Letters

With this piece on "the shrinking atmosphere", we are pleased to launch *Polar Research's* Letters section. We envisage this department as comprising selections from a broad spectrum of correspondence, including comments on papers recently published in the journal, thoughts on current events that relate to the polar regions, and brief notes along the lines of Hall & Brekke's, below. Your contributions are warmly encouraged.

The shrinking atmosphere

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Solar radiation, mainly in the ultraviolet (UV), is intercepted by the Earth and a proportion is absorbed at the Earth's surface. Long-wave radiation is then emitted back into the atmosphere. Unlike short-wave radiation, however, this long-wave radiation does not pass through the atmosphere; it is rather retained as in a greenhouse. Gases like carbon dioxide (CO_2) and methane (CH_4) absorb and emit efficiently in the infrared; therefore, increases in concentrations of these gases contribute to retention of heat, and hence are referred to as "greenhouse gases". In the middle atmosphere, above the "roof" of the greenhouse, CO_2 and CH_4 have the opposite effect: keeping in thermal equilibrium with the other components of the atmosphere, they "refrigerate" it by removing heat and radiating it out to space. CO_2 and CH_4 diffuse upwards from their anthropogenic sources in the biosphere. Thus, after some delay, the very gases held responsible for global warming in the troposphere cause a global cooling in the middle atmosphere. A cooling of the middle atmosphere leads to a shrinking and, as a result, ionization in the upper atmosphere (the ionsphere) occurs at a lower altitude.

Ionization in the atmosphere is characterized by distinct maxima in well-defined height regimes. It is this layering of the ionosphere that radio communications have taken advantage of for almost a century since radio waves may be reflected off the layers enabling transmission over longer horizontal distances. To understand and, in particular, predict, radio communication possibilities, characteristics of the ionospheric layering have been determined for many decades using multi-frequency radars called ionosondes. In Tromsø, these soundings, known as ionograms, have been made since 1932, with available records going back to 1935. We shall not engage upon an explanation of the mechanisms responsible for the layering of the ionosphere, nor shall we attempt to explain the theory of radar echoes from these layers. An easily accessible introduction to both ionosphere and sounding thereof may be found in Hargreaves (1992: 420). Moreover, a wealth of sources of information on the changing occurrence heights of the ionospheric layers is given by Rishbeth & Clilverd (1999). The history of the ionosonde at Tromsø is given by Hall (in press); the necessary parameter for determining the height of the ion layer of interest here, the "F-region", having been recorded in local archives between 1951 and 1980.

Monthly means of the height of the F-region ionization maximum, *hmF2*, at local noon are shown as a function of time in Fig. 1. Similar data exist for Sodankylä in northern Finland; however, the earliest Tromsø data predate it (Ulich & Turunen 1997). Moreover, although data exists from Tromsø after 1980, a significant data gap occurs (until 1992). Since the analysis of the 1951 to 1980 period was performed by staff of the Auroral Observatory in Tromsø as opposed to the

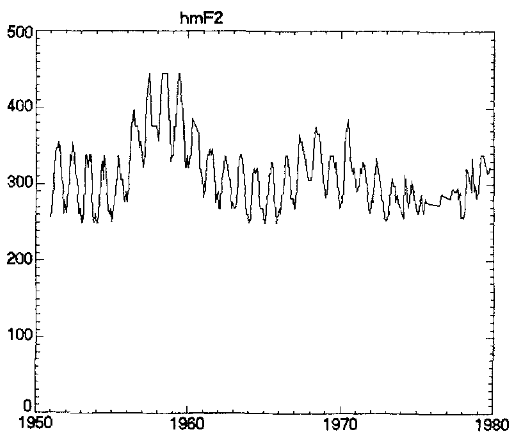

Fig. 1. Estimated true height of the F2 ionospheric layer maximum, *hmF2*, derived from the monthly average of the local noon M(3000)F2 observations at Tromsø, following the method of Ulich & Turunen (1997).

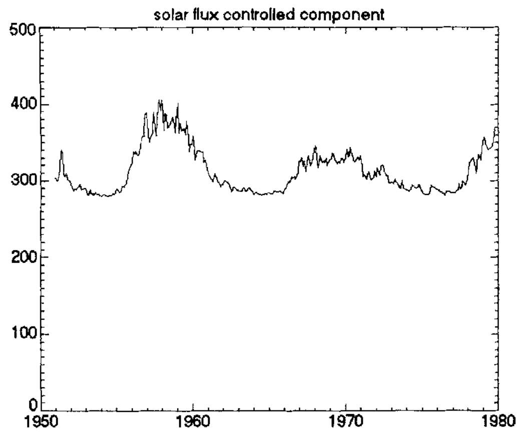

Fig. 2. The solar activity (determined by f10.7 flux) controlled component of the *hmF2* variation corresponding to Fig. 1.

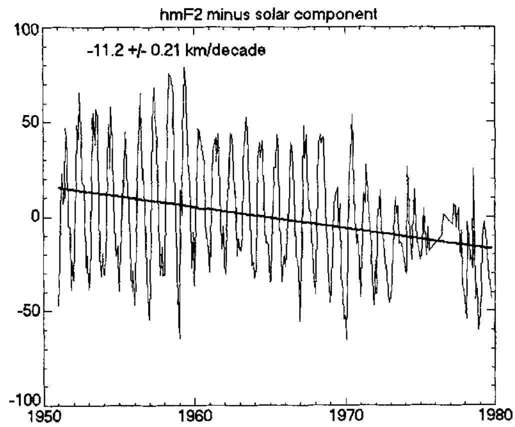

Fig. 3. The residual: the result of subtracting Fig. 3 from Fig. 1. The variations that remain describe the seasonal variations and the overall trend. Although the seasonal variation is significant, the trend is clearly visible: the F2 maximum falls by 11 km per decade, with a 2% uncertainty (1-sigma).

computer-analysis of the post-1992 data, we restrict our attention to the former period. Since solar radiation is the prime cause of ionization in the atmosphere, and this varies, we must remove the solar effects from our time series (following Ulich & Turunen 1997). This is done by performing a linear regression between the flux of 10.7 cm wavelength solar radiation (a commonly used parameter) and *hmF2*. The *hmF2* corresponding to the solar flux is then determined (Fig. 2) and now the 22 year solar cycle can clearly be identified. This is subtracted from the original *hmF2* times series such that all that remains is the annual variation and a trend (Fig. 3). Finally, as is also shown in Fig. 3, a linear fit is performed to isolate the trend. Although filtering out the annual variation would be possible, this would not significantly alter the trend and would only provide a cosmetic change to Fig. 3. We see that the altitude of the F2 layer maximum is progressively lower with time – approximately 1 km per year.

The falling of the ionospheric F2 peak is consistent with the findings of Ulich & Turunen at slightly lower latitude and also with Bremer (1998) over northern Germany. The rate of fall varies from data set to data set as might be expected, since the observational periods considered differ. Furthermore, one cannot assume *a priori* that the rate will be similar above different geographical locations. Nevertheless, our results indicate that the middle atmosphere is indeed shrinking, one of the plausible explanations being increased upward flux of anthropogenic greenhouse gases. Changes in air density have repercussions on calculations of air drag on satellites and therefore on predictions of satellite lifetimes. Perhaps more interesting, however, is the possibility to determine, *a postiori*, greenhouse gas evolution and to forecast the future trend.

References

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