EDGAR: Energy Deposition in the Geomagnetic Cusp Alfvén Resonator

S. M. Hatch,[1] L. J. Baddeley,[2] K. Oksavik,[1] F. Sigernes,[2] J. Moen,[3] J. LaBelle[4]

[1]Birkeland Centre for Space Science, University of Bergen, Norway [2]University Centre in Svalbard, Longyearbyen, Norway
[3]Department of Physics, University of Oslo, Oslo, Norway [4]Dartmouth College, Hanover, NH, USA

I. KEY POINTS

- Models of energy deposition within the ionospheric Alfvén resonator (IAR) have so far not explicitly considered conditions in the geomagnetic cusp.
- EDGAR represents the first attempt to use intra-cusp conditions, as observed by EISCAT and the CAPER-2 sounding rocket, as inputs to an energy deposition model.

II. MOTIVATION

Verkhoglyadova et al. (2018)[1] (hereafter V18) have presented a model for electromagnetic energy deposition (ED) within the IAR via Alfvén waves (**Sec. III**). The ionospheric density and temperature profiles assumed by these authors are based on empirical/statistical models that do not specifically consider the conditions (i.e., enhanced temperatures and densities) that occur within the geomagnetic cusp.

As perhaps the most active site of Alfvén waves over altitudes below ~4000 km,[2,3] the geomagnetic cusp is a primary site of electromagnetic ED. Thus the EDGAR project seeks to answer the following questions:
(i) What are the predicted rates of electromagnetic ED within the overlapping dayside IAR/cusp region when modeled using typical cusp density and temperature profiles as well as electric fields?
(ii) How do these cusp-specific estimates of the rates of electromagnetic ED compare with the theoretical estimates of V18[1]?

These questions will be answered using observations (**Sec. II**) made on January 4, 2019 by UiO all-sky cameras at the Kjell Henriksen Observatory (KHO) in Longyearbyen, the Cusp Alfvén and Plasma Electrodynamics Rocket-2 (CAPER-2) sounding rocket (**Fig.1**) and the EISCAT Svalbard Incoherent Scatter Radar (ESR) (**Fig. 2**). A subset of these observations will be used as inputs for the V18 ED model (**Sec. III**).

II. OBSERVATIONS

The CAPER-2 rocket traveled through red auroral arcs (**Fig. 1a**) caused by a prolonged, negative (approx. -5 nT) *z* component of the interplanetary magnetic field. During the CAPER-2 flight (**Fig. 1b**) the ESR 42-meter dish made complete observations of the electron density (**Fig. 2a**) and electron and ion temperature (**Figs. 2b** and **2c**). The enhanced densities and temperatures that are typical of the cusp begin near 09:30 UT and continue to the end of the period shown in **Fig. 2**.

Observations made by CAPER-2 instrumentation, which are still being processed, include particle measurements and both electric and magnetic field measurements.

FIG. 1: ASC OBSERVATIONS DURING CAPER-2 FLIGHT

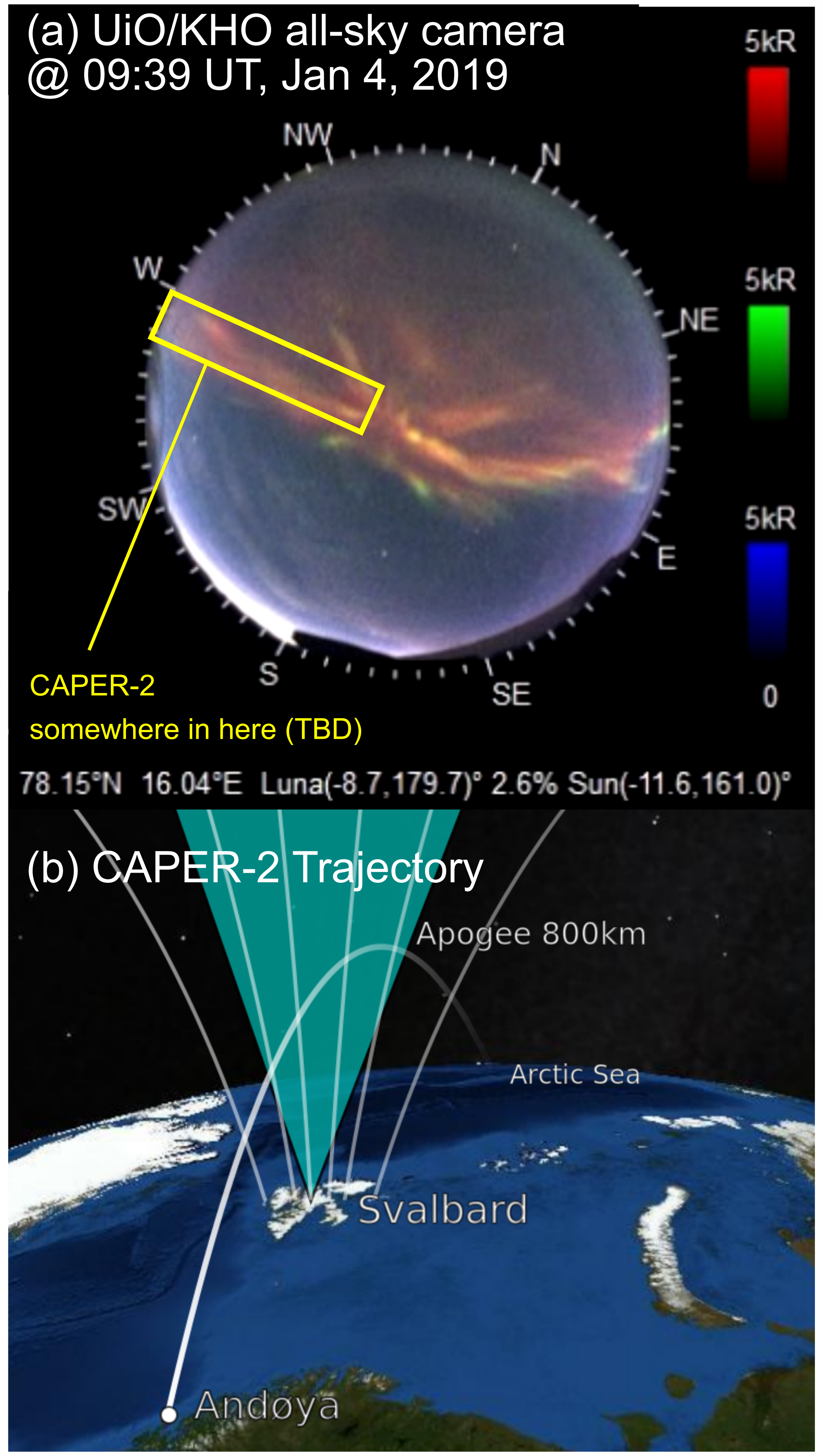

Figure 1. (a) UiO all-sky camera observation of cusp aurora over Svalbard as CAPER-2 flew overhead. (b) Depiction of the CAPER-2 launch trajectory, which was launched at 09:27:58 UT on January 4, 2019 from Andøya Space Centre in Andøya, Norway. CAPER-2 traversed the geomagnetic cusp during an approximately 16-minute flight, flying over ESR around 09:40 UT.

FIG. 2: ESR OBSERVATIONS DURING CAPER-2 FLIGHT

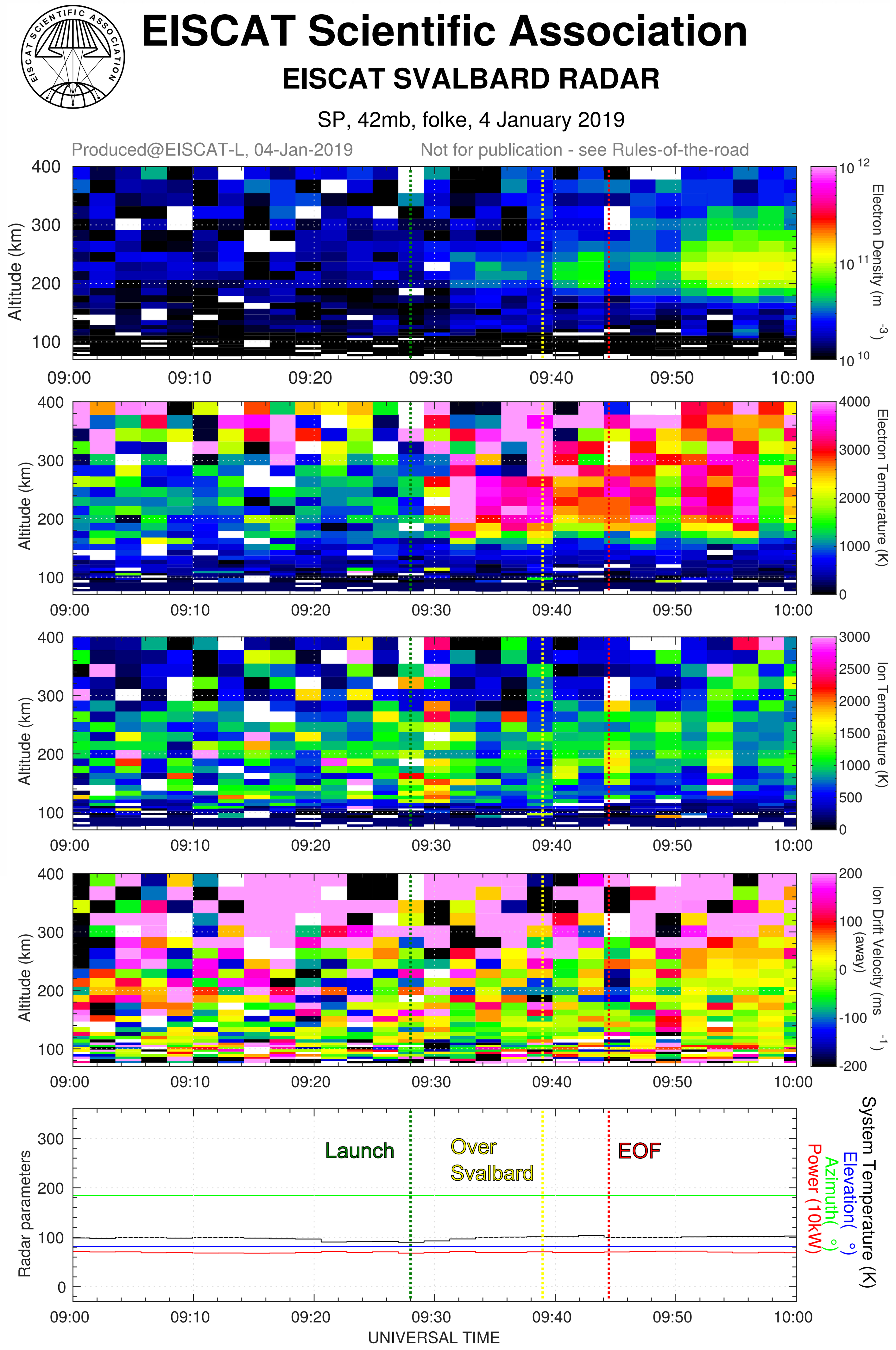

Figure 2. Altitude profiles of (a) electron density, (b) electron temperature, (c) ion temperature, and (d) ion drift velocity observed by the ESR (42-meter dish). CAPER-2 launch (09:27:58 UT), flight over Svalbard (09:39 UT), and end of flight (09:44:20 UT) are respectively indicated by the vertical dotted green, yellow, and red lines.

III. WAVE-MODIFIED CONDUCTIVITIES, V18 ED MODEL

The V18[1] electromagnetic ED model is based on the following expressions for the Pedersen conductivity $\widetilde{\sigma}_P$ and the parallel conductivity $\widetilde{\sigma}_\parallel$.

$$\widetilde{\sigma}_P = \epsilon_0 \sum_\alpha \frac{\nu_\alpha \, \omega_{p\alpha}^2 \left(q_\alpha^2 + 2\omega^2\right)}{q_\alpha^4 + 4\omega^2\nu_\alpha^2}\,; \qquad \widetilde{\sigma}_\parallel = \epsilon_0 \sum_\alpha \frac{\nu_\alpha \omega_{p\alpha}^2}{\omega^2 + \nu_\alpha^2}\,;$$

$$q_\alpha^2 = \nu_\alpha^2 - \omega^2 + \omega_{c\alpha}^2 .$$

The expression for each conductivity explicitly depends on wave frequency ω, which to our knowledge appears in these expressions for the first time in the V18 model.[1] The dependence arises because of the retention of the time derivative in Poynting's theorem. **Fig. 3** illustrates (*based on empirical models, not CAPER-2 or ESR data!*) how these conductivities may change with wave frequency.

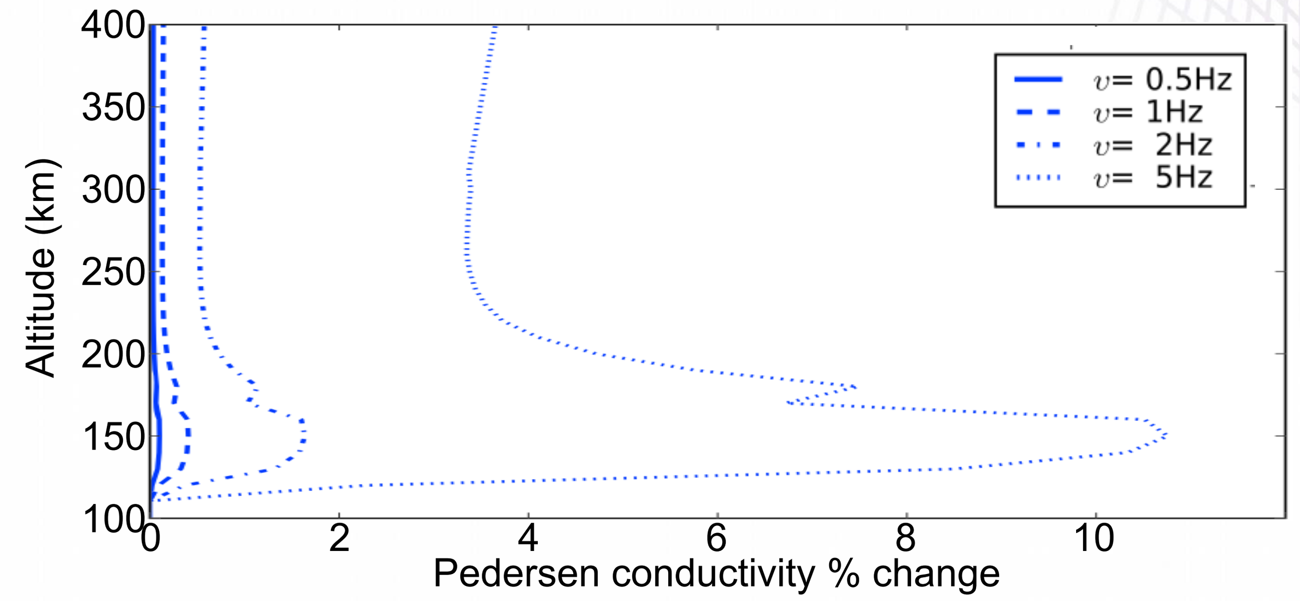

Figure 3. Change in Pedersen conductivity with wave frequency, with density and temperature profiles taken from the the International Reference Ionosphere–12[4] and NRLMSISE-00[5] models. *Note: these profiles are based on empirical models, not CAPER-2 or ESR data!* (Adapted from Fig. 2 of Ref. [1].)

IV. SUMMARY

When CAPER-2 data become available, we will use (i) ESR measurements of electron and ion temperature as well as electron density over altitudes between 100 and 400 km, and (ii) CAPER-2 measurements of electric fields as well as electron density and temperature above 400 km as inputs to the V18[1] model for electromagnetic ED. These results, which will be based on in situ measurements of geomagnetic cusp properties, will be compared with results based on empirical models for ionospheric densities.

REFERENCES

[1] Verkhoglyadova et al. (2018). Semi-analytical estimation of energy deposition [...]. J. Geophys. Res., 123.
[2] Chaston et al. (2007). How important are dispersive Alfvén waves […]. Geophys. Res. Lett., 34.
[3] Hatch et al. (2016). Alfvén wave–driven ionospheric mass outflow […]. J. Geophys. Res., 121(8).
[4] Bilitza et al. (2014). The International Reference Ionosphere–2012 […]. JSWSC, 4(A07).
[5] Picone et al. (2002). NRLMSISE-00 empirical model of the atmos[…]. J. Geophys. Res., 107(A12).

ACKNOWLEDGMENTS

Work at the Birkeland Center for Space Science and the University of Bergen was funded by the Research Council of Norway/CoE under project number 291644, Svalbard Integrated Arctic Earth Observing System – Knowledge Centre, operational phase, and under contract 223252/F50.