

Comparing global 1d and 3d ground conductivity for GIC forecasts

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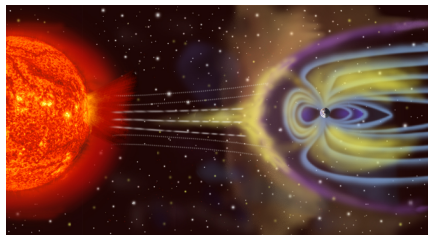
23.10.2019



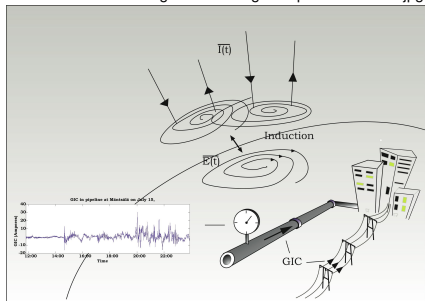
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Overview

1. Simulate near-Earth space and ionosphere
 - Input: solar wind density, velocity, temperature, magnetic field
 - Output: Electric currents in magnetosphere, ionosphere and dipole FAC
2. Derive $dB/(dt)$ on ground
 - Input: Electric currents above ground
 - Output: External(ly produced d)B on ground
3. Simulate induction in ground using 1d and 3d conductivities
 - Input: External B, local 1d or global 3d ground conductivity
 - Output: Total B, E on ground



commons.wikimedia.org/wiki/File:Magnetosphere_rendition.jpg

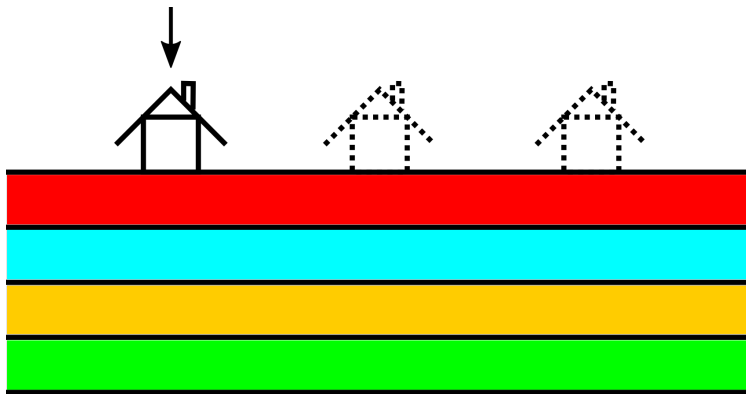


en.wikipedia.org/wiki/File:GIC-generation.jpg



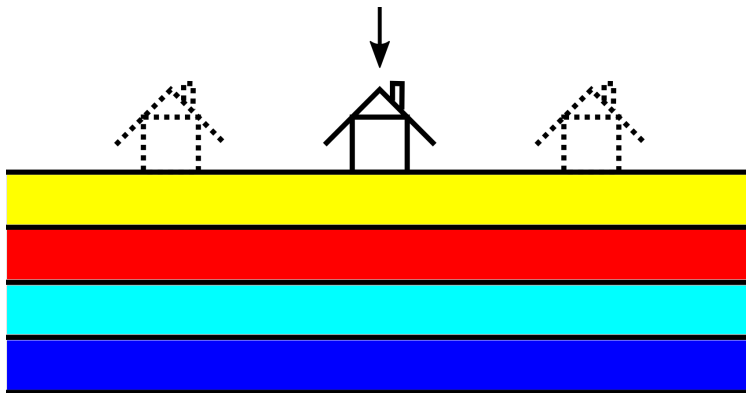
On 1d vs 3d inductance

- 1d: Conductivity model when calculating solution at 1st location



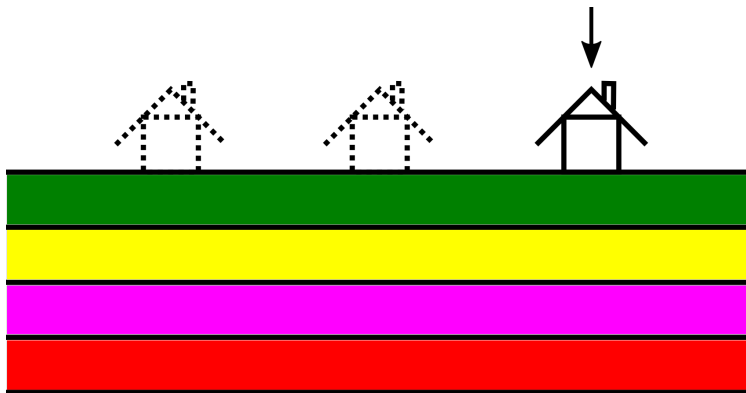
On 1d vs 3d inductance

- 1d: Conductivity model when calculating solution at 2nd location



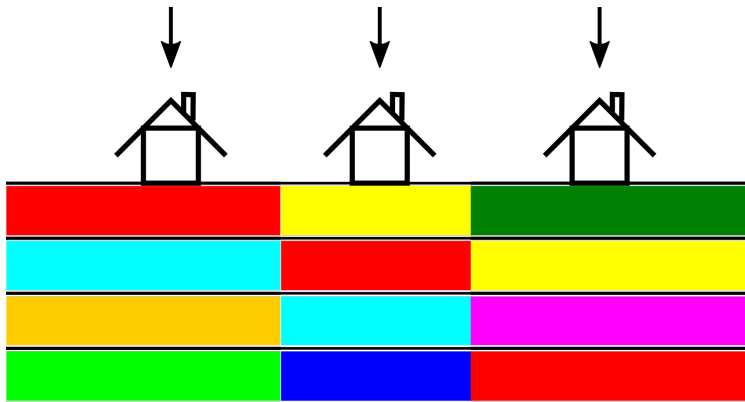
On 1d vs 3d inductance

- 1d: Conductivity model when calculating solution at 3rd location



On 1d vs 3d inductance

- Conductivity model in 3d calculation



Simulated horizontal ionospheric currents

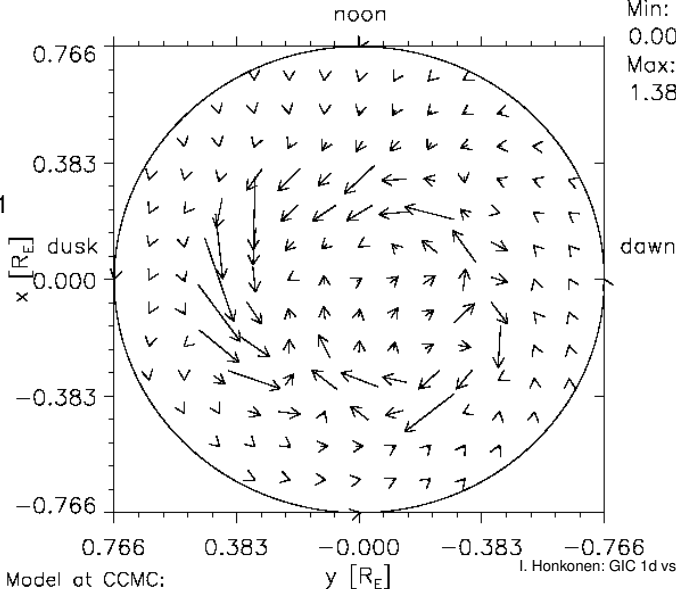
12/14/2006 Time = 22:16:00

Northern Hemisphere

↑ J [$\frac{\mu A}{m}$]

Min:
0.00E+00
Max:
1.38E+06

- Global MHD model:
BATS-R-US
 - CCMC global
msphere run id
SWPC_SWMF_052811
- 1 min cadence
- Ionospheric
resolution approx 1
degree
- Magnetospheric
resolution approx
 $1/4R_E$



Model at CCMC:

I. Honkonen: GIC 1d vs 3d

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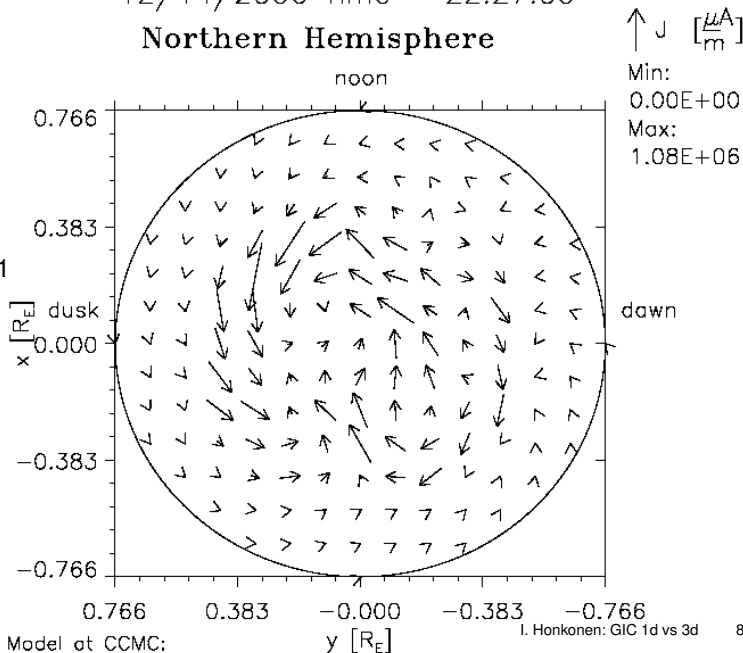
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Simulated horizontal ionospheric currents

12/14/2006 Time = 22:27:00

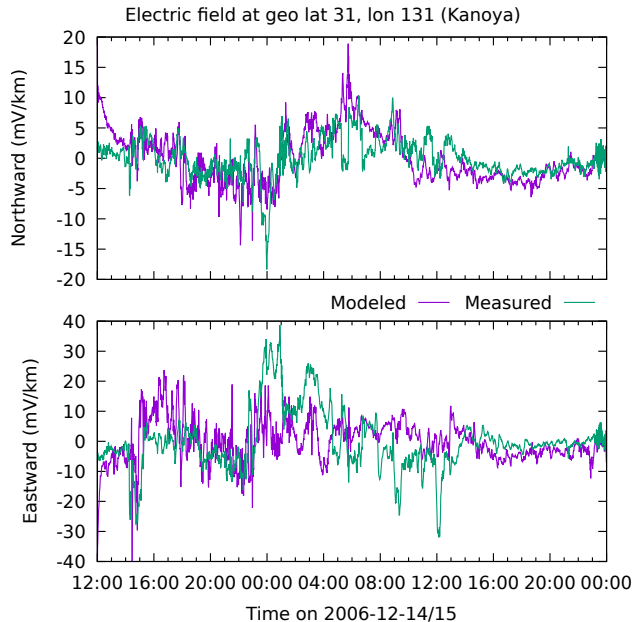
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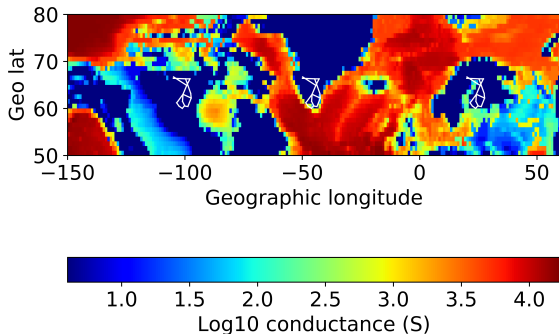
Validation of ground E

- Realistic simulated ground E from solar wind down to earth
- Mag lat 22, lon 158 (in 2019)
- Fairly good at > 1 h time scales
- Best result out of 3 available stations
- doi:10.1029/2018SW001859



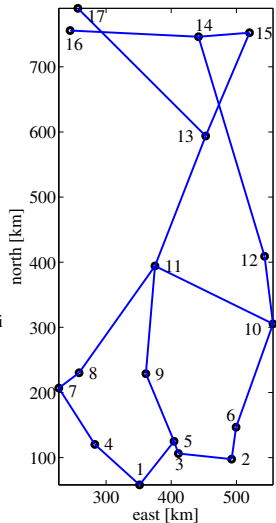
GIC calculation

- Move Finnish power grid in lon with 5 deg increments
 - Grid originally at geo lat 60-67, lon 22-30
 - Stations 16 & 17 located in Sweden
- Calculate 1d & 3d GIC at each offset



Finnish 400 kV power grid in 1978-79

- 1 = Inkoo
- 2 = Loviisa
- 3 = Nurmijärvi
- 4 = Lieto
- 5 = Hyvinkää
- 6 = Koria
- 7 = Olkiluoto
- 8 = Ulvila
- 9 = Kangasala
- 10 = Huutokoski
- 11 = Alajärvi
- 12 = Alapitkä
- 13 = Pikkarala
- 14 = Petäjaskoski
- 15 = Pirttikoski
- 16 = Letsi
- 17 = Messaure

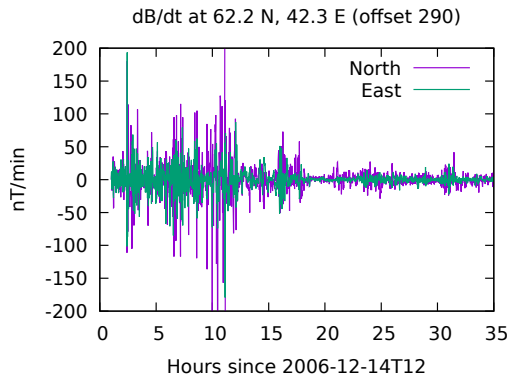
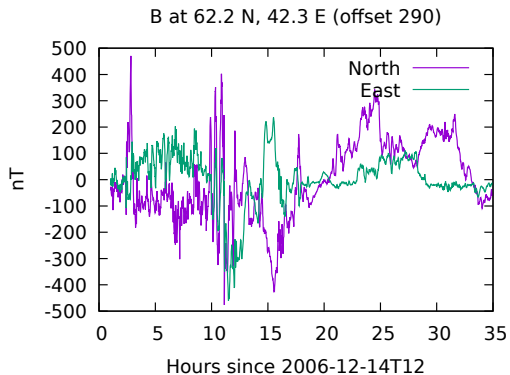


doi:10.1051/swsc/2012017



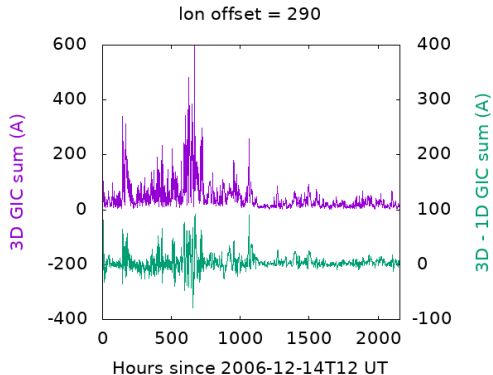
Results 1

Realistic ground B and dB at station with largest GIC

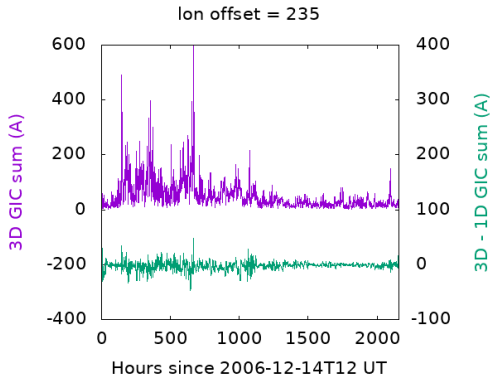


Results 2

Example of similar 3d and different 1d responses, note left scales 2x vs rights

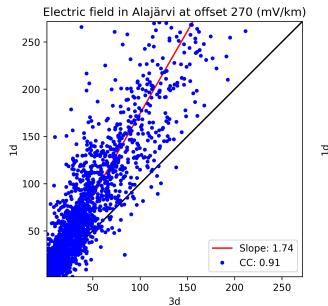
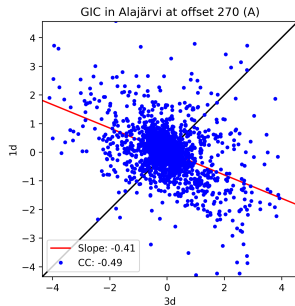
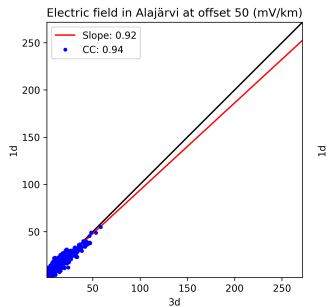
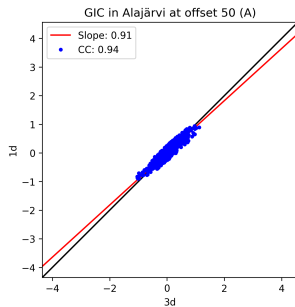


Also minutes not hours since 14T12



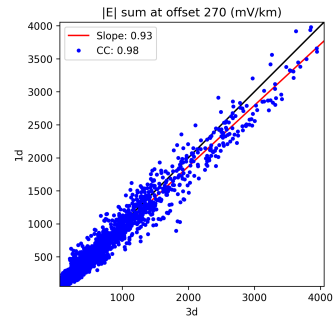
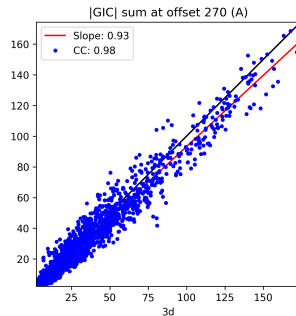
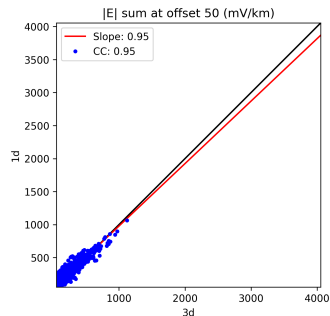
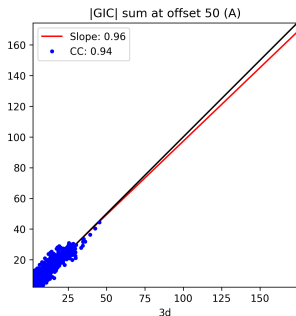
Results 3

- 1d vs 3d GIC (left) and E (right) at Alajärvi
- Grids offset 50 (top) and 270 (bottom) degrees due east from Finland
- Very varied response at single station depending on conductivity near grid



Results 4

- 1d vs 3d GIC (left) and E (right) scatterplot of total network GIC
- Grids offset 50 (top) and 270 (bottom) degrees due east from Finland
- Only magnitudes of response seem to vary at grid scale



Conclusions

- Realistic ground B from solar wind using physics-based modeling
- Simple GIC 1d-3d diff metric reveals large horizontal conductivity gradients
- Very different 1d GIC results can be similar with 3d approach
- Largest observed difference between 3d and 1d total GIC $\sim 20\%$
- Large variation in GIC results at single station reduced drastically at grid scale



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