Data base of Italian velocities and strain rates at permanent GNSS sites

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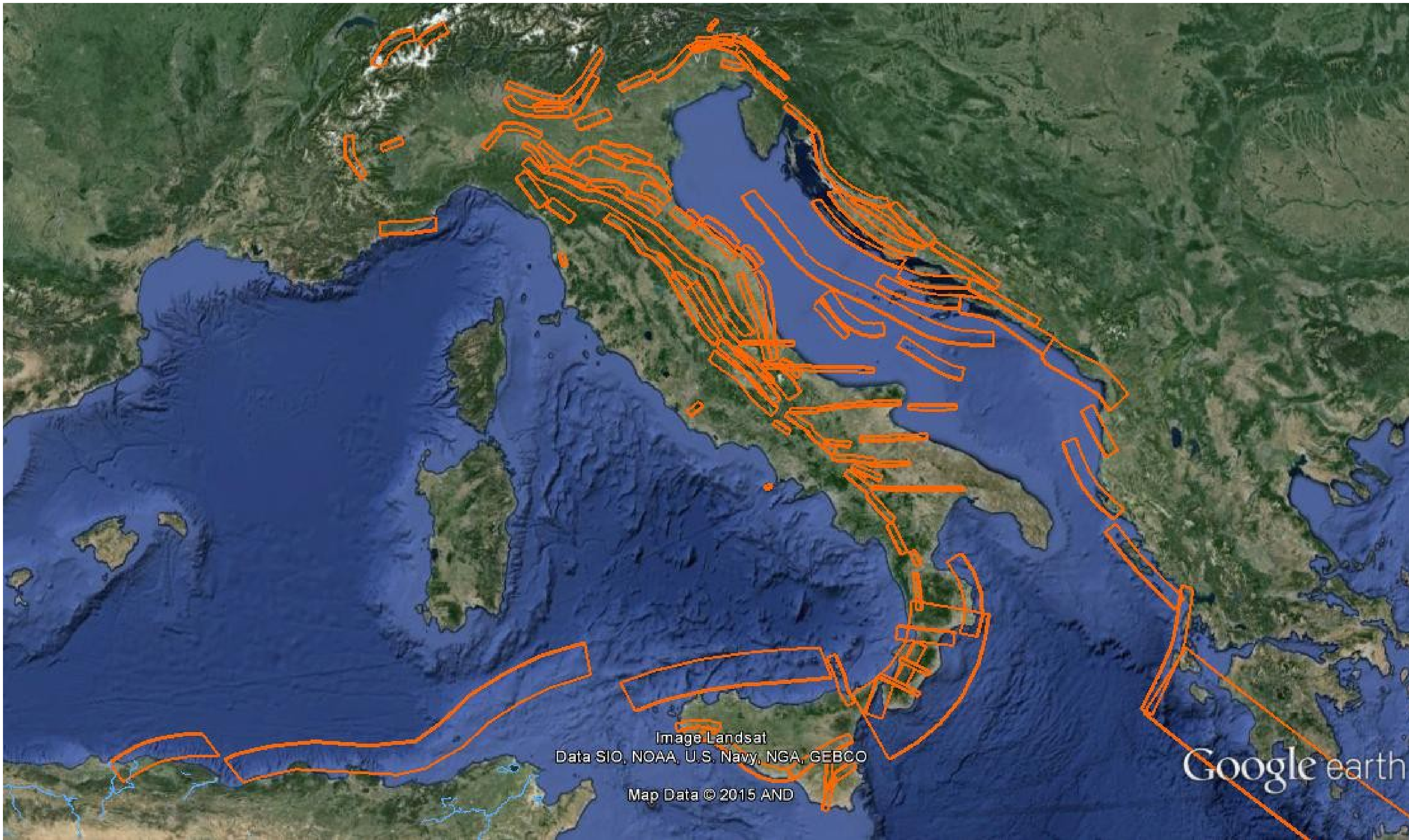
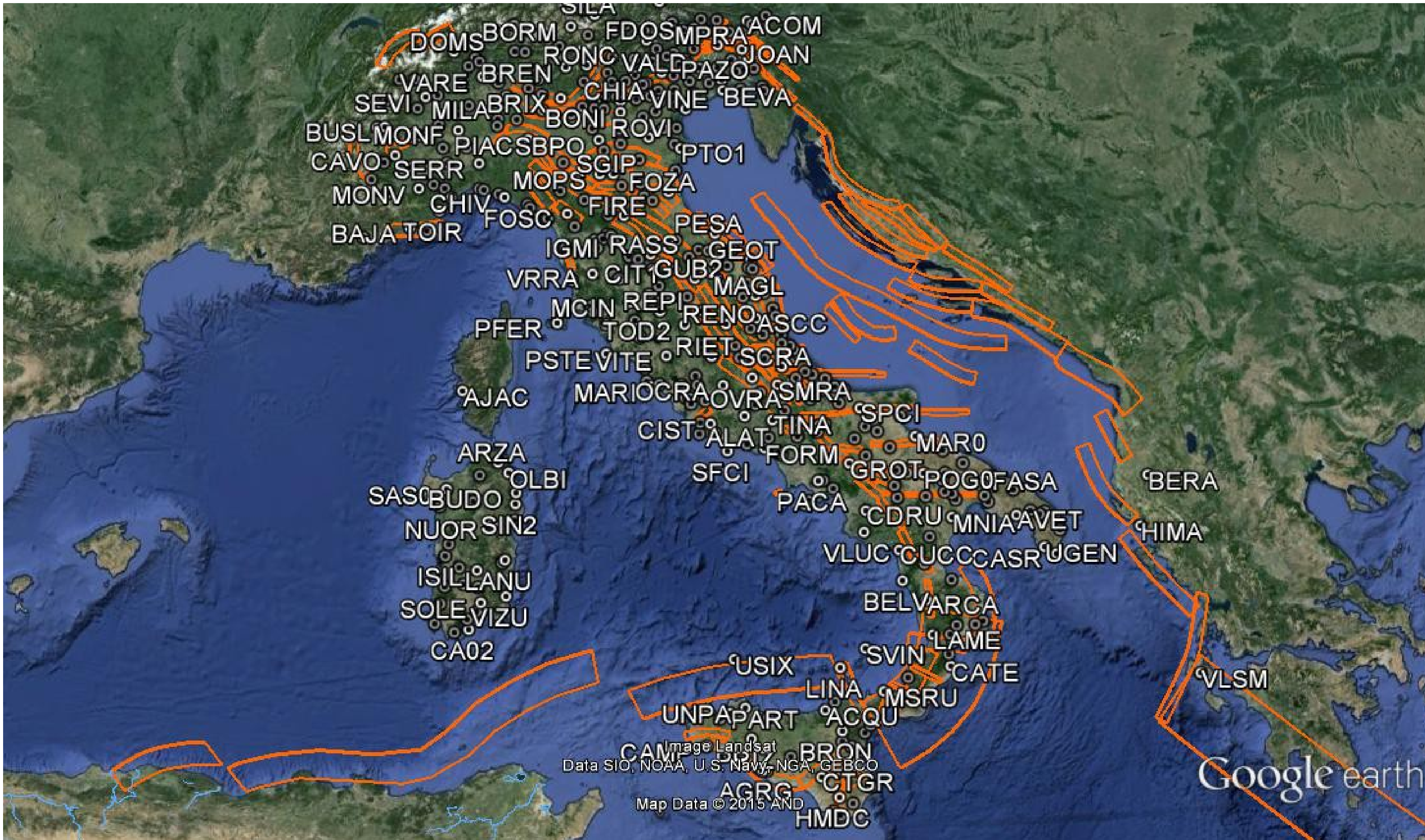
Outlook

- Italian permanent network: 450 sites, unique Domes and 4 char id, IGS/EPN logsheet; weekly sinex’s for densification
- Cumulative solution from wk1632 – present
- STA file links to Time Series web page; solution numbers
- Velocity to strain rate Matlab program generates Geostructures, KML/SHP files
- Overlay to DISS of INGV (surface deformation vs. structural faults/seismogenic areas)

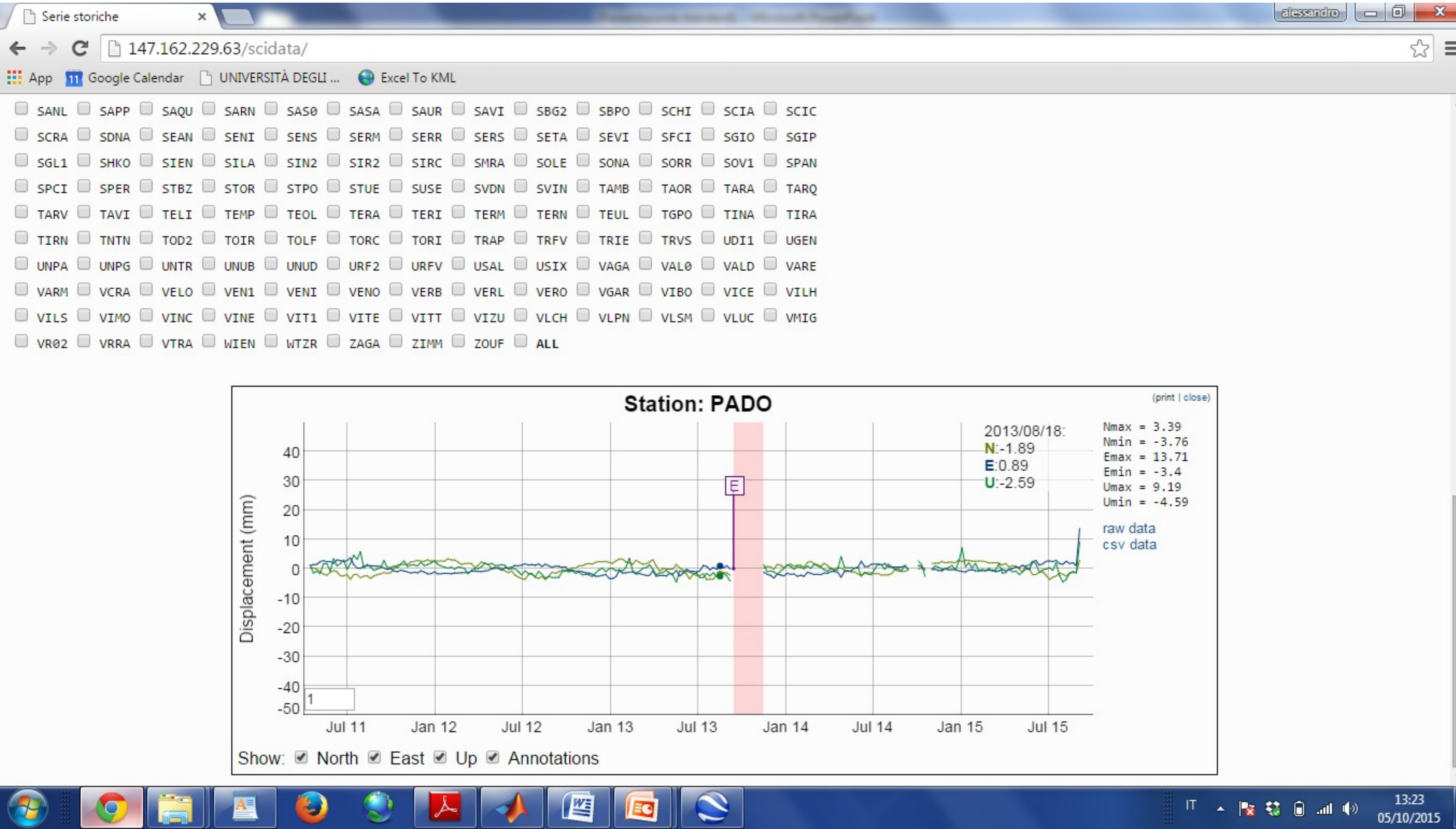
Goal: monitor ground deformation 3D, particularly in the seismogenic areas (orange polygons): need velocity gradients!



Method: use data from >400 permanent sites, EPN_A for georef



Weekly/ multiyear processing according to EPN guidelinesTime series maintenance, dynamic link to STA file



From velocities to strain rate

- Igb08 velocities from MC cumulative solution (weekly update, publish on web site http://retegnssveneto.cisas.unipd.it)
- ETRF2000 velocities using 14 params memo v8 xform
- Convert horizontal velocities to 2D strain rate eigenvectors using weighted least squares collocation (== optimal autoregressive algorithm)

Least Squares Collocation in 3 steps

1) Map scattered velocities to a point P using a covariance function; map variances as well.

2) transform scattered velocities to velocity gradient at a point P using the gradient of the covariance function; map variances of velocities to variances of strainrates .

3)Get maximum extensional/compressional strain rate from matrix diagonalization

$$\begin{bmatrix} v_n \\ v_e \end{bmatrix}_P = \sum_s C(d_{P,s}) \sum_{s'} \left[C(d_{s,s'}) + W_{ss'} \right]^{-1} \cdot \begin{bmatrix} v_n \\ v_e \end{bmatrix}_{s'} \quad s, s' = station \quad indeces$$

$$\begin{bmatrix} \sigma^2{}_n \\ \sigma^2{}_e \end{bmatrix}_P = \left\{ I - \sum_s C(d_{P,s}) \sum_{s'} \left[C(d_{s,s'}) + W_{ss'} \right]^{-1} C^T(d_{P,s'}) \right\} \cdot \begin{bmatrix} \sigma^2{}_n \\ \sigma^2{}_e \end{bmatrix}_{s'}$$

$$W_{ss'} = \frac{\frac{1}{\sigma^2{}_s}}{\sum_{s''} \frac{1}{\sigma^2{}_{s''}}} \delta_{ss'} \qquad C(d) = \frac{1}{1 + \left(\frac{d}{d_0} \right)^2}$$

$$\begin{bmatrix} v_{n,n} & v_{n,e} \\ v_{e,n} & v_{e,e} \end{bmatrix}_P = \sum_s \begin{bmatrix} \frac{\partial C}{\partial n} & \frac{\partial C}{\partial e} \\ \frac{\partial C}{\partial n} & \frac{\partial C}{\partial e} \end{bmatrix}_{P,s} \sum_{s'} \left[C(d_{s,s'}) + W_{ss'} \right]^{-1} \cdot \begin{bmatrix} v_n \\ v_e \end{bmatrix}_{s'} \quad s, s' = station \quad indeces$$

$$\dot{\varepsilon}_1 = \frac{v_{n,n} + v_{e,e}}{2} + \sqrt{\left(\frac{v_{e,e} - v_{n,n}}{2} \right)^2 + \left(\frac{v_{e,n} + v_{n,e}}{2} \right)^2}$$

$$\dot{\varepsilon}_2 = \frac{v_{n,n} + v_{e,e}}{2} - \sqrt{\left(\frac{v_{e,e} - v_{n,n}}{2} \right)^2 + \left(\frac{v_{e,n} + v_{n,e}}{2} \right)^2}$$

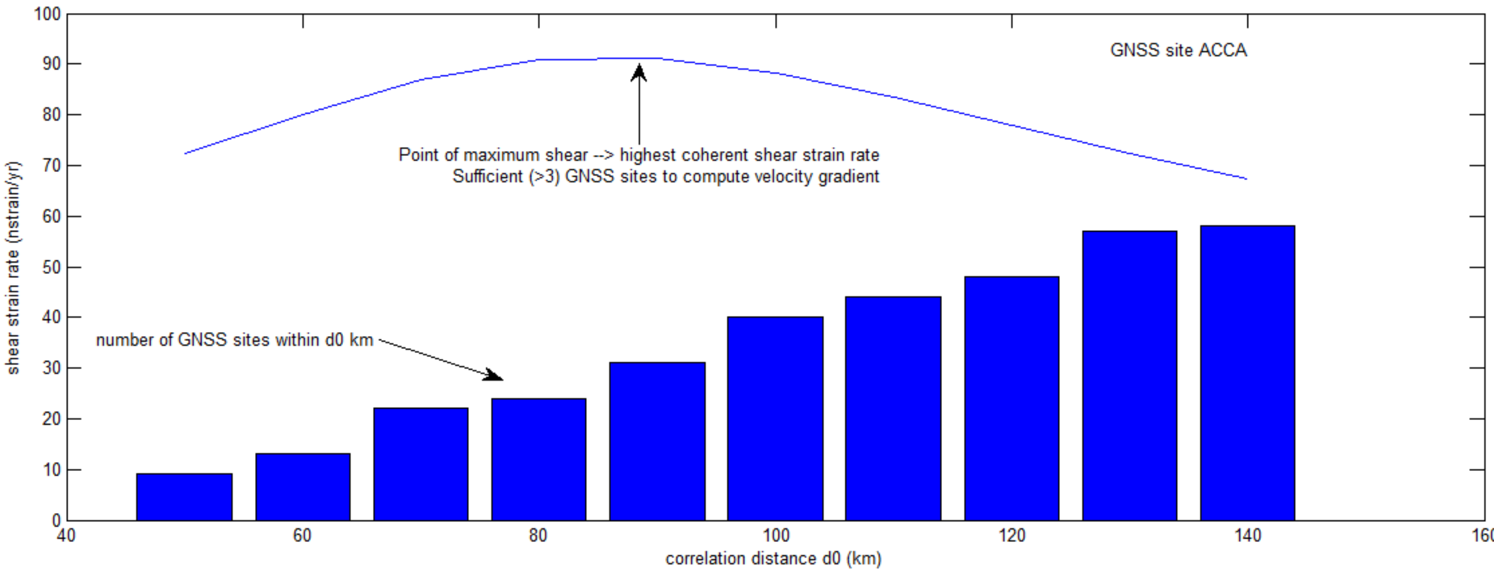
$$\sin 2\theta = \frac{v_{e,n} + v_{n,e}}{\dot{\varepsilon}_2 - \dot{\varepsilon}_1}; \cos 2\theta = \frac{v_{e,e} - v_{n,n}}{\dot{\varepsilon}_1 - \dot{\varepsilon}_2}$$

How to select d_0 in the covariance function

- Covariance function depends on a scale distance which defines the width of the Low Pass Filter
- If the scale distance is too small we are loosing coherent information from nearby sites; if too large, incoherent distant sites decrease the shear signal with random contributions there must exist a scale distance of maximum coherent shear strain
- Select the scale distance with the criteria: maximum shear strain rate & n>3 sites within d_0

$$C(d) = \frac{1}{1+\left(\frac{d}{d_0}\right)^2}$$

$$\dot{\varepsilon}_g = \max(\dot{\varepsilon}_1, \dot{\varepsilon}_2, |\dot{\varepsilon}_1 + \dot{\varepsilon}_2|)$$



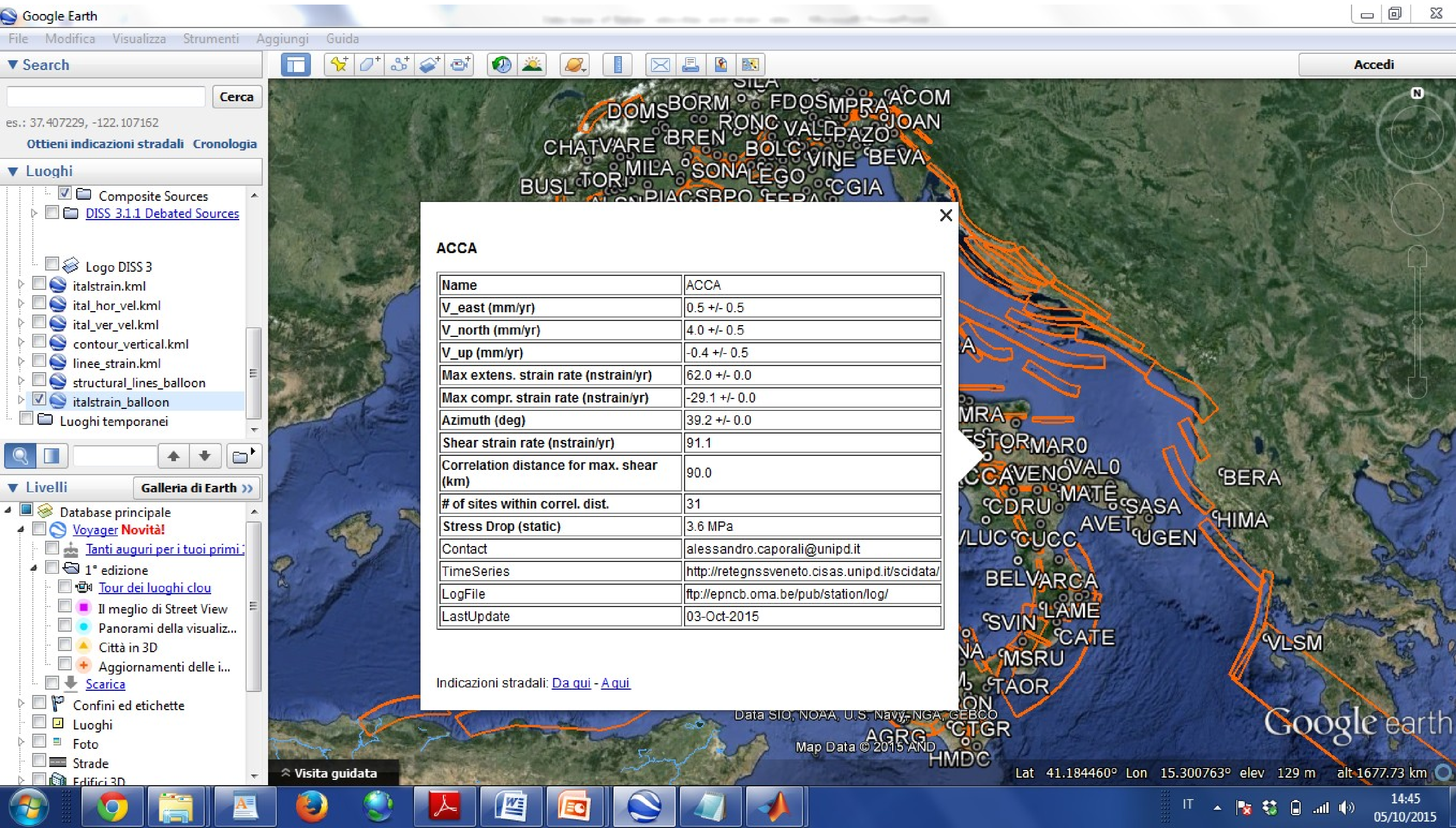
Computing the expected stratic stress drop at each site

- Static Stress drop is the maximum stress expected in an area of known m_{max} , geodetic shear strain, statistical seismicity (Gutenberg Richter *a,b*)
- ‘WC’ stands for Wells and Coppersmith: rupture area + average displacement as a function of magnitude

$$\Delta\sigma \leq \Delta\sigma_g \equiv \frac{2\mu\dot{\varepsilon}_g}{10^{a_s}} \frac{10^{[a_{wc}+b_{wc}m_{max}]} - 10^{[a_{wc}+b_{wc}m_{min}]}}{10^{[a_{wc}+(b_s+b_{wc})m_{max}]} - 10^{[a_{wc}+(b_s+b_{wc})m_{min}]}} \frac{b_s + b_{wc}}{b_{wc}}$$

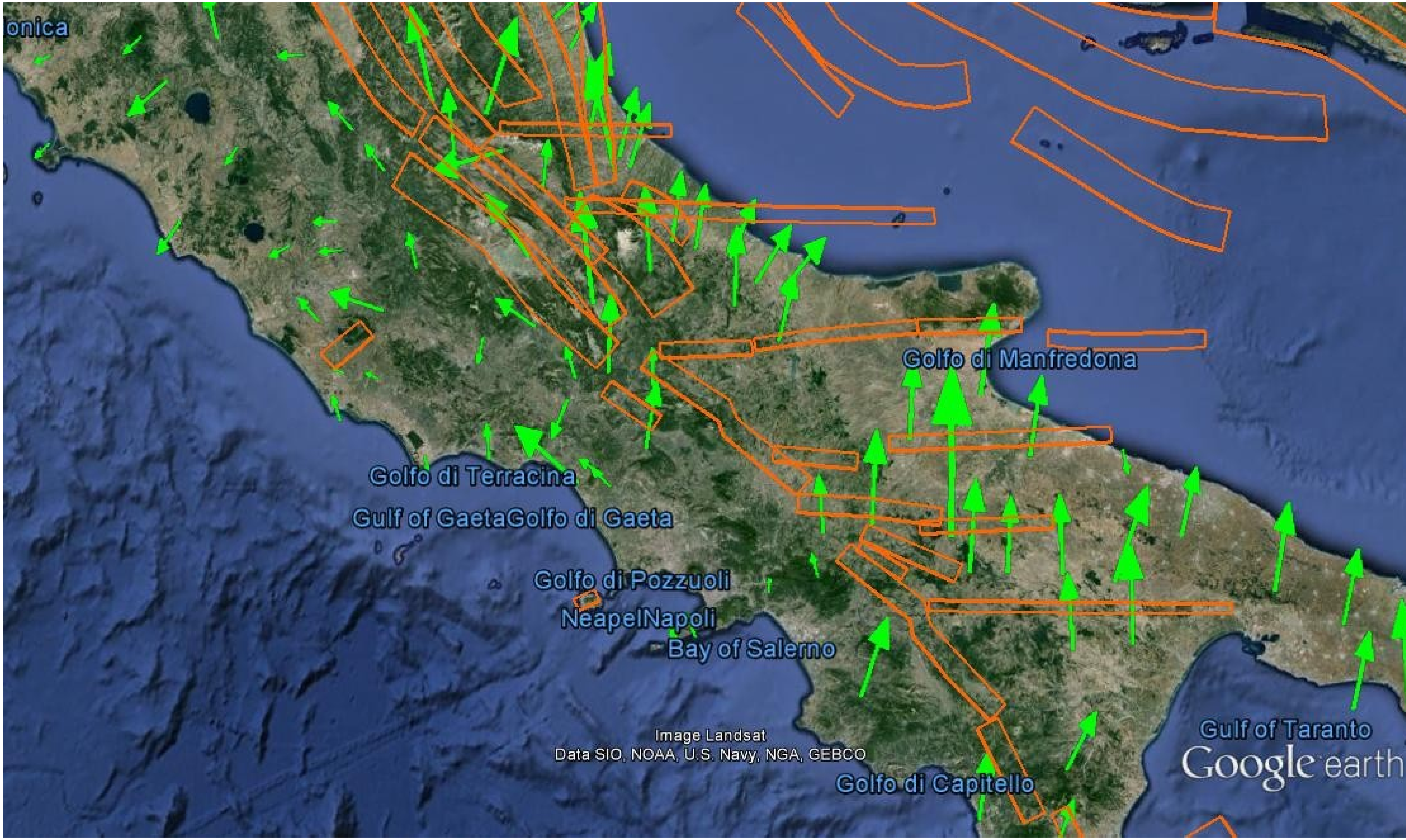
- m_{max} from CPTI04&ZS9 zonation +

Results: all the information is stored in a structured variable/site

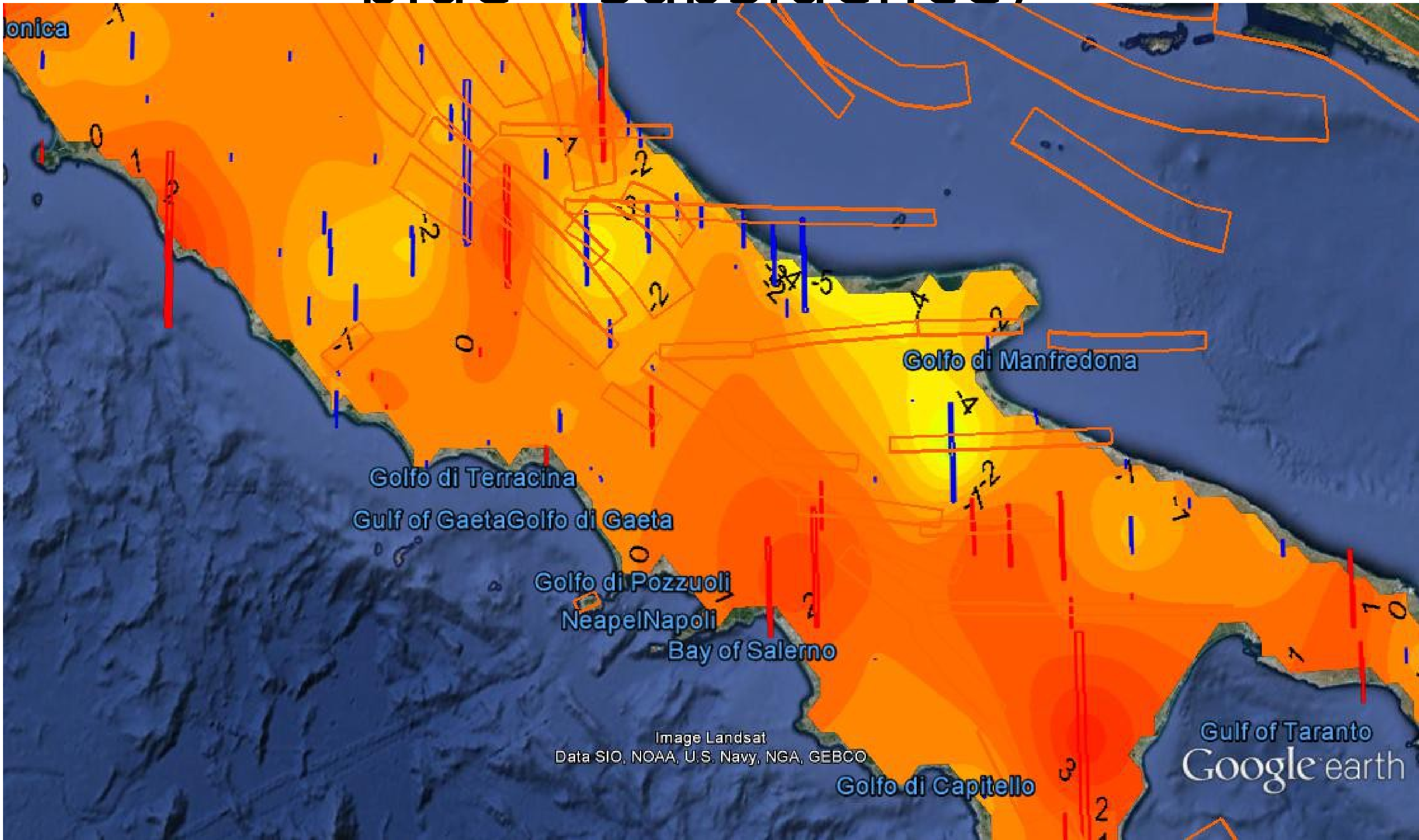


Name	ACCA
V_east (mm/yr)	0.5 +/- 0.5
V_north (mm/yr)	4.0 +/- 0.5
V_up (mm/yr)	-0.4 +/- 0.5
Max extens. strain rate (nstrain/yr)	62.0 +/- 0.0
Max compr. strain rate (nstrain/yr)	-29.1 +/- 0.0
Azimuth (deg)	39.2 +/- 0.0
Shear strain rate (nstrain/yr)	91.1
Correlation distance for max. shear (km)	90.0
# of sites within correl. dist.	31
Stress Drop (static)	3.6 MPa
Contact	alessandro.caporali@unipd.it
TimeSeries	http://retegnssveneto.cisas.unipd.it/scidata/
LogFile	ftp://epncb.oma.be/pub/station/log/
LastUpdate	03-Oct-2015

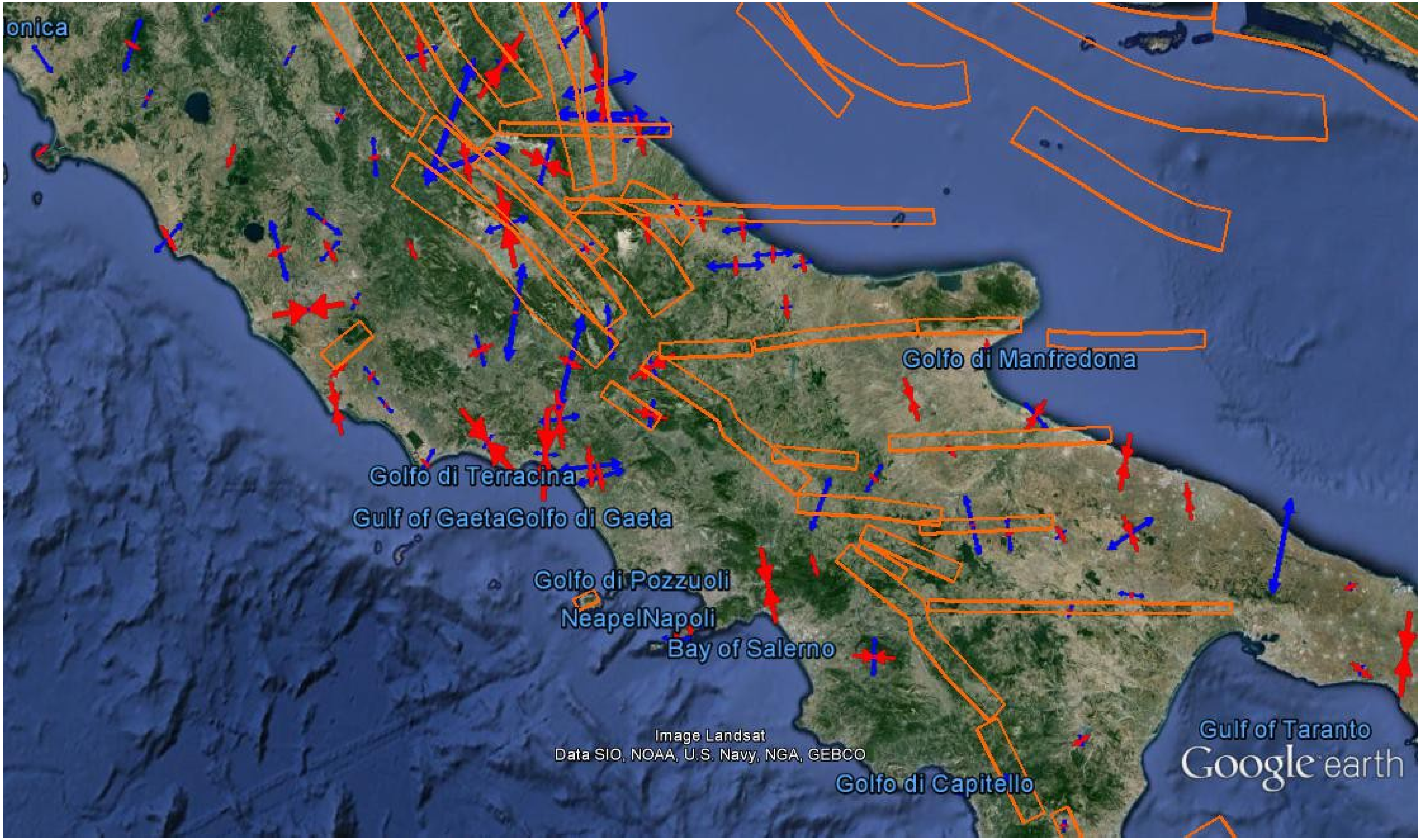
Horizontal velocities (numerical values in GE Balloons)



Vertical velocities (numerical values in GE Balloons: red=uplift; blue= subsidence)



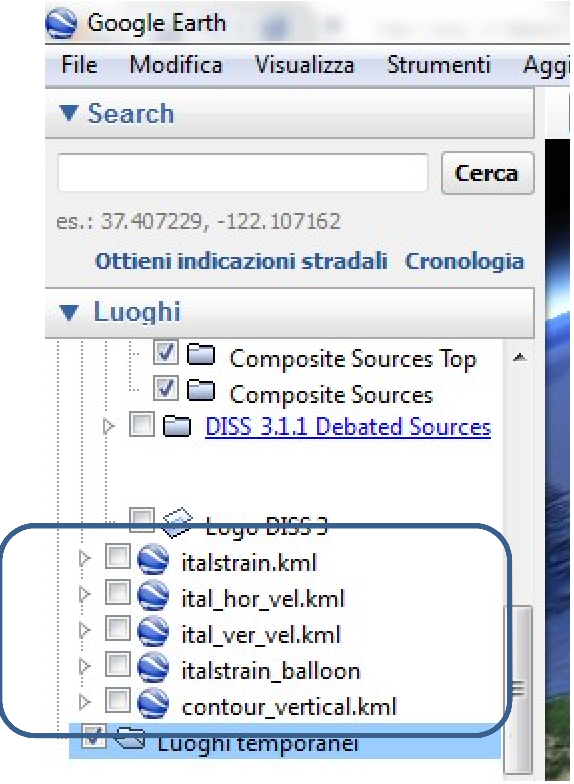
Strain rate (numerical values in GE Balloons: red=compression; blue=extension)



Conclusions

- So far 415 permanent GNSS sites: IGS style logsheet, daily metadata checking in the Rinex files, unique 4 char id and DOMES from IGN
- Regularly updated database using Matlab script
- Geostruct with position, velocity, strain rate, stress drop and related information + hyperlinks
- Can be used to sample geodetic information along structural lines
- Particularly interesting as overlay to DISS 3.x

KML Products



- Italstrain: strain rate map
- Ital_hor_vel: horizontal velocity map (ETRF2000)
- Ital_ver_vel: vertical velocity map
- Italstrain_balloon: balloon with numerical/alphanumerical data
- Contour_vertical: contour of vertical data (inland only)