VOCALS-CUpEx: The Chilean Upwelling Experiment

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1. Presentation

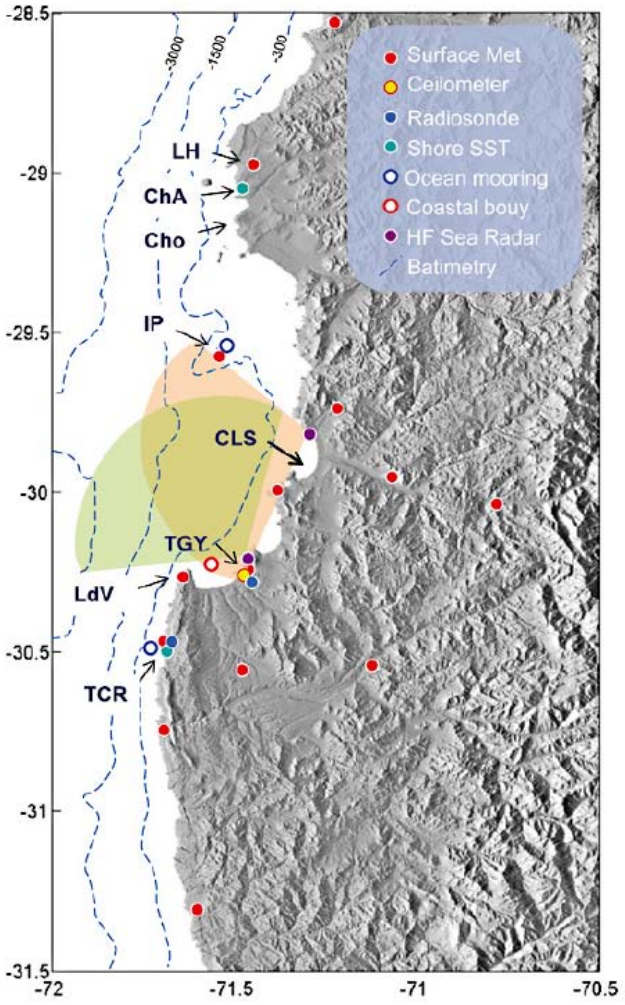
The VAMOS Ocean-Cloud-Atmosphere-Land Study (VOCALS) is an international program that targets the subtropical Southeast Pacific region. To address the many VOCALS' science questions a major regional experiment, VOCALS-REx, was carried out during October and November 2008 off northern Chile and southern Peru, including an unprecedented number of atmospheric and oceanographic measurements taken concurrently from five aircrafts, two research vessels and two land sites. It was originally planned that VOCALS-REx would include a coastal component encompassing the near-shore region at about 30°S. In practice, most of the action during VOCALS-REx took place in a zonal band between 25°S and 16°S because of logistic constrains. About a year later, however, several Chilean institutions (Table 1) have teamed to conduct an additional field experiment to fill our observational gap. The so-called Chilean Upwelling Experiment (CUpEx) is therefore a regional component of VOCALS aimed at understanding the atmosphere-ocean dynamics that characterize the nearshore (0-200 km) region off north-central Chile (30-35°S) (Full details in Garreaud et al. 2010).

2. The study region and experimental setup

The semiarid coast of Chile (25-35°S) is under the year-round influence of the southeast (SE) Pacific anticyclone, resulting in predominantly southerly (coastal parallel) low-level winds, and a strong temperature inversion that caps a cool atmospheric marine boundary layer (AMBL). The surface stress exerted by the southerly winds foster the upwelling of cold, nutrient-rich waters supporting a wealth of fishery resources.

The Chilean coast is oriented almost straight north-south between 33°S and 30°S (Point Lengua de Vaca; LdV), bounded to the east by a mountain range with average elevation between 500 and 1000 m above sea level (ASL, Figure 1). The coastal mountains in this area are interrupted by several river valleys in contrast with a much more continuous coastal cliff of about 1000 m ASL farther north (between Paposo and Arica; 25-18°S). To the north of LdV the coastline sharply retracts eastward about 40 km, forming a wide embayment, including the bays of Tongoy and Coquimbo, and returns to the west at about 29°S (Point Choros).

Figure 1: CUPEX region and stations



VOCALS-CUpEx included long-term monitoring, an intensive two-week field campaign (21 November 21 to 5 December, 2009) and seven off-shore research flights using the DGAC BE90 airplane (Figure 1). Surface meteorology (air temperature, humidity, barometric pressure, wind and solar radiation) is recorded every 15 min in five automatic weather stations (AWS) along the coast. The AWS at Tongoy was complemented with a laser ceilometer providing cloud frequency and cloud base height every 1 minute. All these AWSs were installed during (or prior to) November 2009 and were be maintained for a year, providing a long-term context of the low-level circulation in the CUpEx area.

3. Observational highlights

Figure 2 shows the morning (07-09 LT) and afternoon (16-18 LT) near-surface winds averaged during November-December 2009 around 30°S. The inland stations and those along the bay of Tongoy/Coquimbo show a marked diurnal cycle in speed and direction

associated with the development of a sea breeze during afternoon, as a response to the surface heating and topography. A dramatic case occurs at Tongoy where the afternoon wind blows from the north in an area otherwise dominated by southerly flow. The northerly flow at Tongoy is, however, restricted to the first 200 m capped by southerlies aloft (Figure 3a). The surface stations south of LdV and Islote Pájaros show a weaker diurnal cycle in wind speed, and the direction remains nearly fixed from the S-SW during the whole day.

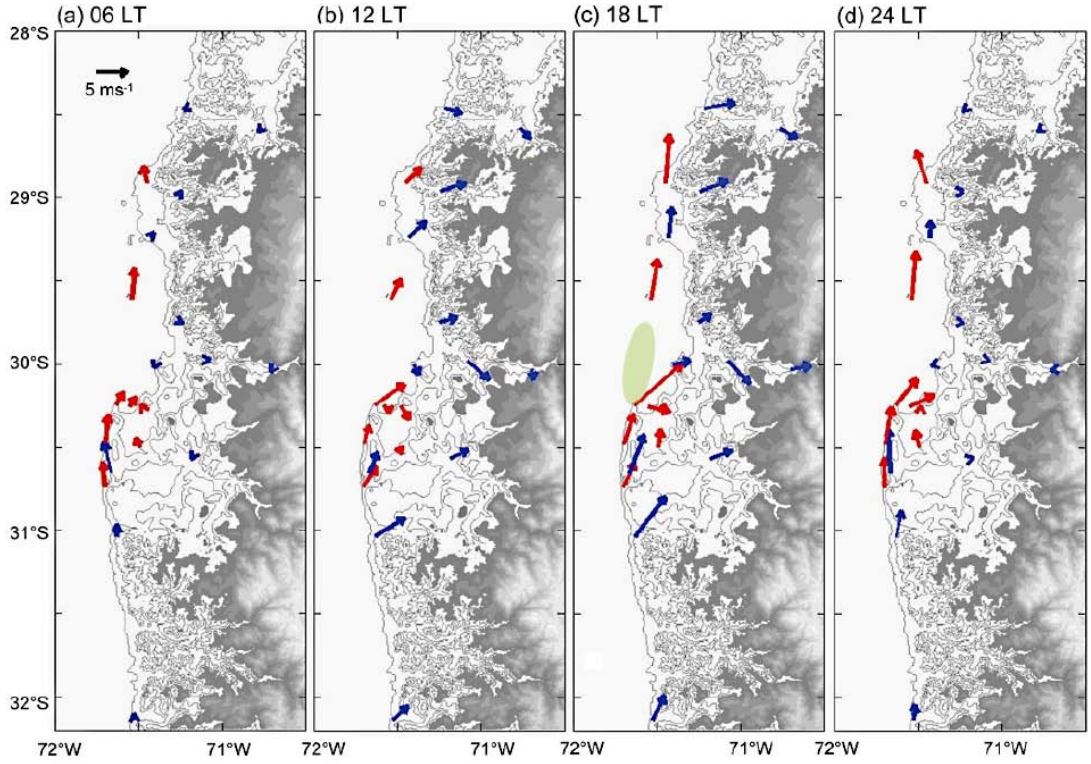


Figure 2: Mean diurnal cycle of the surface winds during austral spring.

Figure 3 shows the AM and PM vertical profiles of meridional wind and air temperature at Tongoy and Talcaruca averaged during VOCALS-CUpEx. In both stations the MBL is about 400 m deep capped by a temperature inversion that extends up to about 1500 m. In the morning there is little difference between the temperature profiles at the two locations. During the day both profiles show a warming of the MBL and the inversion layer, but relatively modest in Talcarruca (2°C) and very strong in Tongoy. The Tongoy profiles also exhibit a significant afternoon drying of the MBL (not shown). We hypothesize that the afternoon warming/drying at Tongoy signals the arrival of continental air parcels. The advection of continental air over the Tongoy bay could

explain the clear sky conditions that often characterize this area in an otherwise cloudy region.

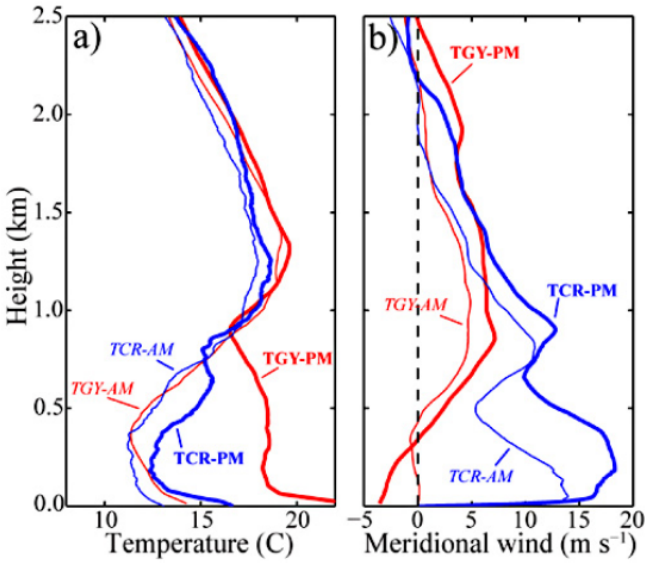


Figure 2: Average vertical profiles during VOCALS-CUpEx from radiosonde observations at Talcaruca (thick lines) and Tongoy (thin lines) at 08:00 LT (solid line) and 17:00 LT (dashed). Left panel: meridional wind; right panel: air temperature.

During the afternoon, the wind speed increases from Talcaruca to Point LdV and decays slightly at Islote Pajaros (Fig. 2). This alongshore variability suggests the existence of a near-shore coastal jet off the bay of Tongoy/Coquimbo, extending a few tens of km to the north of point LdV. Such a feature is consistent with the maximum wind speed during afternoon just to the north-west of point LdV evident in the QuikScat climatology and it is also resolved by high resolution (3 km) atmospheric modelling (Rahn et al. 2010). A very vivid detection of the near-coastal jet immediately north of point LdV was obtained by a research flight over the bay of Tongoy in January 11, 2011 (Figure 4). This strong, diurnally-varying near-coastal atmospheric jet could be a major driver of the oceanic circulation in the CUpEx area, especially in the bay of Tongoy/Coquimbo (Bello and Garreaud, 2011; this conference).

The observational results obtained during CUpEx are now being examined in detail, along with a handful of longer-period records and high-resolution numerical simulations of the atmosphere and ocean. We hope this new information will improve our understanding of the complex interactions among the atmosphere, land and ocean in the near-shore region of north-central Chile. These issues are relevant for the regional meteorology and on the broader subtropical southeast Pacific climate.

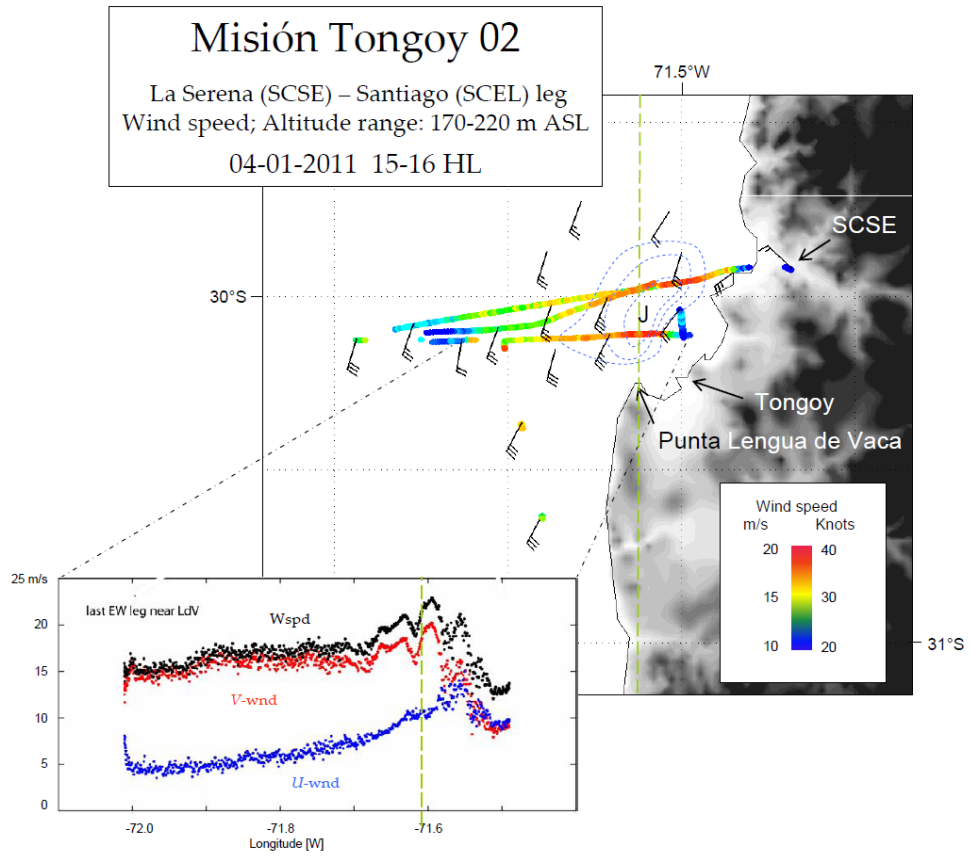


Figure 4: Low-level jet off Lengua de Vaca detected by a research flight.

References

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