DISCOVERING THE TROPICAL GRAVITY WAVE

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SUMMARY

During the November 2019 gliding camp in Atacama (Chile), we discovered that gravity and convergence waves can occur with extremely weak winds, so weak that they were insufficient to produce ridge lift. The strength of the lift sometimes strongly increased with the altitude, all without any turbulence, even inside the rotor clouds around 6.000 m. We did not have specific tools to predict these waves but the "standard" *SkySight*[2] software could help a lot. This lecture shows what we found and the numerous questions that arose around this phenomenon, and we invite experts to continue with research campaigns.

INTRODUCTION

The November 2019 gliding camp in the Atacama Desert was originally intended to discover the volcanic thermals above the volcanoes, using a rented Stemme S10 with an atmospheric Limbach engine. The first flights did not meet our expectations. Since we could not take off early in the morning for technical reasons, the conditions were already dying when we arrived. At noon, the beautiful cumulus with bases up to 8.000 m already started fraying down. We were facing the "*Bolivian Winter*". The local population knew this phenomenon, but there was no aeronautical data or report. More on https://topfly-aero.com/index.php/category/atacama-2019-en/ .

ON-SITE EXPERIMENTATION

We then decided to exploit the weak afternoon westerly breeze, which was blowing 10-15 kt when the north-east wind from Bolivia was not blowing. The ridges did not work because of either the conical shape of the volcanoes or the very irregular and broken shapes of the other mountains. We then decided to check for the presence of the convergence lift on the lee side of the perfectly conical volcanoes. That was rather tricky because this side is in Bolivia, theoretically prohibited airspace, totally unlandable, the altitude of the ground being 4.500 - 5.000 m, with escape cols around 4.500 m. For safety reason, we had to keep the engine running, even if not climbing above 5.000 m (which is the service ceiling of the Limbach engine). Good surprise, the convergence worked perfectly, as in the books, allowing reaching the altitude of the volcano, around 6.000 m. We then tried the other volcanoes, there are dozens all around, they all worked the same way, every cone was producing a convergence, without any turbulence. But hardly reaching more than 6.000 m with 10-15 kt westerly wind and 4.500 m ground altitude.

We then decided to investigate more accurately every time we had a forecast of light westerly flow in altitude, or the presence of jet streams often 500 km to the South, even sometimes 1.000 km away. The convergence lift converted into wonderful and incredibly powerful and calm gravity waves and hydraulic jumps. For health safety reasons, we decided to stop climbing at 8.000 m, once abandoning 7,6 m/s with lenticulars approximately 4.000 m above us, see fig.1. All in tropical light clothing, extremely comfortable living, no turbulence, very light wind (25-30 kt at this altitude can be considered as weak). We repeated this type of flying as much as we could, flying thermals at 6.000-7.000 m only when "desperate".

Fig.1 - 26 Nov 2019, 7.534 m. The top of the volcanoes is 6.000 m Volcano Sairecabur, looking North. Wind 32 kt / 293°

The most difficult activity has been the forecast of the dynamic lift. The tropical aerology is totally unknown to gliding meteorologists. We could not get help from our friends in Europe, just one recommendation: "*look carefully at weak signals*". The Atacama tropical air mass can produce gigantic wave systems with very weak flows. During one month (November), we have not seen one single front passing, at least according to our standards, i.e. clouds, rain and wind. The sky remained desperately blue during 30 days; the wind on the ground in Calama was everyday the same, a typical mountain breeze regime from East or West with 180° rotation every morning around 11 am and 10 pm. See Fig.2.

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[1] Retired Engineer Arts et Métiers, Paris, specialist in fluid mechanics, world level glider pilot, multiple world record holder, expert in wave experimentation and flying, author of the book "*Dancing With the Wind*".

[2] Designed by Matthew Scutter, a professional computer scientist and world top glider pilot, presently the only (and therefore the best) wave prediction software.

The conventional geopotential maps at 500 hPa were unusable, simply because the ground is at 500 hPa. Getting altitude wind forecast and wave prediction was however possible thanks to SkySight, with whom we made a contract. This was by far our best source of information, together with the public websites showing the jet streams. We in fact discovered that, even though we never had any strong flow above the flying area, the presence of jet streams 500 to 1.000 km to the South was generating a totally different behaviour of the air mass. We do not know why, but it worked.

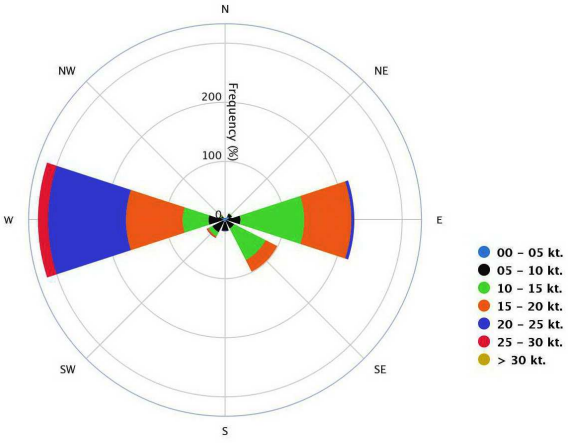

Fig.2 - Windrose November 2018, Calama airport (alt. 2.300 m)

POST-EXPEDITION ANALYSIS AND REFORECASTING

Since the day-to-day life and the organization of the expedition in a so harsh environment did not allow us to investigate immediately about the many surprises we found, I decided to ask two experts in computer science and meteorology to make the re-forecasting of the six particularly interesting wave days. Matthew Scutter and Ezio Sarti[3] of Meteowind made a huge work allowing us to analyse the in-flight findings from our office in Europe one year later, as if we were there.

Among the many surprises we could see, two were particularly amazing:

1. The temperature was always 11 to 14°C higher than the one of the soundings. See fig.3, December 1st, 2019.
   Can that be related to the air mass travelling above the overheated desert for 250 km? Can that be related to the compression resulting by lifting the airmass from sea level to 4.500 m average, thus reducing the section by 40%. See fig.4. Or a combination of both? Or an unlikely lack of initial data of the model?

2. The actual QNH at Calama airport (2.300 m AMSL) was permanently 10-14 hPa higher than the one of the GFS data base.

The QNH and the temperature should be linked, the cause might be the same.

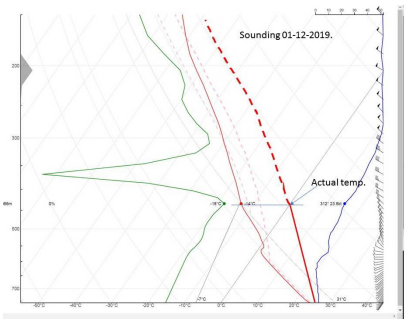

Fig.3 Sounding of 1st Dec. 2019, and actual temperature

This results in an extreme stability of the airmass, as it appears on the annotated Skew-T diagram, and certainly contribute to the unusual power and easiness of the gravity waves and the hydraulic jumps.

CONCLUSIONS

The tropical gravity wave can be an extremely powerful, easy, safe and comfortable phenomenon for glider pilots who want to combine exotic holiday and beautiful flying. However, its forecast is tricky and depends on many other factors than only wind, temperature and gradient.

The purpose of this lecture is both to show to the public how beautiful these waves are and to invite the experts and the meteorological organizations to investigate on how they develop and how to predict their formation. We offer our know-how for organizing research campaigns in San Pedro de Atacama using motorized gliders.

The main issues to be solved for a future research campaign remain:

- Getting a clearance to overfly Bolivian airspace up to FL 280 using gliders with conventional supplemental oxygen delivery systems or even FL 340 when using a pressurized breathing system.
- Getting a reliable pressurized oxygen breathing system and installing it in a S10 or equivalent motorized glider.
- Getting a turbocharged self-launching glider or tow plane.

[3] Ezio Sarti, http://www.meteowind.com/, is a meteorological expert certified by the WMO. He manages a team of computer experts who recently developed a forecasting software very similar to SkySight.

- Finding an agreement with San Pedro municipality and Chilean Civil Aviation Directorate in order to make San Pedro airfield safe and secured during the night.

Contrary to the QNH and the temperature, the wind forecast of either models GFS and WRF used by MeteoWind and SkySight were corresponding to our actual observations.

This is a real enigma that will be exciting to solve, also and above all regarding the phenomenon of the warming of the upper layers of the atmosphere: "Is there something that escapes the current models?".
Can gliding meteorology help finding solutions?

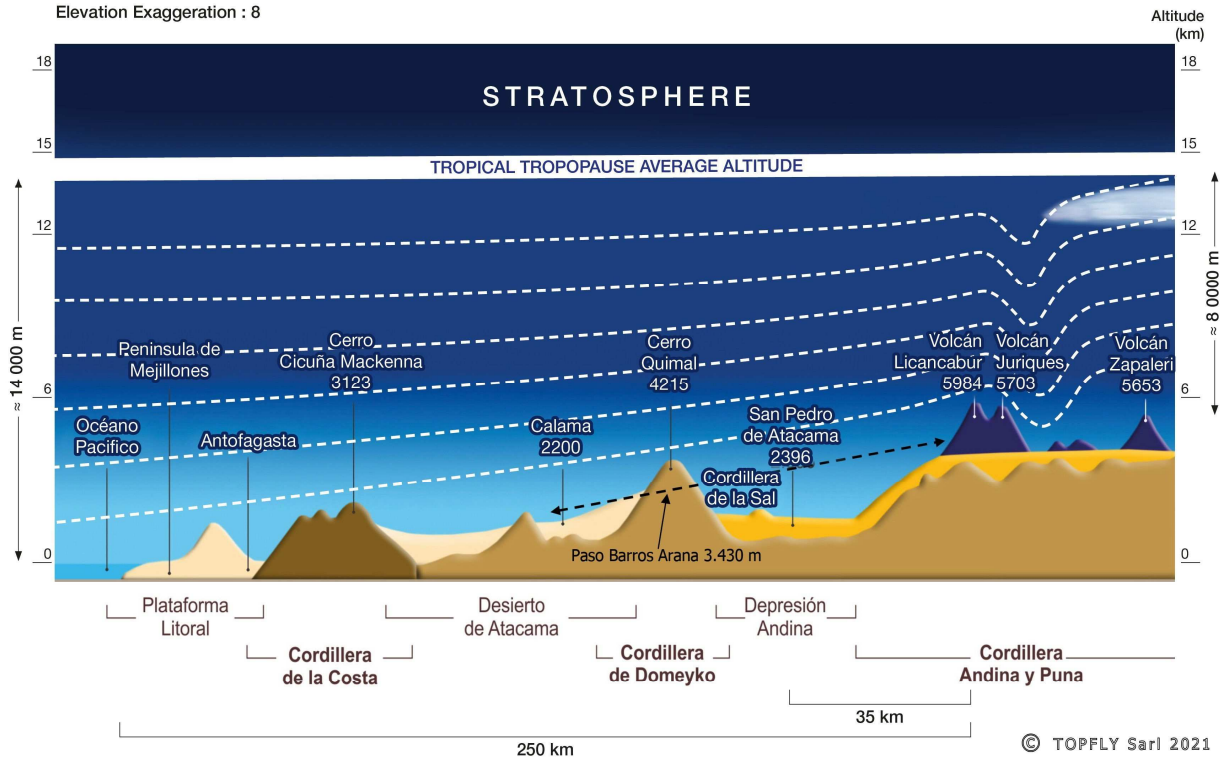

Fig.4 Topographic cross section of Atacama Desert along the Tropic of Capricorn, from the Pacific Ocean up to the volcanoes and the Bolivian Altiplano. The section of the atmospheric westerly flow is reduced by 40% in 250 km, between an overheated ground and the supposedly constant altitude of the stratosphere.

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