Enhanced Model Deployment in GAMS

Using R/Shiny to deploy and visualize GAMS models in a Web Interface

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GAMS Software GmbH

Motivation

Motivation

- AMLs are powerful tools for developing solver-independent optimization models

- However, end-users of optimization software are very often not modeling experts
  - → Models should be robust (informative error messages, no infeasibility, …)

- Need for easy-to-use tool to visualize data and compare results

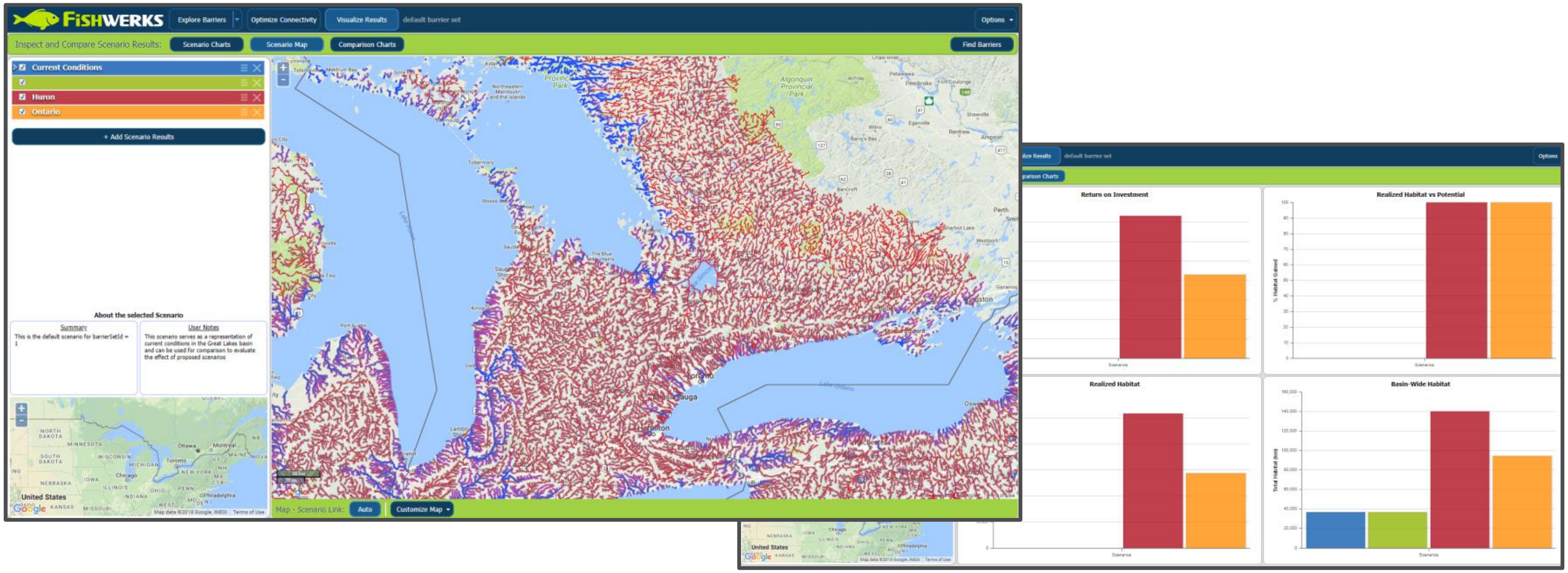
How to address the Need for Visualization?

1. Deployment frameworks like AMPL Quandec, FICO Xpress Insight, IBM Decision Optimization Center, …

   Drawback: High price (costs for these frameworks easily exceed the cost of the modeling system by a factor of 10 to 15)

2. Highly flexible APIs to develop applications (e.g. GAMS comes with several APIs in C++, C#, Java, Python, …)

   Drawback: Requires a lot of programming effort



About the selected Scenario

Summary

This is the default scenario for barrierSetId = 1

User Notes

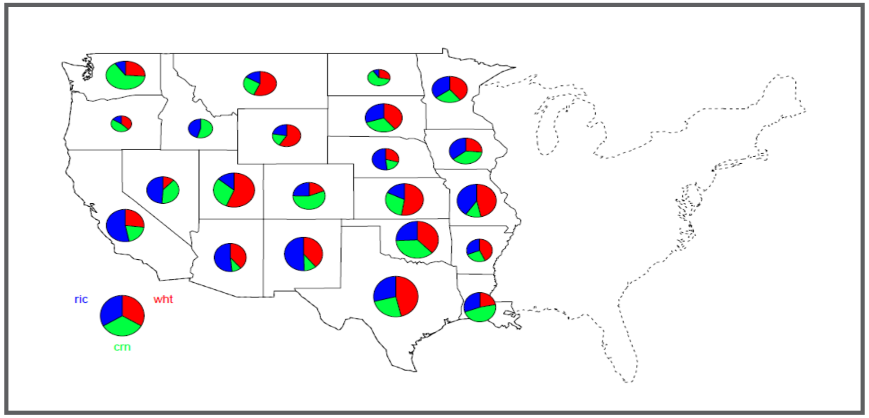
This scenario serves as a representation of current conditions in the Great Lakes basin and can be used for comparison to evaluate the effect of proposed scenarios

Using R/Shiny to deploy GAMS Models

Currently under Development

Background – R

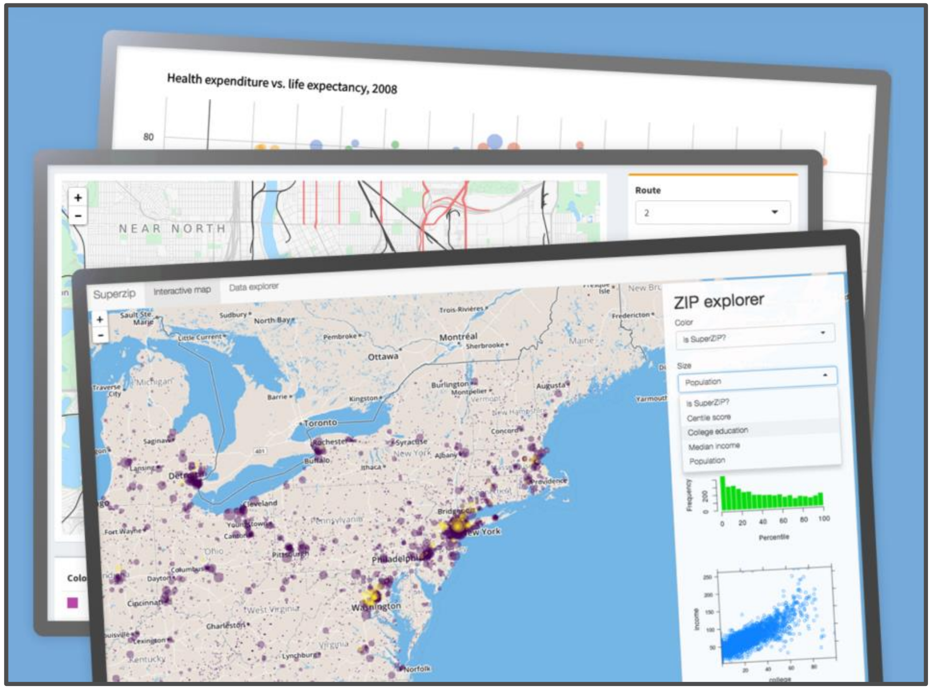
- A language and environment for statistical computing and graphics
- Highly extensible
- Allows to produce well-designed publication-quality plots, including mathematical symbols and formulae
- Runs on Unix, Windows and MacOS
- Available as Free Software under the terms of the Free Software Foundation's GNU General Public License



Source: www.r-project.org

Background – Shiny

- Open source R package to build interactive web applications
- Provides extensive visualization options
- Allows to host standalone apps on a webpage or embed them in R Markdown documents or build dashboards



Source: shiny.rstudio.com

From GAMS Model to Visual User Interface

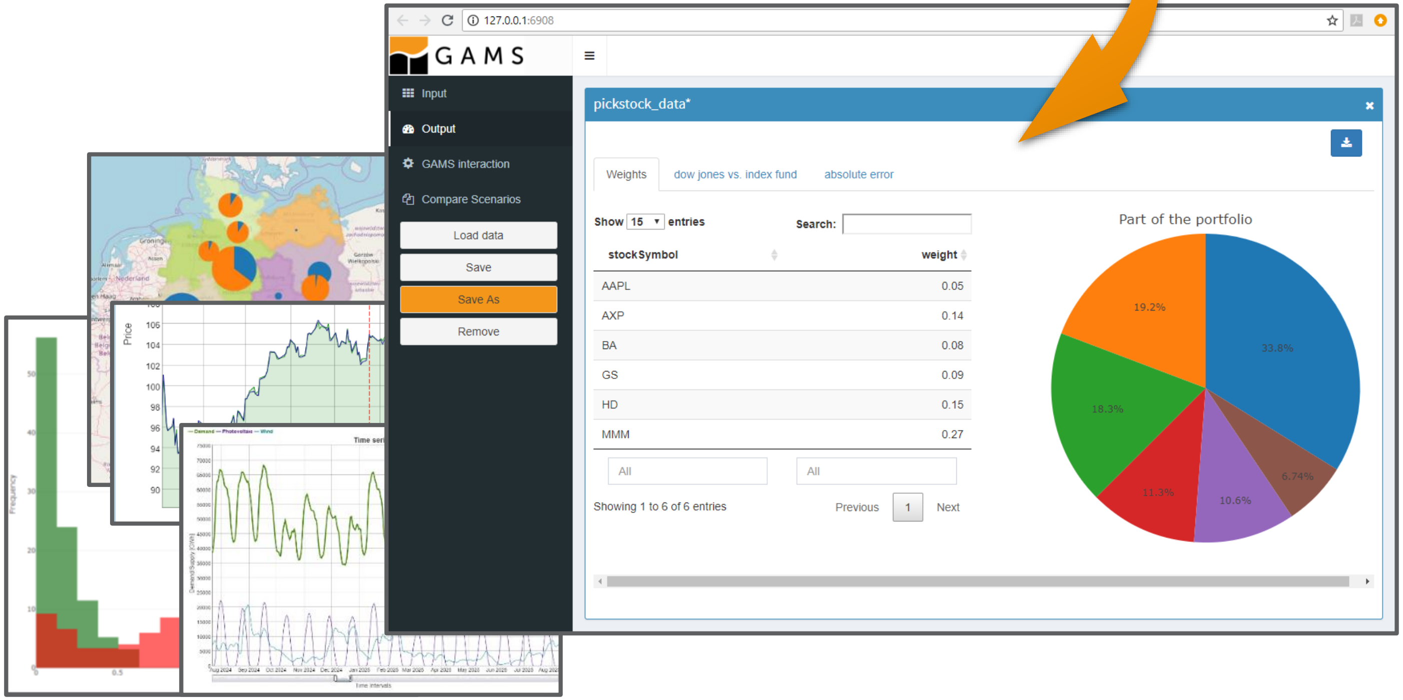
```
Equation
     deffit(date)     'fit to Dow Jones index'
     defpick(symbol) 'can only use stock if picked'
     defnumstock      'few stocks allowed'
     defobj           'absolute violation (L1 norm) from index';

deffit(ds)..  sum(s, price(ds,s)*w(s)) =e= index(ds) + slpos(ds) - slneg(ds);

defpick(s)..  w(s) =l= p(s);

defnumstock.. sum(s, p(s)) =l= maxstock;

defobj..      obj =e= sum(ds, slpos(ds) + slneg(ds));
```



stockSymbol	weight
AAPL	0.05
AXP	0.14
BA	0.08
GS	0.09
HD	0.15
MMM	0.27

Showing 1 to 6 of 6 entries

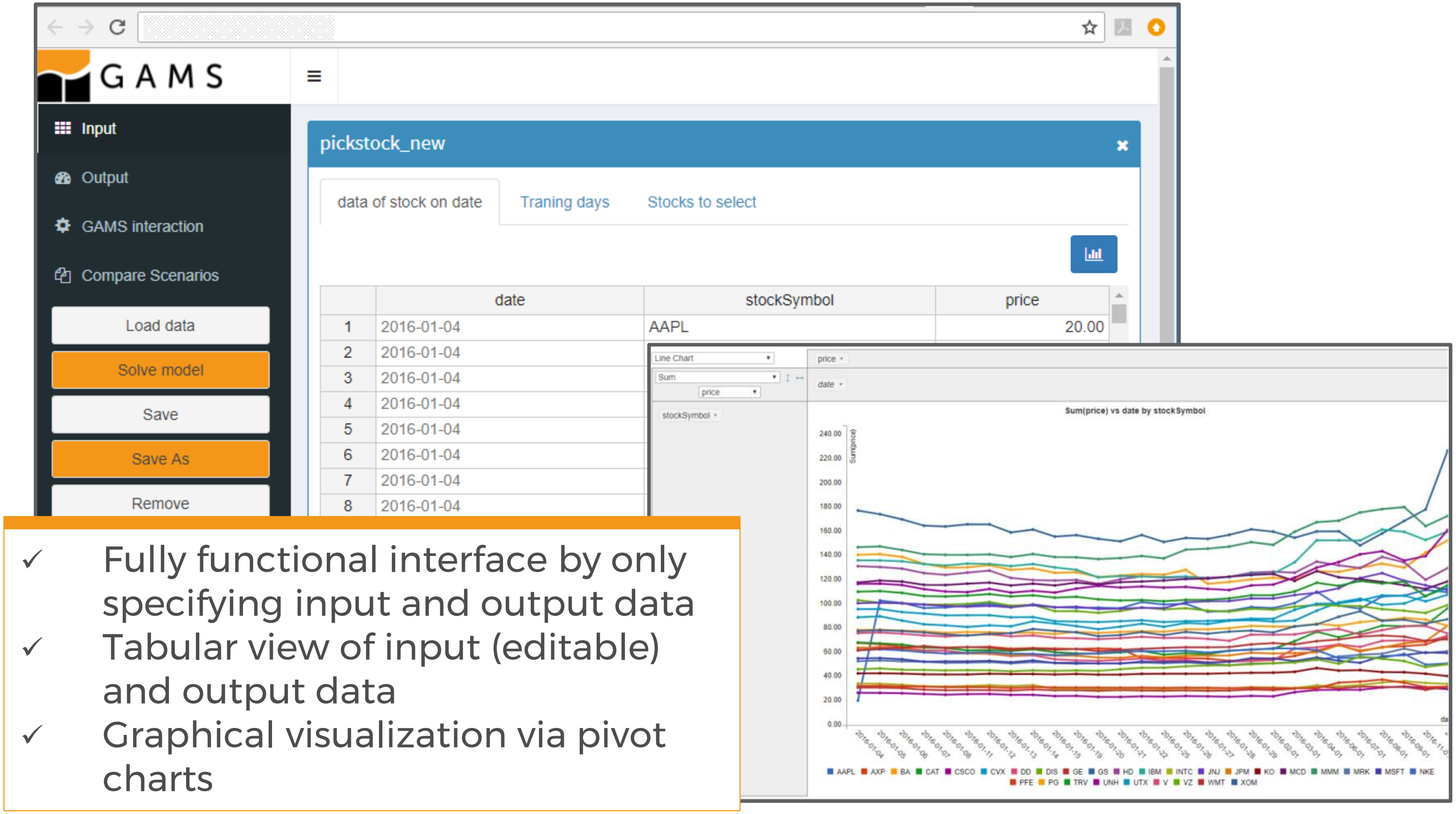
From GAMS Model to Visual User Interface

1

Initialization:

✓ Annotating GAMS model (defining the input and output data to be displayed in the WebUI)

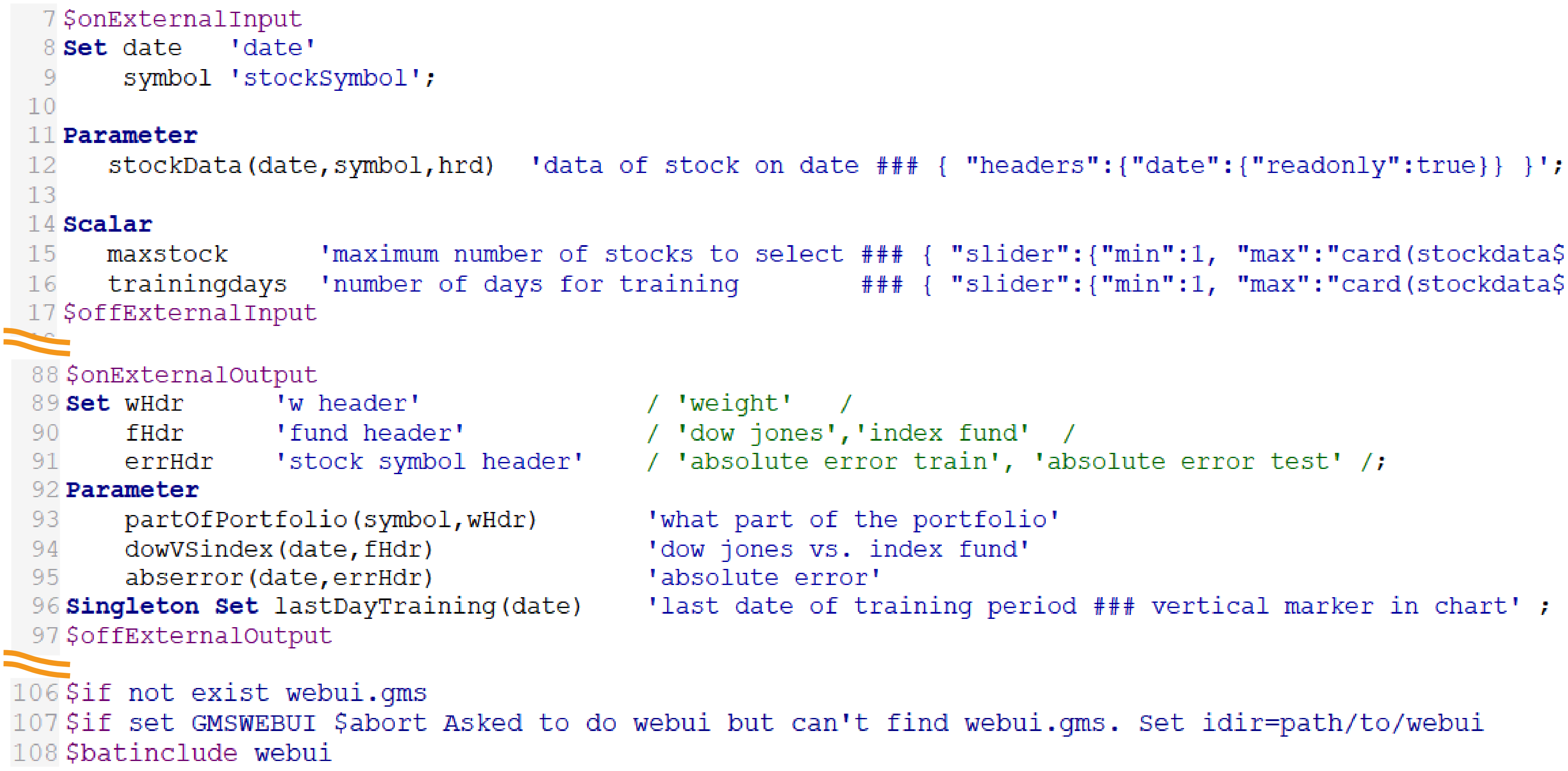
Initialization –
Connection of GAMS and the User Interface



	date	stockSymbol	price
1	2016-01-04	AAPL	20.00
2	2016-01-04		
3	2016-01-04		
4	2016-01-04		
5	2016-01-04		
6	2016-01-04		
7	2016-01-04		
8	2016-01-04		

- ✓ Fully functional interface by only specifying input and output data
- ✓ Tabular view of input (editable) and output data
- ✓ Graphical visualization via pivot charts

Initialization –
Connection of GAMS and the User Interface



```
$onExternalInput
Set date    'date'
    symbol 'stockSymbol';

Parameter
   stockData(date,symbol,hrd)  'data of stock on date ### { "headers":{"date":{"readonly":true}} }';

Scalar
   maxstock      'maximum number of stocks to select ### { "slider":{"min":1, "max":"card(stockdata$
   trainingdays  'number of days for training        ### { "slider":{"min":1, "max":"card(stockdata$
$offExternalInput
```

```
$onExternalOutput
Set wHdr      'w header'             / 'weight'   /
    fHdr      'fund header'          / 'dow jones','index fund'  /
    errHdr    'stock symbol header'  / 'absolute error train', 'absolute error test' /;
Parameter
    partOfPortfolio(symbol,wHdr)     'what part of the portfolio'
    dowVSindex(date,fHdr)            'dow jones vs. index fund'
    abserror(date,errHdr)            'absolute error'
Singleton Set lastDayTraining(date)  'last date of training period ### vertical marker in chart' ;
$offExternalOutput
```

```
$if not exist webui.gms
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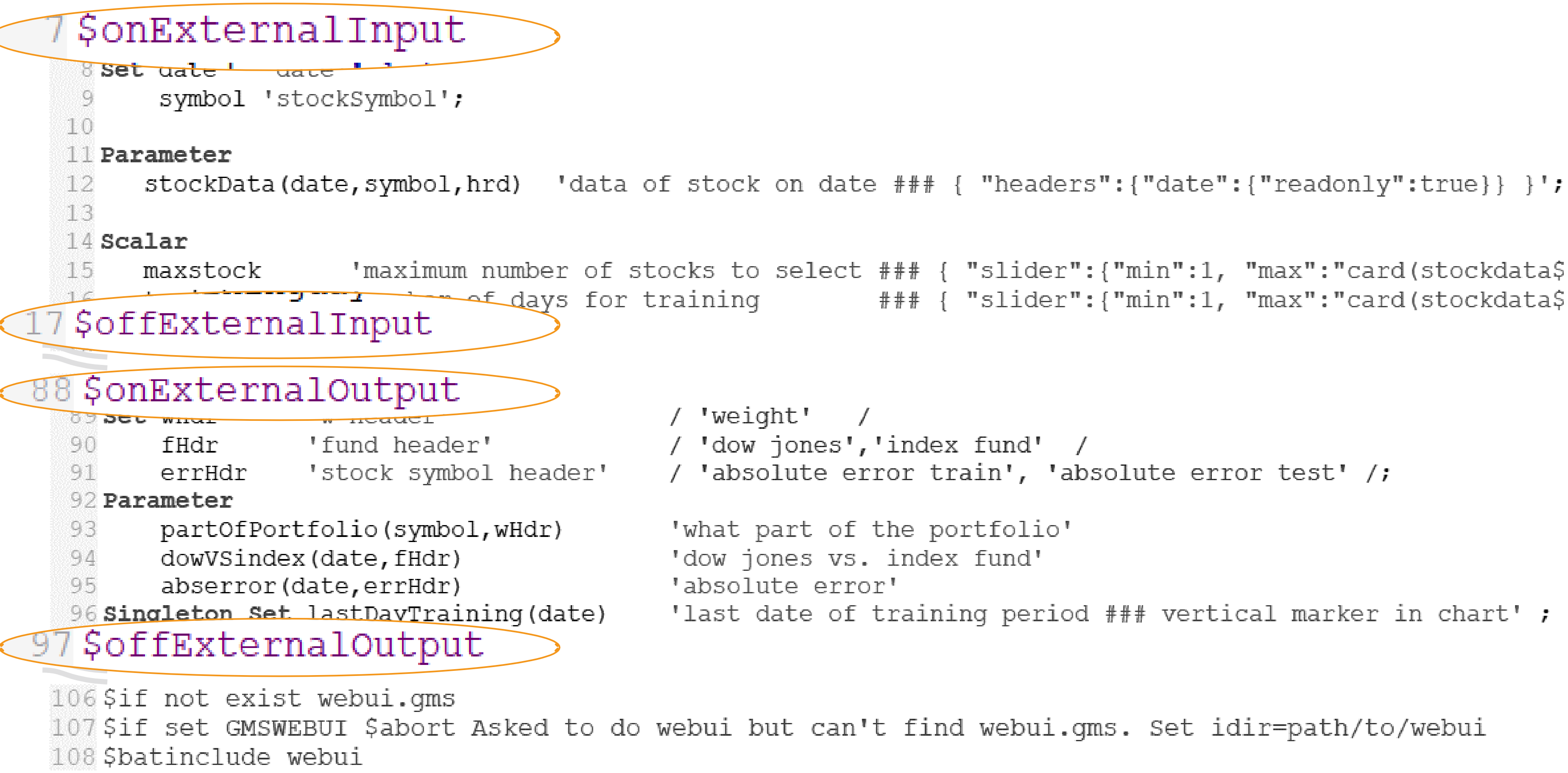

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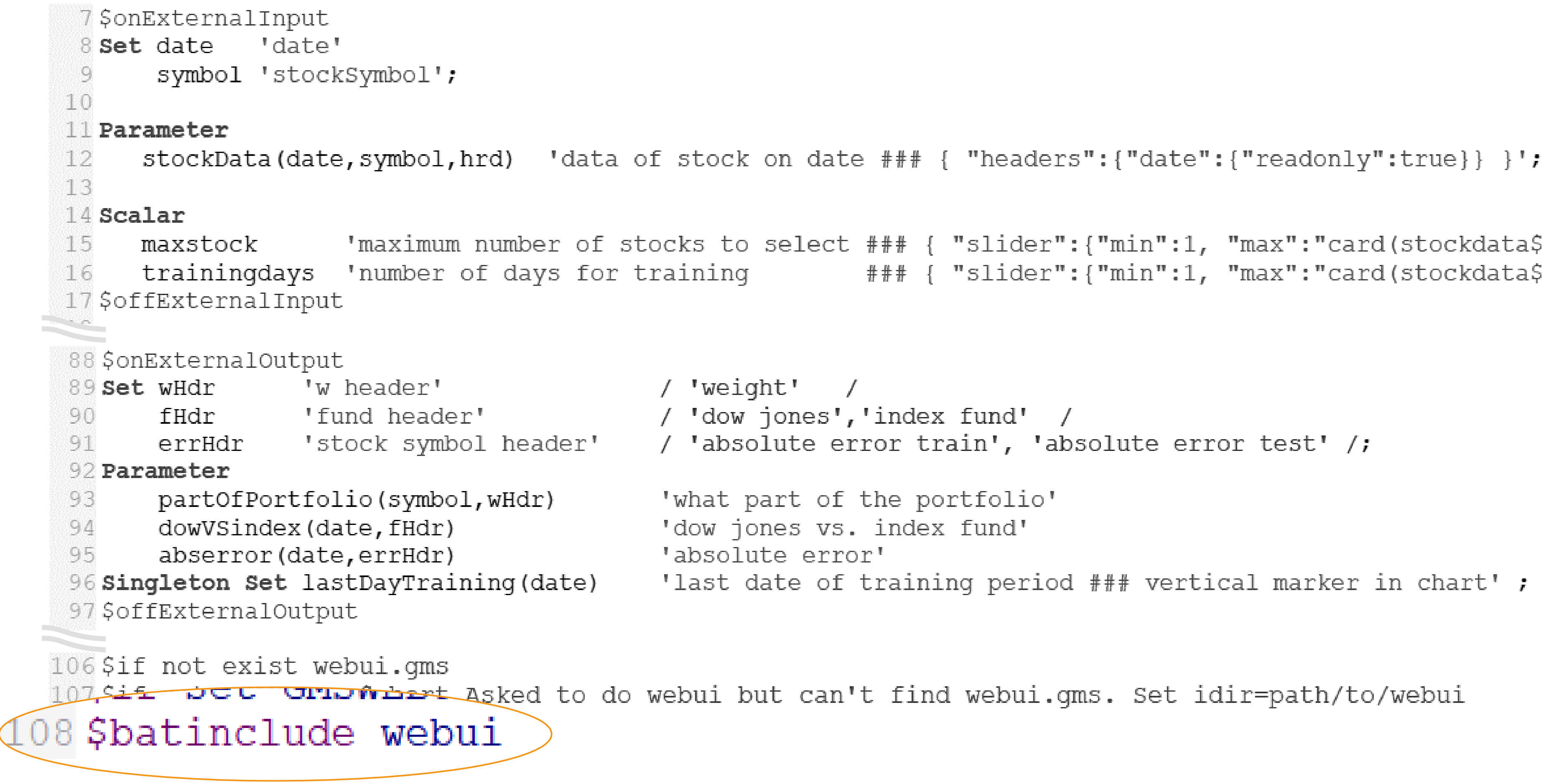

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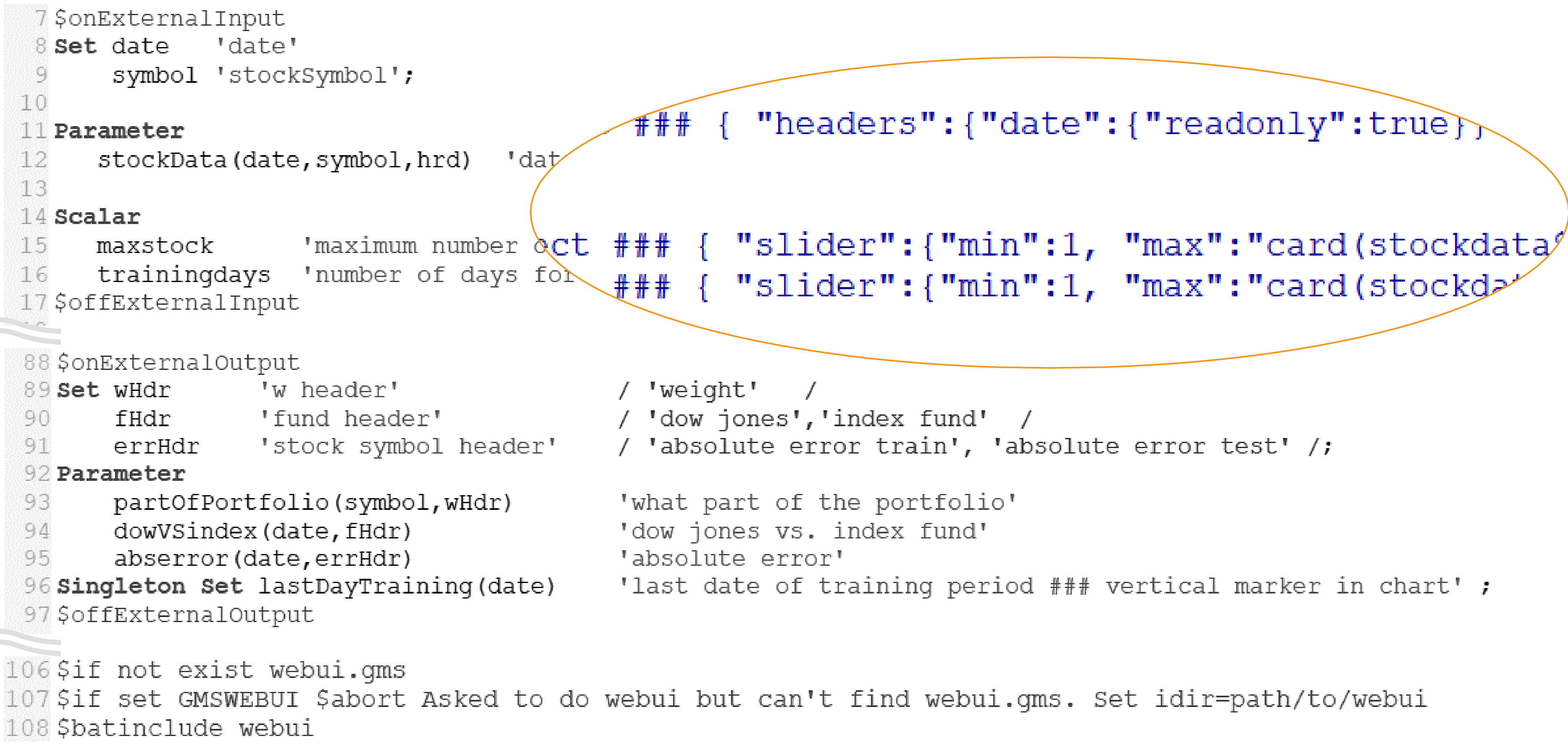

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Parameter
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Scalar
   maxstock      'maximum number oct
   trainingdays  'number of days for
$offExternalInput
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### { "slider":{"min":1, "max":"card(stockdata
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From GAMS Model to Visual User Interface

1

Initialization:

✓ Annotating GAMS model (defining the input and output data to be displayed in the WebUI)

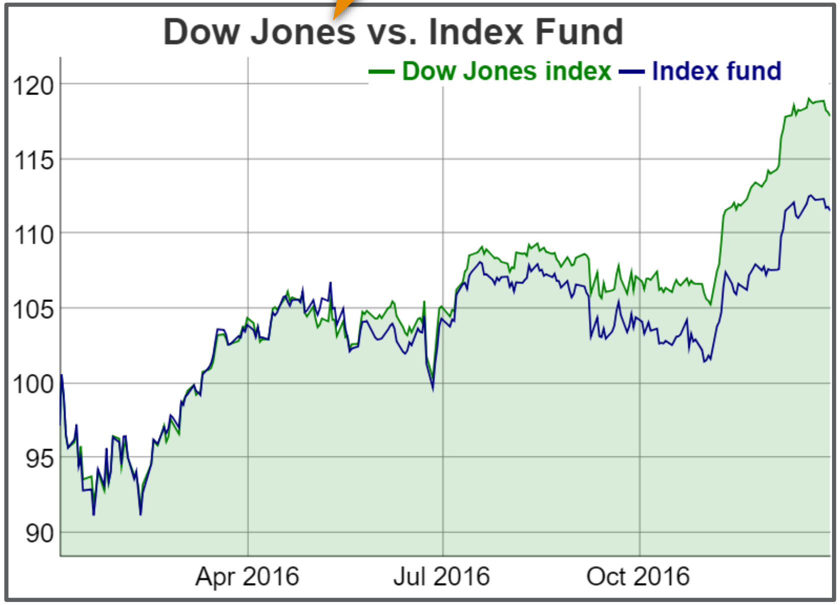
2

Basic setup (optional):

✓ Configuration of graphics and UI

Basic Setup – Configuration

```
"dowvsindex"    : {
    "outType"                : "graph",
    "graph"                  : {
        "tool"                   : "dygraph",
        "title"                  : "Dow Jones vs. Index Fund",
        "xdata"                  : "date",
        "ydata"                  : {
            "dow jones"              : {
                "label"                  : "Dow Jones index",
                "fillGraph"              : true
            },
            "index fund"             : {
                "label"                  : "Index fund"
            }
        }
    }
}
```



- ✓ Configuration via JSON file
- ✓ Access to a number of pre-implemented tools for graphical representation
- ✓ Focus on configuration, not programming

From GAMS Model to Visual User Interface

Initialization:

✓ Annotating GAMS model (defining the input and output data to be displayed in the WebUI)

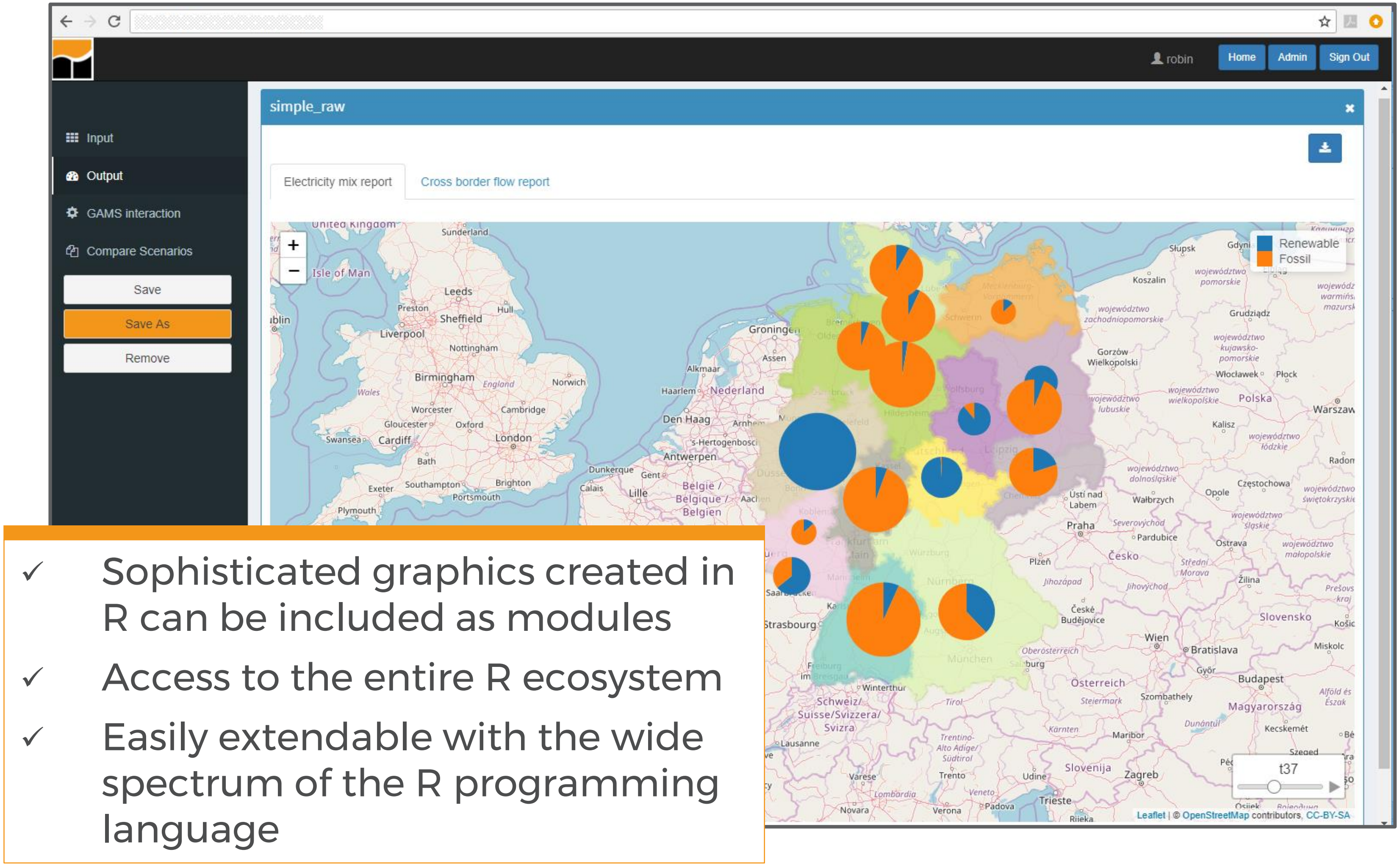
Basic setup (optional):
✓ Configuration of graphics and UI

Advanced setup (optional):

✓ Sophisticated graphics

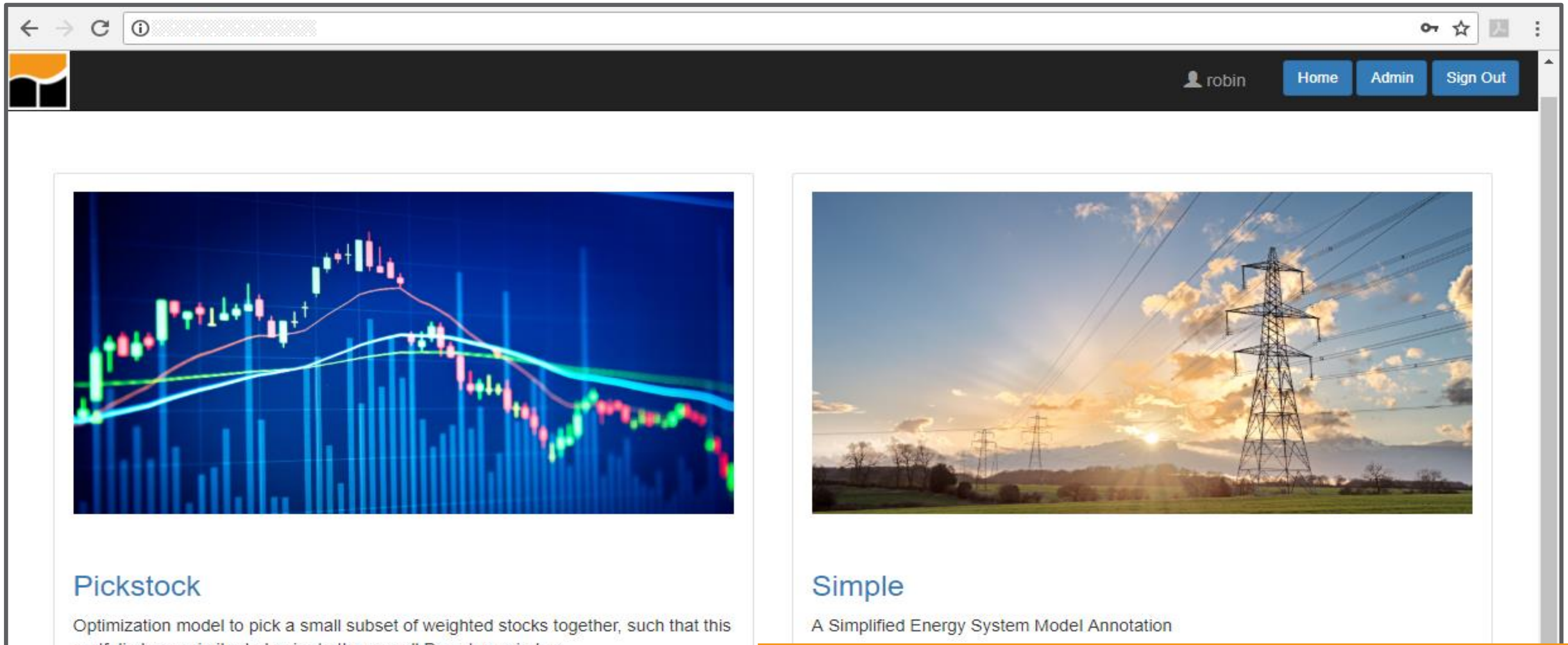
✓ User- and Application management

Advanced Setup – Sophisticated graphics



- ✓ Sophisticated graphics created in R can be included as modules
- ✓ Access to the entire R ecosystem
- ✓ Easily extendable with the wide spectrum of the R programming language

Advanced Setup –
User and Application Management



Pickstock

Optimization model to pick a small subset of weighted stocks together, such that this portfolio has a similar behavior to the overall Dow Jones index.

Simple

A Simplified Energy System Model Annotation

Yaml config file

```
- name: simple
  display-name: Simple
  logo-url: file://localhost/home/ec2-user/simple.png
  description: A Simplified Energy System Model Annotation
  docker-cmd: ["R", "-e", "shiny::runApp('/root/GMSWebUI')"]
  docker-image: gams/app
  docker-network: "my-network"
  docker-env:
    SHINYPROXY_MODELNAME: simple
  groups: GAMS_team, guest
```

- ✓ Local or server-based solution
- ✓ User authentication (e.g. LDAP, Keycloak, Google, GitHub, Facebook)
- ✓ Multi-Application support with docker-based technology

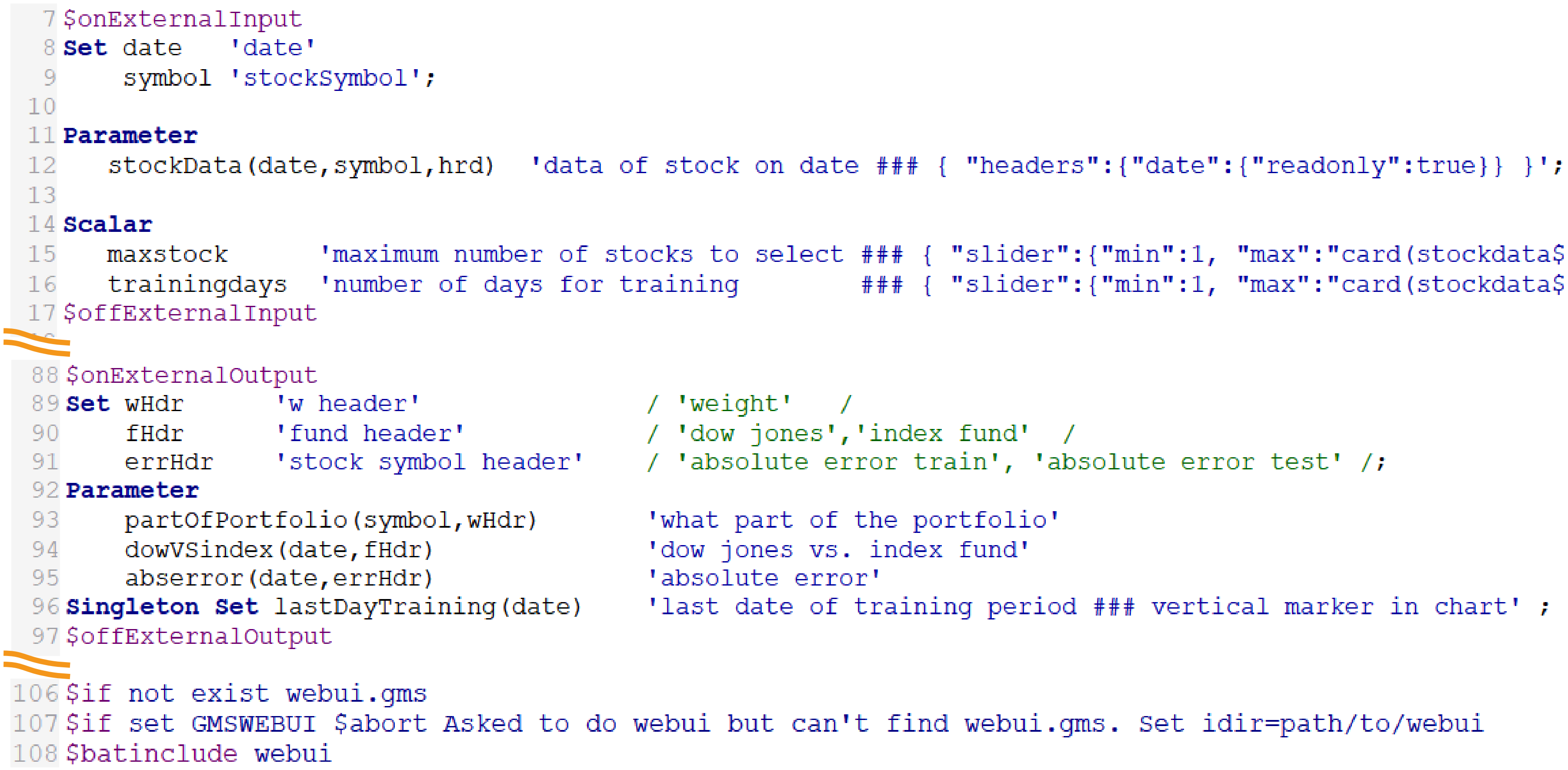
Example – Pickstock

Model Definition

- Goal: Definition of an index fund that follows the Dow Jones (DJ)
- Optimization model: Select a small subset of DJ stocks, along with weights, so that this portfolio behaves similarly to the overall index

$$
\begin{array}{lll}
\text{minimize} & \text{obj} := \sum_{ds} \text{slpos}_{ds} + \text{slneg}_{ds} & \\
\text{subject to} & \sum_{s} \text{price}_{ds,s} \cdot w_s = \text{index}_{ds} + \text{slpos}_{ds} - \text{slneg}_{ds} & (\forall ds) \\
& w_s \leq p_s & (\forall s) \\
& \sum_{s} p_s \leq \text{maxstock} & \\
& w_s \geq 0, \qquad p_s \in \{0, 1\} & (\forall s) \\
& \text{slpos}_d \geq 0, \qquad \text{slneg}_d \geq 0 & (\forall d)
\end{array}
$$

Annotating the GAMS Model



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```
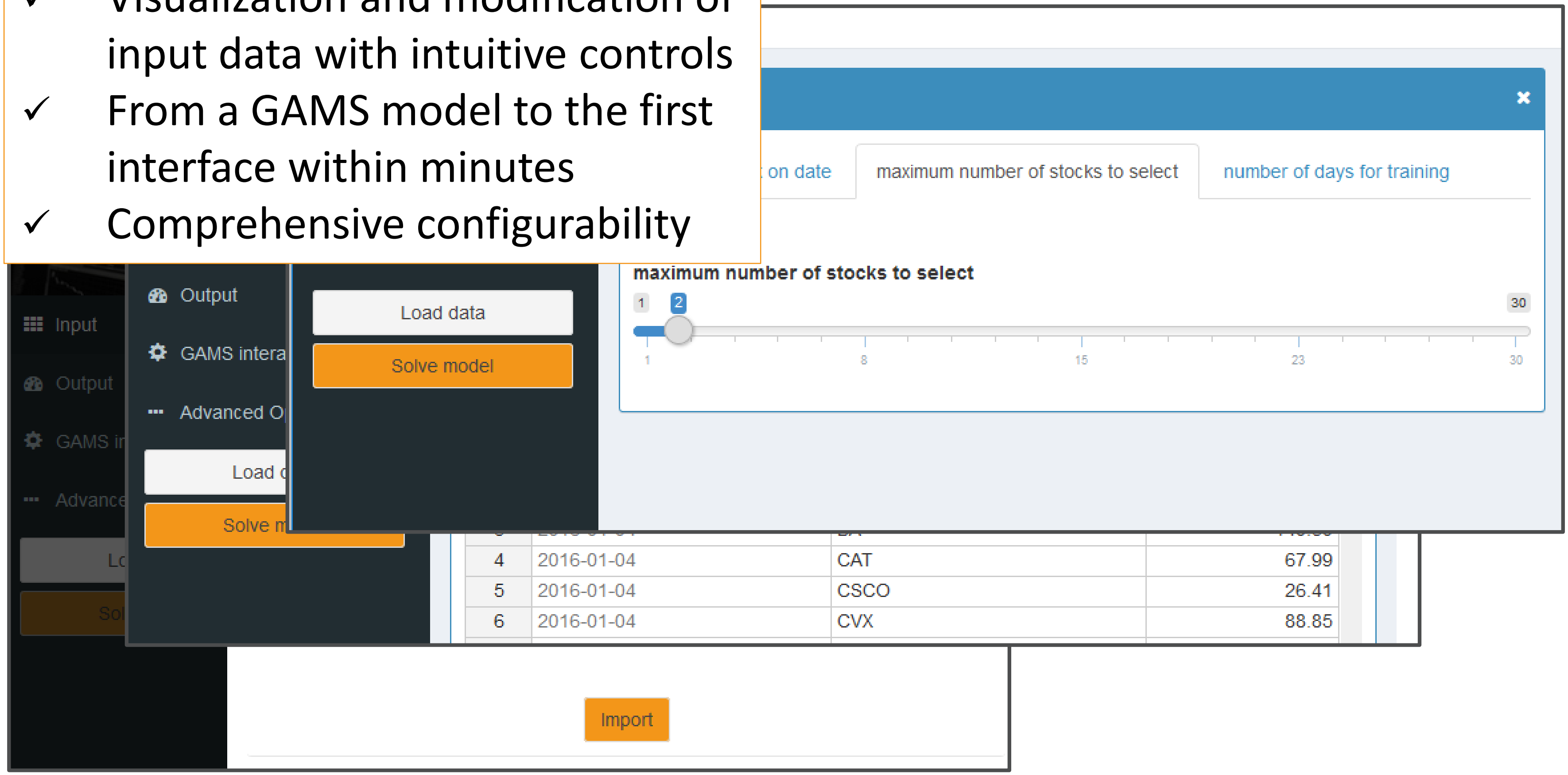
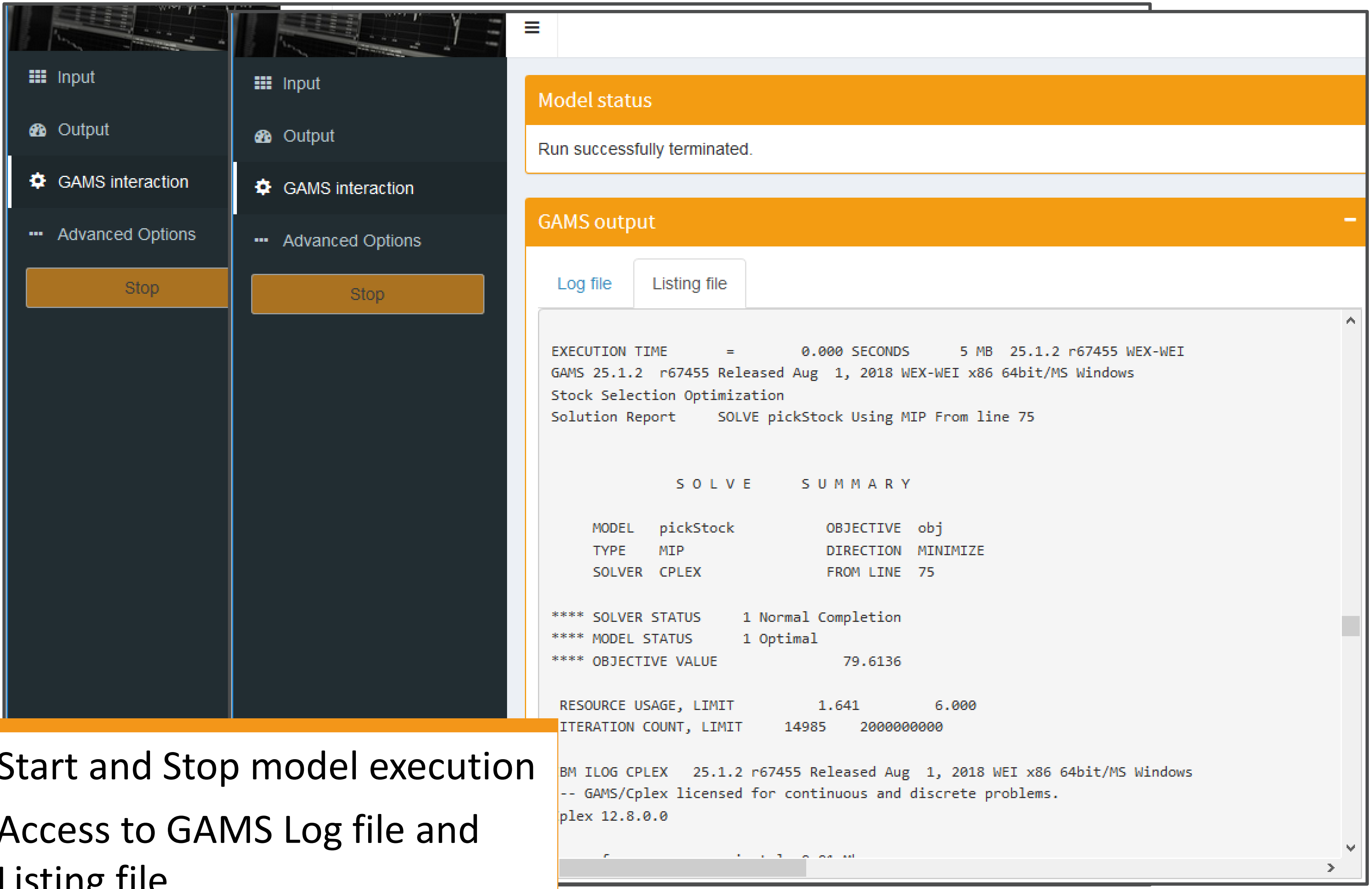

Setting the Model Input Data

- ✓ Data exchange via local files or database connection
- ✓ Visualization and modification of input data with intuitive controls
- ✓ From a GAMS model to the first interface within minutes
- ✓ Comprehensive configurability



4	2016-01-04	CAT	67.99
5	2016-01-04	CSCO	26.41
6	2016-01-04	CVX	88.85

Communication with GAMS



Model status

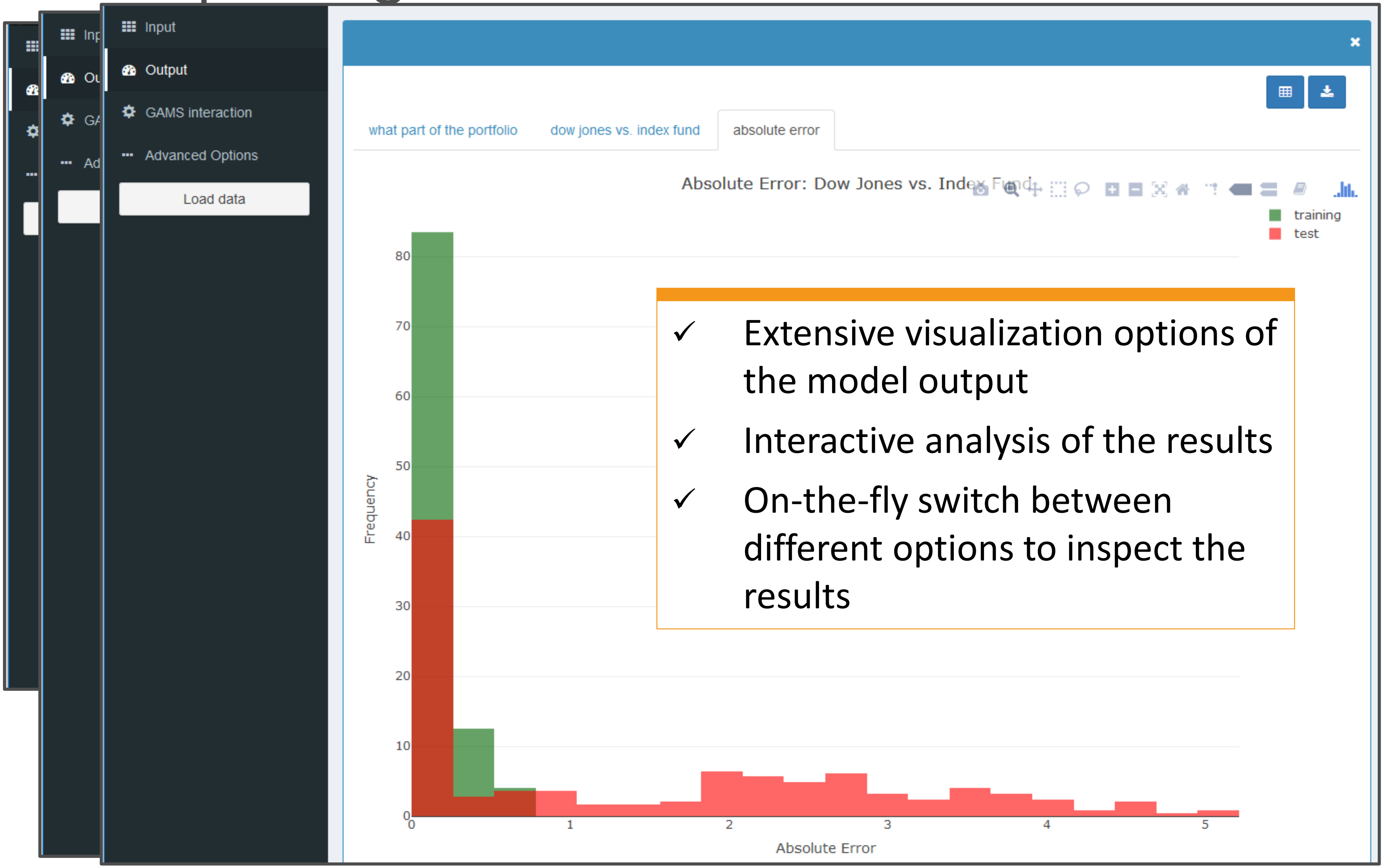
Run successfully terminated.

GAMS output

```
EXECUTION TIME       =        0.000 SECONDS      5 MB  25.1.2 r67455 WEX-WEI
GAMS 25.1.2  r67455 Released Aug  1, 2018 WEX-WEI x86 64bit/MS Windows
Stock Selection Optimization
Solution Report     SOLVE pickStock Using MIP From line 75


               S O L V E      S U M M A R Y

     MODEL   pickStock           OBJECTIVE  obj
     TYPE    MIP                 DIRECTION  MINIMIZE
     SOLVER  CPLEX               FROM LINE  75

**** SOLVER STATUS     1 Normal Completion
**** MODEL STATUS      1 Optimal
**** OBJECTIVE VALUE               79.6136

 RESOURCE USAGE, LIMIT          1.641         6.000
 ITERATION COUNT, LIMIT     14985    2000000000

 BM ILOG CPLEX   25.1.2 r67455 Released Aug  1, 2018 WEI x86 64bit/MS Windows
 -- GAMS/Cplex licensed for continuous and discrete problems.
 plex 12.8.0.0
```

- ✓ Start and Stop model execution
- ✓ Access to GAMS Log file and Listing file

Inspecting the Results

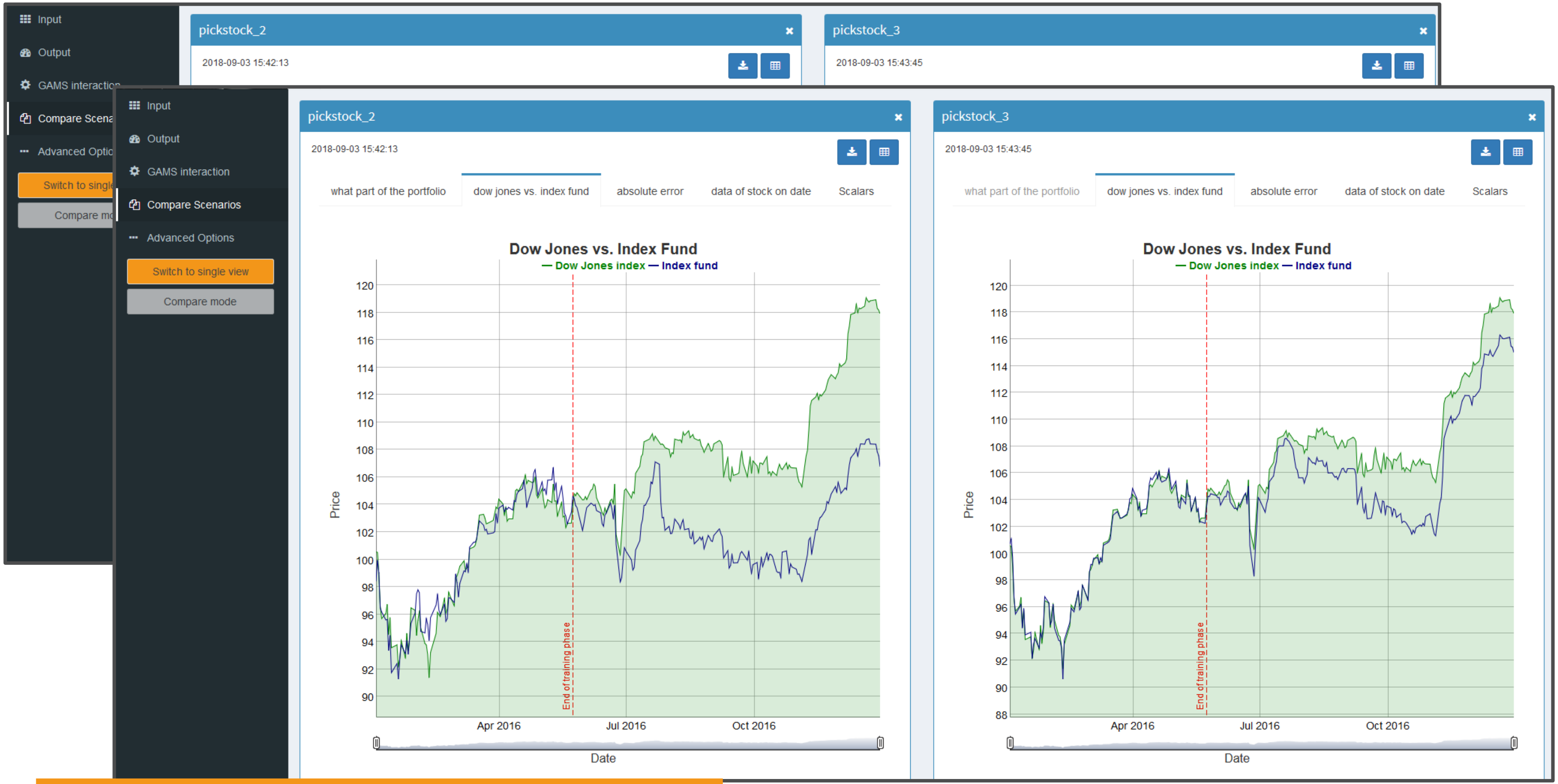


✓ Extensive visualization options of the model output

✓ Interactive analysis of the results

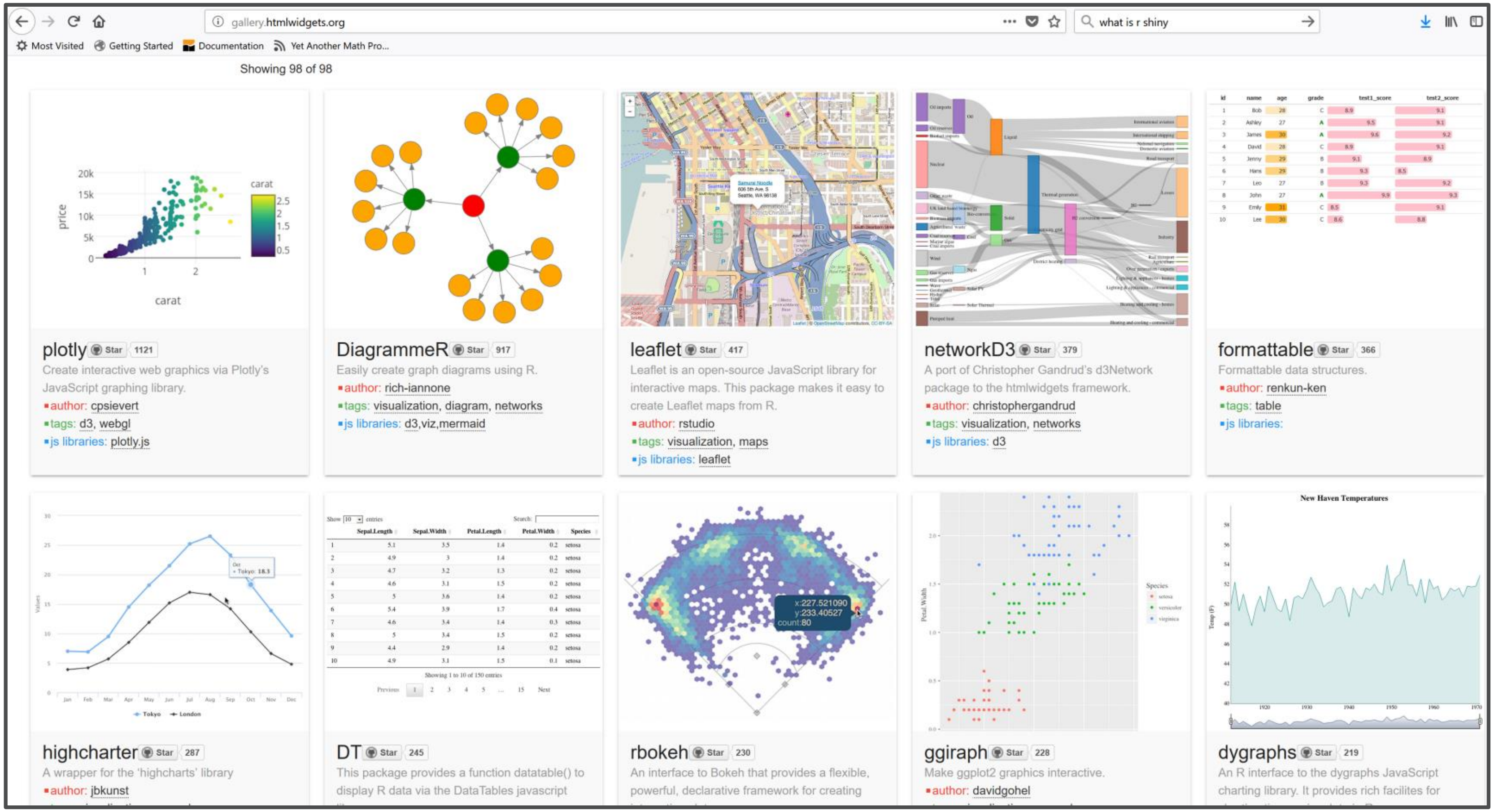
✓ On-the-fly switch between different options to inspect the results

Scenario Management



✓ Solve multiple scenarios or load saved data for comparison

Visualization / Graphics Libraries – Examples



Showing 98 of 98

plotly Star 1121

Create interactive web graphics via Plotly's JavaScript graphing library.

- author: cpsievert
- tags: d3, webgl
- js libraries: plotly.js

DiagrammeR Star 917

Easily create graph diagrams using R.

- author: rich-iannone
- tags: visualization, diagram, networks
- js libraries: d3,viz,mermaid

leaflet Star 417

Leaflet is an open-source JavaScript library for interactive maps. This package makes it easy to create Leaflet maps from R.

- author: rstudio
- tags: visualization, maps
- js libraries: leaflet

networkD3 Star 379

A port of Christopher Gandrud's d3Network package to the htmlwidgets framework.

- author: christophergandrud
- tags: visualization, networks
- js libraries: d3

id	name	age	grade	test1_score	test2_score
1	Bob	28	C	8.9	9.1
2	Ashley	27	A	9.5	9.1
3	James	30	A	9.6	9.2
4	David	28	C	8.9	9.1
5	Jenny	29	B	9.1	8.9
6	Hans	29	B	9.3	8.5
7	Leo	27	B	9.3	9.2
8	John	27	A	9.9	9.3
9	Emily	31	C	8.5	9.1
10	Lee	30	C	8.6	8.8

formattable Star 366

Formattable data structures.

- author: renkun-ken
- tags: table
- js libraries:

highcharter Star 287

A wrapper for the 'highcharts' library

- author: jbkunst

Show 10 entries Search:

	Sepal.Length	Sepal.Width	Petal.Length	Petal.Width	Species
1	5.1	3.5	1.4	0.2	setosa
2	4.9	3	1.4	0.2	setosa
3	4.7	3.2	1.3	0.2	setosa
4	4.6	3.1	1.5	0.2	setosa
5	5	3.6	1.4	0.2	setosa
6	5.4	3.9	1.7	0.4	setosa
7	4.6	3.4	1.4	0.3	setosa
8	5	3.4	1.5	0.2	setosa
9	4.4	2.9	1.4	0.2	setosa
10	4.9	3.1	1.5	0.1	setosa

Showing 1 to 10 of 150 entries

Previous 1 2 3 4 5 … 15 Next

DT Star 245

This package provides a function datatable() to display R data via the DataTables javascript

rbokeh Star 230

An interface to Bokeh that provides a flexible, powerful, declarative framework for creating

ggiraph Star 228

Make ggplot2 graphics interactive.

- author: davidgohel

dygraphs Star 219

An R interface to the dygraphs JavaScript charting library. It provides rich facilites for

Summary & Outlook

What we have done so far

- Application connects Web User Interface with a GAMS model
- User Interface allows
  - ✓ Data exchange via local files or database
  - ✓ Modification of the input data
  - ✓ Extensive visualization options
  - ✓ Comparison of different scenarios
  - ✓ Multi-user support based on Docker technology
  - ✓ User authentication
- Tool with intuitive interface for planners

- This “product” is currently under development. If you are interested in getting involved, please contact support@gams.com (or talk to me directly)

What we plan to do

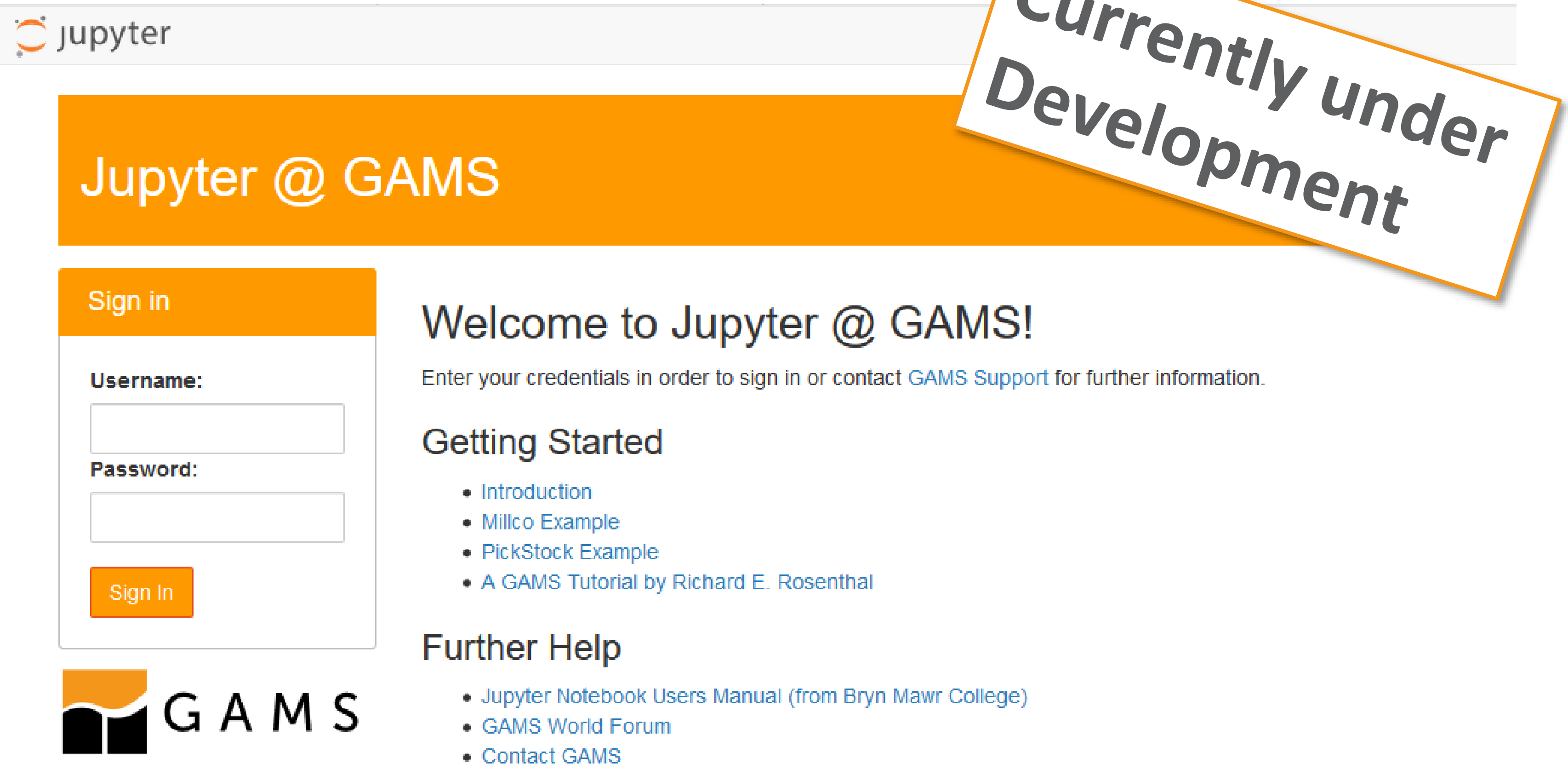
- Batch configuration and execution
  - Running GAMS in a separate container to share resources between different models
- Use docker orchestration tools (Docker Swarm, Kubernetes)
  - Load balancing
  - High availability and scalability

Thank You

Meet us at the GAMS booth!

Reminder: This “product” is currently under development. If you are interested in getting involved, please contact support@gams.com

Welcome to Jupyter @ GAMS!



Currently under Development

Welcome to Jupyter @ GAMS!

Enter your credentials in order to sign in or contact GAMS Support for further information.

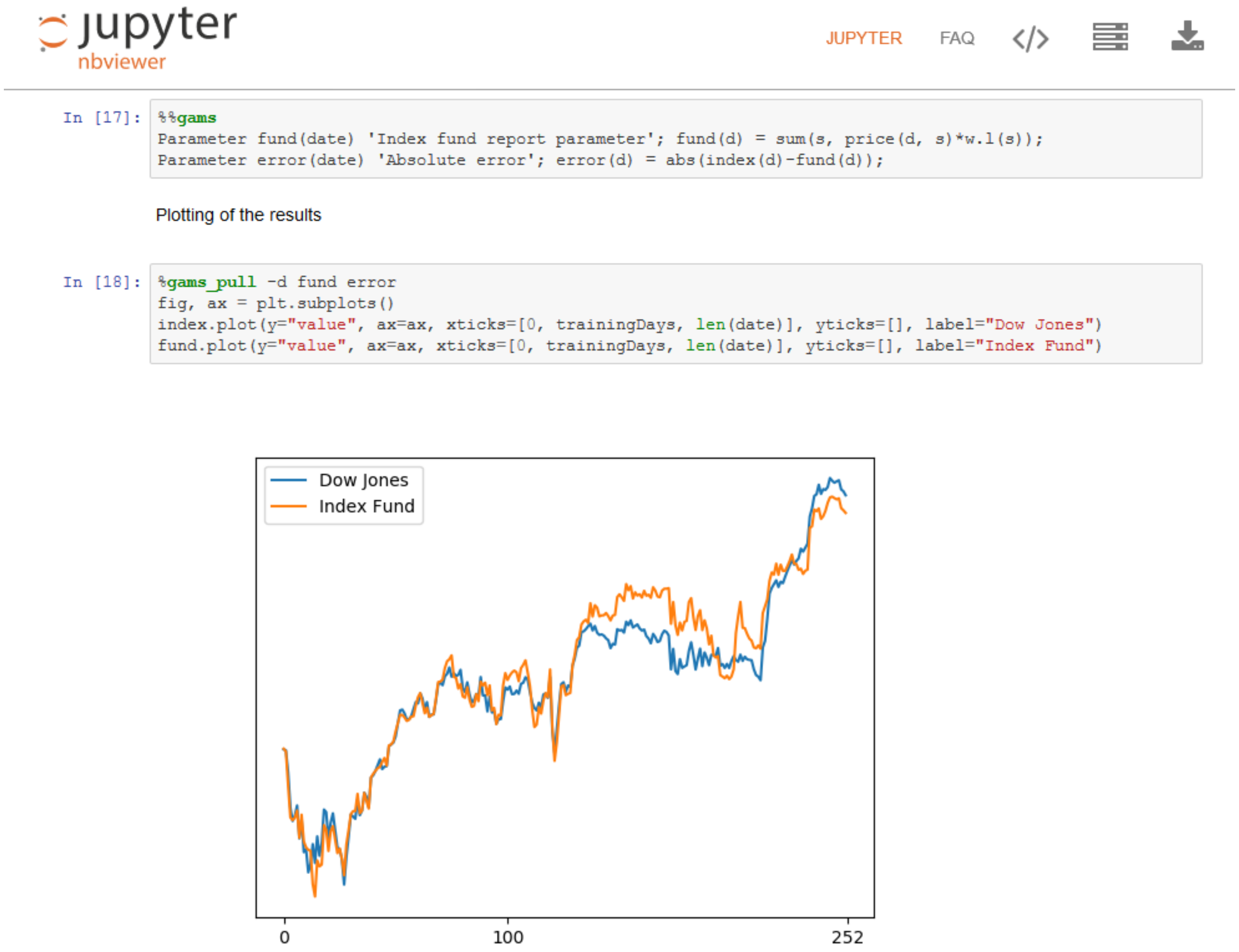
Getting Started

- Introduction
- Millco Example
- PickStock Example
- A GAMS Tutorial by Richard E. Rosenthal

Further Help

- Jupyter Notebook Users Manual (from Bryn Mawr College)
- GAMS World Forum
- Contact GAMS

GAMS Jupyter Example



In [17]:

```
%%gams
Parameter fund(date) 'Index fund report parameter'; fund(d) = sum(s, price(d, s)*w.l(s));
Parameter error(date) 'Absolute error'; error(d) = abs(index(d)-fund(d));
```

Plotting of the results

In [18]:

```
%gams_pull -d fund error
fig, ax = plt.subplots()
index.plot(y="value", ax=ax, xticks=[0, trainingDays, len(date)], yticks=[], label="Dow Jones")
fund.plot(y="value", ax=ax, xticks=[0, trainingDays, len(date)], yticks=[], label="Index Fund")
```

Using GAMS Jupyter Notebooks to tell “optimization stories”

- Runs in a browser/on a server
  → No local installation needed
- Allows to use notebook technology in combination with GAMS
- Notebooks allow to combine GAMS and Python
  - GAMS works great with well structured data and optimization models
  - Python is very rich in features to retrieve, manipulate, and visualize data that comes in all sort of ways
  - ➔ Combining GAMS and Python in a notebook it is relatively easy to tell an optimization story with text, data, graphs, math, and models

- This “product” is currently under development.
  Give it a try at https://jupyterhub.gams.com/hub/login