USER MANUAL · EDITION 3.0

Ballonstart Planer

Trajectory planning with DWD ICON wind data

trajektorienplaner.netlify.app
Wetterauer Montgolfièren e. V.
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Technical handbook for club members and interested pilots

Contents

NEW IN EDITION 3.0

- Sidebar restructured into clearly separated sections **Launch site**, **Start time**, **Weather brief**, **Flight plan**.
- Time control via day, hour and minute steppers plus **quick-time chips** for typical balloon launch slots. The earlier „Now“ mode and the time-window mode have been removed.
- Global **MSL/AGL toggle in the header** — affects the altitude list, the trajectory boxes and the cruise altitude.
- **Auto-save**: the most recent calculation is saved automatically and offered as a restore banner the next time the app opens.
- Prediction and Target are tidied up: Target hides the cruise and duration inputs and expects a map click on the desired landing point.
- **Share URL with re-create parameters**: recipients open the scenario with one click.
- Curated **briefing image when sharing a screenshot** (portrait format with branding, time stamp, map and wind/altitude table).

1 Purpose and scope

The **Ballonstart Planer** is a web-based planning tool for hot-air balloon flights in Central Europe, with a focus on the German federal state of Hesse. It computes expected flight paths (trajectories) from current wind data of the German Weather Service (DWD ICON model, fetched through Open-Meteo) and displays them on a map.

1.1 Main functions

Function	Description
Weather brief	Concurrent display of trajectories at multiple altitudes — a compact visualisation of the upper-air wind profile for situational awareness.
Prediction	Calculation of a realistic flight path with climb, cruise at a single chosen altitude and descent.
Target mode	Optimisation of the cruise altitude(s) to approach a desired landing point, including two-altitude profiles with one altitude change.
Airspace layer	Display of CTR, TMA, restricted areas, RMZ, TMZ and aerodromes from the OpenAIP database, with frequencies in the popup.
NOTAM briefing	Query of active NOTAMs along the flight path through the Autorouter API (10 km corridor).
Surface wind and precipitation	Optional layers showing surface wind as an arrow grid and precipitation as a radar overlay.
Scenarios	Local saving, loading and sharing of complete planning situations, including a re-create link.

1.2 Scope and limits

The planner is a **preparation tool**. It does not replace either an official weather briefing (e. g. pc_met) or a NOTAM briefing from an authorised source (DFS AIS-C), and it does not constitute any form of departure clearance. The final assessment of a flight remains with the pilot in command under applicable regulations.

IMPORTANT

The Ballonstart Planer is *not* an EFB in the sense of EASA definitions. It is a personal planning tool. Before each flight, the official pc_met and NOTAM sources must be consulted.

2 System requirements and setup

2.1 Devices and browsers

The planner runs as a Progressive Web App (PWA) in any current browser:

- **Desktop**: Chrome, Edge, Firefox, Safari (current versions).
- **iOS**: Safari from iOS 15. Installation via „Add to Home Screen“ is supported.
- **Android**: Chrome from version 90. Installation via the browser menu „Install app“.

A screen of at least 360 px width is recommended. On tablets in landscape orientation (e. g. iPad) the sidebar appears on the left and the map on the right; on phones the sections stack vertically.

2.2 Permissions

Permission	Purpose	Optional?
Location (GPS)	Enables the GPS button next to the location search. Without this permission the launch site can only be set by map click or via search.	Yes
Persistent storage	Stores scenarios, auto-save state and the OpenAIP key in the browser's `localStorage`. Typically not requested explicitly.	No
Notifications	Currently not used.	—

2.3 Installation as an app

The planner can be installed on any device as an app, without going through an app store:

1. Open the URL trajektorienplaner.netlify.app.
2. From the browser menu, choose „Add to Home Screen“ (iOS) or „Install app“ (Android, desktop Chrome).
3. On first launch the service worker caches the app shell. After that the app loads even when offline — new forecasts, however, still require a connection.

PRIVACY

There is no central user management. All settings, scenarios and API keys are stored locally in the browser only. Weather and airspace data are proxied through Netlify functions; the request itself contains only coordinates and a timestamp.

2.4 Updates

The planner notifies of new versions automatically through a header button („Update app“). Clicking it clears the service-worker cache and loads the latest version. A list of recent changes appears before the reload.

3 User interface at a glance

The interface comprises three areas: a slim **header** with global settings, the **sidebar** on the left holding the inputs in four clearly separated sections, and the **map and results area** on the right.

3.1 Header

The header carries the global settings, which apply independently of the current scenario:

Element	Function
Unit toggle `m / ft`	Switch between metres and feet. Affects all altitude displays and the cruise-altitude input.
Speed toggle `km/h / kts`	Switch between kilometres per hour and knots.
Altitude reference toggle `MSL / AGL`	Global reference for all altitude displays. `MSL` = metres above mean sea level; `AGL` = metres above ground level. Internal storage is always in metres MSL; the toggle changes only display and input.
Language toggle `DE / EN`	Switch between German and English. The integrated user guide also follows the chosen language.
Theme toggle	Light or dark mode.
User guide	Opens the integrated user guide (this document). Right-click or long-press on a control jumps directly to the matching chapter.
Update app	Clears cache and service worker, loads the latest version.

3.2 Sidebar in four sections

The sidebar is divided top to bottom into four cards, each addressing a conceptually distinct aspect of the planning task.

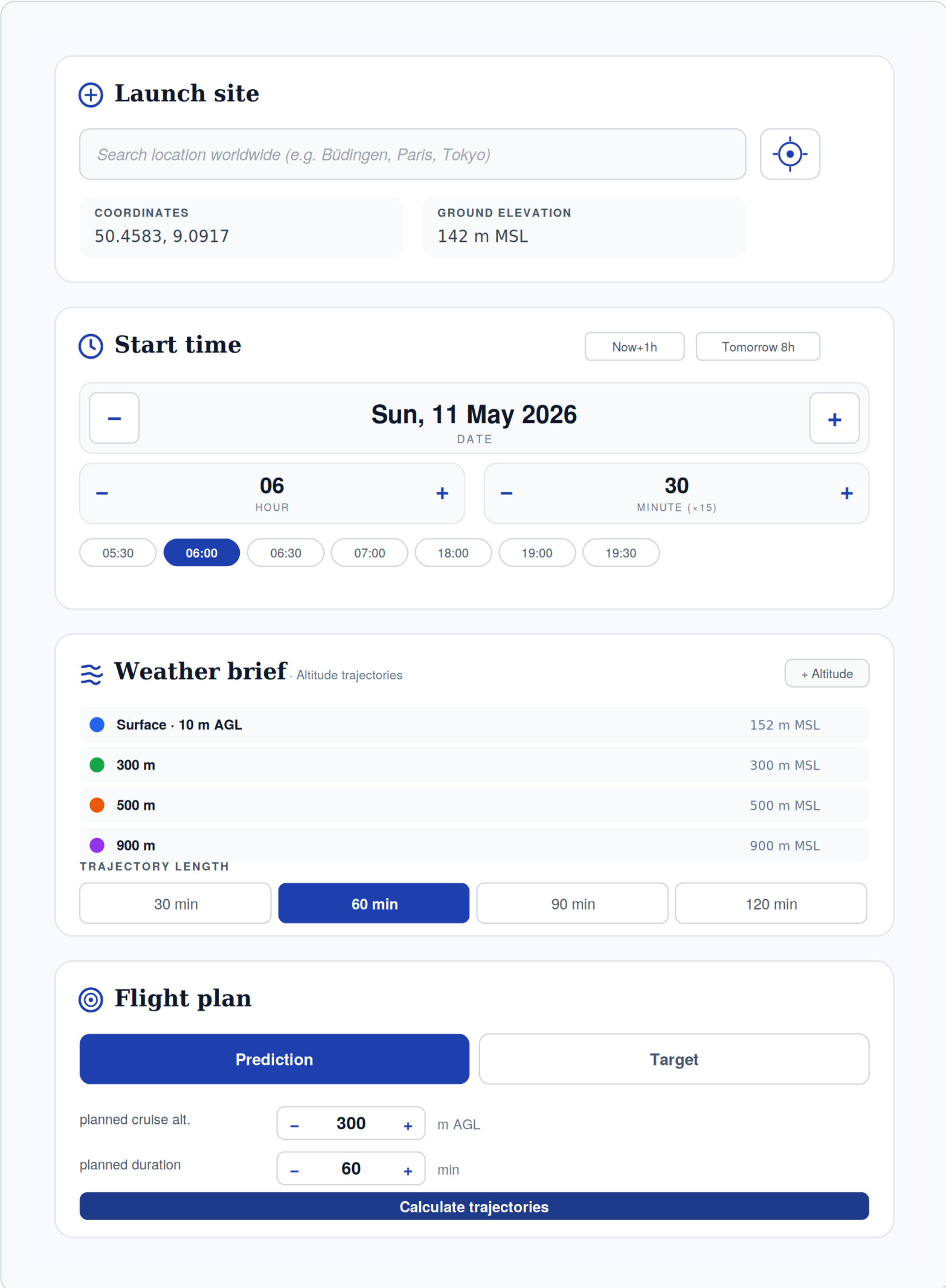

Figure 1 — Sidebar with the four cards Launch site, Start time, Weather brief and Flight plan. Schematic with sample data.

Launch site

Sets the geographic position of the planned flight. Three input methods: **map click**, **GPS button** for the current position, or **location search** with auto-completion (Nominatim/OpenStreetMap). Below the search field the planner displays coordinates and ground elevation in metres MSL. Past launch sites are remembered under „Recently used“, frequently used ones as favourites.

Start time

Input is reduced to a single mode: **planned start time**. A large day stepper, separate steppers for hour and minute (in 15-minute increments) and seven **quick-time chips** for typical balloon launch times in the morning (05:30, 06:00, 06:30, 07:00) and evening (18:00, 19:00, 19:30) allow rapid selection. Quick actions „Now + 1 h“ and „Tomorrow 8 AM“ sit at the top right of the card. The maximum forecast horizon is **three days** — that is the limit of the DWD ICON-D2 forecast.

Weather brief

Several altitudes are displayed at once. By default these are `10 m AGL` (surface), `300 m`, `500 m` and `900 m`. Each altitude produces a colour-coded trajectory on the map. The **trajectory length** can be switched between 30, 60, 90 and 120 minutes. The „+ Altitude“ button adds another altitude. This section is strictly the *brief*: it shows how the wind behaves across the layers. It is not the actual flight plan.

Flight plan

This card switches between **Prediction** (enter your own cruise altitude and flight duration; the app computes the path) and **Target** (mark the desired landing point on the map; the app searches for matching cruise altitudes). The primary button „Calculate trajectories“ runs the calculation for both the weather brief and the flight plan in one step.

3.3 Map and results area

The map (Leaflet, OpenStreetMap tiles) fills the main area. Seven layer buttons sit at the top right for *Focus*, *Airspace*, *NOTAM*, *Surface wind*, *Precipitation*, *Satellite* and *Fullscreen* (see chapter 7). Below the map, once the calculation has completed, you find the predicted landing point, the wind-profile chart, the altitude table and notes on critical conditions.

4 Your first trajectory calculation

A complete calculation in four steps:

4.1 Set the launch site

Click on the map, press the GPS button or search for a location. Once the marker is placed, the map shows the ground elevation in metres MSL. This elevation is the reference for all subsequent AGL values.

4.2 Choose the start time

Set day, hour and minute via the steppers, or tap a quick-time chip. The app allows forecasts up to 72 hours into the future. Outside this window, input is clamped to the next valid value.

4.3 Define the altitudes

The four default altitudes suit most briefings. For a more detailed picture, add a fifth or sixth altitude through „+ Altitude“. Altitudes are entered in the currently selected reference (MSL or AGL, set in the header) and stored internally as metres MSL. The surface altitude `10 m AGL` is anchored and follows the ground elevation.

4.4 Run the calculation

The button **Calculate trajectories** triggers the DWD-ICON forecast query, the spatial and temporal wind interpolation and the calculation of all altitude trajectories plus the prediction. A progress indicator on the map provides feedback; depending on the connection, the calculation takes between one and three seconds.

> **TIP**
>
> When comparing the same site at different times or altitudes, save the scenarios (see chapter 9). Even without explicit saving, the most recent calculation is auto-saved and offered as a *restore banner* on the next app start.

4.5 Reading the result

On the map, four (or more) colour-coded trajectories radiate from the launch point. Each altitude has its own colour and an end-point marker. The app additionally draws the magenta dashed **prediction line**: the actual flight plan with climb, cruise and descent.

Three result cards appear below the map:

- **Predicted landing point** — address display with a direct link for the retrieve team's navigation.
- **Wind profile** — horizontal bar chart of wind speed against altitude. Surface AGL levels (10/80/120/180 m) and DWD-ICON pressure levels are visualised separately.
- **Altitude table** — one row per altitude with wind, drift, expected flight time to the trajectory end and the end coordinates.

4.6 Notes and warnings

A warnings section appears between the sidebar and the map — only when needed — with three levels:

Level	Example	Trigger
Warning	„Elevated wind in landing layer (28 km/h at 180 m AGL) — landing demanding“	Wind > 25 km/h in the landing layer (50–300 m AGL); precipitation above threshold; pronounced inversion or wind shear; surface wind above the configured limit.
Critical	„Wind in landing layer 38 km/h — above 35 km/h, landing dangerous“	Wind > 35 km/h in the landing layer.
Info	„High cruise wind 45 km/h at 900 m AGL: about 45 km drift per hour“	Wind > 40 km/h in the cruise layer (> 300 m AGL).

5 Weather brief — the briefing across multiple altitudes

The *Weather brief* section has a clear briefing character: it shows not the planned flight but **how the wind behaves across the relevant altitude layers**. From this situational assessment the cruise altitude for the flight plan is then derived.

5.1 Why several altitudes?

Hot-air balloons steer their direction exclusively by altitude changes. Because winds at different altitudes blow from different directions and at different speeds, a multi-altitude display gives what pilots call the *drift fan* — the spread of reachable end-points for the chosen flight duration.

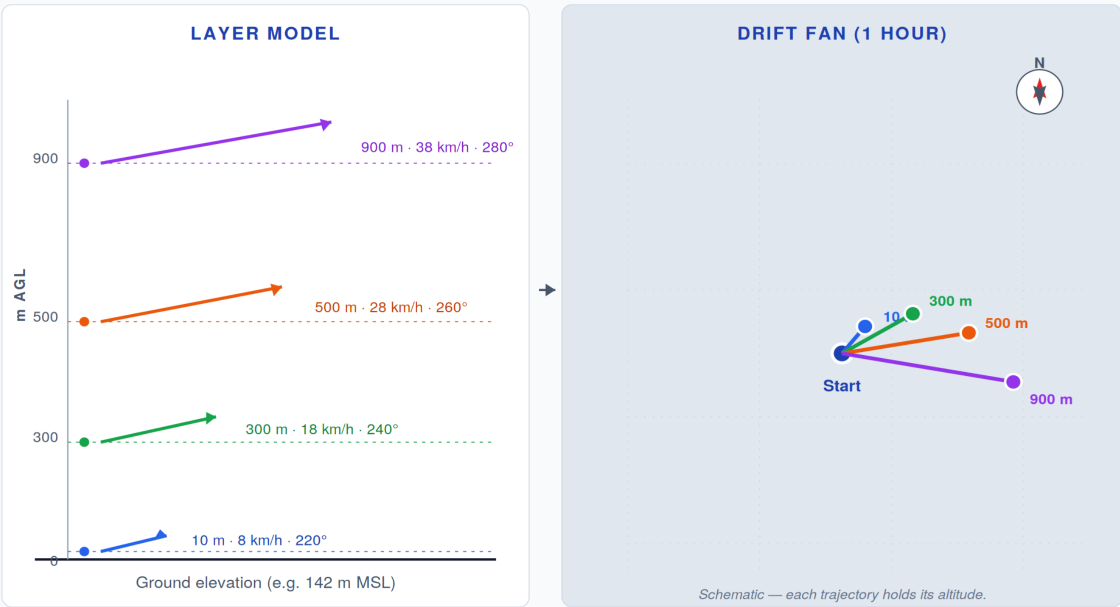

Figure 2 — Layer model and drift fan. From a single launch point, different end-points emerge depending on the altitude held. The app computes each altitude as a constant-altitude cruise and integrates the local wind over the chosen trajectory length.

5.2 Default altitudes and their meaning

Altitude	Meaning
10 m AGL	

Altitude	Meaning
	Surface, „contour“ level. Indicator for the launch phase and the final approach to the landing site. Anchored to the ground elevation — it follows when the launch site is moved on the map.
300 m AGL	Classical low cruise altitude for calm summer flights and short final approaches. Typically still in the morning mixing layer.
500 m AGL	Mid cruise altitude. With active convection the first wind veer often occurs here — an indicator for daytime stability.
900 m AGL	Upper layer. Provides information on the free atmosphere above the boundary layer and thus on long-range drift.

5.3 Adding, editing, removing altitudes

The „+ Altitude“ button adds further altitudes — useful up to about eight. Each altitude can be edited by clicking on its value field. The „×“ to the right of an altitude removes it. The surface altitude is fixed at 10 m AGL and cannot be deleted.

5.4 MSL, AGL and hPa display

The global altitude reference toggle in the header switches between **MSL** (above mean sea level) and **AGL** (above ground). Secondarily, next to each cruise altitude, the alternate reference and an approximate pressure in **hPa** are shown — useful when reading the brief together with pc_met charts.

5.5 Data sources per altitude

The app draws on two data sources, weighted differently per altitude:

- **AGL levels** (10, 80, 120, 180 m) — surface variables from the ICON model in metres above ground.
- **Pressure levels** (1000, 975, 950, 925, 900, 850, 800, 700, 600, 500, 400, 300, 250 and 200 hPa) — the standard ICON vertical grid. Each pressure level also delivers its geopotential height, used to convert pressure values into actual MSL altitudes.

Between available levels the app interpolates the wind components (u/v) vector-wise and linearly in time between successive model hours. Where a chosen altitude lies above the highest available pressure level, an extrapolation hint is shown.

6 Flight plan: Prediction and Target

The flight plan is the *actual* calculation of the planned flight. There are two modes.

6.1 Prediction

In Prediction mode the pilot supplies two values: the **cruise altitude** and the **flight duration**. The app computes a realistic three-phase trajectory from them:

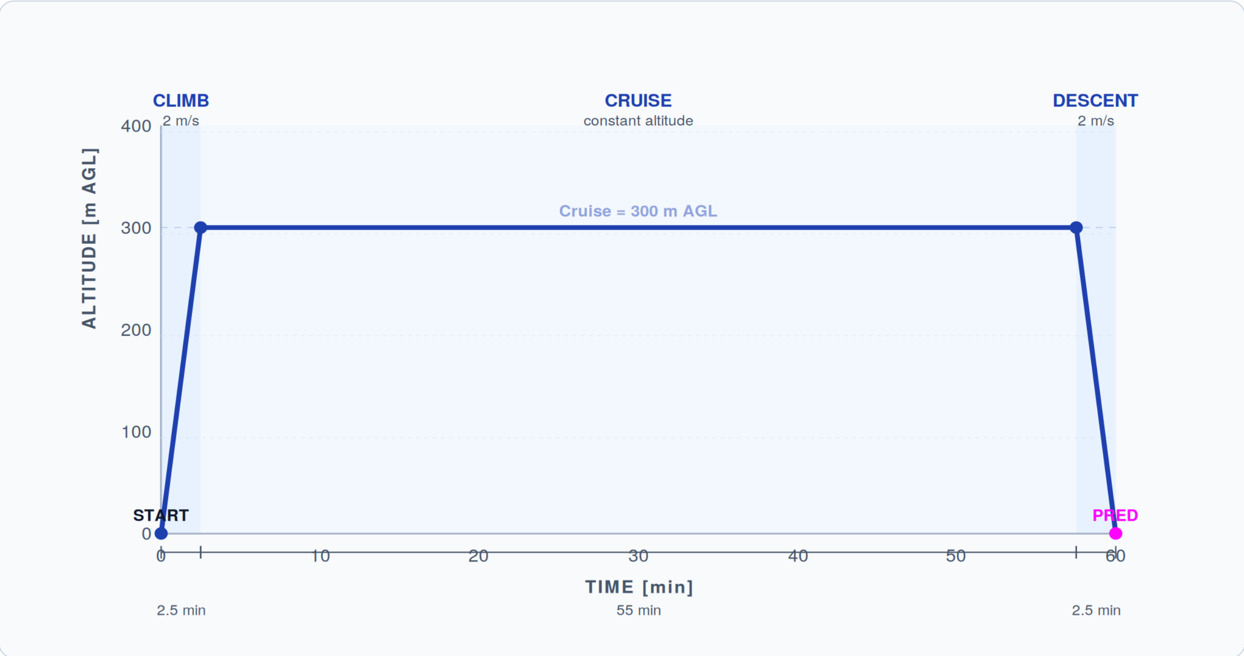

Figure 3 — Altitude profile of the prediction. Climb and descent at a constant 2 m/s, cruise at the chosen altitude in between. Example: 60-min total duration at 300 m AGL cruise altitude.

Phase	Altitude profile	Drift contribution
Climb	Surface → cruise at 2 m/s	Accumulates drift from all traversed layers.
Cruise	Constant at cruise altitude	Drift of a single layer, sustained for the longest period.
Descent	Cruise → surface at 2 m/s	Accumulates drift again from the traversed layers.

The prediction sums the three phases into one path. The cruise altitude is set in 100-metre or 100-foot steps (depending on the unit toggle); the flight duration in 5-minute steps between 15 and 240 minutes.

WHEN CLIMB AND DESCENT BECOME SIGNIFICANT

At 300 m AGL and 2 m/s, climb and descent together take roughly five minutes — less than 10 % of a typical hour. At 1500 m AGL the same 2 m/s already yield 12.5 minutes each, so 25 minutes of climb and descent combined. On short flights or at high cruise altitudes, the prediction path is therefore noticeably shaped by the transition phases.

6.2 Target mode

The Target mode reverses the task: instead of entering cruise altitude and duration, the desired **landing point** is marked by clicking on the map. The app then searches for those cruise altitudes (or pairs of altitudes with one altitude change) that approach the desired target most closely.

Below the Target button, the sidebar shows:

- A hint box prompting you to click on the map.
- Two output fields indicating that *cruise altitudes* and *flight durations* are computed.

The cruise-altitude and duration input fields are hidden in Target mode — the app supplies them as a result. Up to two cruise altitudes with one switch point can be combined; this keeps the combinatorial complexity in check.

6.3 What the calculation does not represent

- **Vertical motion of the air** — thermals, lee waves. Partly captured in the ICON model, but not used in the app trajectories.
- **Pilot inputs** — spontaneous altitude changes due to obstacles, payload or traffic. The app yields a *nominal* profile.
- **Turbulence** — treated statistically by the model, not represented deterministically.
- **Coriolis effect** — negligible on balloon time scales, included by the model on the synoptic scale.

7 Map layers and navigation aids

Seven buttons at the top right of the map switch layers and views.

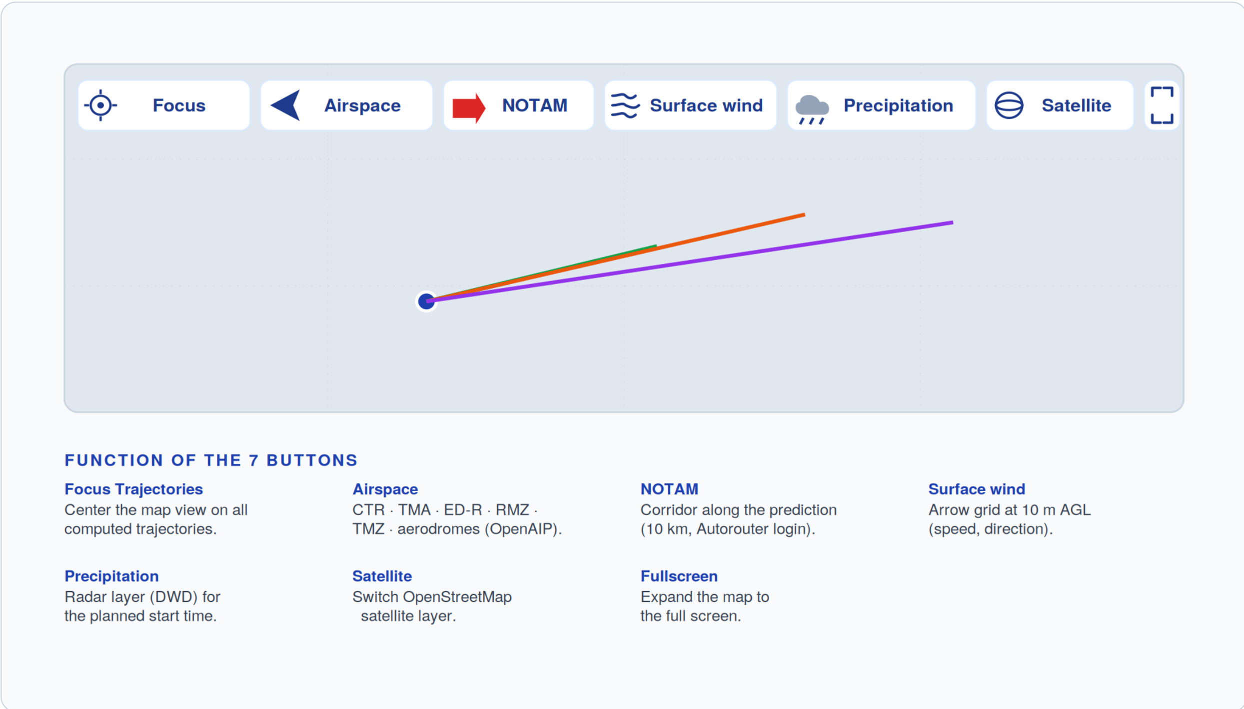

Figure 4 — Map toolbar with the seven layer buttons.

7.1 Focus trajectories

Zooms and centres the map so all trajectories of the current weather brief and the prediction are visible. Useful after each calculation when the chosen map view does not match the trajectory spread.

7.2 Airspace

Shows CTR, TMA, restricted areas, RMZ, TMZ and aerodromes from the OpenAIP database. The popup of an airspace shows its name, class, vertical limits and assigned frequencies (FIS, info, radio); for aerodromes additionally the tower or info frequency and a small runway sketch.

An individual API key can be stored per browser — see chapter 8. Without a key the layer shows a hint in the legend and loads no polygons.

7.3 NOTAM

Opens the NOTAM briefing panel via the Autorouter API. After login with your personal Autorouter account, the app checks the predicted flight path against active NOTAMs in a 10-km corridor. Prerequisite is a previously calculated prediction — see chapter 8.

7.4 Surface wind

Overlays an arrow grid on the map showing wind at 10 m AGL for the planned start time. Arrow colour codes the speed. Useful to find a launch site with minimal surface wind — e. g. when assessing slope and valley positions.

7.5 Precipitation

Overlays a DWD radar-style image for the planned start time. For times in the future the model precipitation field is rendered; for real-time assessment of the current situation, consult the official source *kachelmannwetter.com* or the DWD radar.

7.6 Satellite

Switches between OpenStreetMap tiles and a satellite layer. Useful when assessing the terrain (forests, fields, water) along the flight path.

7.7 Fullscreen

Expands the map to the full screen. A second click leaves fullscreen mode.

> **LONG-PRESS / RIGHT-CLICK ON THE MAP**
>
> A long press (on touch devices) or right-click (desktop) on any map point shows — if the airspace layer is active — a list of airspaces at that position. Useful for quickly checking whether a particular leg passes through controlled airspace.

8 Airspace and NOTAMs

8.1 Airspace from OpenAIP

The airspace layer fetches its data from OpenAIP, a community-maintained database of airspaces, aerodromes and navigation aids. The display includes:

- CTR and TMA with their vertical limits.
- ED-R (restricted) and ED-D (danger) with name and activation times where available.
- RMZ and TMZ with the responsible frequency.
- Aerodromes with a runway sketch (heading and length to scale), tower or info frequency in the popup.

API key

OpenAIP requires a free API key for its map API. There are two ways to provide a key — the first takes precedence:

1. **Per-browser entry** (recommended for end users): Open the airspace legend via the „Airspace“ button and click „Enter API key“. The key is stored only locally in `localStorage` and sent with every request as the header `x-user-openaip-api-key`.
2. **Site-wide as an environment variable** (fallback for all visitors): In Netlify under *Site settings → Environment variables* add `OPENAIP_API_KEY` with the token value and redeploy the site.

Creating a key takes only a few minutes:

1. Sign up at openaip.net.
2. Generate an API key (client-ID token) in your profile settings.
3. Either enter the key in the app (option 1) or set it in Netlify as `OPENAIP_API_KEY` (option 2).

> **DATA CURRENCY**
>
> OpenAIP data is community-maintained. It may differ from the official source or be out of date. Before each flight, consult the **NOTAMs** and the **current DFS briefing**.

8.2 NOTAMs via Autorouter

The app obtains NOTAMs through the Autorouter API. Prerequisites:

- A free Autorouter account at autorouter.aero.
- A computed prediction (click „Calculate trajectories“ in Prediction mode). Without a prediction the app does not know where to query.

Login

Enter username and password in the NOTAM panel and click „Log in“. A successful login is shown as „Logged in as *name*“; the token persists for the active session in memory. „Advanced: use my own client ID“ lets you optionally store a personal client ID — needed only when the server has none configured.

Check the prediction

The button „Check prediction“ queries all active NOTAMs along the prediction path within a 10-km corridor. Hits are listed with their distance to the path, validity period and original text. FIR-wide NOTAMs are flagged as such.

> **STORAGE**
>
> Passwords and the client secret are *never* stored in the browser. The client ID is only saved when „Remember client ID“ is explicitly enabled.

9 Saving, loading, and sharing scenarios

9.1 Save scenario

The button „Save scenario“ stores the current configuration — site, time, altitudes, cruise altitude, flight duration, units and reference — in the browser's `localStorage`. A name can be entered; with „Auto-name with timestamp“ the app generates a suggestion from date and time.

9.2 Load scenario

The button „Load saved“ opens the list of stored scenarios. Clicking an entry restores the full state and automatically runs a new calculation, so the weather brief is updated for the chosen time.

9.3 Auto-save and restore banner

Independently of explicit saving, the app stores the current state as a *last session* after every calculation. On the next app start, a **restore banner** appears above the sidebar, describing the session by site, time and altitude count. „Restore“ reads the session and recomputes; the close cross discards it. The app only triggers a restore as long as the user has not yet set the launch site themselves — an explicit user action always takes precedence.

9.4 Share screenshot

The button „Share screenshot“ produces a **curated briefing image** in portrait format. The image contains:

- Branding and time stamp (time, location).
- A map view with all trajectories.
- A wind/altitude table, compact for on-screen preview.

On devices that support the *Web Share API* (mobile browsers, recent macOS), the system share sheet opens — the image can be sent directly to WhatsApp, Signal, iMessage, Telegram, mail or a retrieve team. On older browsers a download link is offered instead.

9.5 Share URL with re-create parameters

When sharing, the app additionally generates a **share URL** containing all major scenario parameters (site, time, units, altitudes) as a query string. Opening the URL takes you to the same browser tab with the same scenario — the app rebuilds it automatically and runs a fresh calculation.

Example URL:

`https://trajektorienplaner.netlify.app/?lat=50.45830&lng=9.09170&t=2026-05-11T06:00&u=m&alts=152,300,500,900`

10 Settings and display options

10.1 Units

Toggle between `m` and `ft` in the header. The setting affects all altitude displays (altitude list, cruise altitude, wind-profile chart) and is persisted in `localStorage`.

10.2 Speed

`km/h` or `kts`. Affects wind displays, warnings, the surface-wind-limit field and tooltips.

10.3 Altitude reference (MSL / AGL)

Global toggle in the header. Determines the reference in which altitudes are shown and entered:

- **MSL** (mean sea level): the reference common in aviation. Compatible with chart and METAR altitude figures.
- **AGL** (above ground level): pilot-friendly because it describes obstacle clearance.

Internally all altitudes are stored in metres MSL; the toggle is purely a display setting. The ground altitude in the altitude list is anchored at 10 m AGL and follows the ground elevation automatically.

10.4 Language

Toggle `DE / EN`. Switches all UI text and the integrated user guide.

10.5 Theme

Light or dark mode. The map tiles do not adapt — they come directly from OpenStreetMap and are light.

10.6 Surface-wind limit

The surface-wind limit (default 8 km/h) sets the threshold above which the app issues a „Surface wind above limit“ warning. It is configurable between 0 and 25 km/h and is persisted in `localStorage`.

10.7 Flight preparation — external links

At the bottom of the sidebar three external direct links are available:

Link	Target
Weather briefing (pc_met)	DWD aviation weather — GAFOR, charts, TAF/METAR.
NOTAM briefing (DFS AIS-C)	Official Pre-flight Information Bulletin.
Lift planner	Compute payload and lift (sister app).

Weather and NOTAM briefings are part of the mandatory flight preparation. The links are a convenience feature and not a substitute for consulting these sources independently.

11 Weather models: what DWD ICON provides

The Ballonstart Planer relies entirely on the **ICON model** of the German Weather Service (DWD). ICON is a non-hydrostatic numerical weather model on an icosahedral grid; it solves the basic atmospheric equations for pressure, temperature, wind and humidity. DWD operates three configurations, all of which feed into the planner:

Model	Resolution	Coverage and reach
ICON-D2	2.1 km horizontal	Germany and the Alpine region, forecast up to 48 h. Highest detail for Central Europe.
ICON-EU	6.5 km horizontal	Europe, forecast up to 120 h. The standard at the edges of the D2 domain.
ICON-Global	13 km horizontal	Worldwide, up to 180 h. Used for forecasts outside Europe or for longer reach.

The app queries Open-Meteo with the parameter `models=best_match`. Open-Meteo automatically selects the most suitable of the three models for each location and time — in Hesse typically ICON-D2 for the next 48 h, then ICON-EU or Global.

11.1 Variables read by the app

Variable	Use
`wind_speed_*m` / `wind_direction_*m` at 10/80/120/180 m AGL	Surface wind anchors for trajectory calculation in the boundary layer.
`wind_speed_*hPa` / `wind_direction_*hPa` at 14 pressure levels (1000 to 200 hPa)	Wind in the free atmosphere. Pressure levels are converted with their geopotential heights into MSL.
`temperature_2m`, `temperature_*m`	Temperature profile for inversion detection.
`precipitation`, `precipitation_probability`	Precipitation in mm/h and probability in percent — for warnings and the precipitation layer.
	Cloud base and visibility — for warnings.

Variable	Use
`cloud_cover_low`, `cloud_base`, `visibility`	
`boundary_layer_height`, `shortwave_radiation`	Computation of thermal onset and end.
`sunrise`, `sunset`	Astronomical fallback for thermal-window estimation.

11.2 Accuracy and limits

- **Local effects** like valley winds, mountain-and-valley circulations or small-scale convergence are only partially captured at 2.1 km resolution.
- **Surface altitudes** below 10 m AGL lie under the lowest model layer and are not extrapolated by the planner.
- **Forecast uncertainty** grows with the lead time. ICON-D2 is very robust up to +24 h; thereafter the spread increases noticeably.
- **Model vs. reality**: ICON delivers the most likely profile, not a guaranteed one. Ground observation (windsock, swaying vegetation, smoke columns) takes precedence in the final decision.

12 Trajectory calculation in plain language

A trajectory is the path on which a parcel of air — or a balloon riding with the air — moves through space. Mathematically it is the solution of

$$\mathrm{d}\,\boldsymbol{x}(t)\,/\,\mathrm{d}\,t = \boldsymbol{v}(\boldsymbol{x}(t),\,t)$$

— the position changes at the velocity prevailing at the current location and time. That velocity is the wind.

12.1 Euler integration

The app solves this equation with a simple Euler scheme in 15-second steps:

1. Position and time at the start of the step are known.
2. Read the wind at exactly this place and time from the ICON forecast (with spatial and temporal interpolation).
3. Decompose the wind into vector components, multiply by the step length, advance the position by that vector.
4. Advance time by the step length; back to step 1.

The 15-second step is small enough that the error of a first-order scheme over an hour of flight remains well below the modelling uncertainty itself.

12.2 Why the app interpolates the wind

The ICON model does not deliver wind continuously, but on a grid of stations. The balloon, however, typically sits between four grid points and between two model hours. The app therefore interpolates three ways:

- **Spatially**: bilinear interpolation between the four surrounding grid cells.
- **Vertically**: between the available pressure levels or AGL anchors, in u/v components.
- **Temporally**: linearly between successive model hours.

12.3 From wind to drift

Meteorologically, wind direction is reported as the direction *from which* the wind blows (e. g. 270° = westerly). The **drift** — the direction in which a balloon is carried — is the opposite, i. e. wind direction plus 180° (modulo 360°). Internally the app works in u/v components and handles the conversion itself.

12.4 What the trajectory is not

The trajectory is a **predicted** path based on a weather model. It is not a guaranteed course. In particular it does not represent:

- Vertical motion of the air (thermals, lee waves).
- Local micro-effects below model resolution (valley channelling, slope breeze, urban heat).
- Pilot inputs — spontaneous altitude changes are not in the profile.
- Model error — even the best forecast is not reality.

13 Balloon steering through altitude changes

A hot-air balloon has no horizontal propulsion. It moves with the air in which it rides. The only available control dimension is **vertical**: add heat to climb, vent or let heat escape to descend.

The way out of this seemingly restrictive situation is: *winds at different altitudes blow from different directions*. To change drift, change altitude.

13.1 Drift fan as a planning basis

In the weather brief the drift fan appears as a bundle of differently coloured lines emanating from the launch point — one line per altitude. From this bundle three figures can be read:

- **Spread of direction**: how much turning is available? A 30° spread is typical for stable early-morning conditions; a 90° spread can occur with active convection and provides ample steering potential.
- **Spread of speed**: how large is the difference between slowest and fastest layer? This determines whether an altitude change costs little or much in terms of range.
- **Smoothness**: does the drift change smoothly with altitude or in jumps? Jumps indicate an inversion or shear zone that can be used as a deliberate steering element.

13.2 Practical steering plan

A common approach:

1. From the weather brief, read the drift direction of the surface layer (10 m AGL) — that gives the rough approach to the predicted landing point.
2. Choose the cruise altitude so the drift at that altitude best matches the desired destination.
3. Identify a second altitude whose drift in the final third corrects the approach to the landing site — for example to come closer to drivable roads or to avoid a forest.
4. In Target mode, check whether the app finds a better combination.

13.3 Climb and descent rates

The prediction assumes 2 m/s as the vertical rate — a value that is moderate in practice and matches a free climb and a calm descent well. Experienced crews fly steeper (3–4 m/s), particularly during the climb after launch. The app's assumption is conservative and tends to overestimate rather than underestimate the transition time.

14 Atmospheric boundary layer and early launches

The **atmospheric boundary layer** is the lower part of the atmosphere where surface friction modifies the wind — aloft the wind blows more freely. Much of what matters for ballooning takes place in the first hundred to a thousand metres above ground.

14.1 Diurnal cycle of the boundary layer

At night a shallow stable boundary layer of 50 to 200 m often forms. Overnight the surface cools, and cold air collects below; the wind blows unhindered above. Meteorologists call this an *inversion*: temperature rises with altitude (instead of falling), and vertical motion is suppressed.

With sunrise the surface warms. Once warming is strong enough, *convection* begins: warm parcels rise, cool air sinks. The boundary layer mixes and grows to 1000–2000 m. The inversion is gone, surface wind picks up, and thermal activity begins.

14.2 Why early morning or late evening

Hot-air balloon flights take place strictly *outside* thermal hours. Thermals create vertical motion that makes holding altitude impossible and endangers landings. The pilot's rule of thumb is **2–3 hours after sunrise to 2–3 hours before sunset**; the exact window depends on season, cloud cover and soil moisture.

> **BACKGROUND**
>
> A pronounced morning inversion has two complementary effects: it keeps the surface flow calm (good for launch) and decouples it from the upper flow at the same time (relevant for steering). Both make the early launch the preferred time of day — and not only for aesthetic reasons.

14.3 What the app shows during early launches

For a typical early launch the app produces wind profiles with very low speeds below roughly 200–400 m AGL, often pointing in a direction noticeably different from the upper flow. Trajectories for low altitudes are short, those for higher altitudes are longer and point in different directions.

From this configuration comes the value of the app for early-launch planning: it lets you assess, before inflating, how far the turn extends and whether the desired destination is reachable through an altitude combination.

14.4 Thermal-window display in the app

The app estimates thermal onset and end for the planned day and shows the window in the *Start time* section. The estimate combines two sources:

- **Astronomical fallback**: sunrise plus a seasonal buffer (high summer 2.5 h, spring/autumn 2 h, winter 1.5 h), and sunset minus the same buffer.
- **Model-based**: when ICON data is available, additionally the threshold crossing of `boundary_layer_height` (above 500 m AGL) and `shortwave_radiation` (above 150 W/m²), damped under low cloud cover > 80 %.

Conservatively: in case of doubt the app yields the longer „outside-thermal“ window, i. e. an earlier onset and later end of thermal activity.

15 Troubleshooting

A brief overview of the most common issues and their causes.

15.1 Site cannot be set via GPS

- **Symptom**: The GPS button does not respond or returns an error.
- **Cause**: Browser without location permission, GPS disabled on the device, or an HTTP connection rather than HTTPS (some browsers block geolocation outside HTTPS).
- **Fix**: Set the permission for the domain to „Allowed" in the browser settings. On iOS, additionally verify *Settings* → *Privacy* → *Location Services* → *Safari*. Alternatively, set the location via search or map click.

15.2 „Forecast could not be loaded"

- **Cause**: The Netlify function for the Open-Meteo proxy is unreachable — e. g. due to an expired session, a network problem, or ICON maintenance.
- **Fix**: Click „Calculate trajectories" again. If persistent, check the network connection and reload the app via „Update app". As a sanity check, query open-meteo.com directly with the same coordinates and time.

15.3 Airspace layer is empty

- **Cause**: No OpenAIP API key has been set — neither locally in the browser nor site-wide as `OPENAIP_API_KEY` in Netlify.
- **Fix**: Generate an API key at openaip.net and enter it in the airspace legend (see chapter 8.1).

15.4 NOTAM login fails

- **Cause 1**: Wrong credentials or a blocked account on autorouter.aero.
- **Cause 2**: The app has not yet computed a prediction, or the most recent prediction is from an earlier session.
- **Fix**: First compute a trajectory in Prediction mode. Then log in. If needed, enter your own client ID under „Advanced".

15.5 After an app update, functions or data are missing

- **Cause**: The service worker did not fully replace the old cache.

- **Fix**: Click „Update app“ in the header. If that does not help, manually clear the browser cache for the domain and reload. Saved scenarios are kept because they live in `localStorage`, not in the service-worker cache.

15.6 Restore banner does not appear

- **Cause**: The last session was created in private mode, or the browser cleared `localStorage`.
- **Fix**: Use normal mode and let the browser keep the domain's storage. On iOS, check *Safari* → *Advanced* → *Website Data*.

15.7 Surface wind or precipitation layer looks „empty“

- **Cause**: The layer is rendered for the *planned start time*, not for now. In very calm conditions there is simply little to display.
- **Fix**: Intended — an empty surface-wind layer means calm wind. If in doubt, shift the time by an hour and check whether the visualisation is sensible.

16 Limitations — legal context

The Ballonstart Planer is a **private, non-commercial** tool for preparing hot-air balloon flights. It is *not* an EFB in the EASA sense, *not* a certified weather briefing system, and *not* a source of legally binding information. Responsibility for flight preparation and execution rests entirely with the pilot in command under applicable EU regulations (Standardised European Rules of the Air, SERA) and German national implementation (LuftVG, LuftVO, LuftPersV).

16.1 What must be done before each flight

The following sources from authorised providers must be consulted before each flight — the planner does not replace any of them:

- **pc_met** (DWD aviation weather) — GAFOR, aviation forecast, TAF and METAR for the relevant aerodromes.
- **NOTAM briefing** from DFS AIS-C or an equivalent authorised source.
- **AIP Germany** for permanent airspace and obstacle information.
- If needed, telephone consultation with the responsible FIS or local aerodrome.

16.2 What the app does not provide

- No legally binding weather or airspace data.
- No automatic flight clearance or ATC coordination.
- No comprehensive obstacle detection near the surface.
- No real-time traffic situation (no FLARM, no ADS-B).
- No model resolution below 2 km horizontal — local effects (valley winds, slope breeze, urban heat island) are only roughly captured.

16.3 Data currency and liability

Weather and airspace data come from third-party providers. They may be inaccurate, incomplete or out of date. Use of the app is entirely at the pilot's own risk. Liability of the developer or the club for consequences of a wrong decision based on the display is excluded.

17 Glossary

AGL
„Above Ground Level“. Altitude above the ground at the observer's position. Useful for obstacle assessment. The app shows AGL values by subtracting the ground elevation (MSL) from the internally stored MSL value.

Boundary layer
Lower atmospheric layer in which surface friction shapes wind and temperature. Typically 1000–2000 m high during the day; at night often shrunk to 50–200 m with a strong inversion.

Cruise altitude
The level at which the balloon flies steadily after the climb, until the descent for landing begins.

CTR (Control Zone)
Controlled zone around a controlled aerodrome, from the surface to a defined upper limit. For IFR and VFR (other than under special VFR clearance) requires radio contact with ATC.

DWD ICON-D2
High-resolution weather model of the German Weather Service with 2.1 km grid spacing, forecast horizon 48 h. The planner's primary source for Central Europe.

Drift
Direction in which a balloon is carried by the wind. Geometrically opposite to the meteorological wind direction (= wind direction + 180°).

FIR (Flight Information Region)
Large airspace volume in which an air traffic service provides flight information and alerting. Germany: FIR Bremen and FIR München.

hPa (hectopascal)
Pressure unit. In meteorology common for describing pressure surfaces. A pressure surface is an atmospheric layer of constant pressure; its height varies with temperature and synoptic situation.

Inversion
An altitude layer in which temperature increases with altitude (instead of decreasing). Acts as a vertical-mixing damper. A standard feature of the early-morning atmosphere.

MSL (Mean Sea Level)
Reference for absolute altitude. An MSL altitude is independent of the underlying terrain.

NOTAM (Notice to Airmen)
Notice with time-limited changes or restrictions relevant to flight planning — e. g. a closed runway, a temporary restricted area, a helicopter exercise.

OpenAIP

Community-maintained free database of airspace, aerodromes and navigation aids. Source of polygons and frequencies for the airspace layer.

Prediction

Flight-plan mode: cruise altitude and flight duration are entered, the app computes the expected flight path.

RMZ / TMZ

„Radio Mandatory Zone“ and „Transponder Mandatory Zone“. Airspaces with mandatory radio listening or transponder operation.

Target

Flight-plan mode: a desired landing point is marked by clicking the map; the app computes matching cruise altitudes, optionally with one altitude change.

Thermal

Rising warm air bubble above a strongly heated surface patch. Active during a portion of the diurnal cycle. Undesirable for hot-air ballooning because it disrupts altitude control.

TMA (Terminal Manoeuvring Area)

Controlled airspace above a CTR, typically from 1500 to 3500 ft AGL.

Trajectory

Path of an air parcel or balloon through space and time, computed from the local wind.

Wind shear

Pronounced change in wind speed or direction over a short altitude difference. Important for takeoff and landing because of sudden changes in lift and drift.

18 Data sources and licenses

18.1 Weather and airspace data

Source	Use	License
Deutscher Wetterdienst (DWD)	ICON model fields, precipitation radar.	CC BY 4.0
Open-Meteo	Proxy and selection logic (`best_match`) over DWD ICON.	CC BY 4.0 (data); MIT (API).
OpenStreetMap	Map tiles, geocoding (Nominatim).	ODbL 1.0
OpenAIP	Airspace and aerodrome geometry and frequencies.	CC BY-NC-SA 4.0
Autorouter	NOTAM data for the corridor along the prediction.	API, account-based
Esri / ArcGIS Online	Satellite layer (World Imagery).	Esri terms

18.2 Embedded libraries

Library	Purpose	License
Leaflet	Interactive maps and layer management.	BSD-2-Clause
Chart.js	Wind-profile chart, trajectory plots.	MIT
Turf.js	Geospatial calculations (corridor, distances).	MIT
html2canvas	Generation of the briefing screenshot.	MIT
Tailwind CSS (build)	Utility-CSS framework for the sidebar.	MIT

18.3 Acknowledgements

The app is a private development created in the course of voluntary club work for the Wetterauer Montgolfièren e. V. It is maintained without any commercial background. Suggestions, bug reports and improvements are welcome and should be sent directly to the developer.

— End of manual —

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