Segelflugmessungen im Lee der Anden

Andreas Dörnbrack, and many contributors from various institutions
Institut für Physik der Atmosphäre, DLR Oberpfaffenhofen, Germany

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Fotos mit Manfred E. Reinhardt (MER) aus vier Jahrzehnten

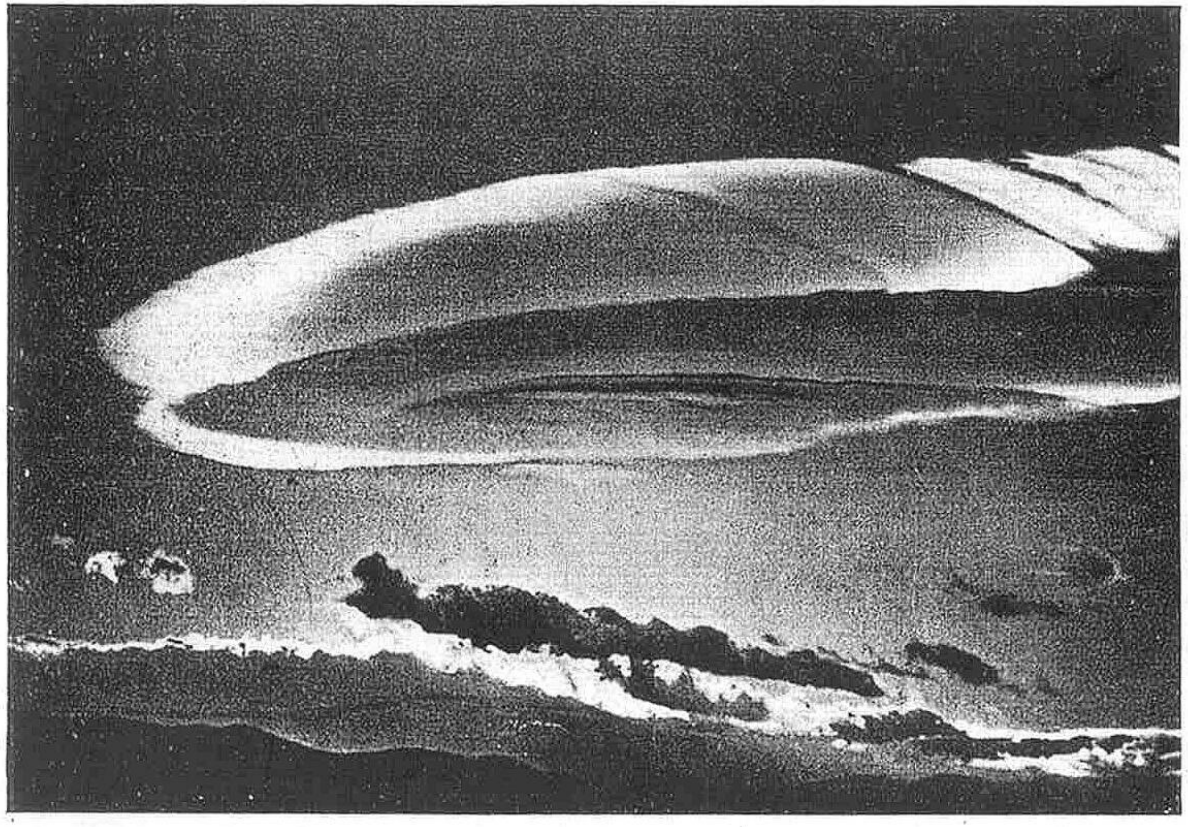
Obere Zeile: Links: OSTIV Panel bei DLR-IPA, 1989 (vorne Mitte: Charles E. Wallington, Joachim P. Kuettner [JPK], MER); Rechts: Französisches Forschungsflugzeug mit Kollegen in Oberpfaffenhofen (Anfang 1980er Jahre);
Mittlere Zeile: MER in und auf dem IPA-Gebäude (von links nach rechts): Als aufmerksamer Zuhörer im Seminarraum (2.2.2007); mit JPK auf der Radar-plattform (Ende 1980er Jahre); mit typischem Lächeln; gelöst im IPA-Foyer im Kreis früherer Mitarbeiter und mit seiner Frau Renate (2.2.2007);
Untere Zeile: MER und Ulrich Schumann (US; von links nach rechts): Gegen Ende der aktiven Zeit (Dez. 1991 - Hans-Jürgen Bolle, Hans-Walter Georgii, MER, Walter Kröll, US); die IPA Ko-Direktoren auf dem Petersberg bei Bonn (Nov. 1990); 50 a IPA mit Dokumenten im Hangar (29.6.2012).

https://elib.dlr.de/100180/

Segelflugmessungen im Lee der Anden

Andreas Dörnbrack, and many contributors from various institutions

Institut für Physik der Atmosphäre, DLR Oberpfaffenhofen, Germany



Das Moazagotl des Riesengebirges, fotografiert am 11. Dezember 1936. Blick von Grunau nach Süden der Strömung entgegen . Die mehrfache Schichtung und die laminare Wellenstruktur der *Lenticularis* Wolke sind erkennbar; darunter die Föhnmauer und die in der Wirbelwalze durch starke Turbulenz zerrissenen *Cumuli fracti* (aus: KÜTTNER, 1938).

Bundesarchiv, Bild 102-11940
Foto: o.Ang. | Juni 1931

Wolfgang Hirth - German gliding pioneer and sailplane designer, 1931 Grunau Selesia

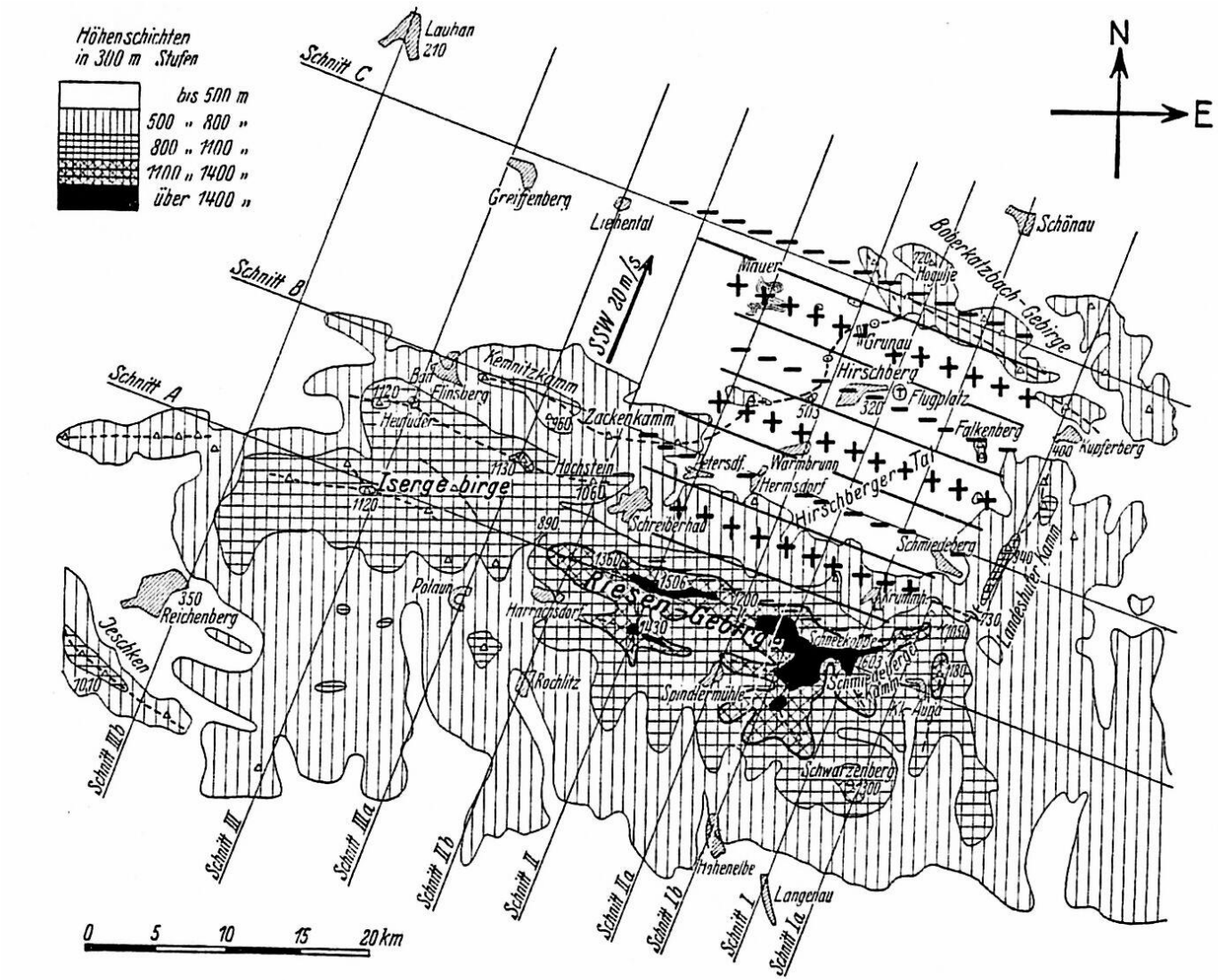
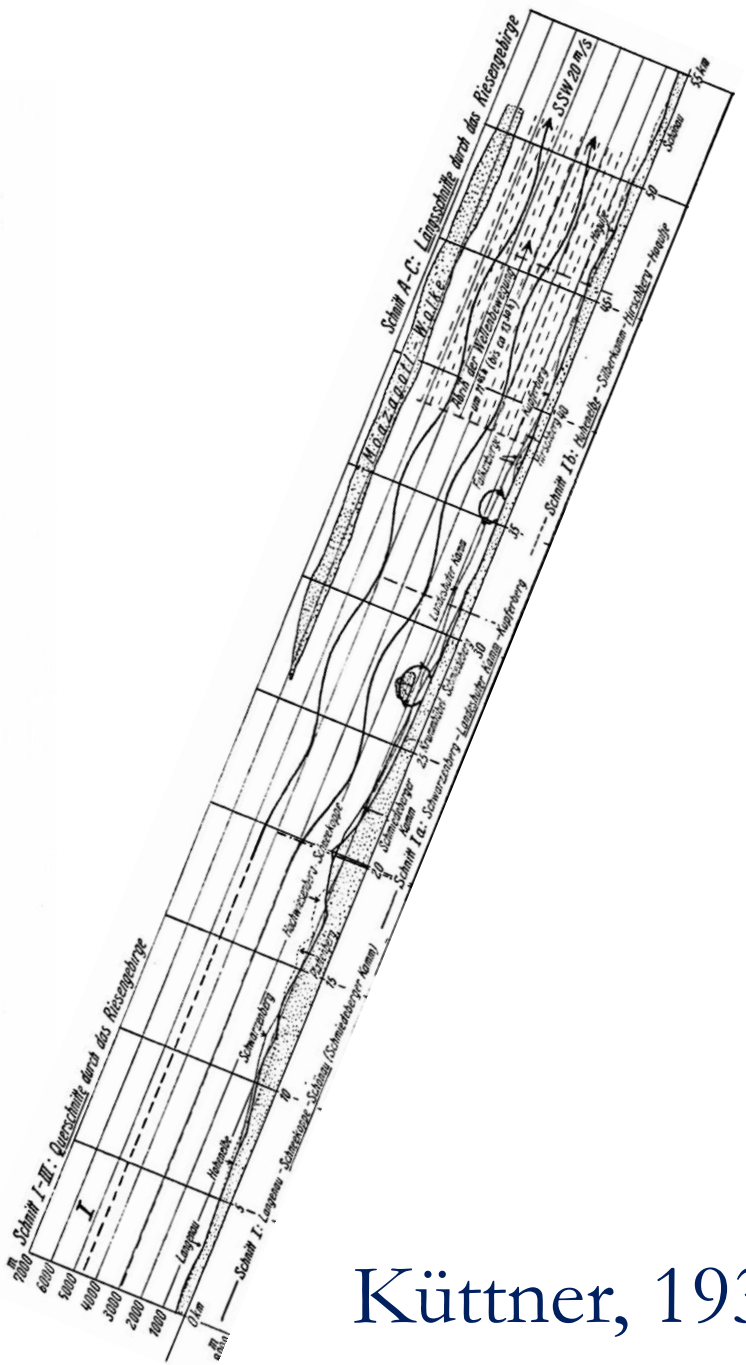


Fig. 32. Grundriß zu Fig. 31, 21. Mai 1937, vormittags.

Pluszeichen: [illegible] aufsteigender Luftbewegung. Minuszeichen: Gebiete absteigender Luftbewe[illegible]



Küttner, 1938

Airborne Measurements over the Southern Andes

Andreas Dörnbrack, and many contributors from various institutions

Institut für Physik der Atmosphäre, DLR Oberpfaffenhofen, Germany

Results based on:

Dörnbrack, A., Kaifler, B., Kaifler, N., Rapp, M., Wildmann, N., Garhammer, M., Ohlman, K., Payne, J., Sandercock, M., and E. Austin, 2020: Unusual appearance of mother-of-pearl clouds above El Calafate, Argentina (50° 21' S, 72° 16' W). **Weather**, **75**, 378-388. https://doi.org/10.1002/wea.3863

Wildmann, N., R. Eckert, A. Dörnbrack, S. Gisinger, M. Rapp, K. Ohlmann, A. van Niekerk, 2021: In-situ measurements of wind and turbulence by a motor glider in the Andes. *J. Atmos. Ocean. Techn.*, **38**, 921-935; https://doi.org/10.1175/JTECH-D-20-0137.1

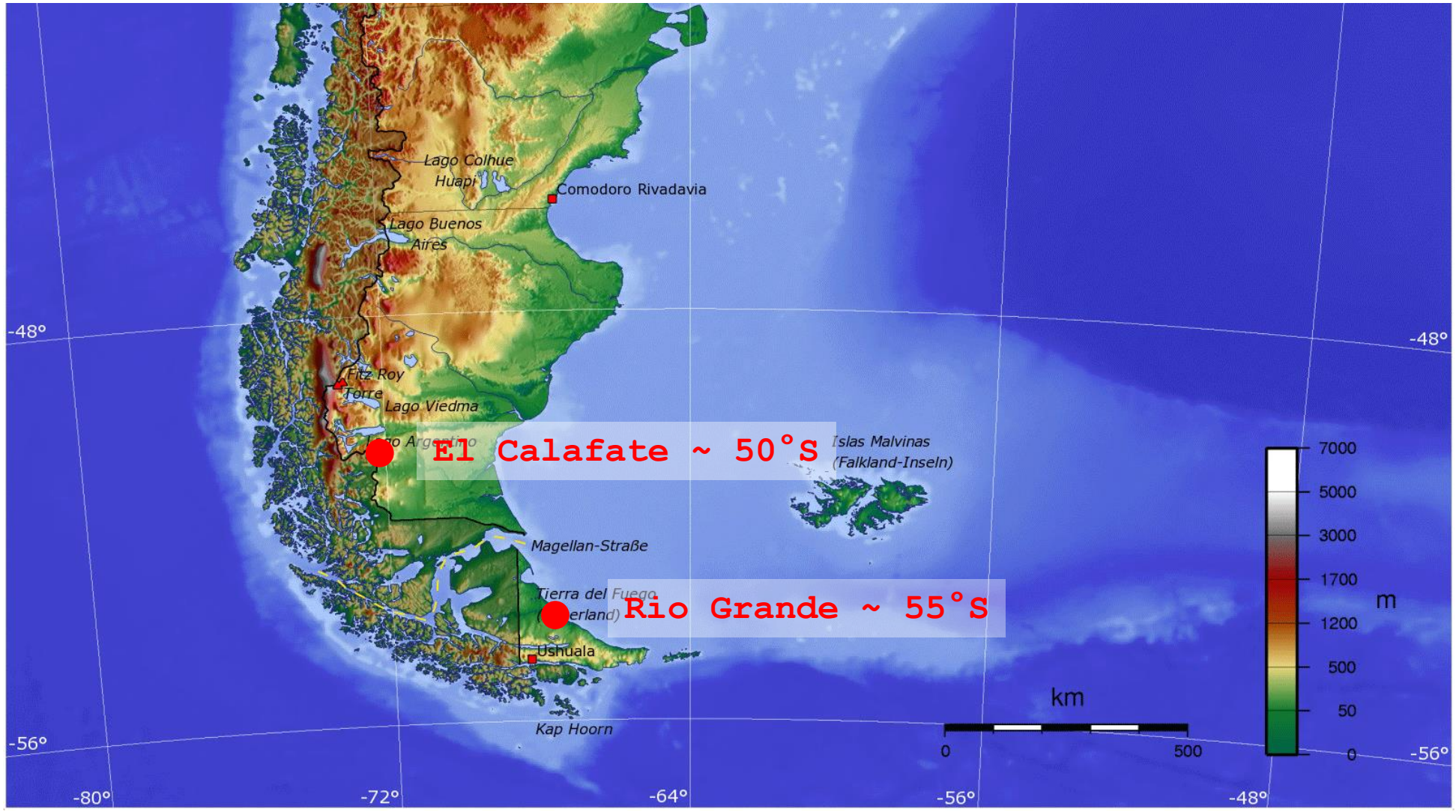
Rapp, M., B. Kaifler, A. Dörnbrack, S. Gisinger, T. Mixa, R. Reichert, N. Kaifler, S. Knobloch, R. Eckert, N. Wildmann, A. Giez, L. Krasauskas, P. Preusse, M Geldenhuys, W. Woiwode, F. Friedl-Vallon, B.-M. Sinnhuber, A. de la Torre, P. Alexander, J. L. Hormaechea, D. Janches, M. Garhammer, J. L. Chau, J. F. Conte, P. Hoor, and A. Engel, 2021: SOUTHTRAC-GW: An airborne field campaign to explore gravity wave dynamics at the world's strongest hotspot. *Bulletin of the American Meteorological Society*, **102**, E871-E893. https://journals.ametsoc.org/view/journals/bams/102/4/BAMS-D-20-0034.1.xml

Dörnbrack, A., P. Bechtold, and U. Schumann, 2022: High-resolution aircraft observations of turbulence and waves in the free atmosphere and comparison with global model predictions. *Journal of Geophysical Research: Atmospheres*, **127**, e2022JD036654. https://doi.org/10.1029/2022JD036654

SOUTHTRAC:

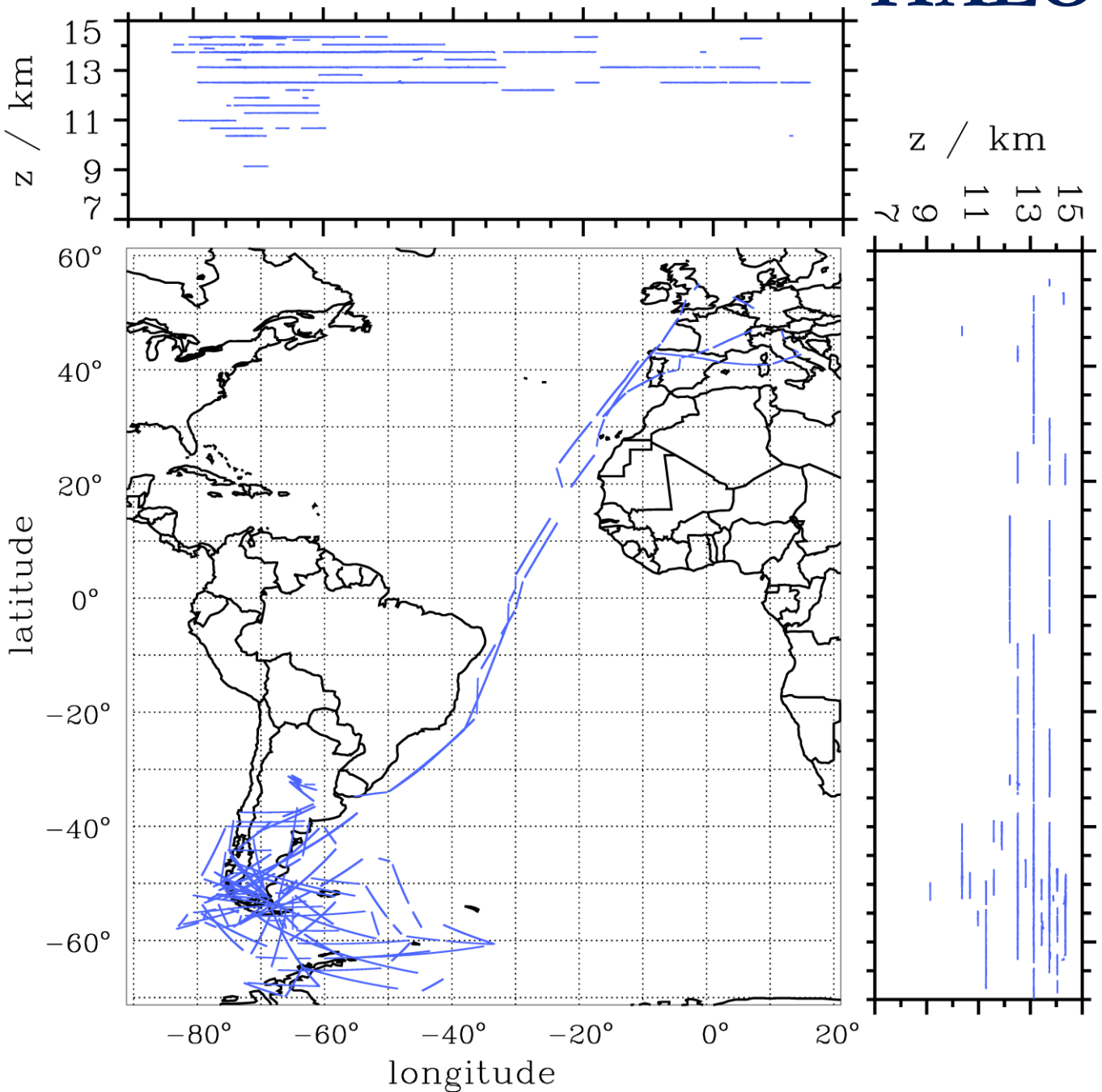
Southern Hemisphere Transport, Dynamics, and Chemistry

The Physical Scenery



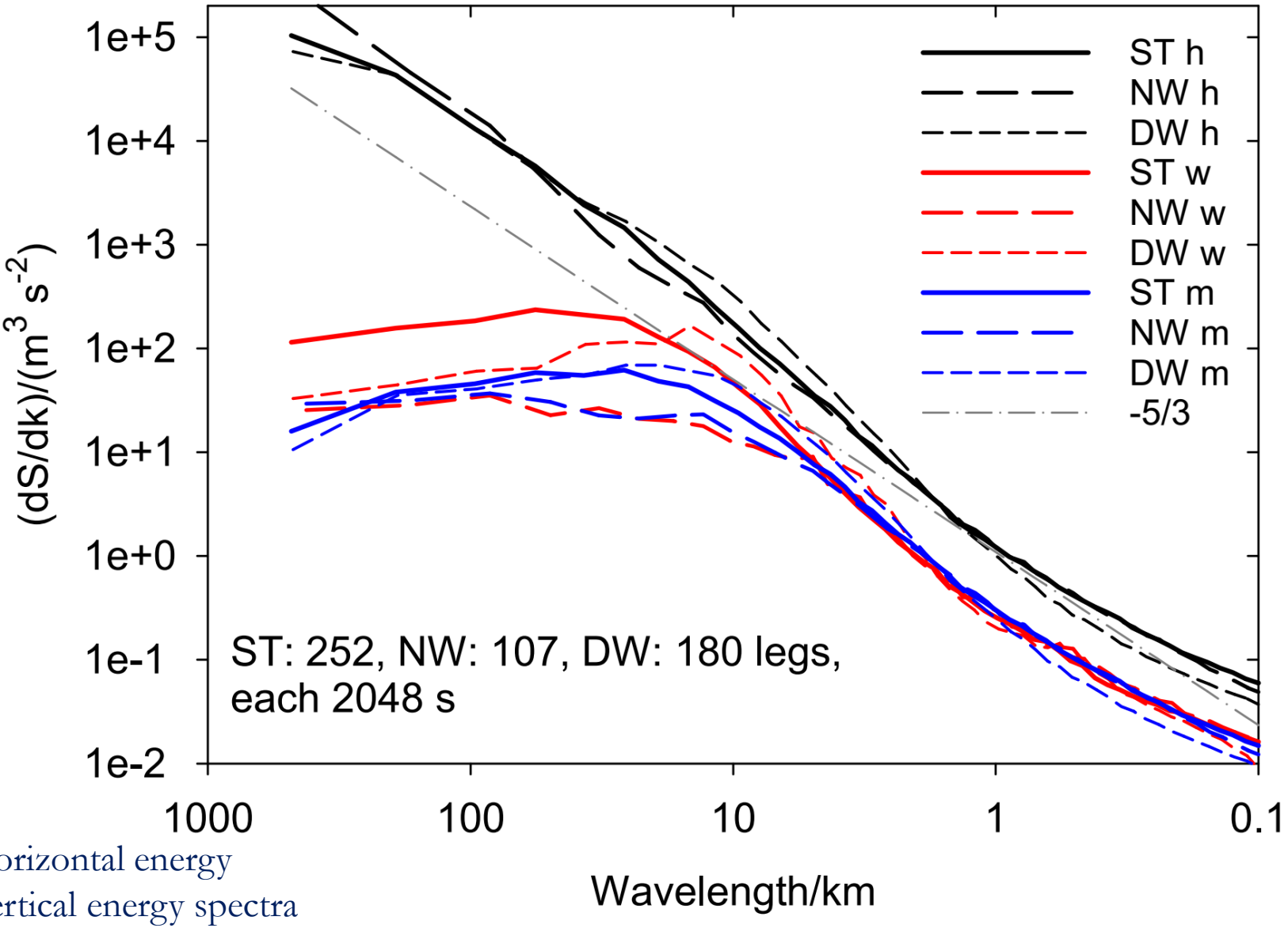
The Aerial Scenery

HALO Research Flights



Dörnbrack, A., P. Bechtold, and U. Schumann, 2022: High-resolution aircraft observations of turbulence and waves in the free atmosphere and comparison with global model predictions. *Journal of Geophysical Research: Atmospheres*, **127**, e2022JD036654. https://doi.org/10.1029/2022JD036654

Mean spectra of kinetic energy



ST SOUTHTRAC 2019

NW NAWDEX 2016

DW DEEPWAVE 2014

"h" horizontal energy

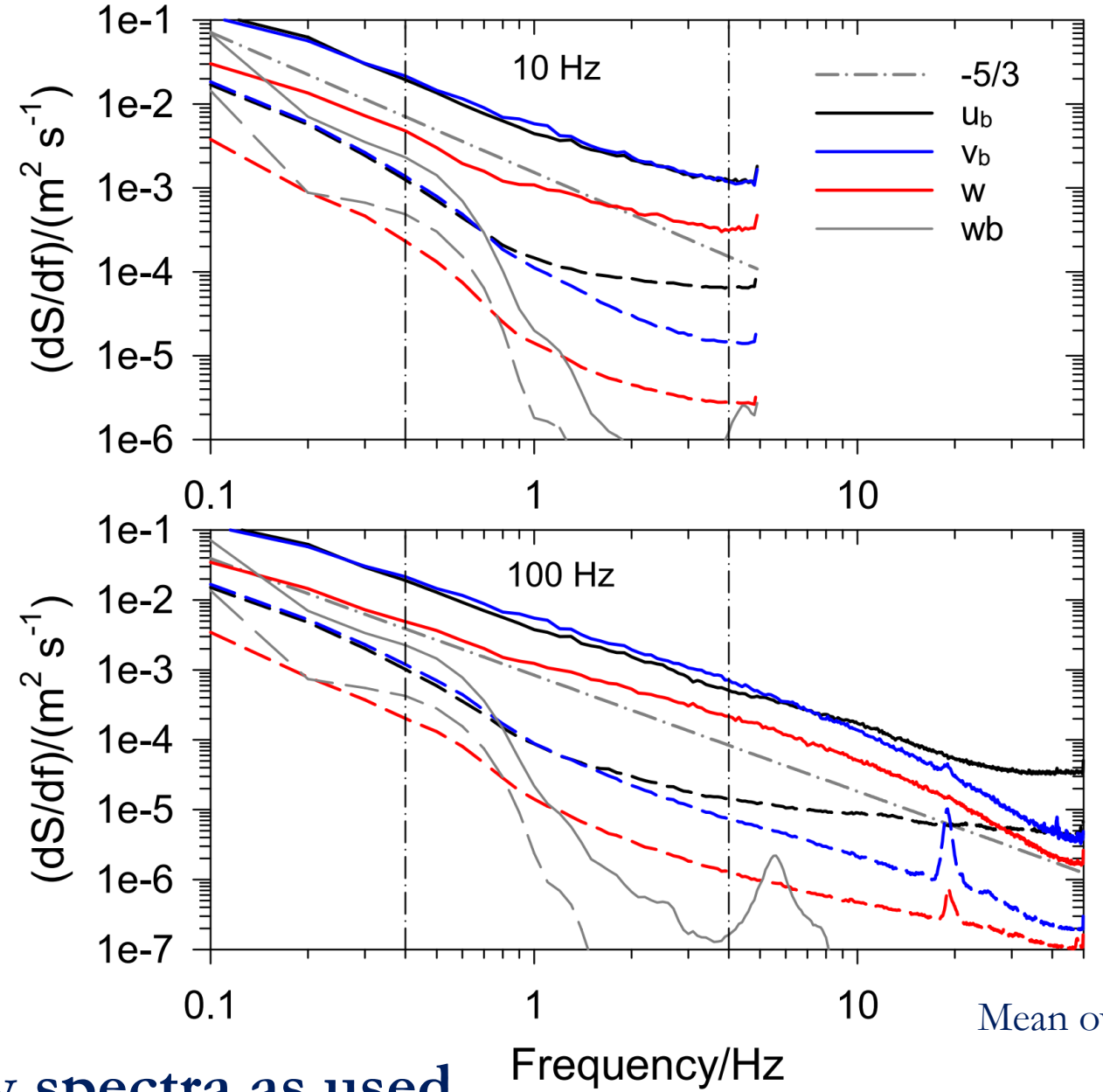
"w" vertical energy spectra

"m" model as introduced in Eq. (7) by Schumann, U. (2019): The Horizontal Spectrum of Vertical Velocities near the Tropopause from Global to Gravity Wave Scales, *Journal of the Atmospheric Sciences*, **76**(12), 3847-3862.

Dörnbrack, A., P. Bechtold, and U. Schumann, 2022: High-resolution aircraft observations of turbulence and waves in the free atmosphere and comparison with global model predictions. *Journal of Geophysical Research: Atmospheres*, **127**, e2022JD036654. https://doi.org/10.1029/2022JD036654

$$S_i(k) = C_i\ \varepsilon_i^{2/3}\ k^{-5/3}$$

$$k = 2\pi\ f\ /\ TAS$$



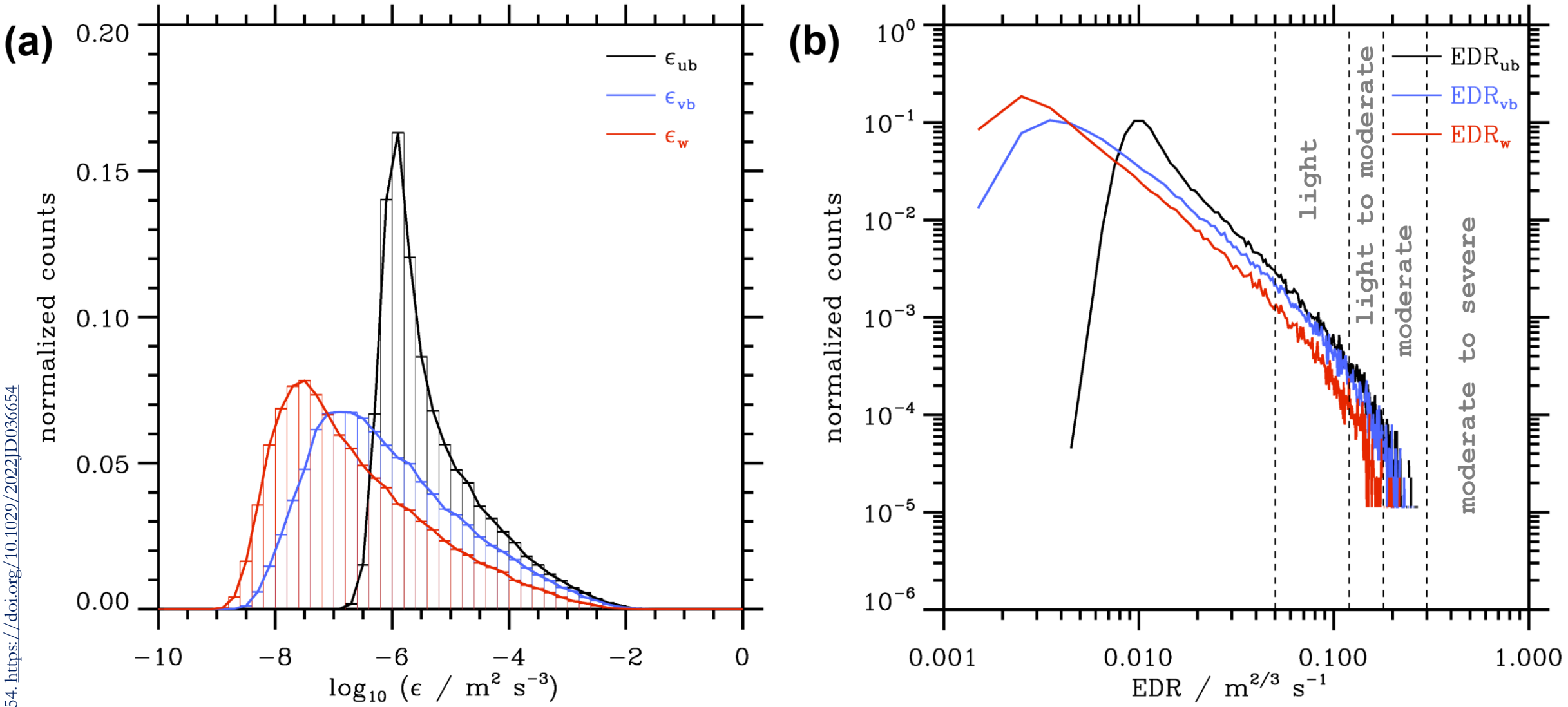
Mean over 6921 legs

Solid : high ε
Dashed: low ε

10 and 100 Hz frequency spectra as used for energy dissipation rate analysis

Dörnbrack, A., P. Bechtold, and U. Schumann, 2022: High-resolution aircraft observations of turbulence and waves in the free atmosphere and comparison with global model predictions. *Journal of Geophysical Research: Atmospheres*, **127**, e2022JD036654. https://doi.org/10.1029/2022JD036654

Observed probability density functions of energy dissipation rates ε_i and $EDR_i = (\varepsilon_i)^{1/3}$



0.05 < EDR < 0.12: light **0.12 < EDR < 0.18: light to moderate**

0.18 < EDR < 0.30: moderate **EDR > 0.30: moderate to severe**

88340 ε_i and EDR values are used for the normalization of the observed probability density functions.

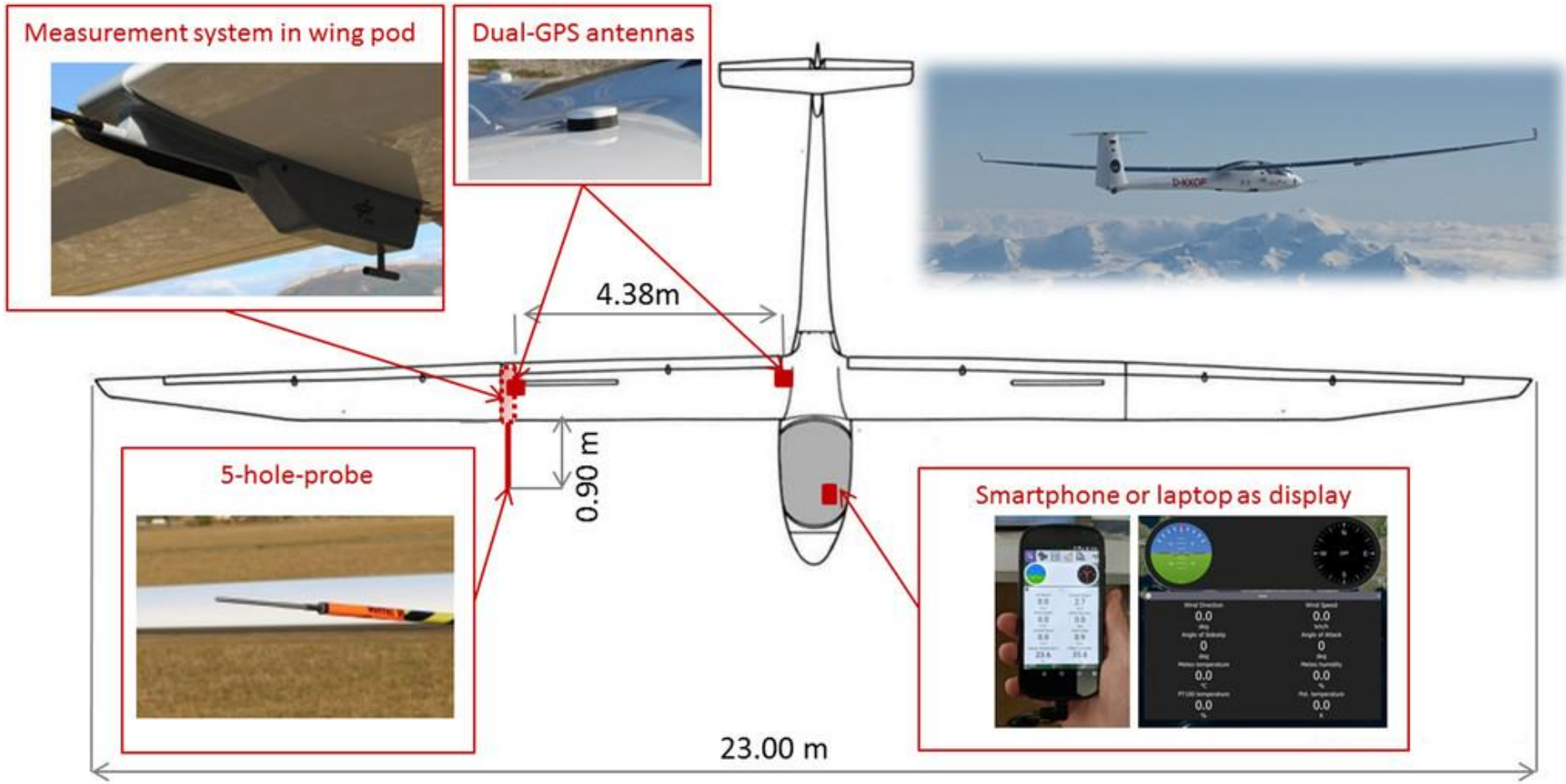
Dörnbrack, A., P. Bechtold, and U. Schumann, 2022: High-resolution aircraft observations of turbulence and waves in the free atmosphere and comparison with global model predictions. *Journal of Geophysical Research: Atmospheres*, **127**, e2022JD036654. https://doi.org/10.1029/2022JD036654

Soaring for Science

Soaring for Science

Instrumented Motor Glider in El Calafate

Instrumented Motor Glider in El Calafate



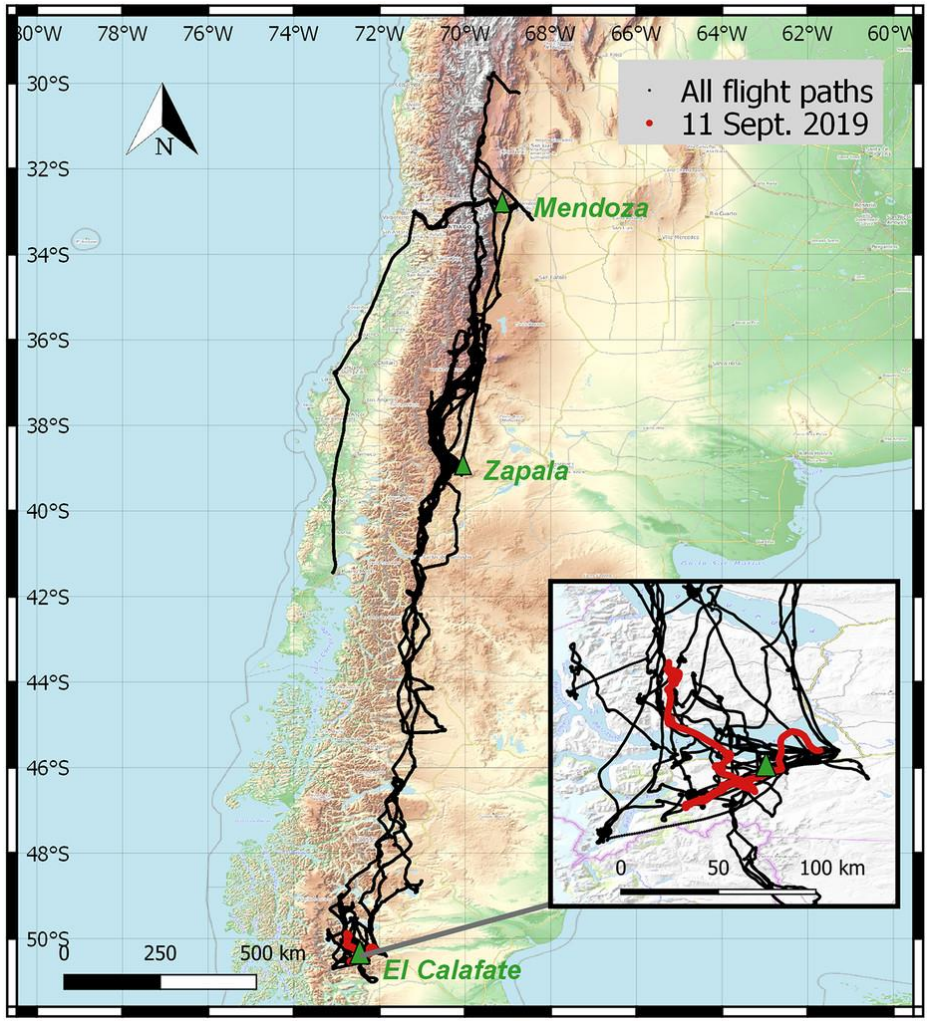
Schematic of the Stemme S10-VT aircraft.
Red markers indicate the location of parts of the wind measurement system

Wildmann, N., R. Eckert, A. Dörnbrack, S. Gisinger, M. Rapp, K. Ohlmann, A. van Niekerk, 2021: In-situ measurements of wind and turbulence by a motor glider in the Andes. *J. Atmos. Ocean. Techn.*, **38**, 921-935; https://doi.org/10.1175/JTECH-D-20-0137.1

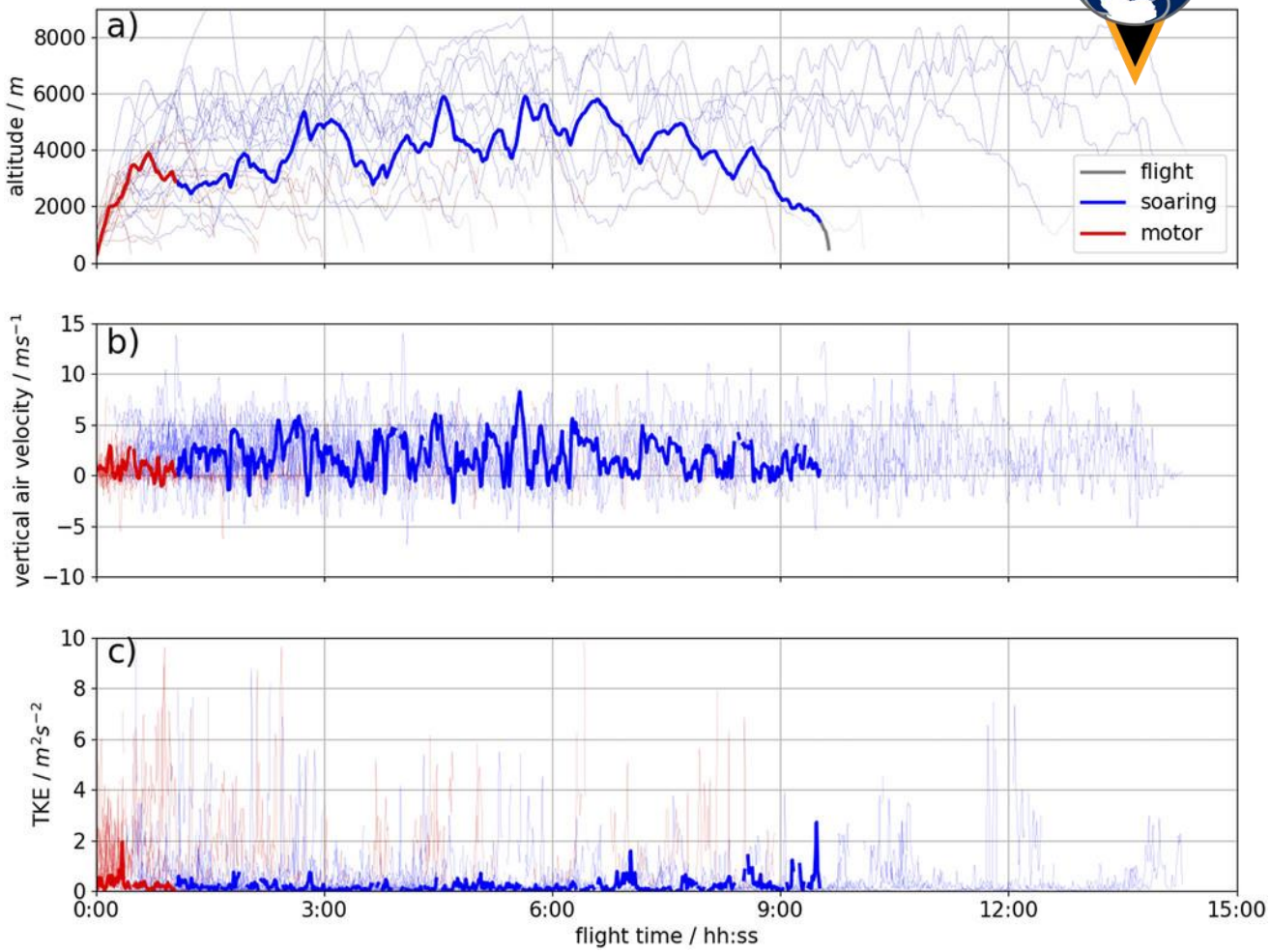
Complementary Ground-Based Observations and Radiosondes Launches in El Calafate

Complementary Ground-Based Observations and Radiosondes Launches in El Calafate

Soaring for Science



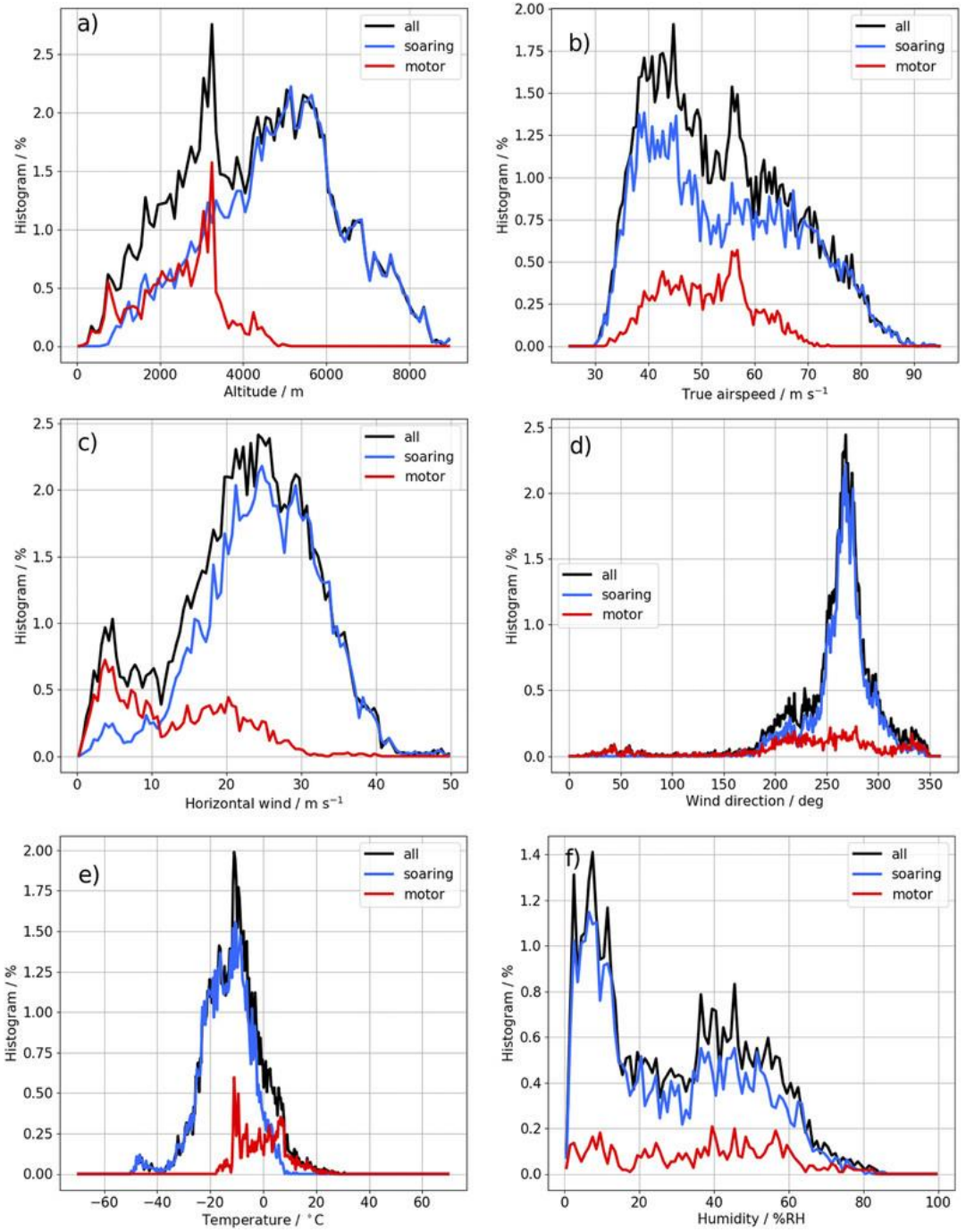
Map of all flight paths over Argentina and Chile between September 2019 and January 2020. The flight on 11 Sep 2019 is marked with red color.

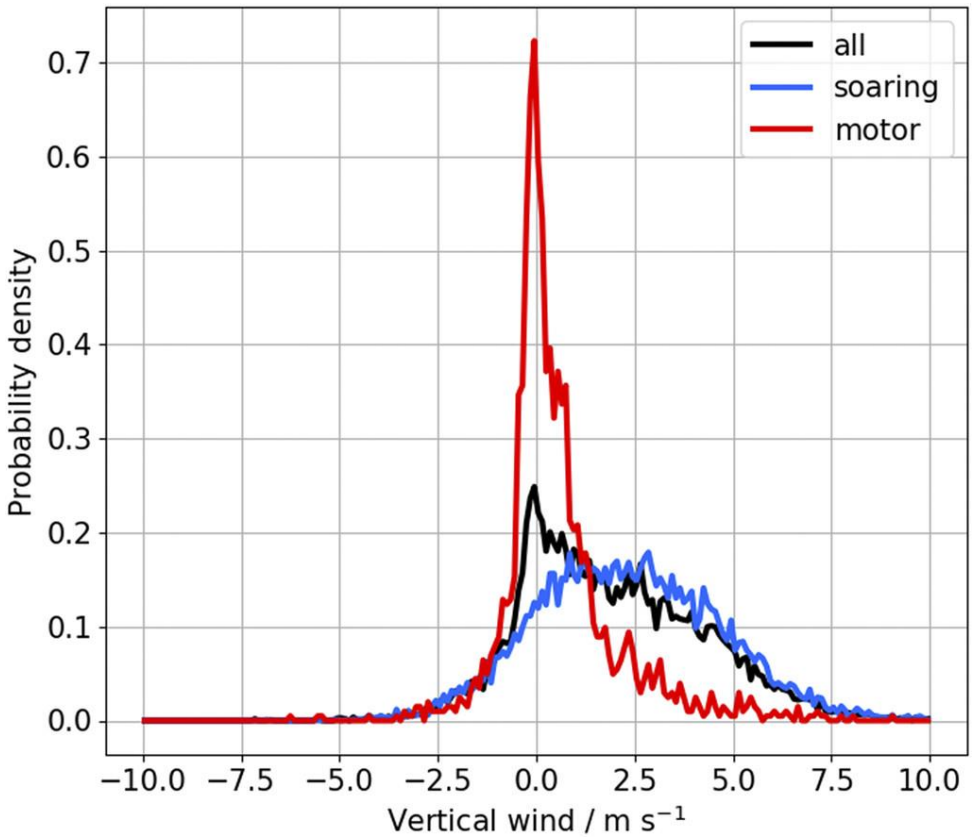


Time series of (a) altitude, (b) vertical velocity, and (c) TKE for all measurement flights. Periods of motor flight are colored red, and periods of soaring flight are colored blue. The flight on 14 Sep 2019 is highlighted in thick lines as an example of a long-distance wave soaring flight.

Wildmann, N., R. Eckert, A. Dörnbrack, S. Gisinger, M. Rapp, K. Ohlmann, A. van Niekerk, 2021: In-situ measurements of wind and turbulence by a motor glider in the Andes. *J. Atmos. Ocean. Techn.*, **38**, 921-935; https://doi.org/10.1175/JTECH-D-20-0137.1

Soaring for Science

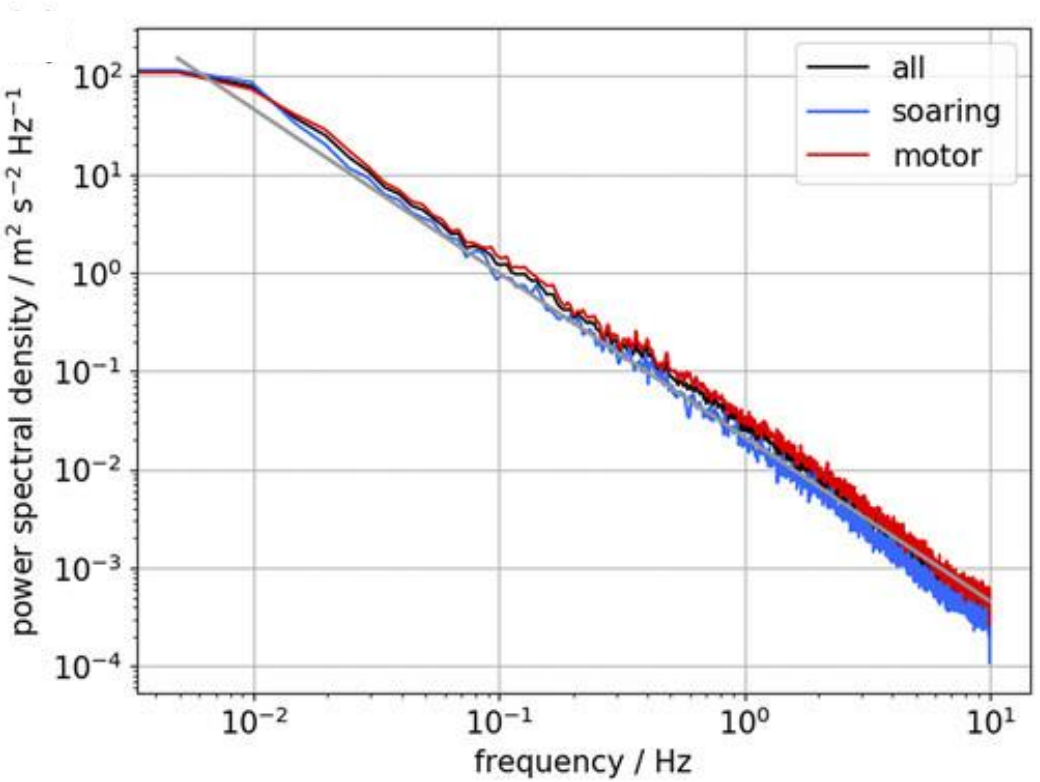




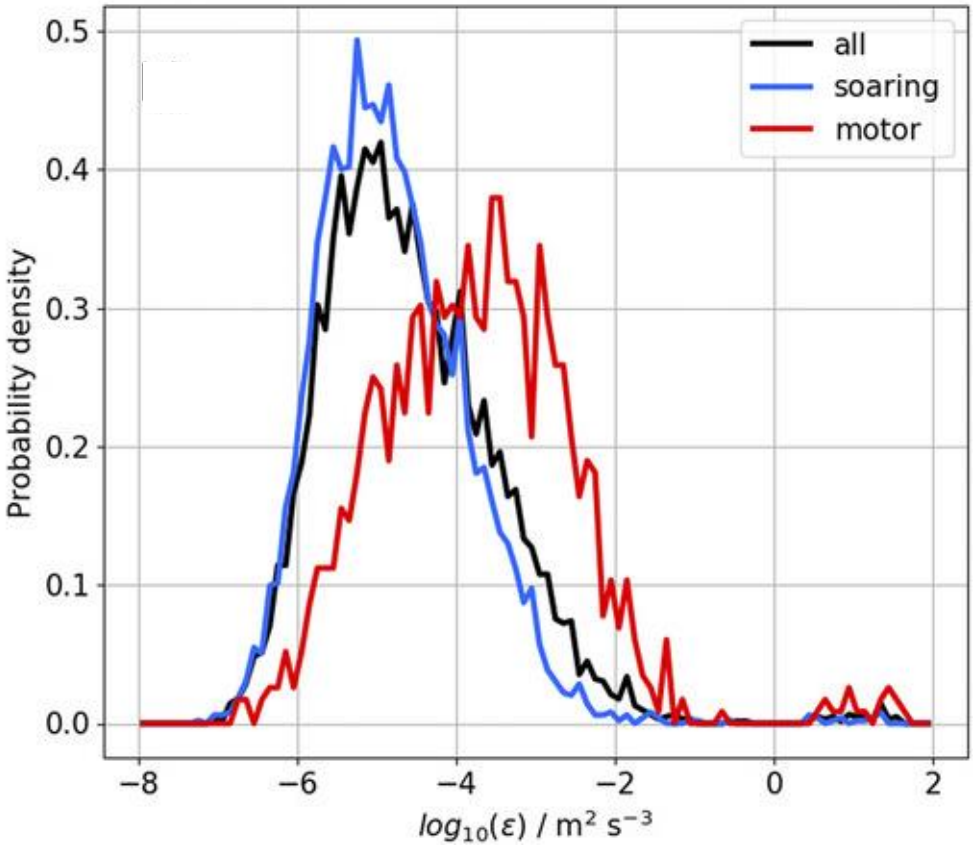
Histograms of various quantities for all measurement flights. The histogram values are normalized by the length of the dataset.

Wildmann, N., R. Eckert, A. Dörnbrack, S. Gisinger, M. Rapp, K. Ohlmann, A. van Niekerk, 2021: In-situ measurements of wind and turbulence by a motor glider in the Andes. *J. Atmos. Ocean. Techn.*, **38**, 921-935; https://doi.org/10.1175/JTECH-D-20-0137.1

Soaring for Science



Power spectra of horizontal wind speed. Shown are averages of all flight periods in motor flight (red), soaring flight (blue), and the average of all (black).



Probability density functions od energy dissipation rate ε for all measurement flights in motor flight (red), soaring flight (blue), and the average of all (black).

Wildmann, N., R. Eckert, A. Dörnbrack, S. Gisinger, M. Rapp, K. Ohlmann, A. van Niekerk, 2021: In-situ measurements of wind and turbulence by a motor glider in the Andes. *J. Atmos. Ocean. Techn.*, **38**, 921-935; https://doi.org/10.1175/JTECH-D-20-0137.1

Unusual appearance of mother-of-pearl clouds above El Calafate, Argentina

Lee wave clouds above the Lago Argentino looking west, 11 September 2019, 0941 local time, 1241 UTC.

Dörnbrack, A., Kaifler, B., Kaifler, N., Rapp, M., Wildmann, N., Garhammer, M., Ohlman, K., Payne, J., Sandercock, M., and E. Austin, 2020: Unusual appearance of mother-of-pearl clouds above El Calafate, Argentina (50° 21' S, 72° 16' W). **Weather**, **75**, 378-388. https://doi.org/10.1002/wea.3863

Unusual appearance of mother-of-pearl clouds above El Calafate, Argentina

Polar stratospheric clouds (PSCs) above the El Calafate looking west, 11 September 2019, 7 pm local time, 23 UTC.

Dörnbrack, A., Kaifler, B., Kaifler, N., Rapp, M., Wildmann, N., Garhammer, M., Ohlman, K., Payne, J., Sandercock, M., and E. Austin, 2020: Unusual appearance of mother-of-pearl clouds above El Calafate, Argentina (50° 21' S, 72° 16' W). **Weather**, **75**, 378-388. https://doi.org/10.1002/wea.3863

https://perlanproject.org/

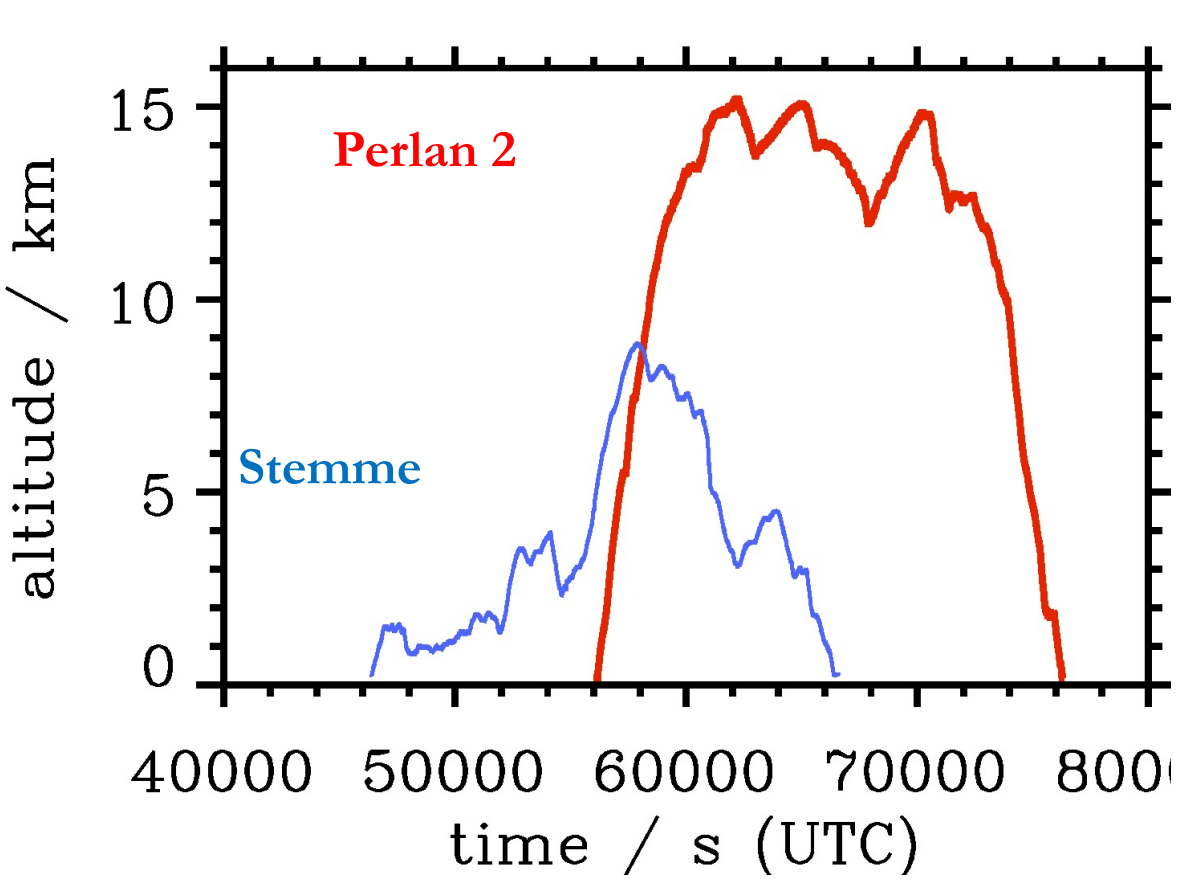
Visual Observations from Perlan 2

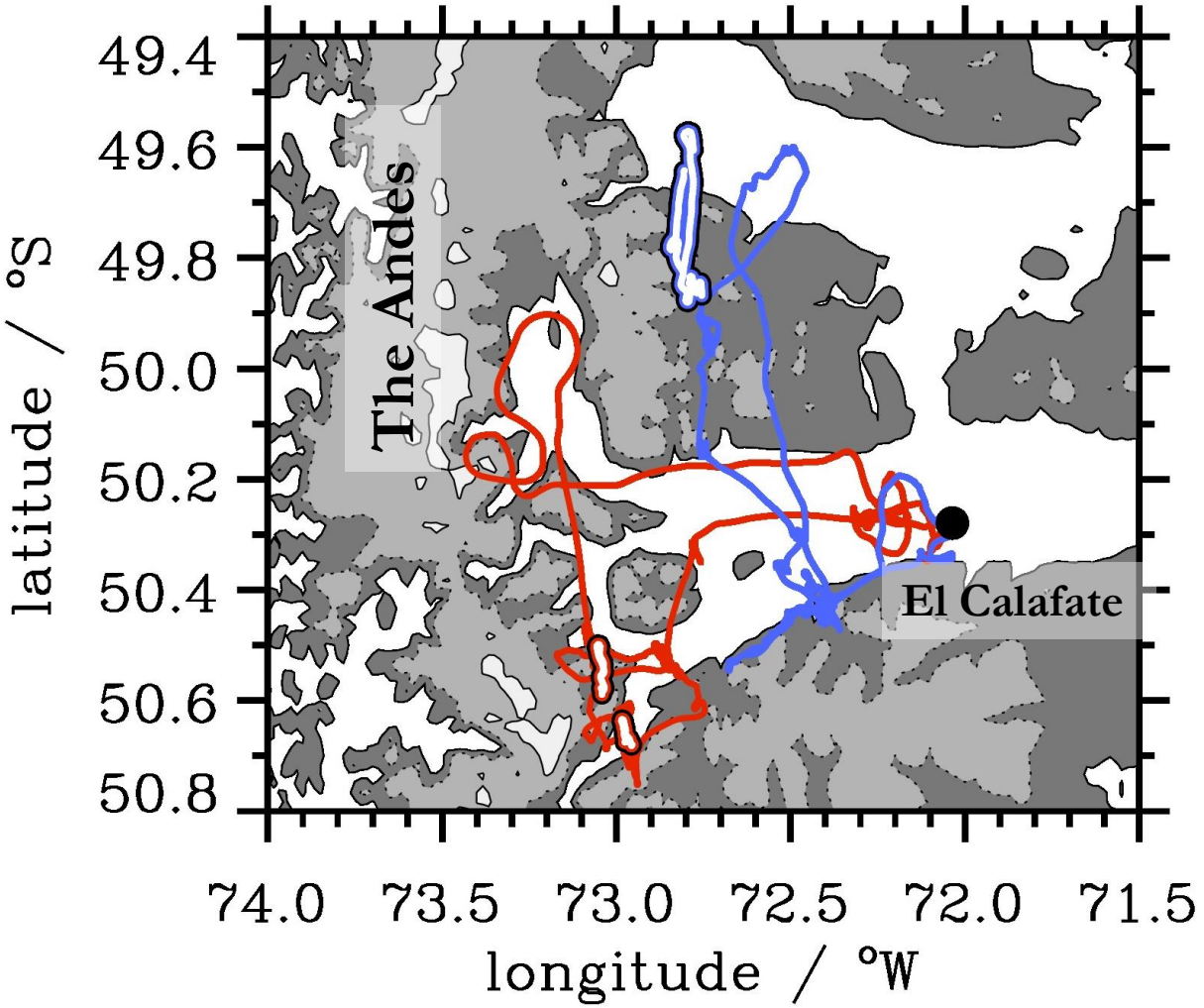
Snapshots of mother-of-pearl clouds from the camera installed at the Perlan 2 aircraft's tail wing.

Left panel: position: 50.66°S, 73.04°W, altitude: 13873 m, true heading: 168.7°, time: 17:28:17 UTC
Right panel: position: 50.59°S, 73.04°W, altitude: 14933 m, true heading: 347.4°, time: 17:19:31 UTC

https://perlanproject.org/blog/perlan-2-soars-rare-stratospheric-perlan-clouds

Two Glider Flights on 11 September 2019



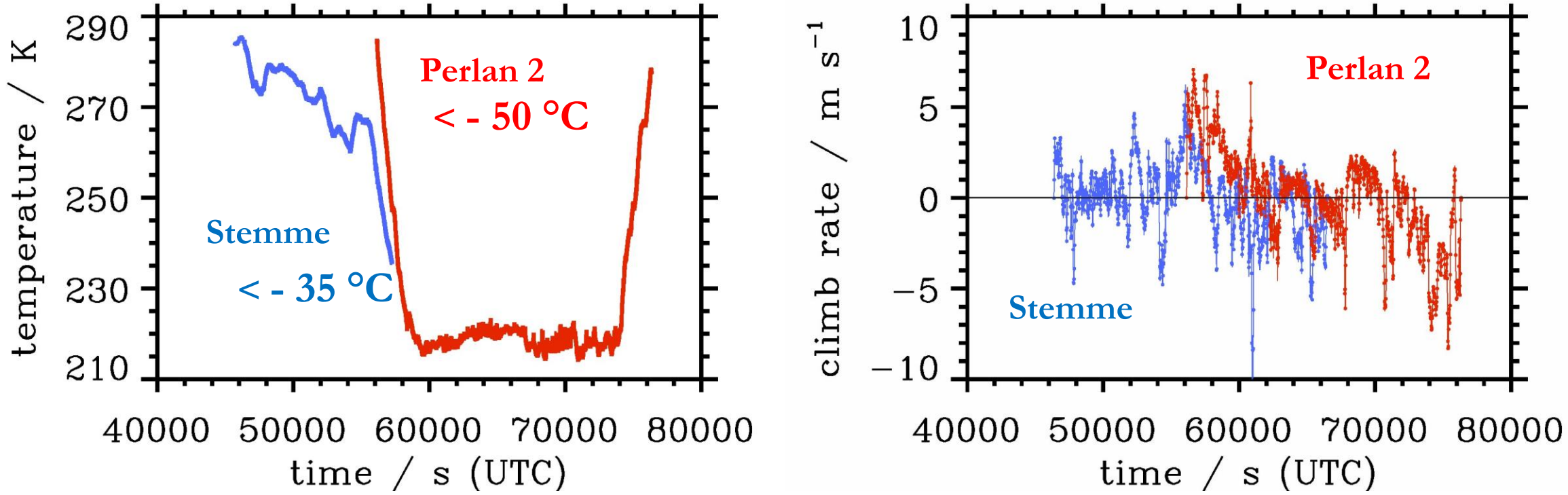


Regions where Perlan 2 was above 15 km altitude and the Stemme was above 8 km altitude are marked with black-encircled white symbols in the right panel.

The orography is shaded from dark to light grey at 500 m, 1000 m, 2000 m, and 3000 m levels.

Dörnbrack, A., Kaifler, B., Kaifler, N., Rapp, M., Wildmann, N., Garhammer, M., Ohlman, K., Payne, J., Sandercock, M., and E. Austin, 2020: Unusual appearance of mother-of-pearl clouds above El Calafate, Argentina (50° 21' S, 72° 16' W). **Weather, 75**, 378-388. https://doi.org/10.1002/wea.3863

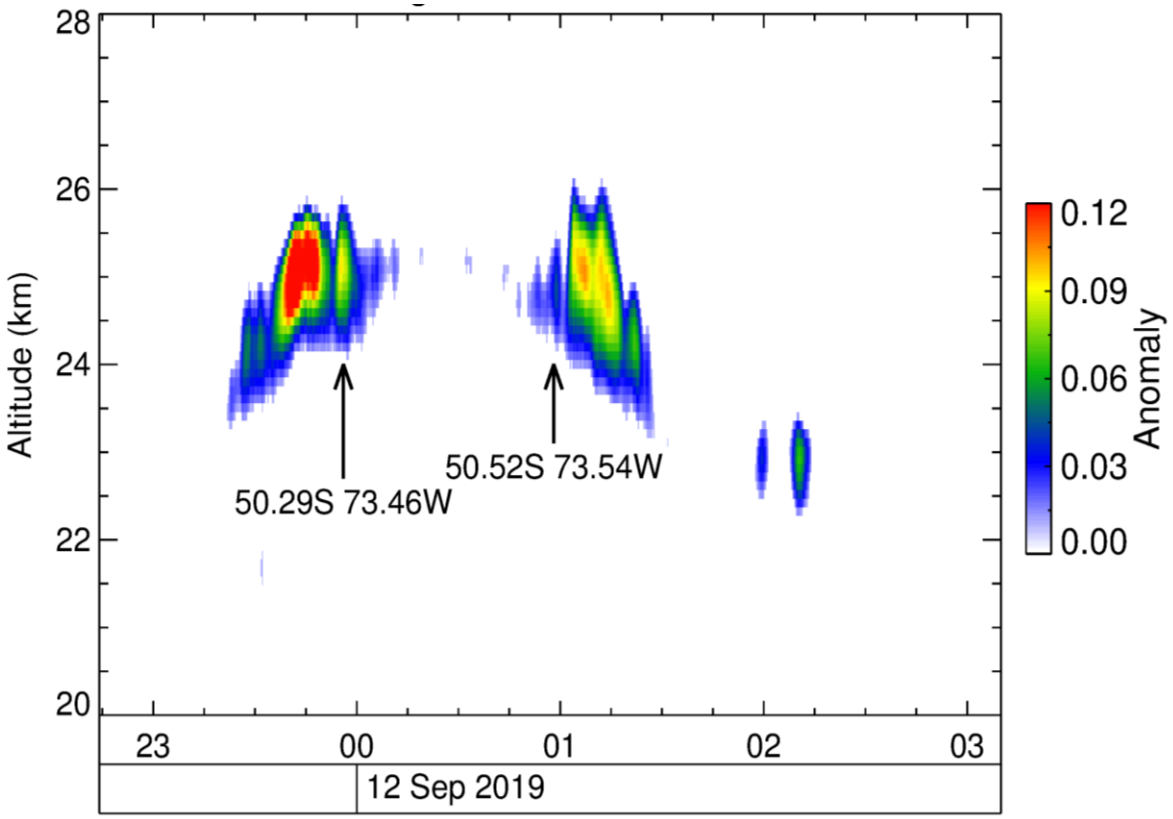
Two Glider Flights on 11 September 2019

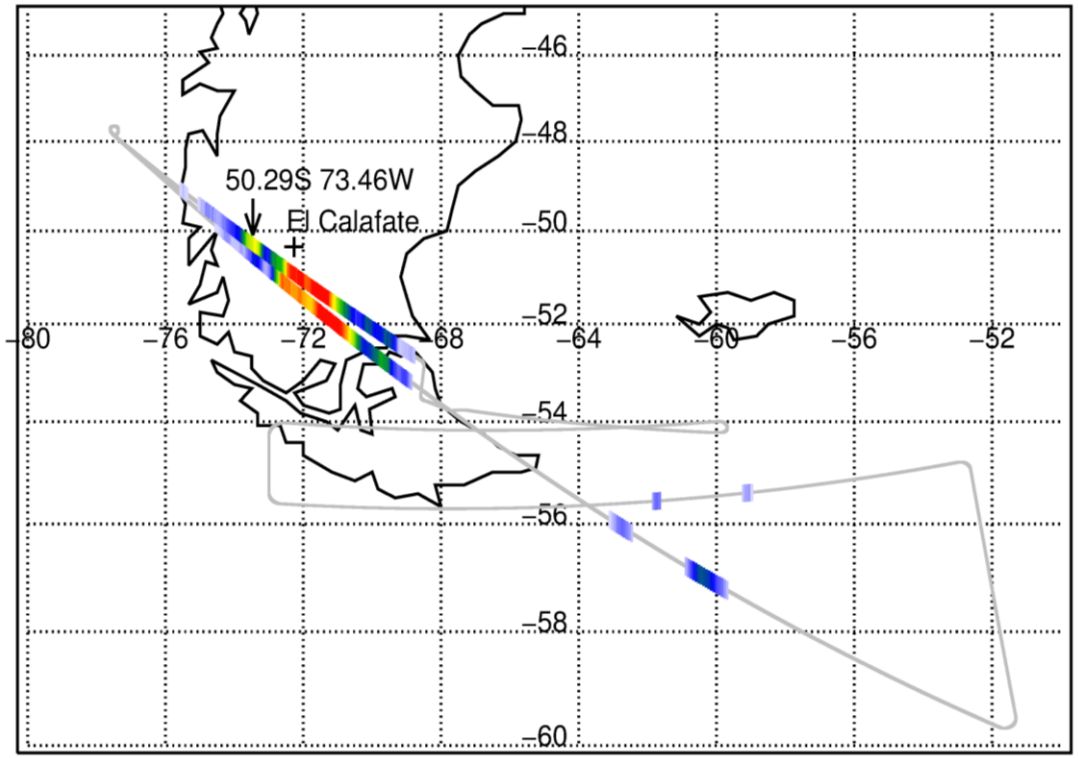


Absolute temperature (left panel) and climb rate (right panel) of the two gliders operating on 11 September 2019 near El Calafate. Red: Perlan 2 and blue: Stemme.

Dörnbrack, A., Kaifler, B., Kaifler, N., Rapp, M., Wildmann, N., Garhammer, M., Ohlman, K., Payne, J., Sandercock, M., and E. Austin, 2020: Unusual appearance of mother-of-pearl clouds above El Calafate, Argentina (50° 21' S, 72° 16' W). **Weather, 75**, 378-388. https://doi.org/10.1002/wea.3863

ALIMA Observations of PSCs from HALO Research Flight ST08



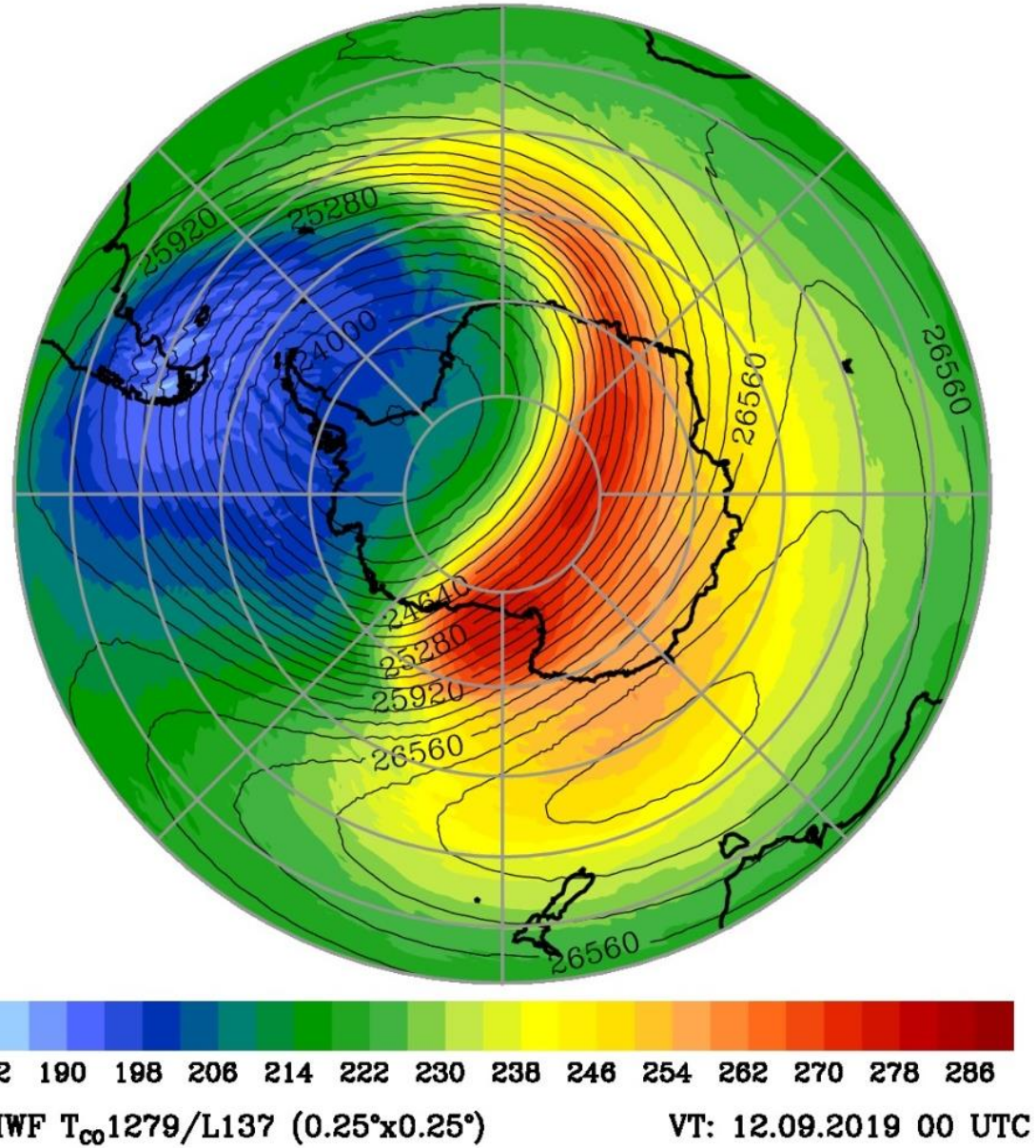


Aerosol anomaly calculated from ALIMA temperature profiles along the whole flight track of HALO during ST08 11 September 2019 23:05 UTC until 12 September 2019 07:21 UTC.

Left: vertical section, right: vertically integrated aerosol anomaly.

Dörnbrack, A., Kaifler, B., Kaifler, N., Rapp, M., Wildmann, N., Garhammer, M., Ohlman, K., Payne, J., Sandercock, M., and E. Austin, 2020: Unusual appearance of mother-of-pearl clouds above El Calafate, Argentina (50° 21' S, 72° 16' W). **Weather, 75**, 378-388. https://doi.org/10.1002/wea.3863

ECMWF IFS Operational Analyses



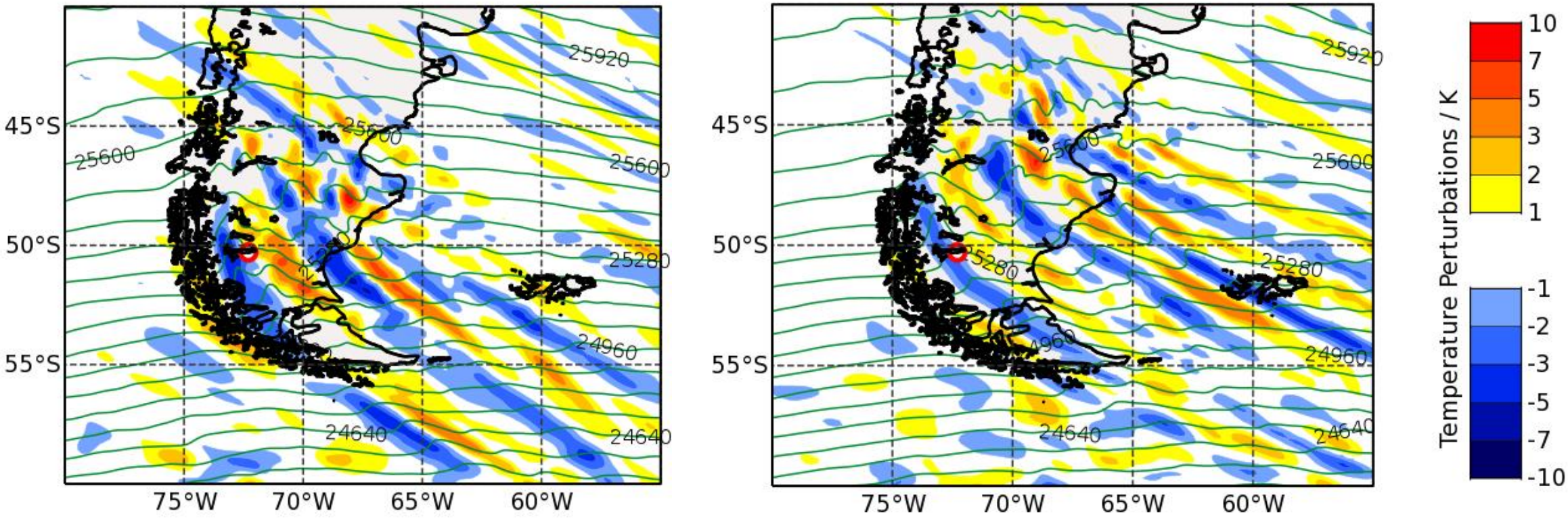
Absolute temperature and geopotential height at the 20 hPa pressure level on 12 September 2019 00 UTC.

Dörnbrack, A., Kaifler, B., Kaifler, N., Rapp, M., Wildmann, N., Garhammer, M., Ohlman, K., Payne, J., Sandercock, M., and E. Austin, 2020: Unusual appearance of mother-of-pearl clouds above El Calafate, Argentina (50° 21' S, 72° 16' W). **Weather, 75**, 378-388. https://doi.org/10.1002/wea.3863

ECMWF IFS Operational Analyses

11 September 2019 18 UTC

12 September 2019 00 UTC



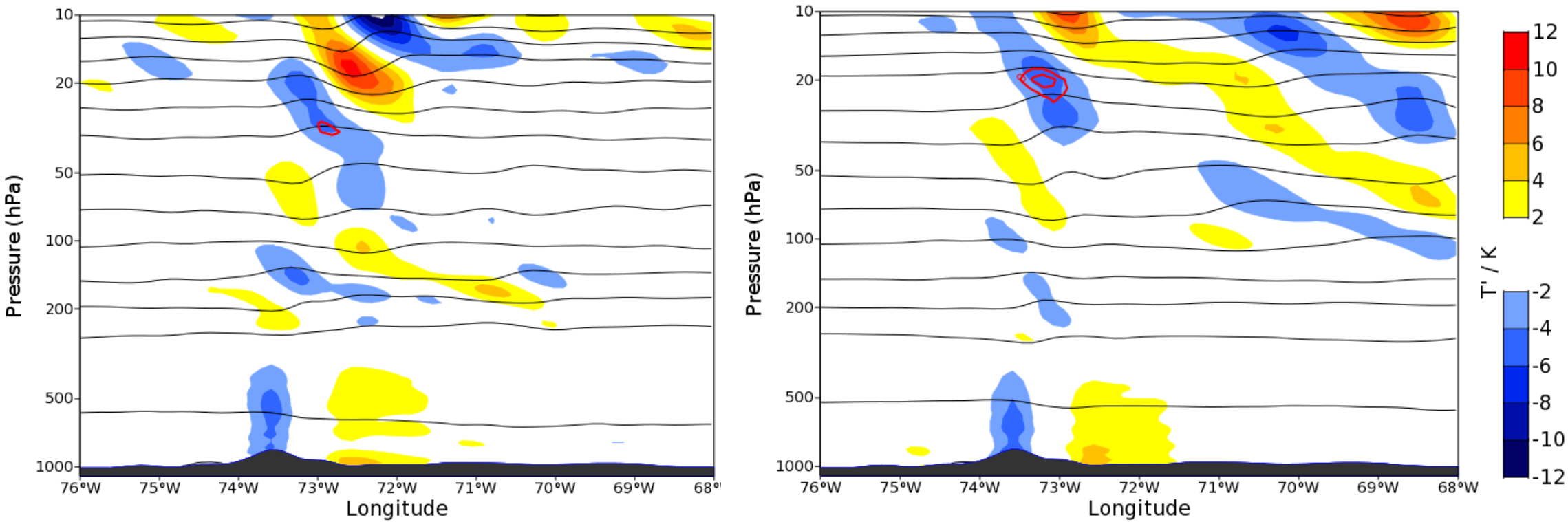
Temperature perturbation T' = T_{1279}-T_{106} (K, colour shaded) geopotential height (m, green lines) at the 20 hPa pressure level. The red encircled symbol marks the location of El Calafate, Argentina.

Dörnbrack, A., Kaifler, B., Kaifler, N., Rapp, M., Wildmann, N., Garhammer, M., Ohlman, K., Payne, J., Sandercock, M., and E. Austin, 2020: Unusual appearance of mother-of-pearl clouds above El Calafate, Argentina (50° 21' S, 72° 16' W). **Weather, 75**, 378-388. https://doi.org/10.1002/wea.3863

ECMWF IFS Operational Analyses

11 September 2019 18 UTC

12 September 2019 00 UTC



Temperature perturbation T' = T_{1279}-T_{106} (K, colour shaded),
ΔT_{ice} = -1 K and 0 K (red contour lines) along 50.25 ° S.

Dörnbrack, A., Kaifler, B., Kaifler, N., Rapp, M., Wildmann, N., Garhammer, M., Ohlman, K., Payne, J., Sandercock, M., and E. Austin, 2020: Unusual appearance of mother-of-pearl clouds above El Calafate, Argentina (50 ° 21' S, 72 ° 16' W). **Weather, 75**, 378-388. https://doi.org/10.1002/wea.3863

Available Datasets

1. **15 glider research flights in the troposphere from El Calafate in the period 8 to 30 September 2019**

- mostly long-distance flights in mountain waves (no thermals)
- vertical profiling by wave climbs, during take-off and landing

2. **160 radiosondes 2017-2019**

- Rio Grande (Graw System): September 2019 29 ascents
- El Calafate (Väisälä System) September 2019 31 ascents
- El Calafate (American system – PERLAN WebSite)
  2017 14 July – 11 September 42 launches
  2018 02 August – 13 September 32 launches
  2019 22 August – 20 September 31 launches

3. **PERLAN data base**: vertical profiles of T up to about 20 km altitude in various stages of the flights (65 flights in 2017, 2018, 2019)

The Aerial Scenery

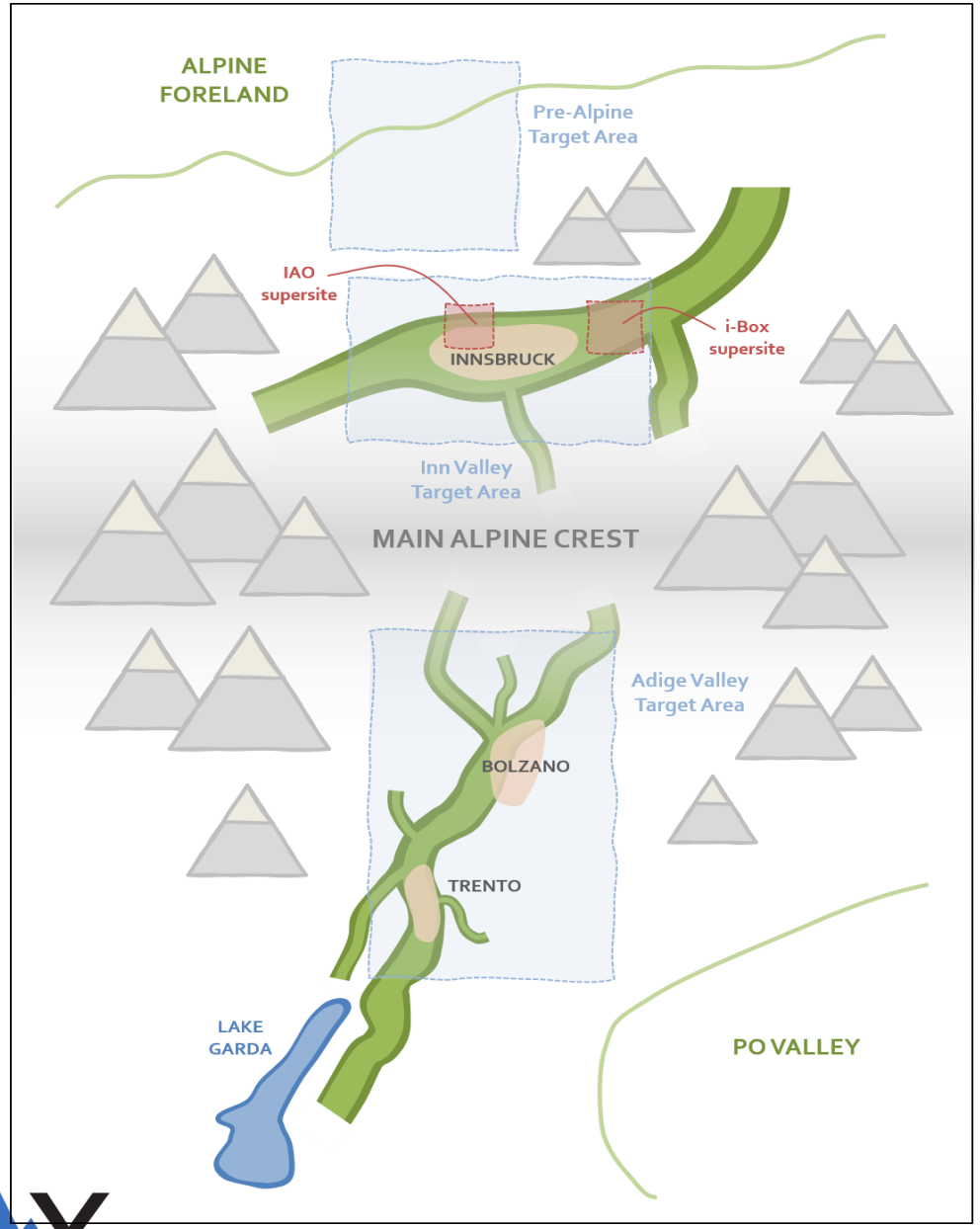
The Aerial Scenery

The Aerial Scenery

Multiscale **T**ransport and **E**xchange processes in the **A**tmosphere over **M**ountains – programme and e**x**periment

DLR-IPA: Coordinated Airborne Observations of Momentum Transport and Turbulence over the Alps

- investigate the momentum transport by propagating and breaking mountain waves by remote-sensing and in-situ observations with DLR Falcon in autumn/winter 2024/25
- improve understanding and advancing the representation of orographic influences within numerical weather, climate and earth-system prediction models, thereby increasing accuracy and reducing uncertainty
- coordinate research effort with TEAMx-UK „Multi-scale transport and exchange processes in the atmosphere over mountains" (NERC proposal submitted in November 2022)
- use the once-in-a-scientific-generation opportunity of a large, coordinated international programme of atmospheric observations and modelling over a major mountain range



TEAMx target areas

www.teamx-programme.org

TEAMx