Advanced Research + Invention Agency ARIA

Scoping Our Planet

Opportunity space

v1.0

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CONTEXT

This document describes an opportunity space - an area that we believe is likely to yield breakthroughs, from which one or more funding programmes will emerge.

You can find out more about opportunity seeds within this space **here**. We have also launched a programme, Forecasting Tipping Points, in this opportunity space. Find out more **here**.

This opportunity space is not currently soliciting feedback – you can stay up to date with this opportunity space, plus others across ARIA, **here**.

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

Current Earth system measurements have serious gaps that lead to uncertainties in weather forecasting and climate predictions. By harnessing the power of optics we can fill these gaps, equipping society to respond confidently to the climate crisis.

BELIEFS

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

1. Current climate measurements fail to provide the coverage, resolution or sensitivity necessary to confidently understand and respond to the climate crisis ⟶ **we need disruptive technologies to parameterise the entire Earth system.**
2. Monitoring and modelling are crucial for effective climate management, but both are limited by measurement gaps ⟶ **without better measurements we won't succeed in climate change mitigation, adaptation, or intervention.**
3. We have entered a new era of optics and photonics, with unprecedented control of light and its interactions with the environment, from molecular to global scales ⟶ **new inventions from the optics community are poised to fill the climate measurement gaps.**

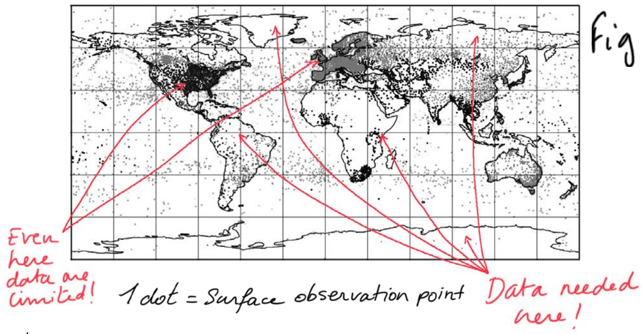
OBSERVATIONS

Some signposts as to why we see this area as important, underserved, and ripe.

Billions of Earth observations are made daily, from satellites to weather stations, but there are major gaps in **sensitivity**, **resolution** and **coverage**.[1,2]

Could new optical tech fill these gaps?

Fig 1

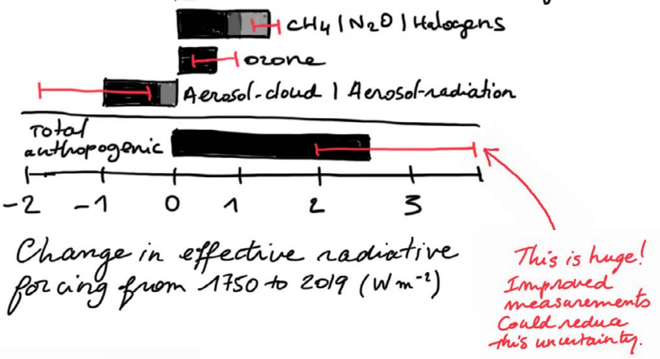


Sensitivity: Accurate time series are needed to observe subtle climate changes over the natural background. Oceanic carbon changes by just 0.007 %/yr due to human activities – a drop in the ocean – difficult to detect but vital for local measurement, reporting and verification (MRV).[3]

How do we improve sensitivity of in-situ measurements?

Coverage: Both land and air measurements are sparse in the global south; the oceans are globally under-observed. More observations will transform forecast accuracy, supporting communities who need them most.[4,5]

Fig 2



Resolution: Instrument resolutions can be multiple orders of magnitude (spatially and temporally) away from the physical processes they are measuring. Huge uncertainties in the contribution of clouds to the Earth's energy balance arise from a lack of observations at the scales that matter.[6,7]

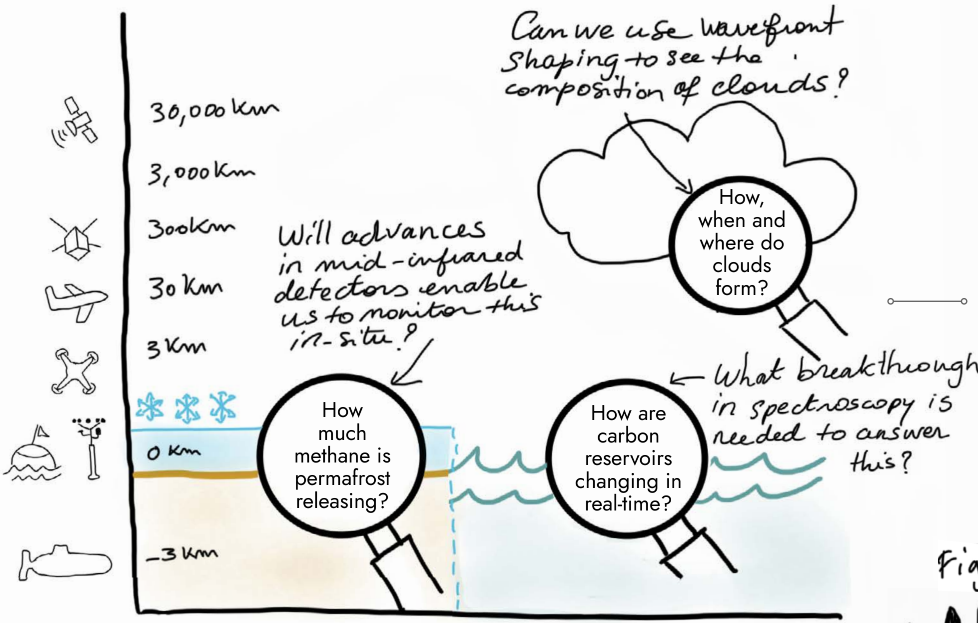


Fig 4

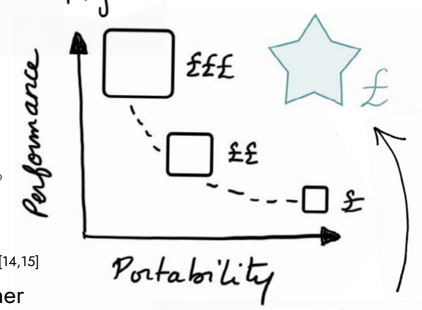
Better measurements underpin more accurate climate predictions, which can create £trillions of economic benefits and allow for enhanced planning to save lives.[8, 9, 10, 11]

You can't manage what you can't measure

By creating accurate, reliable, portable instruments that can be distributed globally and measure a range of parameters, we can enhance weather forecasts and climate projections, providing early warning signs of extreme weather events and tipping points.[12,13]

Where will the next step change in climate monitoring come from?

Fig 3



+ Hyperspectral imaging from defence?
+ Adaptive optics from astronomy?
+ AI-enabled super-resolution from imaging?
+ Interferometry from ophthalmology?

Optics and photonics technologies are low-cost and scalable, so have revolutionised our daily lives.[14,15] Technologies emerging in other application areas could fill the climate measurement gaps.

If we get here, we could better use the existing landscape of platforms (cubesats, drones and buoys) and enable unconventional ones (birds, seals)

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. Global Carbon and other Biogeochemical Cycles and Feedbacks
4. Can AI help weather forecasting save lives?
5. Gridded precipitation and temperature reference datasets in climate change impact studies
6. The impact of aerosols on global climate
7. Clearing clouds of uncertainty (Figure 4)
8. The Earth's Energy Budget, Climate Feedbacks and Climate Sensitivity (Adapted in Figure 2)
9. Value of information for climate observing systems
10. The $10 trillion value of better information about the transient climate response
11. Designing the Climate Observing System of the Future
12. How a 1.5°C increase triggers climate tipping points
13. Global tipping points
14. The future of photonics: the best is yet to come
15. The health of photonics
16. How methane is linked to warming in Siberian tundra (Figure 4)
17. Marine pCO2 measurement technology developments (Figure 4)

ENGAGE

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