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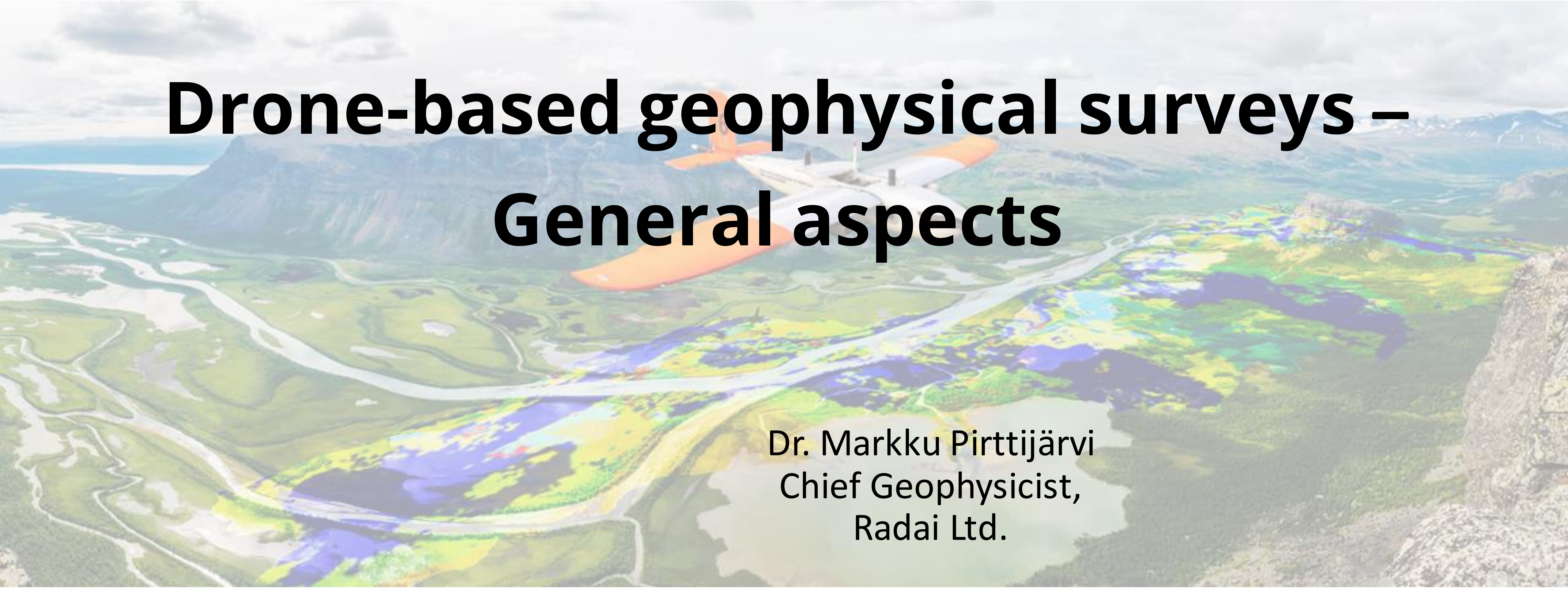

Drone-based geophysical surveys – General aspects

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Contents

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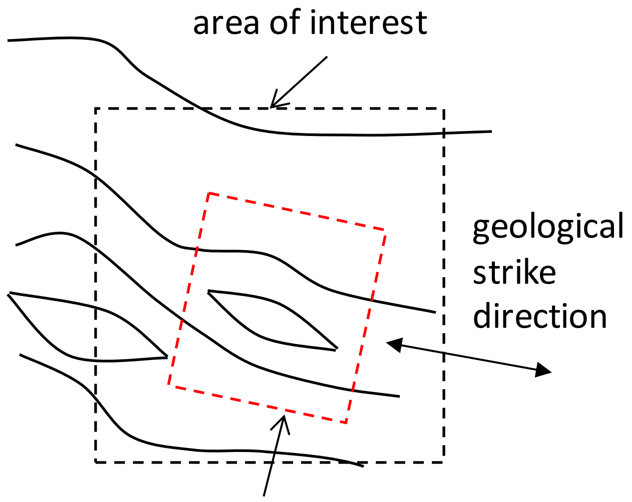
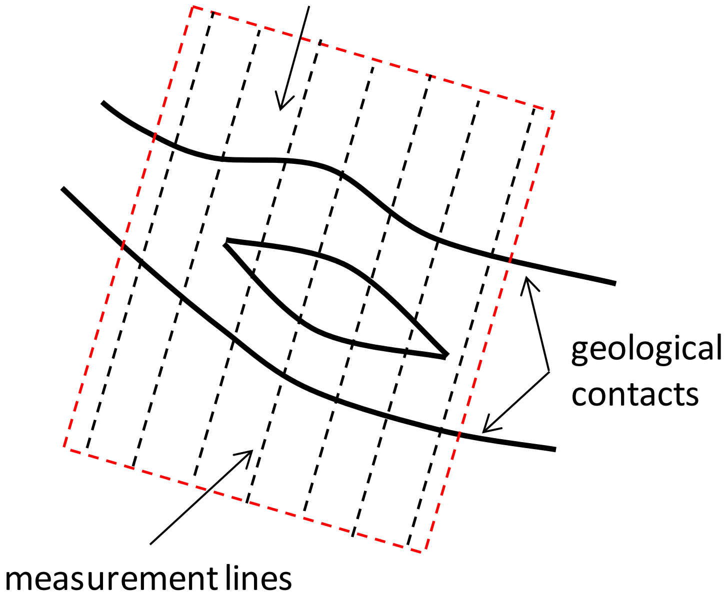
UAV survey design basics

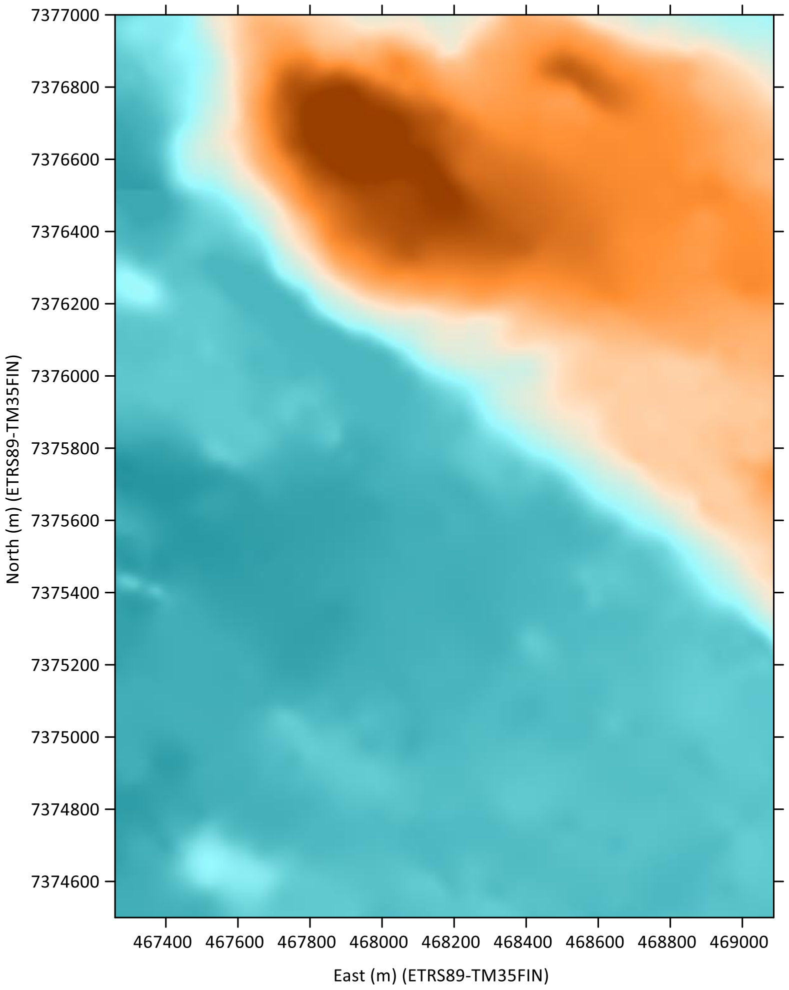
- Geophysical surveys are commonly made along straight profile lines evenly spaced inside the survey area polygon.
- The geographical location of the survey area is defined by the coordinates (x,y or lon/lat) of its corner points as given by the client.
    - Polygons are typically in GIS file formats, such as ESRI SHP, Mapinfo MIF/MID, Google KML.
    - Survey area (and line length) should be large (and long) enough to capture the decaying anomalous geophysical field.
- The location and the direction of the lines are defined by the line (X,Y) origin and azimuth (rotation angle) and line separation (LS).
- The lines are oriented perpendicular (90°) to the geological strike direction.





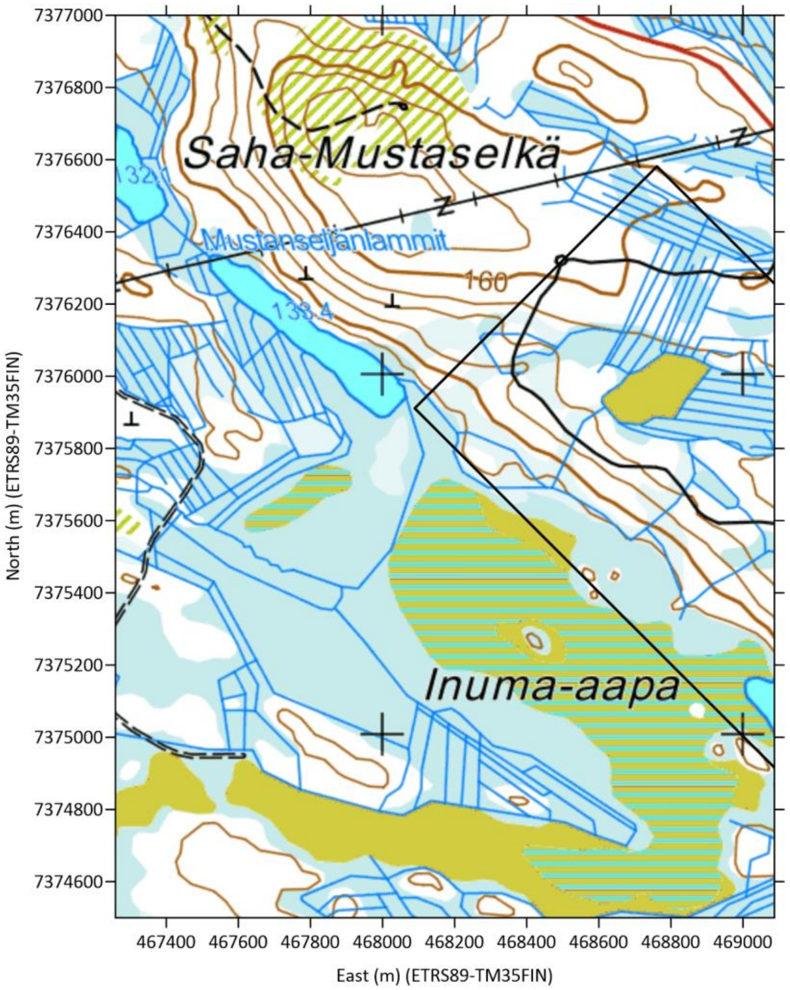
Digital elevation maps (DEMs)

- DEM allows drones to follow the terrain topography (i.e., to keep ”constant” height from the ground)
- Since waypoint separation is 100-400 m, grid sampling does not need to be very dense; 10-20 m cell size is a good compromise between accuracy and file size.
- National Land Survey of Finland has a free service where the DEM data can be downloaded for free (ASC & GeoTIFF).
- **Important**: DEM must be up to date (problems near mines).
- DEMs are also needed in data post-processing.
- Hint: ASTER3 and ALOS are free satellite-based global DEM models, the quality of which is a bit ”dubious”. For example, NASA’s Earthdata service or directly QGIS Mapzen global DEM.



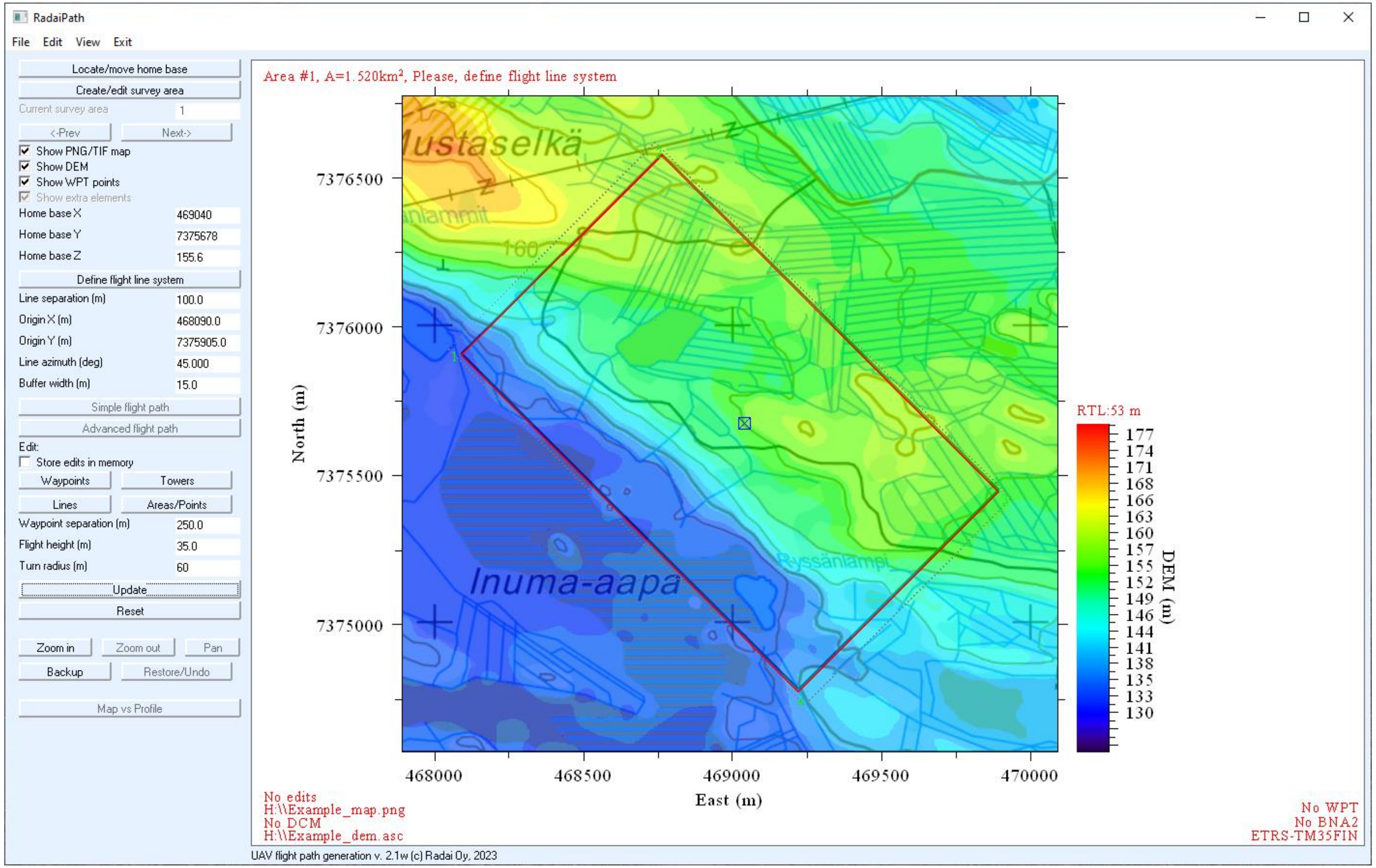
Digital background maps

- Background (topographic) maps are used in drone surveys to help:
  1. Flight planning (e.g. locating GSM towers, wind power plants, inhabited houses, restriction areas)
  2. Orienteering (e.g. finding the roads to access the area and finding good places for flight operations)
- For example, *RadaiPath* software uses PNG and TIF images with associated ESRI world files (PGW or TFW).
  - National Land Survey of Finland provides a free service where (topographic and orthophoto) maps can be downloaded for free (https://asiointi.maanmittauslaitos.fi/karttapaikka/).
- Hint: QGIS can be used to save Google's satellite maps.



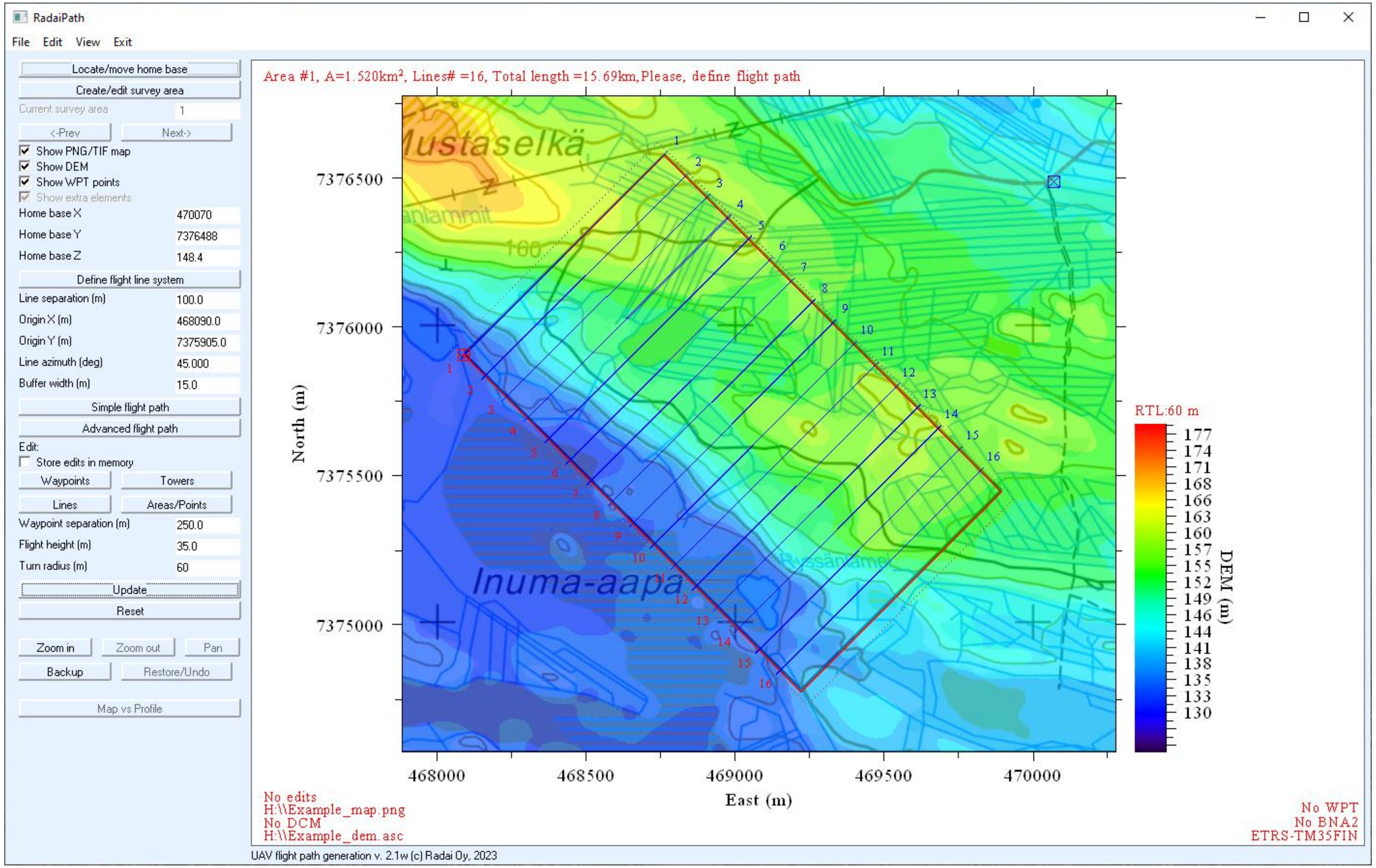
Flight path generation with RadaiPath (part 1)

1. Set correct coordinate reference system (CRS)
2. Open DEM topography (ASC)
3. Open background map (PNG/PGW)
4. Open survey area polygon (KML or BNA)



Flight path generation with RadaiPath (part 2)

1. Define line separation
2. Define flight line origin(red box) and line direction/azimuth (as given or using mouse)
3. Define home base location (blue box) where the flights start and end (as given or using mouse)

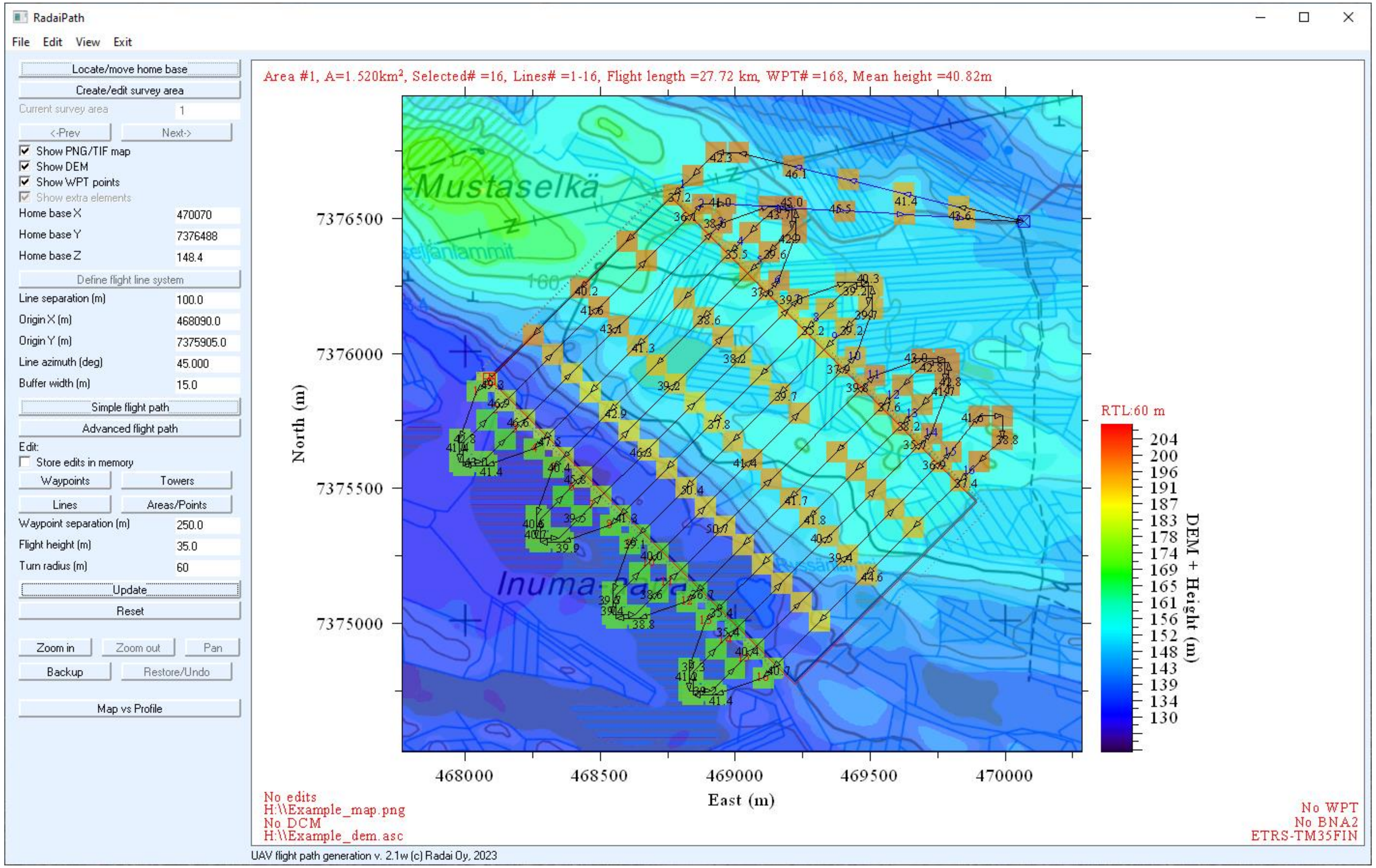


Flight path generation with RadaiPath (part 3)

1. Define waypoint separation, flight height and turn radius
2. Create flight path by giving index number of the first and last line

Note the waypoints added in the turns.

Also note the resulting flight length (28 km) and height (41 m) which is always bigger than nominal height (35 m).



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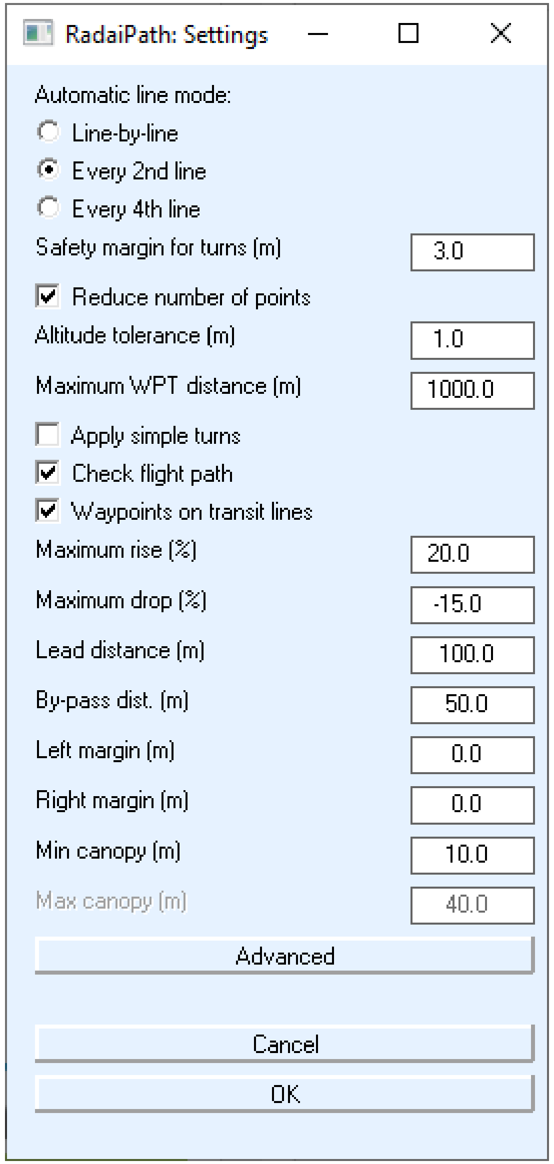
Flight path generation (part 4)

Extra parameters make the drone to:

- Fly either line-by-line, every second line or every 4th line (depends on line separation and turn radius of the drone).
- Prevent flight height getting lower in turns.
- Use maximum rise and drop angle (in percents) during the flight. In practice, this makes the flight height increase over the steepest slopes of a hill. It also changes flight height when going uphill or downhill.
- Use of lead and by-pass waypoints ensures that drones fly straight when entering the start of flight line.
- Digital canopy model (DCM) is experimental.



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Flight path generation with RadaiPath (part 5)

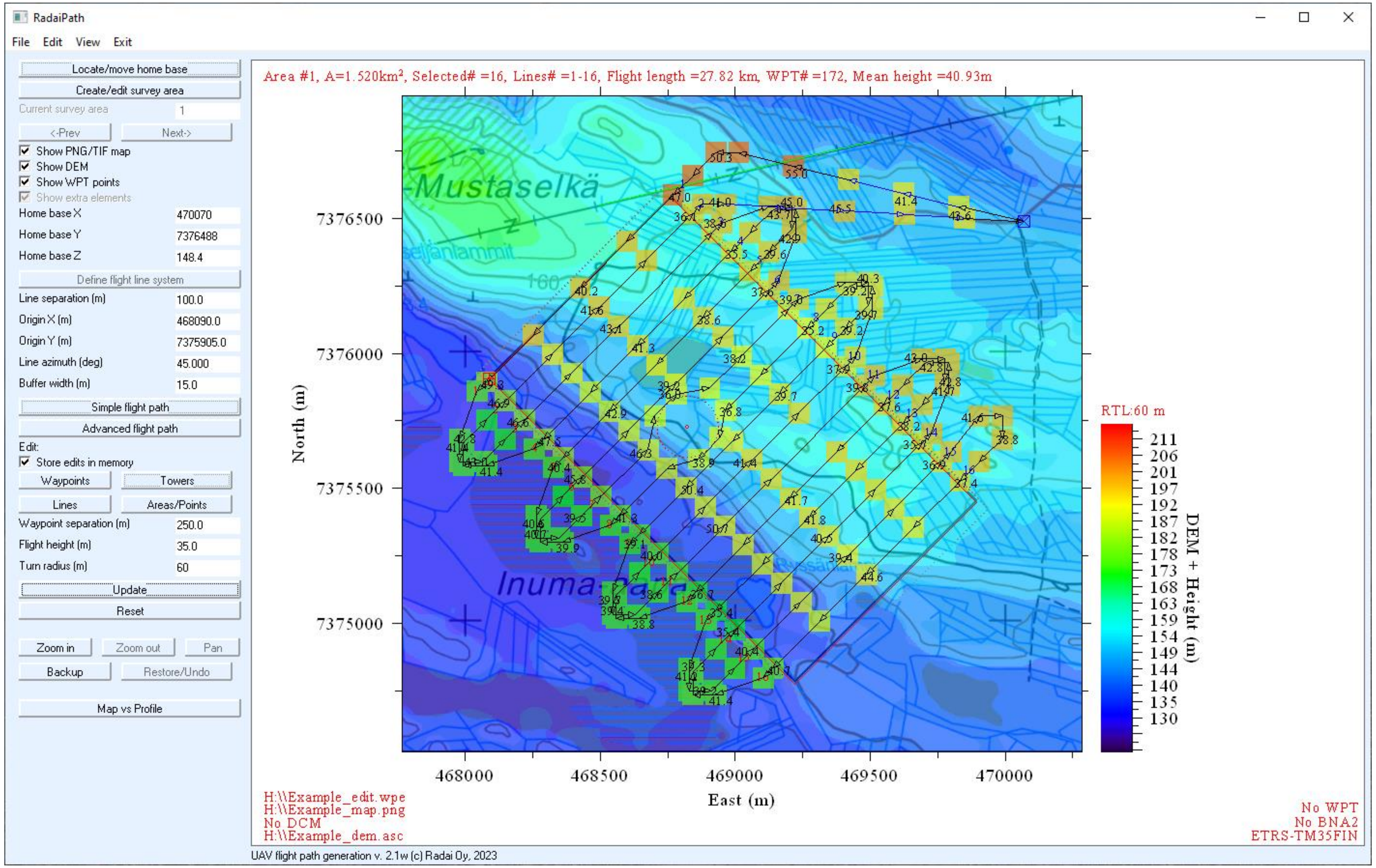
Editable elements are:

a) points to fly around (e.g. towers),

b) lines to fly over at higher altitude (e.g. powerlines),

c) areas to fly higher or lower than the nominal height (e.g. swamps or lakes).

In addition, waypoints can be moved, deleted or created interactively.

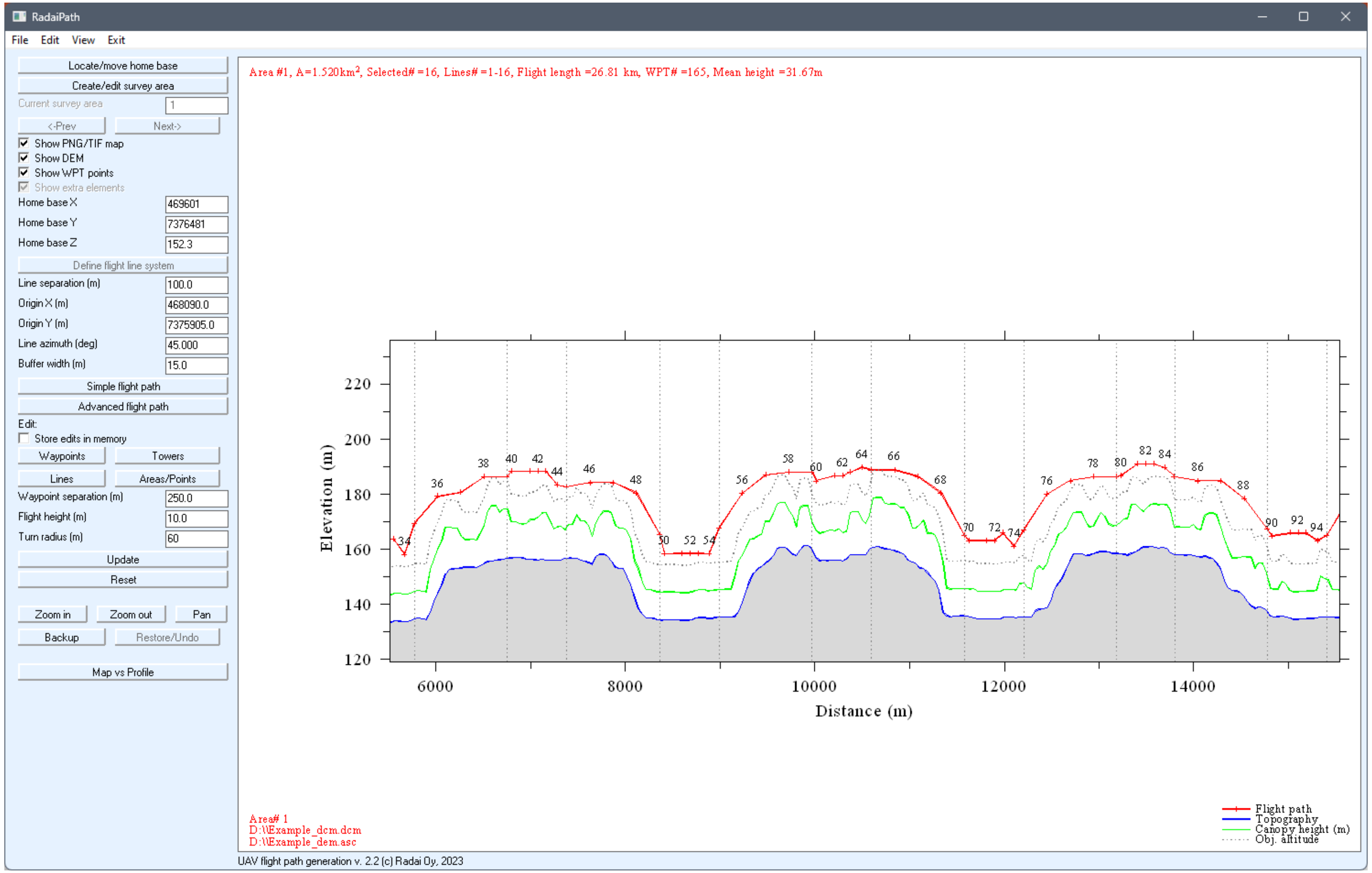


Flight path generation with RadaiPath (part 6)

Checking the flight path:

In profile view, make sure that the flight height (red curve) does not get lower than nominal flight height (dotted curve).

Canopy model, DCM (green curve) can be used to reduce the mean flight height (41→32m).



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Flight path generation with RadaiPath (part 7)

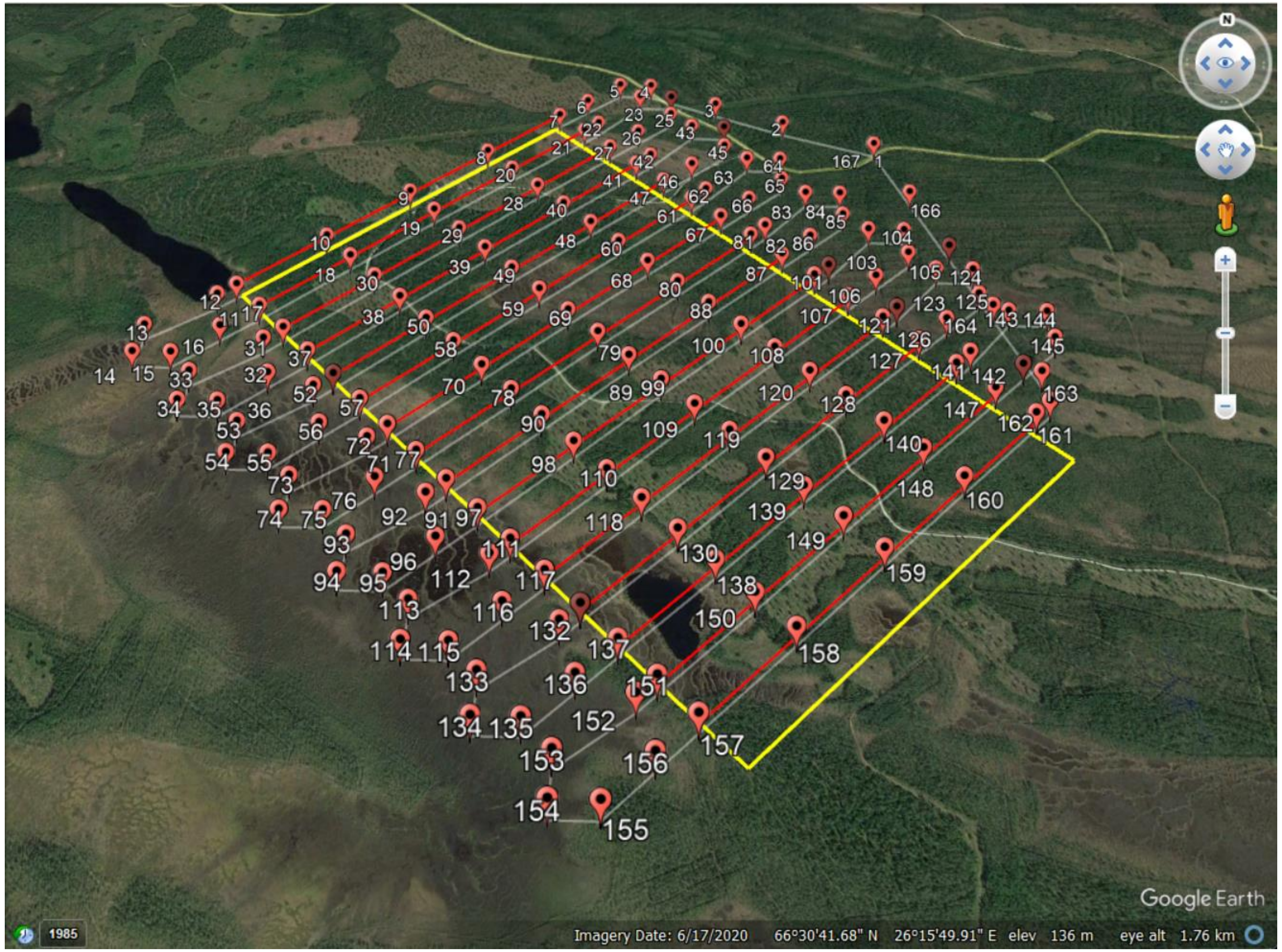
Checking the flight path:

In map view, check the length and edit individual waypoints near houses and towers if needed.

Once the flight path is ready it is saved in

1) RadaiPath’s own WPT format
2) Mission Planner TXT format (ArduPilot/Pixhawk autopilots)
3) KML format (for safe-keeping)

In Google Earth the plans can be checked for correct coordinates



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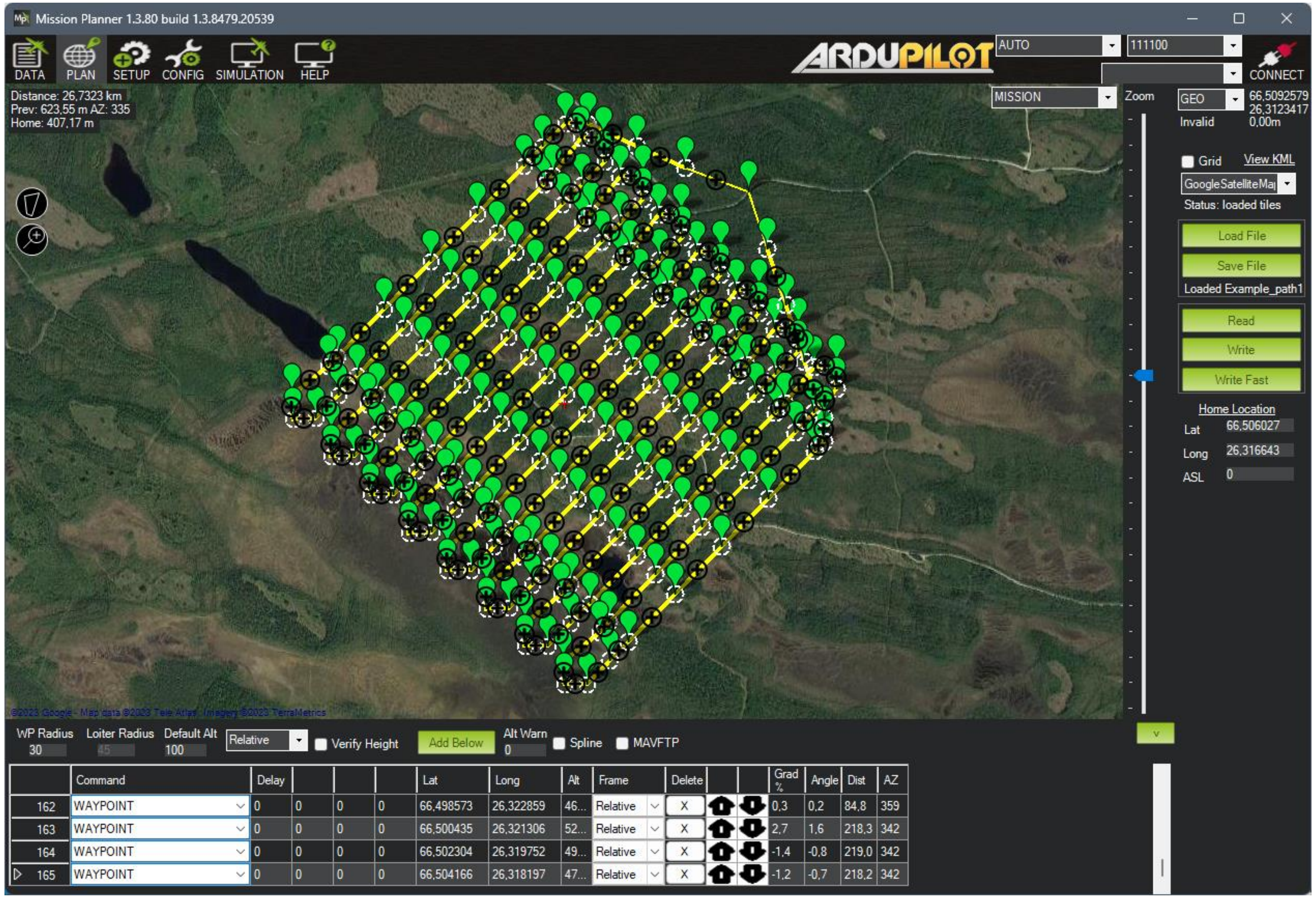
Flight path generation with RadaiPath (part 8)

In Mission Planner, the plan is

1) First read from hard disk,
2) Then uploaded onto autopilot,
3) Then downloaded from autopilot back to Mission Planner to verify that it was correctly written on it.

If needed, individual waypoints can be edited and flight height adjusted.

Geofence can be loaded from a separate *.FEN file generated from RadaiPath



	Command	Delay				Lat	Long	Alt	Frame	Delete			Grad %	Angle	Dist	AZ
162	WAYPOINT	0	0	0	0	66,498573	26,322859	46...	Relative	X			0,3	0,2	84,8	359
163	WAYPOINT	0	0	0	0	66,500435	26,321306	52...	Relative	X			2,7	1,6	218,3	342
164	WAYPOINT	0	0	0	0	66,502304	26,319752	49...	Relative	X			-1,4	-0,8	219,0	342
165	WAYPOINT	0	0	0	0	66,504166	26,318197	47...	Relative	X			-1,2	-0,7	218,2	342

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Beyond Visual Line-of-Sight

- BVLOS mode is in practice compulsory for practical surveys
  - Even in optimal conditions (no trees, clear weather), the drone is visible max 2 km from an observer.
- BVLOS is allowed via restricted flight area (EFD*).
- BVLOS permit is applied from the national authorities e.g. Traficom/FIN (or Transport Styrelsen/SWE)
- The permit costs couple of hundreds of euros per site. It is valid for few weeks or days. Large area may need to be divided into two.
- Operation manual is a preliminary necessity that defines the drone(s), the field operations and, most importantly, the risk management and mitigation (SORA= Specific Operations Risk Assessment).
- Magnetic surveys, for example, belong to low risk (SAIL2) level operations in the new EU legislation.

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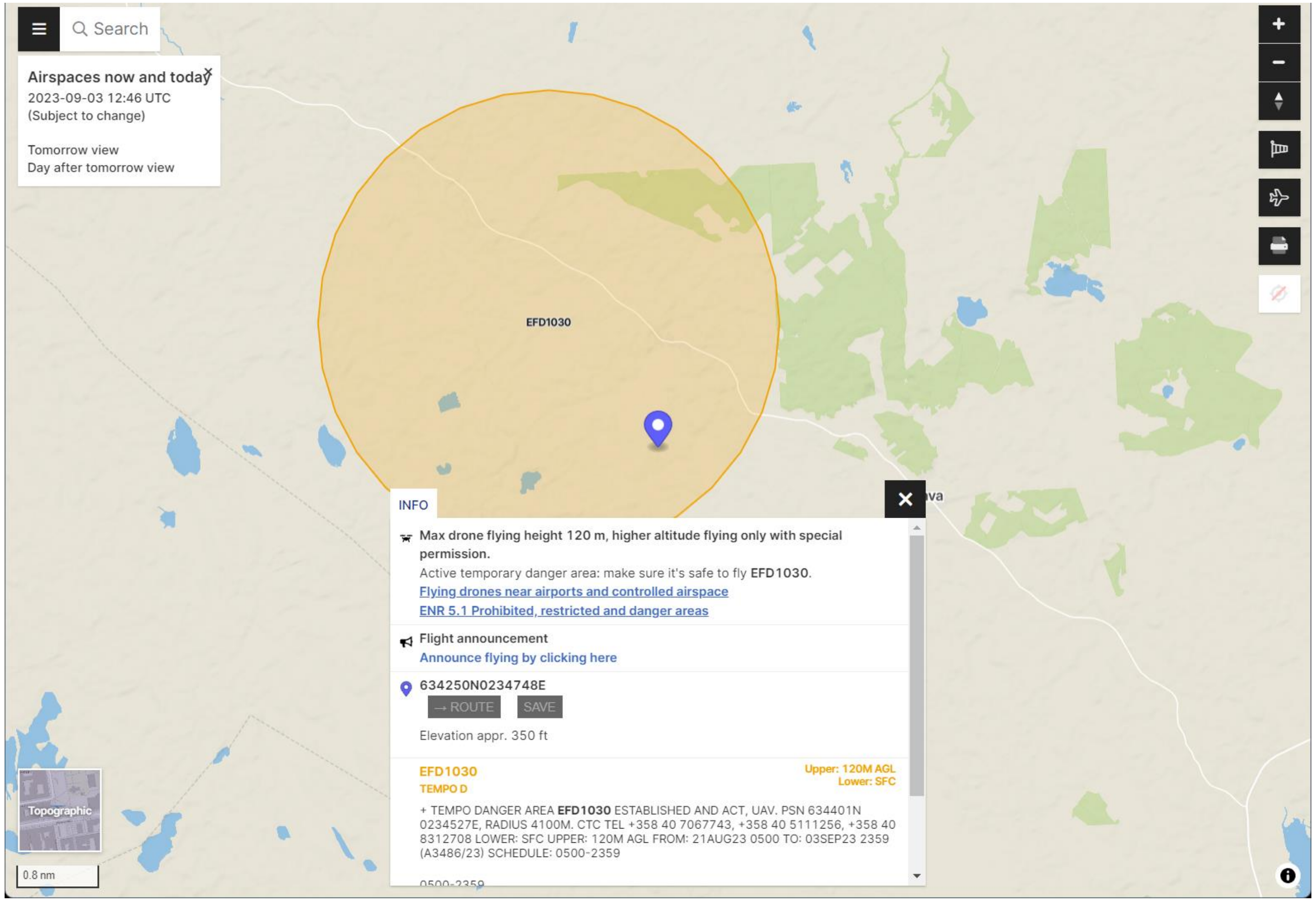
BVLOS (cont.)

- Reserved airspaces are announced (NOTAM) in EU-wide information system:
- https://europeandronecompany.com/european-drone-authorities-and-nofly-zones/
- Despite the BVLOS permit, drones must avoid all other air traffic.
- The pilots must monitor the aviation (VHF) radio of the nearest AMC/ATC. Communication via aviation radio requires special licence.



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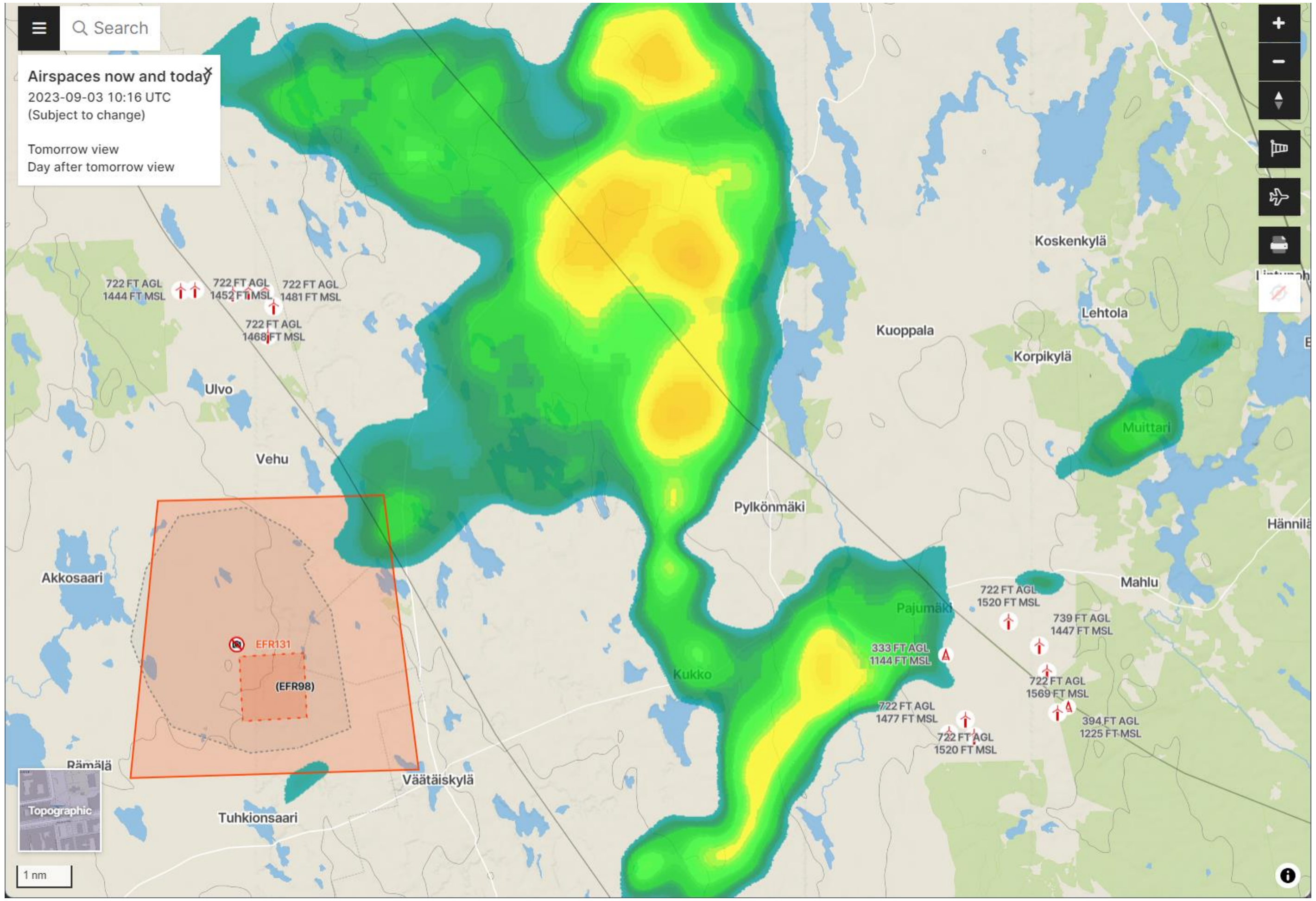
BVLOS (cont.)

Flykt.com (Aviamaps.com) shows restriction areas and NOTAMS for Finland. It also shows tall objects such as windmills and GSM towers.

Important: Info on obstacles higher than 30 m can be purchased as a SHP file from Finntrafic.com.

The objects can be loaded into RadaiPath and used to modify the waypoints near them.



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Restrictions

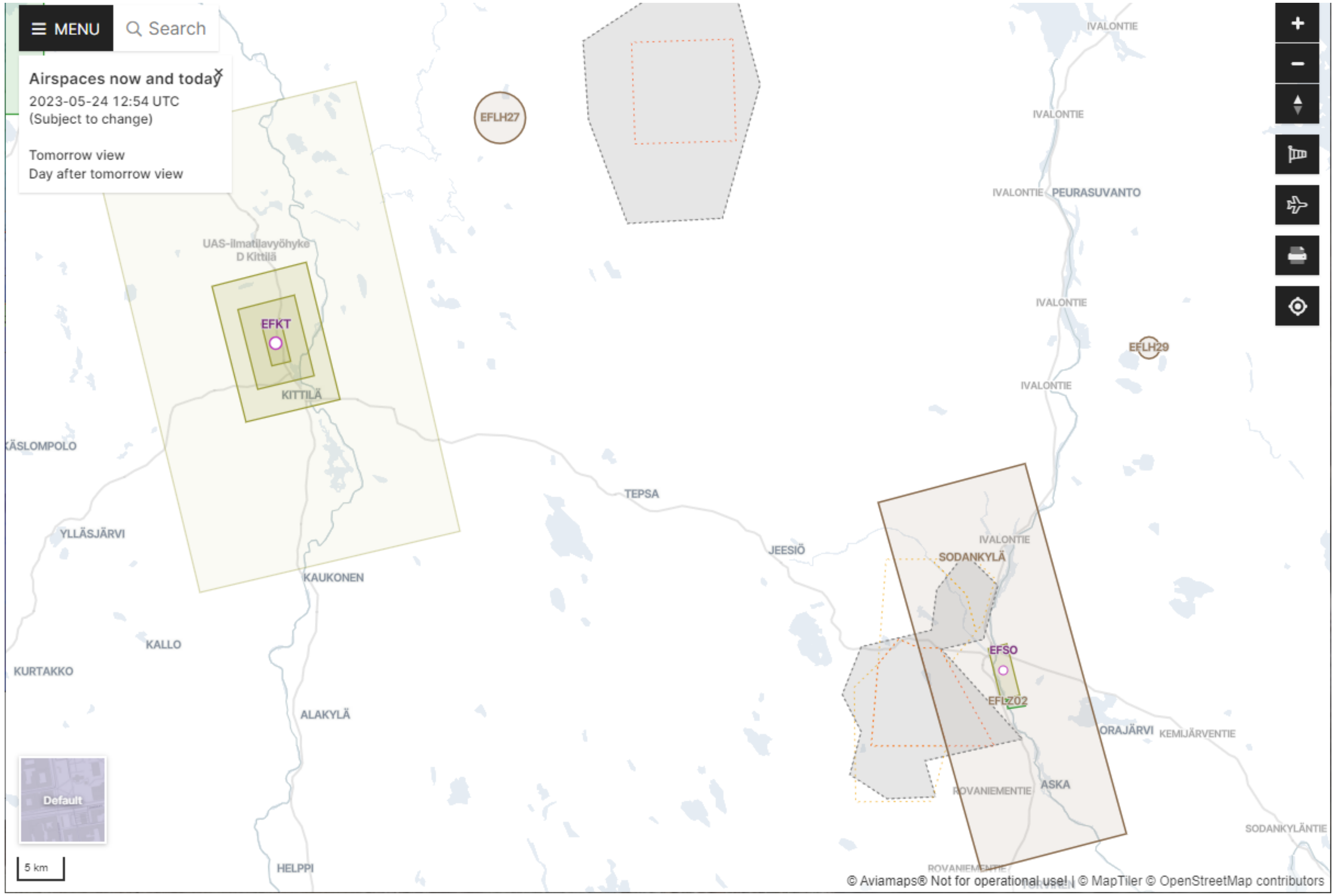
Populated areas, airfields, military areas, and national borders set limitations for drone operations.

Nearby airfields require special attention.

Communication with the air traffic control (ATC) of the airfield is often needed.

Bird nesting (e.g., eagles) and reindeer calving also restrict drone surveys.

The info on bird nests is obtained from AVI (Regional State Administrative Agency).



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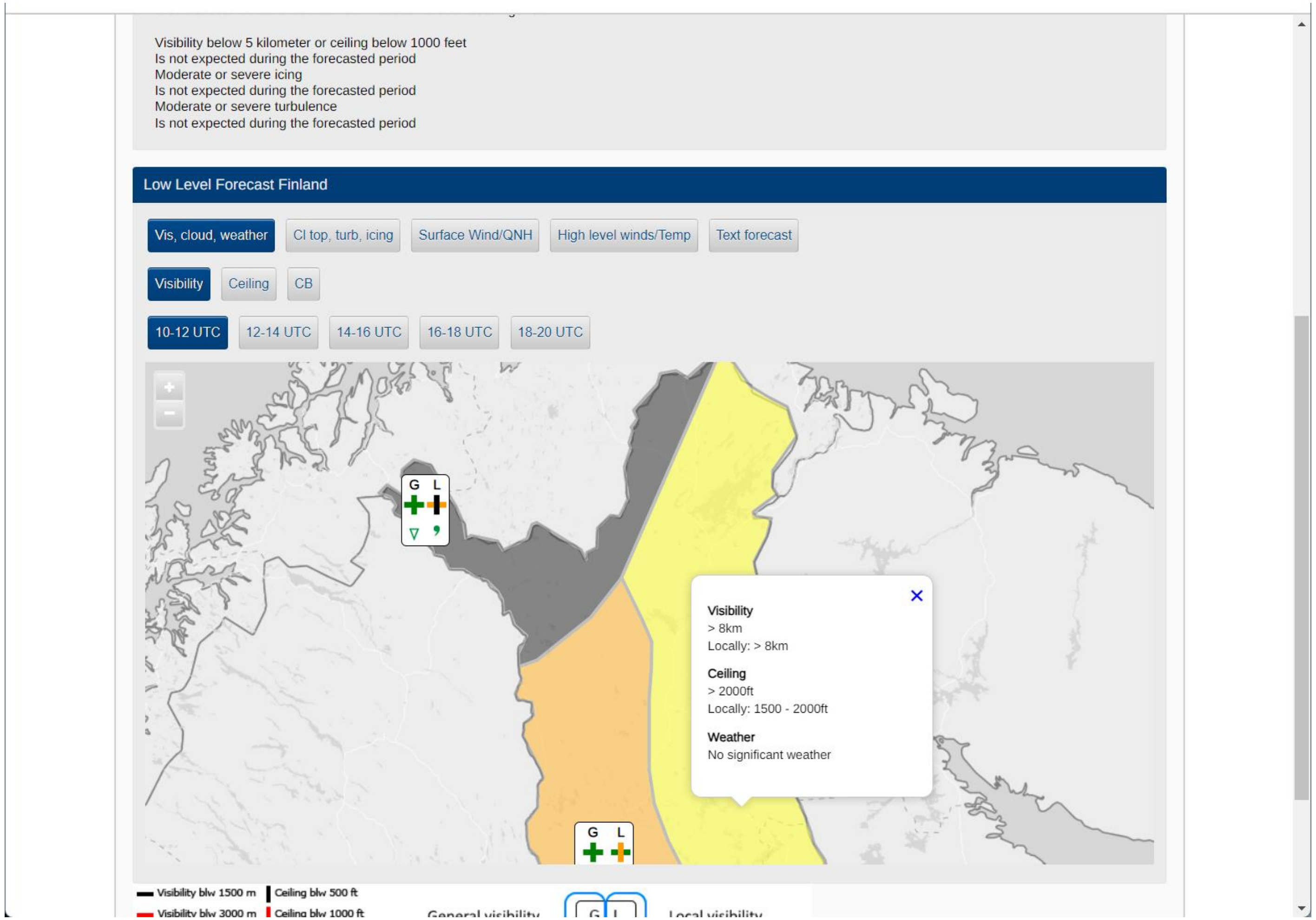
Weather

Finnish meteorological institute (FMI) provides more detailed info about the weather: https://www.ilmailusaa.fi/lowlevelforecast.html.

Rain, wind, temperature, visibility and especially icing in the lower atmosphere.

Icing is a serious issue!



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Radai's UAV surveys in practice

- All survey drones of Radai/Dronnair are of VTOL type (Vertical Take-Off and Landing) with electric engines.
- Drones are purchased from China. Some area fully assembled and some are not. They are need modifications and change of parts.
  - All drones use Pixhawk 4 autopilots.
- Always at least 2 persons in a field crew
  - The main pilot takes care of the drones
  - The co-pilot makes the flight plans and handles the data
  - Both pilots do flight monitoring
- The pilots prepare and maintain their own drones
  - A log-book is kept for each drone
- Accidents are reported in ORs (Occurrence Reports)
  - Investigation and future prevention (learn from mistakes)
- A log is also kept for each battery and its charging tests

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Summary

- Geophysical methods are used to obtain information about the structure and composition of the earth.
- Geophysical measurements are made along survey lines that cover the survey area.
- DEMs allow the drones to follow the terrain.
- Background maps are used for safety.
- RadaiPath software helps flight path design.
- BVLOS permit is a must have for practical measurements.
- Operation manual & risk assessment.
- Good starting point: Droneinfo.fi

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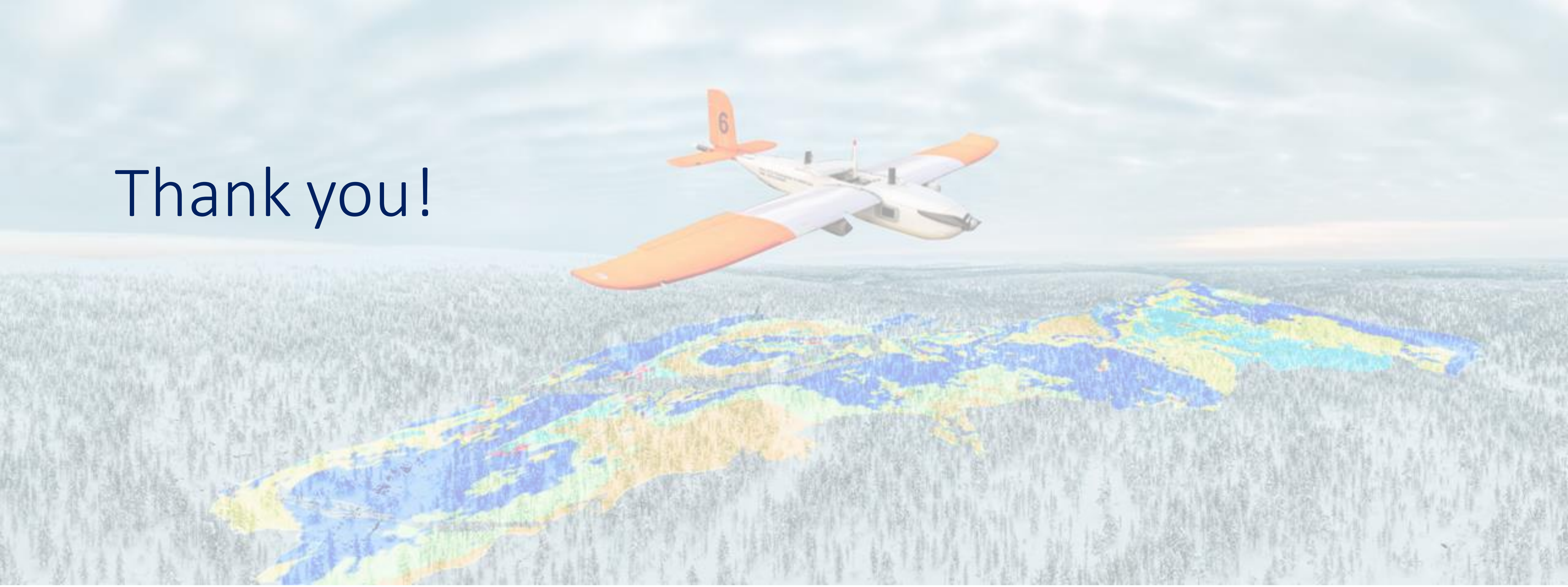
Thank you!



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