APPLICATION OF KOMPSAT-5 DATA FOR EMERGENT OIL SPILL MONITORING

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1. INTRODUCTION

The complex evolution of human society has been causing disruptions and serious damages to our environment, often resulting in loss of properties and human lives. Researchers have focused their effort on such environmental disasters in order to prevent and minimize losses in the future. Remote sensing techniques involving the use of airborne and space-borne systems have been given the highest priority as a means to detect various signs of disasters and support emergency response management. Disasters such as floods, earthquakes, volcanic eruptions, wind storms, wildfires, oil spills, and landslides occur constantly, and the number of such disasters has been increasing annually [1]. Among these disasters, oil spills have raised one of the most significant environmental concerns. Many studies have focused on developing and improving techniques for accurate mapping and efficient surveillance of oil spills by the use of both airborne and space-borne systems. Radar instruments such as synthetic aperture radar (SAR) systems have attracted significant interest in remote sensing communities because they are capable of all-weather imaging in the absence of sunlight. Thus far, in most oil spill studies, the space-borne SAR systems used have been based on C-band SAR systems, including ERS-1/2, RADARSAT-1, and ENVISAT ASAR [2-5]. Oil spill detection using L-band system seems to be not very effective because the ocean Bragg waves that resonate with the electromagnetic waves of the L-band are relatively longer and relatively more difficult to be dampened by oil spills [6]. Recently, several new X-band SAR systems have been developed and put into orbit. Currently, COSMO-SkyMed and TerraSAR-X, which were launched in 2007, are in operation, and KOMPSAT-5 and TanDEM-X are to be launched soon. Thus, there is an urgent need to investigate the characteristics of X-band SAR systems for oil spill monitoring and to examine the suitability of these sensors as tools that support emergency response.

2. KOMPSAT-5'S ABILITY FOR OIL SPILL DETECTION

KOMPSAT-5 (Korean Multipurpose Satellite-5) can be regarded as one of the next-generation earth observation satellite because it carries a high-resolution X-band SAR sensor that can serve for civilian users and it will offer an improved resolution, image quality, and maneuverability compared to other established SAR systems. In order to develop new satellite technology such as KOMPSAT-5, in addition to the discovery of new applications, better communication between scientists and system developers is necessary. It is critical for application developers and data users to understand system parameters in order to achieve better technological advancement. From this point of view, in this study, we have attempted to determine which system parameters of KOMPSAT-5 have the greatest effect on oil spill detection and management, as well as the manner in which the parameters affect the detection, from the case study of the Hebei Spirit oil spill incident that occurred on the west coast of the Korean peninsula in December 2007. Oil spills are very serious environmental disasters and often occur in inaccessible areas. Thus, it appears that surveillance approaches, utilizing the all weather SAR satellites, are the most effective methods for detecting oil spills. Since KOMPSAT-5 operates at the X-band radar frequency, the damping ratios, which are the ratios of the NRCS (Normalized Radar Cross Section) of an oil-free sea surface to that of an oil-covered sea surface, are greater compared to the corresponding values of L-band or C-band frequencies under identical or comparable wind conditions. The greater the damping ratio, the higher the probability of detecting oil spills from SAR data. However, the valid damping ratio can only be achieved only when the NRCS for the oil-covered area is higher than the NESZ (Noise Equivalent Sigma Zero). Therefore, in the design of a SAR payload, the NESZ should be kept as low as possible. In general, the NRCS decreases as the incidence angle increases in the ocean. The NRCS corresponding to the regions where the incidence angle is high should be considered together with the NESZ, because under low wind conditions, some NRCS may even be smaller than the NESZ. We calculated the X-band NRCS using radar scattering model [7] and Romeiser's ocean wave spectrum [8]. The calculation results showed that the NRCS for the wind speed of 4 m/s fluctuate between -23 dB and -20 dB depending on the wind direction. Hence, in the case where the wind speed is lower than 4 m/s, the NRCSs of KOMPSAT-5 for the oil-covered region may be less than -23 dB; these values can be embedded within the noise levels.

3. OIL SPILL MONITORING

We developed a new automatic oil spill detection method which uses damping ratios as input. This method adopts a local optimal threshold which can be determined by the damping ratio. The damping ratio is again estimated from the wind speed and direction of the area as well as radar frequency used. The results obtained after applying the local optimal threshold are then reanalyzed using mathematical morphology to refine the oil spill output. This method was applied to the SAR data capturing the Hebei Spirit oil spill accident. When the oil spills occurred on the west coast of South Korea, TerraSAR-X, ERS-2 SAR, RADARSAT-1, ENVISAT ASAR, and ALOS PALSAR data were acquired over the contaminated area. It was very rare case that all civilian SAR satellites were available for capturing the same oil spill accident. The damping ratios along with the Bragg wavenumber (that is a function of incidence angle and radar frequency) were estimated from the wind speeds and directions observed nearby AWS (automatic weather station), and these values were used for local optimal threshold. The results of oil spill detection showed the location and spread of oil spills, as well as the areal extent of oil spilled area as function of time. The results also indicated that the contaminated area spreads southward relative to the previous oil spill locations. In general, the movement of the oil spill is affected by the wind driven current and tidal current. There were strong winds blowing to the south or to the south-east on December 13, which may cause the southward movement of the oil spill.

4. DISCUSSION AND CONCLUSIONS

There have been numerous environmental disasters such as oil spills, and the importance of synthetic aperture radar as an efficient tool for supporting disaster response has been well recognized. Although the detection of oil spills has its limitations depending on the sea surface wind condition and the presence of look-alikes, SAR is the most powerful sensor because it can acquire images whenever and wherever we need them without fail. When the variation in the damping ratio is examined as a function of SAR frequency, the damping ratio at the X-band is higher than the damping ratios at the C- and L-bands at a fixed incidence angle and wind speed. The probability of detecting oil spills from SAR data increases with the damping ratio. Therefore, it is more advantageous to utilize high-frequency SAR data, such as TerraSAR-X and KOMPSAT-5 data, for the detection of oil spills if the dynamic range between the NRCS of the oil-free surface and the instrument noise level is larger than the damping ratio. From multi-frequency and multi-temporal SAR data acquired for Hebei Spirit oil spill incident, the extent of spill and subsequent movements of crude oil were well monitored using a new automatic oil spill detection method. This is crucial for the planning and execution of the clean-up tasks.

11. REFERENCES

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