Journal of Global Change Data & Discovery. 2024, 8(4): 376-390
www.geodoi.ac.cn

Global Change Research Data Publishing & Repository

Overview of the Earth Observation System of Iberian America

Zhao, C. L.[1,2] Zhang, Q. Q.[1,2] Fan, J. L.[3*] Franch, B.[4] Liu, C.[5] Zhao, X. X.[5]

1. National Satellite Meteorological Center (National Centre for Space Weather), Beijing 100081, China;
2. Innovation Center for FengYun Meteorological Satellite (FYSIC), Beijing 100081, China;
3. Advanced Interdisciplinary Institute of Satellite Applications, Faculty of Geographical Sciences, Beijing Normal University, Beijing 100875, China;
4. University of Valencia, Valencia 46100, Spain;
5. Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China

Abstract: The Global Earth Observation System of Systems (GEOSS) is a coordinated and independent system of Earth observation, data processing and information retrieval that interacts and provides various Earth observations and decision support information to a wide range of public and private sector users. The GEOSS is built on top of Earth observation systems constructed by countries around the world according to their own development needs. The Iberian countries are a large group of Spanish and Portuguese speaking countries, with a population of approximately 680 million. Their Earth observation systems have significant characteristics, with nearly one-third of the 22 countries independently or jointly developing their own high-resolution optical or radar satellite Earth observation systems. The high-resolution satellite image data collected is playing an important role and used for land resource management, disaster risk management, deforestation and illegal logging, crop monitoring, road monitoring, and national security. The independent development of Earth observation systems in Iberian American countries has a reference value for the development of Earth observation systems in developing countries.

Keywords: GEOSS; Iberian America; satellite system; Earth observation; GEO

DOI: https://doi.org/10.3974/geodp.2024.04.05

CSTR: https://cstr.escience.org.cn/CSTR:20146.14.2024.04.05

1 Introduction

The Global Earth Observation System of Systems (GEOSS) is a coordinated and independent system of Earth observation, data processing and information retrieval that interacts to provide information on the state of the Earth and decision support for public and private sector decision-making. The goal of GEOSS is to establish a global integrated Earth observation system framework with a holistic concept and organizational structure that meets user needs, serving decision-making at all levels, particularly in relation to human health and safety, protecting the global environment, reducing natural disaster losses, and

Received: 18-09-2024; **Accepted:** 02-12-2024; **Published:** 24-12-2024
Foundation: Ministry of Science and Technology of P. R. China (2021YFE0117400)
***Corresponding Author:** Fan, J. L., Beijing Normal University, fanjl@bnu.edu.cn
Citation: Zhao, C. L., Zhang, Q. Q., Fan, J. L., *et al*. Overview of the Earth observation system of Iberian America [J]. *Journal of Global Change Data & Discovery*, 2024, 8(4): 376–390. https://doi.org/10.3974/geodp.2024.04.05. https://cstr.escience.org.cn/CSTR:20146.14.2024.04.05.

achieving sustainable development. Through the implementation of the GEOSS Second Decade Implementation Plan, it hopes to make outstanding progress in key areas, conduct annual, ten-year, and longer-term comprehensive monitoring of global and regional climate, generate information products related to biodiversity and climate change, improve global and multi system information acquisition and processing capabilities for disaster prevention and reduction, resource and environmental protection, and biodiversity conservation, and provide decision support information for key users and decision-makers[1,2].

GEOSS is a global integrated system built on top of the Earth observation systems constructed by countries around the world according to their own development needs. Given that the Iberian countries are predominantly Spanish speaking and Portuguese speaking, and have distinctive Earth observation systems, this article provides an overview of the development trends and applications of Earth observation systems in these countries. It is hoped that this will serve as a reference for the development of Earth observation systems in developing countries.

The Iberian American countries[3] include 19 Spanish and Portuguese speaking countries in Latin America, as well as other countries in the Iberian Peninsula of Europe, including Spain, Portugal, and Puerto Rico. These 22 countries are Argentina, Paraguay, Panama, Brazil, Peru, Bolivia, the Dominican Republic, Ecuador, Colombia, Costa Rica, Cuba, Honduras, Mexico, Nicaragua, El Salvador, Guatemala, Venezuela, Uruguay, Chile, Spain, Portugal, and Puerto Rico. Figure 1 shows the distribution of Iberian American countries.

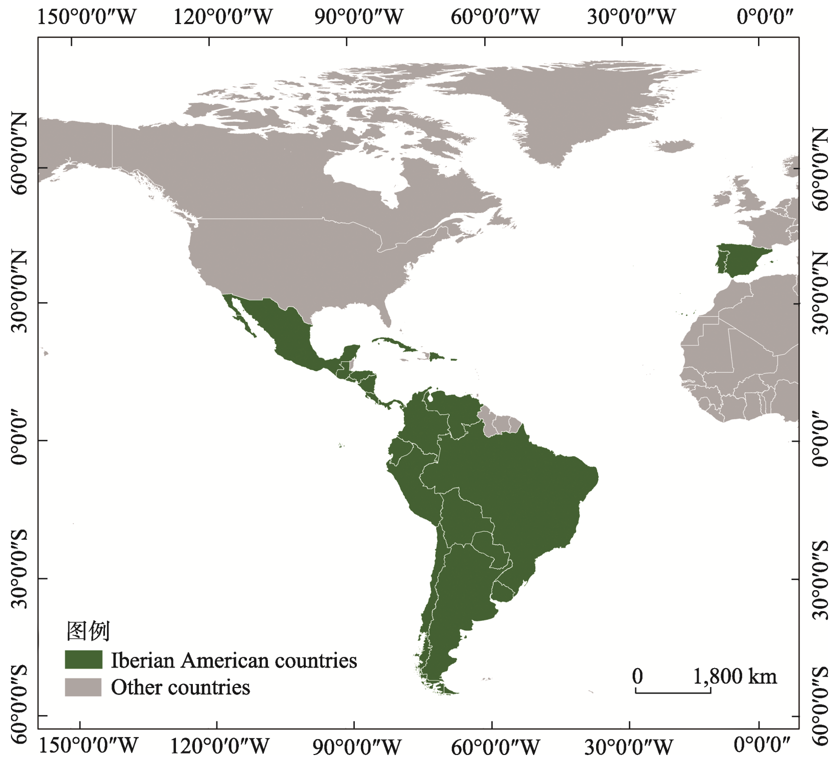

Figure 1 The geographical location of Iberian American countries

The total population of Iberian American countries is approximately 680 million, with Brazil having over 210 million, Mexico having 125 million, Colombia having 49 million, Spain having 46 million, and Argentina having 44 million among the more populous countries[3]. According to the United Nations Development Programme's statistics on the Iberian American countries in 2023, Spain, Portugal, Puerto Rico, Chile, Costa Rica, Argentina, and Uruguay have a high Human Development Index[4] (HDR).

2 Earth Observation Systems in Iberian American Countries

The main countries developing Earth observation systems in Iberia American countries include Spain, Argentina, Portugal, Brazil, Colombia, Mexico, Uruguay, Chile, Paraguay, Peru, Ecuador, Costa Rica, Guatemala, and Venezuela. Among them, countries such as Spain, Argentina, and Brazil have successively launched several Earth observation satellites, possessing strong global comprehensive Earth observation capabilities.

2.1 Spain

Spain is an important member of the Earth Observation Organization from Europe, and its remote sensing satellites typically have high resolution, multispectral imaging capabilities, and a long service life. The sensors carried on Spain's remote sensing satellites can provide high-resolution images, which are widely used in various fields such as environmental monitoring, agricultural assessment, and urban planning. The main observation areas of the Spanish Earth Observation System are Spanish territory, Europe, Iberian America, and North Africa. These characteristics make Spain's remote sensing satellites competitive internationally and widely used worldwide.

2.1.1 GEOSAT-1

GEOSAT-1[5] was launched in July 2009 and is a high-resolution multispectral optical small satellite for Earth observation. It is part of the Disaster Monitoring Constellation (DMC). The GEOSAT-1 satellite has an orbit altitude of approximately 661 km and is in a sun synchronous near circular orbit with an orbital period of 97.7 minutes. GEOSAT-1 is equipped with a multispectral imager MS, which has green, red, and near-infrared bands with a spatial resolution of 22 m. The global average revisit time for ultra wide swath images is 2–3 days, and the average revisit time for mid latitude regions is 1–2 days. The spectral characteristics are shown in Table 1. GEOSAT-1 provides important vegetation index parameters such as Normalized Difference Vegetation Index (NDVI), Green Normalized Difference Vegetation Index (GNDVI), Red Edge Chlorophyll Index (RECI), Soil Adjusted Vegetation Index (SAVI), and Modified Soil Adjusted Vegetation Index (MSAVI), and also provides images for commercial applications, government use, and rapid response after disasters occur.

Table 1 Spectral characteristics of GEOSAT-1 Satellite Sensors[5]

Band	Name	Spectral range (nm)	Ground Sampling Distance (m)	Standard Ortho (m)
1	NIR	770–900	22.0	20.0
2	Red	630–690	22.0	20.0
3	Green	520–600	22.0	20.0

2.1.2 GEOSAT-2

GEOSAT-2[6] is a continuation of GEOSAT-1, launched on November 21, 2013. The GEOSAT-2 satellite has a sun synchronous near circular orbit with an altitude of 630 km, an inclination angle of 98 degrees, and a revisit period of 4 days. This is achieved by the ability to point at the lowest point with a maximum deviation of ± 45 degree[7]. The satellite carries a high-resolution camera with 5 spectral channels (1 panchromatic+4 multispectral), and the spectral characteristics are shown in Table 2.

Table 2 Spectral characteristics of GEOSAT-2 Satellite Sensors[6]

Band	Name	Spectral range (nm)	GSD (m)	Standard Ortho (m)	Enhanced Ortho (m)
1	NIR	770–892	4.0	3.0	2.0
2	Red	640–697	4.0	3.0	2.0
3	Green	532–599	4.0	3.0	2.0
4	Blue	466–525	4.0	3.0	2.0
5	Panchromatic	560–900	1.0	0.75	0.40

2.1.3 PAZ

PAZ[8] (Spanish means "peace") is a Spanish Earth observation and reconnaissance satellite launched on February 22, 2018. PAZ operates in the same orbit as the German TerraSAR-X and TanDEM-X dual satellites, with the three satellites working together as a constellation. PAZ uses high-resolution X-band synthetic aperture radar (SAR). The sensor characteristics are detailed in Table 3. PAZ flies in a polar dawn dusk sun synchronous orbit, covering the entire Earth with an average revisit time of 24 hours. It uses two ground stations (Madrid and Canary Islands) to obtain data, with an average delay of slightly over one day. PAZ is capable of high-resolution mapping of large areas during both day and night, for military operations, border control, intelligence, environmental monitoring, natural resource conservation, urban and infrastructure planning, and natural disaster monitoring.

Table 3 Statistics of characteristics of Spanish high resolution X-band SAR Satellites[8]

Mode ID		StripMap Single (SM-S)	StripMap Dual (SM-D)	Scan SAR (SC)	Wide Scan SAR (WS)	Spotlight Single (SL-S)	Spotlight Dual (SL-D)	High-resolution Spotlight Single (HS-S)	High-resolution Spotlight Dual (HS-D)	Starring Spotlight (ST)
Polarizations		HH, VV, HV, VH	HH/VV, HH/HV, VV/VH	HH, VV, HV, VH	HH, VV, HV, VH	HH, VV, HV, VH	HH/VV, HH/HV VV/VH	HH, VV, HV, VH	HH/VV, HH/HV, VV/VH	HH, VV, HV, VH
Scene size (Range× Azimuth) (km)		30×50	15×50	100×150	[273–196]×208	10×10	10×10	[10–6]×5	10×5	[9–4.6]×[2.7–3.6]
Range Resolution (m)	MGD, GEC, EEC[SE]	2.99–3.52 at [45°–20°]	6	N/A	N/A	1.55–3.43 at [55°–20°]	3.09–3.5 at [55°–20°]	1–1.76 at [55°–20°]	2–3.5 at [55°–20°]	0.96–1.78 at [45°–20°]
	MGD, GEC, EEC[RE]	6.53–7.65 at [45°–20°]	7.51–10.43 at [45°–20°]	16.79–18.19 at [45°–20°]	35	3.51–5.43 at [55°–20°]	4.98–7.63 at [55°–20°]	2.83–3.11 at [55°–20°]	4–6.2 at [55°–20°]	0.97–1.78 at [45°–20°]
	SSC	1.1 [150 MHz] 1.7 (100 MHz]	1.18	1.17–3.4	1.75–3.18	1.18	1.17	0.6	1.17	0.59
Azimuth Resolution (m)	MGD, GEC, EEC[SE]	3.05	6.11	N/A	N/A	1.56–2.9 at [55°–20°]	3.53	1–1.49 at [55°–20°]	2.38–2.93 at [55°–20°]	0.38–0.7 at [45°–20°]
	MGD, GEC, EEC[RE]	6.53–7.60 at [45°–20°]	7.52–10.4 at [45°–20°]	17.66–18.18 at [45°–20°]	39	3.51–5.4 at [55°–20°]	4.99–7.64 at [55°–20°]	2.83–3.13 at [55°–20°]	4–6.25 at [55°–20°]	0.97–1.42 at [45°–20°]
	SSC	3.01	6.04	18.5	38.27	1.46	3.1	1.05	2.16	0.22

Note: HH, horizontal transmit/horizontal receive polarization; VV, vertical transmit/vertical receive polarization; HV, horizontal transmit/vertical receive polarization; VH, vertical transmit/horizontal receive polarization; MGD, Multi-looked ground range detected; GEC, Geocoded ellipsoid corrected; EEC[RE], Enhanced ellipsoid corrected with supplemental elevation; SSC, Terrain corrected and slope corrected.

2.1.4 Ingenio/SEOSAT

Ingenio/SEOSAT[9,10] is the flagship mission of the Spanish space program 2007–2011 and is part of the Spanish Earth Observation Satellite System. Ingenio/SEOSAT is a multispectral high-resolution optical satellite used for Earth remote sensing, aimed at providing images to users in the main observation areas (Spanish territory, Europe, Iberian America, and North Africa), and offering image data services to other European users within the framework of the Global Monitoring for Environment and Security (GMES) and GEOSS. Ingenio/SEOSAT is a sun synchronous orbit satellite with an orbital altitude of 685 km. It includes a 2.5 m resolution panchromatic channel and four 10 m resolution multispectral channels (red, green, blue, and near-infrared). The satellite has the capability of global coverage, but data collection is mainly concentrated on Spanish territory. The satellite has a repetition period of 49 days and a positioning accuracy of 20 m[11]. The satellite was launched in November 2020, but shortly after takeoff, the Vega carrier rocket malfunctioned, causing the orbit to deviate and the mission to fail.

2.2 Argentina

Argentina has successfully launched the SAC[12] series, SAOCOM series, and commercial satellite Newsat constellation series. The National Space Activities Commission of Argentina (CONAE) is the main agency responsible for the development and management of Earth observation satellites. Argentina has made significant progress in its global observation satellites, especially in the development of high-resolution SAR satellites, which not only enhance the country’s position in the field of space technology, but also make important contributions to global environmental monitoring and disaster management.

2.2.1 SAC-D/Aquarius

The SAC-D/Aquius satellite is a joint mission between Argentina (CONAE) and the United States (NASA), launched on June 10, 2011. Its weight is 1,400 kg, its sun synchronous orbit is 657 km (ascending node at 6 pm), and it will revisit for 7 days.

SAC-D/Aquaius includes multi-sensor tasks covering ocean, land, atmosphere, and space environments, with the main goal of understanding the water cycle and ocean circulation of the entire Earth’s climate system. By measuring changes in global sea surface salinity (SSS) through satellites for at least 3 years, the exchange changes between the ocean, atmosphere, and sea ice can be studied, as well as their impact on current and future ocean circulation, weather, and climate. Table 4 shows the feature list of SAC-D/Aquaius satellite sensors.

2.2.2 SAOCOM 1-A/B

The SAOCOM satellite series[14] is equipped with L-band synthetic aperture radar (SAR), which can penetrate clouds and conduct surface observations under poor lighting conditions. SAOCOM-1A and 1B are two satellites in this series. SAOCOM-1A was launched on October 7, 2018, and SAOCOM-1B was launched in August 2020. The sun synchronous orbit has an altitude of 620 km, an orbital period of 97.2 minutes, an orbital inclination of 97.89°, and a temporal resolution of 16 days. Table 5 lists the sensor parameters of SAOCOM 1-A/B SAR satellite.

SAOCOM-1A and 1B carry the same high-resolution multi-purpose radar imager, L-SAR, which can provide data with high radiation quality and geometric accuracy, and offer high revisit frequency (daily) to support specific applications. L-SAR images are suitable for agriculture, fisheries, forestry, weather, hydrology, oceanography, emergency response, land and marine natural resources, urban areas, and mapping.

Argentina and Italy have collaborated to form the “Italy Argentina Satellite System for

Table 4 Statistics of SAC-D/Aquaius Satellite Sensor characteristics[13]

Instrument	Objectives	Specifications	Resolution	Agency
Aquarius	Understanding ocean circulation, global water cycle and climate interaction. soil moisture over Argentina	Integrated L-Band radiometer (1.413 Ghz) and scatero meter (1.26 Ghz) Swath: 390 km	Three beams:76×94, 84×120, 96×156 km	CONAE
MWR (Microwave Radiometer)	Rain rate, winds speed, sea ice concentration, water vapour, cloud liquid water	Bands: 23.8 Ghz (VV) 36.5 Ghz (HV) Band width: 0.5 and 1 Ghz Swath: 380 km	Sixteen beams < 54 km	CONAE
NIRST (New Infrared Sensor Technology)	Hot spot events, sea surface temperature measurements	Bands:4, 11–12 um Instantaneous swath: 182 km Extended swath: 1,000 km Pointing: ±30°	Space resolution: 350 m Min temperature: 0.5 °C Smallest burning detectable area: 200 m^2	CONAE CSA
HSC (High Sensitivity Camera)	Urban lights, electric storms, polar regions, snow cover	Panchromatic: 450–610 nm Swath: 1,600 km	200–300 m	CONAE
DCS (Data Collection System)	Collection System of meteorological and environmental data	401.55 Mhz uplink	2 contacts per day with 200 platforms	CONAE
ROSA (Radio Occultation Sounder for Atmosphere)	Determination of atmospheric profiles on temperature, pressure and moisture	GPS Occultation Techniques	Horiz: 300 km Vert: 300 m	ASI
TDP (Technological Demonstration Package)	Position, velocity and time inertial angular velocity determination	GPS receiver Inertial Unit Reference	Position: 20 m Velocity: 1 m/sec	CONAE

Table 5 Statistics of SAOCOM 1-A/B SAR Satellite Sensor Parameters[14]

Parameter	Value	Parameter	Value
Center frequency	1,275 MHz (L-band)	Antenna looking angle	right (nominal) left (capability)
Mission lifetime	5 years	Incidence angles	18–50º
Maximum bandwidth	50 MHz	Data quantization	4-bit Block Adaptive Quantization
Transmit peak power	6.7 kW	Duty cycle	15% (about 15 minutes per orbit, depending on selected datatakes modes datarate and available ground stations)
Operational modes	Stripmap	Stripmap high resolution	10 m×10 m (pixel)
	TopSAR	TopSAR wide mode	100 m×100 m (pixel)
Stripmap swath width	> 65 km (each beam)	TopSAR narrow swath	150 or 176 km (SP/DP) 109 or 110 km (Quad-Polarization, QP)
Signal transmission	HH or VV polarization	Signal (Single Polarization, SP)	HH or VV (SP)
		Reception (Double Polarization, DP)	HH & HV or VV & VH
NESZ (Noise Equivalent Sigma Zero)	<–28 dB single and dual pol modes	TopSAR narrow mode	30 m×30 m (SP & DP)
	<–34 dB quad pol modes		50 m×50 m (QP)

Disaster Management and Economic Development (SIASGE)". SIASGE consists of two Argentine SAOCOM satellites (X-band SAR) and four satellites from the COSMO SkyMed constellation (L-band SAR). These 6 satellites will provide accurate and up-to-date information on fires, floods, volcanic eruptions, earthquakes, avalanches, and landslides.

2.2.3 NewSat

NewSat[15] is an Argentine commercial Earth observation satellite series designed, built, and operated by Satellogic, with 98 operational satellites deployed to form the Aleph-1 constellation. It was first launched on China's Long March series rockets in 2016. NewSat operates in a 500 km sun synchronous orbit with an orbital inclination of 97.5°, and its specific characteristics are shown in Table 6.

Table 6 Performance comparison of Newsat series satellites[15]

Satellite in orbit	+25	+40	+60	+130	+200
Altitude	470 km	470 km	440 km	440 km	330 km
Ground spatial resolution (GSD)	0.99 m	0.70 m	0.40 m	0.40 m	0.30 m
Daily observations	5	8	12	25	40
Data product release and update	Constellation and service	Global monthly update	Global biweekly update	Global weekly update	Global daily update

The full-color imaging system equipped on NewSat provides ground resolution of 1 m, with 4 spectral channels between 400 and 900 nm, including 3 visible light channels (red, green, blue) and 1 near-infrared channel (750–900 nm), and produces 10 frames per second of monochrome full motion video with a recording time of up to 60 seconds. The temporal resolution of the multispectral imaging instrument carried by NewSat is 7 times per day, while hyperspectral imaging is 1–2 times per day, covering 29 spectral bands (460–830 nm), with a ground resolution of 25 m, as shown in Table 7. This constellation can now be photographed in four different shooting modes, including stripe mode, diagonal stripe mode, spotlight mode, and flat mode. Static and video images are available for users in fields such as mapping and urban planning, climate monitoring, resource management, disaster response, and infrastructure monitoring.

2.3 Portugal

2.3.1 PoSAT-1

PoSAT-1[16] is Portugal's first satellite, launched into orbit on September 26, 1993 from the Kourou Space Center in French Guiana. Its orbit has an altitude of 800 km, an inclination angle of 98.6°, and an orbital period of 100.6 minutes. It was retired in 2006. PoSAT-1 carries two CCD imagers, one is a wide field of view imager with a ground resolution of 2 km, and the other is a narrow field of view imager with a ground resolution of 200 m.

Table 7 Statistics of Newsat series satellites[15]

ALEPH 1 - Payloads	Multispectral	Hyperspectral
Ground Samplig Distance	1 m	25 m
Swath	5 km	125 km
Spectral bands	450–510 nm	460–830 nm
	510–580 nm 590–690 nm 750–900 nm	29 spectral bands (14–35 nm FWHM)

2.3.2 AEROS MH-1

The second satellite of Portugal, AEROS MH-1, was launched into orbit on March 4, 2024 by a SpaceX Falcon9 rocket, with an altitude of 510 km and an orbital period of 90 minutes. MH-1 is equipped with two sensors for reflection measurement of sea surface height and roughness, as well as for ocean color measurement. The AEROS constellation aims to monitor and support sustainable ocean development through the synergy between space and ocean science, contributing to the United Nations Sustainable Development Goals.

2.4 Brazil

2.4.1 CBERS

The China Brazil Earth Resources Satellite (CBERS)[18] is a series of satellites jointly invested and developed by China and Brazil. It is equipped with high-resolution CCD cameras (CCD), infrared multispectral scanners (IR-MSS), and wide field of view imagers (WFI), which are particularly conducive to dynamic and rapid acquisition of Earth's ground information. CBERS[19] includes the China Brazil Earth Resources Satellite 01, 02, 02B, 02C, and 04.

The China-Brazil Earth Resources Satellite (ZY1-02C) was successfully launched on December 22, 2011[19]. The satellite is equipped with a panchromatic multispectral camera (PMC) and a panchromatic high-resolution camera (HRC), which are used for land resource investigation, disaster relief services, agricultural development, forestry, water conservancy, environmental monitoring, urban planning, and other fields. The panchromatic multispectral camera PMC adopts a linear push scan imaging method, which includes one panchromatic band and three spectral bands. The spatial resolution of the panchromatic band is 5 m and the spatial resolution of the three spectral bands is 10 m. The full-color high-resolution camera HRC has a width of 54 km and a spatial resolution of 2.36 m (Table 8).

Table 8 Statistics of Sensor Parameters for ZY1-02C Satellite[18]

Parameters	PMC		HRC	
Spectrum range	Pan	0.51–0.85 μm	Pan	0.50–0.80 μm
	Multispectral	0.52–0.59 μm	Multispectral	/
		0.63–0.69 μm		/
		0.77–0.89 μm		/
Spatial Resolution	Pan	5 m	Pan	2.36 m
	Multispectral	10 m	Multispectral	/
Swath	60 km		54 km (2 camera composite)	
Agile working ability	±32°		±25°	
Revisit	3 Day		3 Day	

The China Brazil Earth Resources Satellite (CBERS-04A) was successfully launched on December 20, 2019, and is the sixth Earth Resources satellite jointly developed by the governments of China and Brazil. The Ziyuan1-04A satellite is equipped with three optical payloads, including a wide swath panchromatic and multispectral camera (WSPMC) equipped by the Chinese side, with a panchromatic resolution of 2 m, a multispectral resolution of 8 m, and a width of 90 km; The multispectral imager (MSI) configured by the Brazil side has a multispectral resolution of 17 m and a width of 90 km; The wide field of view imager (WFI) equipped by the Brazil side has a multispectral resolution of 60 m and a width of 685 km (Table 9). The main task of the Resource One 04A satellite is to collect panchromatic and multispectral image data, which are widely used in land and resources investigation and monitoring, disaster prevention and reduction, agriculture, forestry, water conservancy, ecological environment, and urban planning.

2.4.2 Amazônia-1

Amazônia-1[20] is the first sun synchronous Earth observation satellite developed by Brazil. It was launched on February 28, 2021, with an orbital altitude of 752 km and an inclination angle of 98.4°. The advanced wide field imaging (AWFI)[21] camera is a camera equipped with three visible bands and one near-infrared band, with an observation width of 850 km, a spatial resolution of 60 m, and a temporal resolution of 5 days (Table 10). Amazônia-1 is mainly used for wildfire detection, coastal zone and vegetation monitoring, land cover and land use mapping.

2.4.3 Carcará I/II

Carcará I/II is a low orbit Earth observation SAR satellite launched by the Brazilian Air Force in May 2022 to support efforts to combat drug trafficking and illegal mining, determine river navigation, monitor border control operations, wildfires, natural disasters, and exclusive economic zones. The Carcará I/II SAR is capable of revisiting the same location on Earth on a daily or even sub daily basis, achieving a whole new level of change detection. The detailed specifications are listed in Table 11.

Table 9 Statistics of Sensor Parameters for CBERS-04A Satellite[19]

Camera		Parameters	
WSPMC	Spectrum	Pan	0.45–0.9 μm
		Multispectral	0.45–0.52 μm 0.52–0.59 μm 0.63–0.69 μm 0.77–0.89 μm
	Quantization bits	10 bits	
	Ground spatial distance	Pan 2 m/MS 8 m	
	Swath	≥90 km	
	Geometric accuracy	< 50 m (1σ)	
MSI	Spectrum	Multispectral	0.45–0.52 μm 0.52–0.59 μm 0.63–0.69 μm 0.77–0.89 μm
	Quantization bits	8 bits	
	Ground spatial distance	17 m	
	Swath	≥90 km	
WFI	Spectrum	Multispectral	0.45–0.52 μm 0.52–0.59 μm 0.63–0.69 μm 0.77–0.89 μm
	Quantization bits	10 bits	
	Ground spatial distance	60 m	
	Swath	≥685 km	

Table 10 Statistics of Sensor AWFI[21]

Parameter	Broom pushing mode
Spectrum (μm)	0.45–0.52 Blue
	0.52–0.59 Green
	0.63–0.69 Red
	0.77–0.89 Near Inferred
Spatial resolution (m)	60
Swath (km)	850
Revisit (day)	5

Table 11 Statistics of Carcará I/II SAR[22]

Imaging mode	Strip	Spot	Spot Fine	Dwell	Dwell Fine	SLEA	Scan
Nominal swath (width×length) (km)	30×50	15×15	5×5	5×5		15×15	840×100
Slant resolution (azimuth×range) (m)	3×(0.5–2.5)	0.25×0.5	0.1×0.25	0.05×0.5	0.05×0.25	0.5×0.5	N/A
Ground resolution (m)	3	1	0.5	1	0.5	1	15
Nominal collection duration (sec)	10	10	15	25	25	10	15
Azimuth looks	1–2	4	5	20	10	2	1
Maximum image length (km)	840	5	5	5	5	15	840

2.4.4 VCUB-1

VCUB-1[22] is the first high-resolution Earth observation satellite designed by Visiona Tecnologia Espacial (VTE) and launched on April 15, 2023. The VCUB-1 orbit has an altitude of 530 km and flies over Brazil every 90 minutes. It is equipped with a high-resolution camera with a spatial resolution of 3 m. VCUB-1 is mainly used for monitoring deforestation and supporting agricultural activities in the Amazon region. The detailed specifications are listed in Table 12.

Table 12 Statistics of VCUB-1[22]

Parameter	Value
GSD	3 m, 5 m (@500 km)
Spectral bands	B, G, R, NIR
Swath	14 km
Standard scene and scene size	14 km×14 km=196 km^2

2.5 Colombia

FACSAT-1[23] is Colombia's first satellite, launched in November 2018, with an orbital altitude of 485 km and an inclination angle of 97.5°. FACSAT-1 is equipped with an imaging camera with a resolution of 30 m, covering Colombian territory every day. The data is used to support urban development, land restoration, illegal crop substitution, and natural disaster and fire response.

FACSAT-2[24] was launched on April 15, 2023, with an orbital altitude of 500 km and an inclination angle of 97.379°. FACSAT-2 carries a multispectral imaging instrument with a resolution of 5 m, including 8 bands of visible light and near-infrared. The parameter profiles of FACSAT-1 and FACSAT-2 are shown in Table 13.

Table 13 Statistics of FACSAT[24]

	FACSAT-1	FACSAT-2
Size	3U	6U
Principal payload	NanoCom C1U GomSpace	Simera MultiScape Cis 100
Spatial resolution	30 m per pixel	4.75 m per pixel
Spectral band	R, G, B	R, G, B, NIR, PAN 8 bands
Imagin acquisition	Snapshot	Snapshot + Line scan
Secondary payload	/	Spectrometer Argus 2000
Spectral Range	/	1,000–1,700 nm
Spectral Resolution	/	–6 nm
Spatial resolution	/	1.5 km @500 km

2.6 Peru

2.6.1 Chasqui-1

The Chasqui-1[25] satellite was manually launched from the International Space Station on August 18, 2014. It is equipped with two cameras, one capturing visible light images and the other capturing near-infrared images. The camera's CMOS detector captures images of 640 ×480 pixels. These two cameras will capture images of Peru for agricultural monitoring, resource management, deforestation, and monitoring of natural disasters.

2.6.2 PeruSAT-1

PerúSAT-1[26] is the first sub meter level satellite with a spatial resolution of 0.7 m. It was launched in September 2016, with a sun synchronous orbit altitude of 695 km and an orbital inclination of 98.3°. PeruSat-1 is equipped with a push scan imaging instrument AstroSat optical sensor NAOMI, which provides panchromatic images in the wavelength range of 0.45–0.75 μm and multispectral images in four spectral bands, including blue

(0.45–0.52 μm), green (0.53–0.60 μm), red (0.62–0.69 μm), and near-infrared (0.76 –0.89 μm). In panchromatic mode, the ground sampling distance (GSD) at its lowest point is 0.7–2.5 m, and in multispectral imaging it is 2–10 m. It can be revisited in any region of Peru within 3 days. The specific sensor parameters are shown in Table 14. The high-resolution image data of PerúSAT-1 plays an important supporting role in rural cadastral, disaster risk management, deforestation, eradication of coca cultivation, illegal logging, crop monitoring, road monitoring, and safety applications.

2.7 Ecuador

The NEE-01 Pegaso[27] CubeSat was launched into space on April 26, 2013, aboard China's Long March-2 rocket. Its sun synchronous orbit has an altitude of 657 km, an inclination angle of 98.04°, and a period of 97.45 minutes. NEE-01 Pegaso is Ecuador's first Earth observation satellite, built by the Ecuadorian Civil Space Agency (ECSA), with sensors including visible light and infrared cameras. NEE-02 KRYSAOR is a backup of NEE-01 Pegaso, launched on November 21, 2013, with a sun synchronous orbit altitude of 720 km and an orbital inclination of 98.7°.

Table 14 Statistics of PerúSAT-1 NAOMI[26]

Camera	Broom pushing mode
PAN	0.45–0.75 μm
MS	Blue: 0.45–0.52 μm
	Green: 0.53–060 μm
	Red: 0.62–0.69 μm
	Near Infrared: 0.76–0.89 μm
GSD	PAN: 0.7–2.5 m
	MS: 2–10 m
Detector	N × silicon array, PAN 7,000 pixels, MS 1,750 pixels
Swath	10 km to 60 km up to GSD and the number of detectors
Quantization bits	12 bits

2.8 Venezuela

2.8.1 VRSS-1

VRSS-1[28] is Venezuela's first remote sensing Earth observation satellite, launched on September 29, 2012 from the Jiuquan Launch Center in China by a Long March-2 rocket, with a sun synchronous orbit altitude of 640 km. The VRSS-1 satellite contains two cameras with different resolutions. The highest resolution is 2.5 m in panchromatic mode and 10 m in multispectral mode, as shown in Table 15. The resolution of the lower resolution camera is 16 m, as shown in Table 16.

The VRSS-1 satellite flies over Venezuela three to four times every 24 hours, covering the same area of Venezuela every 57 days. It is used for resource research, vegetation observation, assessment of Venezuela's soil and water resources, urban planning, monitoring of illegal mining and drug activities, and supporting disaster monitoring.

2.8.2 VRSS-2

VRSS-2[29] is the second remote sensing Earth observation satellite owned by Venezuela, launched in October 2017, with a sun synchronous orbit altitude of 645 km. VRSS-2 includes two different cameras, a high-resolution camera (panchromatic and multispectral

Table 15 Statistics of PMC[28]

Camera	Broom pushing with TDI function
Spectral bands	PAN: 0.45–0.90 μm
	B1/Blue: 0.45–0.52 μm
	B2/Green: 0.52–0.59 μm
	B3/Red: 0.63–0.69 μm
	B4/NIR: 0.77–0.89 μm
Swath	–57 km
CCD	Horizon shift: 10 μm×10 μm, pixel ≥ 12,000 (single camera)
	MS: 40 μm×40 μm, Num of pixels ≥ 3,000 (single band and camera)
MTF	≥ 0.18(PAN), ≥ 0.2 (millisecond)
SNR	PAN: ≥ 48 dB (Solar Zenith angle=70º, Surface Albedo=0.65)
	MS: ≥ 48 dB (Solar Zenith angle=70º, Surface Albedo=0.65)

Table 16 Statistics of WMC[28]

Camera	Broom pushing with TDI function
Spectral bands	B1/Blue: 0.45–0.52 μm
	B2/Green: 0.52–0.59 μm
	B3/Red: 0.63–0.69 μm
	B4/ NIR: 0.77–0.89 μm
Swath	–370 km
CCD	CCD 12,000 pixels, size 6.5 μm
Optical system	Refractive optical, focal length= 270 mm
MTF	≥ 0.14(B4), ≥ 0.2(other bands)
SNR	MS: ≥ 20 dB (Solar Zenith angle=15º, Surface Albedo=0.05)
	MS: ≥ 46 dB (Solar Zenith angle=70º, Surface Albedo=0.65)

sensors) and an infrared camera. The image data consists of 10 bands, including the panchromatic band with a spatial resolution of 1 m (band 1), and 9 multispectral bands with spatial resolutions of 3 m (bands 2–5), 30 m (bands 6–8), and 60 m (bands 9–10) (bands 2–10), for a total of 10 spectral bands.

VRSS-2 flies over Venezuela three to four times every 24 hours, mainly used for land and resources census, environmental protection, disaster monitoring and management, crop yield estimation, urban planning, etc. It plays a positive role in Venezuela's development of the national economy, improvement of people's lives, and promotion of social progress.

3 Key EO Application for Iberian America

3.1 Spanish National Plan for Territory Observation, PNOT

The Spanish Earth Observation System will meet some of the user needs in the national and international optical and SAR fields, and is Spain's most important and potential contribution to the GEOSS international initiative. The Spanish Earth Observation System is suitable for complementing other satellites to form global coverage, such as PAZ and Sentinel-1, SEOSAT/Ingenio and Sentinel-2 provide high-resolution images of large areas in a short period of time for seasonal or annual monitoring.

The Spanish National Plan for Territory Observation (PNOT)[30] in Spain includes PNOA (National Plan for Aerial Orthography), PNT (National Plan for Remote Sensing), and SIOSE (Information System for Land Cover and Land Use in Spain). PNOT coordinates the acquisition of aerial images and digital elevation models, providing remote sensing data covering the whole country, including updating aerial multispectral orthophoto every 2–3 years, and using LiDAR to obtain digital elevation models with a resolution of 15 cm for flood control, road engineering, and forest inventory. PNT coordinates Earth observation satellite images and regularly (annually, monthly, and weekly) provides high, medium, and low-resolution satellite images covering the entire national territory. PNT has facilitated the extensive use of satellite imagery by all Spanish public administration agencies, universities, and public research institutions in multiple projects and tasks. PNT provides remote sensing images at three temporal and spatial levels: high-resolution 1 to 10 m, from 2005 to 2013, using SPOT5 2.5 m resolution summer images to form images covering the entire region once per image; medium resolution, spatial resolution ranging from 10 to 100 m, collected all Landsat 5 multispectral 30 m and Landsat 7 images covering Spain since 2009. Deimos-1/2 20 m resolution images were obtained in 2011 and 2012, as well as Landsat 8, mainly used for intra- and inter annual multi temporal environmental and land dynamic monitoring; Low resolution: spatial resolution of 100 to 1,000 m, time frequency of 1 or 2 days, Sentinel-3 is the main data source, mainly used for extracting biophysical parameters (vegetation index, temperature, combustible material quantity, and fire risk), and achieving near real-time environmental variable monitoring. SIOSE mainly executes the CORINE land cover plan of 1:100,000 and the Spanish land cover and land use information system of 1:25,000.

3.2 Brazilian Amazon Forest Application

Brazil is a vast continental country, whose territory is composed of different biological communities, diverse agricultural systems, and complex hydrological, energy, geological, and topographical systems. The natural vegetation in Brazil is very diverse, with only two biomes, the tropical forest and the Cerrado forest, covering more than half of the country’s territory. One of the main environmental issues in Brazil’s biological community is deforestation, especially in the Amazon region. DETER[31] (real-time deforestation detection) is one such measure. The DETER system is INPE’s contribution to the action plan of the Brazilian Ministry of Science, Technology, Innovation and Communication through the Permanent Inter Ministerial Working Group (GTPI), aimed at reducing the legal deforestation rate in the Amazon region. This system has been in operation since 2004 and is an important warning tool for monitoring and controlling deforestation, especially in the Brazilian Amazon region. DETER uses MODIS (Moderate Resolution Spectral Imager on Terra and Aqua satellites in the United States) data with a spatial resolution of 250 m. Due to the spatial resolution of MODIS images being 250 m, the DETER system can only identify deforested areas of 25 ha or more. In addition, cloud cover may also limit the system’s ability to identify deforestation. Therefore, higher spatial resolution remote sensing data is needed. Another operational plan dedicated to monitoring deforestation in the Amazon region is PRODES (Remote Sensing Deforestation Measurement), which measures the area of deforestation based on data from land satellites (Landsat, CBERS, DMC, etc.).

4 Development of Iberian America Earth Observation

The Earth observation systems of Iberian American countries have a certain foundation for development, with some characteristics in the development and construction of SAR satellites and high-resolution optical small satellite constellations, showing a clear trend towards commercialization and marketization. The development of Earth observation systems in Iberian American countries focuses on improving the observation accuracy and practicality of remote sensing data, promoting scientific research and technological applications in related fields. Especially SAR satellite technology has been widely applied in various fields such as agriculture, forestry, urban planning, and environmental monitoring. These applications not only improve the efficiency of resource management, but also play an important role in disaster warning and response.

Despite significant advances in Earth observation technology in Iberian American countries, there is still a gap in the construction of comprehensive Earth observation systems compared to countries such as the United States, Europe, and China. Existing satellites have not yet formed a complete Earth observation constellation, making it impossible to provide full coverage imaging of the world. A low resolution daily Earth observation system has not yet been established.

With the construction and development of GEOSS, Iberian American countries should continue to increase research and development investment, especially in strengthening satellite payloads, data processing algorithms, and satellite platform technology research and development. They should also further strengthen data sharing and cooperation, establish a sound mechanism for sharing Earth observation data, and promote cooperation between governments, scientific research institutions, and commercial enterprises. At the same time, we should actively participate in international Earth observation programs, especially strengthen Earth observation data support services in areas such as climate change, ecosystem monitoring, and disaster management, enhance the international influence of data, jointly promote the sharing and application of Earth observation data, and contribute to global sustainable development.

Author Contributions

Fan, J. L., Zhang, Q. Q., Belen, F., Liu, C. and Zhao, X. X. made the overall design of the investigation; Zhao, C. L. collected the data and wrote the original draft paper; Fan, J. L. reviewed and edited the paper.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Feng, Y., GAO, F., Huang, X. Y. Construction of an integrated global earth observation system [J]. *Advance in Earth Science*, 2005, 20(12): 7.

[2] Xiao, Y. Strengthening global cooperation in Earth observation [J]. *Space International*, 2005(4): 1. DOI: CNKI:SUN:GJTK.0.2005-04-003.

[3] Learner Trip. Countries by population (2023) [EB/OL]. https://learnertrip.com/demography/countries-by-population-2023/.

[4] Undp. Human development report 2023–24 [R]. United Nations Development Programme, 2024.

[5] Jones, S. C., May, C. The Geosat-1 ground station [J], *International Telemetering Conference Proceeding*, 1985(21): 32.

[6] Pirondini, F., López, J., González, E., *et al*. DEIMOS-2: cost-effective, very-high resolution multispectral imagery [C]. Conference on Sensors, Systems, and Next-Generation Satellites XVIII, 2014.

[7] Fernández, C., De Castro, C., Calleja, M. E., *et al*. GEOSAT 2 atmospherically corrected images: algorithm validation [C]. Presented at the 5th International Electronic Conference on Remote Sensing, 2023: 21.

[8] Bonilla, M. J. G., Munoz, J. M. C., Carrasco, E. V., *et al*. PAZ mission science activities [C]. EUSAR 2021; 13th European Conference on Synthetic Aperture Radar, 2021: 1–4.

[9] Marini, A., Barragan, F. J. R., Crippa, G., *et al*. SEOSAT/Ingenio-a Spanish high-spatial-resolution optical

mission [C]. International Conference on Space Optics (ICSO), 2014.
[10] Miravet, C., Zorita, D., Bueno, J. I., *et al*. Development status of the telescope for the Ingenio/SEOSAT mission primary payload [C]. Optical Design and Engineering IV, 2011.
[11] Marini, A., Reina, F., Popescu, A., *et al*. SEOSAT/Ingenio: a high-resolution land imaging mission [C]. International Conference on Space Optics (ICSO), 2018.
[12] Colomb, F., Alonso, C., Hofmann, C., *et al*. SAC-C mission, an example of international cooperation [J]. *Advances in Space Research*, 2004, 34(10): 2194–2199.
[13] Machado, M., Roggero, E., Alonso, R., *et al*. SAC-a satellite [C]. Small Satellite Conference, 1996.
[14] Giraldez, A. E. SAOCOM-1 Argentina L-band SAR mission overview [J]. *ESA Special Publication*, 2004, 565: 27.
[15] Vrabel, J. C., Bresnahan, P., Stensaas, G. L., *et al*. System characterization report on the Satellogic NewSat multispectral sensor [R]. US Geological Survey, 2022.
[16] Leitmann, M. G., Rebordao, J. M., Gomes, N. M., *et al*. PoSAT-1 star imaging system: in-flight performance [C]. Platforms and Systems, 1995: 167–177.
[17] Lammerzahl, P., Rawer, K., Roemer, N. Results of the AEROS satellite program: summary [R]. 1980.
[18] Lino, C. D. O., Lima, M. G. R., Hubscher, G. L. CBERS—an international space cooperation program [J]. *Acta Astronautica*, 2000, 47(2–9): 559–564.
[19] Sausen, T. M. The China-Brazil earth resources satellite (CBERS) [J]. *ISPRS Society*, 2001, 6(2): 27–28.
[20] Silva, D. F. D., Muraoka, I., Garcia, E. C. Thermal control design conception of the Amazonia-1 Satellite [J]. *Journal of Aerospace Technology and Management*, 2014(6): 169–176.
[21] Scaduto, L., Carvalho, E., Santos, A. The advanced wide field imaging camera (AWFI) for the Amazonia 1 Brazilian satellite [C]. International Conference on Space Optics—ICSO 2010, 2019: 840–845.
[22] Morais, M. S. G. D. Trajetória tecnológica do setor espacial: o comportamento das firmas brasileiras no new space [D]. Brasilia: University of Brasília, 2023.
[23] Méndez, G. J. E., Cheng, A. M., Muñoz, S. FACSAT: conception as a cyber-physical system for satellite observation of the Earth: automated mission planning and scheduling [C]. Proceedings of the ACM/IEEE 14th International Conference on Cyber-Physical Systems (with CPS-IoT Week 2023), 2023: 241–242.
[24] Rincón-Urbina, S. R., Cárdenas-García, J. M., Pirazán-Villanueva, K. N., *et al*. Diseño crítico del nanosatélite de la misión FACSAT-2 para la observación y análisis del territorio colombiano [J]. *Revista UIS Ingeniería*, 2023, 22(3): 69–86.
[25] Freese, K. A small box that's a big deal: how Latin American Countries are using CubeSATs and why it matters [J]. *Small Wars Journal*, 2016-07-30.
[26] Colonia, G., Andy, R. Analysis of spectral applications derived from images perusat-1 satellite [J]. *Revista del Instituto de investigación de la Facultad de minas, metalurgiay ciencias geográficas*, 2021, 24(47): 75–81.
[27] Nader, R., Carrion, H., Uriguen, M. The Ecuadorian experience in space: the NEE ALPHA satellite constellation [C]. 1st International Academy of Astronautics Latin America Cubesat Workshop, 2014.
[28] Cheng, Y., Li, Z., Zhao, H., *et al*. VRSS-1 satellite summary [C]. Proceedings of the 64th International Astronautical Congress (IAC 2013), Beijing, China, 2013.
[29] Xuan, G. Alcomsat-1 and VRSS-2 delivered to customers [J]. *Aerospace China*, 2019, 19(1): 56.
[30] Villar, A. A., Asensio, L. G., Alcázar, G. V., *et al*. Spanish national plan for territory observation (PNOT) [J]. *The International Archives of the Photogrammetry*, *Remote Sensing and Spatial Information Sciences*, 2008, 37(B4): 1729–1733.
[31] Diniz, C. G., de Almeida Souza, A., Santos, D. C., *et al*. DETER-B: the new amazon near real-time deforestation detection system [J]. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 2015, 8(7): 3619–3628.