Seven years of water vapour measurements in the mesosphere and lower thermosphere by Odin/SMR

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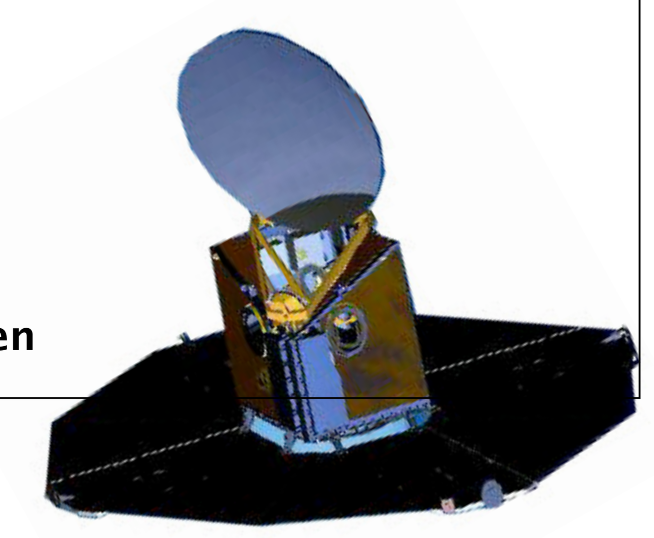
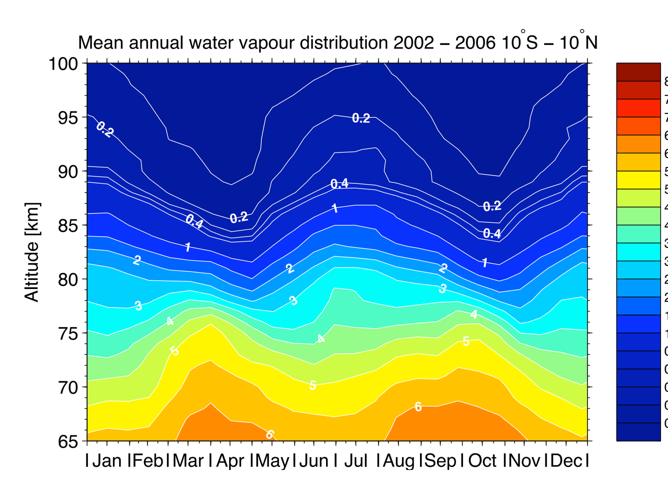


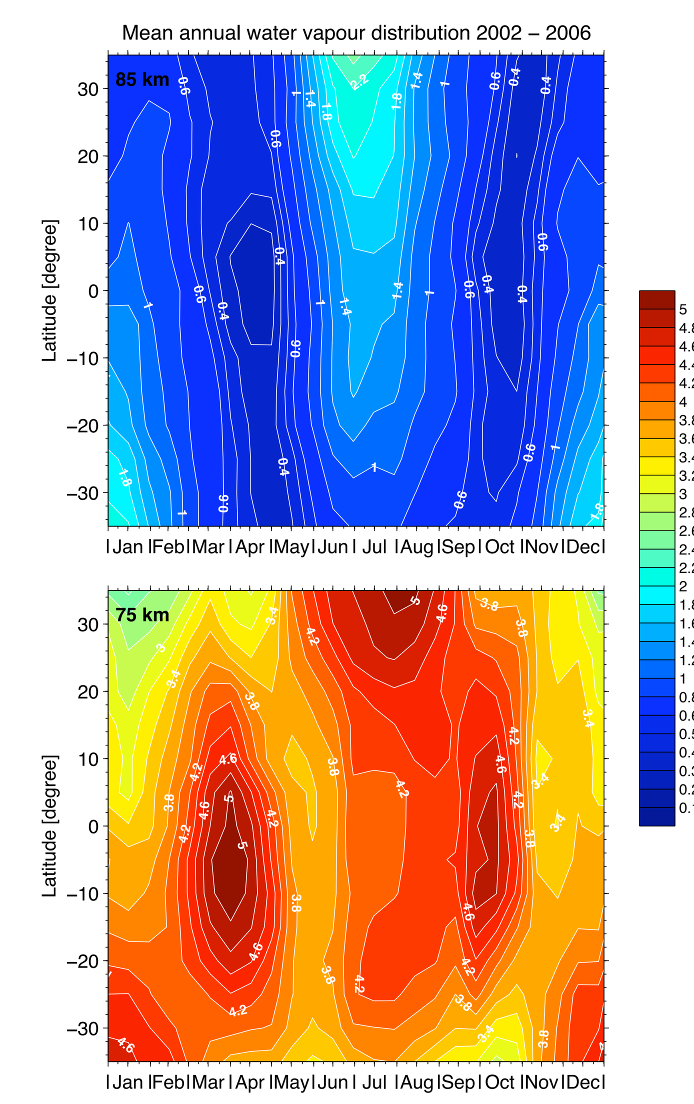
Introduction

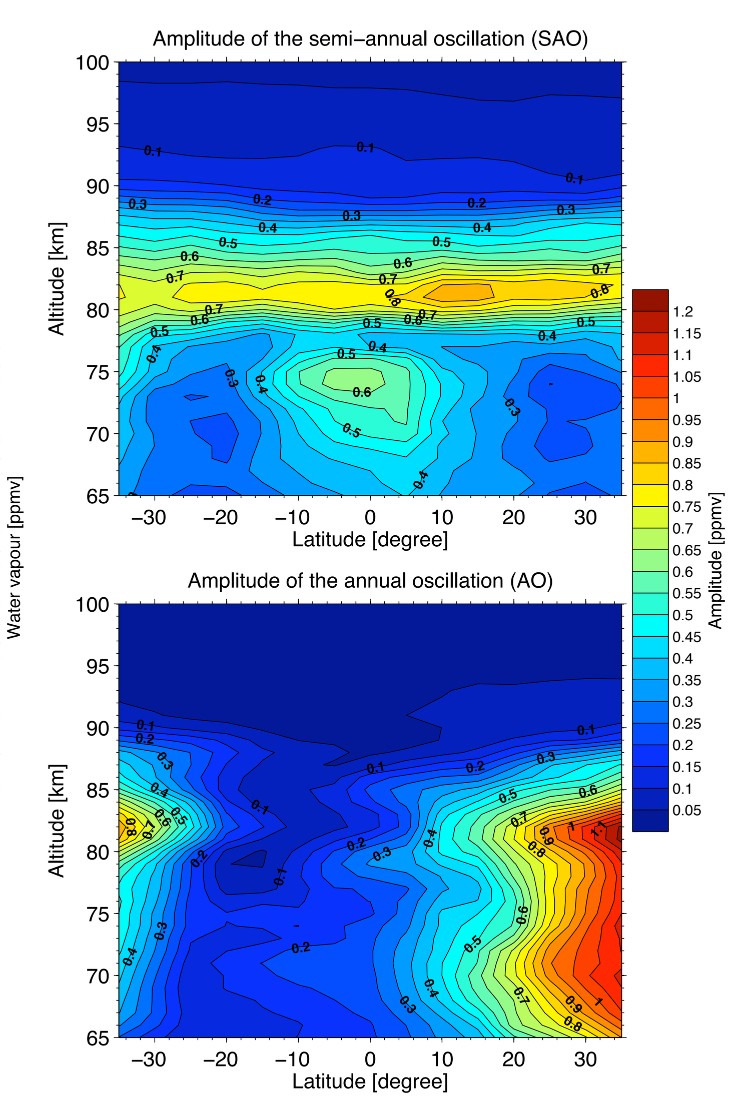
Odin is a Swedish-led small scale satellite mission in co-operation with Canada, Finland and France. Odin has been launched on 20 February 2001 into a quasi-polar, sun-synchronous and near-terminator orbit at altitude of about 600 km. This orbit provides a latitude coverage between 82°S and 82°N when measuring along the orbital track. Since 2004 Odin perfoms 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 557 GHz band. Measurements of this band have initially been performed on 4 days per month. In April 2006 the measurement frequency was increased to 7 days per month. Since May 2007 measurements of this frequency band are performed on 11 days per month. The Odin/SMR measurements of the 557 GHz band allow water vapour to be retrieved from about 40 km up to above 100 km with an altitude resolution of 3 km. 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.

Mesospheric semi-annual oscillation (MSAO) in water vapour

Odin measurement between 2002 and 2006 have been utilized to study the mesospheric semi-annual oscillation in water vapour in the tropics and subtropics. This analysis provides the first complete picture of mesospheric SAO in water vapour, covering altitudes above 80 km where previous studies were limited. Our analysis shows a clear semi-annual variation in the water vapour distribution in the entire altitude range between 65 km and 100 km in the equatorial area. Maxima occur near the equinoxes below 75 km and around the solstices above 80 km. The phase reversal occurs in the small layer in-between, consistent with the downward propagation of the mesospheric SAO in the zonal wind in this altitude range. The SAO amplitude exhibits a double peak structure in the equatorial region, with maxima at about 75 km and 81 km. The upper peak amplitude remains relatively constant with latitude. The lower peak amplitude decreases towards higher latitudes, but recovers in the southern hemisphere subtropics. On the other hand, the annual variation is much more prominent in the northern hemisphere subtropics. Furthermore, higher volume mixing ratios during summer and lower values during winter are observed in the northern hemisphere subtropics, as compared to the corresponding latitude range in the southern hemisphere.

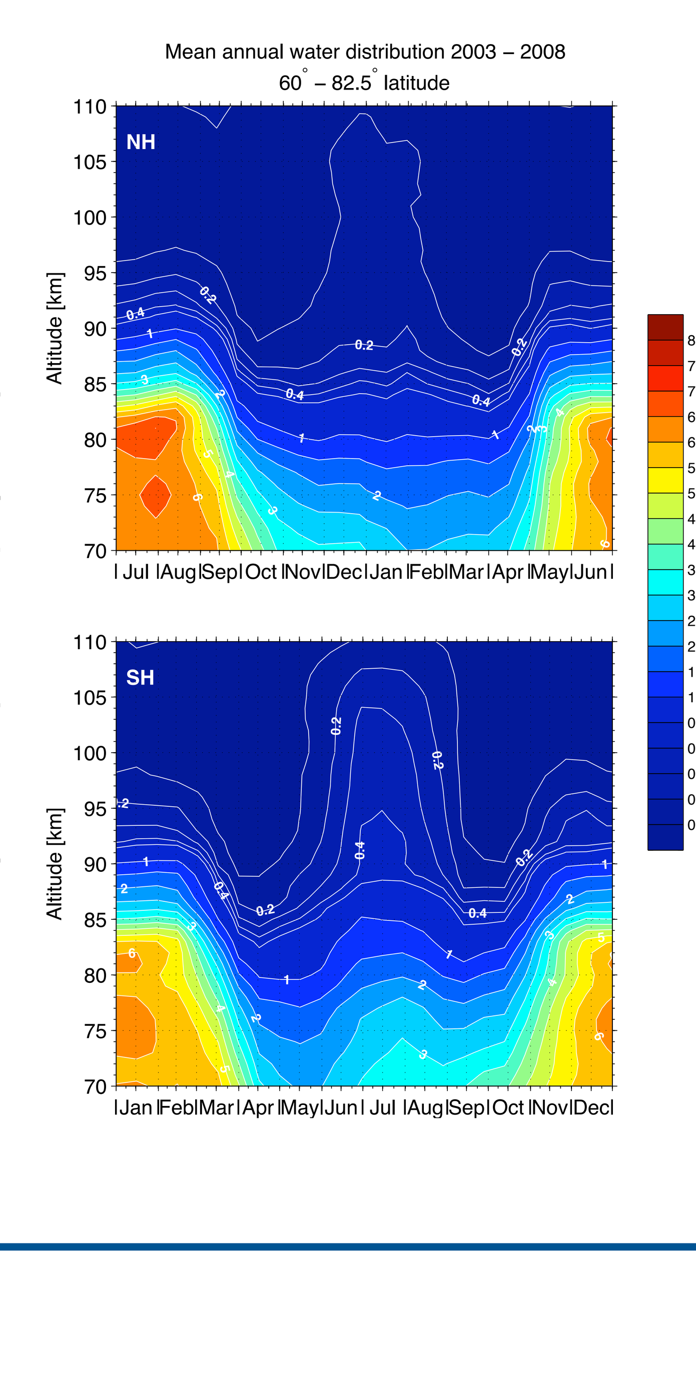


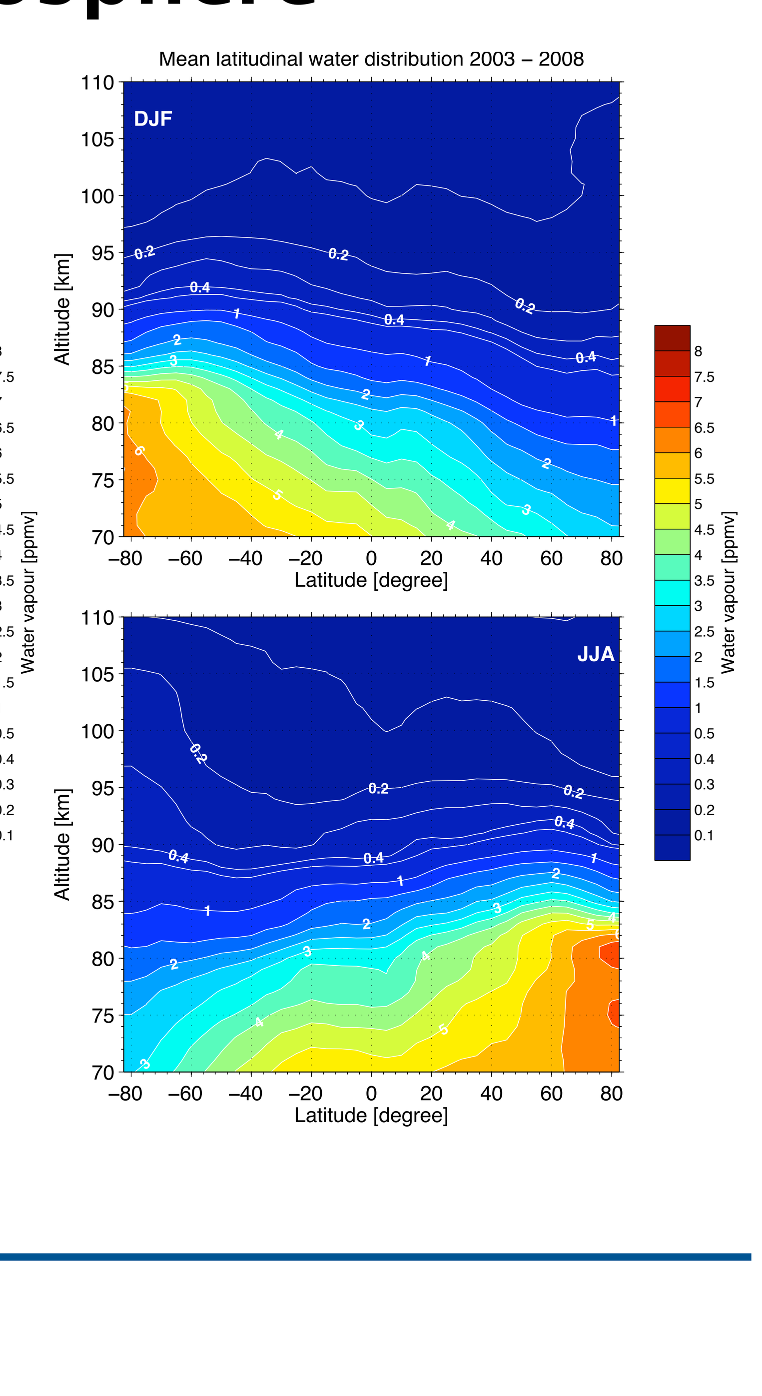




Winter water vapour in the upper mesosphere and lower thermosphere

In the last ~30 years a series of satellite-borne and ground-based measurements have established a general picture of the water vapour distribution in the middle atmosphere. However, so far these measurements were usually limited to a top altitude in the 80 km to 90 km region. Rocket-borne measurements have on very rare occasions explored the water vapour content at altitudes even above 90 km. Odin provides for the first time satellite-borne measurements in the altitude range between 90 km and 110 km. A focus has been put on the water vapour distribution in the polar region during winter time. The observations by Odin/SMR show a distinct seasonal increase of the water vapour concentration during this season at a given altitude above 90 km. Above 95 km the observations exhibit the annual water vapour maximum during winter time, which is a different behaviour as in the subjacent part of the mesosphere where the maximum is observed during summer. Model simulations from HAMMONIA and WACCM3 show very similar results as the observations. We suggest that the observed increase in water vapour during winter is mainly caused by upwelling of moister air from lower altitudes. Distinct inter-hemispheric differences in the winter water vapour distribution in the upper mesosphere and lower thermosphere can be observed, both in the observations and the model results. The seasonal water vapour increase in the polar regions is much more pronounced in the southern hemisphere winter comprising higher concentrations and larger latitudinal extent. In the Odin/SMR measurements this seasonal increase during winter is also observed during a longer period of time in the southern hemisphere polar region than in the northern hemisphere.





Water vapour behaviour above 80 km

The Odin/SMR observations show a steady increase of the water vapour concentrations over time above 80 km. This observation can be made at all latitudes. The most likely explanation for this behaviour is the solar cycle influence on the water vapour. Above 70 km the main sink of water vapour is the photodissociation by Lyman-α radiation (λ=121.6 nm). In 2001 the solar cycle was on its maximum accompanied by a high Lyman-α flux and accordingly in a high water vapour photodissociation rate. Now, the solar cycle is around its minimum, correspondingly leading to a lower water vapour photo-disssociation rate and higher water vapour concentrations.