

Proyecto Bimbache

La erupción submarina de El Hierro:
perturbación físico-química y su respuesta
biológica.

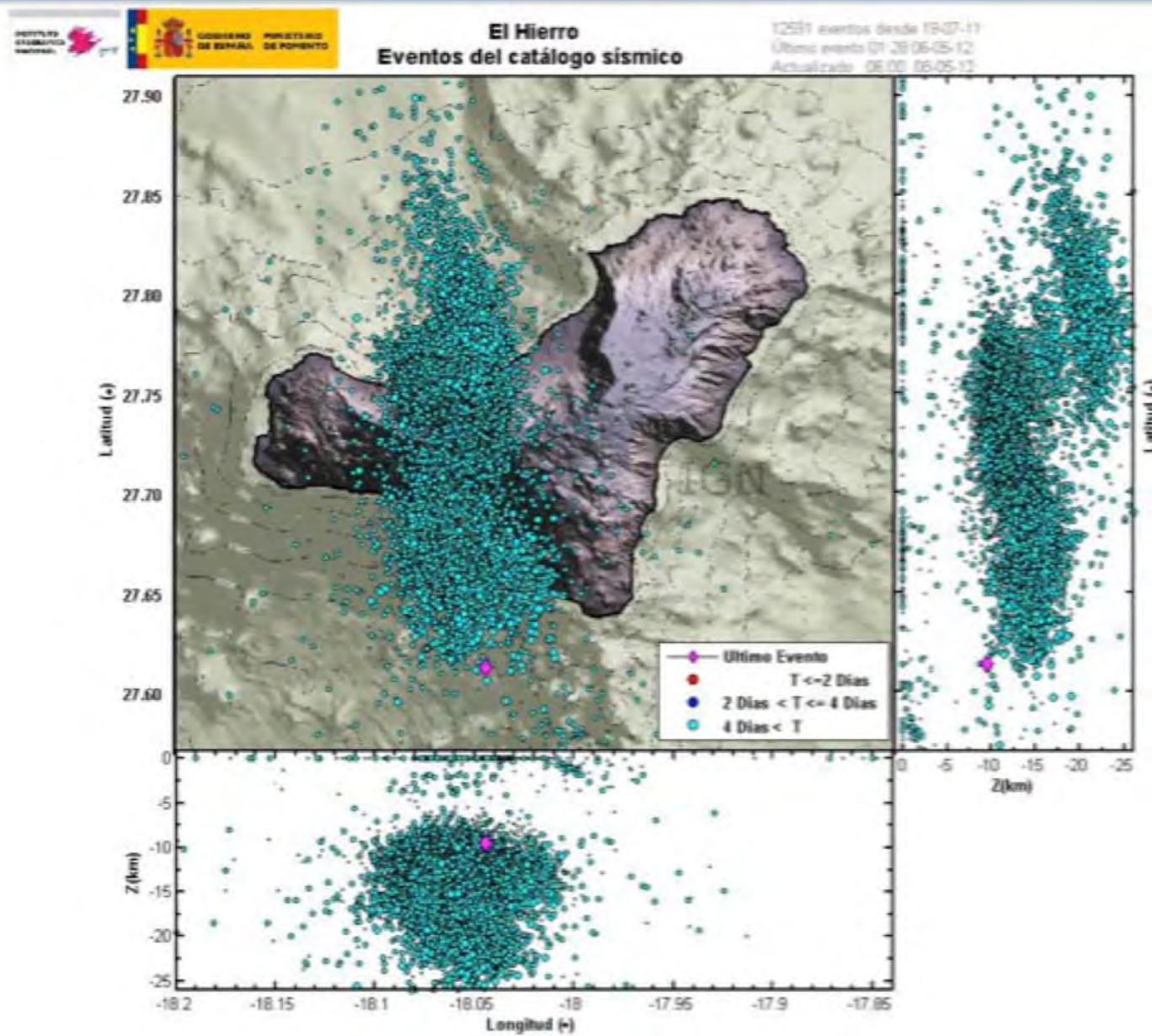
Dr. Eugenio Fraile Nuez

Investigador Titular
Instituto Español de Oceanografía

Las Palmas de Gran Canaria, 20 de Noviembre de 2012



Introducción: inicio de la actividad sísmica



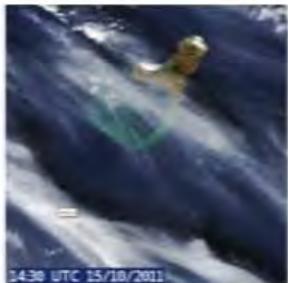
Introducción: inicio de la monitorización por satélite



12:30 UTC 12/18/2011



14:45 UTC 13/18/2011



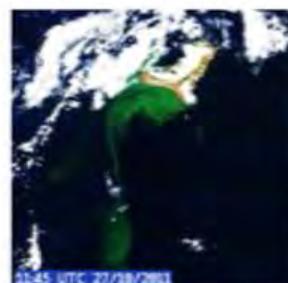
14:30 UTC 15/18/2011



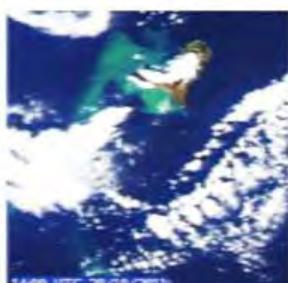
12:30 UTC 25/18/2011



14:15 UTC 26/18/2011



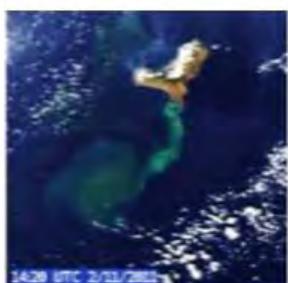
11:45 UTC 27/18/2011



14:00 UTC 28/18/2011



14:30 UTC 31/18/2011



14:20 UTC 2/11/2012



14:30 UTC 4/11/2012



12:40 UTC 5/11/2011



12:50 UTC 9/11/2011



14:00 UTC 13/11/2011



14:30 UTC 26/11/2011



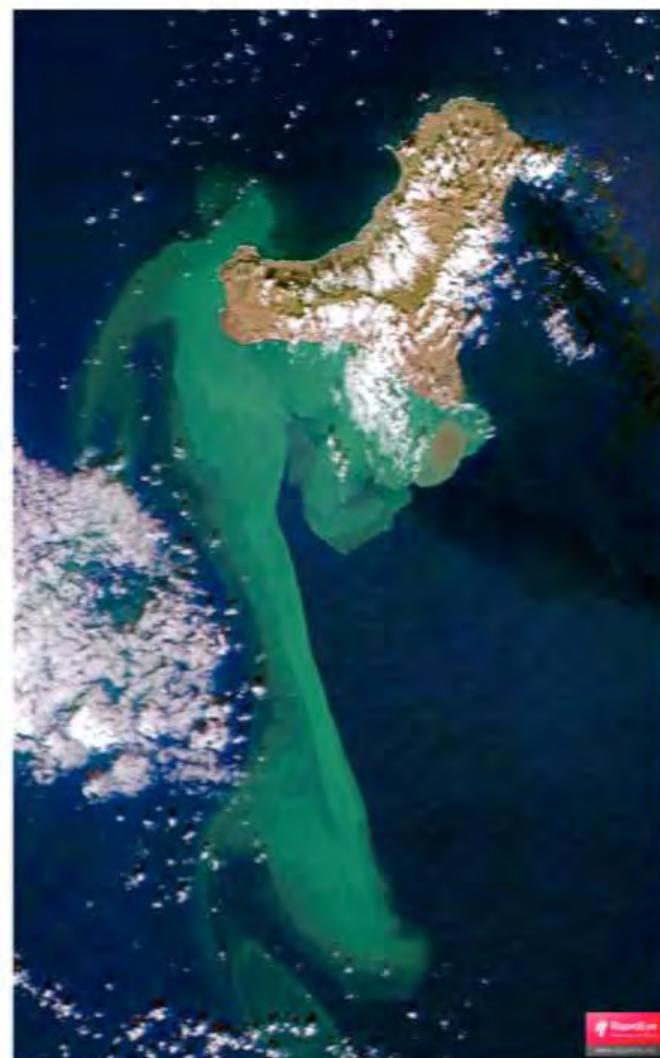
0:210 UTC 24/11/2011

Eugenio, F., 2012



INSTITUTO
ESPAÑOL DE
OCEANOGRÁFIA

Introducción: inicio de la monitorización por satélite



Introducción: inicio de la actividad investigadora en el océano



B/O Cornide de Saavedra



B/O Ramón Margalef

Foto: Vuelo Científico INVOLCAN / Helicópteros Guardia Civil

Introducción: efectos evidentes del desastre ecológico



Introducción: emisiones gaseosas y material en suspensión



Introducción: erupción submarina del 5 noviembre 2011



Video: Javier Arístegui

Introducción: emisiones piroclásticas



Video: Jesús Pérez

Crisis Volcánica de la isla de El Hierro

Gobierno de España

Centro Oceanográfico de Canarias (IEO)



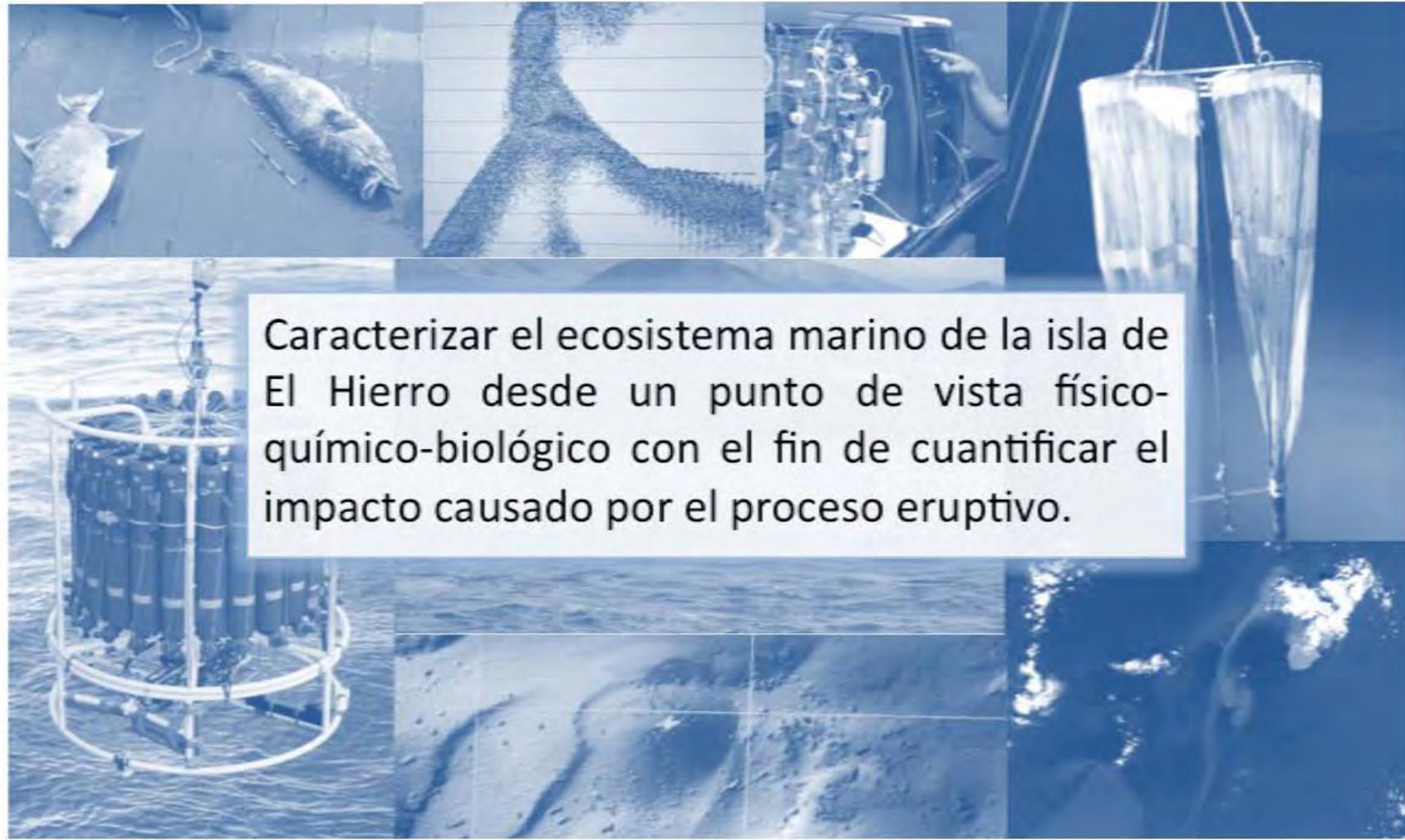
PEVOLCA



Más de 20 investigadores de 6 instituciones distintas.



Objetivo fundamental



Caracterizar el ecosistema marino de la isla de El Hierro desde un punto de vista físico-químico-biológico con el fin de cuantificar el impacto causado por el proceso eruptivo.



Especificaciones:

Tipo: Buque Oceanográfico

Año de Construcción: 2011

Propietario: Instituto Español de
Oceanografía (I.E.O.)

Longitud: 46,70 m

Envergadura: 10,50 m

Calado: 4,20 m

Velocidad Máxima: 13 kn

Autonomía: 10 días

Tripulación + Técnicos: 12+2

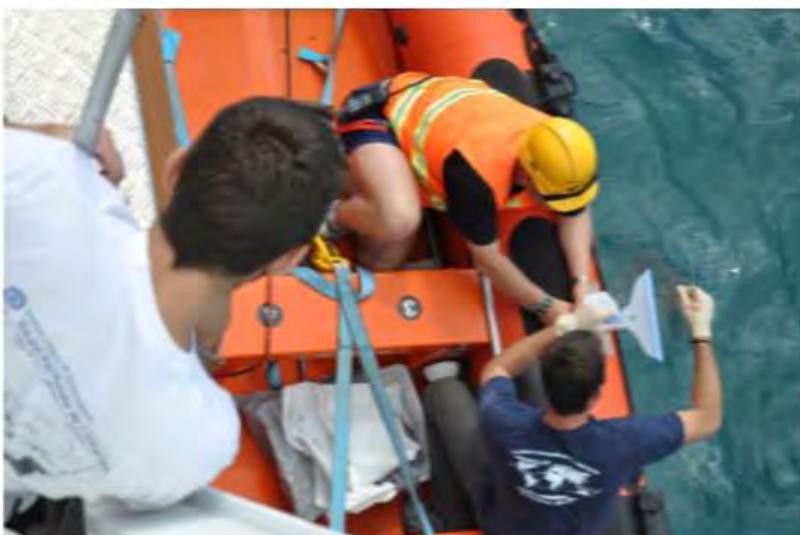
Personal Científico: 12



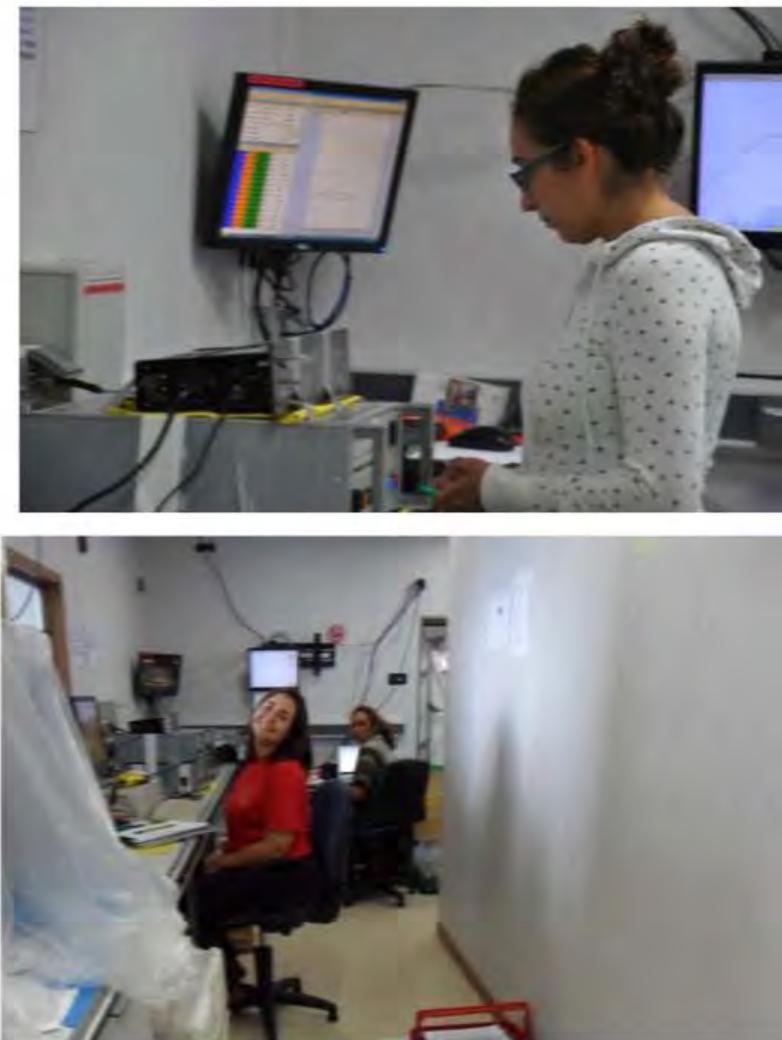
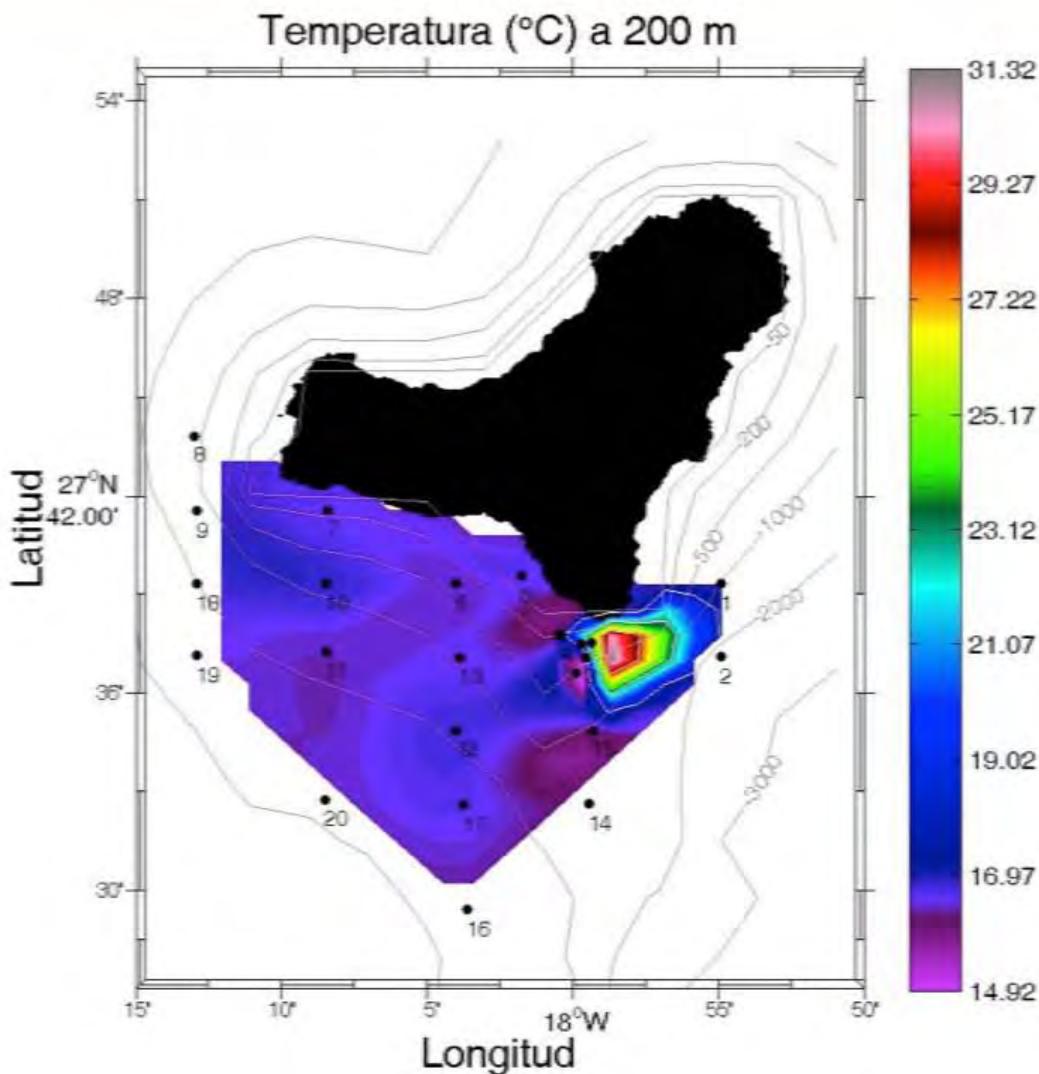
Foto de Isis Comas



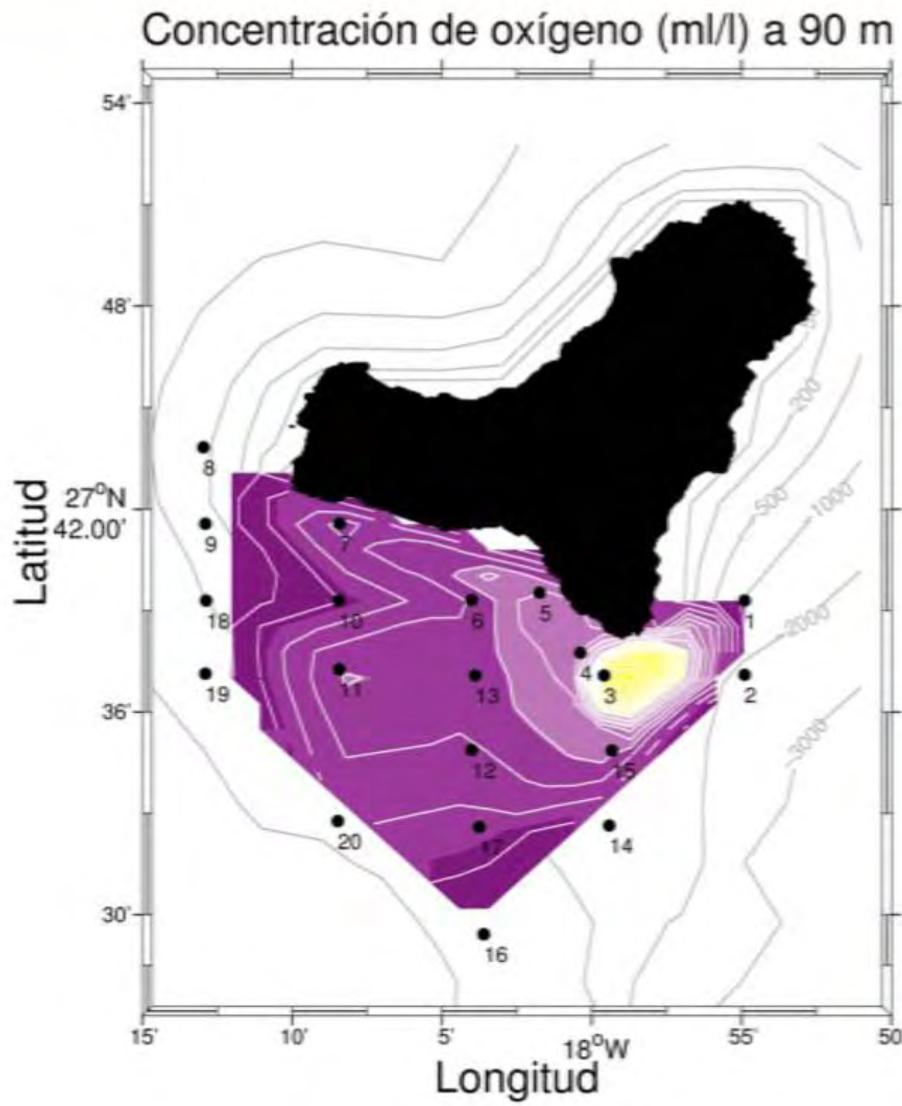
Coordinador del proyecto



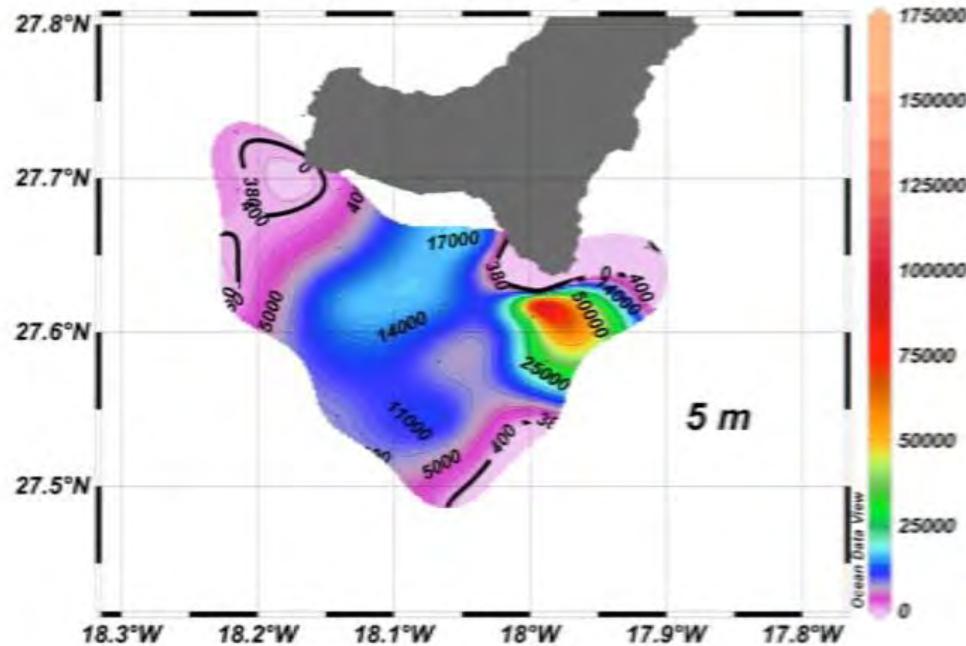




Los Oceanógrafos Químicos



Los Oceanógrafos Químicos



C_T , Carbono inorgánico total disuelto

A_T , Alcalinidad total

pCO₂ en continuo



Los Oceanógrafos Químicos

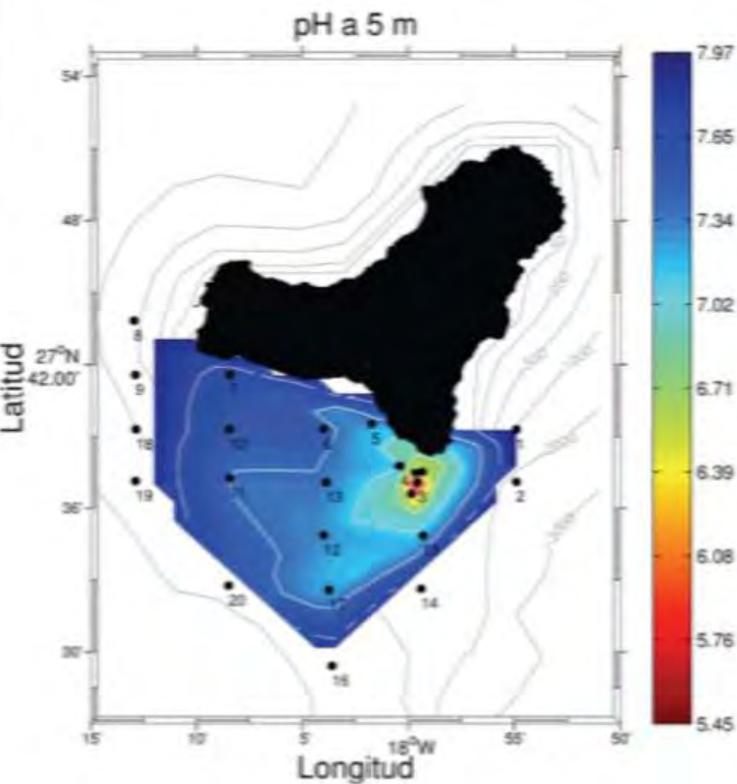


H_2S , HS^- , S^{2-} , SO_3^{2-} E (V)

pH potenciométrico
y espectrofotométrico



Fe(II), Hierro ferroso



Los Oceanógrafos Biológicos

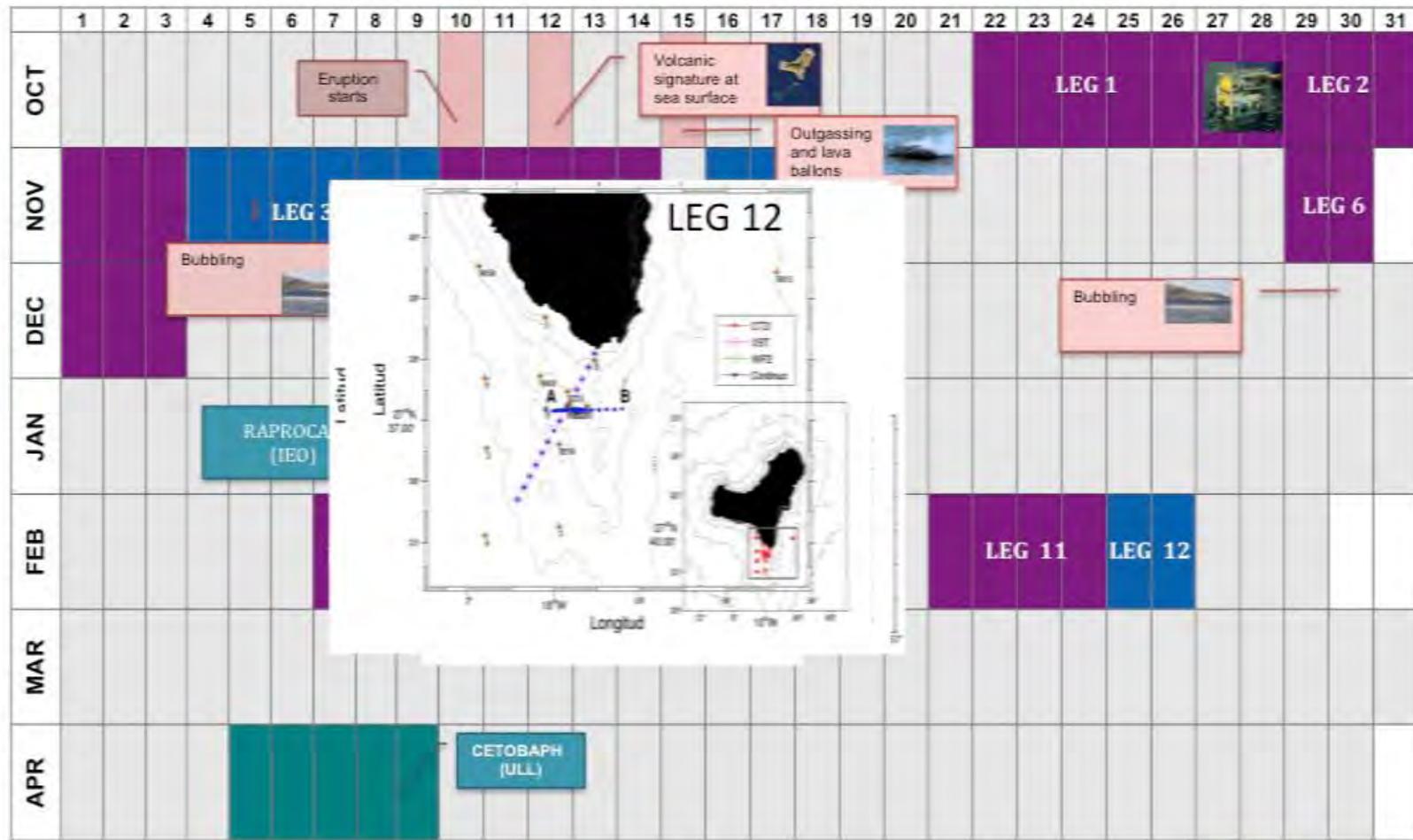


Cronograma



INSTITUTO
ESPAÑOL DE
OCEANOGRÁFIA

2011
2012

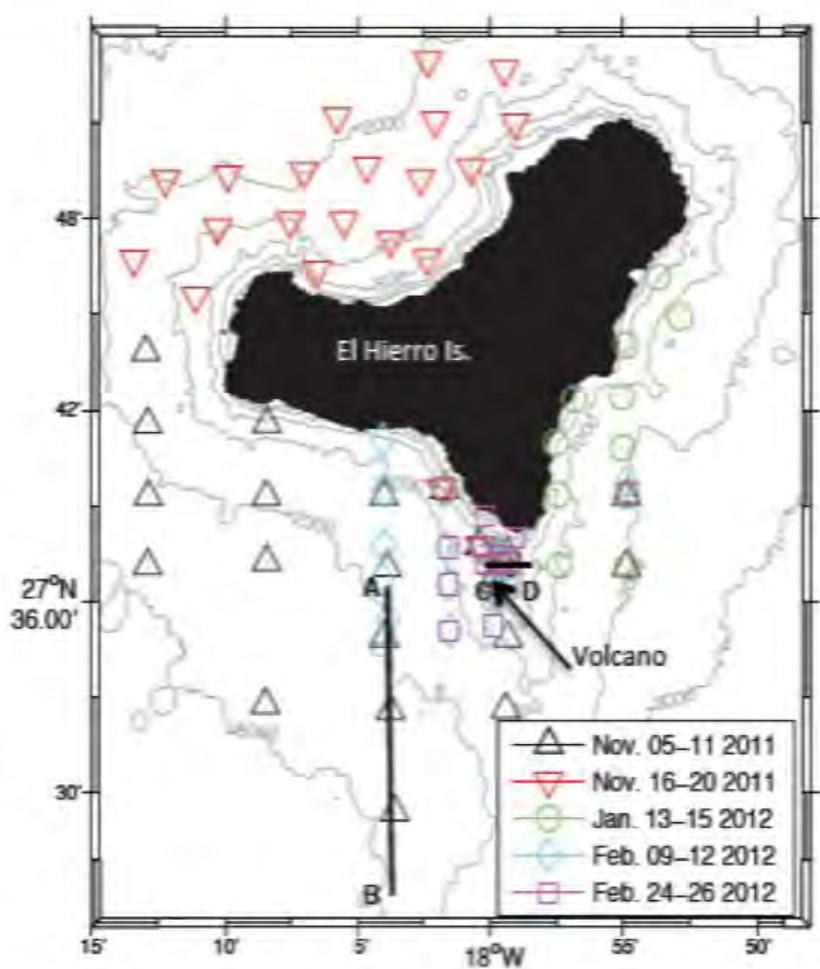


INSTITUTO
ESPAÑOL DE
OCEANOGRÁFIA

Bimbaches Leg 3, 5, 8, 10 y 12, Raprocan1211 y Cetobaph0412: Caracterización Físico-Química-Biológica

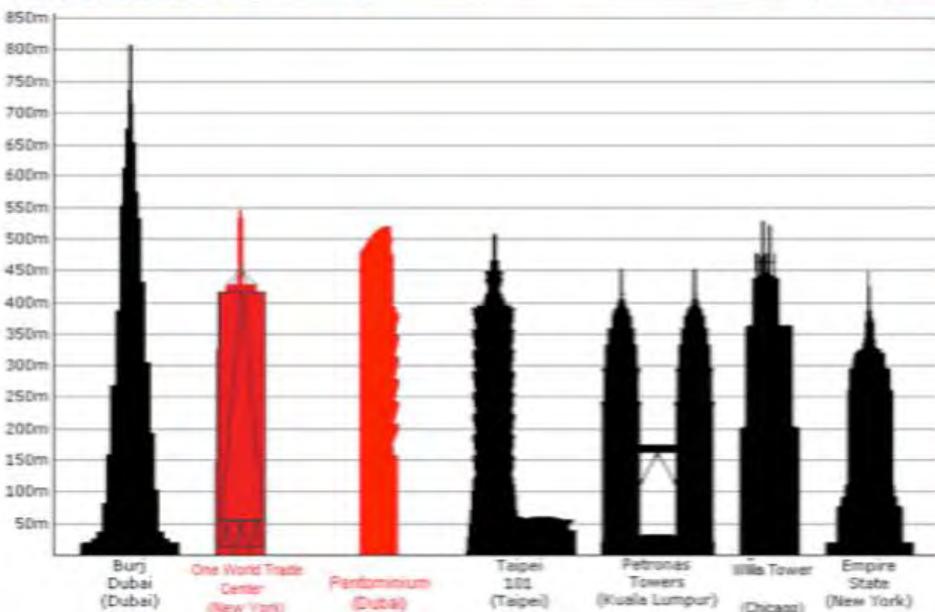
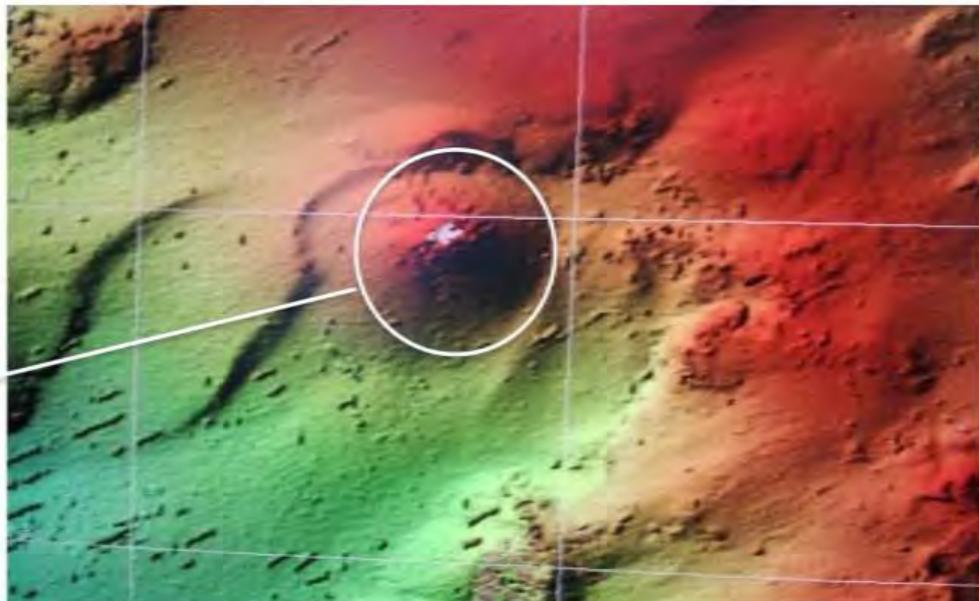


Jefe Campaña: Eugenio Fraile (IEO-Tenerife)

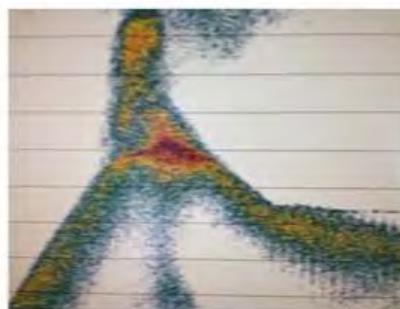


Instrumento/Parámetro	Estaciones	Muestras
CTD	127	> 5 millones de registros de conductividad, temperatura, presión, oxígeno, fluorescencia, materia orgánica disuelta coloreada y transmisor
LADCP	100	> 200.000 registros de las componentes zonal y meridional de la corriente
XBT	66	> 15.000 registros de temperatura
VMADCP	continuo	> 14.000 registros de las componentes zonal y meridional de la corriente
EK60	continuo	> 14.000 registros de backscatters
Termosalinógrafo	continuo	> 14.000 registros de temperatura y salinidad superficial
Meteorología y navegación	continuo	> 8.000 registros de posición y parámetros meteorológicos
Oxígeno	127	1500
Nutrientes	127	1500 muestras para análisis de nitratos, nitritos, fosfatos y silicatos
pH	127	1800
Carbono inorgánico total	127	1800
Alcalinidad total	127	1800
pCO ₂	continuo	> 500.000 registros
Metales	127	1200 muestras para análisis de hierro ferroso (Fe II)
	127	1500 muestras para análisis de aluminio, cobre, cadmio y plomo
Turbidez	127	1500
Fitoplancton	127	1300 muestras para estudio de biodiversidad
	30	100 muestras para análisis de ADN
Microorganismos	127	1300 muestras para el estudio de picoplantón, nanoplantón y bacterias
	30	100 muestras para análisis de ADN
WP2	127	127 muestras para metabolismo
		120 muestras para biomasa y composición

Bimbaches Legs 1, 4, 6, 7, 9 y 11: Levantamientos batimétricos



La cima del cono volcánico ha pasado de 350 a 88 metros de la superficie.



Bimbache Leg 2: ROV y Politolana





1.- Aumento de la Temperatura

2.- Acidificación oceánica

3.- Desoxigenación



The submarine volcano eruption at the island of El Hierro: physical-chemical perturbation and biological response

SUBJECT AREAS:
OCEANOGRAPHY
ADAPTATION
CLIMATE CHANGE
BIOLOGY

Received
14 May 2012

Accepted
11 June 2012
Published
5 July 2012

Correspondence and
requests for materials
should be addressed to
E.F.-N. (eugenio.
fraile@io.es) or
m.fernandez@io.es

Contributed by
C. Gómez-Gesteira
(CGG)

Reviewers
from Spain
(ES)

J. Instituto
de Sistemas
Inteligentes y
Aplicaciones
Inteligentes
(ISI)

* Área de Medio
ambiente y
protección
ambiental (EMPA)



E. Fraile-Nuez^{1*}, M. González-Dávila², J. M. Santoro-Casiano³, J. Ariasga⁴, I. J. Alonso-González⁵, S. Hernández-León⁶, M. J. Blanca⁷, A. Rodríguez-Santana⁸, A. Hernández-Guerra⁹, M. D. Gelado-Caballero⁹, F. Eugenio¹⁰, J. Merello¹¹, D. de Armas¹², J. F. Domínguez-Vives¹³, M. F. Montero¹⁴, D. R. Letuchi¹⁵, P. Vélez-Belchí¹⁶, A. Ramos¹⁷, A. V. Ariza¹⁸, I. Comas-Rodríguez¹⁹ & V. M. Benítez-Banús²⁰

¹Instituto Español de Oceanografía, Centro Geocronológico de Canarias (CEGOC), Santa Cruz de Tenerife, Spain; ²Universidad de Los Polímeros de Gran Canaria, Instituto de Desarrollo y Cambio Global (IDeCaG), Las Palmas, Spain; ³Universidad de los Polímeros de Gran Canaria, Instituto Espacial de Argelia (IEA), Las Palmas, Spain; ⁴Instituto Geográfico Nacional, Centro Geofísico de Canarias, Tenerife, Spain; ⁵Universidad de los Polímeros de Gran Canaria, Facultad de Ciencias del Mar, Las Palmas, Spain; ⁶Universidad de los Polímeros de Gran Canaria, Instituto Universitario de Sistemas Inteligentes y Aplicaciones Inteligentes (ISI), Las Palmas, Spain

On October 18 2011 an underwater eruption gave rise to a novel shallow submarine volcano south of the island of El Hierro, Canary Islands, Spain. During the eruption large quantities of mantle-derived gases, volatiles and heat were released into the surrounding waters. In order to monitor the impact of the eruption on the marine ecosystem, periodic multidisciplinary cruises were carried out. Here, we present an initial report of the extreme physical-chemical perturbations caused by this event, comprising thermal changes, water acidification, degassing and metal enrichment, which resulted in significant alterations to the activity and composition of local plankton communities. Our findings highlight the potential role of this eruptive process as a natural, ecosystem-scale experiment for the study of extreme effects of global change processes on marine environments.

Above submarine volcanoes constitute a significant source of mantle-derived gases, volatiles and heat to the water. Their emissions react with seawater leading to important physical-chemical anomalies that may strongly impact the marine ecosystem.^{1–3} However, the impacts of short-term submarine volcanic activity on the surrounding flora, especially planktonic communities, are still poorly understood. Here, we provide evidence that one of the robust and more sensitive marine ecosystems of the subtropical northeast Atlantic Ocean has been dramatically affected by the recent submarine eruption at the island of El Hierro (Canary Islands).

Results

After three months of volcanic unrest, characterized by more than 10,000 earthquakes (M>4.3) and 5 cm of general deformation, on October 18 2011 the seismic seismic network recorded a substantial decrease of seismicity together with continuous volcanic tremor indicating the beginning of an eruptive phase. Since then, regular multidisciplinary monitoring has been carried out in order to quantify environmental impacts caused by the submarine eruption (Figure 1).

Precise hydrographic measurements located the crater vent 1.6 km offshore of the southern coast of El Hierro and indicated a narrow plume of the volcano, rising at about 300 m depth to just 40 m below the surface. Conductivity-Temperature-Depth measurements of the waters affected by the volcanic emission revealed low pressure and salinity anomalies of +3°C and -0.3, respectively, at 40 m depth, and 200 m from the volcano. Maximum temperature anomalies of +10.9°C were observed over the crater at 110 m depth using expendable bathythermograph probes (Figure 2). The release of CO₂-produced total inorganic carbon concentrations ranging from 1,000 to 7,500 μmol kg⁻¹ cause greater acidification (up to 2.4 units within the first 100 m depth and 2 km from the volcano). These high CO₂ levels generated high pCO₂ (partial pressure of CO₂) waters with values ranging from 12,000 to 25,000 μatm at the surface. The most affected part of the water column was the layer

1.- Aumento de la Temperatura

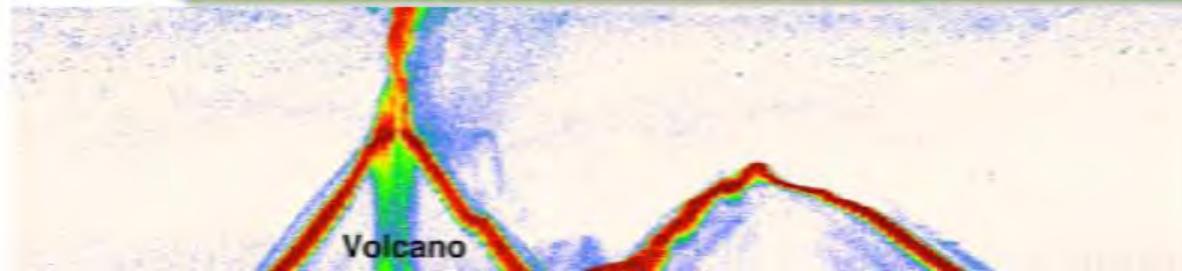
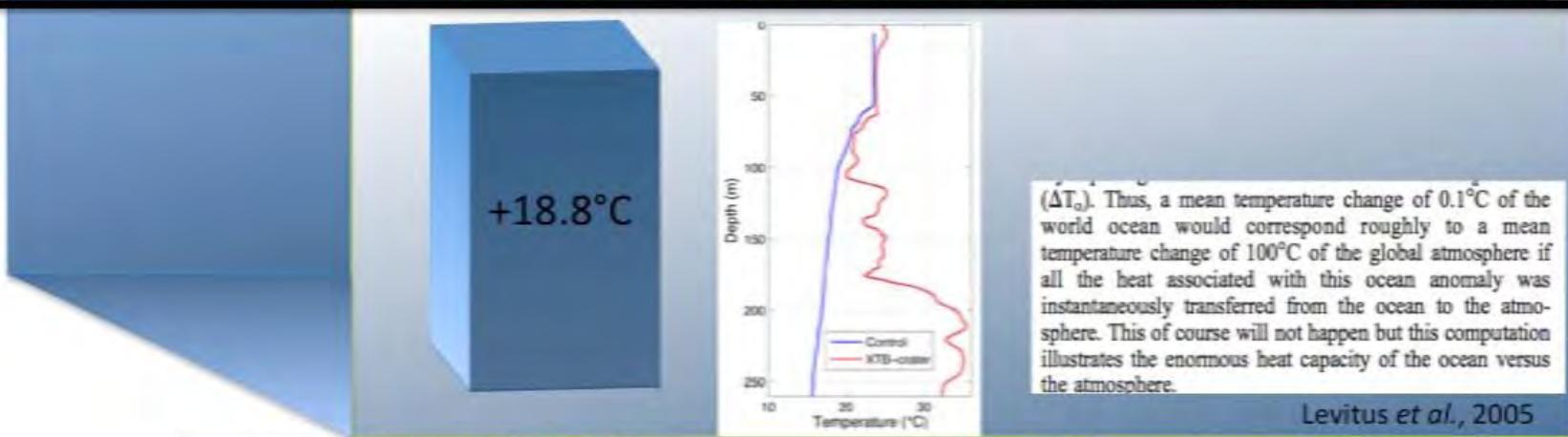
2.- Acidificación oceánica

3.- Desoxigenación

Primer factor: Aumento de Temperatura.

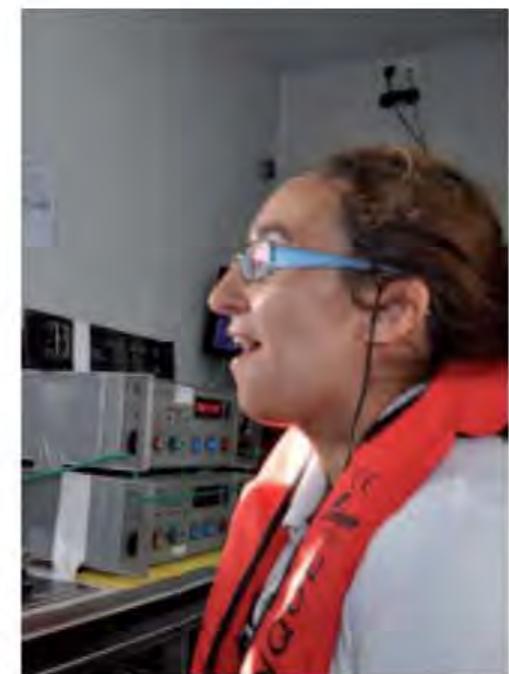
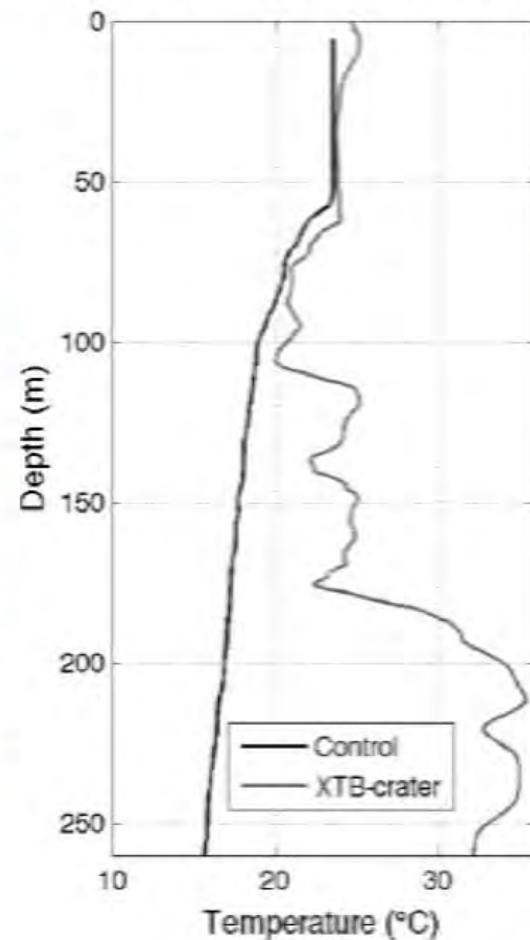
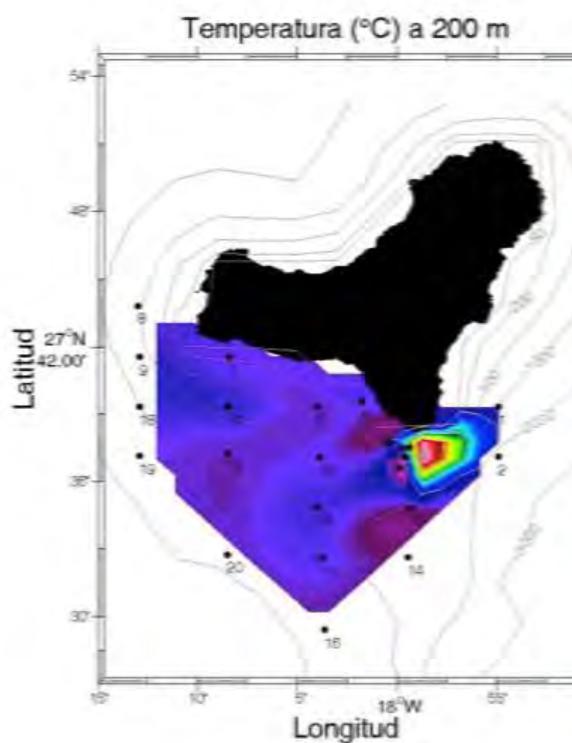
Conductivity-Temperature-Depth measurements of the waters affected by the volcanic emissions revealed temperature and salinity anomalies of $+3^{\circ}\text{C}$ and -0.3 , respectively, at 80 m depth and 290 m from the volcano. Maximum temperature anomalies of $+18.8^{\circ}\text{C}$ were observed over the crater at 210 m depth using expendable bathythermograph probes (Figure 2). The release of CO_2 produced total inorganic carbon concentrations ranging

Fraile-Nuez et al., 2012

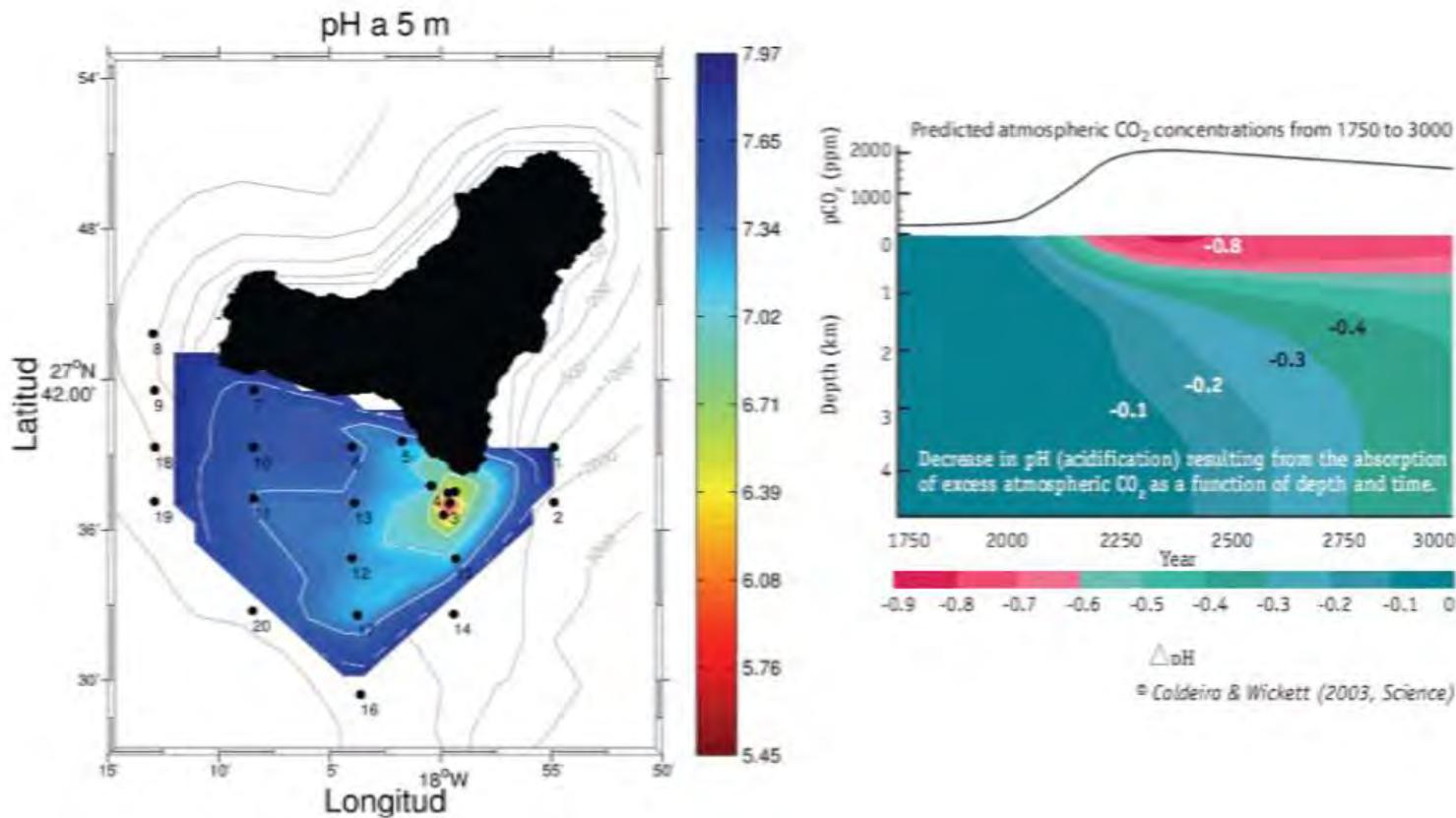


Primer factor: Aumento de Temperatura.

1.- Los primeros 200 metros de la columna de agua sobre el volcán han sufrido un incremento medio de la temperatura de 18.8°C . El calor emitido por el volcán para producir esta variación supondría **una elevación de 20.000°C la temperatura de la atmósfera.**



Segundo factor: Acidificación Oceánica.

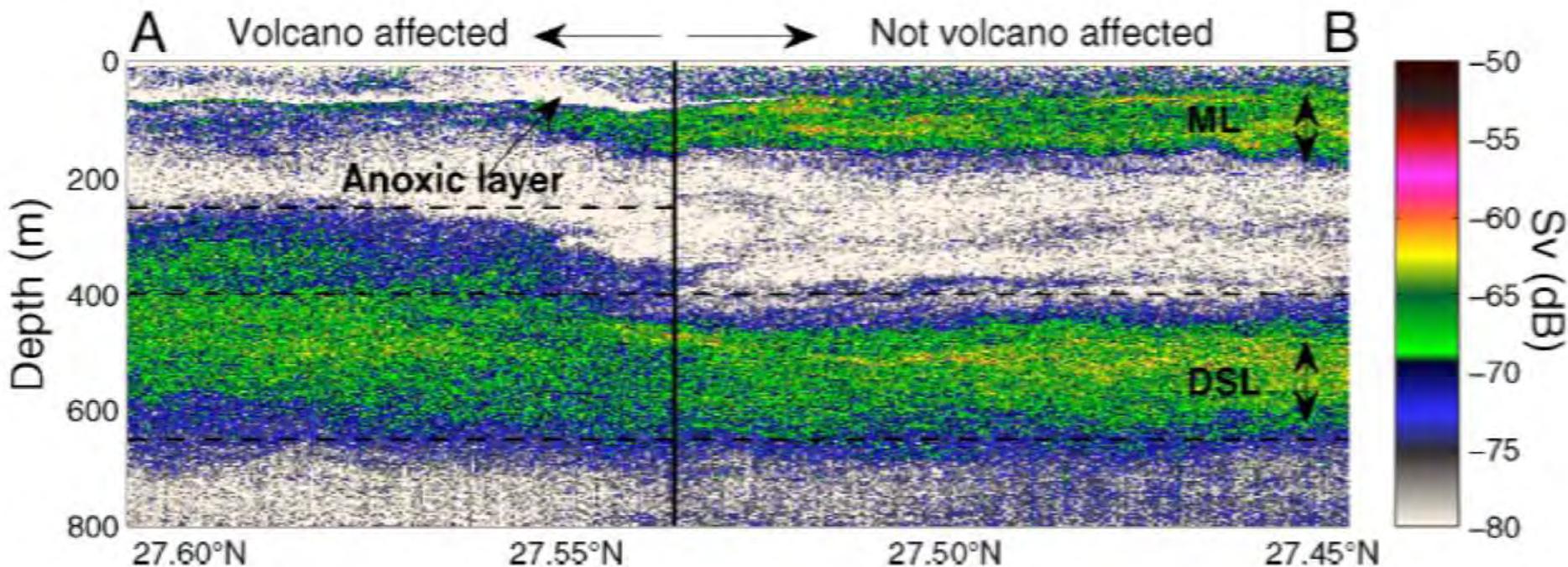


bathythermograph probes (Figure 2). The release of CO₂ produced total inorganic carbon concentrations ranging from 4,000 to 7,500 $\mu\text{mol kg}^{-1}$ causing water acidification of up to 2.8 units within the first 100 m depth and 2 km from the volcano. These high CO₂ levels generated high pCO₂ (partial pressure of CO₂) waters with values ranging from 12,000 to 150,000 μatm at the surface. The most affected part of the water column was the layer

Segundo factor: Acidificación Oceánica.

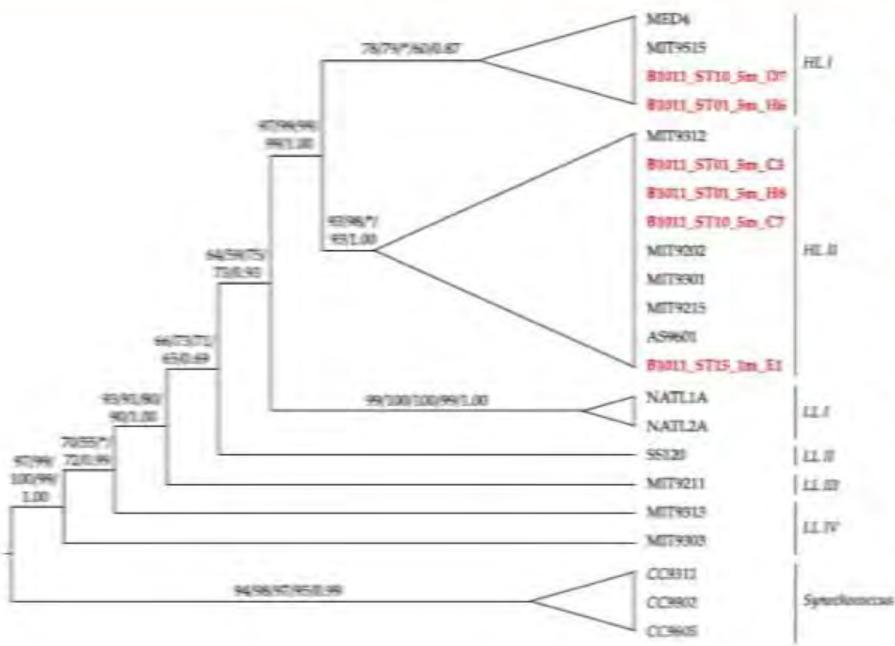
- 1.- El pH disminuyó en 2.8 puntos, lo que supone que el medio está soportando una concentración de ácidos **1000 veces superior** a lo normal.
- 2.- Las concentraciones de ácido sulfhídrico muestran valores medios realmente elevados, entre 50-100 μM , llegando a valores superiores a 400 μM a 75 metros.
- 3.- La concentración de Fe(II) disuelto total en el mar es **4 millones de veces superior** que en condiciones normales.
- 4.- El carbono inorgánico total disuelto ha aumentado un 476%, pasando de 2100 $\mu\text{mol}/\text{kg}$ a 10.000 $\mu\text{mol}/\text{kg}$ de agua de mar.
- 5.- La pCO_2 disuelto ha pasado de 380 μatm a 316.800 μatm .
0.15% de las emisiones diarias mundiales
17% de las emisiones diarias en España

Tercer factor: Desoxigenación



These physical-chemical anomalies had a major impact on local pelagic communities. No fish schools were acoustically detected within the volcano affected area, and many dead fish were observed floating at the surface. Due to low light penetration, the upper limit of the deep scattering layer (produced by plankton and nekton echoes) was around 100 m shallower than usual in waters affected by the volcano. There, diel vertical migration was rather weak or absent as a consequence of anoxic levels in shallow layers (Figure 3). Small

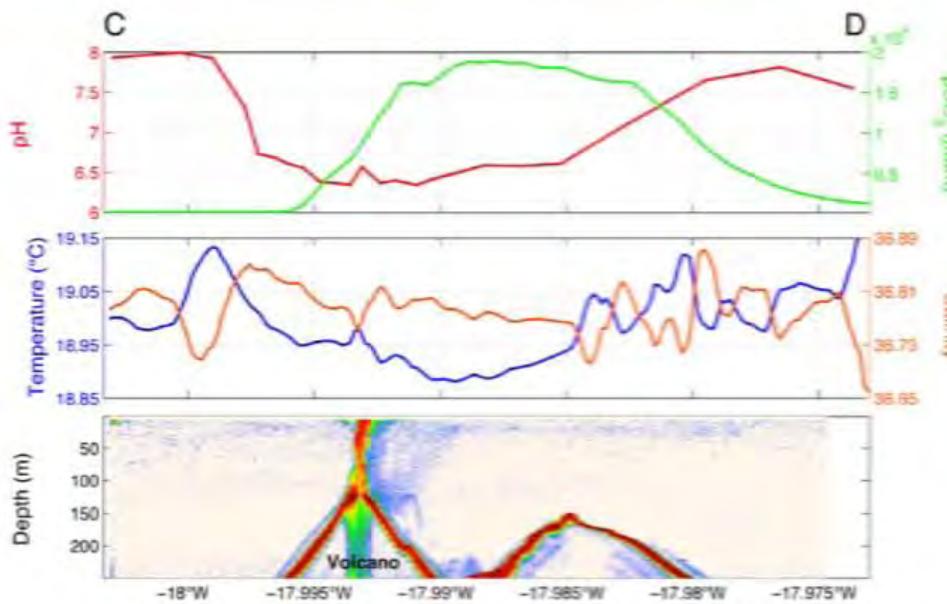
Respuesta biológica:



picoplankton communities showed a variable response to the volcanic emissions. Picophytoplankton at surface layers were not affected. However, at 75 m depth, *Prochlorococcus* showed a three-fold and *Synechococcus* a two-fold significant decline of abundance (t-test, $p < 0.06$ and $p = 0.1$, respectively), compared to far-field stations. Conversely, heterotrophic bacterial abundances (particularly large cells with high green fluorescence) increased dramatically with depth at stations affected by the volcanic emissions. The distinct response of the picophytoplankton groups to the volcano's influence is suggestive of ecotype selection under the rapidly changing conditions. Indeed, preliminary phylogenetic analyses of 16S rDNA from surface waters revealed *Prochlorococcus* ecotypes characterized by lower chlorophyll b/a ratios and higher cupric ion tolerance (High Light-adapted³, HLI and HLII) (Figure 4). The lack of HLI ecotypes in waters affected by the volcanic emissions may indicate a volcano-induced selection towards higher growth-temperature optima, an attribute associated with the HLII ecotypes.

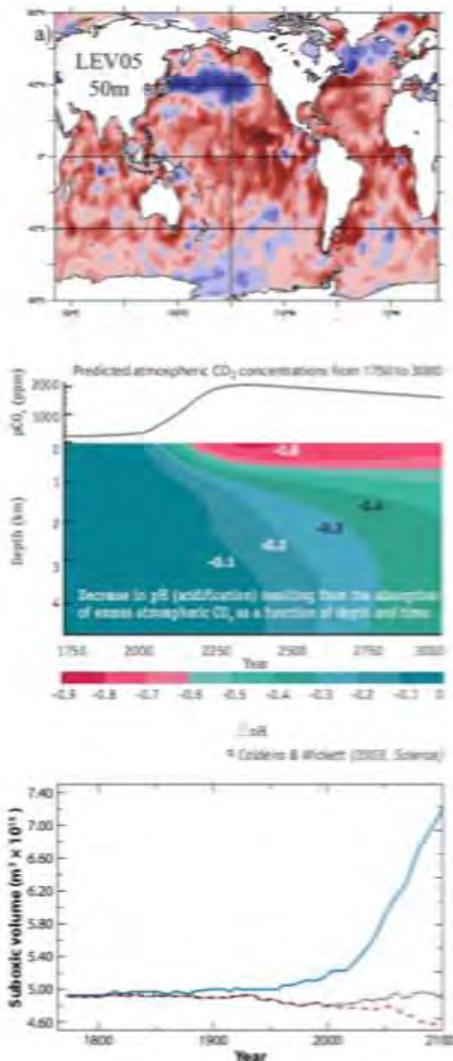
Fraile-Nuez et al., 2012

Atenuación del proceso



Five months after the beginning of the eruptive process, monitoring of the physical-chemical properties around the volcano continues to show significant variations within the different fields being measured (Figure 5). Surface temperature and salinity above the crater show small but notable differences of $+0.02^\circ\text{C}$ and -0.018 , respectively. Although CO_2 values have decreased considerably since the eruption, they continue to be highly variable. $p\text{CO}_2$ ranges between 16,000 and 19,000 μatm (compared with 150,000 μatm at the time of the eruption), and surface pH values show a decrease of 1.8 points below normal levels to 6.2.

Fraile-Nuez *et al.*, 2012



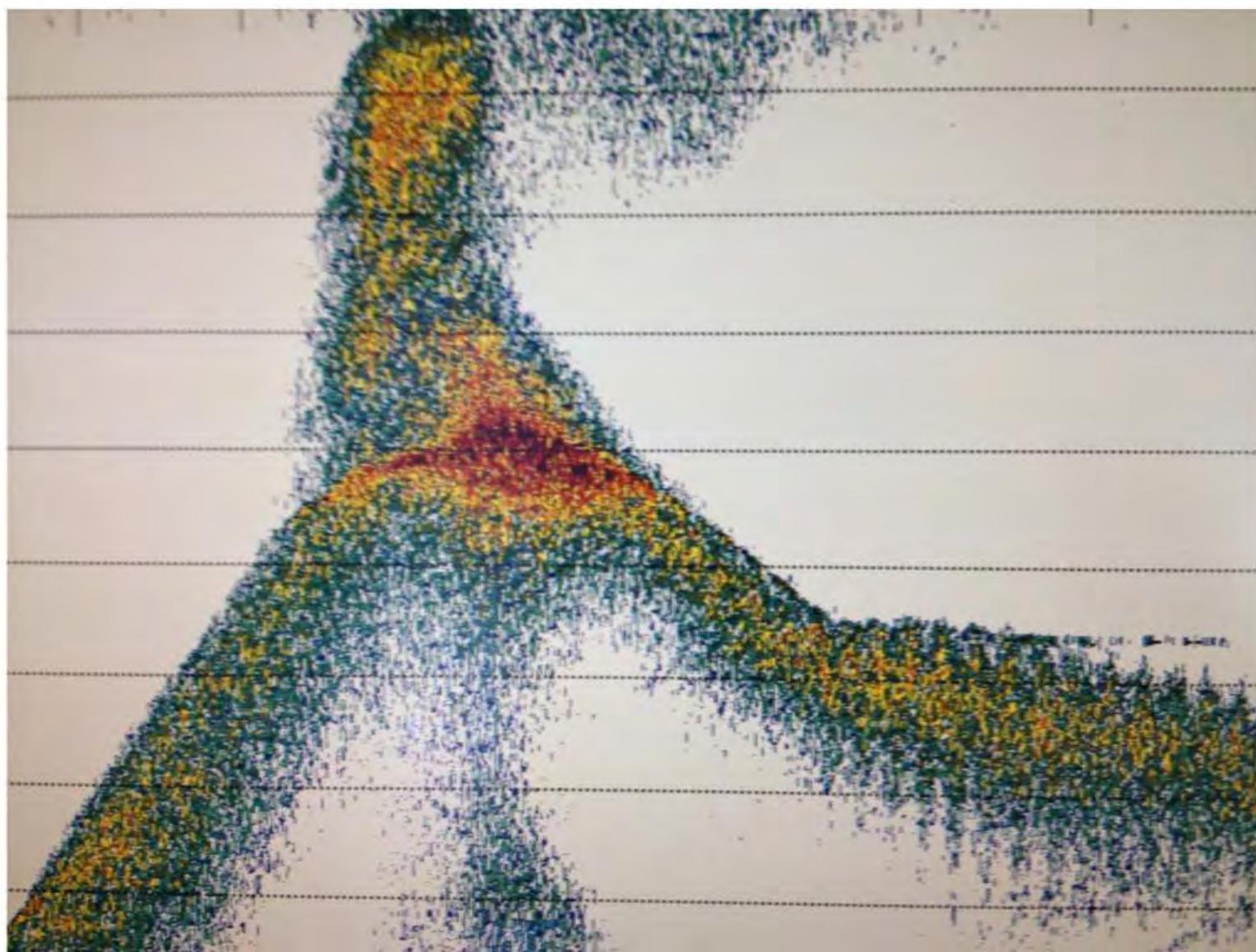
During the eruption of a submarine volcano at the island of El Hierro, volcanic emissions resulted in major physical-chemical alteration of the surrounding waters, such as warming, acidification and deoxygenation. These three processes are also the main stressors of global climate change, driven primarily by elevated anthropogenic release of carbon dioxide into the atmosphere⁴. Global climate models predict for the next century a rise of 0.6°C in ocean surface temperature⁵, a decrease of 0.3 – 0.4 pH units in surface waters⁶, and a decline of 1 – 7% in the global ocean oxygen inventory⁷. Marine organisms have already responded to these changes through variations in their distribution and survival⁸, decreased calcification rates⁶ and alteration of diurnal and ontogenetic vertical migrations of pelagic communities^{9,10}. These effects directly impact the structure and functioning of marine ecosystem.

The volcano affected area has exhibited responses that are occurring globally, making El Hierro into a unique natural laboratory where the principal climate change stressors are acting simultaneously. The results emerging from this volcanic eruption will help to improve our understanding of how future climate change may impact marine biota.



INSTITUTO
ESPAÑOL DE
OCEANOGRÁFIA

Proceso de desgasificación





INSTITUTO
ESPAÑOL DE
OCEANOGRÁFIA

Proceso de desgasificación



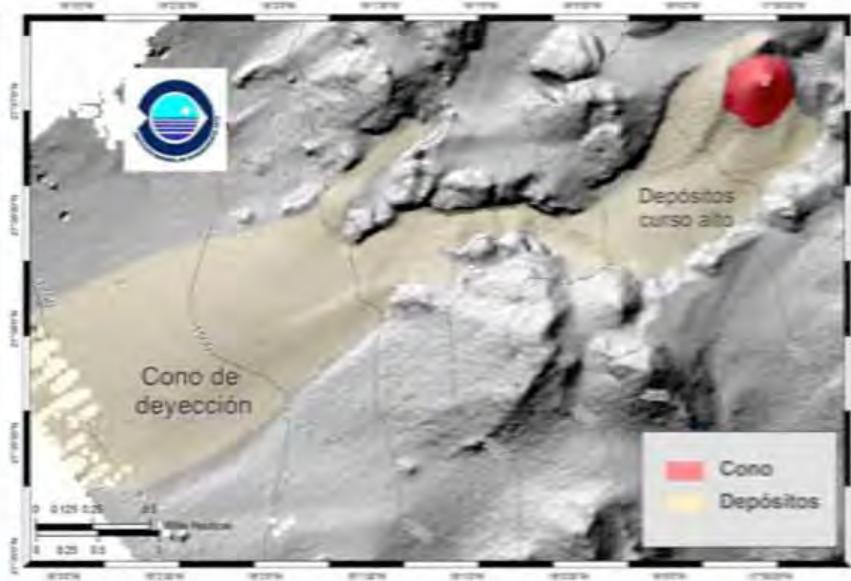
Proyecto VULCANO

Título: Volcanic erUption at El Hierro lsLand. Sensitivity and ReCovery of the mArine EcOsystem

Fuente: MINECO (CTM2012-36317)

Investigador Principal: Eugenio Fraile (IEO)

Duración: dos años (2013 – 2014)





INSTITUTO
ESPAÑOL DE
OCEANOGRÁFIA

Gracias por su atención!



Proyecto Bimbache

La erupción submarina de El Hierro: perturbación físico-química y su respuesta biológica

Dr. Eugenio Fraile Nuez

Investigador Titular
Instituto Español de Oceanografía



Las Palmas de Gran Canaria, 20 de Noviembre de 2012