Ground-based observations for the upper atmosphere at Jang Bogo Station, Antarctica: preliminary results

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The second Korean Antarctic station, Jang Bogo Station (JBS), Terra Nova Bay (74°37.4′S, 164°13.7′E), is operational since March 2014. A Fabry–Perot Interferometer (FPI) and Vertical Incidence Pulsed Ionospheric Radar (VIPIR) were installed in 2014 and 2015 respectively, for simultaneous observations of neutral atmosphere and ionosphere in the polar region. Neutral winds observed by FPI show typical diurnal and semi-diurnal variations at around 250 km and 87 km respectively. VIPIR observations for the ionosphere also show typical electron density distributions in the polar region. Unlike conventional ionospheric sounder, it can measure ionospheric tilts to provide horizontal gradients of electron density over JBS in addition to general ionospheric parameters from sounding observation. In this article, we briefly report the preliminary results of the observations for the neutral atmosphere and ionosphere in the polar cap region.

Keywords: Fabry–Perot Interferometer, polar upper atmosphere, Vertical Incidence Pulsed Ionospheric Radar.

Introduction

SINCE the first Korean polar station, King Sejong Station (KSS), was established in Barton Peninsula (62°13′S, 58°47′W), King George Island (Antarctica) in 1988, we have been conducting ground-based observations for studying the upper atmosphere in the sub-auroral region[1]. In order to expand our observations to the auroral and polar cap regions, we opened a second Antarctic station, Jang Bogo Station (JBS) near the Terra Nova Bay area (74°37.4′S, 164°13.7′E), in March 2014. Before JBS, most of the observations at the Korea Polar Research Institute (KOPRI) were focused on the mesosphere and lower thermosphere (MLT) region. JBS, however, is located in the polar cap and auroral region (77°S in geomagnetic latitude) depending on the local time and geomagnetic activity, which allows us to observe polar upper atmospheric phenomena such as aurora and energetic particle precipitation.

In addition to Fabry–Perot Interferometer (FPI) and Vertical Incidence Pulsed Ionospheric Radar (VIPIR), we currently operate a number of instruments at JBS, which include All-Sky Imager for air glow observations, GPSTEC Scintillation Monitor, Search-Coil Magnetometer, Neutron Monitor and All-Sky Imager for proton aurora. In this article, however, we only introduce FPI and VIPIR observations with their preliminary results.

Fabry–Perot Interferometer

The FPI installed in the same year that the station was set up (2014) in collaboration with the High Altitude Observatory (HAO) of the National Center for Atmospheric Research (NCAR), is an optical instrument providing neutral winds and temperature derived from the Doppler shift and broadening of measured airglow emissions[2,3]. Details of NCAR-FPI instrument as well as the error estimates of measured wind can be found in Wu *et al.*[4]. The observational parameters for each filter used in JBS-FPI are shown in Table 1. Figure 1 shows sample interferometric images of OH Meinel band (left), OI green line (middle) and OI red line (right), which correspond to 87, 97 and 250 km altitudes respectively.

Vertical Incidence-Pulsed Ionospheric Radar

In February 2015, we installed an ionospheric radar called VIPIR in collaboration with the Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado. Because of a problem on VIPIR

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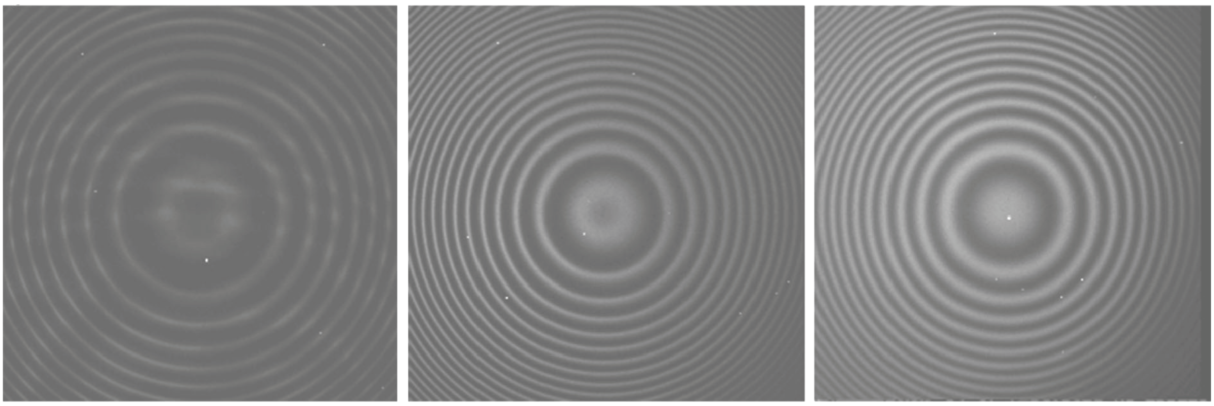

Figure 1. Sample interferometric images obtained from FPI measurement using three filters; (left) OH Meinel band centred at 892 nm, (middle) OI green line centered at 557.7 nm, and (right) OI red line centered at 630 nm, corresponding to the altitudes of 87, 97 and 250 km respectively.

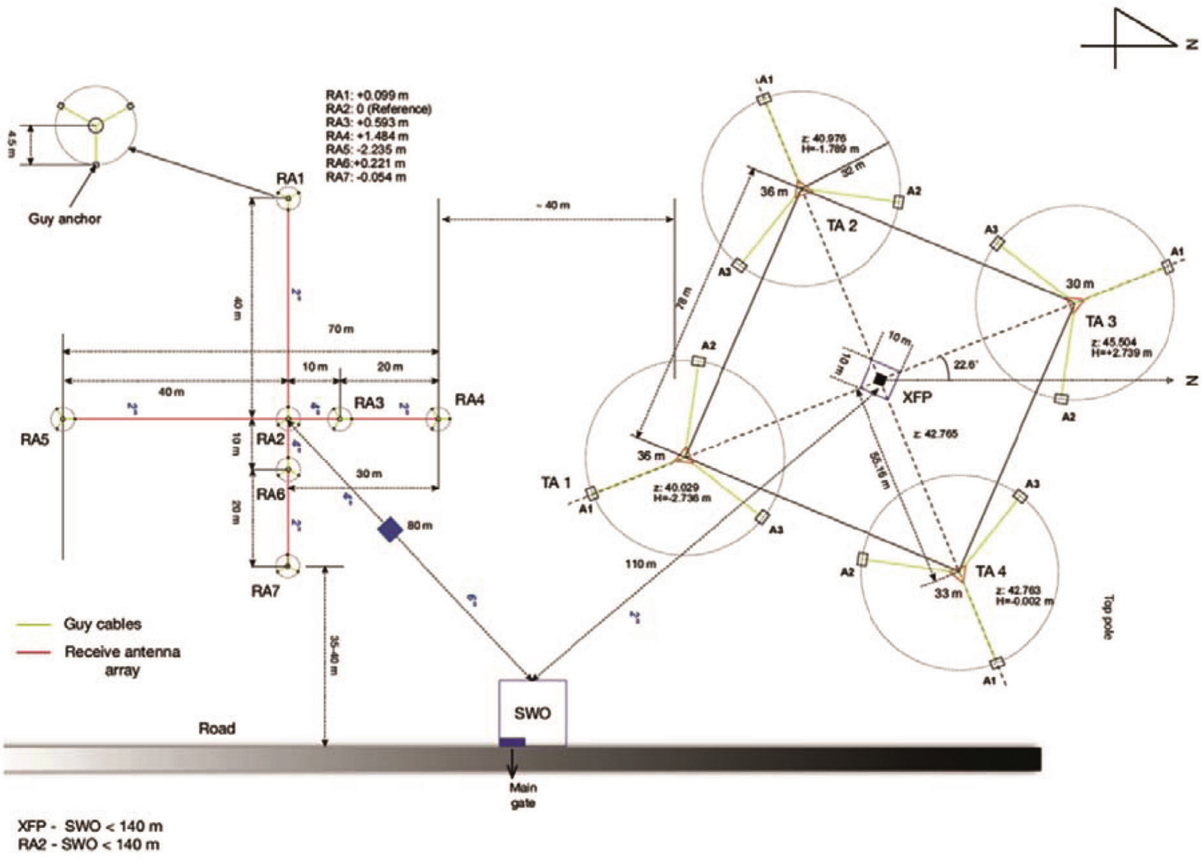

Figure 2. Configuration of JBS-VIPIR antenna arrays. The radiating part in transmitting (Tx) towers consists of wire longer than 1.5 km length in 4 zig-zag planes. Seven receive antennas are cruciformly located beside four Tx towers.

Table 1. Parameters of Fabry–Perot Interferometer operation for each emission

Emission (wavelength, nm)	Integration time (min)	Wind velocity errors (m/s)	Altitude (km)
OH (892.0)	3	6	87
O (557.7)	3	1	97
O (630.0)	5	2–6	250

antenna, caused by extremely strong winds during 2015 and 2016 winters, VIPIR started to operate normally since January 2017. JBS-VIPIR is the first ionospheric sounding system using dyansonde data analysis approach, to observe the ionosphere in the polar cap and/or auroral region in Antarctica. It can provide ionospheric parameters such as electron density, ion drift and ionospheric tilt with a high-temporal resolution of 2 min. Figure 2 shows the overall configuration of VIPIR antenna arrays. Also, brief specifications of JBS-VIPIR are described in Table 2. Details of the system as well as signal processing can be found in Grubb *et al.*[5] and Bullett *et al.*[6].

Preliminary results

Neutral winds in the polar upper atmosphere

It is well-known that the thermospheric wind and temperature in the polar region are significantly affected by not only atmospheric waves from the lower atmosphere but also plasma convection in the polar ionosphere via ion-neutral coupling processes. However, neutral wind measurements in the polar regions, especially in the southern hemisphere, are not sufficient to study the overall characteristics of the winds and their interactions with ions in the polar region. Figure 3 shows the local time variations of zonal and meridional winds at heights of 250 km (top), 97 km (middle) and 87 km (bottom), which were observed during the 20 days in the winter of 2015 by JBS-FPI. The zonal and meridional winds at 250 and 87 km altitudes show dominant diurnal and semi-diurnal variations respectively, indicating that the main drivers of neutral winds are plasma convection at 250 km altitude and the atmospheric semi-diurnal tides at 87 km altitude. However, winds at 97 km altitude show complex diurnal variations with relatively large scatter. This requires careful interpretation because there is a possibility that the aurora activity can affect the neutral wind variation at this altitude as an additional source. The detailed characteristics of polar neutral winds obtained by JBS-FPI are discussed by Lee *et al.*[7].

Table 2. Specifications of vertical incidence pulsed ionospheric radar system

Properties	Value
Frequency	0.3–26 MHz
Immunity	IP3 >45 dBm
Dynamic range	115(I) + 30(V) dB
Direct RF sampling	14 bits at 80 MHz
Waveform agility	2 μs to 2 ms pulse/chip width
Number of antennas	8 coherent receive channels and radiating wire
Amplifier	4 kW class AB pulse 3rd harmonic < –30 dBc
Interfaces	USB-2 data and command/control

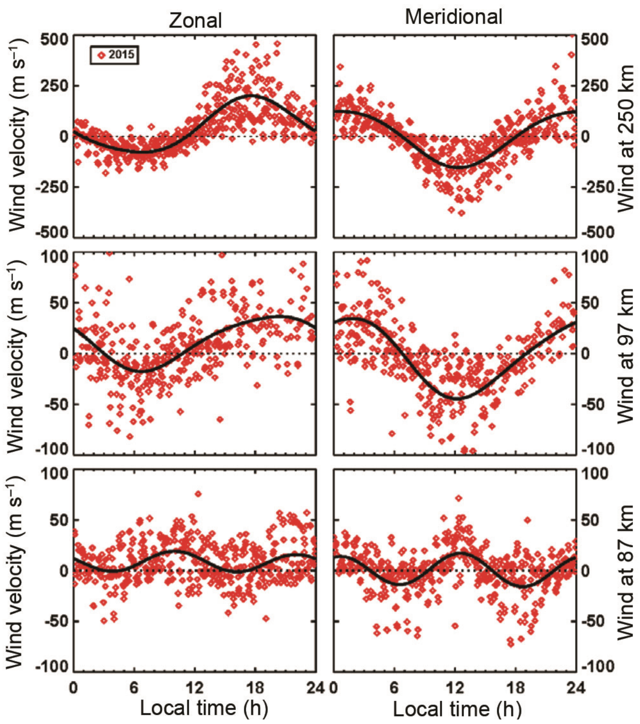

Figure 3. Local time variations of zonal (left) and meridional (right) winds at 250 km (top), 97 km (middle) and 87 km (bottom) observed for 20 days in the middle of winter in 2015. Least-square fitting lines are presented as solid lines over the scatter plot of measured winds.

Polar ionosphere

Figure 4 shows the diurnal variations of monthly mean electron density profiles for January, March and May as observed in 2017. It is evident that electron densities of the F-region ionosphere are strongly dependent on solar EUV radiation, showing the longest daytime ionosphere in January, but shortest in May as the polar night approaches. It is noticeable that there is a distinctive E-region ionosphere, especially during night, probably due to energetic particle precipitation. One of the unique features of VIPIR observations is the measurement of ionospheric tilts. Figure 5 shows monthly averaged ionospheric tilts in the W–E (left panels) and S–N (right panels) directions over JBS in January (top), March (middle) and May (bottom). Note that the positive values indicate east and north for each direction. It is clear from the figure that the ionospheric tilt significantly varies with the season in the S–N direction, being positive in summer but negative in winter, while the tilt of W–E direction does not show any noticeable changes. The tilt information obtained from VIPIR corresponds to the horizontal gradients of ionospheric electron density as described in Wright[8] and can provide additional information for the polar ionospheric electron density distribution. Finally, VIPIR observations provide horizontal component of ion drifts, which is important for the study of ion–neutral interactions together with simultaneous neutral wind observations.

Summary

In this article, we briefly introduced FPI and VIPIR instruments installed at the second Korean Antarctic

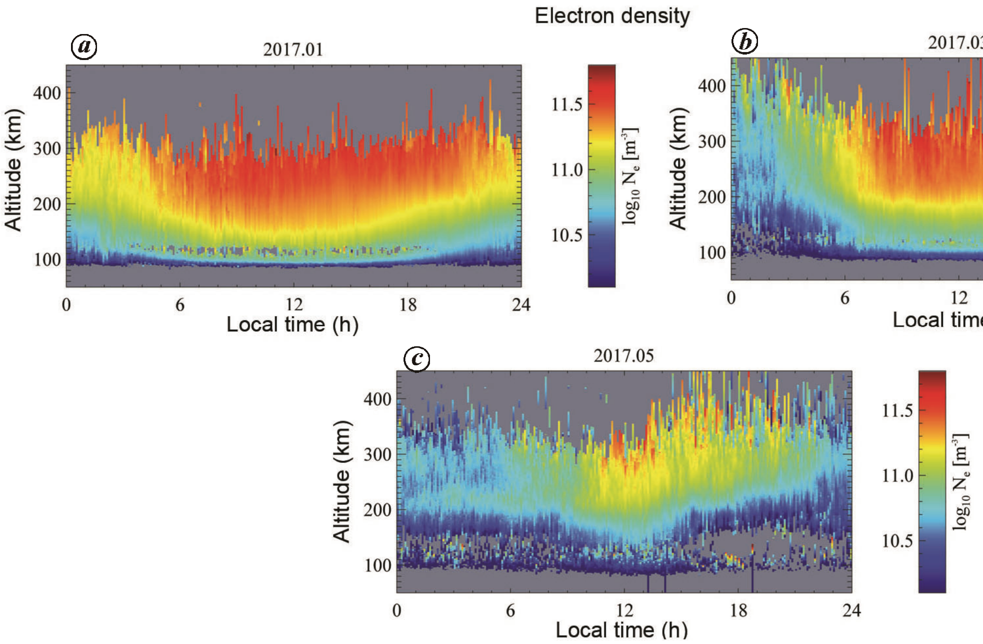

Figure 4. Local time variations of monthly mean electron density during January (***a***), March (***b***), and May (***c***) observed by JBS-VIPIR in 2017.

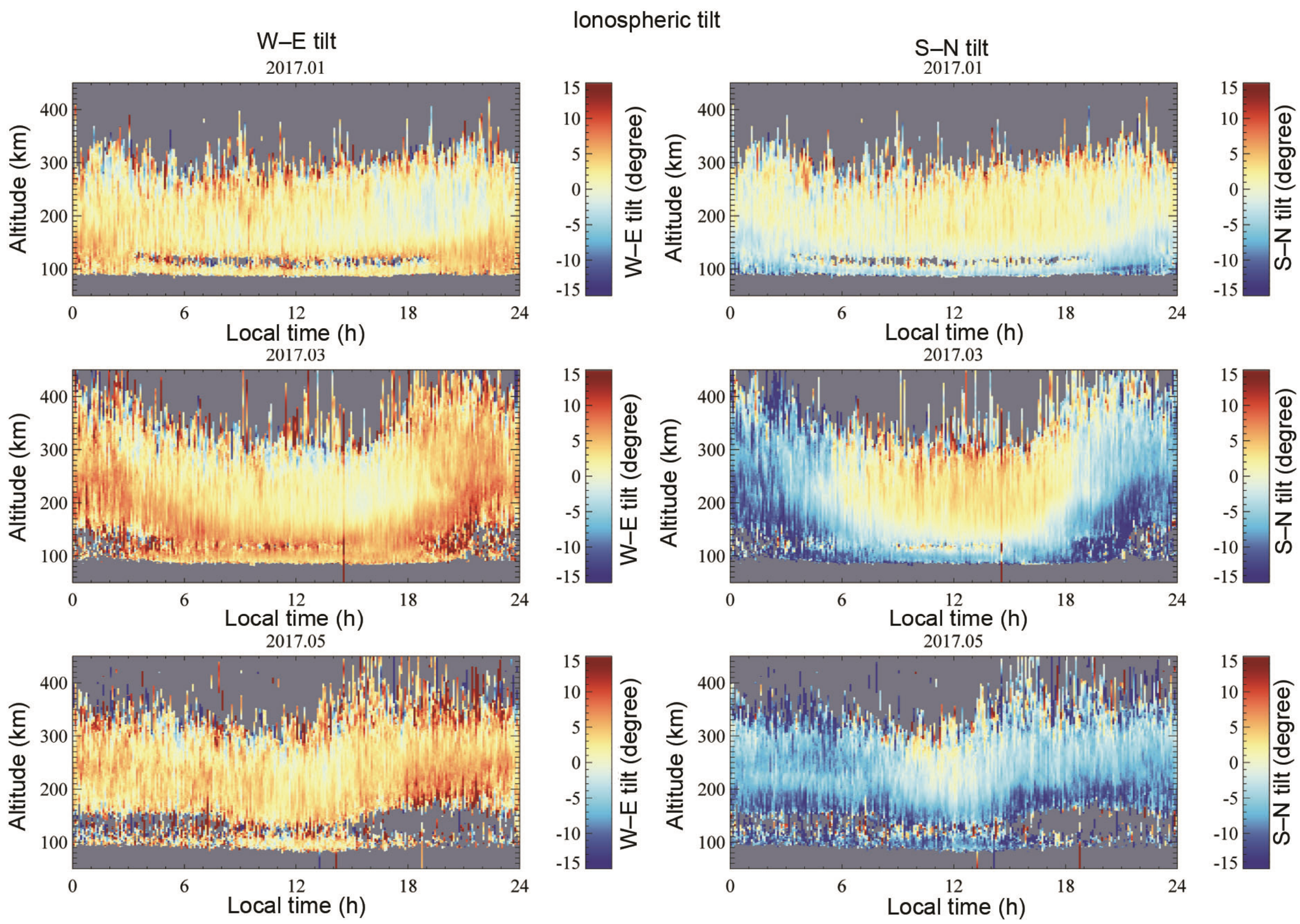

Figure 5. Monthly mean ionospheric tilts of W–E (left panels) and S–N (right panels) directions over JBS during January (top), March (middle), and May (bottom). Positive value indicates east and north directions.

station – JBS, to study the polar upper atmosphere. In addition, we presented preliminary results from measurements made by the two instruments. FPI observations showed that the neutral winds at 250 km have clear diurnal variations and are dominantly influenced by plasma convection in the polar ionosphere. However, the winds at 87 km, showing semi-diurnal variations, seem to be controlled by lower atmospheric tides. The VIPIR observations can provide continuous monitoring of the polar ionospheric parameters such as electron density, ionospheric tilts and ion drift. The simultaneous operation of FPI and VIPIR will help to study not only the physical characteristics of the neutral atmosphere and ionosphere, but also related topics such as atmospheric wave activities and ionosphere–thermosphere coupling over the polar region.

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