Analyzing Earth Signals with J-DSP: Real-Time, Deep-Time, On-line

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TOPICS

Introduction

J-DSP Laboratory

Tutorial 1: global warming

Tutorial 2: Ice Age climate

TOPICS

- Introduction and workshop overview

  "Real-time" v. "deep-time" Earth signals

  Analysis and interpretation of Earth signals

- Using the online J-DSP Laboratory

  Basic signal processing

- Tutorial 1: Global warming in the 20th Century

  How does pCO_2 correlate with global climate change?

  - Seasonal cycle
  - Long-term trend
  - Interannual variations?
  - J-DSP investigation

LUNCH BREAK

- Tutorial 2: Ice Age climate change

  Ice volume, ocean temperature, 0-300,000 years ago

  - $\delta^{18}O$ in *G. bulloides*
  - Abundance of *C. davisiana*
  - Depth-to-time transformation
  - J-DSP investigation

CONCLUSION

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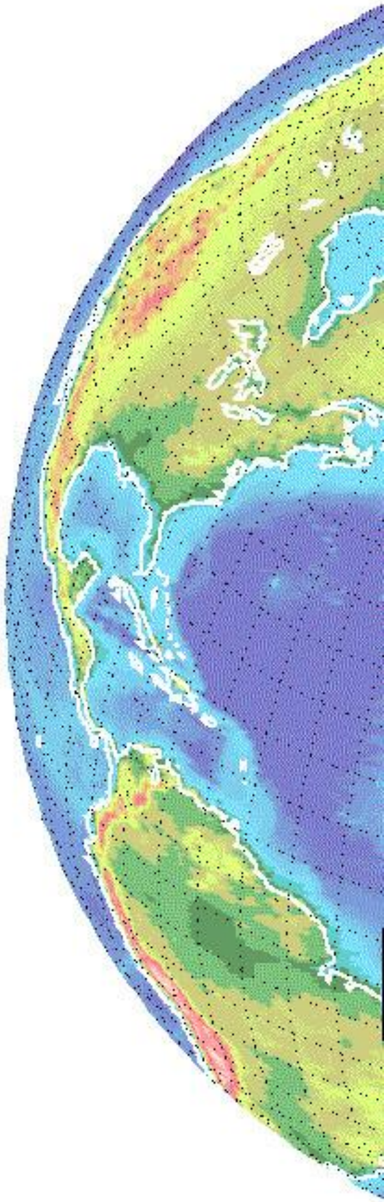
• Introduction and workshop overview

Earth science drivers for the 21st century -

- Climate change
- Global sustainability
- Hazards analysis and prediction
- Origin and evolution of the Earth



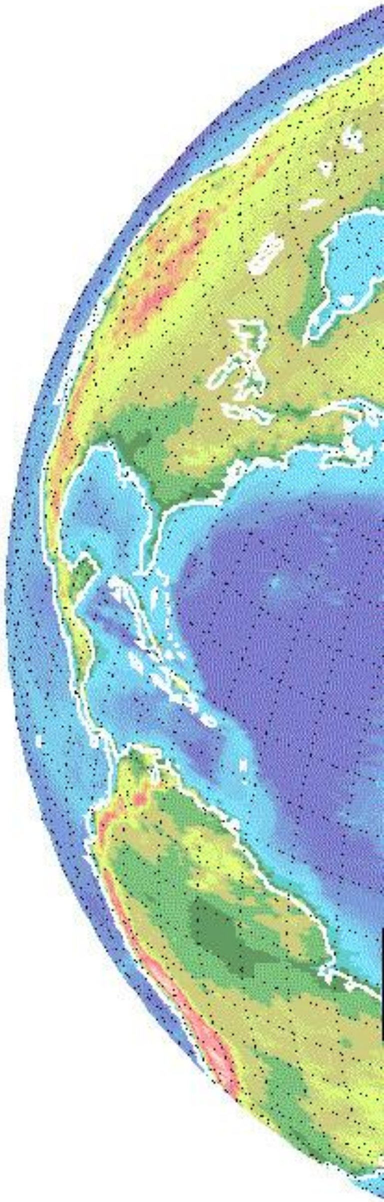
From "11 Grand Research Questions in Earth Science"
US National Academy of Sciences, 2007

• Introduction and workshop overview

"Real-time" Earth signals -

- air pressure, temperature, precipitation
- atmospheric chemistry
- ocean salinity, temperature
- ocean chemistry, productivity
- ocean tides
- geomagnetic field strength
- earthquakes and ground motion
- Earth orientation parameters
- solar irradiance
- river discharge
- soil moisture

etc. etc. ...



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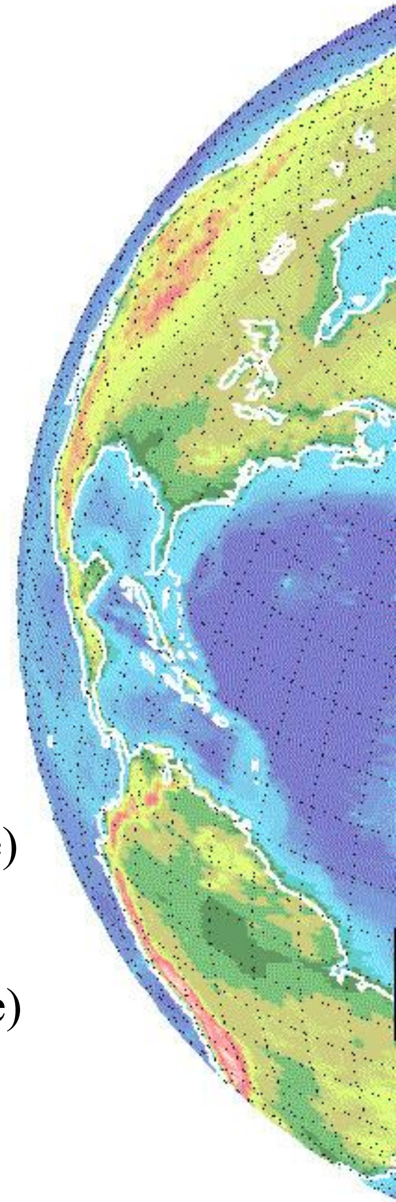
"Deep-time" Earth signals -

- tree ring thicknesses (precipitation/temperature)
- sedimentary rock lithology (sea/lake level)
- microfossil assemblages (ocean salinity)
- Mg/Ca of marine shells (ocean temperature)
- Ti/Al of deep sea sediment (dust/aridity)
- Si/Al of deep sea sediment (ocean productivity)
- sediment paleointensity (geomagnetic field strength)
- oxygen isotopes of ice (air temperature)
- oxygen isotopes of marine shells (ocean temperature)
- magnetic susceptibility of sediment (river flow)
- alkenones in marine microfossils (ocean temperature)

etc. etc. ...



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Analysis and interpretation of Earth signals

Questions:

- is there mean value in the time series?
- is there secular (linear) trend?
- do the variations change with time have constant variance?
- what are the frequencies of variation?

Answers:

- basic statistics
- least squares polynomial fitting
- spectrum estimation (frequency analysis)
- filtering (frequency isolation)

-cross correlation (coherency) analysis

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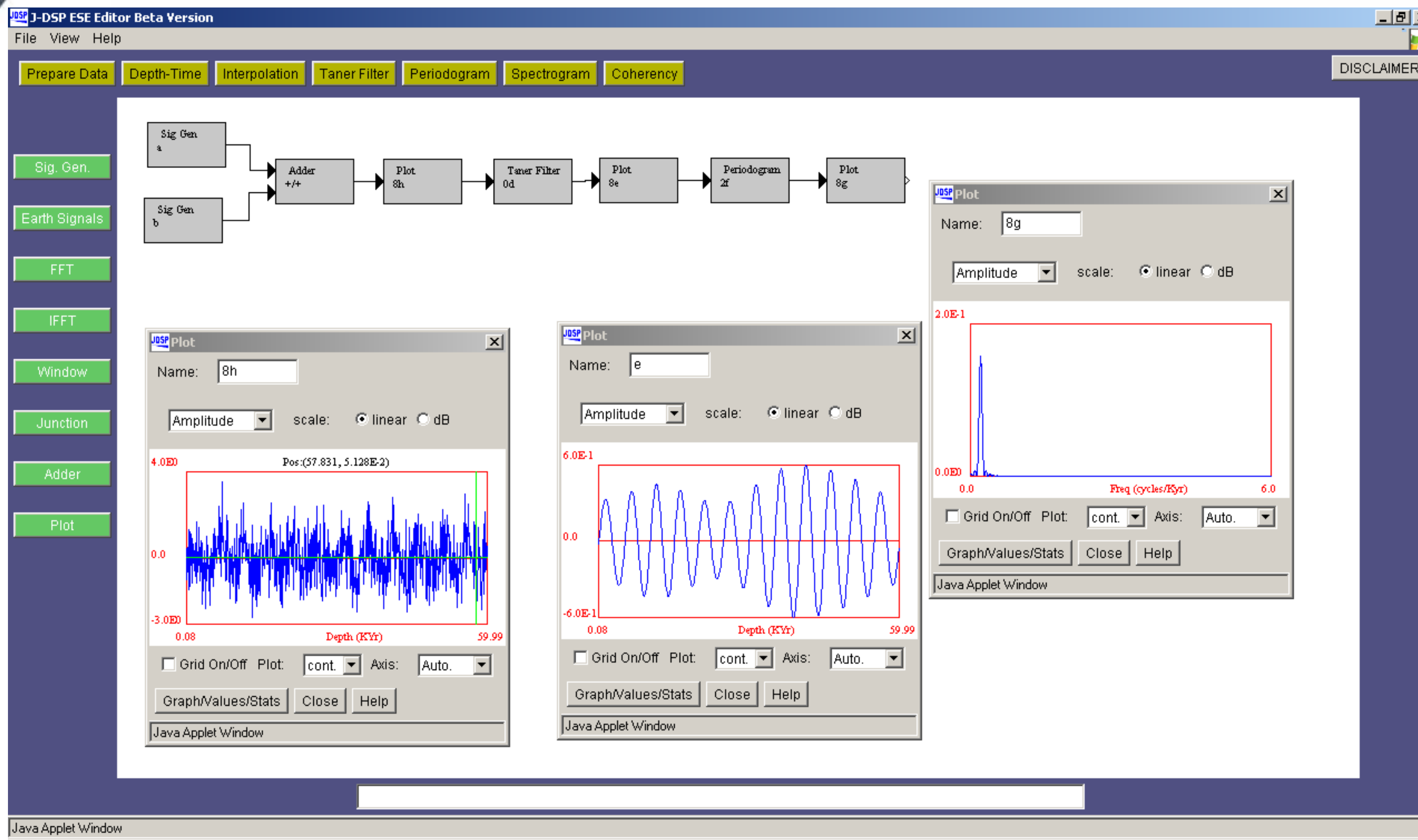

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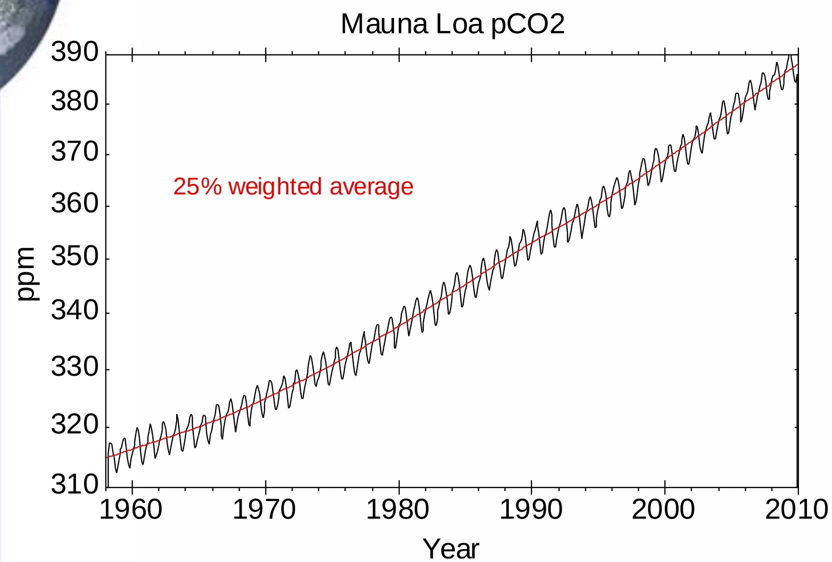
• Tutorial 1: Global warming in the 20th Century

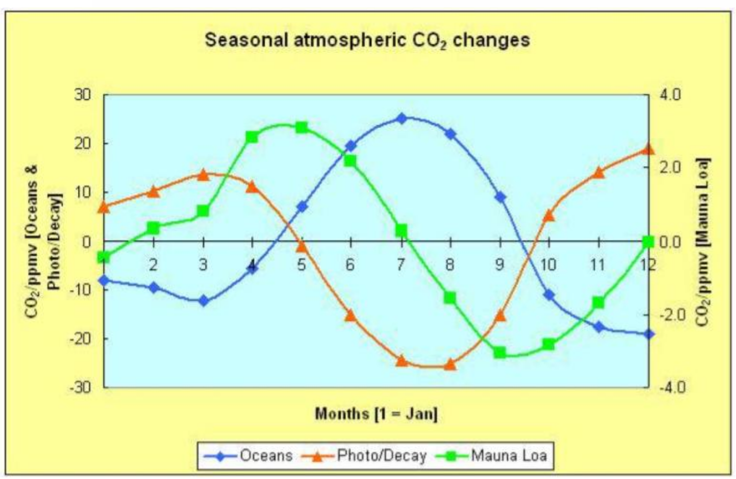
How is pCO_2 correlated with global climate change?



THE SEASONAL CYCLE

Monthly mean values of atmospheric CO_2 concentration (ppm) derived from in situ air measurements at Mauna Loa Observatory, Hawaii: Latitude 19.5ºN Longitude 155.6ºW, Elevation 3397 m, a good representation of global pCO_2.

http://scrippsco2.ucsd.edu/



Mauna Loa monthly mean values of CO_2 concentration and estimates of the variations of the concentration as ***ocean temperature*** varies and the gas in the atmosphere is used in photosynthesis (and restored when vegetation decays).

http://www.barrettbellamyclimate.com/

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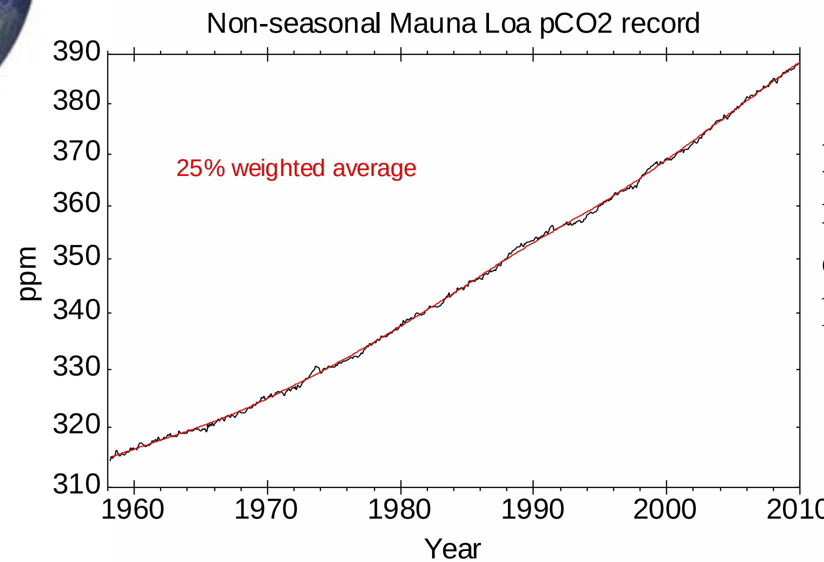
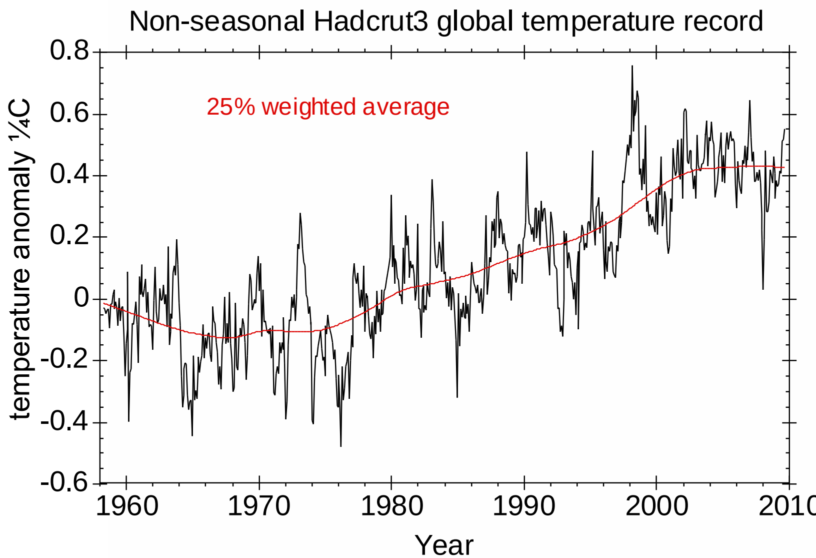


THE LONG-TERM TREND

Mauna Loa atmospheric pCO_2 (ppm) mid-monthly values, with the seasonal cycle removed by subtracting “a 4-harmonic fit with a linear gain factor.”

http://scrippsco2.ucsd.edu/



Monthly global temperature record averaged over 5ºx5º areal grids, from more than 3000 stations temperature time series, preprocessed to remove the seasonal cycle and biases from stations at different elevations and different averaging formulae.

http://www.cru.uea.ac.uk/cru/data/temperature

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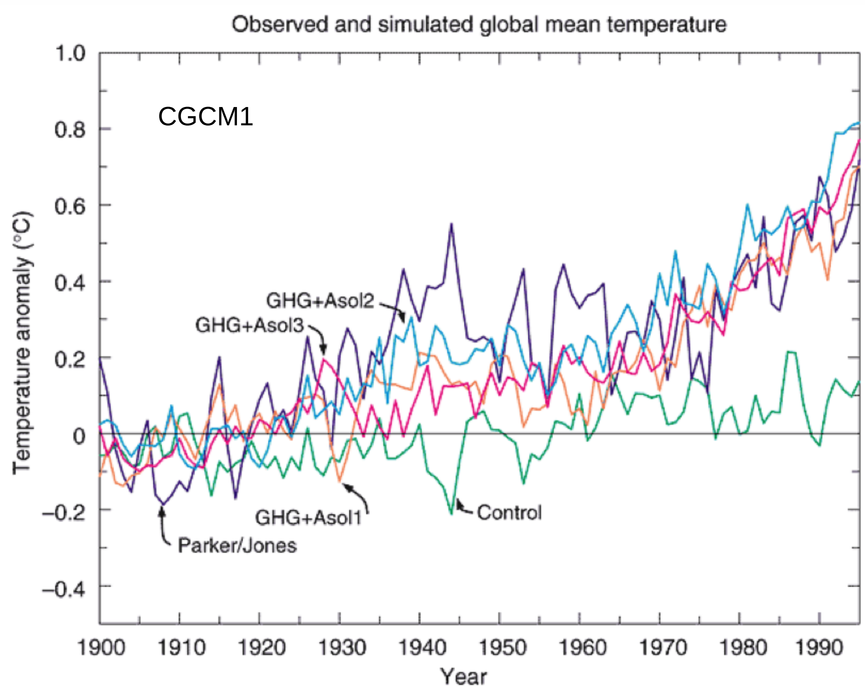
How is pCO_2 correlated with global climate change?

The shared ***increasing trend*** of pCO_2 v. global temperature cannot be interpreted statistically; ***climate modeling is required to establish causality*** between rising atmospheric CO_2 and global temperature.



Observed and modelled global annual mean temperature anomalies (°C). The control (pCO_2 set at constant 330 ppm) is compared with three independent simulations with identical increasing greenhouse gas forcing (based on observations) plus different aerosol forcings and slightly different initial conditions (GHG+Asol1, GHG+Asol2 and GHG+Asol3).

http://www.grida.no/publications/other/ipcc_tar/

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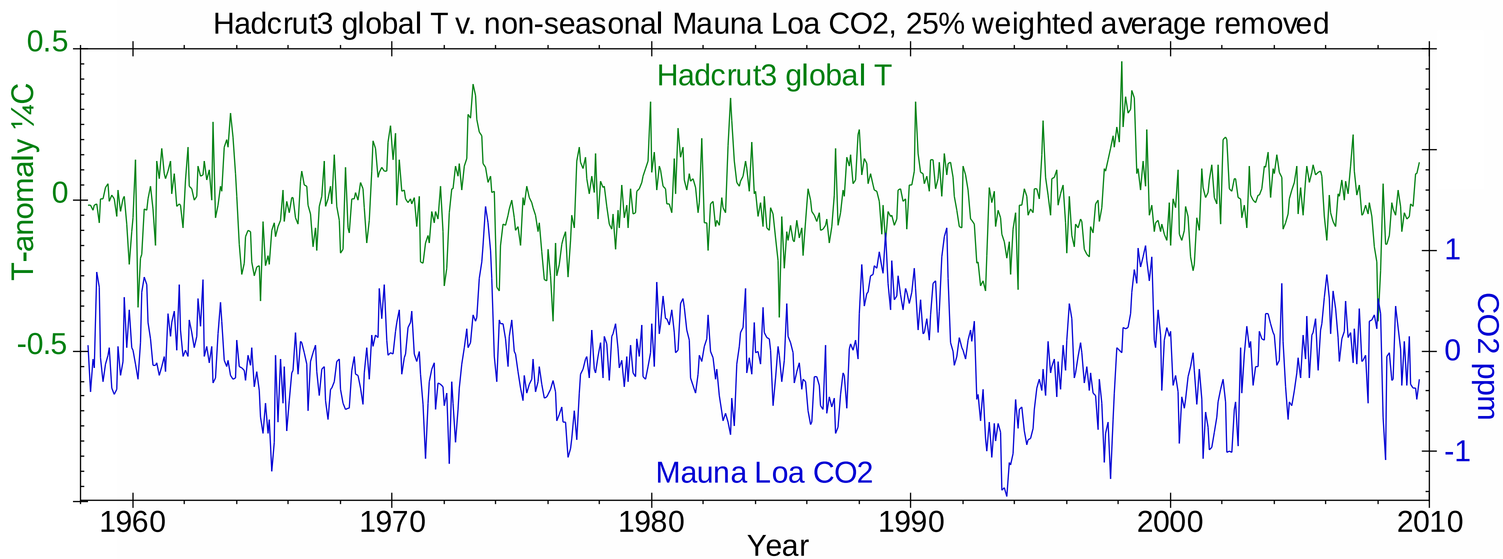
• Tutorial 1: Global warming in the 20th Century

How is pCO_2 correlated with global climate change?

INTERANNUAL VARIATIONS ?

The “interannual” variations in global temperature and their relationship to those in pCO_2 provide additional important information, and are best assessed statistically, through signal processing and time series analysis.

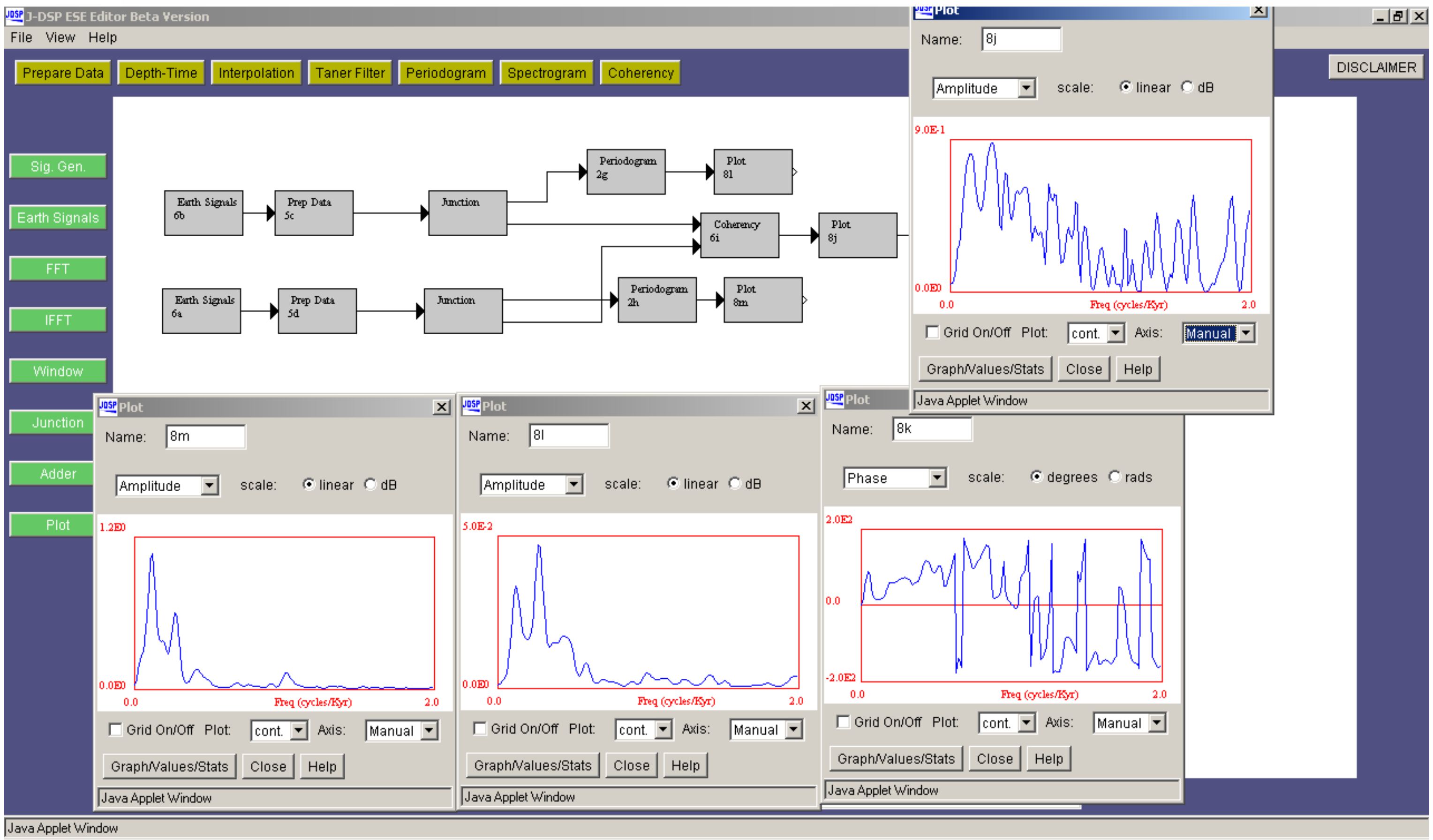
The interannual variations of global temperature v. pCO_2 at Mauna Loa shown below (seasonal cycles and long-term trends removed) appear to share cyclic variations -- are these cycles significant and are they correlated?



• Tutorial 1: Global warming in the 20th Century

How is pCO_2 correlated with global climate change?

Investigate with J-DSP:



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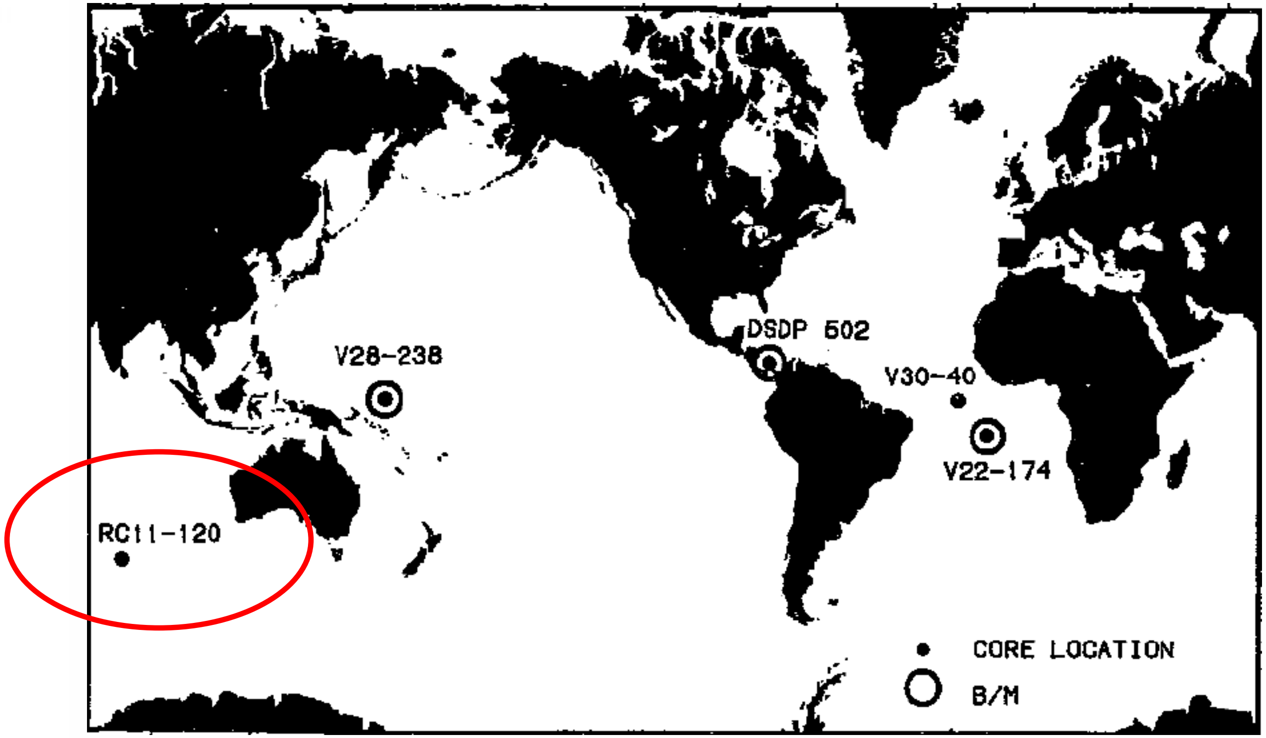
Ice volume, ocean temperature, 0-300,000 years ago



Core RC11-120 was drilled through 953 centimeters of sediment in the Indian Ocean, 43º31'S, 79º52'E from a water depth of 3193 meters, and sampled at 5 cm intervals for oxygen isotope geochemistry. It is one of the 5 original datasets used to construct the classic "SPECMAP Stack" that led to the recognition of astronomical forcing of global climate.

• Tutorial 2: Ice Age climate change

Ice volume, ocean temperature, 0-300,000 years ago

Globigerina bulloides D'orbigny, 1826: cold water planktonic foraminifer, 200 µm (temperate) - 350 µm (subantarctic) (Pliocene-present)

http://www.flickr.com/photos/cazphoto/4274383135

G. bulloides tolerates the global range of sea surface temperatures, salinity, and density stratification. It is most abundant at high southern latitudes, has distinct maxima in high northern latitudes and low latitude upwelling regions. G. bulloides feeds on algal prey. Its geographic distribution suggest a preference for productive environments where it may be related to the phytoplankton bloom succession.

http://www.fuhrmann-hilbrecht.de/Heinz/geology/HH1996/

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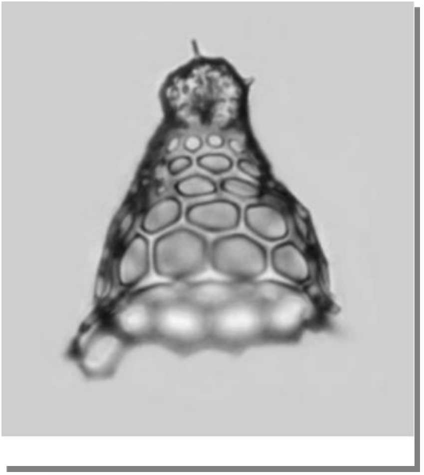
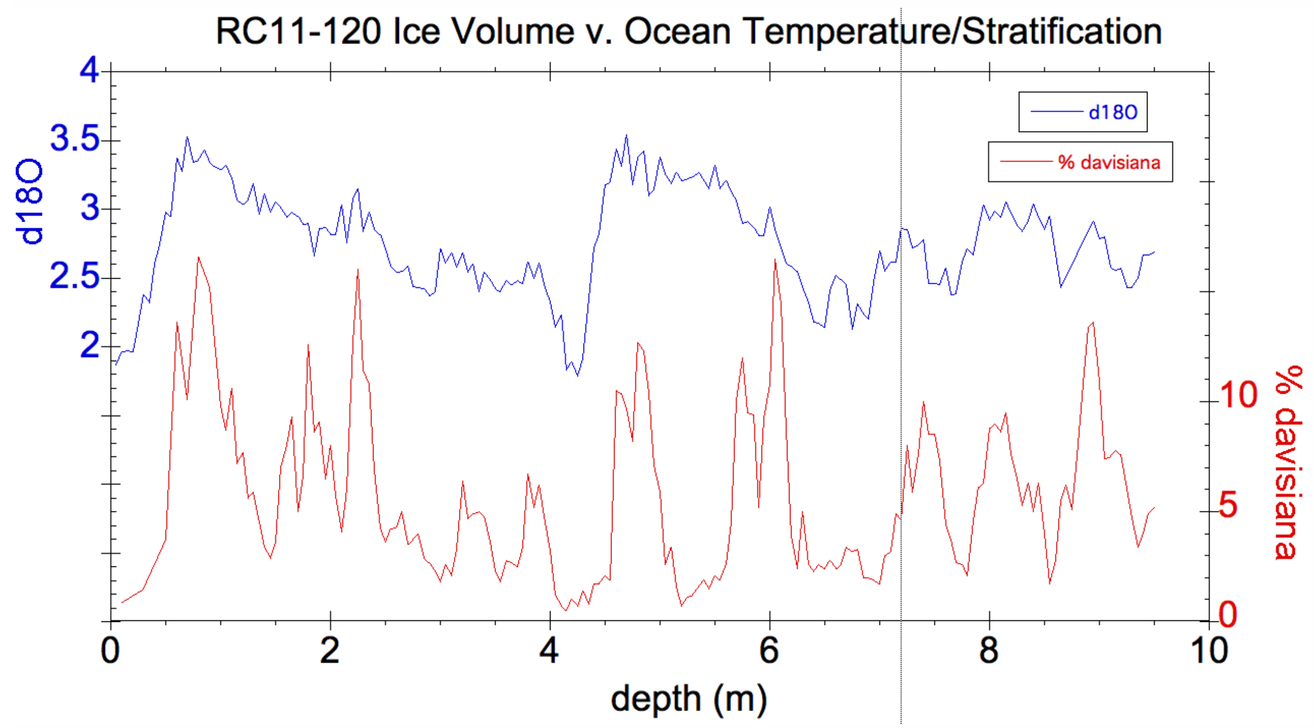


Cycladophora davisiana Ehrenberg, 1861: cosmopolitan radiolarian, ~100 μm (Pliocene-present)

http://www.radiolaria.org

C. davisiana is a radiolarian dwelling at mesopelagic depths, and is a representative glacial fauna. *C. davisiana* is characteristic of high-latitude water masses; its intrusion into low-latitude sites represents the injection of deep cold water of high-latitude origin.



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Ice volume, ocean temperature, 0-300,000 years ago

What is the timescale of this paleoceanographic/paleoclimate record?
What are the frequencies of variation of these records?
What is the relationship between the two records?

Investigate with J-DSP:

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CONCLUSIONS

- Tutorial 1: Global warming in the 20th Century

Seasonal cycle in CO_2 driven by climate/biosphere
Interannual variations in CO_2 driven by global (ocean) temperature
Long-term rise in global temperature driven by CO_2 rise

- Tutorial 2: Ice Age climate change

Long-term variations in phytoplankton biogeochemistry, abundance
Cycles at 100,000 years, 40,000 years, 23,000 years
Abundance of *C. davisiana* (ocean T) leads $\delta^{18}O$ variation (ice volume)