Non-Parametric Regression and Data Analytics Using GRACE (Graphical Alternating Conditional Expectation)

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Outline

- What is multiple regression
- Problems with conventional multiple regression methods
- Optimal transformations by GRACE
- Applications of GRACE
- Conclusions

What is Multiple Regression?

Given:

Dependent Variable Observations y_i

Independent Variable Observations $x_{1i}, x_{2i}, \ldots, x_{pi}$

Develop:

Multiple Regression Model (Parametric)

$g(y) = a_0 + a_1 f_1(x_1) + a_2 f_2(x_2) + \ldots + a_p f_p(x_p) + \varepsilon$

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Why Multiple Regression?

To correlate data from different sources

- Well Performance Analysis in Unconventional Reservoirs
- Permeability Prediction from Well logs (Δt, GR, ϕ_{Log}, etc)
- Correlating PVT Properties
- Relating Petrophysical Properties to 3-D seismic attributes (*Amx, Amn,* Δt_0, etc)

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Problems with Parametric Multiple Regression Methods

- Need to know functional relationships between dependent and independent variables.
- Trial-and-error method for exploring functional forms is time-consuming and not always successful.
- Conventional multiple regression often yields poor results.

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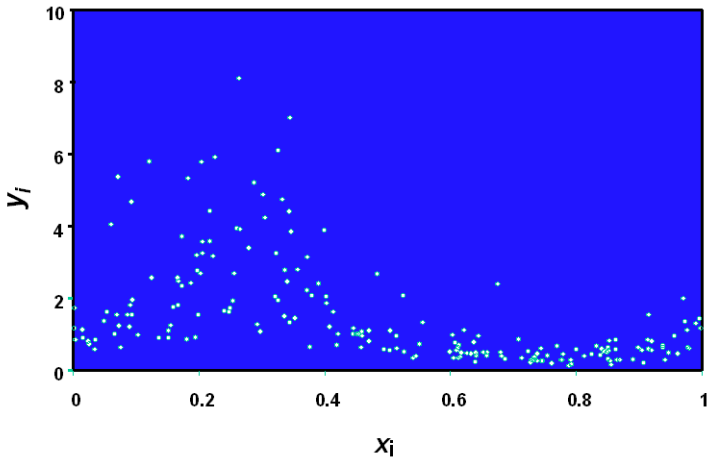
Data Correlation Using GRACE : An Illustration

$$y_i = \text{Exp}\,[\sin(2\pi x_i) + \varepsilon_i/2]$$



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Optimal Transformation

Function Identification - Synthetic Case:

$$y_i = e^{[\sin(2\pi x_i) + \varepsilon_i / 2]}$$

Expected Optimal Transformations:

$$\theta^*(y_i) = \ln(y_i)$$

$$\phi^*(x_i) = \sin(2\pi x_i)$$

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Alternating Conditional Expectation (ACE)
(Breiman and Friedman, 1985)

- Iterative minimization procedure.
- Derived solely on data (no *prior* assumptions of functional forms).
- Computationally-efficient and easy to use.
- Applied to both bivariate and multivariate cases.
- Yields maximum correlations in transformed space.

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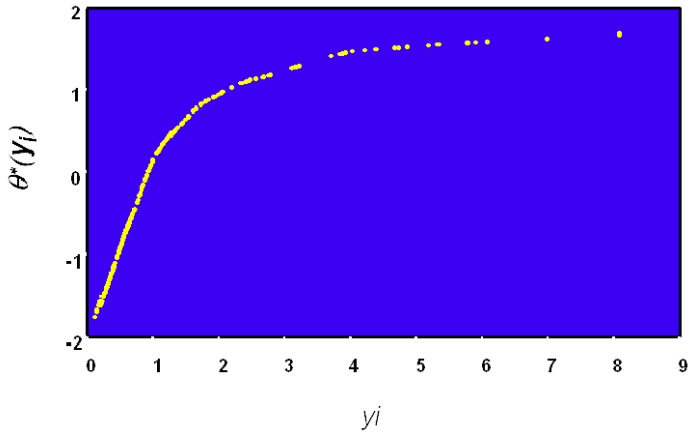
Optimal Transformation of yi



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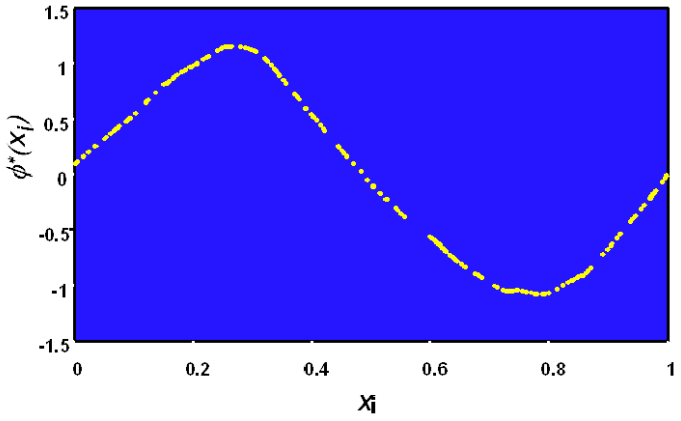
Optimal Transformation of xi



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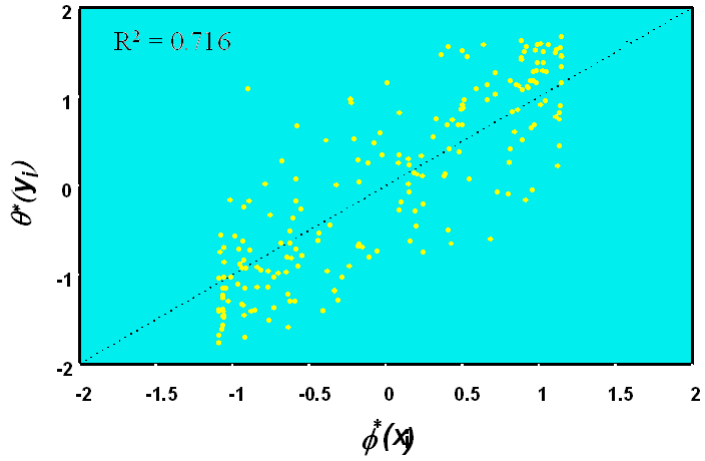
Regressing Optimum Transforms



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Optimal Transformations for Multiple Regression

Given:

Y and $X_1, X_2,...,X_p$

Find Transformation Functions:

$\theta(Y)$ and $\phi_1(X_1), \phi_2(X_2), ...,\phi_p(X_p)$

To Maximize the Correlation:

$\theta^*(Y)$ vs. $\phi_1^*(X_1) + \phi_2^*(X_2) + ... + \phi_p^*(X_p)$

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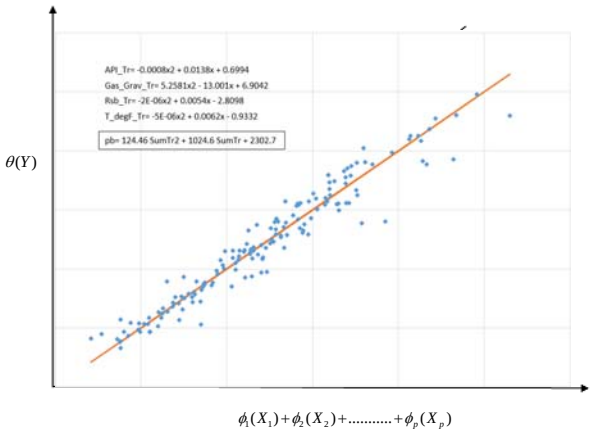
Optimal Transformations for Multiple Regression



Fit the Transformations with Simple Polynomials to develop the Regression Equation

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Demonstration of GRACE using Eagle Ford Data

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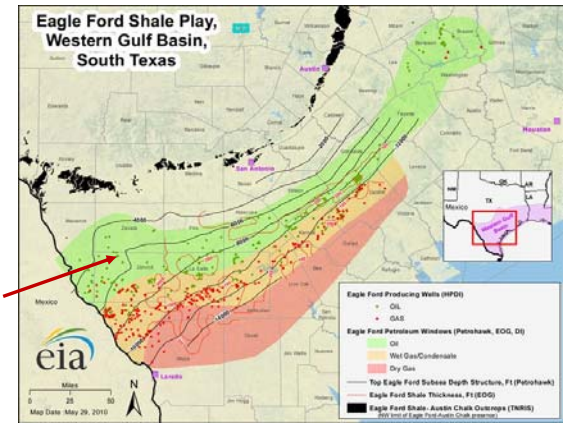
Eagle Ford Application: Well Data

Predictor Variables

- Initial flow Rate (≈ Max. flow rate)
- Well Location
  - Well Latitudes and Longitudes
  - TVD of heel
  - TVD heel-toe difference
- Well Completion
  - Completed Length
  - Number of Fracturing Stages
  - Total amount of Proppants
  - Total volume of Fracturing Fluids



Study Area (green)

Response Variable

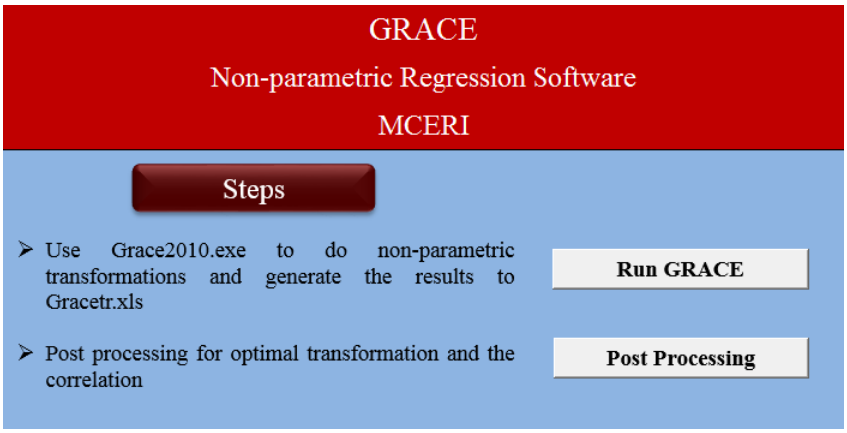
- EUR

GRACE – Regressing Eagle Ford data

Variable	Description	Units
CLENGTH	Completed Length ($MD_{last\ perf} - MD_{first\ perf}$)	ft
FRAC_FLUID_TOTAL	Total Fracturing fluid injected	bbl
LATITUDE	Latitude coordinate	degrees
LONGITUDE	Longitude coordinate	degrees
PROP_TOTAL	Total proppant placed	lbs
qi	Initial flow rate (taken as maximum flow rate)	STB/month
STAGES	No. of Hydraulic Fracturing stages	-
TVD_HEEL	Total Vertical depth	ft
TVD_HEEL_TOE_DIFF	Difference in depths of heel and toe	ft
SEDM_EUR	Estimated Ultimate Recovery using SEDM Model	MSTB

GRACE Software Steps

- **STEP 1 -** Open GRACE_Main.xlsm in GRACE folder



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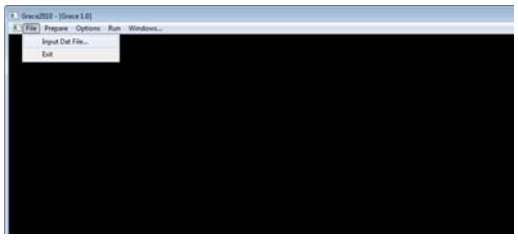
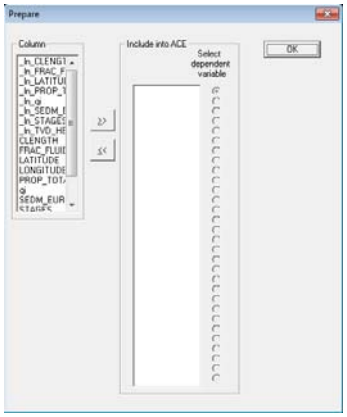
GRACE Software Steps

- **STEP 2 -** Press “Run GRACE” button in the Excel sheet
- **STEP 3 -** Go to File -> Input Dat File and select Eagle_Ford.dat





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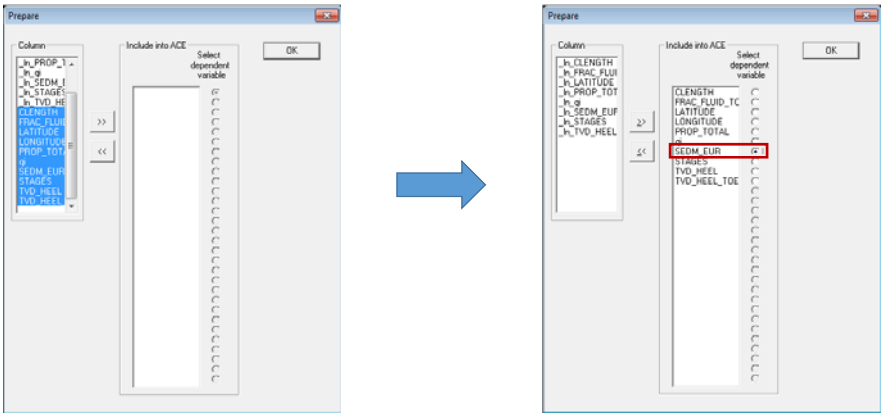
GRACE Software Steps

- **STEP 4 –** Choose variables predictors and response. Select SEDM_EUR as dependent variable and Press OK



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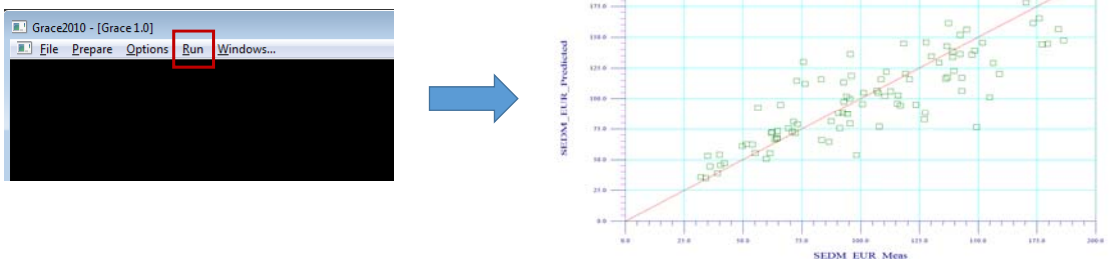
GRACE Software Steps

- **STEP 5 –** Press Run to get ACE regression results



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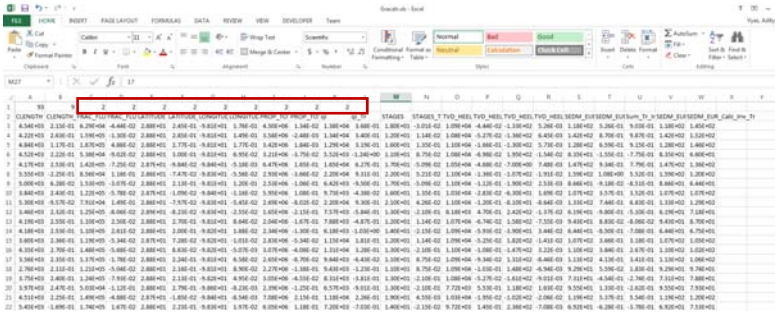
GRACE Software Steps

- **STEP 6 (Optional)**
  - Open output file “Gracetr.xls”
  - Change degree of polynomial if required (Default is 2 and maximum allowed degree is 6). Starting from first row, column C for each variable, specify degree of polynomial to be fitted for transformed-untransformed correlation.
  - Save and close the excel sheet.



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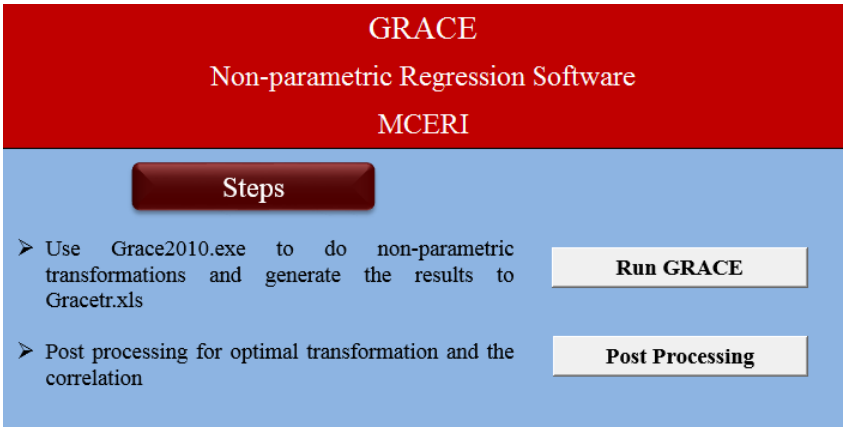
GRACE Software Steps

- **STEP 7 –** In previously opened GRACE_Main.xlsm file, press “Post Processing” button.



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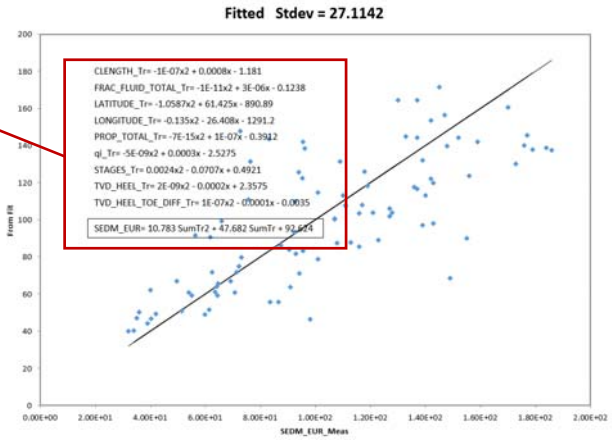
GRACE Software Steps

- Pressing “Post Processing ” button should open “Gracetr.xls”. The optimal transforms for various variables and the fitted model is provided in this sheet.

Transformation Equations



GRACE Software Steps

- **STEP 8 –** In GRACE folder, find “GRACE_Test.xlsm” file and press “Predict Test Data” button. Select “Eagle_Ford_Test.xlsx” in the window.