Comparison of Directional Wave Spectra Obtained from Arrays of Wave Gauges with those Obtained by Airborne Scanning Lidar Systems

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Award Number: N00173001G908

LONG-TERM GOALS

To compare, contrast and attempt to reconcile wave directional spectra obtained in two fundamentally different ways: one from 2-D contour maps of the surface and the other from time series of surface elevation at 3 or more fixed points.

OBJECTIVES

To use surface wave data collected under highly controlled wave flume laboratory conditions to investigate differences in wave directional spectra estimated via different data collection techniques.

APPROACH

High quality two dimensional surface slope data have been acquired using a new Imaging Slope Gauge (ISG) apparatus in the Air/Sea Interaction Saltwater Tank (ASIST) wave flume at the Rosenstiel School of Marine and Atmospheric Science (RSMAS). The ISG is capable of measuring 2-D surface slope at very high temporal and spatial resolutions. The directional variance spectrum of surface slope is computed using the 2-D fast Fourier transform (FFT) method. From this, the wavenumber spectrum of surface elevation can be computed which is equivalent to the wavenumber spectrum determined using the 2-D FFT method on 2-D surface topography data. Using many ensembles of surface slope images, we can simulate the mixing of temporal and spatial domains inherent to surface topography data collected via aircraft-mounted Radar and Lidar systems, i.e. airborne topographical mapping (ATM). The wavenumber spectrum, determined using laboratory data simulating ATM collection techniques, is compared to the spectrum computed directly from the original data images. The analysis of ATM data, distorted by the rolling of the aircraft, is investigated.

WORK COMPLETED

The wavenumber spectrum was computed from 246 ensembles of ISG surface slope images collected during fetch-limited steady state conditions with a 10 m equivalent wind speed equal to 5 m/s. The ISG sampling frequency was set to 60 Hz. For the experimental conditions the peak wavenumber is around 1.0 rad/cm and the resulting directional spectrum is clearly unimodal at all wavenumbers present (fig. 1). To mix the temporal and spatial scales and effectively simulate ATM data collection a higher sampling frequency was required. This was achieved by resampling the 246 collected ISG images at a rate five times greater to yield 1230 linearly interpolated “virtual” images with an effective sampling frequency of 300 Hz. Mosaic images were created by combining 64 swaths from subsequent

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 2003		**00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Comparison of Directional Wave Spectra Obtained from Arrays of Wave Gauges with those Obtained by Airborne Scanning Lidar Systems	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Rosenstiel School of Marine and Atmospheric Science,,University of Miami,,4600 Rickenbacker Causeway,,Miami,,FL, 33149**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**5**	

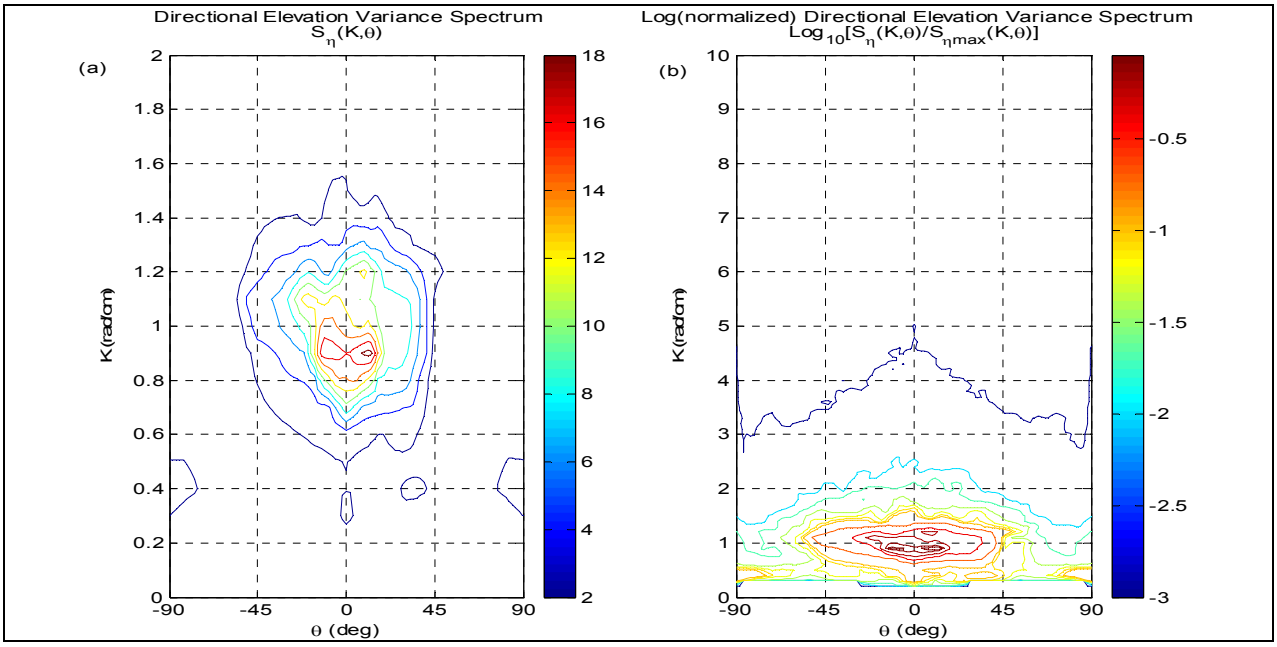

Fig 1. Average of 246 ISG ensembles of elevation spectra

images in time. Adjacent swaths in the mosaic were cut from adjacent images in time, therefore effectively mixing the temporal and spatial domains. The result was 19 mosaic images of surface slope. Figure 2 shows the directional variance spectrum computed from these mosaic images and it is also clearly unimodal at all wavenumbers. The similarity exhibited by figures 1 and 2 indicates that the mixing of temporal and spatial domains in ATM type data does not appreciably affect the directional spectrum computed from such data.

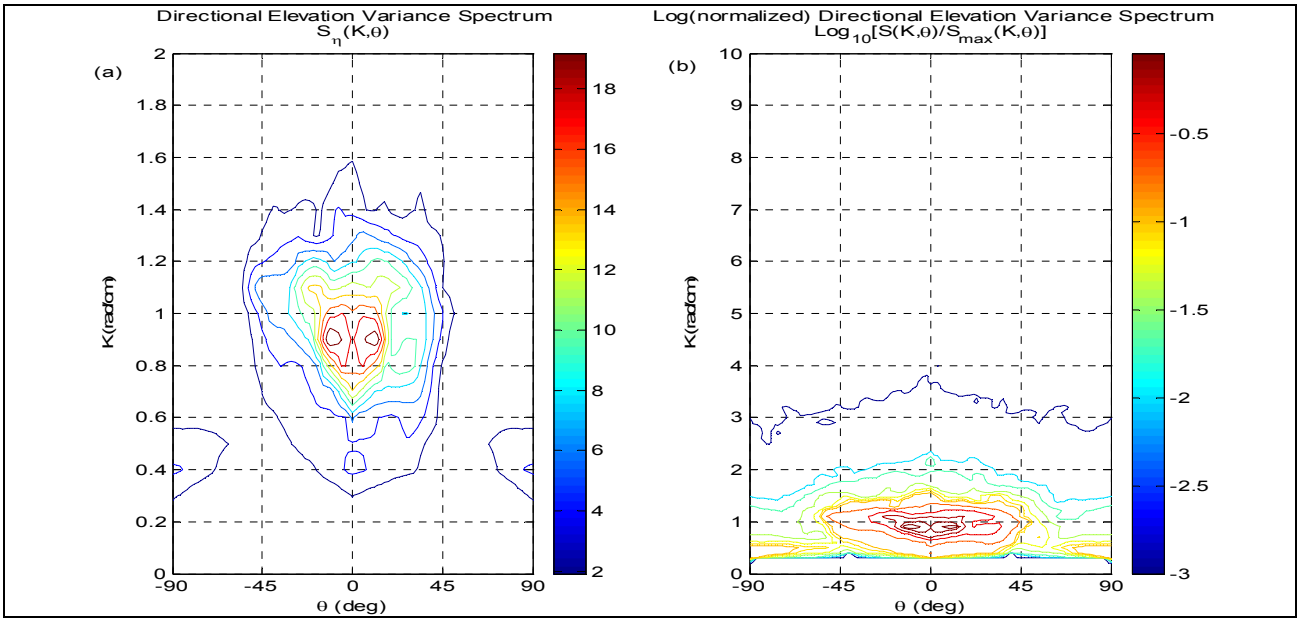

Fig 2. Average of 19 elevation spectra from mosaics representing flight direction WITH the waves (down-tank)

The same cannot be said for a current technique of handling the wavy edges of ATM type data collected from rolling aircraft. The cross track edges of the ATM image are nonlinear and slowly vary with the roll of the aircraft. Laterally out from the edge of the image there exists no data, however the 2-D FFT method requires that the image be rectangular. The technique in question uses a linear interpolation routine in the flight direction to fill the voids between any two points containing data. All other void cells are simply filled with zeros (fig. 3). The computed wavenumber spectrum shows disturbing evidence of spurious additional energy at the cross track angles (+/- 90 degrees) at wavenumbers above the peak (fig. 4b).

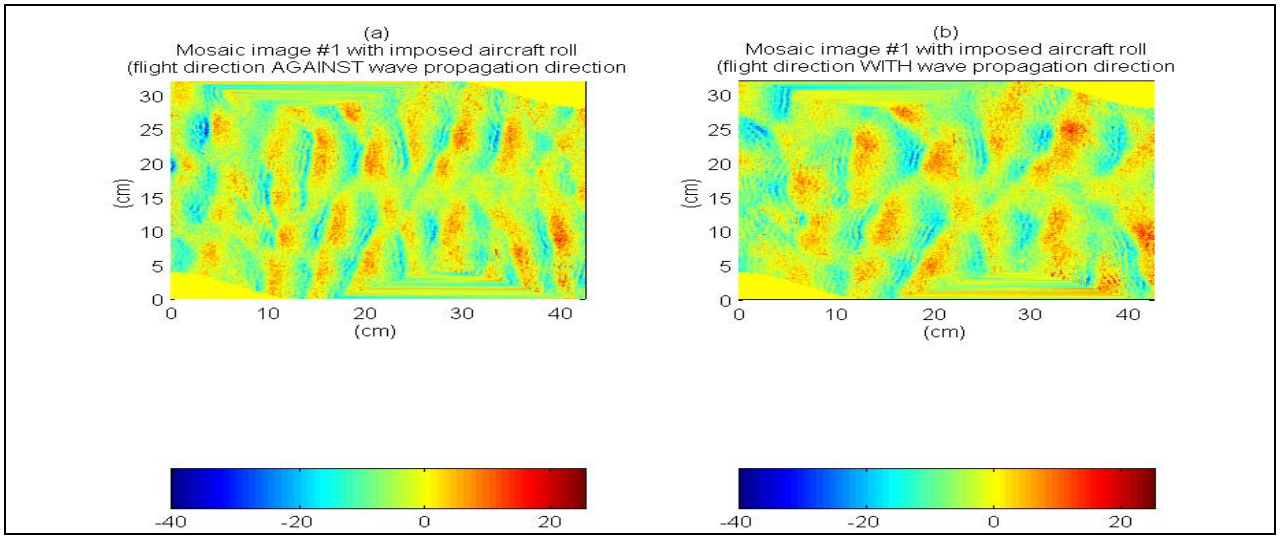

Fig 3 ISG surface slope data simulating ATM data collection from a rolling aircraft flying a) AGAINST (up-tank) and b) WITH (down-tank) the wave propagation direction.

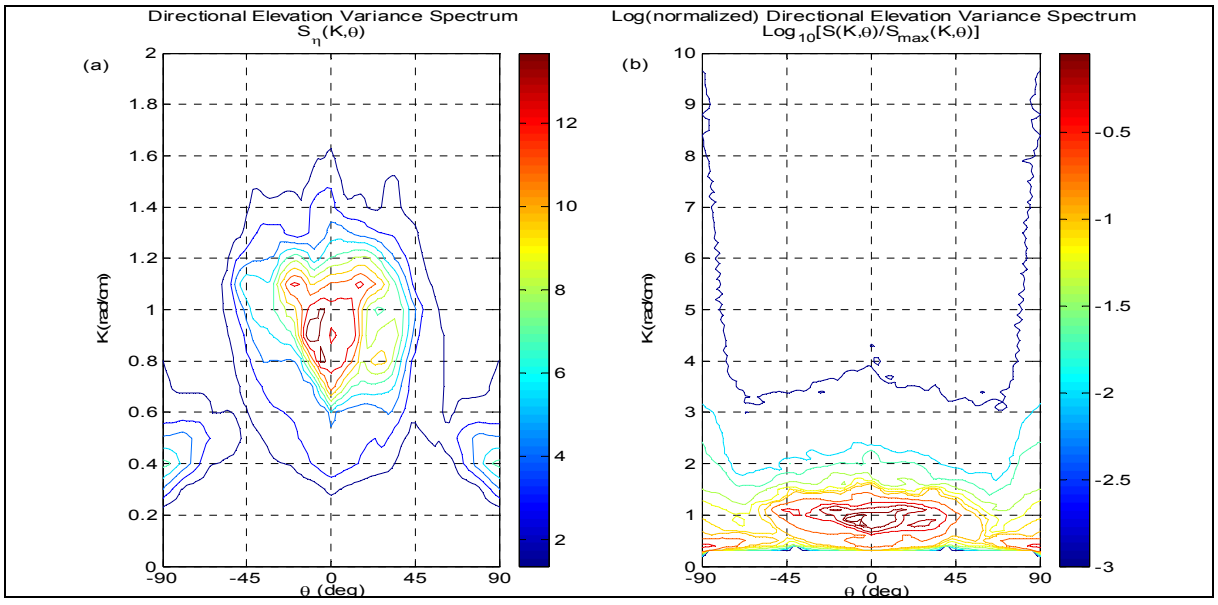

Fig 4. Average of 19 elevation spectra from mosaic with imposed aircraft roll representing flight direction WITH the waves (down-tank)

RESULTS

The mixing of temporal and spatial domains inherent in 2-D surface topography data collected via aircraft mounted Lidar/Radar systems has negligible effect on the wave directional spectra estimated from such data. When compared to the actual directional spectra of the surface waves, the directional spectra computed from topography data collected onboard aircraft traveling in the same direction as the waves are propagating is less accurate than that from aircraft traveling in the opposite direction. This is due to the decreased amount of spatial wave information present in the final images taken from an aircraft making one pass over the image area and flying in the direction of wave propagation. More important, however, is the careful handling of data voids laterally outside of the Radar/Lidar swath edges. It has been determined that interpolating to fill these voids introduces erroneous energy in the directional wave spectrum at angles near orthogonal to the flight direction.

IMPACT/APPLICATIONS

This study helps validate the use of airborne topographic mapping in estimating the wavenumber directional spectrum of surface waves. It further highlights the need for particular care in the analysis and interpretation of such surface topography data.

PUBLICATIONS

Robert D. Wolfe, 2003: *Estimating Directional Wave Spectra from Sea Surface Topography Data and the Effects of Methods Used to Smooth Results*. Master's Thesis University of Miami.