

DISCOVERING THE TROPICAL GRAVITY WAVE

Jean-Marie Clément

San Pedro de Atacama





The aim of the expedition was originally to explore the “volcanic” thermals.

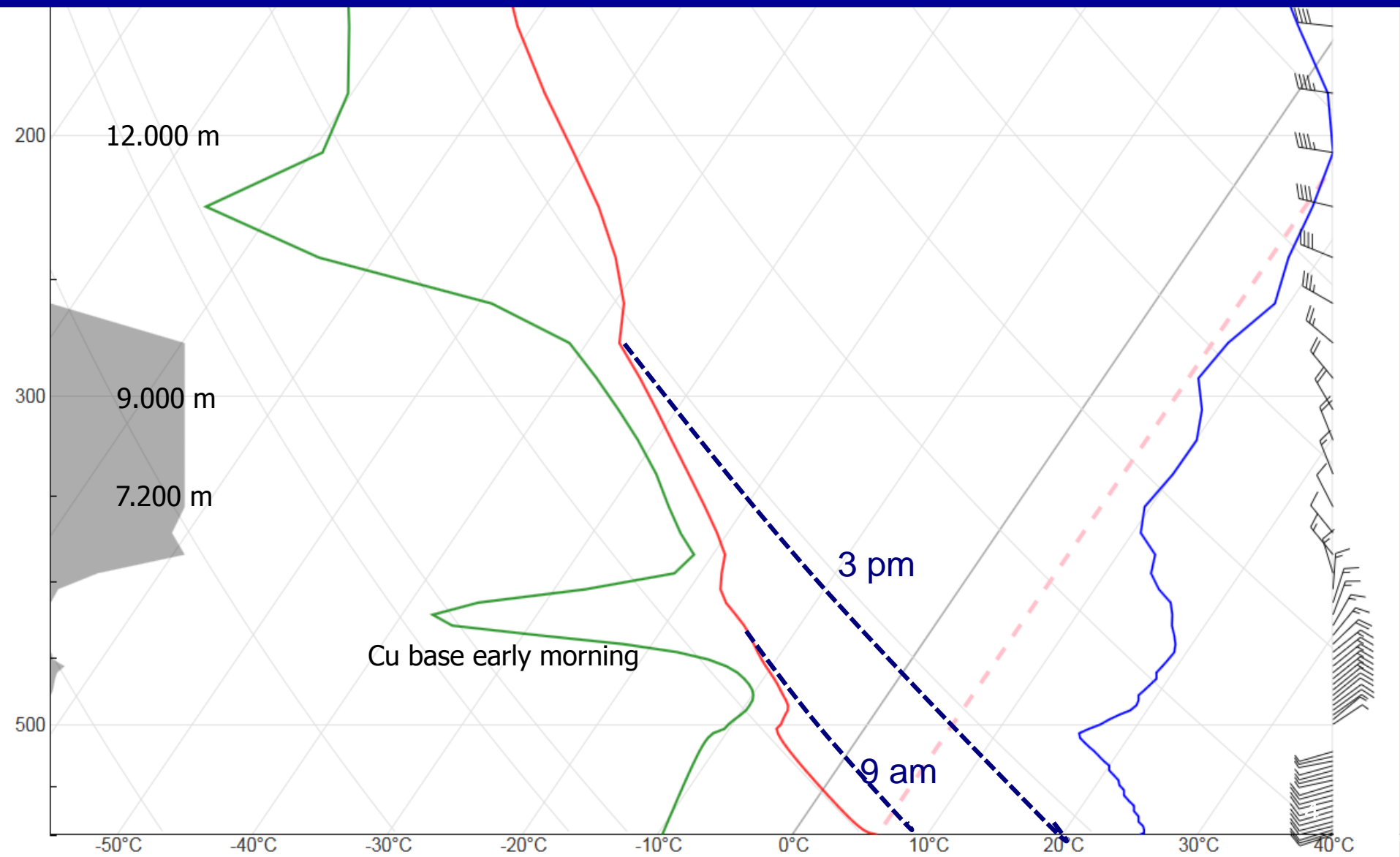
Situation at 9 am, Volcano Miscanti (5.910 m), no wind

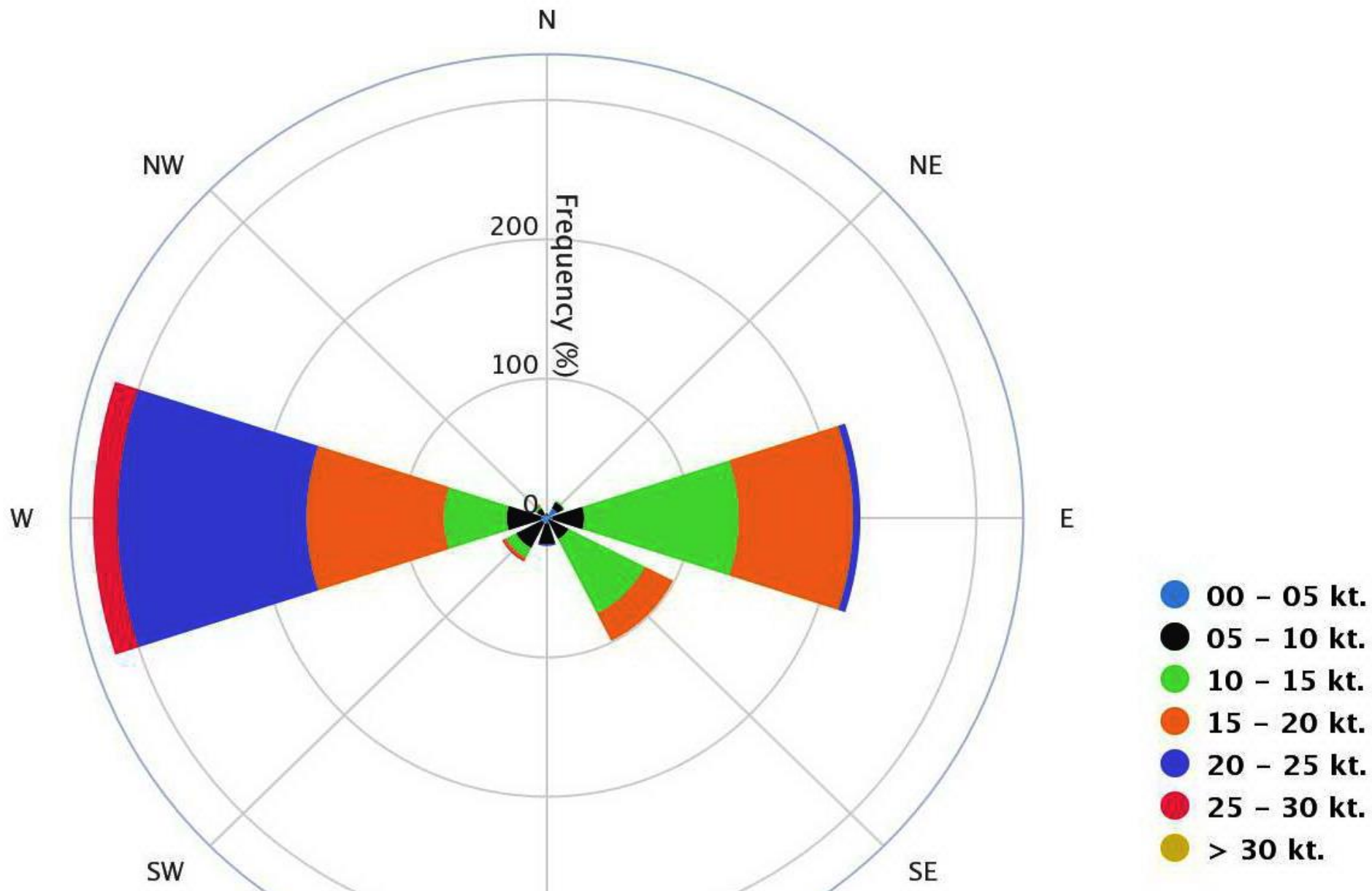
Cumulus base above 8.000 m



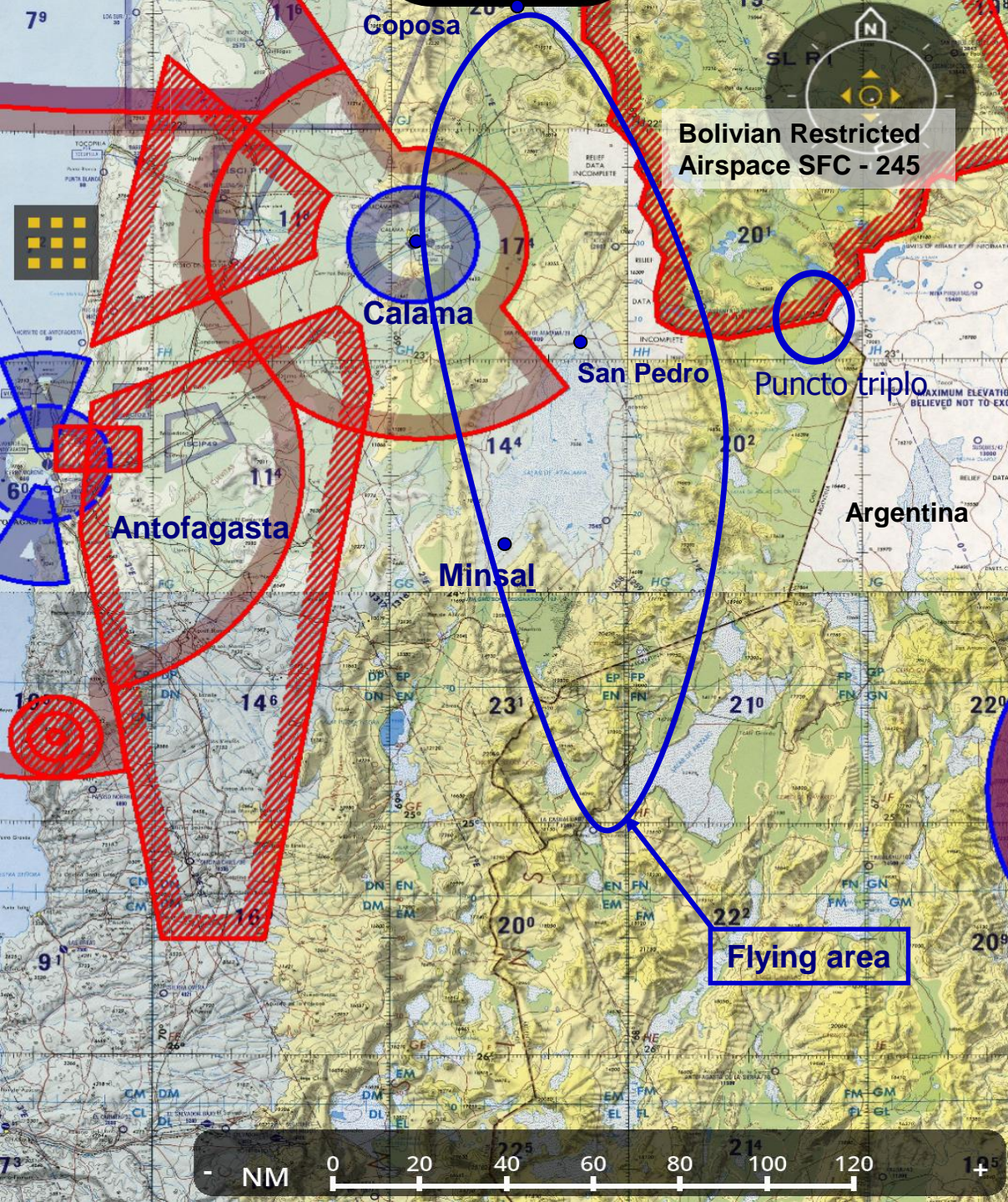
Light Easterly flow: the Bolivian winter comes early afternoon
1 pm LT, Volcano Licancabur is unflyable

Bolivian winter: forecast for 16 Nov. 3pm LT. Small inversion around 500 hPa, moist air until 280 hPa, clouds for sure. Flow E-NE above inversion layer. Total cloud cover at 2 pm, no flight





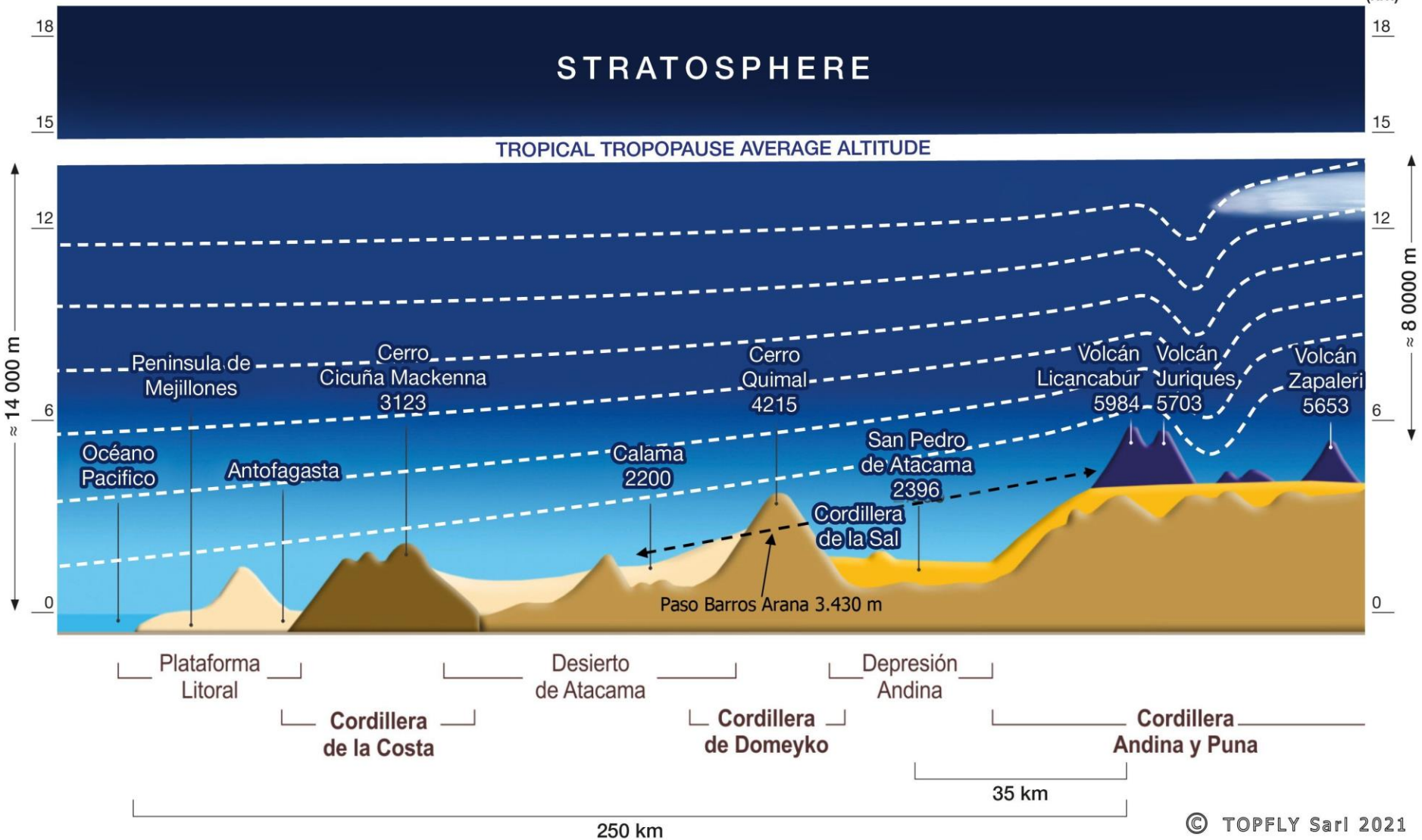
The wind rose in Calama, November 2018.
Some hope for dynamic lift with westerly flow



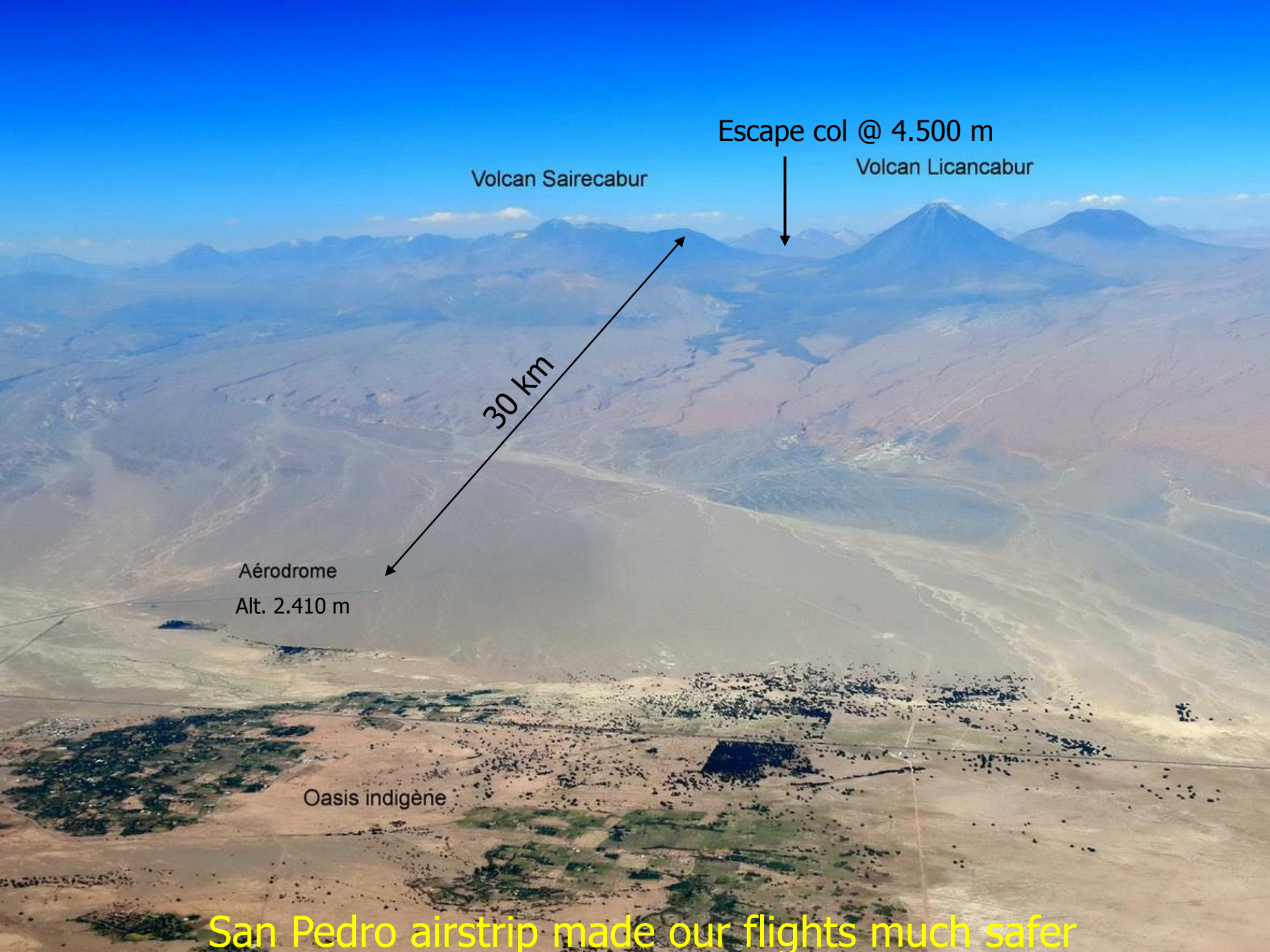
Aeronautical map

Only 4 airports in
350 km

Observe the
"punto triplo" to
easily find the place



Tropical cross section of Atacama desert from the Ocean to the volcanoes⁷



Volcan Sairecabur

Escape col @ 4.500 m

Volcan Licancabur

30 km

Aérodrome
Alt. 2.410 m

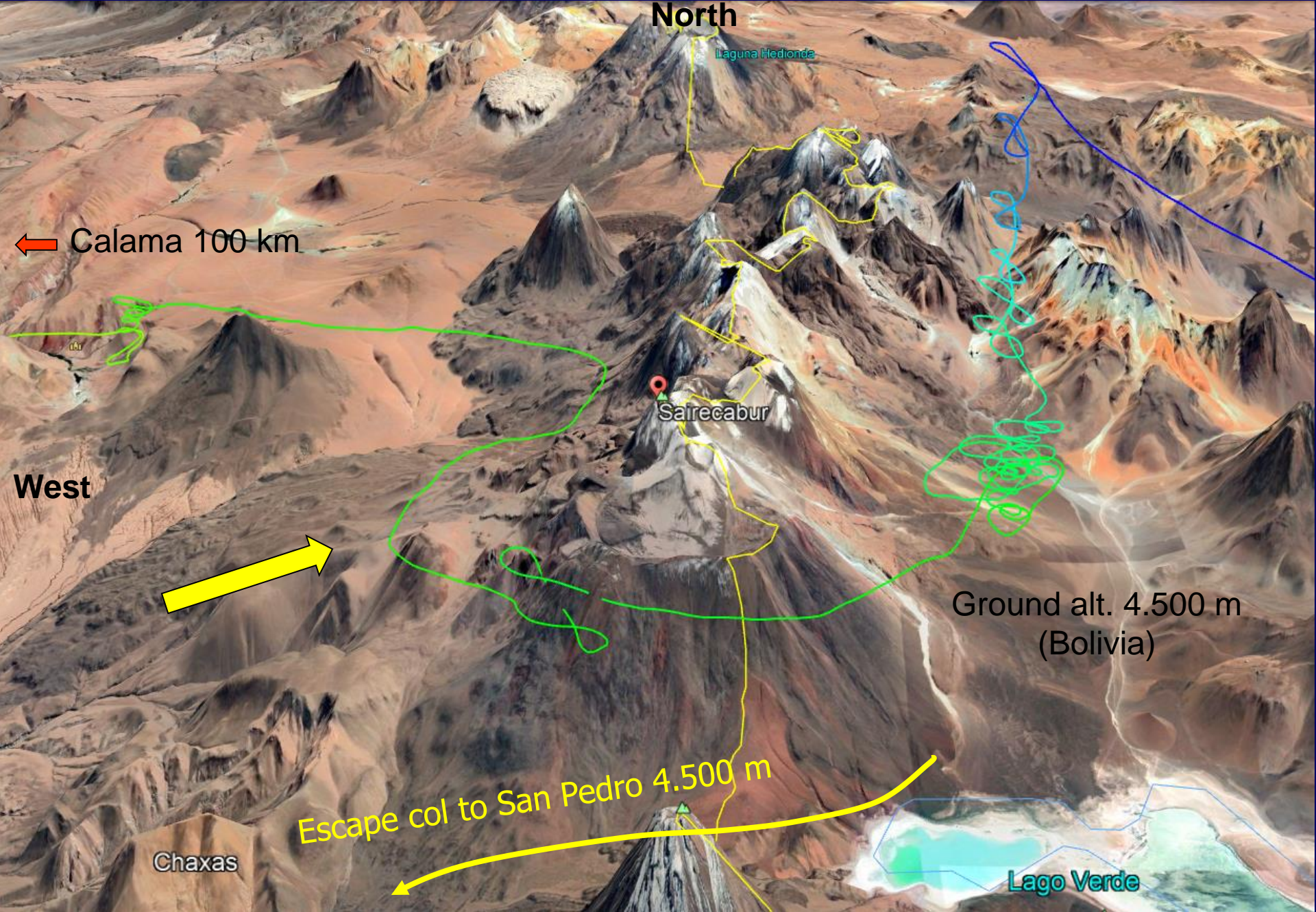
Oasis indigène

San Pedro airstrip made our flights much safer

First contact with conventional

Rebound gravity wave

The SW breeze 10-15 kt was not sufficient
to produce ridge lift (V. Sairecabur)



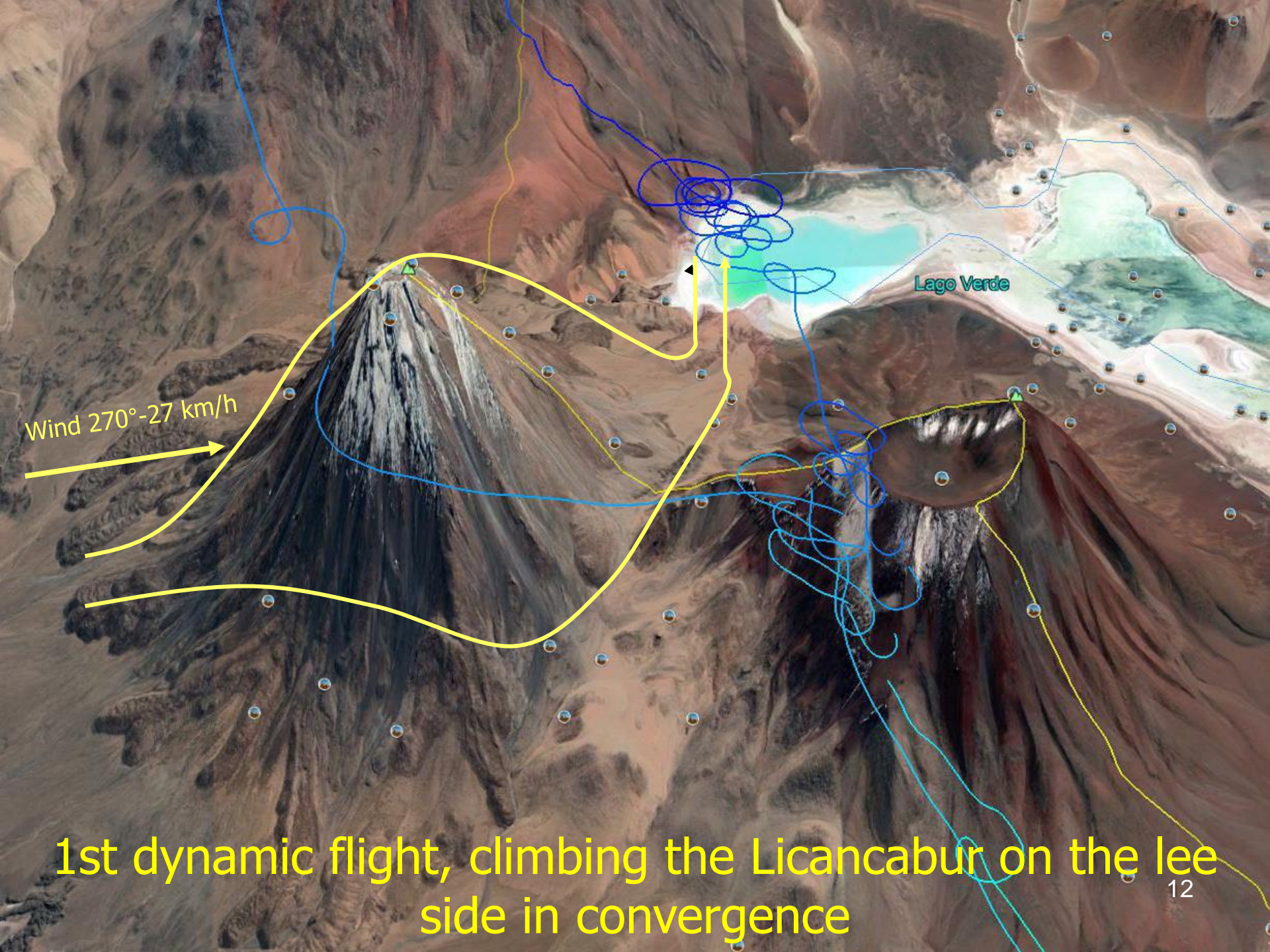
1st flight with light westerly breeze: no ridge lift but good wave

Always using the light W-SW breeze 10-15 kt

I successfully found convergence lift

on the lee side of conical volcanoes

(V. Licancabur)



Wind 270°-27 km/h

Lago Verde

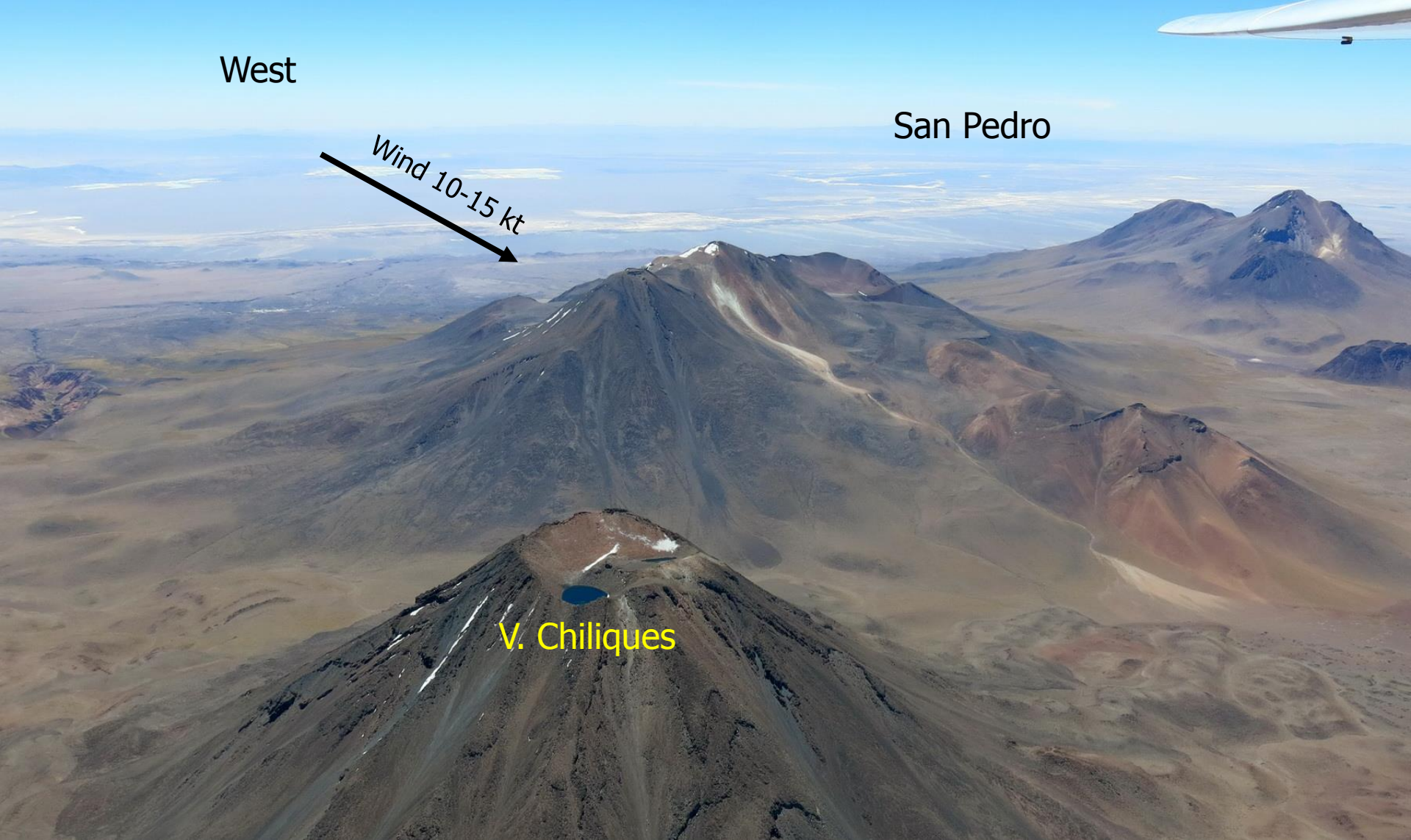
1st dynamic flight, climbing the Licancabur on the lee side in convergence

West

Wind 270°-27 km/h

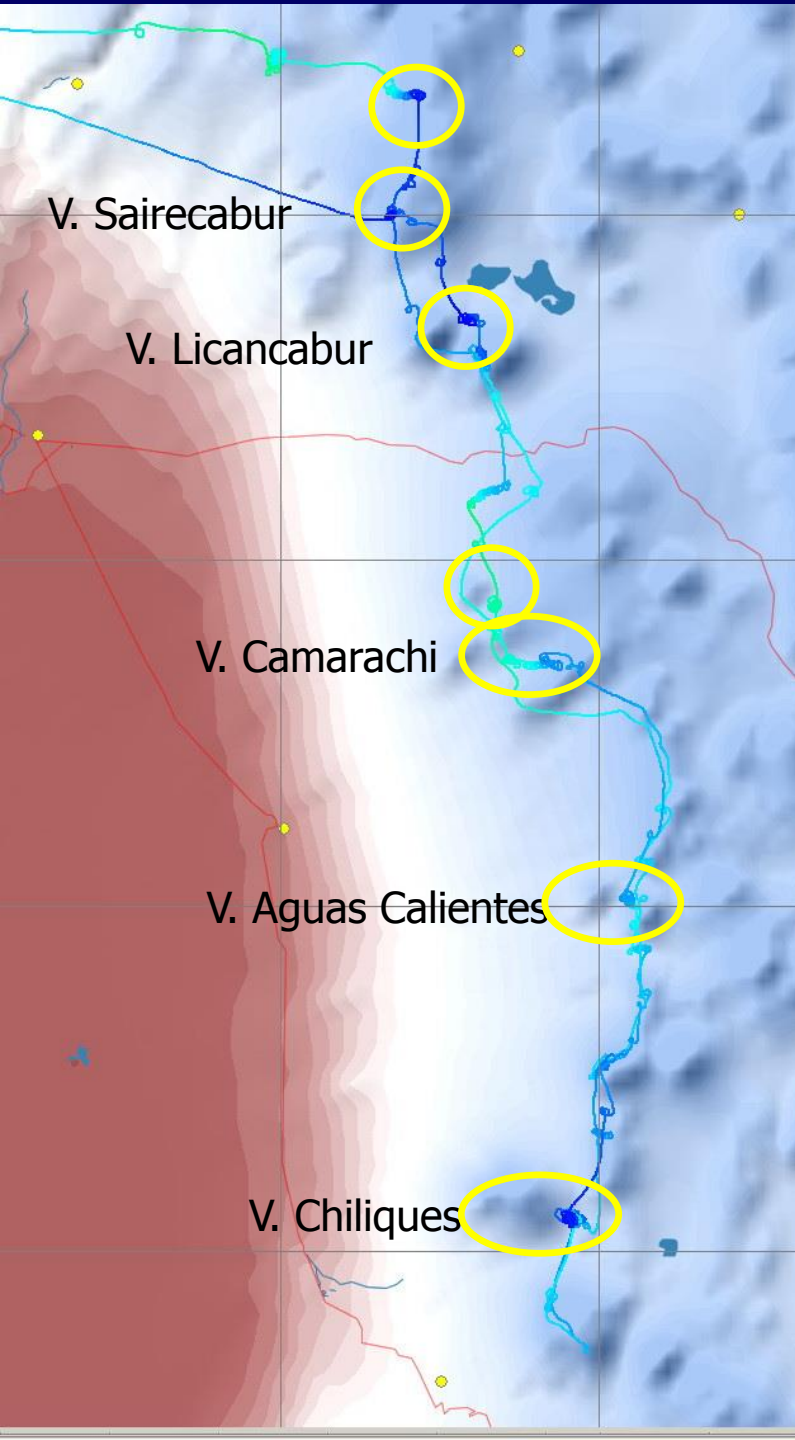
5.916 m

And this is how it looked like, around 6.000 m



We eventually could fly convergence lift on the lee side of every conical volcano

7 Nov. 2019



Flight using only convergence lift on
the lee side of every conical volcano

Without being able to climb above
their top

But sufficient to make a beautiful
touristic trip

The first humans to overfly Atacama
volcanoes without an engine!

7 Nov. 2019

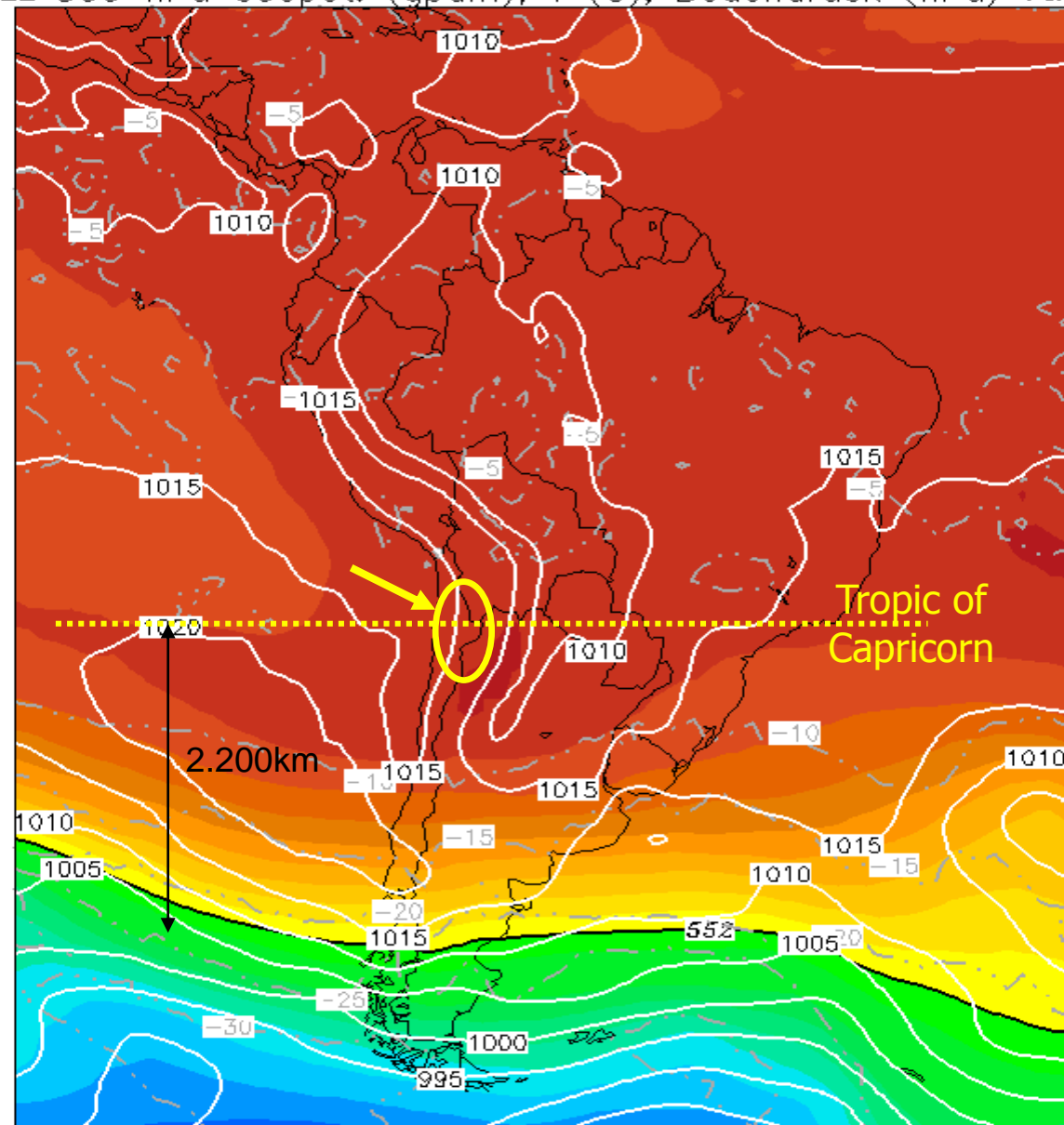
METEOROLOGICAL SUPPORT AND FORECAST

Almost non existing (except Skysight)

- NO historical data
- NO front passing at our latitude
- NO fast air flow
- NO change in 500 hPa geopotential (= ground)
- NO change in the sky at Calama (30 days blue sky)
- NO help from European meteorologists

After 3 weeks, we started to watch carefully at «*weak signals*» for westerly flows at all altitudes

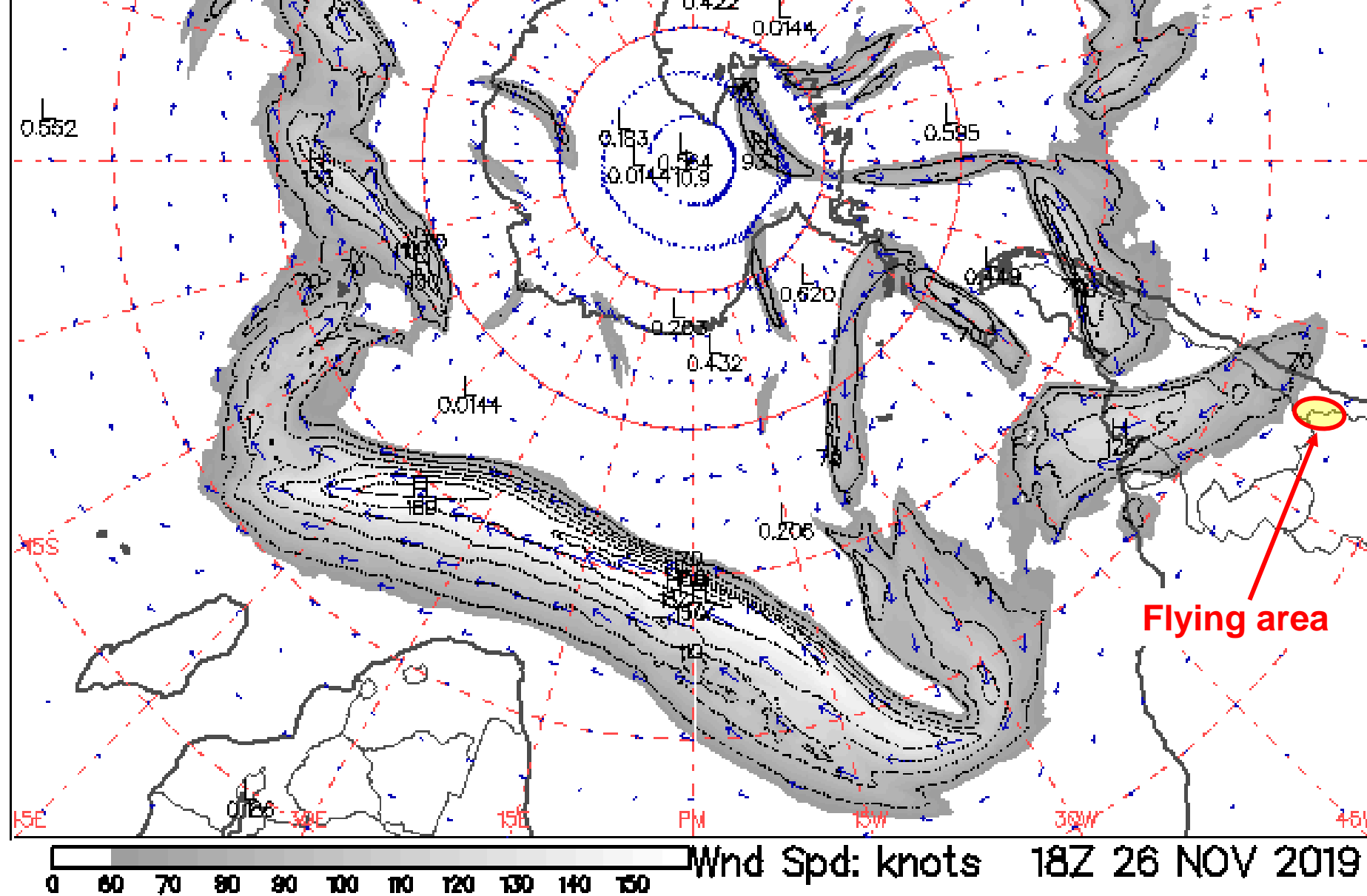
- Jet streams, far away to the South (500-1.000 km)
- The 500 hPa geopotential was unusable (ground altitude!)



Data: GFS OPERATIONAL 0.250°
(C) Wetterzentrale
www.wetterzentrale.de

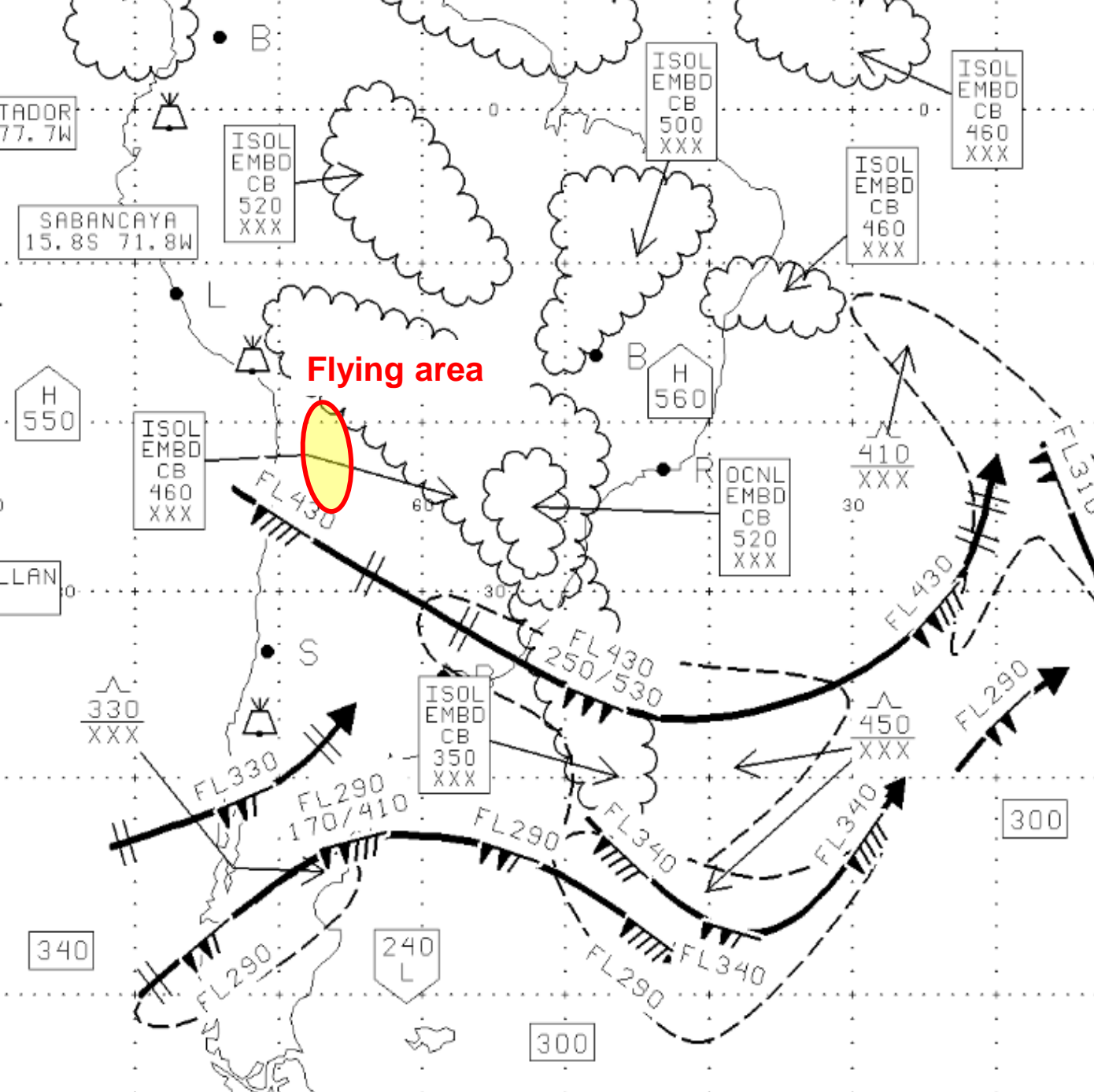


The 500 hPa map is of no use, always the same



Watching the jet streams, even far South (here 500 km)

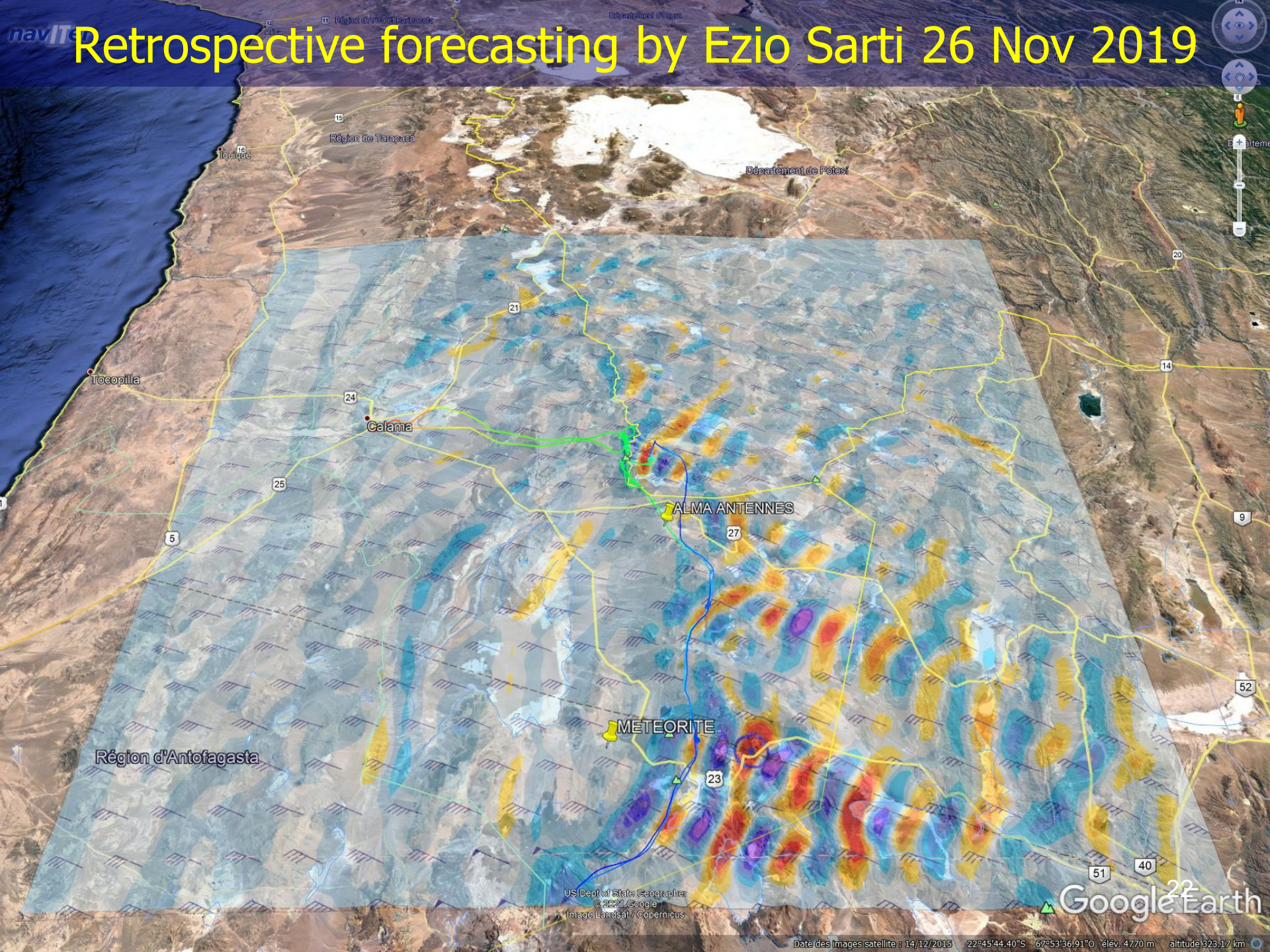
The SIGWX map was very useful to understand the global weather and the nearby jet streams

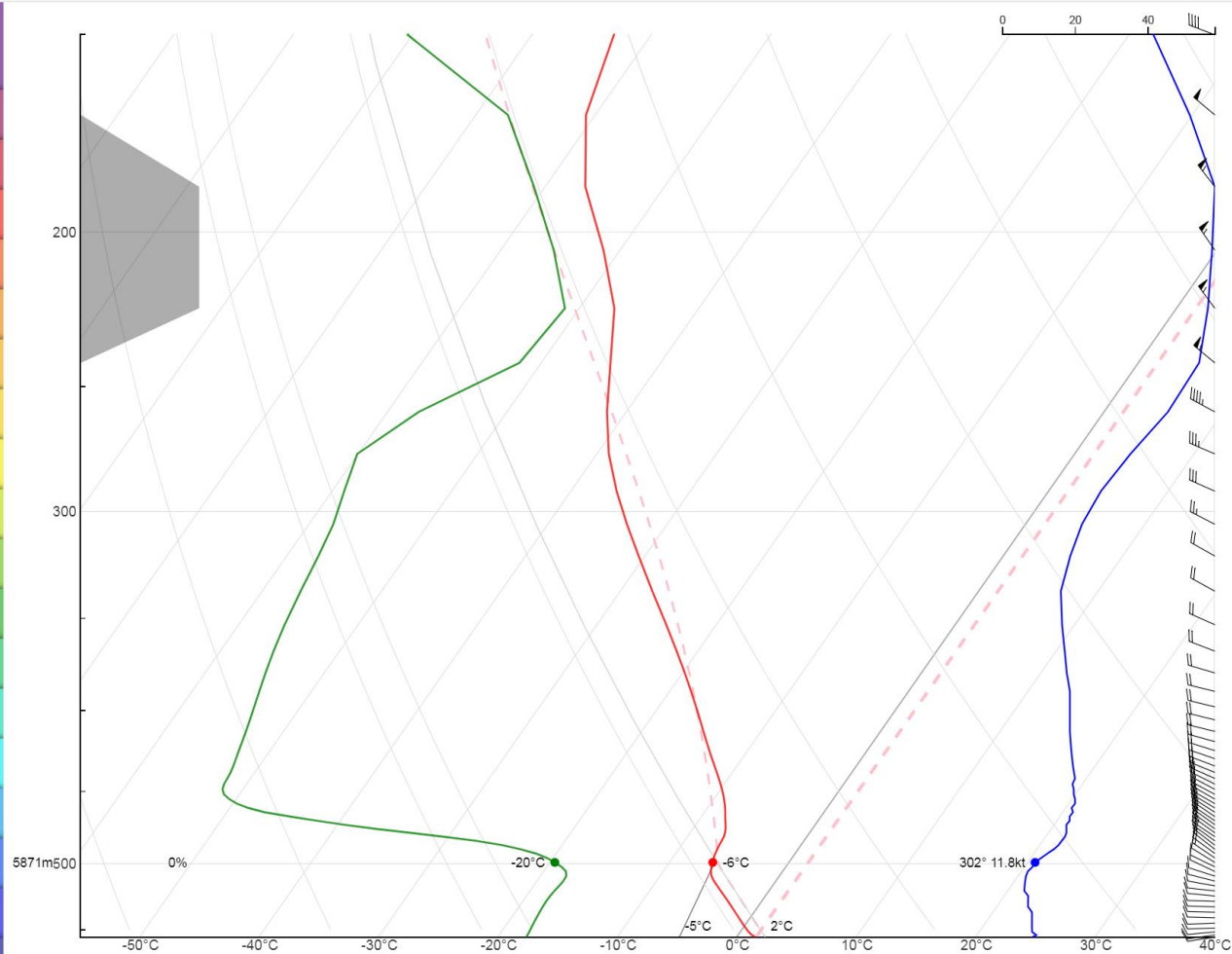
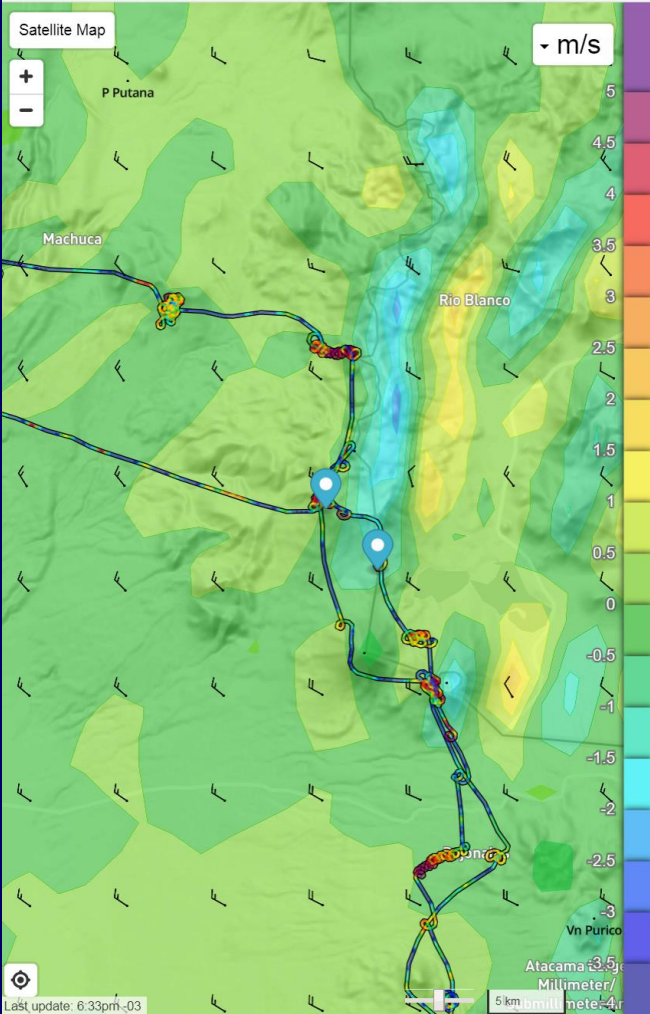


Retrospective forecasting (re-forecasting)

- Since I had no time and no tools to fully understand and forecast what was happening, Matthew Scutter (SkySight) first and Ezio Sarti later (MeteoWind) agreed to rebuild the GFS and WRF data base for the 6 most interesting days and make their software available for any post-flight analysis.
- Ezio, a professional meteorologist, was of great help in technical advising. See <http://www.meteowind.com/>

Retrospective forecasting by Ezio Sarti 26 Nov 2019





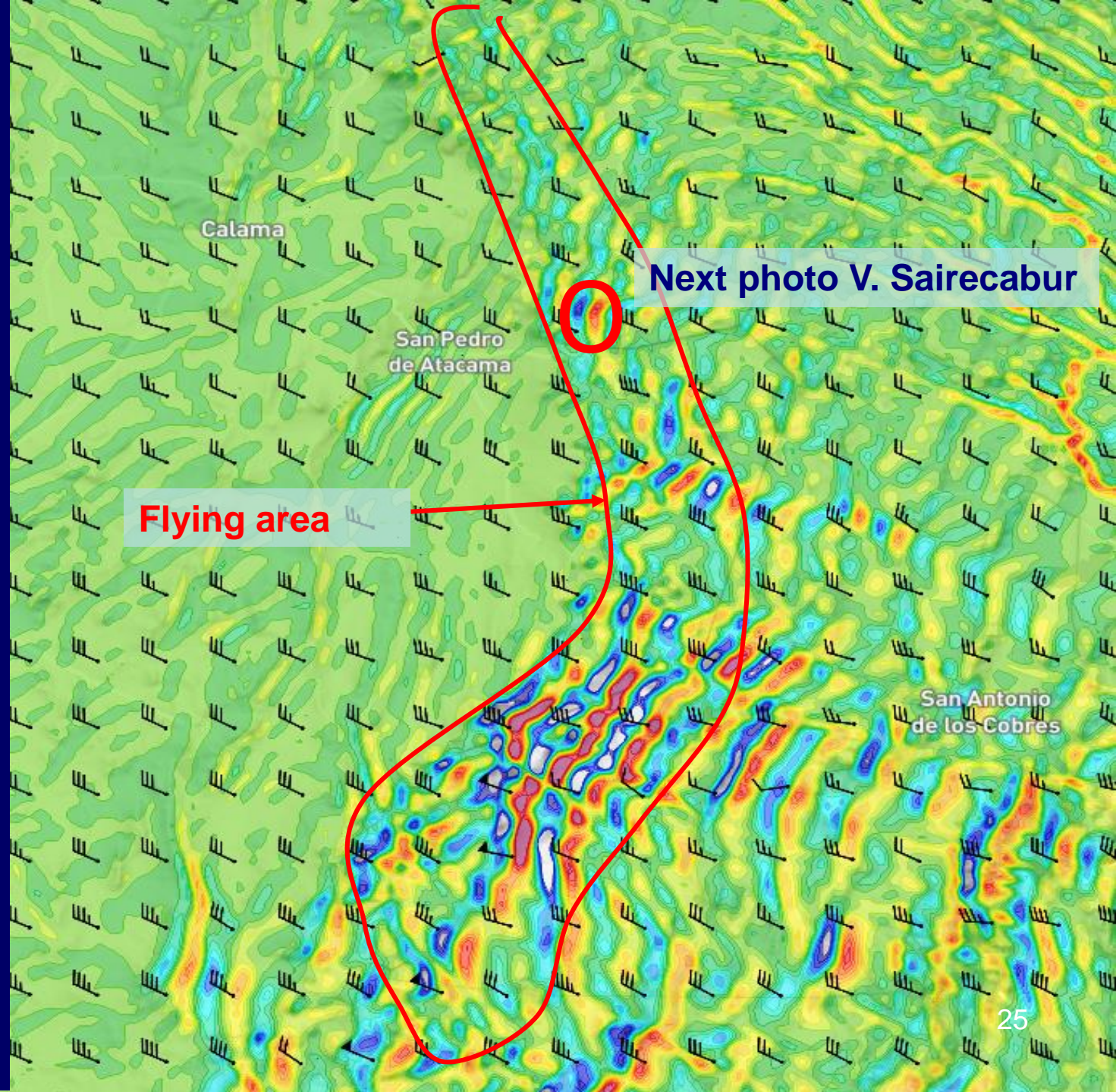
Re-forecasting by SkySight: no wave, 12 kt W-NW wind at 6.000m
 Observe the temperatures: totally wrong (never freezing)
 7 Nov. 2019

Nov 26th, SS shows forecast for wave

- Weak but present in the North (V. Sairecabur)
- Stronger in the South

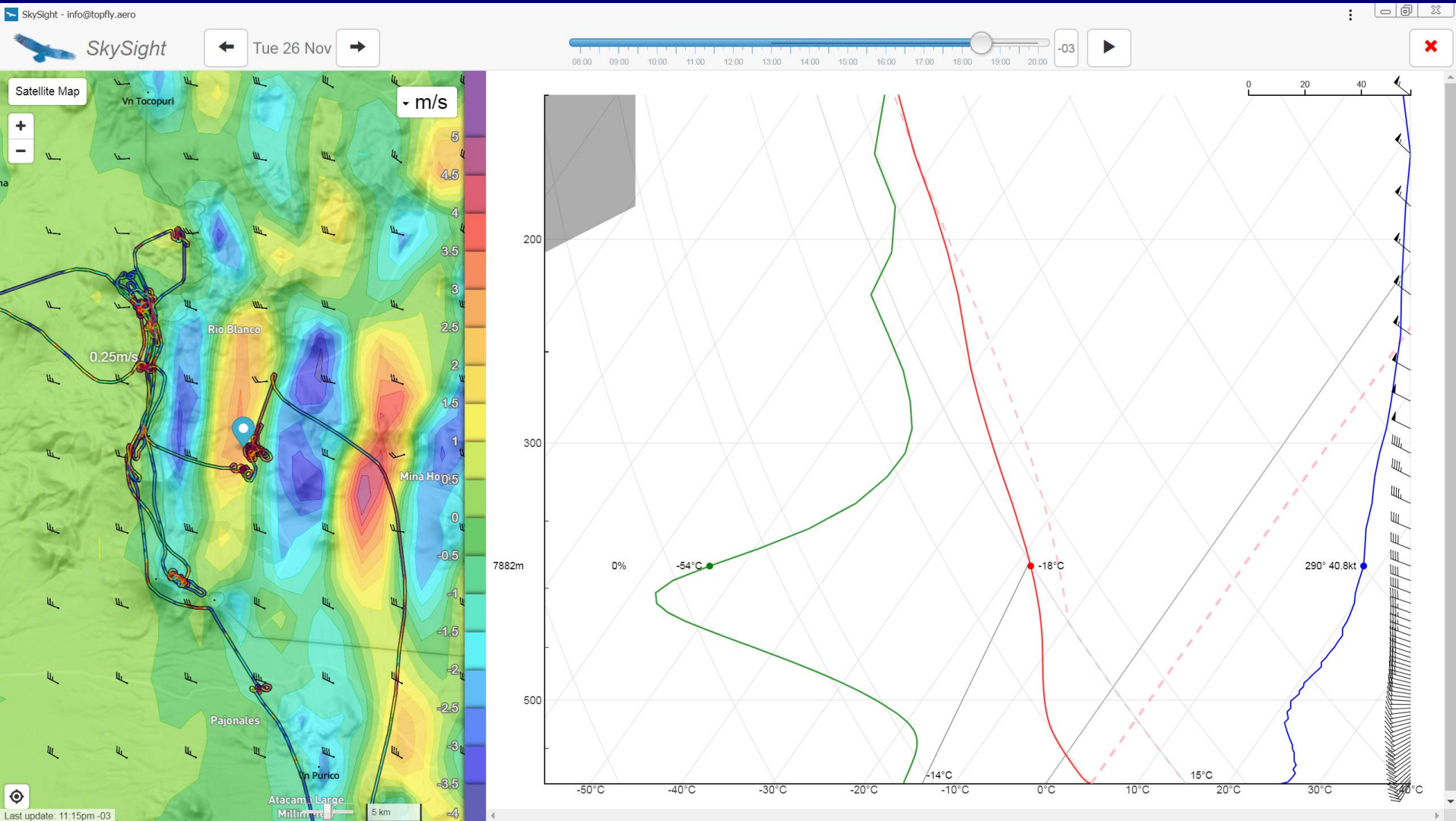
For wave,
SkySight was
always the
best option

Ex. 26 nov
@ 6.000 m
@ 2 pm



Nov 26th, SS shows forecast for wave

- Skew-T shows a very dry layer 5-9 km, then nearly saturated around 11 km, where lenticulars developed
- Temperature totally wrong, was 10-15°C higher



26 Nov 16:00 LT – Wave retrospective forecast by SS + Skewt-T

V. Sairecabur. Notice moisture stratified flow

Wind was true but temperatures 10°C higher.



Bingo! - V. Sairecabur Looking South @ 8.000 m

The local topography alone cannot justify such a huge oscillating system

26 Nov 16:11 LT

28



V. Sairecabur looking North @ 8.000 m

These “pseudo” lenticulars are typical of a hydraulic (Bidone’s) jump

26 Nov 15:55 LT



The higher we climb, the stronger the lift

7,6 m/s @ 8.048 m – Ending climb for safety reason (O₂)

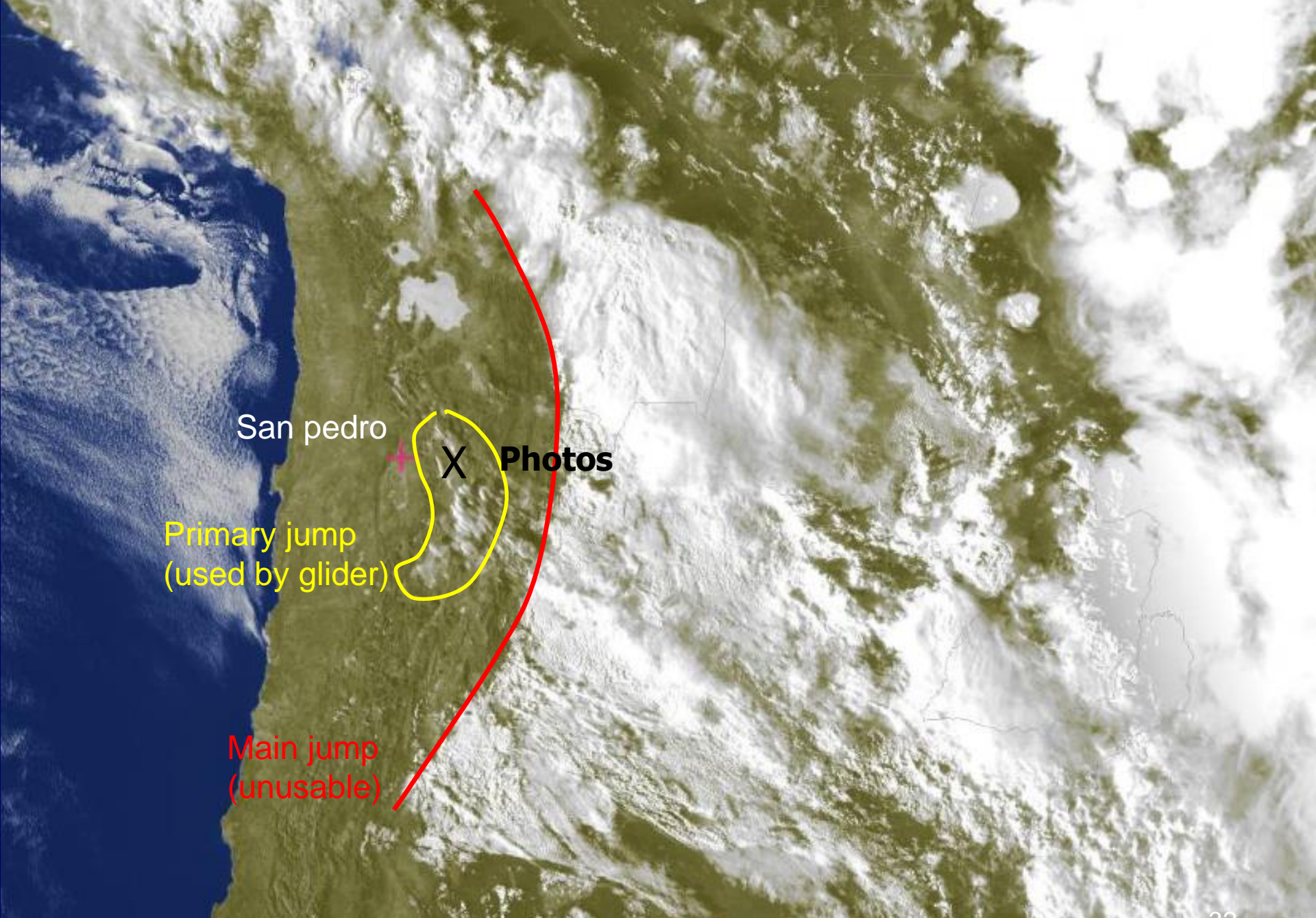
26 Nov 17:08 LT



Looking South @ 8.000 m

These “pseudo” lenticulars are typical of a hydraulic (Bidone’s) jump

26 Nov 18:11 LT



San pedro

X

Photos

Primary jump
(used by glider)

Main jump
(unusable)

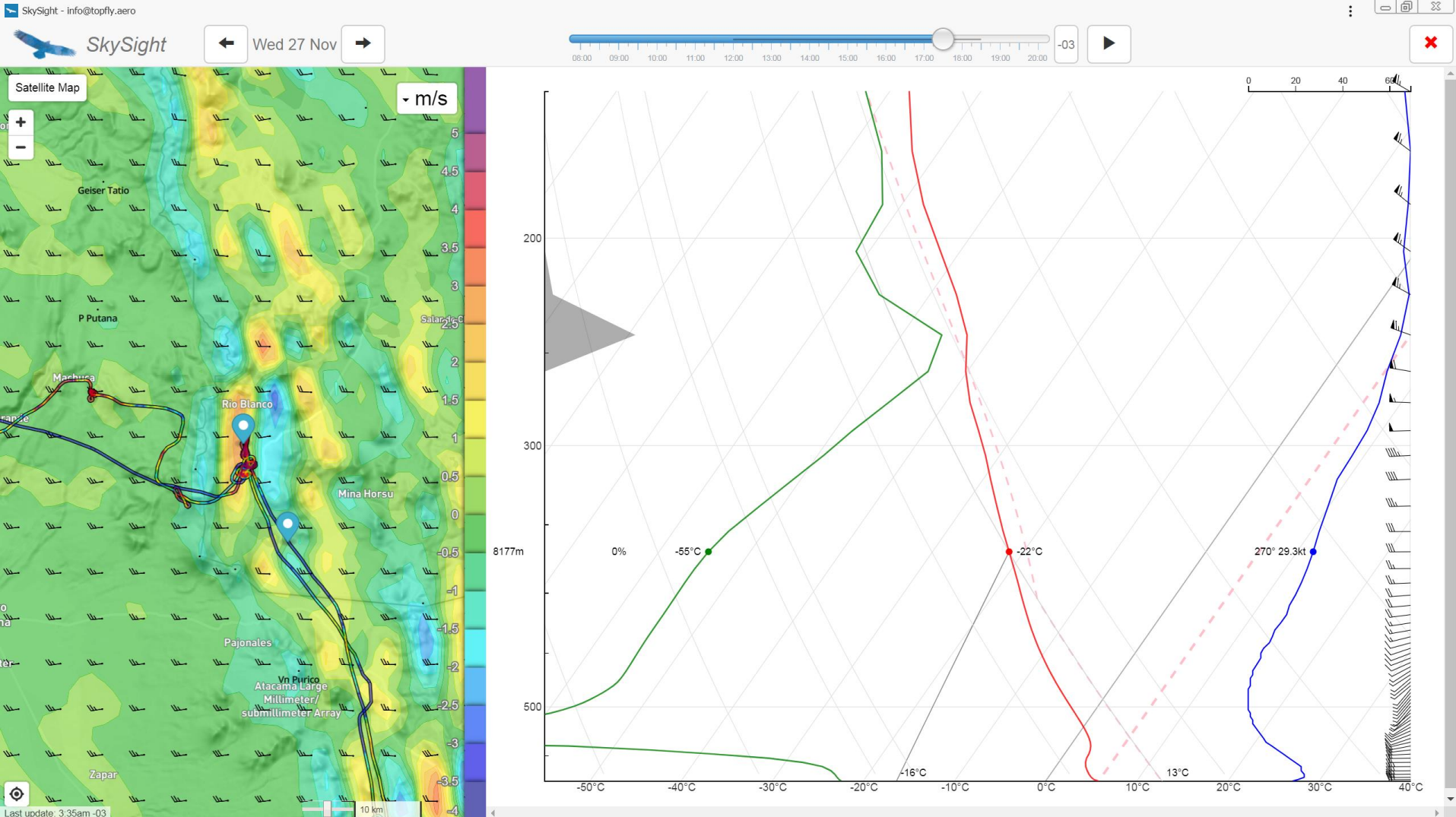


26 Nov 18:11 LT – The sky seen from San Pedro

Typical of a hydraulic (Bidone's) jump, likely generated from the "upwards step" (2.400 to 4.500 m abruptly), the stratified flow and the synchronism between the thermal breeze and the geostrophic wind

Nov 27th, SS shows forecast for wave

- SS shows weak waves along the volcanoes, which was true with increase strength with time, all in blue
- Skew-T shows a very dry layer 5-9 km, then nearly saturated around 11 km, where lenticulars developed
- Temperature at 8.000 m km was 13°C higher than forecast
- Found an interesting view mid afternoon

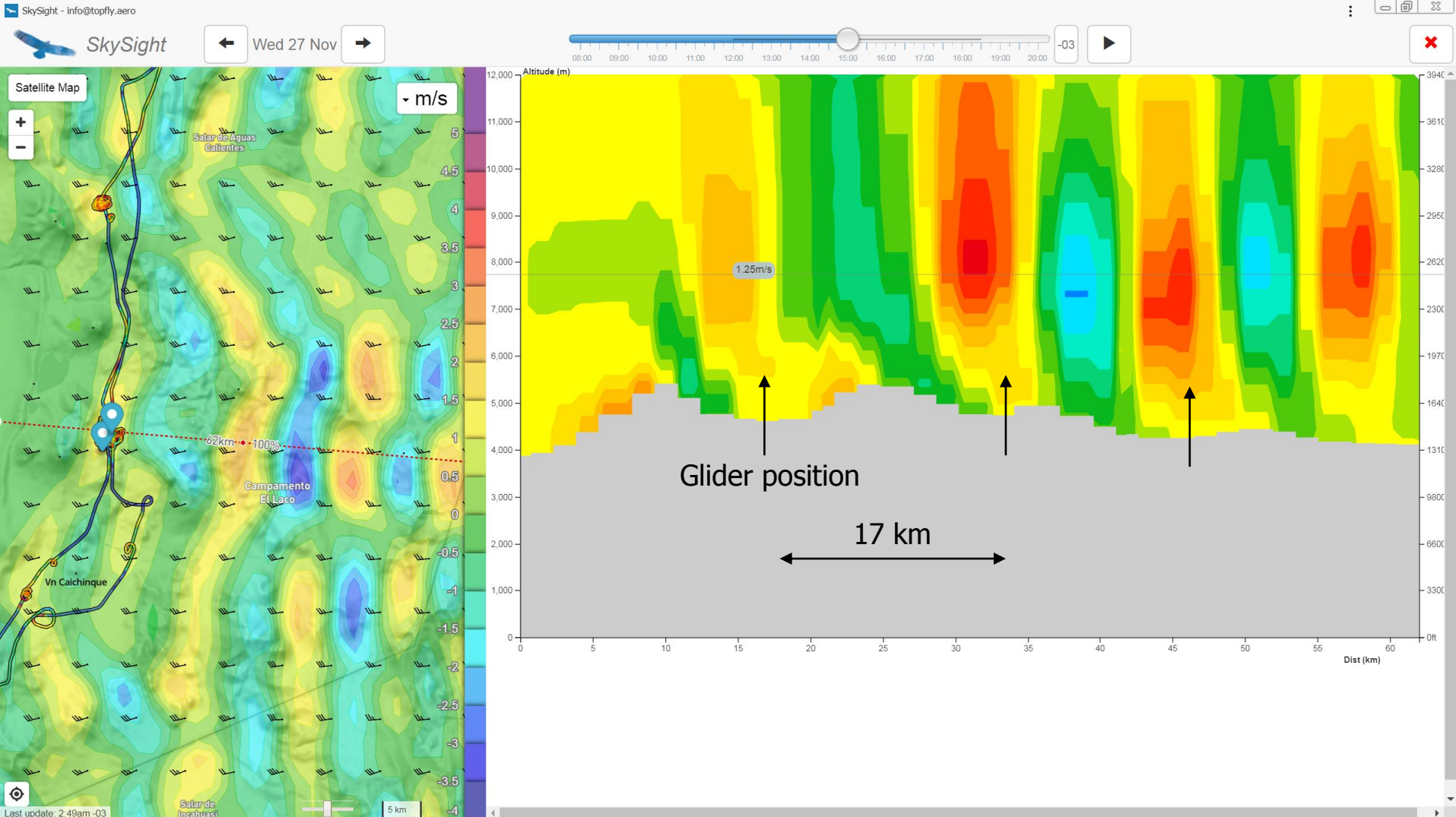




27 Nov 20:06 LT – close to ALMA @ 7.900 m

This jump is unreachable: too far away, not landable

We flew the whole afternoon in blue wave



27 Nov – Wave re-forecast by SS & cross section at the location of the photo

Notice lift was very weak at our location (1st rebound) and becomes usable 1.000-1.500 m AGL. Then increases significantly at 2nd, 3rd, 4th rebound.

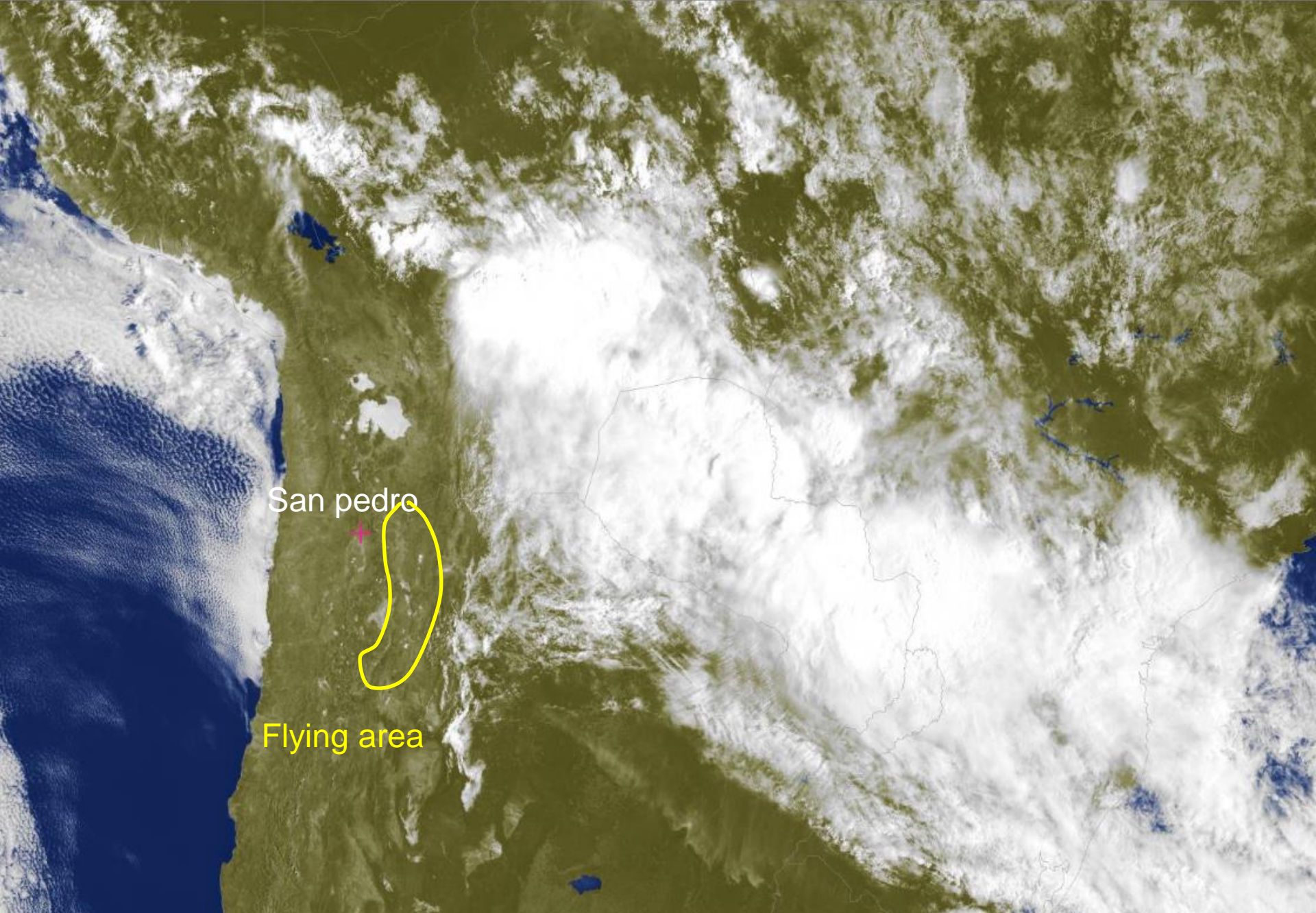


Salar

Altiplano

27 Nov 17:52 LT – Laguna Miscanti seen from 6.500 m

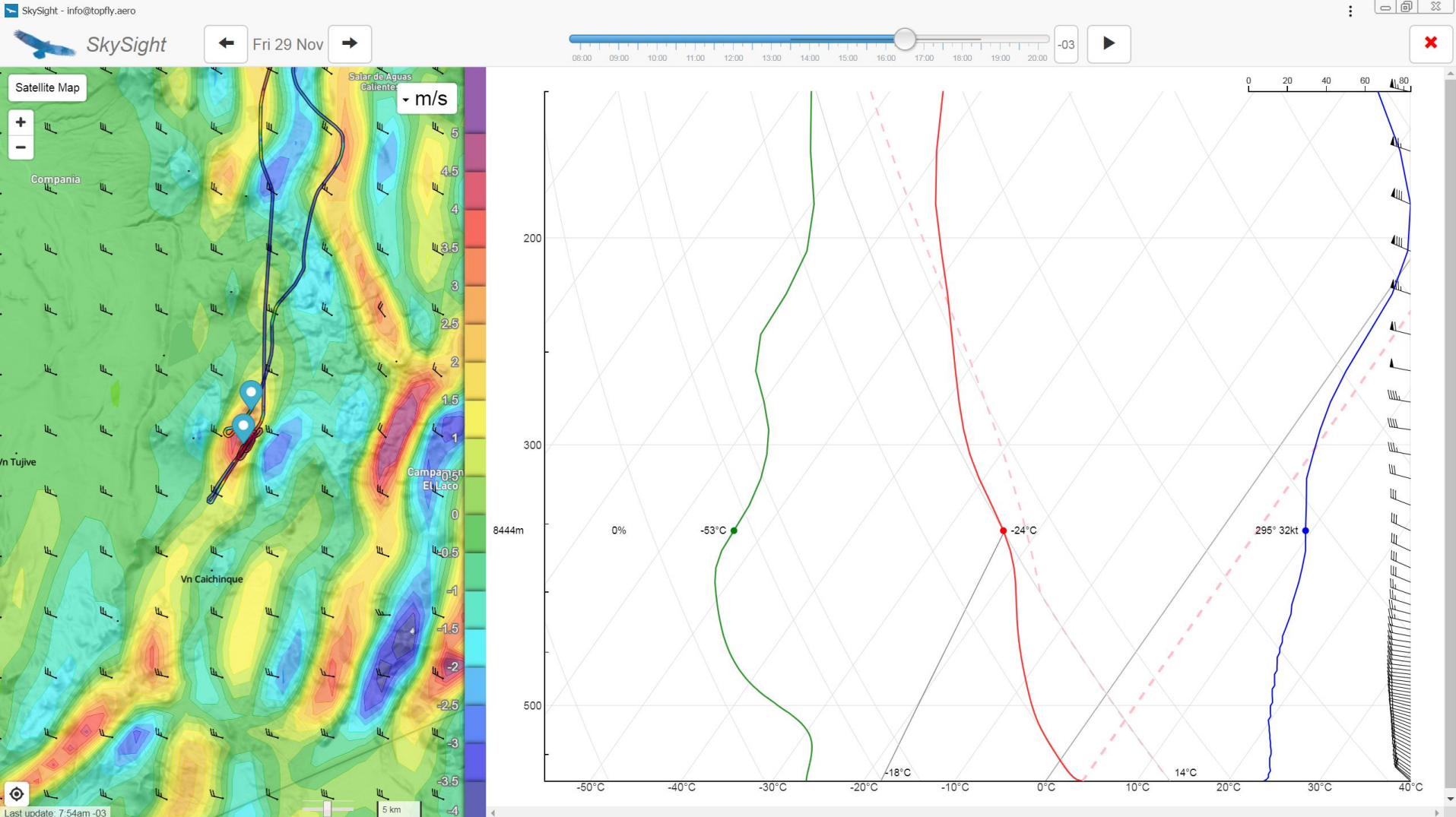
No cloud to the South, whole afternoon in blue wave, between 5.500 and 8.000 m (Altiplano is \approx 4.500 m, Salar \approx 2.400 m)



Sat view 27 Nov. Very few or unreachable clouds, South is blue

Nov 29th, SS shows also possible thermals

- SS shows weak thermals and waves. Difficult start, lift usable above 6.500 m, excellent at 7.000 m
- Skew-T shows does not show any peculiarity

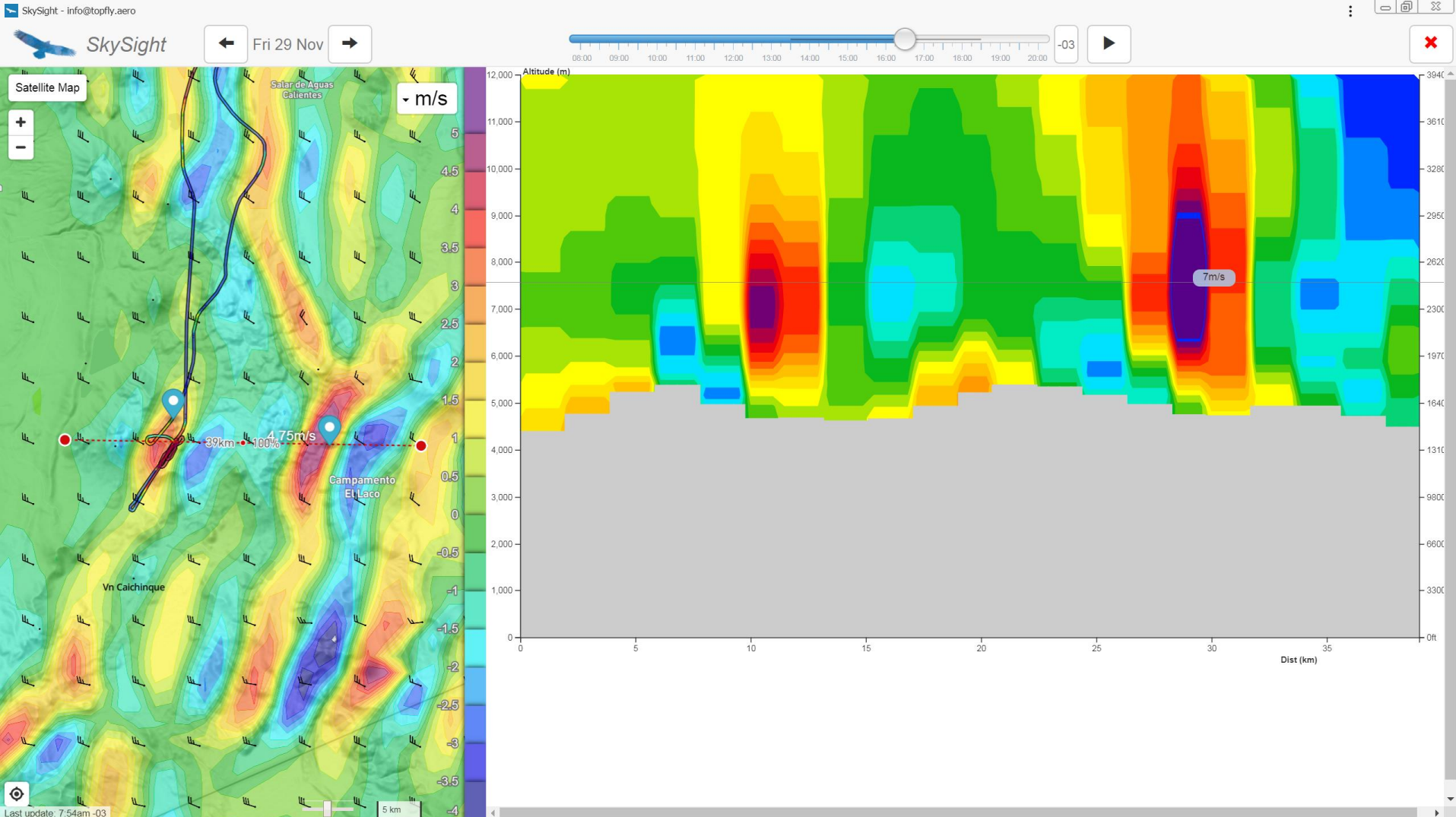


29 Nov 17:52 LT – SS re-forecasting Skew-T

No noticeable wind gradient nor stratified flow, actual wind 27 kt at 8.500 m
Actual temperature 11°C higher than forecast.

Nov 29th, SS shows interesting waves downwind

- Interesting climb 7 m/s 17 km downwind (unreachable)



29 Nov 17:52 LT – SS re-forecasting cross section

Notice how strong the 2nd rebound is

No cloud; the glider is at 8.500 m, in the blue, back home for lack of O₂

Dec 1st, expedition closed, no forecast, only re-forecast

- Had a farewell party in San Pedro with the S10, the sky came out gorgeous late afternoon. The ladies went up to the lennies.



1st Dec 16:22 LT

The sky from San Pedro when leaving the restaurant after the farewell party.

Gigantic hydraulic jump mixed together with single rebound waves



1st Dec 17:37 LT

Playing with the "rotor" (absolutely stable) at 6.800 m downwind of V.
Sairecabur. Wind increased from 12 kt @ 6.000 m up to 32 kt @ 7.000 m



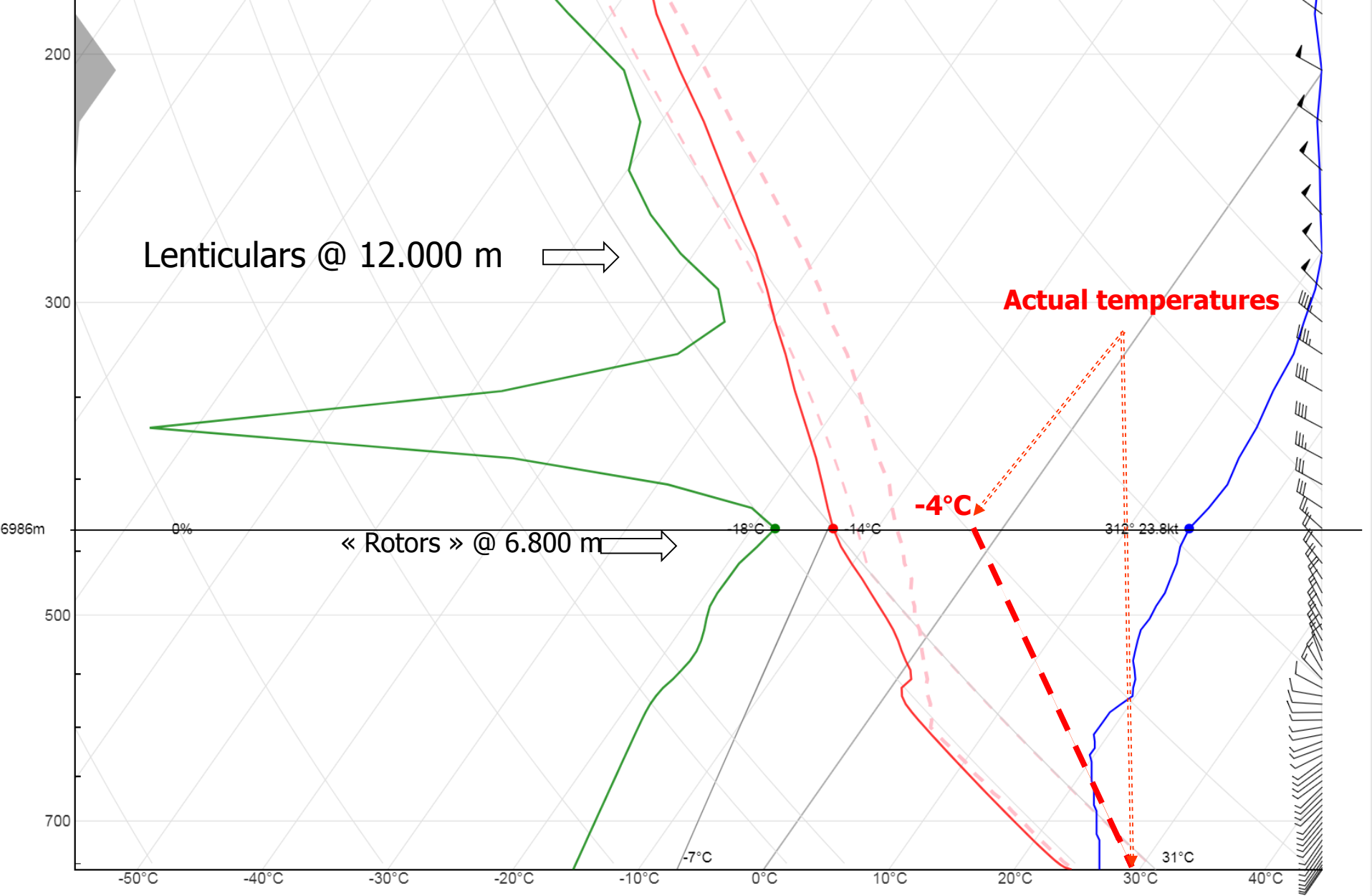
1st Dec, San Pedro

The tropical wave is extremely comfortable, no special dressing, no turbulence

My wife is very cautious but she enjoyed 7.000 m in short sleeves

Dec 1st, expedition closed, no forecast, only re-forecast

- Skew-T shows a stratified dry layer 7.000-9.000 m, with nearly saturation above 9.000 m
- No significant wind gradient 20 kt up to 7.000m, no wind on the ground
- Temperature was $\approx 0^{\circ}\text{C}$ @ 7.000 m against -12°C forecast



SS re-forecasting 1st Dec. 16h43 – Notice strong stratification at rotor altitude, high moisture at lenticulars altitude. Notice extreme stability and high temp.

Peculiarities of the tropical gravity wave and jump

1. The convergence lift works with very weak wind, not even sufficient to produce a ridge lift.

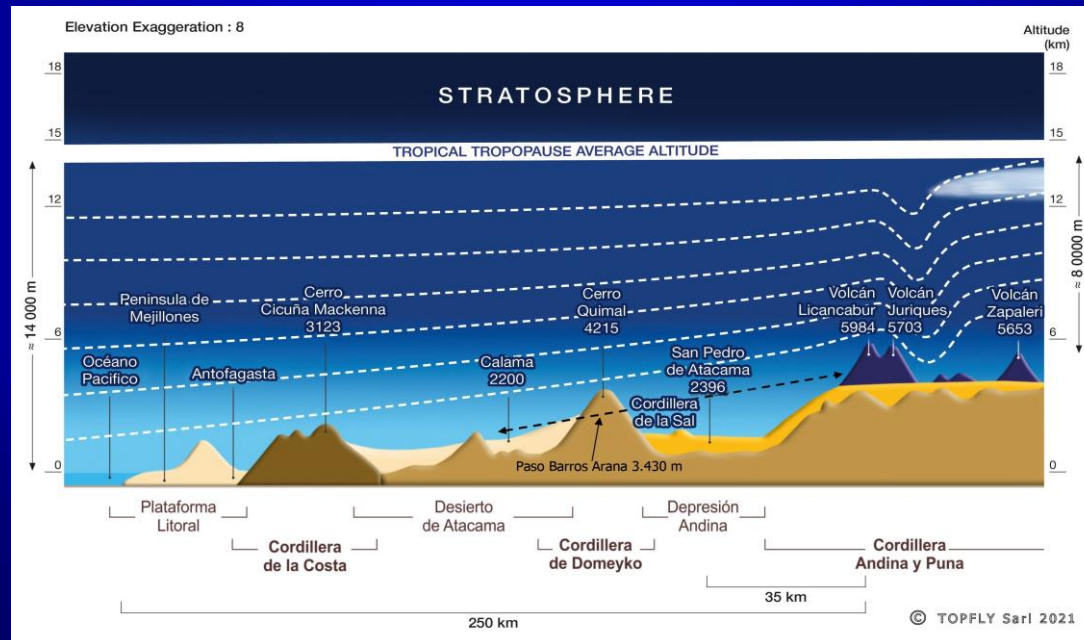
It happens every time the geostrophic wind is aligned with the breeze.

But never continued above the top of the mountain, never converted into «wake wave» as in Argentina

Peculiarities of the tropical gravity wave and jump

2. The jump seems to be triggered by the positive «altiplano step», which is reversed respect to what we know from US and EUR.

Is the «altiplano» creating a supercritical flow (Froude $Nr > 1$) just after the step?





Satellite modified view of the tropical Andes, volcanoes area

Peculiarities of the tropical gravity wave and jump

3. The conventional single rebounds show a lift value that increases with the altitude, contrary to usual US and EUR situations.

Is the «positive step» generating a compression induced stability, which in turn helps the oscillation of the airmass?

Peculiarities of the tropical gravity wave and jump

4. It has not been possible to forecast the presence of «rotors», which were free of any turbulence and did not look like «rotating rotors», but just cumulus.

Why?

Peculiarities of the tropical gravity wave and jump

5. Actual temperatures were always 11-14°C higher than the sounding. Why?
- Compression from the «altiplano step», 40% reduction in section?
 - Overheating due to 250 km travelling over the desert?

Peculiarities of the tropical gravity wave and jump

6. Actual QNH in Calama APT has always been 10-14 hPa higher than the GFS or WRF data base. Why?

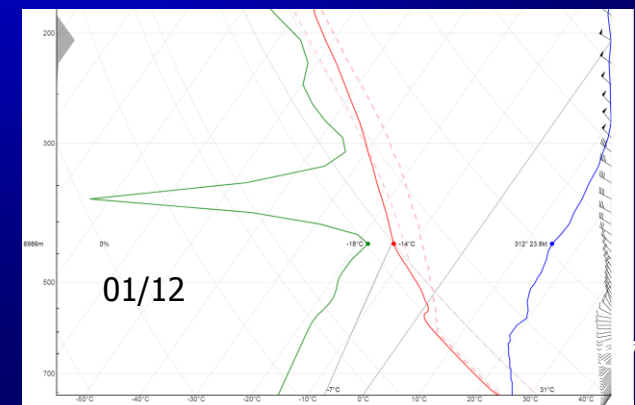
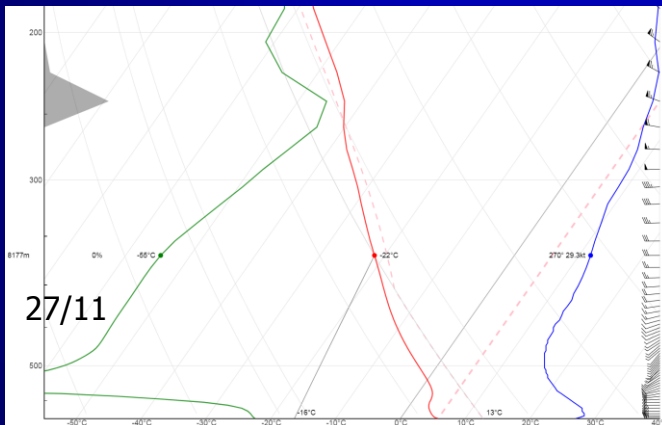
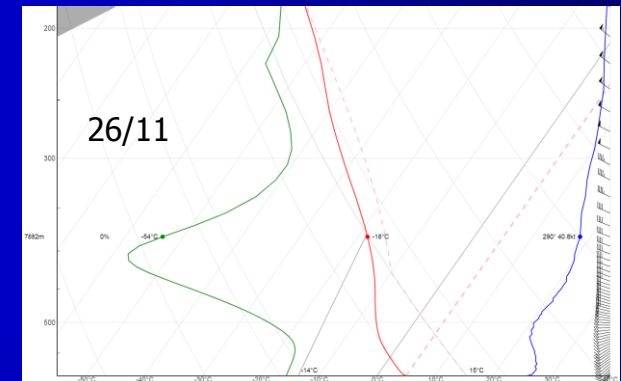
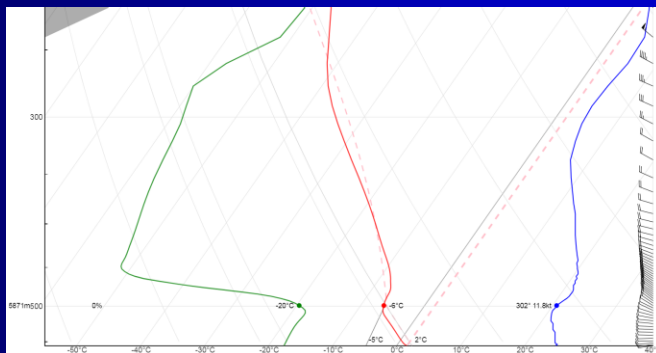
Compression from the «altiplano step» is unlikely since it happened also with easterly downward breeze or days with Bolivian winter (East wind at all altitudes).

Is there a problem with the model, such as the lack of good initial data (unlikely)?

Peculiarities of the tropical gravity wave and jump

7. Were moisture stratified flows a major factor for the presence of waves and jumps? See works of Laurence Armi (<https://larmi.scrippsprofiles.ucsd.edu/>)

07/11



And now?

Organizing an other campaign means:

- Bolivian clearance up to FL340
- Oxygen pressurized breathing
- Turbocharged selfLauncher or tow
- Securing San Pedro airstrip
- Support from Int'l scientific body

and \$\$\$\$!

More info @

www.topfly.aero

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|

THANK YOU



FOR YOUR ATTENTION