VOCALS
Regional Coastal Component

Field Program Strategy

.

Contributions from: José Rutllant[1], René Garreaud[1], Ricardo Muñoz[1], Laura Gallardo[2], Jorge Carrasco[3], Oscar Pizarro[4], Samuel Hormazabal[4], Edward Dever[5], Ricardo Letelier[5], Ted Strub[5], Rob Wood[6], Ana María Cordova[7]

(1) Department of Geophysics. Universidad de Chile; (2) Center for Mathematical Modeling. Universidad de Chile; (3) Dirección Meteorológica de Chile; (4) Department of Geophysics. Universidad de Concepción, Chile; (5) Oregon State University; (6) University of Washignton; (7) Universidad de Valparaiso and CEAZA.

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*Following the introductory arguments and science issues presented in the **Scientific Program Overview**, two distinct geographical areas emerge as candidates for enhanced monitoring and intensive observations during 20-30-day field experiments in November 2008 and November 2009, respectively. At the April 2007 VOCALS workshop, the northern sector emerged as the likely focus of 2008 international field efforts due to its proximity and strong links to the main VOCALS field experiment and STRATUS buoy.*

We also describe in this document the field strategy to tackle our scientific questions on the southern sector (centered at 30°S), the likely focus of field efforts during October 2009.

A Brief Review of the Science Issues

NORTHERN SECTOR (15˚S - 25˚S, centered at 21°S)

The northern geographical area broadly encompasses southern Perú and northern Chile, where the offshore stratus cloud deck is more persistent and where most of the open ocean VOCALS REx observations will take place during November 2008.

In terms of the coastal AMBL dynamics, radiative forcing with topographic influences (diurnal-cycle issues) dominates over synoptic-scale forcing from mid-latitudes. Offshore winds are comparatively weak and persistent with a large offshore influence of the coastal diurnal-cycle signal. Persistent upwelling associated with points and capes along the coast feature strong winds in the afternoon, only slightly modulated by synoptic-scale (~weekly) strengthening-weakening cycles. Regular afternoon coastal clearing and coastal subsidence enhancement are characteristic features there.
On the coastal ocean side, this area is deeply influenced by equatorially-sourced coastally-trapped waves at intraseasonal time scales and westward propagating Rossby waves at semi-annual time scales. Ocean mesoscale features as eddies and filaments are scarce there, except at the northern edge of this region (~15˚S) where high eddy kinetic energy generation is found in connection with the San Juan strong upwelling area. This area is also the site of nearshore anomalies in cloud droplet size distribution, where smaller cloud droplet would be related to a relative abundance of natural and anthropogenic CCN contributions both within and above the AMBL.

There, good surface meteorological records exist at Diego Aracena (Iquique's International Airport). Ocean moorings with subsurface current meters and "looking-up" ADCPs over the continental slope and 200 km offshore have been displayed and maintained for several years.

> For the Chilean component of the field work, we have selected latitude 21˚ S (south of Iquique) to perform special observations including ship and airborne measurement during November 2008. The almost straight and meridionally-oriented coastline and coastal-parallel topographic contours up to the high Andes make it for an ideal place to study and model-simulate thermal and mechanical effects of the relief upon the low-level atmospheric circulation along the coastal strip.

SOUTHERN SECTOR (25˚S - 35˚S)

This area in north-central Chile is a transition zone between the region described above and the region farther south where an increasing influences of synoptic-scale systems is experienced. Strong upwelling-favorable wind episodes occur year-round, with higher intensity in spring-summer. Rapid transitions between clear and overcast conditions frequently occur in connection with coastal lows. Strong upwelling-favorable wind episodes constitute here an ideal place to assess the role of biogenic sulphate aerosols (DMS) and sea-salt as CCN. Also strong downslope wind episodes (*terral)* could be instrumental in bringing inland dust (possible iron-laden) to contribute as CCN (fertilize coastal waters). In this region local wind variability at several time scales force the coastal ocean, leaving coastally-trapped waves in a second place as a forcing factor.

At 30˚S good surface meteorological records exist from the Punta Lengua de Vaca automatic weather station. Ocean moorings with subsurface current meters over the continental slope and 150 km offshore have been displayed and maintained since 1991.

Scientific issues and related hypotheses in connection with the LLJ system and co-located cloud clearings, meandering ocean jet system and high eddy kinetic energy production will be addressed in a similar field experiment at 30˚S (just South of Coquimbo - Chile) around November 2009.

OBSERVATIONAL PLATFORMS / EXPERIMENTAL OVERVIEW

SPRING 2008

Oceanographic Observations

The 2008 coastal field campaign will be tightly coupled to the offshore portion of the October-November 2008 VOCALS-REX experiment. Observing platforms in the 2008 northern Chile coastal experiment will rely largely on the availability of a UNOLS intermediate class R/V (e.g. **Wecoma or New Horizon)** for a 21-day cruise (Figure 1, Figure 2 left panel) in a radiator pattern off the northern region (Punta Patache).

It's envisioned that this coastal VOCALS cruise would occur immediately prior to the offshore VOCALS cruise and in close coordination with the offshore cruise. The coastal cruise would employ the second R/V that is being planned for the offshore VOCALS field campaign when the Ron Brown and the second UNOLS vessel will be operating near the STRATUS and SHOA buoys (20° S, 75-85° W). The same instruments (SeaSoar, CTD, meteorological sensors, and aerosol sampling) would be employed on this ship during both the coastal and offshore VOCALS cruises. Both cruises would observe oceanic mesoscale eddies and air-sea interaction over them. The coastal cruise would aim to characterize the properties and formation processes of coastal eddies while the offshore cruise would aim characterize their properties offshore and their associated transport of coastal waters to the area near the STRATUS and SHOA buoys.

Ocean observations should consist primarily of SeaSoar continuous underway profiling with a CTD, optical properties, dissolved oxygen, and nitrate (Figure 1-2). Other ocean observations from this platform would include a profiling CTD, ship-mounted ADCP, and underway surface temperature, salinity, and optical properties. Water samples for oxygen and salinity will be also taken to depths sufficient to define the oxygen minimum characteristic of the undercurrent (500 m). SeaSoar and CTD data will be complemented by satellite-tracked, surface drifters released in the area. Selected ship-borne radiosonde observations and an on-board automatic meteorological station and a ceilometer should be a part of the observations, and an aerosol sampling lab should be considered.

The 2008 field campaign would also rely on the deployment of one or more gliders to follow the evolution of an eddy as it transited offshore. One or more gliders would be deployed within a coastal eddy immediately prior to, or during, the coastal cruise. The eddy would be identified through satellite observations prior to the cruise if possible. If this is not possible, the eddy would be identified during the coastal SeaSoar cruise. The glider(s) would be guided through the core of the eddy for the remainder of coastal cruise and the immediately following offshore cruise. The total mission length would be about 43 days. During the mission, the gliders would report data in near real time. Following the end of the offshore cruise the glider(s) would be retrieved. Glider sensors would include CTD, optical sensors and dissolved oxygen.

Aircraft-based observations

Selected simultaneous airborne observations are envisaged with a **Twin-Otter** or similar low-speed aircraft (Figure 1) capable of sampling wind, atmospheric pressure, temperature and water vapor content within and above the AMBL, as well as remote SST and simple cloud -microphysics parameters. We envision several types of aircraft missions, each tailored to address specific scientific questions.

- *Diurnal cycle missions in the northern area* (21°S): Zonal cross-section from the coast to about 50 km offshore at 50, 500, 1000 and 1500 m ASL. At least 4 missions in un-perturbed days at dawn (05-06 AM) and afternoon (04-05 PM)

- *Sampling the near stagnation zone in the northern Area* (21°S). Meridional transect from 21° to 18°S about 80 km off the coast at 300 m northbound and 1800 m southbound. Pseudo-vertical profiles at the transect's extremes. At least 4 missions in 4 unperturbed days.

- *Coastal aerosol surveys in the northern area* (21°S). TBD.

Moorings and land-based meteorological observations

In both coastal sites time series with surface meteorological stations and subsurface current-meter moorings will be maintained. Around the field experiments, surface observations will be enhanced with micro-barometers, aerosol sampling devices and eventually a set surface energy budget measurements. Ground-based meteorological observations aloft will include a ceilometer, pibal observations or a wind-temperature vertical profiler, together with an enhancement in the frequency of standard radiosonde observations at Antofagasta (23˚S) and Sto. Domingo (34˚S). During both experiments we also plan to complement the currentmeter moorings with two meteorological buoys located over the shelf near 30°S and 21°S and to better instrument the present moorings by including near surface temperature sensors and extra current-meters.

Land-based aerosol observations

We will perform in situ measurements of aerosol concentrations, composition and size distribution in a coastal site north of Antofagasta (23ºS) over which stratocumulus (Sc) clouds summit, particularly during winter and spring, and on an episodic basis, downwind from a large copper smelter (Chuquicamata, 22.32S, 68.92 W, 2850 m.a.s.l.).

Aerosols will be sampled every three days during a spring period (~October/November 2008), of twenty one (21) days using a standard dichotomous sampler, that separates into two fractions (fine and coarse inhalable particles), and a cascade impactor (MOUDI, Micro-Orifice Uniform Deposit Impactor), distinguishing eight size categories, from 0.18 to 18 m. These samples will be analyzed in terms of their elemental composition using Particle Induced X-ray Emission (PIXE) technique, mass concentration (gravimetry) and cations and anions through ion chromatography . The PIXE analyses will provide a way to identify potential sources of these aerosols when used in combination with receptor models and other statistical techniques.

In addition to the aerosol analyses indicated above, activated aerosols (CCN) in the stratocumulus deck will be sampled and analyzed in situ using the Counterflow Virtual Impactor (CVI) instrument. Sampled air from the CVI probe is directed to instrumentation to measure the concentration, size and chemical composition of the cloud droplet residual particles, and the condensed water content of the clouds. We will be able to measure the concentration and size distribution of particles between 0.01 to ca. 5µm diameter, covering the entire range of particle sizes expected to be important in determining the number concentration of cloud droplets. Particles will also be collected on filters for chemical analysis. One sample will be taken for single particle analysis, allowing determining the elemental composition of individual aerosol particles and thereby determining the chemical composition of the particles controlling the number population of cloud droplets – not just

the bulk composition. A second bulk filter sample will be taken on which a more detailed analysis of the organic compounds can be performed. The Swedish team will also perform measurements of the interstitial aerosol, switching between the CVI to aerosol inlet. Cloud residual particles will be sampled on polycarbonate Nuclepore filters for consecutive analysis using Scanning Electron Microscope (available in Sweden).

Also, in order to provide information on the regional and seasonal distribution of oxidized sulfur, passive samplers will be deployed at four background sites, three in coastal summits and one at the highland (Altiplano) spanning from 20S to 30S, starting in April 2008. The coastal samplers will be collocated with fog traps that provide an indication of liquid water content of the clouds.
During the VOCALS-REx campaign, these measurements will be further complemented with meteorological soundings at Cerro Moreno (23.43°S, 70.43°W, 137 m.a.s.l.), where the Chilean Weather Office operates a synoptic station, that will provide information about stability, mixing processes and the origin of the air masses (oceanic vs. continental). These soundings will be performed on a regular basis (4 per day) in order to characterize relevant synoptic conditions and the diurnal cycle in the boundary layer.

SPRING 2009

Oceanographic Observations

Observing platforms in both field experiments will rely on the availability of a R/V (e.g. **Vidal Gormaz and/or Abate Molina)** for 10-20-day ship-borne observations (Figure 1) in radiator patterns off the corresponding upwelling region (Punta Lengua de Vaca – Coquimbo area).

Ocean observations should include CTD-O (Figure 2, right panel), lowering ADCP, ship-mounted ADCP and thermo-salinograph. Water samples for oxygen and salinity will be also taken at 24 different levels. CTD data will be complemented with XBTs to improve the spatial resolution of the temperature structure and 5 satellite-tracked, surface drifters will be released in each area. Selected ship-borne radiosonde observations and an on-board automatic meteorological station and a ceilometer have been considered.

Aircraft-based observations

Selected simultaneous airborne observations are envisaged with a **Twin-Otter** or similar low-speed aircraft (Figure 1) capable of sampling wind, atmospheric pressure, temperature and water vapor content within and above the AMBL, as well as remote SST and simple cloud -microphysics parameters. We envision several types of aircraft missions, each tailored to address specific scientific questions.

- *Cross-shore coastal jet missions in the southern area* (30°S)*.* Zonal cross-section from the coast to about 200 km offshore at 300, 900 and 1500 m ASL. Pseudo-vertical profiles at the transect's extremes and mid-point. At least 4 missions: 1 @ jet onset, 2 @ full-jet conditions and 1 @ jet demise (wind relaxation period).

- *Along-shore coastal jet missions in the southern area* (30°S)*.* Meridional transect from 32° to 28°S about 100 km off the coast at 300 m northbound and 1500 m southbound. Pseudo-vertical profiles at the transect's extremes. At least 2 missions: 1 @ full-jet conditions and 1 @ jet demise (wind relaxation period).

SUMMARY OF INSTRUMENTATION

Platform	Instrument	Available
Chilean Research Vessel	CTD-O	YES
	ADCP	?
	Ship-mounted ADCP	NO
	XBT	YES
	Surface drifter	YES
	Radiosonde	YES
	AWS	YES
	Ceilometer	YES
UNOLS intermediate Research Vessel	CTD-O	YES
	SeaSoar	YES
	Ship-mounted ADCP	YES
	XBT	YES
	Surface drifter	YES
	Radiosonde	YES
	AWS	YES
	Aerosol sampling	?
	Ceilometer	YES
gliders	CTD-O	YES
	Chl-a, optical backscatter, CDOM	YES
Aircraft	SST Press ion Radiometer	NO
	AIMS (wind, temperature, RH)	NO
	Aerosol instrumentation ?	?
Coastal Stations	AWS	YES
	Micro-barographs	YES
	Ceilometer	NO
	Energy-budget system	YES
	Wind-profiler	NO
	Pibal system	YES
	Enhanced Radiosonde Launching at standard stations	YES

SUMMARY OF PLATFORMS AND SPECIFIC SCIENCE QUESTIONS

	SQA	SQB	SQC	SQD	SQE	SQF	SQG	SQH	SQI	SQJ
Ship transect @ 21°S. Ocean Obs.					●					
Ship transect @ 21°S. Met. Obs.	●				●					
Ship transect @ 30°S. Ocean Obs.										●
Ship transect @ 30°S. Met. Obs.						●	●	●		●
Aircraft: Diurnal Cycle Mission		●	●							
Aircraft: Sampling Stagnation Area	●									
Aircraft: Coastal Aerosols Survey				●					●	
Aircraft: Cross-shore coastal jet						●	●	●		
Aircraft: Along-shore coastal jet						●	●	●		
Enhanced Metor. Coastal Stations	●	●				●	●	●		
Aerosol Coastal Station				●					●	

Specific Science Questions (as defined in the Revised VOCAL-Coastal Scientific Program Overview)

SQ A: Near-stagnation area at 18ºS.
SQ B: Diurnal cycle in the coastal strip
SQ C: The upsidence wave off southern Perú
SQ D: Offshore transport episodes of anthropogenic sulfate aerosols
SQ E: Offshore transport of coastally upwelled water by mesoscale processes
SQ F: Climatological near- coastal wind maxima around 30ºS
SQ G: Coastal Clearing Episodes around 30ºS
SQ H: Coastal Jet events and their impacts on surface ocean around 30ºS
SQ I: Dust and biogenic aerosols downwind from 30ºS
SQ J: The coastal transition zone jet off Chile and its role on the mesoscale

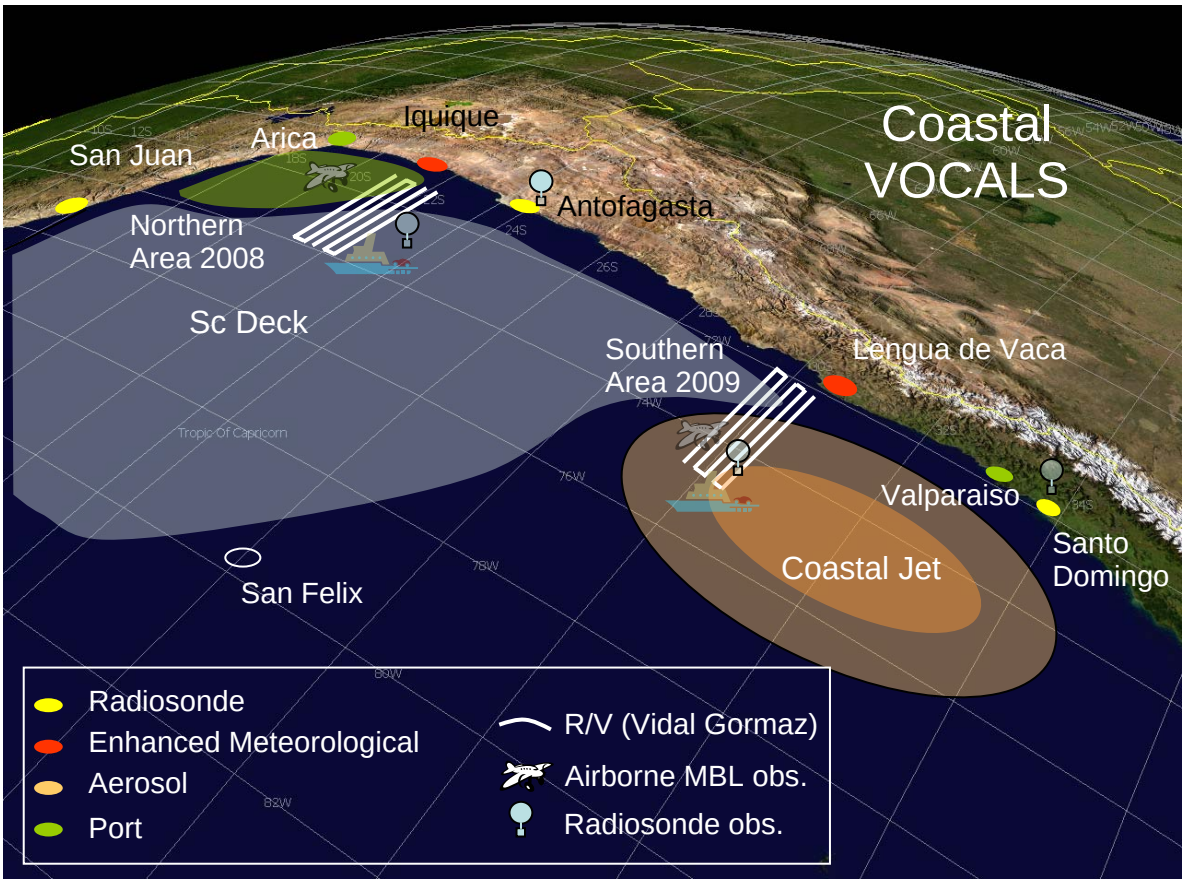

Figure 1. General Overview of platforms and atmospheric phenomena

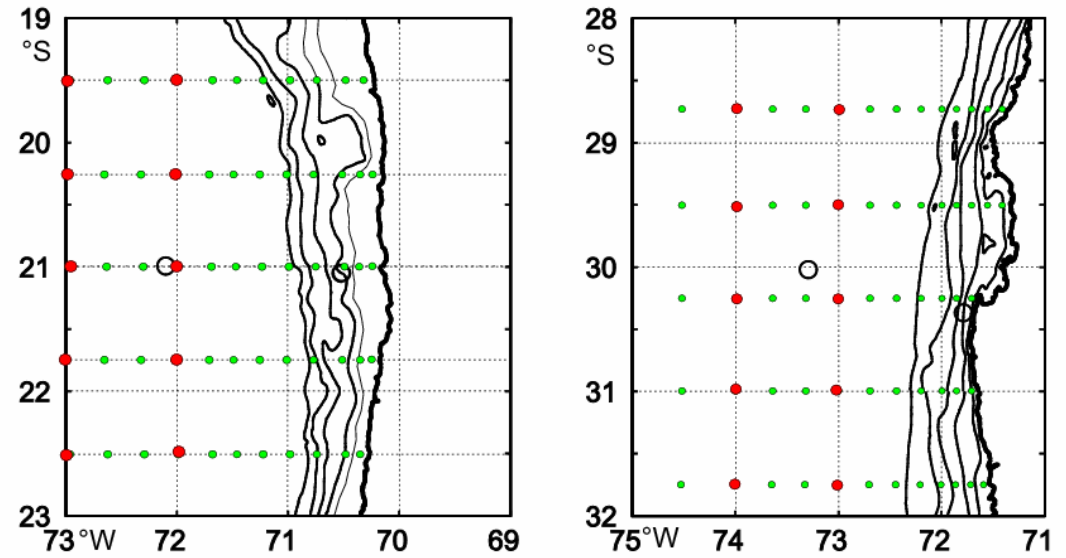

Figure 2. CTD-O stations along the intensive study regions. Red dots show deep (4000 m) CTD casts. Other casts will reach only 1000 m or near the bottom depending on the local depth.