NGGM PERSPECTIVES FROM THE HERITAGE OF GRAVITATIONAL SEISMOLOGY

Gabriele Cambiotti, Anna Maria Marotta and Roberto Sabadini

https://sites.unimi.it/grav_seismology

esa

UNIVERSITÀ DEGLI STUDI DI MILANO

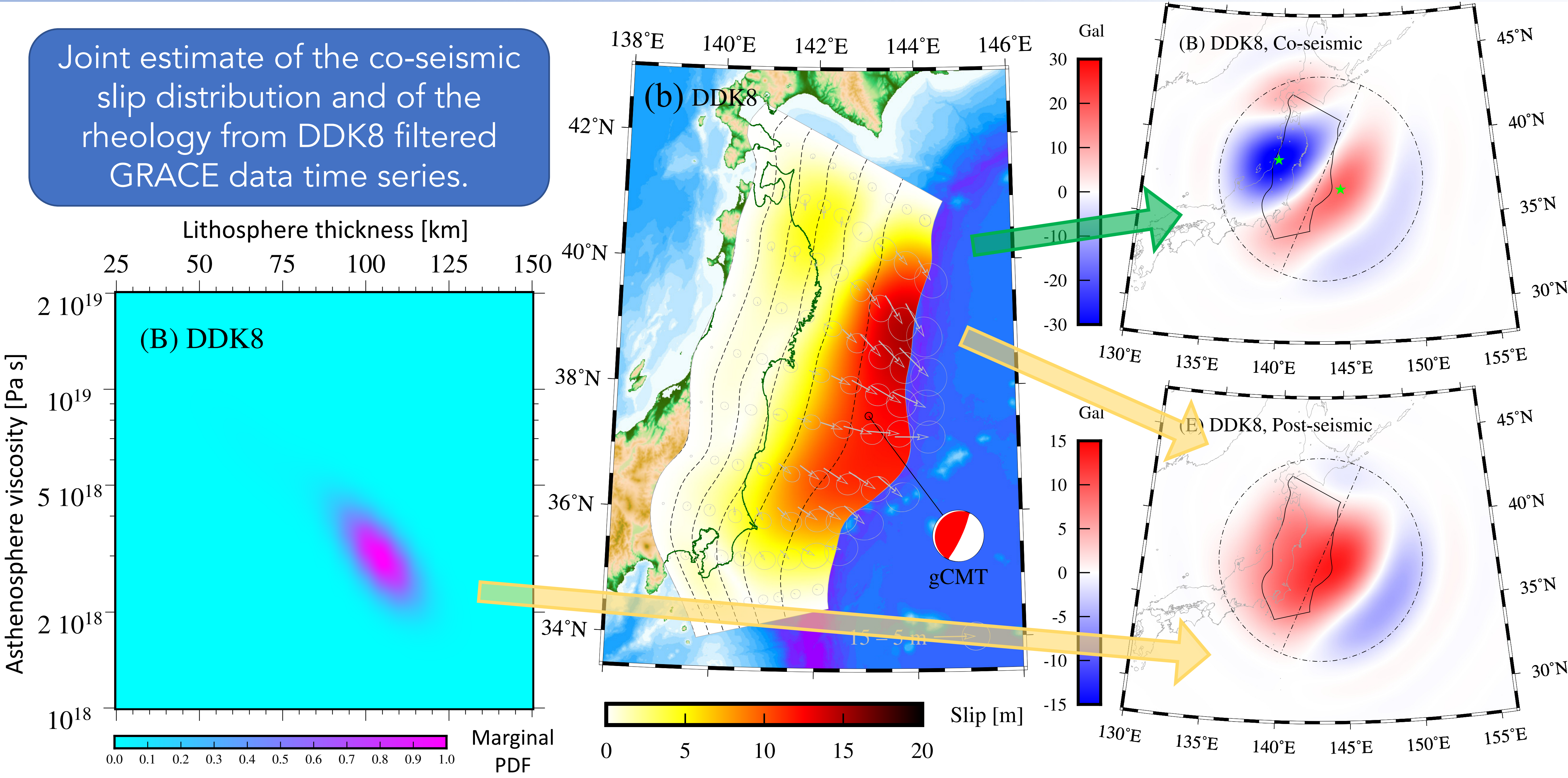
GIS

ThalesAlenia Space
a Thales / Leonardo company

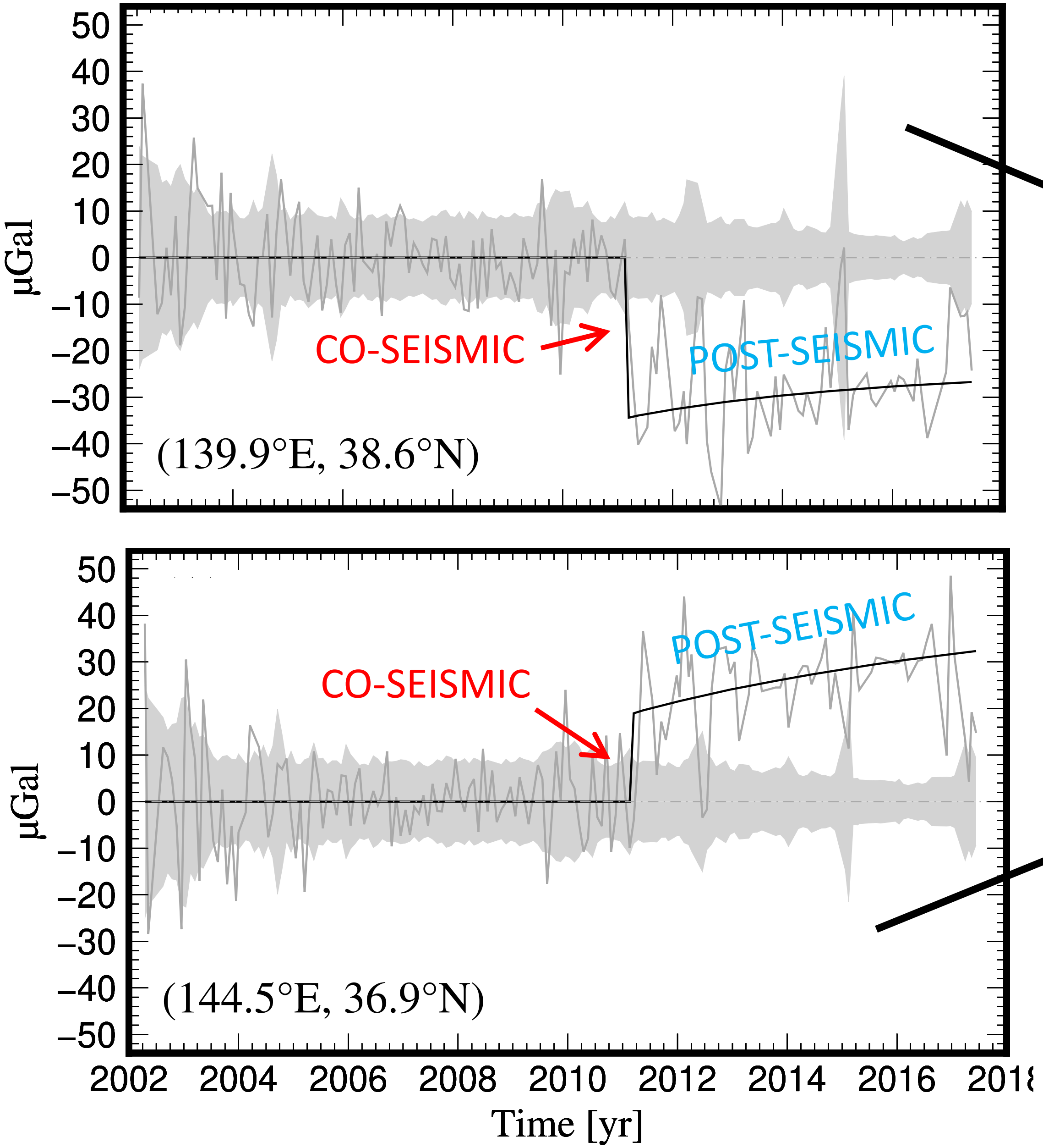
The 2011 Tohoku earthquake and GRACE data

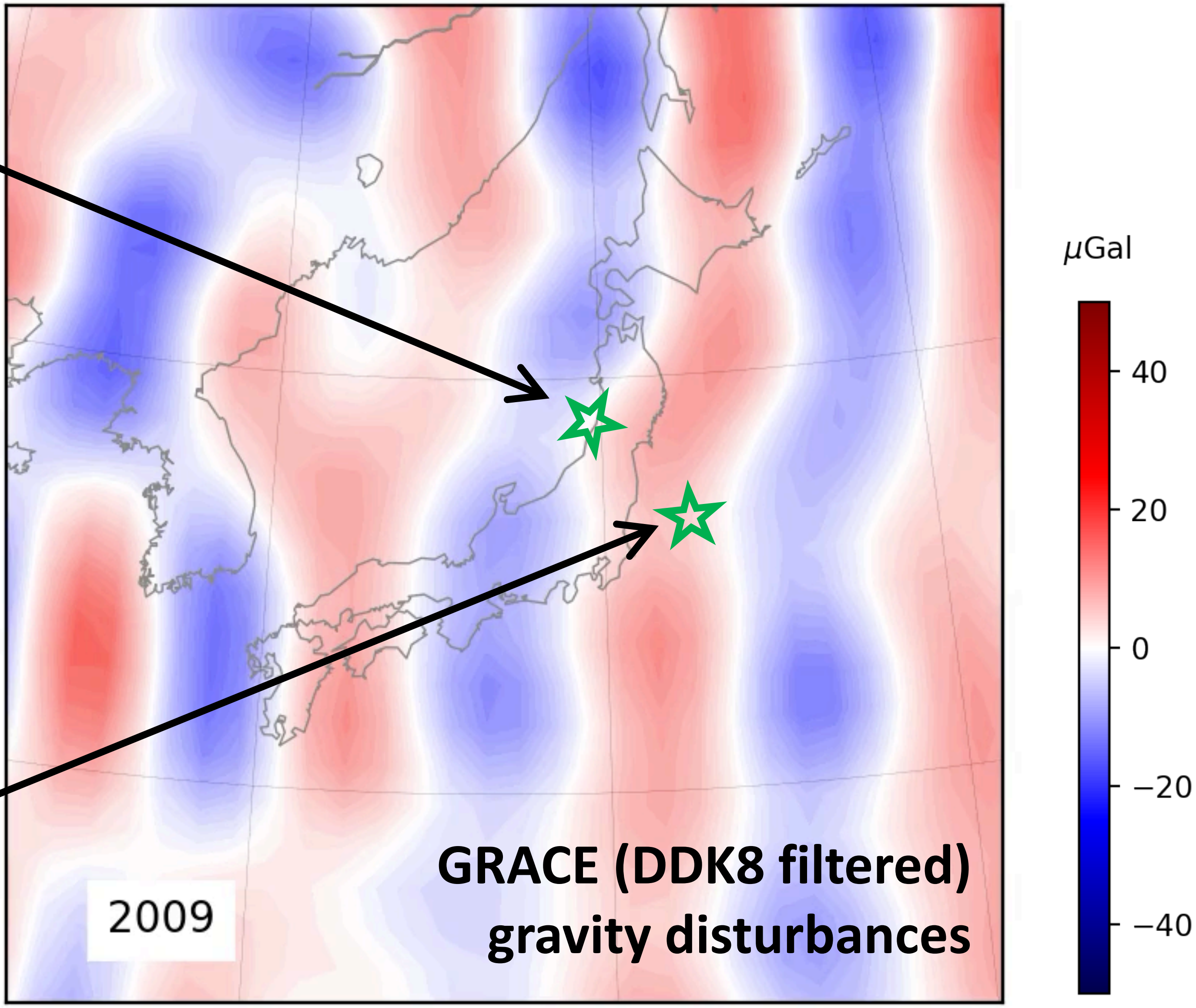
UNIVERSITÀ DEGLI STUDI DI MILANO

Joint estimate of the co-seismic slip distribution and of the rheology from DDK8 filtered GRACE data time series.

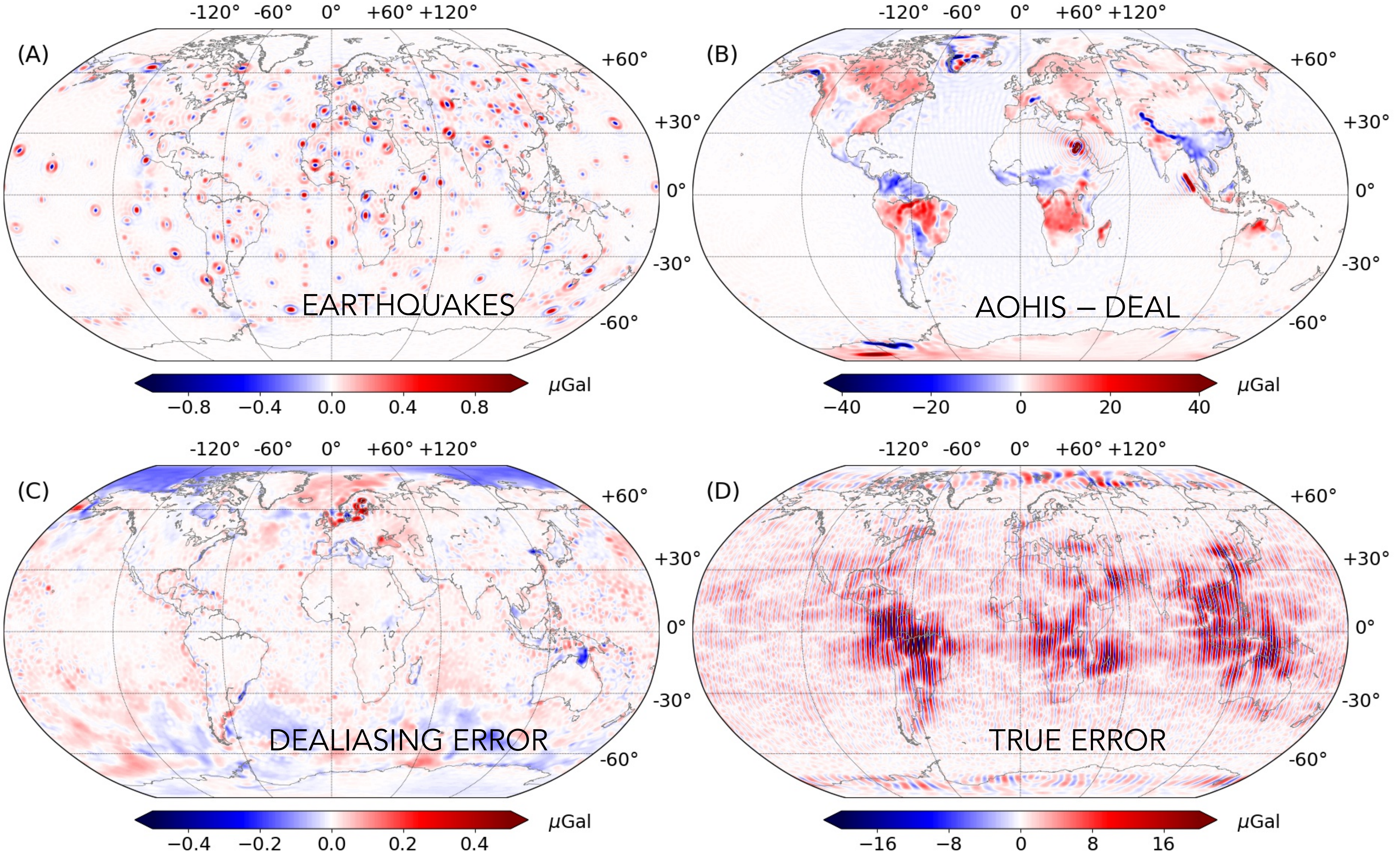


The 2011 Tohoku earthquake and GRACE data





NGGM SYNTHETIC GRAVITI DATA



NGGM SYNTHETIC DATA

=

EIGEN 6c4
static gravity field

+

AOHIS – DEAL
ESA Earth System Model

+

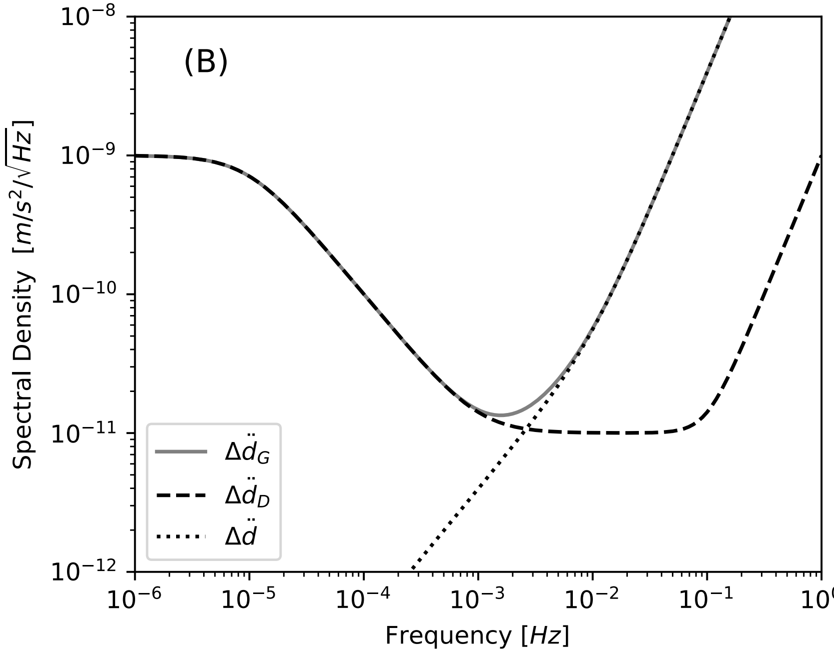
EARTHQUAKE
gravity signature

+

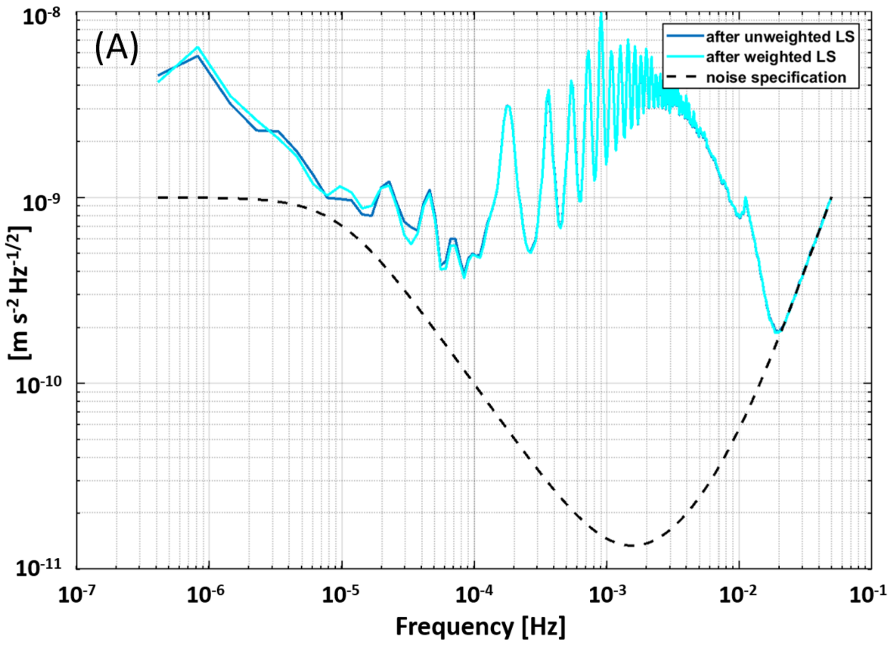
OBSERVATION ERROR

NGGM SYNTHETIC GRAVITI DATA

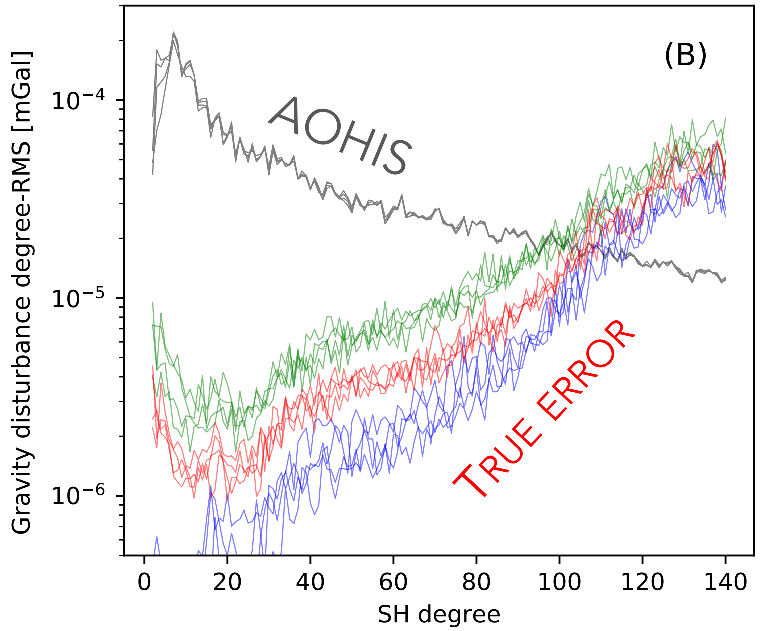
MEASUREMENT NOISE



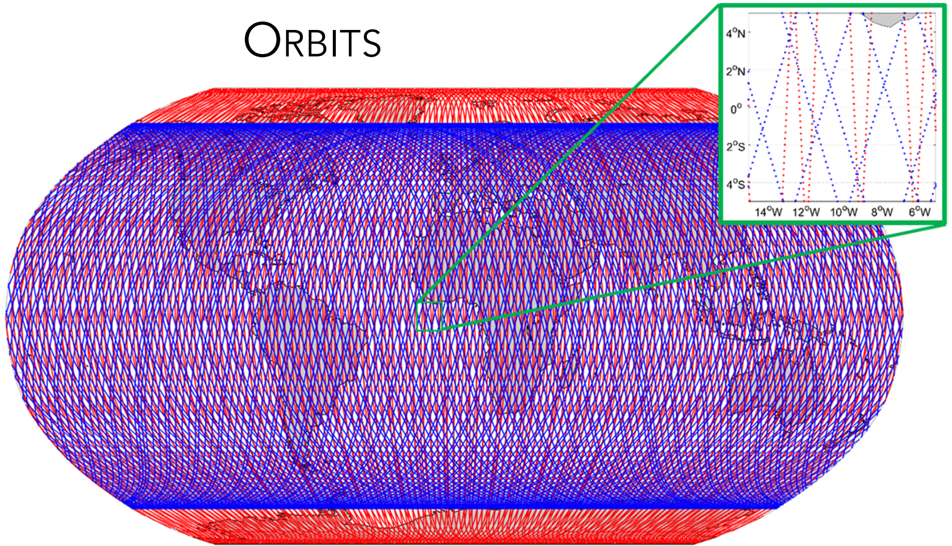
SPECTRAL DENSITY OF THE RESIDUALS



DEGREE – ROOT MEAN SQUARE



ORBITS



Static gravity field recovered over 28-day periods

Maximum spherical harmonic degree and order 140

The true error is mainly due to the assumption that the gravity field is static over the 28-day periods, but for frequencies larger than 0.02 Hz.

The comparison between the degree-RMS of the true error and of the geophysical signals does not provide an accurarte assessment of the spatial resolution of the gravity mission.

A REALISTIC AND SIMPLE WAY OF DETECTING EARTHQUAKES

We assume to know the spatial and temporal pattern of the earthquake gravity signature and we fit this pattern to the synthetic data by estimating a **scaling factor** (and its uncertainity)

DISCRIMINATION. We also fit **a simple AOHIS – DEAL model (linear trends and periodic signals)** in order to check the possibility of discriminating the earthquake signatures from the signatures by other physical process.

DATA = STATIC modelling + AOHIS – DEAL modelling + SCALING FACTOR × QUAKE signature + ERROR observational + modelling

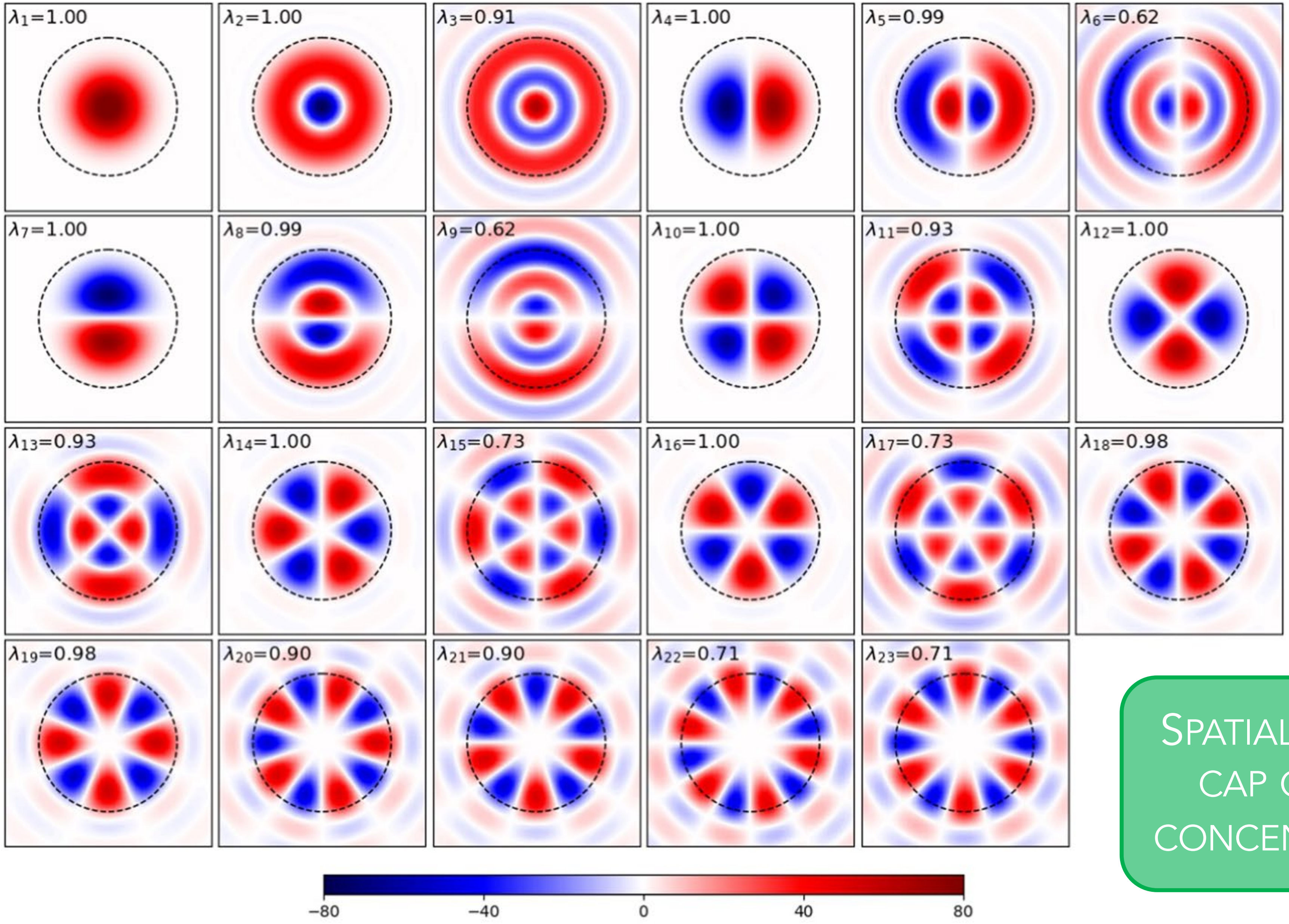
$$\mathbf{g}_{\mathrm{obs}}(t) = \boxed{\mathbf{s}} + \mathbf{K}(t)\boxed{\mathbf{m}} + \boxed{\gamma}\,\mathbf{q}(t) + \boxed{\boldsymbol{\epsilon}(t)} \longrightarrow N(\mathbf{0}, \alpha\,\mathbf{E})$$

SENSITIVITY. We assume to know also the AOHIS – DEAL model. We discriminate the earthquake signature only from the static gravity field (and the observational error).

DATA − AOHIS – DEAL ESAESM = STATIC modelling + SCALING FACTOR × QUAKE signature + ERROR observational

$$\mathbf{g}_{\mathrm{obs}}(t) - \mathbf{g}_{\mathrm{aohis}}(t) = \boxed{\mathbf{s}} + \boxed{\gamma}\,\mathbf{q}(t) + \boxed{\boldsymbol{\epsilon}(t)} \longrightarrow N(\mathbf{0}, \alpha\,\mathbf{E})$$

Earthquake detection



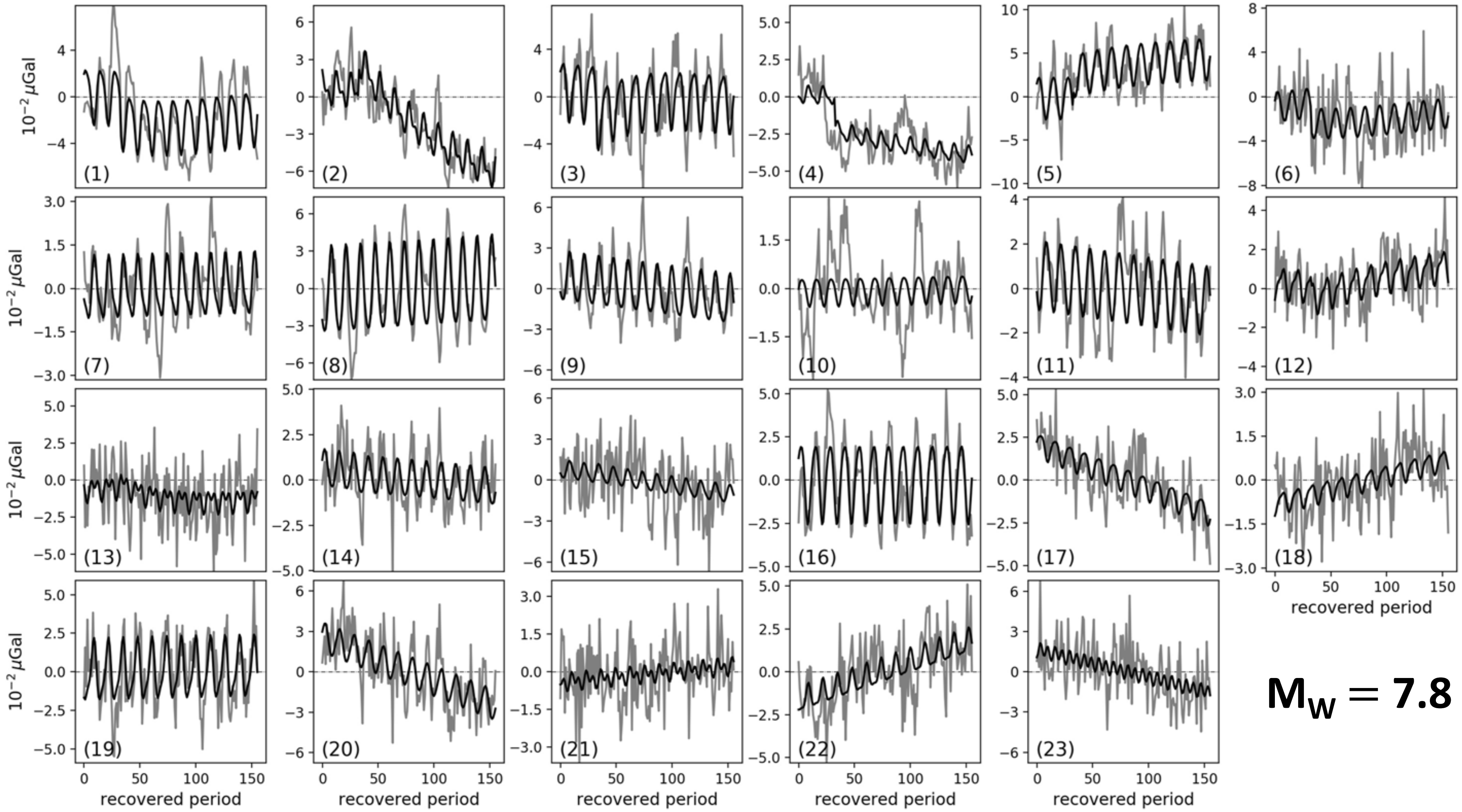
$(L+1)^2 = 19981$

time series of Stokes coefficients

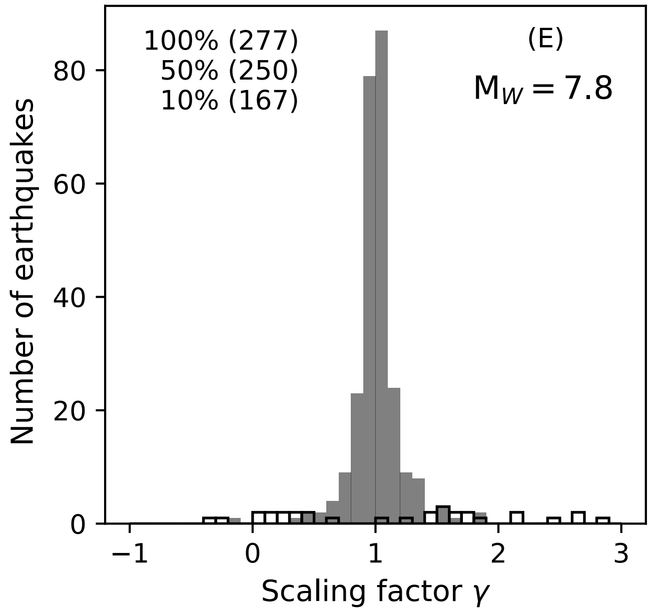
23 time series of Slepian functions

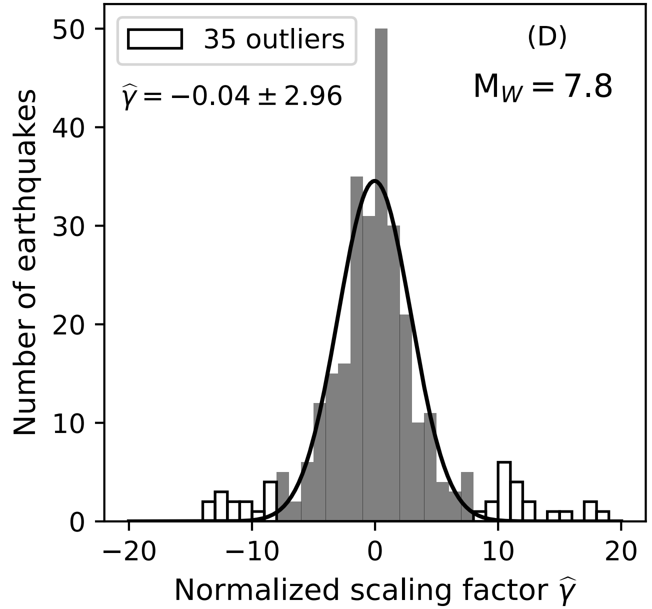
Spatial localization in spherical cap of 4° using 23 optimally concentrated Slepian functions

EARTHQUAKE DETECTION



$M_W = 7.8$



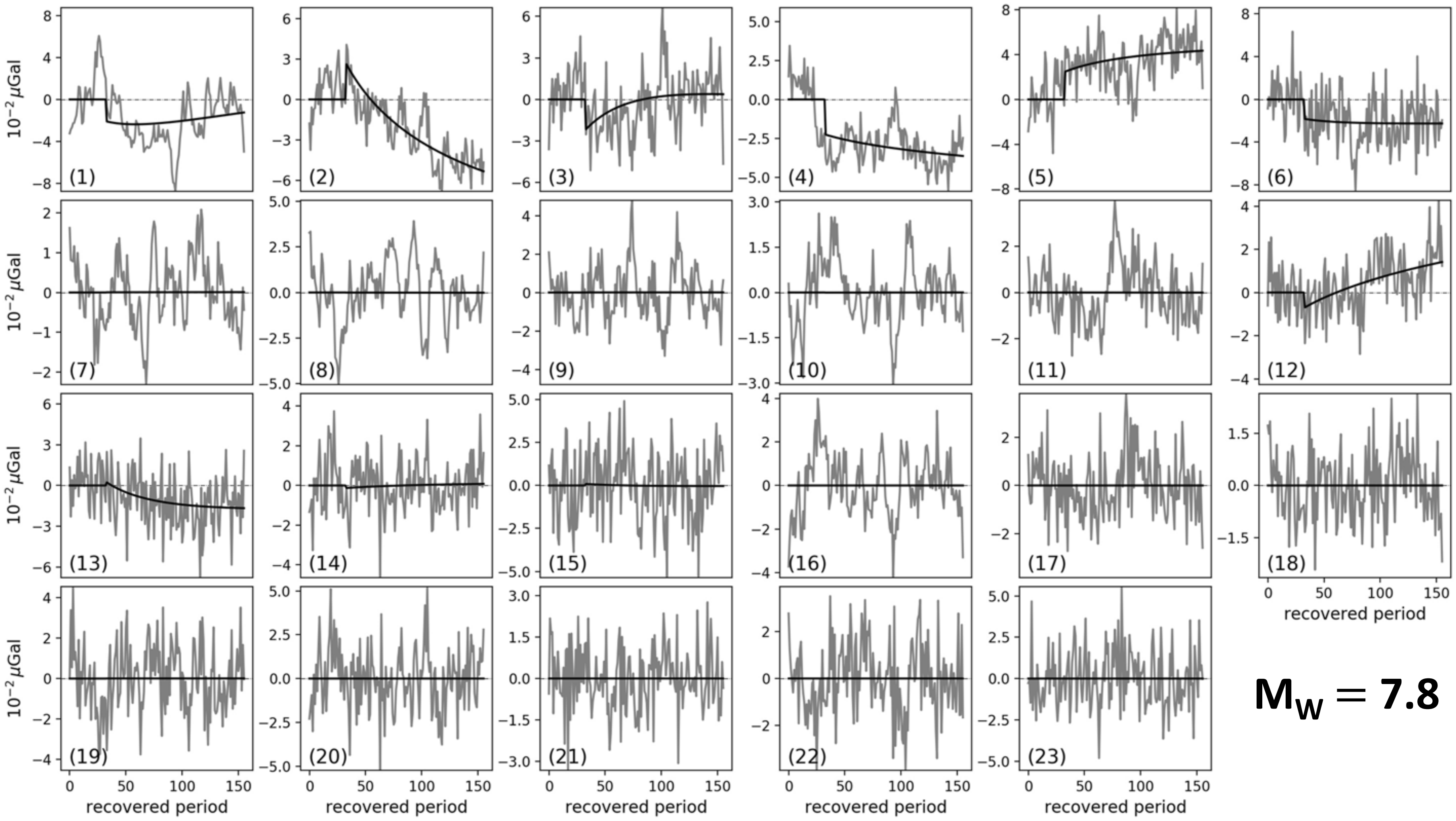


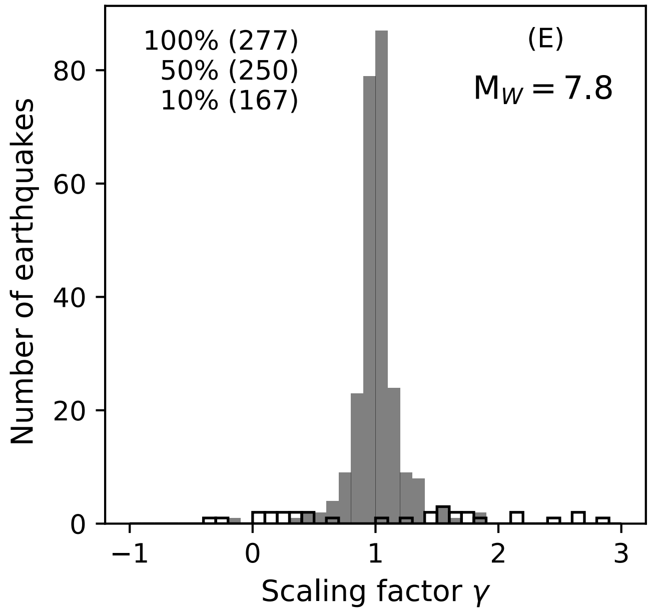
DISCRIMINATION

We also fit **a simple AOHIS – DEAL model**

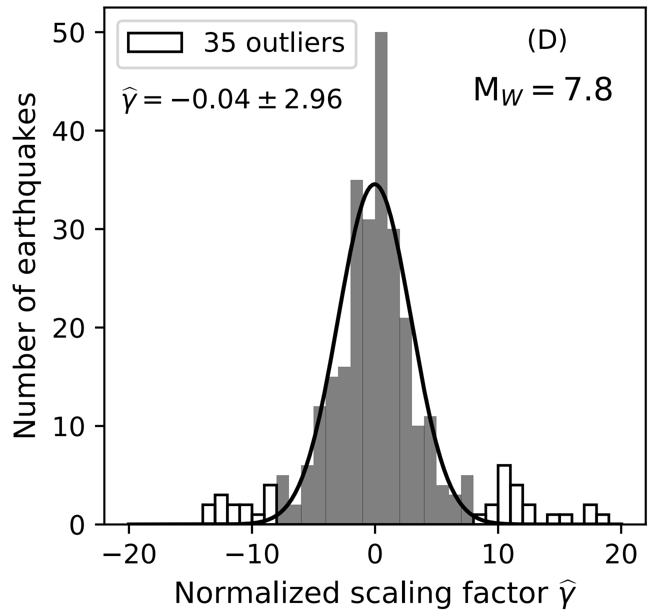
AOHIS – DEAL modelling + SCALING FACTOR × QUAKE signature

EARTHQUAKE DETECTION





$M_W = 7.8$

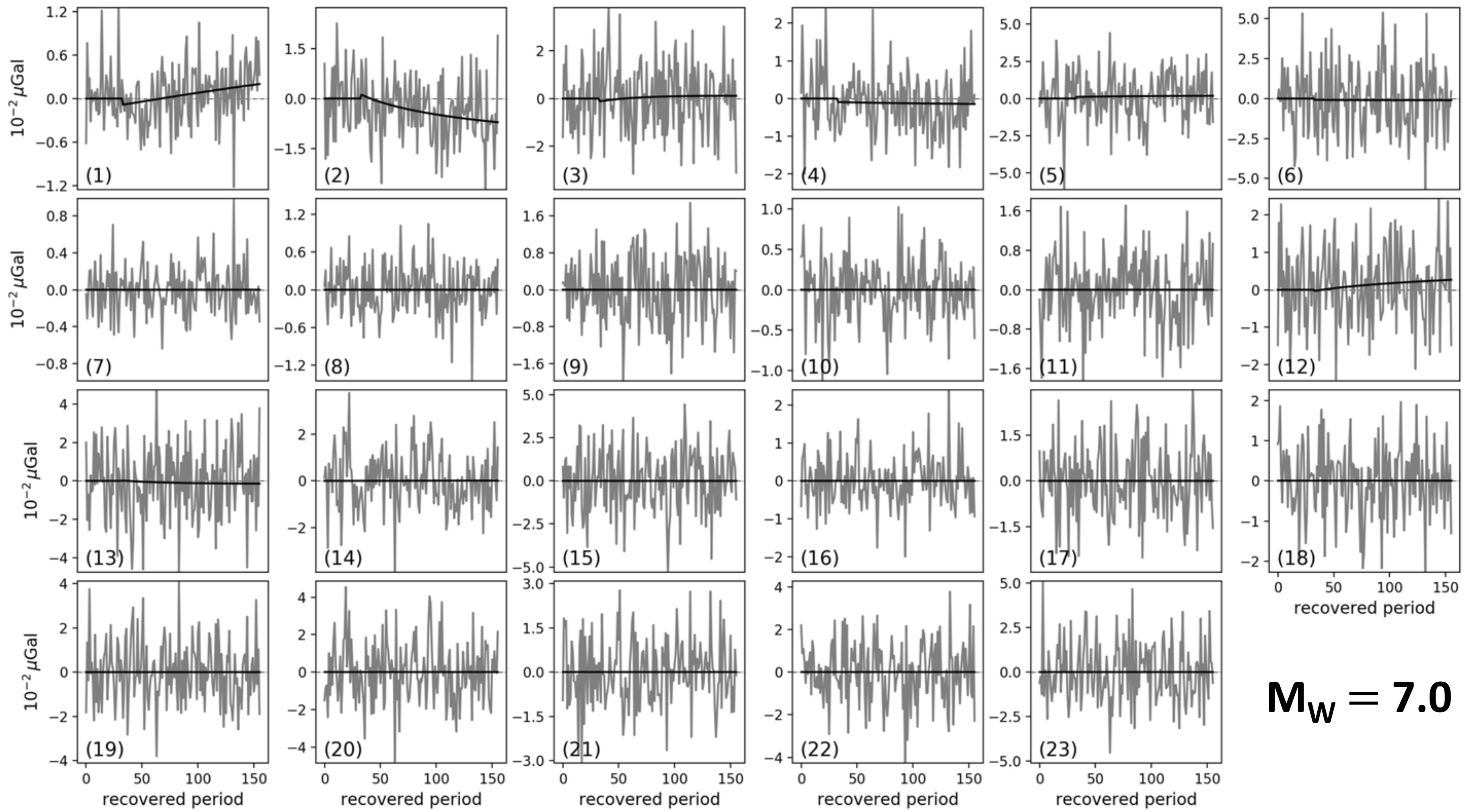


DISCRIMINATION

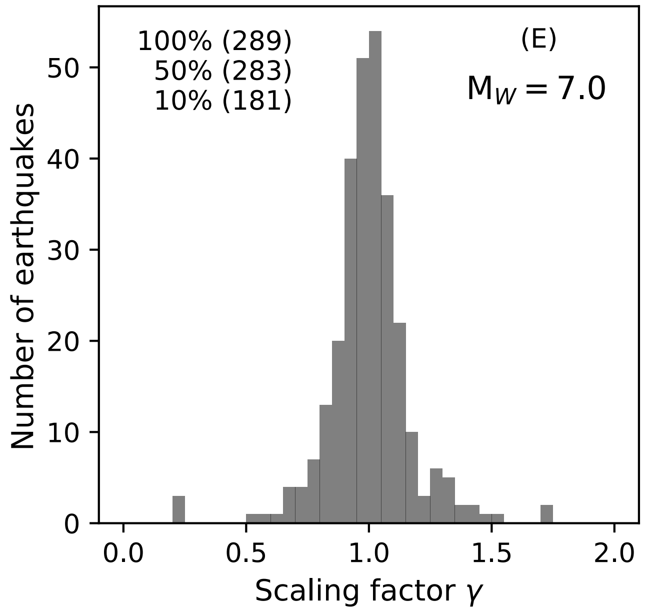
We also fit **a simple AOHIS – DEAL model**

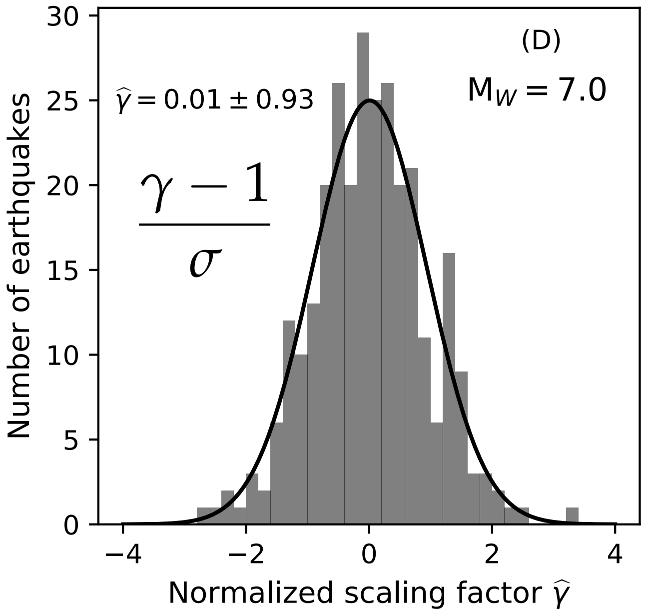
AOHIS – DEAL modelling + SCALING FACTOR × QUAKE signature

EARTHQUAKE DETECTION



$\mathbf{M_W = 7.0}$





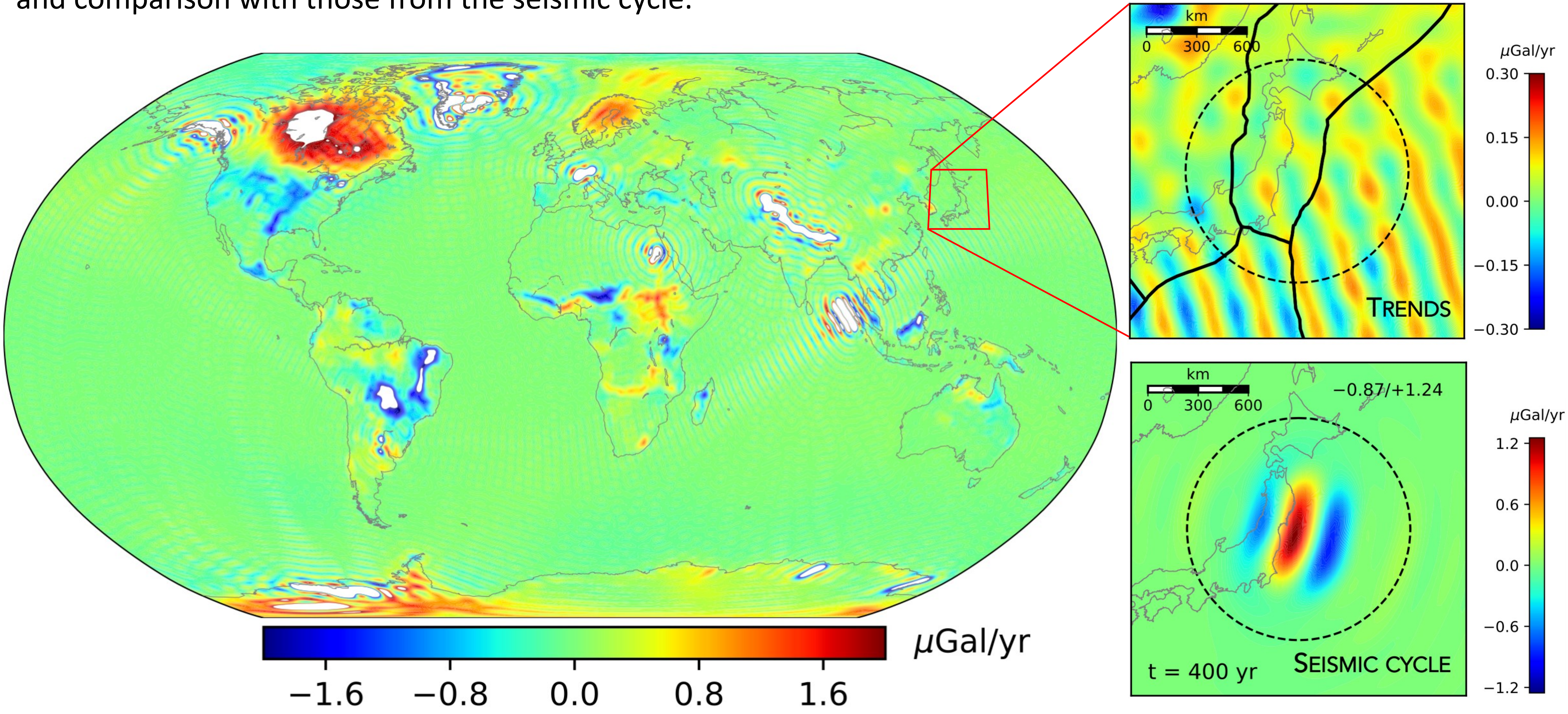
SENSITIVITY

We assume to know also the AOHIS – DEAL model

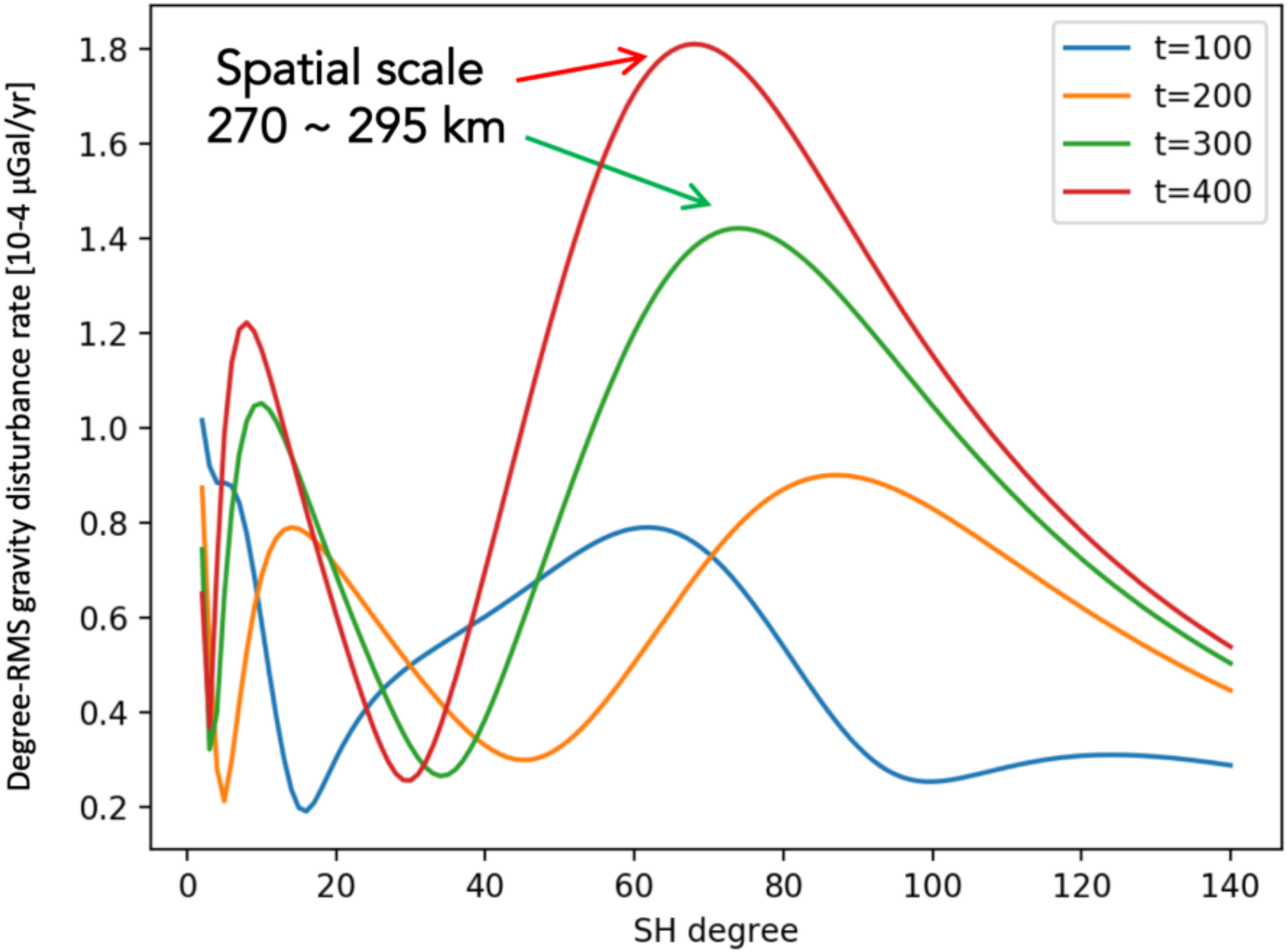
SCALING FACTOR × QUAKE signature

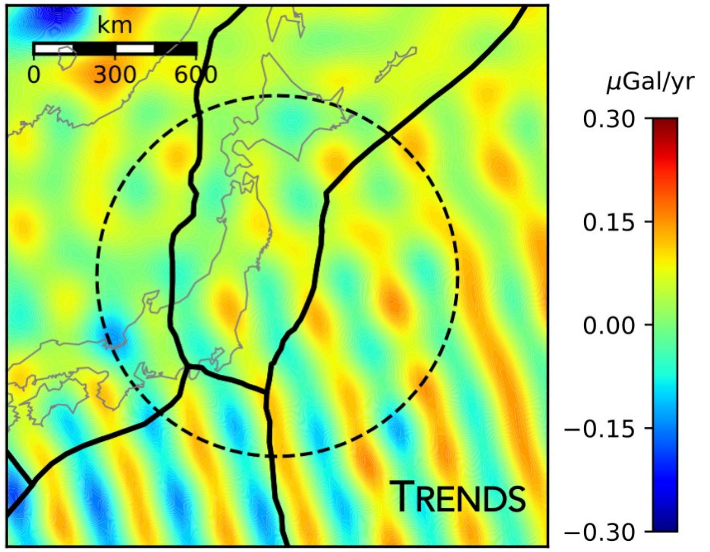
INTER-SEISMIC GRAVITY RATES

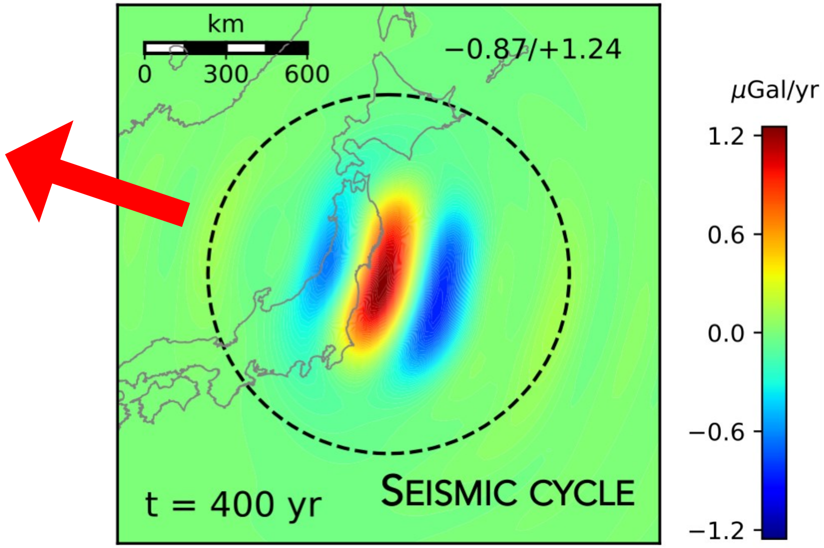
Linear trends from the updated ESA Earth System Model (AOHIS contributions) and comparison with those from the seismic cycle.



INTER-SEISMIC GRAVITY RATES





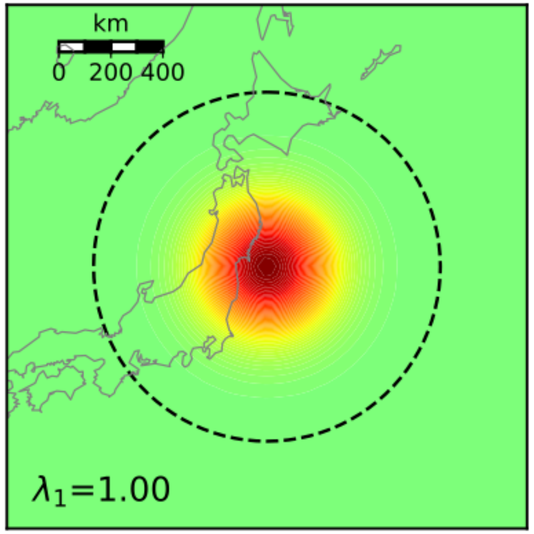


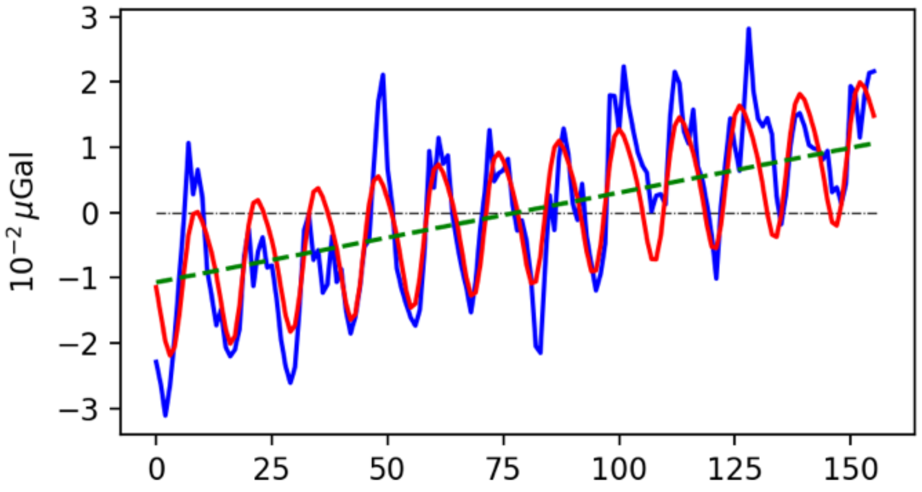
INTER-SEISMIC GRAVITY RATES

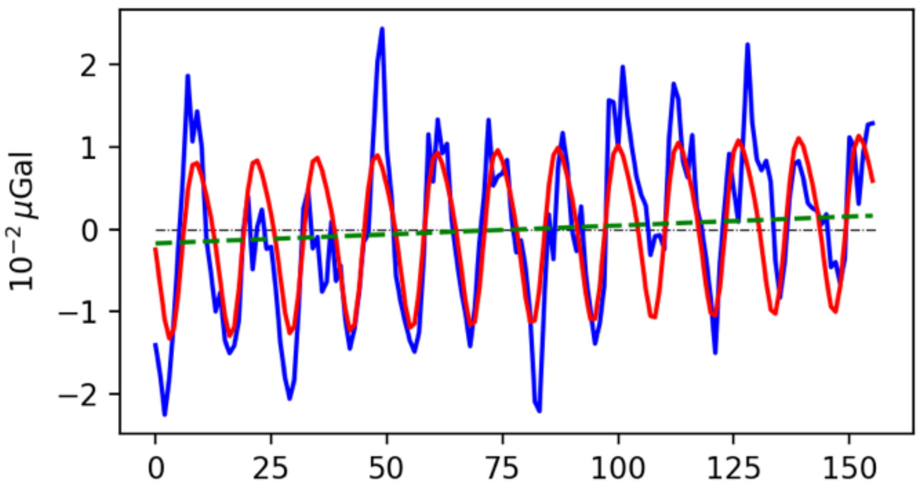
SPATIAL PATTERN
(Slepian function)

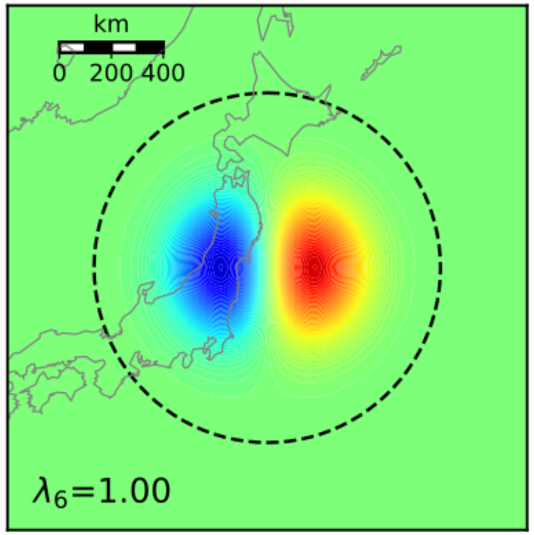
10^{18} Pa s

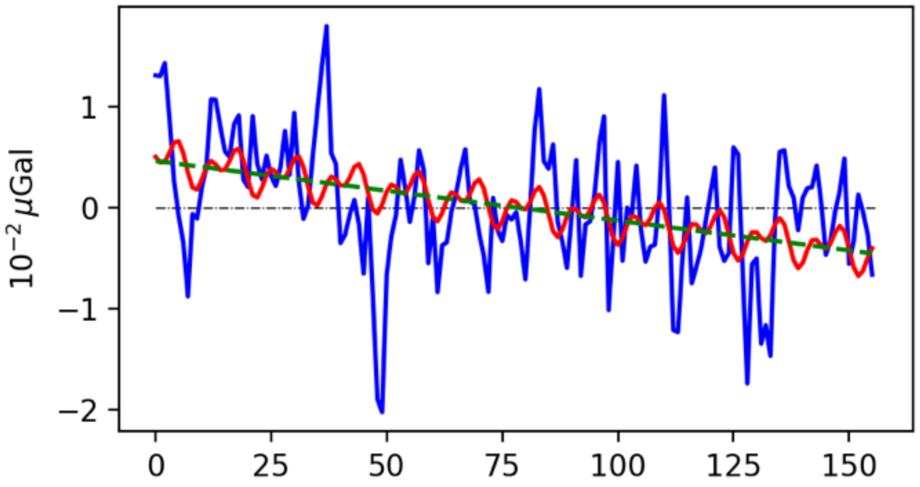
10^{19} Pa s

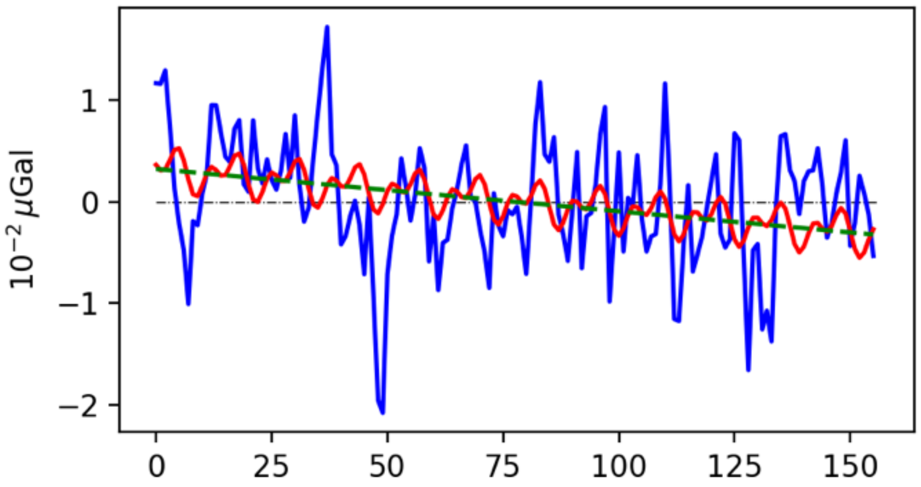








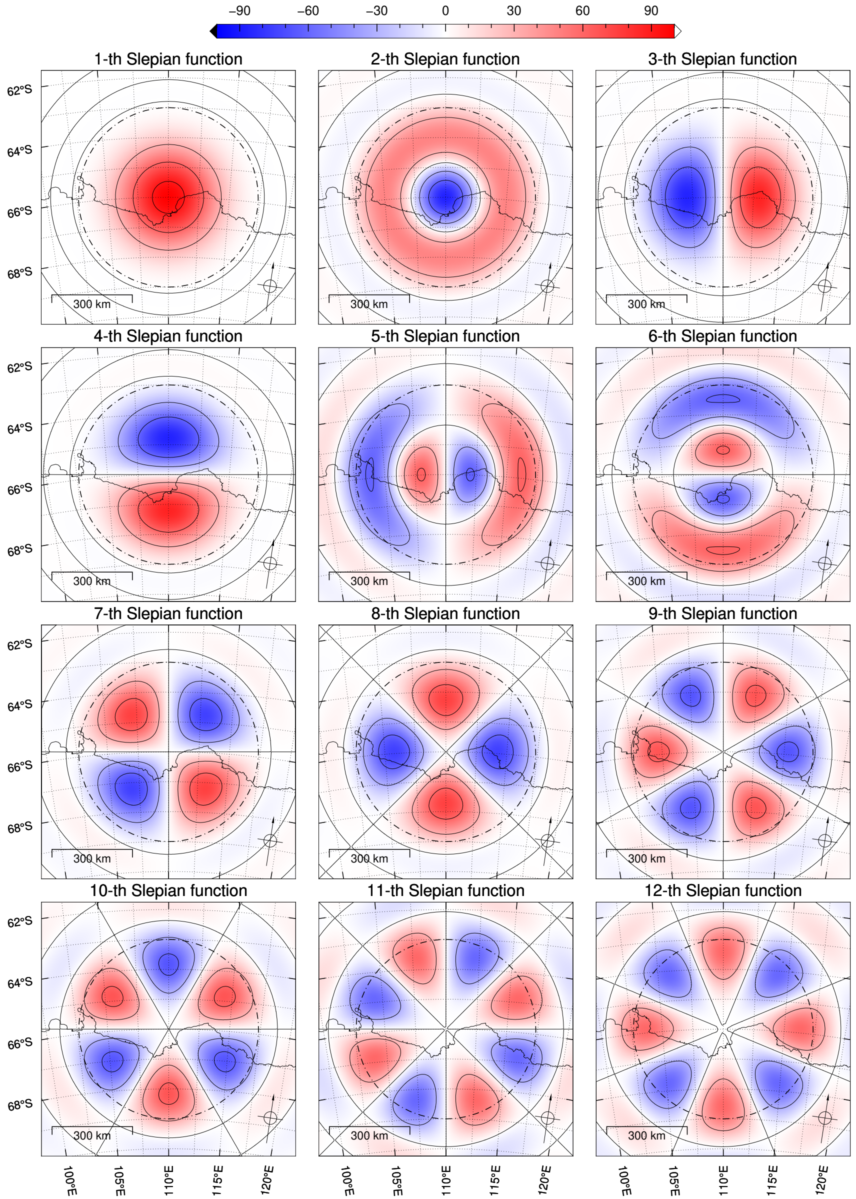




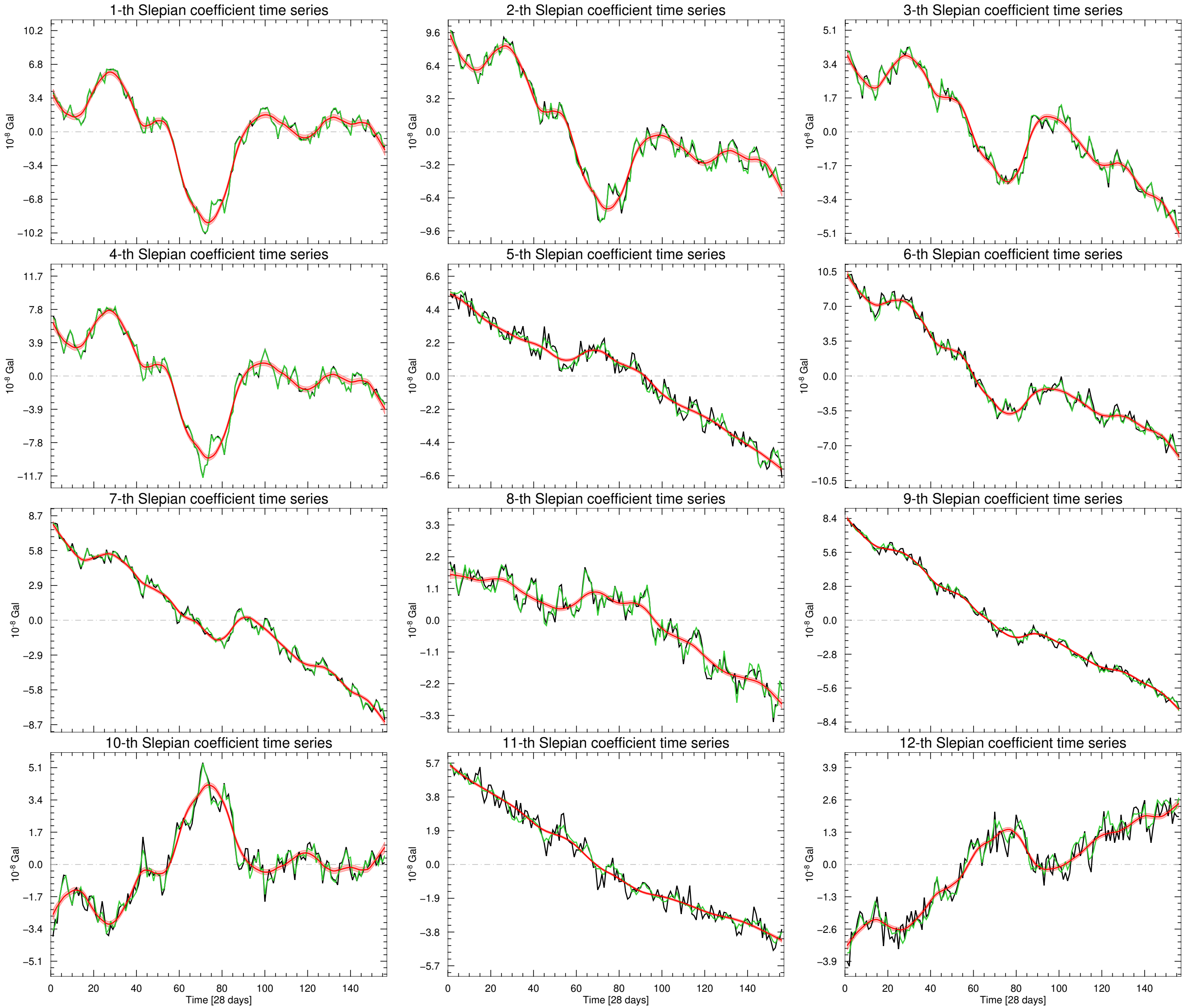
SPATIO-TEMPORAL NGGM DATA ANALAYSIS

UNIVERSITÀ DEGLI STUDI DI MILANO

SLEPIAN FUNCTIONS



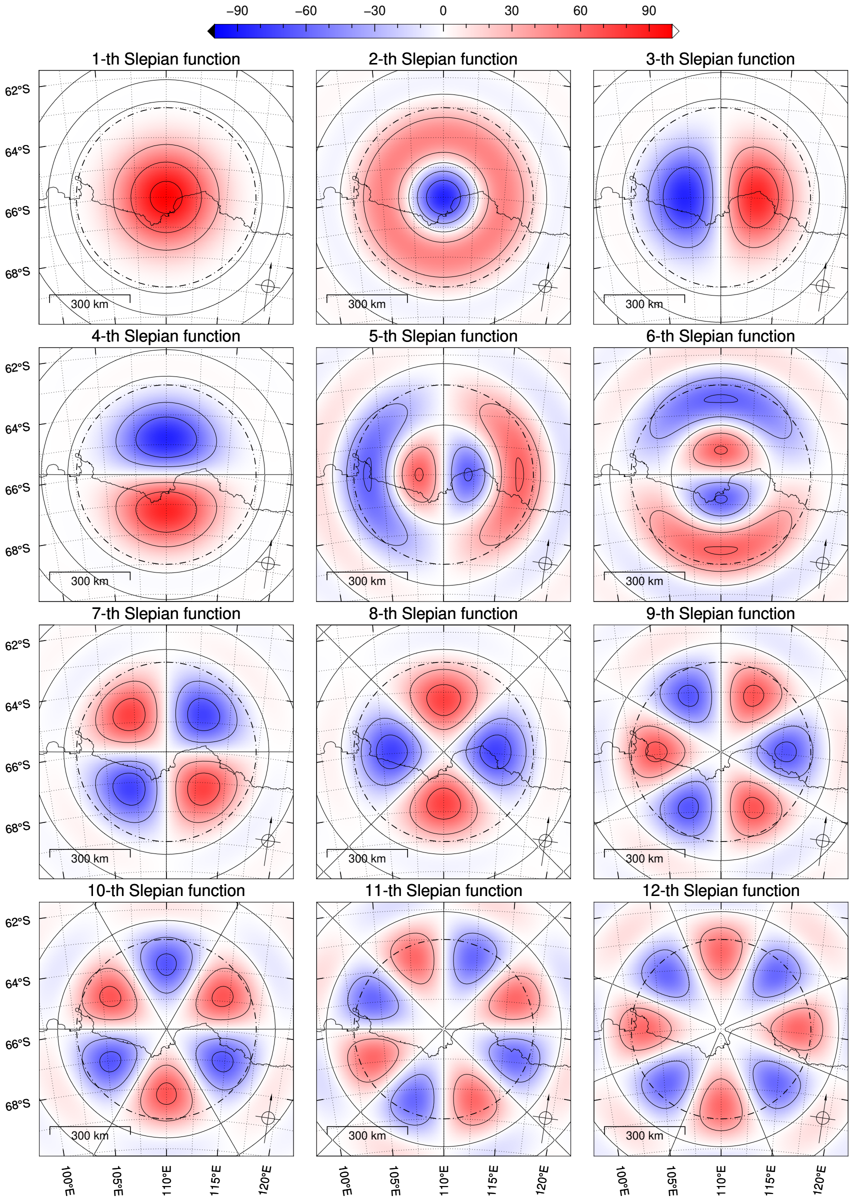
SLOW VARYING TRENDS (CYCLIC CONTRIBUTIONS REMOVED)



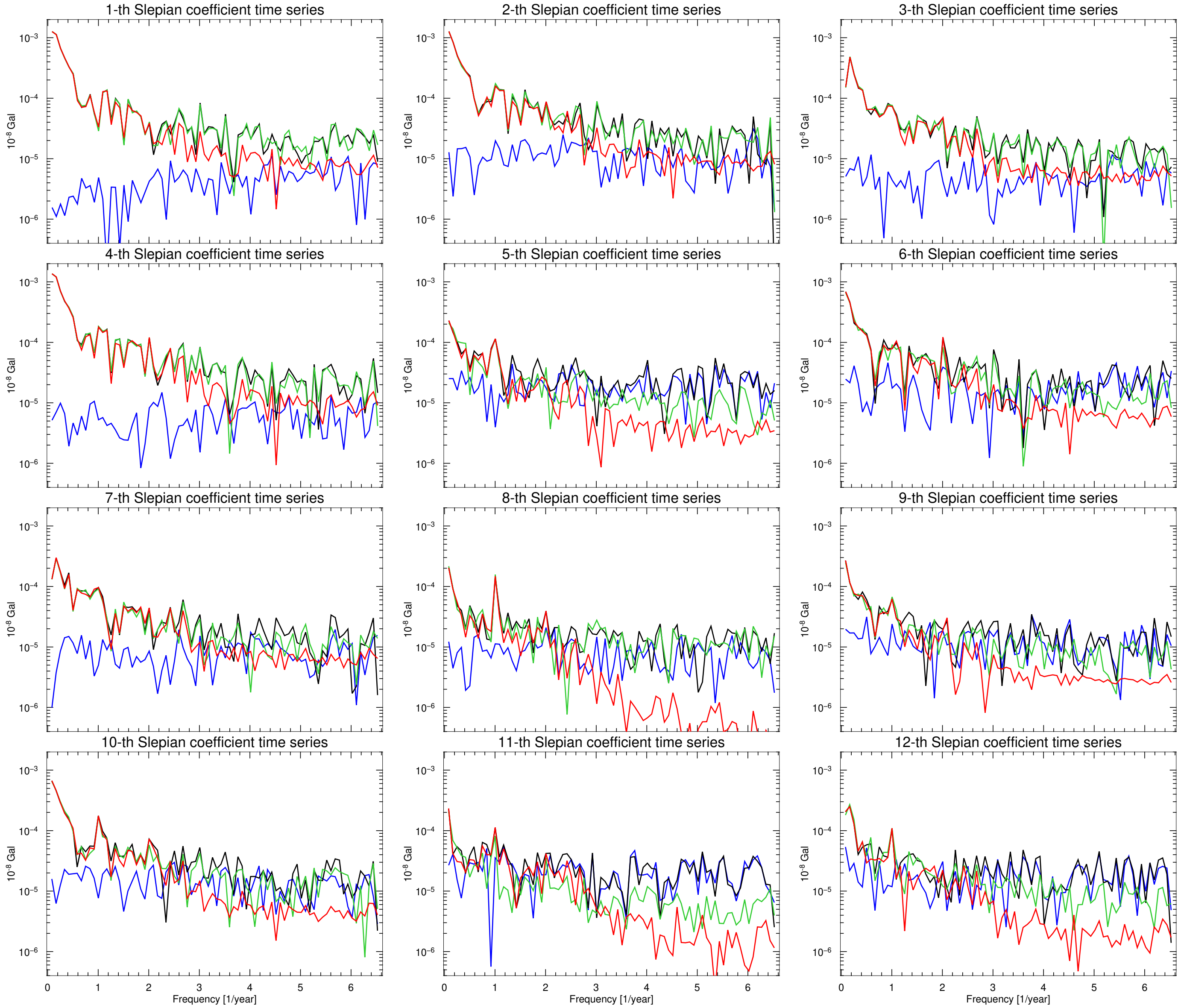
SPATIO-TEMPORAL NGGM DATA ANALAYSIS

UNIVERSITÀ DEGLI STUDI DI MILANO

SLEPIAN FUNCTIONS



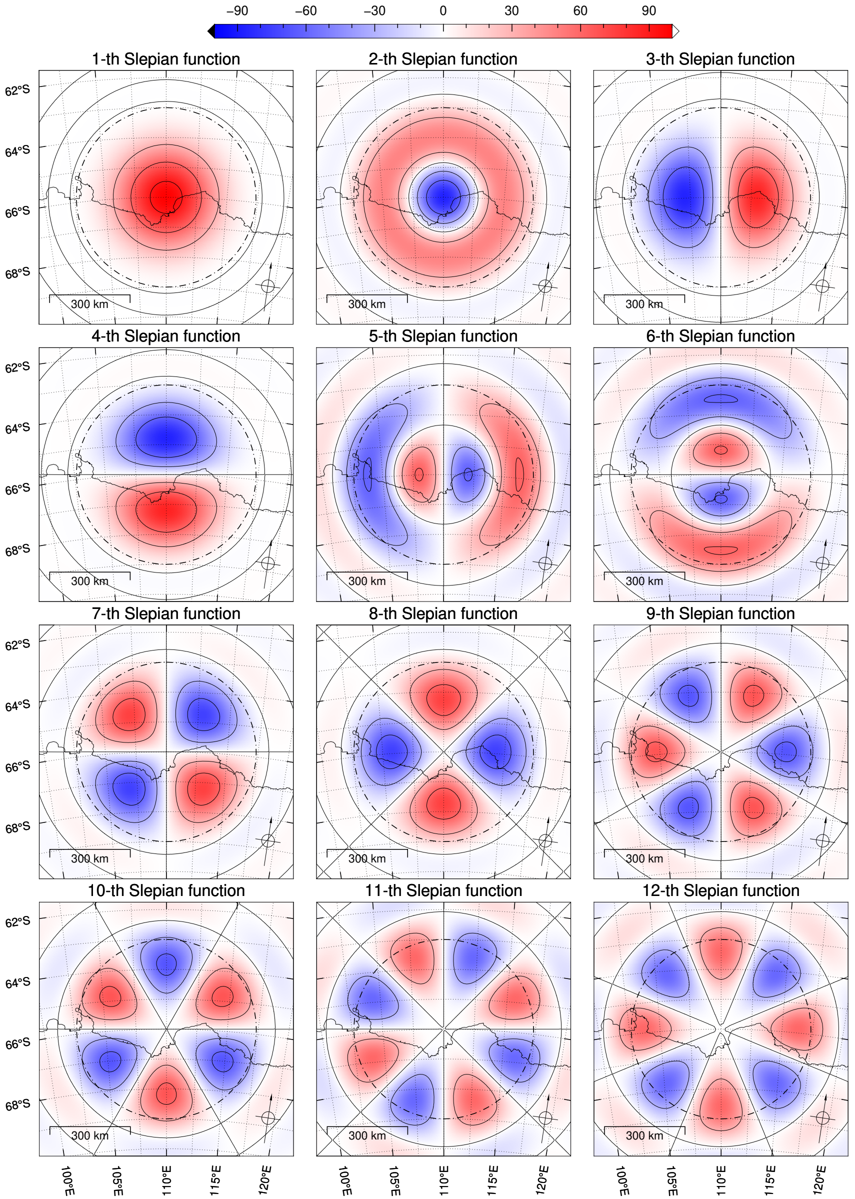
OBSERVED = INPUT + ERROR ≈ MODELLED

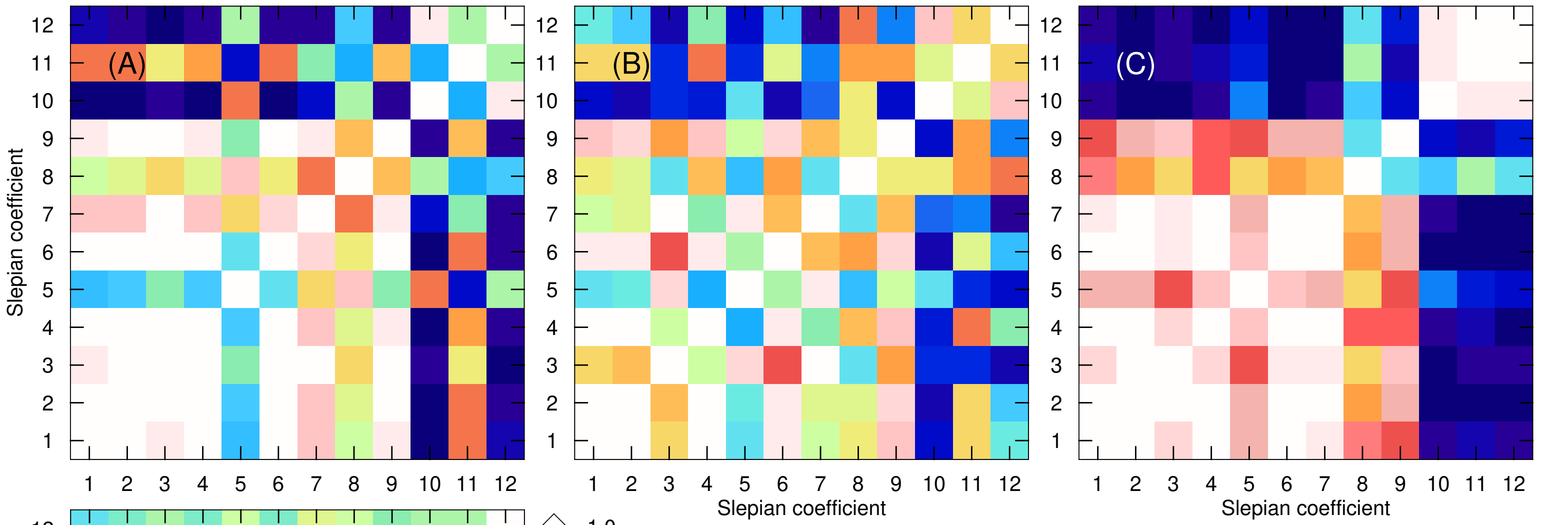


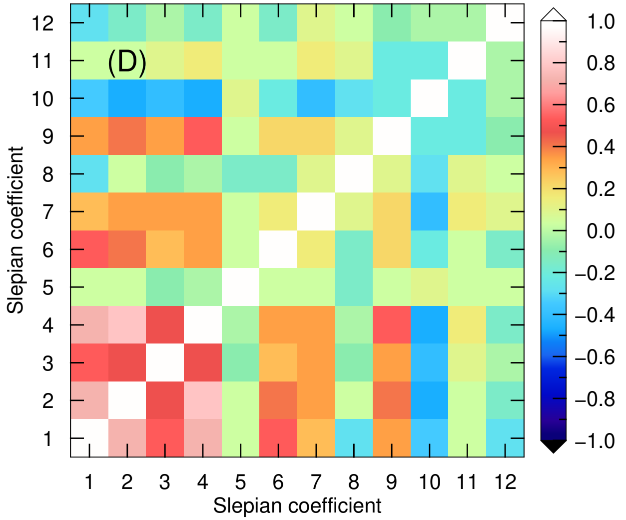
Spatio-temporal NGGM data analaysis

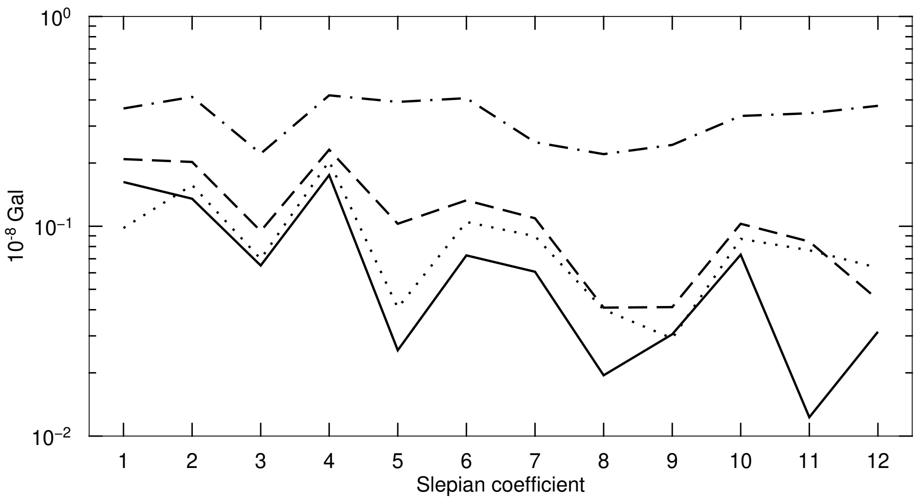
UNIVERSITÀ DEGLI STUDI DI MILANO

Slepian functions









Correlation matrices of the (A) trend, (B) annual and (C) semi-annual components and of the (D) error structure obtained by the likelihood optimization. (E) Standard deviations of the trend, annual and semiannual components and of the error structure (solid, dashed, dotted and dashdotted lines, respectively).

Scientific Readiness Level (SLR) 5

End-to-End Performance simulations

An end-to-end measurement performance simulator is developed, tested and validated using realistic and / or actual measurements. The performance model used is applicable to a predefined range of conditions (including realistic uncertainties of natural and observational nature) and can be used to address the needs originating from the science requirements in an end-to-end manner. Retrieval algorithms applicable for a realistic range of error sources (both geophysical and technical) are demonstrated against a pre-defined performance metric reflecting observation and measurement requirements.

the mass variation measurements.

Is an E2E simulator in place and are the most important processes and input parameters (including uncertainty estimates) properly represented? Yes.

Is an error propagation model in place allowing the rigorous computation of uncertainties (e.g. accounting for co-variant error effects) for measurements and observations? Yes, although the estimated covariance must be still to be validated aginst the true error.

Has a set of realistic test scenarios been established and are they scientifically justified? Yes and no. More work can be done to refine the best scenario in relation with the user needs and strategies.

Is the simulator tested and validated and applied for the predefined set of scenarios? Yes.

Are all assumptions of the performance simulator documented and critically discussed? Yes and no. More tests should be done.

Is there a demonstrated interest of users? Yes.

Is there a first evaluation of (simulated or measured data) in applications? Yes.

NGGM as MAGIC, OBJECTIVE 8: to support monitoring applications of geo-hazards (including Mw 8 earthquakes and Mw 7 as target) over few hundred kilometres areas and deep interior properties and dynamics over large spatial scales (e.g. 6.000 km) for estimating Body tides at millimetre accuracy.