Spatio-temporal variability of fog water and its meteorological conditions in the coastal Atacama Desert, Chile.

Zanetta, N[1]; del Río[1], C.; Osses, P.[1]; García, J.1[1]; Luengo, Y[2].; Wolf, N.[4]; Siegmund, A[34].

1 Instituto de Geografía & Centro UC Desierto de Atacama, Pontificia Universidad Católica de Chile.
2 Programa de Magister en Geografía y Geomática, Instituto de Geografía, Pontificia Universidad Católica de Chile.
3 Heidelberg Center for the Environment & Institute for Geography, Heidelberg University.
4 Research Group for Earth Observation (rgeo), Department of Geography, Heidelberg University of Education

ABSTRACT

The coastal area of the Atacama Desert in northern Chile is punctuated by fog ecosystems. One of these ecosystems includes the fog dependent *Tillandsia Landbeckii* species, which shows altitudinal variability in terms of density and vitality. We hypothesize this could be a response of the amount of fog water received, becoming an indicator of the presence and variability of the fog in this area. The main objective of this study is then to analyze the altitudinal variation of the fog water income in Cerro Oyarbide (20°29'S) and its spatial relation with the distribution of *Tillandsia Landbeckii* through the installation of five Standard Fog Collector in an altitudinal profile. The year 2015 data suggests that the fog water show strong altitudinal gradients, with major water volumes obtained between 1.180 and 1.219 m ASL at Oyarbides Site. From this altitudinal range, fog-water decrease towards lower and higher areas. For instance, during the wettest season (winter-Spring) the SFC at 1219 m collected 70 % more than any of the other four SFC installed in Cerro Oyarbide. In this regard, we found that most (69 %) measured "fog events" occur with air temperatures between 7°C and 13°C and with relative humidity above 90%. Ongoing work will test the correlation of fog-water outcomes with distribution of *Tillandsia Landbeckii* at Oyarbides.

1. INTRODUCTION

The Sc deck offshore Atacama Desert coast is produced by the thermal inversion originated by Anticyclonic air-subsidence, intensified by the Humboldt cold waters (Rutllant et al., 2003; Cereceda et al., 2008). This determines the existence of a dynamic marine advection fog, providing moisture to a hyper-arid environment and allowing the development of ecosystems and

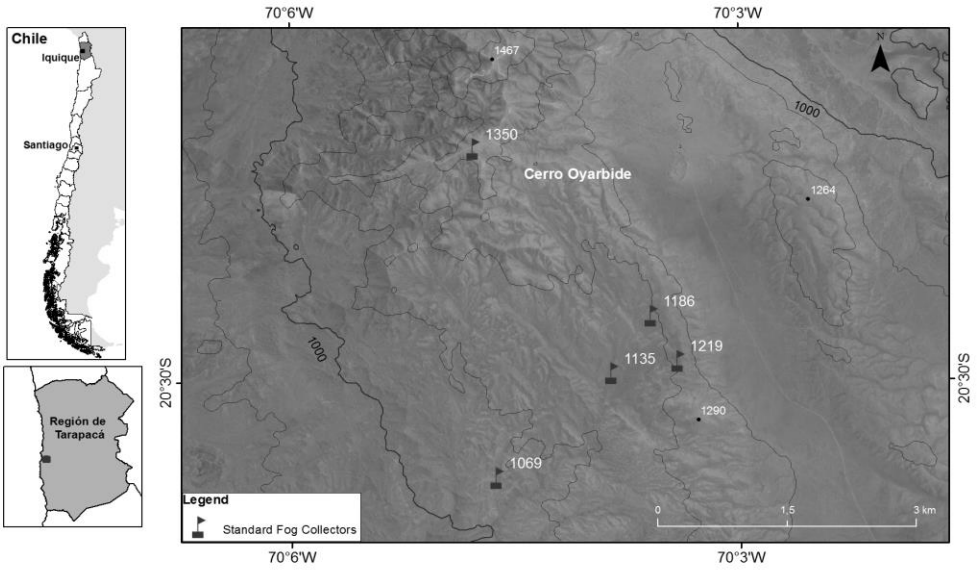

Fig. 1 Map of the study area and SFCs location.

high biodiversity along the Atacama coast. [Pinto et al., 2001; Cereceda at al., 2008b; Garreaud et al., 2008]. Humidity used this way by plants, has proved to be an abundant water resource with great potential for human use. BUT, we still lack basic knowledge of the spatiotemporal distribution /variability of fog-water in the desert. In this work, we analyze the fog-water yields using an altitudinal transect approach to assess how fog changes along this variable. We also asses the meteorological conditions that occur along with fog events, so we can constrained atmospheric variables in a climate change scenario.

2. DATA SOURCES

The coastal topography of the Atacama Desert present optimal conditions to the fog generation because of the existence of the imposing coastal cliff (Cordillera de la Costa) that intercepts the Sc cloud at this latitude (20ºS) between ~ 400 and ~ 1.200 m ASL (Cereceda et al., 2004). The study area is located at Cerro Oyarbide (20°29‘S) (Fig. 1), which includes an extensive *Tillandsia Landbecki* field in a 300 m elevation range. We used the ecologic conditions and elevation of Oyarbide oasis as a base criterion for installing five Standard Fog Collectors (SFC) (Schemenauer and Cereceda, 1994) (Fig. 2) to be representative of local variability. Each SFC includes an automatic 10-minute record (rain gauge and logger) of fog water along an altitudinal gradient from 1.069 m ASL to 1.350 m ASL. . The **SFC 1.219** m ASL includes a temperature and relative humidity sensor. All data was processed to generate hourly averages to the Spatio-temporal and meteorological analysis.

Fig. 2 SFC and Tillandsia field in Cerro Oyarbide.

3. RESULTS

3.1 FOG WATER YIELDS AND ALTITUDE

The fog water derived from the Sc in the coastal Atacama has an altitudinal variability, which was recorded by our SFCs in the altitudinal profile in Cerro Oyarbide (Fig. 1). In this regard, the **SFC 1.219** m ASL has the highest fog water yields compared with the other SFCs throughout the year (Fig. 3) with the highest amount of water with 3.2 $l/m^{-2}/day^{-1}$ in September (early spring) and 3.6 $l/m^{-2}/day^{-1}$ in October, which is consistent with the known cycle of fog-water in Atacama Desert (Farias et al., 2005; Cereceda et al., 2008b; Garreaud et al., 2008). On the other hand, The **SFC 1.350** m ASL, at the top of the Cerro Oyarbide, produced the lowest fog-water yields (close to 0 $l/m^{-2}/day^{-1}$) suggesting the top of the fog cloud at this elevation. Similarly, at the base of the Oyardibe Site, where *Tillandsia Landbecki* find it lowermost distribution, the **SFC 1.069** m ASL (Fig. 1) yielded the second lowest fog-water collection of all five SFCs installed in the area. The data then suggests that fog-water yields decrease upward and downward ~1200 m ASL in our site.

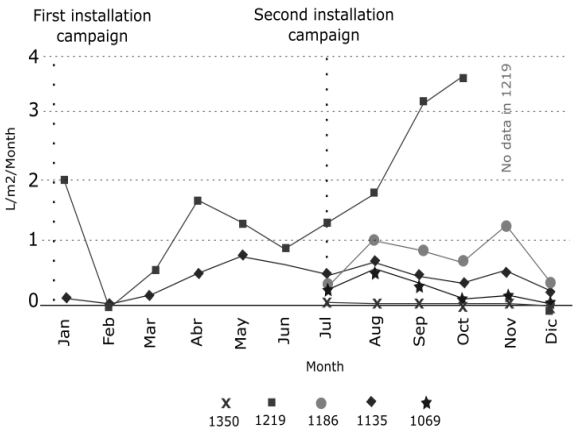

Fig. 3 Altitudinal Variability of Fog Water Income during 2015 in Coastal Atacama.

3.2 THE METEOROLOGY OF FOG EVENTS

Here we define "fog event" as a continues record of fog water during one hour or more, no matter the amount of fog-water collected. A total of 70 fog events were this way identified between January and December 2015 at the **SFC 1.219** m ASL. We analyze their meteorological characteristics to assess the optimal air conditions linked to the presence of wet-fog.
Table 1 and Fig. 4 summarize the meteorological structure of local conditions during the fog events in Cerro Oyarbide during 2015.

Table 1
Local meteorological conditions of fog events at Cerro Oyarbide between January and December of 2015*.

* February and November without register

Parameter	Number of Events
Temperature (°C)	
< 7	8
7 - 10	26
10 - 13	22
13 - 16	8
> 16	6
Relative Humidity (%)	
< 60	3
60 - 80	6
80 - 90	9
90 - 95	19
> 95	33
Fog event duration (Hrs.)	
1 - 2	8
3 - 5	25
6 - 10	18
11 - 15	17
> 15	2

As expected, the air temperatures measured during fog events are linked to the season, with the highest values in summer (late December, January, February and early March) and the minimum in winter (late June, July, August and early September) (Fig. 4).
It is noted that the main fog events occur with temperatures between 7°C and 13°C, concentrating 48 of the 70 events considered (69%).
Moreover, the relative humidity in fog events has a homogeneous behavior throughout the year (Fig. 4), exceeding 90% in the 74% of the events, except in January, which has the lowest percentage of moisture (near to 60%) in fog events (Fig. 4).
Finally, the duration of these fog events varies between 1 hour and 15 hours, with the longest ones occurring during springtime. However, most event durations are between three and five hours. There is a strong correlation between the duration of events and fog water obtained ($r = 0.9$, $p < 0.001$).

4. CONCLUSIONS

Fog water collected shows clear spatial gradients, correlated with the elevation, with the highest volumes obtained at about 1200 m ASL and lowest ones at the top and base of the *Tillandsia Landbecki* field, exposing the direct link between fog and coastal plants. .Despite the fact that the fog events occurs every month, at 1.350 m ASL, the fog water here is close to zero, which indicate that is the top of the stratocumulus cloud. Respect to the meteorological conditions of fog events, most events occur with temperatures between 7°C and 13°C and with relative humidity above 90%. Interesting is what happens in the summer months, where fog events occur in environments with relative humidity close to 60%. There is a strong correlation between the duration of events and fog water obtained ($r = 0.9$, $p < 0.001$).

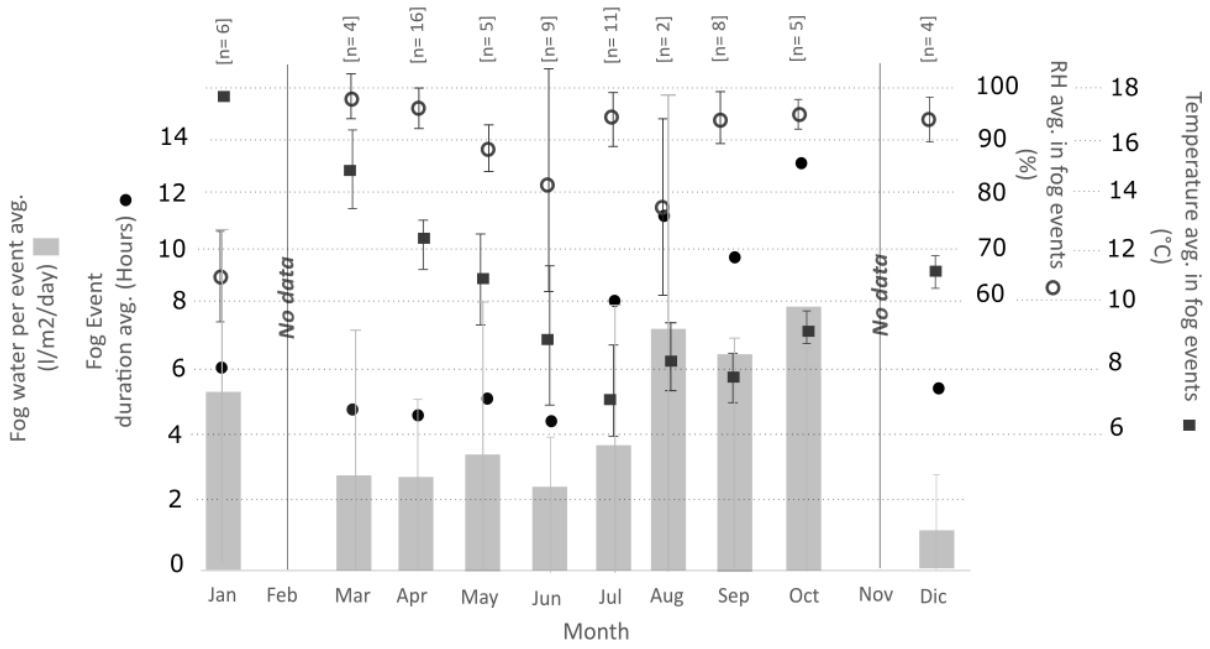

Fig. 4 Local Meteorology of the Fog Events and its annual variability. Bars indicate the standard deviation for the period.

5. ACKNOWLEDGEMENTS

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