First Ethiopian Remote Sensing Satellite (ETRSS-1): Mission information and overview

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Abstract

The amount and quality of land, water and atmospheric information is critical to plan, monitor, predict and mitigate the impacts of climate change, urbanization and population growth. To get reasonably accurate regional information, Ethiopia launched its first Earth Observing satellite on the 20th of December 2019 in collaboration with the government of China. The 65-kg Ethiopian Remote Sensing Satellite (ETRSS-1) carries one earth observing multispectral camera to measure many aspects of land, water and biosphere. It was placed on sun-synchronous orbit at an altitude of 628.61km and collects images at a Ground Sampling Distance (GSD) of 13.75-m within a revisit period of 4 days. Currently, all the instruments are operating as intended and the early-stage images captured by ETRSS-1 are within sensible and acceptable range. This indicates that it can serve as a supplementary and alternative data source to operational and research services.

1. Introduction

Most of the local, regional and international research findings (e.g., Thomson et al., 2011; Koriche et al., 2016; Enenkel et al., 2016; Bayissa et al., 2017) expressed that Ethiopia needs high resolution topographical, meteorological, hydrological and agricultural information to understand and circumvent threats posed by natural and anthropogenic disasters. This is because planning, monitoring and evaluation of urbanization, agricultural productions and natural resources requires high resolution accurate and real time ground measurements or satellite informations (Garuma, 2018). This is true considering the fact that the country has been vulnerable to extremes of climate: for example, persistent droughts and flooding (e.g., Bryan et al., 2009; Lyon and DeWitt, 2012; Robinson et al., 2013; Bahaga et al., 2019). To meet the expressed needs, the Ethiopian Remote Sensing Satellite (ETRSS-1) (Fig. 1.), which is Ethiopia's first Earth observation satellite, was launched on the 20th of December 2019 onboard the Chinese Long March 4B rocket (CZ-4B) at Taiyuan Satellite Launch Center in China. The satellite is launched as a secondary payload together with 8 other satellites. It is to be recalled that most first national satellites were launched by foreign rockets. For example, the first Canadian satellite was launched aboard an American rocket from an American spaceport (Almond et al., 1976). The same applies for Australia, which launched its first satellite aboard the U.S. Redstone rocket (Clarke, A, 1971). Similarly, the first Italian satellite San Marco 1 launched on 15 December 1964 on a US scout rocket from Virginia (Broglio et al., 1967). This shows that most of the satellite technologies develop through collaboration and knowledge transfer which has immense benefits to distribute technological capabilities, to tackle environmental disasters and ensure socioeconomic development beyond the national boundaries. This would increase cooperation between nations, reduce technological competitions that would otherwise take place between few nations and open the stages for less developed nations to participate in the scientific and technological transformations of the world. Furthermore, this plays a pivotal role in achieving the 17 Sustainable Development Goals (SDGs) (Colglazier, 2015) identified by the United Nations that intends to achieve access to clean water, food security, poverty alleviation, health care, environmental sustainability and urban development.

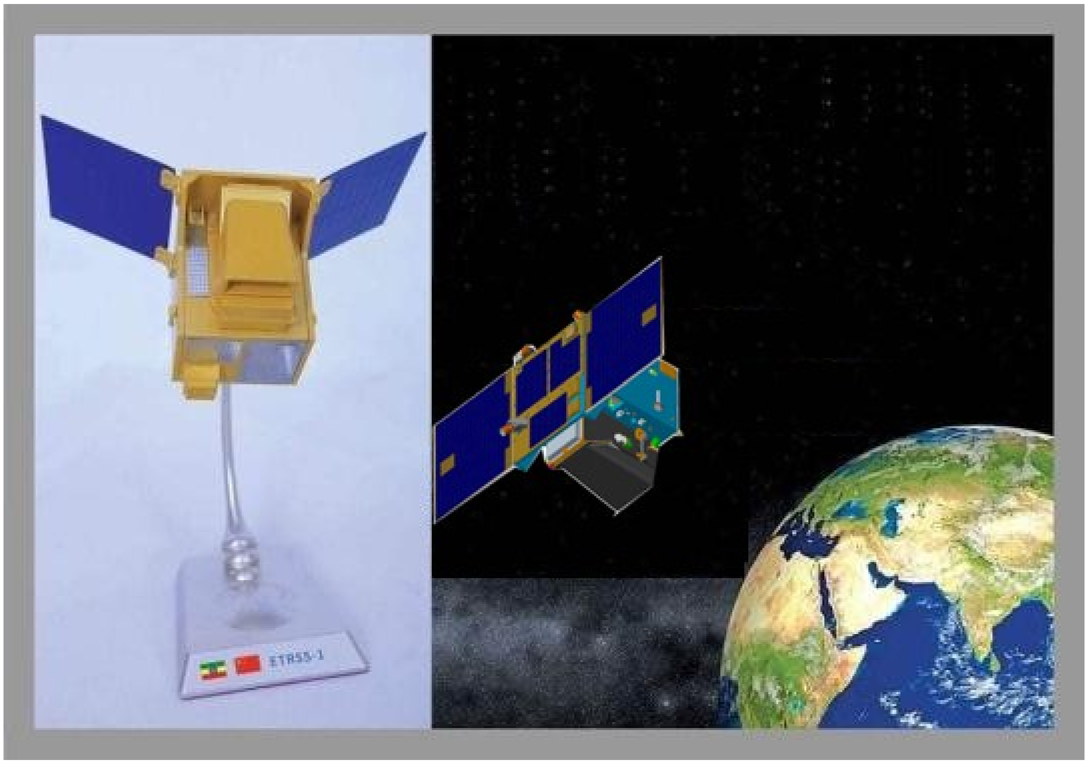

Fig. 1. The left figure shows the symbolic model of ETRSS-1 satellite, whereas the conceptual layout of the satellite in space is shown at the right (source: China Academy of Space Technology, CAST).

Accurate crop yield and production estimate is a critical component of decision making at different levels. Accordingly, Ethiopia has been implementing agricultural data collection since the 1980s (MoANR, 2013). Although such dataset includes important information at district level, they are much more subjective and hence prone for large uncertainties. In this regard, the satellite provides enhanced data on the Ethiopian land surface characteristics useful to estimate crop yield, monitor the evolution of land use or cover changes, water resources management, forest cover monitoring, disaster monitoring, drought monitoring, and for applications in weather and climate prediction models. The satellite's products will be utilized for the country's key economic targets primarily the management and protection of natural resources, and improving agricultural and forestry yields. It is also expected to supplement ground observation information and fill the information gaps in the data scarce sub-saharan Africa and Ethiopia in particular. Further, it saves a lot of currency as the country would no longer need to pay for remote-sensing data from foreign satellites. As such, ETRSS-1 was launched considering the aforementioned advantages and as a signature of cooperation between the two nations: China and Ethiopia to combat global climate change and meet the SDGs by 2030.

ETRSS-1 is a 65-kg multi-spectral remote sensing satellite launched into a sun synchronous orbit to provide earth observation data mainly on the areas of Ethiopia, Middle East, and the rest of Africa. This multi-million dollar experiment (its estimated cost is 8 million USD) is expected to give valuable information along with the high resolution Sentinel-1, 2, and 3 (Torres et. al., 2012; Drusch et al., 2012; and Malenovský et al., 2012), the Moderate-resolution Imaging Spectroradiometer (MODIS) information from aqua (Parkinson, 2003) and terra satellites.

Since its successful launch, ETRSS-1 has motivated many Ethiopians to transform the country from foreign dependent information acquisition systems to self-sustaining and independent. Following this remarkable achievement, many Ethiopians vowed to strengthen their capacity in space, climate and agricultural research. The launch of the space satellite encourages people in the country to value education, science and research beyond classroom environments.

This paper presents, for the first time, about ETRSS-1's satellite mission information and preliminary analyses of the images produced by the sensors onboard the satellite. It is expected to deliver first-hand accurate information about the satellite which is relevant for operational stake-holders and research scientists. The paper is arranged in such a way that section 2 presents details of the satellite information including the space and ground segment instrumentation, control and data acquisition processes followed by section 3 which presents the anticipated advances from the preparation of the satellite instrumentation, launch, post-launch ground control, trainings and preliminary evaluations of the sensor products.

2. ETRSS-1 Satellite Overview

An overview of the satellite orbital characteristics, payload sensor and the ground mission control processes are presented in the following subsections. The discussion starts with the space segment of the payload sensor and satellite information, and ends with elaboration of the ground segment including receiver antenna and mission control processes.

2.1 ETRSS-1 Space Segment

ETRSS-1 is a multispectral wide-field imager that is expected to function very well for at least two years. It operates in a Sun-Synchronous Orbit (SSO) with an altitude of 628.61-km and 10:30±30min Local Time of Descending Node (LTDN) (other orbit information can be found from Table-1).

Table-1. Details of the ETRSS-1 orbit and payload sensor information.

Satellite orbital parameter	**Parameter values**
Orbit type	Sun Synchronous Orbit (SSO), at an altitude of 628km
Orbit Inclination	97.896º
Orbit Period	97.134 minutes
Flight Circles per Day	14 + 25/31
Revisit period	4 days (by 35° roll maneuver)
Observation area	Important observation area: Ethiopia, East and north Africa; Normal observation area; between north and south latitude 80°
Ground Sampling Distance (Nadir)	13.75-m at 628.61-km

Swath (Nadir)	80.27-km at 628.61-km
Band number:4 bands	B1: 0.45µm±0.02µm - 0.52µm±0.02µm
	B2: 0.52µm±0.02µm - 0.59µm±0.02µm
	B3: 0.63µm±0.02µm - 0.69µm±0.02µm
	B4: 0.77µm±0.02µm - 0.89µm±0.02µm

[Source: DFH Satellite Co., Ltd]

ETRSS-l's multispectral remote-sensing images are relevant to obtain information on agriculture, surveying water resources, disaster prevention and relief, and to provide primary information for research and development on climate change and variability. Accordingly, the payload is designed to be a multispectral push-broom type imaging camera sensor with a range of observation frequencies: Band 1 (B1, blue): 0.45-µm - 0.52-µm, Band 2 (B2, green): 0.52-µm - 0.59-µm, Band 3 (B3, red): 0.63-µm - 0.69-µm, and Band 4 (B4, Near Infrared): 0.77-µm - 0.89-µm. The sensor can acquire the image at the Ground Sampling Distance (GSD) of 13.75-m, orbit altitude of 628km, and a swath of 80 km. Some orbital information relevant for operational stake-holder and research scientists are listed in Table 1. The imaging data is recorded and relayed to ground control systems. The information can then be utilized for various purposes.

2.2 ETRSS-1 Ground Control Segment

The satellite's command and control center is located at the premises of Entoto Observatory and Research Center on the outskirts of Addis Ababa at 9.8^0 N and 38.7^0 E geographic coordinates (Fig. 2.). The center is equipped with a 4.5m X-band and S-band antenna capable of receiving mission data and telemetry from the satellite and uplinks telecommand to the satellite. These are receiving spectral data and sending relevant command information to the satellite. The processes in the ground control segment are mission control, data acquisition and information processing. The mission control group monitors the satellite and checks whether it is behaving according to the mission requirements: that is maintaining its orbital status, accepting commands and executing the relevant dynamics. The ground station at Entoto Observatory is also responsible for orbit measuring and providing the necessary orbital forecast.

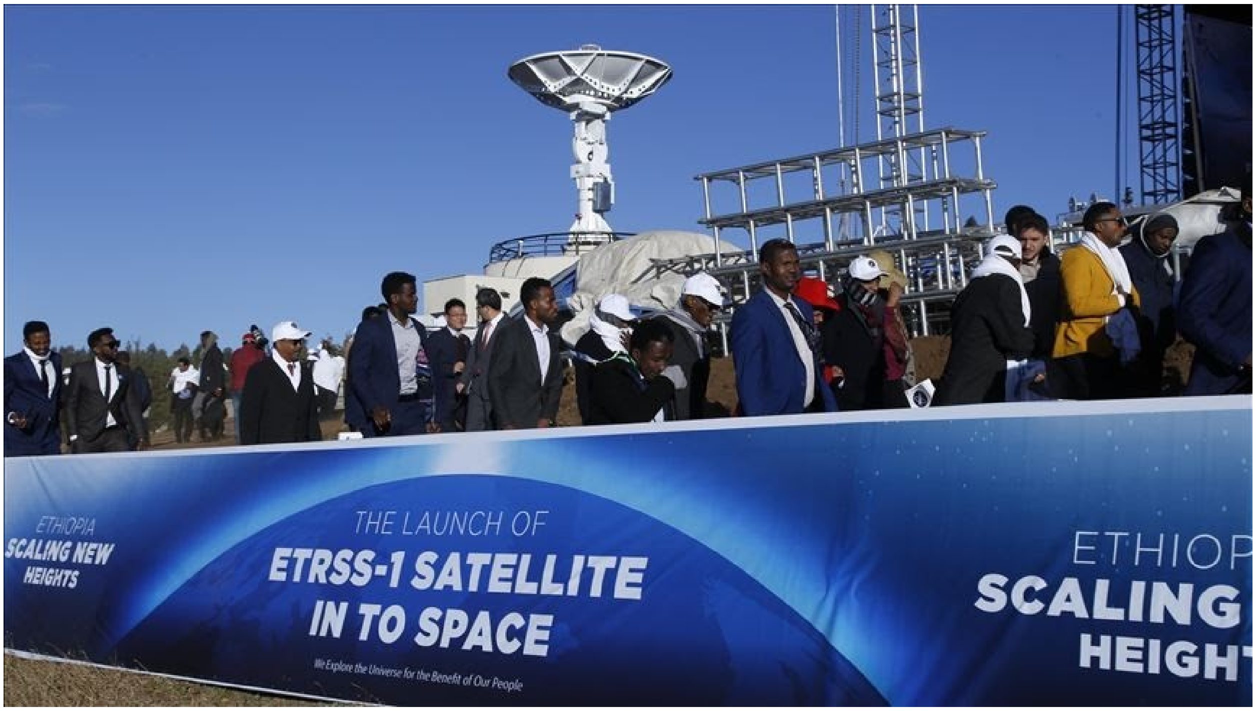

Fig. 2. Figure illustrates ETRSS-1 ground control station at Entoto Observatory (EO) and the satellite launch ceremony by Ethiopian and Chinese Engineers, Scientists and high government officials (picture taken during the launch ceremony on 20th December, 2019). The receiver antenna and dish is visible from the picture.

3. Anticipated advances, sensor outputs and preliminary image analyses

The anticipated advances from the ETRSS-1 mission is that it will allow researchers and scientists to acquire high-resolution satellite information, augment other satellites informations, monitor many Earth variables and analyze the changes attributed to crop yield, land use or land cover changes and their impact on the total climate system. It would also complement the ground measurements of geospatial and meteorological variables to the Ethiopian National

Meteorological Agency (NMA), Ethiopian Geospatial Information Agency, Ethiopian Disaster Prevention and Preparedness Agency and so on. Many national and international research institutions working on sensitive topics of food security, drought and flood monitoring, pastoral farmers, agriculture, urbanization, extremes of weather and climate, resource monitoring and planning, desertification, mining and energy will benefit from the high resolution information obtained from ETRSS-1. This is also crucial to achieve the 17 Sustainable Development Goals (SDGs) (Colglazier, 2015) that intends to achieve access to clean water, food security, poverty alleviation, health care, environmental sustainability and urban development. To provide sensible quality information to operational centers and research scientists and to ensure the continuity of the satellite's services, however, requires careful performance analysis and mission monitoring.

In this regard, it is recommended that ETRSS-1's performance during ground calibration and later while the sensor is on-orbit must be done as frequently as possible. Careful monitoring of the mission performance over time helps to identify anomalies and correct service contamination as early as possible. This is to make sure that the products of the sensors onboard the satellite are sensible and good enough for real time resource monitoring, weather forecasting, climate prediction and serve as input to numerical climate models.

In this paper, the Copernicus Sentinel-2 (Drusch et al., 2012) products are used to evaluate the images captured by ETRSS-1. It is to be noted that this is not a detailed evaluation of the outputs of the satellite, rather it is a preliminary analysis showing whether the images captured are comparable or does not visually deviate much from each other. It is worth mentioning that the aim of the Sentinel-2 mission is to monitor the variability of land surface characteristics similar to ETRSS-1's. Unlike ETRSS-1, the Copernicus Sentinel-2 mission however has two polar-orbiting satellites that were placed in the same sun-synchronous orbit at a phase angle of 180o from each other. It is to be noted that the two sensors, ETRSS-1 and Sentinel-2, are different in terms of sensors design and make-up, the altitude at which images are captured (for ETRSS-1 images are captured at an altitude of 628.61-km while it is 786-km for Sentinel-2), the spatial resolution (the resolution of the RGB bands is 10-m for Sentinel-2 and ~13-m for ETRSS-1) and other orbital characteristics. Moreover, the swath widths' are 82.47-km and 290-km for ETRSS-1 and Sentinel-2 satellites, respectively. Here we took advantage of the fact that the image products from the two sensors are high resolution that differ by only ~3-m in the Red Green and Blue (RGB) spectral bands.

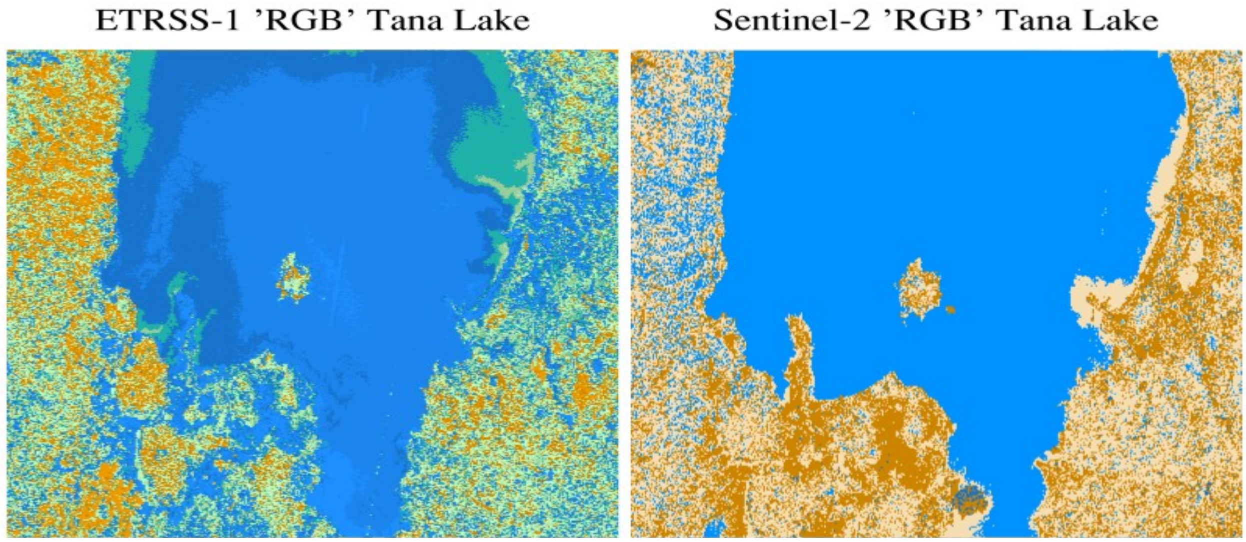

Fig. 3. The first image taken by the ETRSS-1 sensor (on the left) around Lake Tana located at North West Ethiopia and it is compared with the Sentinel image (on the right).

Images from two areas within East Africa: the Tana Lake region (Ethiopia) and the part of the White Nile (Republic of Sudan) are taken for comparison (Figs. 3 and 4). The ETRSS-1 Tana Lake (the main source of the Blue Nile river) image was taken on January 3, 2020 while the Sentinel-2 image of the same area was taken on December 28, 2019. Similarly, the ETRSS-1 image for White Nile around Khartoum was captured on December 31, 2019 while that of Sentinel-2 was captured on December 25, 2019. The reason why the dates do not overlap is because the visit time of the two satellites is not the same for the same area. Nevertheless, we tried to get the images as close in time as possible.

Results showed that ETRSS-1 satisfactorily captured qualitative features of the Lake Tana (in the North Western Part of Ethiopia indicated by Fig. 3, left figure) and part of the white nile in the republic of Sudan (Fig. 4, left figure) rendering distinct land surface characteristics compared to Sentinel-2 images (Figs. 3 and 4 right figures) taken at the same location and closer time periods. However, some minor variations between the two images were observed, for example, in the top left and top right corners of Lake Tana ETRSS-1's image exhibits some localized green features appeared which are not available on Sentinel-2 image (Fig. 3). Similarly, on the left of ETRSS-1 image in Fig. 4, there is a bare-ground land feature while it appears as a green area on Sentinel-2 (Fig. 4). These minor variations might be due to the difference in observation times, orbital features and sensor qualities of the two satellites.

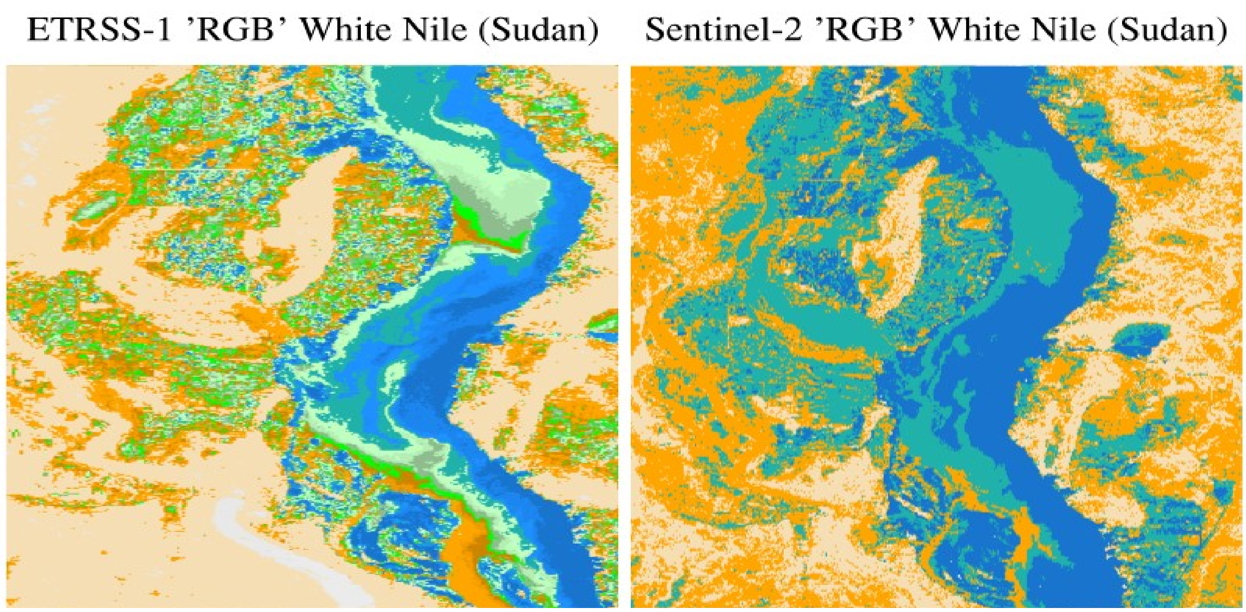

Fig. 4. The left image is captured by ETRSS-1 while the right image is captured by Sentinel-2 around white Nile in Khartoum, Sudan.

The two main tributaries of the Nile river are the Blue Nile whose main source is Lake Tana of Ethiopia and the White Nile which originates from Lake Victoria. Hence, it is worth monitoring the hydrological dynamics of both resources. Lake Tana of Ethiopia is the main source of the

Blue Nile and it is the largest lake in the country. It has many economic importance and it has been utilized mainly for fishing by the local community. It is also an international biosphere reserve site and a source of electricity. The size of the lake decreased over the decades because of alternating droughts and the rise of global temperatures (Setegn et al., 2011). The authors reported that anthropogenic climate change could alter the water balance in Lake Tana basin in the next century. However, there is no clear indication whether it will decrease further in size since there is uncertainty in the long-term prediction of precipitation in the region (Setegn et al., 2011). This has implications for the Nile riparian countries (i.e. Burundi, Democratic Republic of Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, South Sudan, Sudan (Republic of), Tanzania, and Uganda) whose livelihoods depend on the Nile river as their main source of economy. Therefore, continuous observation of the lake for a long time could hint the direction of change in the coming years or decades. More importantly, it can provide data for research and for operational monitoring to understand and plan ahead for economic consequences or to alter undesired changes as result of the anthropogenic influences on the quality and quantity of the Tana lake water reservoir and its drain to the Blue Nile river. Similar uncertainties prevail in predicting the volume of the White Nile system. It was reported (e.g., Sene et al., 2001) that because of the large open water area in the basin; prediction of changes in flows are extremely sensitive to estimates of rainfall and evaporation at lake and swampy surfaces. In this regard, additional observations from multiple sources will augment efforts to clearly understand the uncertainties associated with anthropogenic changes on the volume and hydrologic balance of the water resources.

As such, the early stage images captured by ETRSS-1 displayed distinct and resolved land surface features of the sample images presented in this analyses (Figs. 3 and 4). This shows ETRSS-1 can serve as an alternative and supplementary data source to operational and research services to the national, regional and global communities. Therefore this paper presented for the first time about ETRSS-1's satellite mission information and preliminary analyses of the images produced by the sensors onboard the satellite with the aim to deliver first-hand accurate information about the satellite which is relevant for operational stake-holders and research scientists. It is also hoped that this paper will serve as reference for future works that utilizes data and information from ETRSS-1.

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