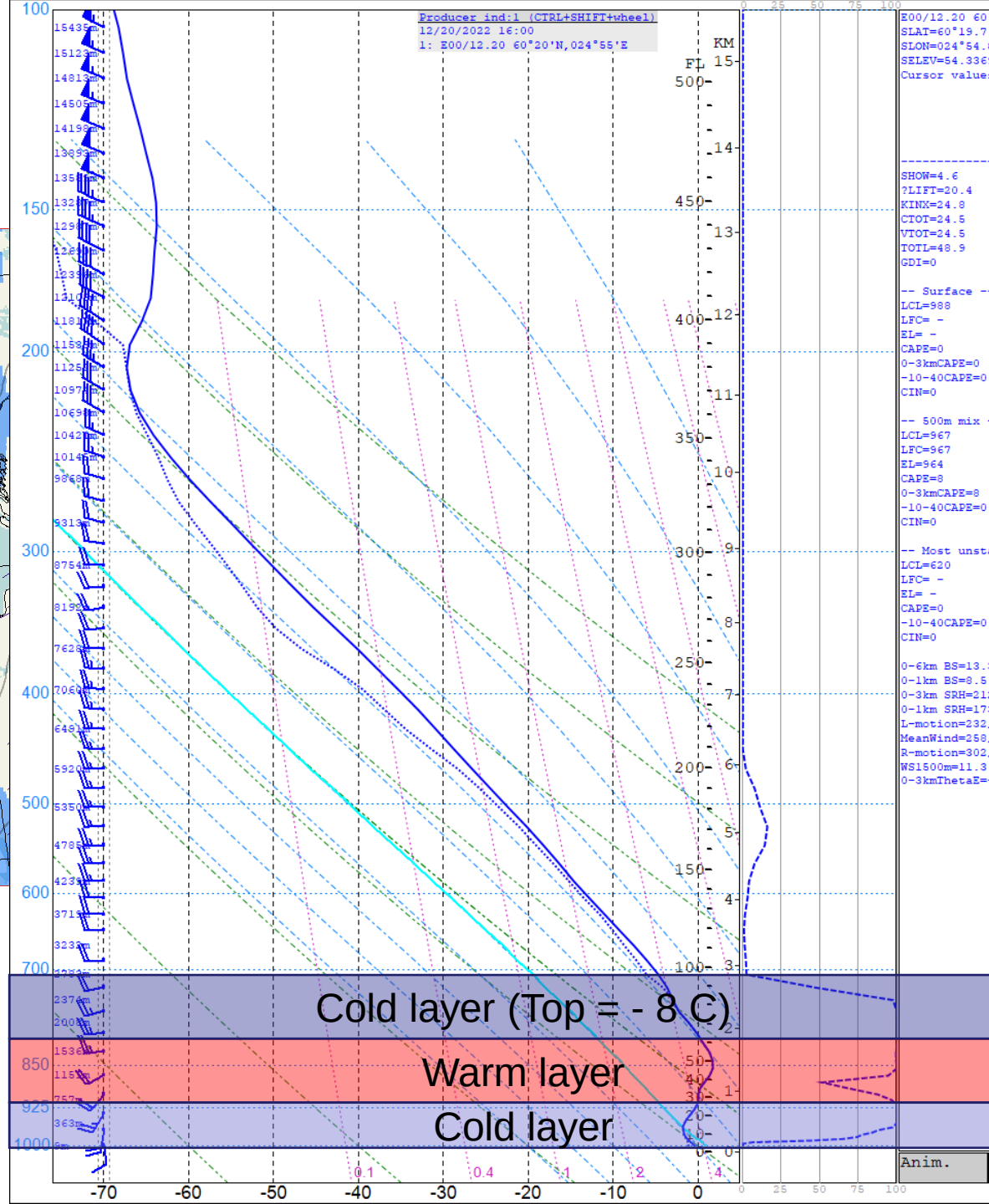

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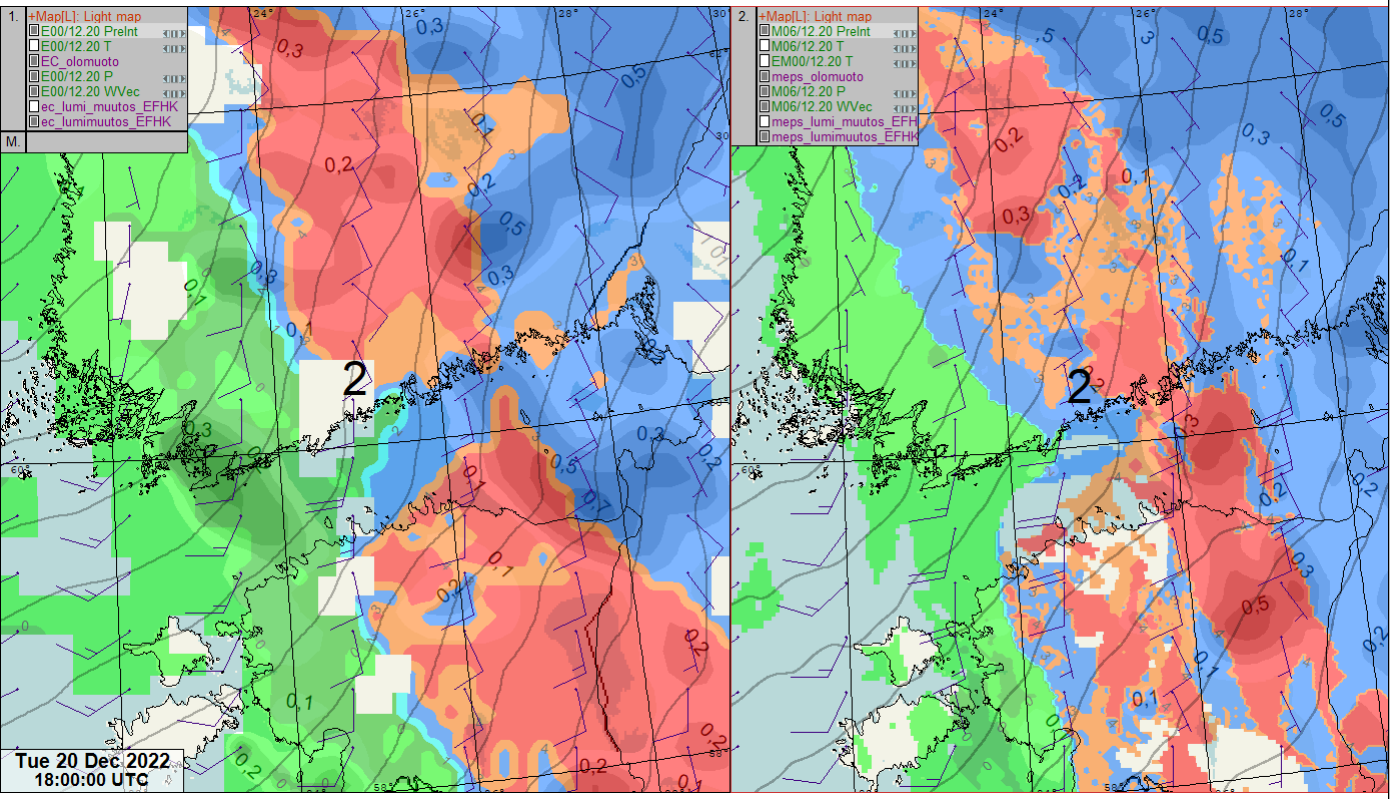

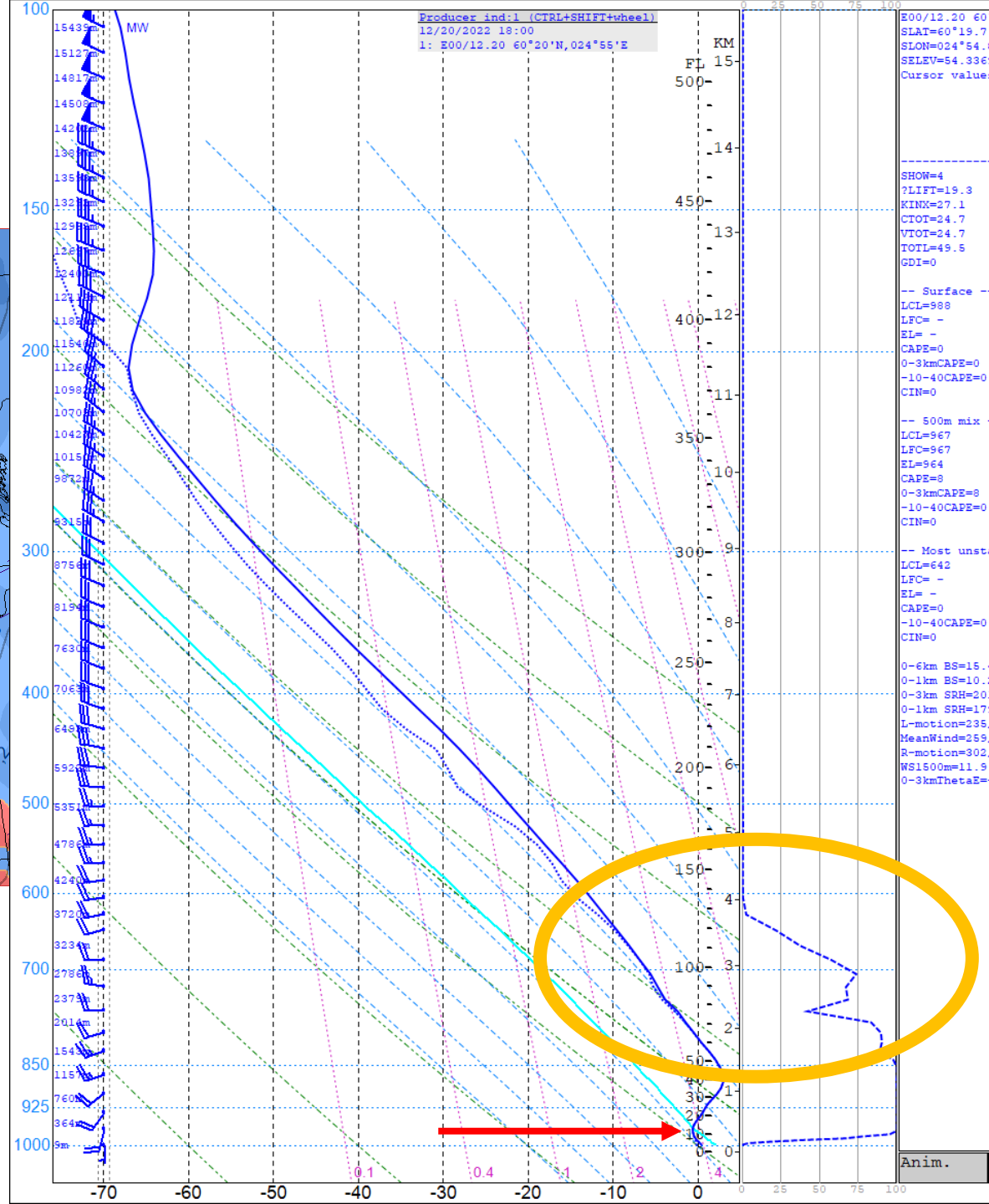

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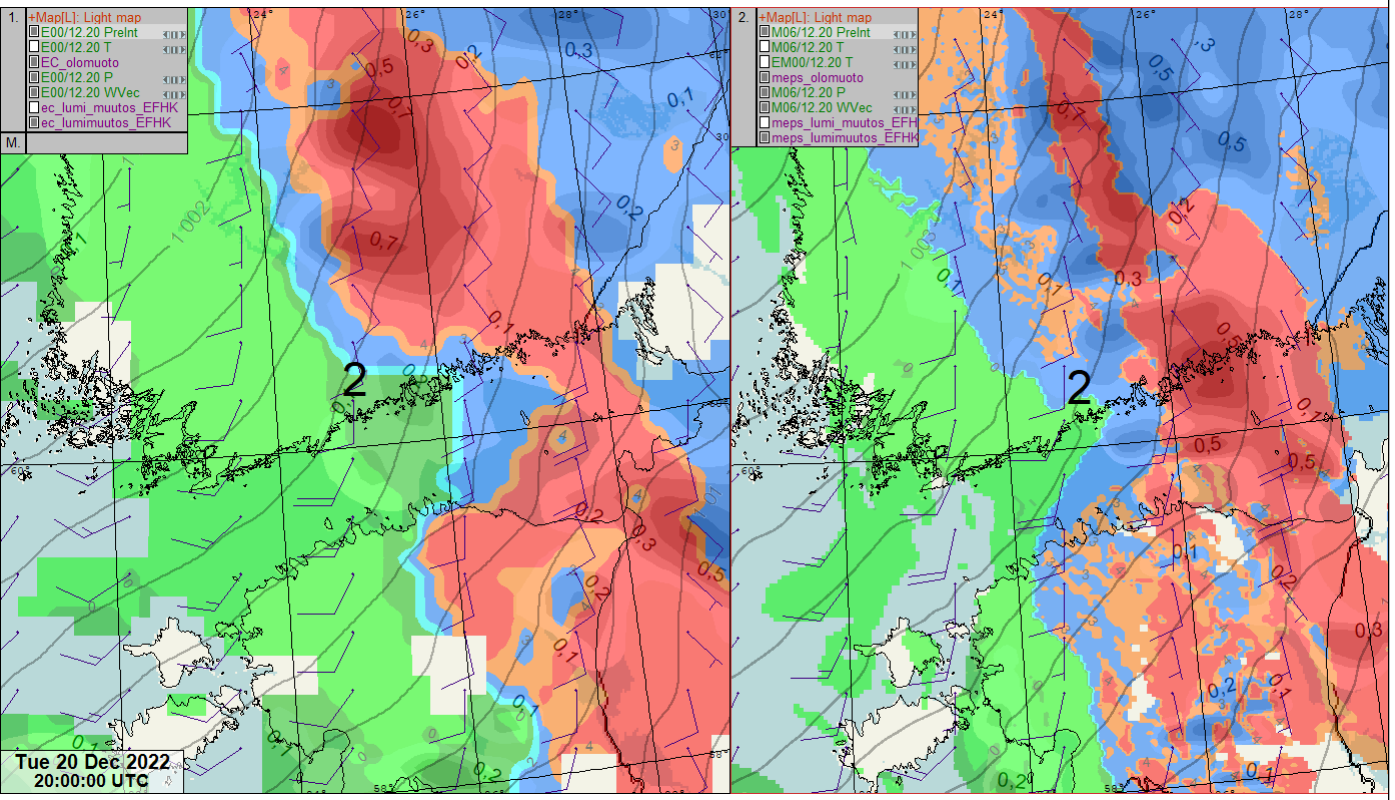

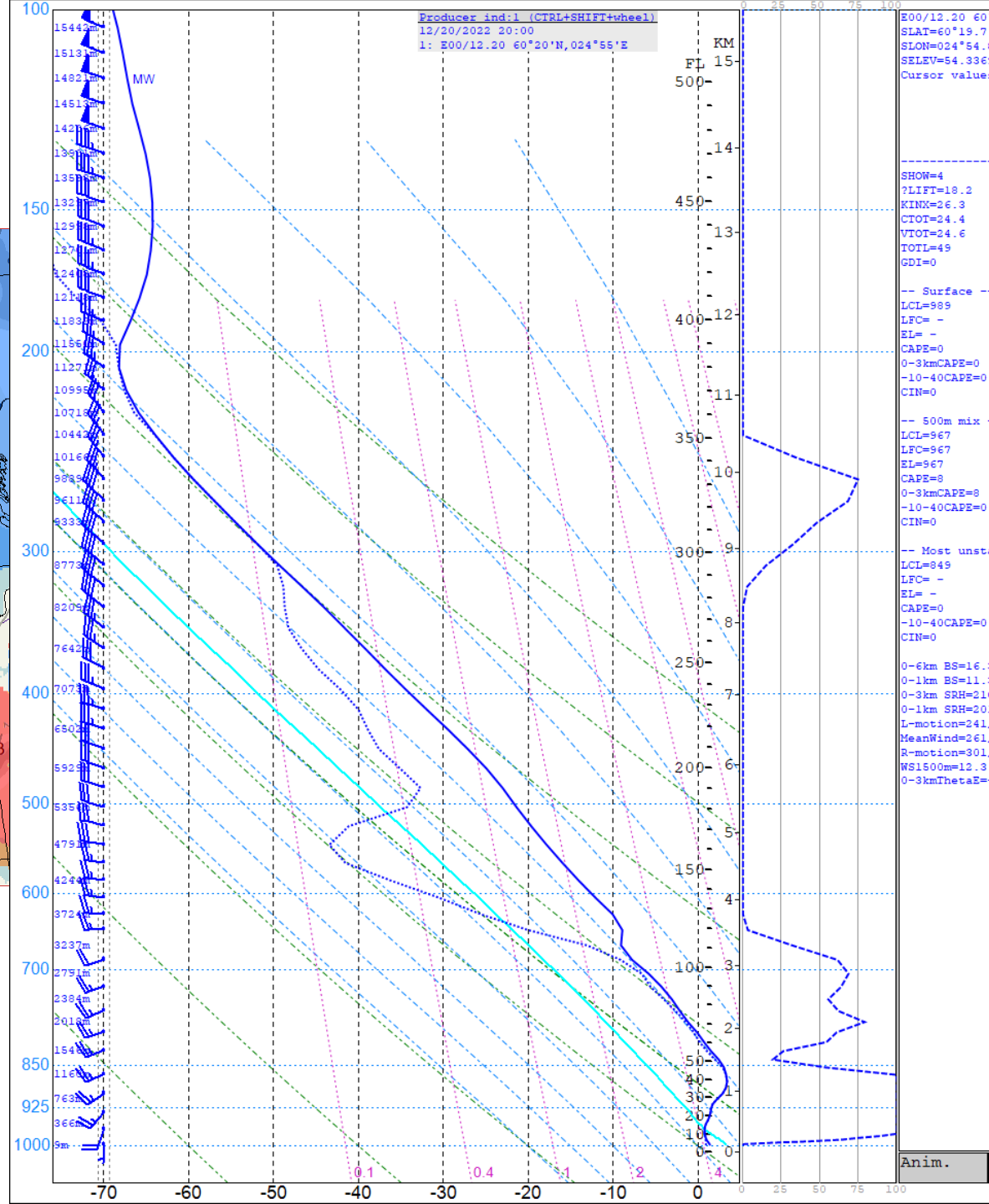

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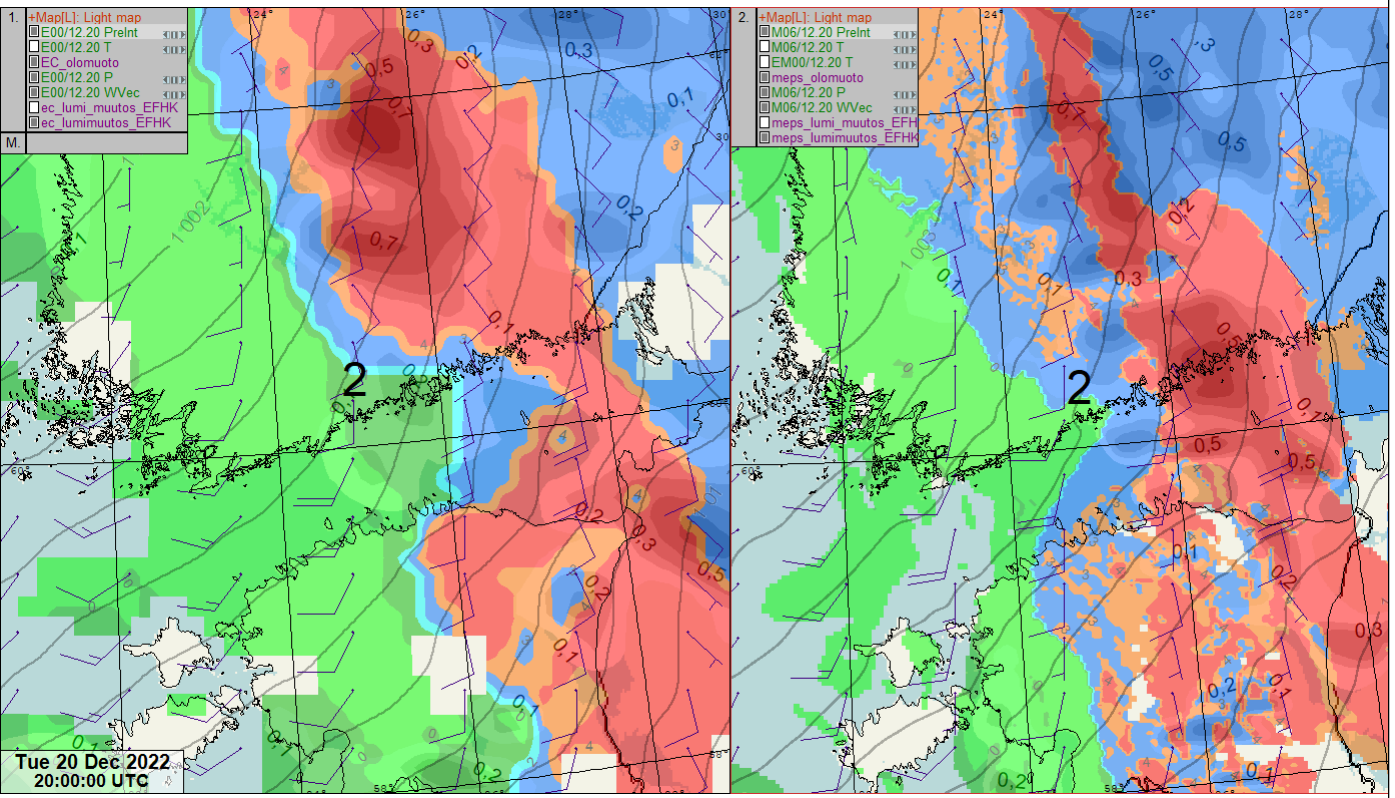

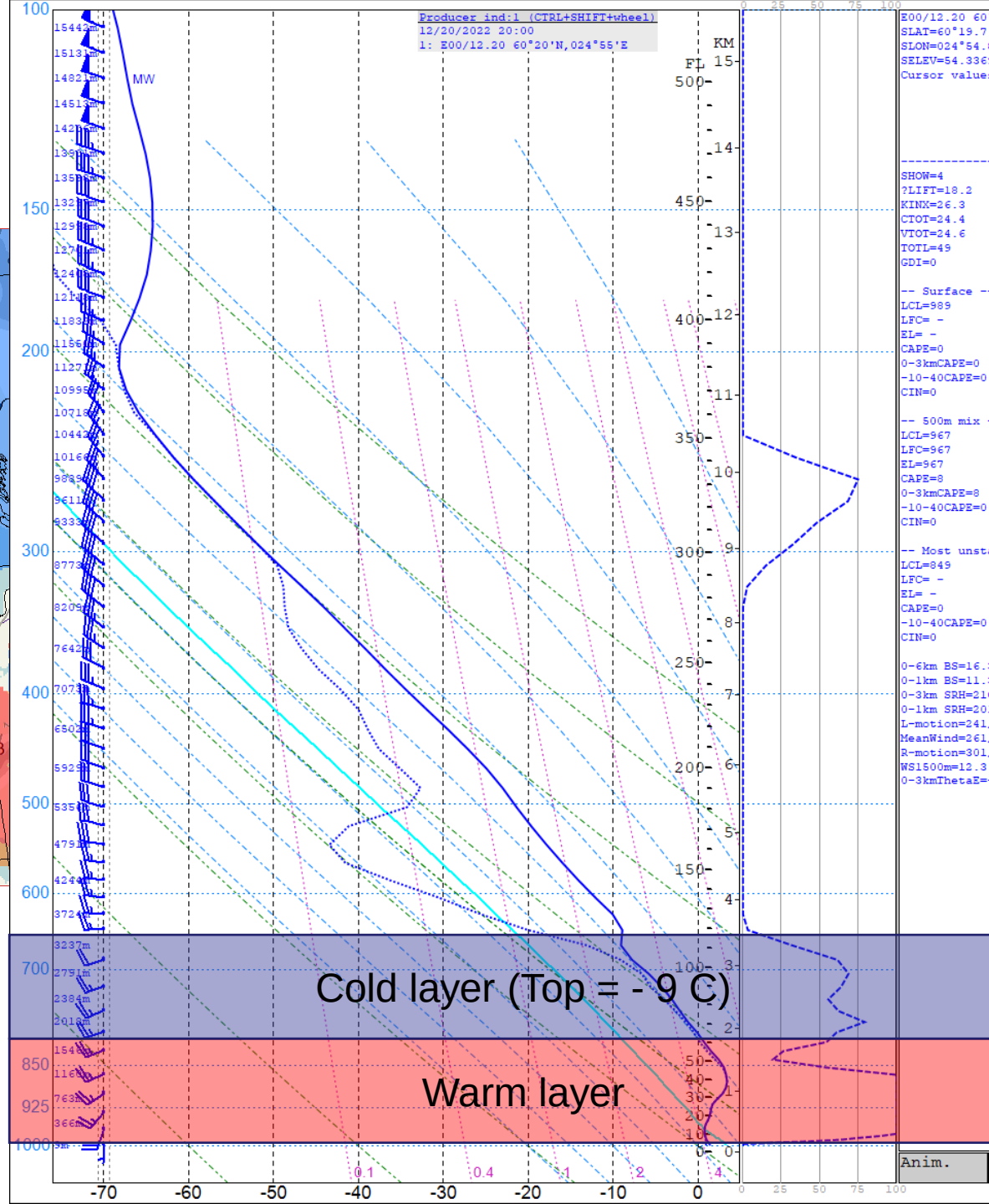

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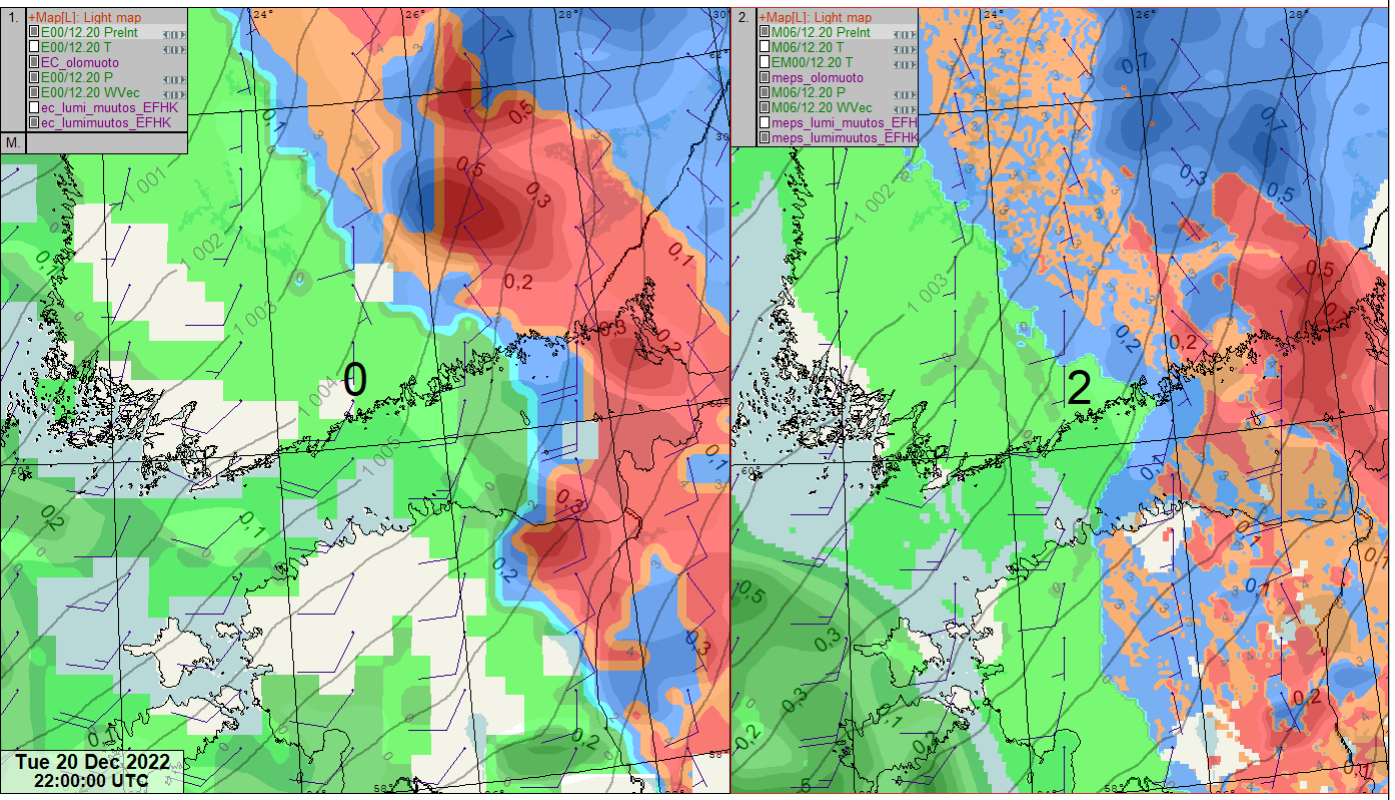

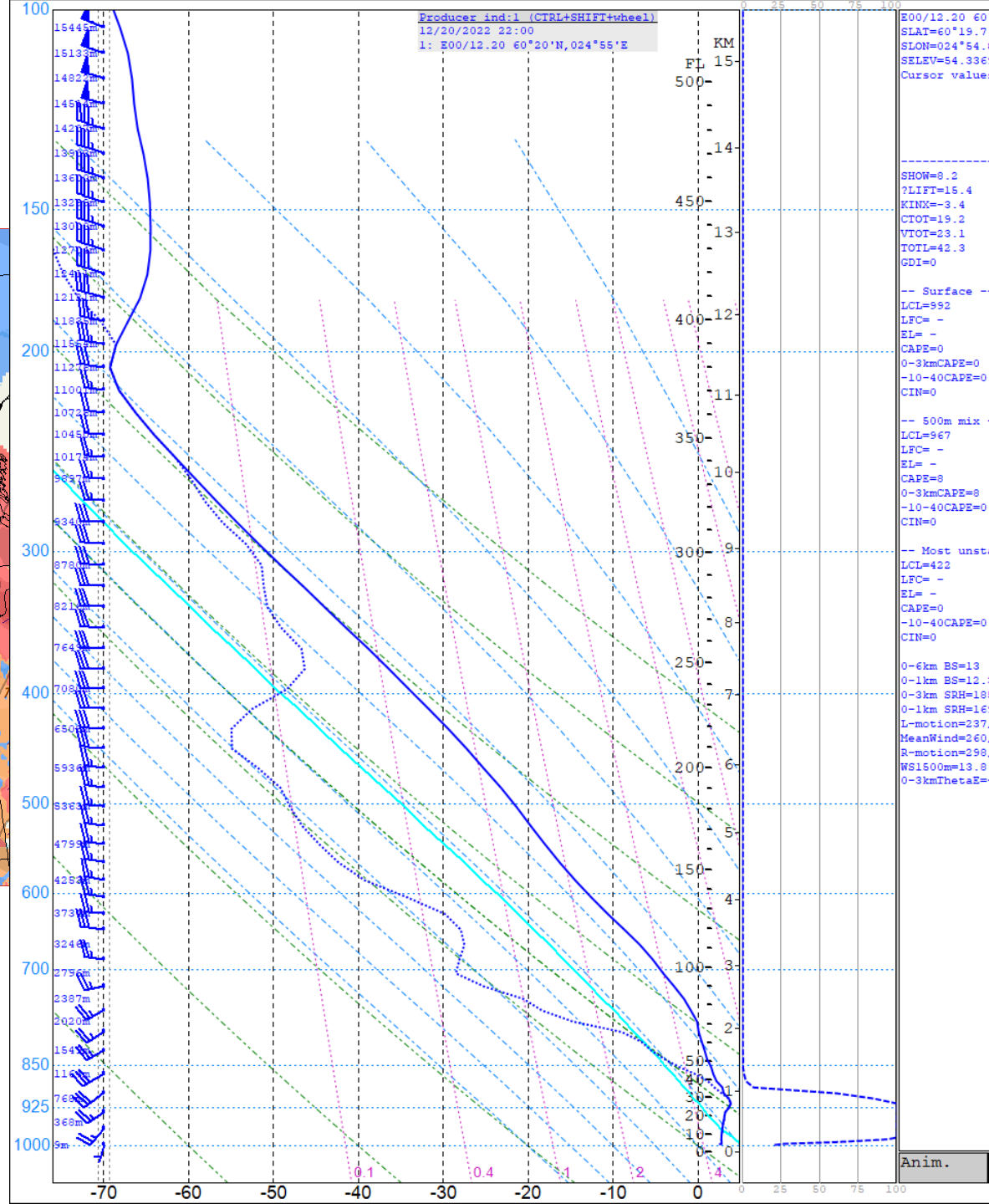

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Forecast 42h in advance
Update on forecast 18h in advance
Weather meeting 16h in advance

Overview 20.12.2022

A warm front is approaching from the southwest on Tuesday (20.12.2022). Light snowfall, freezing drizzle and freezing rain are forecasted to occur during the day. Precipitation is starting during the early morning (approximately between 3 – 6LT). Type of the precipitation is snow and freezing drizzle from the morning till the noon. Intensities for snow and freezing drizzle seem to be mostly weak. Precipitation type is turning into freezing rain during the afternoon (approx. 13 -14 LT) and it can even continue until 17 - 18 LT (worst case). For now, it should be noted, that there are high uncertainties related to the surface temperatures during the afternoon. Especially duration of the freezing rain is uncertain.

Snowfall start time and end time

Light snowfall and freezing drizzle are starting during the early morning, approximately between 3 - 6 LT.

Snowfall and freezing drizzle are turning into freezing rain approximately at 13 - 14 LT. Freezing rain precipitation will end at 17 - 18 LT at the latest. After that precipitation will continue as a rain or drizzle.

Snowfall accumulation

Accumulation for snowfall is 1-3 cm.

Snowfall intensity (cm/h) at peak times (7-9 LT and 14-18 LT)

Tuesday 7-9LT (snow): 0.1 – 0.4 cm/h + freezing drizzle
Tuesday 14-18 LT (freezing rain): 0.1 – 0.4 mm/h

Wind direction, speed, gusts especially at peak times

Tue 7-9 LT: 160 – 180 ° / speed 6 – 8 KT / gusts 12 – 15 KT
Tue 9 -14 LT: 160 – 180 ° / speed 8 - 10 KT / gusts 12 – 16 KT
Tue 14 – 19 LT: 170 – 190 ° / speed 9 - 10 KT / gusts 13 – 16 KT

LVP-probability

LVP probability 0 - 10 % due to low visibility on Tue 03 – 14 LT
LVP probability 10 – 20 % due to low ceiling on Tue 14 – 18 LT
LVP probability 30 – 50 % due to low ceiling/visibility on Tue after 18 LT

Temperature

3 – 14 LT: -2 … 0 °C
14 – 19 LT: -1 … +2 °C

Snow type (wet/dry)

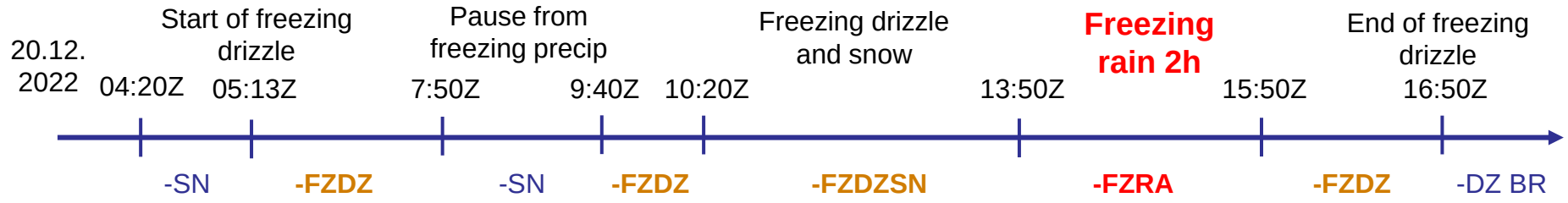
Freezing drizzle and snow between 3 – 14 LT
Freezing rain and rain between 14 – 18 LT
Rain and drizzle after 18 LT

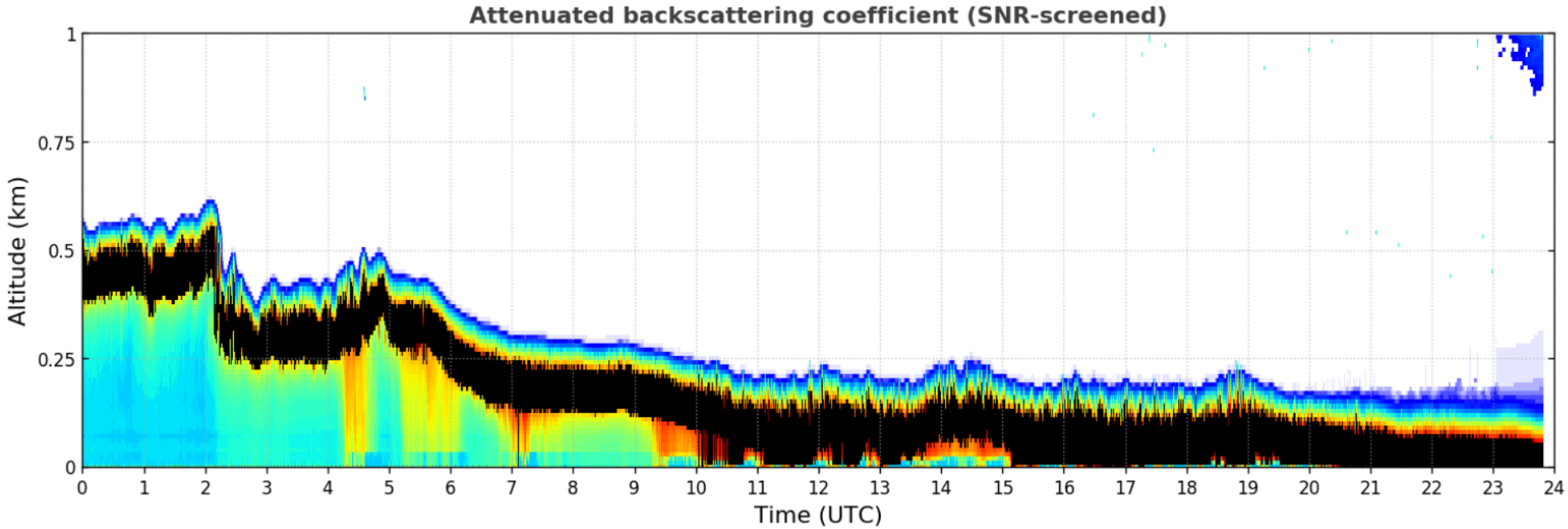
Uncertainty of the forecast

There are uncertainty concerning on the timing of the front arrival. Also, high uncertainties related to surface temperatures which affect to precipitation types, especially duration for the freezing rain. If the surface temperature increases faster during the afternoon, then the duration of the freezing rain is shorter.

Precipitation observations

Precipitation type at Helsinki-Vantaa 20.12.2022 (EFHK:n manual observation/METAR)





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Forecast vs. observations

Parameter	Forecast 18.12.	Forecast 19.12.	Observations 20.12.
Start and end time	Starts: 03-06 LT FZRA: 13-18 LT Ends: 17-18 LT	Starts: 05-07 LT FZRA: 13-22 LT Ends: 20-22 LT	Started: 06:20 LT FZRA: 15:50 – 17:50 LT Ended 18:50 LT
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Summary

Top-down Method

- Estimate the hydrometeors path in the model sounding.
- Ice formation in clouds is based on the cloud temperature:

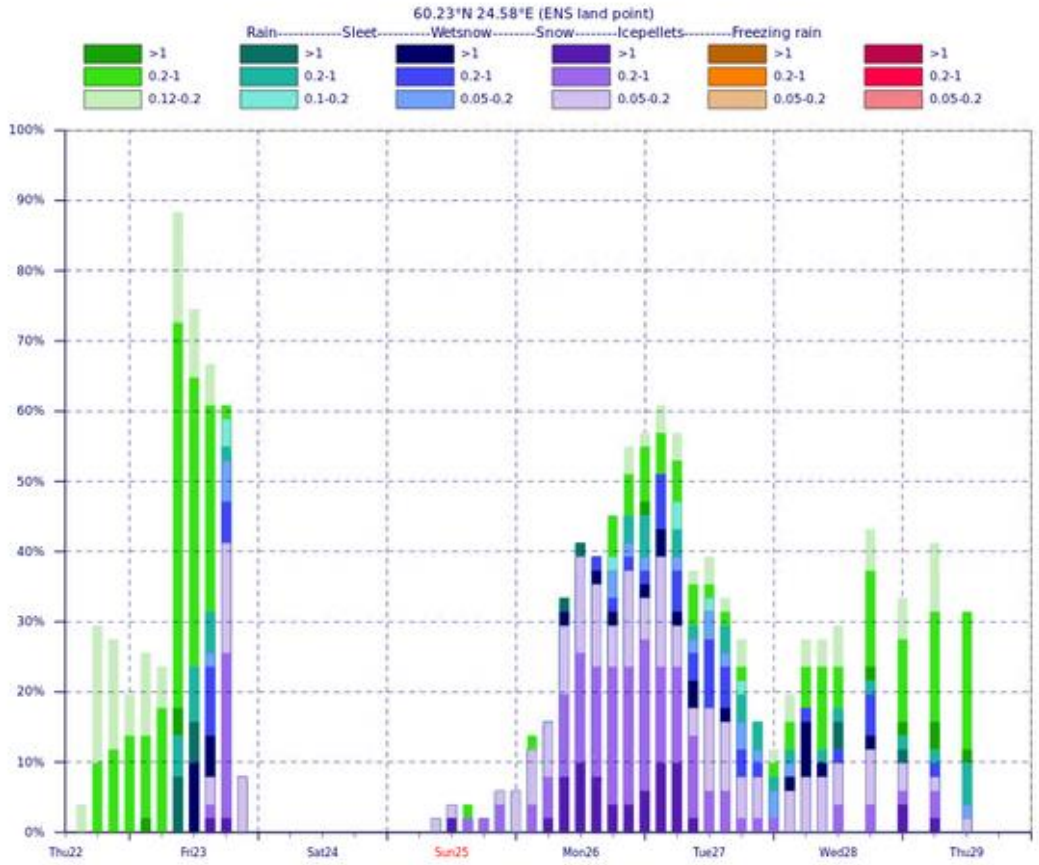
Temperature	Ice formation
> - 4 °C	No ice formation in the cloud
- 10 °C	70 % chance of ice formation in the cloud
- 12 °C	Limit we typically use for ice formation
- 15 °C	90 % chance of ice formation in the cloud
< - 20 °C	Guaranteed ice formation in the cloud

- Couple different layers in soundings:
  - Ice producing layer (ice crystal nucleation/growth)
  - Warm layer (warming/melting)
  - Cold layer (refreezing/contact freezing)

Tips for nowcasting / correcting model

- Follow dewpoint and temperature observations.
  - Compare to model data.
  - Typically, temperature drops slightly once the precipitation starts.
  - Mast-observations if available
- Check latest soundings and possibly AMDARs
  - Compare to model soundings
- Vertical information from radars and ceilometers
  - Precipitation forming layer
  - Melting layer/bright band (Hydro class)
  - Not all precipitation can be seen via radar.
    - Lowest elevation angle is typically at ~2 km altitude at 100 km from radar
- Satellite images
  - Check if cloud top matches model observations
  - Check if the timing matches the model
- Other ground observations for precipitation form (road weather, AWS-metars)
  - Take account the accuracy

Where does uncertainty come from? Timing or route?



- Is it 50 % chance for snow on Monday? As in 50 % of members forecast snow.

Or

- Is it 100 % of members forecasting snow, but 50 % forecast snowfall in morning and 50 % forecast snowfall in the evening.
- Can’t say from this diagram alone.
- Answer can often be found in the accumulation forecasts.

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Thank you

Any questions?