# SYSTEM IDENTIFICATION MATLAB TOOLBOX

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Master Course in Mechatronic Engineering

Master Course in Computer Engineering

**01RKYQW / 01RKYOV “Estimation, Filtering and System Identification”**

Academic Year 2019/2020

# System Identification Matlab Toolbox

- In order to practice the System Identification Toolbox under MATLAB ver. R2014A:
  - type the command `iddemo`
  - enter `1` for linear model and general toolbox features
  - select the example number `1` for a guided tour on the Graphical User Interface *GUI* (required)
  - select the example number `2` for building simple models from real laboratory process data (suggested)
  - select the example number `3` for comparing different identification methods (suggested)
- To open the System Identification Toolbox *GUI*, type the command `ident`

# System Identification Toolbox GUI

- **Main steps** to solve the hair dryer identification problem:
  1) Open the System Identification Toolbox *GUI* typing the command `ident`
  2) Import the dryer data (click on *Import data* and select *Example*, then click on *Import* and *Close* in the *Import Data* window): the `Dryer` window will appear in the *Data Views* area and also as *Working Data* and *Validation Data* boxes
  3) Remove the mean value from the data (click on *Preprocess* operation and select *Remove means*): the `Dryerd` window will appear in the *Data Views*
  4) Make the data without mean as current working dataset, by clicking the `Dryerd` window in the *Data Views* and dragging it to the *Working Data* box
  5) Partition the whole dataset in two subsets, called estimation dataset (ES) and validation dataset (VS) (click on *Preprocess* and choose *Select range*; type `1 500` as Samples for the `Dryerde` dataset and click on *Insert*; type `501 1000` as Samples for the `Dryerdv` dataset and click on *Insert* and *Close*): the `Dryerde` and `Dryerdv` windows will appear in the *Data Views* and the corresponding data may be shown by clicking on the *Time plot* option

6) Set ES as the current working dataset and VS as the current validation dataset, by clicking the `Dryerde` and `Dryerdv` windows in the *Data Views* area and dragging them to the *Working Data* and *Validation Data* boxes, respectively

7) Perform the order selection for an ARX structure (click on *Estimate* and select *Polynomial Models*, then click on *Order Selection* and *Estimate*) in order to consider and compare different model selection criteria:

$$\textbf{Best Fit} = 1 - \sqrt{\frac{MSE}{\frac{1}{N}\sum_{t=1}^{N}(y(t)-\bar{y})^2}} \qquad \text{(index to be maximized)}$$

$$\textbf{AIC} = n\frac{2}{N} + \ln(MSE) \qquad \text{(index to be minimized)}$$

$$\textbf{MDL} = n\frac{\ln(N)}{N} + \ln(MSE) \qquad \text{(index to be minimized)}$$

with $MSE = \frac{1}{N}\sum_{t=1}^{N}(y(t)-\hat{y}(t))^2$, $\bar{y} = \frac{1}{N}\sum_{t=1}^{N}y(t)$ = sample mean of $y$,

$n$ = ARX model complexity (in prediction mode) = $\dim(\theta)$ = `na+nb`

8) Identify several models of different orders and delays using the following structures:

- `ARX(na,nb,nk)`, using `na=nb=1,...,4` and `nk=1,...,3`
  (and also the optimal values of `na`, `nb`, `nk` obtained from step 7)
- `ARMAX(na,nb,nc,nk)`, using `na=nb=nc=1,...,4` and `nk=1,...,3`
- `OE(nb,nf,nk)`, using `nb=nf=1,...,4` and `nk=1,...,3`

by clicking on *Estimate*, selecting *Polynomial Models*, choosing as *Structure* the desired model class, clicking on the *Order Editor* or specifying in *Orders* the model orders and the input-output delay, and finally clicking on *Estimate* in the *Polynomial Model* window: the corresponding window will appear in the *Model Views* area

9) Compare the identified models on the VS dataset considering both the Best Fit index, to be maximized (click on the *Model output* option), and the residual analysis (click on the *Model resids* option).
For the whiteness residual test of each model, the Autocorrelation plot has to be considered: the more residual values are inside the confidence interval, the better is the model; the number of residuals sufficiently outside the confidence interval have to be counted and compared with a threshold:

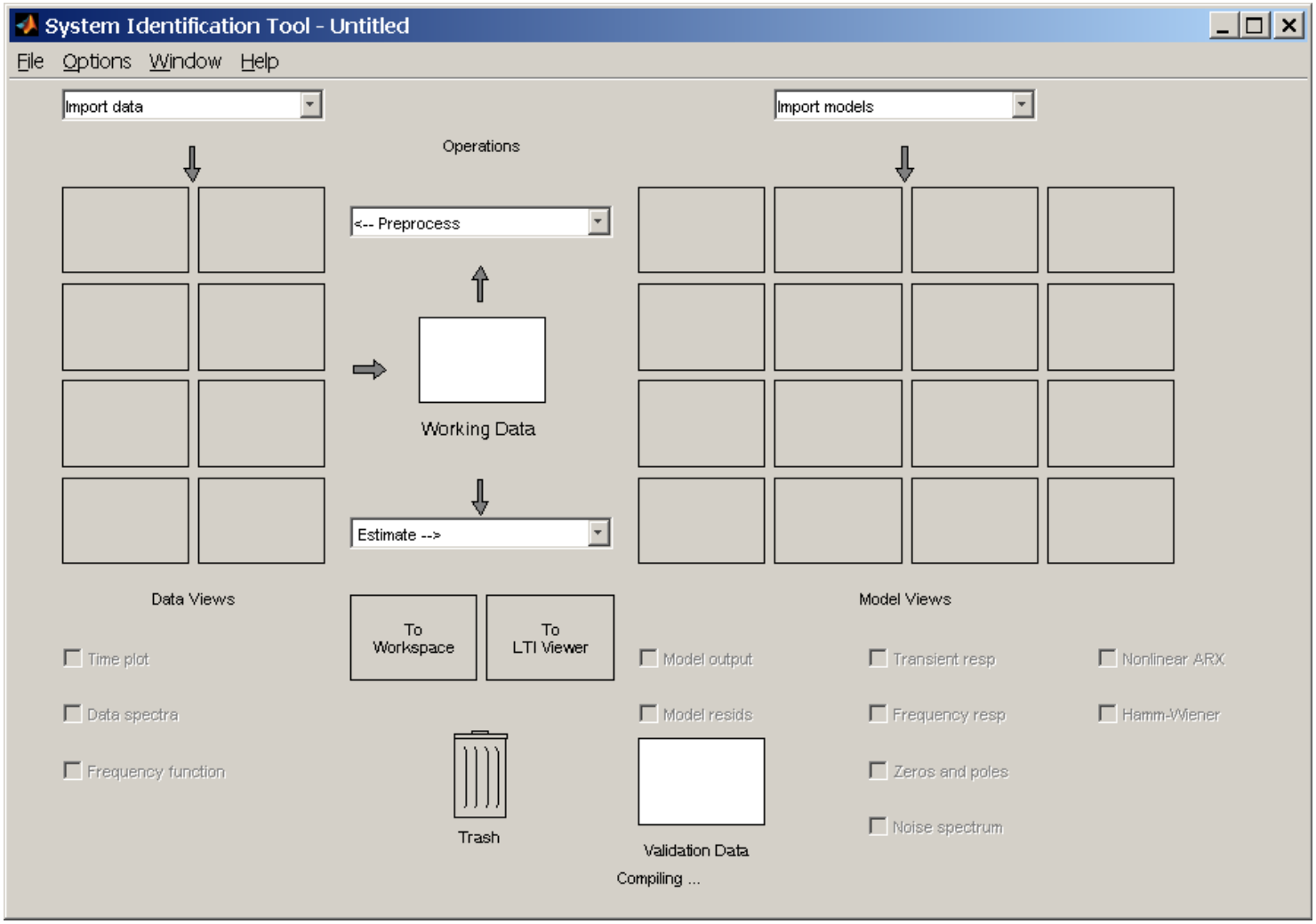
- if this number is greater than the threshold, then the model is wasted,
- otherwise, the model is considered for further analyses;

a reasonable threshold is 4 or 5, corresponding to a 95% confidence level (note that this threshold may be increased, depending on the case study!!)

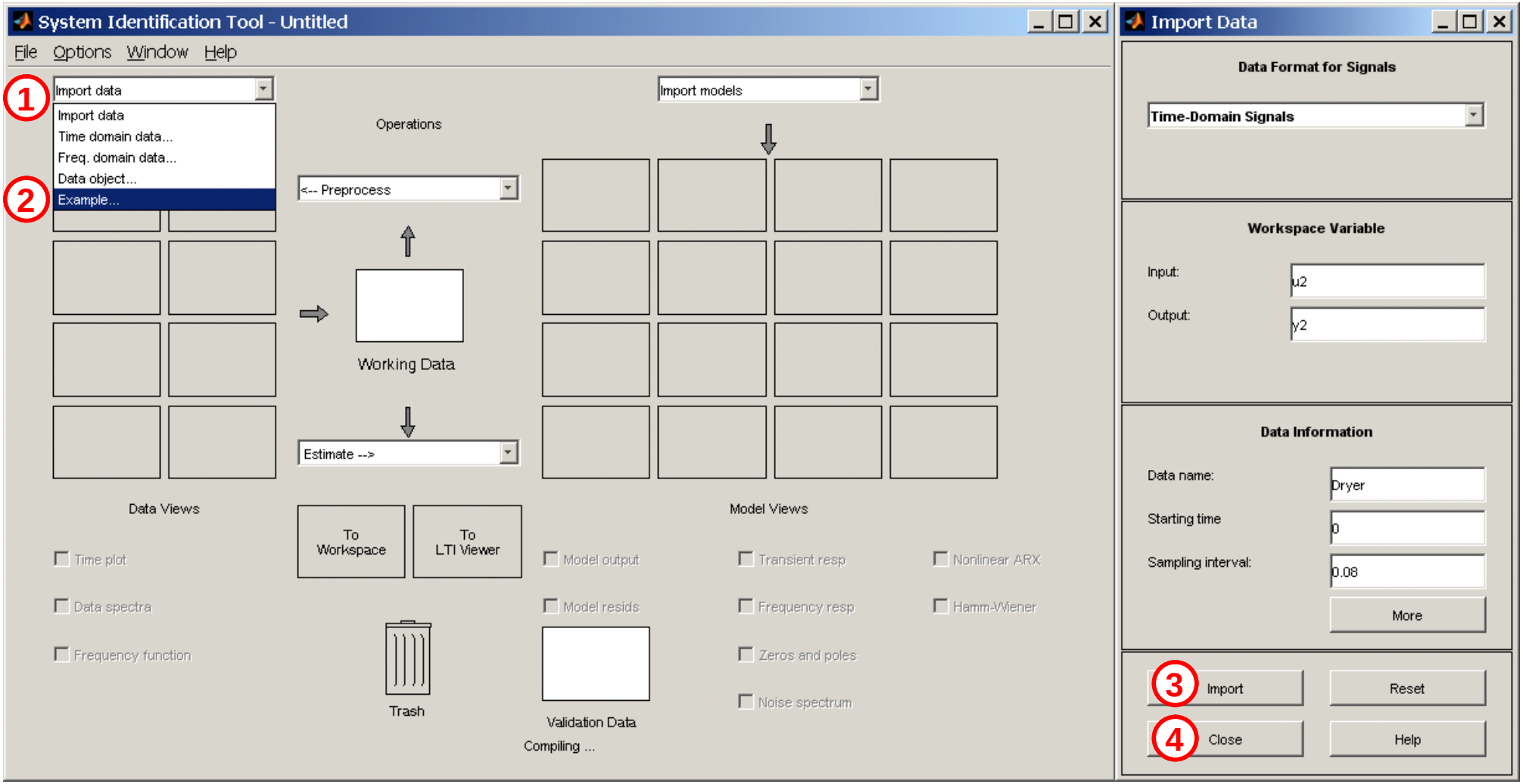
10) Select and export the “best trade-off” model (click the corresponding window in the *Model Views* area and drag it to the *To Workspace* box)

# System Identification Toolbox GUI in detail

1) Open the System Identification Toolbox *GUI* typing the command `ident`



2) Import the dryer data: click on *Import data* and select *Example*, then click on *Import* and *Close* in the *Import Data* window; the `Dryer` window will appear in the *Data Views* area and also as *Working Data* and *Validation Data* boxes



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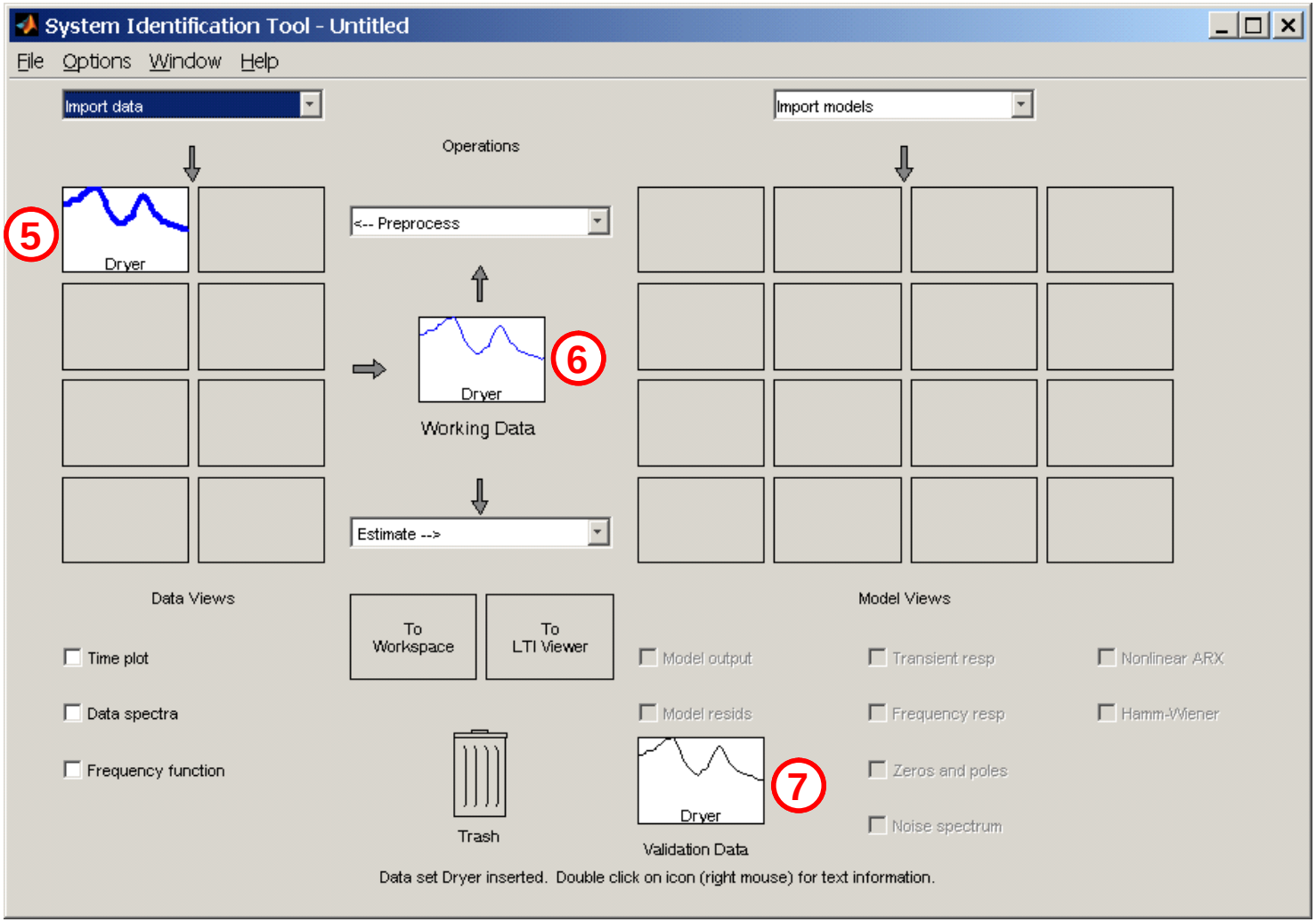
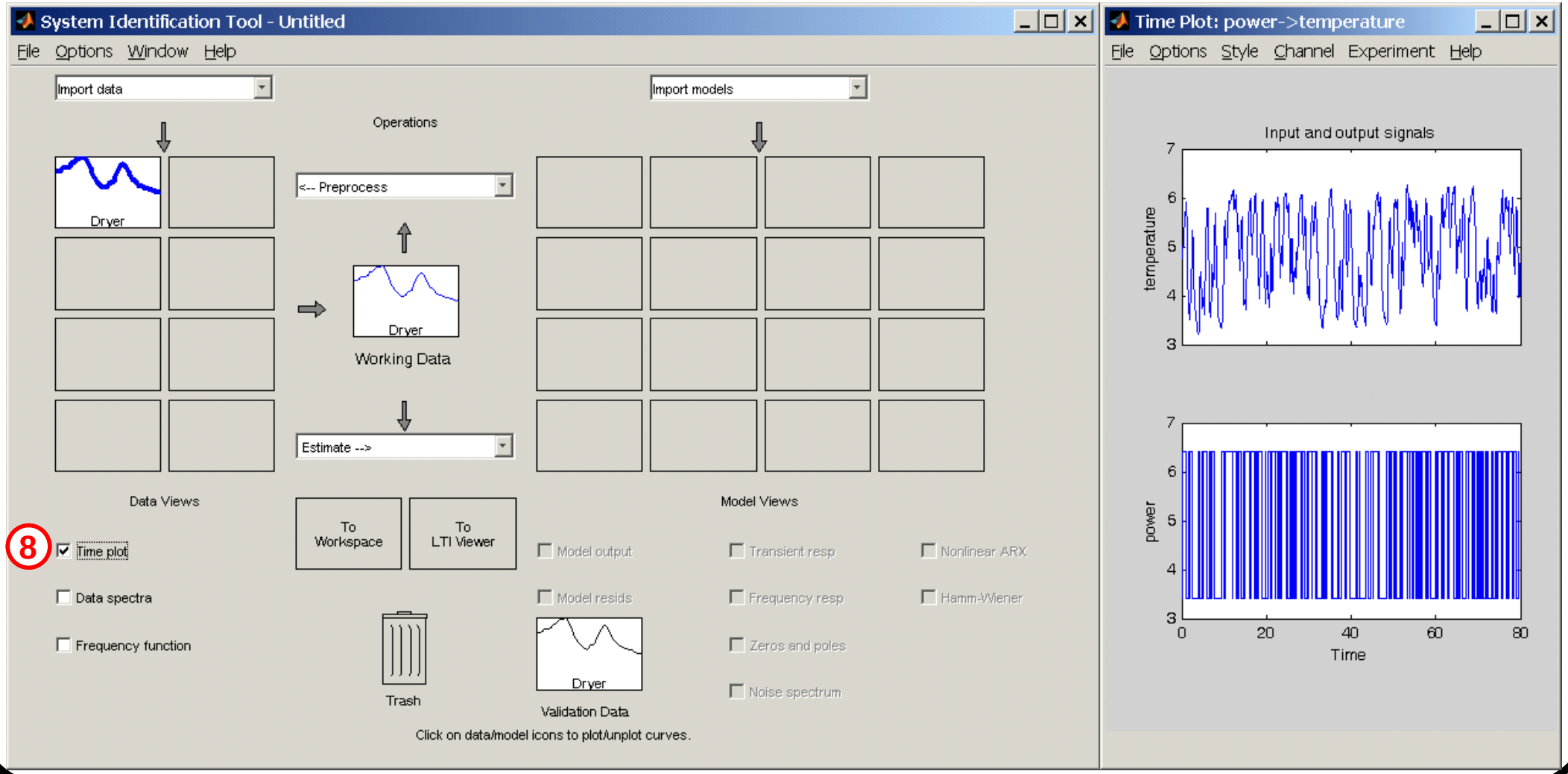
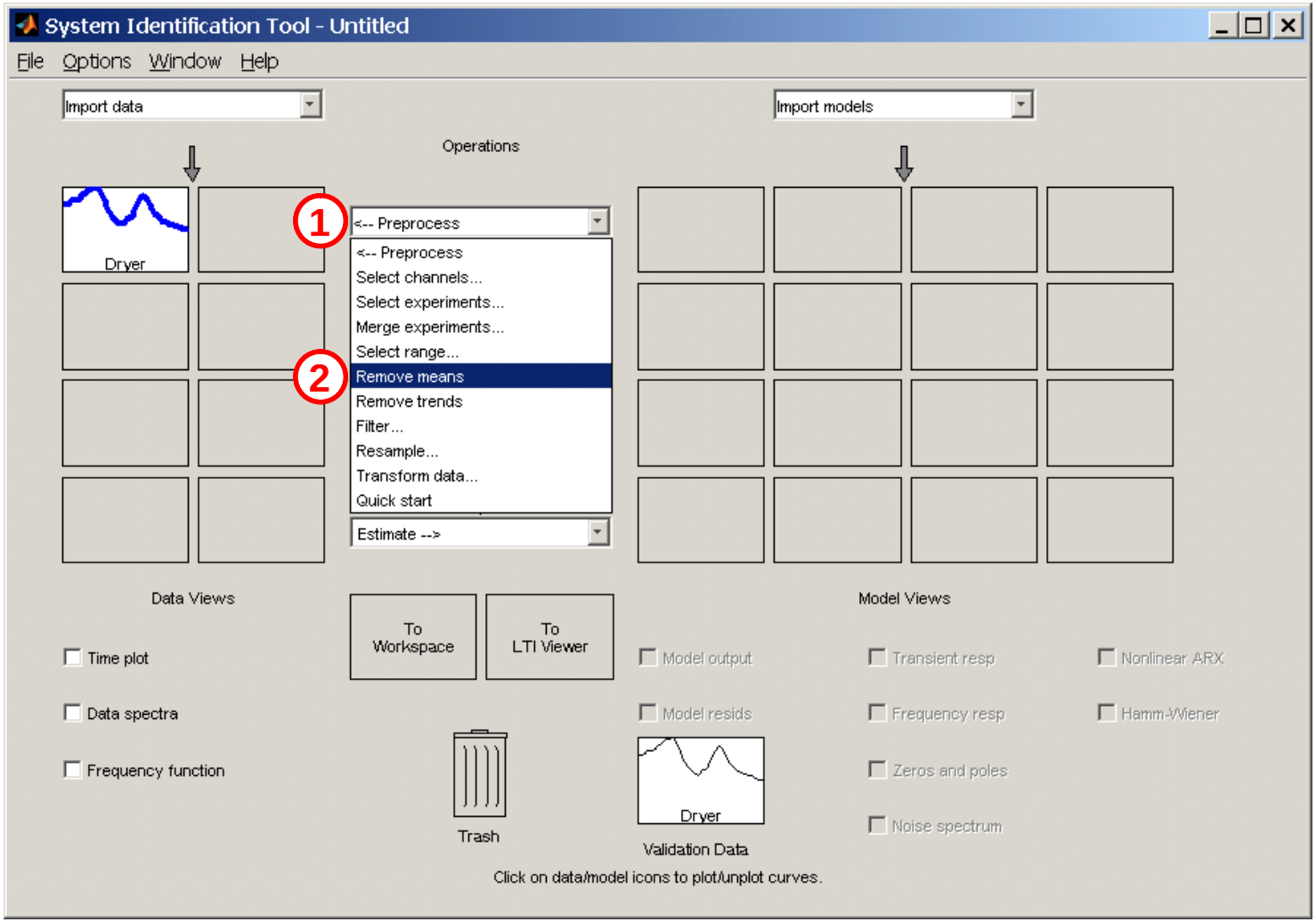


The corresponding data may be shown by clicking on the *Time plot* option:

- the input is the electric power (a Pseudo Random Binary Sequence)
- the output is the air temperature



3) Remove the mean value from the data: click on *Preprocess* operation and select *Remove means*; the `Dryerd` window will appear in the *Data Views* area; the corresponding data may be shown by clicking on the *Time plot* option



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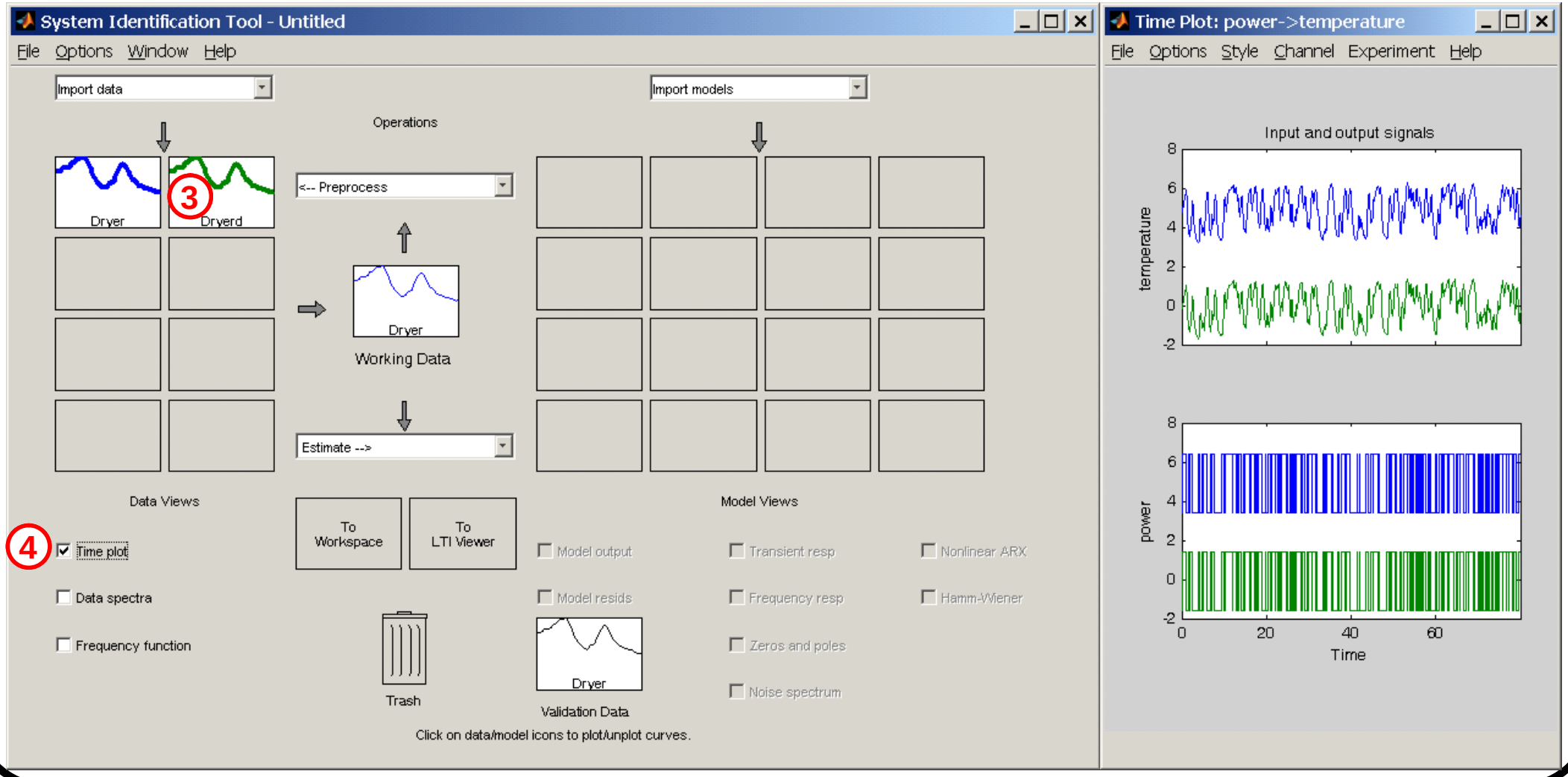
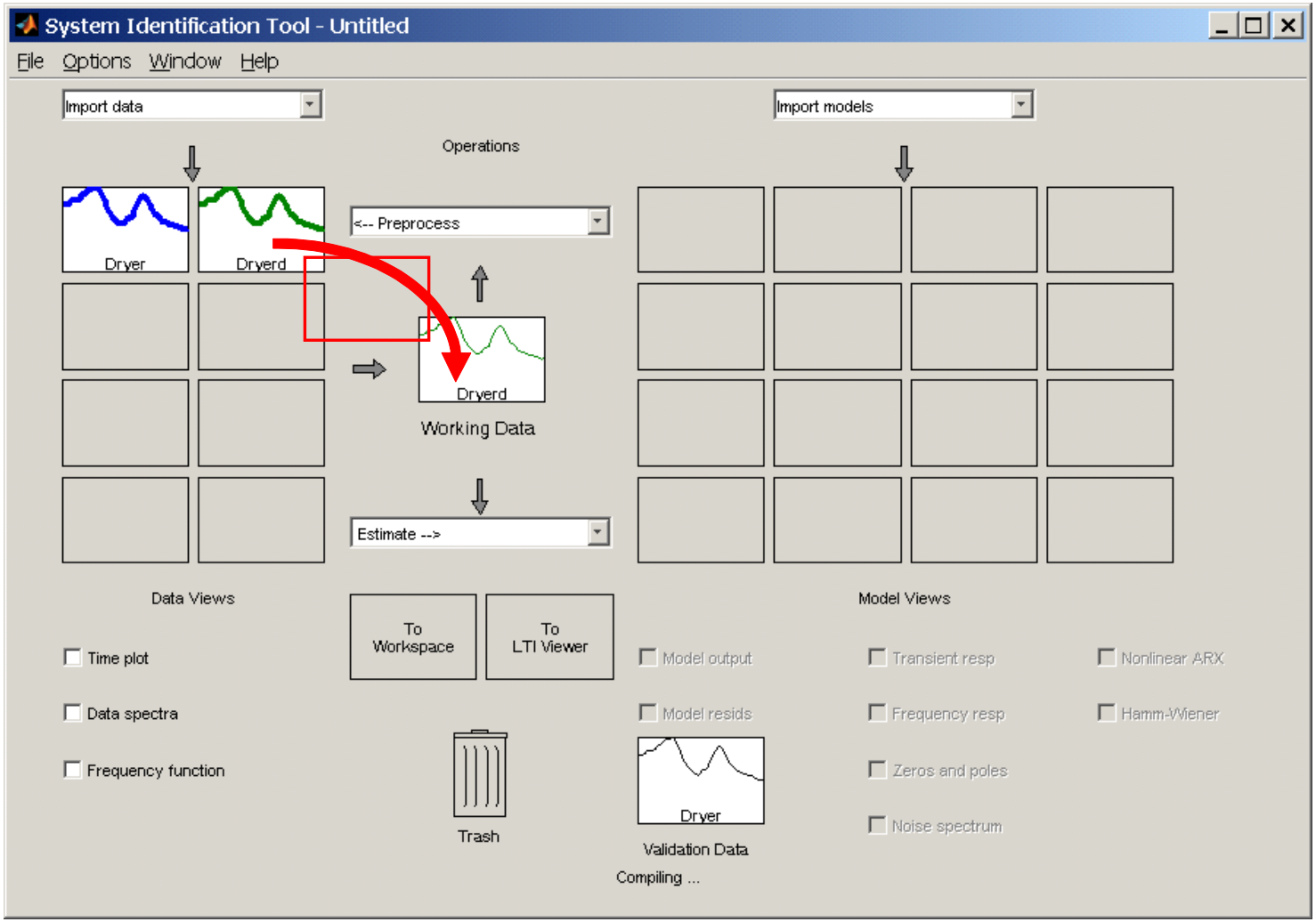
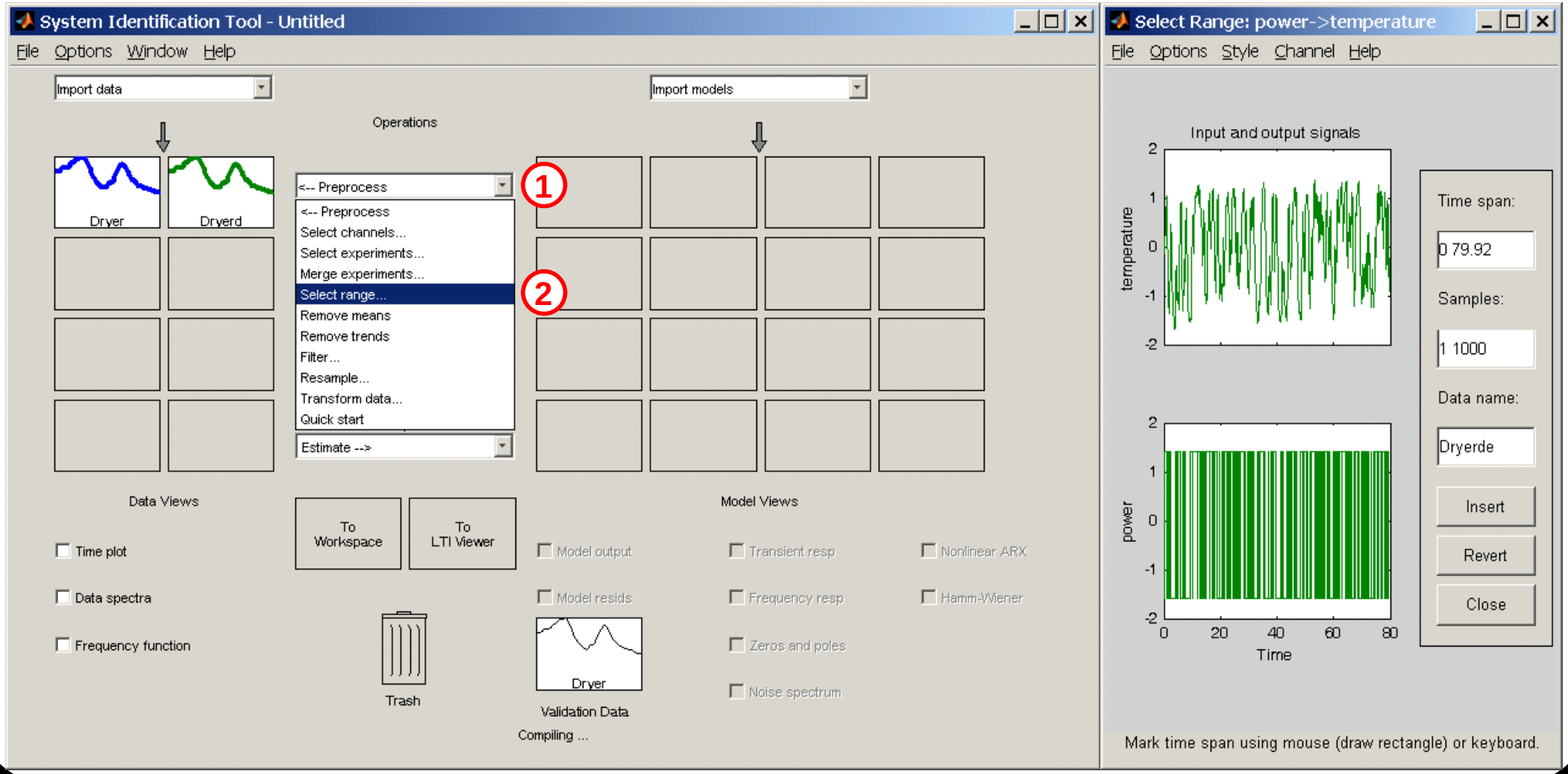


4) Make the data without mean as current working dataset, by clicking the `Dryerd` window in the *Data Views* area and dragging it to the *Working Data* box



5) Partition the whole dataset in two subsets, called estimation dataset (ES) and validation dataset (VS): at first, click on *Preprocess* and choose *Select range*; then, type `1  500` as Samples for the `Dryerde` dataset and click on *Insert*;



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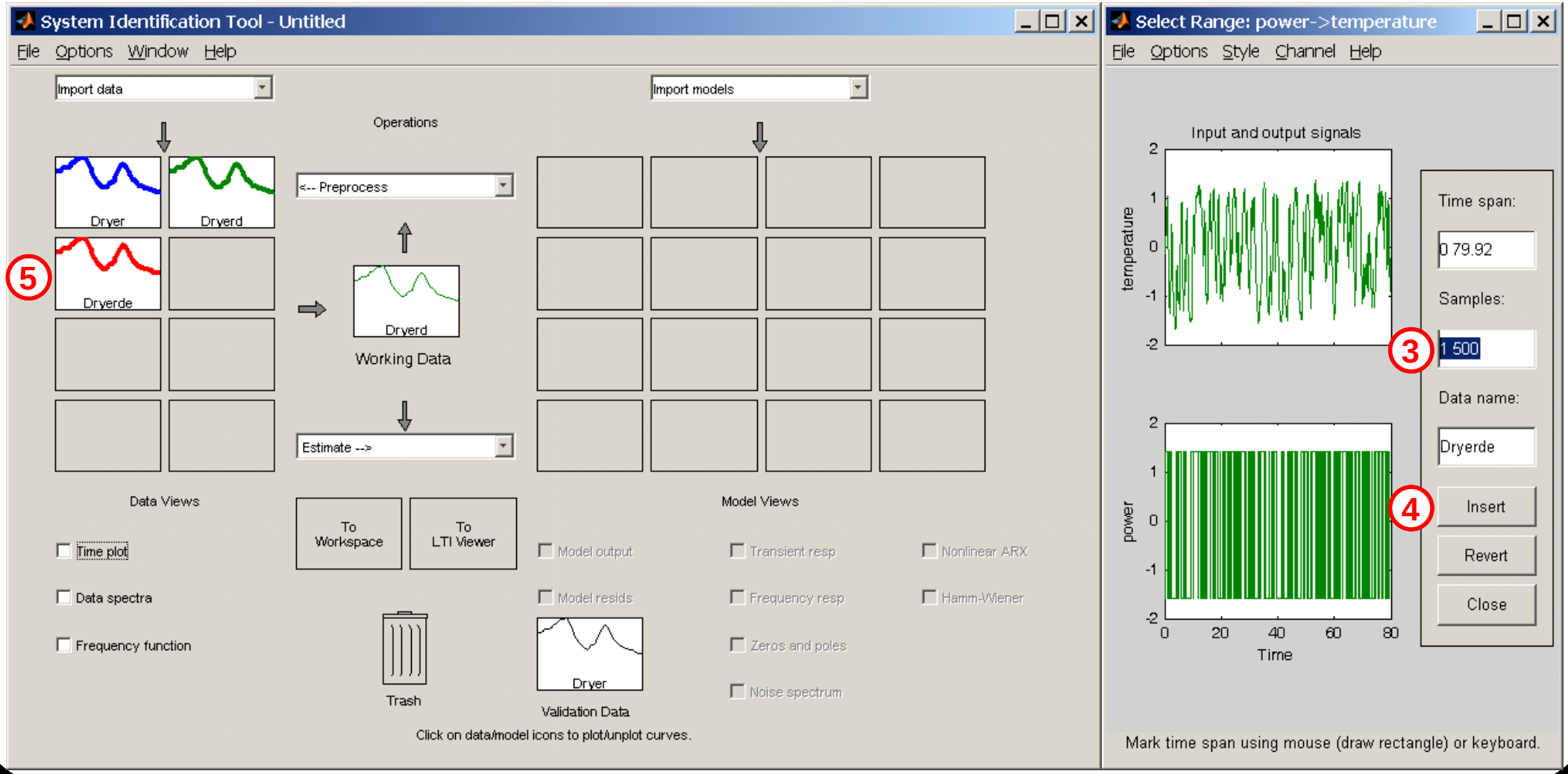
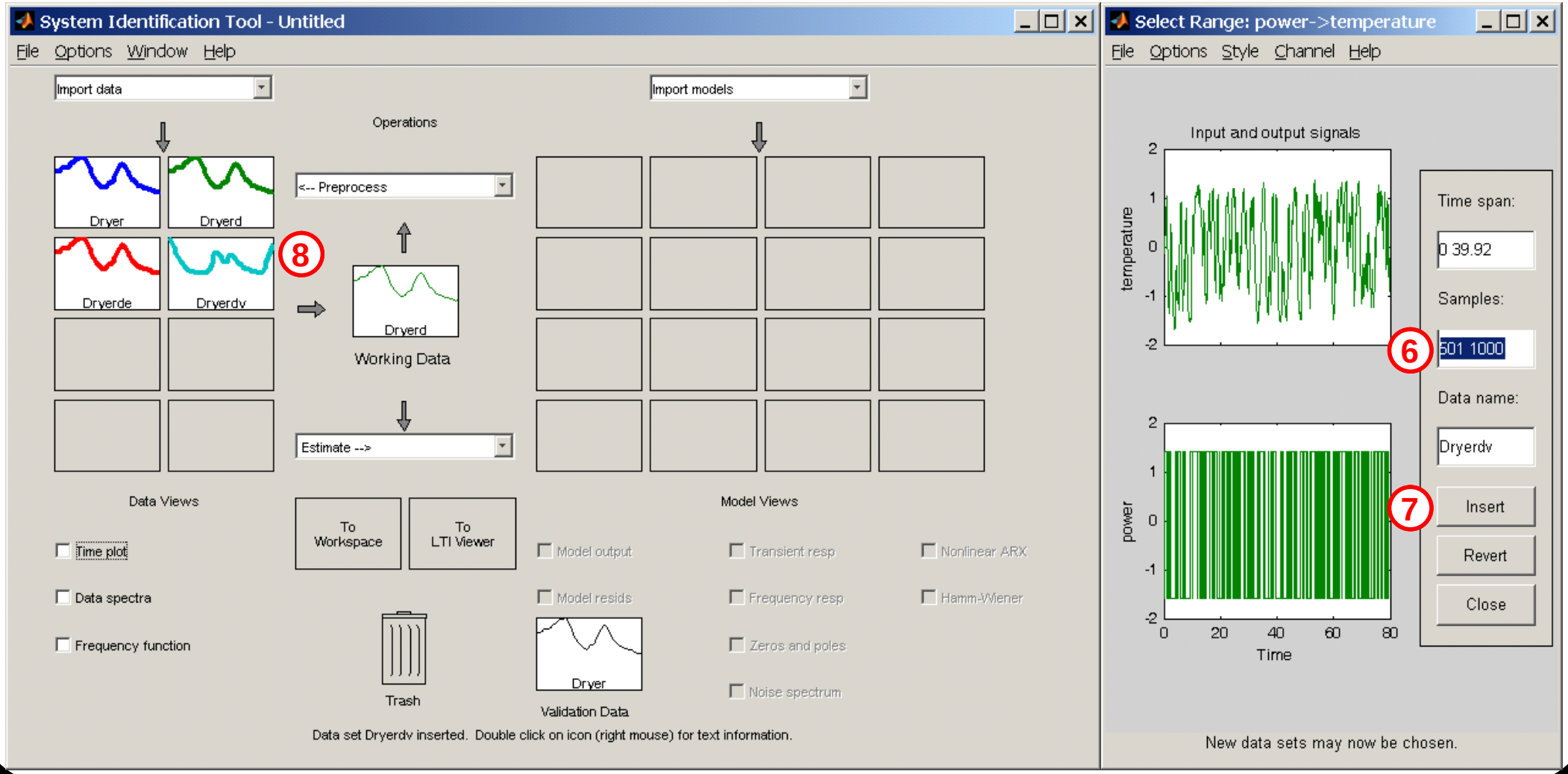
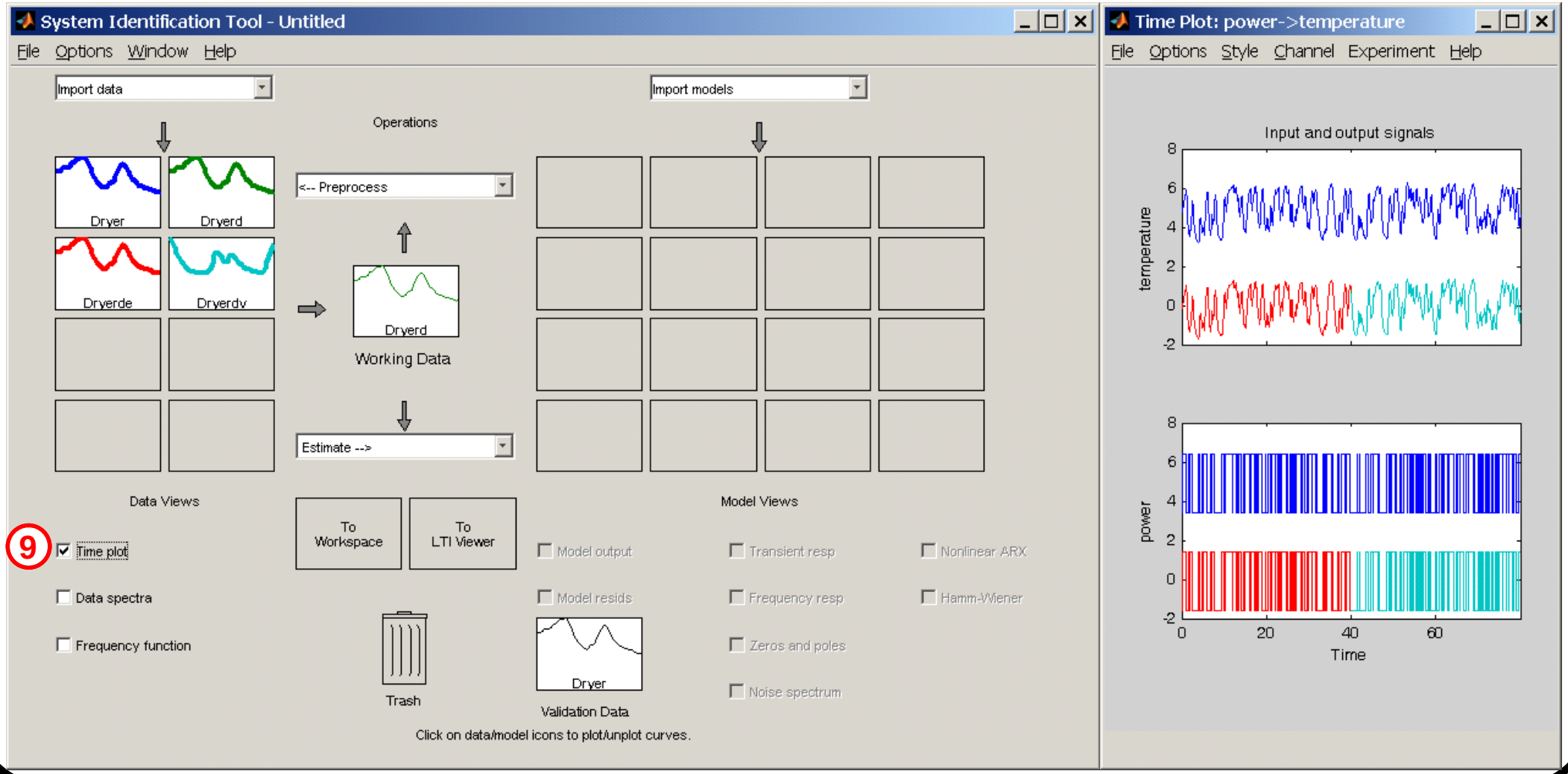


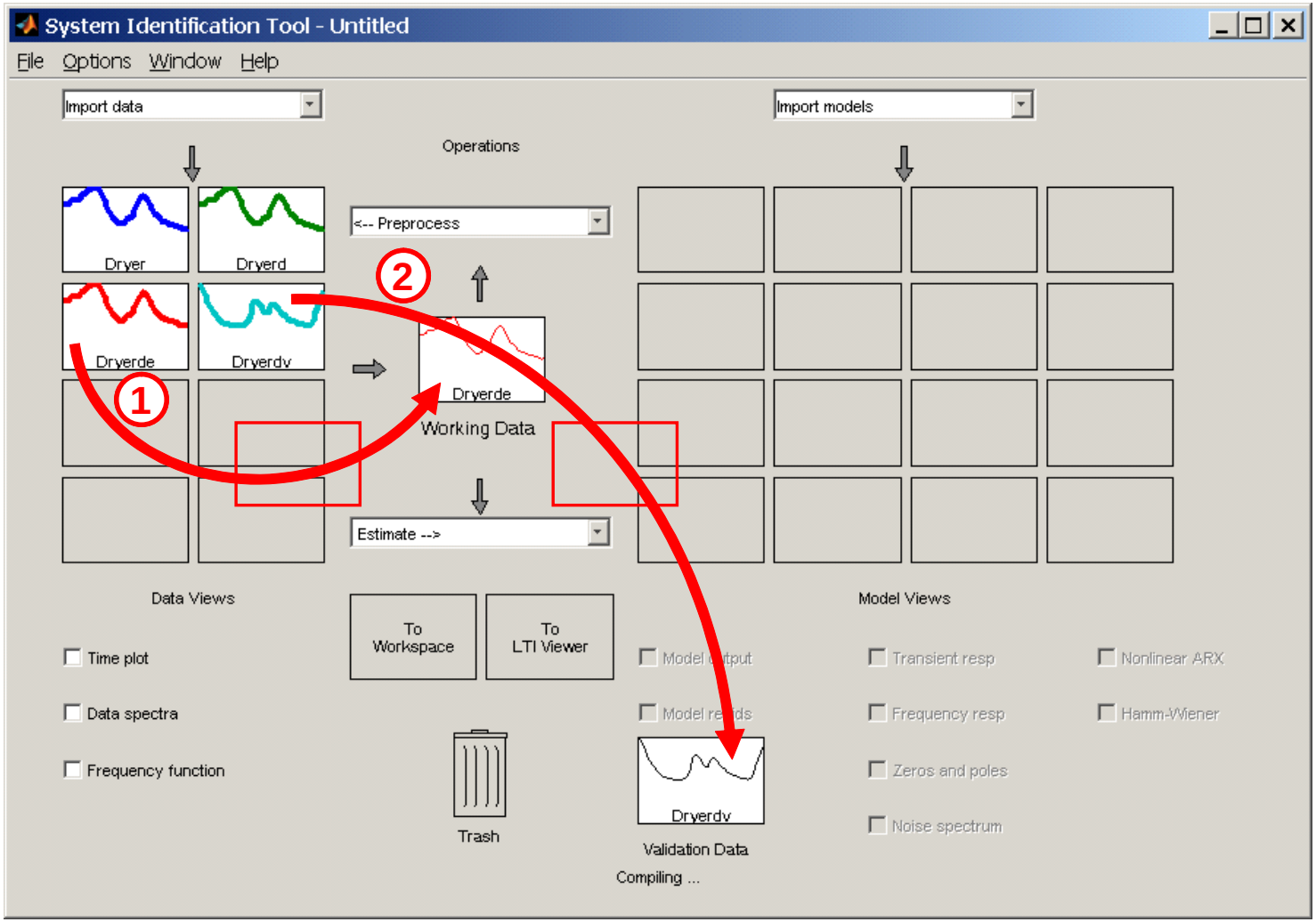
type `501 1000` as Samples for the `Dryerdv` dataset; finally, click on *Insert* and *Close*; the `Dryerde` and `Dryerdv` windows will appear in the *Data Views* area and the corresponding data may be shown by clicking on the *Time plot* option



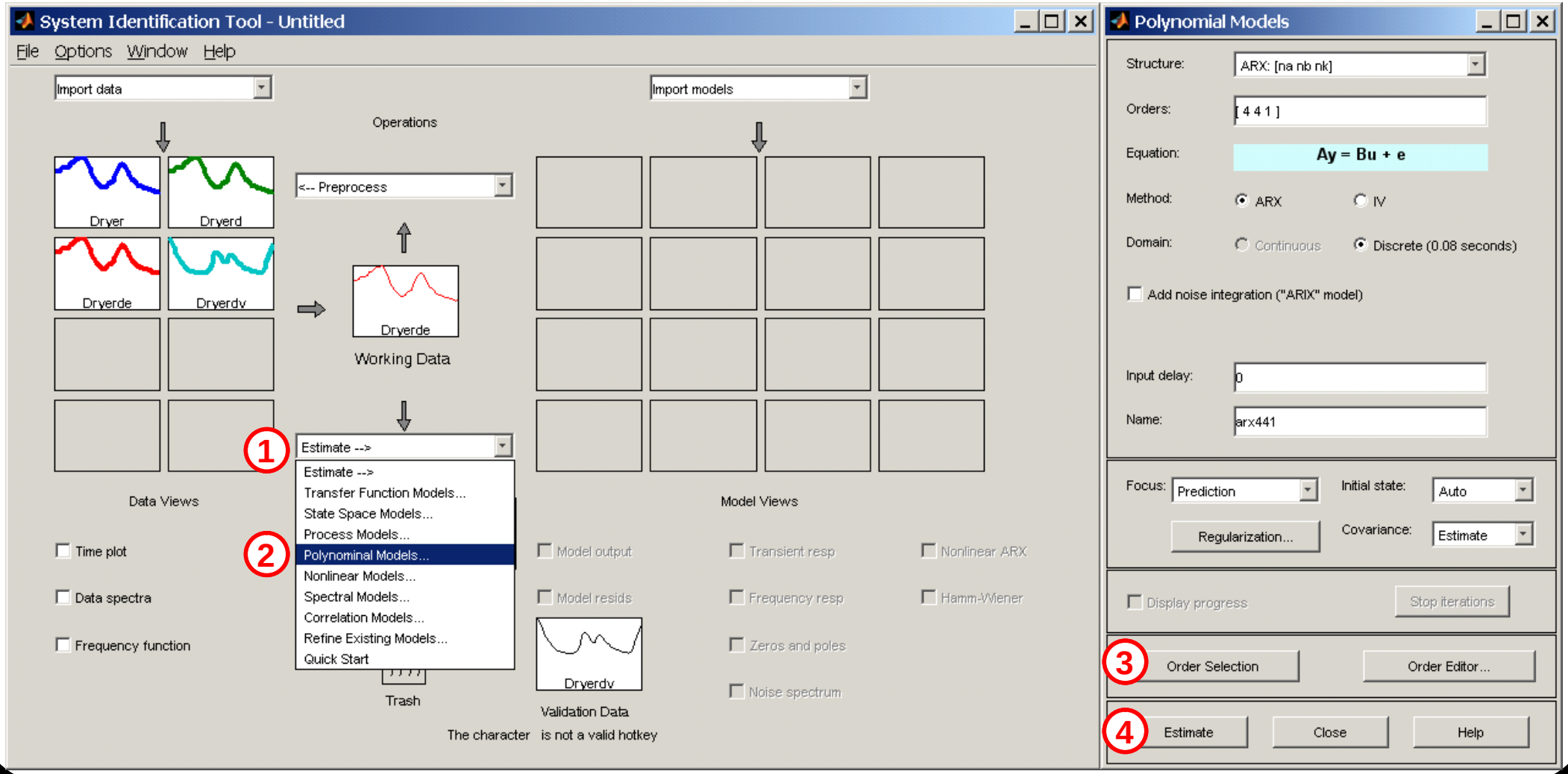
type `501 1000` as Samples for the `Dryerdv` dataset; finally, click on *Insert* and *Close*; the `Dryerde` and `Dryerdv` windows will appear in the *Data Views* area and the corresponding data may be shown by clicking on the *Time plot* option



6) Set ES as the current working dataset and VS as the current validation dataset, by clicking the `Dryerde` and `Dryerdv` windows in the *Data Views* area and dragging them to the *Working Data* and *Validation Data* boxes, respectively



7) Perform the order selection for an ARX structure: click on *Estimate* and select *Polynomial Models*, then click on *Order Selection* and *Estimate*, in order to consider and compare different model selection criteria: Best Fit, AIC, MDL



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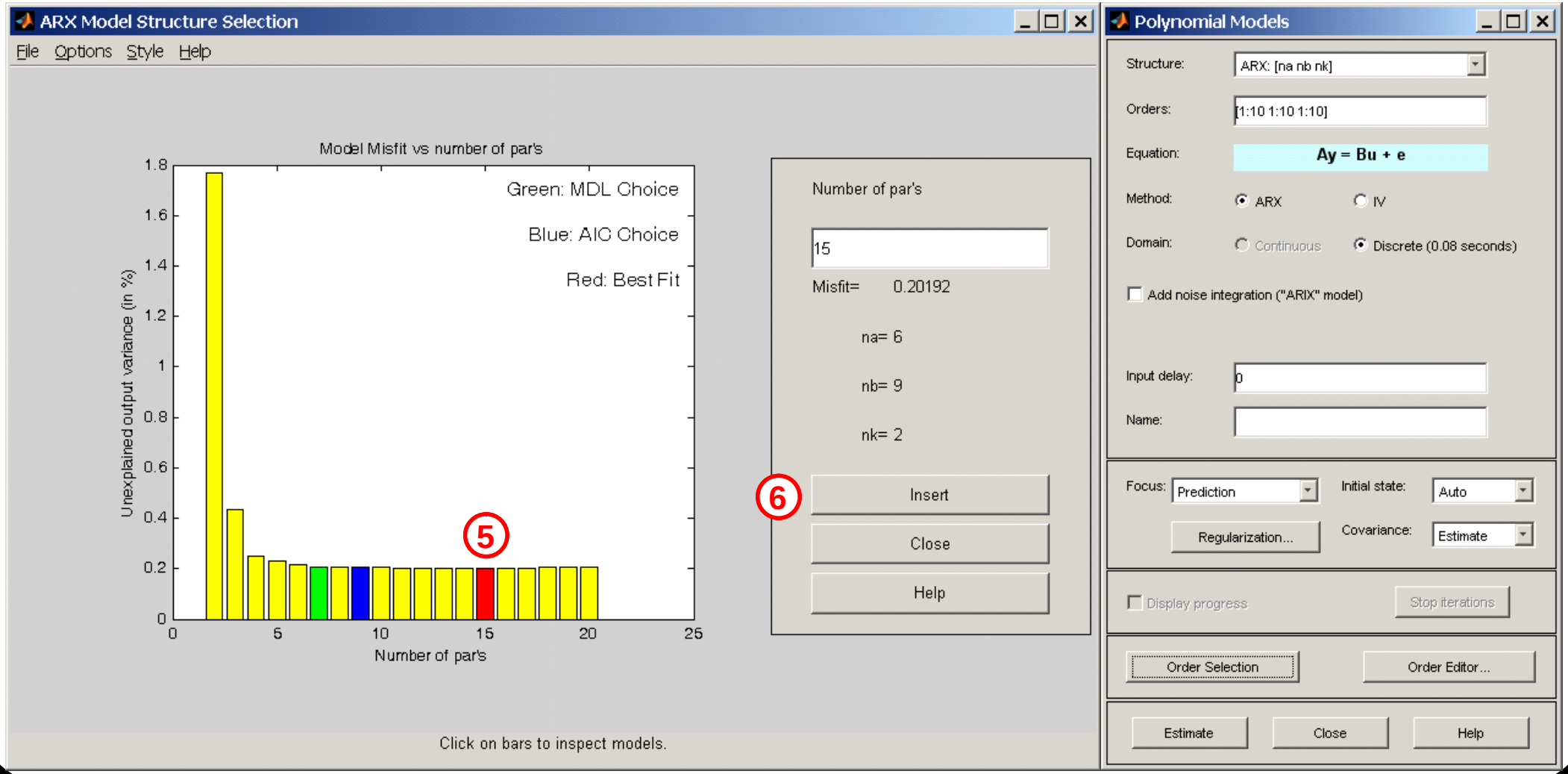

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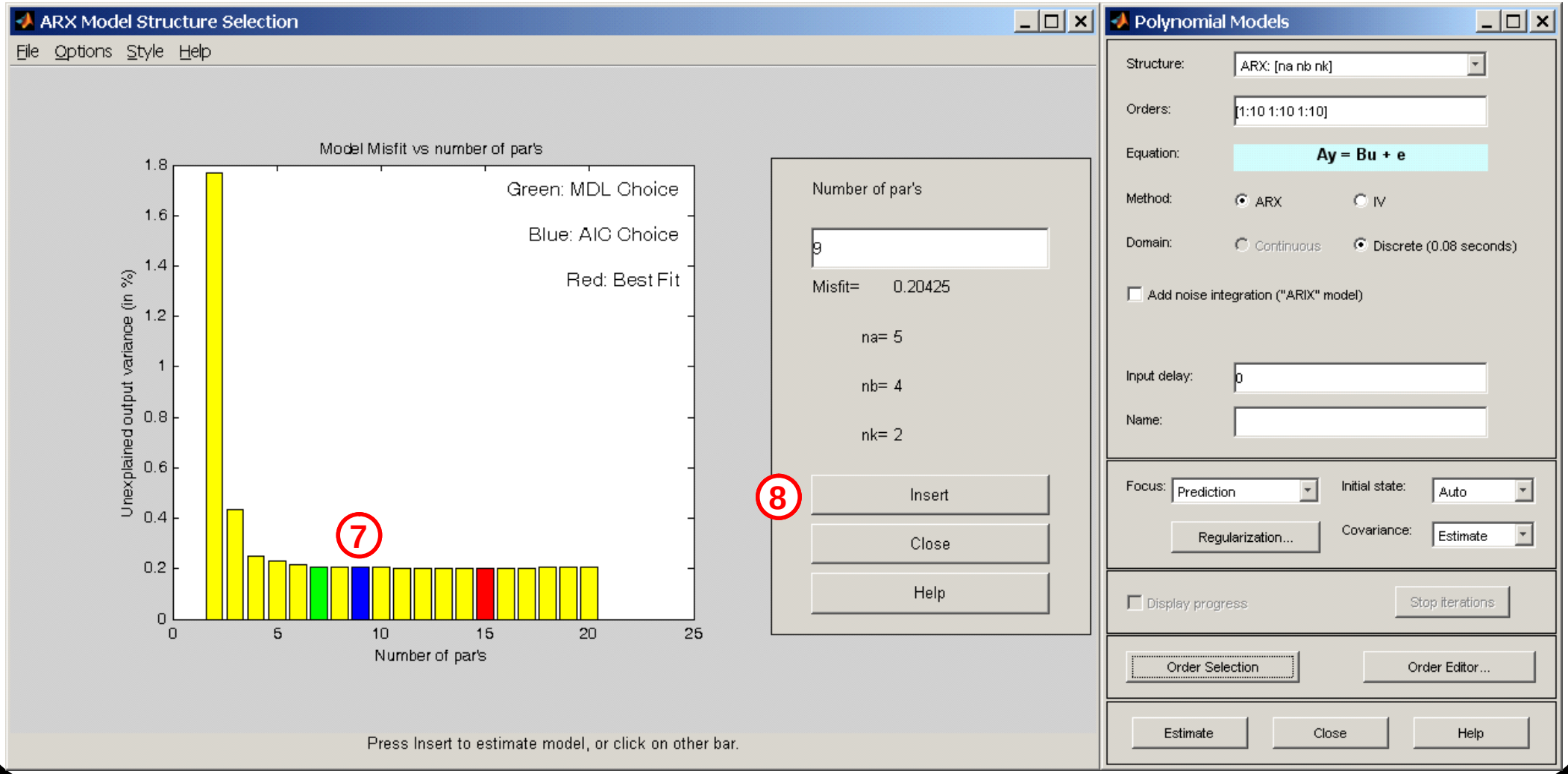

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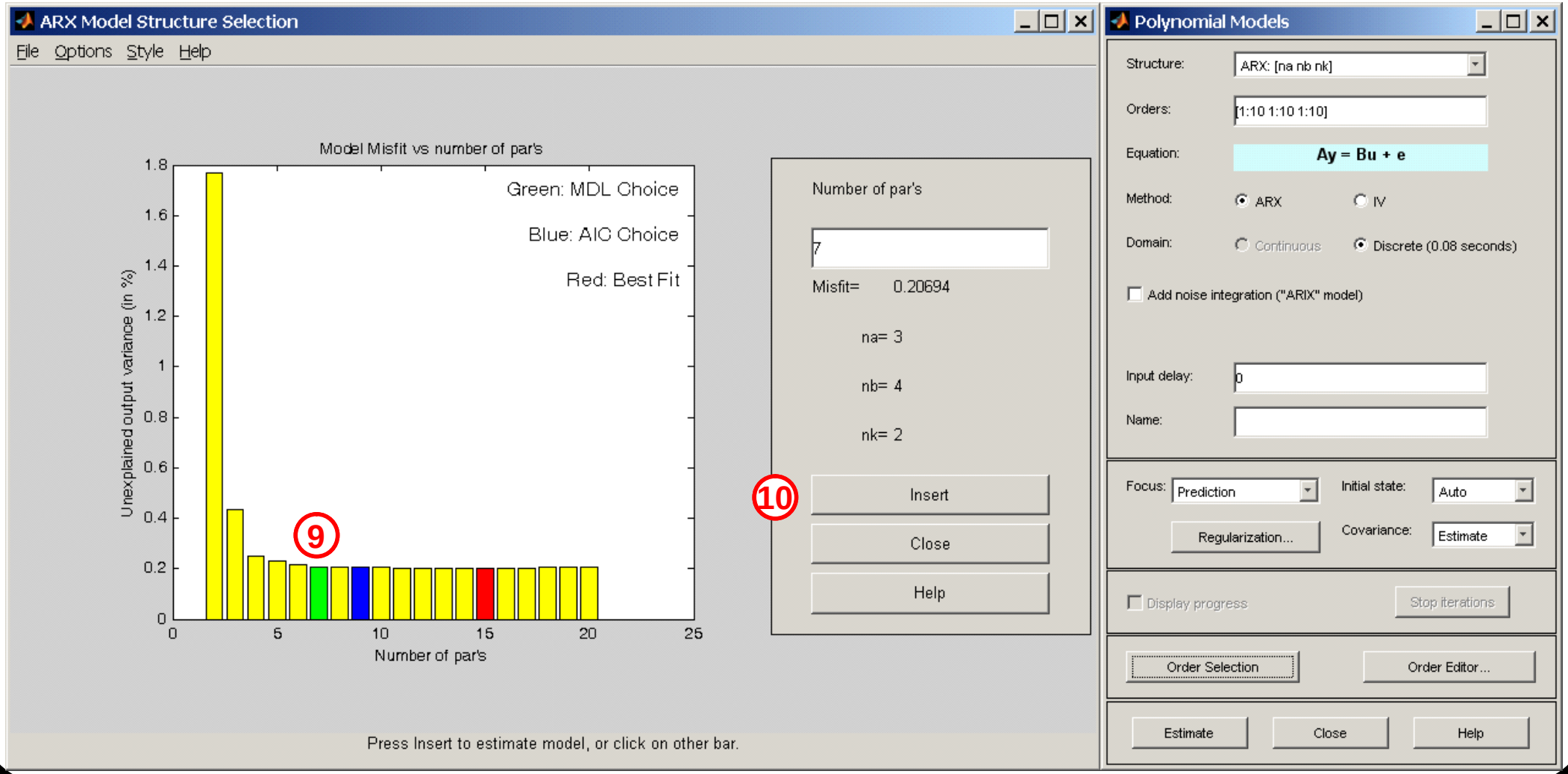
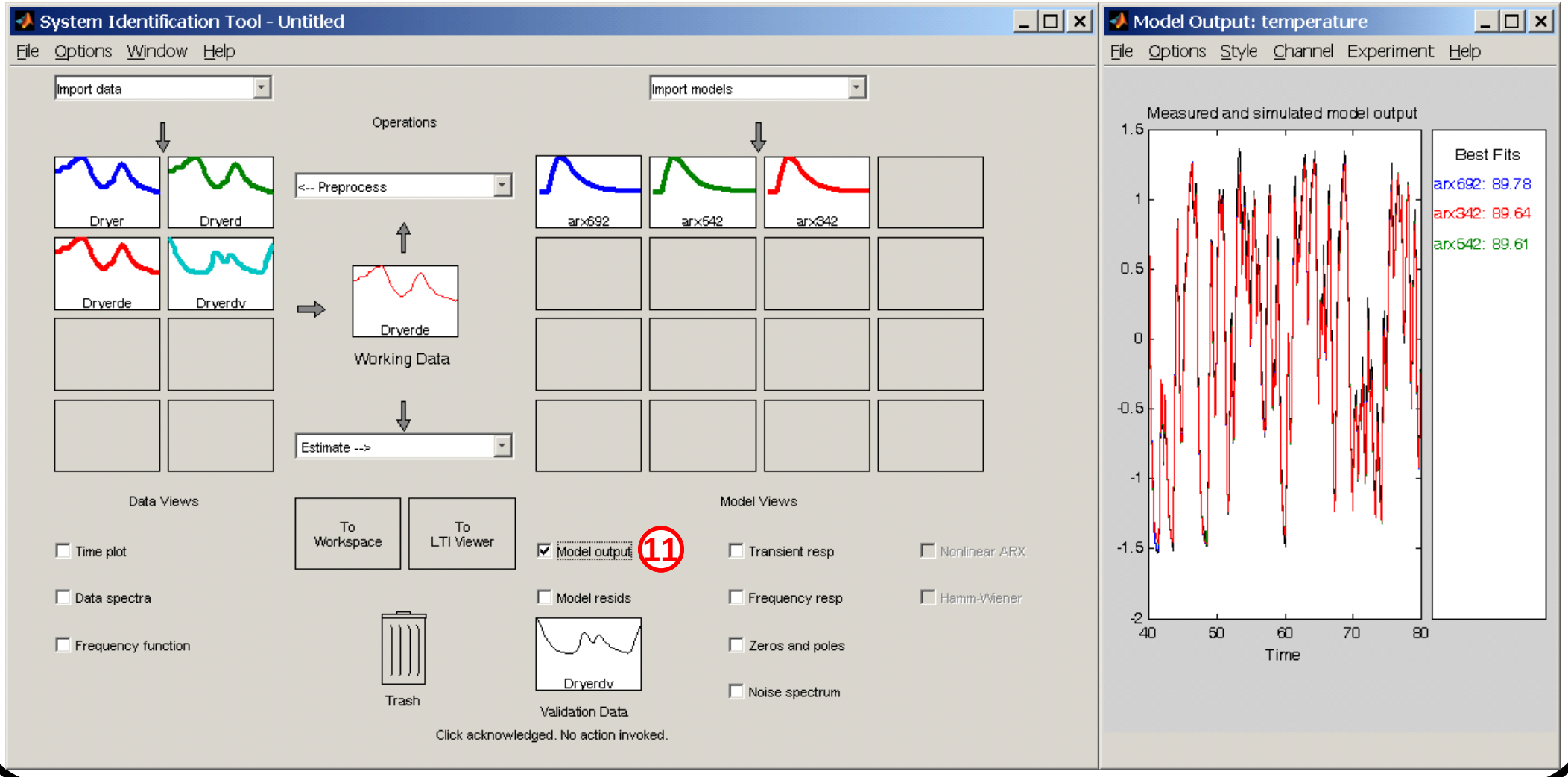


To compare the identified models on the VS dataset considering:

- the Best Fit index (to be maximized), click on the *Model output* option
- the residual analysis, click on the *Model resids* option



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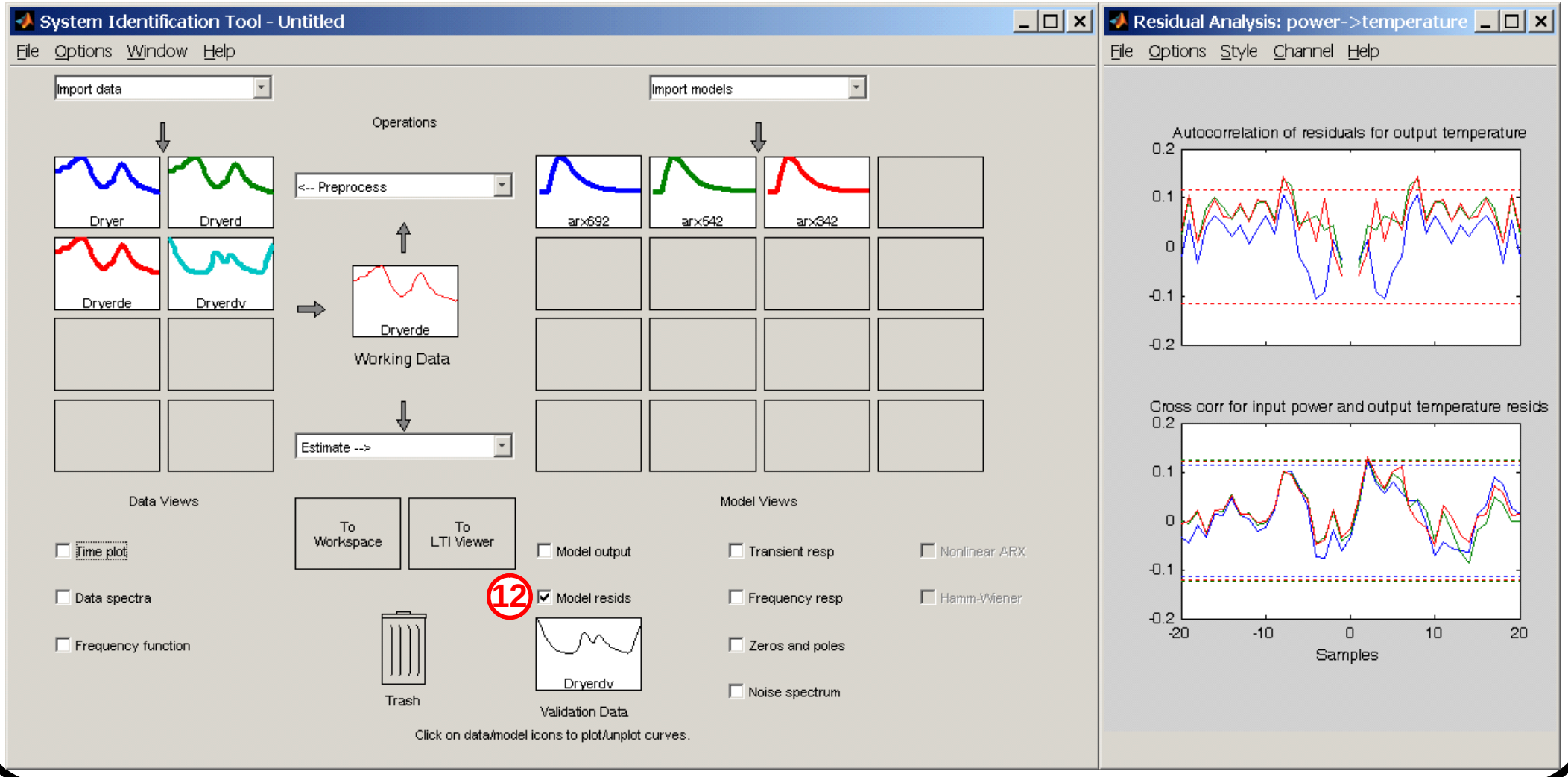
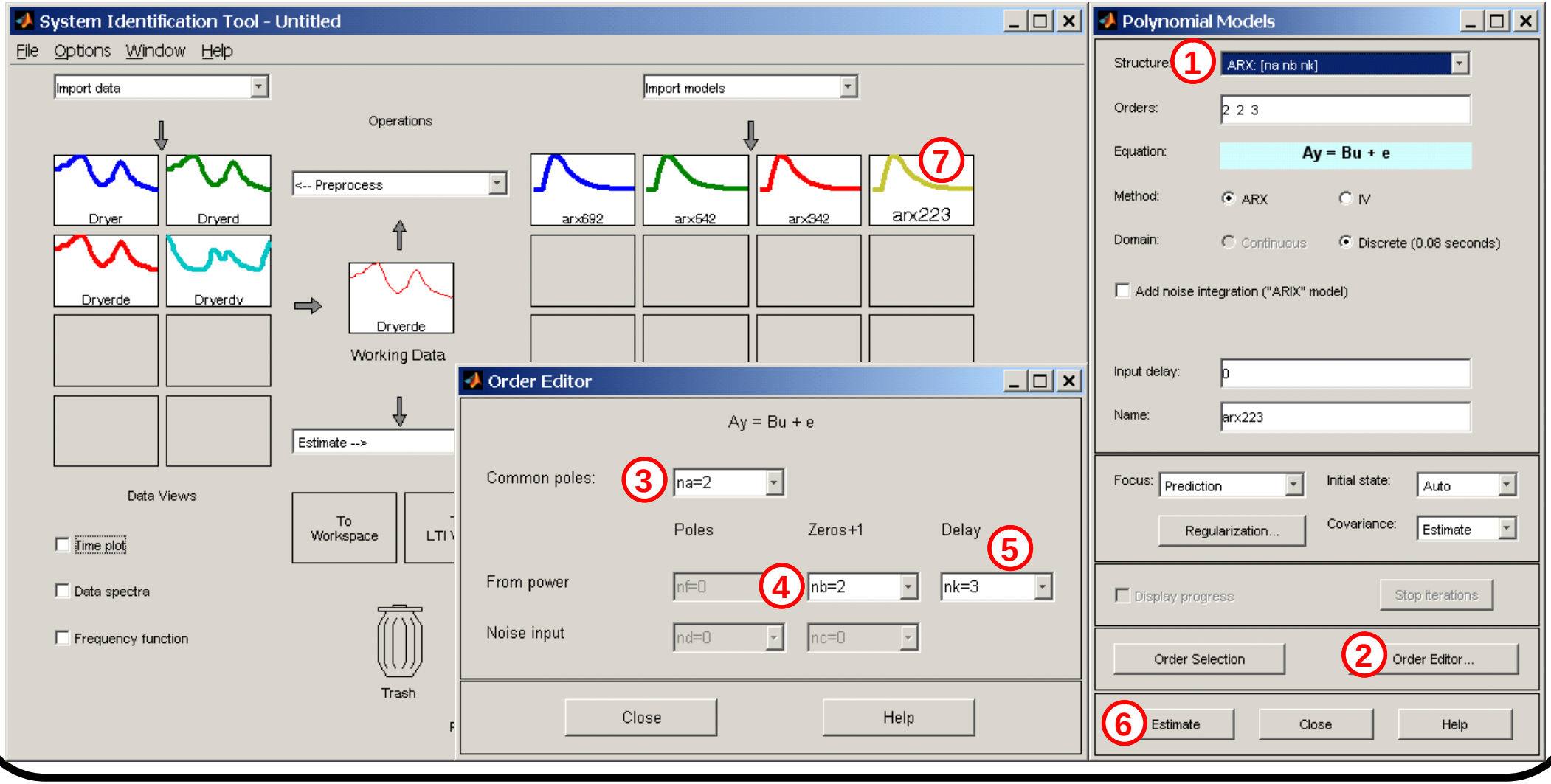
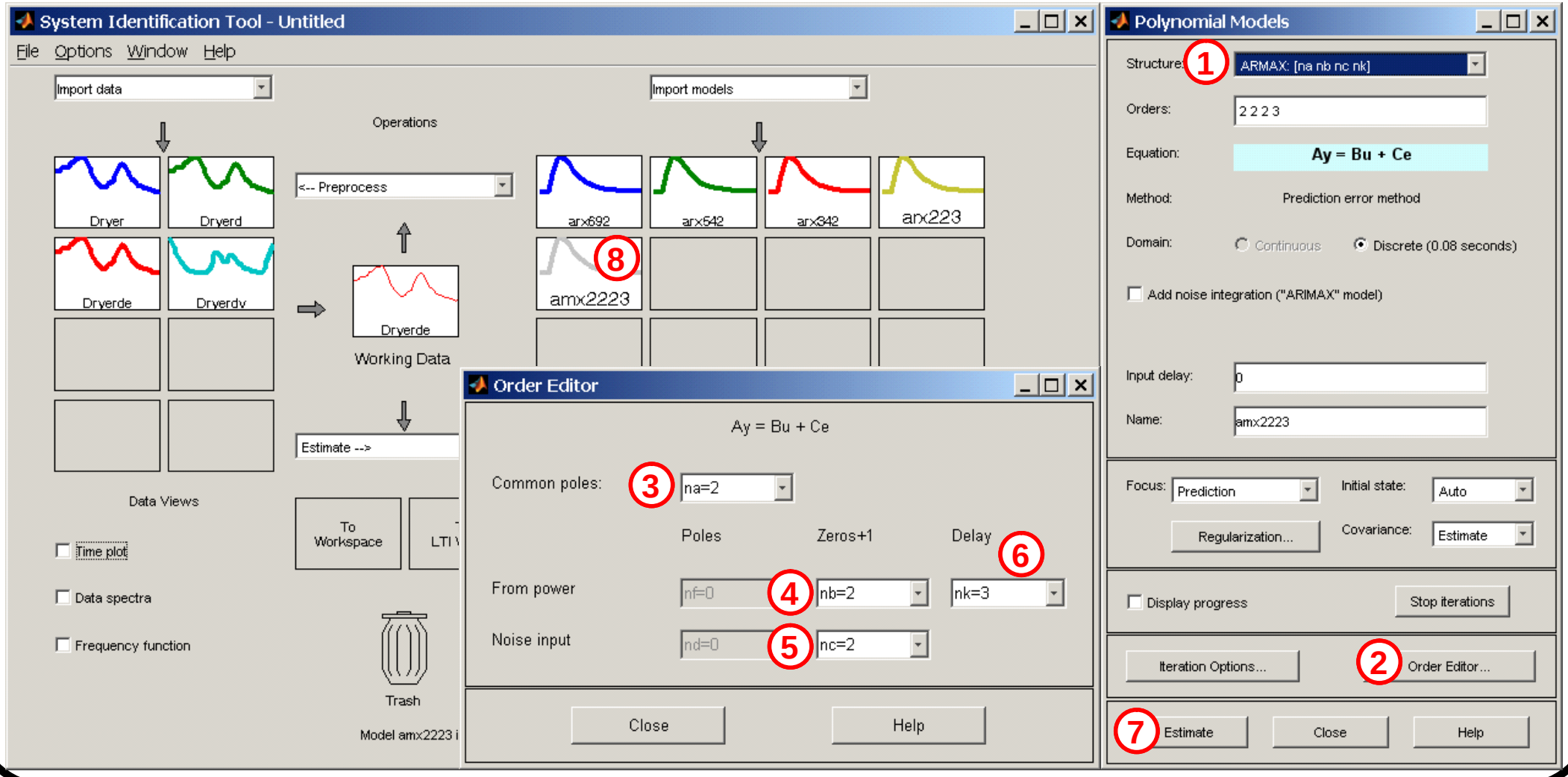


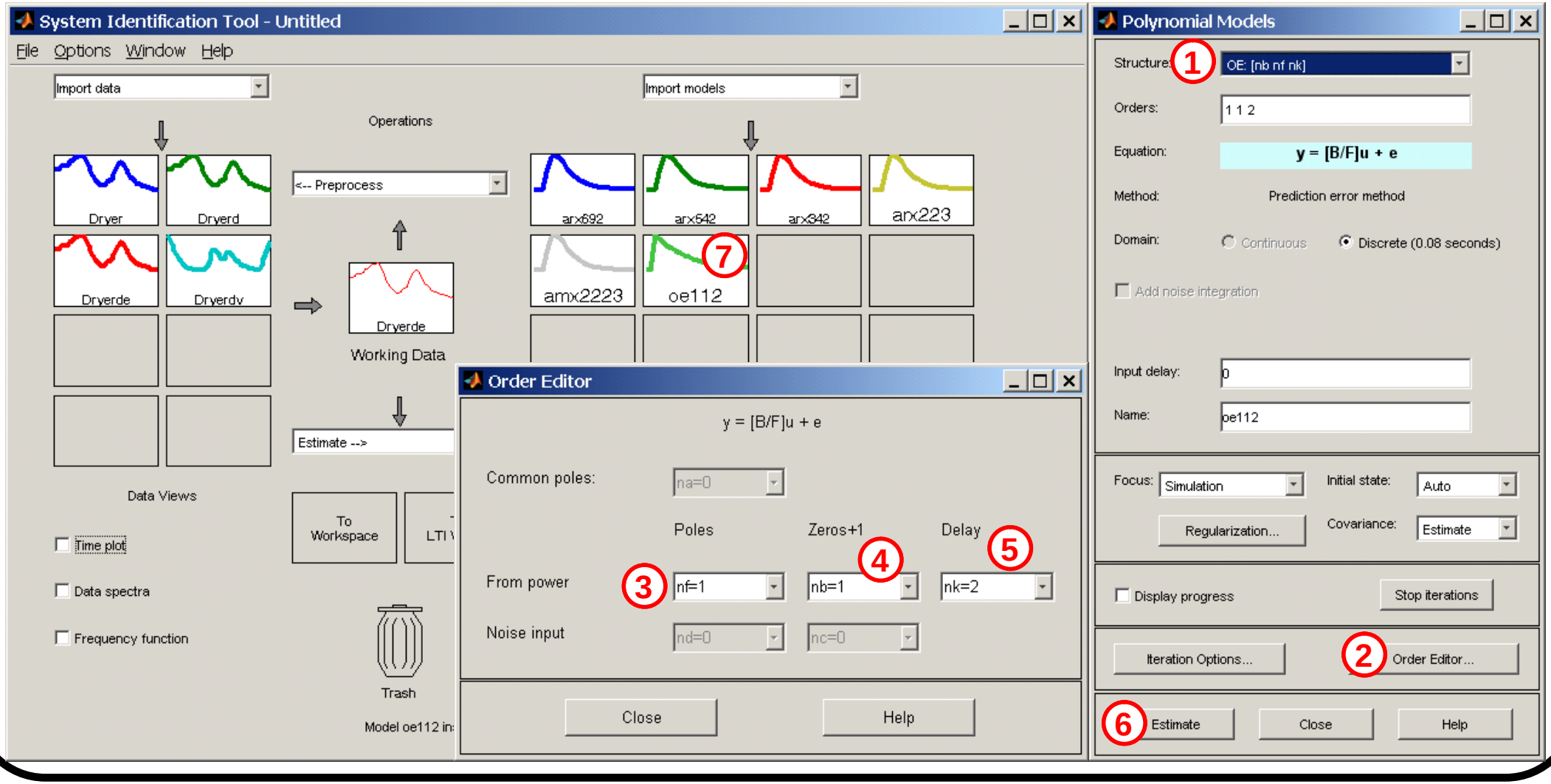
8) Identify several `ARX(na,nb,nk)` models with `na=nb=1,...` and `nk=1,...`: choose as *Structure* the ARX model class (click on the *Order Editor* or specify in *Orders* `na`, `nb`, `nk`), click on *Estimate* in the *Polynomial Model* window



8) Identify `ARMAX(na,nb,nc,nk)` models with `na=nb=nc=1,...` and `nk=1,...`: choose as *Structure* the ARMAX model class (click on the *Order Editor* or specify in *Orders* `na`, `nb`, `nc`, `nk`), click on *Estimate* in the *Polynomial Model* window



8) Identify several `OE(nb,nf,nk)` models with `nb=nf=1,...` and `nk=1,...`: choose as *Structure* the OE model class (click on the *Order Editor* or specify in *Orders* `nb`, `nf`, `nk`), click on *Estimate* in the *Polynomial Model* window



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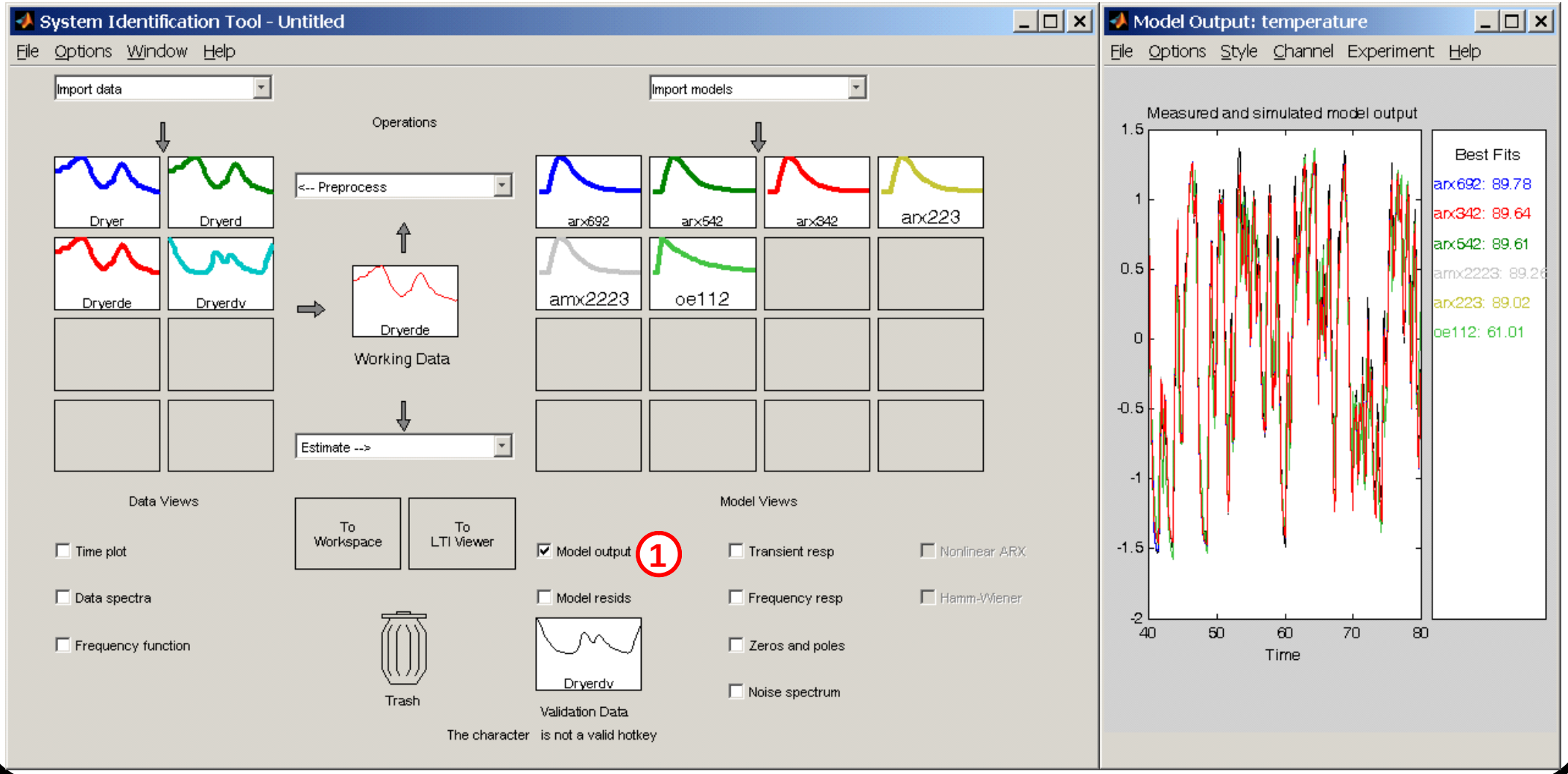

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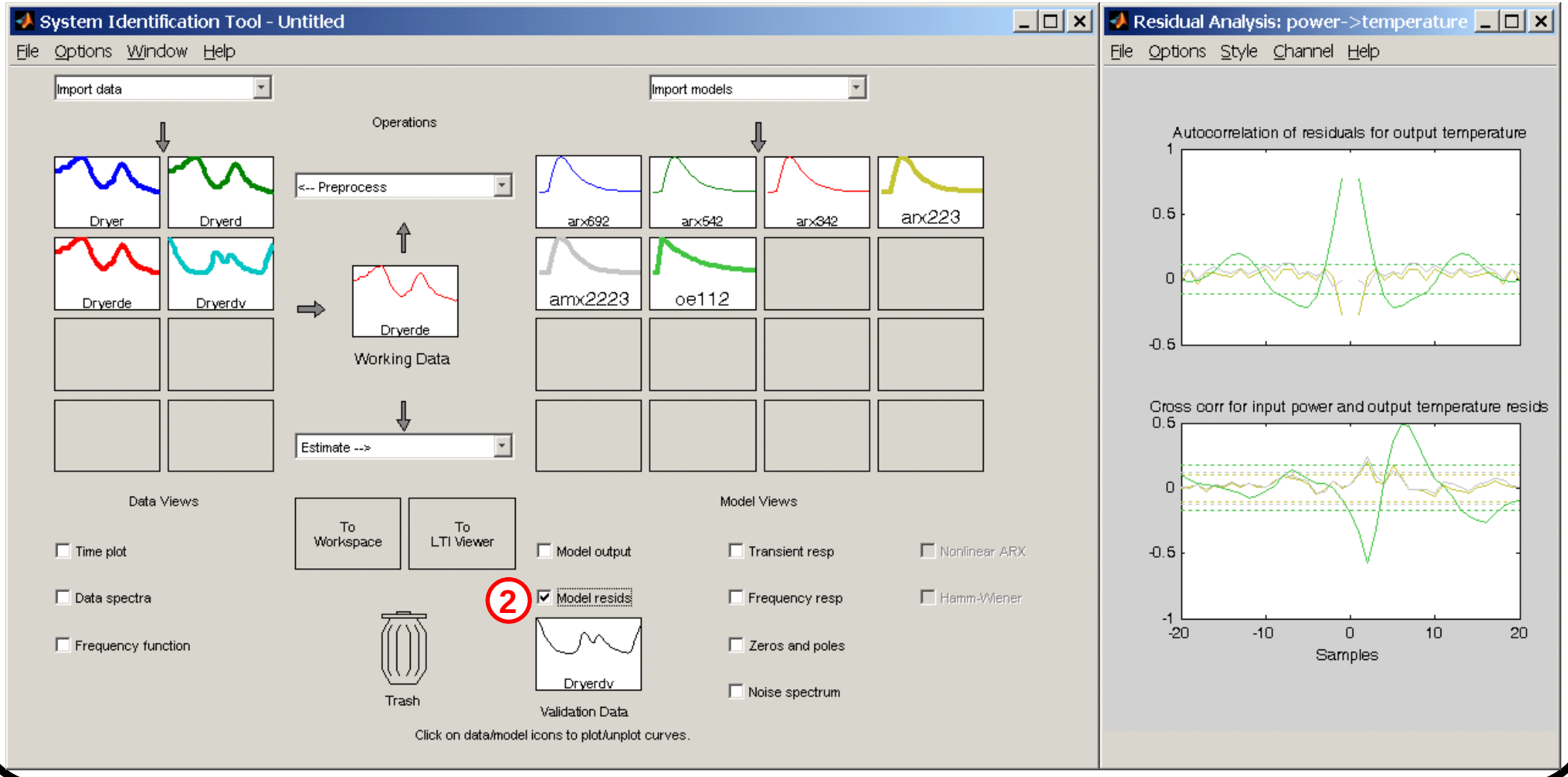

10) Select and export the “best trade-off” model: click the corresponding window in the *Model Views* area and drag it to the *To Workspace* box