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LLNL-TR-428472

MEASUREMENTS OF PAST 14C LEVELS AND 13C/12C RATIOS IN THE SURFACE WATERS OF THE WORLD'S SUBPOLAR OCEANS.

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April 22, 2010

Disclaimer

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

MEASUREMENTS OF PAST ^{14}C LEVELS AND $^{13}C/^{12}C$ RATIOS IN THE SURFACE WATERS OF THE WORLD'S SUBPOLAR OCEANS

LABORATORY DIRECTED RESEARCH AND DEVELOPMENT
(ERI)

Tracking code 97-ERD-052

Final report August 2000

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Administrative Unit:	Center for Accelerator Mass Spectrometry (CAMS)
Project Duration:	1 October 1996 - 30 September 1999

Introduction

Under this project we have developed methods that allow the reconstruction of past ^{14}C levels of the surface waters of the subpolar North Pacific Ocean by measuring the ^{14}C contents of archived salmon scales.

The overall goal of this research was to reduce of the uncertainty in the uptake of fossil CO_2 by the oceans and thereby improve the quantification of the global carbon cycle and to elucidate the fate of anthropogenic CO_2. Ocean General Circulation Models (OGCMs), with their three dimensional global spatial coverage and temporal modeling capabilities, provide the best route to accurately calculating the total uptake of CO_2 by the oceans and, hence, to achieving the desired reduction in uncertainty. ^{14}C has played, and continues to play, a central role in the validation of the OGCMs' calculations, particularly with respect to those model components which govern the uptake of CO_2 from the atmosphere and the transport of this carbon within the oceans.

Under this project, we have developed time-series records of the ^{14}C levels of the surface waters of three areas of the subpolar North Pacific Ocean. As the previously available data on the time–history of oceanic surface water ^{14}C levels are very limited, these time-series records provide significant new ^{14}C data to constrain and validate the OGCMs.

Research Program

The initial step in our research was the establishment of the methods necessary to obtain reliable measurements of the ^{14}C contents of archived salmon scales. We found that straightforward, relatively simple techniques were sufficient to isolate the section of the scales of interest and to clean the scales of undesired remnant materials and of possible contaminants, such as scale-mounting glues. Following these initial steps, the prepared scales could be processed following essentially standard procedures for converting the carbon in the scales to CO_2, and thence, to graphite powder for AMS measurement.

In the second stage of our research we confirmed the reproducibility of ^{14}C values obtained for a specific salmon stock in a given year by testing for differences between ^{14}C values measured on scales from individual salmon and between average ^{14}C values obtained from sets of scales from several salmon (n~10). In general, the variability of ^{14}C between individual salmon and between sets of salmon was consistent with the expected variability due to the ~5‰ uncertainty in each ^{14}C measurement. These results indicate that, when averaged over the annual migration pattern and within–season feedings movements, the differences in the ocean regions occupied by individual fish within a given salmon stock during their ~2 year open–ocean growth do not introduce significant variability in the ^{14}C time history.

As the final part of the our research under this project, and with complimentary support from NSF-OCE funding received by our external

collaborator, we measured sufficient scales samples from the available archives to develop preliminary salmon-scale-based ^{14}C time-series covering 1940–1990 for three regions of the subpolar North Pacific. Three regions of the subpolar North Pacific are shown below (Figure 1).

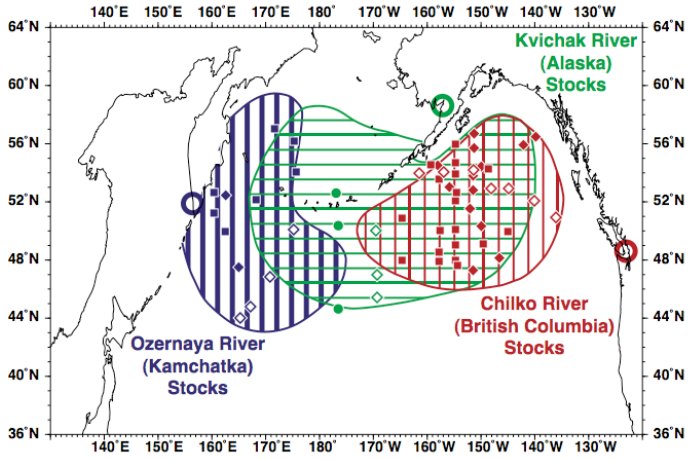

Figure 1. Open-ocean distributions for the three selected sockeye salmon stocks: 1) Chilko River/British Columbia (red thin vertical hatch), 2) Kvichak River/Alaska (green horizontal hatch), and 3) Ozernaya River/Kamchatka (blue thick vertical hatch). These open-ocean distributions encompass both the salmon's within-season feeding movements and their annual north(summer)- south(winter) migrations. The locations of the waterways through which the selected British Columbian, Alaskan and Kamchatkan sockeye salmon enter SubNPac waters are marked by open circles. The locations of relevant direct open-ocean ^{14}C sampling stations are shown (La Jolla: filled squares; GEOSECS: filled circles; UW: open diamonds; WOCE: filled diamonds).

The salmon-scales-based $\Delta^{14}C$ time-series indicate that pre–bomb $\Delta^{14}C$ values in the surface waters of eastern, central and western subpolar North Pacific were -103±4‰, -105±2‰ and -130±3‰, respectively. These pre-bomb ^{14}C values are significantly more precise than the wide range (-86 to -147‰) of previous estimated values from empirical relationships between ^{14}C and either silicate or potential alkalinity measured during GEOSECS.

The scales-based time-series indicate that the surface water $\Delta^{14}C$ peaked in 1969-71 in the eastern, central and western subpolar North Pacific at about 115‰, 80‰ and 50‰, respectively. Following the peak, the $\Delta^{14}C$ values dropped to about 20‰, 10‰, and -10‰ in the eastern, central, and western subpolar North Pacific, respectively, in 1990 at about the time of the WOCE program. There is a clear east–west trend in the bomb-^{14}C increase with the highest build up (peak minus pre-bomb ^{14}C) of 220‰ in the eastern, 180‰ in the central and 170‰ in the western subpolar North Pacific.

As a part of comparing the salmon-scales-based $\Delta^{14}C$ time-series to the predictions of OGCMs, we determined the year of the $\Delta^{14}C$ peak throughout the surface ocean waters as predicted by an OGCM (Figure 2). The OGCM predicts that the bomb-^{14}C peak occurred before 1969 in large regions of the subpolar and subtropical North Pacific, subpolar North Atlantic and Southern Ocean. In

contrast, the available surface ocean ^{14}C time-series records provided by salmon scales for subpolar waters of the North Pacific and by corals for subtropical waters, consistently indicate a bomb-^{14}C peak occurring in 1969 or later.

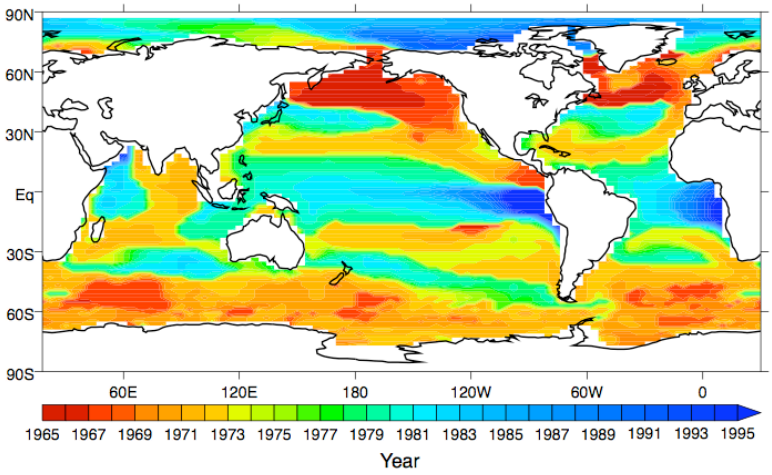

Figure 4. The year of bomb-^{14}C peak in ocean surface waters predicted by the OGCM2. In comparison, the atmosphere bomb-^{14}C peaked in 1964.

Additionally, the OGCM predictions of CO_2 uptake were compared to those of a one-dimensional vertical advection-diffusion model (ADM) whose bomb-^{14}C time-series evolution matched the scales-based $\Delta^{14}C$ time-series. The OGCM predicted penetration depth and burden of anthropogenic CO_2 were 15-18% lower than the values obtained from the ADM.

The OGCM year-of-peak inaccuracy, coupled with these ADM results, suggests that OGCM simulations of anthropogenic CO_2 uptake may be underestimated in large regions of the oceans.

Summary

Under this project, we have demonstrated new methods to reconstruct ^{14}C time–series for cold water regions of the world's oceans. We have applied these methods to archived scales from sockeye salmon that lived in the subpolar North Pacific Ocean. We have developed surface ocean ^{14}C time–series spanning the last ~50 years for three regions of the subpolar North Pacific Ocean. We have compared these salmon-scales-based ^{14}C time-series to OGCM predicted ^{14}C time-series for the same regions. Our results suggest that OGCM simulations of anthropogenic CO_2 uptake may be underestimated in high latitude regions of the oceans. Such high latitude regions are recognized as being very important areas of oceanic CO_2 uptake based on both pCO_2 measurements and OGCM simulations. Notably, CO_2 uptake rates in these cold water regions are sensitive to future warming because of the likely increase in water column stratification. Salmon (or other fish) scale archives potentially provide a means to obtain surface ocean ^{14}C time series in these critical regions. Such surface water ^{14}C time–series records obtained from natural and human–created archives provide

strong criteria against which OGCM predictions of oceanic ^{14}C and, ultimately, anthropogenic CO_2 uptake can be evaluated.

Conference presentations and abstracts

TA Brown, PD Quay, RC Francis and D. Holmgren (1998) (UCRL-JC-130385-ABS) Radiocarbon Time-Histories for Subpolar North Pacific Surface Waters Spanning the Last 50 Years. 1998 Spring AGU Meeting, EOS, April 28, 1998.

TA Brown, KD Freidland, PD Quay and RC Francis (UCRL-JC-138338-ABS) Salmon Scale Derived Open-Ocean Surface Water ^{14}C Concentrations in the Labrador Sea. 17th International Radiocarbon Conference, Judean Hills, Israel, June 18-23, 2000.

External Funding Received by Collaborator:

PD Quay (PI) (1997) Chemical Oceanography Program SGER: Carbon Isotopes of Salmon Scales: A Time History Reconstruction. US NSF OCE SGER-9729728.