Time and terrain: Life on planet Earth in the century of complexities – and the inescapable role of the Earth and environmental sciences

Umberto Fracassi Istituto Nazionale di Geofisica e Vulcanologia, Via di Vigna Murata 605, 00143 Rome, Italy

umberto.fracassi@ingv.it ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA www:

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ABSTRACT

Geosciences are 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 – either too large, or too deep, or too far away to even imagine for us earthlings.

But it's Nature at the core of the geosciences – with its grand size, slow processes, sudden effects, and complex interactions among forces and bodies – across distances and time.

Together with sister disciplines, they are thus paramount for societies to probe a world seemingly inscrutable, increasingly richer in risks and poorer in resources.

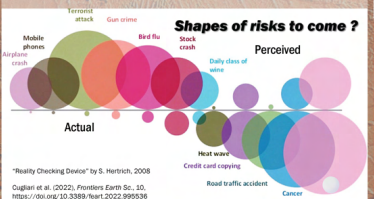
As time goes by, is it just history repeating ?

The 21st century set off quite steeply – and it doesn't look a very smooth journey ahead. Back in the good ol' days, things were much easier, simpler, better. But was this really the case – or ever was along human history? A *very quick* glance back:

The 20th: Belle Epoque, World Wars, nuclear energy; prosperity – though not really for everyone. The 19th: wars and great inventions. The 18th: Enlightenment and revolutions; Newton, Kant, Mozart. The 17th: Galileo and the Inquisition; Bach. The 16th: Reinassance, Leonardo, Reformation; modern slavery.

The 15th: Humanism; great discoveries. The 14th: Black Death and banks. The 13th: universities, Dante... Not one time on Earth was all serene or all ominous; all was and is complex and intriguing, fatiguing and rewarding.

Shapes of risks to come ?



Cugliari et al. (2022), *Frontiers Earth Sc.*, 10, https://doi.org/10.3389/feart.2022.995536

"Individual risk perception is influenced by both probability and severity of damages [...and] depends on reference social models, context, and media."

"While some risks with high probabilities and strong physical impact tend to be downplayed or neglected, other risks with minor physical consequences may trigger strong public concerns and severe social impacts."

Where are the Earth sciences in this game?

Complexities, in their physical, cognitive and socio-economic dimensions, are the factual backdrop made of phenomena and associated risks, beneath our collective activities.

Tackling these draws on diverse efforts, including individual passions, impelled by sensitivities, either geared at specific themes and/or motivated by experience.

All of these make up a dearly needed, multi-faceted toolbox to a) nurture scientific knowledge and b) build strategic intelligence and purview.

These can make up solutions, within the space & time horizon consistent with the remit of the issues at hand and their forecasted impacts and pattern upon contemporary societies.

...as they will provide insight into the future

Historia Magistra Vitae Est (Cicero, 1st cent. b.C.). Yesterday's intellectual tools (like Actualism, by J. Hutton and C. Lyell, 18th, 19th cent.) prove instrumental to decipher tomorrow's issues:

- The long records of natural events (hazards)
- Far-flung origins (our solar system and the universe)
- Far-reaching effects (feedback, recurrence times)
- The need to forecast patterns of contemporary phenomena

In times of the energy-climate-safety trilemma and strategic poly-crises, the Earth Sciences *return to the future.*

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

- Hazards, multiple and overprinting

It's a breezing world out there – and we're in the middle of it

- Geosciences and their many virtues

It's a fascinating, intriguing, ever-changing environment

- Complexities and scenarios

It's not just a matter of complication

- Intelligence, natural and human sciences, resources

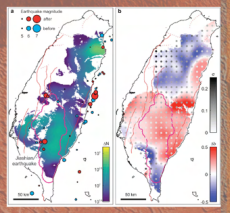
The world can be far more surprising than one'd think

- Cross-disciplinarity, intellectual bridging – solutions?

We strive to concoct overview and co-build the future

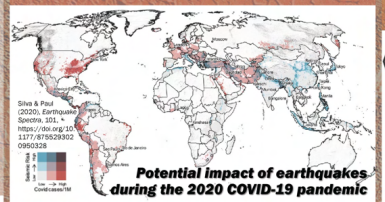
Earthquake statistics & typhoon-driven erosion

"These observations suggest that the progressive removal of landslide debris by rivers [caused by typhoon Morakot in 2009] from southern Taiwan has acted to increase the crustal stress rate to the extent that earthquake activity was demonstrably affected."



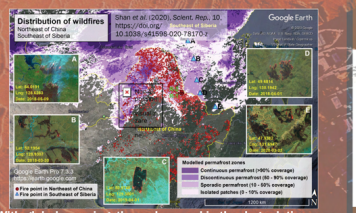
Shyu et al. (2021), *Scient. Rep.*, 10, https://doi.org/10.1038/s41598-020-67865-y

Potential impact of earthquakes during the 2020 COVID-19 pandemic



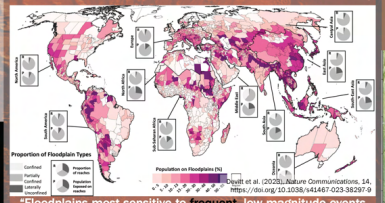
"Some large urban centers with both high prevalence of COVID-19 cases and earthquake risk include Istanbul, the San Francisco Bay Area, Greater Los Angeles, Tehran, Santiago, Lima, Santo Domingo, Panama City, Quito, and Tokyo."

CH_4 and wildfire 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."

Flood hazard potential & settlement patterns



"Floodplains most sensitive to frequent, low magnitude events suggest that people have adapted to this risk."

"In contrast, floodplains subject to extreme, rare events tend to be most densely settled, being endangered from potentially increasing hazard due to climate change."

Tsunami-triggered dispersal of microplastics

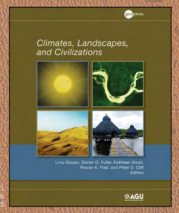
"Our study documents a possible abrupt microplastic depositional event triggered by a tsunami. The sediment layers contaminated by microplastics correspond with horizons [bearing] 137Cs, indicating deposition after 1960s nuclear tests."

"The microplastics were observed in the 2011 Tohoku-Oki tsunami deposits. Tsunamis can thus contribute to the wide dispersal of microplastics from coastal to deep-sea areas, and these anthropogenic particles can be used to date very recent turbidite deposits."

Influences of Active Tectonism on Human Life

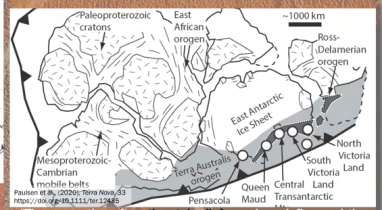
"Active tectonism forced the pace of cultural change in antiquity, accelerating development of cultural complexity in comparison to neighbors in tectonically quiescent areas."

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



Torres & McFadgen (2022), in: *Climates, Landscapes, and Civilizations*, https://doi.org/10.1029/2012GM001228

Crustal thickness, rift-drift, key global events

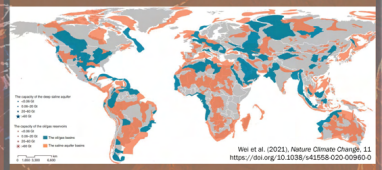


Paulsen & Read, 2020; *Terra Nova*, 33, https://doi.org/10.1111/ter.13465

"The generation of continental relief may have influenced the chemistry of the [..] oceans and atmosphere through time."

"Crustal thickening correlates with passive margin abundance, glaciations and atmospheric oxygenation, suggesting a link between continental rift-drift and transitions in atmospheric and oceanic evolution."

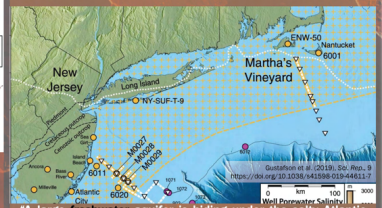
CCUS: Magic wand or (hazardous) costly test ?



Wei et al. (2021), *Nature Climate Change*, 11, https://doi.org/10.1038/s41558-020-00960-0

CCUS could prospectively be deployed across diverse, globally-distributed subsurface settings (IPCC, 2005) at Gton/y operational scale (Mton/y in pilot projects; IEA, 2022) if it is to be an effective game changer to help dent CO2 stock (IEA, 2022) and defray hard-to-abate emitters. It also can be a potentially enormous geoscience opportunity, for hazard monitoring (seismic, geodetic, environmental) and subsurface exploration (or knowledge transfer) purposes.

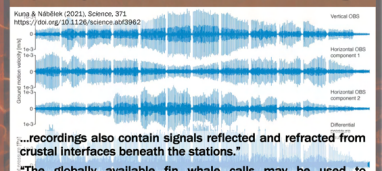
Aquifer systems far offshore the U.S. Atl. margin



"A large freshwater aquifer is hiding under the salty Atlantic Ocean, just off the northeastern coast of the United States."

"Evidence suggests that such aquifers might represent a potential resource for other dry regions elsewhere, from S. California, Australia or the Middle East." (LiveScience)

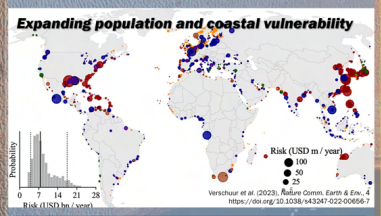
Aquifer systems far offshore the U.S. Atl. margin



...recordings also contain signals reflected and refracted from crustal interfaces beneath the stations."

"The globally available fin whale calls may be used to complement seismic data where conventional air-gun surveys are not available."

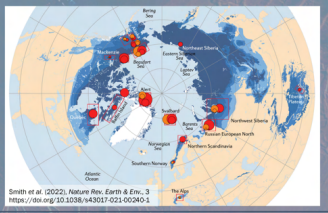
Expanding population and coastal vulnerability



Coastal exposure has vastly grown over the decades, due to shifting population density, development and infrastructure. This results in a novel vulnerability, augmented by sea level rise, subsidence induced by expanding coastal megacities and subsurface resource extraction (Parsons, 2021), accompanied by growing seaports and ship traffic (Lester, 2020).

This circumstance impends on vulnerabilities due to pre-existing geophysical hazards (such as tsunamis or cyclones) or aging building stock and infrastructure (>40% EU population along low-elevation coasts; Eurostat, 2010; EEA, 2015).

The brine that came in from the (no longer) cold



Smith et al. (2022), *Nature Rev. Earth & Env.*, 3 https://doi.org/10.1038/s43017-021-00240-1

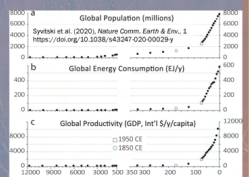
Permafrost thawing causes widespread, short-wave terrain deformation and disruption to infrastructure (Hjort et al., 2022), potentially over regions far broader than earlier estimated (Smith et al., 2022), with revealing medium-term economic consequences (Burke et al., 2015).

Despite lack of public discourse on the subject, thawing phenomena that enormously alter the landscape (and anything built on it) have been documented since the early 1960s (Turetsky et al., 2019).

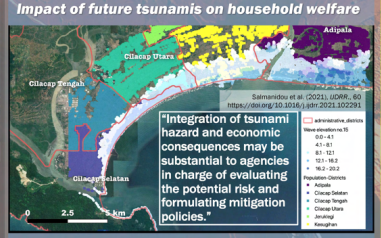
Energy consumption, resultant geological impact

"Human energy [used] in the Anthropocene exceeds that across the prior 11,700 years of the Holocene, largely through combustion of fossil fuels."

"Global warming in the Anthropocene is > 10x greater still."



Impact of future tsunamis on household welfare



"Integration of tsunami hazard and economic consequences may be substantial to agencies in charge of evaluating the potential risk and formulating mitigation policies."

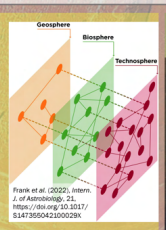
Feedbacks and links in the Earth system

Ex-permafrost areas will affect (Miner et al., 2022) HC exploration and transportation (Mian, 2018) – being shipping a hard-to-abate CO_2 (WEF, 2020).

Due to expected carbon release (Turetsky et al., 2020), this may render CCUS even more pressing – if enough financially de-risked (Wang et al., 2021).

Intelligence as a planetary scale process

"Planetary intelligence, defined as the acquisition and application of collective knowledge at a planetary scale and integrated into planetary systems, can prove a framework for understanding possible paths of long-term evolution of inhabited planets, including future for trajectories for life on Earth and predicting features of planetary evolution on other worlds."



Knowledge (and insight) is paramount

Humankind is going to concentrate more people in areas accessible to development and resources yet more exposed to expectedly larger effects due to natural hazards.

Such concentration will need more energy – diverse, reliable, and affordable. And all of this while curbing their carbon footprint, which may include massive upscaling of CCUS.

While compounded risks may not necessarily "increase", its resulting landscape might morph critically, with patterns and ensuing complexities yet to be assessed (Renn et al., 2020).

"Imagination canyon", © Melvin L. Prueitt (1982), LANL, Orion Computer graphics in: Art and the computer, 1984, McGraw Hill, 246 pp.

Probing space to understand Earth

Lapôtre et al. (2020), Nature Rev. Earth & Env., 1 https://doi.org/10.1038/s43017-020-0029-y

"Earth's present is key to understand its past and future. Knowledge of Earth's geological and atmospheric processes has been applied to study other bodies, whose observations fed back into understanding the Earth."

"Future missions can probe the diversity of planetary environments, and can explore how they might serve as analogues and archives."

The world feels like walking on eggshells?

Geoscientists should demand having a shrewd role in decision making from now on, so they'd better start taking notice.

It's not merely in the best interest of the Earth sciences – it's in the humankind's destiny. Earthquakes, volcanoes, tsunamis, hurricanes, landslides, water, climate, resources...

Since current and future outlooks hold societal and scientific issues that no single social or scientific group can "solve", geoscientists are the ones that can have a thing or two to say.

Better yet: to explain that it's not really eggshells we are walking on – it's called Nature.

"The East African Rift is endowed with significant geothermal potential for electricity production."

"This resource can provide renewable, affordable and stable energy supply ."

"It can also help countries meet the objectives of the 2030 SDGs and the climate objectives set out by the Paris Agreement."

Earth Sciences are a strategic (energy) asset

A year ago, Kim Cobb, a prominent climatologist and co-author of IPCC's AR6 Report, was appointed by the White House as a member of the U.S. National Intelligence Council. She was trained as a geologist and oceanographer.

The U.S. Pentagon and EU's JRC have been recently concentrating on hazards posed by climate change affecting further geophysical ones and their challenge to existing systems, as defense is bound to include the protection of resources from novel, hybrid threats.

Biden administration appoints Brown climate scientist Kim Cobb to President's Intelligence Advisory Board

Cobb, a Brown University professor and director of the Institute at Brown for Environment and Society, will join a White House advisory board charged with providing independent counsel on U.S. intelligence matters.

Department of Defense Climate Risk Analysis

Solutions will come from inquiry across disciplines – and beyond

Sir Hutton was raised as a doctor but his passions for nature surrounding his farm led him to rocks, specimens, fossils. I.e., a comparative physician – the first paleontologist, in fact.

Not only did the lack of a specific scientific discipline bring Sir Hutton to devise a novel field of study – it also molded his formal learning into a synthesis of intellectual tools.

In today's overly specialized science, where disciplines nurture ecological niches, cross-disciplinarity will be an asset in front of cascading, complex events that evade any given single field.

H. Raeburn (1776) – James Hutton, 1726-1797, Geologist. Scottish National Portrait Gallery, Edinburgh

Space elevators are less sci-fi than you'd think

"Although I may come across as a space elevator advocate, I simply enjoy studying their mechanics. In a world with monumental problems, such projects allows me to envision a scenario where we are responsible custodians on this planet."

Sounds absurd and pointless? But the thesis was not to "solve" the problem – rather, to define it from a physical basis, describing how to possibly break it down.

Whether or not it could be achieved, the goal is to learn how to manage scientific challenges that appear impossibly difficult. Further, colossal issues will follow in human history, anyway...

Cohen (2022), Scientif. Am., https://www.scientificamerican.com/article/space-elevators-are-less-sci-fi-than-you-think/

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 (?). Is this the key to a successful narrative? Maybe. Hard facts, tables, diagrams? Maybe (not all the time).

What's the way out to nurture the public discourse with evidence? Can we mend the fault between rhyme and reason? Is reason ever going to sound with rhyme – and not of silence?

We might not need to constantly reaffirm factual evidence. Of course, we have to: Only, the message may be crafted in a far more imaginative way – convincing by knowing. Geosciences have to turn fascinating.

Woody Guthrie © ℗ ™

The (geo)logical song

Besides the scientific contributions from diverse disciplines, the intrinsic 'super-power' of Earth, environmental, planetary sciences lies in the natural web of kinship they collectively interweave throughout our physical world.

This entails a 'revolutionary' perspective to zoom back and forth spatially and time-wise across phenomena throughout the Earth system, to help discriminating natural processes from those where the human contribution is non-negligible.

The Earth in 4D is much like an ever-morphing mesh of occurrences (reasses, processes, hazards) tied by 'sliding doors' (resources, opportunities, tipping points).

Supertramp (1979), "The Logical Song", © A&M

A 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 knowledge, courage, and time.

If our world and its natural manifestations are all perceived as supernatural, or inscrutable, or plainly as capricious as the destiny, then our scope on Earth would just be that of spectators before a malignant, overpowering Nature.

But Nature is great and can be rewarding – as long as exposed communities are: a) collectively knowledgeable that all that can be done to protect their existence is done, and b) involved in a concrete, constructive approach. Even when 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

A body (human or planetary) can be prison and haven – at the same time

Masses through time and space may look sturdy, immutable, unshakable – but none is more vulnerable than our own body. Bodies make societies, shelter life, nurture development – and are exposed to ailments.

Also our own planet is exposed to a number of stressors, not merely environmental, and shows signs of fatigue. But it's the greatest, most durable of its resources – the most delicate.

Personal experiences that span ailments and salvation can endow with a novel, far more profound consciousness of words like threat, vulnerability, fragility. Above all, they also reveal the true nature of resilience, strategy, and planning when aimed at protection and perseverance.

Weather Report (1972), "I Sing the Body Electric", © Columbia Records