Odin/SMR water vapour measurements in the polar summer mesopause region

Stefan Lossow¹, Joachim Urban², Donal Murtagh² & Patrick Eriksson²
(1) Karlsruhe Institute of Technology, Karlsruhe, Germany.
(2) Chalmers University of Technology, Göteborg, Sweden.

Introduction

Odin is a Swedish-led small scale satellite mission in cooperation with Canada, Finland and France. Odin has been launched on 20 February 2001 into a quasi-polar, sun-synchronous orbit with an altitude of about 600 km. This orbit provides a latitude coverage between 82.5°S and 82.5°N when measuring along the orbital track. Since 2004 Odin performs measurements off the orbital track during certain periods, allowing the latitudinal coverage temporarily to be extended towards the poles. The Sub-Millimetre Radiometer (SMR) instrument is one of two instruments aboard the satellite, measuring passively thermal emissions at the atmospheric limb in several frequency bands between 486 GHz and 581 GHz and around 119 GHz. Water vapour in the mesosphere and lower thermosphere is retrieved from measurements of the 5.57 GHz band. Measurements of this band allow water vapour to be retrieved from about 40 km up to above 100 km with an altitude resolution of 3 km.

Multi-year average distribution

Odin observations between 2001 and 2009 have been used to describe the water vapour distribution in the polar summer mesopause region. The distribution in the polar region is characterised by a dominating annual component below about 90 km with maximum concentrations during the summer. Above 90 km the semi-annual variation is dominant with maxima during the solstice seasons and minimum concentrations around the equinoxes. In the polar summer mesopause region the Odin/SMR observations exhibit clear signatures of the water vapour redistribution caused by the ice particles which can exist in this region as a consequence of the very low temperatures occurring during this season. These ice particles typically form around the mesopause (~88 km) and consume the ambient water vapour. As the ice particles grow they get heavier and sediment. When they encounter warmer temperatures (>150 K), typically around 82 km altitude, they quickly sublime and release the consumed water vapour. This causes the peak in the summerly water vapour distribution observed around 80 km. The Odin observations show that the water vapour redistribution by ice particles is a common feature at latitudes polewards of 70° and increases in intensity towards the pole. The closer to the pole the higher the peak concentrations that can be observed around 80 km, while the water vapour concentrations clearly decrease in the altitude range 85 km to 90 km where the ice particles form and grow. In this region higher water vapour concentrations occur again at the end of the summer season when the ice particles disappear as visible in the latitudinal cross section at 88 km.

Aspects

During the 1990s the first measurements of the water vapour peak caused by the ice particles around 80 km became available. Higher up these measurements were unreliable and our knowledge of the water vapour distribution relied on model simulations. These simulations exhibit a strong freeze-drying effect in the altitude range between 85 km and 90 km where the ice particles form and grow. The Odin/SMR measurements, like other new available satellite measurements, do not show this strong freeze-drying effect. Differences in the vertical resolution between observations and model simulations have been pointed out as the key to explain the differences observable in the freeze-drying effect. To investigate this aspect we conducted a case study for July 2007 in which we convolved high vertical model data onto the vertical resolution of the Odin/SMR measurements. While differences in the concentration of the water vapour peak around 80 km could almost be explained by the differences in the freeze-drying essentially remained. This indicates that the model simulations likely overestimate the freeze-drying effect.

The Odin/SMR observations exhibit clear inter-hemispheric differences during summer in the polar regions. The Odin/SMR observations show more water vapour between 70 km and 82 km in the northern hemisphere while above the situation is the opposite. The analysis of these differences is complicated by the fact that the local time coverage of the measurements is different in the polar regions of both hemispheres. Model simulations indicate that the inter–hemispheric differences Odin observes cannot be explained by the diurnal variation of water vapour below 83 km and between about 88 km and 94 km. Below 80 km the inter–hemispheric differences in the water vapour distribution are likely due to a stronger upwelling in the northern hemisphere. Higher up the differences can be explained by inter-hemispheric differences in the ice particle distribution, with less ice particles in the southern hemisphere.

Time series

The water vapour time series from 2001 to 2009 is expected to increase as a consequence of the declining solar cycle and the increase of methane which is a major source of water vapour in the middle atmosphere. This effect can clearly be observed in the mesopause region outside the polar area. In the polar regions however it is not as obvious, likely due to the influence of the ice particles. In general higher water vapour concentrations can be observed at the end of the time series as compared to the beginning. It should also be noted that the time series shown here are to some degree influenced by local time coverage shift of about 1 h over the course of the Odin/SMR measurements.

The statistical error of a single profile retrieved is in the order of 5% to 15% below 80 km. Above 90 km the error easily exceeds 50%, so that averaging is necessary to get sensible results in this altitude region. The data shown here comes from one of in total three configurations to measure the 5.57 GHz band. Measurements in this configuration have been performed with a varying frequency over the course of the Odin mission, i.e. every 9°/18°/14°/7° day.