Ground-based GNSS Atmospheric Monitoring for Weather and Climate Resilience

Haobo Li, Suelynn Choy, Safoora Zaminpardaz, Zhenzhen Peng (Australia) and Xiaoming Wang (China, PR)

Key words: GNSS/GPS; Remote sensing; Risk management

SUMMARY

In recent years, the profound impacts of global warming and large-scale climate changes have significantly amplified the severity and frequency of hazardous weather and climate extremes, like heavy precipitation, convective storms, and droughts, across the planet. Reports indicate that over the past 50 years, these events have increased fivefold, affecting more than 1.5 billion people worldwide. The resulting economic losses exceed USD 1.3 trillion annually. As climate change intensifies, these hazardous events are projected to escalate, leading to increasingly severe and, in some cases, irreversible consequences for human and natural systems. This alarming trend underscores the urgent need for enhanced monitoring of meteorological hazards and climate risks.□Water vapour, a key essential climate variable (ECV) and one of the most active components of the atmosphere, plays a critical role in determining the intensity, time, and extent of extreme weather and climate phenomena. Extensive evidence highlights that large-scale atmospheric circulation, particularly the dynamic movement of water vapour, directly drives meteorological fluctuations. Consequently, accurate and timely information on water vapour is indispensable for effectively monitoring weather and climate extremes.□Modern weather and climate monitoring rely on an extensive global network of Earth observing systems, comprising in-situ and satellite-based systems. Satellite Earth observing techniques, with their unparalleled global coverage and comprehensive observational capabilities, enable the monitoring of ECVs and the detailed tracking and analysis of extreme events. Originally designed for position, navigation and timing (PNT), Global Navigation Satellite Systems (GNSS) have now evolved into valuable tools for atmospheric monitoring. Decades of groundbreaking advancements have positioned GNSS as an important complement to dedicated Earth observation satellites, significantly contributing to atmospheric research and Earth observation.□Developed in the 1990s, ground-based GNSS atmospheric monitoring takes globally deployed GNSS receivers as atmospheric sensors. These receivers capture variations in satellite signals as they traverse the atmosphere, providing accurate,

frequent, and broad-coverage measurements of critical atmospheric parameters, such as the zenith total delay (ZTD) and precipitable water vapour (PWV). Notably, PWV, a key indicator of water vapour, is challenging to accurately observe with standard passive radiometers. Therefore, the innovative application of ground-based GNSS atmospheric monitoring holds significant promise for providing robust data support to facilitate the monitoring of weather and climate extremes. This presentation includes three main parts: Firstly, a systematic analysis of the response of GNSS atmospheric parameters to weather and climate extremes will be presented, revealing some precursory information of extreme events contained in these parameters. Secondly, we will showcase some statistical, numerical, and artificial intelligence (AI)-empowered methods for the detection of weather and climate extremes, using GNSS parameters as indicators. Lastly, an overview of the current barriers and future opportunities for leveraging ground-based GNSS atmospheric monitoring in meteorological and climate applications will be provided. Collectively, these advanced practices not only enhance the reliability and accuracy of detecting weather and climate extremes but also underscore the foundational strength, transformative potential, and broad prospects of GNSS, as a supplementary satellite Earth observing technique, to advance atmospheric monitoring and address challenges associated with climate change.