Unified Structural Representation Workflow for Updating the SCEC CVM-H

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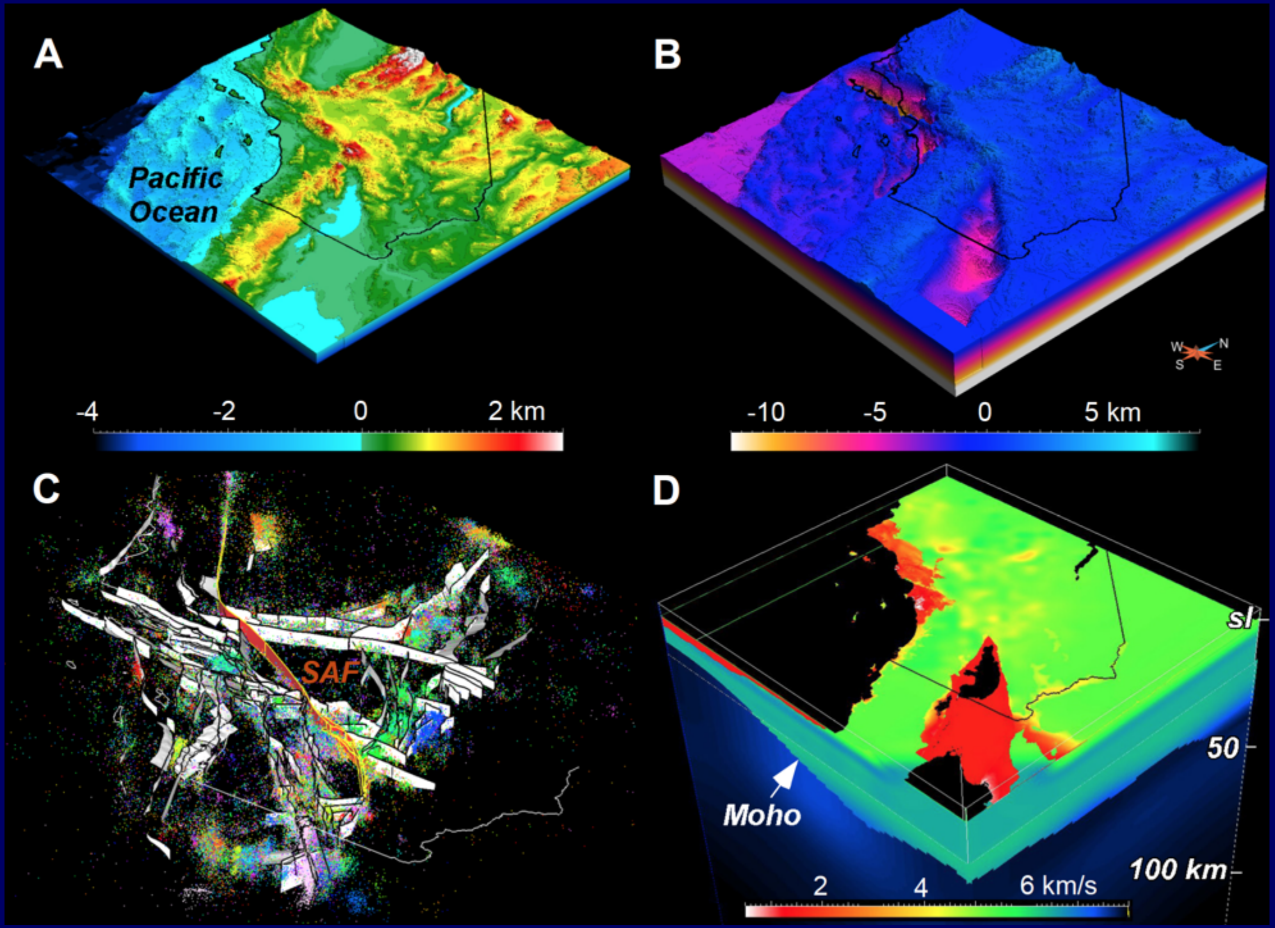
Workshop: San Francisco Bay Area Seismic Velocity Models for Seismic Hazard Assessment, 3/21/18

The Unified Structural Representation (USR)

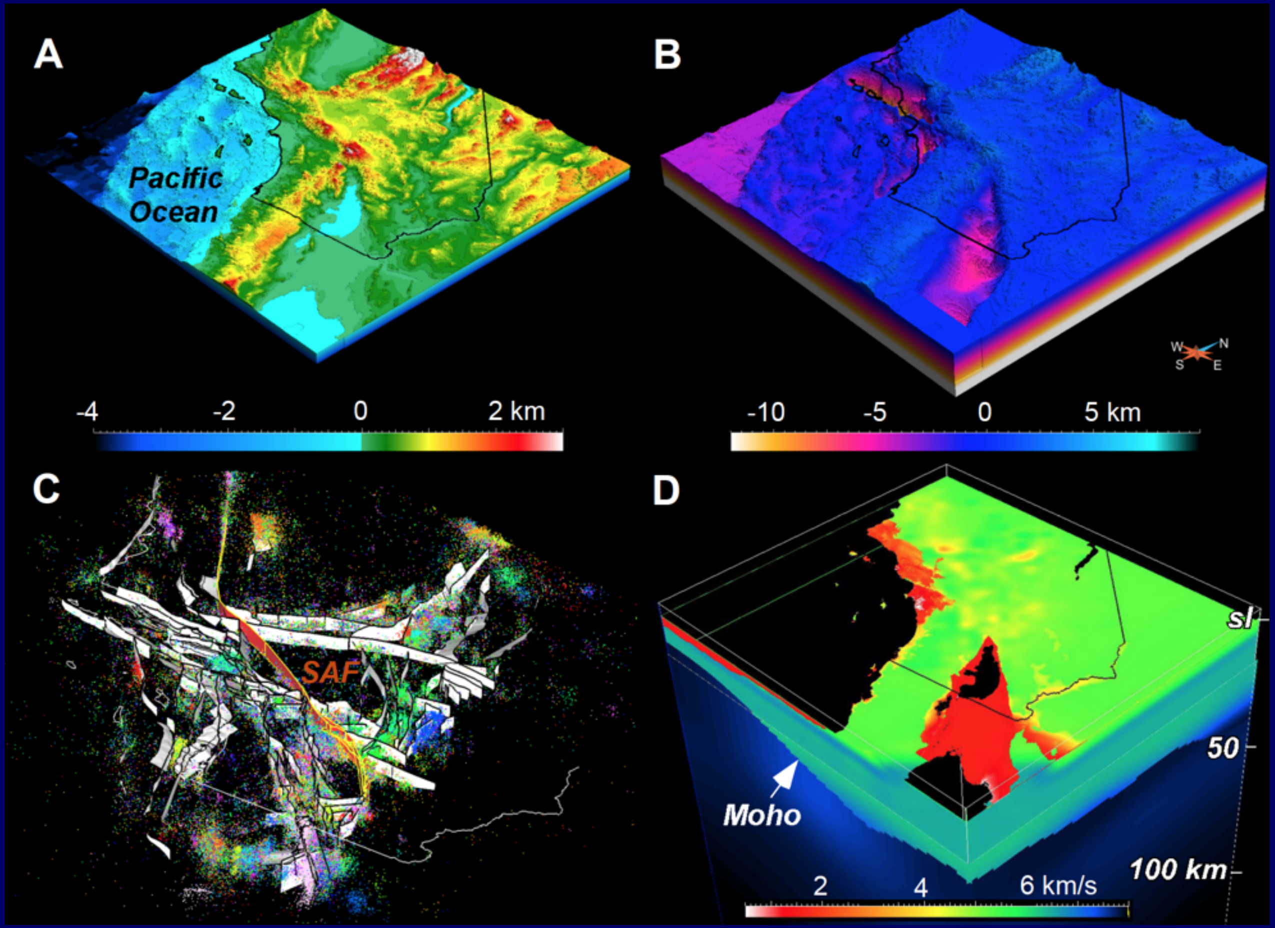
- ❑ Community Fault Model:
- ❑ >300 active faults in seismogenic crust
- ❑ Community Velocity Model:
- ❑ Stacked high resolution Vp model with explicit, high contrast interfaces



SCEC4 Unified Structural Representation (Shaw et al., 2015)

Key Concepts Guiding USR Community Models

- ❑ Consistency across models
- ❑ Multiple types of feature representation
- ❑ Alternative representations of the same feature
- ❑ Easy access
- ❑ Versioned releases
- ❑ Established target: boundaries, depth, resolution



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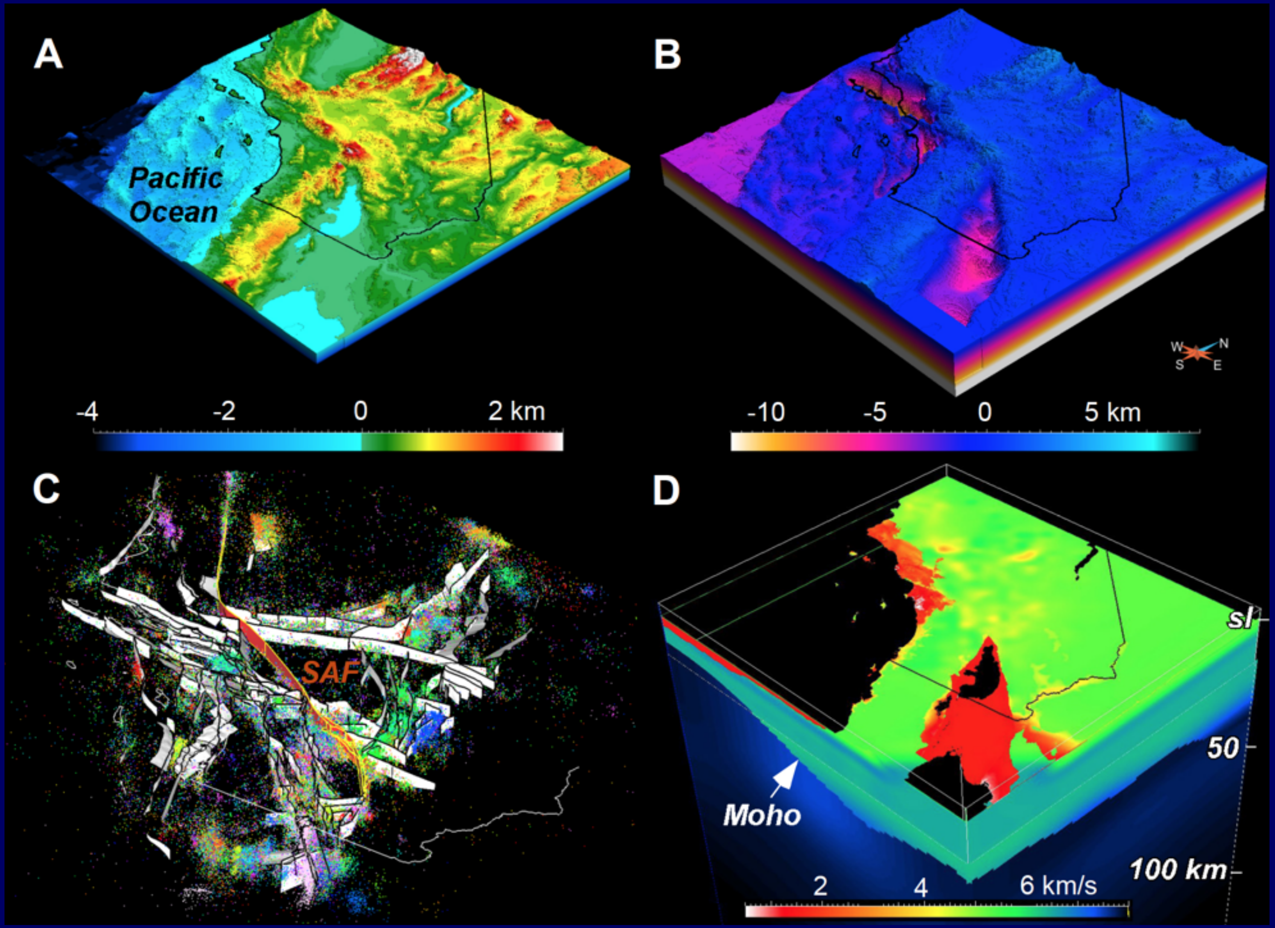
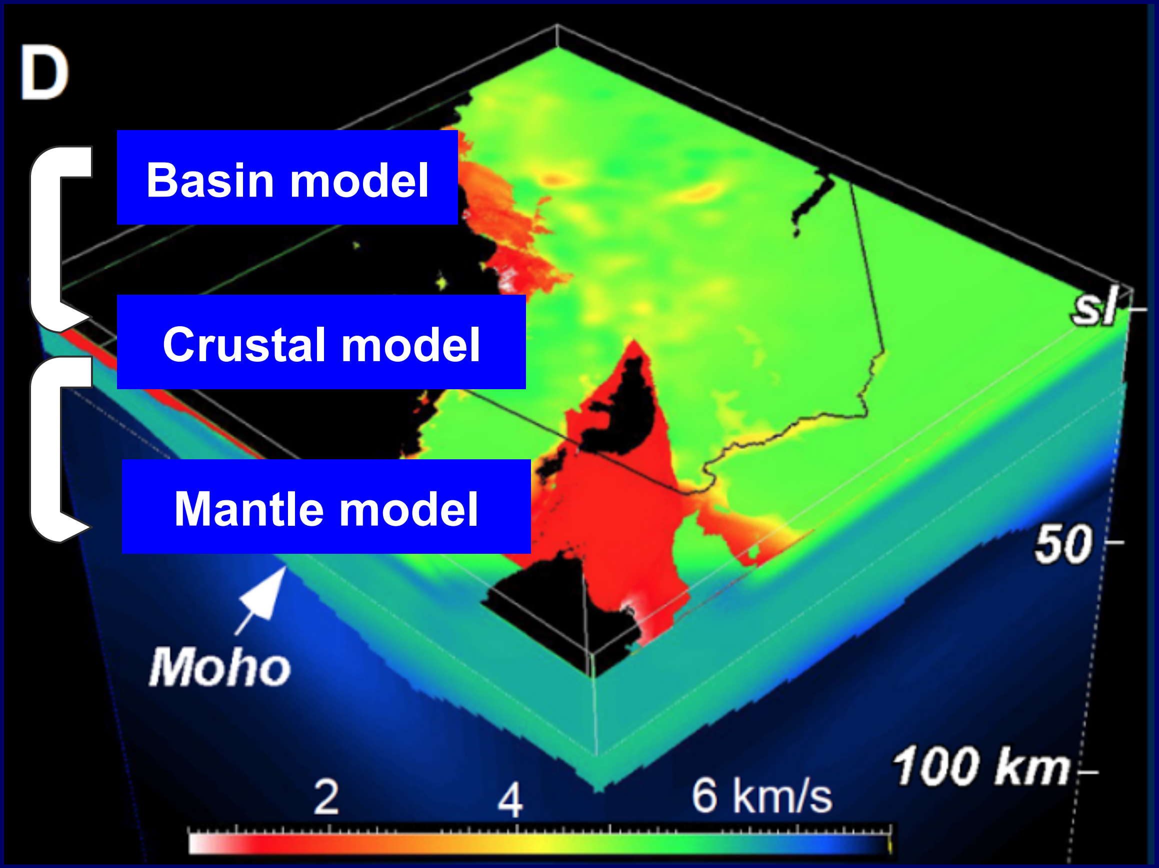


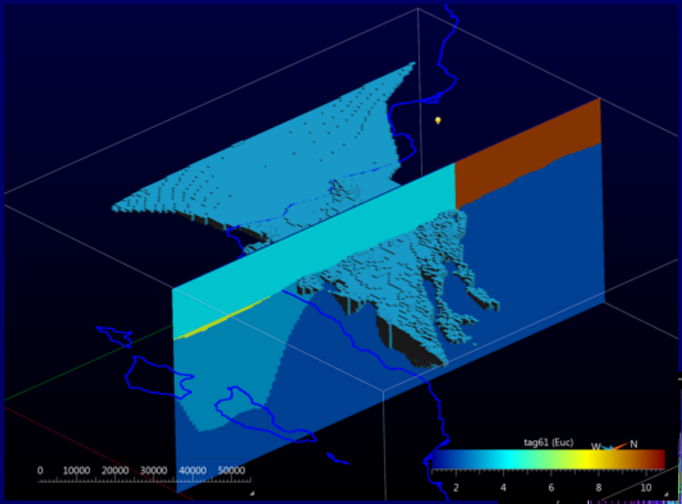
SCEC4 Unified Structural Representation (Shaw et al., 2015)

Model consistency

- CVMH embeds a **basin model** in a **crustal model** in an upper **mantle model**
- Deeper levels were constructed using shallower levels as input to ensure consistency
- Major interfaces are offset at CFM faults

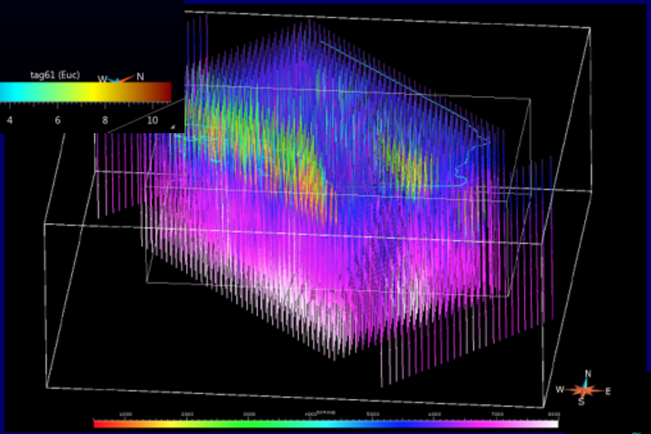


CVM-H 15.11

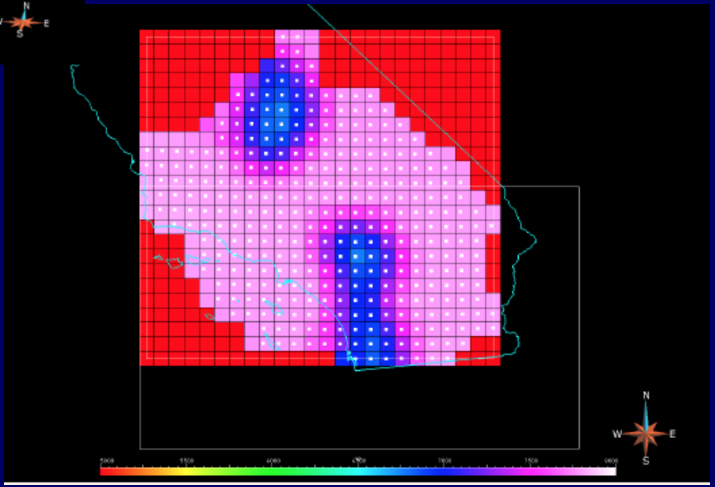


CVM-H Santa Maria

basin

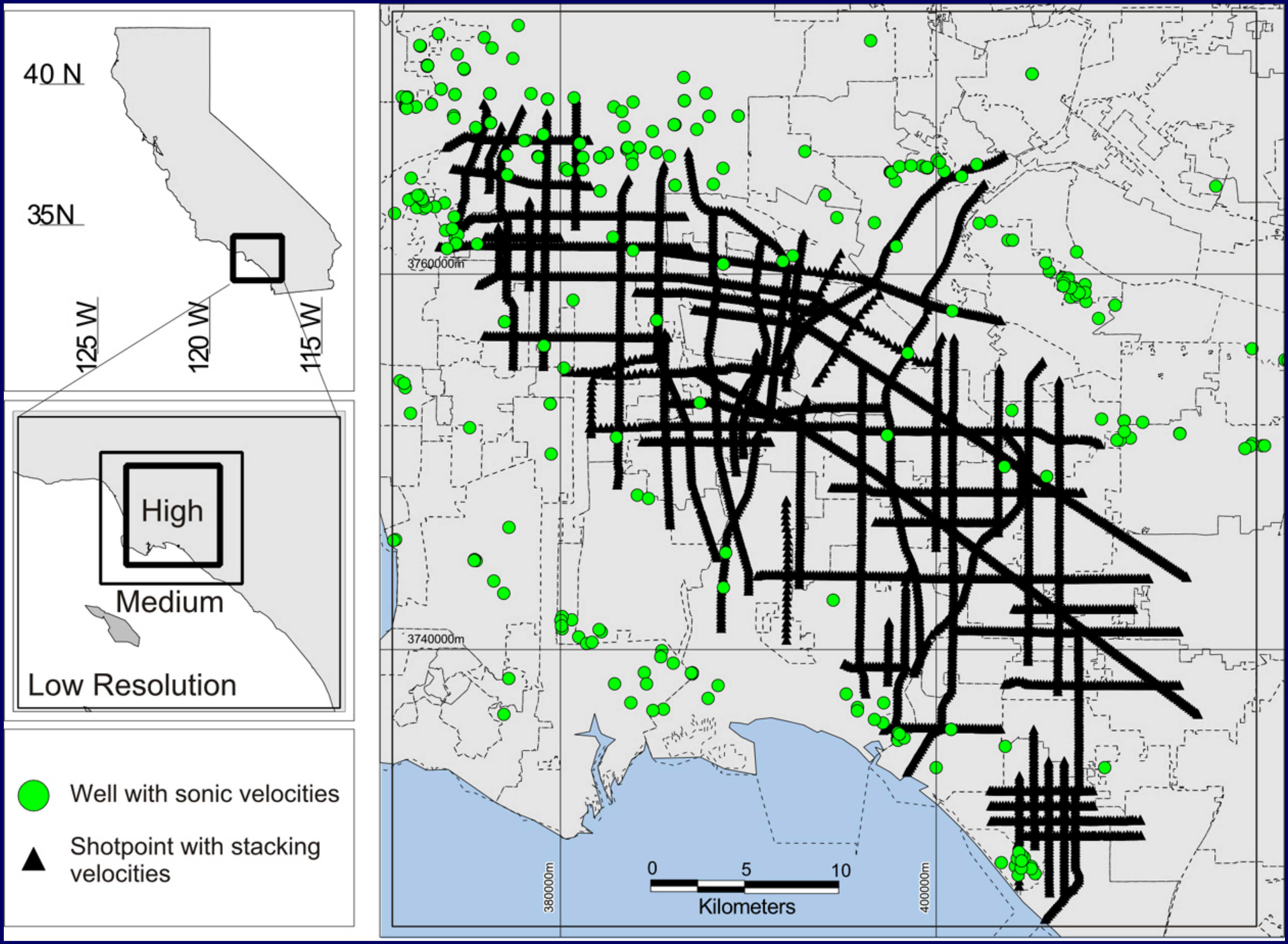


Crustal tomography (after Hauksson et al., 2000)

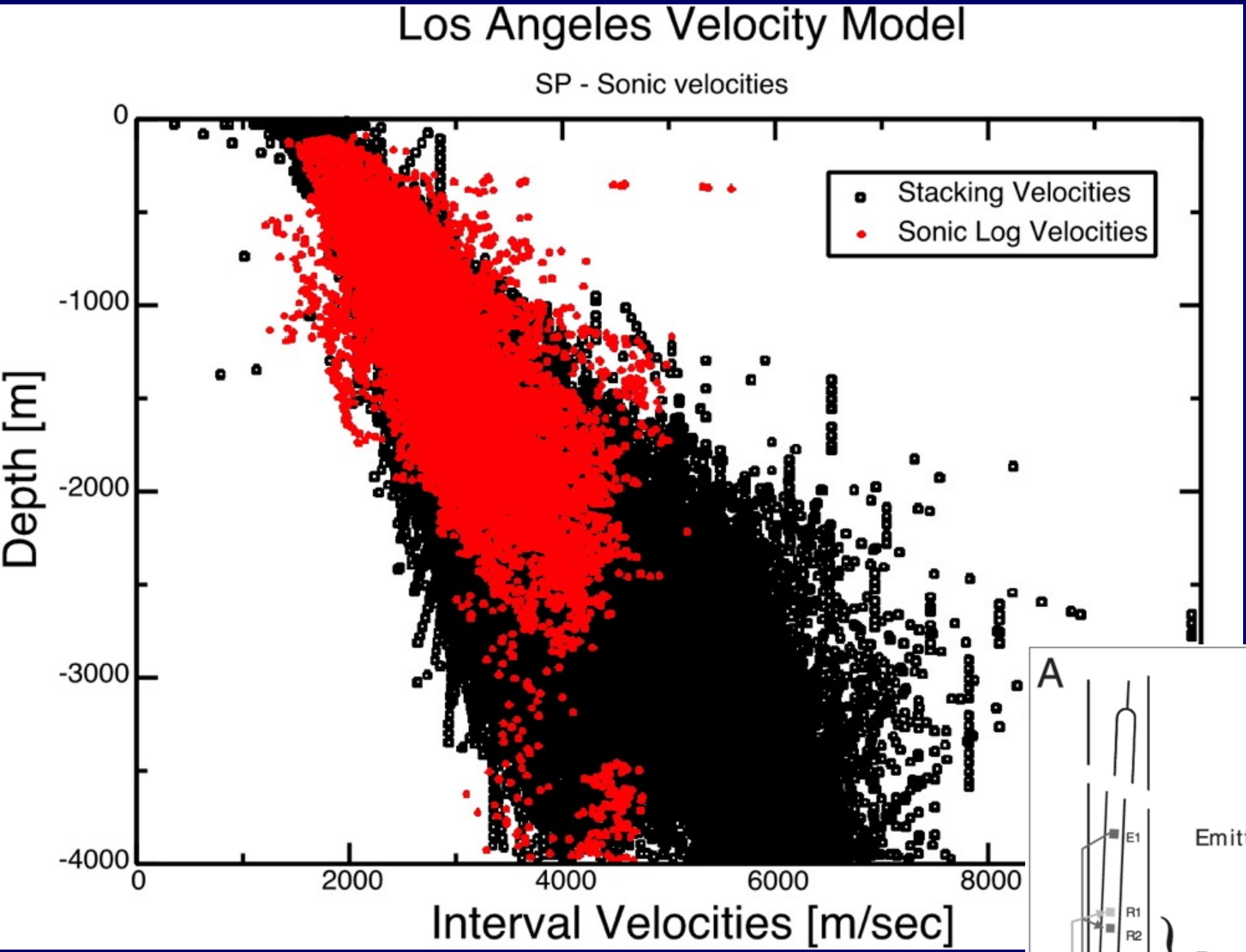


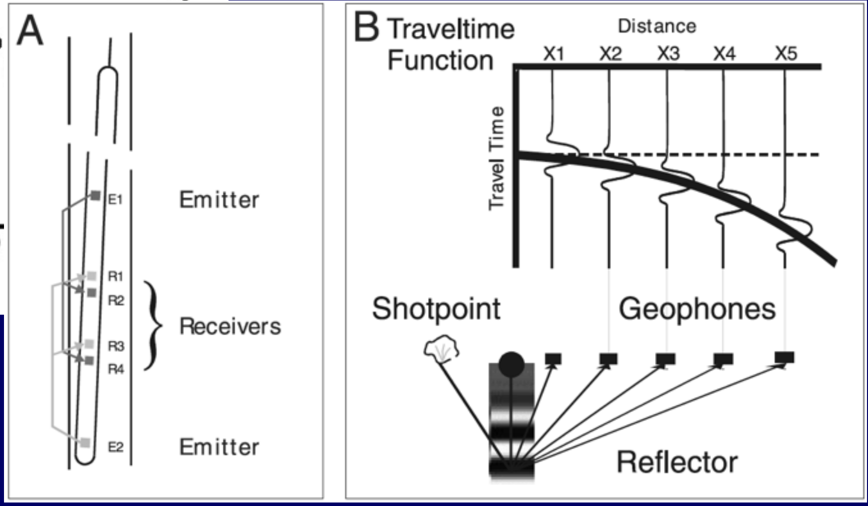
Teleseismic surface wave mantle model (Tanimoto, 2005)

Velocity parameterization through geostatistical interpretation



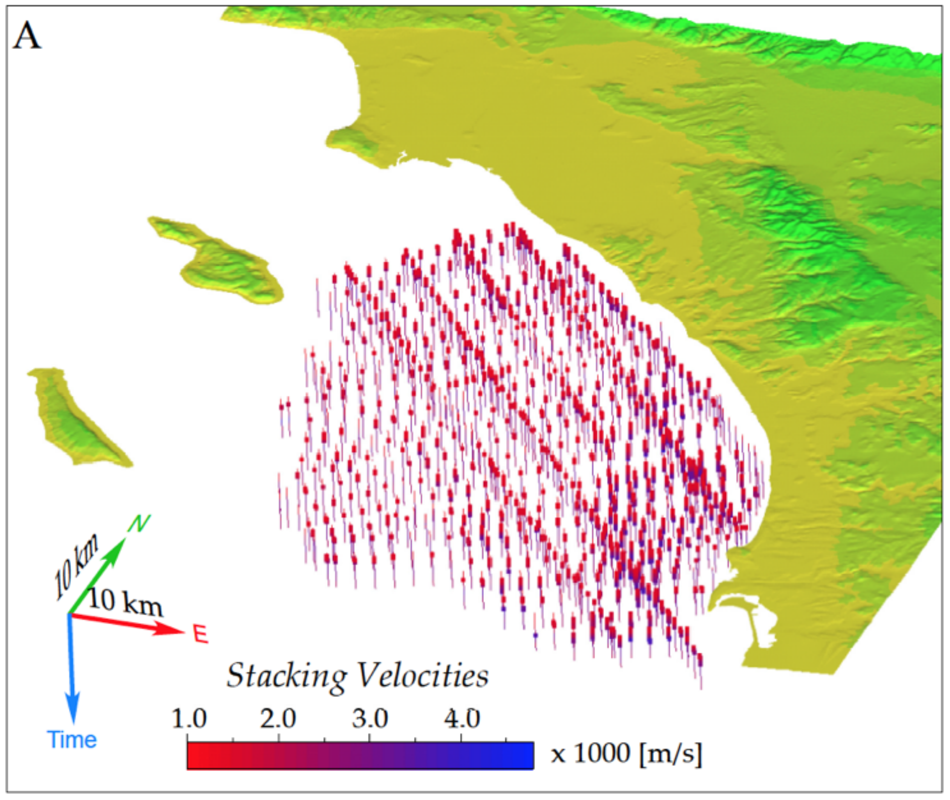
Industry velocity data





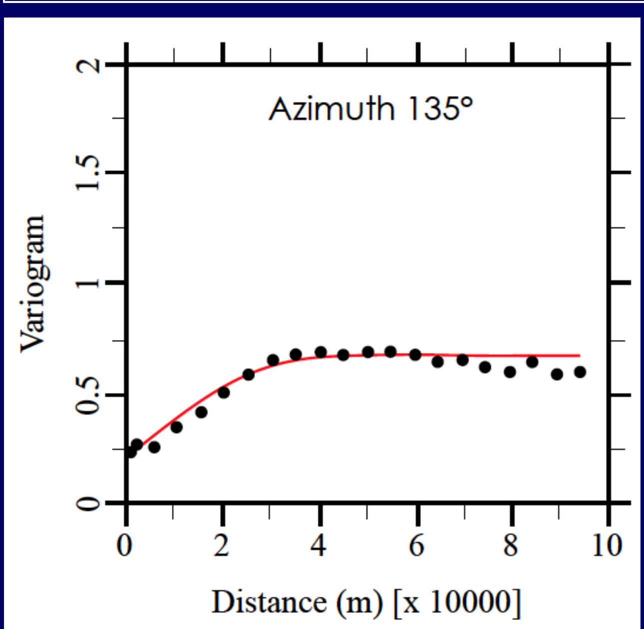
Velocity parameterization through kriging

Velocity data in Inner California Borderlands

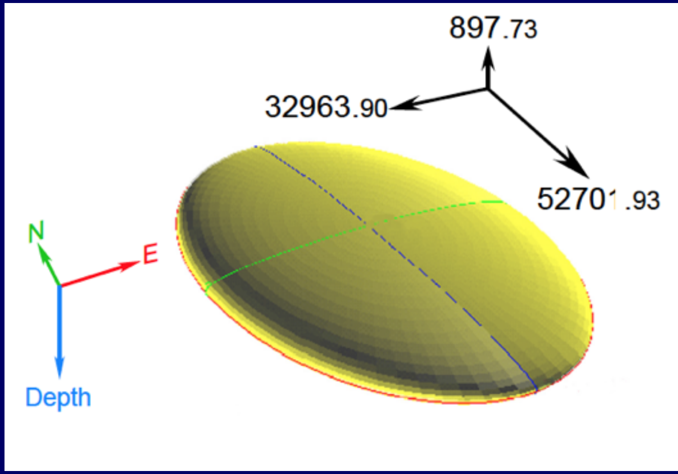


Rivero et al., 2004

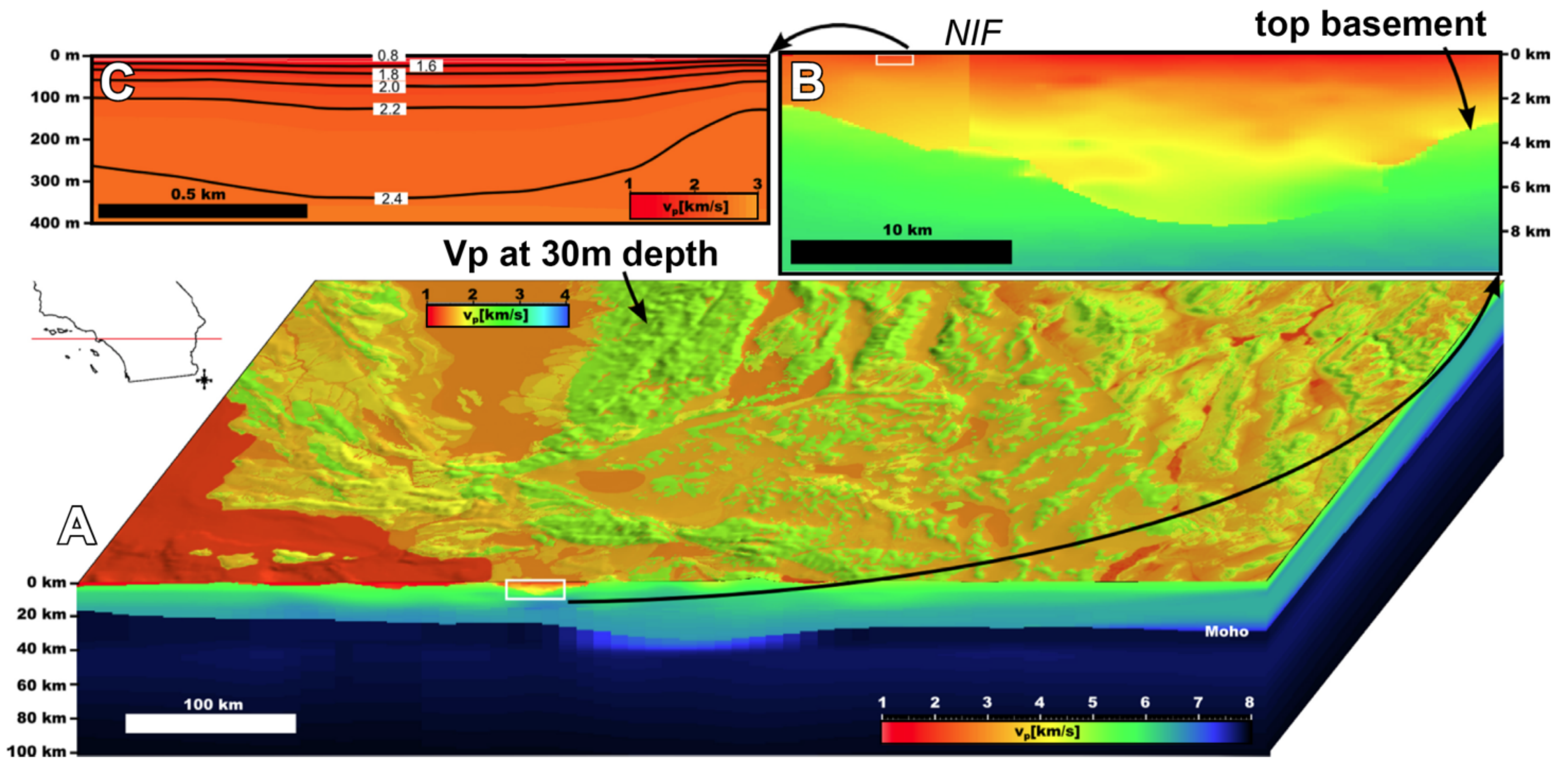
Variance analysis



Define correlation elipsoid



Geotechnical Layer (GTL)



Shaw et al., (2013)

- GTL’s are shallow (< 300 m) velocity descriptions that are necessary for many local seismological and engineering applications.
- The USR/CVM has an optional GTL overlay based on Vs30 measurements.

Geotechnical Layer (GTL)

$$V_S(z) = f(z)V_{ST} + g(z)V_{S30}$$

$$V_P(z) = f(z)V_{PT} + g(z)P(V_{S30})$$

Where z' is depth, V_{ST} and V_{PT} are S- and P-wave velocities extracted from the crustal velocity model at depth z_T, P () is the Brocher (2005) P-wave velocity scaling law, and:

$$z = z'/z_T$$

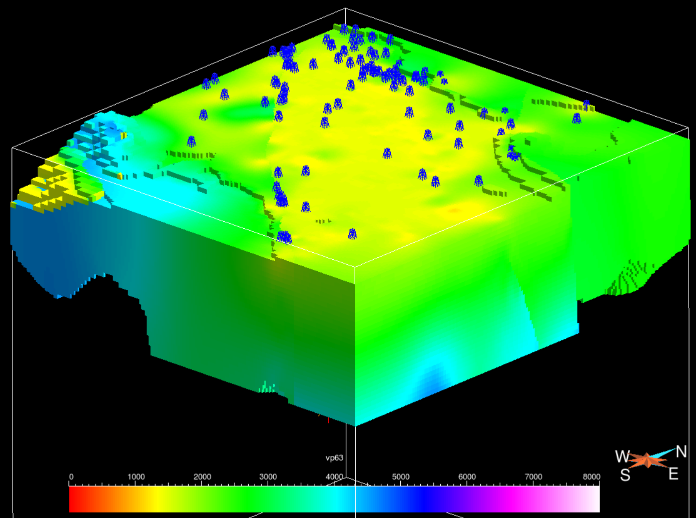
$$f(z) = z + b(z - z^2)$$

$$g(z) = a - az + c(z^2 + 2z - 3z)$$

After Ely et al.

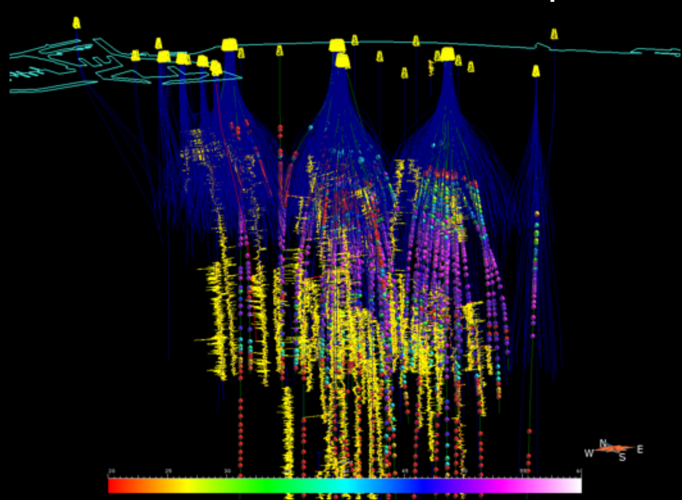
Variability From Sonic Log Data

LA basin

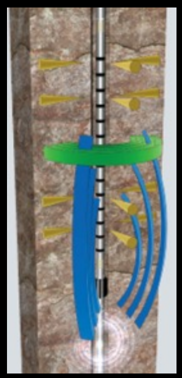


108 wells, > 600K data points

SW LA basin oil field



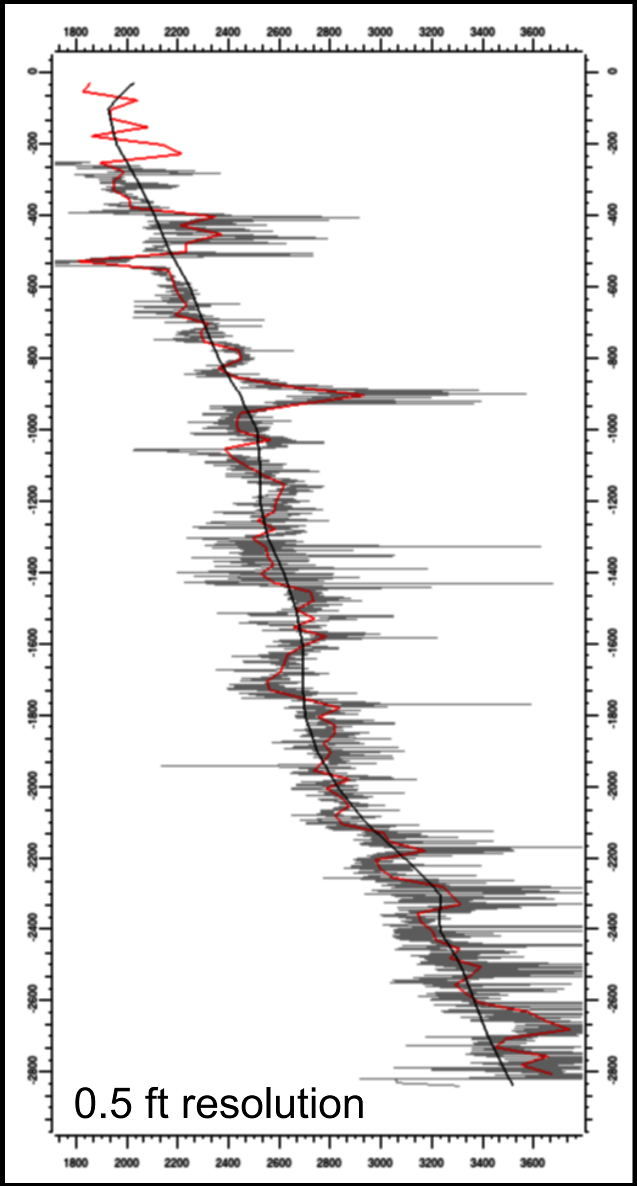
70 wells, > 400K digital measurements – excellent control on geologic structure by 3d seismic and well tops



0

Depth [m]

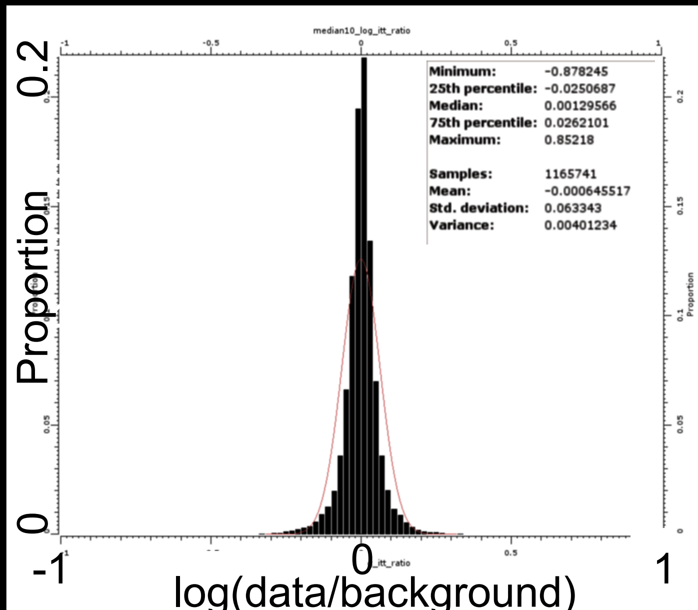
2800



1800 Vp[m/s] 3600

Stochastic Variability overlay

LA basin



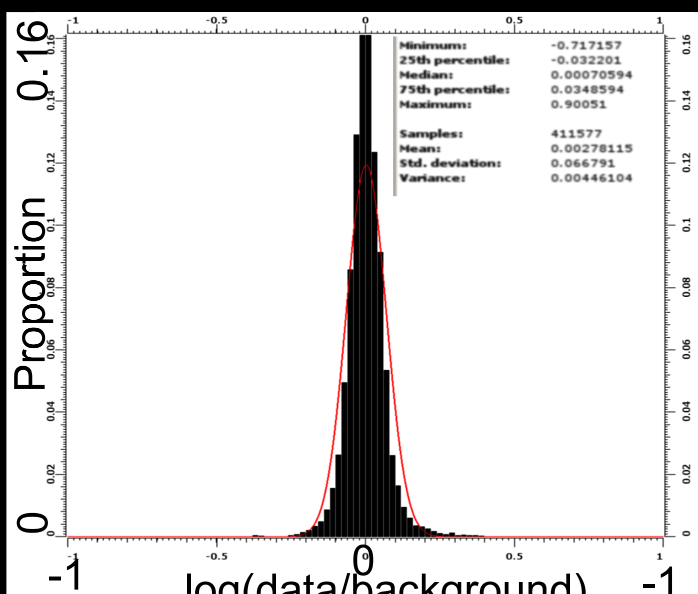
Variability

- Std. deviation: 0.063
- equivalent to a ratio data/background of $e^{0.063} = 1.065$
- or a variability of

+/- 6.5 % at the 1m length scale

- shape is non-Gaussian: Kurtosis is 12.4

SW LA basin oil field



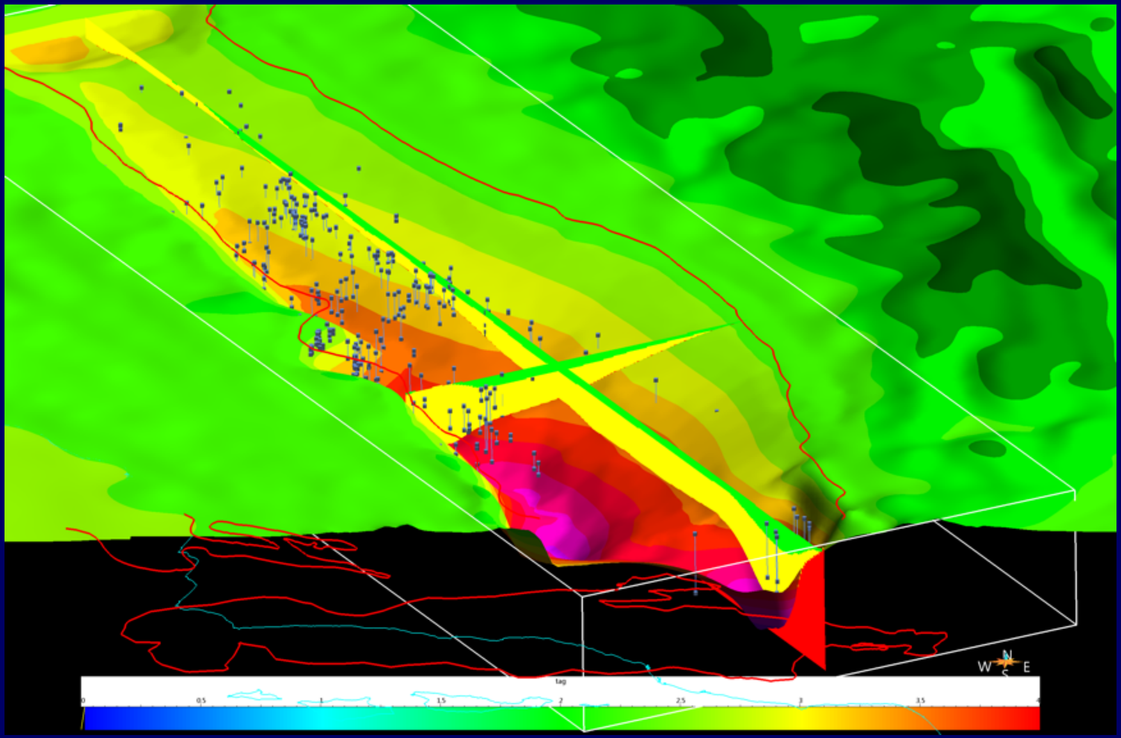
- Std. deviation: 0.067
- equivalent to a ratio data/background of $e^{0.067} = 1.069$
- or a variability of

+/- 6.9 % at the 1m length scale

- shape is non-Gaussian

Self-consistent updates

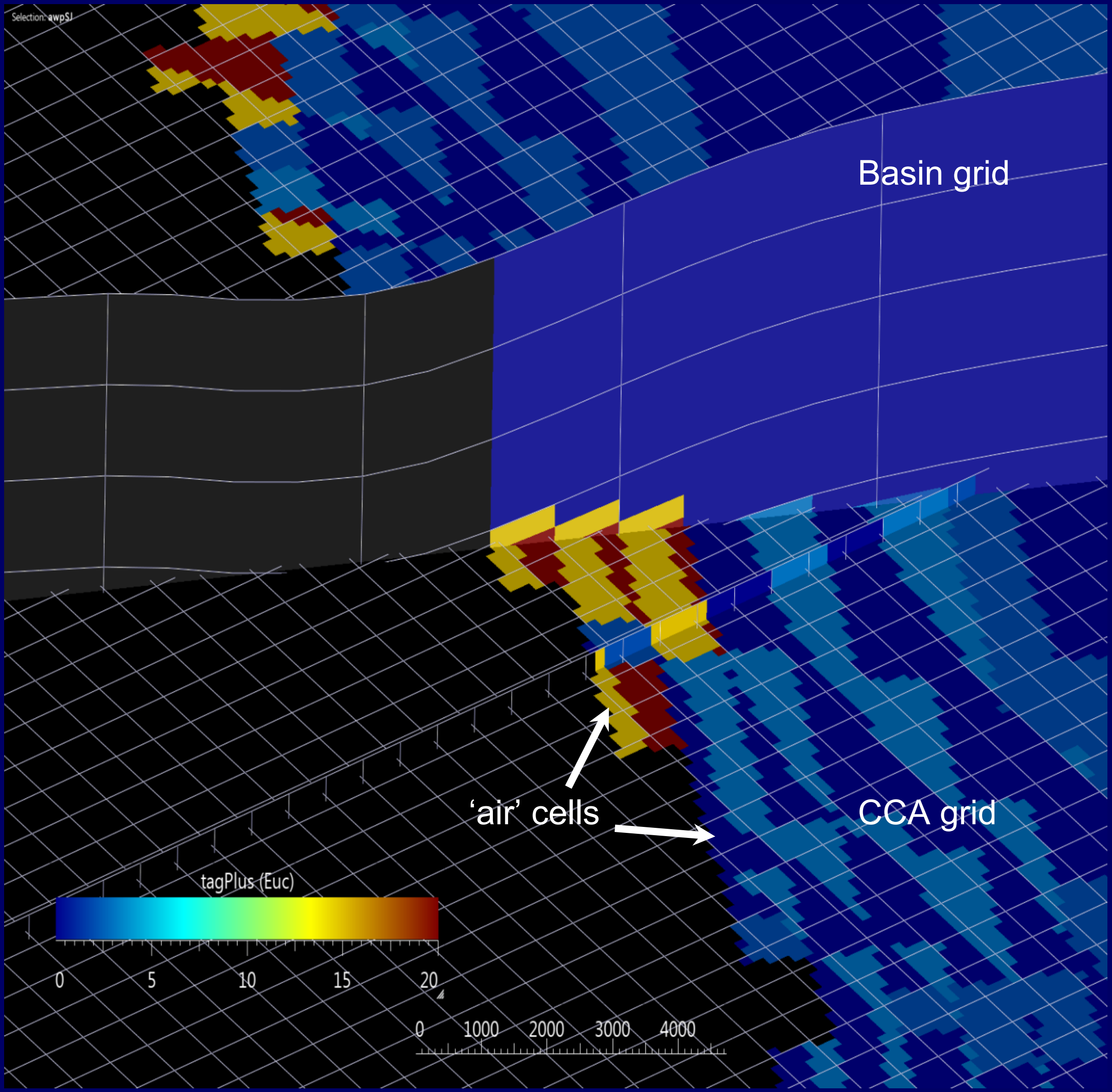
- Changes to basin models require remodeling background/lower crust
- Often update cascades
- Due to history and momentum relatively little automation for CVM-H
- Metadata in grid to keep track of data provenance and rock type



San Joaquin basin Metadata

Mapping:

- Squashed basin grid needs to be mapped to CCA grid
- By nearest neighbour
- Could also be by interpolation from nearest neighbours
- Due to discretization some nearest neighbours for the surface level (z = 0m) are above ground level (air).



S. Joaquin basin metadata

Key Concepts

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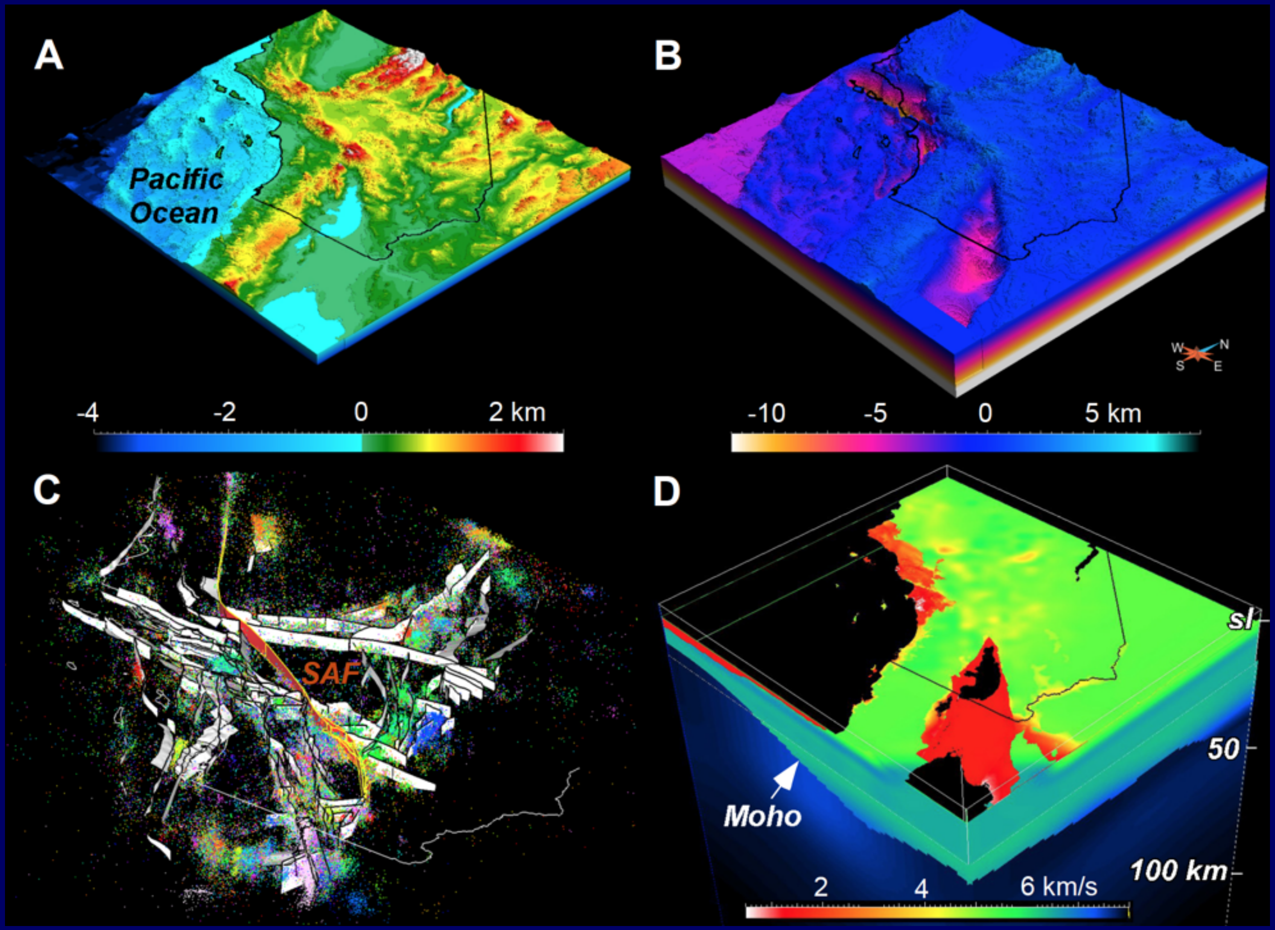
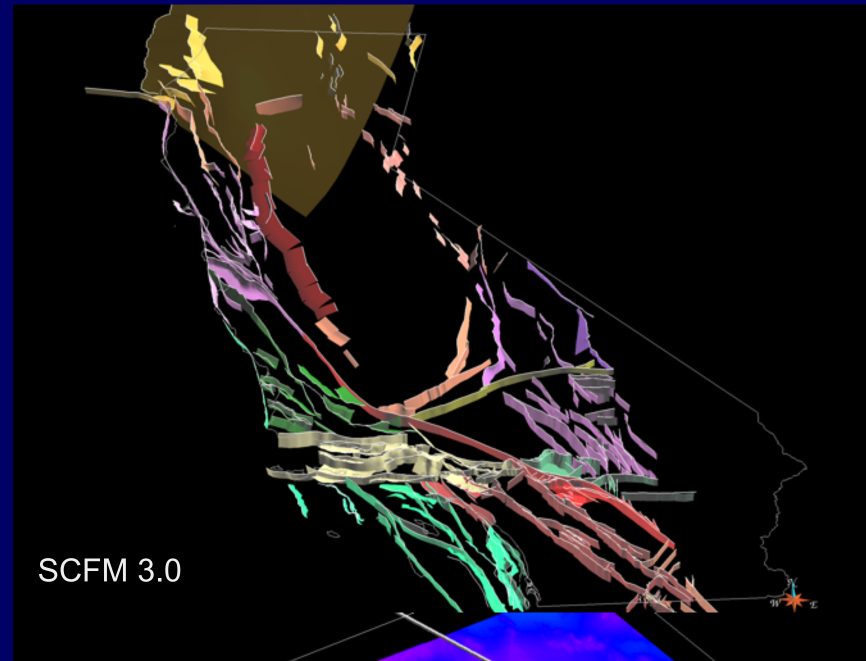
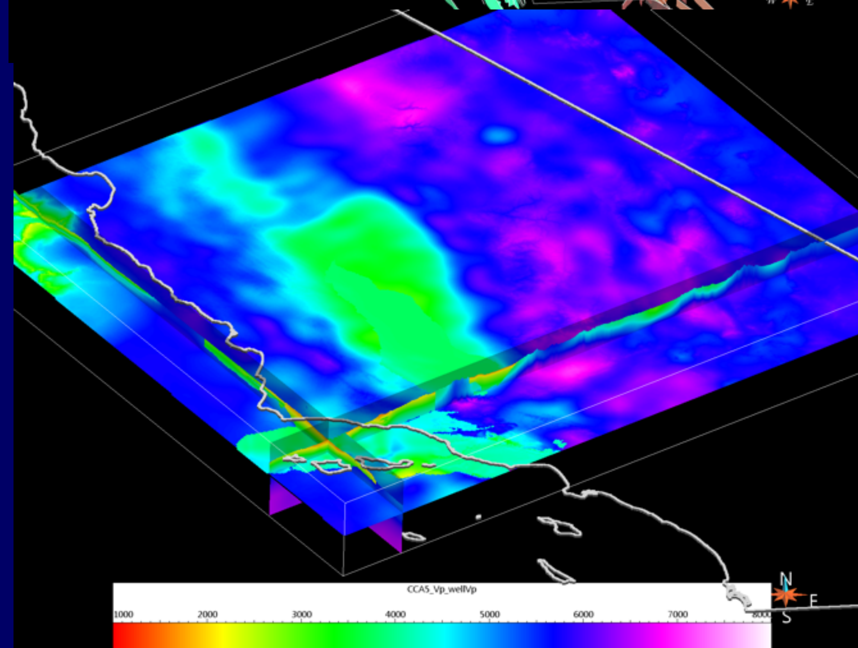


Heterogeneous Feature Representations

- Faults, layers, interfaces: surfaces
- Wave velocity, other geophysical fields, rock properties: grids
- Geologic bodies: volumes, contours
- Dependant properties: rule based representation, functional form

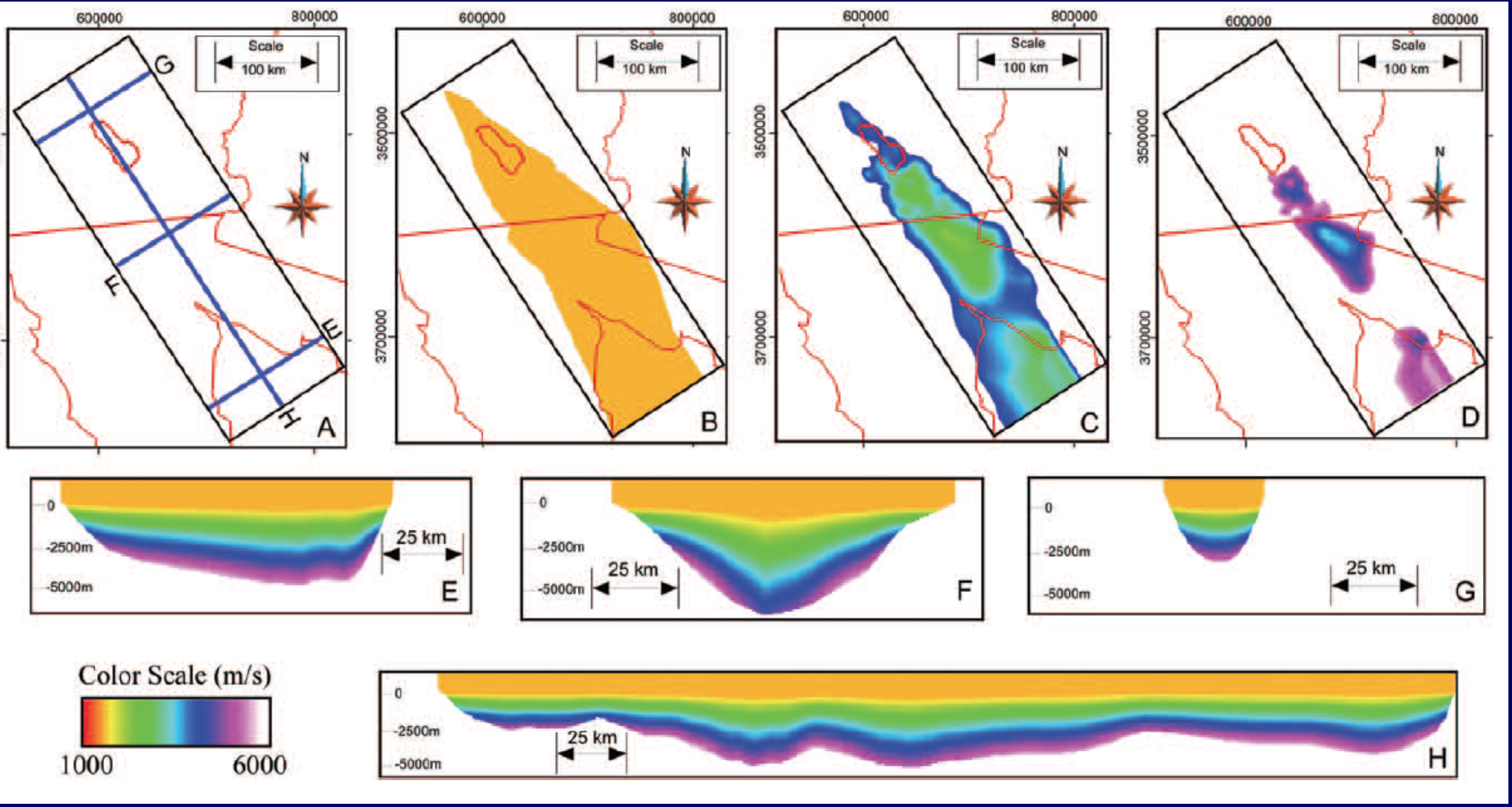




CCA05, 5th iteration

Velocity as a function of depth and total basin depth

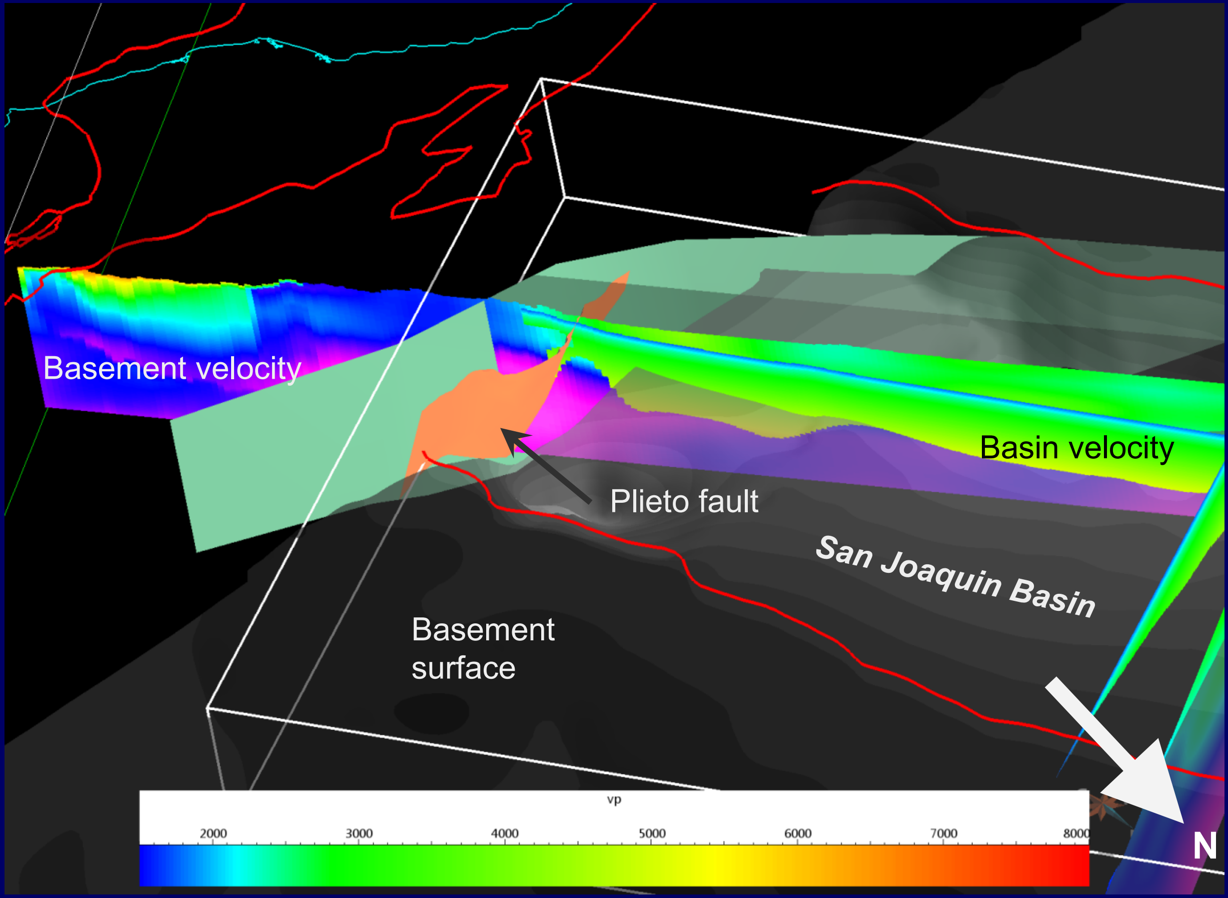
Salton Trough



Lovely et al., (2007)

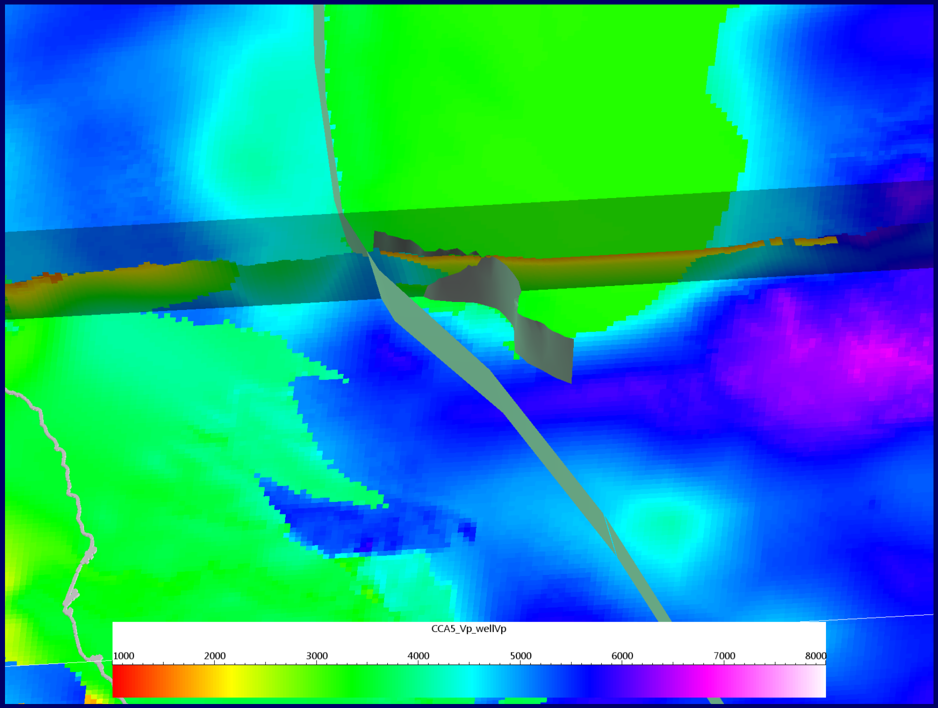
Heterogeneous Feature Representations

- Object based and grid based representations work together for a full description
- Requires attention to cross-compatibility
- Final grid representation is kept in context with other data



Updates to heterogeneous models

- Using mixed feature representations enabled model expansion
- Expansion requires remodeling of model boundaries
- Updating basement surface was possible due to repopulation of final model from basin models and tomography
- Database is not formalized, collection of files



S. Joaquin basin embedded into expanded CVM

Conclusion and Planning

- Internal model consistency requirement has cascading effects after updates to model component, GTL and stochastic overlay largely independent
- It is useful to emphasize the grid representation of the velocity model as the result of a workflow
- It is important to keep the gridded velocity model in context with its components and inputs
- Is it necessary to establish dependencies formally ?
- To what extent is it possible/worthwhile to develop automation/code to link model components and make the workflow efficient and reproducible ?
- Frequent updates vs. a few increments in five years

Additional slides

(try https://andreasplesch.github.io/VR-GeoCal/x3dom/CFM5_CVMH3d.html)

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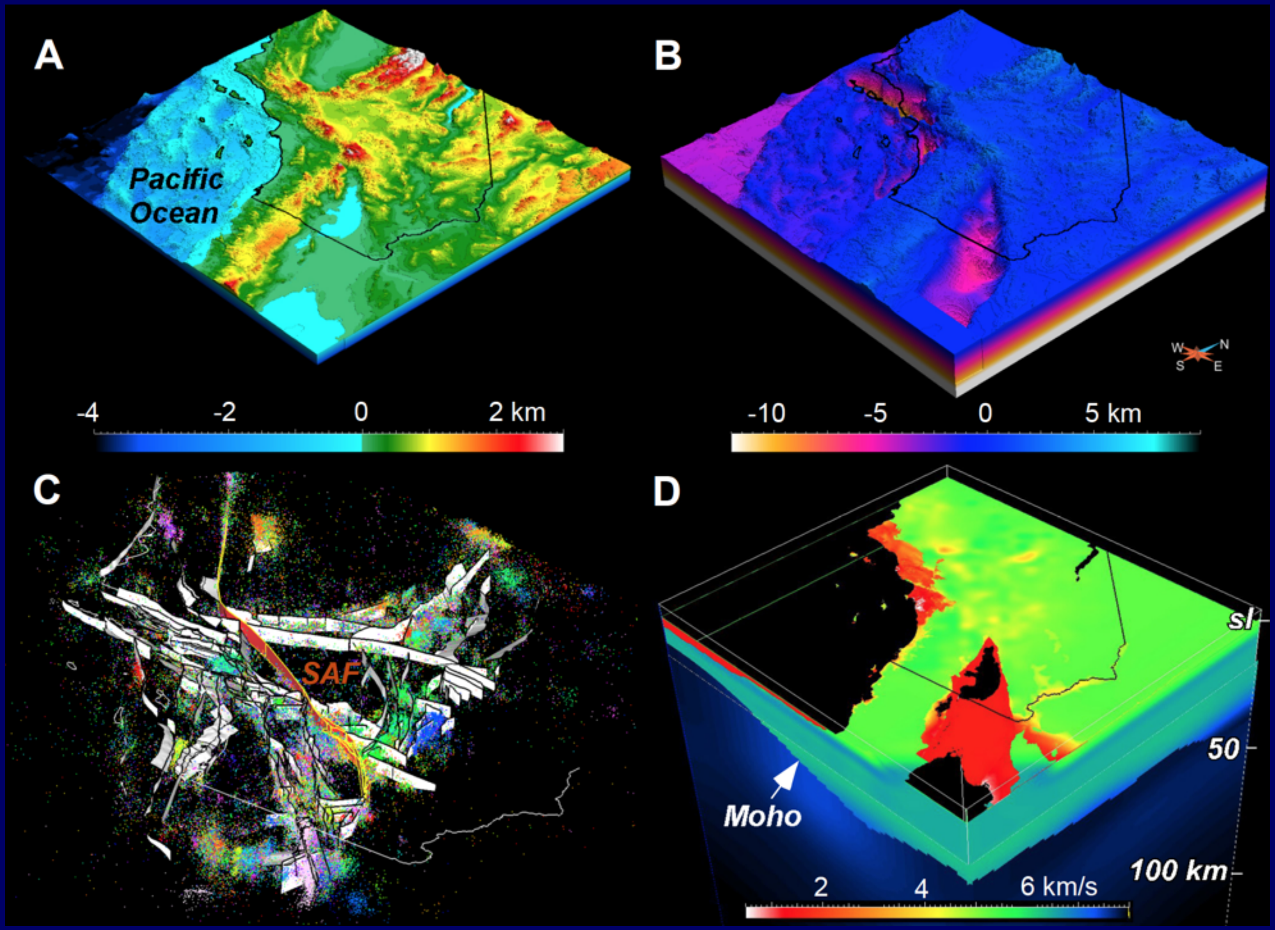
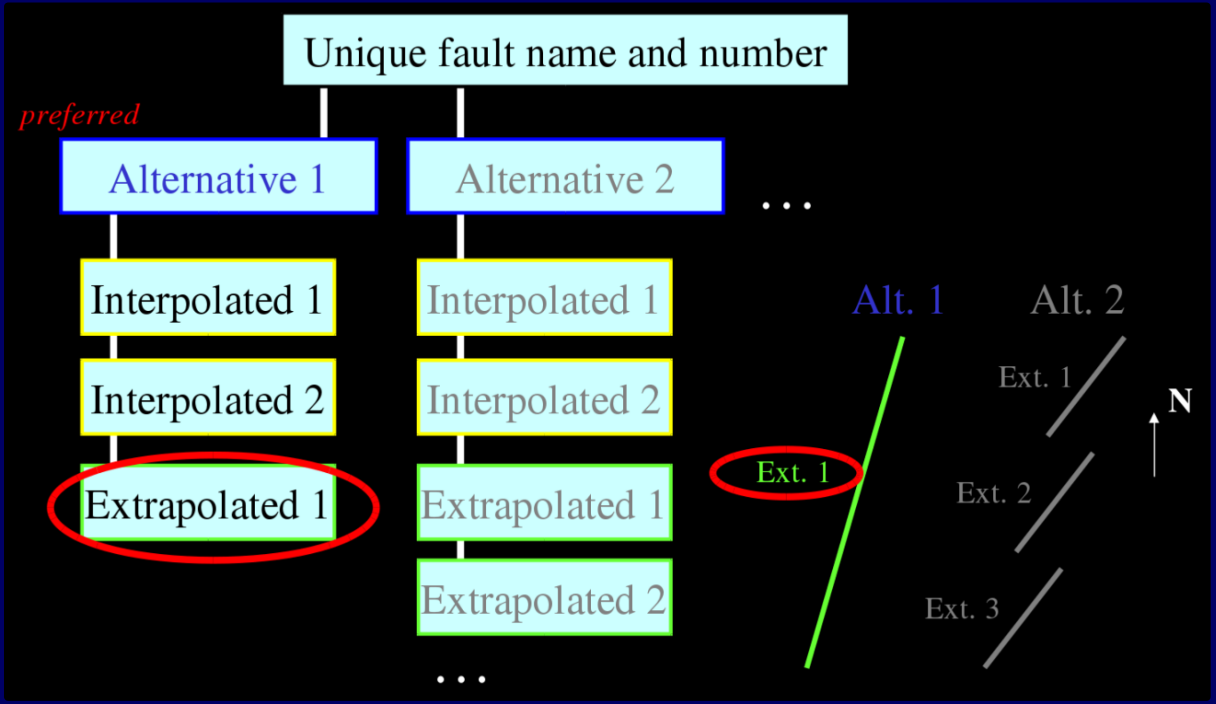
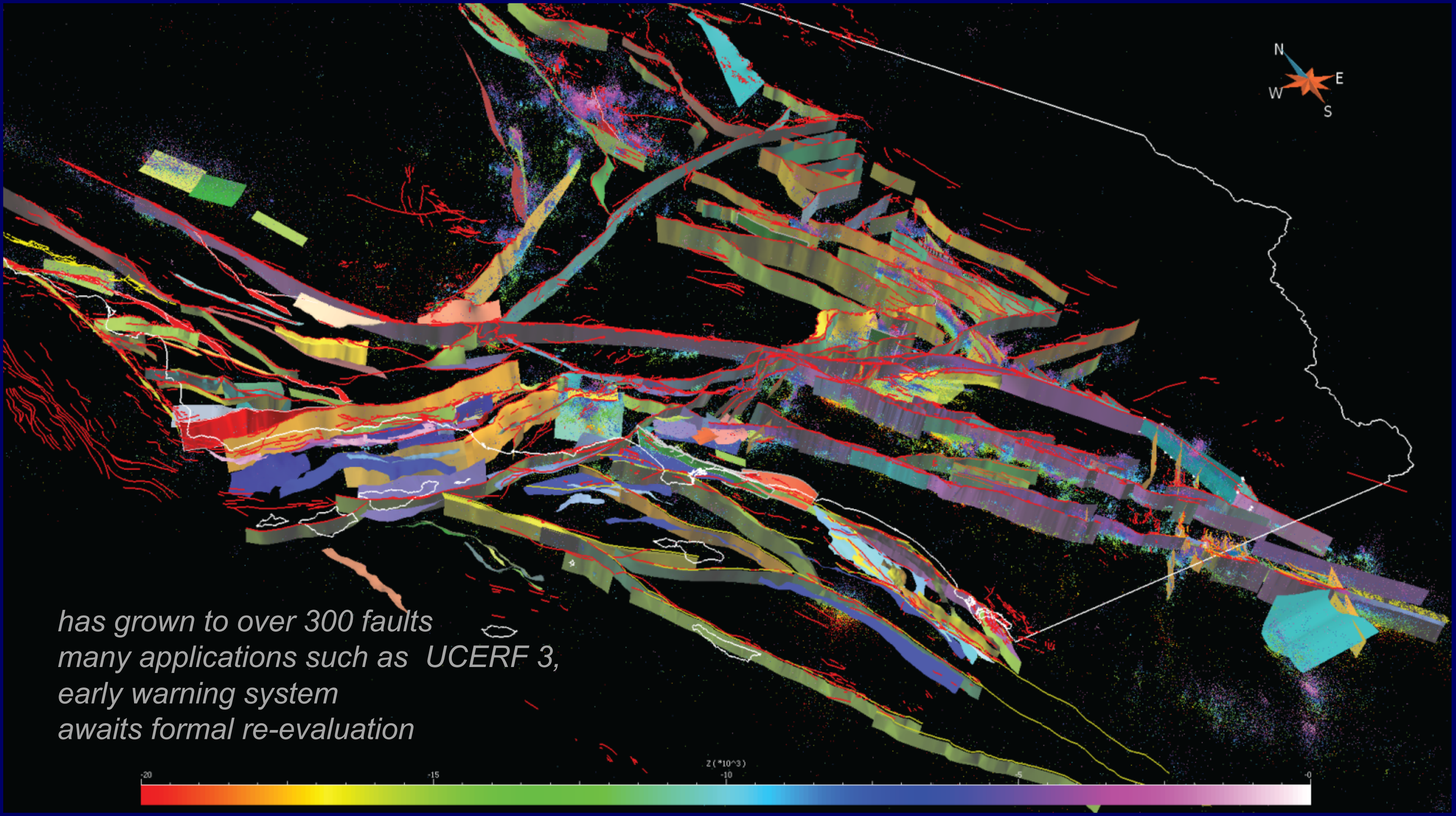


Alternatives

- Benefit: Allows for multiple representation of the same feature to engage community
- Cost: Implies ranking process
- Demand for single best/preferred model

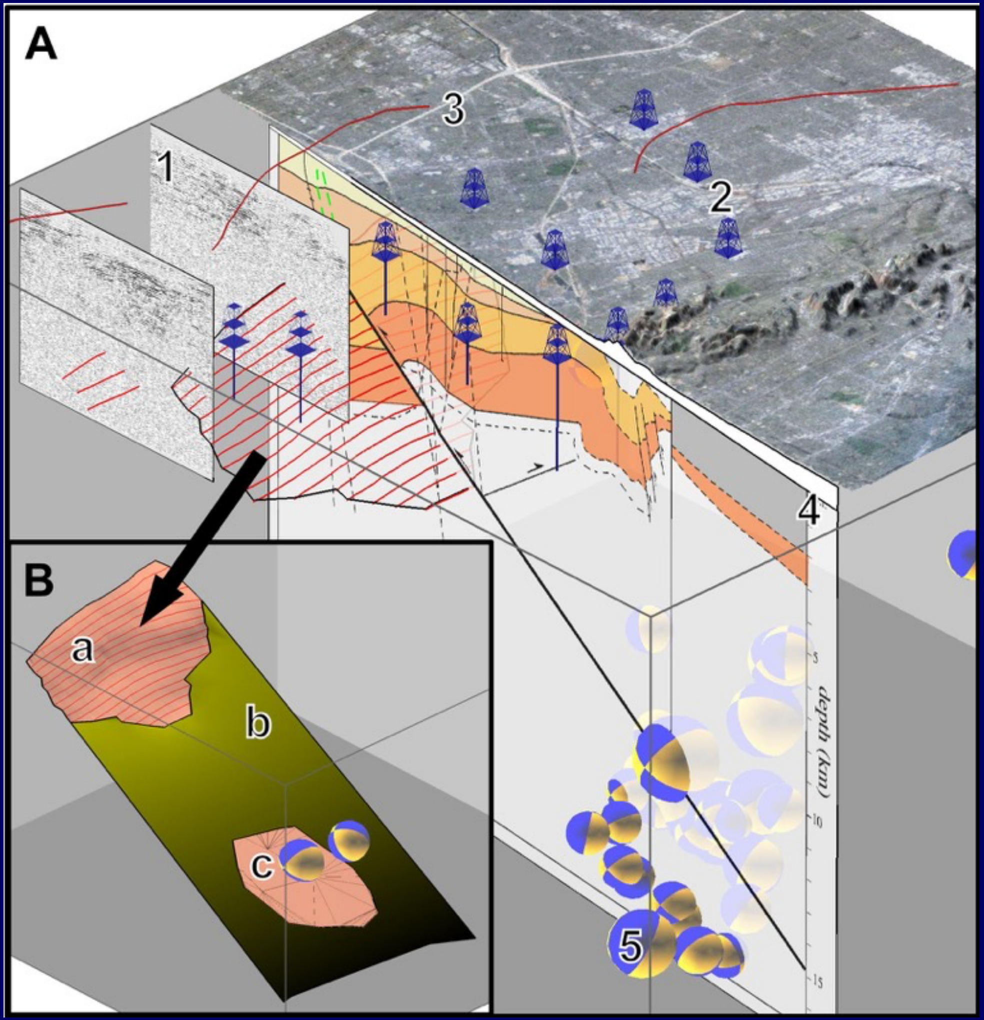


Community Fault Model today



has grown to over 300 faults
many applications such as UCERF 3,
early warning system
awaits formal re-evaluation

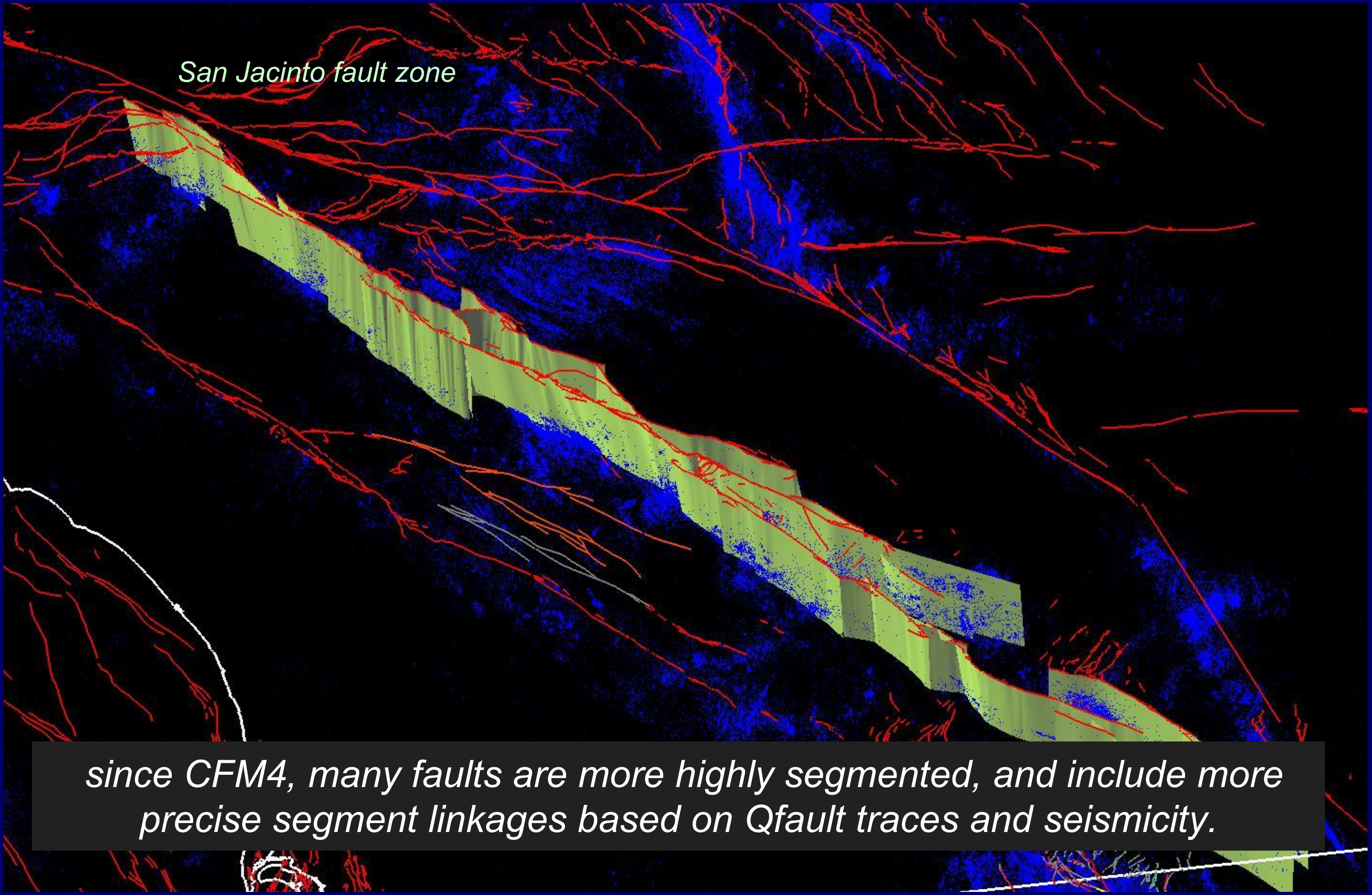
Fault surface development



- integrates many types of data that constrain fault geometries
- interpolated and extrapolated fault patches
- alternative fault representations

Plesch et al., (2005)

CFM 5.2 – updates and improvements



since CFM4, many faults are more highly segmented, and include more precise segment linkages based on Qfault traces and seismicity.