

Relating magnetic field disturbances on ground and in space

Downward propagation of the AMPS model magnetic field

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Introduction to The Average Magnetic field and Polar current System (AMPS) model

A statistical model of ionospheric magnetic field disturbances based on satellite magnetometers

Calculating AMPS model magnetic field on ground - the simplest approach

Comparing with data

Time-scale dependence of solar wind based regression models

Effects of induced currents

The AMPS model

Empirical model based on magnetic field measurements from Swarm and CHAMP

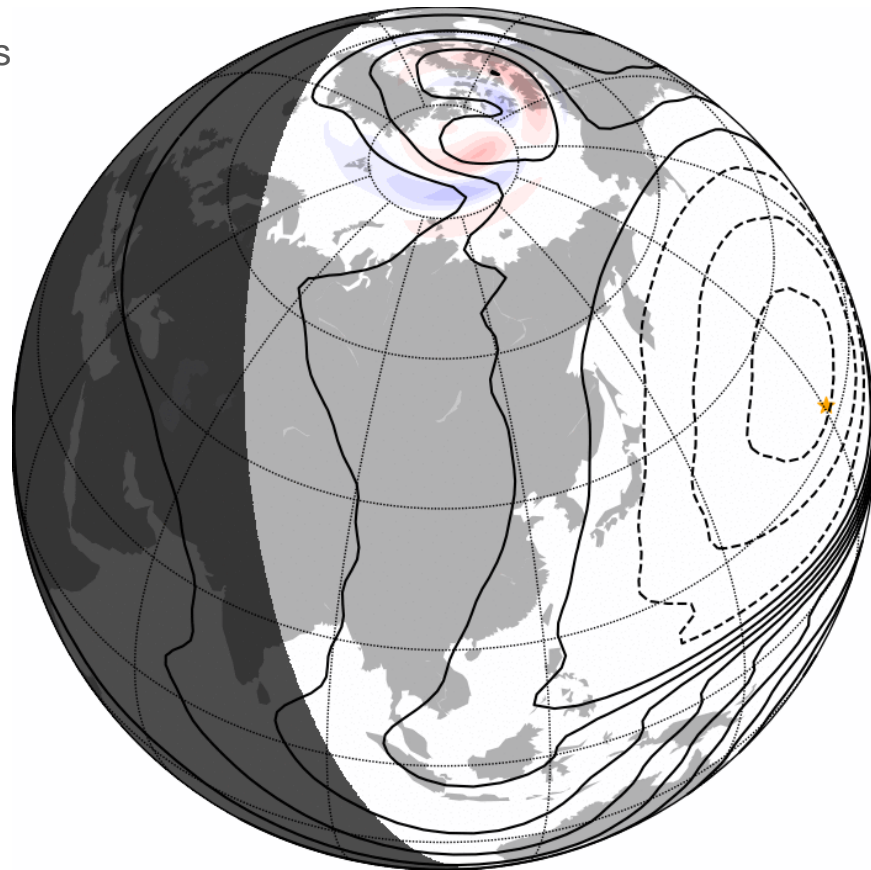
Currents and fields continuous functions of solar wind speed, IMF, dipole til, and F10.7

Global:

Gives both polar and low-latitude currents. No imposed symmetries between hemispheres

Available:

Published as *Swarm* data product, open-source Python forward code on GitHub, Web visualization at <https://birkeland.uib.no/data/amps>



Where to get it

Extensive Python forward code on Github
github.com/klaundal/pyAMPS

Branches: master • New pull request

Find File Clone or download

klaundal version bump

Latest commit bc388ea on 6 May

docs	minor update	last year
pyamps	version bump	4 months ago
tests	added coefficient file from ftp + changed test values	4 months ago
.coveragerc	ready for CI	2 years ago
.gitignore	remove .DS_Store from repo	2 years ago
.travis.yml	reversed changes to setup.cfg, and changed .travis.yml instead	6 months ago
CHANGELOG.rst	Update CHANGELOG.rst	11 months ago
LICENSE	updated name in license	2 years ago
MANIFEST.in	Initial CI settings	2 years ago
README.rst	updated readme	4 months ago
appveyor.yml	and again	last year
requirements.txt	fix error in requirements	last year
setup.cfg	added coefficient file to setup.cfg	4 months ago
setup.py	initial setup configuration	2 years ago

README.rst

Overview

docs • getting • pyip package • 1.0.1 • DOI: 10.5281/zenodo.1161931

Python interface for the Average Magnetic field and Polar current System (AMPS) model.

The AMPS model is an empirical model of the ionospheric current system and associated magnetic field. The model magnetic field and currents are continuous functions of solar wind velocity, the interplanetary magnetic field, the tilt of the Earth's dipole magnetic field with respect to the Sun, and the 10.7 cm solar radio flux index F10.7. Given these parameters, model values of the ionospheric magnetic field can be calculated anywhere in space, and, with certain assumptions, on ground. The full current system, horizontal + field-aligned, are defined everywhere in the polar regions. The model is based on magnetic field measurements from the low Earth orbiting Swarm and CHAMP satellites.

pyAMPS can be used to calculate and plot average magnetic field and current parameters on a grid. The parameters that are available for calculation/plotting are:

- field aligned current (scalar)
- divergence-free current function (scalar)
- divergence-free part of horizontal current (vector)
- curl-free part of horizontal current (vector)
- total horizontal current (vector)
- eastward or northward ground perturbation corresponding to equivalent current (scalars)

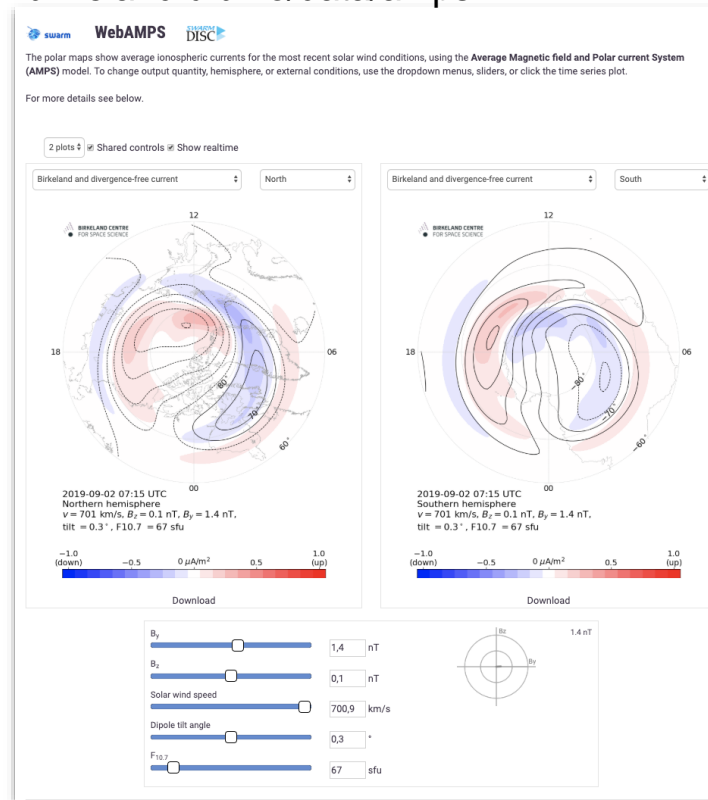
For questions and comments, please contact karl.laundal@ift.uib.no

Installation

Using pip:

```
pip install pyamps
```

Web visualization at
birkeland.uib.no/data/amps



$$\Delta \mathbf{B} = \Delta \mathbf{B}^{\text{pol}} + \Delta \mathbf{B}^{\text{tor}} = -\nabla V + \mathbf{r} \times \nabla T$$

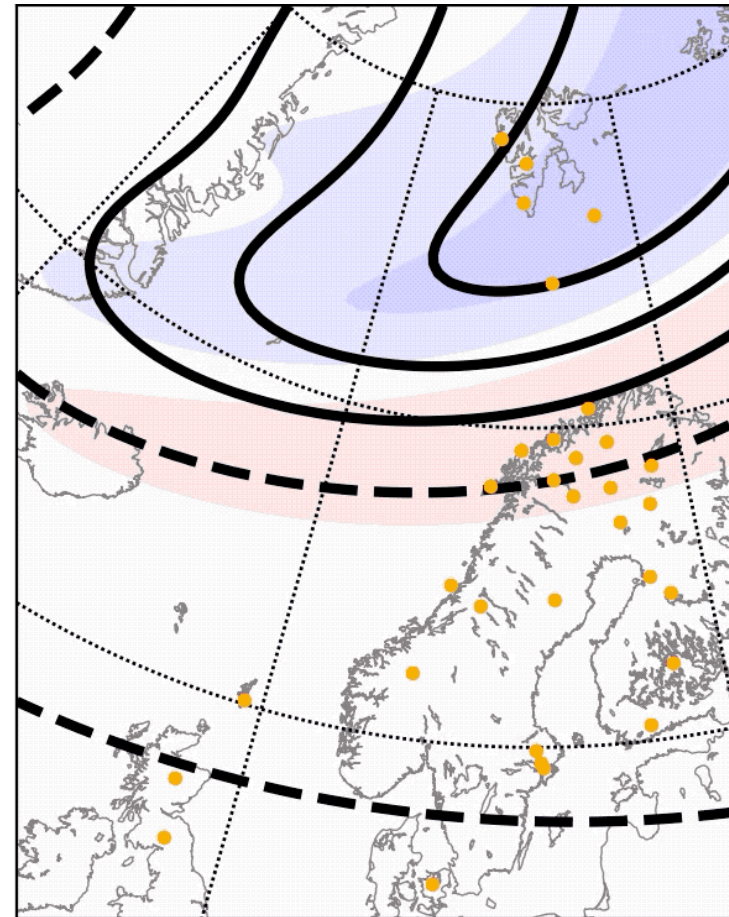
V and T are represented with spherical harmonics:

$$V(\lambda_q, \phi_{\text{mlt}}, h) = R_E \sum_{n,m} \left(\frac{R_E}{R_E + h} \right)^{n+1} P_n^m(\sin \lambda_q) [g_n^m \cos(m\phi_{\text{mlt}}) + h_n^m \sin(m\phi_{\text{mlt}})].$$

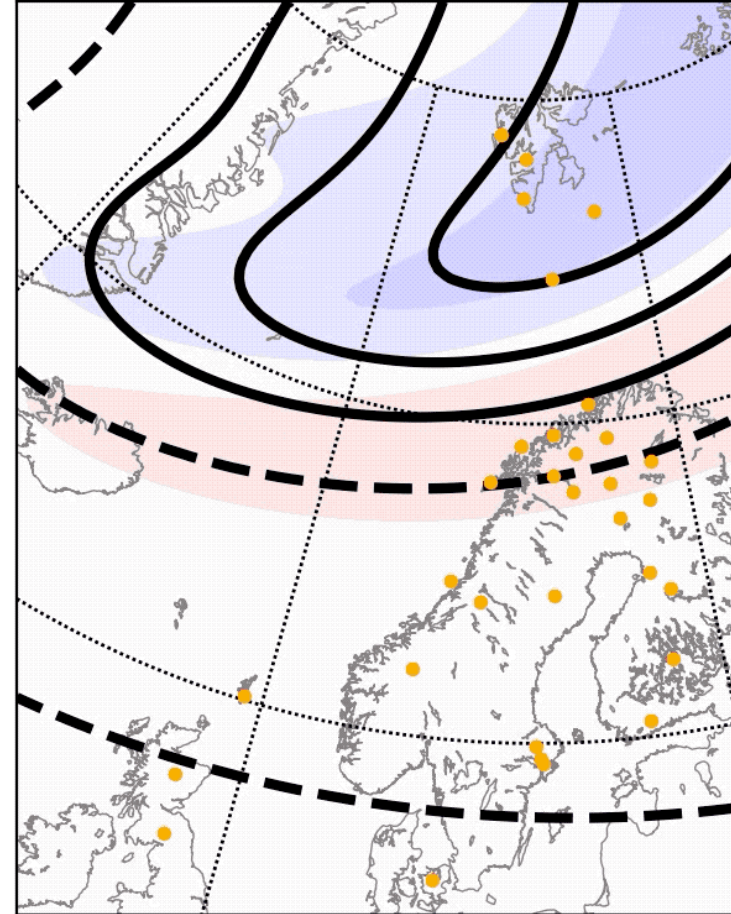
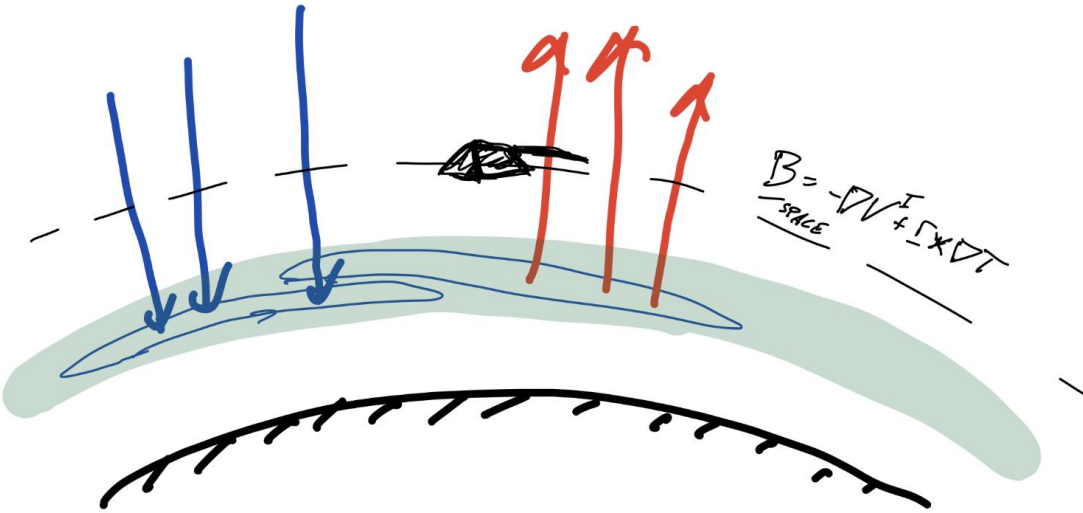
$$T(\lambda_m, \phi_{\text{mlt}}) = \sum_{n,m} P_n^m(\sin \lambda_m) [\psi_n^m \cos(m\phi_{\text{mlt}}) + \eta_n^m \sin(m\phi_{\text{mlt}})],$$

Each SH coefficient is function of external parameters:

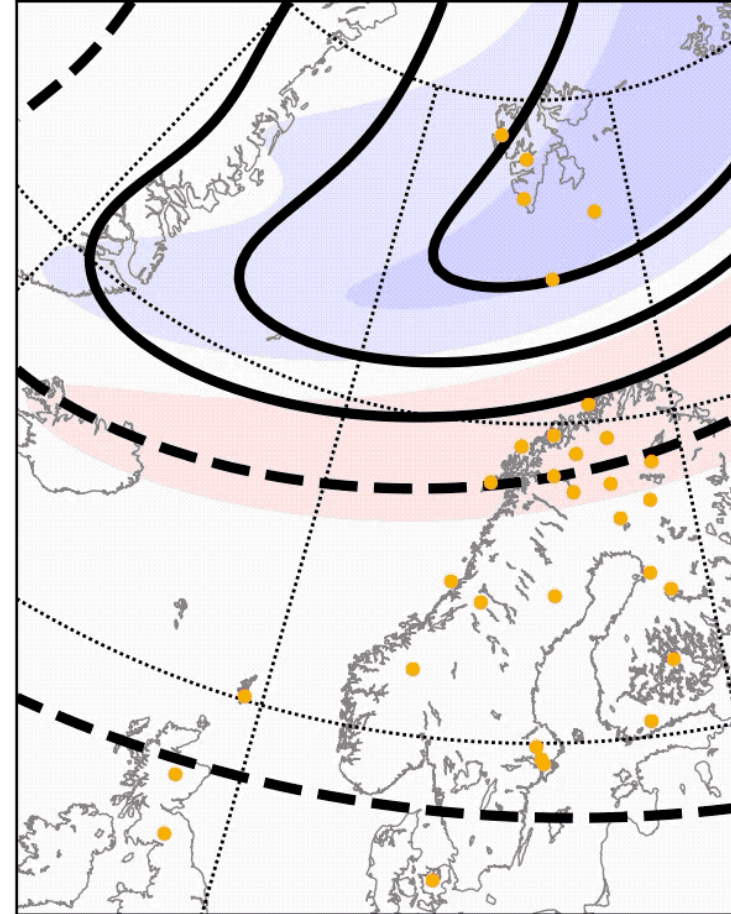
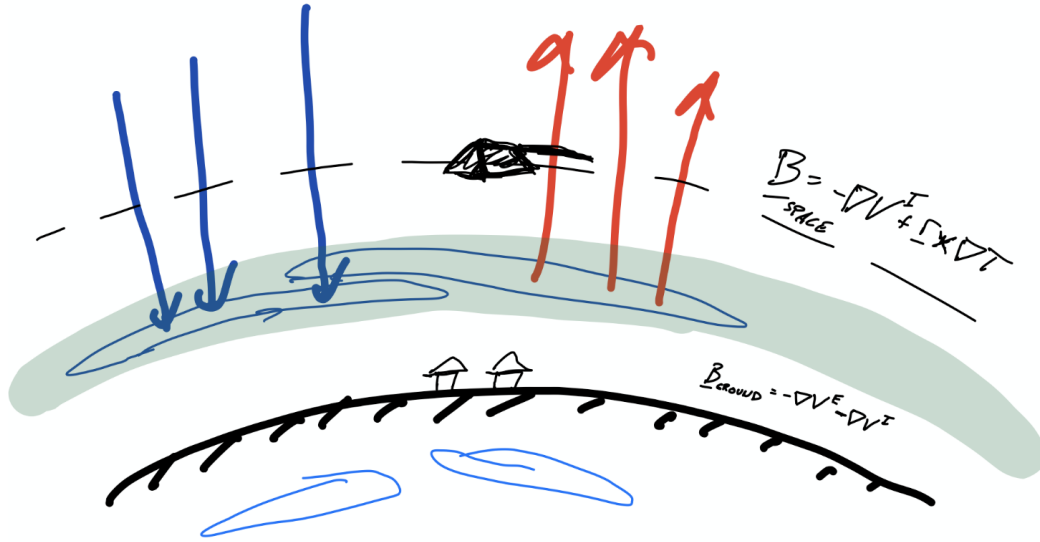
$$\begin{aligned} g_n^m = & g_{n1}^m + g_{n2}^m \sin \theta_c + g_{n3}^m \cos \theta_c + g_{n4}^m \epsilon + g_{n5}^m \epsilon \sin \theta_c + g_{n6}^m \epsilon \cos \theta_c + \\ & g_{n7}^m \beta + g_{n8}^m \beta \sin \theta_c + g_{n9}^m \beta \cos \theta_c + g_{n10}^m \beta \epsilon + g_{n11}^m \beta \epsilon \sin \theta_c + g_{n12}^m \beta \epsilon \cos \theta_c + \\ & g_{n13}^m \tau + g_{n14}^m \tau \sin \theta_c + g_{n15}^m \tau \cos \theta_c + g_{n16}^m \beta \tau + g_{n17}^m \beta \tau \sin \theta_c + g_{n18}^m \beta \tau \cos \theta_c + \\ & g_{n19}^m F_{10.7}. \end{aligned}$$



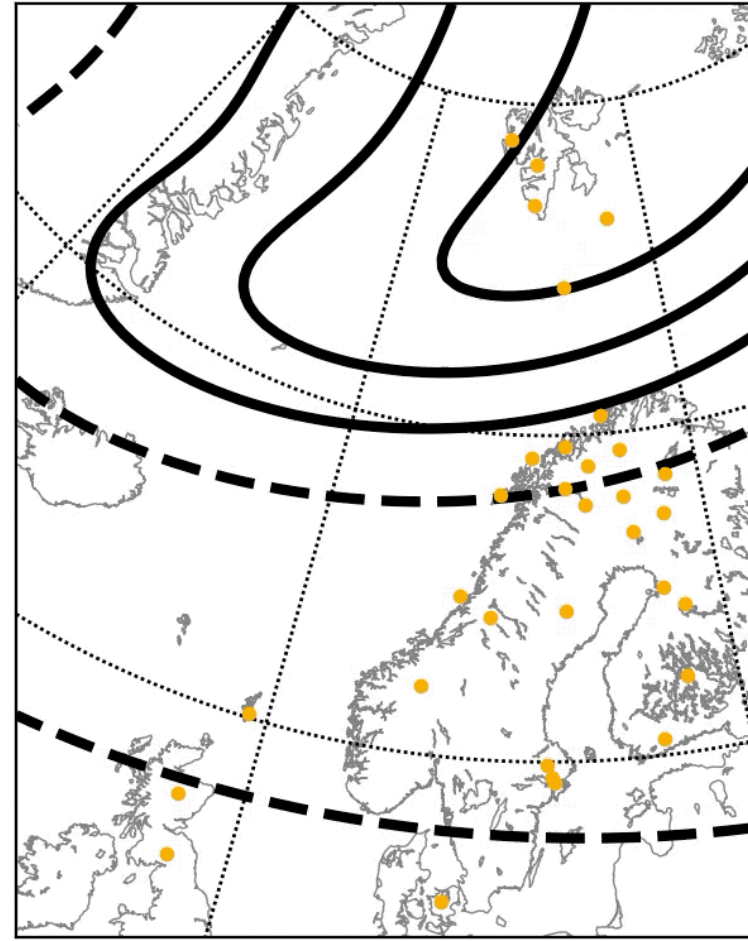
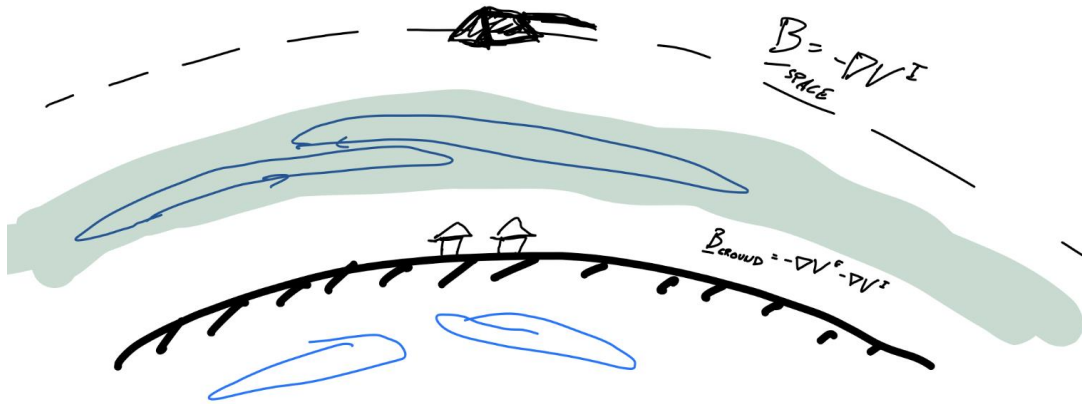
Relating magnetic field and currents



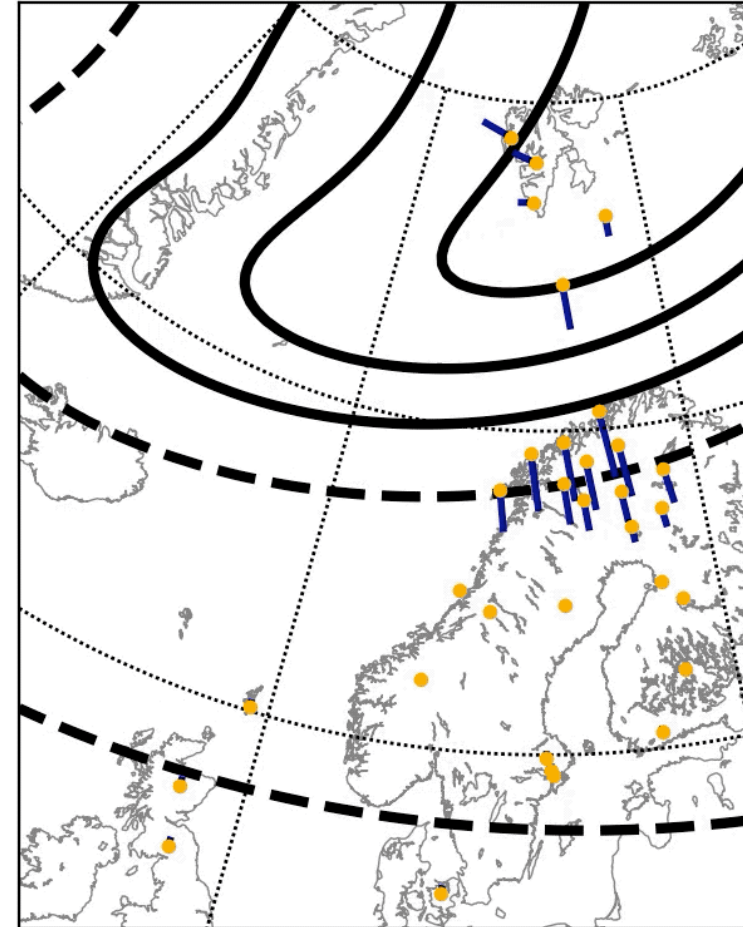
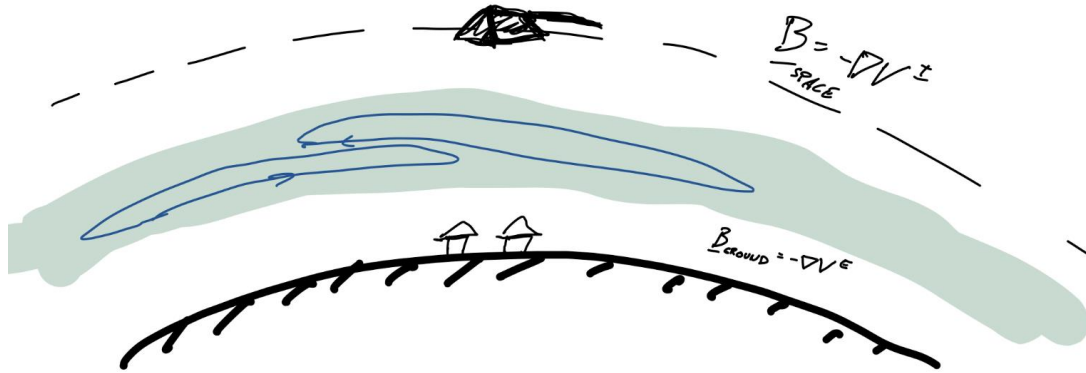
Relating magnetic field and currents



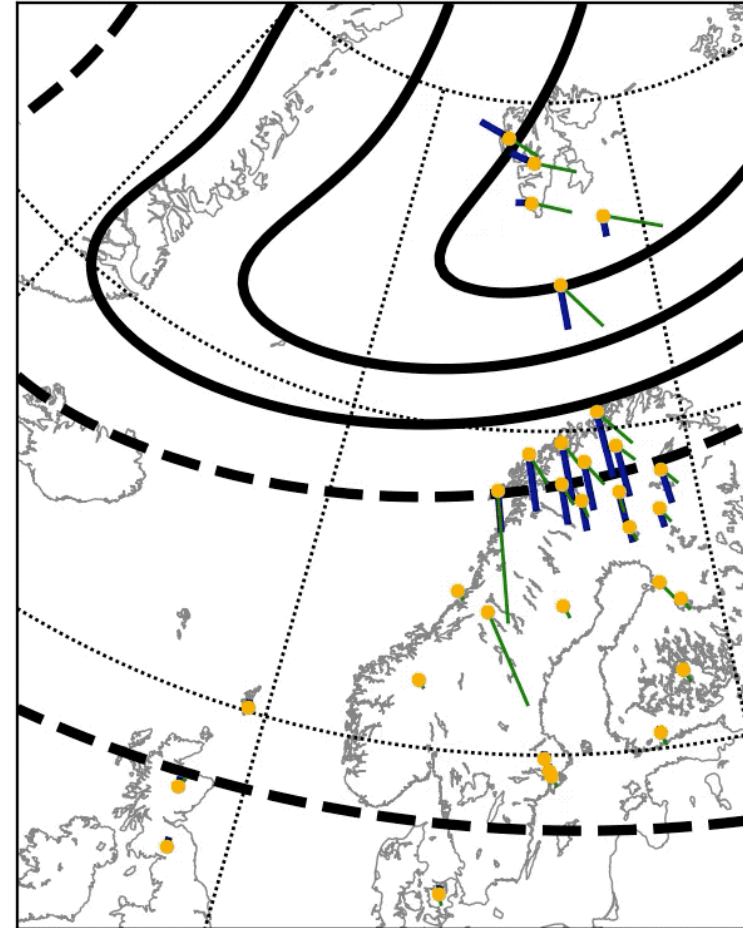
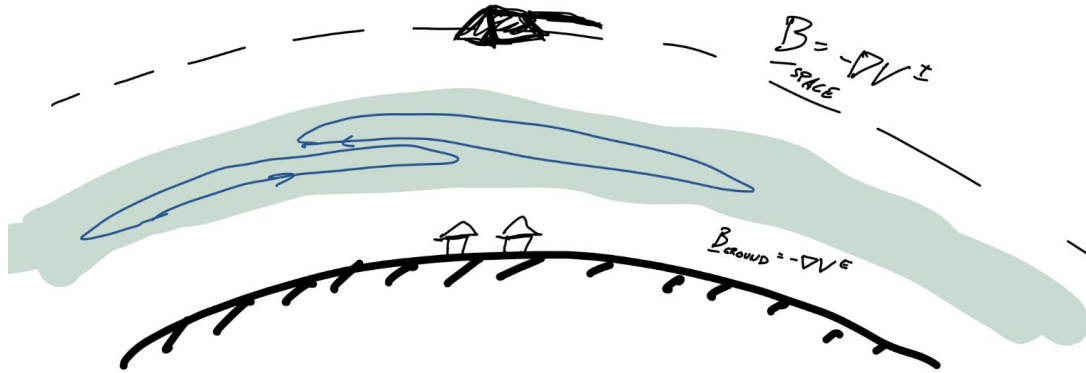
Relating field in space and ground



Relating field in space and ground



Relating field in space and ground

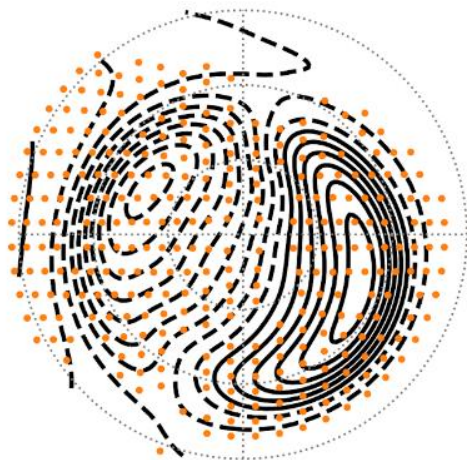


Dependence on current sheet height

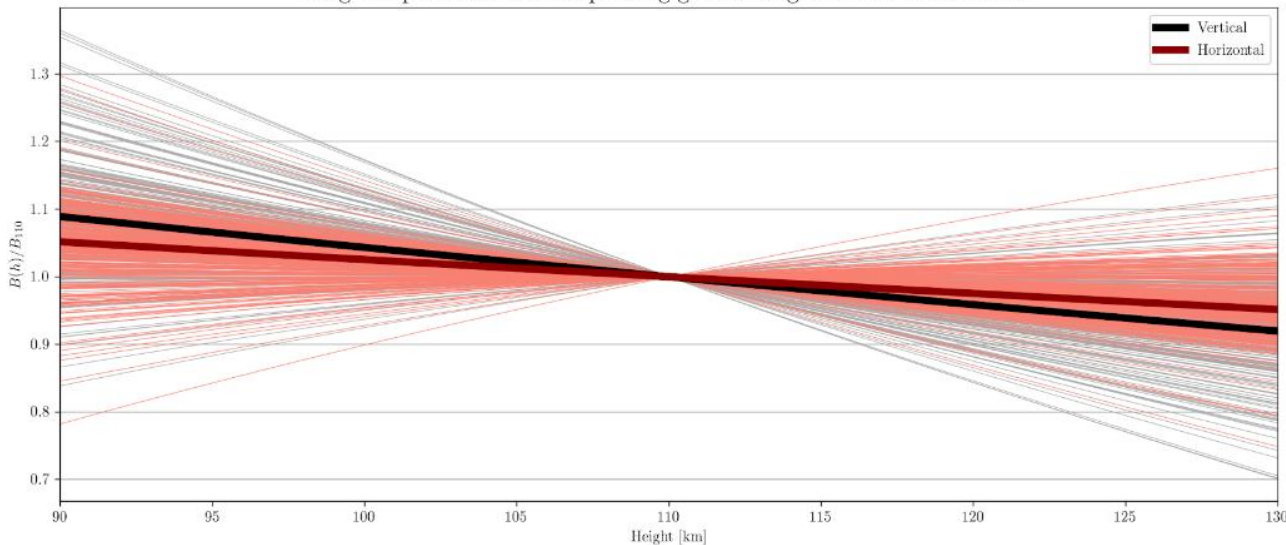
$$B_\phi = -\frac{1}{\cos \lambda} \sum_{n,m} \left(\frac{R_E}{R_E + h_R} \right)^{2n+1} \frac{n+1}{n} P_n^m(\sin \lambda_q) m [g_n^m \sin(m\phi_{\text{mlt}}) - h_n^m \cos(m\phi_{\text{mlt}})]$$

$$B_{\lambda_q} = \sum_{n,m} \left(\frac{R_E}{R_E + h_R} \right)^{2n+1} \frac{n+1}{n} \frac{dP_n^m(\sin \lambda_q)}{d\lambda_q} [g_n^m \cos(m\phi_{\text{mlt}}) + h_n^m \sin(m\phi_{\text{mlt}})]$$

$$B_r = \sum_{n,m} \left(\frac{R_E}{R_E + h_R} \right)^{2n+1} (n+1) P_n^m(\sin \lambda_q) [g_n^m \cos(m\phi_{\text{mlt}}) + h_n^m \sin(m\phi_{\text{mlt}})]$$



Height dependence of corresponding ground magnetic field disturbances





Summary so far:

The AMPS model describes the magnetic field in space as function of dipole tilt and solar wind parameters

Downward propagation to the ground can be performed by “reflection” across a spherical current sheet

Varying the current sheet height within realistic values changes the ground field by about 10%

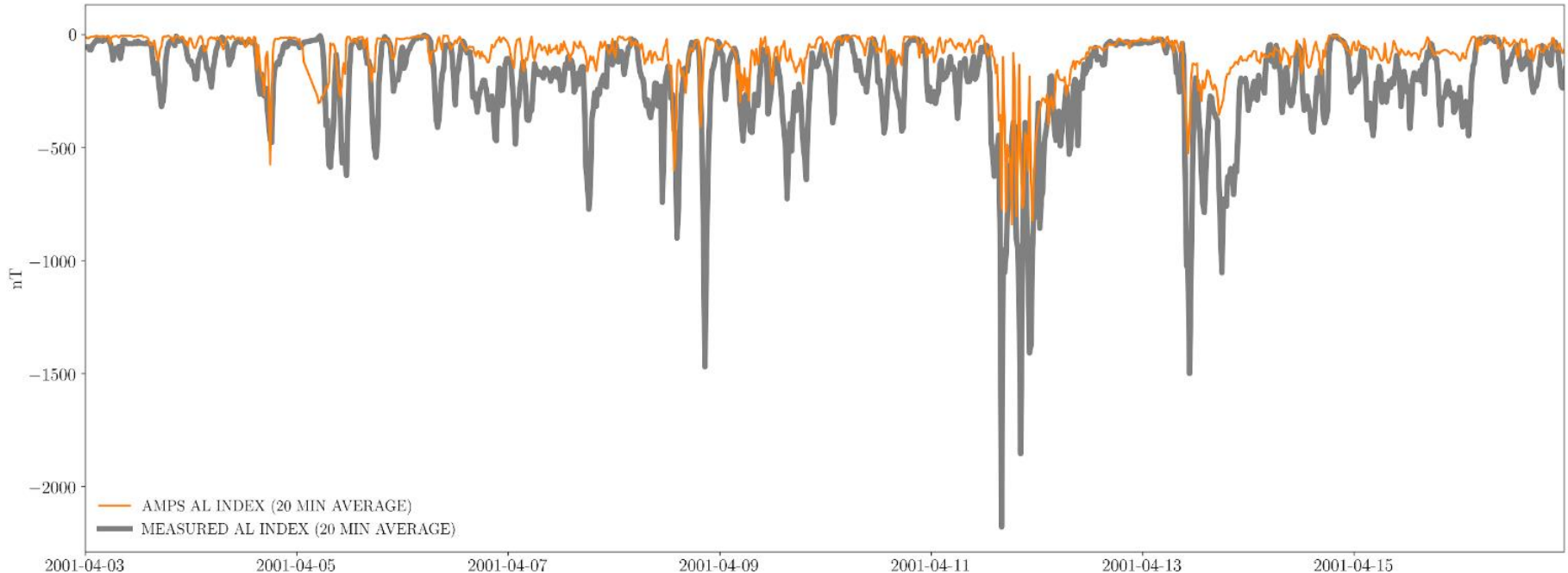
Next:

Quantitative comparison between model and measured AL index

AL model comparison

We calculate AMPS model magnetic field at all AL station locations, and derive synthetic AL index.

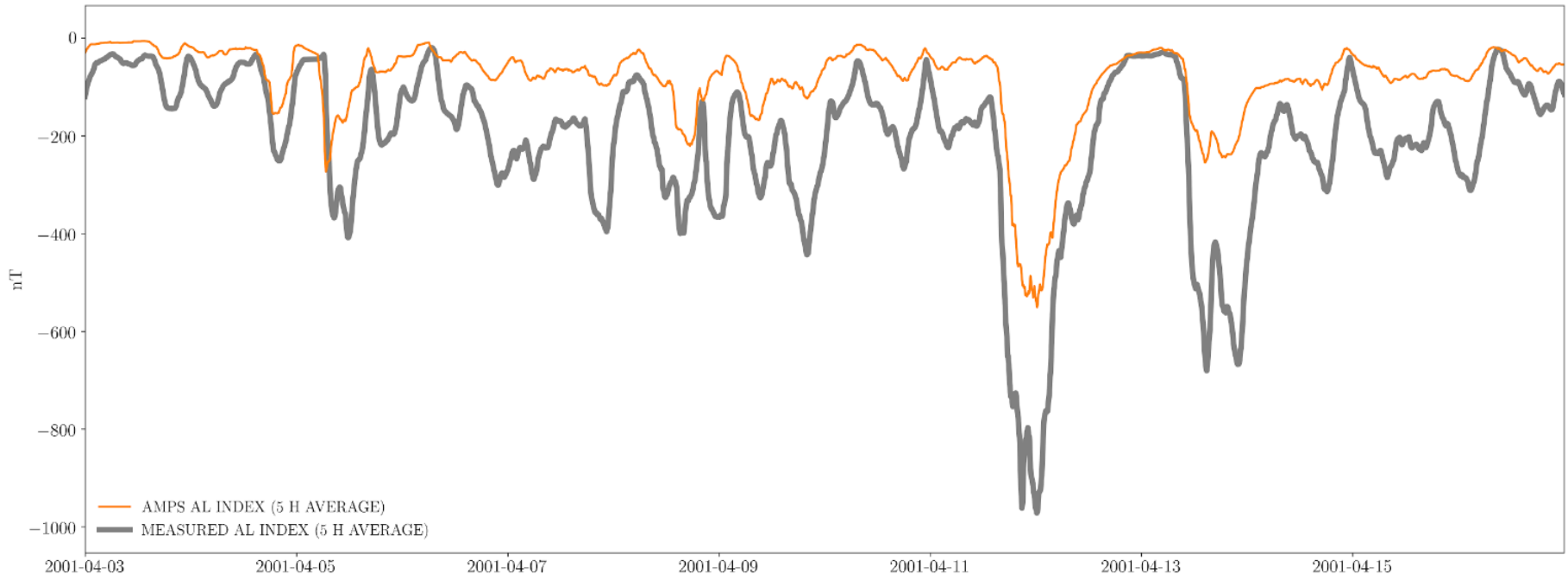
Here is an example of a time series:



AL model comparison

We calculate AMPS model magnetic field at all AL station locations, and derive synthetic AL index.

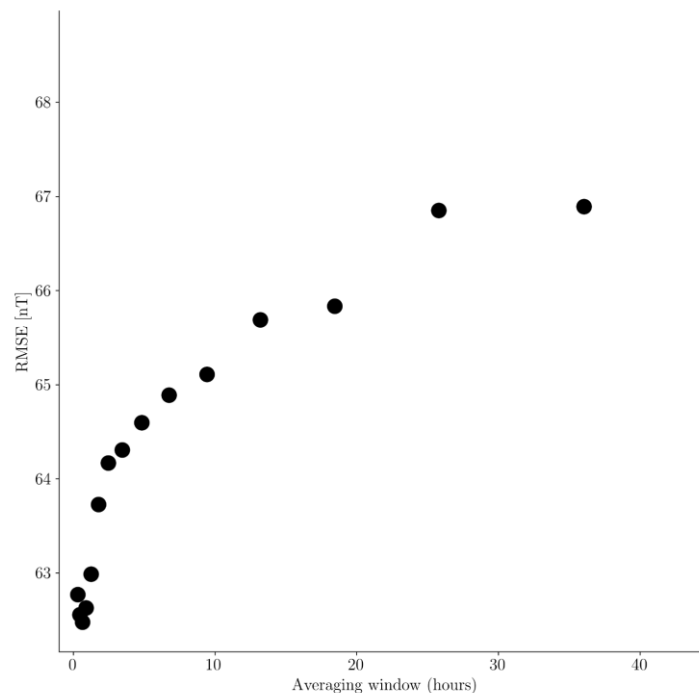
Here is an example of a time series:



AL model comparison

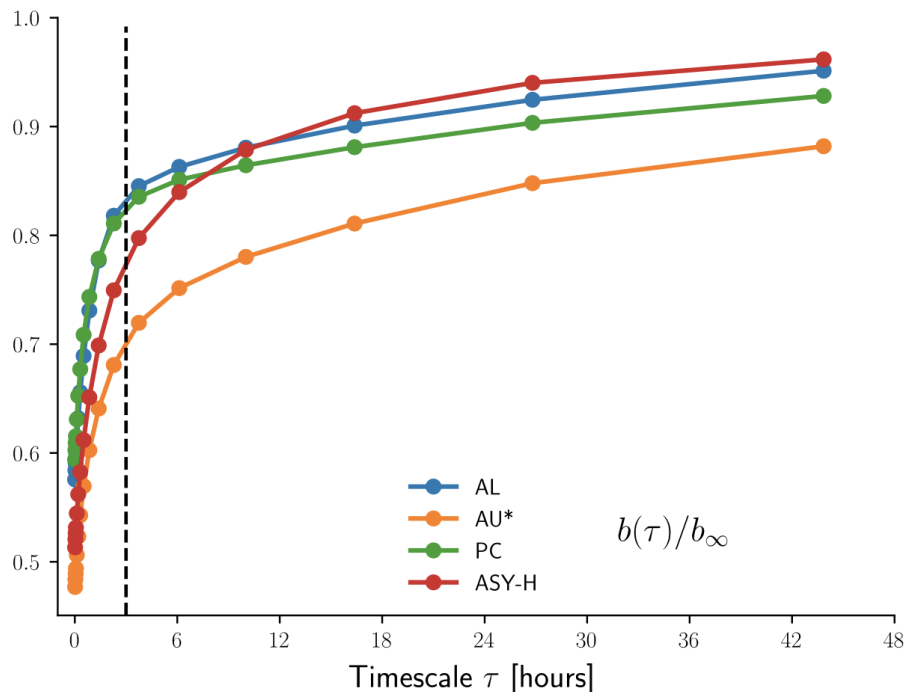
We calculate AMPS model magnetic field at all AL station locations, and derive synthetic AL index.

The misfit increases with time scale:

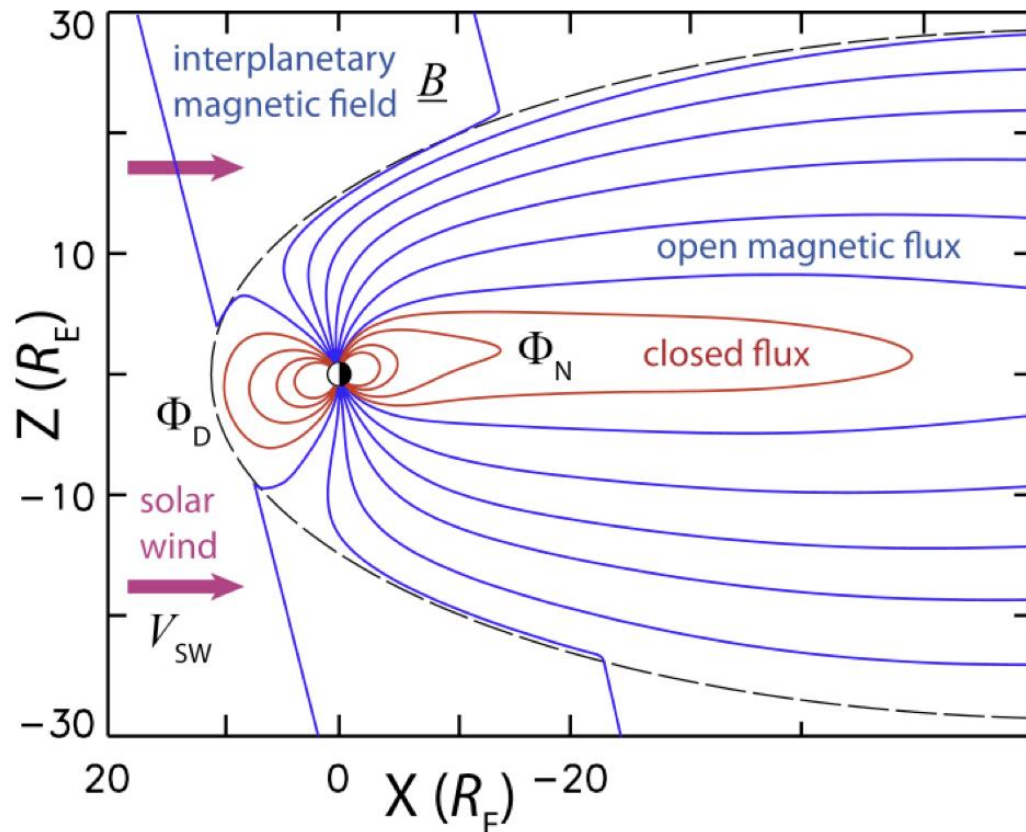


Consider a model on the form $Y = a + b * E$ (**Newell's coupling function**)

The least squares estimate of b depends on the averaging window used on Y and E



The two-step response to changes in the solar wind



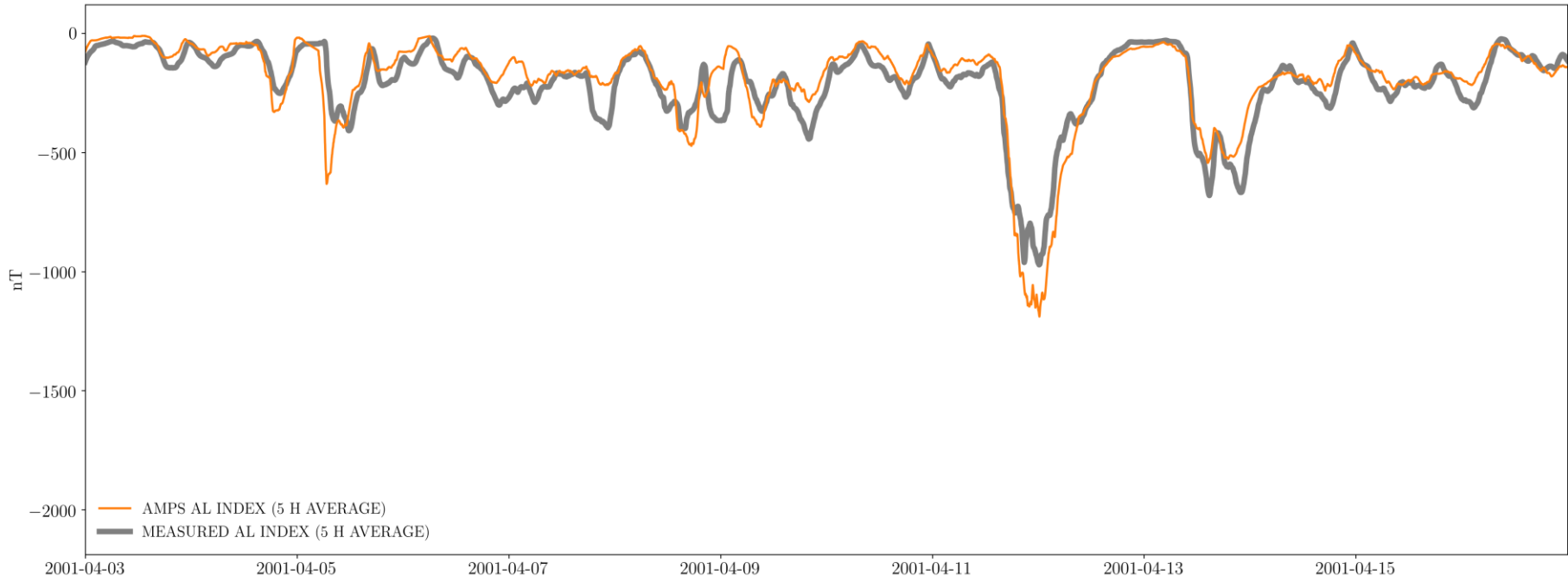
$\Phi_D(\sim E)$ and Φ_N are
 \cong Uncorrelated on short time scales
 \equiv Identical on long time scales

With high time resolution Φ_N signal will be noise and the model scaled only to Φ_D

With time averaging the model will be scaled to both Φ_D and Φ_N

AL model comparison

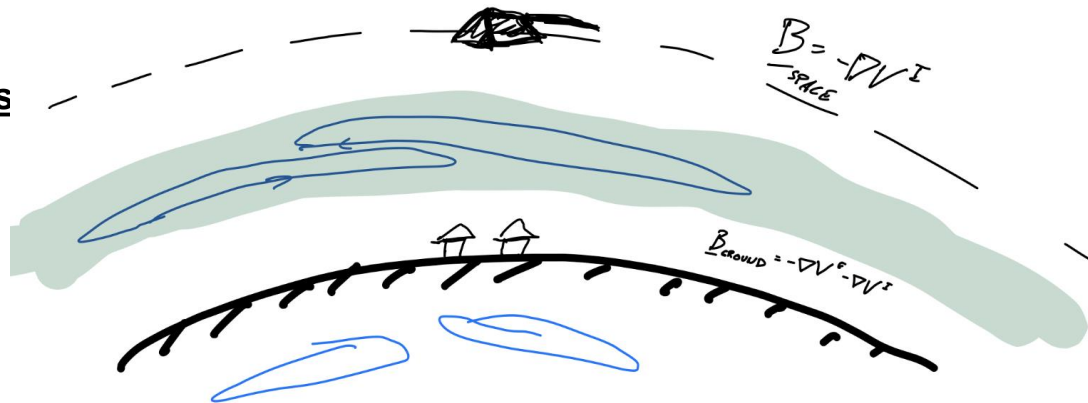
Data model comparison with time-scale dependent scale factor



The AMPS model can be used to describe directly driven variations in magnetic field disturbances on ground.

Two important potential improvements

- 1) Include substorm parameter(s),
Which one? How?
- 2) Account for induced currents
How? Include ground mags?



How to measure the horizontal current

