National Transportation Safety Board

Memorandum

Date: November 28, 2018

To: Stephen Stein
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WPR18MA087 Investigator in Charge (IIC)

From: John O'Callaghan
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WPR18MA087 Aircraft Performance Specialist

Subject: Plots of Appareo Vision 1000 data for May 4, exemplar Papillon flight from KBVU to QMB; testimonies of Papillon pilots re: winds on approach to QMB; Airbus Helicopters yaw control simulations

References:

1. Appareo Vision 1000 electronic data files from May 5, 2018 flight of N836GC from KBVU to Quartermaster Base, provided by Papillon on May 10, 2018.
2. National Transportation Safety Board, Accident No. WPR18MA087: *Interview of Brett Aloha*, February 12, 2018
3. National Transportation Safety Board, Accident No. WPR18MA087: *Interview of Christina Rascon*, February 12, 2018
4. National Transportation Safety Board, Accident No. WPR18MA087: *Interview of Derrick Mojica*, February 13, 2018
5. National Transportation Safety Board, Accident No. WPR18MA087: *Interview of James Finney*, February 12, 2018
6. National Transportation Safety Board, Accident No. WPR18MA087: *Interview of John Davis*, February 12, 2018
7. National Transportation Safety Board, Accident No. WPR18MA087: *Interview of Scott Booth*, August 2, 2018
8. National Transportation Safety Board, Office of Aviation Safety, *Meteorology Factual Report, WPR18MA087*, September 18, 2018
9. Airbus Helicopters, *N155GC – EC130B4 S/N7091, 02/2018 – Grand Canyon accident – simulations results*, September 25, 2018 (*PowerPoint* presentation included as attachment to this memorandum)

Stephen:

This memorandum transmits flight path, speed, and attitude information for the May 4, 2017 “exemplar” flight from Boulder City Municipal Airport (KBVU) to Quartermaster Base (QMB) conducted by Papillon in an Airbus Helicopters (AH) EC-130 T2 helicopter, registration N836GC (Papillon ship # 50). This memorandum also includes, as an attachment, simulator “matches” of this exemplar flight conducted by Airbus Helicopters, that validate the fidelity of the simulator model and quantify the amount of pedal control required to fly in various hypothetical, simulated wind conditions. These data are provided to provide context for the flight route and possible intended landing approach path of N155GC, an AH EC-130 B4 helicopter which crashed while attempting to land at QMB on February 10, 2018 (NTSB accident #WPR18MA087). The testimonies of several Papillon pilots that preceded N155GC into QMB concerning wind conditions on the approach are also discussed.

Overview

The objective of an Aircraft Performance Group during an NTSB investigation is to determine and analyze the motion of the aircraft and the physical forces that produce that motion. In particular, the Group attempts to define the aircraft’s position and orientation throughout the flight, and determine its response to control inputs, external disturbances, and other factors that could affect its trajectory.

The data the Group typically uses to determine and analyze the aircraft motion includes but is not limited to the following:

- Wreckage location and condition.
- Ground scars / markings and damage to ground structures.
- FAA surveillance data (radar, multi-lateration, or ADS-B).
- Data recorded on-board the aircraft, including Flight Data Recorder (FDR) data, GPS data, data retained in the non-volatile memory of avionics, data from flight monitoring devices (such as the Appareo Vision 1000 on board N836GC), etc.
- Cockpit Voice Recorder (CVR) information.
- Enhanced Ground Proximity Warning System (EGPWS) data.
- Weather information.
- Airport navigational aids and surveillance / security videos.
- Data / video recorded on personal electronic devices (PEDs) carried on-board the aircraft.
- Crew and witness statements.

From this list, the only items available in the WPR18MA087 case are the wreckage location and condition, the ground scars, the testimony of the pilot, and the statements of witnesses to the accident. Significantly, there is no recorded data concerning the helicopter’s motion or the motion of the atmosphere (wind) near the accident, except for photographs of the wind sock at QMB (see Reference 8). Consequently, N155GC’s precise movements during the accident sequence cannot be determined and remain unknown, as do the actual wind conditions (as a function of time and altitude) that N155GC encountered during its approach to QMB. Therefore, no quantitative analysis of the helicopter’s motion, or the causes of that motion, is possible for this accident.

The qualitative and subjective descriptions of the sequence of events and of the helicopter motion, provided by witnesses to the accident and by the accident pilot himself, are presented below, in the witnesses' own words, as cited from their interview transcripts. Eight Papillon helicopters had landed at QMB prior to N155GC's accident; the first five had flown through the "notch" (see Figures 3 and 6) and landed facing northwest (downriver); the last three had made a "straight-in" approach to QMB and landed facing southeast (upriver). The accident pilot stated that he was also intending to make a straight-in approach and land facing upriver. Since Papillon's helicopters follow strictly defined routes and altitudes from KBVU to QMB, the flight paths of the eight helicopters that preceded N155GC into QMB, and that of N155GC itself, would likely have been very similar, at least up to the point where each pilot had to decide how to approach and land at QMB. To obtain an estimate of the approach and landing path that the accident pilot may have been attempting on the day of the accident, the NTSB requested that Papillon fly an "exemplar" flight from KBVU to QMB, and approach and land at QMB using a "straight-in" approach that might approximately match what witnesses say they saw the accident pilot doing, and what he likely would have been attempting, given his experience and Papillon's procedures.

Papillon flew such an exemplar flight in N836GC on May 4, 2018, and provided data from this flight recorded by an Appareo Vision 1000 device (Reference 1) to the NTSB. The data is presented here in Figures 1-8. Plan-view plots of the route of this flight, at various scales, serve to provide context to witness testimonies, particularly as they describe Papillon's operations and the significance of waypoints such as the "Bat Towers," the "Ramada," and the "notch." Altitudes, groundspeeds, and Euler angles (pitch, roll, and heading angles) from this exemplar flight are also provided in the Figures. While this data represents a "typical" or "exemplar" flight, and *might* also be an accurate depiction of the approach and landing that the accident pilot was attempting, it is essential to remember that the actual flight path of N155GC, and the intended approach path of the pilot, *might* have been significantly different. The location of N155GC's wreckage underneath the exemplar flight path indicates that N155GC overflew the same area, but it might have been at a different altitude, with different groundspeeds and rates of descent, on a different heading, etc.

As presented below, the accident pilot described the accident as a sudden, catastrophic encounter with a wind gust or shear that resulted in his losing yaw control of the helicopter. During the investigation, consideration was given to comparing the possible wind shear magnitudes attainable near QMB with the magnitudes of wind shear that can be controlled using the full control authority of the helicopter. Both the possible wind shears, and the maximum controllable wind shears, would be quantified through numerical simulation: using Computational Fluid Dynamics (CFD) to statistically describe the possible wind shear magnitudes near QMB, and using AH's engineering simulation of the EC-130 to compute the maximum controllable wind shears.

AH performed simulations that (1) match the N836GC exemplar flight flown on May 4 using the actual wind conditions on that day, and (2) compute the control authority required to match the exemplar flight trajectory in several more challenging wind conditions. These simulations are described further below, and AH's documentation of this work is included here as Reference 9.

NTSB staff discussed the possibility of using CFD to compute attainable wind shears near QMB (a "wind study") with staff from the National Center for Atmospheric Research (NCAR). These discussions revealed that such a wind study is not a trivial task. Addressing the problem through CFD involves modeling the larger, macro-scale meteorology surrounding the area of the Canyon in question, and then progressing into finer-scale modeling of the local weather near QMB and the effects of topography and heating on mechanical turbulence and wind shears. NTSB's discussions with NCAR revealed that this problem is "pushing the envelope" of CFD and weather modeling capabilities, and would involve considerable research time and effort to complete. As a result, the NTSB elected not to pursue such a wind study as part of the WPR18MA087 investigation. However, since as of this writing no estimate of the wind shear that might have been present near QMB during the accident is available, there is no wind data with which to compare the AH simulation scenarios, or to serve as the basis for a refinement of those scenarios. Consequently, all that can be known about the wind shear at the time of the accident is based on the pilot and witness testimonies, which are presented below.

Accident pilot testimony concerning wind gusts / shears

According to the pilot, his flight from KBVU to QMB was "uneventful" and "ordinary" until the approach to landing at QMB, when he encountered a sudden and violent gust of wind that caused him to lose control of the helicopter. His statements to investigators indicate that he believed that the wind gust occurred without warning, was extremely sudden and violent, and was unprecedented in his experience (see Reference 7):

> [Page 14]: And I as I got closer to the landing spot, I was, you know, slowing down, I couldn't go straight-in. I just got hit with a violent gust of wind, like, similar to a microburst that would come down on you. It was like, I don't know, I want to say, like, when you experience low-level wind shear that they talk about sometimes that you experience in Vegas that the ATIS reports.
> And what it did was, it just took the aircraft from me. It just spun it and I couldn't fly it. It just took it so quickly.
>
> [Pages 15-16]: Everything I did was what I've done a thousand-plus times. It was business as usual the whole way down until the gust of wind just picked up and just grabbed the aircraft. ... I don't have any memory of anything out of the ordinary.
>
> [Pages 17-19]: [Question:] So, you've done this so many times. Have you ever felt wind there before?
> [Answer:] Not like this. Nothing even close … I've been in there in thunderstorms in that vicinity, but I've never experienced just -- it was like being blindsided by a wave, like an invisible wave, that just wanted to take the aircraft and run with it.
>
> [Pages 58-59]: It's completely just a freak gust of wind and shift in direction that caught the aircraft. …
> Power wasn't an issue. It's just the issue of having the aircraft taken away from me and started to spin, which I couldn't recover from. …
> I've never had wind like this before. It's just something I've never experienced. …
> I've never experienced a wind shift and power and velocity that I experienced at the accident.
>
> [Page 61]: It was so violent and quick that I don't know what I -- I don't know what I could have done. Even in hindsight, I but I don't -- it was so fast.

Witness statements concerning motion of N155GC

The pilot of helicopter #30, who landed at QMB prior to N155GC's attempted landing, witnessed N155GC's approach and loss of control, and described it as follows (see Reference 2):

> So I don't know why, but I looked up and watched him come in. As [the accident pilot] was coming in, I noticed he was -- let's see. He was in a nose-up attitude, I'd say, of about 15 degrees. Nose up, decelerating to turn to land. Now I've -- as a quick side note off of this, I've done this same exact approach when I was probably 3 months into flying out here. And I had gotten caught in this -- kind of the same situation that he got caught in, where that I experienced a loss of wind entirely and sunk out and had to get out. And so I -- with that experience, I didn't want to do that again, so I took the headwind, and I knew that there was an issue with that. So I kind of felt bad, like thinking about what should these guys do, what kind of approach they should make.
>
> So I looked up, saw him coming in. He was decelerating in a nose-up attitude. You can tell that he was trying to turn around to make this approach to land. I'm assuming it was behind [helicopter #50]. Just one of those spots, the up-canyon wind spots or up-canyon landing spots. As he decelerated, he began the left turn to come in to face -- so he's going nose up, yawing left. And when he comes around to face the landing zone, the aircraft went level and thinned to a nose latitude [sic]. I could tell he was trying to gain airspeed to come back in, but as he was in nose low, he was slightly moving aft. It was that much of a wind shift, from that nose up to trying to get back into it, moving aft.
>
> And now in the nose latitude [sic], that yaw did not stop and continued to a full 360 at that point. Then you could tell he just pulled aft to try to hold level and control the yaw, but it didn't stop. And it started to descend. The aircraft was descending, a flat pitch. Then it continued a second 360, still descending. I started to run over, and then as it began the third 360, it disappeared below the bluff and continued into the impact. I'd say 5 to 10 seconds later, fire started.

Another pilot who witnessed the accident stated (see Reference 4):

> And so, next, another helicopter was making his approach in. I didn't see the tail number. I didn't know who it was, and I knew some new guys were down there with us on the same round of landings from Boulder City. He started coming in to make his left turn. It didn't seem as deep of a turn in as 5-0, but it wasn't just a direct. As he came in -- he came in and, you know, started kind of rotating to the left, and it appeared as if he was doing this to get into the headwind. As he did that, I kind of thought like, okay, that's how we're going to come in to avoid so much -- like too much of a, like a tailwind there.
> …
> Now when [the accident pilot] came in, I didn't know what helicopter he was in. I don't remember if there was one after him or someone immediately before him. He came in, and as I saw at this point right here, I thought he was making a wide left turn, just kind of like 50. But then the helicopter just kept rotating. I saw half the rotation, going onto the -- going onto one full rotation, and he disappeared below my line of sight. Because I was at lower elevation here and then the terrain rises, so he disappeared out of my sight in the middle of almost -- I almost saw a full rotation all the way around, and it just sank.

Testimony concerning wind gusts / shears from pilots preceding N155GC into QMB

The testimonies from pilots who preceded N155GC into QMB on the day of accident suggest that wind conditions quickly became increasingly challenging after 17:00 MST. Table 1 lists the four helicopters that preceded N155GC into QMB, the times that they reported entering the Grand Canyon (the "Canyon Time"), and a summary of their comments concerning wind during their approach to QMB. The full text of their comments is presented and discussed below the Table.

Helo #	Canyon Time MST	Approach to QMB	Summary of pilot comments re: wind
30	17:04	"notch" (land facing northwest /downriver)	warned others over company frequency to watch out for a tailwind and be careful on the approach; from previous experience did not want to take downwind upriver approach again
50	17:08	"straight-in" (land facing southeast /upriver)	stayed higher than normal for turbulence/wind
23	17:09	"straight-in" (land facing southeast /upriver)	During that turn the helicopter shifted pretty rapidly and the tail tried to "kick behind me"; applying heavy amount of right pedal to try to keep the nose straight
53	17:10	"straight-in" (land facing southeast /upriver)	almost lost control of the helicopter; detailed account of control problems attributed to winds
34 (N155GC)	17:12	"straight-in" (land facing southeast /upriver)	Accident helicopter; "it was like being blindsided by a wave, like an invisible wave, that just wanted to take the aircraft and run with it"

Table 1. Summary of pilot statements concerning winds on approach to QMB after 17:00 MST.

The pilot of helicopter #30, that was approximately 8 minutes ahead of N155GC, stated (see Reference 2):

> So 5,000 feet to the Bat Towers. The canyon was a little bit turbulent. It was definitely -- it was my third flight for the day. I had done the first two, and this is -- and that was going to be the last one for the day. So the wind had picked up. It was turbulent in the canyon as we began the descent. Everything was normal for the most part. Passing, there's a boat dock that we call the Ramada. And down, there's a windsock down there that I always look at. And you're about 3,000 feet when you're abeam or next to that Ramada, that windsock.
>
> So I noticed that there was an up canyon wind. So when I see that, I always prepare myself if I'm going to be going -- which direction on how to land. Obviously, the goal is always to be in a headwind. So I always doublecheck that. Then I'm coming down from 3,000 feet to below 2,000 feet. I was about 1800 feet as I crossed the river approaching to Quartermaster Base, and then looked off to my left down below, and on the windsock confirmed the exact same thing. And the pilot in front of me had gone over the river and then -- I don't know if you know, but it's called through the Notch. It's just going around to give myself the headwind approach down into Quartermaster Base.
>
> I noticed there was one last spot open. So as I came across the river and noting -- looking down at that point, I had a left quartering tailwind. As you go through the Notch, there was a little bit of

> turbulence, as I totally expected. And then flew around, continued that left turn to end up on final approach, and checking the windsock one more time. And in that situation, that put me at a right quartering headwind for my approach to land.
>
> And as I set down, I had switched over my frequency from the C-TAC frequency into the Grand Canyon to the -- our company frequency. And there was three people behind me that I knew of. And [the pilot of helicopter #50], that you just talked to, she was in 50. And so I warned, hey, [name], watch out, tailwind. You know, think about -- just be careful on the approach. And then she said yeah, okay, I'm still going to be going upriver. And so she came in, and I saw her making her approach and land, and that was fine.

This pilot reported turbulence, and felt compelled to warn the pilot following him about a "tailwind" and to "be careful on the approach."

The pilot of helicopter #50, behind #30 and about 4 minutes ahead of N155GC, stated:

> It was -- the windsock, windsock was pretty all over the place. It was much like -- I want to say, if that's an accurate assessment of the angle. So this means that the wind is coming in this direction essentially. Wind was about 15 knots, maybe 20. It was strong, but you know, I know a lot of these guys had concerns about -- you know, that they were saying things about the turbulence on the way out there. It honestly never even crossed my mind, any of it. It didn't seem abnormal to me. I was comfortable with it. But it's a definite -- you know, my awareness was heightened, though, for landing because, you know, there's -- there are dangers in landing the other way. So I just used -- exercised caution as much as I could.
>
> …
>
> So it was the same trajectory, you know, as he [the accident pilot] was doing. I was higher, and I believe I was faster. You know, when I saw him, he was already spinning. …. There is a mountain here, but I gave myself a really wide path and got myself right into the wind.
>
> And then I was facing -- the whole way in you can fly sideways. It's not a problem and it's safer. But I was like this until -- once you get closer to the ground, then you get the ground effect. And at that point, you can reposition to line up with the terrain. So that's how I did it. But I was -- I had airspeed this whole time. I was very careful to look at the -- at everything, all the factors.
>
> …
>
> I was going about probably 80 until about here, but I kept it up. I kept the speed until I got into the wind, and at that point you can slow it down. But you know, my main priority is land this way.

This pilot was the first to perform a "straight-in" approach to QMB rather than the "notch" approach used by those preceding her. It appears that she was not very concerned about the wind or turbulence, or in any case compensated for its presence by flying a higher and faster approach than the accident pilot. The two pilots that followed helicopter #50 also successfully landed at QMB using a "straight-in" approach; it is not known whether their approaches more closely resembled that of helicopter #50 or of N155GC, but these pilots expressed more concern about the wind and turbulence than did the pilot of #50. The pilot of #23, which was about 3 minutes ahead of N155GC, stated (see Reference 5):

> It was windy when we went in. We took off and windy throughout the flight. Once we entered the canyon, a little bit of turbulence, a little bit of bumps here and there, which would have been a symptom of the northerly winds that we had that day.

> As I was dropping down into the canyon and making my turn to Quartermaster base, the bumps still continued a little bit, and I recognized that I had a bit of a tailwind, not -- I didn't recognize necessarily how extensive it was, but there was a tailwind. As I continued descending, I tried to slow up airspeed a little bit because of the tailwind.
> …
> So as doing or executing [the "straight-in"] approach, we crossed over the river, and we crossed over a slight rise and kind of up into a slight valley, and then we normally turn around as it -- to kind of set up for our into the landing zone.
>
> It was upon that turn that I -- the aircraft, as I was coming around, shifted pretty rapidly. Not a large amount but it did -- the tail did try to kick behind me. With the big tail on those helicopters that would be -- it kind of acts like a sail to push you around whenever you catch a wind. So at that point in time, with that heavy shift, my eyes immediately jumped down to my rate of descent.
> …
> … as I continued descending, watching the rate of descent, picking my -- or trying to get to the landing zone, applying heavy amount of right pedal to try to keep the nose straight because that wind was so -- really pushing on that tail. And coming inbound, it was actually crabbed, so not going straightforward the majority of the way down to the landing zone, until I got maybe 15, 20 foot above the ground and was able to actually straighten out with, to parallel the slope. At which point I set the aircraft -- was able to set the aircraft down and start the shutdown procedure.

This pilot reported that as a result of wind gusts, the "aircraft … shifted pretty rapidly" and that "the tail did try to kick behind me." He had to apply a "heavy amount of right pedal to try to keep the nose straight because that wind was … really pushing on that tail." In other words, the wind had intensified from being noticeable and requiring "caution" (as reported by the pilot of helicopter #30), to causing uncommanded motions (a rapid "shift" or "kick"), requiring "heavy" control inputs to counter.

Helicopter #53 approached QMB about a minute after #23 and about two minutes before N155GC, and also experienced wind-induced uncommanded motions; and in this case, the pilot reported that the encounter was barely controllable (see Reference 6):

> I landed right before [the accident pilot]. And I knew -- I have experience flying in mountains. And I knew it was windy, and I thought there might be a wind shear right there, so I was prepared for it. And when it hit me, it was more than I expected and it took everything I had to control that helicopter and land it. But I was prepared for it, and I could have got on the radio and said, hey, there -- don't come this way; there's a wind shear. I don't know what happened. I don't -- all I know is it easily could have been me too.
>
> That was -- I almost lost control of the helicopter. I had to pull power completely up and as much right pedal as I could to keep the nose back, coming back straight. I made that turn to go into Quartermaster, my nose swung 90 degrees to the left and I went from having airspeed to not having any at all. I don't know how I kept it straight.

This pilot describes a very severe wind shear encounter, in which he "almost lost control of the helicopter." The next pilot to fly that approach, only two minutes later, did in fact lose control of his helicopter, and crashed. The sequence of statements from the pilots of helicopters numbers 30, 50, 23, 53, and 34 indicates that over a roughly 10 minute period, wind shear conditions on the approach into QMB worsened rapidly, and eventually overwhelmed the control capabilities of the accident helicopter and its pilot.

Engineering simulations performed by Airbus Helicopters

As noted above, AH performed simulations that (1) match the N836GC exemplar flight flown on May 4 using the actual wind conditions on that day, and (2) compute the control authority required to match the exemplar flight trajectory in several more challenging wind conditions. This work is documented in Reference 9 (attached at the end of this memorandum).

The purpose of the simulation match of the May 4 exemplar flight was to demonstrate the fidelity of the simulation, and its ability to manipulate the helicopter flight controls so as to duplicate a pre-defined, desired flight trajectory. The actual flight controls used on the May 4 flight are not available (the Appareo Vision 1000 device does not sense or record this information), so a comparison of the control inputs required by the simulation to the actual control inputs used during the flight is not possible. However, the time-history of the simulation trajectory (north position, east position, and altitude), horizontal and vertical speeds, and Euler angles (pitch, roll, and heading) can be compared with the Vision 1000 data.

Based on these comparisons, a 3.5° offset in the recorded pitch angle while the aircraft was on the ground was observed. This offset is erroneous, and when removed resulted in a good match between the Vision 1000 and simulation pitch angles. The simulation match of the other recorded parameters was also satisfactory, though a trade-off between matching the recorded Euler angles and matching the recorded trajectory was observed. If the simulation targeted the recorded Euler angles, the match of the Euler angles was very good (per design), but the match of the trajectory was not as good. If the trajectory was targeted, then the match of the trajectory was very good, but the match of the Euler angles deteriorated (see pages 11-12 of Reference 9). These observations are likely partly the result of imperfections in the simulation model itself, but can also be the result of uncertainties in the winds at the time (the simulations of the May 4 flight assumed a constant wind from the north at 4 knots). Nonetheless, the simulations of the May 4 flight matched the recorded data well enough to conclude that the simulation was the best tool for examining the controllability margins of the helicopter in various wind conditions for the accident flight.

Subsequent simulations of the accident flight targeted the flight trajectory and heading angle recorded on the May 4 flight (but not the May 4 pitch or roll angles), under the assumption that the accident helicopter was maintaining a trajectory (ground path, altitude, ground speed, and rate of descent) and heading identical to those of the May 4 flight. The simulations computed the collective, lateral cyclic, longitudinal cyclic, and pedal control inputs required to accomplish this task in various horizontal and vertical wind scenarios.

Vertical wind scenarios were included to compute the vertical wind gusts or shears required to induce the vortex-ring state (VRS) on the helicopter; the simulations indicated that vertical gusts of about 6.6 ft/s (approximately 400 ft/min) could induce this state. The VRS state can result in "settling with power," that is, a loss of altitude even when power to the main rotor is increased. However, the accident pilot told NTSB investigators that "power wasn't an issue" during the accident, which is consistent with the helicopter remaining outside the VRS envelope (the simulations were performed prior to the NTSB's interview of the pilot).

Table 2 presents a matrix of some of the horizontal wind simulation scenarios. The table's columns correspond to varying wind speeds, and the table's rows correspond to varying wind directions. In these simulations, the wind was held constant at the speed and direction indicated; since the simulation is manipulating the controls to maintain an identical trajectory and heading angle in all cases, the different winds induce different sideslip angles on the helicopter, which in turn produce different control demands. Of most interest are those wind conditions (and combinations of sideslip angle and airspeed) that saturate any of the helicopter's controls, indicating a control limit.

The value listed in Table 2 for each combination of wind speed and direction is the maximum percentage of available pedal authority required at any given point during the simulated approach and landing for that wind scenario. The pedal position in the simulation is measured in percent, with 0% corresponding to full left pedal (minimum anti-torque applied), and 100% corresponding to full right pedal (maximum anti-torque applied). Consequently, a required pedal authority of 80% indicates that 20% of the total stop-to-stop pedal motion is still available in the anti-torque direction. A required pedal authority of 100% indicates that all of the helicopter's anti-torque capability is required, and that the helicopter is at the limit of controllability. Any additional anti-torque demand cannot be met, and will result in an uncontrolled yaw to the left. The values listed in Table 2 were obtained from the peaks of the plots of pedal position vs. time for the various horizontal wind simulations presented in Reference 9.

The wind speed and direction combinations that were simulated are centered around the nominal wind of 11 kt. from 337.5° with gusts to 25 kt., as estimated from measurements at the "Ramada" location and at Grand Canyon West airport on the day of the accident (see Reference 9, p. 4).

	Wind speed, knots					
Wind direction, degrees true	0	10	11	12	17	39
0			80			
45			77			
90			75			
135			74			
180			75			
225			78			
265			80			
315			81			
337.5	79	80	80	80	81	99

Table 2. Maximum pedal authority (in percent) required during simulations in constant wind conditions. Winds defined by combinations of speed and direction shown in the table.

The only simulated wind condition that reached the limit of pedal authority was the wind from 337.5° at 39 knots. At the point where maximum right pedal was required, the sideslip angle was -61° (freestream coming from 61° to the left of the nose), the calibrated airspeed was 46 kt., the ground speed was 29 kt., the helicopter was decelerating, and the rate of descent was -114 ft./min. Of course, these are not the *only* conditions that could saturate the pedal control; different headings, speeds, and rates of deceleration and descent will alter the main rotor power and consequent anti-torque requirements. Different wind magnitudes and directions might also saturate the controls (the conditions simulated per Table 2 are only a few of countless combinations). Without better knowledge of the helicopter state and wind conditions during the accident, the actual amount of anti-torque control required cannot be estimated. However, the 337.5° at 39 knots case is *one* example of a way to saturate the pedal control.

AH also performed simulations of a sudden gust encounter at various times during the approach and landing. The baseline wind was from 337.5° at 11 kt., and the gust increased the wind speed by about 14 kt. to 25 kt. over 0.1 seconds, while maintaining the wind direction. The maximum pedal input required to maintain the target trajectory during these encounters was 82%. Consequently, these encounters were less demanding than the 39 kt. constant-wind scenario described above. Presumably, larger gusts (that would bring the total wind closer to 39 kt.) would demand more right pedal input to control, and could also saturate the pedal authority.

Gust simulations in which the pedal command was held fixed at the time of the gust (to evaluate the resulting yaw response of the helicopter) resulted in about a 30° heading variation, followed by a return of the heading towards its target value.

Summary

Because there is no recorded data concerning the N155GC's motion or the behavior of the wind near the accident site, the precise movements of the helicopter during the accident sequence cannot be determined and remain unknown, as do the actual wind conditions that it encountered during its approach to QMB. Therefore, no quantitative analysis of the helicopter's motion, or the causes of that motion, is possible for this accident.

However, the qualitative and subjective descriptions of the sequence of events and of the helicopter motion, provided by witnesses to the accident and by the accident pilot himself, indicate that a sudden encounter with a wind gust or shear preceded the pilot's loss of yaw control of the helicopter. While Papillon pilots seemed generally aware that windy conditions could produce challenging tailwinds and turbulence near QMB that required caution, the severity of wind shear encountered during the accident was apparently unprecedented in the accident pilot's experience.

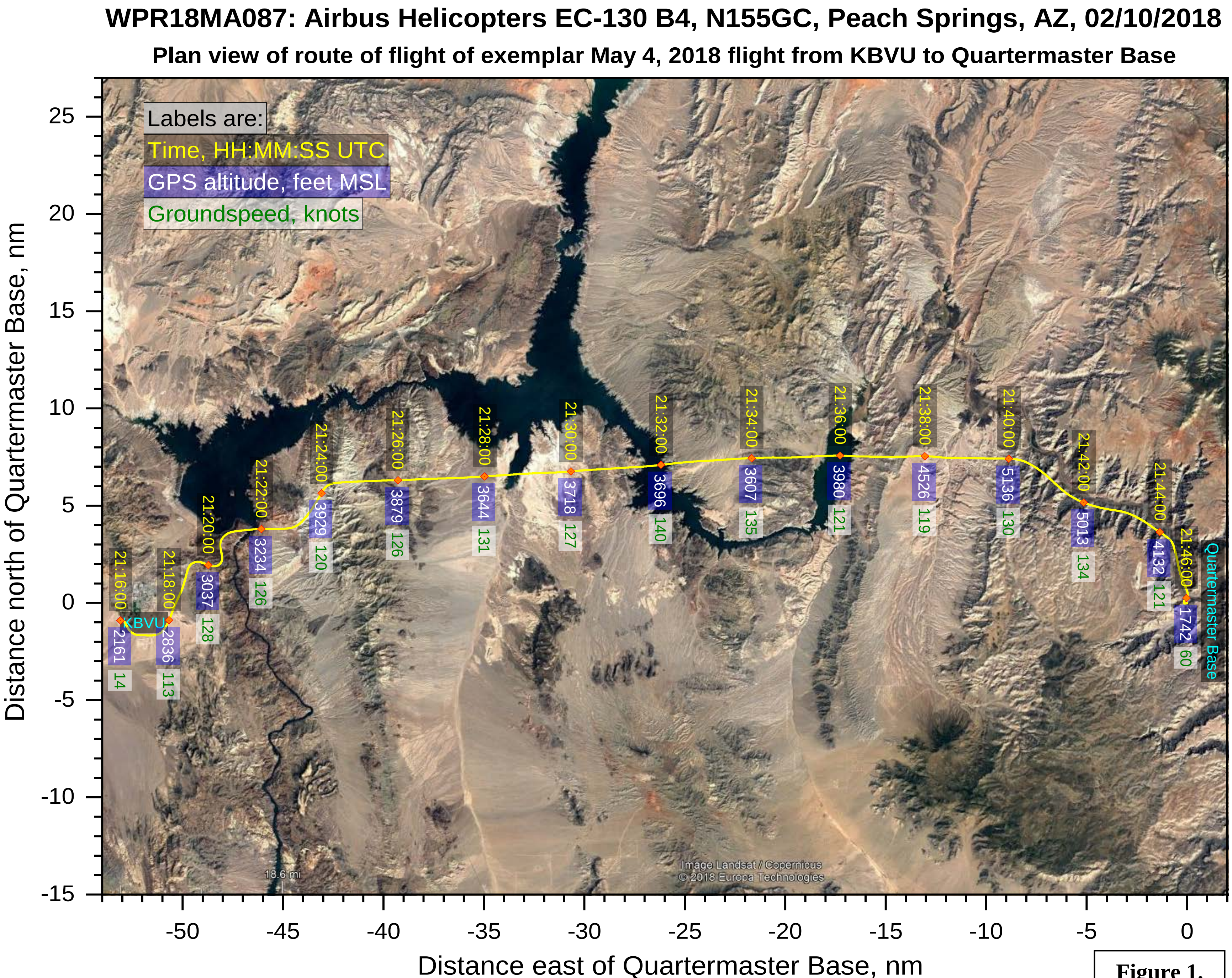
Eight helicopters preceded N155GC into QMB. The sequence of statements from the pilots of several of these helicopters indicates that over a roughly 10 minute period, wind shear conditions on the approach into QMB worsened rapidly, and eventually overwhelmed the control capabilities of the accident helicopter and its pilot.

AH performed engineering simulations to compute the control authority required to match an exemplar flight trajectory in several wind conditions. The simulations indicated that matching the target trajectory and heading in a constant 39 kt. wind from 337.5° would saturate the pedal anti-torque control authority. However, these are not the *only* conditions that could saturate the pedal control; different headings, speeds, and rates of deceleration and descent will alter the main rotor power and consequent anti-torque requirements. Different wind magnitudes and directions might also saturate the controls. Without better knowledge of the helicopter state and wind conditions during the accident, the actual amount of anti-torque control required cannot be estimated.

Please let me know if you would like to discuss the contents of this memorandum further.

Regards,

John O'Callaghan



WPR18MA087: Airbus Helicopters EC-130 B4, N155GC, Peach Springs, AZ, 02/10/2018
Plan view of route of flight of exemplar May 4, 2018 flight from KBVU to Quartermaster Base
Labels are:
Time, HH:MM:SS UTC
GPS altitude, feet MSL
Groundspeed, knots
KBVU
Quartermaster Base
Distance north of Quartermaster Base, nm
Distance east of Quartermaster Base, nm

Figure 1.

WPR18MA087: Airbus Helicopters EC-130 B4, N155GC, Peach Springs, AZ, 02/10/2018

Plan view of route of flight of exemplar May 4, 2018 flight from KBVU to Quartermaster Base (detail 1)

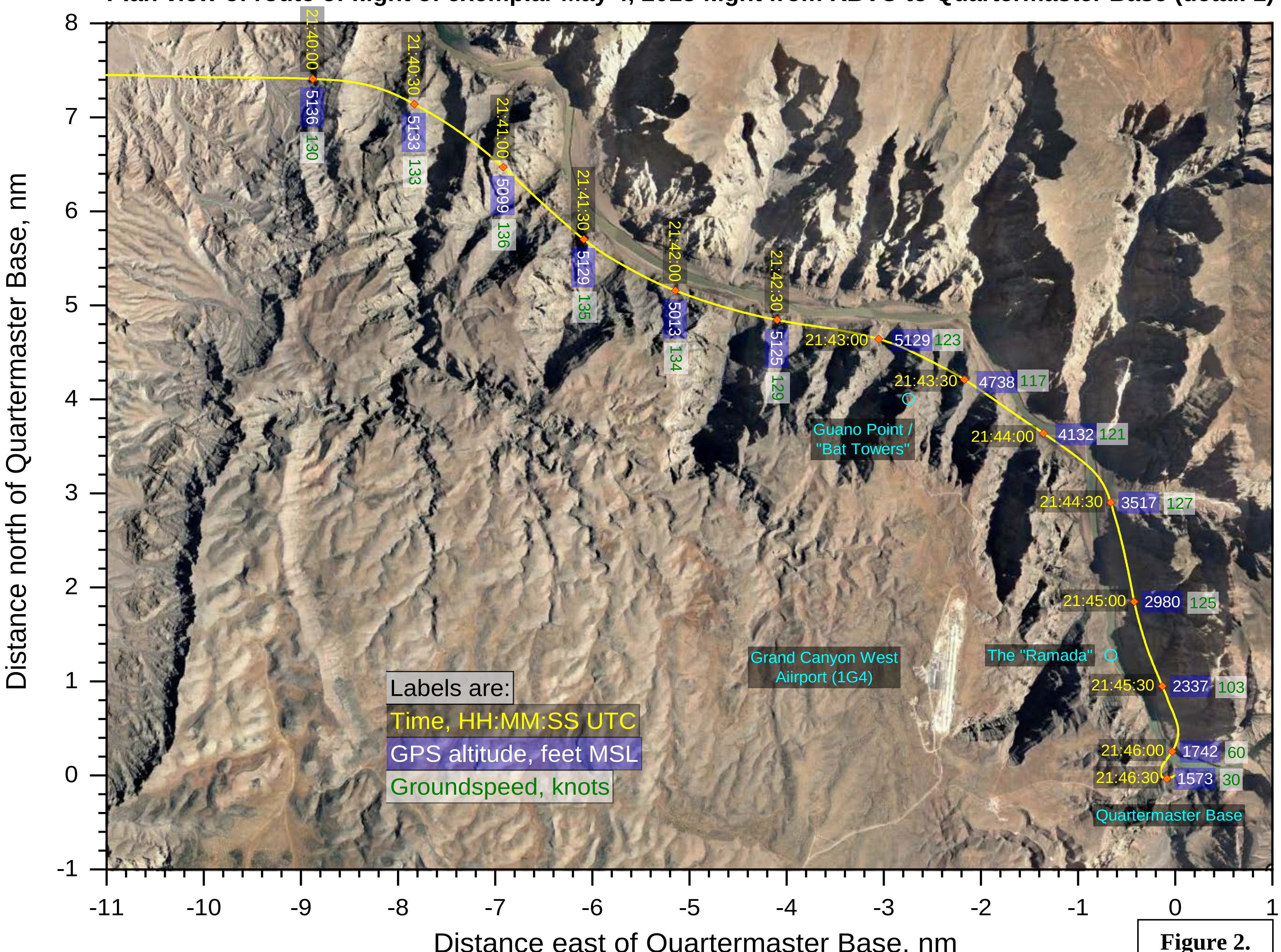


Figure 2.

WPR18MA087: Airbus Helicopters EC-130 B4, N155GC, Peach Springs, AZ, 02/10/2018

Plan view of route of flight of exemplar May 4, 2018 flight from KBVU to Quartermaster Base (detail 2)

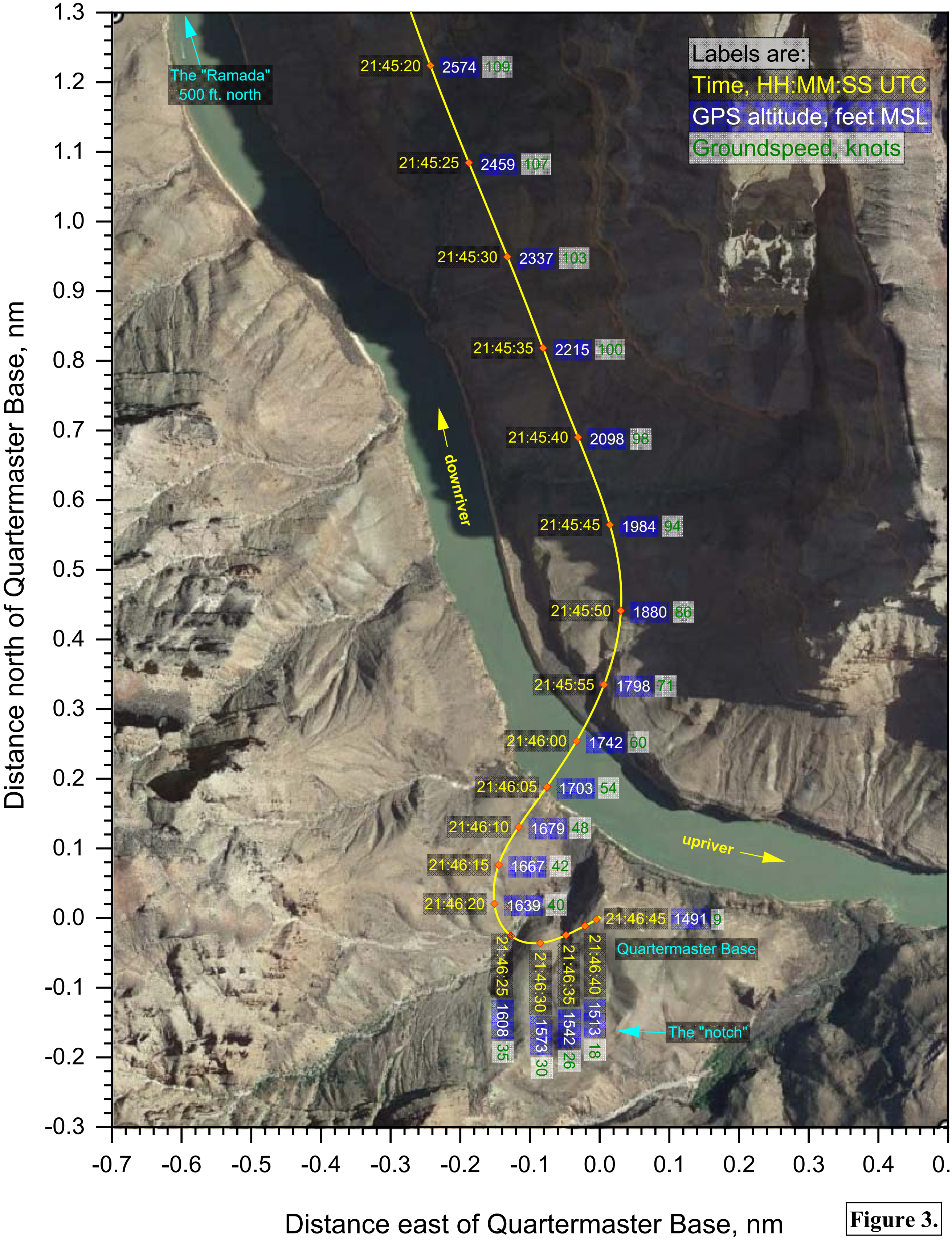


Figure 3.

WPR18MA087: Airbus Helicopters EC-130 B4, N155GC, Peach Springs, AZ, 02/10/2018

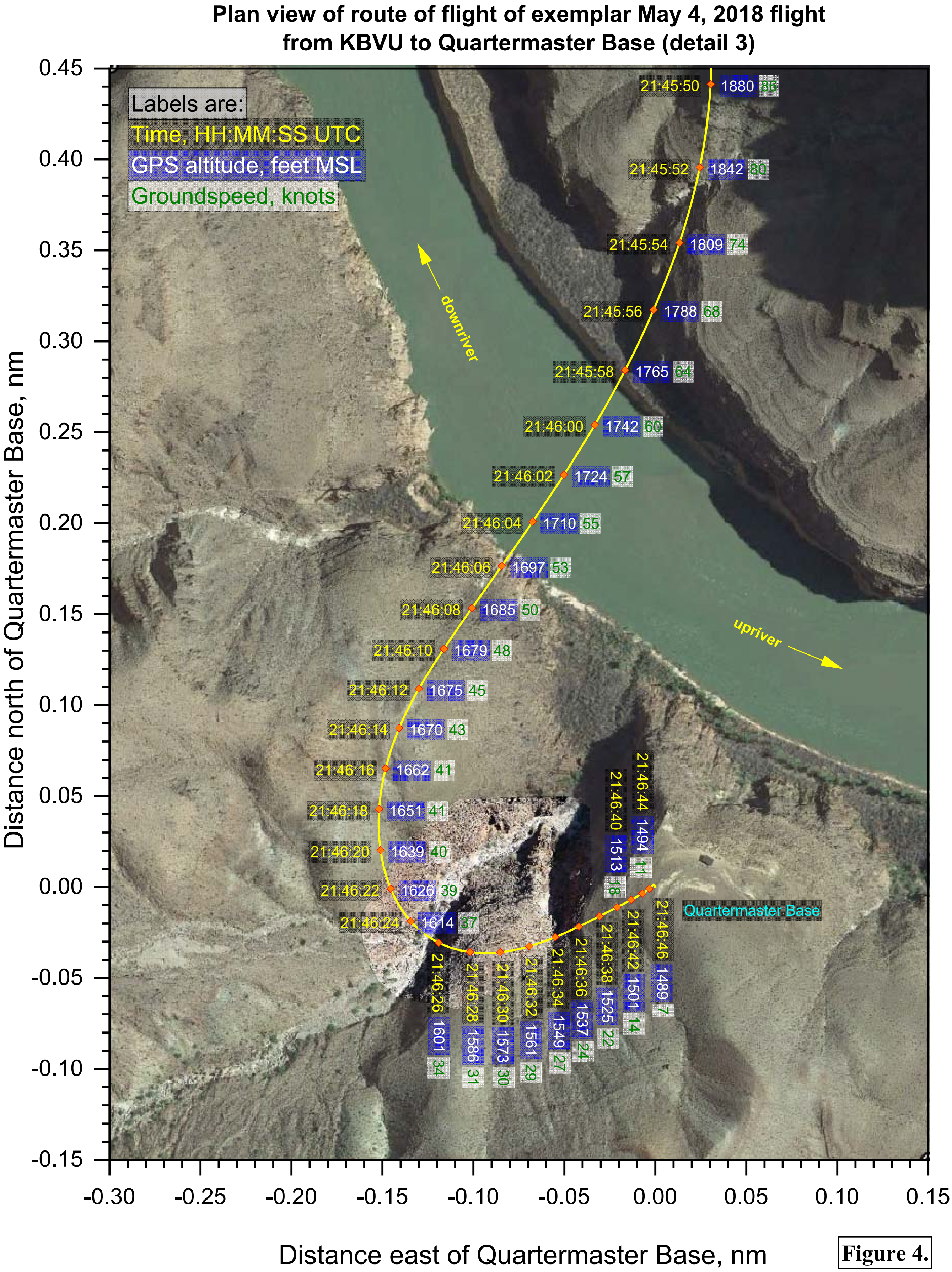
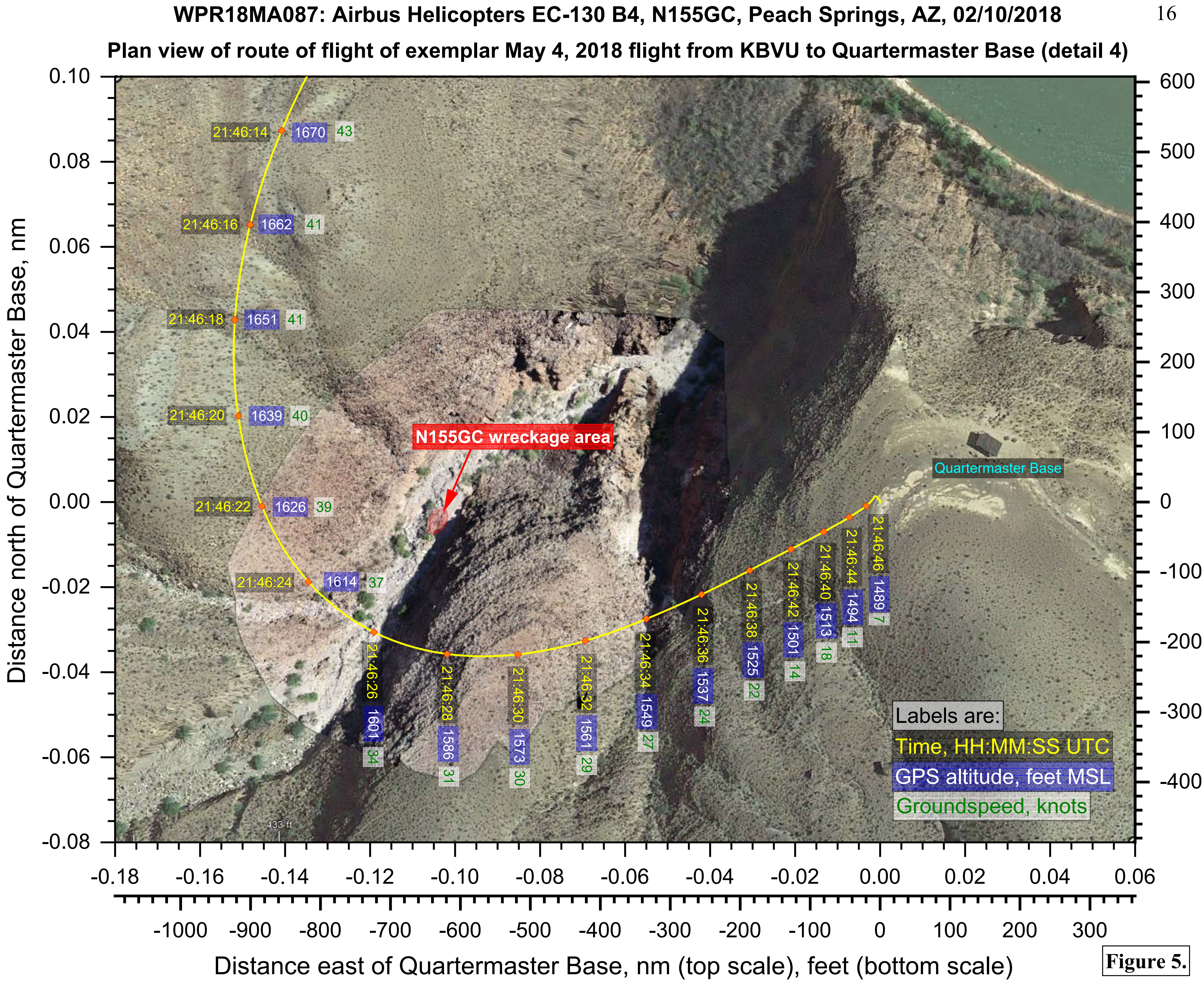


Figure 4.



WPR18MA087: Airbus Helicopters EC-130 B4, N155GC, Peach Springs, AZ, 02/10/2018
Plan view of route of flight of exemplar May 4, 2018 flight from KBVU to Quartermaster Base (detail 4)
Distance north of Quartermaster Base, nm
Distance north of Quartermaster Base, feet
Distance east of Quartermaster Base, nm (top scale), feet (bottom scale)
N155GC wreckage area
Quartermaster Base
21:46:14 1670 43
21:46:16 1662 41
21:46:18 1651 41
21:46:20 1639 40
21:46:22 1626 39
21:46:24 1614 37
21:46:26 1601 34
21:46:28 1586 31
21:46:30 1573 30
21:46:32 1561 29
21:46:34 1549 27
21:46:36 1537 24
21:46:38 1525 22
21:46:40 1513 18
21:46:42 1501 14
21:46:44 1494 11
21:46:46 1489 7
Labels are:
Time, HH:MM:SS UTC
GPS altitude, feet MSL
Groundspeed, knots

Figure 5.

Figure 6. Perspective view of May 4, 2018 exemplar approach into QMB. Data labels are: time (UTC); altitude (ft.); groundspeed (kt.); and rate of climb (ft./min.)

WPR18MA087: Airbus Helicopters EC-130 B4, N155GC, Peach Springs, AZ, 02/10/2018
Altitude & speed for exemplar May 4, 2018 flight from KBVU to Quartermaster Base

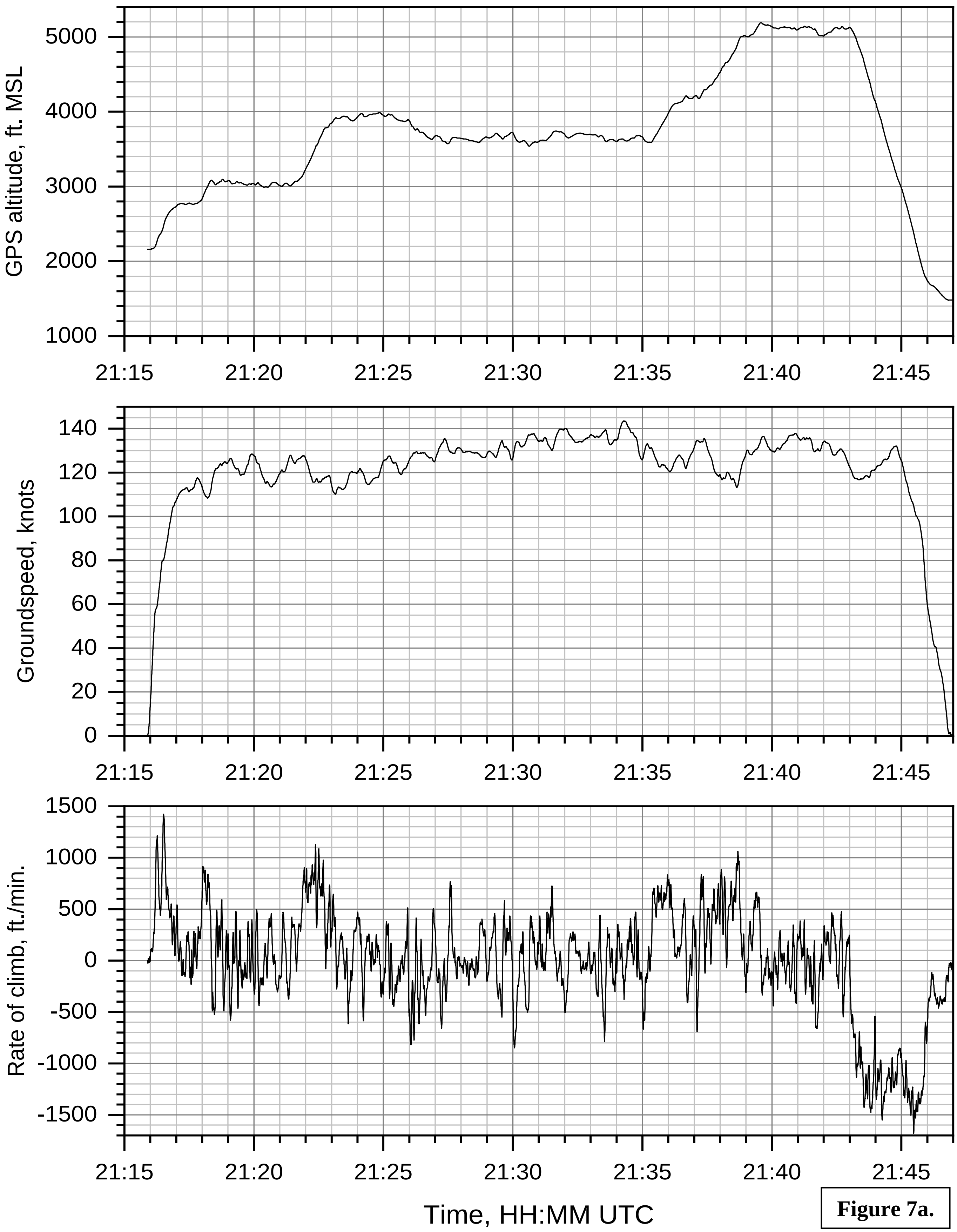


Figure 7a.

WPR18MA087: Airbus Helicopters EC-130 B4, N155GC, Peach Springs, AZ, 02/10/2018
Altitude & speed for exemplar May 4, 2018 flight from KBVU to Quartermaster Base (detail)

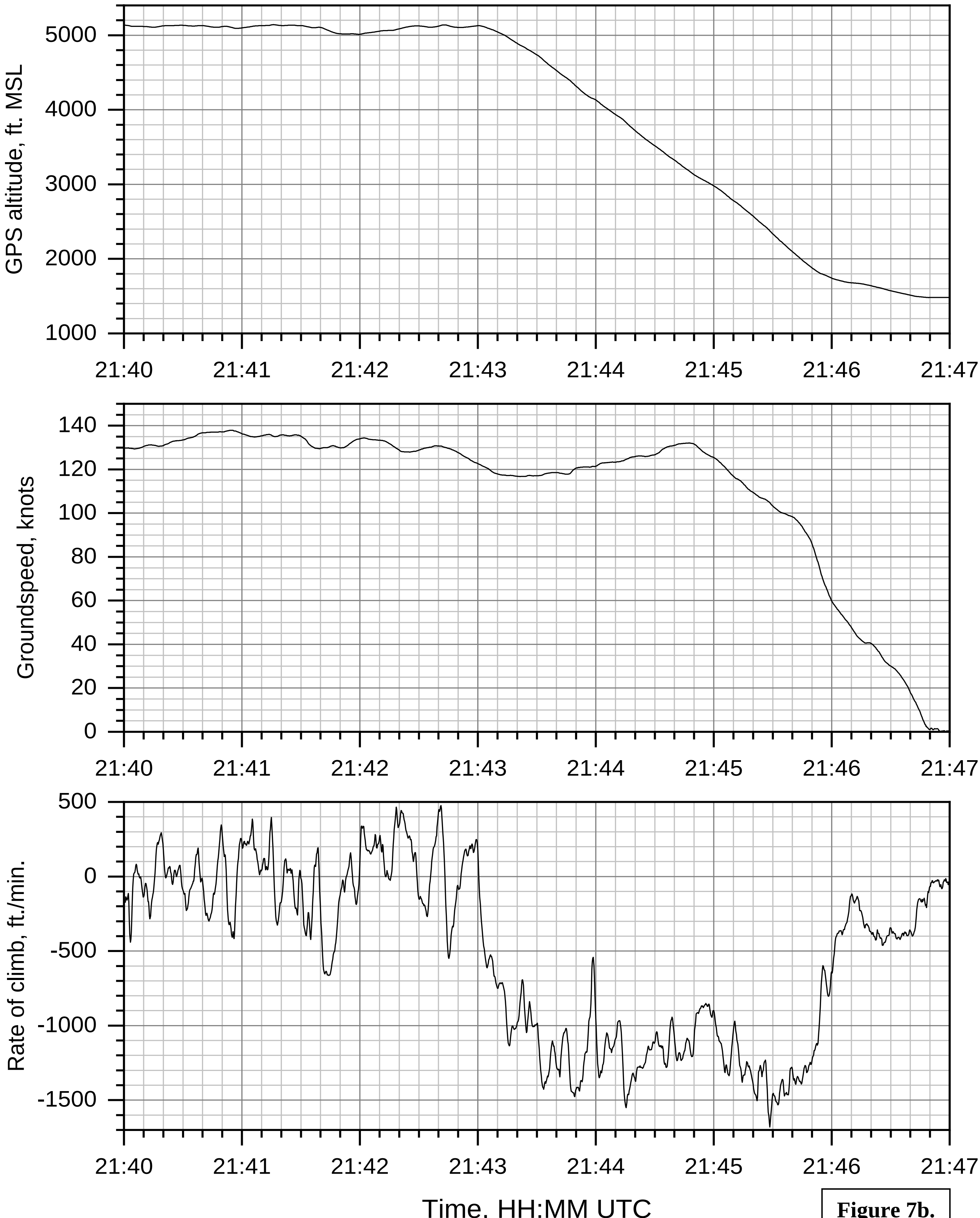


Figure 7b.

WPR18MA087: Airbus Helicopters EC-130 B4, N155GC, Peach Springs, AZ, 02/10/2018

Euler angles for exemplar May 4, 2018 flight from KBVU to Quartermaster Base

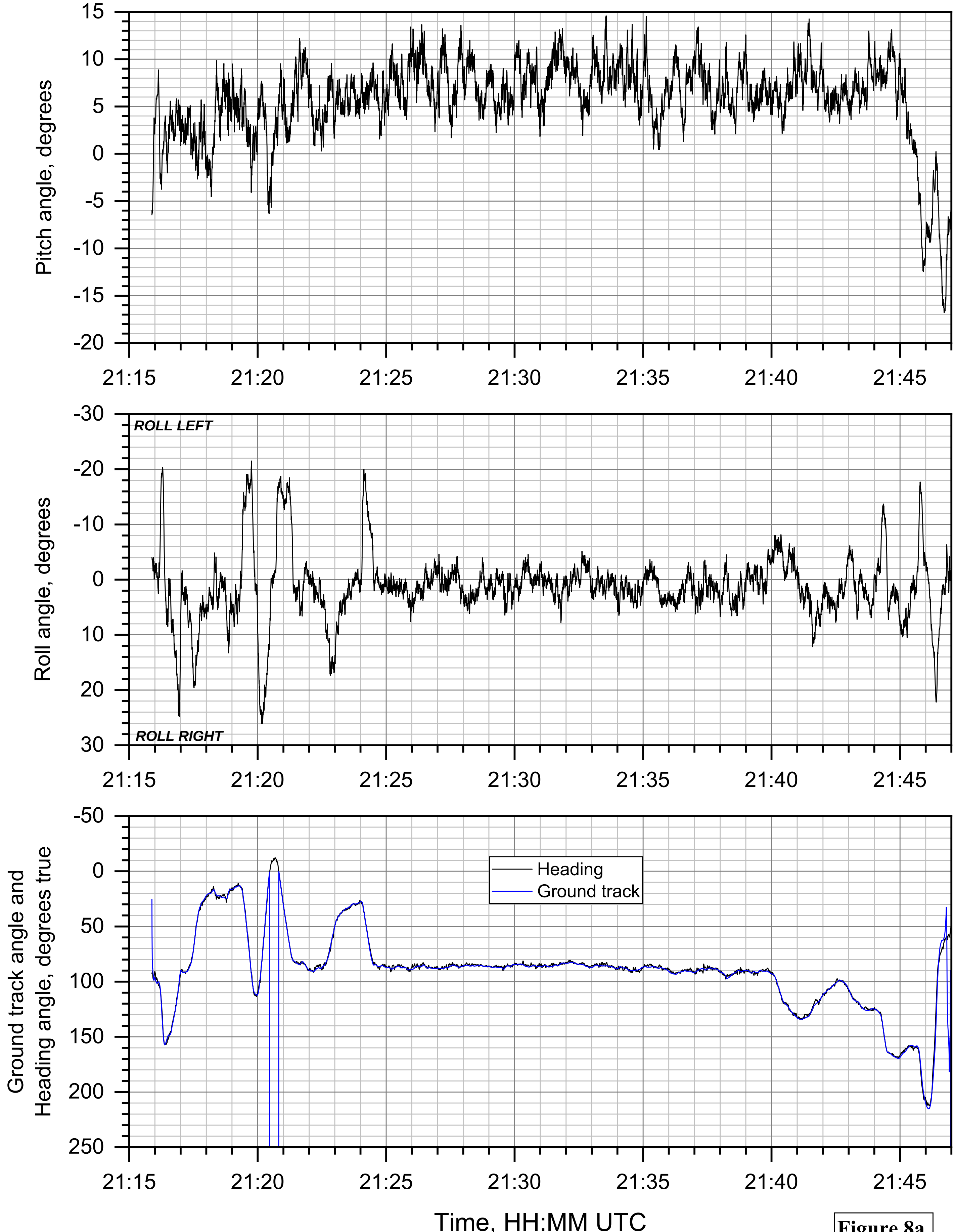


Figure 8a.

WPR18MA087: Airbus Helicopters EC-130 B4, N155GC, Peach Springs, AZ, 02/10/2018

Euler angles for exemplar May 4, 2018 flight from KBVU to Quartermaster Base (detail)

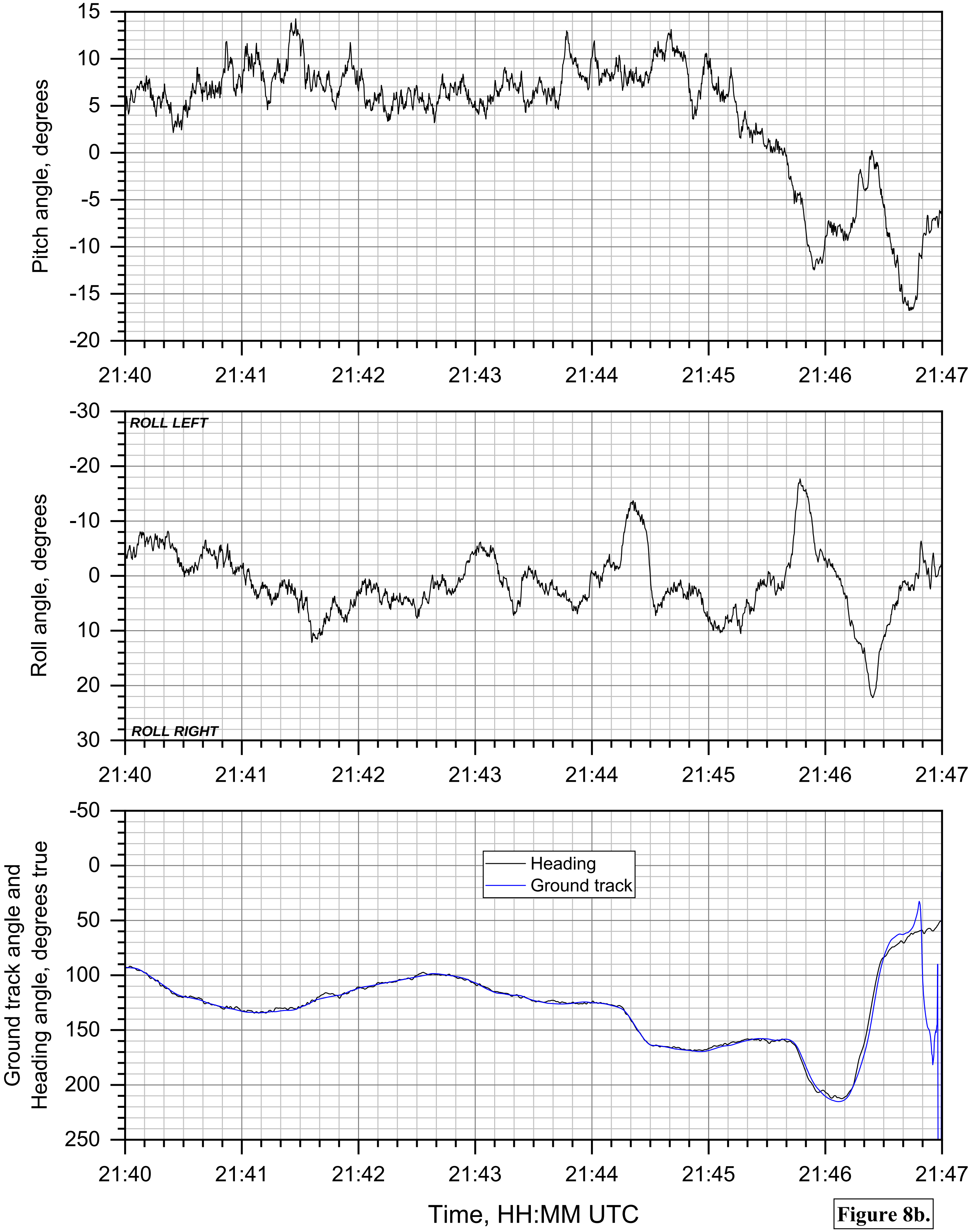
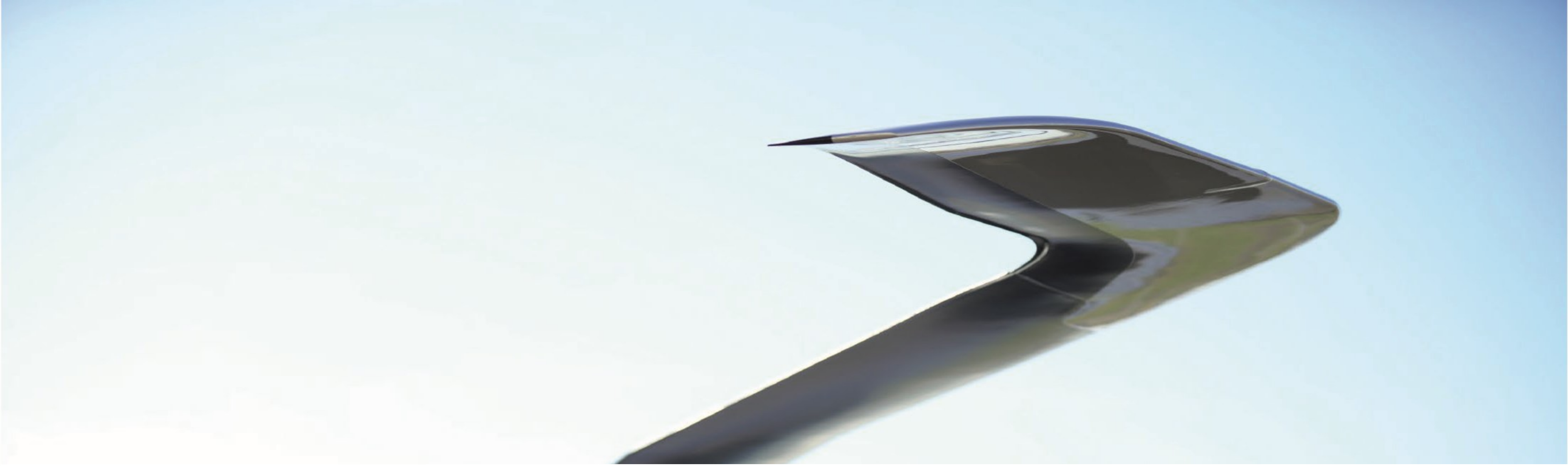


Figure 8b.

Attachment:

Airbus Helicopters, *N155GC – EC130B4 S/N7091, 02/2018 – Grand Canyon accident – simulations results*, September 25, 2018

(*PowerPoint* presentation, Reference 9)



HELICOPTERS

N155GC – EC130B4 S/N7091

02/2018 – Grand Canyon accident – simulations results

18 June 2018

Acronyms & Notations

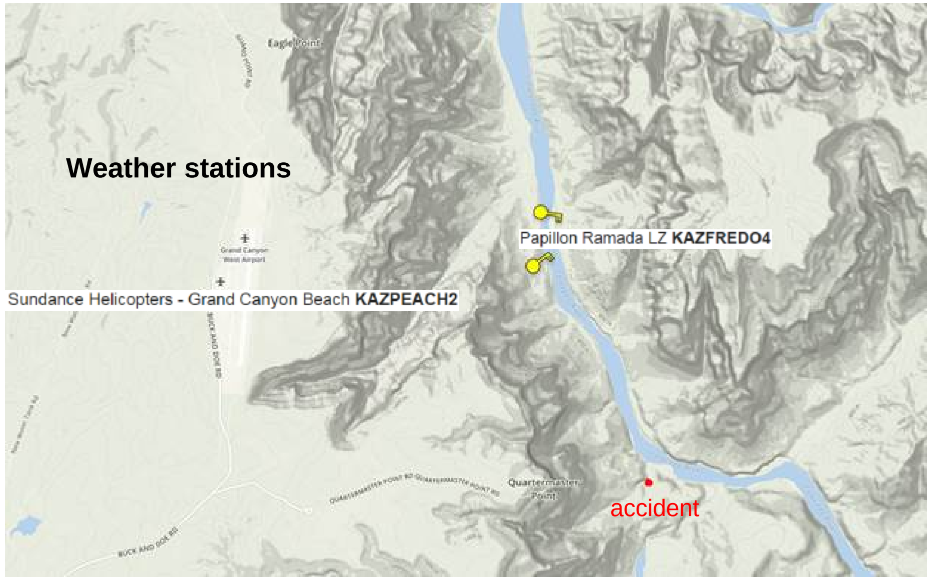
Notation	Name
VRS	Vortex Ring State
FFS	Full Flight Simulator
MASSE [kg]	H/C mass
XG [m]	Longitudinal Center of Gravity position
PHI [deg]	Roll angle
TETA (θ) [deg]	Pitch angle
PSI (Ψ) [deg]	H/C heading
ALTITUDE [m]	Altitude Pressure
VH [km/h]	H/C Horizontal ground speed
GS [m/s]	H/C Horizontal ground speed
VZ [m/s]	H/C Vertical ground speed
VXSOL [m/s]	H/C Ground speed on projected X axis of the H/C frame
VYSOL [m/s]	H/C Ground speed on projected Y axis of the H/C frame
NZ [g]	Normal load factor
PHEL [deg/s]	X component of ground angular speed in H/C frame
QHEL [deg/s]	Y component of ground angular speed in H/C frame
RHEL [deg/s]	Z component of ground angular speed in H/C frame

Notation	Name
BETA-CEL (β) [deg]	Sideslip angle
TAS	True AirSpeed
GS	Ground speed
βc [deg]	Main rotor longitudinal flapping angle
γq [deg]	Main rotor mast inclination
TPP [deg]	Tip path plane – MR disk inclination wrt earth.
VHW [m/s]	Horizontal wind speed
VZW [m/s]	Vertical wind speed
KHIW [deg]	Wind direction [0°=North / 90°=East / 180°=South / 270° = West]
DDZ [%]	Collective stick position [0%=down / 100%= up]
DDL [%]	Lateral cyclic stick position [0%=left / 100%= right]
DDM [%]	Longitudinal cyclic stick position [0%=pitch up / 100%= pitch down]
DDN [%]	Pedal position [0%=full left feet/ 100%= full right feet]
X0XG [m]	X position in earth frame (X towards North)
Y0YG [m]	Y position in earth frame (Y towards East)

Simulations Inputs and Logic

Data for simulation

	02/2018 accident flight (5:12 PM)	04/05/2018 flight
Wind	11.9 to 14.1mph / 337.5 deg (NNW) – Gust 28.6mph (source: email Keliher Zoe 17/05/2018 – KAZFREDO4 & KAZPEACH2)	4.5mph / 0 deg (N) (source: Papillon RAMADA LZ data)
Temperature	74.4°F (23.5°C) (source: email Keliher Zoe 17/05/2018 – KAZFREDO4 & KAZPEACH2)	90.5 °F (32.5°C) (source: Papillon RAMADA LZ KAZFREDO4 data)
QNH	A2959 (≈1002 hPa) (source: email Keliher Zoe 17/05/2018 – KAZFREDO4 & KAZPEACH2)	A3017 (≈1021.7 hPa) (source: METAR info around 21:35 / average of KBVU, KIGM, KSGU)
Weight and Balance	Take off: 5226lb / 127.00 (2370kg 3.22m) Landing: 4904lb / 126.36 (2224kg 3.21m) (source: Papillon Airways, Inc. (PG9A) – 3239275)	Take off: 4494lb / 136.65 (2038kg 3.47m) Landing: ~~4494lb~~ 4172lb / 136.65 (1892kg 3.47m) (source: Papillon Airways, Inc. (PG9A) – 3845715)



Simulation logic

Objectives (NTSB request No. WPR18MA087):

a) Determine control inputs (cyclic, collective, and pedals) required to fly a target flight path in the presence of different wind fields.

b) Determine the wind fields or shears required to saturate any of the helicopter controls while the simulated “math pilot” attempts to maintain the target flight path.

c) Determine the wind fields or shears required to induce vortex ring state (VRS) on the helicopter while the “math pilot” attempts to maintain the target flight path.

VRS not appropriately modeled in the simulation tool, VRS area based on flight test data

1 “05/18 flight” simulation
(Model and data evaluation)

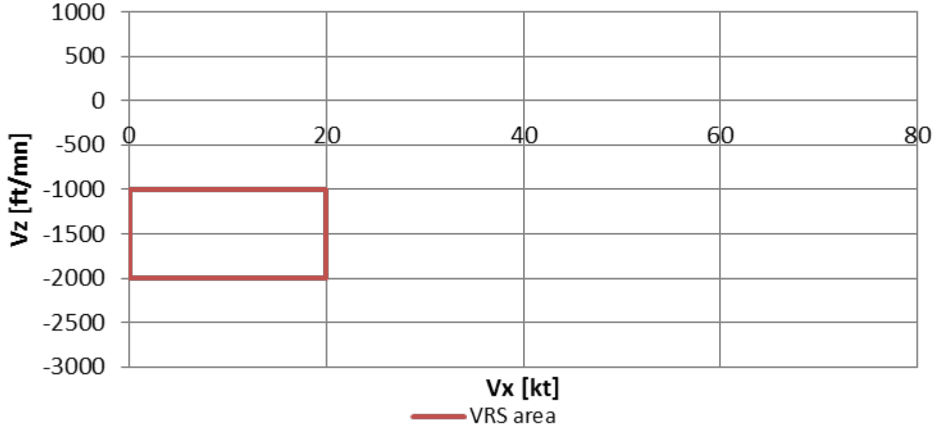
2 “02/18 accident” simulation
(Trajectory 1 with accident flight data)

Simulations

- Simulations with constant wind (variations around 13mph from NNW)
- Simulations with constant wind up to commands saturations
- Simulations with wind gust of 28.6mph from NNW at different time of the simulation

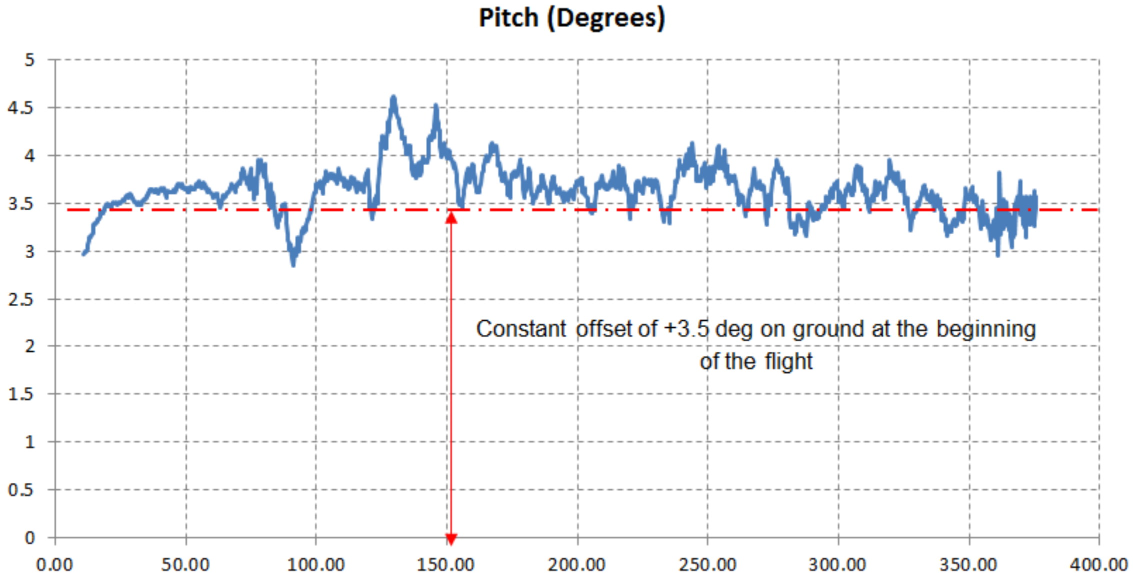
Observations

- Position of the controls
- Local horizontal and vertical speed at the main rotor disk level (comparison with VRS area)



Important warning: for Full Flight Simulator the tolerance for control position is of ±10%. As no certified FFS EC130 model exist today, variations with the reference model used can then be larger than ±10%

4th May 2018 flight



The offset observed has been corrected for comparisons with simulation

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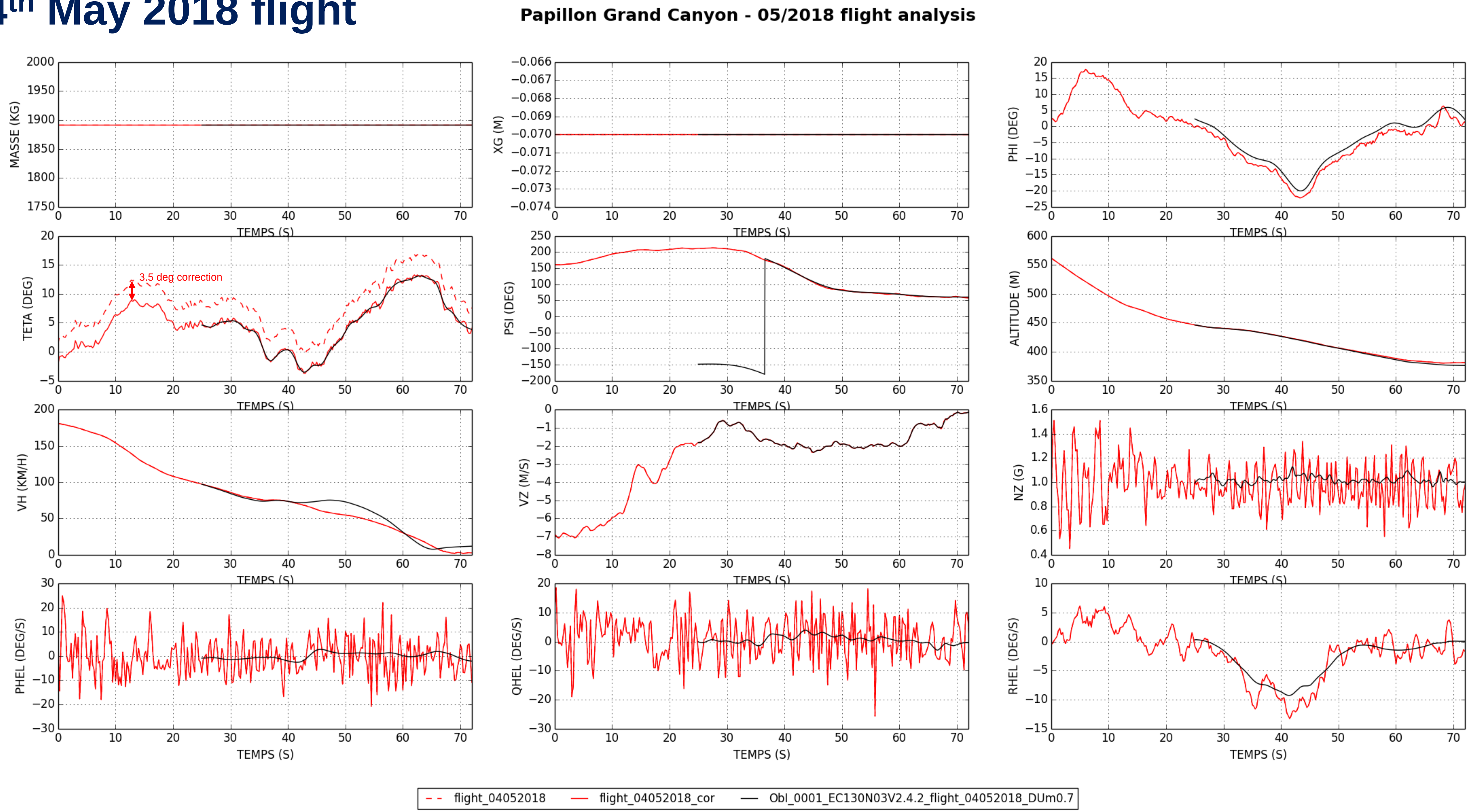
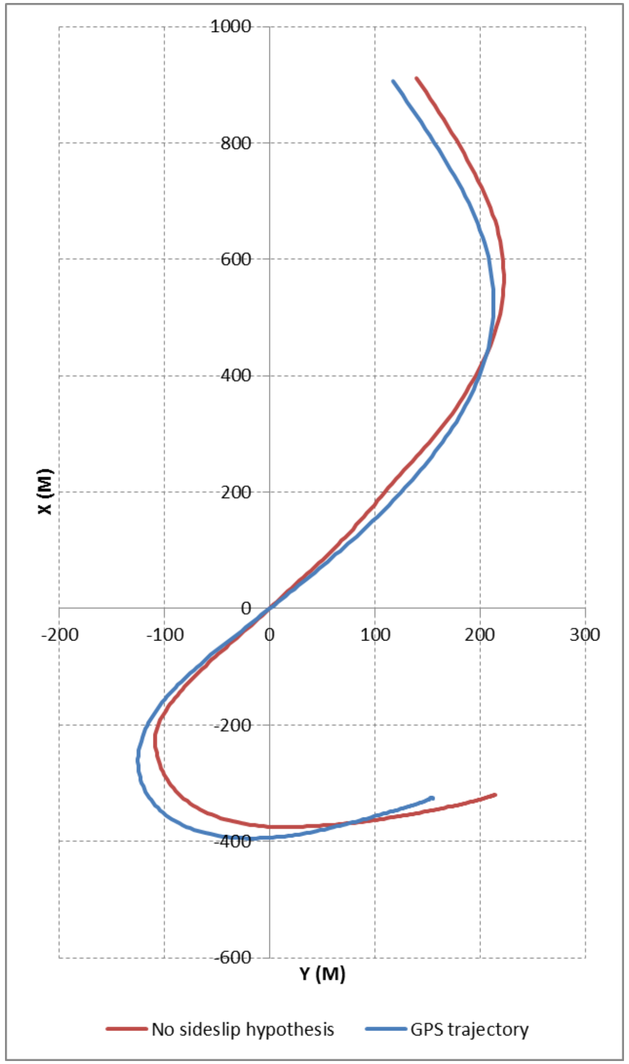
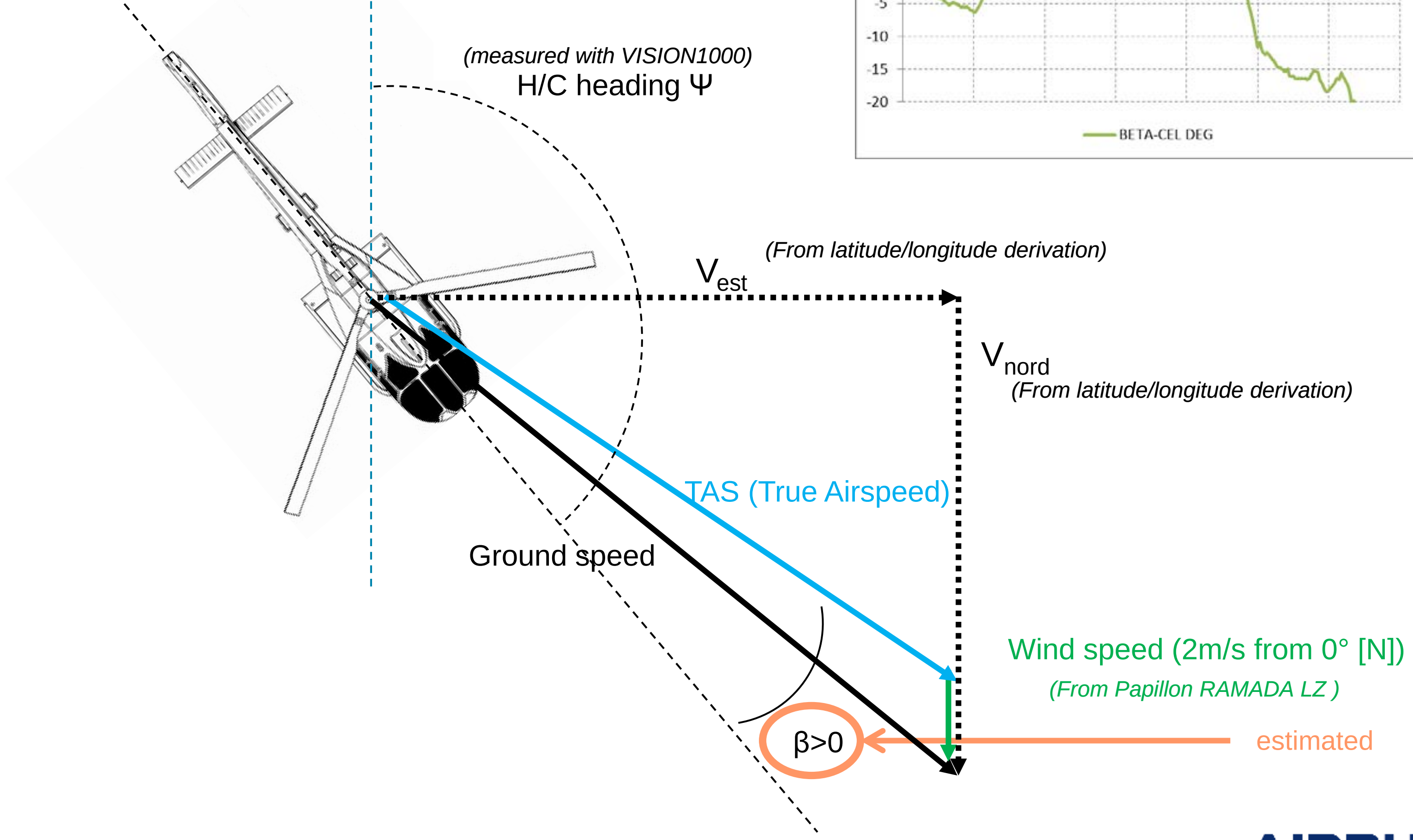
4th May 2018 flight

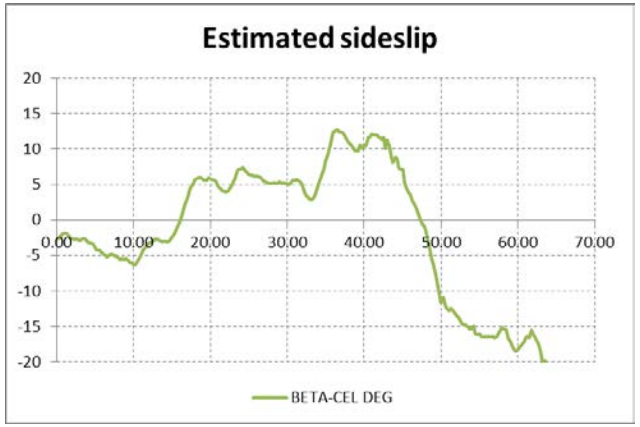


Simulations Methodology

Sideslip estimation during 04/05/2018 flight







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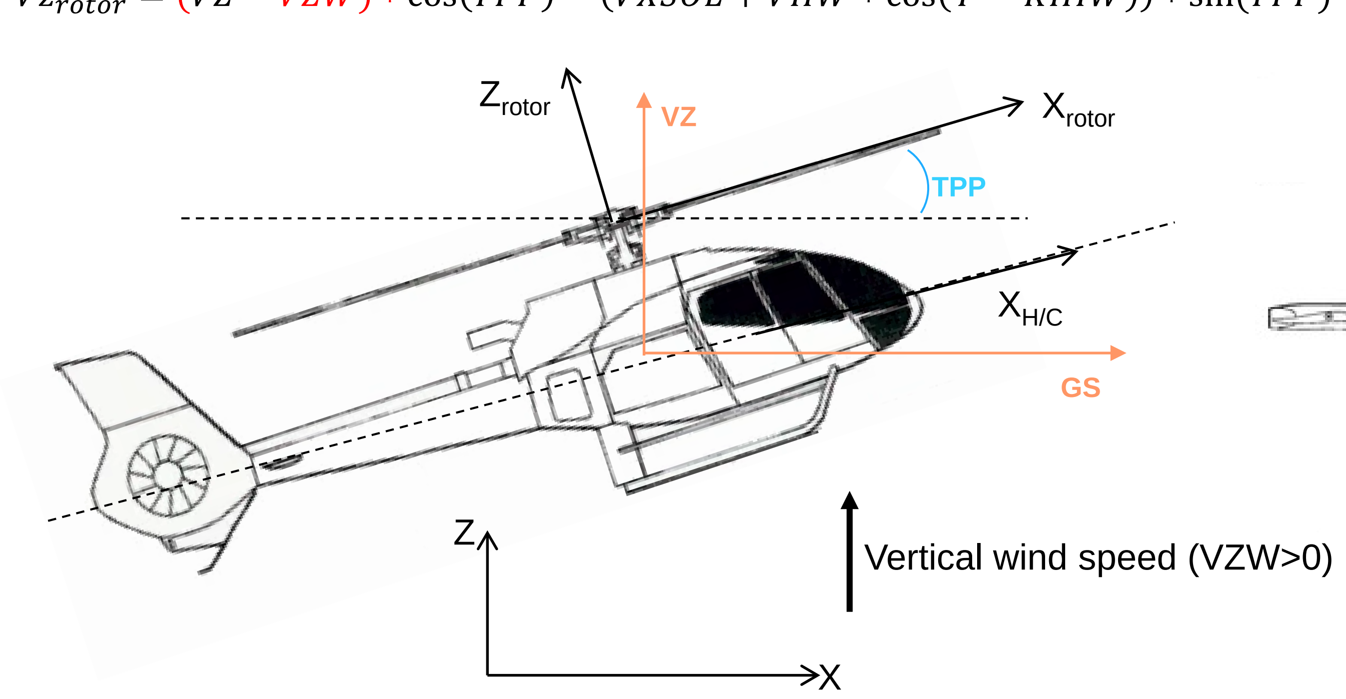
VRS area - Methodology

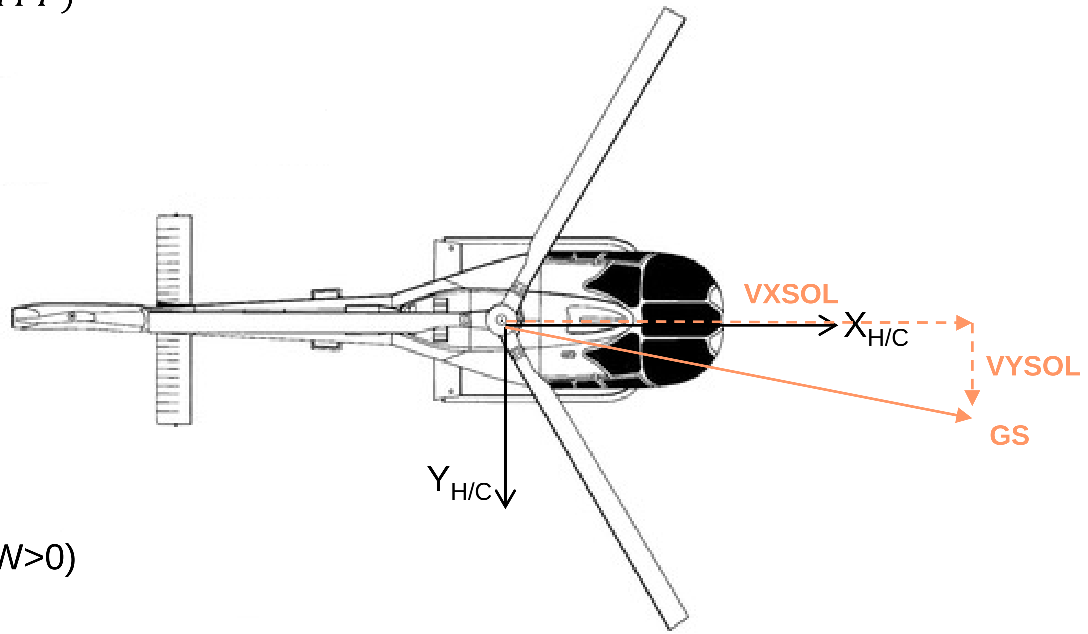
$$GS = \sqrt{VXSOL^2 + VYSOL^2}$$

TPP= $\theta + \beta c + \gamma q$ (tip path plane)

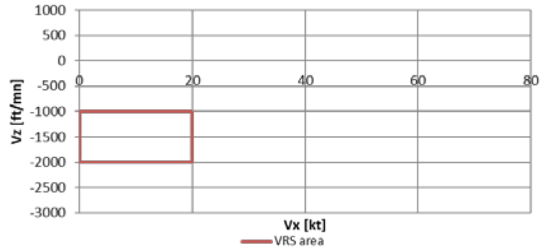
$$Vx_{rotor} = (VXSOL + VHW * \cos(\Psi - KHIW)) * \cos(TPP) + (VZ - VZW) * \sin(TPP)$$

$$Vz_{rotor} = (VZ - VZW) * \cos(TPP) - (VXSOL + VHW * \cos(\Psi - KHIW)) * \sin(TPP)$$





The objective is to compute the airspeed in the main rotor frame and compare it to the experimental VRS area →



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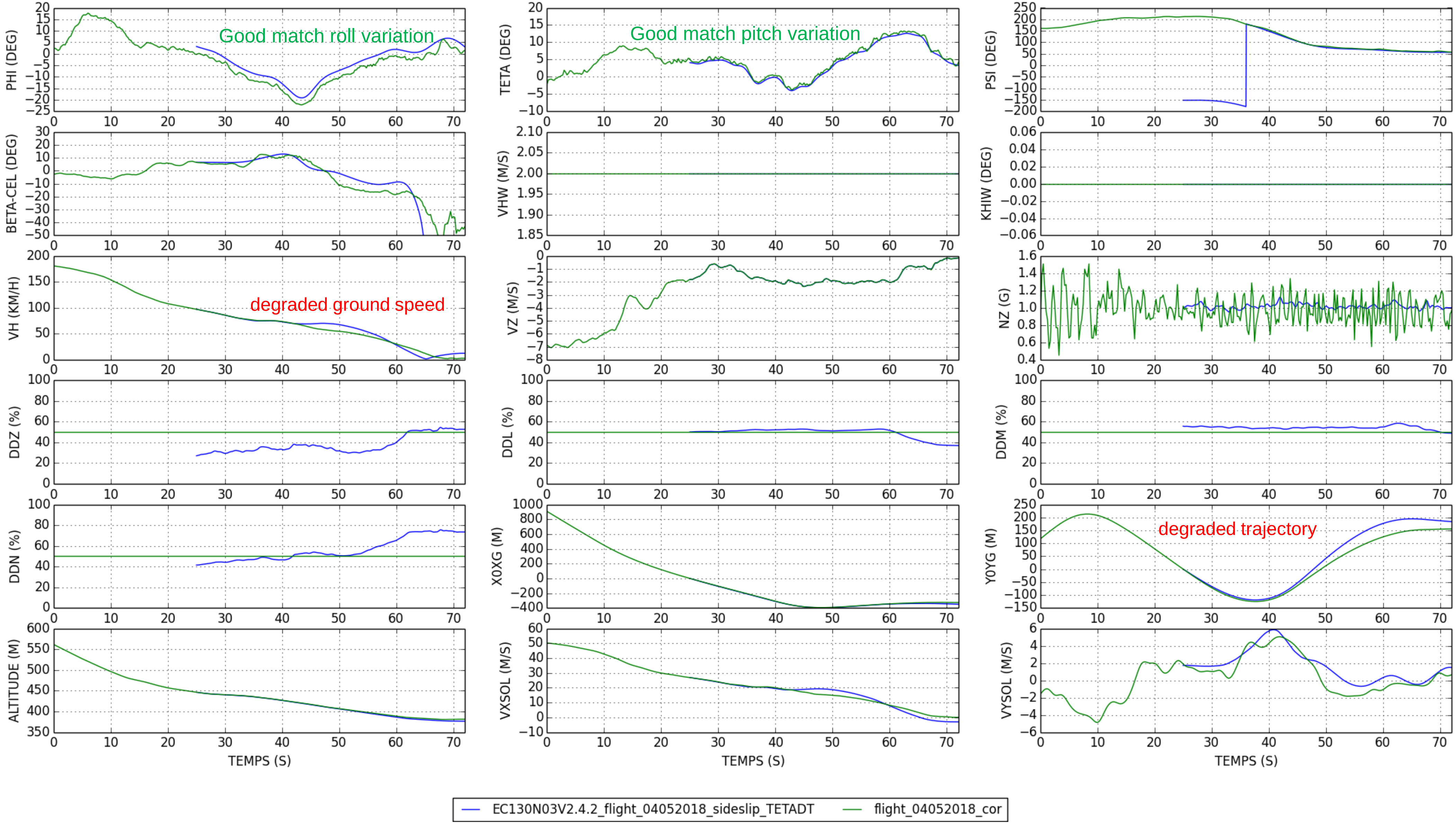
4th May 2018 flight – Attitudes simulation



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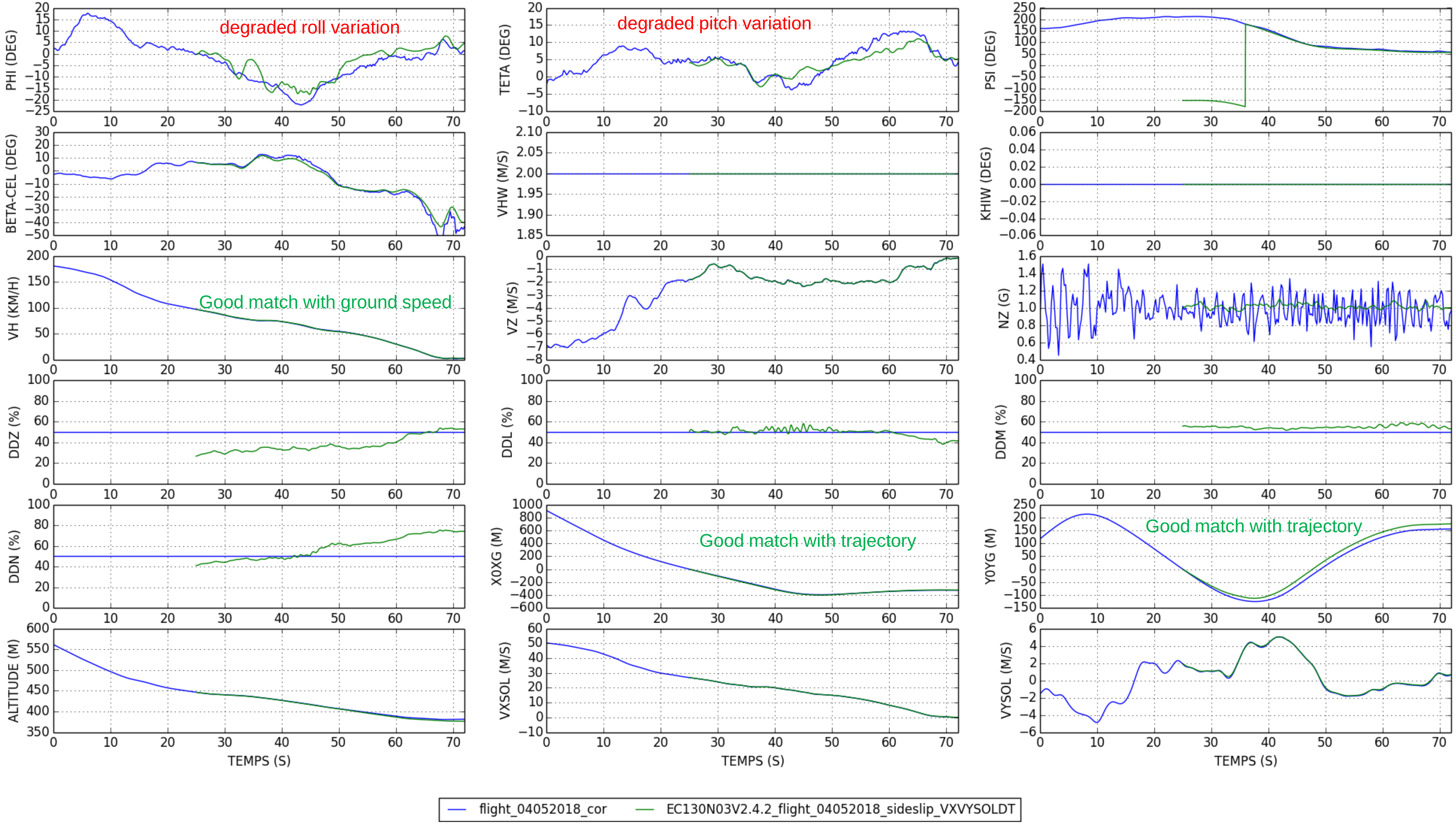
4th May 2018 flight – Trajectory simulation

BEST OPTION FOR INVESTIGATIONS

Try to keep the same earth trajectory whatever the wind



Conclusions on Methodology

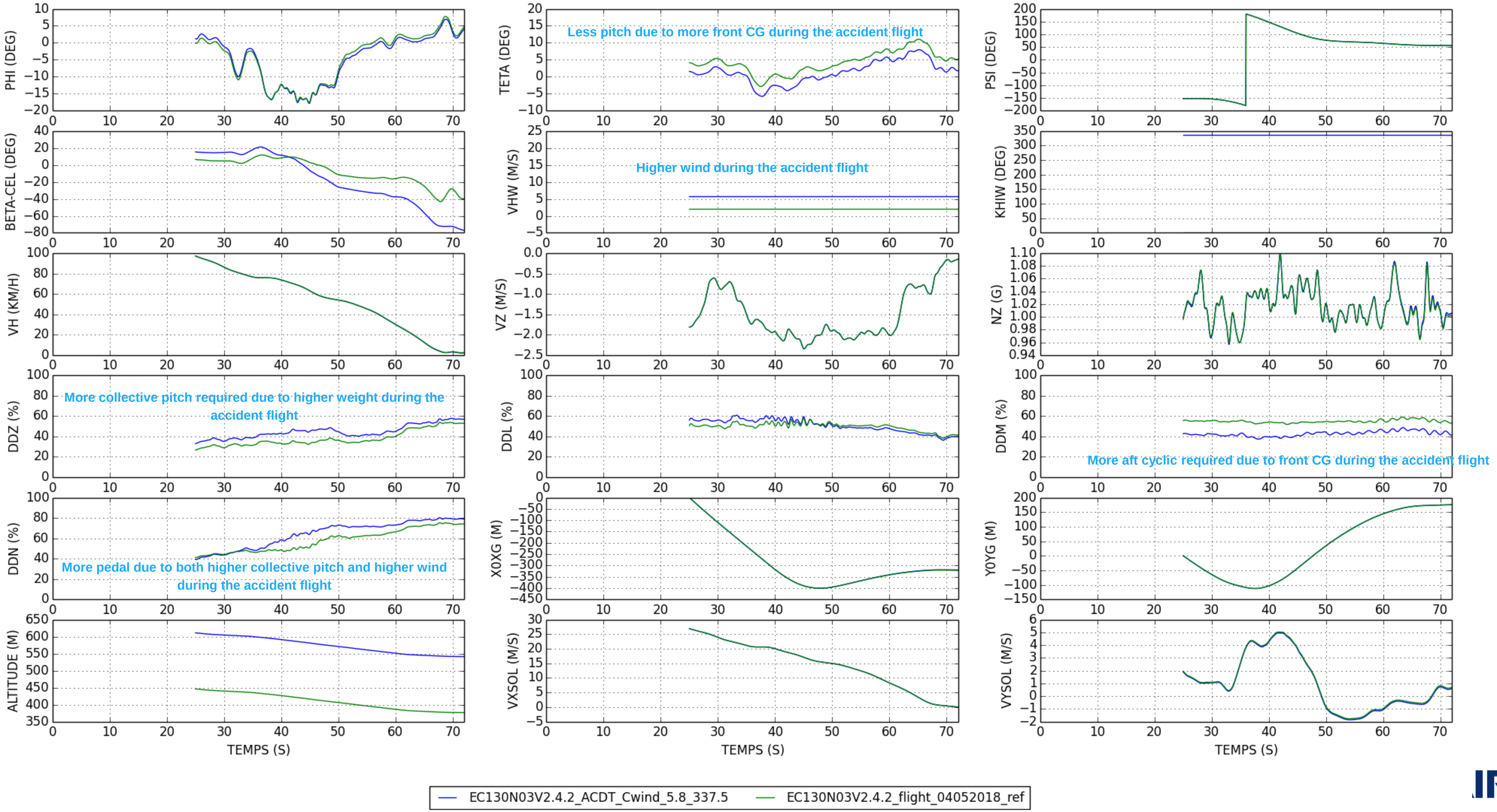
Main hypothesis for the simulation

- Same ground speed and trajectory than 4th May flight
- Same heading than 4th May flight

- Varying the wind conditions will then lead to sideslip variations compared with 4th May flight

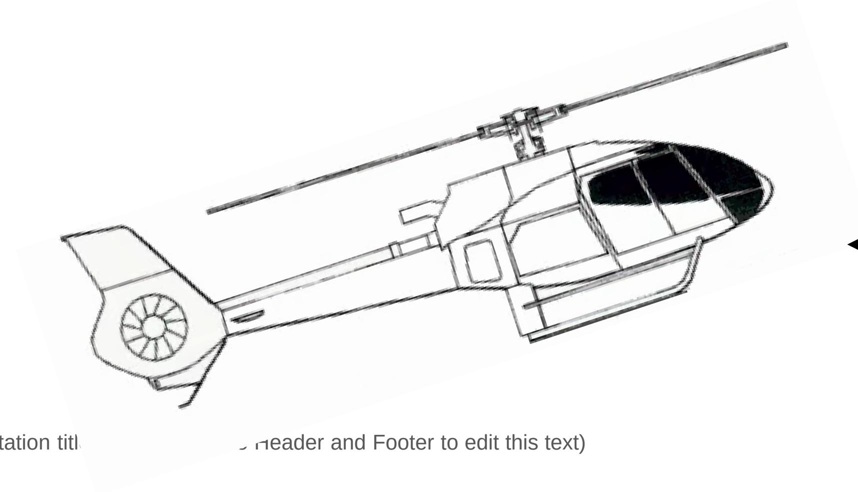
Simulations results
Constant wind

4th May flight condition vs. Accident flight conditions



Simulations with constant horizontal wind – magnitude variations

Name	Conditions		Associated script	comment
	Wind [VHW (m/s)]	Wind direction [KHIW (deg)]		
EC130N03V2.4.2_ACDT_Cwind_5.8_337.5	5.8 (13mph)	337.5 (NNW)	N155GC_accident_constant_wind_5.8_337.5.script	Average wind measured at the time of the accident
EC130N03V2.4.2_ACDT_Cwind_6.3_337.5	6.3 (14.1mph)	337.5 (NNW)	N155GC_accident_constant_wind_6.3_337.5.script	Maximum wind measured at the time of the accident
EC130N03V2.4.2_ACDT_Cwind_5.3_337.5	5.3 (11.9mph)	337.5 (NNW)	N155GC_accident_constant_wind_5.3_337.5.script	Minimum wind measured at the time of the accident
EC130N03V2.4.2_ACDT_Cwind_0_337.5	0 (0mph)	337.5 (NNW)	N155GC_accident_constant_wind_0_337.5.script	No wind
EC130N03V2.4.2_ACDT_Cwind_8.9_337.5	8.9 (20mph)	337.5 (NNW)	N155GC_accident_constant_wind_8.9_337.5.script	Up to 20mph constant wind
EC130N03V2.4.2_ACDT_Cwind_20_337.5	20 (44.7mph)	337.5 (NNW)	N155GC_accident_constant_wind_20_337.5.script	Up to ≈45mph constant wind

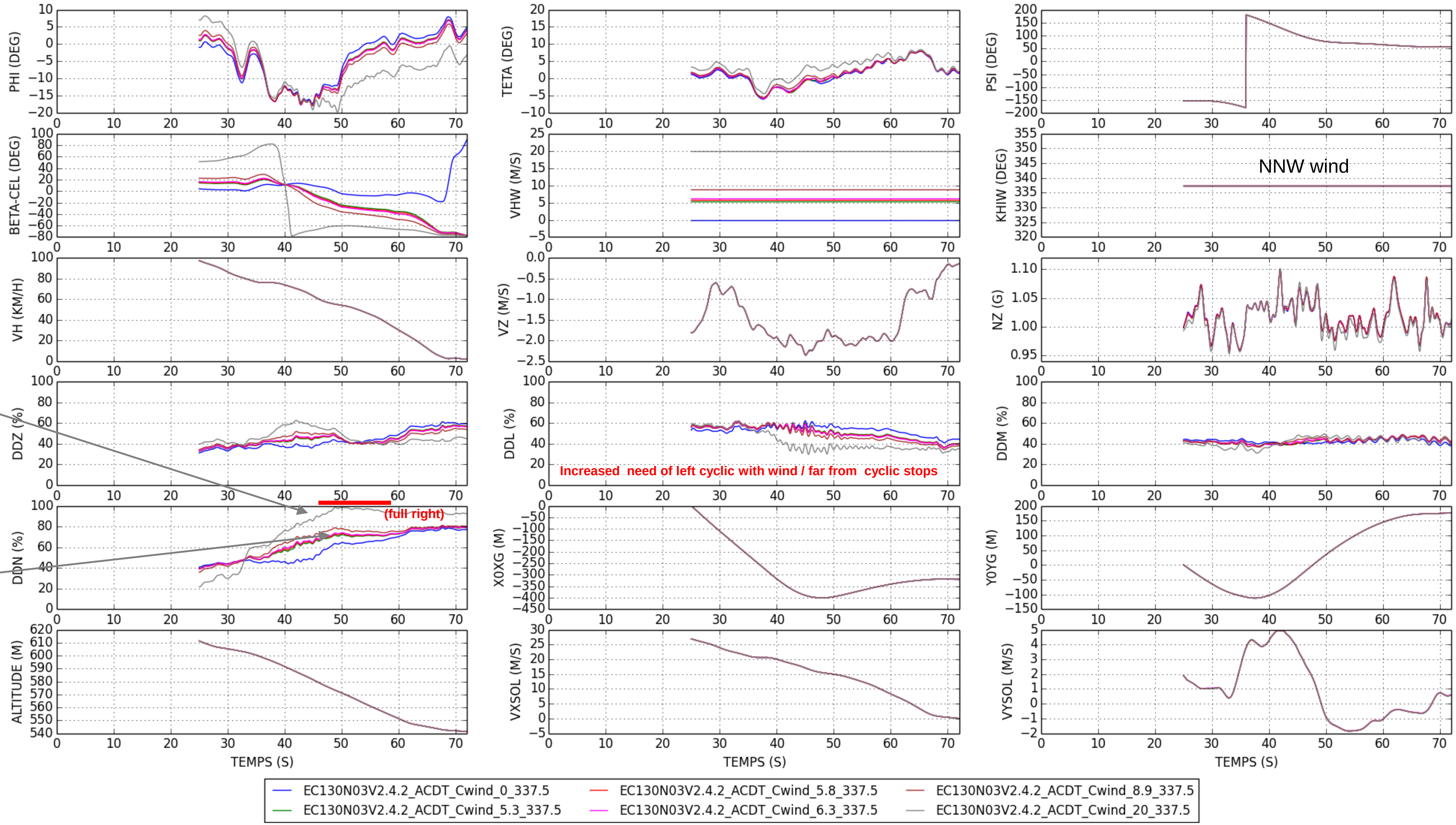


VHW (Horizontal wind speed)

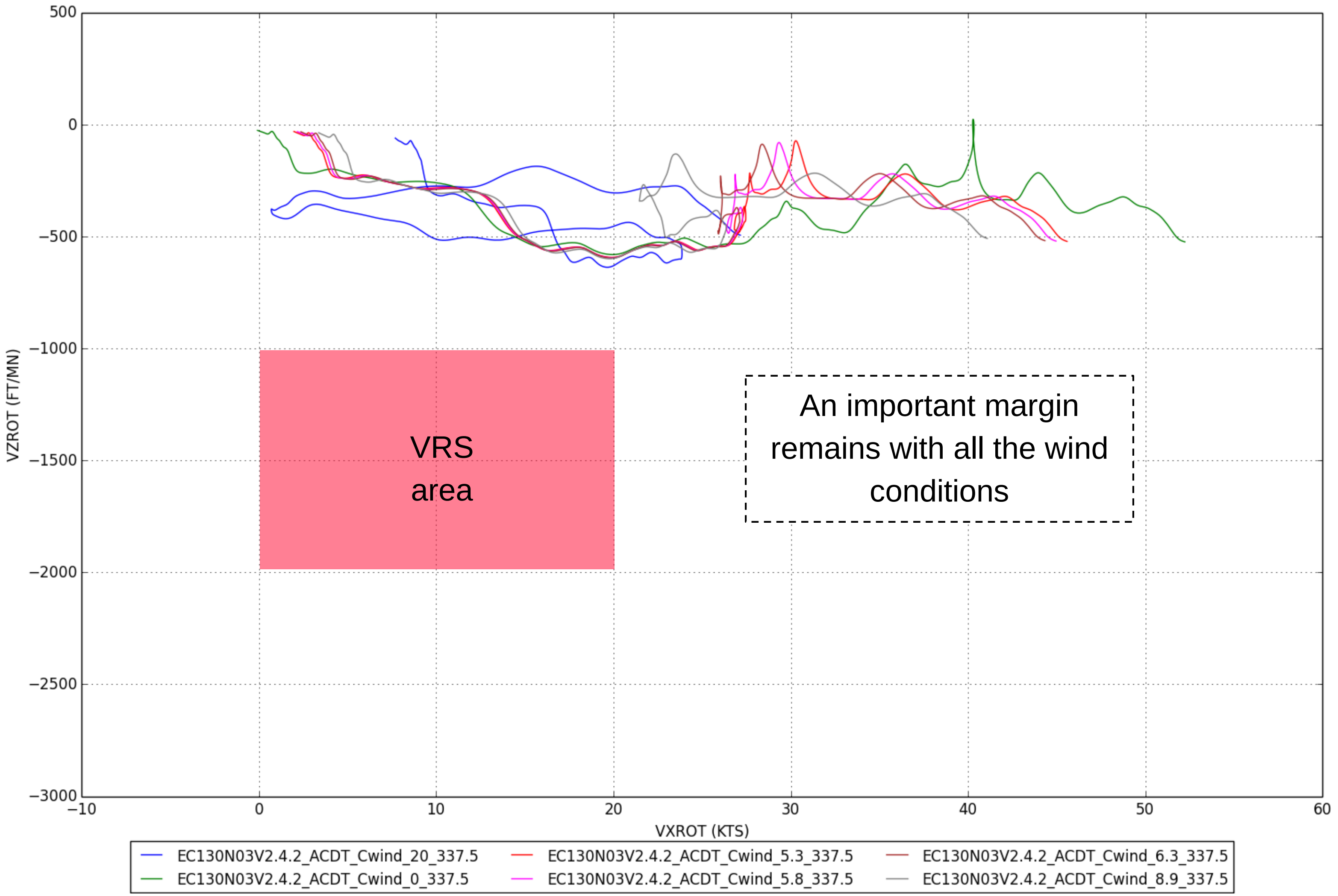
Simulations with constant horizontal wind – magnitude variations

20m/s (44.7mph) of wind from NNW to reach pedal command saturations

20% pedal margin with nominal wind conditions measured at the time of the accident (5.8mph)



Simulations with constant horizontal wind – magnitude variations - VRS area



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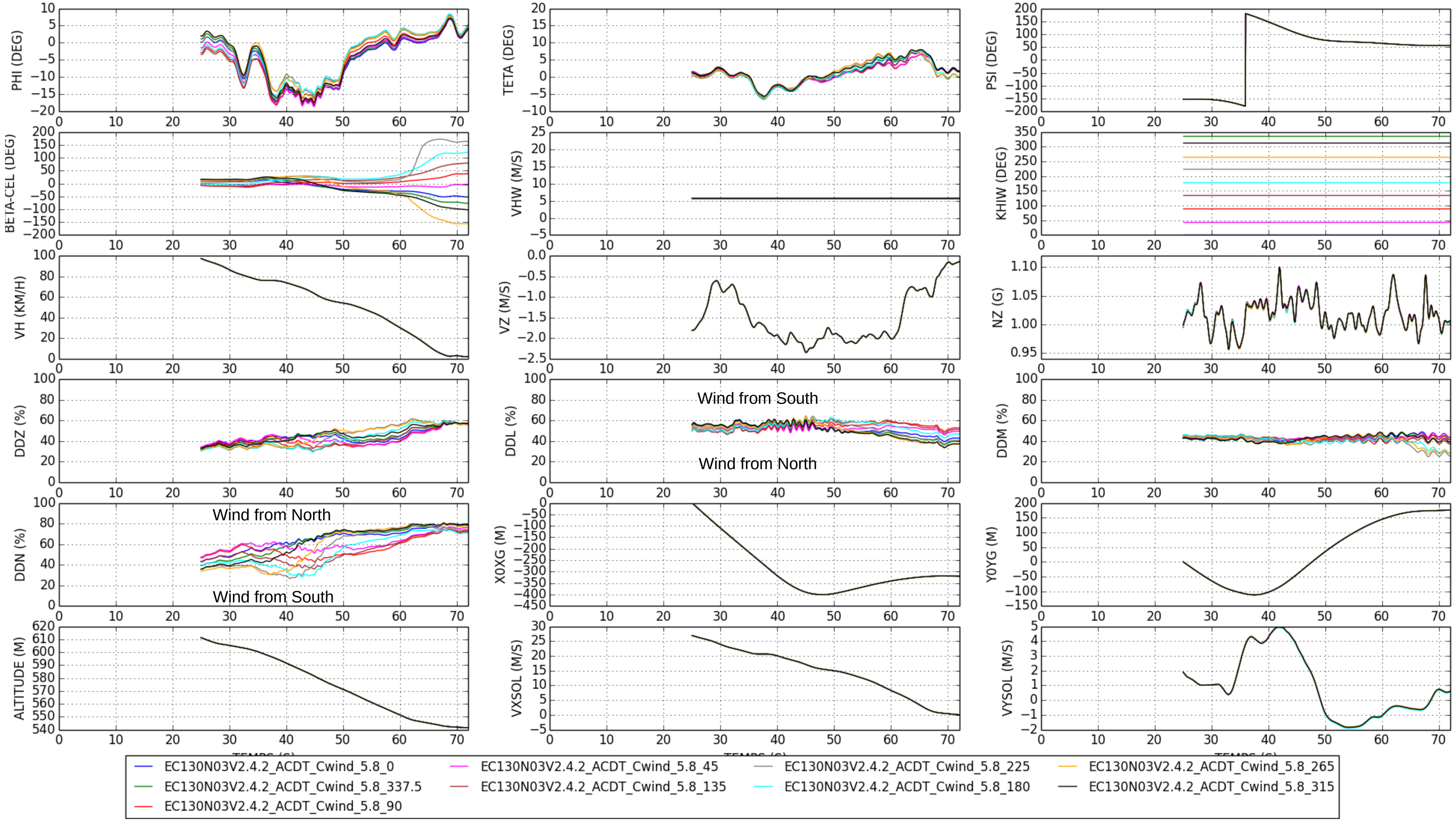
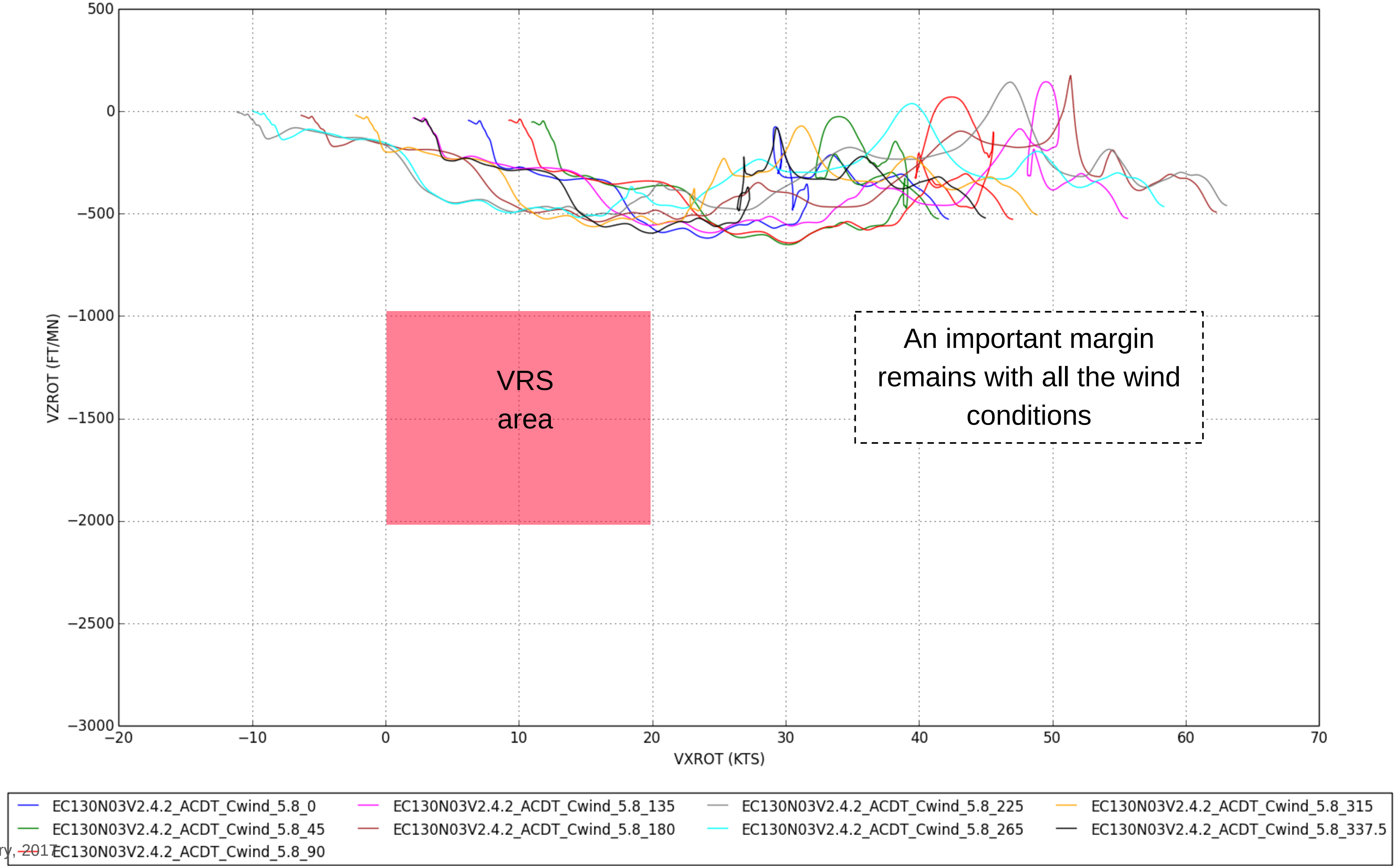
Simulations with constant horizontal wind – Azimuth variations

Name	Conditions		Associated script	comment
	Wind [VHW (m/s)]	Wind direction [KHIW (deg)]		
EC130N03V2.4.2_ACDT_Cwind_5.8_337.5	5.8 (13mph)	337.5 (N)	N155GC_accident_constant_wind_5.8_0.script	Average azimuth measured at the time of the accident
EC130N03V2.4.2_ACDT_Cwind_5.8_0	5.8 (13mph)	0 (N)	N155GC_accident_constant_wind_5.8_0.script	-
EC130N03V2.4.2_ACDT_Cwind_5.8_45	5.8 (13mph)	45 (NE)	N155GC_accident_constant_wind_5.8_45.script	-
EC130N03V2.4.2_ACDT_Cwind_5.8_90	5.8 (13mph)	90 (E)	N155GC_accident_constant_wind_5.8_90.script	-
EC130N03V2.4.2_ACDT_Cwind_5.8 135	5.8 (13mph)	135 (SE)	N155GC_accident_constant_wind_5.8_135.script	-
EC130N03V2.4.2_ACDT_Cwind_5.8_180	5.8 (13mph)	180 (S)	N155GC_accident_constant_wind_5.8_180.script	-
EC130N03V2.4.2_ACDT_Cwind_5.8_225	5.8 (13mph)	225 (SW)	N155GC_accident_constant_wind_5.8_225.script	-
EC130N03V2.4.2_ACDT_Cwind_5.8_265	5.8 (13mph)	265 (W)	N155GC_accident_constant_wind_5.8_265.script	“numerical issues with azimuth 270 → 265 instead”
EC130N03V2.4.2_ACDT_Cwind_5.8_315	5.8 (13mph)	315 (NW)	N155GC_accident_constant_wind_5.8_315.script	

Simulations with constant horizontal wind – Azimuth variations



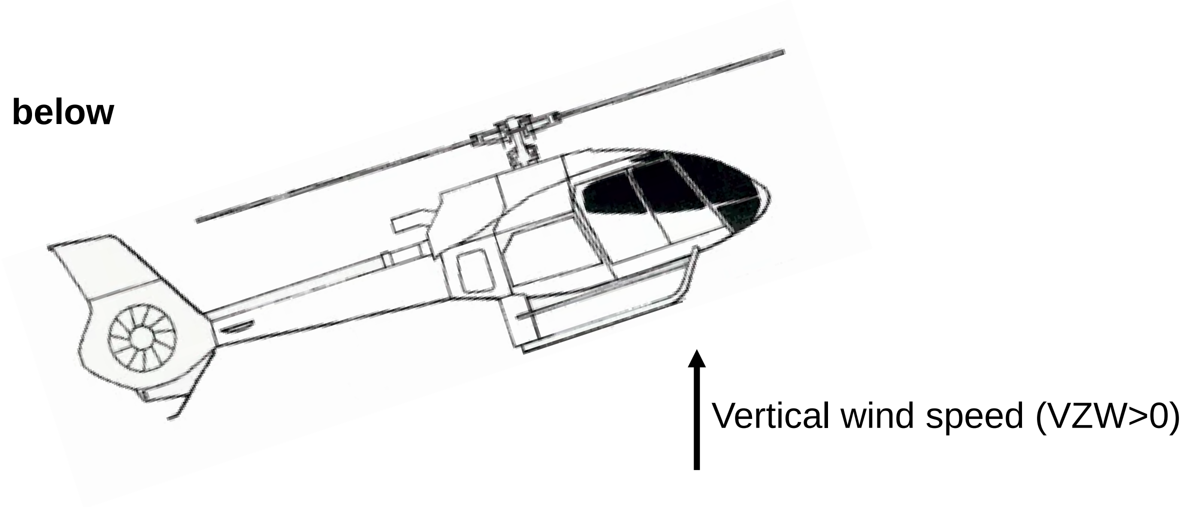
Simulations with constant horizontal wind – azimuth variations - VRS area



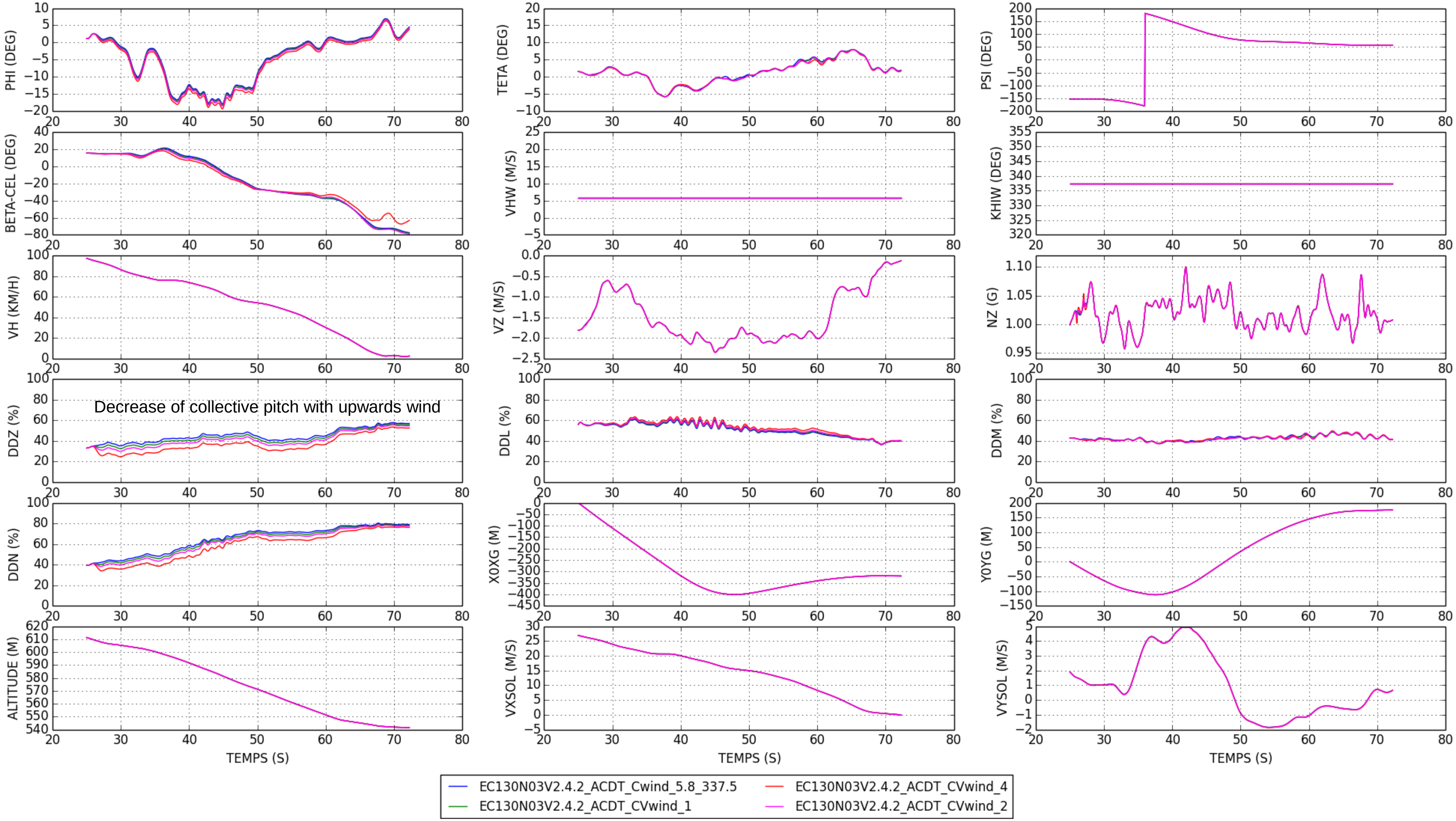
Simulations with constant vertical wind – magnitude variations

Name	Conditions	Associated script	comment
	Wind [VZW (m/s)]		
EC130N03V2.4.2_ACDT_Cwind_5.8_337.5	0	N155GC_accident_constant_wind_5.8_337.5.script	VHW kept at 5.8 NNW (337.5) – nominal no vertical wind
EC130N03V2.4.2_ACDT_CVwind_1	1 (3.3 ft/s)	N155GC_accident_constant_Vwind_1.script	VHW kept at 5.8NNW – 1 m/s from upwards wind
EC130N03V2.4.2_ACDT_CVwind_2	2 (6.6 ft/s)	N155GC_accident_constant_Vwind_2.script	VHW kept at 5.8NNW – 2 m/s from upwards wind
EC130N03V2.4.2_ACDT_CVwind_4	4 (13.1 ft/s)	N155GC_accident_constant_Vwind_4.script	VHW kept at 5.8NNW – 4 m/s from upwards wind

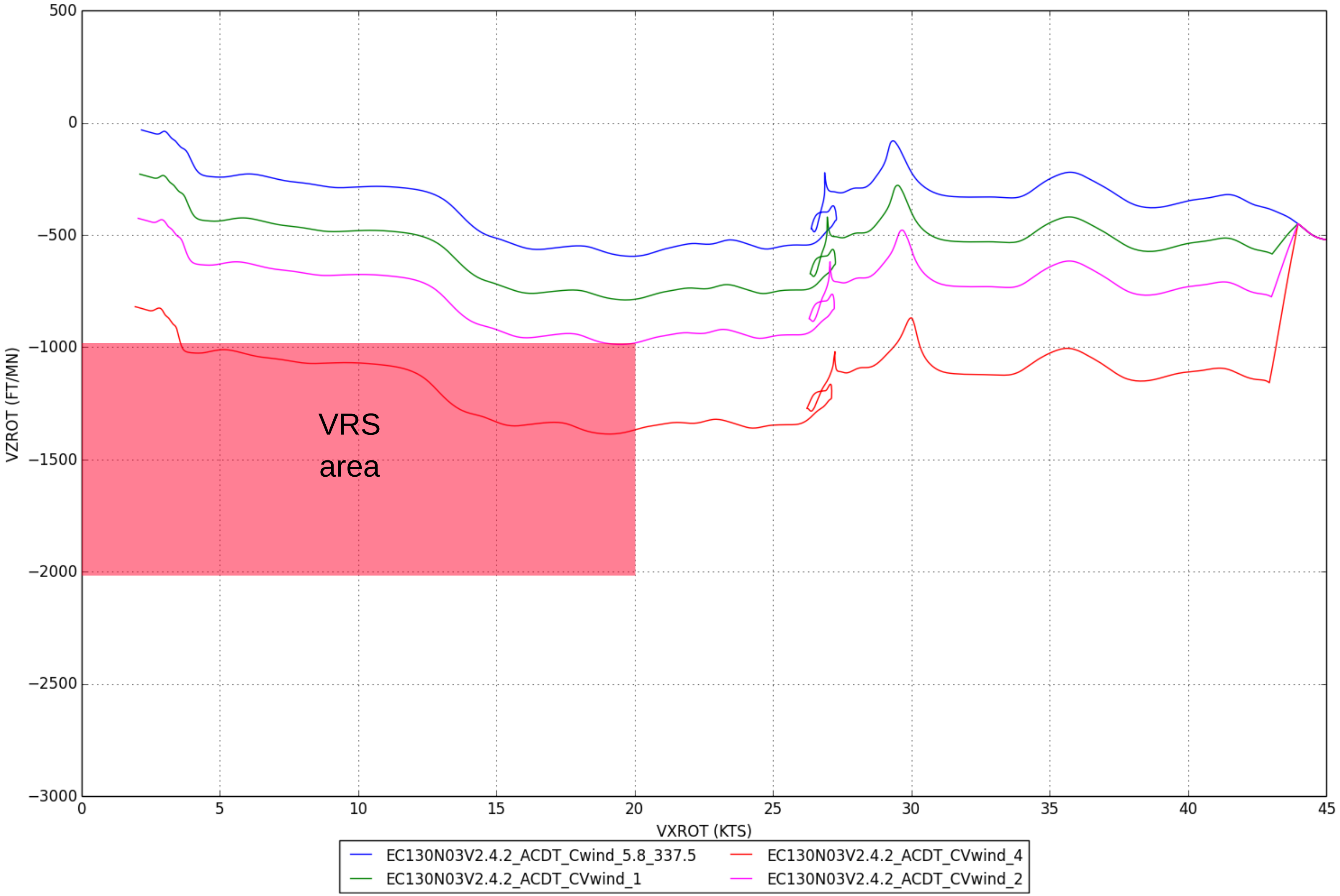
Convention: VZW positive when the air is coming from below



Simulations with constant vertical wind – magnitude variations



Simulations with constant vertical wind – magnitude variations – VRS Area



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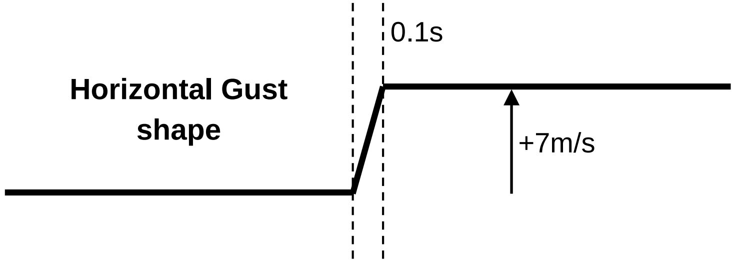
Simulations results
Gusts

Horizontal wind gusts simulations

Name	Conditions	Associated script	comment
	Gust Wind [VHW (m/s)]		
EC130N03V2.4.2_ACDT_Cwind_5.8_337.5	+0	N155GC_accident_constant_wind_5.8_337.5.script	nominal no gust
EC130N03V2.4.2_ACDT_Gwind_5.8+7_337.5_t30	+7 (=12.8 m/s) [total 28.6mph] @ t=30s	N155GC_accident_Hgust_5.8+7_337.5_t30.script	Gust of 7m/s to get a total of 12.8m/s (28.6mph) at t=30s
EC130N03V2.4.2_ACDT_Gwind_5.8+7_337.5_t40	+7 (=12.8 m/s) [total 28.6mph] @ t=40s	N155GC_accident_Hgust_5.8+7_337.5_t40.script	Gust of 7m/s to get a total of 12.8m/s (28.6mph) at t=40s
EC130N03V2.4.2_ACDT_Gwind_5.8+7_337.5_t50	+7 (=12.8 m/s) [total 28.6mph] @ t=50s	N155GC_accident_Hgust_5.8+7_337.5_t50.script	Gust of 7m/s to get a total of 12.8m/s (28.6mph) at t=50s
EC130N03V2.4.2_ACDT_Gwind_5.8+7_337.5_t60	+7 (=12.8 m/s) [total 28.6mph] @ t=60s	N155GC_accident_Hgust_5.8+7_337.5_t60.script	Gust of 7m/s to get a total of 12.8m/s (28.6mph) at t=60s
EC130N03V2.4.2_ACDT_Gwind_5.8+7_337.5_t70	+7 (=12.8 m/s) [total 28.6mph] @ t=70s	N155GC_accident_Hgust_5.8+7_337.5_t70.script	Gust of 7m/s to get a total of 12.8m/s (28.6mph) at t=70s

Horizontal Gust shape

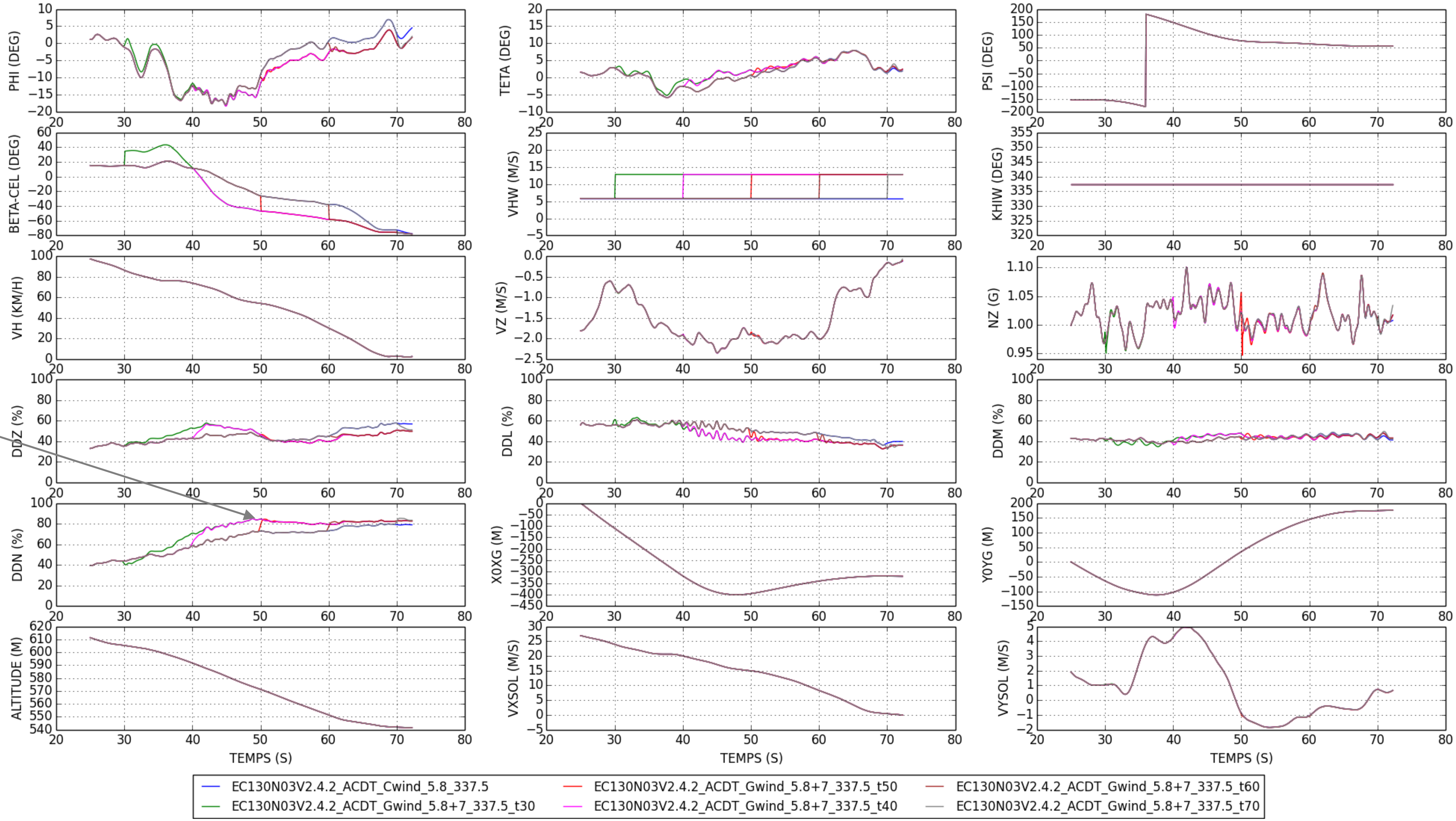


AIRBUS

Horizontal wind gusts simulations

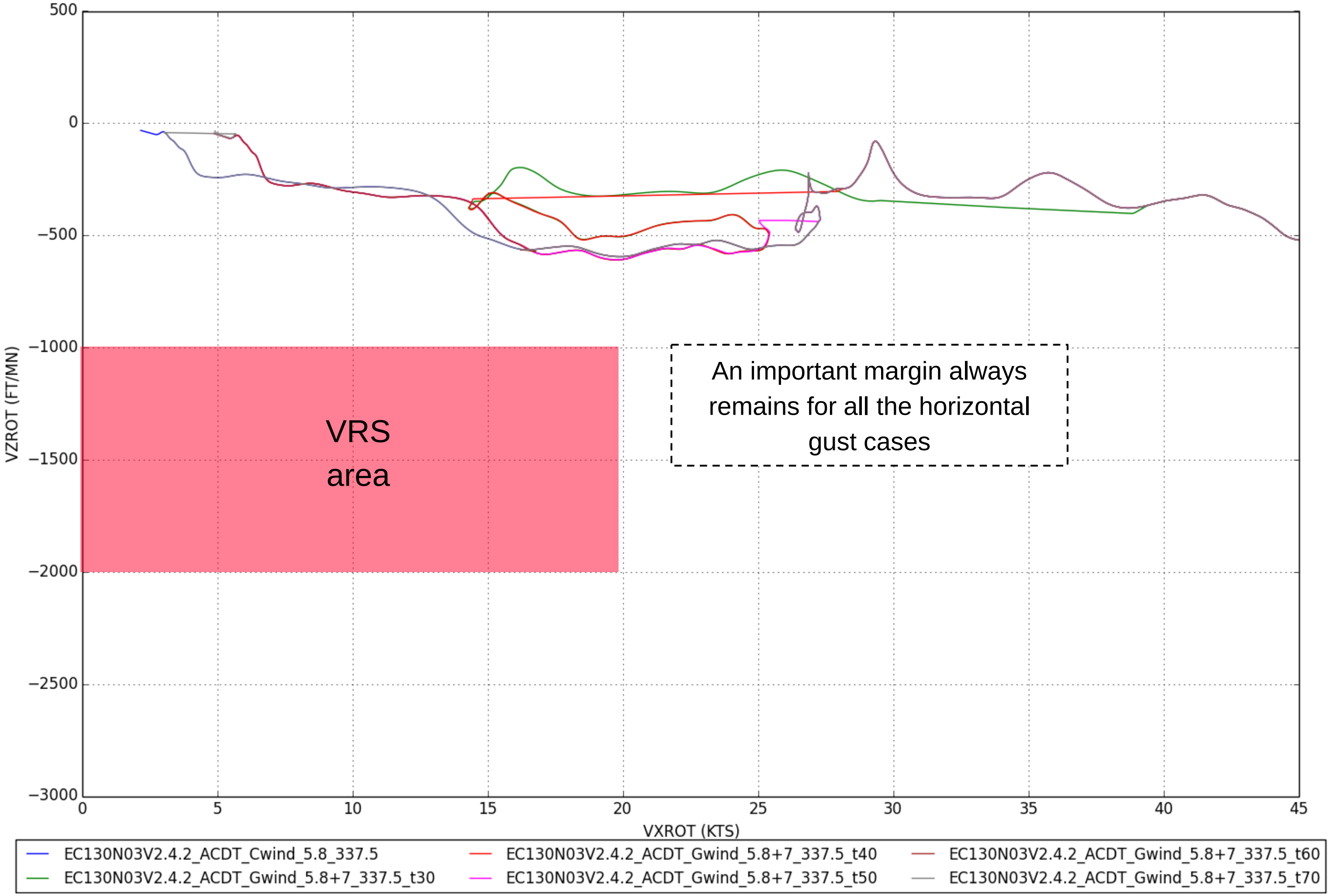
GUST ANTICIPATED BY THE SOFTWARE TO MAINTAIN THE SAME TRAJECTORY

≈18% pedal margin when the gust occurs at t=50s



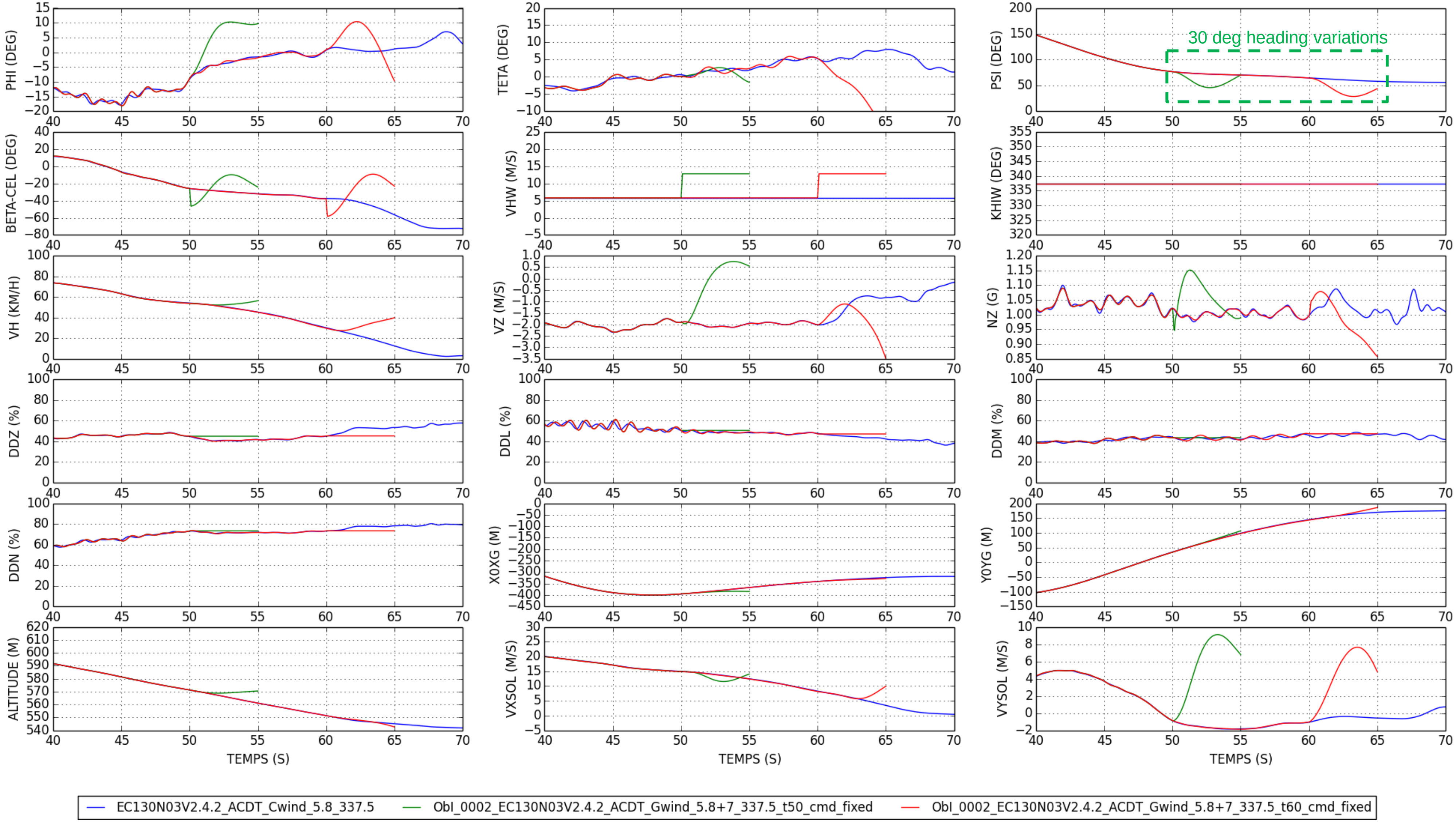
Horizontal wind gusts simulations

GUST ANTICIPATED BY THE SOFTWARE TO MAINTAIN THE SAME TRAJECTORY



Horizontal wind gusts simulations

GUST NOT ANTICIPATED – FIXED COMMAND AT THE TIME OF THE GUST (t=50s and t=60s only)



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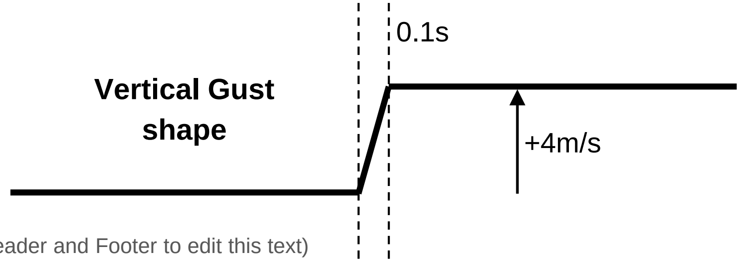
Vertical wind gusts simulations

GUST ANTICIPATED BY THE SOFTWARE TO MAINTAIN THE SAME TRAJECTORY

Name	Conditions Gust Wind [VHW (m/s)]	Associated script	comment
EC130N03V2.4.2_ACDT_Cwind_5.8_337.5	+0	N155GC_accident_constant_wind_5.8_337.5.script	nominal no gust
EC130N03V2.4.2_ACDT_VGwind_5.8_337.5_+4_t30	+7 (=12.8 m/s) [total 28.6mph] @ t=30s	N155GC_accident_Vgust_5.8_337.5_+4_t30.script	Gust of 4m/s upwards at t=30s
EC130N03V2.4.2_ACDT_VGwind_5.8_337.5_+4_t40	+7 (=12.8 m/s) [total 28.6mph] @ t=40s	N155GC_accident_Vgust_5.8_337.5_+4_t40.script	Gust of 4m/s upwards at t=40s
EC130N03V2.4.2_ACDT_VGwind_5.8_337.5_+4_t50	+7 (=12.8 m/s) [total 28.6mph] @ t=50s	N155GC_accident_Vgust_5.8_337.5_+4_t50.script	Gust of 4m/s upwards at t=50s
EC130N03V2.4.2_ACDT_VGwind_5.8_337.5_+4_t60	+7 (=12.8 m/s) [total 28.6mph] @ t=60s	N155GC_accident_Vgust_5.8_337.5_+4_t60.script	Gust of 4m/s upwards at t=60s
EC130N03V2.4.2_ACDT_VGwind_5.8_337.5_+4_t70	+7 (=12.8 m/s) [total 28.6mph] @ t=70s	N155GC_accident_Vgust_5.8_337.5_+4_t70.script	Gust of 4m/s upwards at t=70s

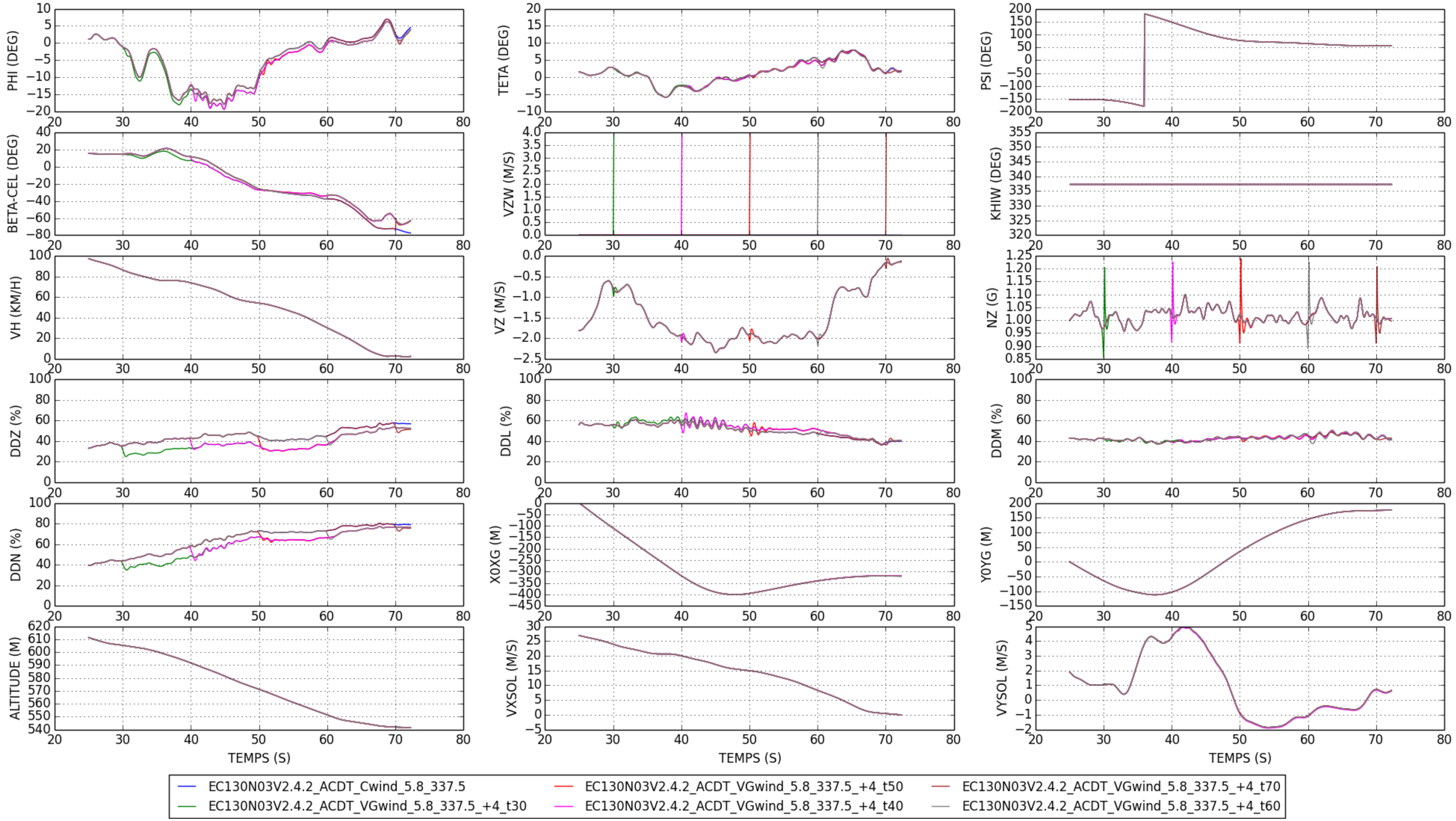
Vertical Gust shape



AIRBUS

Vertical wind gusts simulations

GUST ANTICIPATED BY THE SOFTWARE TO MAINTAIN THE SAME TRAJECTORY



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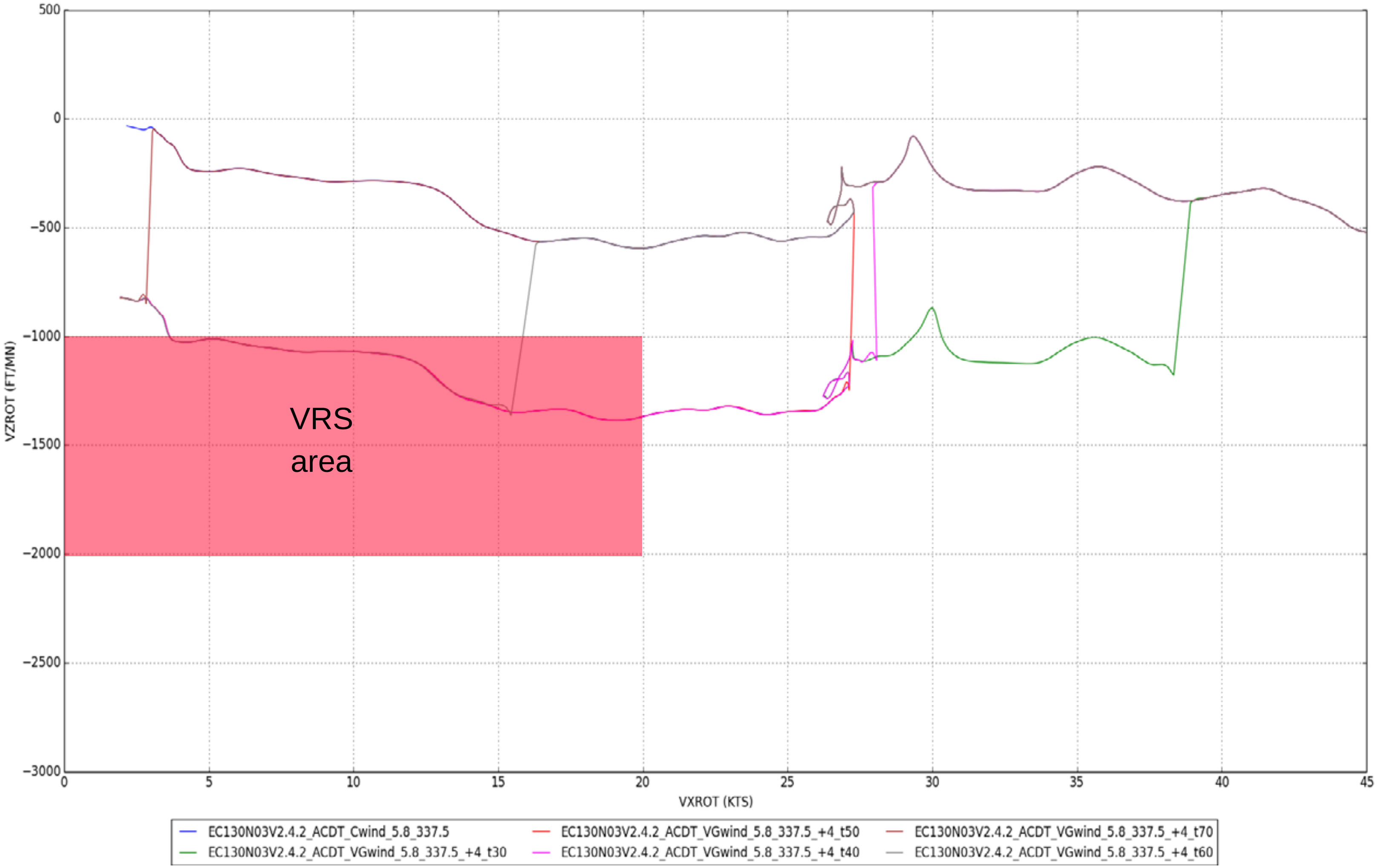
Vertical wind gusts simulations

GUST ANTICIPATED BY THE SOFTWARE TO MAINTAIN THE SAME TRAJECTORY



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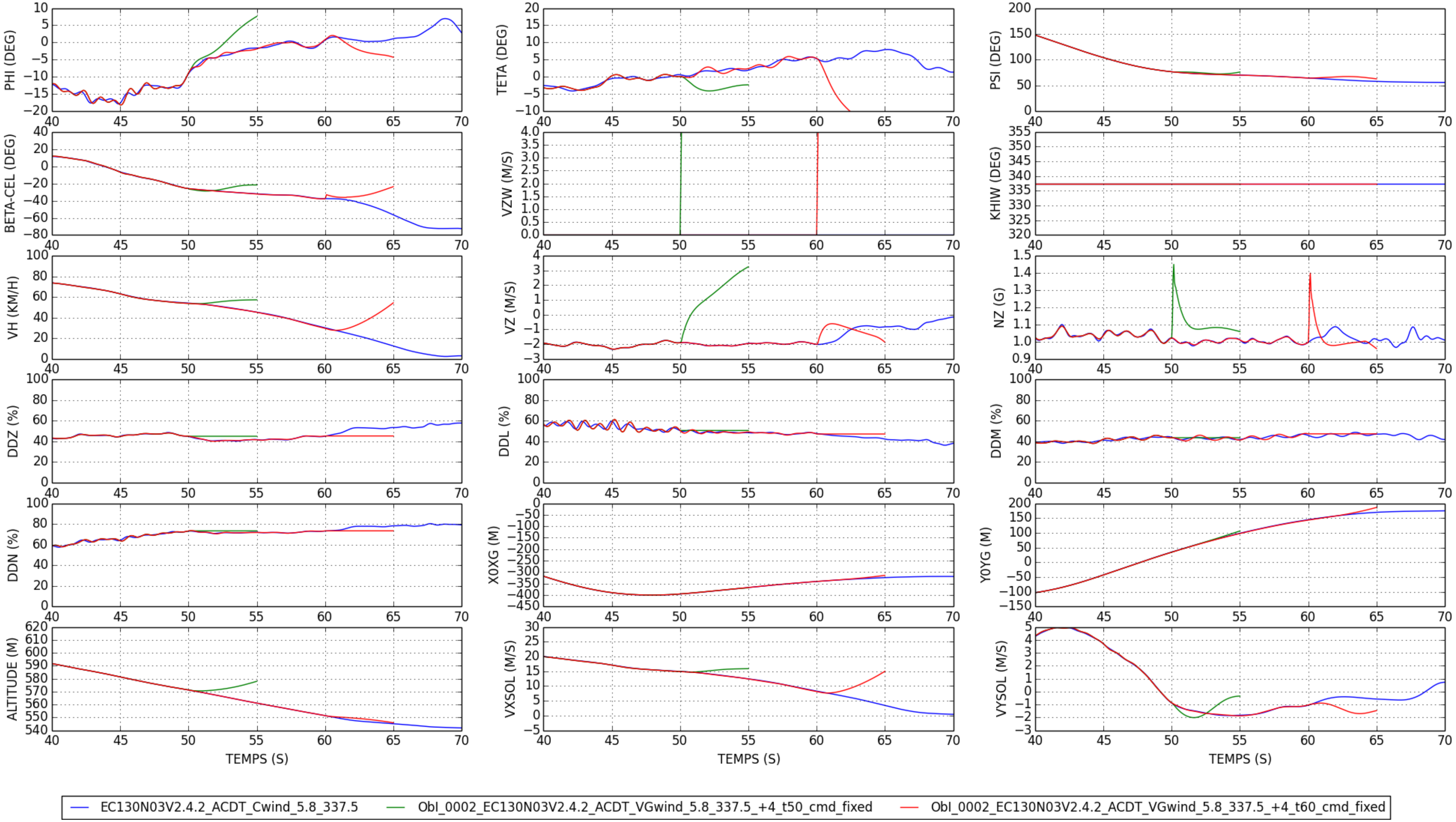
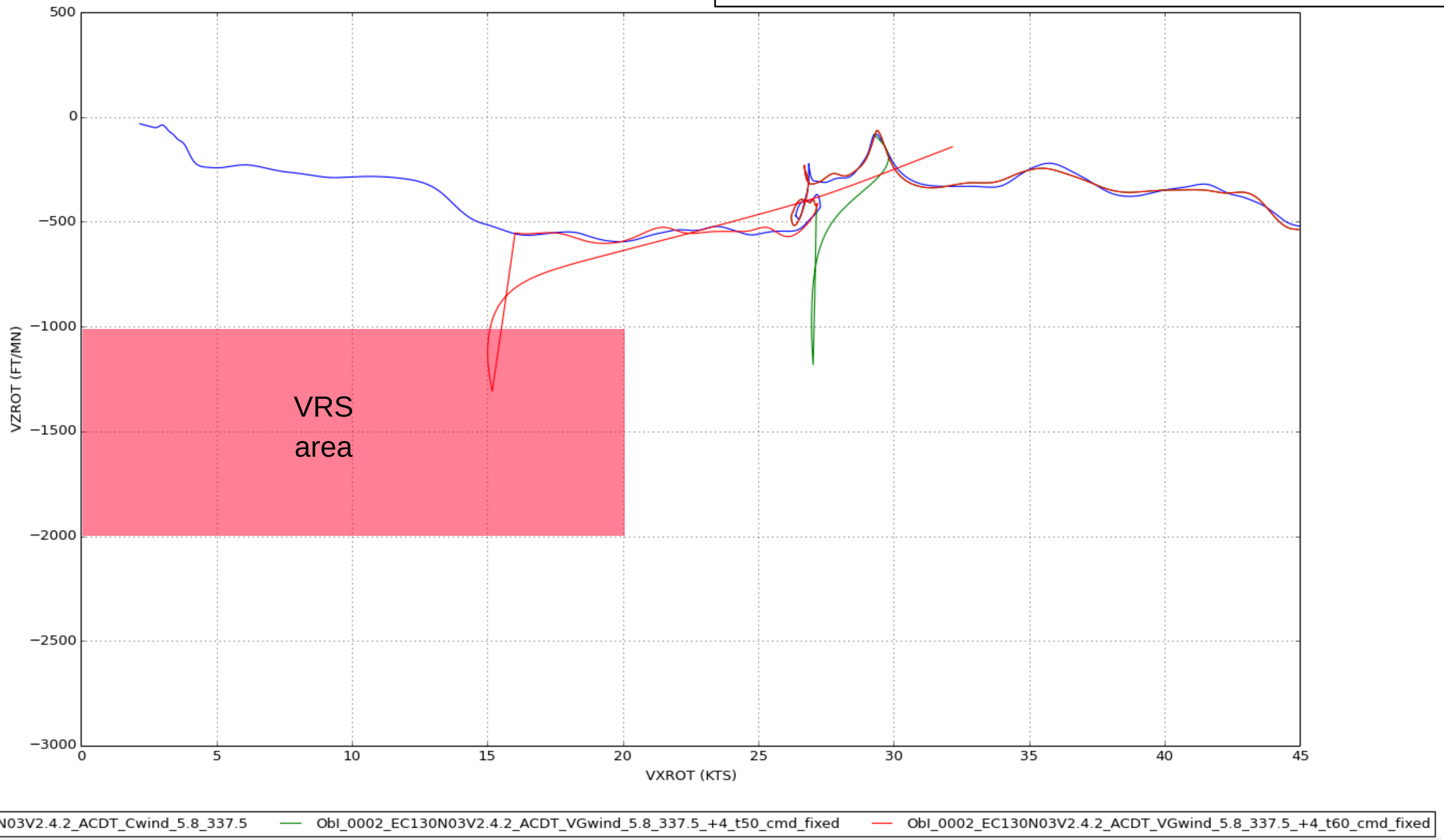
Vertical wind gusts simulations

GUST NOT ANTICIPATED – FIXED COMMAND AT THE TIME OF THE GUST (t=50s and t=60s only)



Vertical wind gusts simulations

GUST NOT ANTICIPATED – FIXED COMMAND AT THE TIME OF THE GUST (t=50s and t=60s only)



Conclusions

- Considering a wind azimuth of 337.5 NNW, a pedal margin of around 20% appears with the wind conditions extracted from KAZFREDO4 & KAZPEACH2. The azimuth considered is also the worst in terms of pedal margin

- Considering a wind azimuth of 337.5 NNW, a wind of around 45mph is required to reach the pedal stop.

- The margin on the others axis (collective, cyclic) is important

- VRS conclusions: No important pitch attitude nor important rate of descent during the flight of the 4th of May. Hence even with important rearward wind, the VRS area is not reached in simulations.

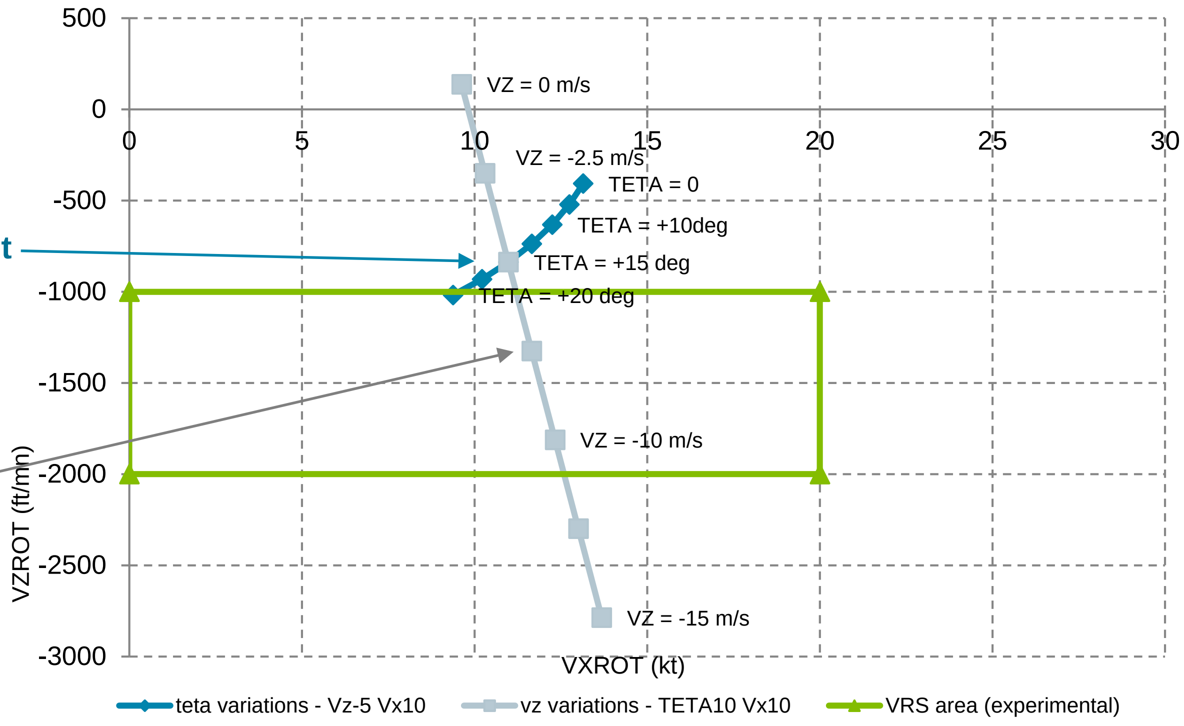
  Aggravating factor for entry into VRS:
  - Important pitch attitude (up to <u>only</u> 10° in the 4th of May flight, 8° in simulation)
  - Important rate of descent (always above -2.5m/s (-500ft/mn) in the 4th of May flight

- 6.6 ft/s of constant upwards wind allows to reach the borders of the VRS Area

H/C pitch impact on VXrot and VZrot

- No important additional information brought by the gust simulations
  - Similar Vx/Vz rotor
  - 30deg heading variation observed following horizontal gust

H/C VZ impact on VXrot and VZrot



Thank you