Stratospheric Waves over the Southern Andes

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SouthTRAC:

Southern Hemisphere Transport, Dynamics, and Chemistry

Motivation

NWP systems are essential elements used for all field campaigns

- preparation phase
- actual forecasts during the campaign
- postprocessing and putting observations into context

How can data from a field campaign devoted to the coupling of troposphere to stratosphere be used for improving numerical prediction systems of the atmosphere?

- strengths: combination of different sensors covering multiple temporal and spatial scales, non-assimilated data, …
- weaknesses: field campaigns are episodical events, …

Plot

Summary of goals

Actors

Setting the stage

- physical and aerial scenery
- meteorology in austral winter/spring 2019
- remote sensors and in-situ instrumentation

Selected Results phase 1 of SouthTRAC

- deep mountain wave propagation
- soaring for science
- radiosonde data

SouthTRAC Research Areas

Transport and Dynamics:

- gravity waves in the southern hemisphere (SH)
- transport processes affecting the SH upper troposphere/lower stratosphere (UTLS)

Chemical processes:

- halogen-induced ozone changes in the SH-UTLS: impact of very short-lived species and ozone hole recovery
- impact of biomass burning on the composition in the SH-UTLS

National Partners

DLR - German Aerospace Center

KIT - Karlsruhe Institute of Technology

FZJ - Research Center Jülich

University of Mainz

University of Frankfurt

University of Wuppertal

University of Heidelberg

Partners in Argentina

EARG

Estacion Astronomica Rio Grande
Universidad de la Plata

CONICET

Consejo Nacional de Investigaciones Científicas y Técnicas

UNIVERSIDAD AUSTRAL

Universidad Austral

UTN FACULTAD REGIONAL MENDOZA
UNIVERSIDAD TECNOLÓGICA NACIONAL

Universidad Tecnológica Nacional, Facultad Regional Mendoza

Servicio Meteorológico Nacional

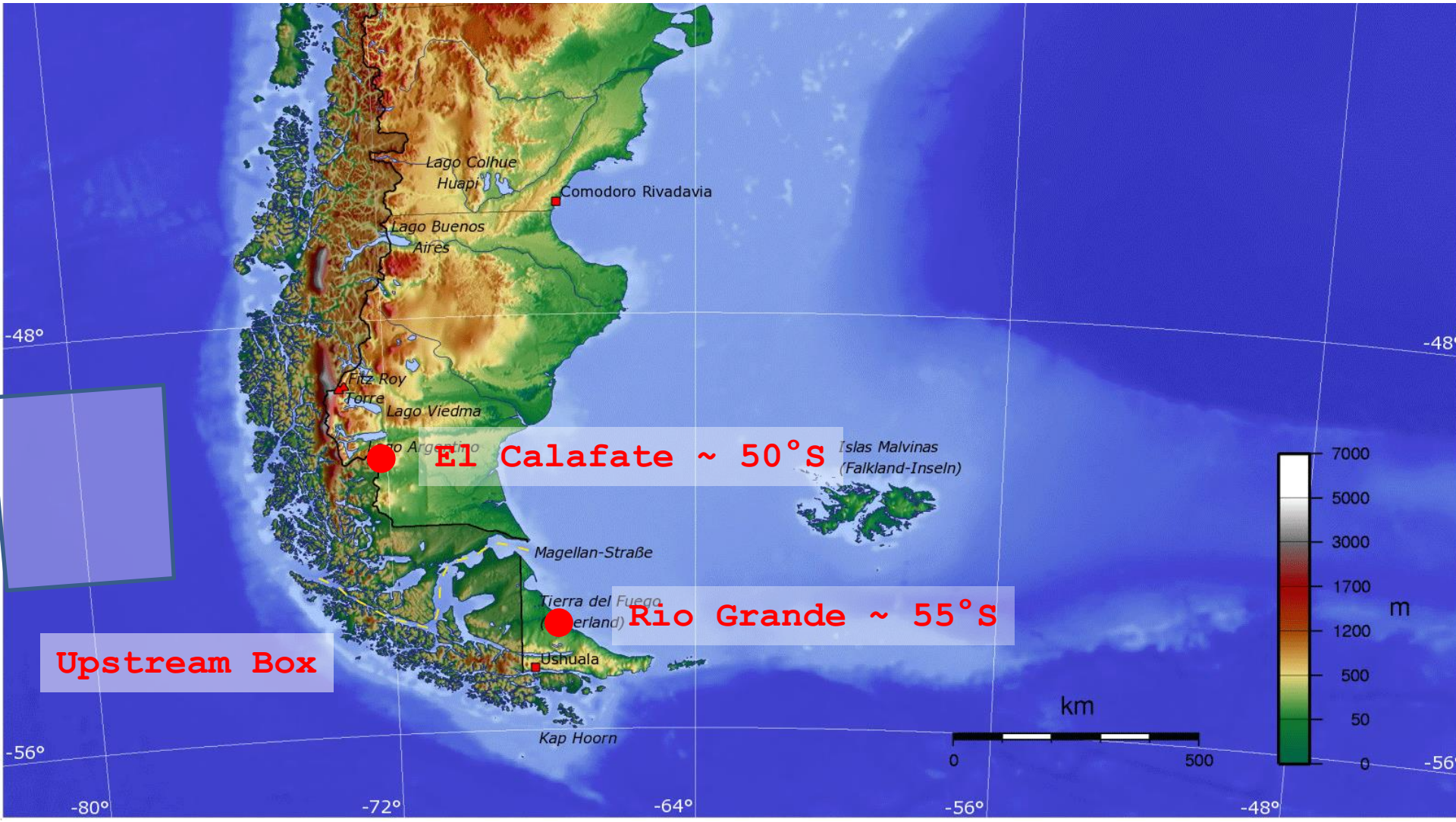
Servicio Meteorológico Nacional

International partners

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

UNIVERSIDAD TECNICA
FEDERICO SANTA MARIA

The Physical Scenery



The Aerial Scenery

The Aerial Scenery

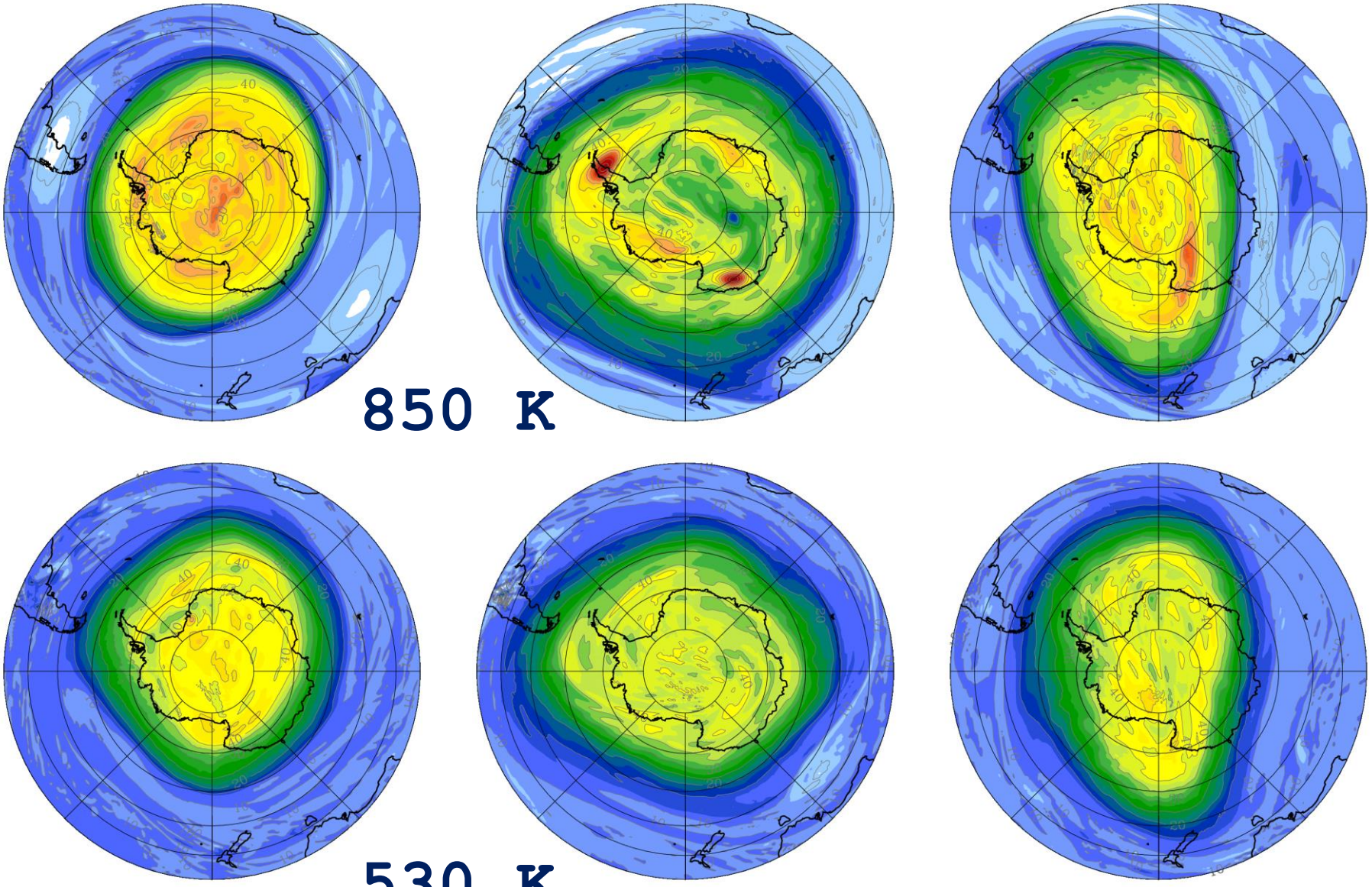
The Aerial Scenery

Meteorology in Austral Winter/Spring 2019

- evolution of the polar vortex
- zonal mean zonal winds and temperature
- upstream wind profiles

ERA5 analyses valid at 11 August 12 UTC

2002 2006 2019



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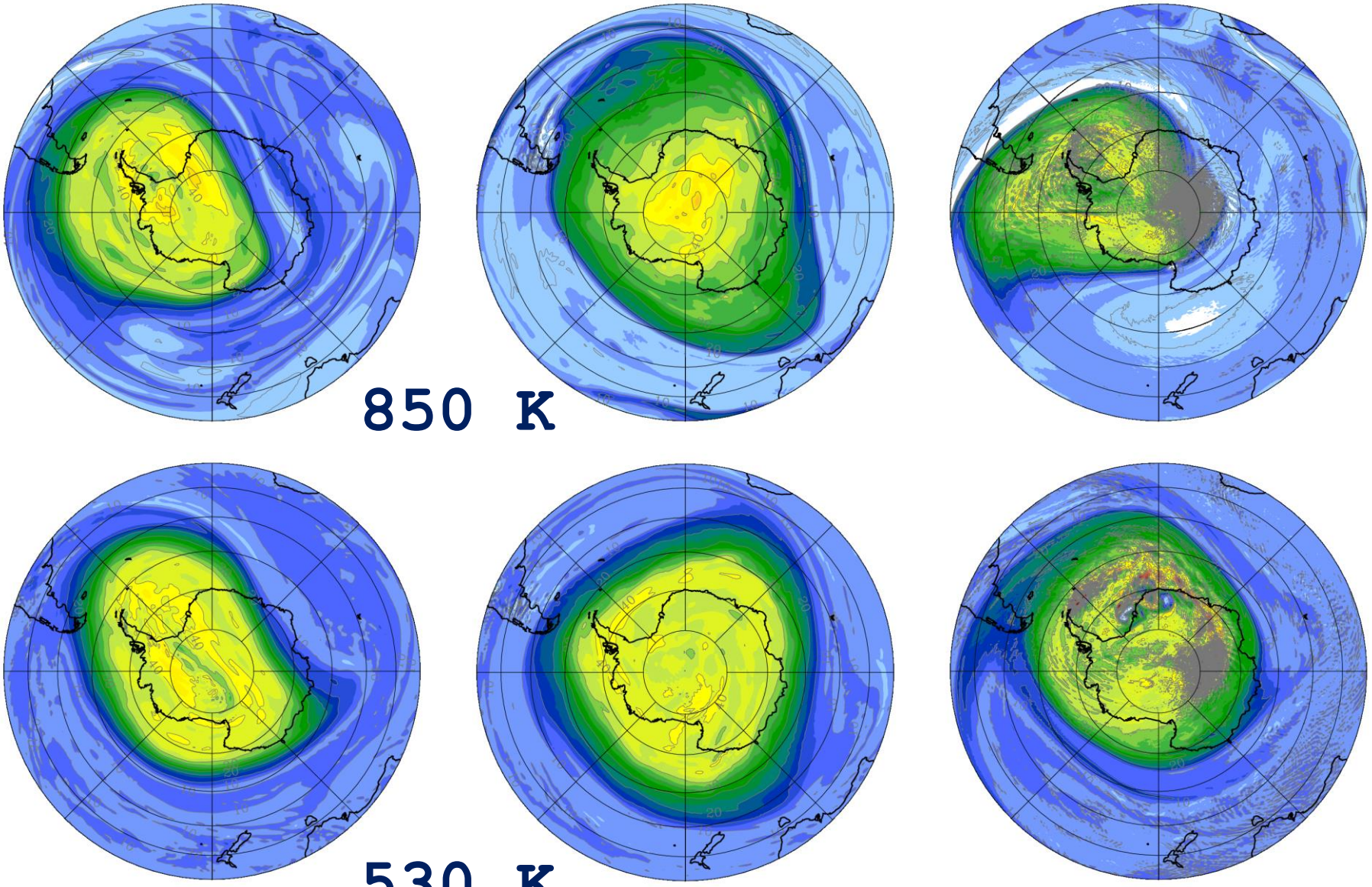
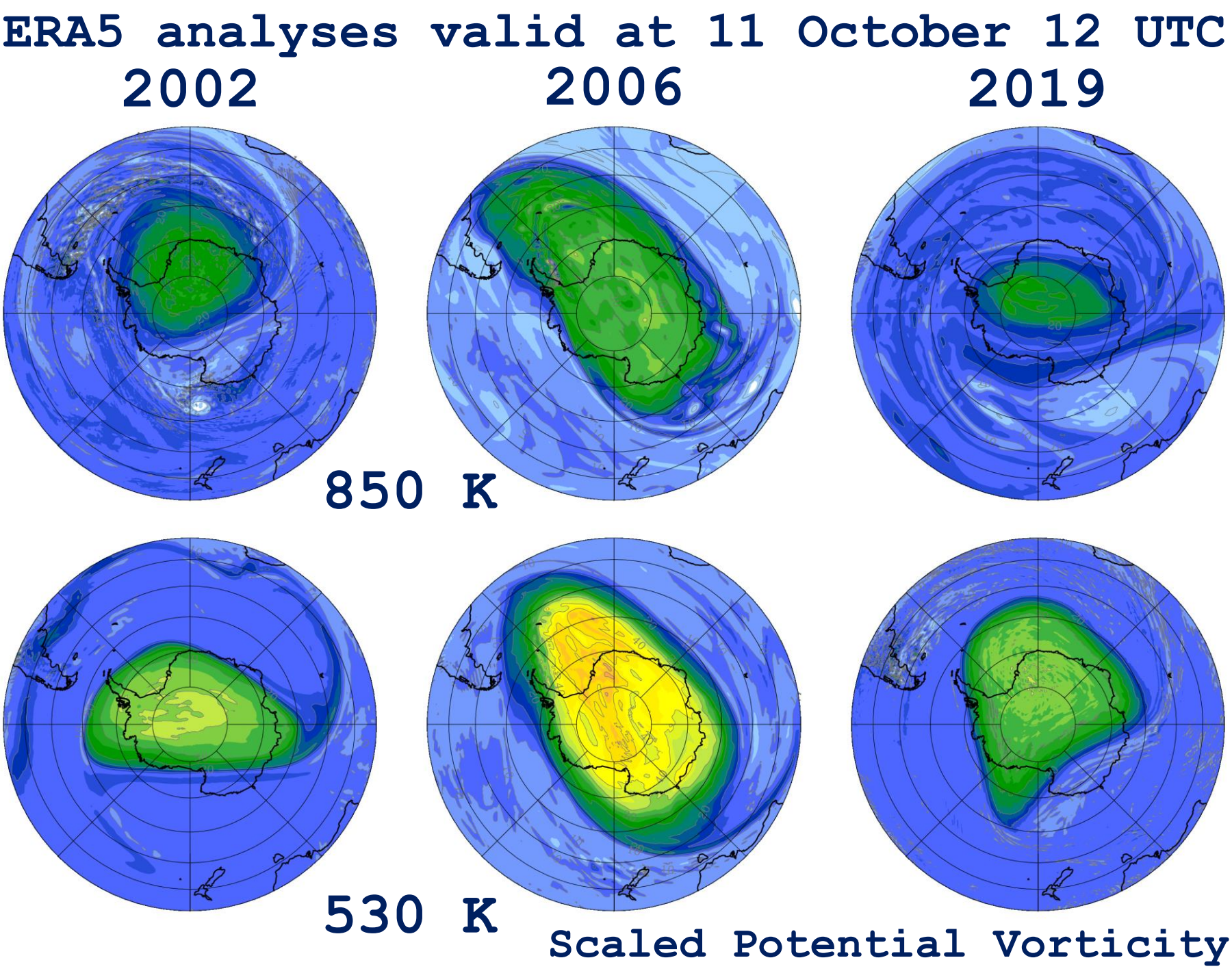
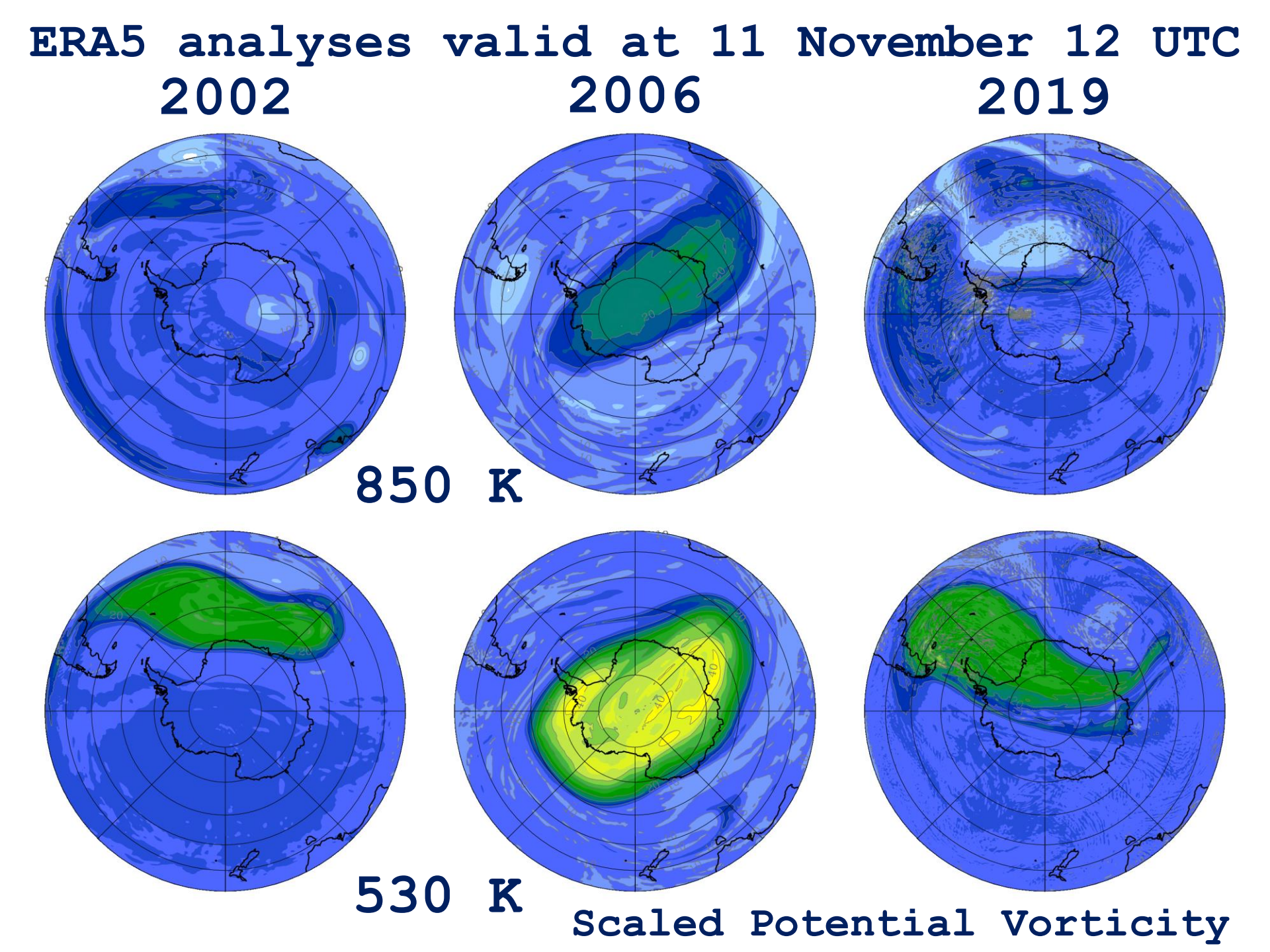
2002 2006 2019




ERA5 analyses valid at 11 October 12 UTC
2002
2006
2019
850 K
530 K
Scaled Potential Vorticity


ERA5 analyses valid at 11 November 12 UTC
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2006
2019
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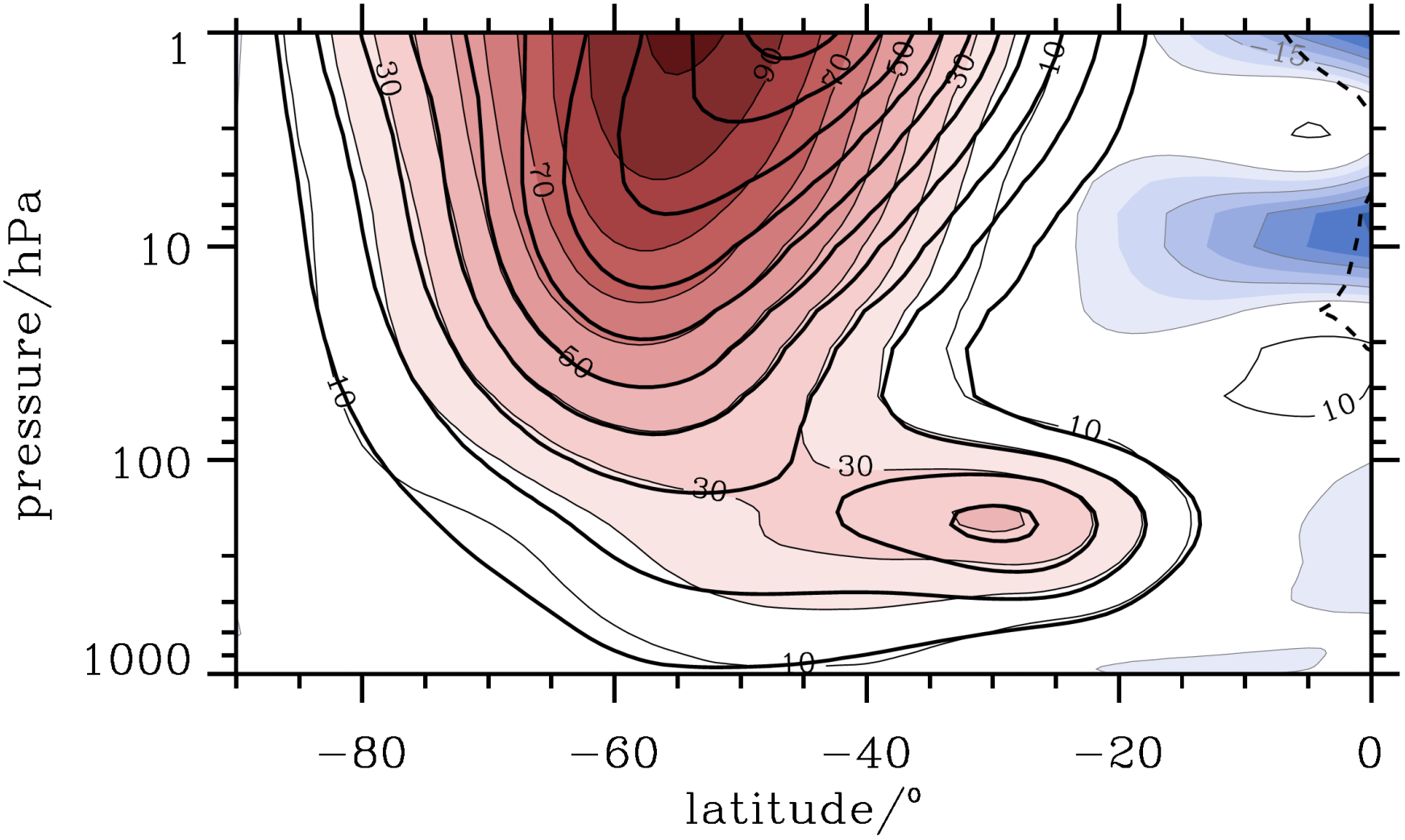
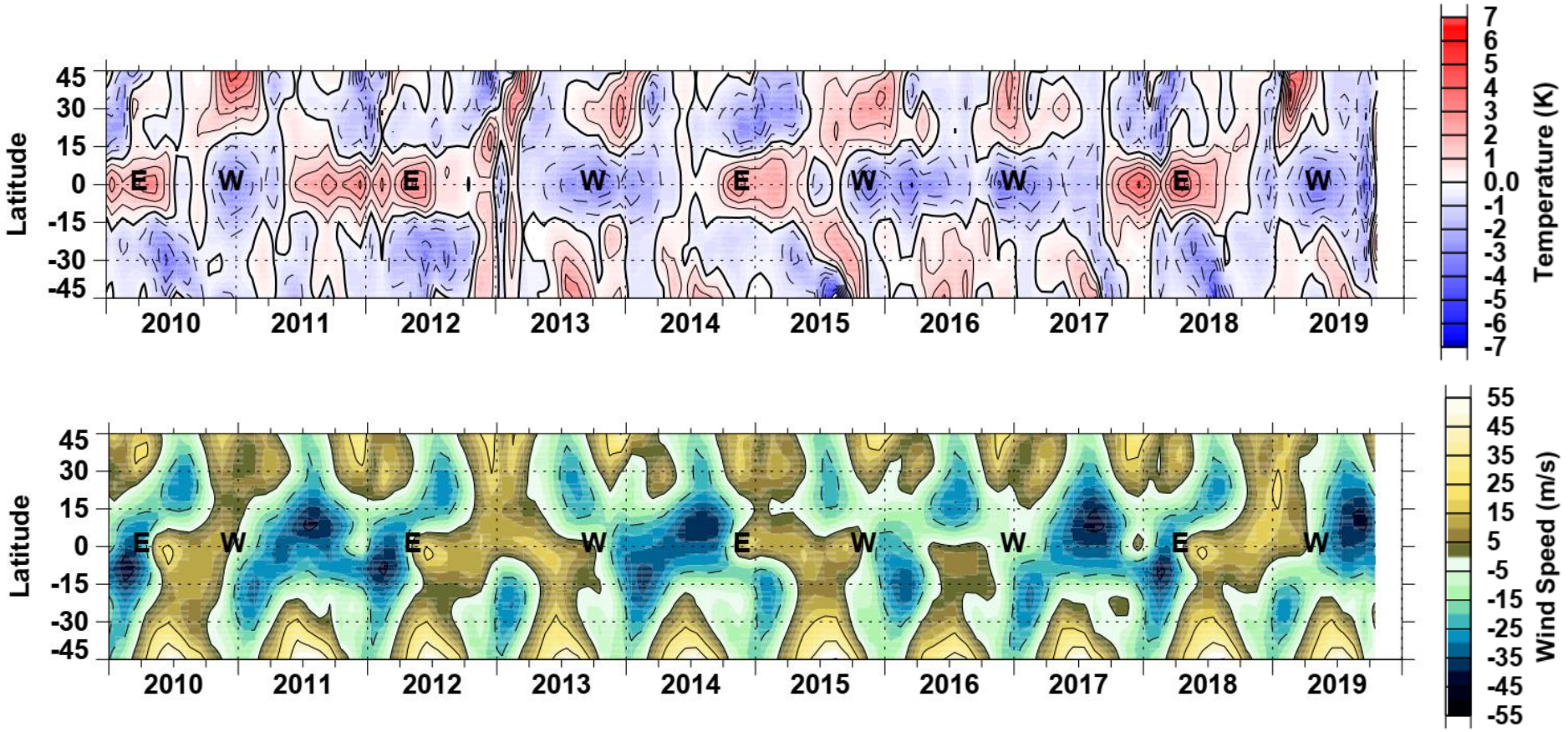
Scaled Potential Vorticity

Zonal Mean of Zonal Wind for July



color shaded: July 2019 (ERA5)
thick black lines: climatological mean ERA5

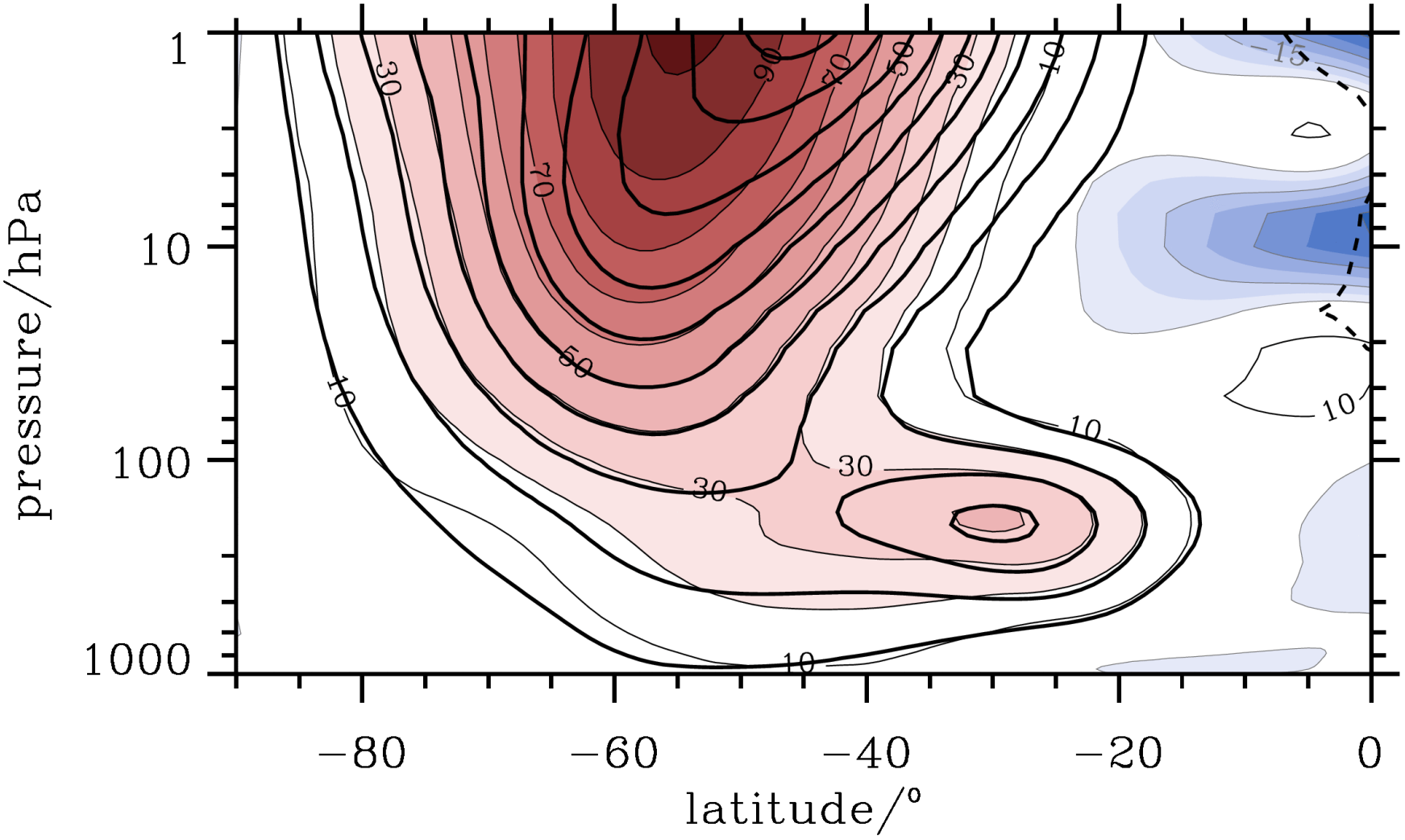
Quasi-biennial Oscillation



MERRA2-analyses

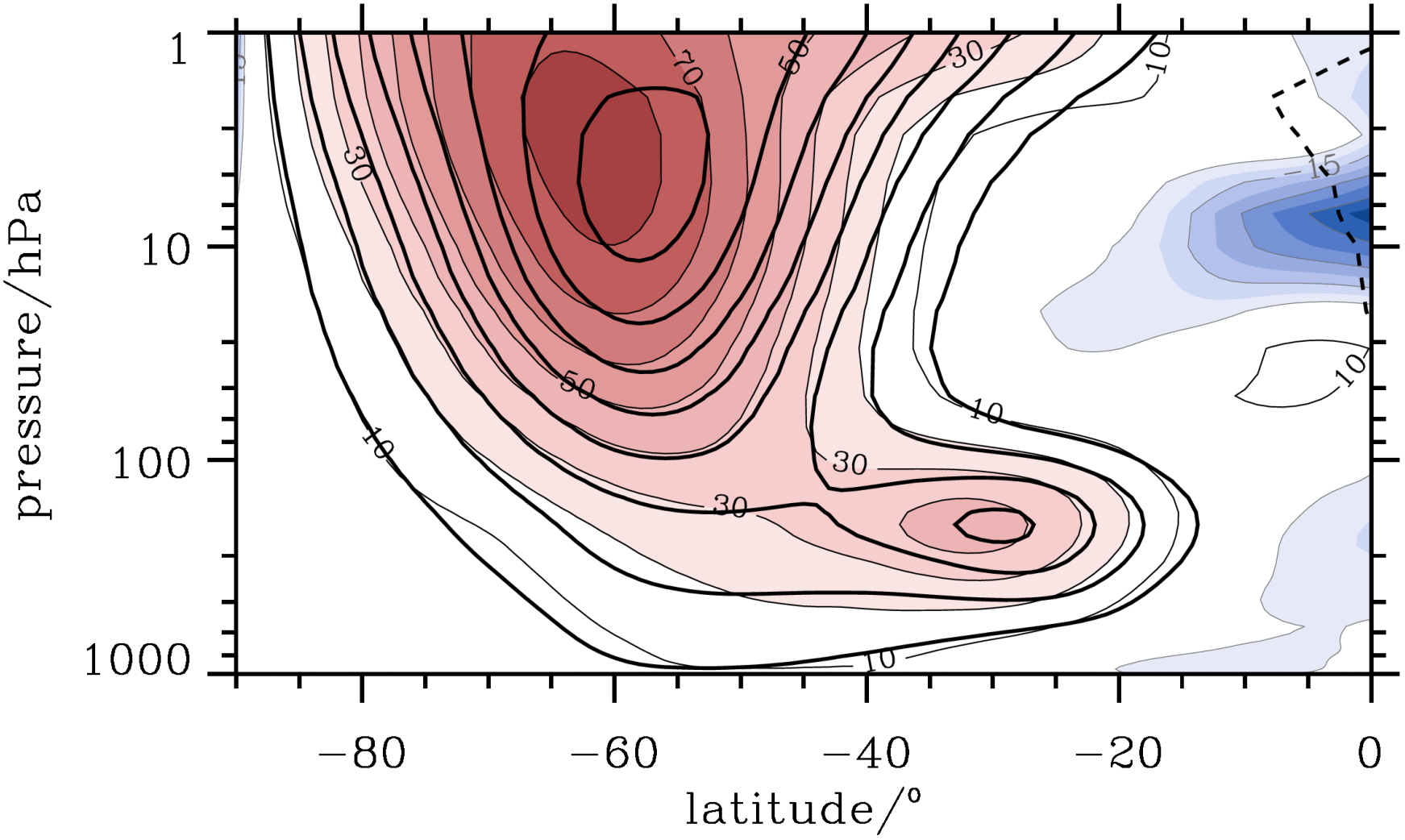
https://acd-ext.gsfc.nasa.gov/Data_services/met/qbo

Zonal Mean of Zonal Wind for July



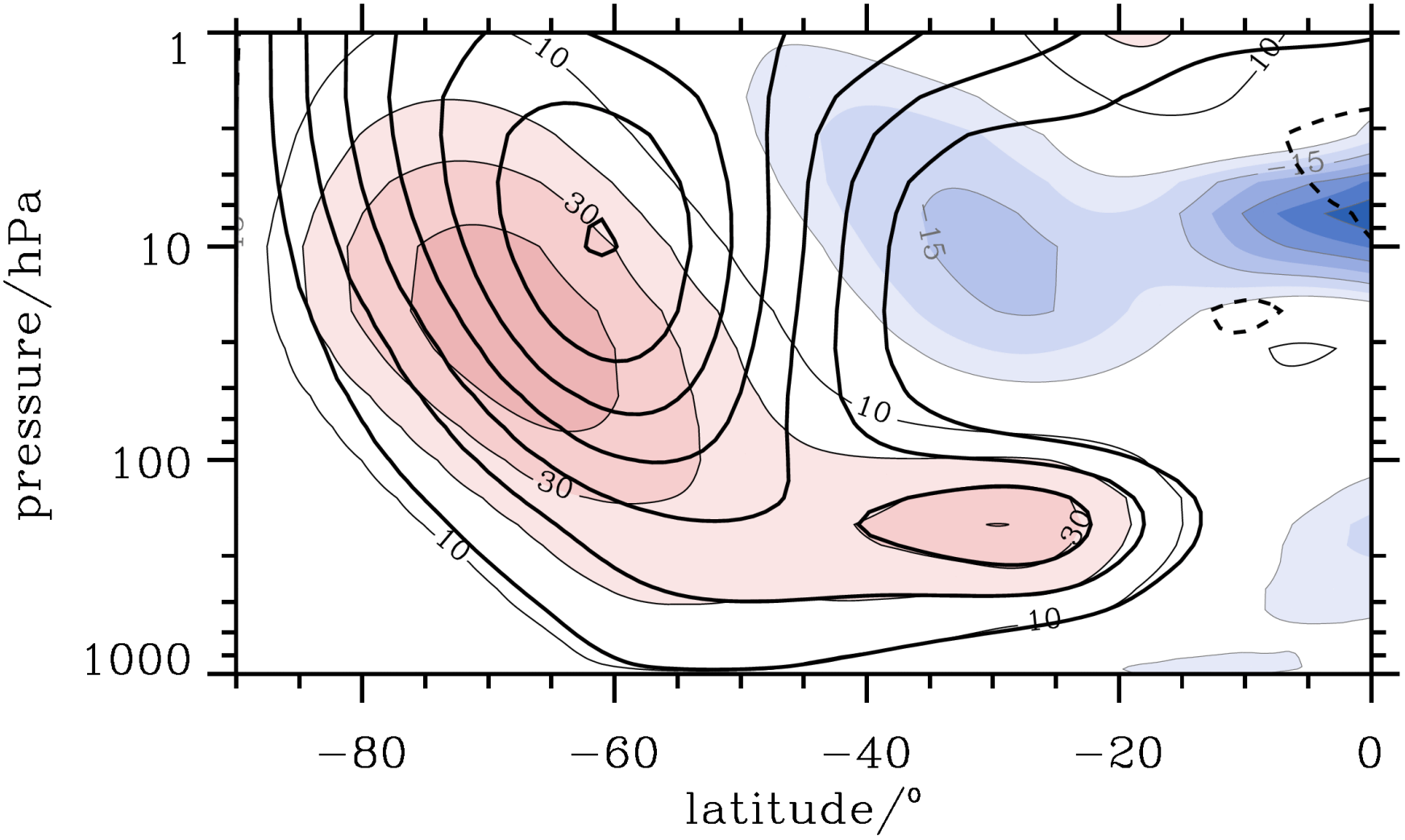
color shaded: July 2019 (ERA5)
thick black lines: climatological mean ERA5

Zonal Mean of Zonal Wind for August



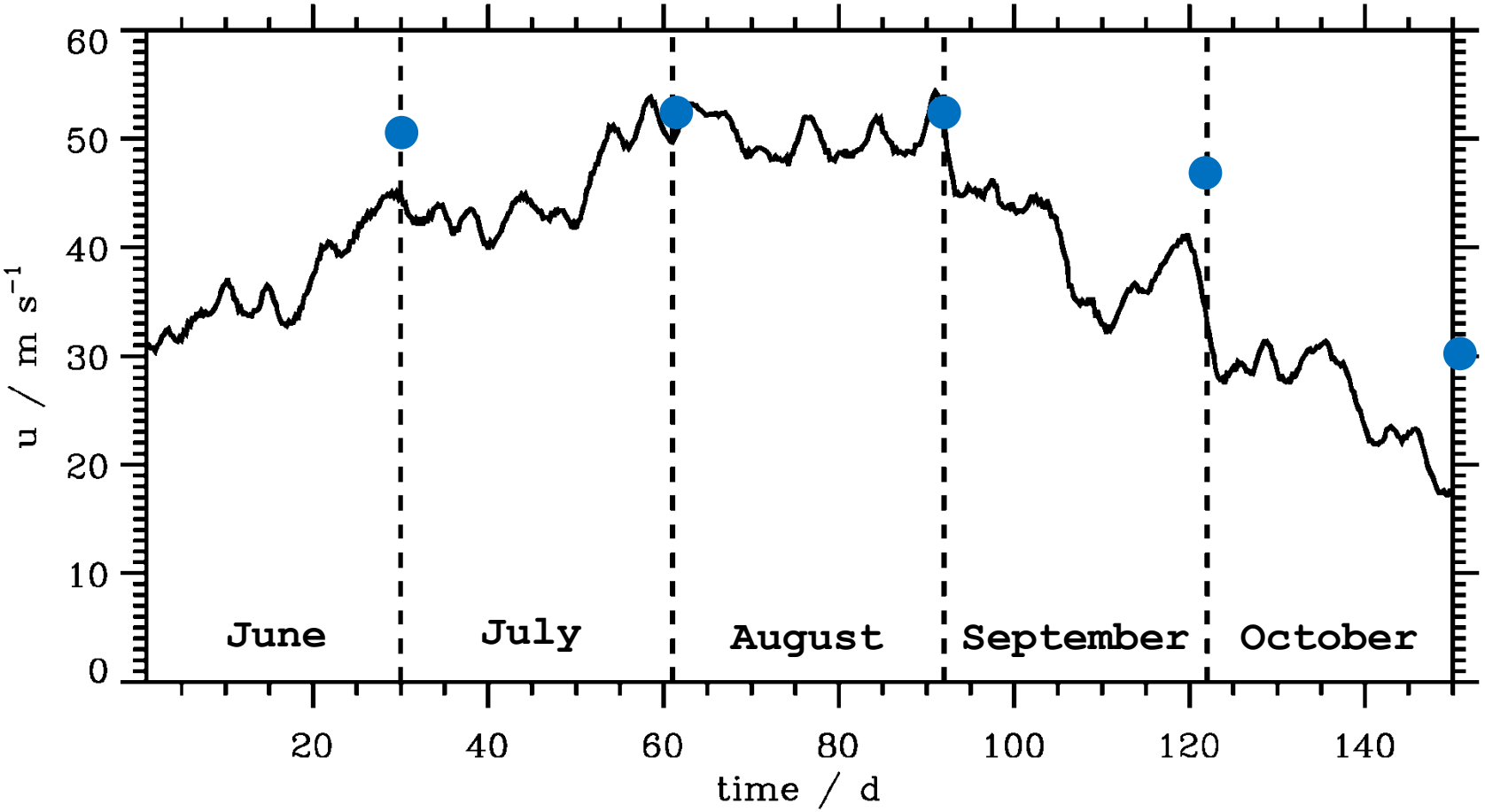
color shaded: August 2019 (ERA5)
thick black lines: climatological mean ERA5

Zonal Mean of Zonal Wind for September



color shaded: September 2019 (HRES)
thick black lines: climatological mean ERA5

Downward Shift of the Polar Vortex
June-October 2019

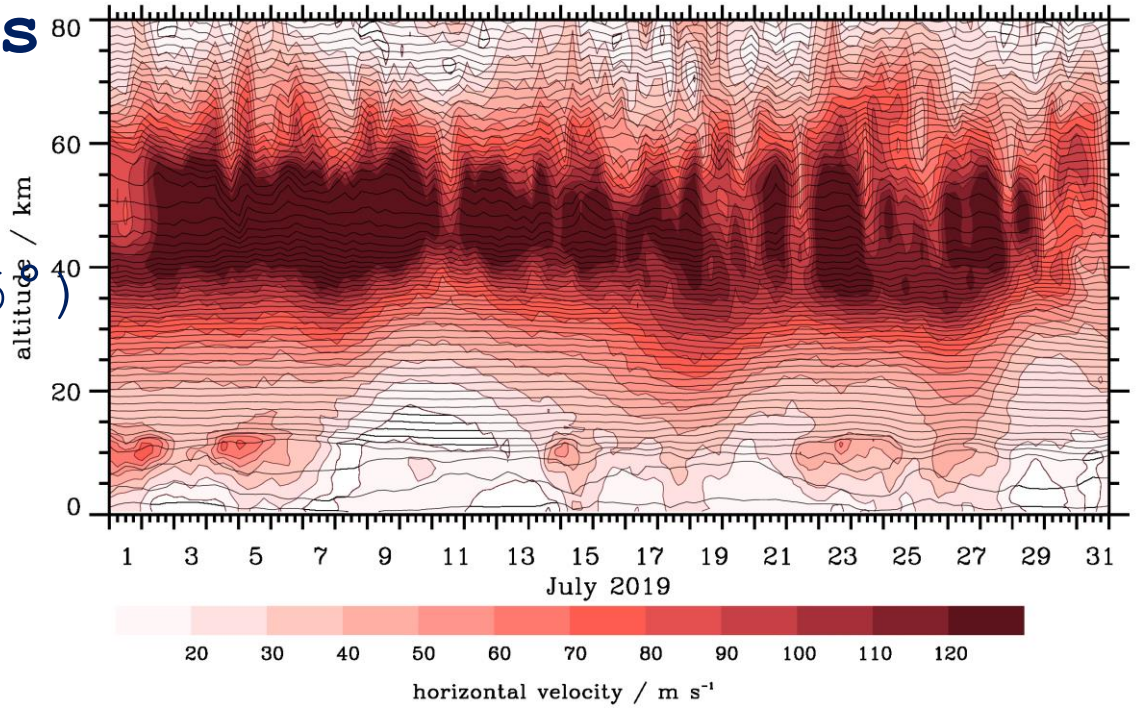


Zonal mean zonal winds between 55°S and 65°S

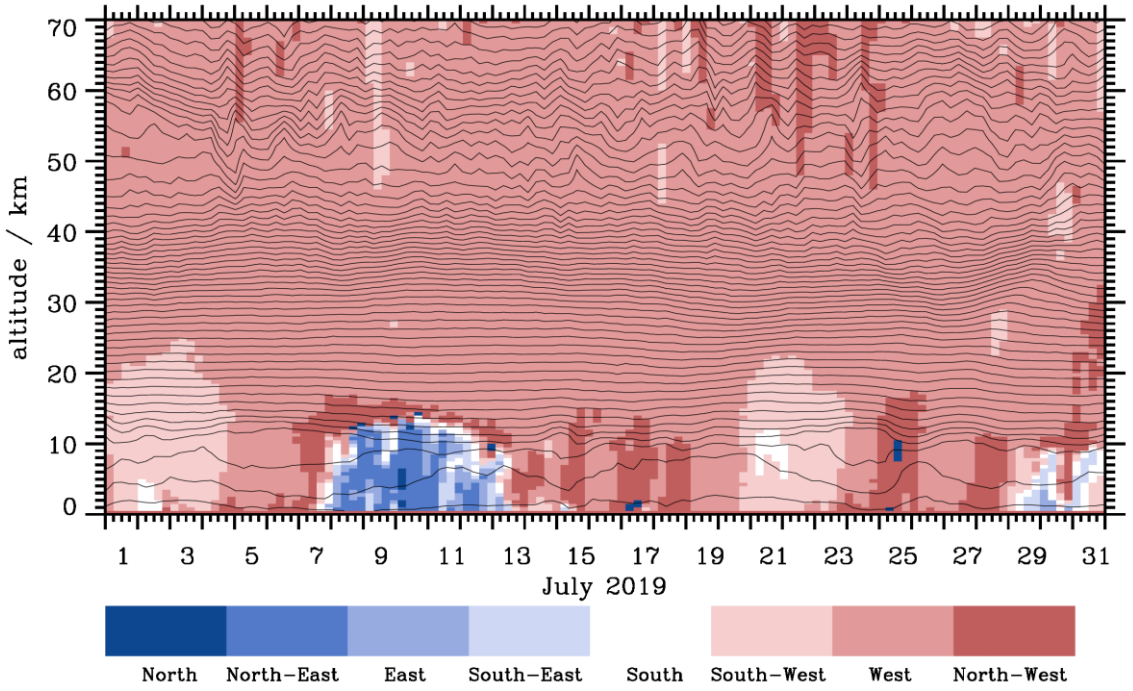
Upstream Profiles
July 2019

(80°W ± 5° 50°S ± 5°)

V_{HOR} (m/s)



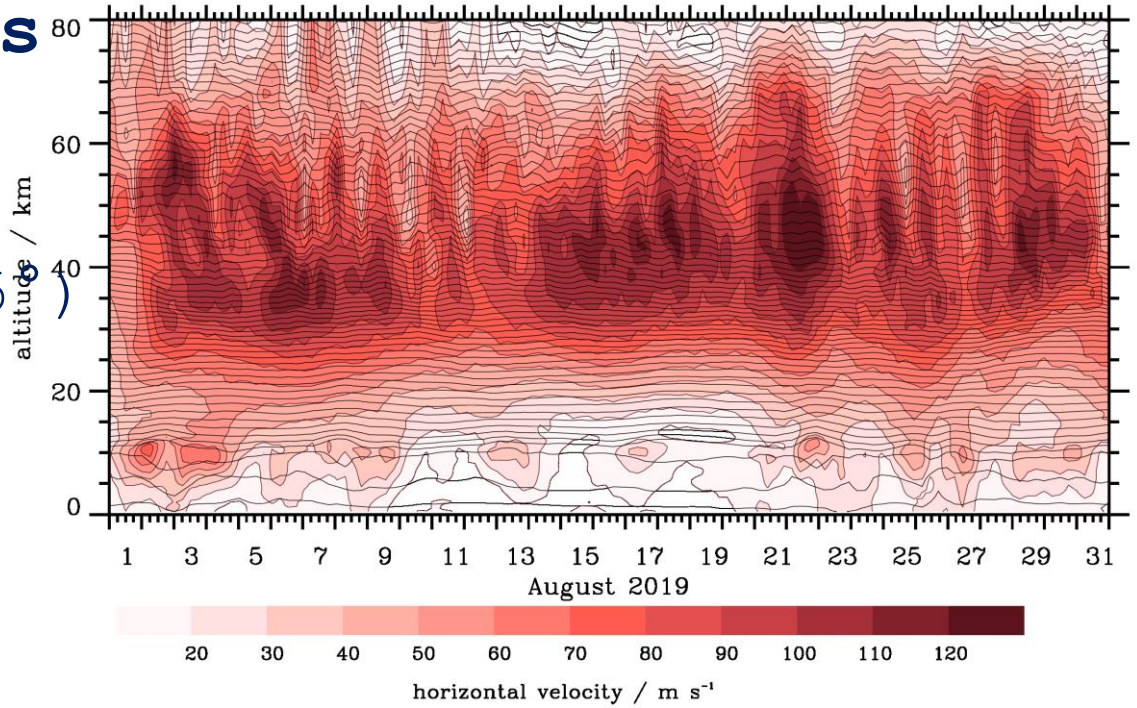
α_{HOR}



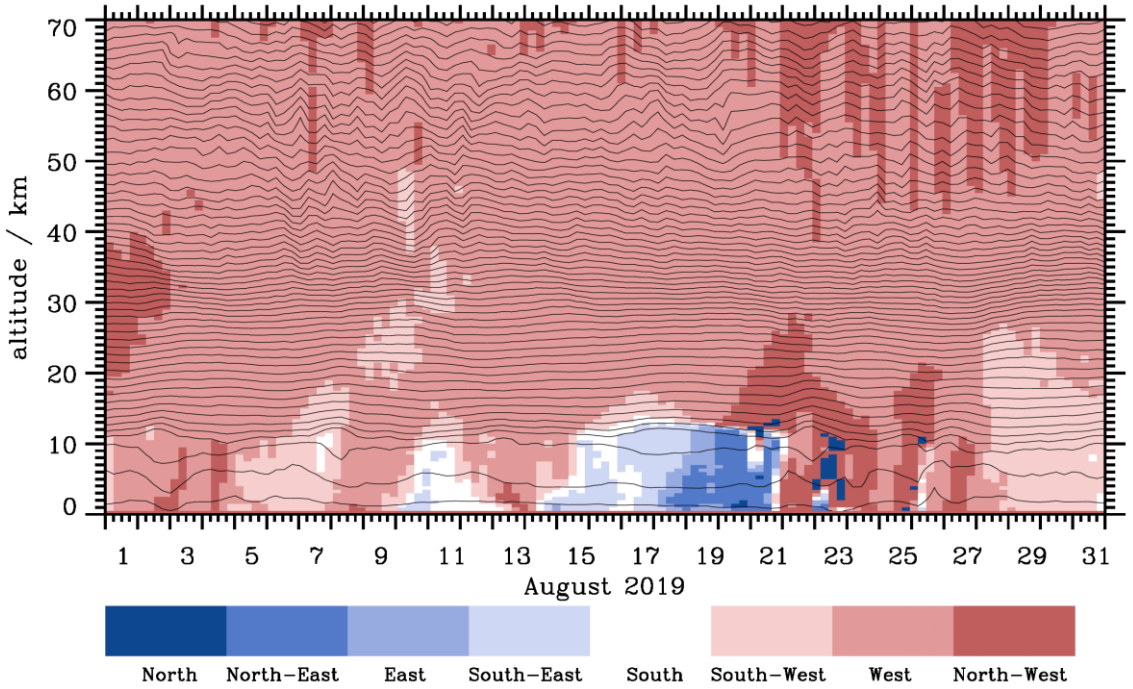
Upstream Profiles
August 2019

(80°W ± 5° 50°S ± 5°)

V_{HOR} (m/s)



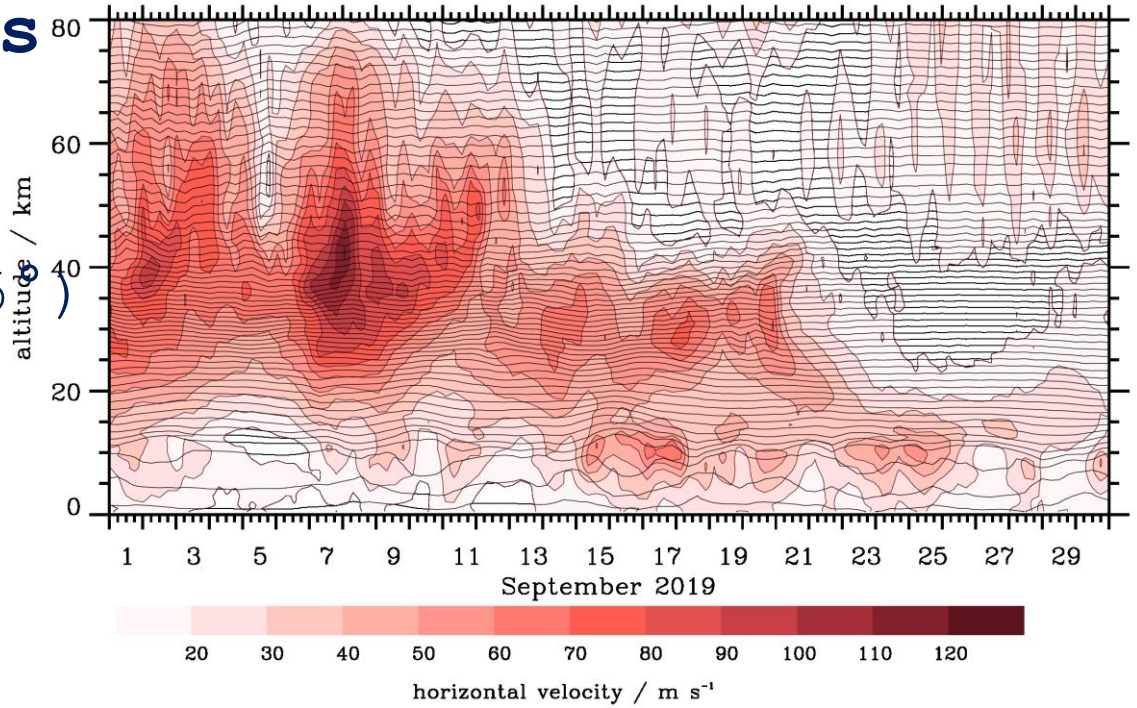
α_{HOR}



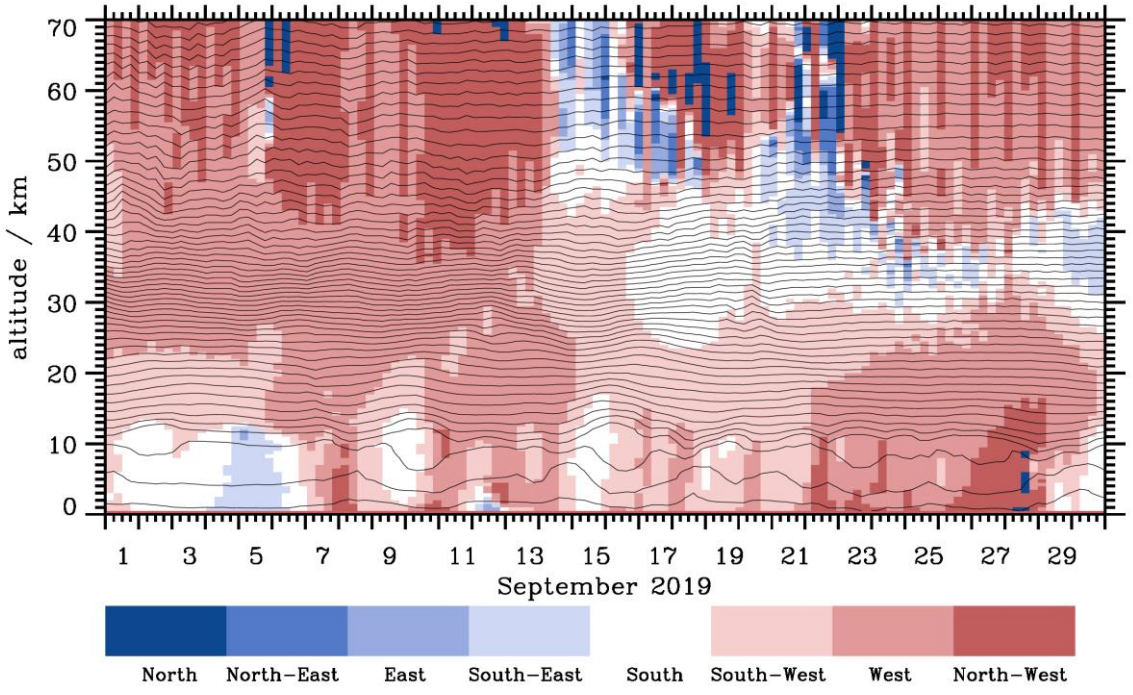
Upstream Profiles September 2019

(80°W ± 5° 50°S ± 5°)

V_{HOR} (m/s)



α_{HOR}



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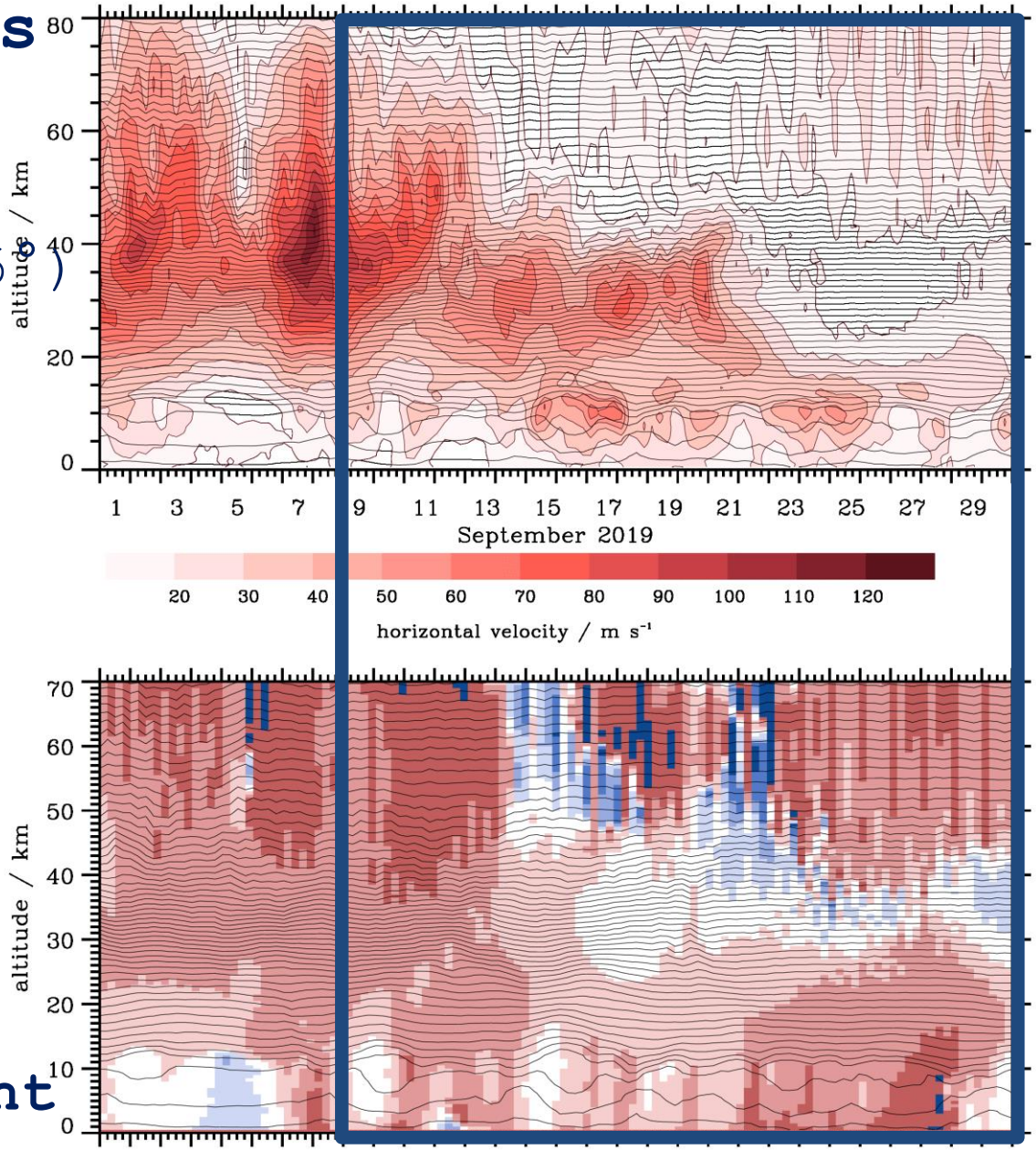


SouthTRAC deployment

α_{HOR}

Remote sensors and in-situ instrumentation

- **HALO**
- **CORAL**
- **gliders**
- **radiosondes**
- ……

HALO –
High Altitude and LOng range research aircraft

Gulfstream G550 special mission

- scientific payload up to 3 tonnes
- flight top height up to 15.5 km
- typical crew 7-8 (pilots, technician, scientists)
- > 8000 km range

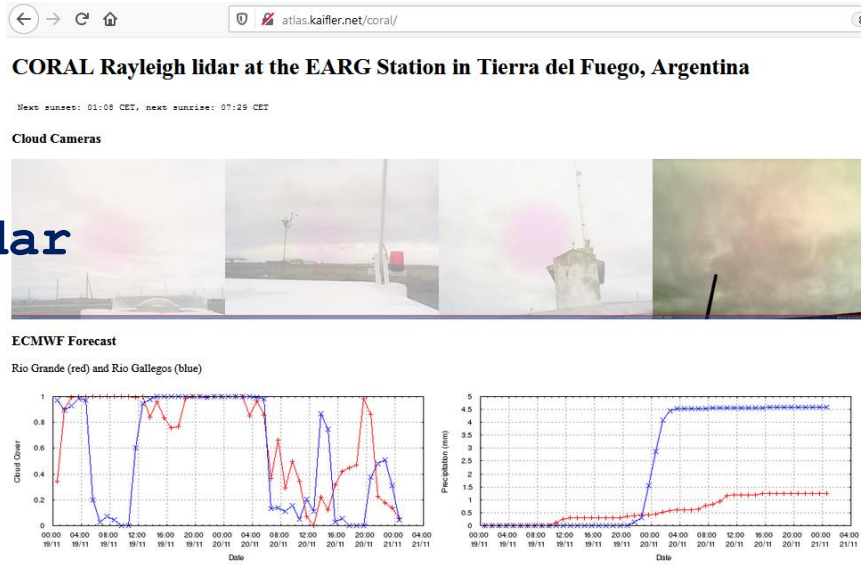
GLORIA instrument

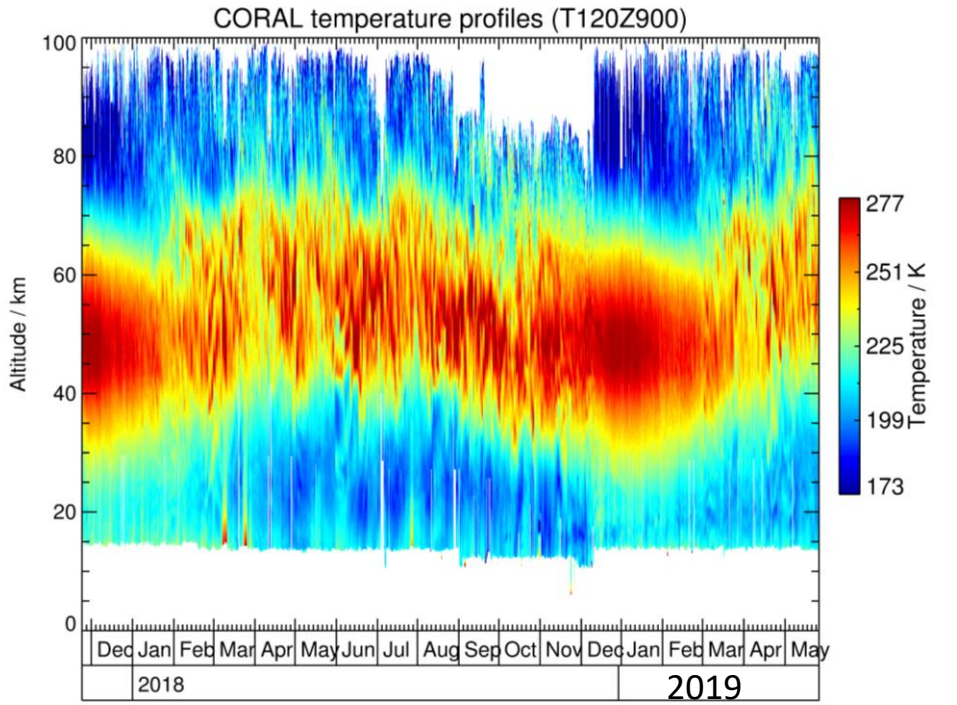
Airborne Lidar for the Middle Atmosphere(ALIMA)

Long-term, ground-based observations at Rio Grande

CORAL –

Compact Rayleigh Autonomous Lidar





Complementary ground-based observations and radiosondes launches at Rio Grande and El Calafate

Instrumented Motor glider in El Calafate

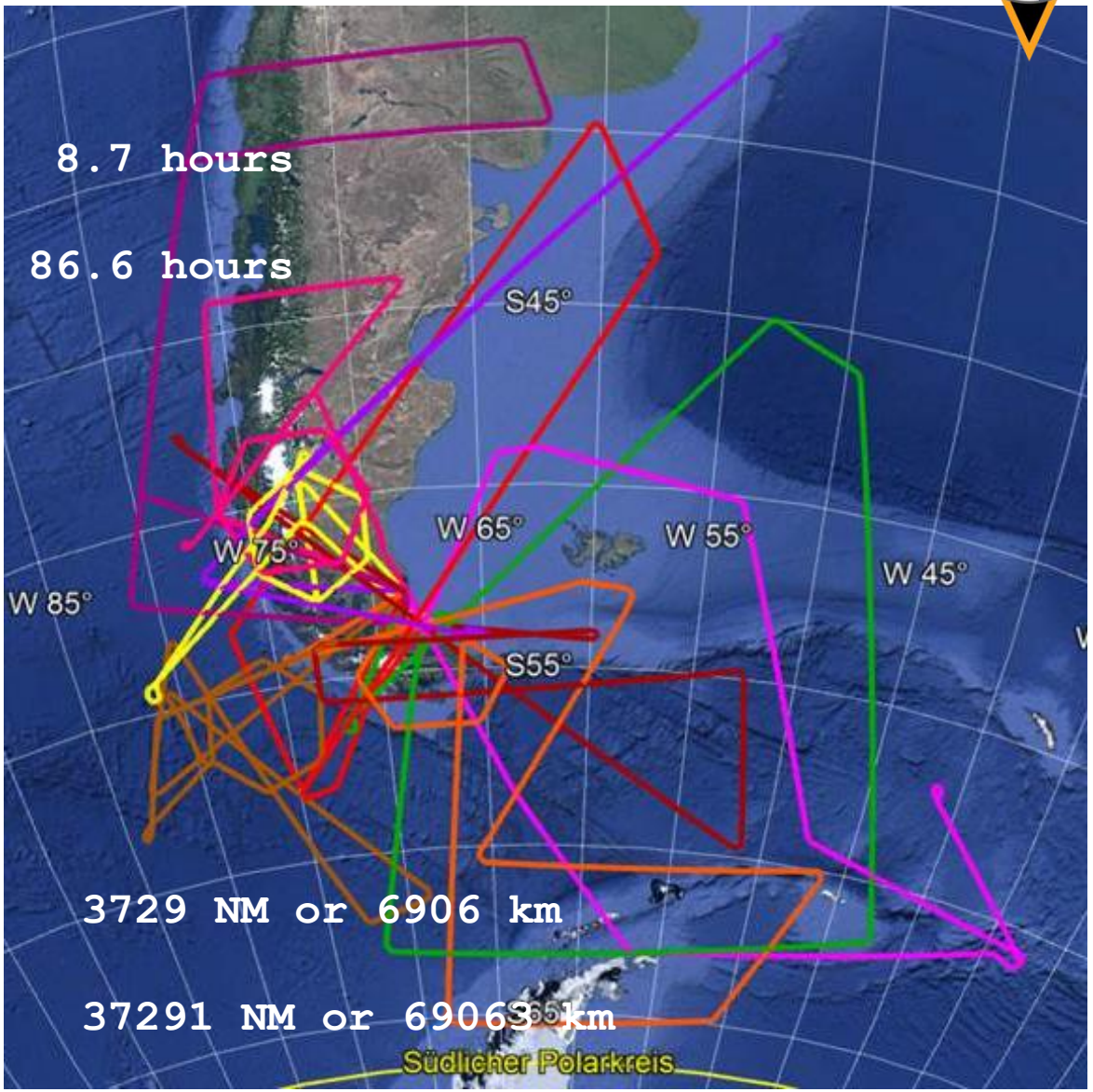

D-KKOP

Overview SouthTRAC Phase 1 September 2019

10 local flights

Average flight duration 8.7 hours

Total flight duration 86.6 hours



Average flight distance 3729 NM or 6906 km

Total flight distance 37291 NM or 69063 km

Selected Results from SouthTRAC Phase 1

1. Deep wave propagation case 9 September 2019
2. Mountain waves in UTLS 20 September 2019
3. Soaring for science – glider measurements

Selected Results from SouthTRAC Phase 1

1. **Deep wave propagation case 9 September 2019**
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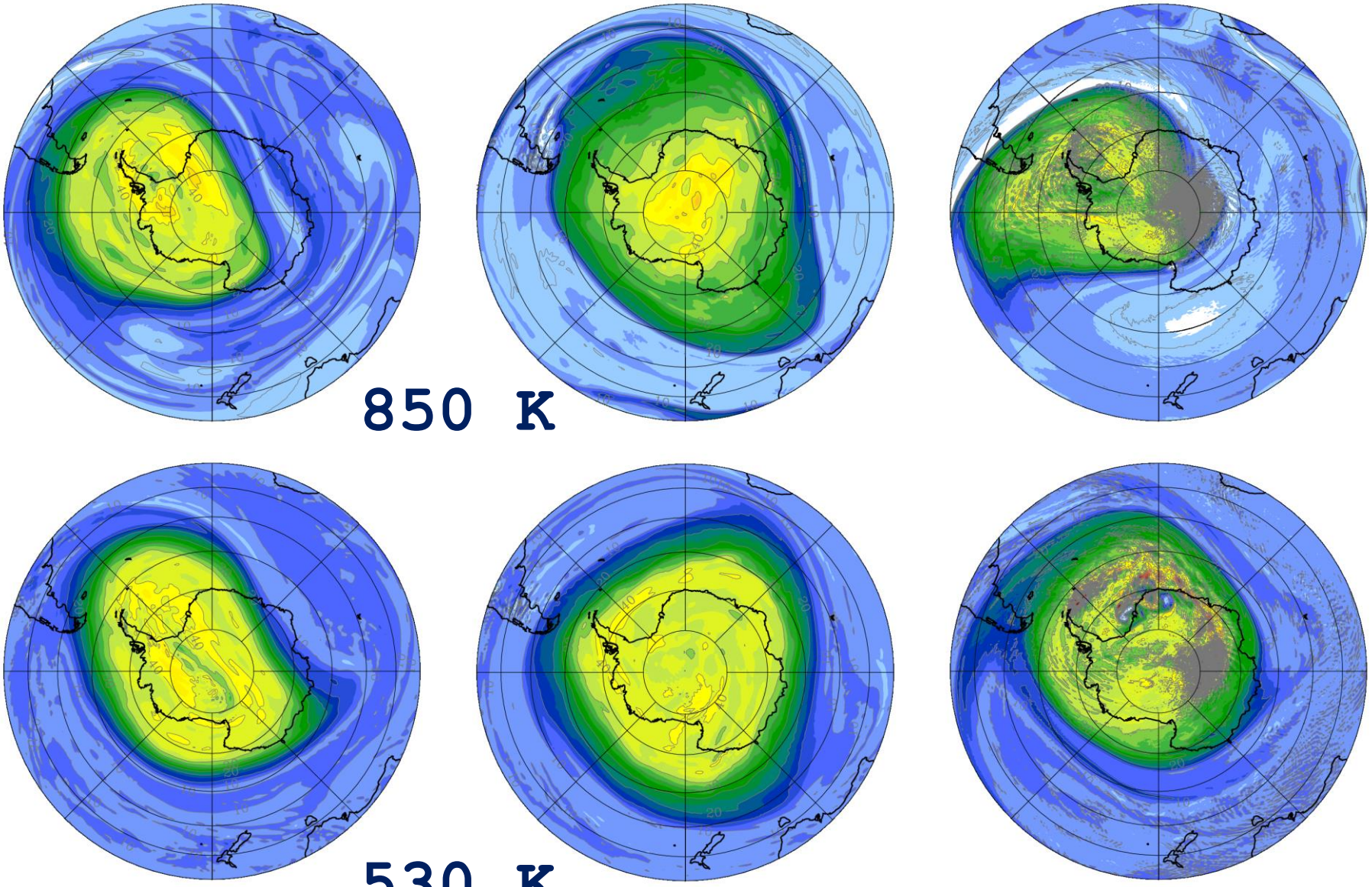
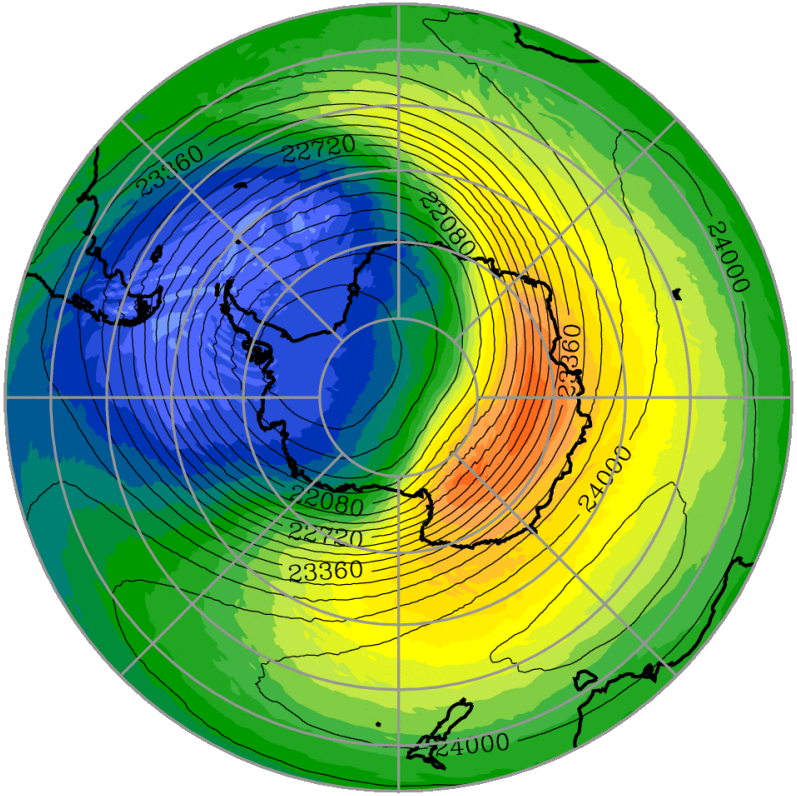
ERA5 analyses valid at 11 September 12 UTC

2002 2006 2019

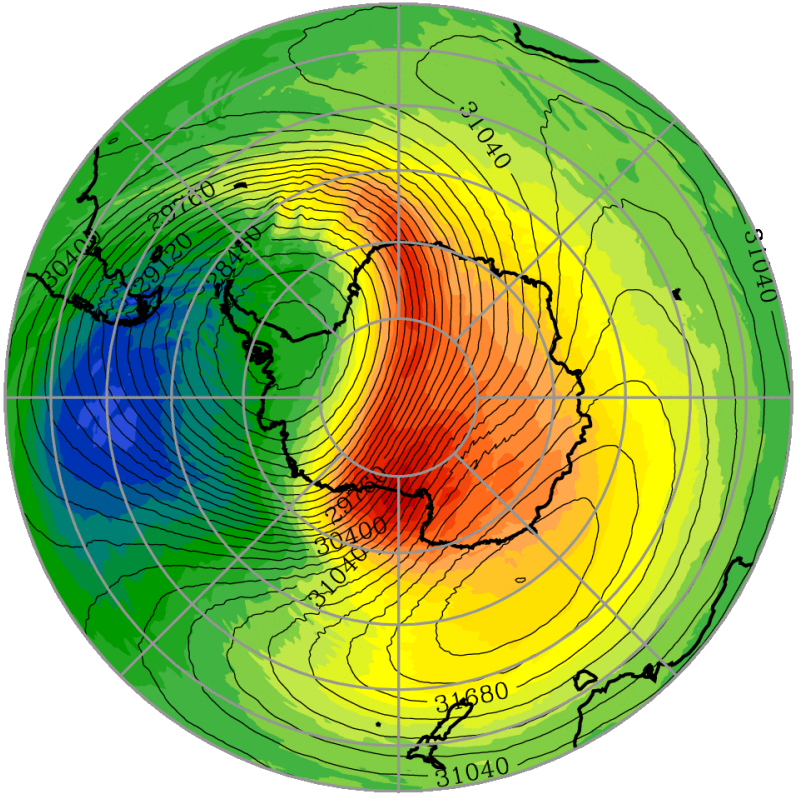


Absolute Temperature (K) at 30 hPa



ECMWF T_{co}1279/L137 (0.25°x0.25°) VT: 11.09.2019 18 UTC

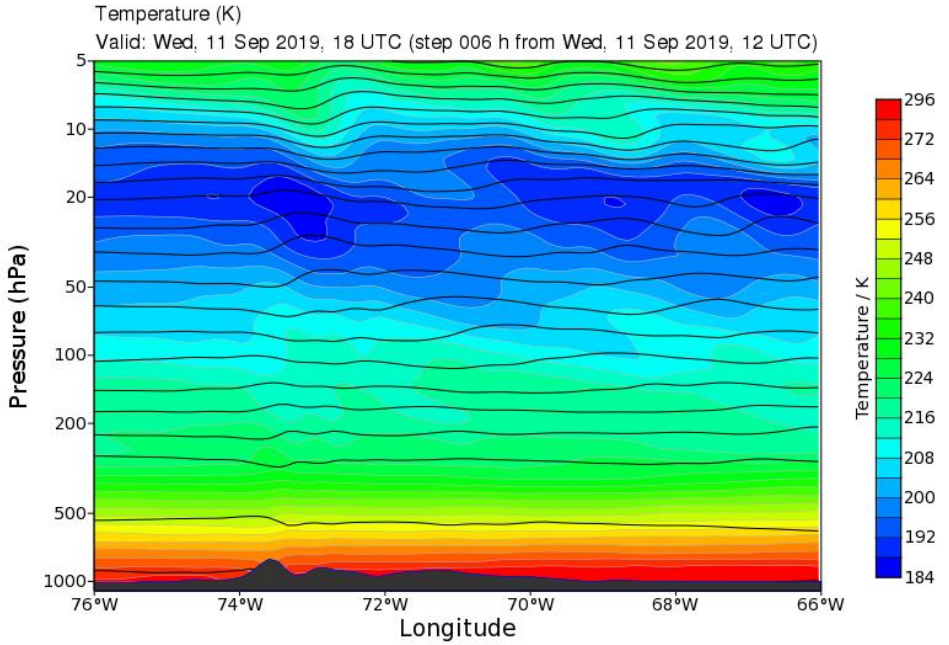
Absolute Temperature (K) at 10 hPa

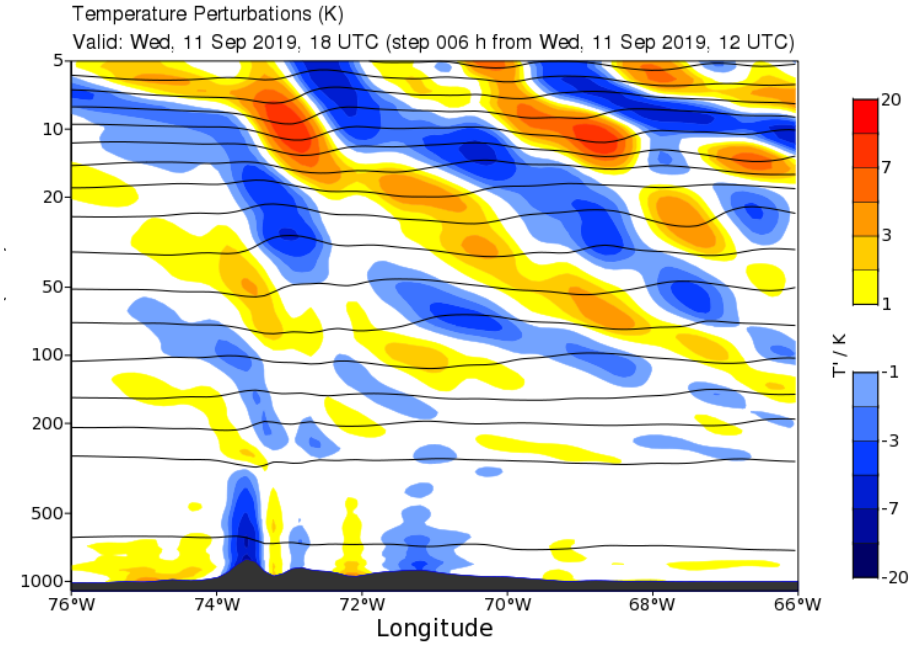


ECMWF T_{co}1279/L137 (0.25°x0.25°) VT: 11.09.2019 18 UTC

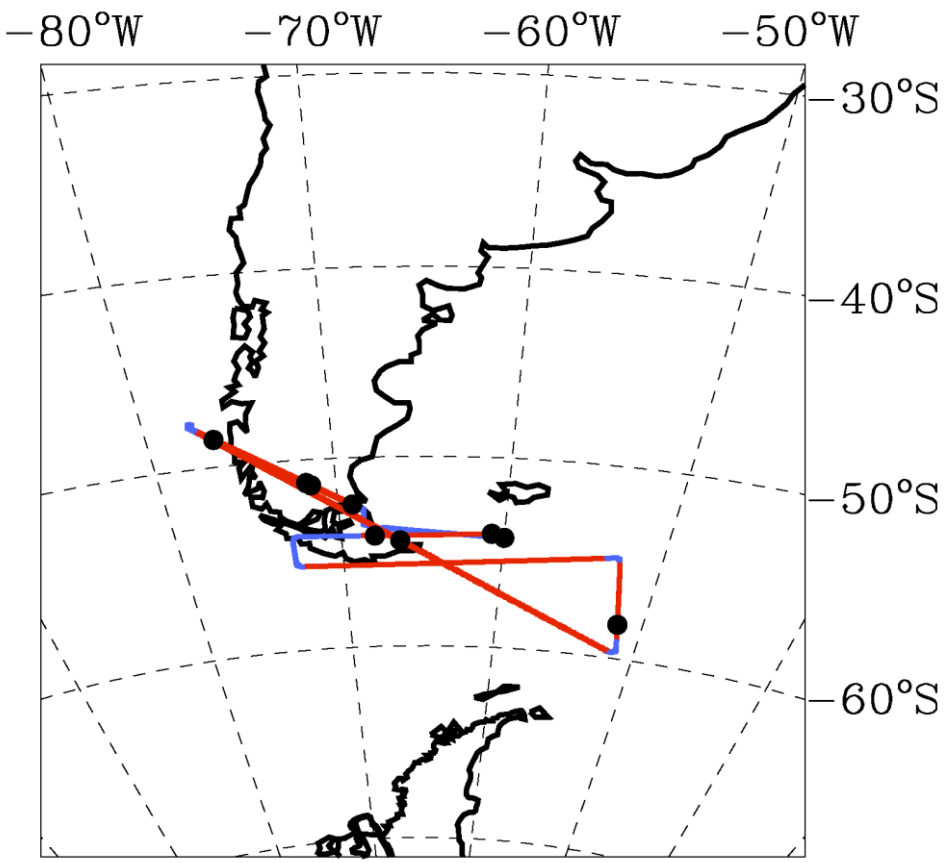
Research Flight ST08 on 11/12 September 2019

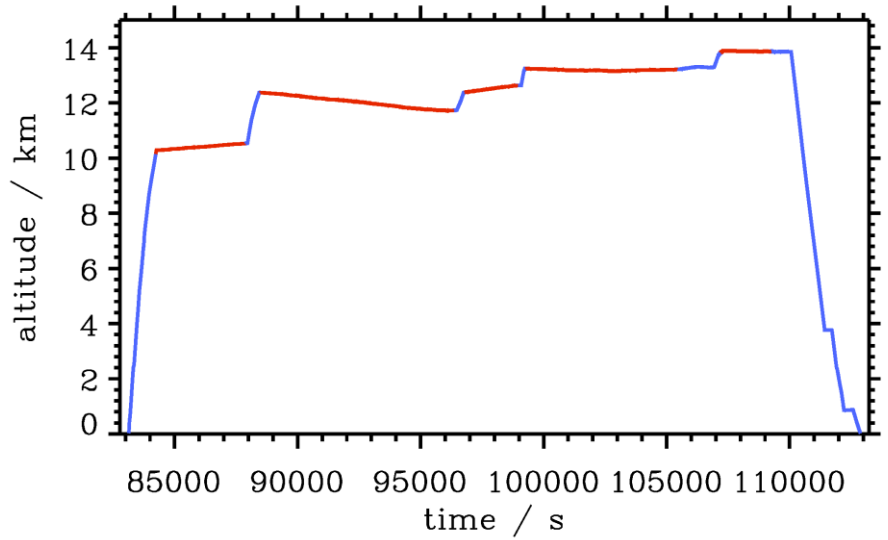
Polar Stratospheric Cloud over El Calafate 11 September 2019

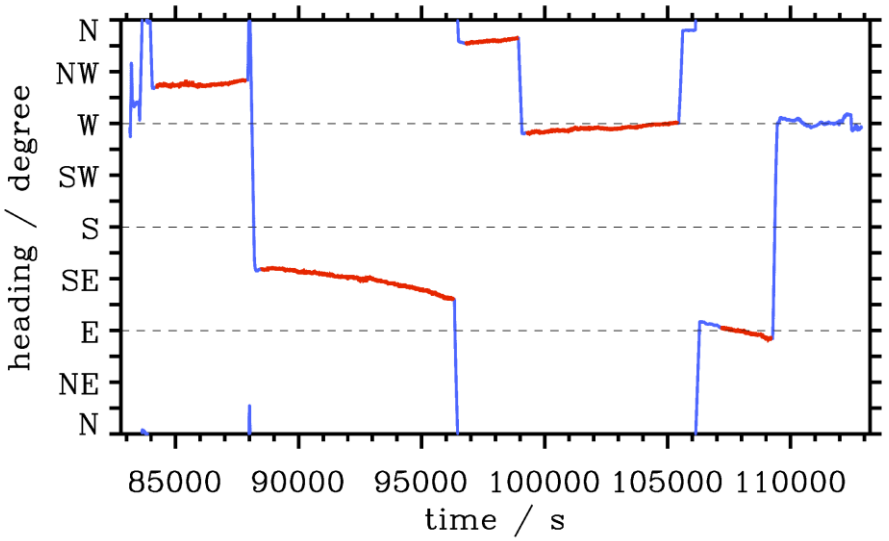

Temperature (K)
Valid: Wed, 11 Sep 2019, 18 UTC (step 006 h from Wed, 11 Sep 2019, 12 UTC)
Pressure (hPa)
5
10
20
50
100
200
500
1000
76°W
74°W
72°W
70°W
68°W
66°W
Longitude
Temperature / K
296
272
264
256
248
240
232
224
216
208
200
192
184


Temperature Perturbations (K)
Valid: Wed, 11 Sep 2019, 18 UTC (step 006 h from Wed, 11 Sep 2019, 12 UTC)
5
10
20
50
100
200
500
1000
76°W
74°W
72°W
70°W
68°W
66°W
Longitude
T' / K
20
7
3
1
-1
-3
-7
-20

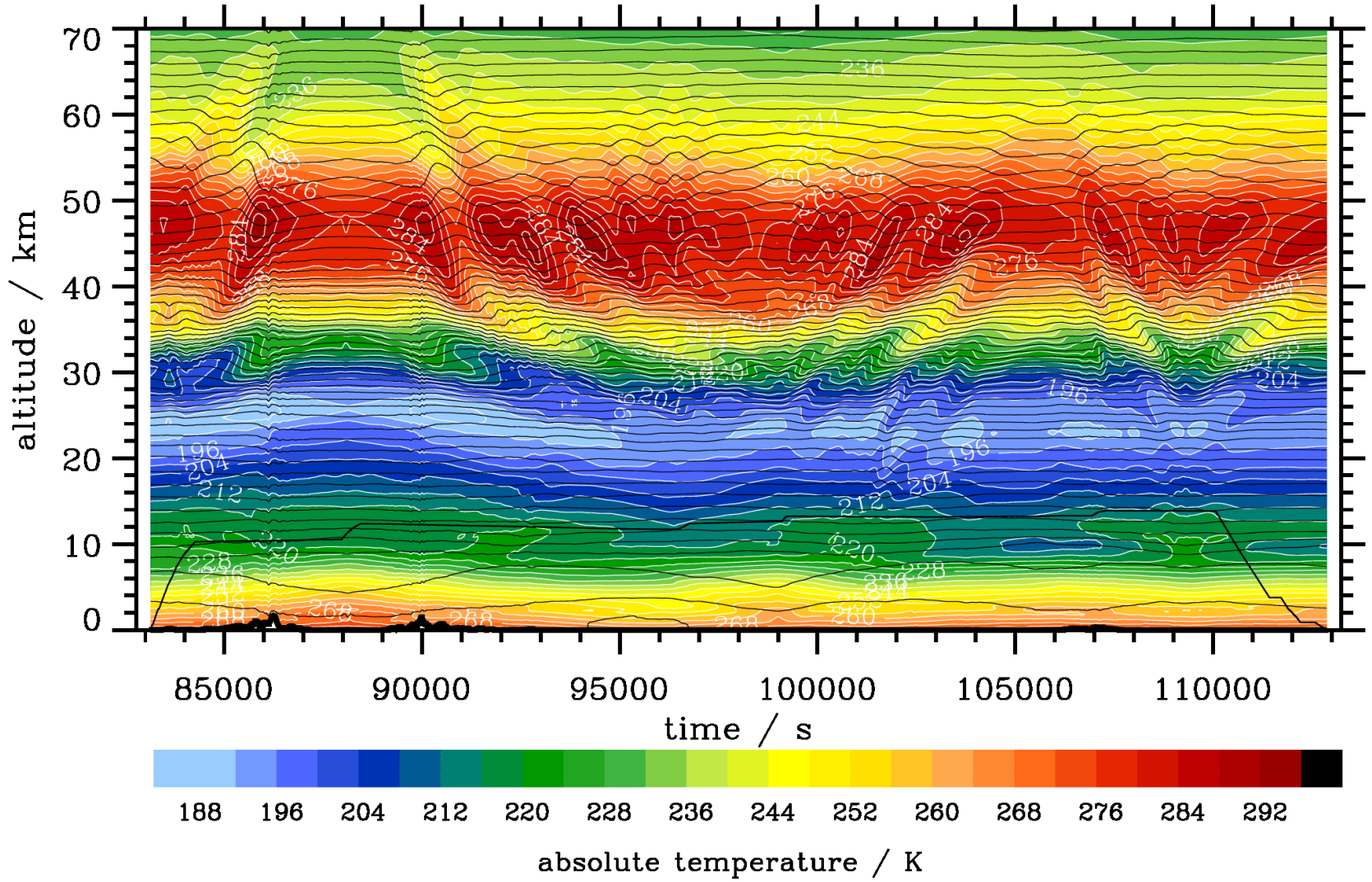
Research Flight ST08 on 11/12 September 2019





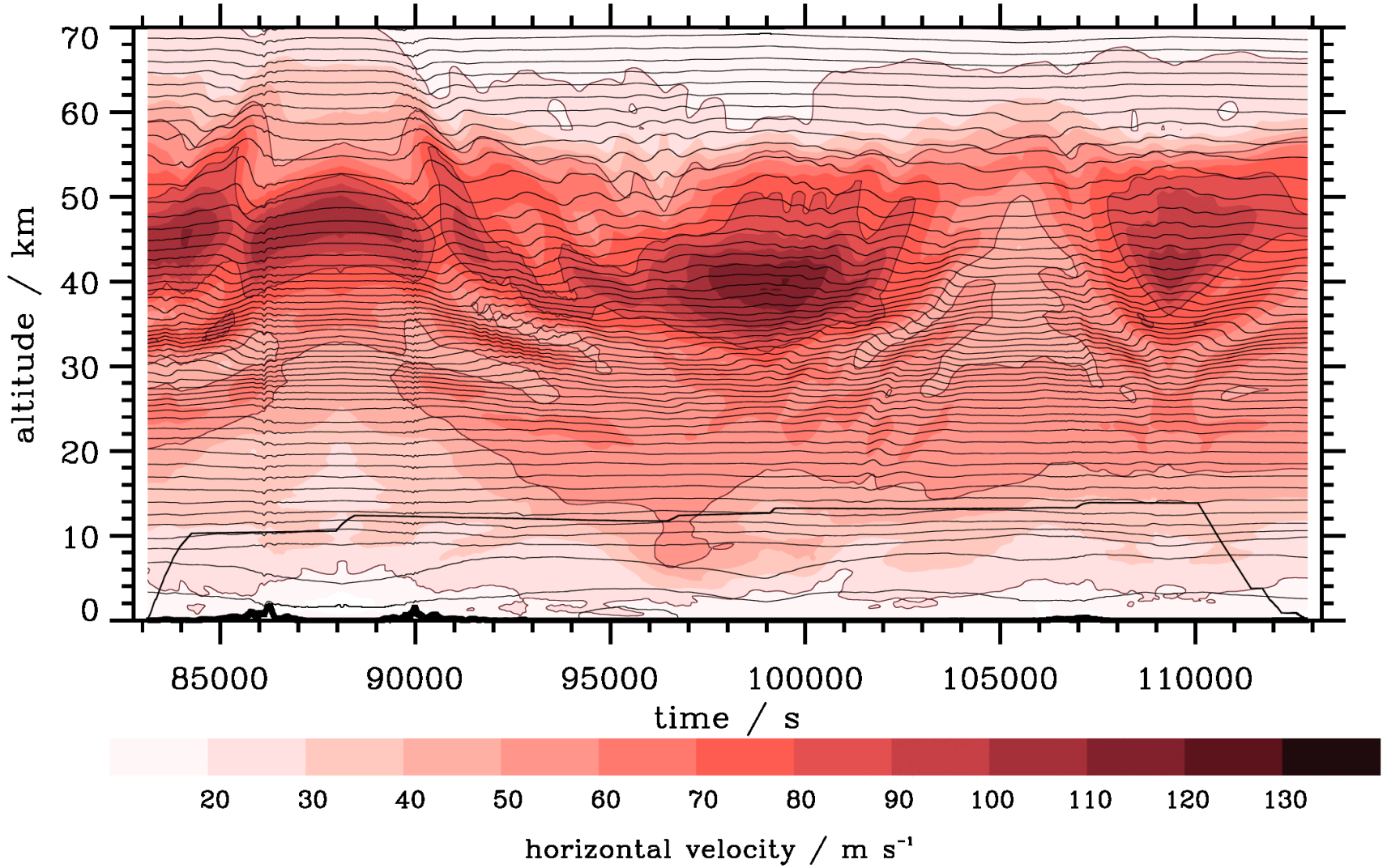


Research Flight ST08 on 11/12 September 2019



IFS HRES analyses and short-term forecasts interpolated on flight track

Research Flight ST08 on 11/12 September 2019



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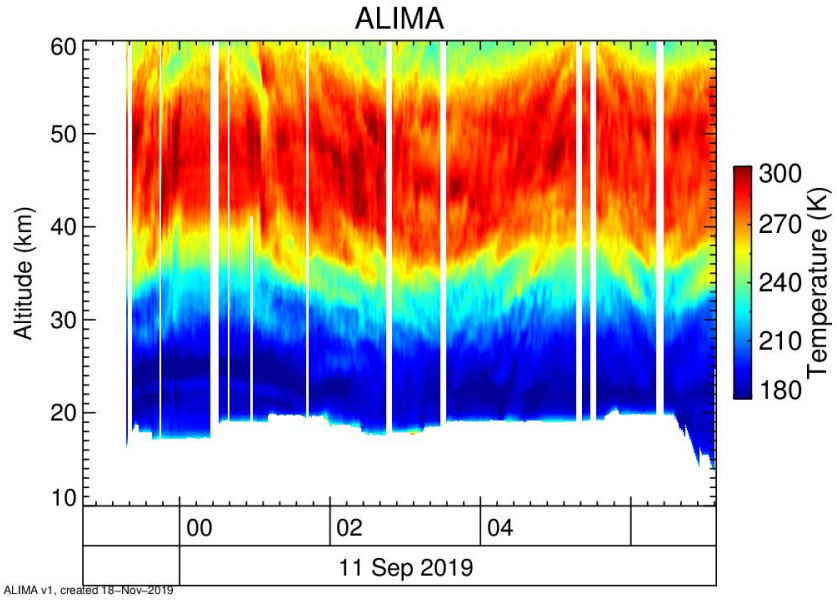
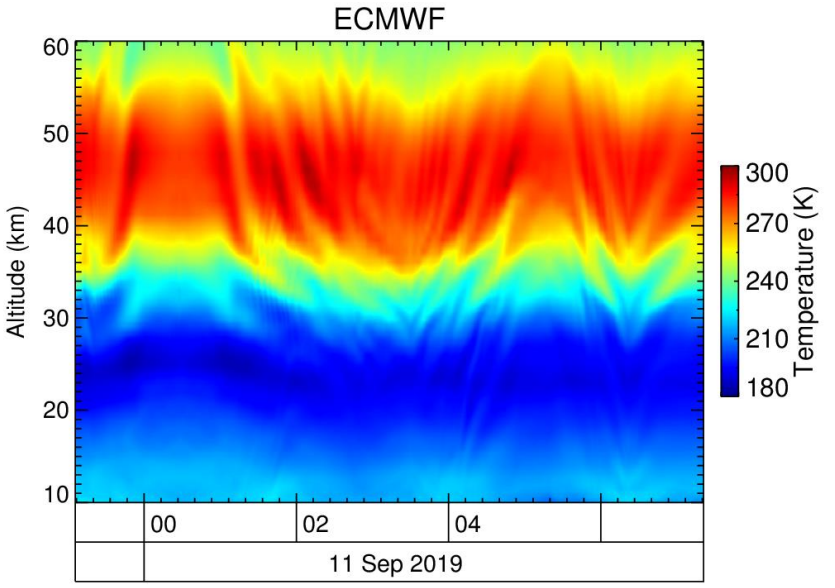
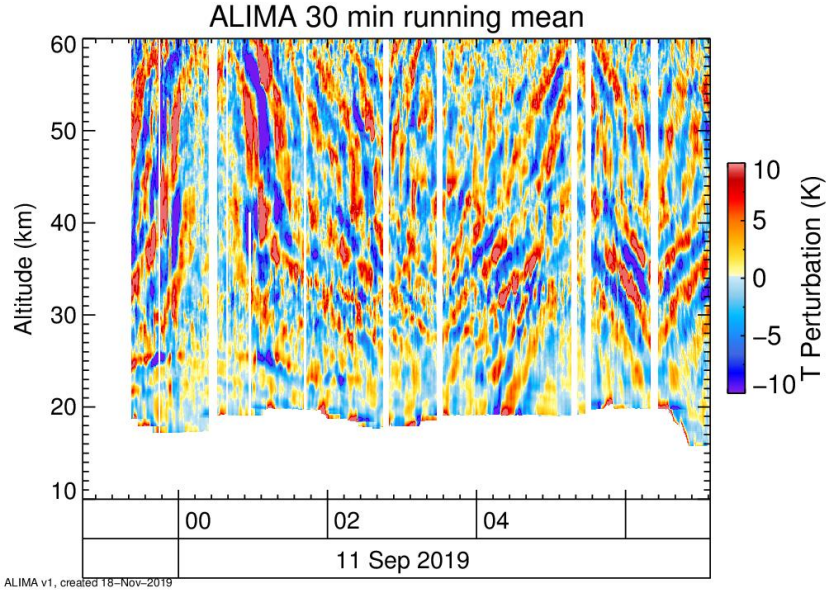
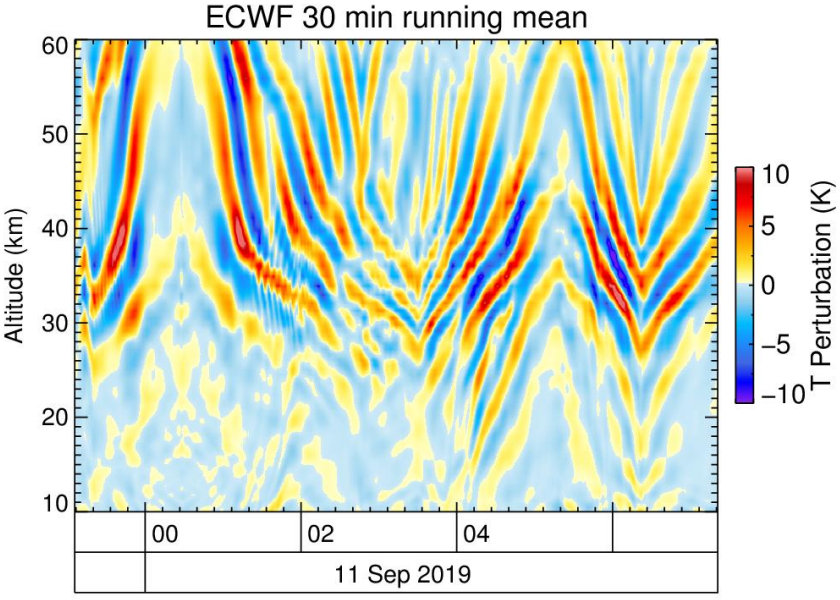




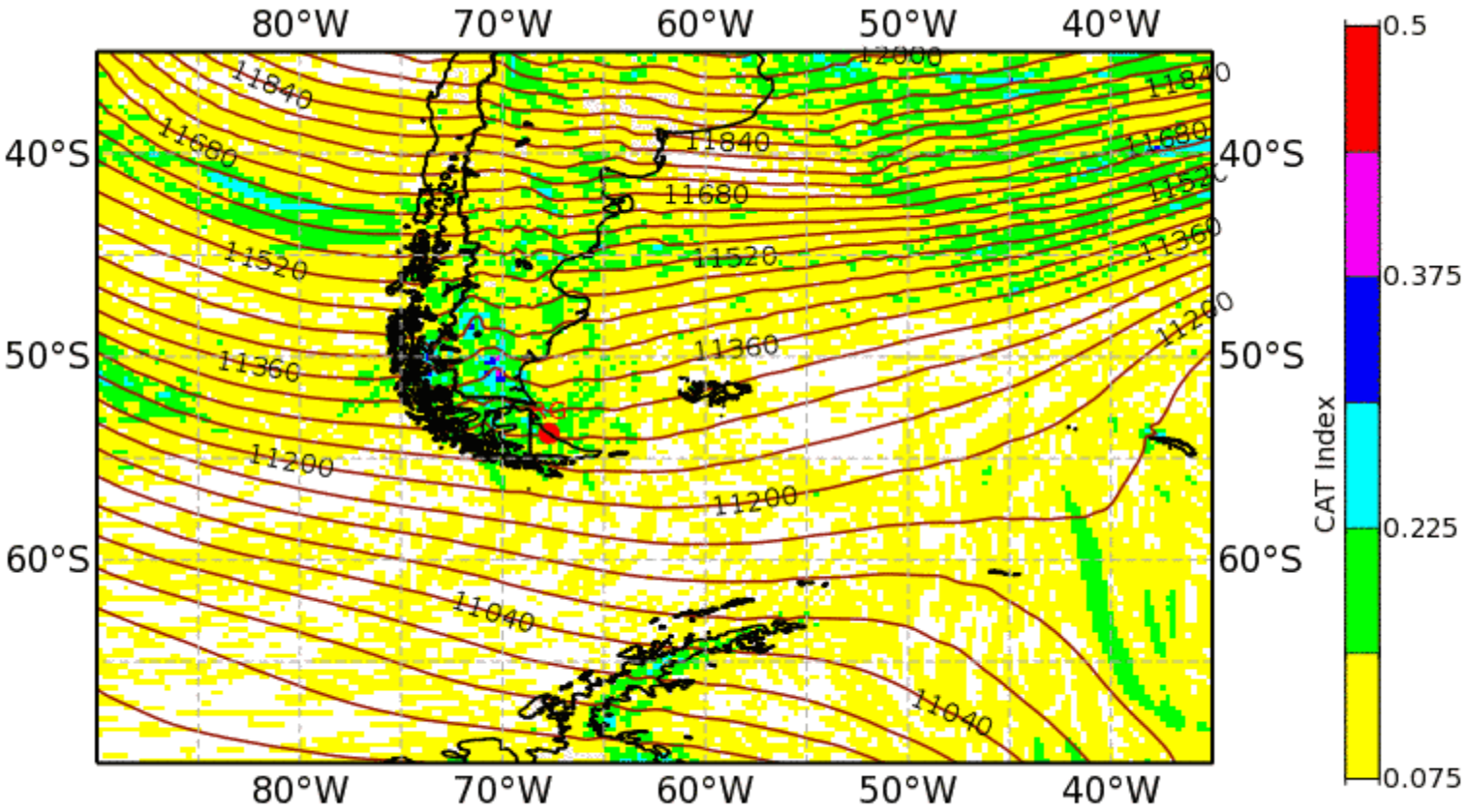




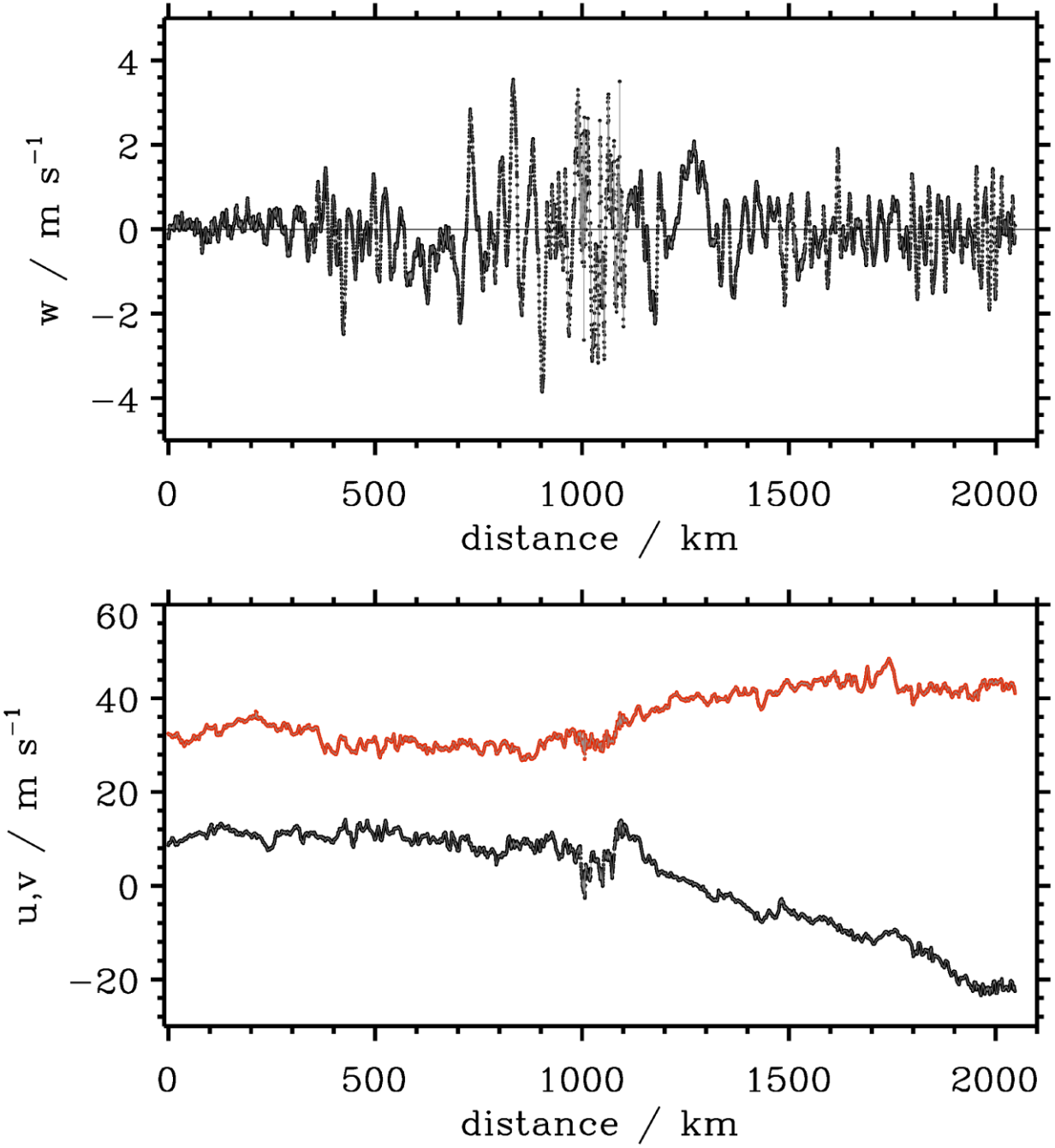
ALIMA onboard HALO (Kaifler, DLR)

IFS HRES analyses and short-term forecasts interpolated on flight track

Quasi-operational CAT forecasts for research purposes



Provided by Peter Bechthold, ECMWF
Martina Bramberger, CORA/DLR


w / m s^{-1}
4
2
0
−2
−4
0
500
1000
1500
2000
distance / km
u,v / m s^{-1}
60
40
20
0
−20
0
500
1000
1500
2000
distance / km

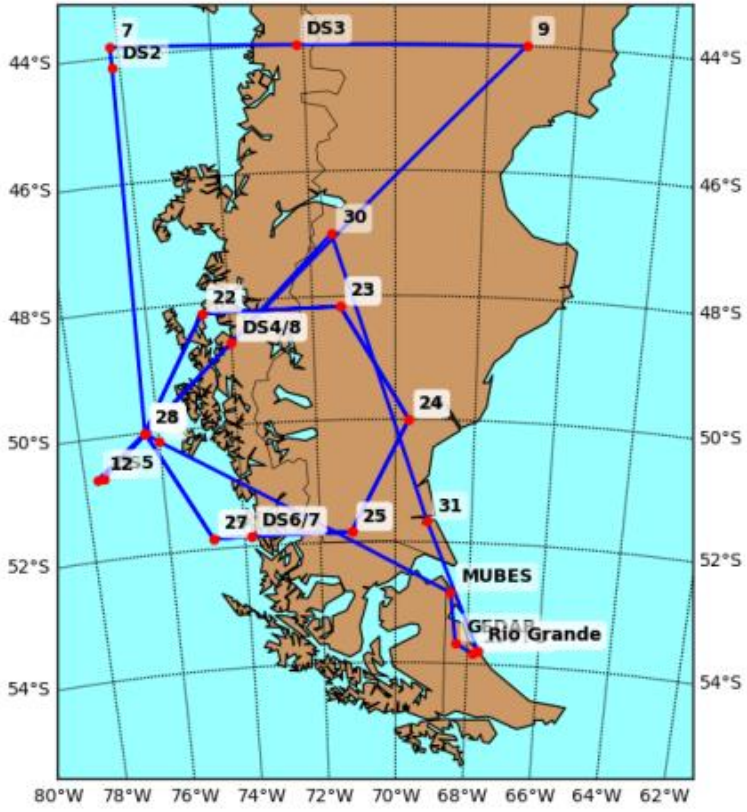
Selected Results from SouthTRAC Phase 1

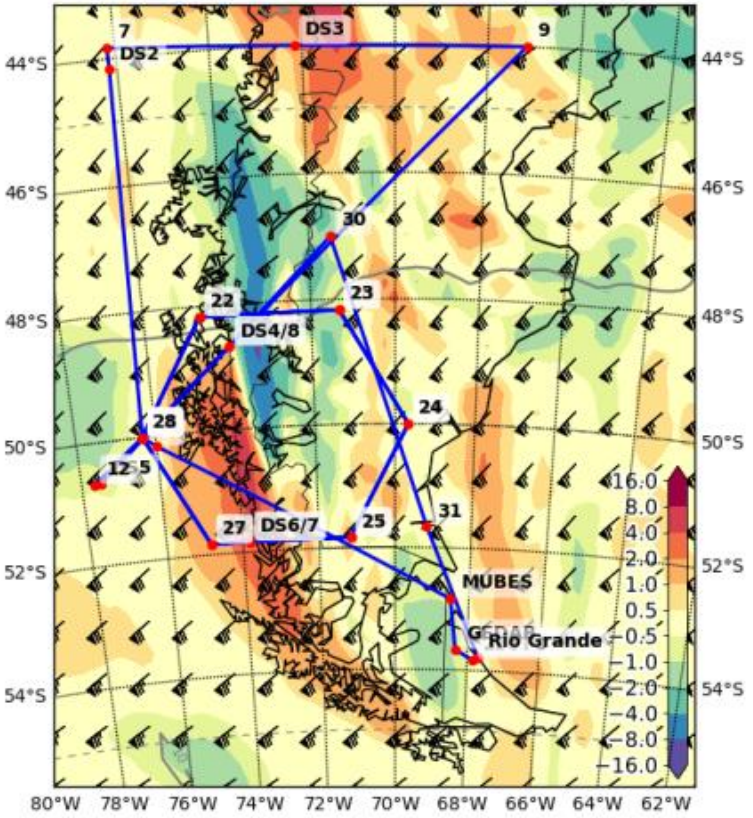
1. Deep wave propagation case 9 September 2019

2. **Mountain waves in UTLS 20 September 2019**

3. Soaring for science – glider measurements

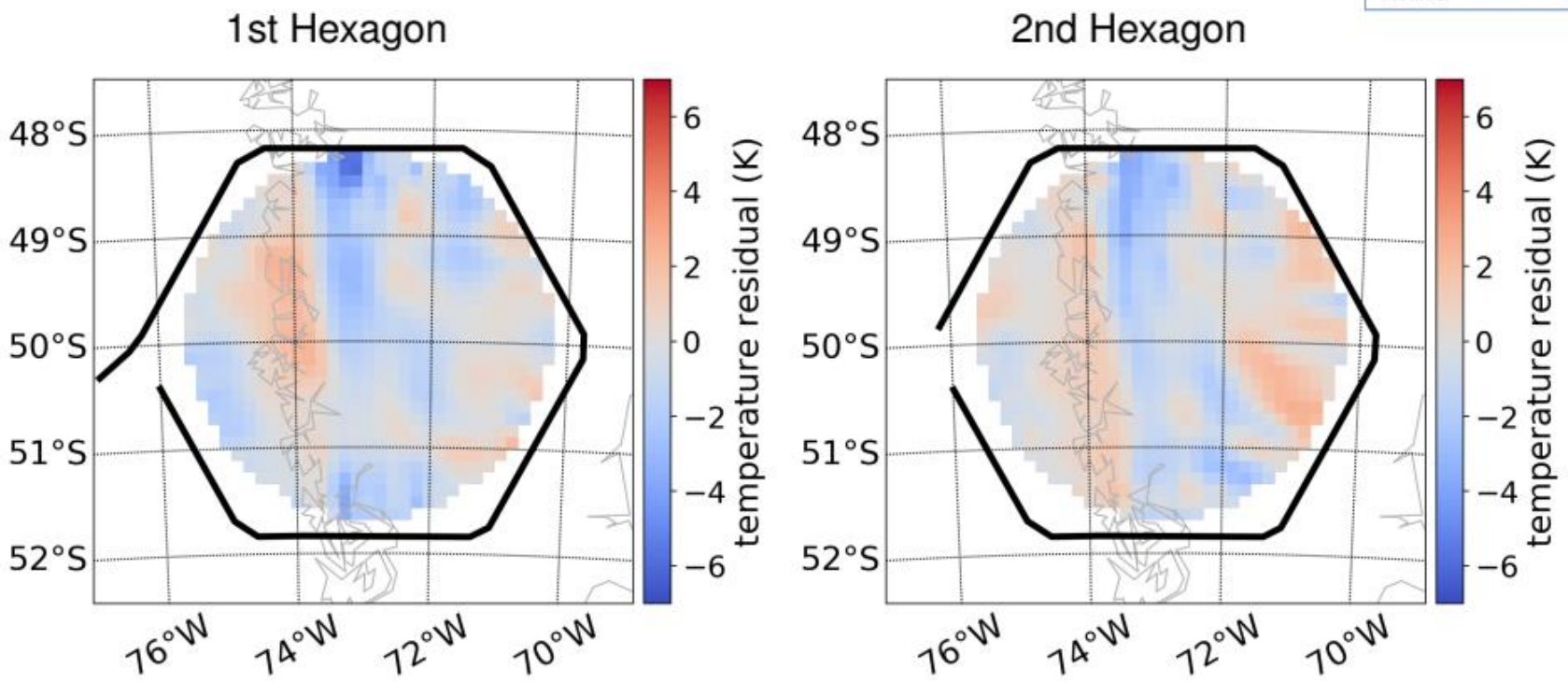
FLIGHT 12 OF SOUTHTRAC; 20 SEPTEMBER





GLORIA 3D TEMPERATURE RETRIEVAL

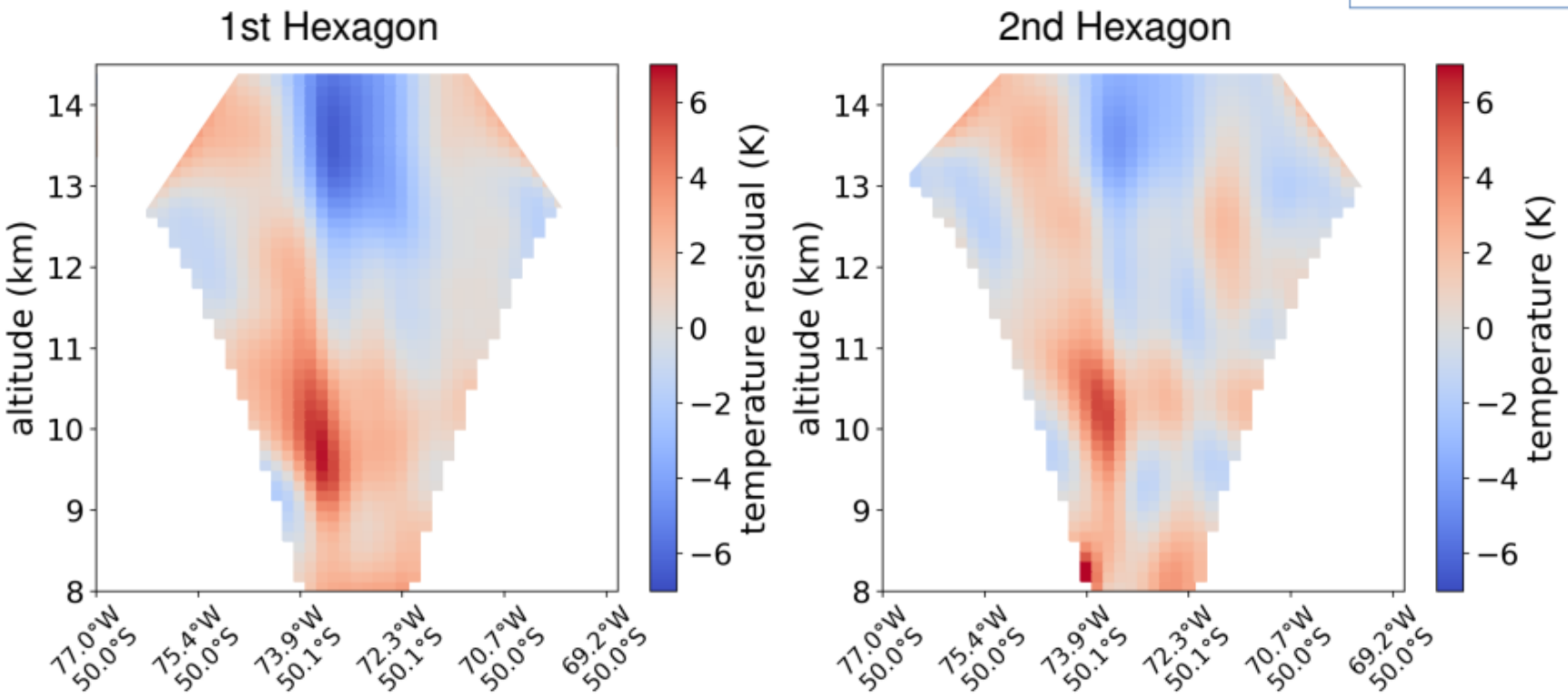
Horizontal maps at 12km altitude **(preliminary data!)**



Retrieval: Lukas Krasuaskas, FZJ

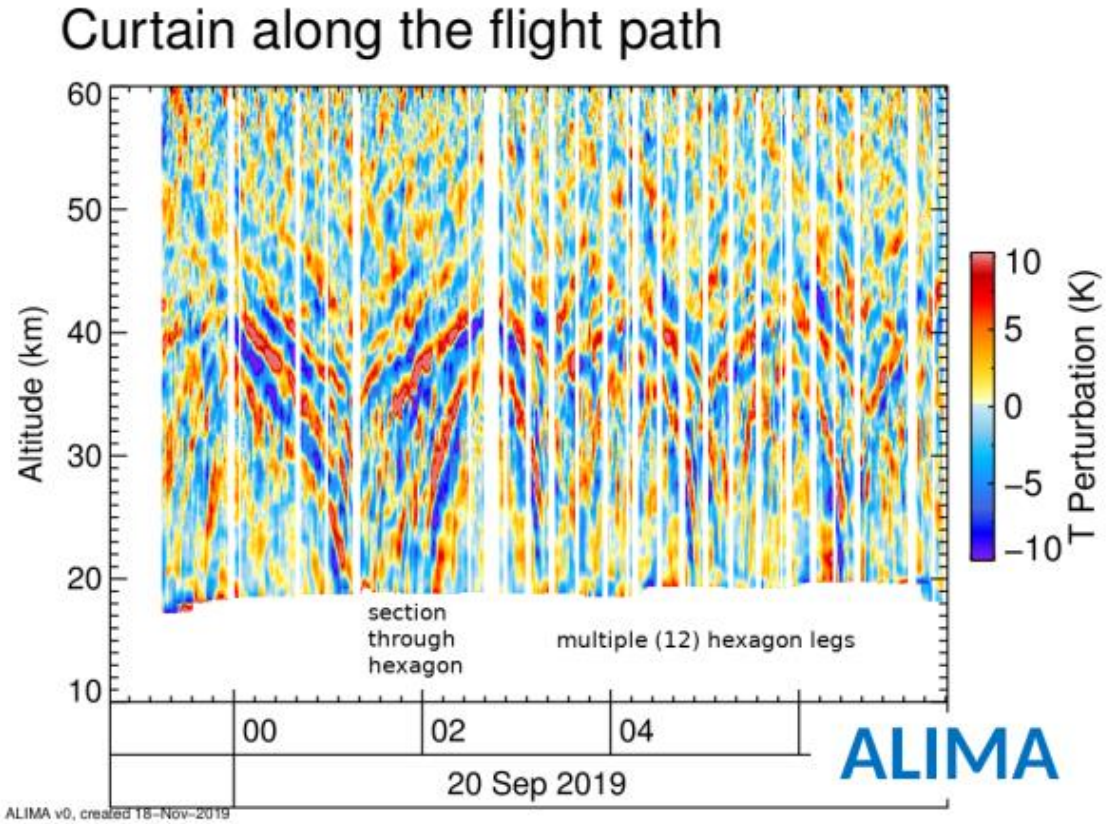
GLORIA 3D TEMPERATURE RETRIEVAL

Vertical cuts at 50°S **(preliminary data!)**



Retrieval: Lukas Krasuaskas, FZJ

ALIMA LIDAR OBSERVATIONS

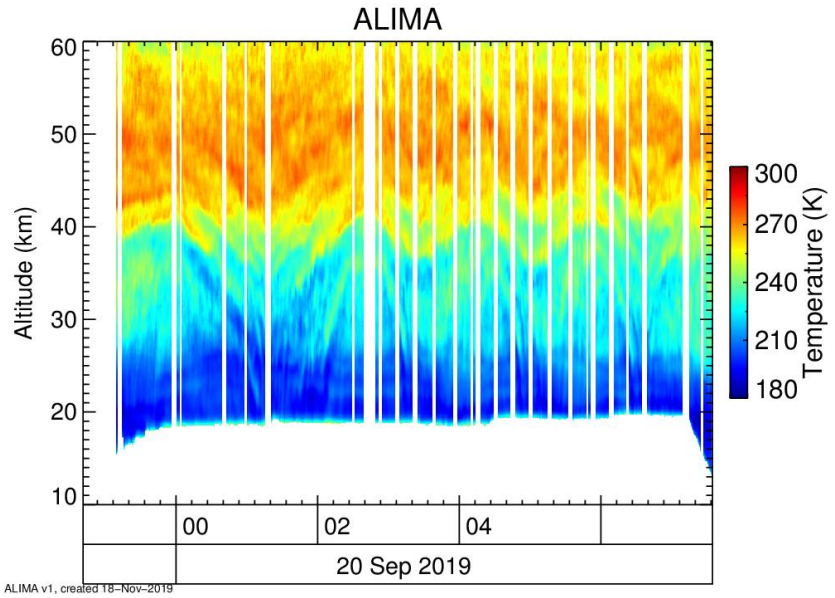


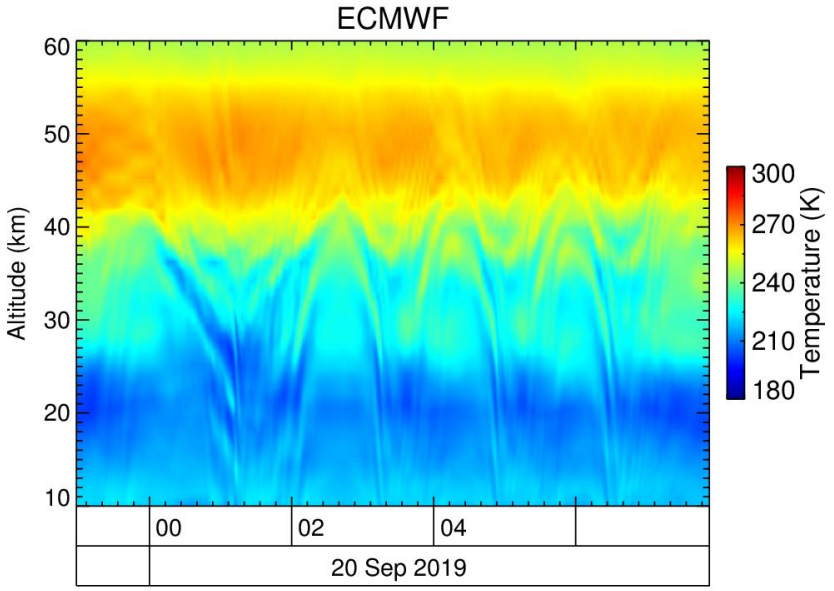
ALIMA and GLORIA: consistent picture

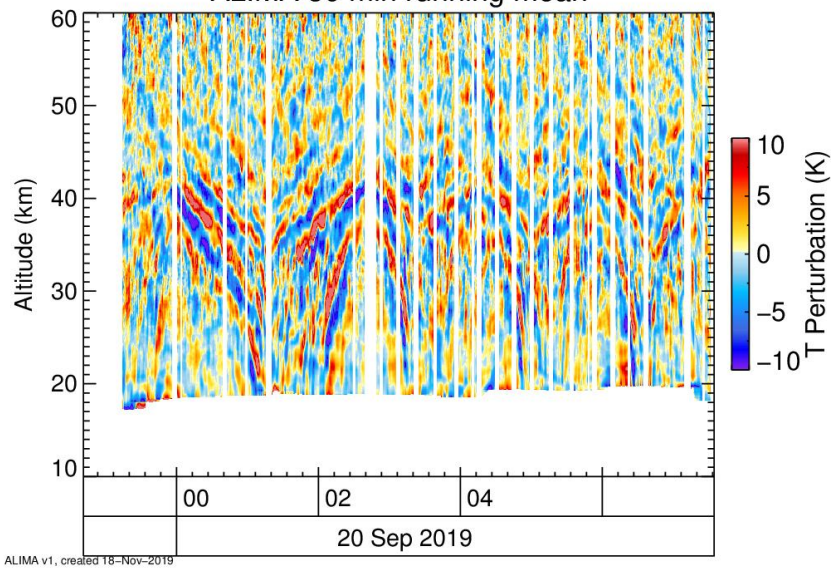
- long λ_z in lower startosphere
- pronounced wave at 02 UT $\leftarrow$ Andes
- critical level around stratospause

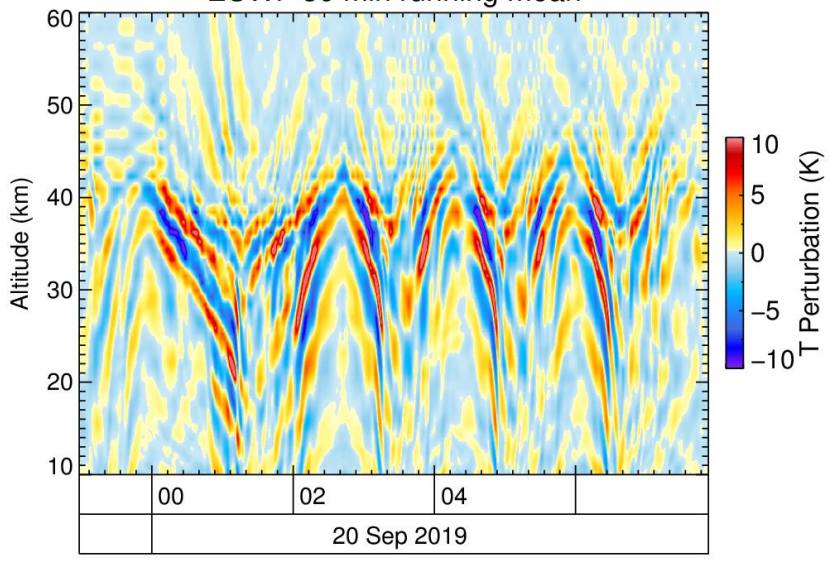
Retrieval: Bernd Kaifler, DLR

Research Flight ST12 on 20/21 September 2019









ALIMA onboard HALO (Kaifler, DLR)

IFS HRES analyses and short-term forecasts interpolated on flight track

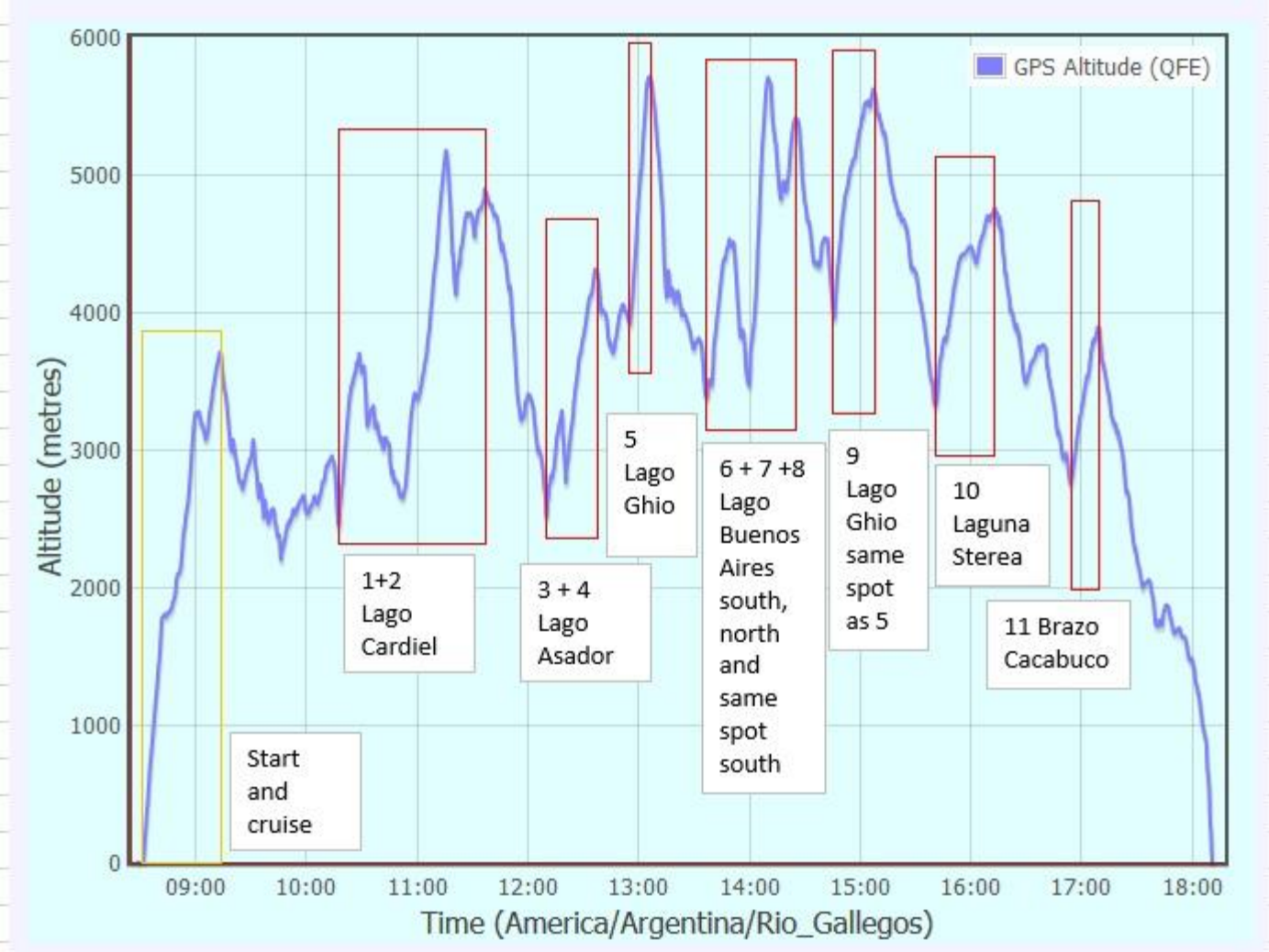
Selected Results from SouthTRAC Phase 1

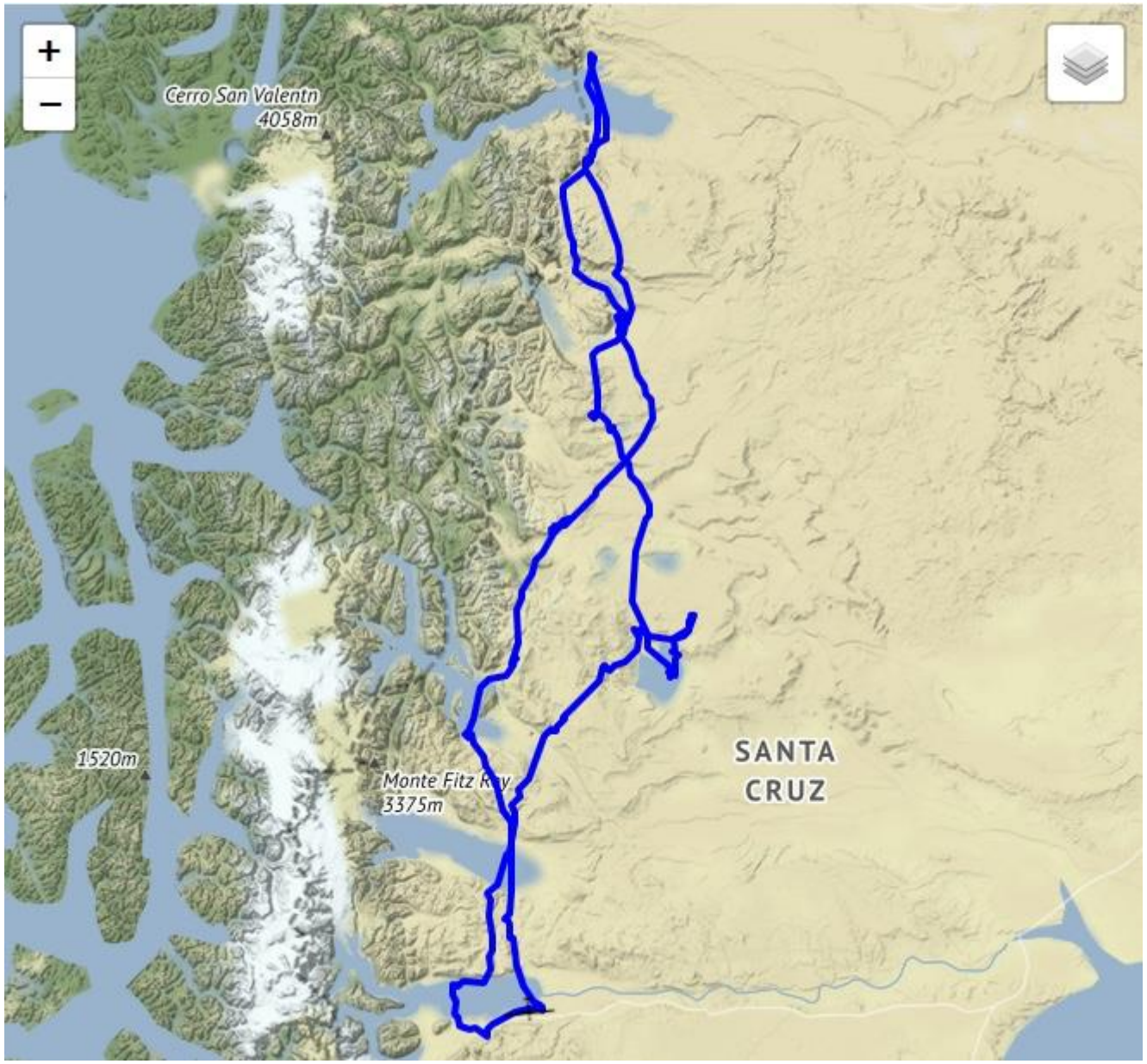
1. Deep wave propagation case 9 November 2019

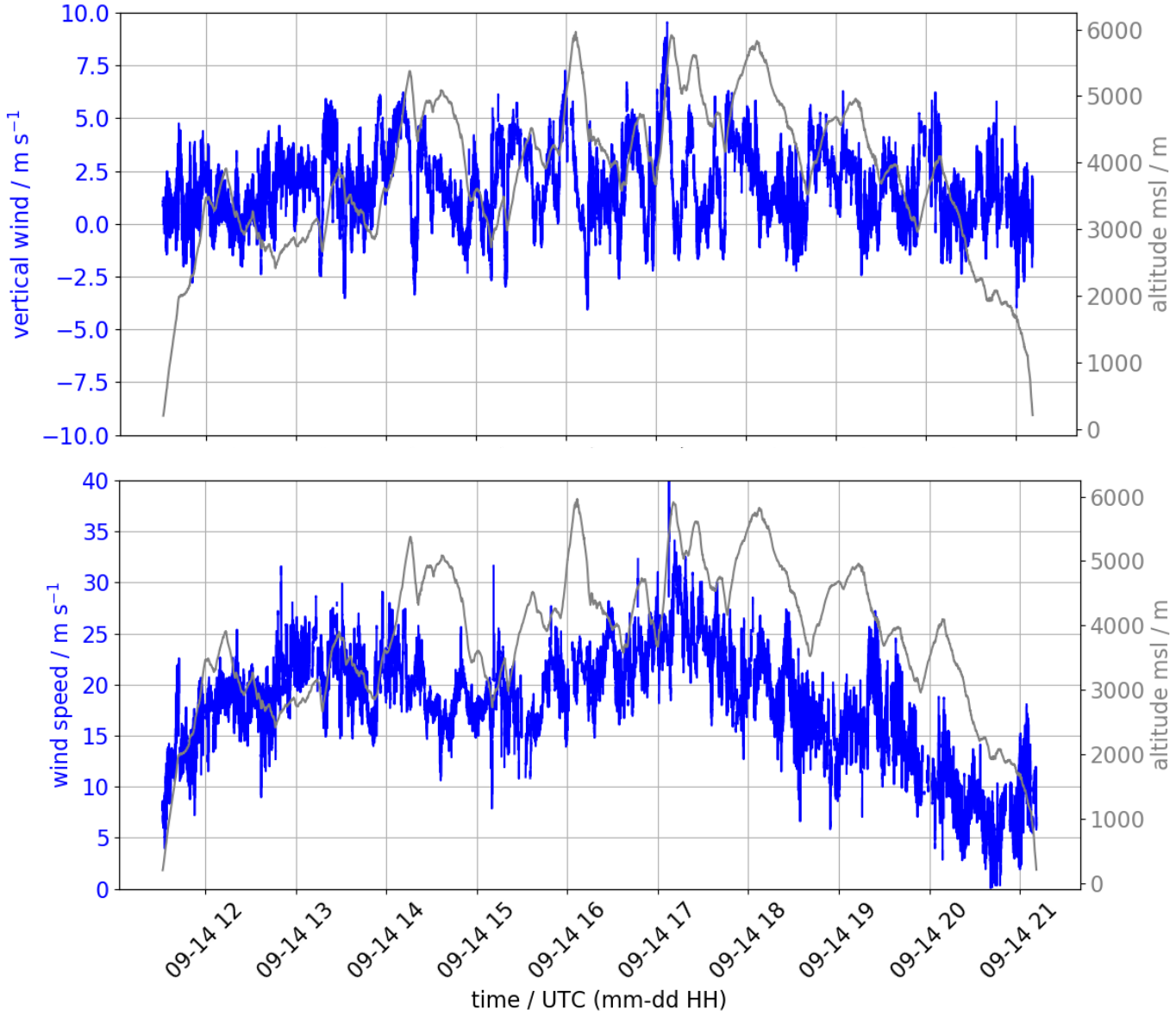
2. Mountain waves under SSW in lower and upper stratosphere

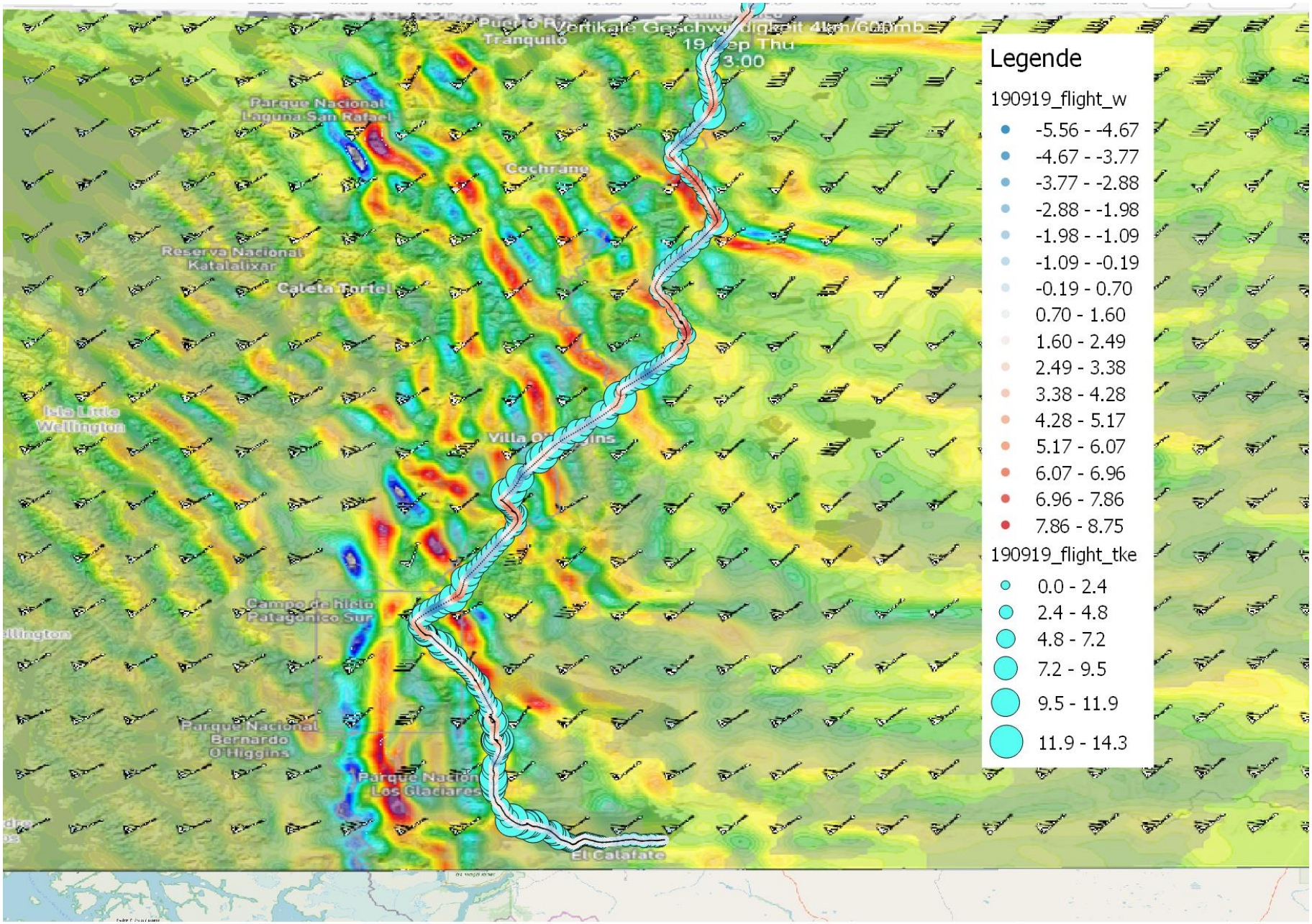
3. **Soaring for science – glider measurements**

Soaring for Science


GPS Altitude (QFE)
Altitude (metres)
6000
5000
4000
3000
2000
1000
0
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
Time (America/Argentina/Rio_Gallegos)
Start and cruise
1+2 Lago Cardiel
3 + 4 Lago Asador
5 Lago Ghio
6 + 7 +8 Lago Buenos Aires south, north and same spot south
9 Lago Ghio same spot as 5
10 Laguna Sterea
11 Brazo Cacabuco


Cerro San Valentn
4058m
1520m
Monte Fitz Roy
3375m
SANTA
CRUZ


vertical wind / m s⁻¹
altitude msl / m
wind speed / m s⁻¹
altitude msl / m
09-14 12
09-14 13
09-14 14
09-14 15
09-14 16
09-14 17
09-14 18
09-14 19
09-14 20
09-14 21
time / UTC (mm-dd HH)



WRF 2 km runs for planning PERLAN flights in El Calafate

Available Independent (not assimilated) Datasets

1. **24 HALO research flights (21 November 2019)**
   - 9 transfer flights OP – RGA
     6 – 9 Sep 2019, 6 – 9 Oct 2019, 2 – 6 Nov 2019
   - 15 local flights 11 Sep – 2 Oct 2019, 9 – 16 Nov 2019
2. **2 years long record of ground-based stratospheric temperature observations at Rio Grande**
3. **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
4. **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

Available Independent (not assimilated) Datasets

5. **Observations by international partners**
   - meteor radar, airglow cameras, satellites, …

6. **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)**