REFLECT: A REsponsible innovation Framework for assessing noveL spray tEChnology research To examine local albedo changes from marine brightening and its multi-scale impacts

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Image Credit: Bryan Rodriguez

Project Overview:

Marine Cloud Brightening (MCB) and Marine Sky Brightening (MSB) are potential climate interventions using sea salt aerosols to reflect more sunlight and cool the planet [1]. A major challenge lies in producing the right size and quantity of aerosols efficiently in real-world conditions. To this effect, REFLECT is a multi-institutional effort to develop, test, and evaluate novel marine spray technologies [2].

The REFLECT programme proposes a **responsible, stepwise approach** to:

- Develop and test novel **spray technologies** for MCB/MSB.
- Build an **experimental framework** to evaluate effectiveness and environmental impacts.
- Use **multi-scale modelling** to extrapolate findings and assess broader climate effects.

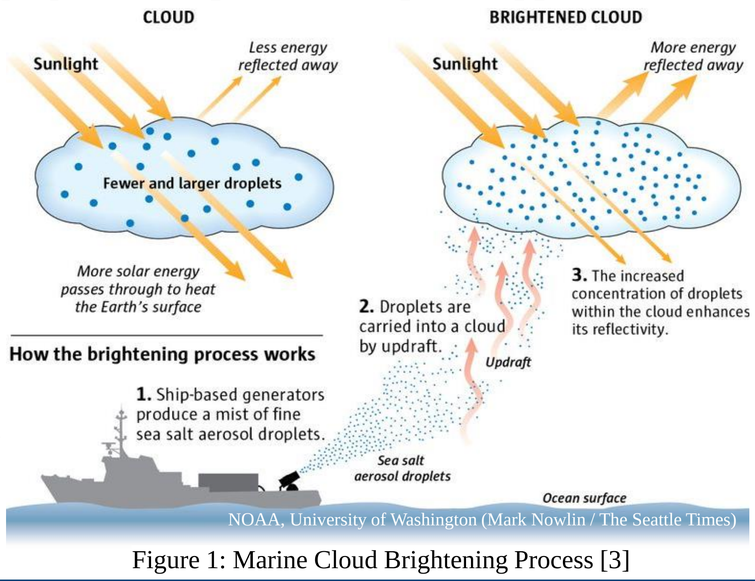


Figure 1: Marine Cloud Brightening Process [3]

Research Objectives:

1. Designing robust and scalable long-term spray systems (O1).
2. Validating cloud activation models in lab settings (O2).
3. Conducting real-world trials on cloud and albedo response (O3).
4. Assessing impacts from local to global scales (O4).
5. Evaluating risks and benefits (O5).
6. Embedding public engagement and responsible research principles throughout (O6).

Work Packages (WP's) & Key Questions:

WPA: Effective Spray Generation of Aerosols

- Can spray systems reliably produce desired particle distributions?
- Lab → Wind Tunnel → Indoor Prototypes → Manchester Ice Cloud Chamber (MICC)

WPB: Field Trials

- Can real-world sprays induce detectable albedo shifts?
  - Where: Coastal UK (e.g., Weybourne)
  - How: UAVs, lidar, radiometers
  - Stages:
    - B1: Safety and baseline emissions
    - B2: Open-air trials (40 days)
    - B3: Cloud impact study

WPC: Modelling

- Can we scale up findings to predict climate-relevant outcomes?
  - Simulations Target: Cloud formation, regional radiative forcing, global cooling, air quality

WPD: Responsible Innovation and Societal Engagement

- How do we embed societal values and transparency in field experimentation?
  - Interviews & workshops
  - Public survey
  - Social stage-gate before field trials

Experimental Approach:

Lab + Field + Modeling Synergy

- Lab Experiments: Spray innovation and particle characterisation
- Field Trials: Sea spray deployment under real meteorological conditions
- Data via lidar, satellite, and in situ aerosol/cloud sensors
- Models: LES to global scale, integrating observational data

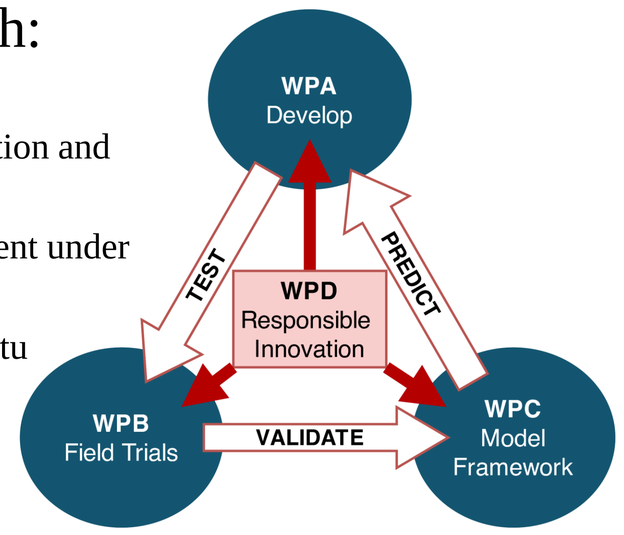


Figure 2: Diagram of Work Package Collaborative Flow

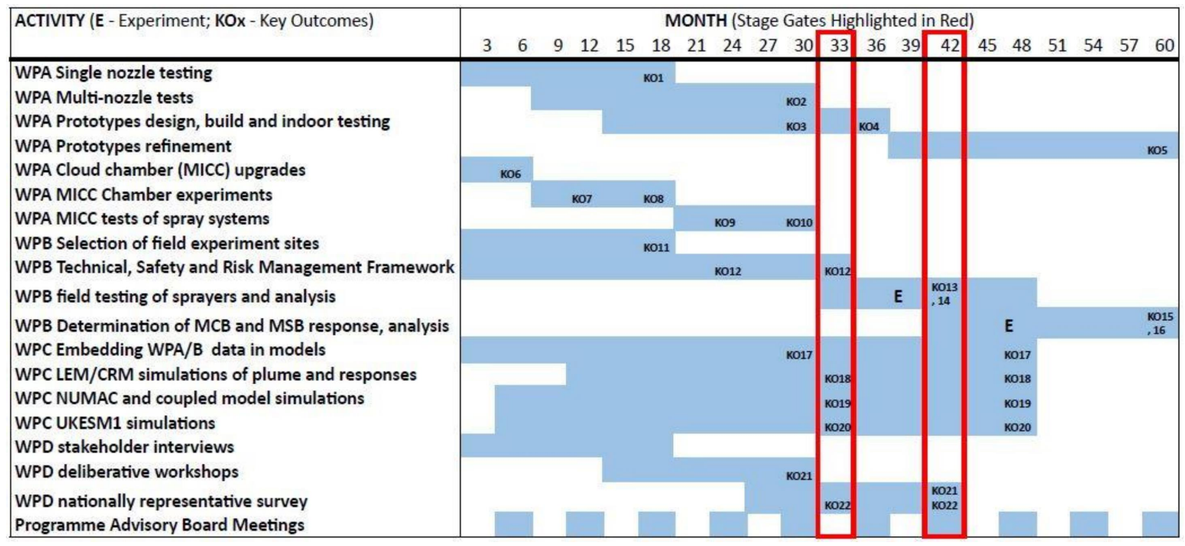
Project Team & Timeline:

Project Institutions: University of Manchester, University of Cambridge, University of Exeter, Archipelago Technologies, University of Leeds, Finnish Meteorological Institute

WP's Leads:

- PI: Hugh Coe (Manchester) - WPB: Field Trials
- Shaun Fitzgerald (Cambridge) - WPA: Spray Generation
- Jim Haywood (Exeter) - WPC: Modelling
- Rob Bellamy (Manchester) - WPD: Responsible Innovation

Gantt Chart Timeline for REFLECT:



Summary & Outlook:

Scientific:

- Scalable spray delivery methods for climate intervention
- UK's first MCB/MSB experimental testbed

Policy & Society:

- Evidence base for regulation of climate intervention technologies
- Informed stakeholder and public engagement

Innovation:

- Field-ready spray prototypes
- Multi-scale models and open data for future applications

Climate interventions are controversial and potentially high-impact, REFLECT bridges the gaps between **lab, field, and global models** to:

- Evaluate MCB/MSB safely and ethically
- Guide deployment in climate emergency scenarios
- Support international leadership in responsible climate innovation

References:

[1] Latham, J, et al. (2008). Global temperature stabilization via controlled albedo enhancement of low-level maritime clouds, Phil. Trans. R. Soc. A, vol. 366, pp. 3969–3987.

[2] Coe, H, et al. (2025). A Responsible Innovation Framework for assessing NOvel Spray Technology Research to examine local AlbeDo changes from Marine brightening and its mUlti-Scale impacts (formerly NOSTRADAMUS, now REFLECT), research proposal submitted to the Advanced Research and Innovation Agency (ARIA)

[3] NOAA, University of Washington (2024). Image: Cloud brightening research vessel off Washington coast. Published in The Seattle Times, 8 April 2024. Image by Mark Nowlin