Non-stationarity in induction arrows derived from IMAGE data

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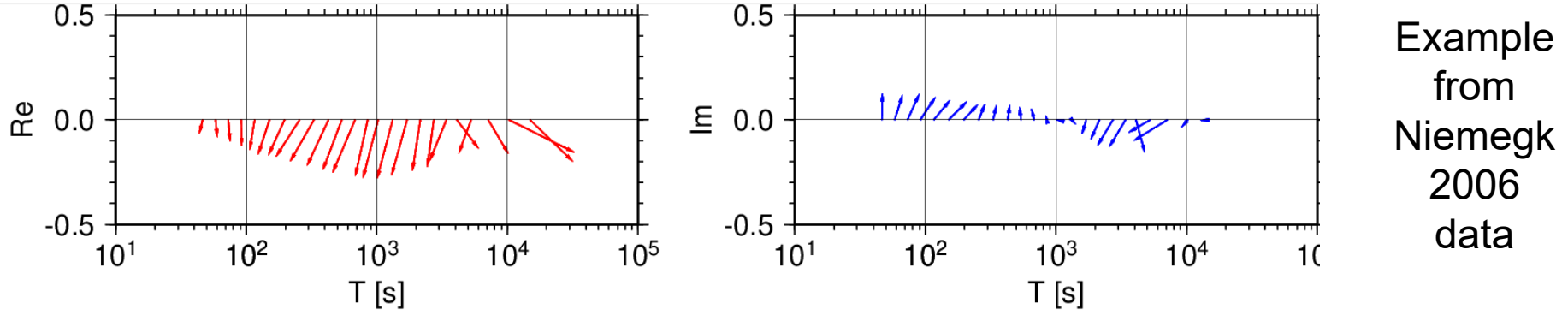
Induction arrows I

- Belong to the domain of passive electromagnetic induction soundings
- Transfer function *(A,B)* between vertical *(Z)* and horizontal *(X,Y)* magnetic components:

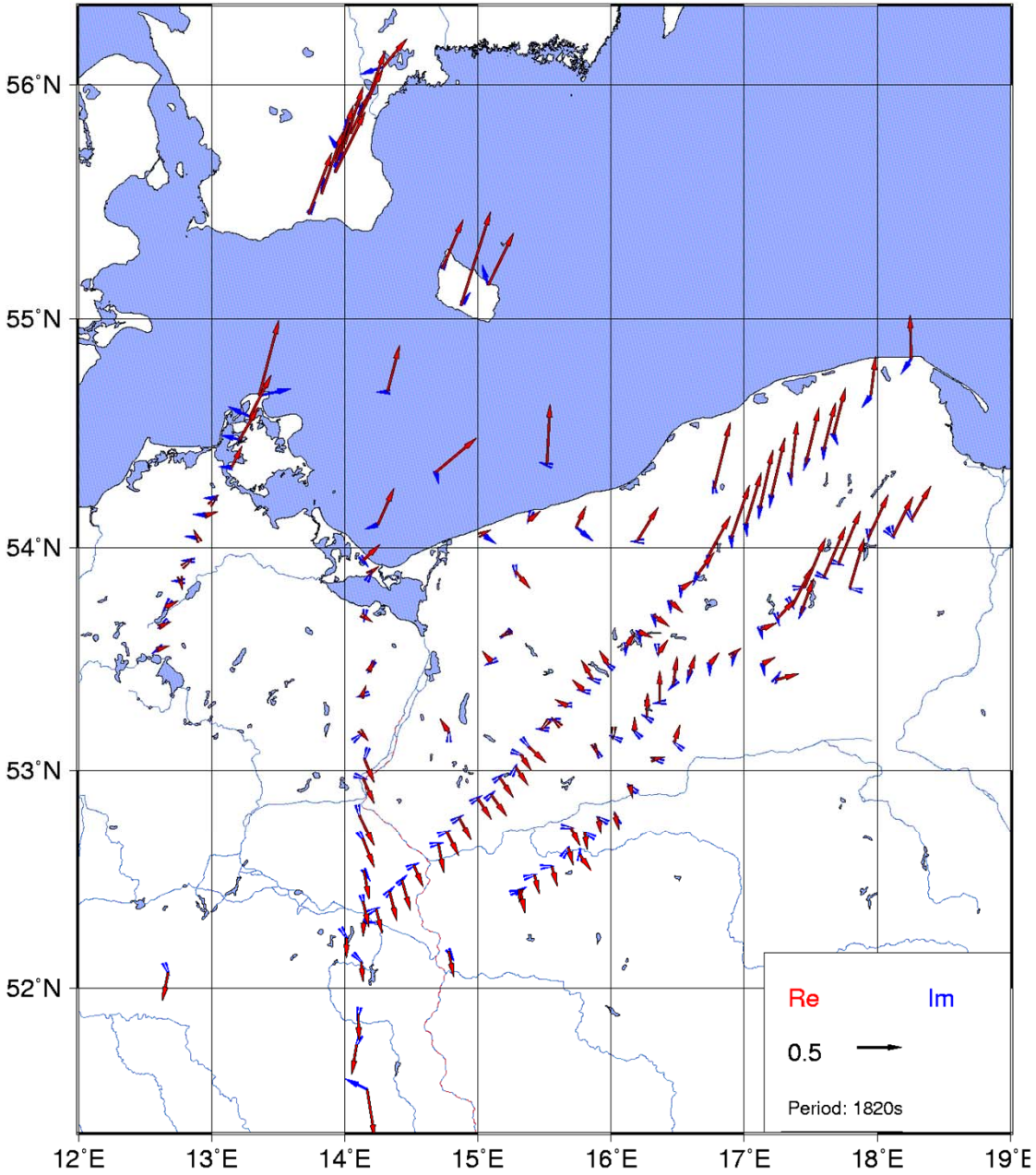
  $Z(\omega) = A\,X(\omega) + B\,Y(\omega)$, ω angular frequency

- Displayed as real and imaginary vector over period *T*

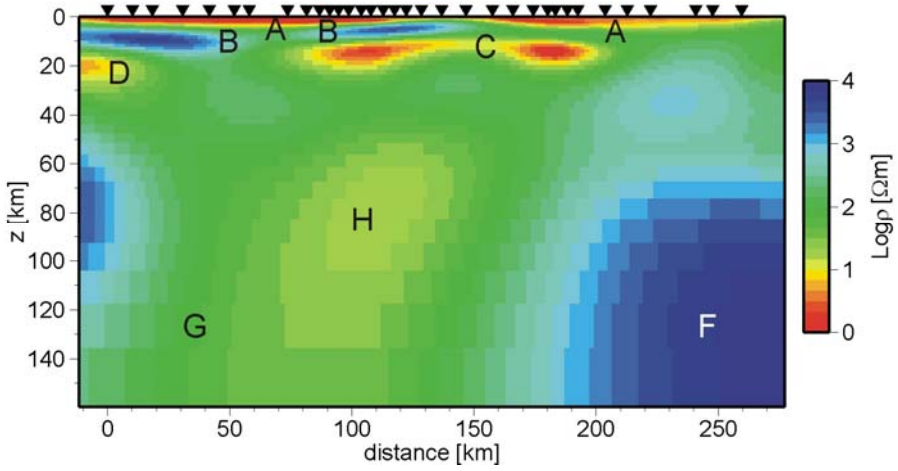


Example from Niemegk 2006 data

Induction arrows II



Real induction arrows of many stations at one period plotted on a map help finding well-conducting structures since they point away from them



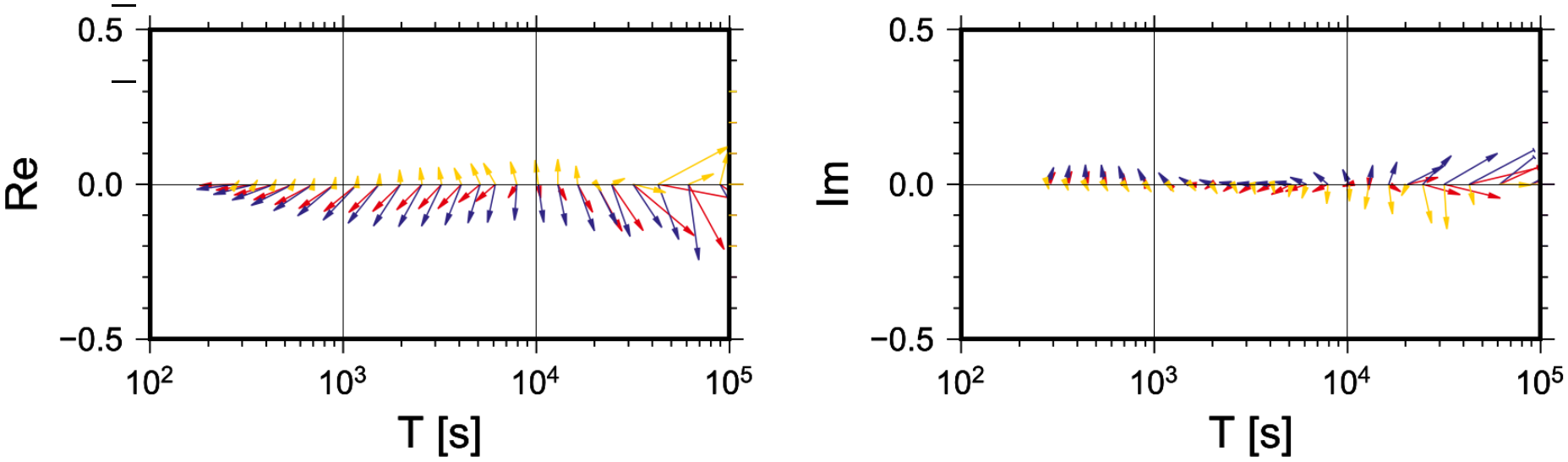
P2 profile model from Ernst et al. 2008 (GRL)

Stationarity

- Induction arrows usually are expected to be constant in time since the subsurface conductivity structure can change only in tectonically active regions
- Monitoring experiments in tectonically active regions show that substantial changes in induction arrows occur and that they are not mainly correlated to tectonic events
- The pattern of changes (e.g., seasonal variations) rather suggest a violation of the plane-wave assumption that is crucial for a functioning of the electromagnetic far-field methods
- Such violations are expected, e.g., beneath localized ionospheric currents like electrojets. However, experience shows that non-stationarity is (to some degree) an ubiquitous phenomenon.

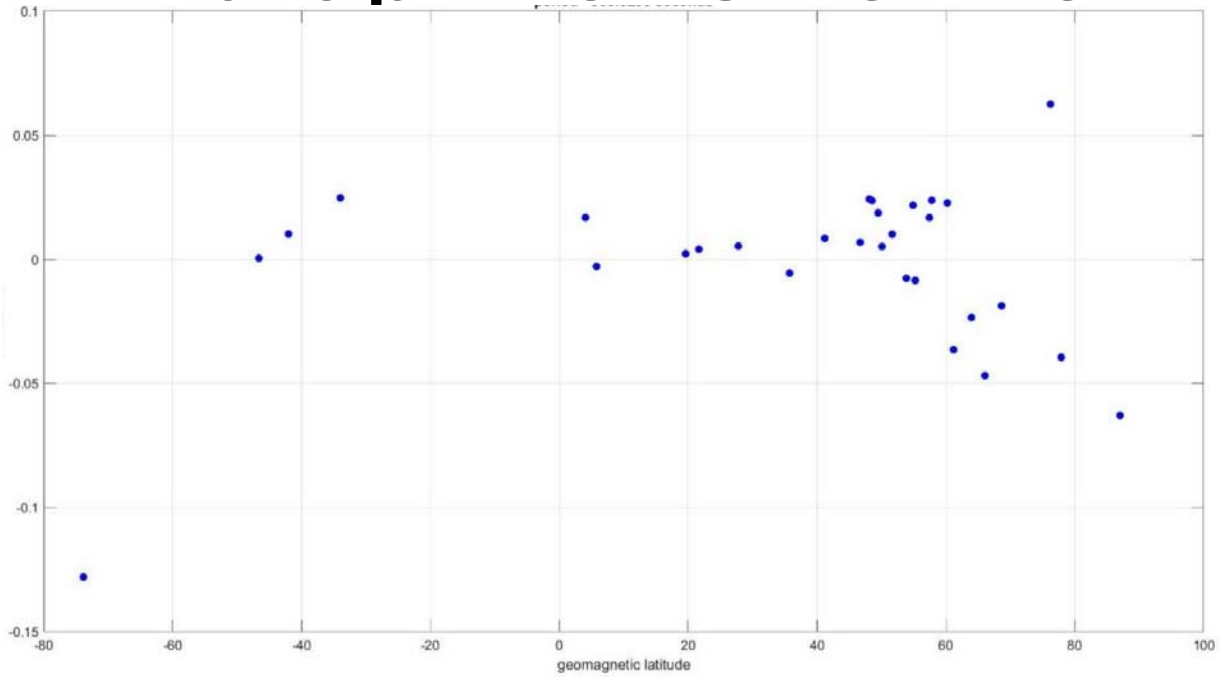
Non-stationarity and latitude

- Low latitudes: *Brändlein D, Lühr H, and Ritter O (2012), Direct penetration of the interplanetary electric field to low geomagnetic latitudes and its effect on magnetotelluric sounding, J Geophys Res, 117, A11314, doi:10.1029/2012JA018008.*
- Mid latitudes: *Araya Vargas J and Ritter O (2016), Source effects in mid-latitude geomagnetic transfer functions, Geophysical Journal International, 204, 606–630, https://doi.org/10.1093/gji/ggv474*



Czech Budkov observatory, winter, summer, difference, picture by A. Bury

Abrupt transition to the high latitudes

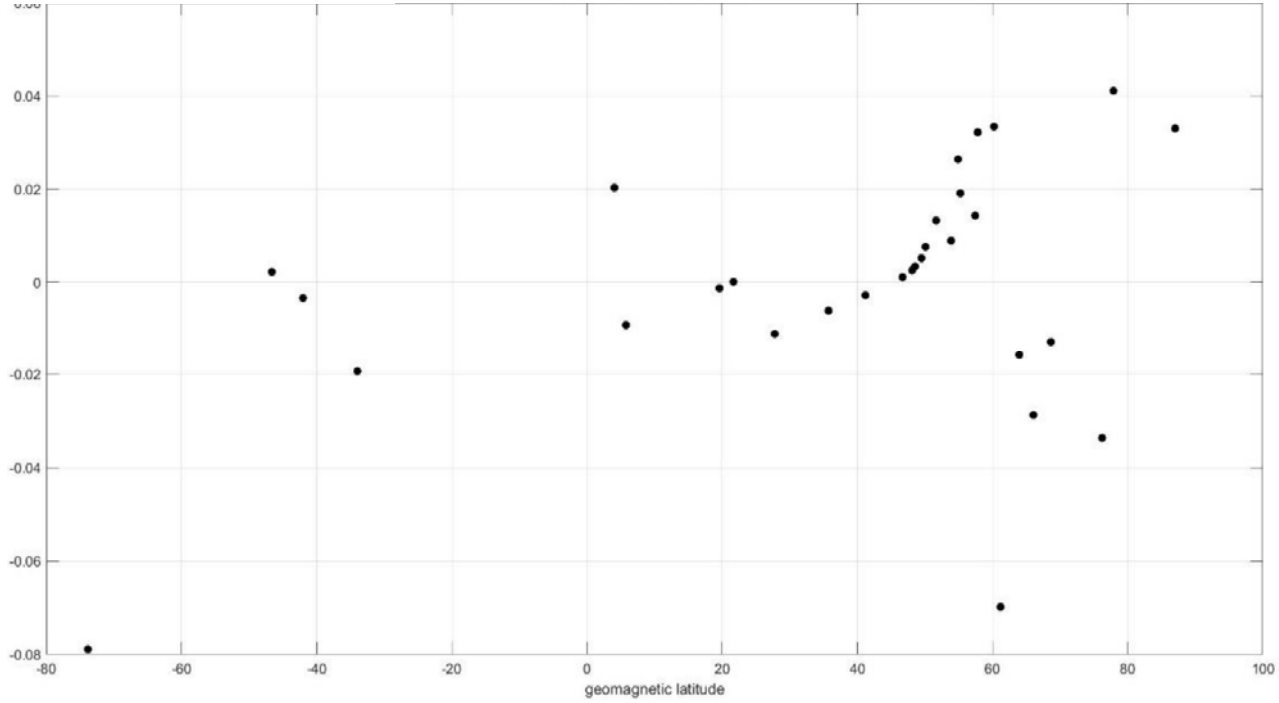


at 60° geomagnetic North

→ Motivation to look at IMAGE data

*Difference between summer and winter induction arrows at 900s (real **North** and **East** component) for data of the 23rd solar cycle from 30 INTERMAGNET observatories versus geomagnetic latitude*

Pictures by A. Bury



For a very preliminary investigation of the IMAGE area ...

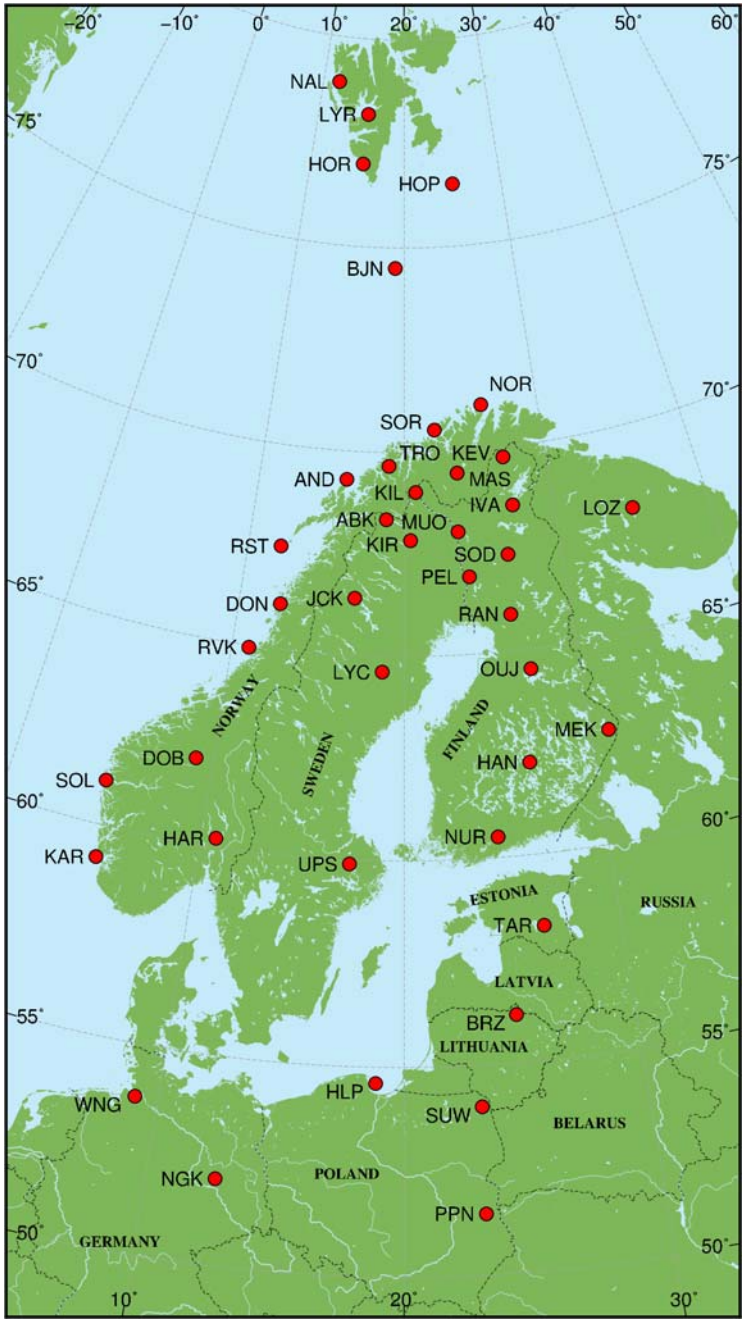
… induction arrows have been calculated

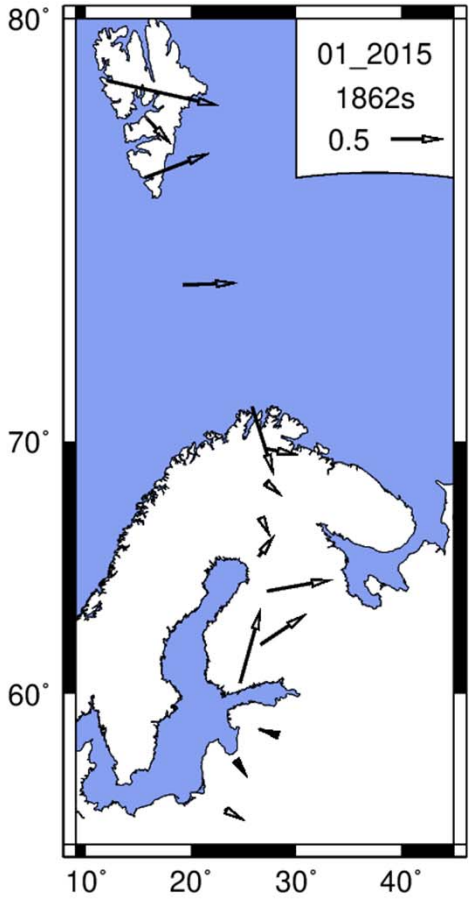
for 48 months from Jan 2015 to Dec 2018

for 15 stations on a N-S chain

from Svalbard over Finland to Poland.

NAL
LYR
HOR
BJN
NOR
KEV
IVA
SOD
RAN
OUJ
HAN
NUR
TAR
BRZ
SUW





The first impression of the result (real induction arrows at ~1800s) is terrifying.

The time changes are such big that one may wonder if induction sounding can be applied at all in the high latitudes.

The problem is in principle known and induction methods are – with some caution – used in Scandinavia and on Svalbard.

Obvious criticism of the appied approach

- Very simple data processing (not statistically robust against outliers and some types of bias)
- No QC of data (some effects may be due to local noise)
- Merely phenomenological (no idea about sources)
- Possibly too rough time and space resolution to catch some structural features well

Wanted (instead of an outlook)

- Induction arrows from a more sophisticated processing (e.g. *Egbert 1997 [GJI]* which provides additional information on source structure)
- Better resolution in time (but trade-off with statistical needs of data amount in transfer function estimation) and space (include more stations)
- Some quantity to correlate the time changes with
- Some detailed idea on source mechanisms, i.e., ionospheric currents – when and where to expect them?

Thank you for attention.

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