which are suited for specific time windows and spatial domains, lead to divergent inferences and budget estimates (e.g., Berelson, 2001; Ducklow et al., 2001). Experiments that simultaneously utilize these various methodologies are needed for closure.

Observations have driven most of the new discoveries and paradigm shifts. However, biogeochemical models have rapidly evolved, generally becoming increasingly complex, to incorporate the plethora of new processes described in the previous paragraph. It is easier in many cases to add new model formulations than to develop and deploy new sensors to measure requisite variables and rates. Yet, models cannot advance without vital data sets for developing proper parameterizations that have universal applicability and for testing and evaluating models so that they be reformulated and improved (e.g., Doney, et al., 2001; Dickey, 2002). Nonetheless, it must be recognized that models are absolutely essential for synethsizing data sets and predicting biogeochemical variability and trends.

Despite the large number of challenging issues, there is cause for considerable optimism. For example, large numbers of sensors are being developed for many purposes outside of oceanography; likely some will be directly, or after modification, useful for ocean measurements. One possible benefit of advanced sensor technologies may well be more capable, smaller, simpler, less power-hungry, and less expensive sampling systems (e.g., "chip-based" chemical and biological sensors with automated data processing and transmission; Kaku, 1997), which will benefit oceanographic programs regardless of present technical capabilities and skill levels. There is increasing interest in making platforms available (e.g., platforms-of-opportunity) for a broader suite of interdisciplinary measurements. Also, there is growing support for systematic approaches that incorporate data acquisition, data telemetry, data assimilative modeling, prediction, and capability for adaptive sampling through redirection of assets.

There is now a strong international focus on global ocean observing systems for both the coastal and open oceans. These developments will likely reflect in improved sampling systems that will provide more variables and better spatial and temporal coverage. Importantly, data assimilation modeling is considered a key element of these systems (Le Traon et al., 2001; Matear and other chapters in this volume), and thus observational and modeling components are being developed synergistically. Joint instrumentation/data assimilation system testbeds need to be initiated as soon as possible to accelerate progress in this direction (e.g., Robinson and Dickey, 1997). There remain a myriad of challenges to be met in order for us to advance our knowledge of and predictive capabilities for biogeochemical variability on scales from minutes to the interannual. Nonetheless, we have great cause for optimism as the oceanographic