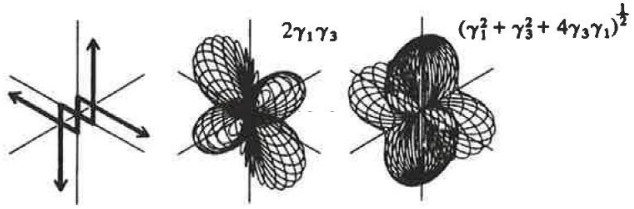


Opportunities for Source Modelling to Support the Seismic Hazard Estimation for NPP's

SYP2016/NST2016
Vilho Jussila, Ludovic Fülöp

Content

1. Introduction of Probabilistic Seismic Hazard Analysis PSHA, used for seismic hazard estimation of Finnish NPP's.
2. Problem statement. Goals of this study.
3. Capabilities of the Compsyn modelling
4. A case study of ~5.5Mw earthquake
    1. How results fit to Ground Motion Prediction Equation (GMPE)?

Disclaimer: Promising unpublished preliminary results of the AddGround NKS2016 project are included.

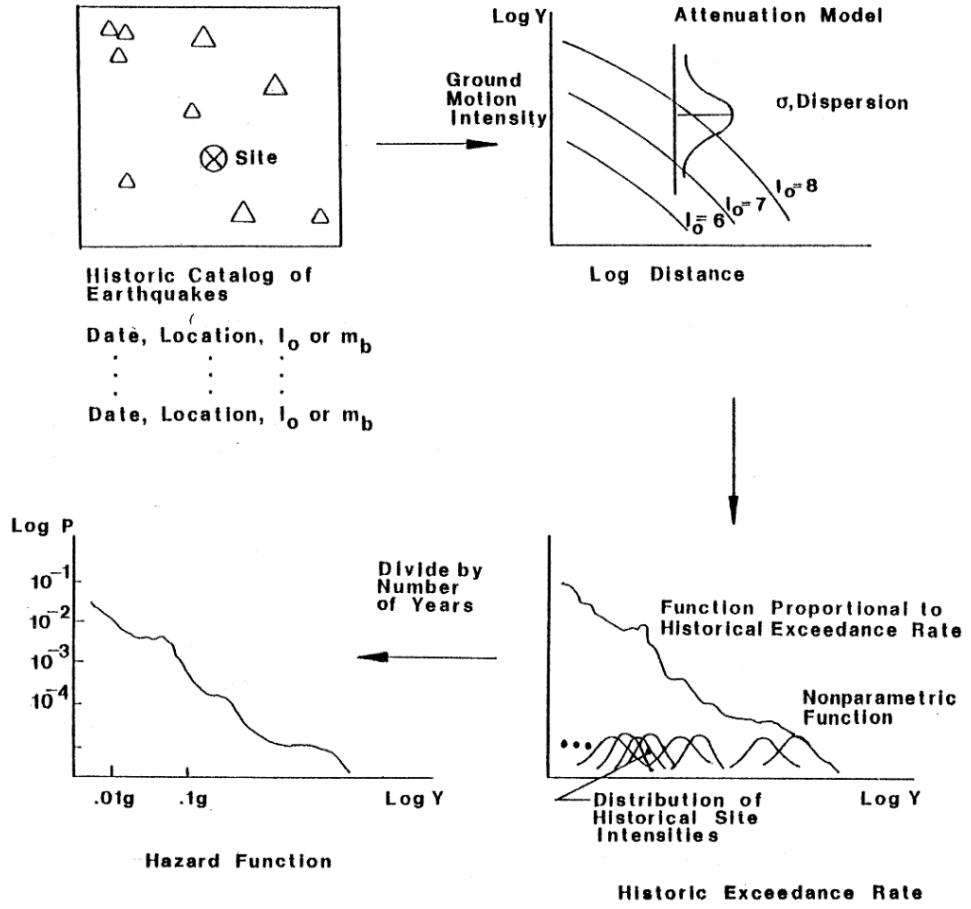
Introduction to PSHA (1)

- **Methodology**

PSHA is a methodology of establishing the probability of an occurrence, by accounting the effects of continuous independent random variables affecting the occurrence.

- **Benefit**

It is a rational way to estimate hazard. For surface infrastructure, the aim is to calculate the probability of exceedance of a ground motion level P[A]. The “occurrence” is the exceedance of a ground acceleration or spectral acceleration level, while the independent variables are earthquake size (I_o, m_b, M_w) and a distance measures.



$$P[A] = \int\int P[A \mid s \text{ and } r]\, f_S(s)\, f_R(r)\, ds\, dr$$

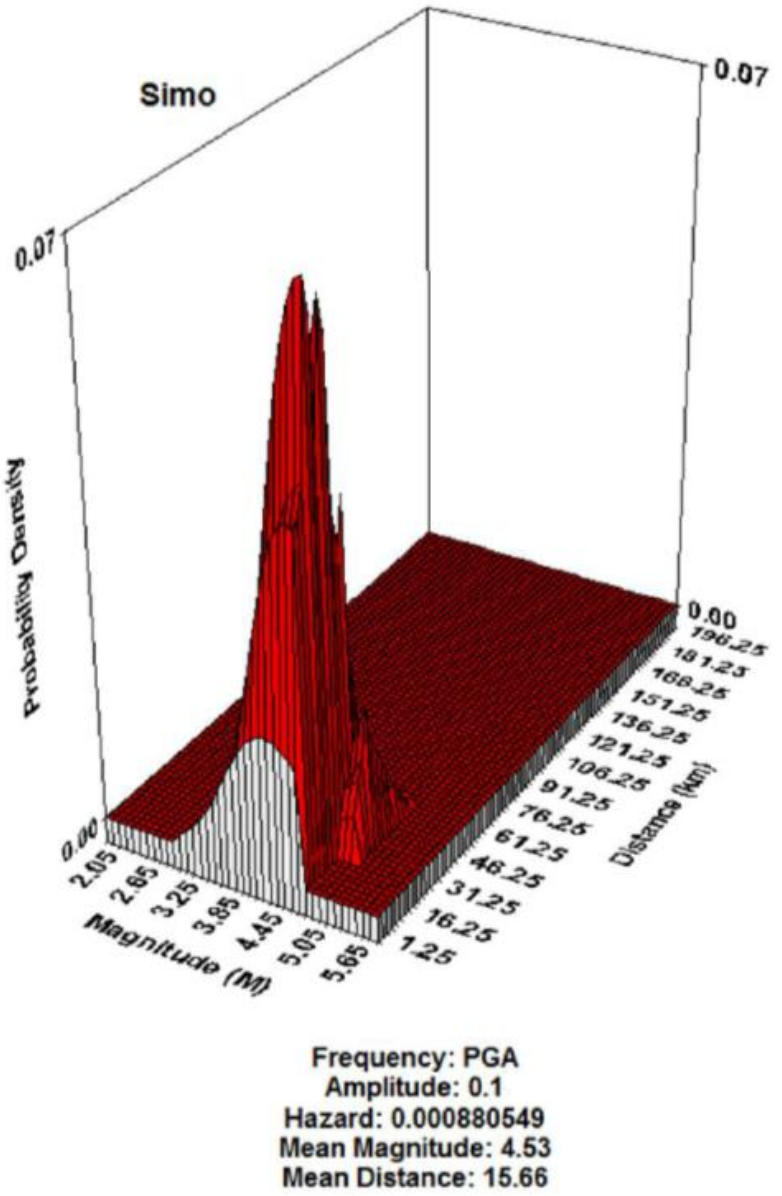
* D. Veneziano, C. A. Cornell, and T. O’Hara, “Historical Method of Seismic Hazard. Analysis,” Electric Power Research Institute Report EPRI NP. 3438, 1984.

Introduction of PSHA (2)

- Until recently seismic hazard in Finland is defined using
  - (1) locally available earthquake catalogue data combined with
  - (2) ground motion prediction equations (GMPE's) calibrated based on strong motions from geologically similar areas to Fennoscandia (Canada / Australia).
- In 2015, a GMPE was calibrated using Fennoscandian data and proposed for smaller magnitudes (T. Vuorinen, 2015).
- However, there are no observations of large magnitude earthquakes in Fennoscandia (M_{Lmax}~4-4.2). Very few observations of even M_L4 earthquakes from the near-field.

Dominating source of hazard

- De-aggregation shows that vibrations of engineering/safety significance (0.05*g-0.1*g) are from earthquakes in the range of M=3-5;
- Hazard is most significant from earthquakes with the epicenter distance below D=40km;
- In the *Hanhikivi NPP study* (Saari *et al.* 2015) M_{wmax} was 5, 5.5 and 6, and sensitivity to these was considered;



- X = Magnitude
- Y = Distance
- Z = Probability Density

* M. Malm and J. Saari, “SESA, Subproject 1 - Earthquake Hazard Assessment, Progress Report 2014,” ÅF-Consult Ltd, Research Report DSAF14R, Dec. 2014.

Problem statement. Goals of this study.

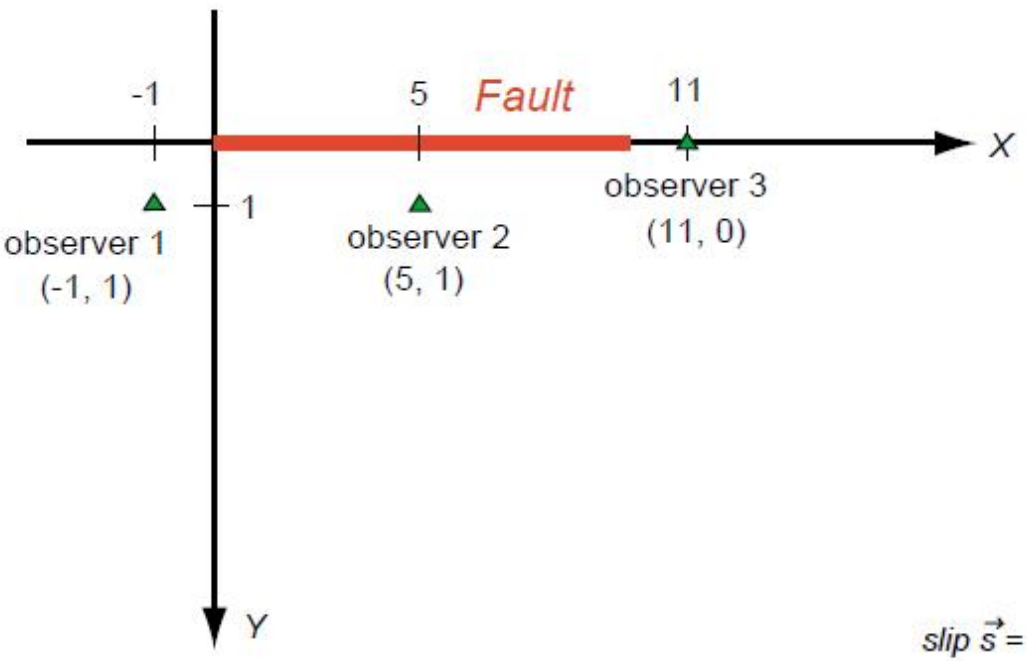
- In other words dominating hazard is from parameters where GMPE's are "extrapolated".

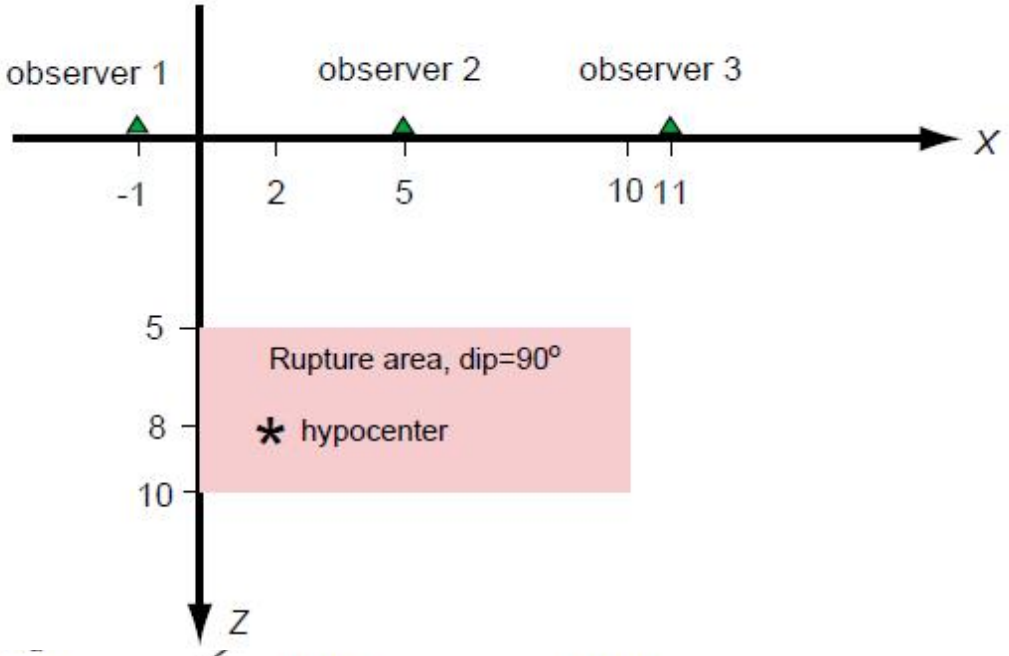
- Since no measurements exist from reasonable magnitude earthquakes in Fennoscandia, one solution to increase the reliability of prediction in the near-field is direct source modelling. This is what we propose to develop in the context of the Fennoscandian conditions.

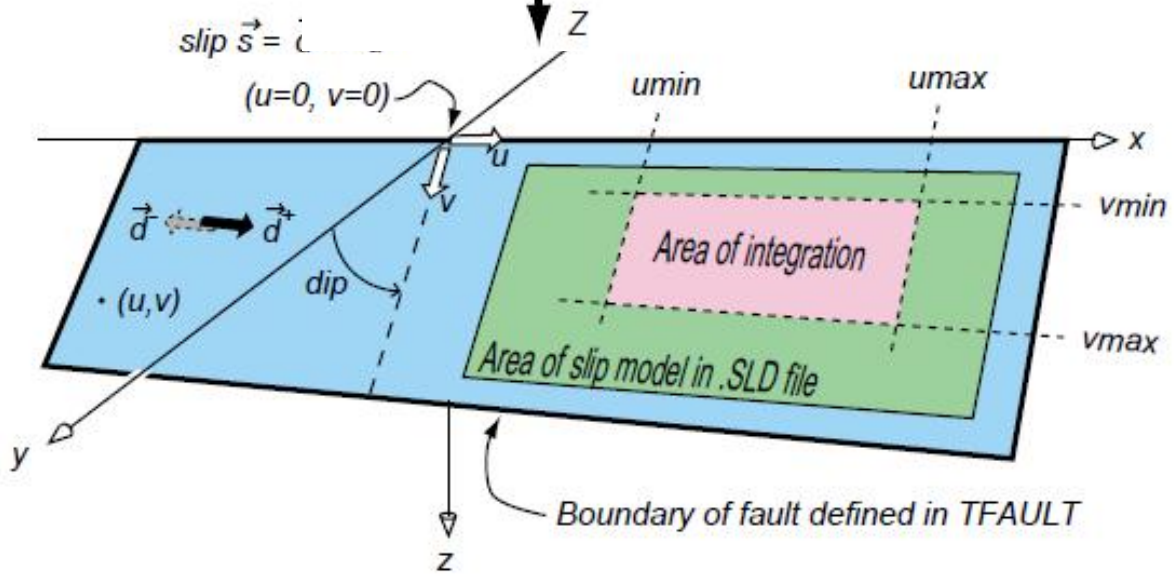
Compsyn

- Compsyn is a package in which ground motion is simulated from source to receiving station.
  - Uses Green's function as the energy potential
- Earth surface and fault model is 3D
- Earth structure is 1D, the variable is depth, density and velocities
- Compsyn is capable to include to the displacement and velocity ground motion:
  - Computes complete response of earth structure
  - Computes all P-wave, S-wave, surface waves
  - Computes engineering near field terms
  - Computational effort increases heavily above 10-15Hz, ISOSYN or alternative package is for higher frequencies

Defining fault in Compsyn



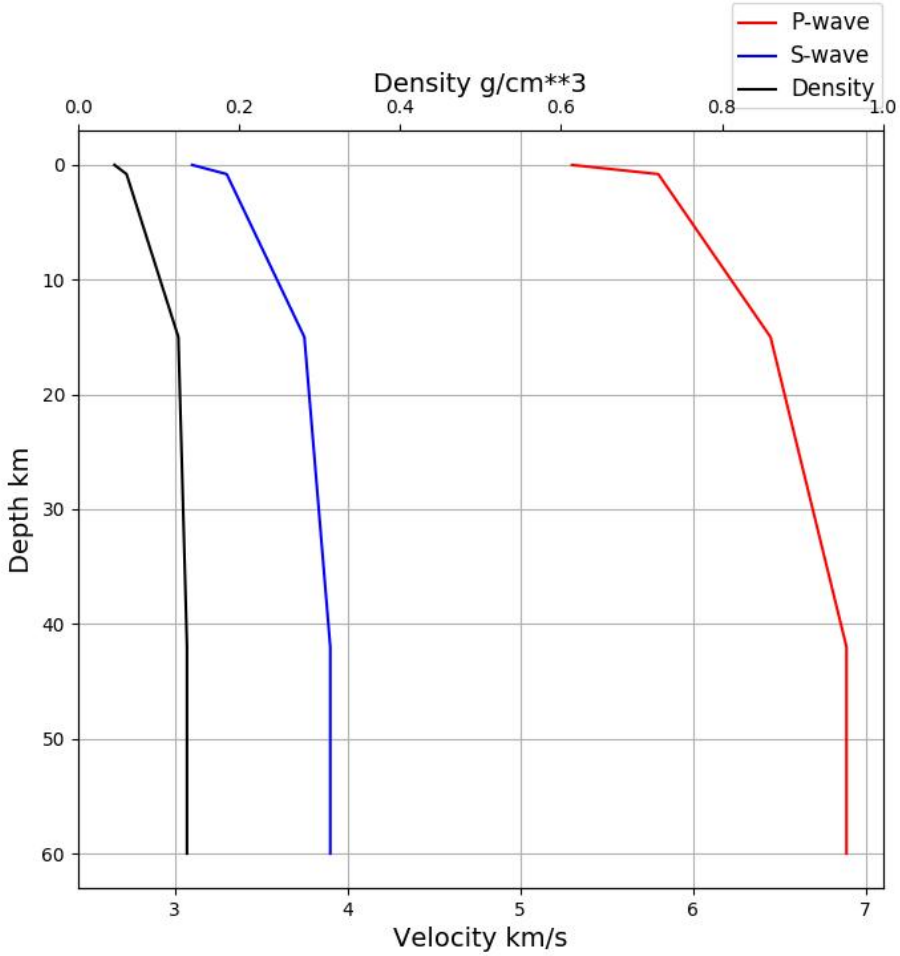




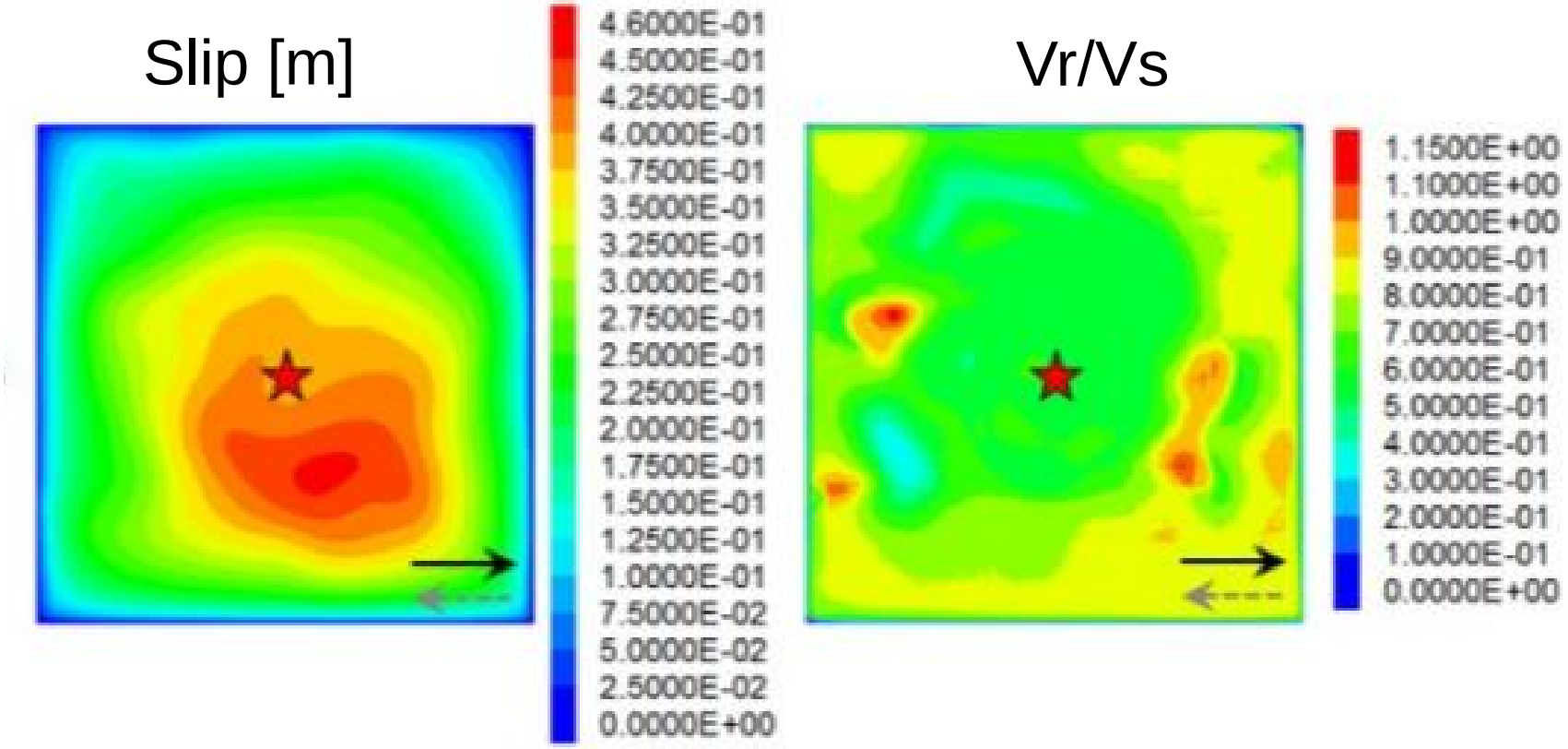
Spudich and Xu, Compsyn user manual

Considered Fault

- A left lateral strike-slip with 90deg dip
- Rupture area about 25km**2 (5x5km) and hypocenter 7.5km
- Varied friction coefficients
- ~5.5 Mw

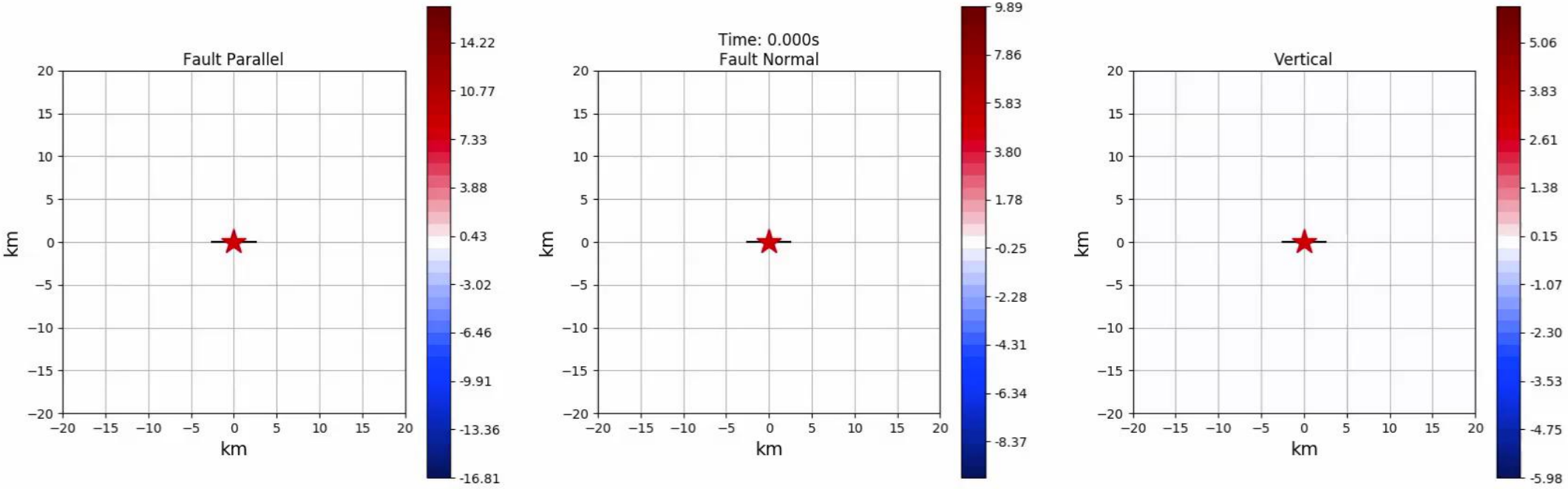


Considered Slip on Fault



Vr = Rupture Velocity
Vs = Shear Velocity

Animation of Ground Motion in mm



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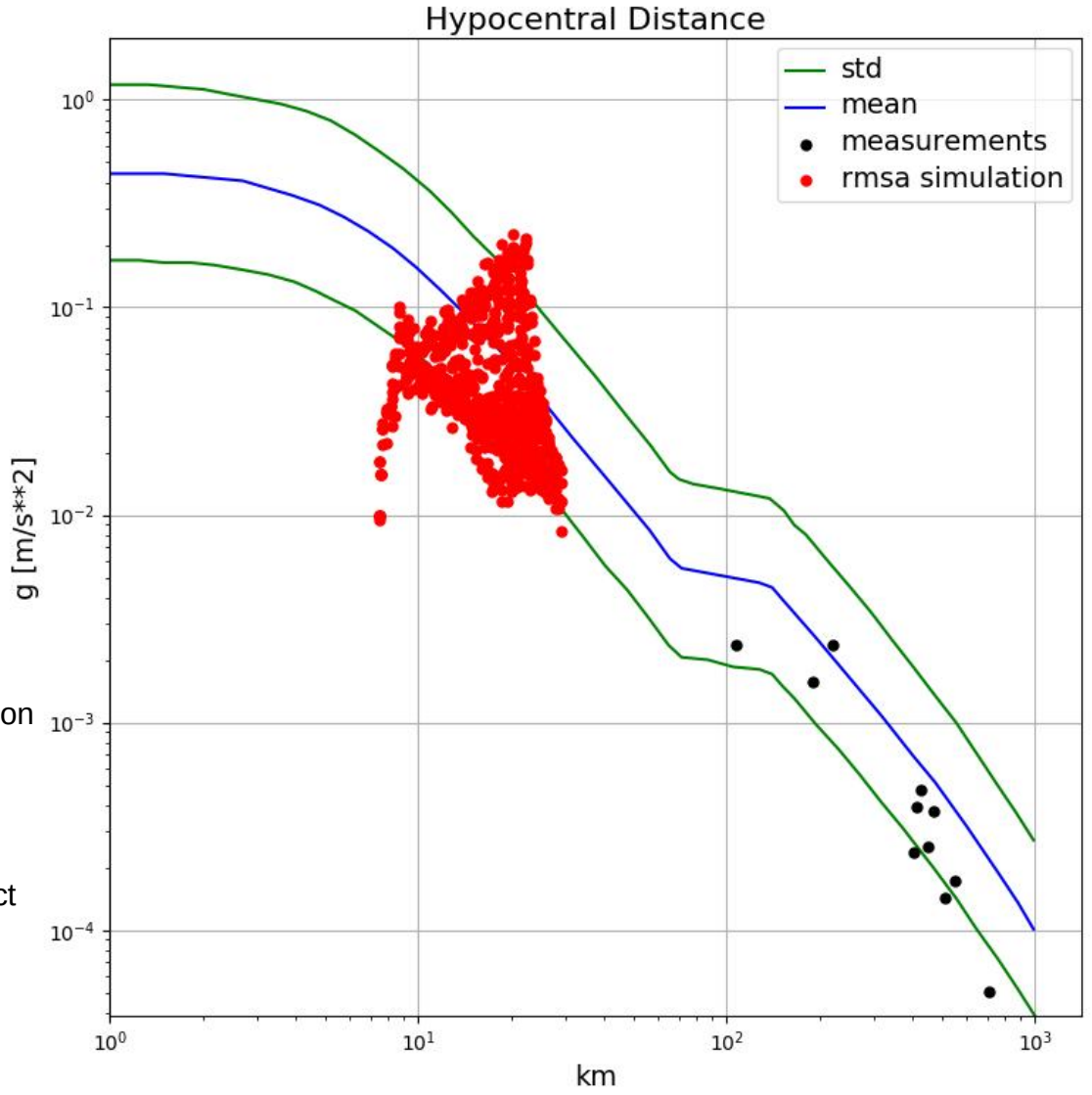
RMSA fit to GMPE



RMSA = Root Mean Square Acceleration
GMPE = Ground Motion Prediction Equation

Disclaimer: Promising unpublished preliminary
results of the AddGround NKS2016 project are included.

GMPE from Tommi Vuorinen, Institute of Seismology

Discussions

- De-aggregation results, suggest that the principal source of hazard to plants is within close range of the plant (~60km).
- The modelling offers a realistic method to substantiate GMPE's where there is no data especially in the near field.
- In view of maximum acceleration of simulated ground motion of the case study, it is reasonable to simulate 5.5Mw earthquake
- Simulation results fit quite well to GMPE
- Compsyn works reasonable well
- Ways forward:
  - Higher frequency, different fault typologies, different moment magnitudes
  - It replaces data which we do not have

Acknowledge

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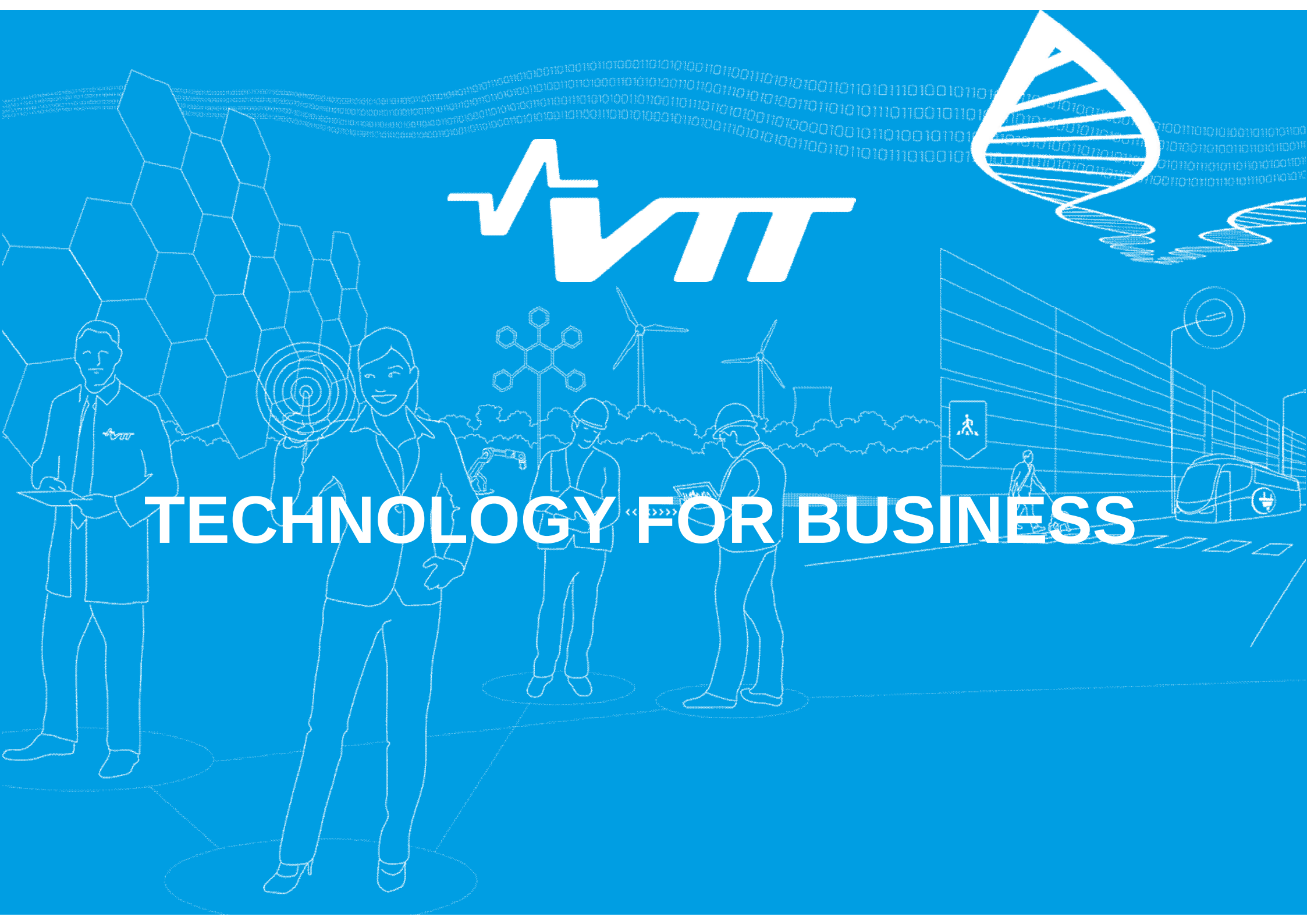
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