12th Meeting of the Ozone Research Managers of the Parties to the Vienna Convention for the Protection of the Ozone Layer

Geneva, Switzerland, 24 - 26 April 2023

Chile – National Report

Introduction

Chile is located in South America, from 17°29'57" S in the north to 56º32'12" S (Cape Horn), bordering the South Pacific Ocean. The country extends over 4,300 km (2,700 mi) along the southwestern coast of South America from north to south, with an average width 177 km (110 mi) east to west. Due to its extensive territory, it has a variety of climates and geographies, from the arid Atacama Desert in the north to the Patagonia region in the south.

The most austral region is the nearest one to the Antarctic continent, therefore during the Ozone Hole activity in every spring season it is possible to measure events of depletion of the ozone column. In this way, the observation activities of ozone column and ultraviolet radiation are of great importance for the international scientific community.

Chile's geographic location has a relatively quick access to Antarctic, and its commitment to scientific research makes this country an important player in global efforts to understand and address the challenges associated with the Antarctic region and climate change.

The figure below shows the network of UV radiation and ozone observations throughout the country.

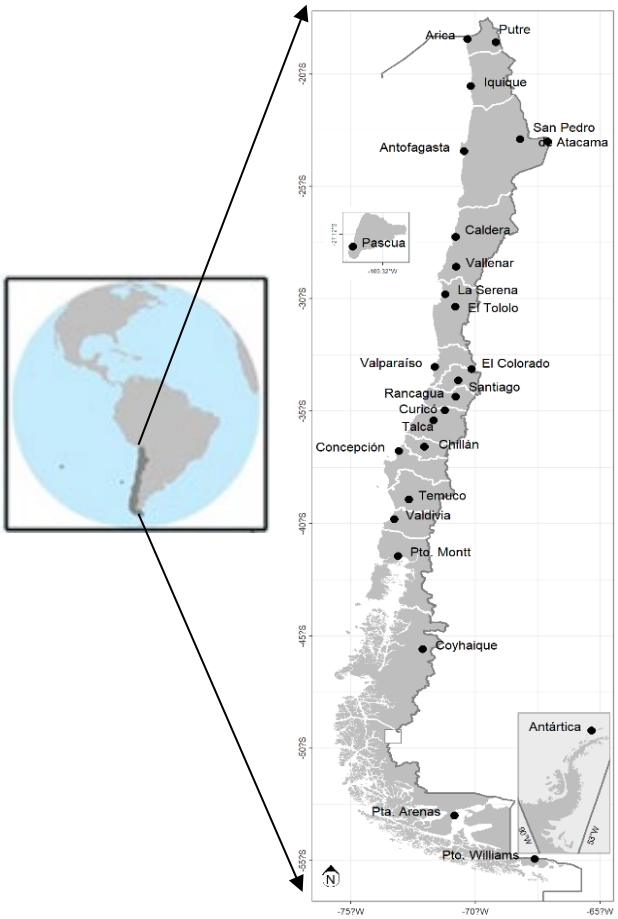

Figure 1. Chile's geographic location and the network of UV radiation and ozone observations.

1. OBSERVATIONAL ACTIVITIES

Continuous monitoring of UV radiation in major cities is mainly operated and maintained by the National Meteorological Service of Chile (DMC, Dirección Meteorológica de Chile), which belongs to the General Directorate of Civil Aviation.

- Observations of total ozone column: are carried out by a spectroradiometer Brewer located in Punta Arenas city in a station operated and maintained by the University of Magallanes (UMAG).
- Ozone profile measurements: there are two stations operating. One is located Easter Island (Rapa Nui) since 1994. The station located in Punta Arenas city carried out continuous observations during 2009-2012 and 2014-until now using ECC ozonesonde.
- Solar spectrum and ozone column: Two stations are carrying out observations. The University of Santiago (USACH) develops the project "*Transportable Antarctic Research Platform*" (TARP-04) which became operational in July 2016 on the Chajnantor plateau (located at 5,100 meters above sea level in the Atacama Desert, nearby the ALMA Observatory). TARP-04 is a twin unit of TARP-02, deployed early 2015 in King George Island (62° 12' S; 58° 57' W, Antarctic Peninsula). TARP- 04 is fitted with state-of-the-art instruments aimed at measurements of the solar spectrum.

1.1 Column measurements of ozone

Table 1. Measurements of ozone column.

Station	Instruments	Institution	LAT.	LONG.	Period of observations
Punta Arenas	Brewer MKIII 180	University of Magallanes	53°18´S	70°54´W	Nov.2007-today

1.2 Profile measurements of ozone

Table 2. Measurements of ozone profile.

Station	Type	Institution	LAT.	LONG.	Period of observations
Punta Arenas	Ozonesondes - ECC-Z LMG6	University of Magallanes	53° 18´ S	70° 54´ W	2009 – today
Eastern Island	Ozonesondes ECC	DMC*	27° 09´ S	109° 27´ W	1994 – today

*DMC: Dirección Meteorológica de Chile (National Meteorological Service of Chile)

1.3 UV measurements

Table 3. Broadband measurements.

Station	Instruments	Institution	LAT.	LONG.	Period of observations
Santiago	Solar Light 501	University of Santiago	33° 26' S	70° 40’ W	1999 – today
Puerto Natales	Solar Light 501	University of Magallanes	51° 43' S	72° 31’ W	1997 – today
Punta Arenas	Solar Light 501	University of Magallanes	53° 18' S	70° 54’ W	1997 – today

Table 4. DMC UV network measurements.

STATION	**TYPE**	**LAT**	**LONG**	**ELEV**	**PERIOD OF OBSERVATIONS**
Arica	Pyranometer YES UV–B	18° 28' S	70° 19' W	23m	2006 – Oct. 2023
Putre	Pyranometer YES UV–B	18° 12' S	69° 34' W	3532m	2017 – 2024
Iquique	Pyranometer YES UV–B	20° 33' S	70° 11' W	48m	1998 – today
San Pedro de Atacama II	Kipp&Zonen	22° 54' S	68° 12' W	2451m	Nov. 2016 – today
Antofagasta	Pyranometer YES UV–B	23° 27' S	70° 27' W	112m	Mar. 2006 – Oct. 2023
Isla de Pascua	Pyranometer YES UV–B	28º 09’ S	109° 26' W	44m	Nov. 2014 – today
Desierto de Atacama	Pyranometer YES UV–B	27° 15' S	70° 47' W	197 m	Dec. 2011 – today
Vallenar	Kipp&Zonen	28° 36' S	70° 45' W	535m	Aug. 2019 – today
La Serena	Pyranometer YES UV–B	29° 55’ S	71º 12’ W	137m	2003 – today
El Tololo	Pyranometer YES UV–B	30° 10’ S	70° 48’ W	2154m	1997 – Jul. 2023
Valparaíso	Pyranometer YES UV–B	33° 2' S	71° 37' W	28 m	Jul. 2012 – 2023
	Biometer Solar Light				2024 – today

STATION	TYPE	LAT	LONG	ELEV	PERIOD OF OBSERVATIONS
Farellones	Pyranometer YES UV–B	33° 21’ S	70° 17’ W	2746m	2011 – Aug. 2021
	Biometer Solar Light				Dec. 2021 – today
Santiago- Quinta Normal	Pyranometer YES UV–B	33° 26’ S	70° 40’ W	520m	2002 – Sep. 2019
	Biometer Solar Light				Oct. 2019 – today
Rancagua	Pyranometer YES UV–B	34° 10’ S	70° 46’ W	482m	Nov. 2010 – May. 2023
Curicó	Kipp&Zonen	34° 58’ S	71° 13’ W	229m	Sep. 2019 – today
Talca	Pyranometer YES UV–B	35° 25’ S	71° 40’ W	100m	Jul. 2010 – 2023
Concepción	Pyranometer YES UV–B	36° 47’ S	73° 04’ W	13m	Dec. 2002 – today
Termas Chillán	Pyranometer YES UV–B	36° 54' S	71° 24' W	1708m	Dec. 2013 – Mar. 2020
María Dolores-Los Ángeles	Kipp&Zonen	37° 24' S	72° 25' W	118m	Sep. 2022 – 2023
Temuco-Universidad Católica de Temuco	Pyranometer YES UV–B	38° 42' S	72° 32' W	153 m	Dic. 2012 – Mar. 2020
La Araucanía	Kipp&Zonen	38° 56' S	72° 39' W	96m	May. 2020 – Oct. 2023
Valdivia – UACH	Spectroradiometer SUV 100	39º 48’ S	73º 14’ W	9m	1998 – 2007
Valdivia – CECS	Pyranometer YES UV–B	39° 49’ S	73° 15’ W	18m	2010 – today
Puerto Montt	Pyranometer YES UV–B	41° 25’S	73° 05’ W	87m	2001 – today
Coyhaique	Pyranometer YES UV–B	45° 35’S	72° 06’ W	300m	2001 – today
Punta Arenas	Pyranometer YES UV–B	53° 00’ S	70° 50’ W	36m	Abr. 2001 – today
Centro Meteorológico Antártico Presidente Eduardo Frei	Pyranometer YES UV–B	62° 12’ S	58° 59’ W	45m	1992 – Aug. 2022
	Biometer Solar Light				Abr. 2023 – today

Source: National Meteorological Service internal database.

Table 5. Narrowband filter instruments.

Station	Instruments	Institution	LAT.	LON.	Period of observations
Puerto Natales	GUV 512	University of Magallanes	51° 43' S	72° 31' W	2016 – today
Base Prof. Julio Escudero	NILU UV	University of Magallanes	62° 12' S	58° 57' W	Sep. 2005 – today

Source: http://www.umag.cl/lia/ (accessed on February, 2024).

Table 6. Radiometers.

Station	Instruments	Institution	LAT.	LON.	Period of observations
Chajnantor Plateau Atacama Desert	Bentham Double Monochromator	University of Santiago (USACh)	23° 1' S	67° 5' W	2016 – today
Santiago	Bentham Double Monochromator	University of Santiago (USACh)	32° 27´ S	70° 41´ W	2013 – today
Escudero Antarctic Peninsula	Bentham Double Monochromator	University of Santiago (USACh)	62° 01´ S	58° 6´ W	2015 – today

Source: http://ambiente.usach.cl/uv/ (accessed on February, 2024).

1.4 Calibration activities

a) DMC-network: In collaboration with University of Santiago (USACh), the following calibration activities were developed:

Table 7. DMC network calibration.

Year	Station	Start	Finish
2021	La Serena	08/Feb/2021	18/Feb/2021
	Valparaíso		
	Talca		
	Coyhaique		
	Antártica		
	Solar Light		
2022	Temuco	14/Nov/2022	22/Nov/2022
	Isla de Pascua		
	Puerto Montt		
2023	Rancagua	04/Apr/2023	14/Apr/2023
	Curicó		
	Concepción		
	Antofagasta	21/Nov/2023	27/Nov/2023
	Tololo		

Reference instrument: Bentham Monochromator.

b) Biometers network (University of Magallanes): The Solar Light instruments of the University of Magallanes, are calibrated every two years using the Brewer 180 located in Punta Arenas.

2. RESULTS FROM OBSERVATIONS AND ANALYSIS

Preliminary evaluation of the TUV model implemented in the National Meteorological Service:

The TUV model implemented in the DMC was evaluated using observations from the radiometric network (Antofagasta, Santiago, Puerto Montt and Antártica stations) for the period 2014-2020. The evolution of the IUV shows a clear seasonal behavior in all of the studied locations, both for the observed and forecast data, with maximum values in summer (December, January and February), and minimum values in winter (June, July and August). In general, although there is a good correlation between the observed and predicted data, it was observed that the TUV model overestimates the measurements, with the difference between the observed and predicted data being maximum for the winter and spring months, and minimum in the summer months.

The differences observed in this study may be explained by the influence of atmospheric parameters such as aerosols, since this parameter is used in the same way for all forecast points in the country and ozone (extracted from satellite information). Although these possible causes of error in the results obtained have not been analyzed in this study, it is especially important to investigate the influence of these factors on the TUV model in order to improve their quality.

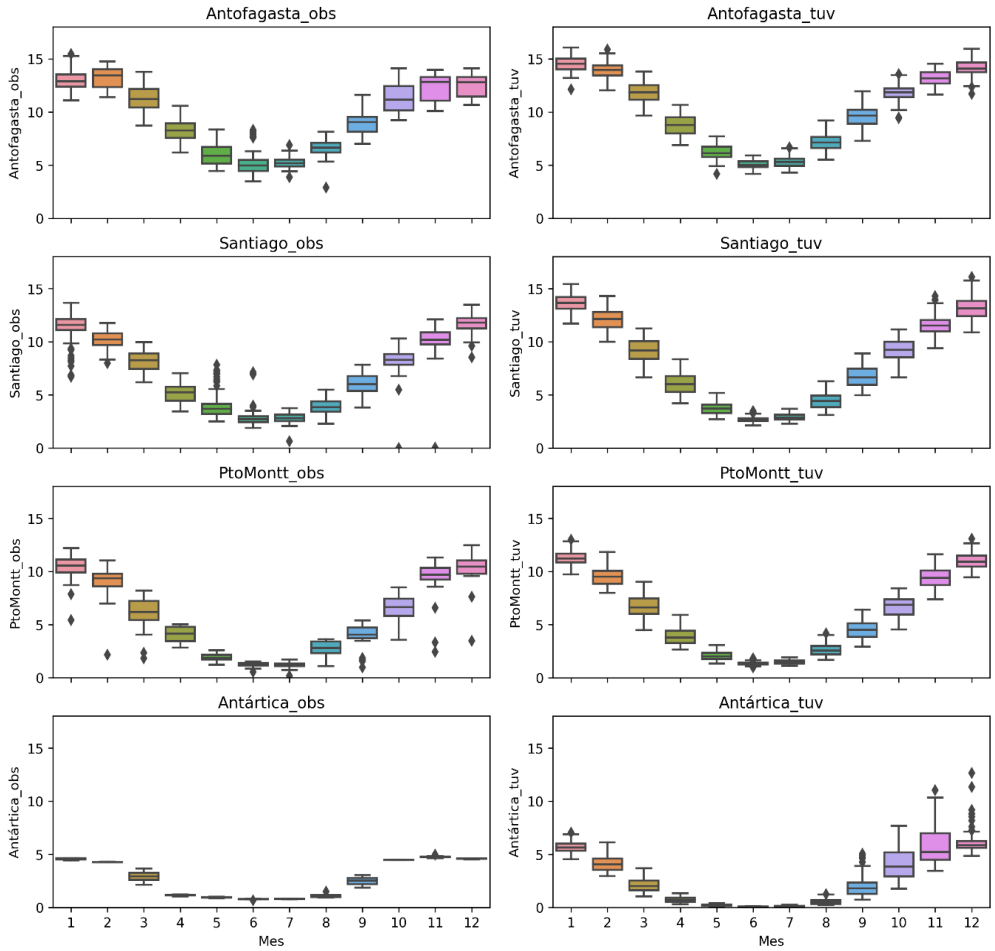

Figure 2. Monthly statistics of the UV Index obtained from observations (left) and those predicted by the TUV model (right) for the period 2014 to 2020 in 4 places in the country.

3. THEORY, MODELLING, AND OTHER OZONE RELATED RESEARCH

Ozone research

The first twenty years (1994-2014) of ozone soundings from Rapa Nui (27ºS, 109ºW, 51 m a.s.l.):

Ozone (O_3) soundings were performed on Easter Island or Rapa Nui (27ºS, 109ºW, 51 m a.s.l.) since 1994 as part of the Global Atmospheric Watch (GAW) Programme of the World Meteorological Organization (WMO). Under this work, 260 soundings were analyzed and compiled over the period of 1994-2014 to make the data available for the international community. The O_3 profiles were characterized over this remote area of the Pacific by means of statistical analyses that consider, on one hand, a traditional climatology that describes the data in terms of seasonal cycles based on monthly averages and, on the other hand, a process-oriented analysis based on self-organizing maps.

4. DISSEMINATION OF RESULTS

4.1 Data reporting

University of Magallanes stations

- Data from Brewer 180 periodically sent to the WOUDC.
- Data of ozone profiles obtained in Punta Arenas, which are periodically sent to the WOUDC.

DMC stations

- Currently in the database of DMC and under review to be shared with the WOUDC.
- Submission of greenhouse gases data (CH_4, CO, CO_2, O_3) from GAW station Tololo to WDCGG.
- Data of ozone profiles obtained in Rapa Nui, which are sent in a quarter basis to the WOUDC.

4.2 Information to the public

National Meteorological Service (www.meteochile.gob.cl)

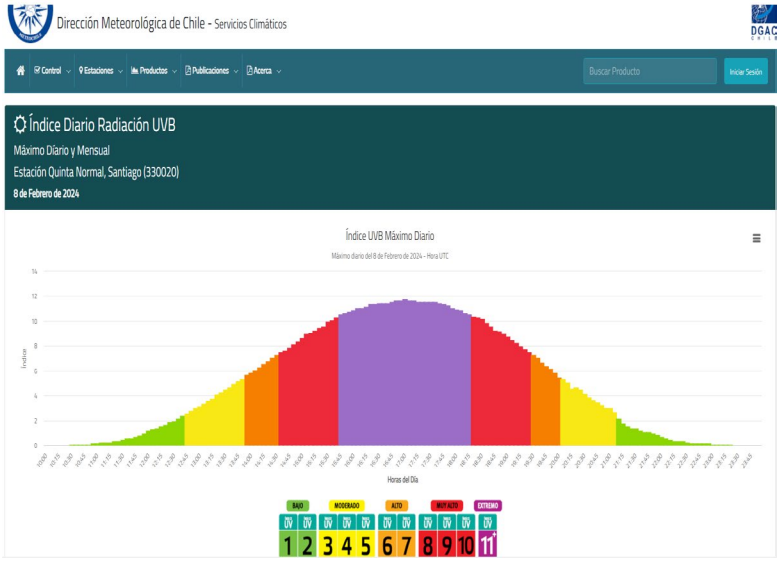

Figure 3. UVI hourly monitoring for 26 places along the country. For example, Quinta Normal station.

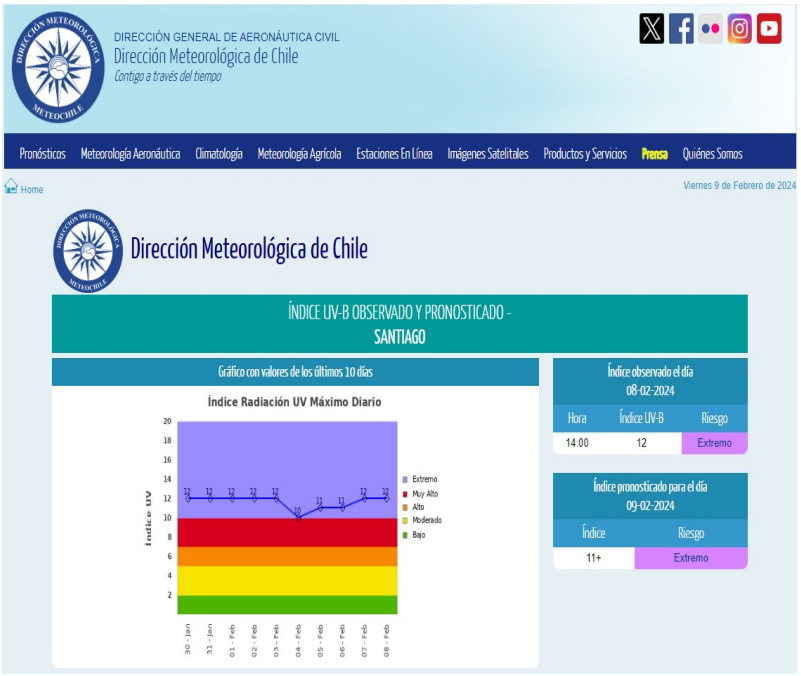

Figure 4. UVI daily forecast for 26 places along the country, by 24 hours and with Clouds. For example, Santiago.

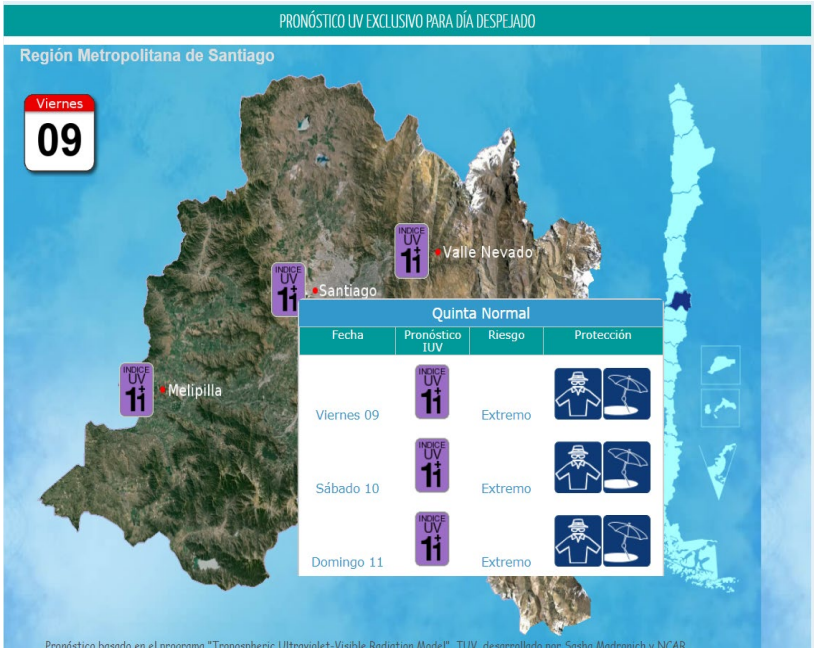

Figure 5. UVI daily forecast by three days. Without Clouds.

University of Magallanes

Since 1999 the Ozone Laboratory and RUV of the University of Magallanes provides a UV-Index daily forecast during spring and summer time (TEMIS).

4.3 Relevant scientific papers

- *Sepúlveda, E., Cordero, R.R., Damiani, A. et al. Evaluation of Antarctic Ozone Profiles derived from OMPS-LP by using Balloon-borne Ozonesondes. Sci Rep 11, 4288 (2021). https://doi.org/10.1038/s41598-021-81954-6*

- *González-Rodríguez, L., Jiménez, J., Rodríguez-López, L. et al. Ultraviolet erythemal radiation in Central Chile: direct and indirect implication for public health. Air Qual Atmos Health 14, 1533–1548 (2021). https://doi.org/10.1007/s11869-021-01037-3*

- *Angeles Suazo, . J. M., Angeles Vasquez, R., Suazo, N., Navarro, J., Flores Rojas, J., Lavado, C., & Abi Karam, H. (2022). Variación espacial de la columna total de Ozono en Huancayo, Santiago de Chile y Antártida durante 2005-2020. TAYACAJA, 5(2), 33–37. https://doi.org/10.46908/tayacaja.v5i2.200*

- *Miguel Rivas, Gloria M. Calaf, David Laroze, Elisa Rojas, Joaquín Mendez, Juan Honeyman, María C. Araya, Solar ultraviolet A radiation and nonmelanoma skin cancer in Arica, Chile, Journal of Photochemistry and Photobiology B: Biology, Volume 212, 2020, 112047, ISSN 1011-1344. https://doi.org/10.1016/j.jphotobiol.2020.112047*

- *Rivas, M., Rojas, E., Laroze , D. ., Pérez , L. M., & de Paula Correa, M. (2023). Very high erythemal doses of ultraviolet radiation around solar noon measured in Arica, northern Chile. Atmósfera, 37, 475–480. https://doi.org/10.20937/ATM.53184*

- *Cordero, R.R., Feron, S., Damiani, A. et al. Persistent extreme ultraviolet irradiance in Antarctic despite the ozone recovery onset. Sci Rep 12, 1266 (2022). https://doi.org/10.1038/s41598-022-05449-8*

- *Gallardo L, Henríquez A, Thompson AM, Rondanelli R, Carrasco J, Orfanoz-Cheuquelaf A,*

Velásquez P. THE FIRST TWENTY YEARS (1994-2014) OF OZONE SOUNDINGS FROM RAPA NUI (27°S, 109°W, 51 M A.S.L.). Tellus B Chem Phys Meteorol. 2016;68(1):29484. https://doi.org/10.3402/tellusb.v68.29484

5. PROJECTS, COLLABORATION, TWINNING AND CAPACITY BUILDING

Collaboration between DMC and Center of Climate and Resilience Research (CR2) of University of Chile. A web platform was created to visualize Greenhouse Gases data from Tololo station (https://tololo.wayra.cr2.cl/, at left) and Ozone profiles from Easter Island (https://rapanui.wayra.cr2.cl/, at right).

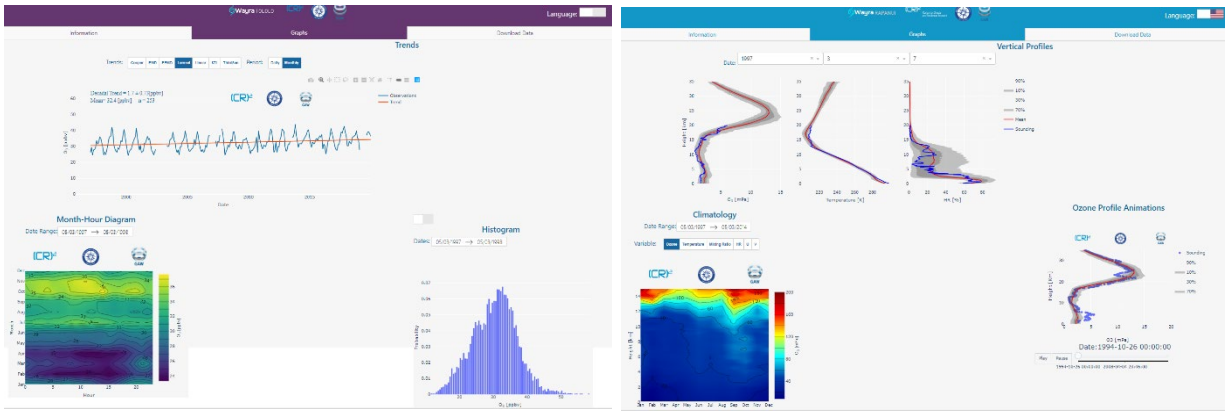

Figure 6. Web platform for Greenhouse Gases from Tololo station (left) and Ozone profiles from Easter Island (right). (https://tololo.wayra.cr2.cl/ - https://rapanui.wayra.cr2.cl/)

There is also continuous collaboration between the DMC and some universities in the country.

6. IMPLEMENTATION OF THE RECOMMENDATIONS OF THE 11th OZONE RESEARCH MANAGERS MEETING

It has been difficult for Chile to accomplish with several of the recommendations of the 11th meeting. However, efforts have been made to carry out many of them. During the last 3 years our country made efforts to develop research about stratospheric ozone and ultraviolet radiation. In this sense, the research and measurement projects in Antarctic and solar radiation on the health of the population stand out.
The DMC continue informing to the citizenship about the Ozone Hole and its effects on UV radiation. Data sharing also continues with the Global Data Center.

7. FUTURE PLANS

The research groups of the University of Magallanes and University of Santiago continue measuring UV radiation and ozone column.

Currently DMC is evaluating the replacement of old or damaged sensors with new ones, in order to provide quality information to the citizenship about the UVB Index. The calibration of the instruments will also continue with the University of Santiago.

Additionally, DMC will evaluate the incorporation of forecast maps where the UV index information for the population is displayed in greater detail (better spatial resolution). Processes for sending data to Global Data Centers will also be automated.

8. NEEDS AND RECOMMENDATIONS

For Chile, it is essential to keep the UV radiation monitoring network operational and continue with the ozosondes on Easter Island and Punta Arenas due to South America is still the best region to observe and measure the Antarctic Ozone Hole.

Due to the large latitudinal extension of Chile, there is a need of more UV stations to cover the monitoring along the entire national territory.

It is necessary to participate in training courses and scientific workshops on ozone and UV radiation, related to tools and support, specifically to developing countries (Region III South America).

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