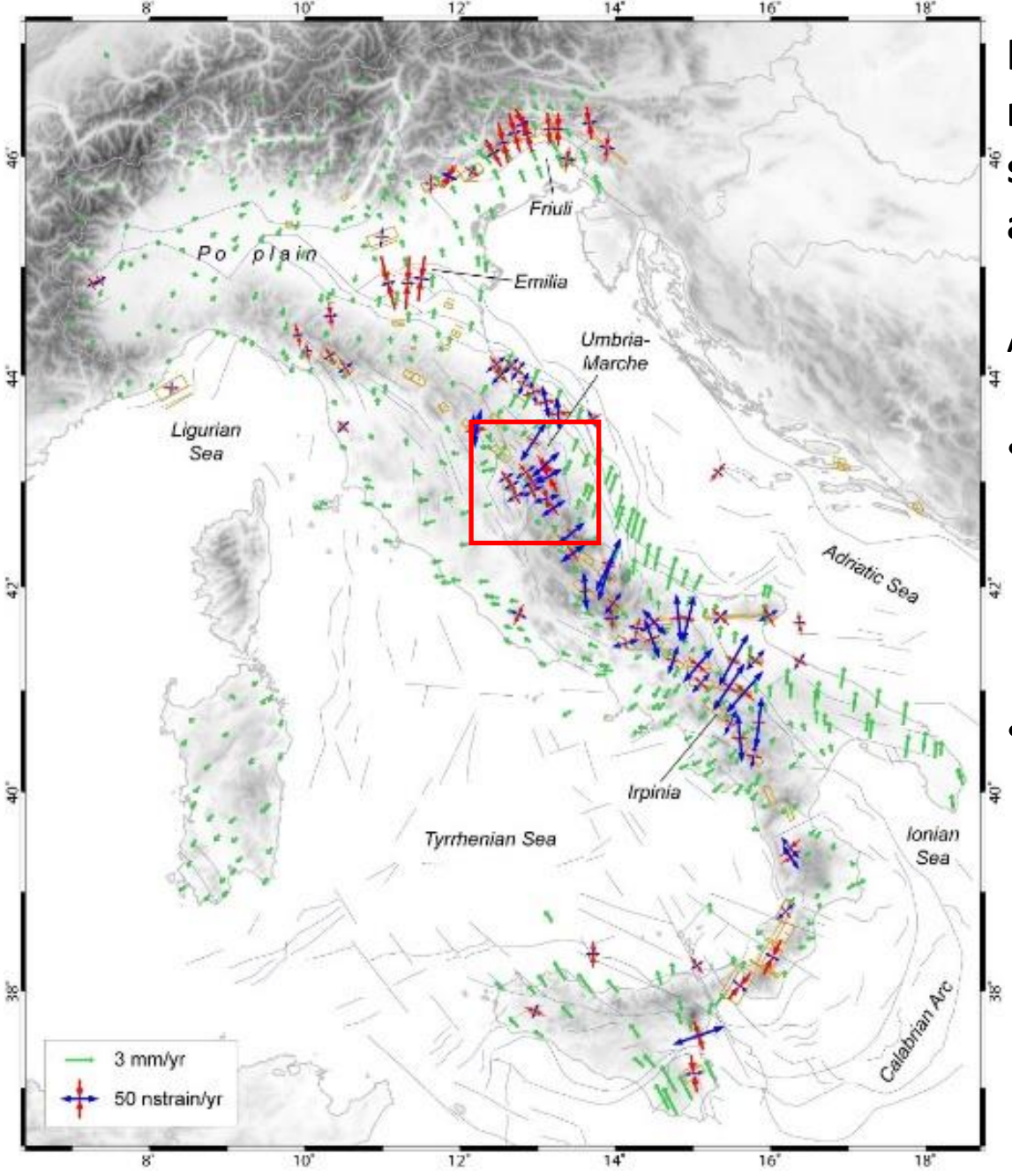


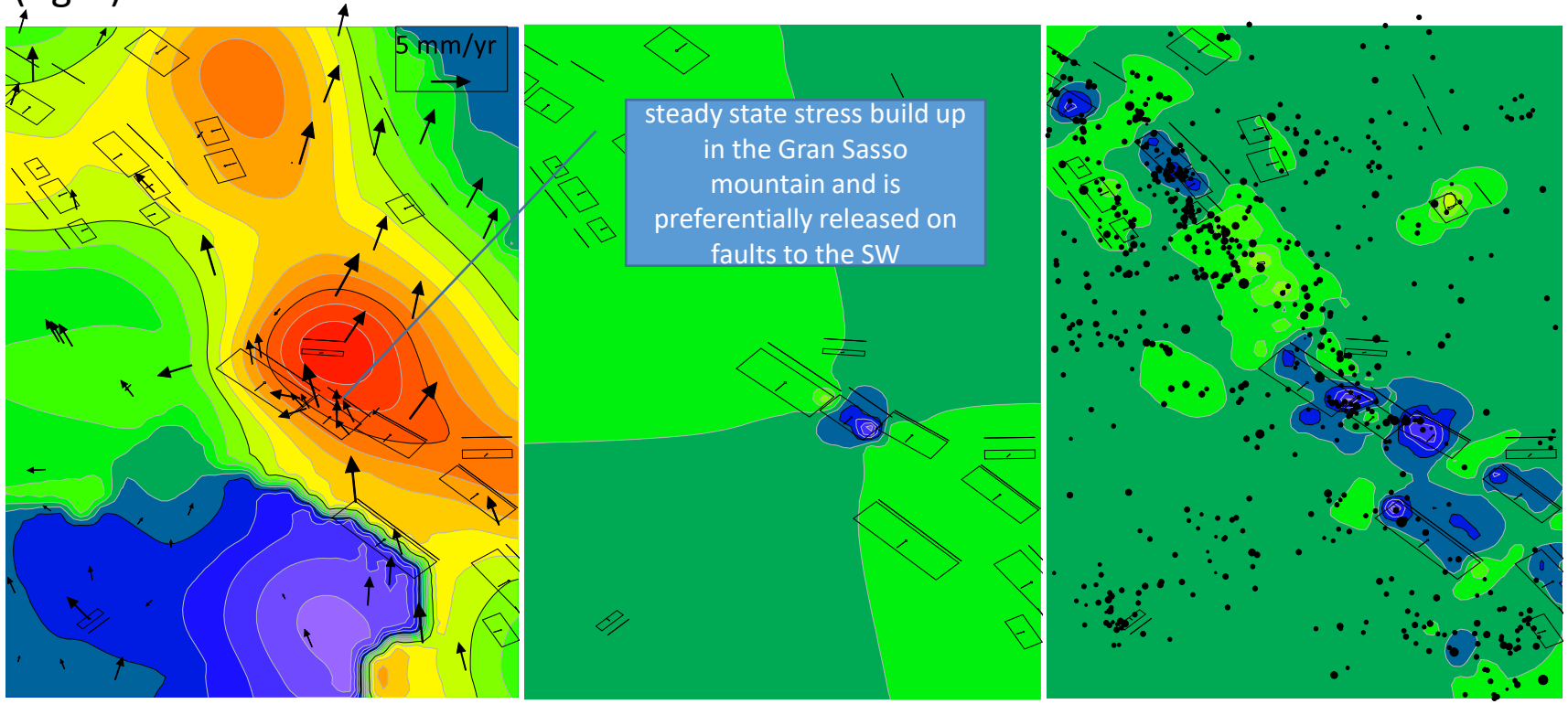
How can historical seismicity data and GNSS strain rate data be merged to generate a time dependent stress map? Crucial question for a geophysical approach to seismic hazard!

Available data

- INGV:
  - Historical data sets: Parametric Catalogue CPTI15
  - DISS 3.2.0

- University of Padova:
  - Strain rate maps from dense GNSS velocities, updated weekly
  - Coulomb stress rate maps computed on seismogenic faults of DISS (Caporali et al., GJI 2018)
  - Strain release from Gutenberg Richter seismic zonation, regional stress drop (Caporali et al., JGR/SE 2010)

Break stress into three components: steady state buildup (left), release by individual event (center), cumulative release by previous events (right)



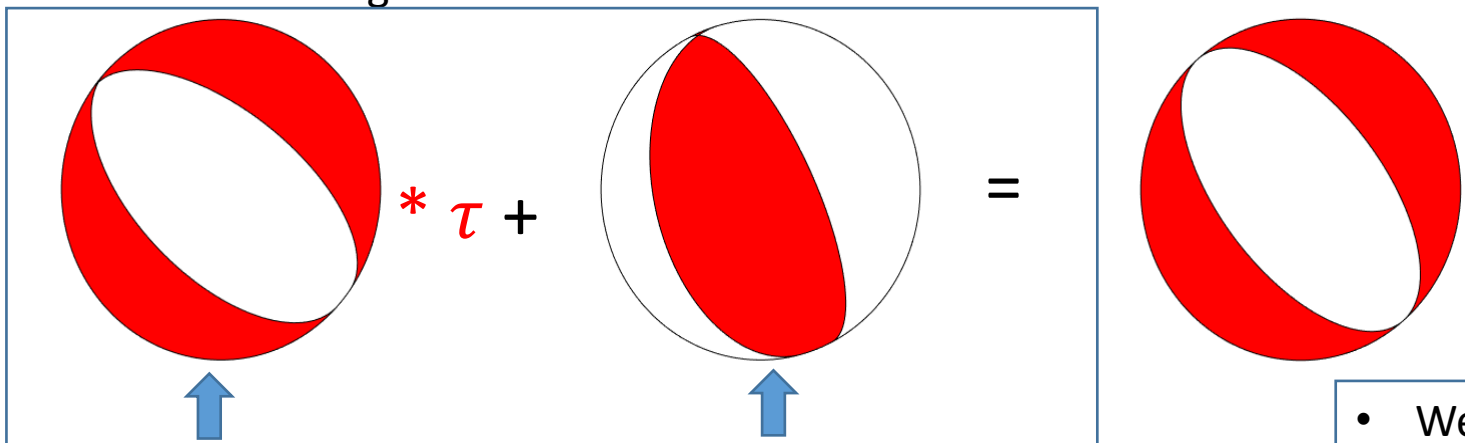
L'Aquila test case

Multiply the geodetic stress rate by an empirical time constant + Coulomb stress released by events from 1315 to 2009-: is the resulting stress aligned with the moment tensor of the 2009 L'Aquila earthquake?
Yes if the time constant is at least 2kyrs

Stress orientation at L'Aquila 2009

Details in Caporali et al. JGR/SE 2019

Total stress = regional stress + transferred stress



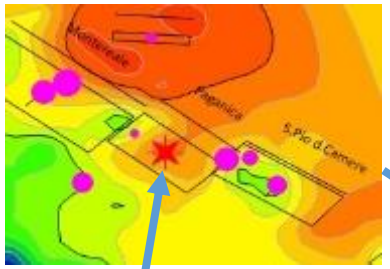
Regional stress **rate** from GPS

Transferred stress at L'Aquila hypocenter from 36 previous events (DISS, CPTI, CFTI) (1315, 1461 and 1703 mostly)

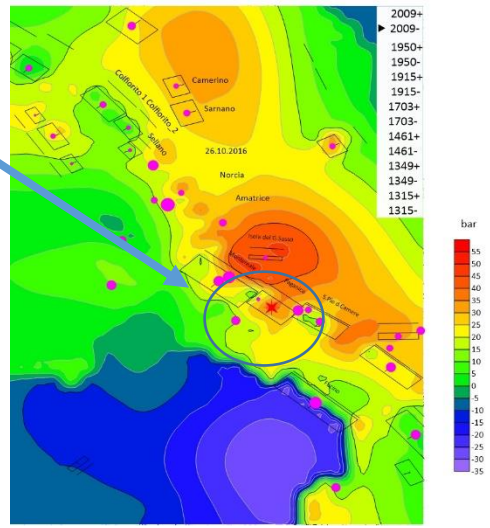
Moment Tensor 2009

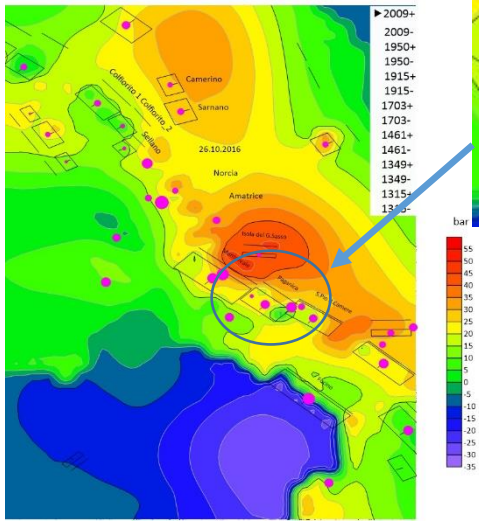
Find an empirical time constant τ such that:

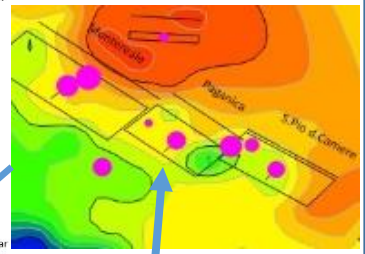
$$\text{Eig}(\dot{\sigma}_{regional} \times \tau + \sigma_{previous\ events}) = \text{Eig(MT)}$$



Coulomb stress excess on fault **prior** the 2009 earthquake



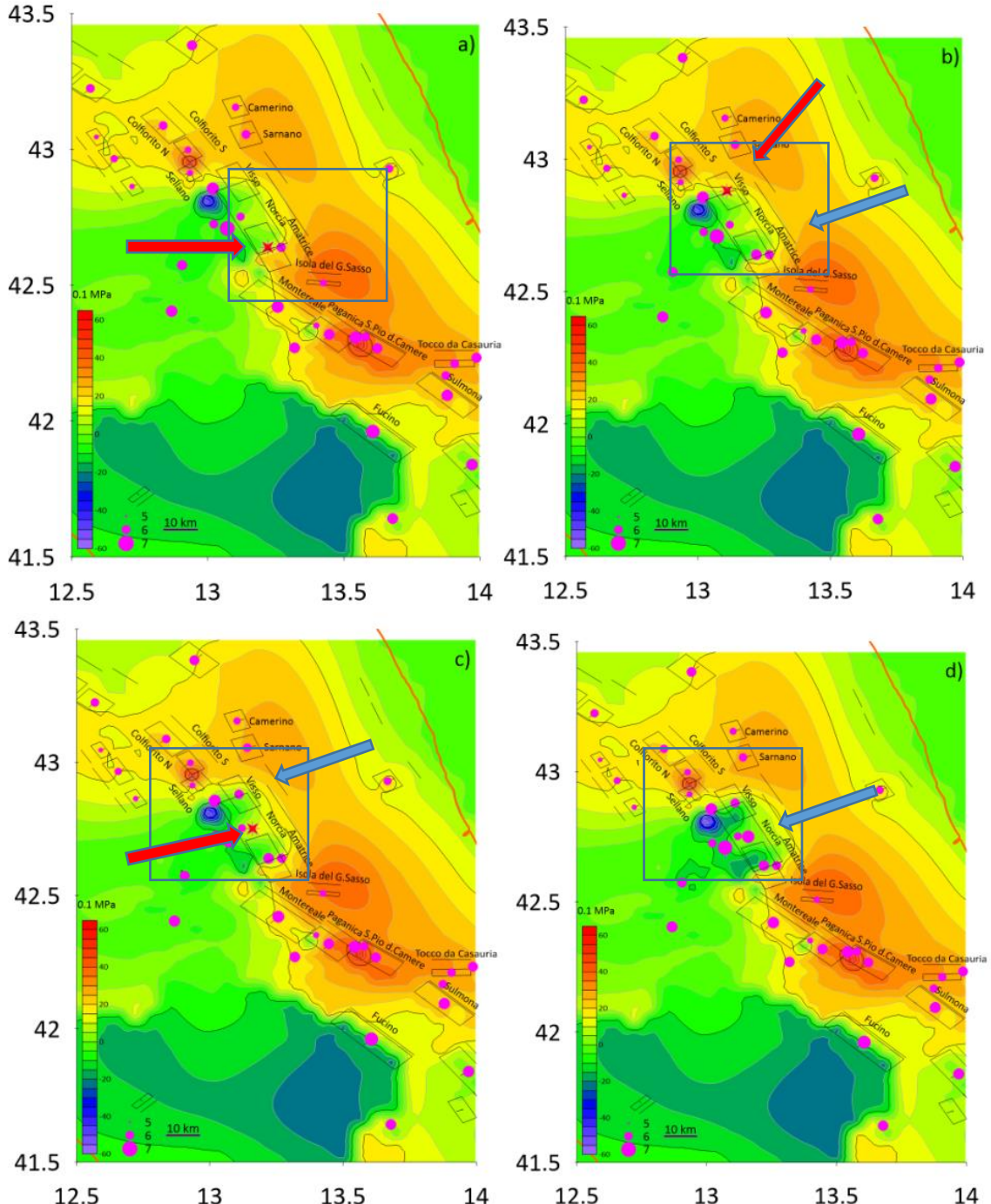




Coulomb stress on fault **after** the 2009 earthquake

- We require that the eigenvectors of the total stress and the Moment Tensor (MT) are aligned: the empirical constant τ is thus constrained to be at least 2kyr at 2009.
- Mapping the Coulomb stress on the fault geometry of L'Aquila shows that prior to the 2009 event there was a Coulomb stress excess at L'Aquila, ca. 2MPa of which was then released by the 2009 event.
- Similar results for the 2016 and 1999 sequences, and for earlier historical events

The Amatrice - Visso Norcia 2016 sequence (Mw 6.3 to 6.5)



<24.08.2016 (Amatrice)

24.08.2016 – 28.10.2016 (Amatrice - Visso)

28.10.2016 – 30.10.2016 (Visso- Norcia)

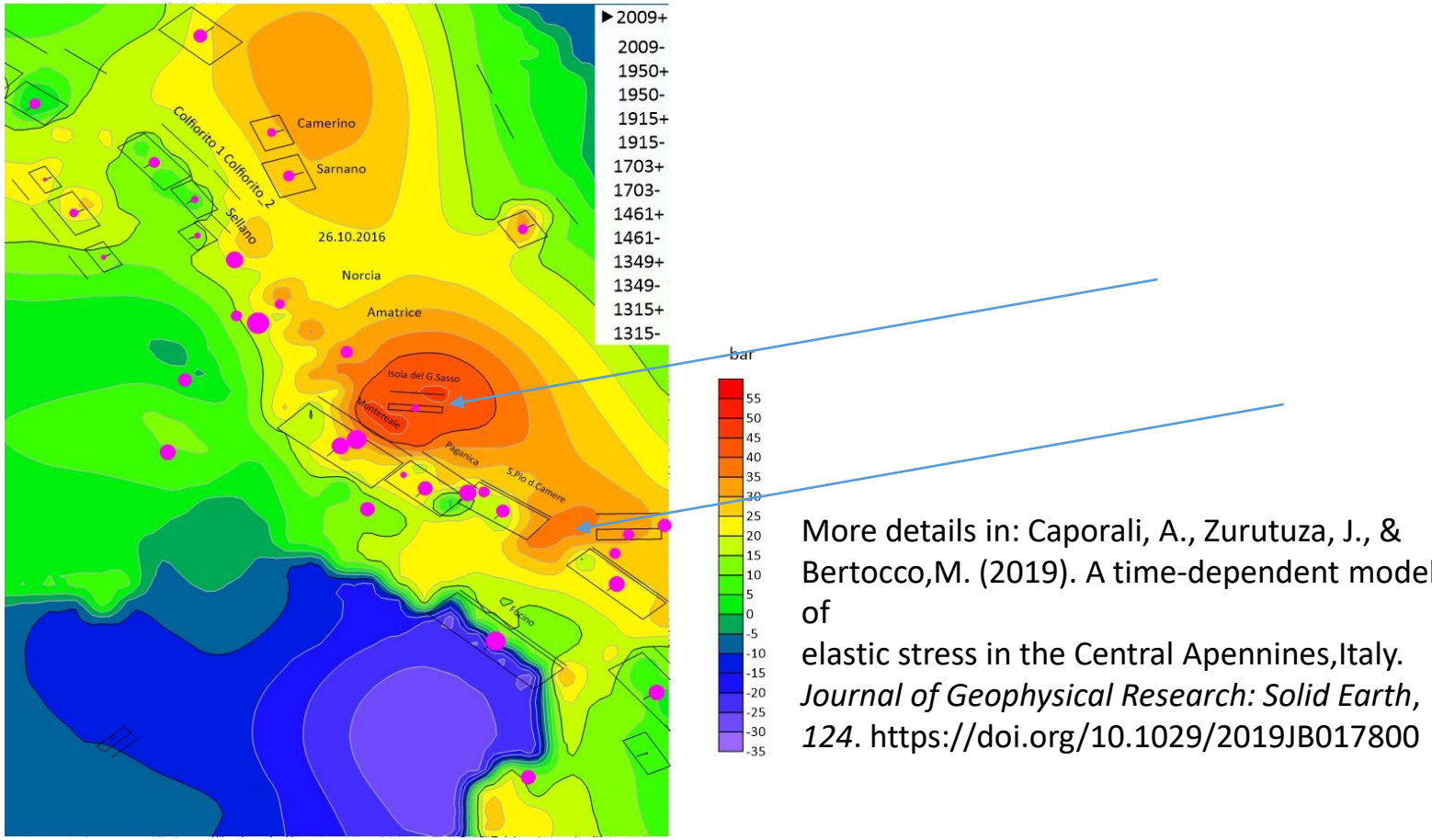
> 30.10.2016 (Norcia)

Stress excess before the event

Stress deficit after the event

Seismic gaps: areas of highest Coulomb stress

Coulomb stress at Aquila mapped on faults with:
strike=133; dip=43; slip=-85; Mw=6.3;refz_qk=-6.25; FRIC=0.4



More details in: Caporali, A., Zurutuza, J., & Bertocco,M. (2019). A time-dependent model of
elastic stress in the Central Apennines,Italy. *Journal of Geophysical Research: Solid Earth*, *124*. https://doi.org/10.1029/2019JB017800

Final remarks

- Critical assumptions to this model:
  - The scaling time is the minimum time to align the stress eigenvectors to the eigenvectors of the moment tensor of L'Aquila 2009
  - Longer scaling times would do the same alignment but put the crust in a state of higher stress. Hence we assume that the crust is in a state of minimal stress to yield
  - We do not know the moment tensors and hypocenters of the historical earthquakes, but we have assumed them based on present day seismicity and historical data
  - Is the scaling time related to the recurrence time for a Mw=6 - 6.5 event based on the Gutenberg Richter? Could be ….!