Geothermal impacts of volcanoes: atmospheric plumes and oceanic blobs

Wyss Yim

Volcanoes Study Group, Hong Kong /
Association for Geoconservation, Hong Kong /
Institute of Space & Earth Information Science, Chinese University of Hong Kong /
Guy Carpenter Asia-Pacific Climate Impact Centre, City University of Hong Kong /
Department of Earth Sciences, The University of Hong Kong

Acknowledgements –
NOAA, NASA, Wikipedia and the Global Volcanism Program. This research is a contribution to the Volcanic Impacts on Climate and Society (VICS) Working Group of the Past Global Changes Project.

Thomas Nelson Podcast presentation on 19th December, 2023

*Types of volcanic eruptions**

(1) Sub-aerial / terrestrial –
Geothermal warming through atmospheric plumes and lavas flows entering the sea (atmospheric warming/cooling, injection of ash, gases and aerosols, reduction of shortwave radiation, cloud formation, circulation changes, moisture redistribution, atmospheric rivers, ozone depletion, continental cooling and extreme weather)

(2) Submarine / sea floor –
Geothermal warming of seawater to form oceanic blobs (sea-surface temperature anomalies, pressure changes, circulation changes including ENSO conditions and polar sea-ice retreat, Greenland ice sheet melting, moisture redistribution, continental warming and extreme weather)

(3) Mixed –
Initially submarine later sub-aerial (oceanic blob followed by atmospheric plume).

Regional changes impacted by geothermal warming in addition to monsoons

Atlantic Multidecadal Oscillation AMO

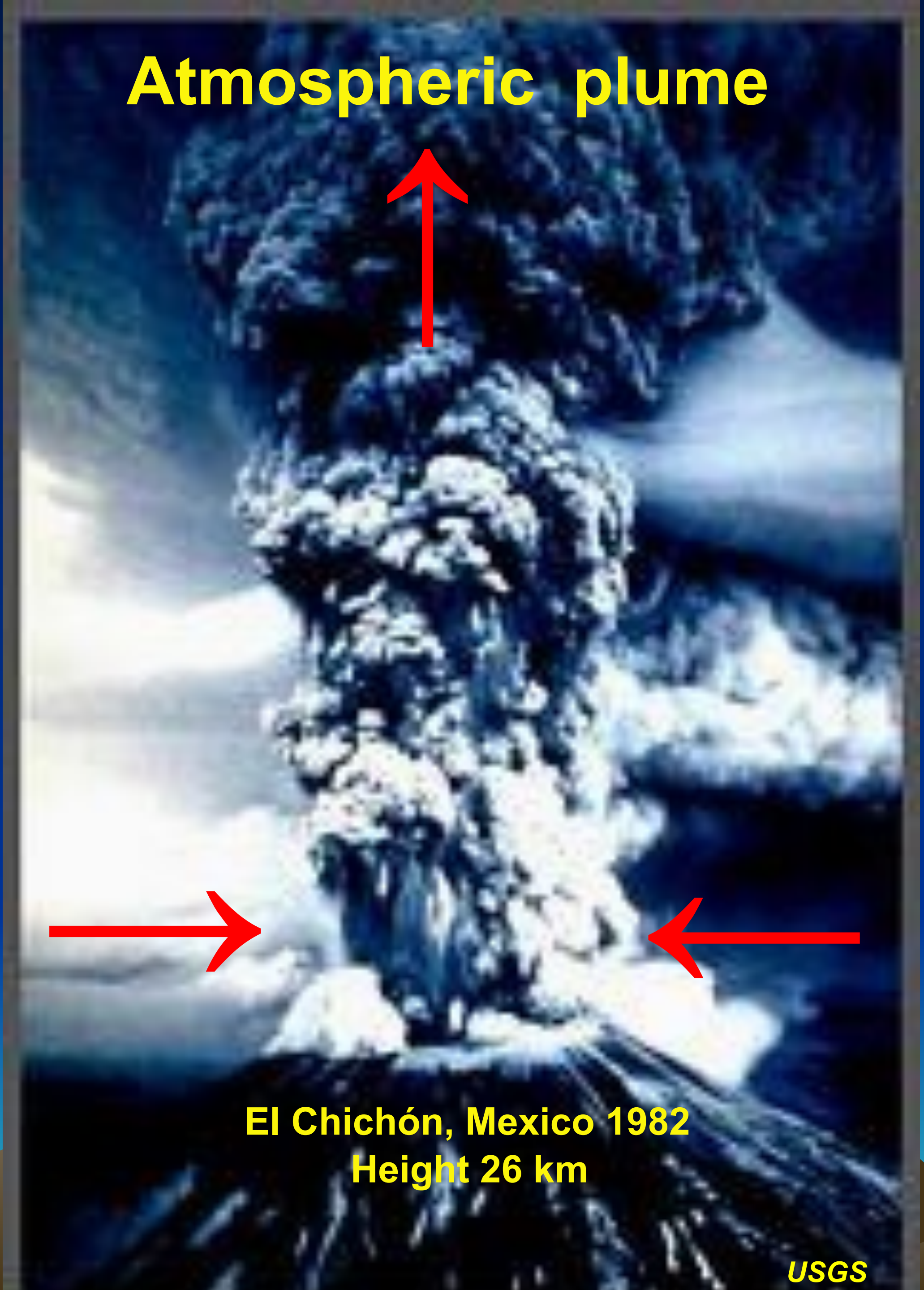
Sub-aerial volcano model

Ash & aerosols reduce solar radiation leading to cooling

Warm air stores more moisture – water vapour redistribution

Air pressure changes (low)

Cooling



Eruption changes normal air circulation / creates clouds / destroys O_3

SO_2, HCl CO_2 & H_2O degassing

Cool air stores less moisture

Cooler air

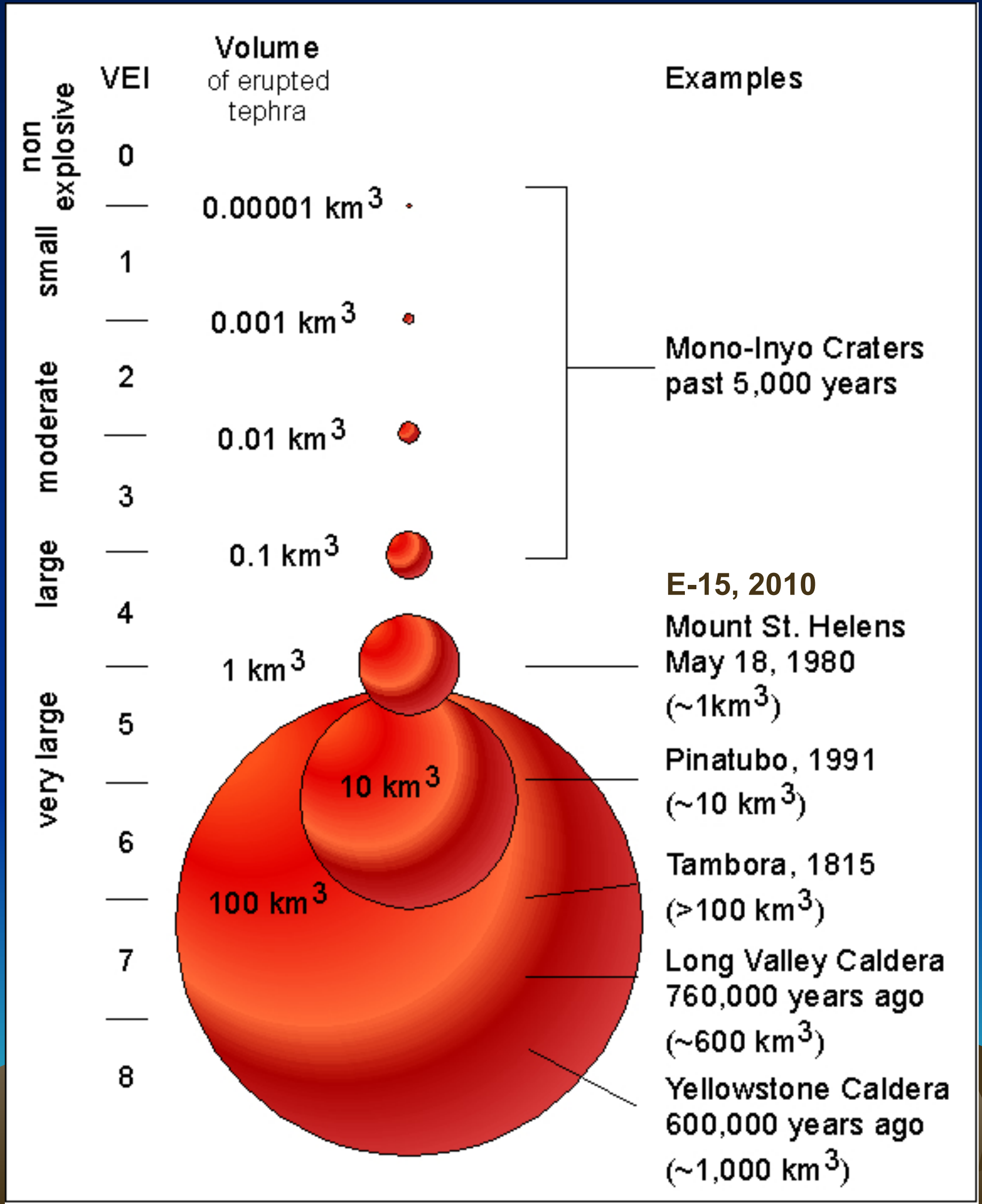
Impact longer lasting if higher VEI

Volcanic Explosivity Index (VEI)

Based on explosiveness of volcanic eruptions on land (sub-aerial)

(Newhall and Self 1982)

Acid magma most explosive but cooler than basic magma

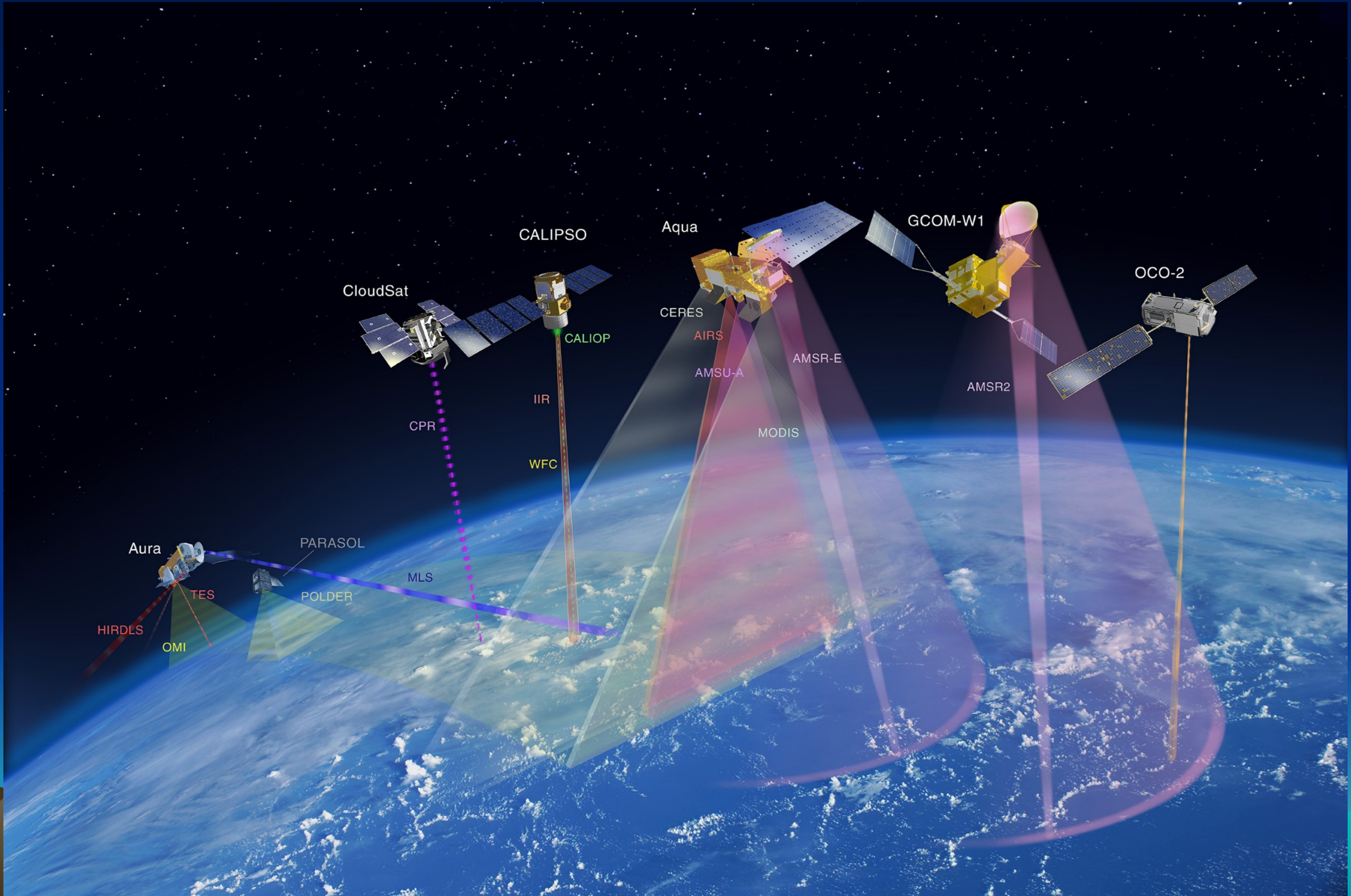


Above VEI 2 regional impacts on weather already detectable

Impact factors of atmospheric plumes –

Location of volcano
Cloud formation and plume height
Volcanic Explosivity Index VEI
Timing, duration and history of eruption
Weather conditions
Input of solid materials
Input of water vapour
Input of gases including sulphur dioxide, hydrogen chloride and carbon dioxide

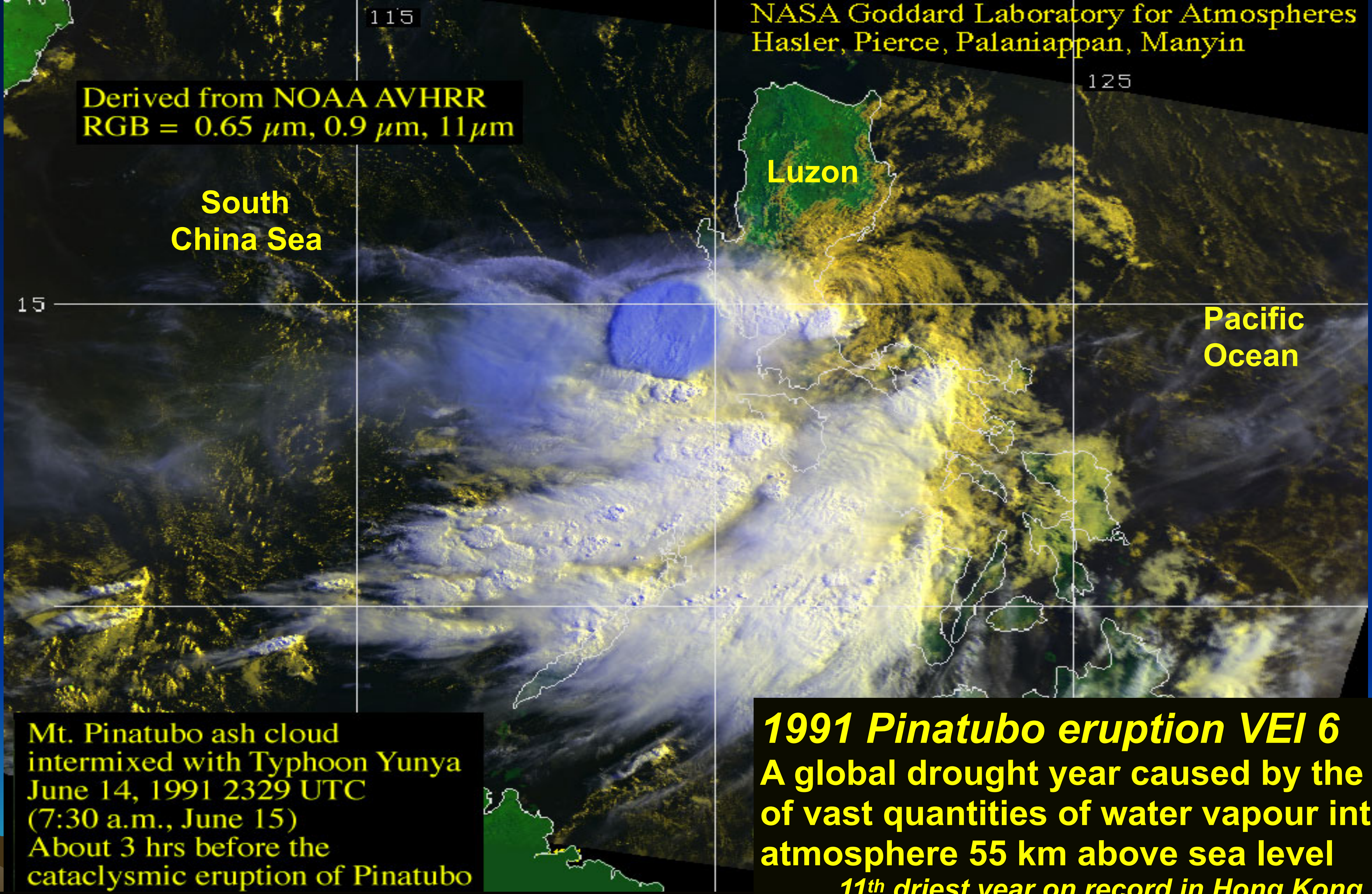
NASA's A-Train including CALIOP provides profiles of aerosols



Satellite tracking and observations since late 1970s

Some climatic impacts of selected atmospheric plumes

Volcano	Locatiom	Year	VEI	Height (km)	Climatic impacts
Agung	Indonesia	1963	4	18	Global temperature decline; driest year on record since 1884 in Hong Kong caused by predominantly offshore wind
El Chichón	Mexico	1982	5	26	Circled globe in 21 days; global temperature decline; second wettest year on record since 1884 in Hong Kong caused by predominantly onshore wind
Pinatubo	Philippines	1991	6	55	Large volume of water vapour entering stratosphere assisted by Typhoon Yunya; global temperature decline; abnormally dry year in Hong Kong
Chaitén	Chile	2008	5	30	Heavy rainfall in South Africa and parts of Australia spreading from west to east; record rainstorm and wettest June on record since 1884 In Hong Kong consistent with SO_2 e-folding time
Soufriére Hills	Montserrat	2010	2	12	Disastrous frontal activity storm in Madeira 20/2/2010; Cyclone Xynthia flood and wind damage in western Europe 26-28/2/2010
Eyjafjallajökull (E15)	Iceland	2010	4	9	Transfer of moisture into continental interiors; wettest year on record in Slovakia since 1881; disastrous flooding in central Europe, Pakistan and China; severely cold winter in eastern north America and northern Europe
Hunga Ha'apai	Tonga	2022	6	58	Large volume of water vapour entering stratosphere; record rainfall and severe flooding in eastern Australia and New Zealand



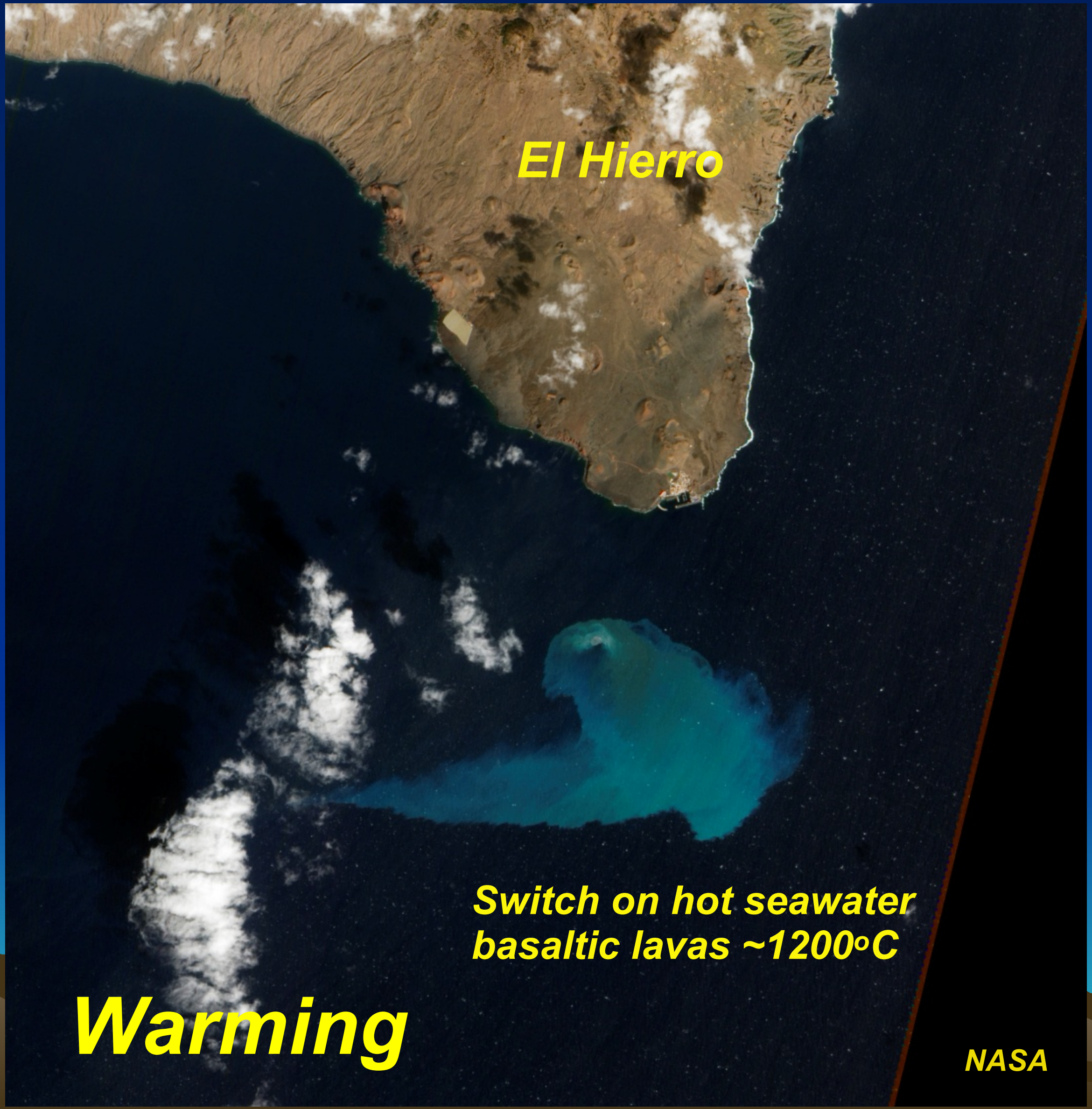
1991 Pinatubo eruption VEI 6

A global drought year caused by the transfer of vast quantities of water vapour into the atmosphere 55 km above sea level

11th driest year on record in Hong Kong

E-folding time of sulphur dioxide ~35 days reduction in solar radiation

Submarine volcano model



Examples –

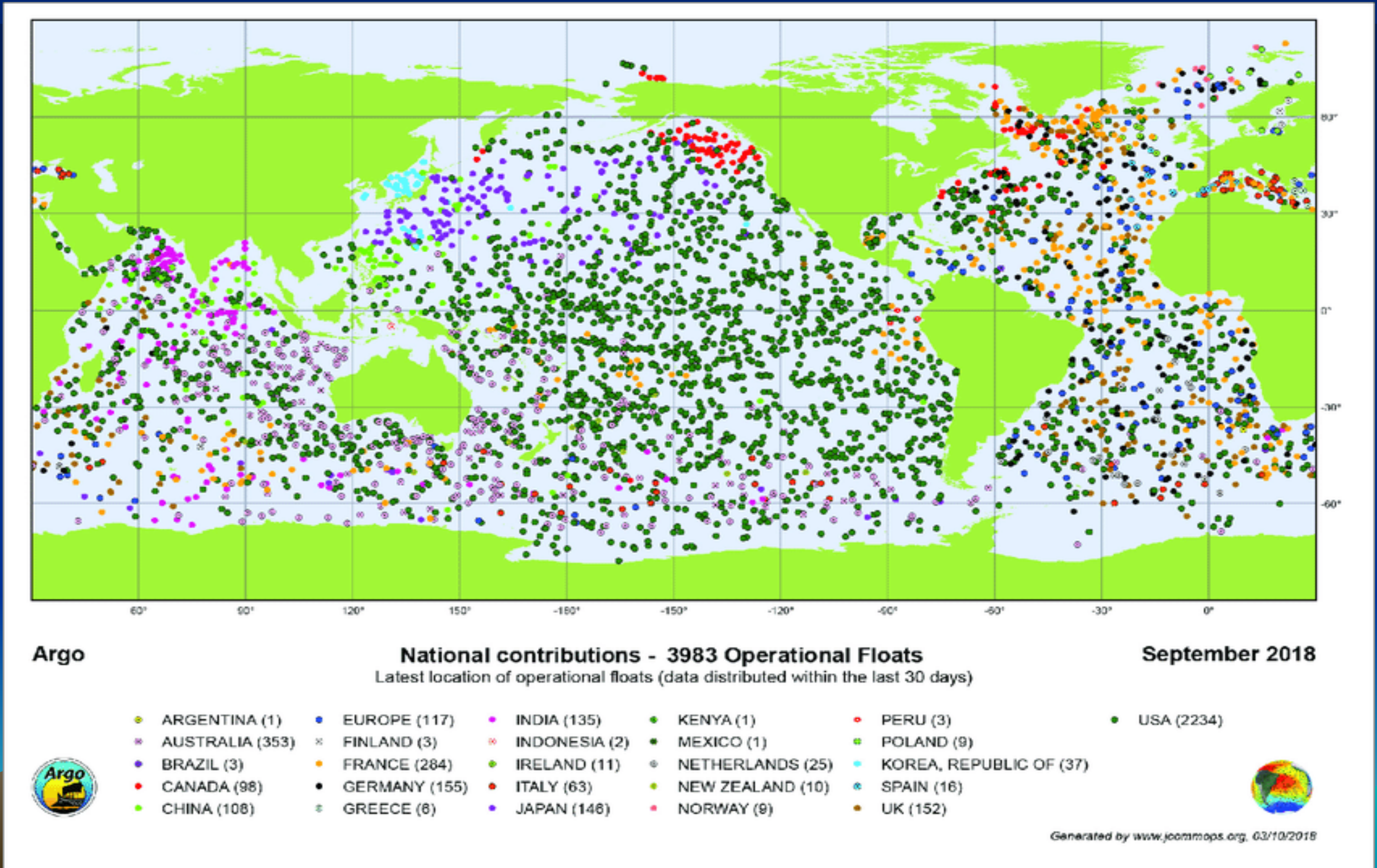
El Hierro volcano, Canary islands
10/2011 – 3/2012 (north Atlantic)

Hunga volcano, Tonga
12/2014 – 1/2015 (south Pacific)

Nishinoshima, 940 km south of Tokyo 3/2013 – 9/2015 (north Pacific)

Impacts –
Formation of oceanic blobs
Pressure changes
Surface wind changes
Sea-level changes
Ocean current changes
Polar sea-ice retreat

ARGO network of oceanic floats since early 2000s



Temperature / salinity profiling improves detection / observations

Impact factors of oceanic blobs –

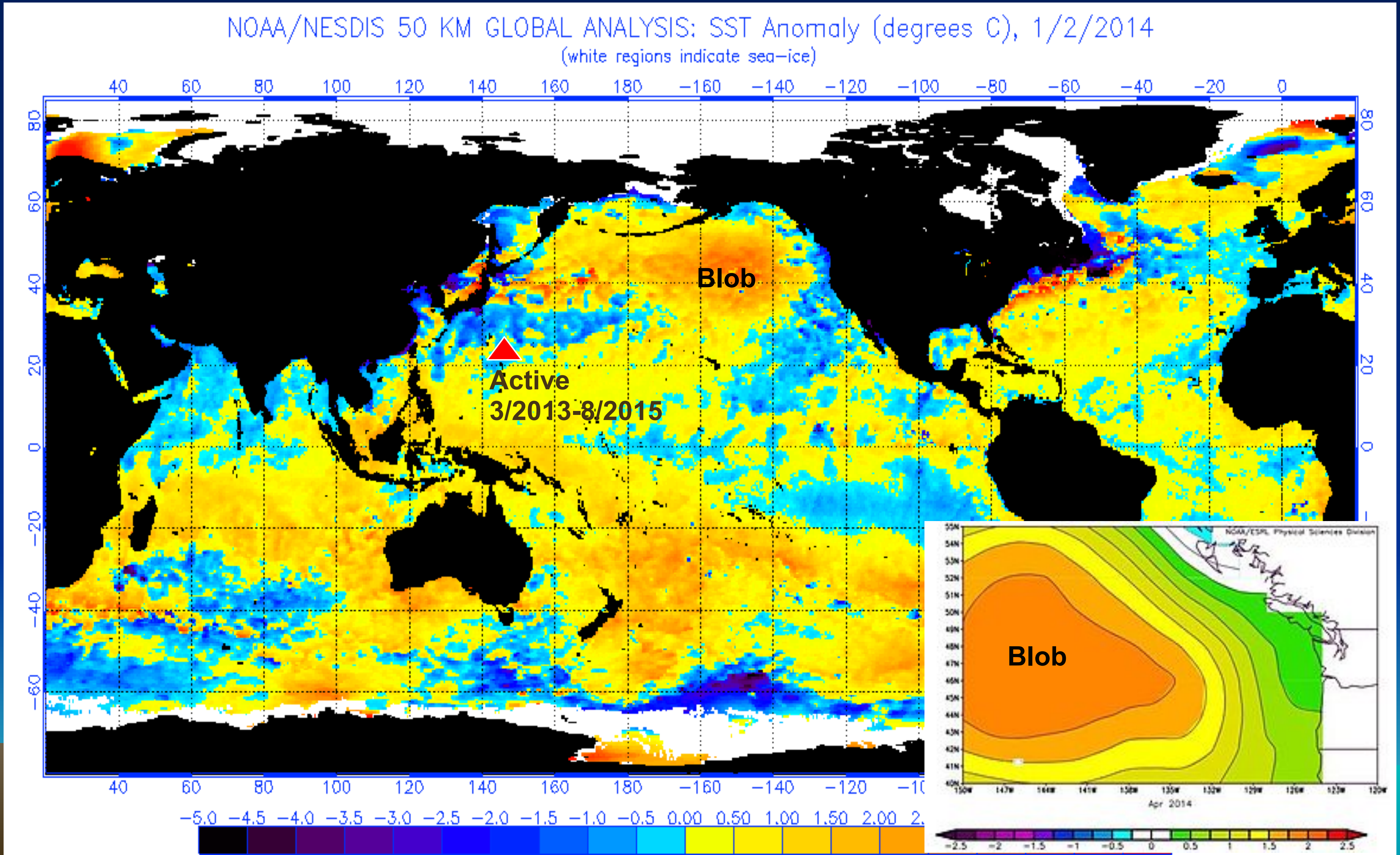
Location of submarine volcano
Seabed depth of eruption
Timing, duration and history of eruption
Oceanic conditions
Number and distribution of vents
Magma composition e.g. hotter if basaltic, more explosive and cooler if acidic
Composition of gases

Some climatic impacts of selected oceanic blobs

Location	Timing	Volcano(es)	Climatic impacts
North Atlantic Ocean	2012	El Hierro	Record low Arctic sea ice; wettest summer in England and Wales in 100 years; severe summer melting of the entire Greenland ice sheet; extremely active hurricane season including Sandy estimated damage US$65 billion and 147 fatalities; most severe drought in central north America since 1895
North Pacific Ocean	2014-2015	Nishinoshima*	Retreat of Arctic sea ice near Bering Strait; two years without winter in northeast Pacific; ecological changes including mass mortality and algal blooms; major contributor of the 2014-2016 ENSO; polar vortex in north American interiors during winter
South Pacific Ocean	2014-2015	Hunga	Super cyclone Pam devastating Vanuatu; contributor of the 2014-2016 ENSO
Southwest Indian Ocean	2018-2019	Mayotte	Record breaking season of intense tropical cyclones with disastrous wind damage, heavy rainfall and severe flooding
South Pacific Ocean	2019-2020	F / Lateiki*	Record temperature at Esperanza base; Antarctic sea ice melting in February 2020
South Pacific Ocean	2021-2022	Hunga Ha'apai	Record rainfall, severe flooding and/or landslides in New Zealand and eastern Australia; contributor of the La Niña condition

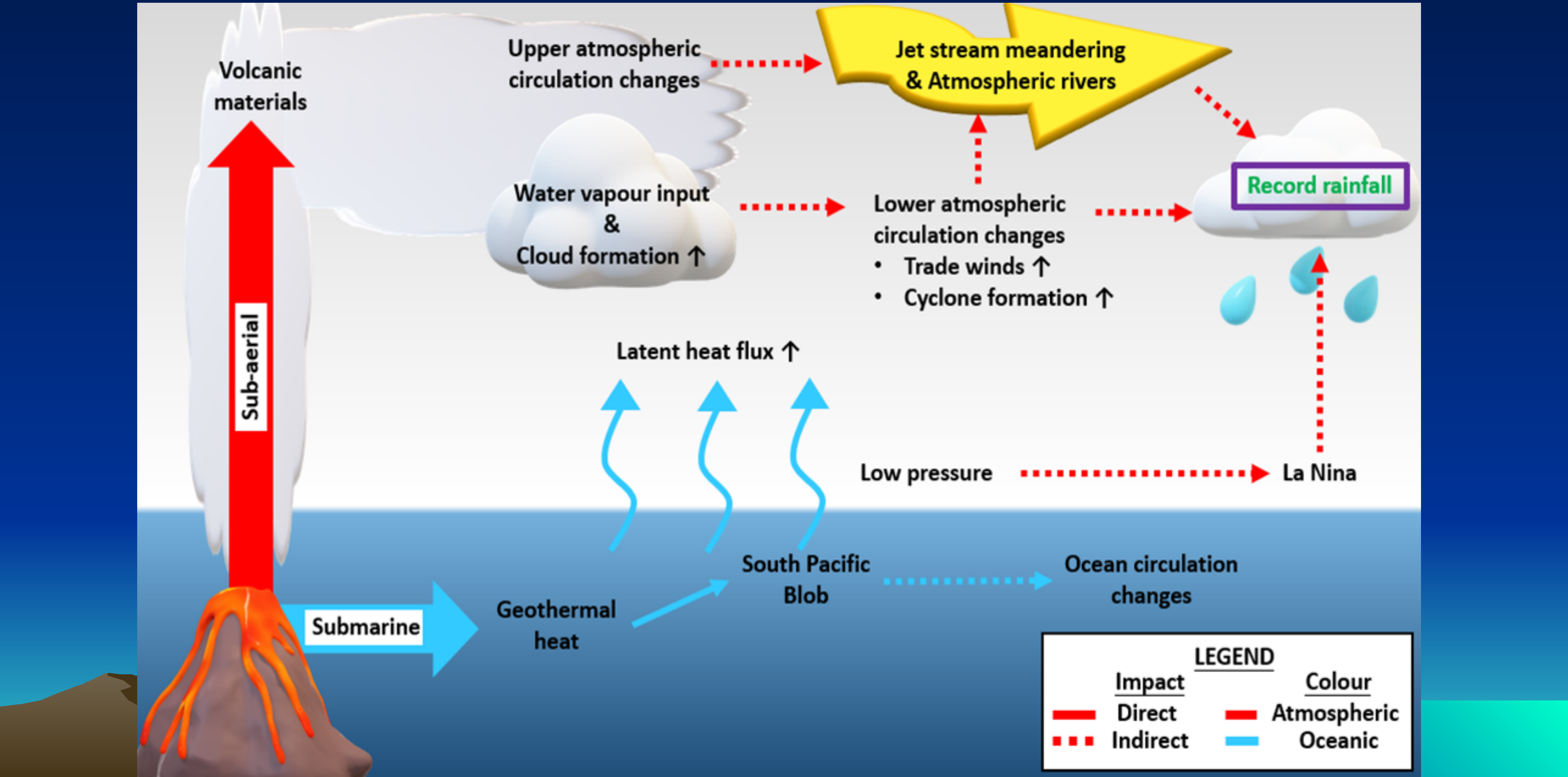
* Main contributor(s) but multiple eruptions including mixed eruptions were also involved.

Nishinoshima mixed eruption main cause of the North Pacific Blob on January 2, 2014



Located near Marianas Trench

Model of the 2021-2022 Tongan mixed eruption (Wong & Yim 2022)



Conclusions

Geothermal heat released naturally through volcanic eruptions in combination with the sun is an underestimated cause of both regional warming and cooling.

Atmospheric plumes predominated by cooling are generated by sub-aerial eruptions. They are responsible for extreme weather including severe winters, cyclonic activity, droughts, heavy rainfall, floods and landslides.

Oceanic blobs are formed by submarine and mixed eruptions. The main volcano contributing heat to the North Pacific Blob Nishinoshima, was active for up to 30 months. Their climatic impacts include mild winters, heatwaves, cyclonic activity, droughts, heavy rainfall, floods, polar vortex, ENSO conditions, polar sea-ice retreat and Greenland ice sheet melting.

The missing heat attributed to CO_2 stored in oceans is better explained by the release of geothermal heat from submarine volcanoes.

The role of geothermal heat in atmospheric and oceanic circulation changes needs to be taken into account in climatic modelling.

Volcanic eruptions –

a natural diversity experiment to learn from

May 23, 2006 Cleveland, Aleutian islands

NASA

The present assisted by the best observation records is a key to the past and the future

Thank you