HORIZON 2020

ExchangeRisk

EXperimental & **C**omputational **H**ybrid **A**ssessment of **N**atural **G**as Pipelines **E**xposed to Seismic **Risk**

Università degli Studi di Napoli Federico II

WP5 - Multi-damage seismic risk assessment of soil- NG pipeline networks

16TH EUROPEAN CONFERENCE ON EARTHQUAKE ENGINEERING THESSALONIKI 18 - 21 JUNE 2018

Project Workshop 18/06/2018

WP5 - REASSESS

REgionAl, Single-SitE and Scenario-based Seismic hazard analysis

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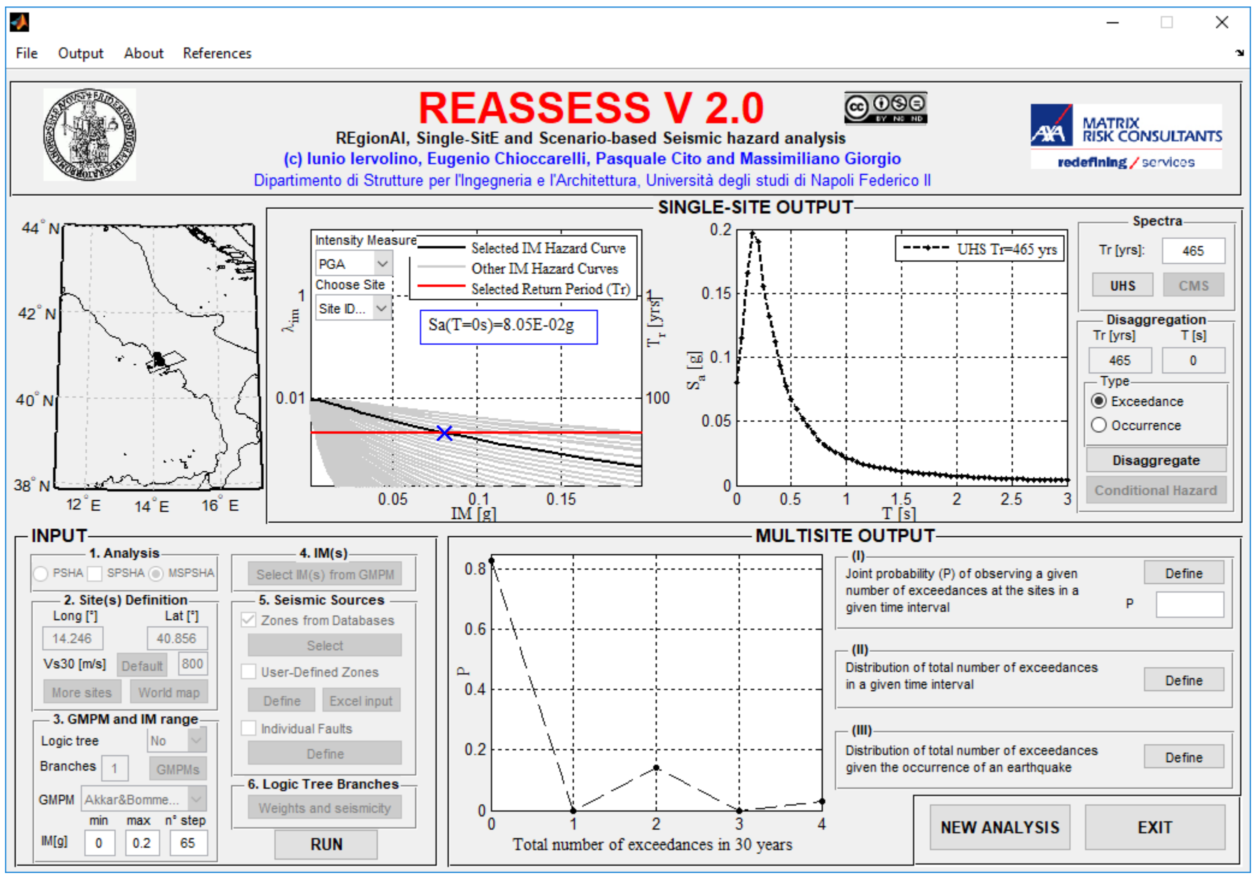
OBJECTIVE

D5.2. Comprehensive methodology & software for generating seismic scenarios of NG pipelines



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Secondment duration:
17/07/2017 to 17/08/2017 (one month)
Planned 07-09/2018 (two months)

VCE Vienna Consulting Engineers ZT GmbH

Pasquale Cito, Structural Engineer, Ph.D. Student in Structural, Geotechnical and Seismic engineering

Research interests: Seismic hazard assessment.

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Secondment duration:
28/08/2016 to 28/09/2016 (one month)

Eugenio Chioccarelli, Structural Engineer, Ph.D.
Researcher at the Construction Technology Institute

(Italian National Research Council , ITC – CNR; affiliate of UNAP in the project)

Research interests: Long- and Short-Term Seismic Risk Assessment for Civil Structures, Engineering Seismology, Probability Seismic Hazard Analysis in Far-Field and Near-Source Conditions, Characterization of Seismic Input

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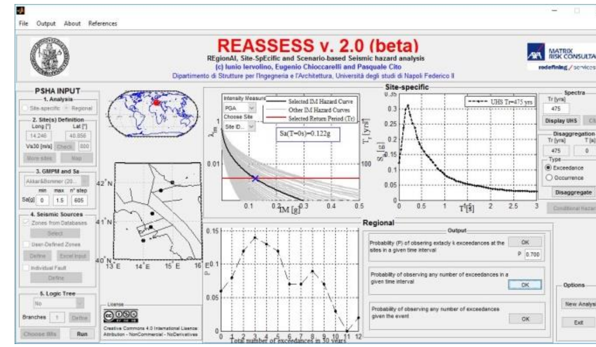
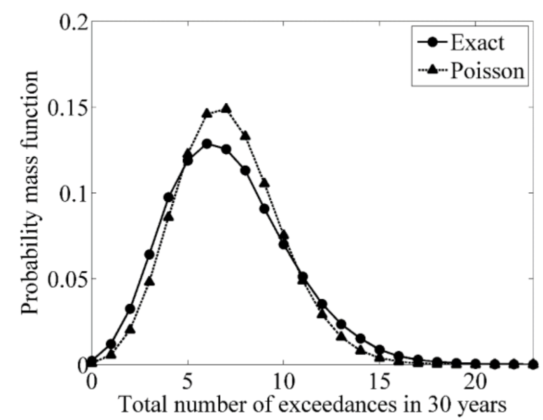
Outline of research activities during secondments

Eugenio Chioccarelli, Ph.D.
One month from University of Naples
to Norwegian Geotechnical Institute

Pasquale Cito, Ph.D. Student
Three months from University of Naples
to Vienna Consulting Engineers

- Risk estimation calculations for distributed systems such as buried pipelines require **multiple-site (regional) probabilistic seismic hazard analysis (PSHA)** that takes spatial correlation of seismic intensity measures into account.
- **Multisite PSHA** accounts for the stochastic dependence among the site-specific processes counting the number of exceedance of a ground motion intensity measure threshold at single site.
- These secondments have contributed to the elaboration of a user-friendly and **stand-alone software**, named **REASSESS**, for the probabilistic seismic hazard assessment of single- and multiple-sites.





Anticipated publication:
E. Chioccarelli, P. Cito, I. Iervolino, M. Giorgio. "REASSESS V2.0: software for single- and multi-site probabilistic seismic hazard analysis", submitted to the Bulletin of Earthquake Engineering

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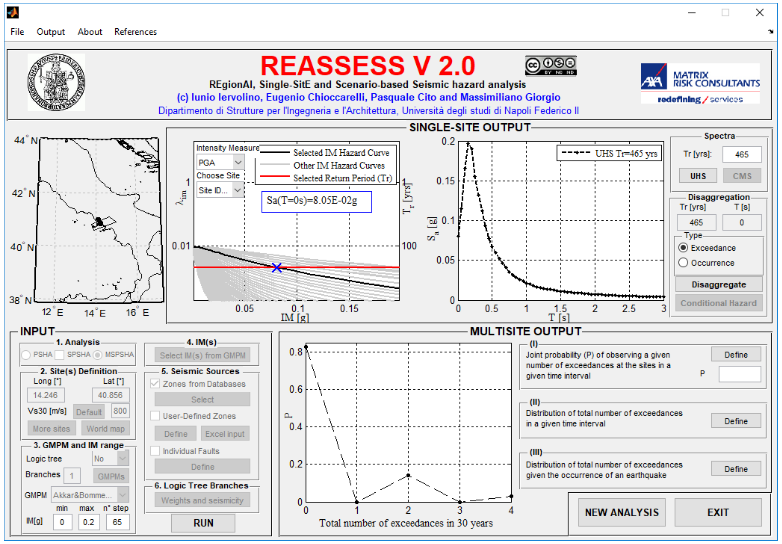
REgionAl, Single-SitE and Scenario-based Seismic hazard analysis

UPDATES IMPLEMENTED DURING AND AFTER SECONDMENTS:

- ✓ Procedure for sequence-based PSHA*;
- ✓ Spatial cross-correlation of spectral accelerations at multiple periods is taken into account in multisite PSHA**;
- ✓ Conditional hazard also provides the distribution of a secondary **intensity measure** (e.g., PGV) given the occurrence of a primary one (e.g., S_a);
- ✓ Possibility of PSHA for advanced IMs (I_{NP} and S_{avg}).



* Implemented in part during the first secondment at VCE (from July 17th to August 17th, 2017)

** Spatial correlation implementation closed during the first secondment at VCE. Spatial-cross correlation implementation to be optimized during the second secondment at VCE (from July 9th to September 27th 2018)

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SOFTWARE AVAILABILITY VIA WEBPAGE http://wpage.unina.it/iuniervo/

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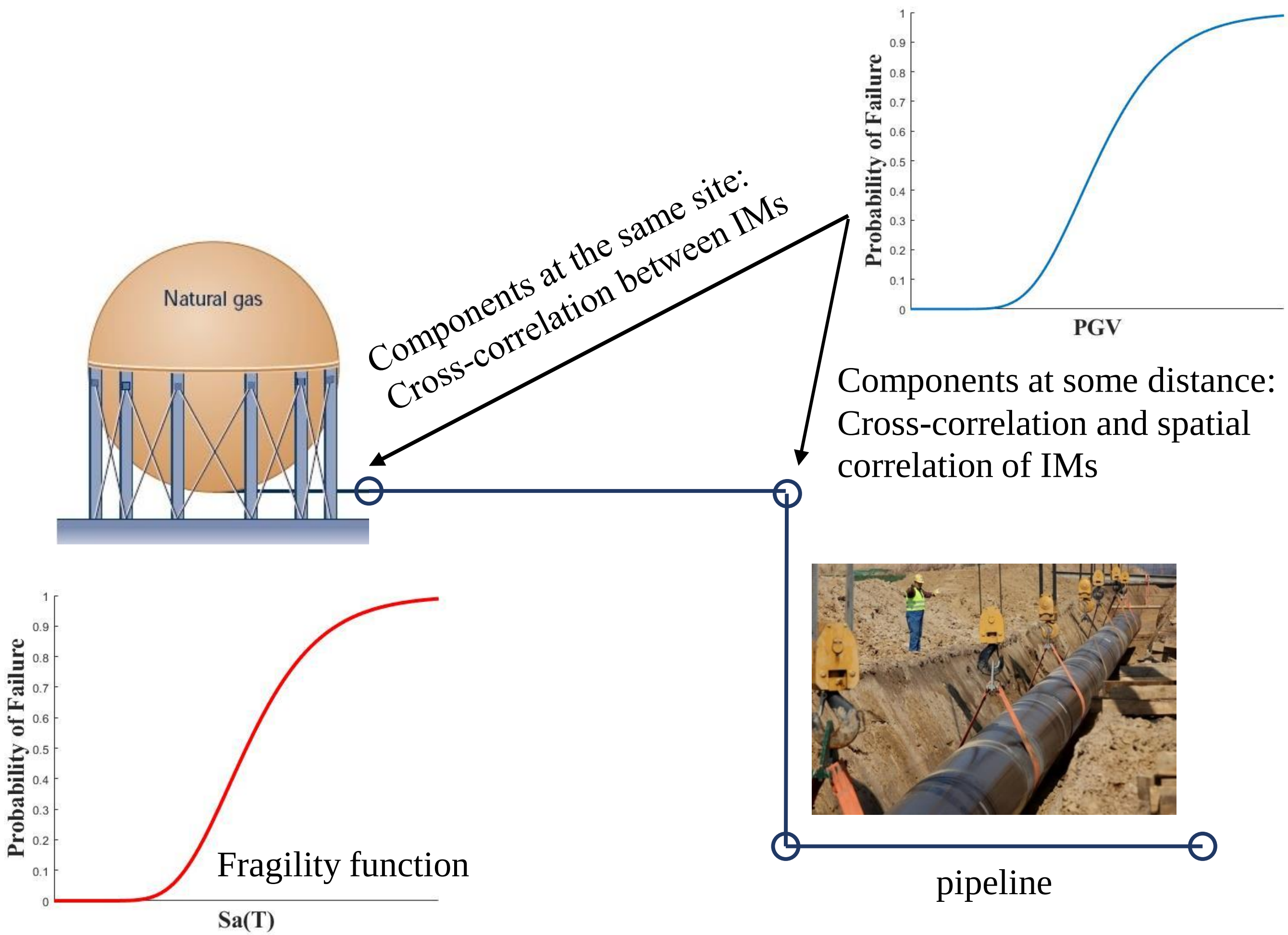
Network component fragilities expressed in terms of different intensity measures for different component types: Risk assessment can be performed by using **conditional hazard** (distribution of the secondary IM given a certain value of the primary IM).



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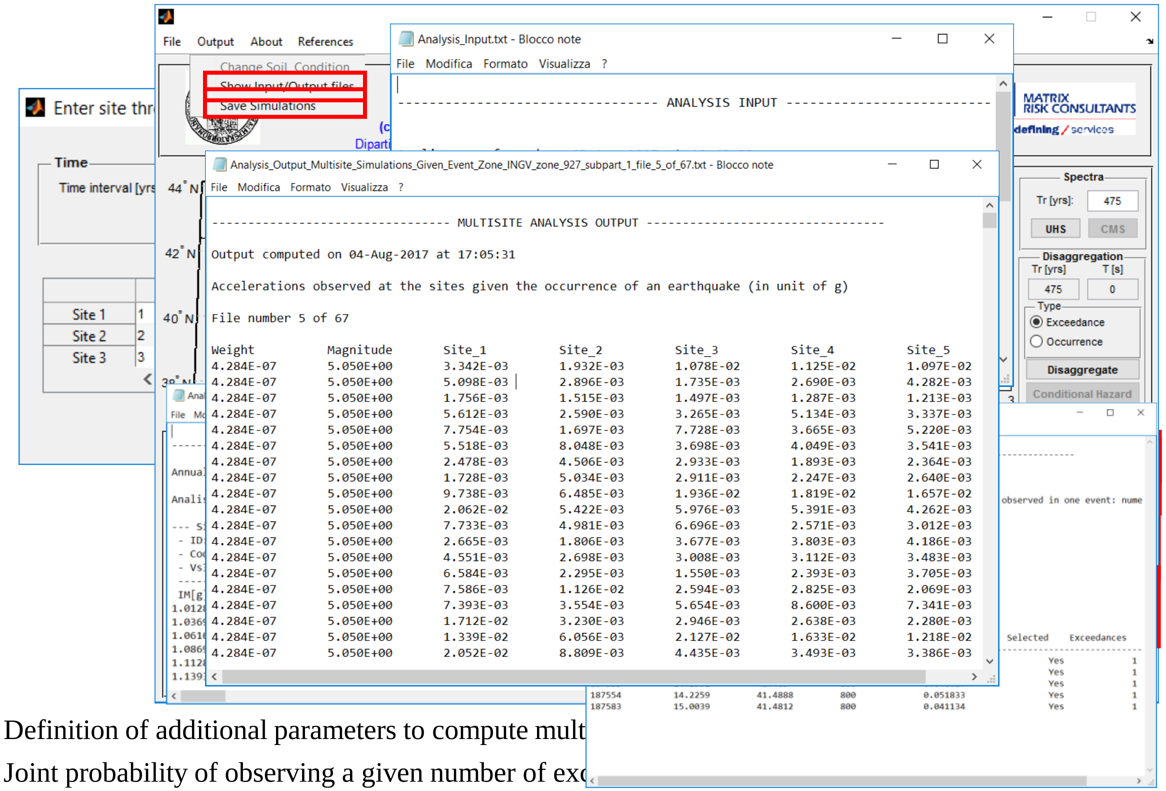
Graphical interface and multisite outputs



- Definition of additional parameters to compute mult
- Joint probability of observing a given number of exc
- Distribution of the total number of exceedances at the sites in a given time interval
- Distribution of the total number of exceedances at the sites given the occurrence of an earthquake
- Export input and output files
- Save simulations

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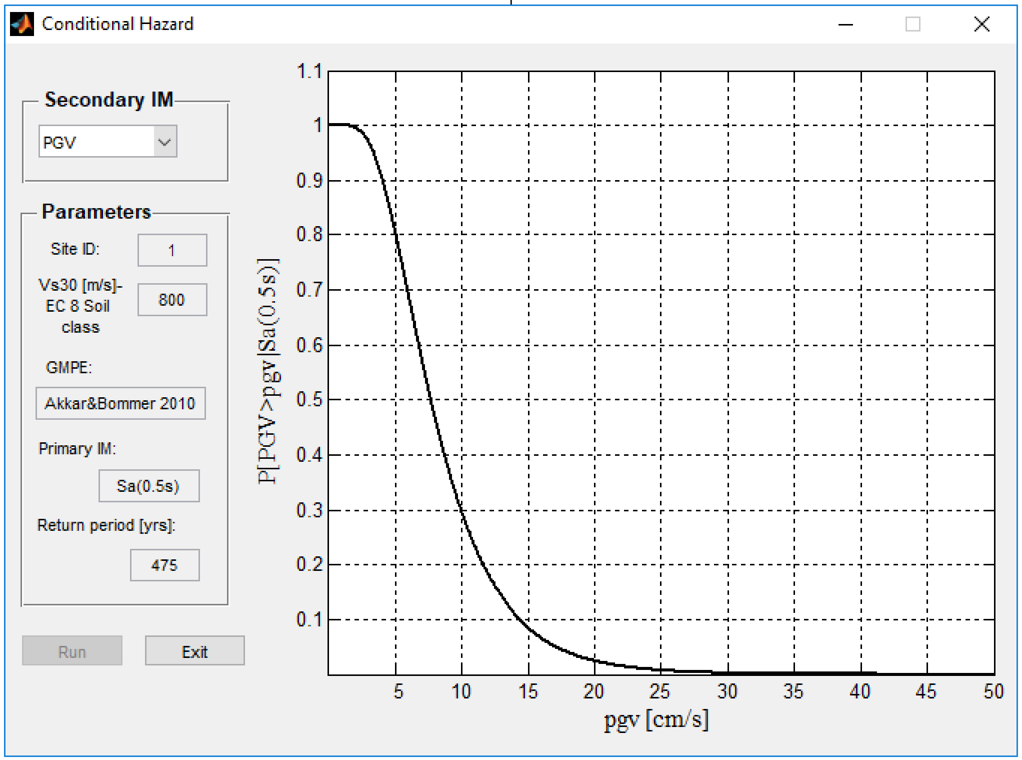
REgionAl, Single-SitE and Scenario-based Seismic hazard analysis

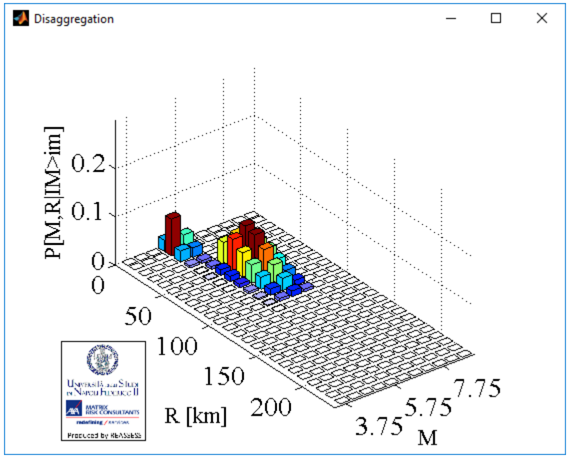
Distribution of peak ground velocity (PGV) conditional on the occurrence of a primary intensity measure (IM_1):

$$\underline{f_{\log PGV|IM_1}\left(\log pgv\right)} = \int_M \int_R \underline{f_{\log PGV|IM_1,M,R}\left(\log pgv|im_1,m,r\right)} \cdot \underline{f_{M,R|IM_1=im}\left(m,r\right)} \cdot dm \cdot dr$$



Distribution of log(PGV) given IM_1, magnitude and distance.

Disaggregation of magnitude and distance given the occurrence of IM_1.



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Goals for upcoming secondment (optimization of software implementation)

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Multisite PSHA which involves k pseudo spectral accelerations at k spectral periods (T) as intensity measures (IM) at n sites ($h_{1,n}$ is the inter-site distance between site *1* and site *n*)

The logs of IMsat the sites assumed to follow a multivariate normal distribution

Covariance matrix: $\Sigma = \Sigma_{INTER} + \Sigma_{INTRA}$

σ_{ii}: standard deviation of the intra-event residual of log(IM_i)

ρ: spatial cross-correlation between the intra-event residuals of the log of IMs

η: cross-correlation between the intra-event residuals of the log of IMs

n x *n* matrix (variance of the inter-event residual of log(IM_1))

n x *n* cross-correlation matrix of the inter-event residuals of log(IM_1) and log(IM_k)

$$\Sigma_{INTER} = \begin{bmatrix} \eta(T_1,T_1)\cdot\tau_1^2 & \eta(T_1,T_1)\cdot\tau_1^2 & \cdots & \eta(T_1,T_1)\cdot\tau_1^2 & \cdots & \eta(T_1,T_k)\cdot\tau_1\cdot\tau_k & \eta(T_1,T_k)\cdot\tau_1\cdot\tau_k & \cdots & \eta(T_1,T_k)\cdot\tau_1\cdot\tau_k \\ \eta(T_1,T_1)\cdot\tau_1^2 & \eta(T_1,T_1)\cdot\tau_1^2 & \cdots & \eta(T_1,T_1)\cdot\tau_1^2 & \cdots & \eta(T_1,T_k)\cdot\tau_1\cdot\tau_k & \eta(T_1,T_k)\cdot\tau_1\cdot\tau_k & \cdots & \eta(T_1,T_k)\cdot\tau_1\cdot\tau_k \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \eta(T_1,T_1)\cdot\tau_1^2 & \eta(T_1,T_1)\cdot\tau_1^2 & \cdots & \eta(T_1,T_1)\cdot\tau_1^2 & \cdots & \eta(T_1,T_k)\cdot\tau_1\cdot\tau_k & \eta(T_1,T_k)\cdot\tau_1\cdot\tau_k & \cdots & \eta(T_1,T_k)\cdot\tau_1\cdot\tau_k \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ & & & & \cdots & \eta(T_k,T_k)\cdot\tau_k^2 & \eta(T_k,T_k)\cdot\tau_k^2 & \cdots & \eta(T_k,T_k)\cdot\tau_k^2 \\ & & \text{symmetric} & & \cdots & \eta(T_k,T_k)\cdot\tau_k^2 & \eta(T_k,T_k)\cdot\tau_k^2 & \cdots & \eta(T_k,T_k)\cdot\tau_k^2 \\ & & & & \ddots & \vdots & \vdots & \ddots & \vdots \\ & & & & \cdots & \eta(T_k,T_k)\cdot\tau_k^2 & \eta(T_k,T_k)\cdot\tau_k^2 & \cdots & \eta(T_k,T_k)\cdot\tau_k^2 \end{bmatrix}$$

n x *n* spatial cross-correlation matrix of the intra-event residuals of log(IM_1)) at sites

n x *n* spatial cross-correlation matrix of the intra-event residuals of log(IM_1) and log(IM_k) at sites

$$\Sigma_{INTRA} = \begin{bmatrix} \sigma_1^2 & \rho(T_1,T_1,h_{1,2})\cdot\sigma_1^2 & \cdots & \rho(T_1,T_1,h_{1,n})\cdot\sigma_1^2 & \cdots & \rho(T_1,T_k,h_{1,1})\cdot\sigma_1\cdot\sigma_k & \rho(T_1,T_k,h_{1,2})\cdot\sigma_1\cdot\sigma_k & \cdots & \rho(T_1,T_k,h_{1,n})\cdot\sigma_1\cdot\sigma_k \\ \rho(T_1,T_1,h_{2,1})\cdot\sigma_1^2 & \sigma_1^2 & \cdots & \rho(T_1,T_1,h_{2,n})\cdot\sigma_1^2 & \cdots & \rho(T_1,T_k,h_{2,1})\cdot\sigma_1\cdot\sigma_k & \rho(T_1,T_k,h_{2,2})\cdot\sigma_1\cdot\sigma_k & \cdots & \rho(T_1,T_k,h_{2,n})\cdot\sigma_1\cdot\sigma_k \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \rho(T_1,T_1,h_{n,1})\cdot\sigma_1^2 & \rho(T_1,T_1,h_{n,2})\cdot\sigma_1^2 & \cdots & \sigma_1^2 & \cdots & \rho(T_1,T_k,h_{n,1})\cdot\sigma_1\cdot\sigma_k & \rho(T_1,T_k,h_{n,2})\cdot\sigma_1\cdot\sigma_k & \cdots & \rho(T_1,T_k,h_{n,n})\cdot\sigma_1\cdot\sigma_k \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ & & & & \cdots & \sigma_k^2 & \rho(T_k,T_k,h_{1,2})\cdot\sigma_k^2 & \cdots & \rho(T_k,T_k,h_{1,n})\cdot\sigma_k^2 \\ & & \text{symmetric} & & \cdots & \rho(T_k,T_k,h_{2,1})\cdot\sigma_k^2 & \sigma_k^2 & \cdots & \rho(T_k,T_k,h_{2,n})\cdot\sigma_k^2 \\ & & & & \ddots & & & & \vdots \\ & & & & \cdots & & & & \sigma_k^2 \end{bmatrix}$$

n x *n* spatial cross-correlation matrix of the intra-event residuals of log(IM_k)) at sites

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