



Introducing new global electromagnetic modeling solver

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GEMMIE: Global ElectroMagnetic Modelling based on Integral Equation approach

New (**GEMMIE**) solver is considered as a successor of **X3DG** solver (Kuvshinov 2008) which is also based on integral equation (IE) approach. **X3DG** has been using in numerous studies* to compute EM field in spherical 3-D conductivity models induced by the sources of different (oceanic, ionospheric and magnetospheric) origin

* Chen et al (2020), Chulliat et al (2013, 2016), Grayver et al (2016, 2017, 2019), Guzavina et al (2018, 2019), Honkonen et al (2018), Irrgang et al (2017, 2019), Kelbert et al (2014), Khan et al (2011), Manoj et al (2006), Munch et al (2018, 2020), Petereit et al (2019), Puethe et al (2014, 2015), Sabaka et al (2015, 2018), Sachl et al (2019), Saynisch et al (2016, 2017, 2018), Schnepf et al (2014, 2015, 2018), Telschow et al (2018), Velimsky et al (2019); among many others

Comparison of X3DG and GEMMIE solvers

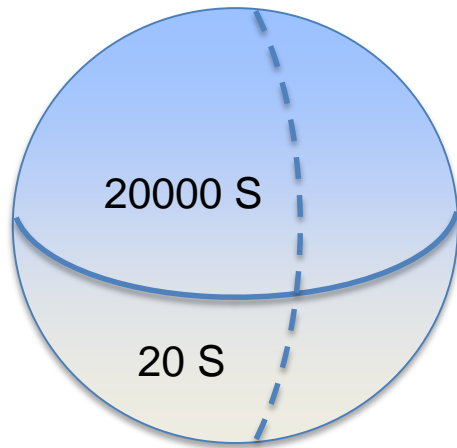
X3DG

- Based on contracting IE (CIE) method
- Collocation method is used to obtain system of linear equations (SLE): in theory, it does not guarantee convergence of SLE iterative solution
- Sequential

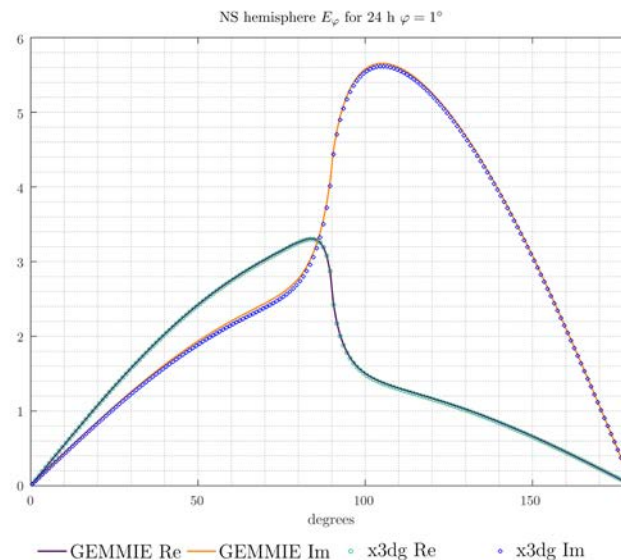
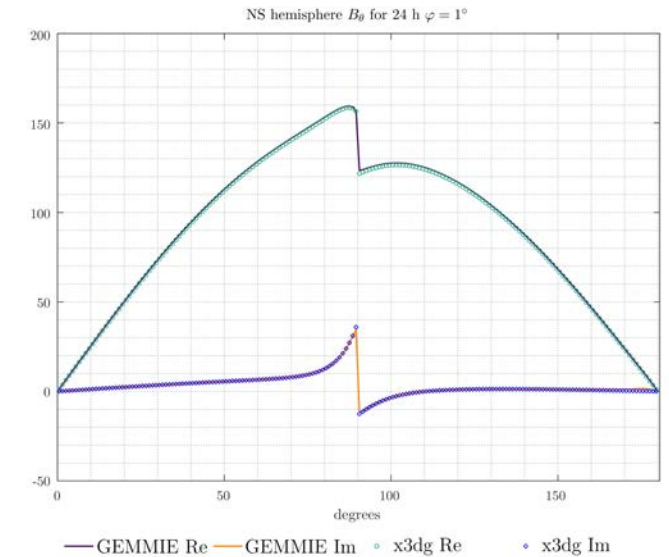
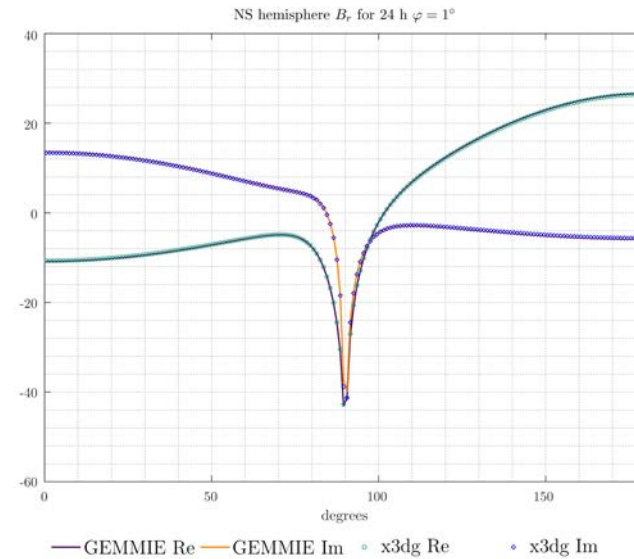
GEMMIE

- Based on the same, CIE, method
- Galerkin method is used to obtain SLE; it guarantees convergence of SLE iterative solution
- Scalable up to hundreds CPUs
- More accurate calculation of Green's tensors' elements
- Will be available under GPLv2 licence

Verification of GEMMIE solver. Thin-shell model with North-South hemispheric conductance distribution



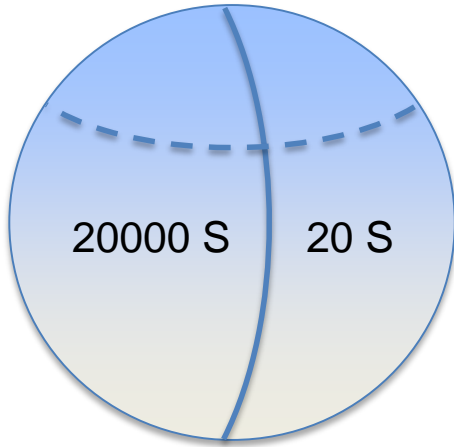
- Source: symmetric ring current (described via first zonal harmonic, Y10)
- Period: 1 day
- Underneath shell: 1-D mantle



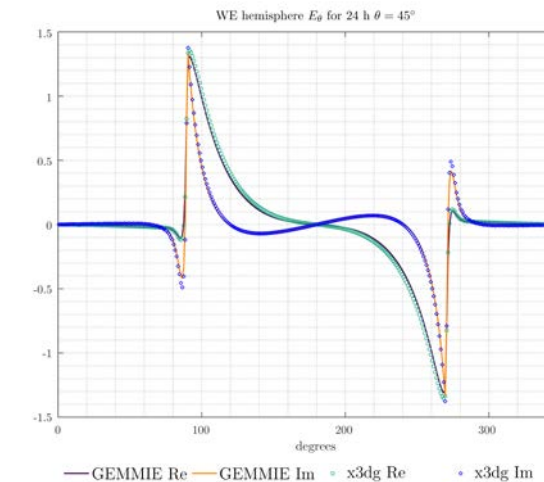
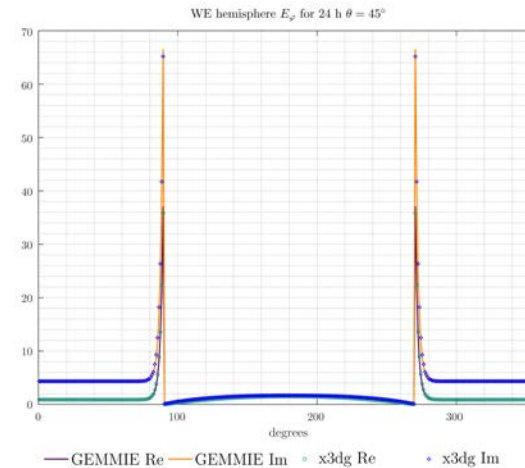
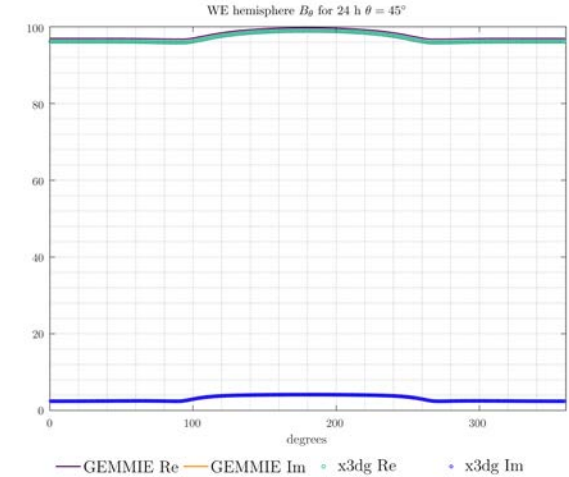
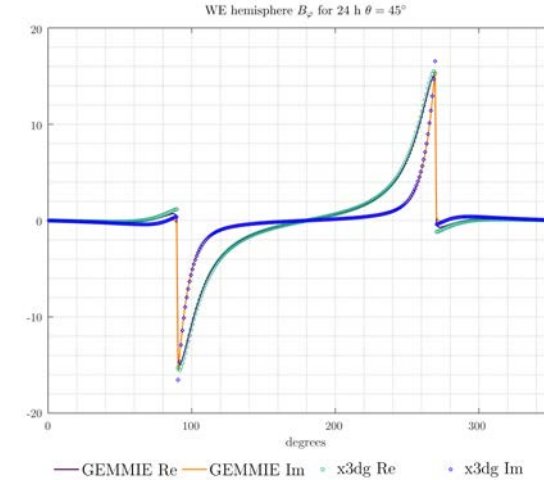
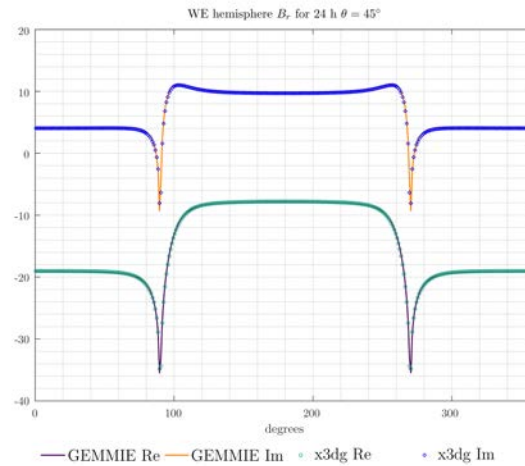
Perfect agreement with X3DG results

2-D problem: no dependence on longitude; results are shown along profile (dashed line)

Verification of GEMMIE solver. Thin-shell model with West-East hemispheric conductance distribution



- Source: symmetric ring current (described via first zonal harmonic, Y10)
- Period: 1 day
- Underneath shell: 1-D mantle



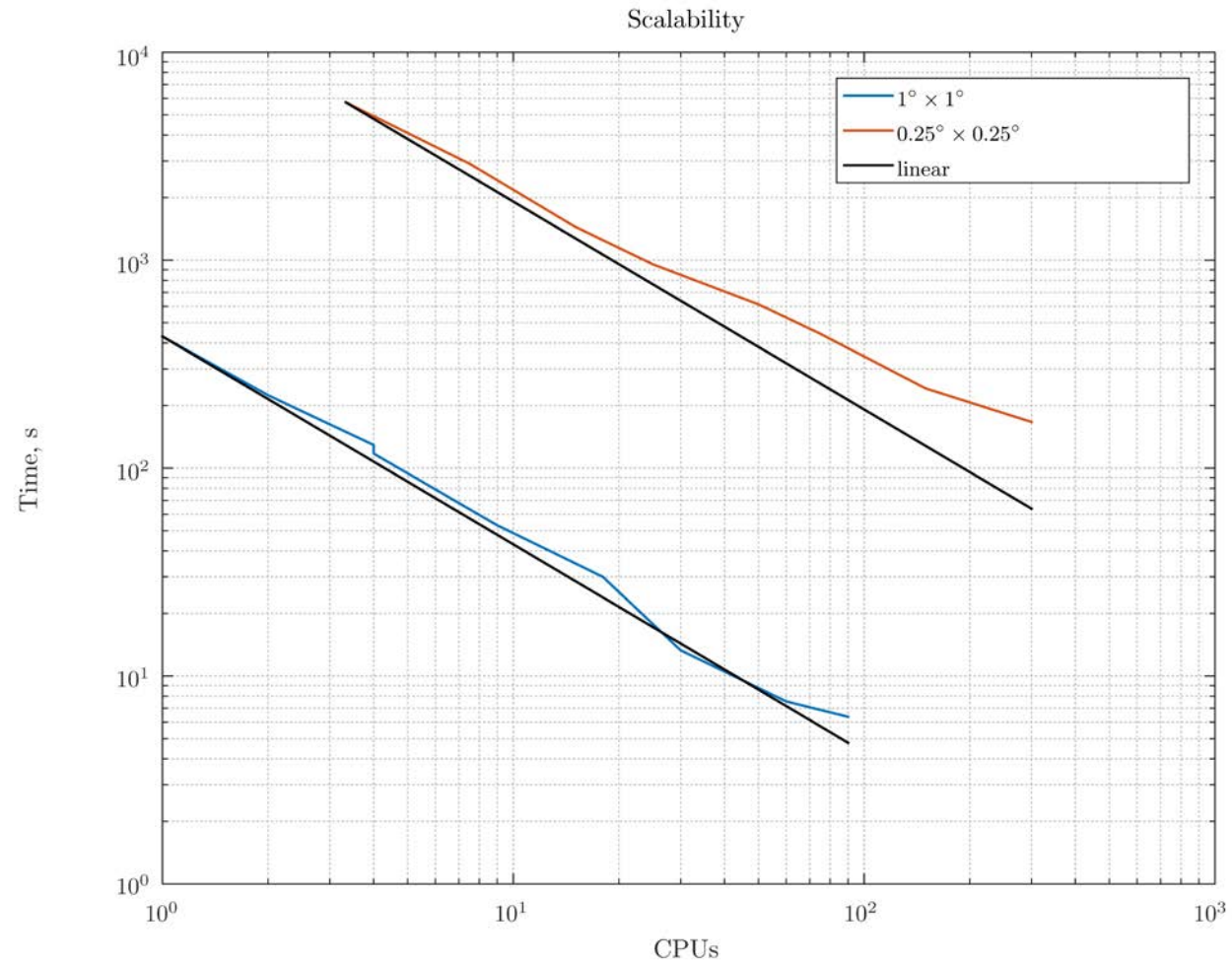
Perfect agreement with X3DG results

Some numbers: CPU time for $0.25^\circ \times 0.25^\circ$ grid (720 x 1440 cells)

GEMMIE	3 min*
X3DG	157 min

* At 360 processors (further optimization is feasible)

Scalability of GEMMIE solver



Deviation from linear behavior is under investigation

Summary and outlook

- New scalable global EM modelling solver (GEMMIE) based on IE approach has been developed and validated
- It is planned that GEMMIE will substitute (with time) X3DG solver in applications
- Next step is to develop nested version of GEMMIE