VOCALS
Regional Coastal Component

Scientific Program Overview

.
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1. Introduction

The nearshore strip off the subtropical west coast of South America is the longest and perhaps the most productive area of the world's ocean in terms of pelagic fisheries. Its shape and latitudinal extent, in combination with a sharp and coast-parallel orography, support the most stable and strong subtropical anticyclone and associated coastal upwelling system. Pronounced diurnal, weekly and subseasonal signals in the upwelling-favorable wind field are modulated by large swings at interannual (ENSO cycle) and interdecadal time scales. Strong SST gradients and associated meandering of shearing ocean currents at the offshore edge of this coastal strip are the site of ocean eddy generation and changes in the atmospheric marine boundary layer depth and structure, including its capping marine stratus cloud deck (e.g. Garreaud and Muñoz, 2004).

Along the coast of Peru and north-central Chile, winds are persistently favorable to coastal upwelling all year long. On intraseasonal to interannual timescales, the thermo/nutricline depth is largely modulated by the propagation of coastal Kelvin waves originating in the equatorial waveguide and associated westward propagating Rossby waves off the coast, with strong effects on upper ocean temperature, currents and nutrient supply**.** The coastal Kelvin waves, as well as upwelling in general, are affected by the variability of the wind. The structure of the wind variability in a narrow strip (~50 km) along the coast along the coast and its interaction with coastal Kelvin/Rossby waves are not presently fully understood. Furthermore, the feedbacks between sea surface conditions with the atmospheric flow and cloudiness in this region remain also largely unknown.

Along north-central Chile Hormazabal et al.(2001) have documented remote changes in SST in connection with equatorially-sourced intraseasonal coastally-trapped ocean waves. On the other hand, intraseasonal upwelling-favorable wind variability at 30°S appears connected to fluctuations in the strength of the subtropical anticyclone at this time scale (Rutllant et al., 2004). At around 30-35°S a complex southerly low-level jet (LLJ) system develops during upwelling-favorable wind events (Rutllant 1993, 1997; Garreaud and Muñoz, 2005; Muñoz and Garreaud, 2005) that is co-located with the area of maximum ocean eddy mesoscale kinetic energy (Hormazabal et al, 2004), where offshore and equatorward transports and advection of "coastal" properties develop. A similar area has been found centered at around 15ºS off Peru. (Hormazabal et al, 2004). These processes should have an imprint on the stratus cloud deck time and space variability (e.g. Garreaud and Muñoz, 2004), influencing their long-term statistics as a major global climate regulator.

The optical properties of the stratus deck depend on both atmospheric and oceanic dynamics and to the abundance of cloud condensation nuclei (CCN). In fact, air-sea exchange of trace gases and particles, e.g., dimethyl sulfide and sea-salt, which provide efficient CCN, is thought to be very important within the Humboldt Current System off Chile and Southern Peru (e.g., Boucher et al, 2003). This is due to the fact that these cold nutrient-rich waters are continuously renewed by wind-driven coastal upwelling and exposed to light allowing phytoplankton and zooplankton production, which in turn give rise to the accumulation and degassing of climatically relevant trace species such as carbon dioxide (CO2), dimethylsulfide (DMS, CH3-S-S-CH3), nitrous oxide (N2O), etc.

Also, the subduction of the Nazca plate under the Andes and the South American continent induces an area of distinct volcanic activity along the Central Andes where numerous volcanoes show persistent fumarolic activity that probably provides a rather continuos source of sulfate (e.g., Mather et al, 2004), which in connection with downslope winds may supply effective CCN over the stratocumulus deck. Furthermore, there is evidence of a potential perturbation of the subtropical stratocumulus deck due to anthropogenic emissions of oxidized sulfur (SOx) that occur mainly due to copper smelting along the continental strip of Chile and Peru (Kuang and Yung, 2000; Huneeus et al, 2006). Anthropogenic sulfate aerosols emitted from smelters located uphill the Andes would reach the stratus deck in connection with strong easterly wind events, whereas coastal emissions would be advected by trade winds. In addition to the copper industry, urban centers, particularly Santiago (33.5S, 70.5W, 500 m.a.s.l) and Lima (12S, 80W, 50 ma.s.l.), also constitute significant sources of aerosols and trace species that may have an impact on the stratus deck off the coast. Finally, dust, particularly in semi-desertic areas at the Southern bound of the Atacama desert may also provide particles that may become activated as CCN and perhaps more importantly, affect the coastal biochemistry by means of iron deposition (Jickells et al, 2005).

In addition to this, valuable information for the exploitation of coastal clouds as a source of fresh water for human consumption and small-scale agricultural needs for communities living in the coastal areas of the Atacama Desert could result. Furthermore, as an increasing number of sophisticated satellite products (e.g., cloud droplet radii, aerosol optical depth, etc.) are becoming available, a thorough evaluation of these products is required to assess both global and regional impacts of aerosols in the stratus cloud deck.

In-situ atmospheric and oceanic time series are scarce in this region, where observational studies rely mostly upon satellite-derived products as scatterometer winds, altimeter sea-level heights, , radiance-based cloud properties, etc. However a satellite-blind coastal strip of about 30 km prevents a better knowledge of the intervening processes (e.g. windstress curl contribution to upwelling) within this highly productive area. The lack of in situ measurements of aerosol and cloud properties precludes an adequate validation of satellite products. Consequently, there is an urgent need to simulate and validate, during special observation periods, those coastal conditions through regional ocean (e.g. ROMS, POM) and atmospheric (e.g. MM5, WRF, MATCH, RCA, etc) models with some degree of interaction (e.g. SST, winds, cloud-cover, chlorophyll –a, biogeochemistry etc.).

2. General Objective and Scientific Themes

VOCALS Regional Coastal Component (VOCALS-Coastal) is aimed at improving our capability to understand regional environmental variability directly related to a sustainable management of natural resources (e.g. fisheries, solar and wind energy, fresh water from coastal clouds) while contributing to the international effort to understand the processes responsible for the maintenance and variability of the stratus cloud cover and cold tongue in the tropical-subtropical Southeastern Pacific (SEP) as a key factor in the global climate.

In this context, we expect to benefit from open ocean observations and regional coupled modeling efforts during VOCALS-REx centered around November 2008 and contribute to the world scientific community a set of coastal measurements fulfilling international standards.

More specifically, we aim to understand air-sea-land-cloud interactions explaining the time-space variability of the nearshore (0-200 km) stratocumulus cloud deck off southern Peru and north-central Chile and the associated atmosphere-ocean upwelling dynamics and climate, organized within 5 broad scientific themes encompassing the synoptic scale (T1), diurnal cycles (T2), long-term air-sea interaction (T3), aerosols (T4), offshore consequences of coastal processes (T5):

T1. The impacts of the synoptic-scale features upon the lower troposphere circulation, thermo-dynamical structure and cloudiness within the nearshore region.

T2. The impact of the continental heating and mechanical forcing of the atmospheric flow impact on the AMBL clouds and structure in the upwelling-sensitive coastal strip (0-50 km).

T3. The feedbacks of AMBL circulation / structure, clouds, SST and ocean circulation within the coastal strip. Upwelling, by changing the physical and chemical properties of the upper ocean, has a systematic and noticeable effect on aerosol precursor gases and the aerosol size distribution in the MBL over the SEP

T4. The effect of natural (biogenic sulfate, sea-salt, mineral dust, volcanic sulfate) and anthropogenic (copper smelting, power plants) aerosols on the AMBL clouds (in terms of cloud cover, droplet radii, albedo, drizzle suppression) along the Peru-Chile coastal strip.

T5. The offshore influences of coastal atmospheric / oceanic variability and the offshore transport of heat and fresh water by oceanic mesoscale eddies from coastal upwelling regions.

In addition to the in-situ and remote observations to be gathered during VOCALS Coastal, we will make ample use of regional numerical models (atmospheric / oceanic / coupled) for both processes study and guidance during the intensive observation period. On the other hand, the observational database will allow us to assess the ability of the regional modeling systems to simulate the key coastal features and processes.

3. Specific questions / Hypotheses / Observational strategies

Within the broad scientific themes listed above, there are many specific questions motivated by physical phenomena and processes along the coast of southern Perú and north-central Chile. These phenomena and processes have a sizable impact in the coastal meteorology and oceanography but we don’t yet have a complete understanding of them nor are the current models capable of an accurate representation of them.

We have defined two major regions in which there are enough specific questions that could be answered using targeted observations amenable to be obtained in an experiment of the kind of VOCALS-Coastal. The first area encompasses southern Perú and Northern Chile (around 21°S) and including the coastal “elbow” at 18ºS where the coast line experiences a sharp change in direction. The second region is centered at about 30ºS (central Chile) and includes one of the most active upwelling areas.

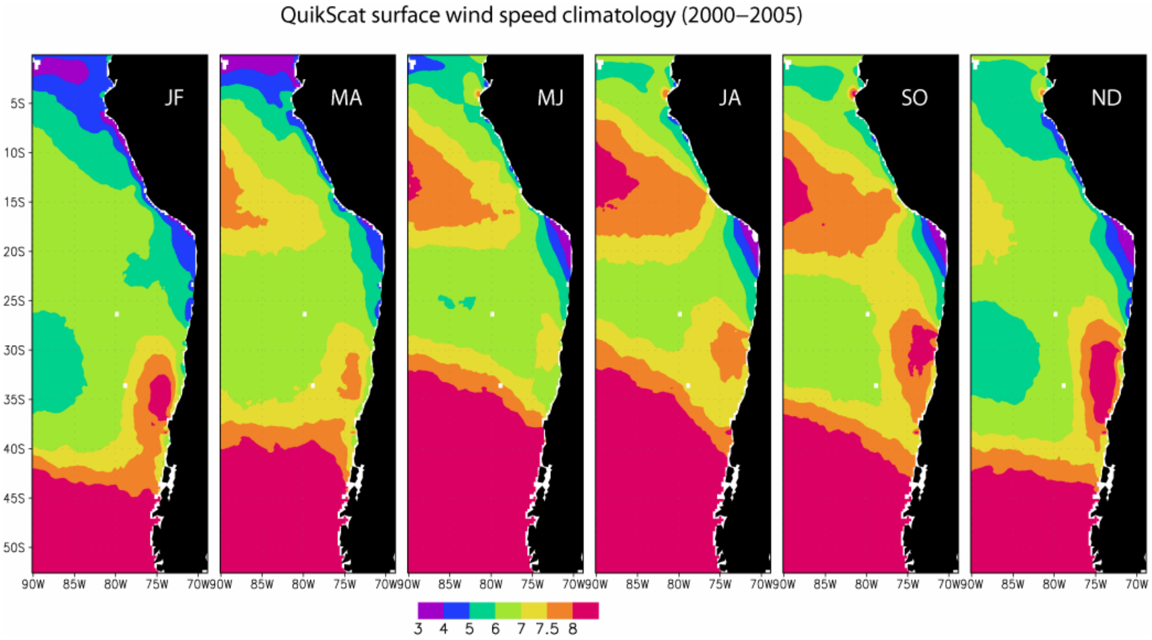
In the following we provide a brief motivation for each specific question, a preliminary hypothesis and the observational and modeling requirements to address the questions.

At the coastal VOCALS workshop that occurred as part of VPM-10, we identified the northern region as a high priority for the VOCALS coastal field campaign. Specific science questions are organized with questions relating to the northern region first (SQ A-E), followed by questions related to the southern region (SQ F-J). To reduce confusion with the earlier draft of VOCALS science questions, specific science questions are here identified by letter rather than by number.

The specific questions in the northern region will be largely advanced on the basis of the observations taken during VOCALS-Rex (2008), gathered from international (US, Chile, Perú) platforms near the coast or those that committed for the offshore region that will depart/arrive from Iquique (e.g., the R/V Ron Brown). In contrast, the specific questions in the southern region will be advanced on the basis of observations gathered from Chilean platforms during 2009. Details on the field program strategy are included in a companion document.

SQ A: Near-stagnation area at 18ºS. (Northern region)

Figure 2 shows the climatology of surface wind speed based on 5 years of Quikscat data. There is a well defined minimum centered at 18ºS (the coastal elbow), where surface wind speed is 2-3 times slower than the surrounding areas both offshore as well as to the north and south of this area. This near-stagnation area coincides with a maximum in cloud droplet concentration seen in satellite derived estimates. Given the long time of residence of the air parcels within this region, one may speculate that the air-sea interaction there would be significantly different from its counterpart elsewhere along the coast.



While Quikscat provide enough data to describe the synoptic and seasonal variability of this near-stagnation area, little is known about its three-dimensional structure (e.g., its vertical extent) and the specific thermodynamic conditions in its interior.

Hypothesis A1: The near-stagnation area around 18ºS is produced by the mechanical blocking of the southerly wind by part of the coastal mountains of southern Perú.

Hypothesis A2: The low wind speeds in this area are conducive for a build-up of pollutants, some of which may act as CCN leading to significant high cloud droplet concentration.

Observational / Modeling requirements

Low-speed flights within and above the AMBL should measure wind and temperature so as to describe the three-dimensional wind and temperature structure over the near-stagnation area. Radiosondes launched from a ship crossing this area will also help to elucidate its structure.

SQ B: Diurnal cycle in the coastal strip (Northern region)

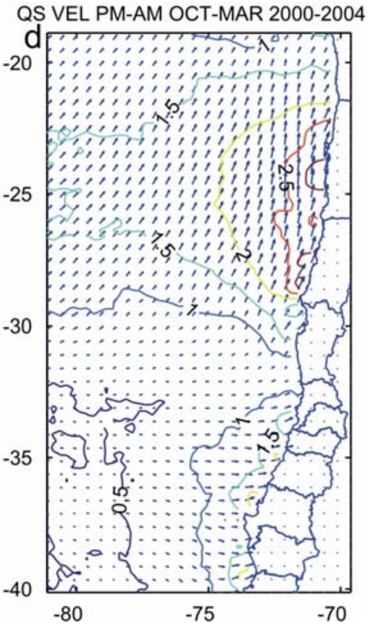
QuikScat data and GOES satellite imagery show that the diurnal cycle in the near surface coastal meteorology is more prominent in northern Chile (22^{o}S - 28^{o}S). Main features of the afternoon phase of this diurnal cycle are the intensification of the southerly (along the coast) winds and the clearance of a coastal strip (Figure 5, Muñoz et al., 2006). In the nocturnal phase, on the other hand, winds at the coast decrease significantly, inducing a coastal rotor important in oceanic upwelling. Enhanced afternoon subsidence occurring along the coast in the lower troposphere (500 - 4000 masl) may play a role in the coastal diurnal cycle as suggested by past field measurements in the Antofagasta (22^{o} S) area (Rutllant et al., 2003).

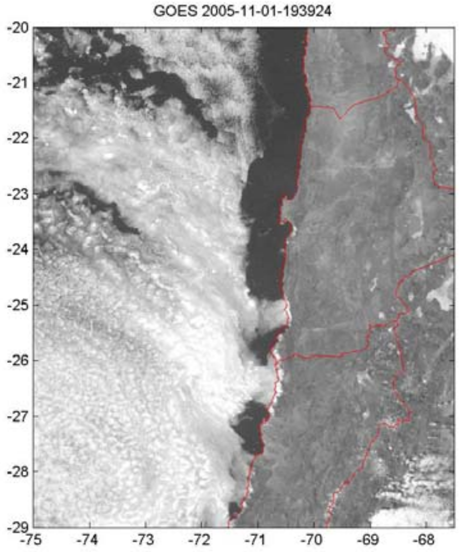
Remaining questions in this regard are: 1) What is the forcing of this coastal subsidence?, 2) What is the nature of the MABL response to this subsidence aloft?, 3) What is the offshore scale of the region with enhanced diurnal cycle?. One might consider that parameters like the offshore extension of the clear coastal strip, the acceleration of the coastal southerlies, the time scale of the return of the clouds to the coast during the night, etc., may be controlled by the MBL height and wind speed, intensity of the subsidence aloft, etc.

Hypothesis B: Increased afternoon subsidence in the coastal area at levels 500-4000 masl is forced by a mechanical/heating effect of the Andes mountains to the east and controls the diurnal cycle of the MABL at the coast.

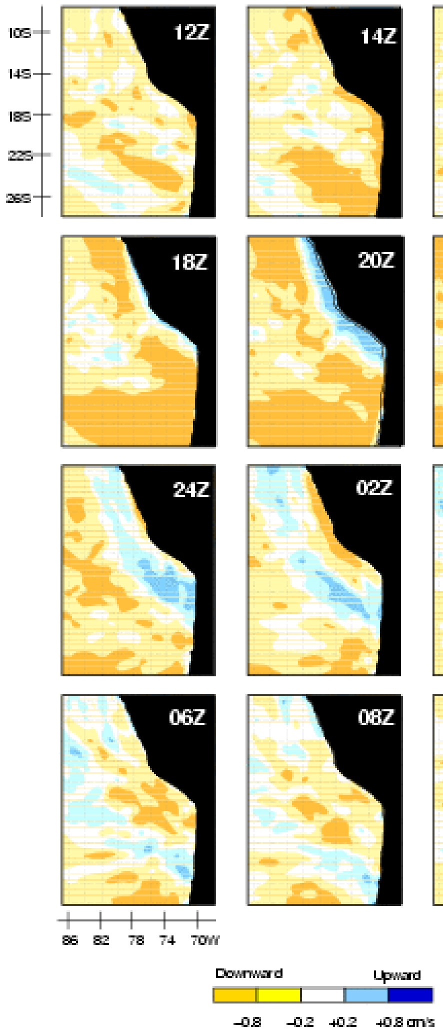
Observational / Modeling requirements

Observations: wind and temperature profiles at the coast and inland with high time resolution. Observations of the coastal MABL during the afternoon and during the night in the coastal strip (50 km near the coast). Meteorological stations along the coast including microbarometers.
Modeling: should concentrate in reproducing the dynamics of the MABL height near the coast, establishing its sensitivity to the upper circulation. Idealized model runs modifying the topography of the coastal and the Andes Mountains will shed light on their role in affecting the coastal low-level circulation.





SQ C: The upsidence wave off southern Perú (Northern region)



A distinctive feature of the SCu deck off the coast of subtropical South America is its pronounced dawn-to-afternoon decrease in cloud amount and liquid water path (e.g. Wood et al. 2002; Rozendaal et al. 1995). This decrease is observed in satellite imagery an extend several thouthans of kilometers offshore (i.e., can not interpreted in terms of the diurnal cycle documented in SQ5).

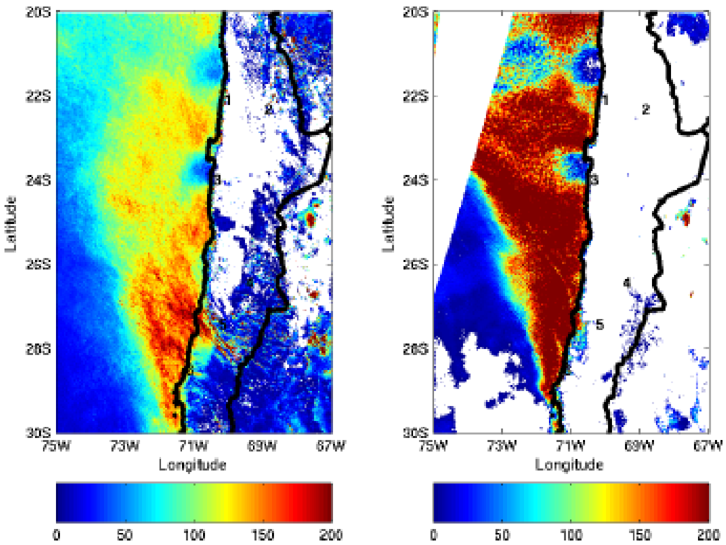
A few observations in the offshore area (Bretherton et al. 2004) suggest that afternoon thinning of the SCu is largely produced by a regular decent of the inversion base. These observation are in line with modeling results reported by Garreaud and Muñoz (2003). In this later study, the use MM5 to simulate one month during austral spring, and they found that the diurnal warming / nocturnal cooling of the lower troposphere is produced by an alternation of subsidence / upsidence associated with the passage of a gravity wave generated diunarlly along the coast of Southern Perú. For instance, Fig. 7 shows the anomalies (departure of the day mean) of vertical velocity at 800 hPa obtained from the MM5.

Hypothesis C: The marked diurnal cycle of cloudiness and temperature off the coast of northern Chile and Southern Perú is largely caused by a gravity wave generated along the coast that acts on a very stratified troposphere.

Observational / Modeling requirements

Observations: wind and temperature profiles at the coast and offshore along a line that coincide with the phase speed direction of the upsidence wave. This profiles could be aquired using a low-speed aircraft with standard meteorological instrumentation.

SQ D: Offshore transport episodes of anthropogenic sulfate aerosols (Northern region)



Increases in cloud droplet number concentration (CDNC) can be observed in connection with easterly wind events downwind from anthropogenic sources, mainly copper smelters in Northern Chile (Huneeus et al, 2006). Figure XX shows cloud droplet number concentration (CDNC, in cm-3) as derived from satellite data. Average CDNC for the period between July 20 and August 20, 2000, is shown on the left panel; the right panel shows CDNC for July 26th in connection with a strong easterly wind event (winds in excess of 5 m/s). Displayed on the figure are the location of the power plant Tocopilla (1) and cooper smelters Chuquicamata (2), Noranda (3), Potrerillos (4) and Paipote (5). The oxidized sulfur emissions of these sources add up to 215 GgS/y.

Circulation conditions favorable for the occurrence of easterly wind events present a synoptic structure typical of the coastal troughing at the onset stage of coastal-low events farther south in Chile (e.g. Garreaud et al., 2002). Huneeus et al (2006) have suggested that these changes in CDNC obey to the impact of anthropogenic sulfur sources, mainly copper smelters. However, other aerosol sources may also be be at play. For instance, easterly wind events are concurrent with an enhancement of the LLJ system that may drive stronger air-sea exchange inducing sea-salt emissions and enhanced biogenic activity. Also, along the central Andes, multiple volcanoes show quasi-permanent fumarolic activity that may constitute a significant natural source of aerosols, particularly sulfate aerosols. In summer, when convection over the Amazon basin disturbes or often disrupts the prevailing westerlies in the upper troposphere, volcanic aerosols may become relevant as precursors of CCN, particularly when the upper easterlies are enhanced by coastal low like circulation patterns in the lower atmosphere.

Hypothesis D1. In connection with easterly wind events associated with coastal lows, anthropogenic sulfate reaches the stratus deck altering its optical properties.
Hypothesis D2. The composition and size distribution of activated aerosols acting as cloud condencation nuclei (CCN) changes in connection with easterly wind events, showing a distinct signal of anthropogenic sulfate, particularly in nearshore stratus.

Observational / Modeling requirements

In addition to wind, humidity and temperature profiles, the composition and size distribution of CCN must be monitored at a site located downwind from anthropogenic sources. These measurements require complementary measurements and characterization of aerosol precursors (e.g., sulfur dioxide) and particulate matter on a regional scale. Also, aerosol loading and vertical distribution would be necessary. Satellite products should also be analyzed to ascertain the changes in cloud properties.

Modeling should focus on the relative contribution of the various aerosol sources present in the region, and their distribution in connection with relevant weather patterns. This, in addition to observations would help dilucidating the origin of the CCN actually activated in nearshore stratus.

SQ E: Offshore transport of coastally upwelled water by mesoscale processes (Northern region)

In-situ and remote-sensing observations (Figure E1) show the presence of oceanic mesoscale eddies all along the Peruvian and Chilean coasts. These eddies are formed in the coastal region and transit offshore at speeds of 3-7 cm/s (Chaigneau and Pizarro, 2005). They carry with them physical (e.g., temperature and salinity) and biochemical (e.g., chlorophyll-a, dimethyl sulfide) signatures. Temperature and salinity signals consistent with coastally-derived eddies occur as far east as the STRATUS buoy and may affect heat and salinity balances there (R. Weller, personal communication).

Despite their importance, coastal eddies are not well-described by available in-situ and remote observations. Persistent cloud cover makes observations of surface chlorophyll and temperature spotty. Sea surface temperature signals of the eddies are weak. Altimetric observations are problematic within several degrees of the coast and do not describe the vertical structure of the eddy field. The lack of coastal observations means that the processes governing the formation of coastal eddies are not well understood.

Remaining questions in this regard are: 1) What are the processes that contribute to the formation of these eddies? 2) What is the vertical structure of these eddies? 3) How do these eddies change as they propagate offshore and over the region of persistent stratocumulus cloud deck that is the focus of VOCALS?

Hypothesis E1: Oceanic mesoscale eddies are generated in the coastal region. Their generation is affected by wind events, topography, interactions with the undercurrent and the poleward propagation of coastally-trapped waves.

Hypothesis E2: Oceanic mesoscale eddies generated in the coastal region transit offshore to the VOCALS region and affect oceanic properties and air-sea interaction there.

Observational / Modeling requirements

A ship based mesoscale SeaSoar survey between the coast and approximately 300 km offshore is necessary to describe the horizontal structure of the oceanic mesoscale field inshore of satellite altimetric observations. This survey will make possible the estimate of modes of baroclinic instability. It will also describe the vertical structure of the mesoscale field and its associated biochemical properties. Shipboard meteorological observations are needed to describe air-sea interaction over coastal ocean features. Deployment of one or more gliders is needed to map mesoscale features and observe their evolution. Surface drifter deployments would be useful to describe mixing processes associated with mesoscale eddies using single and multiple particle Lagrangian statistics. The field observations can be used to make qualitative comparisons to modeled oceanic mesoscale fields and to improve ocean model initialization.

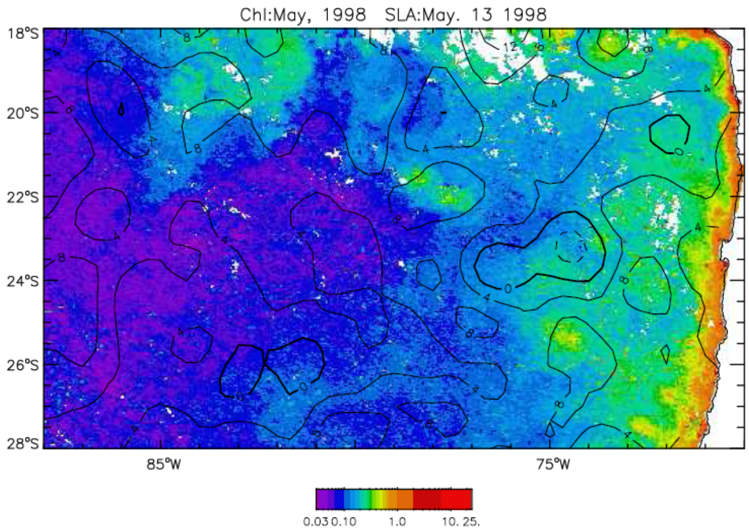


Figure E1 Chlorophyll-a (colored) and satellite-based altimetry (contoured) showing mesoscale features off the coast of central Chile. Higher chlorophyll values appear as orange, yellow and green.

SQ F: Climatological near- coastal wind maxima around 30ºS (Southern region)

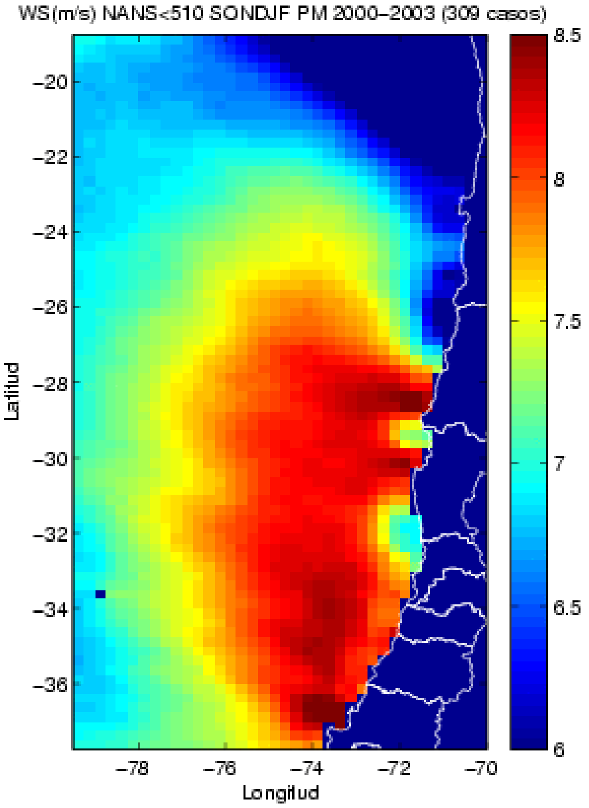


Figure 1 shows the long-term mean surface wind speed (WS) for austral spring and summer off the Chilean coast. There is a coastal jet (also present in austral winter with lower frequency/strength) characterized by a broad area of maximum of between 38-28°S, with its axis at about 150 km of the coast. This coastal jet is primarily maintained by a balance between the meridional pressure gradient and friction, as shown in the modeling study of Muñoz and Garreaud (2005).

The Quikscat data also reveal that strong wind speeds extend all the way to the coast in three areas, just to the north of the major capes in this region, where persistent upwelling sources are located : Punta Lavapie (37°S), Punta Lengua de Vaca (30°S) and Cape Carrizal (28-29°S). At 30°S coastal afternoon winds are well correlated with the nearest Quikscat ones. What causes the near-shore wind maxima in those specific regions? Is the AMBL structure in these regions significantly different from what is found elsewhere?

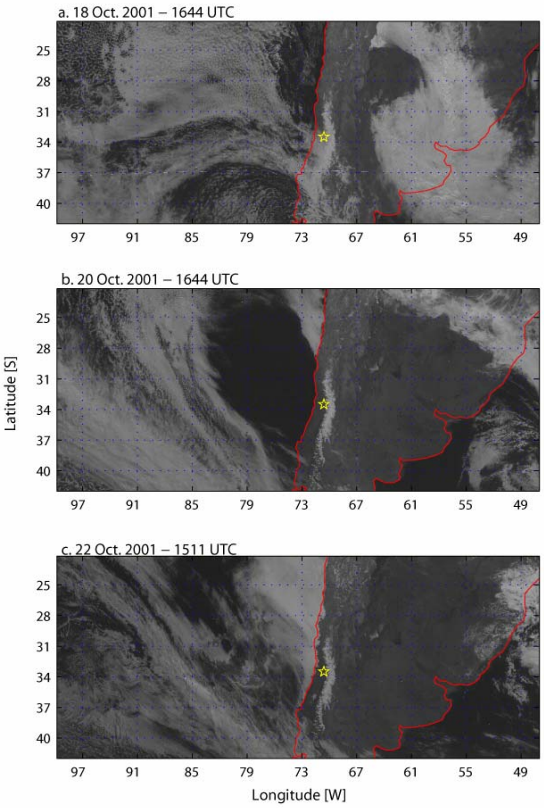
Hypothesis F: Large-scale southerly winds (i.e., those within the broad coastal jet) promote coastal upwelling all along central Chile, and lead to minimum of SST just to the north of the major points and capes. The cold SST locally depresses the AMBL and increases the low-level southerlies.

Observational / Modeling requirements

We propose to test this hypothesis for the area of Punta Lengua de Vaca. Low-speed flights within and above the AMBL should measure standard meteorological variables as well as SST in 100-km cross-shore transects at around 30°S, so as to describe the three-dimensional structure of the AMBL and their connection with SST gradients.

The role of the SST mean structure in supporting these near-coastal areas of maximum WS should also be tested with regional numerical simulations, including a control simulation forced by observed mean SST fields and a sensitivity experiment using a SST field constant along the coast.

SQ G: Coastal Clearing Episodes around 30ºS (Southern region)



GOES-8 visible images during 3 consecutive days in October 2001 (Fig. 3) illustrate the rapid transitions from cloudy to clear to cloudy conditions that are often seen off the coast of central Chile. The cloud free area extends several hundreds of Km offshore. The clearing of the SCu occurs in conection with the development of a coastal low in central Chile (e.g., Garreaud and Rutllant 2003). Furthermore, the area of clear skies tends to coincide with the area of enhanced southerly winds during coastal jet events both offshore and at the coast.

On the basis of observations at the coast and modeling results, the clearing of the SCu has been associated with enhanced subsidence and advection of continental air during the first stage of coastal low episodes. It is not clear, however, what are the actual mechanisms responsible for the rapid cloud dissipation, especially far from the coast, and the subsequent cloud re-formation.

After the coastal low culminates, there is a rapid advance of the coastal stratus from northern to central Chile. In this stage, there are a few cases in which the MBL near the coast become deeper than normal leading to an intrusion of cool, moist air and low clouds inland. Is not clear yet under which specific condition the decaying phase of a coastal low produce an inland intrusion.

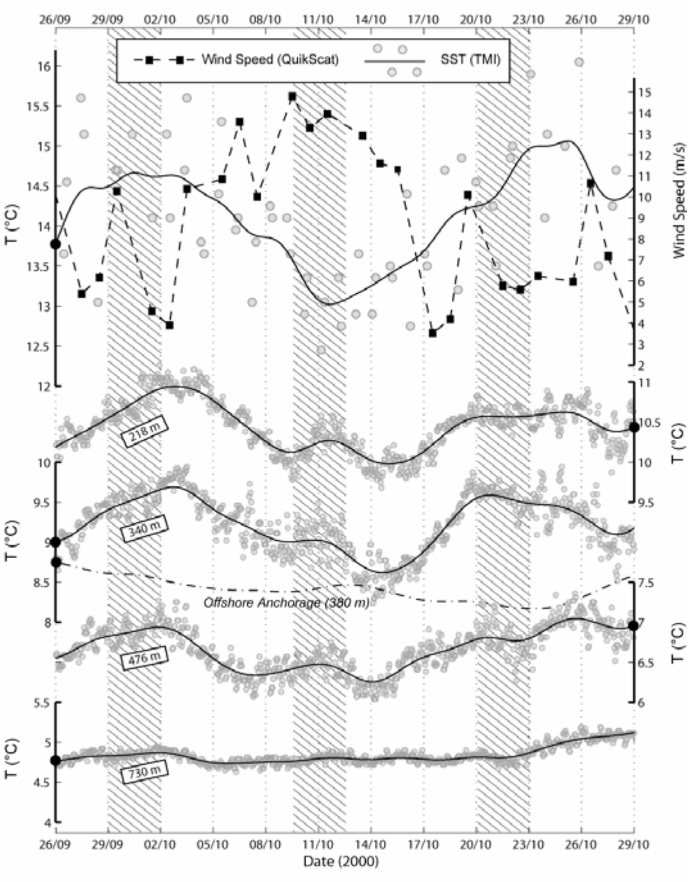
Hypothesis G: SCu over the SEP dissipate in conection with a decrease of the MBL depth, which is in turn produced by the advection (at about 850 hPa) of warm air from the continent during coastal low episodes. Near the coast (0-100 km), enhanced synoptic-scale subsidence might also play an important role.

Observational / Modeling requirements

Low-speed flights with standard meteorological instrumentation should be conducted during the onset of a clearing episode. Using real-time satellite imagery, the offshore edge of the clear skies (roughly parallel to the coast line) will be identified, and the aircraft should flight across that edge at several levels, thus sampling the environmental conditions (including the wind direction and MBL depth) that characterize the clear and cloudy regions.

Additional insights could be obtained from ceilometer observations, and temperature and wind profiles taken on research vessels in this area. If a cloud clearing event is in progress, radiosondes should be launched frequently (e.g., every 2 hr) to provide a near-fixed point description of the temporal evolution of the MBL depth and changes in circulation.

SQ H: Coastal Jet events and their impacts on surface ocean around 30ºS (Southern region)



The surface wind field off central Chile exhibits an intermittent formation of a coastal jet (CJ) (Garreaud and Muñoz 2005; Muñoz and Garreaud 2005) that lasts 5-10 days, forced by the passage of migratory anticyclones farther south. They are characterized by a meridionally elongated core of southerly winds between 10-15 m/s (twice the climatological mean) some 300 km wide and usually centered about 100 km offshore.

The coastal jet provides a particularly favorable environment for enhanced sea surface cooling. Stronger than normal southerlies may be expected to increase coastal upwelling via Ekman drift and Ekman pumping, also enhancing air-sea exchanges of sensible and latent heat. For instance, Fig. 4 shows the evolution of the surface wind, SST and ocean temperature at depth for a CJ during October 2001.

Lack of in-situ data, however, precludes quantifying the actual impact of the CJ events upon the oceanic temperatures, identifying the leading processes, and documenting any potential feedback between SST and MBL circulation during these events.

Along the near shore coastal strip, and particularly around upwelling foci, a concomitant near-surface coastal jet has been evidenced through pilot balloon observations (30°S), coinciding with the climatological features depicted in Figure 1.

Hypothesis H1: CJ events leads to a near simultaneous cooling of the ocean mixed layer more or less coincident with the area of strongest winds, mostly because of an increase in Ekman upwelling.

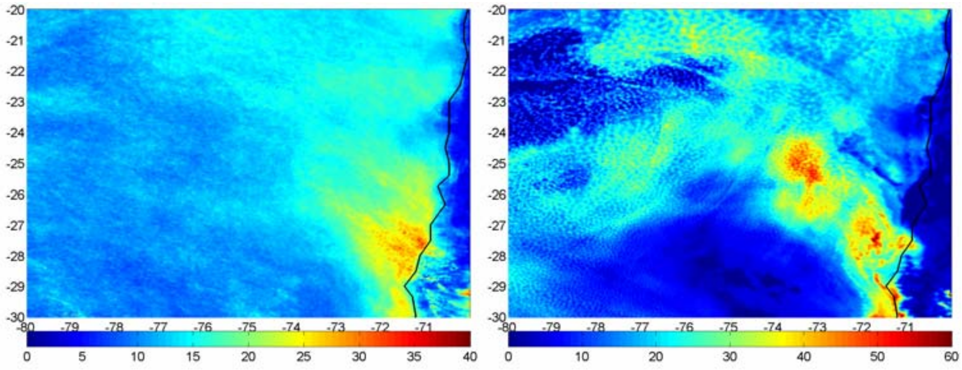
Hypothesis H2: LLJ events along the coast at upwelling foci (e.g. 30°S) result from positive feedback of regional land-sea temperature differences (clear-sky conditions) on coastal winds together with momentum transfer from the upwelling-front jet above the MBL caused by diurnal subsidence enhancement in the afternoon.

Observational / Modeling requirements

Coordinated air-borne, coastal vertical profiles and ship-borne observations during a coastal jet event. Aircraft SST measurements (and satellite estimates) should provide the evolution of the SST field in the near-costal area during the CJ lifecycle. Ship-borne and existing ocean moorings would document changes of ocean temperature and currents with depth. Ship-borne measurements of air-sea fluxes are also important

SQ I: Dust and biogenic aerosols downwind from 30ºS (Southern region)

In Figure 8, an area with persistently high CDNC is noticed along the coast and offshore between 30ºS and 26ºS, which is not readily associated with anthropogenic sulfur emissions (Huneeus et al, 2006). This is also apparent in the corresponding images for coud optical thickness (COT) derived from SeaWiFS imaginery shown in Figure 9 (Glantz, personal communication).



Alongshore, this area coincides with the location of the atmospheric low level jet referred to earlier (SQ1), which in turn is associated with air-sea exchange and upwelling of cold and nutrient rich waters that may be favorable for biogenic emissions of dimethyl sulfide, and therefore of biogenic sulfate aerosols. Also, as air-sea exchange and near-surface strong winds are present, this may lead to emissions of sea-salt aerosols which can act as effective CCN. Further, the semi-desertic areas at the Southern bound of the Atacama desert may also provide particles that may become activated as CCN and perhaps more importantly, affect the coastal biochemistry by means of iron deposition (Jickells et al, 2005). Finally, it is plausible that a signal of somewhat aged air masses exposed to urban emissions from the centrak region of Chile could also affect the composition of aerosols and CCN at the area of interest.

Hypothesis I: The persistently high CDNC observed along the coast and offshore between 30ºS and 26ºS is mainly explained by dust and biogenic aerosols, whose emissions are modulated by the presence of the LLJ system.

Observational / Modeling requirements

Similar to those indicated in for SQ8 but including a characterization of coarse mode aerosols and foot prints of urban pollution (Santiago).

SQ J: The coastal transition zone jet off Chile and its role on the mesoscale (Southern Region)

Satellite images, drifter trajectories and shipborne data show the presence of filaments of cold (and chlorophyll-rich) waters that extend hundreds of km offshore in all major coastal upwelling systems. These cold filaments are associated with the offshore branch of a continuous, meandering, equatorward jet that separates warm and chlorophyll-poor offshore water from colder and chlorophyll-rich, upwelled coastal waters (Strub et al., 1991). This meandering jet is a major component of the eastern boundary current system, it plays a main role transporting surface water equatorward and interacting with upwelling and mesoscale eddies. Whereas the presence of eddies and filaments off Peru and Chile have been widely recognized in satellite images, there is a complete lack of evidences of the jet based on direct hydrographic data or current observations. Most of the traditional oceanographic surveys in this region have considered too sparse sampling to suitably study the properties of the jet.

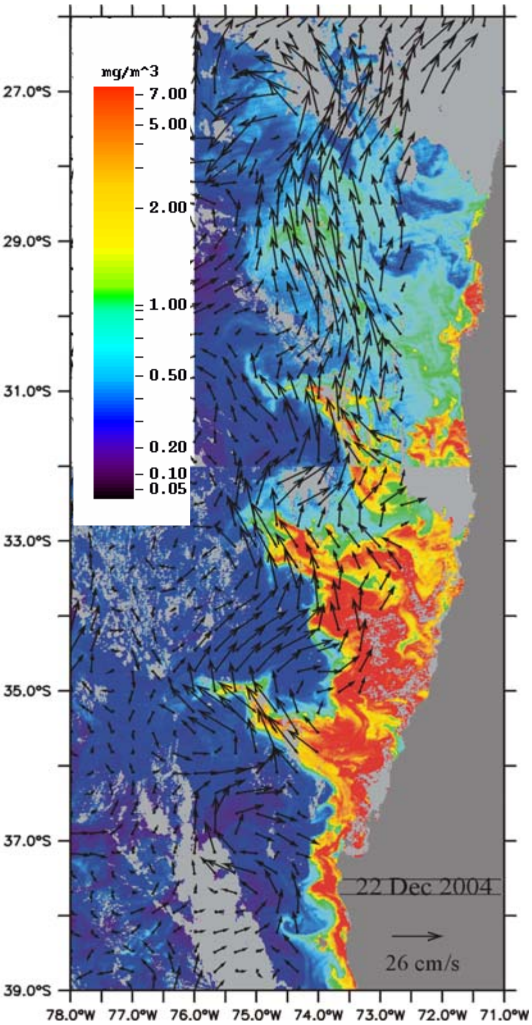


Figure 1 shows absolute surface geostrophic velocity and chlorophyll concentrations from Moderate Resolution Imaging Spectro-radiometer (MODIS) between 26°S and 39°S. Surface geostrophic velocity field is derived from a combination of data from different altimetry missions and absolute dynamic height estimated from hydrographic climatology. A meandering jet flowing northward from 38°S is clearly visible. This jet is the Southern Hemisphere counterpart of the California Current observed along the coastal transition zone in the subtropical eastern North Pacific. The offshore branches of the menders are associated with filaments of water with high values of chlorophyll. In general, the distribution of cold water follows a similar pattern as high chlorophyll concentration.

Mean surface circulation based on satellite-tracked drifters shows a predominant northward flow off central Chile (Figure 2). This flow is consistent with the large-scale gyre circulation and the surface Ekman transport associated to the regional wind field (Chaigneau and Pizarro, 2005). Nevertheless the presence of the jet and it seasonal variability is difficult to evaluate based on the small amount of drifter data presently available for the region.

Hypothesis J: The characteristics of the jet and its evolution during the austral spring and summer are strongly modulated by the evolution of the coastal jet in the atmosphere and the formation of the upwelling front.