Greet, P. A.; Murphy, D. J.; Vincent, Robert Alan; Dyson, P. L.
A comparison of optical and radar measurements of mesospheric winds and tides,
Geophysical Research Letters, 2000; 27(16):2477–2480.

GEOPHYSICAL RESEARCH LETTERS, VOL. 27, NO. 16, PAGES 2477-2480, AUGUST 15, 2000

A comparison of optical and radar measurements of mesospheric winds and tides

P. A. Greet, D. J. Murphy
Australian Antarctic Division, Kingston, Tasmania, Australia

R. Vincent
The University of Adelaide, South Australia, Australia

P. L. Dyson
La Trobe University, Bundoora, Victoria, Australia

Abstract. Optical measurements of mesospheric winds by Fabry-Perot spectrometers, FPSs, at Mawson, 67.6° S 62.9° E, and Davis, 68.6° S 78.0° E, Antarctica are compared with similar measurements obtained using a spaced-antenna MF radar at Davis. The FPSs observed the OH emission. Different analysis procedures, used to determine the mean wind, and amplitude and phase of the semidiurnal tide, have been compared. At these latitudes the diurnal tide is weak and the semi-diurnal tide, although highly variable in amplitude, is usually the dominant periodicity. When comparing the amplitude and phase of the semidiurnal tide good agreement is obtained between measurements by the two instruments.

Introduction

Comparing optical and radar measurements of mesospheric winds advances our understanding of both techniques and also of mesospheric processes. Observations of mesospheric winds have been made using MF radars for decades. In the last decade determination of mesospheric winds from Fabry-Perot Spectrometer, FPS, observations of mesospheric emissions has also become a routine technique.

As yet there is no FPS-radar combination which samples precisely the same volume at the same time. Co-located instruments do not sample the same volume as FPSs observe off-zenith and spaced-antenna MF radars observe the zenith. Meteor radars look off-zenith but often infer wind measurements for a single height representative of the mean height of meteor ablation. Matching fields of view is another difficulty. Spaced-antenna radars make measurements through the atmosphere at typically 2 km height intervals. FPS observations result from emissions integrated through a layer with a full-width at half-intensity of 8–15 km. The full-width at half-intensity will be referred to as the width of the layer. Most ground-based comparisons have involved FPS observations of either the oxygen λ558 nm airglow layer near 97 km, e.g. [*Hernandez and Roper*, 1979; *Manson et al.*, 1996; *Hines et al.*, 1993], or the hydroxyl airglow layer near 87 km, e.g. [*Meek et al.*, 1997; *Hernandez et al.*, 1996]. Intercomparisons of a number of radar techniques and FPS observations have been attempted [*Hines et al.*, 1993; *Plagmann et al.*, 1998]. In general reasonable agreement is found, however differences in sampling location and/or time of observation do lead to significant differences e.g. [*Hines et al.*, 1993].

Comparisons of satellite observations of mesospheric winds, using the HRDI instrument on board UARS, with ground-based radars have produced more controversial results. Comparisons of individual wind measurements have shown consistent differences between ground-based and satellite instruments [*Meek et al.*, 1997]. Comparisons of inferred tidal parameters between HRDI and ground-based radars have found differences involving factors of 2 [*Khattatov et al.*, 1997].

We have compared mesospheric measurements from FPSs at Mawson, 67.6° S 62.9° E, and Davis, 68.6° S 78.0° E, Antarctica, observing the OH emission, with an MF radar at Davis. In view of the inherent differences in the two techniques, we have compared tidal analyses of the two data sets rather than individual measurements. Mesospheric winds at these latitudes are dominated by the semidiurnal tide. The amplitude of the diurnal tide is generally less than 5 ms^{-1}.

Instruments

Fabry-Perot Spectrometers

The FPS at Mawson has been used for OH observations on a campaign basis since 1993 [*Greet et al.*, 1994; *Greet and Dyson*, 1999]. A second instrument became operational at Davis in 1997, with dual-channel output optics permitting more frequent OH campaigns. In total nine campaigns of FPS OH data have been analysed, 4 using Mawson data and 5 using Davis data. The instruments can make OH observations only when the sky is dark. The maximum number of hours of FPS observations, through the night, for each campaign is given in Table 1. At least five nights of FPS data are required for tidal analysis. Analysis of subsets of the campaigns presented here did not produce any significantly different results.

The OH emission is from a layer near 87 km with a width of 8 km [*Baker and Stair*, 1988]. The FPS instruments have fields-of-view of 26 mrad. This corresponds, at a 75° zenith angle, to a column through the OH layer approximately 40 km in diameter. Two volumes, separated by 650 km, are

Paper number 2000GL000036.
0094-8276/00/2000GL000036$05.00

Table 1. Davis and Mawson FPS OH Campaigns.

station	year	doys	date	dark hours
Mawson	1995	229-243	17-31 August	14
Mawson	1996	074-086	15-27 March	10
Mawson	1996	135-146	15-26 May	16
Mawson	1997	206-212	25 Jul-2 Aug	14
Davis	1997	215-226	3-14 August	15
Davis	1998	108-119	18-29 April	13
Davis	1998	123-143	03-23 May	16
Davis	1998	194-205	13-24 July	16
Davis	1998	224-240	12-19 August	13

observed along the meridian and zonally. For the purpose of the analysis presented here the two meridional and two zonal observations were combined to provide a more highly sampled meridional and zonal data set. An attempt was made to separately analyse the individual directions but in general there were insufficient data for this to be useful. An observation in a given direction takes approximately 15 minutes. Thus a zonal and meridional measurement is obtained approximately every half hour.

MF radar

The Davis MF radar is an upgraded version of that run at Mawson from 1981-1993 [e.g. *Vincent*, 1994]. The radar operates at a frequency of 1.94 MHz and consists of a square transmitting array and three cross-dipole receiving arrays that are arranged in an equilateral triangle of side-length 180 m. The radar beam is approximately 40° but the actual field of view is controlled by the angular spectrum of the scattering irregularities. On average, the angular spectrum was no wider than 15° at Mawson [*Lesicar et al.*, 1994]. Assuming similar conditions at Davis, the effective field-of-view would be less than 50 km in diameter at an altitude of 87 km. The radar beam points to the zenith. Winds are sampled from 64 to 102 km with measurements every 2 km. The radar transmits at 2 minute intervals and reflections from a region with a width of 5 km are recorded. Thus successive height bins are not completely independent.

Rather than weight a number of successive radar height intervals by a postulated OH layer shape it was decided to use only one height interval for the radar FPS comparison. A height of 86 km was chosen. At this height the radar has a high data acceptance rate during both day and night. At times, there are gaps in the radar data due to instrument down times and also due to abnormal ionization associated with, for example, large geomagnetic storms. For the comparisons presented here an hourly average of the meridional and zonal radar winds was used.

The radar has been in continuous operation at Davis since 1994. Data were available for all of the FPS campaigns although small gaps were present during some campaigns. The radar was originally operated at Mawson and long-term tidal averages are available for that station [*Vincent*, 1994]. A comparison was made between the 1997 Mawson FPS campaign with both the Mawson average tide and data obtained simultaneously at Davis. The Davis radar data were in much better agreement with the Mawson FPS data than the long-term Mawson radar average.

Comparison

A comparison of the mean wind and amplitude and phase of the semidiurnal tide using standard radar and FPS analysis techniques is given in Figure 1. Radar values were determined from a five-component fit, of the mean wind and amplitude and phase of the diurnal and semidiurnal tide, to the times-series of data obtained during the FPS campaign interval. Errors in the fit to the radar data were less than the size of the symbols. FPS values were determined from a three-component fit, of the mean wind and amplitude and phase of the semidiurnal tide, to a 24-hour superposed-epoch data set. For campaigns using the Mawson FPS the phase of the FPS semidiurnal tide has been advanced by 1 hour to allow for the longitudinal displacement of 15° between the two stations. Errors in the FPS values are indicated by bars. Better agreement is obtained between the two techniques for the amplitude and phase of the tide than for the mean wind, but there is general agreement in all cases. It should be noted that the amplitude of the semidiurnal tide varies substantially, from ~5 ms^{-1} to ~20 ms^{-1}.

Five-component fits to FPS data resulted in aliasing from the fitted diurnal component into the mean. In some cases this also affected the fitted semidiurnal component. To test for other sampling and analysis effects time series of radar data were obtained by using only radar data during hours of FPS operation e.g. for the July 1998 campaign only radar data between 10 and 02UT were accepted for analysis. We will call this sampled radar data. Figure 2 compares the mean wind and amplitude and phase of the semidiurnal tide from radar data with the standard five-component fit to sampled radar data with a three-component fit. Sampling during dark hours seems to bias the phase towards lower values by approximately one hour and has also introduced spread in the mean wind and amplitude of the semidiurnal tide. Using a three-component fit instead of a five-component fit, apart from removing aliasing in the fitting procedure, should have little effect on the fitted semidiurnal component as the amplitude of the diurnal component is generally less than 5 ms^{-1} at these latitudes. This

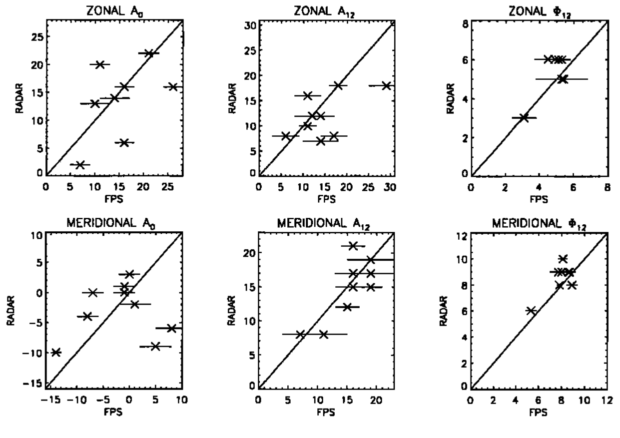

Figure 1. Mean wind and amplitude and phase of the semidiurnal tide for zonal (top row) and meridional (bottom row) components. MF radar values for the mean, and diurnal and semidiurnal tide were obtained from a five-component fit to a time-series. FPS values were obtained from a three-component fit to super-posed epoch data. A line where FPS and radar values are equal has been included to facilitate the comparison.

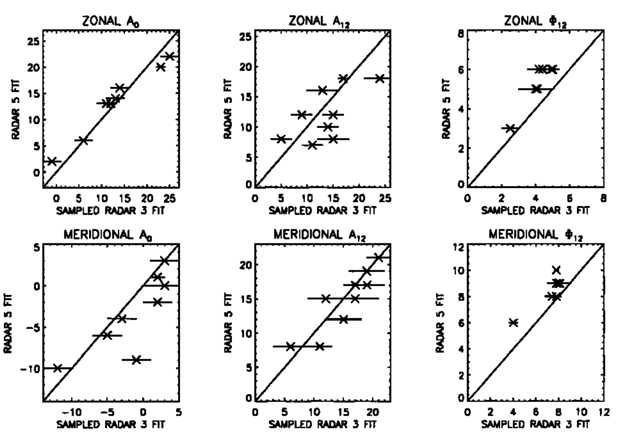

Figure 2. As for Fig 1 except comparison of two different analyses of MF radar data. MF radar values, as in Fig 1, are compared to radar values obtained using a three parameter fit to superposed-epoch data sampled at times of FPS data during the campaign interval.

was confirmed by comparing three and five component fits to the full radar data set.

A three-component fit to the FPS data and a three-component fit to sampled radar data are compared in Figure 3. The root mean square differences between the FPS and radar values are given in Table 2. In all parameters except the zonal mean wind sampling the radar data improves the agreement between the two techniques. For the amplitude and phase of the semidiurnal tide the improvement is by ~30%.

Discussion

As well as the semidiurnal tide, planetary and gravity waves are usually present. Radar measurements show there are fewer planetary waves in the equinox campaigns. In only one of the nine campaigns studied was there no significant gravity-wave periodicities. It is not unusual for a gravity wave or planetary wave to be the dominant periodicity. Variability in the semi-diurnal tide and wave activity has been reported by other Antarctic radar studies e.g.[*Portnyagin et al.*, 1998; *Charles and Jones*, 1999].

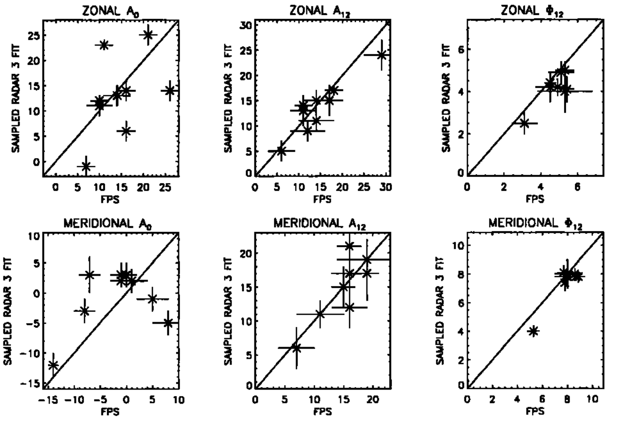

Figure 3. As in Fig 1, except using sampled radar data as in Fig 2.

Table 2. Root mean square difference between FPS and radar values, for the complete, (1), and sampled, (2), radar data sets. Difference in the amplitude of the mean wind and tide in m s^{-1}, phase in h.

	Zonal			Meridional		
	A_0	A_{12}	Φ_{12}	A_0	A_{12}	Φ_{12}
(1)	4.6	4.1	0.8	5.8	2.2	0.9
(2)	5.8	2.3	0.6	5.2	1.4	0.6

Sampling during wave activity may lead to aliasing of power into the fitted component or the mean. We tested fitting three components to the radar time series, the 12 and 24 hour periodicities and one other planetary wave periodicity e.g. 38, 56, 72, or 96 hours. The periodicity of the third component was determined from Lomb-Scargle periodograms. The amplitude of the fitted planetary waves was typically 5–10 ms^{-1}. In some cases the fitted semi-diurnal tide was in better agreement with the FPS value, but not in every case.

We have improved agreement between the two techniques by better matching of the sampling interval between the FPS and MF radar. Differences in spatial sampling, both horizontally and vertically, remain.

These comparisons have been done using radar data from 86 km. The radar sample width is 5 km. The OH layer width is typically 8 km. With strong waves and/or tides present the OH layer shape may vary through the night. Our current optical techniques do not permit any height resolution. There have been few measurements of the OH layer shape in winter time at polar latitudes. It would be possible to weight the radar measurements with an OH layer shape, but this would involve many assumptions. In view of the reasonable agreement between the FPS and radar measurements, we conclude that the OH layer is near or at 86 km altitude.

At mid-latitudes the phase of the semi-diurnal tide has been used to determine the height of the FPS observations [*Plagmann et al.*, 1998]. Davis radar data from all heights were analysed and compared with FPS measurements. An attempt was made to locate the OH layer by comparing the phase of the tide. Due to the uncertainties in our measurements and the usually slow rate of change in phase with height between 80 and 90 km, the results were inconclusive.

In summary, mean winds and tidal parameters determined from Fabry-Perot spectrometer observations of the OH emission and MF radar measurements of winds at 86 km from Davis, Antarctica, are in reasonable agreement. The key point is that agreement is improved by better matching sampling intervals. Spatial differences, possibly related to planetary and/or gravity waves, may account for some of the remaining differences. The agreement between two ground-based experiments contrasts with similar comparisons between satellite and ground-based experiments.

Acknowledgments. This project was financially supported by the Australian Antarctic Science Advisory Committee, the Australian Research Council, the University of Adelaide, and La Trobe University. We thank members of the Australian National Antarctic Research Expeditions for their support for these experiments. Particularly Simon Edwards (Mawson 1995), Alan Ng (Mawson 1996), Chris Boucher (Mawson 1997), Mike Manion (Davis 1997), and John French (Davis 1998) for their dedication in running the Fabry-Perot Spectrometers.

References

Baker, D.J. and Stair, A.T., Rocket Measurements of the Altitude Distributions of the Hydroxyl Airglow. *Physica Scripta, 37,* 611-622, 1988.

Charles, K. and Jones, G.O.L., Mesospheric mean winds and tides observed by the Imaging Doppler Interferometer (IDI) at Halley, Antarctica. *J. Atmos. Terr. Phys., 61,* 351–362, 1999.

Greet, P.A. and Dyson, P.L., Tidal Periodicities in Observations of the OH(6–2) Emission from Mawson, Antarctica. *Advances in Space Research 24(5),* 579–582, 1999.

Greet, P.A., Innis, J. and Dyson, P.L., High resolution Fabry-Perot observations of mesospheric OH (6–2) emissions. *Geophys. Res. Lett., 21,* 1153-1156, 1994.

Hernandez, G. and Roper, R.G., A comparison between radio meteor and airglow winds, *Journal of Geomagnetism and Geoelectricity 31,* 419–426, 1979.

Hernandez, G., Forbes, J.M., Smith, R.W., Portnyagin, Y., Booth J.F., and Makarov N., Simultaneous mesospheric wind measurements near South Pole by optical and meteor radar methods. *Geophys. Res. Lett., 23,* 1079–1082, 1996.

Hines, C.O., Adams, G.W., Brosnahan, J.W., Djuth, F.T., Sulzer, M.P., Tepley C.A., and Van Baelen, J.S., Multi-instrument observations of mesospheric motions over Aricebo: comparisons and interpretations. *J. Atmos. Terr. Phys., 55,* 241–287, 1993.

Khattatov, B.V., Yubin, V.A., Geller, MA., Hays, P.B., and Vincent, R.A., Diurnal migrating tide as seen by the high-resolution Doppler imager/UARS. 1. Monthly mean global meridional winds. *J. Geophys. Res., 102,* 4405–4422, 1997.

Lesicar, D., Hocking W.H., and Vincent, R.A., Comparative studies of scatterers observed by MF radars in the southern hemisphere mesosphere. *J. Atmos. Terr. Phys., 56,* 581–591, 1994.

Manson, A., Yi. F., Hall G., and Meek C., Comparisons between instantaneous wind measurements made at Saskatoon (52N, 107W) using the colocated medium frequency radars and Fabry-Perot interferometer instruments: Climatologies (1988-1992) and case studies. *J. Geophys. Res., 101,* 29553–29563, 1996.

Meek, C.E., Manson, A.H., Burrage, M.D., Garbe, G., and Cogger, L.L., Comparisons between Canadian prairie MF radars, FPI (green and OH lines) and UARS HRDI systems. *Annales Geophysicae, 15,* 1099–1110, 1997.

Palo, S.E., Portnyagin, Y.I., Forbes, J.M., Makarov, N.A., and Merzlyakov, E.G., Transient Eastward-propagating long-period waves observed over South Pole. *Annales Geophysicae, 16,* 1486–1500, 1998.

Plagmann, M., Marsh, S.H., Baggaley, W.J., Bennett R.G.T., Deutsch, K.A., Fraser, G.J., Hernandez, G., Lawrence, B.N., Plank, G.E., and Smith, R.W., Annual variation of airglow heights derived from wind measurements. *Geophys. Res. Lett., 24,* 4457–4460, 1998.

Portnyagin, Y.I., Forbes, J.M., Makarov, N.A., Merzlyakov, E.G., and Palo, S., The summer-time 12-h wind oscillation with zonal wavenumber s=1 in the lower thermosphere over the South Pole. *Annales Geophysicae, 16,* 828–837, 1998.

Vincent R.A., Gravity-wave motions in the mesosphere and lower thermosphere observed at Mawson, Antarctica. *J. Atmos. Terr. Phys., 56,* 593–602, 1994.

P.A. Greet and D.J. Murphy, Australian Antarctic Division, Channel Highway, Kingston, Tasmania 7050, Australia. (email: pene.greet@antdiv.gov.au; damian.murphy@antdiv.gov.au)

R.A. Vincent, Department of Physics and Mathematical Physics, The University of Adelaide, Adelaide 5005, Australia. (e-mail: robert.vincent@adelaide.edu.au)

P.L. Dyson, School of Physics, La Trobe University, Bundoora, Vic 3083, Australia. (e-mail: p.dyson@latrobe.edu.au)

(Received February 9, 2000; revised April 3, 2000; accepted June 7, 2000.)