A review of the past half-century Geostationary Satellite Thermal Observations for Global Precipitation Estimation: Developments, Achievements, and Future Prospects

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Abstract

Over the past half-century since 1975, the development and improvement of meteorological geostationary (GEO) satellites have played a pivotal role in observing cloud dynamics and subsequently in advancing spaceborne precipitation estimation. Infrared (IR) observation from GEO satellites offers unique advantages such as broad spatial coverage, high temporal resolution, and long-term consistency, motivating extensive research to unlock the potential of GEO IR-based data for capturing precipitation structure and dynamics. This paper reviews the major developments and milestone achievements of GEO IR-based precipitation estimation over the past five decades, and summarizes the future prospects including potential directions and remaining challenges. By examining the history of global GEO satellites and over a hundred references in this domain, we categorize the development of GEO IR-based precipitation estimation methodology and technology into three distinct stages: (1) Exploration Phase (1975 to ca. 1995); (2) Growth Phase (ca. 1995 to ca. 2015); and (3) Exploitation Phase (ca. 2015 to present). As we transition into an emerging new stage, these efforts collectively point toward multispectral retrievals, lifecycle-aware machine learning, smart sensing, and advanced multisource integration as key directions shaping the future of GEO IR–based precipitation estimation. In summary, GEO

IR–based precipitation estimation has made substantial contributions over the past half century, and will play an increasingly important role with great potential in future precipitation science.