Scoping Our Planet

Opportunity space

v2

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CONTEXT

This document describes an opportunity space from which one funding programme has already emerged, and from which we believe more can emerge in the future. We've evolved the early thinking set out in v1 of this opportunity space and now invite you to help shape the direction of future programmes. We may publish updated versions of this document as our thinking progresses.

Sign up **here** to receive those updates and learn about further funding opportunities within this opportunity space.

An ARIA opportunity space should be:

+ important if true (i.e. could lead to a significant new capability for society),
+ under-explored relative to its potential impact, and
+ ripe for new talent, perspectives, or resources to change what's possible.

SUMMARY

Our understanding of the Earth system is limited by serious measurement and modelling gaps that lead to unacceptable uncertainties in weather and climate predictions. By cultivating frontier technologies, from measurement platforms to artificial intelligence models, we can fill these gaps and generate actionable knowledge to serve society in diverse and so far impossible ways.

BELIEFS

The core beliefs that underpin/bound this area of opportunity.

1. Earth measurement and modelling gaps exist in space and time → **Closing these gaps is crucial to unlock actionable information.**
2. A dynamic interplay of frontier platforms, sensors, and models could parameterise the entire Earth system → **The resulting forecasts will revolutionise global business and maximise planetary resilience.**
3. Technology innovation alone is not enough; fragmentation of Earth system research, disconnected from the needs of industry, policymakers, and society, is severely impeding progress → **Transforming data into knowledge and accountability is vital for a future of human prosperity on a flourishing planet.**

OBSERVATIONS

Some signposts as to why we see this area as important, under-explored, and ripe.

Billions of Earth observations are made daily, on platforms ranging from satellites to buoys, while ever-increasing computational power enables huge model runs and artificial intelligence-powered operational weather forecasting. Yet there remain major gaps in sensitivity, resolution, and coverage[1,2] that contribute to uncertainties in weather and climate information in diverse ways.

Fig 1 [3]

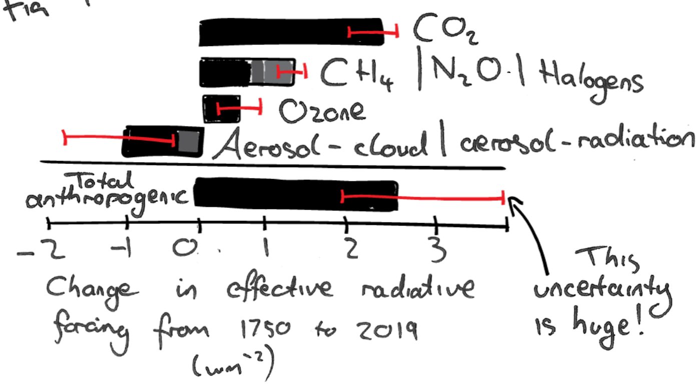
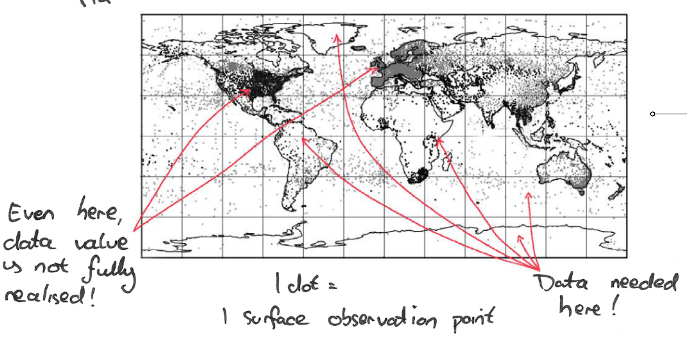


Fig 2



Sensitivity: Detecting subtle, yet critical, Earth system changes requires accurate long-term time series. For instance, oceanic carbon shifts by 0.007%/yr due to human activity, a change that is difficult to observe, preventing attribution and accountability for emissions[4].

Coverage: Current models are primarily fed by satellite and sparse surface measurements, with extremely limited vertical coverage[5,6]. Adding observations in underserved regions, such as radiosonde sampling for numerical weather predictions, already dramatically improves forecasts[7,8]. Progress requires better access to existing data, alongside targeted, timely collection of new data.

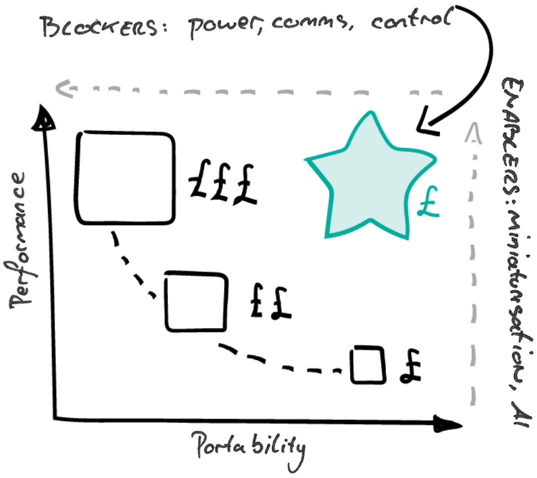
Resolution: The inherent chaotic nature of the Earth system impedes our ability to predict sub-kilometre weather events, including turbulence and lightning. Advancing resolution limits on current observations and models is essential, e.g. to overcome vulnerability to extreme precipitation[9,10] or effectively derive energy from the weather[11,12].

Closing gaps in sensitivity, resolution, and coverage is increasingly critical for life to thrive on our changing planet. Tsunami early warning systems exemplify the potential of uniting real-time measurements and models to provide actionable warnings to communities[13].

Could we deliver early warning for a range of Earth system threats, from earthquakes to climate tipping points?[14-16]

If we get here, we could better use the existing landscape of platforms (e.g. cubesats, drones, and buoys) and enable unconventional ones (e.g. animals and vehicles[23,24]).

Fig 3



Driven by consumer connectivity, sensor technologies are available at lower size, weight, power, and cost (SWaP-C) than ever before. Interdisciplinary innovation will enable the global distribution of accurate and portable instruments to parameterise the Earth system.

Sensors from wearables? Miniaturisation LIDAR from autonomous vehicles? Microcontrollers from the maker movement?

Autonomous platforms prowling the planet delivering real-time data could unlock vast economic value—if power and communication constraints are overcome. Energy capture and transmission innovations could extend platform endurance[17-19]. Networking these platforms could address bandwidth and spectrum scarcity[20], accelerating progress in industries like superfast communications, remote asset monitoring, or autonomous shipping[21,22].

Current weather forecasts can assimilate a mere fraction of available earth observations[25], yet enable £trillion industries from energy to aviation. AI models can now directly ingest streams of raw observations to produce forecasts, drastically reducing computational cost[26]. Emerging Earth-scale AI models[27] are pushing to longer time-scales, creating new climate forecasting opportunities if validation and uncertainty quantification are embedded.

Fig 4

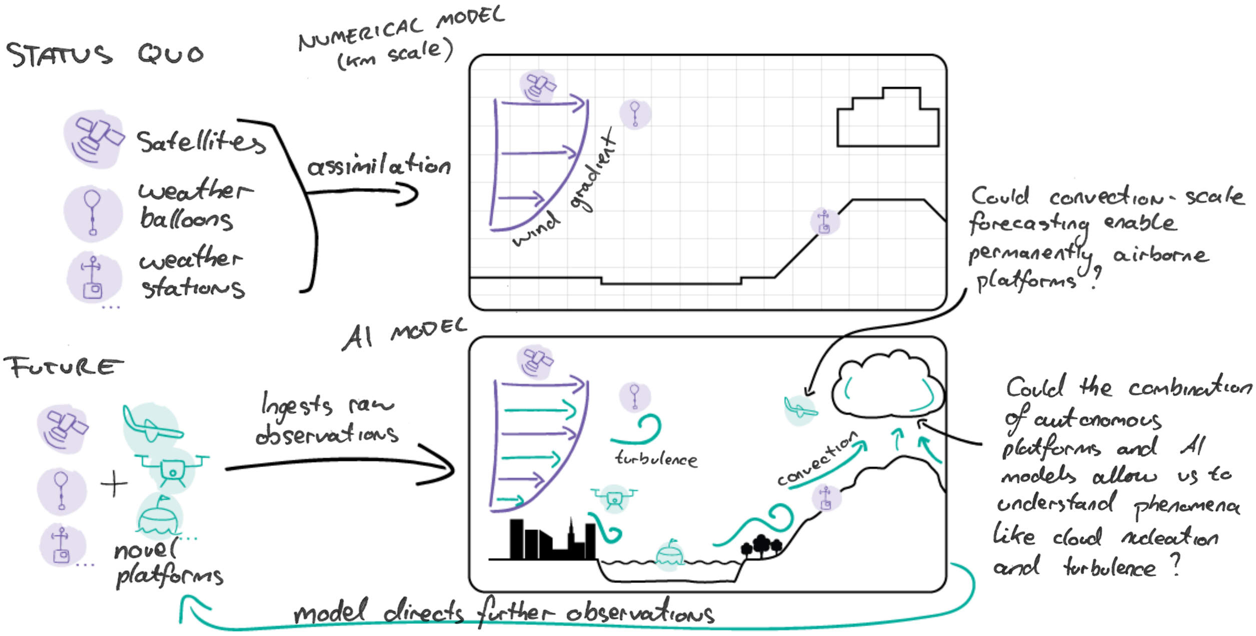
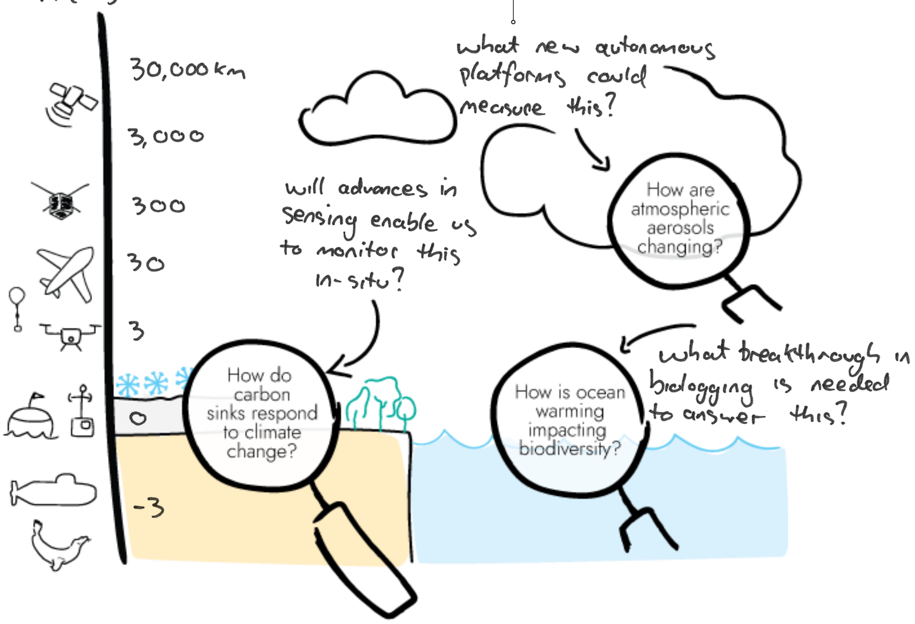


Fig 5



Actionable forecasts yield direct economic and societal benefits when co-designed with the relevant stakeholders and communicated effectively[28]. For example, ensemble-based seasonal weather forecasting optimises water resource management for economic savings and preventative humanitarian action[29,30].

Poor observational capabilities, model biases, and the lack of modern data infrastructure lead to uncertainties that undermine resilience-building in vulnerable communities and hard-to-reach geographies[31-34]. Reducing the disconnect between physical, biological, societal, and economic risks will lead to better investment planning, resulting in £trillions of economic benefits and promoting adaptation[35,36].

Building climate resilience depends in part on reducing uncertainty, and even more so on generating robust, decision-relevant information aligned with real options. Fields like national security show that effective action and accountability are possible under deep uncertainty. For planetary risks, this means linking richer observations with better designed modelling experiments to explore actionable futures, supported by interdisciplinary systems thinking[30,37].

Can we make robust decisions under deep uncertainty to deliver a collective global response to civilisational climate threats?

SOURCES

A compiled, but not exhaustive list of works helping to shape our view and frame the opportunity space (for those who want to dig deeper).

1. Global Climate Observing System 2021 Report
2. Vision for the WMO Integrated Global Observing System in 2040
3. Figure is adapted from The Earth's Energy Budget, Climate Feedbacks and Climate Sensitivity
4. Global Carbon and other Biogeochemical Cycles and Feedbacks
5. Met Office: Observations
6. Gridded precipitation and temperature reference datasets in climate change impact studies
7. The Impact of Radiosounding Observations on Numerical Weather Prediction Analyses in the Arctic
8. Influence of radiosonde observations on the sharpness and altitude of the midlatitude tropopause in the ECMWF IFS
9. The benefits of increasing resolution in global and regional climate simulations for European climate extremes
10. Big Data Assimilation: Real-time 30-second-refresh Heavy Rain Forecast Using Fugaku During Tokyo Olympics and Paralympics
11. Learning to soar in turbulent environments
12. Wind driven effects on the fine-scale flight behaviour of dynamic soaring wandering albatrosses
13. Evolution of tsunami warning systems and products
14. Earthquake early warning: Advances, scientific challenges, and societal needs
15. How a 1.5°C increase triggers climate tipping points
16. Global tipping points
17. Towards net zero: A technological review on the potential of space-based solar power and wireless power transmission
18. Preliminary design and technology forecast synthesis for solar-powered high altitude aircraft
19. Windward Performance Perlan II
20. Looming spectrum shortfall could cost America's GDP $1.4tn
21. Remote asset management market overview
22. The rising tide of the autonomous ships market
23. The internet of animals: what it is, what it could be
24. Movebank for Animal Tracking Data
25. NOAA Releases 10-Year Strategy for Data Assimilation
26. End-to-end data-driven weather prediction
27. A foundation model for the Earth system
28. Artificial intelligence for modeling and understanding extreme weather and climate events
29. Seasonal forecasts offer economic benefit for hydrological decision making in semi-arid region
30. Water resource planning under future climate and socioeconomic uncertainty in the Cauvery river basin in Karnataka, India
31. Can AI help weather forecasting save lives?
32. Polar Ocean Observations: A Critical Gap in the Observing System and Its Effect on Environmental Predictions From Hours to a Season
33. GBON - Global Basic Observing Network
34. Challenges to Understanding Extreme Weather Changes in Lower Income Countries
35. Value of information for climate observing systems
36. The $10 trillion value of better information about the transient climate response
37. Designing the Climate Observing System of the Future

ENGAGE

We invite you to shape our efforts by providing feedback and surfacing breakthrough ideas related to this opportunity space. Our next step will be to formulate a programme that directs funding across research disciplines or institutions toward a focused objective. We also plan to open up seed funding for researchers whose bold aspirations are unlikely to be funded elsewhere.

Sign up for updates and share your feedback **here** — we will read anything you send.