DubaiSat-1 mission and its potential to advance research on semi-arid and arid environments

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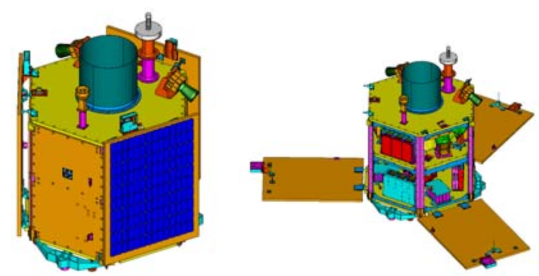
Abstract – DubaiSat satellite system will be the first spatial program in the United Arab Emirates (UAE) that is fully dedicated to earth observation and monitoring. The launch of the first platform (DubaiSat-1) is scheduled for the second quarter of 2009 by the Moscow-based International Space Company (ISC) Kosmotras. The preliminary design work has already started for the second platform DubaiSat-2 planned to be launched by 2012. DubaiSat-1 will observe the Earth from a sun-synchronous orbit providing new and unique opportunity for continuous monitoring of the local and regional environment. The new DubaiSat-1 data, combined with existing polar orbiting and geostationary missions, will provide potentially significant enhancements to the predictive capabilities of the existing environmental models as well as improved capabilities for monitoring and predicting natural hazards such as water pollutions, land degradation, desertification and droughts. DubaiSat-1 will deliver multispectral images with 5-meter resolution using three visible bands (420 to 510 nm, 510 to 580 nm and 600 to 720 nm) and one near-IR band (760 to 890 nm). It will also have a panchromatic channel with 2.5-meter resolution (420 to 720 nm).

Keywords: national programs, environmental remote sensing, high resolution multispectral systems.

1. INTRODUCTION

The launch of DubaiSat-1 by the second quarter of 2009 on board Dnepr Rocket will inaugurate UAE's program in the field of earth observation and remote sensing. The satellite which is fully owned and operated by Emirates Institution for Advanced Science and Technology (EIAST) - Dubai Government, and developed by Satrec Initiative - Korean satellite manufacturer, is considered UAE's first earth observation satellite. DubaiSat-1 is designed to be compatible with low earth orbit with an altitude ranging from 500 km to 800 km. DubaiSat-1 with its stowed solar panels is compatible with most of small satellite launchers (i.e. Dnepr, Falcon) as primary or secondary payload. DubaiSat-1 will have an electro-optical payload carrying Dubai Medium Aperture Camera (DMAC) with 5 linear detectors for one panchromatic, three visible and one near-infrared channels. The spacecraft bus provides a typical pointing performance of 0.2 deg. DubaiSat-1 weighs less than 200 kg including 50 kg payload mass. The average power consumption is less than 150 Watts. The next two figures depict DubaiSat-1 platform in both launch configuration and exploded view. The origin of the satellite coordinates is located at the geometric centre of the launch adaptor bottom plane as shown in Figure 1(a). The +Z-axis is toward the payload optical axis. +X-axis is defined along the scanning direction of the DMAC, which is normal to the detector lines. The DMAC payload consists of a Telescope, Focal Plane Assembly (FPA), Signal Processing Module (SPM), two Mass storage & Control Modules (MCMs), and Thermal & Power Module (TPM). DMAC also has a direct link to an Image Transmission Unit (ITU).



(a) (b)

Figure 1. Illustration of DubaiSat-1 platform in launch (a) and operational (b) configurations

2. OUTREACH

DubaiSat-1 design and manufacturing has been performed during the past two years at Satrec Initiative facilities in South Korea with strong participation of UAE engineers from EIAST. In addition to the satellite itself, the partnership initiated with Satrec Initiative was aimed toward fostering advanced technology transfer of South Korean space technology to the UAE including space hardware and software, and the techniques necessary for creating it. Developing a core team of UAE scientists and experts in space technology was the most definitive outcome of DubaiSat program. Indeed, developing a base of UAE scientists and engineers in this very high advanced field is a crucial first step to enhance and solidify UAE presence within the international scientific community.

As soon as DubaiSat-1 enters its final orbit, satellite control and data receiving and processing will be conducted from EIAST Center in Dubai. EIAST will receive and pre-process images in real-time and make them ready for distribution to the end users. EIAST ground station is currently receiving daily data from other polar orbiting platforms (Aqua).

DubaiSat development team is already finalizing the design work for DubaiSat-2, and will continue with its plans to create the first constellation of earth observation satellites in the region. The design concept of DubaiSat-2 is being laid down and strategic partners for its construction are being selected.

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Figure 2. EIAST Engineers working on DubaiSat-1 assembly at Satrec Initiative Lab in South Korea

3. CURRENT RESEARCH PROJECTS

Several remote sensing projects have been initiated recently at EIAST. These projects cover different application topics of environmental remote sensing. A special focus was given on local and regional environmental concerns such as sand and dust storms, fogs, drought, vegetation stress…etc. Most of these projects are based on Geostationary (MSG-SEVIRI) and coarse-resolution polar orbiting data (MODIS). DubaiSat-1 data will be incorporated to these projects as soon as it becomes available. Brief overviews of some of these projects are presented in the following sections.

3.1 Water quality monitoring surrounding desalination plants

The objective of this project is to develop an automated approach for monitoring water quality and temperature (thermal properties) surrounding the discharges of desalination plants in the UAE coastal areas.

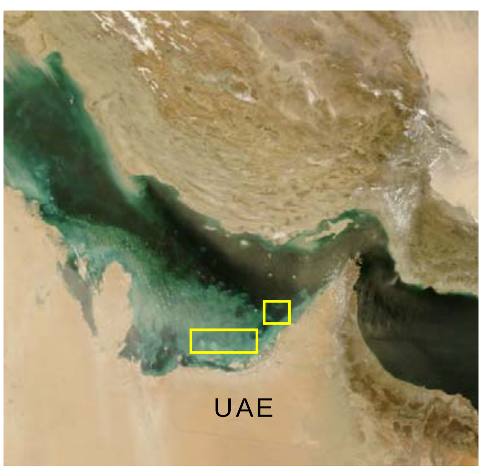

Figure 3. Study areas shown in a true-color MODIS composite acquired by EIAST ground station on February 21st, 2008

Visible and thermal measurements provided by MODIS sensors on board of Aqua satellite were used in this project. Bands 1, 3 and 4 (visible) and 31 & 32 (thermal) were selected for this project. Parameters of interest include chlorophyll concentration, temperature, color, and total suspended solids. Similar MODIS-based algorithms have also been developed to map the Total Suspended Matter (TSM) distribution and Sea Surface Temperature (SST) (Koponen et al, 2004). Future multi-spectral data from DubaiSat-1 (5-m resolution) will be also used to detect small changes in water color that cannot be detected with the MODIS data (250 m).

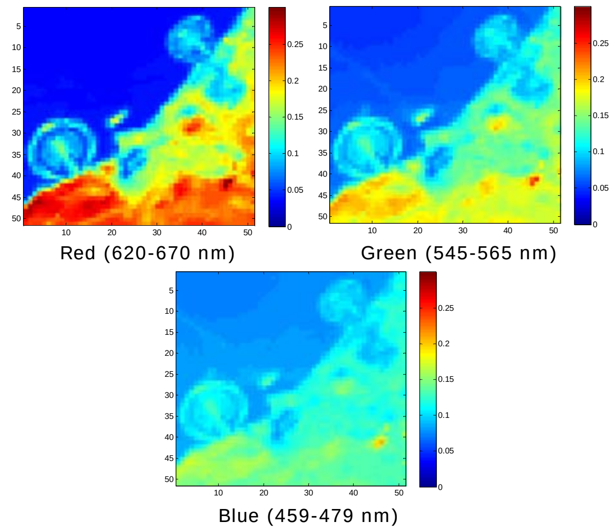

Figure 4. Water reflectance measured by MODIS three visible channels on January 10th 2009

The images presented in figure 4 show the sensitivity of the three visible channels of MODIS to the variation of water properties. High sensitivity was observed with the blue channel where the reflectance has the better response to the variation in water turbidity. The spatial and temporal variation of water reflectance will be analyzed in two study areas next to two major desalination plants in the UAE. The correlation level between satellite reflectances and concentrations of some water quality parameters will be then explored.

3.2 Sandstorms Detection and Monitoring

Dust and sand storms create potentially hazardous air quality to humans, and adversely affecting climate on a regional and world-wide scale. Remote sensing has shown to be a valuable tool in detecting, mapping and forecasting such events. Application of geostationary and polar orbiting remote sensing in dust and sand storms has been widely investigated in the past two decades. The objective of this project is to develop a new automated tool for detecting and monitoring dust and sand storms in the Gulf region using MODIS and METEOSAT SEVIRI-MSG data.

In this project, a neural-network-based technique will be used to detect and mask pixels with moving dust from SEVIRI HRV and the two other visible channels. This tool will be helped with a second neural network system that detect and extract predefined features in the dust and sandstorm fields. The obtained dust storm simulations will be then re-sampled and compared to the ones obtained by the NCAR WRF regional prediction model at 16-km resolution (Caquineau, 2002), (Evan et al, 2006). Several well documented dust storm events that occurred between 2006 and 2008 will be used to calibrate and validate the developed tool. The images shown in figure 5 illustrate the temporal evolution of one dust storm event detected by METEOSAT SEVIRI-MSG. With their high temporal resolution, geostationary satellites are indispensable for detecting and tracking dust and sand storms.

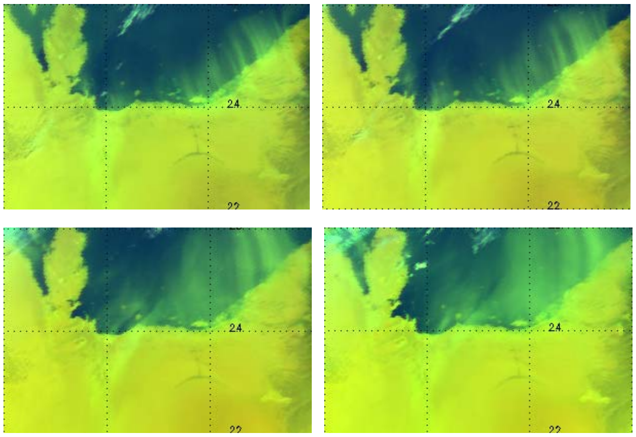

Figure 5. Dust storm event over the UAE captured by METEOSAT-SEVIRI on February 28th, 2009

3.3 Developing a BRDF model for the UAE coastal and inland zones

The objective of this project is to develop and apply a Bidirectional Reflectance Distribution Function (BRDF) model to quantify the effect of sun illumination and SEVIRI-MSG observation angles on measured reflectance for both land (mostly desert) and coastal water pixels in the UAE. The approach used in this project involves fitting the model to collected water and land pixels and inverting it. The need of a strong BRDF model is especially important for EIAST research projects based on geostationary data due to the wide range of variation of both illumination and observation angles of this type of platforms compared to polar orbiting platforms.

An Artificial Neural network technique has been developed to train and validate the BRDF model. The neural network model has been adapted from a similar technique developed for SEVIRI-MSG data as a part of sea-ice mapping and classification tool (Ghedira et al., 2008).

In this project, a total of 10,000 water and land pixels were selected at different locations and acquisition times. For each pixel, three reflectance values (R01, R02, and HRV) and three acquisition angles (solar, satellite, and azimuth) were retrieved. Two neural networks (water and land) were trained, calibrated and validated for each of the three visible channels (R01, R02, and HRV). The available data have been subdivided into three equal sets: training, validation, and testing. The preliminary results are promising. The Temporal behavior of observed and simulated R02 reflectances of November 30, 2008 is shown in the figure below (Figure 6). The maps presented in figure 7 show the simulated results of the six trained nets.

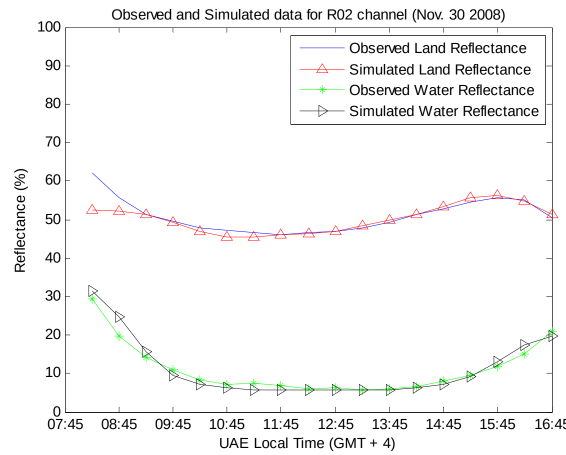

Figure 6. Temporal behavior of observed and simulated reflectances for MSG-SEVIRI R02 channel.

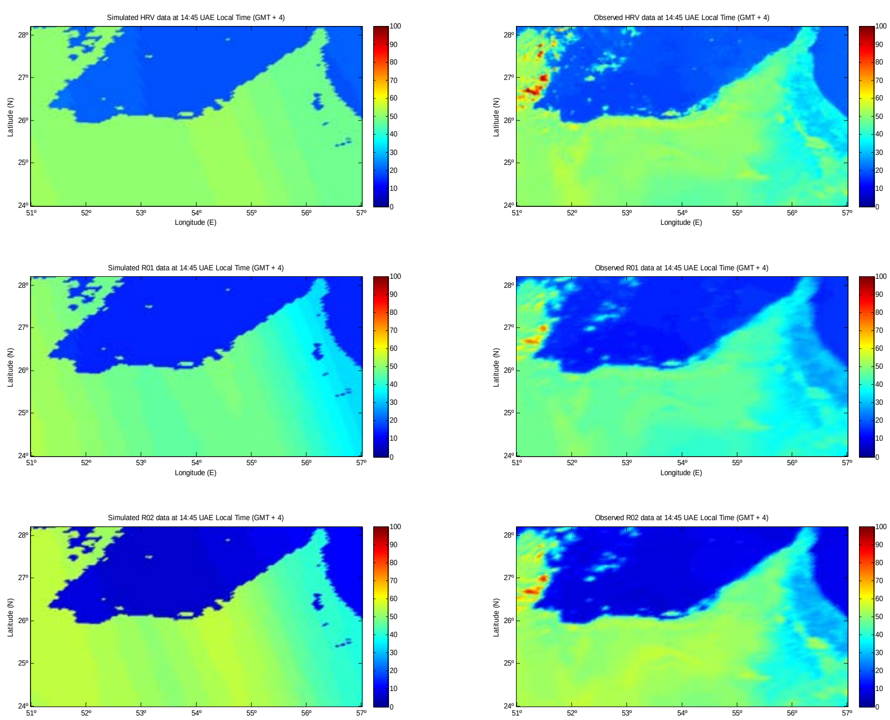

Figure 7. Comparison between observed and simulated reflectances for the three visible refectances

3.4 Fog detection and monitoring

The objective of this project is to develop a satellite-based tool for forecasting, detection and classification of fog events. The UAE location on the edge of a very warm sea and a hot and dry desert create the optimal conditions of inland fog forming. The afternoon sea breeze, which is almost a daily event in UAE coastal areas, transports moisture inland. At clear sky conditions at night, the desert environment radiates heat very efficiently and temperatures fall quickly (Thomas, 2008). The rapid cooling of accumulated inland moisture during the night represents the optimal conditions for fog development. The temperature difference between two infrared bands (11 µm and 4 µm) forms the basis for fog detection and classification (Bendix, 2000). These two frequencies, available in the European geostationary satellite Meteosat-MSG, are widely used in fog detection and monitoring in both Europe and Asia (Ajjaji et al., 2008).

The developed tool will be used to characterize fog formation, evolution, and dissipation in land and coastal areas in the UAE. Fog forecasts will be first generated before sunrise using thermal imagery collected at night. The predicted maps will be then corrected and updated with the first visible images received and processed as soon as the sun rises. Web-based fog maps will be generated by the developed tool in near-real time.

The maps presented in figure 8 show the temporal evolution of one dense fog event occurred over the UAE on December 24, 2008.

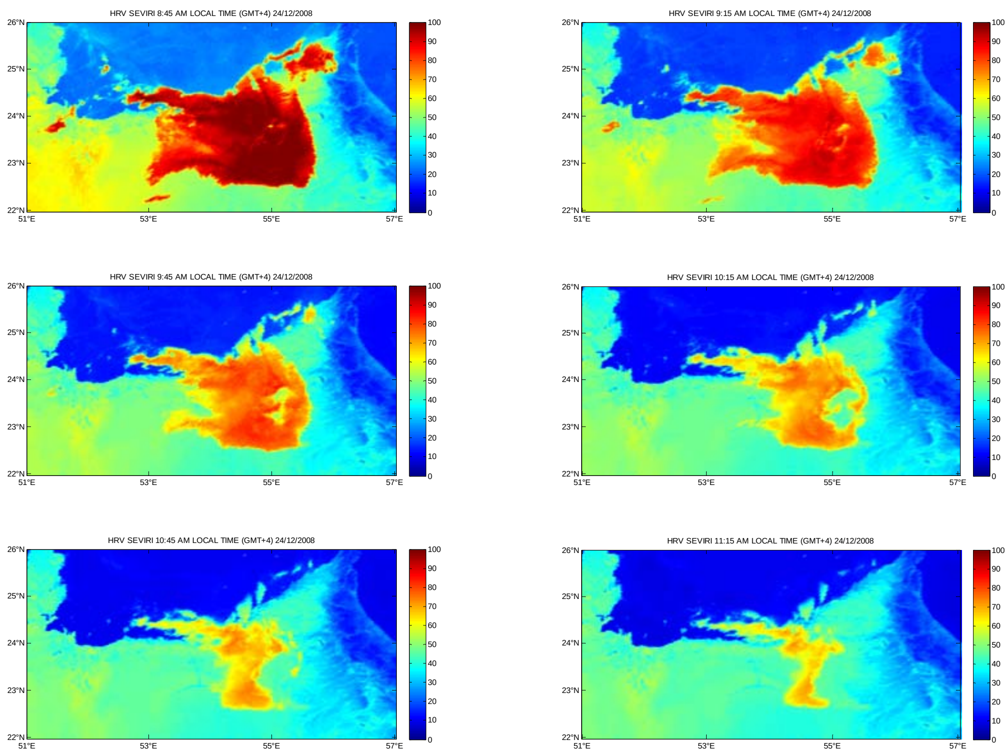

Figure 8. Reflectance values measured in the high resolution visible channel (HRV) of SEVIRI-MSG

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