GLOBAL WAVEFORM SHAPE ANALYSIS FOR THE DETECTION AND MONITORING OF EPHEMERAL SURFACE WATER

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ABSTRACT

The past 15 years of satellite radar altimeter missions have resulted in the creation of a huge database of echoes collected over the Earth’s land surfaces. These echoes contain information on the changing distribution of surface water in the form of snow, ice and liquid water. Key to the interpretation of this information is the detailed analysis of echo shapes. This paper presents results from the global analysis of multi-mission altimeter waveform data, illustrating the unique information content of these echoes, and demonstrating the potential for detection and monitoring of the changing patterns of ephemeral surface water using this approach.

INTRODUCTION

Over the past 15 years of satellite radar altimetry missions there has been a vast amount of radar altimeter data collected over all of the Earth’s surfaces from multiple missions. Although for some missions, Jason-1 and TOPEX, the radar altimeters were configured for ocean operation, ERS-1, ERS-2 and Envisat were configured for multi-mode operation, with ocean and ice modes for the ERS missions and three modes, loosely described as ocean, ice and land modes, for Envisat.

The work of the EAPRS Lab in retracking the received waveforms to obtain accurate heights of the Earth’s land surface has been well documented [1]. For this paper, the authors will concentrate on the information contained within the echo shapes. Previous studies have described the global analysis of multi-mission waveform shapes [2] and the information contained therein, which includes surface roughness and terrain type. However, the emphasis in this paper is on surface water in the form of snow, ice and liquid water.

WAVEFORM SHAPES

The EAPRS Lab has developed a rule-based expert system [3] which is currently based on 10 different echo shapes, which are described as:

- Wide with anomalies in shape,
- High slope,
- Wide with pre-peak,
- Bog,
- Quasi-specular,
- Very thin quasi-specular,
- Simple multi-target,
- Complex multi-target,
- Ocean-like,
- Flat patch.

An example of the very thin quasi-specular waveform shape received over inland water is shown in Fig. 1. It can be seen that this shape is common to multiple missions, and shown here are echoes from TOPEX and ERS-2. Examples will be shown in later sections of this paper of the analysis of the spatial and temporal distribution of the different waveform shapes that are received in response to different types of surface water conditions.
METHODOLOGY FOR GLOBAL PLOTS

The data for the global plots are summed over one orbit repeat period, or cycle number. Because different missions and different orbit repeat cycles have different spacings, the pixel size is chosen to obtain the best spatial resolution for each orbit repeat pattern. Thus for ERS1-3 day data the pixel size represents 3° and for TOPEX & Jason-1 a 2° pixel is used. For the ERS and Envisat 35-day cycles, 45° pixel size is used and for the Geodetic mission, 7.5°.

Thus, within each pixel, for each orbit cycle, the number of waveforms in each shape category is summed. From this, global numbers of waveforms and percentages are produced. The resulting spatial and temporal distributions can then be analysed. For this paper, work has concentrated on a 3-year period of ERS-2 data from January 1998 to December 2000, with the production of global statistics for specific waveform shapes of a 3-year mean and standard deviation, and monthly differences from the mean.

WAVEFORM SHAPES FOR DETECTION AND MONITORING OF SURFACE WATER

Of the waveform shapes described above, there are four shapes of particular interest for the detection of surface water. These will be described in turn, with examples and illustrations of analyses of results.

Spike

The very thin, quasi-specular waveform shape, with its characteristic spike is predominantly produced over water and especially melting snow. In the percentage plots in Fig.2., areas that are always wet, such as the Amazon, the Ganges and Entre-Rios / Gran Chaco show high mean occurrences of the ‘Spike’ waveform shape, whilst the standard deviation plot shows the snow melt in North America and Russia and floods in South America, the Congo and the Ganges.
Fig. 3. 3-year Mean and Standard Deviation of percentage occurrence of Quasi-specular Waveform Shape

**Quasi-specular**

The quasi-specular shape is a bright quasi-specular response which is produced over inland water. As with the ‘Spike’ waveform shape, this waveform can be seen in wet areas of the world. Noticeable in Fig. 3 is that South America and the Amazon in particular is always wet with a high mean occurrence and low standard deviation. Also noticeable in Fig. 3 is that the ERS-2 ocean/ice mask is clearly visible. It is also clear that this waveform shape is not generated by echoes from land ice, as can be seen by the total absence of occurrences in Greenland and the Antarctic.

**Flat-patch**

It is clear that the Flat-patch waveform shape enables the identification of snow and ice; however, the presence of snow is shown by an absence of this waveform shape. As can be seen in Fig. 4, this waveform shape also occurs round the coasts and is indicative of calm water. Inland water, such as the Great Lakes in Canada, is also visible. The plots of the mean and standard deviations seem fairly static, however, there are particularly dramatic seasonal effects visible in the differences from the 3-year mean. These are shown in Fig. 5, where the seasonal changes in the Arctic and Antarctic are extreme. Note that the differences change in the range -35% to +35%.

**Wide with anomalies in shape**

Finally, the wide waveform with anomalies in shape is found over oceans and ocean-like terrain, in particular deserts and sea ice. As would be expected, the plot of the 3-year mean in Fig. 6 shows a high mean and low standard deviation over the oceans. Also in Fig. 6 it can be seen that over Greenland and the Antarctic there is a high mean, indicating the presence of land ice. Then, particularly in the Antarctic but also in some areas in the Arctic, the standard deviation detects the changing extent of the sea ice.

Fig. 4. 3-year Mean and Standard Deviation of percentage occurrence of Flat-patch Waveform Shape
DISCUSSION

There has been a vast amount of data collected from over 15 years of altimeter missions. The EAPRS Lab at De Montfort University has developed a rule-based expert system with 10 retrackers for different waveform echo shapes, which was originally devised to obtain accurate estimates of the orthometric height of land. However, there is a huge amount of information about the Earth’s surface encoded in the waveform shapes.

In this paper, the authors have concentrated on the temporal variation of waveform shapes that highlight the changing patterns of water in the form of surface water, snow, land ice and sea ice. Examples have been presented using ERS-2 data to produce 3-year mean and standard deviation and 3-year series of differences from mean for the different waveform shapes.

The technique of producing long-term mean and standard deviation for different waveform shapes, makes it possible to determine norms for particular water conditions. Differences from the mean enable the monitoring of unusual and intermittent events such as flooding. Seasonal changes in water, snow and ice can be mapped and it would be possible to monitor annual changes and determine any significant trends.

The vast amount of data available from satellite radar altimetry is a major resource and together with the techniques discussed here offers great potential for the detection and monitoring of ephemeral surface water.

REFERENCES

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