Assignment3

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March 2018

1 Question1

1.1 Ocean acoustic tomography

The problem of ocean acoustic tomography is to infer form precise measurements of travel time, or of other properties of acoustic propagation, the state of the ocean traversed by the sound field.

1.2 Ocean acoustic tomography relies on the fact:

1. travel time and other measurable acoustic parameters are functions of temperature, water velocity, and other parameters of oceanographic interest and can be interpreted to provide information about the intervening ocean using inverse methods

2. the ocean is nearly transparent to low-frequency sound, so the signals can be transmitted over distances of many thousands of kilometers.

1.3 Summary of technique

1. The technique relies on precisely measuring the time it takes sound signals to travel between two instruments, one an acoustic source and one a receiver, separated by ranges 100-5000km.If the locations of the instruments are known precisely, the measurement of time-of-flight can be used to infer the speed of sound, averaged over the acoustic path. Changes in the speed of sound are primarily caused by changes in the temperature of the ocean, hence the measurement of the travel times is equivalent to a measurement of temperature. A 1 C change in temperature corresponds to about 4 m/s change in sound speed. An oceanographic experiment employing tomography typically uses several source-receiver pairs in a moored array that measures an area of ocean.

2. One of the intriguing aspects of tomography is that it exploits the fact that acoustic signals travel along a set of generally stable ray paths. From a single transmitted acoustic signal, this set of rays gives rise to multiple arrivals at the receiver, the travel time of each arrival corresponding to

a particular ray path. The earliest arrivals correspond to the deeper-traveling rays, since these rays travel where sound speed is greatest. The ray paths are easily calculated using computers ("ray tracing"), and each ray path can generally be identified with a particular travel time. The multiple travel times measure the sound speed averaged over each of the multiple acoustic paths. These measurements make it possible to infer aspects of the structure of temperature or current variations as a function of depth. The solution for sound speed, hence temperature, from the acoustic travel times is an **inverse problem**.

1.4 Forward and Inverse Problem

1. The **forward or direct problem** can be stated as follows: given (Speed of Sound)C(x,y,z) and u(a,y,z) together with the characteristics of the sound source, compute the detailed structure of the signal at the receiver. This is the classical problem of finding solutions to the wave equation.

2. The **inverse problem** demands calculation of the ocean properties, C(x,y,z) and/or u(x,y,z), given the properties of the transmitted and received signals. The inverse problem is of considerable interest in oceanography.

3. Consider ray travel times in motionless ocean. We can define two tomographic problems:

   (a) Given the positions of source and receiver and a measured set of travel times γ_i, find the best estimates C(z) and $\hat{C}$(z).

   (b) Given the best estimate, $\hat{C}$(z,-), of the "prior profile", a set of prior travel times $\{\gamma_i(\text{-})\}$, compute for the prior profile,and given the set of measured travel times $\{\gamma_i\}$,calculate improved estimates for $\hat{C}$(z). The argument (-) is introduced into the definitions to denote their dependence only on the prior model profile, independent of the measurements.

4. The difference between problems (a) and (b) is in the introduction of a prior estimate of the sound-speed. Because we normally know a good deal about the ocean in any region where experiment is to be conducted.

1.5 Reference

1. Ocean acoustic tomography Book by Walter Munk Peter Worcester Carl Wunsch

2. Wikipedia Ocean acoustic tomography