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Fennoscandian strain rates and seismicity

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STARTING POINTS

1- To what extent is the deformation field of Fennoscandia driven by tectonic forces (ridge push and gravitational collapse) or by glacial isostatic adjustment (GIA)?

2- Which footprint do tectonic forces and glacial isostatic adjustment leave on the deformation field?

3- In which part of Fennoscandia these driving forces prevail?

WORK OUTLINE

TECTONIC MODEL – building a FEM tectonic model (TEC) and comparing it to the World Stress Map (Heidbach et al., 2008) and earthquakes data (Norsar Bulletin). No GIA considered in the modeling.

MODEL VALIDATION –distinguishing which World Stress Map (WSM) entry is better compatible with TEC model and/or with the GIA model respect to its tectonic regime and the most-compressive horizontal axis (sh1) direction.

MODEL CONSTRUCTION

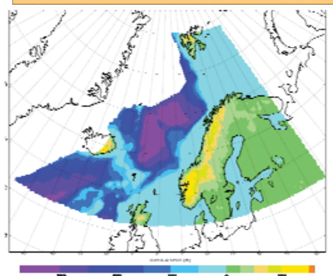
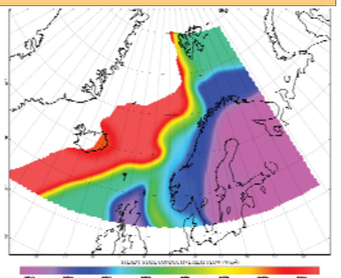
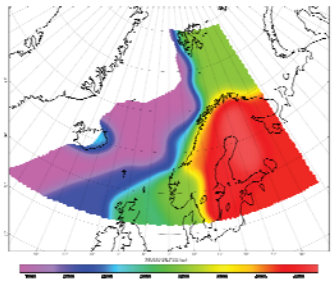
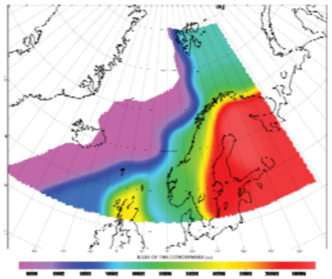
USED CODE: SHELLS (Bird, 1999).

Main approximations and assumptions of the code:

-Vertical heat conduction and constant thermal properties;
-Assumed rheology (frictional, dislocation "power law " creep and pure plastic);
-Two-layered lithosphere (crust and mantle);
-Vertical integration of stresses.

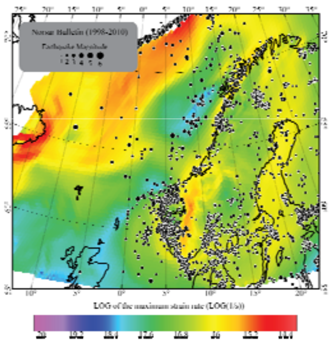
BOUNDARY CONDITIONS: MOR (Middle Ocean Ridge) opening respect to fixed Eurasia (based on EUREF Solution of 31st July 2010).

MESH CHARACTERISTICS

TEC MODEL RESULTS

Strain rate



To check the consistency of TEC deformation field and seismicity, we used the Strain Rate correlation Coefficient (Jimenez Munt et al., 2003).
The SRC for the *N* nodes of the model is defined as:

$$SRC = \frac{\sum_{i=1}^{N}[\log\dot{\varepsilon}_i - <\log\dot{\varepsilon}>][\log(\dot{\varepsilon}_{seismic})_i - <\log(\dot{\varepsilon}_{seismic})>]}{\sqrt{\left[\sum_{i=1}^{N}(\log\dot{\varepsilon}_i - <\log\dot{\varepsilon}>)^2\right]\left[\sum_{i=1}^{N}(\log(\dot{\varepsilon}_{seismic})_i - <\log(\dot{\varepsilon}_{seismic})>)^2\right]}} = 0.2514$$

We think that TEC model strain rate and 12 years of seismicity are fairly correlated except for the central Norwegian Sea.

Horizontal Stress directions and Tectonic Regime

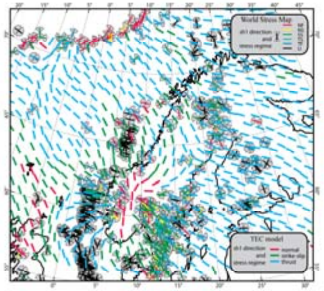
We scored the sh1 direction of the TEC model against the *N* WSM data falling in the studied area:

$$err_{sh1} = \frac{\sum_{i=1}^{N}\alpha\left|\theta_{TEC} - \theta_{WSM}\right|}{N} = 33°$$

where $\alpha=4$ for WSM data with quality A, $\alpha=3$ for quality B, $\alpha=3$ for quality B, $\alpha=2$ for quality C, $\alpha=1$ for quality D. Data with quality E were not considered.

The highest deviations from the WSM data directions were found for some (not ALL) data located in central Norwegian Sea, North Sea and Sweden.

TEC model is able to explain the main trend of strain rates and seismicity, but at the same time it suggests a strong interaction among driving forces in certain areas (sedimentation + TEC model for central Norwegian Sea / North Sea / Barents Sea and GIA + TEC model for Sweden).



MODEL VALIDATION

We assigned each data entry of the WSM dataset falling within our study area to GIA and/or to TEC model. For this scope we compared each WSM data to the most compressive stress axis (actually the strain-rate axis) of the GIA model (Scherneck et al., 2010) and of the TEC model obtained using SHELLS.

ASSIGNMENT CRITERIA 1 (MISFIT25)

For each WSM datum:

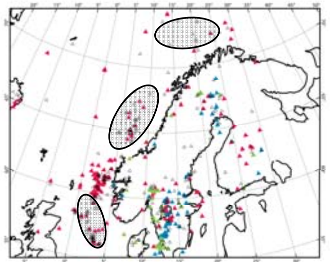
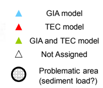
1. We consider only the $N_{1,GIA}$ nodes of GIA and $N_{1,TEC}$ of TEC models far less then 50 km from the WSM datum. All the remaining nodes are not considered;
2. we consider only the $N_{2,x}$ (<= $N_{1,x}$) nodes of GIA and TEC models having compatible tectonic regime with the one of the WSM data. All remaining nodes ($N_{1,x}$-$N_{2,x}$) are not considered;
3. we consider only the $N_{3,x}$(<=$N_{2,x}$) nodes of GIA and TEC models having misfit respect to the WSM-datum azimuth < 25°. All remaining nodes $N_{2,x}$-$N_{3,}$x are not considered:
   - if $N_{3,TEC}$>0 AND $N_{3,TEC}$>0 then "COMMON DATUM" (both the GIA or TEC model are compatible with the WSM-datum azimuth)
   - if $N_{3,TEC}$=0 AND $N_{3,TEC}$>0 then "TEC DATUM" (the WSM datum is better explained by TEC model);
   - if $N_{3,TEC}$>0 AND $N_{3,TEC}$=0 then "GIA DATUM" (the WSM datum is better explained by by GIA model);
   - if $N_{3,TEC}$=0 AND $N_{3,TEC}$=0 then "NOT ASSIGNED DATUM" (both GIA and TEC models fail to reproduce WSM datum);349 data.

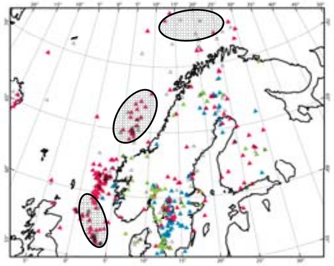
ASSIGNMENT CRITERIA 2 (MISFIT40)

For each WSM datum:

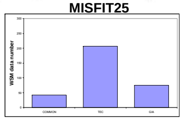
1. We consider only the $N_{1,GIA}$ nodes of GIA and $N_{1,TEC}$ of TEC models far less then 50 km from the WSM datum. All the remaining nodes are not considered;
2. we consider only the $N_{2,x}$ (<= $N_{1,x}$) nodes of GIA and TEC models having compatible tectonic regime with the one of the WSM data. All remaining nodes ($N_{1,x}$-$N_{2,x}$) are not considered;
3. we consider only the $N_{3,x}$(<=$N_{2,x}$) nodes of GIA and TEC models having misfit respect to the WSM-datum azimuth < 40°. All remaining nodes $N_{2,x}$-$N_{3,x}$ are not considered:
   - if $N_{3,TEC}$>0 AND $N_{3,TEC}$>0 then "COMMON DATUM" (both the GIA or TEC models are compatible with the WSM-datum azimuth)
   - if $N_{3,TEC}$=0 AND $N_{3,TEC}$>0 then "TEC DATUM" (the WSM datum is better explained by TEC model);
   - if $N_{3,TEC}$>0 AND $N_{3,TEC}$=0 then "GIA DATUM" (the WSM datum is better explained by GIA model);
   - if $N_{3,TEC}$=0 AND $N_{3,TEC}$=0 then "NOT ASSIGNED DATUM" (both GIA and TEC models fail to reproduce WSM datum); 253 data.

MODEL VALIDATION RESULTS



MISFIT25



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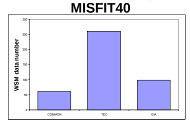
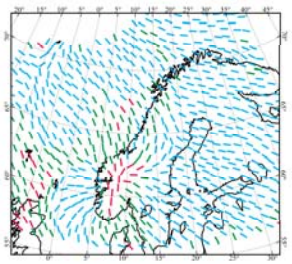


CONCLUSIONS



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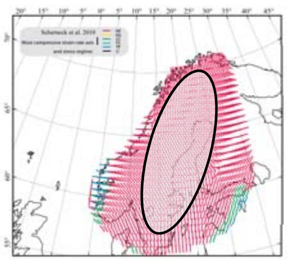

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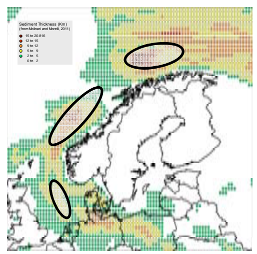

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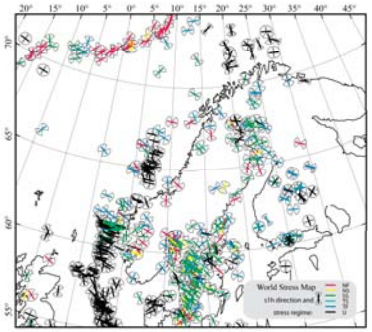

Driving force	Ridge push + gravity force	Glacial Isostatic Adjustment	Sediment load
WHERE?	WIDESPREAD	SWEDEN – North NORWAY	locally in Barents Sea and Norwegian Sea

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Bird P., [1999], **Thin-plate and thin-shell finite element programs for forward dynamic modeling of plate deformation and faulting,** *Computers & Geosciences, 25*(4), 383-394.
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Heidbach, O., Tingay, M., Barth, A., Reinecker, J., Kurfeß, D., and Müller, B., [2008], **The World Stress Map database release 2008,** doi:10.1594/GFZ.WSM.Rel2008**.**