Glider deployments in the Peruvian upwelling system: from process studies to coastal monitoring

A. Pietri, F. Colas, , V. Echevin, D. Correa,
D. Gutierrez, J.-L. Fuda, P. Testor, N.Dominguez

La Seyne, September 9st, 2019

LOCEAN

INSTITUTO DEL MAR DEL PERU
CIENCIA Y TECNOLOGIA

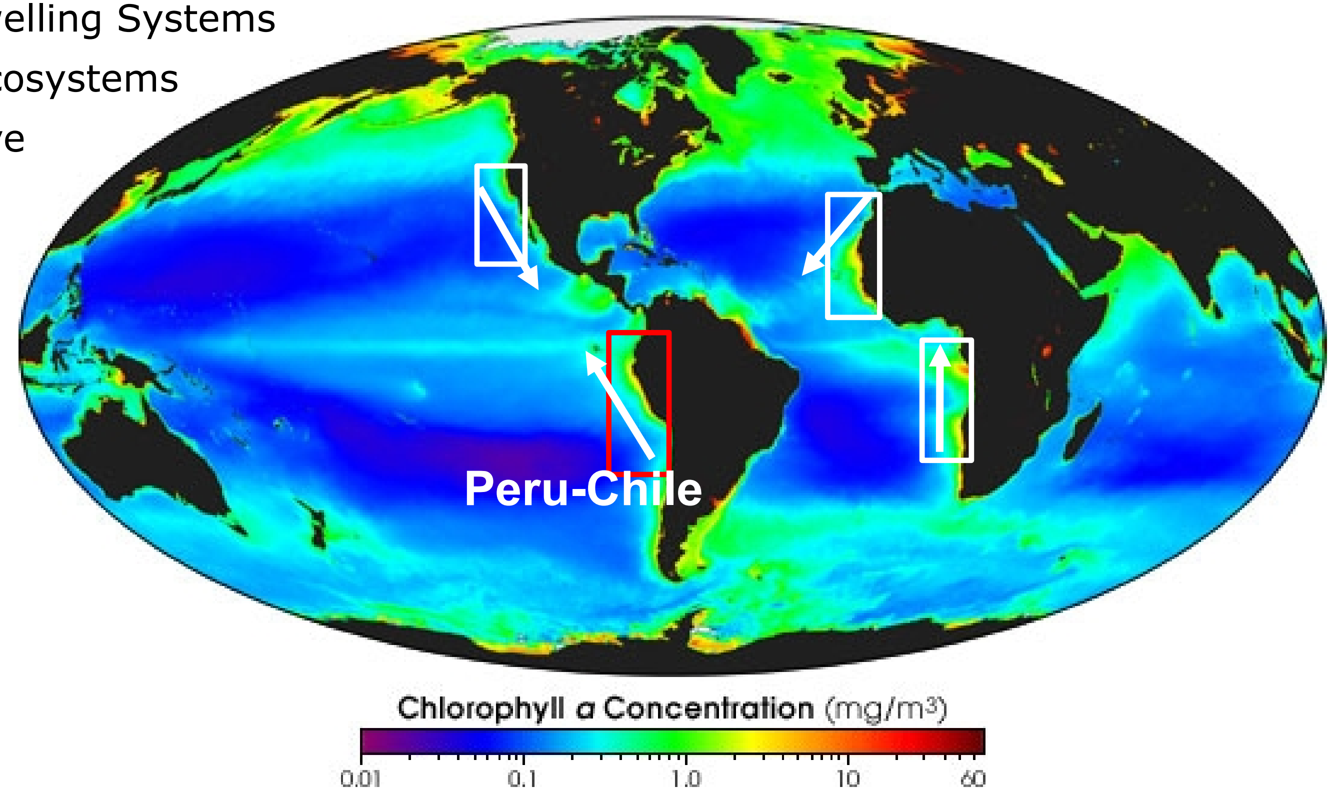
IRD
Institut de Recherche pour le Développement

Dynamics of the Humboldt Current system
DISCOH

The Peru-Chile eastern boundary upwelling system

Four Eastern Boundary Upwelling Systems

- Very productive coastal ecosystems
- Peru is the most productive



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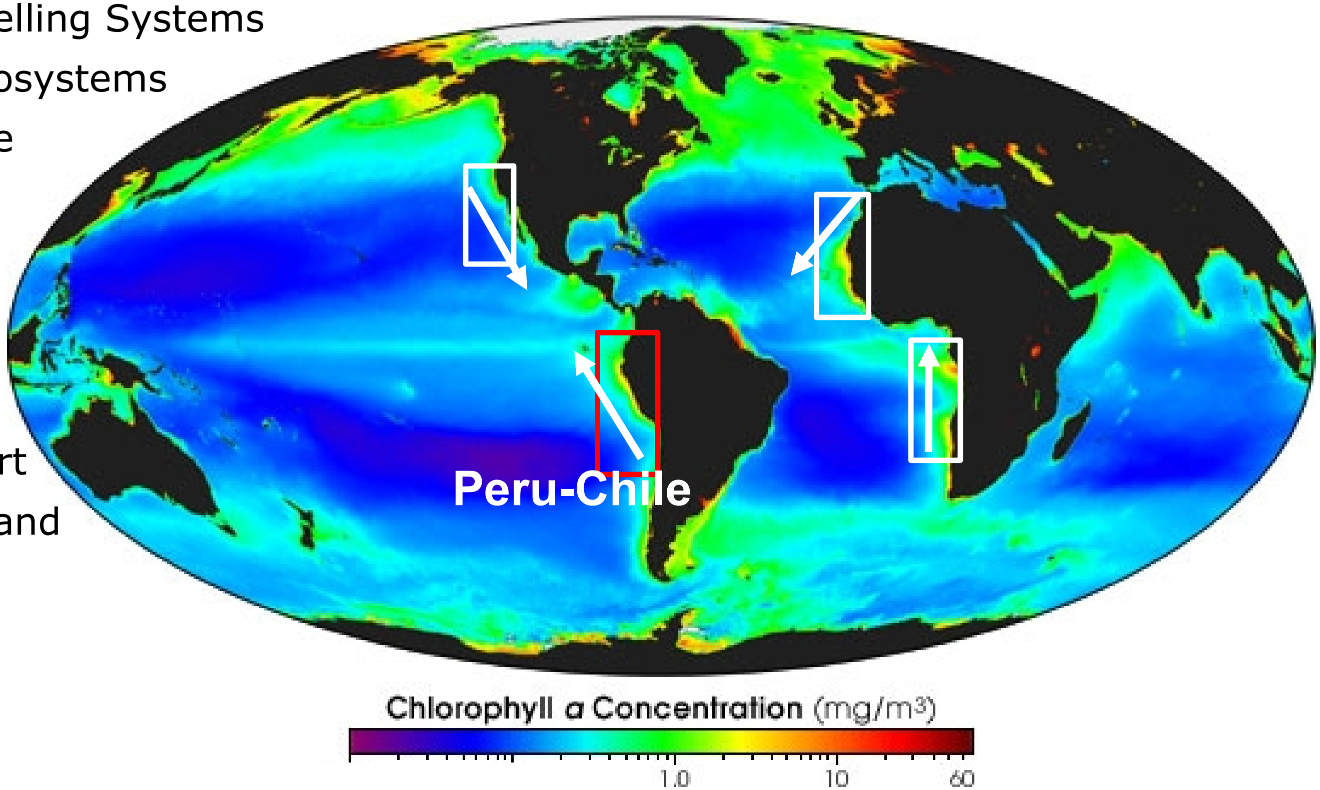
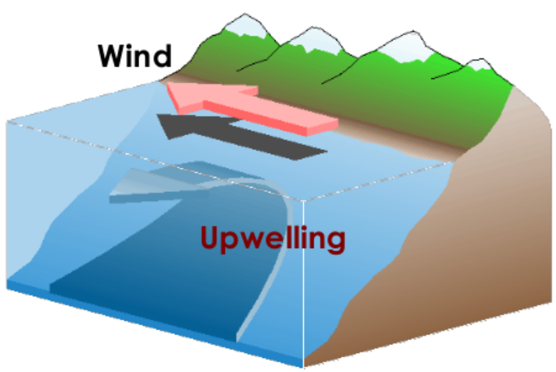


- Wind parallel to the coast

→ Offshore surface transport

→ coastal upwelling of cold and nutrients-rich water



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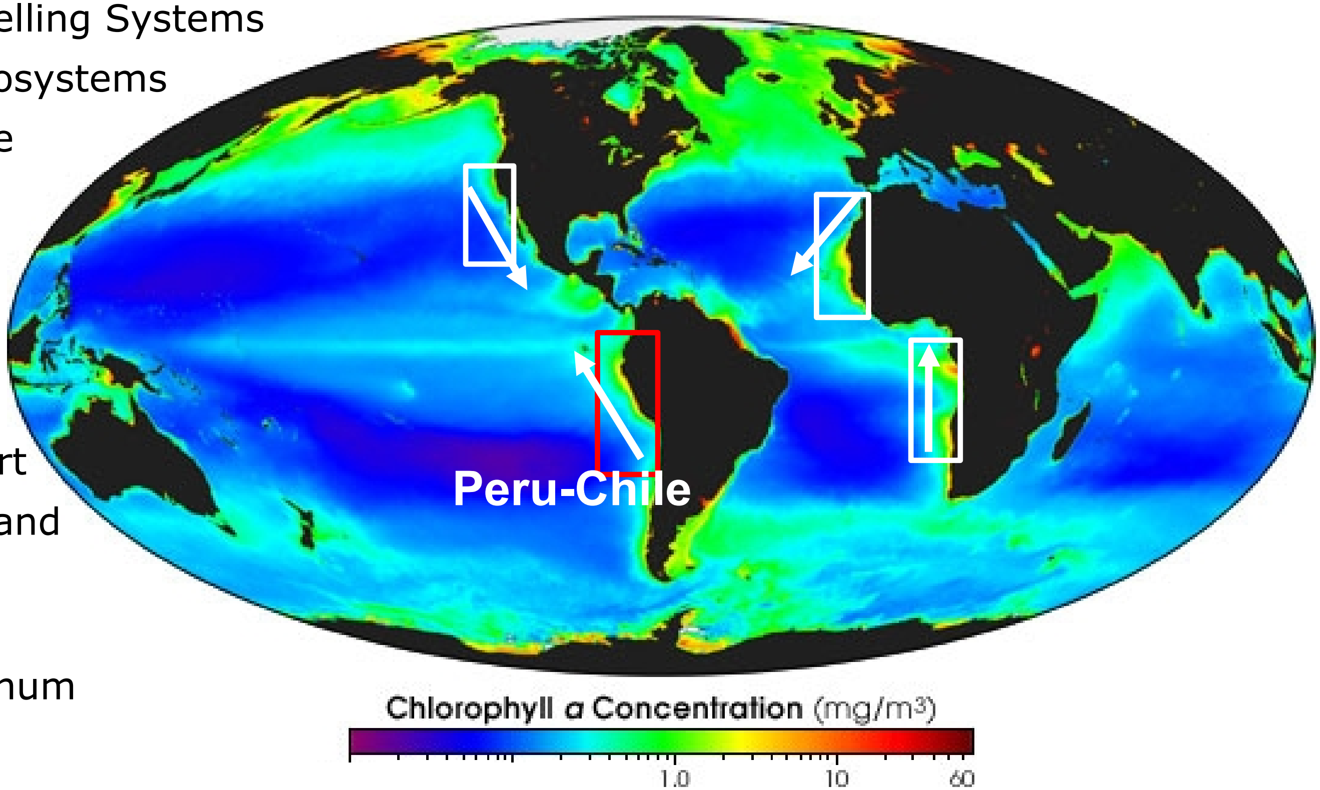

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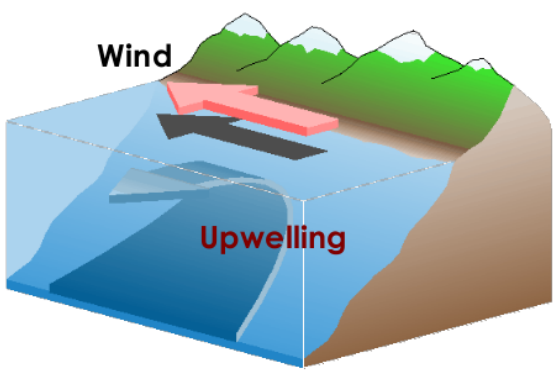
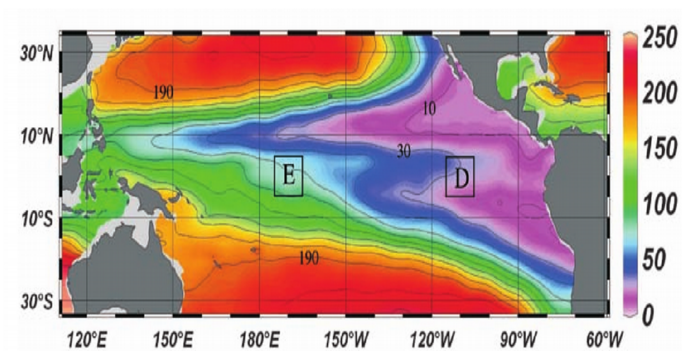
→ coastal upwelling of cold and nutrients-rich water

- Very intense oxygen minimum zone (shallow oxycline)





(Dissolved Oxygen – 400m depth; Stramma et al. 2008)

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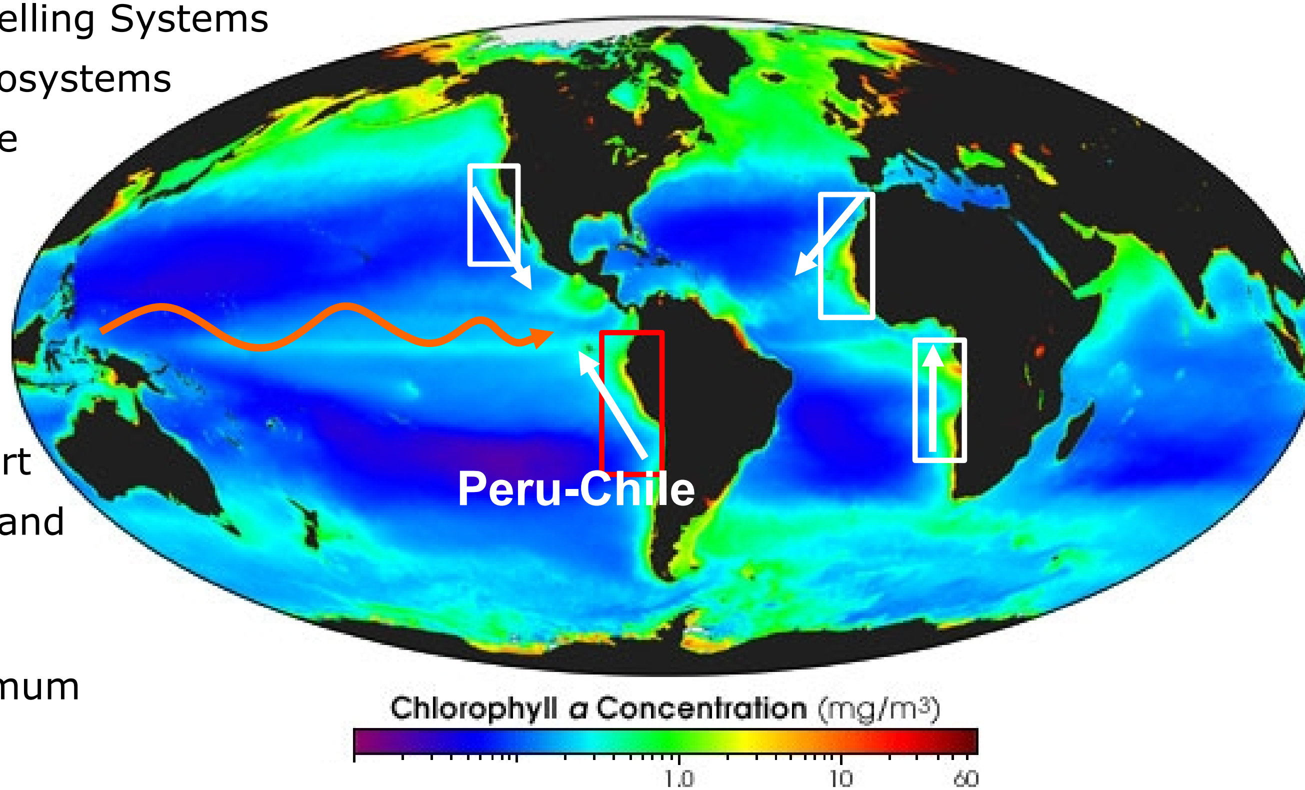
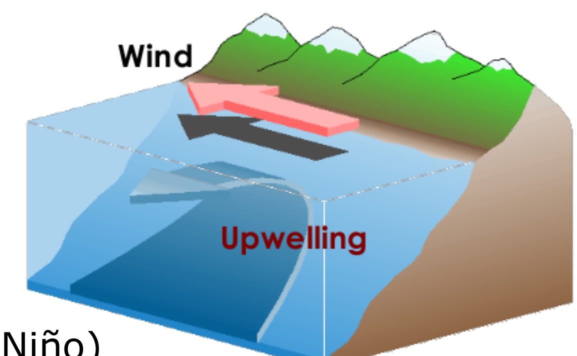
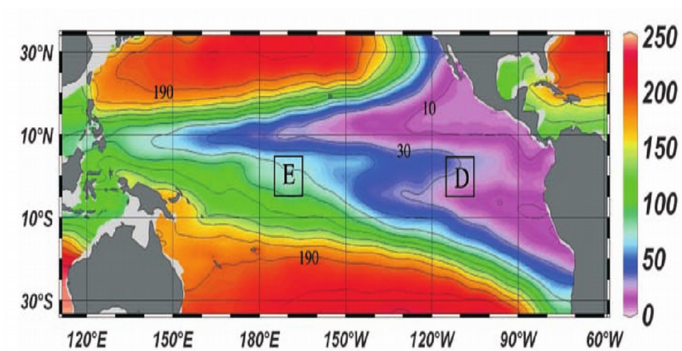


- Wind parallel to the coast
→ Offshore surface transport
→ coastal upwelling of cold and nutrients-rich water

- Very intense oxygen minimum zone (shallow oxycline)

- Direct connection with equatorial Pacific (Waves and Currents)
→ strongly impacted by equatorial variability at interannual time scale (El Niño)





(Dissolved Oxygen – 400m depth; Stramma et al. 2008)

Gliders to survey boundary currents

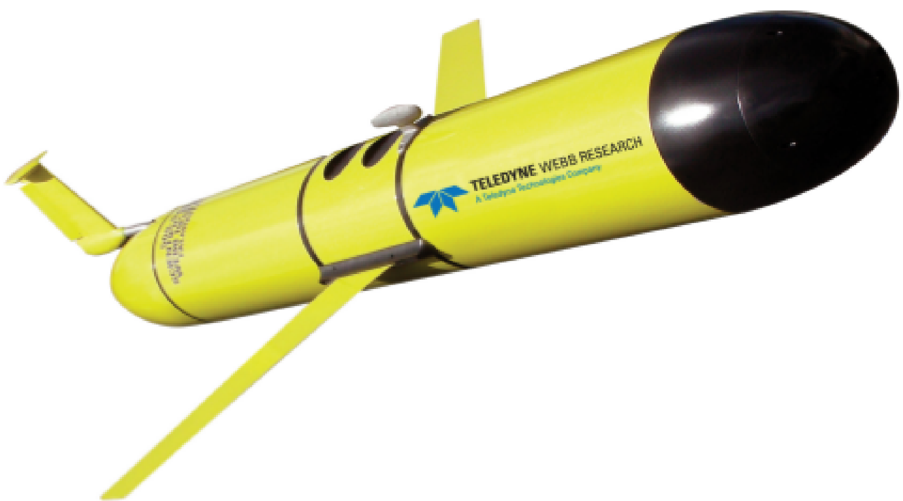
Gliders are the ideal tool to connect the coast and open ocean :

• Gliders missions can be sustained indefinitely

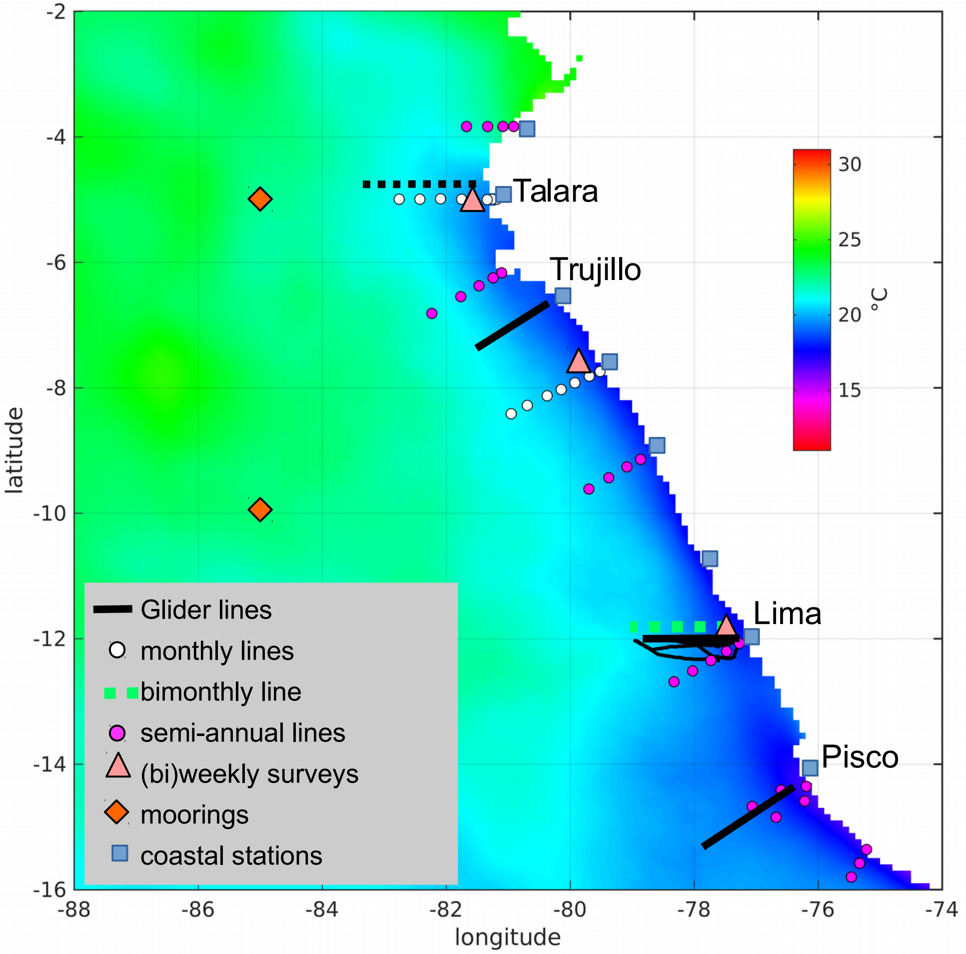
• Glider sampling is a good match to the resolution needed in boundary currents (~ 1-2 km)

• Gliders record physical and biogeochemical parameters

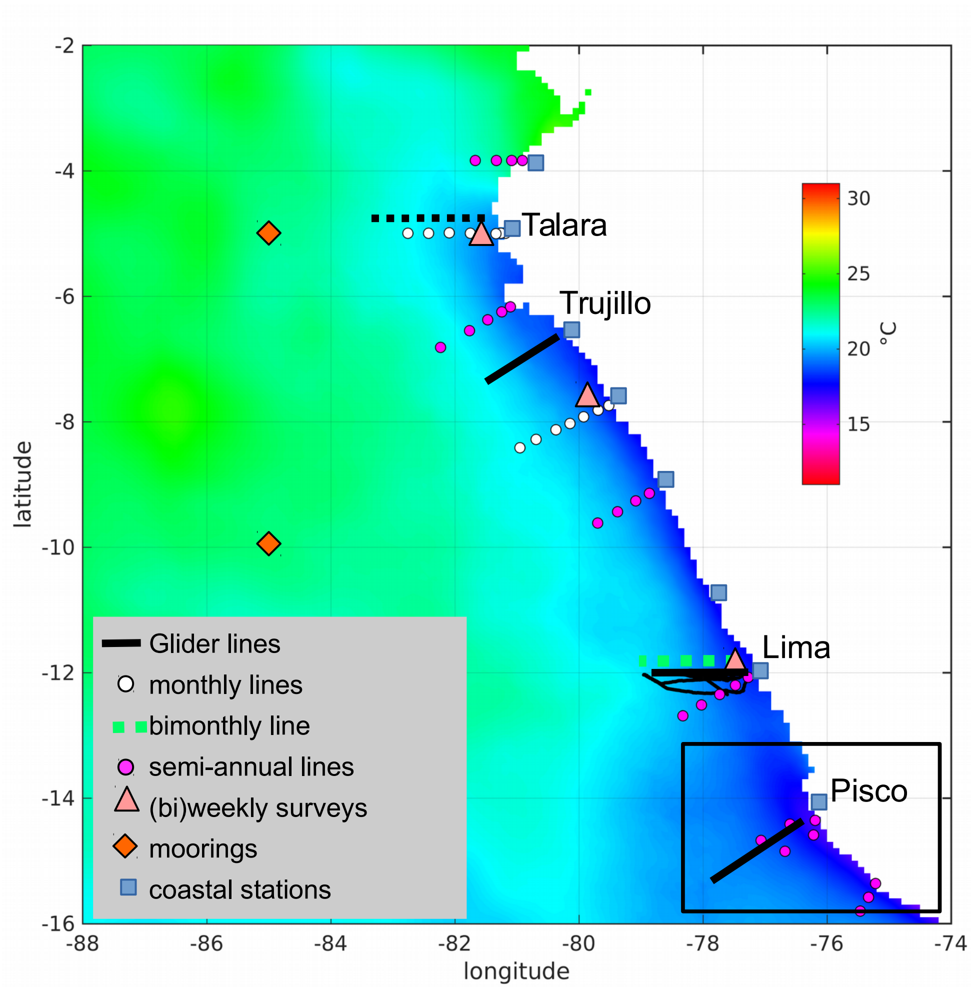
• Gliders are well suited for coastal survey since they can be easily deployed from small boats



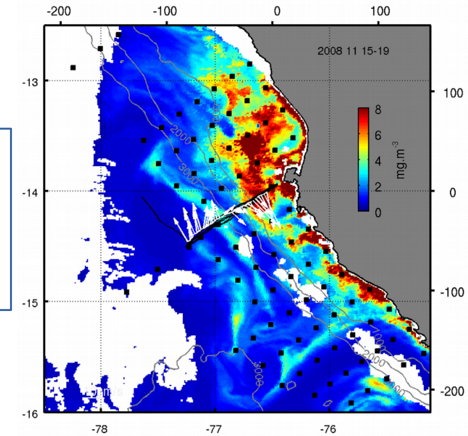
Observing systems off Peru



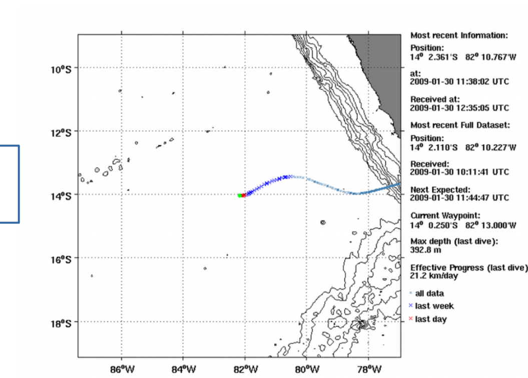
Glider deployments off Peru: Pisco



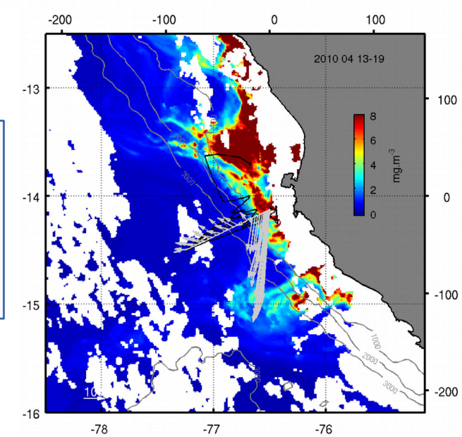
Pytheas: **Nov 2008**
Submesoscale strucutres
(Pietri et al. 2013)



Ifm 07 **Jan 2009**



- Nearchos: **Apr 2010**
Coastal trapped wave
(Pietri et al. 2014)



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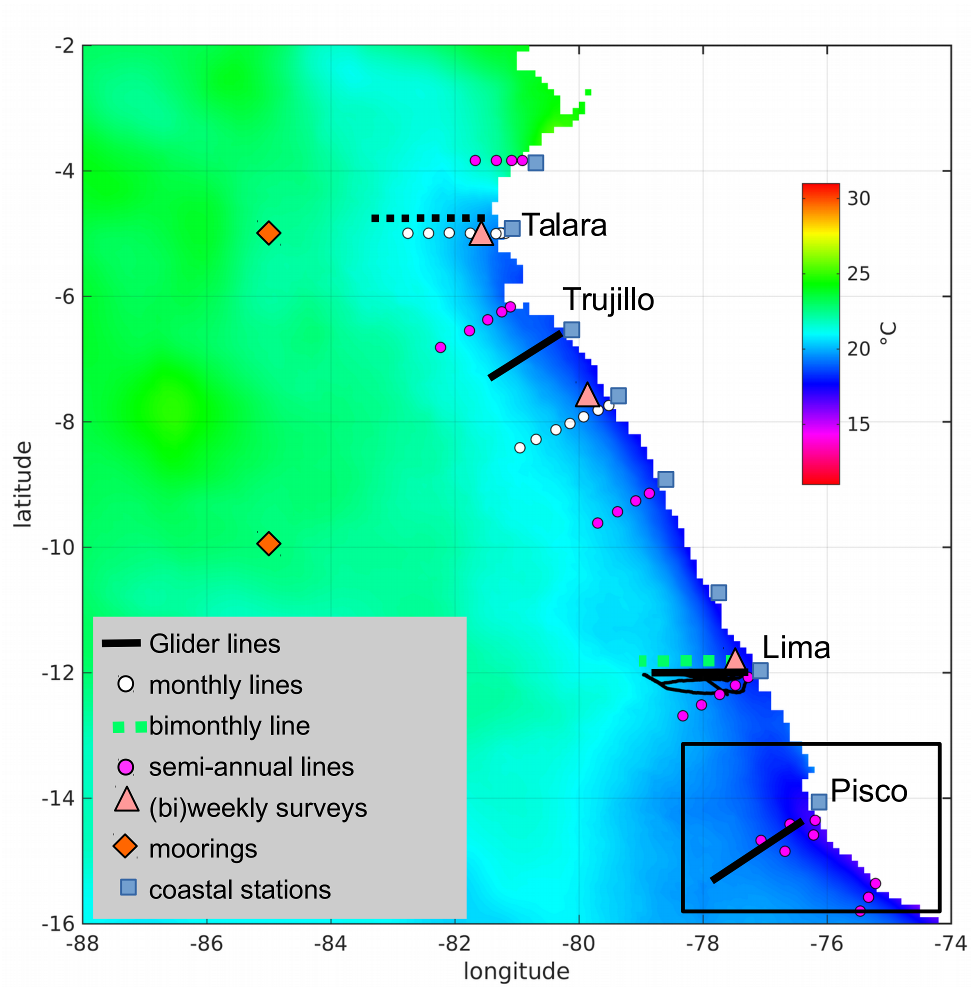

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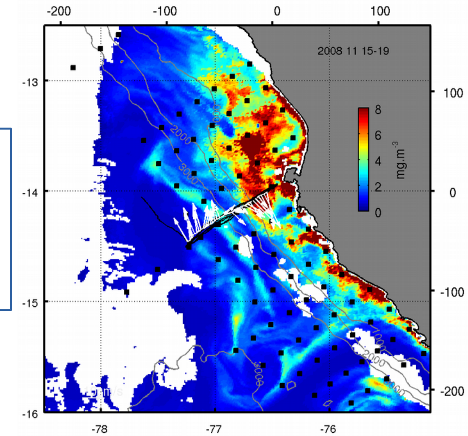

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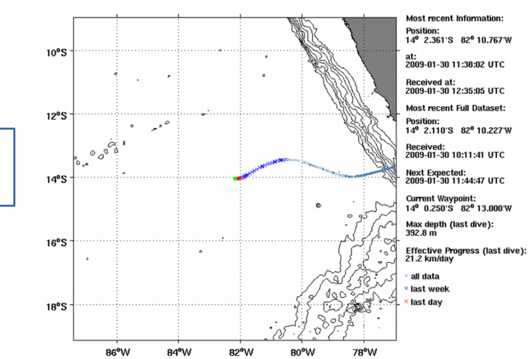

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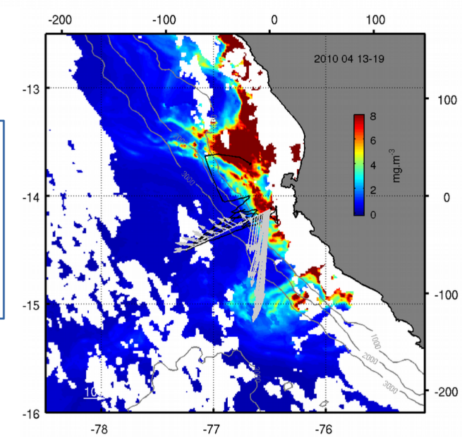
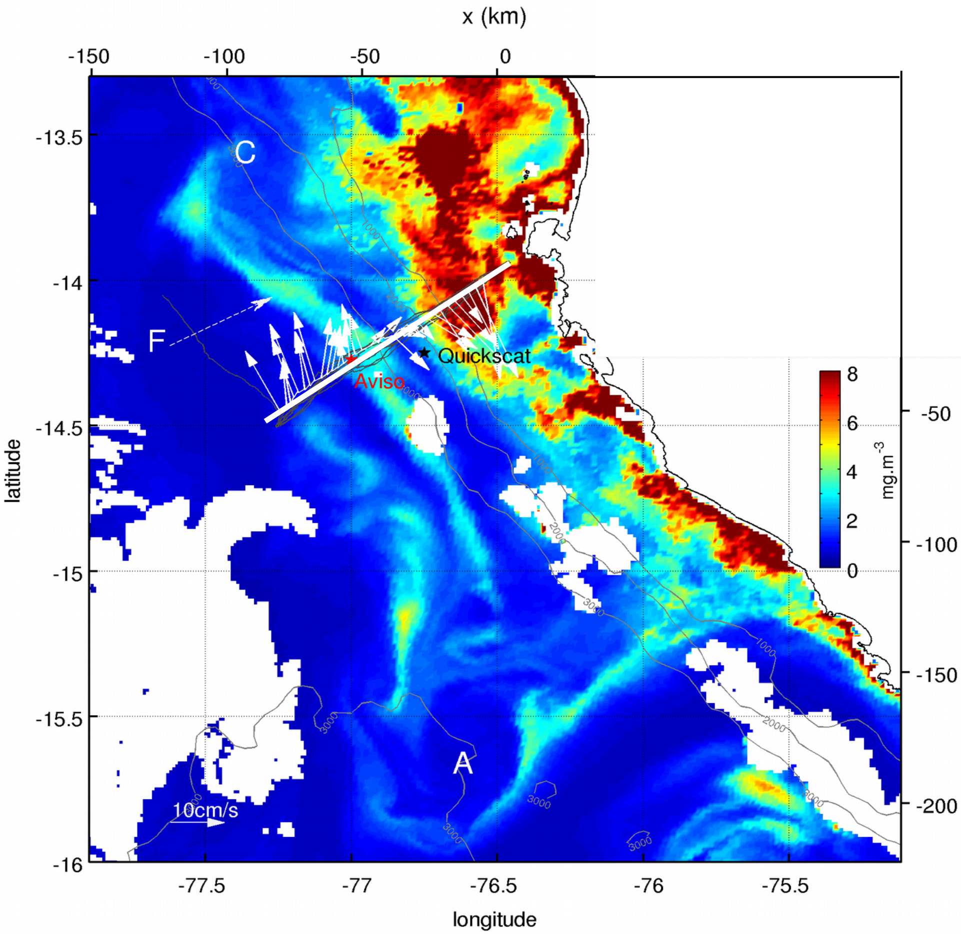
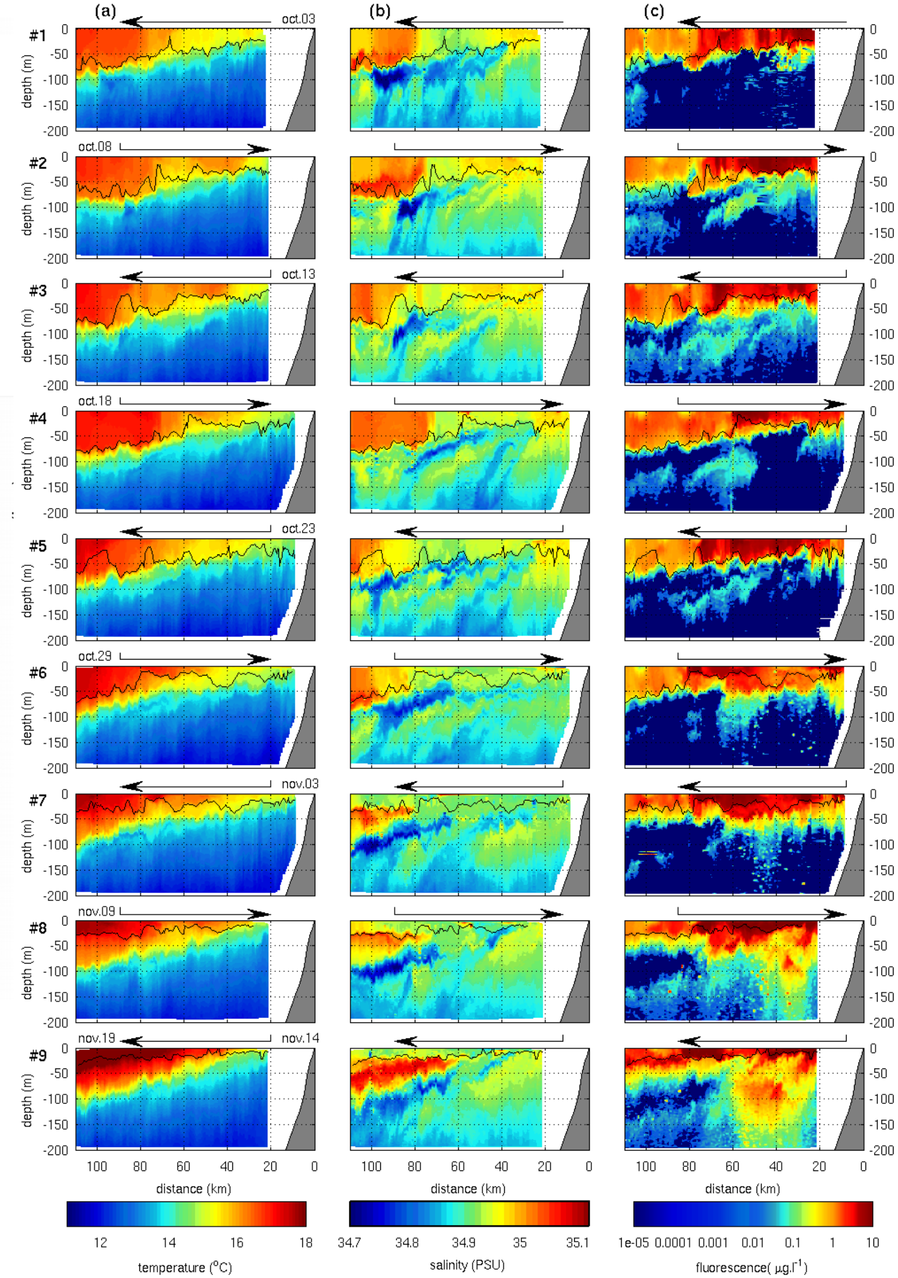


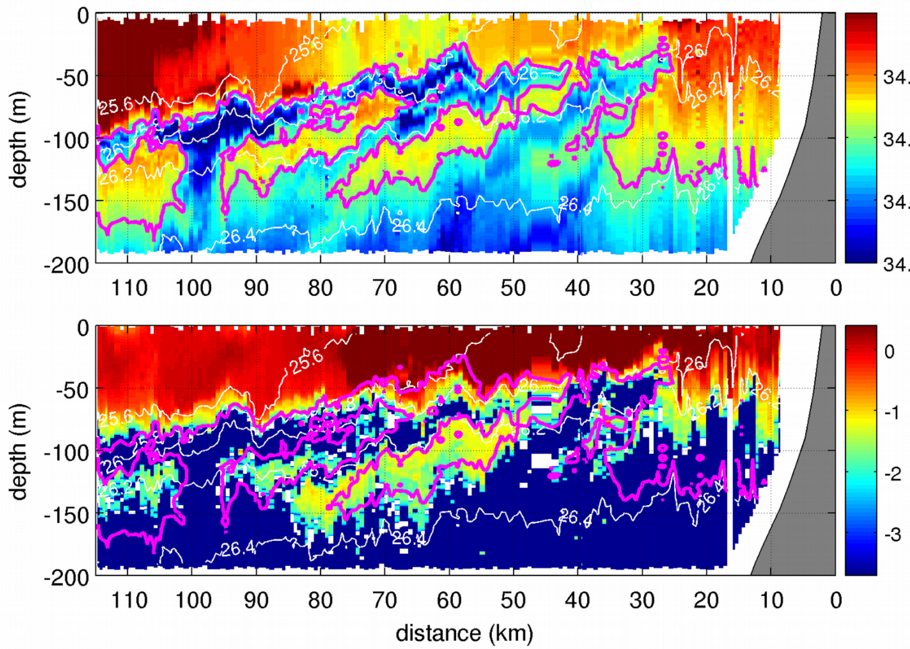
Submesoscale activity: October 2008

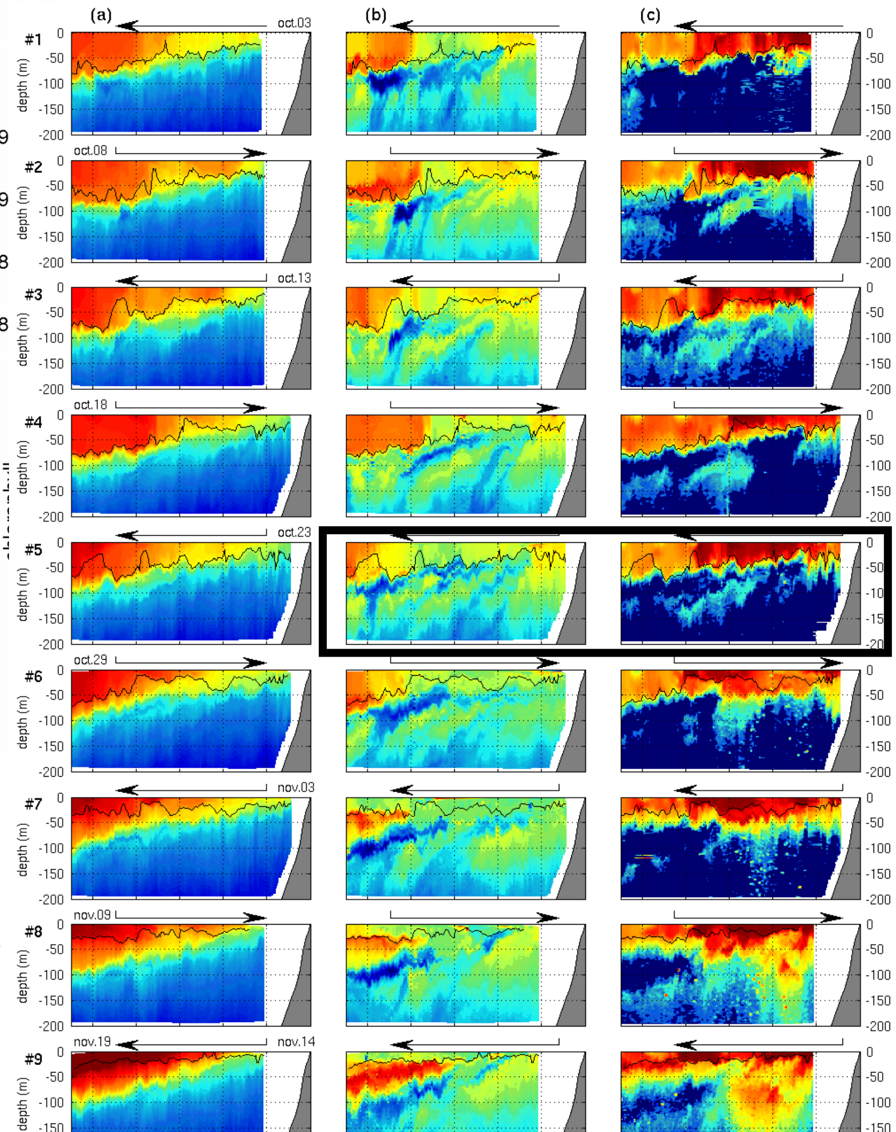




Pytheas:
- 03 Oct – 19 Nov
- 9 sections (~100 km*200m), 1400 profiles
- T, S, O², Chl

Submesoscale activity: October 2008





→ Cross-isopycnal submesoscale thermohaline and chlorophyll intrusions at 50-150 m depth between the coastal upwelling area and the open sea

→ Several structures generally at a distance of 20–40 km were observed on each section which suggest an important process for the repartition of physical and biogeochemichal properties

→ Vertical fluxes could not only enhance phytoplankton growth due to upwelling of subsurface nutrients into the euphotic layer, but also decrease the surface biomass due to submesoscale downwelling

Pietri, A., P. Testor, V. Echevin, A. Chaigneau, L. Mortier, G. Eldin and C. Grados (2013), *Finescale Vertical Structure of the Upwelling System off Southern Peru as Observed from Glider Data*, J. Phys. Oceanogr., 43, 631–646.

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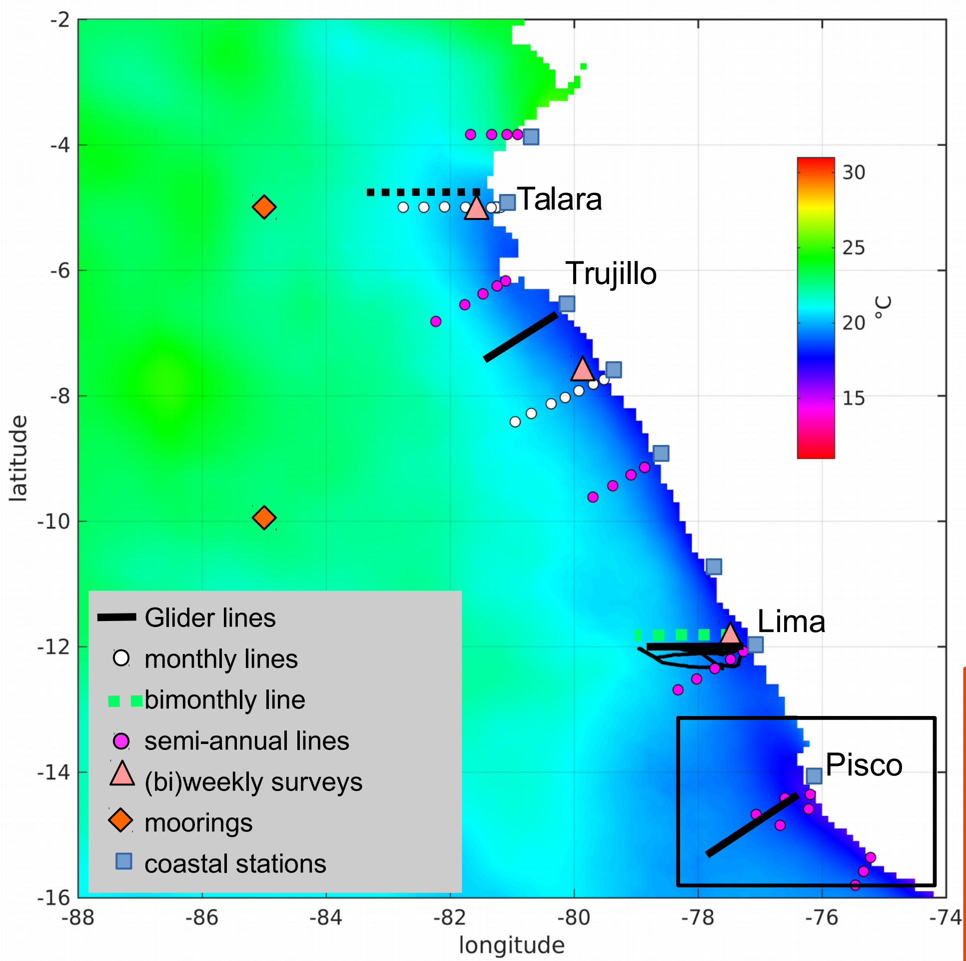

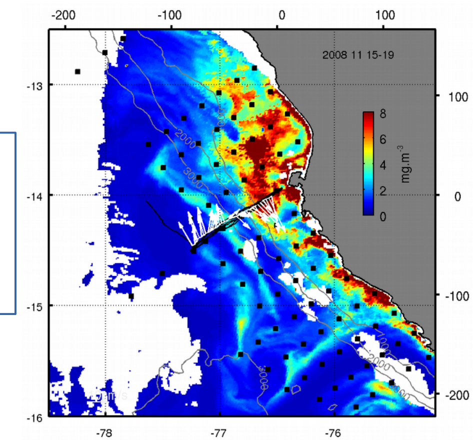

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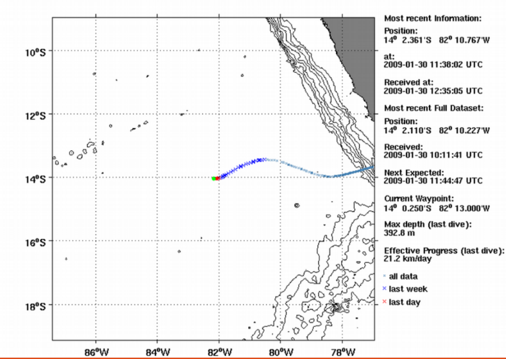

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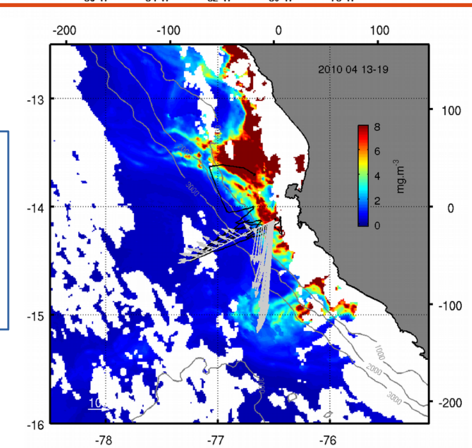


- Nearchos: **Apr 2010**
Coastal trapped wave
(Pietri et al. 2014)

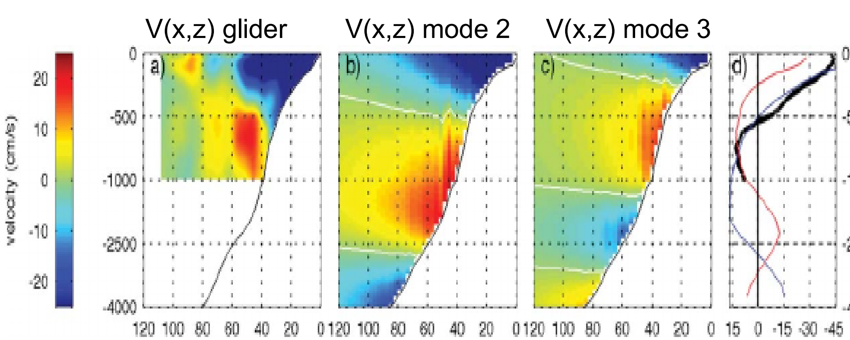
Coastal trapped wave: April 2010

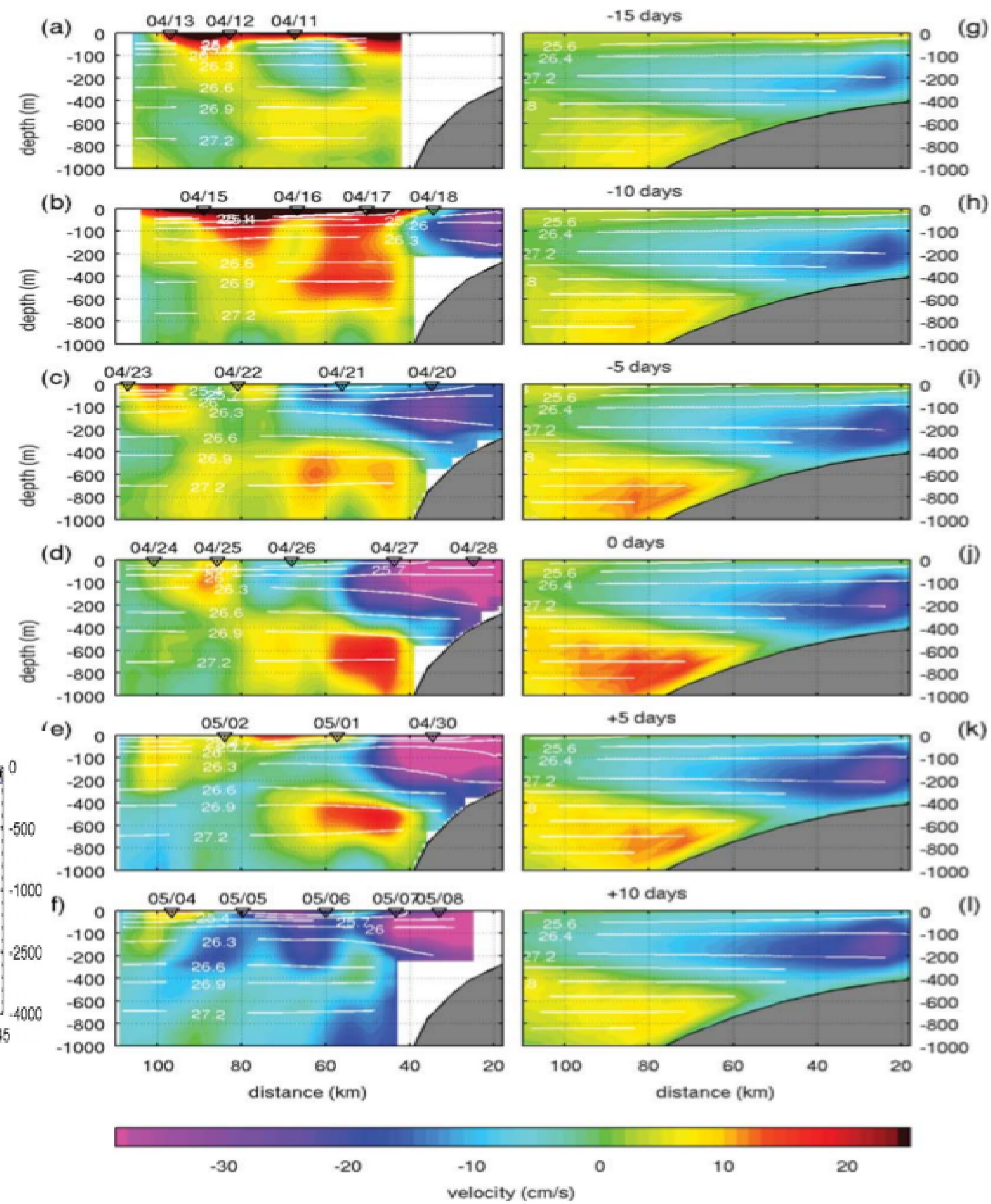
Model composite:

- ROMS-AGRIF, 1/9° (~12km), (Echevin et al., 2013)
- 16 events over 6 years

CTW attributes:

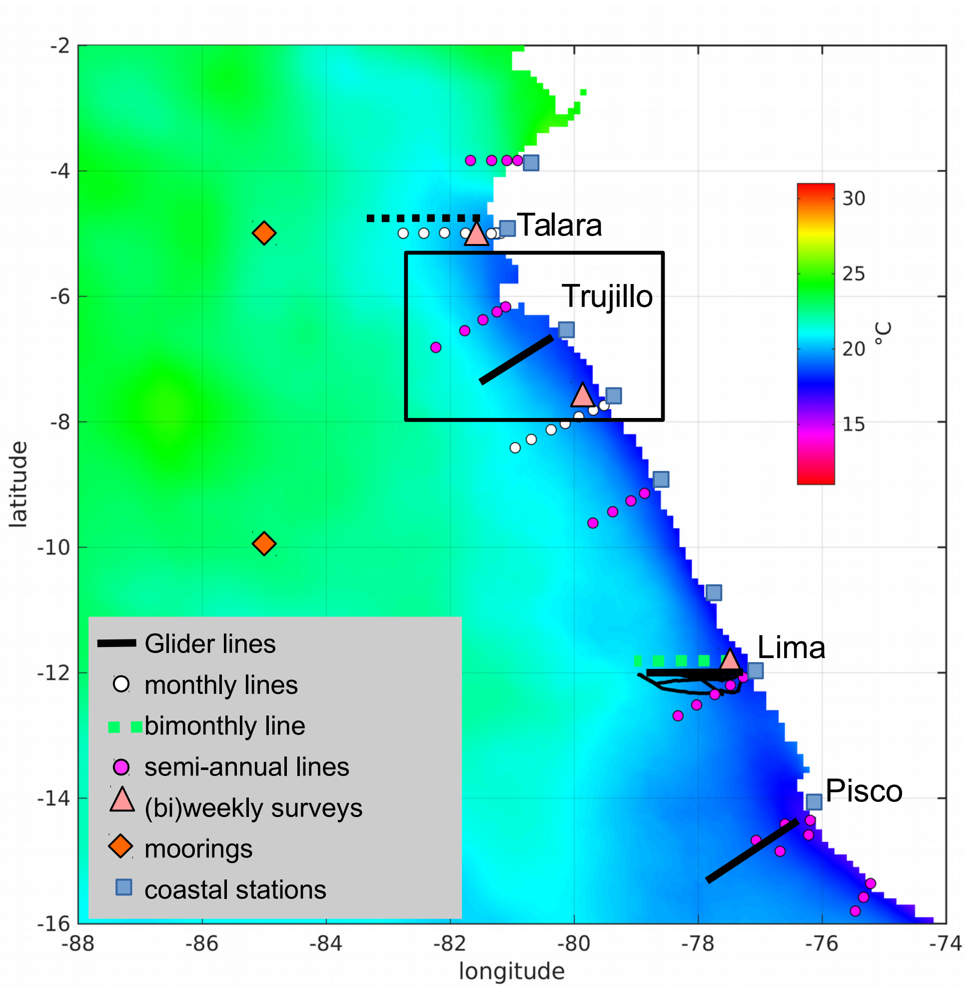
- time scale of ~70 days
- propagation speed along the coast at 700 of ~1.2 m/s
- mix between mode 2 and mode 3



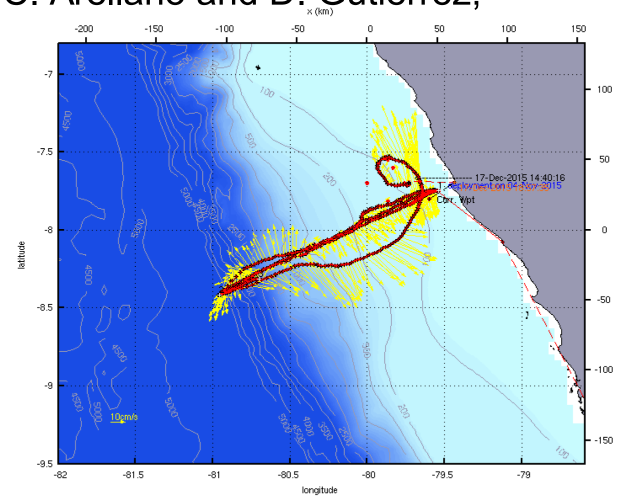


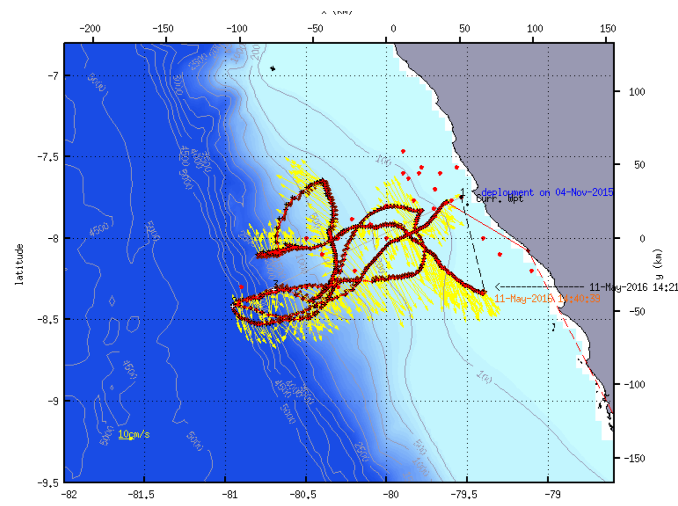
Pietri, A., V. Echevin, P. Testor, A. Chaigneau, L. Mortier, C. Grados, and A. Albert (2014), *Impact of a coastal-trapped wave on the near-coastal circulation of the Peru upwelling system from glider data*, J. Geophys. Res., 119, 2109–2120.

Glider deployments off Peru: Trujillo

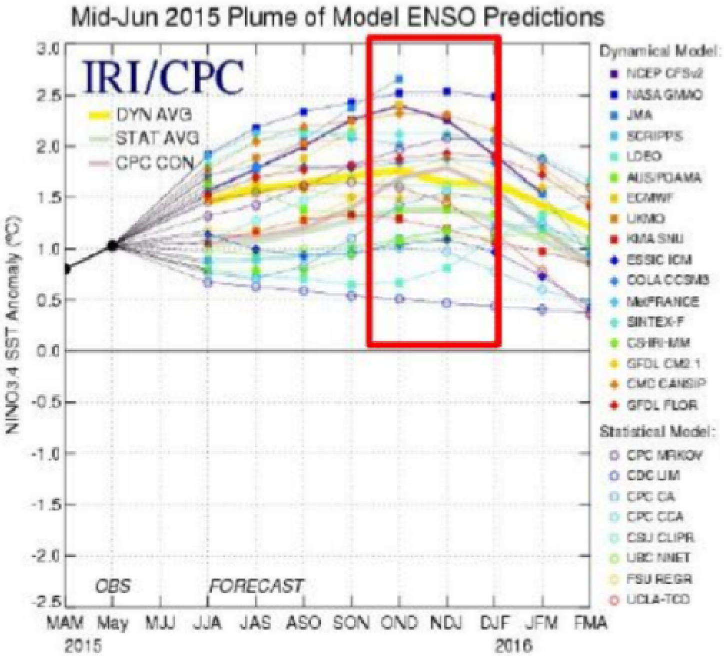


2015-2016 El Niño:
Tenuse (Dec 2015) and Bonpland (Mar 2016)
François Colas, V. Echevin, D. Correa, D. Espinoza, M. Campos, H. Demarcq, A. Chamorro, C. Arellano and D. Gutierrez,





Observing and modelling the 2015/2016 El Niño at higher resolution



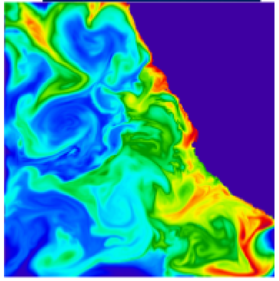
June 2015

Expectations for an extremely intense El Niño event, with maximum anomaly near the end of 2015

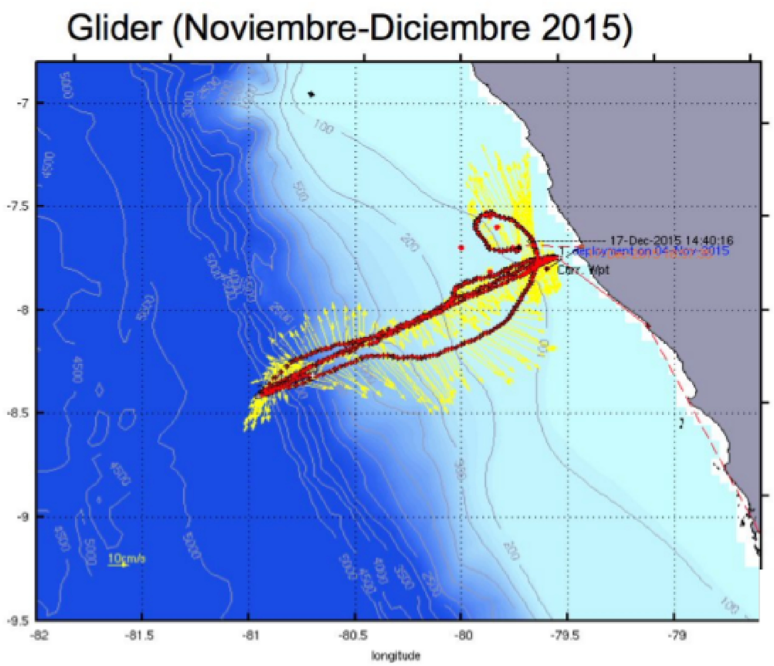
To complement IMARPE's measurements (oceanographic cruises, ~ 2 months) : "Cienperu Project" (IRD-IMARPE)

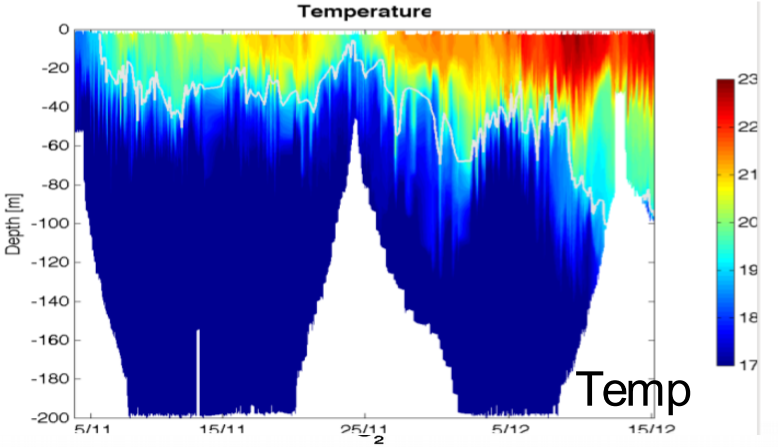
- Deployments of 2 gliders off 8°S : Nov-Dec 2015 and March-April 2016
- Deployments of 6 ARGO floats (T/S floats)
- Coastal sensors of temperature and salinity
- Regional model : ROMS-PISCES nested domains : 10 - 2.5 km (2008-2016)

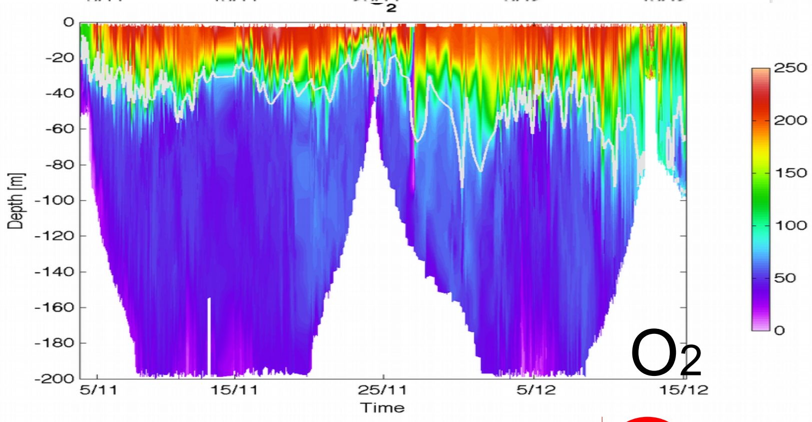
  Nested domain at 700 m resolution (ROMS only; 2013-2015)

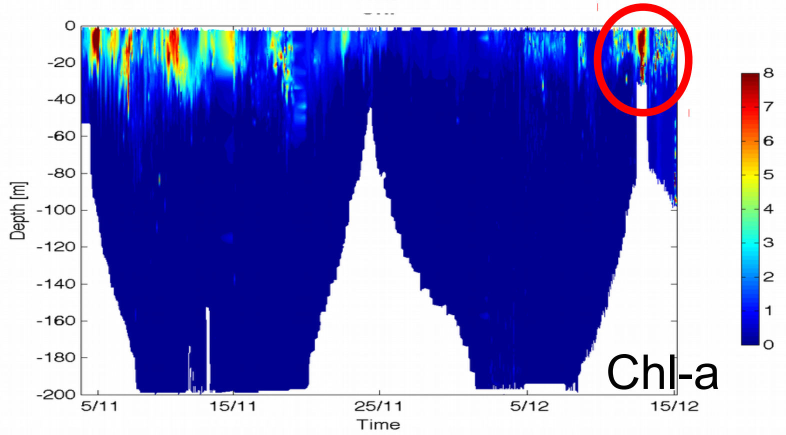


Glider off 8°S Nov-Dec 2015









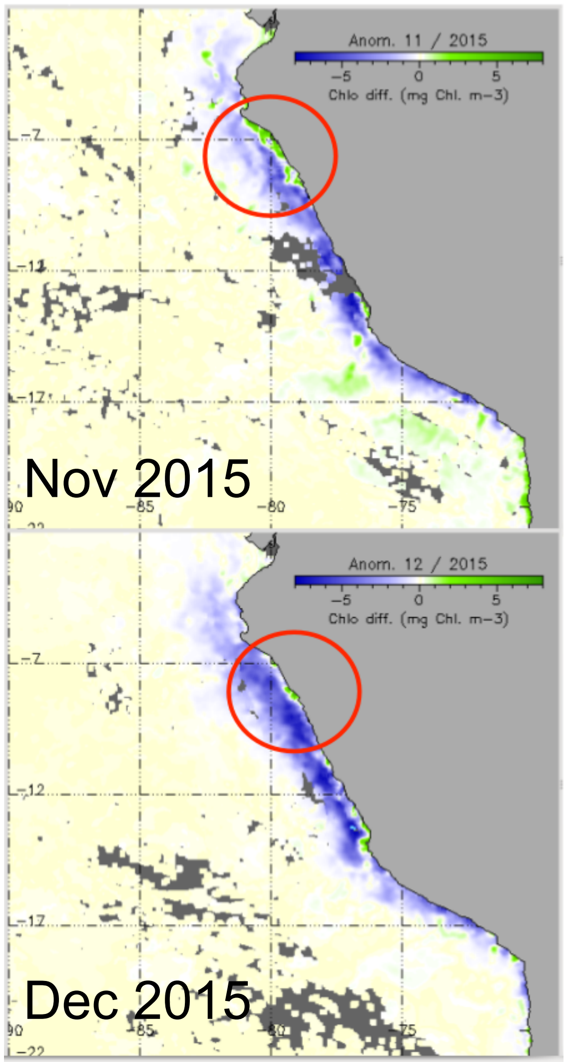
Warm anomaly intensifies end of november / early december

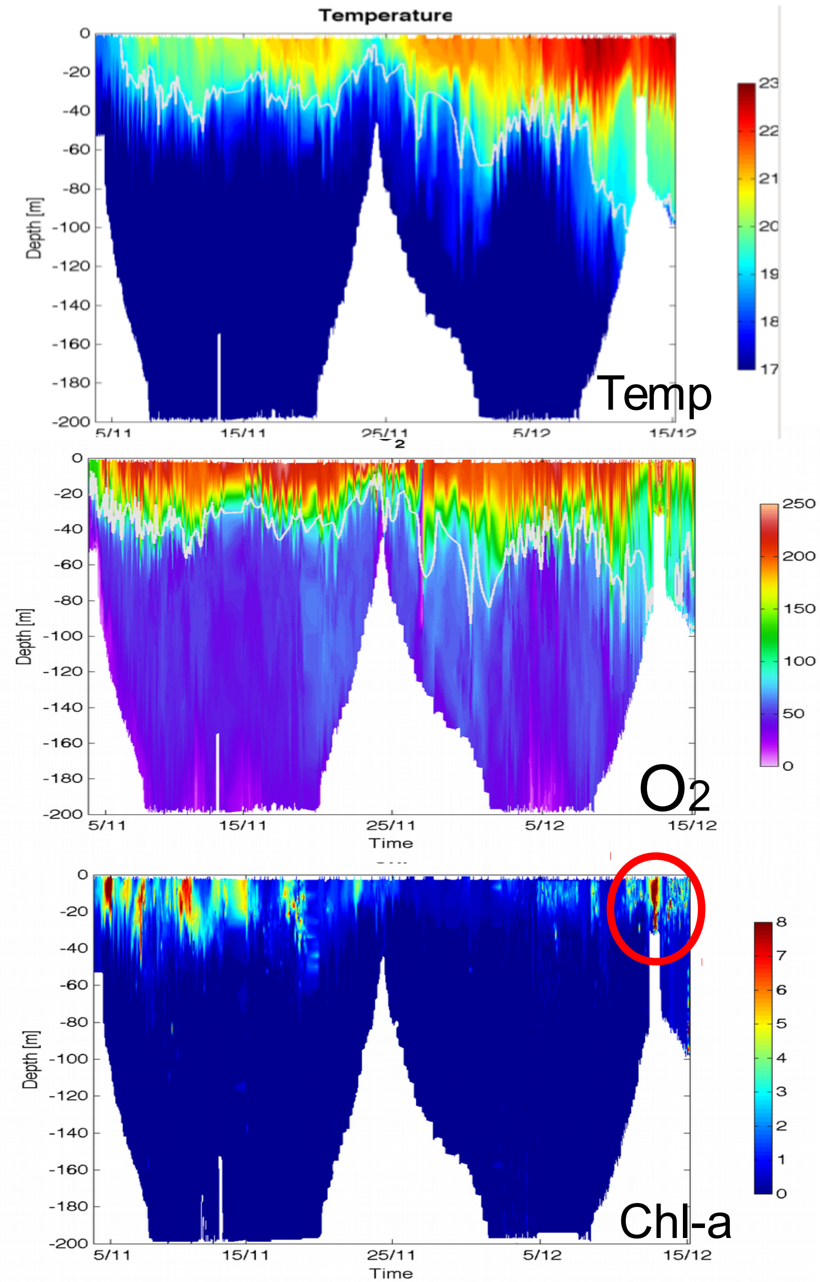
Thermocline and oxycline deepening

(and nutricline; Imarpe cruise)

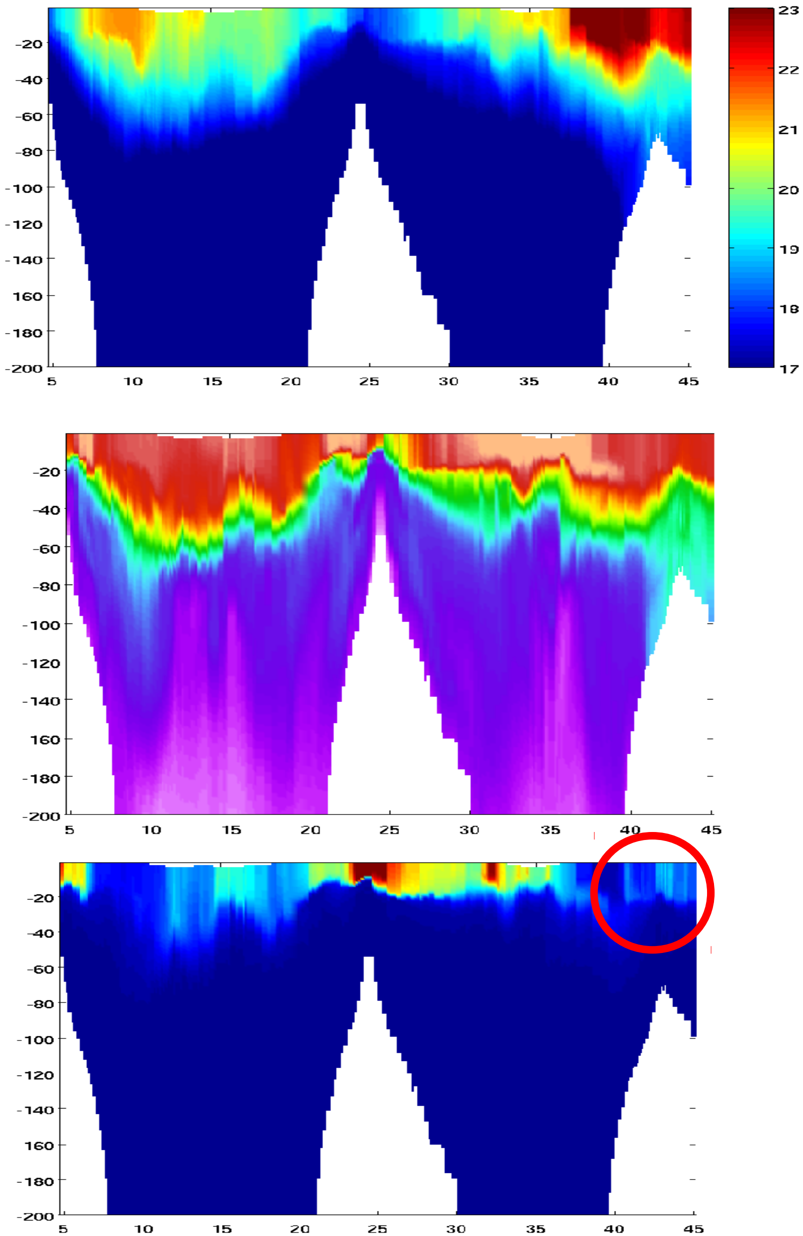
Glider off 8°S Nov-Dec 2015

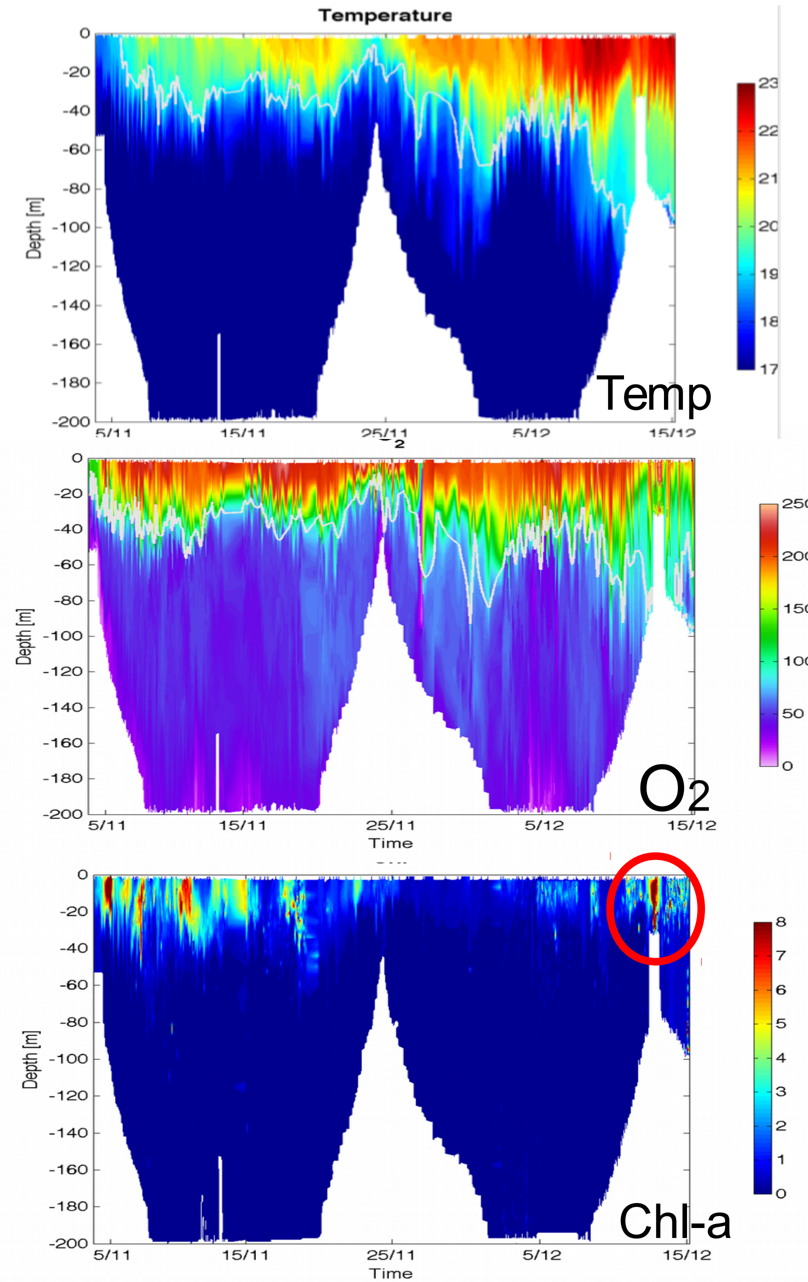
Observations SeaWifs Chl
Monthly anomaly (2003-2015 clim)



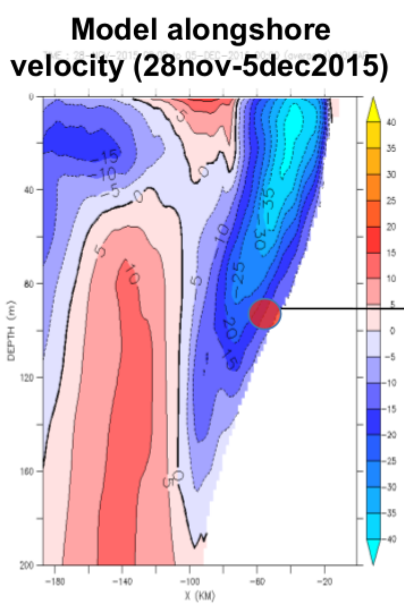


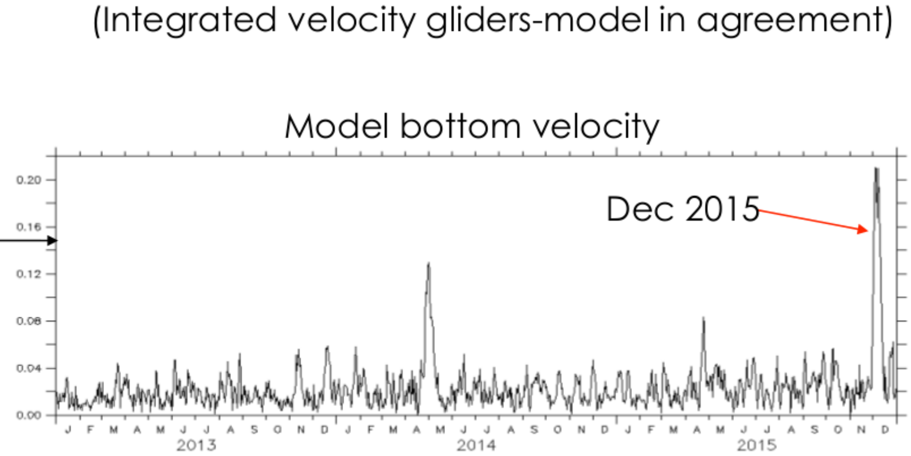
Regional model results : Croco-Pisces





Could it be sediment resuspension?

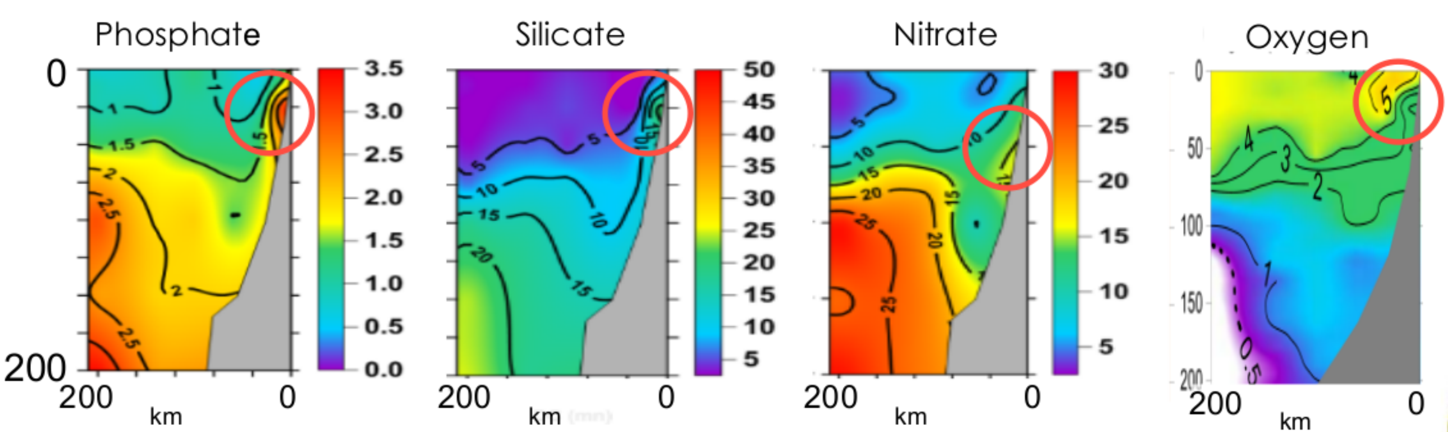




→ Intense bottom velocity

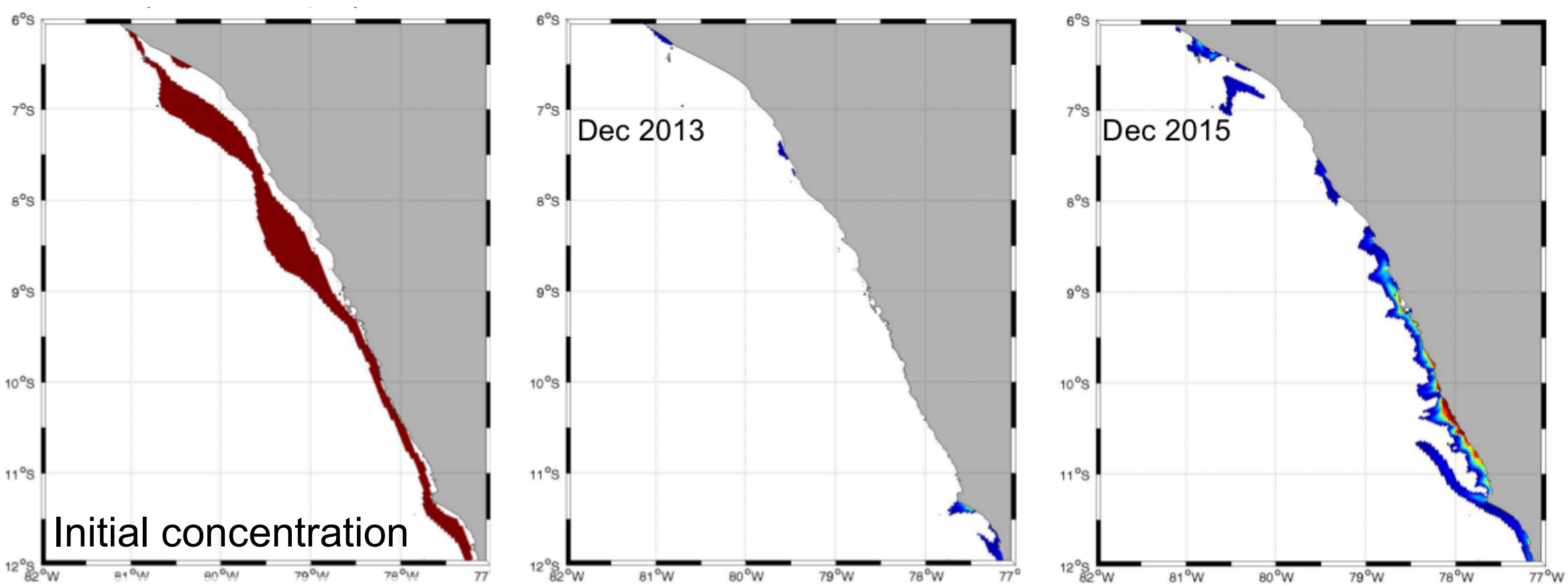
→ missing nutrient fluxes

IMARPE ship section (17-18 Dec) :



Could it be sediment resuspension?

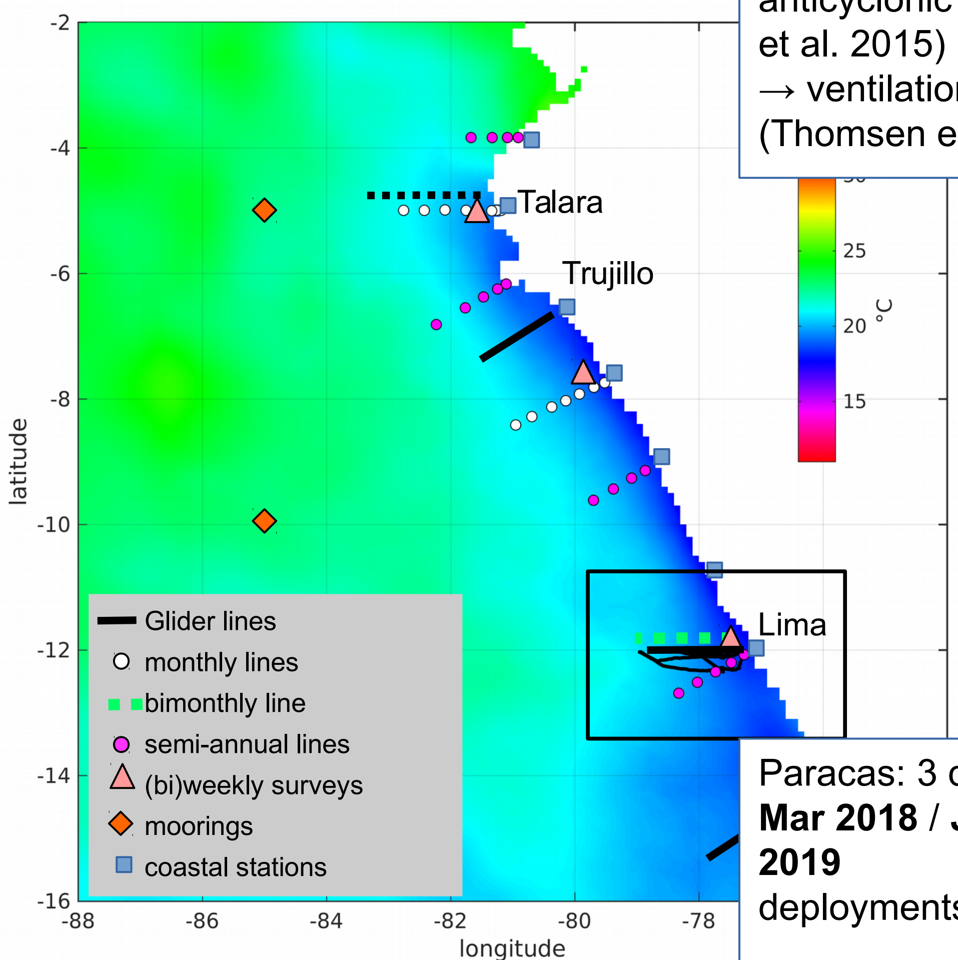
Passive tracer experiment :



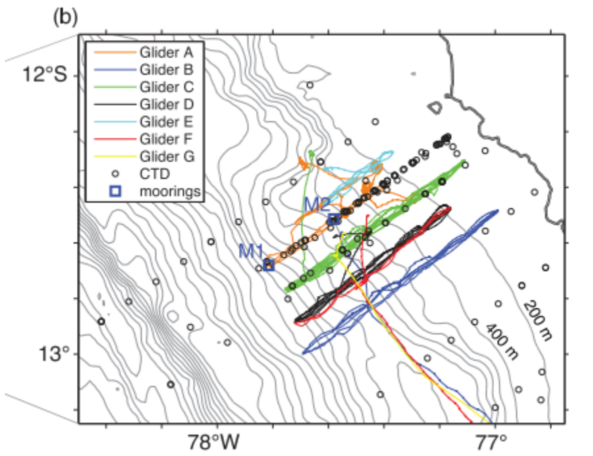
Bottom layer : 1st vertical model level between isobaths 40 and 80 m

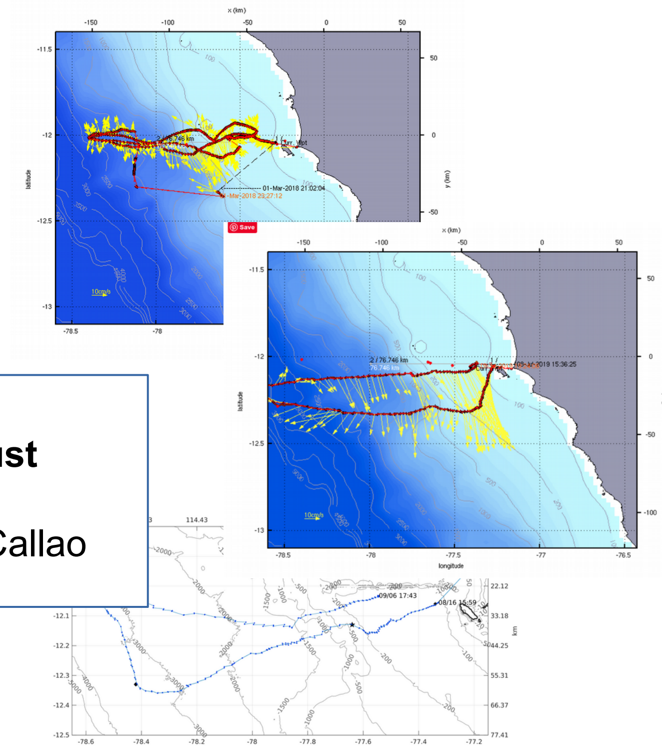
Surface tracer concentration (after 4 days)

Glider deployments off Peru: Lima



7 gliders: **Jan 2013**
→ formation of a subsurface anticyclonic eddy (Thomsen et al. 2015)
→ ventilation of the OMZ (Thomsen et al. 2016)

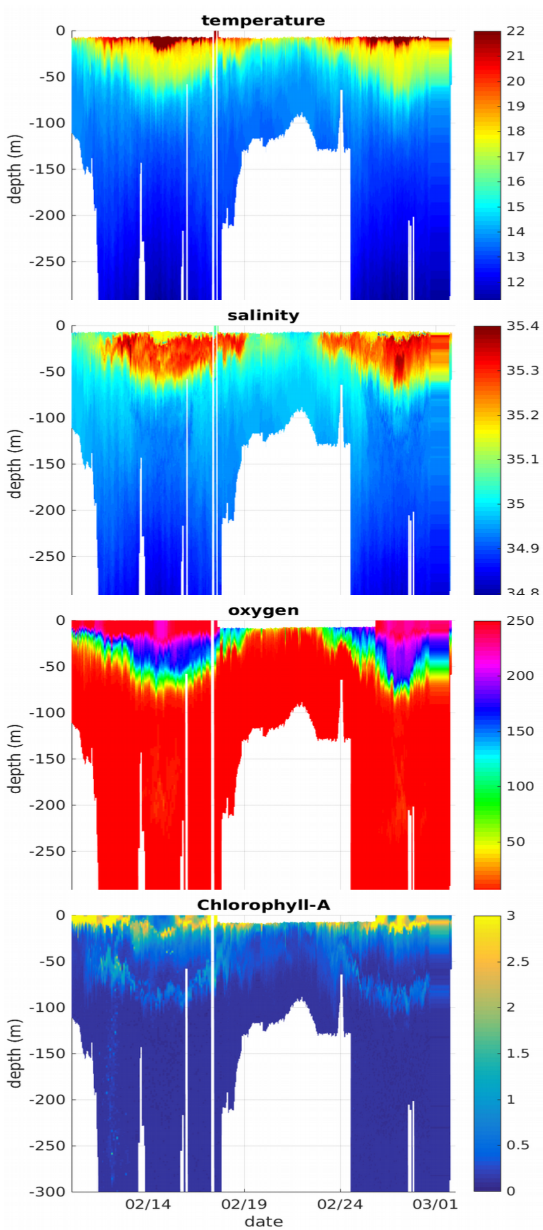




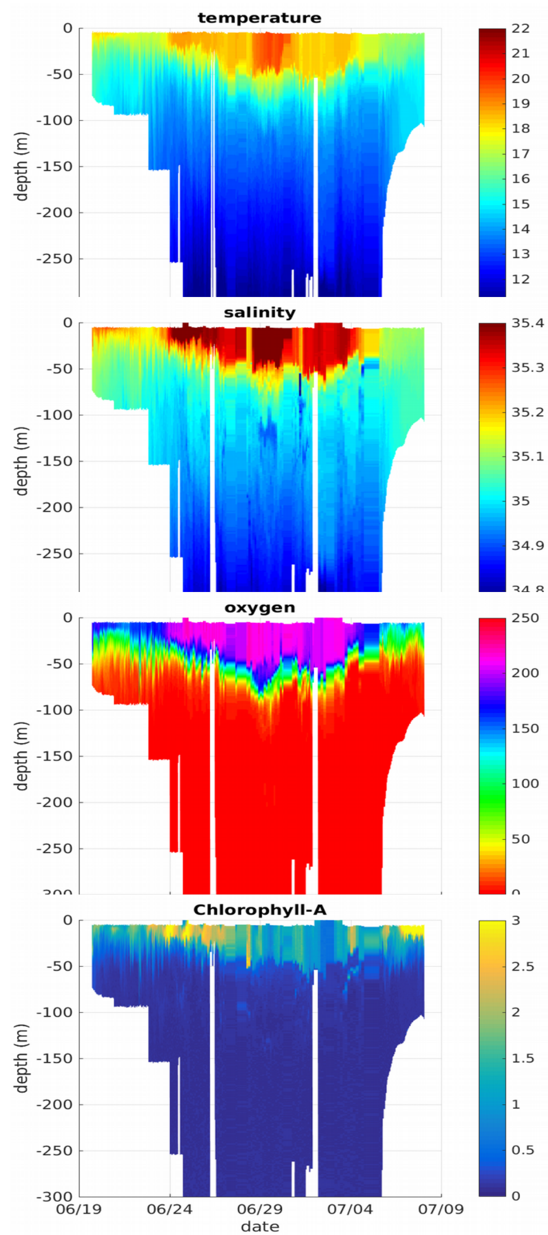
Paracas: 3 deployments
Mar 2018 / July 2019 / August 2019
deployments of Paracas off Callao

Glider deployments off Peru: Lima

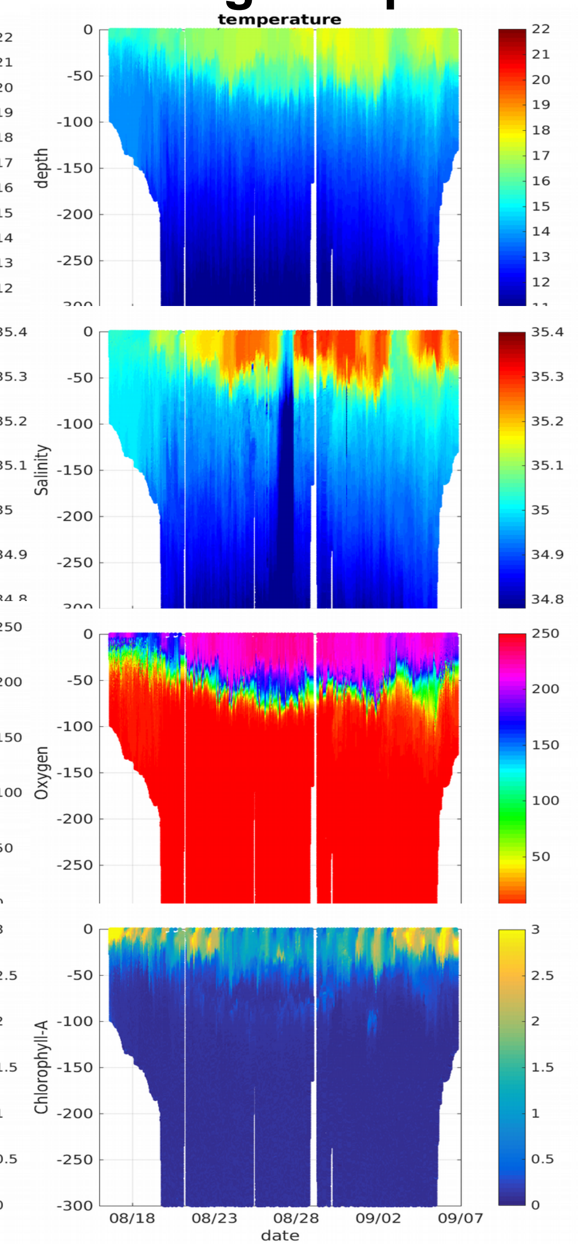
8-28 Feb 2018



19 Jun-9 Jul 2019

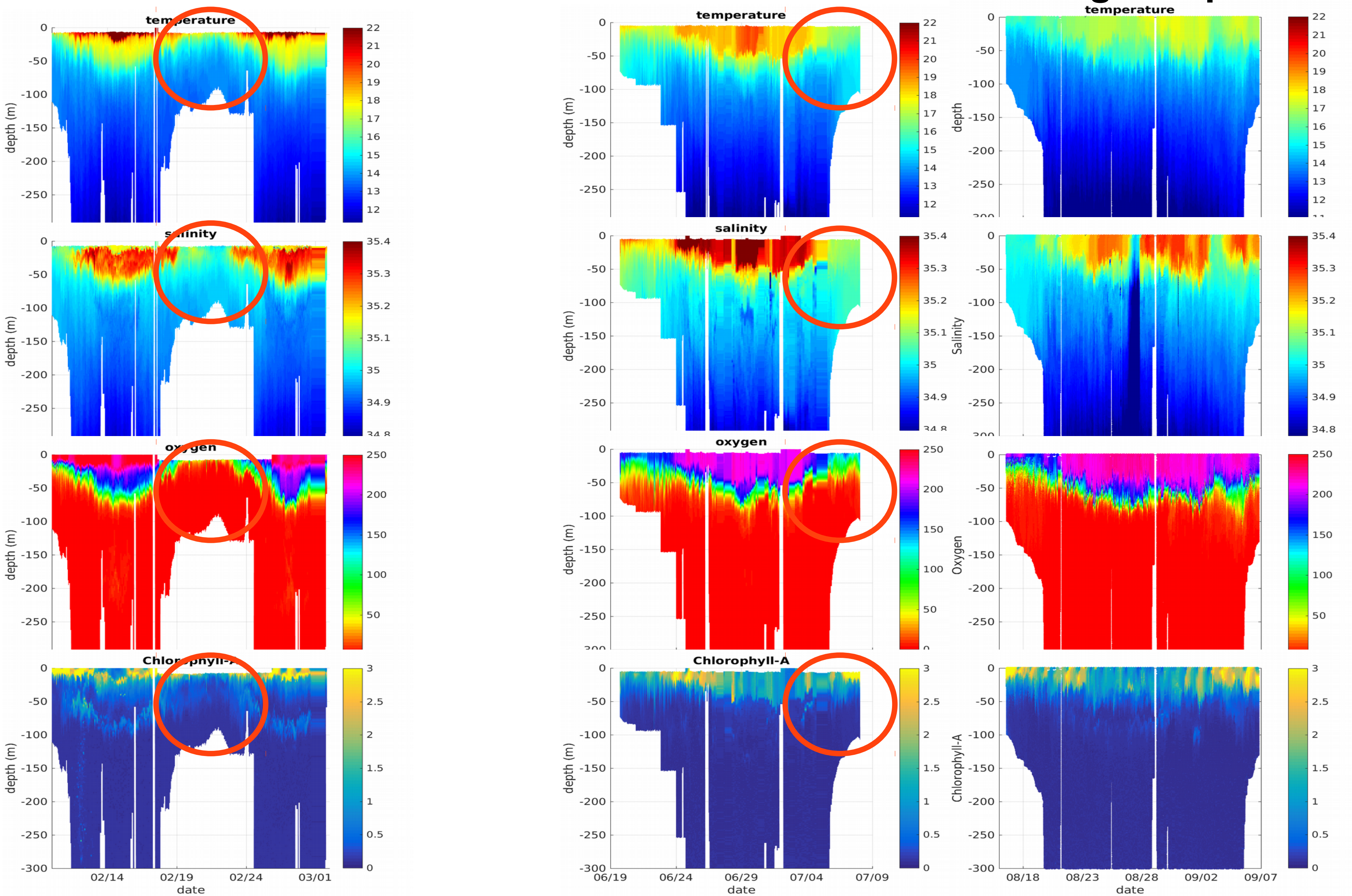


16 Aug-6 Sep 2019



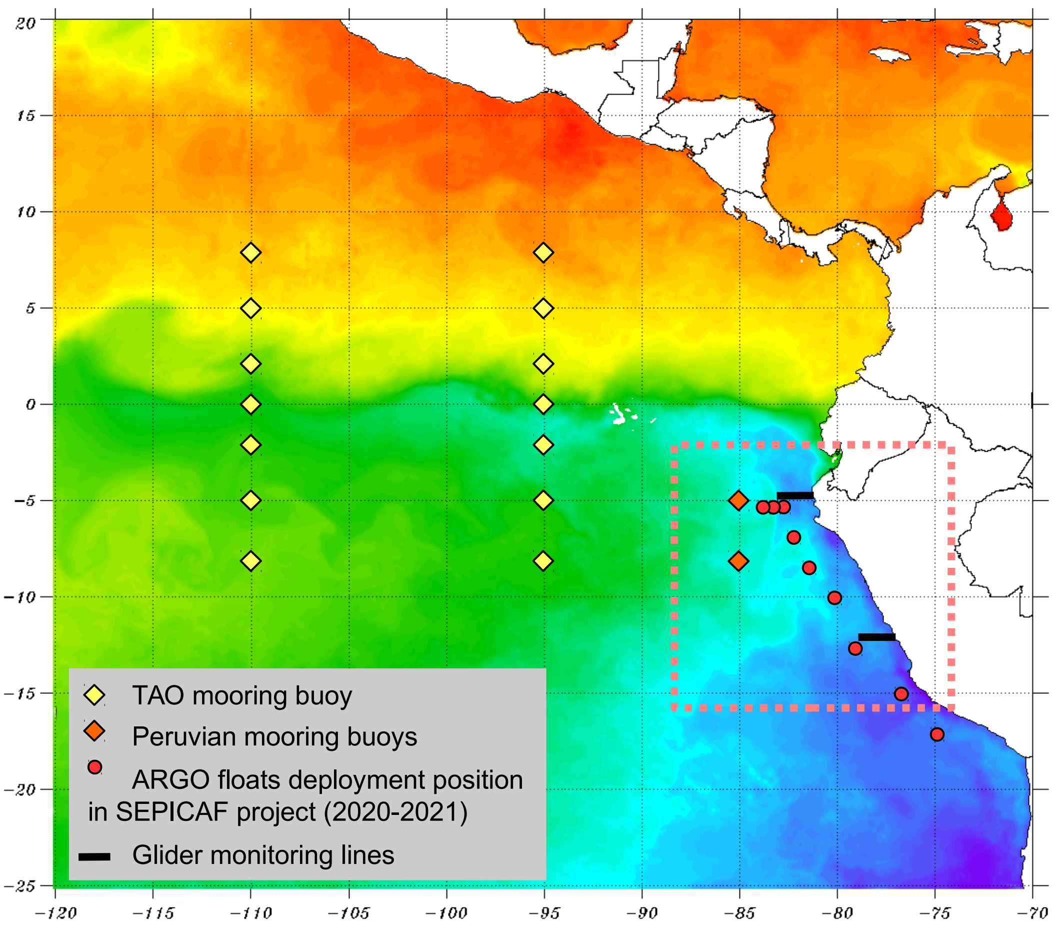
Glider deployments off Peru: Lima

8-28 Feb 2018 | 19 Jun-9 Jul 2019 | 16 Aug-6 Sep 2019



Conclusions

- Almost all of the deployments off Peru brought a significant contribution to the understanding of the upwelling dynamics : submesoscale intrusions, ventilation of the OMZ, CTW, high coastal productivity during an El Niño event, etc.



- Gliders are very versatile so they can be used for “in the moment” process studies (sampling of a front, wave, etc.)

- They are well designed to study local (submesoscale) dynamics as well as large scale forcing (El Niño) and long time monitoring

- The acquisition by the IMARPE in 2020 of three more gliders should provide the opportunity to monitor at a higher resolution this very important boundary system.