Simone Mancini,[1,2] Margarita Segou,[1] Max Werner[2]

[1] British Geological Survey, The Lyell Centre, Edinburgh (UK)

[2] School of Earth Sciences, University of Bristol (UK)

REDUCING EARTHQUAKE FORECAST UNCERTAINTY IN THE REAL WORLD

"BUILDING RESILIENCE TO GEOHAZARDS IN THE FACE OF UNCERTAINTY"

The Geological Society

London, 7th - 8th September 2017

PHASE 1

24th August (Mw 6.0)

26th October

PHASE 2

26th October (Mw 5.9)

30th October

PHASE 3

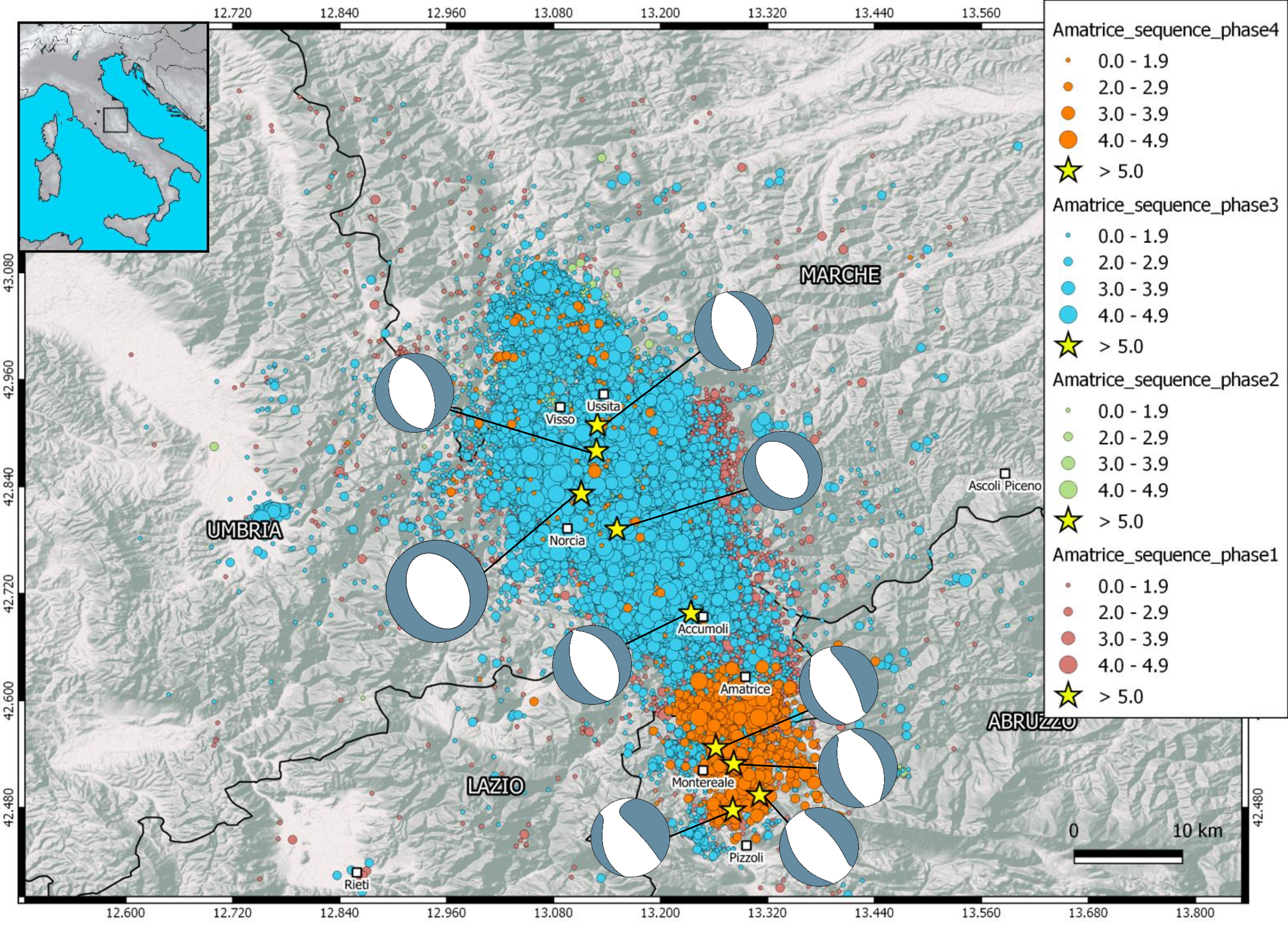
30th October (Mw 6.5)

18th January

PHASE 4

18th January (Mw > 5)

Today …



CREATING A PROTOCOL FOR OPERATIONAL EARTHQUAKE FORECASTING

Operational Earthquake Forecasting (**OEF**) "*comprises procedures for gathering and disseminating authoritative information about the time dependence of seismic hazards to help communities prepare for potentially destructive earthquakes*."

(Jordan et al, 2011)

The 2016 Central Italy sequence is a long and complex sequence consisting of multiple damaging earthquakes, which occurred from days to months after the first devastating event. This shows the importance of capturing the time dependence in the seismic rate so as to provide more accurate information about seismic risk.

In order to improve any future operational efforts, a timeline should be defined for the development of time-dependant and testable forecast models. Depending on the quality of available data, we can perform:

A) **"Preliminary knowledge" models** (using data available from minutes to few hours after a main event)

B) **"Intermediate knowledge" models** (using intermediate data updates that bring refinements to the first estimations)

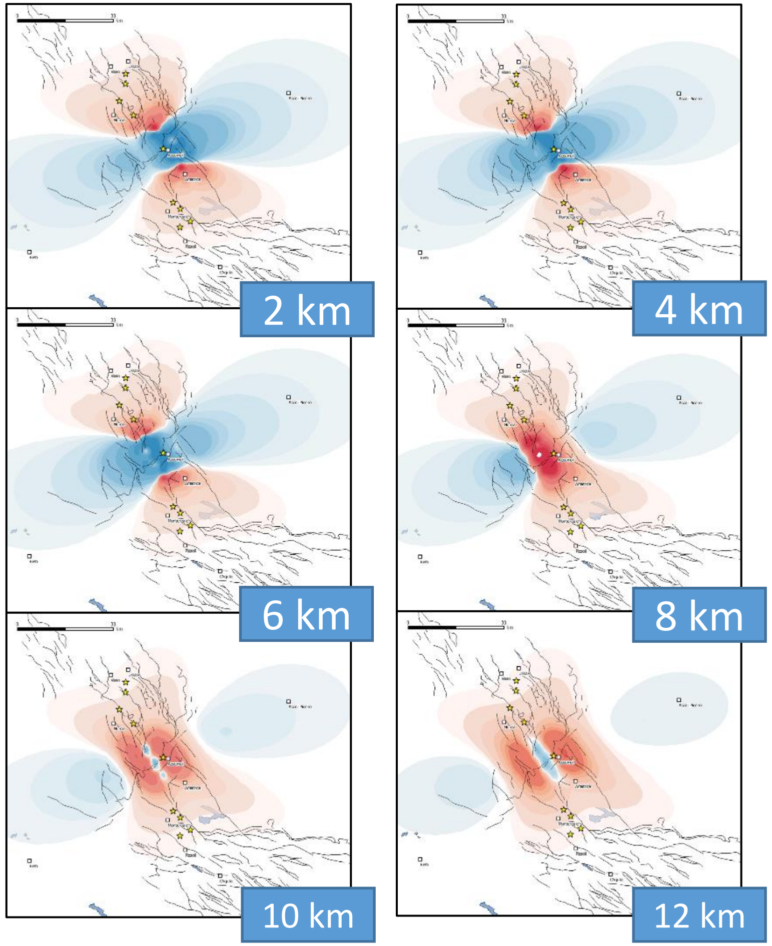
C) **"Advanced knowledge" models** (using data of the best quality)

MODEL A – “PRELIMINARY KNOWLEDGE”

- Preliminary ML, depth and focal mechanism;

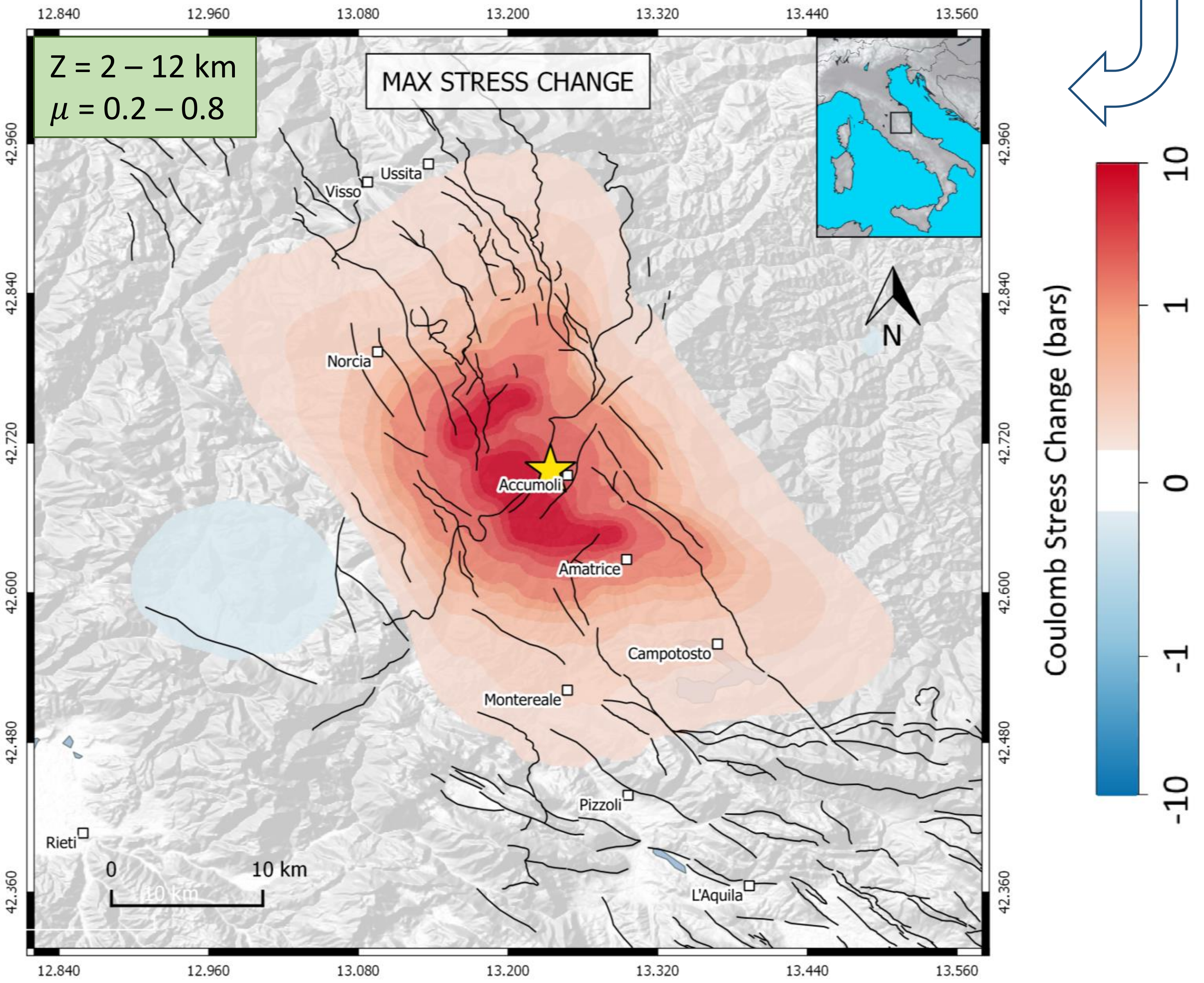
- Uniform slip model

- Receivers modelled with the same geometry of the source and unknown reference depth



CALCULATING THE STRESS CHANGE IN THE CRUST AFTER A HIGH MAGNITUDE EARTHQUAKE…

Mw 6.0 Amatrice – Coulomb stress change



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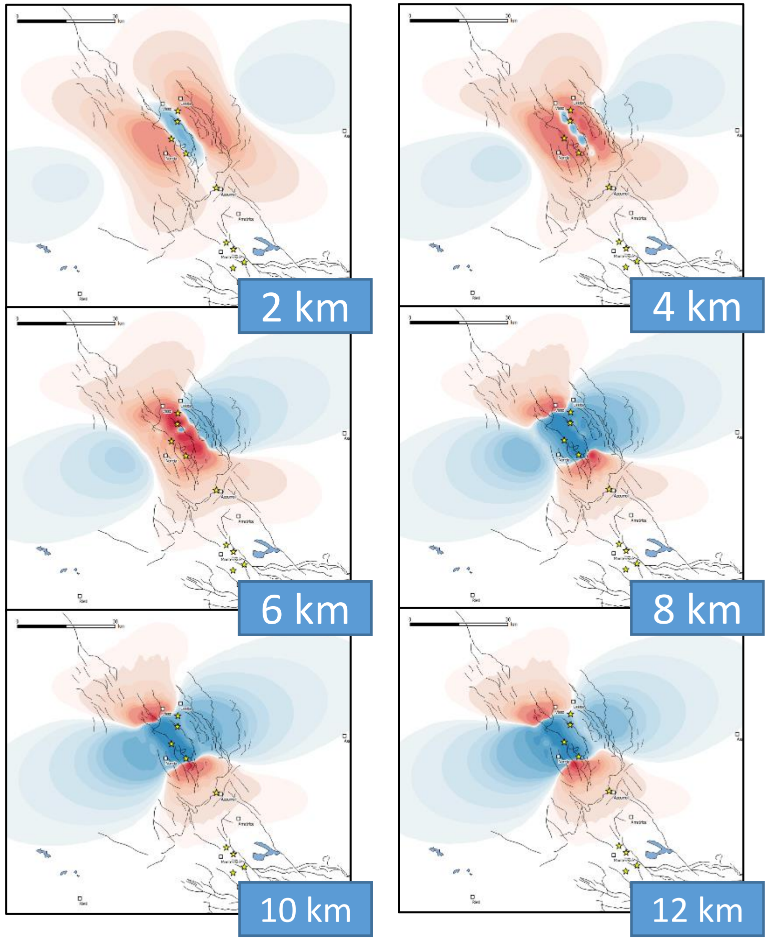
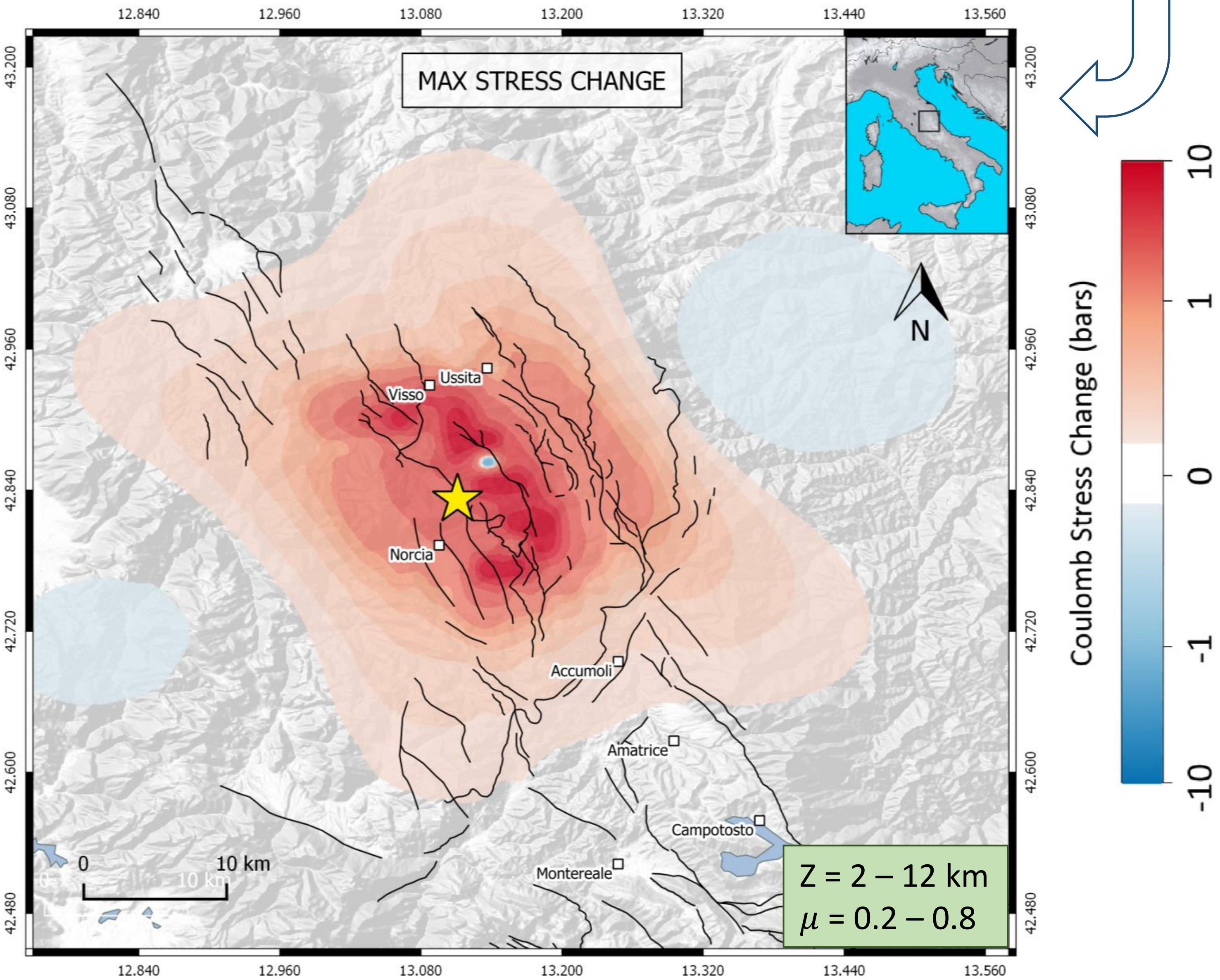


Mw 6.5 Norcia – Coulomb stress change



RATE-AND-STATE FRICTION THEORY

(TRANSLATING STRESS CHANGE INTO SEISMICITY RATE CHANGE)

No stress perturbation?

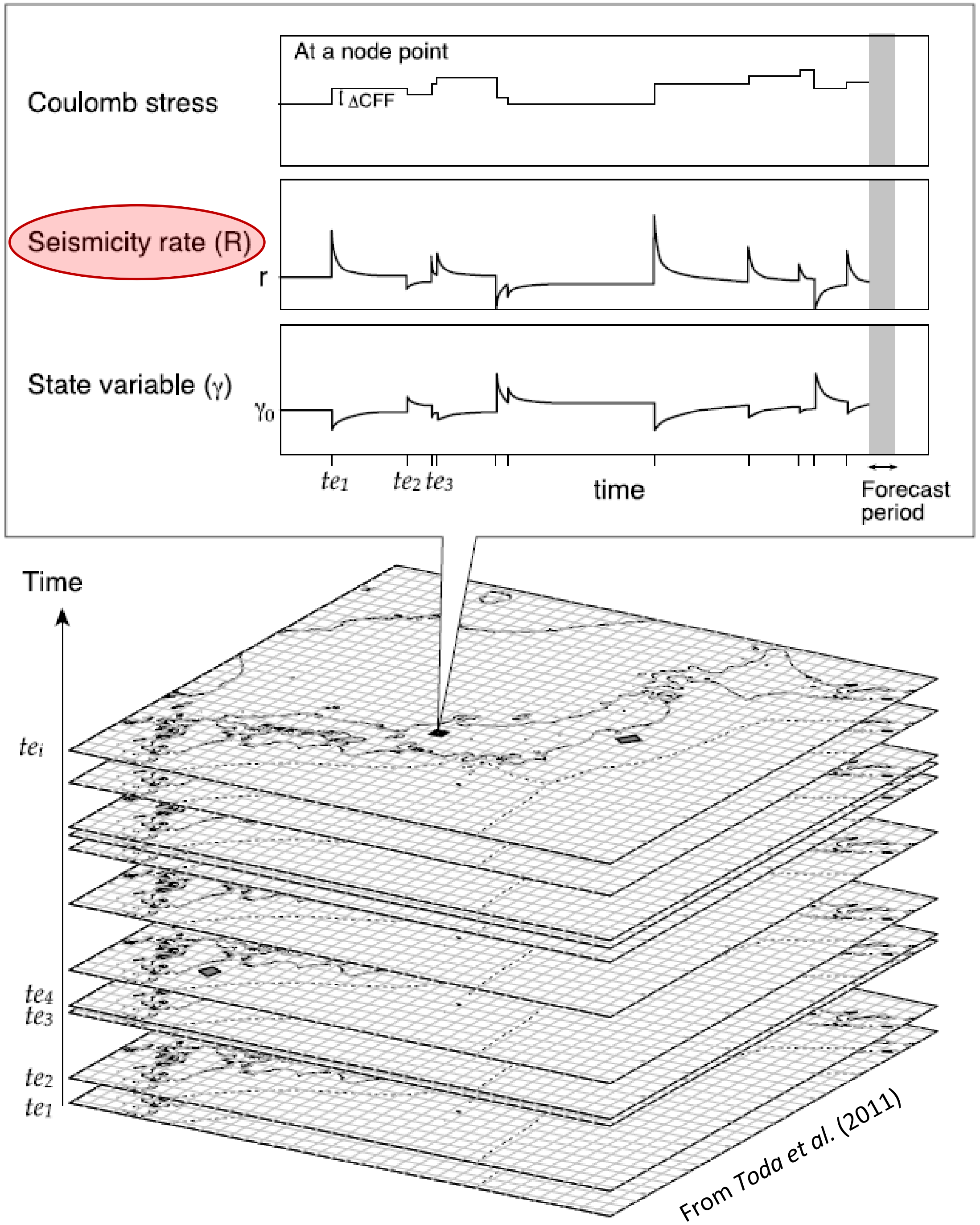
SEISMICITY RATE = BACKGROUND RATE

After a stress perturbation from a large event…

NEW SEISMICITY RATE at each node point:

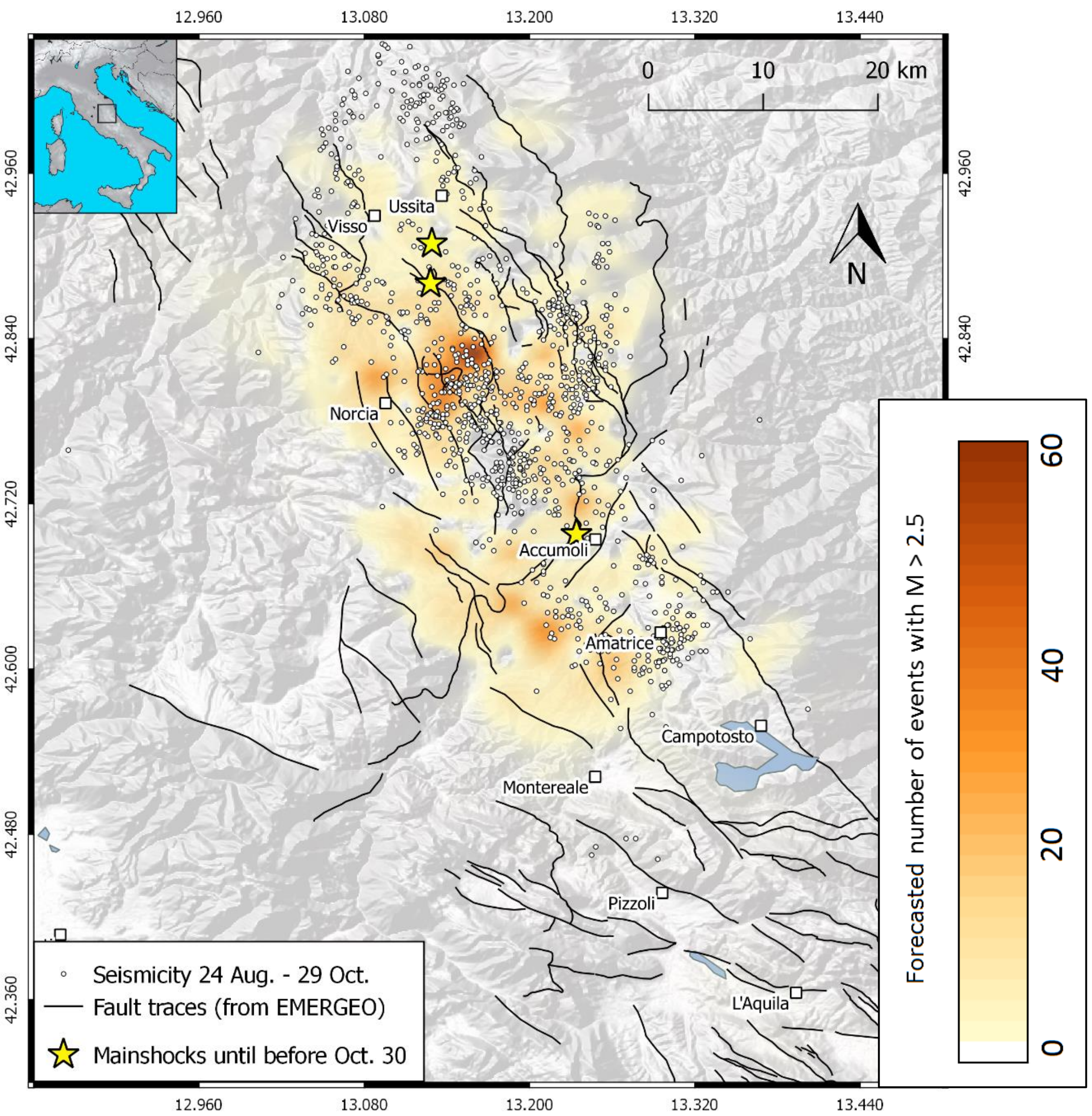
Proportional to:
- Stress change
- Background rate
- Secular shear stressing rate

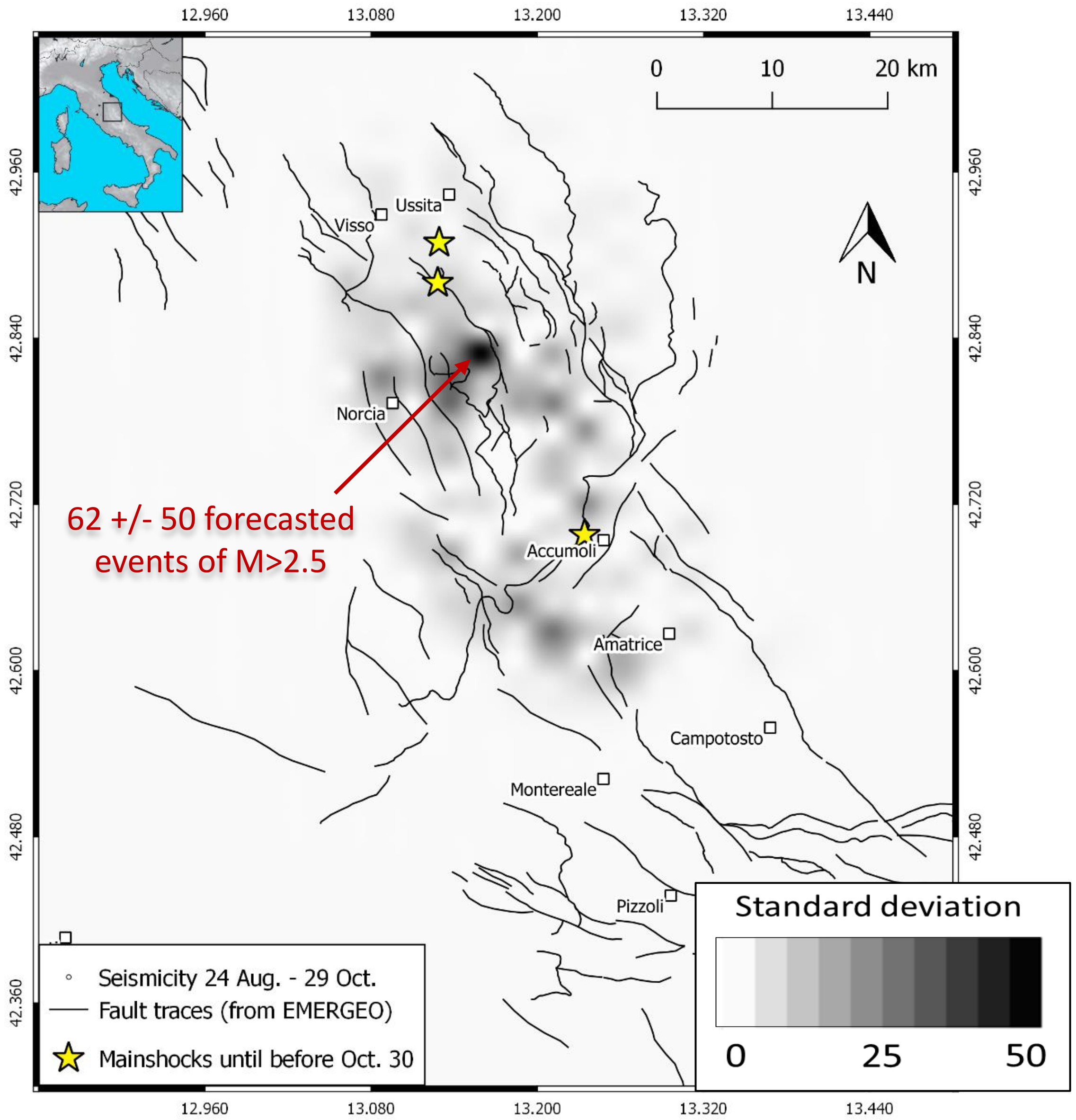
Inversely proportional to: Normal stress



MODEL A - Forecast from 24th August to 29th October (Rate-and-State friction theory)

- Reference rate evaluated from 1990 to 2016 with magnitude of completeness = 2.5, on a 2x2 km spatial grid;
- Wide range of 10 possible shear stressing rate taken from literature
- Normal stress = 0.1 MPa/year;





MODEL A - Forecast from 30th October to 17th January (Rate-and-State friction theory)

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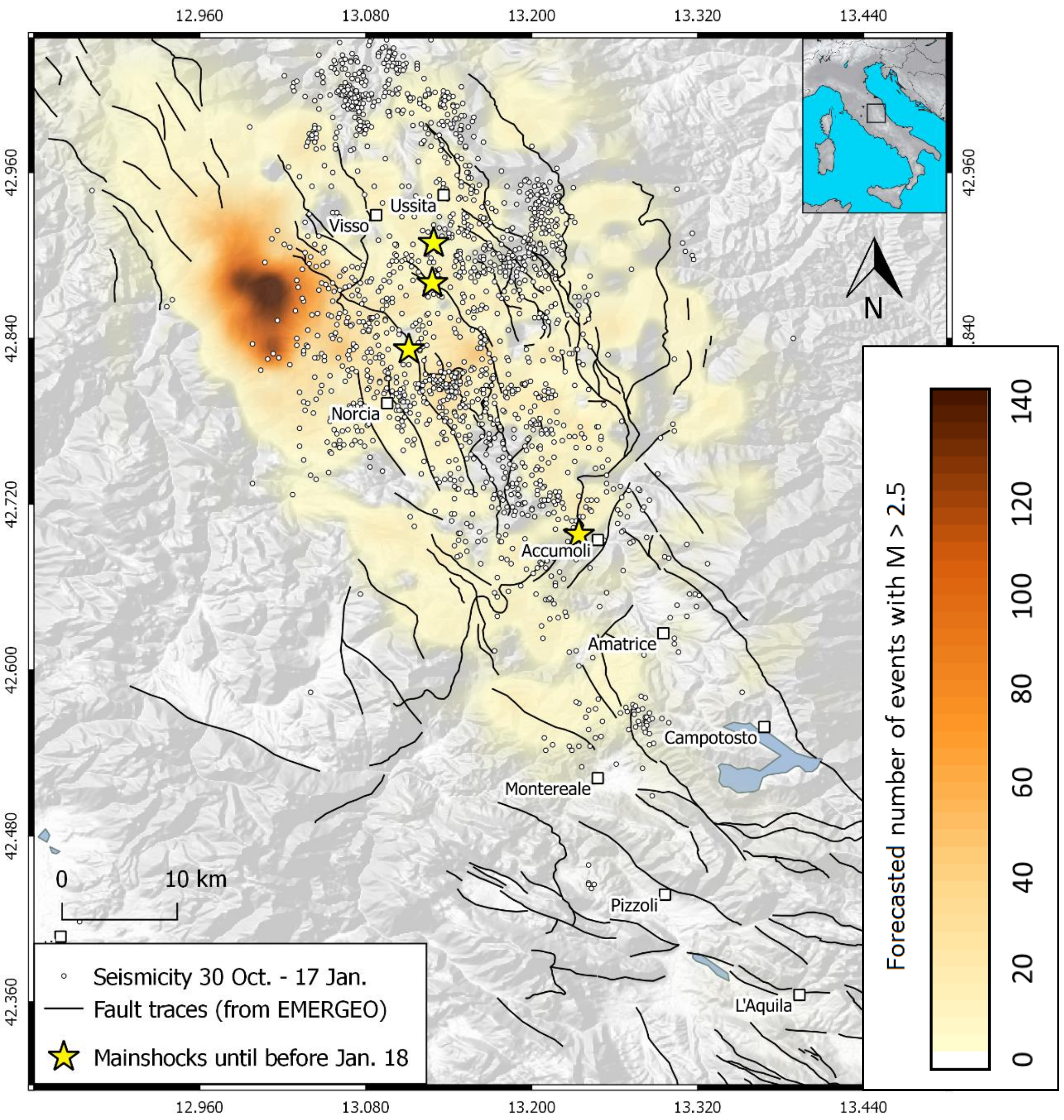
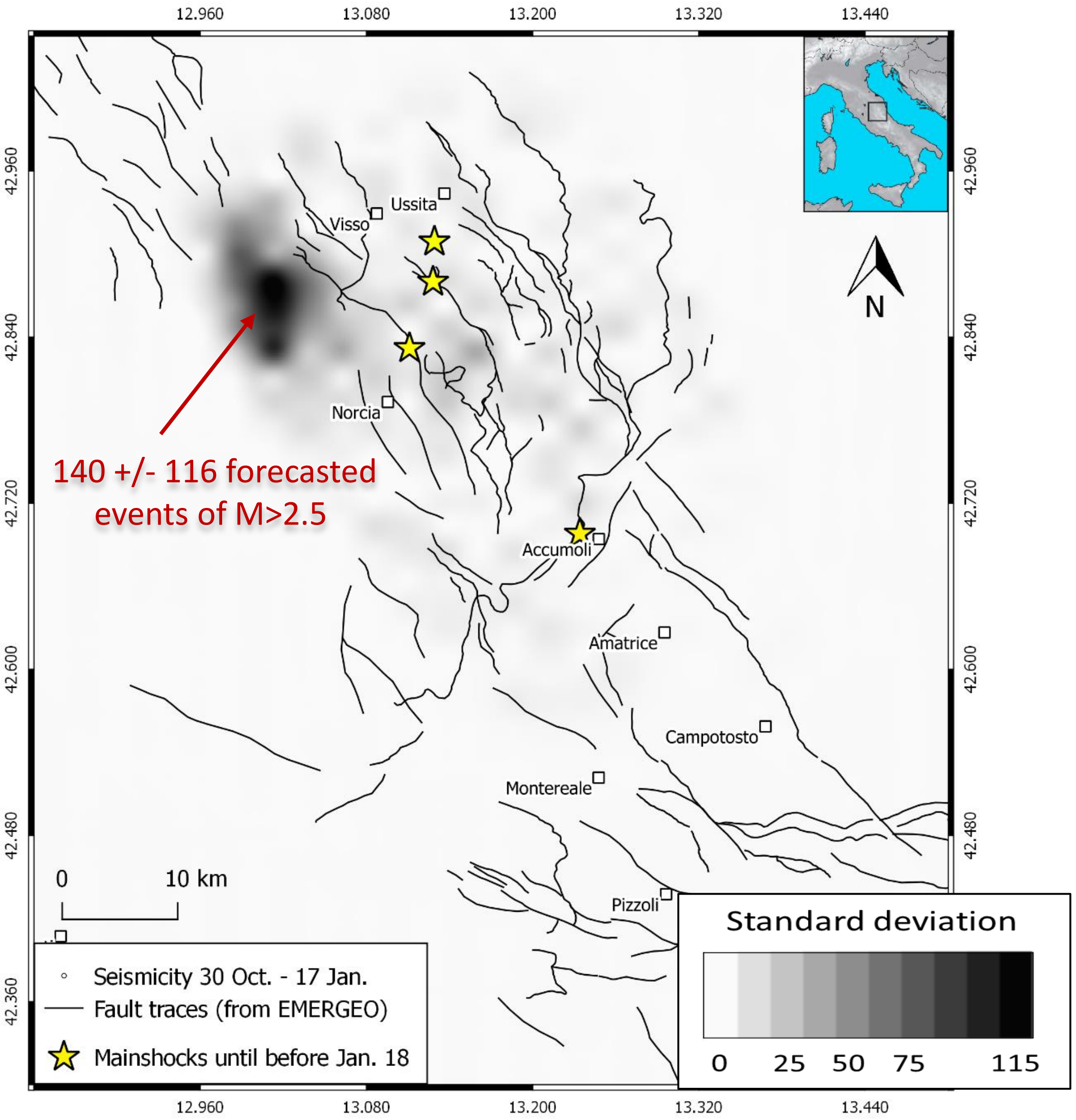
- Normal stress = 0.1 MPa/year;





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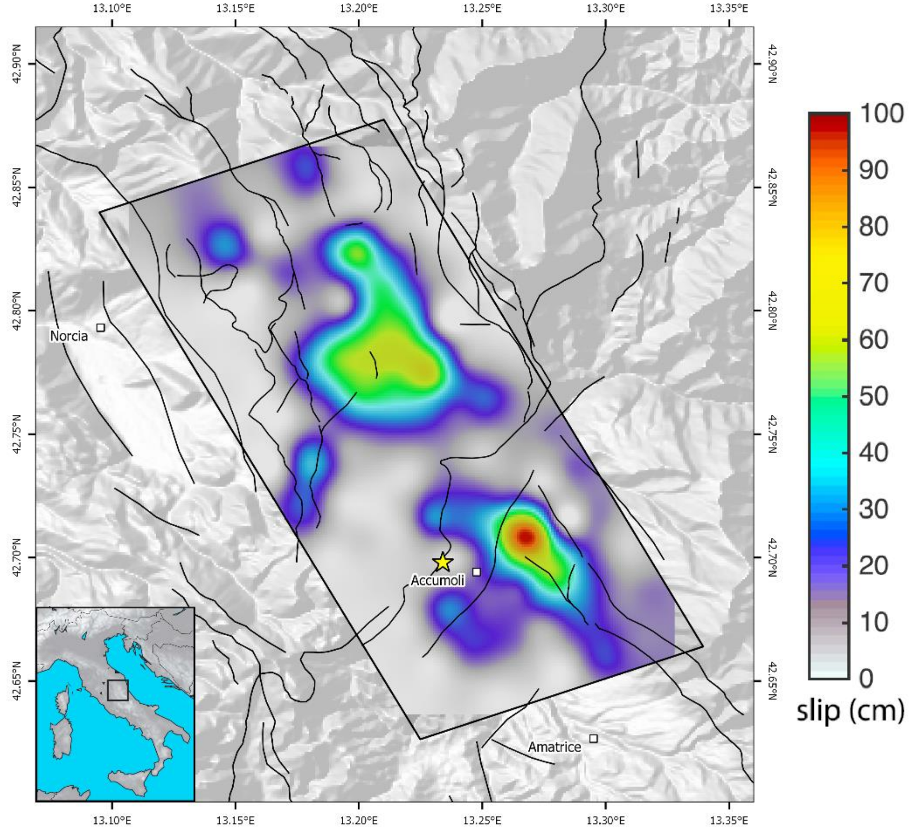
C) **“Advanced knowledge” models** (using data of the best quality)

- Final estimation on Mw, depth, focal mechanism and fault dimensions.

- Best available version of the slip model (*finite fault model*);

- Receivers modelled with the same geometry of the source and with weighted reference depths between 2-12 km



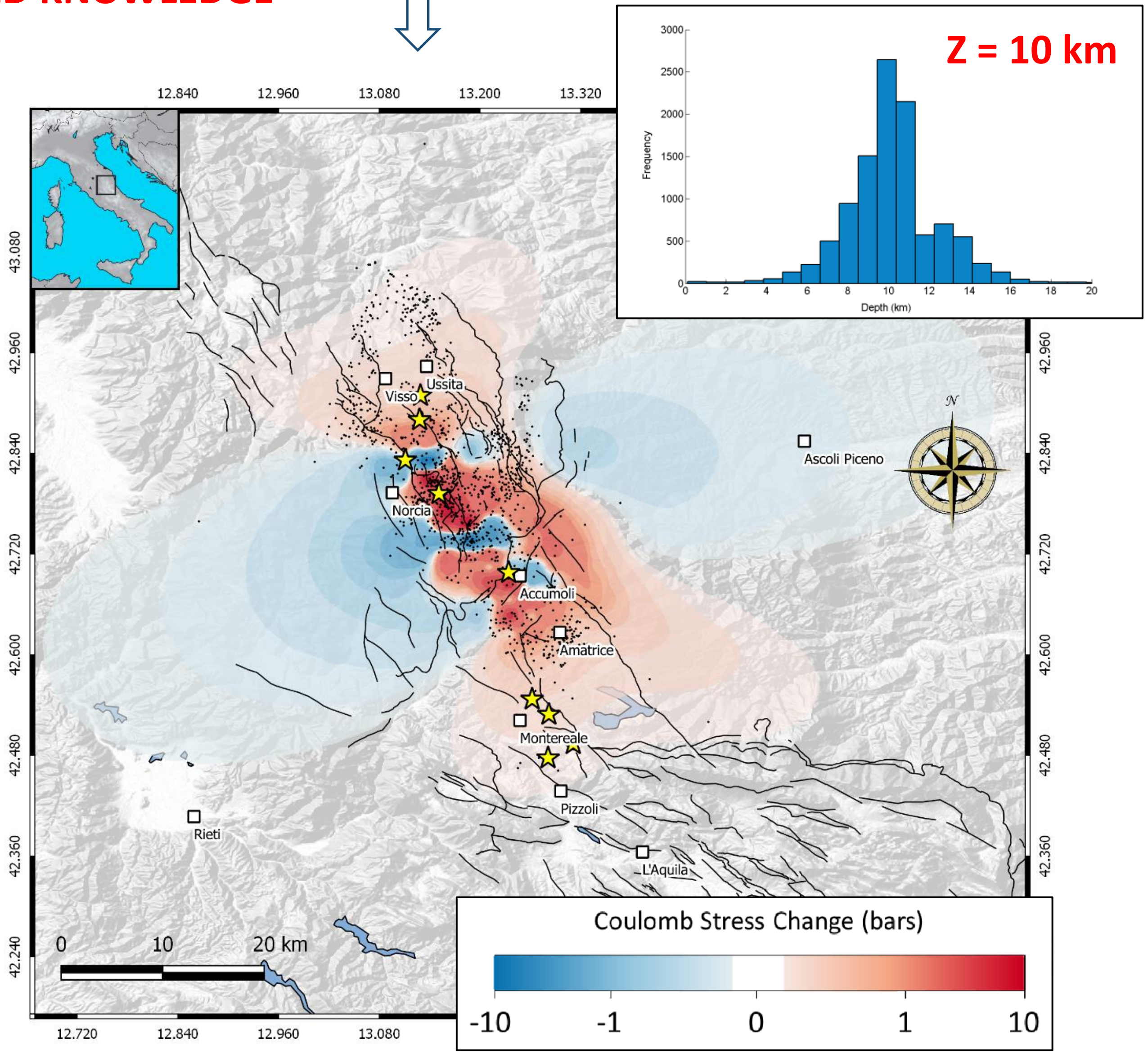
Slip model by *Tinti et al.* (2016)

MODEL C

the stage of

"ADVANCED KNOWLEDGE"

Mw 6.0 Amatrice – Coulomb stress change



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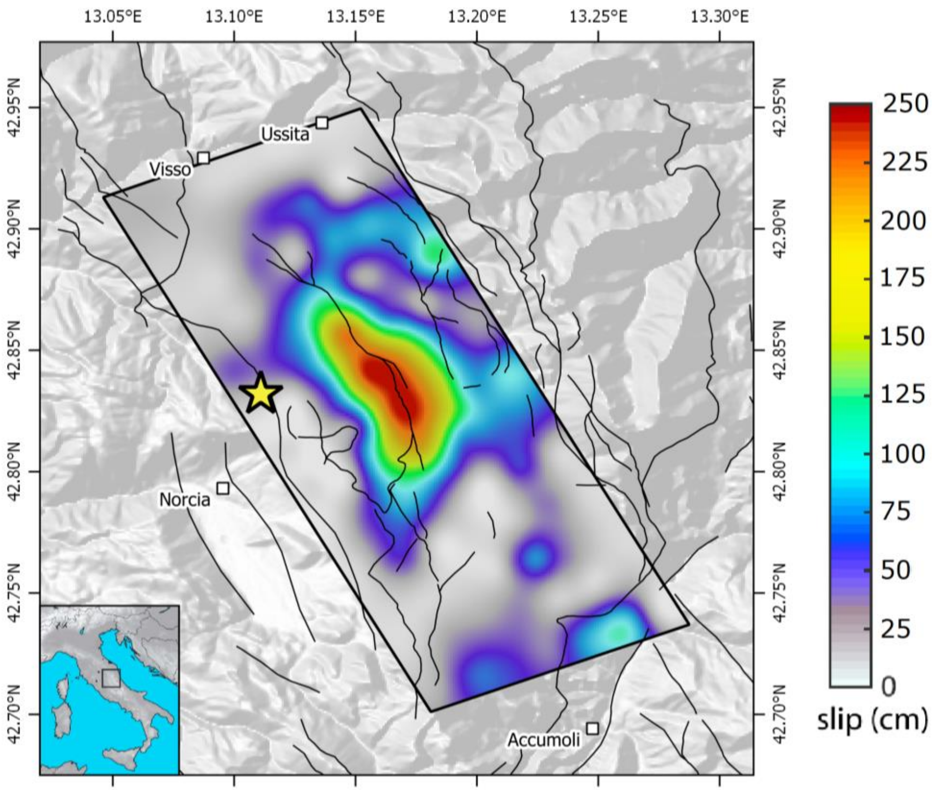
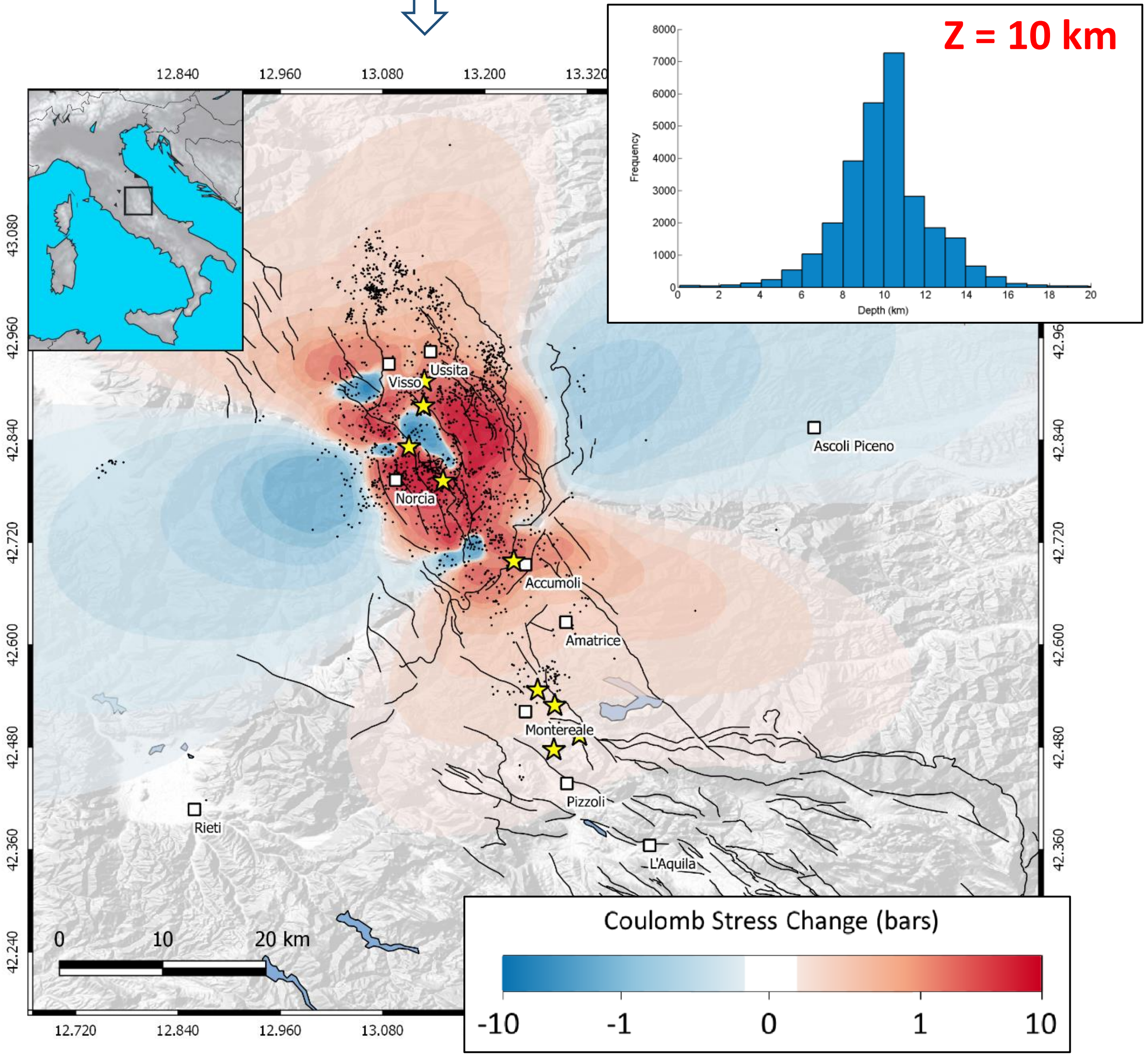
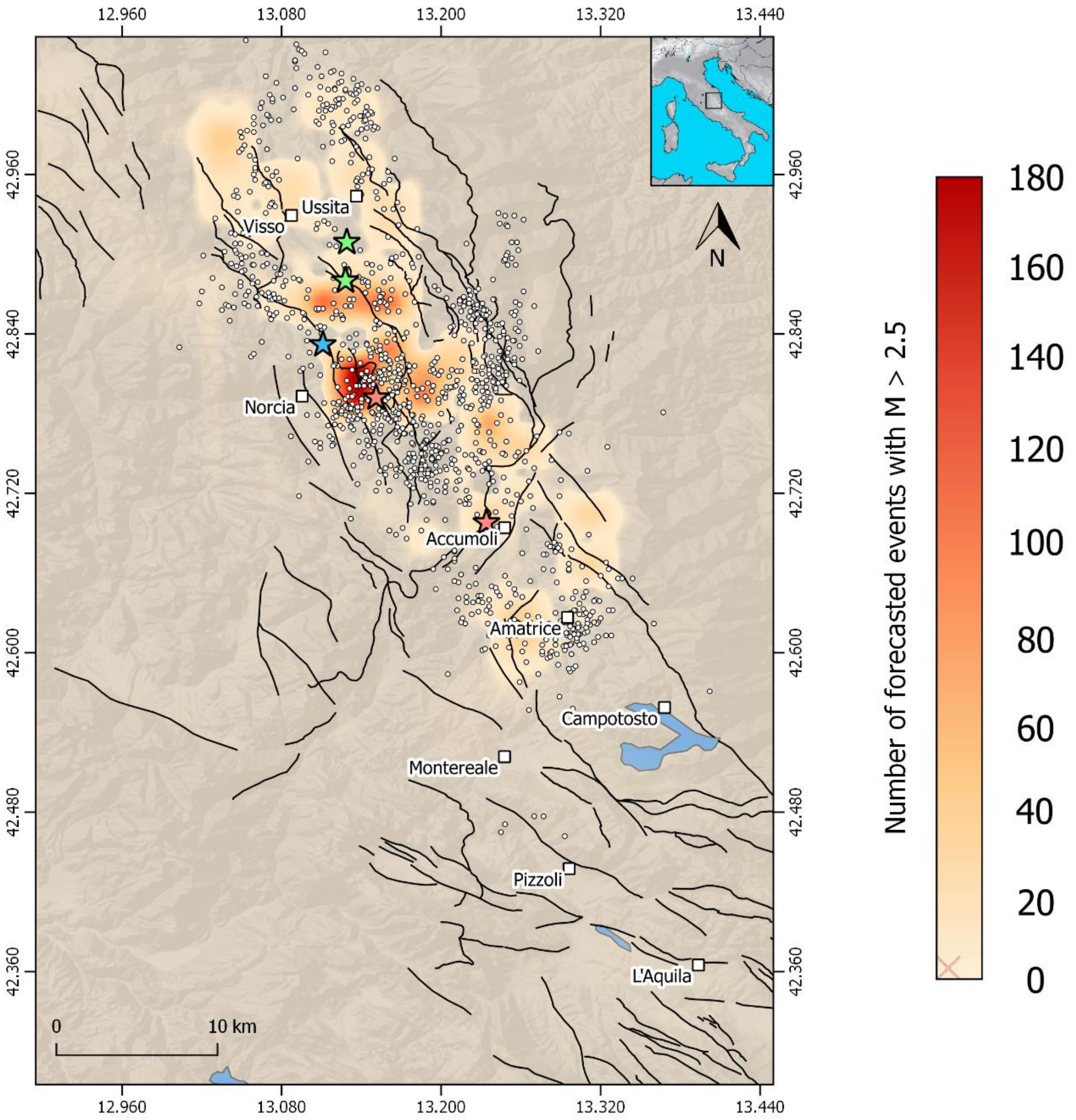


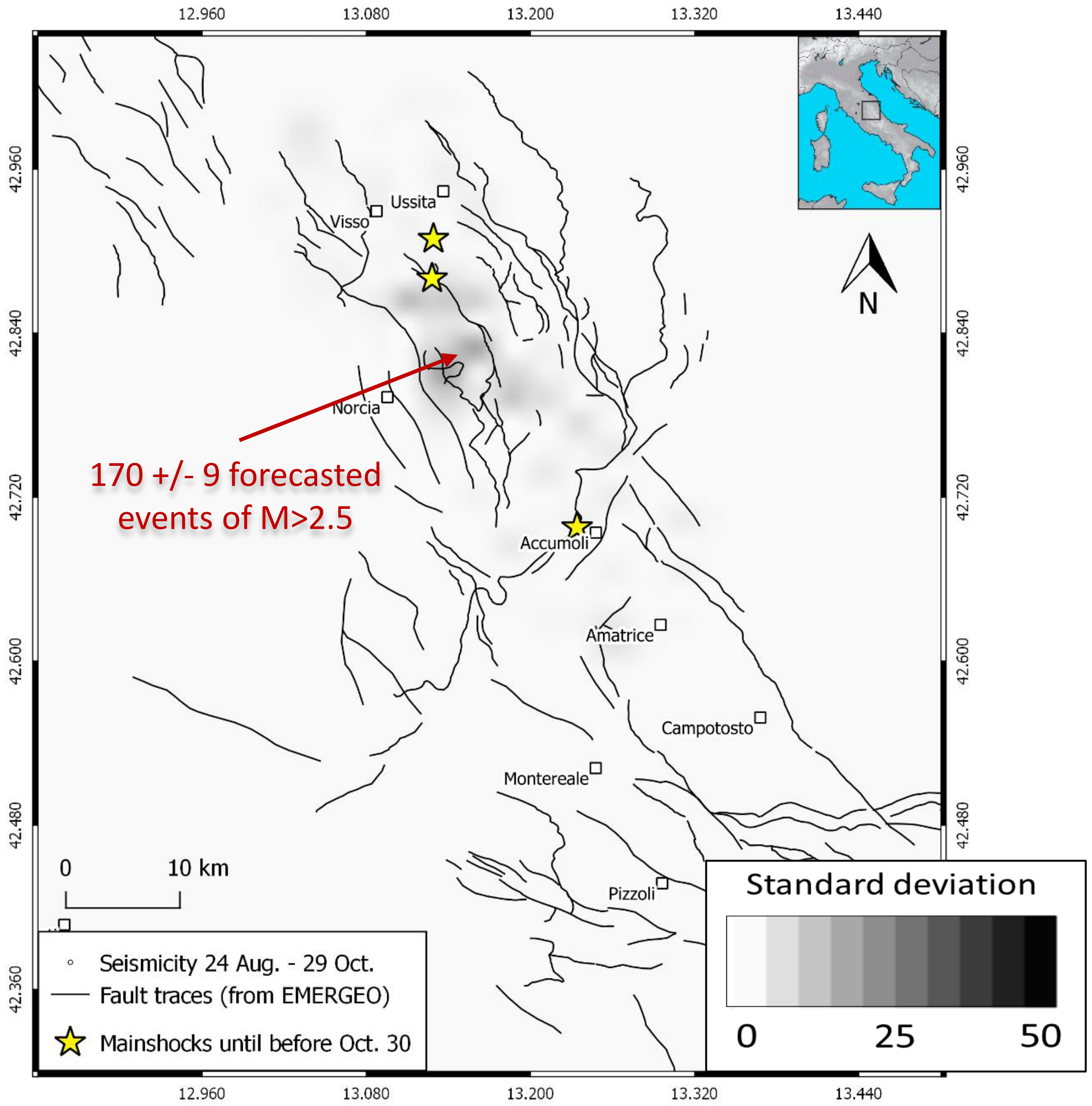
Slip model by *Chiaraluce et al.* (2016)



MODEL C - Forecast from 24th August to 29th October (Rate-and-State friction theory)

- Reference rate evaluated from 1990 to 2016 with magnitude of completeness = 2.5, on a 2x2 km spatial grid;
- Shear stressing rate retrofitted using the observed seismicity;
- Forecast weighted by the depth of the observed seismicity.





MODEL C - Forecast from 30th October to 17th January (Rate-and-State friction theory)

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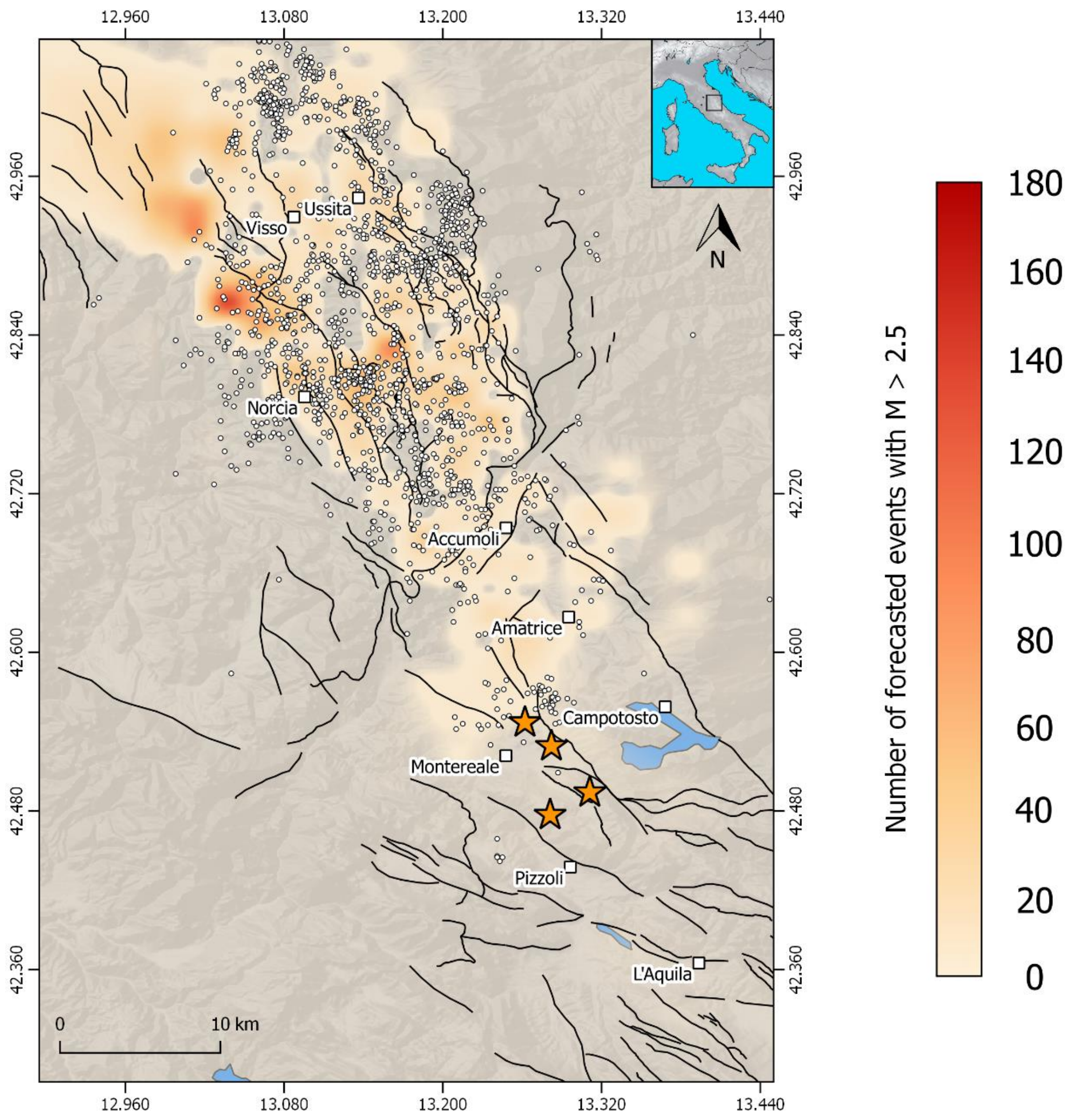
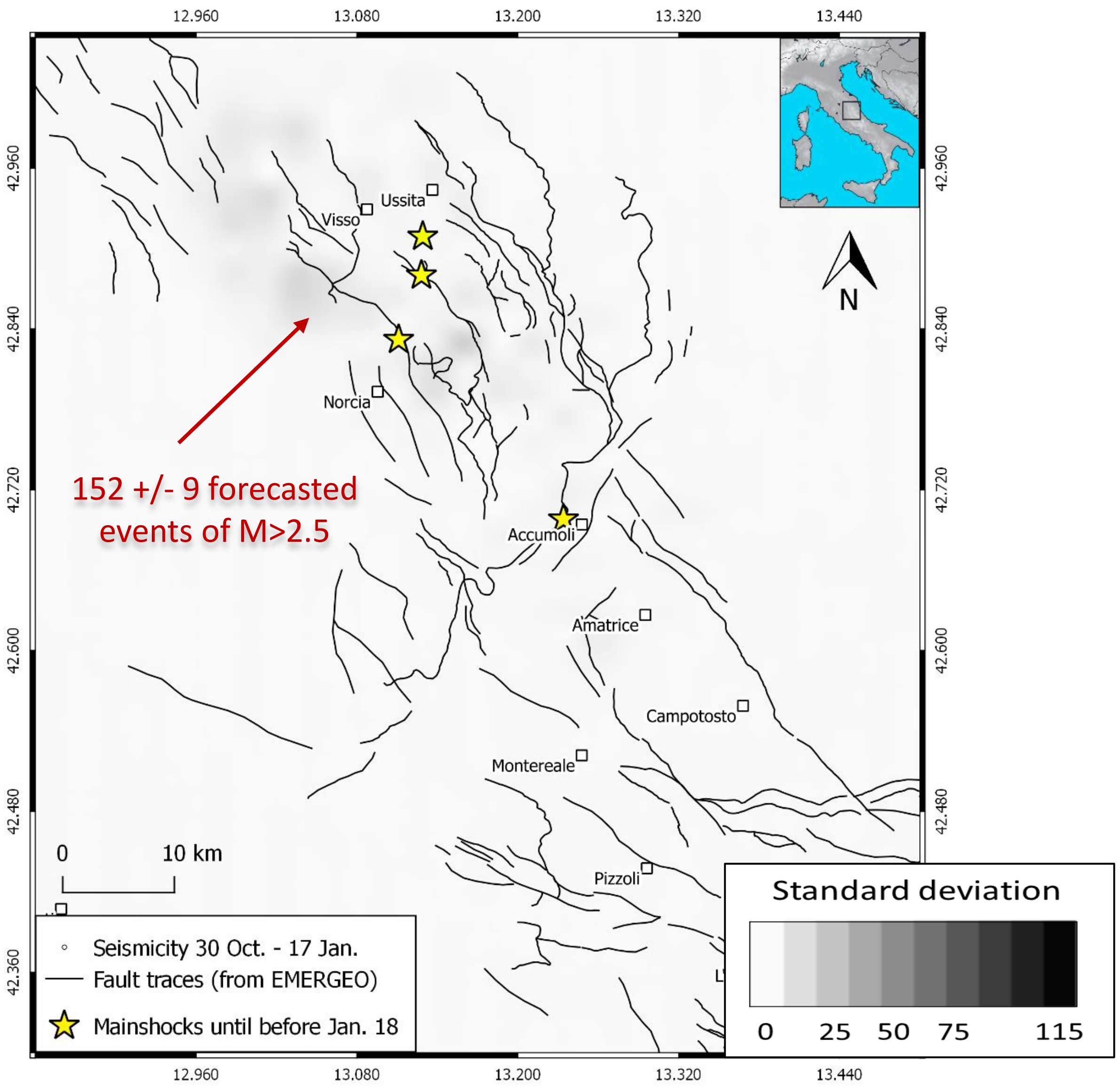
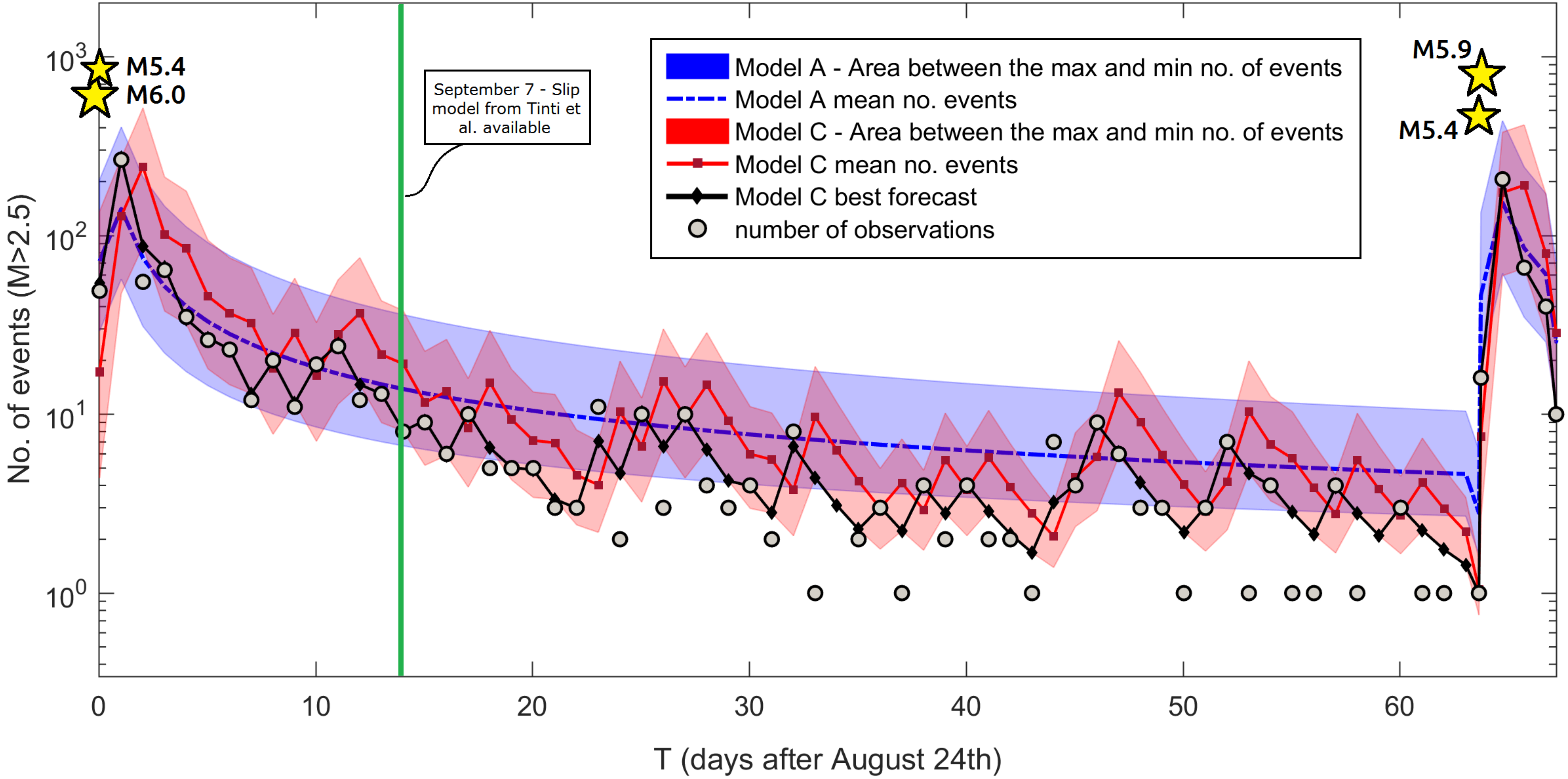
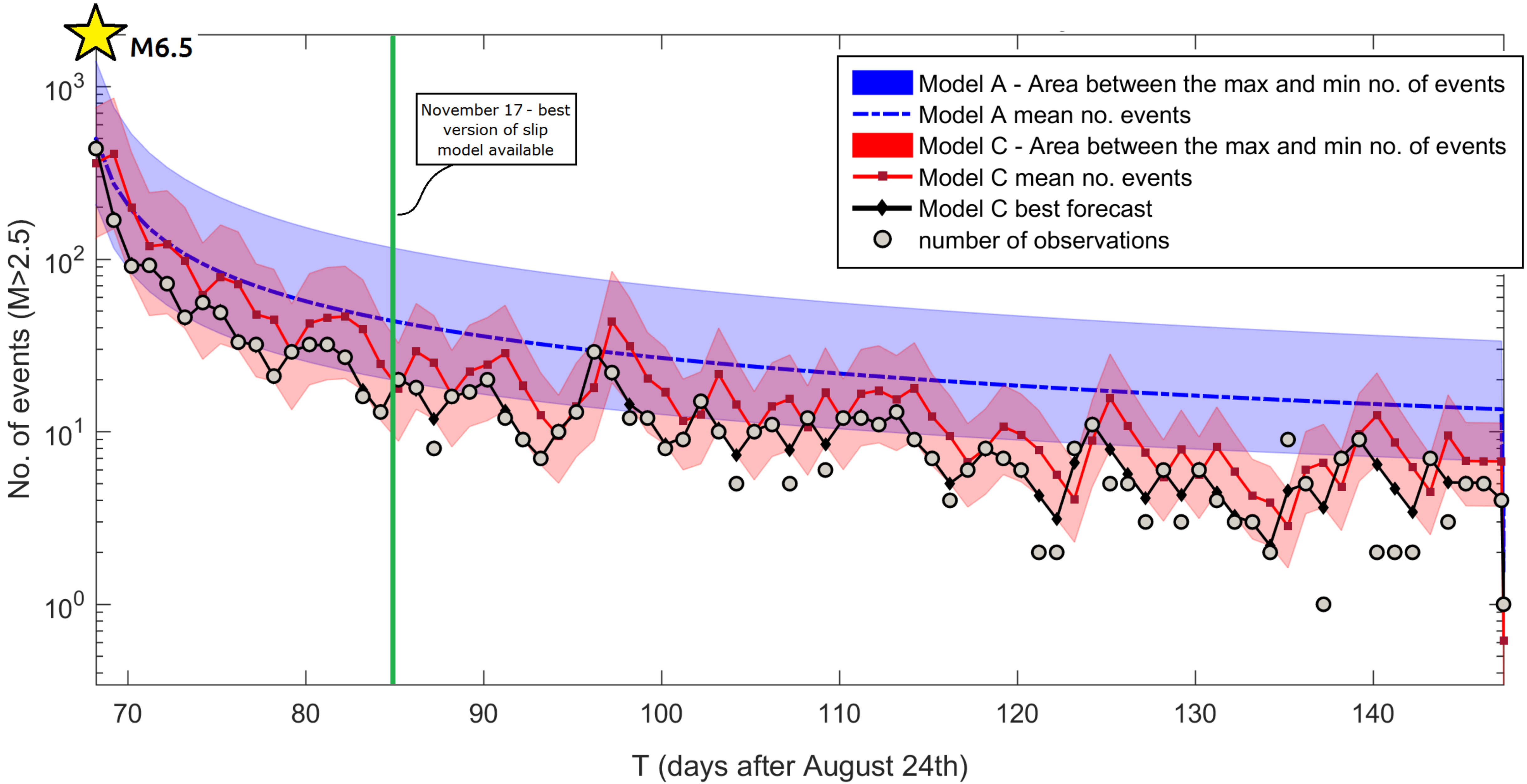




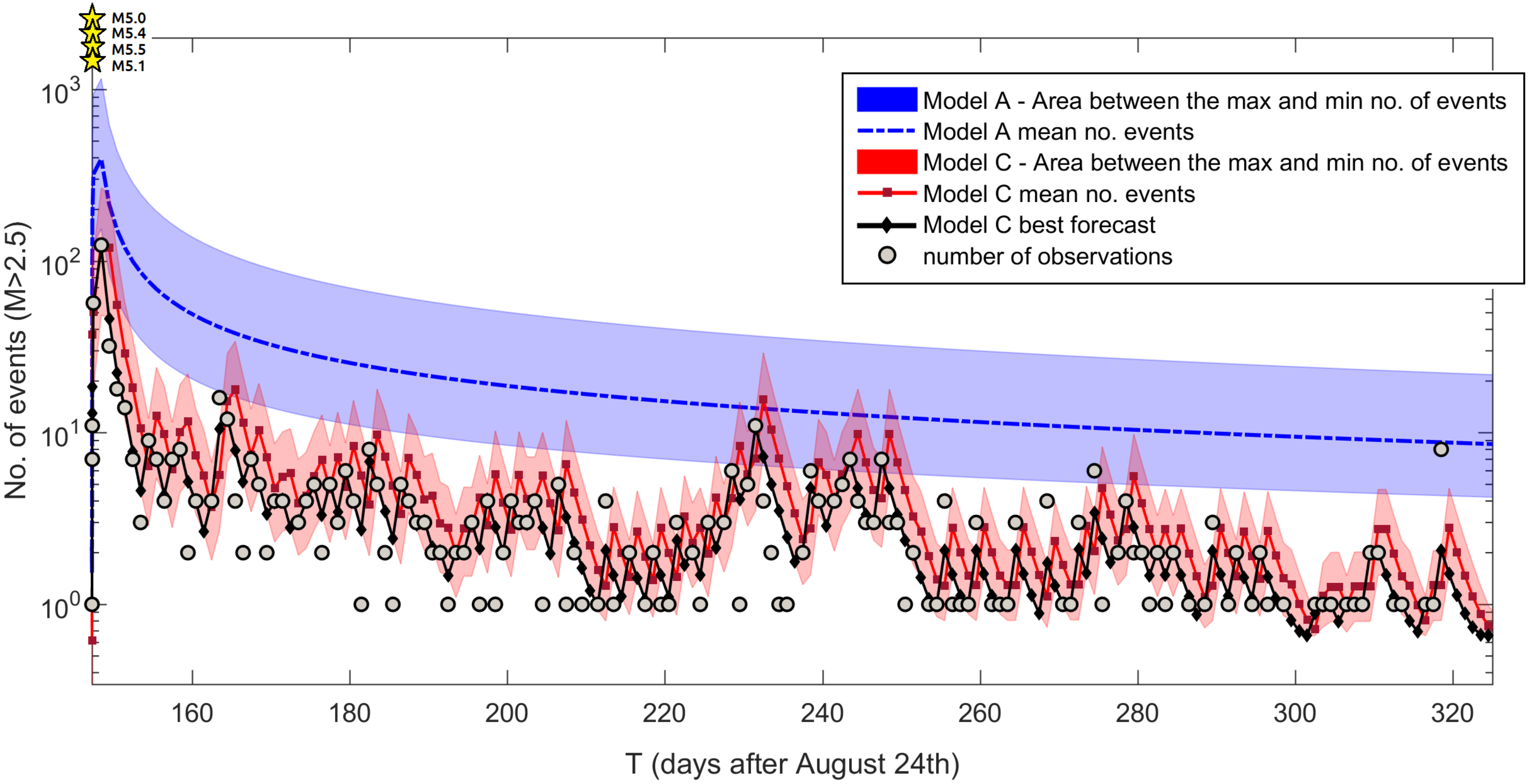
Forecast time series: from August 24 to October 29



FORECAST TIME SERIES: FROM OCTOBER 30 TO JANUARY 17



FORECAST TIME SERIES: AFTER JANUARY 18



CONCLUDING REMARKS

AND FUTURE DEVELOPMENTS

1. The case study of the last Central Apennines sequence is ideal to quantify the influence of data quality in preliminary forecast efforts in a well-instrumented region;

2. During the early post-disaster phases, our preliminary forecasts are affected by limitations and high errors;

3. As soon as we can use updated geological and seismological data, we can compute more informed models which enhance the accuracy of our forecasts.

Expected developments:

- Inclusion of intermediate models ("*models B*") to better observe the evolution of the forecasts with time, as well as at least one more informed model ("*model D*") which takes into account a real geological model for the receivers.

- Statistical evaluation of the models and comparison with empirical/statistical models (i.e. ETAS);

"ESSENTIALLY, ALL MODELS ARE WRONG, BUT SOME ARE USEFUL"

GEORGE E. P. BOX (1987)

THANK YOU FOR YOUR ATTENTION

ANY QUESTIONS?