Performance Analysis
First Upwind Leg

2025 Formula Kite World Championships

A GPS-based performance analysis comparing Riccardo Pianosi and Maximilian Maeder, the top two athletes of the 2025 Formula Kite World Championships Final.

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Research questions

Main Research questions

How do technical and strategic choices during the start phase and the tacking manoeuvres influence overall performance on the first upwind leg in a Formula Kite race?

How do Pianosi and Maeder differ in their acceleration patterns and speed development during the start window, and how do these differences affect their initial upwind progression?

How does the execution of tacking manoeuvres—considering speed loss, VMG drop, turning radius, and recovery time—impact each athlete's ability to maintain efficient progress toward the wind?

Data Sources

The GPS tracks used in this study were downloaded from the public platform *metasail.it*, event archive:

Data are provided in GPX format, containing timestamped latitude–longitude points for each athlete.

Methodology Overview

Speed, acceleration, VMG, Distance Lost, and Turn Radius were computed using custom Python scripts.

Start line, finish line, and marks were approximated because no official GPS coordinates were provided.

Tack moments were manually identified due to insufficient granularity to detect them algorithmically.

Reproducibility

The entire analysis pipeline is deterministic.

All results can be reproduced exactly using the same GPX files and manually selected tack timestamps and influent points

About data

Data Sources and Structure

The analysis is based on three primary components: the raw GPX tracks of Riccardo Pianosi and Maximilian Maeder, the Excel file *Formula Kite Men FINAL.xlsx* and a set of manually annotated tack timestamps. The GPX tracks provide high-frequency geo-referenced coordinates, enabling the reconstruction of trajectories and the computation of key performance metrics such as Speed Over Ground (SOG), Velocity Made Good (VMG), curvature radius, and distance lost during manoeuvres.

Critical Issues and Limitations

The dataset has several intrinsic limitations. No official coordinates were provided for the start line, marks, or finish line; all these elements were reconstructed computationally using geometric offsets, introducing unavoidable spatial uncertainty. Tacks are not encoded in the GPX files and cannot be detected automatically with sufficient precision due to computational limits. Tack events were identified manually by inspecting the trajectories, SOG profiles, and race simulation. Additional data-quality issues include GPS jitter and slightly irregular sampling frequency, although these affect both athletes symmetrically and do not compromise comparative analysis.

Data Cleaning & Preparation

Preprocessing tasks included filtering GPS points, correcting temporal anomalies, converting latitude–longitude coordinates into a local metric frame, extracting time windows around the start and tack events and computing derived metrics such as SOG, acceleration, VMG, and curvature radius. These operations ensured a coherent and analysis-ready dataset.

Methodology

Processing Pipeline and Tools

The full analysis pipeline was implemented in Python, using *gpxpy* for parsing GPS data, *numpy* for numerical processing and *matplotlib* for visualization. No external APIs or web scraping were required. The code reconstructs the racecourse geometry through trigonometric offsets, projects geographic coordinates into a 2D metric system and extracts analysis windows around manoeuvres and around the start.

Analytical Techniques

Metrics are computed through both descriptive and kinematic methods: speed before/during/after the tack, VMG loss, curvature radius estimation, distance lost, and recovery time. For the start analysis, symmetric 10-second windows around the official start time allow comparison of acceleration behaviour. Maps, trajectory plots, SOG and acceleration profiles, and normalized comparison charts (as radar plots) provide a clear visual interpretation of performance differences between the athletes.

Reproducibility

The entire workflow is fully deterministic. Given the same GPX files and manually annotated tack timestamps, all metrics and visual outputs are reproduced exactly. AI tools were used only for technical assistance, code refinement and documentation—not for data generation or modification. This guarantees transparency of the methodology and full reproducibility of the results.
https://github.com/nicolonucci/GPS-Analysis-of-the-2025-Formula-Kite-World-Championships

Sailing knowledge

A Formula Kite race is sailed around a fixed course marked by buoys. The first leg is an *upwind* section where athletes must advance against the wind by performing a sequence of tacks.

Turn Radius / Distance Lost: Indicators of maneuver efficiency. Smaller radii or higher speeds do not necessarily imply better upwind progress.

The Start Line is a imaginary line separating riders from the beginning of the race. Crossing early results in a penalty.

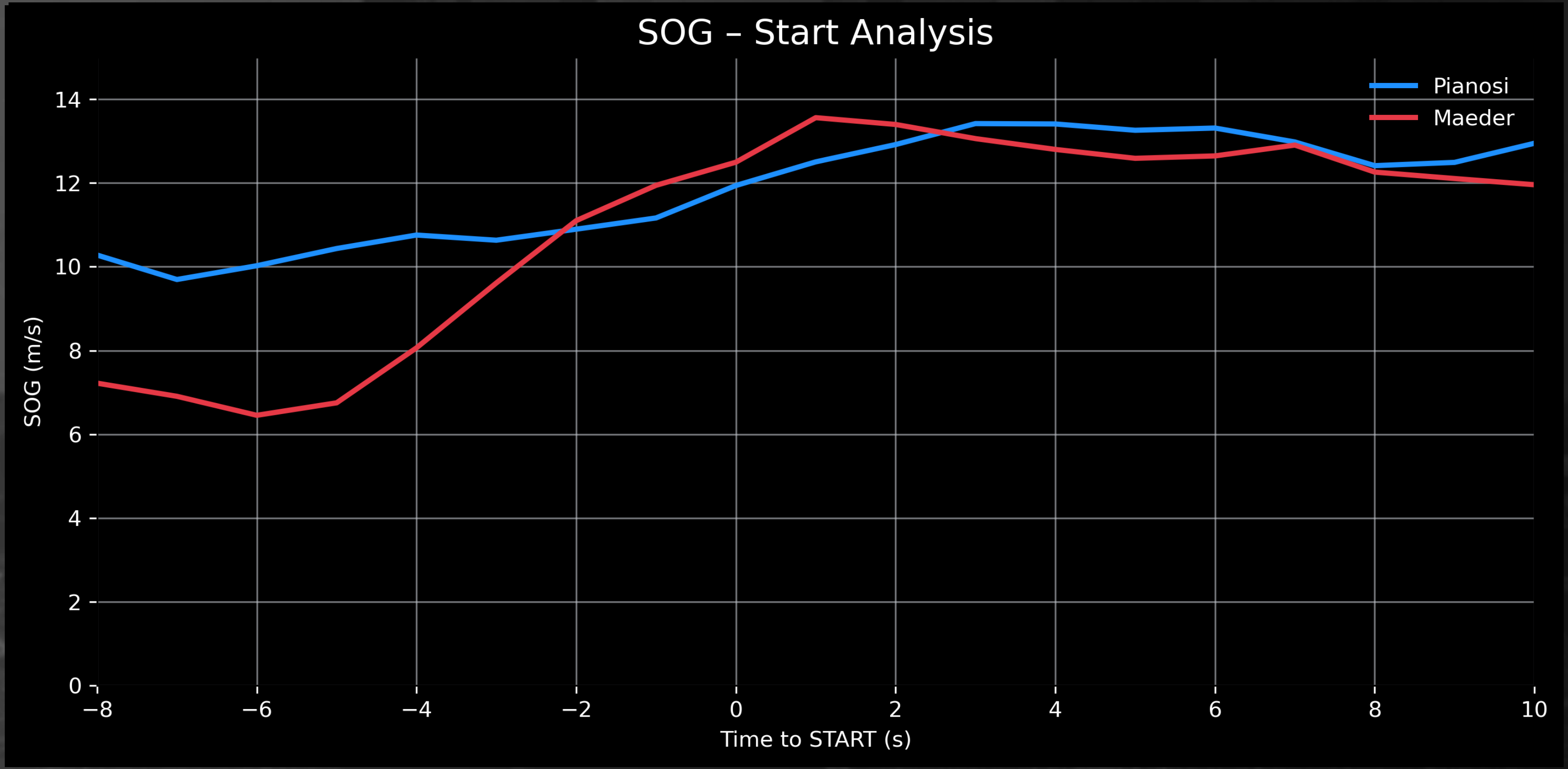
Key concepts

Speed over Ground (SOG): The actual speed measured relative to the Earth's surface.

Tack: A maneuver where the athlete turns the board through the wind to change direction, essential for upwind progression.

Velocity Made Good (VMG): The effective component of speed directed toward the upwind mark.

Start Phase: Speed (SOG) Analysis



Pianosi maintains a stable and high pre-start speed

Maeder approaches the line slower and relies on a sharp acceleration to recover

Right after the start, Maeder briefly surpasses Pianosi with a peak of 13.5–14 m/s.

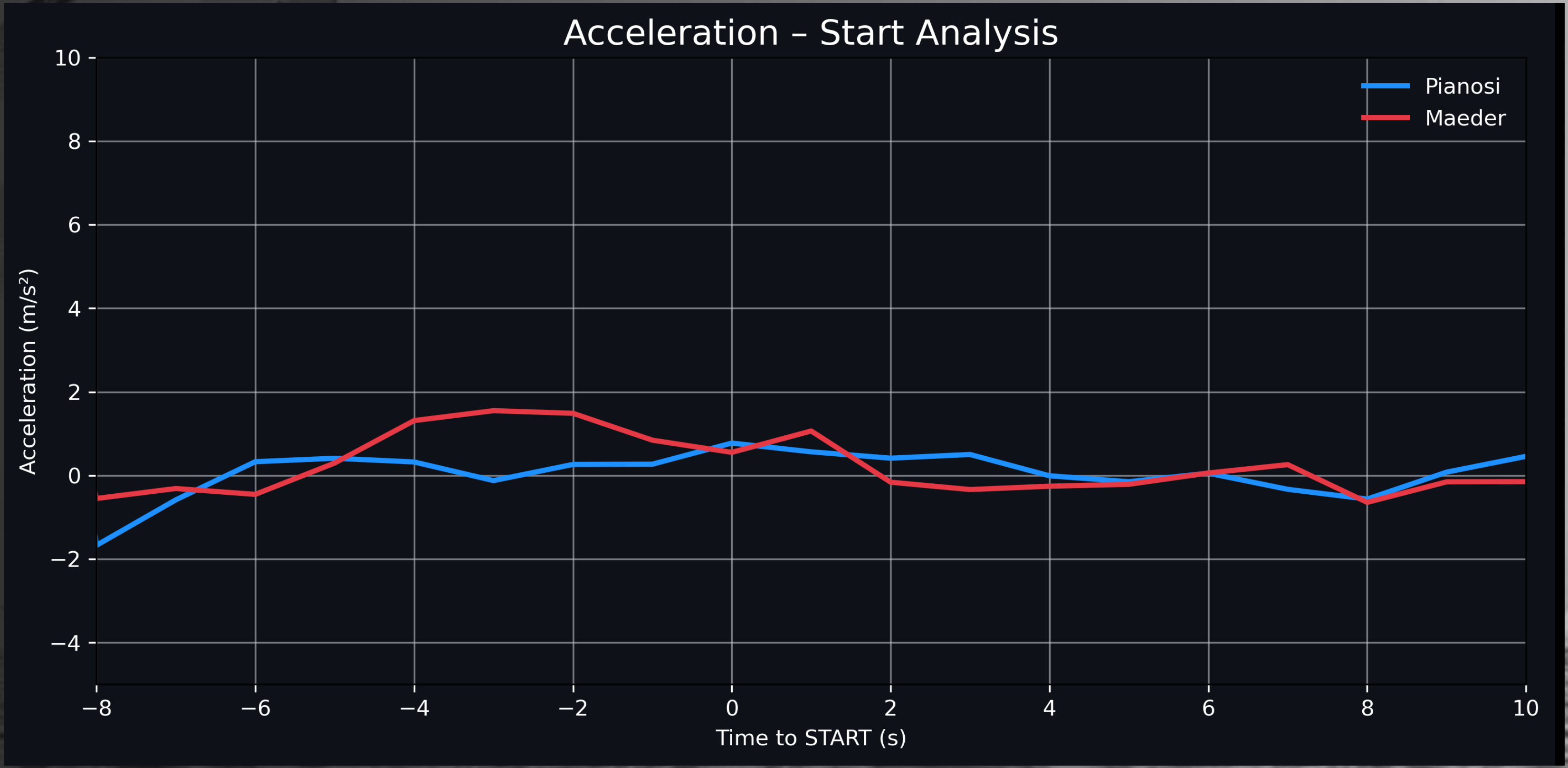
Overall, Pianosi enters the race with stability, while Maeder adopts a more explosive but variable approach.

Acceleration Around the Start

Pianosi maintains a smoother and more stable acceleration range

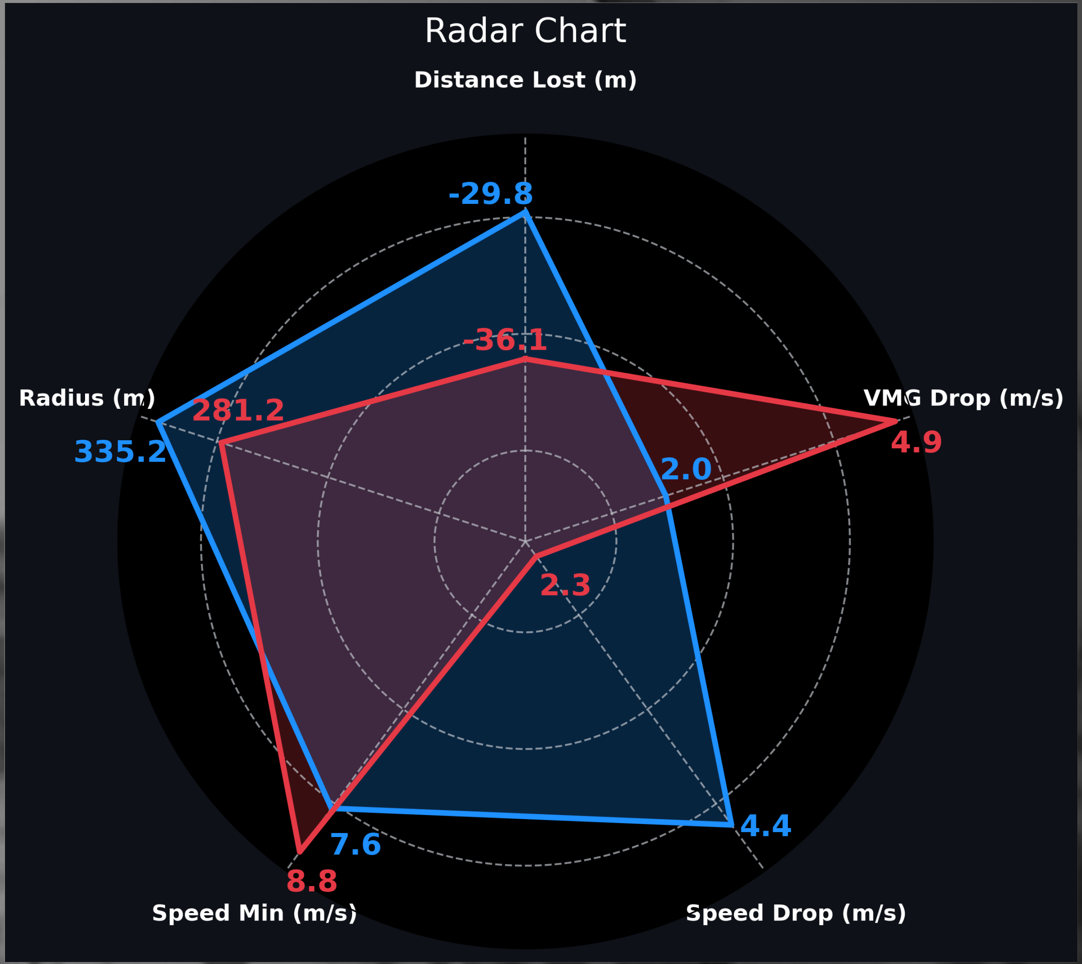
Maeder produces a strong acceleration ramp between −5s and −2s

After the start, both stabilize, though Maeder shows a brief deceleration followed by a secondary acceleration spike



Maeder's aggressive acceleration compensates for his lower entry speed but increases variability. Pianosi's steadier approach limits fluctuations and promotes greater control during the critical pre-start phase.

First Tack Analysis



Maeder preserves a higher minimum speed and performs a tighter turn radius.

Pianosi shows a deeper speed drop but completes a smoother and wider maneuver

Distance Lost: Pianosi loses **6.3 m less** than Maeder

VMG Drop: Pianosi's VMG reduction is **less than half** of Maeder's

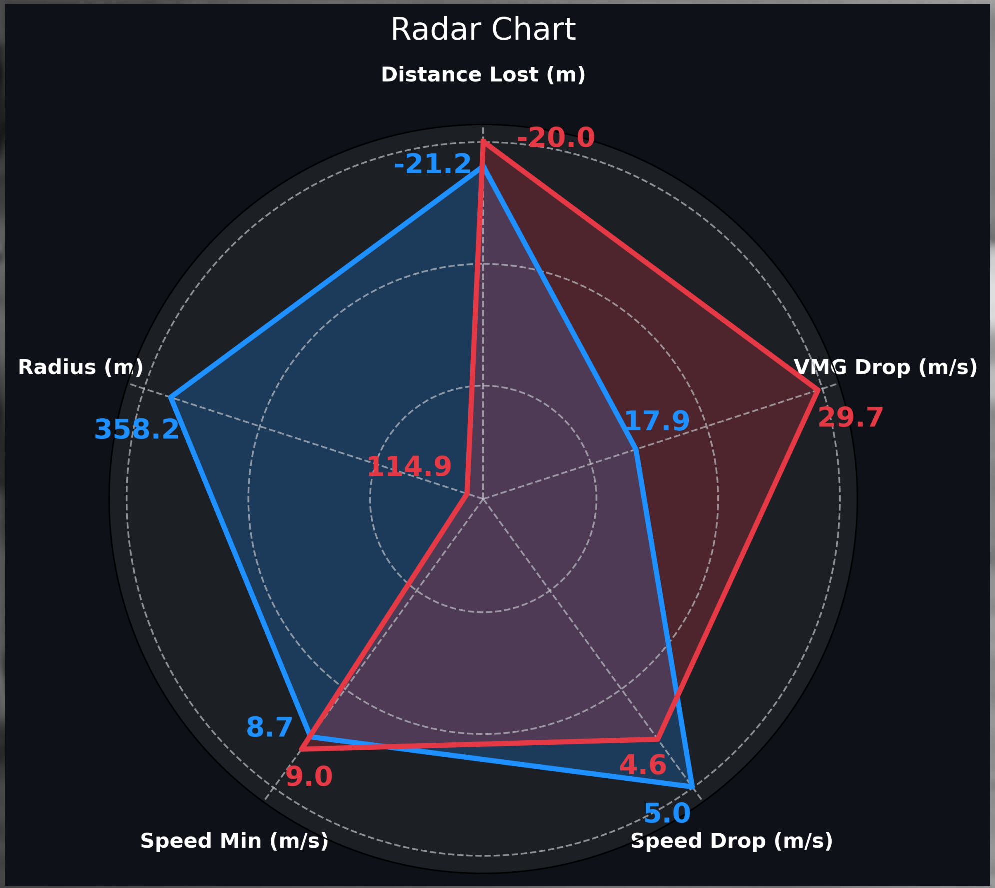
Maeder's maneuver is mechanically sharper, but Pianosi's tack is **strategically more efficient**, prioritizing alignment with the wind and maximizing effective progress. A technically clean turn does **not** always translate into optimal upwind efficiency

Second Tack Analysis

Maeder executes an extremely tight tack with a turn radius nearly three times smaller than Pianosi's

Both athletes maintain high minimum speeds, with Maeder again showing a slight advantage

VMG Drop: Maeder loses 29.7 m/s, far exceeding Pianosi's 17.9 m/s – a substantial tactical disadvantage



Maeder's aggressive maneuver maximizes raw speed but compromises heading efficiency, leading to reduced effective upwind progress.
Pianosi's more conservative turn preserves a stronger tactical trajectory toward the mark. High speed alone does not guarantee good upwind performance – **directional efficiency is equally critical**

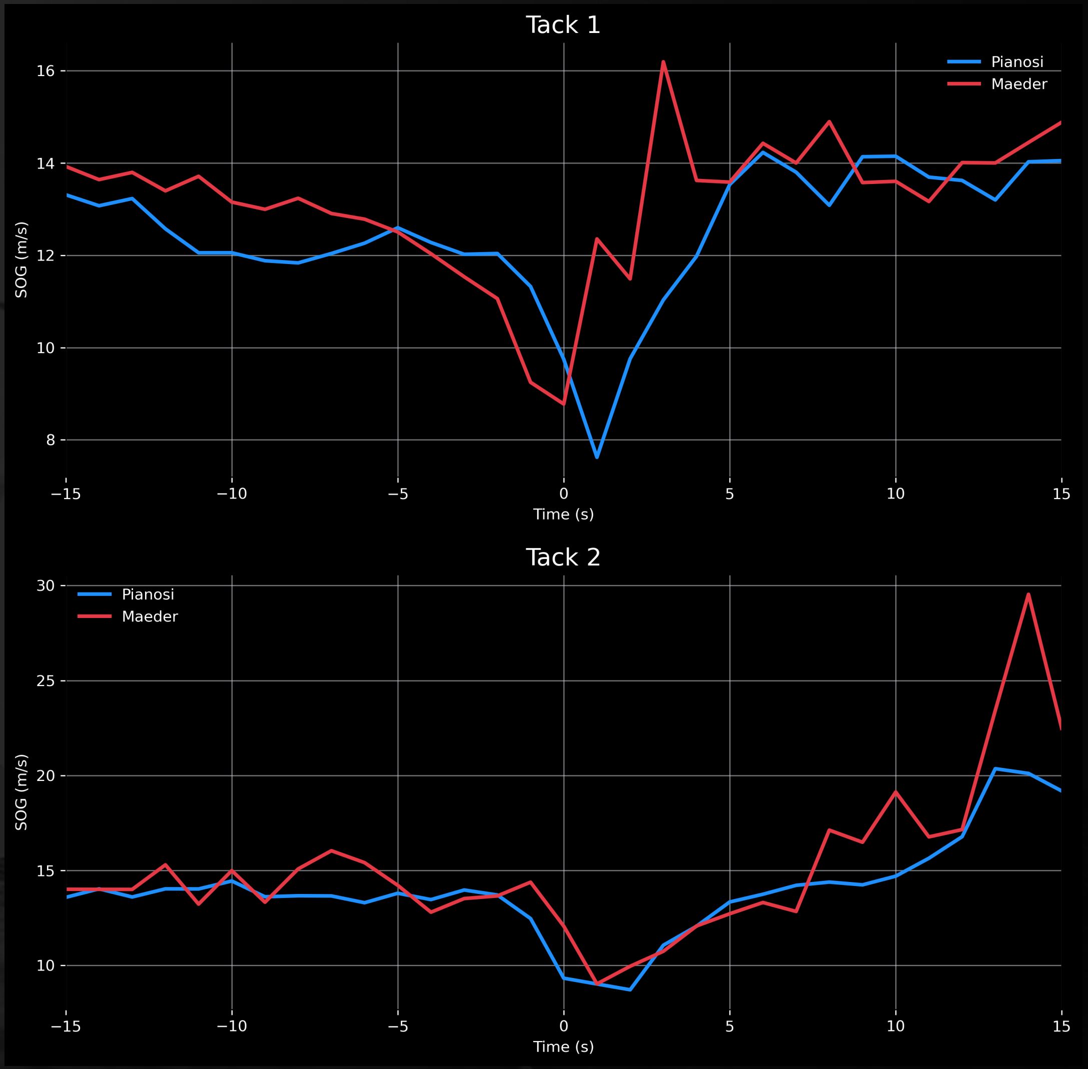
Speed Comparison During Tacks

Maeder produces strong **post-tack acceleration spikes**, reaching up to 29 m/s

Pianosi exhibits **deeper speed minima** but a **more controlled and stable recovery**

The pronounced spikes in Maeder's profile correspond to **greater heading deviations**, which align with his larger VMG losses

Explosive speed spikes highlight strong power output but often reflect a **less efficient upwind angle**.
In contrast, Pianosi's smoother speed evolution suggests a **more strategically optimized trajectory** toward the mark.



Final Conclusions

Maeder relies on sharp accelerations and tight turns, achieving higher short-term speeds but at greater tactical cost

In both tacks, Pianosi preserves significantly more VMG, gaining more effective distance toward the upwind mark

Maeder’s mechanical superiority is offset by larger directional inefficiencies

Pianosi shows superior **baseline stability**, smoother accelerations, and more consistent control during the start

In conclusion, in upwind racing **efficiency and trajectory optimization outweigh sheer speed.** Pianosi’s approach converts a larger portion of his motion into real tactical advantage, explaining his stronger performance in the first leg.

Legal and Reproduction Notes

Data Availability
GPS tracks are publicly accessible and downloadable from *metasail.it*
No personal or confidential data were used.

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