De complexitate mundi

What a complexful world

Time and terrain – and life

Natural (multi-)hazards

Global extents and effects

Energy budget and costs

Geosphere-biosphere feedback

Insighting the future

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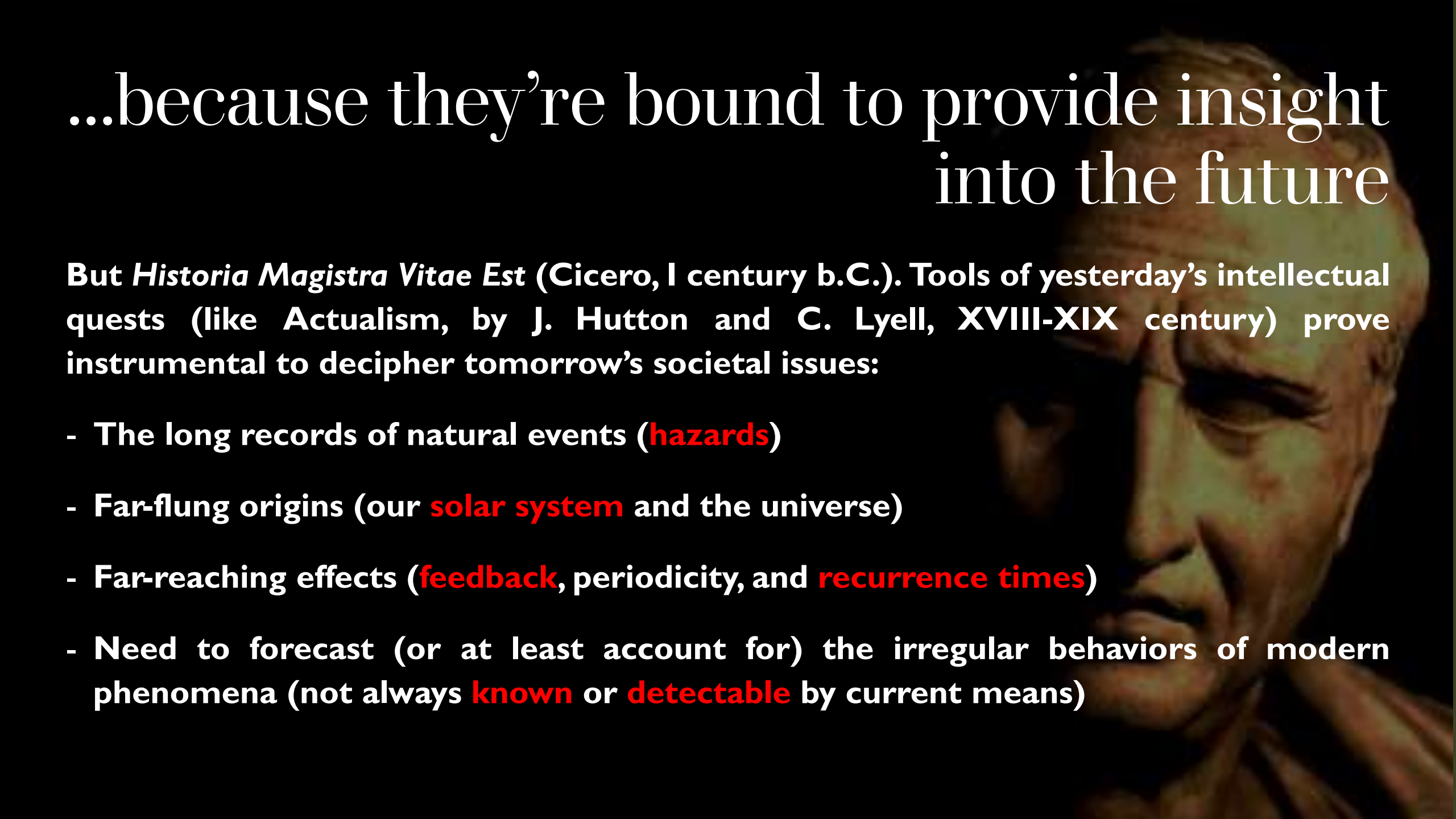
Geosciences are not (and *will not*) what they used to be...

Geoscientists were once thought to study ancient rocks, fiddle with very slow moving tectonic plates, and bantering about invisible earth's features, too large, or too deep, or too far away to even imagine for us earthlings.

But this is really no longer the case – and maybe never has been.
Nature for what it is lies at the core of geosciences' interests – with all its grand size, seemingly slow processes that unveil sudden effects, complex interactions among forces and bodies across distances and time.

These prove to be paramount tools to probe a world perceived as inscrutable, increasingly richer in risks and poorer in resources.

...because they're bound to provide insight into the future



But *Historia Magistra Vitae Est* (Cicero, I century b.C.). Tools of yesterday's intellectual quests (like Actualism, by J. Hutton and C. Lyell, XVIII-XIX century) prove instrumental to decipher tomorrow's societal issues:

- **The long records of natural events (hazards)**
- **Far-flung origins (our solar system and the universe)**
- **Far-reaching effects (feedback, periodicity, and recurrence times)**
- **Need to forecast (or at least account for) the irregular behaviors of modern phenomena (not always known or detectable by current means)**

“Danger is my job” is no longer (only) James Bond’s stance

The knowledge of compounded risks of natural origin provides an outlook on where and what to call for enduring communities.

This applies also to risks resulting from interaction among natural events and anthropic components.

Since natural phenomena embed complexities due to multiple variables and intrinsic feedback, interaction among natural and non-natural ones brings novel issues, requiring a remarkably broad outlook – global and beyond.

There comes gauging natural risks against population distribution, spatial extents of natural resources, size, and time window of induced effects.

J. Glen (1985), “A View to a Kill”, © MGM/United Pictures

“This world is too small for the two of us” never really applied – and will no longer

The history of gestures seems to point to a specific slice of the globe where geography (that is, the landscape results of million years of far-field and deep-seated deformation – and of dwellers’ cumulative labor) put populations in close contact.

In fact, the history of the Mediterranean Sea and surrounding shores is precisely composed of an array of populations and ports, lands and temples, pacts and wars, commerce and robbery.

Unsurprisingly, people that geography and history (i.e, *destiny*) take the burden of confronting may not share (clashing) religions but may well share festivities; may not share alphabets but share words; may not share food but share recipes. Eventually, they end up needing to compete for a living in a confined, if protective, space.

La Battaglia di Lepanto (1571) – anonymous, http://www.arsbellica.it/pagine/moderna/Lepanto/Lepanto.html

So, what *on Earth* is this talk about?

Well, the Earth, at large in fact – you'll see *how much*

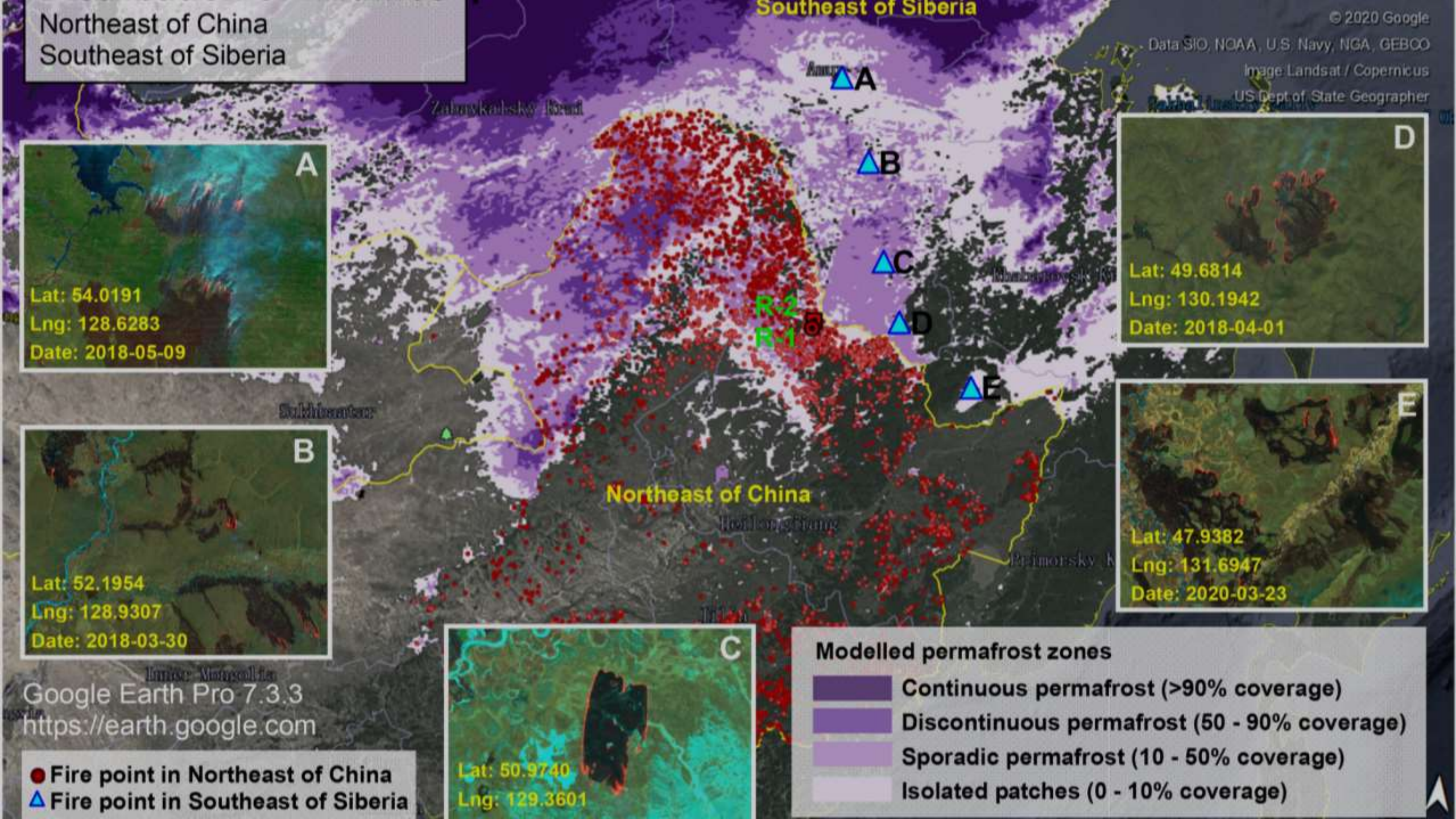
1. **Hazards stemming from multiple, at times unpredictable sources**
   Interaction and triggering – close or afar in time and space

2. **The precious role of geosciences to decipher them – and to forecast them**
   "I have no clue" does not apply (even we *do not* have a clue)

3. **Complexity of natural hazards, flexibility of human planning**
   Thinking big, multifaceted and resourceful does help

4. **Modern issues challenging societies and economies, today and tomorrow**
   Geosciences know where resources lie – and where fragilities lurk

1. Natural hazards – of all sorts – and how they mingle with the environment – *including us*


Northeast of China
Southeast of Siberia
Southeast of Siberia
© 2020 Google
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
US Dept of State Geographer
A
B
C
D
E
R-2
R-1
A
Lat: 54.0191
Lng: 128.6283
Date: 2018-05-09
B
Lat: 52.1954
Lng: 128.9307
Date: 2018-03-30
C
Lat: 50.9740
Lng: 129.3601
D
Lat: 49.6814
Lng: 130.1942
Date: 2018-04-01
E
Lat: 47.9382
Lng: 131.6947
Date: 2020-03-23
Northeast of China
Google Earth Pro 7.3.3
https://earth.google.com
Fire point in Northeast of China
Fire point in Southeast of Siberia
Modelled permafrost zones
Continuous permafrost (>90% coverage)
Discontinuous permafrost (50 - 90% coverage)
Sporadic permafrost (10 - 50% coverage)
Isolated patches (0 - 10% coverage)

Geological CH4 emissions and wildfire risk in degraded permafrost areas

"With global warming, the carbon pool in the degradation zone of permafrost around the Arctic will gradually be disturbed and may enter the atmosphere in the form of released methane gas, becoming an important factor of environmental change in permafrost areas.""

"Since 2004, the permafrost thickness […] in the study area has gradually reduced and the degradation rate obviously accelerated; the organic matter and methane hydrate stored in the permafrost under the marsh wetland are gradually entering the atmosphere as CH4 gas."

"The high concentration of CH4 gas entering the surface […] is expected to increase the risk of wildfire in the permafrost degradation by increasing the regional air temperature and self-combustion. The increase in the frequency of wildfires is projected to further generate positive feedback on climate change by affecting soil microorganisms and soil structure."

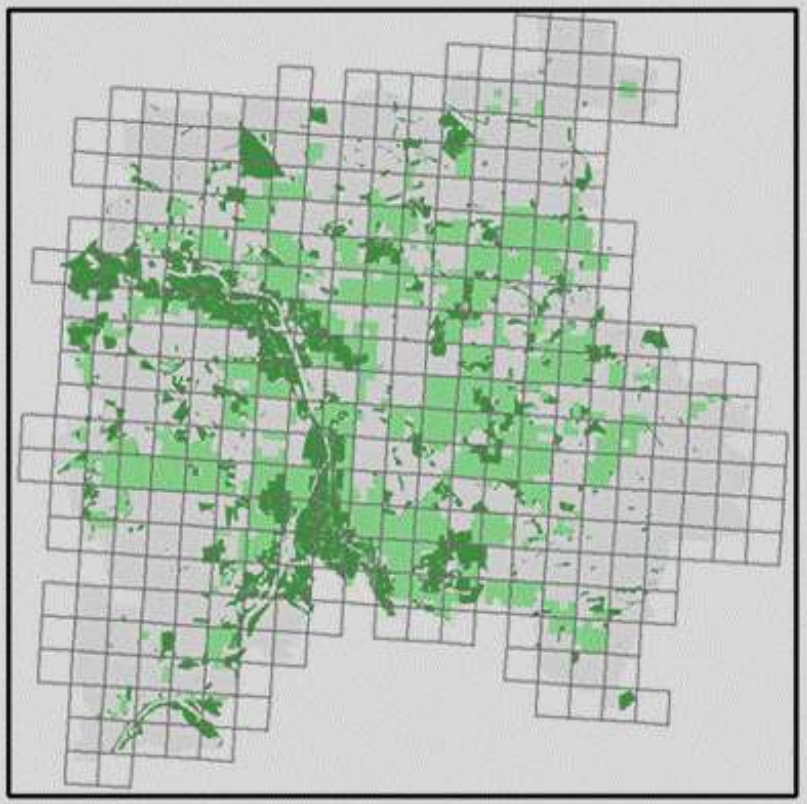
Shan *et al.* (2020), *Sci. Rep.*, 10, https://doi.org/10.1038/s41598-020-78170-z

Area within 150 m of major roads

GDR

Post-Reunification

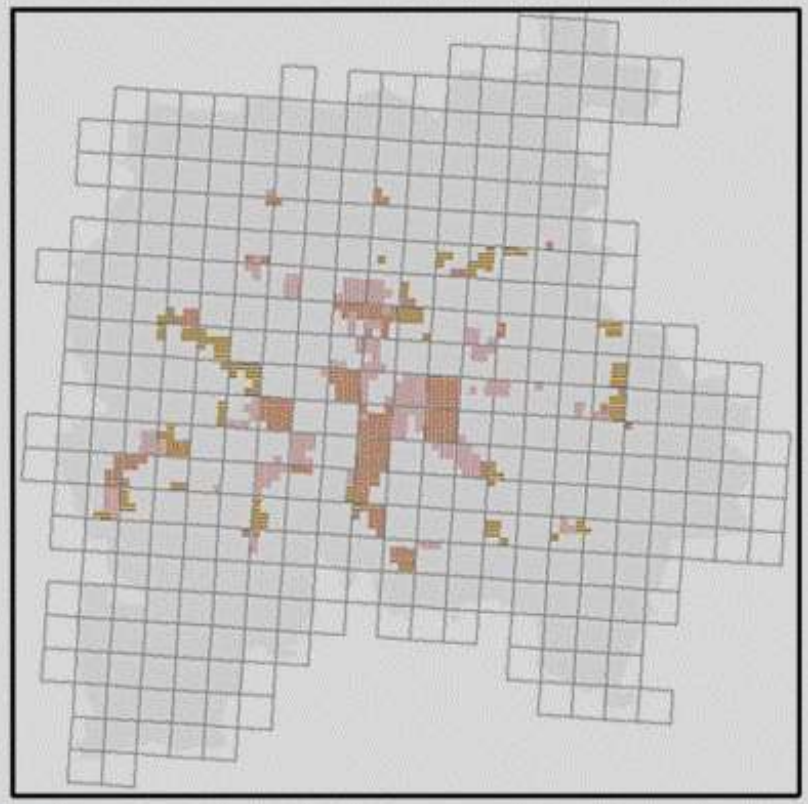
Urban green areas and SHU within 250 m walking distance of urban green



Urban green area

Areas within 250 m walking distance

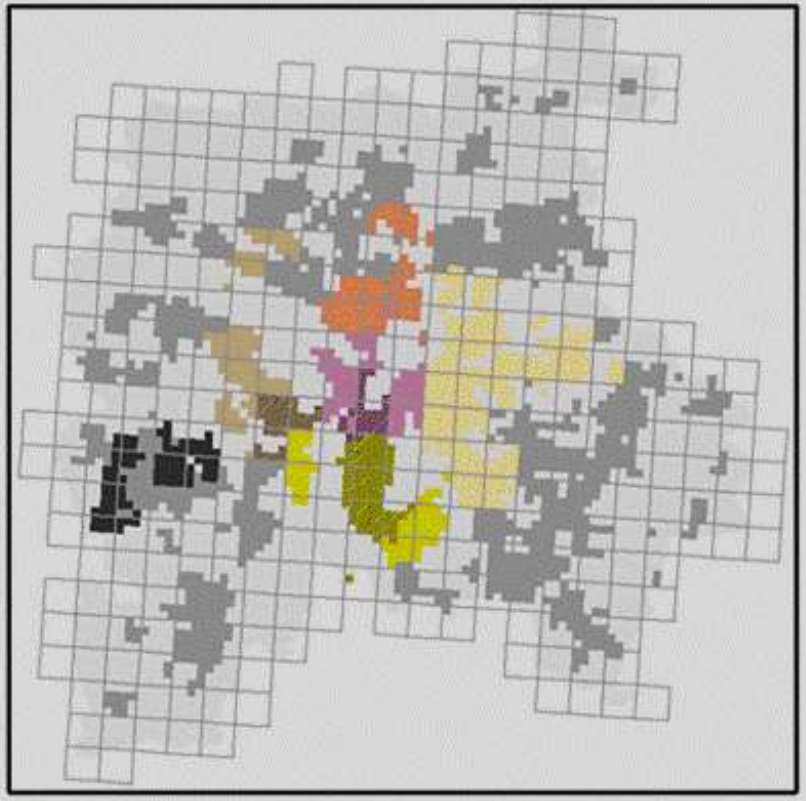
SHU within service areas (500 m walking distance) of local suppliers and pharmacies



Service areas of local suppliers

Service areas of pharmacies

Categorized location and multiculturality



Centre

Grünau

West

East

Outskirts

Gohlis

South

with multicultural image

A glimpse into the future of vulnerabilities in cities? Residential location vs. forest

"Residential-choice behaviour can inform disaster risk assessment through several means. The proposed methodology allows for identifying hot spots and cold spots of residential choice for distinct socioeconomic groups […]. The hot spots […] highlight where a progressive concentration of the respective group of the population is likely."

"The spatial pattern of hot spots is seen to directly reveal the shaping of exposure and vulnerabilities towards specific hazards through residential-choice processes. The impact on disaster risk becomes obvious when the elicited hot-spot or cold-spot pattern is overlaid with hazard-prone areas to account for the hazard dimension of disaster risk."

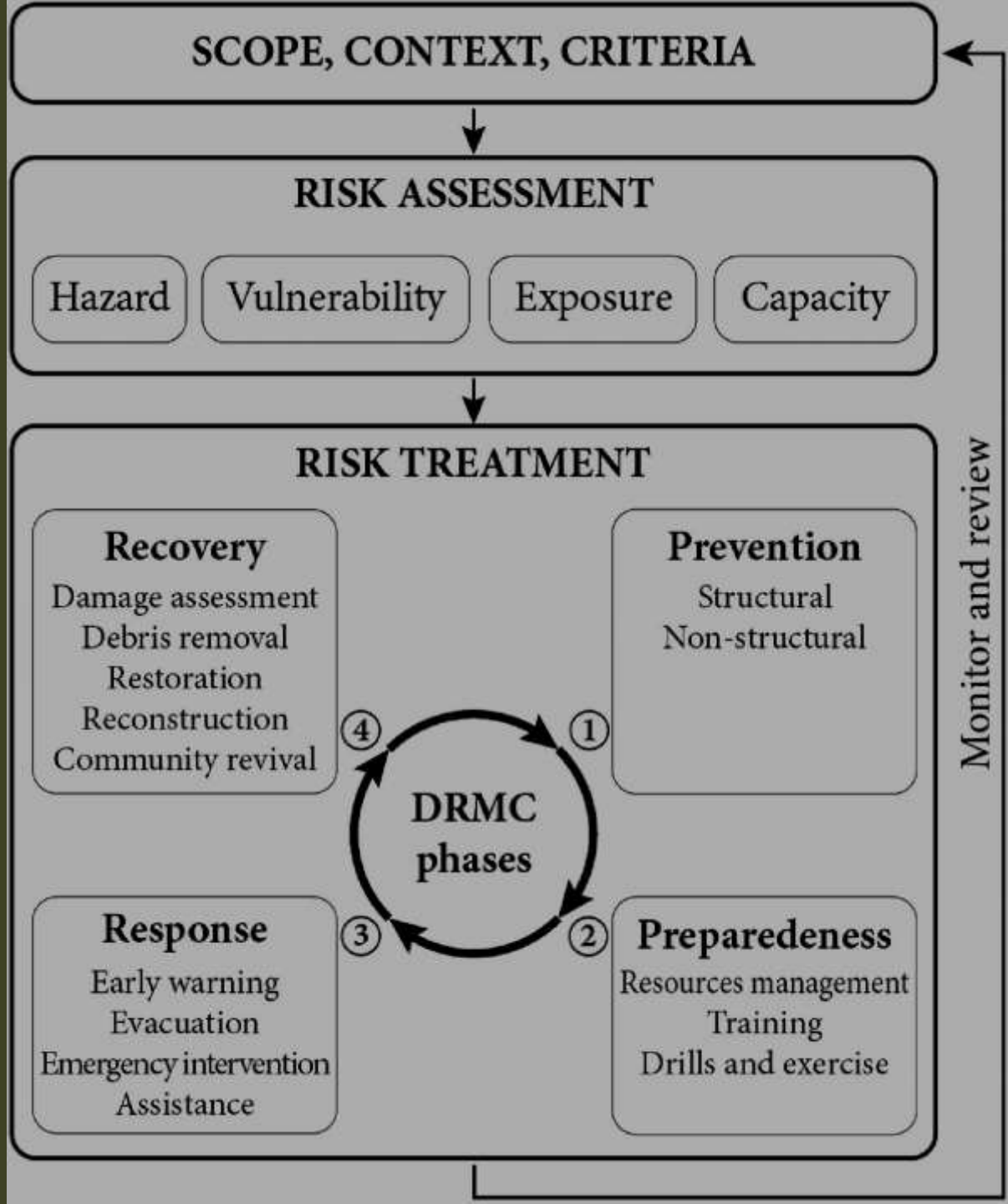
Scheuer *et al.* (2021), *NHESS*, 21, https://doi.org/10.5194/nhess-21-203-2021

Unpacking seismic risk in Italian historic centres

"Historic centres are cultural, social and economical resources […], but also fragile areas […] often […] damaged or destroyed by earthquakes."

"The main challenge that Italy faces in coping with the impacts of seismic events is the reduction of vulnerabilities and exposure within these large-scale heritage-listed urban areas."

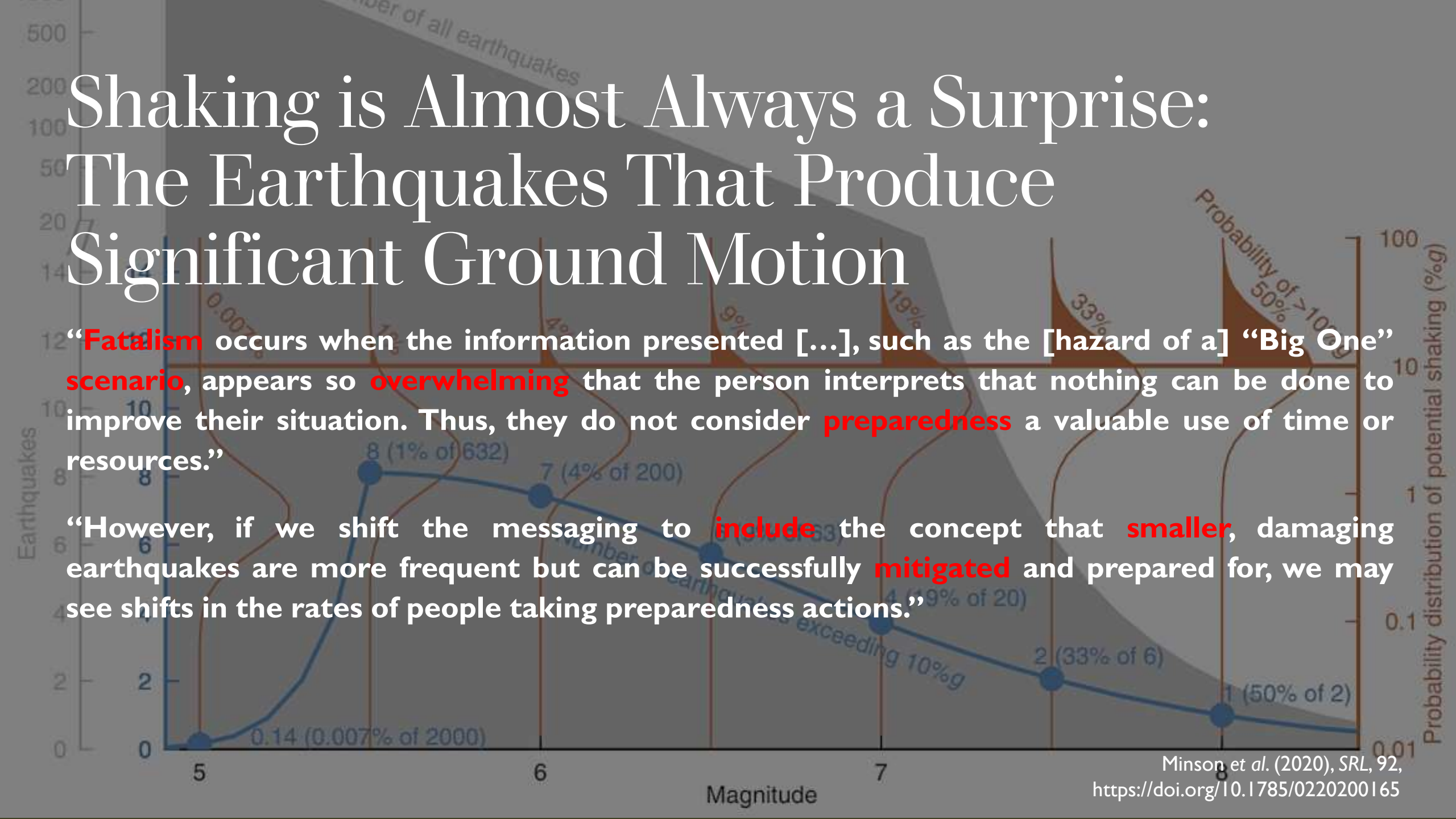
Giuliani et al. (2021), *Int. J. Disaster Risk Reduction*, 59
https://doi.org/10.1016/j.ijdrr.2021.102260



Shaking is Almost Always a Surprise: The Earthquakes That Produce Significant Ground Motion

"Fatalism occurs when the information presented […], such as the [hazard of a] "Big One" scenario, appears so overwhelming that the person interprets that nothing can be done to improve their situation. Thus, they do not consider preparedness a valuable use of time or resources."

"However, if we shift the messaging to include the concept that smaller, damaging earthquakes are more frequent but can be successfully mitigated and prepared for, we may see shifts in the rates of people taking preparedness actions."



Minson *et al.* (2020), *SRL*, 92, https://doi.org/10.1785/0220200165

The rising tide: assessing the risks of climate change and human settlements

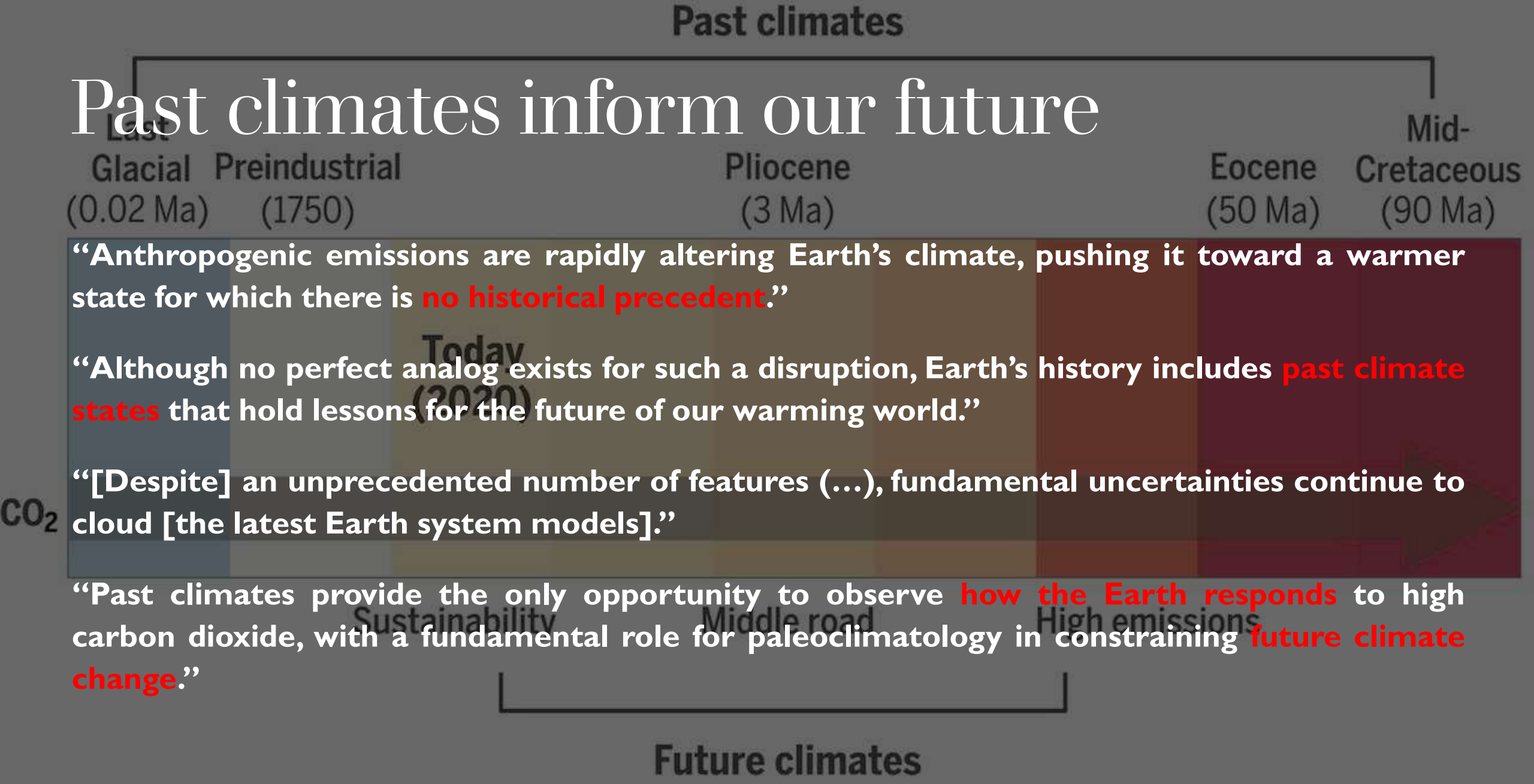
The area of sea under jurisdiction of EU States is larger than the total land area of the EU. The EU has the world's largest maritime territory (source: EEA, EU WISE).

The EU coastline is 68 000 km long – more than three times longer than that of the USA and almost twice that of Russia (source: EEA, EU WISE).

Almost half of the EU population lives < 50 km from the sea, primarily in urban areas along the coast in low elevation coastal zones. In 2011, 206 million people (41 % EU population) lived in Europe's coastal regions (source: EEA, Eurostat).

McGranahan *et al.* (2007), *Environm. & Urbanis.*, 19, https://doi.org/10.1177/0956247807076960

Past climates inform our future



"Anthropogenic emissions are rapidly altering Earth's climate, pushing it toward a warmer state for which there is no historical precedent."

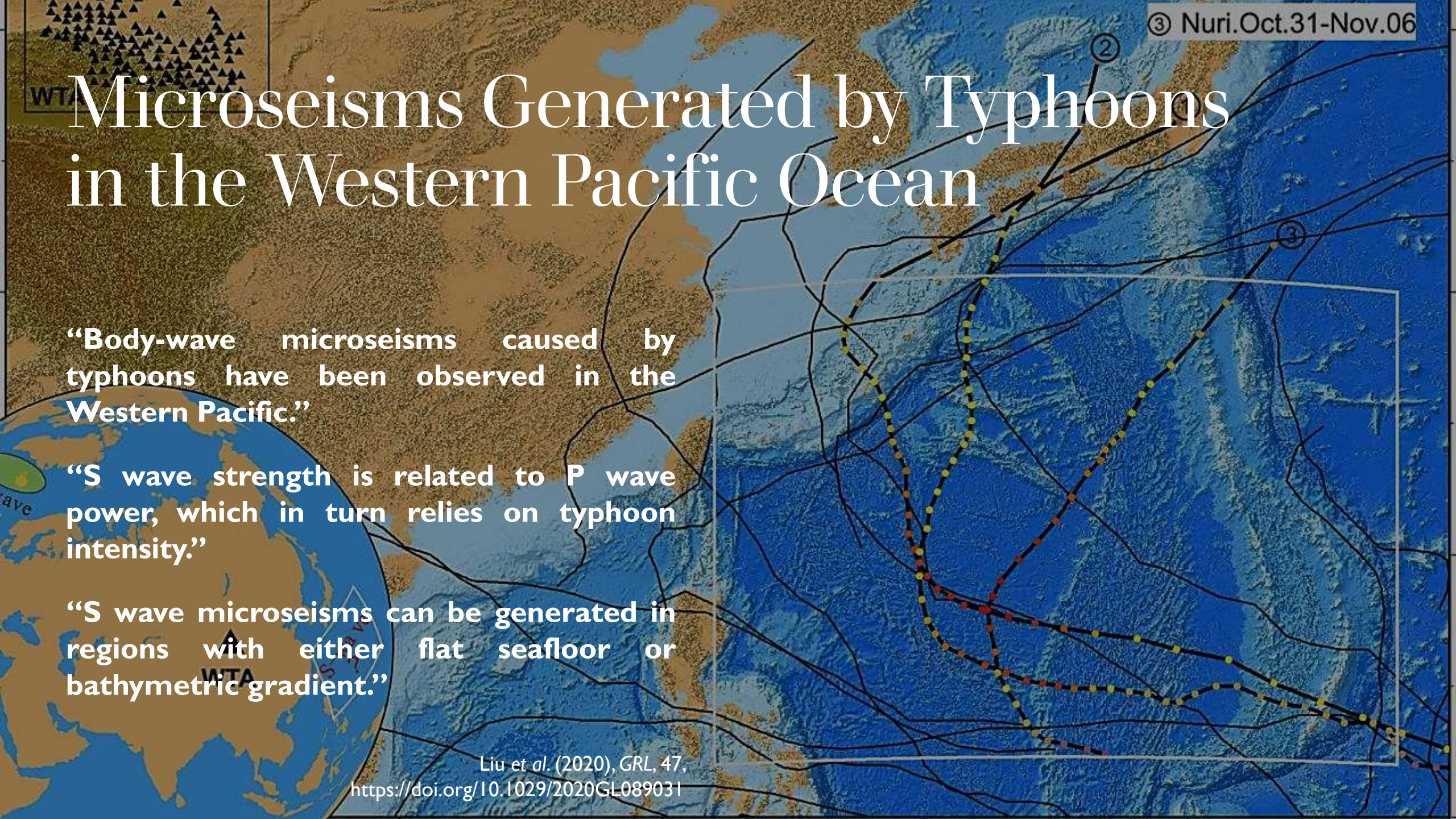
"Although no perfect analog exists for such a disruption, Earth's history includes past climate states that hold lessons for the future of our warming world."

"[Despite] an unprecedented number of features (…), fundamental uncertainties continue to cloud [the latest Earth system models]."

"Past climates provide the only opportunity to observe how the Earth responds to high carbon dioxide, with a fundamental role for paleoclimatology in constraining future climate change."

Tierney *et al.* (2020), *Science*, 370, https://doi.org/10.1126/science.aay3701

Microseisms Generated by Typhoons in the Western Pacific Ocean



"Body-wave microseisms caused by typhoons have been observed in the Western Pacific."

"S wave strength is related to P wave power, which in turn relies on typhoon intensity."

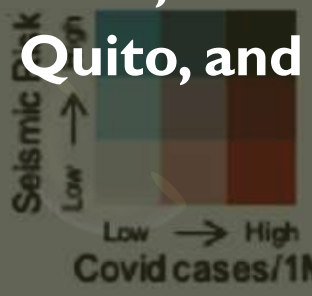
"S wave microseisms can be generated in regions with either flat seafloor or bathymetric gradient."

Liu *et al.* (2020), *GRL*, 47,
https://doi.org/10.1029/2020GL089031

Potential impact of earthquakes during the 2020 COVID-19 pandemic

Combination between the number of COVID-19 cases per 1 million habitants and seismic risk.

"Urban centers with both high prevalence of COVID-19 cases and earthquake risk. Some of these large urban centers include Istanbul and western Turkish cities, the Po Valley in Italy [Milan], the Great Metropolitan Area of Lisbon, San Francisco Bay Area, Greater Los Angeles, Tehran, Santiago, Lima, Santo Domingo, Panama City, Quito, and Tokyo."



Silva & Paul (2020), *Earthquake Spectra*, 101, https://doi.org/10.1177/8755293020950328

Poorly planned urban development: Urbanization creates new risk

"Whether or not disaster risk is factored into investment, decisions in urban development will have a decisive influence on the future of disaster risk reduction." (UNDRR, 2013)

"Estimates suggest that by 2050, urban population exposed to cyclones will increase from 310 to 680 M; exposure to major earthquake will increase from 370 to 870 M." (World Bank, 2013)

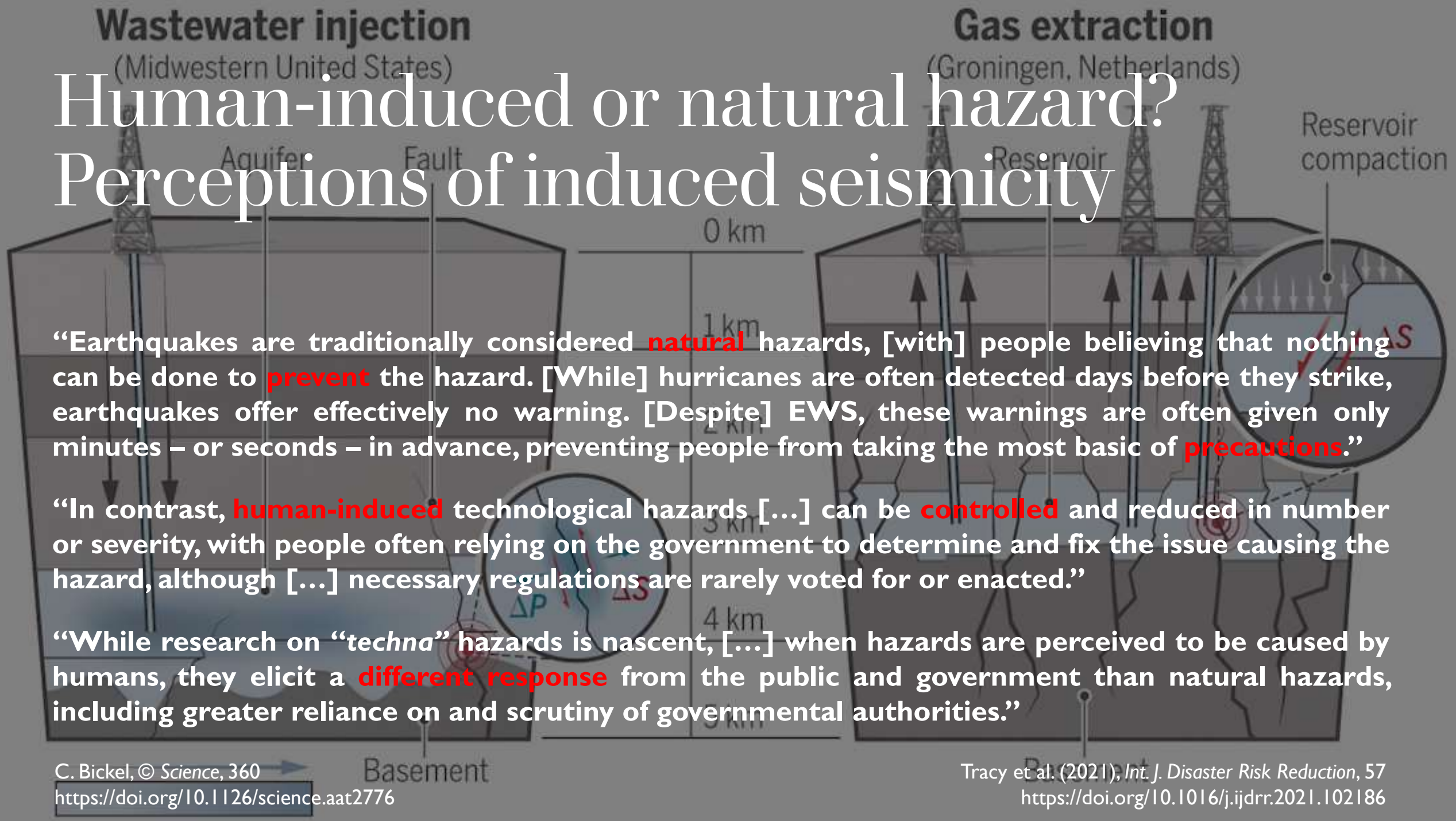
"Disaster risk may be increasing faster in rapidly growing small- and medium-sized urban centers than in either rural areas or larger cities" (UNDRR, 2011).

"Strengthening urban governance to involve and empower citizens [...] is probably the most important factor in addressing urban risk." (UNDRR, 2015)

Tectonic Hazards Case Study 1: Haiti, January 10, 2010
https://www.jkgeography.com/earthquake-case-study-1-haiti.html

U.N. Office for Disaster Risk Reduction
https://www.preventionweb.net/disaster-risk/risk-drivers/urban/

Human-induced or natural hazard? Perceptions of induced seismicity



"Earthquakes are traditionally considered natural hazards, [with] people believing that nothing can be done to prevent the hazard. [While] hurricanes are often detected days before they strike, earthquakes offer effectively no warning. [Despite] EWS, these warnings are often given only minutes – or seconds – in advance, preventing people from taking the most basic of precautions."

"In contrast, human-induced technological hazards […] can be controlled and reduced in number or severity, with people often relying on the government to determine and fix the issue causing the hazard, although […] necessary regulations are rarely voted for or enacted."

"While research on "*techna*" hazards is nascent, […] when hazards are perceived to be caused by humans, they elicit a different response from the public and government than natural hazards, including greater reliance on and scrutiny of governmental authorities."

C. Bickel, © *Science*, 360
https://doi.org/10.1126/science.aat2776

Tracy et al. (2021), *Int. J. Disaster Risk Reduction*, 57
https://doi.org/10.1016/j.ijdrr.2021.102186

Tsunami Warnings, Written in Stone

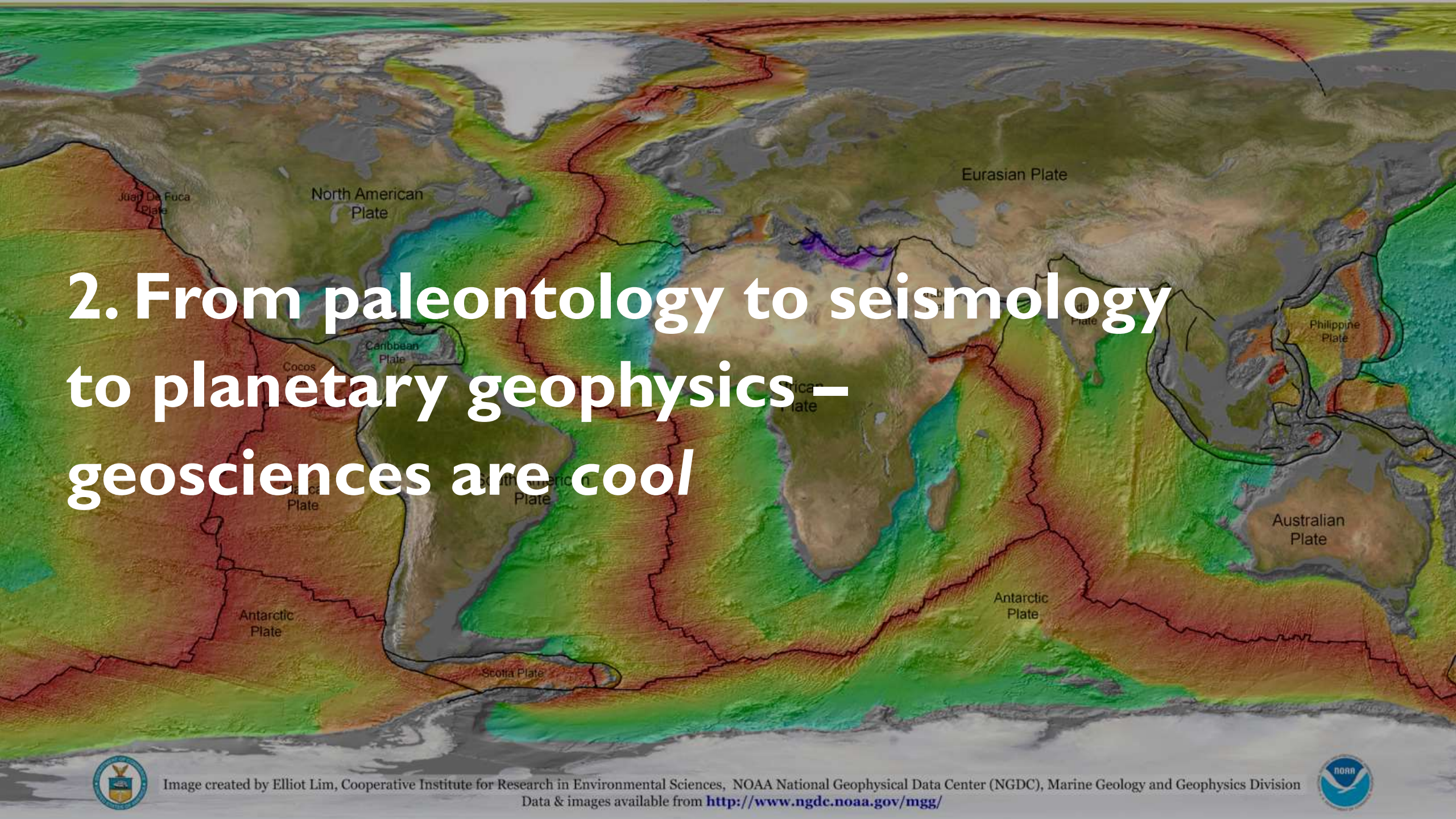
"Do not build your homes below this point!" Residents say this injunction from their ancestors kept their tiny village […] safely out of reach of the deadly tsunami […] that […] rose to record heights near here. The waves stopped just 300 feet below the stone.

"They knew the horrors of tsunamis, so they erected that stone to warn us," said Tamishige Kimura, 64, the village leader of Aneyoshi. Hundreds of so-called tsunami stones, […] centuries old, dot the coast of Japan, silent testimony to the past destruction that these lethal waves have frequented […]. But modern Japan, confident [in …] technology and […] seawalls […], came to forget […] these ancient warnings, dooming it to repeat bitter experiences […].

"The tsunami stones […] warn across generations, telling descendants to avoid the suffering of their ancestors," said Itoko Kitahara, a specialist in the history of natural disasters at Ritsumeikan Univ. in Kyoto. "Some places heeded these lessons of the past, but many didn't."

K. Sasaki © The New York Times

M. Fackler (2011), *New York Times*, 21 April, A, 6
https://www.nytimes.com/2011/04/21/world/asia/21stones.html



2. From paleontology to seismology to planetary geophysics– geosciences are *cool*

Image created by Elliot Lim, Cooperative Institute for Research in Environmental Sciences, NOAA National Geophysical Data Center (NGDC), Marine Geology and Geophysics Division
Data & images available from **http://www.ngdc.noaa.gov/mgg/**

Braiding Indigenous Knowledges with Geomorphology

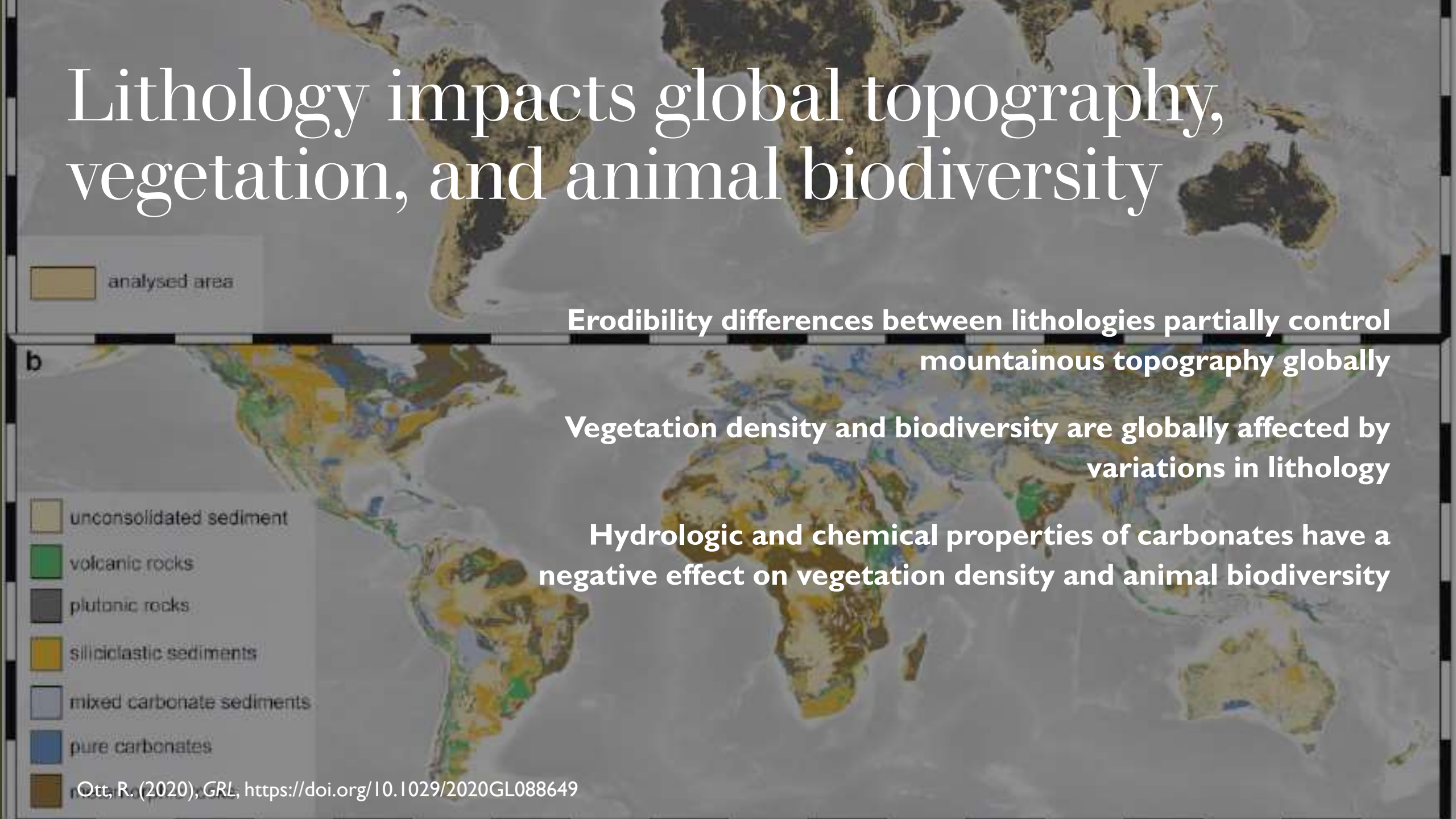
Landscape accumulated cognition

Spatial historical landmarks

Memory of past events

Evans, K. (2020), *Eos*, 101, https://doi.org/10.1029/2020EO148717

Lithology impacts global topography, vegetation, and animal biodiversity



Erodibility differences between lithologies partially control mountainous topography globally

Vegetation density and biodiversity are globally affected by variations in lithology

Hydrologic and chemical properties of carbonates have a negative effect on vegetation density and animal biodiversity

Ott, R. (2020), *GRL*, https://doi.org/10.1029/2020GL088649

Presence of hydrocarbons on Mars: A possibility

"There exists a fair degree of geological similarity between the internal structure of Mars, its orbital cycle, and axis tilt with that of Earth. The ancient Valles Marineris equatorial rift basin of Mars could have resulted because of lithospheric dynamics."

"The presence of lake and ocean and evidence of glaciation infer probable evolution of life in early Mars. The depositional morphology like alluvial fans, debris flow fans, deltas, and lacustrine fans implies possible sedimentation processes active on early Mars."

"The presence of organic molecules of benzene and propane in 3-billion-year-old rock samples has been evidenced in Gale crater. Deposition of source rock and subsequent decomposition of organic matter could have generated hydrocarbons in early Mars."

Valles Marineris, THEMIS infrared imagery from 2001 *Mars Odyssey*
NASA / JPL-Caltech / Arizona State University – http://themis.asu.edu/vallesspecial

Padhy (2021), *Env. Geosci.*, 28
https://doi.org/10.1306/eg.11032019026

Crustal thickness, rift-drift and potential links to key global events

"The generation of significant continental relief has the potential to have profoundly influenced the chemistry of the Earth's oceans and atmosphere as it evolved through time."

"Increased crustal thickness correlates with increased passive margin abundance and overlaps with snowball Earth glaciations and atmospheric oxygenation, suggesting a causal link between continental rift-drift phases and major transitions in Earth's atmospheric and oceanic evolution."

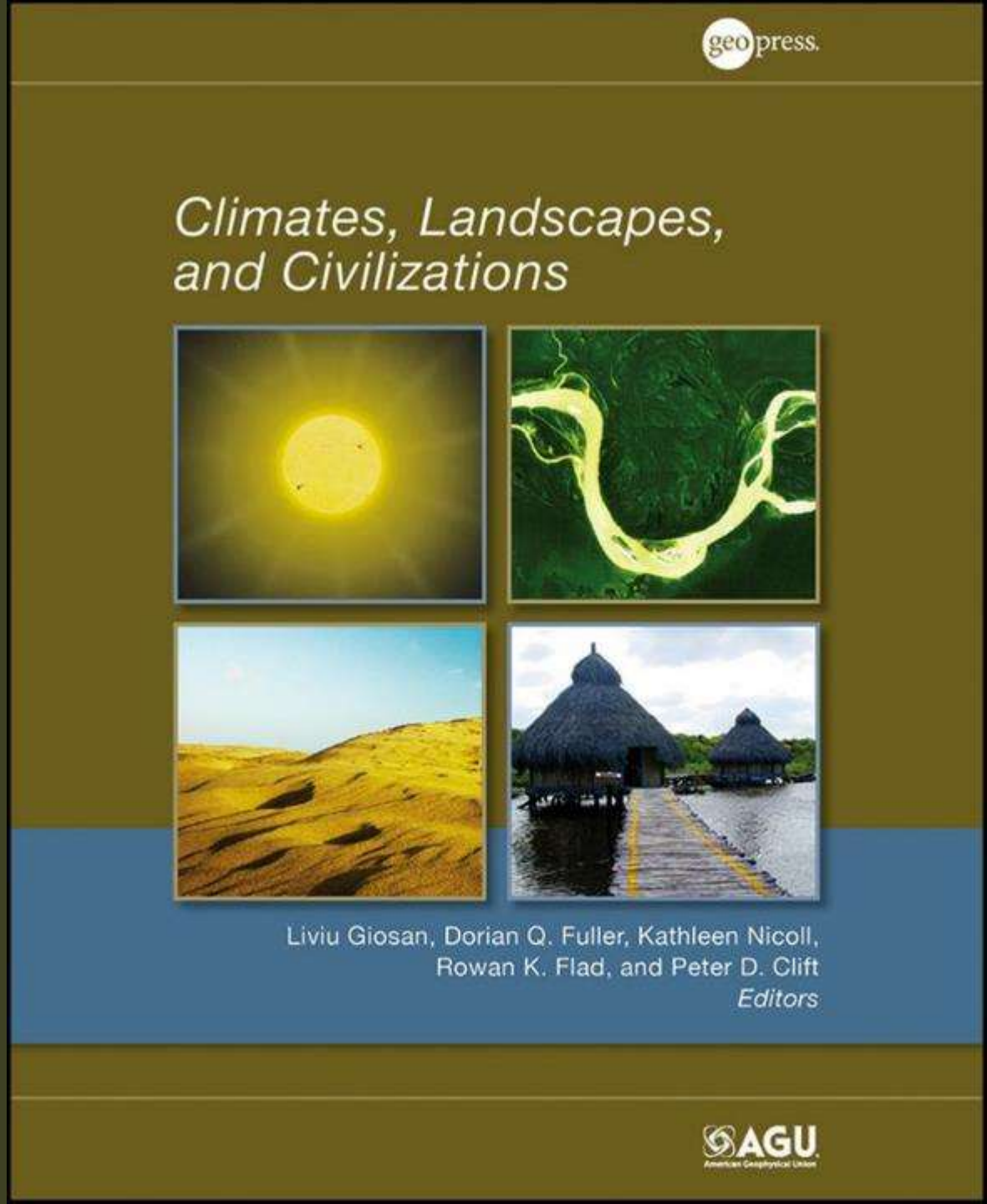
Paulsen et al., (2020), *Terra Nova*, https://doi.org/10.1111/ter.12485

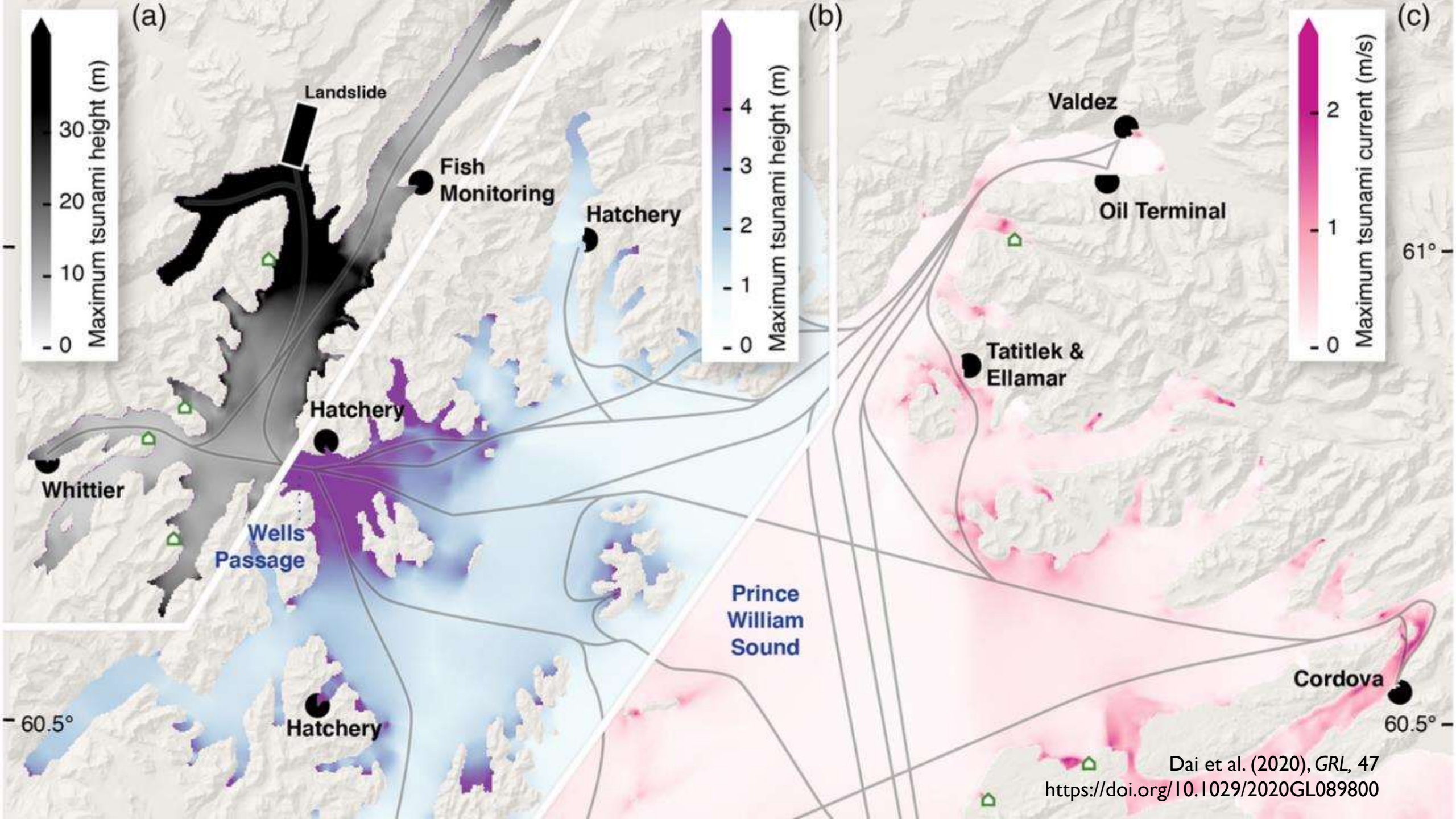
Influences of Active Tectonism on Human Development

"Active tectonism forced the pace of cultural change in antiquity, accelerating development of cultural complexity in comparison to neighbors in tectonically quiescent areas."

"Tectonic activity should be considered along with other factors such as climate change in evaluating human activity and development."

Force & McFadgen (2012),
in: *Climates, Landscapes, and Civilizations,*
https://doi.org/10.1029/2012GM001215





Dai et al. (2020), *GRL*, 47
https://doi.org/10.1029/2020GL089800

Large and Potentially Tsunamigenic Periglacial Landslide in Alaska

"The retreat of glaciers in response to global warming has the potential to trigger landslides in glaciated regions around the globe. Landslides that enter fjords or lakes can cause tsunamis, which endanger people and infrastructure far from the landslide itself."

"Should the entire unstable slope collapse at once, preliminary tsunami modeling suggests a maximum runup of 300 m near the landslide, which may have devastating impacts on local communities."

"Our findings highlight the need for interdisciplinary studies of recently deglaciated fjords to refine our understanding of the impact of climate change on landslides and tsunamis."

Dai et al. (2020), *GRL*, 47
https://doi.org/10.1029/2020GL089800

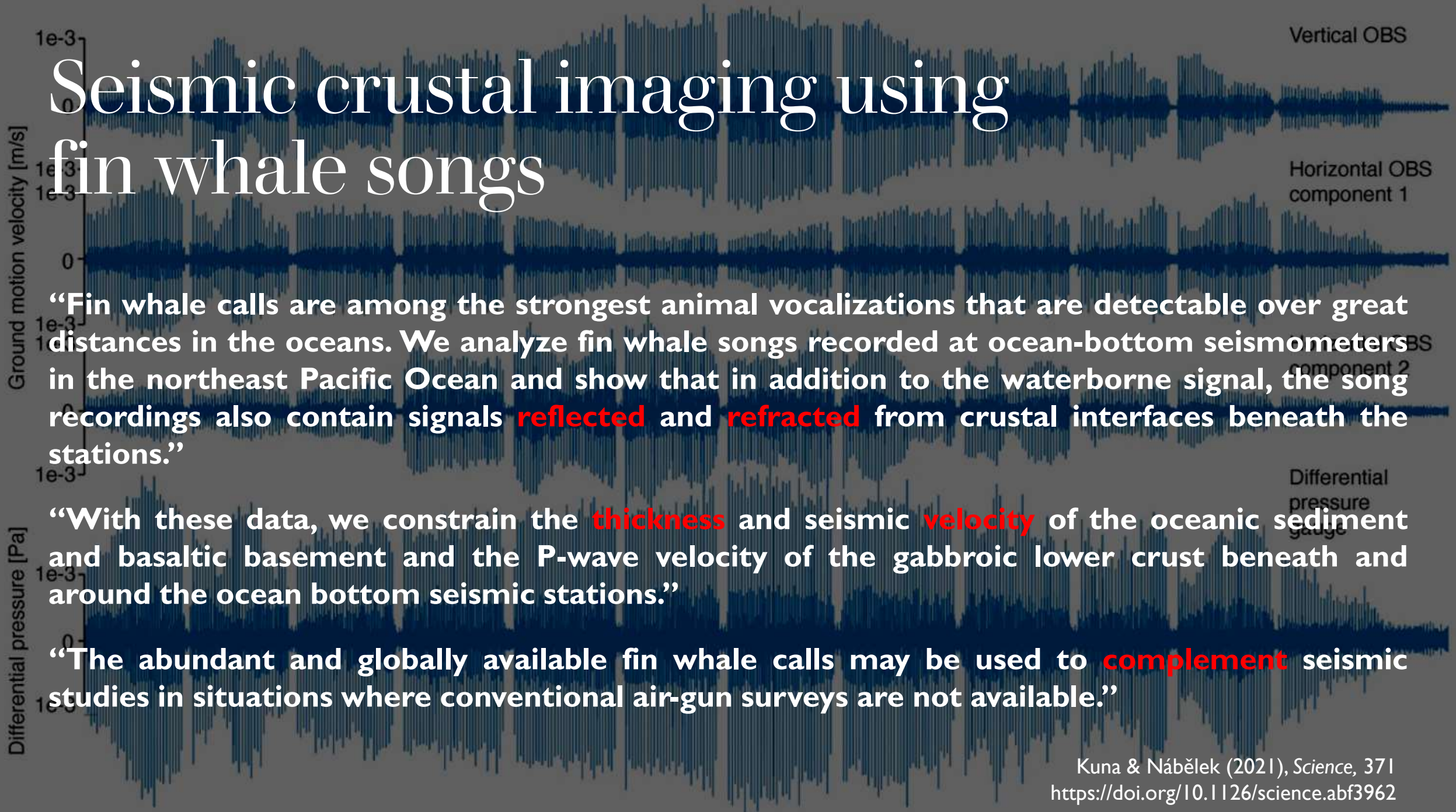
Aquifer systems extending far offshore on the U.S. Atlantic margin

"A remarkable freshwater aquifer is hiding under the salty Atlantic Ocean, just off the northeastern coast of the United States. While the aquifer's exact size is still to be defined, it may be the largest of its kind, stretching from at least Massachusetts to southern New Jersey, or nearly 350 kilometers, at ca. 200-400 m below seafloor."

"The aquifer may contain about 2,800 cubic kilometers. It is freshest close to shore and saltier seaward. It could date to the last ice age (20-15 Ky). Evidence suggests that such aquifers might potentially represent a resource to supplement other dry regions elsewhere, from southern California, Australia or the Middle East." (source: LiveScience)

Gustafson et al. (2019), *Sci. Rep.*, 9
https://doi.org/10.1038/s41598-019-44611-7

Seismic crustal imaging using fin whale songs



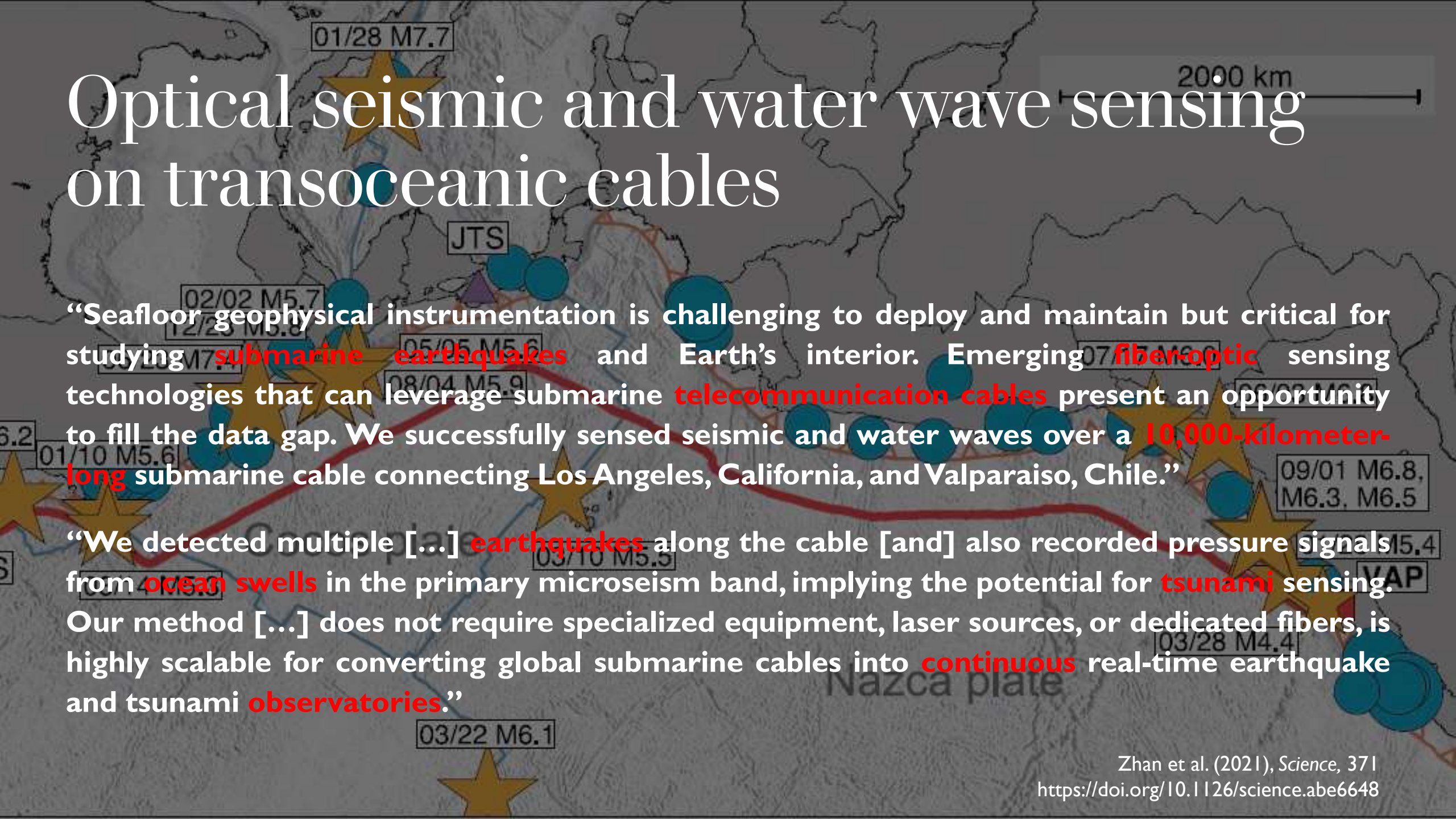
"Fin whale calls are among the strongest animal vocalizations that are detectable over great distances in the oceans. We analyze fin whale songs recorded at ocean-bottom seismometers in the northeast Pacific Ocean and show that in addition to the waterborne signal, the song recordings also contain signals reflected and refracted from crustal interfaces beneath the stations."

"With these data, we constrain the thickness and seismic velocity of the oceanic sediment and basaltic basement and the P-wave velocity of the gabbroic lower crust beneath and around the ocean bottom seismic stations."

"The abundant and globally available fin whale calls may be used to complement seismic studies in situations where conventional air-gun surveys are not available."

Kuna & Nábělek (2021), *Science*, 371
https://doi.org/10.1126/science.abf3962

Optical seismic and water wave sensing on transoceanic cables



"Seafloor geophysical instrumentation is challenging to deploy and maintain but critical for studying submarine earthquakes and Earth's interior. Emerging fiber-optic sensing technologies that can leverage submarine telecommunication cables present an opportunity to fill the data gap. We successfully sensed seismic and water waves over a 10,000-kilometer-long submarine cable connecting Los Angeles, California, and Valparaiso, Chile."

"We detected multiple [...] earthquakes along the cable [and] also recorded pressure signals from ocean swells in the primary microseism band, implying the potential for tsunami sensing. Our method [...] does not require specialized equipment, laser sources, or dedicated fibers, is highly scalable for converting global submarine cables into continuous real-time earthquake and tsunami observatories."

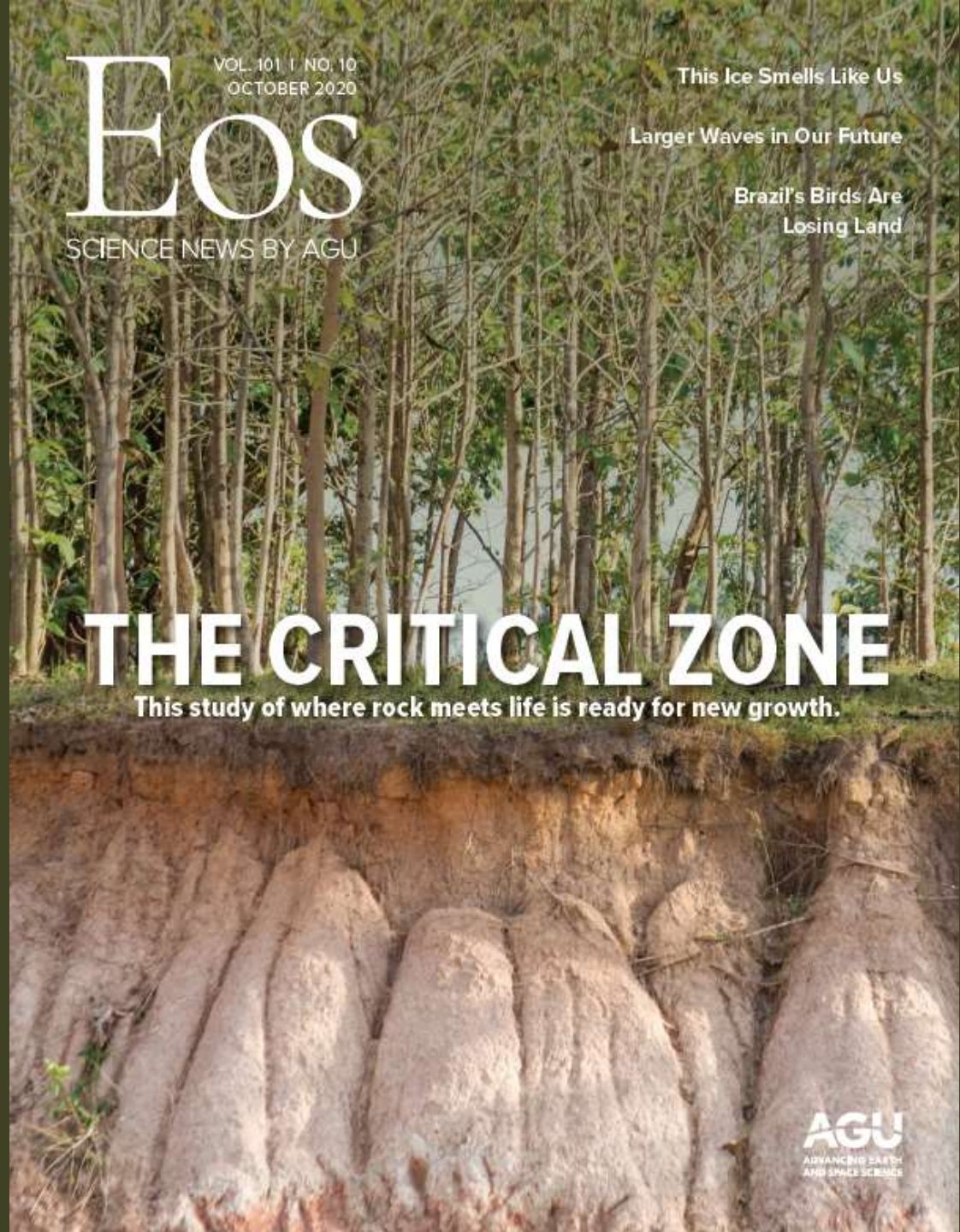
Zhan et al. (2021), *Science*, 371
https://doi.org/10.1126/science.abe6648

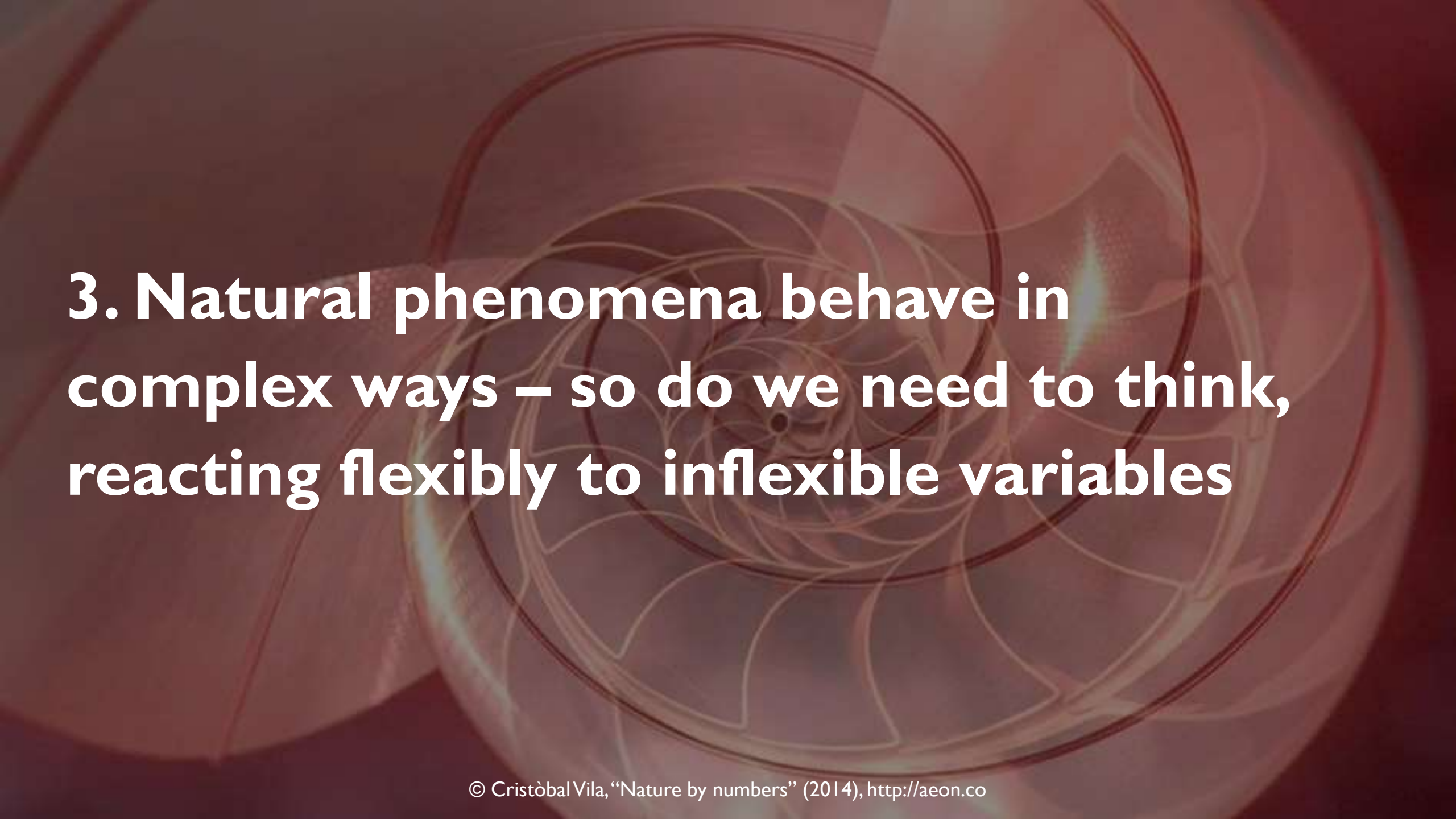
Critical Zone Science Comes of Age

"More than a concept, it's an interdisciplinary endeavor that draws on multiple fields to piece together the complicated interactions between water, air, life, rock, and soil that support terrestrial life."

"By understanding and modeling these relationships and how they evolve, scientists can predict how human activities threaten these necessary, life-sustaining systems."

Waldron (2020), *Eos*, 101, https://eos.org/features/critical-zone-science-comes-of-age





3. Natural phenomena behave in complex ways – so do we need to think, reacting flexibly to inflexible variables

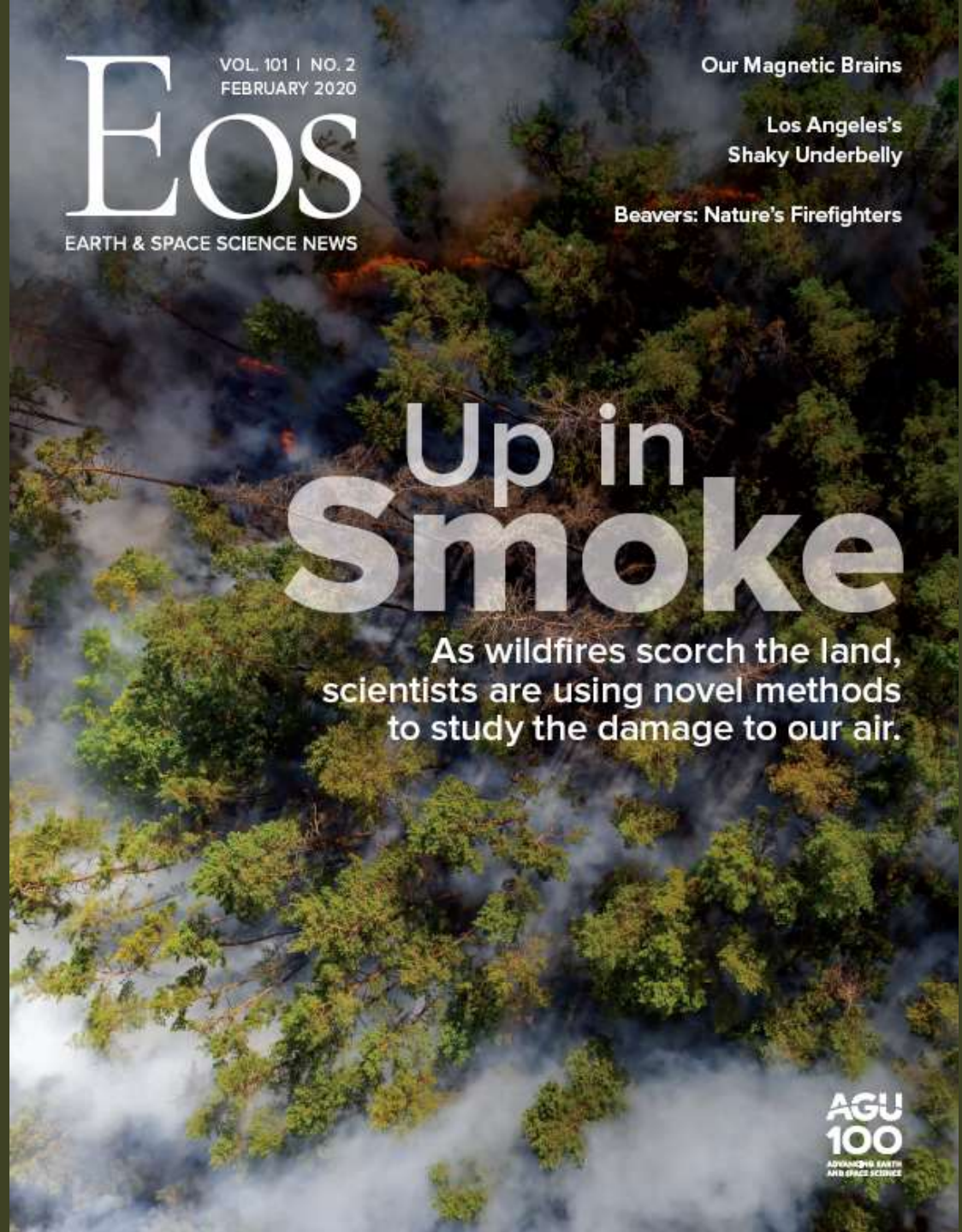
© Cristòbal Vila, "Nature by numbers" (2014), http://aeon.co

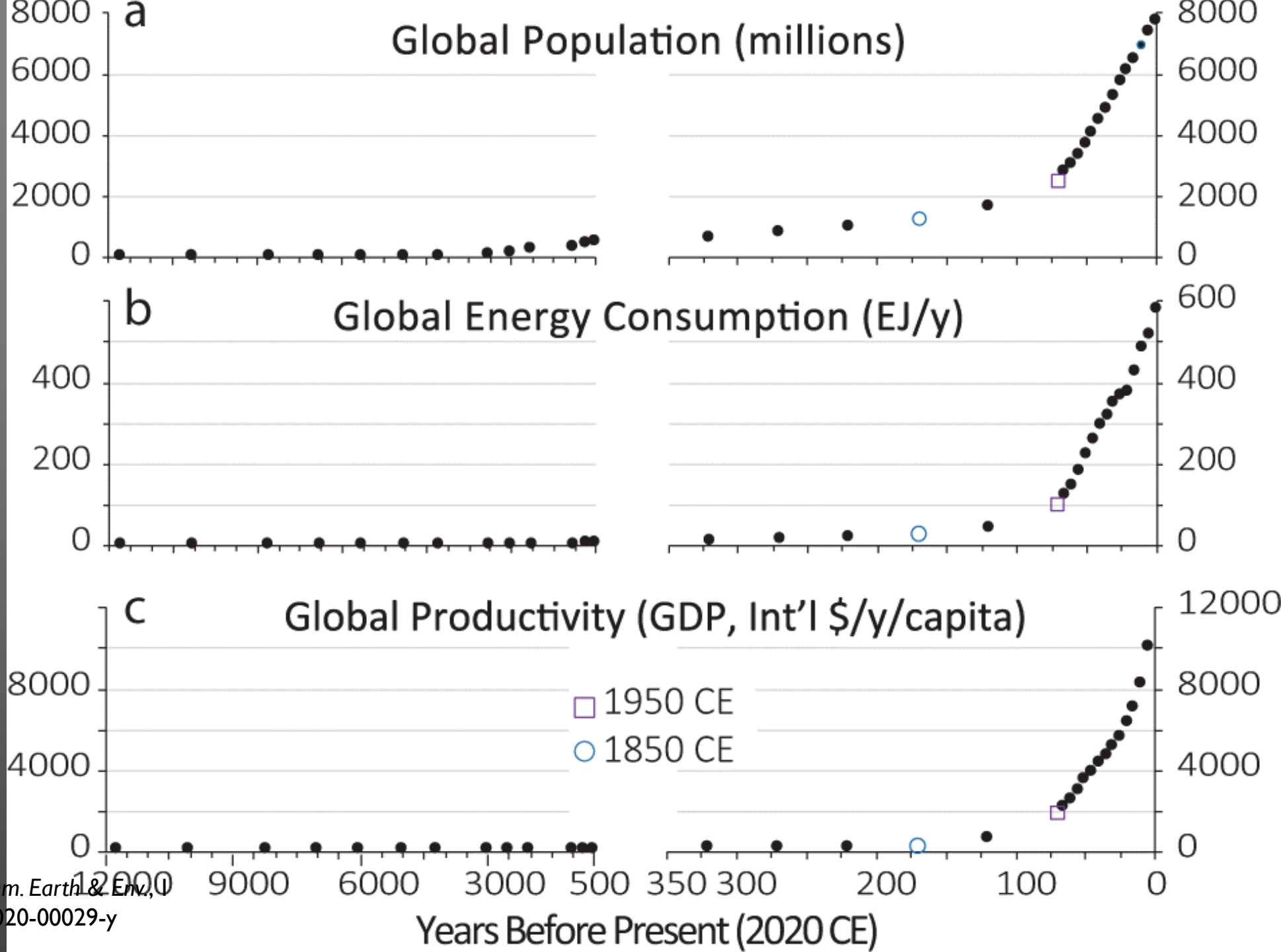
Fire in our future

"There is no single driver except humanity behind this outbreak. Increasingly, anthropogenic climate change is recognized as an enabler, performance enhancer, and globalizer."

"Fire seasons are lengthening, fire severity is escalating, and collateral damages are compounding."

Covington & Pyne (2020), *Science*, 370, https://doi.org/10.1126/science.abe9780





Syvitski et al. (2020), *Nature Comm. Earth & Env.*, I https://doi.org/10.1038/s43247-020-00029-y

Extraordinary energy consumption and resultant geological impact

"Human energy expenditure in the Anthropocene, ~22 zetajoules (ZJ), exceeds that across the prior 11,700 years of the Holocene (~14.6 ZJ), largely through combustion of fossil fuels."

"The global warming effect during the Anthropocene is more than an order of magnitude greater still. Global human population, their productivity and energy consumption, and most changes impacting the global environment, are highly correlated."

"This extraordinary outburst of consumption and productivity demonstrates how the Earth System has departed from its Holocene state since ~1950."

Syvitski et al. (2020), *Nature Comm. Earth & Env.*, 1
https://doi.org/10.1038/s43247-020-00029-y

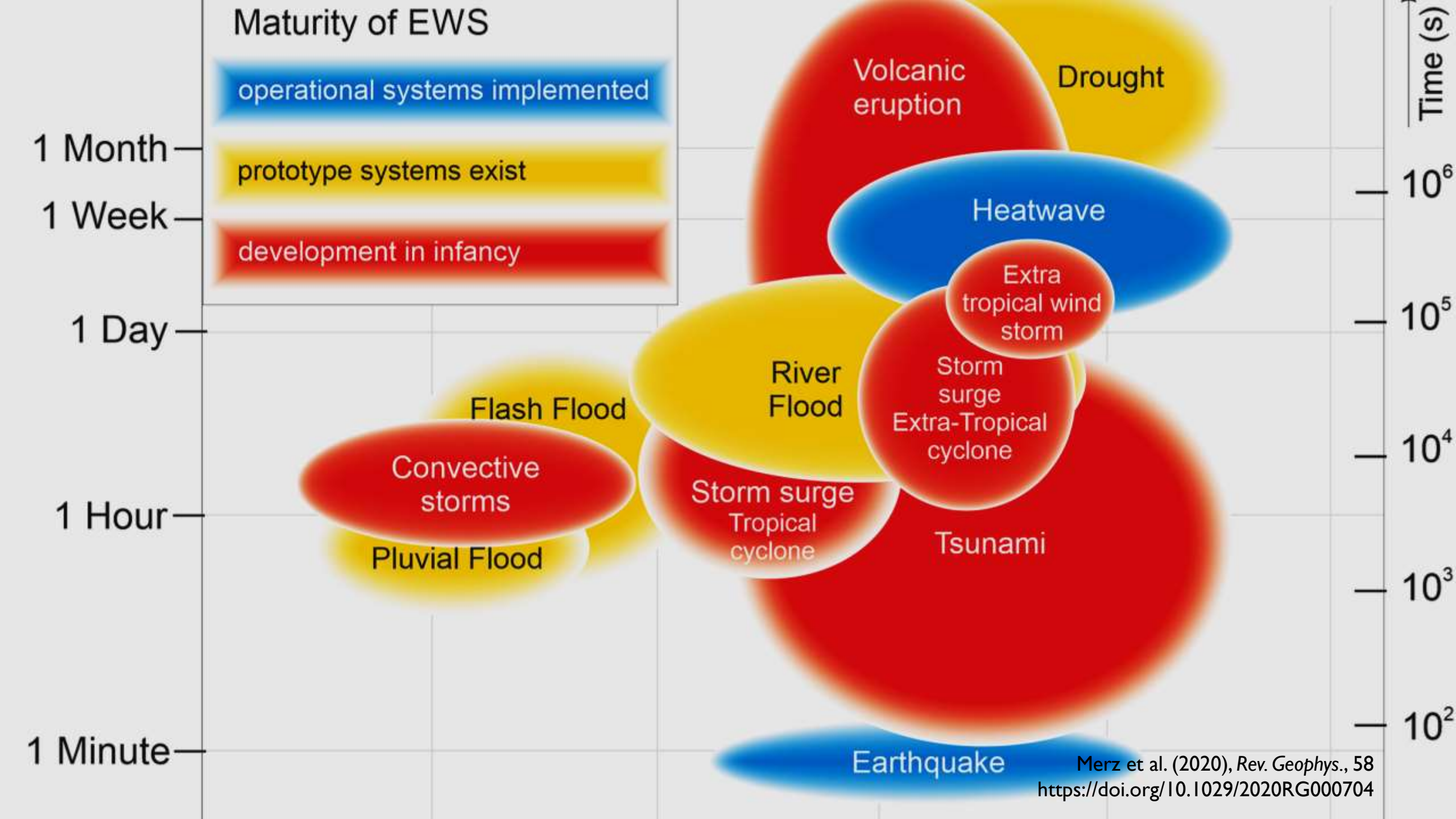
Seaports Expected to Grow up to Fourfold by 2050

Population growth brings to commodities need growth

More sea-going transport means more goods and higher value exposed

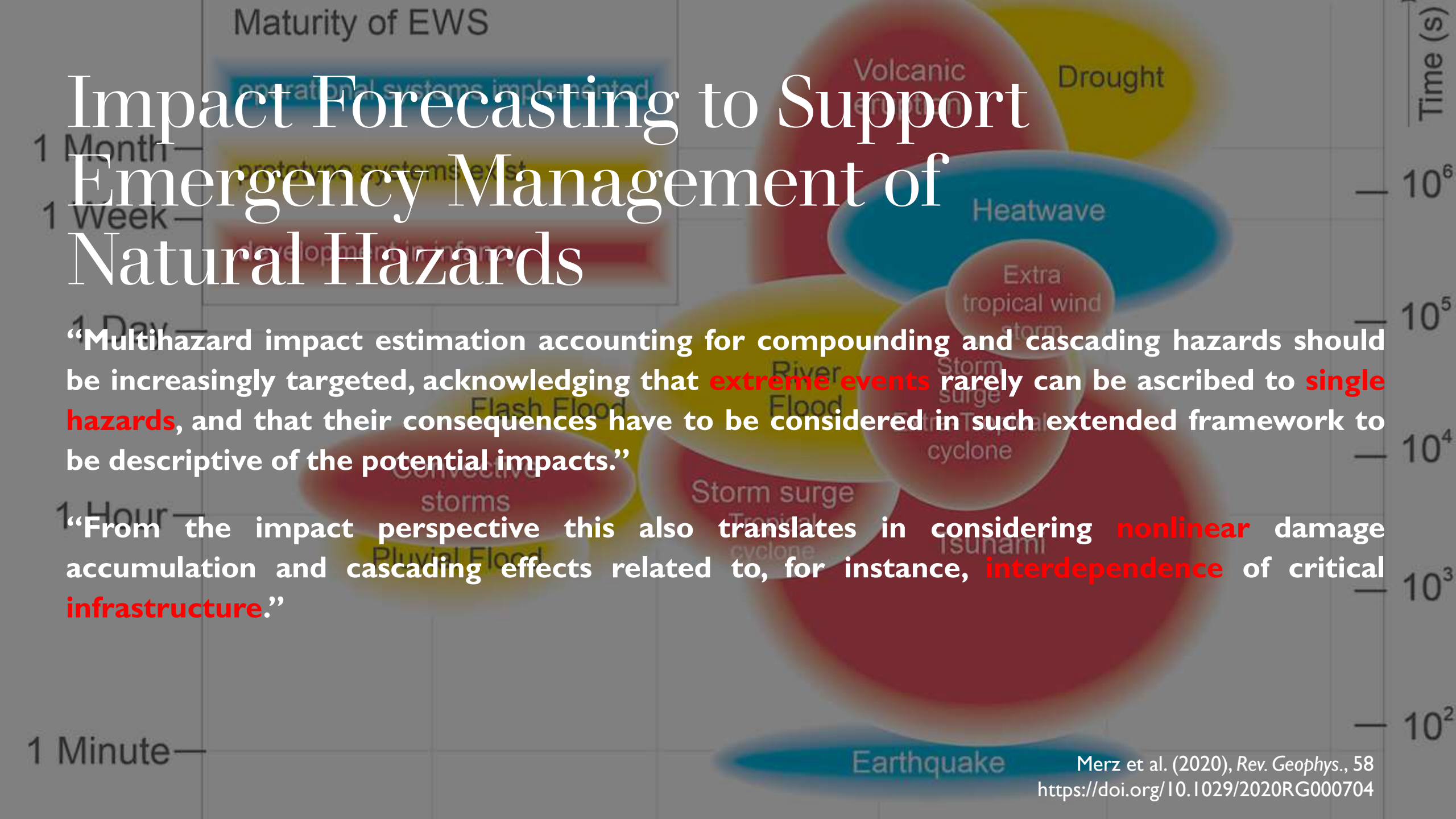
Shipping companies could provide at no extra cost navigation altimetry for global tsunami early-warning

Lester (2020), *Eos*, 101
https://doi.org/10.1029/2020EO148750



Merz et al. (2020), *Rev. Geophys.*, 58
https://doi.org/10.1029/2020RG000704

Impact Forecasting to Support Emergency Management of Natural Hazards



"Multihazard impact estimation accounting for compounding and cascading hazards should be increasingly targeted, acknowledging that extreme events rarely can be ascribed to single hazards, and that their consequences have to be considered in such extended framework to be descriptive of the potential impacts."

"From the impact perspective this also translates in considering nonlinear damage accumulation and cascading effects related to, for instance, interdependence of critical infrastructure."

Merz et al. (2020), *Rev. Geophys.*, 58
https://doi.org/10.1029/2020RG000704

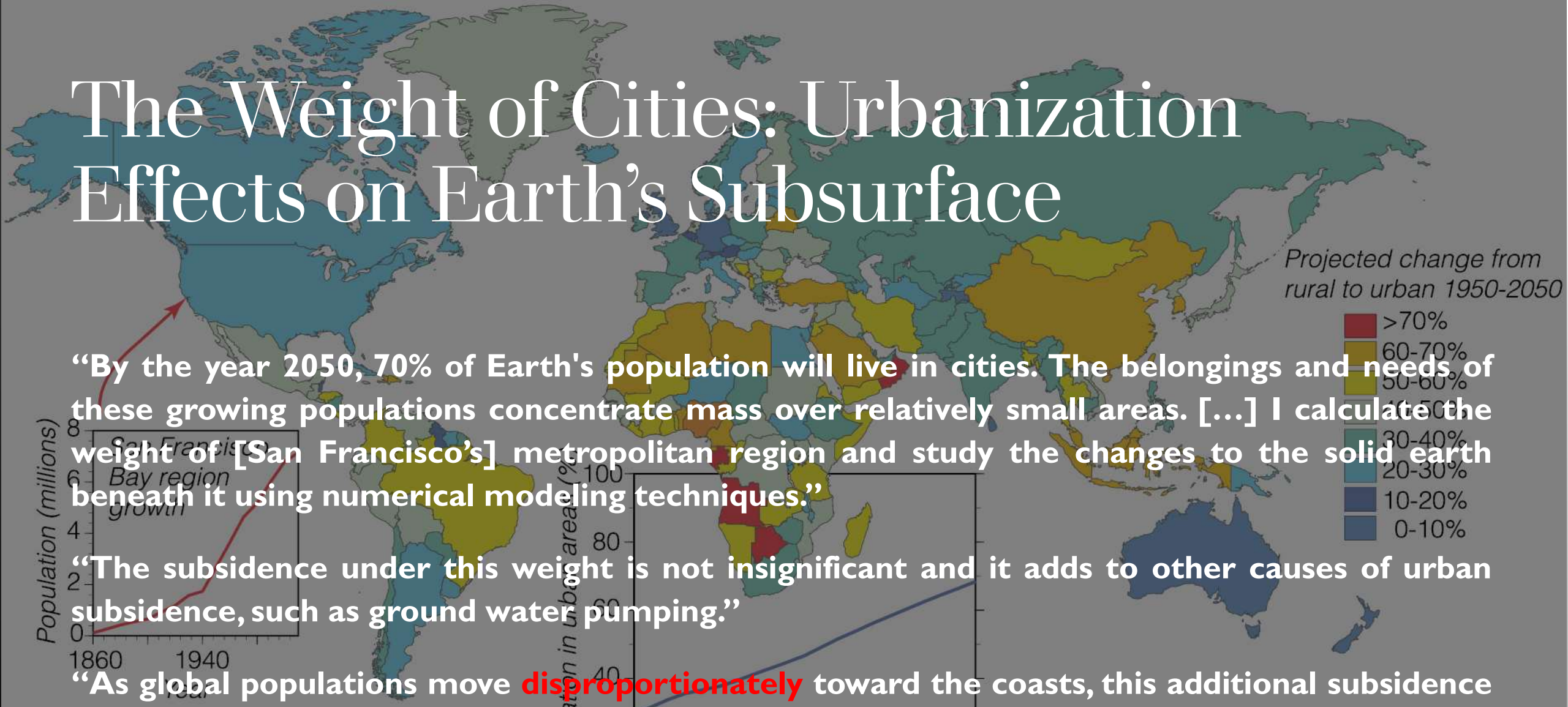
Natural hydrogen: A geological curiosity or the primary energy source for a low-carbon future?

"Hydrogen is an appealing low-carbon fuel that can be used for heat, transportation, power generation, and manufacturing […]. Conventional methods for manufacturing hydrogen are CO2-intensive or expensive. Therefore, large-scale, clean, affordable and natural sources of hydrogen from geological processes are very attractive and might solve several problems simultaneously."

"Overall, our latest data and understanding suggest that natural hydrogen is available at globally-relevant volumes with potentially easier and cheaper accessibility and lower emissions, which means it could be the dominant primary energy source we need for a low-carbon future."

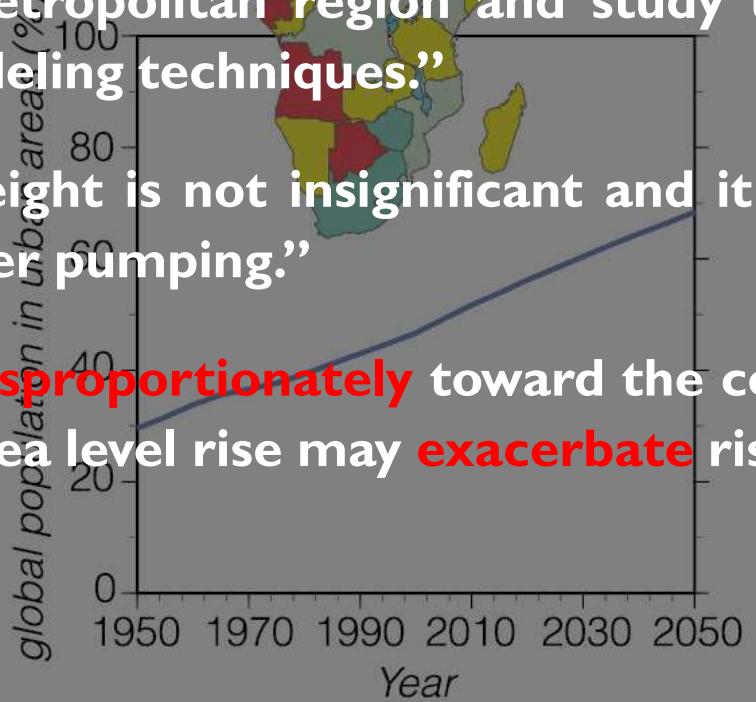
Moretti & Webber (2021), *Ren. Matter*
https://www.renewablematter.eu/authors-2/author/697

The Weight of Cities: Urbanization Effects on Earth's Subsurface



"By the year 2050, 70% of Earth's population will live in cities. The belongings and needs of these growing populations concentrate mass over relatively small areas. […] I calculate the weight of [San Francisco's] metropolitan region and study the changes to the solid earth beneath it using numerical modeling techniques."

"The subsidence under this weight is not insignificant and it adds to other causes of urban subsidence, such as ground water pumping."



"As global populations move disproportionately toward the coasts, this additional subsidence in combination with expected sea level rise may exacerbate risk associated with inundation."

Parsons (2021), *AGU Advances*, 2
https://doi.org/10.1029/2020AV000277

4. Geosciences and our collective future – as societies, continents, planets

American Geosciences Institute (2020)

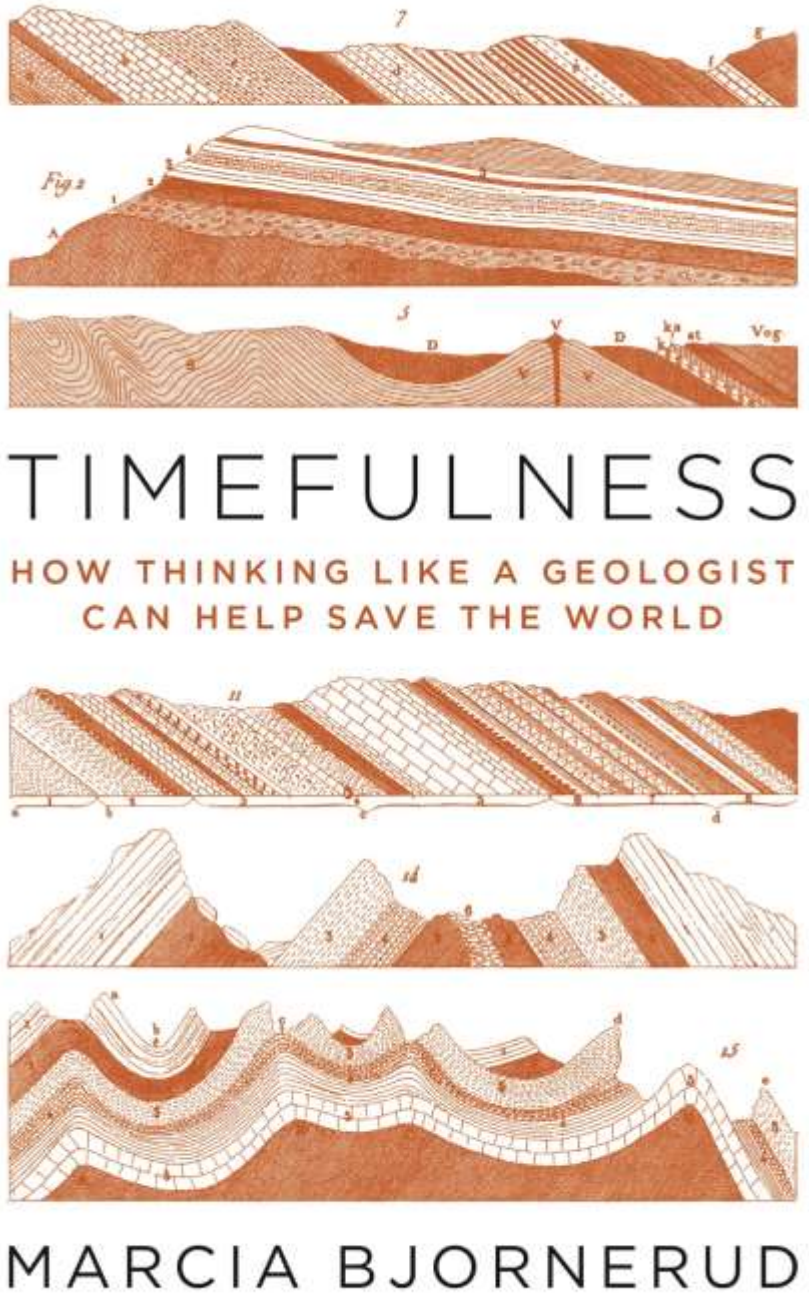
Timefulness: Thinking Like a Geologist Can Help Save the World

"Natural scientists already serve as a kind of impromptu international diplomatic corps who demonstrate that it is possible for people to cooperate, debate, disagree, and move toward consensus."

"We are all citizens of a planet whose tectonic, hydrologic, and atmospheric habits ignore national boundaries."

"The Earth itself, with its immensely deep history can provide a politically neutral narrative from which all nations may agree to take counsel."

Bjornerud (2018), *Timefulness*, Princeton Univ. Press
https://doi.org/10.2307/j.ctvc772cs



Geosciences Supporting a Thriving Society in a Changing World

Climate Change: Resilience, Adaptation, Sustainability

Natural Hazards, Global Change, Infrastructure

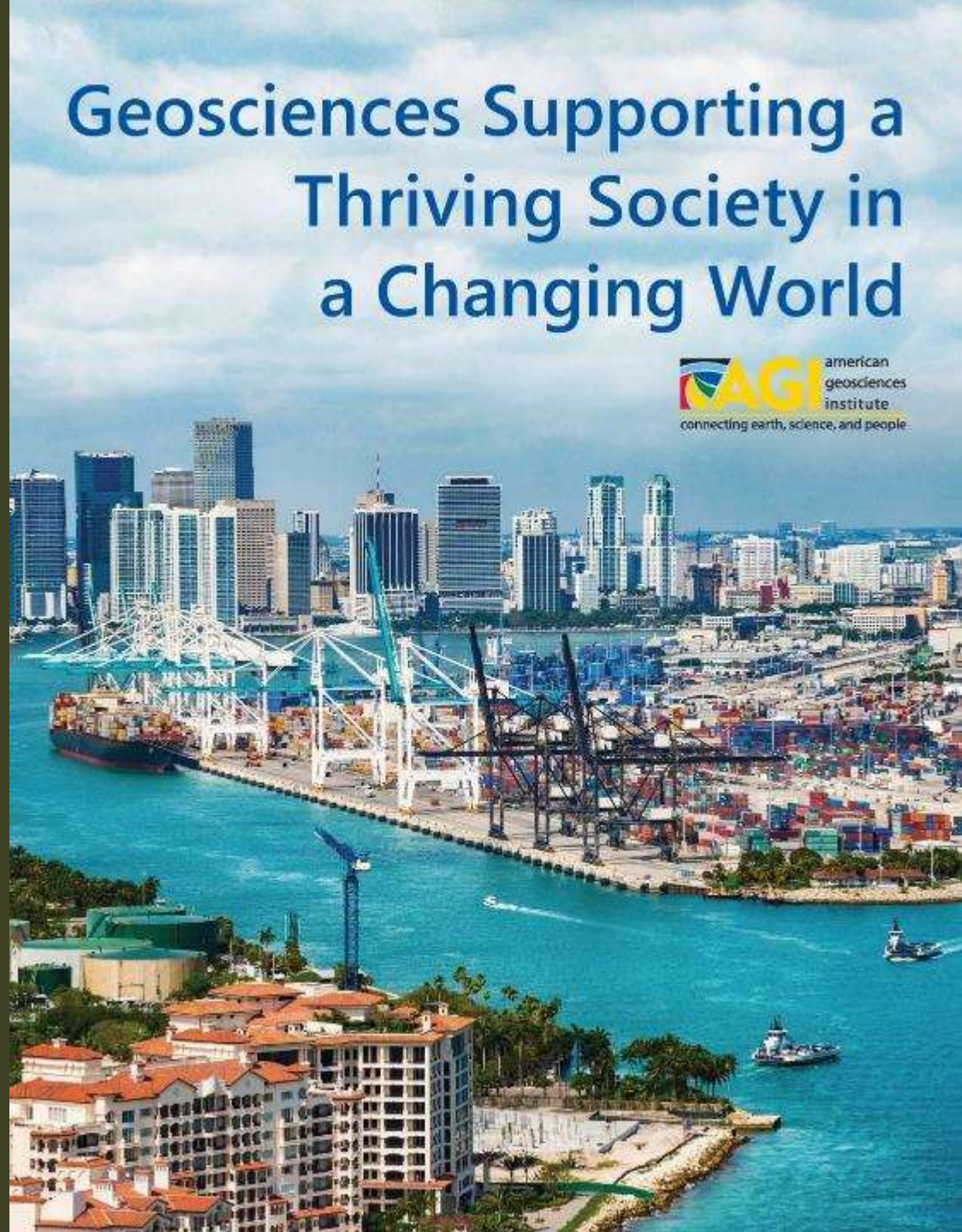
High Quality Geospatial Data and Maps

Energy, Technology, Engineering

Oceans, Coasts

Waste Disposal, Soils & Public Health

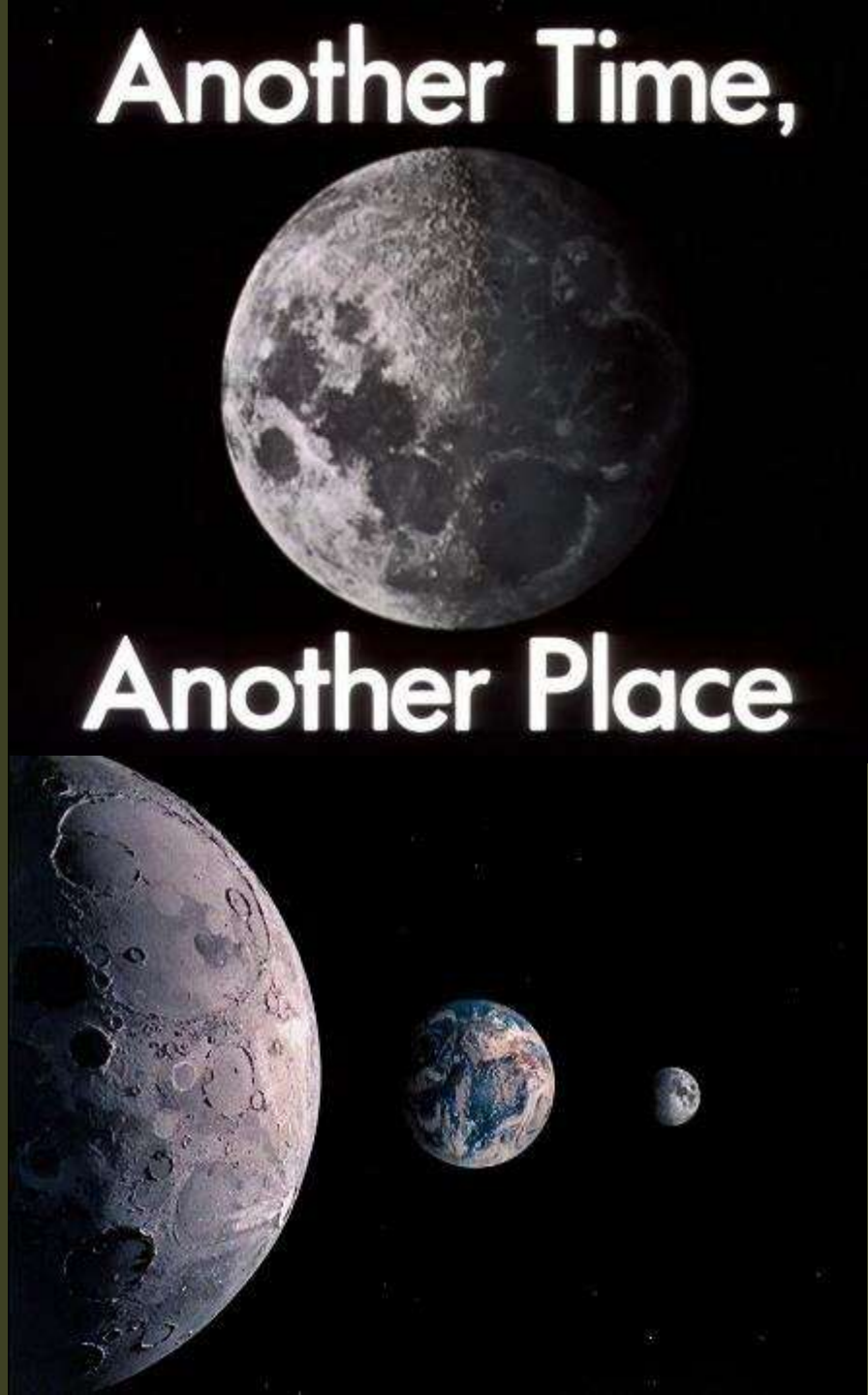
American Geosciences Institute (2020)
https://www.americangeosciences.org/policy/critical-needs/2020



Is there more than one planet Earth for us?

Rising global population, long-term migration shifts of continental extents – due to risks, climate, resources – and unpredicted factors – from vulnerabilities to instabilities – pressure on the environment (natural and built) in unprecedented scale.

Although science fiction may be based on physical nonsense, collective handling of resources and (associated) hazards on Earth is all but devoid of poor planning – well, nonsense – more often than we are eager to admit.



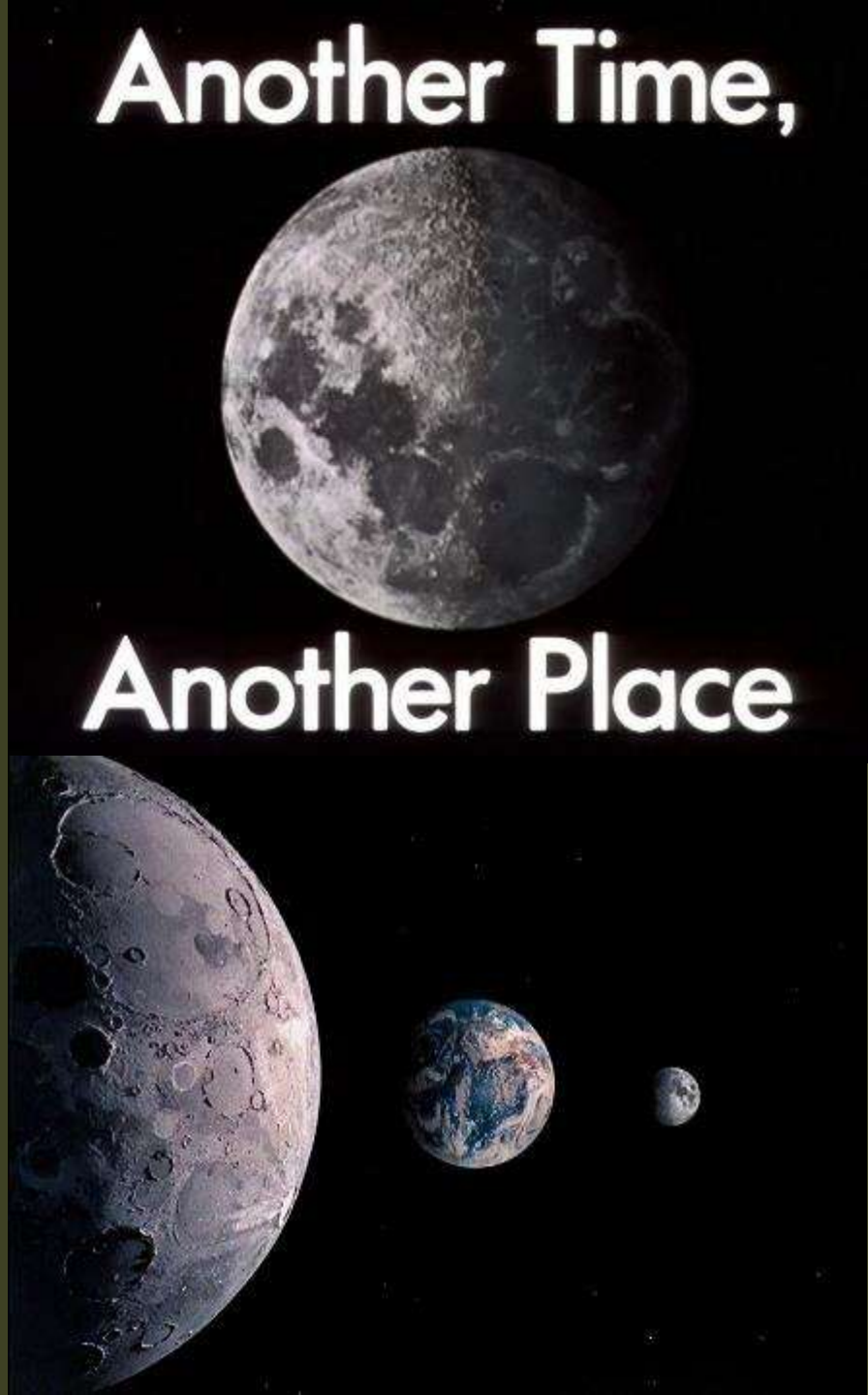
ITN & RAI (1975), *Space 1999*

Is there more than one planet Earth for us?

Natural resources are finite, dwindling, or less accessible, more costly – not only on mere economic grounds.

The Earth Sciences were born out of deciphering ancient life forms teeming in an aboriginal environment, unfolding on a planet that could be explained only by looking at the Solar system – and the inception of the Universe.

So the tools of modern Geosciences are among the best ones to gauge location, amount, economic turnout, and societal costs of those very resources.



ITN & RAI (1975), *Space 1999*

Surprising energy: the past, the future, the unpredictable

In the heart of post-WW II Europe

At the very center of 20° century oil business

Surprising energy: the past, the future, the unpredictable

"With the successful arrival of its Hope spacecraft into Mars orbit this week, the United Arab Emirates (UAE) became the first Arab nation to achieve an interplanetary mission."

"It launched its orbiter a mere six years after the nation announced the project, which it hopes will help to transform the country's oil economy into a knowledge economy."

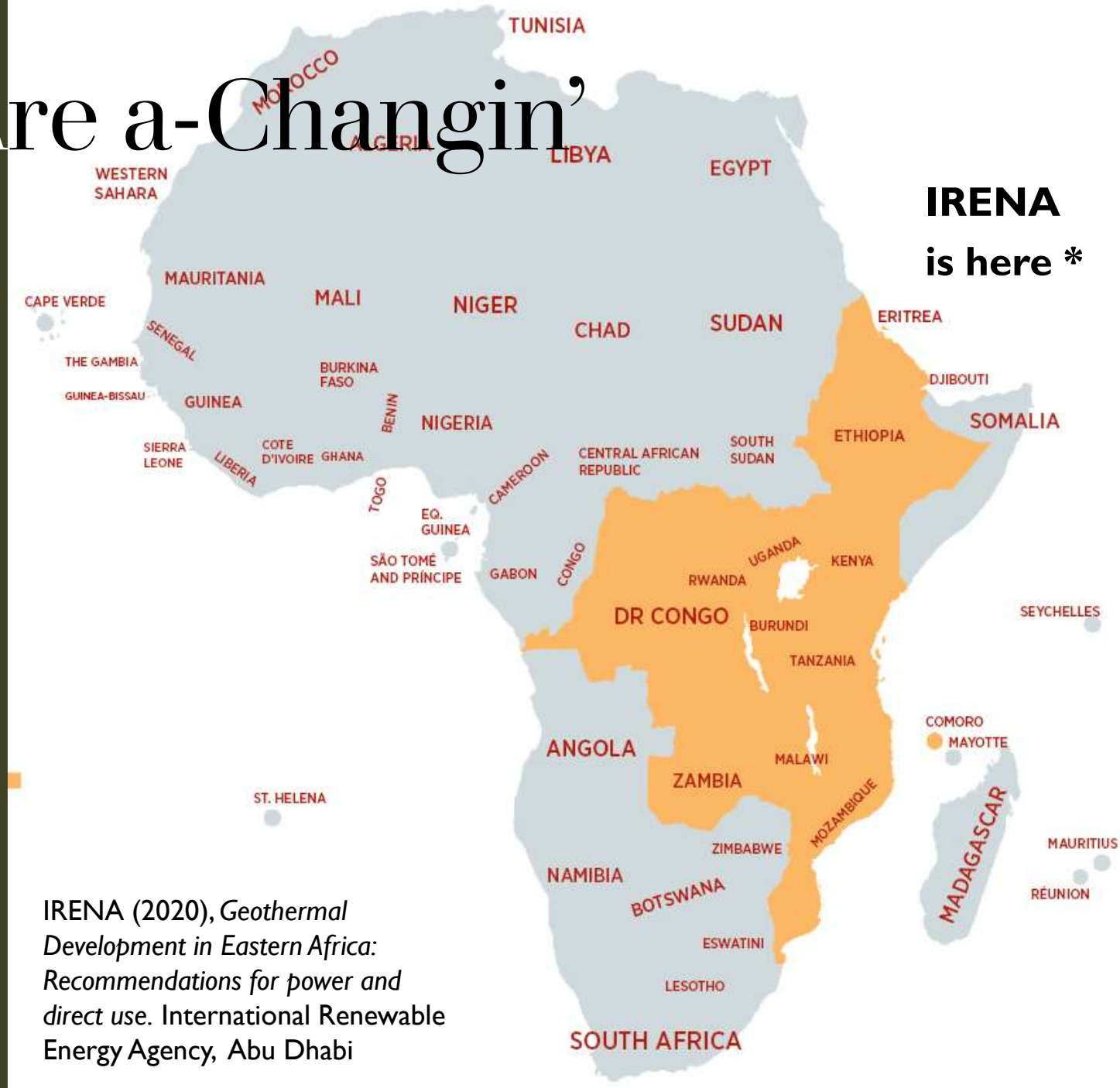
E. Gibney (2020), *Nature*
https://www.nature.com/immersive/d41586-020-01862-z/index.html

The Times They Are a-Changin'

"The countries of the East African Rift region are endowed with significant geothermal potential for electricity production."

"Harnessing these resources can provide a renewable, affordable and stable energy supply."

"It can also help governments meet the objectives of the 2030 Agenda for Sustainable Development and the climate objectives set out by the Paris Agreement."



IRENA is here *

IRENA (2020), *Geothermal Development in Eastern Africa: Recommendations for power and direct use*. International Renewable Energy Agency, Abu Dhabi

Counting countries, hidden resources, and deceitful maps

"In addition to (...) illiteracy and innumeracy, [we] also should [consider] "*immappancy*", meaning insufficient geographical knowledge."

"(…) In a survey random American schoolkids guess population and area of their country (…) [as] "1-2 billion" and "largest in the world". (…) Asian and European college students (…) [perform similarly]."

"This is partly due to the (…) nature of predominant mapping projections (…). An extreme example is the worldwide misjudgement of the true size of Africa."

Krause (2015), *True Size of Africa*,
http://kai.sub.blue/images/True-Size-of-Africa-kk-v3.pdf

Home is where your language is – if it is yours...

If you are convinced **English** is the most spoken language in the world, you are right – and you are wrong, too.

It is the most widely spoken one by non-native speakers due to historical reasons, but **Chinese** (a collection of languages) is the one most spoken by native speakers.

Spanish, **Hindi** (as with Chinese), and **Arabic** (similarly) are the other key global idioms.

…and did you know?

The US have an official language *only* since 2019. India (another federal nation) *does* have English as its official language since 1963, besides Hindi. And in both countries several languages are spoken…

Ethnologue (2020)

Nationalencyklopedin (2007)

...because, if not, you may wish it were the day an (unpredicted?) hazard occurs

"d/Deaf people, as well as those from other marginalised or minority groups, are particularly vulnerable to hazard risk; they have low levels of risk awareness and preparedness largely due to limited access to information in accessible forms, […] and higher levels of dependency on family and friends for assistance."

"But the root cause of their vulnerability does not stem from their invisible disability, as is often assumed. It is rooted in a mismatch of cultures – the dominant English-speaking/hearing world, institutional cultures found within the emergency services, – […] and response plans that are biased towards helping those from the dominant culture, who are already privileged."

(in: *Silent no more: Identifying and breaking through the barriers that d/Deaf people face in responding to hazards and disasters*)

Pieter Bruegel the Elder (1563), "The Tower of Babel"
Kunsthistorisches Museum, Vienna

Calgaro et al. (2021), *Int. J. Disaster Risk Reduction*, 57
https://doi.org/10.1016/j.ijdrr.2021.102156

Reach Out – I'll be There. Yes, but where? A bitter lesson from Covid-19 tracing

Apps for contact tracing can be successful – and stealth – or unsuccessful – in clear sight. South Korea's one proved very effective, while Italy's failed. This (also) depends on the level of anticipated acceptance (or distrust, or refusal altogether) by citizens.

What if we were to apply the same procedure to, say, Early Warning protocols for seismic, tsunami or volcanic hazard? Civil protection agencies could well need to know where any given citizen is – at *any* given moment – should a damaging natural phenomenon occur, with ensuing need to deploy rescue efforts, devise escape routes.

Planning beforehand is fundamental; yet, knowing active population's live distribution could be life-saving, also depending on how damaged infrastructure could be – something that only can be administered centrally. *Would we agree?*

C. Columbus (1990), "Home Alone", © 20th Century Fox – S. Spielberg

Slowly sensing means slowly acting – unpleasant when things precipitate

Natural phenomena may appear and often are very slow, due to the often overarching dimensions of engaged masses. But their trends rarely are, thus resulting in patterns that appear – and sometimes are – unpredictable.

In fact, physical behaviours – be it of seismic loading, glacial retreat, advancing fire fronts, or virus spreading – are:

- **inherently complex, elusive to detect and, ultimately, uneasy to perceive for the everyday observer**
- **prone to swiftly change, often in seemingly abrupt manifestations which may well cause societies to be caught off-guard – even when they have been well guarded and informed**

Fresco from a Bronze Age excavation of Akrotiri, Santorini, Greece (ca. 1600 BC), unknown minoan artist. Public domain, via Wikimedia Commons

“We are not alone”
Hazards are an integral part of this world

Natural phenomena with a disruptive potential never “show up” *when* we are most ready to face them or *where* we are more eager to react. In fact, they simply occur when conditions concoct their manifestation – that’s it.

“I am especially worried about novel poverties that 2020 is creating, bound to increase. Impoverished citizens cannot obtain appropriate nutrition and health assistance and are ultimately destined to weaken – thus being more exposed to maladies” (M.R. Capobianchi, M.D., Head of Virology Lab and Epidemiology Dept., “L. Spallanzani” Hospital, Rome, Italy).

And that implies something else…

S. Spielberg (1977), “Close Encounters Of The Third Kind”, © Columbia Pictures

“We are not alone”
Hazards are an integral part of this world

…precisely because being pressed by crucial, incompressible needs (water, food, shelter, sanitation) puts non-negligible sectors of populations – even in *statistically* affluent societies – in conditions that set them astray of care for further societal issues. And with some reason, too.

It is (tragically) ironic that measures that can positively – and undoubtedly – make a difference between life and death (fleeing a perilous building likely to collapse or wearing protective gear to shield a pandemic off – it’s the same) end up being perceived as “less critical”, even with a fully rational approach.

Watkis (2015), “What can marketers do to minimise the effect of Murphy's law?”, Mycustomer.com

Evidence, data, reports, science news – No, it's not going to convince anyone...

…who is not already eager to be convinced – or on "our" side anyway.

One of the authors of the UN IPCC 2015 Report had an implacable argument with her father, who would not buy the evidence about climate change that she, his very daughter – a world-class climate scientist – had contributed to make it the compelling, ultimate piece of science it is…

…until she broke in tears and, crying out loud, pressed her father with "But do you believe *me*? Do you believe *in* me?" That was the moment her father faltered and, yes, started to listen to his reputable scientist of a daughter. Science had not bought him – his father's feelings did. (Source: Nat. Geographic)

R. Morris & L. Gasté (1974), "Feelings", © Vogue-Copacabana

People come in all sorts and science has to convince them – just the way *they* are

Indisputably, humankind is as diverse as the big world we all live in. Likewise, it can be foolish and deceitful to solely stand on (not so stable) scientific grounds, hoping that evidence will prove convincing to all sorts of people just because it should be…

…for the simple, yet intellectually challenging, reason that population groups, societies, and their intertwining connections are not going to change, and may well resist adaptation – even fiercely so, and sometimes with good reason.

So, rather than explaining to seek understanding, the goal should dearly move towards sharing to pursue convincing. Communities may not feel "fooled" and follow directions by at least openly involving them, striving to avoid "teaching a lesson", which may avert people's hearts.

B. Joel (1977), "Just The Way You Are", © CBS

The world feels like walking on eggshells? It ain't necessarily so

Geoscientists should and shall have a shrewd role in decision making from now on, whether they like it or not, so they'd better start taking notice – and demand so.

In fact, it's in the best interest not merely of the Geosciences – it's in the humankind's destiny. Earthquakes, volcanoes, tsunamis, hurricanes, landslides, water, climate, resources – you name it, we have been studying them for some time now.

Since current and future outlook does unquestionably hold societal and scientific issues of exceptional, compounded complexity that no single social or scientific group can "solve", geoscientists are the ones that can have a thing or two to say about what those very shells are made of.

Maybe to forecast their strength, or to devise ways to improve it. Better yet: to explain that it's not really eggshells we are walking on – it's called Nature.

Because Nature can be such a wonderful thing...

Sebastiao Salgado (2013), "Genesis". Taschen, Köln

...or an overpowering, terrible force

Meulaboh, Aceh, Sumatra (2004) © Antara News/AFP

To know or not to know – *that* is the risk

Think about burglaries. You can protect your home with the most suitable systems (shielded locks, multi-sensor alarms, CCTV, etc.), although no one single system may suffice. Maybe a combination of them can fence off ill-intentioned visitors…

…because, after all, you know what they are like: they can be quite shrewd, they may be tough and strong, or well-provided and weaponed. Still, they are human beings, with the intrinsic physical limitations that this entails.

In fact, the burglars might come in a group, could have devised an evil plan with various alternatives, and they might even be able to carry a large equipment to break in. Still, these are outcomes you may think of in devising your *own* defense models against a number of *their* possible breach models.

W. Shakespeare (1602), "The Tragedy of Hamlet, Prince of Denmark", Stationers' Register

To know or not to know – *that* is the risk

So, to be a great burglar you first have to be an ordinary one, with additional, maybe special characteristics. And, maybe, with a good band. No true novelty – rather, a multiplier of what is already more or less at hand.

Yet, this does not rule out the possibility – if improbable, or unique – that *novel* burglars could be the new kids in town. Burglars like no one before – *really*.
With four arms and legs? Or immaterial? Invisible, maybe? And how could we know?

By tsunami hazard (PTHA) parlance, this occurrence would be associated with a low probability, high disruptive impact. Indeed low (no mutants or aliens to land any time soon), but very high too, because predicting their behavior would be rather impossible, since no previous occurrence is on record – you cannot forecast what you cannot know. *Or can you?*

W. Shakespeare (1602), "The Tragedy of Hamlet, Prince of Denmark", Stationers' Register

The complication of complexity

Ever thought why it is so difficult to communicate complexity? Unpredictable, inscrutable, invisible – it must not exist ! (Not quite, regrettably)

An example stems from the exponential growth of water lilies – suffocating the very pond they grow into. It doesn't quite look radical, and it is not – until the last day, when it's too late. It happened to the Persian ruler too before the inventor of chess.

Our cognitive limitation is a fact, a common human factor, affecting learned minds too, since it is an evolutionary trait (a constraint?). Can it be overcome?

It does not apply to pandemics only, rather to any phenomenon whose spatial-temporal pattern is minimal at the beginning, or that increases at very little pace – yet with gigantic gradient, until the result is staggering, i.e. too late. *Fatal error.*

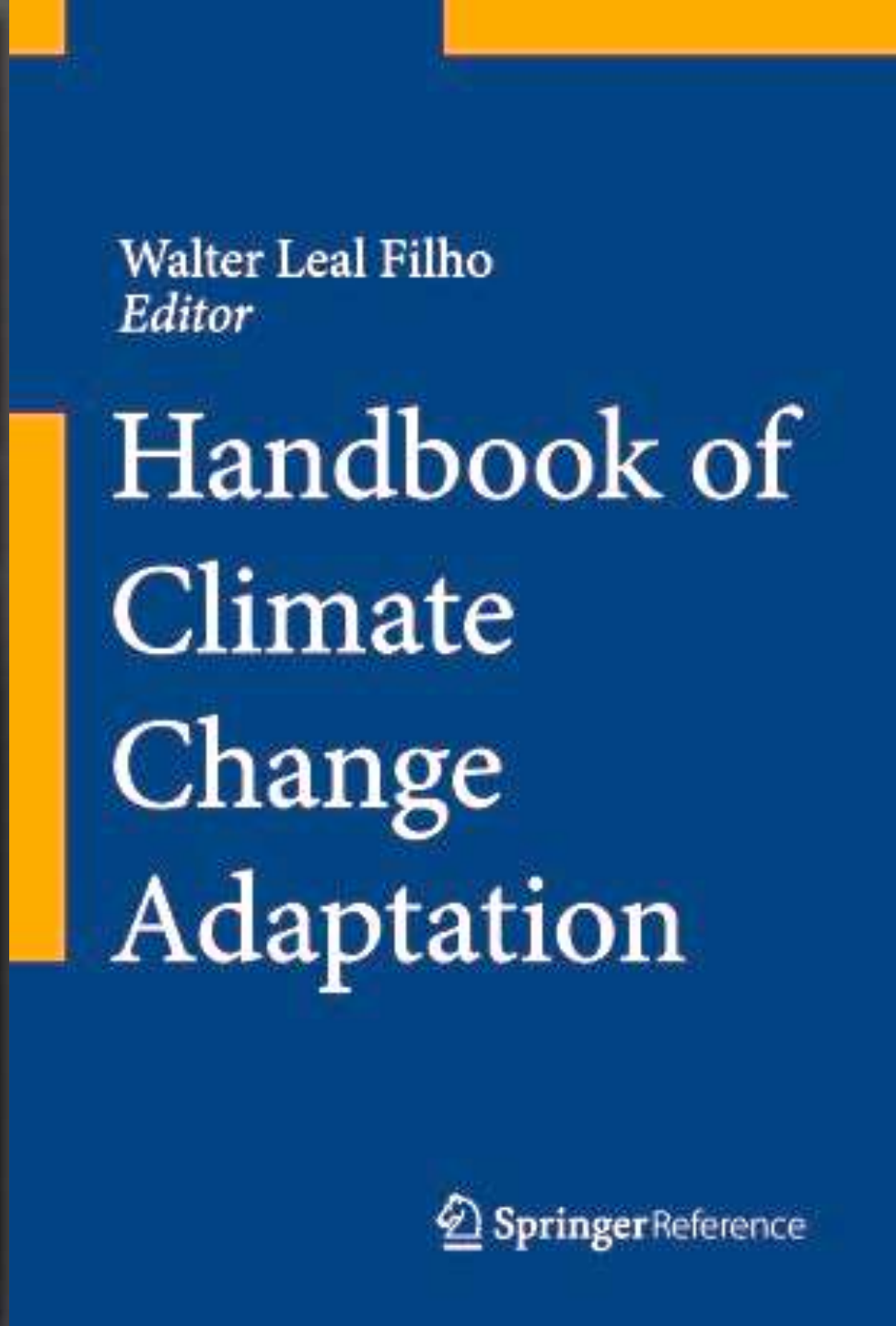
© Getty Images

The Blues and the Abstract Truth

"Some of the most common misconceptions related to climate change are:

- **Climate change is too abstract an issue**
- **Climate change is too broad a topic**
- **Climate change is mostly a technical matter where calculations and forecasts are made**
- **There are no trained people to handle the approach of climate change topics in an understandable way**
- **The amount of resources needed to communicate climate change do not justify it**
- **Climate change has too wide a scientific basis"**

ICCIRP, Hamburg Univ. Appl. Sc., https://www.haw-hamburg.de/en/ftz-nk/programmes/iccirp/



The never ending problem?
We can do much better

Discussing possible (roads to) solutions is a far more creative, inspirational, and inclusive process than outlining problems. It takes stewardship, courage, and calm.

If our world and its natural manifestations are all perceived as supernatural, or inscrutable, or plainly as capricious as the destiny – worse: designed and piloted by global, hidden powers – then our scope on Earth would just be that of spectators before a malignant, overpowering Nature – or of rebels against it and its servants.

But Nature is great and can be grandiose – as long as exposed communities a) are collectively demonstrated that all that can be done to protect our very existence *gets* done, and b) are more and more involved in a positivistic, constructive approach. Even when the things to be done are *not* within reach in a snap. *They never are*.

S. Ghosal (2015), *That never ending cycle of our problems and solutions*, https://esgeemusings.com

Challenges turned opportunities – *really*?

The public discourse on knowledge, denialism, combined natural and anthropogenic hazards, and energy can and certainly does collectively pose a burden even on the shoulders of scientists, practitioners, stakeholders and decision-makers – let alone on exposed populations.

Such issues are imbued with complexities, which is the norm in any large-scale occurrence. But for the 'ordinary' citizen complexities rhime with difficulties and look obscure to decipher and tackle – maybe impossible to.

Likewise, the need to adapt to these efforts is no little feat either, especially if such far-reaching phenomena are perceived as elusive, impalpable – until it could be too late. In one word, this paves the road to fatalism.

E. Magie (1936) – Monopoly. © Parker Brothers, USA

Challenges turned opportunities – *really*?

Also, complexities reveal problems in flesh and bone, not mere challenges, if fancy-sounding. Ultimately, the flesh and bone at the core are those of the very human beings involved in some way, along the way, rarely the way anyone might enjoy.

On the other hand, opportunites do lurk in troubles – although well hidden – or may spring suddenly out of a seemingly vicious circle. This can be the case only as long as a leap of vision, of collective effort, a sense of necessity enters the scene.

E. Magie (1936) – Monopoly. © Parker Brothers, USA

The Moon is always a brilliant teacher

"Missions inspire because of their wider societal relevance. Apollo demonstrated the need to encourage multiple solutions instead of focusing on one […] technology. Today, many challenges would fit the mission approach."

"These 'Earthshots' are much harder to accomplish than literal Moonshots because their goals are harder to define; they involve global commons such as air and water; and they are affected by social and political complexities […], as well as competing interests and concerns about inequality and justice. These […] require even greater public ambition and commitment."

Ghosh (2021), *Nature*, 589
https://doi.org/10.1038/d41586-021-00076-1

The everlasting power of (majestic) narrative

«Voi sentirete fra i più degni eroi,
che nominar con laude m'apparecchio,
ricordar quel Ruggier, che fu di voi
e de' vostri avi illustri il ceppo vecchio.

L'alto valore e' chiari gesti suoi
vi farò udir, se voi mi date orecchio,
e vostri alti pensier cedino un poco,
sì che tra lor miei versi abbiano loco»

L. Ariosto (1516), I canto, "L'Orlando furioso". Ferrara, G. Mazocco

The everlasting power of (majestic) narrative

«Thou shalt listen among the greatest heroes,
that I am bound to highly nominate,
remind Ruggero, that used to be
thy oldest root and your ancestors'.

The high value and his famed gestures
I shalt have thou listen, if thou lend me your ear
and let thy high thoughts subside,
so that among them my verses may find room»

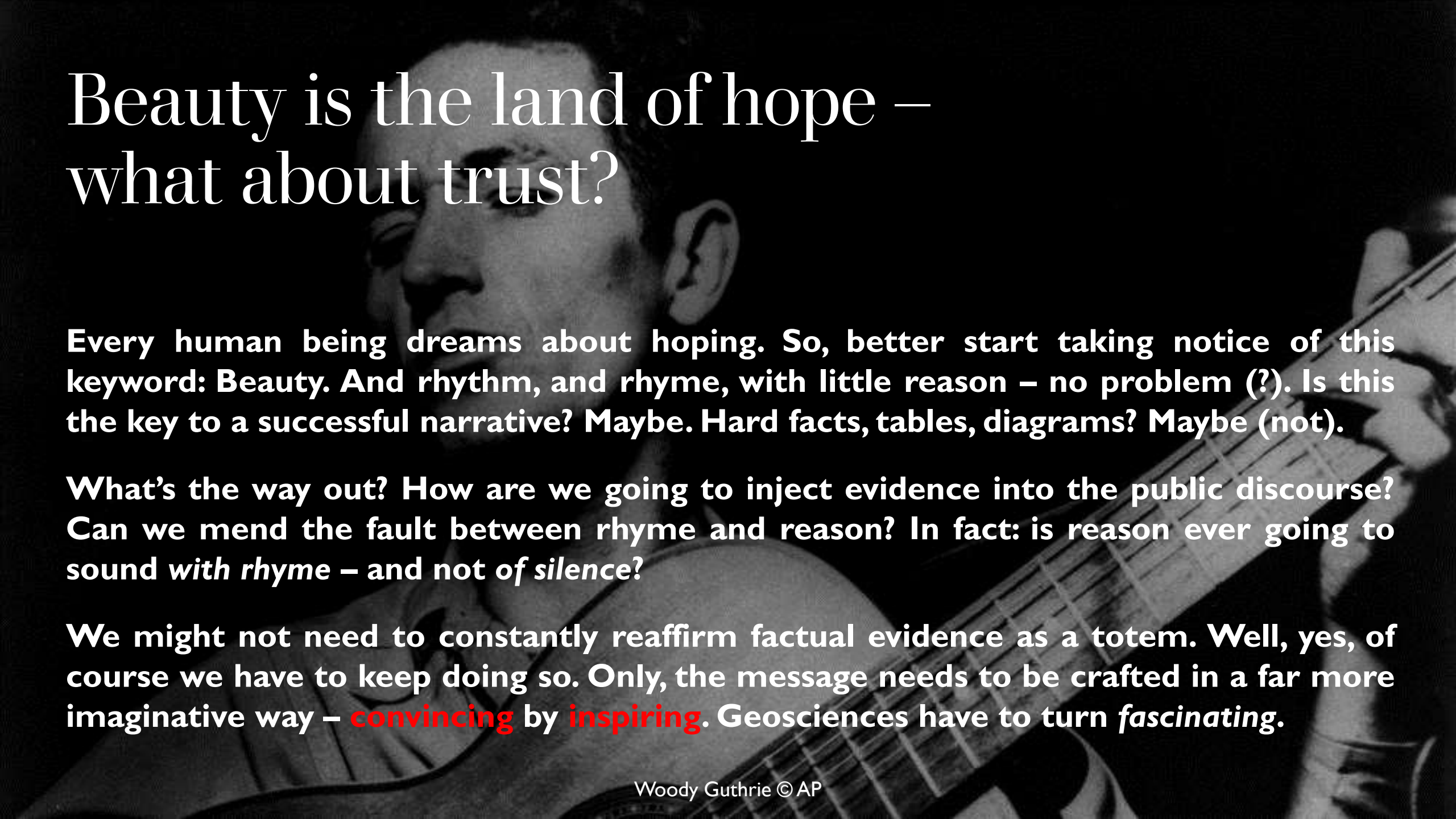
L. Ariosto (1516), I canto, "L'Orlando furioso", Ferrara, G. Mazocco

Beauty is the land of hope – what about trust?

Every human being dreams about hoping. So, better start taking notice of this keyword: Beauty. And rhythm, and rhyme, with little reason – no problem (?). Is this the key to a successful narrative? Maybe. Hard facts, tables, diagrams? Maybe (not).

What's the way out? How are we going to inject evidence into the public discourse? Can we mend the fault between rhyme and reason? In fact: is reason ever going to sound *with rhyme* – and not *of silence*?

We might not need to constantly reaffirm factual evidence as a totem. Well, yes, of course we have to keep doing so. Only, the message needs to be crafted in a far more imaginative way – convincing by inspiring. Geosciences have to turn *fascinating*.



Woody Guthrie © AP

An Officer and a Gentleman? Lessons from military command to civil service

Orders, dispatches, directions – they're the tools any chain of command needs to employ. This is due to the need to deliver a specific, broken down task with precision and reliability – spot-on. Yet no order can be convincing – *commanding* – by itself.

Stark discipline can be a needed instrument in the military but, without credibility (by valor, example – even sacrifice), no high-rank official may ever expect to obtain not just 'obedience' but trust – ultimately leading to effective, coordinated action.

In civil life, be it a central bank, a national security agency, or an emergency management infrastructure, you may face needs not so different from the logic of the chain of command – only, without command, orders, discipline. How can this be done?

T. Hackford (1982), "An Officer and a Gentleman", © Lorimar-Paramount

Adaptation of sperm whales to whalers: rapid social learning on a large scale?

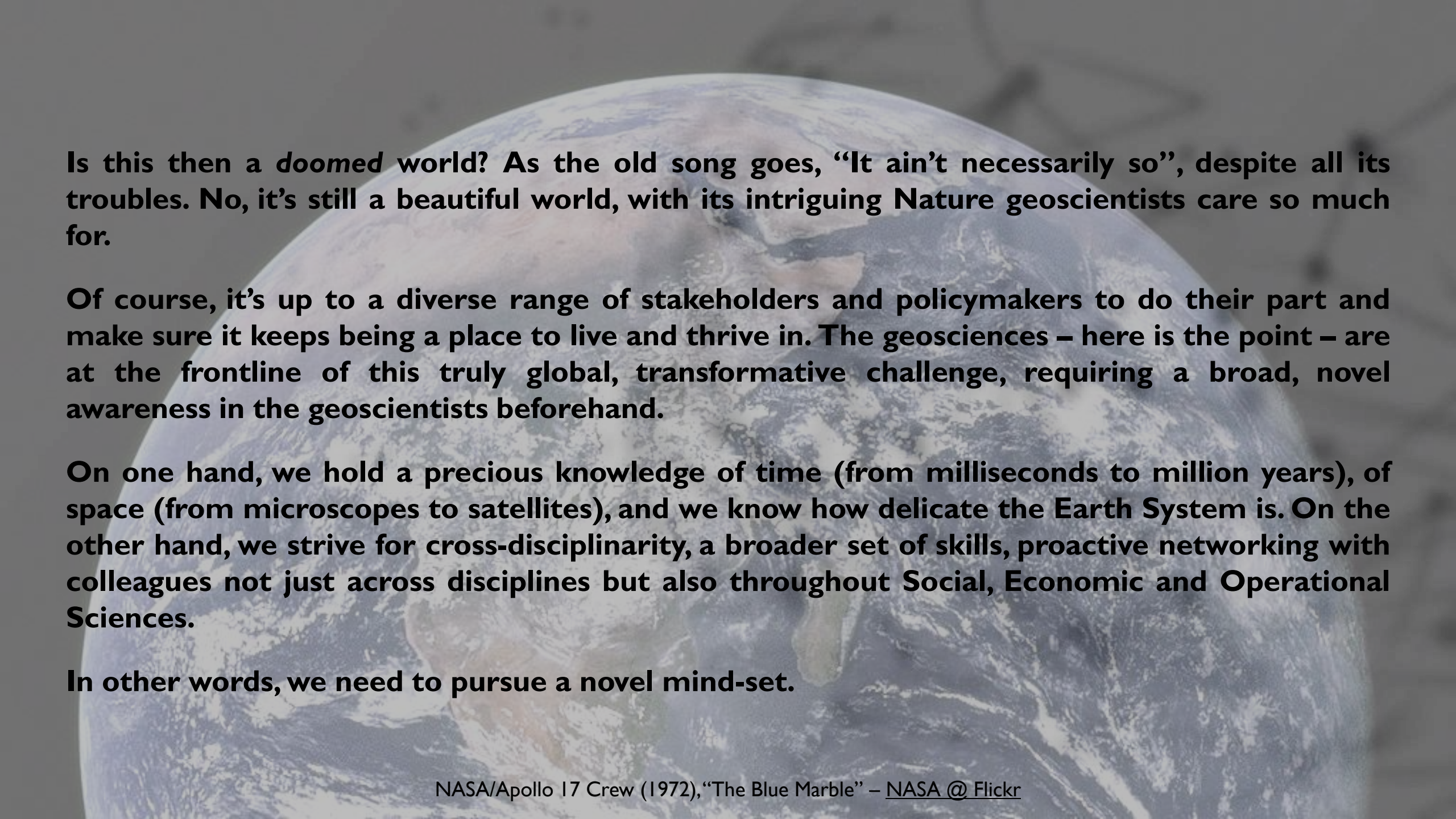
"Digitized logbooks of American whalers in the North Pacific found that the rate at which whalers succeeded in harpooning sighted whales fell by about 58% over the first few years of exploitation in a region."

"This decline cannot be explained either by earliest whalers being more competent, as their strike rates outside the North Pacific […] were not [high], or by initial killing of […] vulnerable individuals."

"Models show that, […] when confronted by whalers, [whales] learned defensive measures from grouped social units with experience […]. This rapid, large-scale adoption of new behaviour enlarges our concept of the spatio-temporal dynamics."

O. Wilcox (1837), watercolour, © New Bedford Whaling Museum

Whitehead *et al.*, (2021), *Biol. Lett.*, 17. https://doi.org/10.1098/rsbl.2021.0030



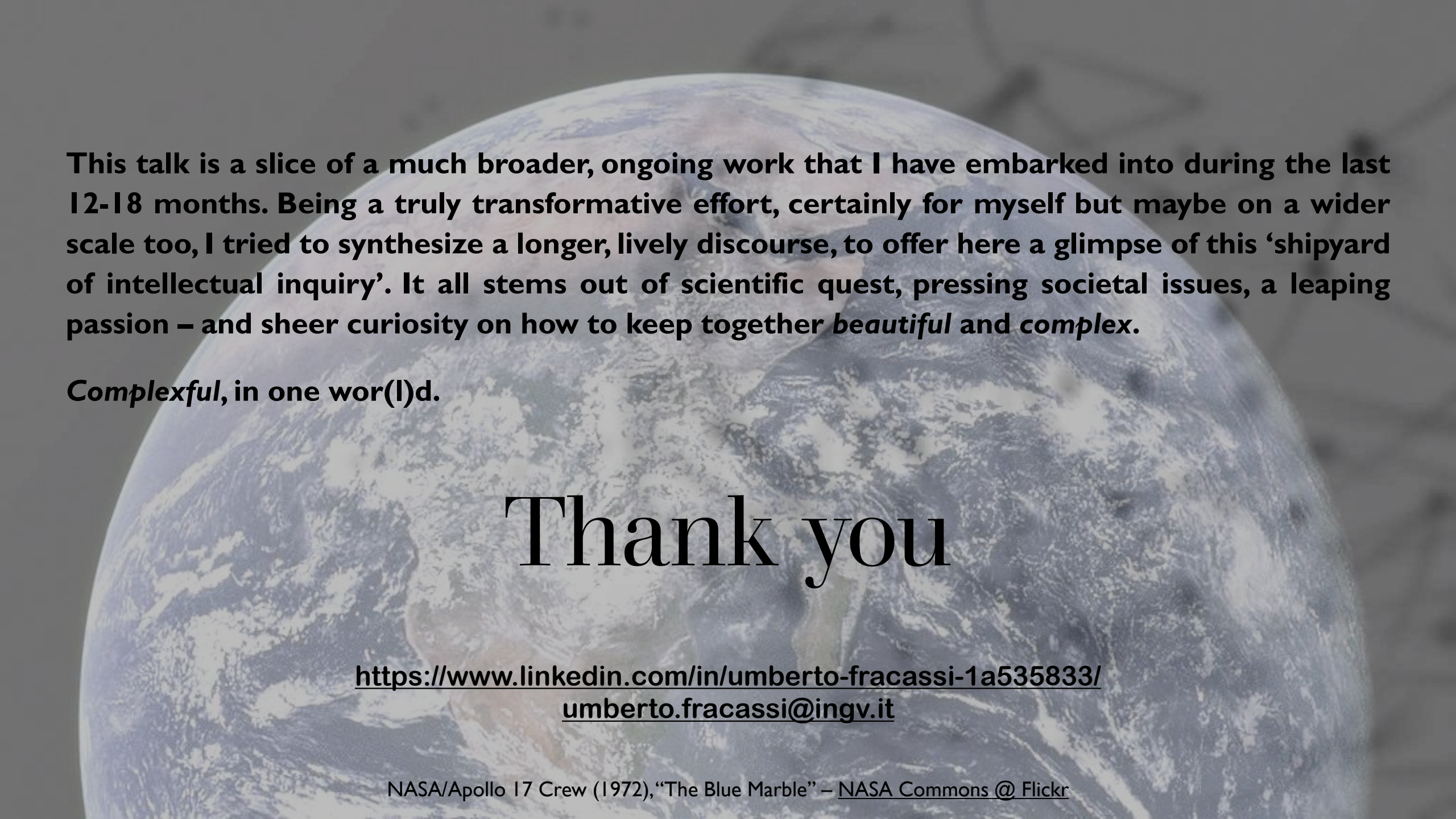
Is this then a *doomed* world? As the old song goes, "It ain't necessarily so", despite all its troubles. No, it's still a beautiful world, with its intriguing Nature geoscientists care so much for.

Of course, it's up to a diverse range of stakeholders and policymakers to do their part and make sure it keeps being a place to live and thrive in. The geosciences – here is the point – are at the frontline of this truly global, transformative challenge, requiring a broad, novel awareness in the geoscientists beforehand.

On one hand, we hold a precious knowledge of time (from milliseconds to million years), of space (from microscopes to satellites), and we know how delicate the Earth System is. On the other hand, we strive for cross-disciplinarity, a broader set of skills, proactive networking with colleagues not just across disciplines but also throughout Social, Economic and Operational Sciences.

In other words, we need to pursue a novel mind-set.

NASA/Apollo 17 Crew (1972), "The Blue Marble" – NASA @ Flickr



This talk is a slice of a much broader, ongoing work that I have embarked into during the last 12-18 months. Being a truly transformative effort, certainly for myself but maybe on a wider scale too, I tried to synthesize a longer, lively discourse, to offer here a glimpse of this 'shipyard of intellectual inquiry'. It all stems out of scientific quest, pressing societal issues, a leaping passion – and sheer curiosity on how to keep together *beautiful* and *complex*.

***Complexful*, in one wor(l)d.**

Thank you

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NASA/Apollo 17 Crew (1972), "The Blue Marble" – NASA Commons @ Flickr