Visual Data Science: Vis tools for decision making

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Quiz

- "Each match must agree within 15 degrees orientation, $\sqrt{2}$ change in scale, and 0.2 times maximum model size in terms of location. If fewer than 3 points remain after discarding outliers, then the match is rejected."
- Lowe, 1999, Object recognition from local scale-invariant features (SIFT); citations: 10,500 (+33,200 of 2004 journal paper)

Tuning of parameters

SIFT/Lowe

Wikipedia


Wikipedia

Overview

- Today: 4 case studies
  - Tuner — Image segmentation
  - FluidExplorer — Fluid animation
  - Vismon — Fisheries science
  - FeatureExplorer — Classification
- Tomorrow: Abstraction / Theory
  - Design Studies
  - Principles of visual parameter space exploration
  - Visual Data Science — visual tools for modeling

Tuner
Image segmentation

NSERC CRSNG

Acknowledgments

Thomas Torsney-Weir
U of Vienna

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SFU

Britta Weber
Zuse I Berlin

Hans-Christian Hege
Zuse I Berlin

Jean-Marc Verbavatz
MPI-CBG Dresden

Image Segmentation

- Partitioning the image into disjoint regions of homogeneous properties
- Useful for statistical analysis, diagnosis, and treatment evaluation

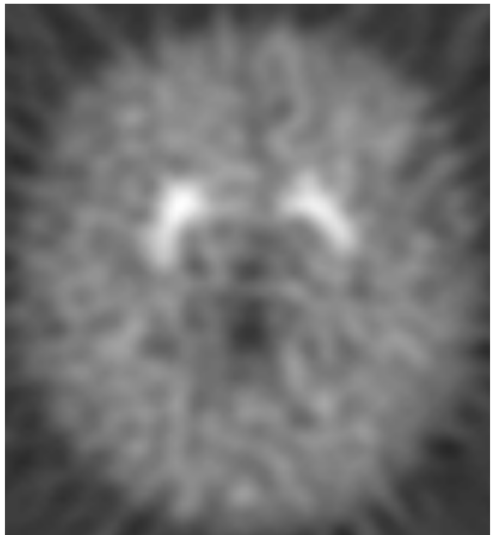
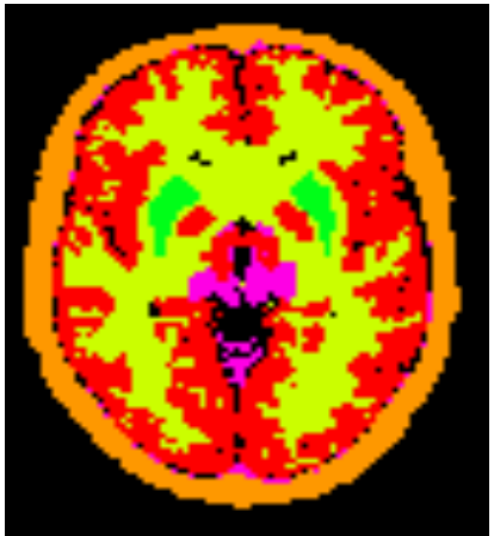


Image Segmentation



Segmentation by Thresholding

Sigma = 1.0

- traditionally - finding edges
- Canny edge detection ... needs thresholds!
  - width of Gaussian
  - low and high thresholds

courtesy of http://www.cs.washington.edu/research/imagedatabase/demo/edge/

Segmentation by Thresholding

Sigma = 2.0

- traditionally - finding edges
- Canny edge detection ... needs thresholds!
  - width of Gaussian
  - low and high thresholds

courtesy of http://www.cs.washington.edu/research/imagedatabase/demo/edge/

Energy functionals

- minimize energy $E(\phi, I)$
- often times:

$$E(\phi, I) = \alpha_1 E_1(\phi, I) + \alpha_2 E_2(\phi, I) + ... + \alpha_k E_k(\phi, I)$$

- where
  - I - input image
  - φ - segmentation
  - α - different weights

The Zen of tuning parameters!

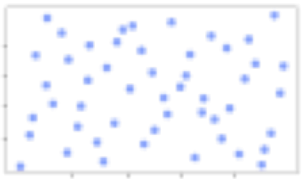
- very tedious and time consuming
- loop over
  - guess a parameter combination
  - wait for segmentation result (often minutes)
  - evaluate result (often visually)
- did we reach a stable parameter region?

Parameter Tuning

Principle ideas

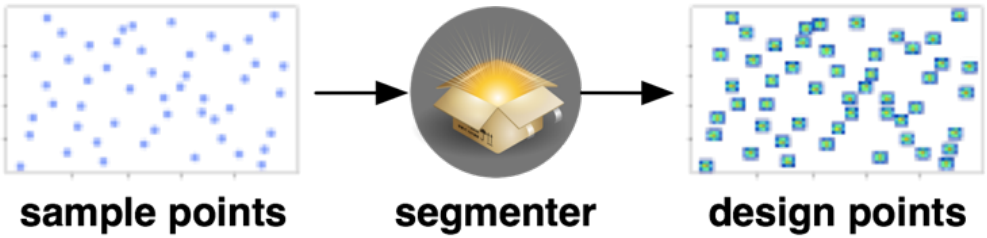
- Assumptions
  - ground truth is given
  - we use a quality measure (e.g. DICE-coefficient or Precision-Recall)
- Requirements
  - No stone unturned
  - Separate the wheat from the chaff
  - Stability

Sampling high-D space

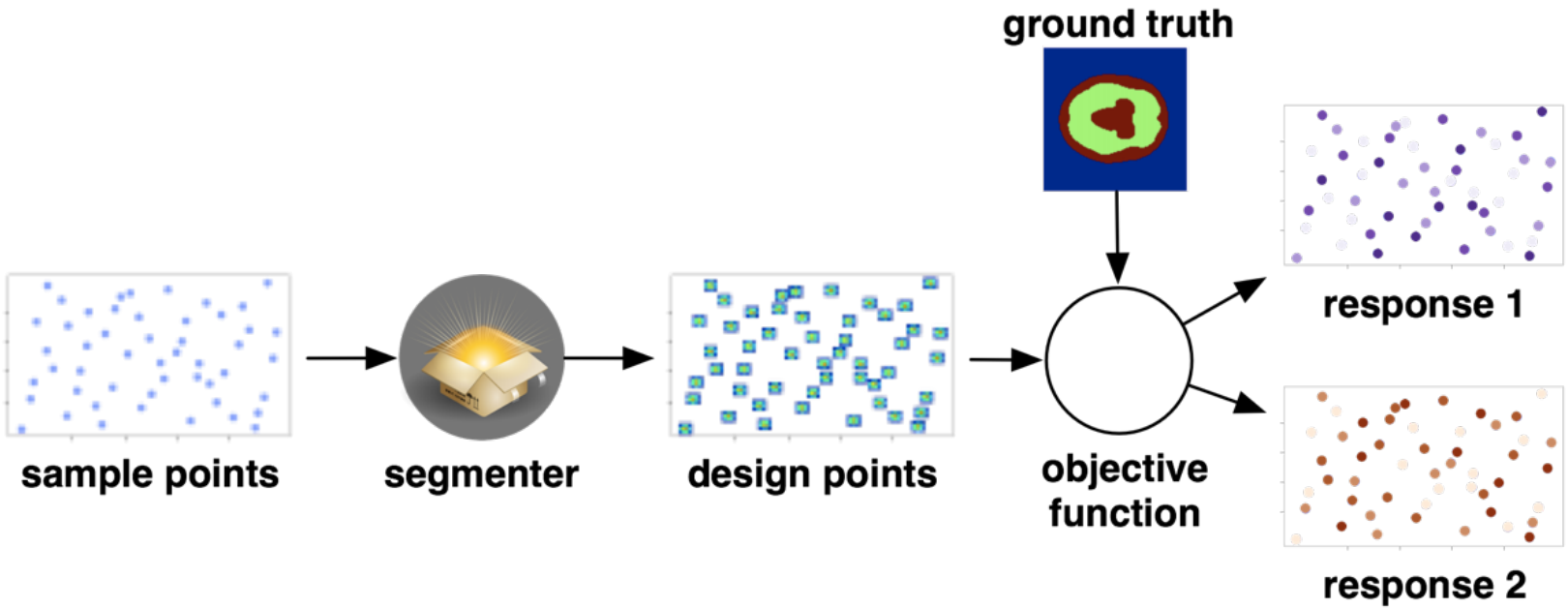


sample points

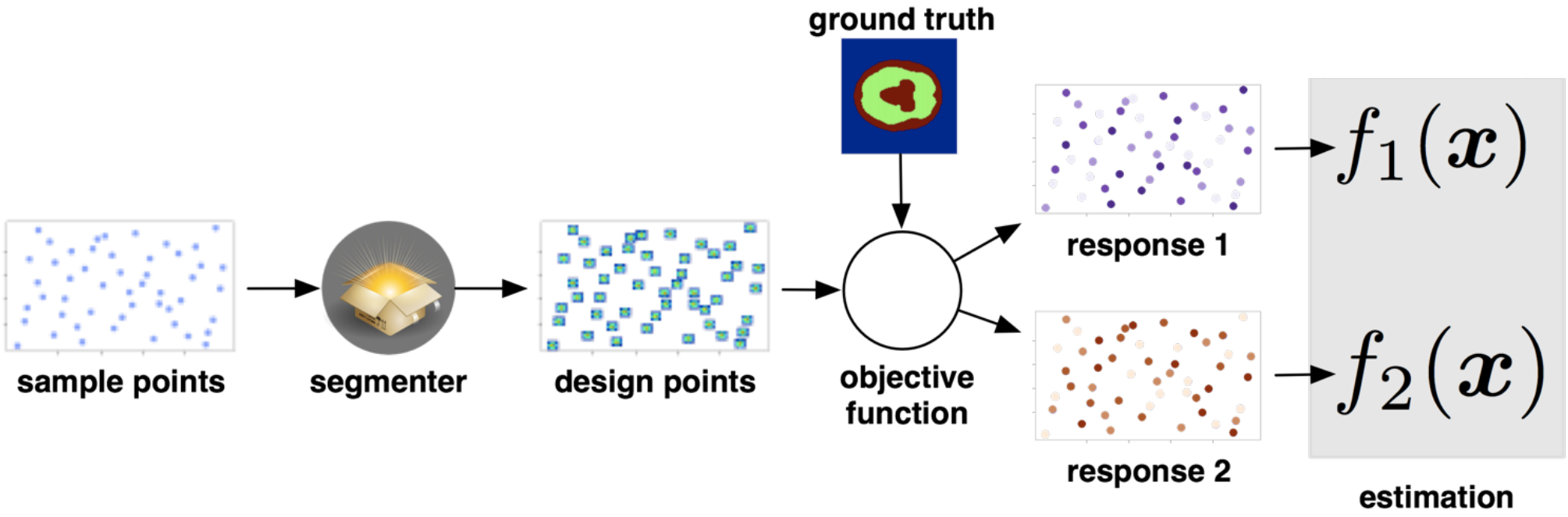
Apply (black-box) Segmentation



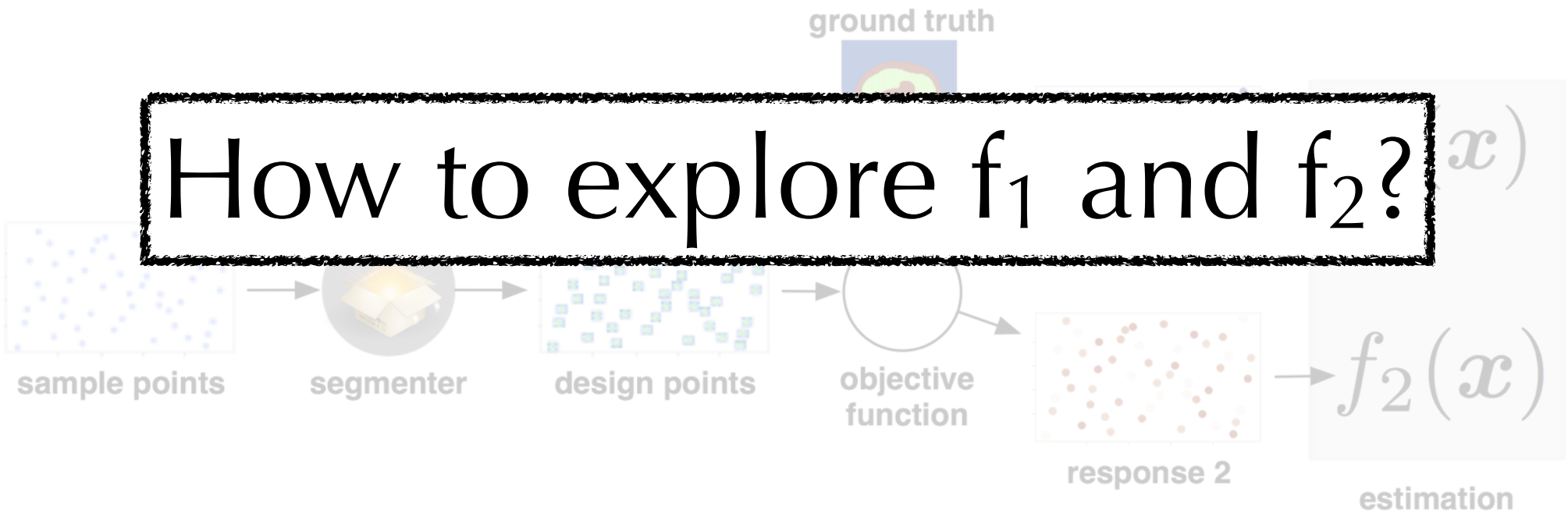
Compare to ground-truth



Build an estimator

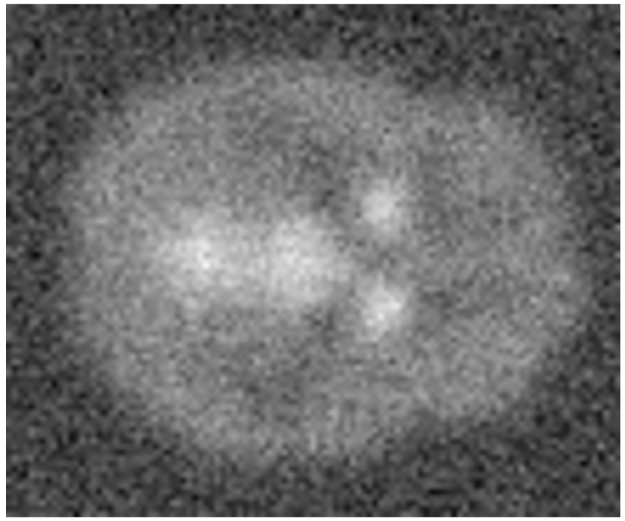


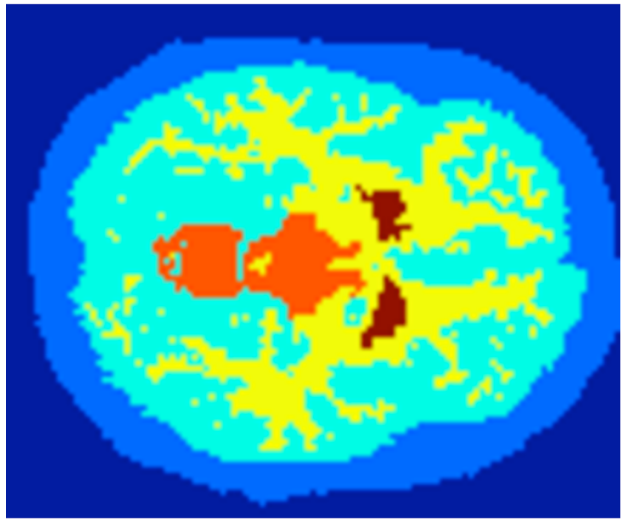
Build an estimator



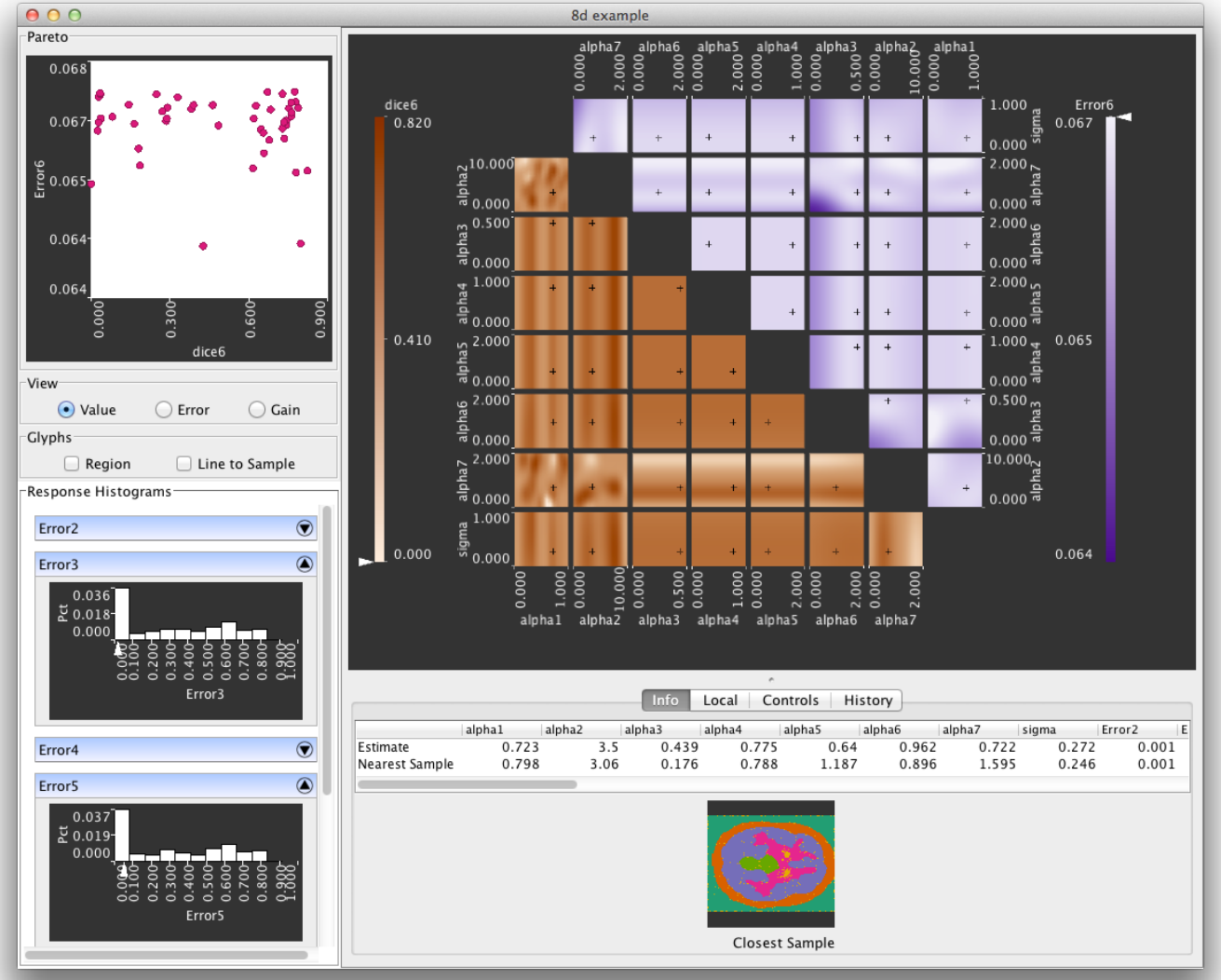
Case study - Brain dynamic PET

- 46 time steps
- very noisy
- challenging to segment
- 8 energy model to explore





Tuner


8d example
Pareto
Error6
dice6
View
Value
Error
Gain
Glyphs
Region
Line to Sample
Response Histograms
Error2
Error3
Pct
Error3
Error4
Error5
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dice6
Error6
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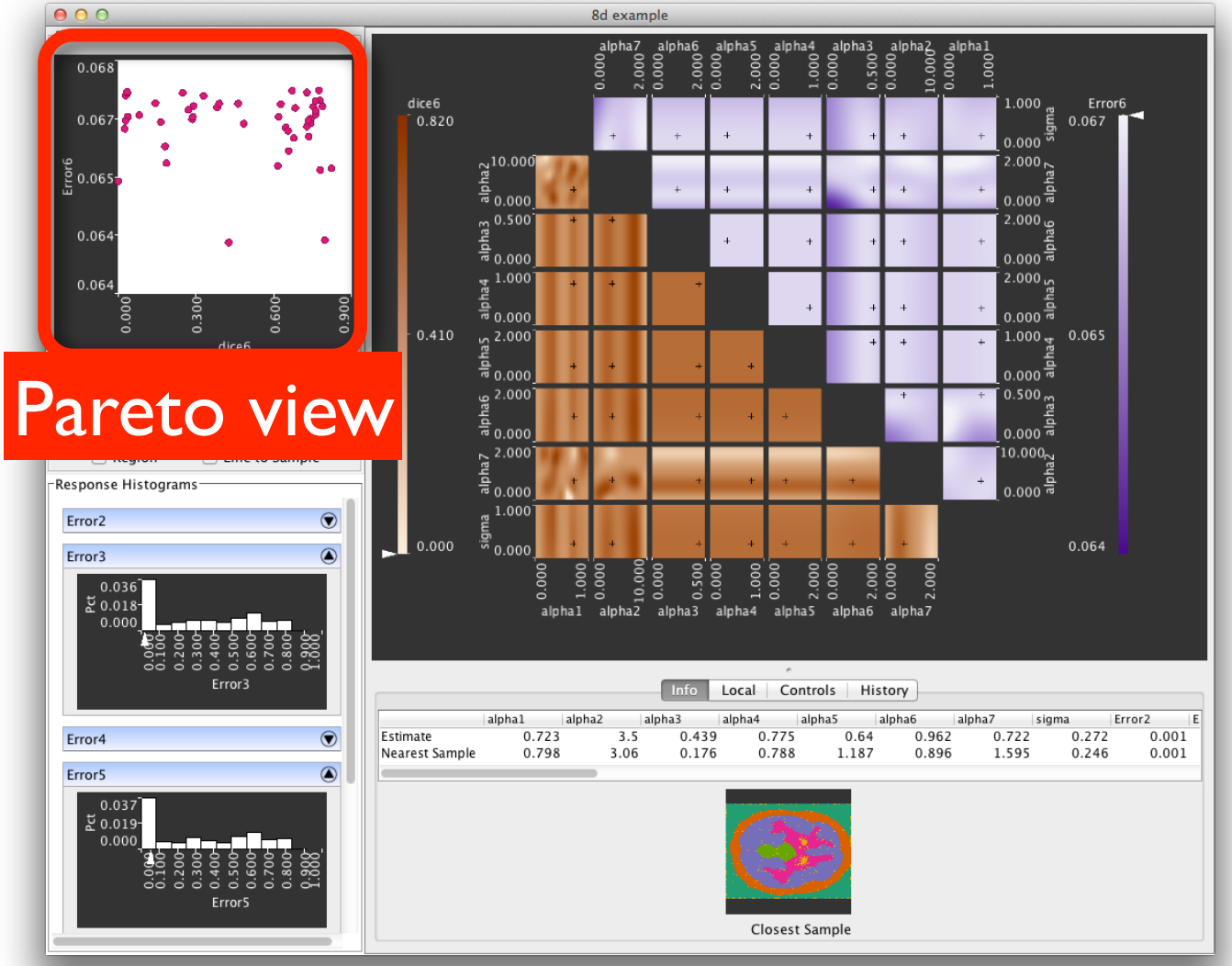
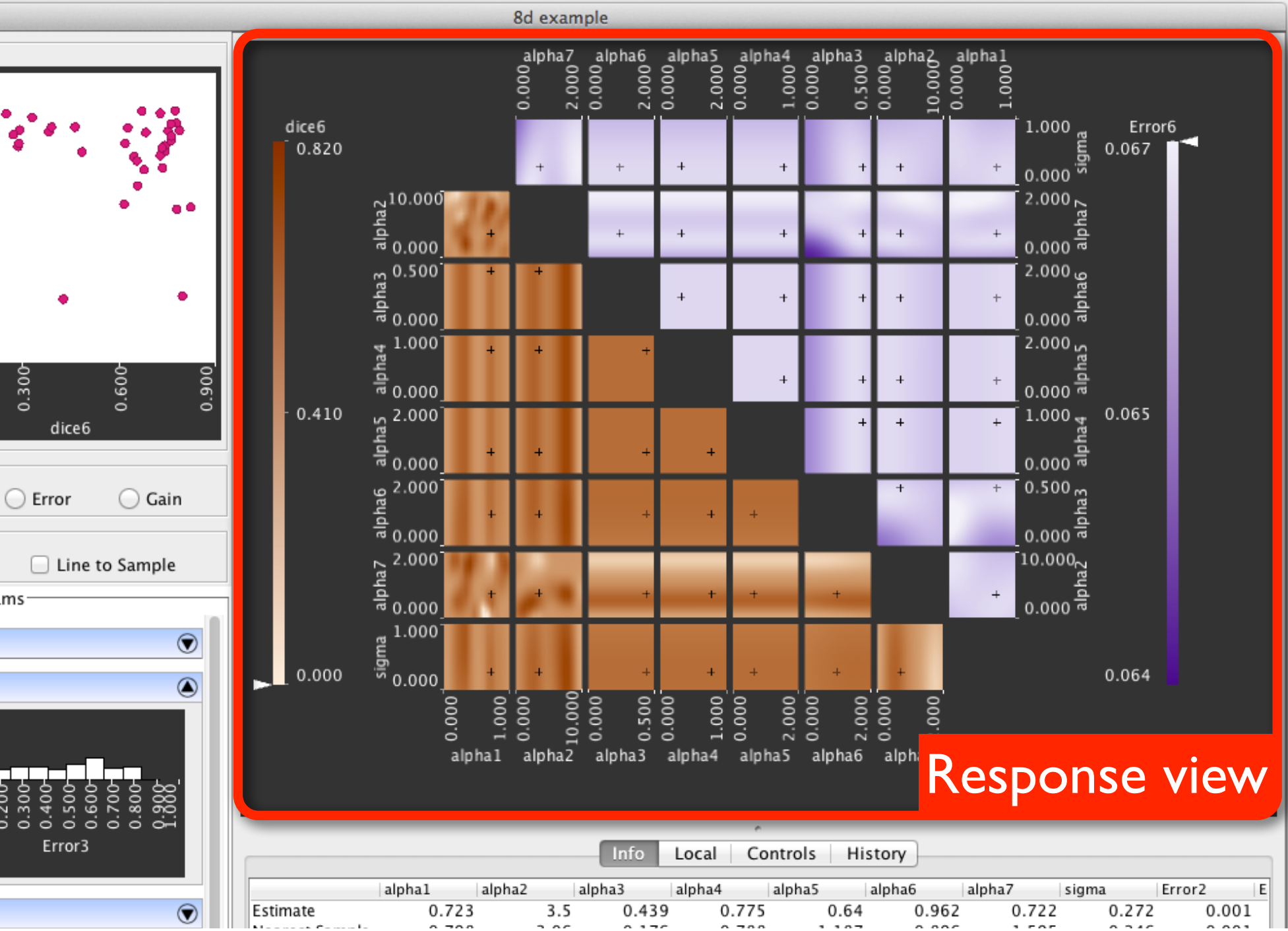
alpha1
alpha2
alpha3
alpha4
alpha5
alpha6
alpha7
Info
Local
Controls
History
Estimate 0.723 3.5 0.439 0.775 0.64 0.962 0.722 0.272 0.001
Nearest Sample 0.798 3.06 0.176 0.788 1.187 0.896 1.595 0.246 0.001
Closest Sample

Global - Pareto Front



Local - HyperSlice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Error3
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History
alpha1 alpha2 alpha3 alpha4 alpha5 alpha6 alpha7 sigma Error2
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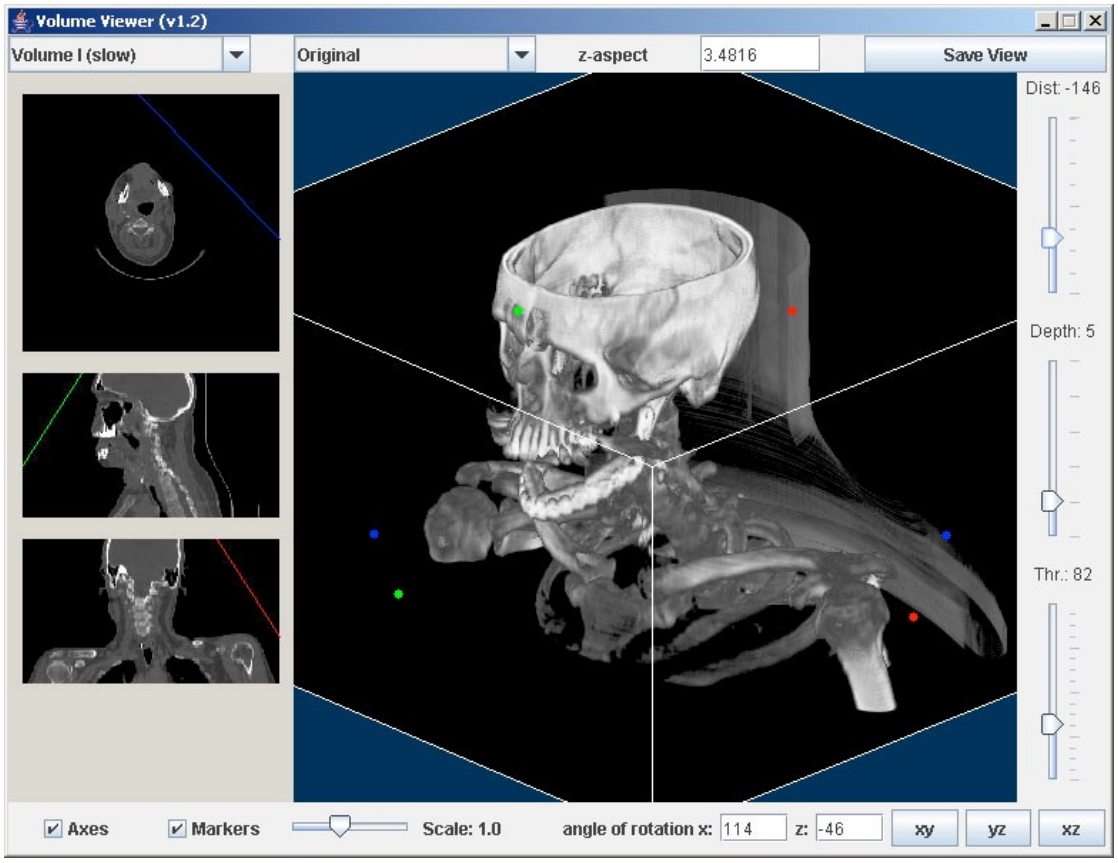
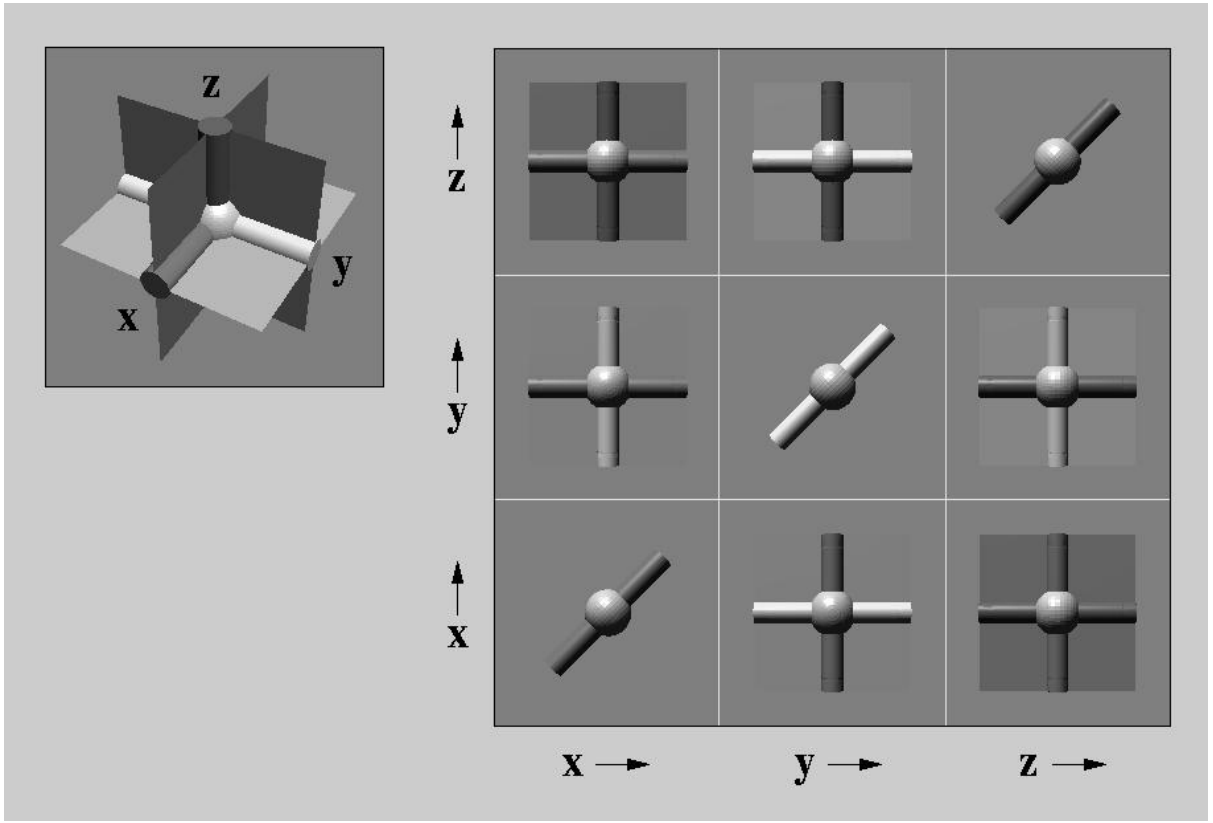
Hyperslice?

better slicer image

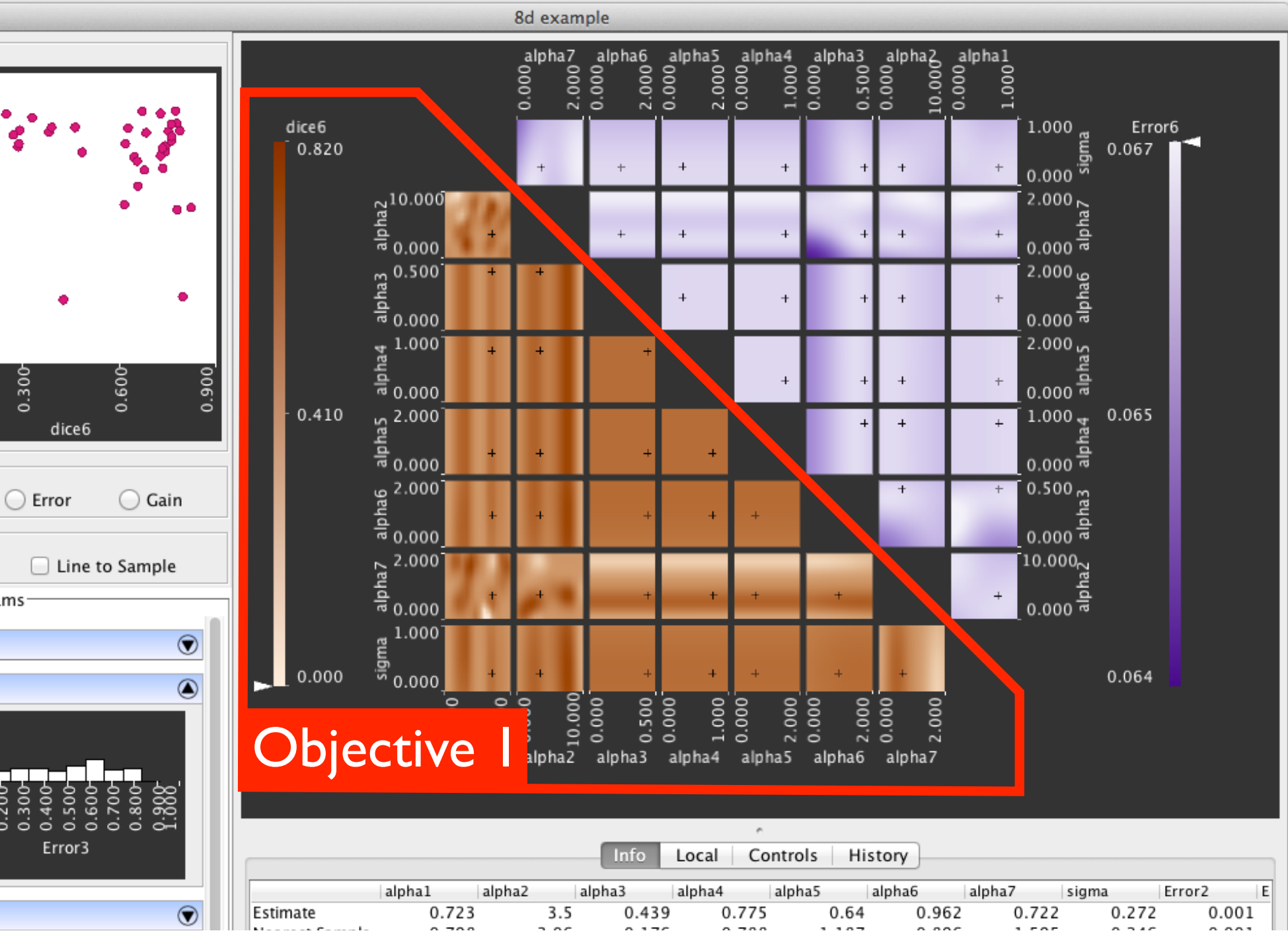


http://rsbweb.nih.gov/ij/plugins/volume-viewer.html

Hyperslice?



van Wijk and van Liere 1993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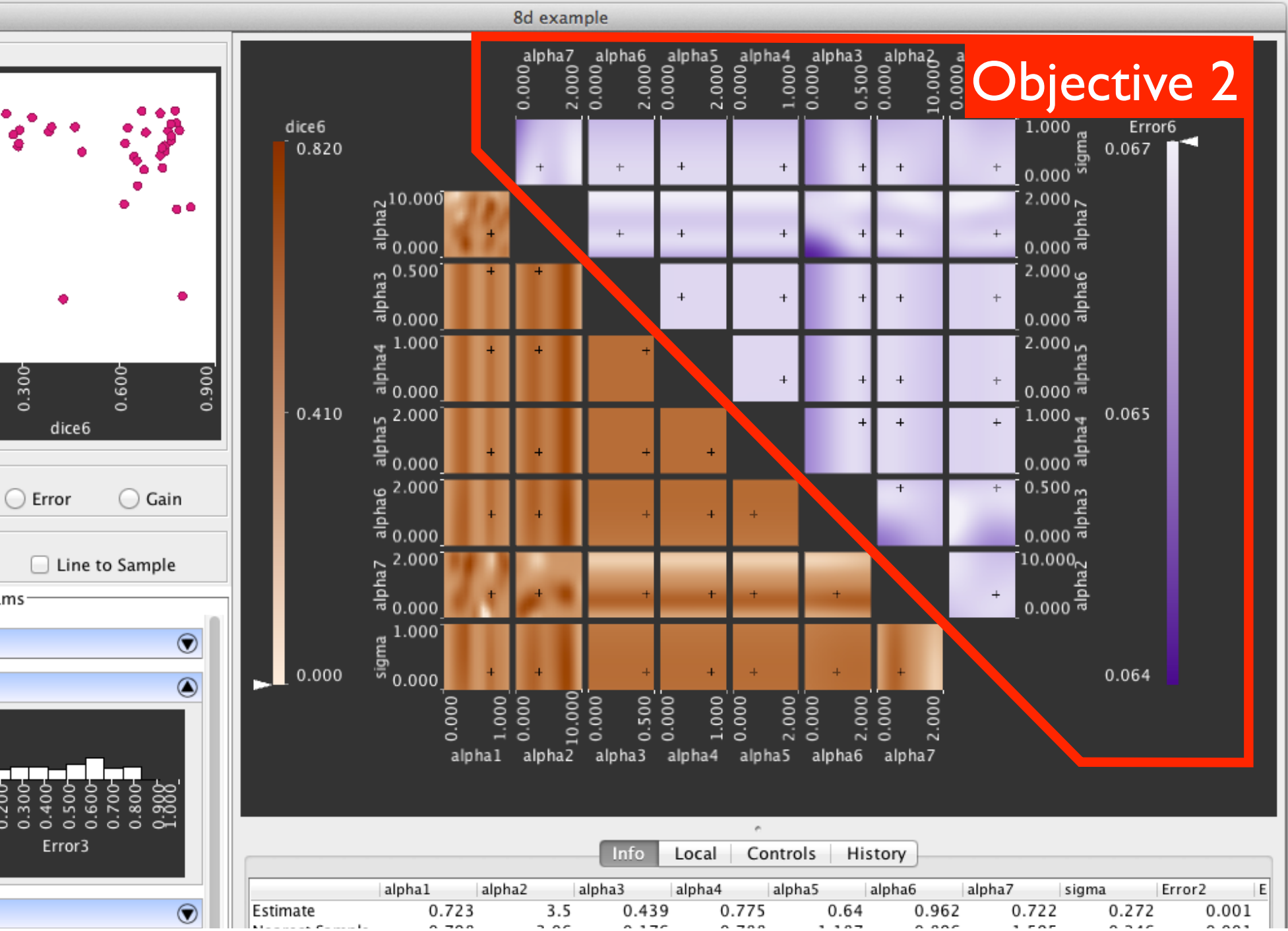
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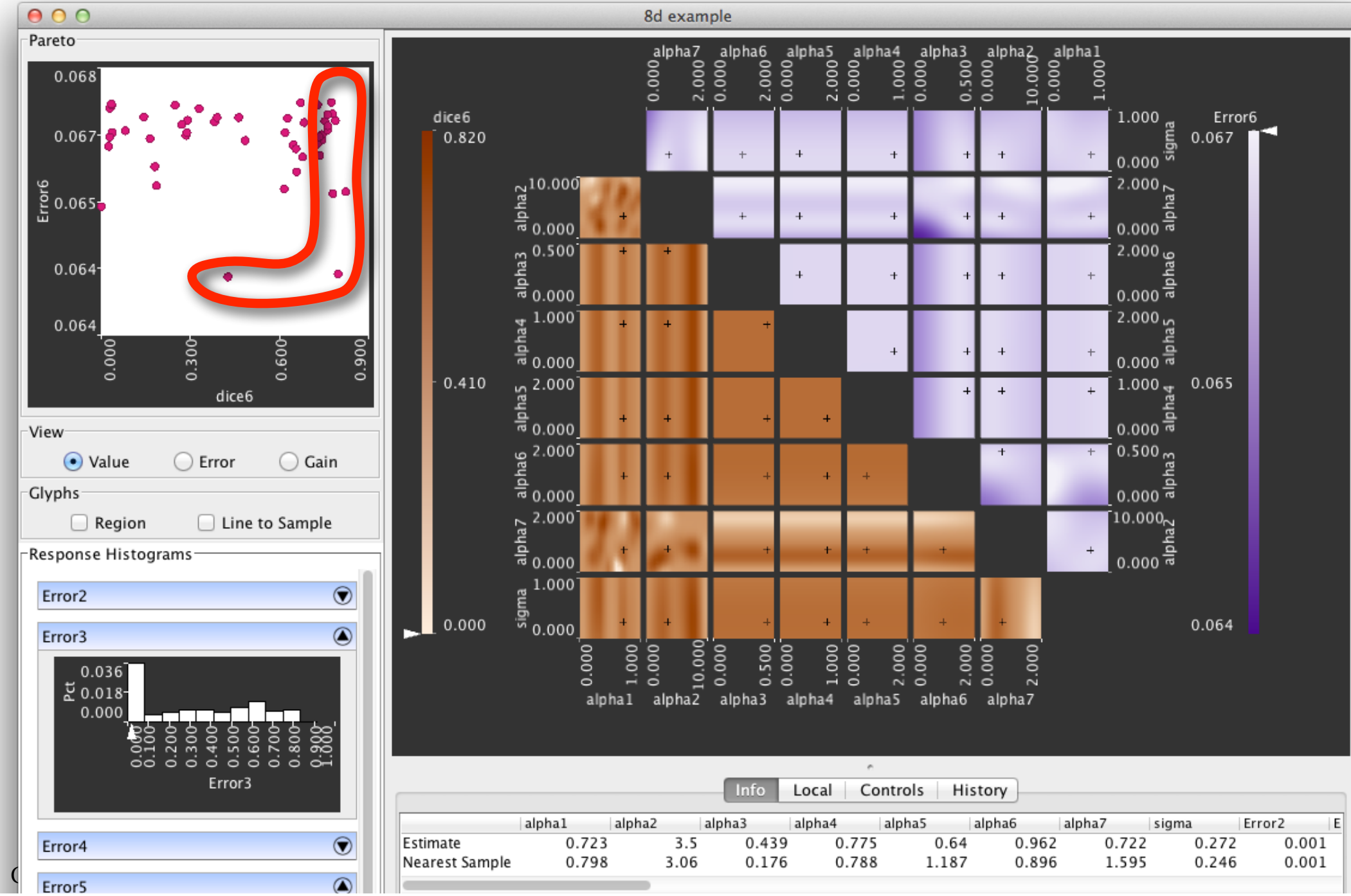
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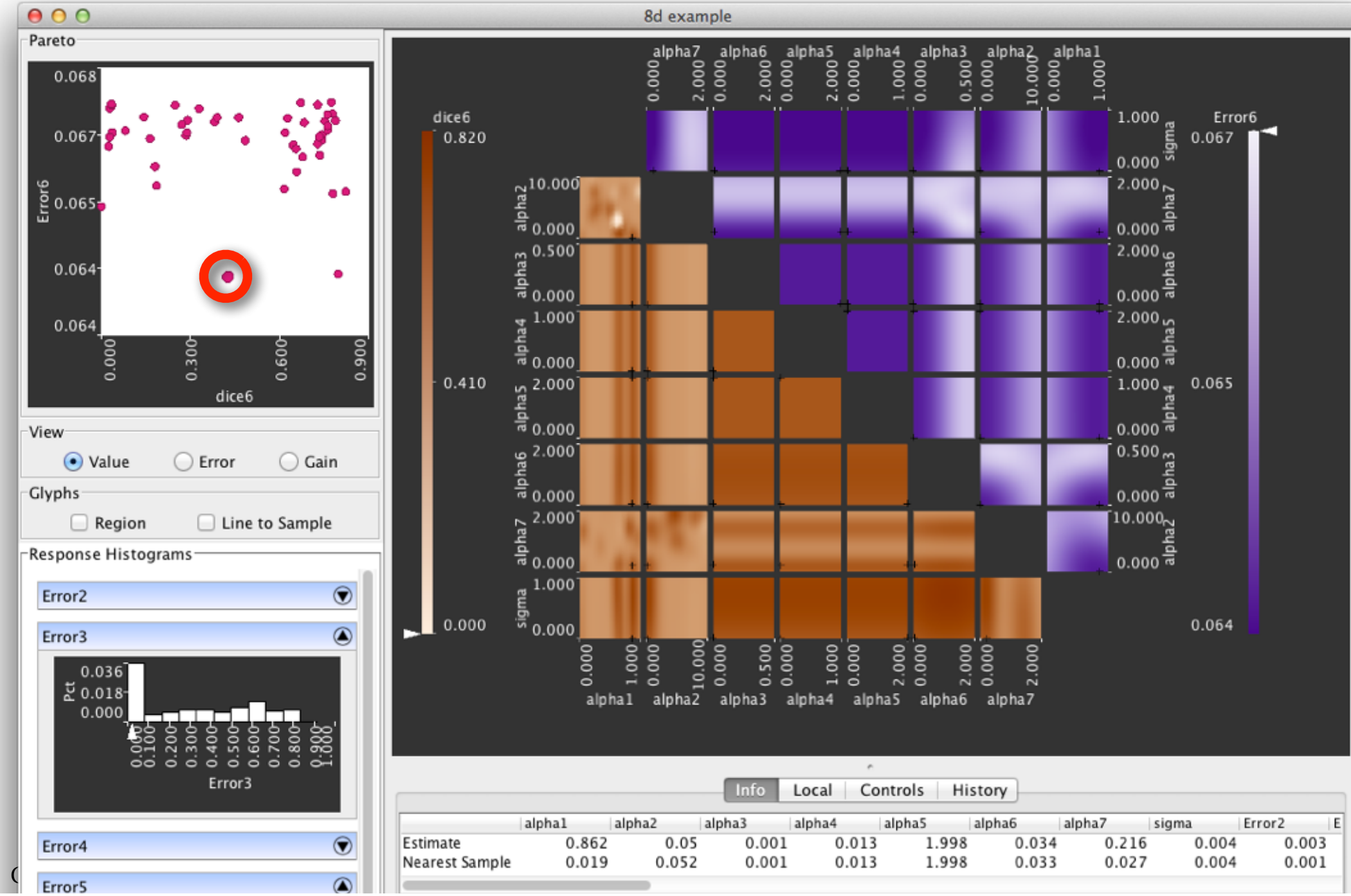
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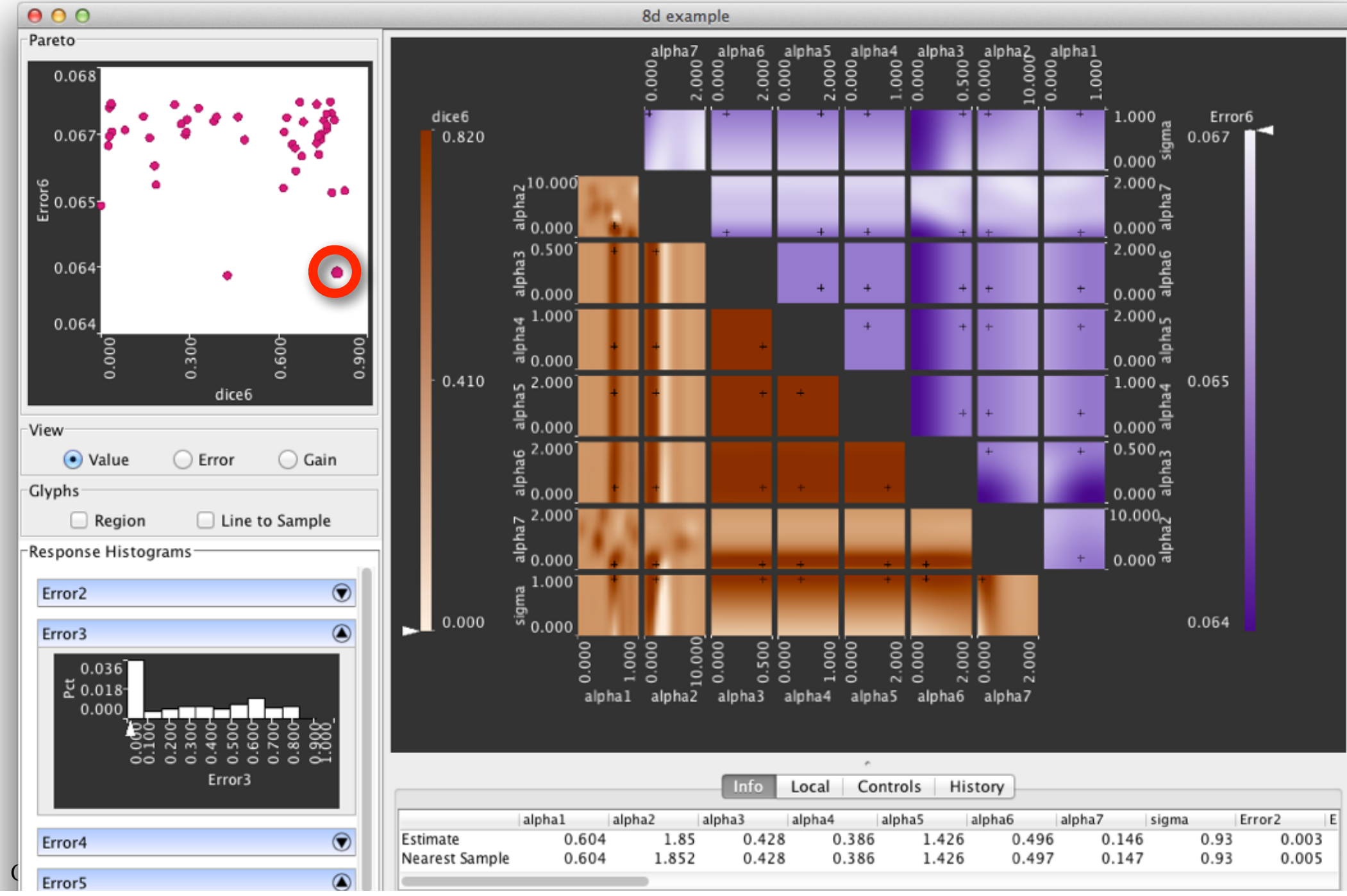
Nearest Sample 0.019 0.052 0.001 0.013 1.998 0.033 0.027 0.004 0.001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alpha1 alpha2 alpha3 alpha4 alpha5 alpha6 alpha7 sigma Error2 E
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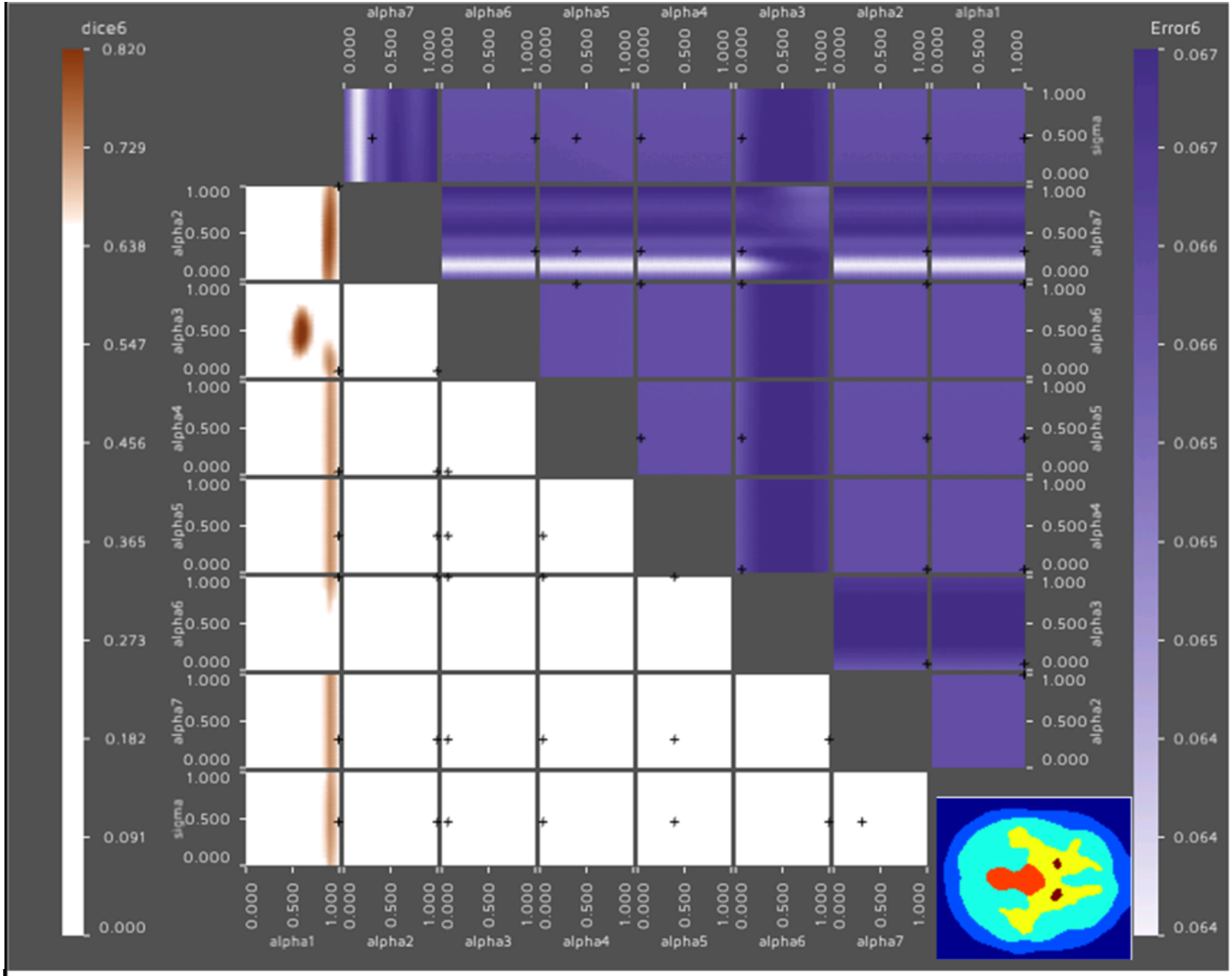
Nearest Sample 0.604 1.852 0.428 0.386 1.426 0.497 0.147 0.93 0.005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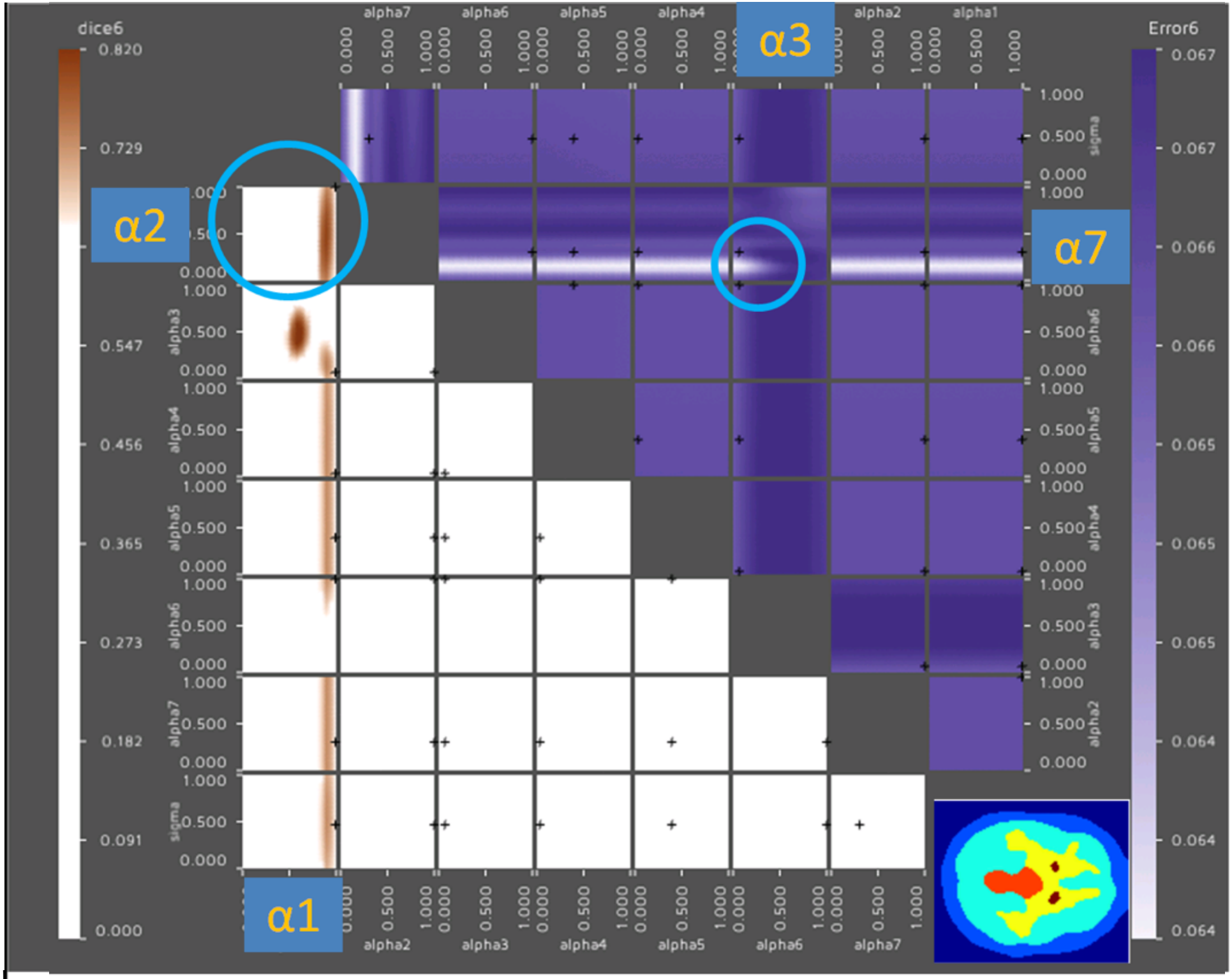
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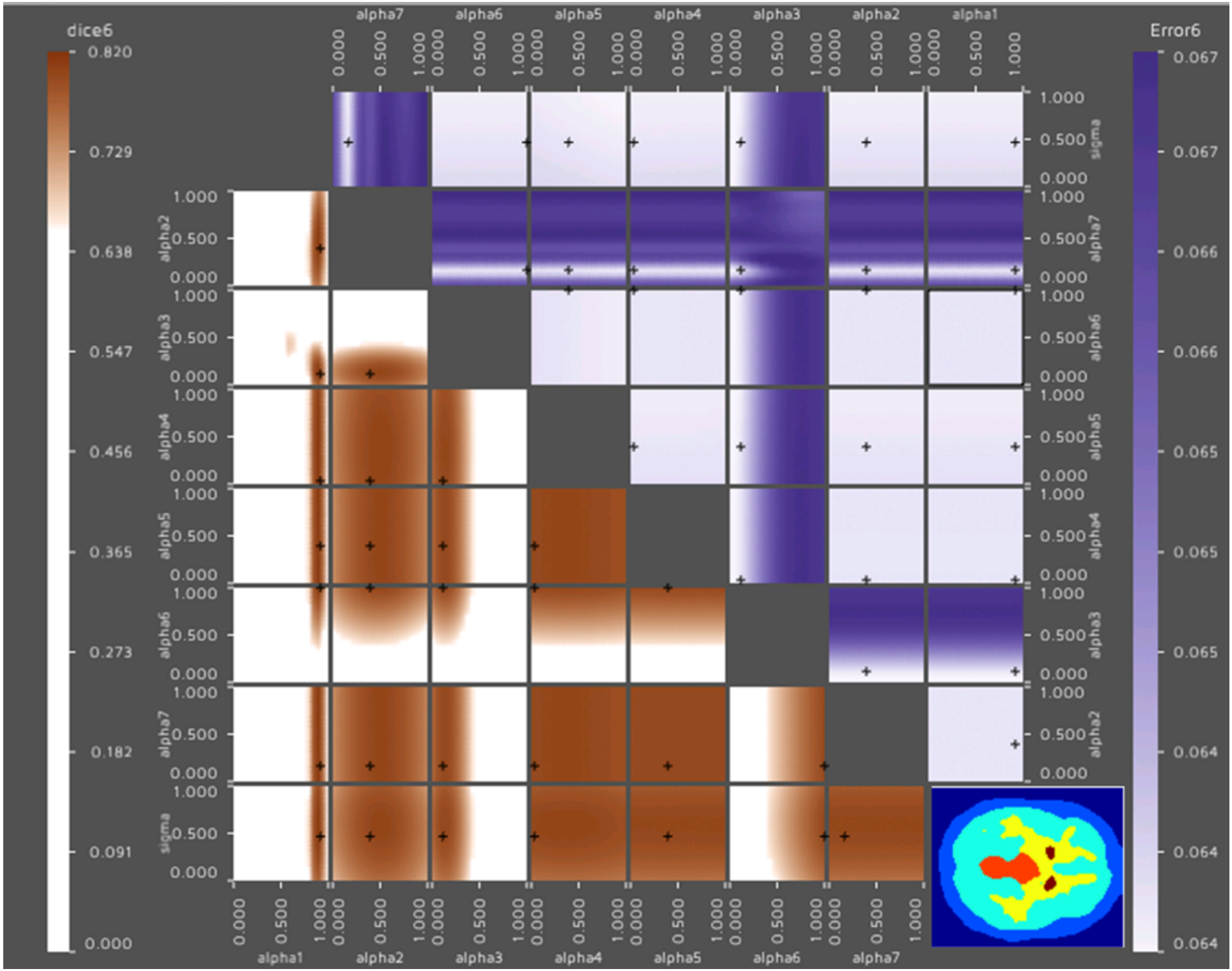
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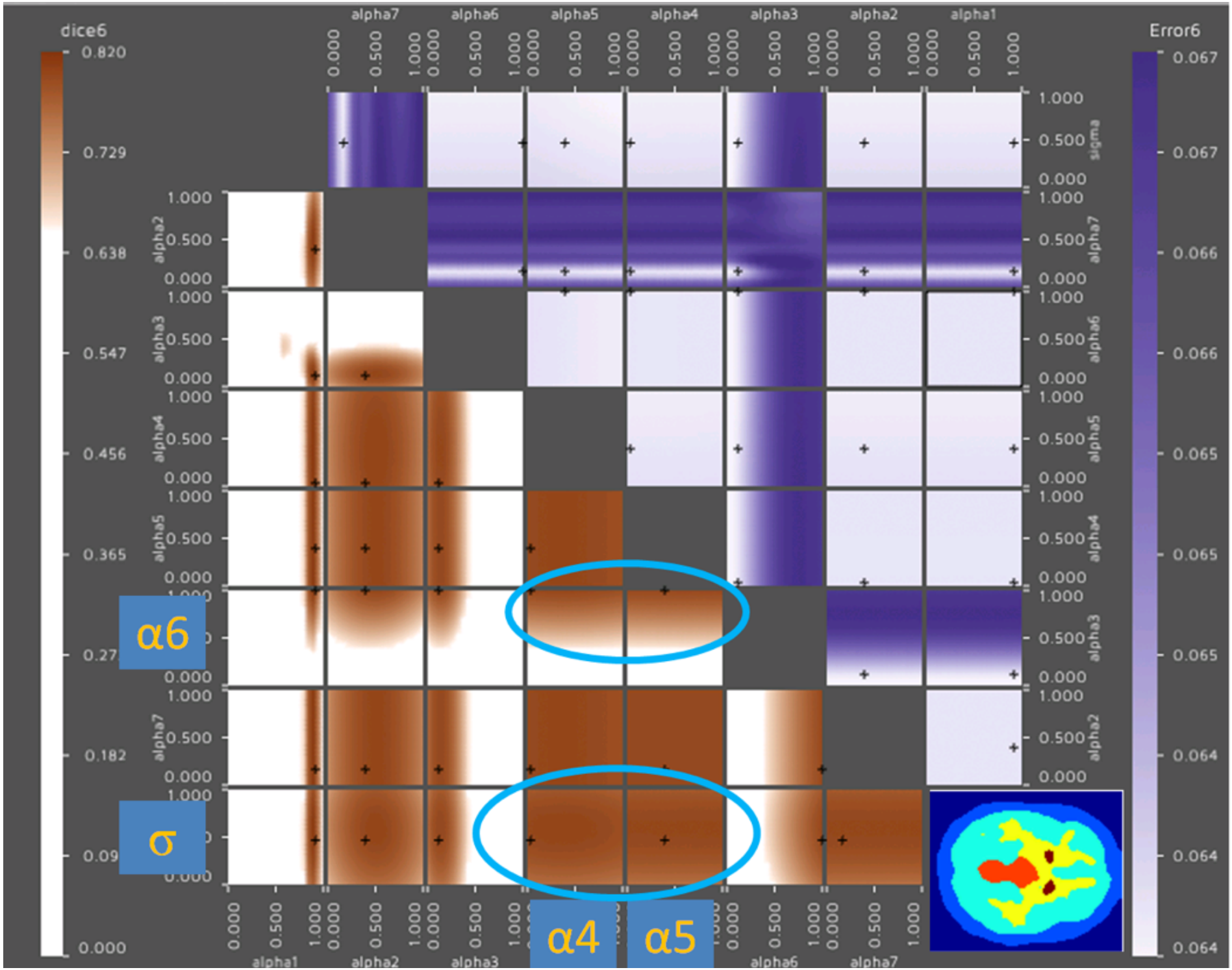
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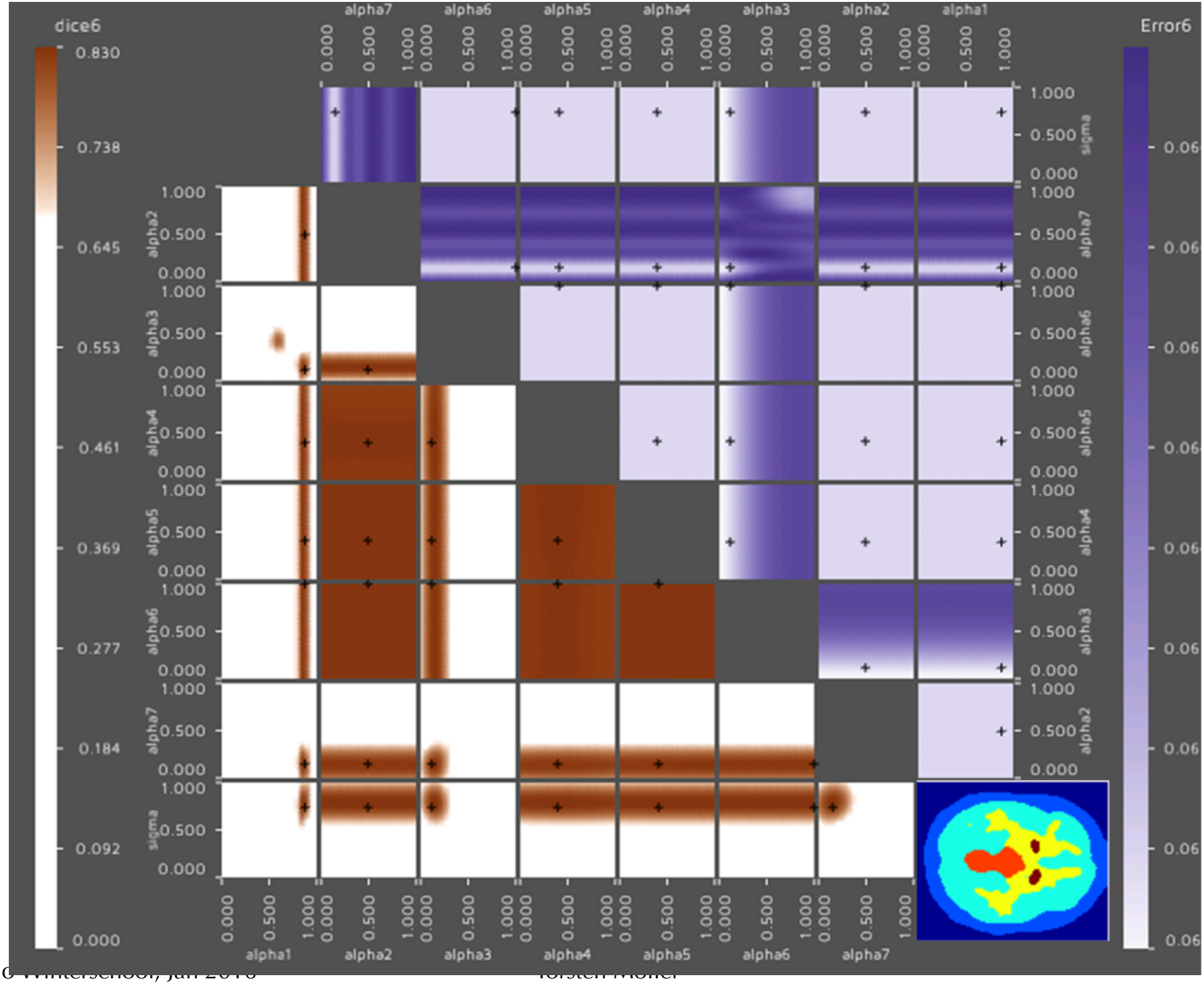
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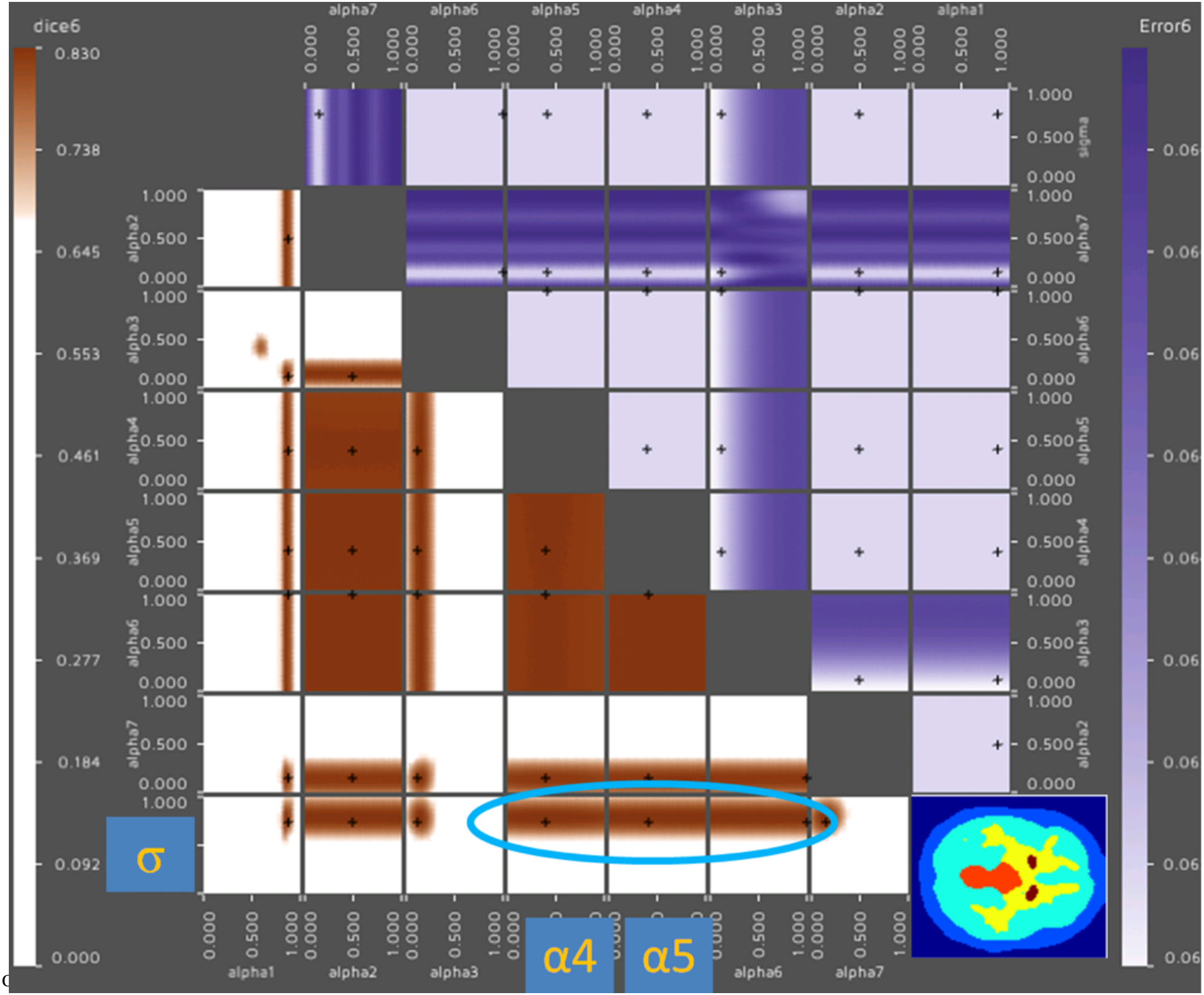
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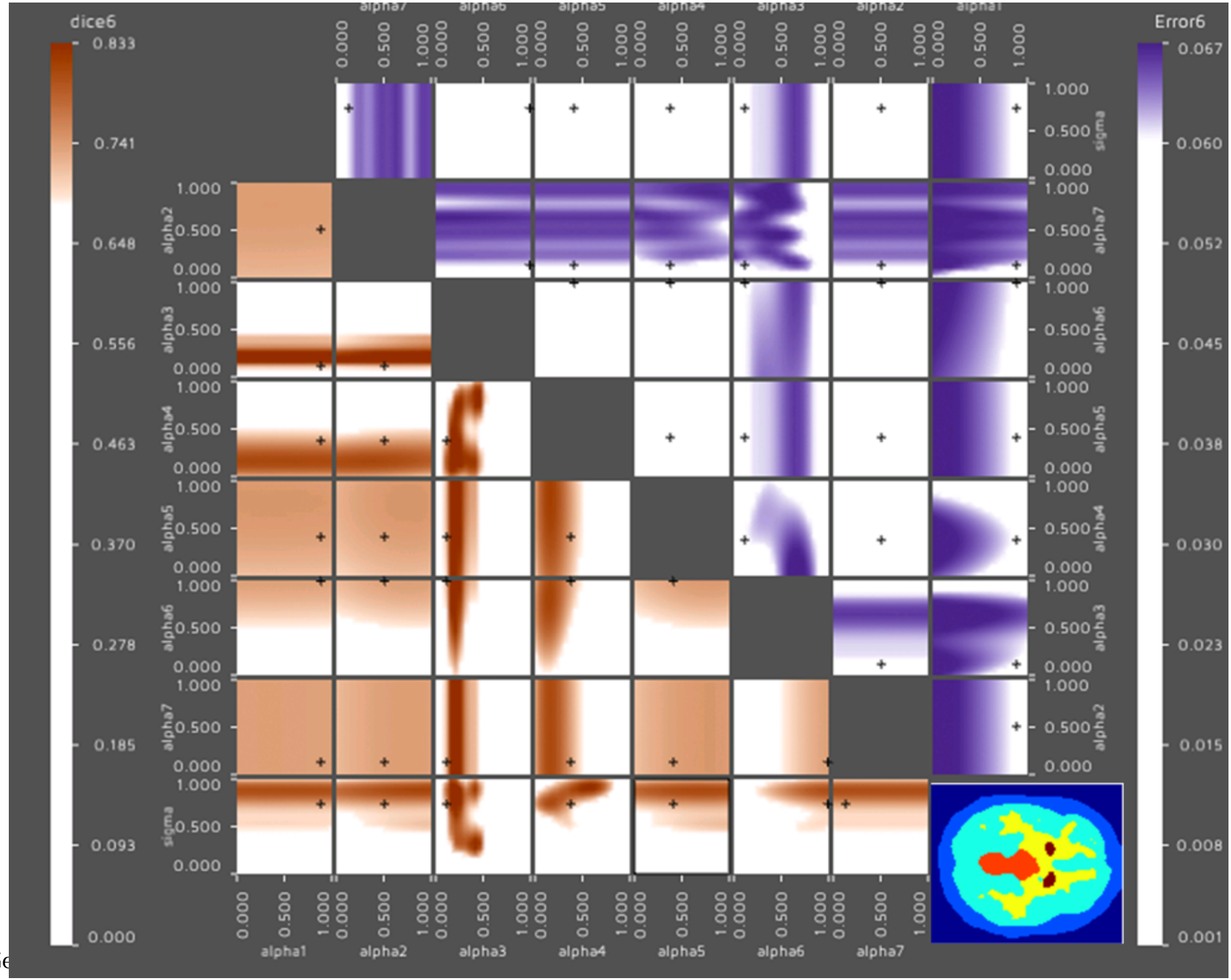
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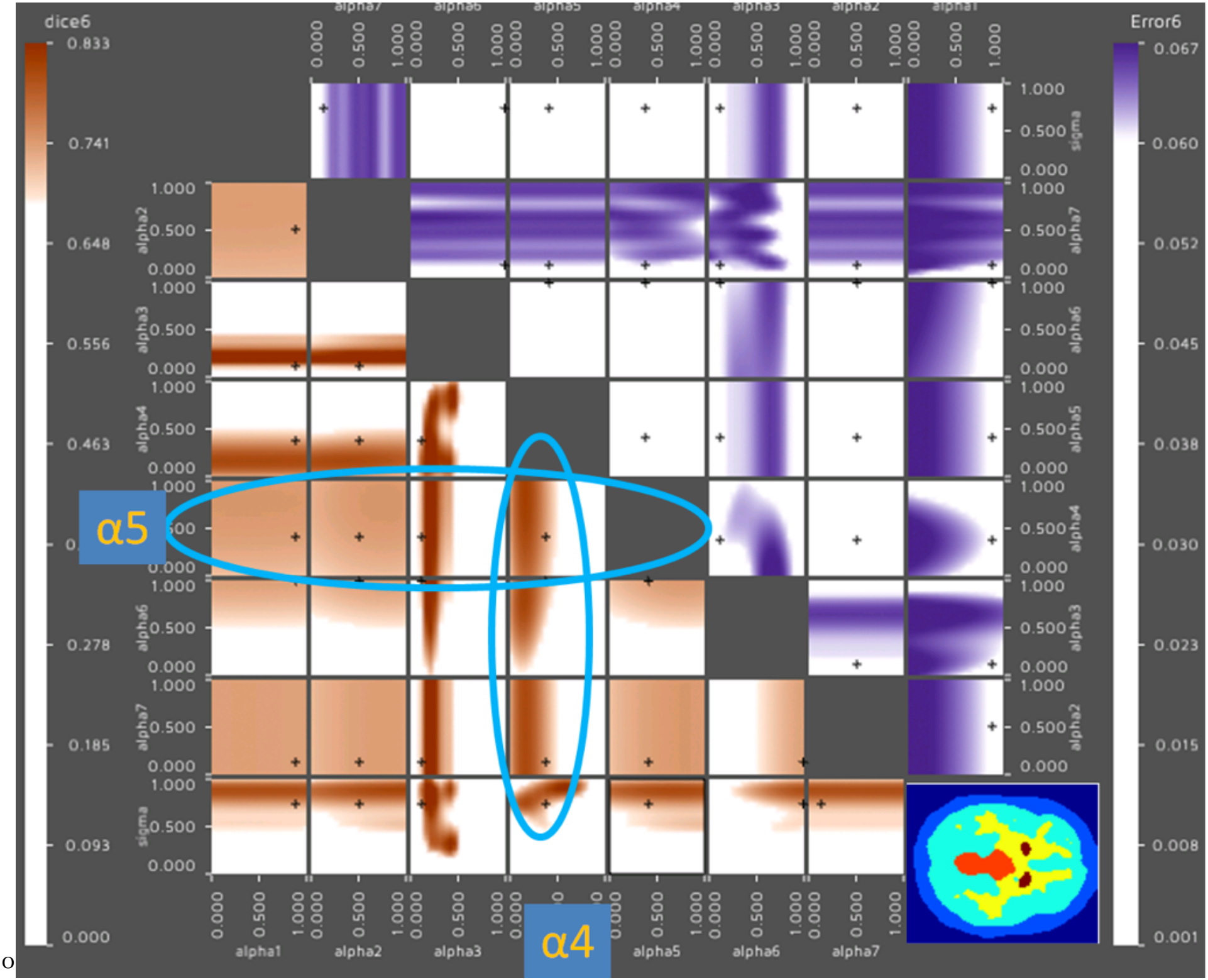
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α5
α4

FluidExplorer
Fluid animation

NSERC CRSNG

Acknowledgments

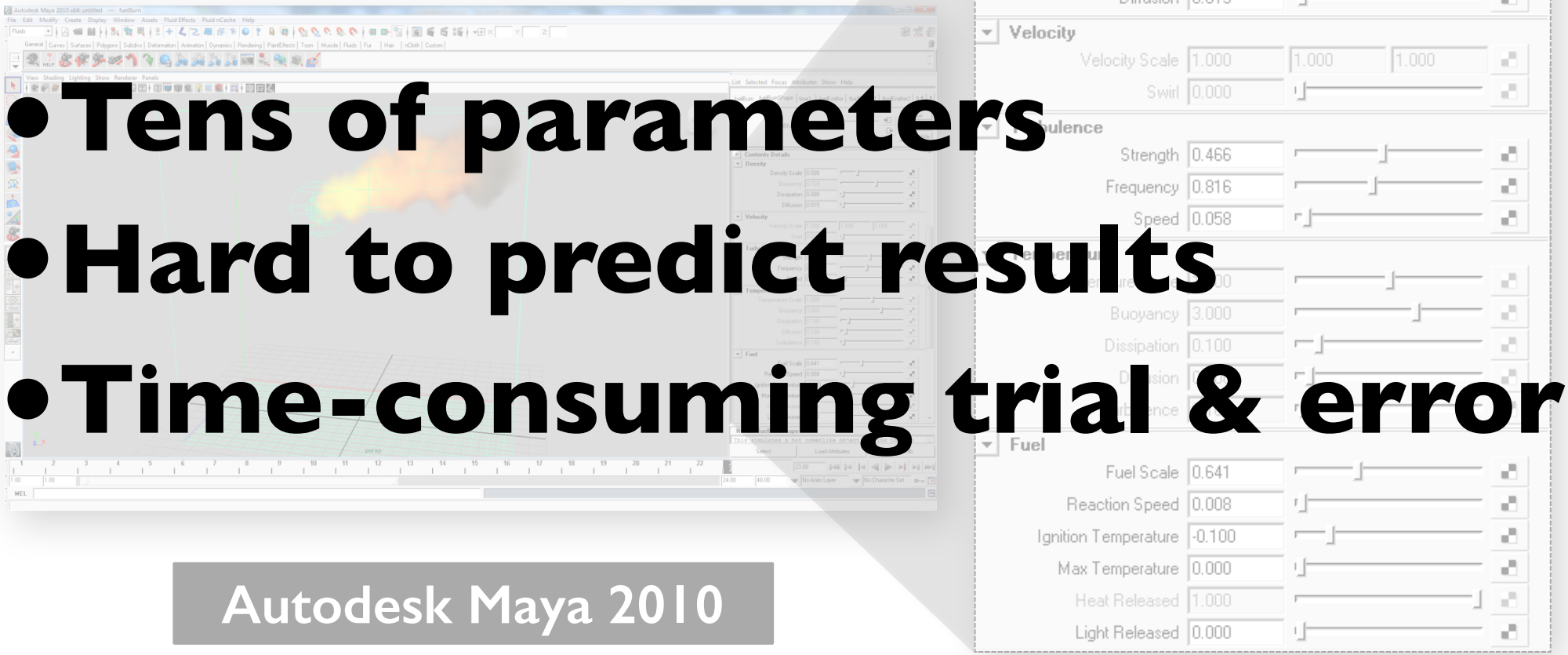
Stefan Bruckner
TU Wien

Blair Tennessy
SpinPro

Special effects

- Fluid simulation is heavily used in the motion picture industry
- Most common animation packages include solvers or offer add-ons
- Problem: Difficult to control for visual effects artists

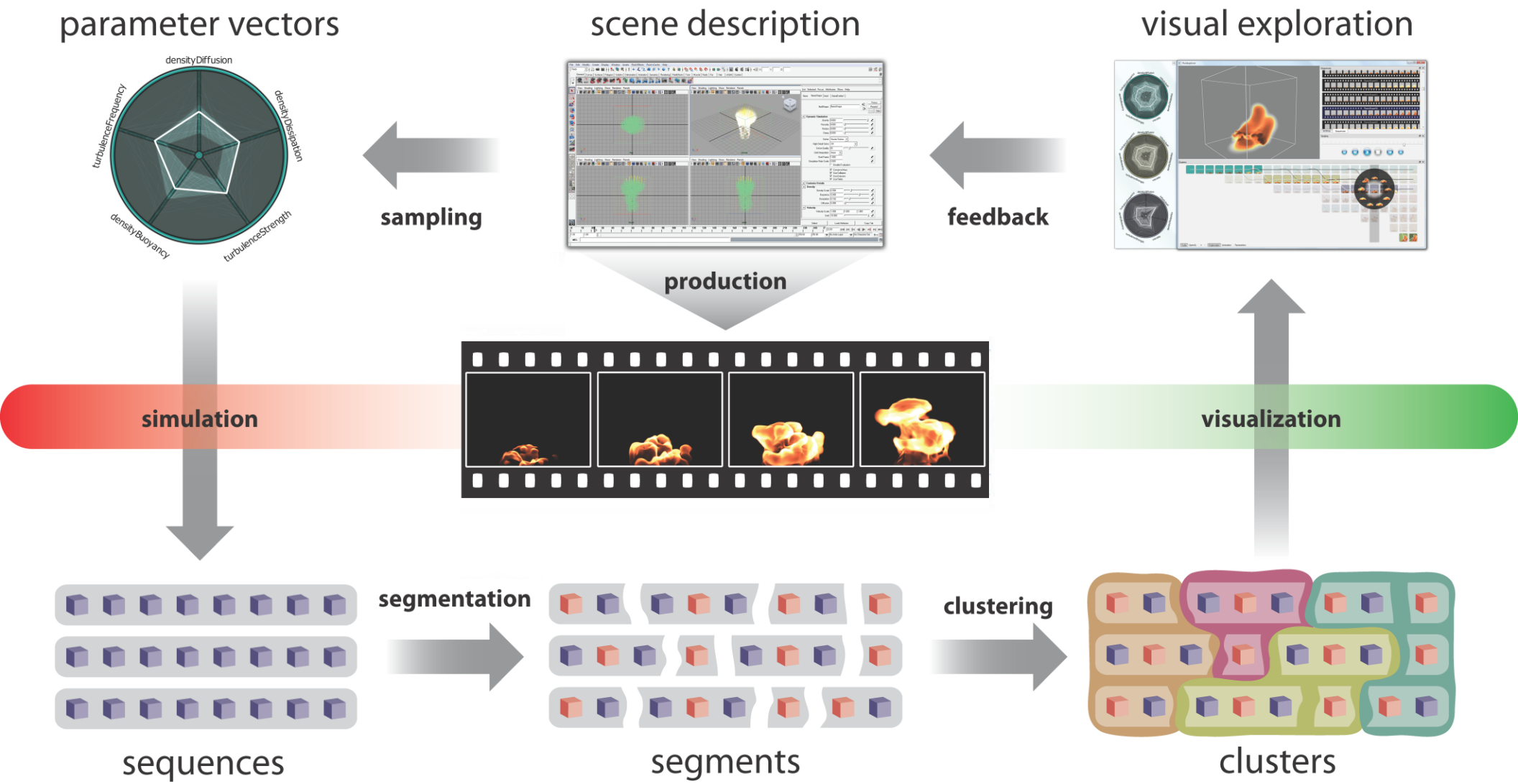
Special effects (2)



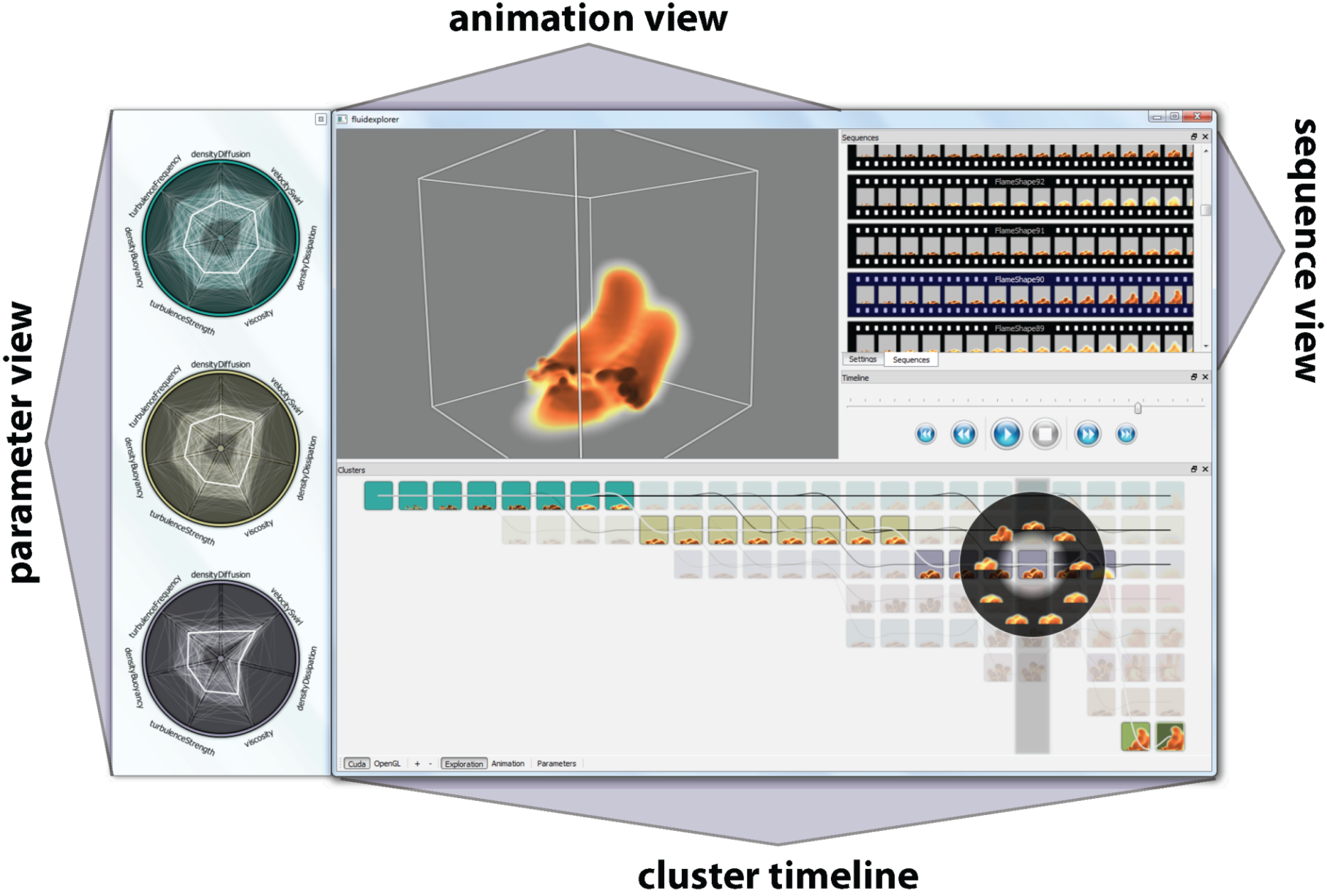
- **Tens of parameters**
- **Hard to predict results**
- **Time-consuming trial & error**

Autodesk Maya 2010

Overview


parameter vectors
scene description
visual exploration
densityDiffusion
densityDissipation
turbulenceStrength
densityBuoyancy
turbulenceFrequency
sampling
feedback
production
simulation
visualization
segmentation
clustering
sequences
segments
clusters

Visualization



Video

Vismon
Fisheries science

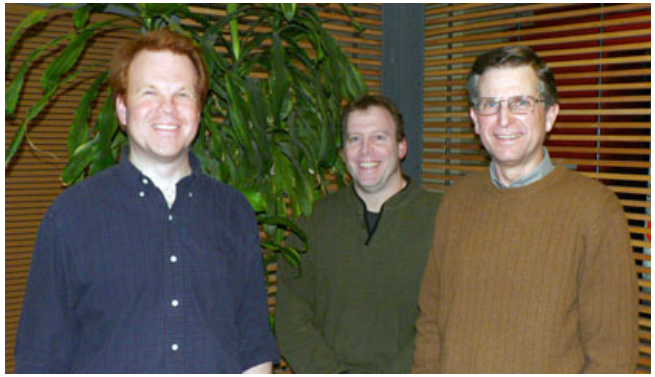
NSERC CRSNG

Canada Foundation for Innovation
Fondation canadienne pour l'innovation

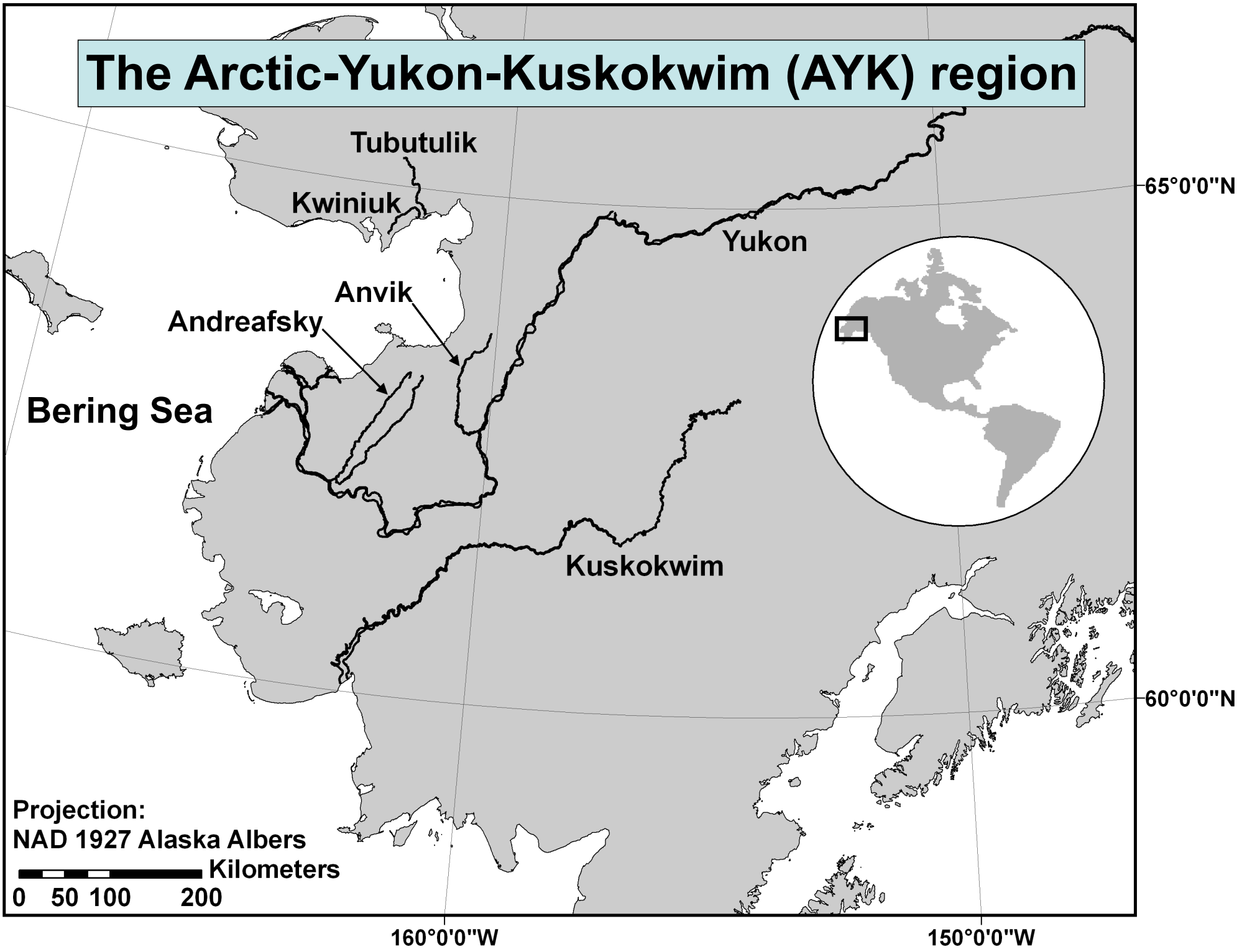
Acknowledgments

Maryam Booshehrian
Muprime Tech

Tamara Munzner
UBC



A. Cooper, S. Cox, R. Peterman,
REM


The Arctic-Yukon-Kuskokwim (AYK) region
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Kwiniuk
Yukon
Anvik
Andreafsky
Bering Sea
Kuskokwim
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160°0'0"W
150°0'0"W
Projection:
NAD 1927 Alaska Albers
Kilometers
0 50 100 200

Roles - old days

Recommendations

Objectives

Scientists

Managers

Goal

Scientists

Simulation worksheet

Data-driven decision making

Managers

Goal:
move data-driven decision making from scientists to managers

Data-driven decision making

Managers

Simulation data

Interests

Goal:

move data-driven decision making from scientists to managers

Scientists

Stakeholders

Alaskan Salmon Model

Harvest Rate

Escapement

Bill Reid, Haida Dog Salmon - Skaagi, 1974. © Bill Reid Estate

Stochastic

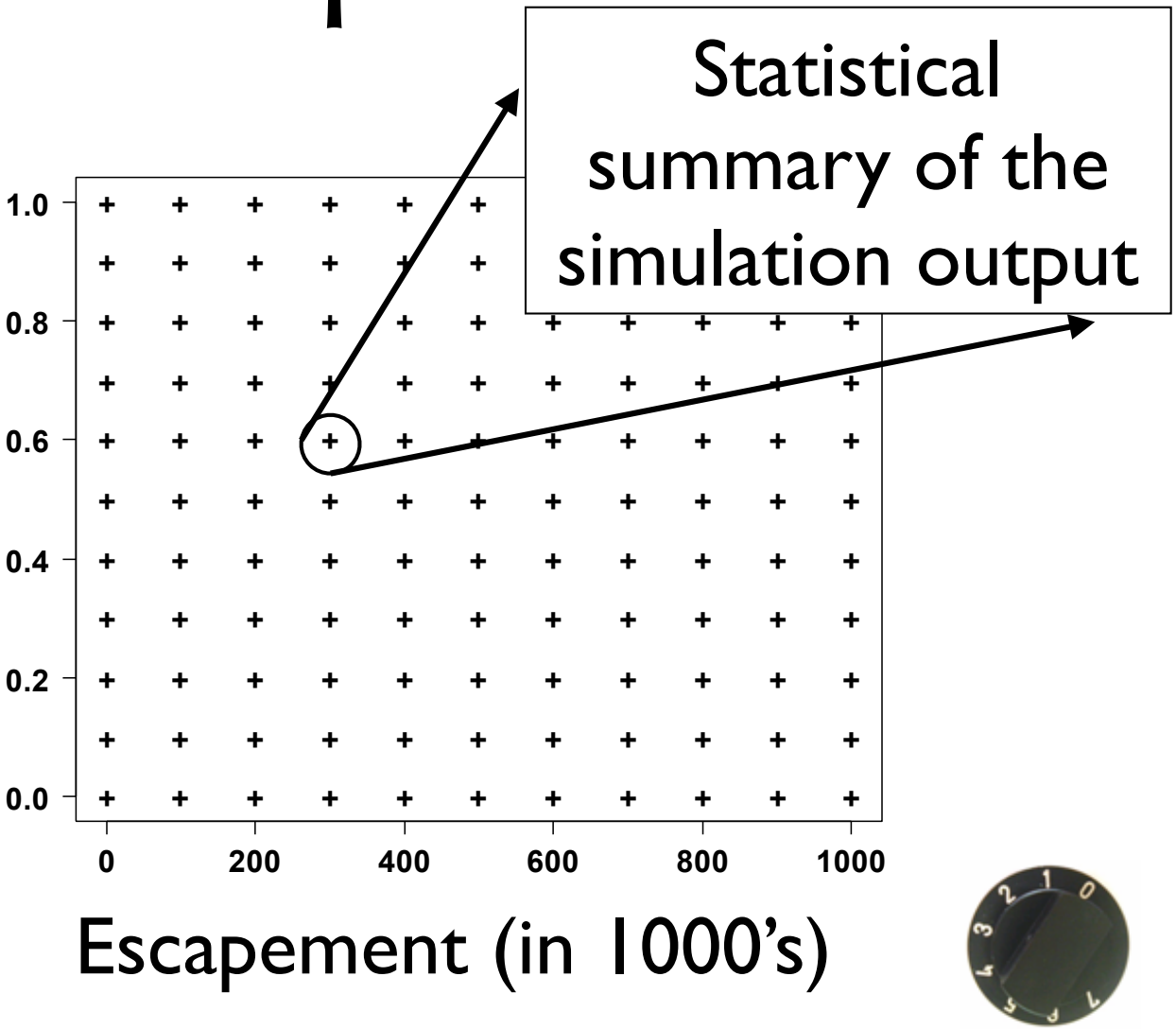
Food

$

Spawners

Scenario: 2 input values

Harvest rate



Output summarized …

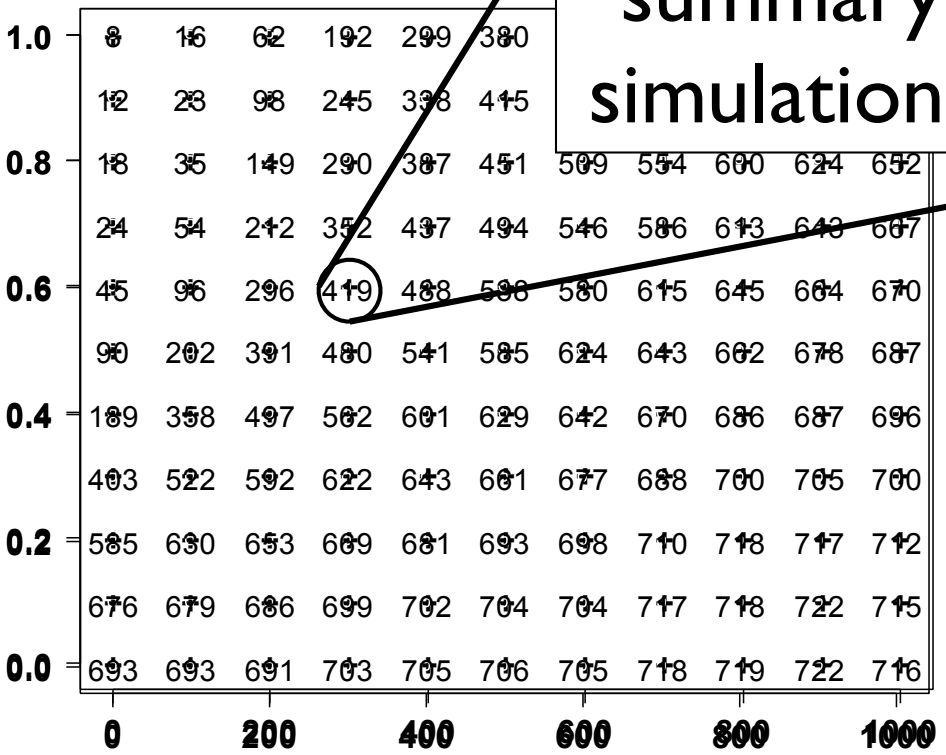
Statistical summary of the simulation output

- Average
- Median
- Coefficient of variation
- % of years something bad happens

Scenario: 2 input values

Statistical summary of the simulation output

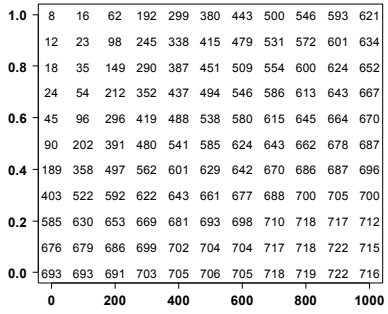
Harvest rate



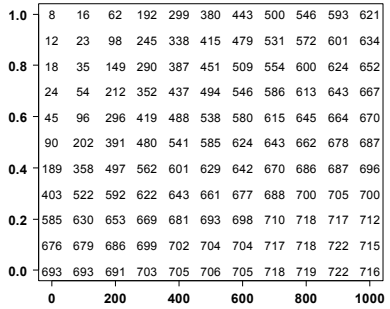
Escapement (in 1000's)

Scenario: 2 input values

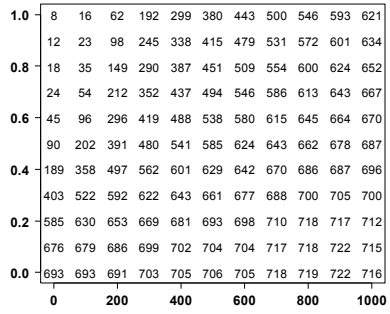
Avg



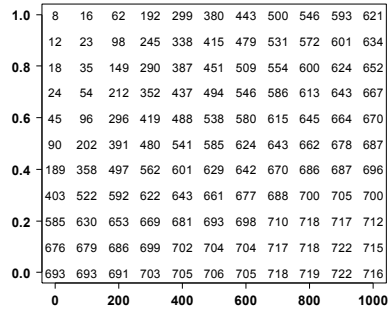
Median



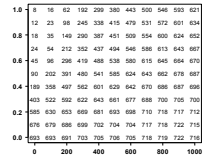
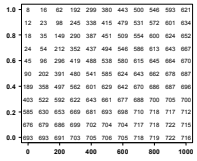
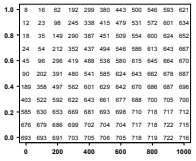
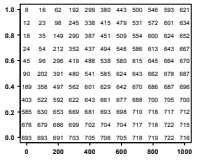
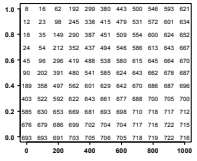
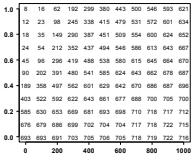
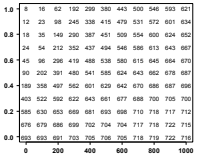
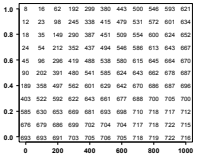
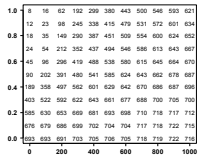
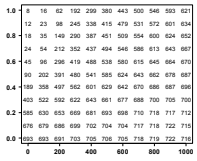
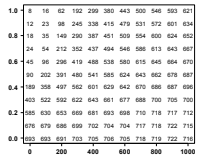
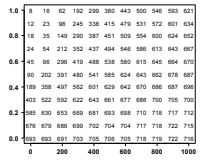
CV



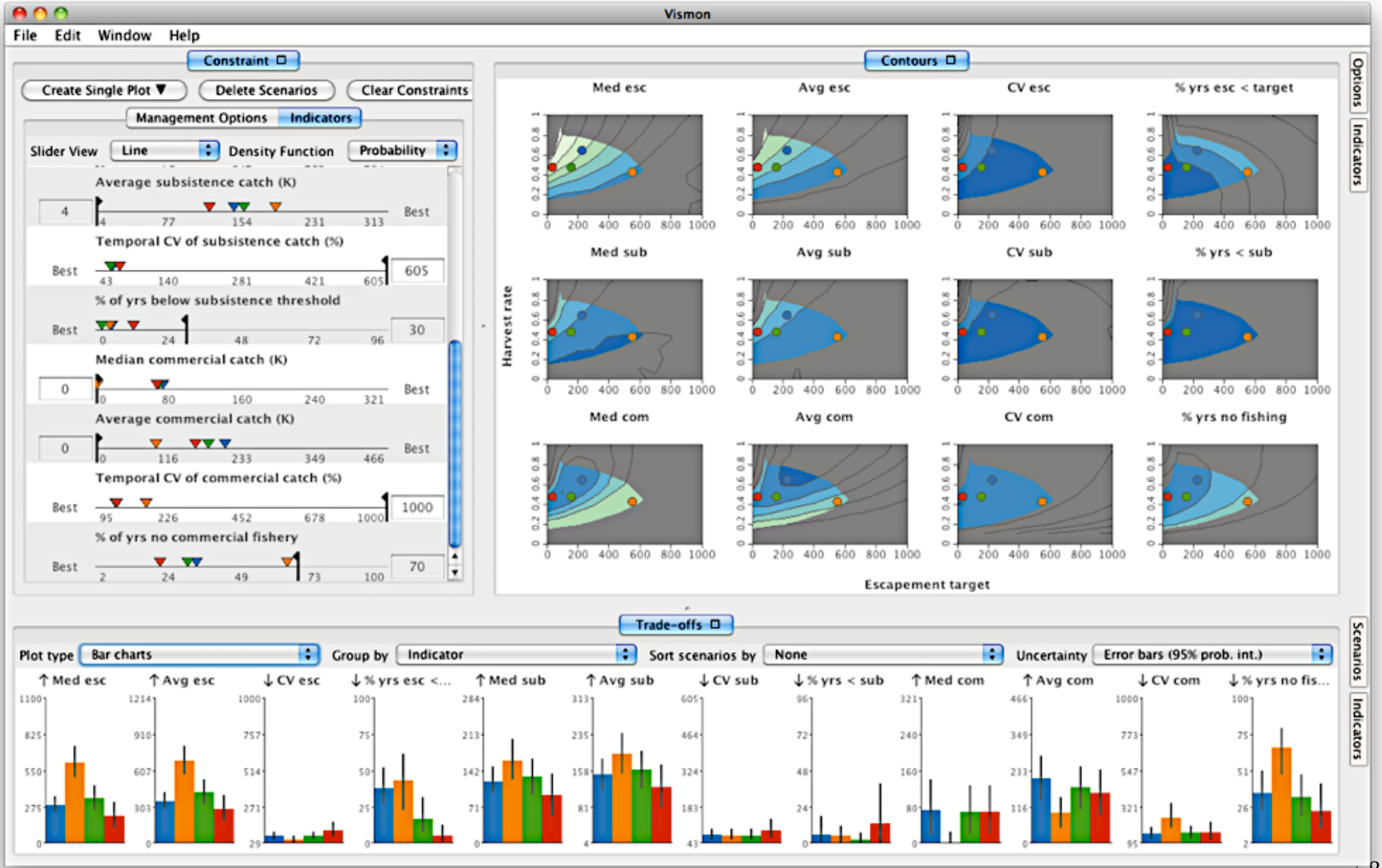
%



12 Outputs / Indicators

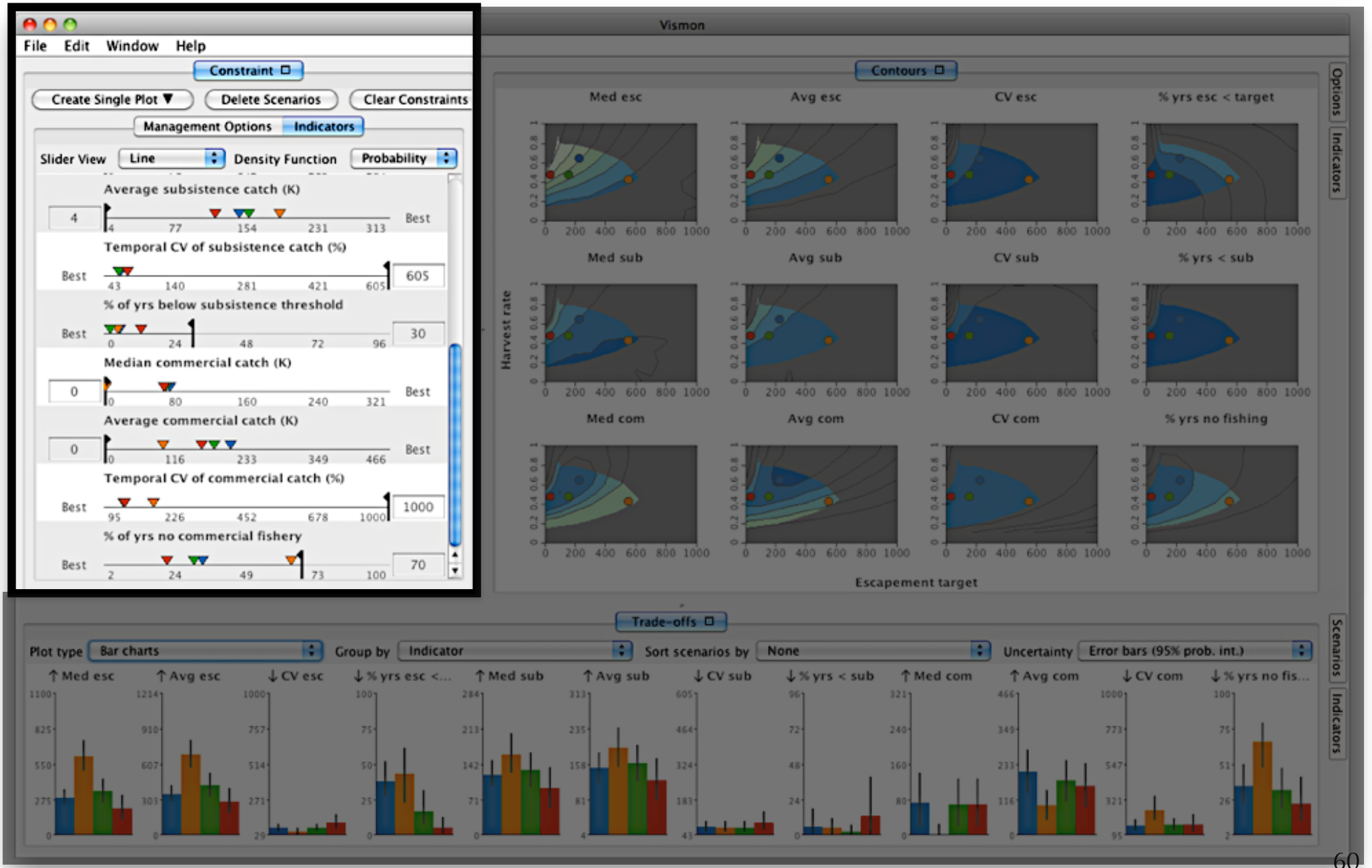
	Avg	Median	CV	%
Spawners (Escapement)				
$ (commercial)				
Food (subsistence)				

Vismon

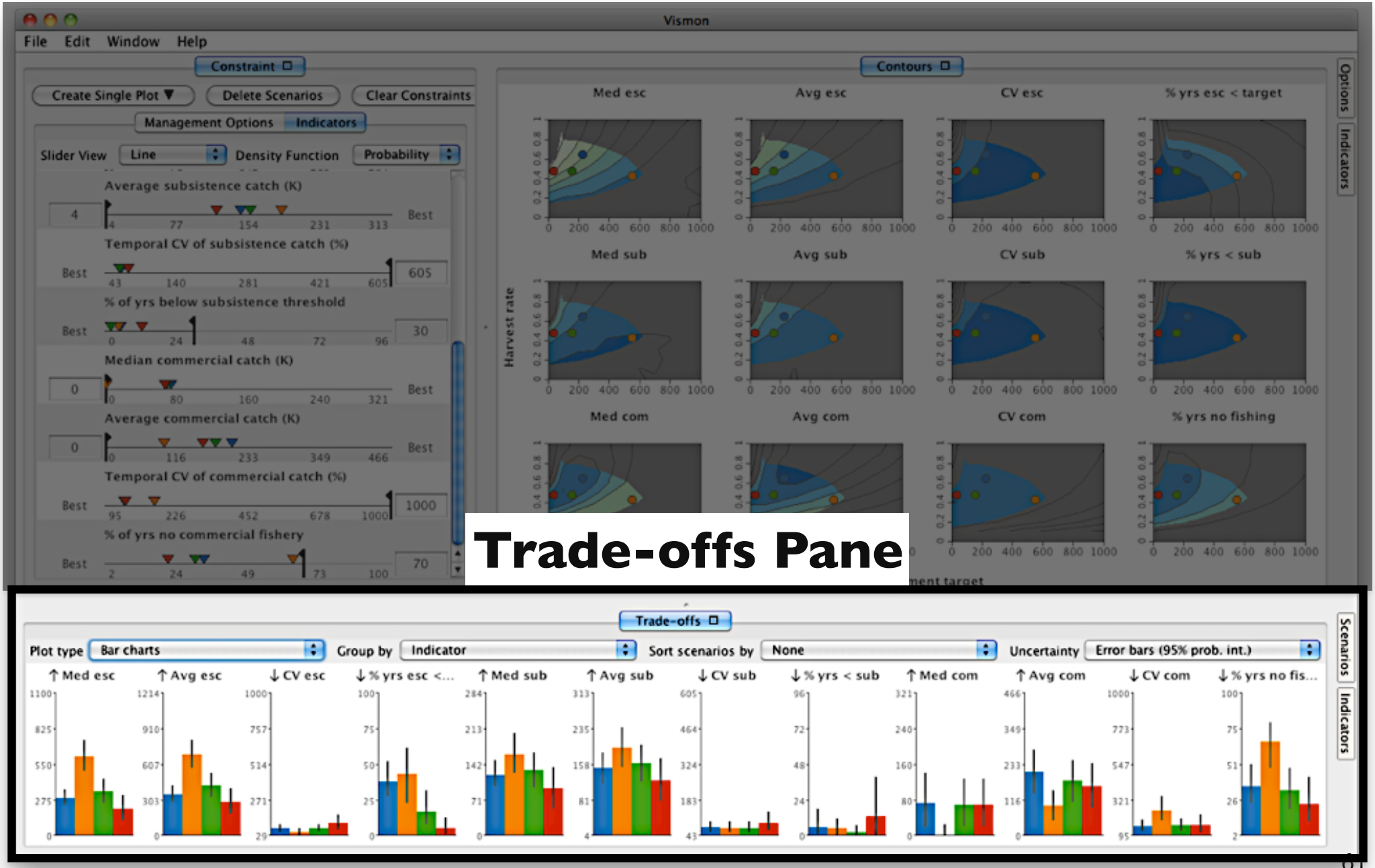

Vismon
File Edit Window Help
Constraint
Create Single Plot
Delete Scenarios
Clear Constraints
Management Options
Indicators
Slider View
Line
Density Function
Probability
Average subsistence catch (K)
Temporal CV of subsistence catch (%)
% of yrs below subsistence threshold
Median commercial catch (K)
Average commercial catch (K)
Temporal CV of commercial catch (%)
% of yrs no commercial fishery
Best
Contours
Med esc
Avg esc
CV esc
% yrs esc < target
Med sub
Avg sub
CV sub
% yrs < sub
Med com
Avg com
CV com
% yrs no fishing
Harvest rate
Escapement target
Options
Indicators
Trade-offs
Plot type
Bar charts
Group by
Indicator
Sort scenarios by
None
Uncertainty
Error bars (95% prob. int.)
↑ Med esc
↑ Avg esc
↓ CV esc
↓ % yrs esc <...
↑ Med sub
↑ Avg sub
↓ CV sub
↓ % yrs < sub
↑ Med com
↑ Avg com
↓ CV com
↓ % yrs no fis...
Scenarios
Indicators

Vismon **Contours Pane**

Constraint Pane Vismon

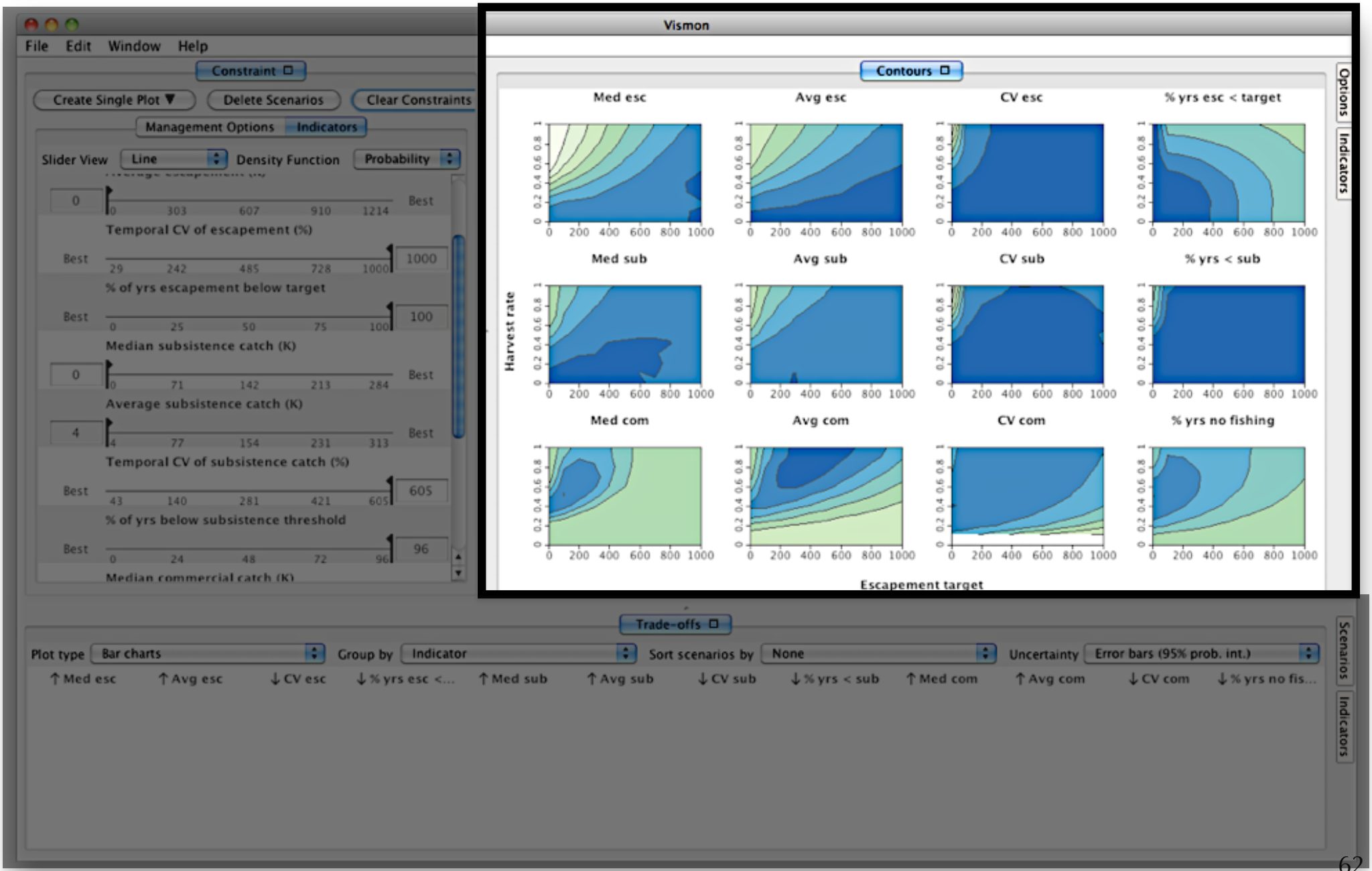


Vismon

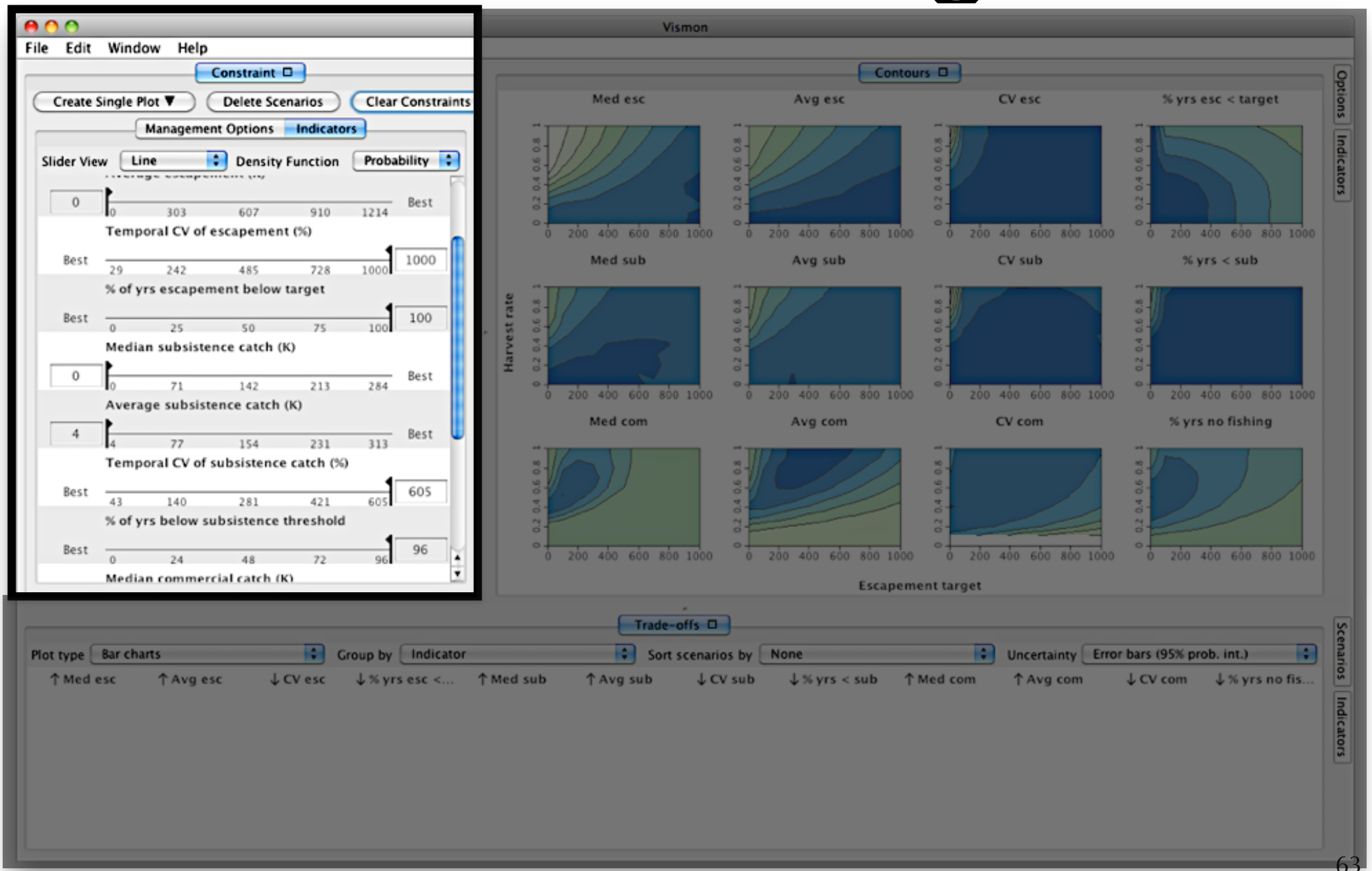


Trade-offs Pane

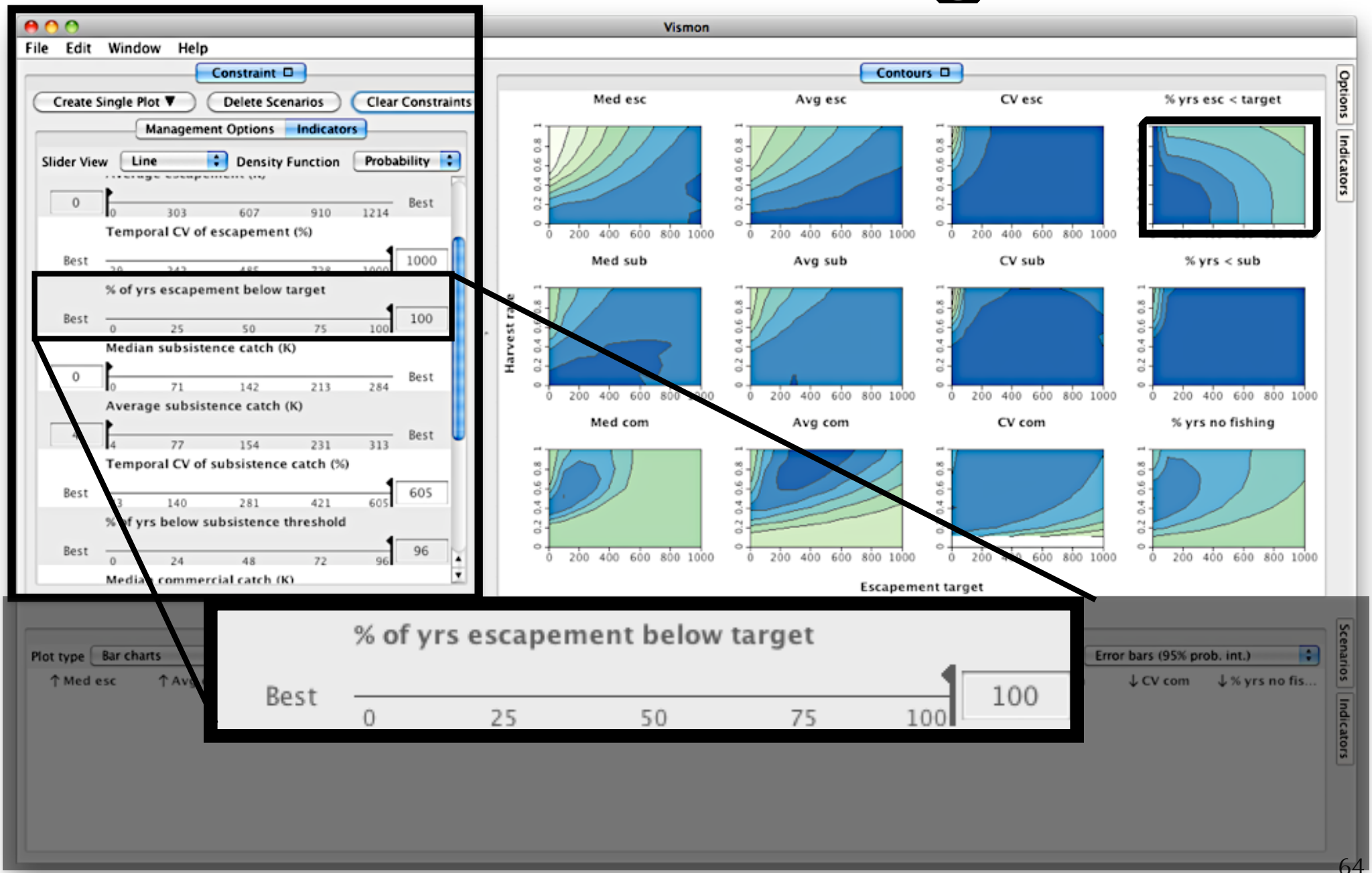
Summarization



Constraining



Constraining



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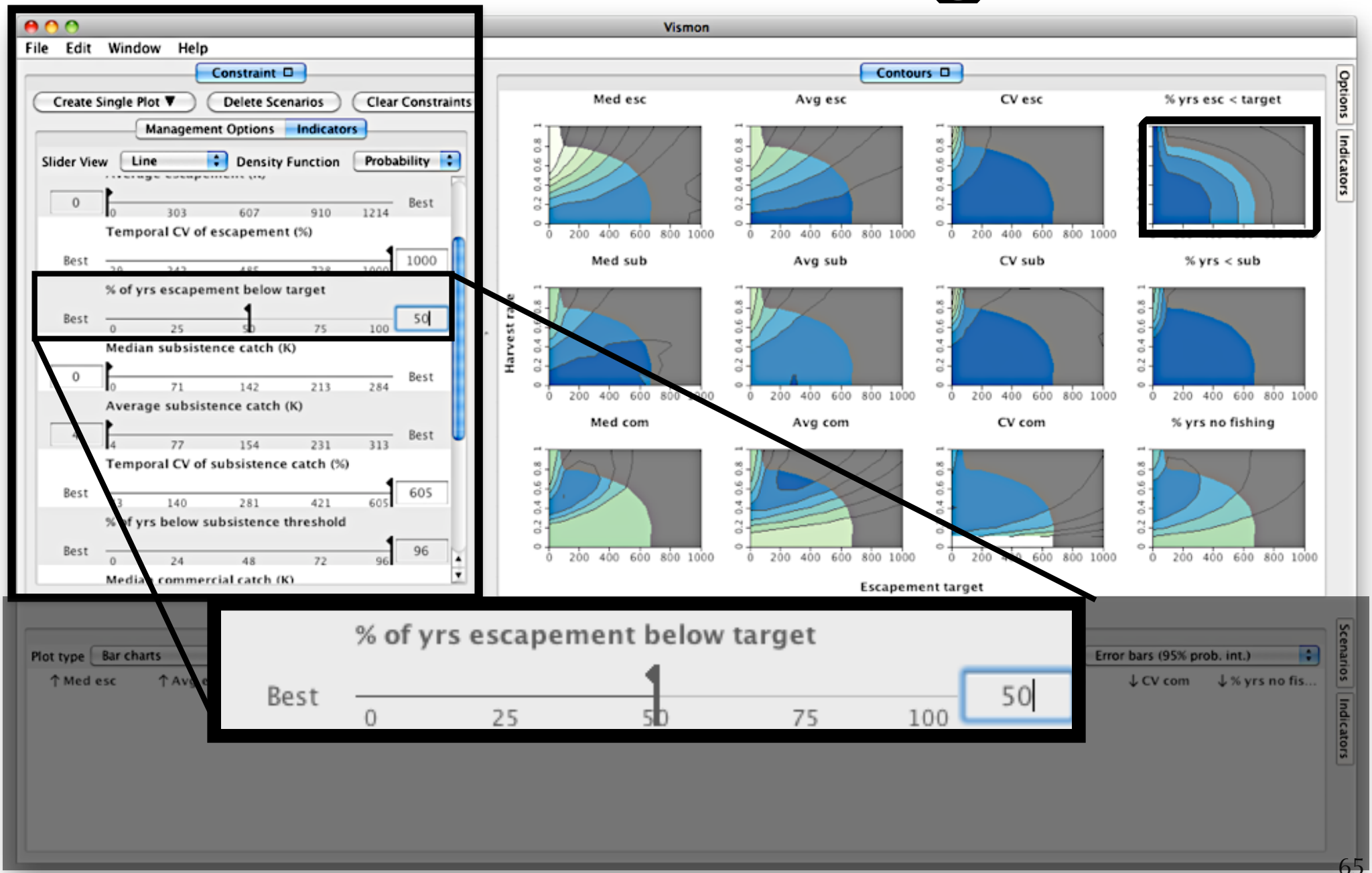
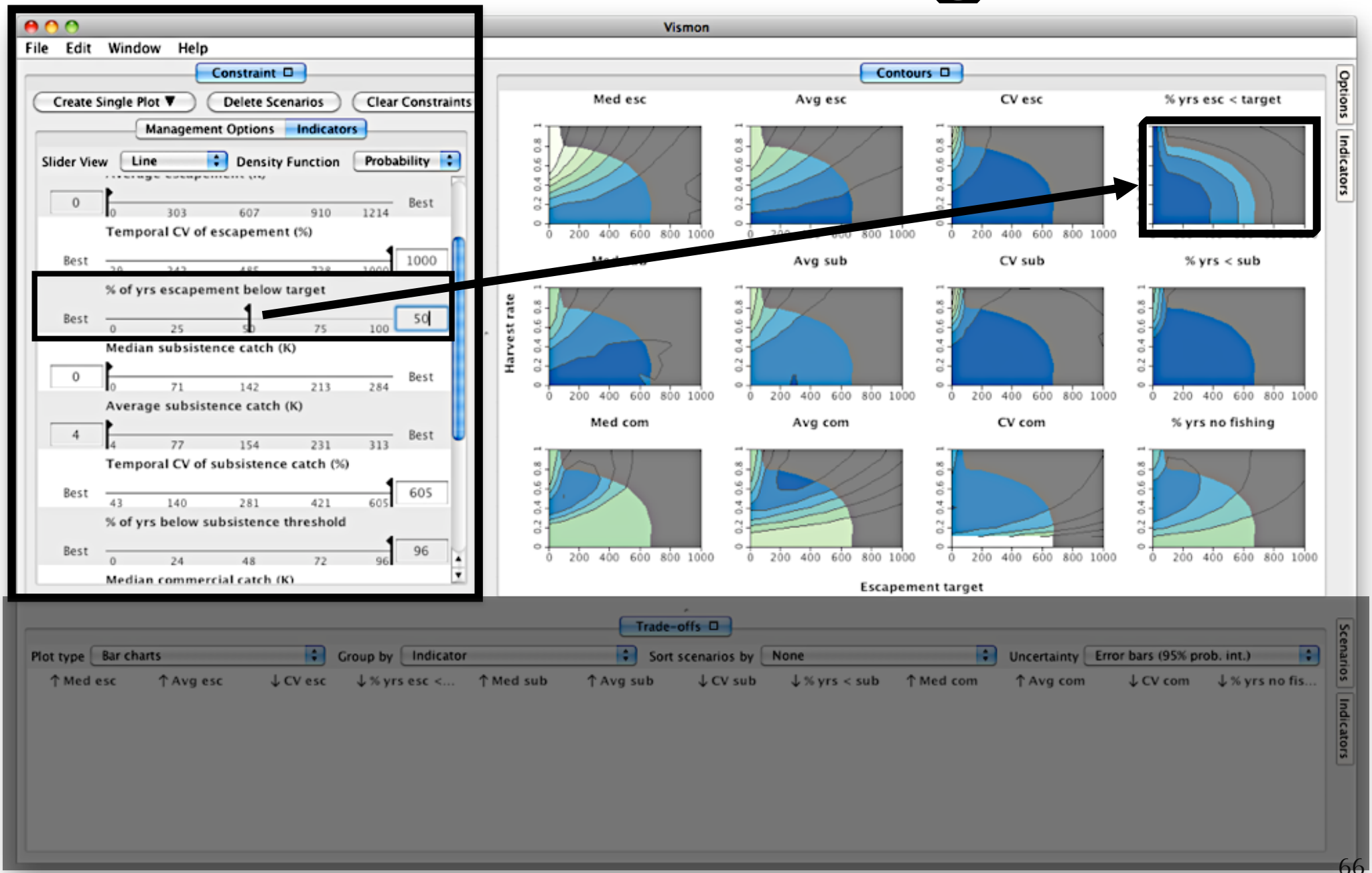


Constraining



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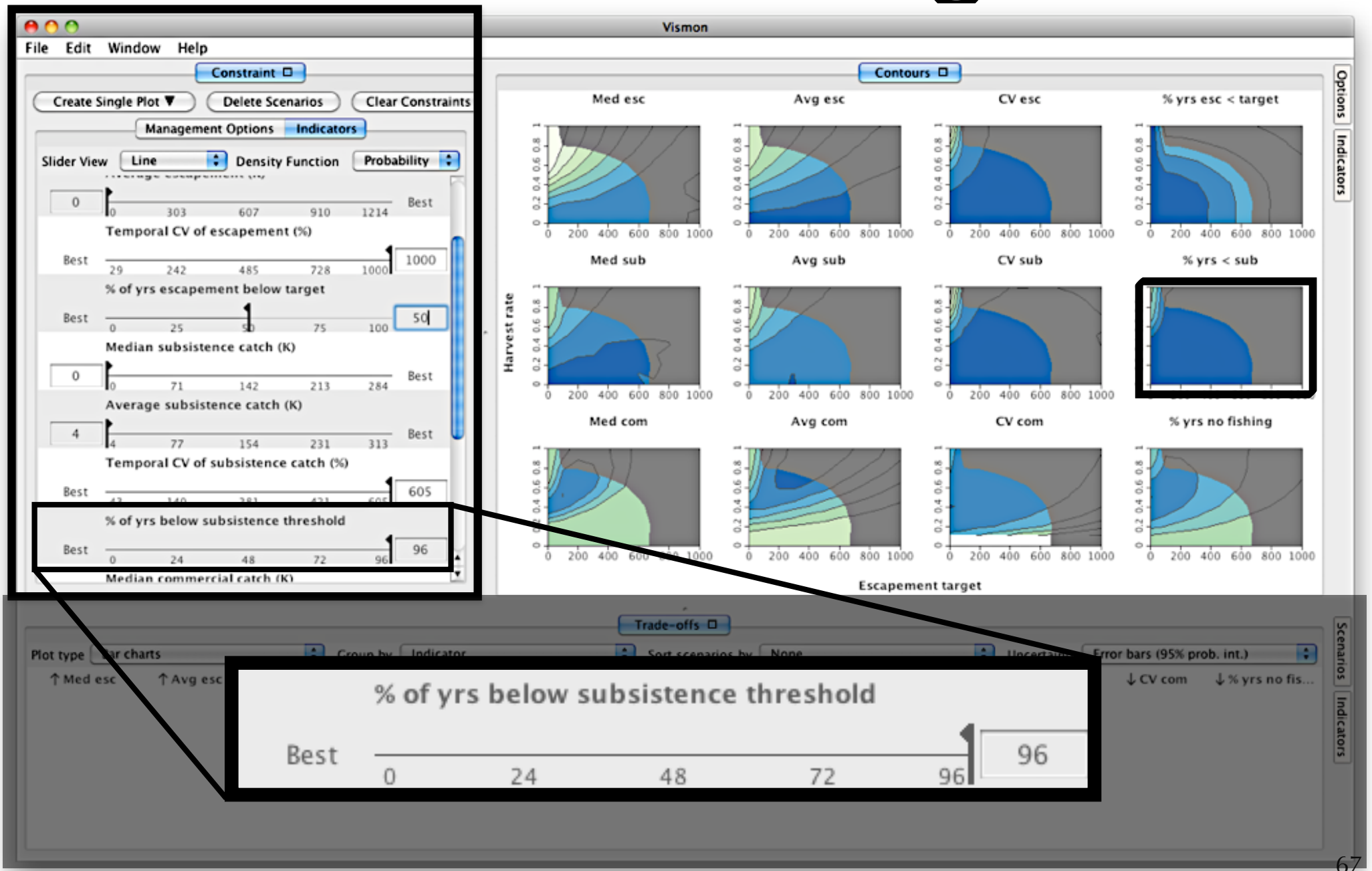

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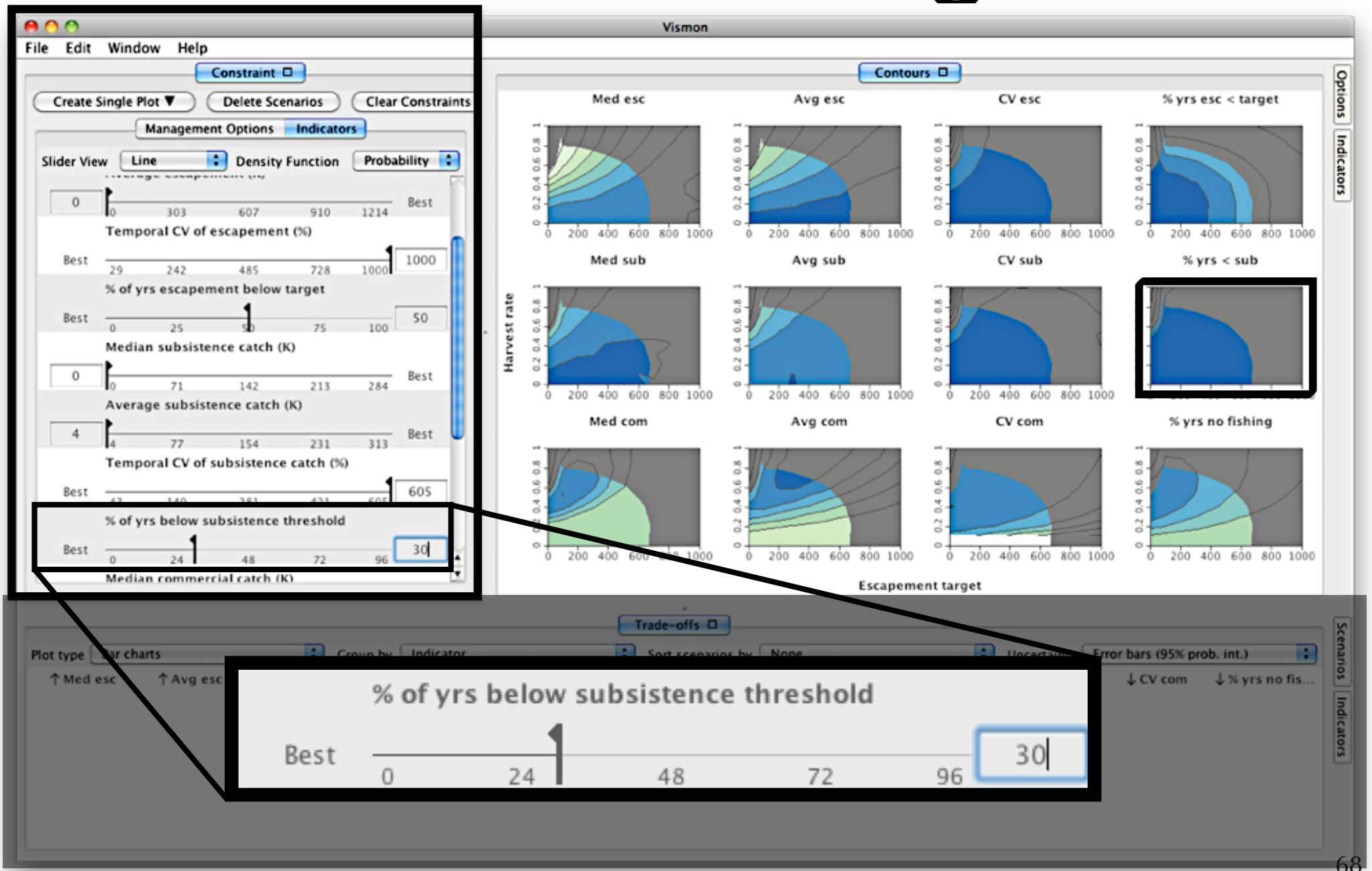

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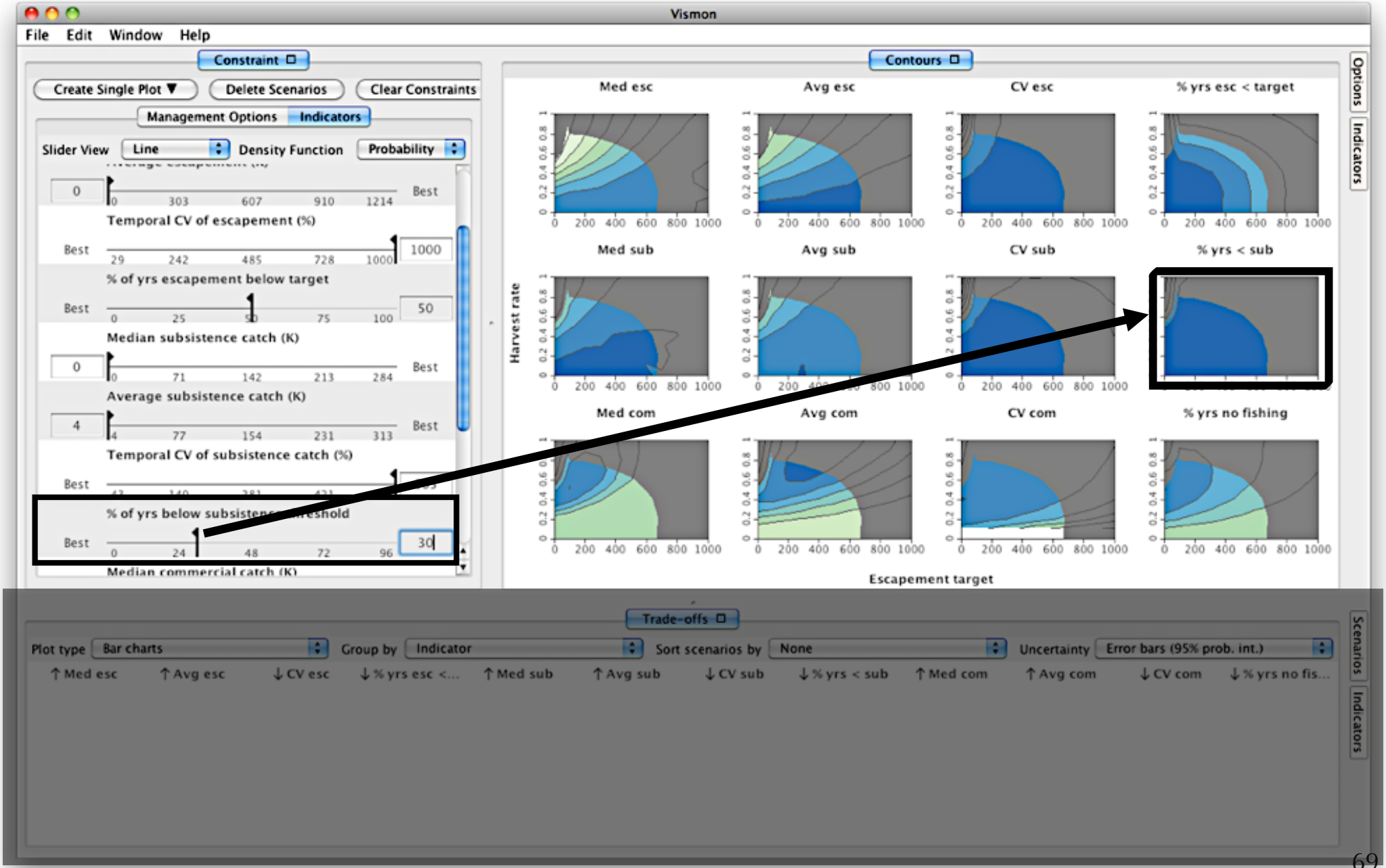

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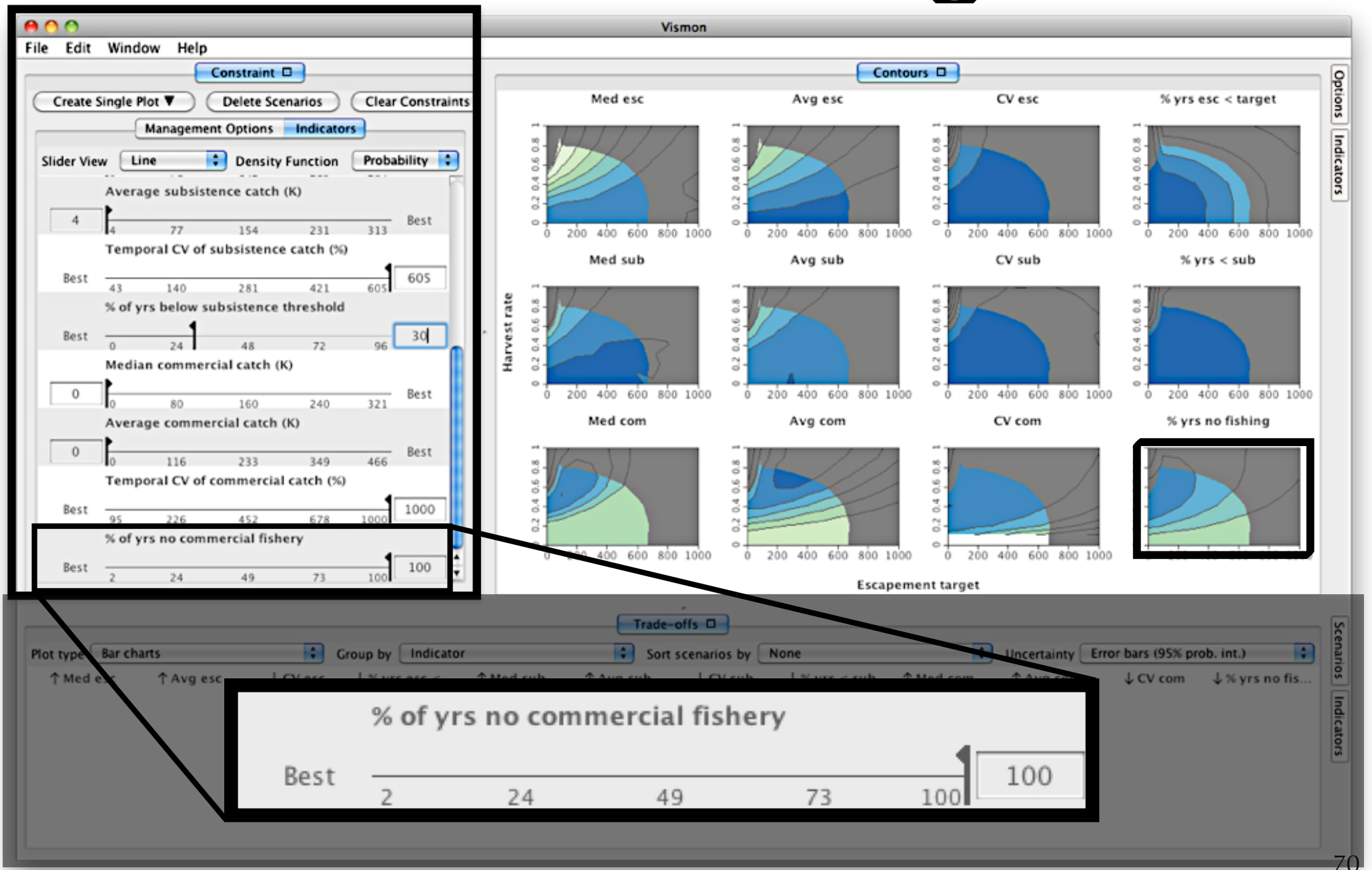
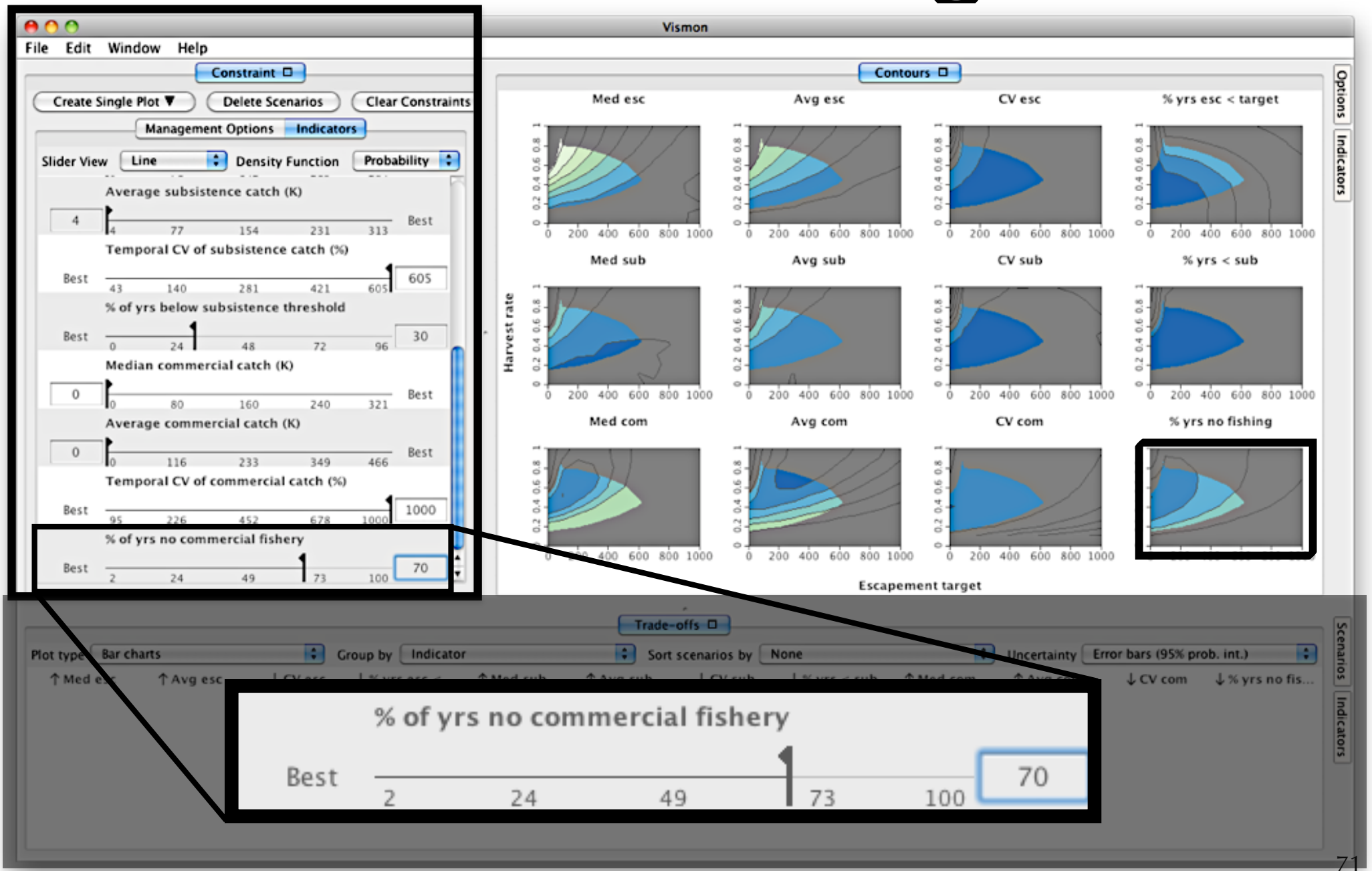
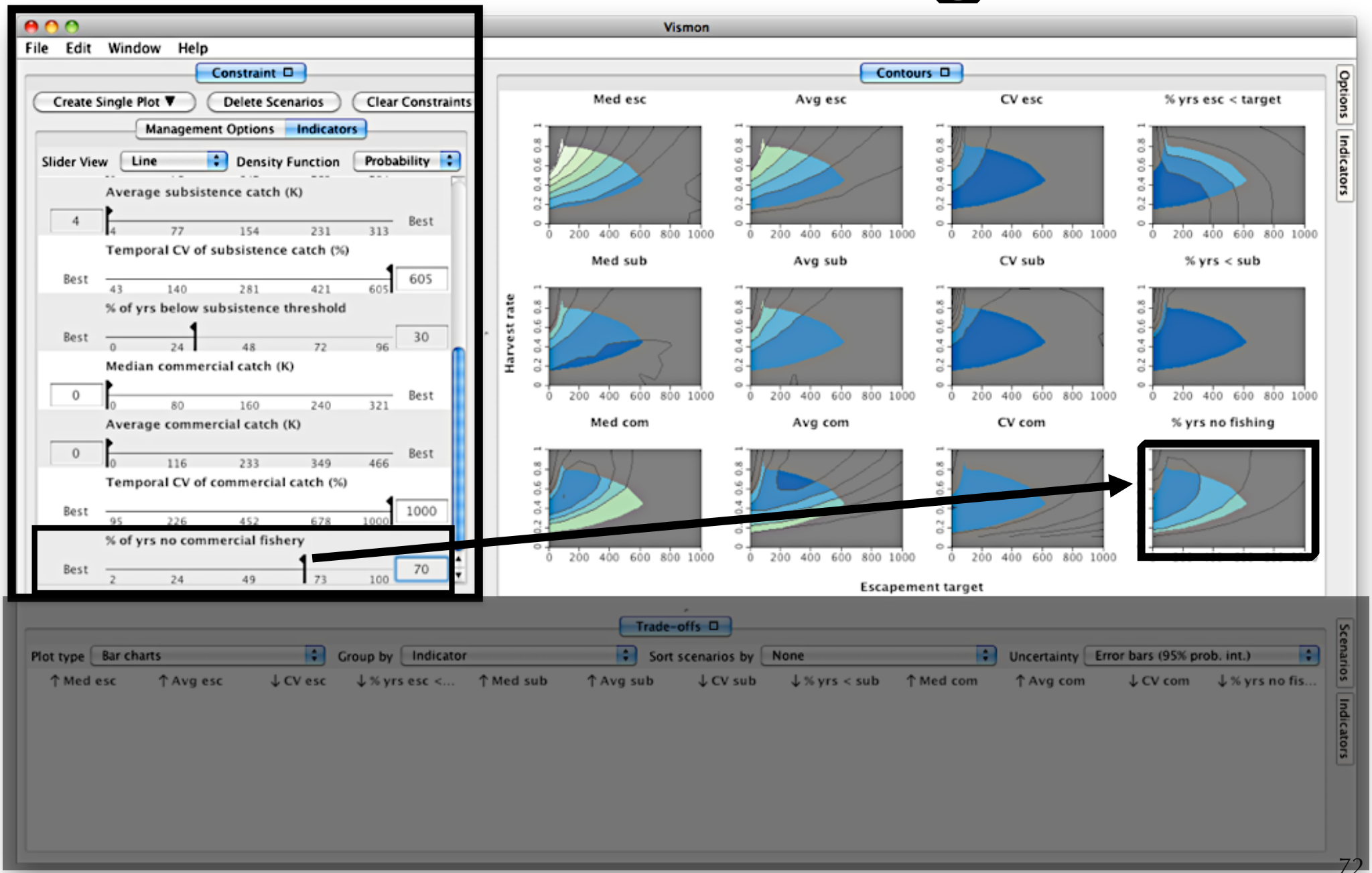


Constraining



Constraining



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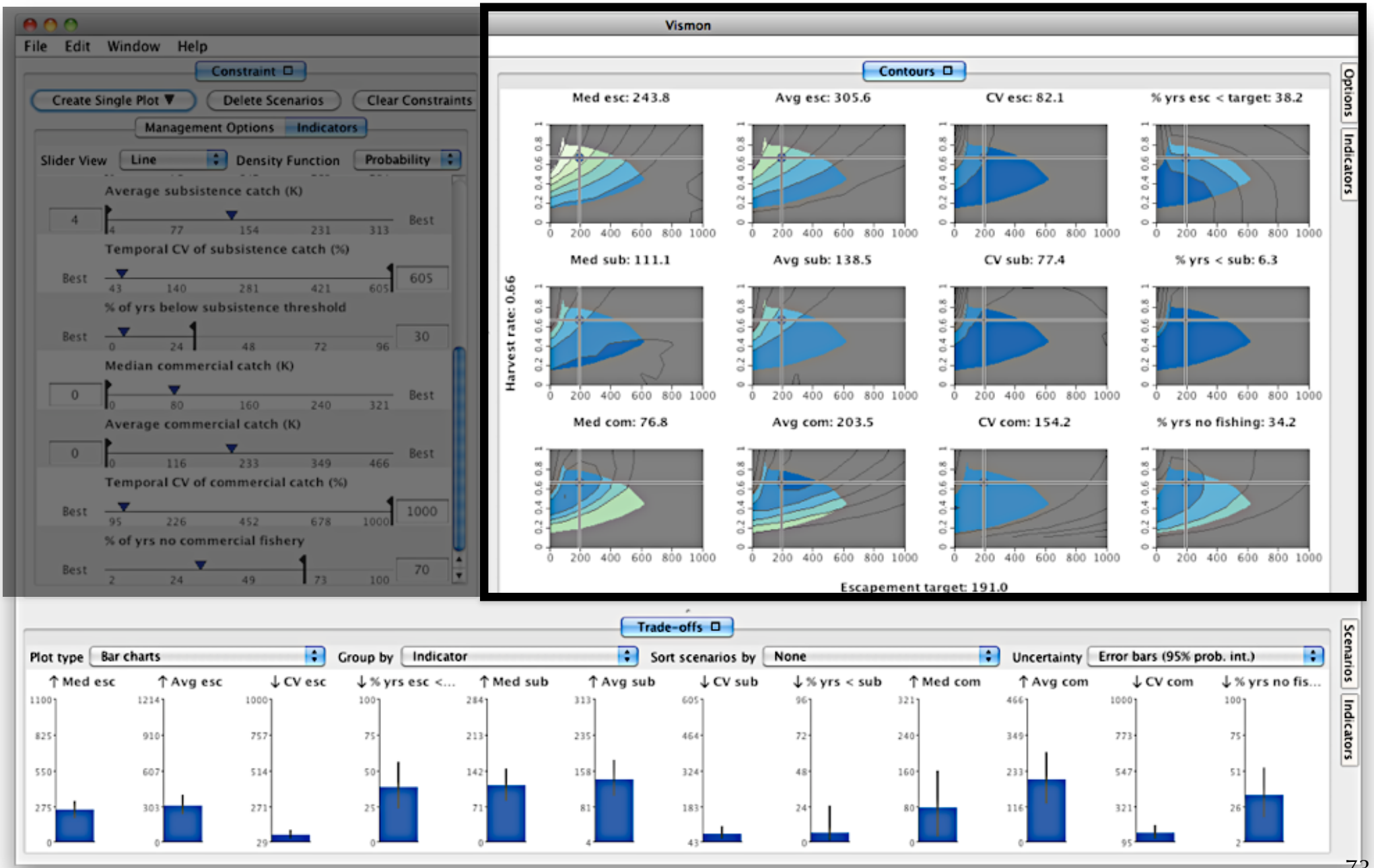
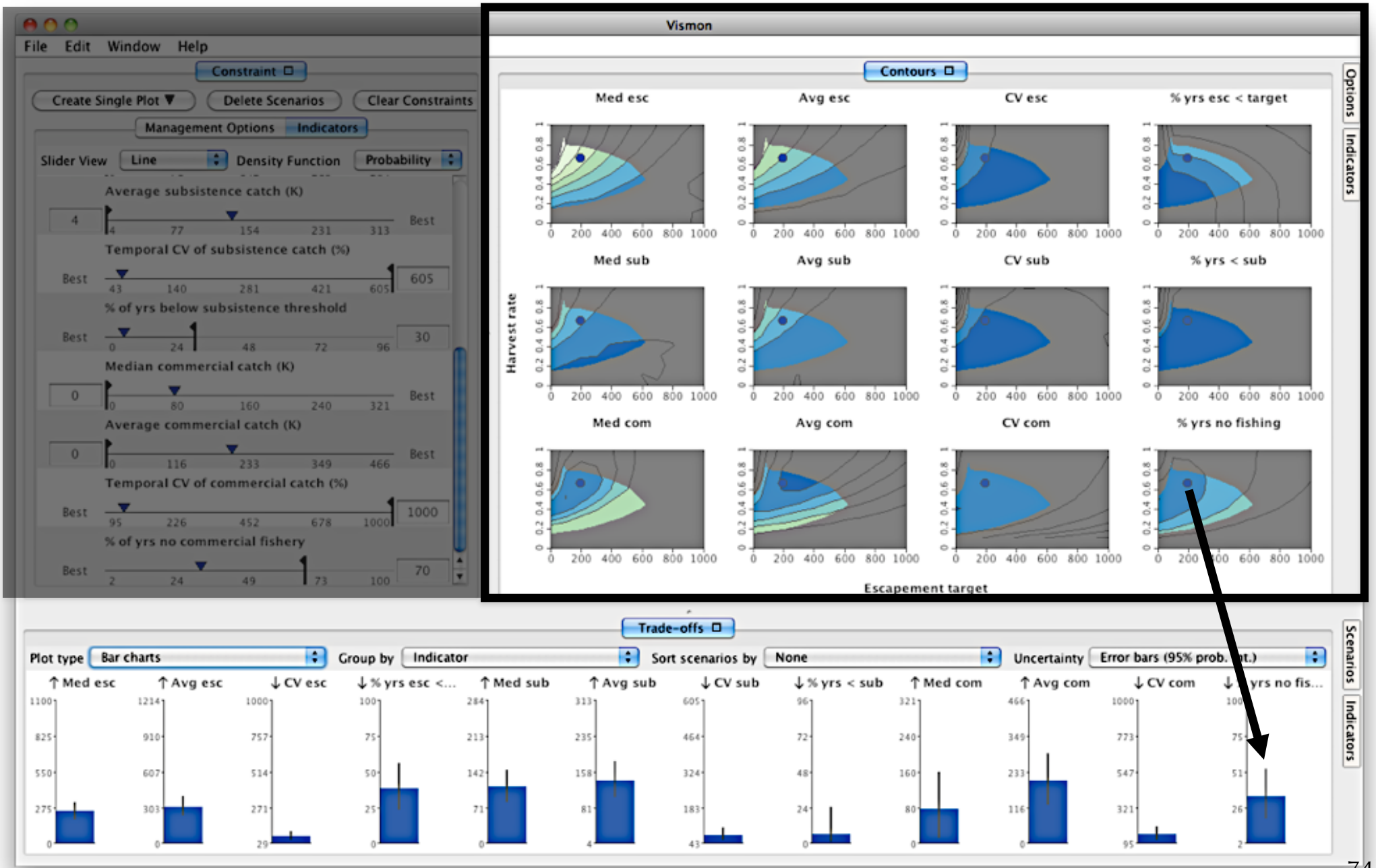

File Edit Window Help
Constraint
Create Single Plot
Delete Scenarios
Clear Constraints
Management Options
Indicators
Slider View
Line
Density Function
Probability
Average subsistence catch (K)
Temporal CV of subsistence catch (%)
% of yrs below subsistence threshold
Median commercial catch (K)
Average commercial catch (K)
Temporal CV of commercial catch (%)
% of yrs no commercial fishery
Best
Vismon
Contours
Med esc: 243.8
Avg esc: 305.6
CV esc: 82.1
% yrs esc < target: 38.2
Med sub: 111.1
Avg sub: 138.5
CV sub: 77.4
% yrs < sub: 6.3
Med com: 76.8
Avg com: 203.5
CV com: 154.2
% yrs no fishing: 34.2
Harvest rate: 0.66
Escapement target: 191.0
Options
Indicators
Trade-offs
Plot type
Bar charts
Group by
Indicator
Sort scenarios by
None
Uncertainty
Error bars (95% prob. int.)
↑ Med esc
↑ Avg esc
↓ CV esc
↓ % yrs esc <...
↑ Med sub
↑ Avg sub
↓ CV sub
↓ % yrs < sub
↑ Med com
↑ Avg com
↓ CV com
↓ % yrs no fis...
Scenarios
Indicators

Selection


File Edit Window Help
Constraint
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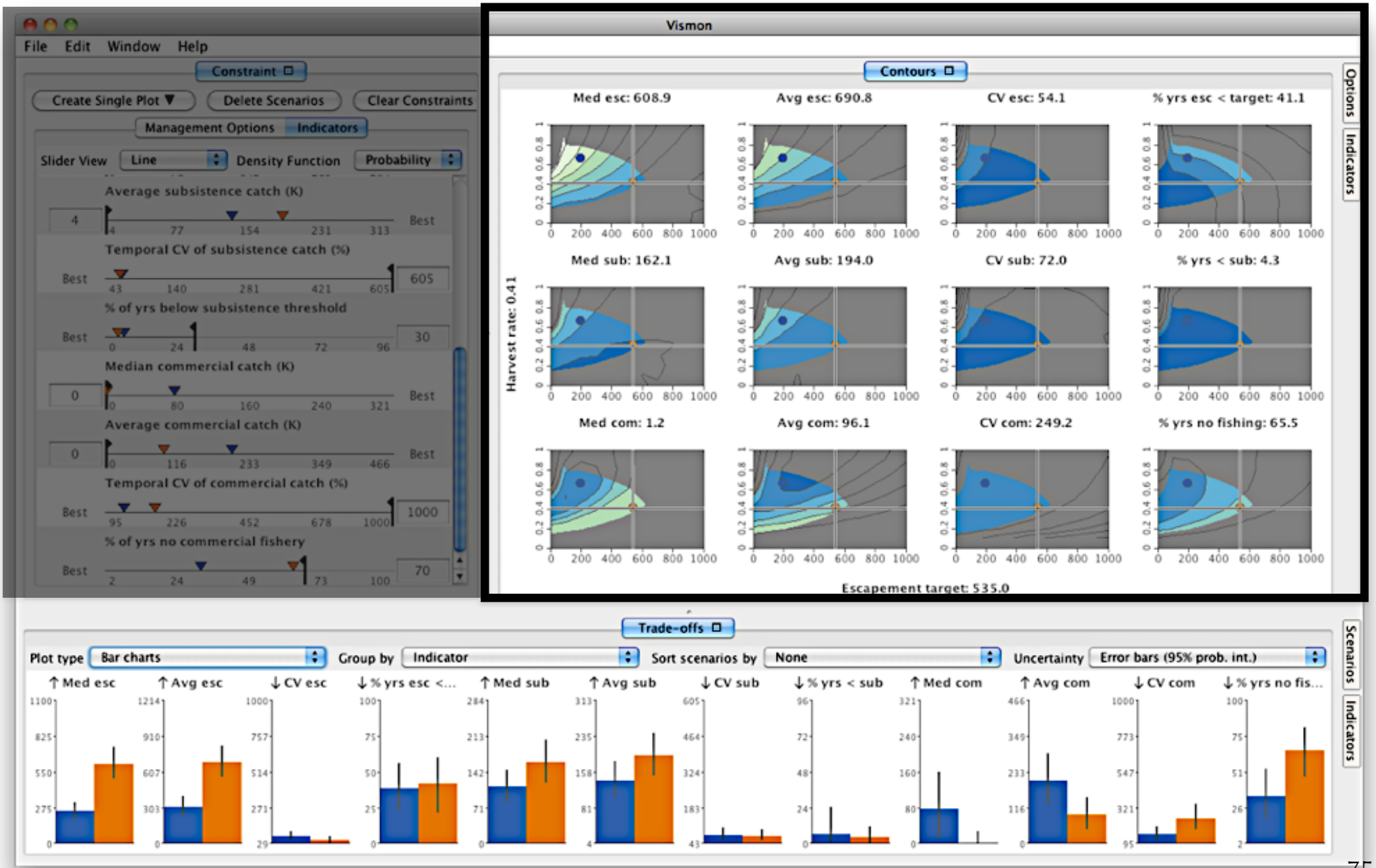
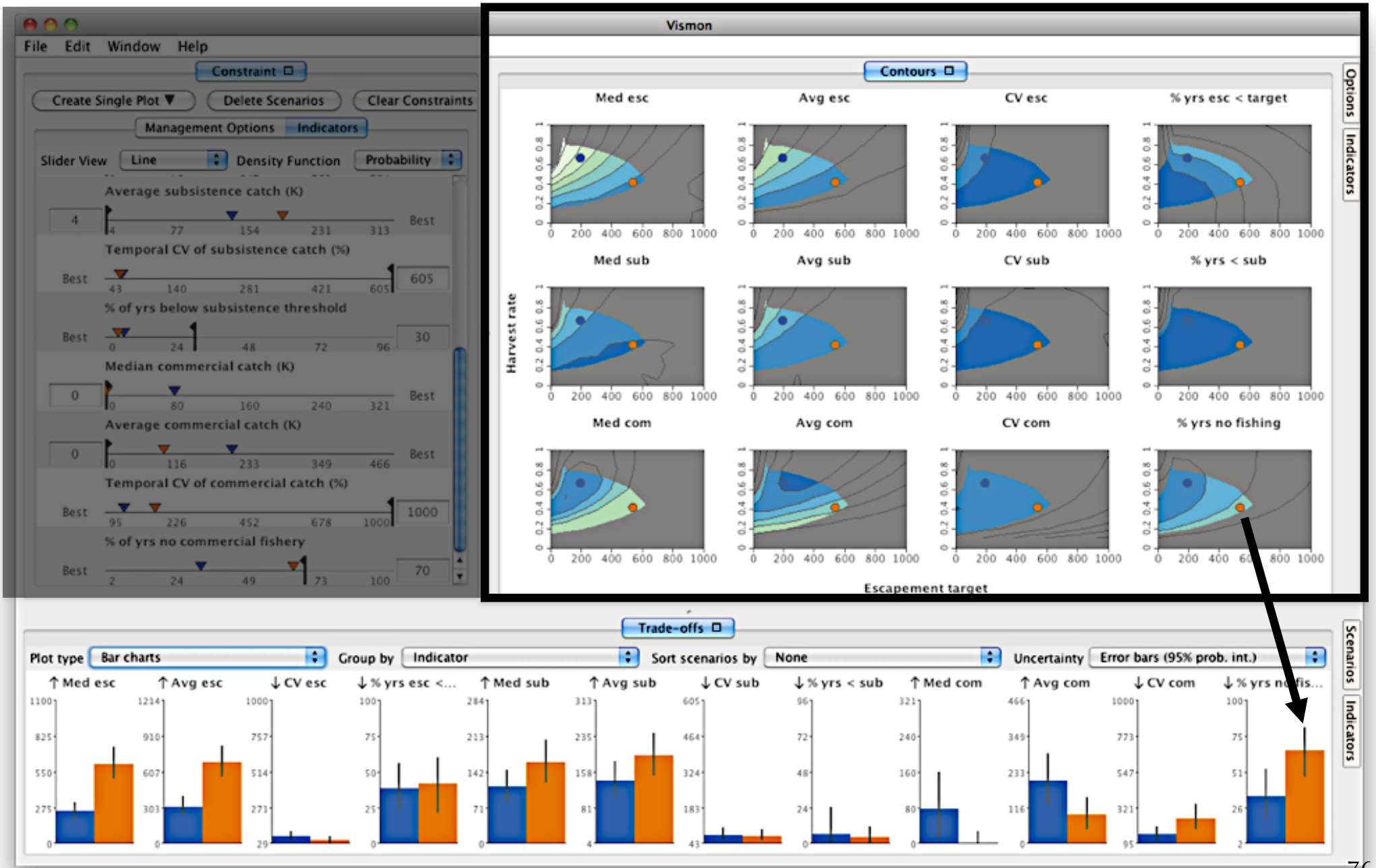
Clear Constraints
Management Options
Indicators
Slider View
Line
Density Function
Probability
Average subsistence catch (K)
Temporal CV of subsistence catch (%)
% of yrs below subsistence threshold
Median commercial catch (K)
Average commercial catch (K)
Temporal CV of commercial catch (%)
% of yrs no commercial fishery
Best
Vismon
Contours
Med esc
Avg esc
CV esc
% yrs esc < target
Med sub
Avg sub
CV sub
% yrs < sub
Med com
Avg com
CV com
% yrs no fishing
Harvest rate
Escapement target
Options
Indicators
Trade-offs
Plot type
Bar charts
Group by
Indicator
Sort scenarios by
None
Uncertainty
Error bars (95% prob.
↑ Med esc
↑ Avg esc
↓ CV esc
↓ % yrs esc <...
↑ Med sub
↑ Avg sub
↓ CV sub
↓ % yrs < sub
↑ Med com
↑ Avg com
↓ CV com
Scenarios
Indicators

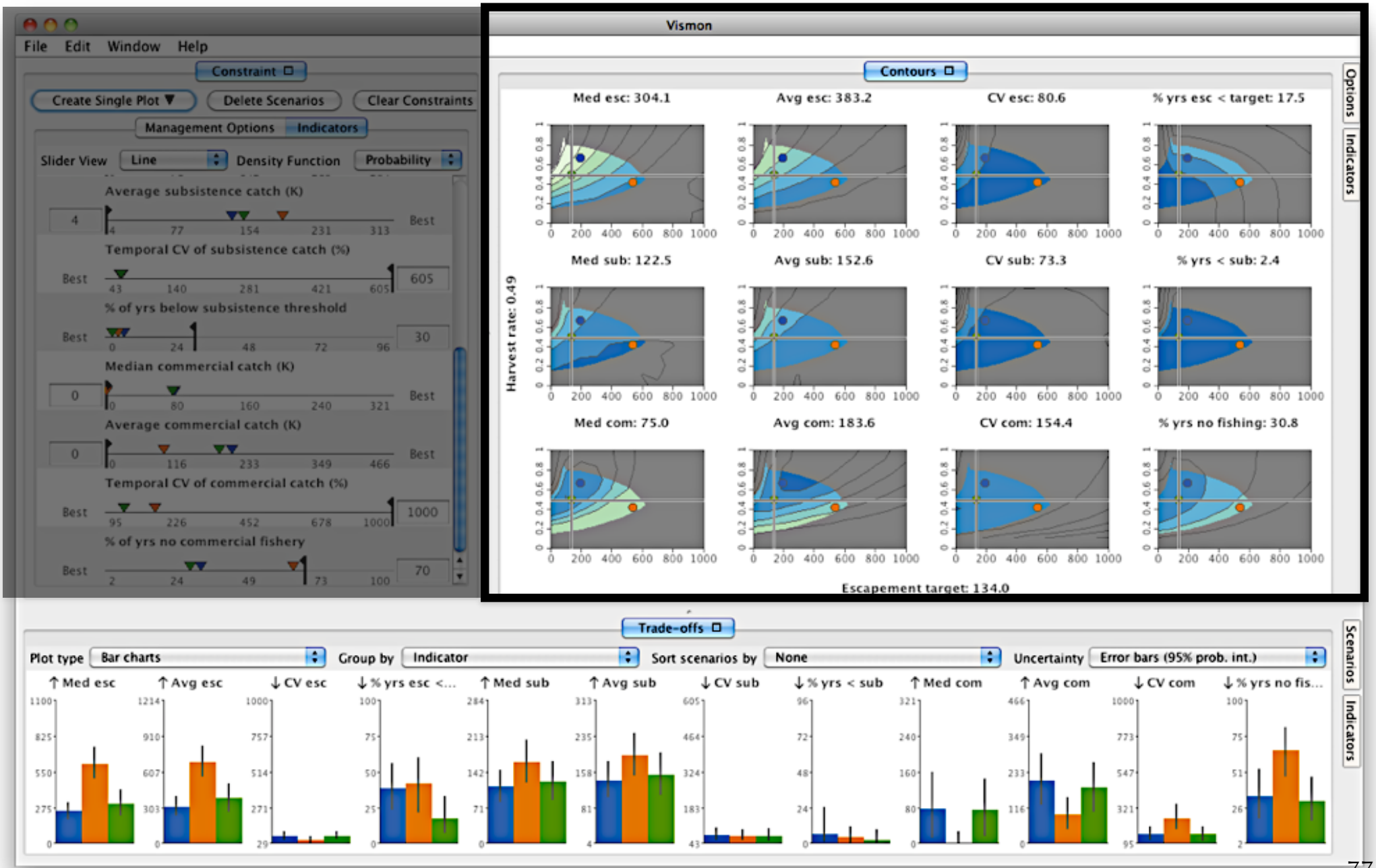
Selection


File Edit Window Help
Constraint
Create Single Plot
Delete Scenarios
Clear Constraints
Management Options
Indicators
Slider View
Line
Density Function
Probability
Average subsistence catch (K)
Temporal CV of subsistence catch (%)
% of yrs below subsistence threshold
Median commercial catch (K)
Average commercial catch (K)
Temporal CV of commercial catch (%)
% of yrs no commercial fishery
Best
Vismon
Contours
Med esc: 608.9
Avg esc: 690.8
CV esc: 54.1
% yrs esc < target: 41.1
Med sub: 162.1
Avg sub: 194.0
CV sub: 72.0
% yrs < sub: 4.3
Harvest rate: 0.41
Med com: 1.2
Avg com: 96.1
CV com: 249.2
% yrs no fishing: 65.5
Escapement target: 535.0
Options
Indicators
Trade-offs
Plot type
Bar charts
Group by
Indicator
Sort scenarios by
None
Uncertainty
Error bars (95% prob. int.)
↑ Med esc
↑ Avg esc
↓ CV esc
↓ % yrs esc <...
↑ Med sub
↑ Avg sub
↓ CV sub
↓ % yrs < sub
↑ Med com
↑ Avg com
↓ CV com
↓ % yrs no fis...
Scenarios
Indicators

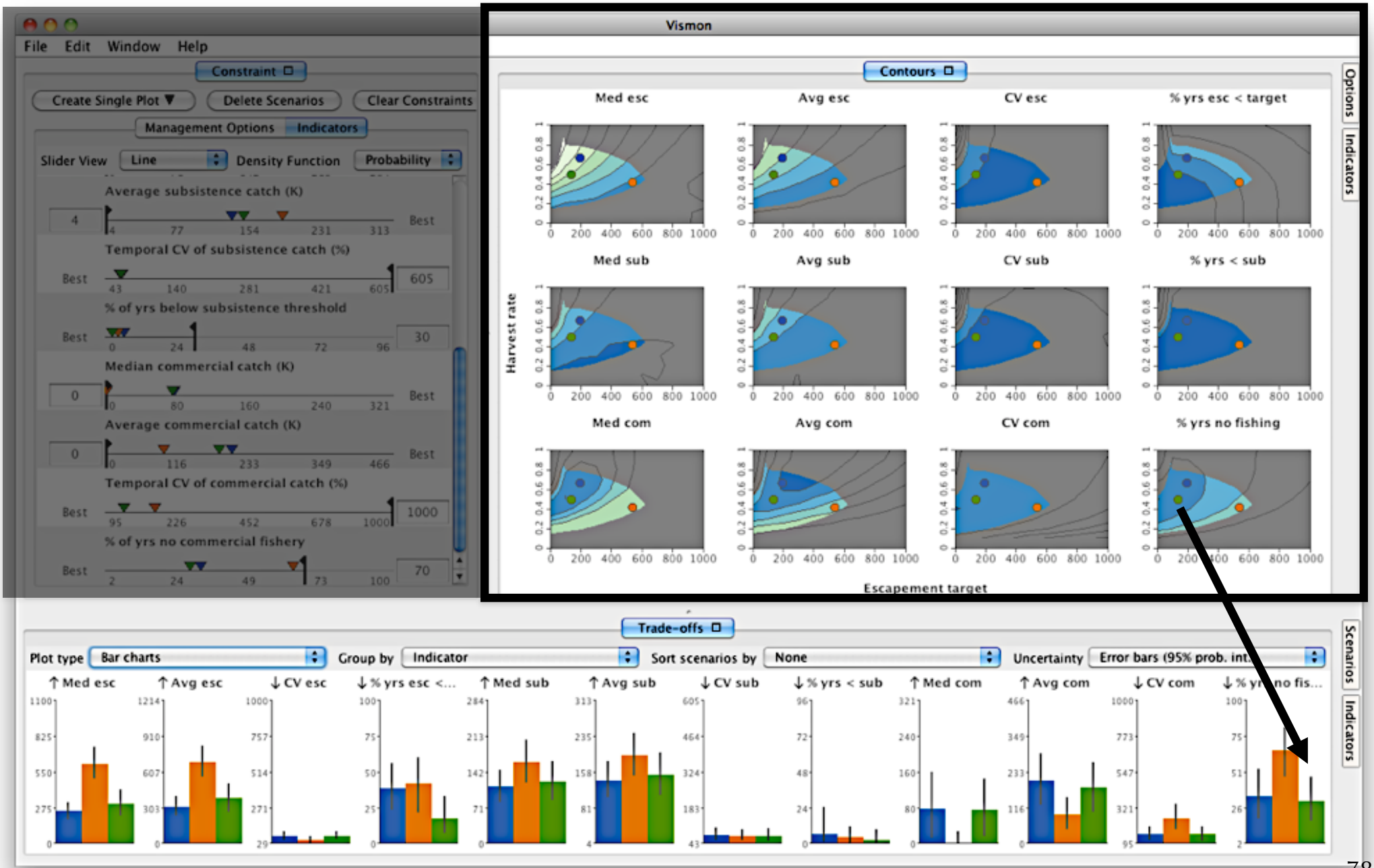
Selection


File Edit Window Help
Constraint
Create Single Plot
Delete Scenarios
Clear Constraints
Management Options
Indicators
Slider View
Line
Density Function
Probability
Average subsistence catch (K)
Temporal CV of subsistence catch (%)
% of yrs below subsistence threshold
Median commercial catch (K)
Average commercial catch (K)
Temporal CV of commercial catch (%)
% of yrs no commercial fishery
Best
Vismon
Contours
Med esc
Avg esc
CV esc
% yrs esc < target
Med sub
Avg sub
CV sub
% yrs < sub
Med com
Avg com
CV com
% yrs no fishing
Harvest rate
Escapement target
Options
Indicators
Trade-offs
Plot type
Bar charts
Group by
Indicator
Sort scenarios by
None
Uncertainty
Error bars (95% prob. int.)
↑ Med esc
↑ Avg esc
↓ CV esc
↓ % yrs esc <...
↑ Med sub
↑ Avg sub
↓ CV sub
↓ % yrs < sub
↑ Med com
↑ Avg com
↓ CV com
Scenarios
Indicators

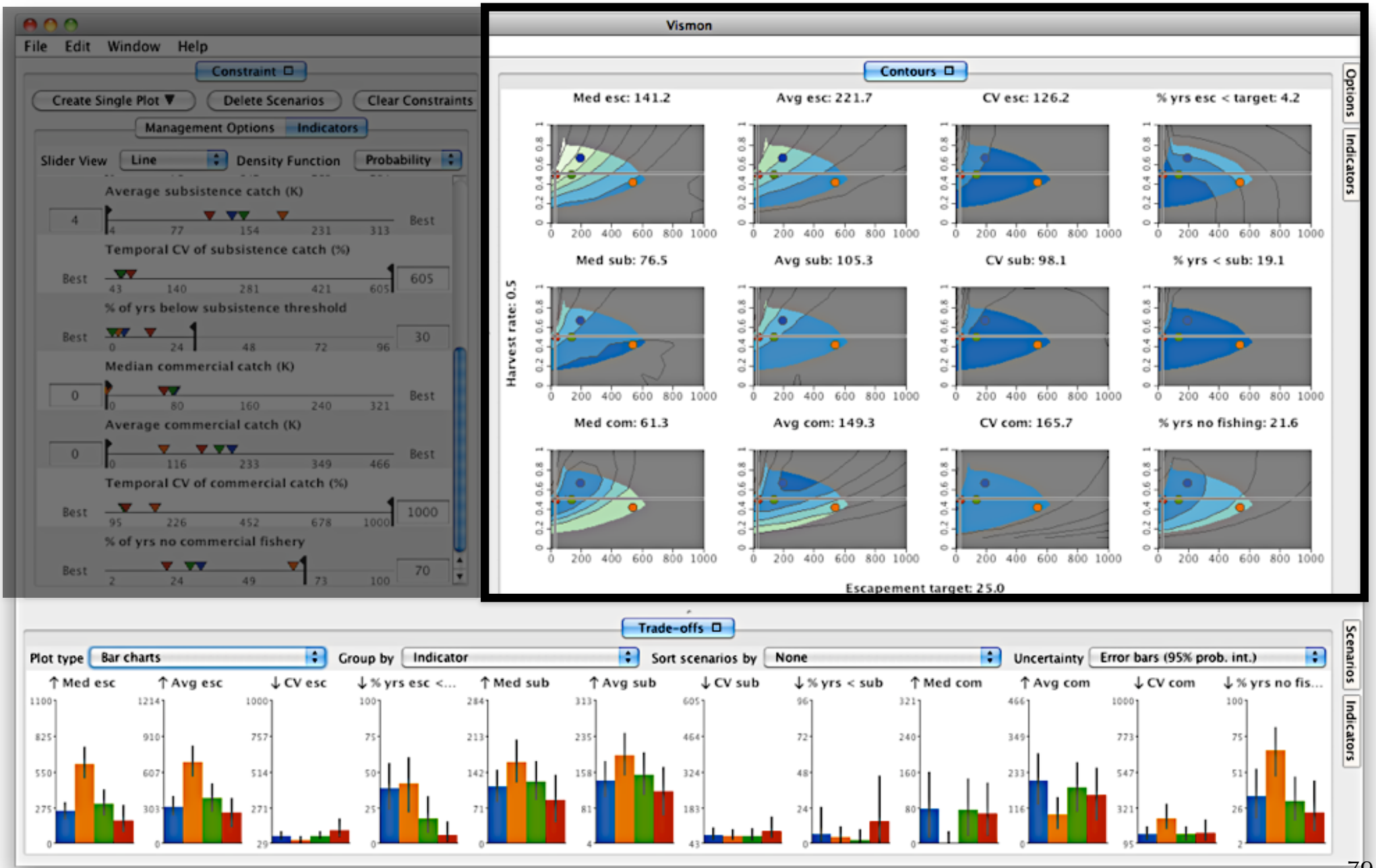
Selection


File Edit Window Help
Constraint
Create Single Plot
Delete Scenarios
Clear Constraints
Management Options
Indicators
Slider View
Line
Density Function
Probability
Average subsistence catch (K)
Temporal CV of subsistence catch (%)
% of yrs below subsistence threshold
Median commercial catch (K)
Average commercial catch (K)
Temporal CV of commercial catch (%)
% of yrs no commercial fishery
Best
Vismon
Contours
Med esc: 304.1
Avg esc: 383.2
CV esc: 80.6
% yrs esc < target: 17.5
Med sub: 122.5
Avg sub: 152.6
CV sub: 73.3
% yrs < sub: 2.4
Med com: 75.0
Avg com: 183.6
CV com: 154.4
% yrs no fishing: 30.8
Harvest rate: 0.49
Escapement target: 134.0
Options
Indicators
Trade-offs
Plot type
Bar charts
Group by
Indicator
Sort scenarios by
None
Uncertainty
Error bars (95% prob. int.)
↑ Med esc
↑ Avg esc
↓ CV esc
↓ % yrs esc <...
↑ Med sub
↑ Avg sub
↓ CV sub
↓ % yrs < sub
↑ Med com
↑ Avg com
↓ CV com
↓ % yrs no fis...
Scenarios
Indicators

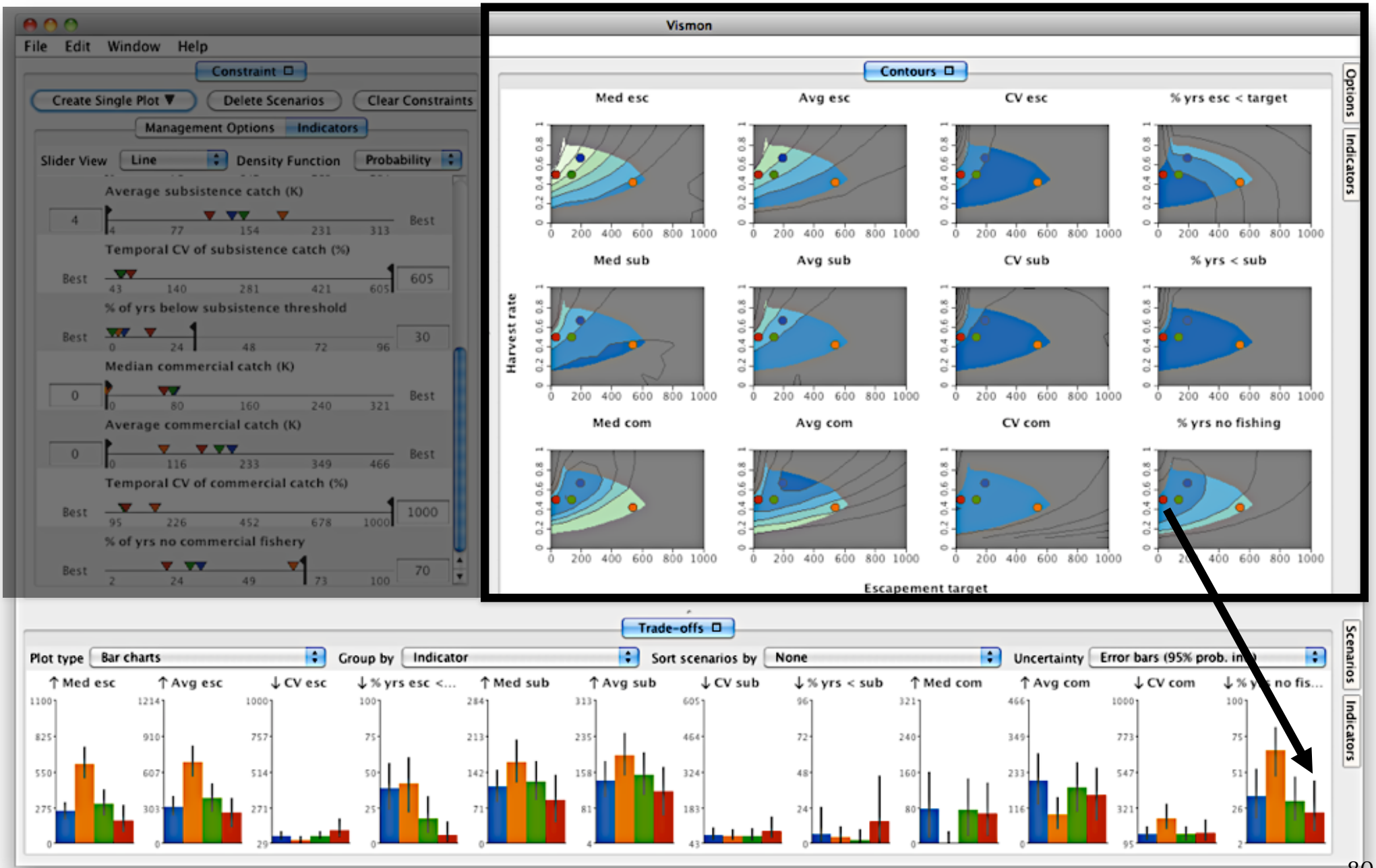
Selection


File Edit Window Help
Constraint
Create Single Plot
Delete Scenarios
Clear Constraints
Management Options
Indicators
Slider View
Line
Density Function
Probability
Average subsistence catch (K)
Temporal CV of subsistence catch (%)
% of yrs below subsistence threshold
Median commercial catch (K)
Average commercial catch (K)
Temporal CV of commercial catch (%)
% of yrs no commercial fishery
Best
Vismon
Contours
Med esc
Avg esc
CV esc
% yrs esc < target
Med sub
Avg sub
CV sub
% yrs < sub
Med com
Avg com
CV com
% yrs no fishing
Harvest rate
Escapement target
Options
Indicators
Trade-offs
Plot type
Bar charts
Group by
Indicator
Sort scenarios by
None
Uncertainty
Error bars (95% prob. int.)
↑ Med esc
↑ Avg esc
↓ CV esc
↓ % yrs esc <...
↑ Med sub
↑ Avg sub
↓ CV sub
↓ % yrs < sub
↑ Med com
↑ Avg com
↓ CV com
Scenarios
Indicators

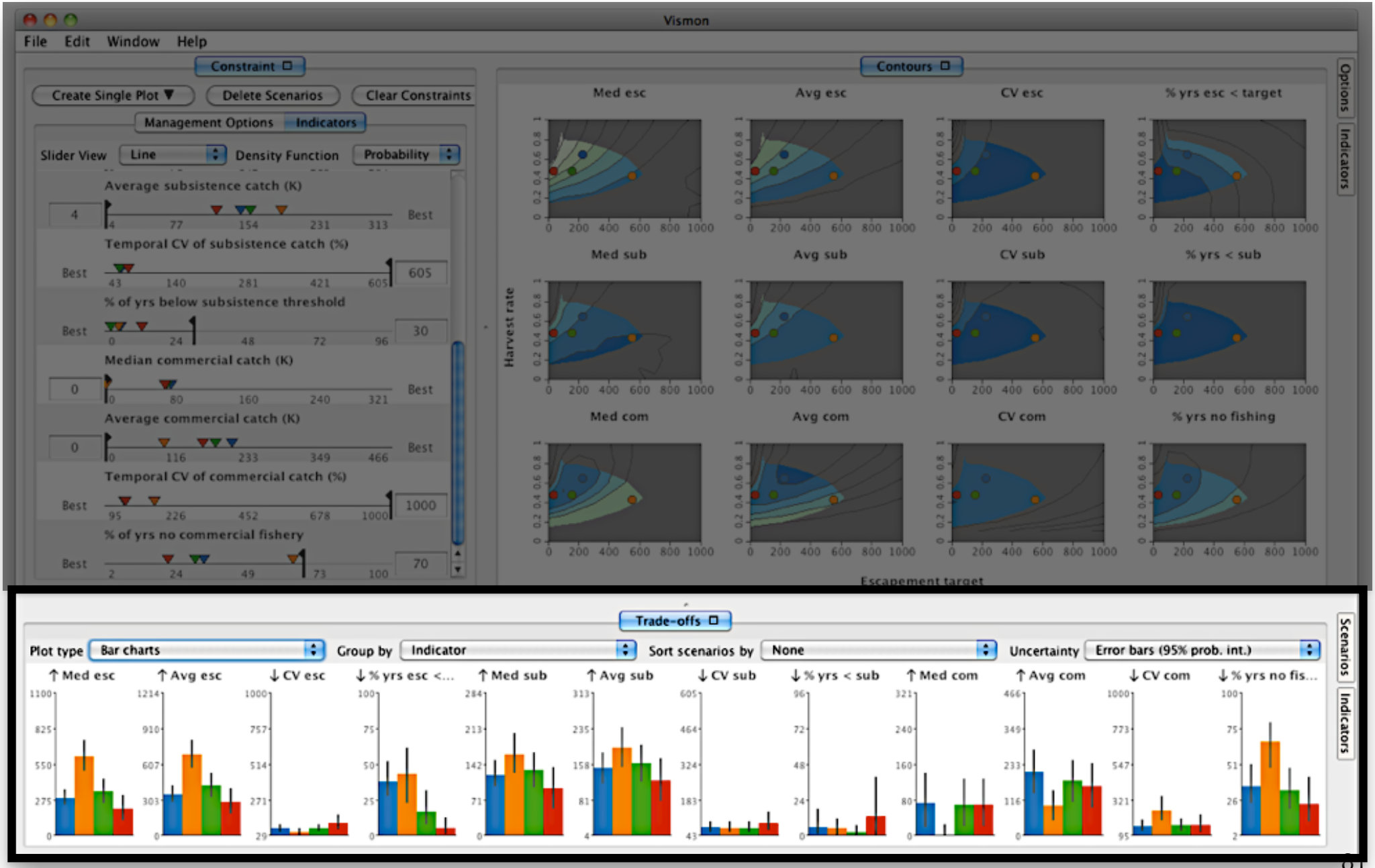
Selection


File Edit Window Help
Constraint
Create Single Plot
Delete Scenarios
Clear Constraints
Management Options
Indicators
Slider View
Line
Density Function
Probability
Average subsistence catch (K)
Temporal CV of subsistence catch (%)
% of yrs below subsistence threshold
Median commercial catch (K)
Average commercial catch (K)
Temporal CV of commercial catch (%)
% of yrs no commercial fishery
Best
Vismon
Contours
Med esc: 141.2
Avg esc: 221.7
CV esc: 126.2
% yrs esc < target: 4.2
Med sub: 76.5
Avg sub: 105.3
CV sub: 98.1
% yrs < sub: 19.1
Med com: 61.3
Avg com: 149.3
CV com: 165.7
% yrs no fishing: 21.6
Harvest rate: 0.5
Escapement target: 25.0
Options
Indicators
Trade-offs
Plot type
Bar charts
Group by
Indicator
Sort scenarios by
None
Uncertainty
Error bars (95% prob. int.)
↑ Med esc
↑ Avg esc
↓ CV esc
↓ % yrs esc <...
↑ Med sub
↑ Avg sub
↓ CV sub
↓ % yrs < sub
↑ Med com
↑ Avg com
↓ CV com
↓ % yrs no fis...
Scenarios
Indicators

Selection


File Edit Window Help
Constraint
Create Single Plot
Delete Scenarios
Clear Constraints
Management Options
Indicators
Slider View
Line
Density Function
Probability
Average subsistence catch (K)
Temporal CV of subsistence catch (%)
% of yrs below subsistence threshold
Median commercial catch (K)
Average commercial catch (K)
Temporal CV of commercial catch (%)
% of yrs no commercial fishery
Best
Vismon
Contours
Med esc
Avg esc
CV esc
% yrs esc < target
Med sub
Avg sub
CV sub
% yrs < sub
Med com
Avg com
CV com
% yrs no fishing
Harvest rate
Escapement target
Options
Indicators
Trade-offs
Plot type
Bar charts
Group by
Indicator
Sort scenarios by
None
Uncertainty
Error bars (95% prob. in
↑ Med esc
↑ Avg esc
↓ CV esc
↓ % yrs esc <...
↑ Med sub
↑ Avg sub
↓ CV sub
↓ % yrs < sub
↑ Med com
↑ Avg com
↓ CV com
Scenarios
Indicators

Trade-off quantification



FeatureFinder — Classification

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U of Vienna

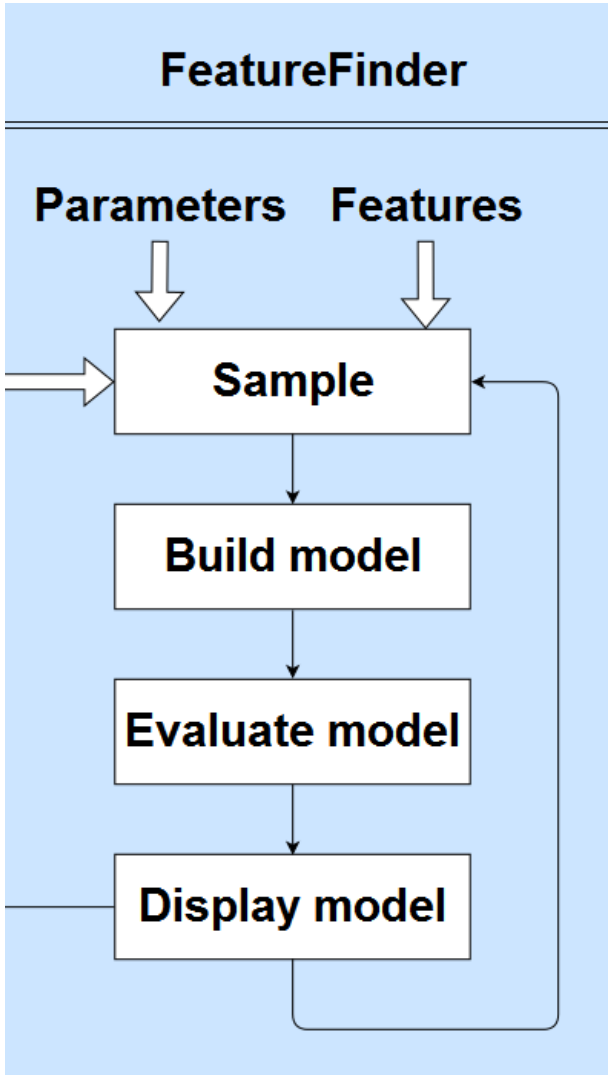
Classification

- a form of supervised “learning”, i.e.
- Given: a set of labeled data items
- Problem: find the right label for new data items

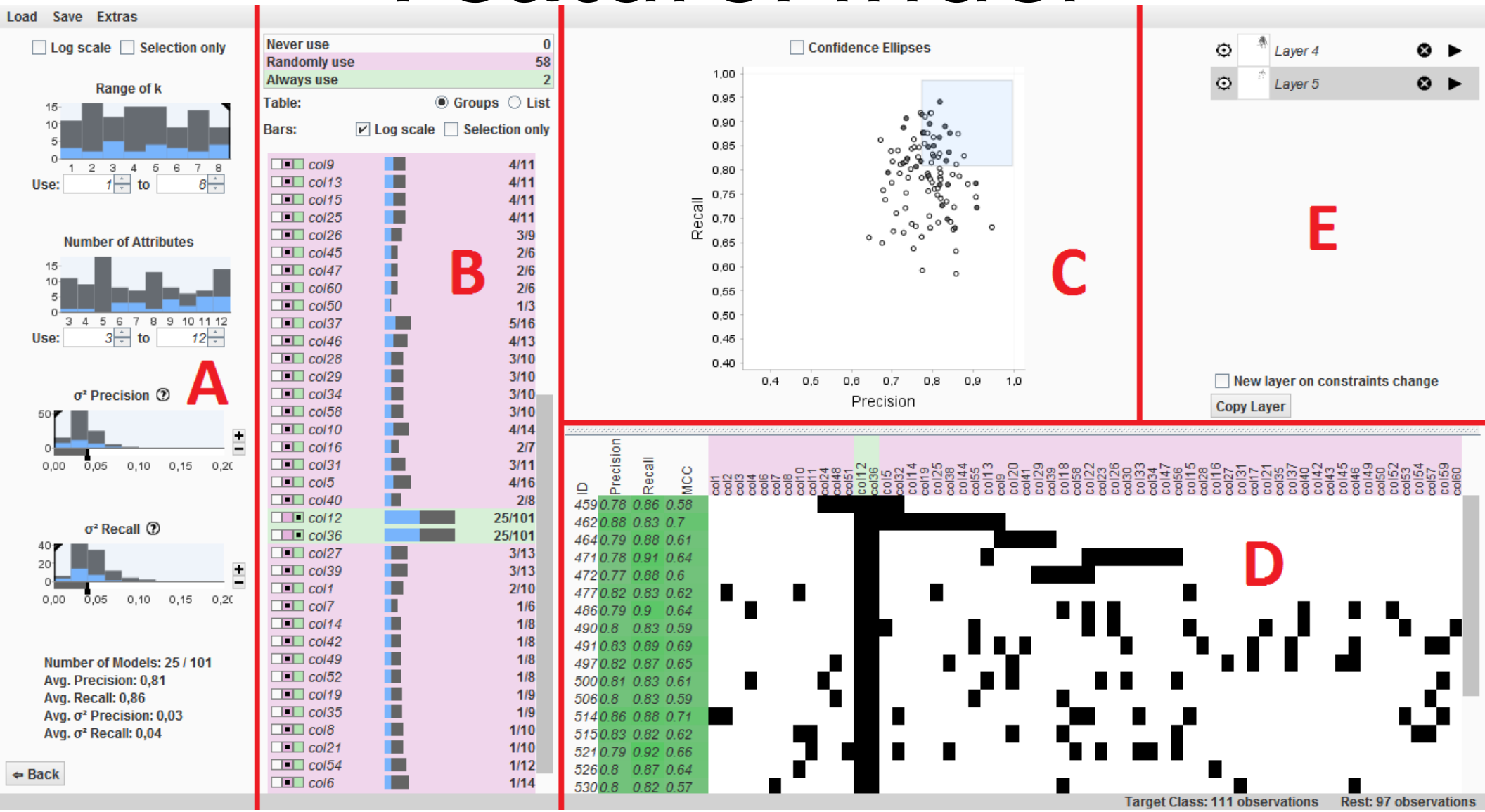
Classification — Example

- Patients with and without cancer
- What features will help me predict whether a person has cancer, given a set of people that do and don’t have cancer!?
- Features — can be age, income, address, but surely also anatomical features, etc.
- potentially LOTS of features — which to pick?

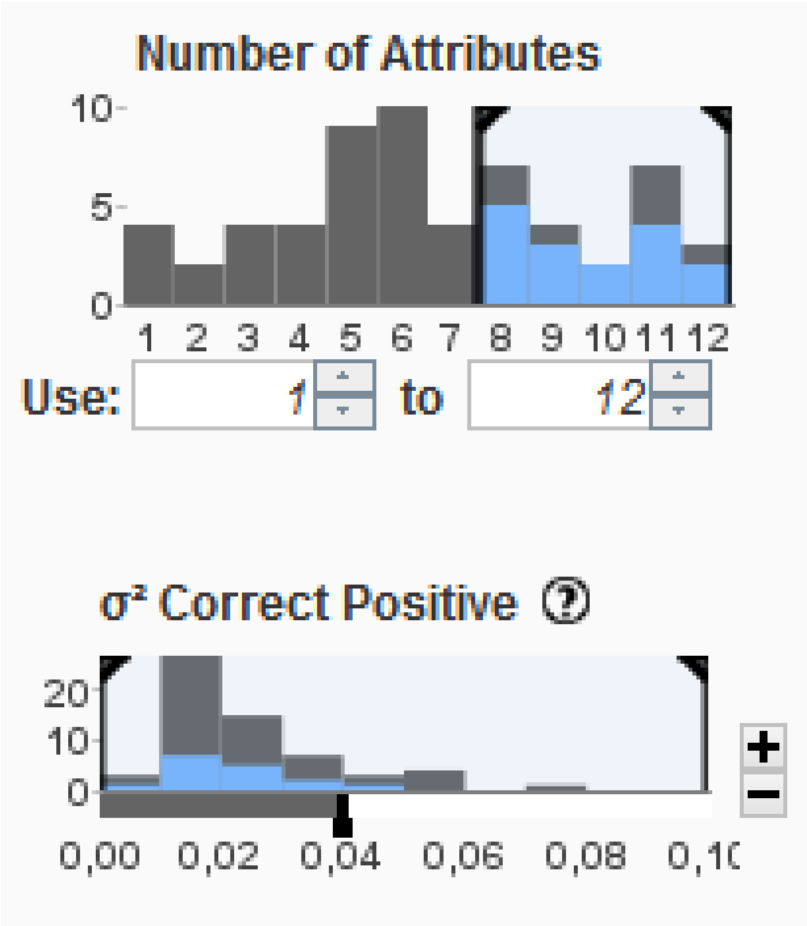
Principle idea



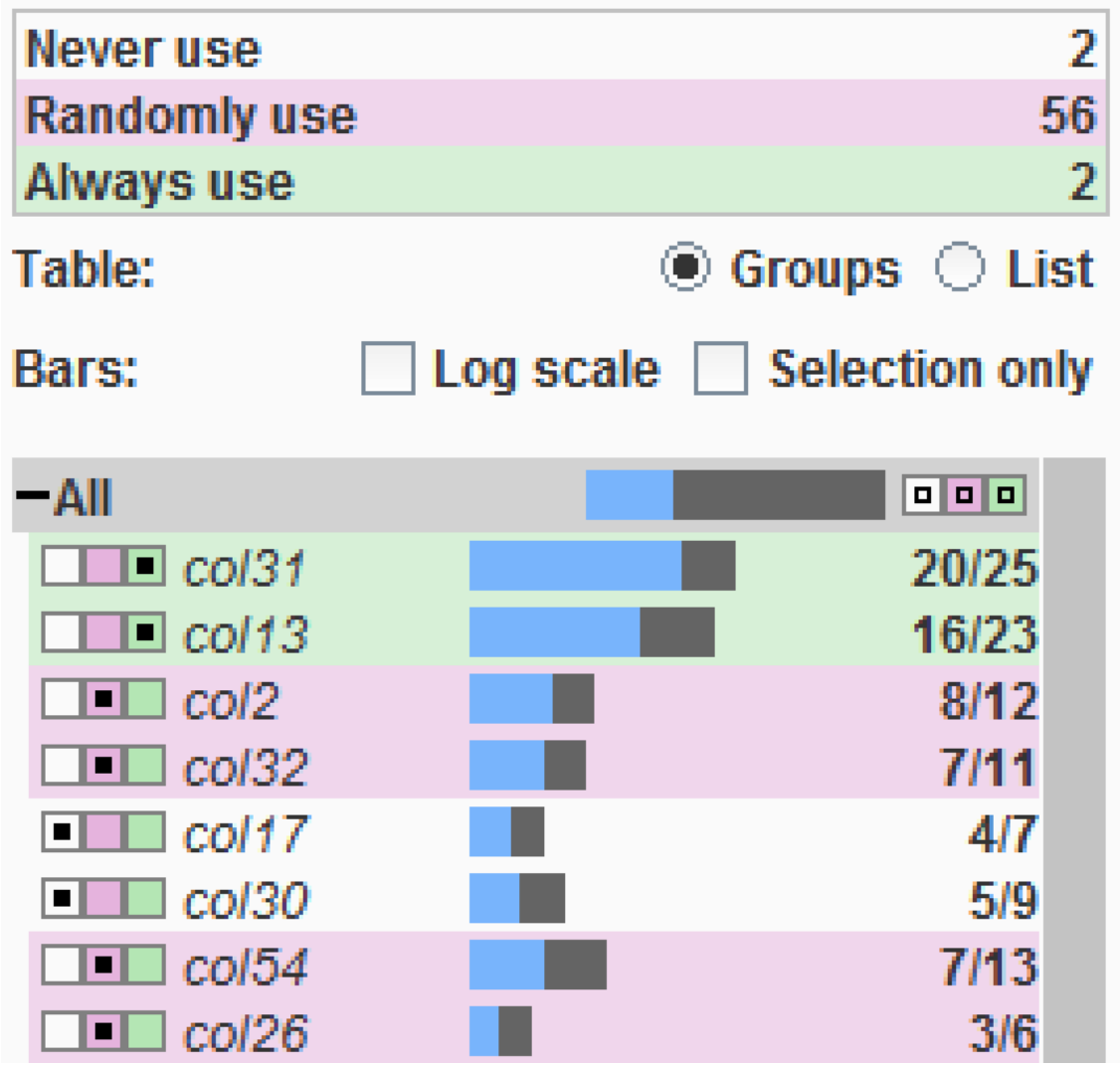
FeatureFinder



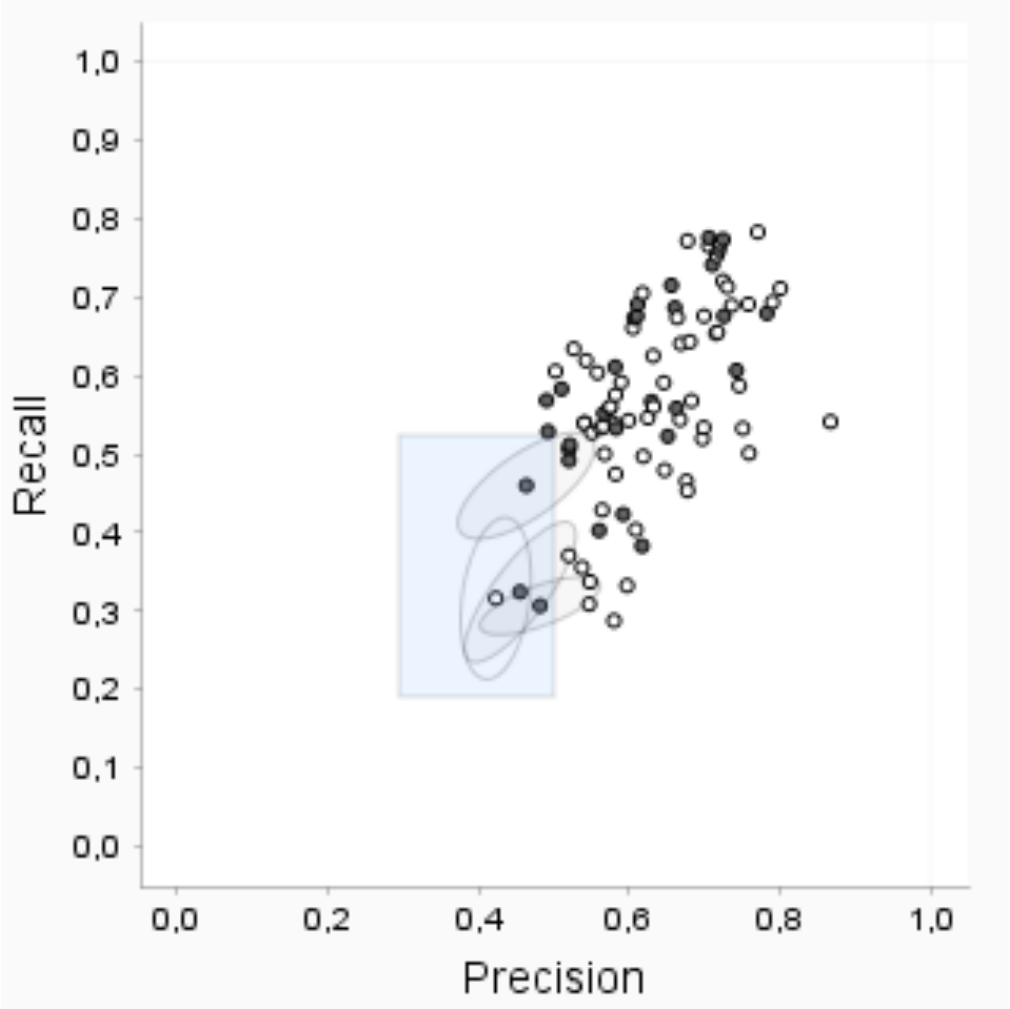
Filter on Input & Output parameters



Set constraints on features to use



Overview over all models



Summary of feature performance

Performance

- Matthews correlation coefficient (MCC)
  - -1 — bad
  - +1 — good

Dataset	Method	Nr. Features	MCC
Splice	None	60	0.501
	CFS	12	0.702
	ReliefF	16	0.712
	Wrapper	**3**	**0.784**
	User1	17	0.608
	User2	5	0.659
	User3	**3**	0.729
	User4	4	0.606
	User5	**3**	0.648
Stellar	None	102	0.707
	CFS	12	0.801
	ReliefF	22	0.602
	Wrapper	14	**0.808**
	User1	12	0.745
	User2	5	0.762
	User3	20	0.769
	User4	**4**	0.628
	User5	50	0.781

Overview

- Today: 4 case studies
  - Tuner — Image segmentation
  - FluidExplorer — Fluid animation
  - Vismon — Fisheries science
  - FeatureExplorer — Classification
- Tomorrow: Abstraction / Theory
  - Design Studies
  - Principles of visual parameter space exploration
  - Visual Data Science — visual tools for modeling

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Questions?

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