Recent Progress in Quantitative Land Remote Sensing in China

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During the past forty years, since the first book with a title mentioning quantitative and remote sensing was published [1], quantitative land remote sensing has advanced dramatically, and numerous books have been published since then [2–6] although some of them did not use quantitative land remote sensing in their titles. Quantitative land remote sensing has not been explicitly defined in the literature, but we consider it as a sub-discipline of remote sensing including the following components (see Figure 1): radiometric preprocessing, inversion, high-level product generation, and applications. Many inversion algorithms rely on physical models of radiation regimes of landscapes, which link with remotely-sensed data. Generating high-level satellite products of land surface biophysical and biochemical variables create the key bridge between remote sensing science and applications. Conducting in situ measurements for validation of inversion algorithms and satellite products is also a critical component. Application of satellite products to address scientific and societal relevant issues will ultimately decide the future of quantitative land remote sensing.
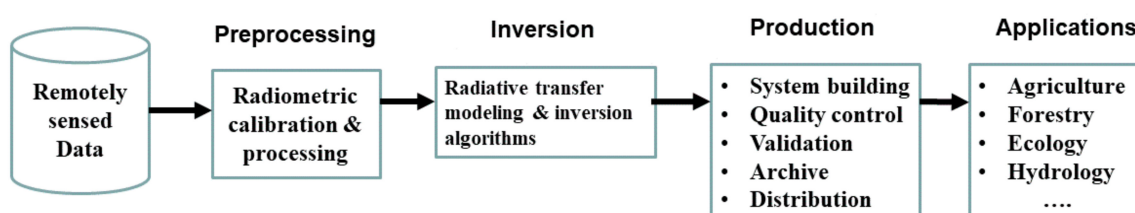

Figure 1. The scope of quantitative land remote sensing.

One of the major drivers of the rapid development of quantitative remote sensing in China is the availability of a huge amount of satellite data not only from the international space agencies but also from Chinese satellite sensors. Figure 2 shows the major Chinese satellite missions for land surface monitoring, such as the China-Brazil Earth resource satellites (CBERS), environment (Huang-Jing, HJ), resources (Zhi-Yuan, ZY), meteorological (Feng-Yun, FY), and high-resolution (Gao-Fen, GF) satellite series. Most of them are polar-orbiting satellites, but GF-5 and FY-4 are geostationary satellites. With the constellation of multiple satellites, both high spatial and temporal resolutions are being achieved.
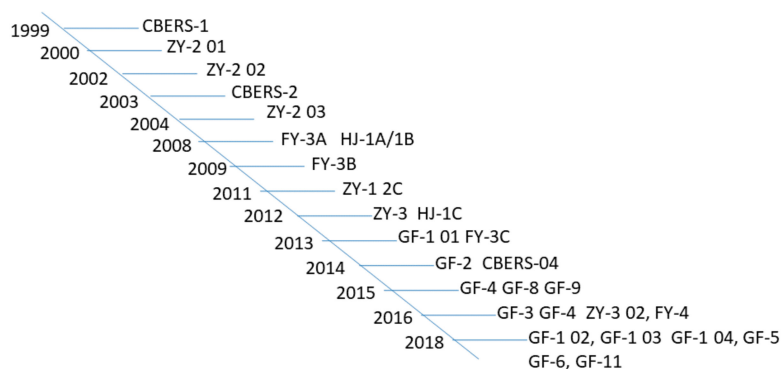
Figure 2. Major Chinese satellites relevant to land remote sensing.

Because of the increased data volume and sophistication of information extraction, one of the trends in quantitative remote sensing is the production of high-level satellite products, mostly by the data centers with centralized facilities and specialized experts. It started from the NASA Earth Observing System (EOS) program in the 1990s. Since then, China has started to produce and distribute satellite products worldwide. One of the major product suites is the Global Land Surface Satellite (GLASS) products [7,8]. It has been expanded from the original 5 products into the present 12 products (see Table 1) that are being distributed free of charge through the China National Data Sharing Infrastructure of Earth System Science (http://www.geodata.cn/thematicView/GLASS.html) and the Global Land Cover Facility at the University of Maryland (http://glcf.umd.edu/data).

The GLASS products have some unique features, for example, long-time times series (several products span from 1981 to present), high-spatial resolution of the radiation products (5 km instead of the typical resolutions of ~100 km), and high quality and accuracy [9–11]. Efforts are being made in China [12] to develop more Climate Data Records (CDR) that are defined as the time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change by the National Research Council [13].

Table 1. Overview of the Global Land Surface Satellite (GLASS) products and their characteristics.

No.	Product	Spatial Resolution	Temporal Resolution	Temporal Range	References
1	Leaf area index	1–5 km, 0.05°	8 days	1981–2017	[14,15]
2	Albedo	1–5 km, 0.05°	8 days	1981–2017	[16–18]
3	Emissivity	1–5 km, 0.05°	8 days	1981–2017	[19,20]
4	FAPAR	1–5 km, 0.05°	8 days	1981–2017	[21]
5	Downward shortwave radiation	0.05°	1 day	1983, 1993, 2000–2017	[22]
6	PAR	0.05°	1 day	1983, 1993 2000–2017	[22]
7	Longwave net radiation	0.05°	Instantaneous	1983, 1993, 2003, 2013	[23,24]
8	All-wave net radiation	0.05°	1 day	1983, 1993 2000–2017	[25]
9	Land Surface Temperature	1–5 km, 0.05°	Instantaneous	1983, 1993, 2003, 2013	[26]
10	Fraction of vegetation cover	500 m, 0.05°	8 days	1981–2017	[27]
11	Latent heat (ET)	1–5 km, 0.05°	8 days	1981–2017	[28]
12	Gross Primary Productivity	1–5 km, 0.05°	8 days	1981–2017	[29]

Many members of our community have made significant contributions to the development of quantitative land remote sensing. Professor Xiaowen Li was one of leading figures. Trained as an electrical engineer, Professor Li started to work on physical modeling of the vegetation radiation

field in the early 1980s under the supervision of Professor Alan Strahler. He developed the well-known Li–Strahler geometric-optical vegetation reflectance model [30,31], and later coupled it with radiative transfer modeling [32,33]. He pioneered the simplified "kernels" to model land surface directional reflectance for developing the MODIS surface albedo products [34], These "kernels" have been widely used for analyzing various satellite observations. He also explored the angular behavior and scaling of the thermal-infrared remote sensing signatures [35], and proposed to constrain the remote sensing inversion using prior knowledge [36]. In the second half of his career, Professor Li devoted his time and energy to facilitate and promote quantitative land remote sensing research in China by leading several extensive research projects, directing the Research Institute on Remote Sensing under the Chinese Academy of Sciences, and helping establish the State Key Laboratory of Remote Sensing Science under the Chinese Ministry of Science and Technology. Those are just few examples of areas where Professor Li has made outstanding contributions. A comprehensive summary of his achievements has been provided by Liu et al. [37].

In memory of Professor Li, we organized the Third National Forum on Quantitative Remote Sensing at Beijing Normal University during 14–15 July 2017. There were 296 meeting participants from 65 research institutes and universities in China, and almost all aspects of quantitative land remote sensing were discussed.

The papers of this Special Issue are mainly from this forum. Although 40 articles cannot comprehensively characterize different aspects of quantitative land remote sensing in China, they clearly represent the current level of research in this area by Chinese scientists. These papers are related to various satellite data products, such as incident solar radiation [38–40], chlorophyll fluorescence [41], surface directional reflectance [42–44], aerosol optical depth [45], albedo [46,47], land surface temperature [48–50], upward longwave radiation [51], leaf area index [52–55], fractional vegetation cover [56], forest biomass [57], precipitation [58], evapotranspiration [59–61], freeze/thaw [62], snow cover [63], vegetation productivity [64–68], phenology [69,70], biodiversity indicators [71], drought monitoring [72], forest disturbance [55], air-quality monitoring [73], sensor design [74], and sampling strategy [75] for validation with in situ measurements. Most of these papers are based on optical-thermal remotely-sensed observations, but a few papers are also based on microwave [62,63] and Lidar [54,76] data.

Although these 40 papers do not represent a large sample, they demonstrate that few studies have been undertaken on physical modeling for understanding remotely-sensed signals and use of Chinese satellite data in their analysis. This latter shortcoming calls for the further improvement of Chinese satellite data quality.

Conflicts of Interest: The authors declare no conflicts of interest

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