OC 683: Data Analysis in the Frequency and Wavenumber Domains

Spring 2019

Theory of techniques for analysis of data in the frequency and wavenumber domains with applications to real and simulated oceanographic and atmospheric data. Topics include sampling theory, filtering, one-dimensional autospectral analysis, multi-dimensional autospectral analysis, coherence and phase analysis, confidence tests, and wavelet analysis.

SYLLABUS:

1) Fourier Analysis Techniques
   - Fourier series and integral representations of periodic and nonperiodic time series
   - Fourier transform theorems
   - Generalized functions
   - Convolution
2) Sampling Theory
   - Discrete sampling, infinite record length: aliasing
   - Continuous sampling, finite record length: leakage and smearing
   - Data windowing and leakage effects
   - Discrete sampling, finite record length: combined aliasing and leakage and aliased leakage
3) Discrete Fourier Transform
   - Definition
   - Fast Fourier Transform
   - Useful techniques (zero-padding, multiple simultaneous analysis of real time series, design of numerical simulations and synthetic time series)
4) Filtering by Fourier analysis
   - Low-pass, high-pass and band-pass filtering
   - Tapering at band edges
   - Endpoint detrending
5) Brief Overviews of Probability and Statistics
   - Probability distribution functions
   - Sample statistical estimates of probabilistic parameters
   - Confidence intervals, significance tests, degrees of freedom
6) Autospectral Analysis
   - Power spectral density
   - Fourier transform vs. autocorrelation analysis
   - Frequency resolution
   - Leakage and bias of raw power spectral density estimates
   - Data Windowing
   - Spectral smoothing techniques and confidence intervals
   - Pre-whitening/post-coloring techniques
7) Cross-Spectral Analysis
   - Cross-spectral density
   - Coherence and phase spectra
   - Coherence significance levels and phase confidence intervals
   - Smoothed cross spectra
8) Two-dimensional Autospectral Analysis
   - 2-d Fourier transform as a sequence of 1-d Fourier transforms
   - 2-d power spectral density from the 2-d Fourier transform
   - Confidence intervals for 2-d power spectral density
9) Wavelet Analysis for Time-Frequency Analysis
   - Windowed Fourier transform
   - Uncertainty principle for time versus frequency localization of a signal
   - Continuous wavelet transform
   - Real wavelets for detecting abrupt signal transitions
   - Complex wavelets for determining amplitude and phase of a band-pass filtered signal
   - Discrete wavelet transform