

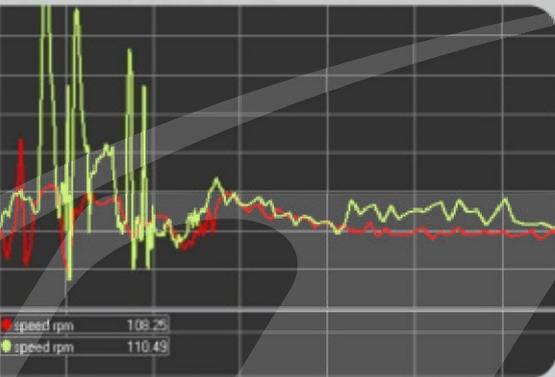


Racing Data Power

GPS MODULE

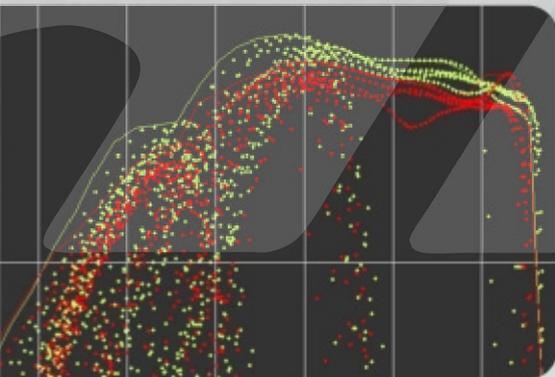
A REVOLUTION IN YOUR KART TECHNICAL ANALYSIS

ON-TRACK SESSIONS



TRACK SESSION

**Comparative test
Morbidelli-Dovizioso**



A WINNING TOOL

**To enhance your performance
and optimize kart set-up**

Date: 8 November 2007

Track: Cervia (RA, Italy)

Kart: VanSpeed Omega ICA 100

Engine: Maxter MX-L 100cc

**Instrumentation:
MyChron4 + GPS Module**

DYNAMIC ANALYSIS

RELEASE 1.01



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Test: comparative analysis of the performances of two drivers

The collaboration with TKart allowed us to analyze data concerning the track session with two absolutely valuable drivers: Gianni Morbidelli and Andrea Dovizioso. Used logger is MyChron4 with GPS Module. Aim of this document is to show the result of the analysis of a couple of instruments so friendly and quick installing.

The session

We chose the track of Cervia (near to Ravenna in the centre of Italy, shown below). The session took place on September 9th 2007. The track map comes from: www.happyvalleykart.com website and it will be very useful because we are going to use the track naming shown in the figure below to analyse this session.

Magnetic strips placement does not include start/finish line of the time-keepers. This make use using some more function of the analysis software.

We decided to use the third magnetic strip of the track as strip reference because it is the nearest to start/finish line of time-keepers (highlighted by the red rectangle in the figure).

MyChron4 settings regards the third magnetic strip after the pit lane as start/finish line and the others as split.

Track Corners

- 1 - La Staccata
- 2 - La Tecnica
- 3 - La Prima delle Esse
- 4 - La Seconda delle Esse
- 5 - Il Canneto
- 6 - La Variante (linked in races to create the main straight)
- 7 - La Casaccia
- 8 - Il Rampino
- 9 - Primo Tornantino
- 10 - Secondo Tornantino
- 11 - Curva dei Box
- 12 - Curva del Bar

TRACK LENGTH M 1000
TRACK WIDTH M 800
Track direction of travel: clockwise

On the track are installed 3 magnetic strips (**b**) for Alfano and AIM telemetric systems

Comparing the two drivers, Morbidelli runs 4 tenth of second faster. We are now trying to understand where he is faster and if there is any point where he is slower. We will consider the three best laps of each driver to avoid blunders depending on lucky conditions of the single fast lap.

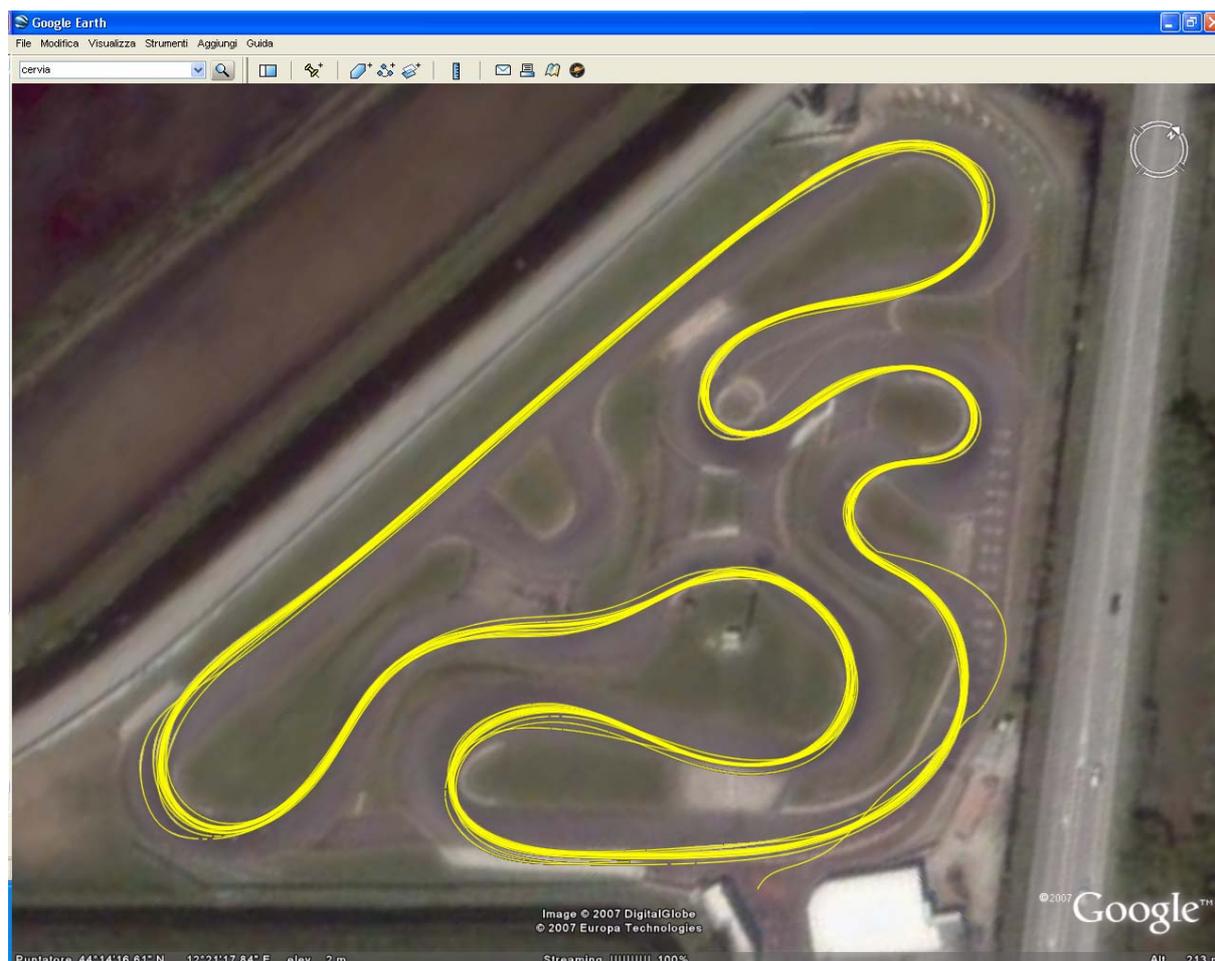
We will analyse GPS speed (absolutely reliable!), lateral and longitudinal acceleration graphs, drawing from them considerations on the behaviour of vehicle and driver. We will also calculate the line bending, the slip and the sum of lateral and longitudinal acceleration.

Always considering the three best laps we will also analyse the lines corner by corner, trying to understand the track secrets. As a premise, please know that this track is very technical and hard to interpret.

We will moreover analyse lap and split times to find possible margins of improvement for each driver.

The track map in Google Earth

Thanks to the possibility of exporting data to Google Earth we have an additional instrument to associate data shown by the graphs to a very realistic positioning.



Morbidelli and Dovizioso

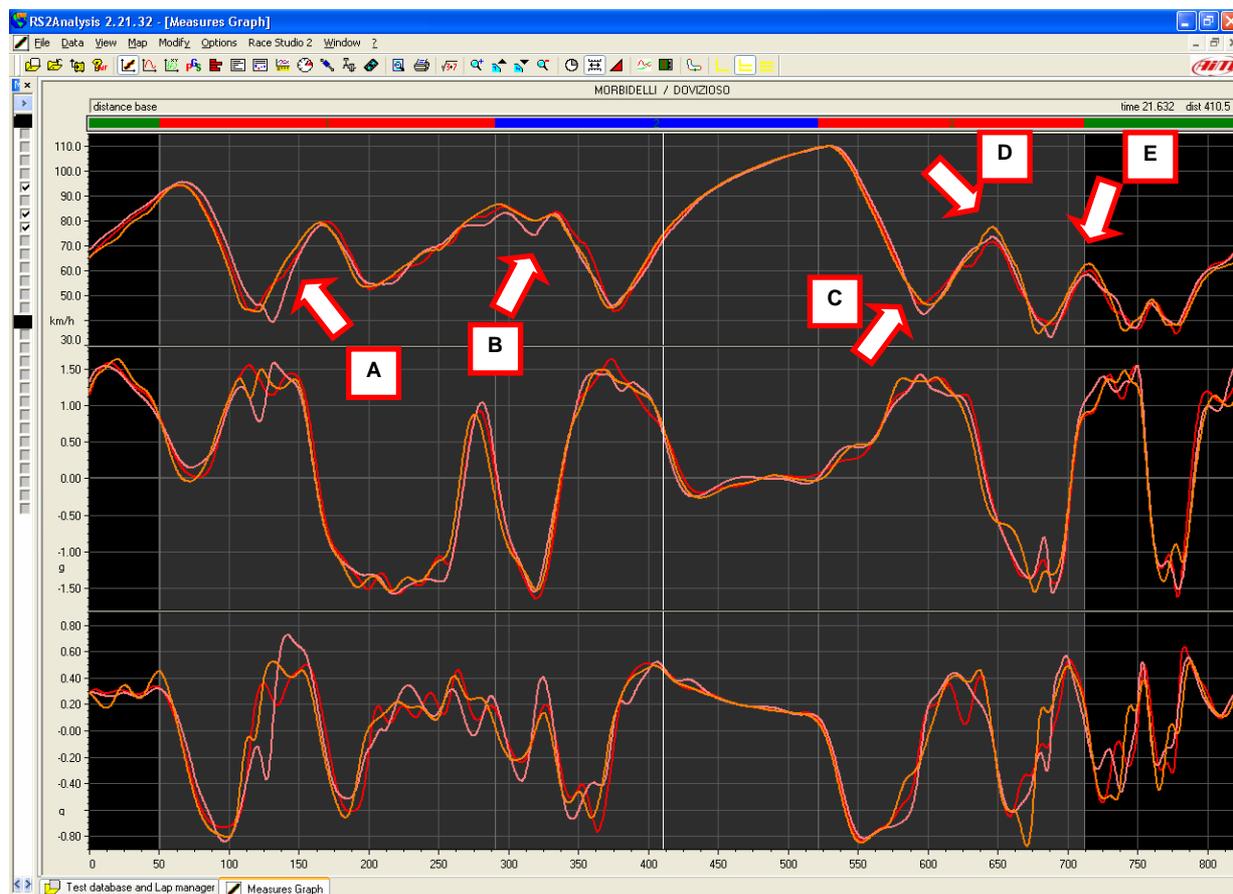
The analysis of measures graphs shows how Morbidelli cannot run steady. In comparison Dovizioso showed more steadiness, also if some corners were hard for him too (red arrows in the following figures: when measures signals lines does not superimpose the behaviour on the track has been different).

Being unsteady can mean a lot of things: the track makes it very difficult, vehicle setup can be improved, the driver is tired. In this particular case, unsteadiness indicates that the drivers felt a lot the competition and took each corner by assault, lap after lap, looking for the limit, until when they went a bit over (and in some cases made a mistake). Making performances repeatable is the secret to be fast and our two drivers know it very well but a challenge is always a challenge and nobody likes loosing.

In the following graphs Morbidelli laps will be shown as follows: red coloured the best lap (lap 8: 45.320), pink coloured the second best lap (lap 9: 45.380) and orange coloured the third best lap (lap 7: 45.460).

After a glance, we pleasantly "criticised" Morbidelli for his unsteadiness in most part of the track and in particular, according to the track map, the following corners are highlighted:

- A – Run of "La Staccata".
- B – Passage from "Prima delle Esse" to "Seconda delle Esse".
- C – Run of "La staccata della Casaccia".
- D – The "Tornantini".
- E – Entrance in the "Curva dei Box".



In the following graphs Dovizioso laps will be shown as follows: dark green coloured the best lap (lap 14: 45.730), light green coloured the second best lap (lap 11: 45.900) and green water coloured the third best lap (lap 12: 45.970).

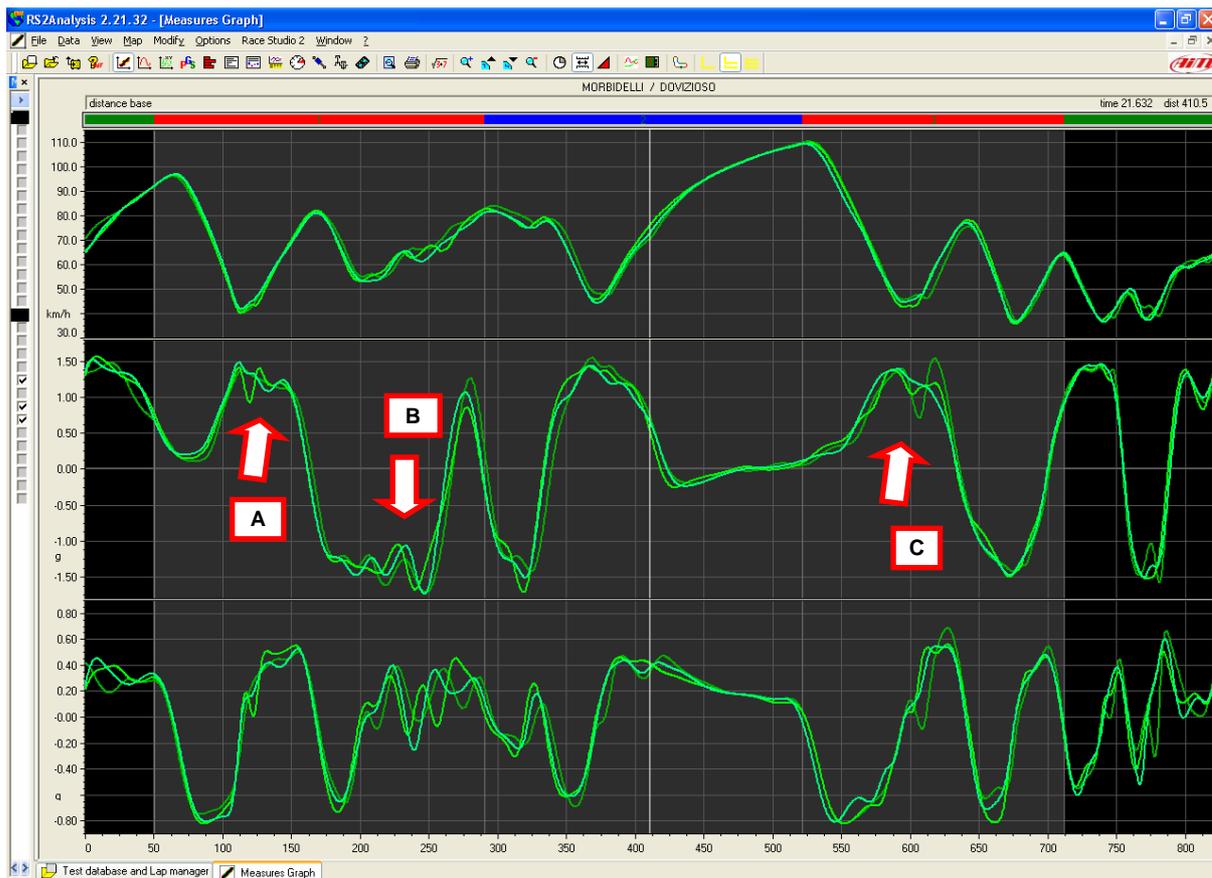
We underline that percentage difference between the two drivers is less than 1% which means the drivers are absolutely comparable.

According to the second track map, shown before, corners run differently are:

A – Entrance of “La Staccata”.

B – Exit of “La Tecnica” and entrance of “La Prima delle Esse”.

C – Run of “La Casaccia”.



Time Compare

Some advices to use Time Compare: best lap is shown as horizontal comparison line (red of Morbidelli), while the other lines (colours corresponding to the laps in the other graphs) highlight increasing gap if they go upwards and decreasing gap if they go downwards if compared to best lap.

Time Compare is shown on bottom of Race Studio Analysis measures graph; this way, analysing the signals of the measures shown over, we can know the reason of the differences between the two drivers.

Trying to understand where the gap accumulates, we have to compare two sections where Time Compare graph shows a flat line, mainly if comparing drivers that face corners in different ways like, in this case, a rider and a driver. In effect it often happens that the two drivers choose different way of running corners. One enters slow to exit faster while the other does the opposite way. This makes Time Compare graph “bumpy” what could deceive (red arrows in the figure). For a correct reading of Time Compare its always worth making the balance between cornering in and cornering out.

Looking at Morbidelli’s laps (red, pink and orange coloured in the following figure), in the best one (red coloured) he runs very well the first part of the corner (until the “*Staccata della Casaccia*”), while in the second one, always referring to his best lap, he could not express itself as in the other two.

Comparing Morbidelli with Dovizioso, Morbidelli does better in the first part of the track, while in the second one Dovizioso manages to recover. The green lines in fact go downwards to the end of the diagram, reaching the reference lap line.



Split analysis and research of a mistake

Time analysis on the splits allows us to see that Morbidelli, differently from Dovizioso, could be slightly faster with a lap time of 45.190. Dovizioso on the contrary could offer its best in a single lap

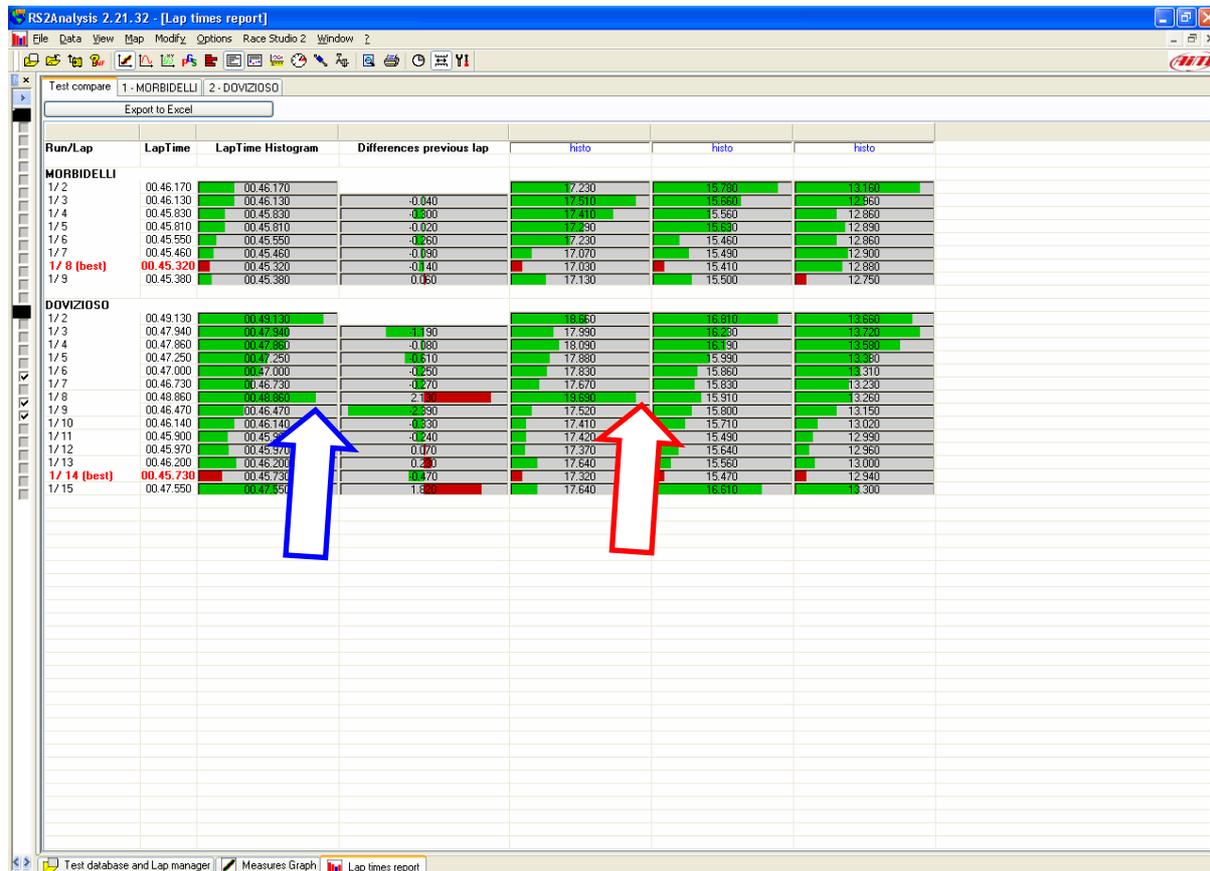
Faster splits are written in blue in Split Times report window (highlighted by red arrows in the figure).

Lap times histograms (highlighted by a blue arrow) indicates that Morbidelli (on top) went constantly improving its performance lap after lap. Looking at Dovizioso histograms we can notice that he too improved at the beginning but the research of the limit took him under 46.000 in the final laps to re-ascend and re-descend to the definitive 45.730.

Run/Lap	LapTime	LapTime Histogram	Differences previous lap	histo	histo	histo
MORBIDELLI						
1/2	00:46.170	00:46.170		17.230 [s]	33.010 [s]	46.170 [s]
1/3	00:46.130	00:46.130	-0.040	17.510 [s]	33.170 [s]	46.130 [s]
1/4	00:45.830	00:45.830	-0.300	17.410 [s]	32.970 [s]	45.830 [s]
1/5	00:45.810	00:45.810	-0.020	17.290 [s]	32.920 [s]	45.810 [s]
1/6	00:45.550	00:45.550	-0.260	17.230 [s]	32.690 [s]	45.550 [s]
1/7	00:45.460	00:45.460	-0.090	17.070 [s]	32.560 [s]	45.460 [s]
1/8 (best)	00:45.320	00:45.320	-0.140	17.030 [s]	32.440 [s]	45.320 [s]
1/9	00:45.380	00:45.380	0.060	17.130 [s]	32.630 [s]	45.380 [s]
1/10	00:47.250	00:47.250	1.870	17.400 [s]	33.800 [s]	47.250 [s]
DOVIZIOSO						
1/2	00:49.130	00:49.130		18.660 [s]	35.470 [s]	49.130 [s]
1/3	00:47.940	00:47.940	-1.190	17.990 [s]	34.220 [s]	47.940 [s]
1/4	00:47.860	00:47.860	-0.080	18.090 [s]	34.280 [s]	47.860 [s]
1/5	00:47.250	00:47.250	-0.610	17.880 [s]	33.870 [s]	47.250 [s]
1/6	00:47.000	00:47.000	-0.250	17.830 [s]	33.690 [s]	47.000 [s]
1/7	00:46.730	00:46.730	-0.270	17.670 [s]	33.500 [s]	46.730 [s]
1/8	00:48.860	00:48.860	2.130	19.690 [s]	35.600 [s]	48.860 [s]
1/9	00:46.470	00:46.470	-2.390	17.520 [s]	33.320 [s]	46.470 [s]
1/10	00:46.140	00:46.140	-0.330	17.410 [s]	33.120 [s]	46.140 [s]
1/11	00:46.300	00:46.300	0.160	17.420 [s]	32.910 [s]	46.300 [s]
1/12	00:45.970	00:45.970	-0.330	17.370 [s]	33.010 [s]	45.970 [s]
1/13	00:46.200	00:46.200	0.230	17.640 [s]	33.200 [s]	46.200 [s]
1/14 (best)	00:45.730	00:45.730	-0.470	17.320 [s]	32.790 [s]	45.730 [s]
1/15	00:47.550	00:47.550	1.820	17.640 [s]	34.250 [s]	47.550 [s]
1/16	00:50.330	00:50.330	2.780	17.790 [s]	35.900 [s]	50.330 [s]

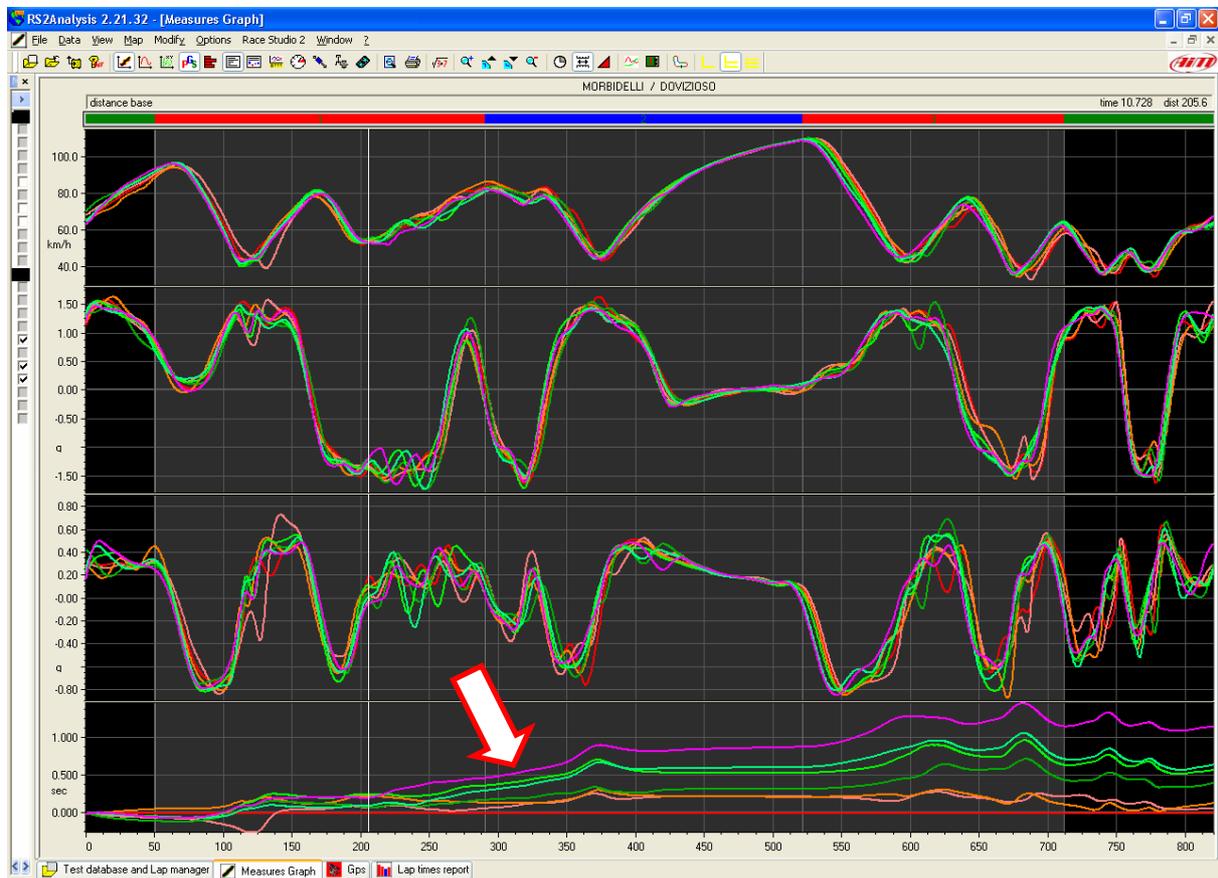
In the next figure we deleted Morbidelli's Lap 10 and Dovizioso's lap 16 (the last two laps for both of them) because evidently slowing down laps.

Dovizioso run a lap in 48.860 (highlighted by the blue arrow in the figure). It's a very slow time. What happened? He slowed down to cool the tyres? He made a mistake? Lap histograms analysis highlights (red arrow in the next figure) that in the first split he made a mistake, while split times of the other two splits reflects lap times and are quite regularly going down. Let's have a look in detail to the first split of the bad lap using the other available data.



The first window to look at is Time Compare.

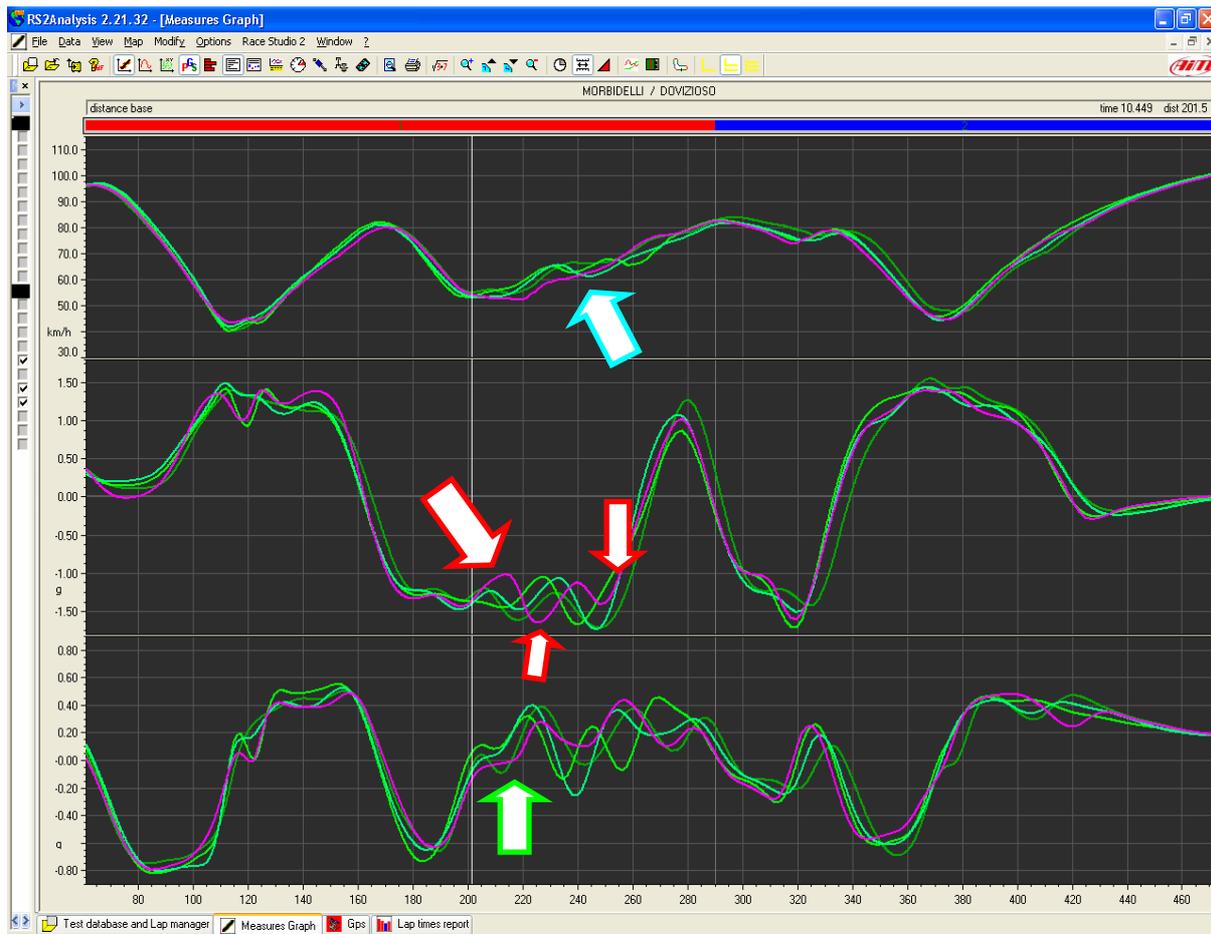
We will superimpose Dovizioso's Lap 8 in purple, the one with the mistake, to the other laps we are considering. The comparison highlights that there is a section of the track between 250 and 350 metres where the gap between the drivers grows steady (red arrows in the figure); a mistake just before the 250 metres were dearly paid after.



We are now showing only Dovizioso's measures. Looking at the lateral acceleration diagram (red arrows in the figure) we see a peak towards zero meaning a side slip and a successive peak towards the bottom of the lateral acceleration, meaning a re-keeping of grip: as the kart re-takes grip it loses it again. This side slip (green arrow in the figure) implied a great waste of time, used to control the vehicle, when accelerating was impossible.

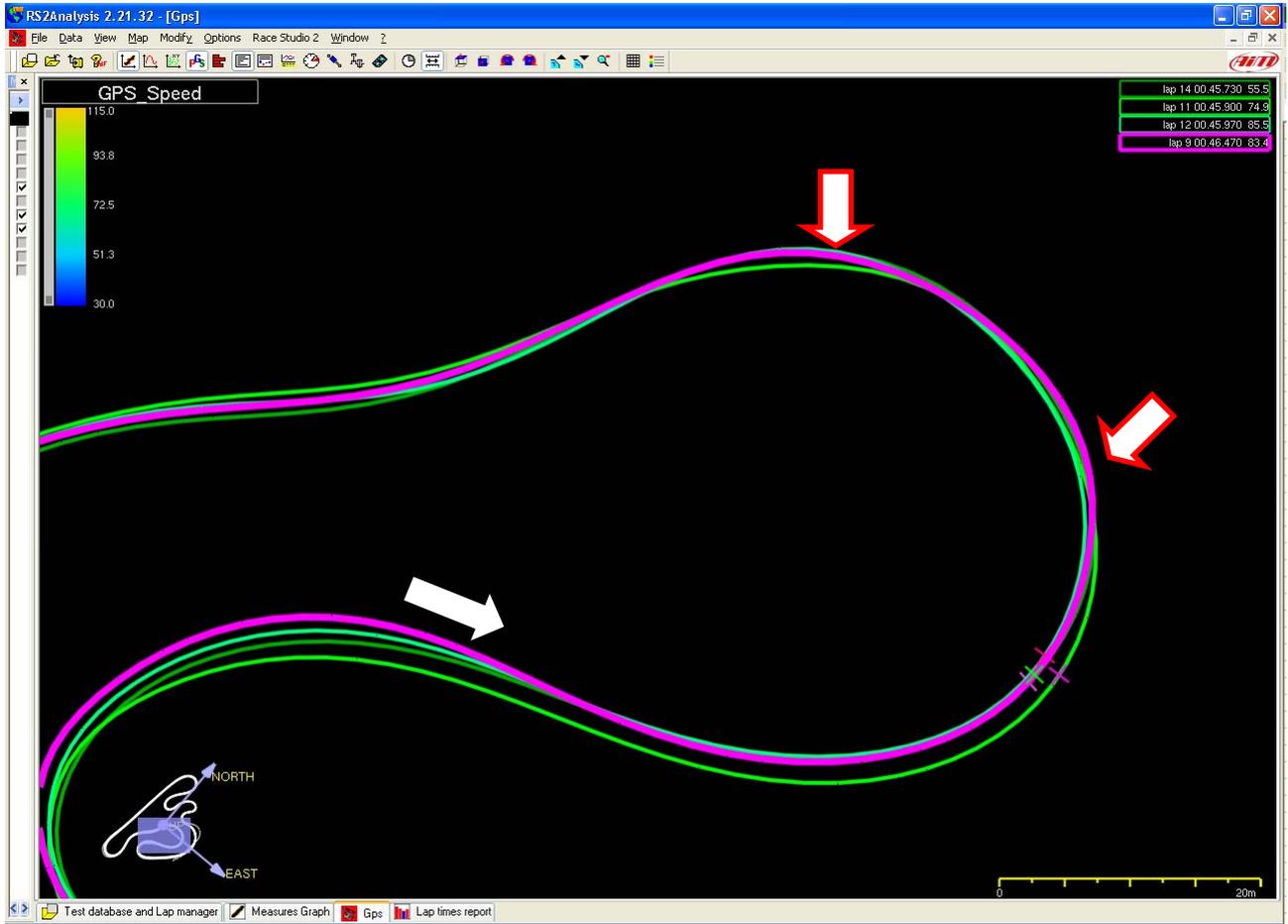
Please remind that lateral acceleration is negative in left corners so peaks upwards (towards zero) indicate a fall of lateral acceleration.

Looking to the other laps, there too he went a little over the limit, but in the lap we are analysing he exaggerated and could no more re-keep speed (light blue arrow in the figure).



Line analysis highlights the two points (red arrows in the figure) where the vehicle lost grip and moved from the inner part of the corner (where its line matches the others) to the outer one along the tangent of the same corner.

The summary map (bottom on the left) indicates where on the track all happened: “*La Tecnica*”.

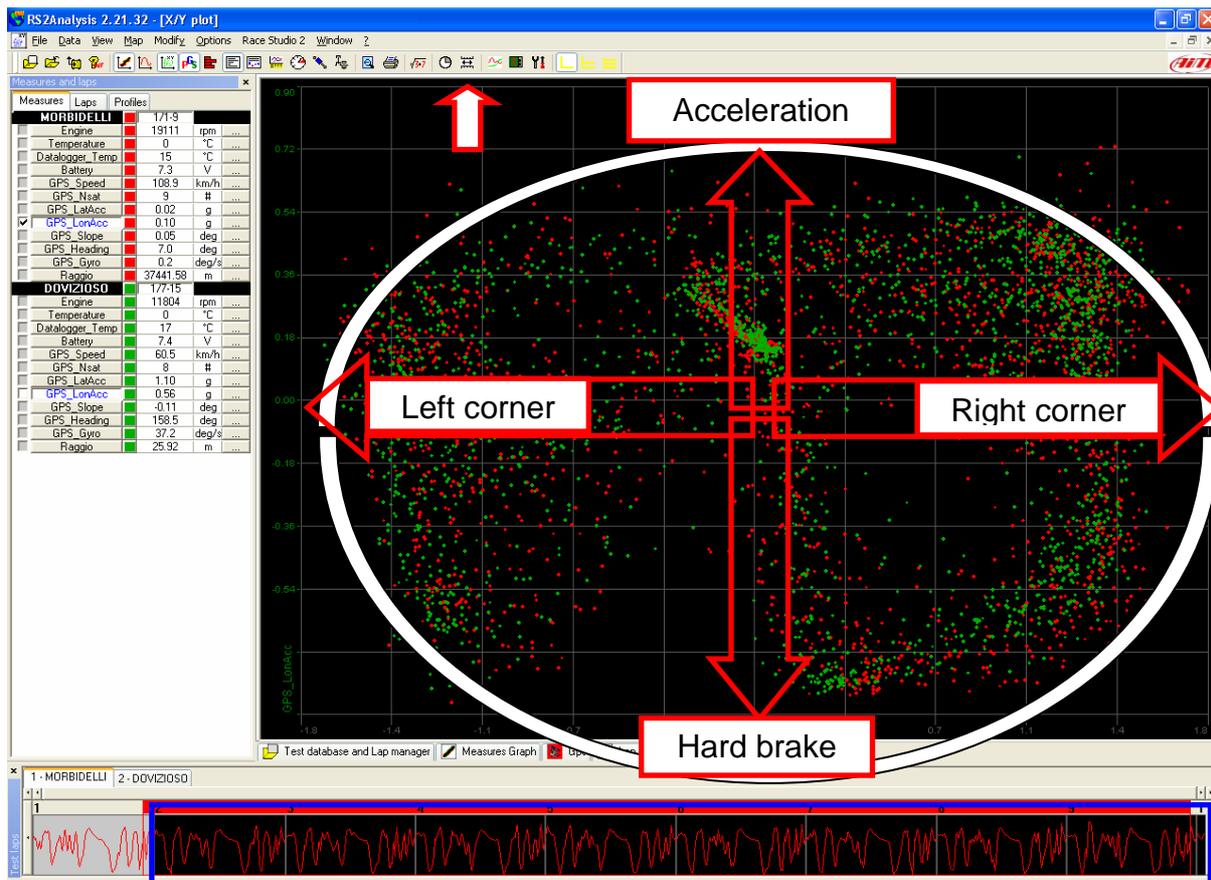


G-G Diagram

The use of this graph is related to how much grip the vehicle can express and which part of it the driver uses. In theory maximum grip is along a circle: the near the driver is to the limit circumference the more he exploits vehicle grip. We will see corner by corner how to “read” this diagram. At present we are making some considerations on the all test.

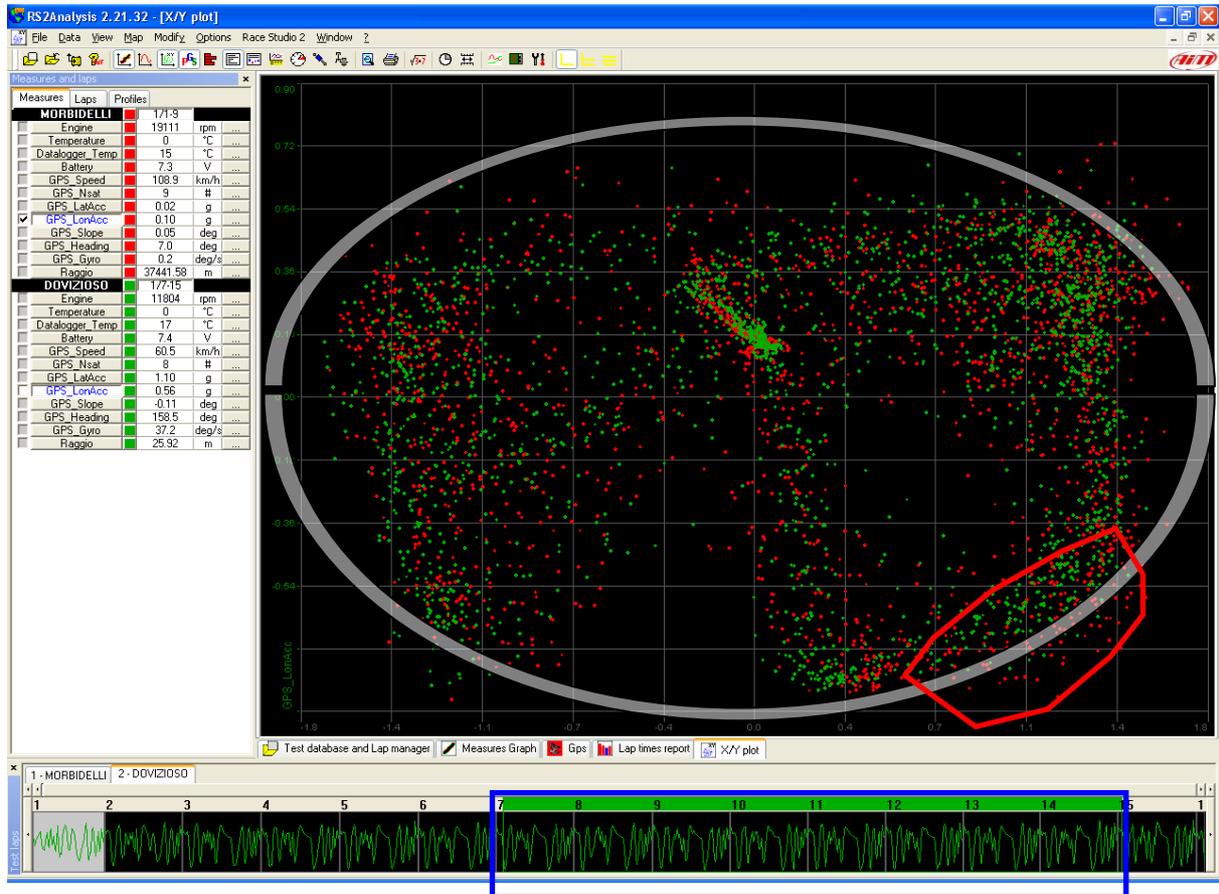
To make this analysis we switched to software Snap OFF mode (red arrow in the figure) and we considered a very big range, whose centre are the two drivers best laps (blu rectangle in the figure).

We are using a big range to have redundant data.



The graph shows there are not big differences between the two pilots, except for right corner entrances (area highlighted in red in the figure) where Morbidelli can better exploit the vehicle grip. To say the truth the difference with Dovizioso is really minimal.

The next figure refers to the same section of the track; we only changed the bottom folder to highlight the selected range in Dovizioso's test.



Total Acceleration – Gsum

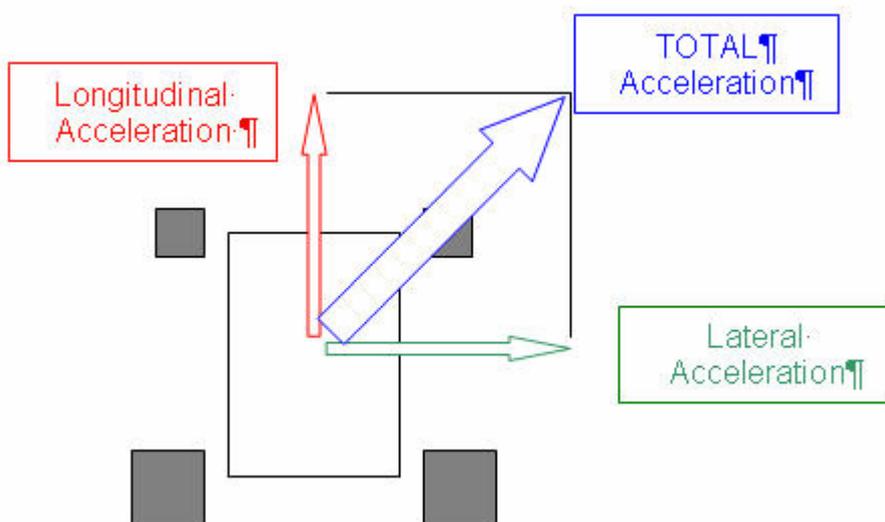
G-G diagram analysis is useful to graphically understand how important is to stay near to the maximum grip circumference and advantage of the vehicle grip. We can thereby calculate, as shown in the following figure, the sum of the two accelerations to see on measures graph if and how we can approach the maximum grip. We will also see how worth is in terms of lap time exploiting the vehicle at its maximum.

Total acceleration (graphically represented in the following figure) can be calculated with a math channel through this formula

$$\sqrt{LateralAcceleration^2 + LongitudinalAcceleration^2}$$

that in Race Studio Analysis becomes a math channel called Gsum

`sqrt((GPS_LatAcc^2) + (GPS_LonAcc^2))`.

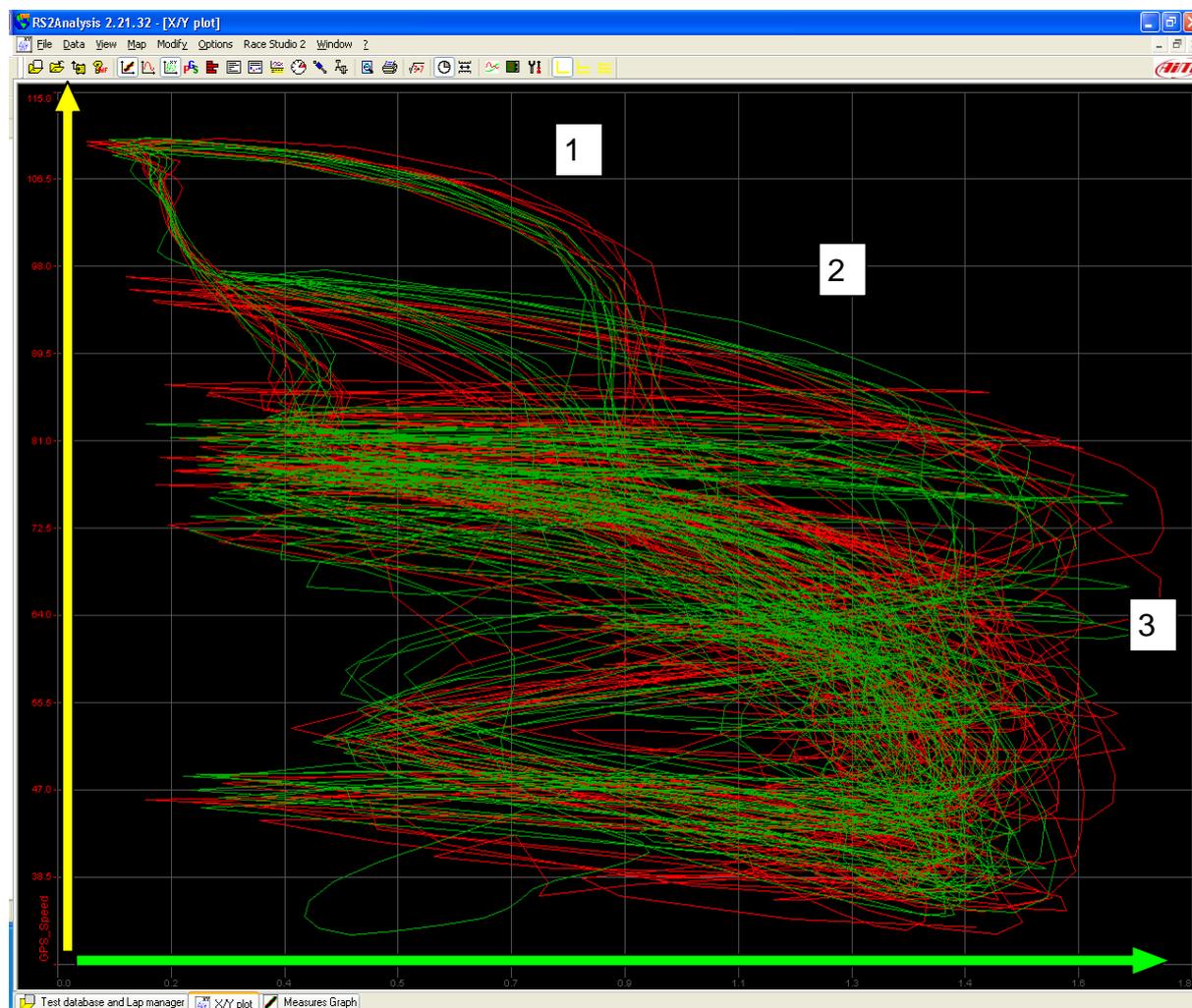


On an XY graph we set Gsum on the abscissa axle (X) and speed on the ordinates one (Y) and will see the analysis made on the overall of the two drivers best laps.

On the upper part of the graph we will see the part where speed is high (growing along the yellow arrow in the figure). The more we go down the graph the more speed decreases. The more we reach the right part of the graph (along the green arrow in the figure) higher grip exploitation of the vehicle is. It's intuitable that, being vehicle grip exploited in the corner, lines on the right (point 3) are lower than lines on the left (point 1) because... it seems obvious, corners speed is lower than straights one.

Areas near to point 1 (high speed and low total acceleration) in the figure are likely to indicate that Morbidelli (in red) exploits more grip at high speed; in areas near to point 2 (medium speed and medium acceleration) Dovizioso seems to be faster, while in areas near to point 3 (low speed) Morbidelli can express an higher total acceleration.

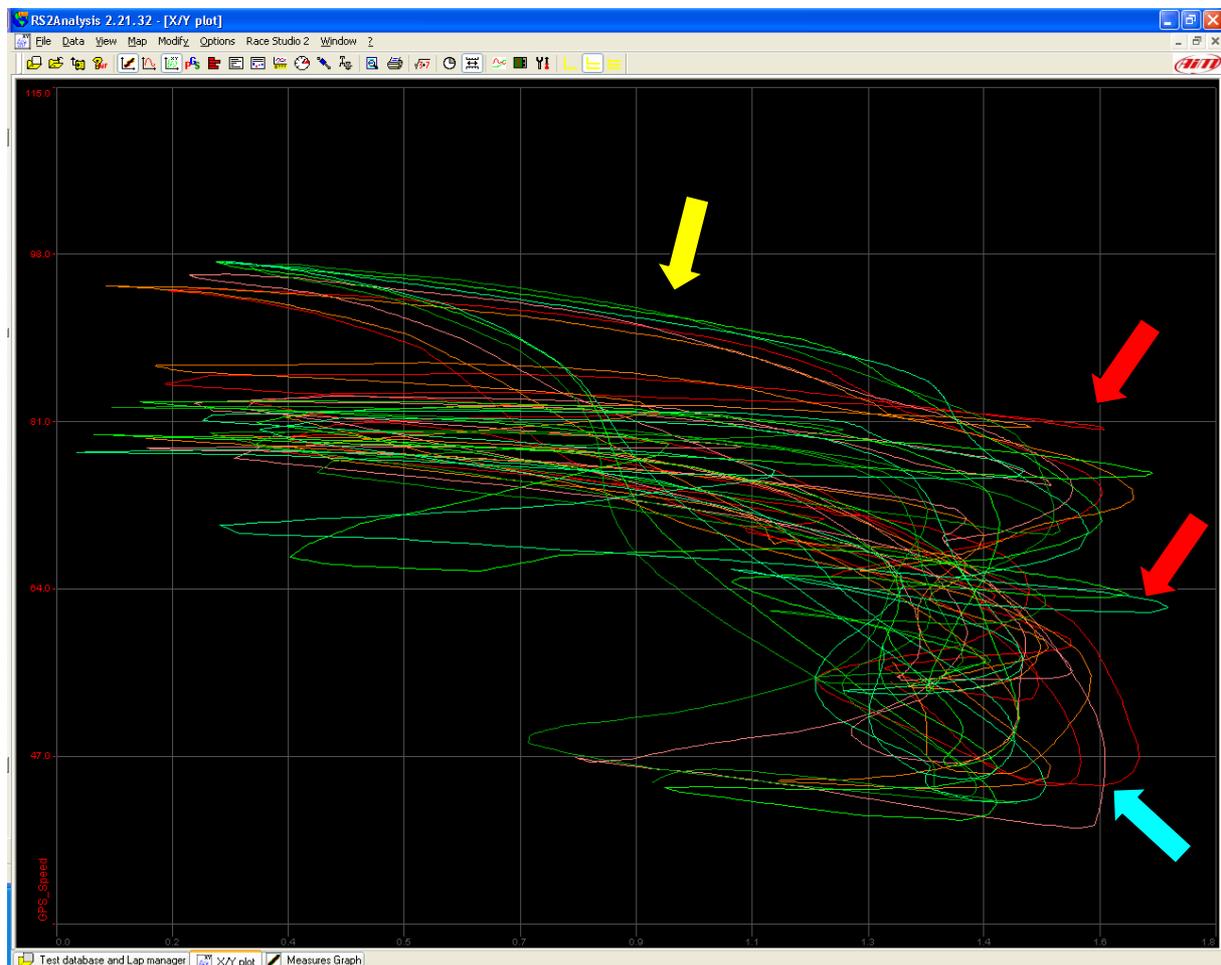
We remind that great total acceleration means: a big hard brake, a corner run with grip and very fast, a situation where braking and bending to the limit.



With reference to Time Compare graph, in the first part of the track Morbidelli made the difference while in the second one Dovizioso partially recovered.

If we apply this graph to the first part of the track we can see that Dovizioso uses slightly more acceleration in medium speed sections (yellow arrow in the figure, where Dovizioso's green lines are more on the right), but the real difference between the drivers in the sections with great total acceleration (light blue arrow in the figure, where Morbidelli's red lines are a lot more rightwards). The analysis seems saying that the difference in the first part of the track can be done with low speed. This underlines that Morbidelli used the vehicle slightly better in the situations we spoke about: corners in grip and hard braking in corners.

Peaks towards the right of the graph highlighted by the red arrows indicates sections where an high total acceleration is reached to be suddenly abandoned; these peaks indicates re-keeping of lateral grip of the kart that follows side slips due to over steering and thereby not very useful to our comparison between the two drivers.



In the second part of the track we can see how Morbidelli better advantages of grip at very high speed (yellow arrow in the figure, Morbidelli's red lines are more rightwards). The Casaccia hard braking is the last point where Morbidelli gains on Dovizioso, better managing the first part of the hard braking.

In the slower parts of the track (light blue arrow, where Dovizioso's green lines are more rightwards) on the contrary, Dovizioso better advantages of the vehicle: he stays on the right part of the graph for a wider part of the track, while Morbidelli in two laps upon three reaches an high total acceleration only for rightwards peaks related to side slips.

It's thereby evident again that to go fast we have to stay on the right part of the graph, that means taking advantage of the grip the kart offers.



Slip

Measuring GPS speed (the measure is really very accurate!) and having RPM value allows us to compare the two channels and see how to exploit cornering out grip or to understand if the driver locks the rear axle (it is true that aside the track we can see it very well) and how (try do it on the edge of the track if you can!).

To calculate the grip we added the math channel:

“Engine/GPS_Speed”

We assume this channel will have very high values: around 17,600 RPM we are running at 100 km/h, so in this situation the compute is 176. Assuming that around 100 km/h the kart does not slip (that would just crown it!) we can modify the math channel formula as follows:

“(Engine/GPS_Speed)/176”

This way speed channel will be 1 in absence of slip (red arrow in the figure), higher than 1 when the kart slips (light blue arrow, the engine revs faster than the detected instant speed) slightly lower than 1 in case of braking (green arrow, the engine revs slower than the speed), a lot lower than 1 in case of hard braking near to the block (yellow arrows shows points where the engine revs a lot slower than speed).

This procedure is called “normalisation”: please pay attention to pinion crown changes: value 176, that here can seem magical will need to be re-computed as said before.

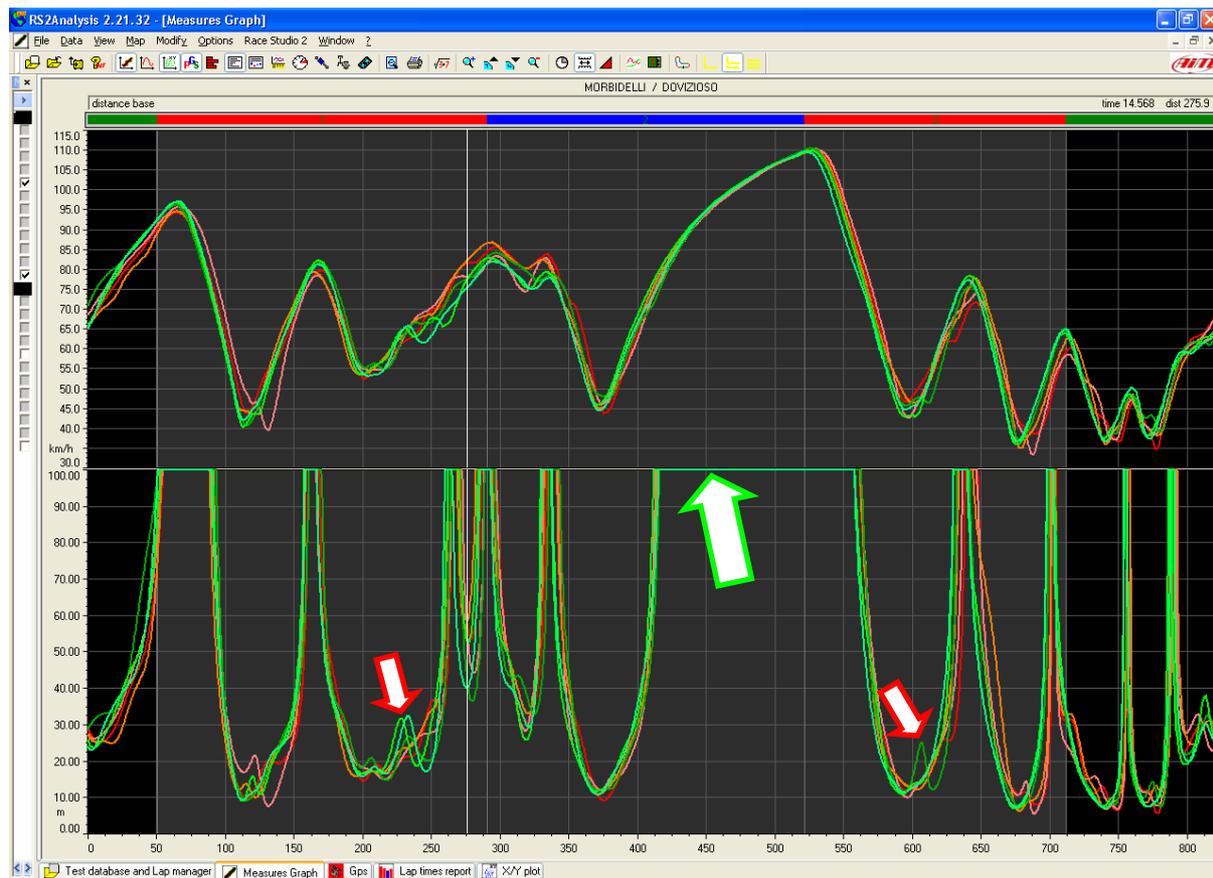


Line bending radius

We asked ourselves what the bending radius of the two drivers lines was. It can be calculated with a math channel through the formula: "GPS_Speed / GPS_Gyro". What comes out is that there are no particular cornering preferences.

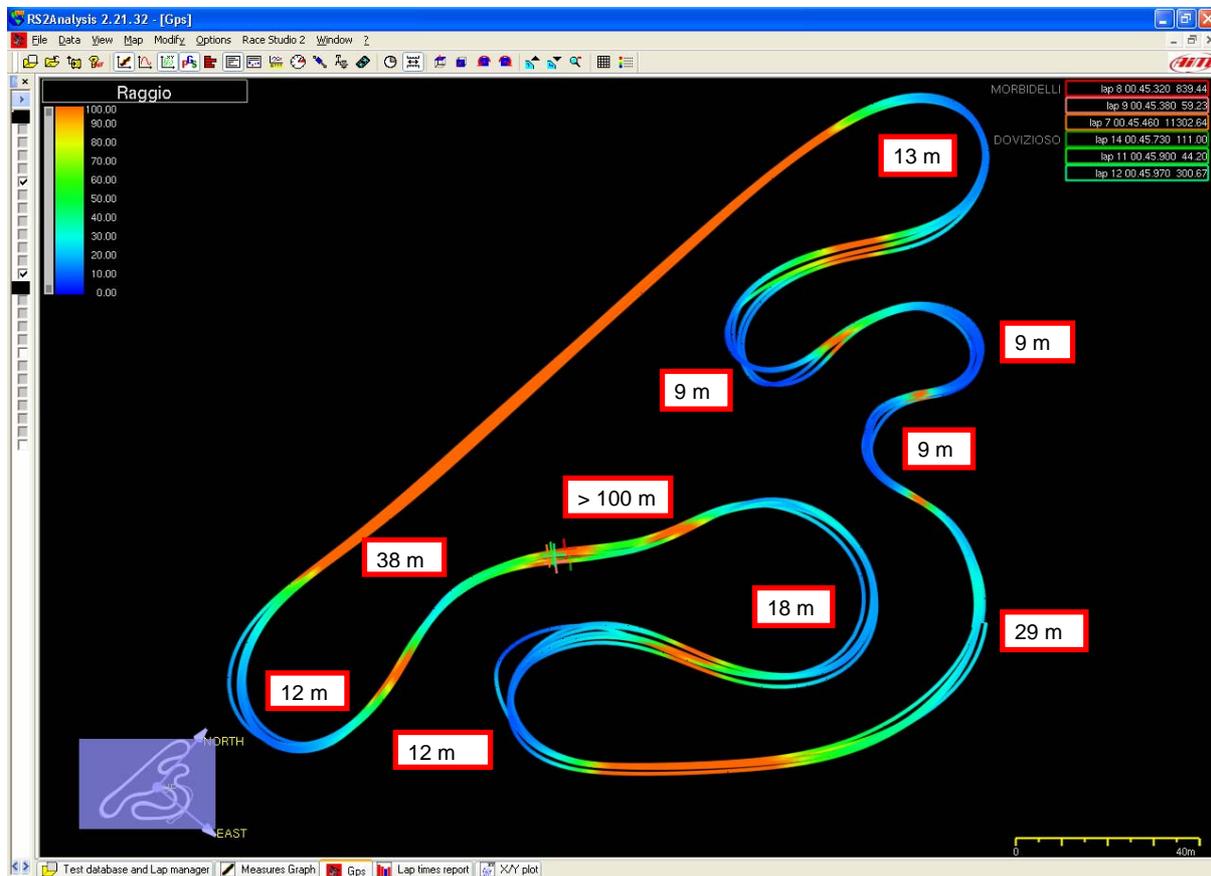
Mistakes on the track causes upwards peaks on the bending radius because the vehicle tends slipping away while straightening the line.

It's important noticing that we are speaking about bending radius that has nothing to do with over or under steering.



Bending radius increases on straights until very big values (green arrow in the figure); this is due to the fact that on a math channel point of view a straight is a corner with "infinite" radius and thereby very big.

To be more clear, through Race Studio Analysis software we indicated lines bending radius on the same lines. The three following corners “Rampino” + “Tornantini” are the narrowest part of the track with a 9m bending radius. Moreover the two corners “Dei Box” and “Del Bar” are to link in one only corner of around 29 metres radius. Please note that “La Prima delle Esse” is to straighten as more as possible with a bending radius of more than 100 metres (nearly a straight in practice).

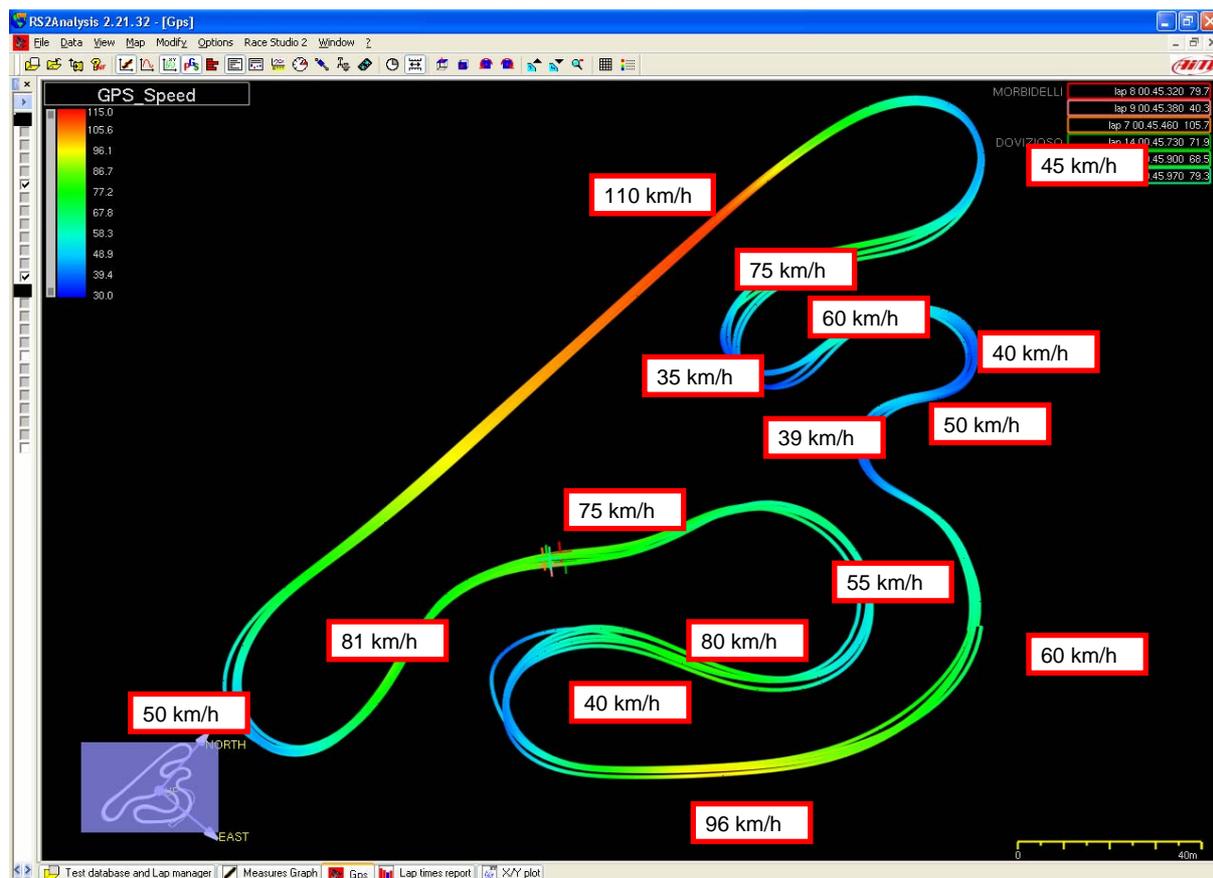


GPS Speed

The faster point of the track is the hard braking “La Casaccia”, where the driver arrives at around 110 km/h. The slower point is “Il Rampino” with around 35 km/h.

We remind how GPS speed is here the best way (at present offered by technology), to measure vehicle speed, reaching an accuracy of around 0,1 km/h.

The first part of the track (bottom left in the figure) includes three strong hard braking and a mixed part of from 50 to 80 km/h, that takes to the straight and then to the track most difficult hard braking. After the main straight there are various left and right corners to be run from around 35 to 70 km/h, that lead to the two fast final corners to be run in acceleration.



Lateral Acceleration

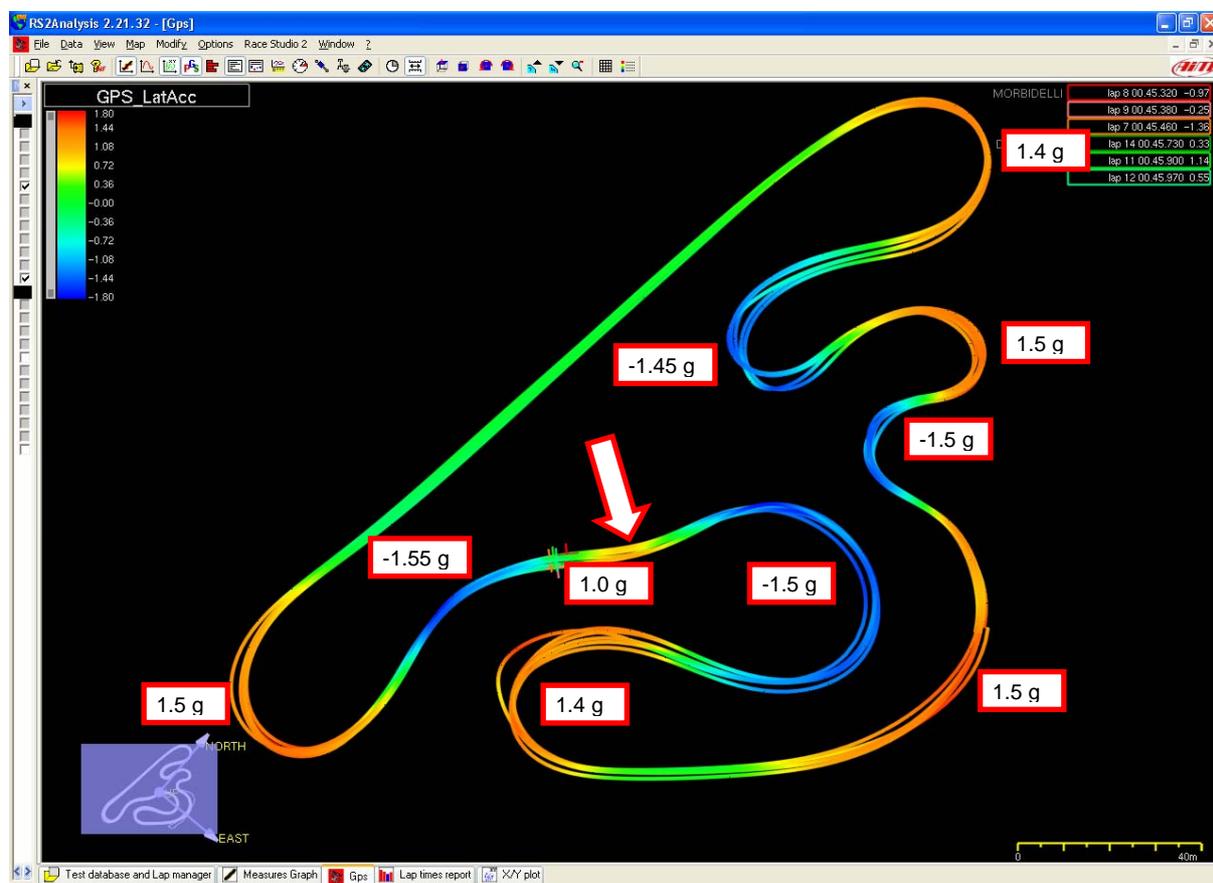
Please remind that lateral acceleration is negative in left corners and positive in right ones. The measure supplied is calculated using the GPS line.

Values are shown using corner colours: green colour is neutral situation (straight), leaning to yellow and to red for right corner, leaning to blue for left corner.

Analysing the following figure (and lateral acceleration graphs to) we can see how in practice the kart uses maximum lateral grip at each corner, around 1,55 g.

One only exception: the “Prima delle Esse” (red arrow in the figure), where the line needs to be most straightened to reach maximum speed.

It is difficult to find the points where maximum lateral accelerations is reached also because numerous side slips and re-keepings of grip have been found. At the beginning of side slips lateral acceleration suddenly decreases (just before reaching max value), and a re-keeping of grip occurs where there is an acceleration peak that does not indicate max lateral acceleration the vehicle develops in normal conditions.

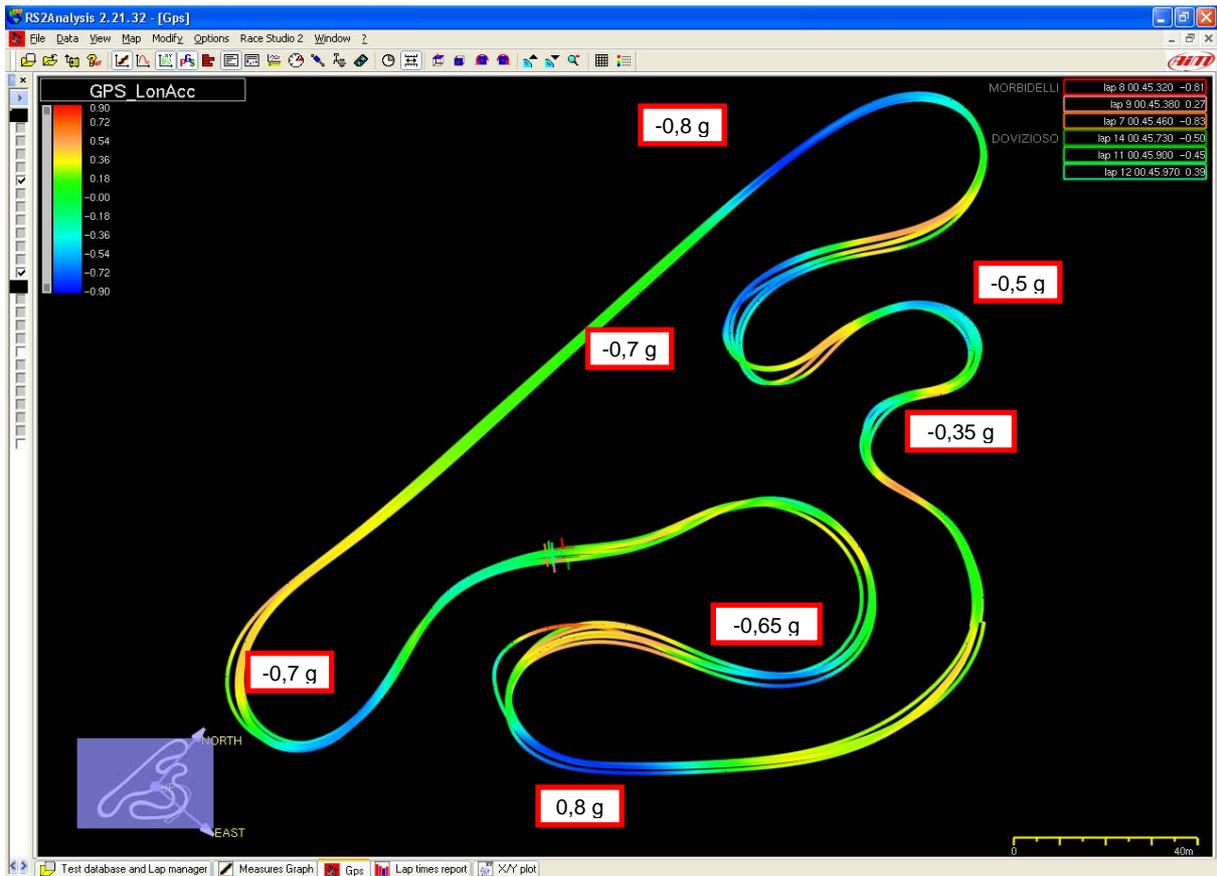


Longitudinal Acceleration

Please remind: longitudinal acceleration is positive in accelerations and negative in brakes. The measure supplied is computed starting from GPS line.

Values are drawn with corner colours: green coloured is neutral situation, leaning to yellow and to red for the acceleration, leaning to darker and darker bleu for the brake. Points where hard braking is necessary on this track are the “*Staccata*” and the “*Casaccia*”, where deceleration reaches around 0,8 g, followed by the “*Rampino*” and the “*Tecnica*”, whose cornering in reaches 0,7 and 0,65 g respectively.

Please note: the “*Prima delle Esse*” and the “*Curva dei Box*” needs braking, to be linked again in acceleration with the “*Curva del Bar*”.



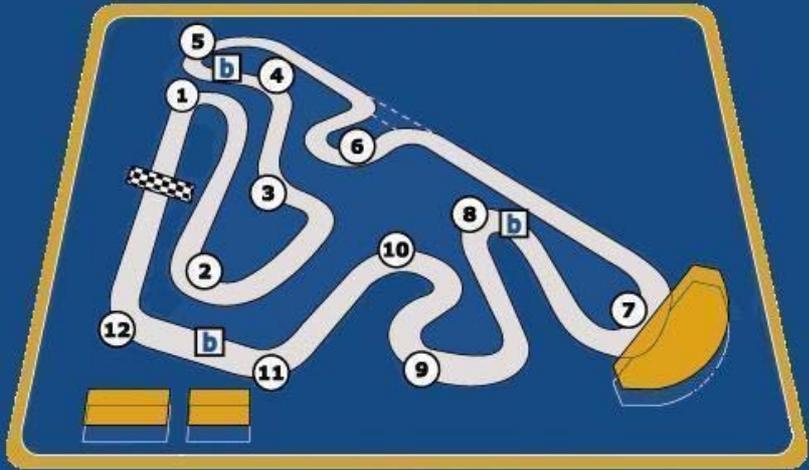
Track analysis

We are now going to analyse data sampled by **MyChron4** and **GPS Module** in each section of the track.

We refer to the track map published on the go-kart track website.

Track Corners

- 1 - La Staccata
- 2 - La Tecnica
- 3 - La Prima delle Esse
- 4 - La Seconda delle Esse
- 5 - Il Canneto
- 6 - La Variante (linked in races to create the main straight)
- 7 - La Casaccia
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TRACK LENGTH M 1000
TRACK WIDTH M 800
Track direction of travel: clockwise

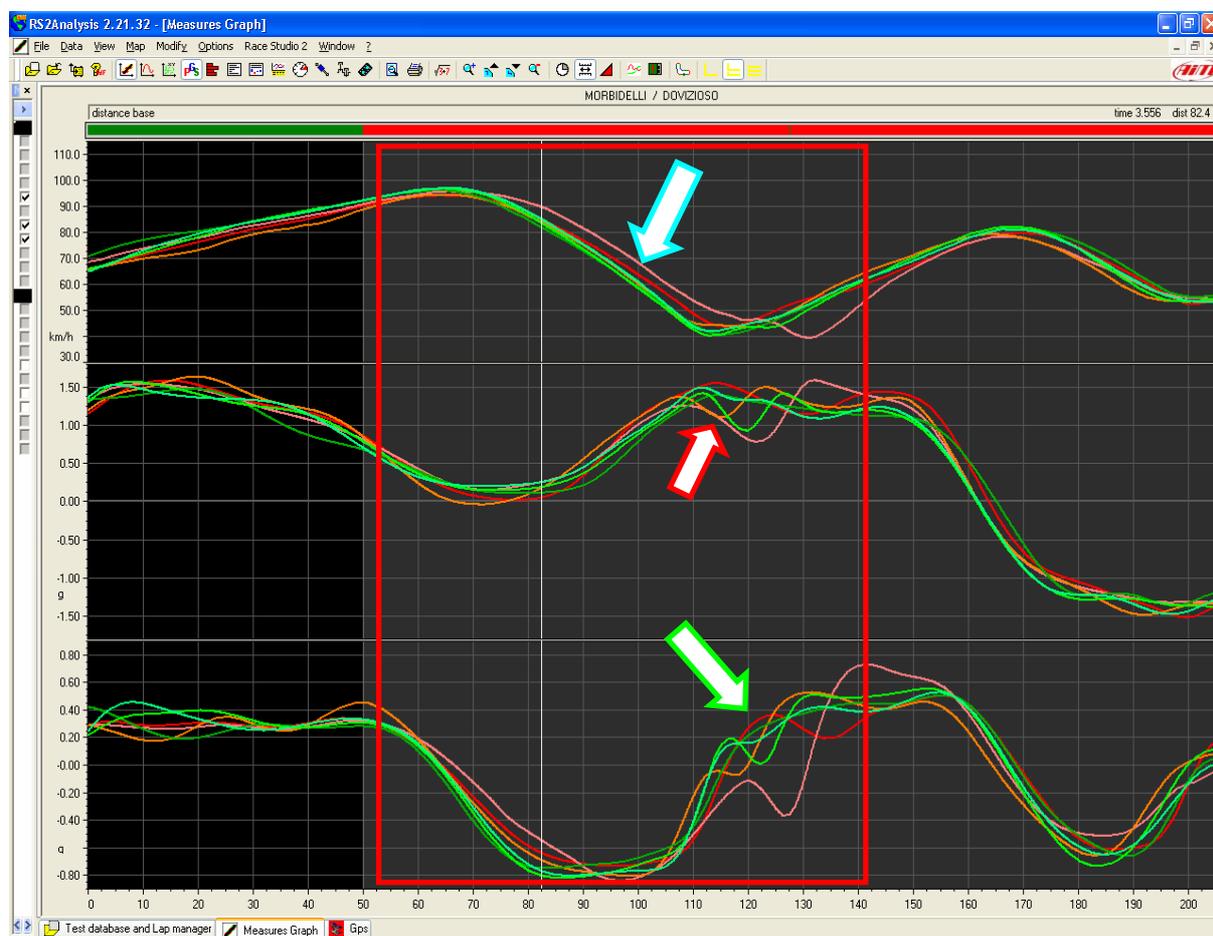
On the track are installed 3 magnetic strips (**b**) for Alfano and AIM telemetric systems

Section 1 – The Staccata

The corner is characterised by a long hard braking where drivers slow down from around 100 Km/h to around 40 km/h, with around 0,8 g deceleration, to corner in at around 1,4 g lateral acceleration.

The graph shows, from top to bottom, speed, lateral and longitudinal acceleration. Morbidelli corners in faster in two laps upon three (light blue arrows in the figure) and in one case (pink line) this leads to a mistake, highlighted by a strong lateral and longitudinal acceleration fall (strong side slip) and by a successive loss of speed. Please note the difficulty of this corner: lateral acceleration course (red arrow in the figure) of the all six laps is unstable as well as longitudinal accelerations course (green arrow).

Dovizioso was generally more steady than Morbidelli but the second driver demonstrated (and we told it analysing Time Compare) that taking a risk on this corner and on the following one is profitable.



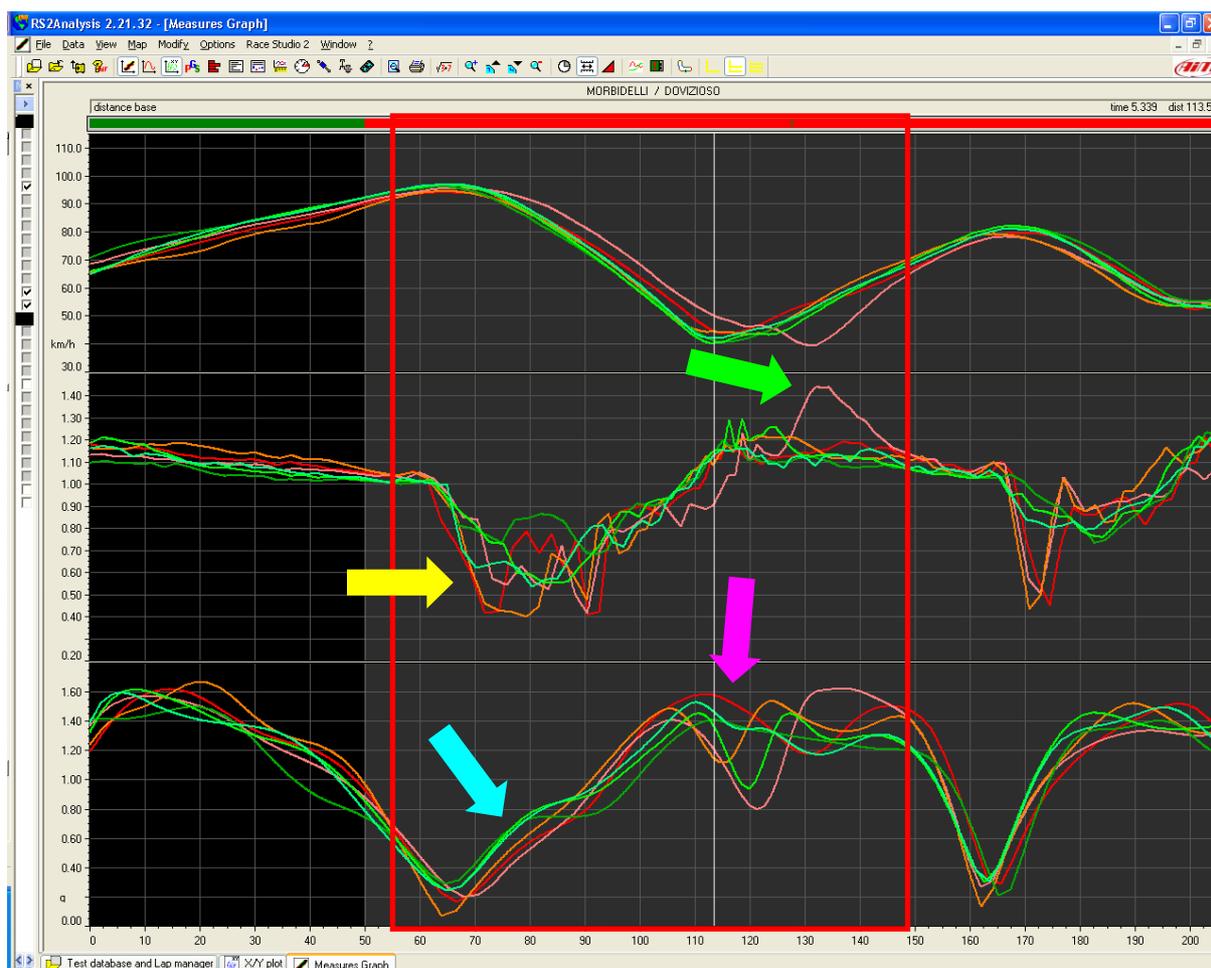
On the main straight slip value is 1 and goes under 1 during brake.

The graph shows, from top to bottom, speed, slip and accelerations sum.

Slip graph shows that Morbidelli is more aggressive on the brakes: the yellow arrow in the figure points out the brake as a point where slip is lower than 1.

The green arrow in the figure points out the strong slip that occurred when Morbidelli made the described mistake during the pink coloured lap.

Accelerations sum tells us that Morbidelli's total acceleration is low at the beginning of the strong brake (light blue arrow) what means that also braking he cannot decelerate. In the G-G diagram that will follow we see that Dovizioso brakes looking for in-cornering adding then lateral acceleration to the longitudinal one. Please note how on the good lap, the one red coloured and highlighted by the purple arrow, the driver uses more total acceleration.



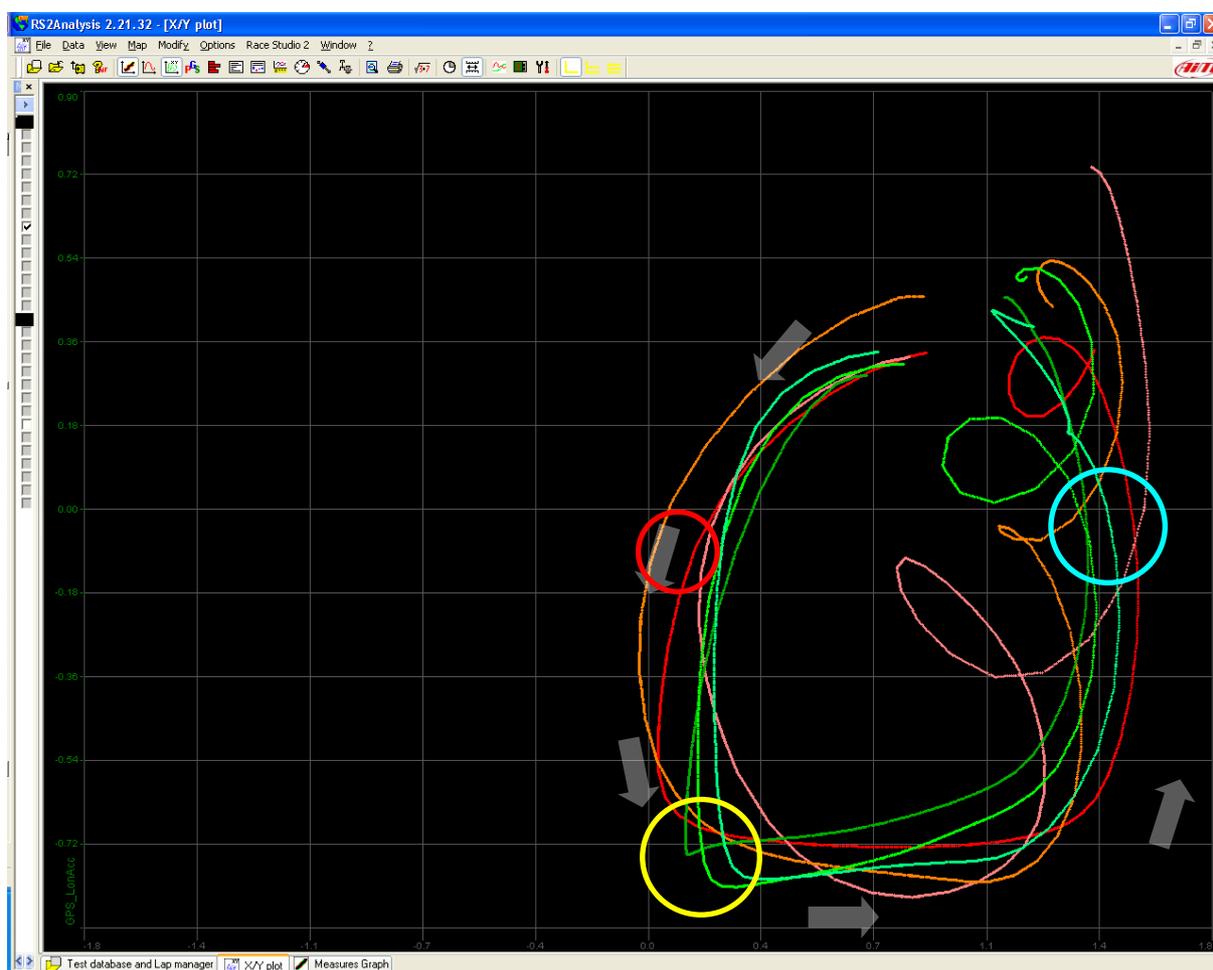
The following figure shows G-G diagram of the range highlighted in red in the previous figures.

Left part shows the beginning of the hard brake when from the centre of the diagram (pointed out by a red circle in the figure) we move downwards (the kart brakes and we reach the bottom part of the diagram).

The beginning of the corner is when from bottom centre point (yellow circle in the figure) we move rightwards. The diagram raises when the drivers leave the brake (the kart is in pure lateral acceleration when we are in the light blue circle in the figure).

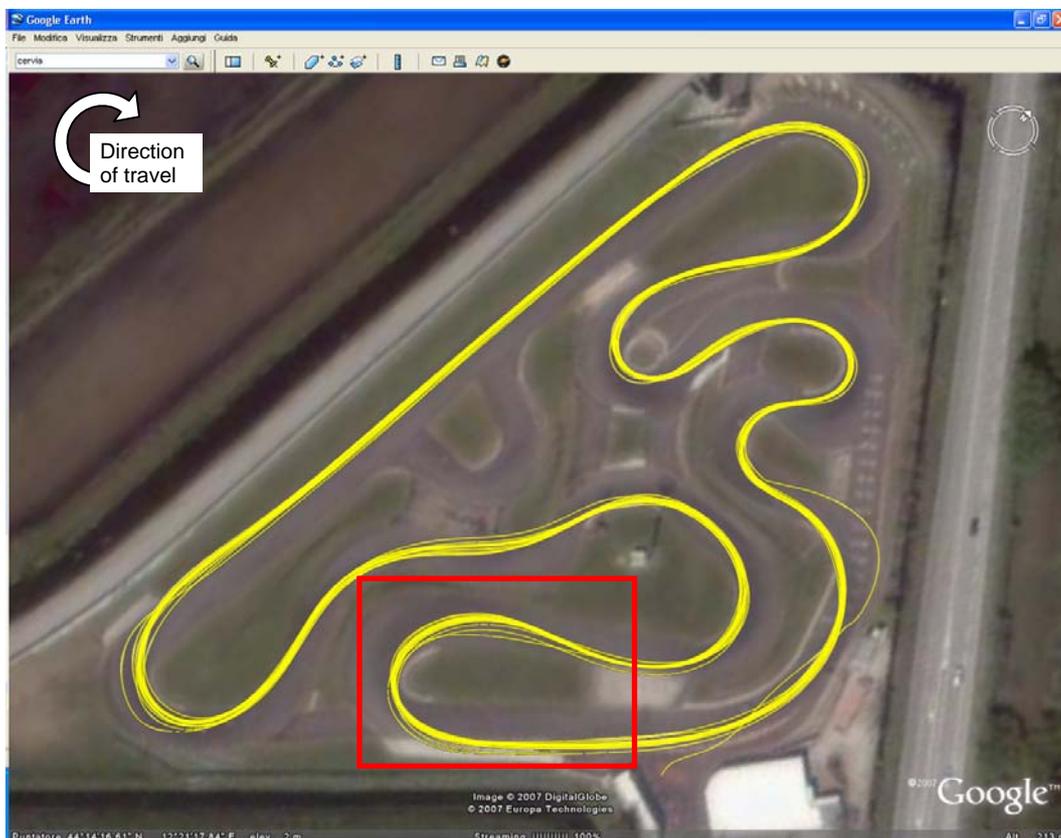
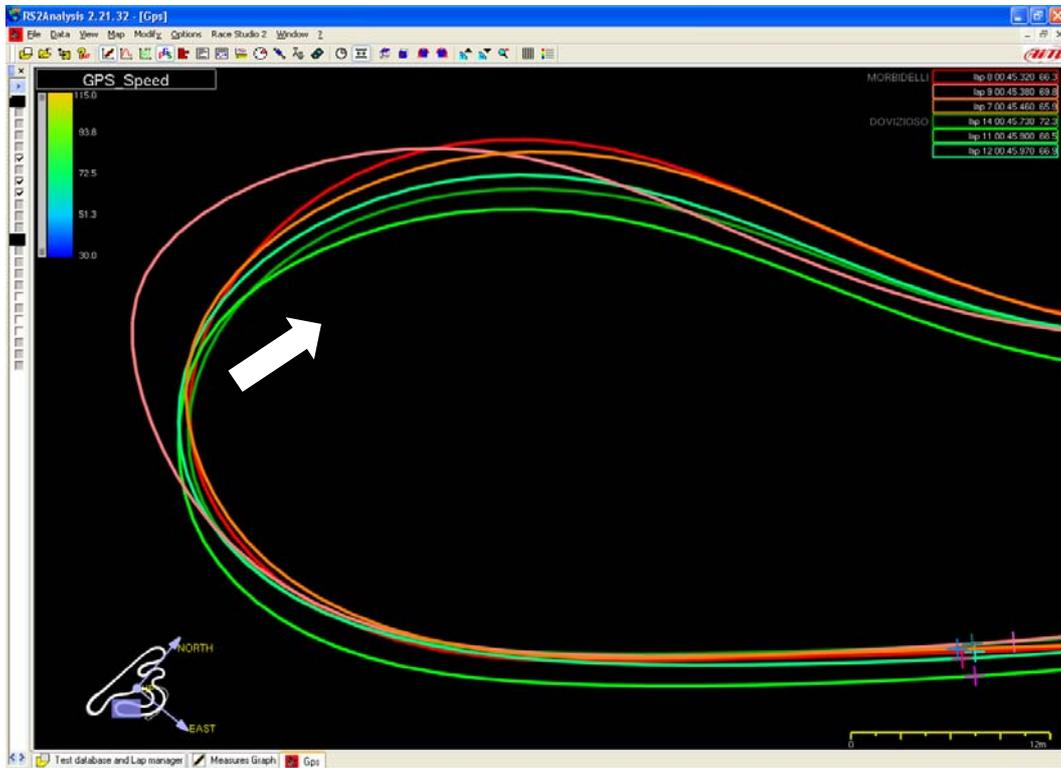
Please note how in the G-G diagram side slips create curls (near to the light blue circle).

The analysis of the diagram tells us that Morbidelli brakes more straight (in the first part of the diagram he stays more in the centre, horizontally, if compared to Dovizioso) and obtains more lateral acceleration in the red lap. In the pink lap Morbidelli "lost" the kart before reaching maximum lateral acceleration.



Analysing the lines, we can see that Morbidelli rounds off the line and let the kart running a lot more while cornering out. Please note, pink coloured, the line when Morbidelli lost the kart while cornering in.

The following figures show GPS trajectory of the analysed laps and track section detail highlighted in Google Earth map.

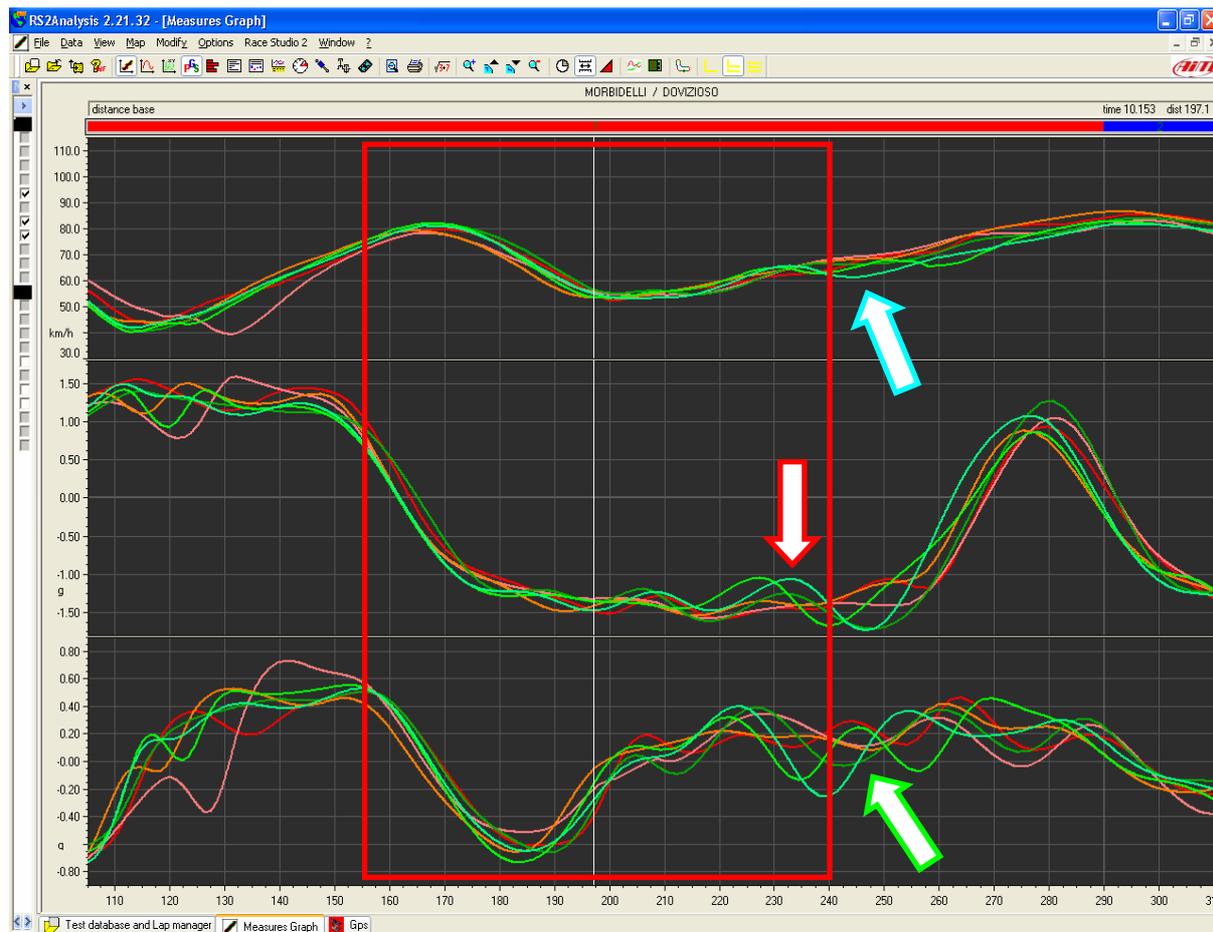


Section 2 – The Tecnica

Cornering in is at around 80 km/h to brake until 55 km/h with around 0,6 g deceleration, 1,5 g lateral acceleration and more than 50 km/h.

The graph shows, from top to bottom, speed, lateral acceleration and longitudinal acceleration.

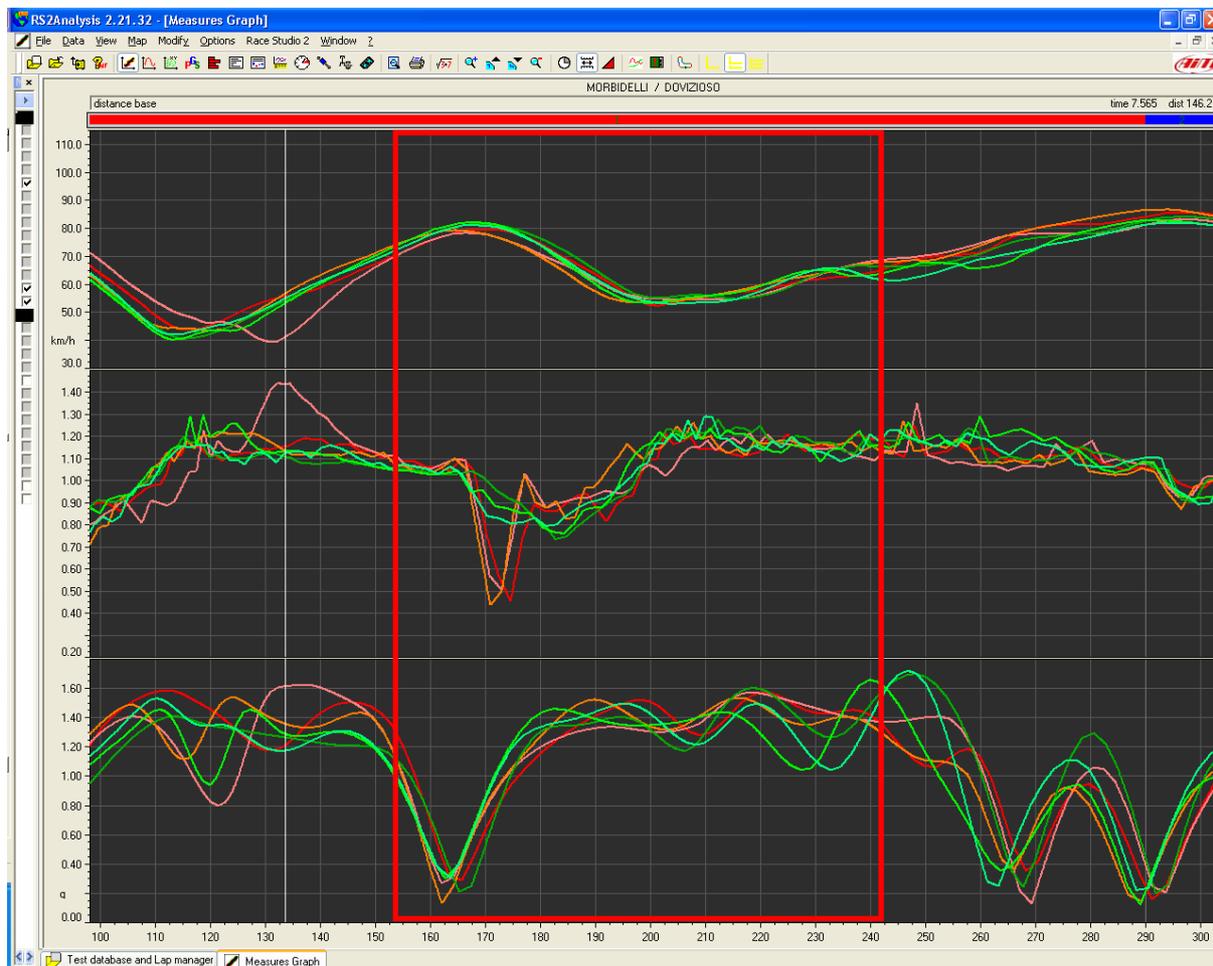
Graph lines of both drivers are “smooth”. Dovizioso makes some little mistakes while cornering out; you can in fact notice (red arrow in the figure) losses of lateral acceleration due to little side slips. These causes low longitudinal acceleration (green arrow) and thereby impossibility of gaining speed on the following section of the track (light blue arrow, also if slightly out of the analysed section).



The graph shows, from top to bottom, speed, slip and accelerations sum.

Looking at the slip we can notice how Morbidelli hard brakes until almost locking (45%) and after he reduces the braking. Low accelerations sum indicates how he is braking straight, while Dovizioso is cornering in.

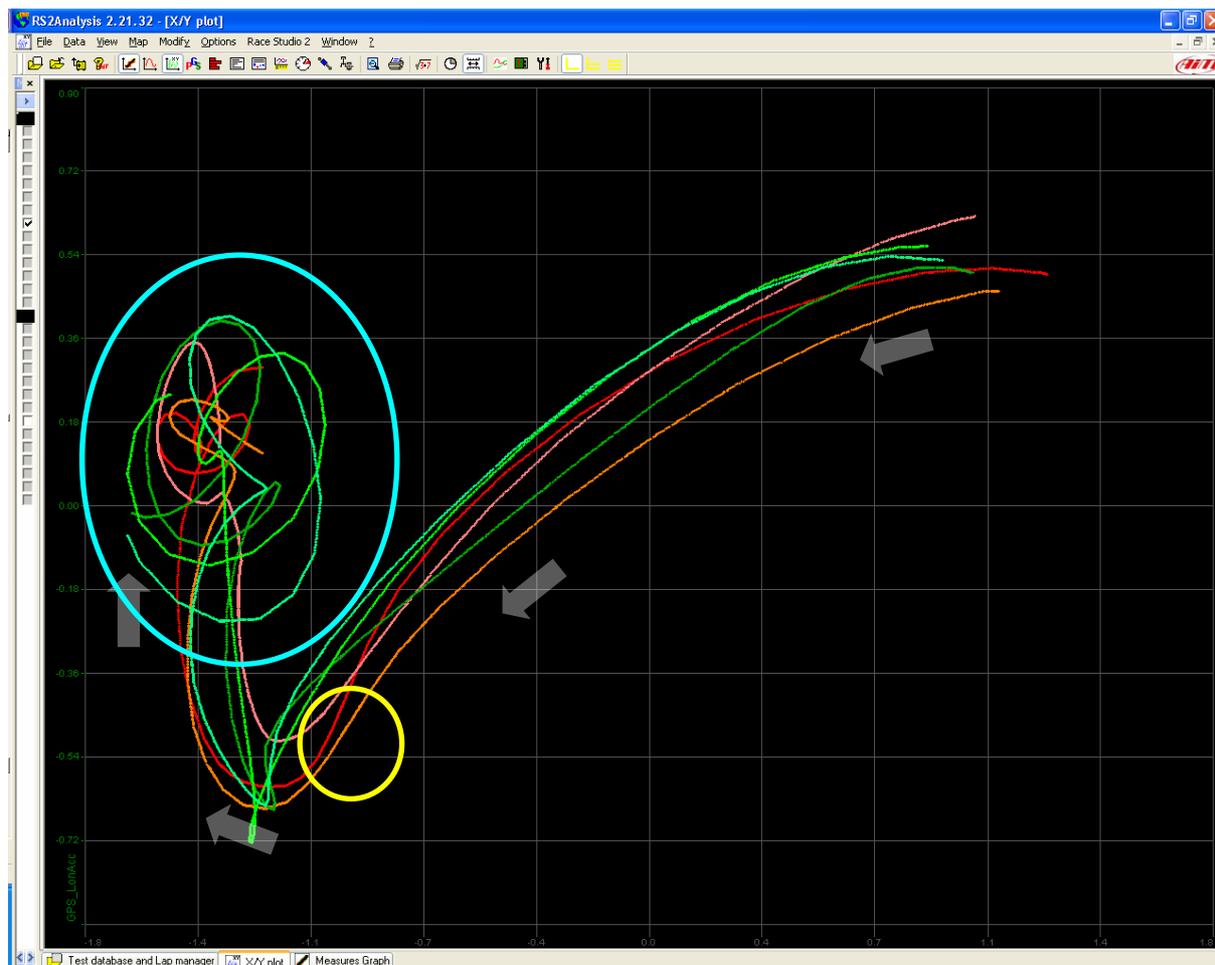
In the second part of the range (red rectangle) Morbidelli can have an higher total acceleration, while Dovizioso's total acceleration swings. The reason is a little slipping (that causes a side slip, probably due to over-steering), higher than 1 just before grip losses.



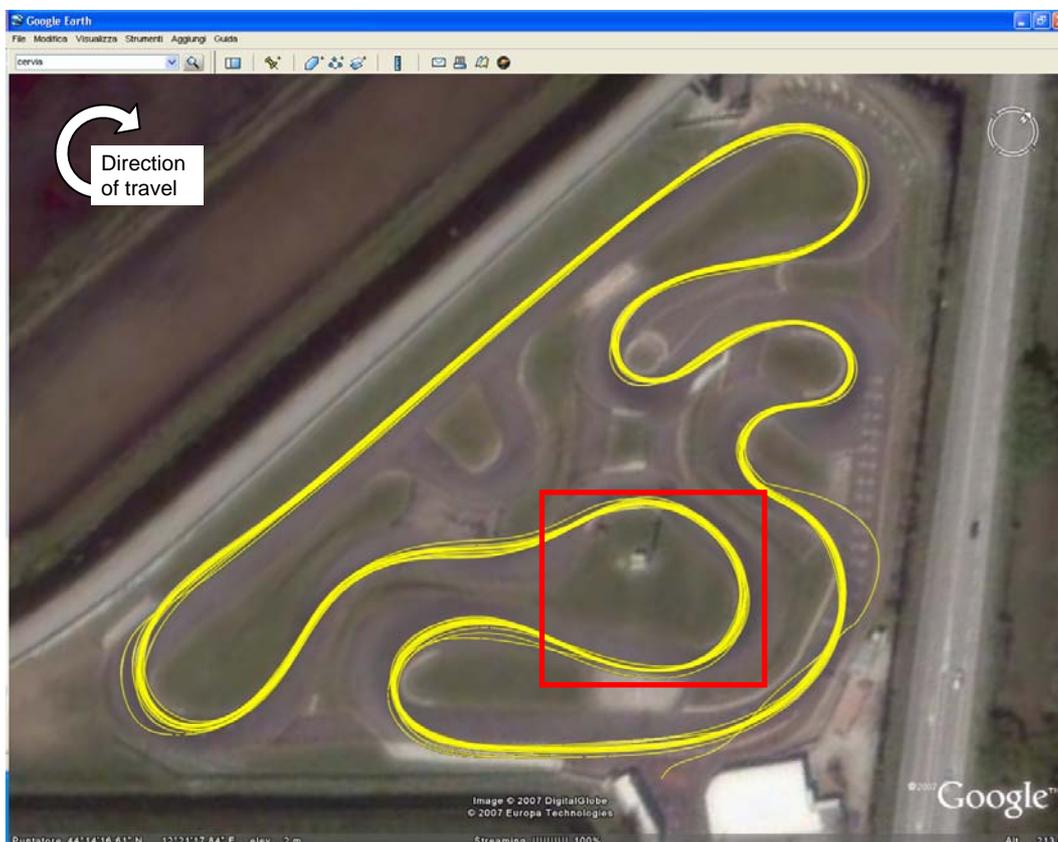
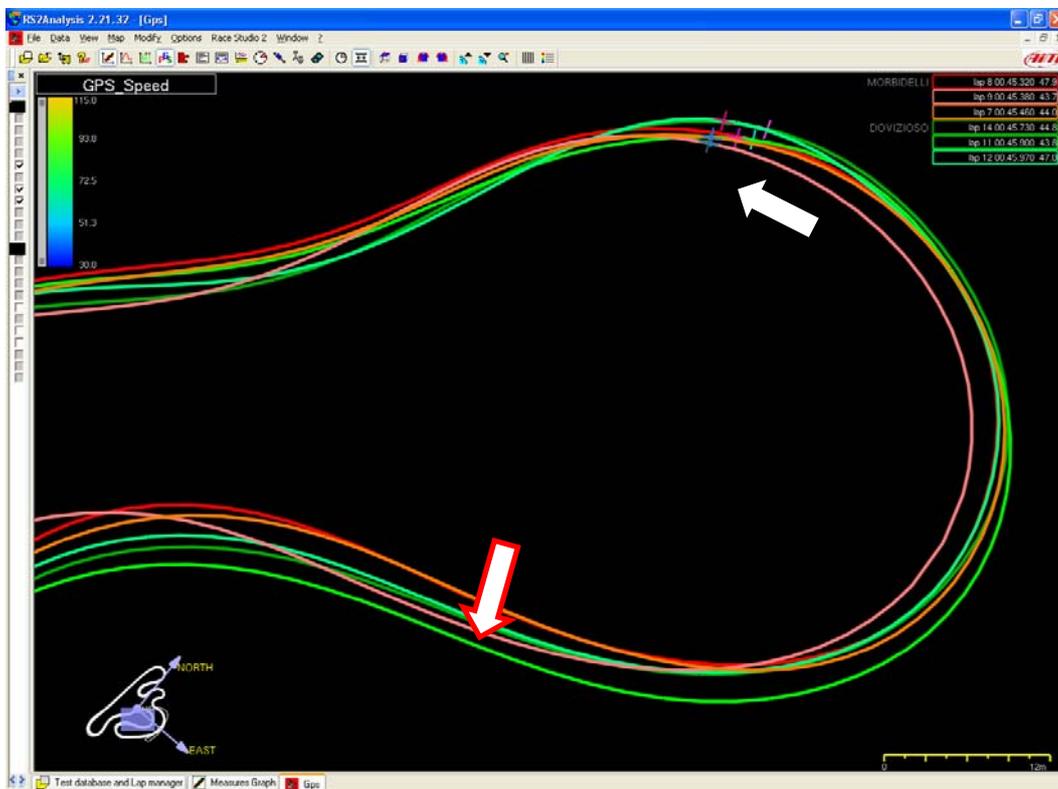
The following figure shows G-G diagram of the range highlighted in red in the previous figures.

We can see again how Morbidelli brakes looking for less lateral acceleration (in the yellow circled areas of the figure he is more in the centre of the G-G diagram considering an horizontal direction) and start cornering while still braking (on the diagram the line moves leftwards rising a little).

Dovizioso, as seen in the previous graphs, corners in faster but cannot generate a strong lateral acceleration; please note how in the light blue circle in the figure green lines makes a little wider curls.



Smoothness of the previous graph lines causes also smoothness of trajectories. In the fast lap Morbidelli linked better cornering out with cornering in (red arrow in the figure, where he brakes more straight and corners in with a lower bending radius). The following figures show GPS trajectory of the analysed laps and track section highlighted in Google Earth map.



Section 3 – The Prima delle Esse

It's a left-right corner in full acceleration run between 70 and 80 km/h.

The graph shows, from top to bottom, speed, lateral acceleration and longitudinal acceleration.

How you can see from the growing course of the speeds (light blue arrow) the all chicane is run in full acceleration.

As said before, this cornering in is linked to the previous cornering out, in fact lateral acceleration is already at its max values (red arrows) while entering the chicane. Both drivers have difficulties in keeping lateral acceleration steady high, what probably means that the corner is hard to run.

Looking at the yellow rectangle in the figure we can see that each “fall” towards zero of the lateral acceleration means a grip loss and implies the vehicle is loosing its capacity of producing longitudinal acceleration.

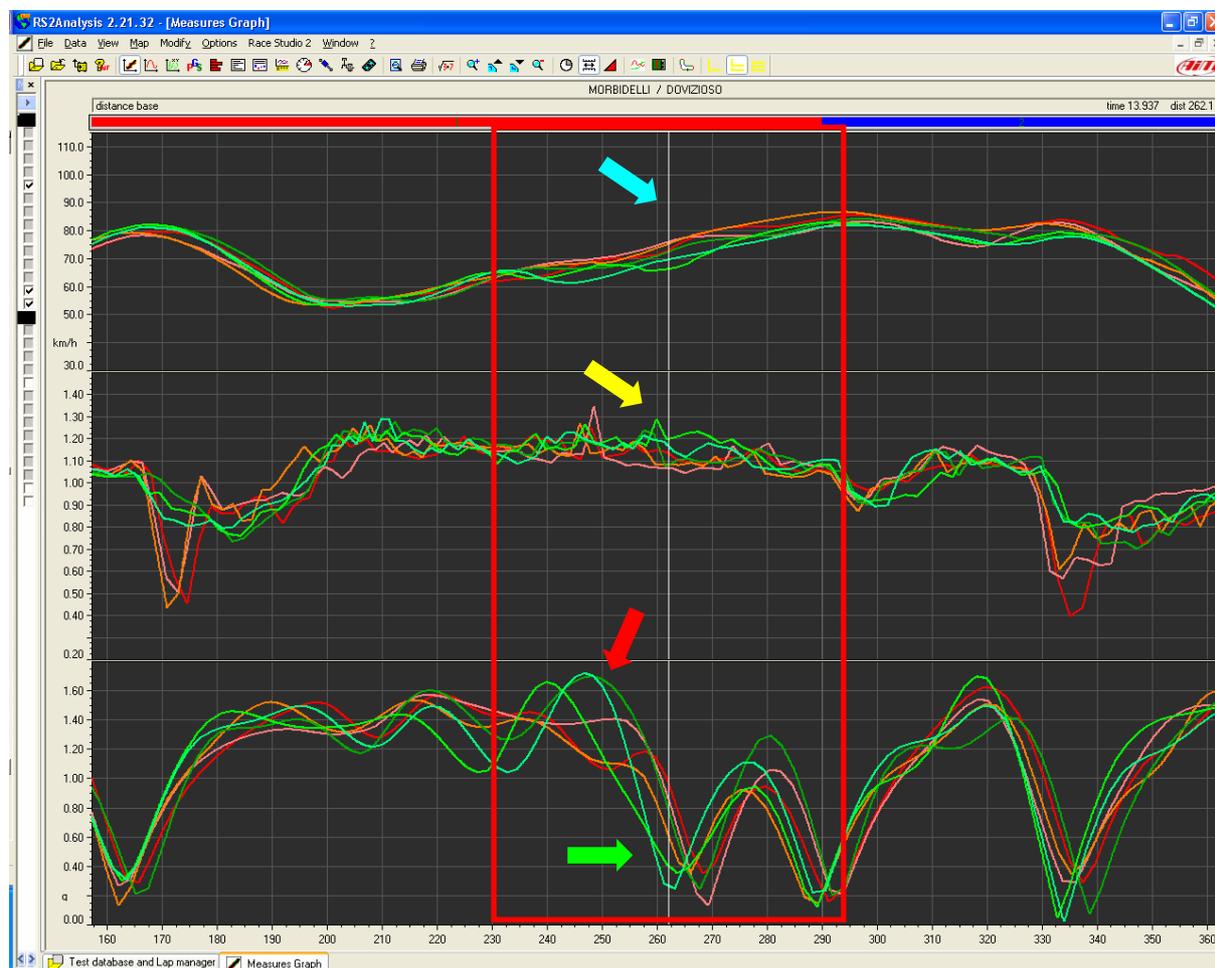


The graph shows, from top to bottom, speed, slip and accelerations sum.

Dovizioso's slip is slightly higher while left cornering in (yellow arrow in the figure), but is similar in value just before and just after. Morbidelli can gain a little more speed (light blue arrow). Reviewing the trajectories of both drivers while cornering out the "Tecnica" we would remember that he corners out with an higher bending radius to cut this one. This higher speed comes from the preparation of the "Esse" since the "Tecnica".

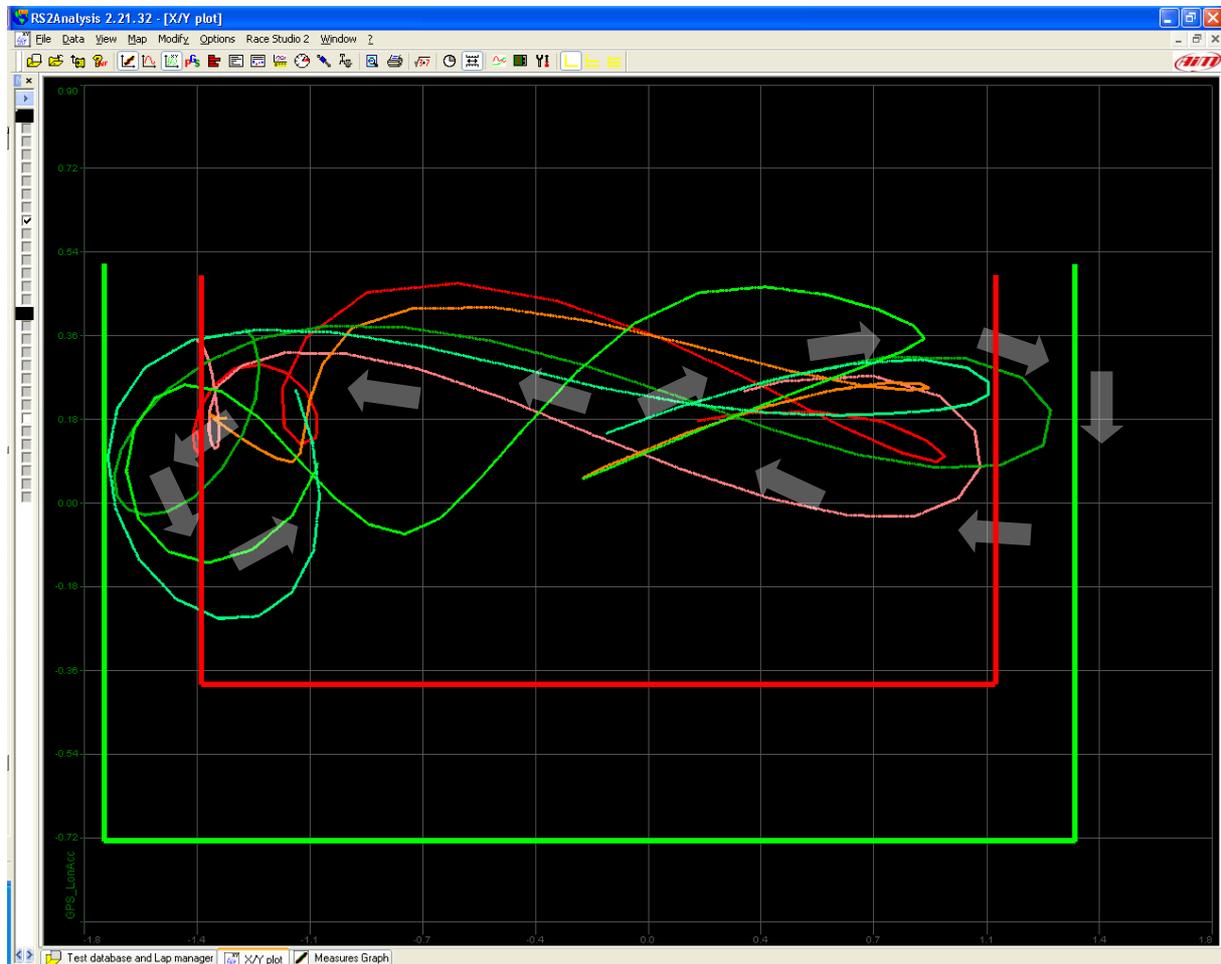
Total acceleration is higher for Dovizioso (red arrow in the figure) but is swinging and unstable if compared with Morbidelli's. This means that Dovizioso wastes time over-steering.

Please note how both drivers (green) loose total acceleration in correspondence with a change of direction from left to right in the "Esse". This means that, without longitudinal acceleration changes (in this chicane there is not hard braking), lateral acceleration grows as absolute value during the left corner, diminishes when the driver straightens the steer and grows again when he right corners.

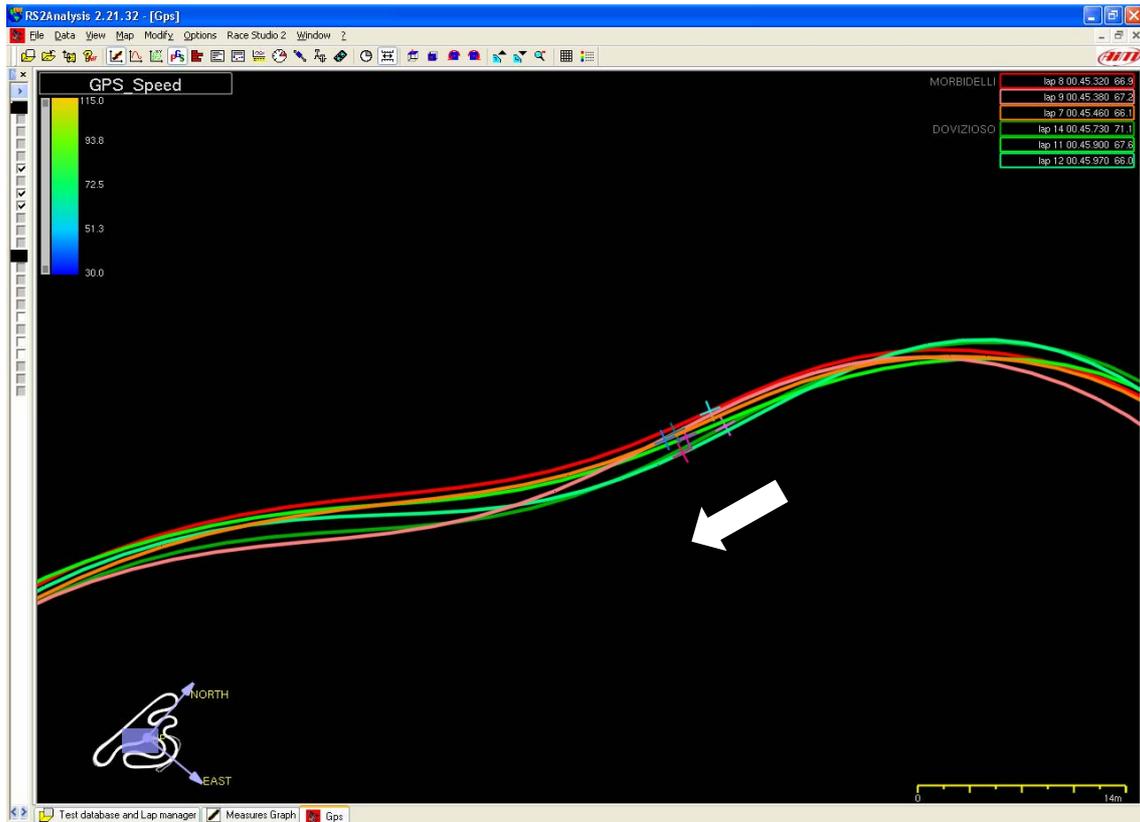


The following figure shows G-G diagram of the range highlighted in red in the previous figures.

Morbidelli's lateral acceleration values are lower than Dovizioso's, that means he can straighten his trajectory as more as possible in the chicane. Lower lateral acceleration can be noticed in the following graph because Morbidelli's red lines are horizontally more internal than Dovizioso's.



The following figure shows GPS trajectory of the analysed laps and track section detail highlighted in Google Earth map.



Section 4 – The Seconda delle Esse

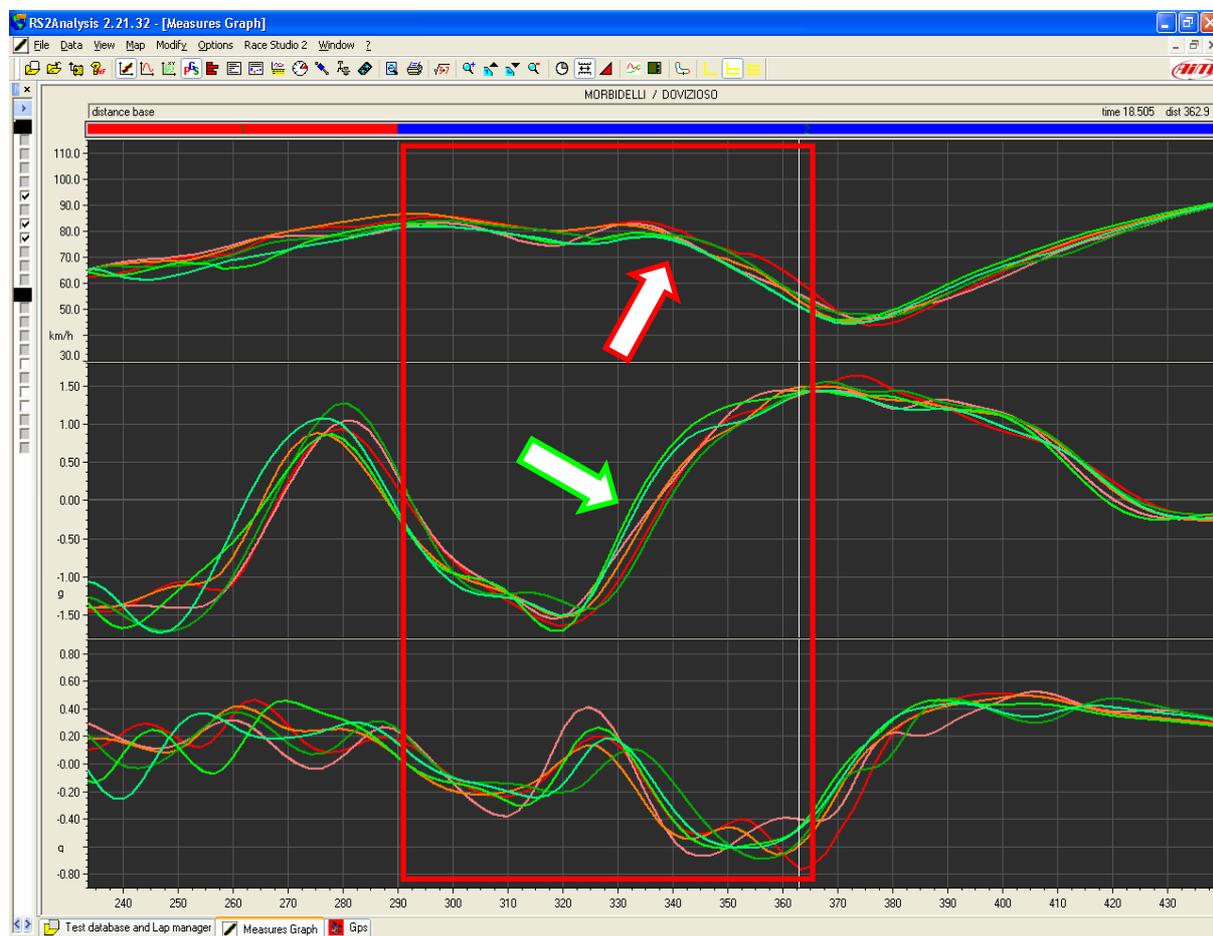
A left-right corner again with around 80 km/h initial speed, 1,55 g lateral acceleration in the left corner and very difficult hard braking in right cornering.

The graph shows, from top to bottom, speed, lateral acceleration and longitudinal acceleration.

The all “Esse” is run with decreasing speed, except for a little exception (red arrow) where Morbidelli has an higher speed.

Time Compare tells us that in this chicane Morbidelli made a lot of difference also between his fast laps. The drivers are coupled in the left corner while lateral acceleration graphs tells us that Dovizioso moves ahead the right corner in respect of Morbidelli (highlighted from green arrow in the figure, lateral acceleration rises a little before).

Longitudinal acceleration course tells us that Dovizioso brakes a little more in the left corner while Morbidelli brakes a lot more before (and during) the right corner; on the other hand he is also faster.



The graph shows, from top to bottom, speed, slip and accelerations sum.

Slip graph confirms that Morbidelli's braking between left and right corner is a lot stronger (we saw that he brakes a lot while going straight).

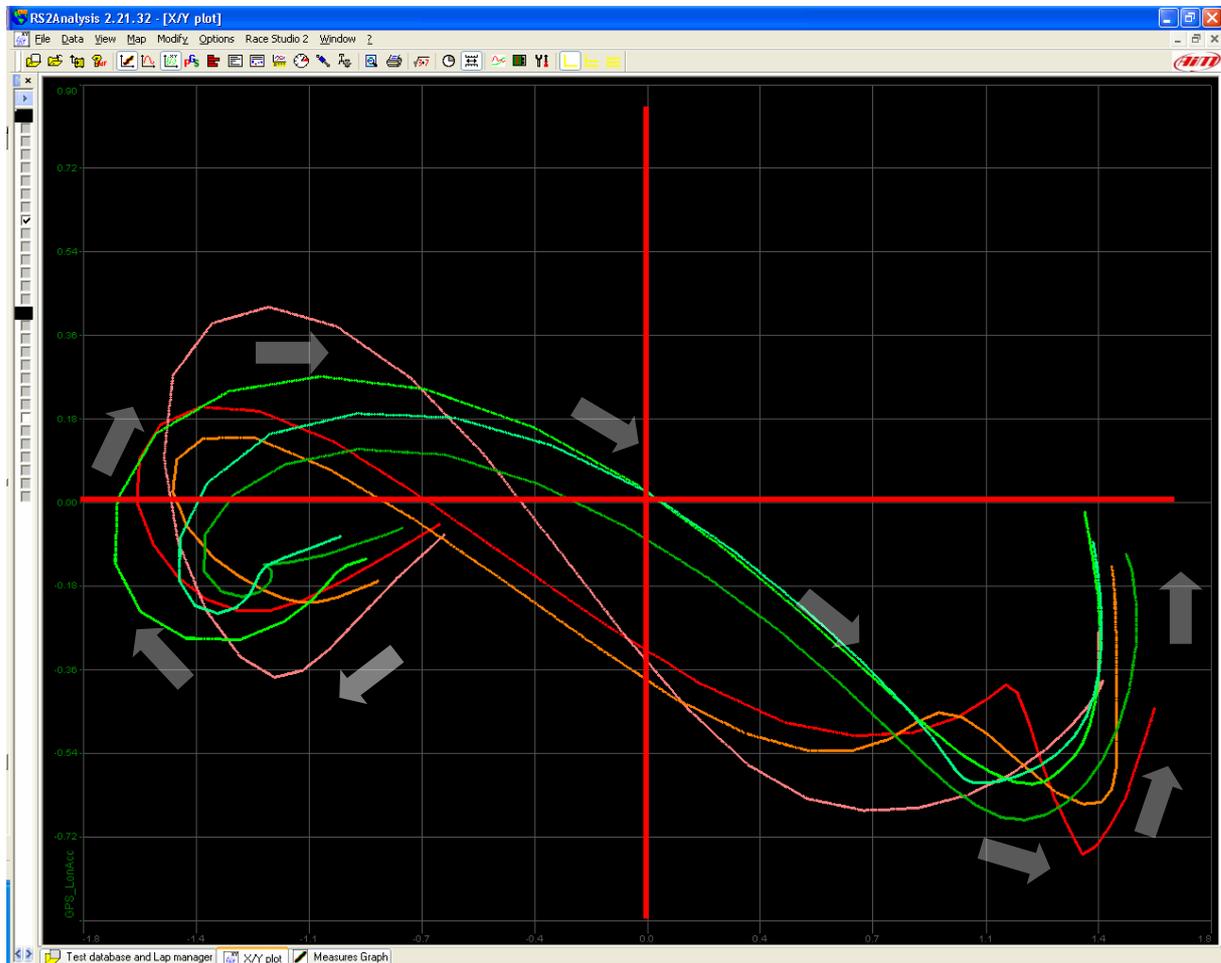
Total acceleration values are similar, what means that kart exploitation is similar, also if on two trajectories that looks similar without being identical.



The following figure shows G-G diagram of the range highlighted in red in the previous figures.

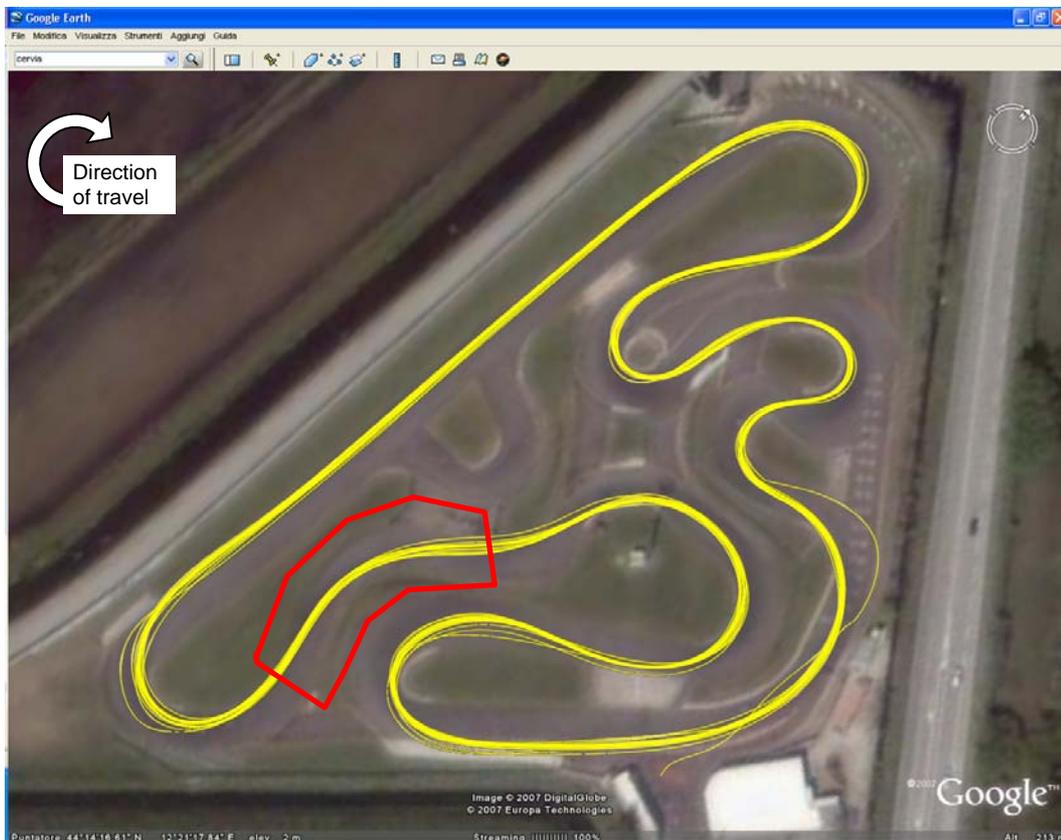
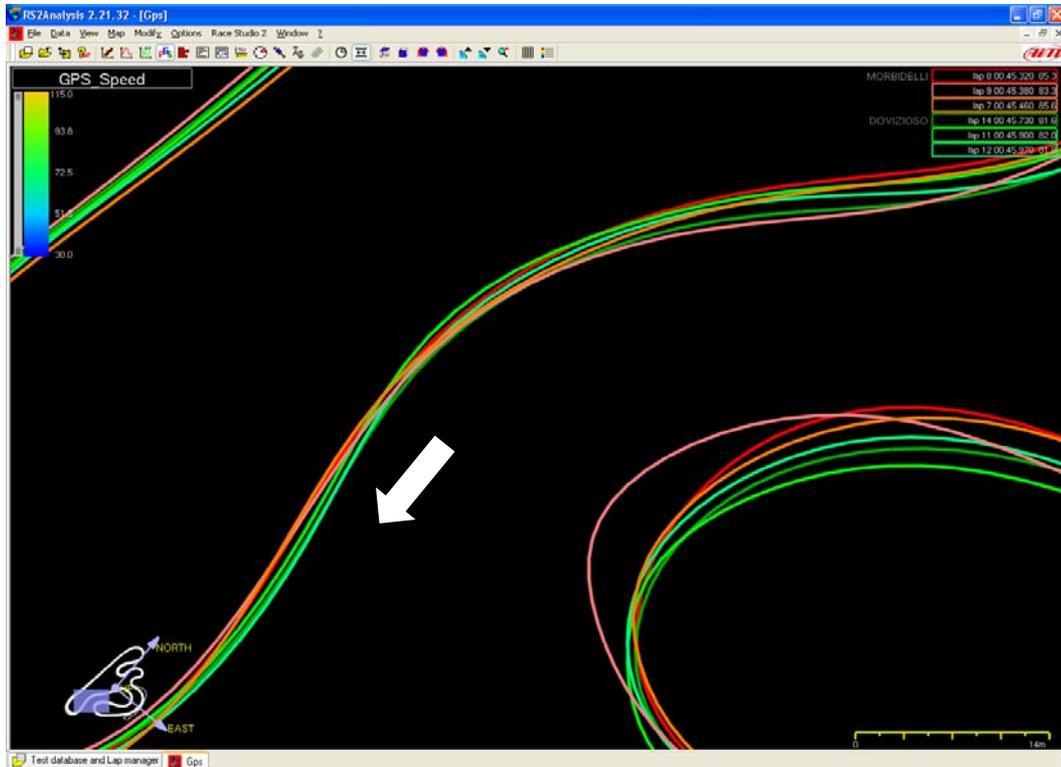
G-G diagram helps highlighting the difference between the trajectories:

- Dovizioso passes from left to right corner without braking until right cornering
- Morbidelli passes from left to right corner having already start braking and using a good deceleration with the kart free from lateral acceleration.



Here Morbidelli makes the difference (we already saw it in Time Compare analysis): corners in with a lower bending radius but can keep the edge of the corner like Dovizioso and has a good cornering out speed.

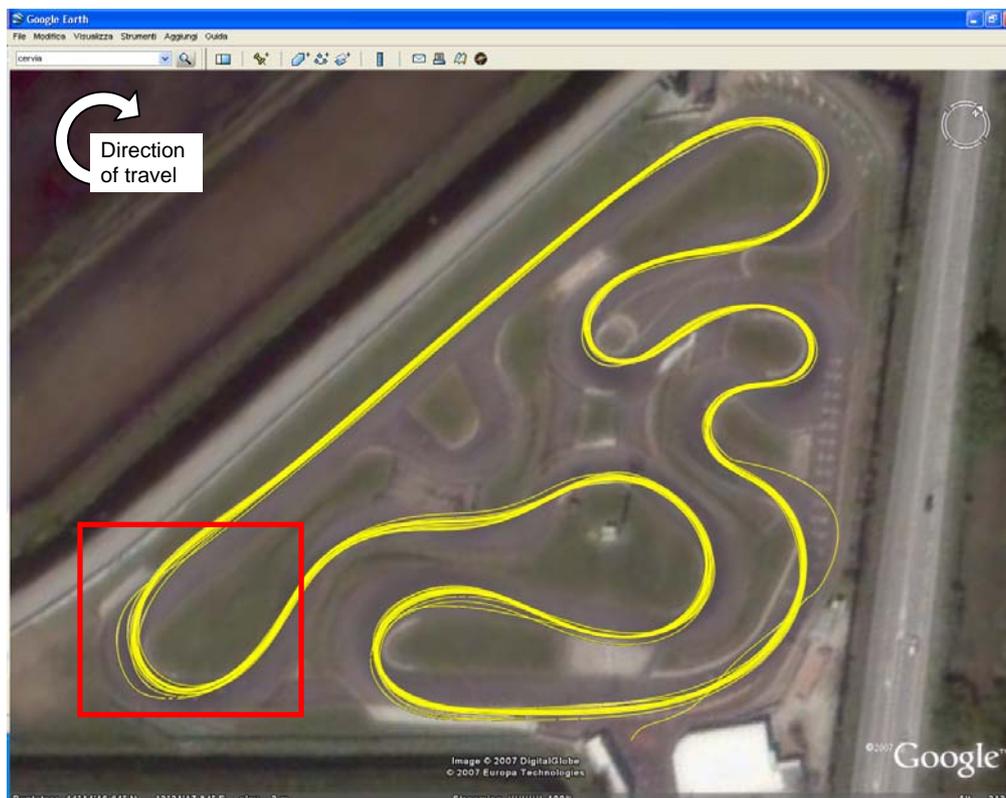
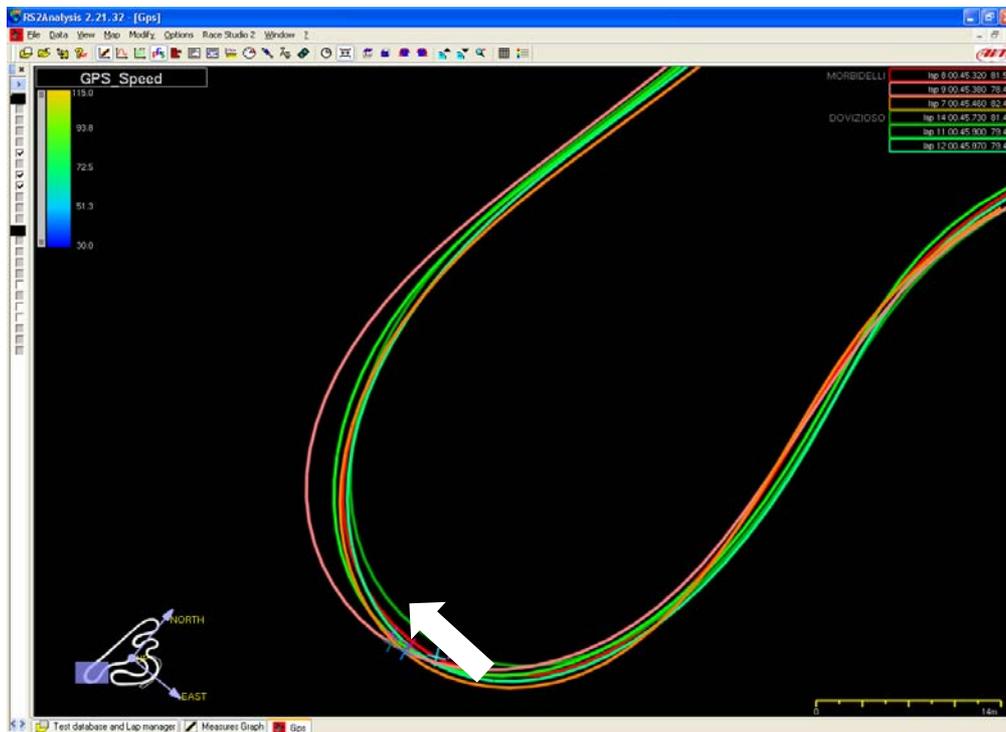
The following figures show GPS trajectory of the analysed lap and track section detail highlighted in Google Earth map.



Section 5 – The Canneto

A right corner reached at around 80 km/h, braking with 0,65 g deceleration and cornering in with more than 1,5 g lateral acceleration with around 50 km/h speed. The analysis of the trajectory shows a big difference between Morbidelli's second lap and the other laps. What happened? Let's have a look to measures graph.

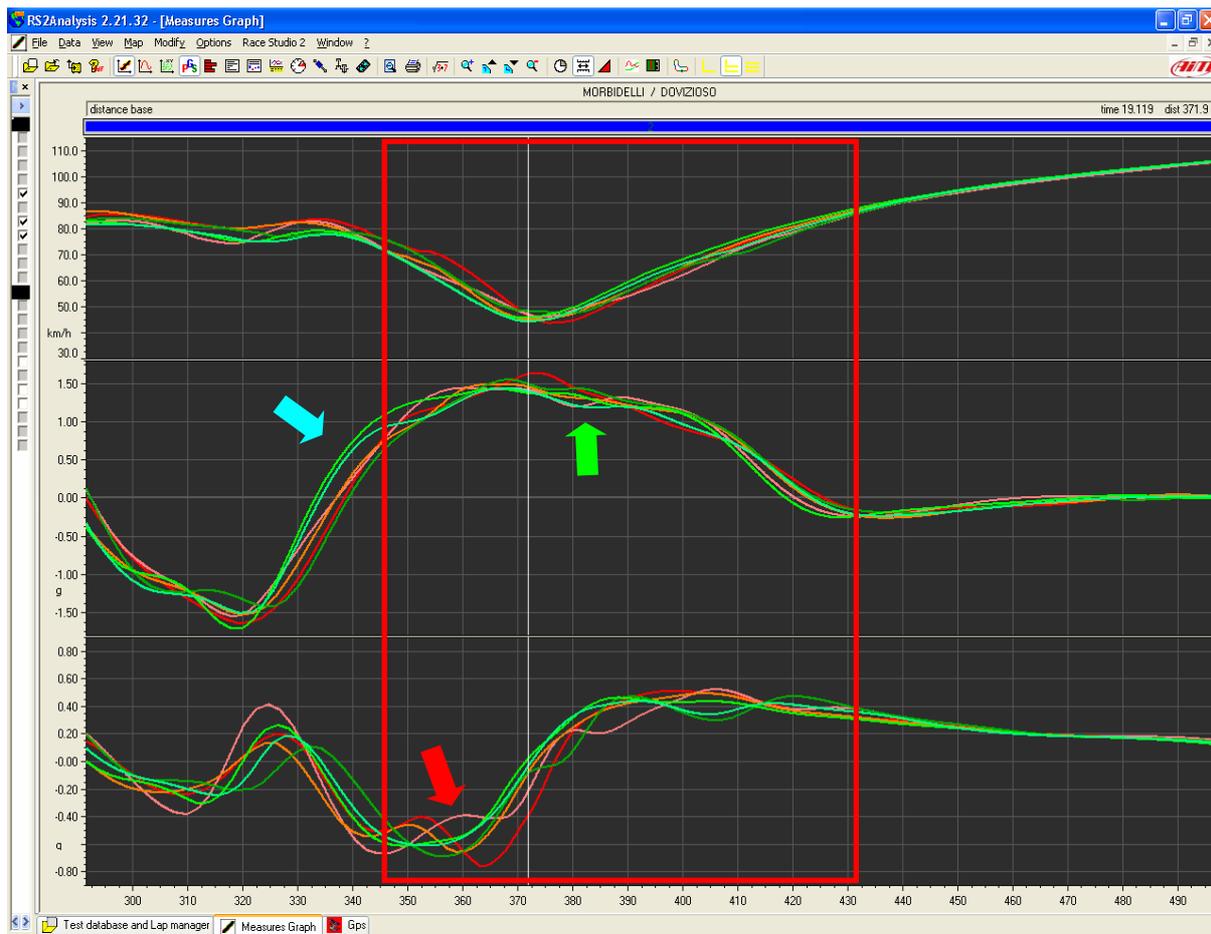
The following graphs shows GPS trajectory of the analysed laps and track section detail highlighted in Google Earth map.



In best lap (red line) Morbidelli seems having only tried to release the brake (a fall in deceleration points this out – red arrow in the figure) and cornering in, without success. Morbidelli let anyway the kart running on a more external trajectory to avoid side slipping too much (there is a little fall of lateral acceleration, green arrow in the figure) and loosing speed on the following straight.

The graph shows, from top to bottom, speed, lateral acceleration and longitudinal acceleration.

With reference to the light blue arrow, please note how from the “*Seconda delle Esse*” to the “*Canneto*” the kart never runs straight: lateral acceleration remains always well positive.



The graph shows, from top to bottom, speed, slip and accelerations sum. In this figure you can very clearly notice how slip is slightly lower than 1 during braking because of the rear locking, to become higher than 1 in acceleration because of a little over-steering (it will become stable at 1 in the following straight). Differences between the two drivers are not very significant. It's worth noticing, on the other hand, how Morbidelli can gain more total acceleration (in its peak value, green arrow in the figure) and how total acceleration falls more.



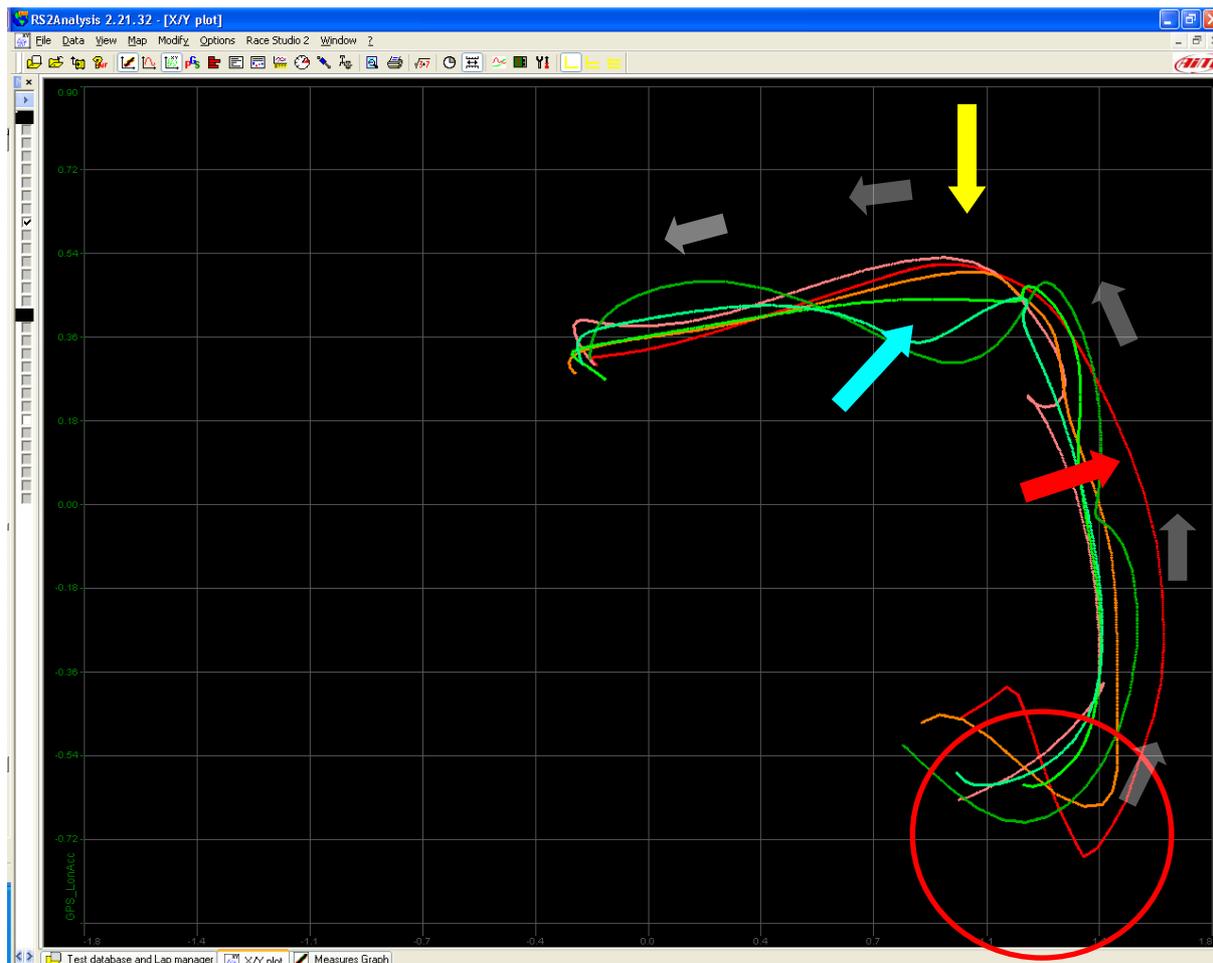
The following figure shows G-G diagram of the range highlighted in red in the previous figures.

Please note how the corner (highlighted by a red circle in the figure) does not begin with a hard braking but there is a cornering in with lateral acceleration (right cornering out of the “*Seconda delle Esse*” is to be linked with “*Canneto*” cornering in).

As you can see Morbidelli stands out (red arrow also if in one lap only) in the max lateral acceleration value and keeps it steady, differently from Dovizioso.

Here Morbidelli stands out for his longitudinal acceleration too (yellow arrow, in all the three laps!) while cornering out.

You can moreover see how (light blue arrow, in two laps out of three) Dovizioso has difficulties keeping the longitudinal acceleration while re-opening the gas.



Section 6 – The Variante

The “*Variante*” is not run because the test was held running the all main straight.
The following figure shows the track section detail highlighted in Google Earth map.



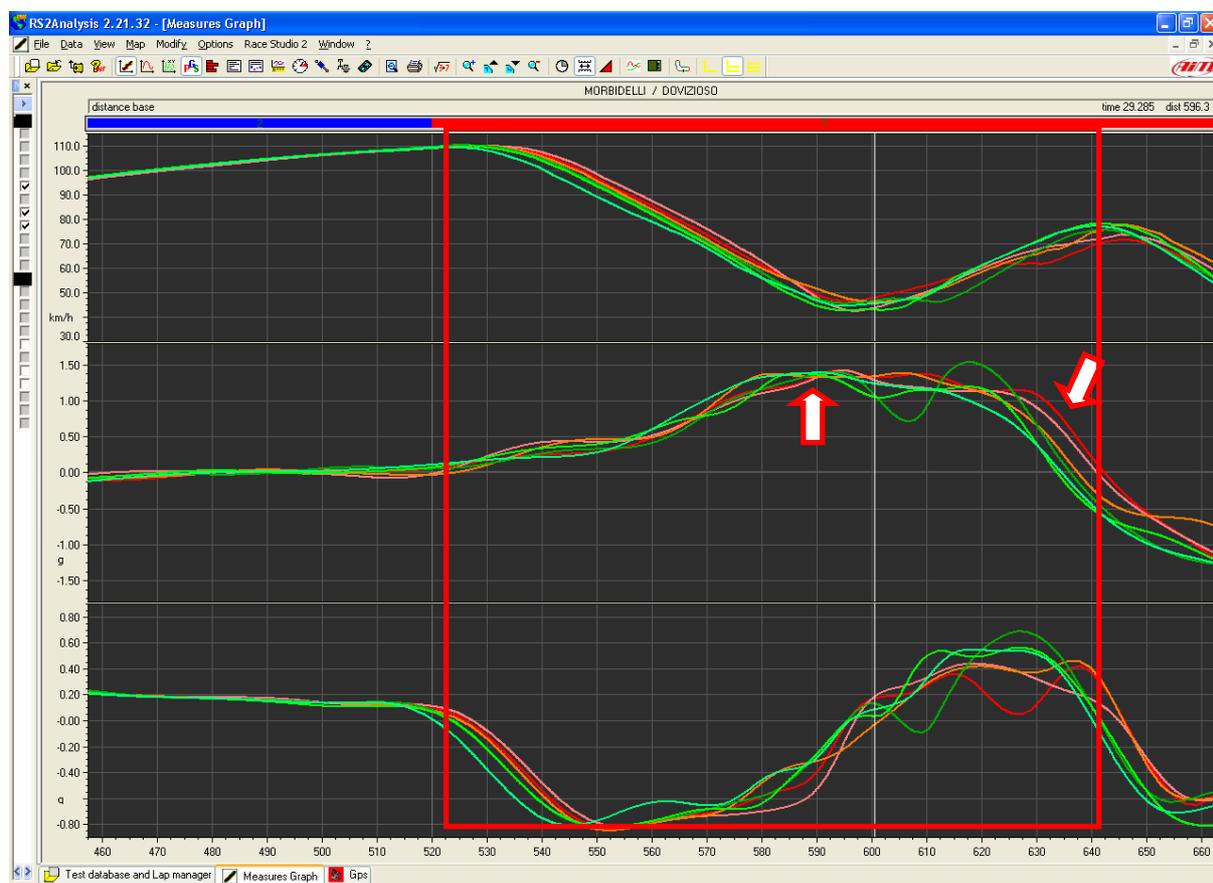
Section 7 – The Casaccia

Drivers brake slowing down from the max speed value reached on the track (more than 110 km/h) to around 45 km/h. Deceleration value is the higher of the lap and is more than 0,8 g; max lateral acceleration is around 1,4 g with a speed of around 50 km/h.

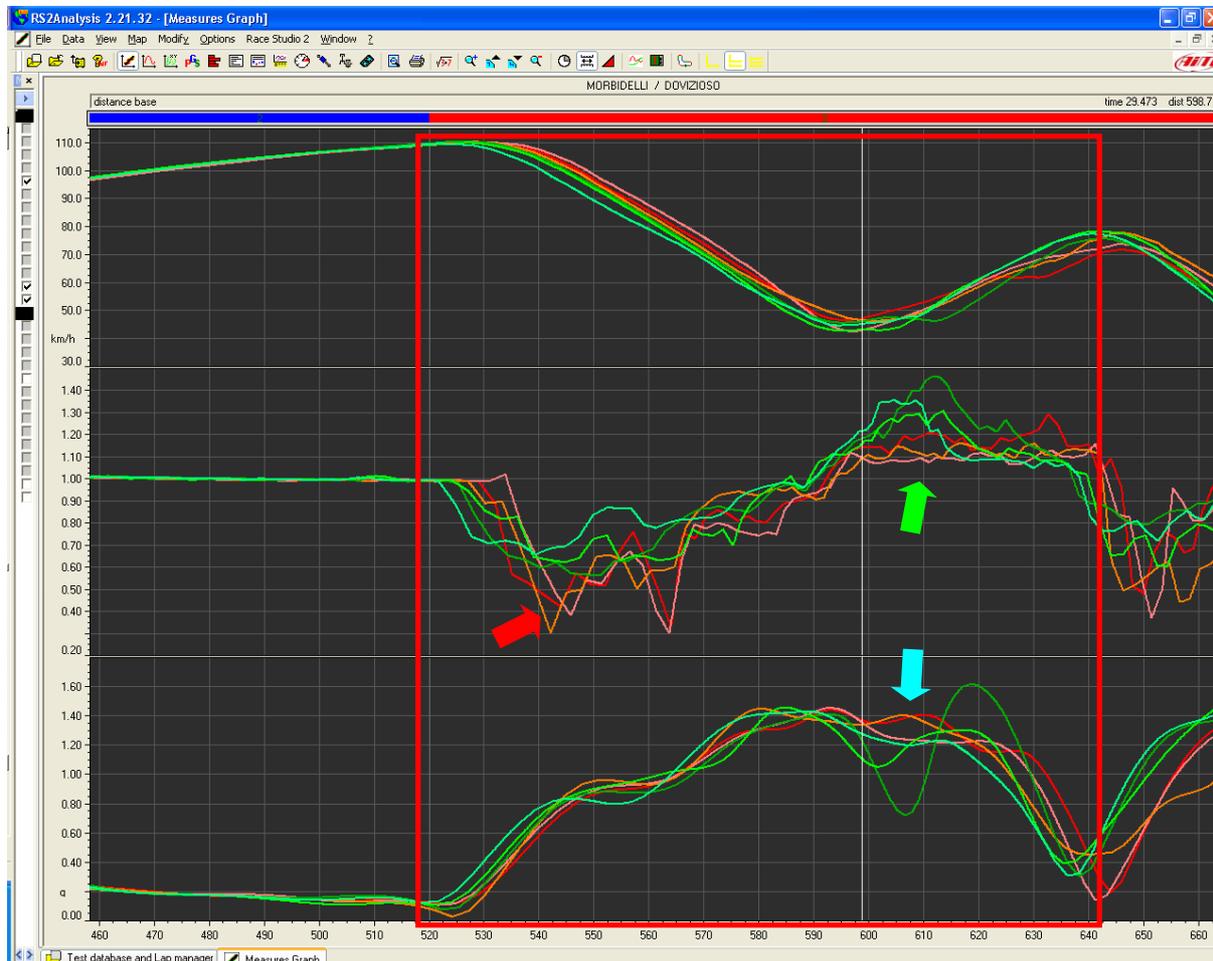
The graphs shows, from top to bottom, speed, lateral acceleration and longitudinal acceleration.

Looking at speed diagram you can notice how Morbidelli is a little more self-confident on the hard braking (few metres) and looking at lateral acceleration diagram (red arrows in the figure) you can notice how it grows more slowly (what means that the trajectory remains straight for more time) and falls towards zero a little after (what means that Dovizioso straightens the cornering out to open gas before).

Time Compare analysis already told us that in this section of the circuit Dovizioso did better.

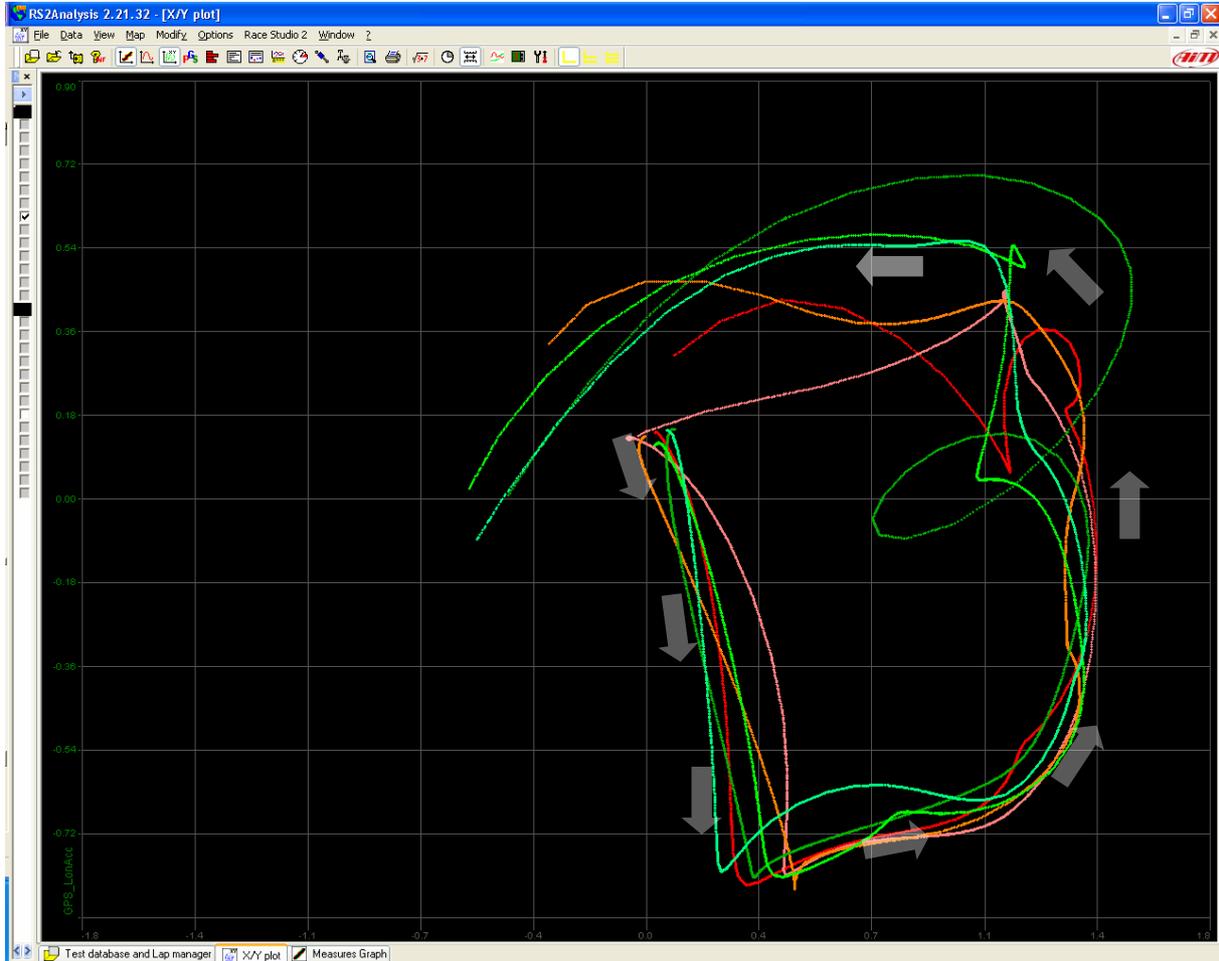


The graphs shows, from top to bottom, speed, slip and accelerations sum.
Slip value points out very well how Morbidelli releases the brake slightly after (between 5 and 10 metres) and brakes more strongly (red arrow, slip falls to 30%!).
Slip at gas re-opening (green arrow) is a lot lower for Morbidelli, while its total acceleration in the same point is much higher (light blue arrow); this means that he corners with maximum grip.

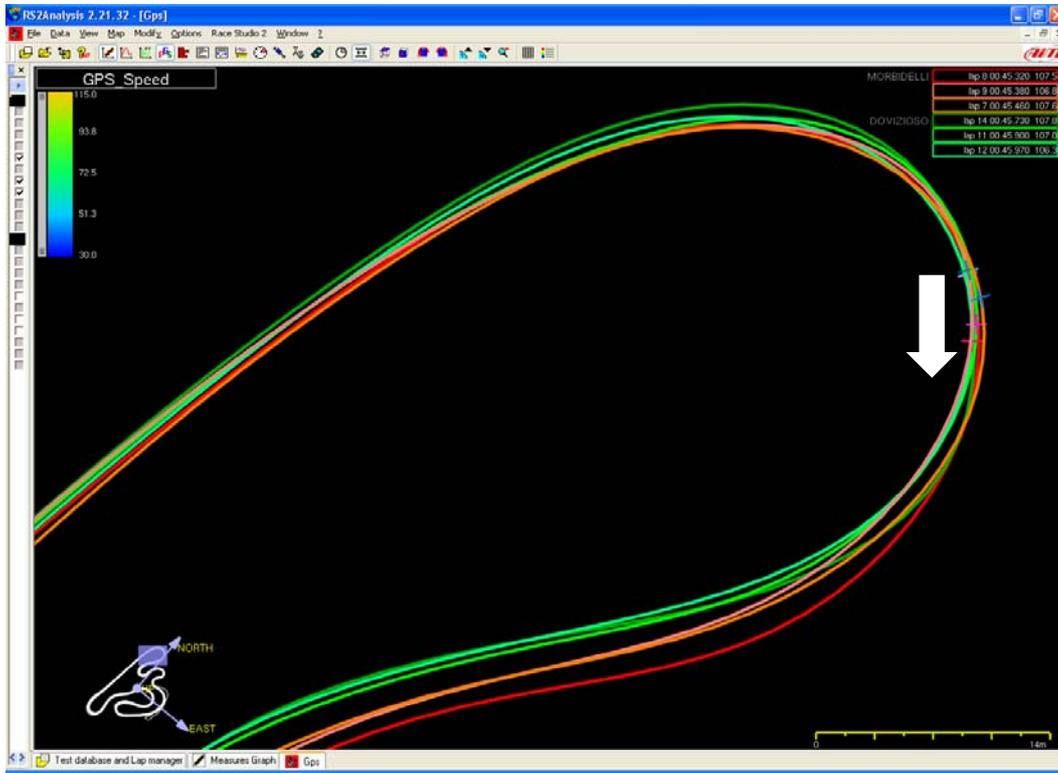


The following figure shows G-G diagram of the range highlighted in red in the previous figures.

This a perfect example of G-G diagram: the driver starts with a straight (centre of the graph), brakes running straight (going centre down in the graph), corners in keeping total acceleration at max allowed value (bottom right of the graph), releases the brake (going upwards keeping the right part of the graph) and opens gas straightening the trajectory (moving upwards the diagram and then to the centre).



Analysis of the trajectories indicates how Morbidelli releases the brake more internal in the corner and leaves the kart running more external while cornering out. The following figures show GPS trajectory of the analysed laps and track section detail highlighted in Google Earth map.

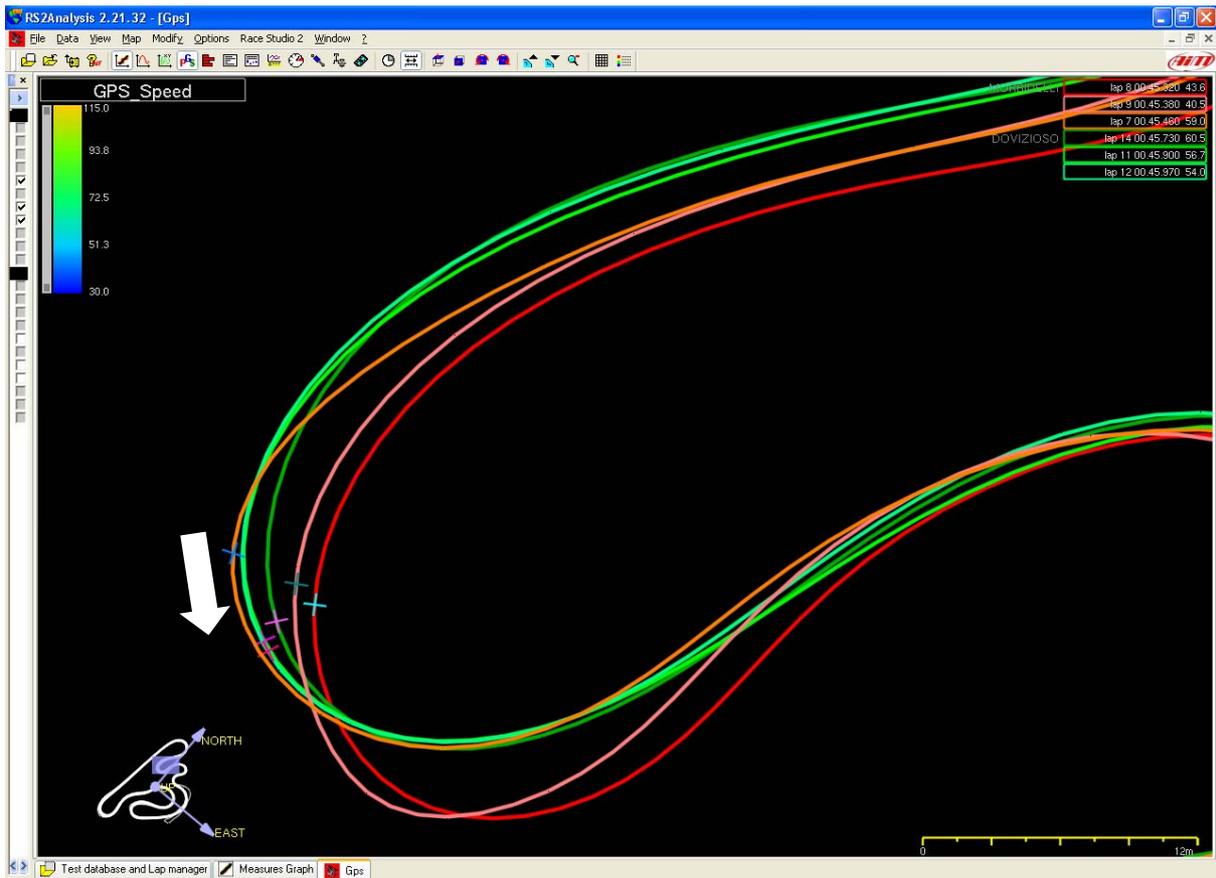


Section 8 – The Rampino

Drivers reach this corner at about 75 km/h, brake with about 0,7 g and run the corner with a maximum lateral acceleration of more than 1,4 g at around 40 km/h.

Analysis of the trajectories points out that Morbidelli tries keeping speed at high values on this fast section (this manoeuvre has been prepared with a wide cornering out of the previous corner) sacrificing cornering out of “Rampino” knowing that there is surely a section where speed will be lower. Time Compare told us that this behaviour is unprofitable.

The following figures shows GPS trajectory of the analysed laps and track section detail highlighted in Google Earth map.





The graph shows, from top to bottom, speed, lateral acceleration and longitudinal acceleration.

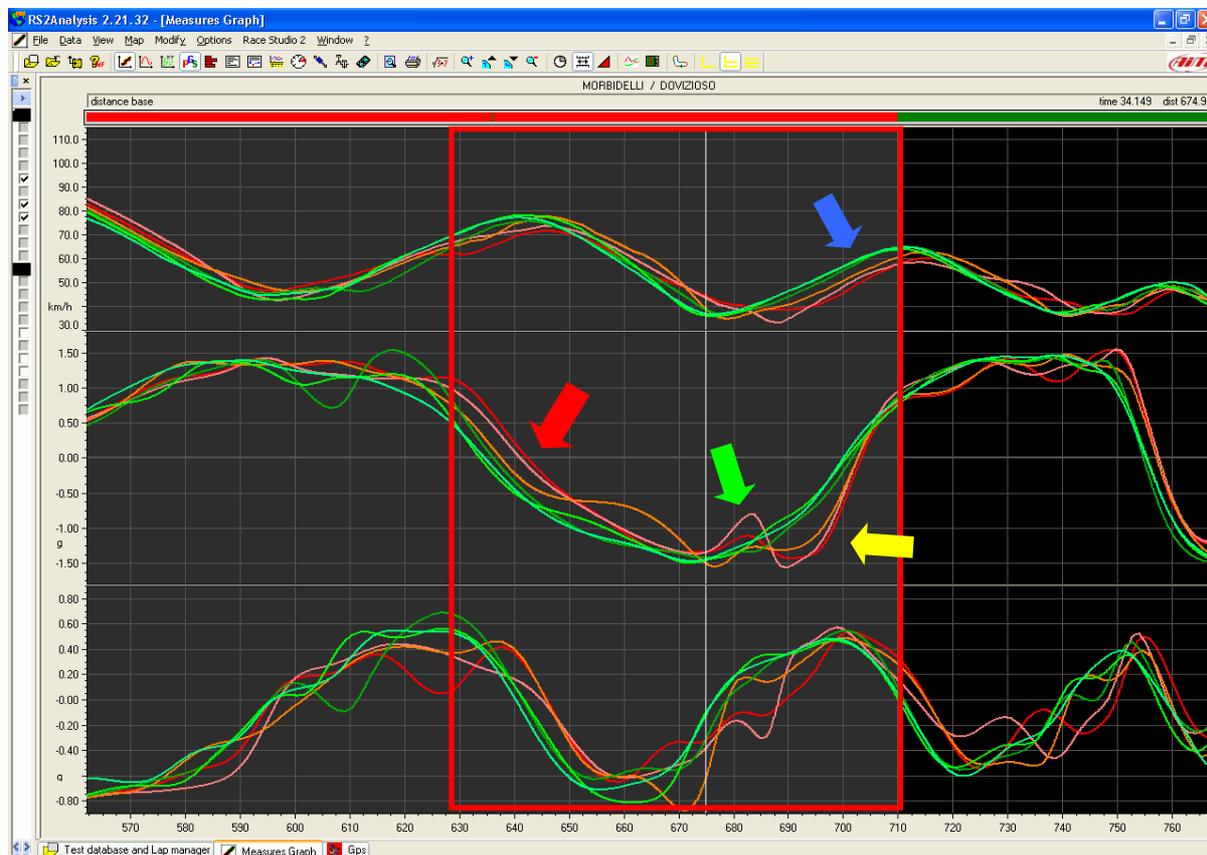
Looking at lateral acceleration diagram we see that Morbidelli has no side slips while cornering in (red arrow, there are no peaks towards low values) and loses a little grip while cornering out, probably when he tries opening the gas.

Looking at Dovizioso we can notice in general a more linear course of the lateral acceleration (and longitudinal too), that means a smoother driving in this corner.

Please note how Dovizioso (bleu arrow in the figure) reaches a significantly higher speed on the following straight.

Time Compare already told us how Morbidelli is slower in the second part of the track in all laps except for the orange coloured one (where lateral acceleration shows a trajectory similar to Dovizioso's); in this last lap (orange coloured) Morbidelli runs faster than Dovizioso on the same trajectory.

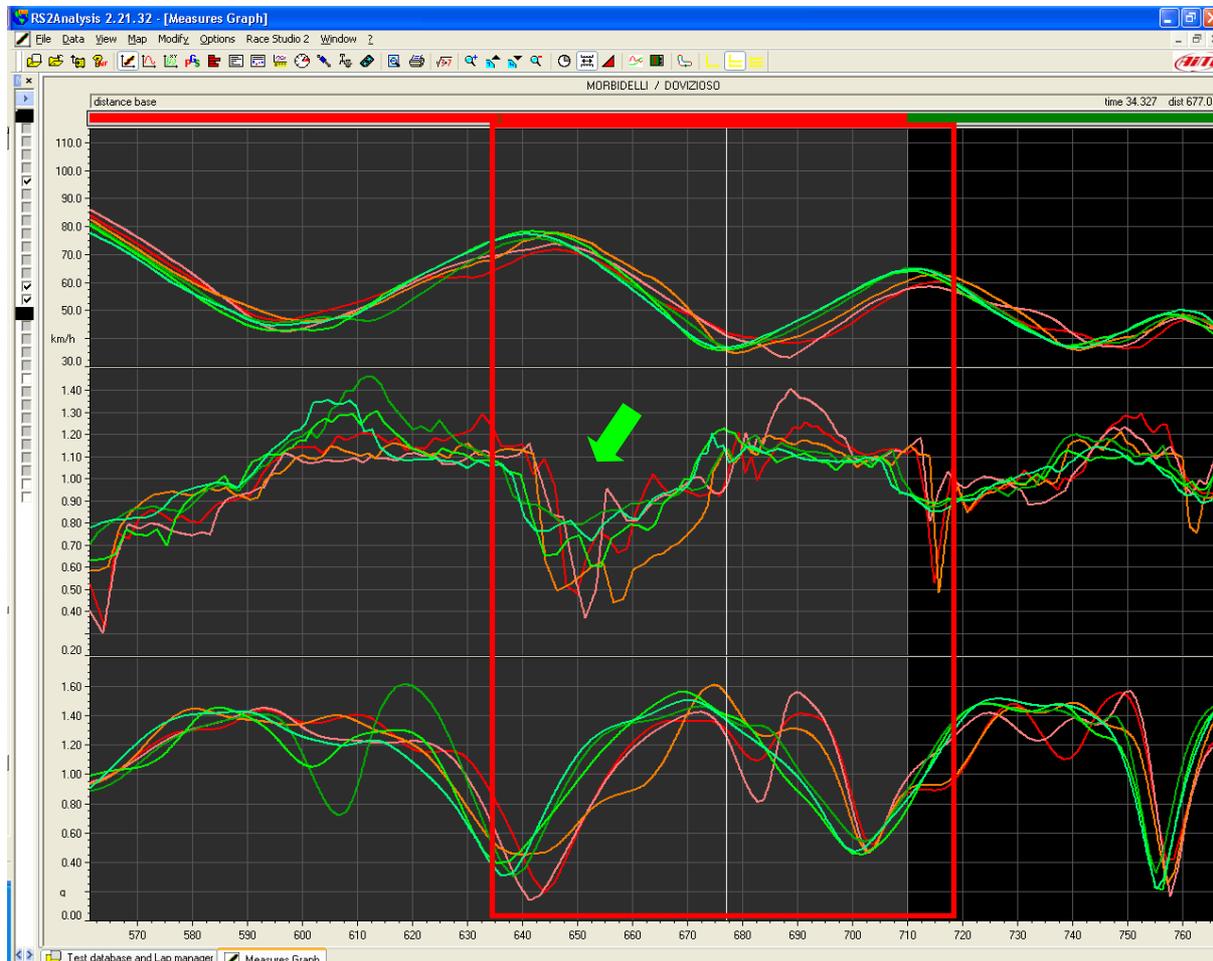
The yellow arrow in the figure points out how Morbidelli keeps lateral acceleration on the left a little longer, that means he extends the left corner and then changes its direction more suddenly.



The graph shows, from top to bottom, speed, slip and accelerations sum.

Slip shows (green arrow) how Morbidelli brakes as late as possible succeeding in it but Time Compare already showed us that in this part of the track Morbidelli loses and this change of trajectory is not profitable.

Total accelerations course is not very helpful because the trajectories of the two drivers are really very different.



The following figure shows G-G diagram of the range highlighted in red in the previous figures.

The diagram confirms once again how Morbidelli has a bent to hard braking straight and manages better the acceleration while cornering out. To have a good and steady lateral acceleration the correct lines are Dovizioso's.



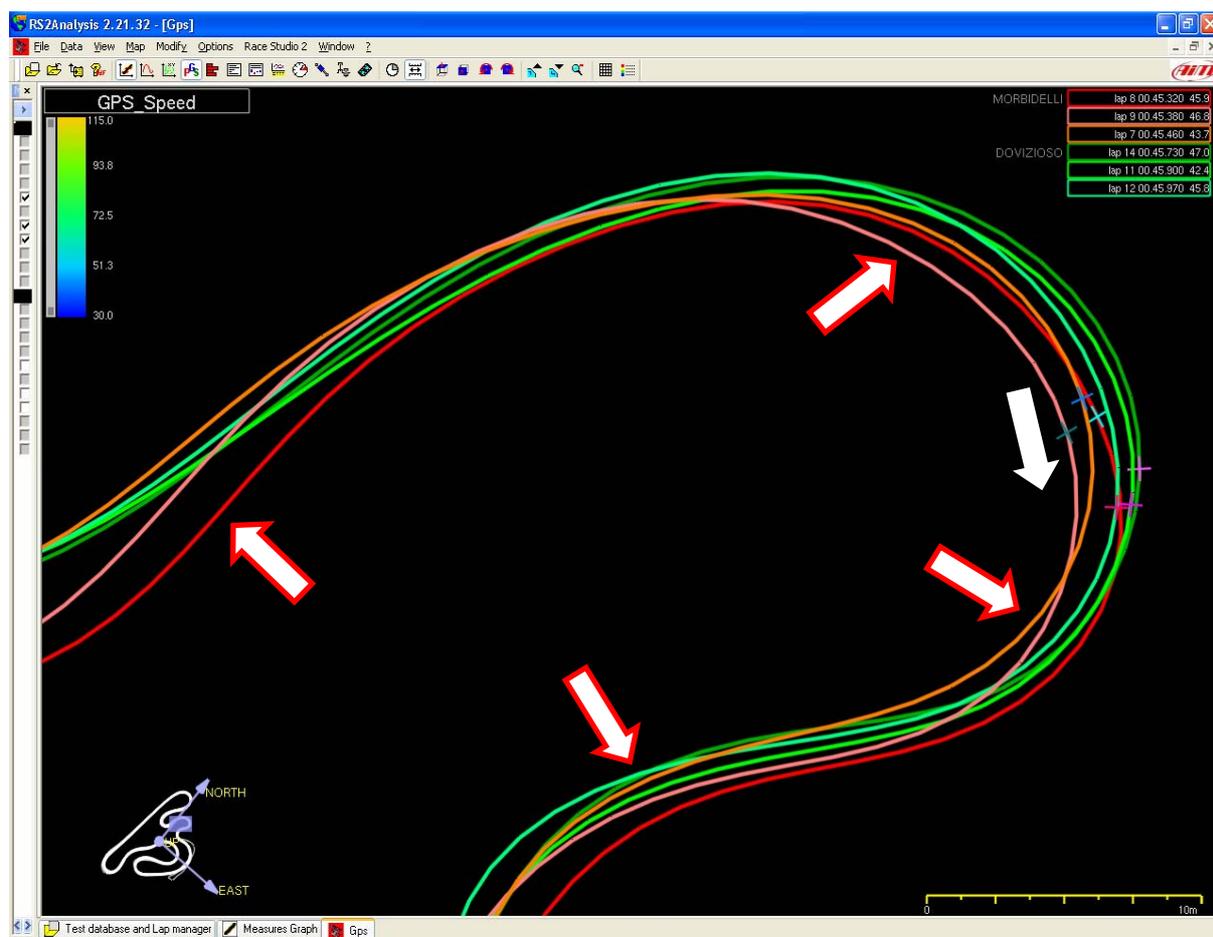
Section 9 – The Primo Tornantino

The corner is reached at around 60 km/h; drivers brake at more than 0,5 g to join around 1,5 g lateral acceleration at around 40 km/h speed.

On this hairpin Morbidelli looks for alternative trajectories, as red arrows show; he reaches the corner differently from the previous one, corners in narrower the hairpin and closes the trajectory while cornering out.

Dovizioso, on the contrary (and Time Compare told us this choice is profitable) corners in wider, let the kart running in the hairpin and corners out narrower to better prepare the following corner.

The following figures shows GPS trajectory of the analysed laps and track section detail highlighted in Google Earth map.





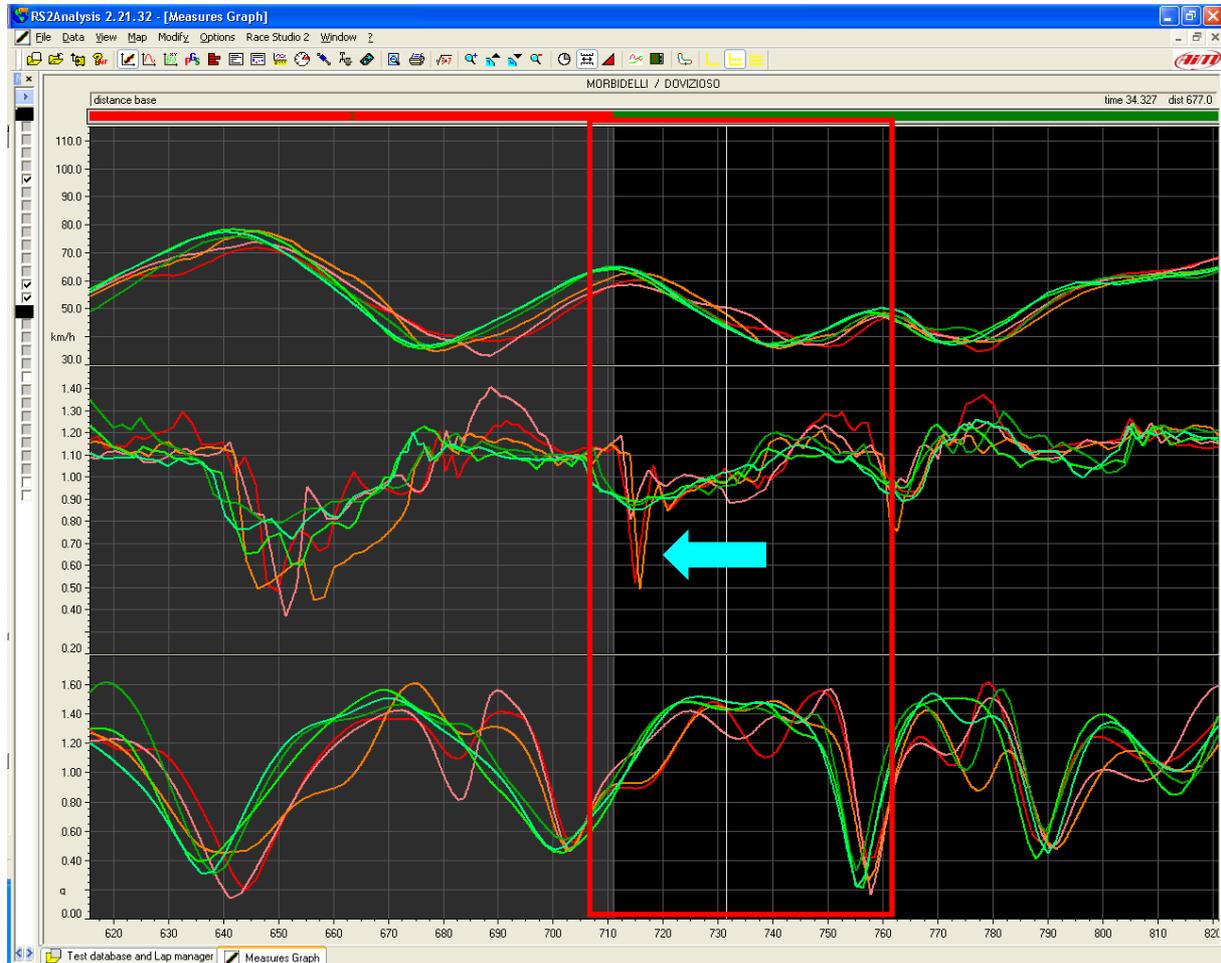
The graph shows, from top to bottom, speed, lateral acceleration and longitudinal acceleration.

In general we can see how green lines are a lot more gathered than red ones, what means that Dovizioso is a lot more steady than Morbidelli and that (especially in accelerations) green lines are a lot less sudden than the other, signal of more smoothness in driving.

Dovizioso comes faster to the hard brake (red arrow in the figure) and, braking before (light blue arrow in the figure), can find immediately a good level of lateral acceleration (green arrow in the figure).



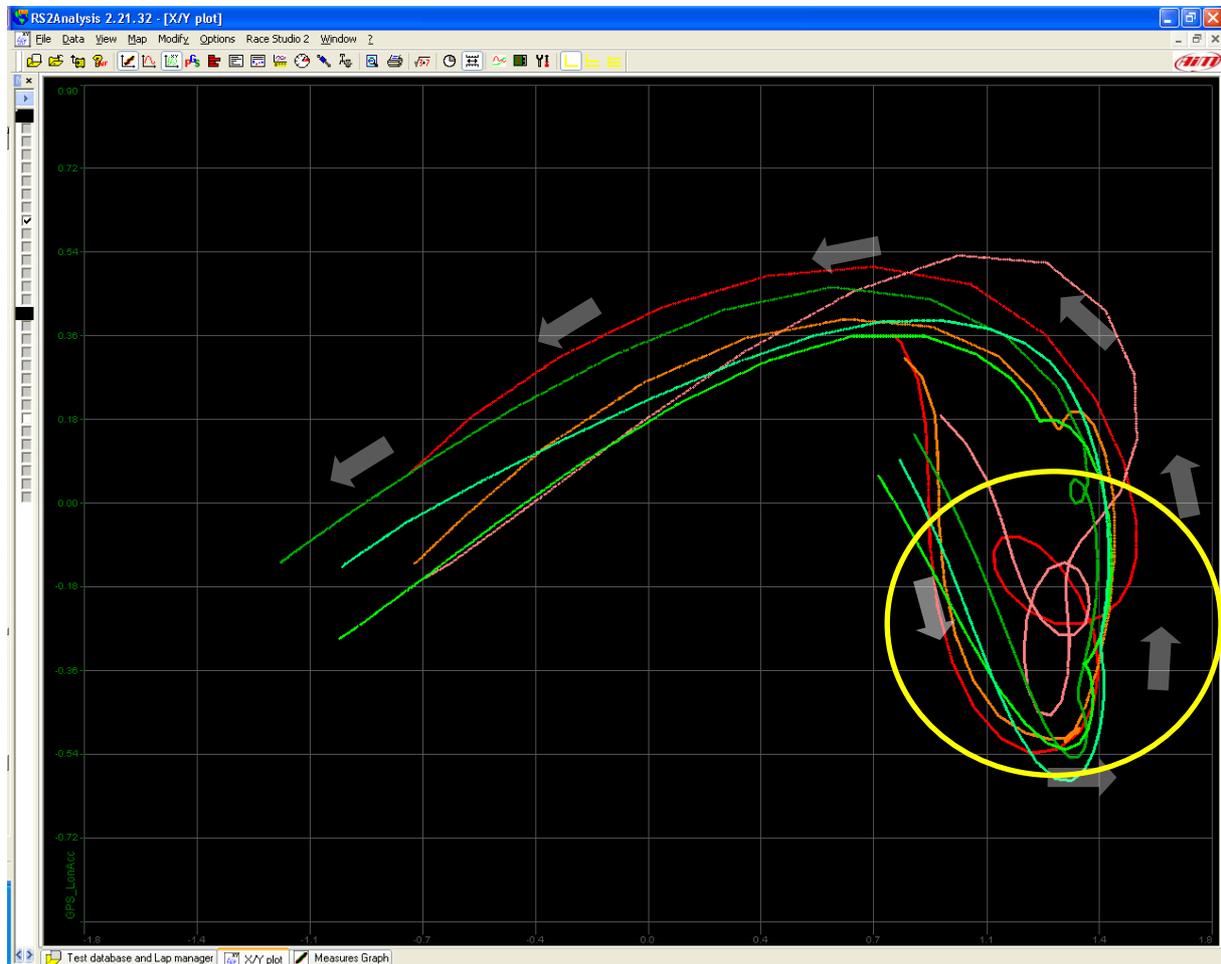
The graph shows, from top to bottom, speed, slip and accelerations sum.
Please note again (light blue arrow): slip makes visible how the two drivers uses the brake in a different way and how Morbidelli is more hard in braking.
Once again trajectories are very different and total accelerations are not very helpful.



The following figure shows G-G diagram of the range highlighted in red in the previous figures.

Cornering in of “*Tornantino*” shows for both drivers a hard brake with an already high lateral acceleration value (both of them brakes in the corner).

The yellow circle highlights how Morbidelli had a little more difficulty in keeping a good lateral acceleration, helped by a little higher speed.



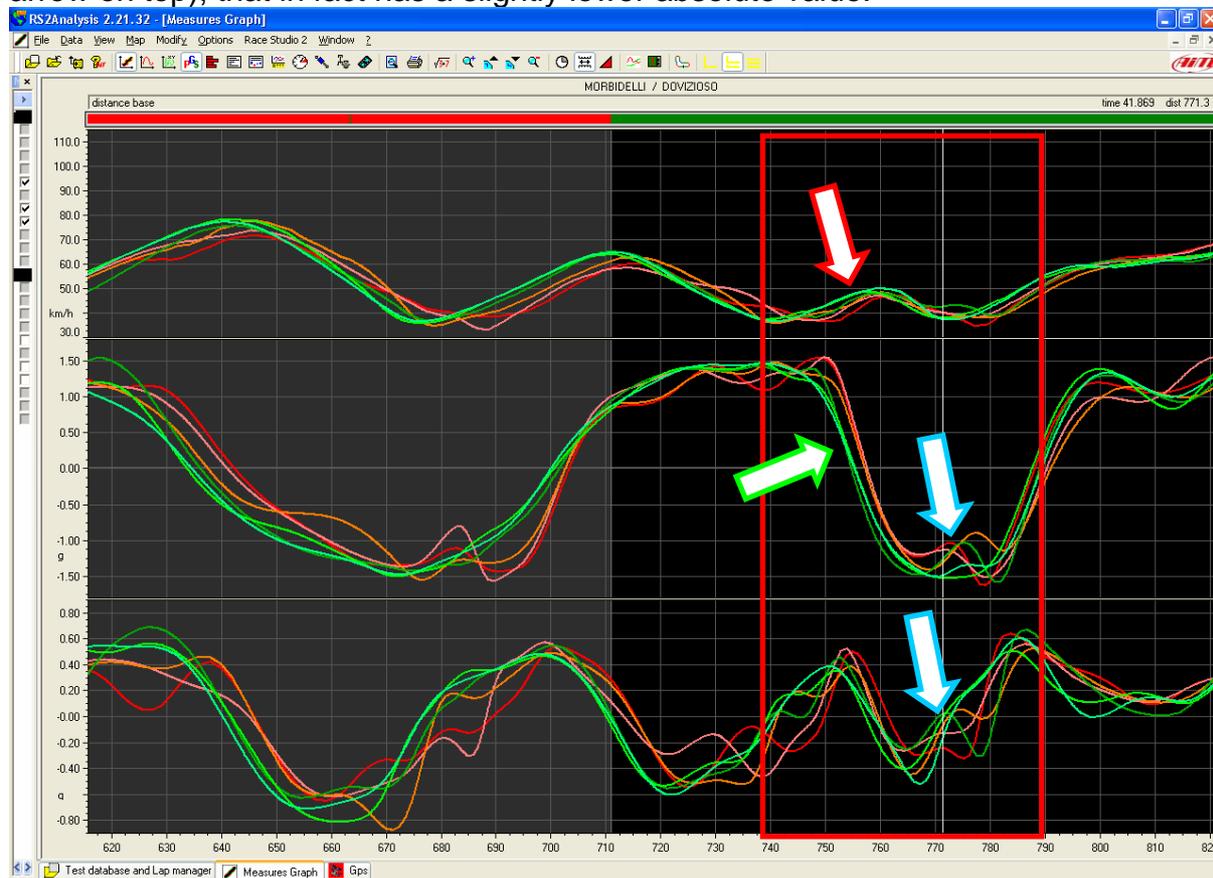
Section 10 – The Secondo Tornantino

Drivers reach the corner at around 50 km/h, brakes until reaching a speed a little lower than 40 km/h with a deceleration slightly lower than 0,3 g, to run the corner at more then 1,5 g lateral acceleration at around 40 km/h.

The graph shows, from top to bottom, speed, lateral acceleration and longitudinal acceleration.

Dovizioso reaches the hard brake slightly faster (red arrow in the figure) and corners in slightly before (green arrow); in effect lateral acceleration moves faster on negative values (please remember that lateral acceleration has positive values in right corners and negative values in left corners).

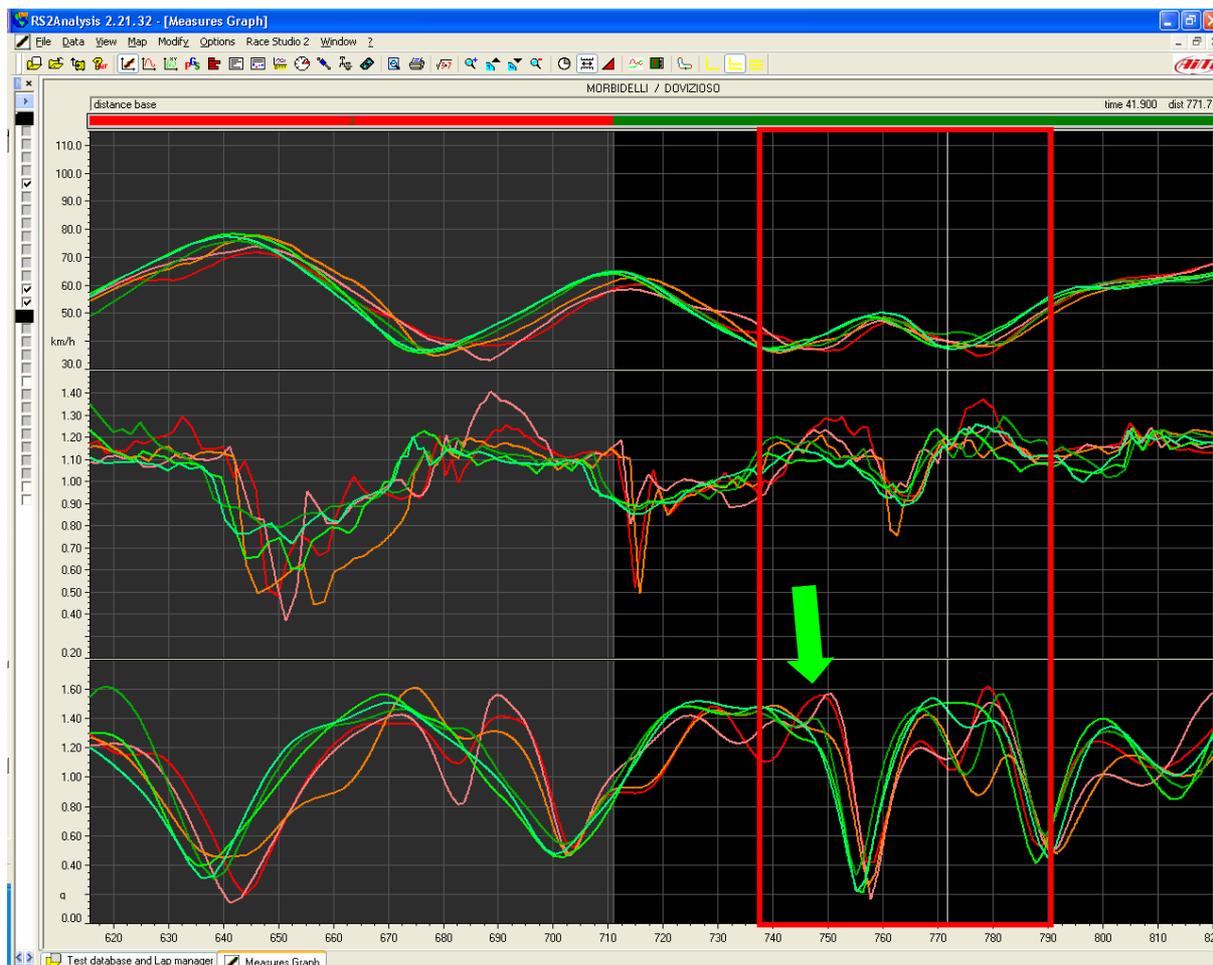
Accelerations (light blue arrows) highlights how Morbidelli brakes a little less while cornering in (longitudinal acceleration in the point just before the light blue arrow on bottom of the graph) and how he extends the braking in the all hairpin (longitudinal acceleration remains more negative that Dovizioso's). Asking the kart for more longitudinal acceleration Morbidelli has to sacrifice a part of the lateral one (light blue arrow on top), that in fact has a slightly lower absolute value.



The graph shows, from top to bottom, speed, rear wheels slip and accelerations sum. Slips points out a little difficulty for Morbidelli to face this corner: he brakes more strongly while accelerating, also if his speed is slightly lower. Most likely it's exactly the slip that causes a lower speed.

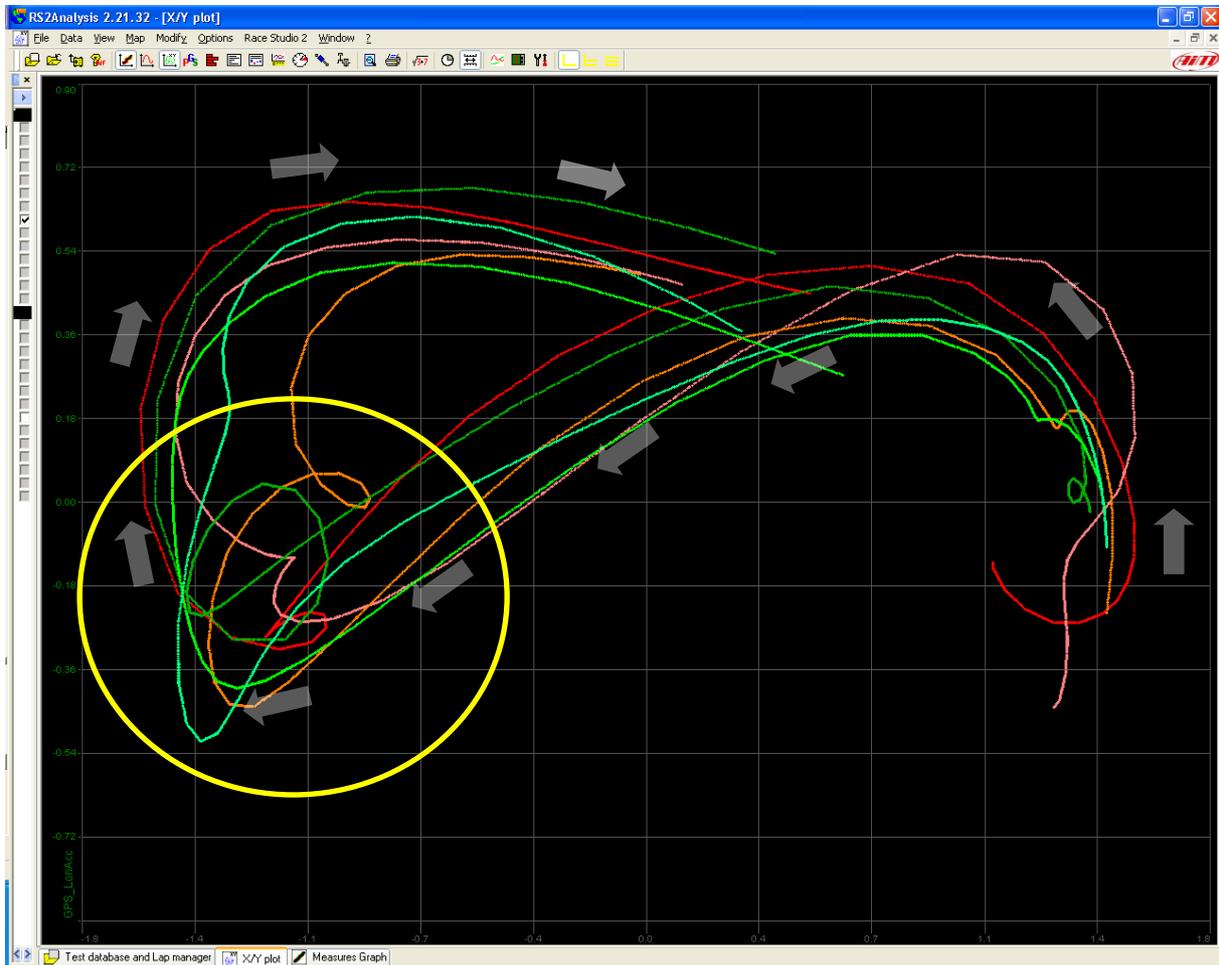
Total accelerations are in favour of Morbidelli in the first part (green arrow in the figure, it's the change of direction from the previous corner), to pass in favour of Dovizioso after.

Managing so suddenly a change of direction isn't probably profitable, as we saw in the previous graph: Dovizioso open the gas before and better.



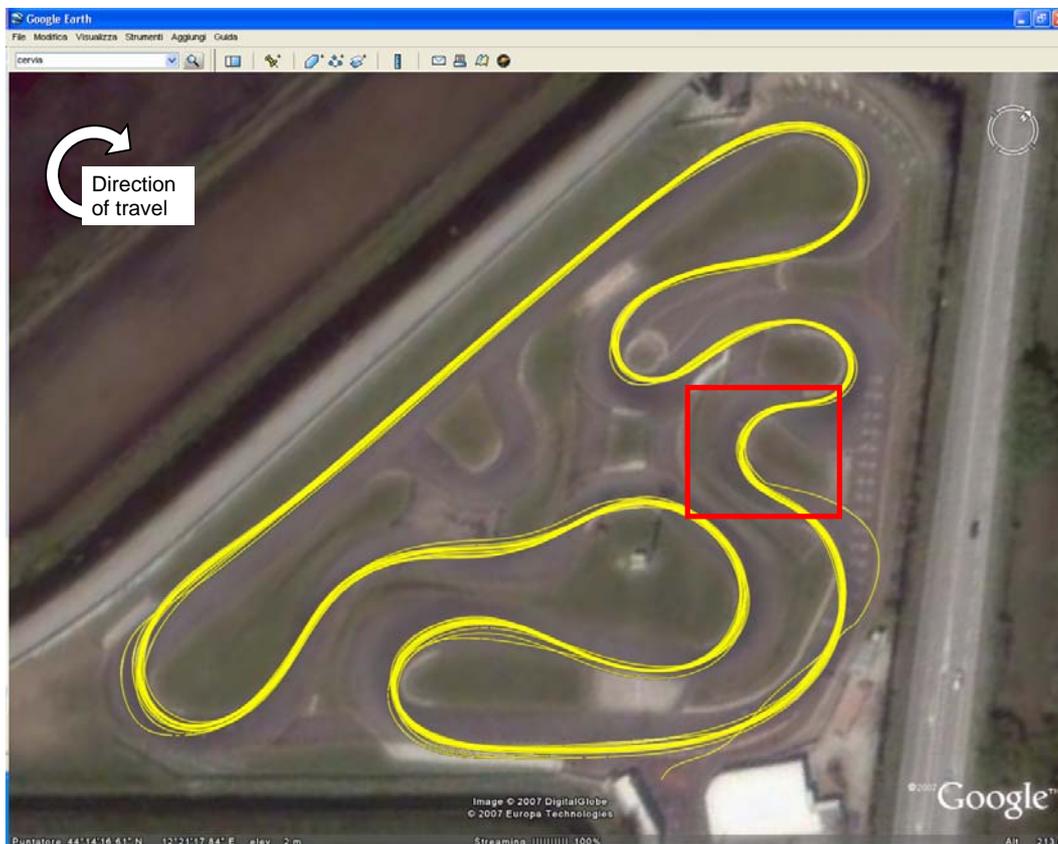
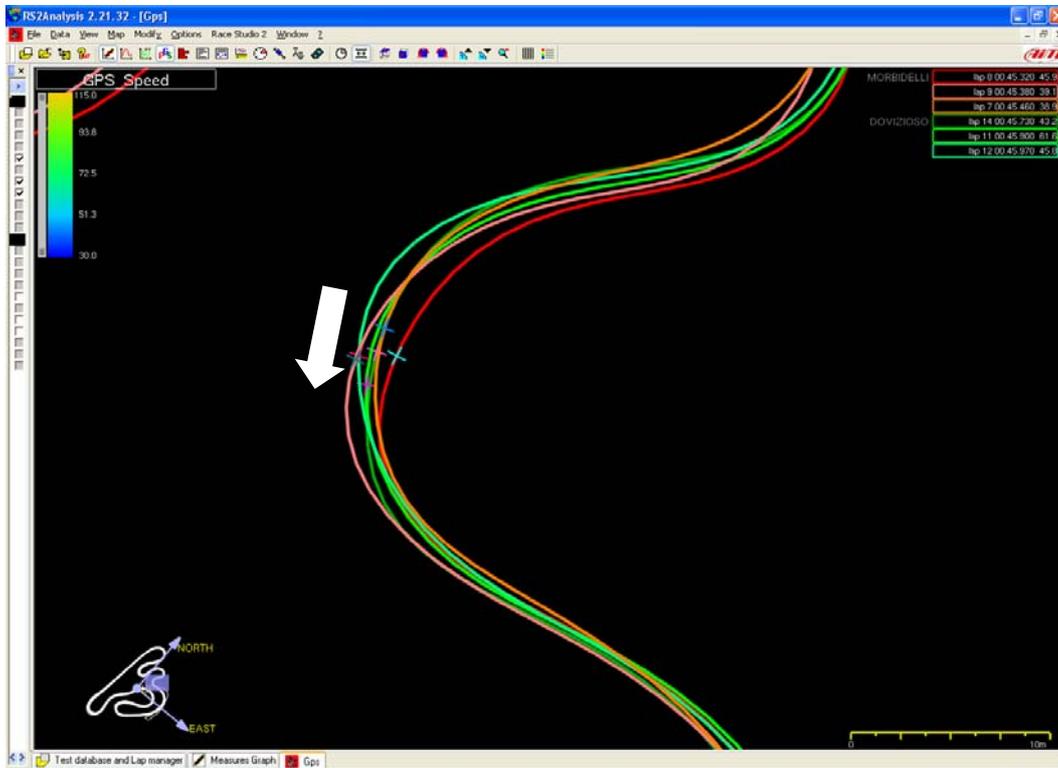
The following figure shows G-G diagram of the range highlighted in red in the previous figures.

The course of the two drivers is very similar. The yellow circle points out that hard brake and cornering in of this hairpin is difficult for both drivers, probably because of the grip conditions of the track in this section.



In the fast lap (red trajectory in the figure), Morbidelli corners in narrower to brake later. Time Compare already showed that this is not profitable if compared with the other 5 laps in analysis.

The following figures show GPS trajectory of the analysed laps and track section detail highlighted in Google Earth map.



Section 11 – The Curva dei Box

This is the penultimate corner of the track and its trajectory has to be linked with that of the following corner to create one only corner. It is all run at growing speed, with cornering in lateral acceleration higher than 1,2 g reaching 1,5 g while speed grows. The graph shows, from top to bottom, speed, lateral acceleration and longitudinal acceleration.

This corner crosses start/finish line of the measured lap. To better analyse it we are now passing to Snap OFF mode (please note the disabled icon highlighted by the light blue arrow in the figure) and ranging perfectly finish lines, clicking and dragging the grid of the horizontal axle (green rectangle in the figure) that in Snap OFF mode shows one axle for each lap.

As shown by speed course, the corner is run with continuous acceleration (red arrow in the figure).

How highlighted by the green arrows in the figure, in the second or third best lap Morbidelli let the kart side slip (pink and orange coloured lines); this implies differences in the trajectory until the following corner! For all laps of both pilots lateral acceleration diminishes a little. Dovizioso is more steady lap after lap, Morbidelli cannot, probably also because he faces the corner with a slightly higher speed (red arrow in the figure).

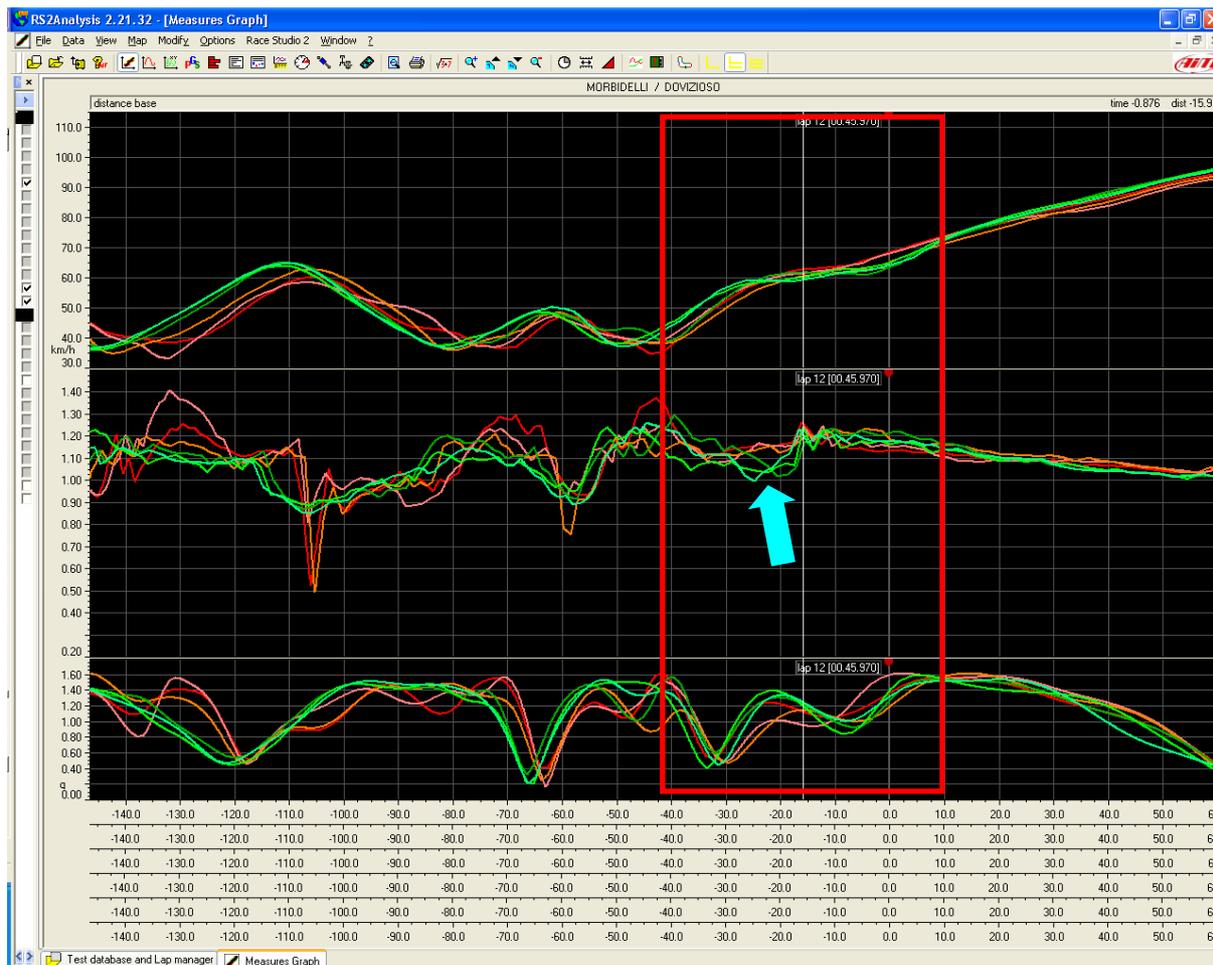


The graph shows, from top to bottom, speed, slip and accelerations sum.

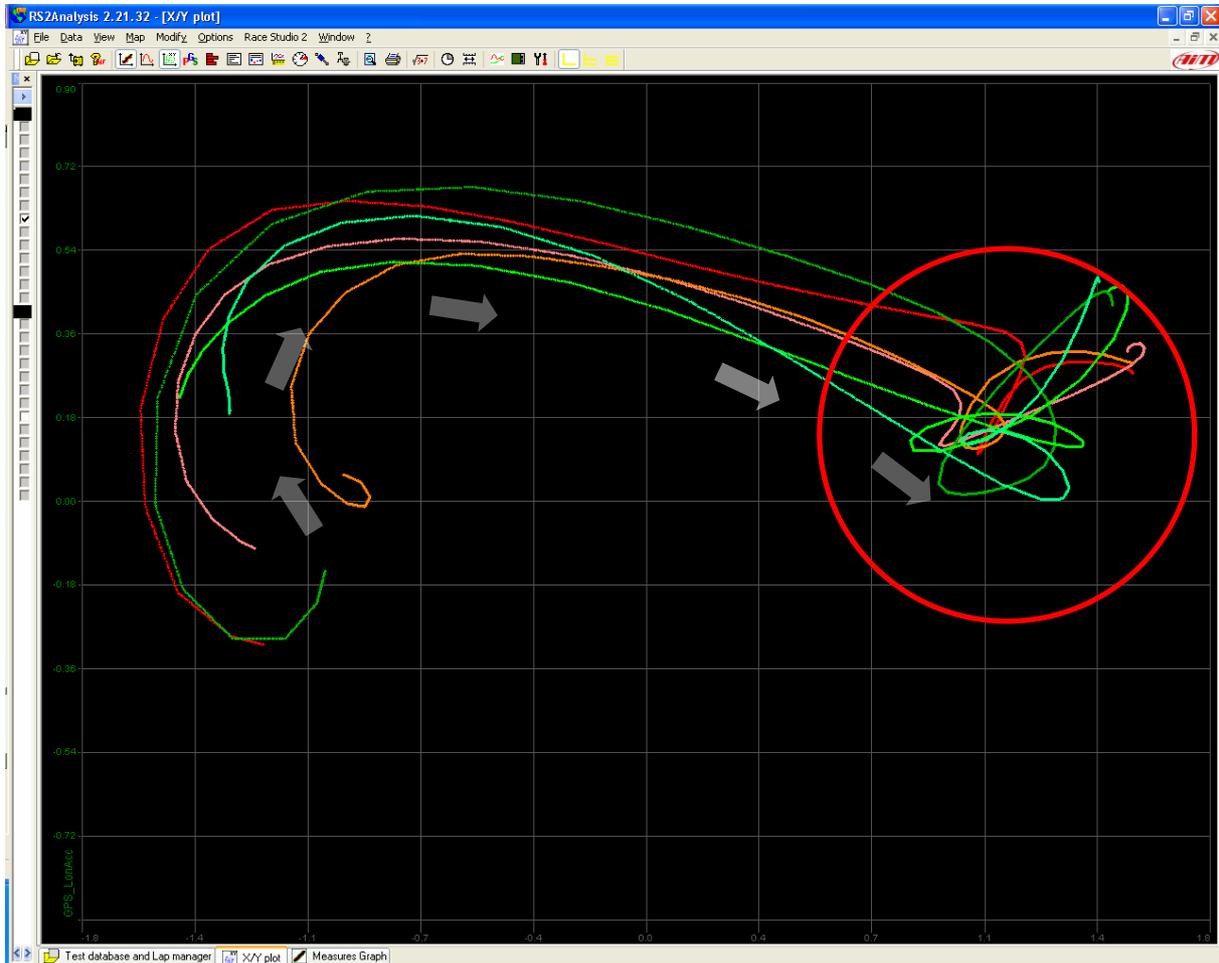
Slip is higher for Morbidelli while cornering in, afterwards values are identical for both drivers.

Total acceleration is lower for Morbidelli at cornering in because he has less lateral acceleration; this happens because, running the same trajectory, he has a little less speed.

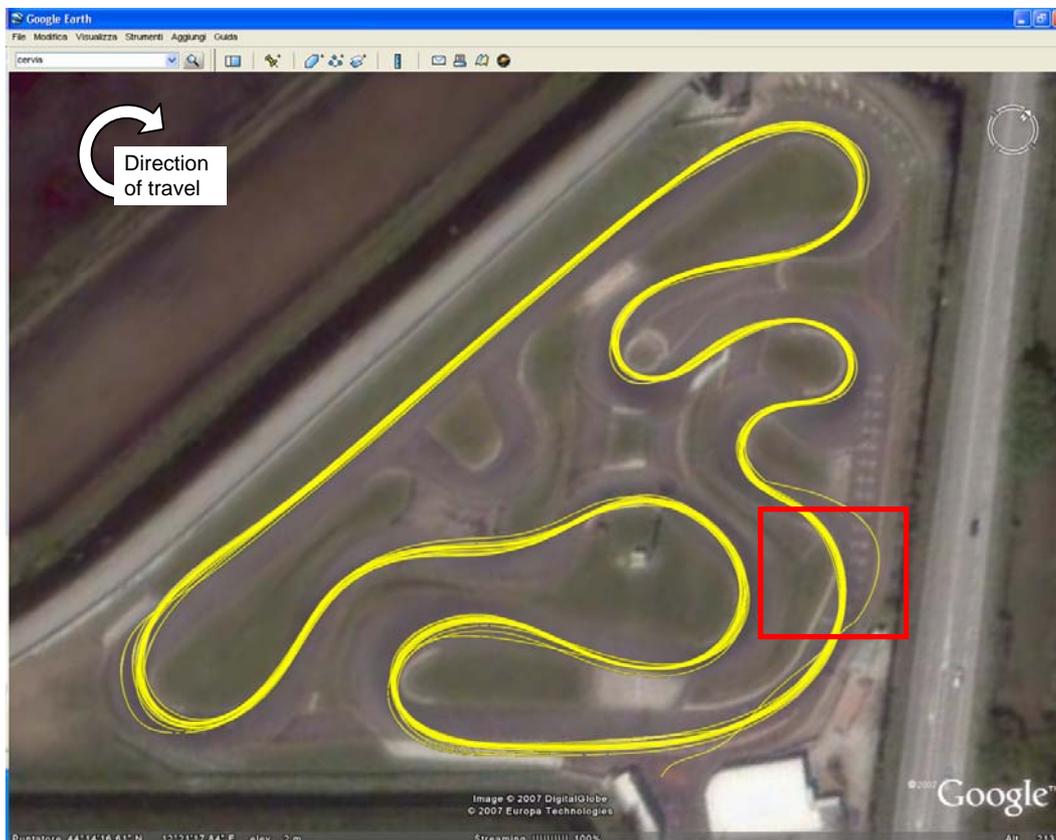
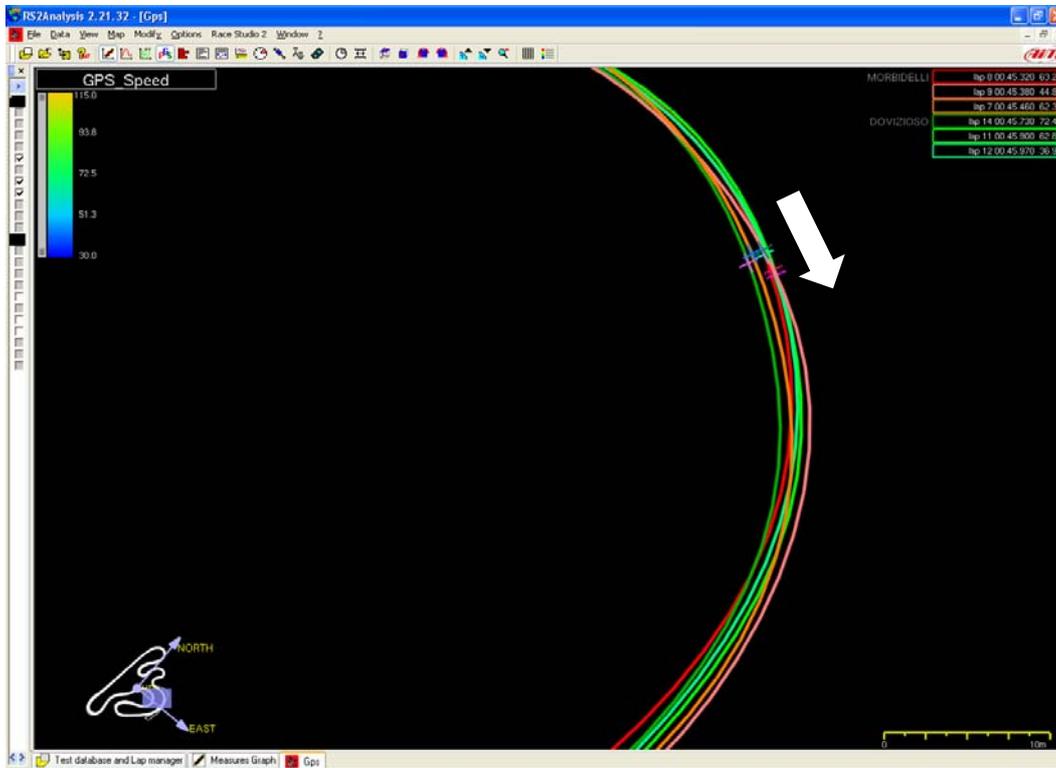
We already saw that Dovizioso ask the kart for a lot of acceleration while cornering in. This leads to the fact that the kart cannot give longitudinal acceleration too. The light blue arrow highlights the fact that Dovizioso closes gas a little (slip goes near to 1 but never under this value) to allows the kart giving lateral acceleration. Time Compare already told us that this is the best that can be done.



The following figure shows G-G diagram of the range highlighted in red in the previous figures.
Highlighted in the red circle the point where Dovizioso closes the gas (green lines are a little downward) to gain lateral acceleration.



There are not particular differences between the trajectories of the two drivers. Running the most profitable trajectory means cornering in widely to corner out narrower, like Dovizioso does in two laps out of three and Dovizioso in his best lap. The following figures show GPS trajectory in the analysed laps and the track section detail highlighted in Google Earth map.



Section 12 – The Curva del Bar

The “*Curva del Bar*” is at the end of Cervia track but, because of the magnetic strips disposition on the track, looking to our graph it comes out to be at the beginning of the lap. To better appreciate the complete course we should switch to Snap OFF mode in Race Studio Analysis and re-range the ranges shown on finish lines positions.

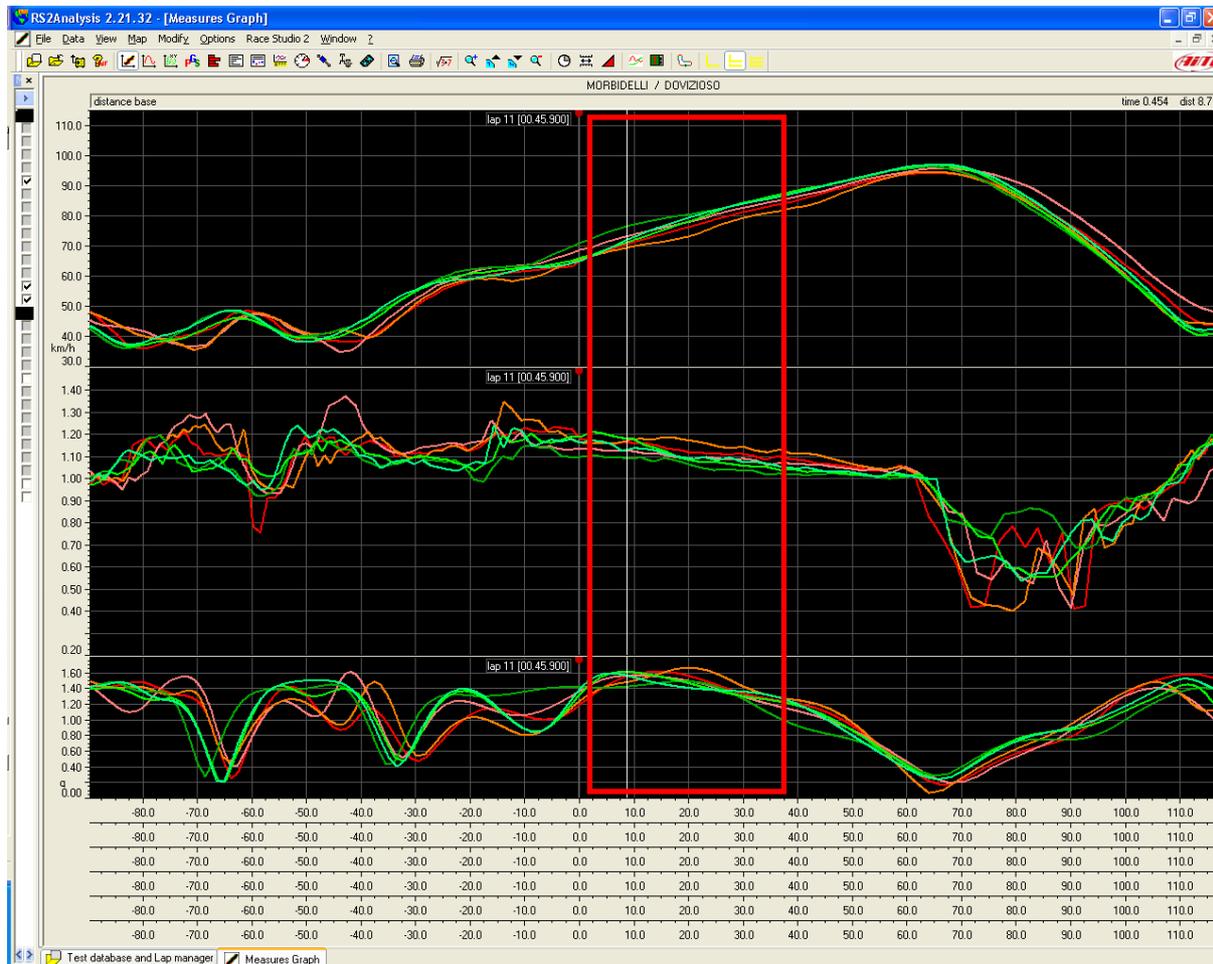
The graphs shows, from top to bottom, speed, lateral acceleration and longitudinal acceleration.

Speed diagram has a growing course (red arrow in the figure) and indicates a continuous acceleration since the previous corner; longitudinal acceleration (light blue arrow) is in fact always positive. Lateral acceleration (green arrow) diminishes slowly and this implies that the trajectory opens quietly. We are entering a quite long straight and it is thereby better leaving the kart running while cornering out. Please note how Dovizioso can do this better thanks to the fact that he corners better out the previous corner.

At cornering in of this corner speed difference is around 8 km/h in favour of Dovizioso.



The graph shows, from top to bottom, speed, slip and accelerations sum.
Please note how slip is higher than 1 in the all considered range, what means that the corner is run with a slight over-steering, Morbidelli more than Dovizioso.
Time Compare told us that in the second part of the track, generally, Morbidelli lost in respect of Dovizioso but not in this corner, what means that this is the correct way to run it.
Total acceleration course indicates an higher value for Morbidelli and confirms again that Morbidelli's style is the most profitable.



The following figure shows G-G diagram of the range highlighted in red in the previous figures.

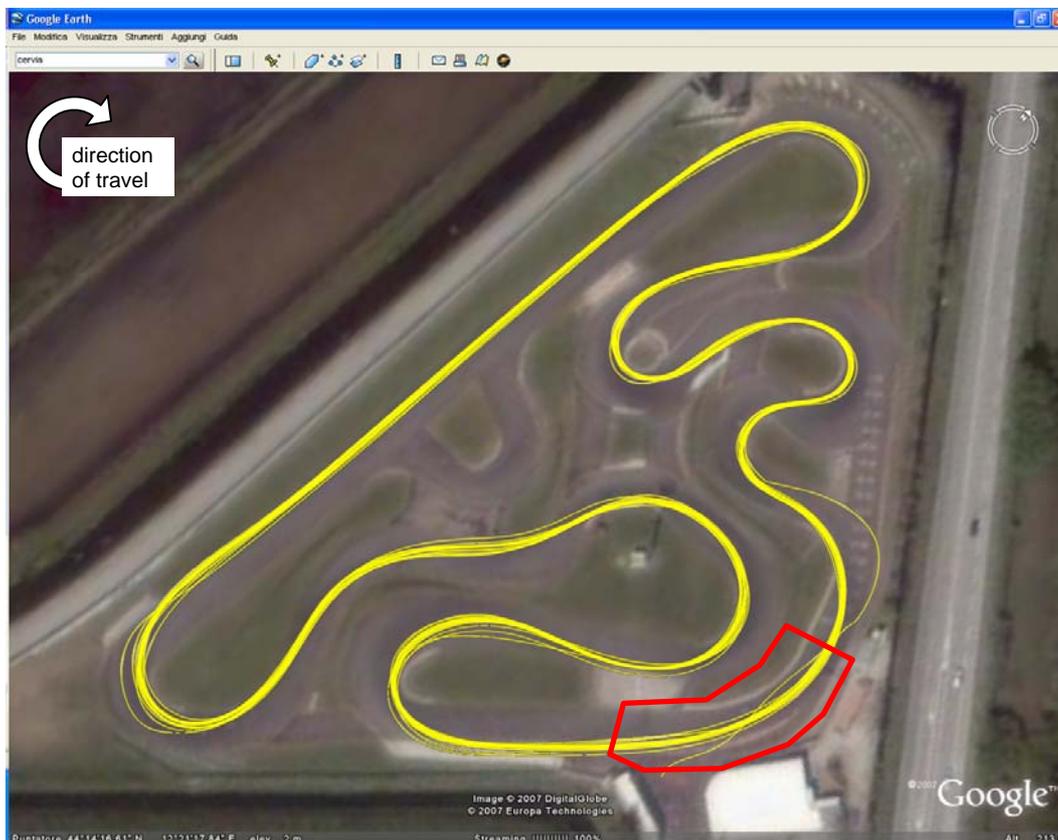
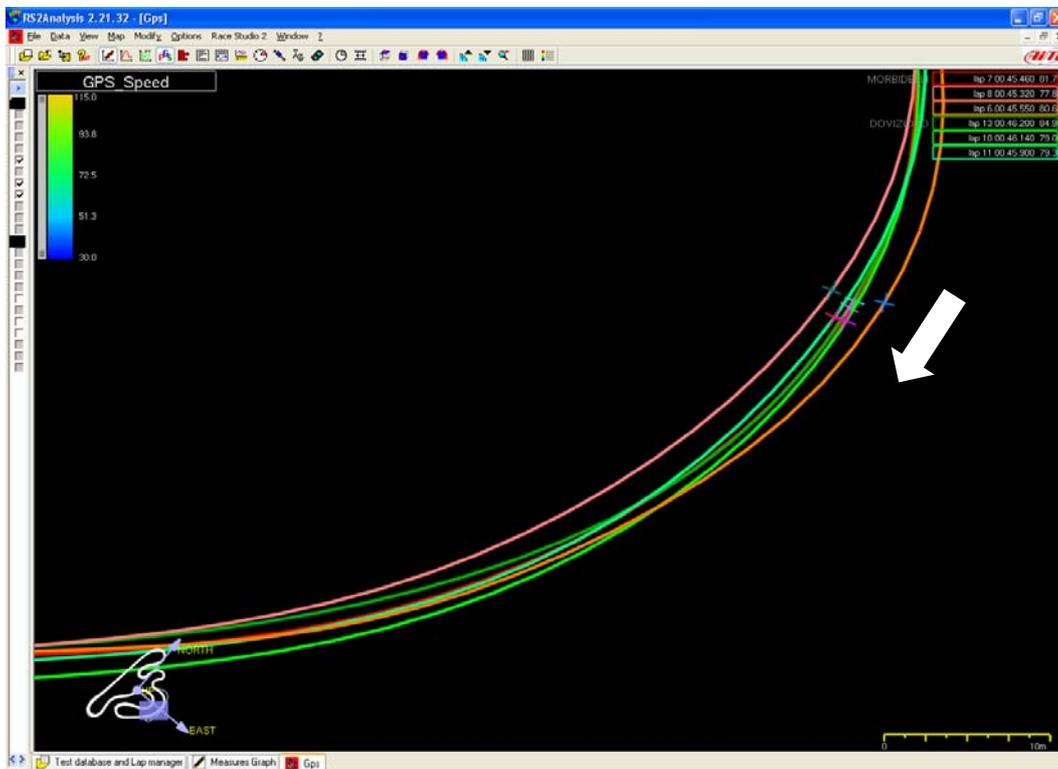
The following figure represents a textbook case for the G-G diagram: right corner with steady acceleration, lateral and longitudinal: all points are in the top right quadrant.

Style is similar for both drivers (driving with slight over-steer), but Morbidelli can develop more lateral acceleration, probably because he uses the steering slightly differently.



Trajectory differences in Morbidelli's less fast laps come from side slips in the previous corner. Looking at the graphs we would say that Dovizioso can be more steady in this corner but it's behaviour is only determined by the previous cornering out, that in fact links with this one.

The following figures shows GPS trajectory of the analysed laps and track section detail highlighted in Google Earth map.





Racing Data Power

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© 2008 AIM Srl - Via Cavalcanti, 8 20063 Cernusco sul Naviglio (MI) - Italy
Tel. +39.02.9290571 - info@aim-sportline.com

www.aim-sportline.com