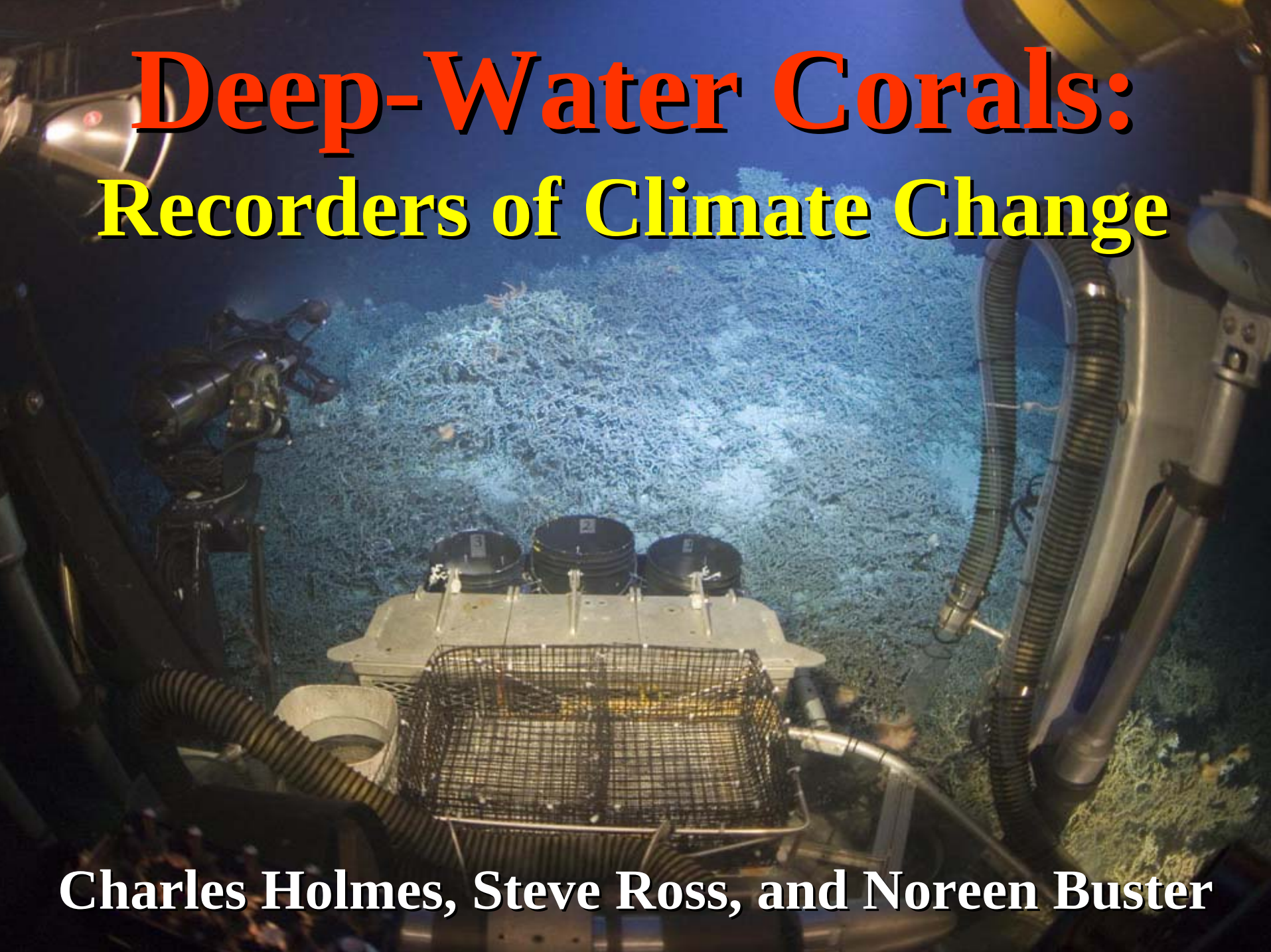
Deep-Water Corals:
Recorders of Climate Change



Charles Holmes, Steve Ross, and Noreen Buster

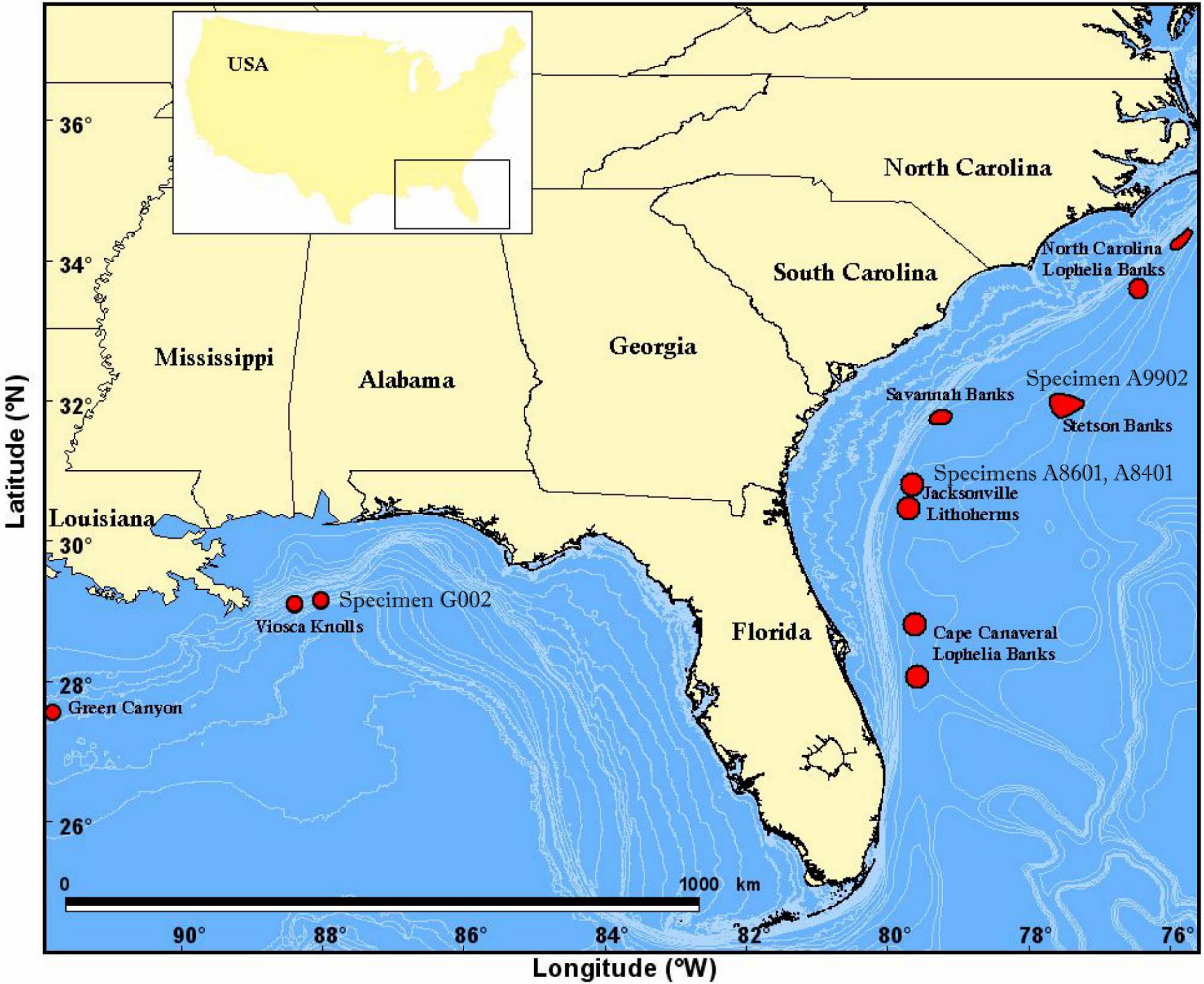
Deep-Water Coral Proxies

- Dated by counting bands and tagging

  Grigg 1976; Wilson 2002

- Dated by Radiometric methods (C-14 and U-series)

  Griffin and Druffel 1989; Druffel et al. 1990; Druffel and Williams 1990; Druffel et al. 1995; Adkins et al. 1998; Mangini et al. 1998; Adkins et al. 1999; Cheng et al. 2000; Goldstein et al. 2001; Adkins et al. 2002; Heikoop et al. 2002; Bond et al. 2005; Roark 2005; Roark et al. 2005; Hill et al. 2006; Williams et al. 2006; and Williams et al. 2007

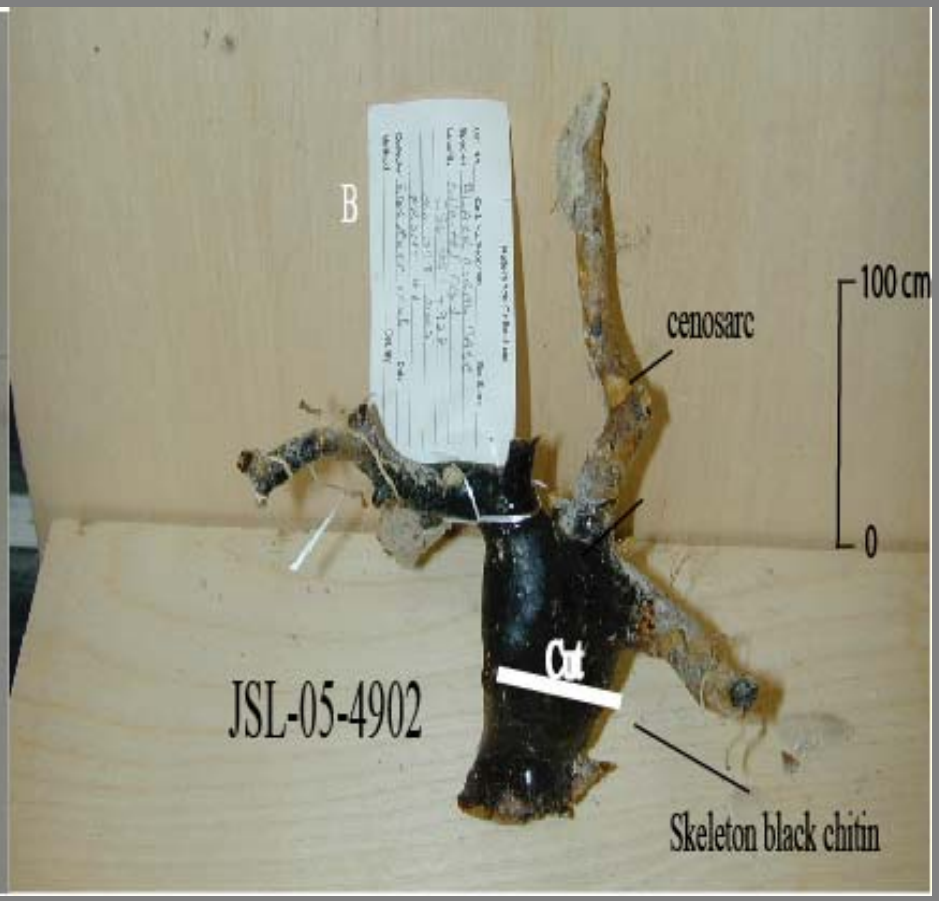

USA
North Carolina
South Carolina
Georgia
Alabama
Mississippi
Louisiana
Florida
North Carolina Lophelia Banks
Specimen A9902
Savannah Banks
Stetson Banks
Specimens A8601, A8401
Jacksonville Lithoherms
Specimen G002
Viosca Knolls
Cape Canaveral Lophelia Banks
Green Canyon
36°
34°
32°
30°
28°
26°
Latitude (°N)
0
1000 km
90°
88°
86°
84°
82°
80°
78°
76°
Longitude (°W)

Antipathidae

é kana ku moana

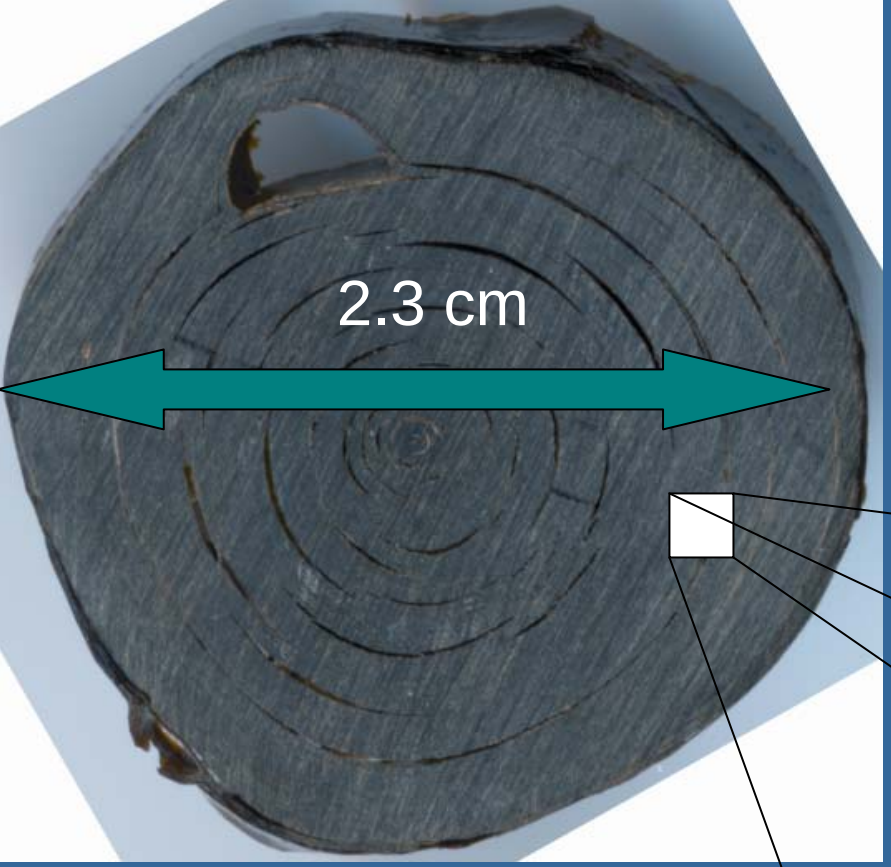
Black coral

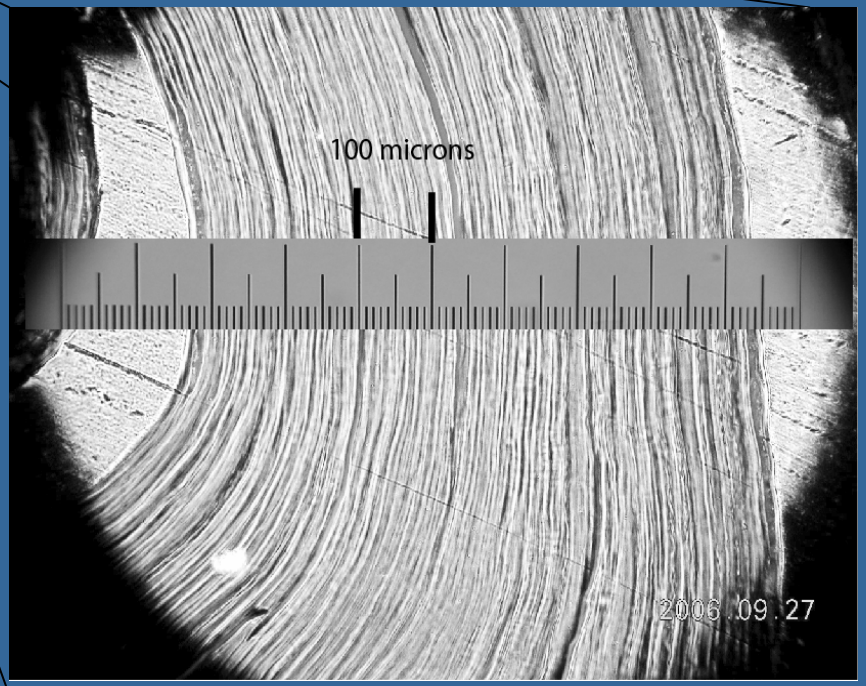
Leipathes glaberrima



Stetson Bank

Savannah Bank

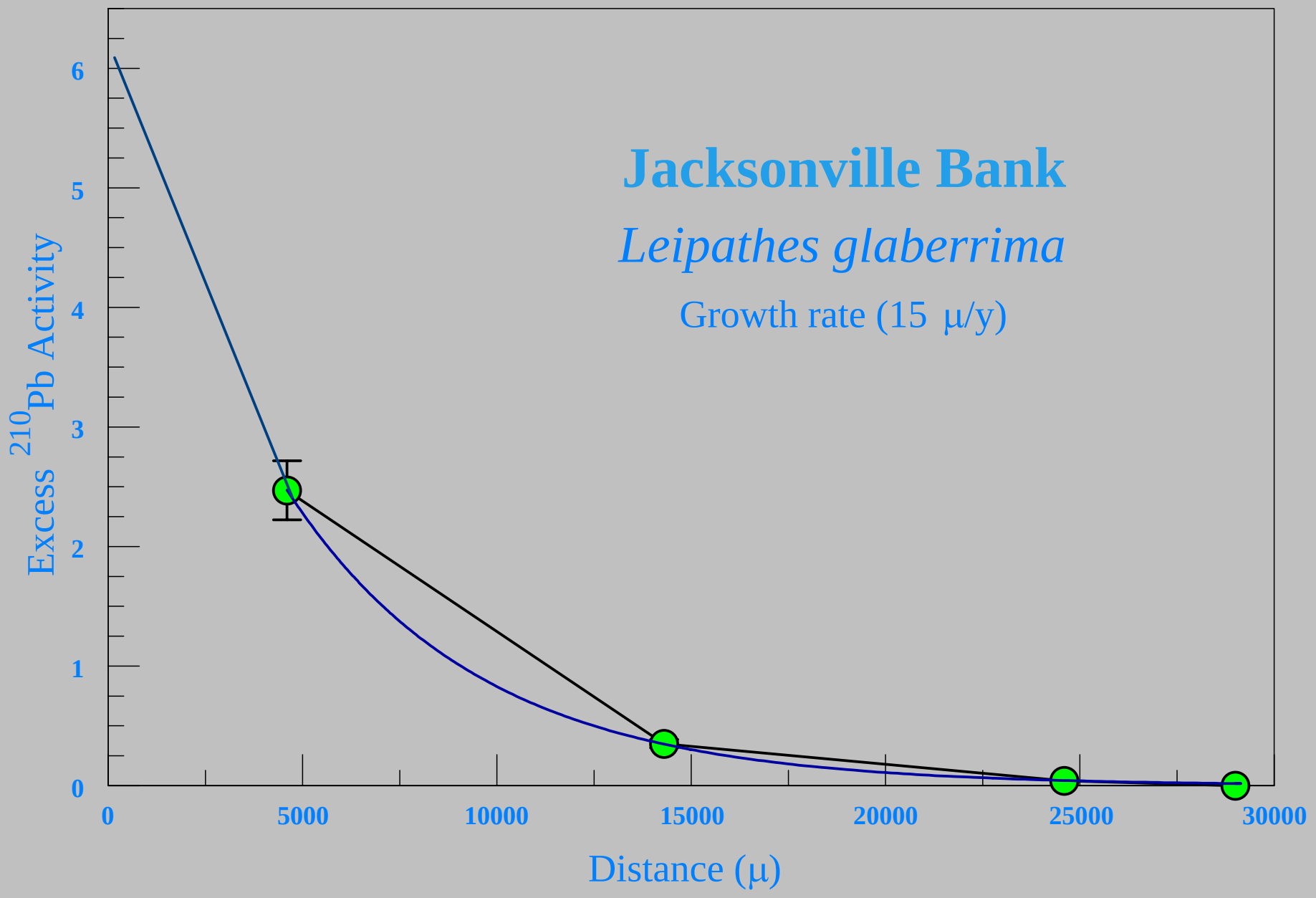

2.3 cm

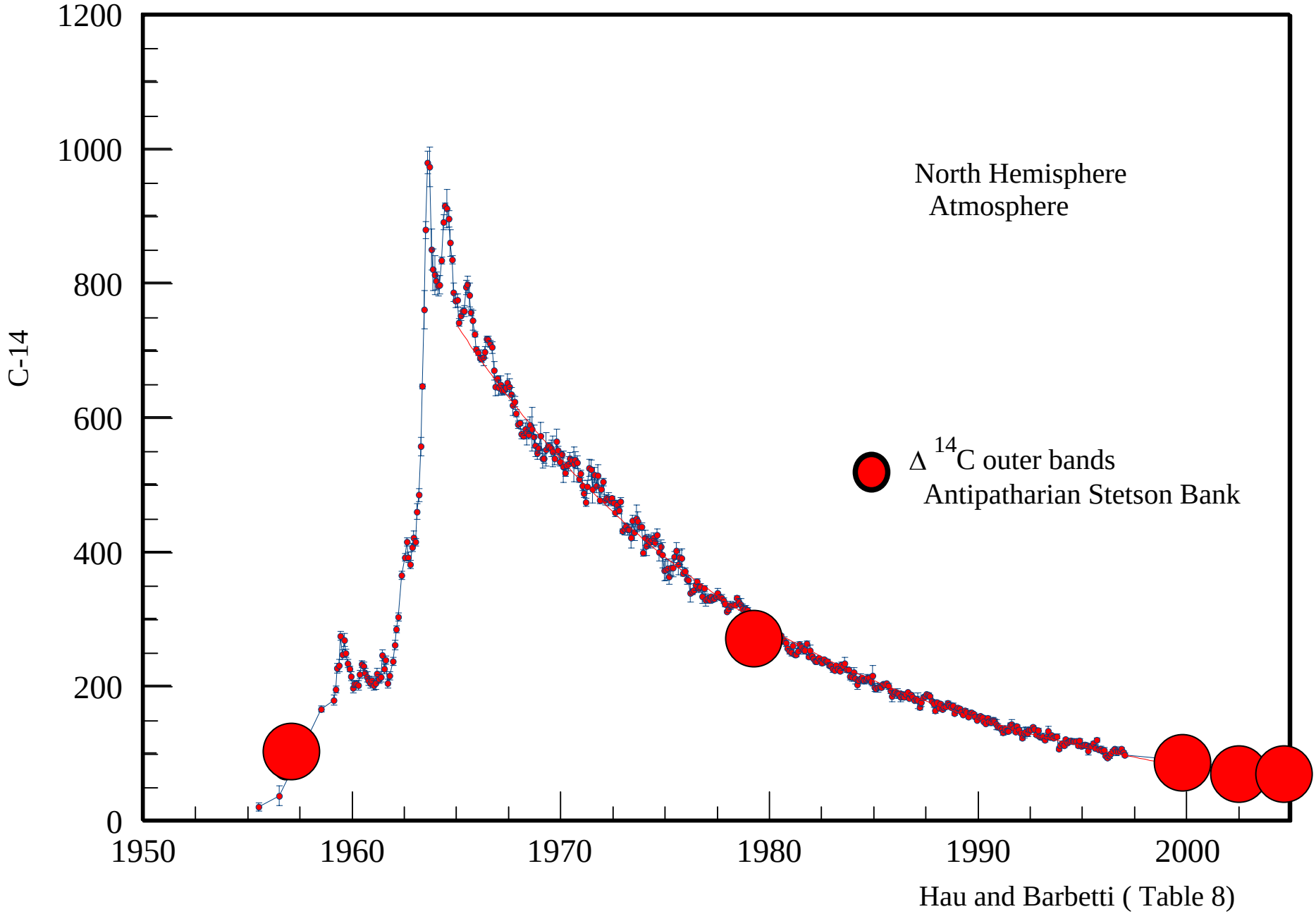

100 microns
2006.09.27

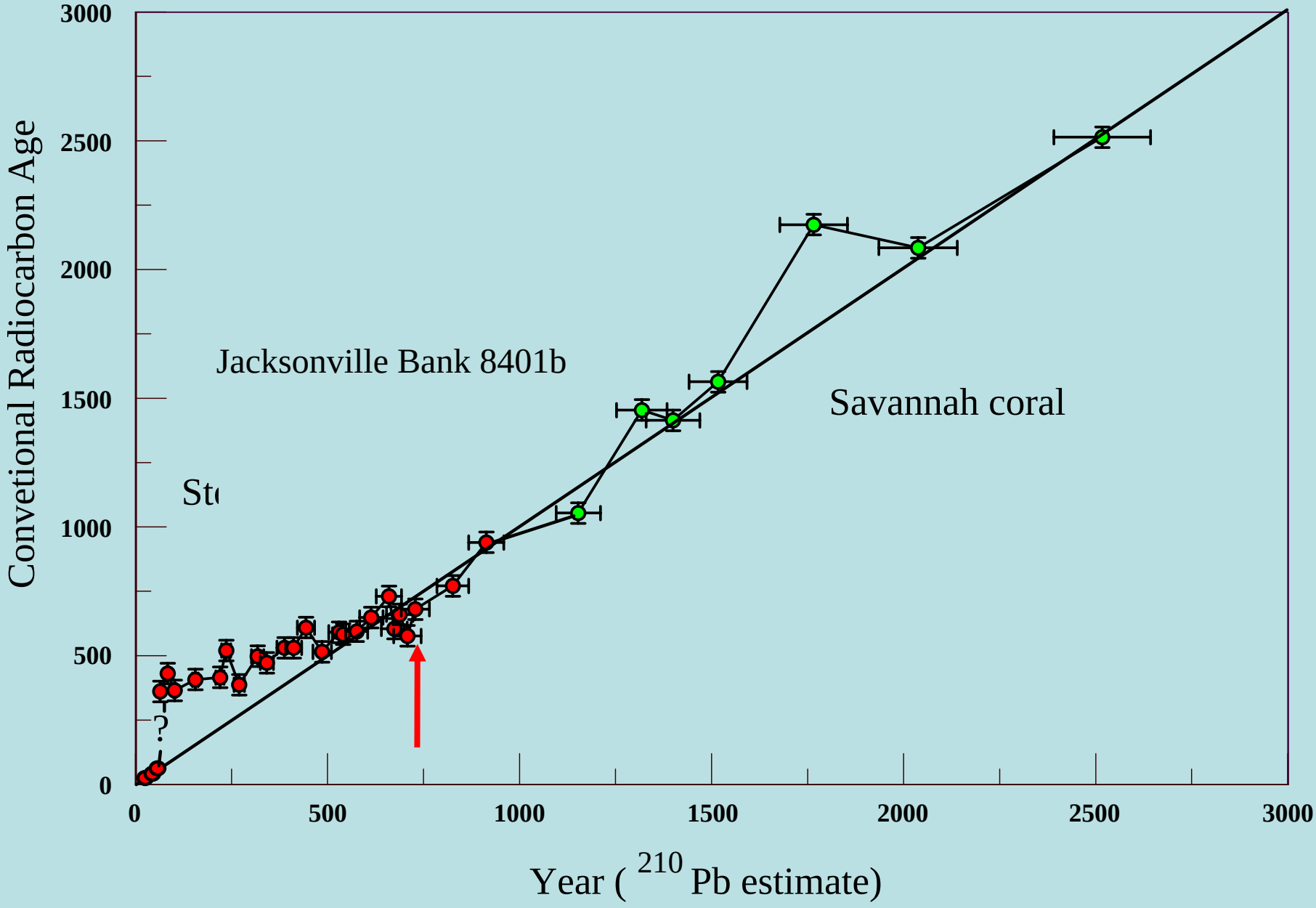
Chronology

Pb-210

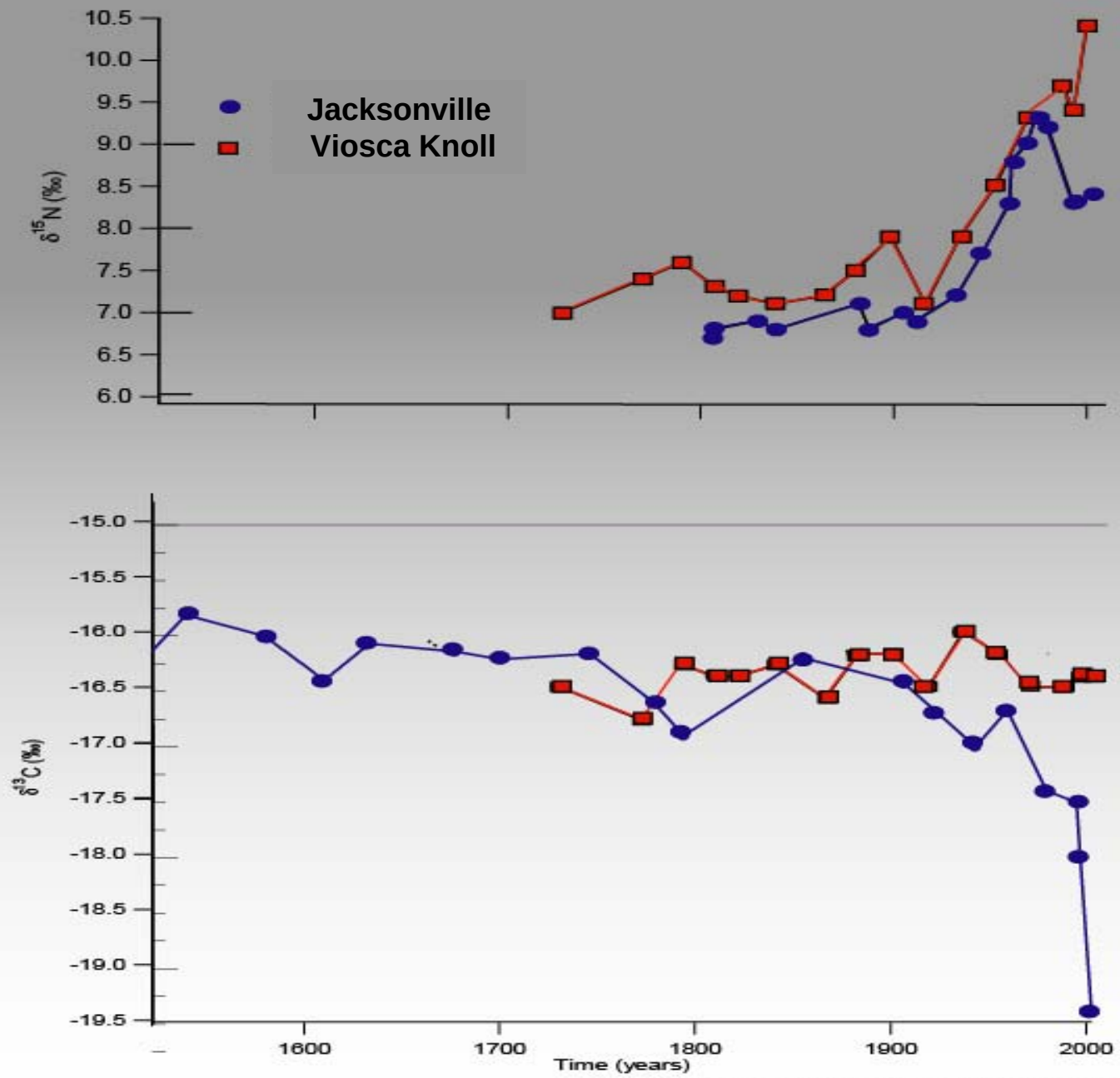
C-14


Jacksonville Bank
Leipathes glaberrima
Growth rate (15 μ/y)
Excess 210Pb Activity
0
1
2
3
4
5
6
0
5000
10000
15000
20000
25000
30000
Distance (μ)


1200
1000
800
600
400
200
0
C-14
1950
1960
1970
1980
1990
2000
North Hemisphere
Atmosphere
Δ 14C outer bands
Antipatharian Stetson Bank
Hau and Barbetti (Table 8)

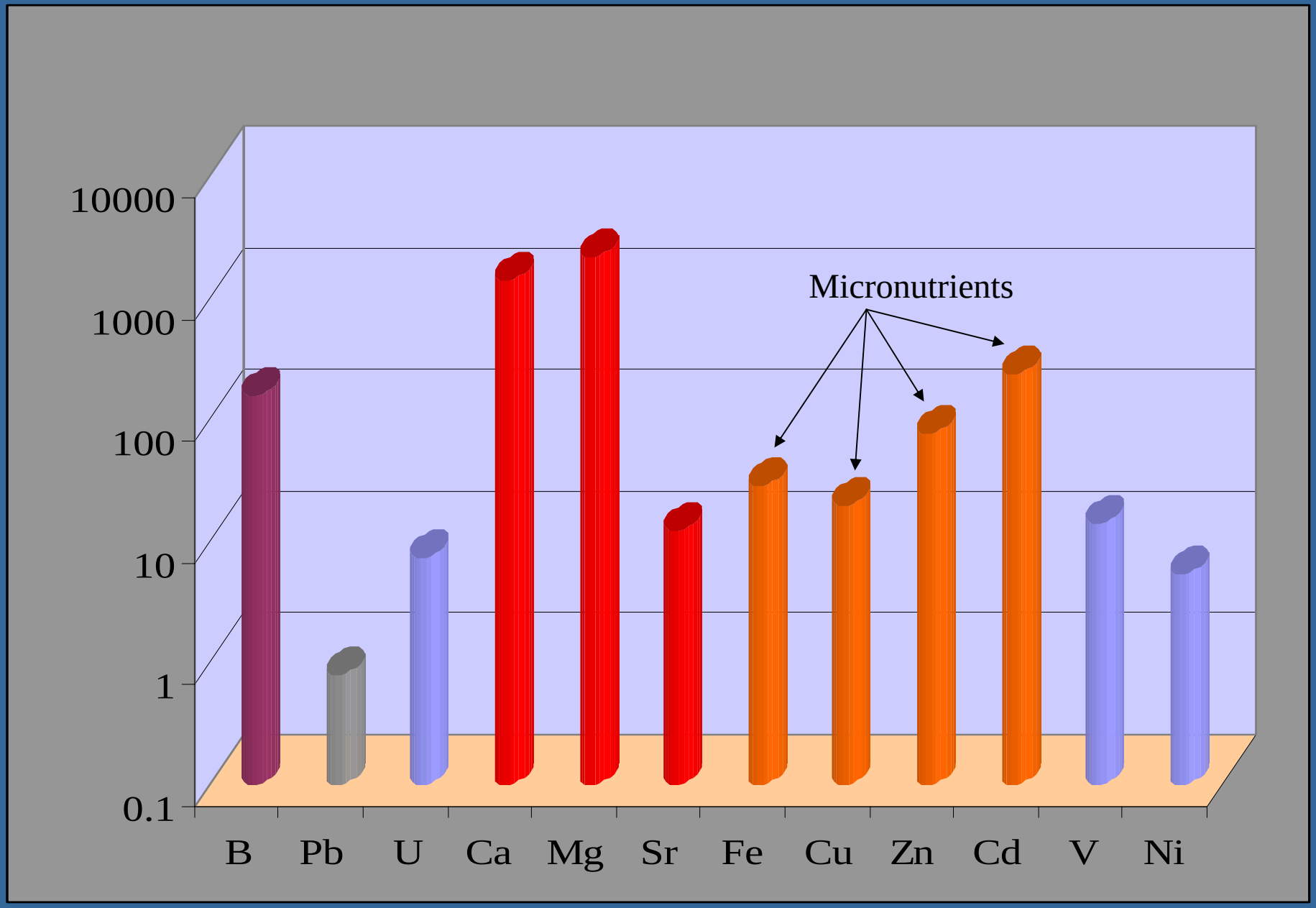

Convetional Radiocarbon Age
Year (210 Pb estimate)
Jacksonville Bank 8401b
Savannah coral
St
?
0
500
1000
1500
2000
2500
3000

Stable Isotopes

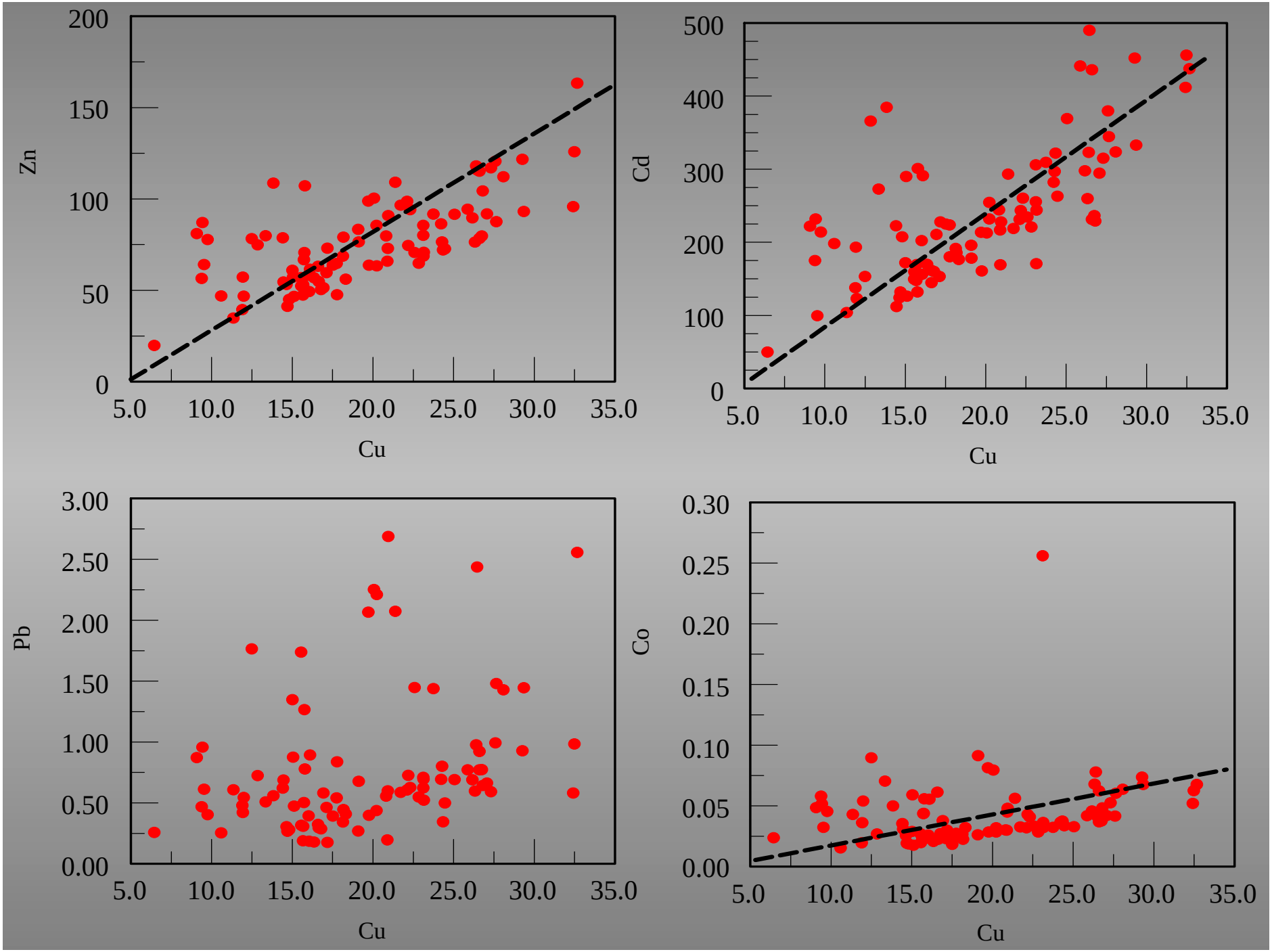


Nitrogen and Gulf data from Williams, 2005

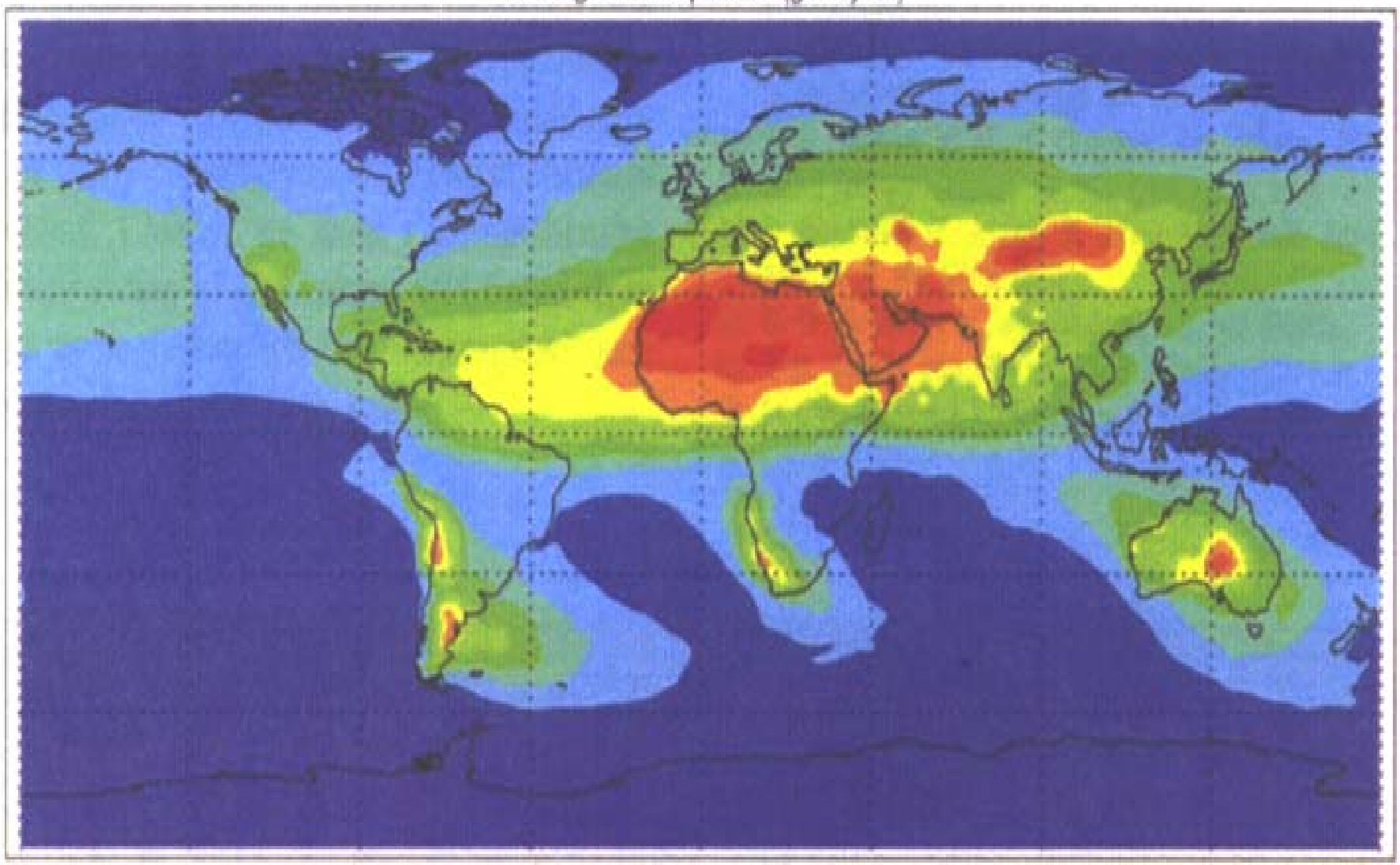
Metals

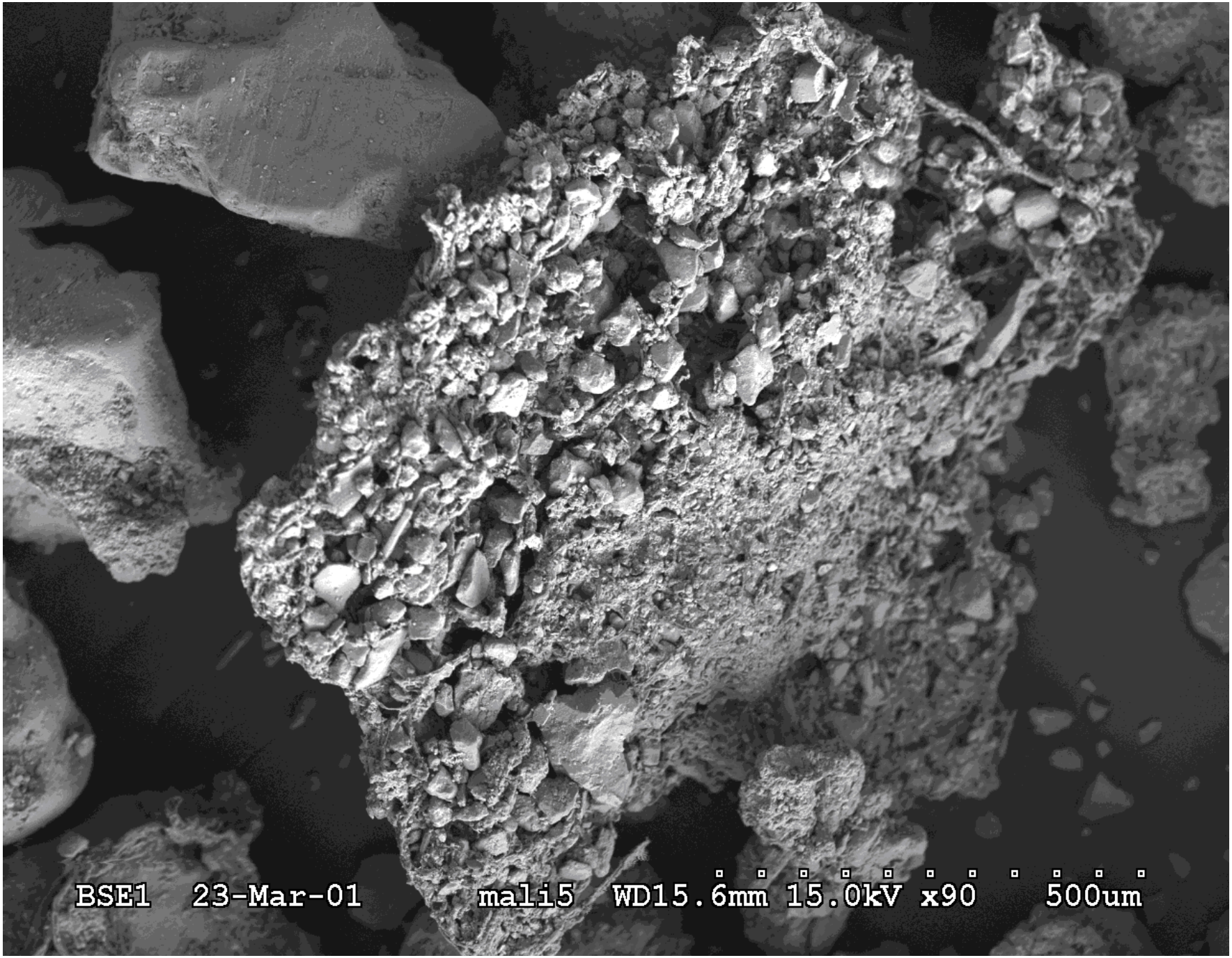


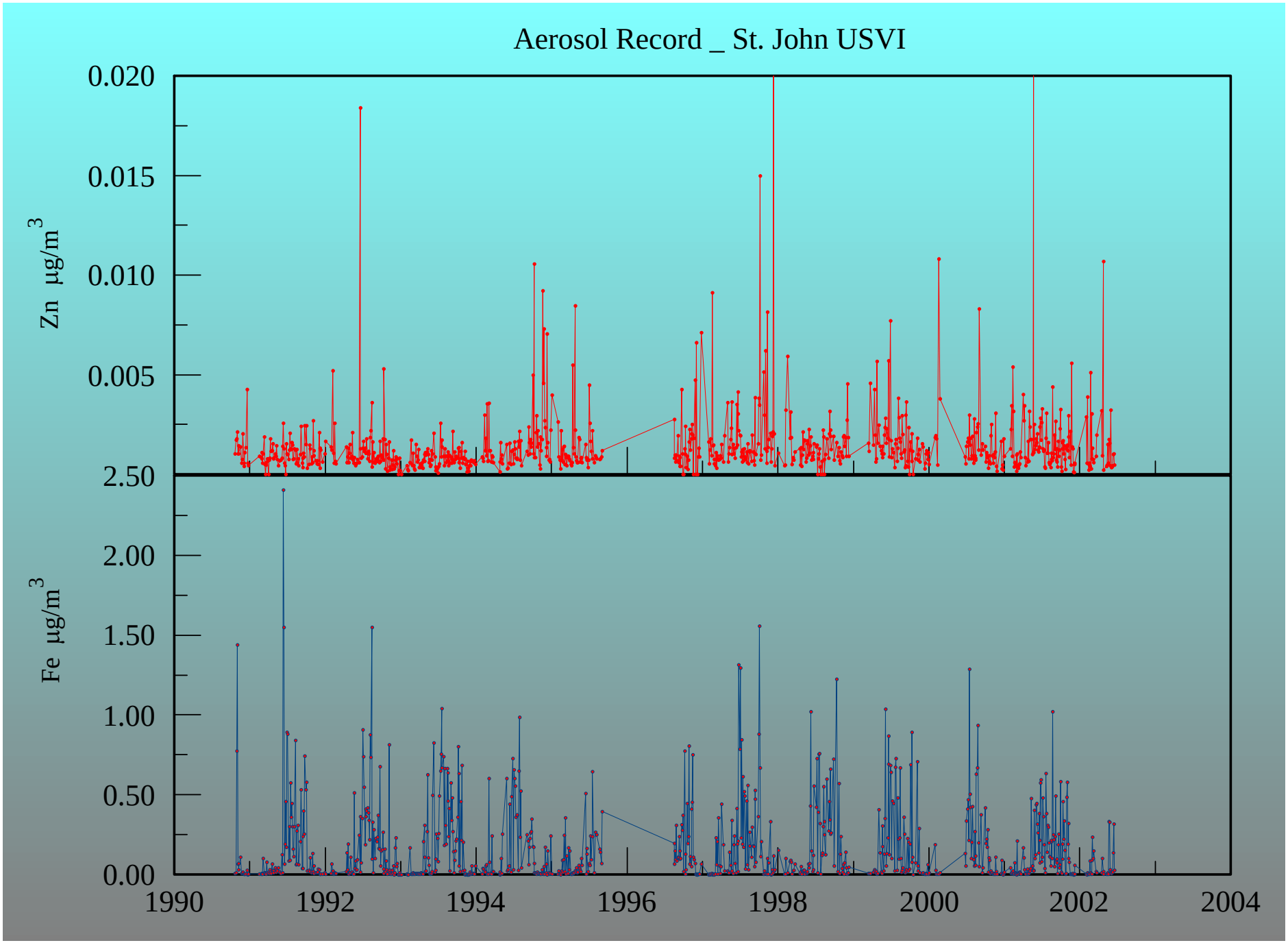
Mean trace metal concentration (ppm)

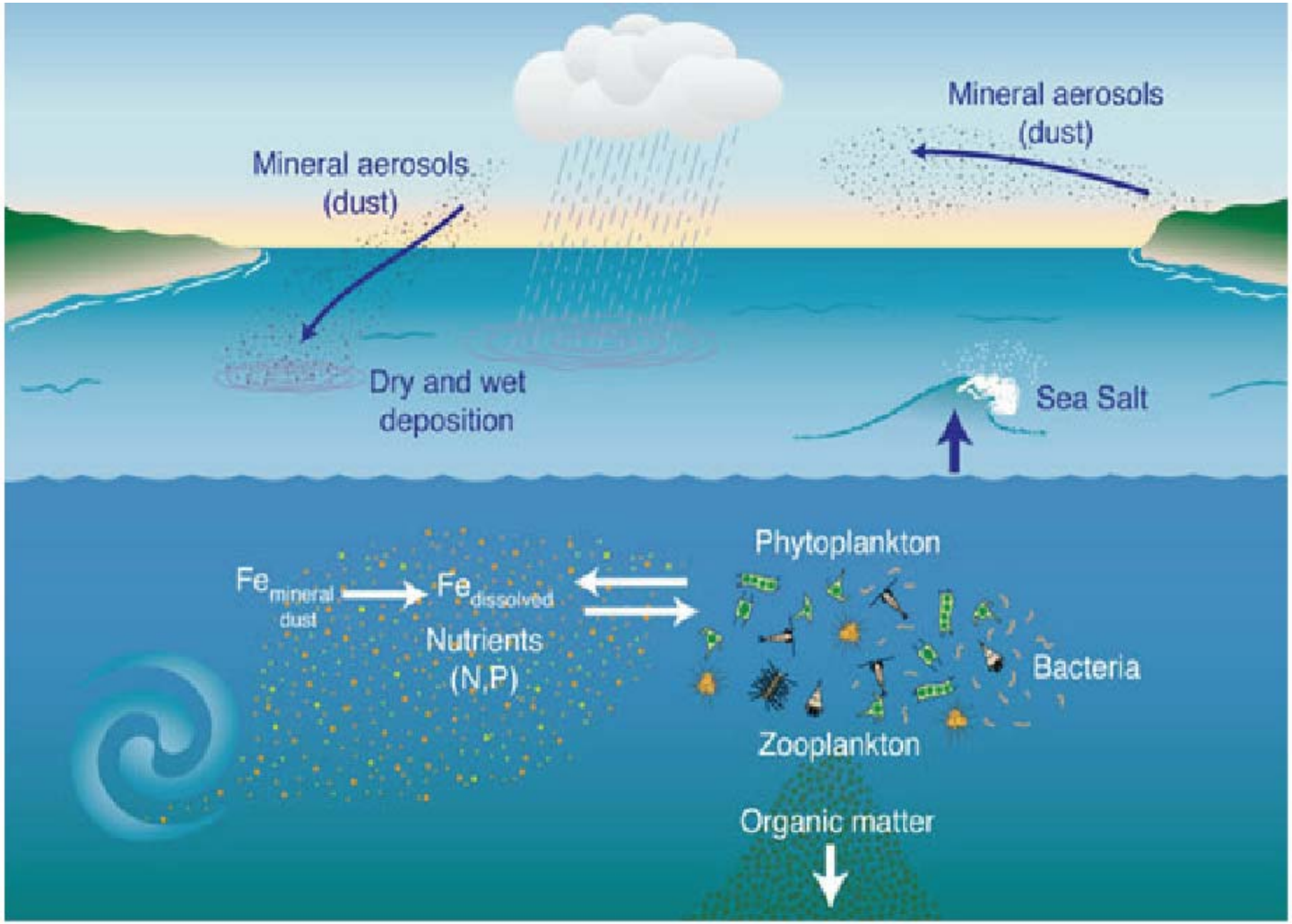

Zn
Cu
Cd
Cu
Pb
Cu
Co
Cu

Average dust deposition (g/m^2/year)

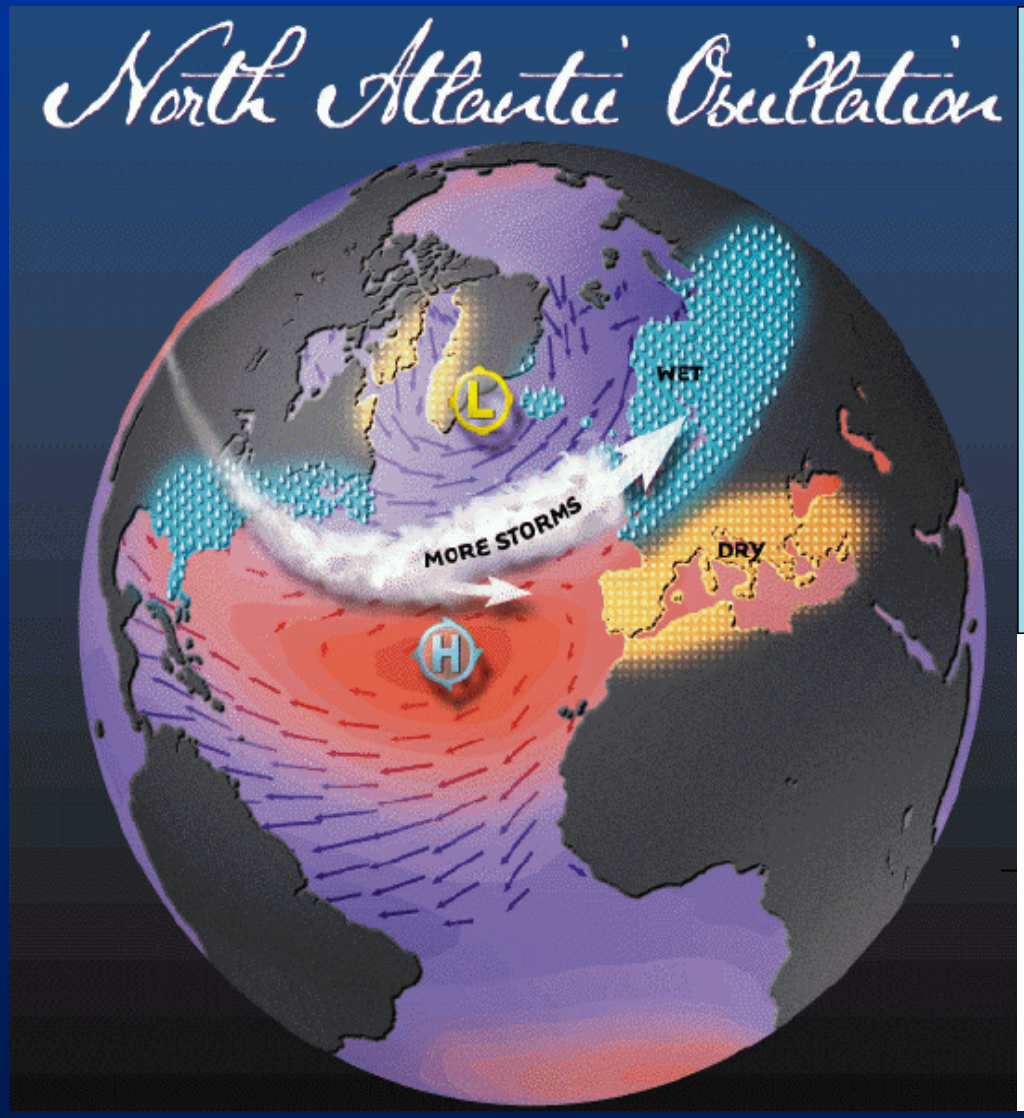


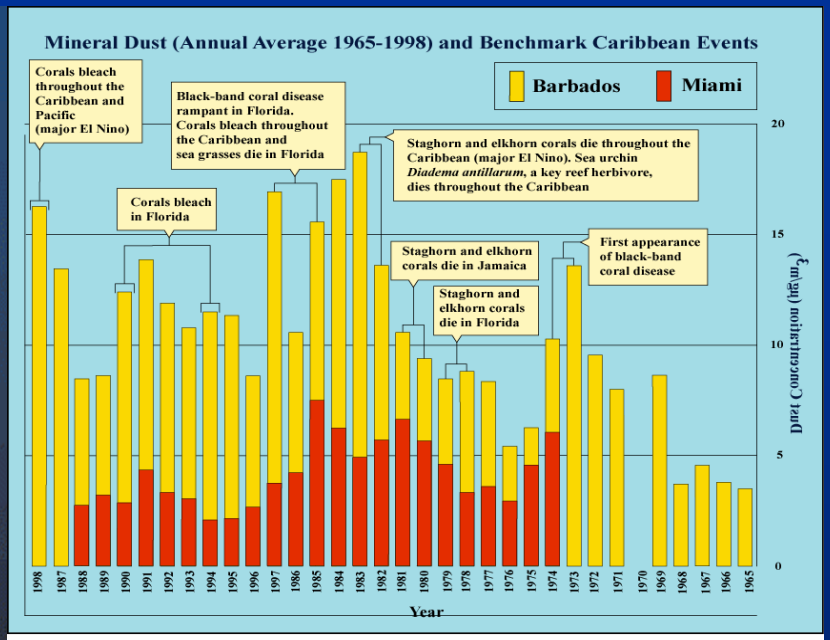

BSE1 23-Mar-01 mali5 WD15.6mm 15.0kV x90 500um

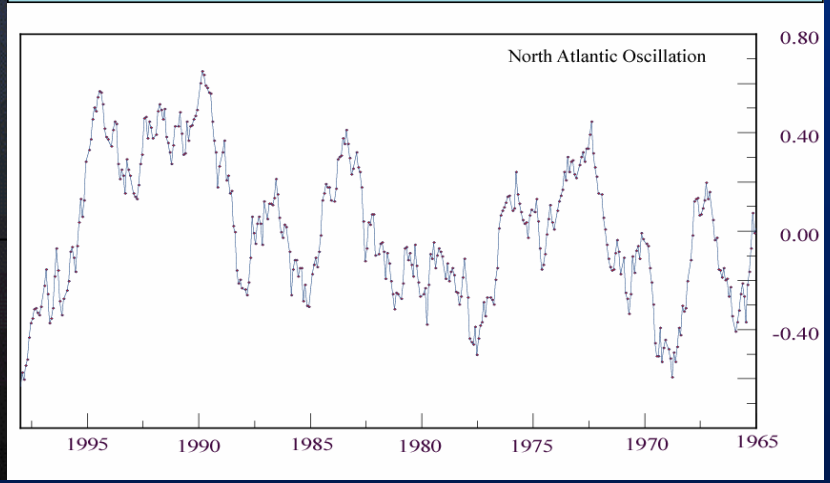

Aerosol Record _ St. John USVI
Zn µg/m3
0.020
0.015
0.010
0.005
2.50
Fe µg/m3
2.00
1.50
1.00
0.50
0.00
1990
1992
1994
1996
1998
2000
2002
2004

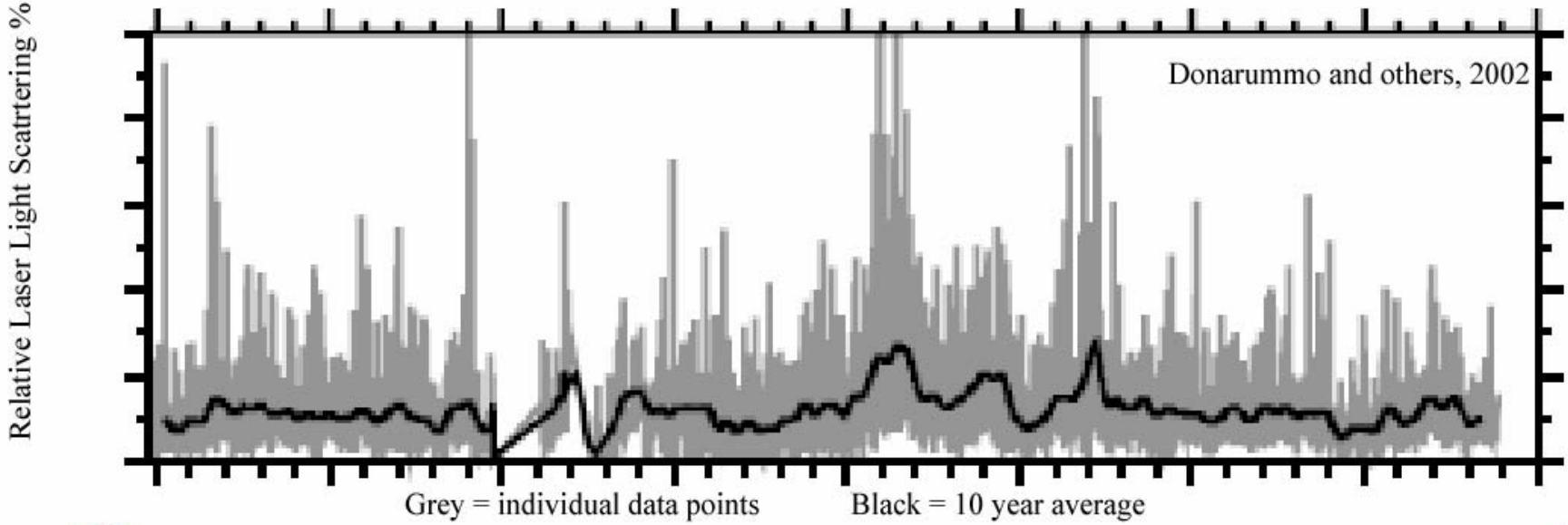


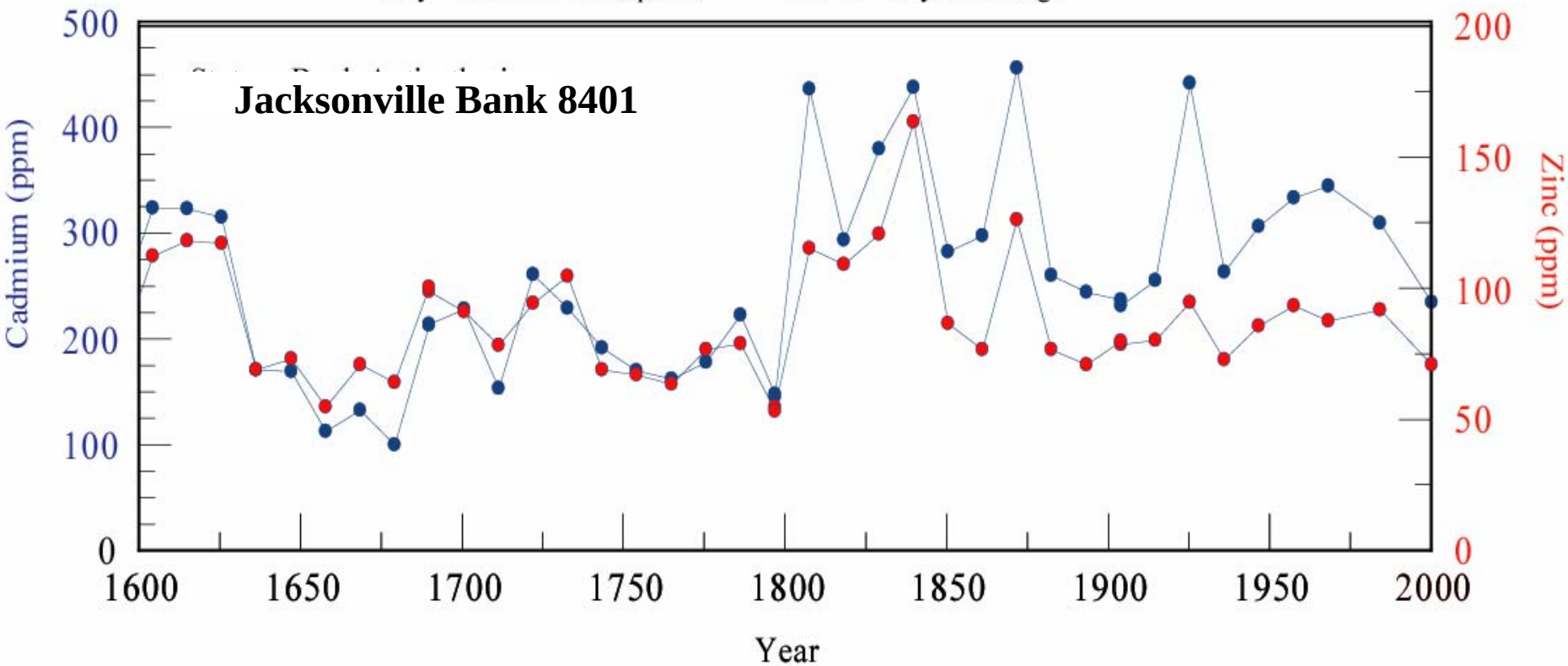
Dust storms sweep iron-rich particles (mineral aerosols) from the continents into the atmosphere. They fall into, or are rained into, the oceans, where iron dissolves into a form that is used, along with other nutrients such as nitrate (N) and phosphate (P), by phytoplankton and bacteria to live and grow. Small marine animals (zooplankton) eat phytoplankton and bacteria. When they excrete fecal pellets or die, organic matter is transferred to the depths. (Jack Cook, Woods Hole Oceanographic Institution)

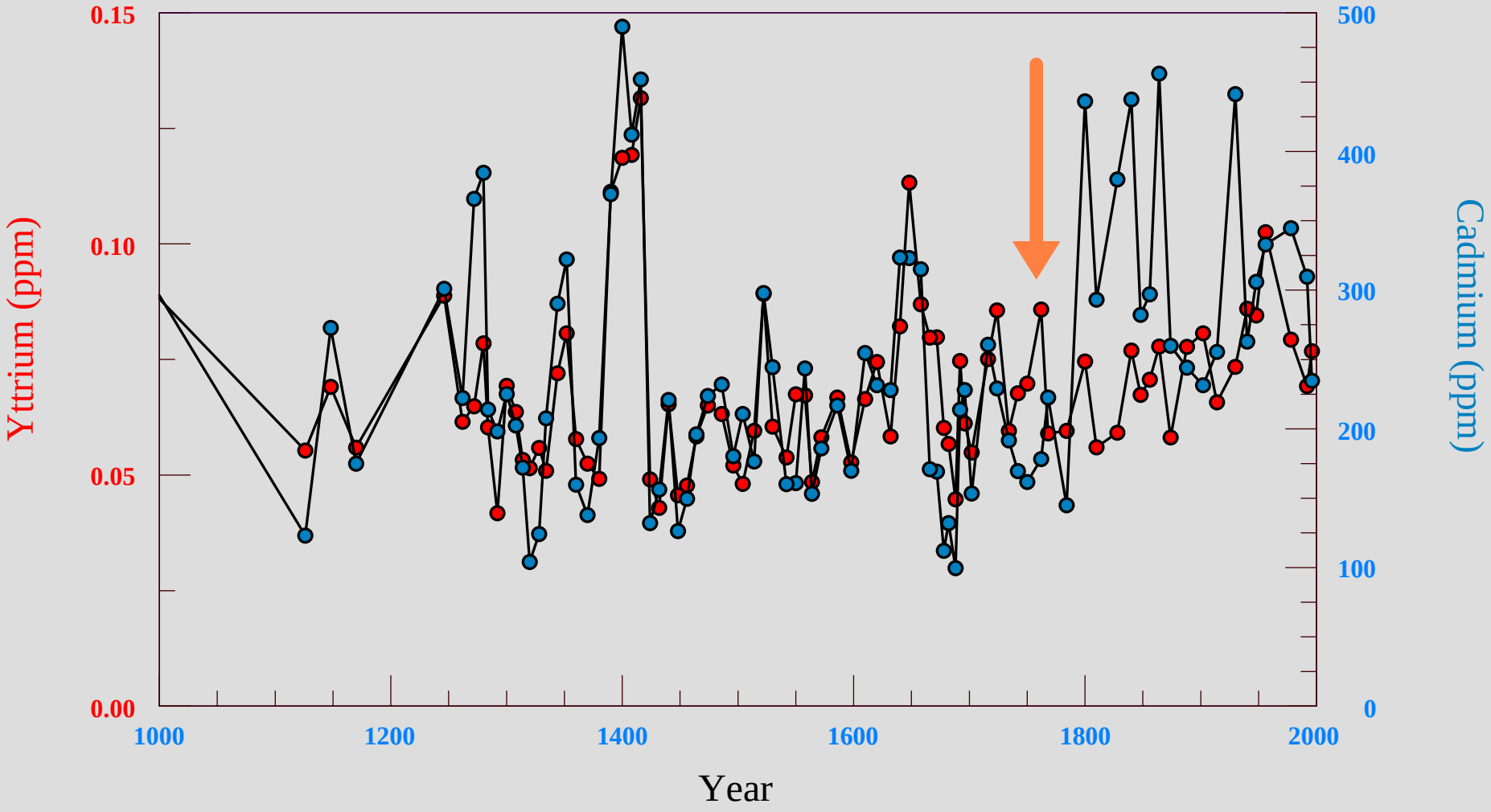

North Atlantic Oscillation
WET
MORE STORMS
DRY
L
H

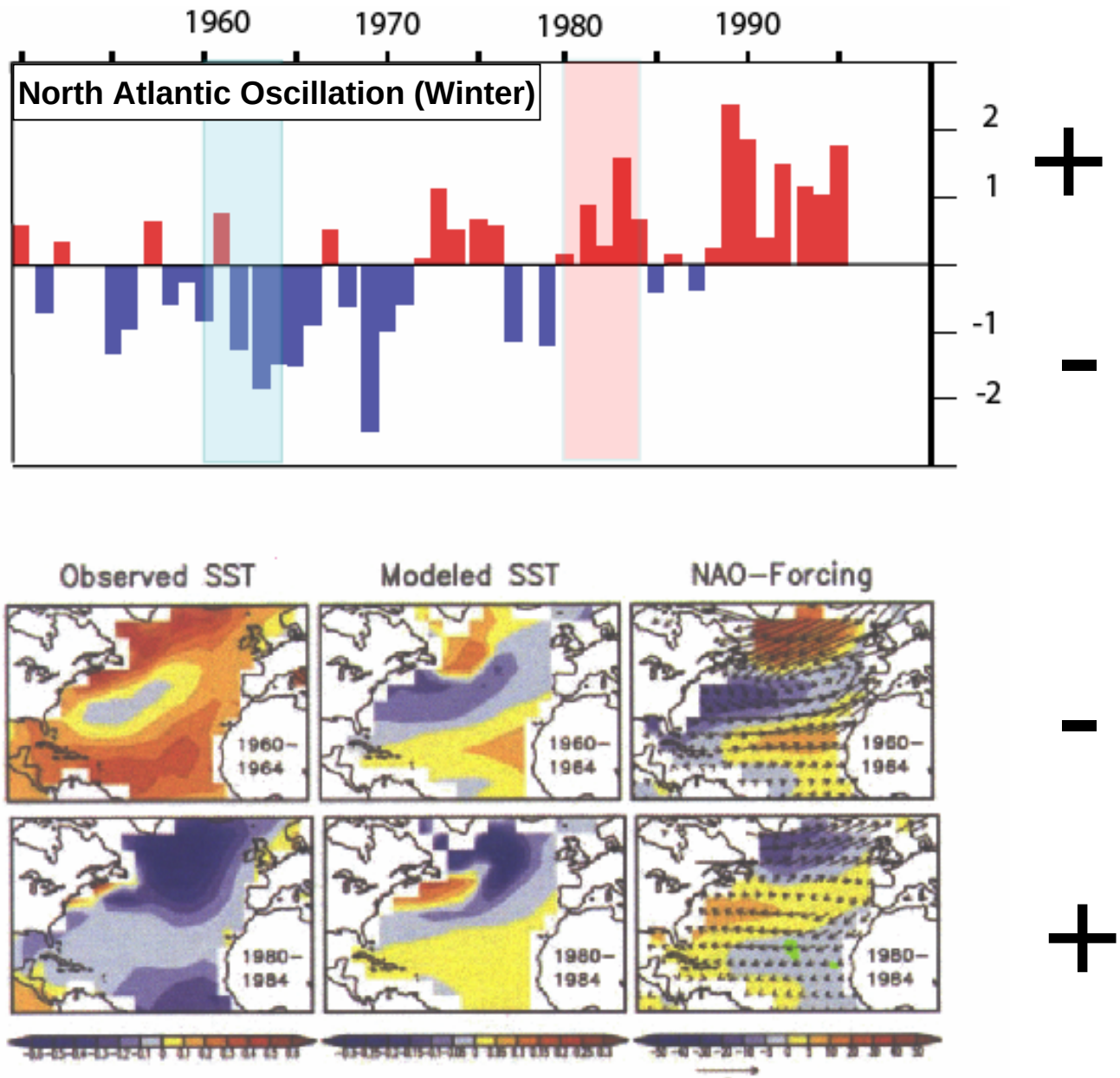

Mineral Dust (Annual Average 1965-1998) and Benchmark Caribbean Events
Barbados
Miami
Corals bleach throughout the Caribbean and Pacific (major El Nino)
Black-band coral disease rampant in Florida. Corals bleach throughout the Caribbean and sea grasses die in Florida
Staghorn and elkhorn corals die throughout the Caribbean (major El Nino). Sea urchin *Diadema antillarum*, a key reef herbivore, dies throughout the Caribbean
Corals bleach in Florida
Staghorn and elkhorn corals die in Jamaica
Staghorn and elkhorn corals die in Florida
First appearance of black-band coral disease
Dust Concentration (µg/m³)
0
5
10
15
20
1998 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1986 1985 1984 1983 1982 1981 1980 1979 1978 1977 1976 1975 1974 1973 1972 1971 1970 1969 1968 1967 1966 1965
Year


North Atlantic Oscillation
0.80
0.40
0.00
-0.40
1995
1990
1985
1980
1975
1970
1965


Relative Laser Light Scattering %
Donarummo and others, 2002
Grey = individual data points
Black = 10 year average

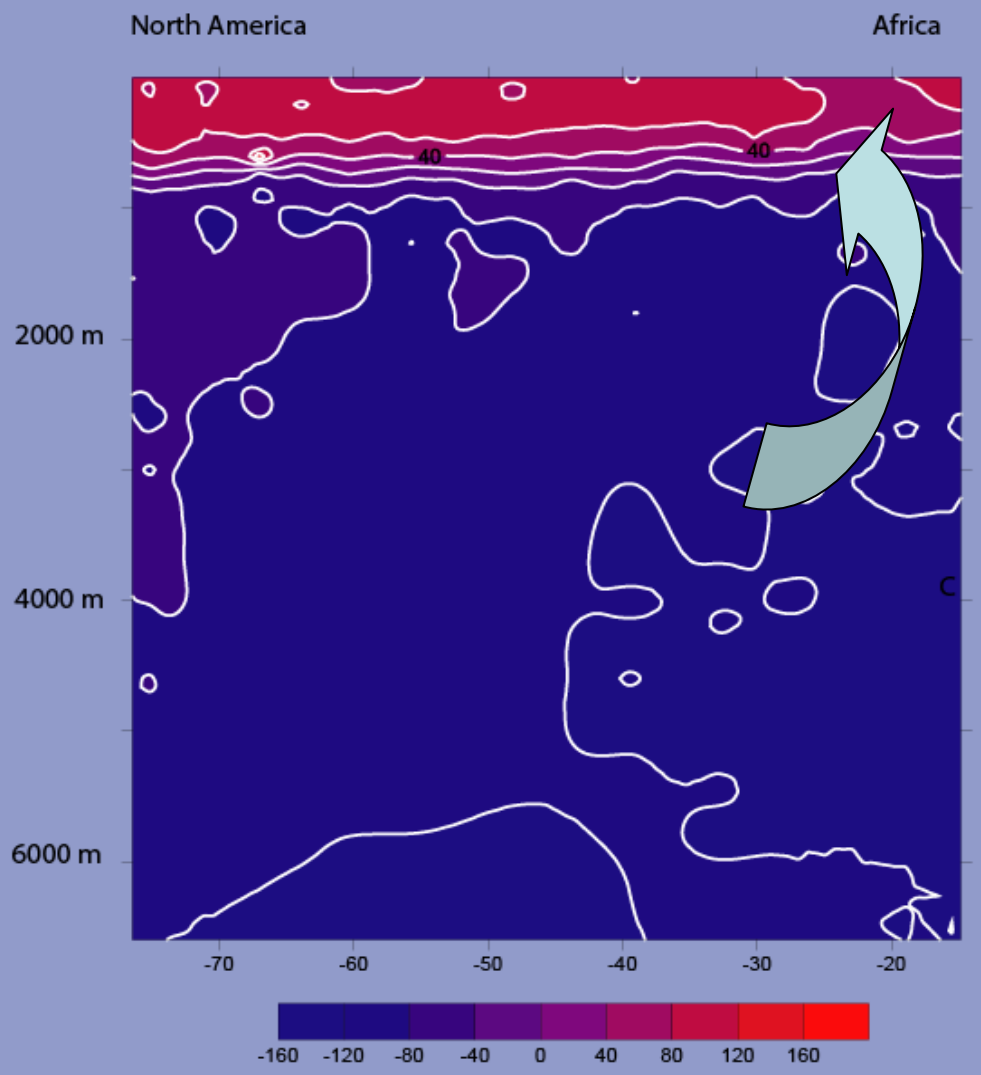

Jacksonville Bank 8401
Cadmium (ppm)
Zinc (ppm)
Year
0
100
200
300
400
500
0
50
100
150
200
1600
1650
1700
1750
1800
1850
1900
1950
2000


0.15
0.10
0.05
0.00
Yttrium (ppm)
500
400
300
200
100
0
Cadmium (ppm)
1000
1200
1400
1600
1800
2000
Year

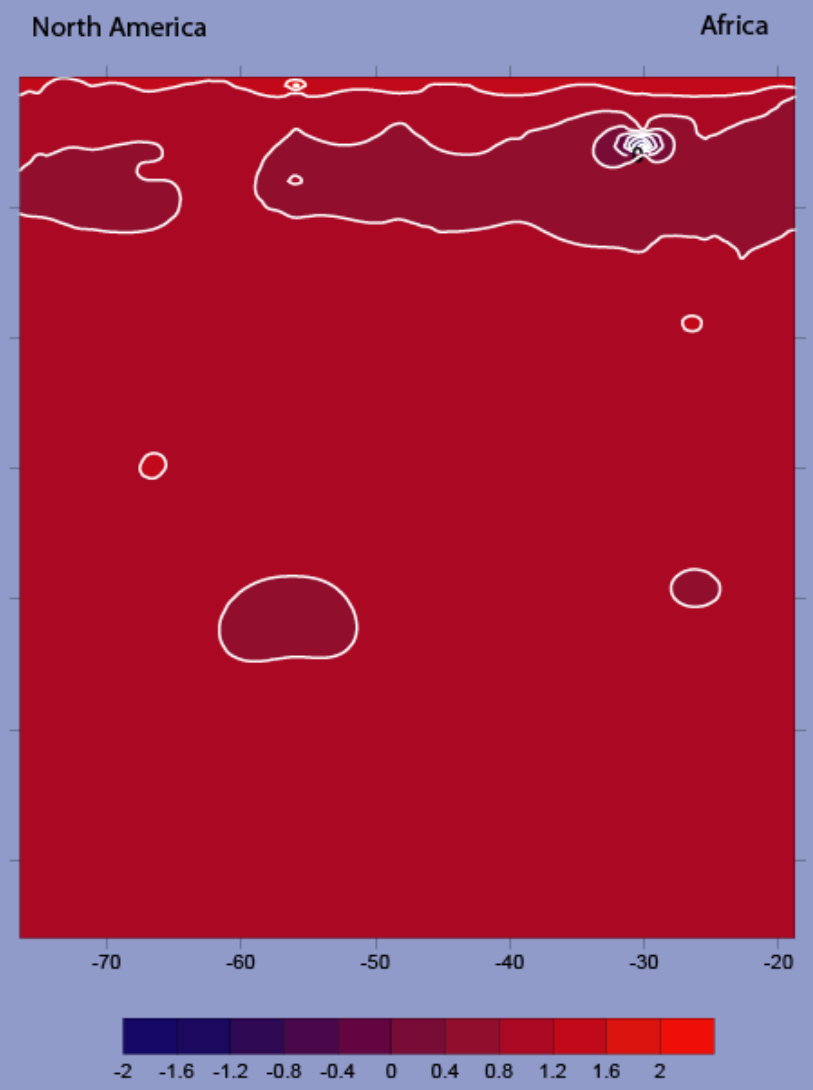


Modified from Greatbatch, 2000

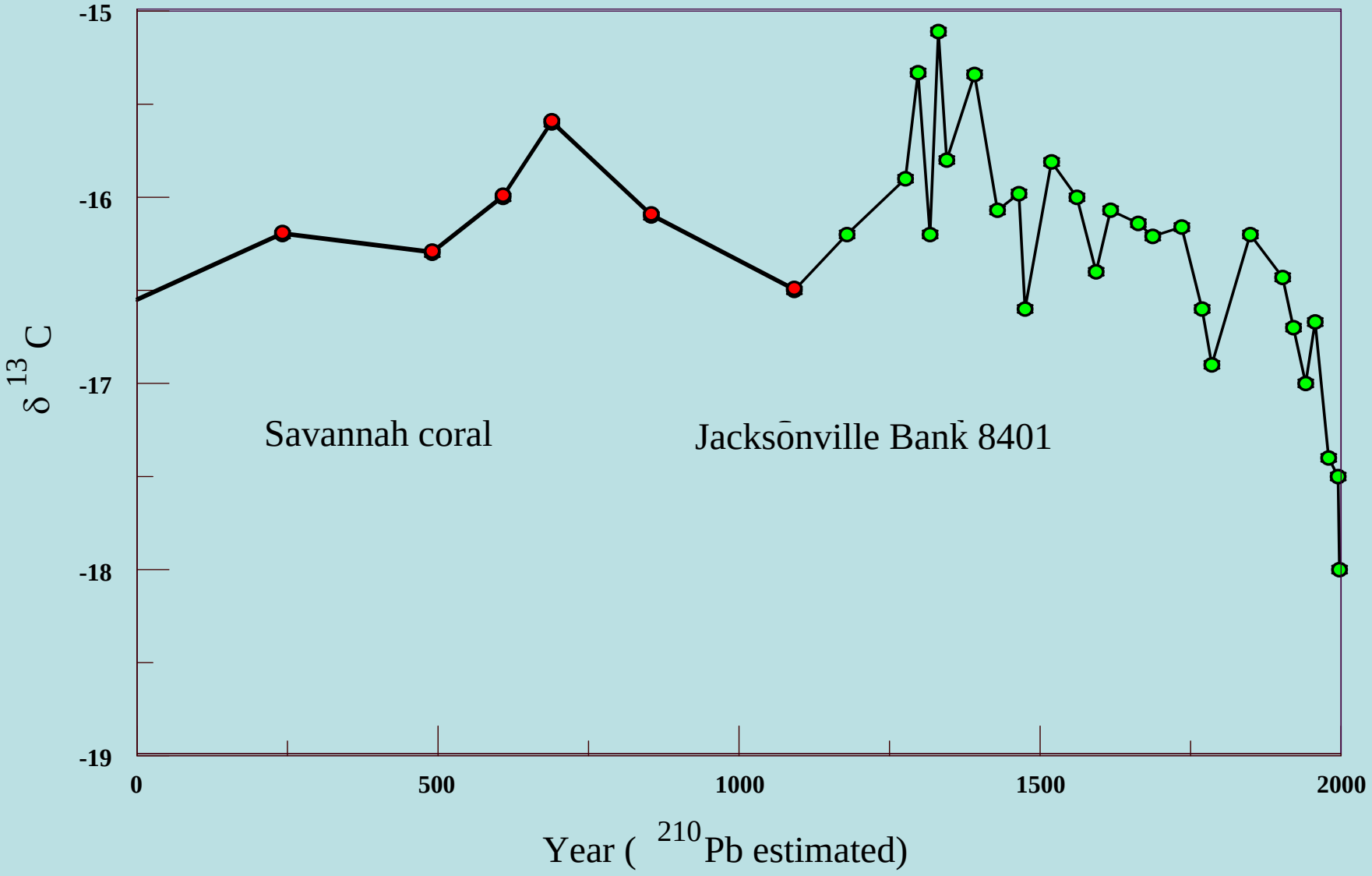
Carbon isotopic composition of DIC transatlantic Cross Section at 25 degrees North



$\Delta\ ^{14}C$



$\delta\ ^{13}C$


-15
-16
-17
-18
-19
0
500
1000
1500
2000
δ 13 C
Savannah coral
Jacksonville Bank 8401
Year (210 Pb estimated)

Future Work

- Carbon, Nitrogen, and Sulfur – information on trophic intensity
- Metals and Metal Isotopes – will identify metal sources and water mass exchange
- Boron – water chemistry – history (pH)
- Calcium and Magnesium – water temperature and chemistry
- Rare earths – erosion rates and sources

Conclusion

Long-lived black corals in the waters of the East-coast of the United States contain an incomparable chemical and climate history of the Western Atlantic Ocean. With annual concentric bands, these corals have been growing for hundreds to thousands of years recording annual oceanographic, climatic and atmospheric changes.

References

Adkins, J.F., and E.A. Boyle. 1999. Age screening of deep-sea corals and the record of deep North Atlantic circulation change at 15.4 ka. In: Abrantes, F. and A. Mix, eds. Proceedings of the Sixth International Conference on Paleoceanography. Elsevier. 246 pp.

Adkins, J.F., H. Cheng, E.A. Boyle, E.R.M. Druffel, and R.L. Edwards. 1998. Deep-sea coral evidence for rapid change in ventilation of the deep North Atlantic 15,400 years ago. Science 280:725–728.

Adkins, J.F., S. Griffin, M. Kashgarian, H. Cheng, E.R.M. Druffel, E.A. Boyle, R.L. Edwards, and C. Shen 2002. Radiocarbon dating of deep-sea corals. Radiocarbon 44:567–580.

Bond, Z.A, A.L. Cohen, S.R. Smith, and W.J. Jenkins. 2005. Growth and composition of high-Mg calcite in the skeleton of a Bermudian gorgonian (Plexaurella dischotoma): Potential for paleothermometry. Geochem. Geophysic. Geosystems 6(8), doi: 101029/2005GC000911.

Cheng, H., J. Adkins, R.L. Edwards, and E.A. Boyle. 2000. U-Th dating of deep-sea corals. Geochim. Cosmochim. Acta 64:2401–2416.

References (cont.)

Donarummo, J., M. Ram, and M.R. Stolz. 2002. Sun/dust correlations and volcanic interference. Geophys. Res. Lett. 29(9):1361, doi: 10.1029/2002gl014858.

Druffel, E.R.M., S. Griffin, A. Witter, E. Nelson, J. Southon, M. Kashgarian, and J. Vogel. 1995. Gerardia: Bristlecone pine of the deep-sea? Geochim. Cosmochim. Acta 59:5031–5036.

Druffel, E.R.M., L.L. King, R.A. Belastock, and K.O. Buesseler. 1990. Growth rate of a deep-sea coral using Pb-210 and other isotopes. Geochim. Cosmochim. Acta 54:1493–1500.

Druffel, E.R.M. and P.M. Williams. 1990. Identification of a deep marine source of particulate organic carbon using bomb14C. Nature 347:172–174.

Goldstein, S.J., D.W. Lea, S. Chakraborty, M. Kashgarian, and M.T. Murrell. 2001. Uranium-series and radiocarbon geochronology of deep-sea corals: Implications for southern ocean ventilation rates and the oceanic carbon cycle. Earth Planet Sci. Lett. 193:167–182.

References (cont.)

Greatbatch, R.J. 2000. The North Atlantic Oscillation. Stochastic Environmental Research and Risk Assessment 14:213–242.

Griffin, S. and E.R.M. Druffel. 1989. Sources of carbon to deep-sea corals. Radiocarbon 31:533–542.

Grigg, R.W. 1976. Fishery management of precious and stony corals in Hawaii. Report No. UNIHI-SEAGRANT-TR-77-03. University of Hawaii Sea Grant Program, Honolulu, HI.

Heikoop, J.M., D.D. Hickmott, M.J. Risk, C.K. Shearer, V. Atudorei. 2002. Potential climate signal from the deep-sea gorgonian coral Primnoa resedaeformis. Hydrobiologia 471:117–124.

Hill, T.M., H.J. Spero, D. Clague, and J. Barry. 2006. Decadal-scale intermediate water geochemistry record by bamboo corals on the California Margin. EOS Trans. 86(36), AGU, Ocean Sci. Meeting Suppl. Abs. OS24J-05.

Hua, Q. and M. Barbetti. 2004. Review of tropospheric bomb 14C data for carbon cycle modeling and age calibration purposes. Radiocarbon 46(3):1273–1298.

References (cont.)

Mangini, A., M. Lomitschka, R. Eichstaedter, N. Frank, S. Vogler, G. Bonani, I. Hajdas, and J. Paetzold. 1998. Coral provides way to age deep water. Nature (London) 392(26 Mar 1998):347–348, doi: 10.1038/32804.

Roark, E.B. 2005. Biogeochemical proxies of environmental change in surface and deep-sea corals from the Pacific. Ph.D. thesis, University of California, Berkeley. 188 pp.

Roark, E.B., T.P. Guilderson, S.R. Flood-Page, R.B. Dunbar, B.L. Ingram, S.J. Fallon, and M.T. McCulloch. 2005. Radiocarbon-based ages and growth rates for bamboo corals from the Gulf of Alaska. Geophys. Res. Lett. 32:L04606, doi: 04610.01029/02004GL021919.

Williams, B. 2005. Deep-water antipatharian and gorgonian corals as proxies of environmental processes. M.S. thesis, University of Quebec, Montreal, Quebec. 68 pp.

Williams, B., M.J. Risk, S.W. Ross, and K.J. Sulak. 2006. Deep-water antipatharians: Proxies of environmental change. Geology 34(9):773–776, doi: 10.1130/G22685.1.

References (cont.)

Williams, B., M.J. Risk, R. Stone, D. Sinclair, and B. Ghaleb. 2007. Oceanographic changes in the North Pacific Ocean over the past century recorded in deep water gorgonian corals. Mar. Ecol. Prog. Ser. 335:85–94.

Wilson, M.T., A.H. Andrews, A.L. Brown, and E.E. Cordes. 2002. Axial rod growth and age estimation of sea pens, Halipteris willenmosi Kolliker. Hydrobiologia 471:133–142.