BATS

BEHAVIOR ANALYSIS AND TESTING SOFTWARE

Can Sücüllü
Gönenç Yücel

32th ISDC, Delft, Netherlands

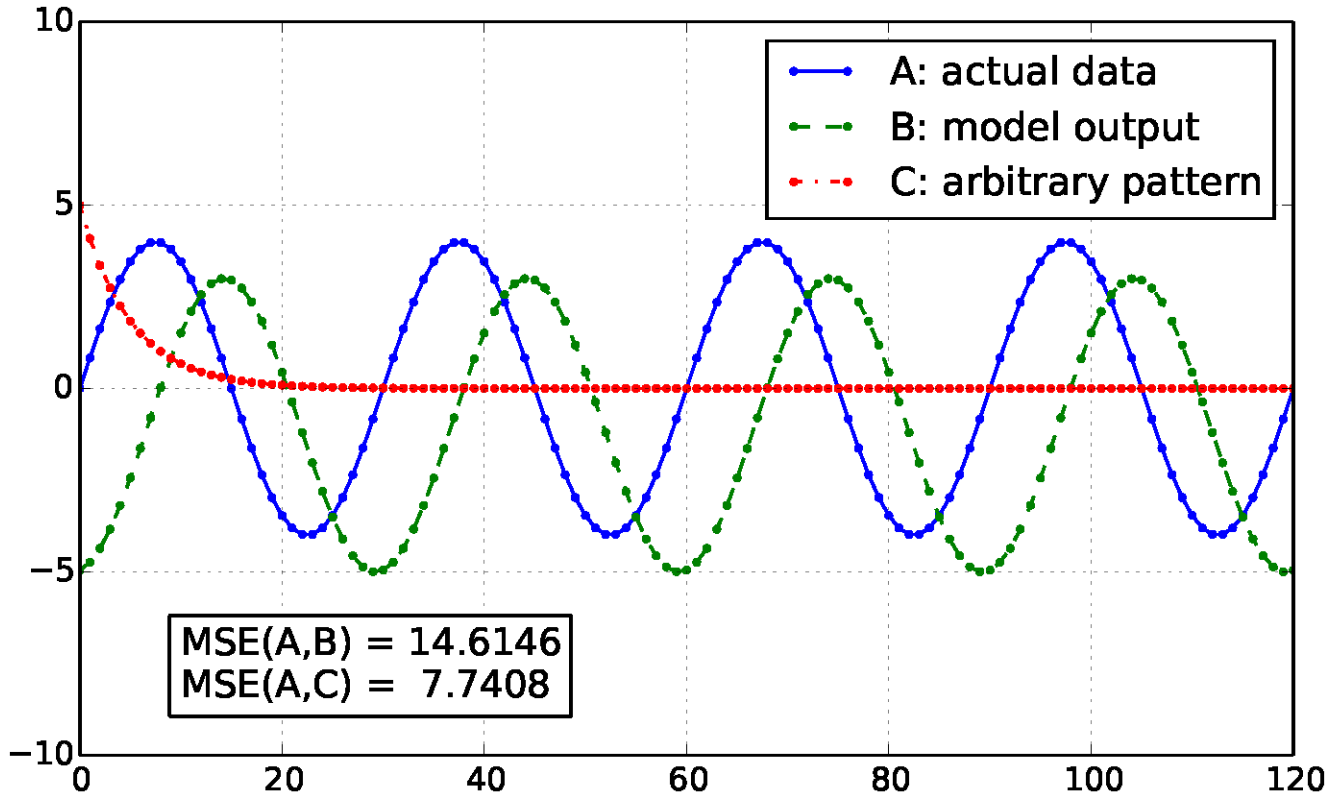
Outline

- Background
- BATS with Time-Series Data
- BATS with Vensim Models
- Conclusion and Further Studies

Background on Structure and Dynamic Behavior

- Structure is the totality of relationships that exist in the system
- Dynamic behavior is the performance pattern of the variables created by the operation of the structure of the system over time
- SD is a long term policy oriented methodology
  - Emphasis is on pattern characteristics rather than point-based metrics and similarity
- The important elements are:
  - Pattern modes; oscillatory, s-shaped, linear, exponential
  - Pattern components; trend, slope, curvature, period, amplitude, mean

Patternwise Comparison



Motivations

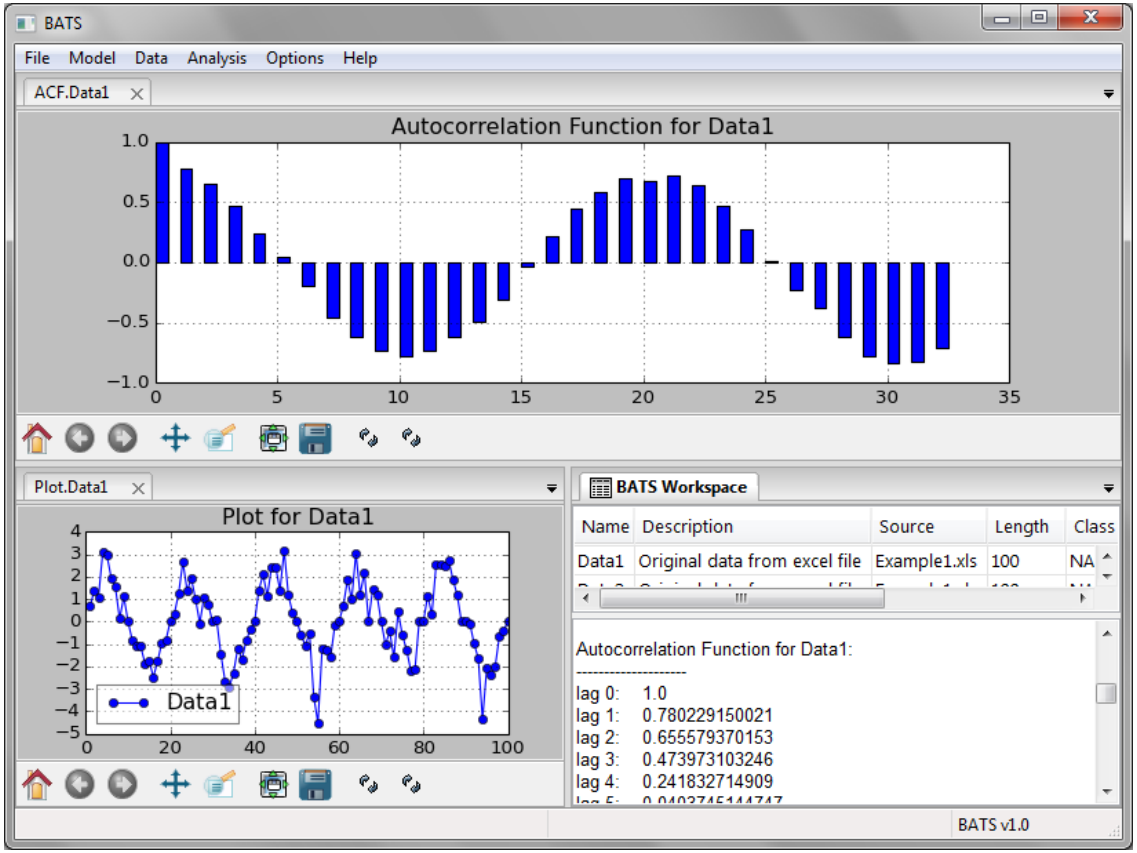
- Behavior analysis practice involve **subjective** aspects
- Analyzing large numbers of simulation output is **time-consuming**
- Existing functions / methods / algorithms / prodecures **are not extensively and effectively used** due to them being available in separate working environments (e.g. Statistical Screening, POPS, EEA, LEEA, Barlas' 6-Step)
- Existing tools / software **are not extensively used** due to usability issues (e.g. BTS, SiS)

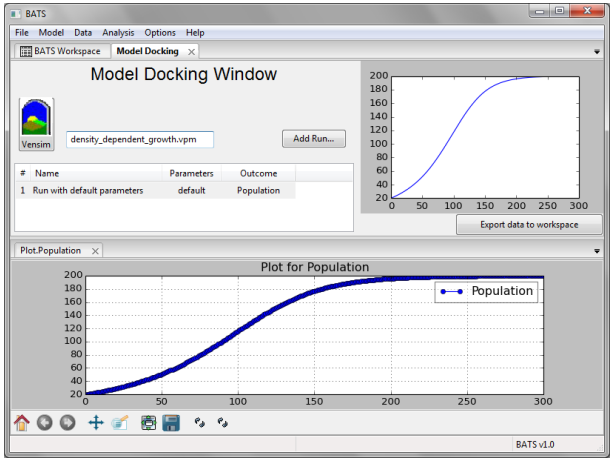
Objectives

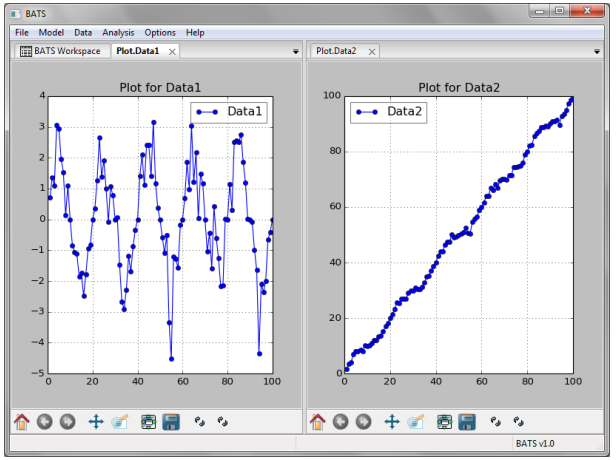
- ✓Review and gather existing functions, methods, algorithms, tools, procedures
- ✓Formulate new ones or design new procedures & usage modes based on the existing ones
- ✓Maintain a high level of automation
- ✓Communicate with existing modeling software
- ✓Achieve a high level of user-friendliness (efficient human-environment interaction)

Designing an integrated model / behavior analysis and testing software

Behavior Analysis and Testing Software

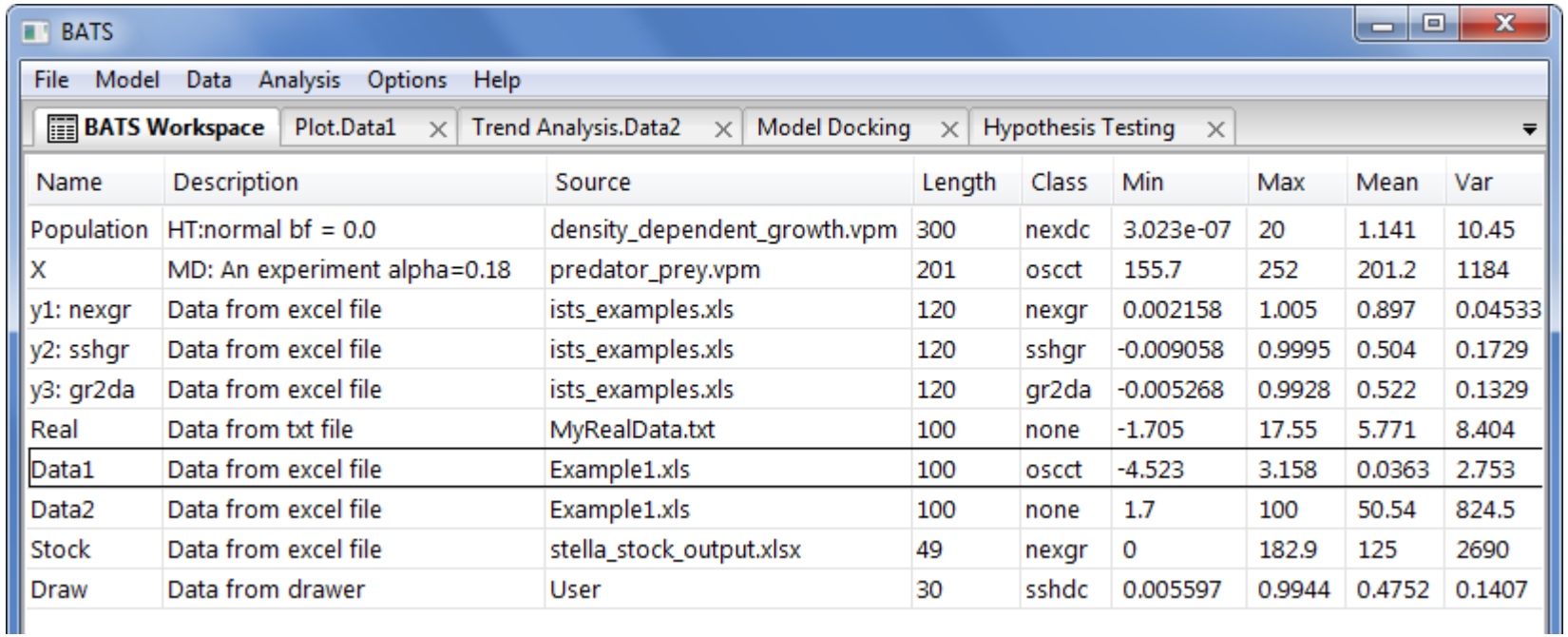






BATS with Time-Series Data

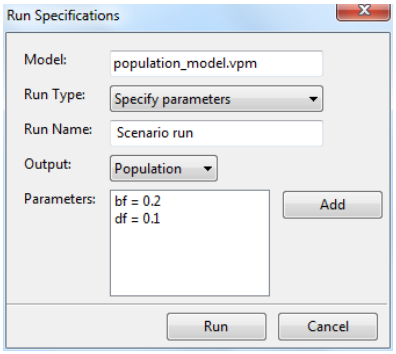
- Main unit of analysis is time-series data
- Imports time-series data by various methods
- Provides pattern related statistical properties and descriptive information
- Classifies/labels imported behavior using an advanced pattern classification algorithm

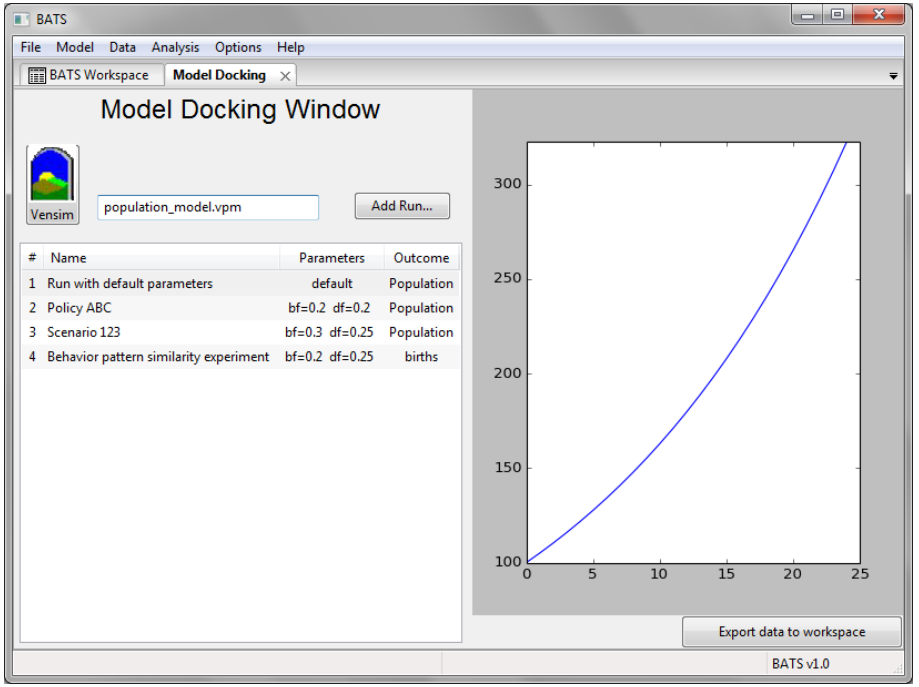


Name	Description	Source	Length	Class	Min	Max	Mean	Var
Population	HT:normal bf = 0.0	density_dependent_growth.vpm	300	nexdc	3.023e-07	20	1.141	10.45
X	MD: An experiment alpha=0.18	predator_prey.vpm	201	oscct	155.7	252	201.2	1184
y1: nexgr	Data from excel file	ists_examples.xls	120	nexgr	0.002158	1.005	0.897	0.04533
y2: sshgr	Data from excel file	ists_examples.xls	120	sshgr	-0.009058	0.9995	0.504	0.1729
y3: gr2da	Data from excel file	ists_examples.xls	120	gr2da	-0.005268	0.9928	0.522	0.1329
Real	Data from txt file	MyRealData.txt	100	none	-1.705	17.55	5.771	8.404
Data1	Data from excel file	Example1.xls	100	oscct	-4.523	3.158	0.0363	2.753
Data2	Data from excel file	Example1.xls	100	none	1.7	100	50.54	824.5
Stock	Data from excel file	stella_stock_output.xlsx	49	nexgr	0	182.9	125	2690
Draw	Data from drawer	User	30	sshdc	0.005597	0.9944	0.4752	0.1407

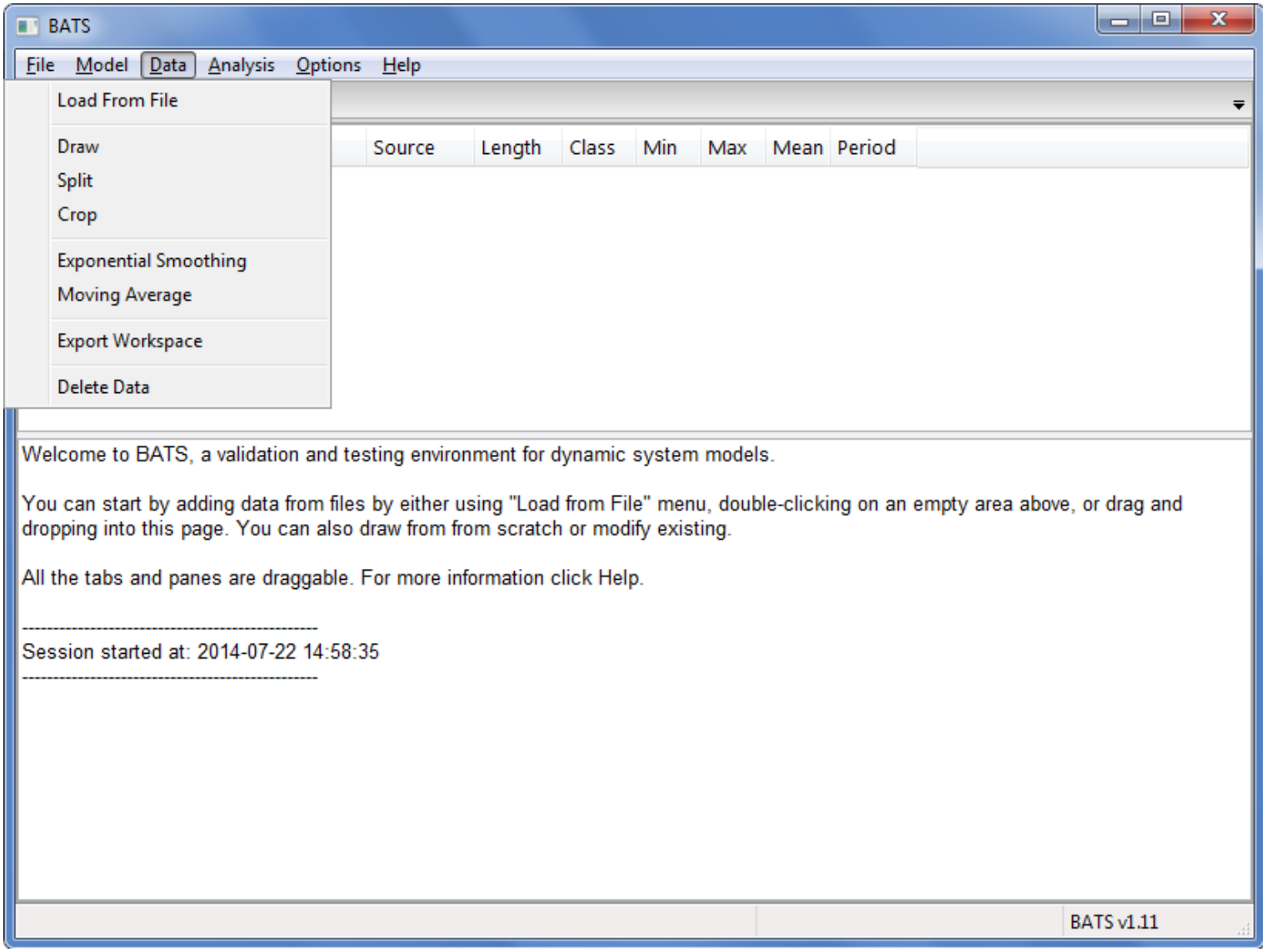
Data Importing Methods

- Excel
- txt, csv, tab
- Drawn by the *user*
- Vensim results files (.vdf)
- Vensim models through Model Docking Window





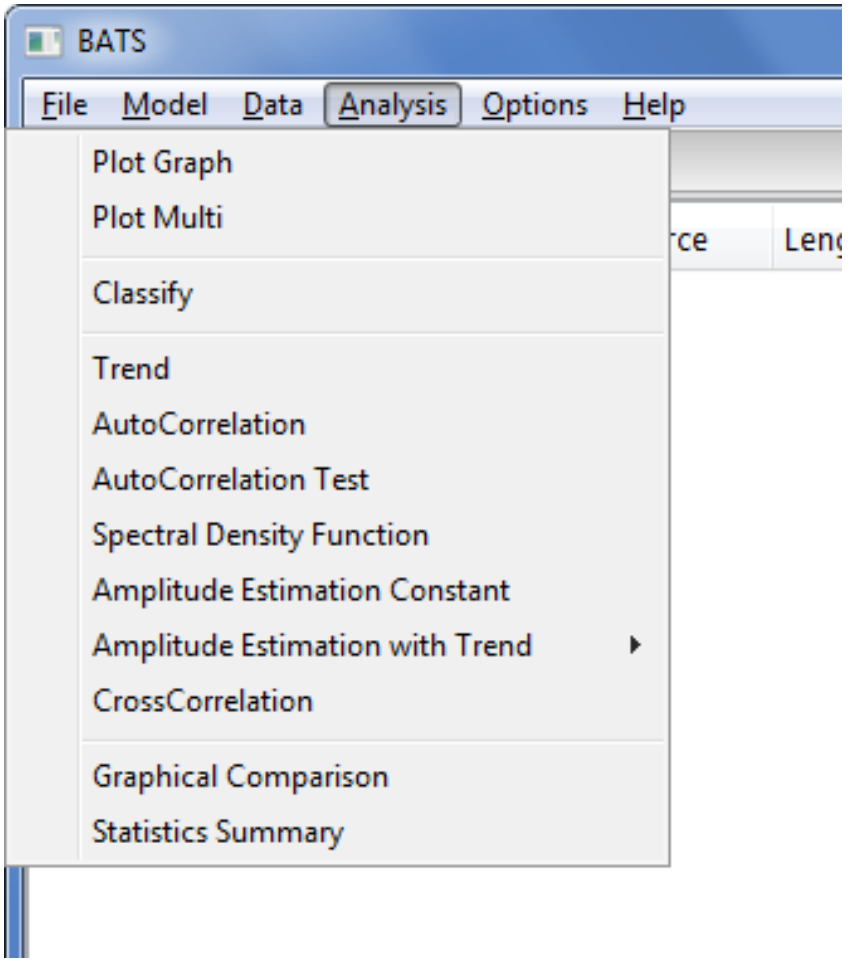
Time-Series Data Preparation Features



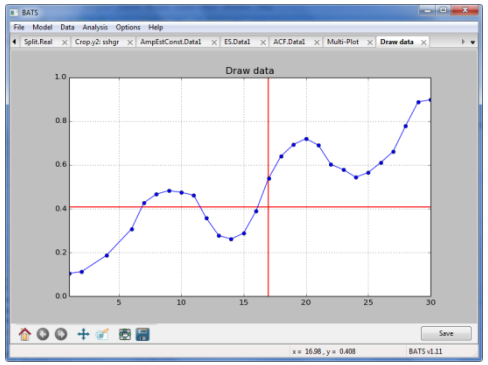
Time-Series Comparison Features

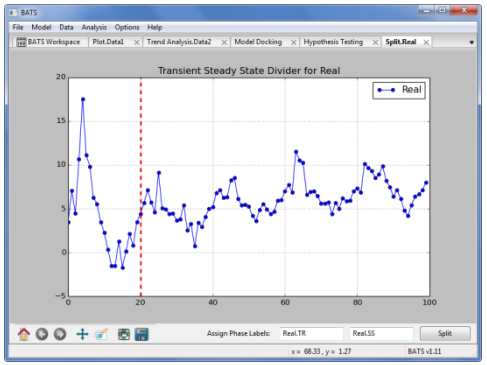
Barlas, 1996

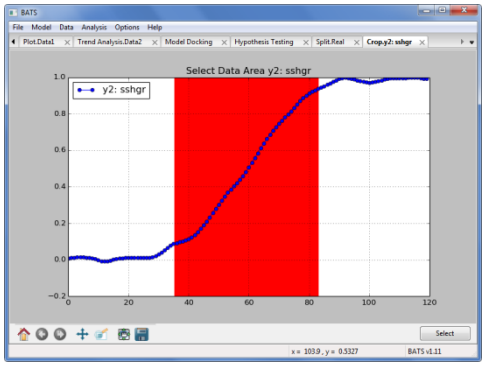
- Trend regression
- Autocorrelation
- Autocorrelation test
- Spectral densities
- Mean and variance
- Amplitude estimation
- Crosscorrelation
- U, MSE, discrepency coefficient
- Graphical comparison

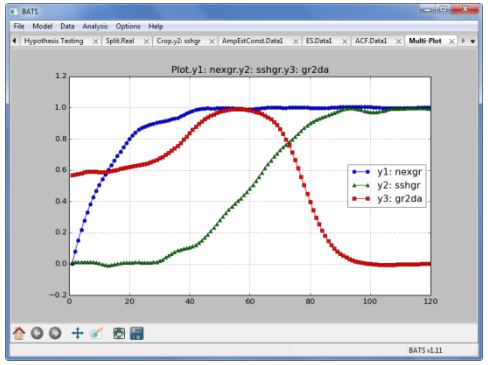


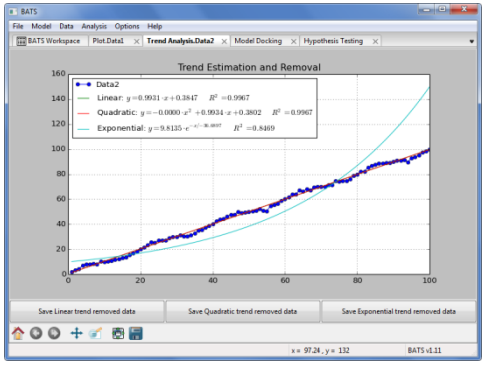
BATS with Time-Series Gallery

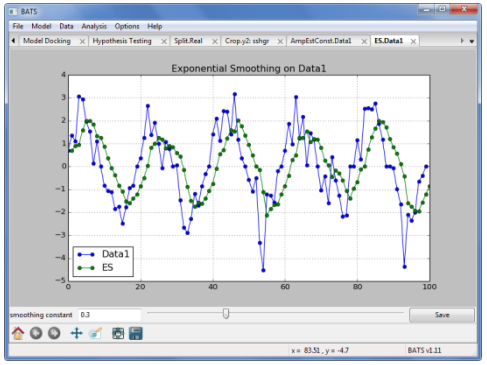


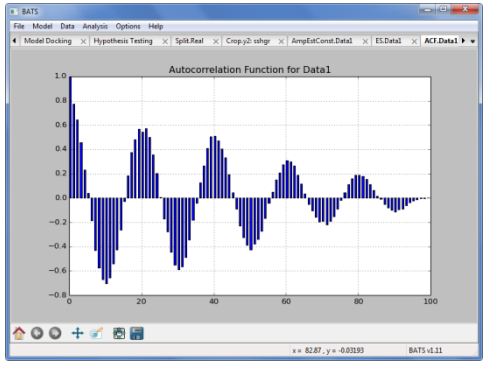


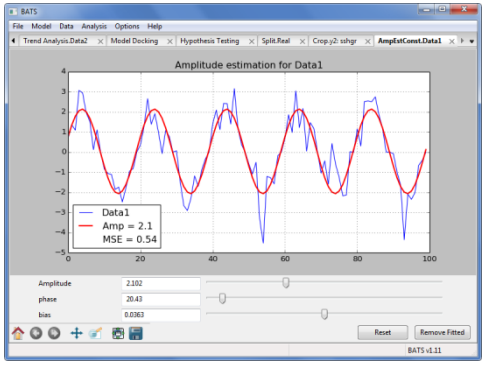


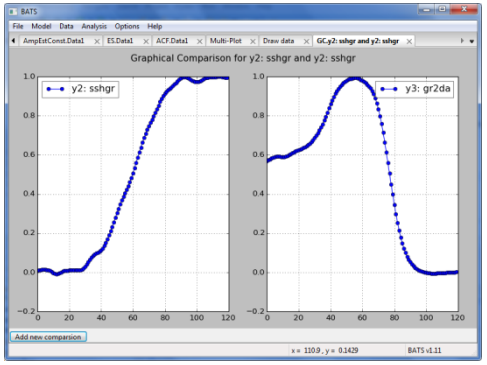




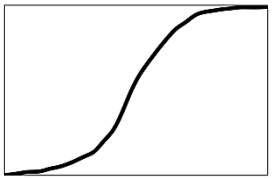








Pattern Classification Using ISTS Algorithm



input

time-series data

ISTS Algorithm

output

behavior class

i.e. generic dynamic pattern

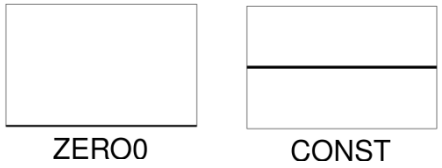
SSHGR

S-Shaped Growth

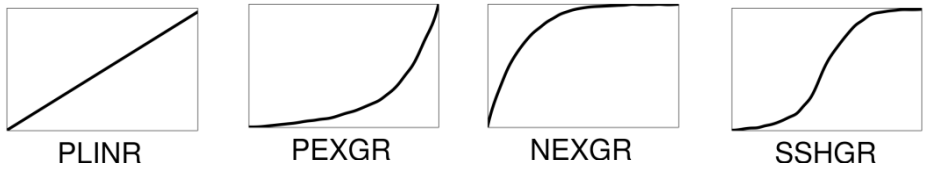
Developed by (Kanar, 1999)
Used in Barlas and Kanar, 1999; Bog and Barlas, 2005; Yücel and Barlas, 2011

Generic Dynamic Patterns

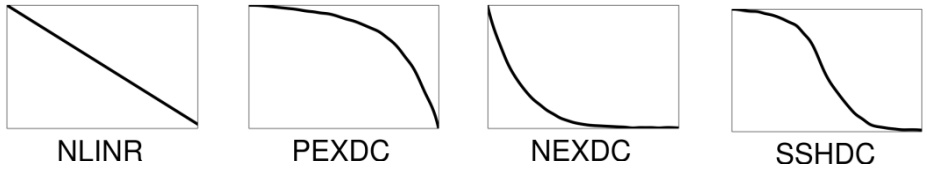
Constant



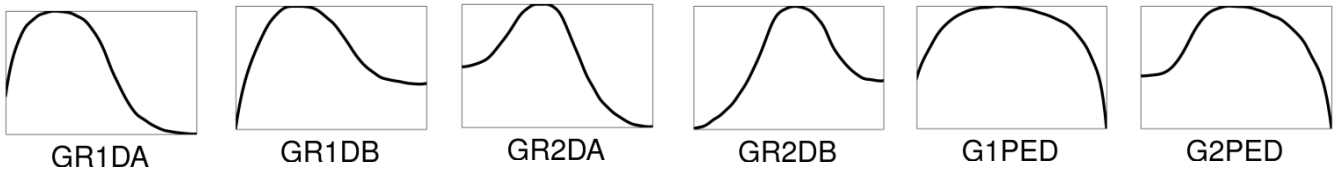
Growth



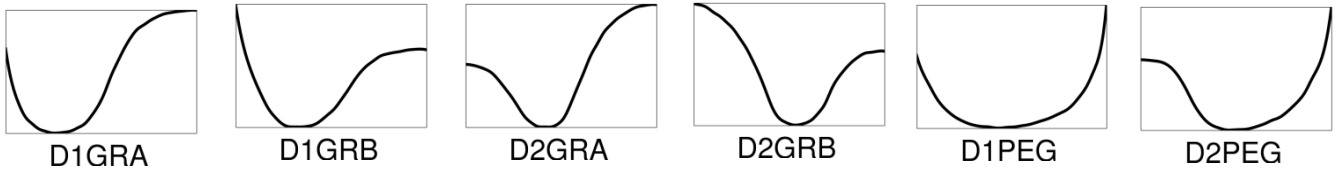
Decline



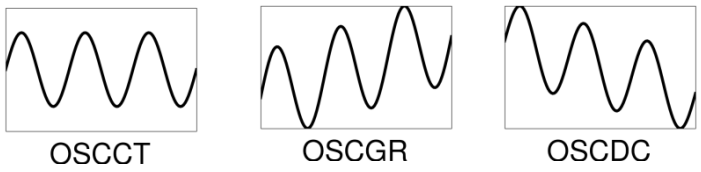
Growth-and-decline



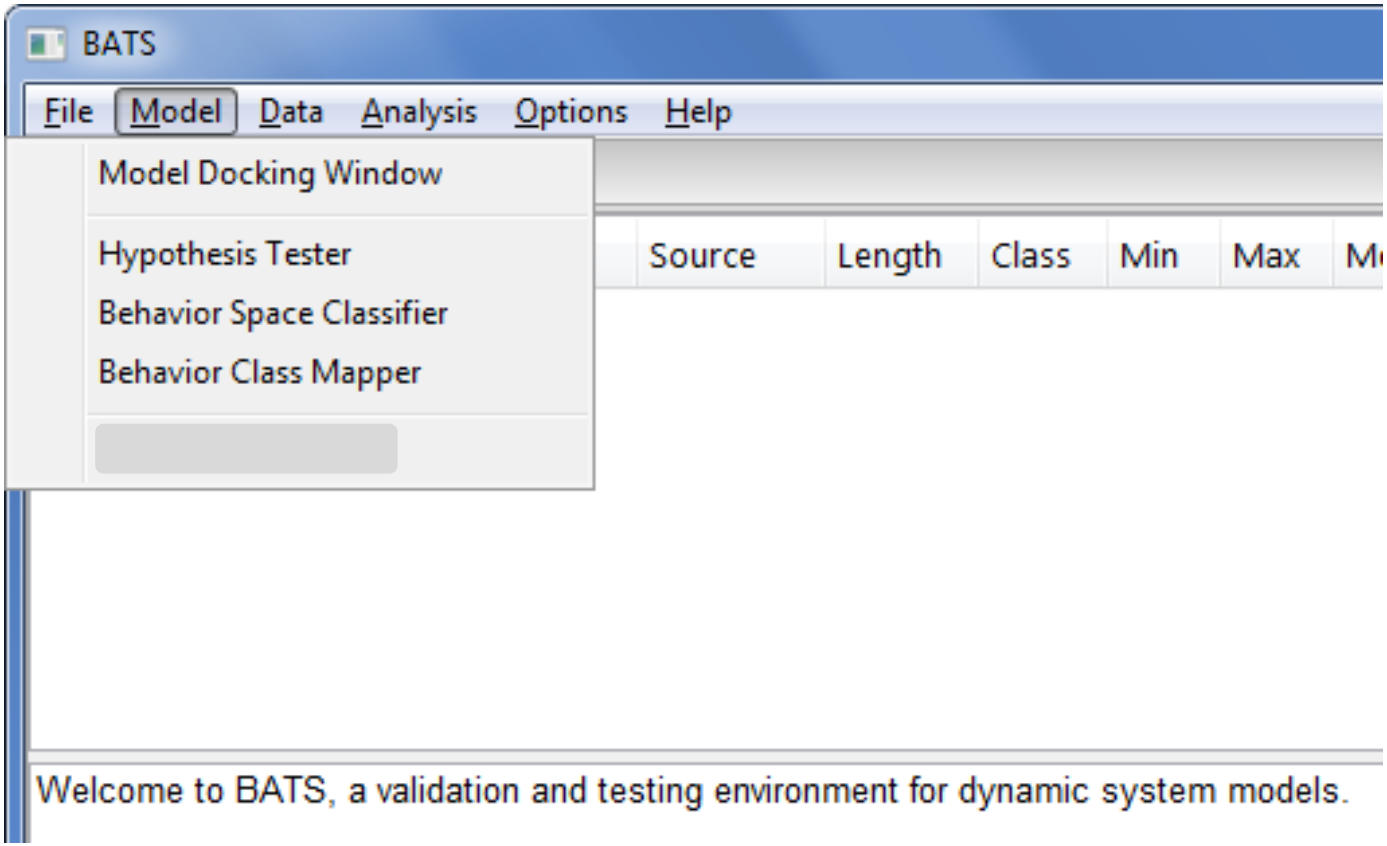
Decline-and-growth



Oscillatory



BATS with Vensim Models

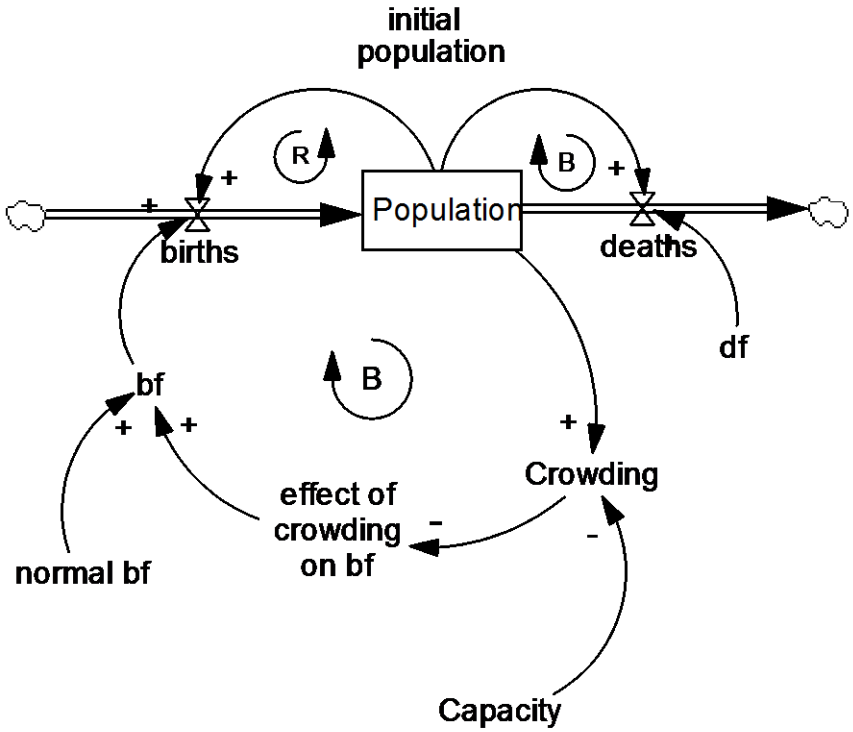


Hypothesis Tester

Allows for performing automated hypothesis testing on the model behavior.

Conditions are defined by setting specific values to parameters.

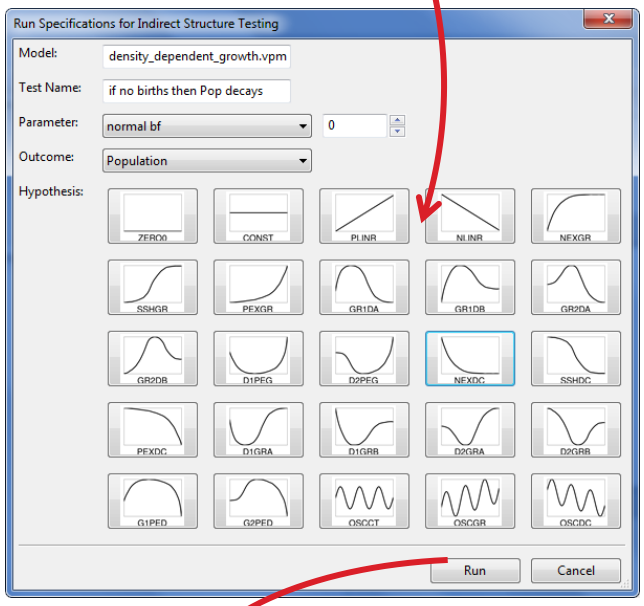
Typically can be used for Extreme Condition Tests for structure validity (Barlas, 1996)

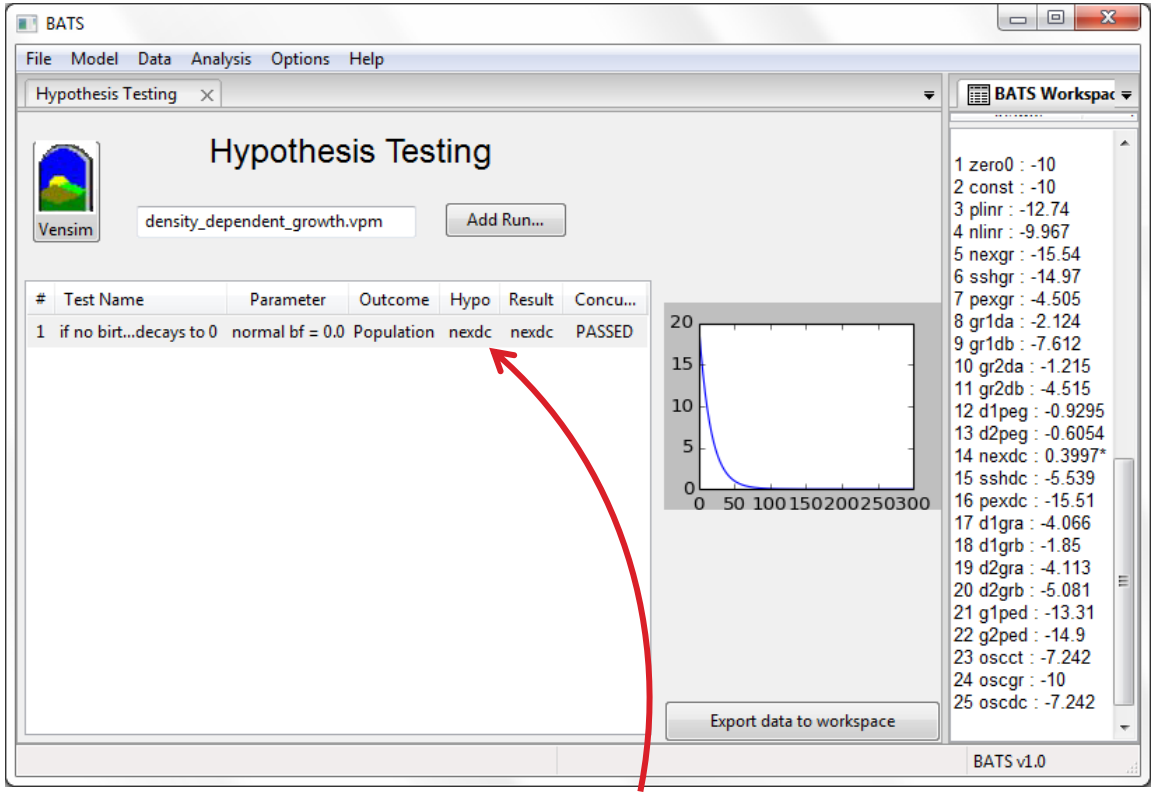


Example: in density-dependent-growth model, if the birth rates become zero, then the population goes to extinction (decay to zero)

Hypothesis Tester

Extreme conditions are imposed by setting parameter values

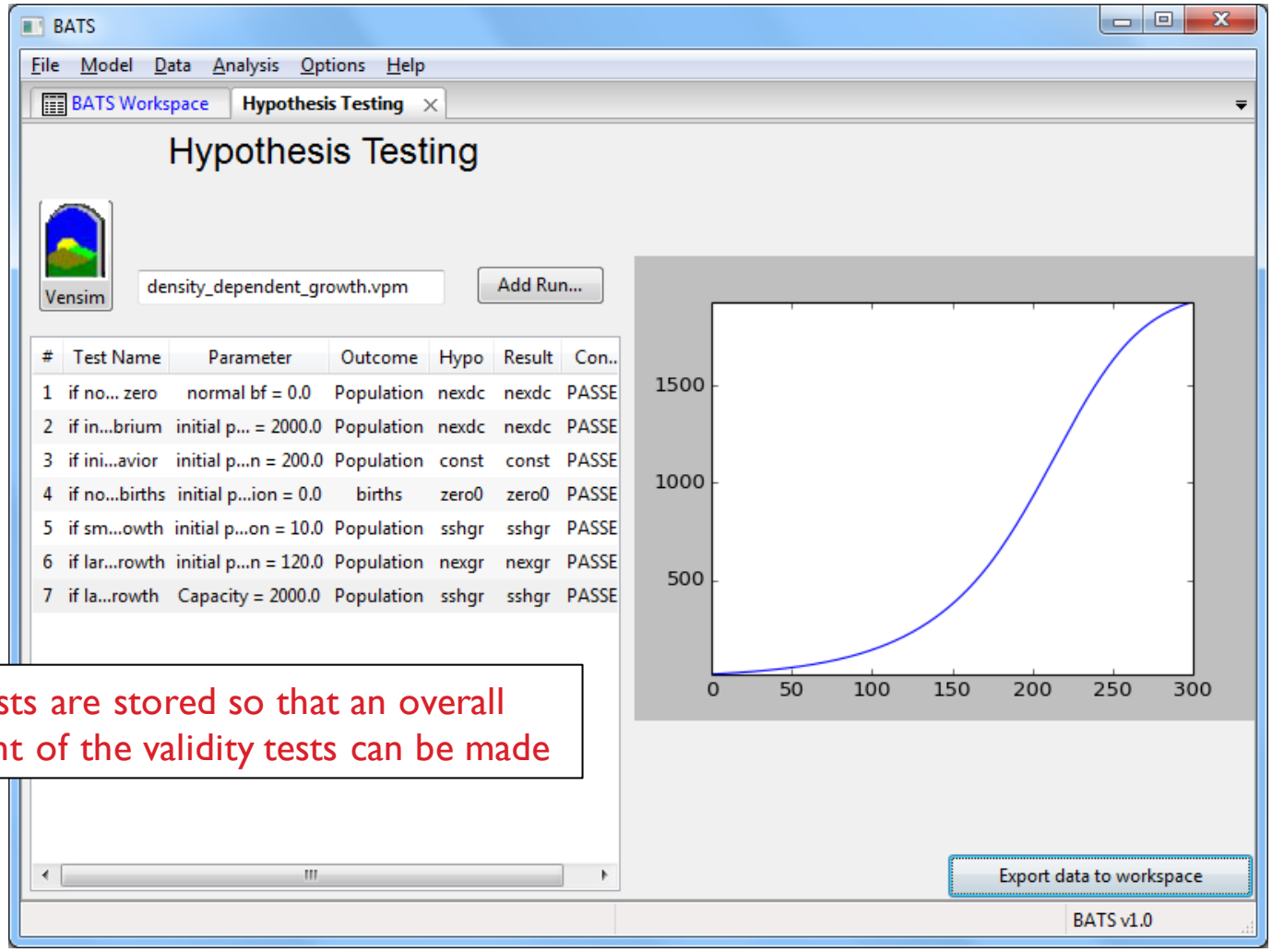




Model is run and output is obtained → ISTS Algorithm is called and likelihoods are calculated →

- IF hypothesized behavior <-3 THEN FAILED
- IF hypothesized behavior >-3 THEN PASSED
- IF hypothesized behavior >-3 AND another behavior is larger THEN INCONCLUSIVE

Hypothesis Tester

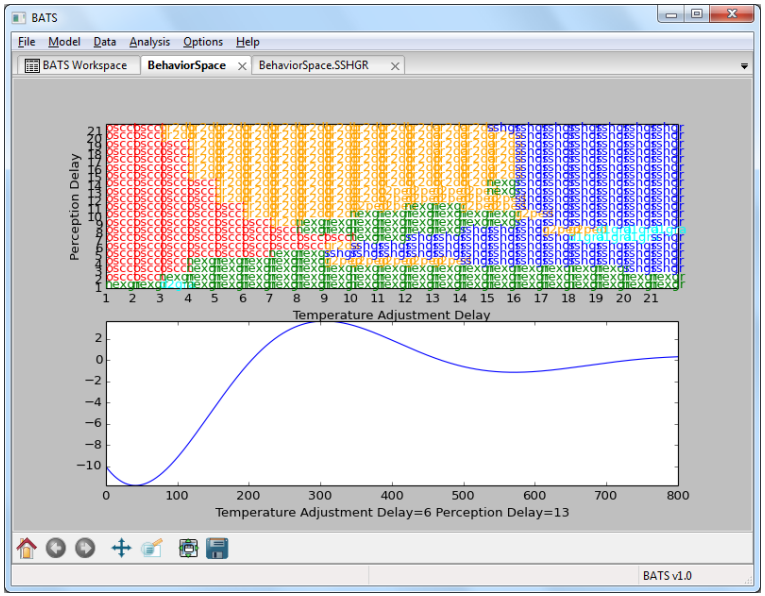


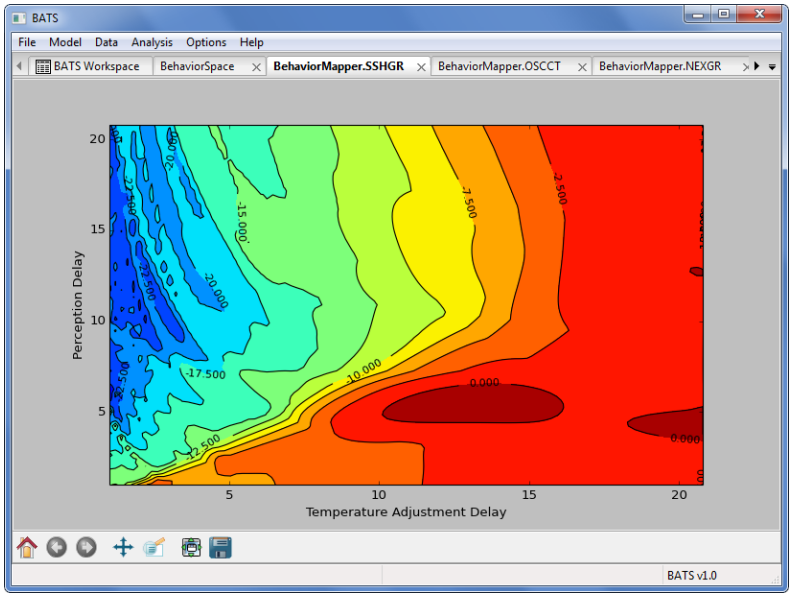
All the tests are stored so that an overall assessment of the validity tests can be made

Behavior Space Classifier

&

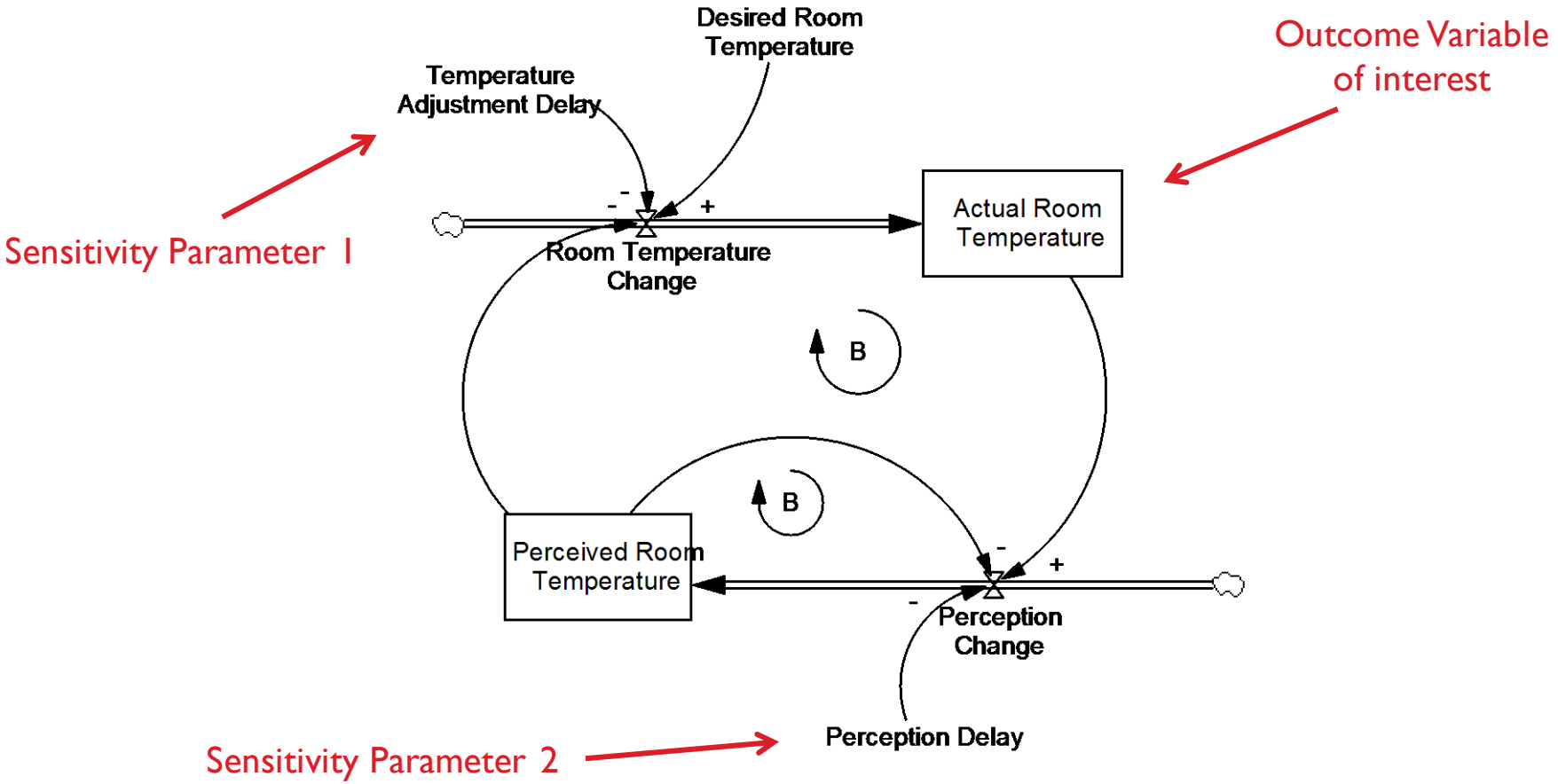
Behavior Class Mapper





Temperature Adjustment Model

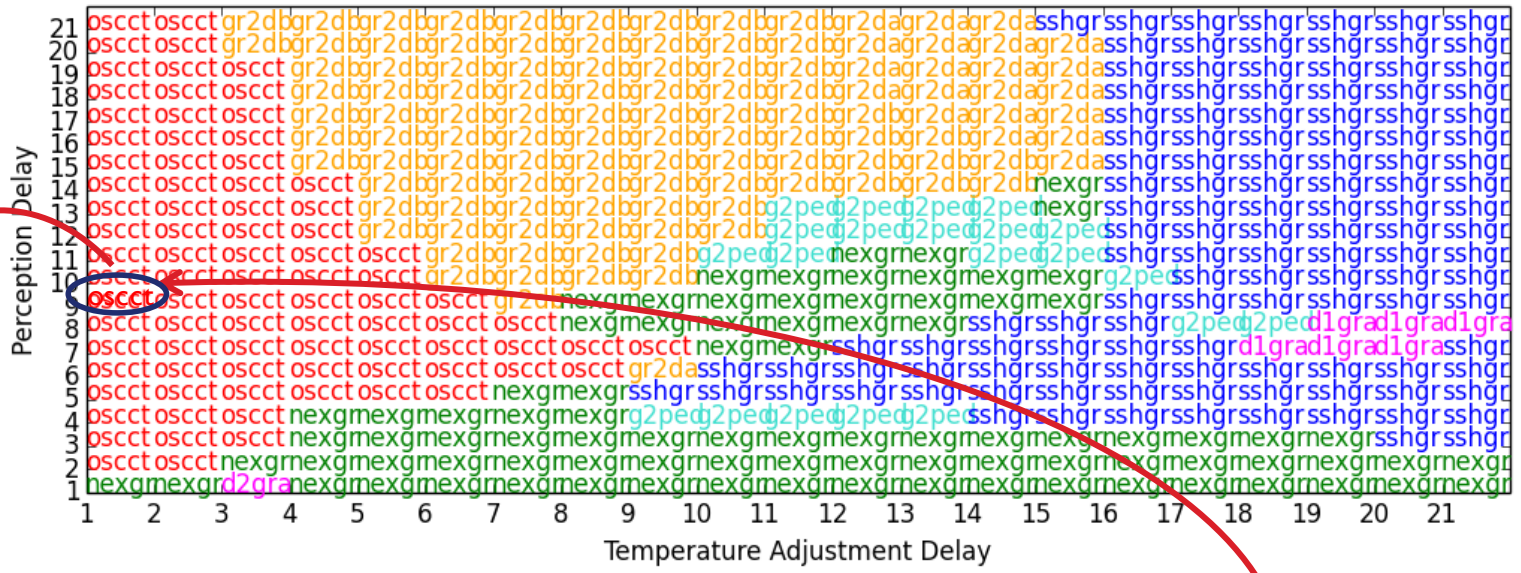
Model that is used for demonstration of **Behavior Space Classifier** and **Behavior Class Mapper**



Behavior Space Classifier

Actual Room Temperature

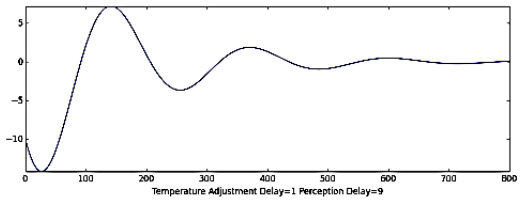
Classifier Grid



Each cell on the classifier grid corresponds to one simulation run

Param1=1
Param2=9

Model output is automatically taken from Vensim



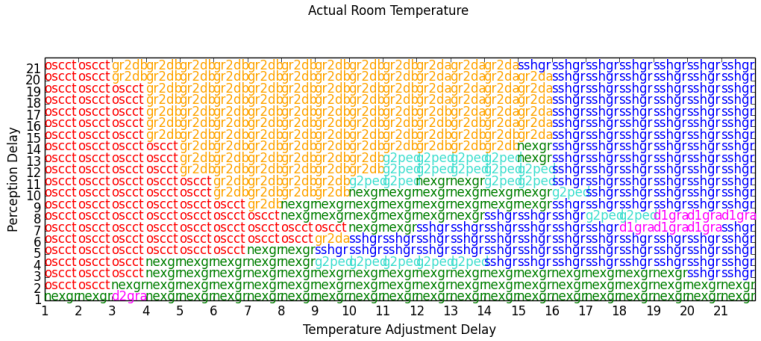
ISTS Algorithm is called

Behavior class of the run is determined

Class label is written on the grid

oscct

Behavior Space Classifier

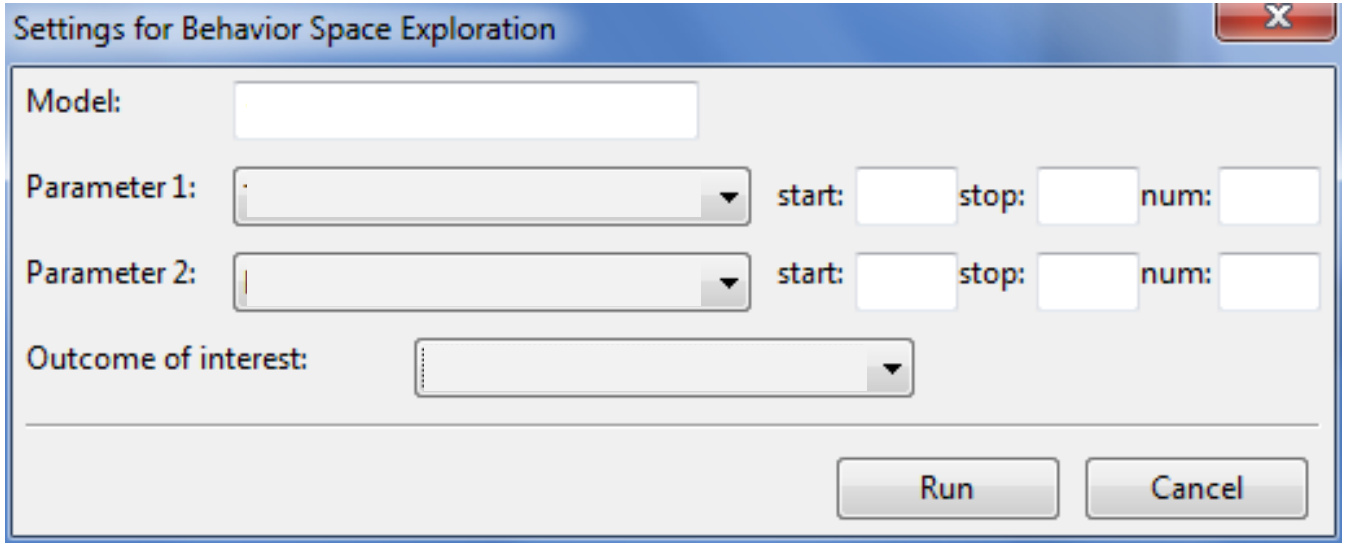


- Behavior pattern sensitivity with respect to changes in parameters
- Colors have categorical meaning, different colors imply different classes

- Usage alternatives:
  - **Sensitivity analysis:** How does the behavior mode of my model change as a result of parameter changes
  - **Model Calibration:** Suppose that the real data imply that the model behavior should be s-shaped growth
  - **Policy Analysis and Design:** My policy objective is to avoid oscillations, which parameter region is more desirable? (regard them as policy decision parameters)

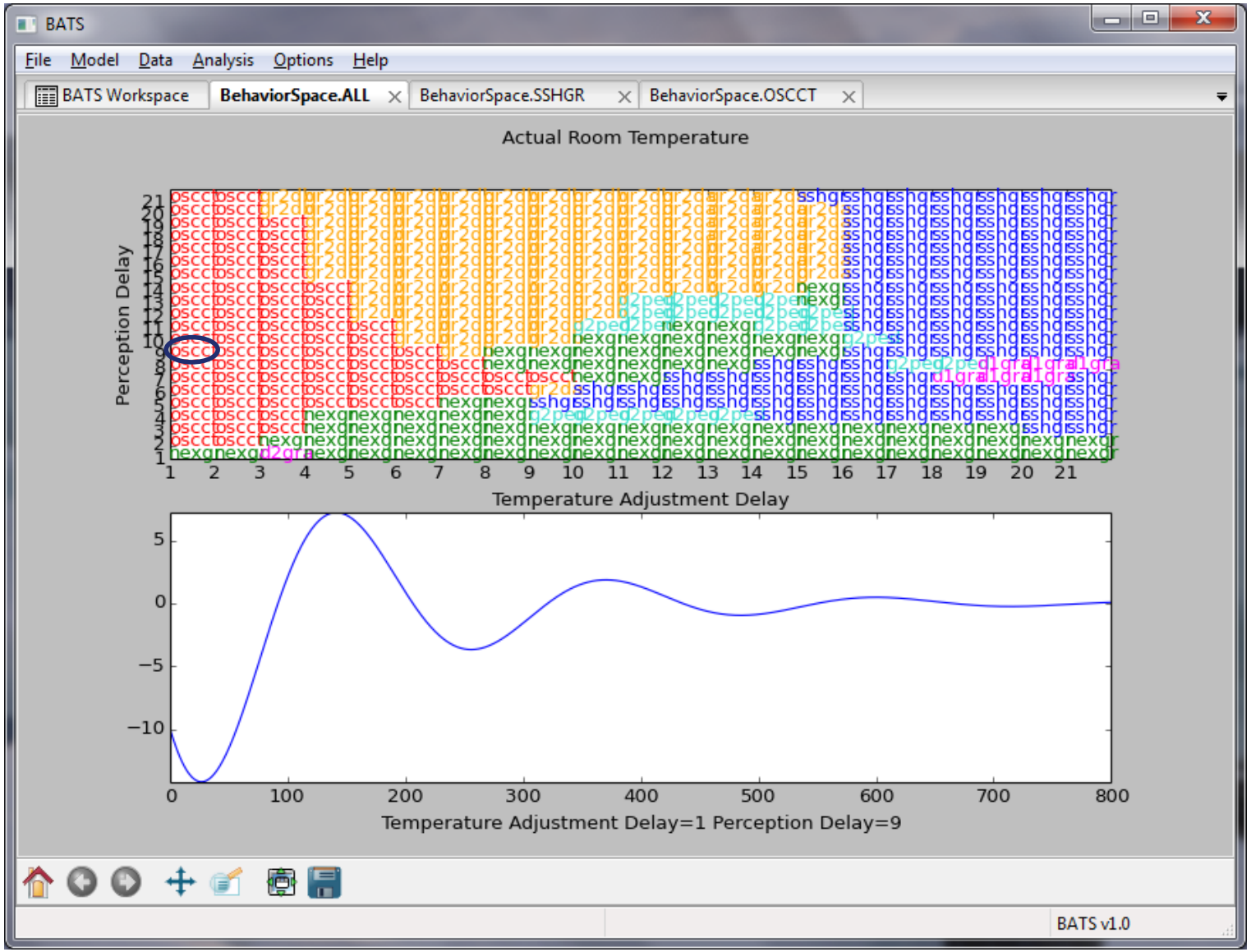
Behavior Space Classifier

Settings



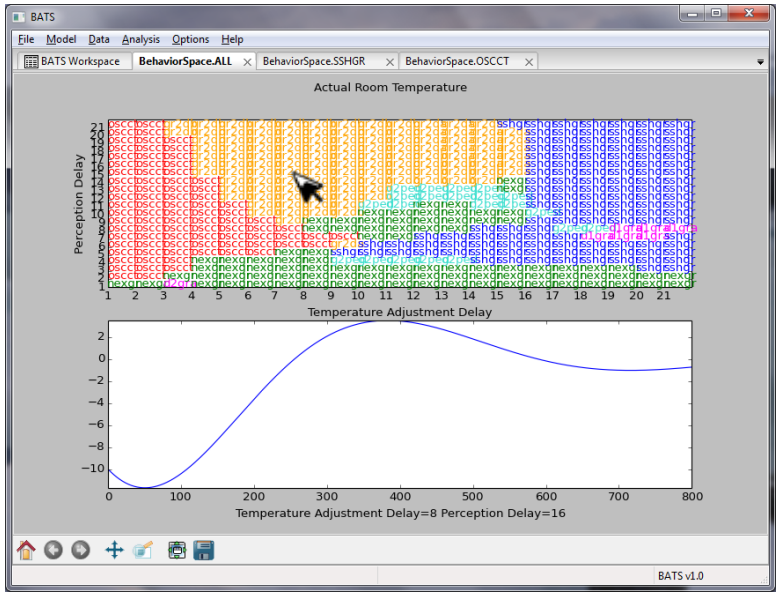
Behavior Space Classifier

Results

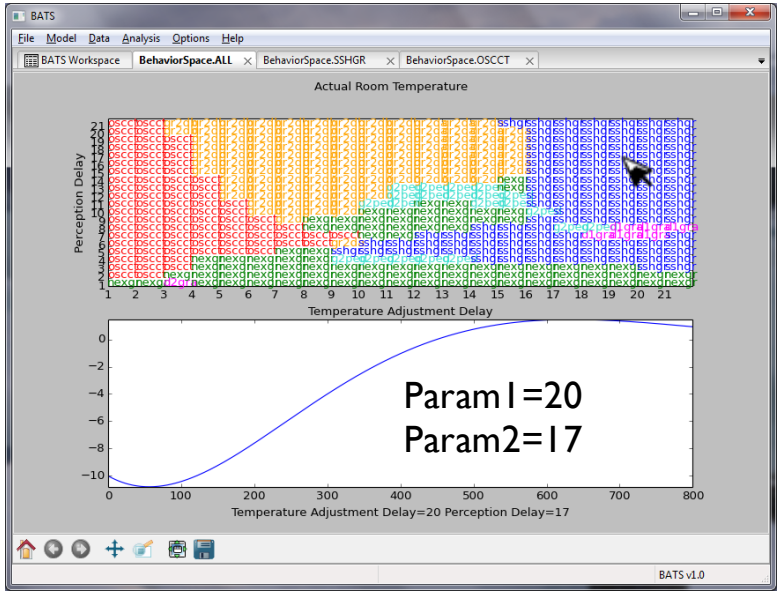


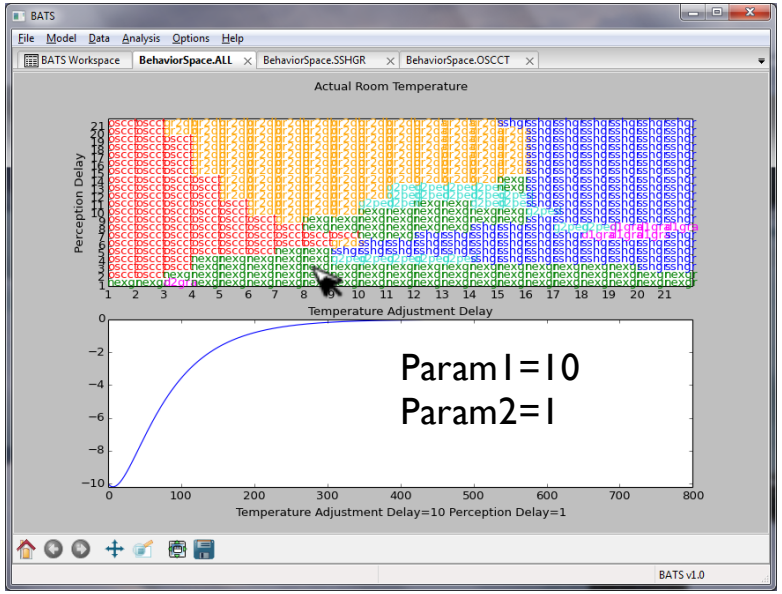
Behavior Space Classifier

Bottom plot is dynamic!



Param1=8
Param2=16

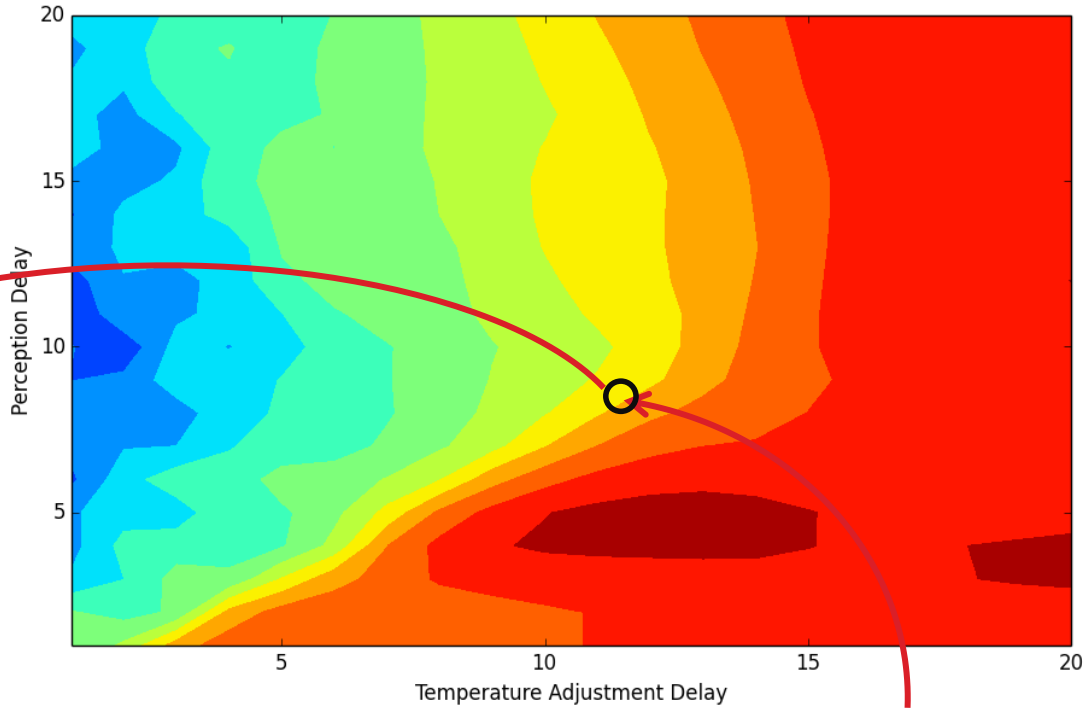




Behavior Class Mapper

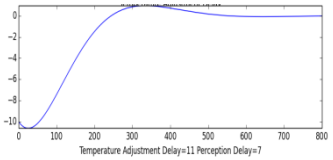
Pre-specified class is **sshgr** (s-shaped-growth)

Behavior Class Map



Each point corresponds to one simulation run

Model output is taken from Vensim



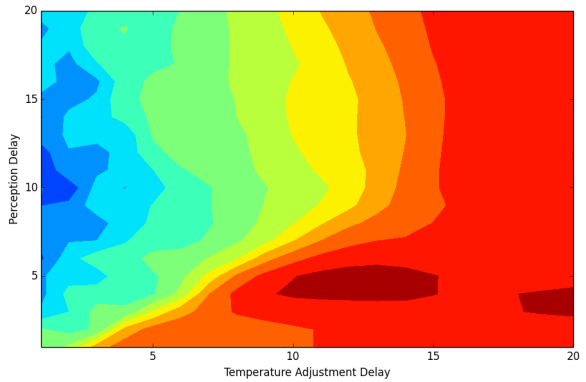
Param1=8
Param2=16

ISTS Algorithm is called

The **likelihood for pre-specified** class is plotted on the graph as a **numeric value**

-3.99

Behavior Class Mapper

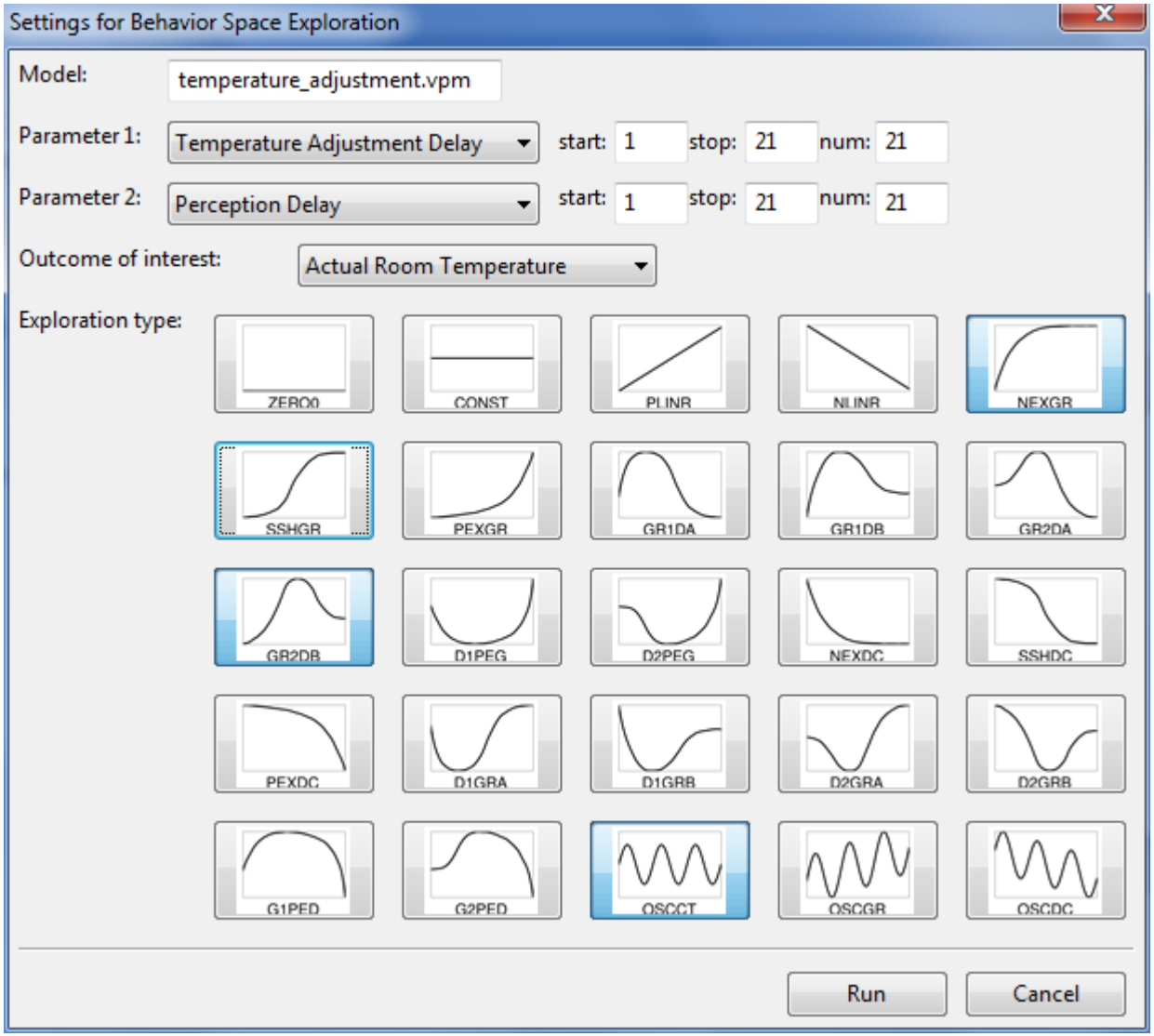


- Intermediate values are interpolated and a contour-plot is displayed
- Colors have numerical meaning, darker colors imply higher likelihoods

- Specific behavior class sensitivity with respect to changes in parameters
- Usage alternatives:
  - **Sensitivity analysis:** How does the behavior of my model changes as a result of parameter changes
  - **Model Calibration:** Suppose that the real data imply that the model behavior should be s-shaped growth (set the parameters in the dark region)
  - **Policy Analysis and Design:** My policy objective is to avoid oscillations, which parameter region is more desirable?

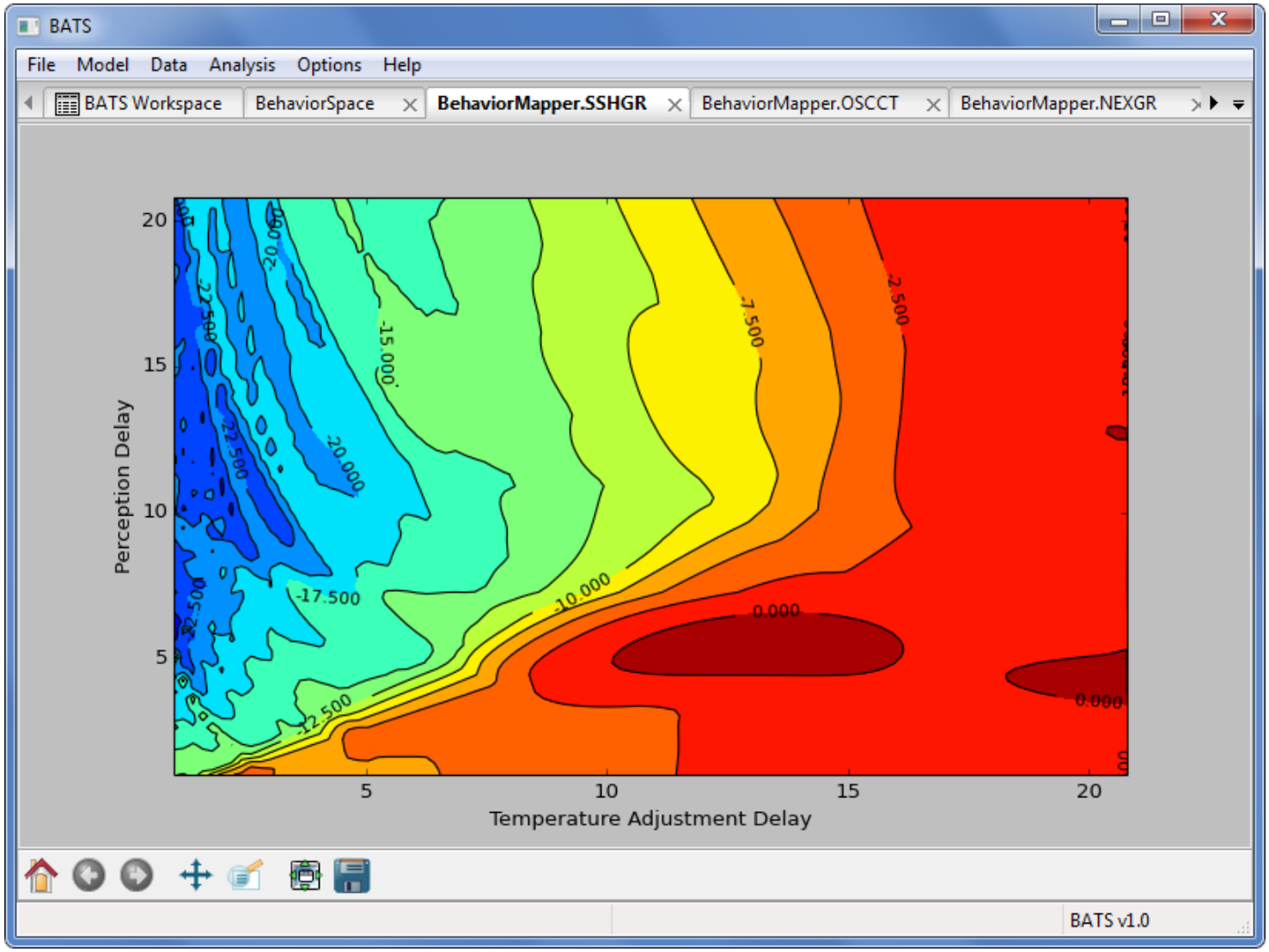
Behavior Class Mapper

Settings

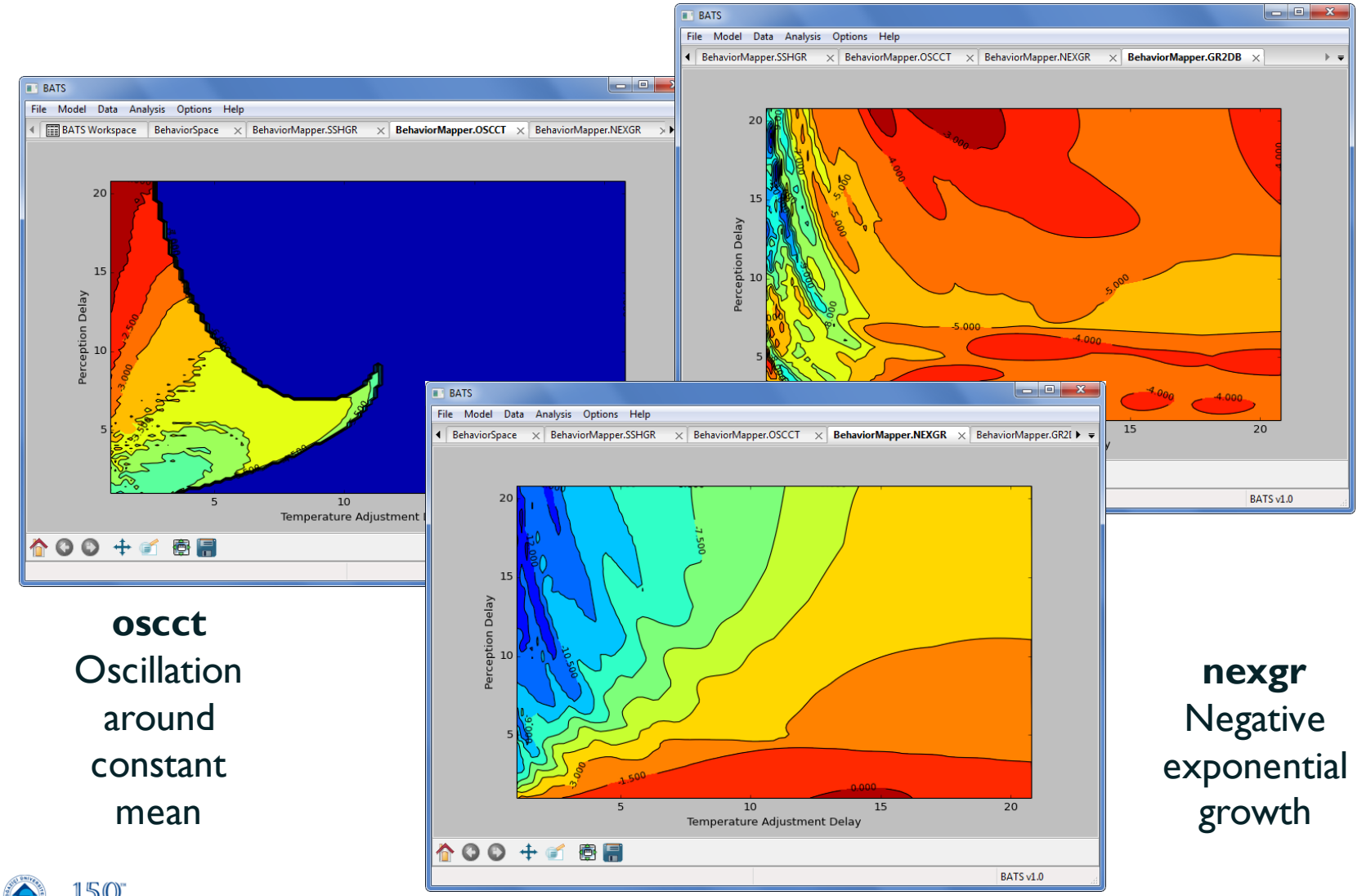


Behavior Class Mapper

Results



Behavior Class Mapper (different behavior modes)

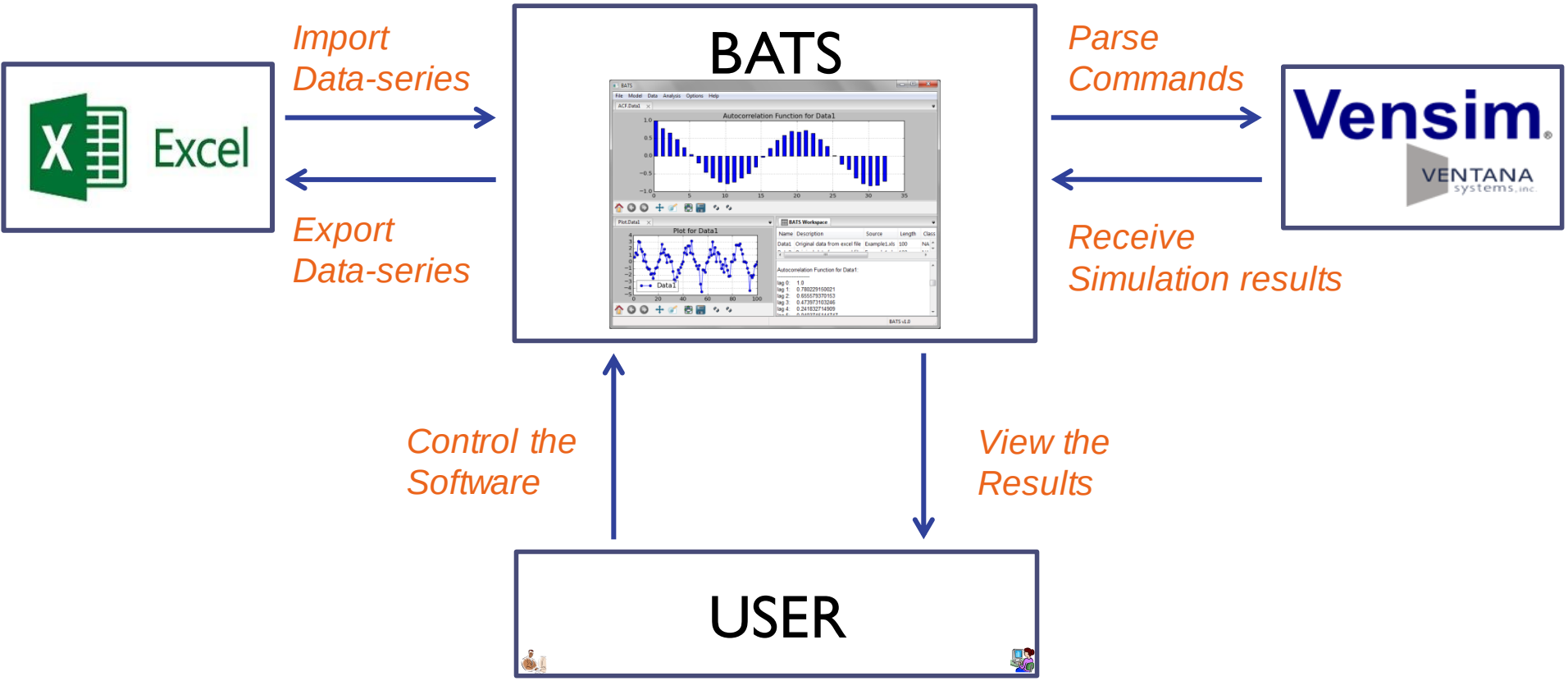


gr2db
Growth and decline

oscct
Oscillation around constant mean

nexgr
Negative exponential growth

Overview of BATS with External Parties



Overview of Features of BATS

Data Importing
- Load From File
- Model Docking Window
- Draw

Data Preparation
- Split
- Select
- Exponential Smoothing
- Moving Average
- < Trend >

Data Visualization
- Plot

Data Analysis
- Classify
- Trend
- Autocorrelation
- Autocorrelation Test
- Spectral Density
- Amplitude Estimation
- Crosscorrelation
- Summary Stats
- Graphical Comparison

Model Analysis
- * Hypothesis Tester
- * Behavior Space Classifier
- * Behavior Class Mapper

Identified Usage Modes

1. Structure-oriented behavior validity testing
    - Extreme condition tests using Hypothesis Tester
2. Behavior pattern validity testing
    - Barlas' Multi-Step procedure and Graphical Inspection
3. Sensitivity analysis
    - Behavior pattern sensitivity with respect to parameter changes
4. Model calibration
    - Parameter calibration based on behavior patterns
5. Policy analysis and design
    - Policy parameter specification based on behavior patterns

Future Work

- New analysis methods/algorithms/procedures can be added into BATS that work with either with
  - time-series (e.g. trend analysis, autocorrelation) or
  - models (e.g. hypothesis tester, behavior space classifier)
- A new pattern clustering algorithm will be included in the upcoming versions
- Collaboration with existing methods by other research groups such as *Statistical Screening* by *Ford and Flynn, 2005*
- More connectivity with modeling software; Vensim on Mac, Stella, Netlogo, Anylogic

Downloads and Feedbacks

- You can find BATS in the following webpage:
  - www.ie.boun.edu.tr/labs/sesdyn/projects/bats/index.html
- Download link:
  - www.ie.boun.edu.tr/labs/sesdyn/projects/bats/bats_v1_11_win.zip

- Also for an hands-on experience you are invited to Model Analysis session tomorrow on Thursday 24th July at 8:30
- Your immediate or later feedback is always welcome

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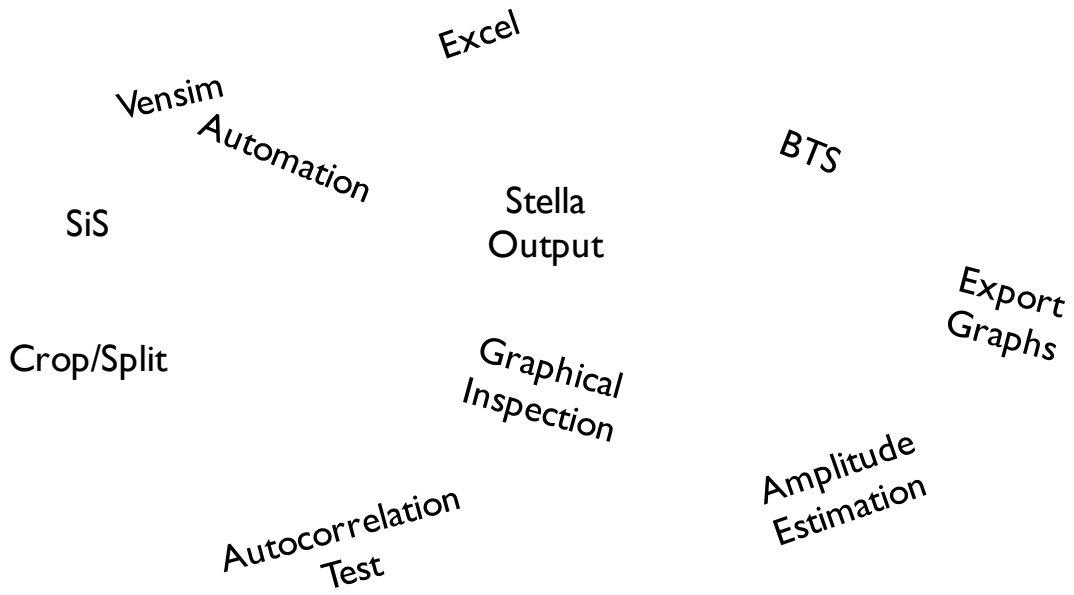
Thanks! Questions and Answers!

Before


Excel
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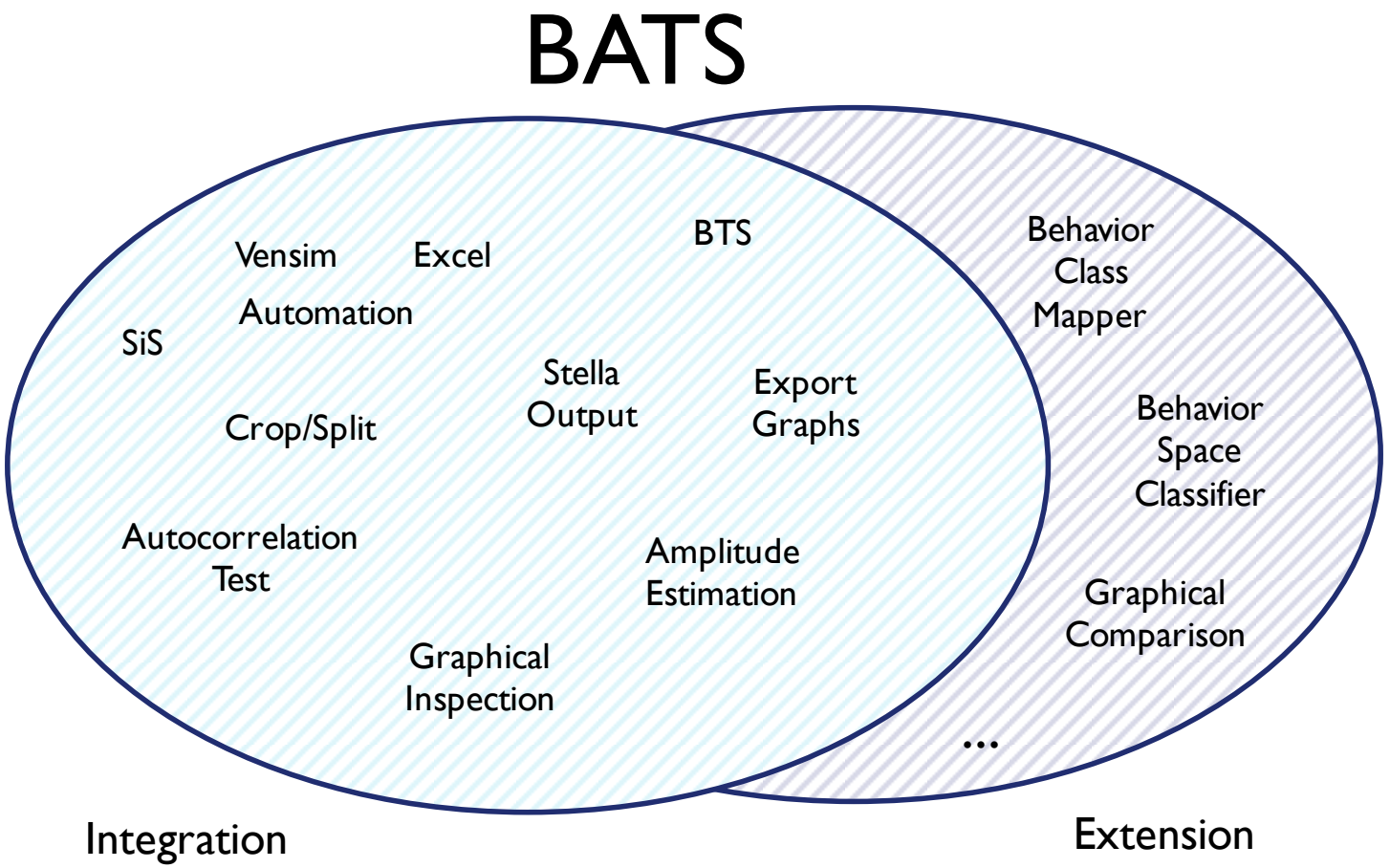
Graphical
Inspection
Amplitude
Estimation
Autocorrelation
Test

After


BATS
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Behavior Class Mapper
Behavior Space Classifier
Graphical Comparison
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Integration
Extension