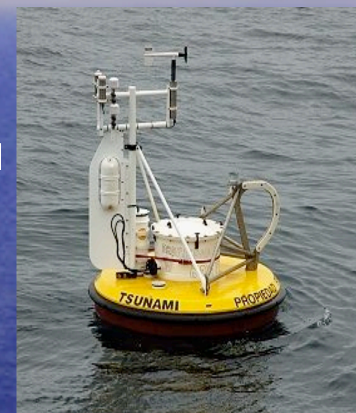
Part I

Ship-Based Observations

R/V Ronald H. Brown, NOAA, USA

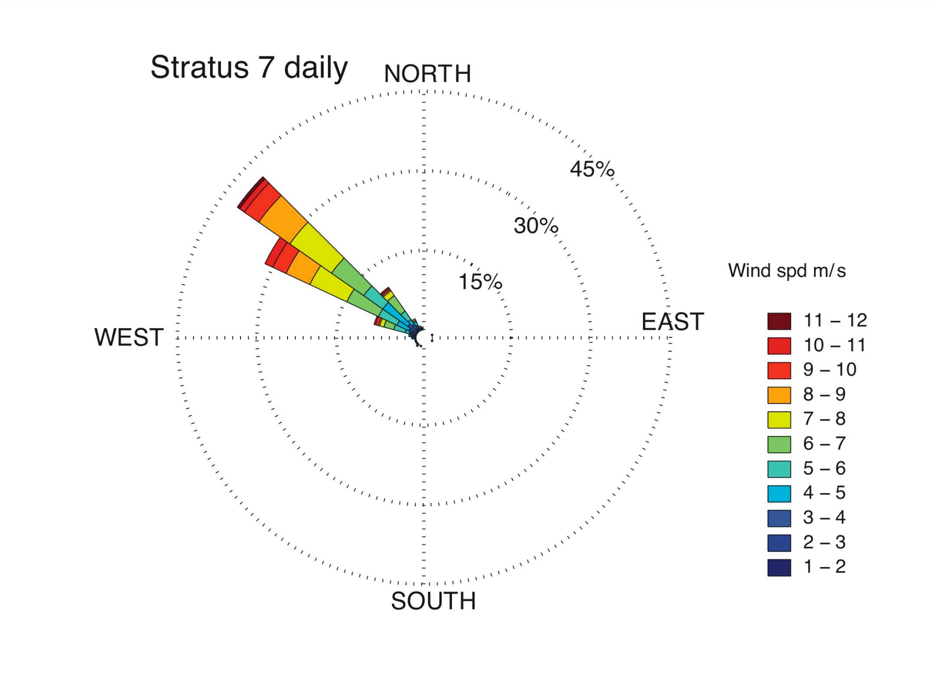
SHOA DART buoy
Chilean Navy Hydrographic and Oceanographic Service tsunami warning buoy, fitted with WHOI bulk meteor. sensors and ocean T and S sensors in upper 300 m.

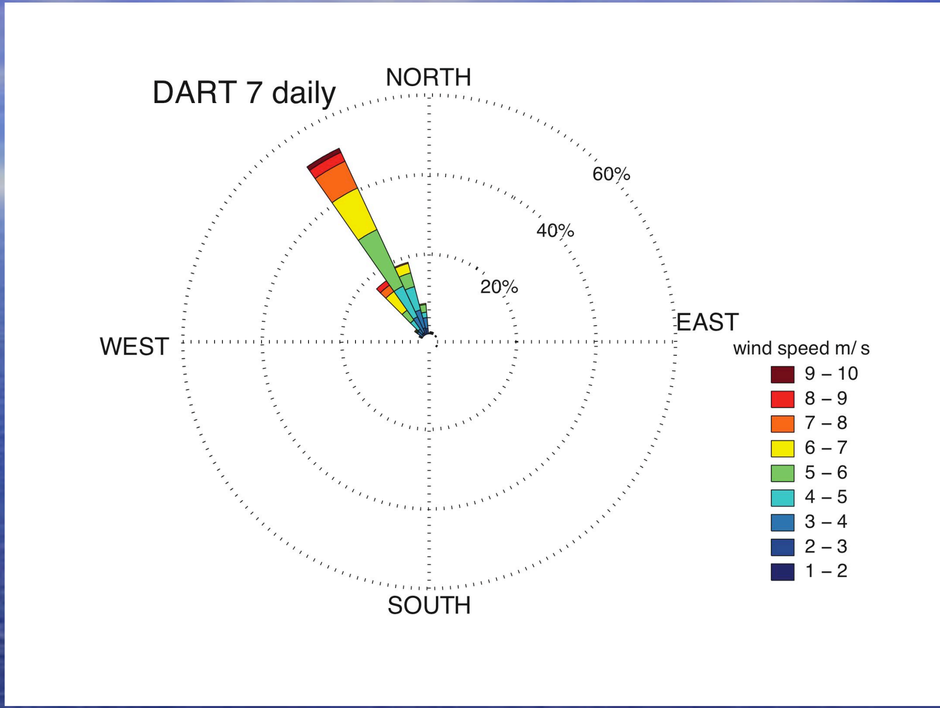


R/V Jose Olaya, IMARPE, Peru

WHOI Stratus buoy
bulk meteorology; ocean temperature, salinity, velocity time series in upper 1500 m.

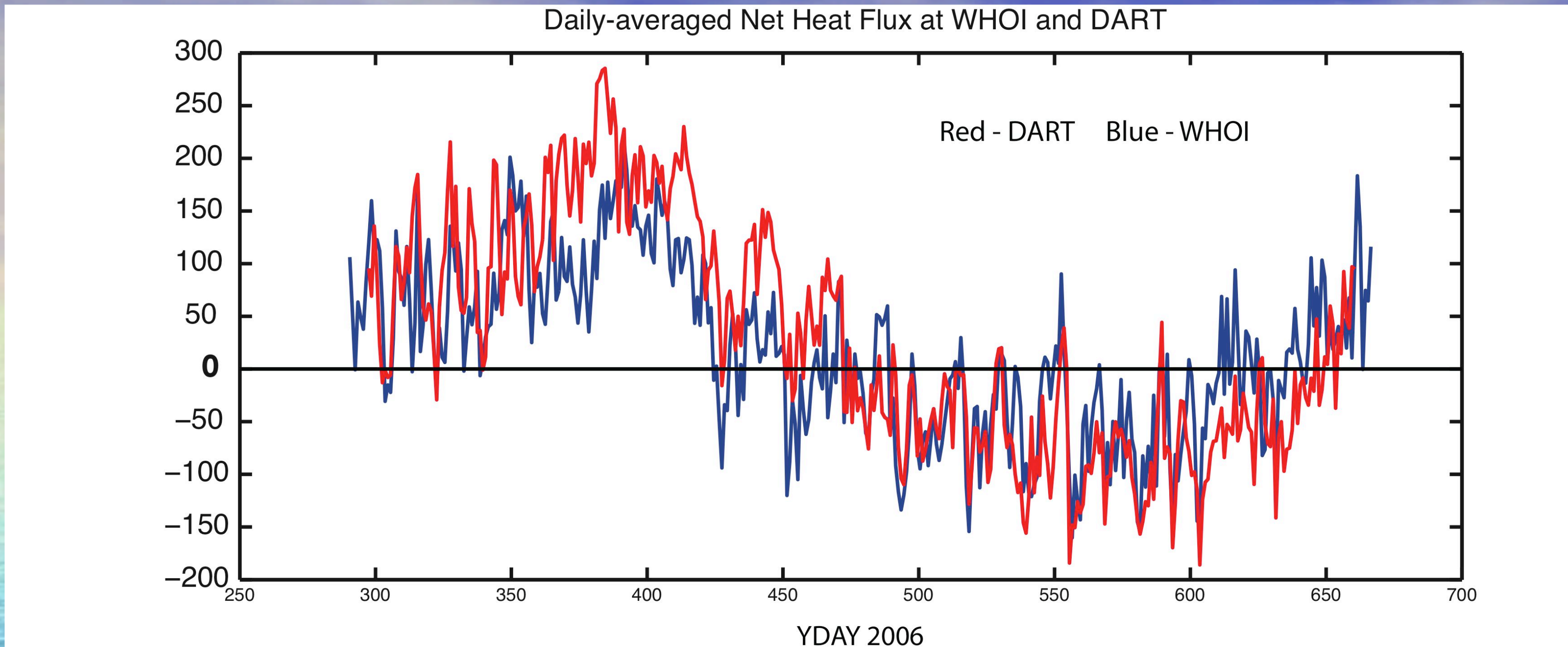
Buoy Data





WHOI Stratus buoy 2007
Mean wspd 6.6 m s^{-1}
Mean incoming swr 205.7 W m^{-2}
Mean incoming lwr 371.8 W m^{-2}
Mean sst 20.09°C
Mean at 18.97°C

Chilean Navy Hydrographic and Oceanographic Service (SHOA) DART buoy 2007
Mean wspd 5.4 m s^{-1}
Mean incoming swr 178.2 W m^{-2}
Mean incoming lwr 378.5 W m^{-2}



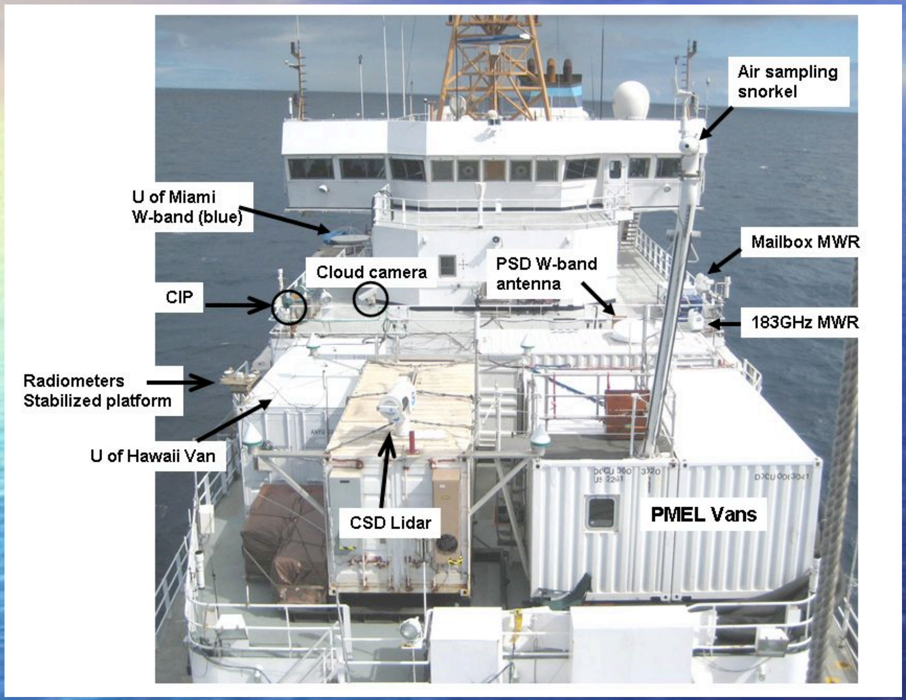
WHOI Stratus buoy 2006-2007

Net heat flux 18.1 W m^{-2}
Net swr 194.4 W m^{-2}
Net lwr -45.0 W m^{-2}
Net sensible-10.9 W m^{-2}
Net latent-120.3 W m^{-2}

DART buoy 2006-2007

Net heat flux 27.5 W m^{-2}
Net swr 168.4 W m^{-2}
Net lwr -36.2 W m^{-2}
Net sensible-10.1 W m^{-2}
Net latent-94.7 W m^{-2}

NOAA Ship Ronald H. Brown

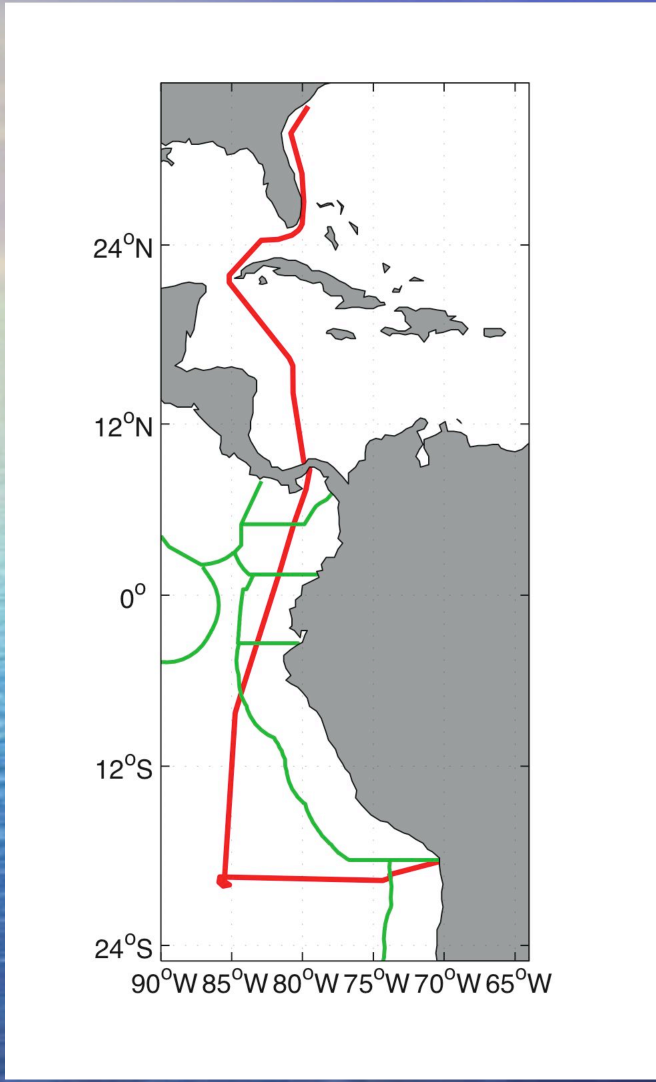


For VOCALS-REx, the Brown fielded one of the most comprehensive sets of observing systems ever assembled on a research vessel. The ship is festooned with 6 seatainer laboratories and all manner of instruments including five meteorological radars, a Doppler Lidar, four different ocean profiling systems, and a variety of chemical, aerosol, and biological measurements.

Some 40 scientists from have participated in two deployment legs. The science party includes representatives from three NOAA labs, 13 Universities, and three research laboratories in Chile and Peru.

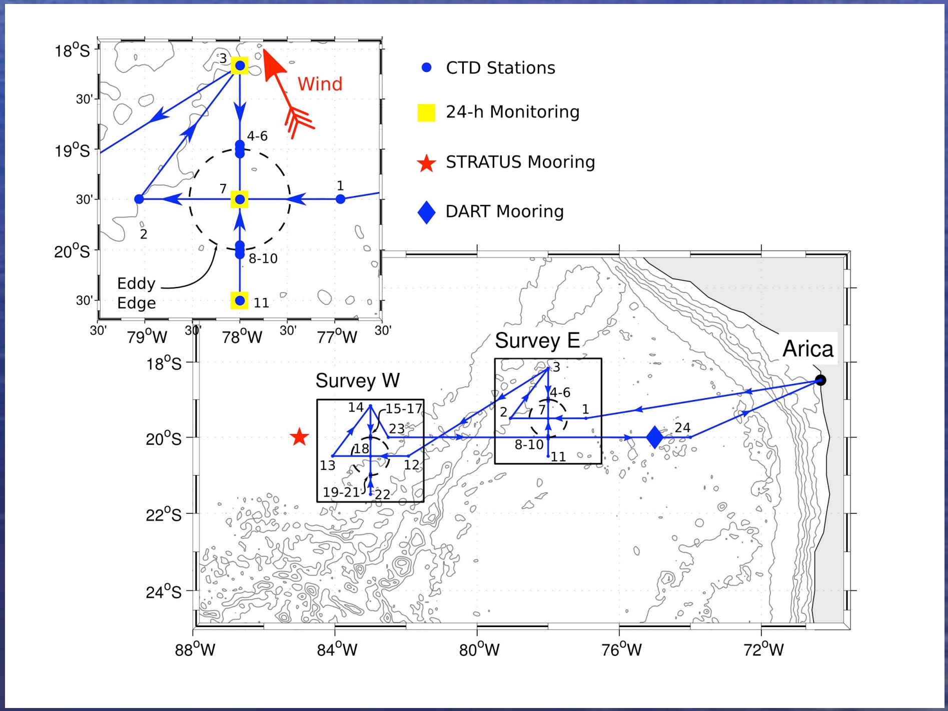
Leg 1: Charleston, SC Oct 6 – Arica Nov 3

Ronald H Brown Sampling



Sampling in Ecuadorian, Peruvian, international and Chilean waters.

Leg 2: Arica Nov 9 – Arica Dec 2



Sampling in international and Chilean waters.

Oceanographic Observations During VOCALS, Leg 1

Arica, November 6th and 7th, 2008

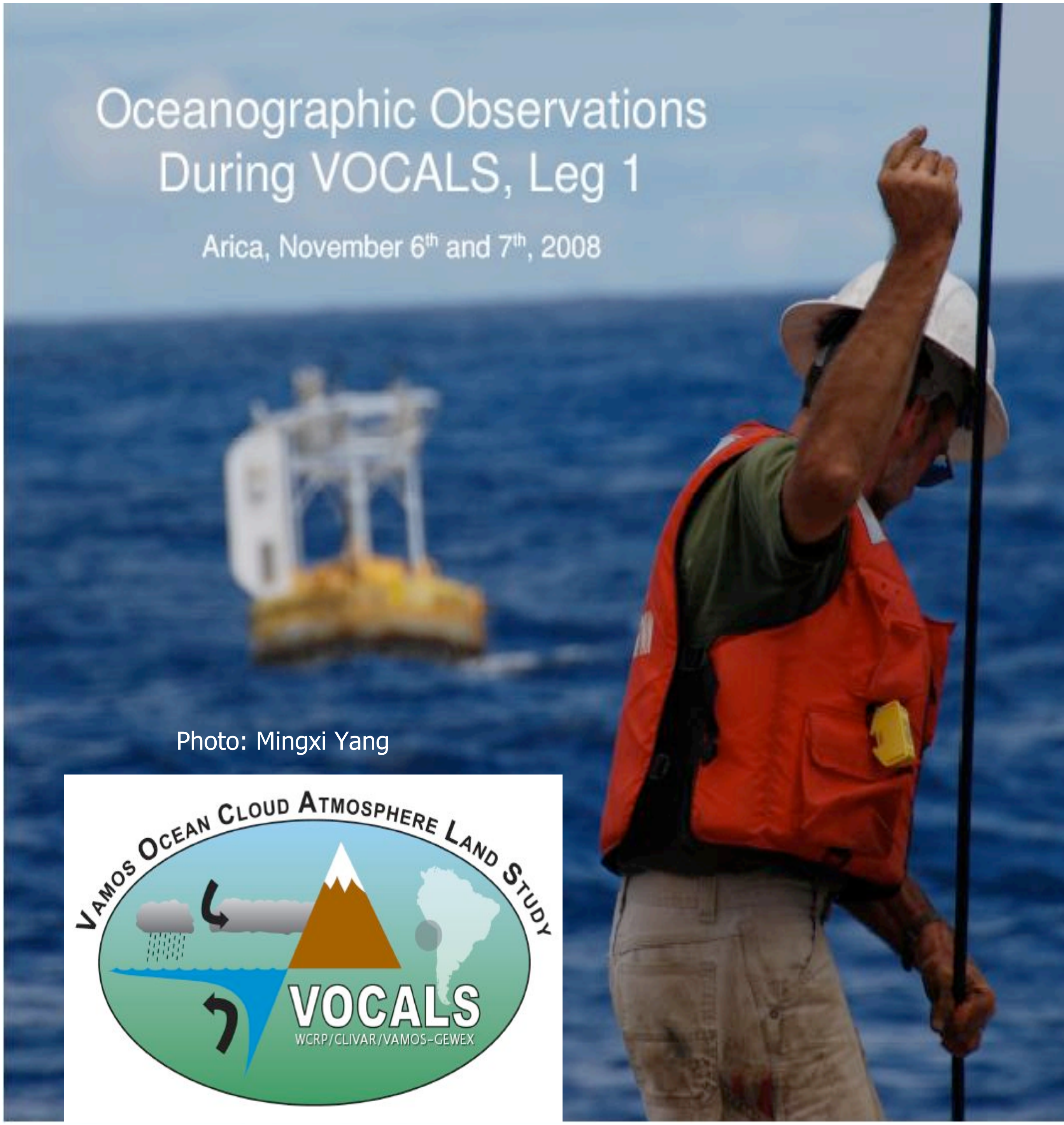
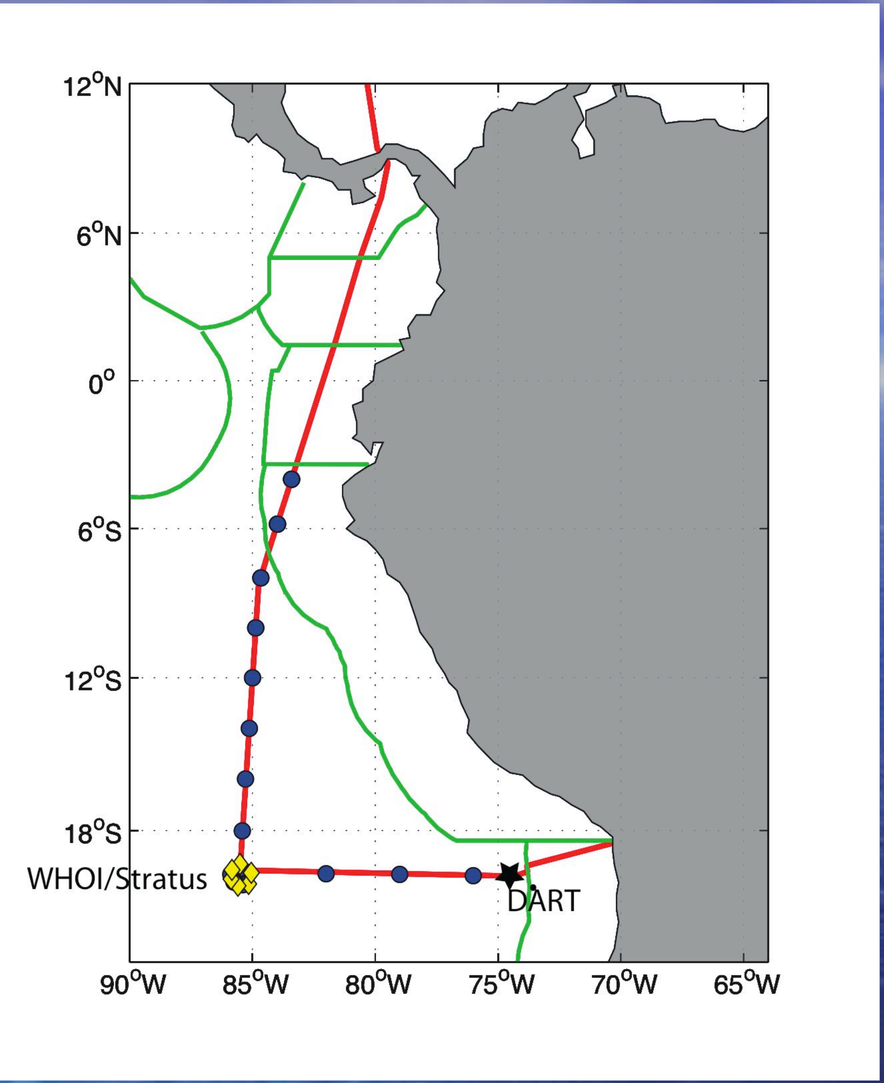


Photo: Mingxi Yang

- Robert A. Weller
- Sean P. Whelan
- Jeffrey B. Lord
- Nancy R. Galbraith
- Carlos F. Moffat Varas
- David Painemal
- Avy N. Bernales Jimenez
- Carlton D. Rauscheberg
- Andrew J. Hind
- Derek Coffman
- Simon P. de Szoeke
- Daniel E. Wolfe
- Roman Sinreich
- Lelia N. Hawkins
- David S. Covert
- Christopher J. Zappa
- Matthew Miller
- Mingxi Yang
- William A. Brewer
- Sara C. Tucker
- Catherine A. Hoyle
- Alvaro G. Vera Tisandie
- Jorge E. Araya Leal

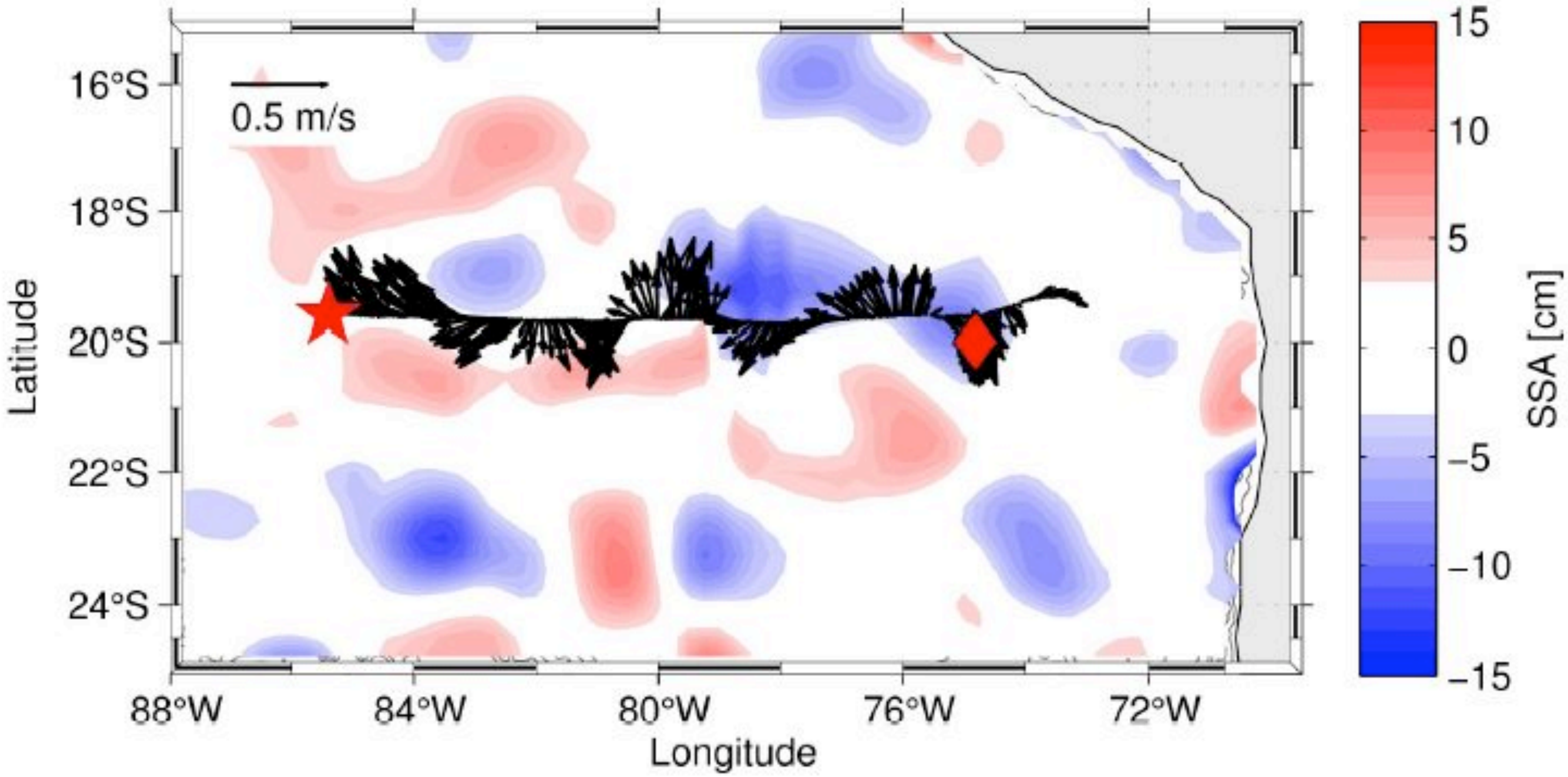


Blue circles – SST drifters
Yellow diamonds – Profiling floats

Underway from Rodman to Arica with ~2.5 days at WHOI/Stratus mooring and ~3 days at DART

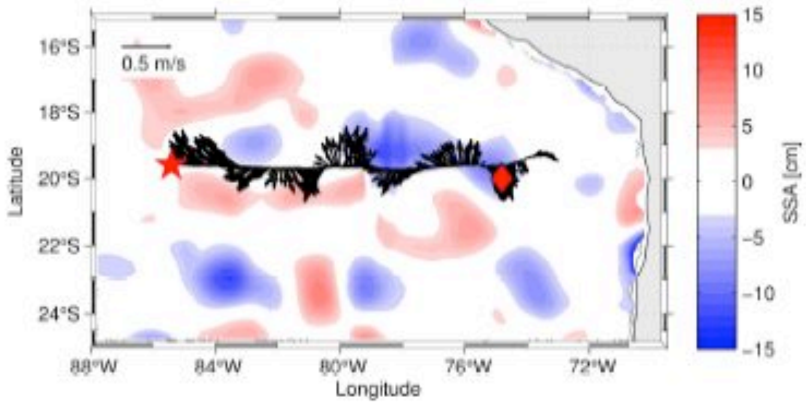
- Air-sea fluxes, bulk meteorology
- Atmospheric profiling
- Cloud properties, photographs
- Aerosol physics, chemistry, optics
- Recover/deploy WHOI mooring
- Recover/deploy DART mooring
- Underway ocean sampling (T,S, vel)
- Radiosondes
- SST drifters
- Profiling ocean floats (T,S, O)
- Phytoplankton sampling
- Seawater DMS, DMSP, chlorophyll
- Underway PCO2
- Optical absorption spectroscopy
- C and X band radars
- CTD profiles, water sampling
- Ocean vertical microstructure profiles

Mesoscale features as seen from satellite altimetry and the *R.H. Brown*'s current profiling system



- Found several cyclonic features along 20°S
- Diameter of O(200 km)

Hydrographic and velocity structure of mesoscale features

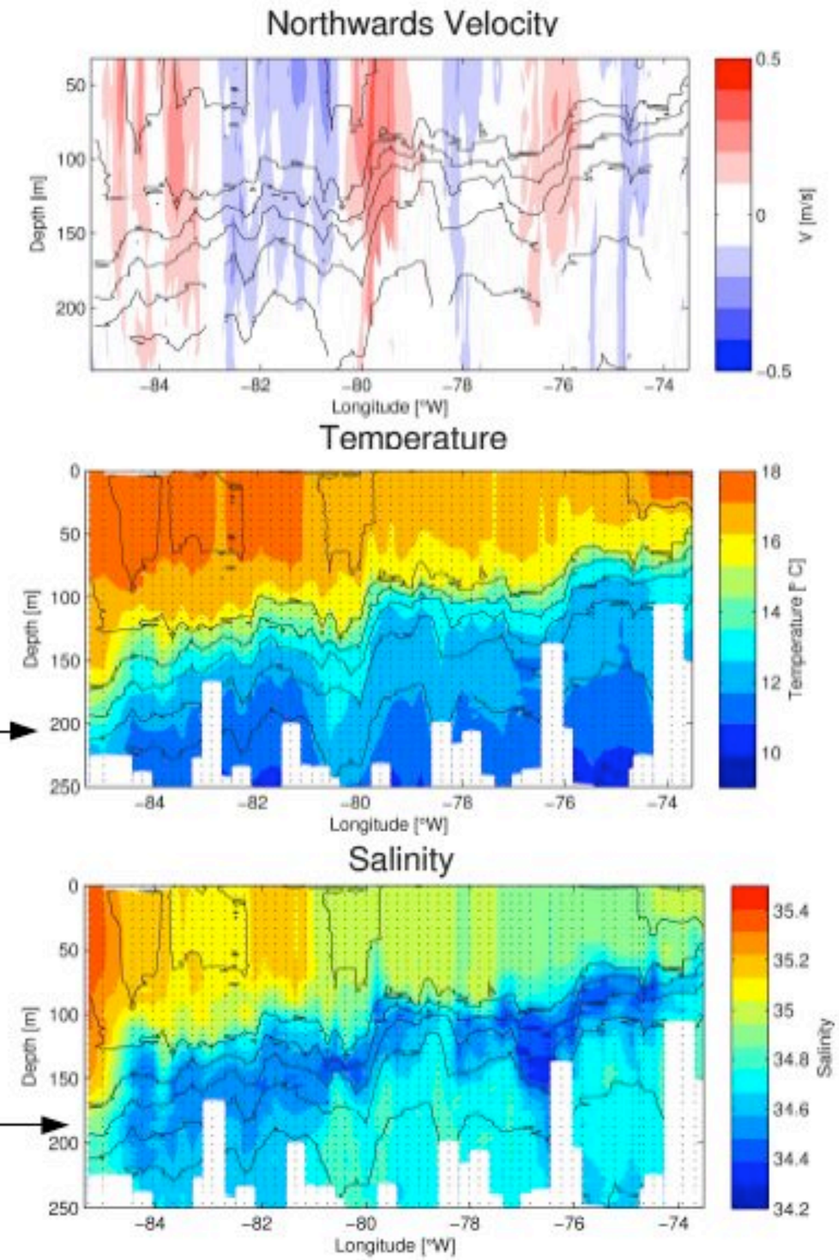


Scales:

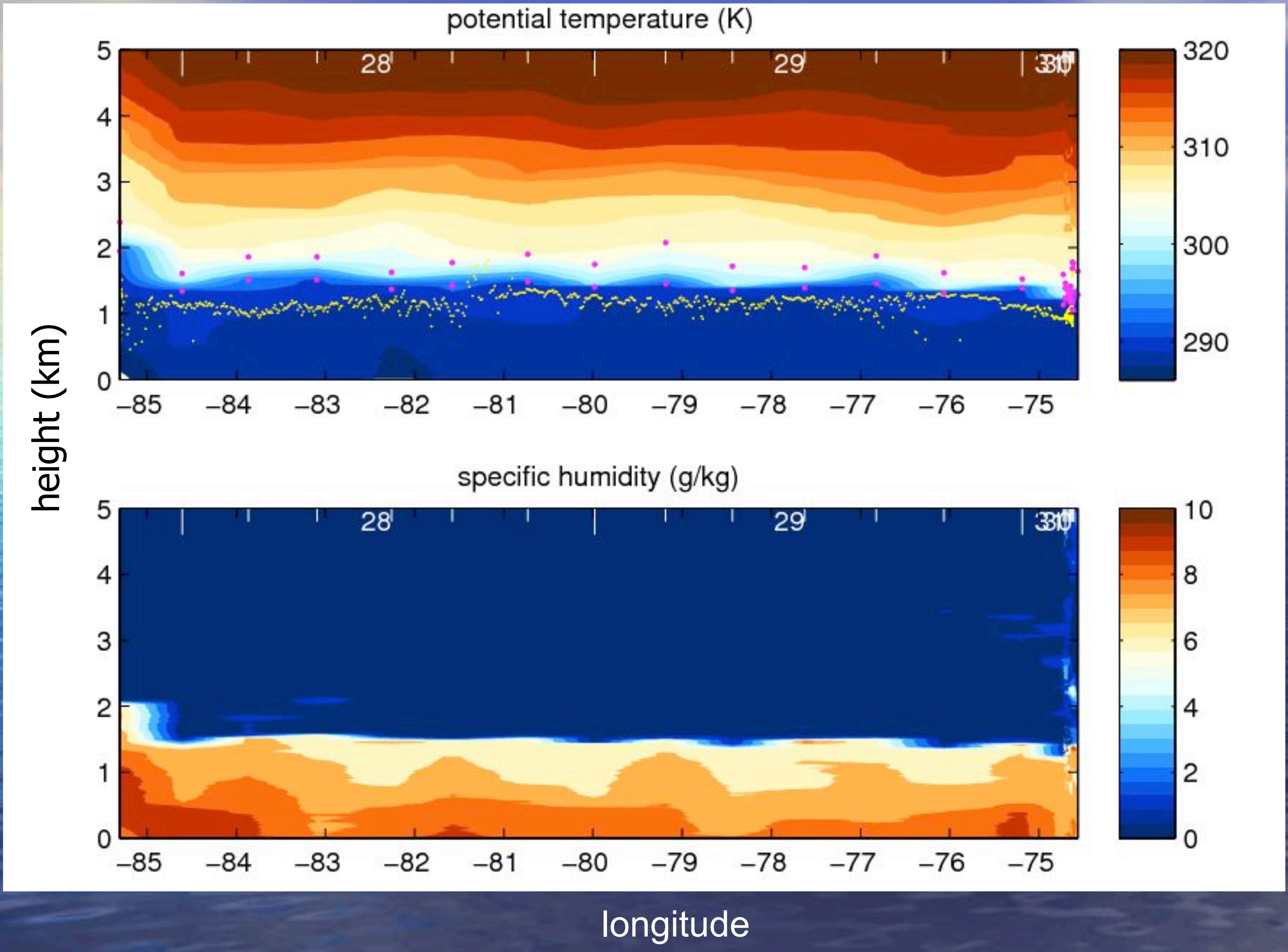
- 150-200 m deep
- 30-50 cm/s
- Weak surface T/S signal

Cold Lower Layer

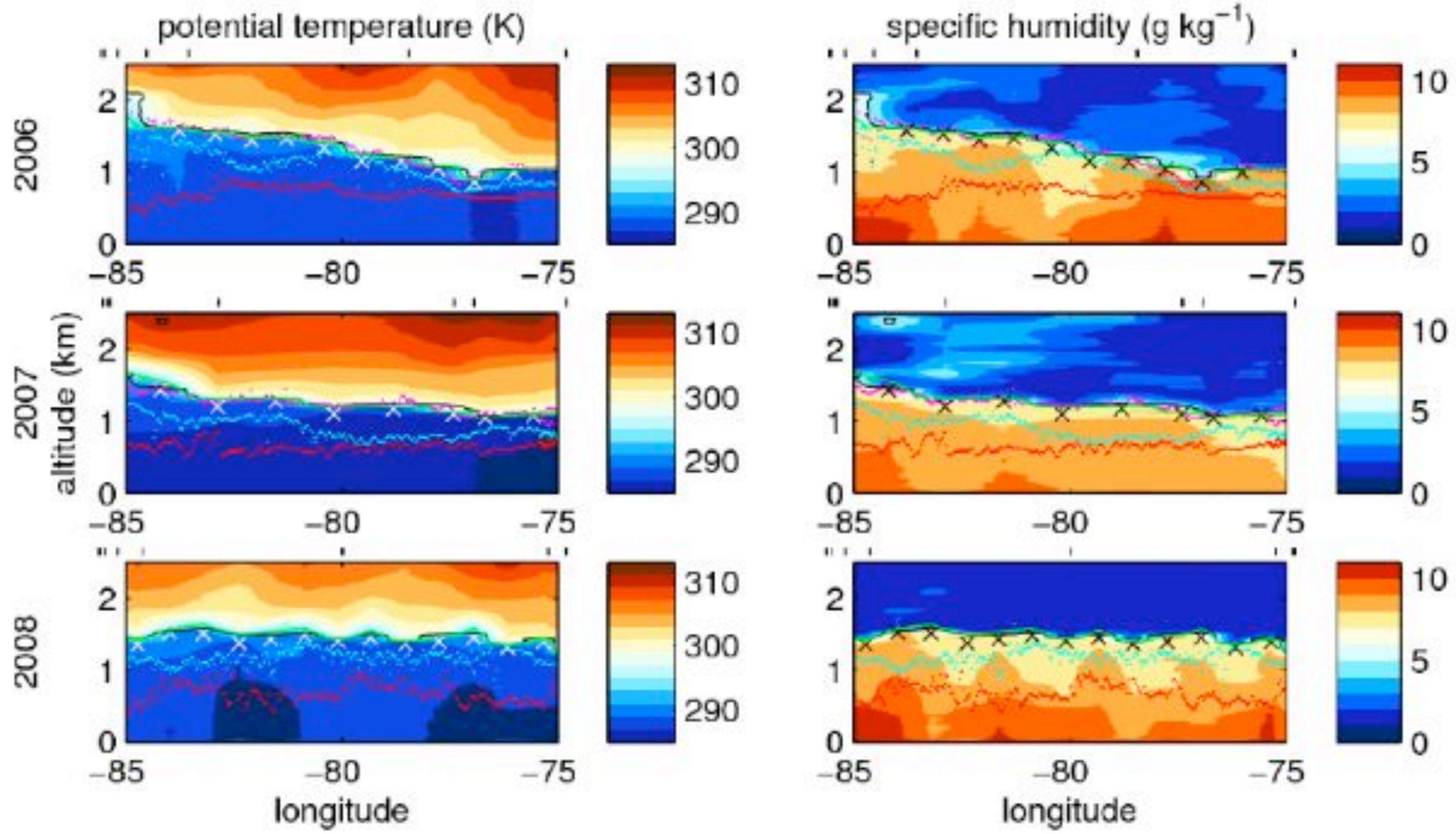
Salinity Minimum



VOCALS 2008 20S section



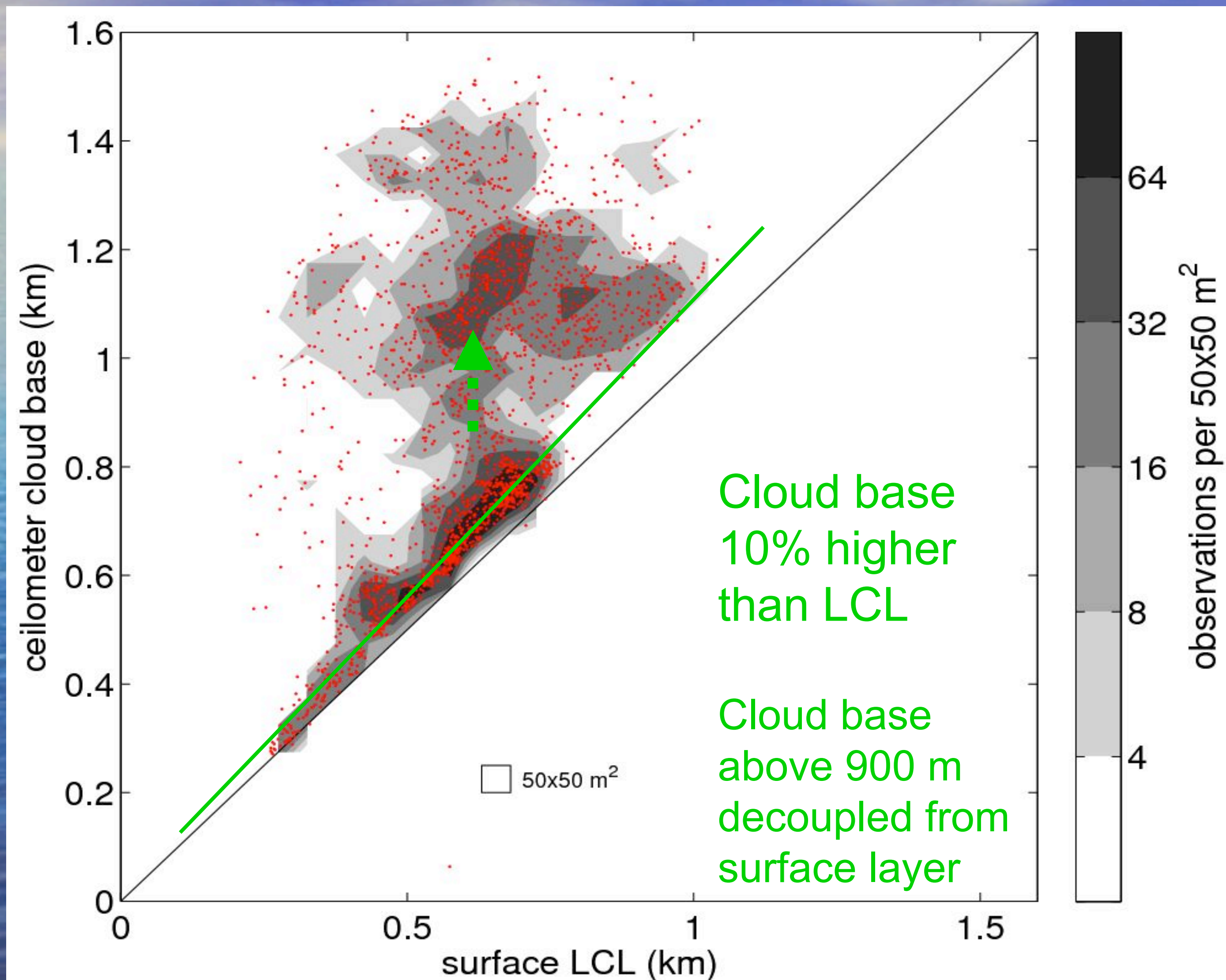
Radiosonde profiles along 20°S



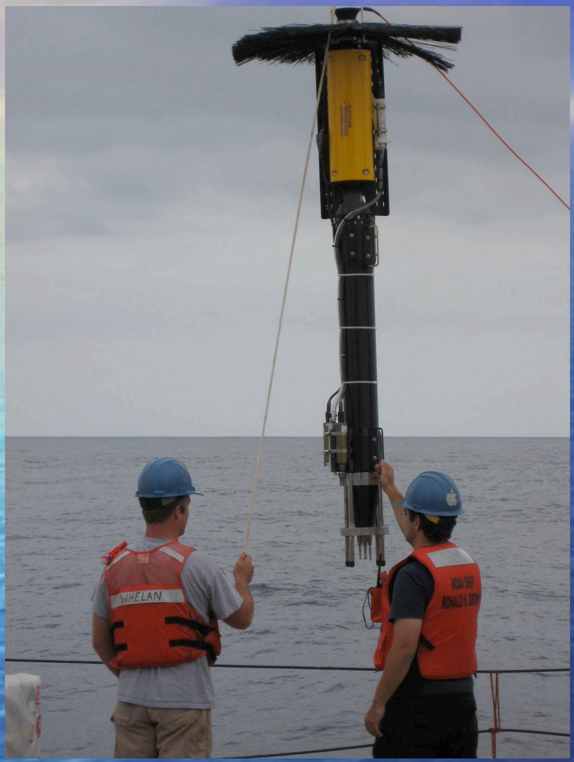
PBL height tilted west in 2001, 2005, 2006, 2007;
no tilt in 2003, 2004, 2008 (leg 1).

C-130 85° W sections can identify if this is synoptic variability.

Decoupling observed from the ship (2007)



Oceanographic Observations during VOCALS Leg 2



Vertical Microstructure Profile
(photo F. Straneo)

- Sean P. Whelan
- Fiamma Straneo
- Carlos F. Moffat Varas
- James D. Grant
- Xue Zhang
- Paquita Zuidema
- Carmen Grados Ouispe
- Flor C. Chang Loo Kung
- Carlton D. Rauschenberg
- Andrew J. Hind
- Derek Coffman
- Christopher W. Fairall
- Sergio A. Pezoa
- Lelia N. Hawkins
- David S. Covert
- Justin A. Crouch
- Thomas Toniazzo
- Barry J. Huebert
- Sean Coburn
- Sarah C. Tucker
- Ann Marie Weickman
- Catherine Ann Hoyle
- Rebecca M. Calvillo Simpson

SUMMARY OCEAN MEASUREMENTS VOCALS REX
R.H. BROWN LEG 2 (Nov. 9th – Dec. 2nd 2008)

Compiled by Fiamma Straneo (WHOI)

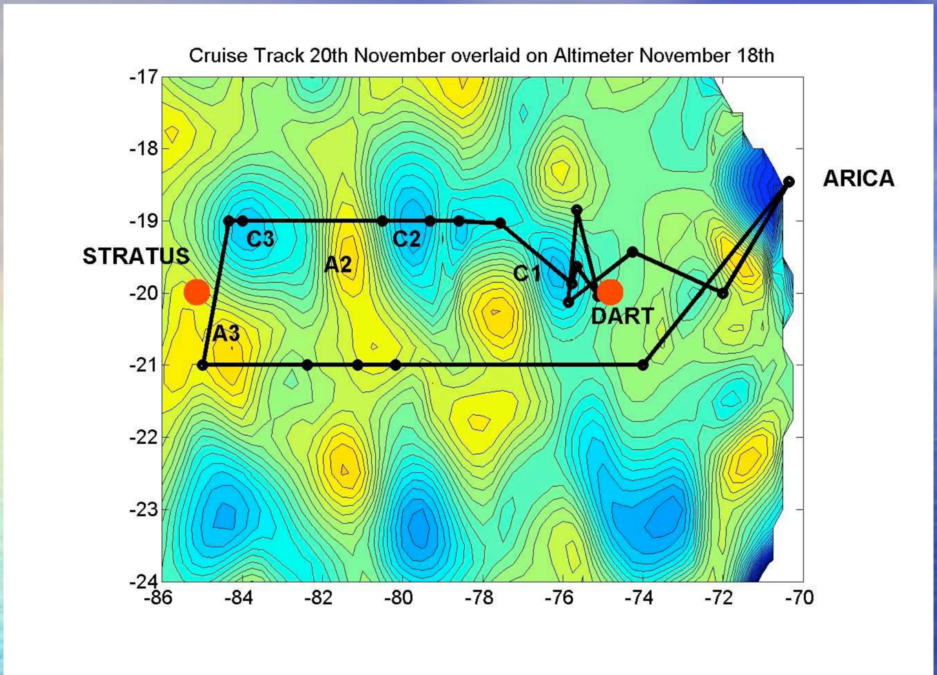
30 CTD (conductivity, temperature, depth) profiles (to 1000-2000m) were collected in eddies, fronts and the boundary current together with oxygen, turbidity and fluorometer pofiles. Water samples were collected for nutrients, chlorophyll and dimethylsulfide by C. Grados (IMARPE), B. Huebert (U. Hawaii), A. Hind and P. Matrai (Bigelow).

300 Underway CTD profiles (to 300-700m) were collected to map the large-scale, mesoscale and submesoscale structure of the upper ocean

4 Surface Drifters and 4 Profiling SOLO floats were deployed in the center of eddies or in frontal regions to provide long-term context to the VOCALS-Rex measurements.

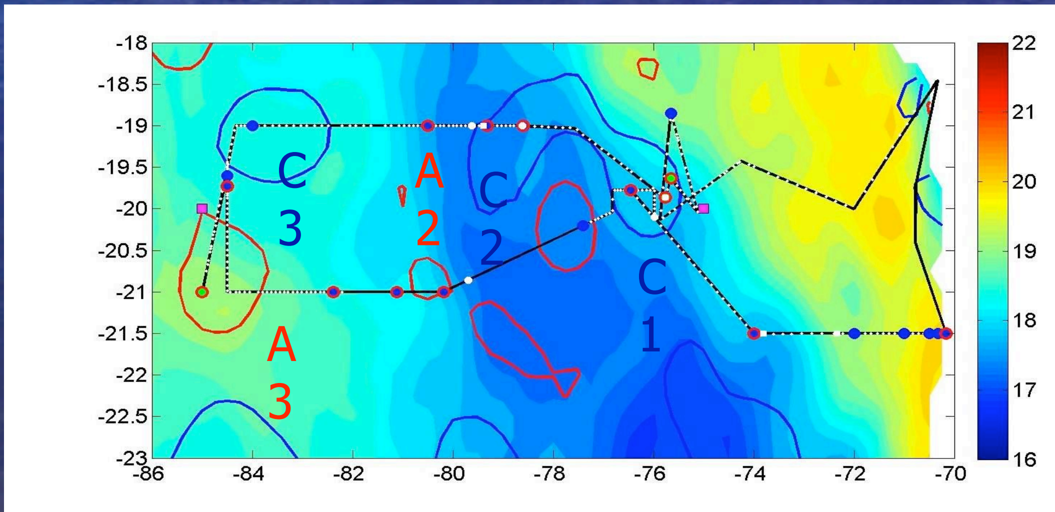
15 VMP (vertical microstructure profiles) were collected to quantify mixing rates in the range of oceanic environments of the SEP (center and edges of mesoscale cyclones and anticyclones, the offshore region and the coastal upwelling region)

Underway data (velocity, temperature, salinity, fluorometer) was collected along the way throughout Leg 2.

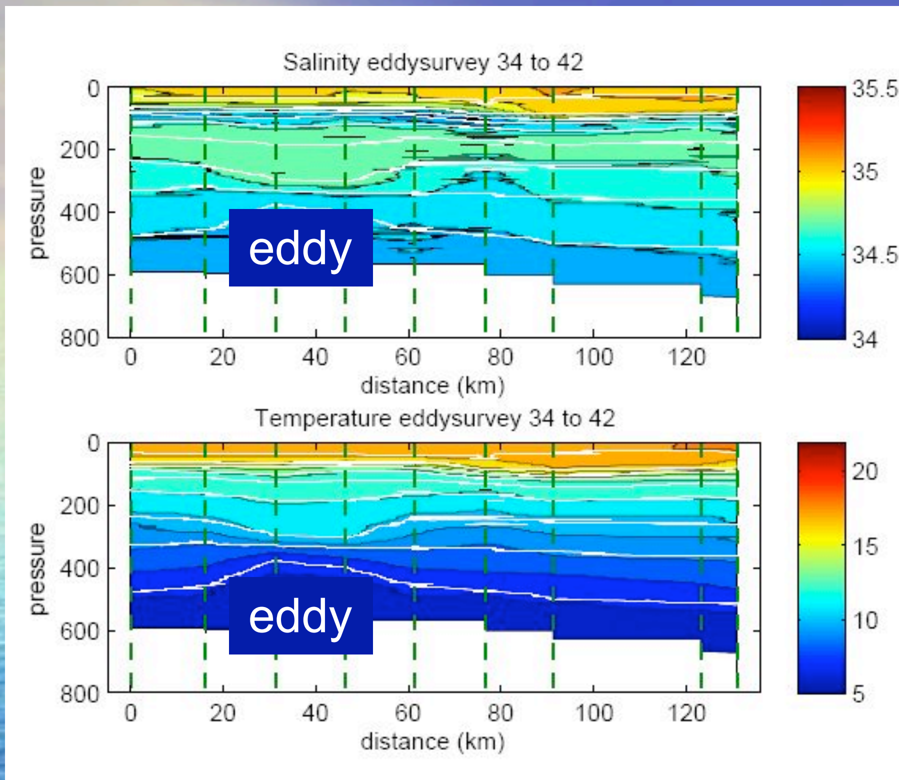


The Brown made transects across several eddies and cyclonic-anticyclonic eddy boundaries.

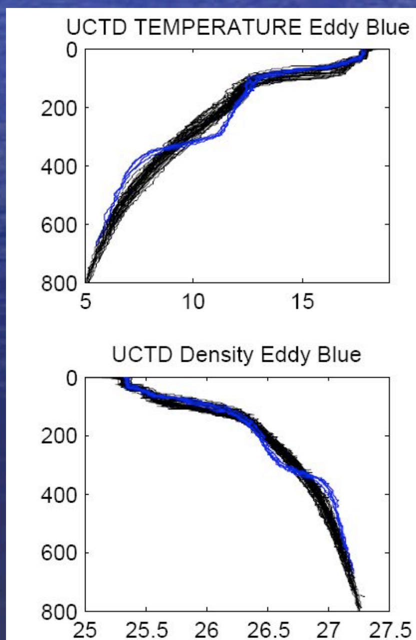
Brown's trajectory (black) and underway CTD sections (white dash)
CTD stations (blue circles),
VMP and CTD (blue with red rim),
24 hour monitoring stations (green circles – red rim),
float and drifter deployments (white squares and circles), green circles
Background field is SST from November 18th. Red and blue contours show the positive and negative 5 cm sea-surface height.



Preliminary Results 1: Characteristics of the Cyclonic Eddies



3 Cyclonic eddies (C1, C2 and C3) were sampled in Leg 2



Property Profiles

Eddy-blue, mean-black

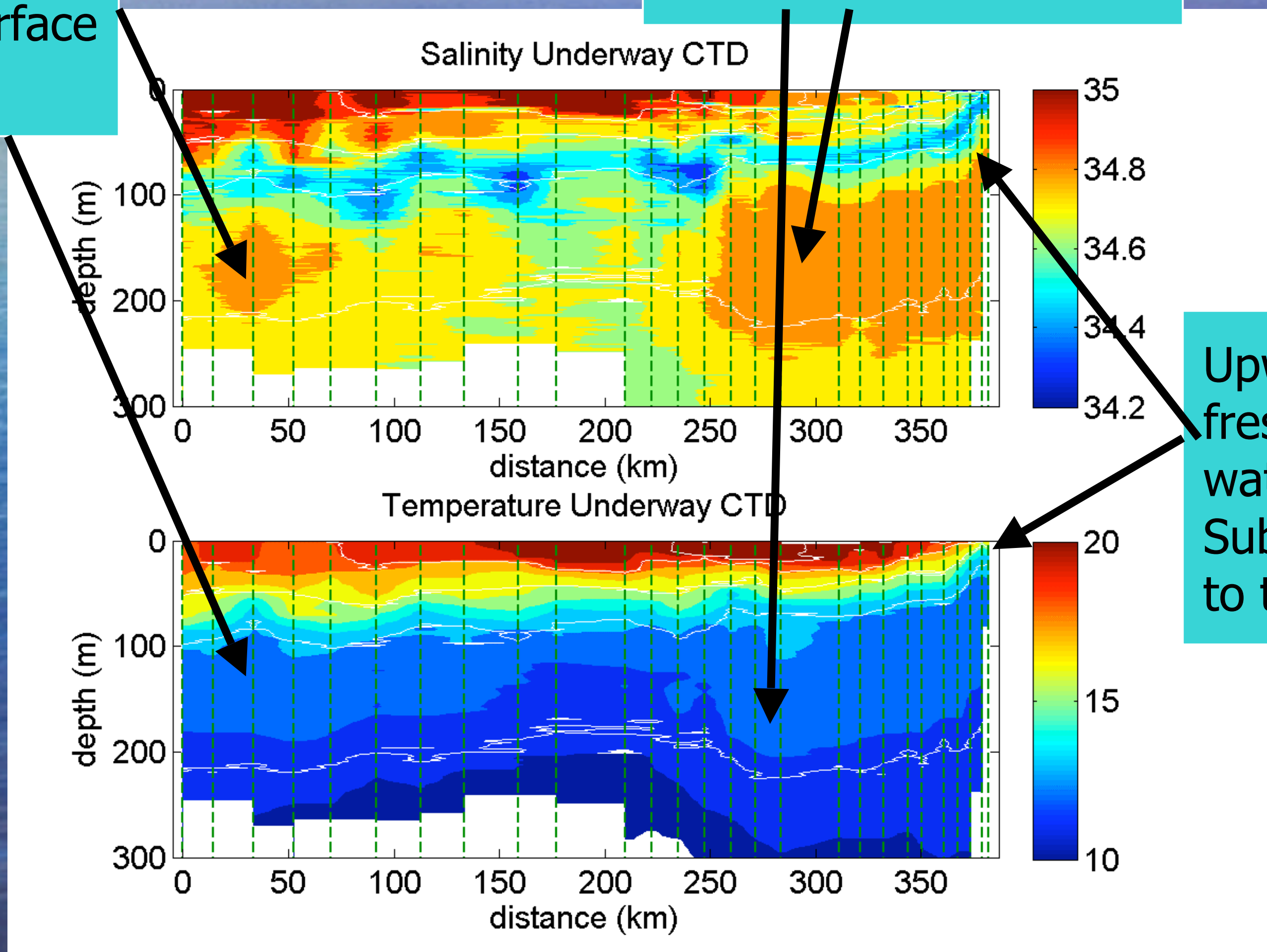
Characteristics
- cold SST anomaly
- a shallow mixed layer
- a sub-surface warm, salty core (300m)

Preliminary Results 2: Coastal Upwelling Region and source of Eddies:

Figure shows an underway CTD section up to the coast of Chile.

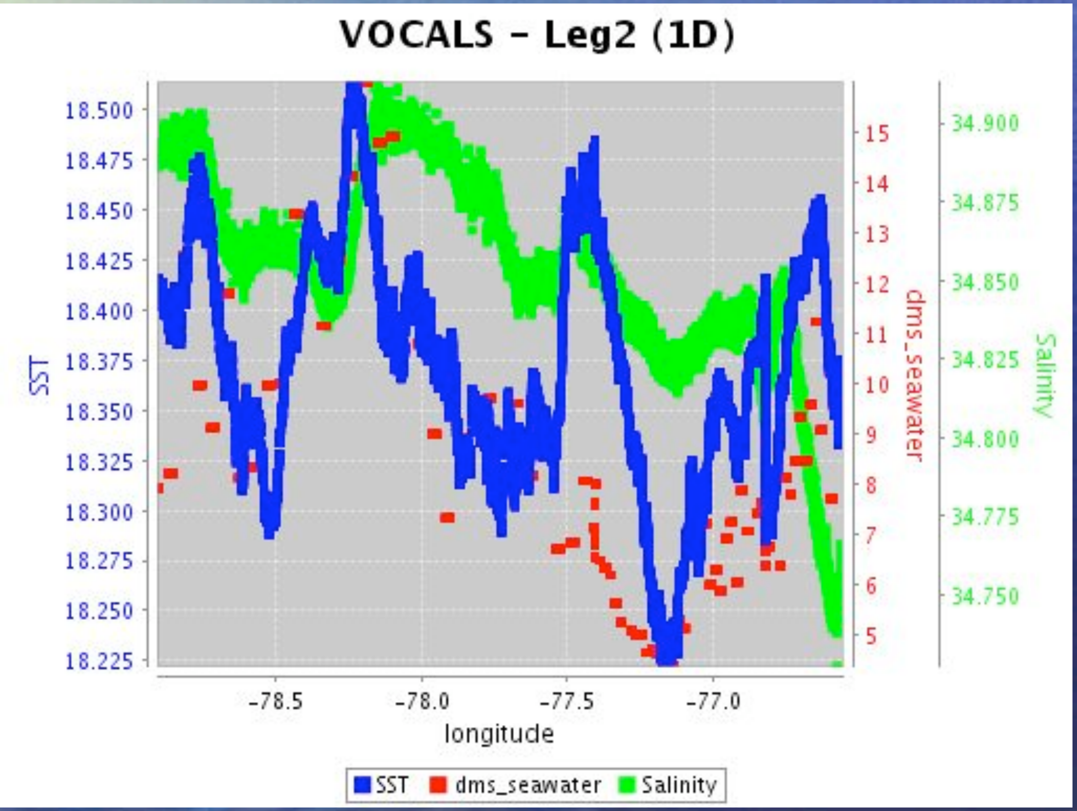
Cyclonic Eddy with a warm salty sub-surface core

Boundary current with same properties As the eddies’ core



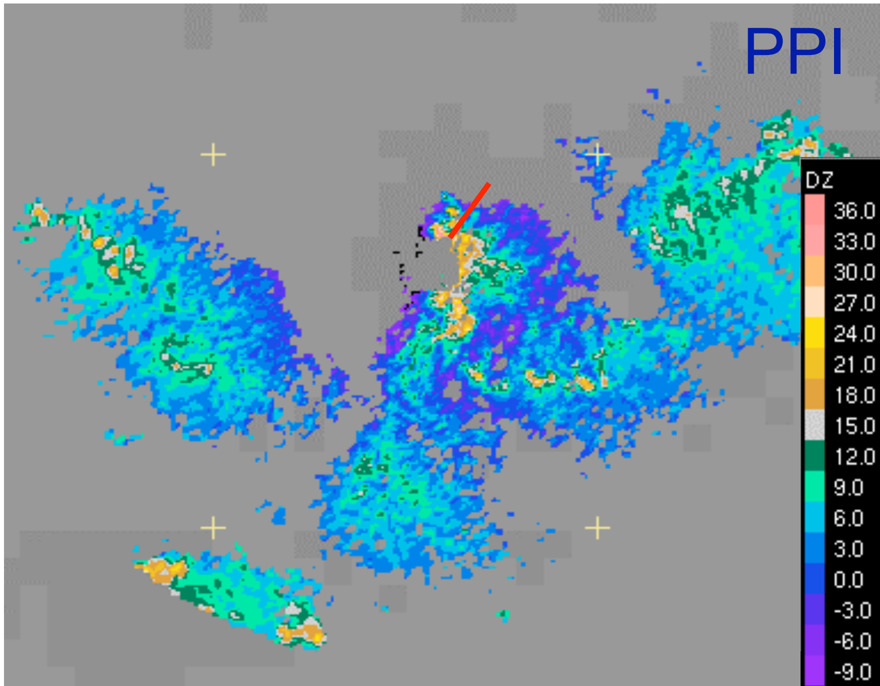
Upwelling of fresh and cold waters of Subpolar origin to the surface

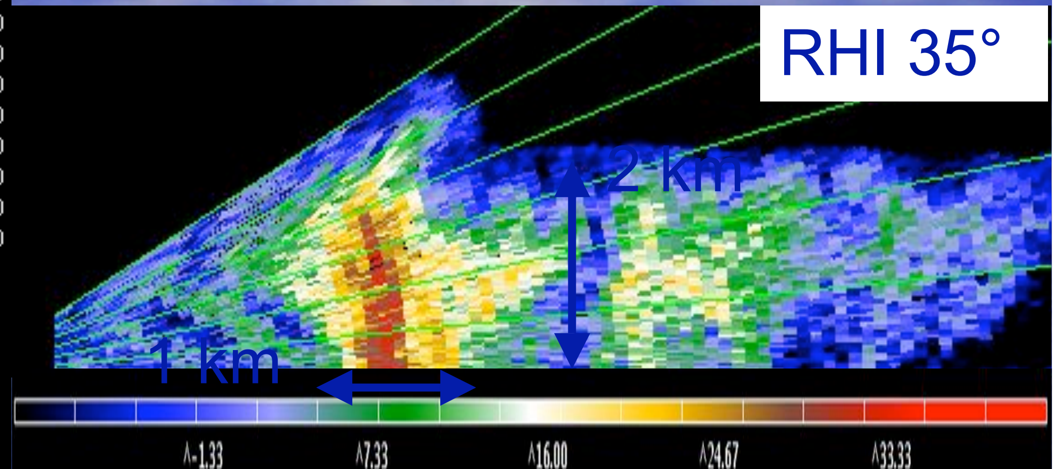
Preliminary Results 3: Sea water DMS (dimethylsulfide) was elevated around the edges of the cyclonic eddies likely due to the entrainment of nutrients into the mixed layer – these regions also had more elevatedvalues of atmospheric DMS and, thus, play a role in offshore aerosol production

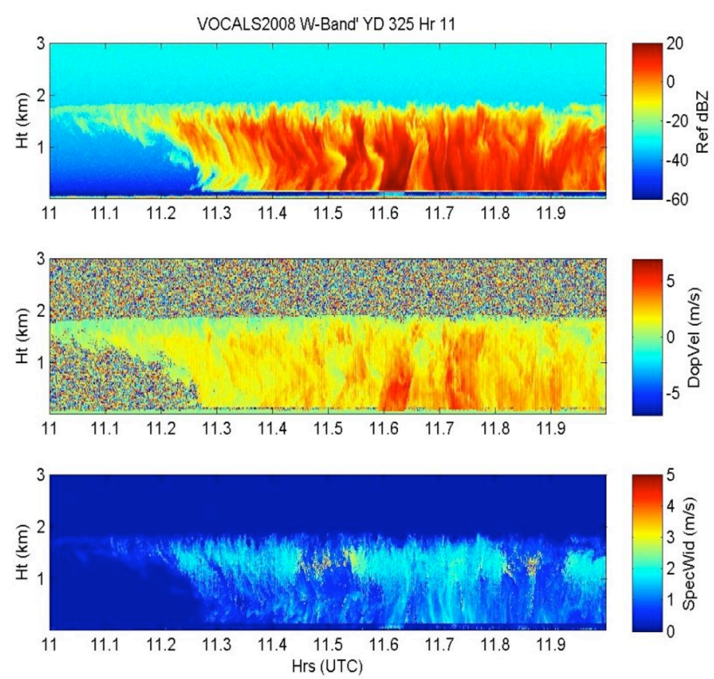


Sea water DMS variations are correlated with the upper ocean's temperature and salinity variations.

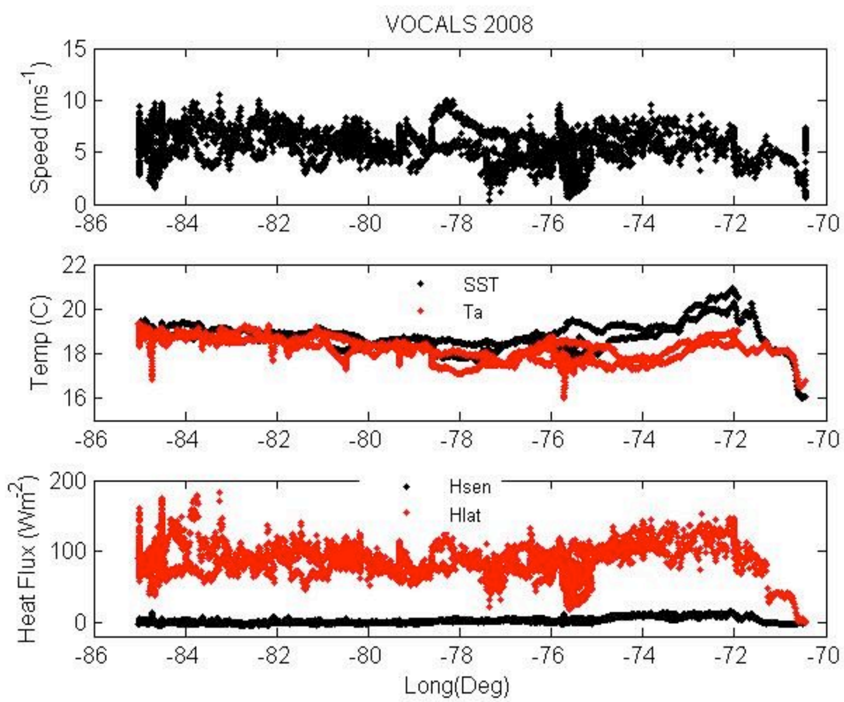
Unexpectedly Strong Convection
11:23 UTC 20 NOV 08

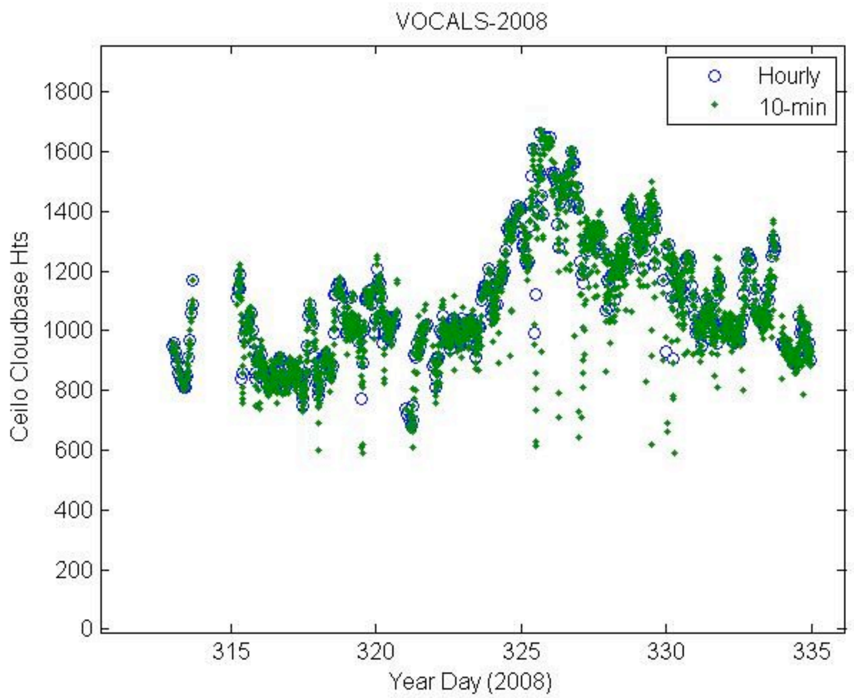






Air-Sea Flux and Cloud Samples





- **Selected variables from the W-E transect along 20 S from 85 W to 70 W. Upper panel is wind speed; the middle panel is sea surface and air temperatures; the lower panel shows sensible (Hsen) and latent (Hlat) heat fluxes.**

Leg 2 time series of ceilometer cloud base height

High Resolution Doppler Lidar (HRDL) Measurements from the RV Brown

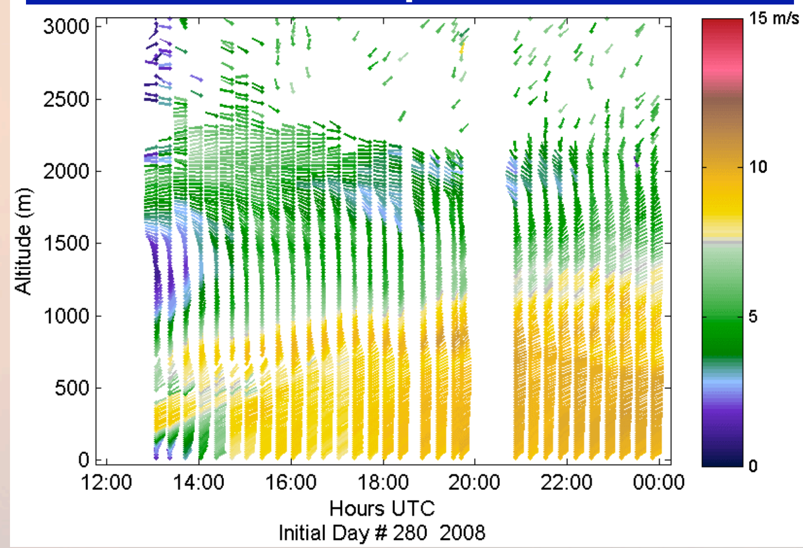
Alan Brewer, Sara Tucker, Ann Weickmann, and Scott Sandberg

Continuous operation provides vertical profiles updated every 20 minutes:

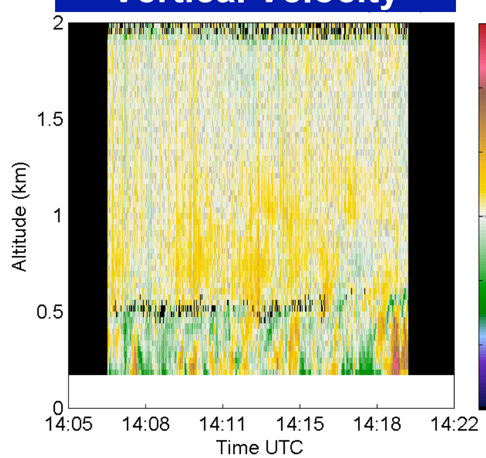
- Horizontal wind speed & direction
- Vertical velocity & velocity variance
- 2 micron backscatter intensity

Image archive:
http://www.esrl.noaa.gov/csd/lidar/vocals/

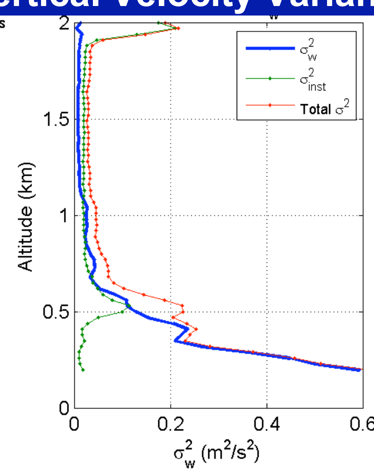
Horizontal wind speed and direction



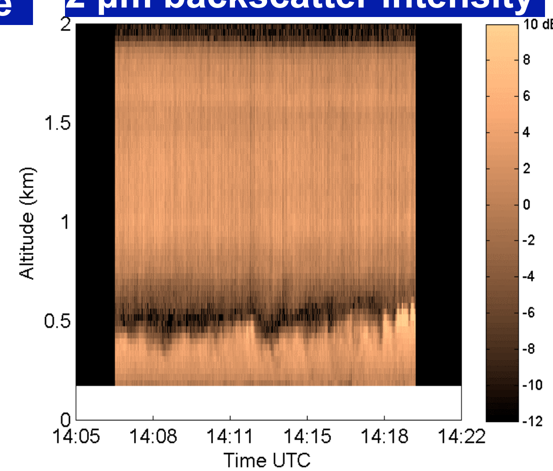
Vertical Velocity



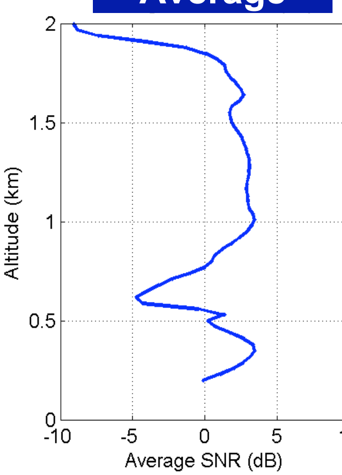
Vertical Velocity Variance



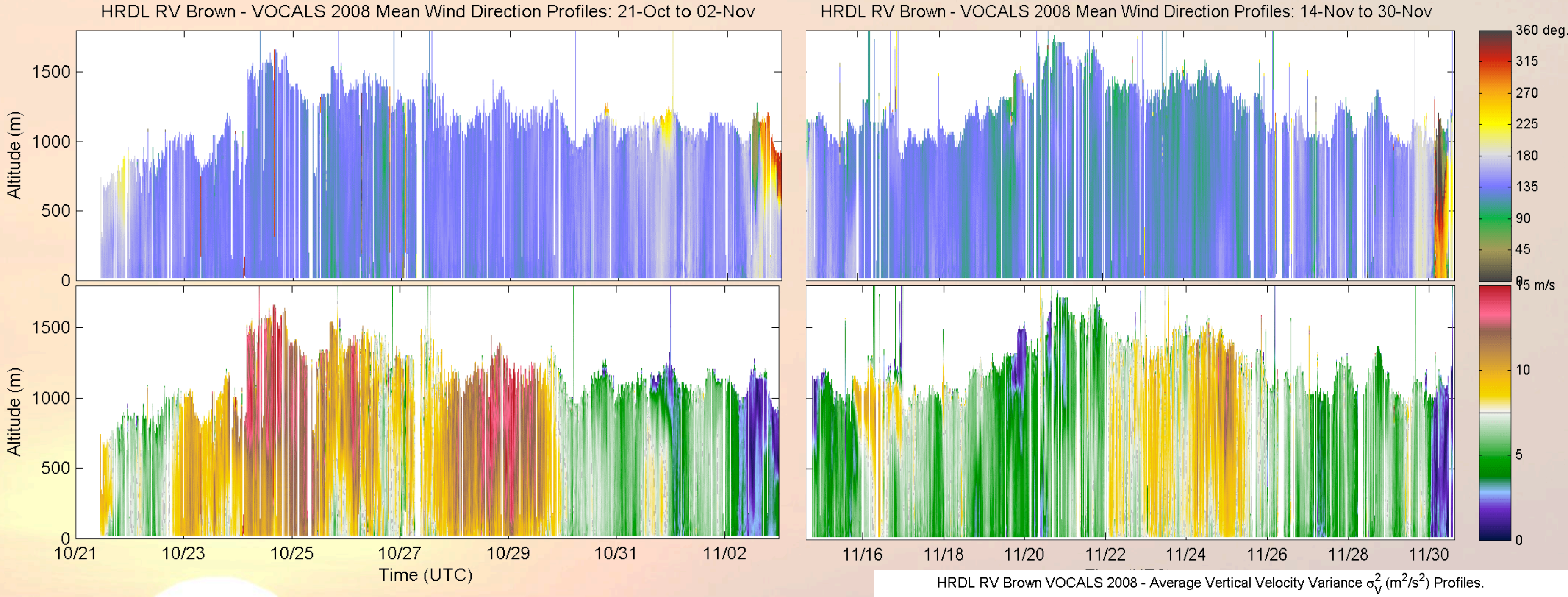
2 µm backscatter intensity



Average



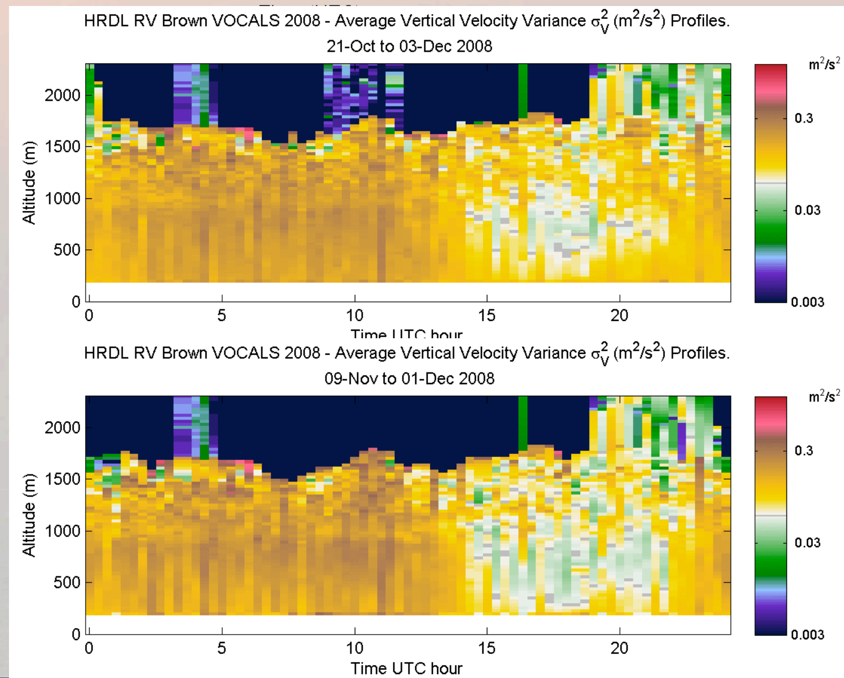
21 Oct – 30 Nov Horizontal wind direction (top) Horizontal wind speed (bottom)



Long term, continuous coverage

The upper images show a compilation of the 20 minute wind profiles from the entire VOCALS-REX experiment. They show that the Brown experienced generally higher winds in the first leg.

Images to the right show averages of the 20 minute vertical velocity variance profiles for leg 1 (top) and leg 2 (bottom) displayed against altitude and time of day. These images demonstrate evidence of atmospheric decoupling during the afternoons.

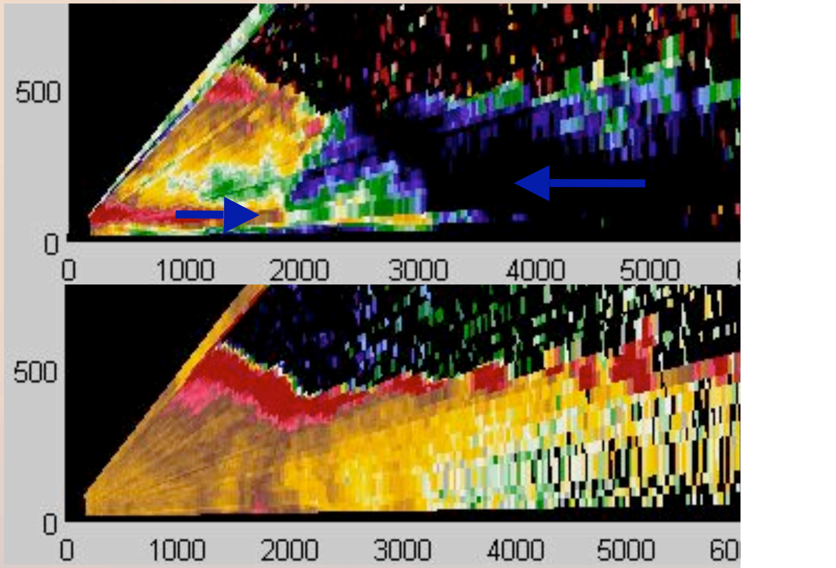


Motion stabilized scanning provides multiple, high-resolution slices through a time-evolving outflow collision

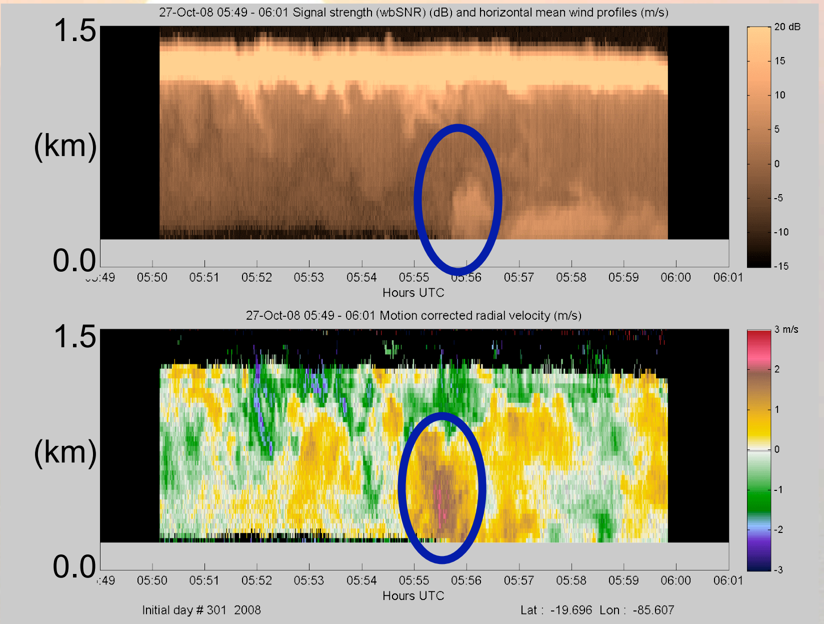
The following series of plots show the same colliding outflows as sampled during a sequence of scans (ccw from bottom left): zenith stare, low-elevation-angle, horizontal scan (PPI) and an elevation scan (RHI). The two fields depicted for each scan are the aerosol backscatter signal strength (different colors are because of different scales), and either the vertical velocity for the zenith stare or the residual velocity (mean wind removed) for the scanning data.

The azimuth of the RHI scan is shone as a dashed line on the PPI plots. The white arrows indicate the direction of the colliding outflows. The circles indicate the same transition – the lidar was staring vertically as the surface convergence passed overhead – note the resulting uplift (warm color) in the lower zenith velocity plot. The RHI's show the relative depths of the colliding flows (the black region in the RHI is off scale blue >2.5m/s towards the lidar)

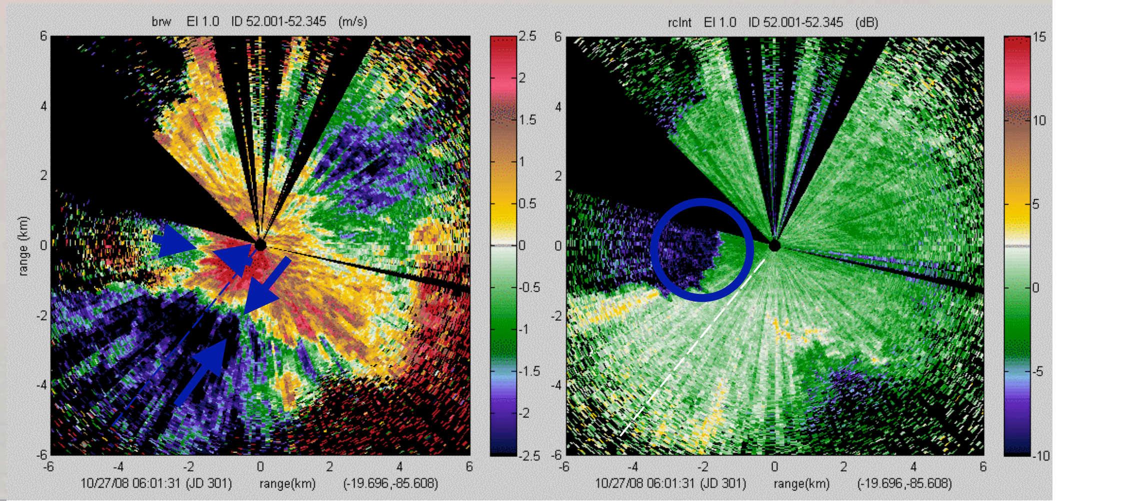
RHI



Zenith



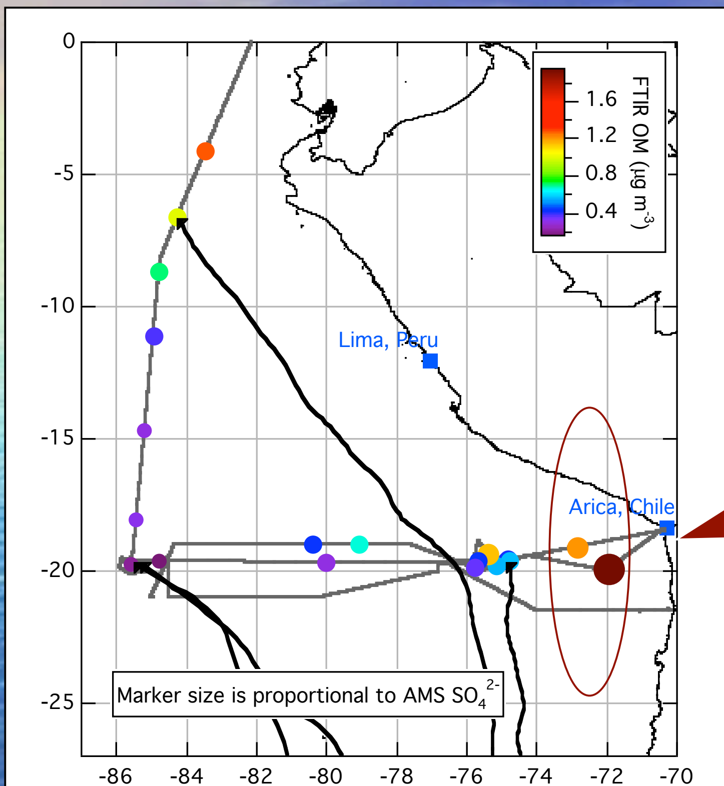
PPI

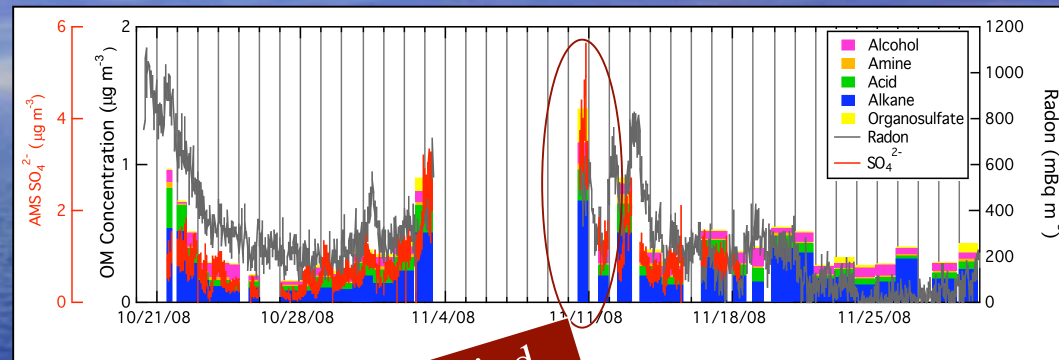


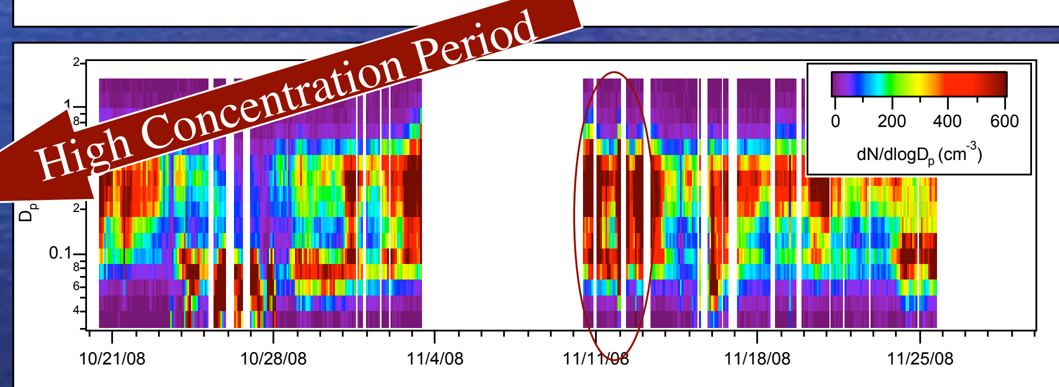
NOAA R/V R. H. Brown Aerosol Chemistry

Preliminary results

L. N. Hawkins, L. M. Russell, P.K. Quinn, D. S. Covert, D. Coffman, and T. S. Bates







- 12-24 hour filters measured organic mass (OM).
- AMS sulfate averaged to filter times.
- Concentrations were highest near the continent.

- OM comprises 5 functional groups and correlates to radon (a continental tracer) and sulfate.
- During periods of low OM and sulfate, the size distribution shows mainly small particles (less than 100 nm).
- Near the continent, the larger particles increase dramatically in number concentration.

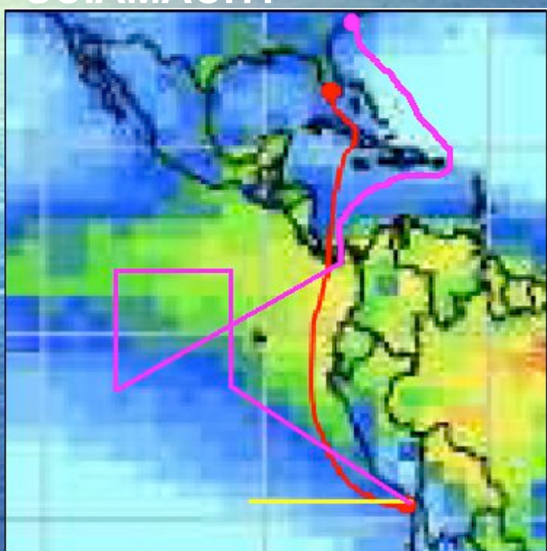
CU Boulder Ship MAX-DOAS

PI: Rainer.Volkamer@colorado.edu

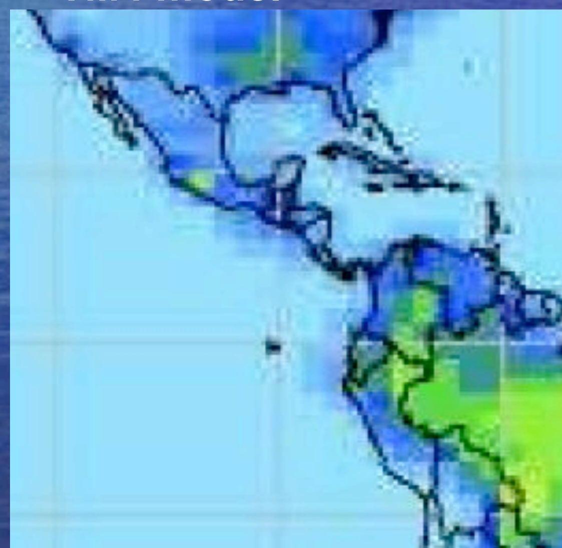
target gases: **CHOCHO, IO** (OIO, I_2, BrO, HCHO, NO_2, SO_2, O_4)

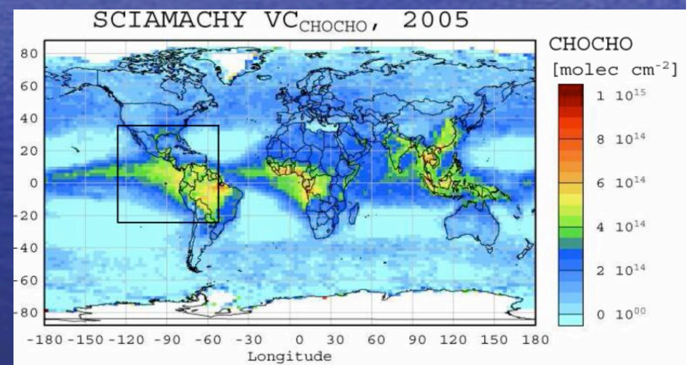
- Is CHOCHO over the oceans real or a satellite measurement artifact?
- Are there missing ocean sources for hydrocarbons from the oceans?

SCIAMACHY

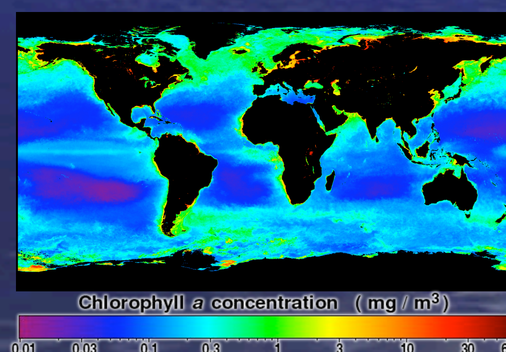


TM4 model





MODIS Chlorophyll-a, 2005 (ocean color)

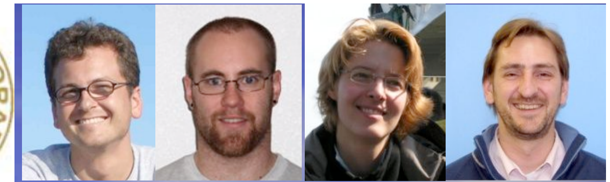


CHOCHO is an indicator molecule for active hydrocarbon oxidation chemistry, and a precursor for Secondary organic aerosol formation in cloud droplets and aerosols.

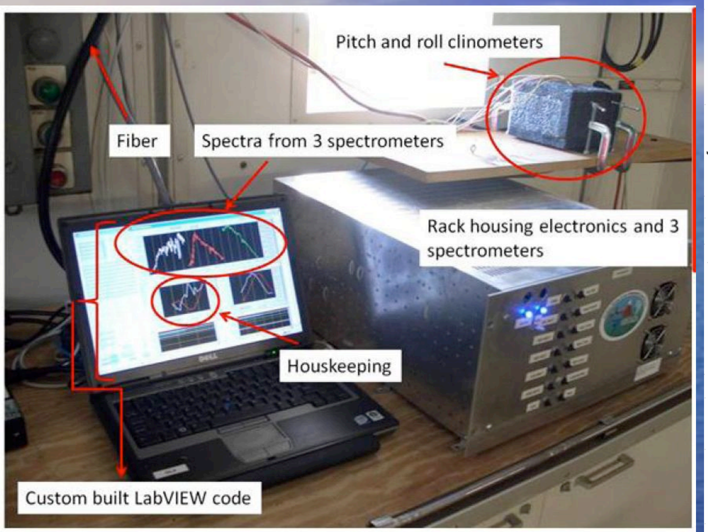
Volkamer et al. 2005, 2007, 2008; Wittrock et al 2006; Kanakidou et al. 2008

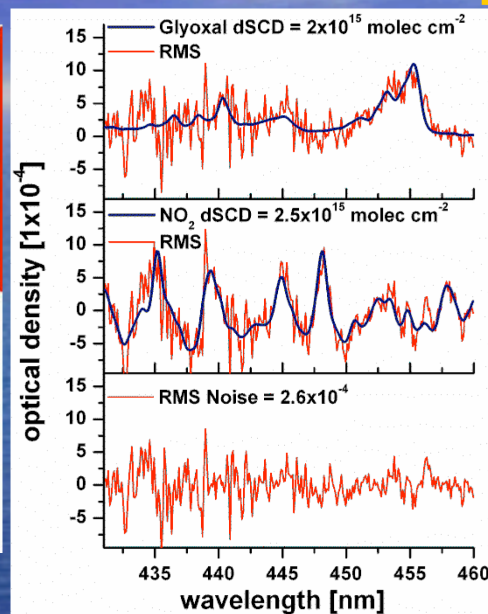
CU Ship MAX-DOAS

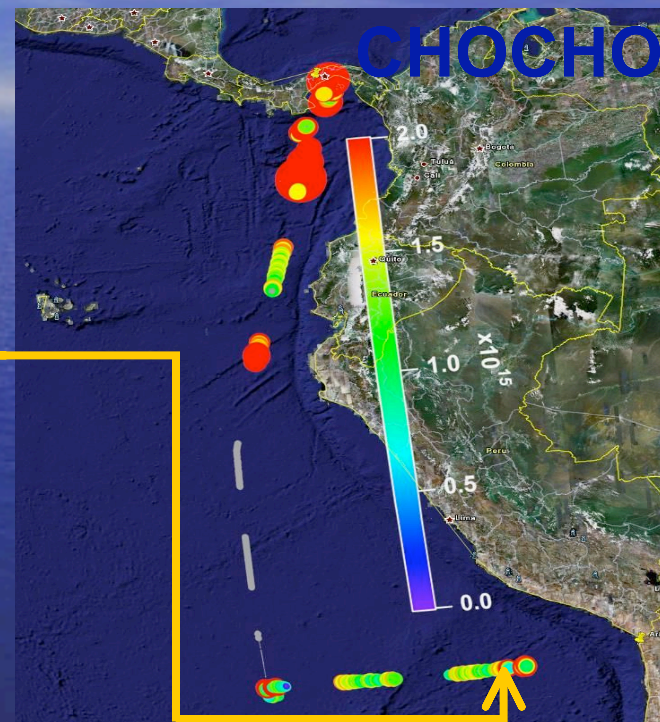
PI: Rainer.Volkamer@colorado.edu

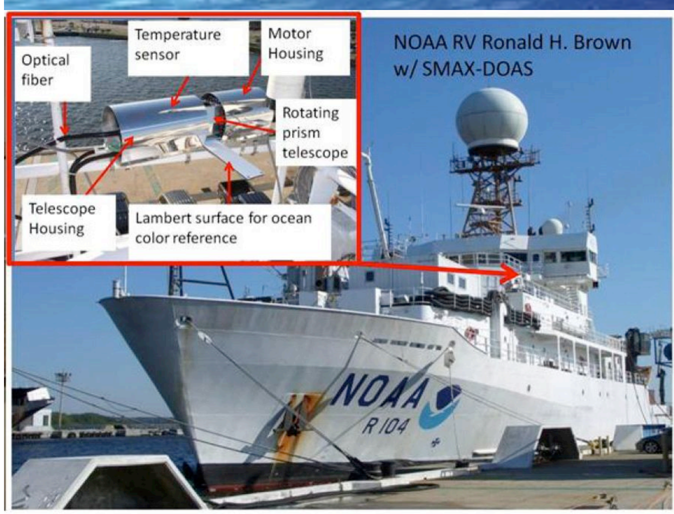


target gases: **CHOCHO, IO** (OIO, I_2, BrO, HCHO, NO_2, SO_2, O_4)









Science questions:

- Is the Pacific Ocean a source for halogens?
- Is Glyoxal (CHOCHO) over the oceans a satellite measurement artifact? **CHOCHO directly confirmed !**

=> Missing ocean sources for hydrocarbons in models !

Useful complimentary measurements:

- ocean biology: Chlorophyll-a, DMS fluxes
- aerosols: AMS, SMPS, aircraft VOC data

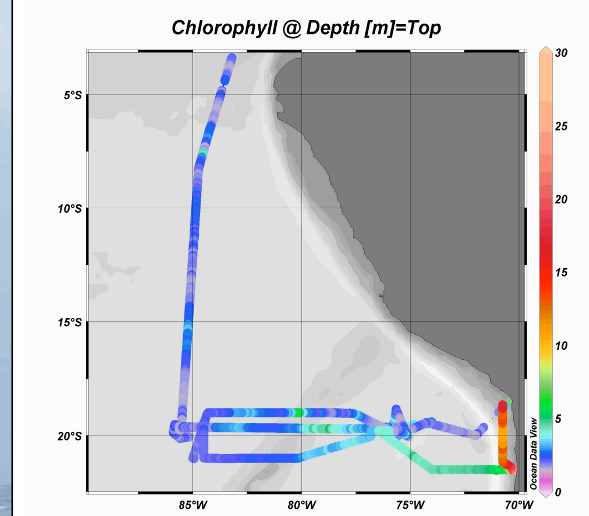
VOCALS Activities

Sampling from CTD and flow-through system for chlorophyll, nutrients, DMS and its principle precursor DMSP, both dissolved and particulate.

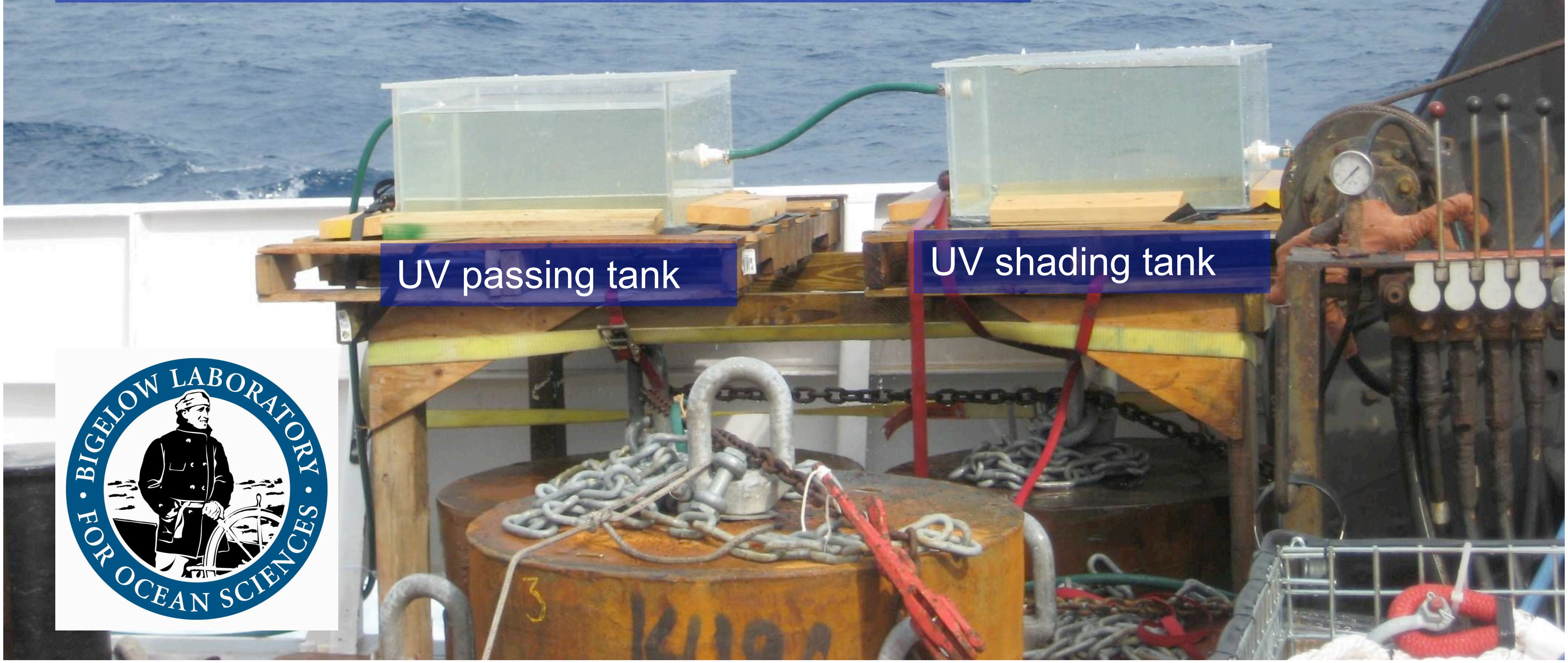
A correlation between solar radiation/UV and DMS production has been proposed (Vallina and Simó 2007 *Nature* **315:** 506). Is this true in VOCALS region?

10 incubation experiments performed to determine rates of DMS and DMSP production and examine the influence of ambient PAR and UV to better understand the role of cloud cover in oceanic DMS

Andy Hind, Carlton Rauschenberg and Patricia Matrai



Preliminary surface chlorophyll during VOCALS



Preliminary Results

Incubation	DMS net production rate (nM day^{-1})		
	UV	No UV	
1	0.03	-1.18	>
2	-0.21	0.26	<
3	3.44	2.31	>
4	0.10	-0.78	>
5	1.12	1.76	<
6	8.57	7.17	>
7	0.07	-0.06	>
8	0.48	0.03	>
9	0.56	0.53	>
10	0.92	0.29	>

Daily net DMS production higher in 8 of 10 experiments of surface seawater exposed to ambient UV versus those shaded from it

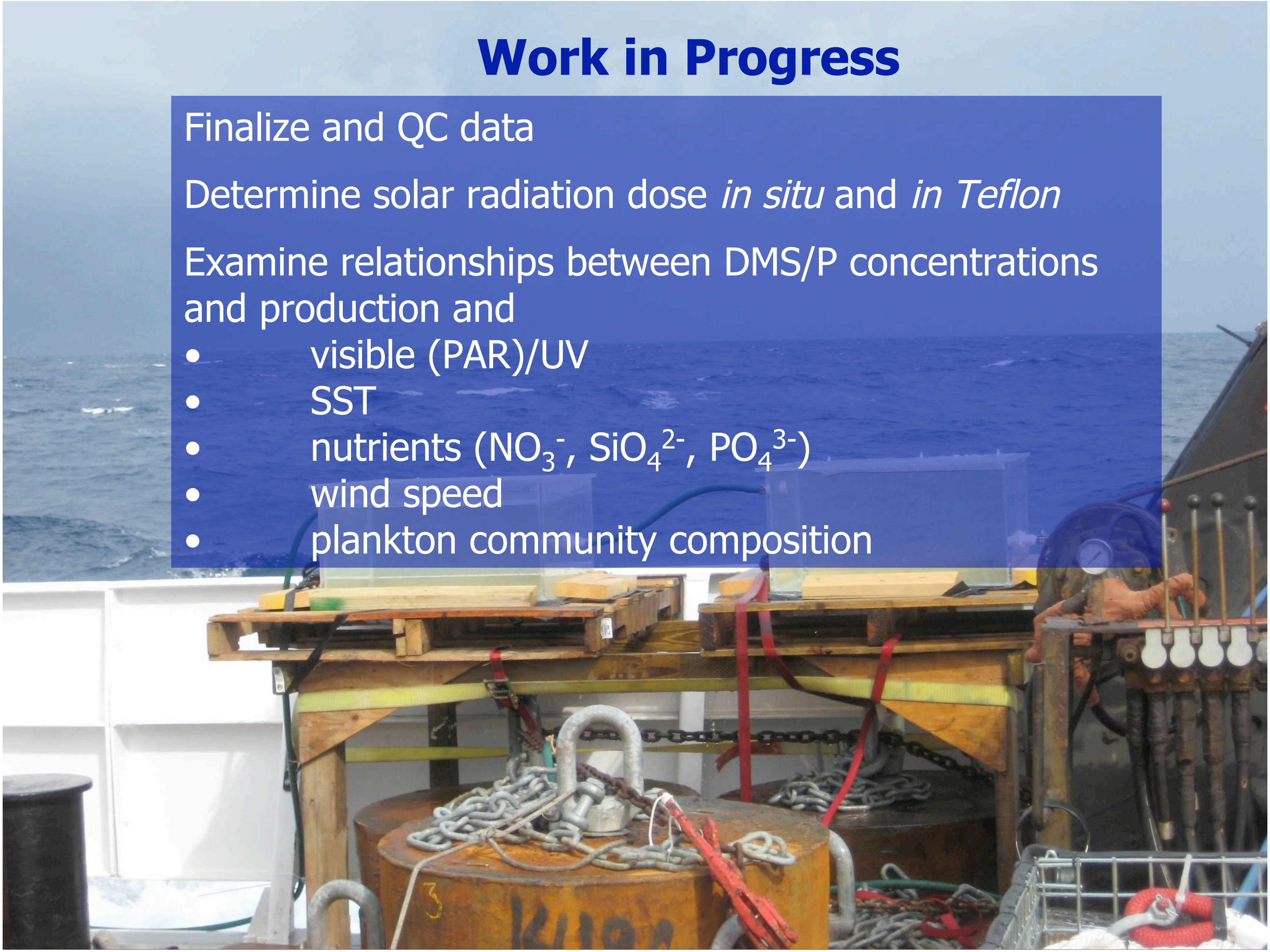
Work in Progress

Finalize and QC data

Determine solar radiation dose *in situ* and *in Teflon*

Examine relationships between DMS/P concentrations and production and

- visible (PAR)/UV
- SST
- nutrients (NO_3^-, SiO_4^{2-}, PO_4^{3-})
- wind speed
- plankton community composition



VOCALS - Peru participants

IMARPE – Marine Research Institute of Peru

Physical Oceanography: Carmen Grados, Luis Vasquez, Jose Tenorio
Biogeochemistry: Michelle Graco, Jesus Ledesma (O_2, Chl-a,Nutrients, pCO_2)
Biology: Sonia Sanchez, Patricia Ayon, Avy Bernales, Roberto Quesquen (Phyto/Zooplankton)
Fisheries Hydroacoustics: Anibal Aliaga, Luis Escudero
Physical/Biogeochemical modelling: David Correa, Jorge Tam

IGP - Geophysical Institute of Peru

Meteorology and Atmospheric Modelling: Ken Takahashi, Yamina Silva, Kobi Mosquera, Percy Condor

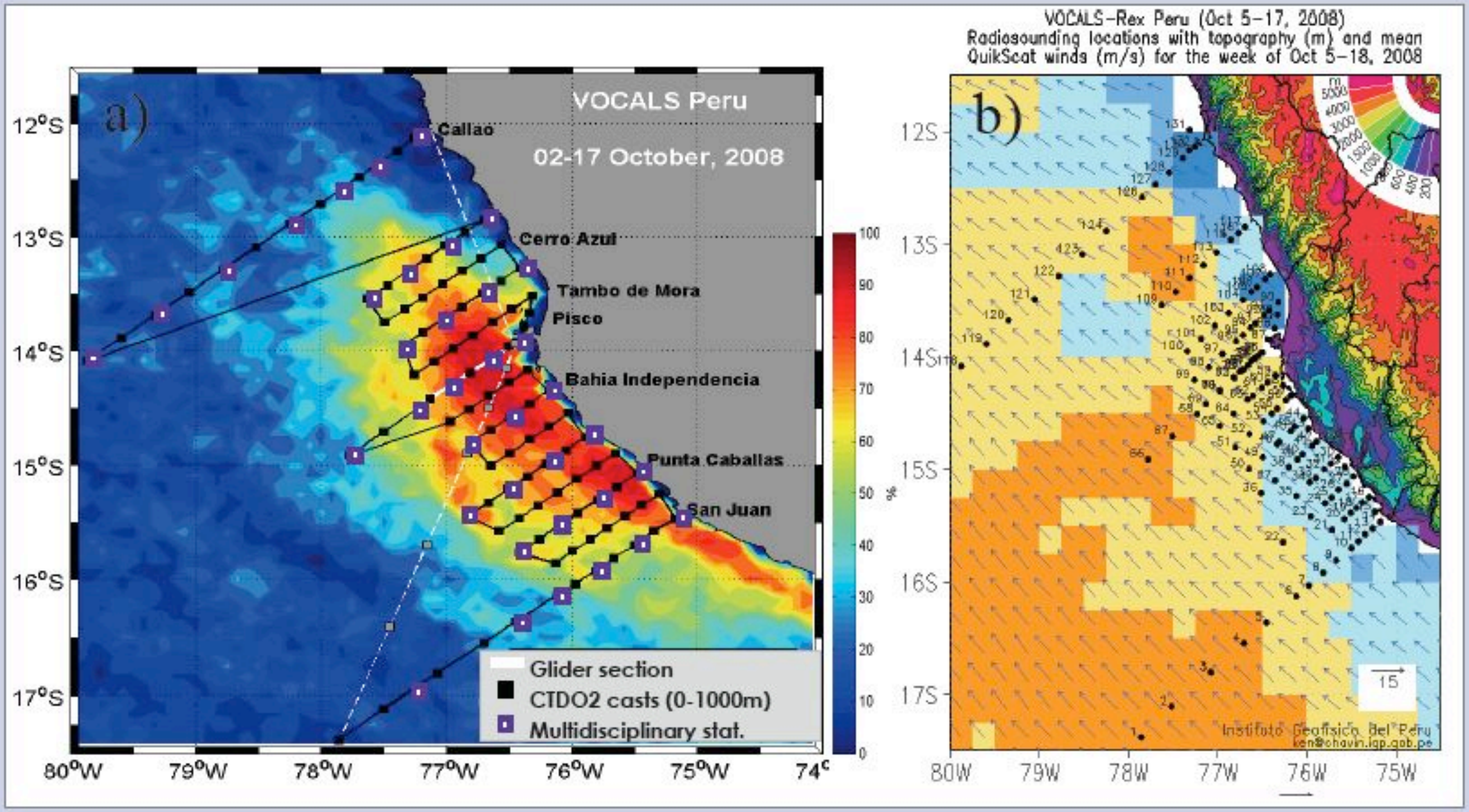
LEGOS - Laboratoire d'Etudes en Géophysique en Océanographie Spatiales, CNRS/CNES /IRD/Université Paul Sabatier

Physical Oceanography: Gérard Eldin, Yves du-Penhoat
Physical Modelling: Boris Dewitte, Gildas Cambon

LOCEAN - Laboratory of Ocean, Climate and Numerical Analysis

Physical Oceanography: Alexis Chaigneau, Pierre Testor
Physical/Biogeochemical Modelling: Vincent Echevin, Francis Codron

Surveyed region a) Survey track and stations beneath, the mean average of total fraction of cloud clearing area (%) for October, as obtained from SeaWIFS data, b) Radiosounding locations



Measurements and volume samples collected

Atmospheric :

- Bulk meteorology
- Radiosondes
- Cloud properties, photographs

Oceanographic :

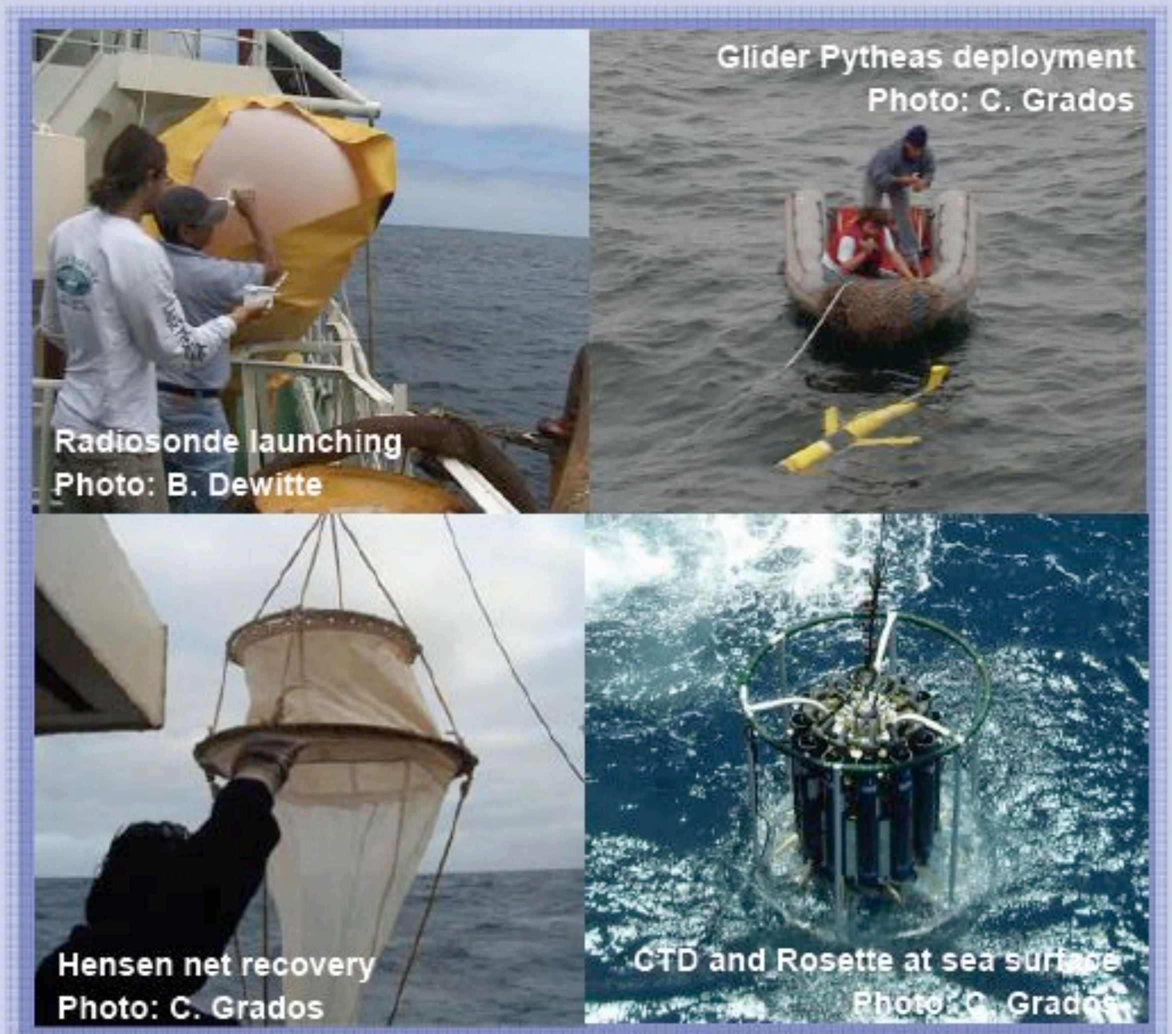
- WOCE/SVP drifters
- CTD
- Glider
- ADCP

Biogeochemistry :

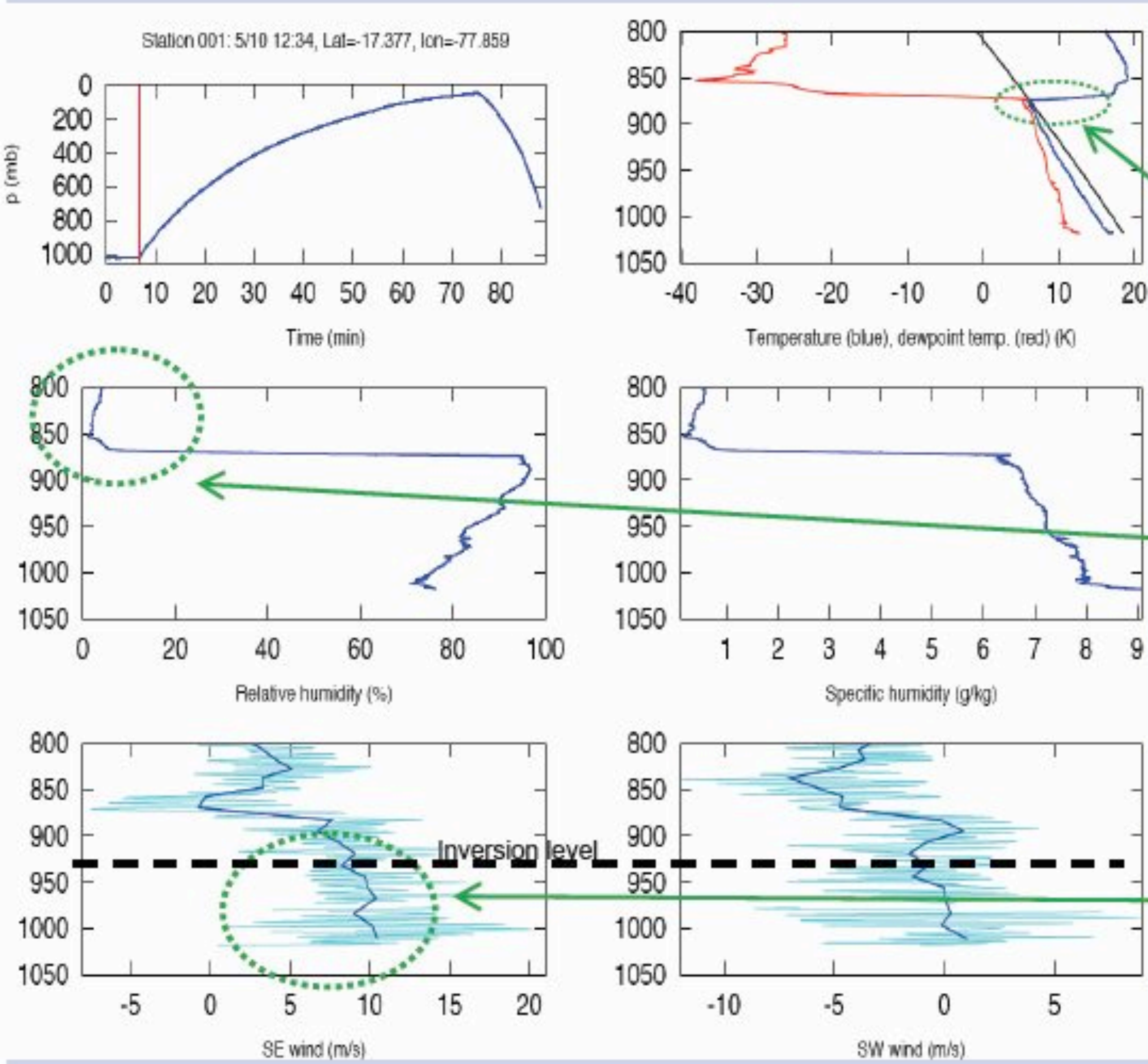
- Oxygen and Fluorescence
- Chlorophyll-a
- Nutrients
- Underway PCO_2

Biology and Hydroacoustics :

- Phytoplankton sampling
- Zooplankton sampling
- CUFES
- Underway hydroacoustics



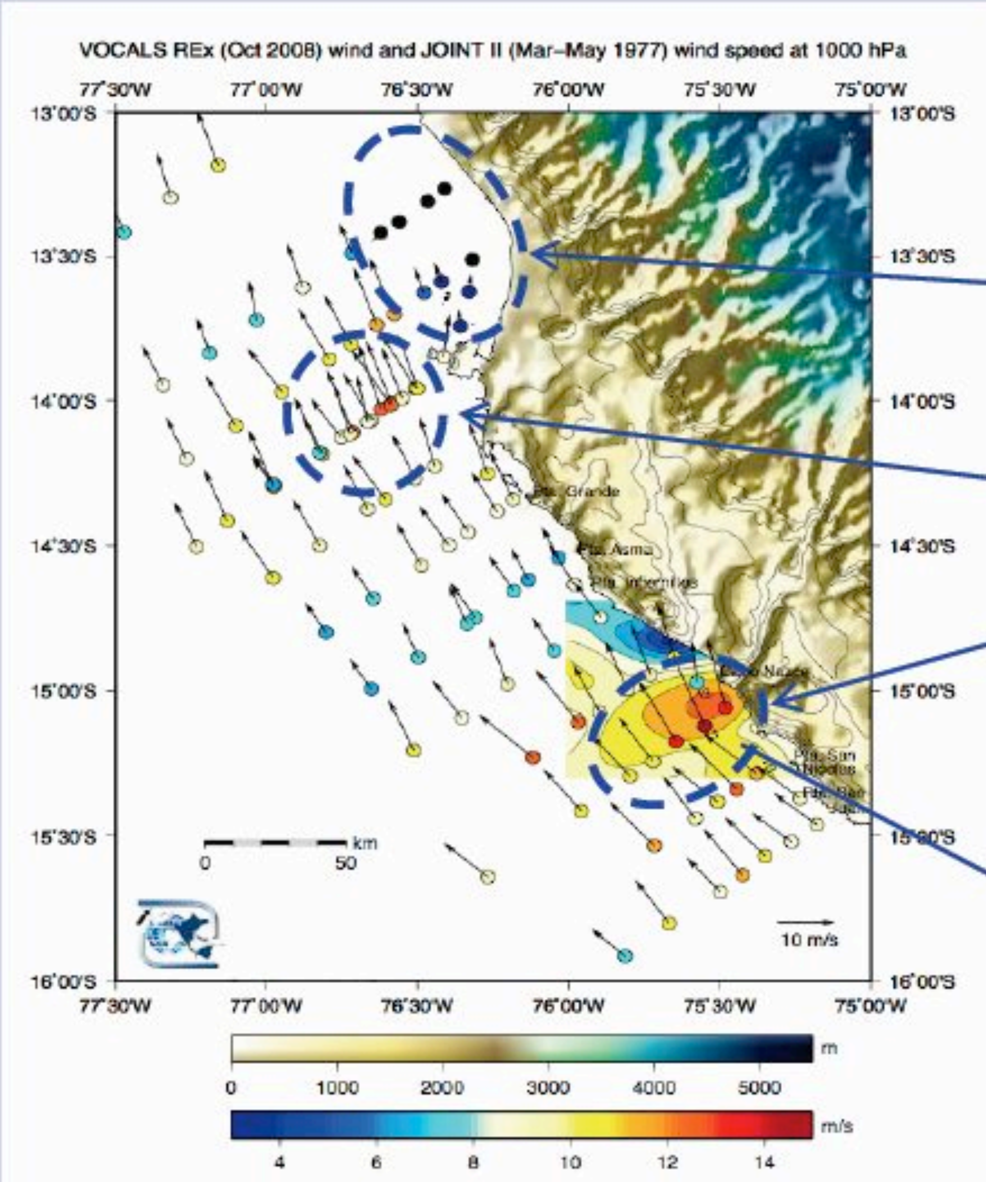
Characteristics of the marine Planetary Boundary Layer



Some preliminary observations

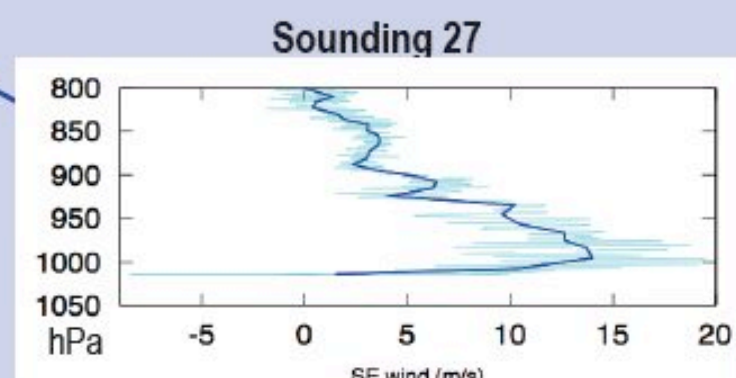
- Strong thermal inversions were typical ($\Delta\theta$~10 K) but in other cases they were very eroded.
- Inversion levels varied between 870 and 980 hPa.
- Very dry air above the PBL (RH apparently as low as 1%) in many cases, with moist intrusions in others.
- Vigorous turbulent motions apparent in the wind
- Trade-wind jet generally located under the thermal inversion

Low-level coastal winds

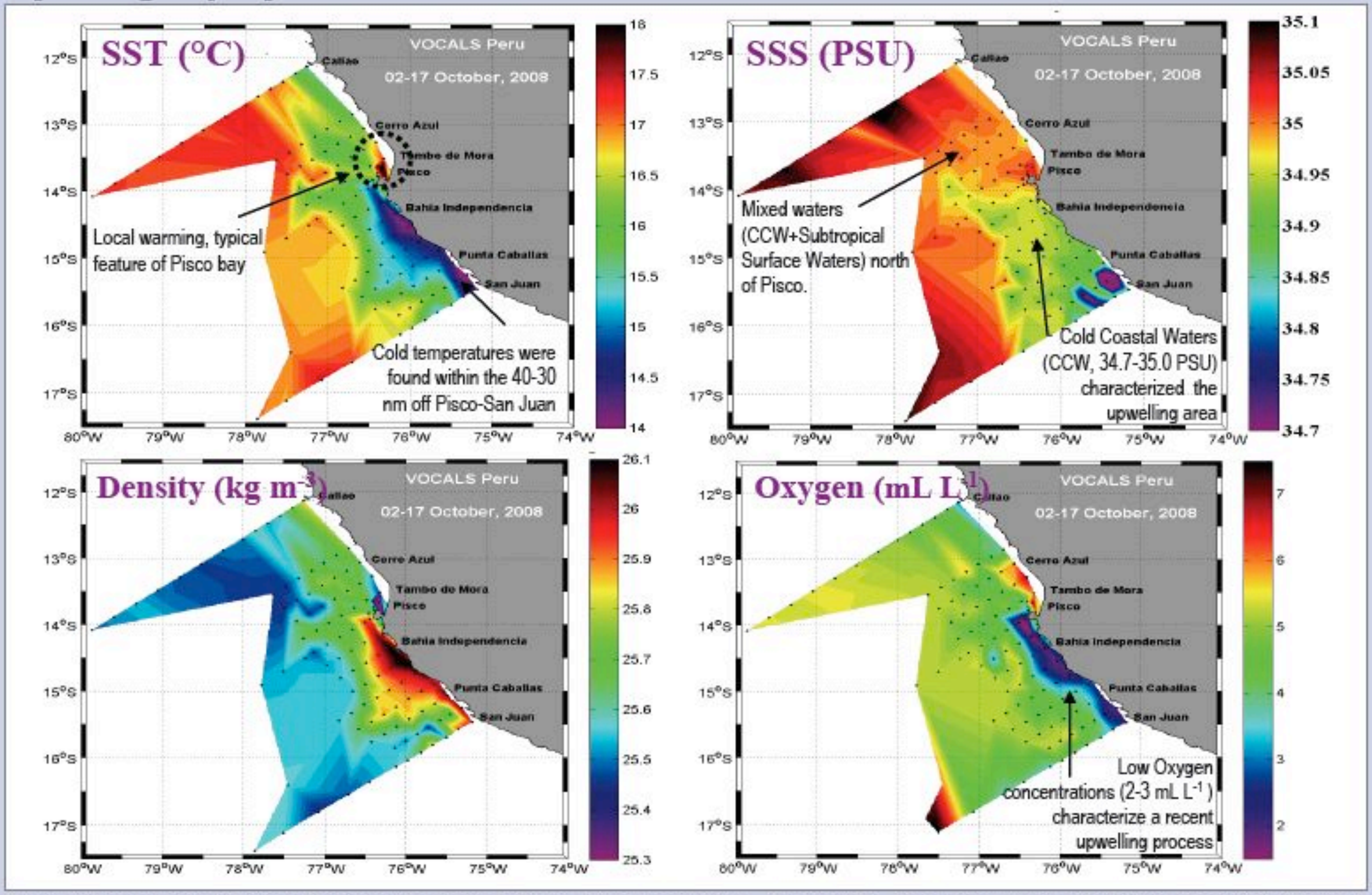


Some preliminary results

- Stagnant flow downstream of Paracas peninsula
- Strong wind west of Paracas peninsula, but with strong temporal variability
- Results consistent with the mesoscale (< 50 km) jet observed in 1976-77 (JOINT II).

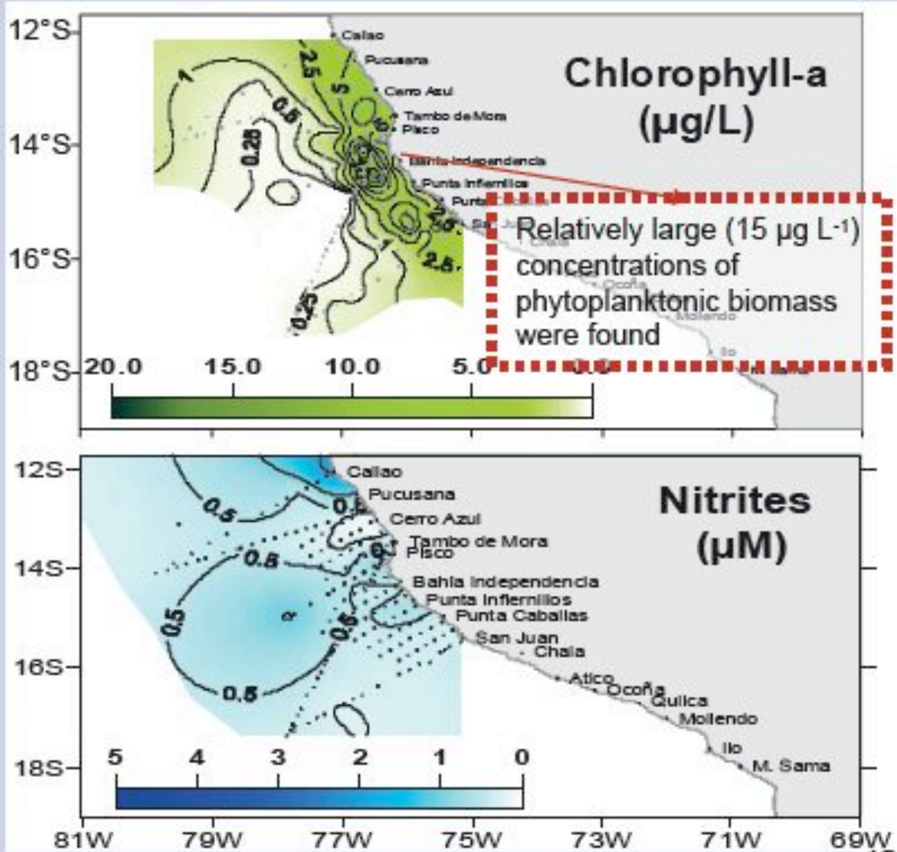


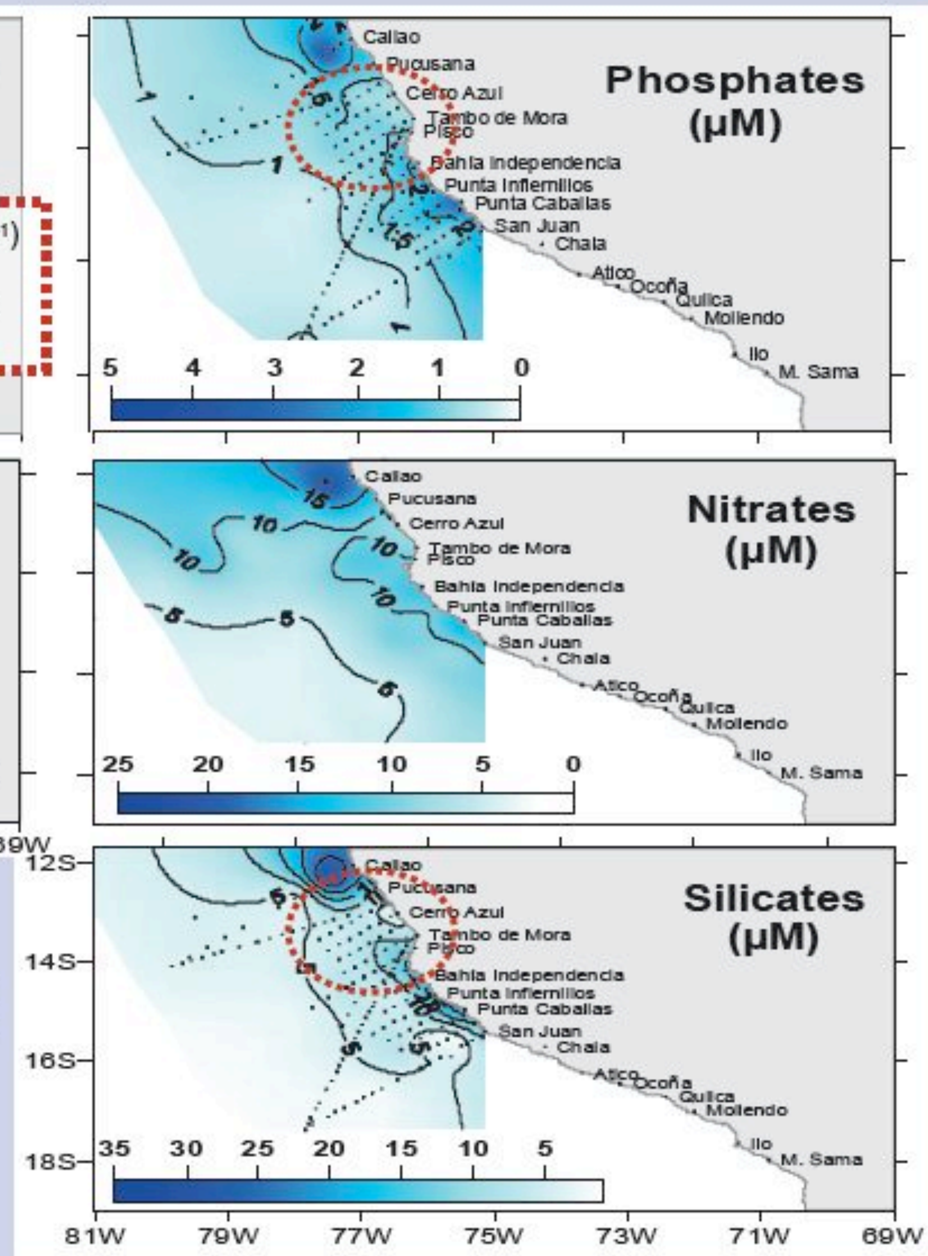
Hydrography at surface



An intense upwelling cell was observed from Pisco to San Juan with the presence of Cold Coastal Waters (CCW) characterized by temperature values of 14°C, surface salinities of 34.70-35.0 PSU and very low oxygen concentrations of 2-3 mL L^{-1}. The separation of this CCW from offshore SubTropical Surface Waters (STSW) waters was characterized by strong physical/biogeochemical fronts.

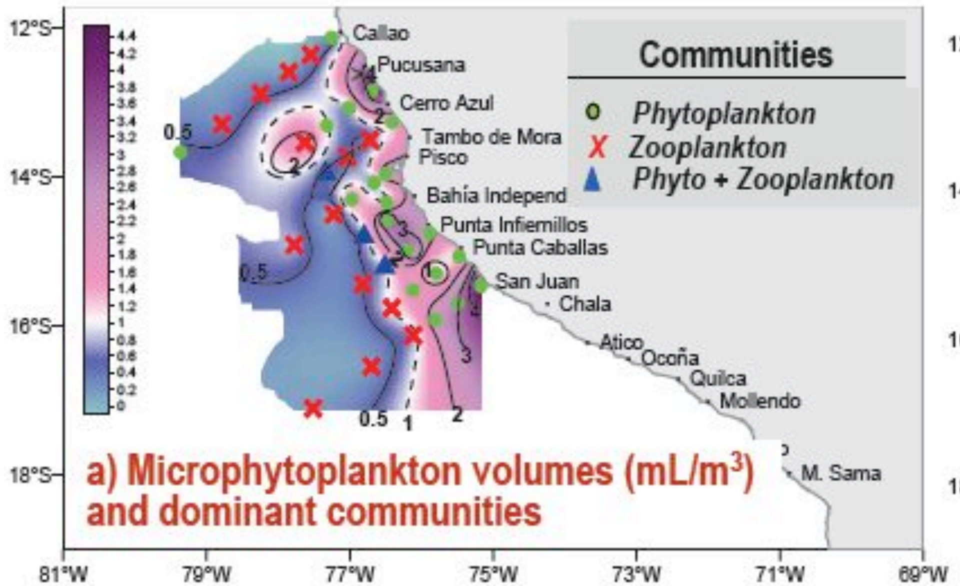
Chlorophyll-a and Nutrients concentrations

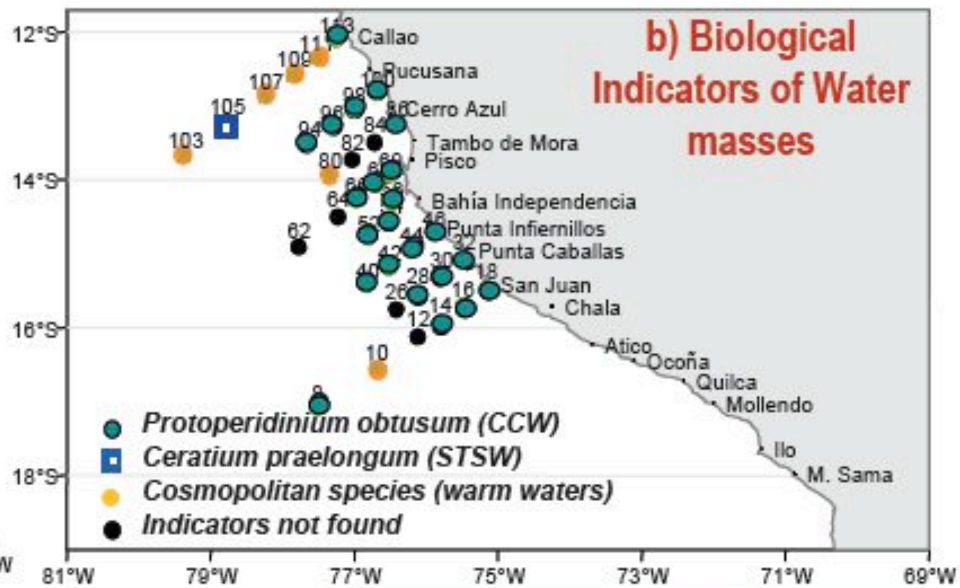




Nutrient concentrations of 1.5-2.0 µM (phosphates), 10 µM (nitrates), 10-15 µM (silicates) characterized this region. Only between Pucusana (12º30`S) and Cerro Azul (13ºS), the onshore advection of STSW and the biological consumption seem to have reduced the phosphate and silicate concentrations.

Biology and Fisheries

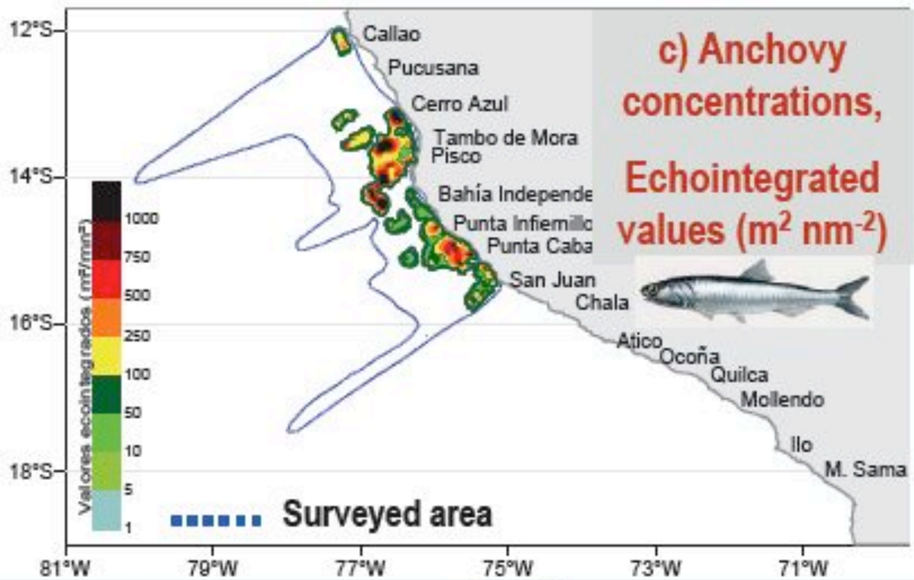




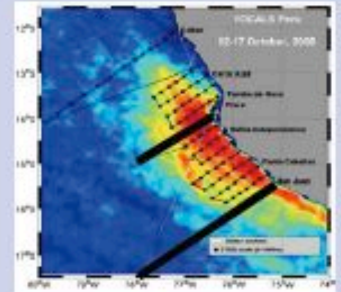
Phytoplankton volumes varied between 0.015 and 4.6 mL m^{-3} and values higher than 2 mL m^{-3} were observed within the 50-60 nm from the coast. In this area, diatoms of initial and intermediate stages were dominant (*Chaetocerus compressus*, *Ch. Constrictus*, *Ch. Affinis*, *Ditylum brigthwelli*, *Lithodesmium undulatum*, mainly).

From Callao to Cerro Azul, the distribution was narrower, only extending to 30 nm offshore.

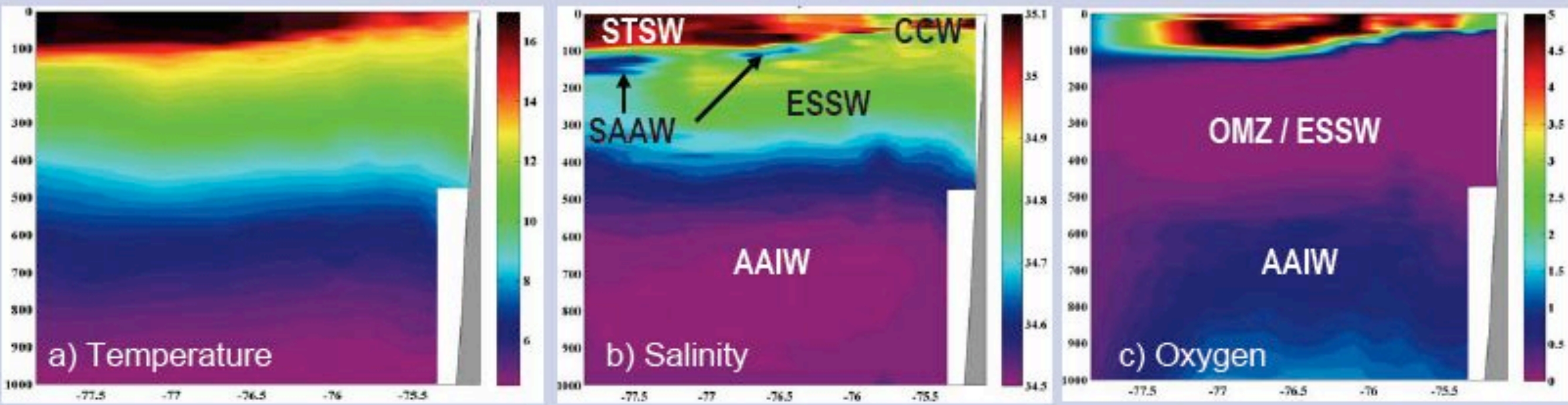
P. Obtusum, a phytoplankton species indicator of CCW was extensively distributed between Pucusana and San Juan, where it was found as far as 120 nm offshore.



Vertical structure of a) Temperature, b) Salinity (PSU) and c) Oxygen (mL L^{-1})



San Juan section (15S)

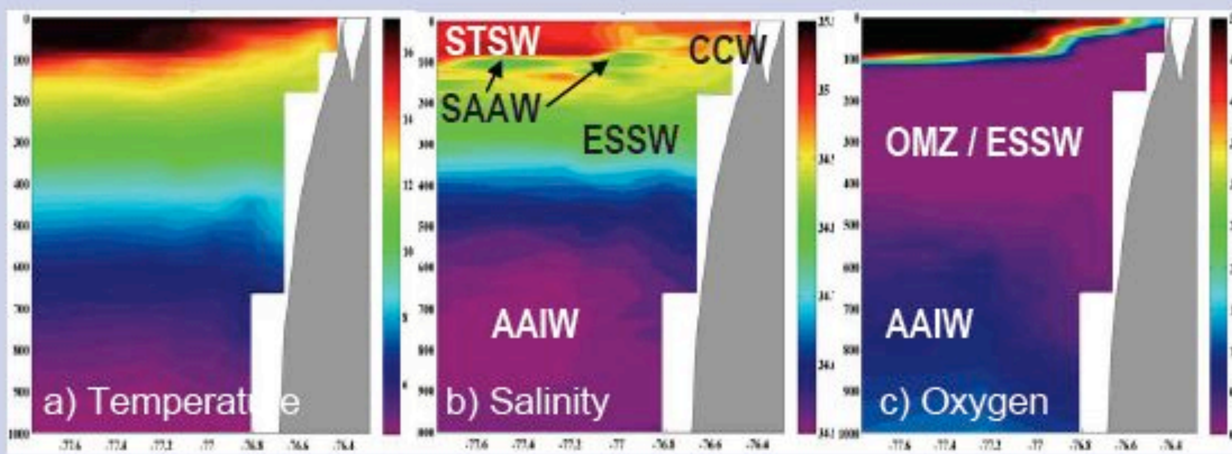


Pisco section (13S)

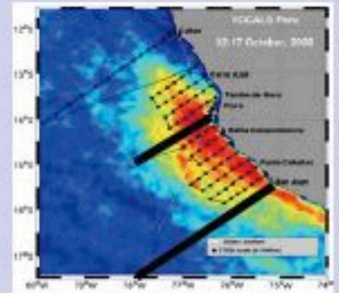
Five water masses were observed:

- Subtropical Surface Water (STSW)
- Cold Coastal Water (CCW)
- Sub-Antarctic Water (SAAW)
- Equatorial SubSurface Water (ESSW)
- Antarctic Intermediate Water (AAIW)

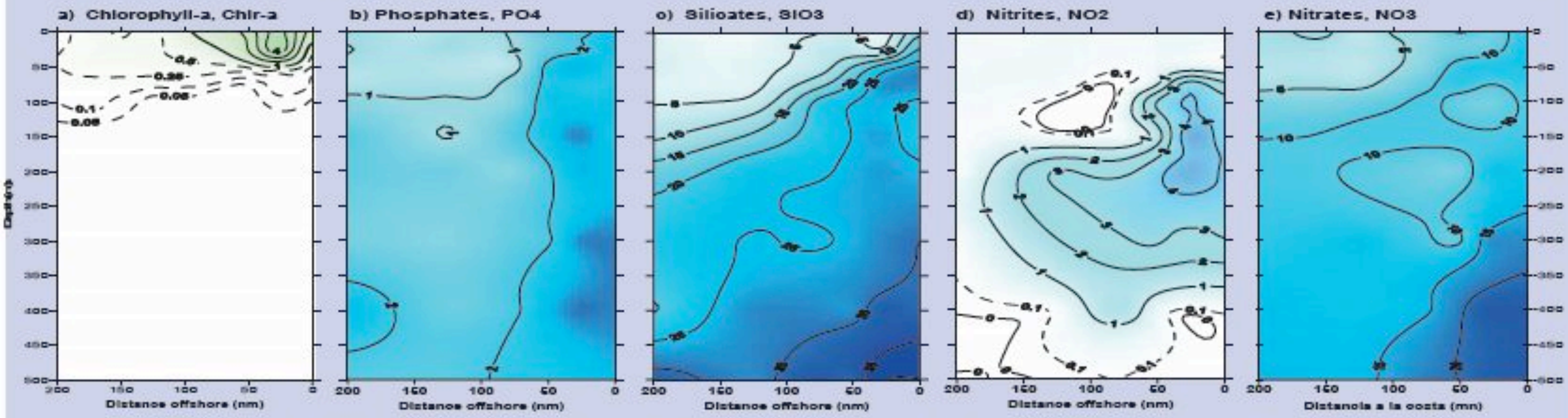
Both sections show near the coast an active upwelling of CCW, associated with the shoaling of the OMZ (0.5 mL L^{-1})



Biogeochemistry: a) **Chlorophyll-a** [Chlr-a, µg/L], b) **Phosphates** [PO4, µM], c) **Silicates** [SiO3, µM], d) **Nitrites** [NiO2, µM], e) **Nitrates** [NiO3, µM] concentrations

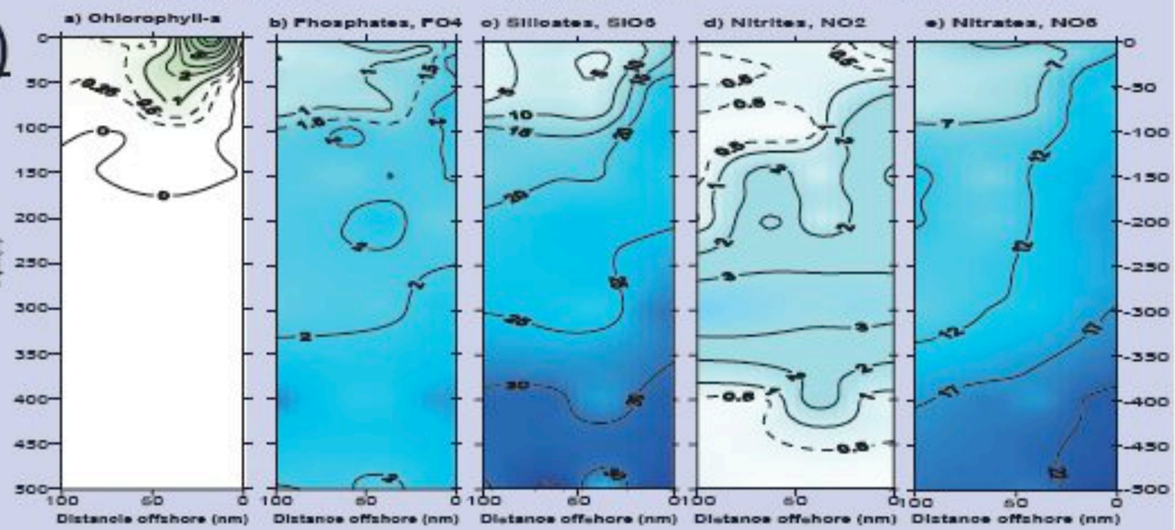


San Juan section (15S)

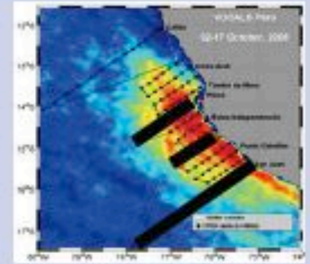


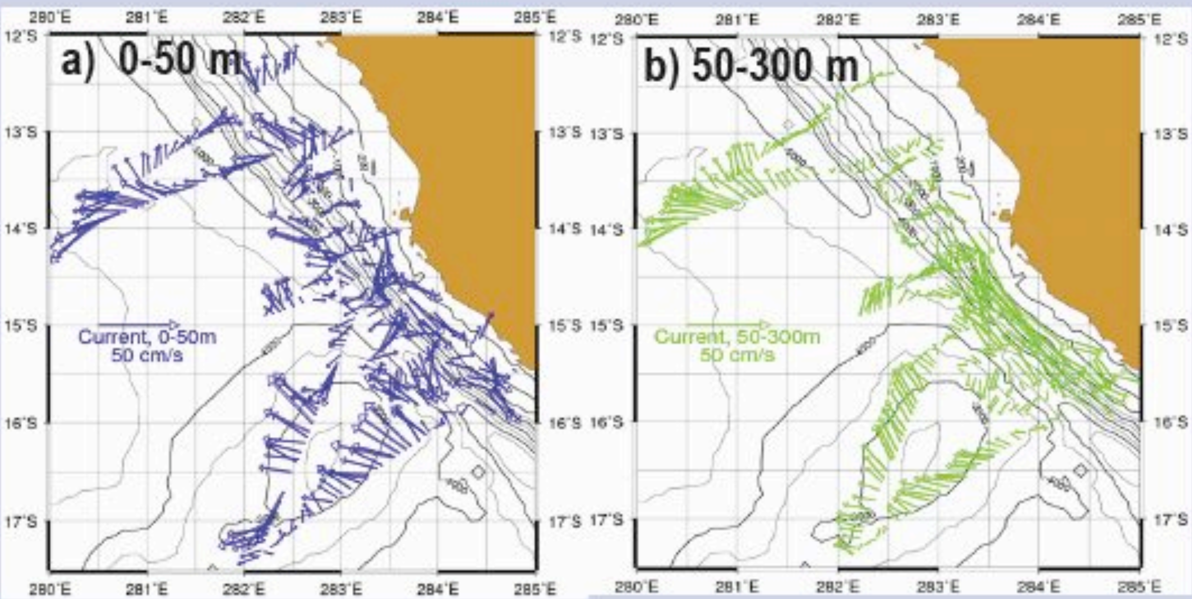
Pisco section (13S)

Both sections show a nucleus of maximum Chlr-a (> 4 µg/L) onshore. A similar pattern is observed in the nutrients distribution, with maximum levels near the coast. High nutrient concentrations are also observed at depth. The shoaling of the isolines near the coast (e.g. Silicates, Fig. c) are related to an active upwelling event.



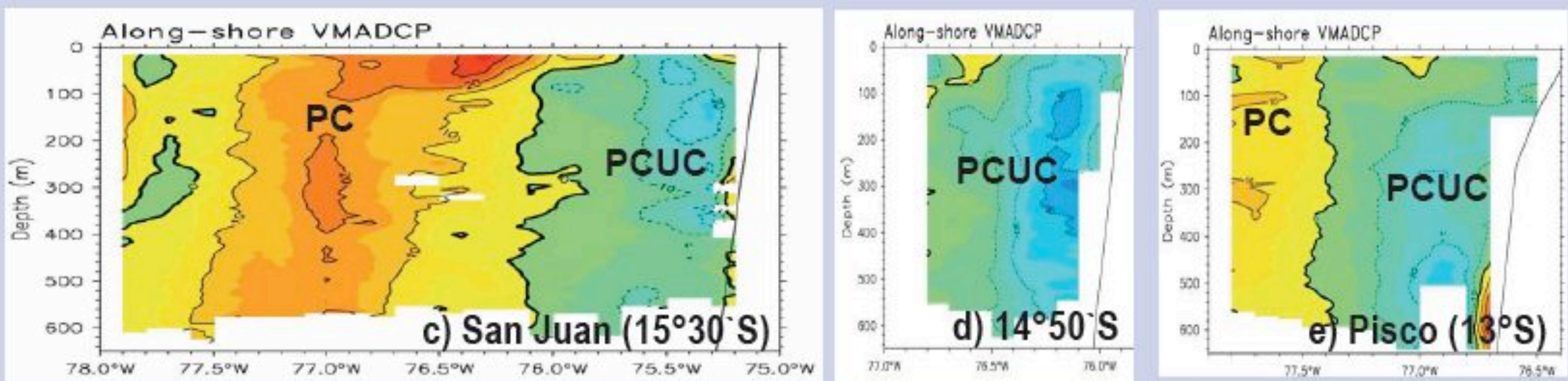
Averaged Currents at layers **a) 0-50**m, **b) 50-300**m (Upper pannel) and **Along-shore VMADCP currents** off **c) San Juan** (15°30`S), **d) 14°50´S**, and **e) Pisco** (13°S) (Lower pannel)





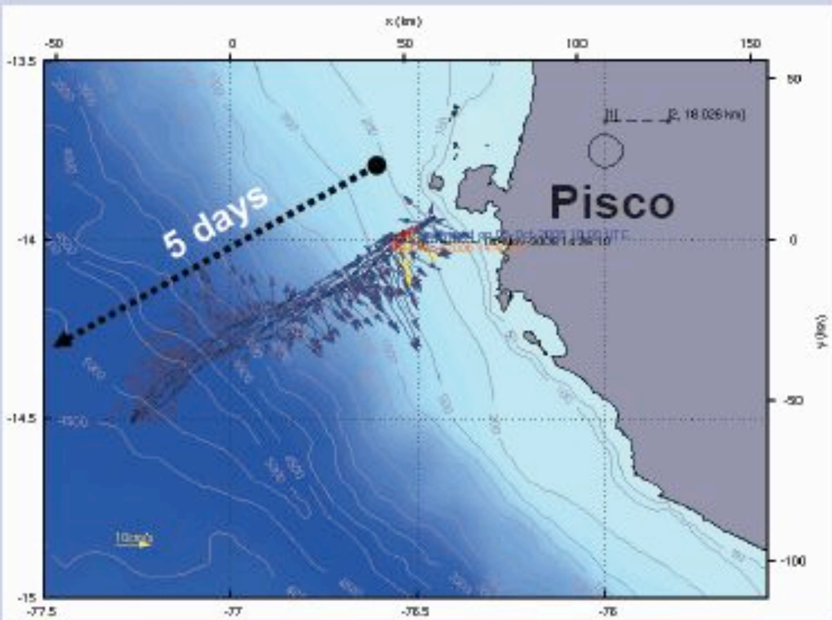
Two main currents were detected: The Peru Current (PC) flowing northward in the surface layers of the offshore ocean; the Peru-Chile UnderCurrent (PCUC), centered at ~200 m depth, flowing southward along the continental shelf and reaching surface layers.

The PCUC transport and core location evidenced strong spatio-temporal variability. .

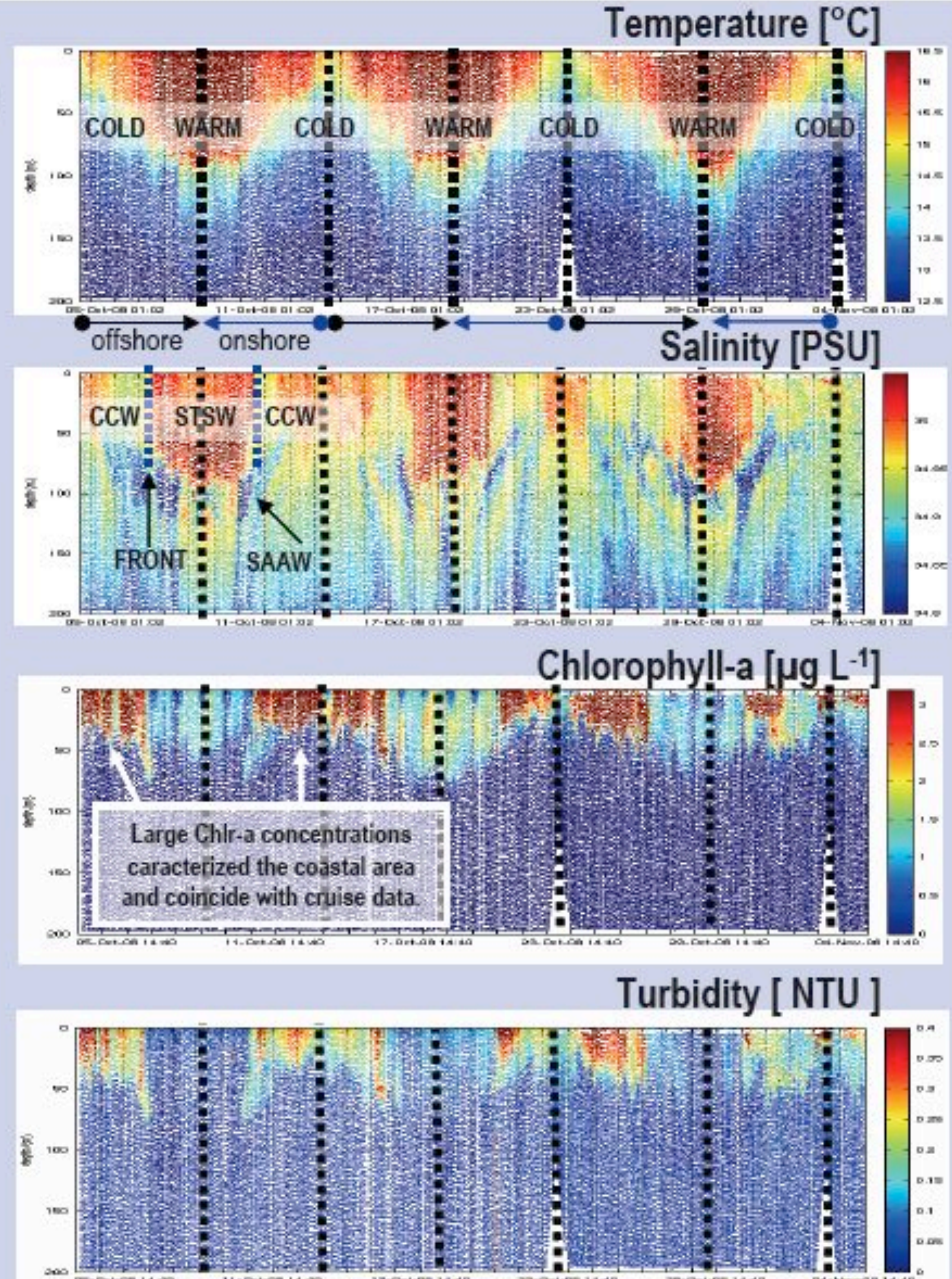


Investigating the high-frequency variability of the upwelling plume and front off Pisco (13S)

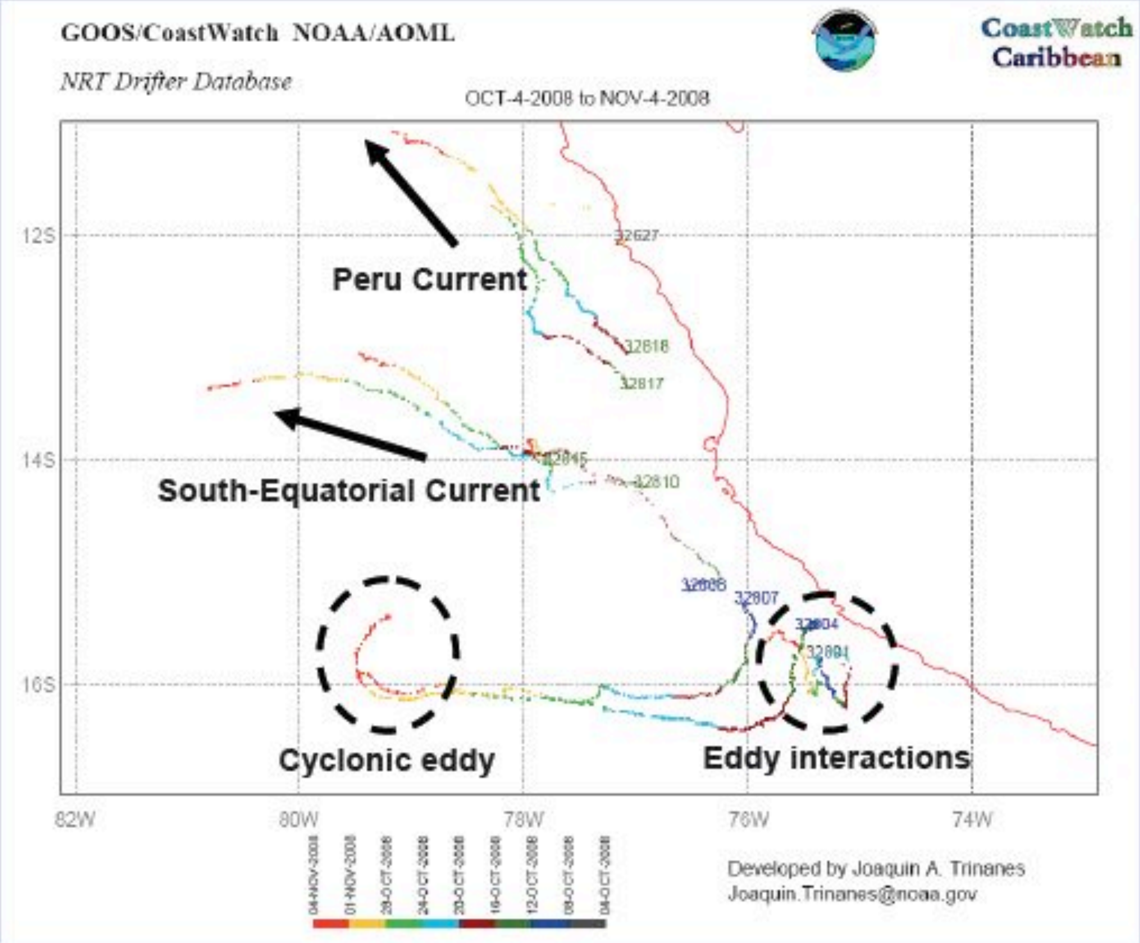
Repeated hydro/ biogeochemical survey of the glider Pytheas

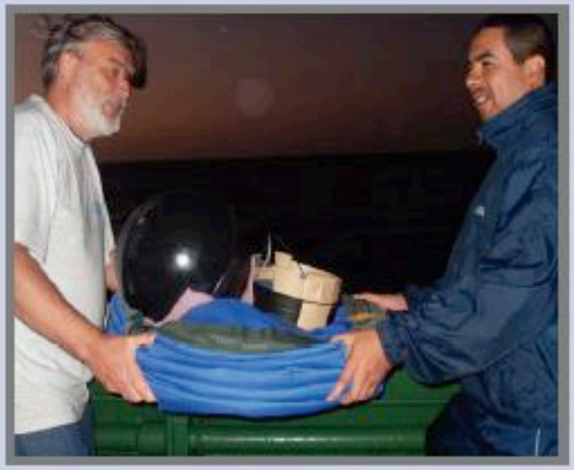


Distance : ~70 nm offshore
Parameters : T,S,O2,Chl-a,Turbidity
Max. Depth : 200m
Data acquisition: 1 profile each ~500 m



Surface drifters trayectories deployed during VOCALS Peru Cruise



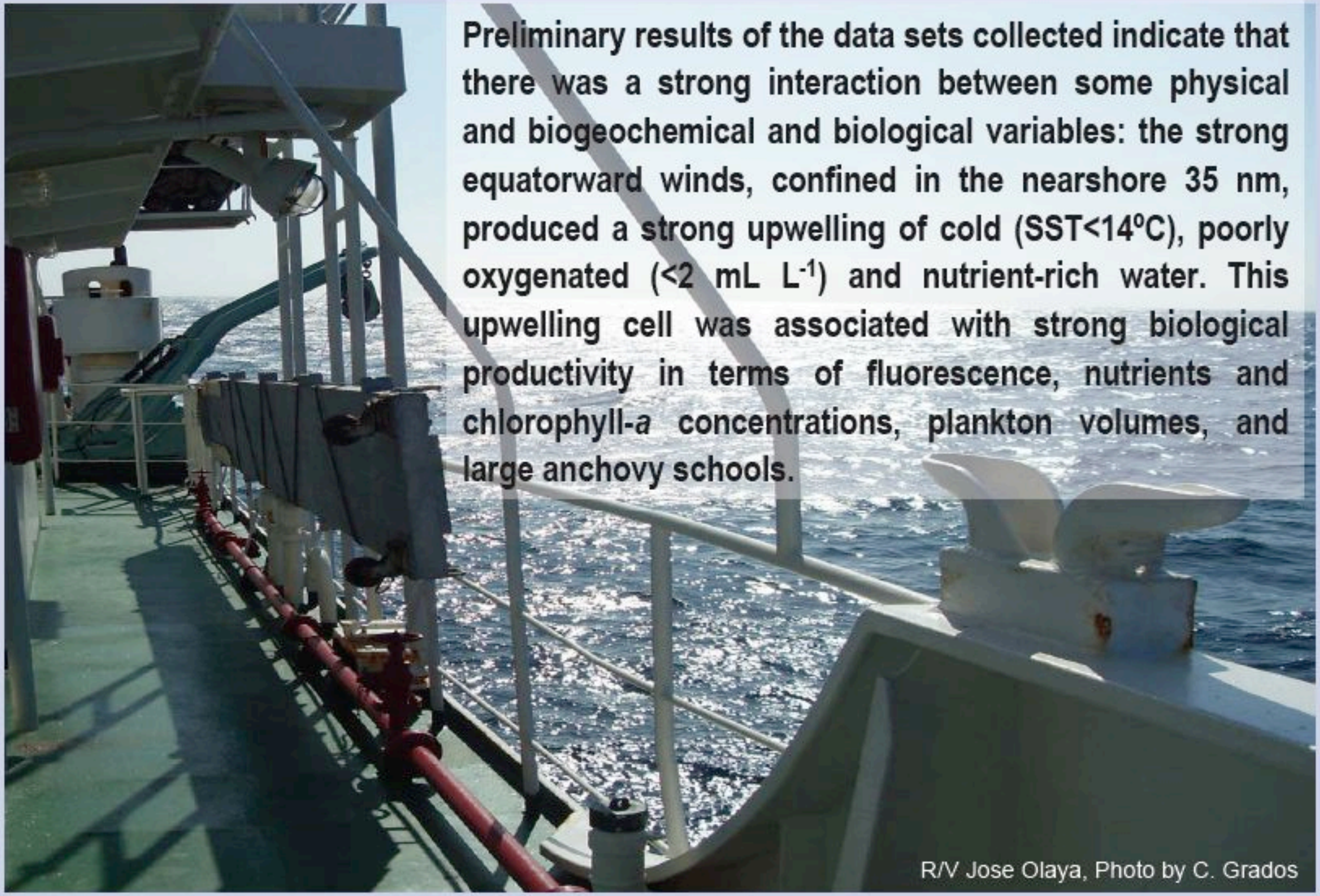


Deployment of a WOCE/SVP drifter during VOCALS cruise

Photo by C. Grados

Summary

Preliminary results of the data sets collected indicate that there was a strong interaction between some physical and biogeochemical and biological variables: the strong equatorward winds, confined in the nearshore 35 nm, produced a strong upwelling of cold (SST<14ºC), poorly oxygenated (<2 mL L^{-1}) and nutrient-rich water. This upwelling cell was associated with strong biological productivity in terms of fluorescence, nutrients and chlorophyll-*a* concentrations, plankton volumes, and large anchovy schools.



R/V Jose Olaya, Photo by C. Grados

Observations of oceanic currents structures off Southern Peru

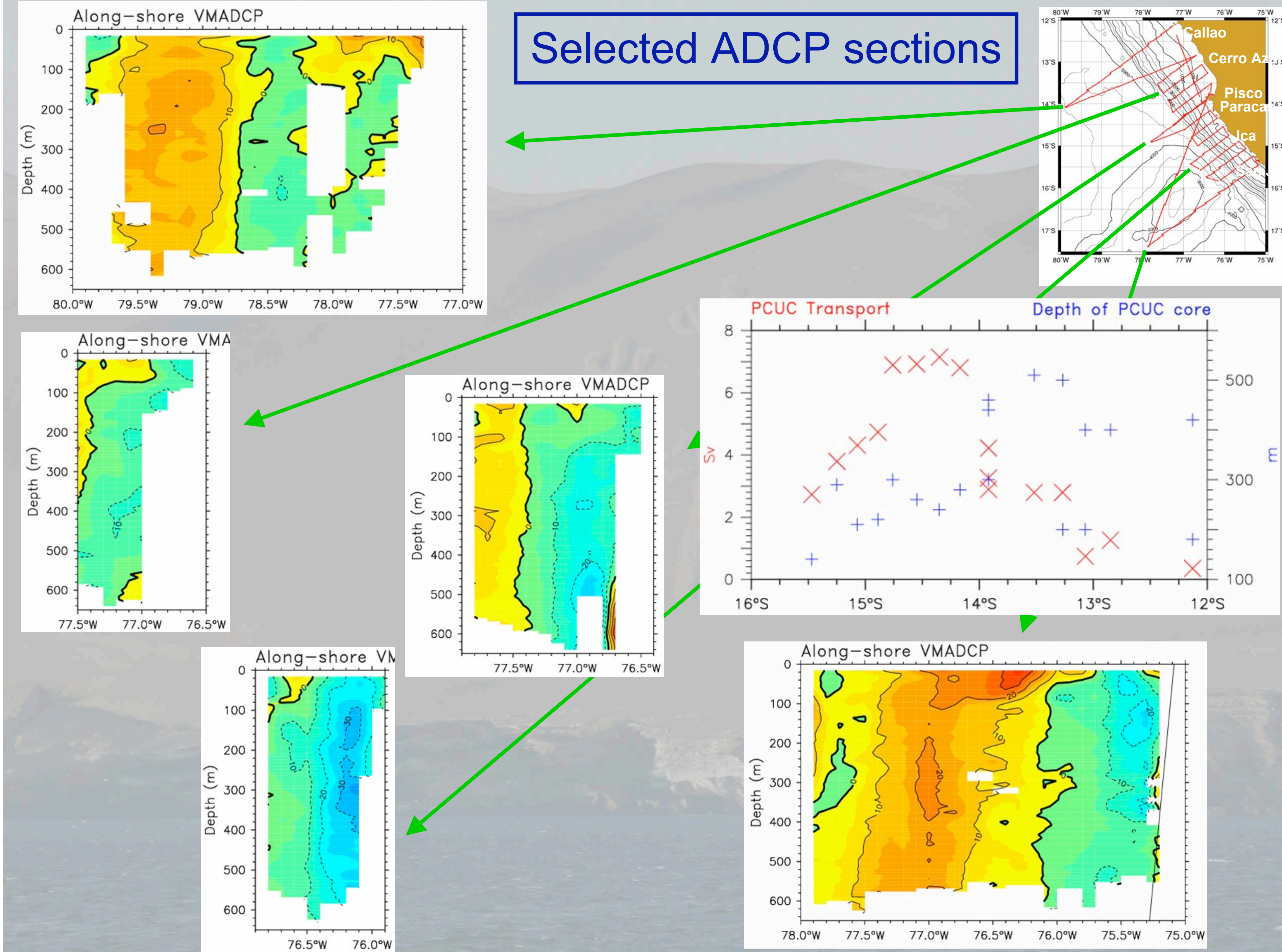
Gérard ELDIN (LEGOS, Toulouse, France)

Thanks to Carmen GRADOS and the scientific party onboard R/V José Olaya

Data presented were obtained during the VOCALS-REx cruise of R/V José Olaya:

- 03-17 October 2008
- RDI 0S-75 VM-ADCP
- 8 m bins, 10 mn averages, ~16-600 m
- CODAS3 processing software and database

Selected ADCP sections

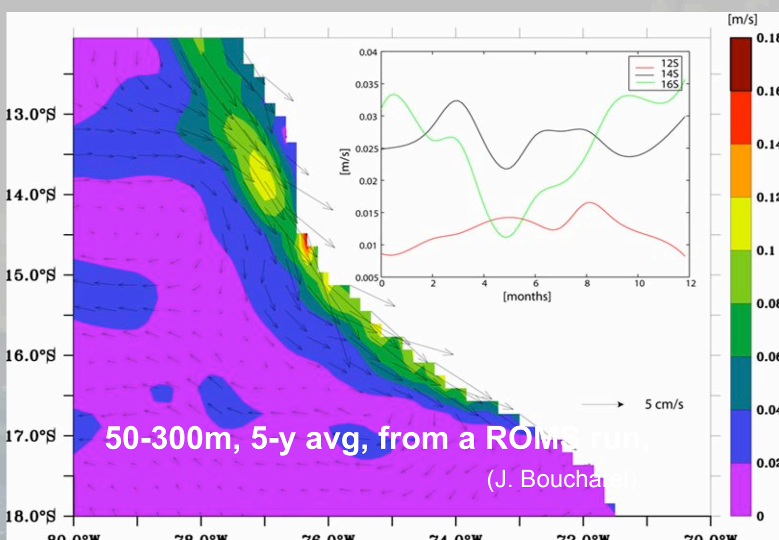


Summary

• The Peru Current and Peru-Chile Under-Current (PCUC) were the dominant features of the circulation during VOCALS-REx.

• Strong small scale variability was noted in the surface layer.

• Surface flow was mostly southward and partly non-geostrophic. Whether that flow formed an independent Peru Chile Counter Current, or was an upward extension of the PCUC is under investigation.



• Strong spatial/temporal variability in PCUC transport and core location were observed. Model results confirmed such a variability, even at moderate resolution.