Variable Atmosphere Laboratory (VAL):
A National Tool for Experimental Study of Climate Change

Many components of the Earth's atmosphere and environment are changing regionally and globally in response to human activities. Historically, these changes have been even greater in magnitude, but slower in rate, as earth's climate and biota have responded to changes in solar input, geologic processes, and the evolution of life. The most recent Intergovernmental Panel on Climate Change (IPCC) report suggests that the resilience of many of Earth's ecosystems will be compromised by climate change in the coming century, potentially leading to major crises in food and water supply that call out for major changes in energy use and environmental regulation. However, key uncertainties remain in understanding the effects of atmospheric and climatic change on ecosystems and organisms, and these unknowns make predictive models, administrative policies and political decisions very challenging. A national Variable Atmosphere Laboratory (VAL) consisting of multiple, replicated "miniworlds" capable of containing small communities and regulating all relevant environmental variables would provide a key tool for rigorous evaluation of hypotheses concerning the effects of past, current, and future climate change on earth processes.

Our uncertainties about the effects of climate change arise from the generally large scale and multi-component nature of such influences and our inability to predict the responses of ecosystems and organisms. At the ecosystem level, the feedback links between atmospheric and biogeochemical processes remain too poorly understood to allow accurate modeling of key questions like how the CO_2-sequestration capacity of different ecosystems will respond to changes in soil temperature or land use, a critical aspect of global climate models. Climate change today and historically includes major changes in trace gases such as nitrogen dioxide (NO_2), ozone (O_3) and sulfur dioxide (SO_2), yet we know very little about how trace gases enter biogeochemical cycles and how they are used by plants and micro-organisms. At the organism level, we still understand little about the potential for plants, animals and microbes to adapt or evolve in response to interactive changes in temperature, atmospheric composition and soil nutrient levels; such process will be decisive in determining climate change effects on species extinctions and biodiversity. In terms of human health, although air pollutants have been implicated in exacerbating lung disease, the mechanisms of these effects remain unclear, and we understand little about the effects of actual complex pollution mixtures applied over long periods of time. Together, these fundamental questions limit our capacity to understand the biological and geological effects of climate change and develop rational control strategies. Valuable insights into evolutionary responses to climate change can also come from the fossil record, but these need to be complemented by knowledge of processes that operated in paleo-environments.

Key features of a national VAL should include: 1) a variety of well-replicated miniworlds, including some sized for small tree-dominated communities, 2) capacity for regulation of all relevant atmospheric and climatic variables over ranges that capture historical and predicted future conditions, 3) capacity for measurement of net fluxes of key molecules between communities and environment, 4) laboratories and instrumentation to support science, 5) embedded sensors for remote monitoring of experiments, and 6) sophisticated technical, animal and horticultural support. A centralized national facility would provide economies of scale, ensure that experiments are sufficiently large and replicable, and promote an interdisciplinary focus on questions critical to sustainable stewardship of the Earth's resources.

Fig. 1. Overview of proposed national Variable Atmosphere Laboratory (VAL). IDC Architects (CH2MHill) prepared these draft drawings based on scientific input from two NSF-funded workshops, and preliminary engineering and design analyses. VAL includes 12 mesocosms capable of containing small forest plots, and an additional 80 smaller miniworlds, as well as adjacent laboratory, office, and educational/visitor space.

Fig. 2. Building section for VAL and one of the mesoscale miniworlds. Basement level contains infrastructure and access for soil sampling to mesocosms and the 80 smaller miniworlds, ground level includes laboratories and circulation corridors, 2nd floor includes public space and offices.