Recent Advances in GNSS Atmospheric Monitoring: New Datasets, Innovative Methodologies, and Emerging Applications

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

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SUMMARY

Climate change is increasingly intensifying the frequency and severity of weather and climate extremes worldwide, leading to profound social and economic disruptions and posing critical challenges to the sustainable development of human societies. At the same time, the recent curtailment in climate data collection and sharing has raised serious concerns regarding the resilience of early warning systems and the provision of comprehensive climate services. Addressing these challenges requires the generation of high-quality datasets, the advancement of methodological frameworks, and the development of innovative applications to strengthen our capacity to respond to climate change and manage meteorological hazards.

Modern weather and climate monitoring relies on a global network of Earth observation systems, comprising in-situ and satellite-based systems. Among these, satellite Earth observing techniques provide unparalleled global coverage and comprehensive capabilities, enabling the monitoring of essential climate variables and the detailed tracking of extreme events. Originally designed for Positioning, Navigation, and Timing (PNT), Global Navigation Satellite Systems (GNSS) have evolved into powerful tools for atmospheric monitoring. Decades of development have positioned GNSS as a significant complement to dedicated Earth observation satellites, contributing to the monitoring of key variables like precipitable water vapour, zenith total delay, refractivity, and bending angle. These diverse data streams offer distinct benefits to deepen our understanding of atmospheric dynamics and to enhance the monitoring of high-impact weather and climate extremes.

This presentation is structured into three parts. First, we provide a comprehensive review of our data processing platforms and introduce the first GNSS climate data record we have developed, including the determination of maximum, minimum, diurnal, monthly, and annual mean values, as well as the analysis of their behaviours across diverse climatic zones. Second, we showcase

advanced methods that leverage GNSS atmospheric parameters for the early warning of weather and climate extremes. Finally, we present current barriers and future opportunities. Collectively, these developments highlight the reliability and accuracy of GNSS-based climate analysis and risk assessment, while underscoring the transformative potential of GNSS as a complementary satellite Earth observing technique to advance atmospheric monitoring, address climate change challenges, and support sustainable strategies and informed decision-making.