A Comparison of Vertical Thermospheric Winds from Fabry-Perot Interferometer Measurements over a 50 km Baseline

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ABSTRACT

During the nights of 8-9 and 9-10 February 1997, Fabry-Perot interferometers were operated from Ramfjord and Skibotn, Norway, a longitudinal baseline of ~45 km. From Skibotn, thermospheric vertical winds were measured in the lower and upper thermosphere on both nights using the auroral/airglow emissions at 557.7 and 630 nm, respectively. From Ramfjord, neutral winds were measured, using the same wavelengths, parallel to the local magnetic field line on the first night and in the local zenith on the second night. Vertical neutral winds in both height ranges show essentially no correlation between the two stations. Some correlation between the vertical wind in the upper and lower thermosphere over individual stations does exist.

INTRODUCTION

During the nights of 8-9 and 9-10 February 1997, Fabry-Perot interferometers (FPI) were operated from the EISCAT radar site at Ramfjord (69.59° N, 19.23° E) and Skibotn (69.35° N, 20.36° E) in northern Scandinavia. The 2 sites are separated by ~50 km, or equivalently ~45 km in longitude. Vertical neutral winds were measured in the lower and upper thermosphere using the Doppler shift of the auroral/airglow emissions at 557.7 and 630 nm, respectively. The effective emission altitude in the lower and upper thermosphere corresponds to approximately 115 km for 557.7 nm (Price and Jacka, 1991; Smith and Hernandez, 1995; Price *et al.*, 1995) and 240 km for 630 nm (Sica *et al.*, 1986; Solomon *et al.* 1988), respectively. Both instruments have narrow fields of view which can be orientated through movable mirrors. The Japanese FPI at Ramfjord (Ishii *et al.*, 1997) is equipped with a dichroic beamsplitter and 2 detectors allowing measurements at both wavelengths simultaneously with a time resolution of about 1 minute. A running average of 5 minutes is used to improve the fit result. This instrument was pointing along the local magnetic field line during the first night and in the local zenith on the second night. The German FPI at Skibotn measured in the local zenith on both nights using the same wavelengths and a 1 minute integration. This FPI (Kosch *et al.*, 1997a, 1997b) has a single detector. Due to sequential scanning of the sky (for horizontal winds not presented here) and wavelengths, the measurement cycle is about 16 minutes.

The FPI permanently located at Skibotn was built in 1996 to augment the EISCAT incoherent-backscatter radar (Rishbeth and van Eyken, 1993) at Ramfjord. The FPI was not co-located with the radar due to strong artificial illumination contamination and generally greater cloud cover. Both these factors greatly reduce the effectiveness of ground-based interferometers. The vertical wind is important for geophysical studies such as tides and gravity waves but the separation between EISCAT and Skibotn may complicate any comparison. Hence, it is of interest to establish how well the vertical neutral winds between the 2 sites are related, if at all. Previous studies have found that the horizontal scale size of vertical thermospheric motions to be several hundred kilometers (Spencer *et al.*, 1982; Crickmore, 1993; Price *et al.*, 1995). As no suitable spectral lamp or laser exists at the chosen wavelengths, there exists the problem of determining the zero wind baseline for each FPI. An estimate of the zero velocity fringe position for the chosen wavelength is obtained by assuming that the vertical wind averaged over an entire night is approximately zero. This may introduce a systematic error of 10-20 m/s (Aruliah and Rees, 1995) since only a fraction of any one 24 hr period is used.

Auroral optical intensities over Skibotn and Ramfjord are obtained every 10 s from the digital all-sky imager (DASI) (Kosch *et al.*, 1996, 1998) located at Skibotn. This instrument has been calibrated in absolute units (Rayleigh) for 557.7 nm. The data has been averaged down to 1 minute time resolution. The 50 km baseline means that the DASI viewing direction is not parallel to that of the Ramfjord FPI.

The first night was geomagnetically disturbed (Kp = 4^- - 5^o) prior to magnetic midnight (≈ 21:30 UT) but much quieter thereafter (Kp = 2^o - 2^+). The second night was geomagnetically active throughout (Kp = 4^- - 5^+), especially around magnetic midnight. All correlation coefficients, including 95% confidence limits, are computed for zero time lag only. The low time resolution at Skibotn (16 min.) means that only very small zonal winds (< 23 m/s) would result in no aliasing between the stations for other lags. This was not the case for most of the time. The 95% confidence intervals for Skibotn tend to be large due to the small number of data points (< 50). For Ramfjord, the higher time resolution (1 min.) gives more data points (> 250) resulting in less uncertainty.

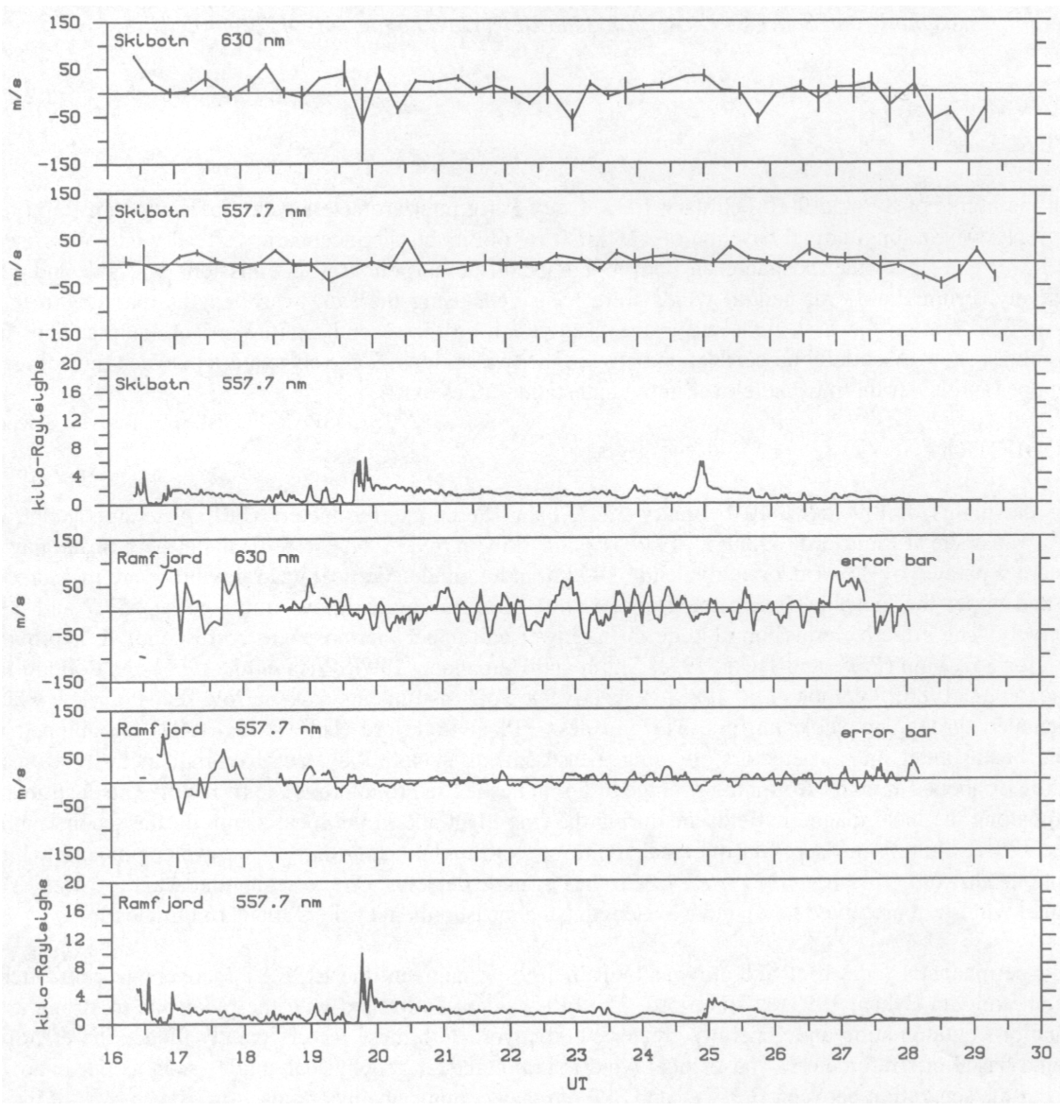

Fig. 1. Fabry-Perot interferometer Doppler shifts and auroral intensity for the night of 8-9 February 1997. The Ramfjord and Skibotn data are along the local magnetic field line direction and in the local zenith, respectively. Up is positive. The estimated error bars are also shown.

RESULTS AND CONCLUSIONS

For the night of 8-9 February 1997, figure 1 shows vertical winds from Skibotn for both altitudes, magnetic field aligned winds from Ramfjord for both altitudes and the auroral intensity at 557.7 nm over both stations. The winds over Skibotn have been cross-correlated with the auroral optical intensity. For winds from 630 and 557.7 nm the correlation coefficients are $0.19^{-0.3}_{+0.27}$ and $0.28^{-0.3}_{+0.26}$, respectively. This indicates a weak upwelling of the neutral gas with increased particle precipitation which may be expected from localised energy inputs (Rees *et al.*, 1984a, 1984b) such as Joule and particle heating. This measurement has not been done for Ramfjord due to the difficulty in locating the correct emission volume as seen from Skibotn because of the unknown height of the emission: attempts have resulted in correlation coefficients of essentially zero. The winds in the upper and lower thermosphere over each site have been cross-correlated. For Skibotn and Ramfjord the correlation coefficients are $0.19^{-0.3}_{+0.27}$ and $0.28^{-0.1}_{+0.1}$, respectively, indicating weak coupling between 240 and 115 km altitude for both stations.

Unfortunately, the winds between the stations cannot be cross-correlated because of the different viewing directions. The magnetic field direction is ~13^{o} south of zenith, which introduces a significant meridional wind

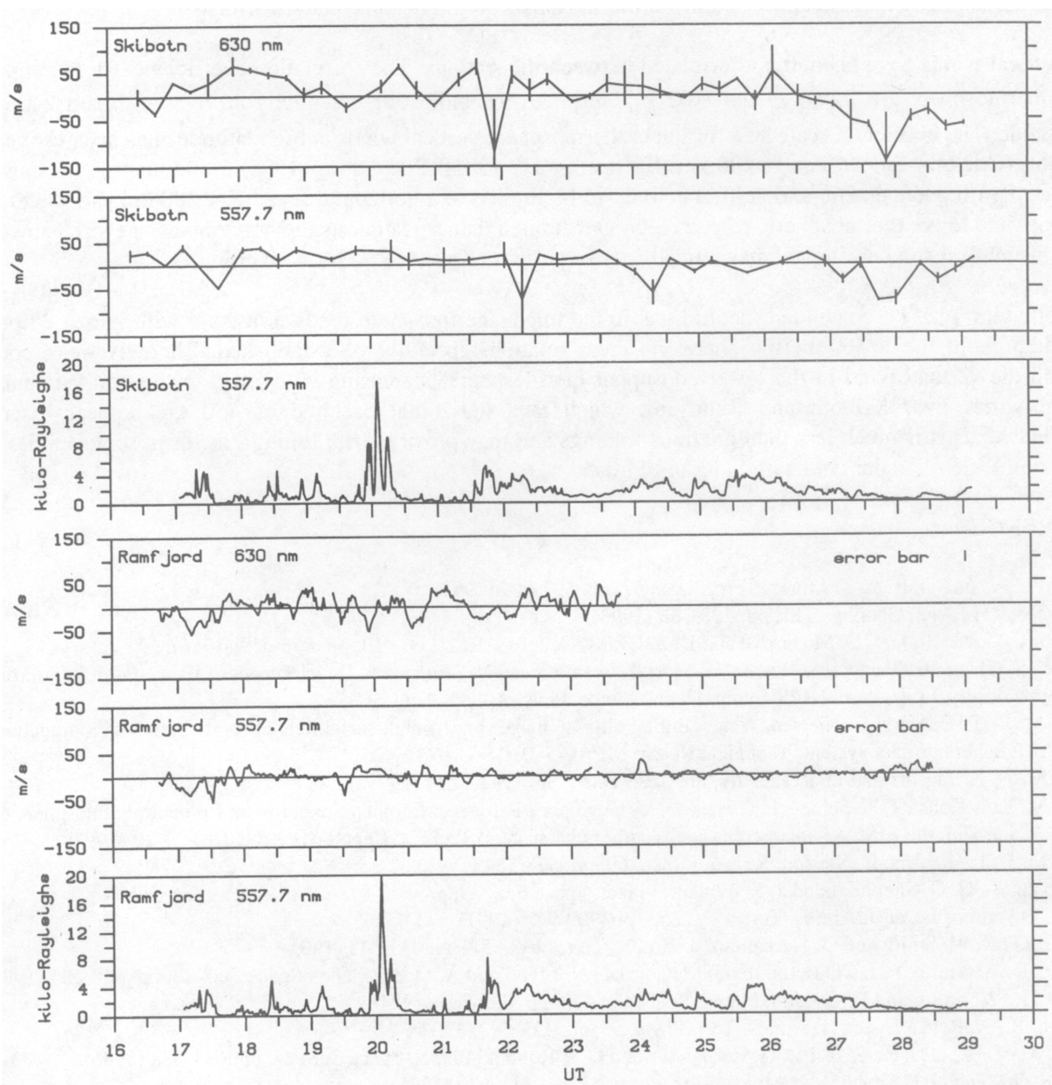

Fig. 2. Fabry-Perot interferometer Doppler shifts and auroral intensity for the night of 9-10 February 1997. The Ramfjord and Skibotn data are both in the local zenith. Up is positive. The estimated error bars are also shown.

component. Since the horizontal wind is estimated at 45° elevation, it is difficult to deconvolve it from the field aligned observation to reproduce the vertical wind with any confidence.

For the night of 9-10 February 1997, figure 2 shows vertical winds for both altitudes, and auroral intensities at 557.7 nm, for both stations. The winds over Skibotn have been cross-correlated with the auroral optical intensity. For winds from 630 and 557.7 nm the correlation coefficients are $0.34^{-0.3}_{+0.24}$ and $-0.15^{-0.31}_{+0.34}$, respectively. Upwelling of the neutral gas in the upper thermosphere with increased particle precipitation is greater than for the previous night. This is consistent with the higher Kp and brighter aurora of the second night. In the lower thermosphere, the neutral gas shows no clear relationship with increased particle precipitation. Peteherych *et al*. (1985) found that the vertical wind from 557.7 nm would either descend or ascend in the presence of a low (110 km) or high (135 km) altitude aurora. Unfortunately, we have no means to determine the altitude of the aurora. The winds in the upper and lower thermosphere over each site have been cross-correlated. For Skibotn and Ramfjord the correlation coefficients are $0.43^{-0.27}_{+0.21}$ and $0.32^{-0.11}_{+0.1}$, respectively, indicating some coupling between 240 and 115 km altitude for both stations. Compared to the previous night, coupling is greater, especially for Skibotn. This may be due to the increased energy input into the thermosphere as indicated by Kp (Foster *et al.*, 1986). Given the greater driving input, it seems likely that the upper and lower thermosphere would become better correlated.

The vertical winds have been cross-correlated between the stations. The correlation coefficients for the upper and lower thermosphere are $0.14^{-0.39}_{+0.35}$ and $0.02^{-0.28}_{+0.31}$, respectively, indicating essentially no relationship at 240 or 115 km altitude. The horizontal scale size for upper thermosphere vertical winds at high latitudes has been estimated at ~360 km (Crickmore, 1993) and ~400 km (Spencer *et al.*, 1982). Price *et al.* (1995) found neutral gas upwelling associated with geomagnetic and auroral activity to be limited to a horizontal scale of < 800 km and < 320 km in the upper and lower thermosphere, respectively. Our limited data set suggests the horizontal scale size can be < 50 km in the auroral zone during geomagnetically active periods ($Kp = 4^- - 5^+$) for both altitudes.

The following may be concluded: neutral gas in the upper thermosphere tends to ascend with increased particle precipitation. In the lower thermosphere, no clear relationship could be established. There is weak coupling between the vertical wind in the lower and upper thermosphere, increasing with Kp. For this limited study, the vertical winds over Skibotn and Ramfjord, which is a horizontal baseline of ~50 km, appear essentially uncorrelated. This is much less than previous findings and may prove to be a limiting factor in some studies when comparing EISCAT radar data with Skibotn FPI data.

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