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Problems in satellite production caused by high latitudes and some solutions for the problems

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2.2.2023 Eumetrain Event Week

Aviation weather forecast in Northern Finland

Our office is located in Rovaniemi Airport, Lapland. We produce aviation weather products for Northern Finland, approx. latitudes between 63 º N - 71 º N

- Lots of civilian charter flights during the winter months, especially near Christmas.
- Finnish Air Force, Finnish Border Guard, Emergency helicopters…

Our products:

- TAFs, manual METARs
- Products for civilians: Low level forecasts, avalance warnings, 24h phone service
- Products for military purporses / authorities: tailored aviation weather products with 24h phone service (details classified)

This presentation

Problems caused by high latitudes in satellite production:

- Limb cooling
- Parallax shift
- Low Sun elevation angle
- Blurring

Some products that help counter these problems:

- The obvious ones (Models, soundings etc.)
- More advanced ones

Limb Cooling Effect

- The limb-cooling is a result of an increase in measurement (optical) path length of the absorbing atmosphere as viewing zenith angle increases

- Major absorbing variables are water vapor, ozone and carbon dioxide.

- Satellite instrument IR measurements are colder at locations that are far from sub-satellite point (nadir). This affects to RGB composite interpretation -> The color interpretation of the water vapor RGB composite images are changed.

Limb Cooling Effect

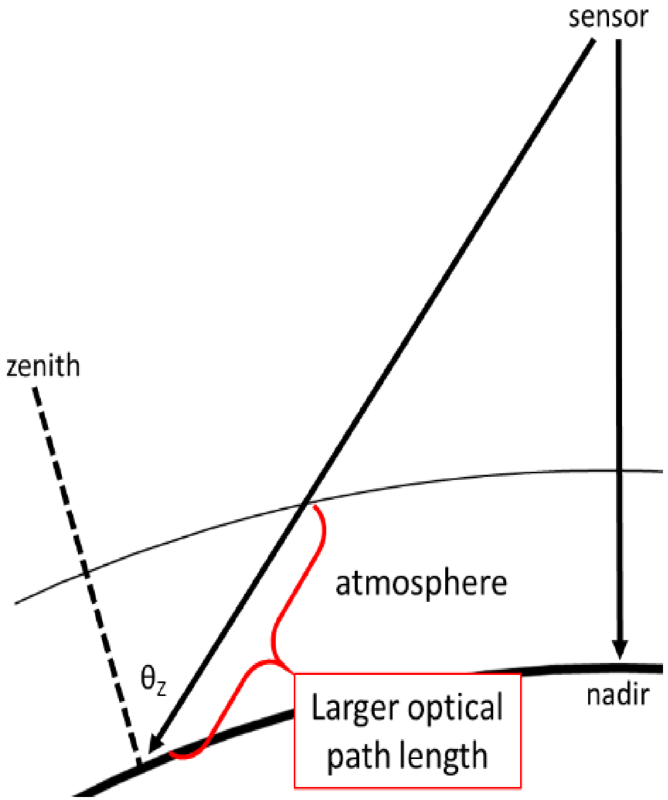


Figure 1. As the satellite scans from nadir to the limb, the optical path length of the absorbing atmosphere increases, resulting in limb-cooling.

Limb Cooling Effect

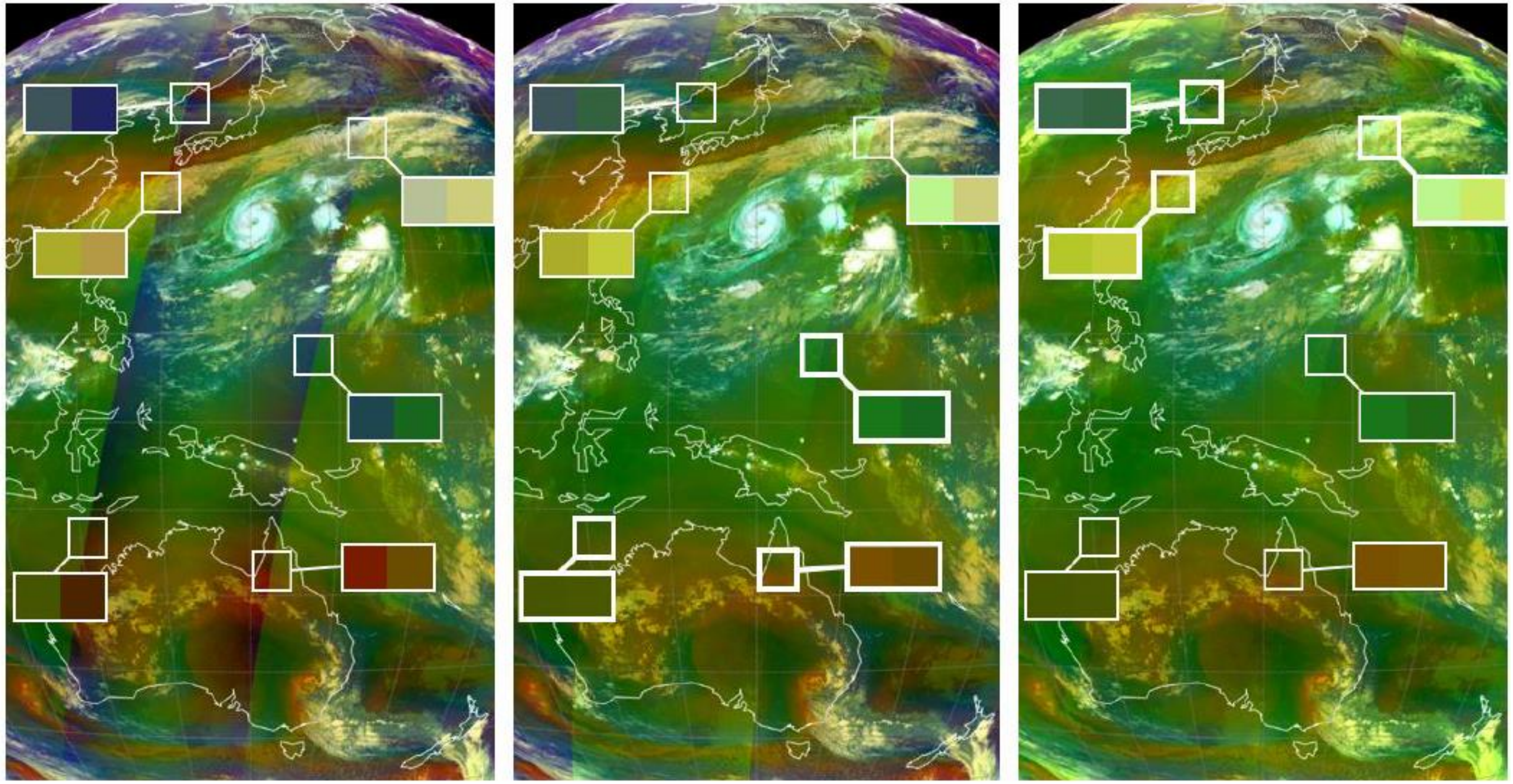


Figure 6. 1640 UTC 21 October 2015 (left) uncorrected Aqua MODIS and uncorrected AHI Air Mass RGB, (center) limb-corrected Aqua MODIS and uncorrected AHI Air Mass RGB, and (right) limb-corrected Aqua MODIS and limb-corrected AHI Air Mass RGB. Color insets compare the RGB coloring between the MODIS and AHI.

Parallax Shift

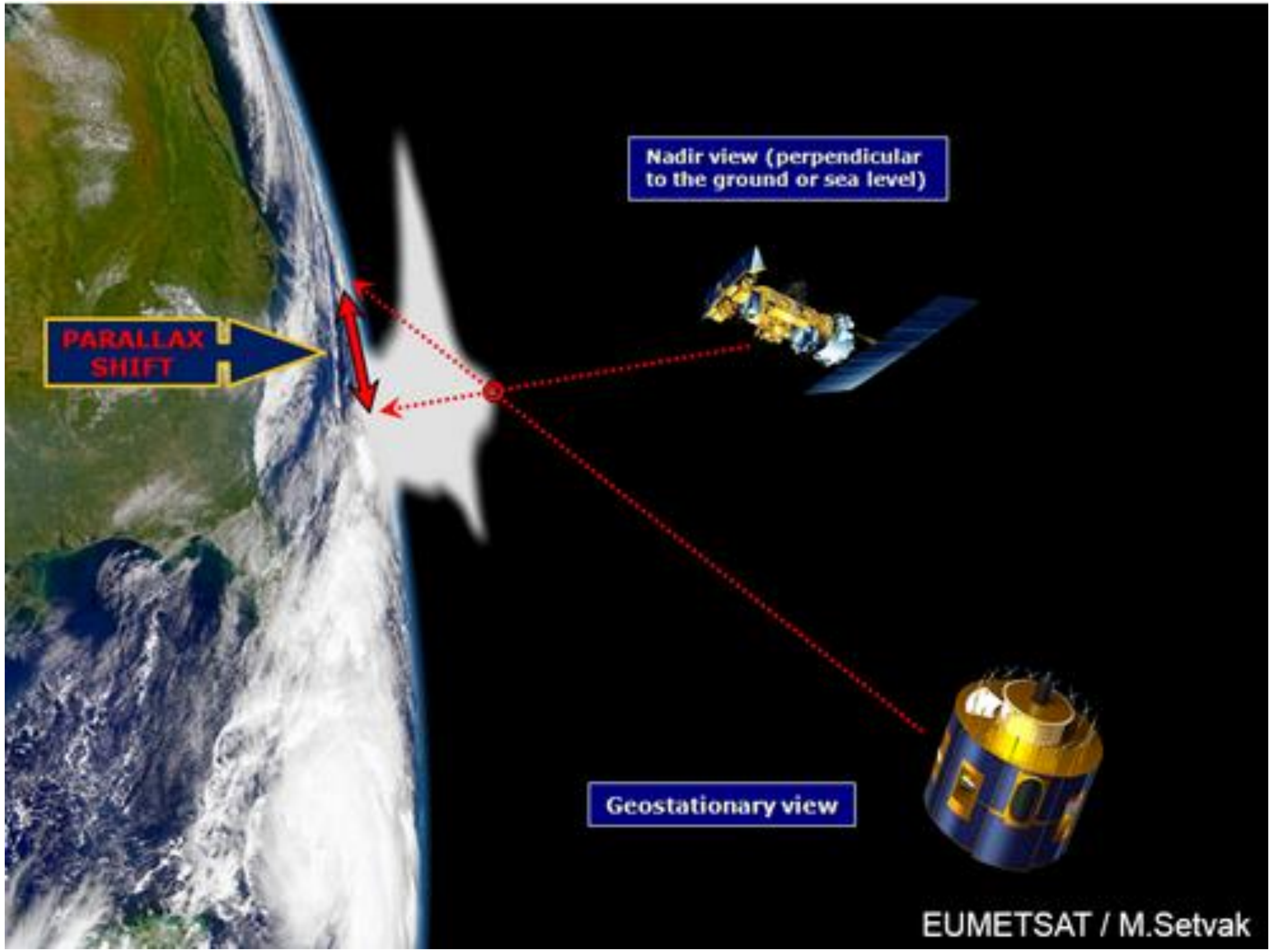
- When satellite viewing angle is away from the sub-satellite point (nadir), an object’s position is shifted. Displacement grows more quickly with increasing distance from the nadir.

- At very slated view, satellite actually measures the side of clouds rather than top.

- Affects both Geostationary and polar satellites.

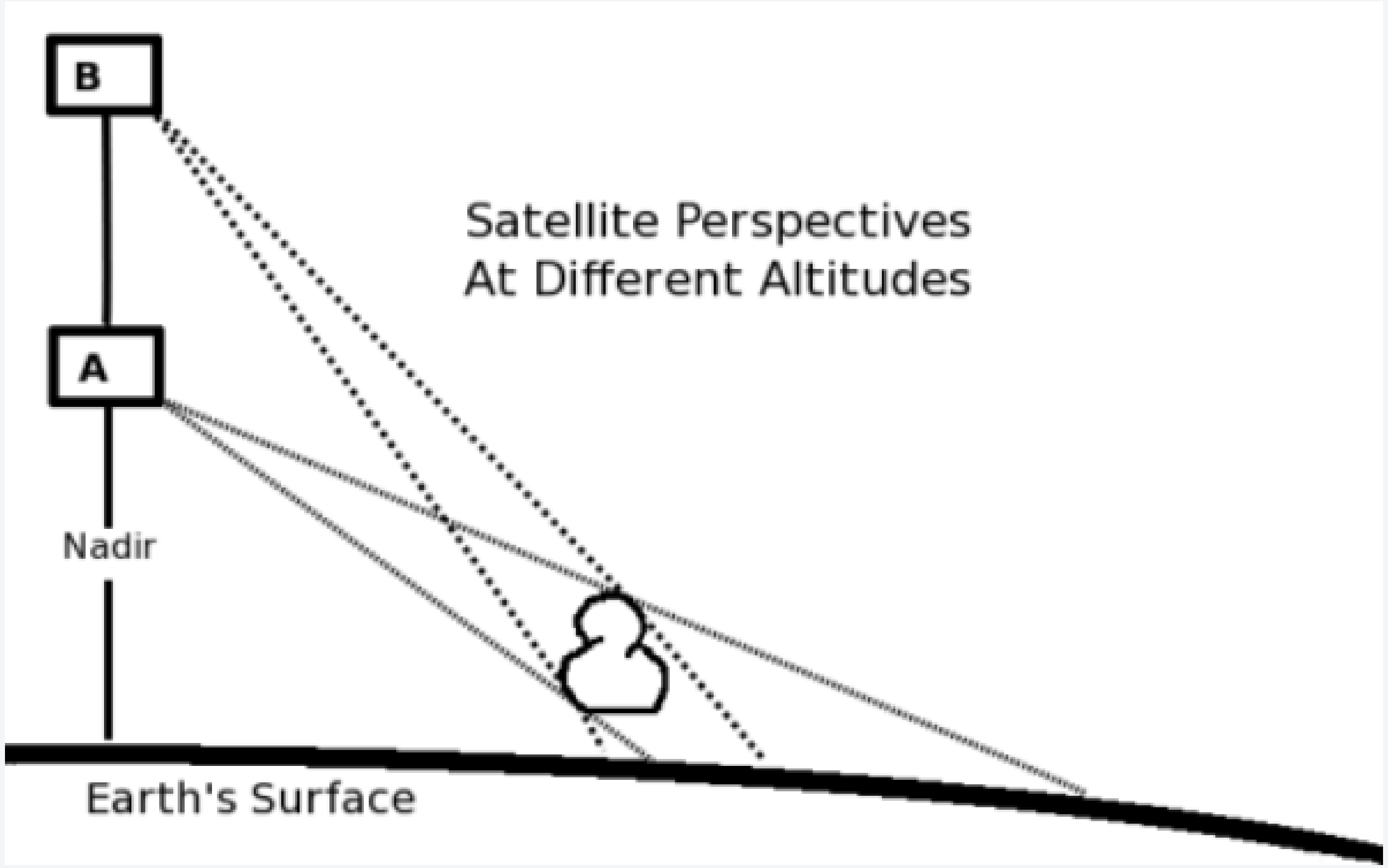
- For polar satellites the viewing angle and parallax displacement grows more quickly with increasing distance from nadir.

Parallax shift



Source: https://convectivestorm.blogspot.com/p/parallax-shift-effect.html

Parallax shift



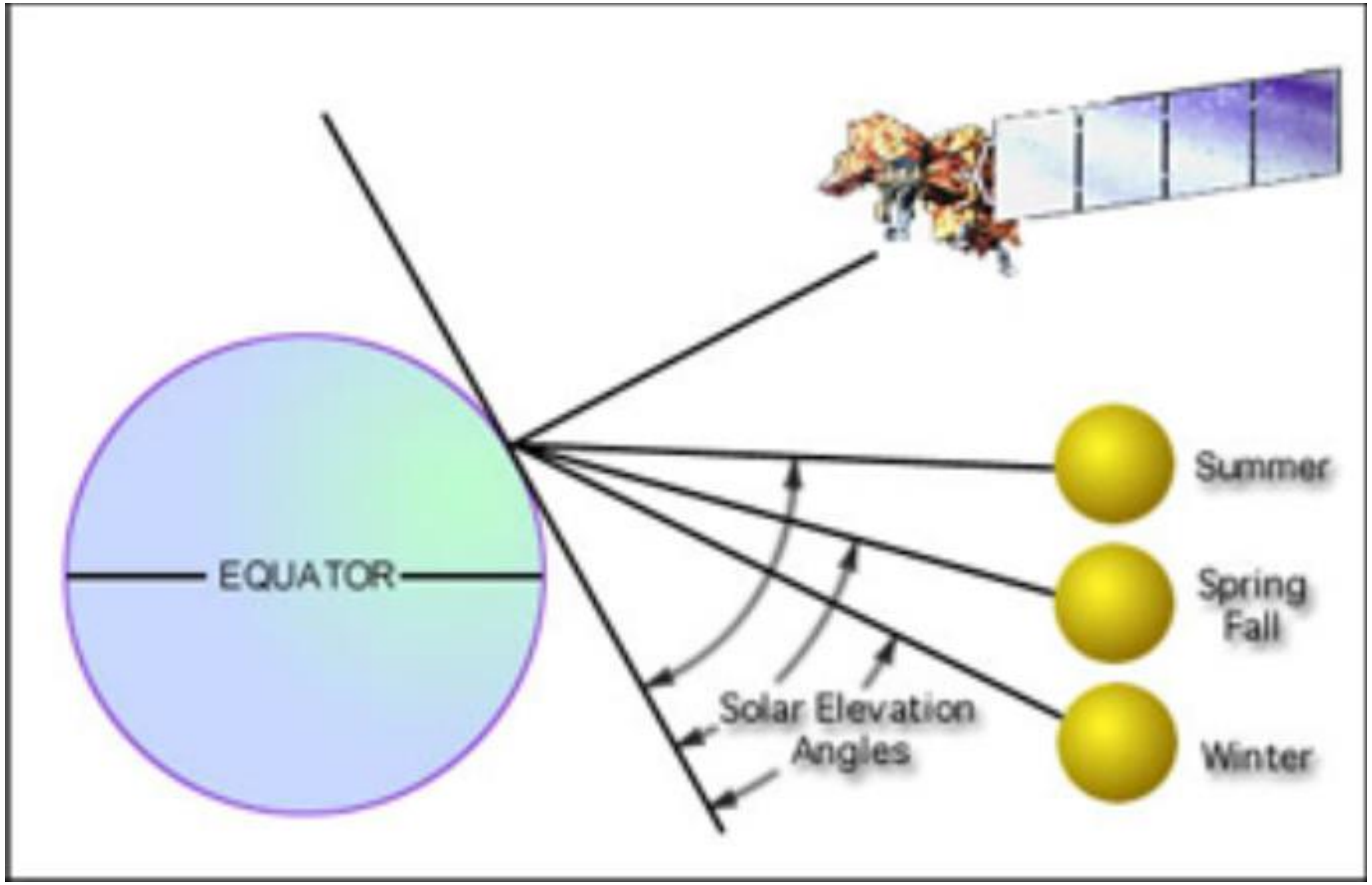
Low sun elevation angle

- Geostationary satellite viewing angle does not change with time because satellite is situated in a fixed location. In the case of polar satellite, viewing angle changes as satellite moves along its orbital path.

- The solar and satellite viewing directions influence significantly on satellite measurement when sun elevation is low. This affects the calculated RGB composite so that the same composite could look very different for polar satellites compared to geostationary ones.

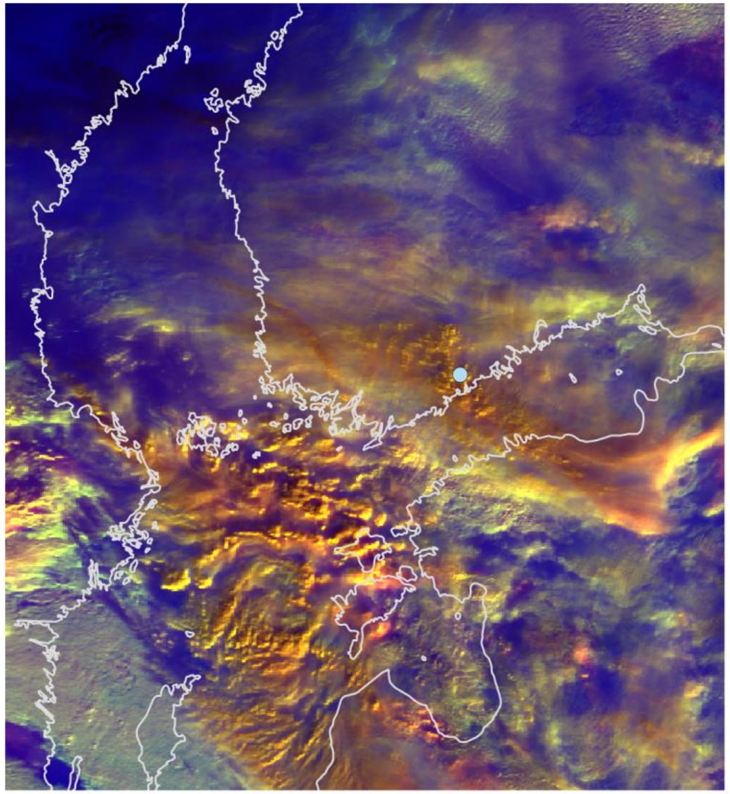
- Geostationary satellite measurements are more often saturated than polar satellites due to unfavorable sun-satellite geometry in winter.

Low sun elevation angle

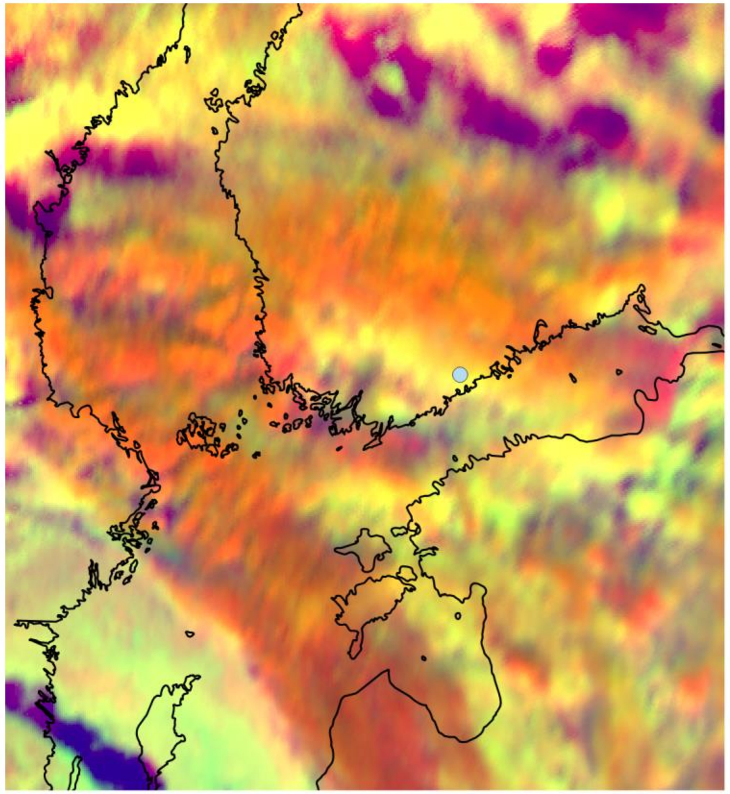


Source: https://www.usgs.gov/media/images/earth-s-axial-tilt-and-seasonal-effects

Low sun elevation angle



Observed Day Microphysical RGB from AVHRR at 11.12.2021 08:16 UTC



Observed Day Microphysical RGB from SEVIRI at 11.12.2021 10:00 UTC

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Blurring

- In ideal world, there should be just one exact value for radiance coming out from a pixel

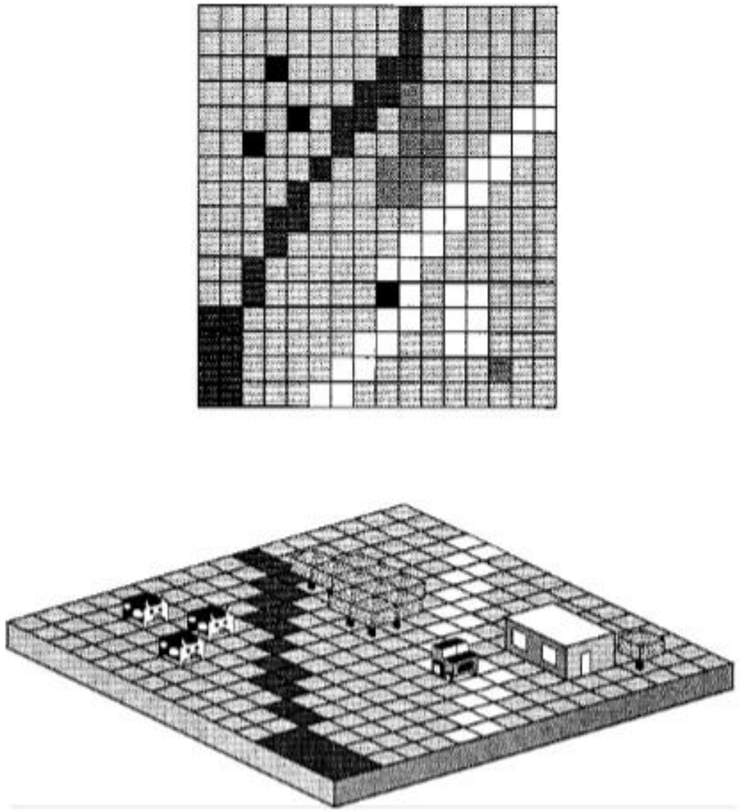


Figure 2. Idealised objects exactly occupying whole pixels and with uniform horizontal top surfaces (Fisher 1997).

Blurring

- However, in reality the radiance coming out from the pixel is not homogeneous

- Part of the radiance comes from the surrounding pixels.

- This energy from outside the pixel introduces the blurring influence, which degrades the image quality.

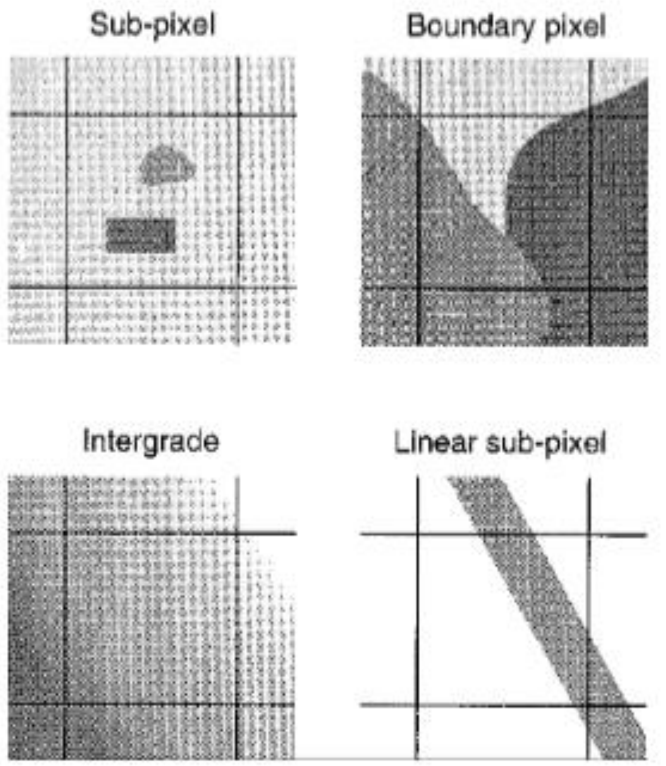
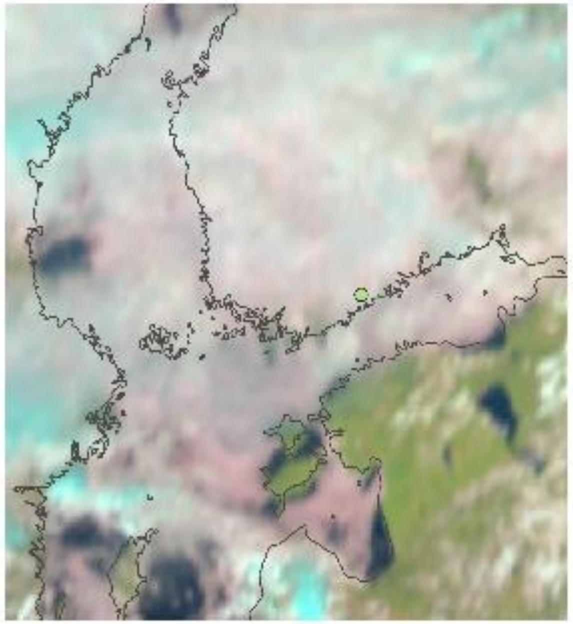
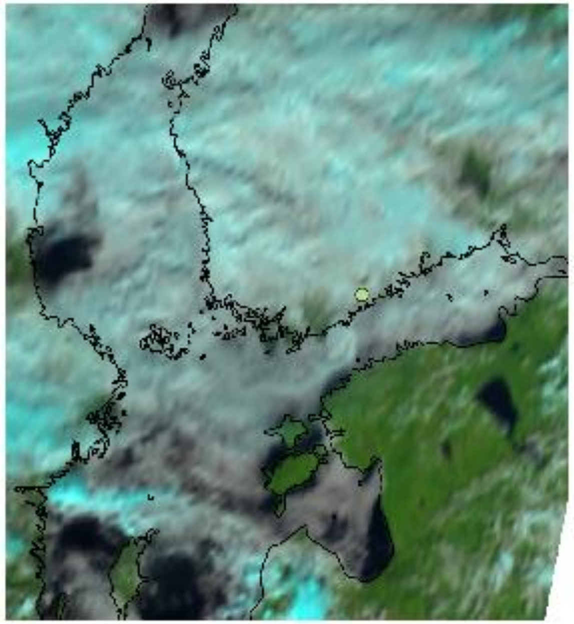


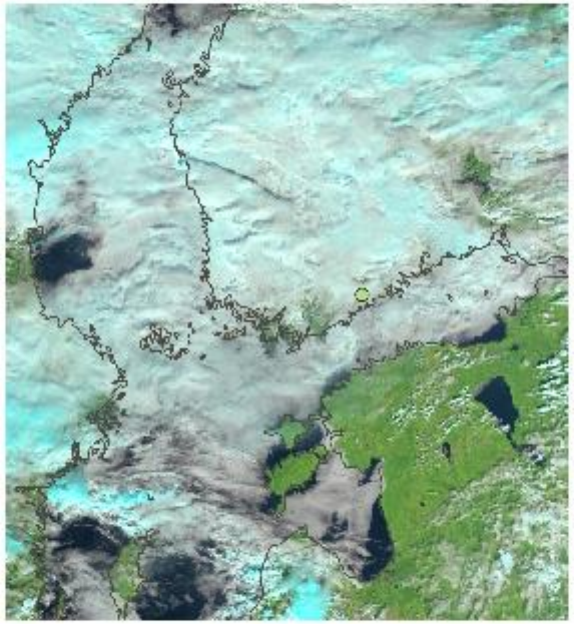
Figure 3. Examples of mixed pixels (Fisher 1997).

Blurring

Simulated SEVIRI-image 11.9.2021 12 UTC (Natural colors RGB)







Seviri (res. 3km)   Simulated Seviri with VIIRS data(res. 3km)   VIIRS (res. 1km)

What information are we missing without satellites?

- Overall cloudiness
- ~Cloud top
- ~Cloud thickness
- ~Supercooled water / ice in cloud

Some tools to gather this information elsewhere

The obvious ones:

- METARs and other observations (traffic cameras etc.)
- Soundings
- Models
- Radars

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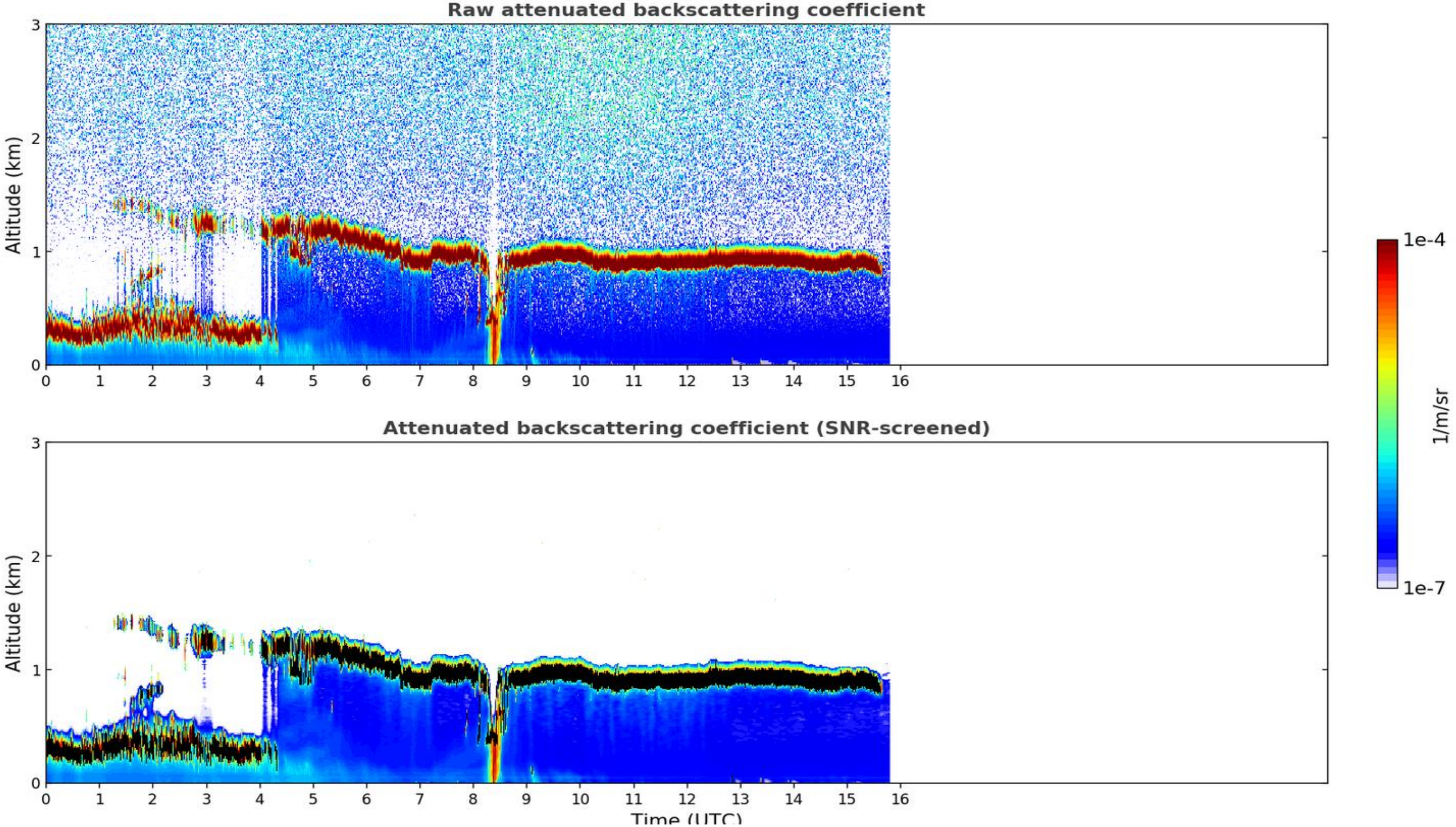
Advanced tools to gather the missing information

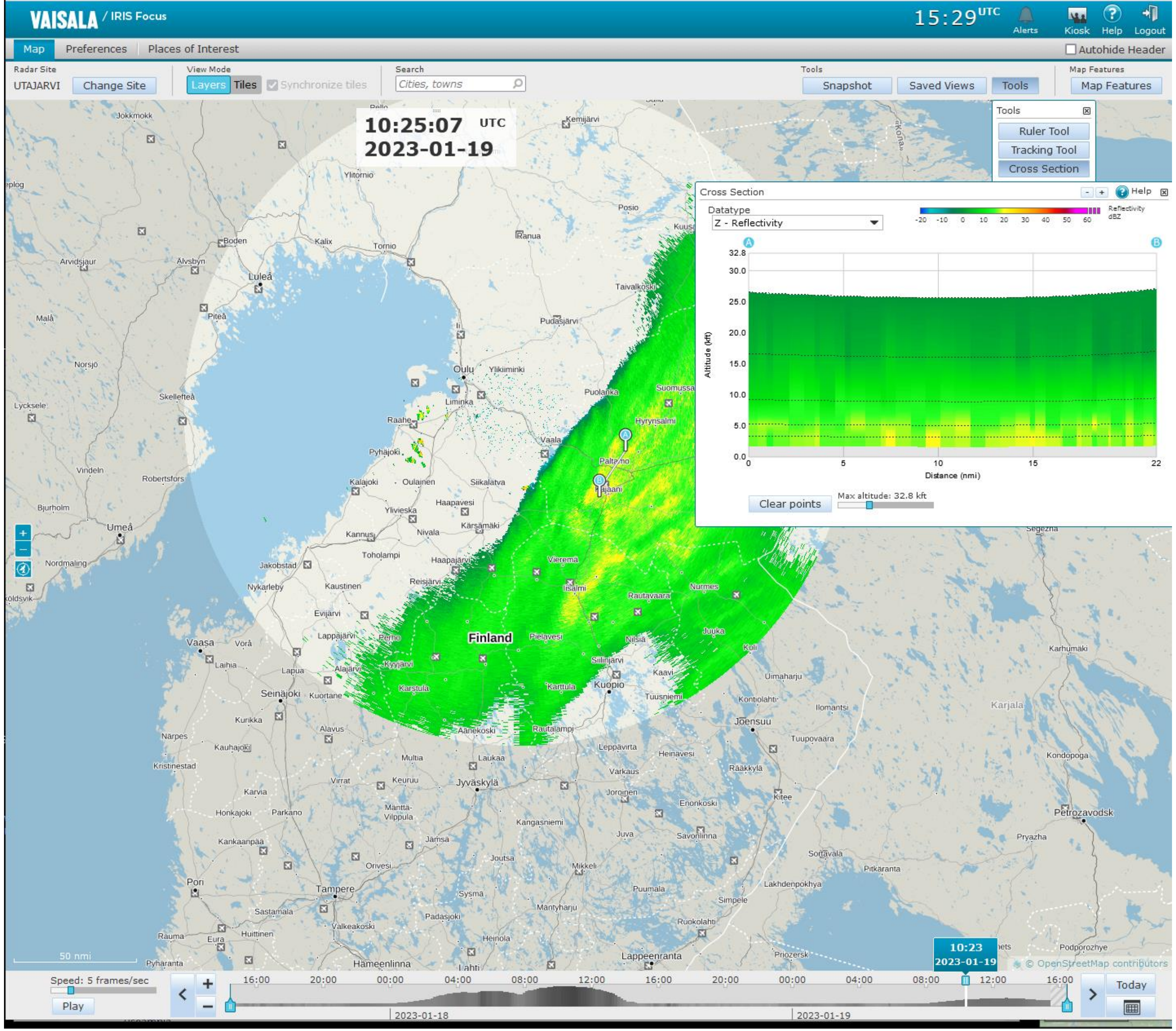
- Lidar ceilometers for low level clouds
- Radar cross sections

A quick demonstration of these tools:

19.1.2023. at Rovaniemi Airport (EFRO) and around Kajaani airport (EFKI): A normal winter day in Northern Finland. An occluded front with snowfall and thick layered cloud going over the area, elsewhere low level clouds.

Rovaniemi: 19/01/2023





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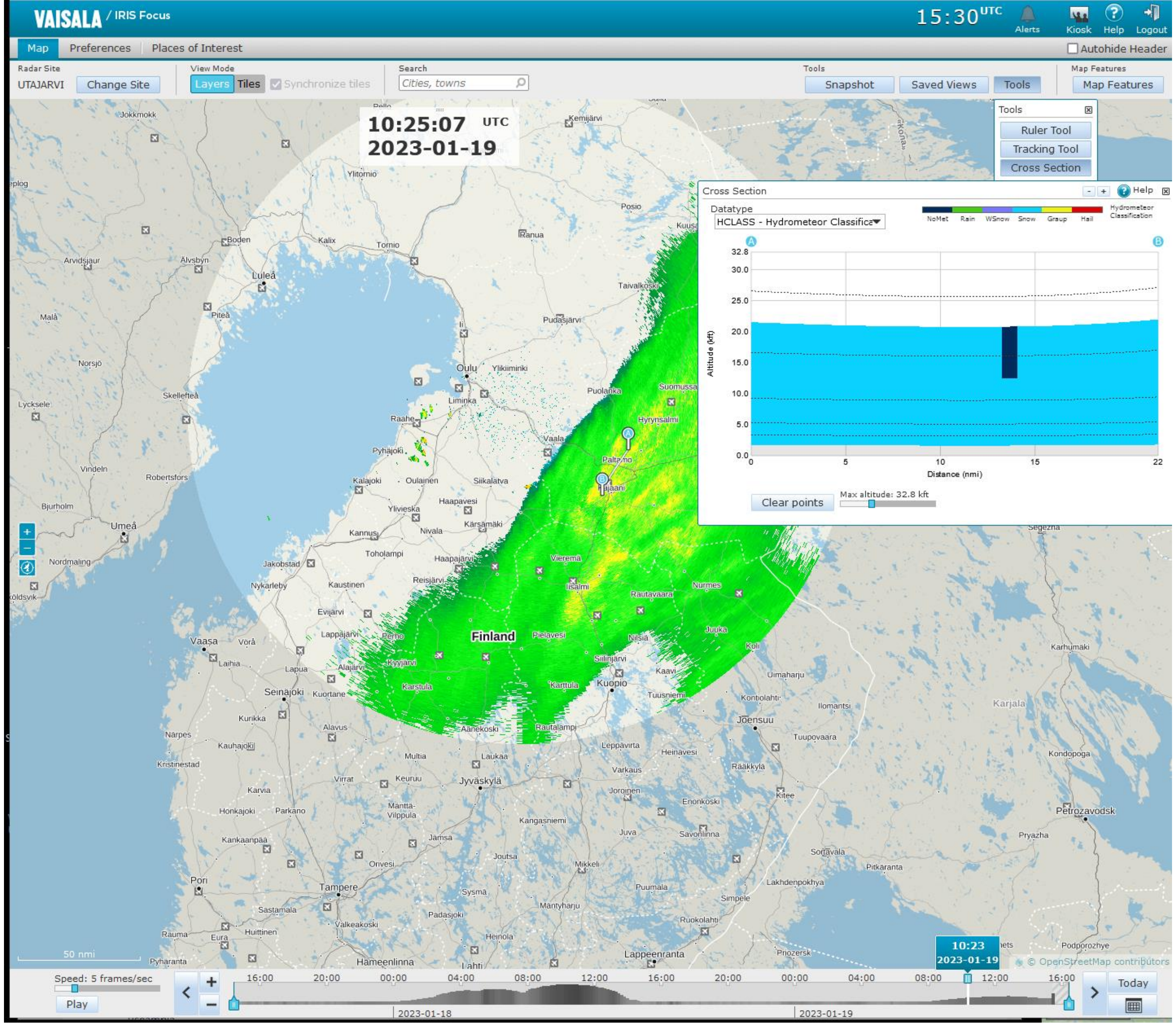

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Thank you!

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