Thunderbird

The Thunderbird utility is used for planning flights of small aircraft and UAVs, taking meteorological information into account.

For data visualization, the Thunderbird program uses a web browser and can operate in both online and offline modes.

The general layout of the screen is shown in Figure 1 and consists of the following components:

- A map display area with terrain and weather parameters (the main section in the center).
- A text display in the lower right corner of the screen, showing the coordinates of the aircraft or UAV (AV) along with corresponding meteorological values—wind speed and direction, temperature, cloud base height, and a number of other weather factors.
- A color palette located in the upper left corner of the screen, used for color-coding weather parameters.
- A menu for setting visualization parameters (upper right section of the window).
- A scale slider for altitude and atmospheric pressure levels, located on the left side of the window.
- A scale slider for selecting the forecast time, located in the center at the top of the screen.

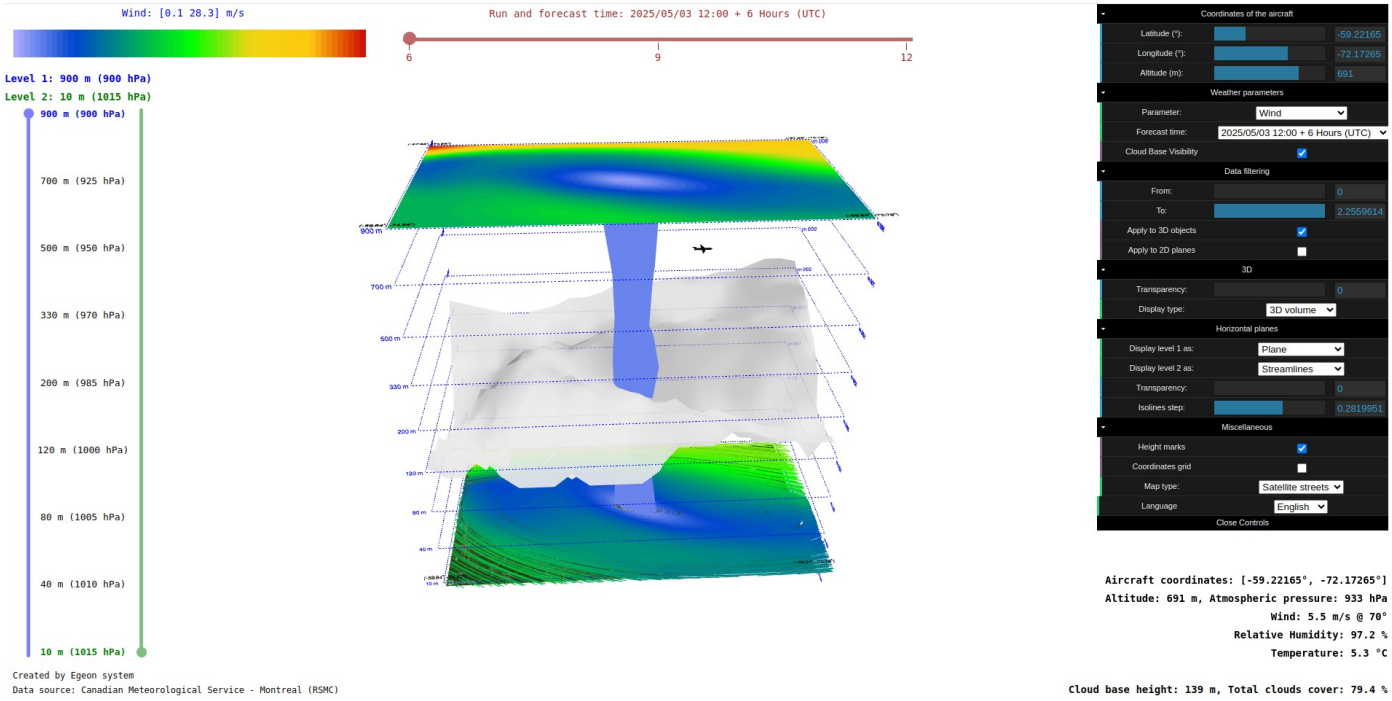


Figure 1. General view of the Thunderbird utility.

1. Weather Parameters Display Area

This region is located in the center of the screen and displays meteorological data for the selected parameter.

The data is color-coded according to the palette set in the color-coding section (see Section 3).

For ease of orientation, this area also includes:

1) A schematic representation of the AV.
2) A coordinate grid on latitude and longitude.

3) Altitude markers ranging from sea level to the maximum altitude set in the data preparation block.
4) A selector for choosing the type of terrain map.

For more details on working with the data and visualization methods, see Section 4 – “Visualization of Meteorological Parameters Using the Menu”.

The AV’s position can be set either through the menu (see Section 4.1) or using the mouse. The projection of the AV on the ground is displayed as a red dot. The coordinate grid, altitude markers, terrain map, and the AV’s position relative to the ground are shown in Figure 1.1.

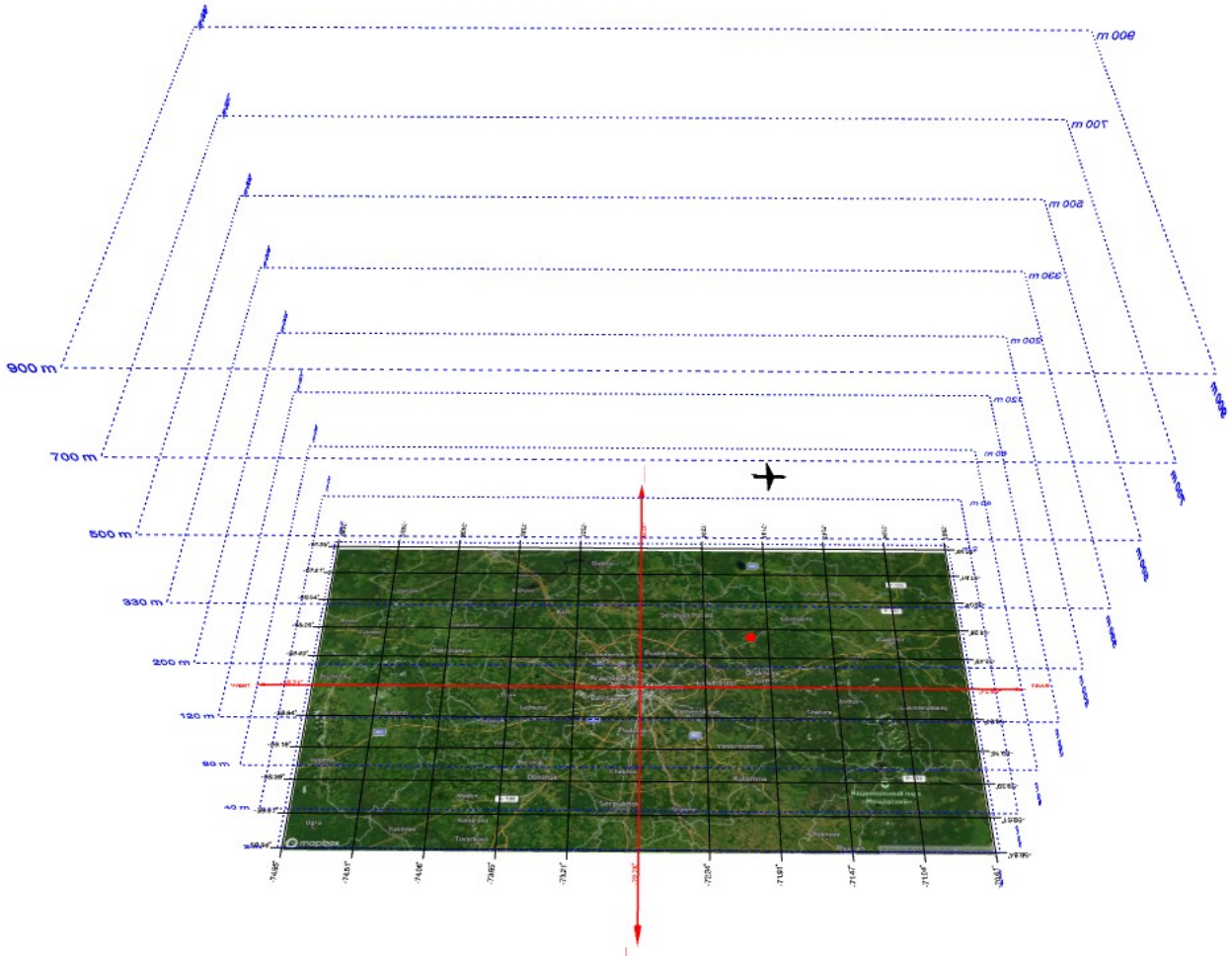


Figure 1.1 The coordinate grid, altitude markers, terrain map, and the aircraft’s position relative to the ground.

1. Data Display Area

The data display area is located in the lower right corner of the screen. When the AV image is moved using the mouse or via the menu (see Section 4.1), the following information is displayed there (see Fig. 1):
1. Geographical coordinates of the aircraft or UAV (latitude and longitude)
2. AV altitude and the corresponding atmospheric pressure level
3. Wind speed and direction
4. Cloud base height and cloud coverage level
5. Temperature, relative humidity, and several other parameters.

The weather parameter values are shown for the forecast time selected on the forecast time scale slider (see Section 5).

3. Color Palette

The color palette is located in the upper left part of the screen. It is used for the color-based representation of meteorological data.

When the mouse cursor is moved along the color palette, the selected value range of the meteorological parameter is highlighted.

For example, in Figure 3, all spatial areas where the relative humidity is within the range of 99.2% to 99.5% are highlighted in white.

For more details on working with data and visualization methods, see Section 4.

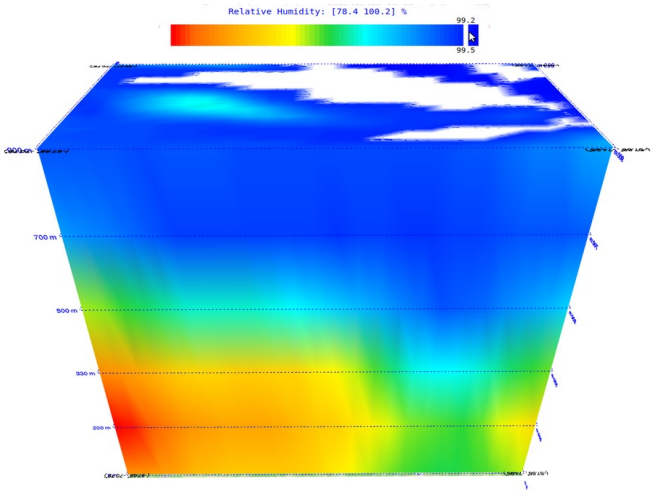


Figure. 3 Highlighted range of relative humidity.

4. Visualization of Meteorological Parameters Using the Menu

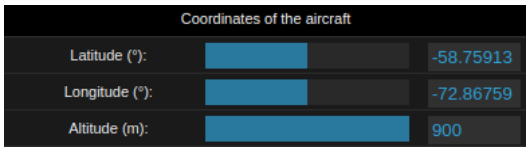
All menu options are divided into the following categories:

- **Coordinates of the aircraft**
- **Weather factors**
- **Data filtering**
- **3D**
- **Horizontal planes**
- **Miscellaneous**

The purpose of each menu option is described below.

4.1 Coordinates of the aircraft

In this submenu, the latitude, longitude, and altitude of the aircraft are set. Once the coordinates and altitude are specified, the aircraft image will move to the corresponding point on the screen. Conversely, if the aircraft image is dragged with the mouse, the values in the menu will update to reflect the new position.

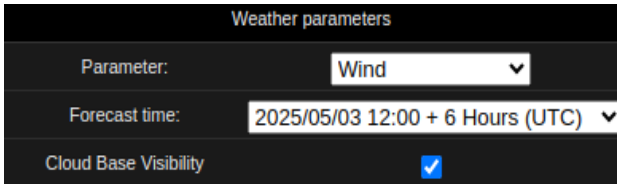


The aircraft coordinates are also displayed in the lower right corner of the screen (see Fig. 1). The projection of the aircraft onto the ground surface is shown as a red dot, as illustrated in Figure 1.1. The lower right corner also displays the corresponding aircraft position, atmospheric pressure level, and meteorological parameter values:
- wind speed and direction,
- temperature,
- relative humidity,
- cloud base height and cloud coverage level,
- a number of other weather factors.

The values of the weather parameters are shown for the forecast time selected on the forecast time slider.

4.2 Weather parameters

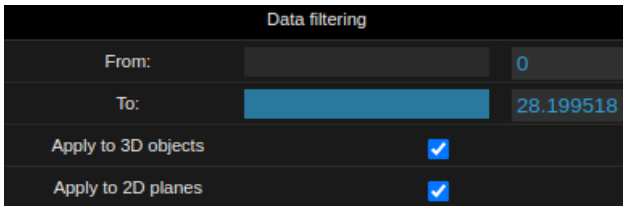
This submenu is used to select the type of meteorological parameter, the forecast time, and to set the cloud visibility on the screen. The chosen weather factor - such as wind, temperature, relative humidity, and other parameters - is further analyzed using the options in the **3D** and **Horizontal Planes** menus.



4.3 Data filtering

The data filtering menu sets the data display range for the selected parameter. Values outside the filter range will not be shown.

Data filtering can be applied independently for both planar and spatial data.



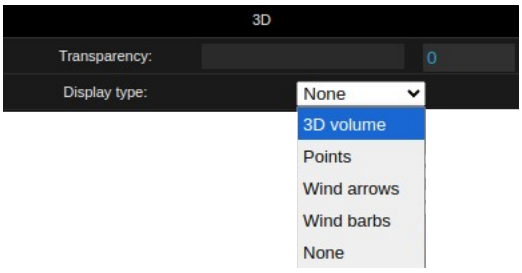
For example, in Figure 1, a filter for wind speed is set in the range of [0, 2.26] m/s. This filter is applied to spatial data filtering (the “Apply filter to 3D” option is enabled) but is not used for displaying wind as a plane and streamlines (the “Apply filter to 2D” option is disabled).

4.4 3D

This section sets the display type for the selected weather factor.

For example, wind can be shown as a 3D volume, points, wind arrows, or wind barbs. Scalar parameters such as temperature, humidity, and others are displayed in 3D only as points and volumetric shapes, the form of which is determined by the filter settings - values outside the filter range are not shown.

You can also adjust the transparency level of the volumetric shapes.



The following figures provide examples of visualizing wind speed and direction in three-dimensional space.

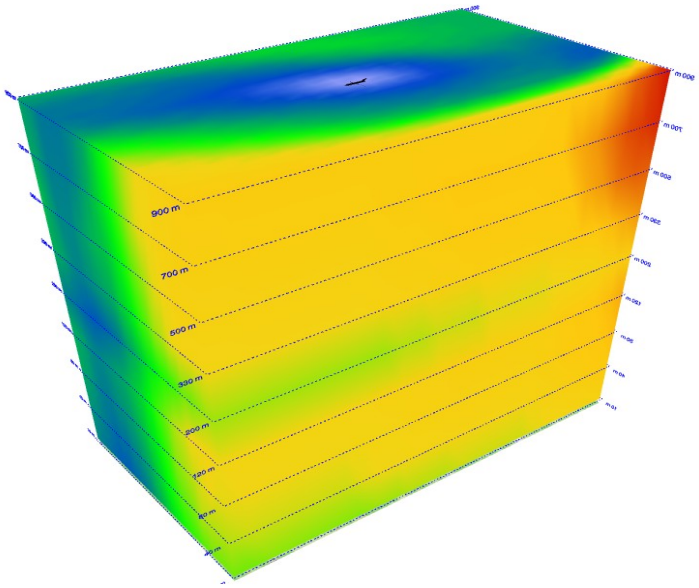


Fig. 4.1 Color coding of wind speed in three-dimensional space.

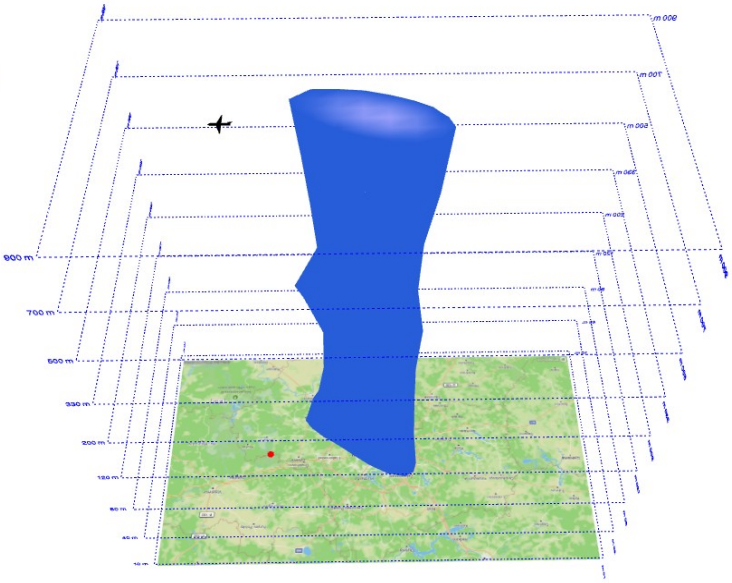


Fig. 4.2 Area where wind speed does not exceed 4 m/s.

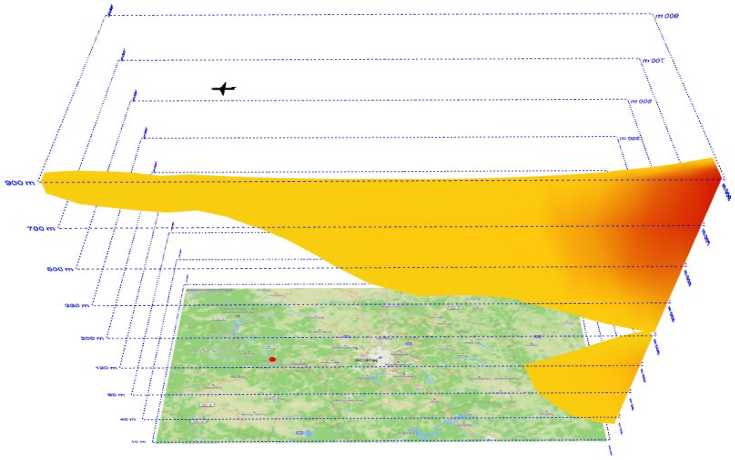


Fig. 4.3 Zone of strong wind exceeding 22 m/s.

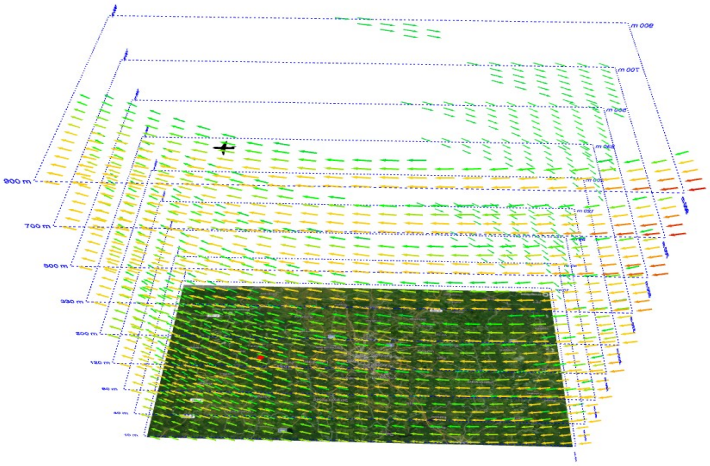


Fig. 4.4 Wind arrows with a speed filter from 12 to 28 m/s.

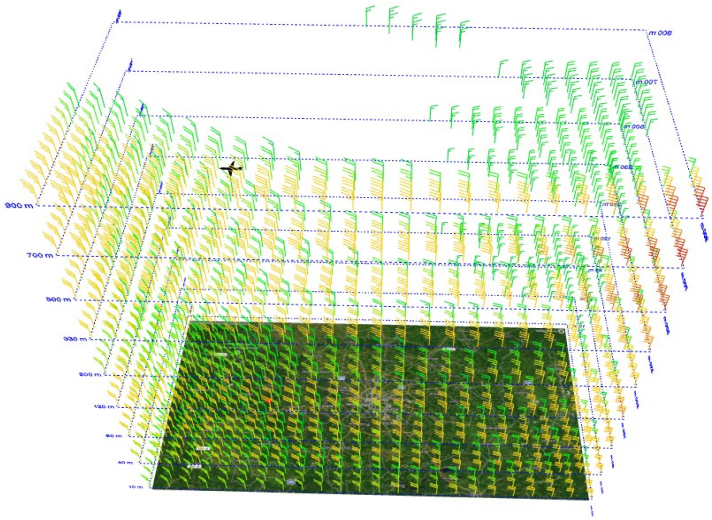


Fig. 4.5 Wind barbs with a speed filter from 12 to 28 m/s.

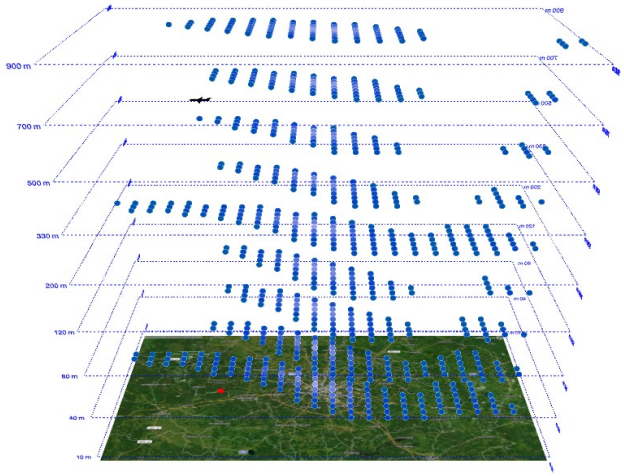


Fig. 4.6 Points in 3D space where wind speed is less than 6.2 m/s.

When visualizing the spatial distribution of weather factors, different transparency levels can be set. For example, Figure 4.7 shows the temperature distribution by altitude with a transparency coefficient of 0.5. It is also possible to highlight a specific data range and combine it with filtering and transparency levels, as shown in Figure 4.8.

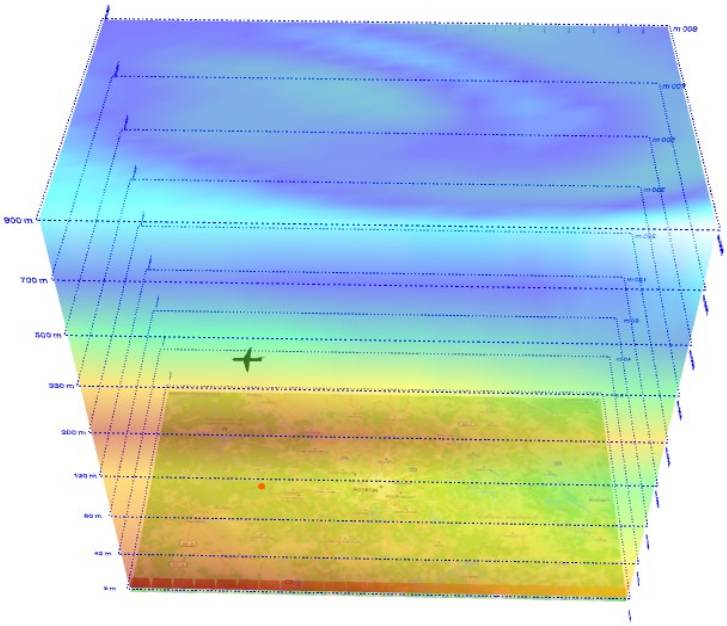


Fig. 4.7 Use of transparency level for temperature analysis.

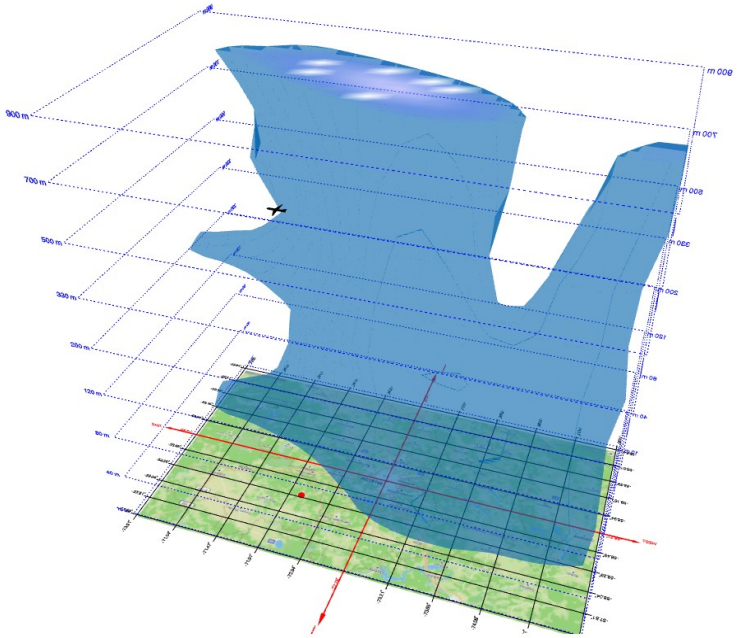
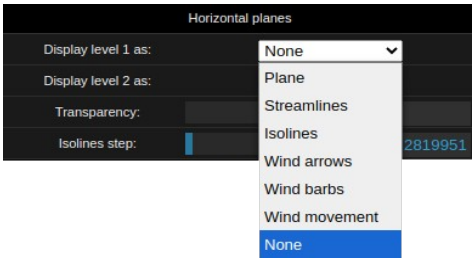


Fig. 4.8 Highlighting the low wind speed zone. Transparency level 0.4.

4.5 Horizontal planes



This menu is used to compare meteorological data at two different altitudes or to display weather parameters at a selected altitude.

The menu includes two selectors for choosing the analysis altitudes and two selectors specifying how the meteorological parameters should be displayed.

For example, wind can be displayed as a color-coded plane, wind vectors and wind barbs, isolines, streamlines, and animated wind flows. Scalar parameters such as temperature, humidity, and others are shown as color-coded planes and isolines.

For color-coded planes, you can also set the transparency level, apply a filter, and highlight a specific data range.

When the menu is activated, a scale slider of altitudes and atmospheric pressure levels appears on the left side of the screen (see Figs. 4.9, 4.13, 4.14). This scale slider allows you to set the altitude or atmospheric pressure level at which the meteorological parameters should be displayed.

The following figures provide examples of comparing weather factors at different altitudes.

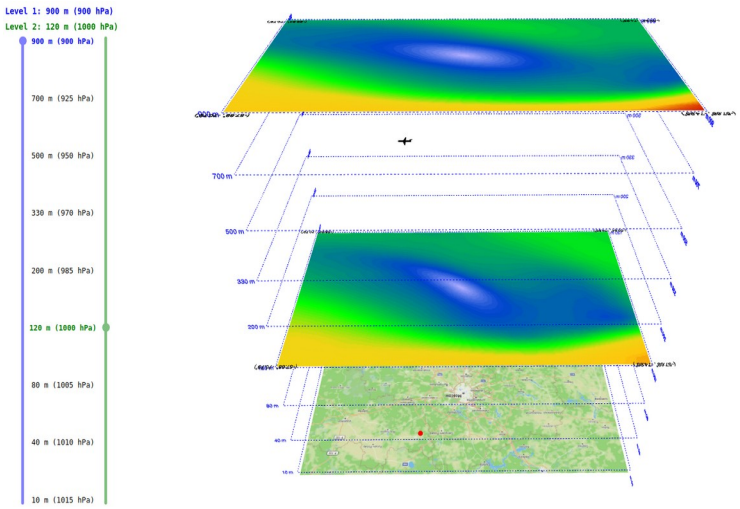


Fig. 4.9 Wind distribution at altitudes of 900 m and 120 m shown as color-coded planes.

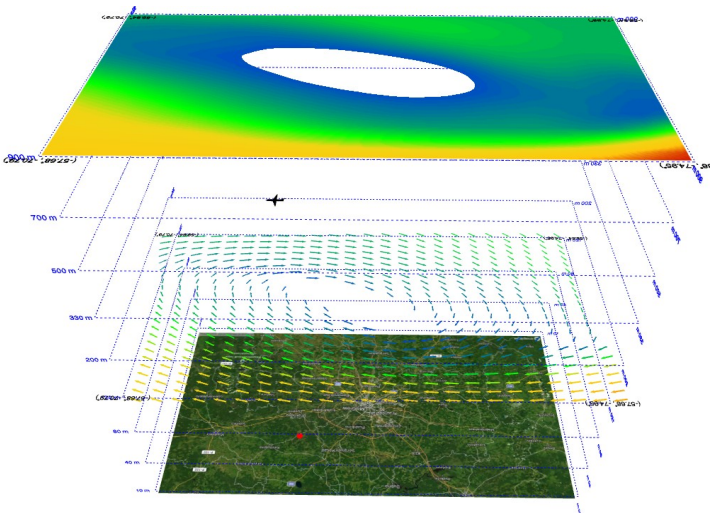


Fig. 4.10 Wind distribution above 5 m/s at 900 m (color-coded plane) and 120 m (wind arrows).

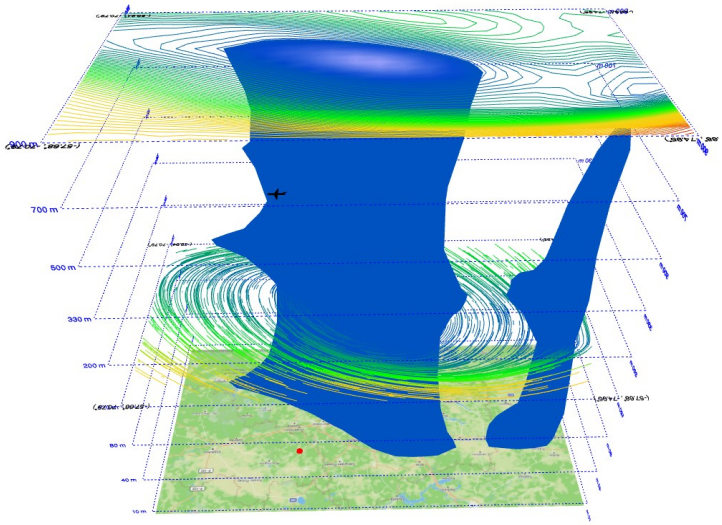


Fig. 4.11 Wind distribution at 900 m (isolines) and 120 m (animated streamlines).

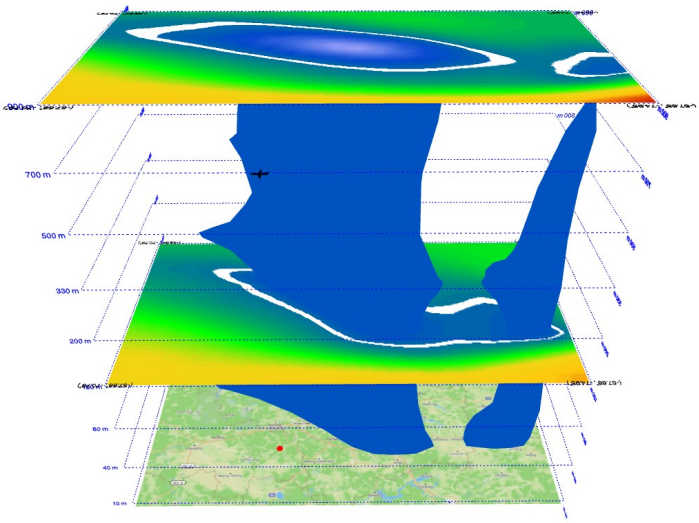


Fig. 4.12 Highlighting a specific wind speed range at altitudes of 120 m and 900 m.

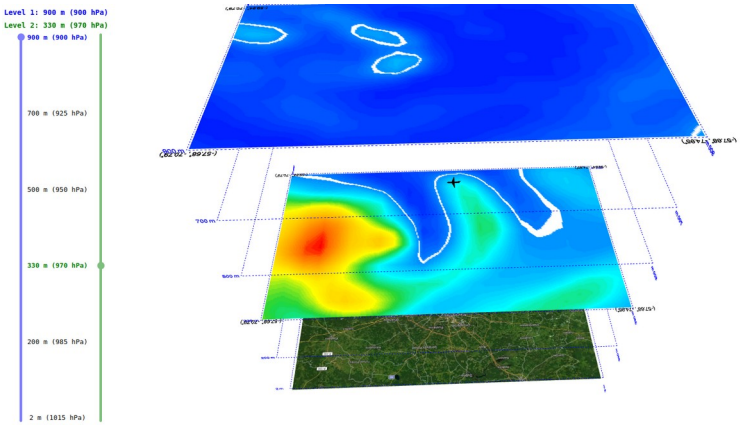


Fig. 4.13 Relative humidity distribution at altitudes of 330 m and 900 m. Region with 95% relative humidity is highlighted.

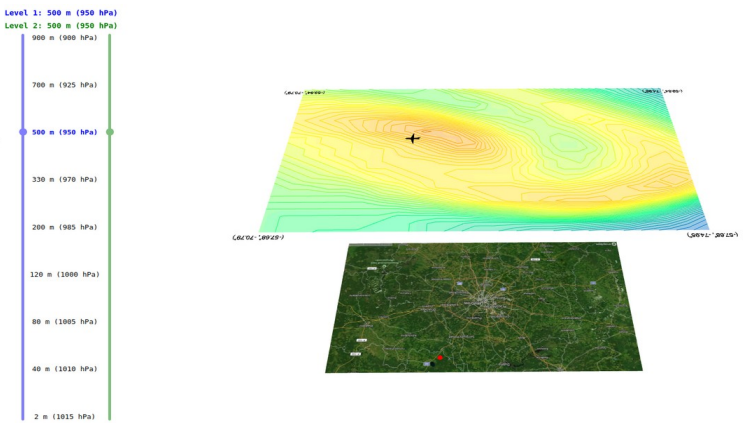
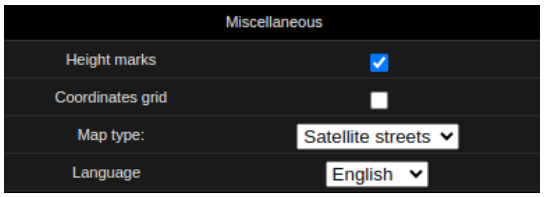


Fig. 4.14 Temperature distribution isolines at an altitude of 500 m. Temperature is also shown as a semi-transparent color-coded plane.

4.6 Miscellaneous

This menu item includes several options to assist with map navigation:
- A coordinate grid on latitude and longitude.
- Altitude markers from sea level up to the maximum altitude set in the data preparation block.
- A selector for choosing the type of terrain map.



There is also a selector for choosing the interface language and the language used to display data parameters - French, Spanish, German, and several others are available.

The coordinate grid, altitude markers, terrain map, and the aircraft's position relative to the ground are shown in Fig. 1.1.

Figures 4.15–4.18 illustrate different terrain map options.

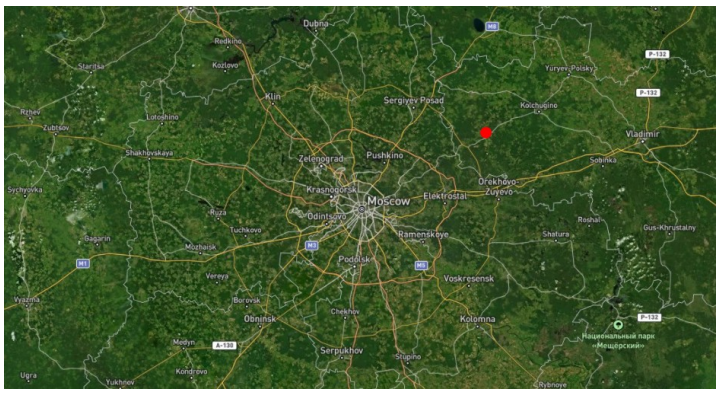


Fig. 4.15 Satellite map.

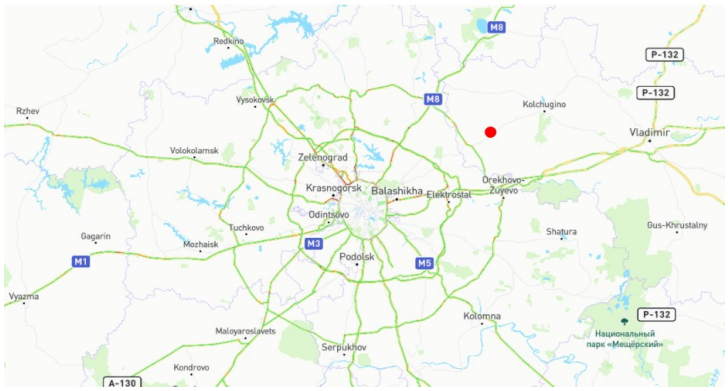


Fig. 4.16 Navigation map.

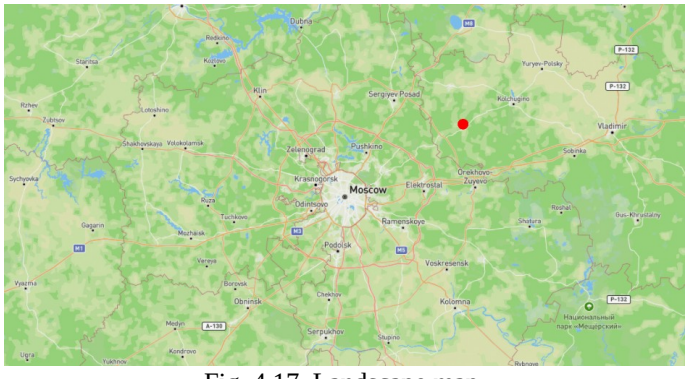


Fig. 4.17 Landscape map.

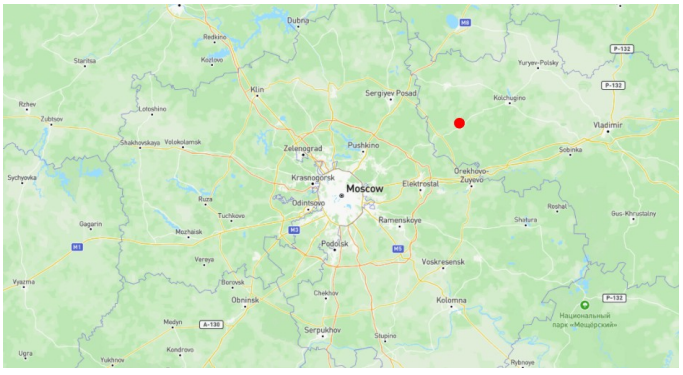
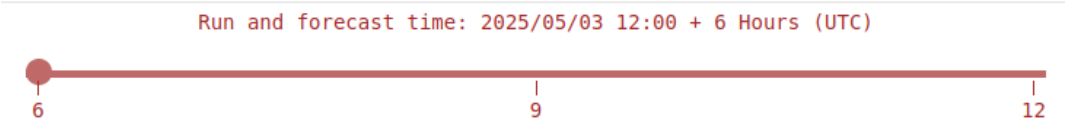


Fig. 4.18 Street map.

5. Forecast Time Selection

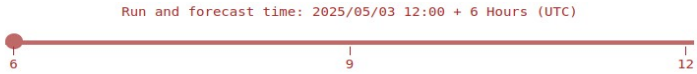
The forecast time selection scale slider is located at the top center of the screen.



This scale slider displays the forecast run time along with a list of forecasts. The forecasting time range depends on the data source and can extend up to 10 days with a 1-hour step.

When the forecast time is changed, the corresponding meteorological data will be used for visualization and analysis.

Figures 5.1 and 5.2 show the cloud cover forecast 6 and 12 hours ahead from the run time, while Figures 5.3 and 5.4 present the wind conditions forecast for the same period.



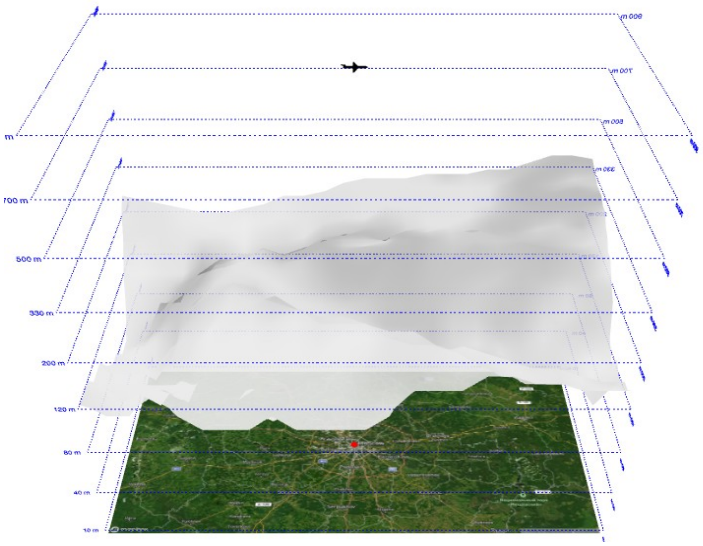


Fig. 5.1 Cloud cover forecast 6 hours ahead.

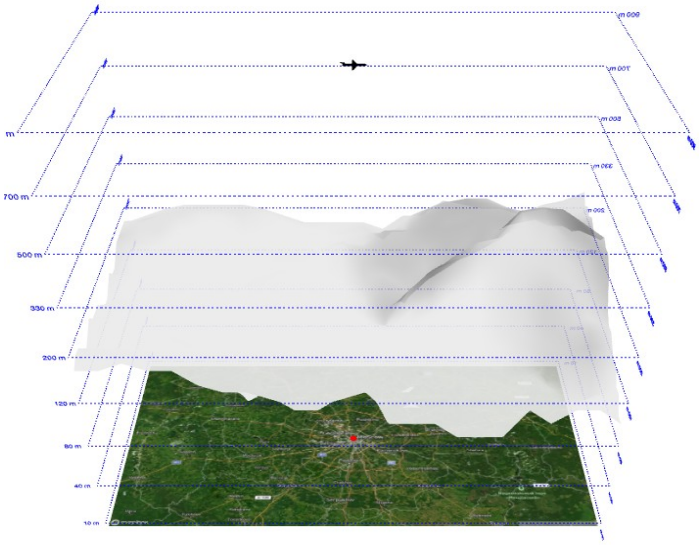


Fig. 5.2 Cloud cover forecast 12 hours ahead.

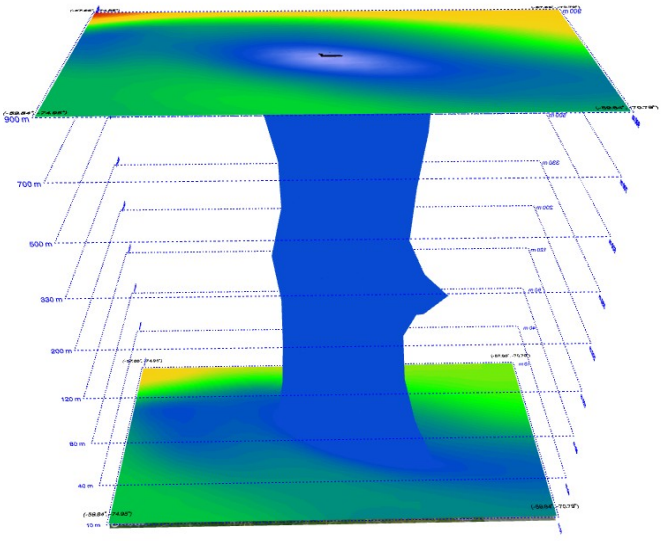


Fig. 5.3 Wind conditions forecast 6 hours ahead.

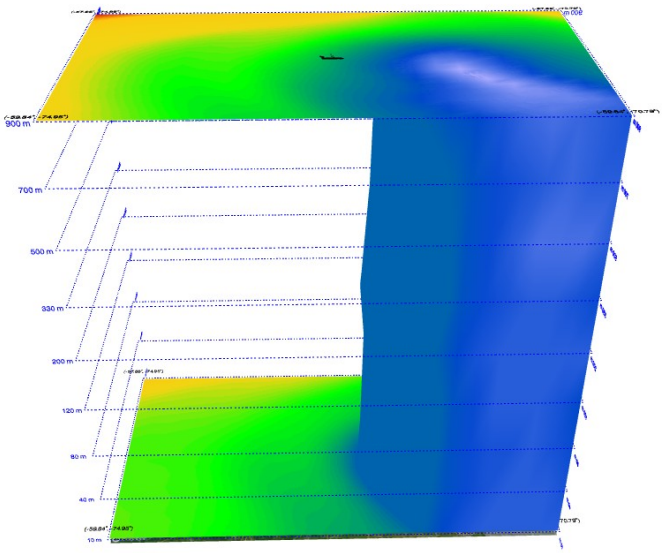


Fig. 5.4 Wind conditions forecast 12 hours ahead.