Agent-based modelling of Archean biogeochemistry and the Great Oxidation

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Recent work has suggested the delay between the emergence of oxygenic photosynthesis and the Great Oxidation may be explained by a bistability in atmospheric oxygen [1]. The origin of the bistability relates to a nonlinear increase in the liftime of atmospheric oxygen when levels exceed ~10^{-5} present atmospheric levels (PAL). At this point, ozone becomes effective at shielding the troposphere from ultraviolet radiation, permitting oxygen levels to rise. However, the trigger that might have caused the system to flip from the low oxygen state into the high oxygen state (~0.01 PAL) remains uncertain. Here we expand upon the work of Goldblatt *et al.* [1] by building an agent-based model of marine life in the Archean. The model is a three-box representation of the ocean-atmosphere system. Into it are placed a number of microbial guilds, containing species that perform similar metabolic transformations, e.g., photoautotrophy, methanogenesis etc. The growth of organisms is modelled as a balance between anabolic and catabolic processes, and includes an explicit representation of energetic yields from various forms of metabolism. Within each guild, multiple species may coexist and compete on the basis of various physiological traits.

Each organism posesses an artificial genome that specifies physiological traits that ultimately determine the organism's competitiveness within the environment. Mutations, prescribed as chance events at the point of reproduction, introduce variability into emergent populations, and supply handles upon which selection may act. Early simulations show organisms evolving with their environment, resulting in a relatively well oxygenated surface ocean, populated by aerobic lifeforms, while an anoxic deep ocean plays host to a small population of anaerobic methanogens. Despite posessing a completely different architecture, the model is able to reproduce a similar transition in atmospheric oxygen as observed by Goldblatt *et al.* [1]. This work represents initial progress made in utilising agent-based models to study the co-evolution of life and its environment.

[1] Goldblatt *et al.* (2006) *Nature* **443**, 683-686.

Aerosol and ocean-atmosphere processes over the Pacific Ocean

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The flux of gas and particles across the ocean surface in either direction has significant influence on both atmospheric and oceanic processes. These effects are often studied and described for the "local" scale in the vicinity of the ocean surface, marine boundary layer and/or for the air mass to which they are related. There are also larger scale couplings between ocean and atmosphere within which these processes are active, including large convective systems, oceanic gyres, upwelling regions, Hadley circulation etc. that are also coupled to transport regimes, cloud coverage, precipitation processes etc. Aerosol properties responsible for local direct and indirect radiative effects, can influence and be influenced by these larger scale systems. Some of these may give rise to teleconnections where source regions or scavening regions can have influences over thousands of kilometers, often when transport in the free tropopshere is involved.

For 15 years we have participated in numerous NASA and NSF aircraft campaigns over diverse Pacific oceanic regions and continental margins (see Figure below). These allowed us to explore processes active over hemispheric scales. Here we will illustrate aerosol microphysics and chemistry linked on these scales including: nucleation; sea-salt production; long range transport of dust, pollution and biomass burning; boundary layer CCN and relations to cloud scavenging; entrainment and deposition.

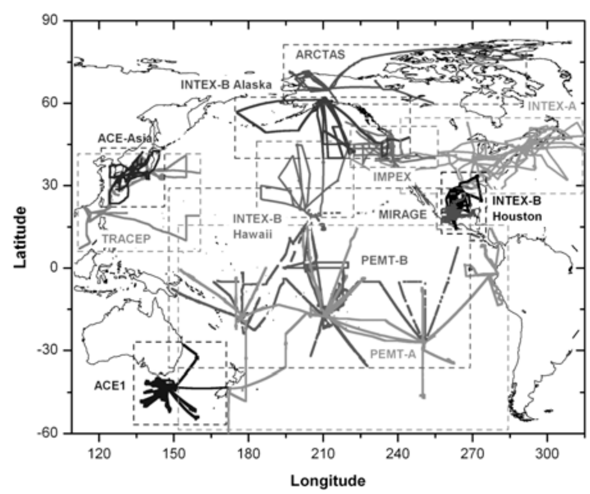

Figure 1: Pacific airborne missions over past 15 years.