ON THE USE OF JAVA-DSP IN EARTH SYSTEMS

presented by

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Also core software used in an NSF CRCD 2004-2006

Motivation

- J-DSP is a web-based, platform-independent and visual programming environment.
- It has a rich set of signal processing functions built into an intuitive block-based programming environment.
- Strong need for introducing signal analysis tools to students in Earth Systems courses.
- Students lack training in modelling and analysis of natural signals.
- J-DSP can be easily tailored to perform analysis and visualization of these signals.

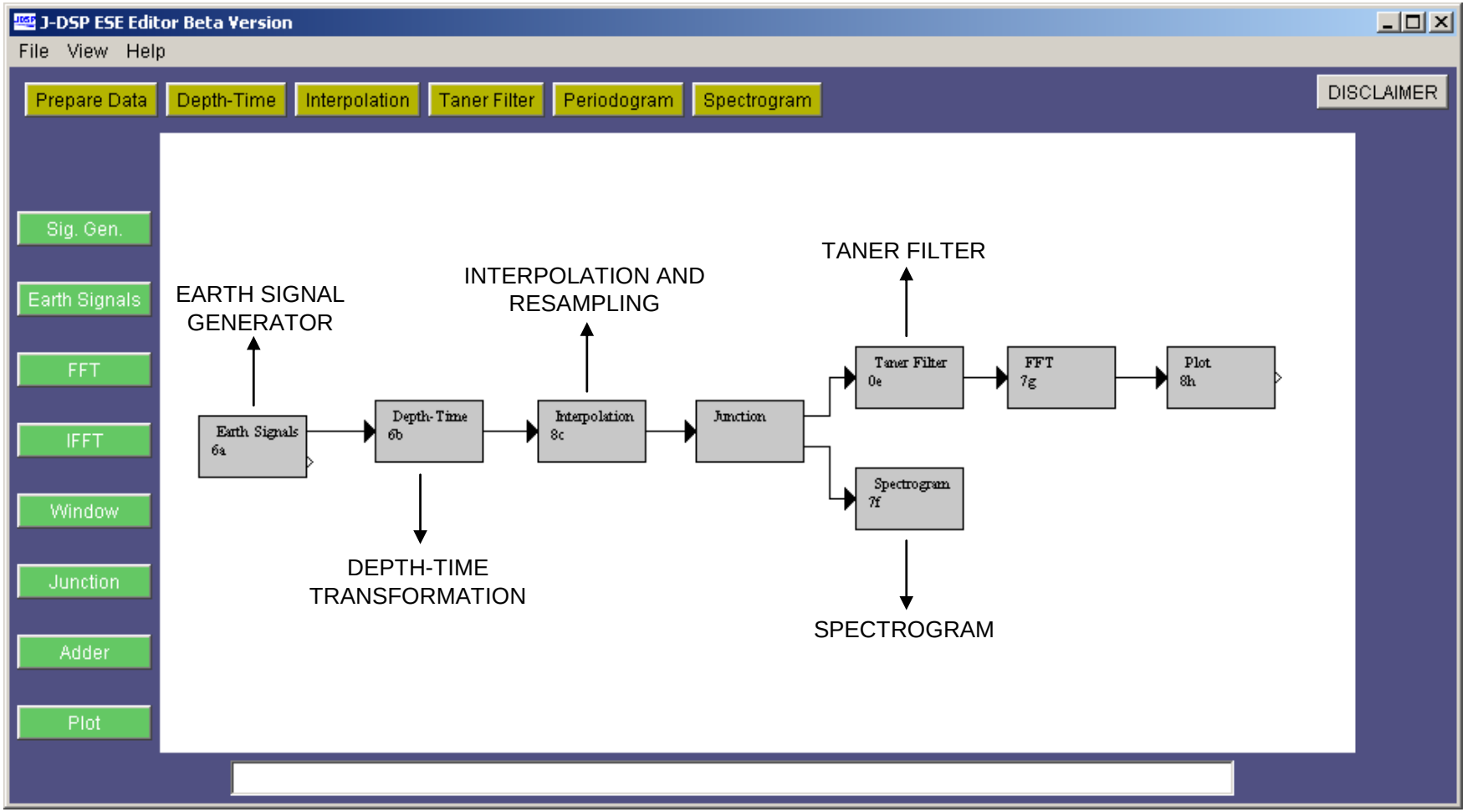
Earth Systems Signals

- "Real-Time" monitoring of natural phenomena
  - River flow, atmospheric pressure, earth orientation.
  - Geoscientists have assembled/developed algorithms and software.
- "Deep-Time" proxy data
  - Proxy data that are representative of past Earth system behaviour.
  - Ice sheet isotopes (air temperatures), tree ring thicknesses (hydrology), magnetic intensity of ancient sediment (geomagnetic field).
  - Independent variable is represented by a proxy, that complicates the analysis.
- Typical needs are re-sampling, interpolation, de-noising, signal frequency evaluation and correlation.

J-DSP Earth Systems Edition

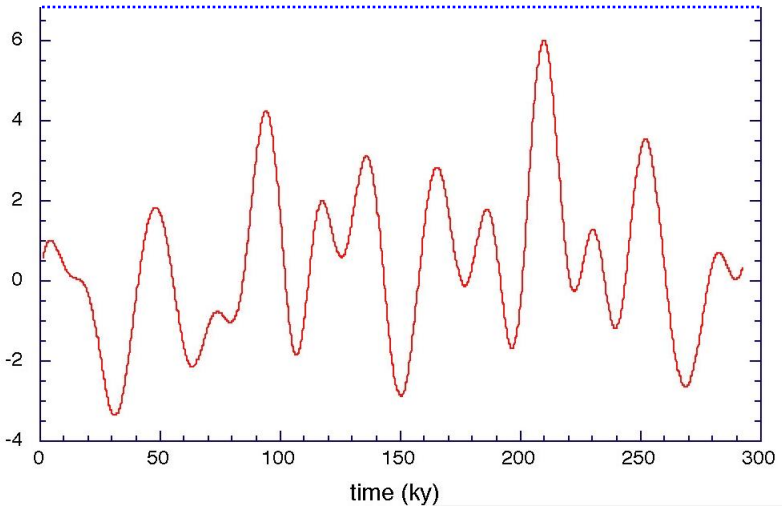
- J-DSP Earth Systems Edition (J-DSP/ESE) developed exclusively for handling Earth systems signals.
- Can handle long signals (8192 points) and uses time and frequency units familiar to geoscientists, kiloyears (Kyr) and cycles/Kyr respectively.
- Includes functions like
  - Earth Signal Generator.
  - Data preparation, Depth-time transformation, Interpolation and re-sampling (Linear, cubic and staircase).
  - Filter design (Taner filter).
  - Windowing (Rect., Bartlett, Hamming, Hann, Blackman, Kaiser, Tukey and Gauss).
  - FFT/IFFT, Spectrogram and Periodogram.
  - Time-frequency analysis (Spectrogram).
  - Other functions (Adder, Junction).

J-DSP/ESE Editor



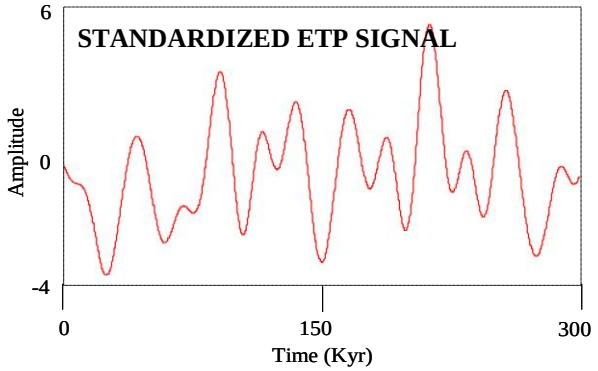
Expected Astronomical Frequencies

- Earth's astronomical frequencies that affect changes in solar radiation have three basic origins
  - Earth's orbital eccentricity E (cycle periods 400,000 and 100,000 years).
  - Axial tilt T (cycle period 41,000 years).
  - Precession P (cycle periods of 23,000 and 19,000 years).
- ETP model signal by adding together their standardized curves.

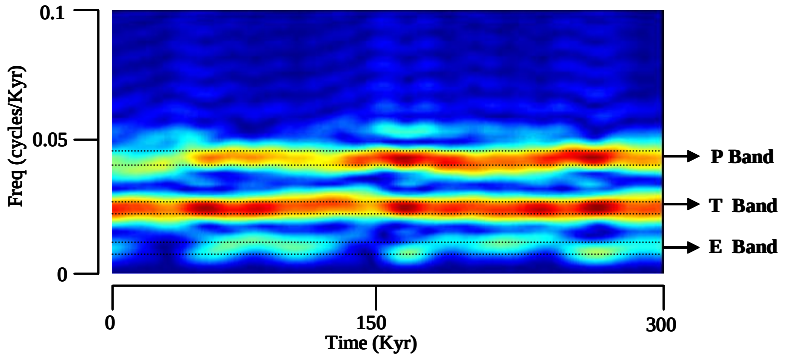


ETP Model Signal

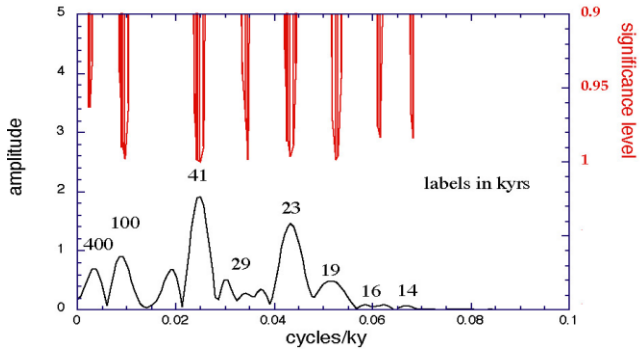
ETP Model Analysis

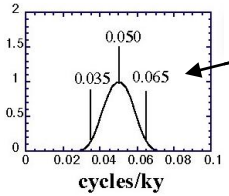


SPECTROGRAM



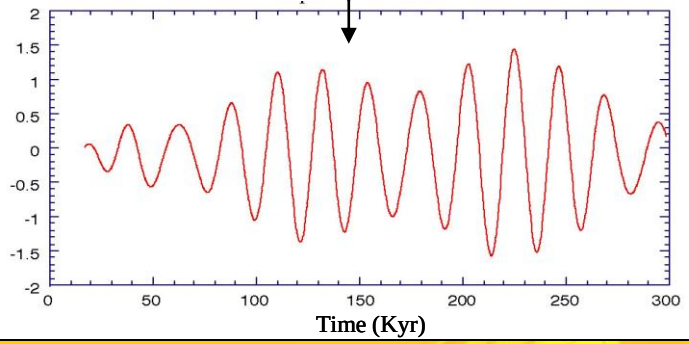
MULTIPLE PROLATE TAPER SPECTRUM





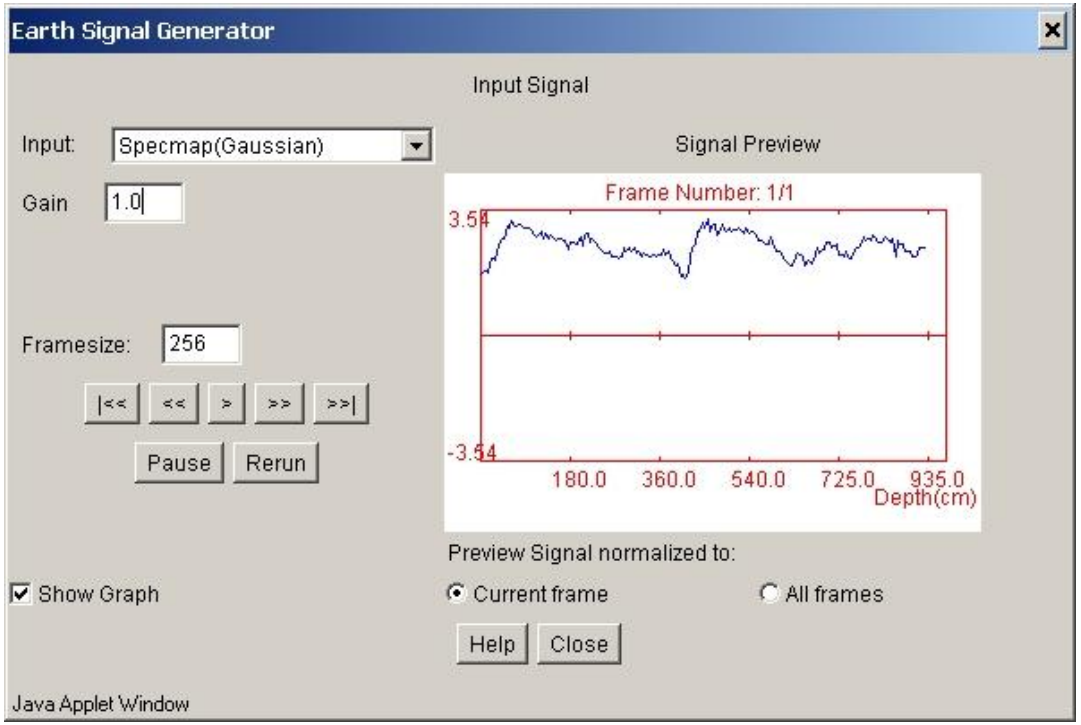
TANER FILTER

FILTERED SIGNAL P-BAND



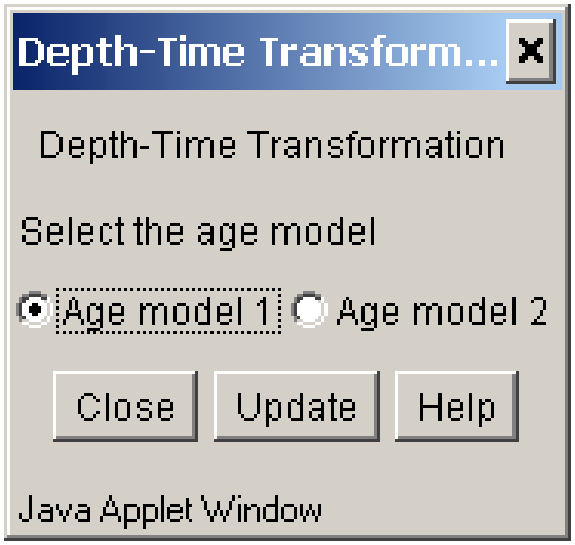
Graph the data series

- Earth System data sets
  - Spectral Mapping (SPECMAP) – Gaussian, RC11-120.
  - Lake Baikal – non-Gaussian, composite biogenic silica record.
  - Trubi Marls – binary, alternating limestone beds.



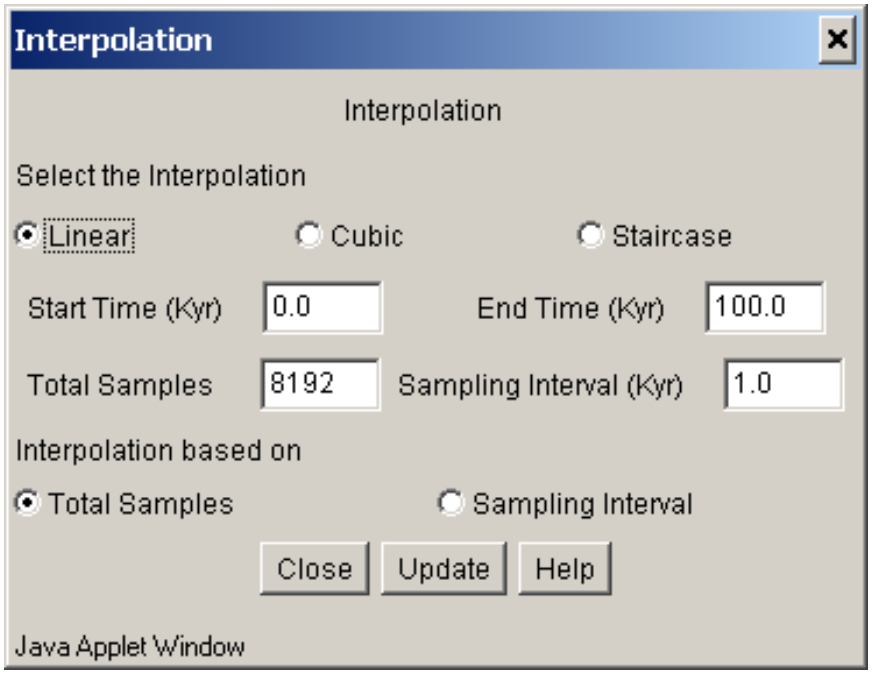
Convert to Time Series

- Data sampled in depth scale corresponds to time scale.
- Generally depth scale is uniformly sampled.
- Time scale in years Before Present (BP).
- User specified standardized age models.



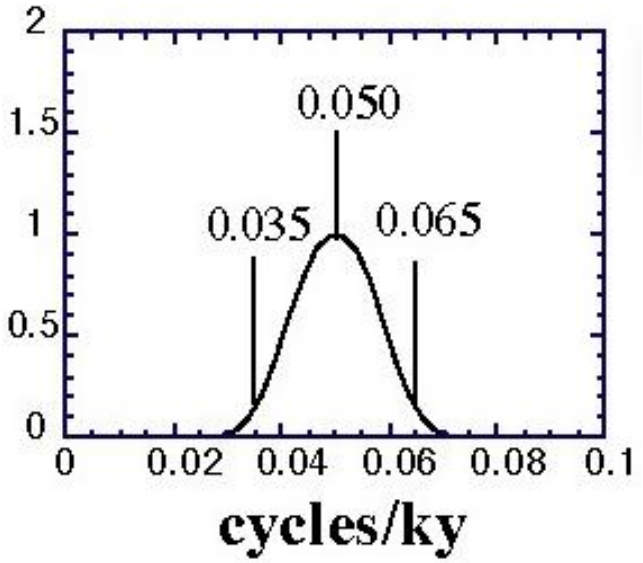
Re-sample to Uniform Rate

- Converting from depth to time results in non-uniformity in sampling.
- Non-linear relationship between depth and time scales – variable depositional rate of sediments.
- Interpolation (linear, cubic and staircase) and re-sampling to a required number of samples is done.



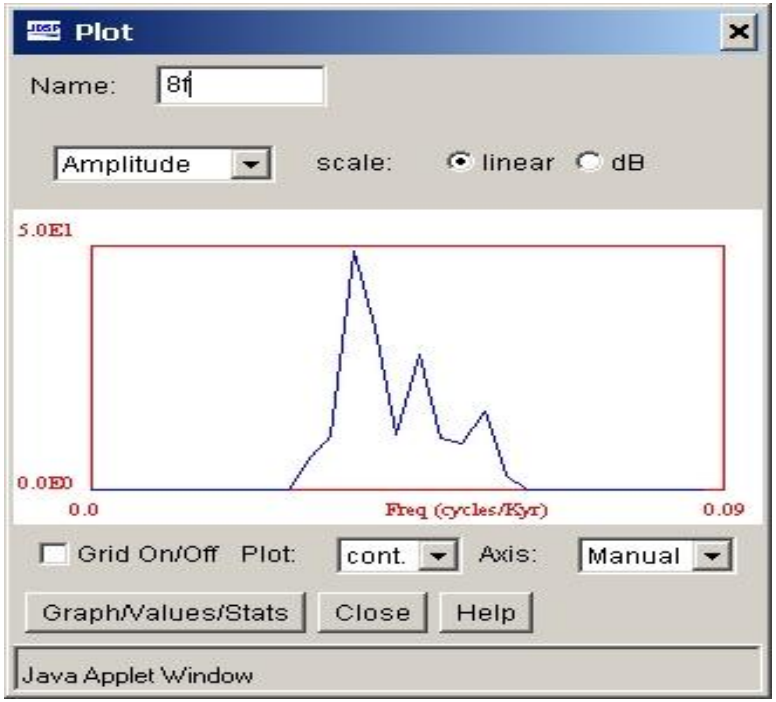
Filter the data

- RC11-120 time series was tuned closest to the ETP model.
- The spectrum is closest match to the ETP spectrum over the same time interval.
- To isolate the P band, Taner bandpass with cutoff frequencies of 0.035 cycles/Kyr and 0.065 cycles/Kyr are used

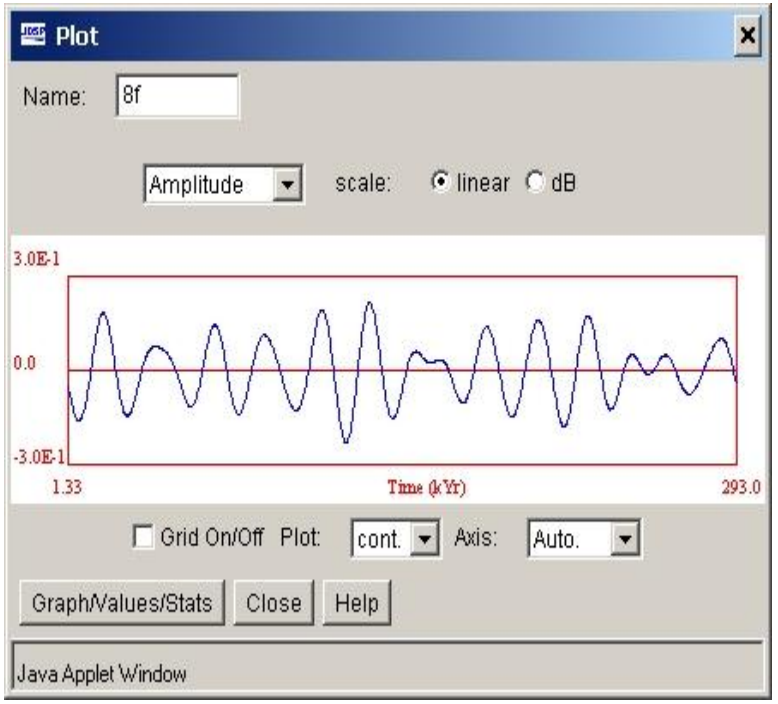


Taner bandpass response

Filter the data



Filtered Signal - Frequency Domain



Filtered Signal - Time Domain

Time-Frequency Analysis

- Spectrogram of RC11-120 time series indicates the presence of E,T and P frequency bands.
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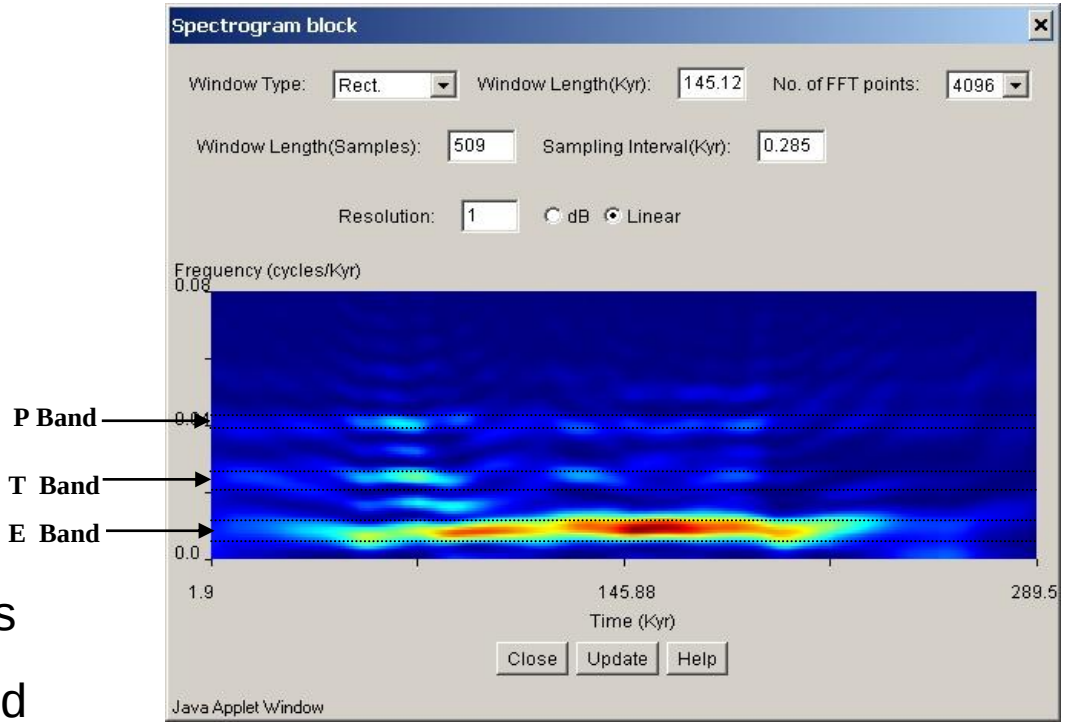
- E band is well-defined , P band not properly visible, which means that the iterative tuning performed can be improved.



J-DSP/ESE Exercises

- J-DSP/ESE exercises have been developed which will be used in assessment of the software in Earth systems class at JHU.
- The exercises include:
  - A one page tutorial on getting started with J-DSP.
  - Basics of spectral analysis.
  - Earth's orbital parameters and Milankovitch cycles.
  - Analysis of Milankovitch cycles in the Triassic Lockatong formation.
- The exercise questions will facilitate the understanding of concepts through simple J-DSP/ESE block diagrams that the students can create for themselves.
- An assessment module will be developed and will be used for gauging the effectiveness of the software. The feedback obtained will be used for future improvements.

Conclusions

- JDSP software extensions developed for the new J-DSP/ESE version to be used in Earth systems and geology education and research.
- Geology students and researchers are introduced to basic DSP concepts and get hands-on experience with analysis of Earth Systems data.
- Future versions will include
  - Multi-taper method for line spectra, red noise fitting and interactive target tuning.
  - Education modules for
    - Sustainability (Global temperatures through the 20th century).
    - Earth Systems (Polar motion).
    - Hazards Research (Earthquake/seismic data analysis).
- Publication: Ramamurthy K., Spanias A., Hinnov L. and Ogg J., "On the use of Java-DSP in Earth systems", *Proceedings of ASEE Annual Conference and Exposition*, Pittsburgh, PA, June 2008.