INGV

GIFT – Geoscience Information For Teachers

EGU European Geosciences Union

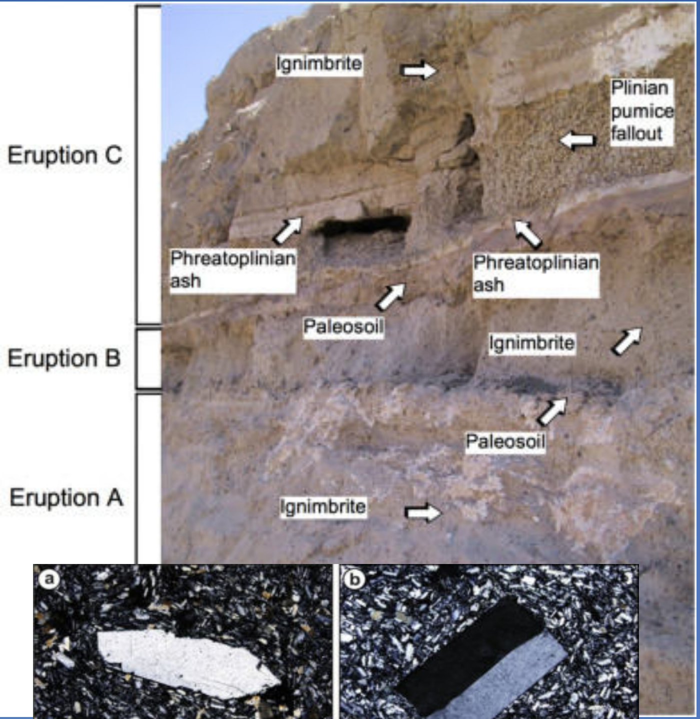
Challenges and perspectives for the science of volcanoes in the current decade

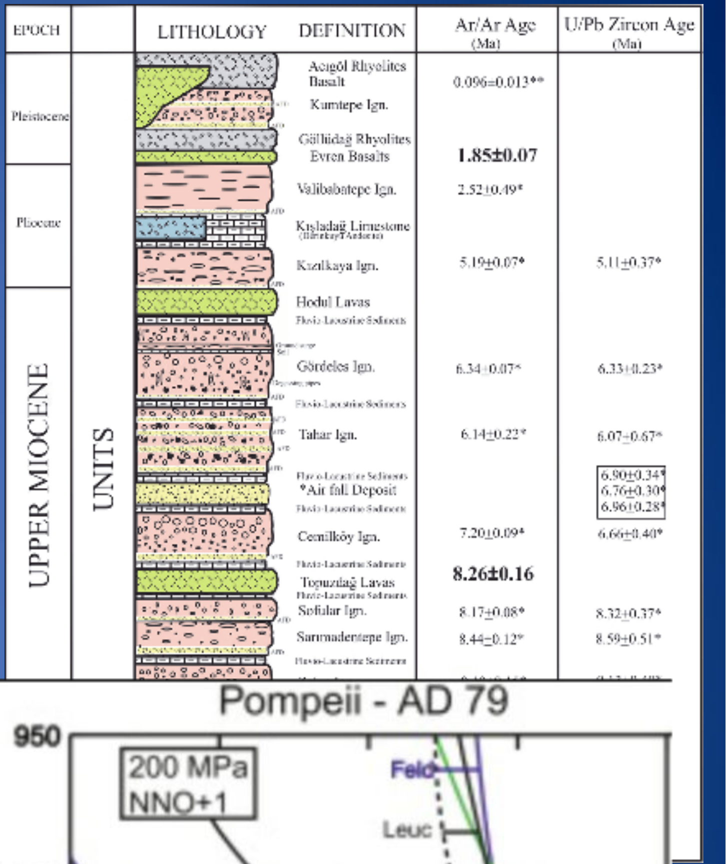
Paolo Papale

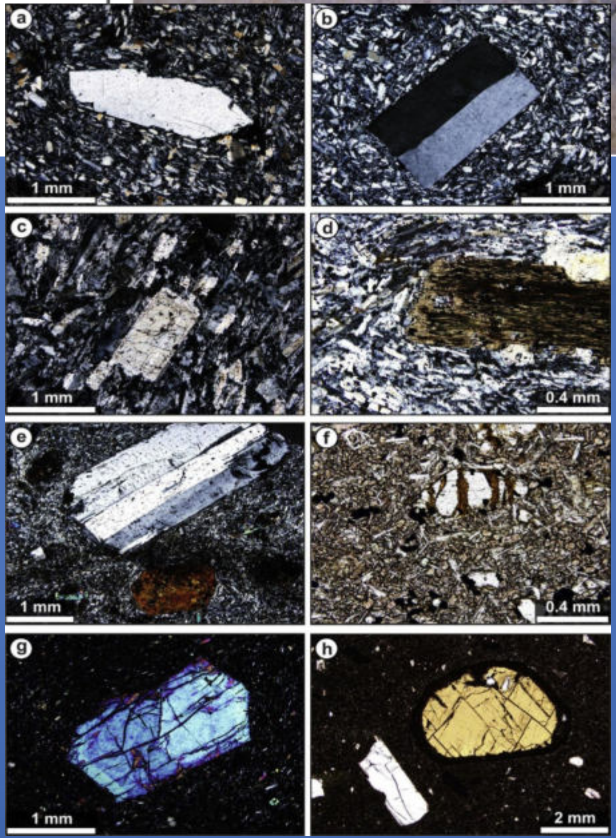
INGV – Istituto Nazionale di Geofisica e Vulcanologia, Italy

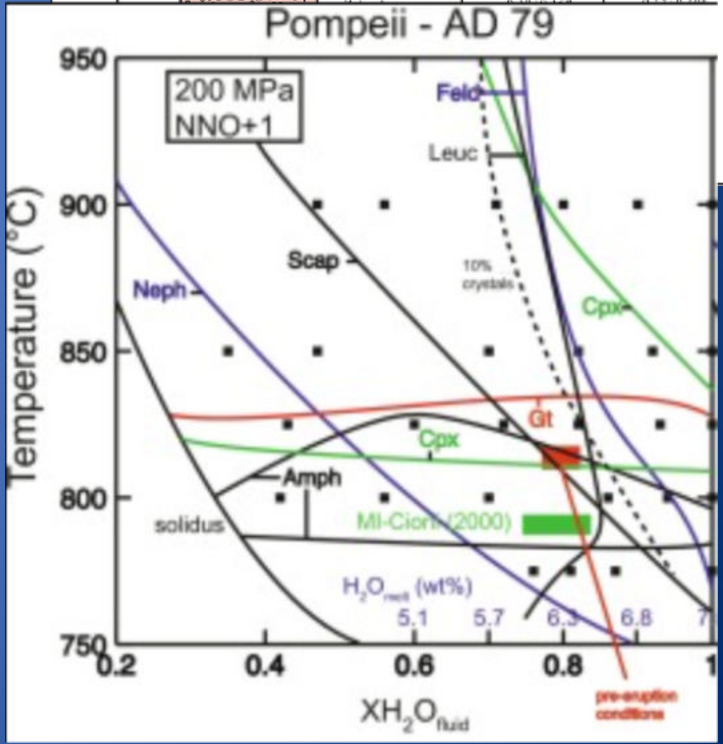
Disciplines and approaches that characterized Volcanology in the past decades

Seventies: stratigraphy, petrology


Eruption C
Eruption B
Eruption A
Ignimbrite
Plinian pumice fallout
Phreatoplinian ash
Phreatoplinian ash
Paleosoil
Ignimbrite
Paleosoil
Ignimbrite


EPOCH
UNITS
LITHOLOGY
DEFINITION
Ar/Ar Age (Ma)
U/Pb Zircon Age (Ma)
Pleistocene
Pliocene
UPPER MIOCENE
Acıgöl Rhyolites Basalt
Kumtepe Ign.
Göllüdağ Rhyolites Evren Basalts
Valibabatepe Ign.
Kışladağ Limestone
Kızılkaya Ign.
Hodul Lavas
Gördeles Ign.
Tahar Ign.
Air fall Deposit
Cemilköy Ign.
Topuzdağ Lavas
Sofular Ign.
Sarımadentepe Ign.
0.096±0.013**
1.85±0.07
2.52±0.49*
5.19±0.07*
5.11±0.37*
6.34±0.07*
6.33±0.23*
6.14±0.22*
6.07±0.67*
6.90±0.34*
6.76±0.30*
6.96±0.28*
7.20±0.09*
6.66±0.40*
8.26±0.16
8.17±0.08*
8.32±0.37*
8.44±0.12*
8.59±0.51*


a
b
c
d
e
f
g
h
1 mm
1 mm
1 mm
0.4 mm
1 mm
0.4 mm
1 mm
2 mm


Pompeii - AD 79
200 MPa
NNO+1
Feld
Leuc
Scap
Neph
Cpx
Gt
Cpx
Amph
solidus
Ml-Cioni (2000)
Temperature (°C)
950
900
850
800
750
0.2
0.4
0.6
0.8
1
5.1
5.7
6.8
pre-eruption conditions

Deposits related to their generating processes

Different types of eruptions recognized and characterized

Fundamental processes occurring during volcanic eruptions described and understood

Pyroclastic fall

deposits

processes

Pyroclastic flow

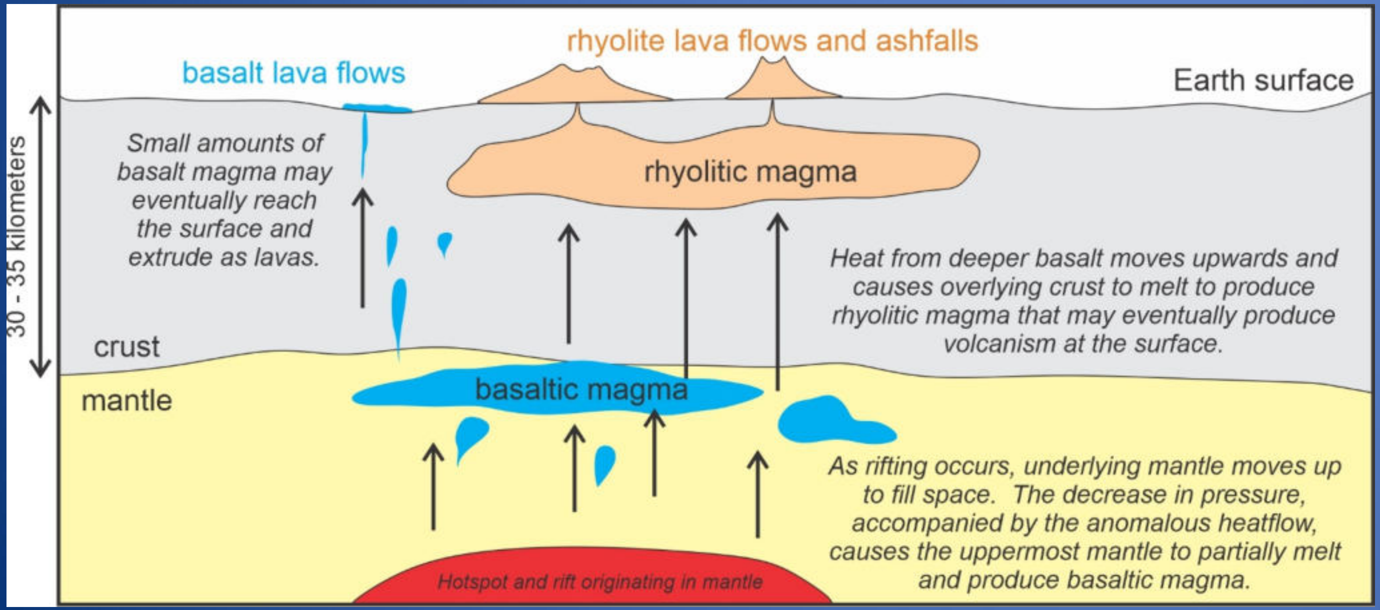
deposits

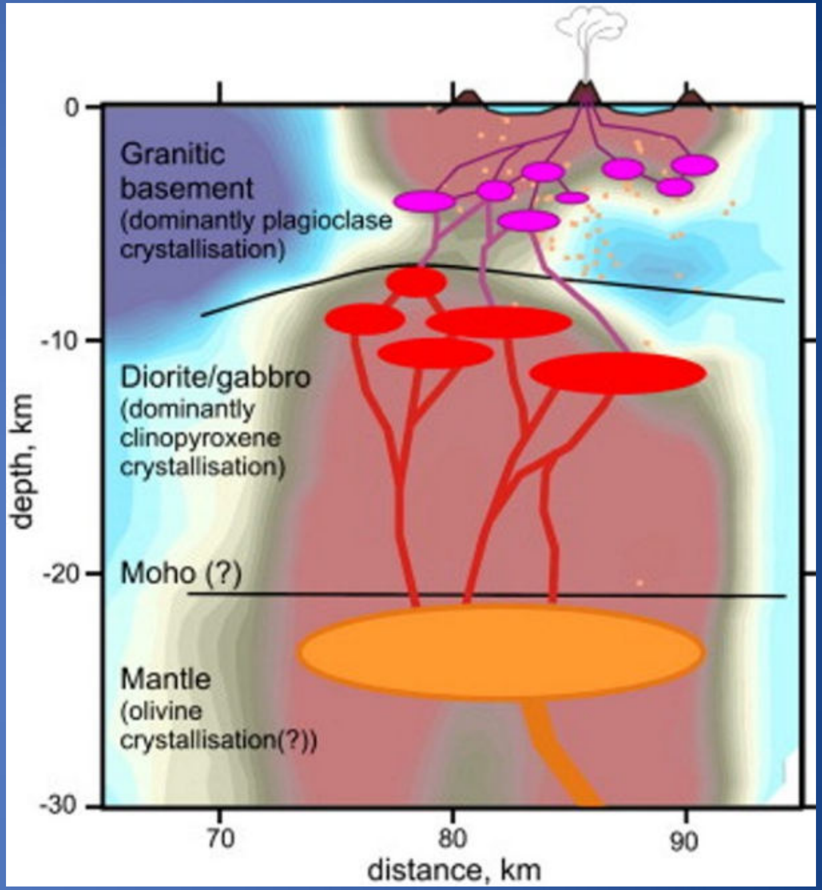
processes

Physical and chemical conditions during magma evolution and their path towards the surface

Complexities of magma plumbing systems, and of the processes leading to them

Conditions prior/leading to eruptions





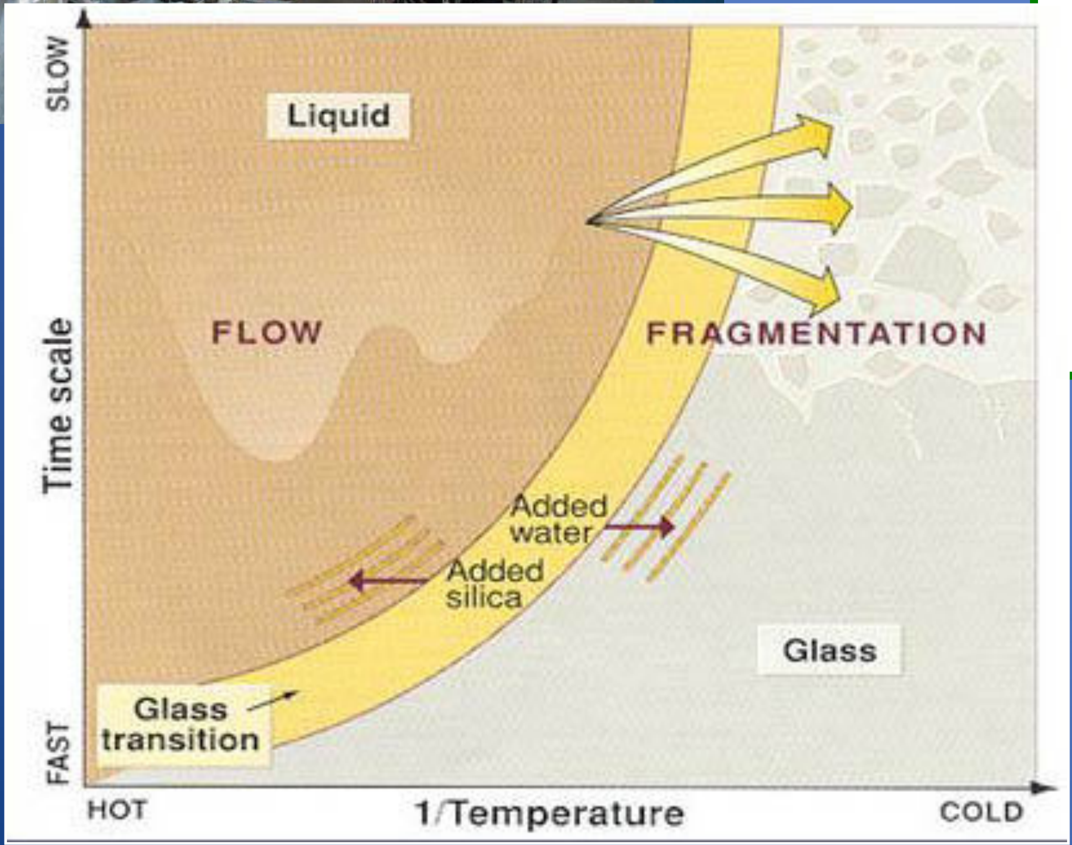
Krakatau, Indonesia

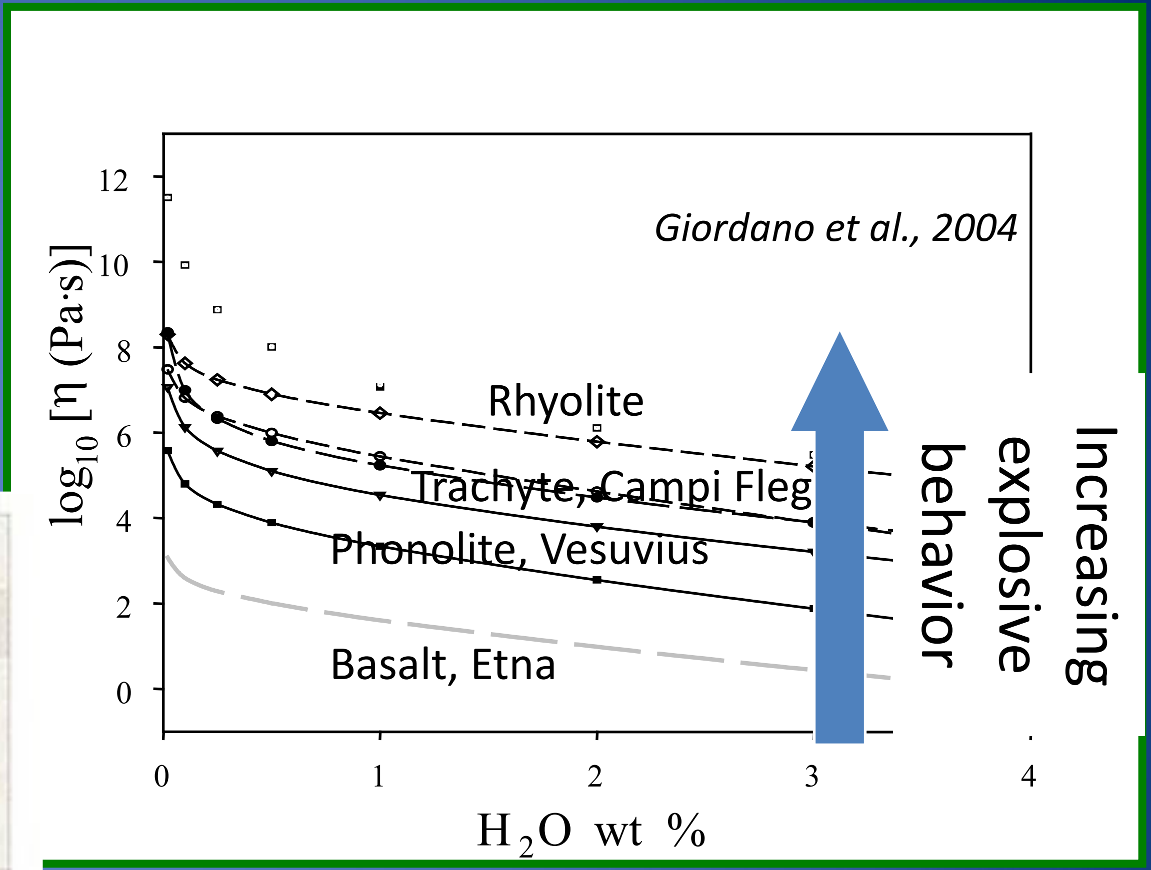
Disciplines and approaches that characterized Volcanology in the past decades

Seventies: stratigraphy, petrology

Eighties, Nineties: experiments, numerical modeling, geophysical surveys

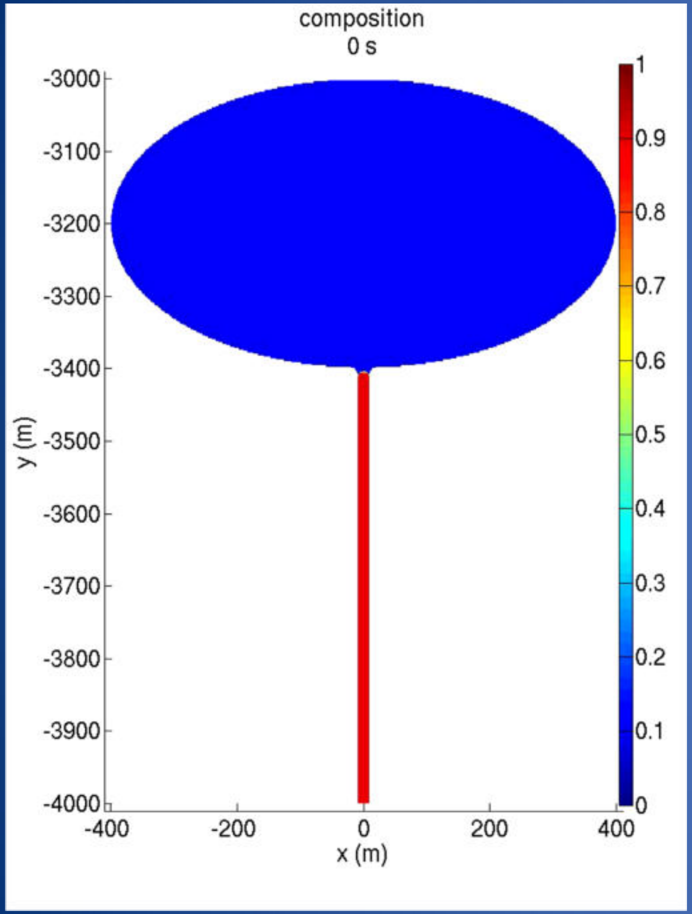

HP-HT lab at INGV Rome

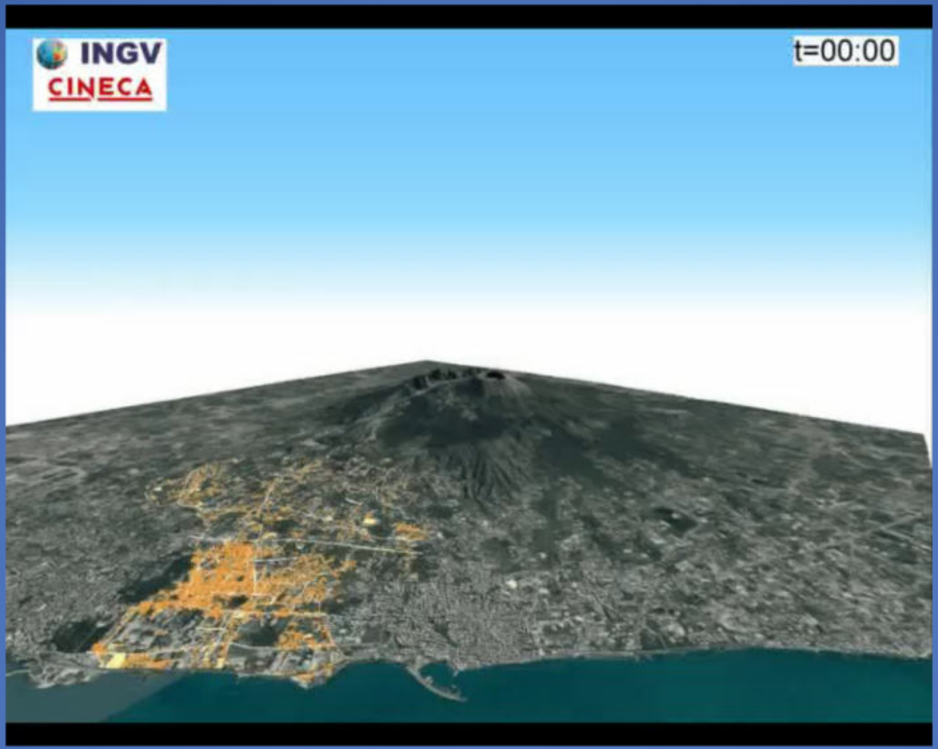

SLOW
Time scale
FAST
Liquid
FLOW
FRAGMENTATION
Added water
Added silica
Glass
Glass transition
HOT
1/Temperature
COLD


Giordano et al., 2004
Rhyolite
Trachyte, Campi Fleg
Phonolite, Vesuvius
Basalt, Etna
Increasing explosive behavior
log10 [η (Pa·s)]
H2O wt %
12
10
8
6
4
2
0
0
1
2
3
4

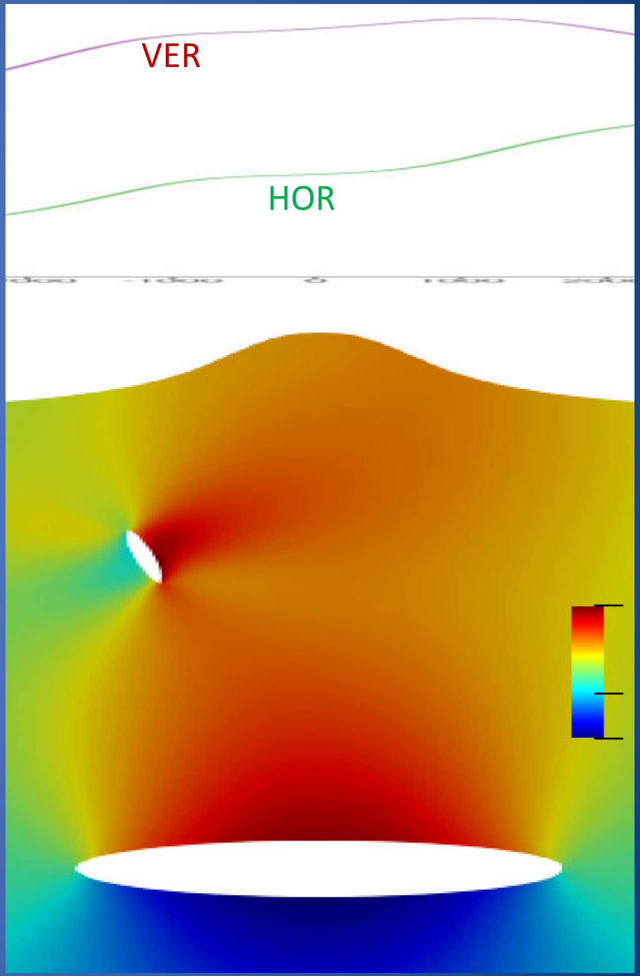
Eruption plume dynamics

Magma chamber dynamics





Volcano deformation



…and many other processes and domains

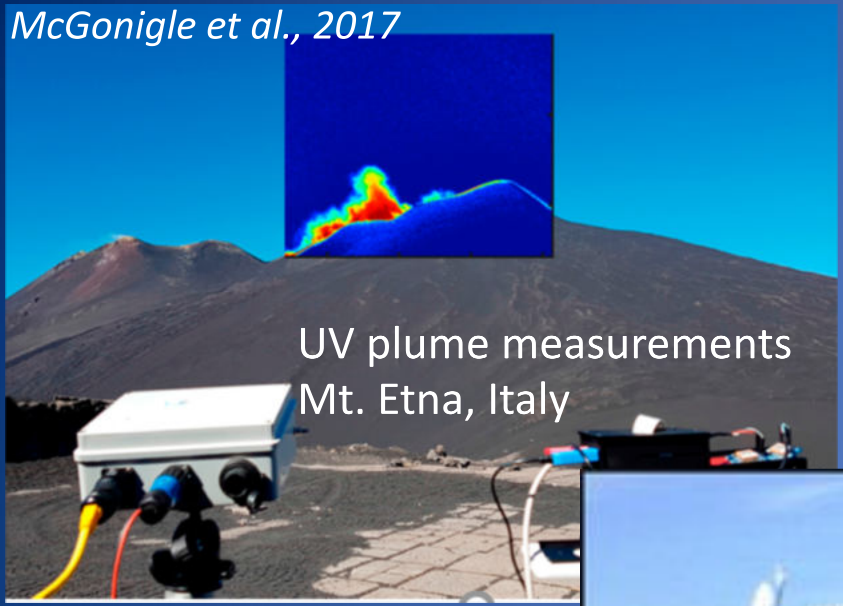
Note: the results shown here are all post-2000

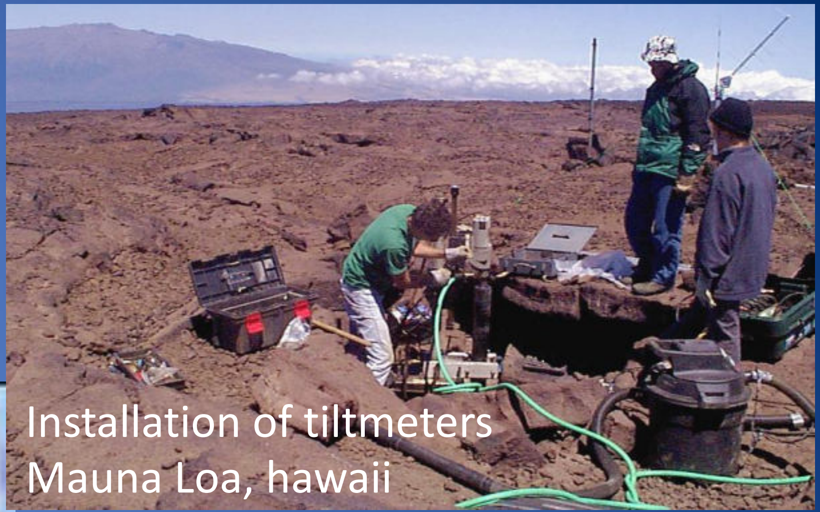
Disciplines and approaches that characterized Volcanology in the past decades

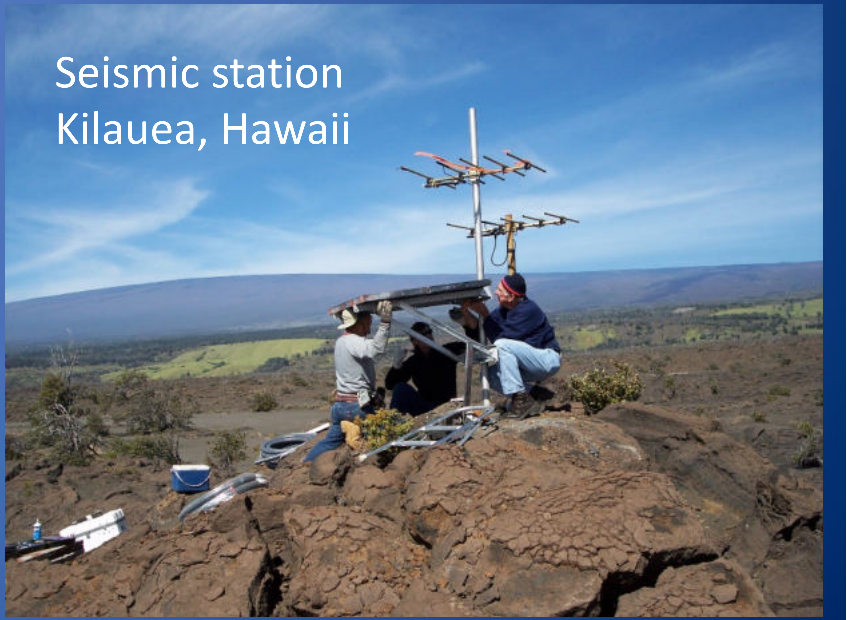
Seventies: stratigraphy, petrology

Eighties, Nineties: experiments, numerical modeling, geophysical surveys

2000-2020: instrumentation, signals, monitoring

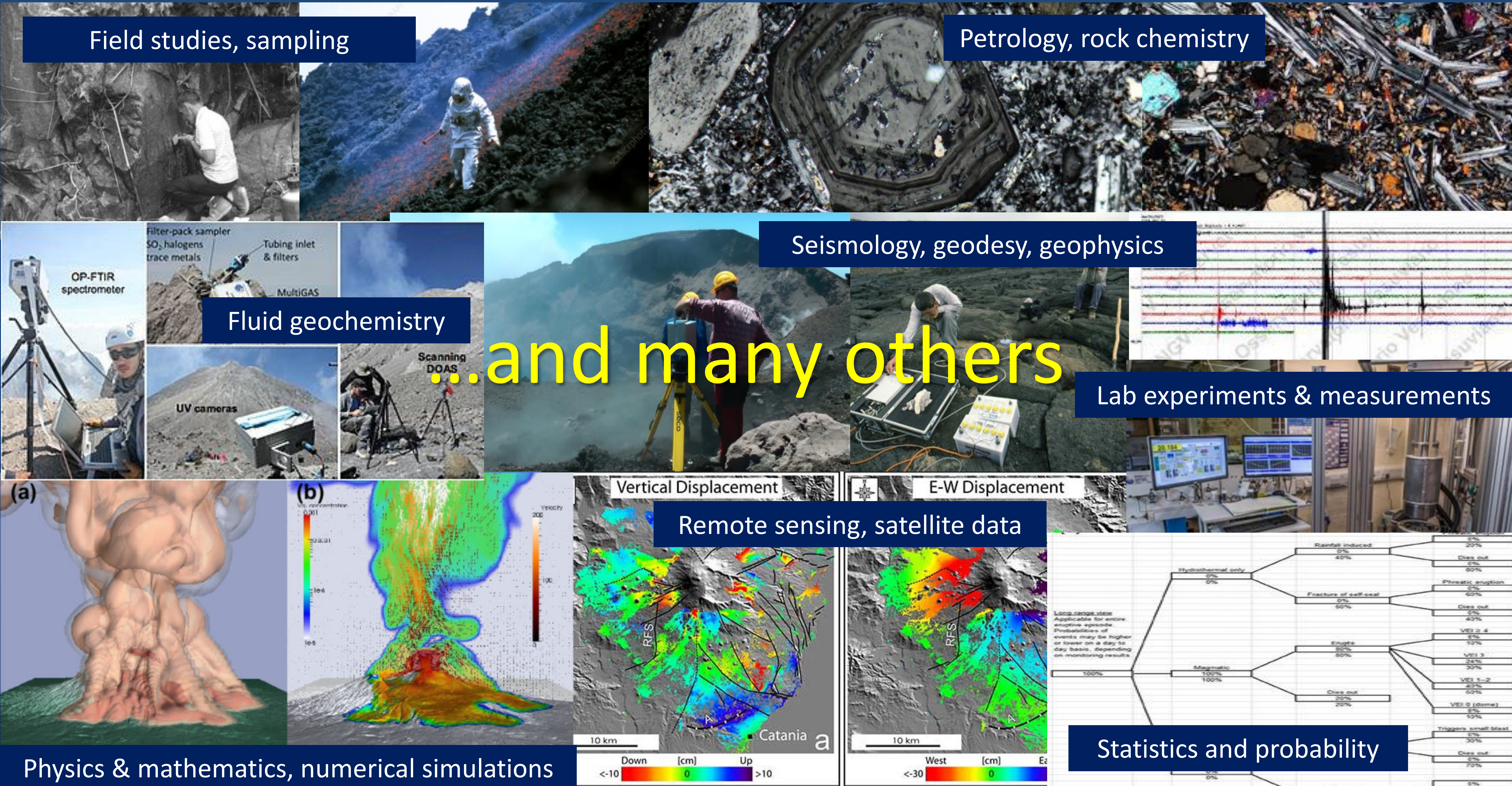






…and much more

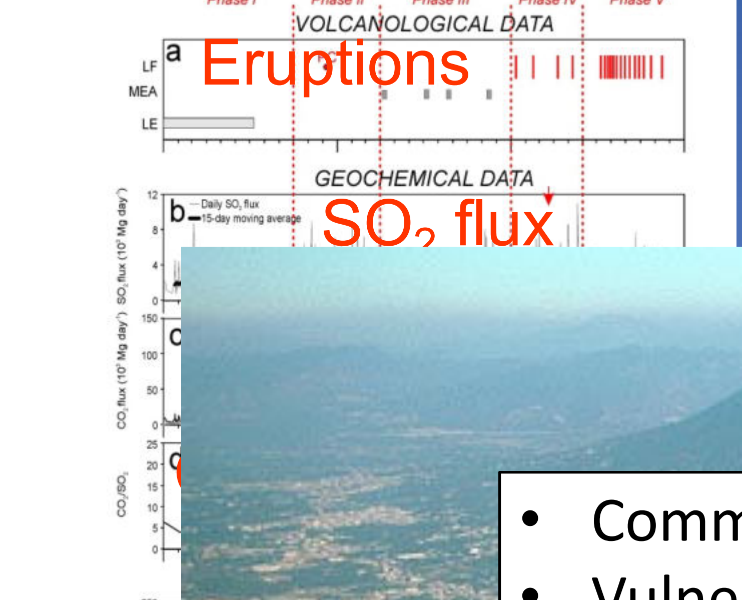
THE MODERN VOLCANOLOGY LANDSCAPE



Vesuvius Observatory
INGV Napoli

- Short-period and broadband seismic networks
- GPS networks
- Infrasonic networks
- Clinometric networks
- Borehole strainmeters
- Hydrometry
- Tidal gauges
- Gravimetric strations
- Visible light / IR cameras
- Meteorological stations
- Multiparametric geochemical stations (P-T-X, fluxes)
- SAR interferometry, satellite imagery
- ……

Data from Mt. Etna



BIG DATA → Machine learning, AI

- Communication, social sciences
- Vulnerability, cost/benefit analysis

If you are any sort of an expert, you are welcome to become a volcanologist

What for the decade 2020 – 2030?

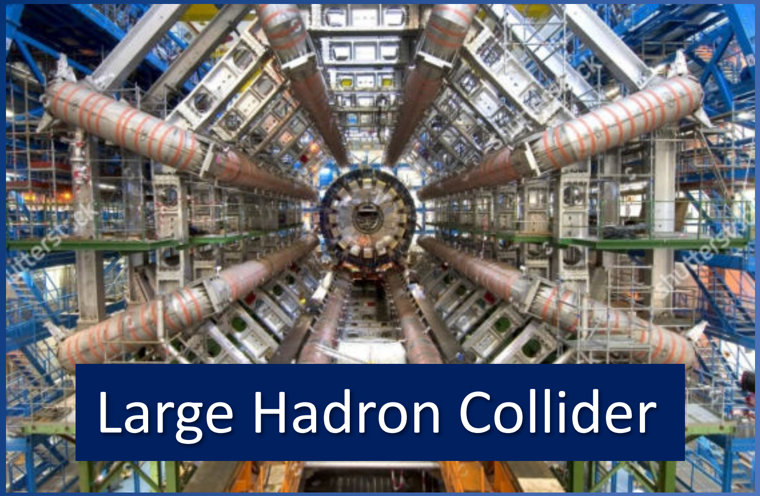
- Increasing levels of cooperation and sharing
- Technological improvements

↓

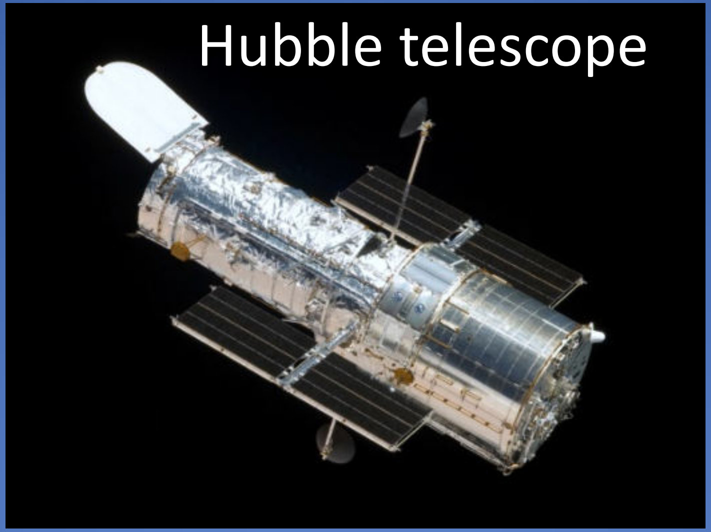
BIG questions in fundamental and applied science

↓

BIG Science



Large Hadron Collider



Hubble telescope

Gran Sasso laboratories

Human Genome Project

- BIG budgets
- BIG staff
- BIG machines
- BIG laboratories

Do volcanoes need BIG science?

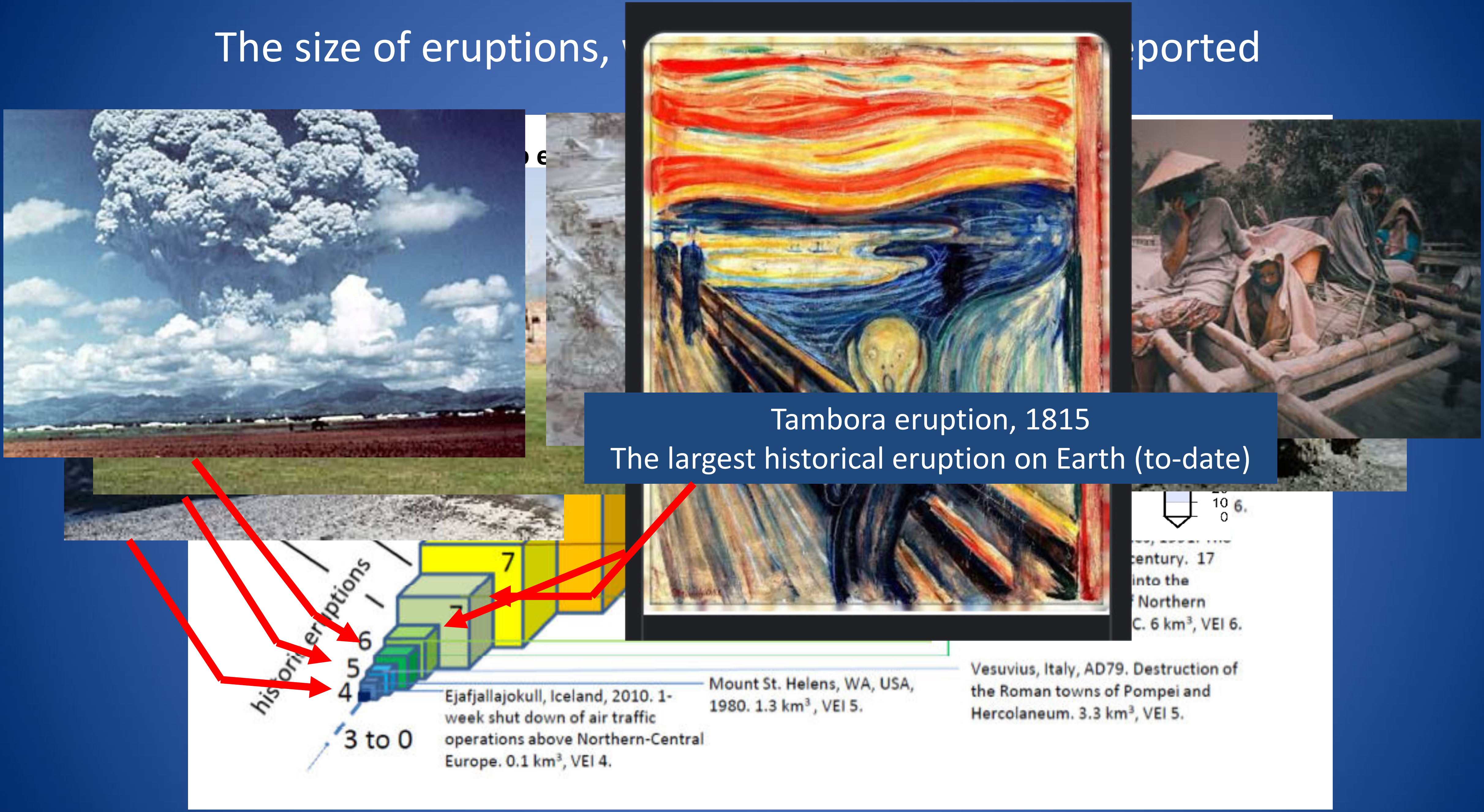
- We miss **direct observations** of most processes and dynamics constituting the object of our investigation

- We still do not have any **global volcano simulator**; by comparison, atmospheric scientists have developed many

- We miss global **databases** for most relevant volcano-related quantities

- We deal with processes causing **extreme risks** from the local to the global scale

The size of eruptions, … eported



Mount Piñatubo, The Philippines, 1991 CE.

(Instrumental records)

Measurable global impacts

M = 6.1, VEI = 6

Average cooling of Northern hemisphere by 0.5-0.6°C, increase of the ozone hole to unprecedented size in 1992.

Mount Tambora, Lesser Sunda Islands, Indonesia, 1815 CE.

(historical accounts)

Substantial global impacts

M = 7.0, VEI = 7

«Year without summer» in Europe: disruption of crops, severe famine, massive emigration; estimated indirect casualties ~ 100,000. Average cooling of Northern hemisphere by up to 1°C for 2-3 years.

Toba caldera, Sumatra Island, Indonesia, 74 ka.

(geologic and other types of reconstructions)

Potentially catastrophic global impacts

M = 8.8, VEI = 8

Associated (controversial) to the Toba Catastrophe Theory. 6-10 years global cooling by 5-6°C (or 10-12°C) (Volcanic Winter), possibly triggering a ~1000 years cooling period nearly leading to extinction of several species.

IMPACTS FROM VEI 8 SUPER-ERUPTIONS

"Super-eruptions are different from other hazards such as earthquakes, tsunamis, storms or floods in that – like the impact of a large asteroid or comet – their environmental effects threaten global civilisation."

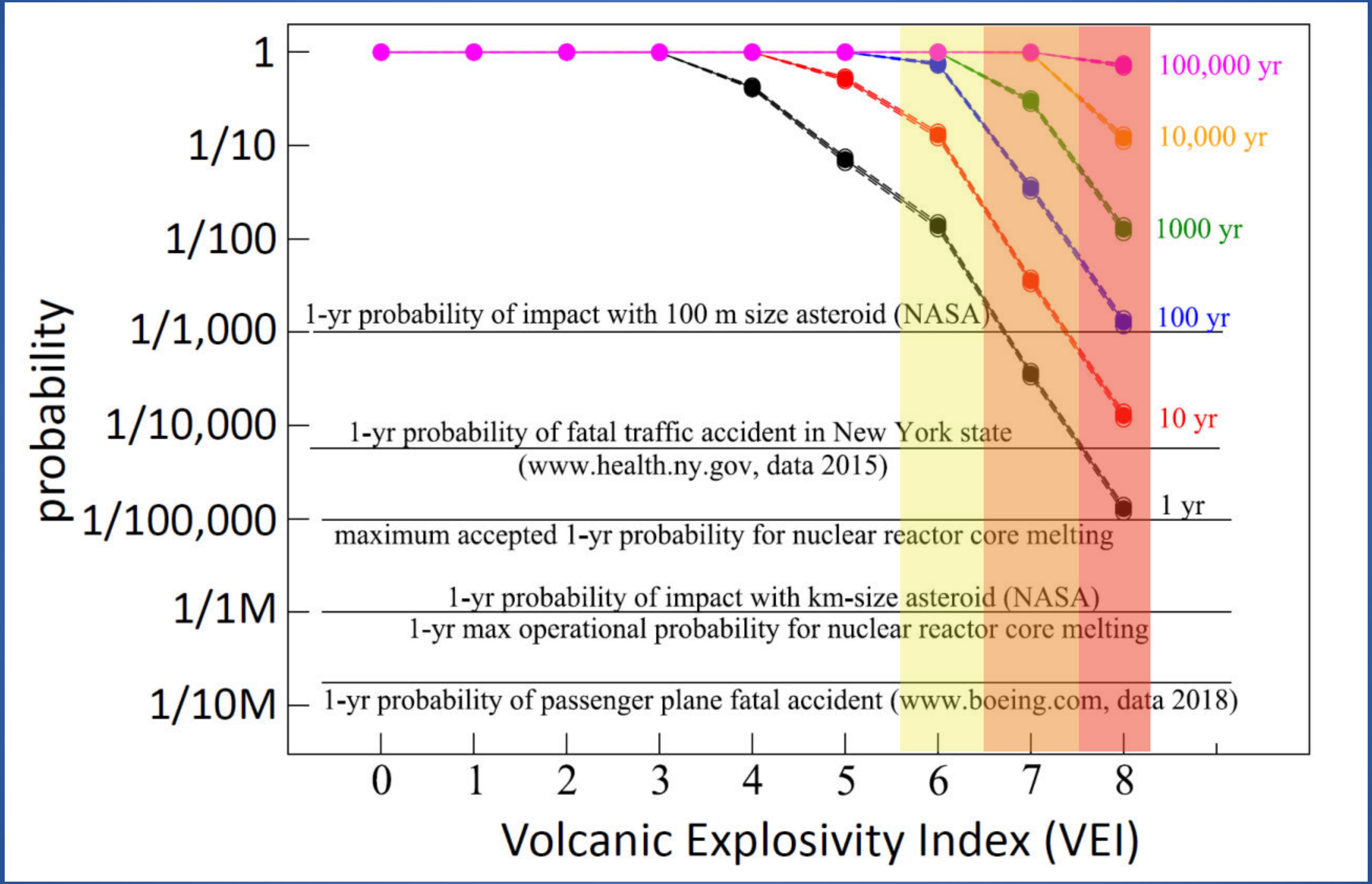
"Our present civilisation depends on global trade and food production, with much reliance on air travel and space-born communications, all of which could be at considerable risk if a super-eruption occurred."

"An area the size of North America or Europe could be devastated, and pronounced deterioration of global climate would be expected for a few years following the eruption. Such events could result in the ruin of world agriculture, severe disruption of food supplies, and mass starvation. The effects could be sufficiently severe to threaten the fabric of civilisation."

"Sooner or later a super-eruption will happen on Earth and this is an issue that also demands serious attention. While it may in the future be possible to deflect asteroids or somehow avoid their impact, we know of no strategies for reducing the power of major volcanic eruptions."

S. Sparks, S. Self, et al.,
Report of a Geological Society of London Working Group, 2005

Global volcanic hazard



Papale and Marzocchi, Science, 2019

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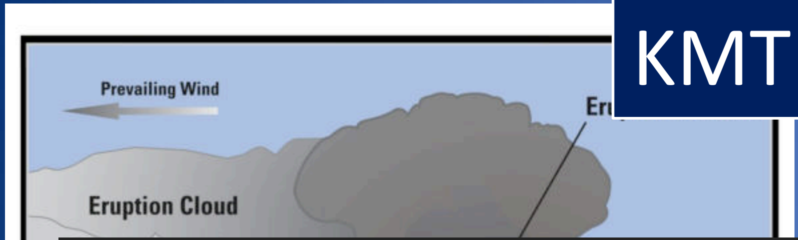
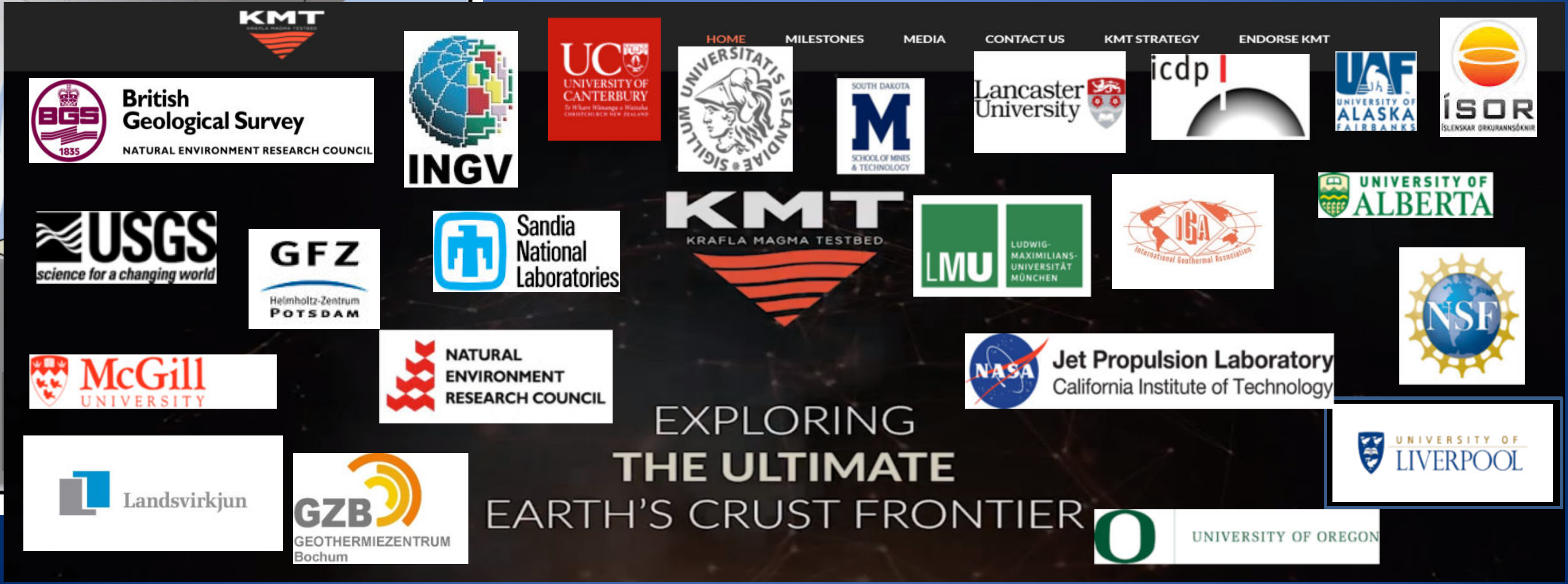


KMT – Krafla Magma Testbed

www.kmt.is



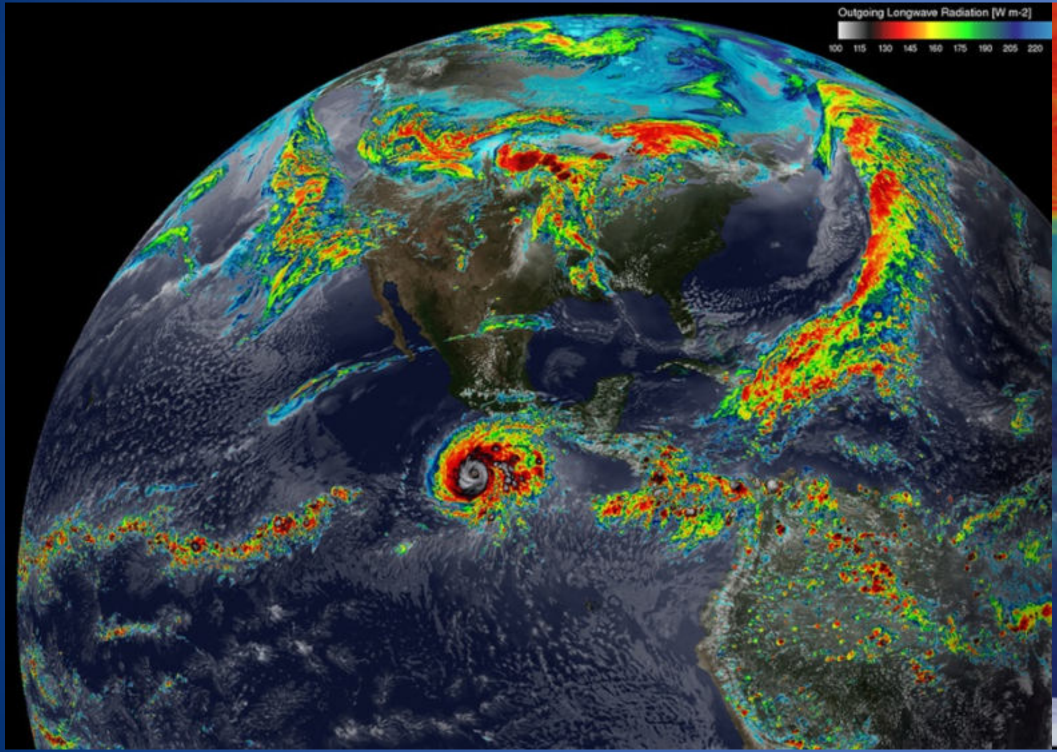
KMT
KRAFLA MAGMA TESTBED

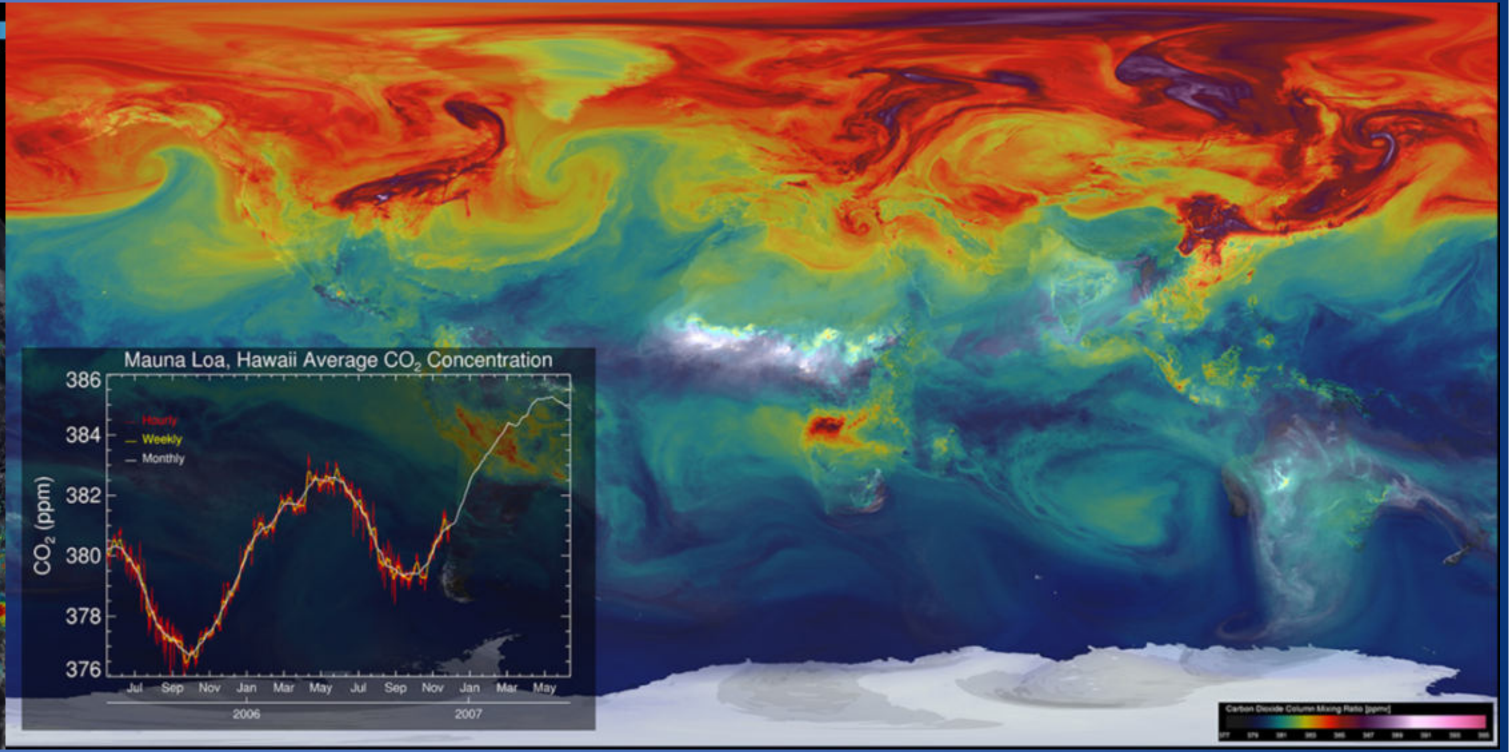
In the frame of an ICDP project, magma was serendipitously hit at 2.1 km depth while drilling at the Krafla caldera, Iceland

Krafla is now the place where better than anywhere else we know where the magma is located

KMT aims at being the unique magma observatory in the world: a series of wells open inside and around an active magma body, for sampling and monitor magma in situ, for conducting real-scale experiments on magma dynamics and volcanic unrest, and for exploring the potential for energy production directly from magma or its immediate surroundings

We still do not have any **global volcano simulator**; by comparison, atmospheric scientists have developed many

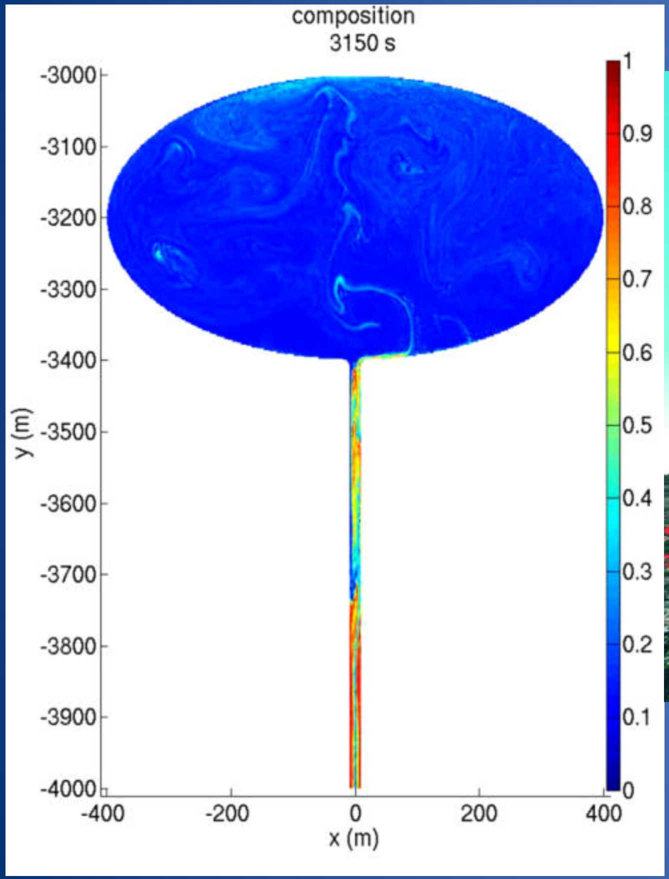


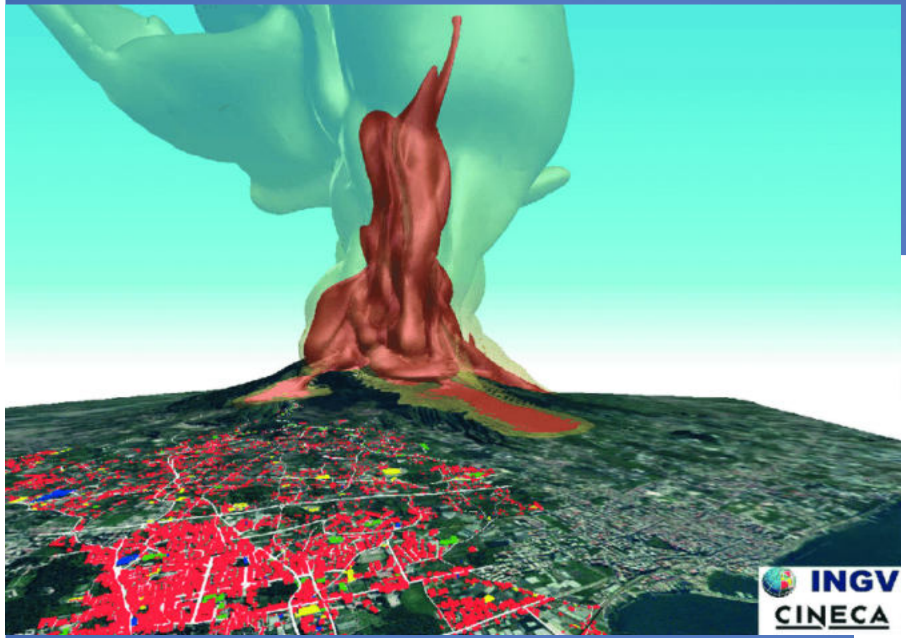


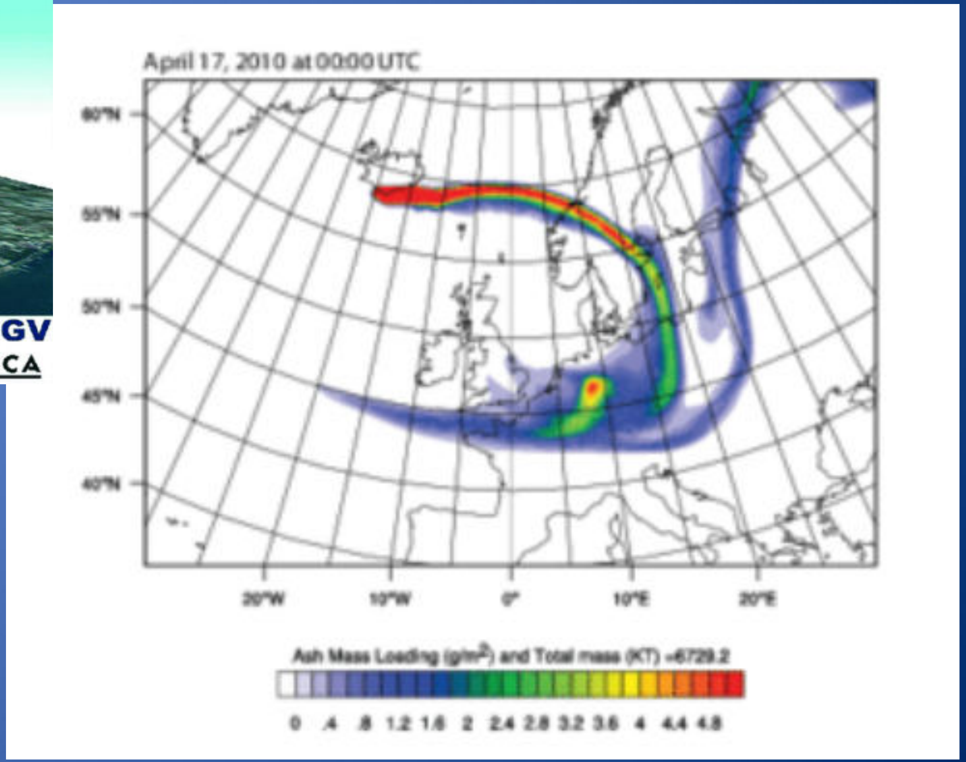
NASA Global Mesoscale Modeling with GEOS-5

The developments in the capability to simulate volcanic processes have been enormous

Still, we miss a Global Volcano Simulator







Global Volcano Simulator

A mathematical representation of a generic volcanic system, and computer code to explore time-space system evolutions; including the plumbing system domain, rock and geothermal circulation domain, shallow conduit/fissure domain, and atmospheric and Earth surface domains

The GVS would allow relating the surface records to the deep magmatic processes, as well as simulating scenarios to anticipate system evolution and estimate the associated uncertainty

The GVS should be modular, and allow a variety of stakeholders to interrogate it (from scientists to decision-makers) and for a variety of purposes (pure science, hazard evaluations, …). It should be therefore highly performant in terms of computational time and resources

ChEESE

Center of Excellence in Solid Earth

Address exascale computational challenges in the Solid Earth domain

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

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ETH zürich

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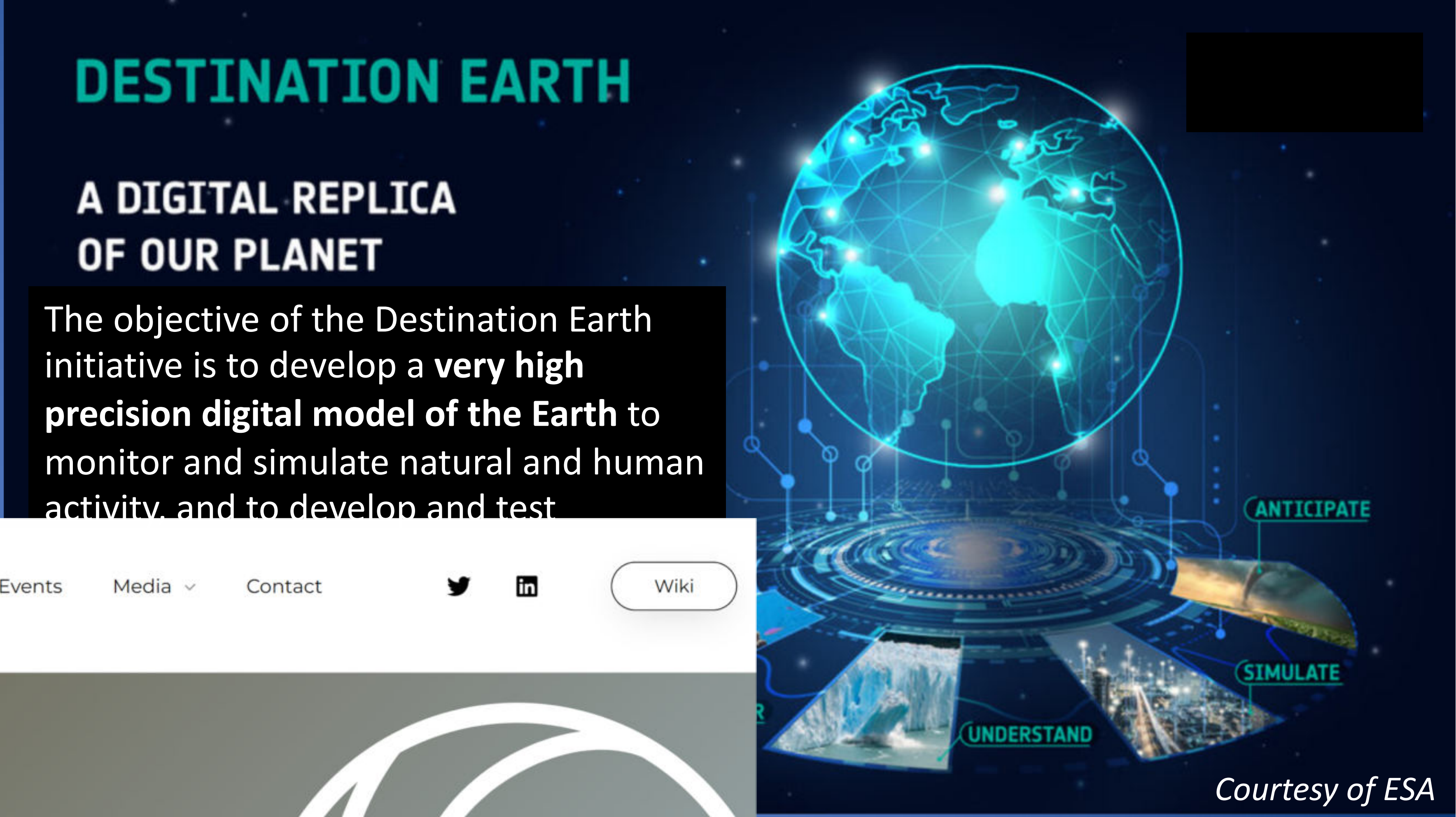
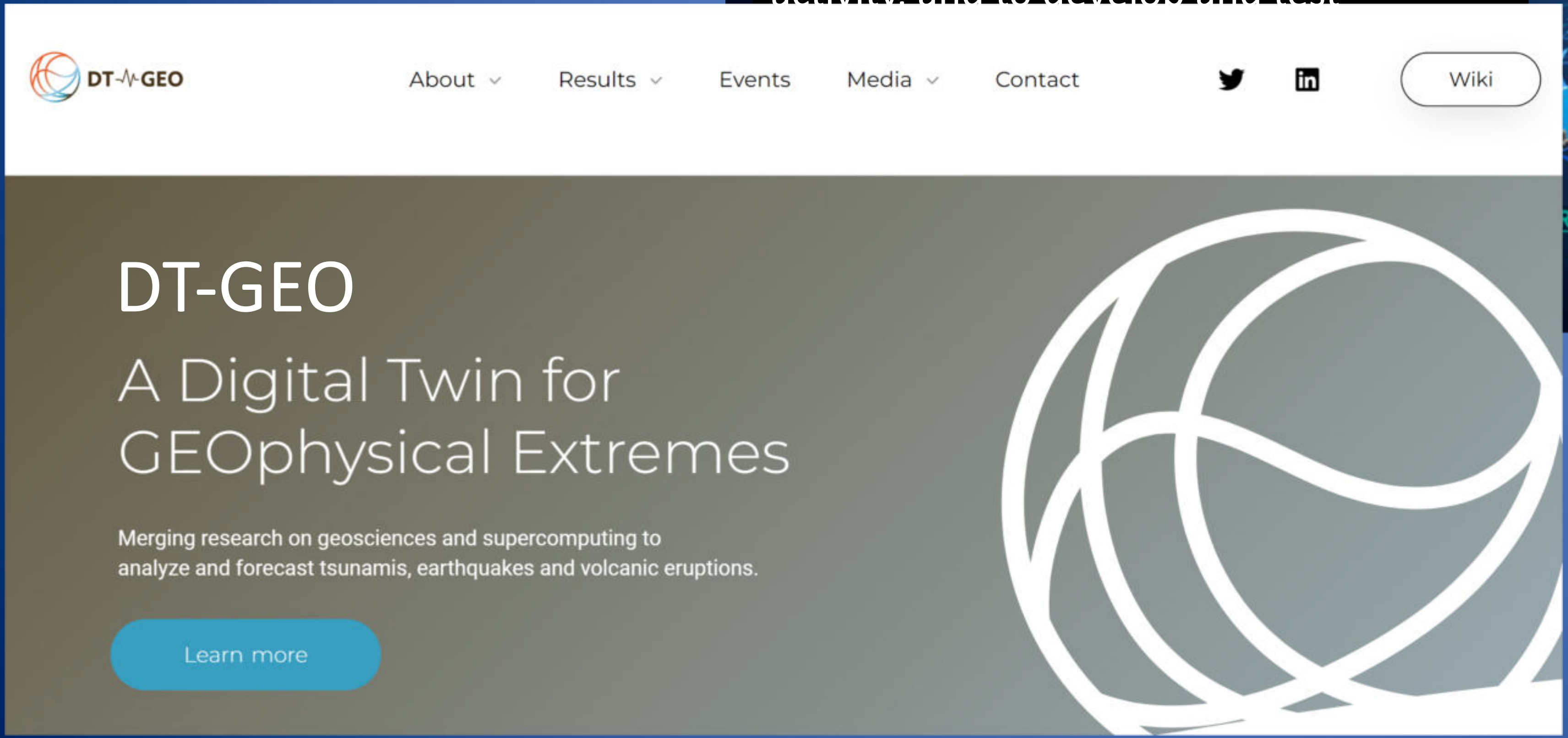
Atos

- Volcanoes
- Tsunamis
- Earthquakes
- Anthropogenic geophysical hazards

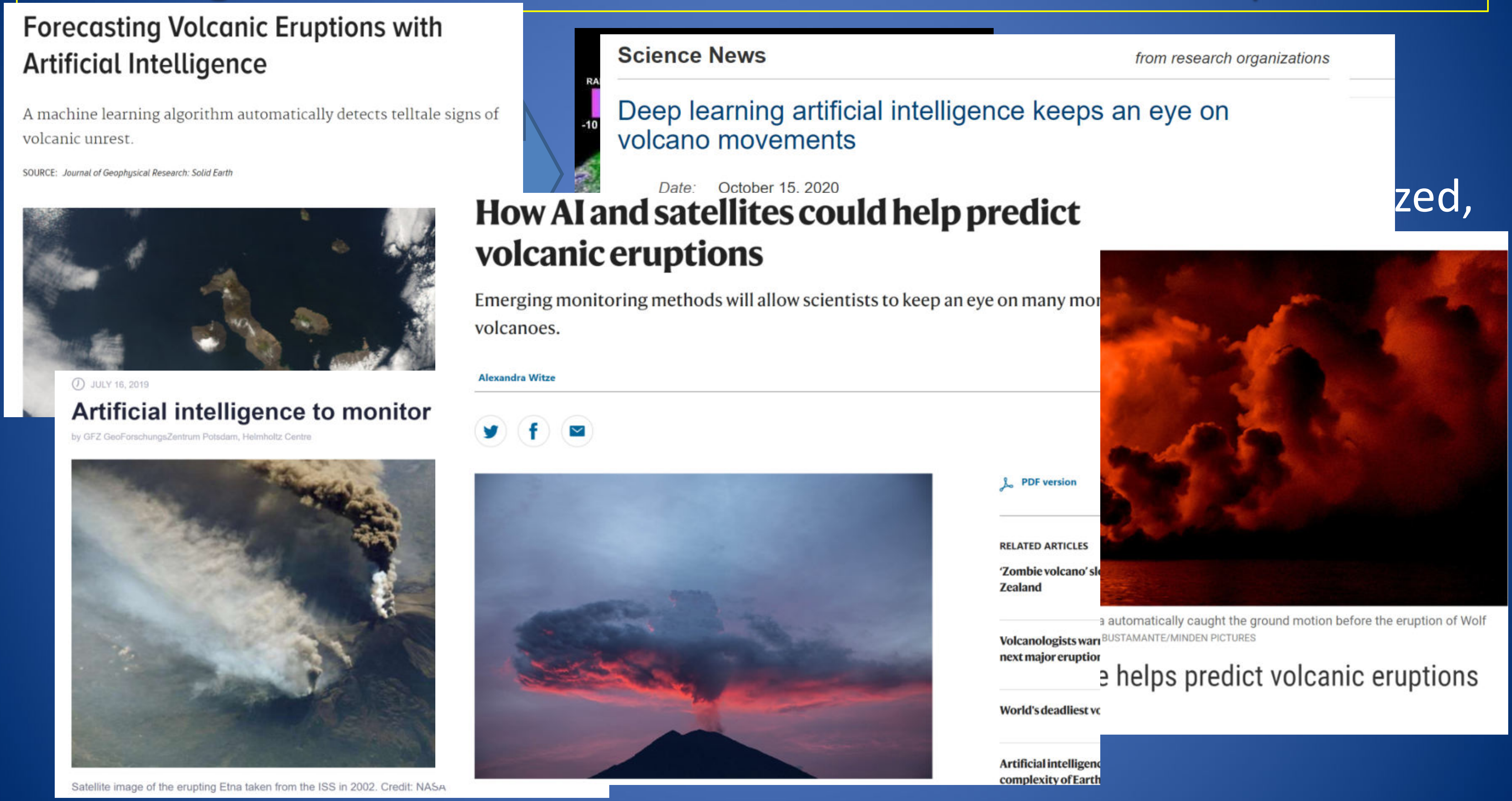


Courtesy of ESA



We miss global **databases** for most relevant volcano-related quantities

zed,



for most relevant volcano-related quantities

[redacted]

INGV ANNALS OF GEOPHYSICS

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Home > Vol 62, No 2 (2019) > **Hajian**

Classification of Mt Etna (Italy) Volcanic Activity by Machine Learning Approaches

Alireza Hajian, Flavio Cannavò, Filippo Greco, Giuseppe Nunnari

Abstract

Most ground-based data are not!

Machine Learning, Artificial Intelligence

For ground data, mostly (but not exclusively, re: Etna) applied to individual datasets (e.g., to only seismic data)

Urgent need to develop global, standardized, freely available databases of volcanic activities

- Unrest
- Syn-eruptive
- Impacts
- …

- GVP
- LaMEVE
- WOVO
- …..

Volcanology in this and the next decade

BIG

- BIG budgets
- BIG staff
- BIG machines
- BIG laboratories

strong (BIG) will of SHARING

- Large infrastructures (KMT)
- Global approaches:
  - Global Volcano Simulator
  - Global databases
  - ML & AI

Thank you

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