Scripps Carbon Dioxide and Oxygen Programs

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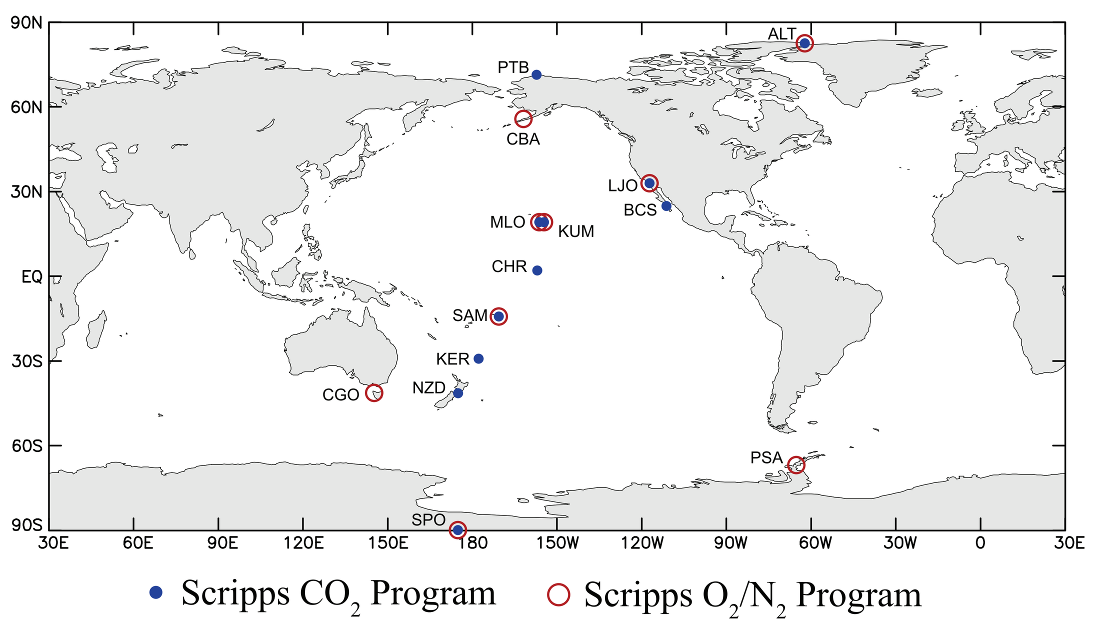
Scripps CO_2 Program - www.scrippsco2.ucsd.edu   Scripps O_2 Program - http://bluemoon.ucsd.edu   Ralph Keeling - rkeeling@ucsd.edu

INTRODUCTION

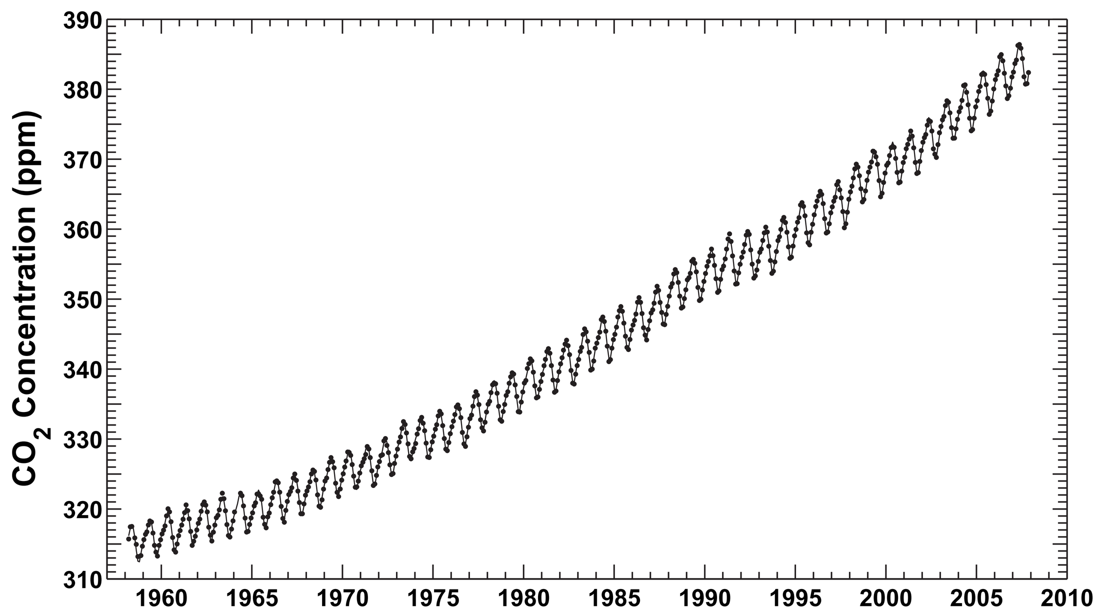
The Scripps CO_2 program was initiated in 1956 by Charles David Keeling and operated under his direction until his passing in 2005. It is currently being continued by Ralph F. Keeling, who also runs the parallel Scripps O_2 program. The combined programs are sustaining the longest continuous measurements of changes in atmospheric carbon dioxide concentration, the isotopes of CO_2, and the atmospheric O_2 concentration (as O_2/N_2 ratio). The program involves flask collections made through cooperative programs with field stations at roughly a dozen stations around the world. The emphasis in the program is in the detection of global and hemispheric trends in these species.

1 SCRIPPS SAMPLING NETWORK

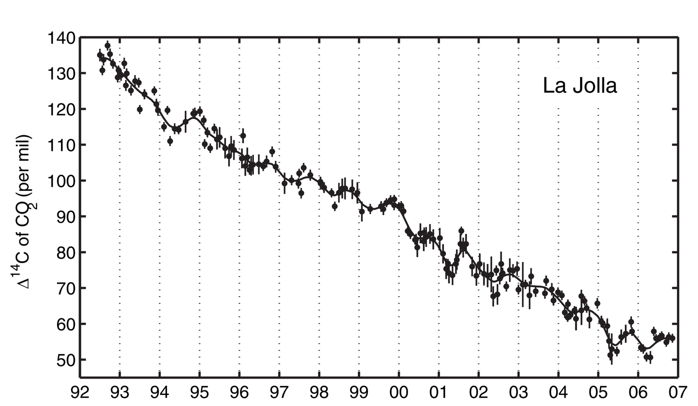


Station symbols: ALT = Alert; PTB = Point Barrow; CBA = Cold Bay; LJO = La Jolla; BCS = Baja California Sur ; KUM = Cape Kumukahi ; MLO = Mauna Loa Observatory; CHR = Christmas Island ; SAM = Samoa; KER = Kermadec; CGO = Cape Grim; NZD = New Zealand ; PSA = Palmer Station ; SPO = South Pole

2 MAUNA LOA CO_2 RECORD

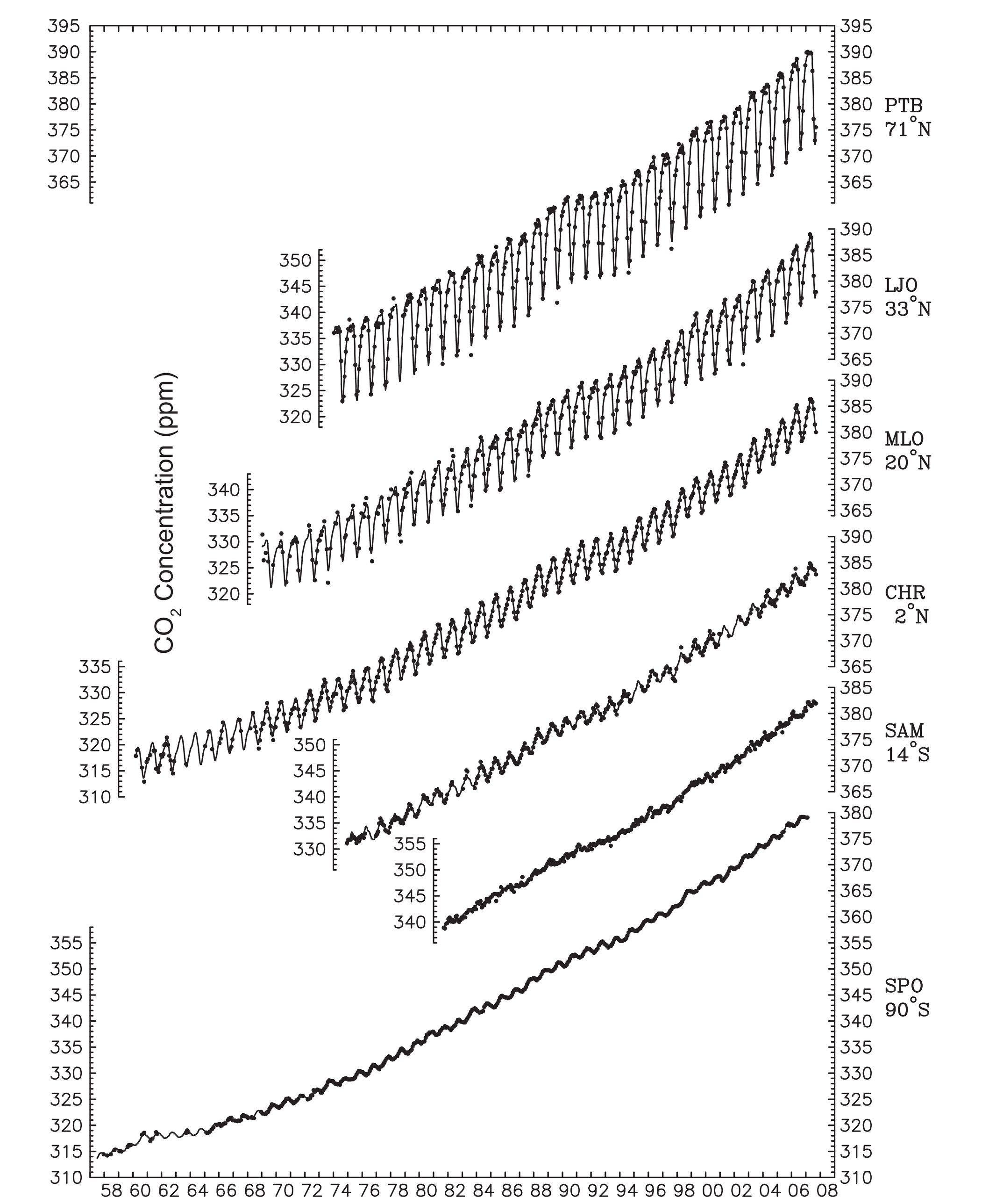


3 $^{14}C/^{12}C$ TREND



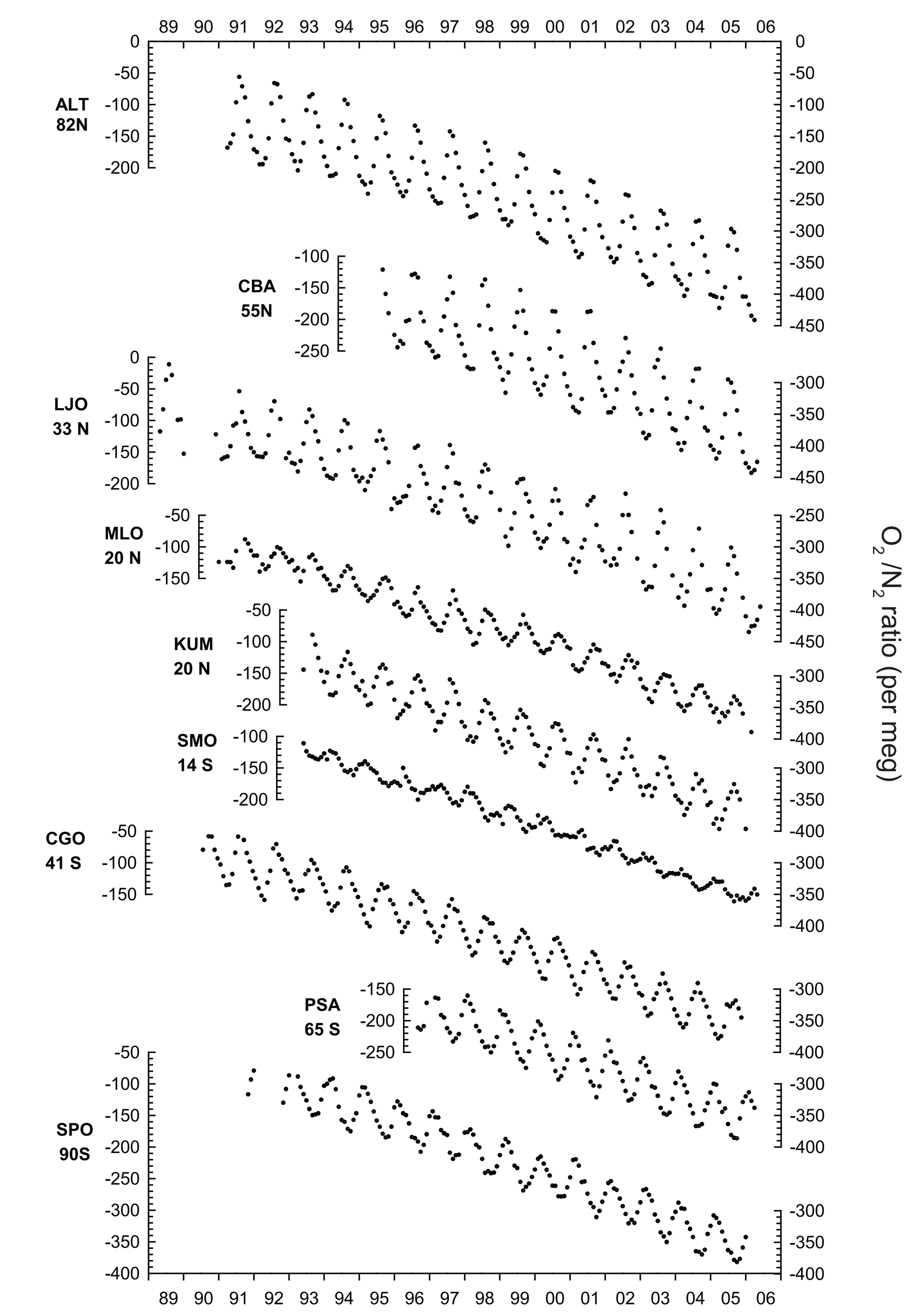
Observations of $^{14}C/^{12}C$ ratio expressed as $\Delta^{14}C$ from CO_2 samples collected at La Jolla. The analyses were made in collaboration with Thomas Guilderson at the Center for Accelerator Mass Spectrometry at the Lawrence Livermore National Laboratory. The downward trend is the result of the redistribution of bomb ^{14}C into the oceans and land biosphere. The trend is also influenced by the rate of fossil-fuel burning.

4 CO_2 TREND



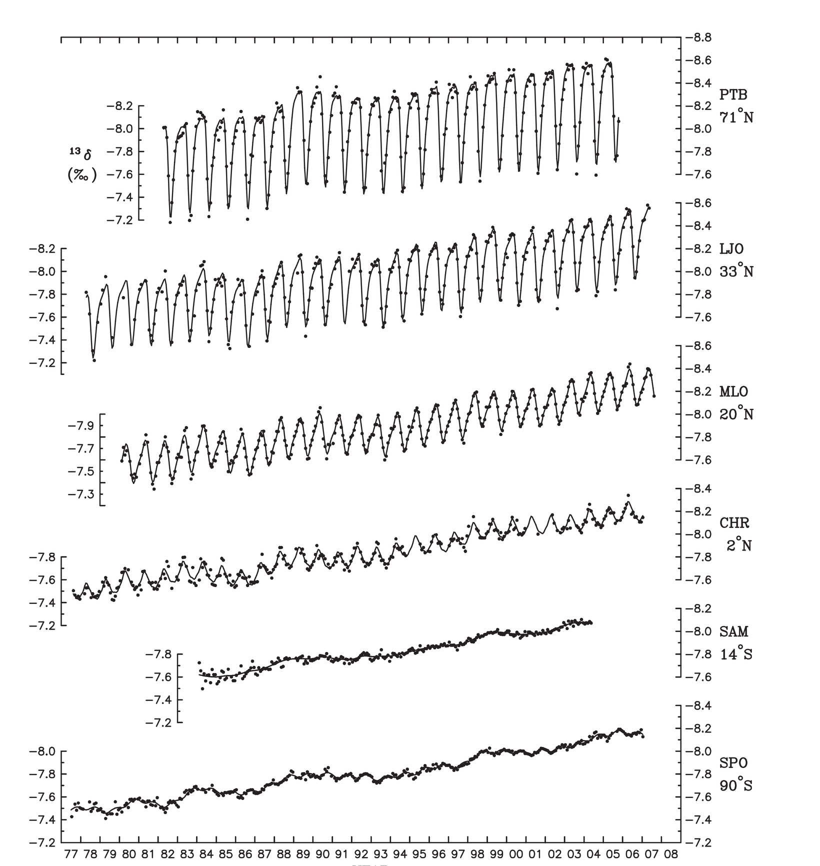
The concentration of atmospheric CO_2 (ppm = µmol mol-1) at six of the eleven stations in the Scripps CO_2 sampling network. The oscillating curves are fits of monthly mean concentration to a spline function and four harmonic terms. The dots denote monthly mean concentrations.

5 O_2 TREND



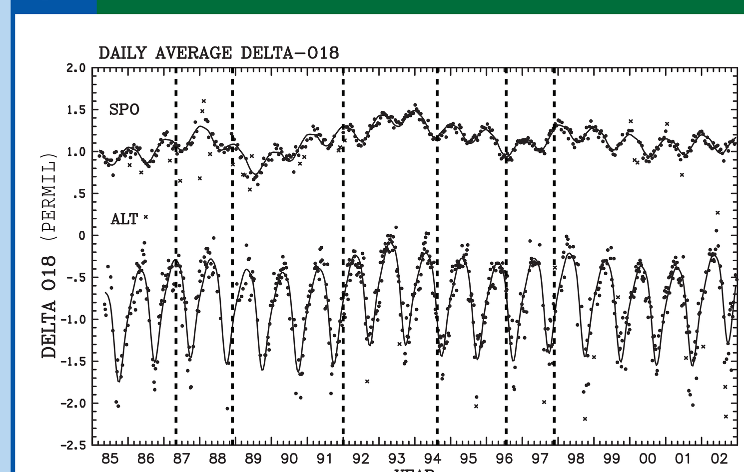
Atmospheric O_2 concentration (reported as O_2/N_2 ratio) from flasks collected in the Scripps O_2 sampling network. Each point represents monthly mean. The O_2 trends tend to mirror the CO_2 trends, with an opposing seasonal cycle and long-term trend. The rate of O_2 loss helps to establish the relative magnitude of the land and ocean sinks for CO_2 globally. The seasonal cycle contains information about rates of metabolic activity in both the land and ocean biospheres.

6 $^{13}C/^{12}C$ TREND



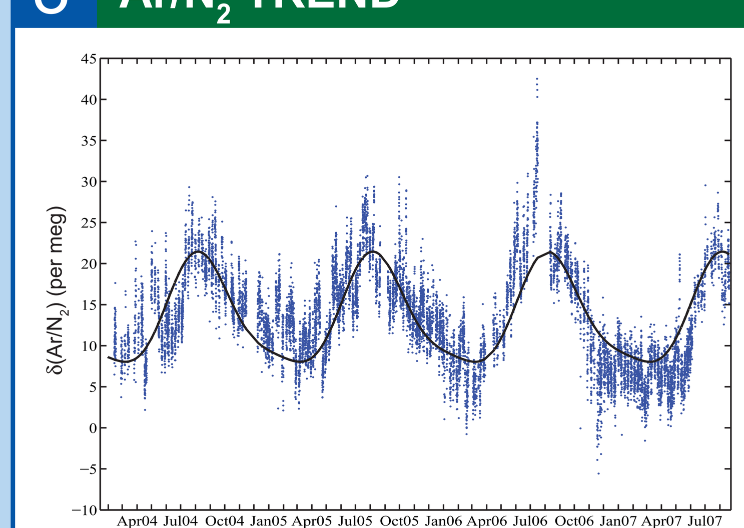
The $^{13}C/^{12}C$ isotopic ratio, expressed as $\delta^{13}C$ (in per mil from isotope standard PDB), for the same stations as in the CO_2 trend figure. The dots indicate monthly averages. The oscillating curves are fits similar to those in the CO_2 trend figure. Note the expanded time-scale and inverted isotopic scale (the latter so that phasing is seen to be similar to that of the CO_2 concentration). The $^{13}C/^{12}C$ data contain useful constraints on changes in metabolic activity and sources and sinks of CO_2 with the land biota.

7 $^{18}O/^{16}O$ TREND



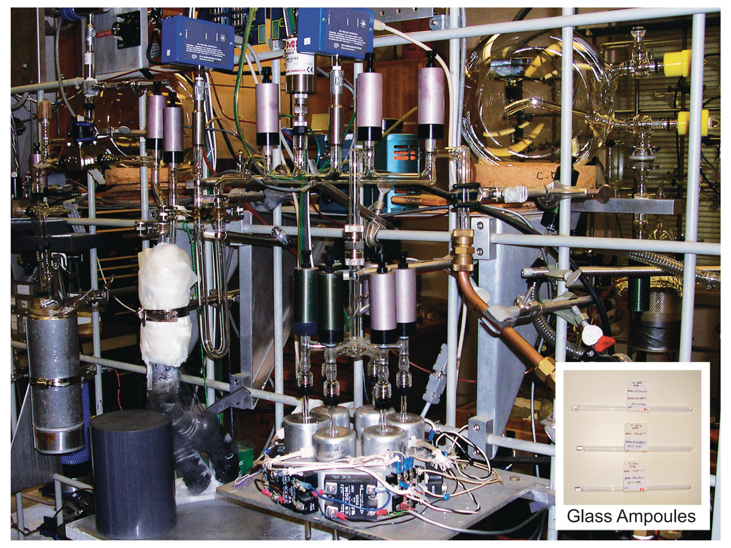
The $^{18}O/^{16}O$ isotopic ratio, expressed as $\delta^{18}O$ (in per mil, positive upwards) for South Pole (SPO, 90ºS) and Alert (ALT, 82ºN). The $^{18}O/^{16}O$ ratio is sensitive to the gross (i.e. back and forth) exchanges of CO_2 with the land biosphere and to the distribution of water isotopes driven by hydrological cycle. Note the coherent interannual variations at these stations, which is evidently a global phenomenon.

8 Ar/N_2 TREND



The Ar/N_2 ratio of the air at La Jolla, California expressed as relative deviation from a reference. These data were obtained by using a continuous analyser (mass spectrometer) to directly analyze the air at La Jolla. Blue points: hourly Ar/N_2 data from La Jolla. Black curve: fit to semi-continuous data based on a two harmonic function and no trend. The Ar/N_2 ratio is potentially useful to trace large-scale warming and cooling of the oceans. The Ar/N_2 ratio is higher in the summer than the winter due to warming of the surface ocean which drives outgassing of Ar due to the temperature dependence of the Ar solubility. The Ar release is offset by a small opposing N_2 release.

9 CO_2 EXTRACTION RACK



System for extracting CO_2 from flasks into glass ampoules. CO_2 is trapped cryogenically from the air using liquid nitrogen, and then transferred into a 1/4" O.D. glass tube. The tube is then sealed using an electronic heating element. Examples of the glass ampoules are shown in the insert. The system allows for up to six flask to be extracted in series. The archived samples have been used in support of $^{14}C/^{12}C$ analyses and for retrospective cross-checks on the calibration of $^{13}C/^{12}C$ and $^{18}O/^{16}O$ ratios.

GOALS & METHODS

Our measurements are pertinent to assessing global and hemispheric sources and sinks of CO_2 and their changes from year to year. The records are also relevant source/sink estimates on finer spatial scales, and are among the first places to look for evidence of climate feedbacks or other "surprises" in the records.

For more than decade, the program has been archiving CO_2 from air samples in sealed glass ampoules for retrospective analysis. As an example of an application, these archives have recently allowed the generation of time series of the radiocarbon $^{14}C/^{12}C$ content of atmospheric CO_2, which is relevant for assessing the distribution of carbon between reservoirs and the rates of fossil-fuel burning.

The O_2 program has also expanded recently to include measurements of the Ar concentration (as Ar/N_2 ratio). This ratio varies as the ocean warms and cools due to thermally-driven ingassing and outgassing of Ar and N_2 by the oceans. The long-term trend in Ar concentration is expected to be useful for assessing the global ocean warming rate.

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