How Do We Reconcile Models and Observations?

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Ecology, Physiology, and Physics

- Does physics drive structure and variability of phytoplankton ecosystems?
  - What are roles of physiology and ecological processes?
  - Regulation versus limitation
- Evolutionary and ecological response depends on:
  - Heterogeneity of environment
  - "Perception" by organism
- Will climate change be characterized by changes in patterns of variability as well as by changes in mean conditions?

"There are more things, Horatio, than are dreamed of in all your books…"

- What physical processes must we resolve?
  - Interannual variability
  - Mesoscale variability
- How much detail do we need in the ecosystem models?
  - Zooplankton grazing
  - Multiple nutrient regulation
  - Viruses and vitamins
- Which biogeochemical processes must be modeled explicitly?
  - Nutrient regeneration
- Stop Dave Karl from thinking, writing, and measuring

Where We Started

- Observations
  - Transects and process studies
  - Moorings for ocean physics
- Models
  - The 3-Box World
    - Warm, cold, and deep
  - The Aquarium Ocean
    - Flat bottom, rectangular sides
  - N/P/Z models (Riley, Walsh, Wroblewski)
  - Heuristic models

Where We Went

- Observations
  - Extensive tea-bag dipping along global transects
  - High-resolution biophysical moorings
  - Satellite remote sensing, drifters
  - New variables and new processes
- Models
  - Eddy-permitting OGCM's
  - Adjoint and other inverse techniques
  - Multi-compartment N/P/Z models with O(100) parameters

Got Science?

- Understanding requires close integration between observing systems and modeling/analysis
  - As our understanding of the ocean system develops, we will refine our observing requirements and add new capabilities
  - Or are we driven by technology and what is feasible?
- More data or better data?
  - What are the tradeoffs between making higher resolution but lower quality measurements and high accuracy but sparse measurements?
  - What will improve our models and hence our understanding?
- More complex models or more understandable models?
  - Balance between implicit and explicit processes
- The need for quantitative tests for both models and observations
  - Move beyond the "Looks Good" version of statistics

Challenges for the Future

- Observations drive understanding and understanding drives observations
- More observations, better models
  - Will this necessarily lead to improved understanding?
  - Or reduced uncertainty?
  - Or more uncertainty, following Dave Karl's study of the North Pacific Subtropical Gyre
- Keeping up with technology while maintaining a solid scientific foundation
  - Do I only need to know Matlab to use a Fast Fourier Transform?
- Sensors become models
  - Satellites measure radiance, not chlorophyll
  - Modern sensors are far removed from the actual variable
    - Does acoustic backscatter = copepod biomass?
- Specialization vs. a broad perspective
  - Increasingly complicated technology and models may require increasing specialization

And a Caution

- Our science will become increasingly linked to policy and to economic issues
  - And perhaps even corporate issues?
- Our research will increasingly be under scrutiny by the public
  - Will iron fertilization come under environmental regulation?
  - Issue is not necessarily the direct environmental impacts but rather the issues under study (such as carbon sequestration) may be controversial
  - Marine mammal studies and acoustical sampling
  - What you don't know, you can't regulate (or utilize)
- But certainly the next generation of researchers are up to these challenges!