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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Change in turbopause altitude at 52 and 70 N" *by* C. M. Hall et al.

C. M. Hall et al.

chris.hall@uit.no

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Although the referee feels that the results presented are a repetition of earlier publications, we wish to point out that: (a) we have significantly extended the length of the time series, which in itself is important for re-asserting the trends; (b) the possibility of superimposed temperature trends has been addressed and demonstrated not to affect the results; (c) the results have been applied to oxygen density and demonstrated to be commensurable with independent observations.

The constructive advice is, of course, much appreciated. Our views on the respective concerns are as follows:

That the manuscript does not contain a proper description of methods and observations.

This is true; moreover, the referee's summary of the method is correct. The detailed descriptions are omitted because they have been reported earlier in a number of publications all accessible via the references. It would be no problem to expand the descriptions of theory and observation and add further references in a revision, depending on ACP's policy.

The use of the empirical model

NRLMSISE-00 is indeed used for the Brunt-Väisälä frequency estimate that is subsequently used for determination of the minimum turbulent energy dissipation rate supported by the atmosphere (εmin) and for the conversion of fading times to turbulent energy dissipation rate, ε. The model also provides the neutral density for obtaining the (altitude-dependent) kinematic viscosity from the dynamic viscosity. We recognize that alternatives exist (viz. satellite observations) that, today, could be viable alternatives to NRLMSISE-00. Incorporating (e.g.) AIM/SOPHIE temperatures would represent a radical change. Furthermore, these time series do not cover the entire time and altitude ranges of the radar observations and would therefore have to be formed into an empirical model (e.g. seasonal climatology) for use with the entire data-set. We are positive to exploring this route, but feel it is outside the realms of this manuscript.

Uncertainties (assumptions)

We appreciate the referee's concerns regarding the uncertainties (via a number of assumptions) regarding the conversion of the observed fading times into turbulent energy dissipation rates. This has always been the case, but due to the difficulty in measuring neutral air turbulence in the upper mesosphere / lower thermosphere, the radar method has perhaps been regarded as "better than nothing" hitherto since in situ methods are both expensive and only provide snapshots at irregular times. Simply documenting the fading time would avoid the need to make the offending assumptions, and the kinematic viscosity could be "converted" to an equivalent fading time in order to establish a *maximum* (the fading time is inversely proportional to the square root of the energy dissipation rate). The physical meaning of the fading time in terms of atmospheric parameters would then remain and be more prevalent. We would be interested in exploring this approach; the philosophy is radically different and would be a new study and hopefully new and separate publication.

Uncertainties above 100km

Again, we appreciate the referee's concerns regarding the uncertainty, this time of using MF-radar data from (apparently) above 100km. As explained to referee#1, the idea is that the ionospheric conditions that cause significant group delay in the radio wave occupy a small amount of time compared to the entire time series, so that statistically the "virtual height" problem is not significant. We accept, however that this is a hypothesis. A "radio science" study would be needed to establish the maximum altitude at which MF-radar echoes are useful as a function of local ionospheric conditions.

Specific questions

1. As far as we are aware, no. We have not noted any publications that report estimates of turbopause altitude over > 1 solar cycle, and earlier (discontinued) regular in situ soundings do not span such a length of time and nor do they offer such time resolution.

2. It is normally accepted that the neutral atmosphere dominates dynamics up to an altitude of around 130km. Incoherent scatter radars, for example, cannot differentiate between plasma parameters around 100km altitude. Under *auroral* conditions, the ion density can reach 10ˆ13 m-3 typically whereas the neutral density is typically ∼10ˆ20 m-3.

Interactive comment on Atmos. Chem. Phys. Discuss., 15, 20287, 2015.