Historical Perspective: Ocean Productivity in the 20th Century

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Introduction

ASLO, Boulder, CO, 1987

Obstacles both large and small

The Ocean is Big

Oceanography, Ecology

Phytoplankton are Tiny

Physiology

1940s

Oceanographic, Ecologic Approach to Productivity

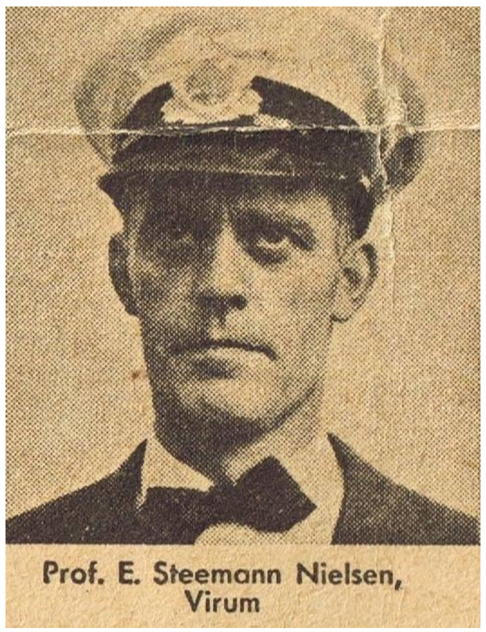
Gordon A. Riley

Riley, G. A., H. Stommel, and D. F. Bumpus. **1949**. "Quantitative Ecology of the Plankton of the Western North Atlantic." *Bulletin of the Bingham Oceanographic Collection* 12(3): 1–169

A marriage of biological, physical, and chemical dynamics

1950s

Introduction of the C-14 Method

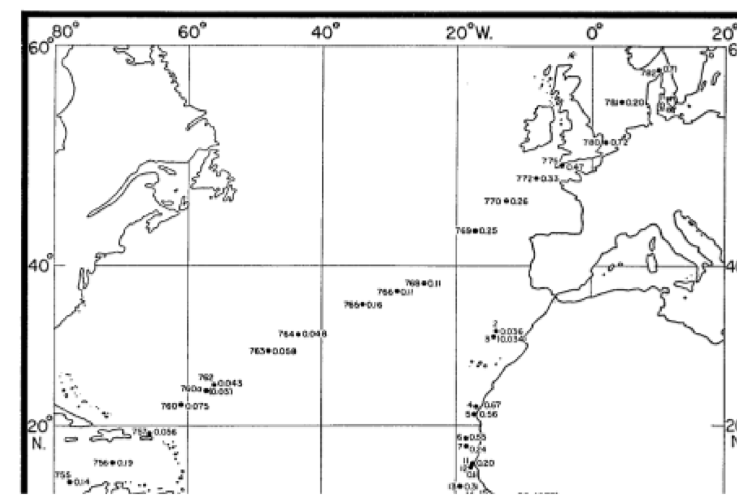


PRIMARY OCEANIC PRODUCTION

THE AUTOTROPHIC PRODUCTION OF ORGANIC MATTER IN THE OCEANS

By E. STEEMANN NIELSEN *and* E. AABYE JENSEN
Copenhagen Vejle

CONTENT



Decade also marked by dispute between Riley and Steemann Nielsen, between an oceanographic and physiologic approach to productivity

1960s

Global Surveys Using the C-14 Method

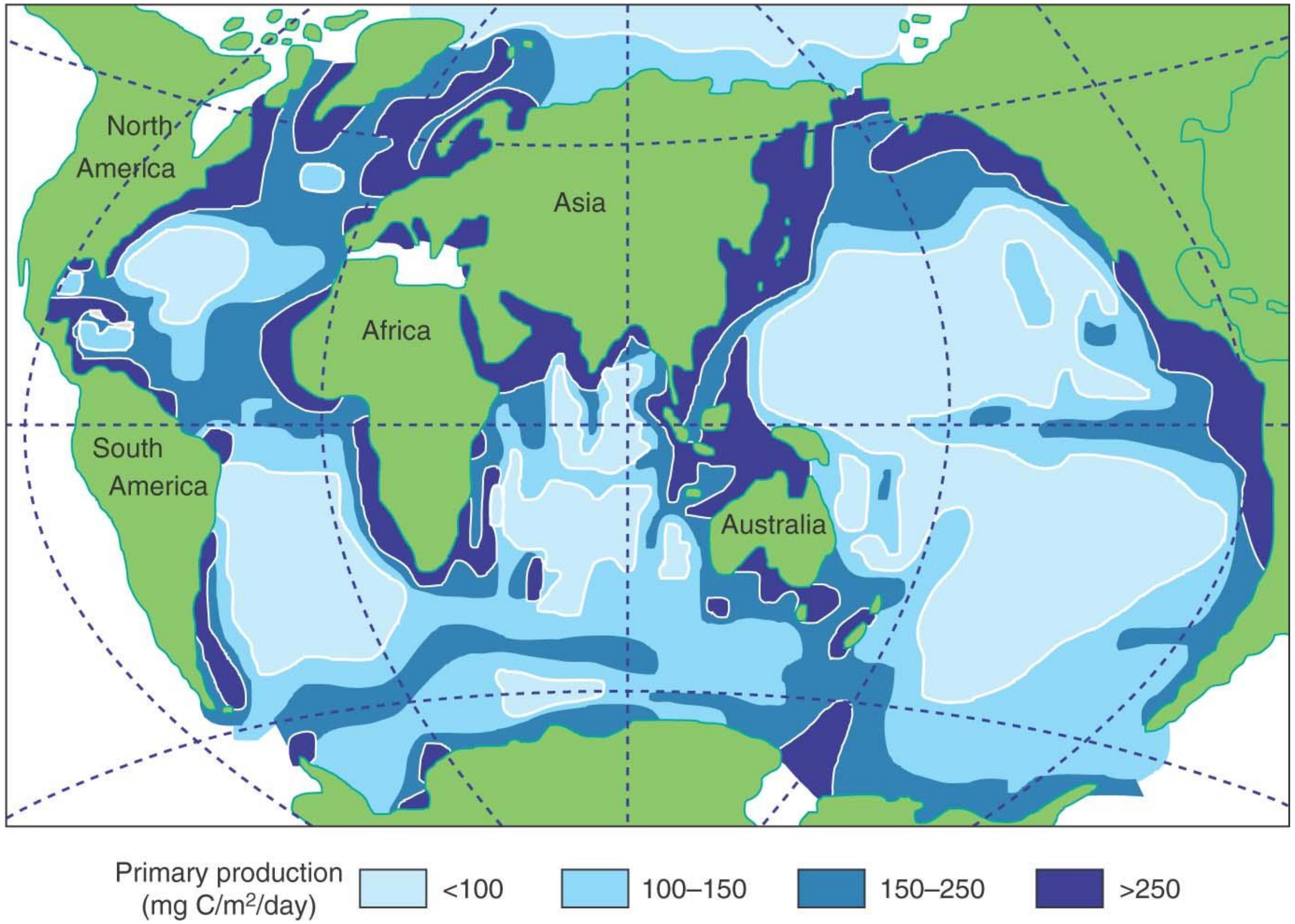


FIG. 10.6 Distribution of primary production in the oceans. (After Koblentz-Mishke et al., 1970.)

1970s

Questions

Oceanography

- Bacterial Respiration too large to be supported by 14C PP
- Rain rate of particles
- Oxygen utilization in the deep ocean implies higher surface PPs than measured
- Fish catches require higher PP

(these are difficult to evaluate)

Phytoplankton

- Effects of Incubation?
- Contamination from
  - sampling and samplers?
  - incubation containers?
  - the isotope itself?

There were other fundamental problems with the C-14 Method

- The method is easy
- Only a positive result (C assimilation) is possible
- Extremely sensitive: it can’t be compared to other flux measurements

As a result, you can make lots of measurements, can console yourself by the positive results, and not worry about validation.

1980s

The PRPOOS Project, and Some Resolution

Dick Eppley (with Ed Renger)

"It is difficult to conceive of success at understanding marine ecosystems or chemical cycles in the ocean without accurate knowledge of the rate of primary photosynthetic production, closely tied as it is to the distributions and abundances of nearly all marine organisms and all particle-reactive elements.

"Yet there is currently large uncertainty and abundant debate about this rate brought about by inferred imbalances between measurements of photosynthetic carbon fixation and measurements of consumption or loss elsewhere in the oceanic carbon cycle."


PRPOOS
FAHRTLEITER
IN
PRPOO

Did PRPOOS Double Oceanic Productivity?

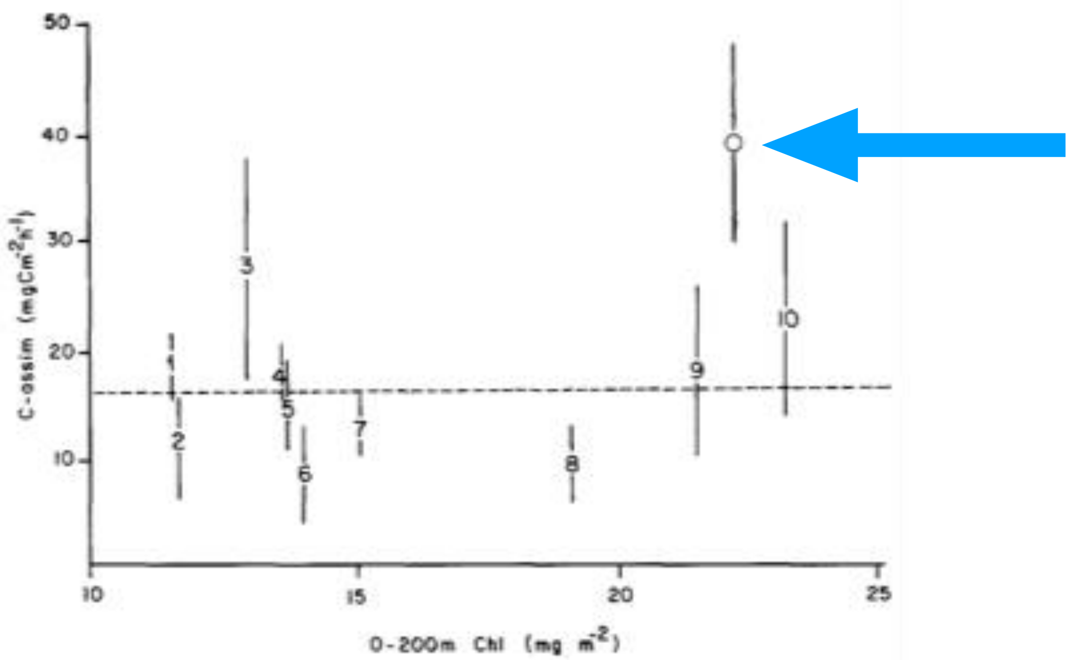


Fig. 1. A comparison of ^{14}C-derived carbon assimilation (C-assim) values from historical data (1968–1980; HAYWARD *et al.*, 1983) and from the PRPOOS cruise (16 August–8 September 1985) for 28°N/155°W in the North Pacific Central Gyre. These data are plotted against chlorophyll for convenience; error bars are standard deviations. Open circle, PRPOOS data; 1, CLIMAX I (September 1968); 2, ARIES IX (September 1971); 3, CLIMAX II (August 1969); 4, TASADAY XI (February 1974); 5, CATO I (June 1972); 6, CLIMAX VII (August 1973); 7, INDOPAC XV (June 1977); 8, SOUTHTOW XIII (February 1973); 9, DRAMAMINE II (May 1974); 10, FIONA (August 1980). For the historical data, the means represent from 3 to 18 experiments per cruise (HAYWARD *et al.*, 1983). The dashed horizontal line is the mean of the historical data. The PRPOOS data is an average of 6 experiments. The lack of trend in this plot is because of the different depths of integration for production and chlorophyll. Chlorophyll is reported (HAYWARD *et al.*, 1983) as an integral to the depth at which it decreases to background concentrations; this occurs at 200 m depth, about twice the depth of the euphotic zone.

rrived at a “canonical” value for the daily rate of C-assimilation under a square meter of oc

1990s

The Joint Global Ocean Flux Study

- JGOFS
  - biological and chemical oceanography go international
  - establishes protocols for PP and other “core” measurements
- Process Studies: NABE Arabian Sea Exp., EqPac, AESOPS
- Time series: HOT, BATS

A Comparison of Methods: NABE

POC (beam-c) and TCO_2 are measured in the water column

^{14}C assimilation and Net O_2 are measured in incubations

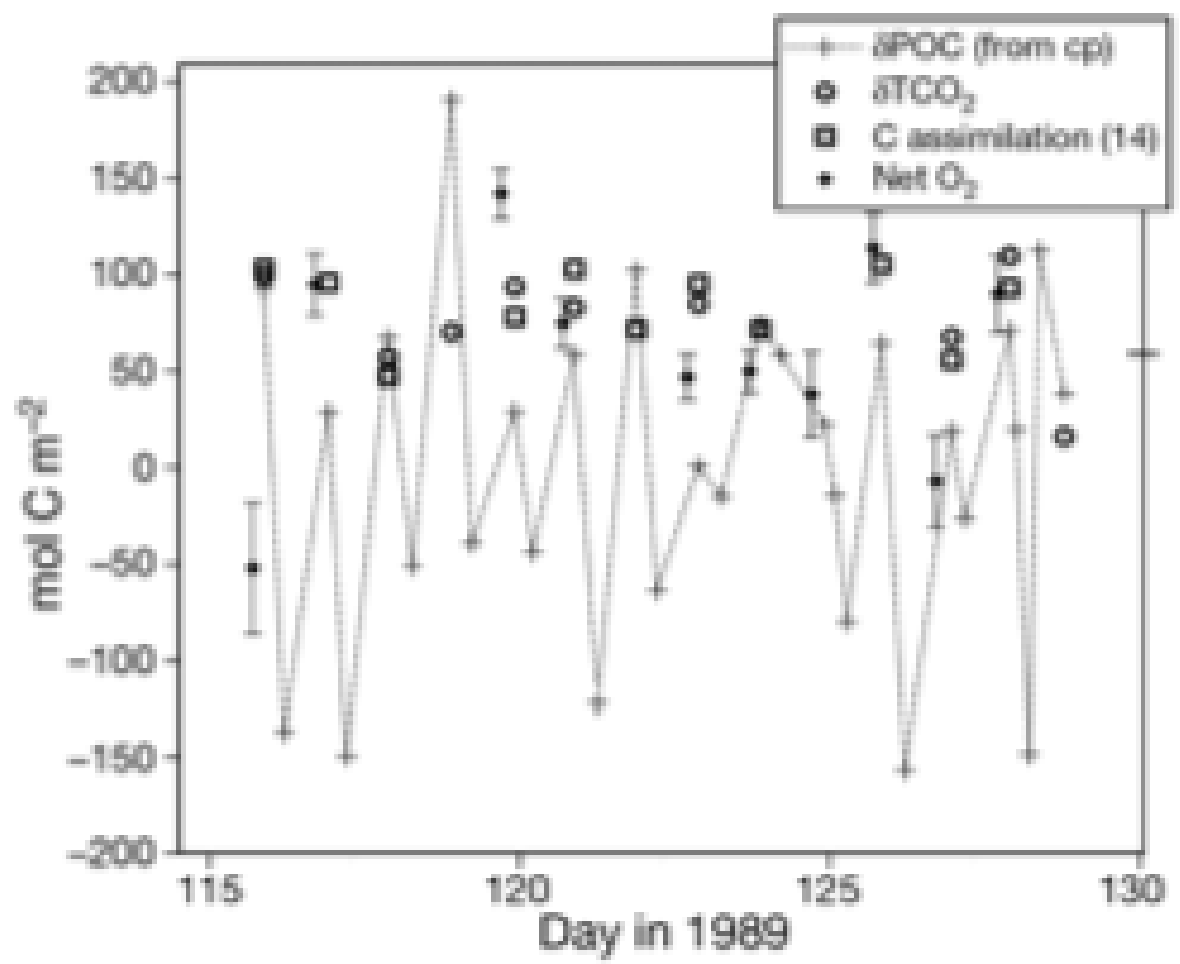


Fig. 4. Comparison of rates determined using incubation methods (C assimilation and net O_2 production) with rates determined from *in situ* changes (δTCO_2, δPOC) in the mixed layer for the North Atlantic Bloom Experiment (NABE) in 1989 (from Marra 2002). The low points in the δPOC data are rates of loss overnight. The horizontal line on the right *y*-axis indicates the mean of all productivity measurements. Reproduced with permission from Blackwell Scientific

Marra, 2009

In Conclusion…

Both water column (in situ, oceanographic) and physiological (incubations) approaches have their advantages and disadvantages.

Water column methods give a number, useful for budgets and serve as a valuable check.

Incubations can show which organisms are photosynthesizing, and interactions among the plankton.

If the water column is highly variable, physically, both approaches will have problems