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Atmospheric Measurement Techniques
Discussions

# *Interactive comment on* "First Observations of the McMurdo-South Pole Ionospheric HF Channel" *by* Alex T. Chartier et al.

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Specific Comments

lines 1-2, title: I would suggest highlighting the oblique ionosonde aspect in the title, as ionosondes typically operate in both the MF and HF bands (however, it is recognized that no MF data was available in this demonstration experiment due to technical issues).

We have added the word "oblique" to the title: "First Observations of the McMurdo-South Pole Oblique Ionospheric HF Channel"

Section 1.1: Are there only scientific questions of interest in the Antarctic ionosphere dealing with its variability?



We have added a note on the question of E-F coupling and the scientific potential of the Antarctic ionosphere:

"Another area of current scientific interest is E-F coupling, where forcing applied to the E-layer through neutral dynamics or other drivers appears to map into the F-layer (e.g. Cosgrove and Tsunoda, 2004; Saito et al., 2007). This phenomenon is perhaps easiest to observe at high Magnetic latitudes, where the dip angle is almost vertical and so any E-F coupling should be spatially localized, rather than being separated by hundreds or thousands of kilometers as is the case at middle or low latitudes. In general, the Antarctic ionosphere is of great scientific interest because it provides potentially the best ground base from which to observe deep polar cap dynamics, which may reveal new insights into direct coupling between the Solar wind and Earth's atmosphere. This is because Magnetic fieldlines at very high latitudes are typically "open" rather than closing in the magnetosphere."

A few other examples of the new abilities and questions which could be answered with an oblique ionosonde network in the Antarctic is needed? Contrast benefits/challenges associated with oblique versus vertical observations, etc.

The following text has been added to 1.2: "Oblique sounding has some advantages compared to vertical-mode operation for ionospheric sounding. Principal among these is the ability to observe a location (or locations) in the ionosphere spatially separated from the ground infrastructure. This is important when operating in remote areas such as Antarctica, where the cost of installing and maintaining ground stations is high. Of course, this benefit comes with an associated challenge in interpreting the data, as the signal path through the ionosphere is unknown. Oblique sensing also provides for potentially large networks of observations to be built using a relatively small number of transmitters. That is important because HF transmitters require far more power and larger antennas than receivers, and also often create broadcast licensing issues. Therefore, oblique sounding may be useful in expanding the spatial coverage of ionospheric observations, especially in remote areas."

Section 2.1: Much more detail on the new oblique ionosonde is needed. For example: 1) the unaliased range resolution is given, but this needs to be related to (virtual) height measurements; 2) Doppler resolution is not given, although the Doppler extent is given but at a much later point in the manuscript; 3) what is the range-gate size?; 4) what is the baud length?; 5) is there time averaging and, if so, what is it and how does this relate to the 5-seconds between frequency switches?; 6) how were the frequencies selected for this study? 7) why not use 60 frequencies for a sweep if the instrument was capable of this as stated?; and so on. A succinct and convenient method to present this instrument technical data, or at least most of it, is in a table. It makes for easy comparison to other instruments.

We have added a table (now Table 1) covering all relevant instrument parameters. The choice to use 12 frequencies is now explained: "the smaller number of frequencies allows for longer integration time and therefore increases sensitivity." There is no time averaging beyond the 5-second integration period.

lines 133-134: Please include a description of the methodology used to produce the calibration factors, C_E and C_F, for the E- and F-regions. Please justify the calibration factors due to its importance relating virtual range to virtual height.

An explanation for the calibration factors has been added: "C is a calibration factor used to account for a reduction in the angle of incidence due to signal refraction. Based on empirical comparison with the Jang Bogo VIPIR data, we use a calibration factor of 0.9 in the E-region and 0.75 in the F-region."

line 139: Include a reference to Dynasonde data processing if not already supplied in Bullett et al., 2016. Also, present key parameters of the VIPIR Jang Bogo ionosonde and compare to the new oblique ionosonde. If this new instrument is to complement current ionosonde networks, how it compares to them is of great interest.

References added. Figure 4 provides a direct comparison of the most reliable ionosonde parameter, NmF2, from VIPIR Jang Bogo and our new instrument.



Section 3.1, line 167: Is it possible to show an oblique ionogram from the new ionosonde? However, it is understandable that these ionograms may not 'look' like a typical ionogram due to the lack of sweep frequencies – only 12 were available and only 5 of those received signal.

As the reviewer notes, ionogram-style plots do not add that much information as they have a maximum of five points on them. However, we have added all the daily range-time-intensity and range-time-Doppler plots as supporting information, so interested readers can see what the underlying data looks like.

Section 3.3 and lines 203-209 in Discussion section: I am not sure of the point of the comparison with ground-based TEC measurements and MIDAS. What is unique about TEC being greater than or less than 6 TECU and how does this related to 7.2 MHz? And how/why was 7.2 MHz selected? What is the expected outcome of this comparison?

The following explanation has been added to the text: "MIDAS TEC data at the reflection point are compared against the maximum frequency (7.2 MHz) HF returns in order to determine whether observed density enhancements are correlated across the two datasets. High TEC values at the midpoint between McMurdo and South Pole could be a predictor of maximum-frequency (7.2 MHz) links between the two stations because of the association between NmF2 (and therefore critical frequency) and TEC. A 6 TECU threshold was found to provide a good association with the 7.2 MHz propagation data. Several free parameters escape this comparison, notably variations in signal absorption from the D- and E-layers, scattering by irregularities, variations in the peak height (hmF2) and sub-grid-scale variability missed by the TEC images, so an exact match is not expected."

line 225: Again, how does the "multi-static" configuration of a large network of oblique ionosondes supply new insights into the ionosphere? What would be the benefit of this?

An explanation has been added: “Such a network would dramatically expand the spatial coverage of ionospheric observations while requiring a relatively small number of new transmitters.”

Technical Comments

line 41: Please include, in parenthesis, the standard notation used to express drift velocity values in the ionosphere.

Added: “High temporal cadence is also essential, given that horizontal drift velocities of 5000 km/hour (approximately 1400 m/s) have been reported by Hill (1963).”

lines 53 and 56 (referring to Equations 1 and 2): Reference(s) is needed for equations. Equ. 2 is well know, but still should be referenced; Equ. 1 is not so well know, at least at this time.

Equation 1 is an approximation of the well-known relation FoF2 = MUF/sec theta. A reference has been added to Budden (1961), who provides a thorough description of ionospheric HF propagation.

Section 1.3: Suggest last sentence (lines 75-77) should come after sentence on line 71. A reference is needed for Digital RF.

Text reordered (see also response to other reviewer). Volz et al (2019) added.

line 105: What is a ’V8 vault’? Reference. And/or short description. What was the transmitter equipment housed in?

It is “the” V8 Vault: a plywood enclosure that was buried just below the ice some years ago and has sunk down over the years, with sections of ladder added periodically. The description has been expanded as follows: “The receiver is at South Pole Station, with the electronics housed in the V8 Vault (also home to VLF electronics used by LaBelle et al., 2015), currently located around 30’ under the ice around 1 km from the main base”



The transmitter was housed in a galvanized steel shed manufactured by Northern Tool and assembled by me at McMurdo. Apparently it survived quite well (see Figure 1 attached).

lines 111-112: Please include references for N210 and Motorola AN762-180 transmitter.

These have been added.

line 159: Virtual height and maximum Doppler velocity are parameters which should have been first presented in Section 2.1. Is a virtual height of 2500 km scientifically useful?

These have been added to Section 2.1. The scientific utility of large observing scope is explained there: “The observed ranges and Doppler velocities are tightly clustered within physically realistic parts of the system’s unaliased observing scope,”

If the observing scope were much smaller, it would not be obvious that the system is working properly. As it is, the probability of our data landing at random in the physically-realistic part of the observing scope is small, so we believe the system is working as expected.

line 182: The VIPIR ionosonde does have higher sensitivity, but is not the reason it collects more data compared to the oblique ionosonde mostly due to the fact that fewer sweep frequencies were used by the oblique ionosonde? This is noted in the caption for Figure 4, but not in the main text.

The statement has been modified: “The Jang Bogo VIPIR reports more NmF2 values due to its higher sensitivity, and due to the fact that it covers more frequencies.”

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**Fig. 1.** mcmurdo_electronics_housing