

# Visualization and Visual Analysis of Multi-faceted Scientific Data: A Survey

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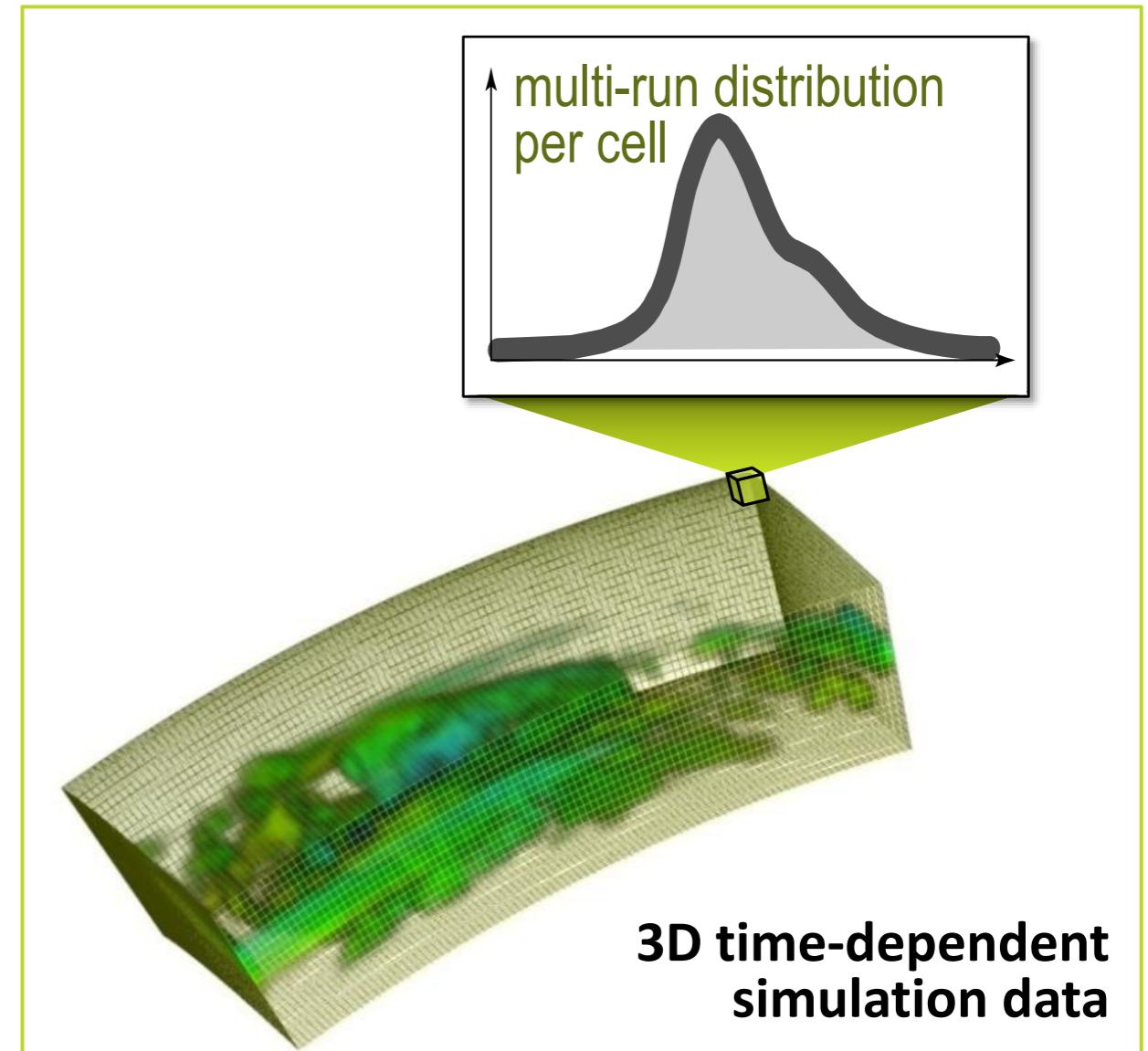
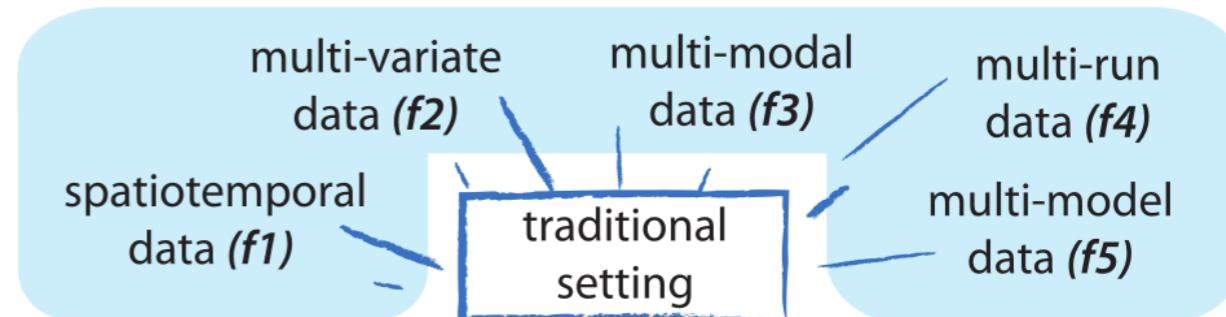
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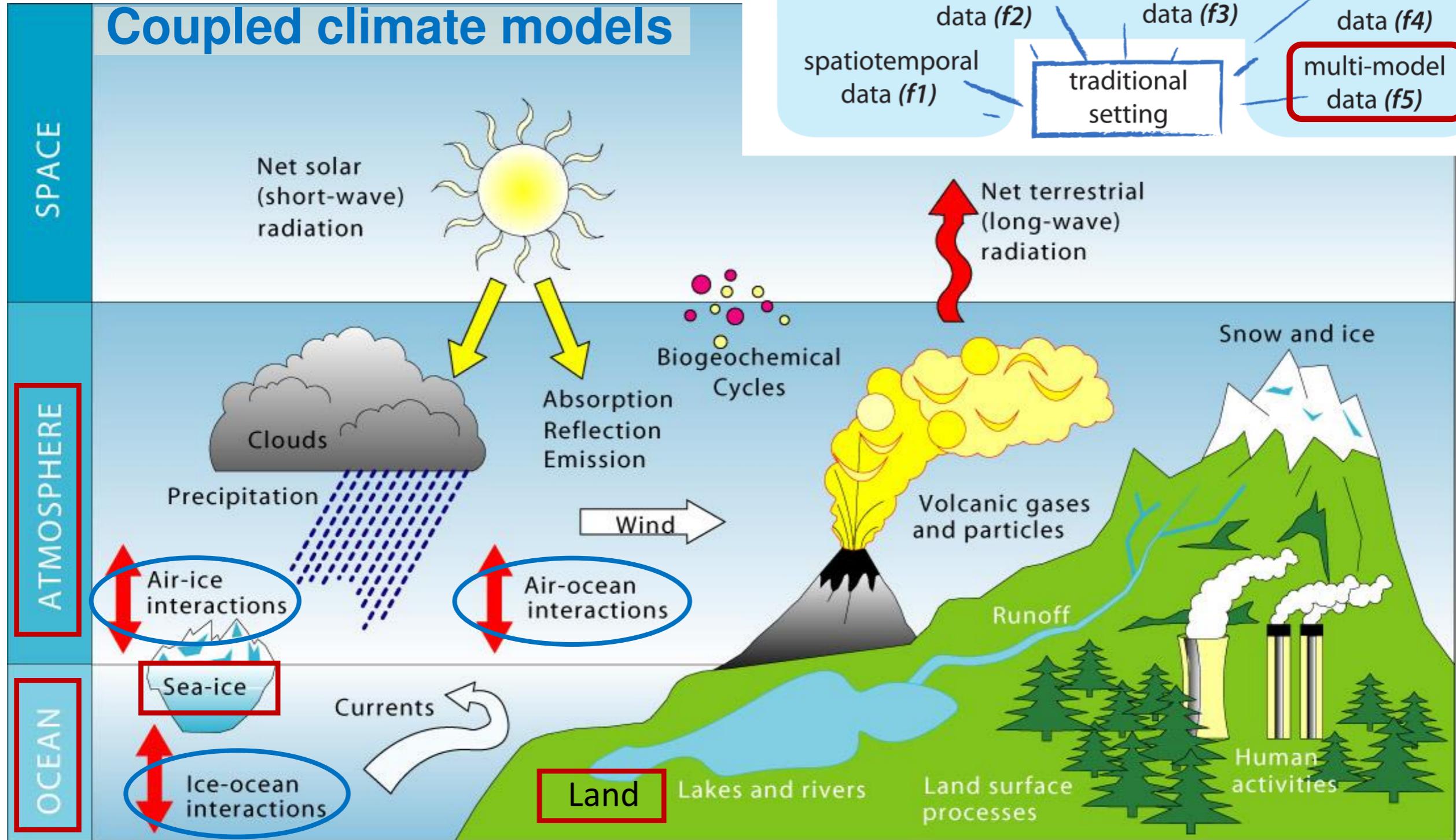
# Multi-faceted Scientific Data

- **Spatiotemporal data**
- **Multi-variate/multi-field data**  
(multiple data attributes, e.g., temperature or pressure)
- **Multi-modal data**  
(CT, MRI, large-scale measurements, simulations, etc.)
- **Multi-run/ensemble simulations** (repeated with varied parameter settings)
- **Multi-model scenarios**  
(e.g., coupled climate model)



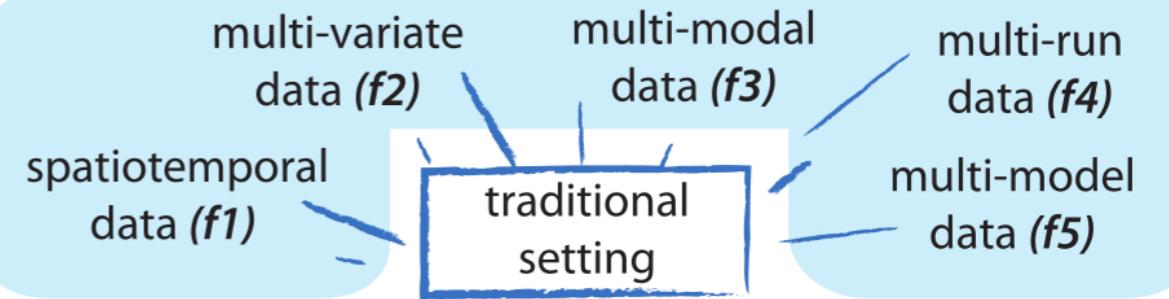
# Multi-faceted Scientific Data

## Coupled climate models

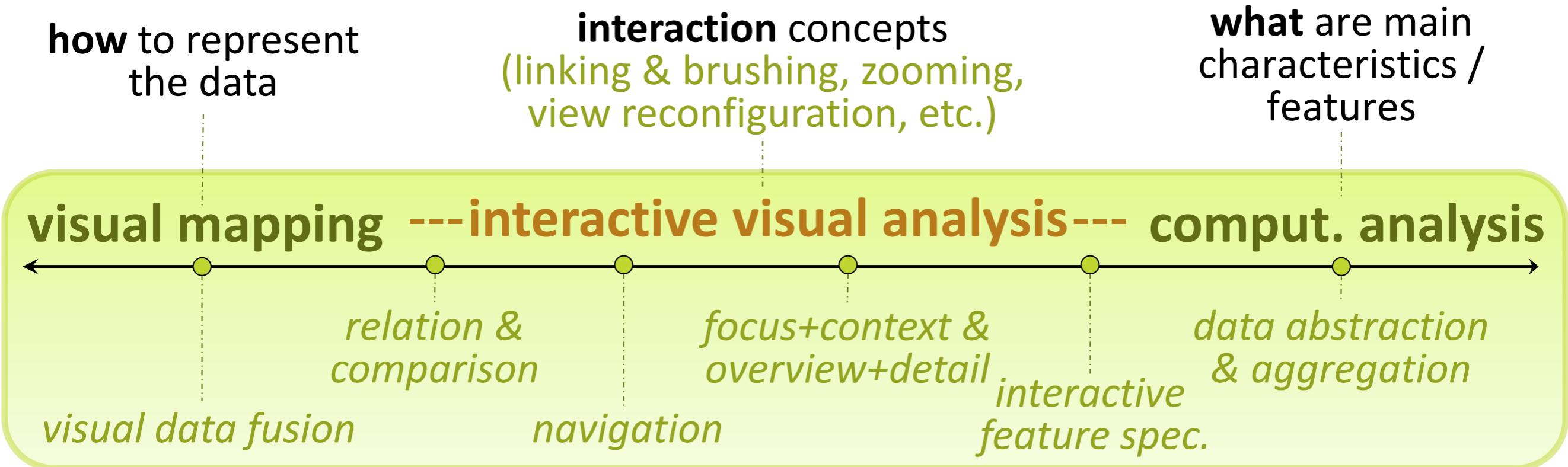


[ Böttinger, Climavis08 ]

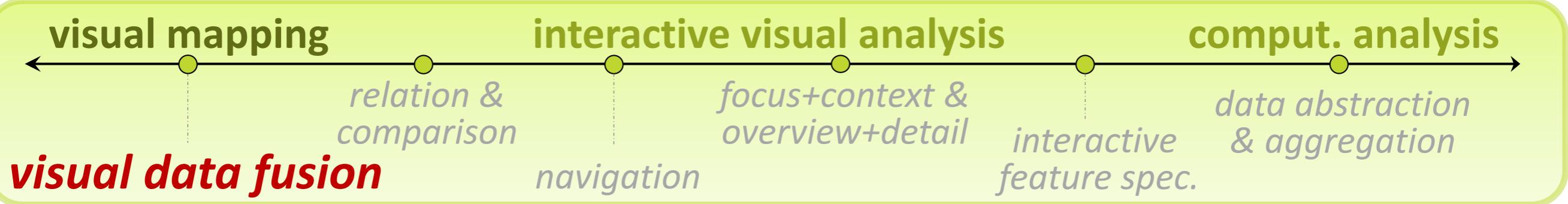
# Categorization



- Literature review of 200+ papers on scientific data
- How are vis., interaction, and comput. analysis combined?

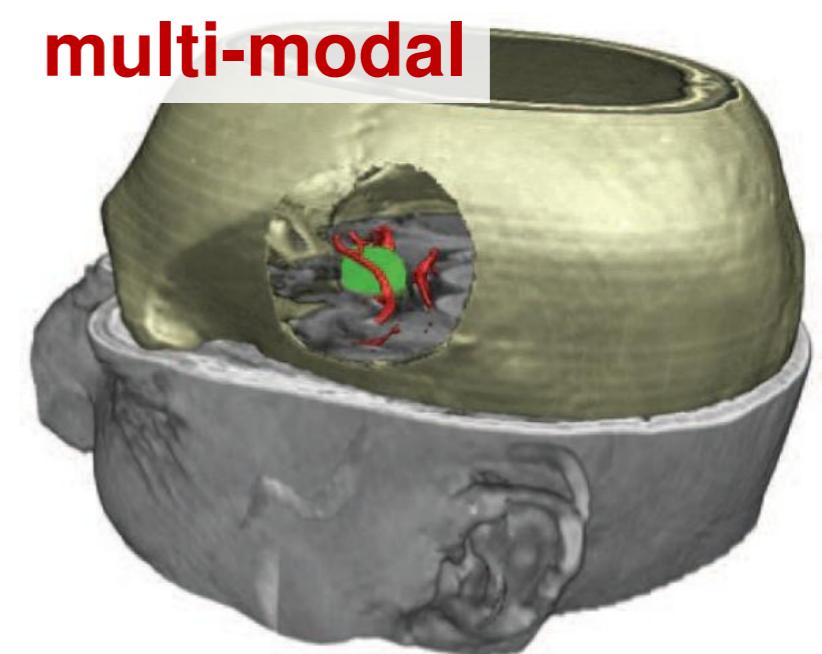
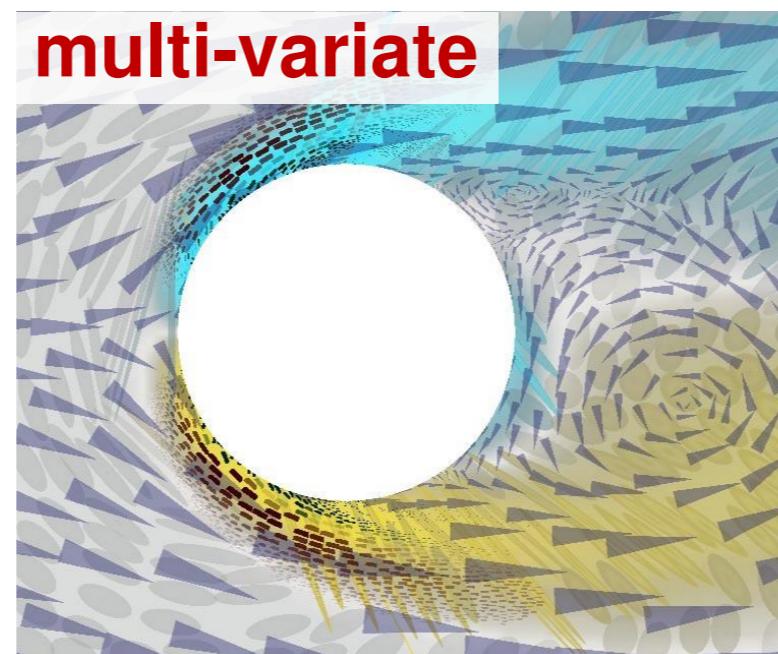
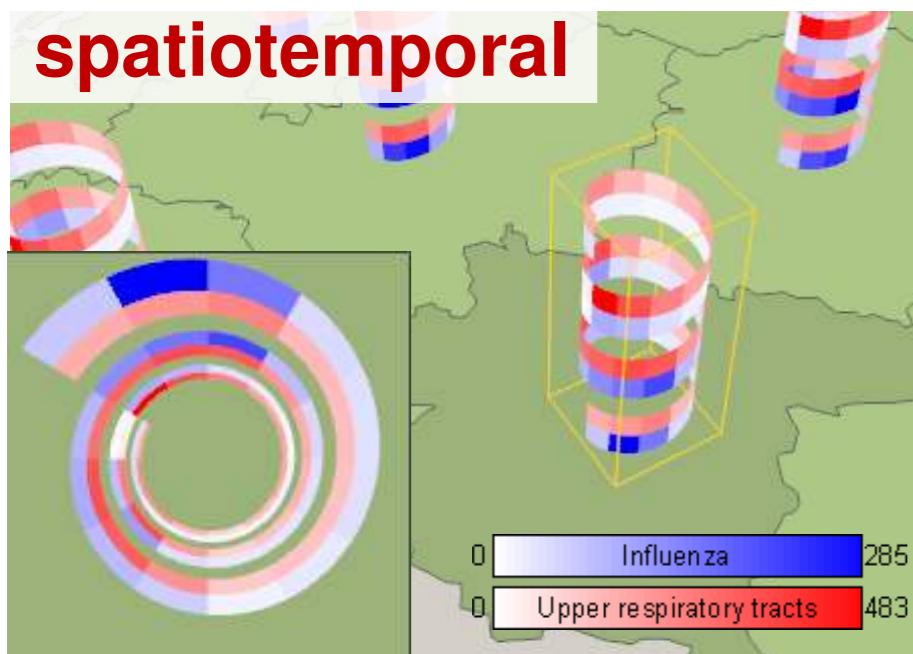


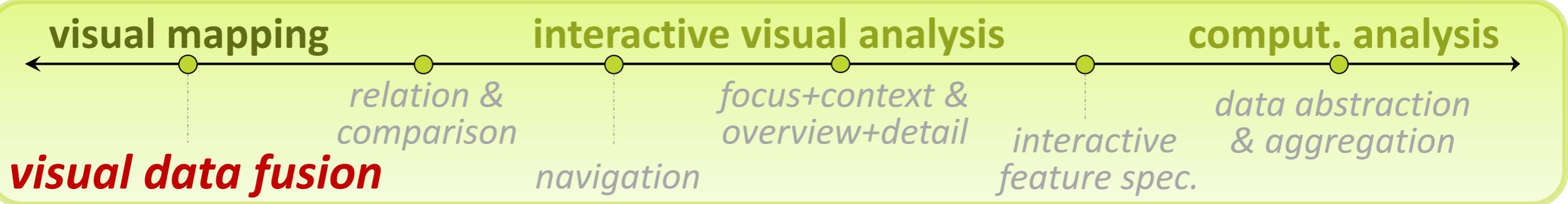
[compare to Keim et al. 2009;  
Bertine & Lalanne 2009]



## Fusion within a single visualization

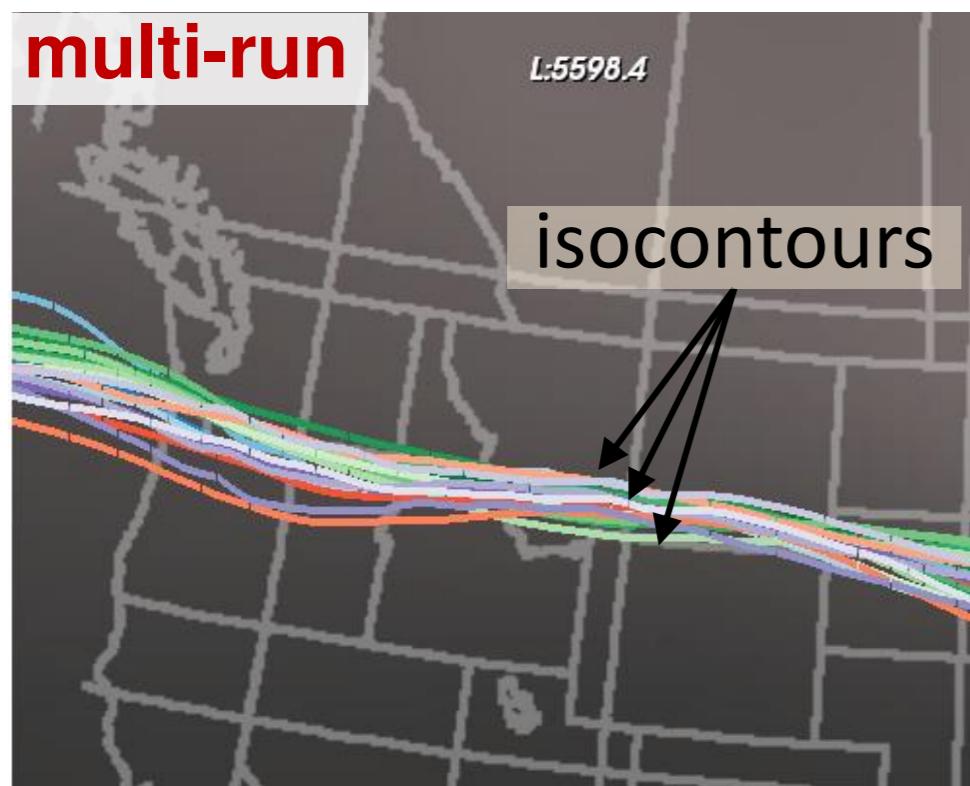
- common frame of reference
- layering techniques (e.g., glyphs, color, transparency)
- multi-volume rendering (coregistration, segmentation)



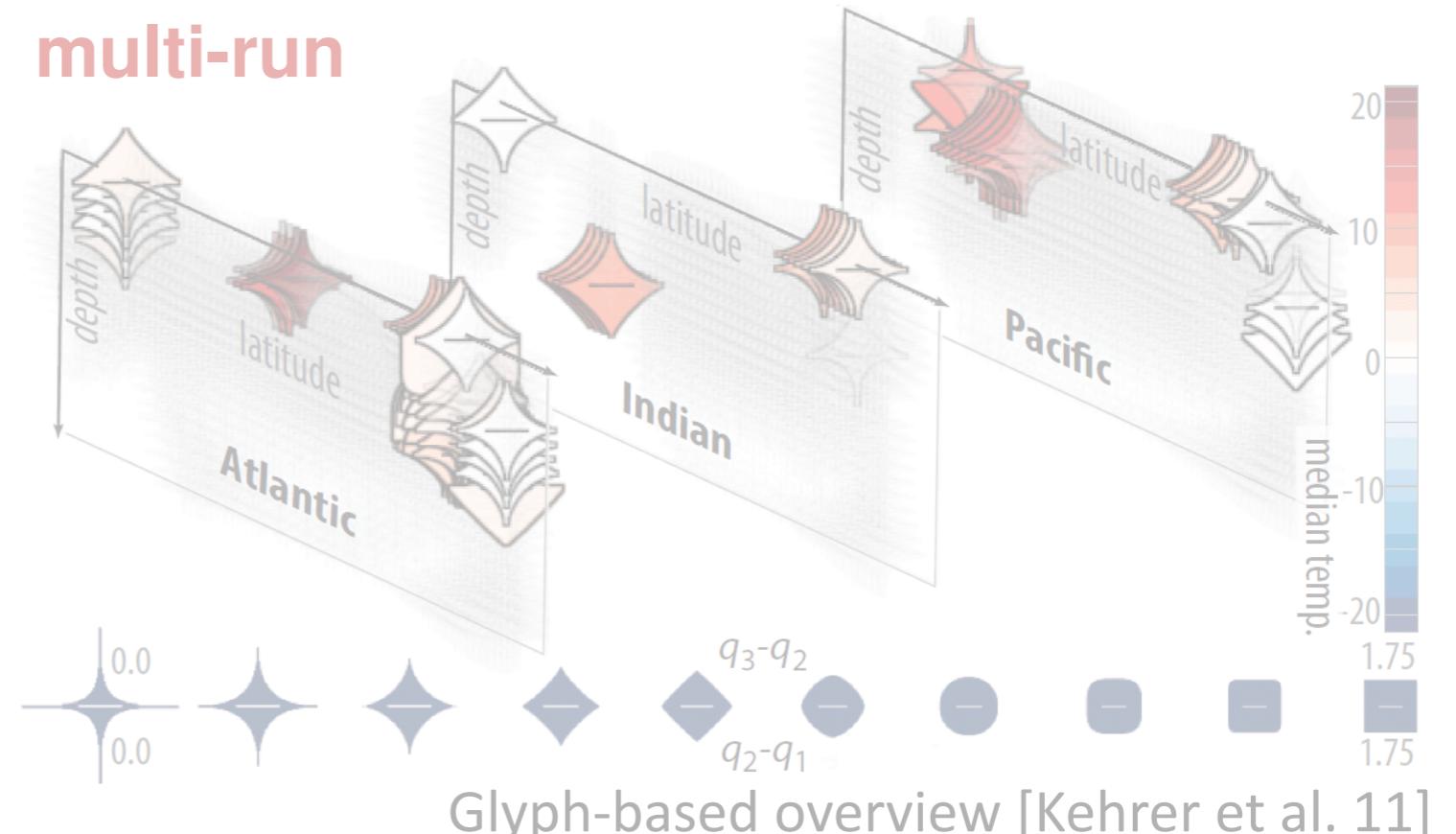


## Fusion of multiple simulation runs

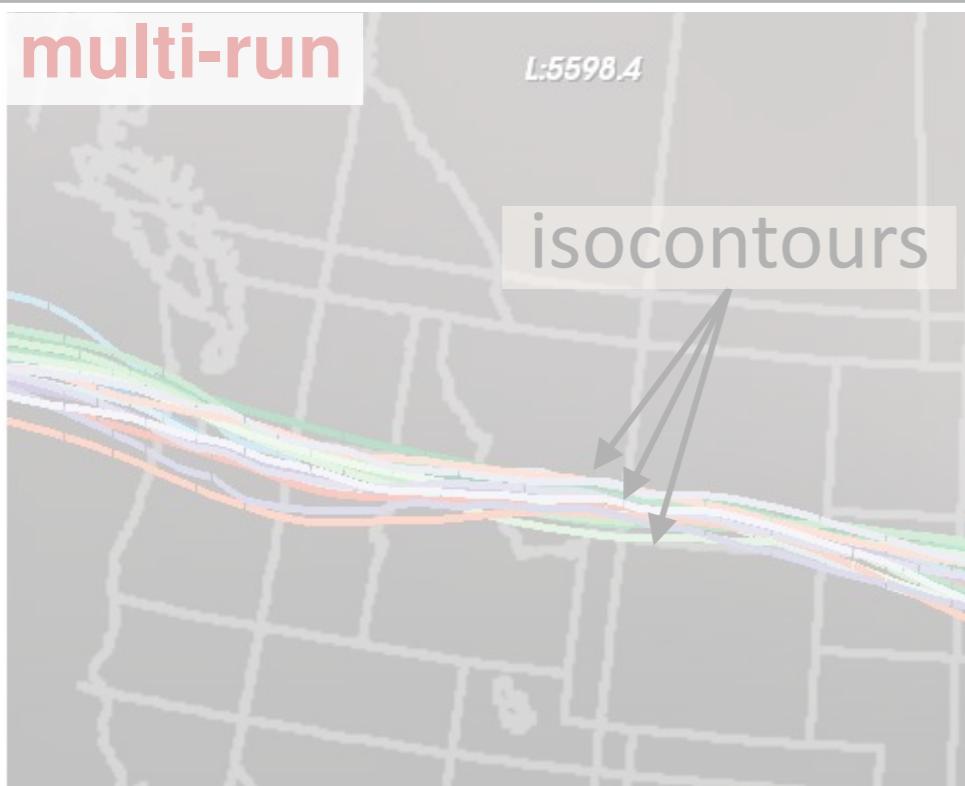
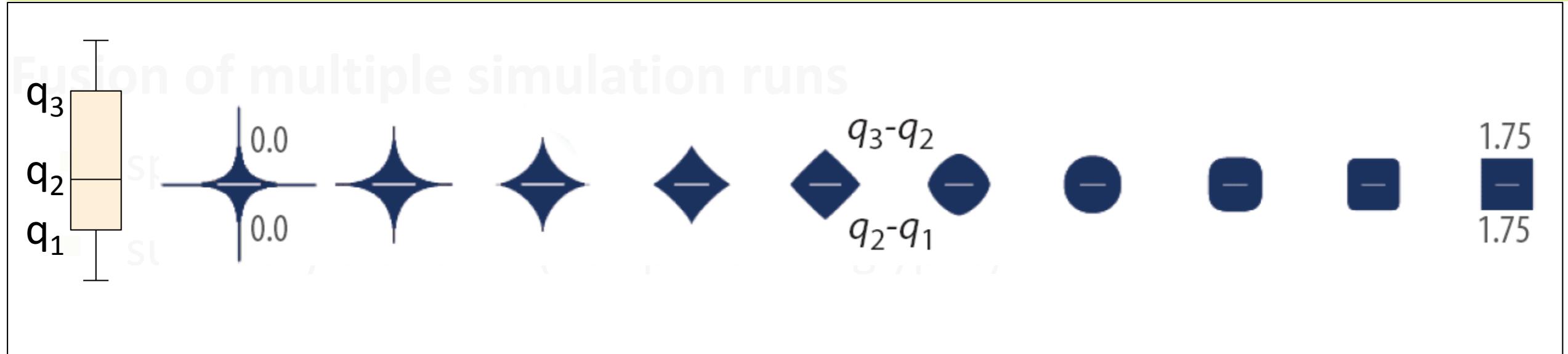
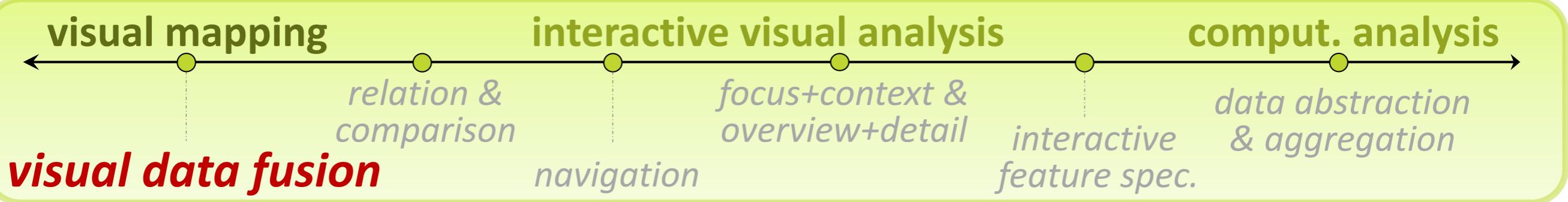
- spaghetti plots [Diggle et al. 02]
- summary statistics (box plots and glyphs)



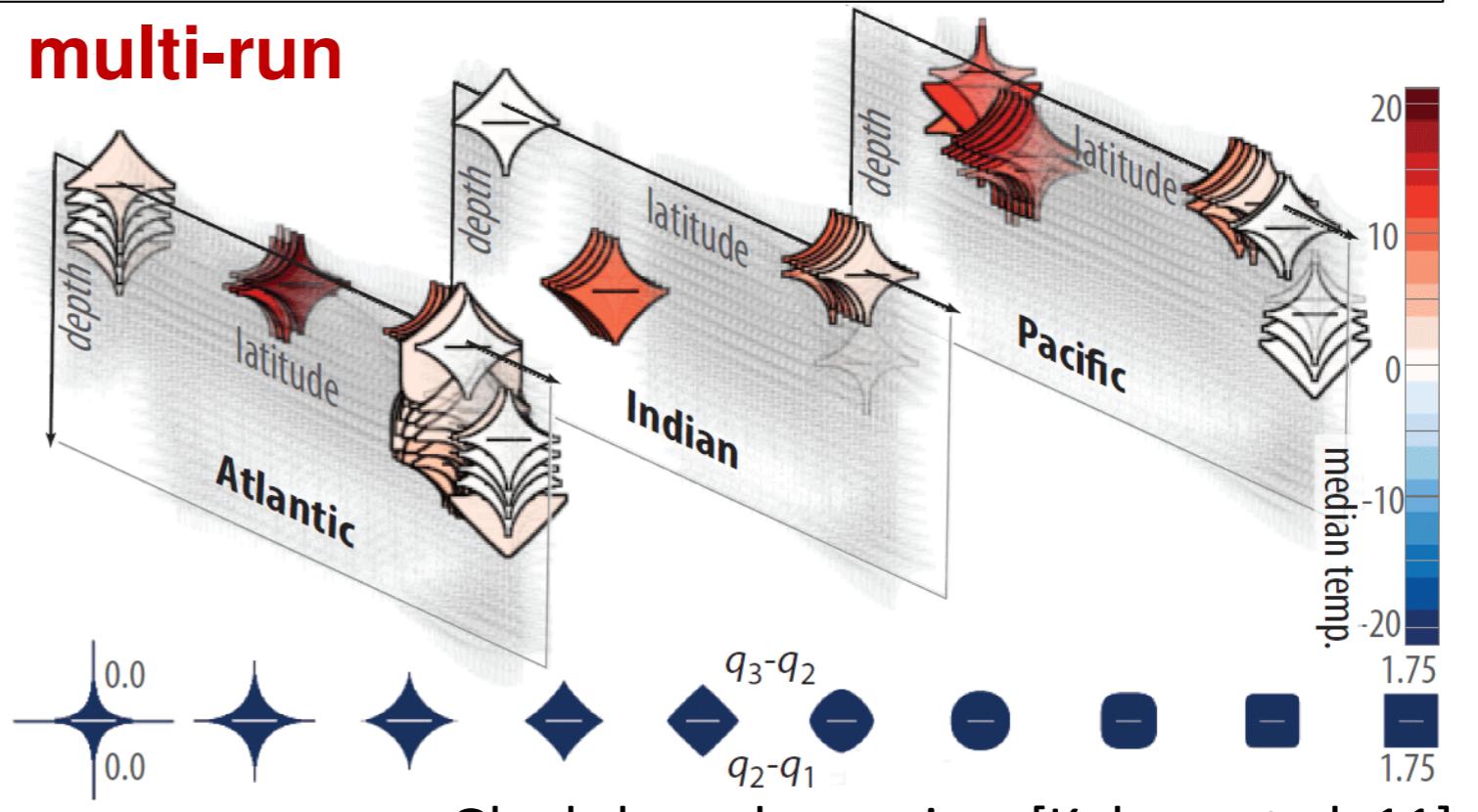
EnsembleVis [Potter et al. 09]



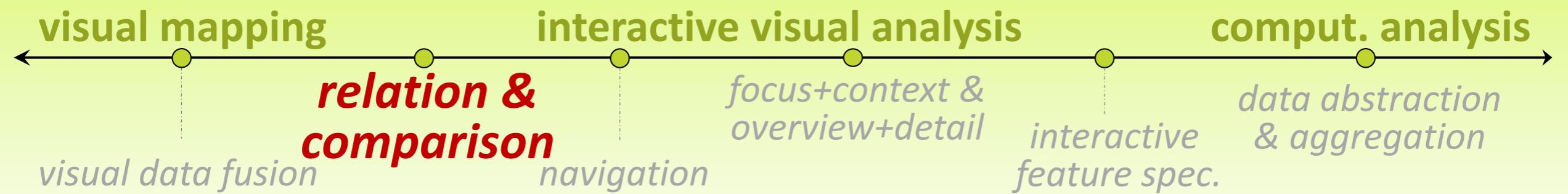
Glyph-based overview [Kehrer et al. 11]



EnsembleVis [Potter et al. 09]

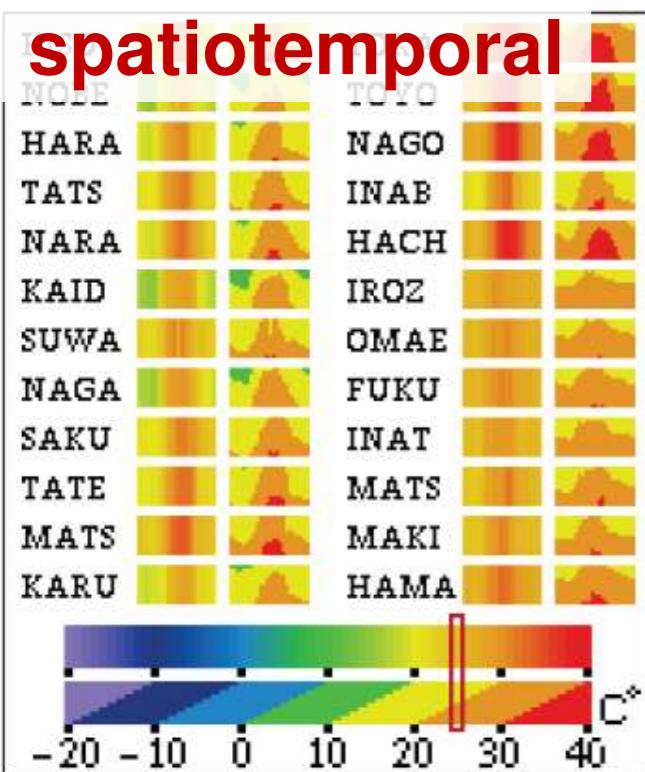


Glyph-based overview [Kehrer et al. 11]

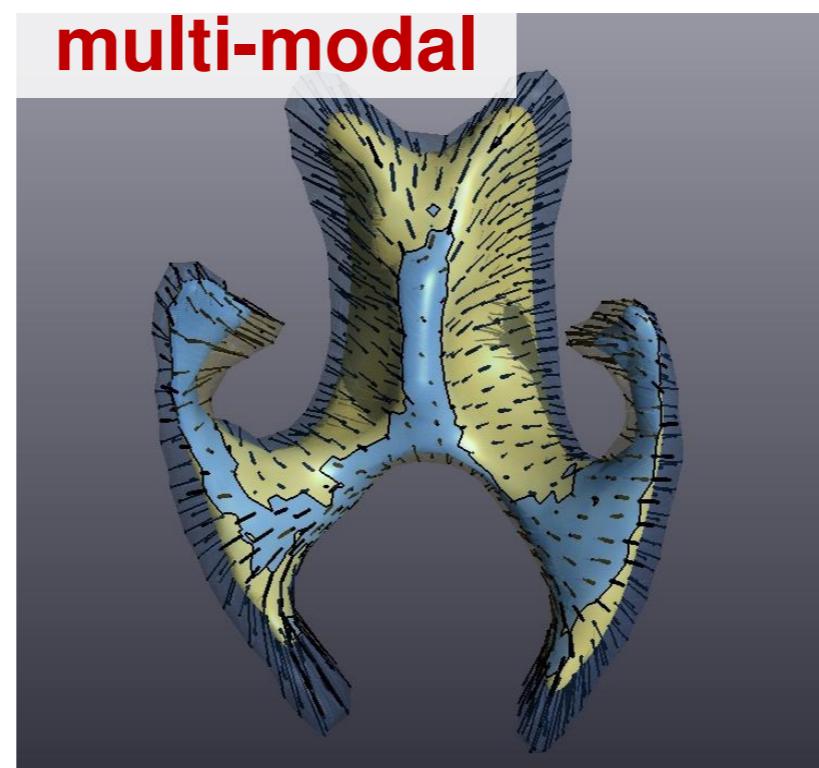


## Taxonomy [Gleicher et al. 2011]

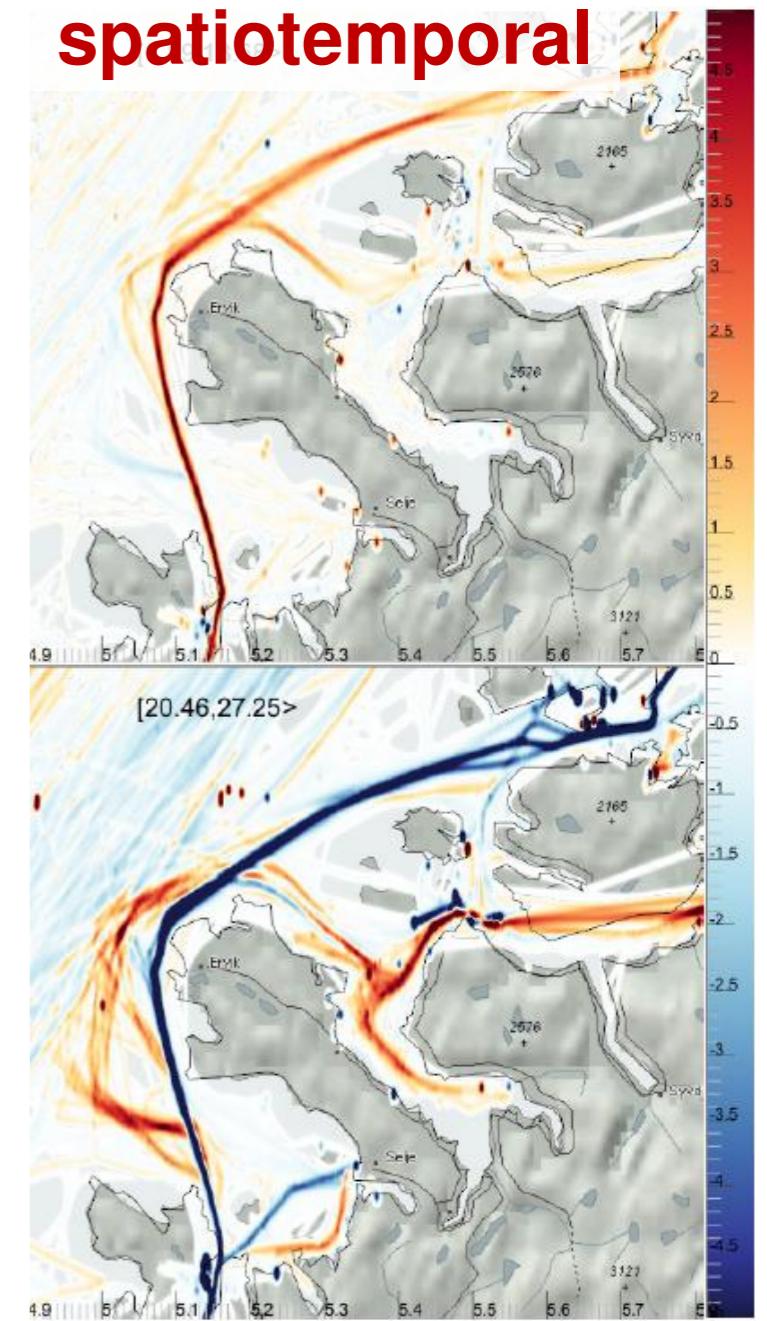
- side-by-side comparison
- overlay in same coordinate system
- explicit encoding of differences / correlations



2-tone coloring [Saito et al. 05]



Nested surfaces [Buskin et al. 11]



Difference views [Lampe et al.]

## visual mapping

## interactive visual analysis

## comput. analysis

visual data fusion

*relation & comparison*

## **navigation**

*focus+context & overview+detail*

*interactive feature spec.*

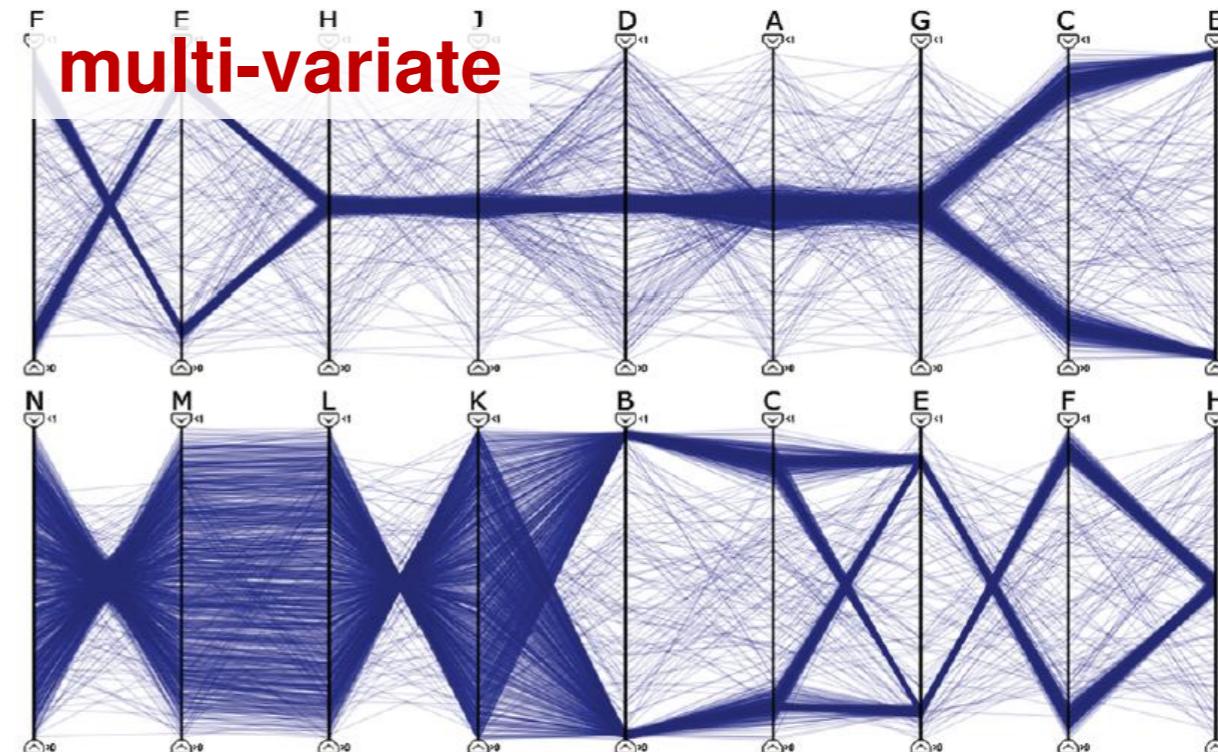
*data abstraction & aggregation*

### Interactive search, zooming, and panning

### Ranking/quality metrics

[Bertini et al. 2011]

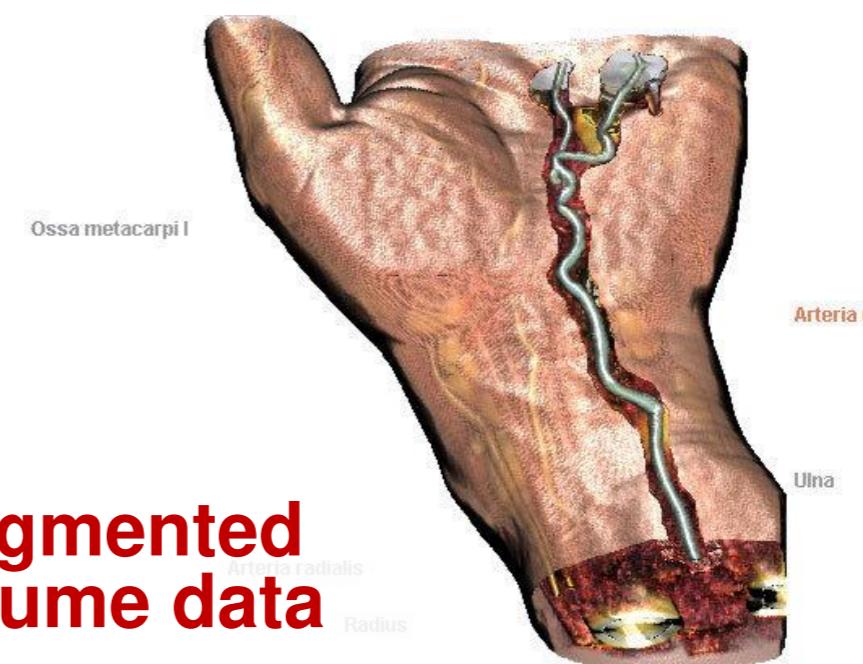
- clustering, correlations, outliers, image quality, etc.



[Johansson & Johansson 09]

### Automated viewpoint selection

- information-theoretic measures



[Viola et al. 06]

visual mapping

interactive visual analysis

comput. analysis

visual data fusion

relation & comparison

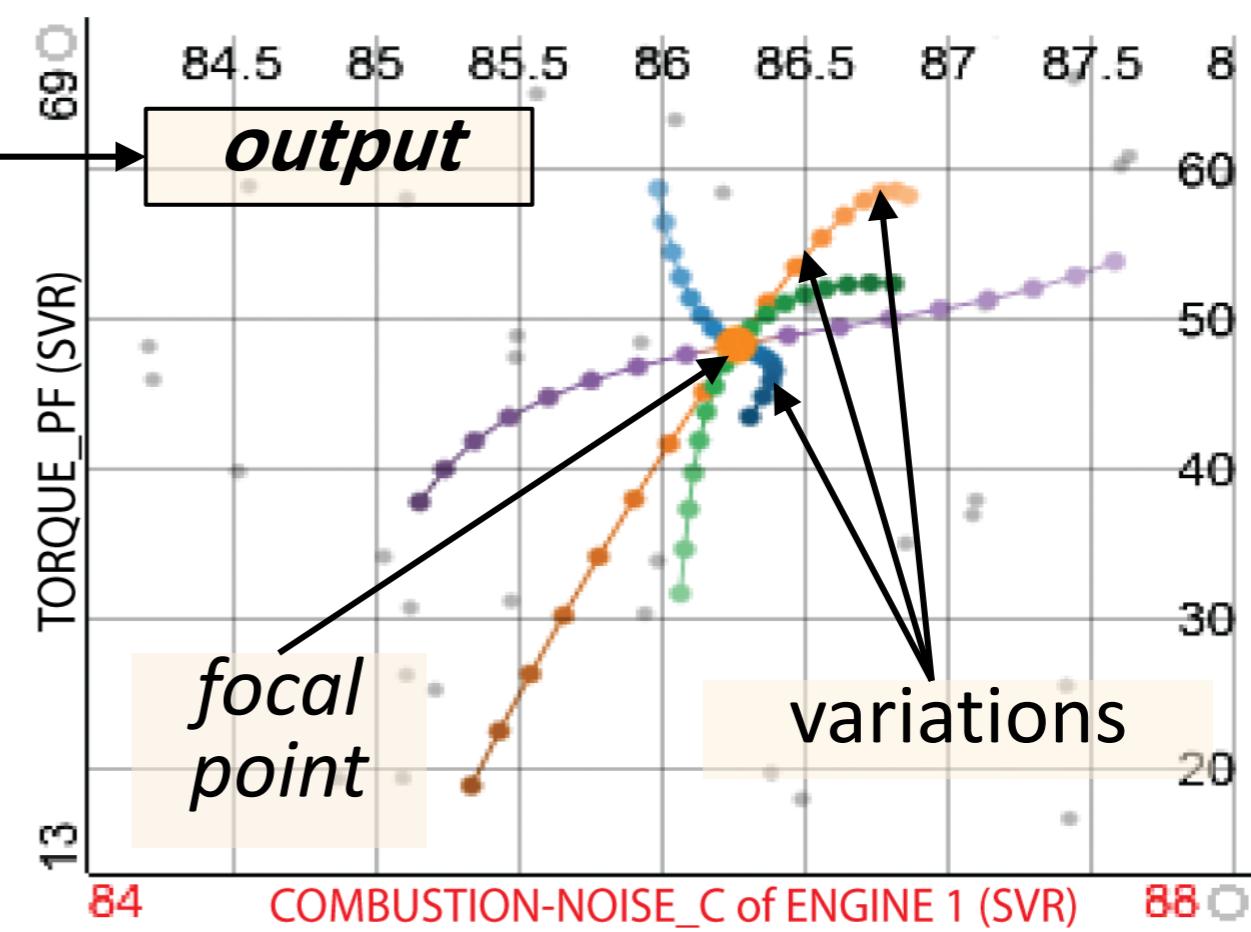
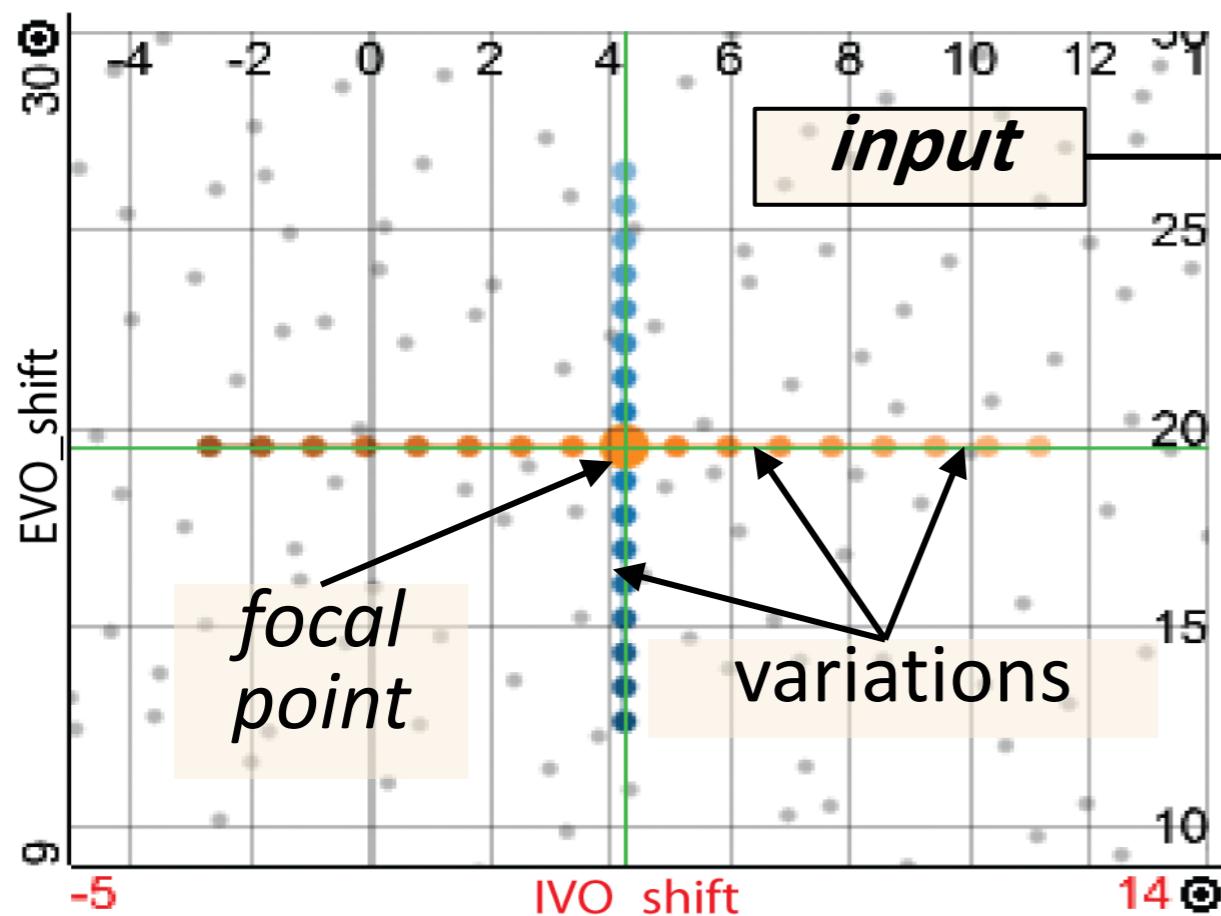
**navigation**

focus+context & overview+detail

interactive feature spec.

data abstraction & aggregation

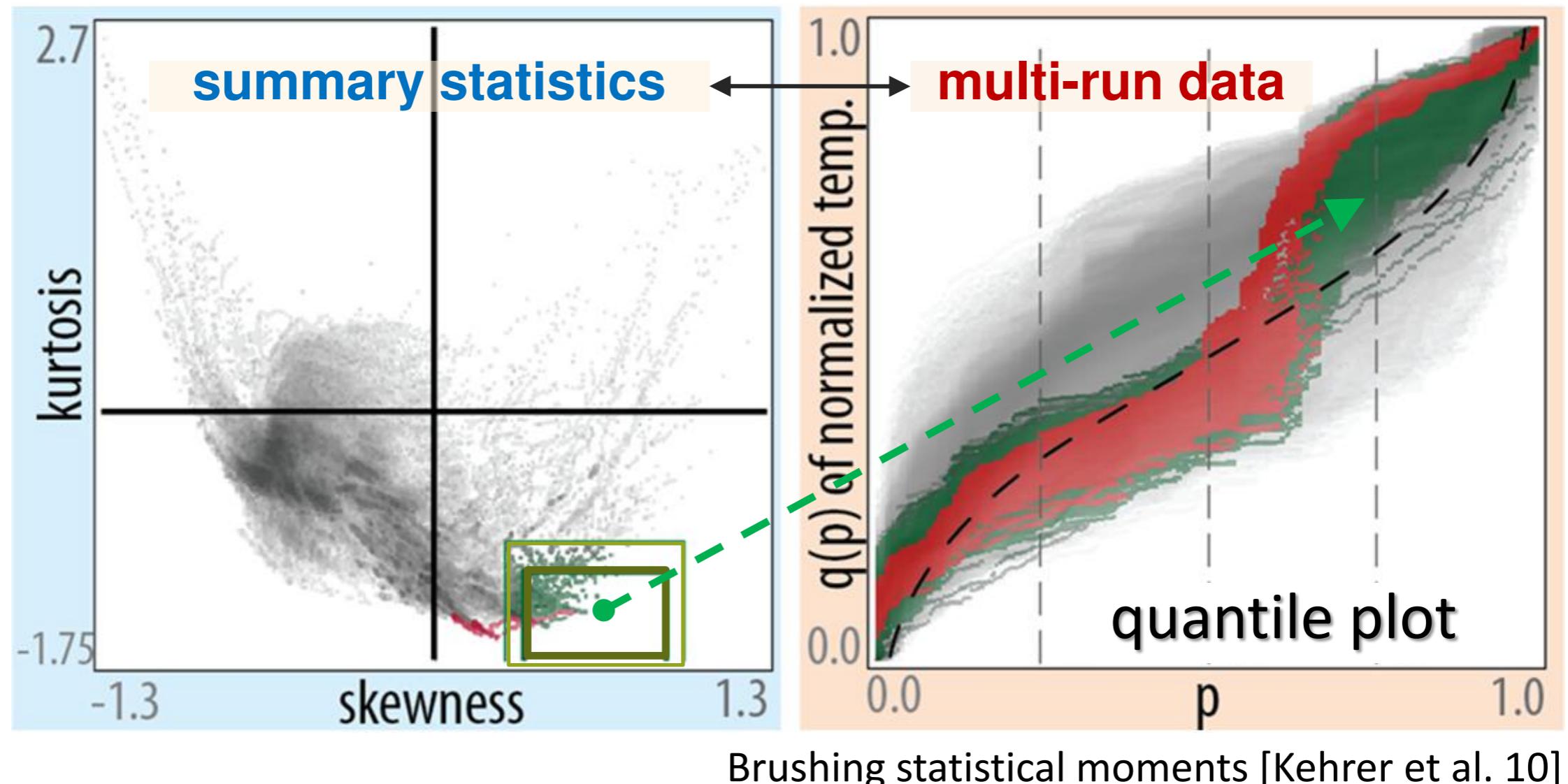
## Parameter space navigation (multi-run data)

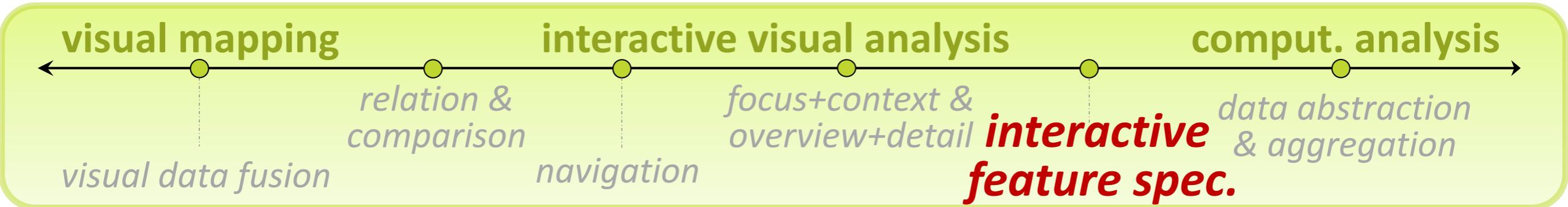


[Berger et al. 11]

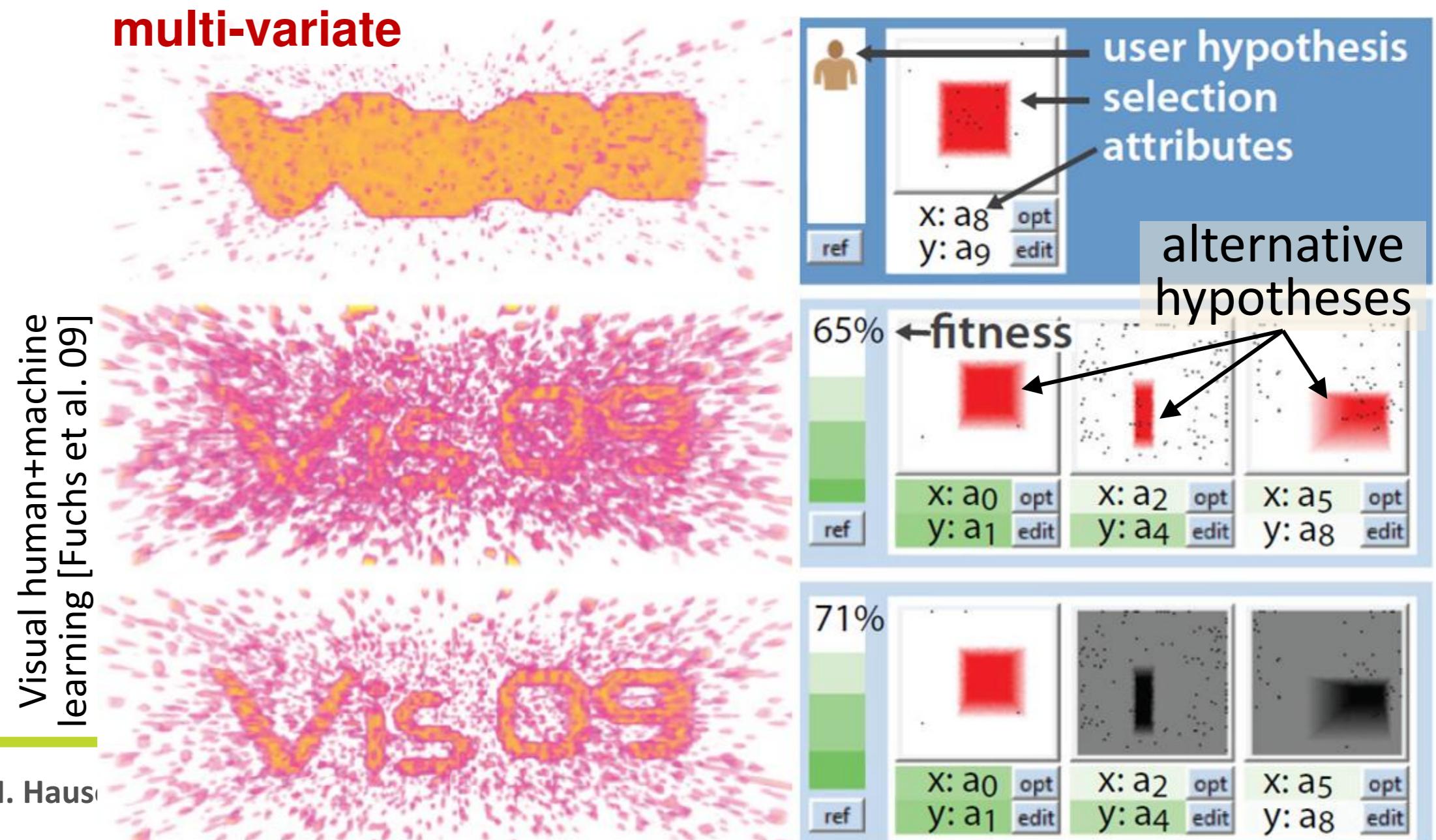


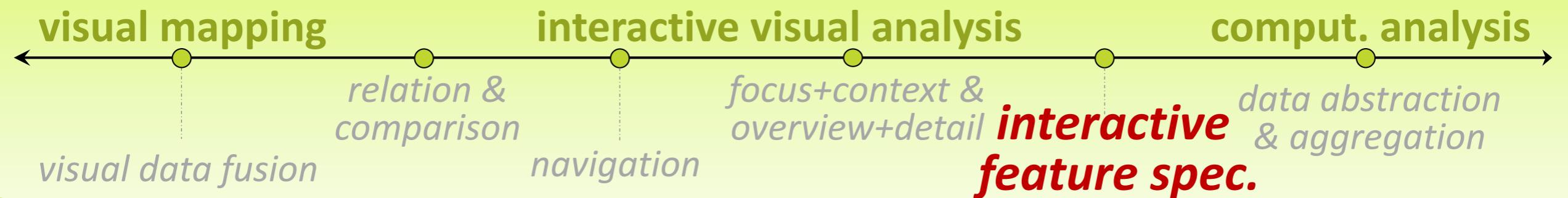
## ■ Overview+detail representation of multi-run data





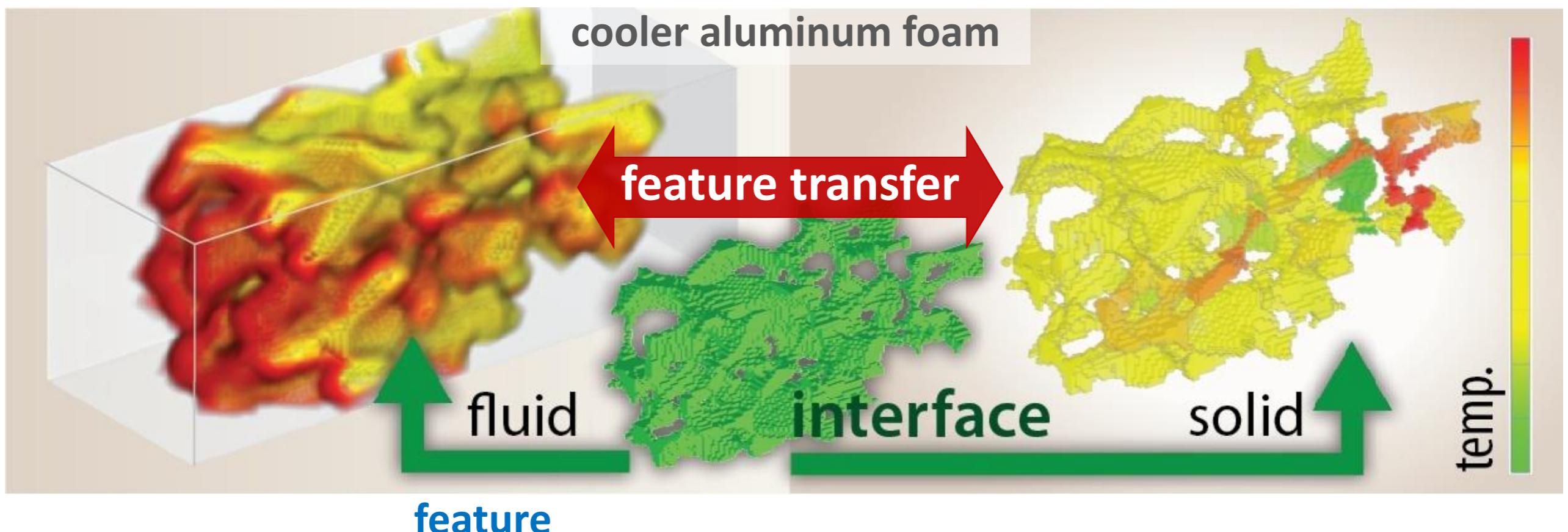
- Brushing in multiple linked views
- Tight integration with supervised machine learning

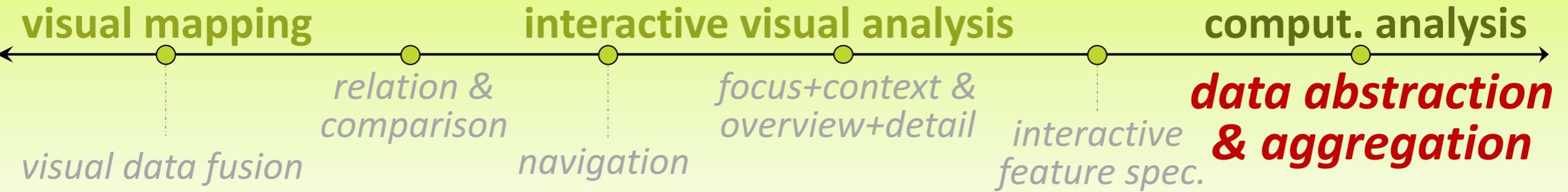




## Fluid-structure interactions (multi-model data)

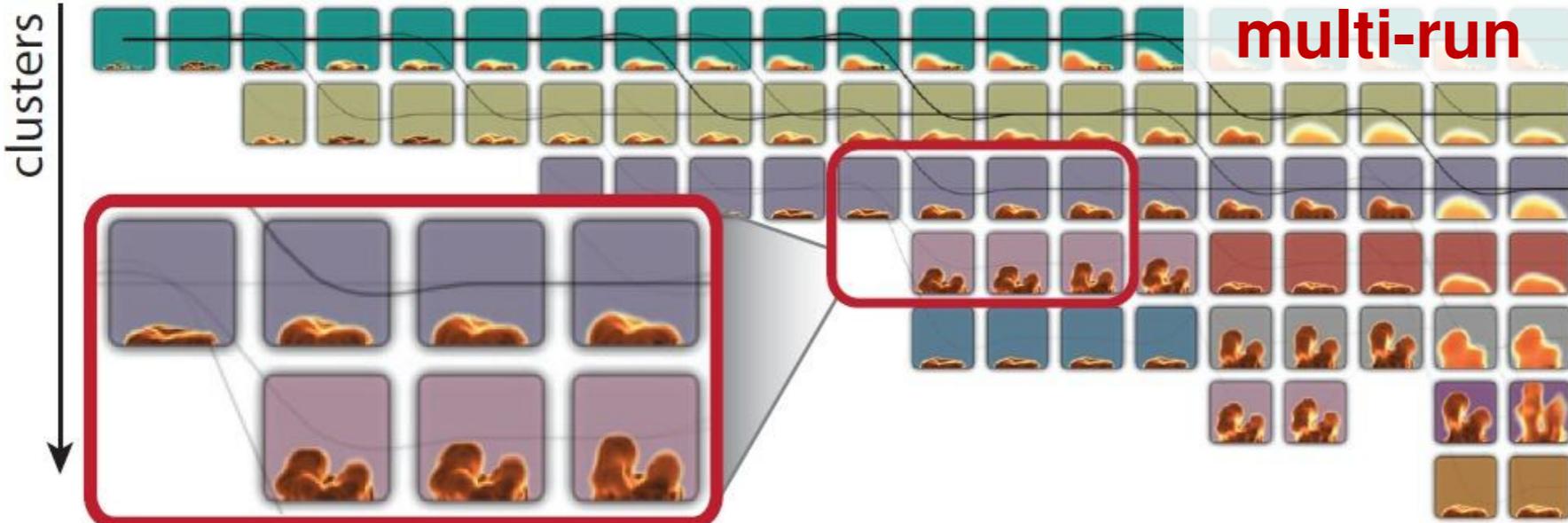
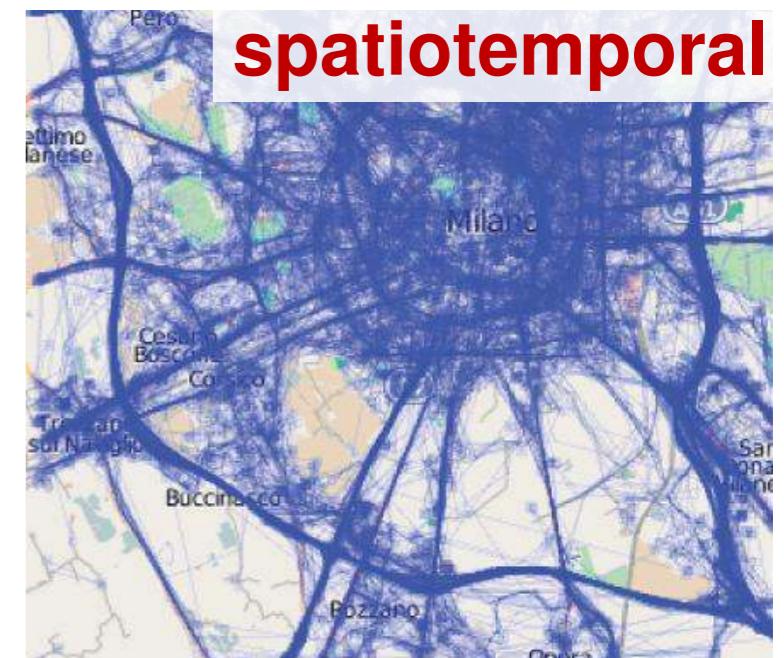
- heat exchange between fluid  $\leftrightarrow$  structure
- feature specification/transfer across data parts [Kehrer et al. 11]





## Algorithmically extract values & patterns

- dimensionality reduction (PCA, SOM, MDS)
- aggregation, summary statistics
- clustering, outliers, etc.



clustering of multi-run simulations [Bruckner & Möller 10]

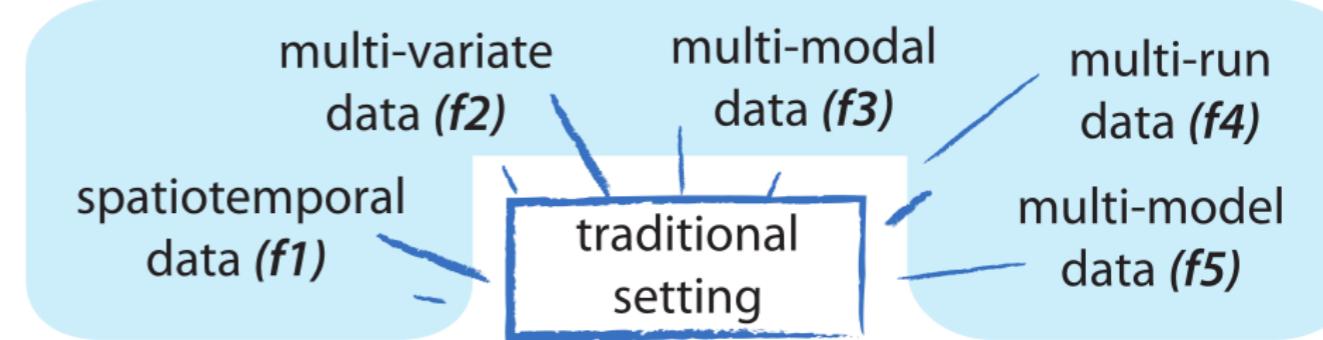


[Andrienko & Andrienko 11]

# Categorization of approaches

	visual mapping	interactive visual analysis			computational analysis	
	↔	↔	↔	↔	↔	
multi-dimensional	<p>maps [13], [14], [92]; Helix glyphs [93]; flow maps [105]; function graphs [70], [71], [72]; Time Histograms [94], [110], [111]; chrono volumes [98]; illustrative techniques [99]; texture-based flow vis. [100]</p>	<p>2-tone coloring [20]; Helix glyphs [93]; juxtaposed views [19], [110]; difference views [107]</p>	<p>navigation search, zooming and panning [40], [54]</p>	<p>focus+context &amp; overview+detail 2-tone coloring [20]; multi-level focus+context [71]; pixel-based multi-resolution techn. [104]</p>	<p>interactive feature specification brushing [21], [70], [71], [95], [113]; transfer functions [110], [111]</p>	<p>aggregation [15], [103], [105]; trends [21]; flow features [82]; clustering [83], [84], [110]; PCA [17], [78], [85]; SOM [89], [90]; KDE [106], [107]; information theory [108]; wavelet analysis [109], [110]</p>
multi-variate	<p>attribute views [22], [50], [67]; color &amp; texture [119]; layering [115], [124], [126]; 2-level volume rendering [127], [128]; glyphs [120], [121], [122], [123], [124], [125]</p>	<p>correlation fields [133]; operators [134]; multiple linked views [9], [26], [29], [73], [74], [76]</p>	<p>grand tour [47]; ScatterDice [46]; ranking &amp; quality metrics [48], [130], [131], [132]</p>	<p>illustrative vis. [115], [116]; outlier-preserving methods [69]; smooth brushing [80]</p>	<p>brushing [9], [50], [74], [75], [112]; multi-dim. transfer func. [114], [115]; machine learning [91], [135], [136]</p>	<p>clustering [68], [130]; data binning [69]; PCA [78]; MDS [86], [87]; SOM [88], [89]; projections [47], [48], [130], [132]; point clouds [129]</p>
multi-modal	<p>resampling [138]; data model [142]; illumination model [143]; multi-volume rendering [128], [139], [143], [144], [145], [146]</p>	<p>difference views [107]; multi-image view [153]; nested surfaces [31], [154], [156]; features [44], [155]</p>	<p>viewpoint selection [49]</p>	<p>cutaway views [147], [139], [49]</p>	<p>transfer functions [143], [144]</p>	<p>registration [27]; mutual information [28]; comparison metrics [148], [151], [152], [133]</p>
multi-run	<p>glyphs &amp; box plots [37], [43], [162], [163], [164]; shape descriptors [164]; families of surfaces [41]; spaghetti plots [35], [42], [165]</p>	<p>aggregated &amp; multi-run data [36], [37], [41], [174]; HyperMoVal [51], [52]</p>	<p>aggregated &amp; multi-run data [36], [37], [41]; parameter space nav. [51], [52]</p>	<p>aggregated &amp; multi-run data [36], [37], [41]; simulation process vis. [173], [174]</p>	<p>trends &amp; outliers [36], [37], [41]; visual steering [172]</p>	<p>overview statistics [31], [35], [36]; projections [41], [51], [170], [171]; operators [33]; PCA [169]; clustering [167], [168], [169]</p>
multi-model	<p>feature fusion across multiple data parts [37]</p>	<p>feature relation across data parts [37]</p>	x	x	<p>feature spec. across data parts [37]</p>	x

# Open Issues



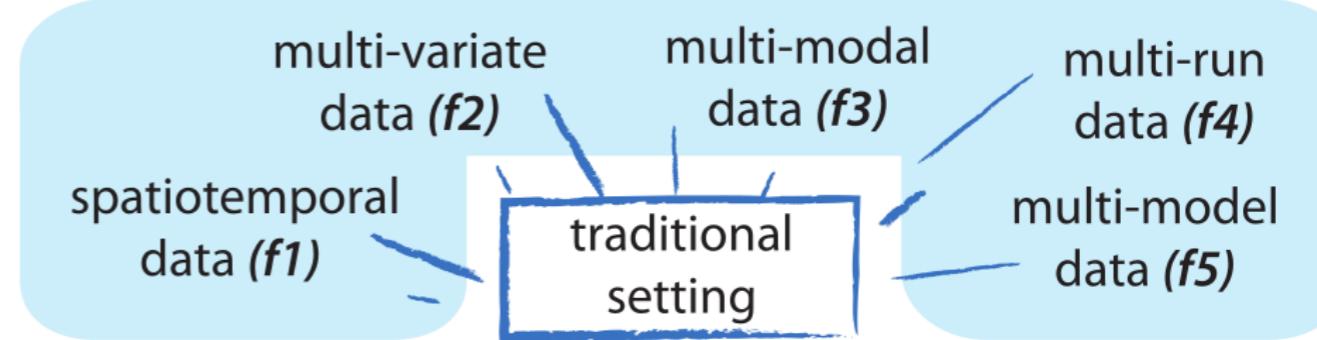
## ■ How to deal with data heterogeneity?

- most approaches only address one or two data facet
- coordinated multiple views with linking & brushing
- investigation of features across views, data facets, levels of abstraction, and data sets
- fusion of heterogeneous data at feature/semantic level

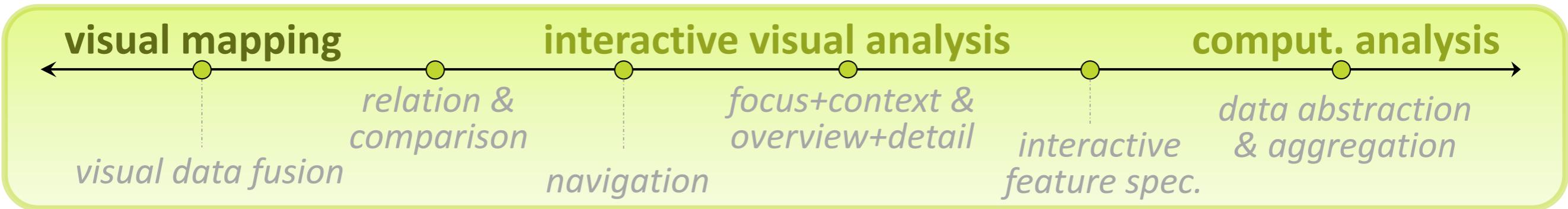
## ■ Combination of vis., interaction, and comput. analysis

- analytical methods can control steps in visualization pipeline (e.g., visualization mapping or quality metrics)
- interactive feature specification + machine learning

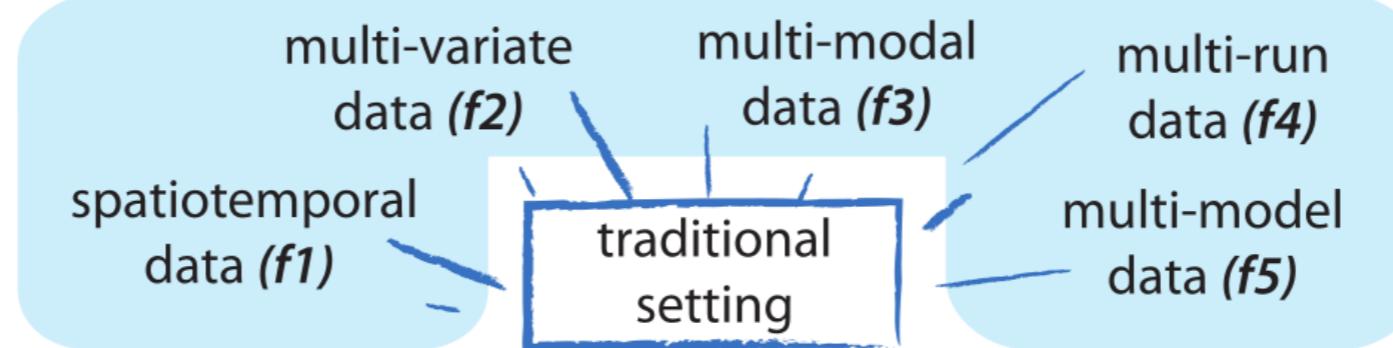
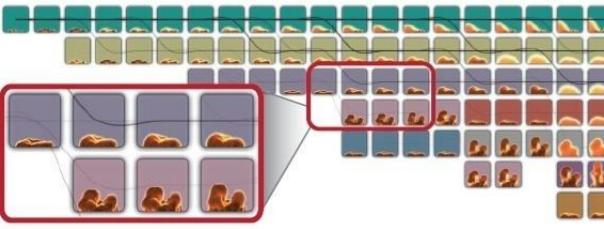
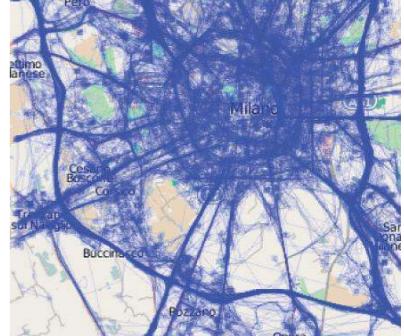
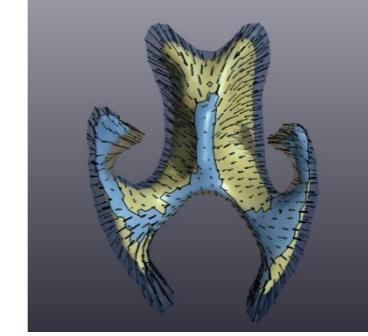
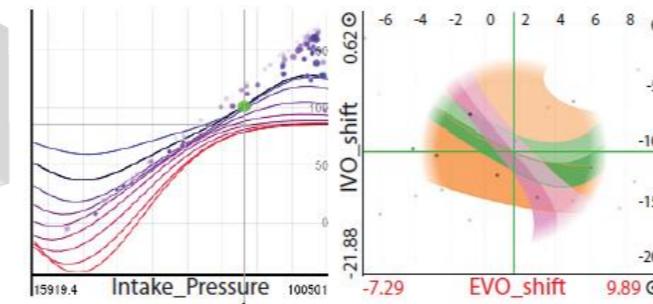
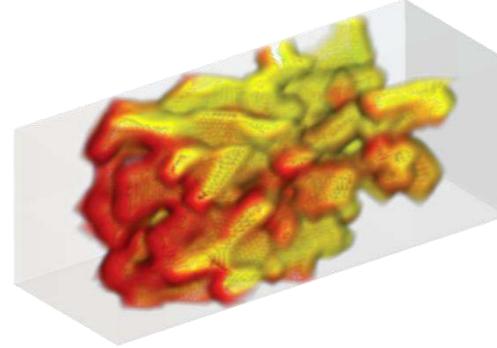
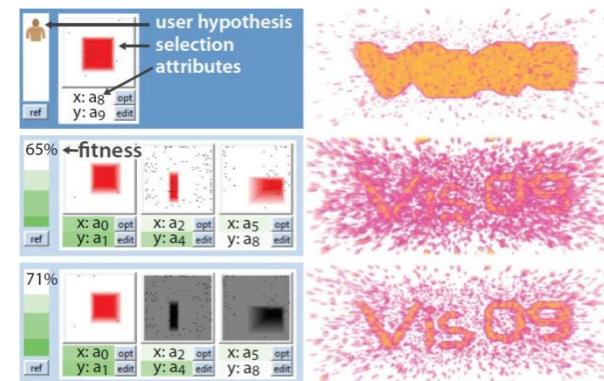
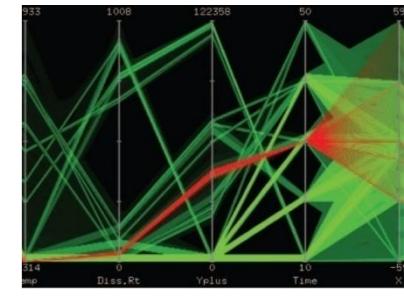
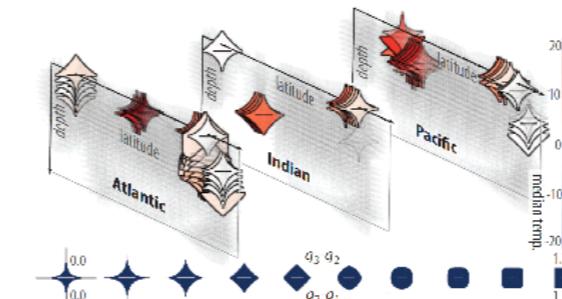
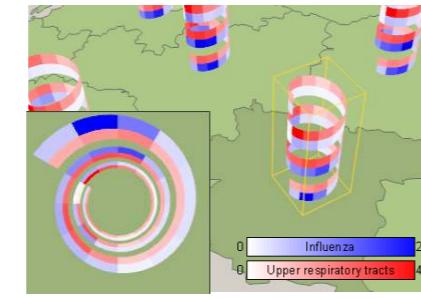
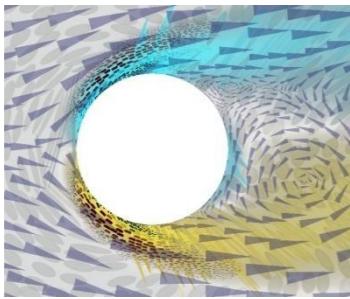
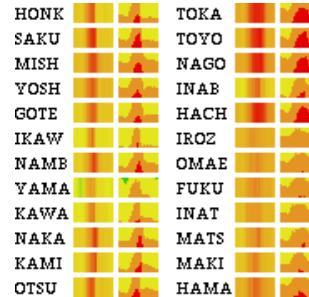
# Conclusions



- Scientific data are becoming multi-faceted
- Categorization based on common visualization, interaction, and comput. analysis methods



- Promising data facets, e.g., multi-run & multi-model data



# Thank you for your attention!

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