Volcanism generated ocean heat waves and biodiversity

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Association for Geoconservation, Hong Kong presentation with the support of the Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government, November 15, 2020

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Assisted by MSc Earth Systems Science graduates, Chinese University of Hong Kong / Volcanoes Study Group, Hong Kong

North Pacific Blob
2013-2015

Manuel Leung

Chaitên 2008
and Calbuco
2015 eruptions

Kenneth To

Arctic sea ice
2008-2017

Alvin Wong

Hunga eruption
2014-2015

Tina Yau

2

Plan

Background information

4 examples of regional ocean heat waves –

2012 North Atlantic Blob

2013-2016 North Pacific Blob

2018-2019 Southwest Indian Ocean Blob

2019-2020 South Pacific Blob

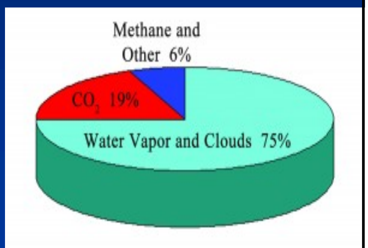
Conclusions

3

Possible factors controlling ocean heat waves?

Air circulation/pressure changes (heat distribution)

Greenhouse gases mainly –
- Carbon dioxide CO_2
- Methane CH_4
- Water vapour H_2O (most important)



Water/cloud/ice distribution
Vegetation distribution
Ocean circulation changes
Astronomical factors e.g. sun & orbital changes
Submarine volcanic eruptions/lava flows into oceans
Heat generation through human activities

4

What is the order of importance?

1st order

Astronomical forcing and the Sun e.g. glacial/interglacial cycles, solar cycles, monsoons and seasons

2nd order

Volcanism generated geothermal heat/plate climatology

www.plateclimatology.com

How geological forces affect the hydrosphere and atmosphere including terrestrial and submarine volcanic eruptions, their associated circulation changes and the release of CO_2 and methane

3rd order

Human-induced changes including urbanization, water cycle changes and emissions of greenhouse gases

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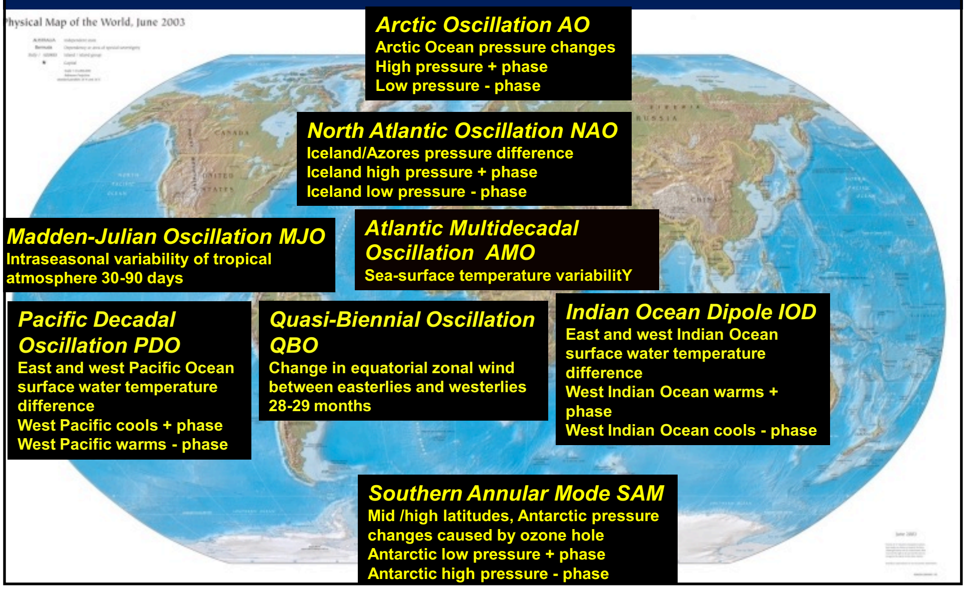
Known regional climatic variability additional to monsoons



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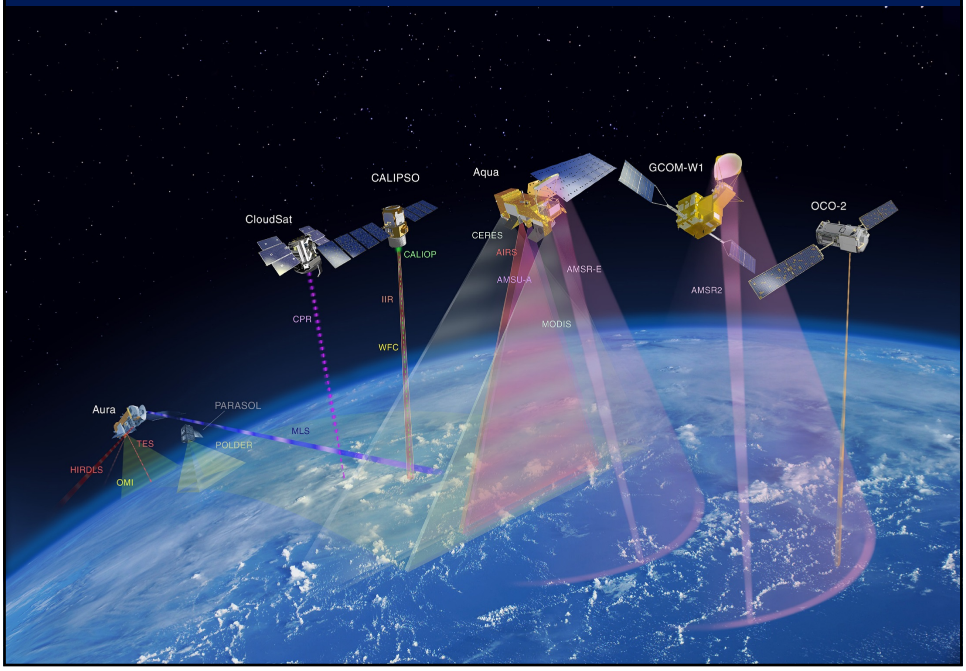
NASA’s A-Train including CALIOP vertical profiles of aerosols



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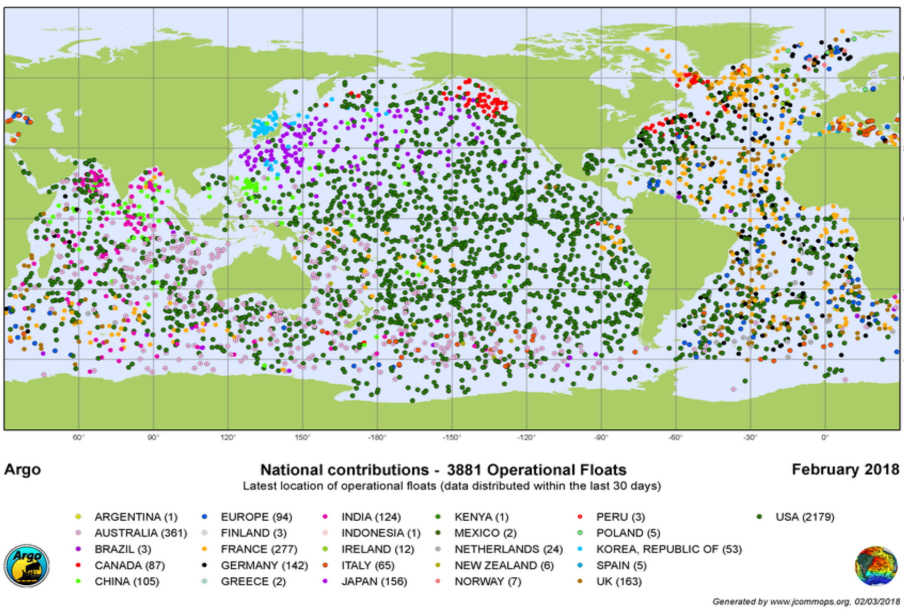
ARGO ocean network of profiling floats since early 2000s



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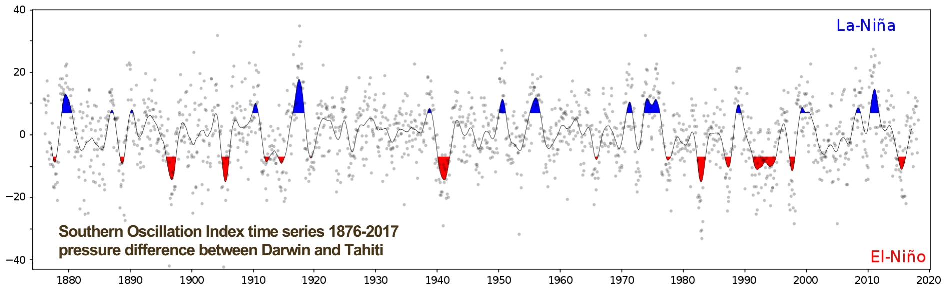
What is ENSO?

El Niño Southern Oscillation

Note – Pre-industrial era existence shown by coral archives.

An irregularly periodic variation in winds and sea surface temperatures over the tropical eastern Pacific Ocean, affecting the climate of much of the tropics and subtropics. The warming phase of the sea temperature is known as *El Niño* and the cooling phase as *La Niña*. The *Southern Oscillation* is the accompanying atmospheric component, coupled with the sea temperature change: *El Niño* is accompanied by high air surface pressure in the tropical western Pacific and *La Niña* with low air surface pressure there.



Source: Wiki

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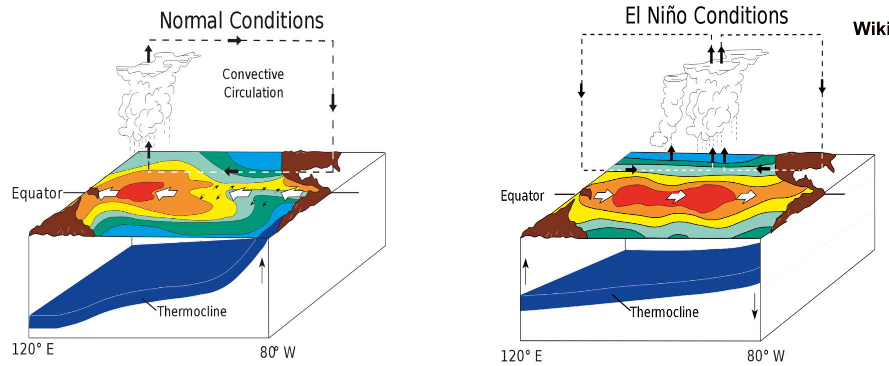
Normal and El Niño conditions

in the Pacific Ocean



Wiki

Warm pool in the west drives deep atmospheric circulation. Local winds cause nutrient rich cold waters to upwell along the South American coast.

Warm water and atmospheric circulation moves eastwards. In strong El Niños deeper thermocline off south America means upwelled water is warm and nutrient poor.

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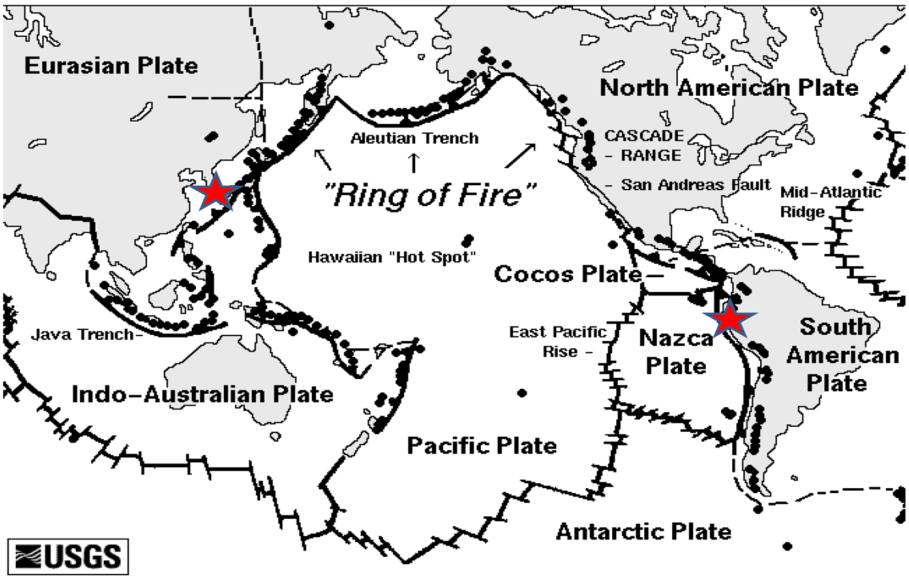
Why ENSOs occur in the Pacific?



Topinka, USGS/CVO, 1997, Modifed from: Tilling, Heliker, and Wright, 1987, and Hamilton, 1976

Note – Volcanism within the ocean basins currently comprises 70% of Earth's magma output.

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Classification of volcanic eruptions*

(1) Sub-aerial / terrestrial
- switches on hot air followed by cooling (atmospheric warming, injection of ash, gases and aerosols, blockage of shortwave radiation, cloud formation, pressure changes, moisture redistribution, continental cooling, ozone depletion, circulation changes, severe weather)

(2) Submarine / sea floor
- switches on hot seawater (cause of sea-surface temperature anomalies, pressure changes, circulation changes, moisture redistribution, continental warming, severe weather events including cyclones)

(3) Mixed
- initially submarine later sub-aerial (combination of 1 and 2).

* Magmatic composition also important.

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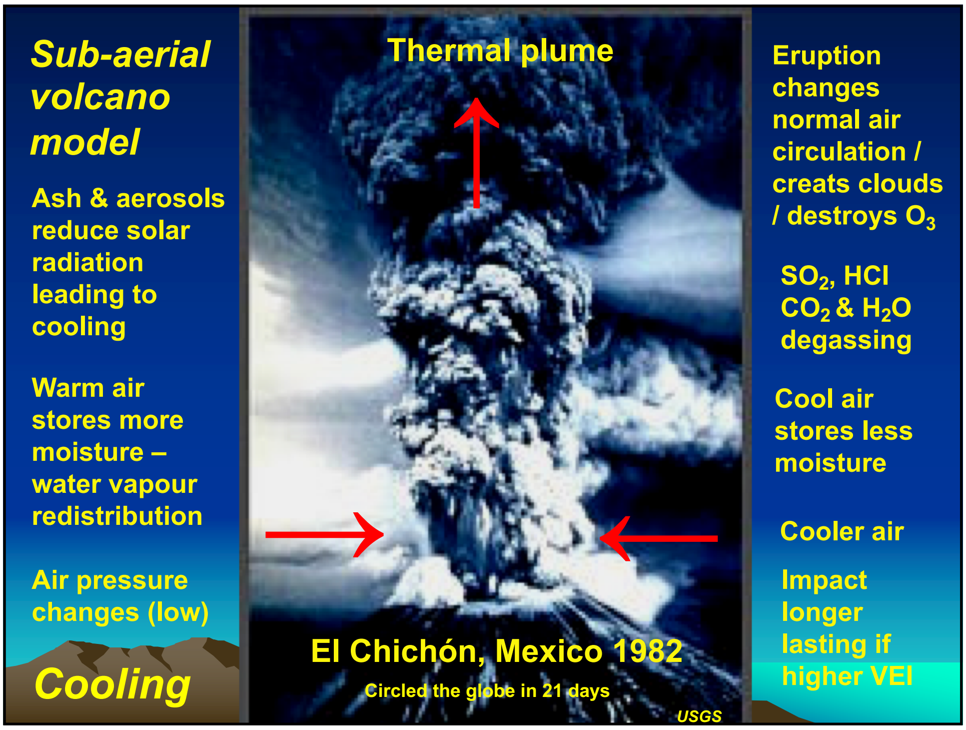
Sub-aerial volcano model
Ash & aerosols reduce solar radiation leading to cooling
Warm air stores more moisture – water vapour redistribution
Air pressure changes (low)
Cooling
Thermal plume
El Chichón, Mexico 1982
Circled the globe in 21 days
USGS
Eruption changes normal air circulation / creats clouds / destroys O_3
SO_2, HCl CO_2 & H_2O degassing
Cool air stores less moisture
Cooler air
Impact longer lasting if higher VEI

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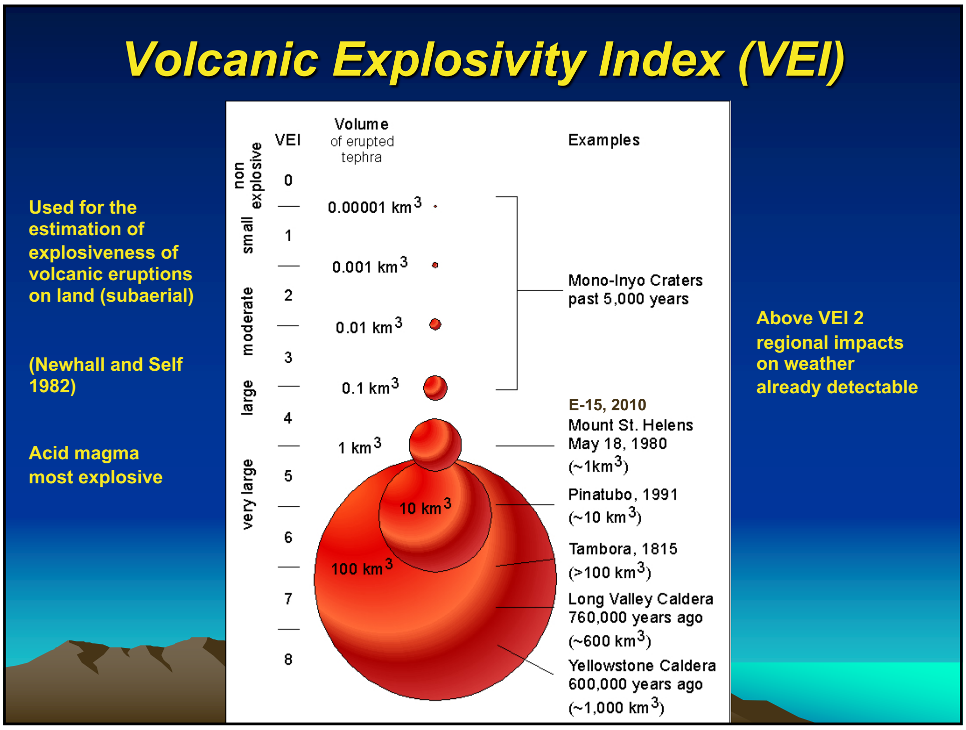
Volcanic Explosivity Index (VEI)
Used for the estimation of explosiveness of volcanic eruptions on land (subaerial)
(Newhall and Self 1982)
Acid magma most explosive
VEI
Volume of erupted tephra
Examples
non explosive
small
moderate
large
very large
0
1
2
3
4
5
6
7
8
0.00001 km^3
0.001 km^3
0.01 km^3
0.1 km^3
1 km^3
10 km^3
100 km^3
Mono-Inyo Craters past 5,000 years
E-15, 2010
Mount St. Helens May 18, 1980 (~1km^3)
Pinatubo, 1991 (~10 km^3)
Tambora, 1815 (>100 km^3)
Long Valley Caldera 760,000 years ago (~600 km^3)
Yellowstone Caldera 600,000 years ago (~1,000 km^3)
Above VEI 2 regional impacts on weather already detectable

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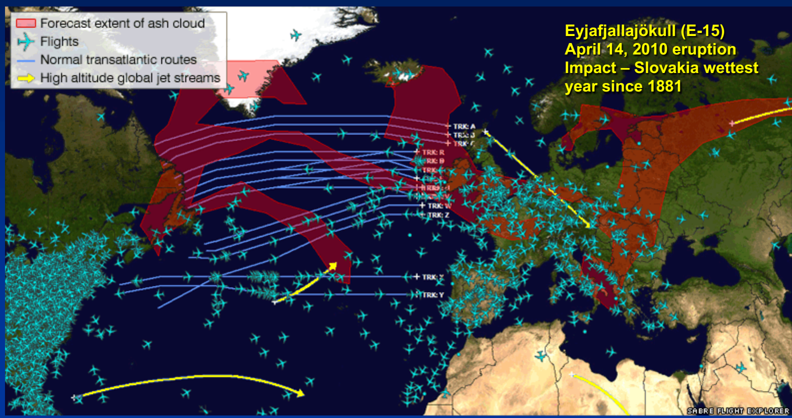
Why study the present day? e.g. Iceland 2010 event



Most reliable record – Information age
Importance – societal e.g. farming, climate model testing

(Meteorological observations
(Satellite observations since ~1980
(Weather disaster media reports
(Aviation safety studies

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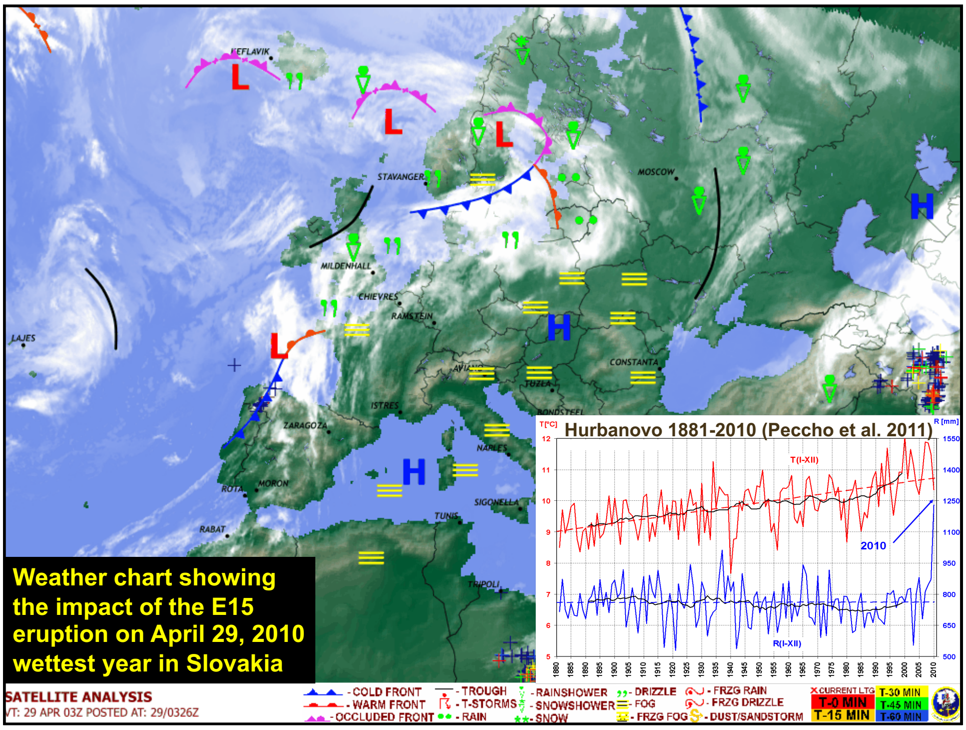

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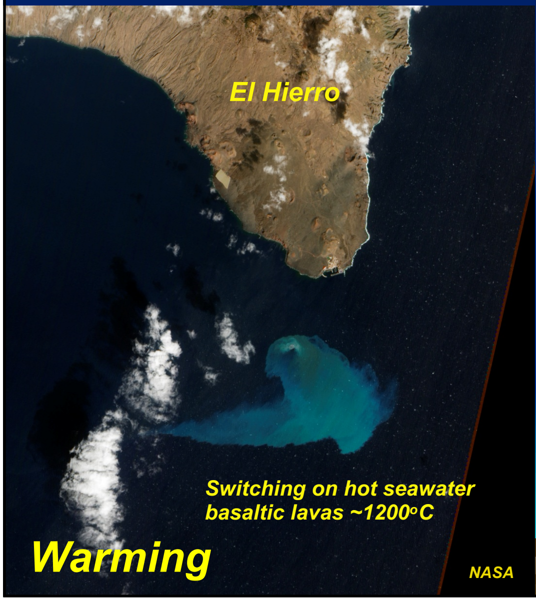
Submarine volcano model



Examples –

El Hierro volcano, Canary islands 10/2011 – 3/2012

Nishinoshima, 940 km south of Tokyo 3/2013-9/2015

Off Mayotte 11/2018-4/2019

Possible effects –
Heating up seawater
Pressure changes
Surface wind changes
Sea-level changes
Ocean current changes
Polar sea ice changes
Biodiversity changes

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Statistics on submarine volcanoes

Total number	1 million
Number rising 1 km from seabed	75,000
Magma output in oceanic ridges	75%
Active submarine volcanoes	~5000

Important facts –

Geothermal heat is released during eruptions changing the 'normal' ocean circulation

Known for volcanic ecosystems

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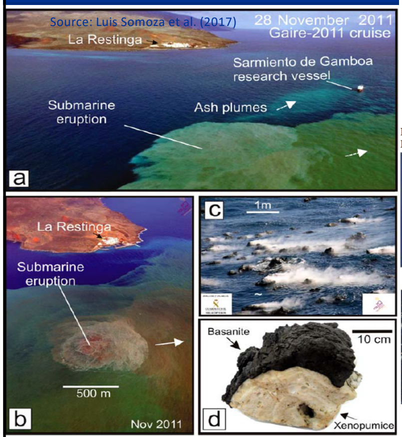
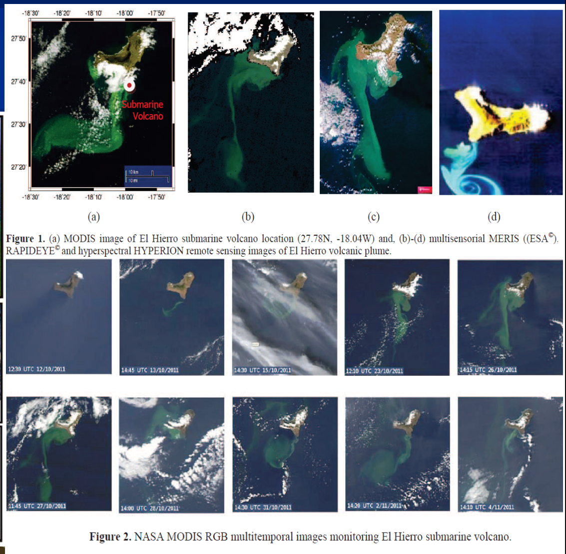
El Hierro submarine eruption, Canary Islands October 2011-March 2012

- The discoloured water was at least 20-30km wide and 100km long
- Spread southward





Source: Eugenio et al. (2014)

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What was the observed impact of the hot seawater in the North Atlantic Basin overlooked by atmospheric scientists?

Brownish plume created

Source: Daily Mail

A new island emerged briefly from the sea along the coast of Restinga, Canary Islands

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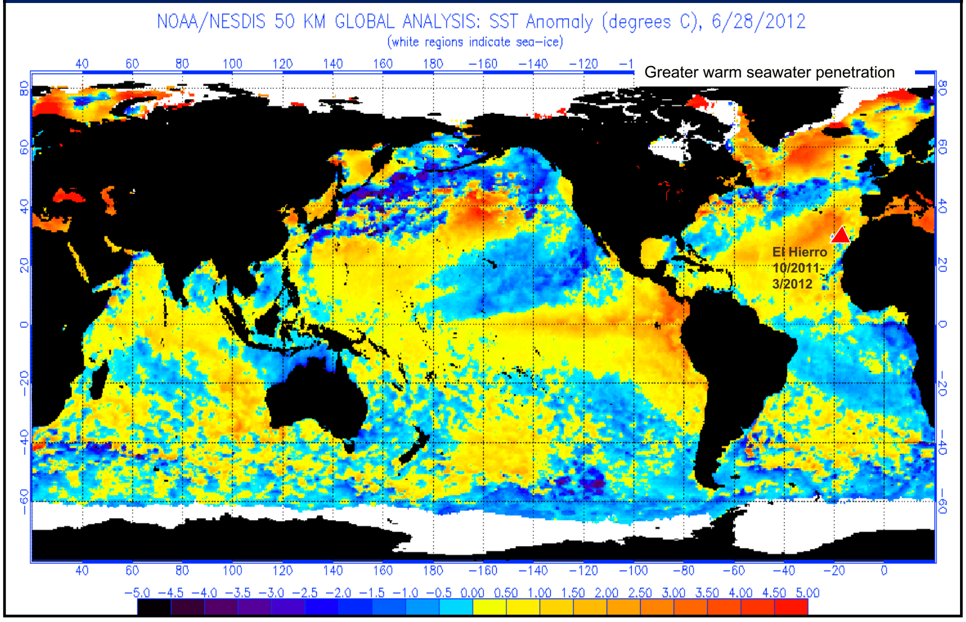
North Atlantic Blob – combined effect of the Sun and El Hierro on SST on 28 June 2012



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Weather-related events or pattern in the North Atlantic Basin during 2012

Date	Affected region	Events or pattern
April-July	England and Wales	Wettest summer in 100 years with annual rainfall of 1331 mm (115% above average) and severe flooding
May-August	Central North America	Drought estimated damage US$30 billion; most severe since 1895
Summer	Arctic Ocean	Record low sea ice
Summer	Northern/central Europe	Abnormally wet summer with moisture able to penetrate the continental interiors
June-November	US east coast	Extremely active hurricane season, tied with 1887, 1995, 2010 and 2011 for having the third-most named storms on record but few made landfall
July	Virginia	Hottest on record
July	Greenland	Period of extended surface melting across almost the entire ice sheet
July-October	Western/central Africa	Abnormally wet with flood conditions
October	US east coast	Hurricane Sandy estimated damage US$65 billion; 147 fatalities
October	North Atlantic	Tropical storm Nadine tied record for the longest lasting Atlantic storm
November	England	Wettest week in last 50 years with severe flooding
Winter	US east coast	Abnormally cool and wet due to the active polar airstream
Winter	British isles	Abnormally cold due to the active polar airstream

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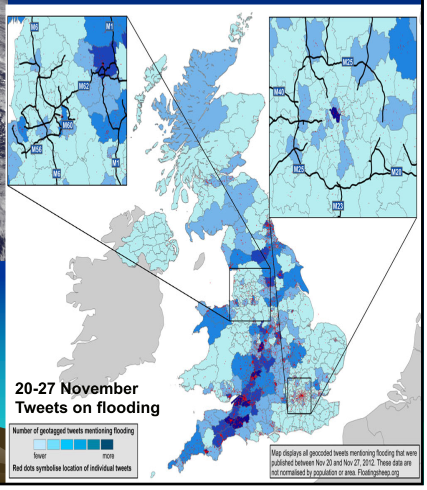
Notable severe weather events in 2012

Hurricane Sandy October 2012
147 fatalities; estimated damage US$65 billion

New records for England & Wales –
wettest summer in 100 years
wettest week in last 50 years
explained by increase in storms



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2012-2016 volcanic eruptions in the Pacific

Date	Volcano	Activity
7/2012	Havre, north of New Zealand	Largest deep-ocean silicic eruption of the past century with a 400 km^2 pumice raft, lava sourced from 14 vents 900-1220 m depth
3/2013-9/2015	Nishino-shima, South of Tokyo	Eruption was initially submarine until a new island appeared in November 2013
12/2014-1/2015	Hunga, Tonga	Initially submarine until a new island was created
5/2015-6/2015	Wolf, Galapagos	Basaltic lava flows into the Pacific Ocean
7/2016-onwards	Kilauea, Hawaii	Basaltic lava flows into the Pacific Ocean

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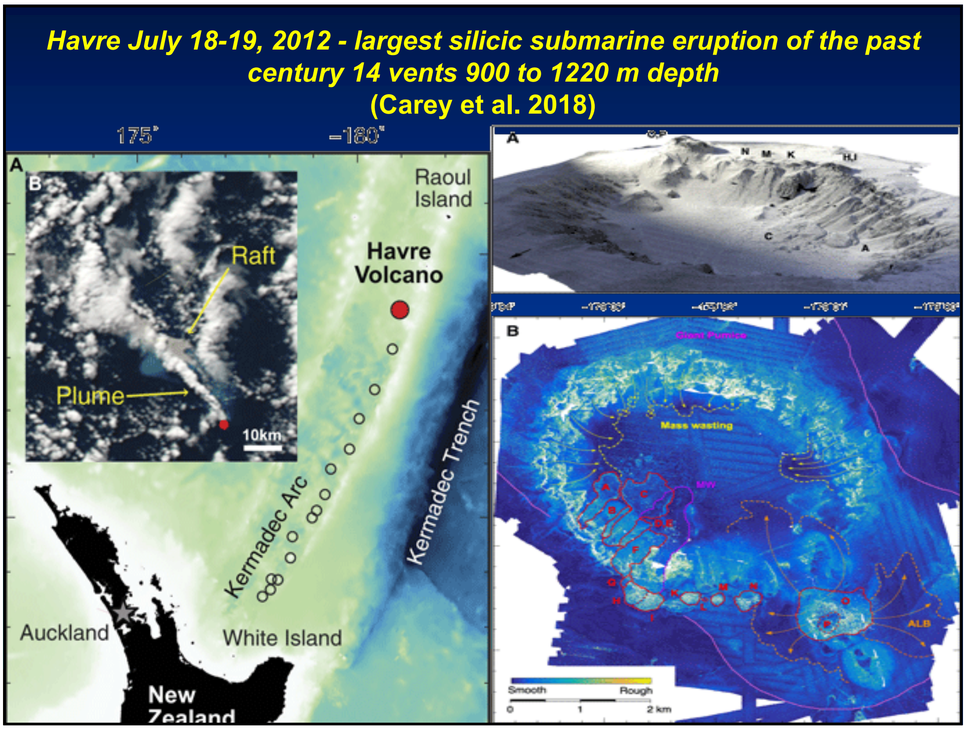
Havre July 18-19, 2012 - largest silicic submarine eruption of the past century 14 vents 900 to 1220 m depth
(Carey et al. 2018)
175°
−180°
A
B
Raft
Plume
10km
Raoul Island
Havre Volcano
Kermadec Arc
Kermadec Trench
Auckland
White Island
New Zealand
Mass wasting
ALB
Smooth
Rough
0
1
2 km

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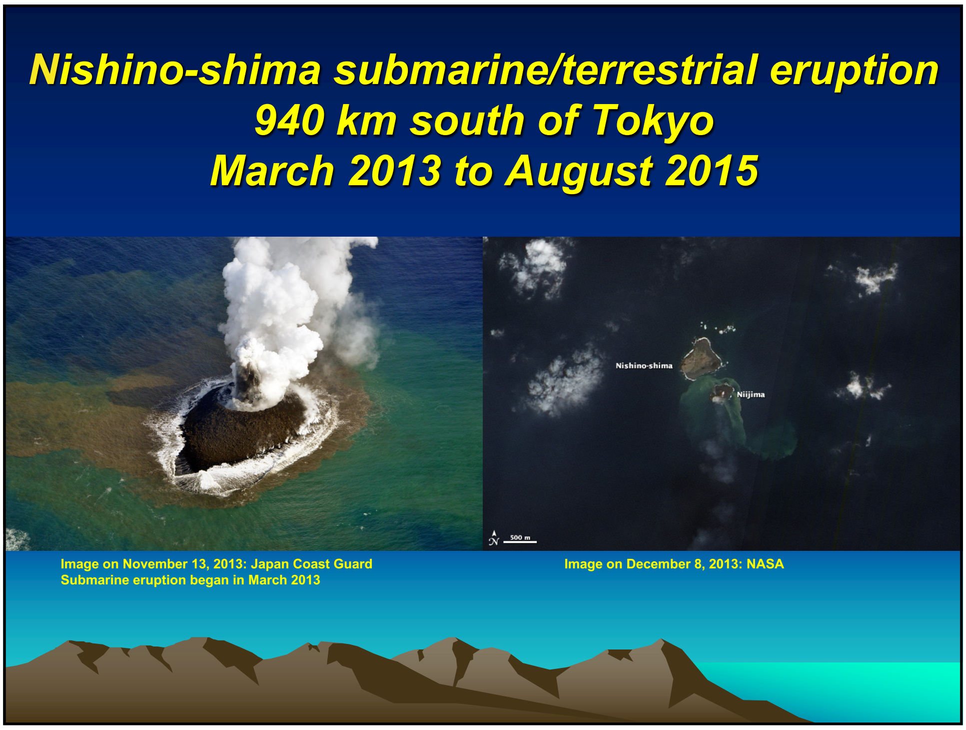
Nishino-shima submarine/terrestrial eruption
940 km south of Tokyo
March 2013 to August 2015
Nishino-shima
Niijima
500 m
Image on November 13, 2013: Japan Coast Guard
Submarine eruption began in March 2013
Image on December 8, 2013: NASA

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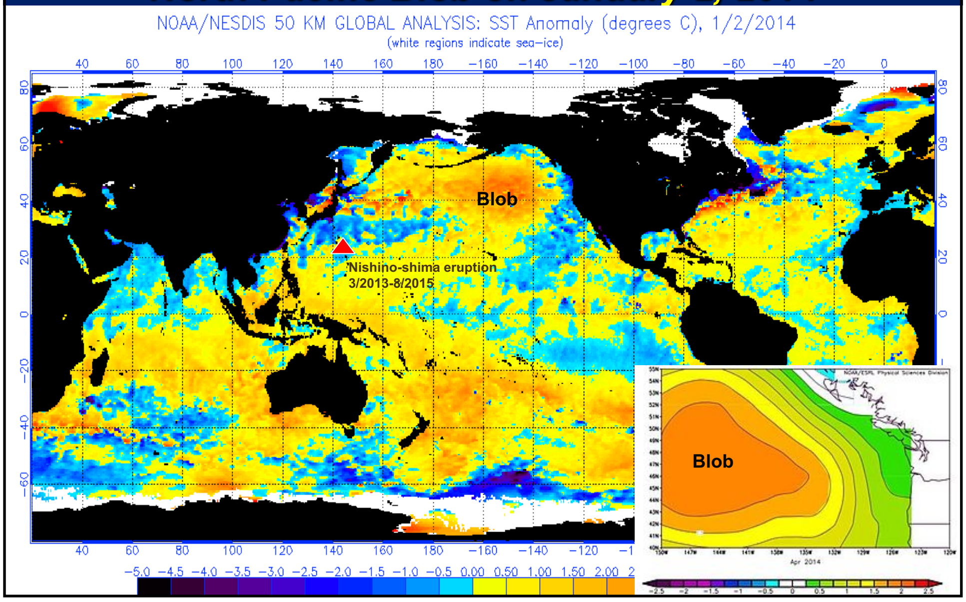
Main trigger of 2014-2016 ENSO sea-surface temperature anomalies created the North Pacific Blob on January 2, 2014



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Events linking the Blob to the Nishino-shima eruption

Date	Nishino-shima eruption activity	Northern Pacific Blob
March 2013	Hot seawater first appeared	Initial warming in the northwest Pacific
November 2013	Appearance of a new island	Initial Blob 800 km wide and 91 m deep
December 2013	Island rose 20 to 25 m above sea level with an area of 5.6 km^2	-
February 2014	-	Temperature was around 2.5°C above normal
June 2014	-	Name ‘Blob’ coined by Nicholas Bond, Blob size reached 1600 km x 1600 km and 91 m deep spread to coastal North America with three patches off Alaska, Victoria/California and Mexico
December 2014	Island nearly 2.3 km in diameter and rose to about 110 m above sea level	2014 year without winter western Pacific coast major biodiversity impacts including algal bloom
January-August 2015	Volcanic eruption continued with episodic lava flows	Continuation of biodiversity impacts with sustained toxic bloom in Monterey Bay
Early 2016	-	Blob persisted and ended

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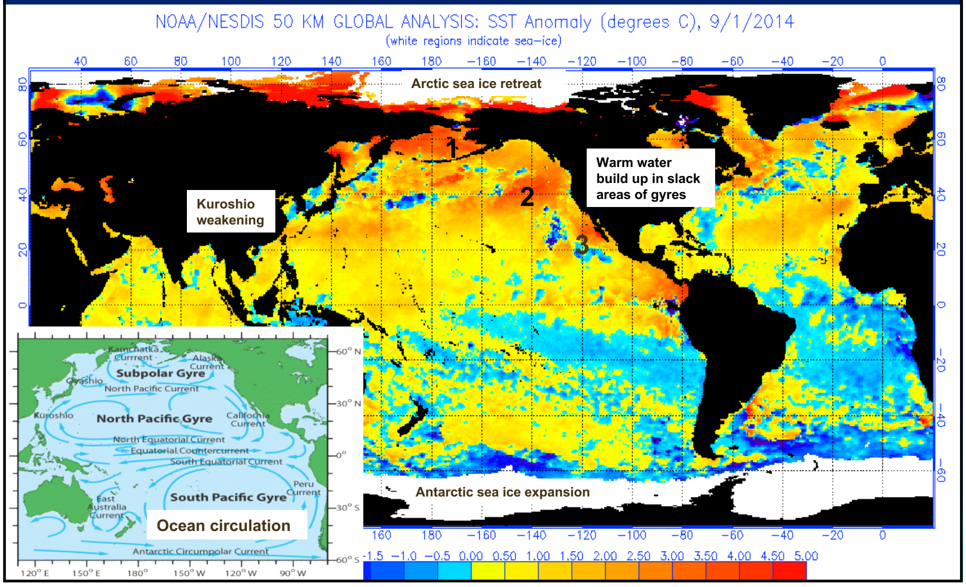
The Blob separated into three parts on September 1, 2014



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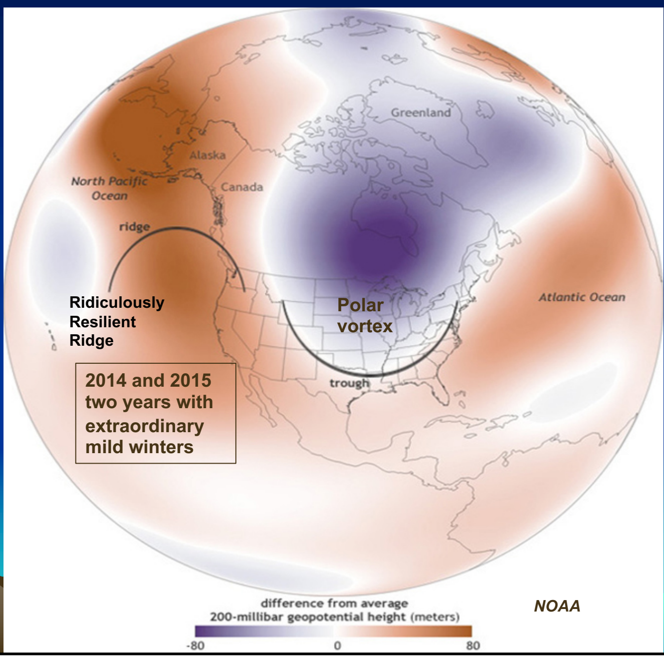
Pressure distribution during the North Pacific Blob



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Heat wave
National Geographic
September 2016
Dead sea lion

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Dying sea otter
Starving sea lion pups
Mass mortality of sea otters
Carcass of orca

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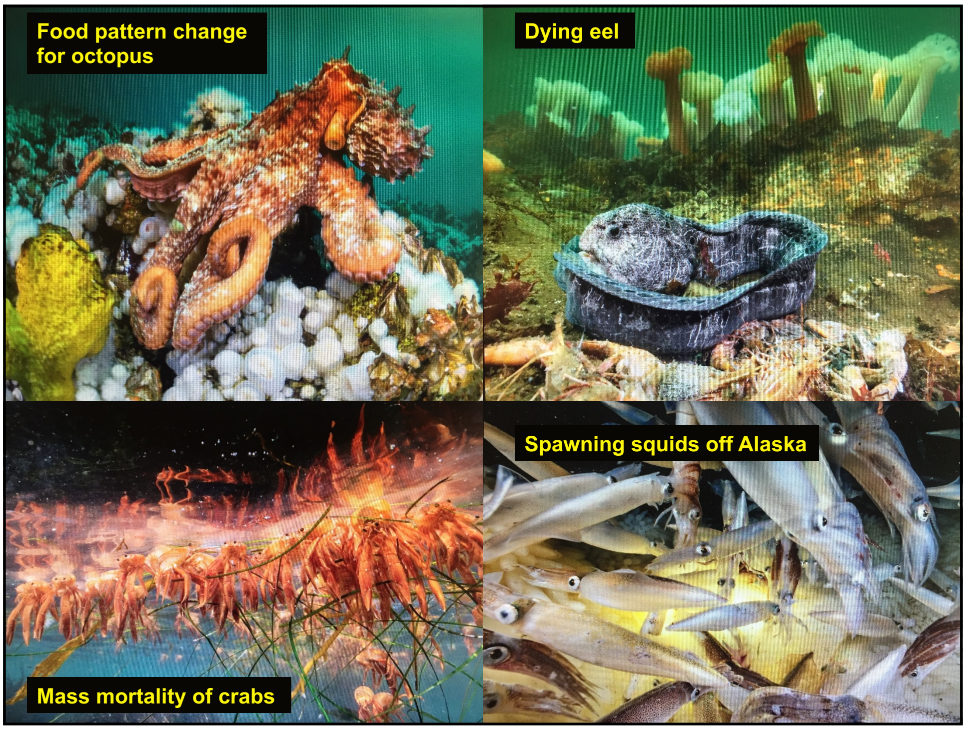
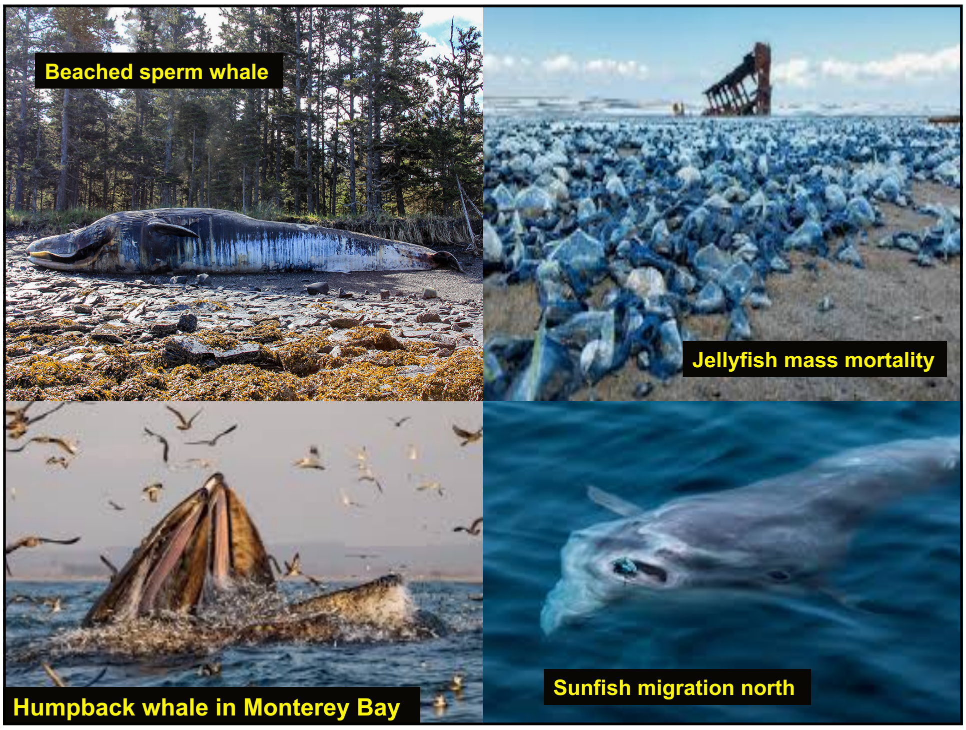

Food pattern change
for octopus
Dying eel
Spawning squids off Alaska
Mass mortality of crabs

33


Beached sperm whale
Jellyfish mass mortality
Humpback whale in Monterey Bay
Sunfish migration north

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Ecosystem changes

Warm seawater much less nutrient rich than cold seawater

Impacts –

- Reduction in coastal upwelling
- Reduction in phytoplankton productivity with knock on effects on zooplankton
- Food chain effect
- Salmon catches dropped drastically
- Death of almost 1 million birds between summer 2015 to Spring 2016 (reported by the Guardian on January 16, 2020)
- Tropical organisms including squids migrated to Alaskan coast

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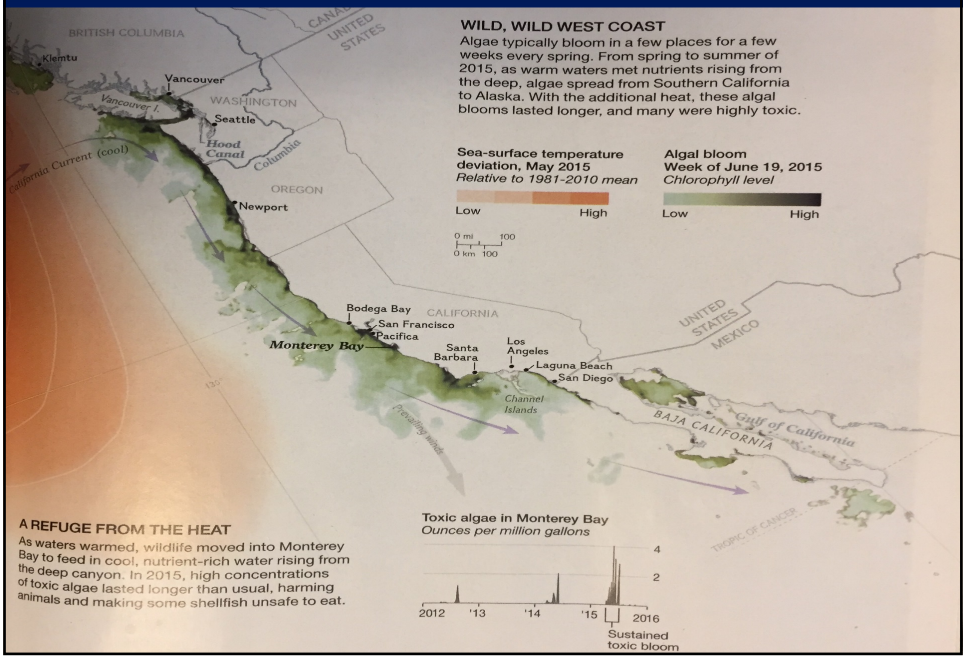
Toxic algal bloom along the west coast of North America



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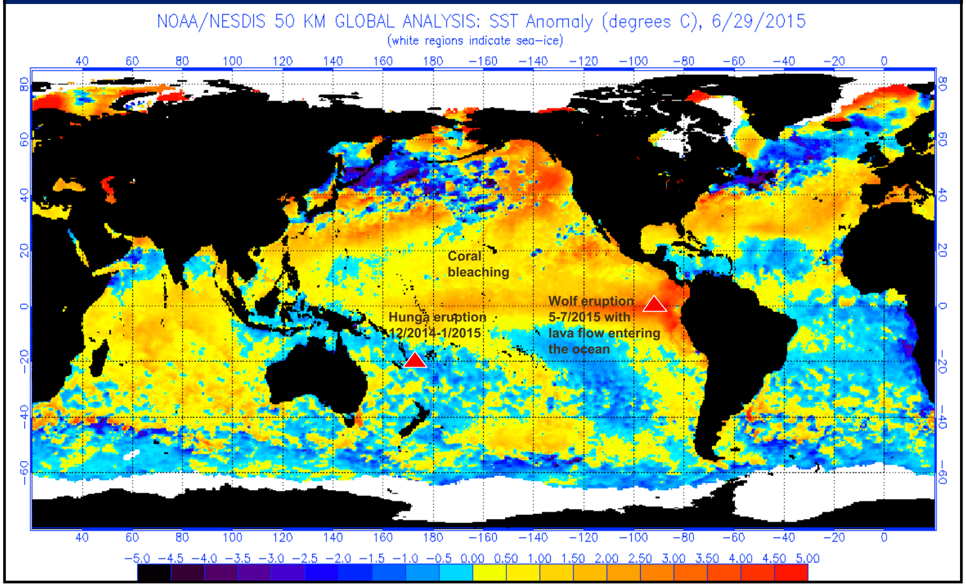
Sea-surface temperature anomalies on June 29, 2015 after the Wolf eruption ended



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A natural cause of Great Barrier Reef coral bleaching in January 2015

Note - Rise in ocean acidity caused by SO_2 degassing may also be at work.

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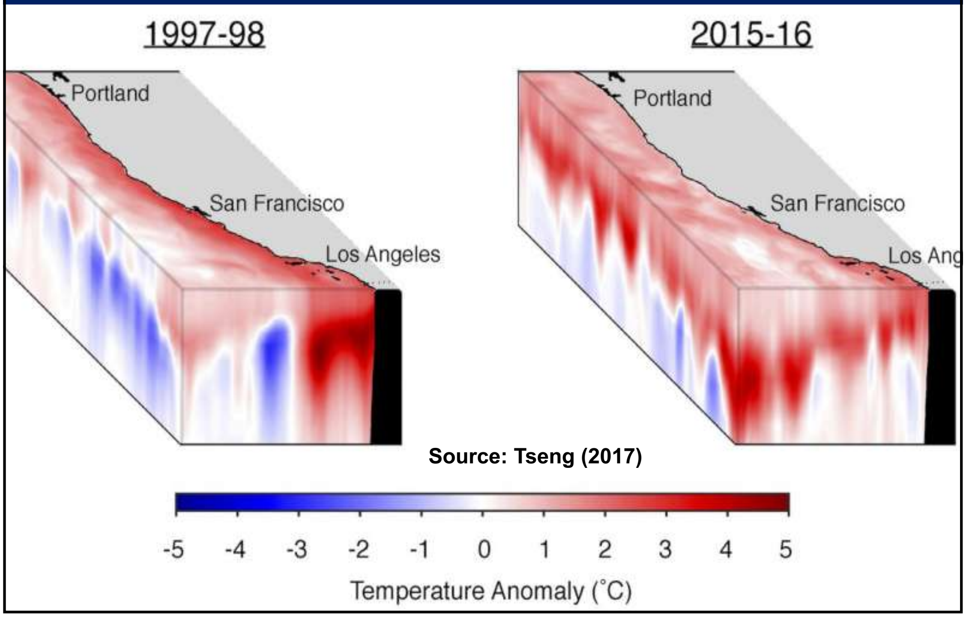
ENSO 2014-2016 was stronger because of the Blob

comparison of seawater temperature anomaly US west coast



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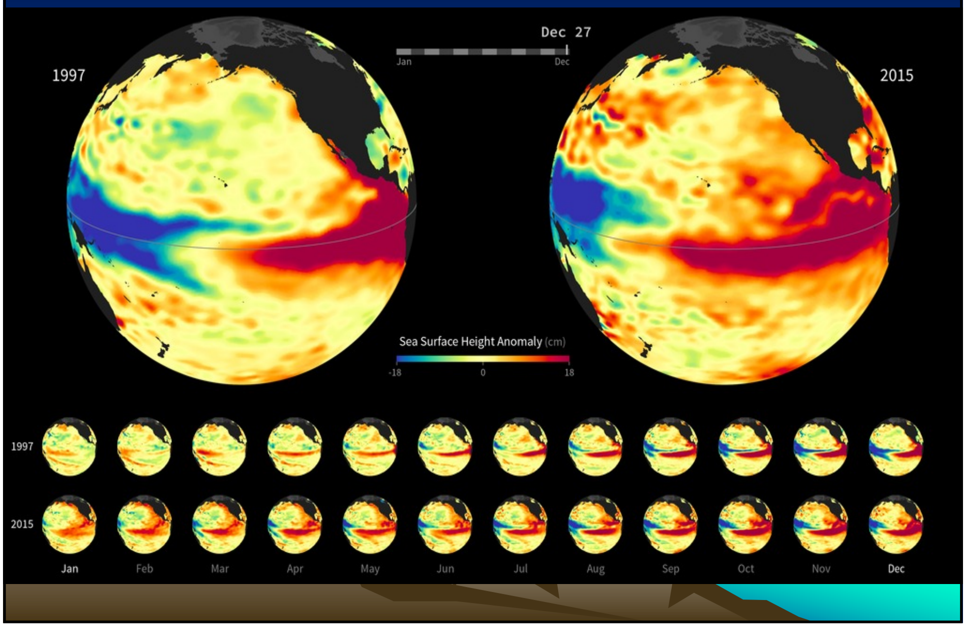
Comparison of sea-level anomaly 1997 and 2015

Source: Jentoft-Nilsen (2015)



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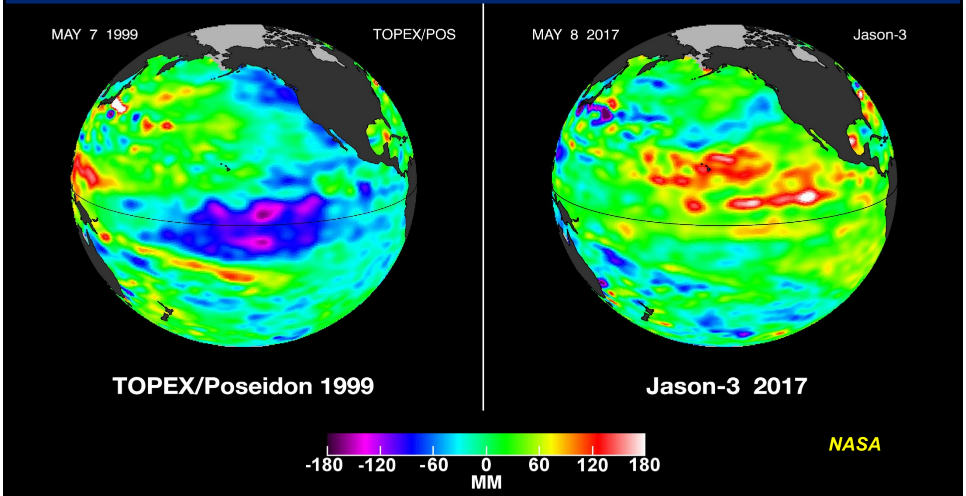
Comparison of ocean surface topography during El Niño 1997-1998 and 2015-2016



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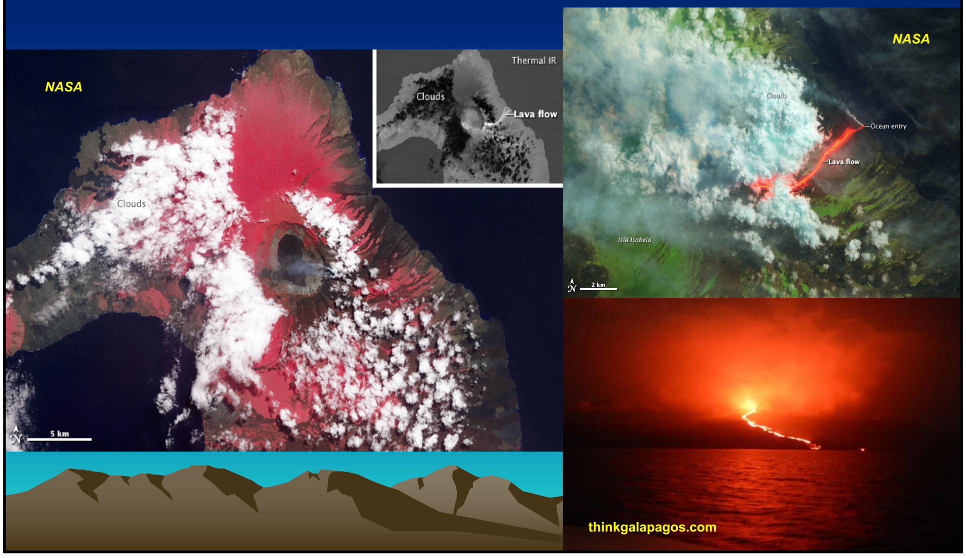
Eruption of Wolf volcano, Galapagos late May to June 2015 VEI 4



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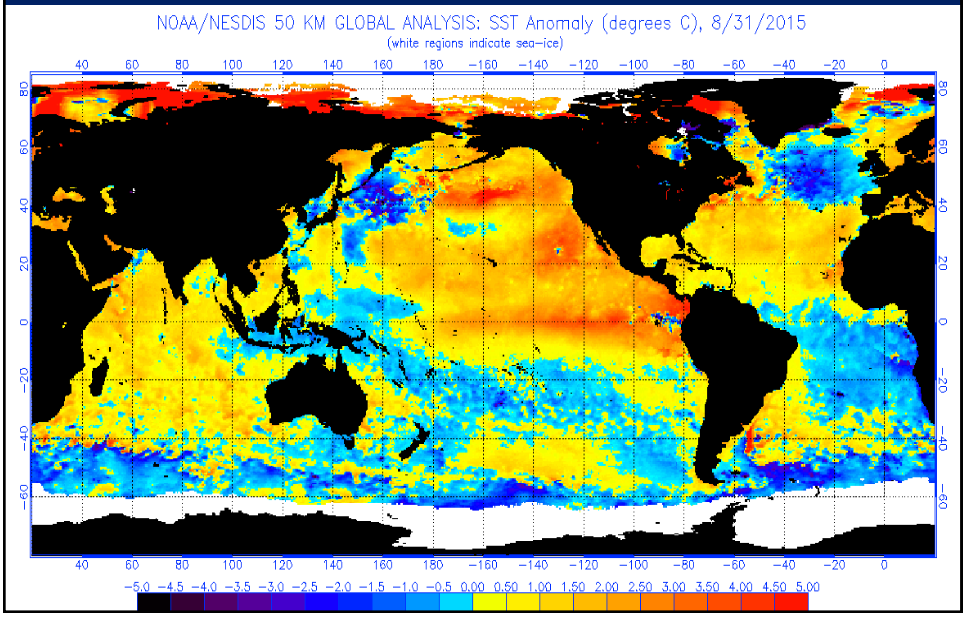
Establishment of the strong and long-lasting 2014-2016 El Niño August 31, 2015



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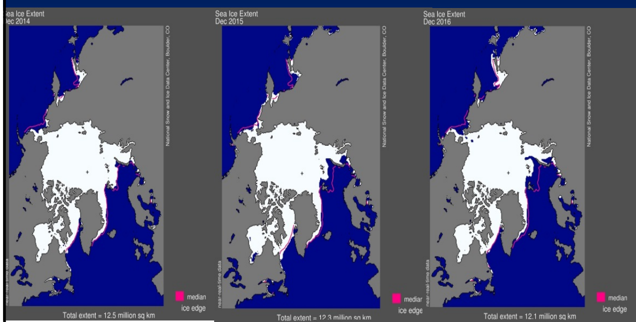
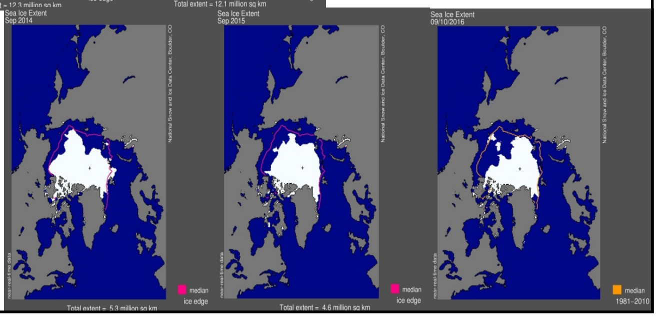
Influence on Arctic sea ice NISDC.org



Winter 2014-2016

Summer 2014-2016



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September Arctic sea ice extent 2007-2016
Source: National Snow & Ice Data Centre

YEAR	MINIMUM ICE EXTENT			DATE
	IN MILLIONS OF SQUARE KILOMETERS		IN MILLIONS OF SQUARE MILES	
2007	4.15		1.6	Sept. 18
2008	4.59		1.77	Sept. 20
2009	5.12		1.98	Sept. 13
2010	4.62		1.78	Sept. 21
2011	4.34		1.67	Sept. 11
2012	3.39	Record minimum	1.31	Sept. 17
2013	5.06		1.95	Sept. 13
2014	**5.03**		**1.94**	**Sept. 17**
2015	**4.43**	Gradual decline	**1.71**	**Sept. 9**
2016	**4.14**		**1.6**	**Sept. 10**
1979 to 2000 average	6.7		2.59	Sept. 13
1981 to 2010 average	6.22		2.4	Sept. 15

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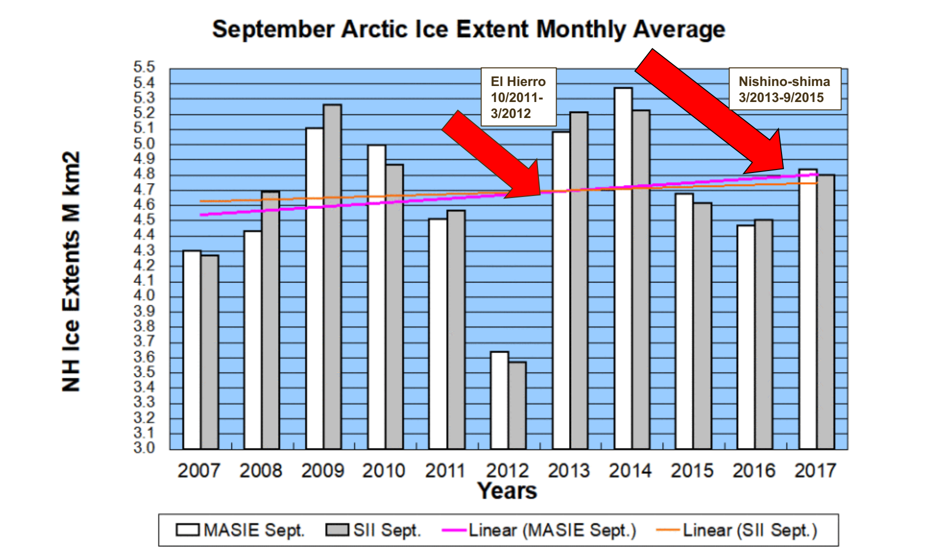
Arctic sea ice changes 2007-2017
Explained by the release of geothermal heat through volcanism
(Source: Clutz 2017)



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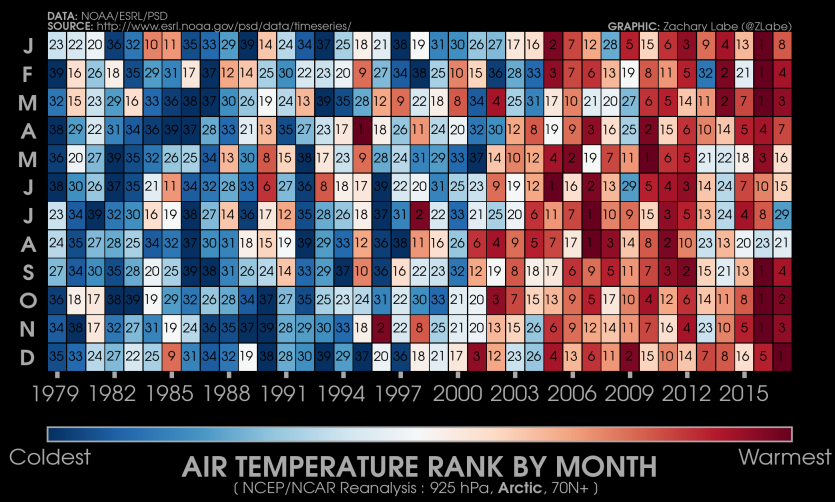
Ranking of Arctic monthly air temperatures 1979-2017



NOAA

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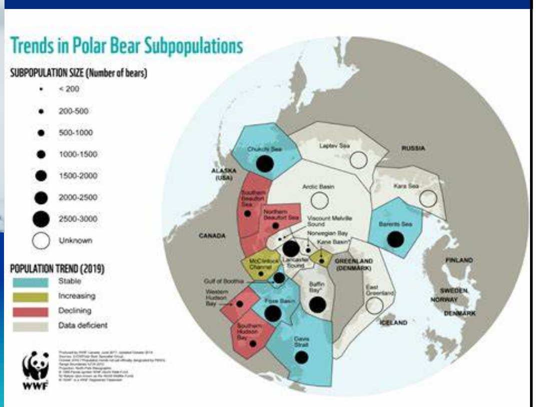
Are Polar Bears running out of habitats?



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New submarine volcanic eruption discovered in the Mozambique Channel November 2018-May 2019

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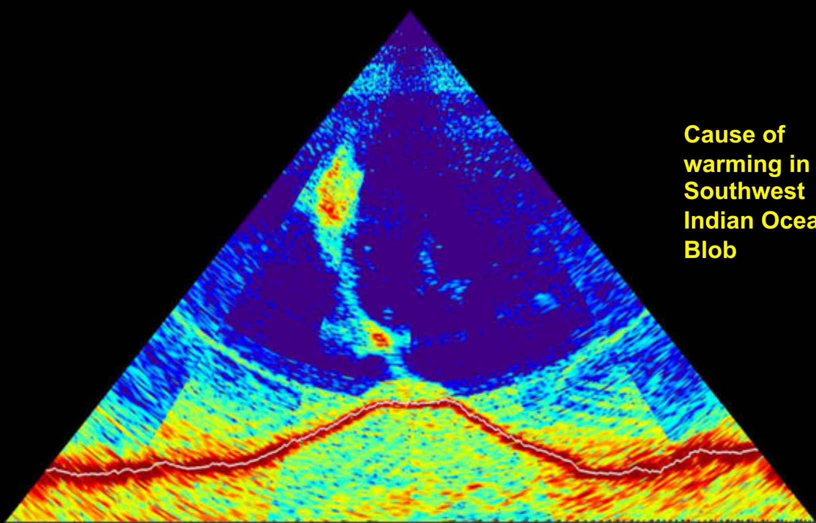
Multibeam sonar waves, reflecting off the sea floor southeast Mayotte, showing an 800-m-tall volcano with a 5 km diameter anda rising gas-rich plume



Cause of warming in Southwest Indian Ocean Blob

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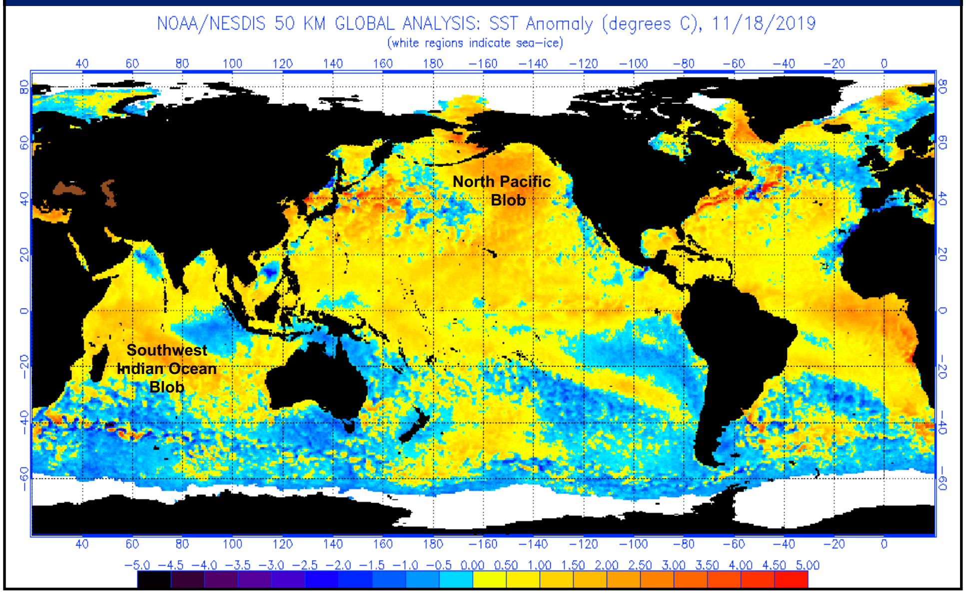
Global map of sea-surface temperature anomalies on November 18, 2019



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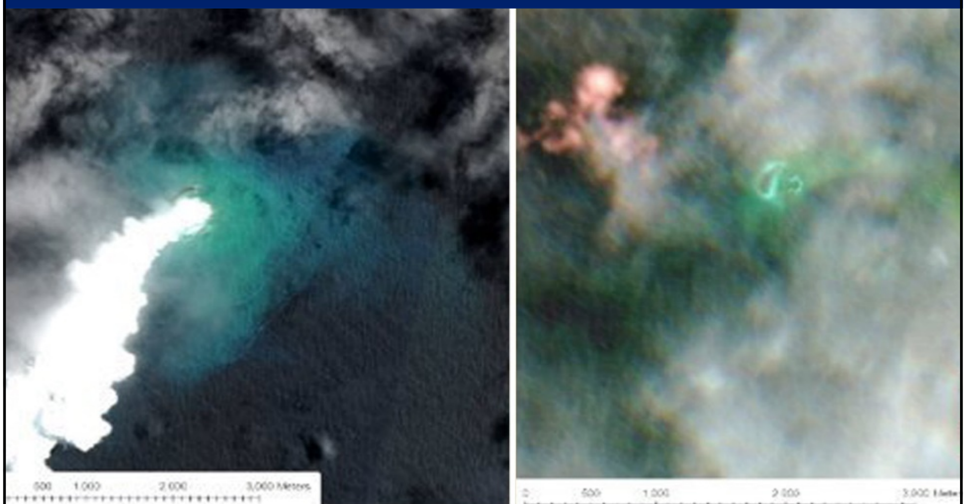
Lateiki submarine eruption, Tonga new island created November 7, 2019



Old island destroyed and replaced by a bigger new island

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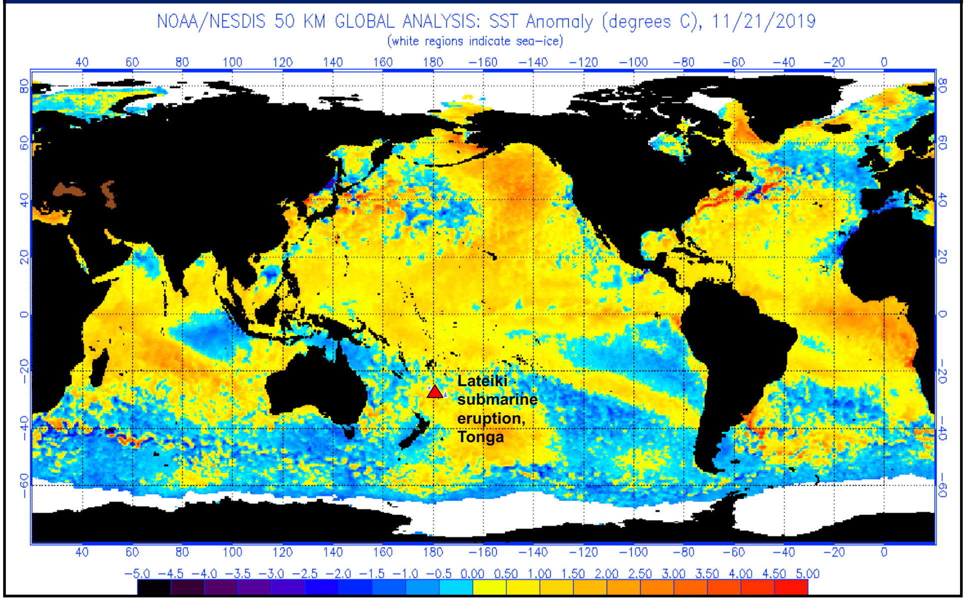
Global map of sea-surface temperature anomalies on November 21, 2019



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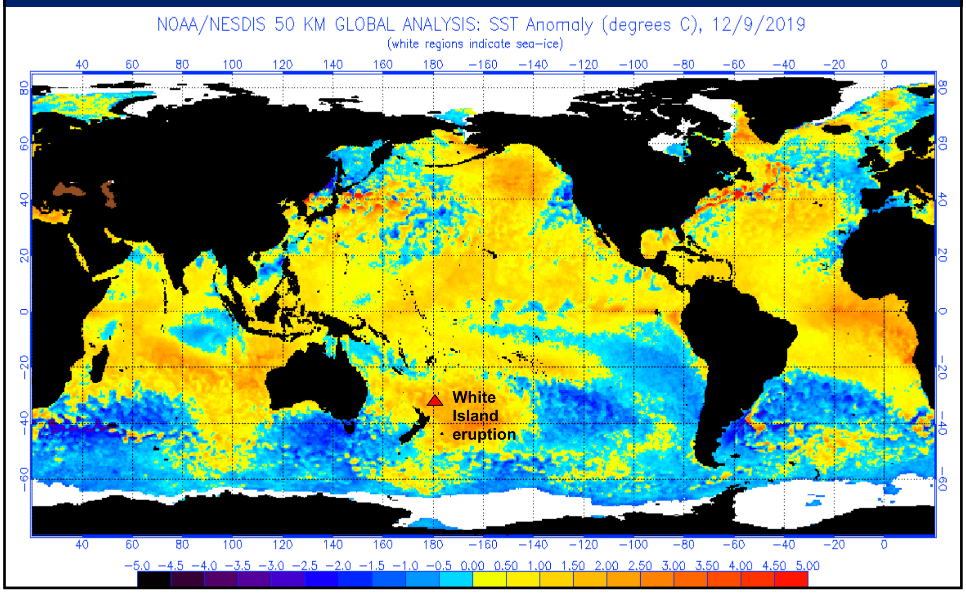
Global map of sea-surface temperature anomalies on December 9, 2019



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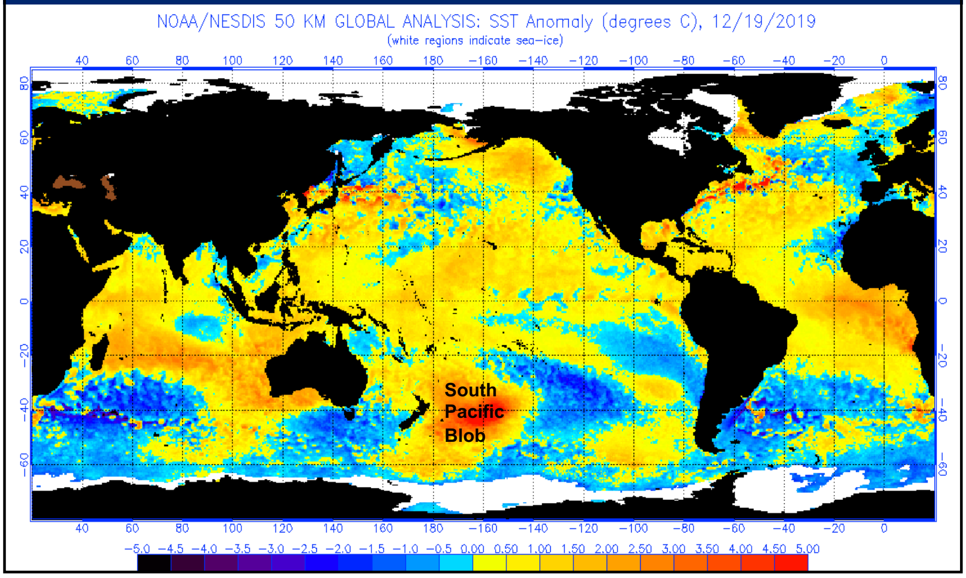
Global map of sea-surface temperature anomalies on December 19, 2019



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Statistics of the South Pacific Blob

Marine heat wave east of New Zealand – High pressure, sunny sky and light wind

1 million square kilometers (size of Texas)

6 degree Celsius above normal

Total thickness of hot seawater 50 metres

Prof. J. Renwick – Heated by the sun through natural causes not by global warming

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Marine heatwave brings tropical grouper from 3000 km away to New Zealand waters

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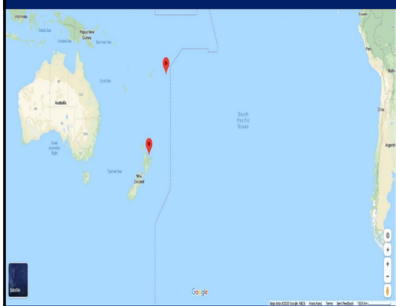
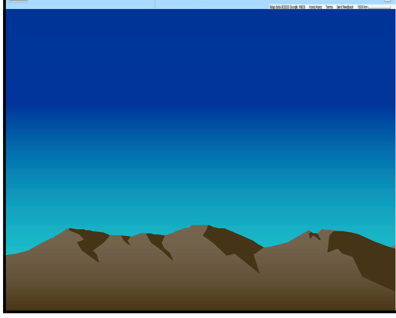
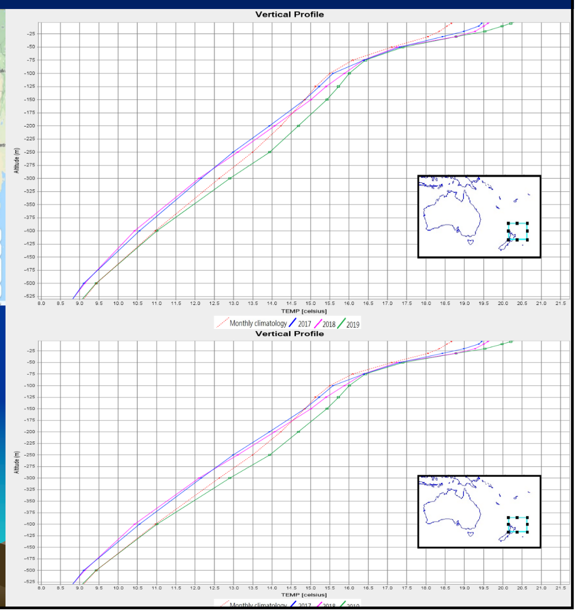
Submarine volcanic eruptions contributing geothermal heat to the South Pacific Blob







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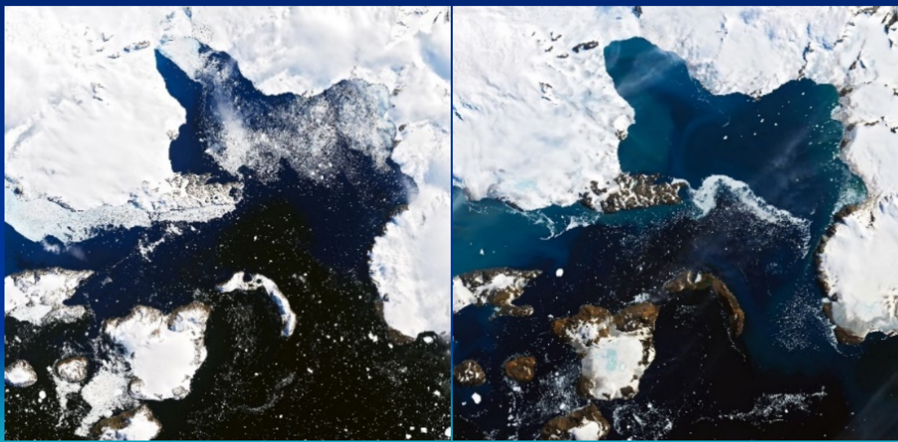
Landsat images showing dramatic melting in the Eagle Island region of Antarctica on February 4, 2020 in comparison to February 13, 2020. Source: NASA



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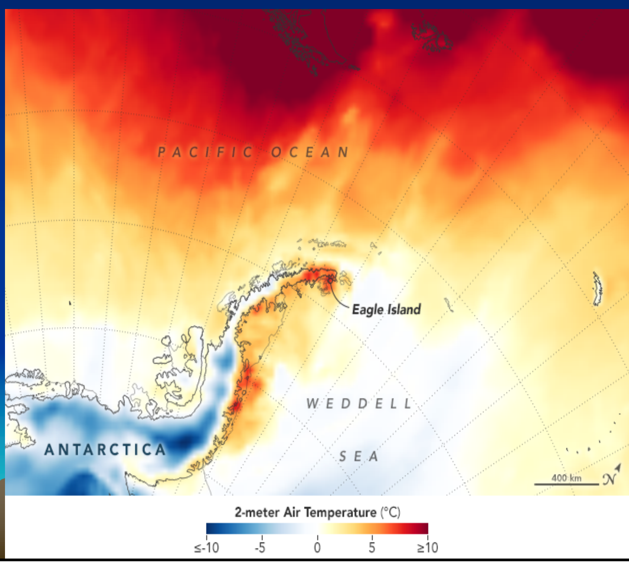
Map derived from the Goddard Earth Observing System model representing air temperatures at 2m above the ground on February 9, 2020. Source: NASA.



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Conclusions

(1) Volcanism is an underestimated natural cause of ocean heat waves.

(2) All 4 examples of regional ocean heatwaves were caused mainly by by the release of geothermal heat through volcanism.

(3) Man-made carbon dioxide from fossil fuels cannot be responsible for such heat waves.

(4) The occurrence of heat waves have important influence on the ice extent in both the Arctic and the Antarctic.

(5) The biodiversity changes observed were of a temporary nature which is inconsistent with global warming.

(6) Because sulphur oxides released into seawater through volcanism is much more acidic than carbon dioxide, it is more likely to be the the cause of coral bleaching.

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