Atmos. Meas. Tech., 9, 5385–5406, 2016
www.atmos-meas-tech.net/9/5385/2016/
doi:10.5194/amt-9-5385-2016

Atmospheric Measurement Techniques
Open Access
EGU

Review of the state of the art and future prospects of the ground-based GNSS meteorology in Europe

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Received: 10 April 2016 – Published in Atmos. Meas. Tech. Discuss.: 6 June 2016
Revised: 16 October 2016 – Accepted: 18 October 2016 – Published: 8 November 2016

Abstract. Global navigation satellite systems (GNSSs) have revolutionised positioning, navigation, and timing, becoming a common part of our everyday life. Aside from these well-known civilian and commercial applications, GNSS is now an established atmospheric observing system, which can accurately sense water vapour, the most abundant greenhouse gas, accounting for 60–70 % of atmospheric warming. In Europe, the application of GNSS in meteorology started roughly two decades ago, and today it is a well-established field in both research and operation. This review covers the state of the art in GNSS meteorology in Europe. The advances in GNSS processing for derivation of tropospheric products, application of GNSS tropospheric products in operational weather prediction and application of GNSS tropospheric products for climate monitoring are discussed. The GNSS processing techniques and tropospheric products are reviewed. A summary of the use of the products for validation and impact studies with operational numerical weather prediction (NWP) models as well as very short weather prediction (nowcasting) case studies is given. Climate research with GNSSs is an emerging field of research, but the studies so far have been limited to comparison with climate models and derivation of trends.

More than 15 years of GNSS meteorology in Europe has already achieved outstanding cooperation between the atmospheric and geodetic communities. It is now feasible to develop next-generation GNSS tropospheric products and applications that can enhance the quality of weather forecasts and climate monitoring. This work is carried out within COST Action ES1206 advanced global navigation satellite systems tropospheric products for monitoring severe weather events and climate (GNSS4SWEC, http://gnss4swec.knmi.nl).

1 Introduction

Atmospheric water vapour has a complex life cycle in the troposphere, including vertical and horizontal transport, mixing, condensation, precipitation, and evaporation. Due to its high temporal variation (more than 50 % within a few hours, Johansson et al., 1998) and its complex distribution, linked to its relationship with atmospheric dynamics and the role