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Measuring Ocean Coherence Time with Dual-Baseline Interferometry

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ABSTRACT

Using the JPL AIRSAR interferometer, measurements of the ocean coherence time at L and C band can be made at high spatial resolution. Fundamental to this measurement is the ability to image the ocean interferometrically at two different time-lags, or baselines. By modifying the operating procedure of the existing two antenna interferometer, a technique has been developed make these measurements. L band coherence times are measured and presented in this paper.

Introduction

Over the past 20 years or so there have been many theories and models put forth concerning microwave sensing of the ocean surface and the importance of the time scale at which the scattering remains coherent. The coherence time in SAR is particularly important since SAR imaging relies on coherent integration to achieve the along-track resolution. Some recent estimates of the ocean coherence time at L band have been made on the order of 0.05 to 0.1 seconds [1,2,3].

The along-track interferometric SAR used by JPL [4] to measure ocean surface "velocities" makes a direct measurement of the coherence of the ocean surface over the lag time separating the observations by the two antennas. A technique has been devised [5] where measurements at two baselines, or lag times, may be acquired simultaneously with the existing AIRSAR two antenna L band system by taking advantage of the multichannel transmit and receive capability required for polarimetric data acquisition. The AIRSAR polarimeter acquires full polarization information by transmitting H and V alternately while receiving H and V from each transmit event. Using an identical scheme, radar pulses are emitted from the forward (F) and aft (A) antennas alternately and received by both. This produces four channels of data, FF, FA, AF and AA, which may be processed to imagery analogous to the polarimetric case. Two unique interferometric baselines may be constructed using these data, one being the separation distance of the antennas and the second being half this distance.

Example data

The AIRSAR instrument imaged the Strait of Messina in the summer of 1991. The mode of operations for one data take was the dual ATI baseline mode for L and C, and standard quad-pol for P band. A phase difference image is obtained (after processing to remove aircraft motion and sensor geometry phase effects) by combining the LAA complex image *(A)* with (in this case) the LAF *(F)* complex image according to the following formula:

$$\Delta\phi = tan^{-1} \left(\frac{imag(C)}{real(C)} \right) \quad (1)$$

where:

$$C = F\,A^{*} \quad (2)$$

A multi-look phase is determined by coherently summing the interferogram pixels, C, and retaining the resultant phase. This method has been shown by Rodriguez [6] to be the maximum likelihood estimator for determining the interferometric phase. In this case summation over 16 azimuth pixels was used. The phase difference may be converted to interferometric velocities using the following equation:

$$u = \Delta\phi \frac{\lambda v}{4\pi B} \tag{3}$$

where $\Delta\phi$ is the observed phase change, B is the baseline length, v is aircraft speed and λ is the radar wavelength. The ratio of B/v represents the time lag, τ, between forward and aft imaging. The interferometer velocity represents the radial component of the phase change. To project this onto the ground image plane, to extract the surface component, one must divide by $sin(\theta)$, where θ is the incidence angle. The surface interferometer velocity may be written as:

$$u_s = \frac{\Delta\phi}{k_b \tau} \tag{4}$$

where $k_b = 4\pi/\lambda\, sin(\theta)$ and is identified as the Bragg wavenumber.

Measuring coherence time with ATI

In addition to observing the phase difference and producing interferometer velocity maps, correlation maps of the ocean surface may be produced for each baseline. With this dual baseline information, the coherence time of the ocean surface can be measured directly. The coherence time is defined here as the time it takes the autocorrelation function of the backscatter field from the ocean to be reduced to $1/e$. The correlation strength between two images forming a baseline is given by ρ_i where i denotes which of the two baselines the correlation calculation is being carried out on. The correlation image may be calculated as follows:

$$\rho_i = \left| \frac{\Sigma f\, a^*}{\sqrt{\Sigma |f|^2 \; \Sigma |a|^2}} \right| \tag{5}$$

where f and a are the pixels of the forward and aft phase center images for baseline i, and the summations are carried out over an adjacent number of pixels, typically 8 or 16, similar to a multilook filter.

By using the two baselines available with the AIRSAR data, one may measure two values of ρ: ρ_s and ρ_l where s and l indicate "short" and "long" baselines. The nominal time lags associated with the two AIRSAR baselines corresponding to these measurements are 0.05 and 0.10 seconds respectively. Assuming a Gausian correlation function, the $1/e$ coherence time, τ_c, may be calculated using these two measurements:

$$\tau_c = \sqrt{- \frac{\tau_s^2 + \tau_l^2}{ln\,(\rho_s \rho_l)}} \tag{6}$$

High resolution correlation images for the short and long baseline of the Messina data have been formed using (5). From these short and long baseline correlation images, a coherence time image has been formed using (6). The image was quantized to 16 levels going between 0.0 seconds and 0.32 seconds in linear units of 0.02 seconds. The land areas exhibit coherence times greater than the 0.32 maximum. There is quite a bit of structure to this map, both large scale and small scale. There are areas in which the coherence time is noticeable larger than other areas. Ocean coherence times observed in this L-band image vary from about 0.09 seconds to 0.27 seconds.

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A BIBLIOGRAPHY OF GLOBAL CHANGE, AIRBORNE SCIENCE, 1985-1991

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In response to mounting scientific evidence that the biosphere and atmosphere of the earth are undergoing significant anthropogenic changes that appear to be increasing in magnitude and rate, the United States launched the Global Change Research Program (USGCRP) in 1989. The goal of the program is to "...Gain a predictive understanding of the interactive, physical, geological, chemical, biological and social processes that regulate the total earth system." Seven government agencies are involved in the program with the National Aeronautics and Space Administration (NASA) playing a key role by providing space based and earth based data.

The mission elements of NASA's approach to global change research involve the collection and analysis of satellite data from earth probes, geostationary platforms and the primary element of the NASA effort, the Earth Observing System (EOS). EOS consists of a series of polar orbiting platforms that will carry a variety of sensors capable of collecting digital data with spectral and spatial resolution suitable to support multi-disciplinary research in earth system science.

Many of the new remote sensing systems that will begin generating data by the end of this century are based on experiments conducted, and knowledge gained, using airborne platforms, especially within the last 25 years. Although the capability to conduct large scale monitoring of earth processes may be dated from July, 1972 with the launch of Landsat 1, neither the Landsat system nor any of the numerous devices launched since Landsat 1, or now planned for launch, preclude the need to develop and operate remote sensing systems on aircraft. Airborne remote sensing will continue to have scientific merit because 1) new concepts in remote sensing can be developed and proved faster and more cheaply on aircraft than on satellites; 2) the capabilities of aircraft systems are likely to improve, e.g. long duration, pilotless flights, increasing the utility of aircraft for earth observation measurements, especially observations required in response to unusual, rapidly developing events; 3) measurements from aircraft have been shown to be critical in studies of the expression of biophysical processes in the landscape; and 4) evidence indicates that data from airborne sensors increases the value of satellite derived data on global change processes by supplying information that lowers the error associated with satellite-data-driven estimates of the output of those processes.

A bibliography of global change, airborne science from 1985 to 1991 was assembled that may be of utility to the science community. The bibliography was compiled using EndNote® Plus, a software system that operates in Macintosh and PC environments. The intent of the bibliography is to include all articles (primarily in refereed journals) that address global change issues and that utilize aircraft to acquire data. The bibliography is a tool that has a variety of functions. It can be used by the science community as a reference to search for articles on specific topics, and it is gauge for assessing the impact of airborne sensors on global change science. From the bibliography data base information can be extracted on who is performing global change airborne science, who is sponsoring the research, where the research is being performed and what type of research is being done.

The bibliography includes entries for journal articles, conference proceedings, book and book sections, and reports. For journal articles the data base includes author(s), title, journal name, volume number, year of publication, month of issue, affiliation of author(s), key words, a label field, and abstract (if available). The software allows for inclusive and exclusive searches of the bibliography by character string. Citations can formatted in numerous ways for entry as in-text citations or bibliographic references. The current version of the bibliography will be updated periodically, and new versions should be available bi-annually.