Geological control of hydrological transient deformation in the Venetian Southern Alps

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Focus: study of transient ground deformation.

Organization of the talk:

1) summary of previous results;

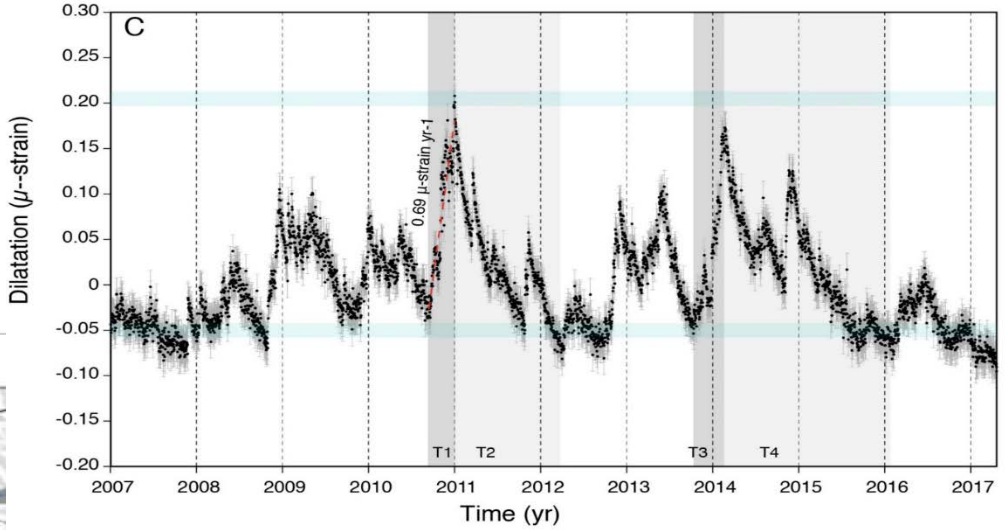
2) correlation with water storage variations;

3) identification of the deformation source;

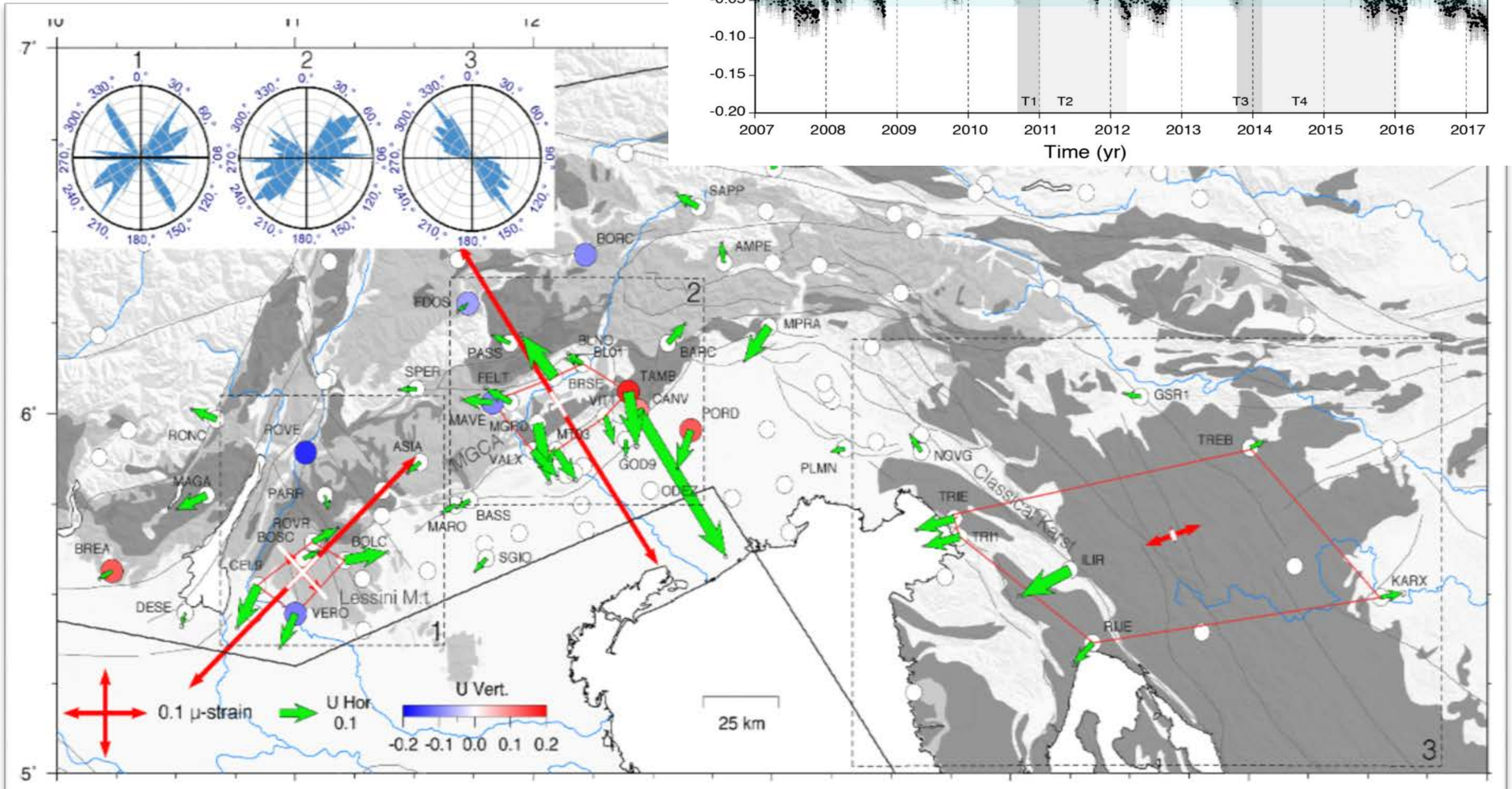
4) seismotectonic implications.

Transient deformation in the Alps

- Serpelloni *et al.*, JGR, 2018 found geodetic evidence of a transient deformation signal causing a sequence of compressional and extensional horizontal deformation.



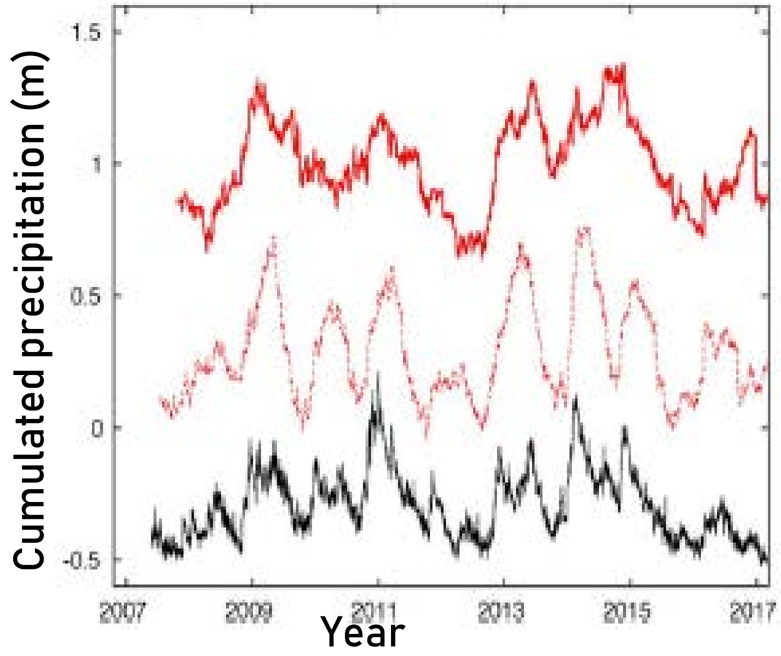
- Strains are larger in three areas, corresponding to three karst systems.
- Deformation axis perpendicular to orientation of rock fractures.

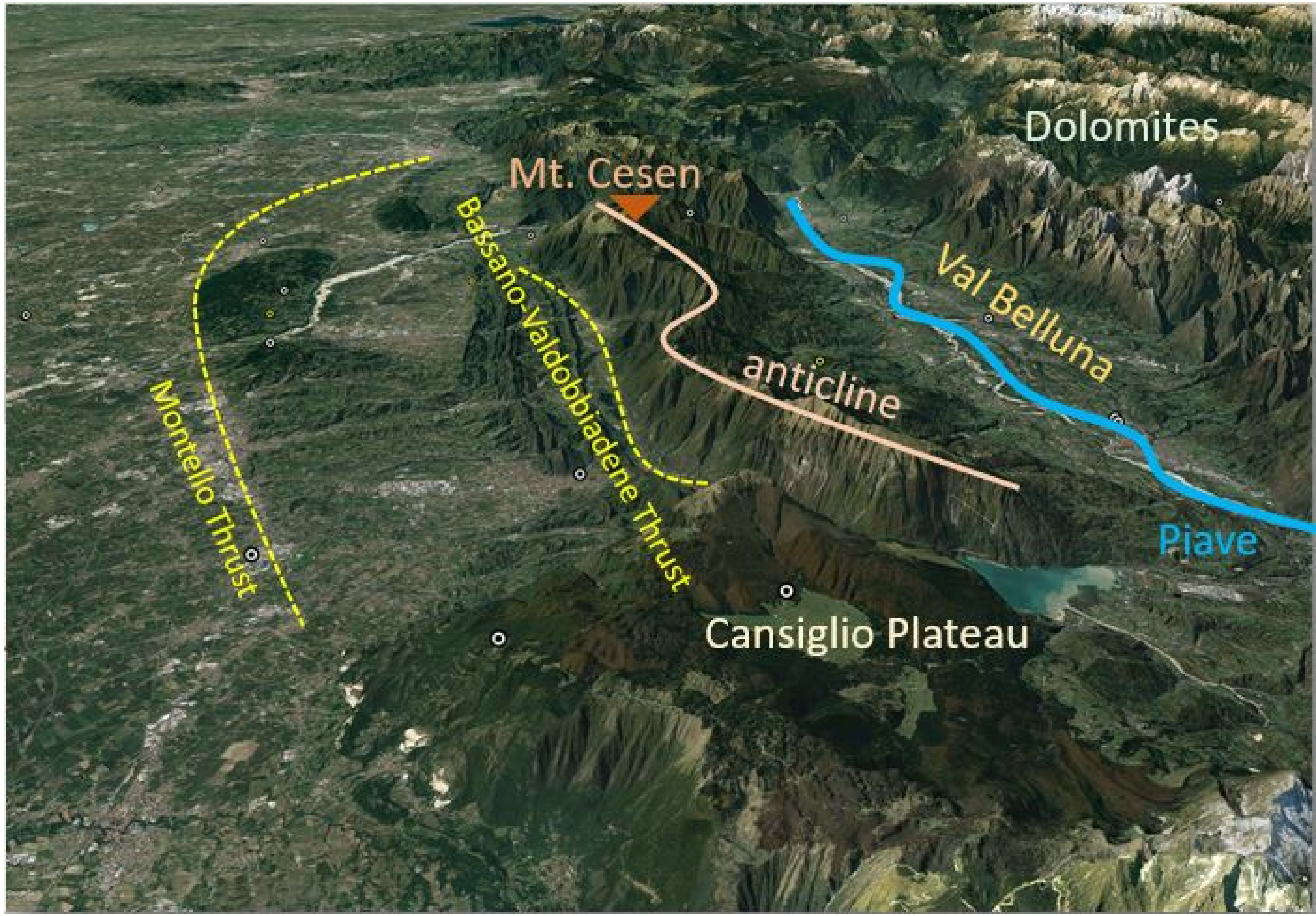


Correlation with precipitation

- Correlation between the time evolution of the strain with curves of cumulated precipitation (solid lines) and cumulated effective precipitation (dashed lines).

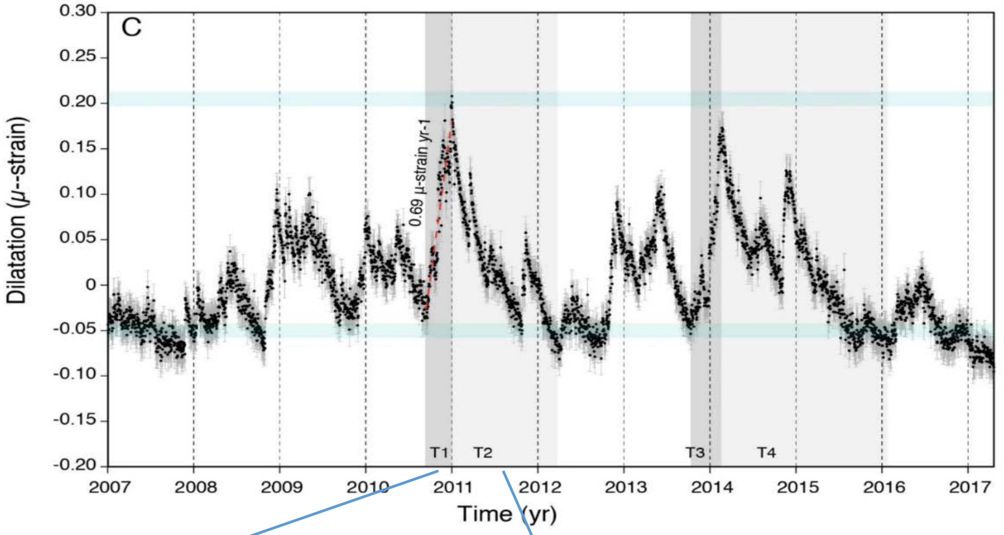
- Focus on Montello, M.te Grappa-M.te Cesen anticline and the Val Belluna:
- tectonically active area;
- denser GPS network;
- good availability of hydrological data.



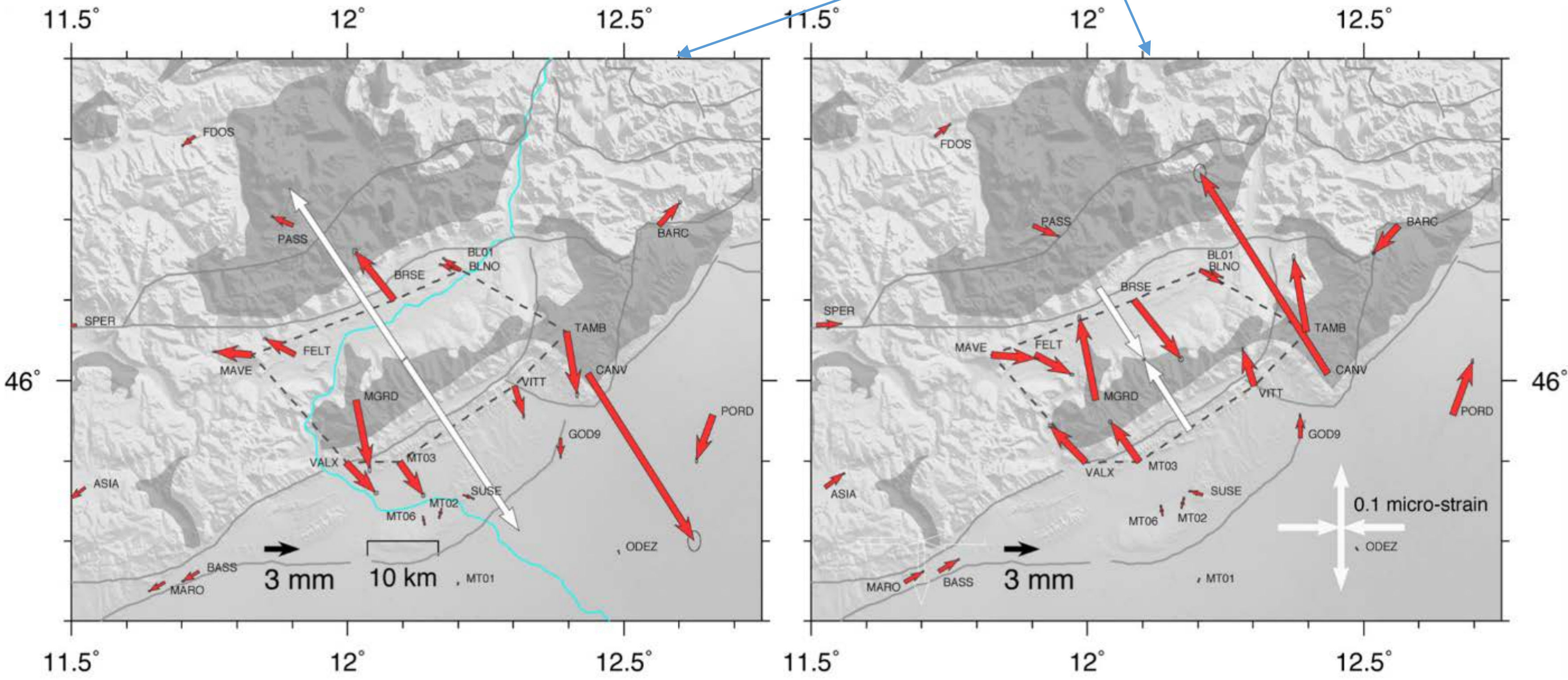


Hydrological-induced deformation in the Alps

- Extensional deformation when strain time series is increasing (e.g. T1 corresponding to mid-September to end of December 2010, left figure).
- Contractional deformation when strain time series is decreasing (e.g. January 2011 to end of April 2012, right figure).

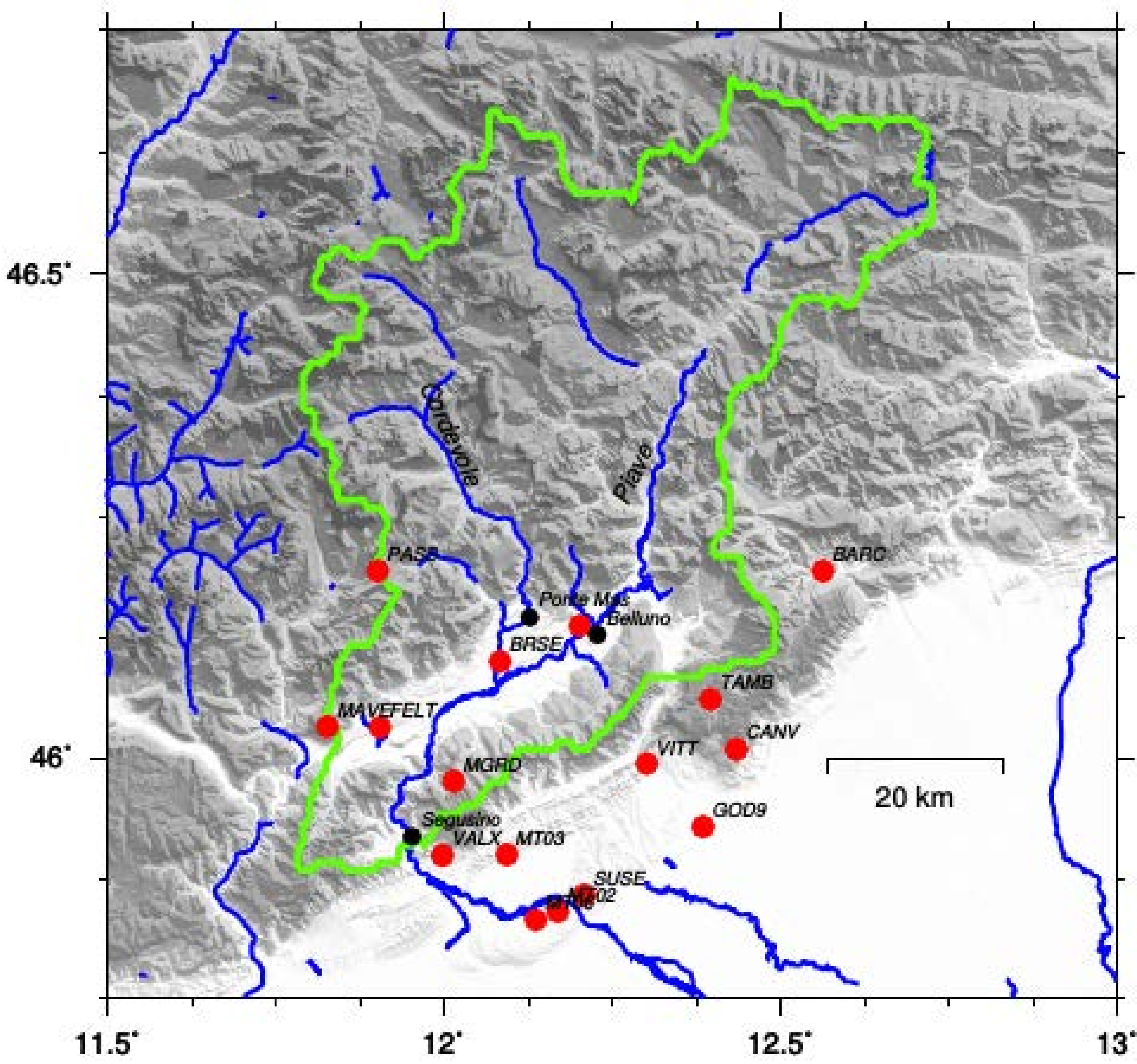


- Strain rate during T1: 0.69 microstrain/year, an order of magnitude greater than the rates of tectonic deformation from GPS velocities in this area.
- Displacement through the anticline hosting a karst aquifer.
- Displacements during T1 and T2: from mm to cm scale.



Transient deformation correlates with water storage variations

- Is correlation with precipitation a hint that transient deformation is caused by water storage (WS) variations in karst systems?
- Rainfall-runoff model to compute WS in the hydrological basin (green line) of Val Belluna.
  Model inputs:
  - potential evapotranspiration,
  - precipitation,
  - temperature.
  Model calibrated with Piave river flow.

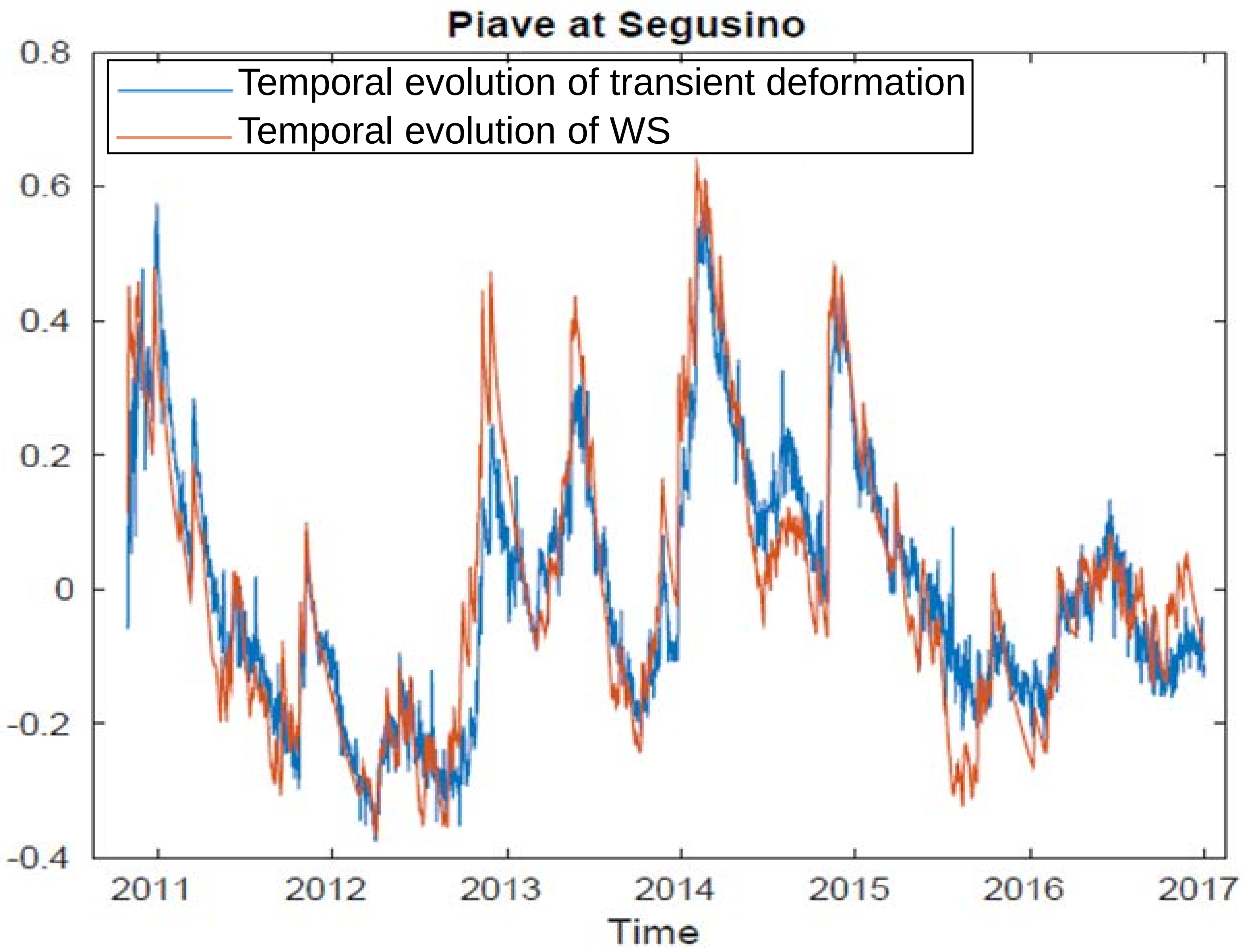


Transient deformation correlates with water storage variations

- The WS variations better correlates with the temporal evolution of the geodetic transient deformation than cumulated precipitation:

  - Highlight of a link between subsurface hydrological processes and deformation.

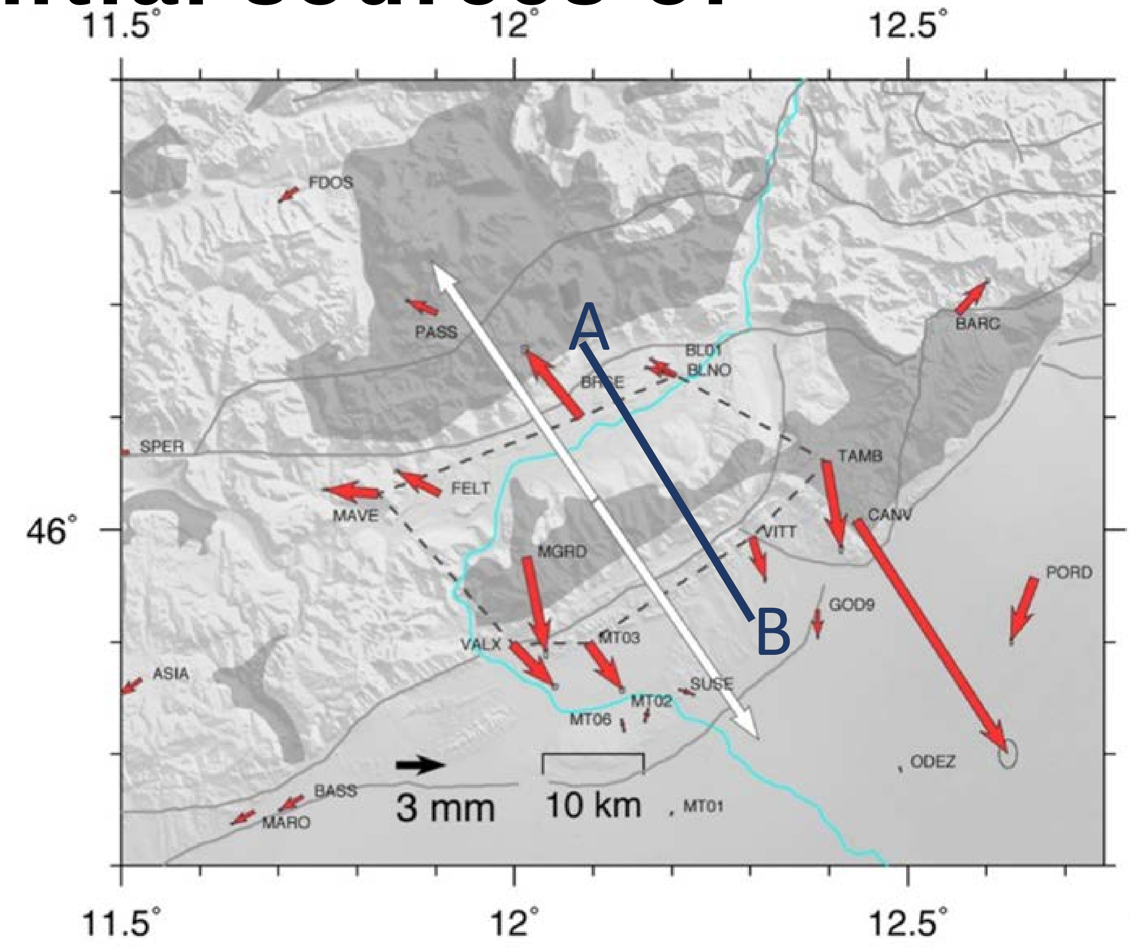
- How do WS variations cause strain?

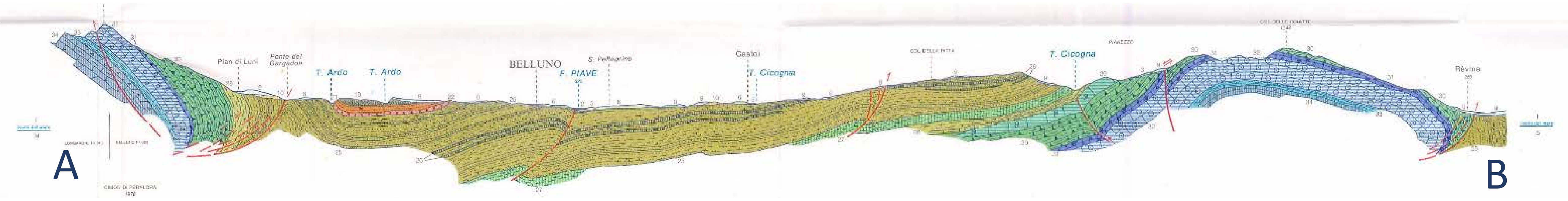


Numerical model to test potential sources of deformation

Model features:

- 2D model built across the Valbelluna, M.te Grappa-M.te Cesen anticline and the Montello hill (blue line).
- implementation of a geological profile taken from *Carta Geologica d'Italia* (bottom figure): geological features of the area are taken into account.
- finite element method accounting for topography and rock's mechanical properties.



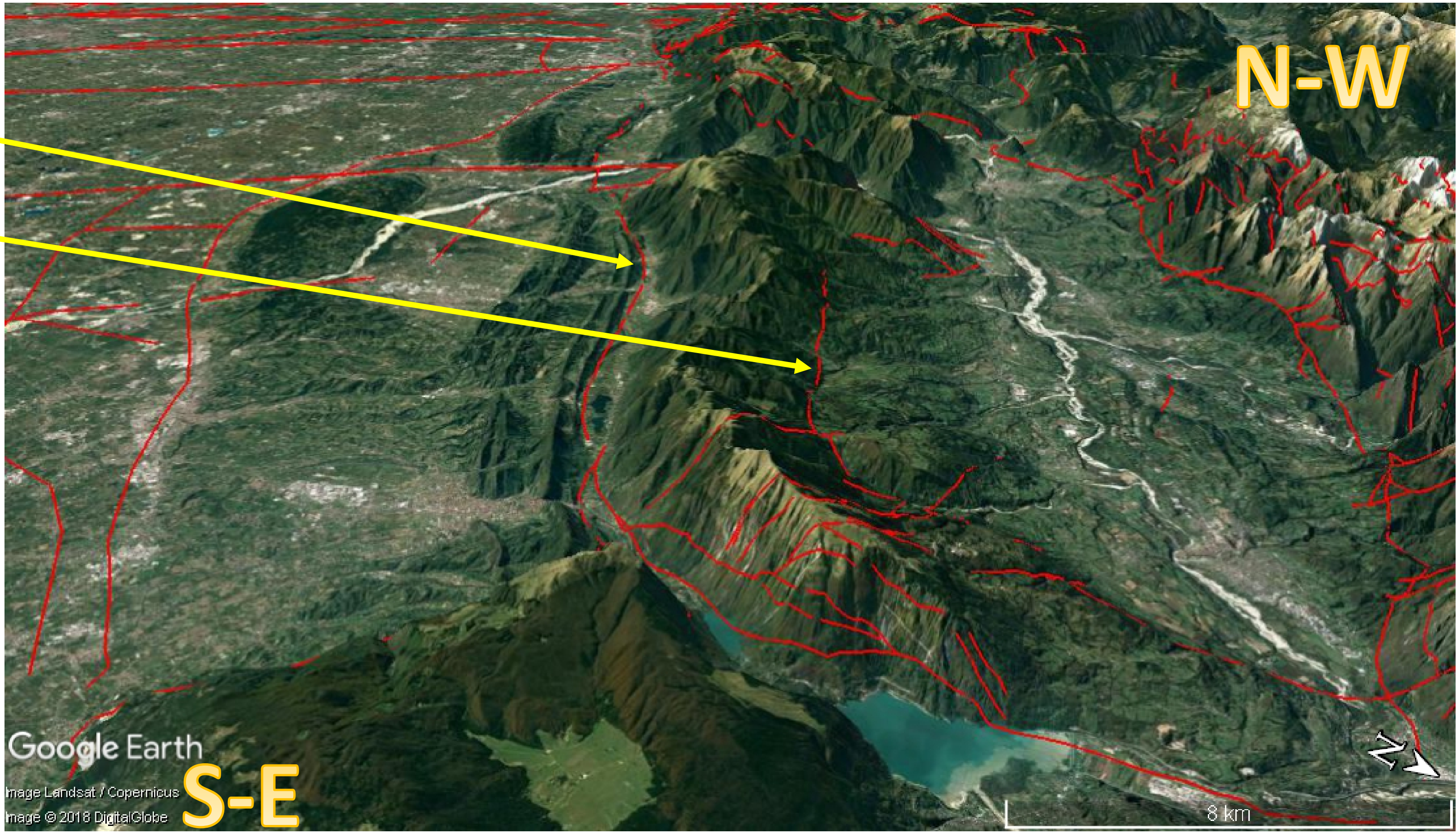


Tested sources of deformation

- Fractures associated with existing faults:

- Bassano-Valdobbiadene (BV) thrust;
- backthrust of BV thrust.

- Loading on the interface between rock layers having different permeability.



Results

Preferred source: fracture associated with the backthrust fault of the BV thrust:

- horizontal displacements are well reproduced in each station;
- vertical displacements are small as expected.

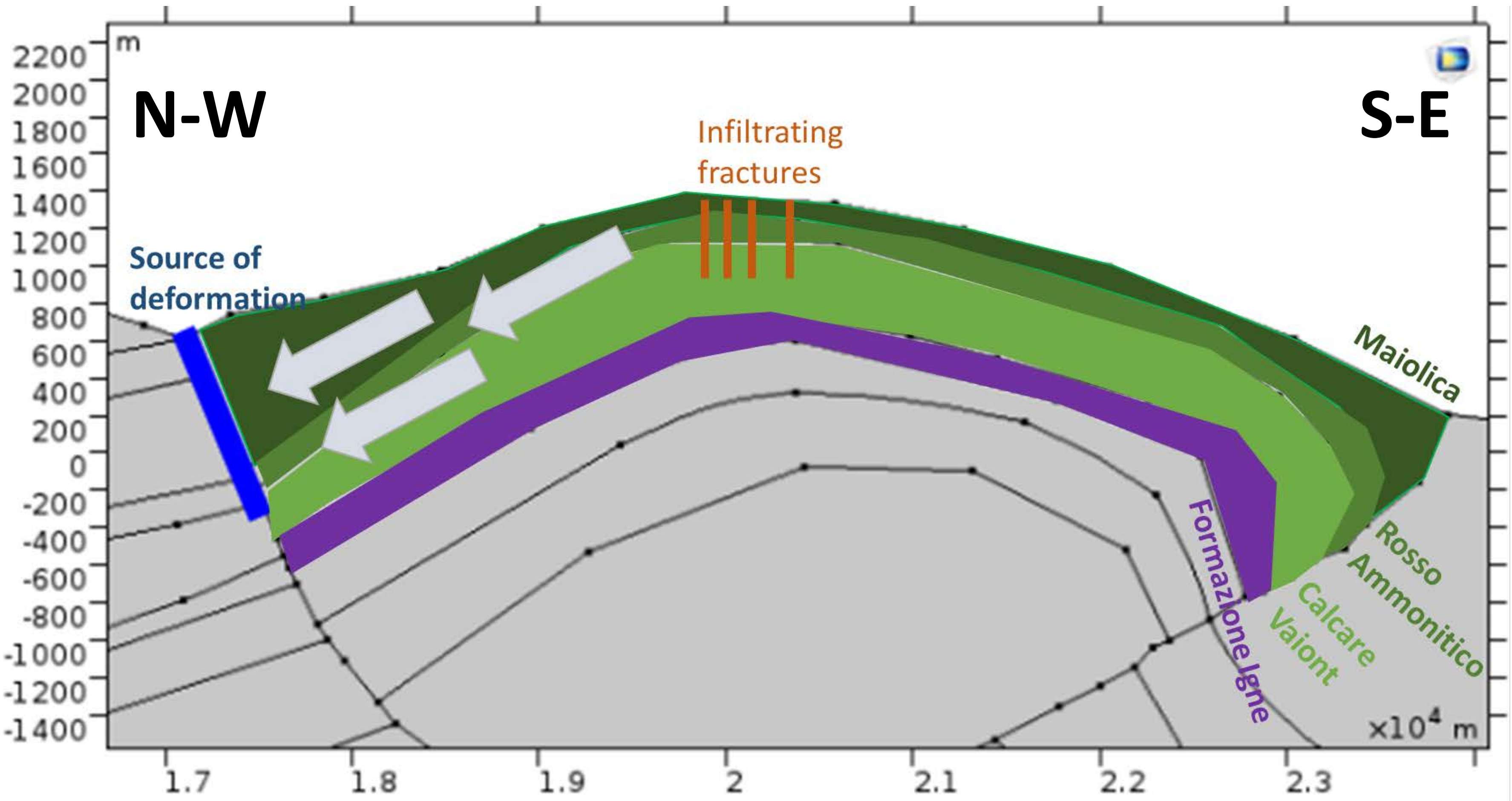
BV thrust case: horizontal displacements do not correspond to the observed ones in each station.

Loading on the interface: too large vertical displacements.

Physical process driving to deformation

- Precipitation water penetrates the rock because of fractures at the hinge of the M.te Grappa-M.te Cesen anticline;
- Flows in the subsurface through permeable layers (Maiolica and Rosso Ammonitico);
- Filling of the fracturated area, i.e. the upper part of the BV backthrust. Fracture width: ~1km;

- During the largest extensional deformation phase: Pressure increase: ~1MPa; corresponding to water level rise inside the fracture of ~100m.
- Water level variation in the fracture reflects WS variations.



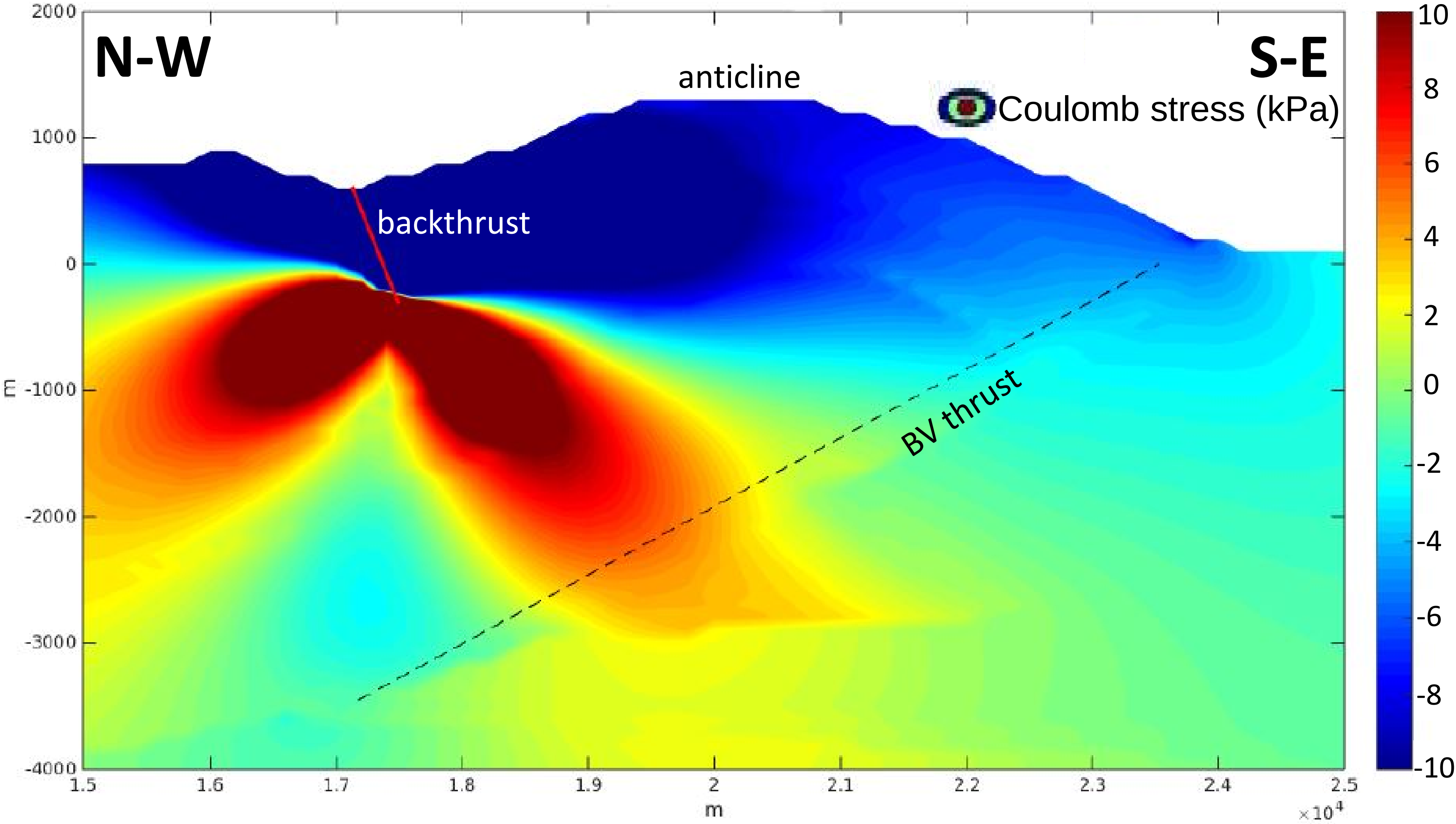
Seismotectonic implications

Test the effect of stress variations on active faults (Bassano-Valdobbiadene thrust? See *Insights into the seismic potential of the Venetian Southern Alps (Italy) from the integration of GPS and InSAR velocities* by Anderlini *et al.*, h 14:45)

Stress variation on fracture walls: +1MPa.

Maximum stress increase on fault plane: ~ 10^4Pa at -2500m.

Maximum stress decrease on fault plane: ~ 10^4Pa at the surface.



Conclusions

- We detected spatially coherent transient horizontal deformation signals in GPS displacement time-series in the Southern Alps.

- We focused on a tectonically active segment of the Venetian Southern Alps thrust belt, across the Montello and Bassano Valdobbiadene thrust faults, where slow tectonic deformation rates ask for the highest accuracies in the measurements of the geodetic rates.

- We found that the temporal evolution of the transient geodetic signal is correlated with the temporal evolution of water storage changes of the Piave hydrological basin in the Val Belluna.

- By developing a numerical finite element model, we identified the source of deformation generating the observed displacements in the backthrust of the Bassano-Valdobbiadene thrust fault.

- Changes of water levels of the order of 100 m in the highly permeable fault-rock associated with the backthrust fault cause changes of the Coulomb stress on the Bassano-Valdobbiadene thust of the order of 10 kPa down to 2.5 km.