Economic Risk and Decision Analysis for Oil and Gas Industry CE81.9008

School of Engineering and Technology
Asian Institute of Technology

January Semester

Presented by
Dr. Thitisak Boonpramote

Department of Mining and Petroleum Engineering, Chulalongkorn University

Simulation using @RISK

What is @RISK?

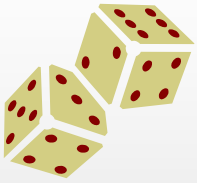
- @RISK is a modeling tool that allows you to incorporate (and quantify) uncertainty in your decision making
- Similar software is Crystal Ball
- Implements Monte Carlo simulation via an Excel Add-in
- Leverages power of Excel to facilitate model construction, analysis and presentation of results

Why use @RISK?

- Statistical and uncertainty models can range from very simple to very complex
- Models can quickly become too complex for manual calculations
- Best explained with an illustration

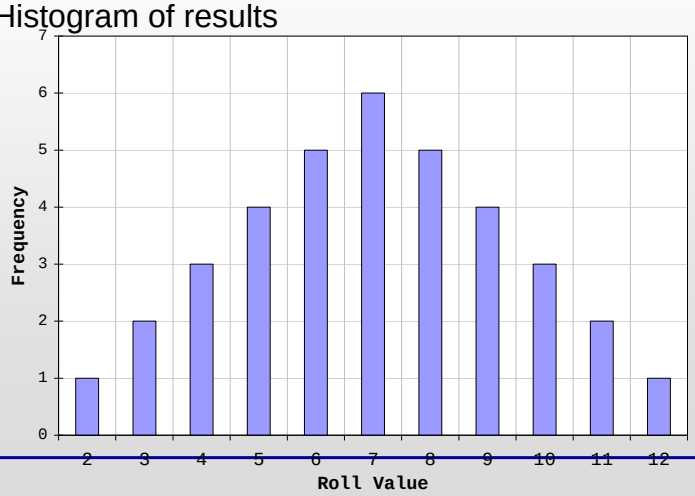
Rolling the Dice – A simple @RISK model

- Two six-sided dice, numbering 1 to 6
- Questions
  - What are the possible combinations of numbers that can occur on any roll?
  - What is the frequency of occurrence of each number?
- Both questions can be answered with simple manual calculations – don't need @RISK for this

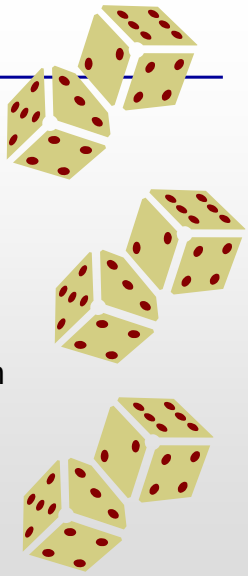


Outcomes of rolling two dice

- Range of values is 2 through 12
- Histogram of results



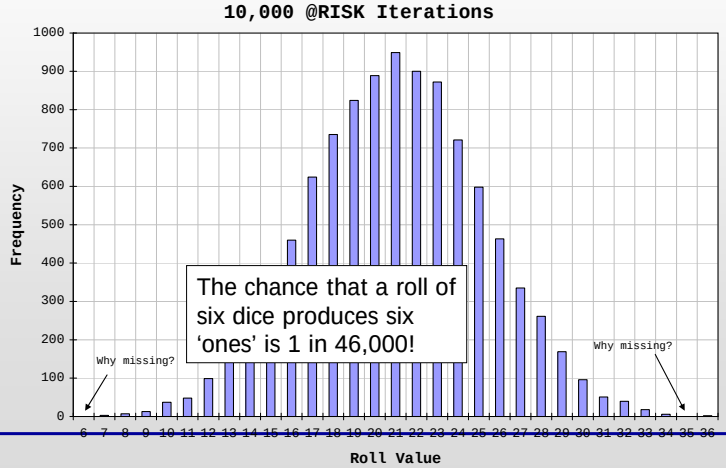
Let's Increase the Complexity



- Six dice, each with numbers 1 through 6
- Questions are the same
  - What are the possible combinations of numbers that can occur on any roll?
  - What is the frequency of occurrence of each number?
- No longer a simple, manual calculation
- We'll show how these models are set up in @RISK later

Outcomes of rolling six dice

- Range of values is 6 through 36
- Histogram of results



Extend Model Complexity

- Models are often very complex
- Can involve many variables, not all of which are independent and/or linear in their behavior
- Examples
  - Estimating fluids in place (gas PVT v Pres)
  - Decline curve analysis (decline curve parameters)
  - Reservoir modeling (porosity, permeability, thickness variations, vertical vs horizontal, lateral lengths, etc)
  - Economic analysis (costs, prices, drilling schedules, expectations for success, dry holes, etc)

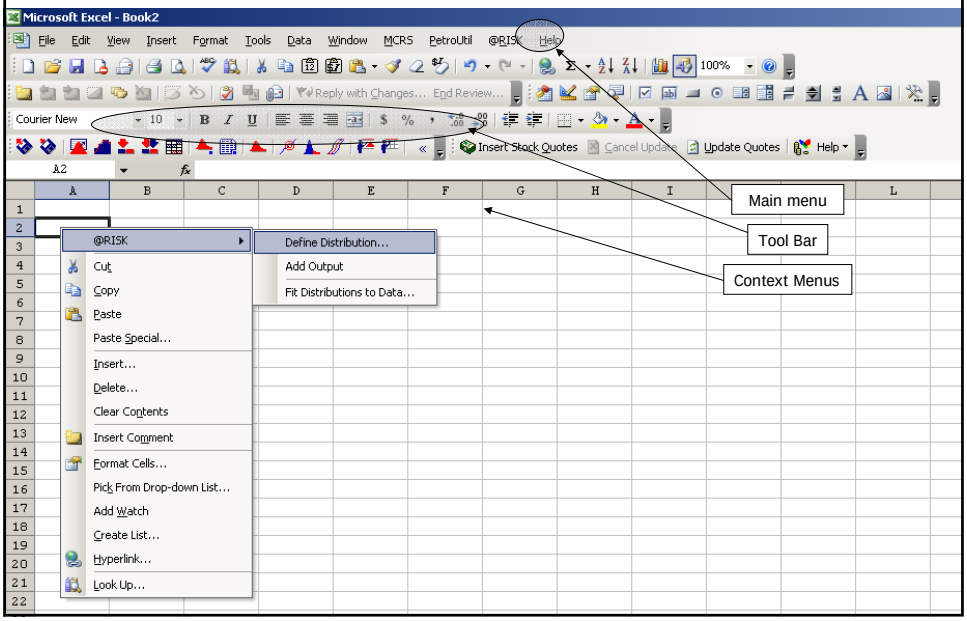
Getting Back to Why Use @RISK?

- When you want to take a *probabilistic* approach rather than a deterministic (or limited scenario) approach
- When you want to understand how *uncertainty* in your inputs affects the outcome of your analysis
- When you want to make decisions in the context of a *range* of possible outcomes (is this better?)
- @RISK facilitates our ability to do all these things

Overview of Basic Features in @RISK

- **Primary functions** (what you'll do most often)
  - Inputs – getting data in using mathematical representations of distribution functions
  - Outputs – capturing, accessing, reviewing and graphing results
  - Settings – setting up the model iterations, sampling scheme, etc.
- **Secondary capabilities**
  - Calibrating (fitting) data to distribution functions
  - Correlation
  - Sensitivity analysis (tornado charts)
- **Integration with Excel** – powerful
  - Excel will be the most commonly used, day-to-day tool in your career
  - @RISK extends that into the probabilistic analysis/statistics realm

@RISK User Interface

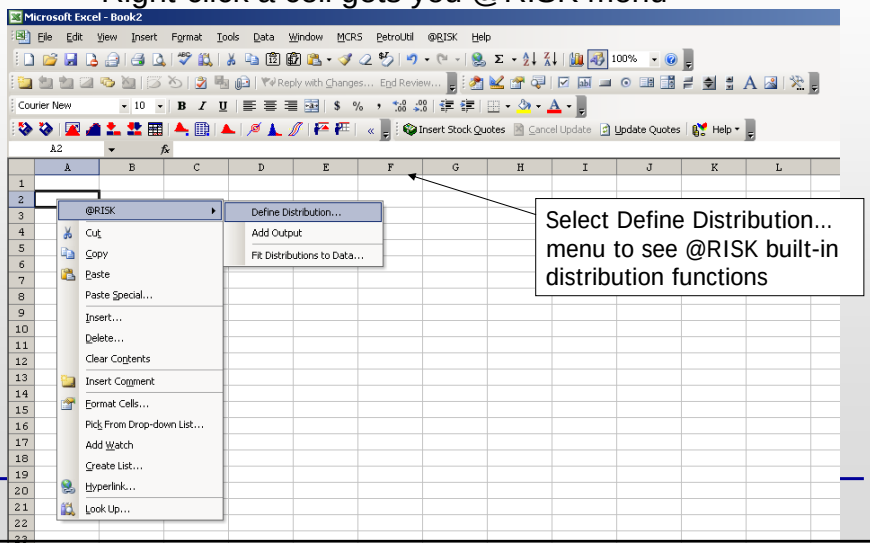


@RISK Input Functions

- Primary mechanism for data input is a collection of @RISK distribution functions
- Can be entered directly or use context menus to access them
- Can be used in a cell by themselves, or combined into any Excel cell formula

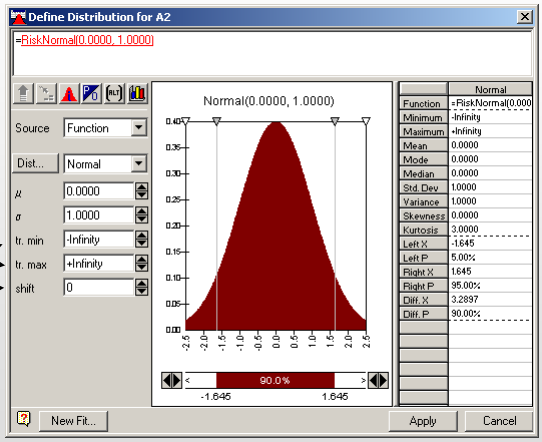
Accessing @RISK Distribution Functions

- Right-click a cell gets you @RISK menu



Accessing @RISK Distribution Functions

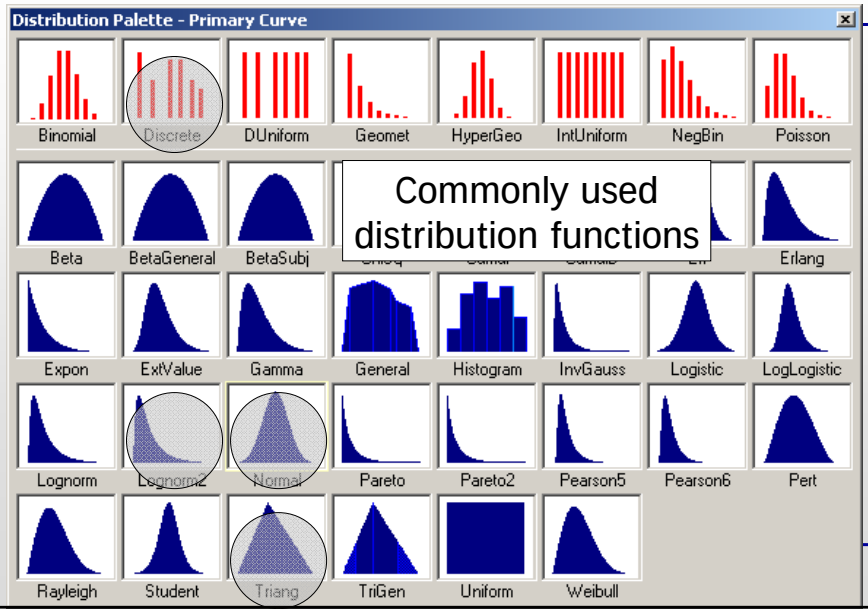
- @RISK Normal Distribution function



- User Inputs:
- Palette
- Mean*
- Std Dev*
- Boundaries
- Shift

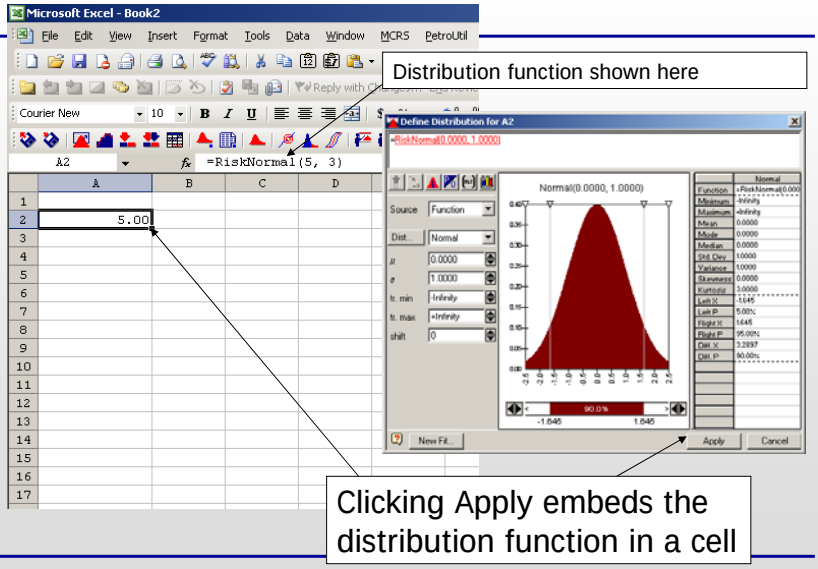
* - Most **distribution functions** are defined simply with **a mean** and **a standard deviation**

@RISK Distribution Functions Palette



Commonly used distribution functions

@RISK Distribution Function in a Cell

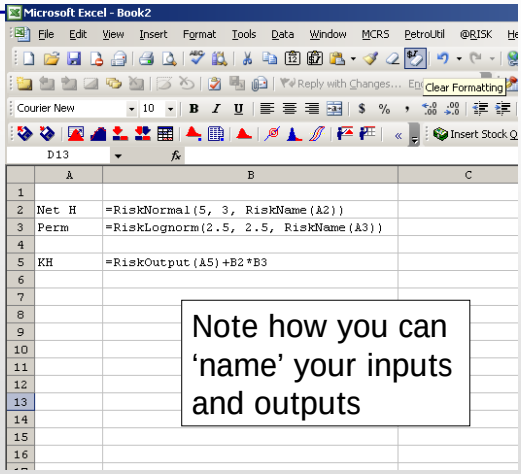


@RISK Output Functions

- @RISK output function ‘captures’ any information in your spreadsheet model resulting from calculations in @RISK
- Use ‘=Riskoutput()+formula’ syntax
- Can be a single cell reference or a formula that combines @RISK distribution values with other items in the spreadsheet

Example @RISK Model Showing Formulas

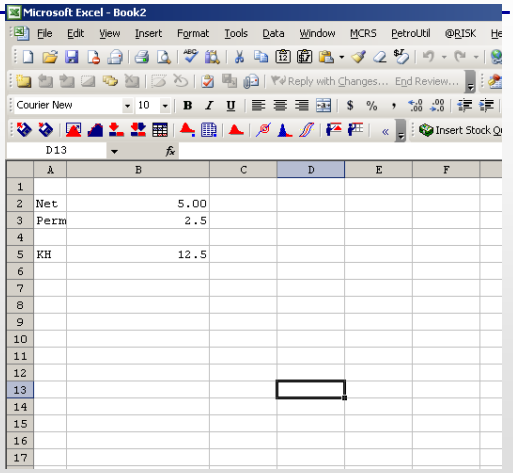
- Normal & log normal distributions
- Output is product of the two distributions



Note how you can 'name' your inputs and outputs

Example @RISK Model Showing Values

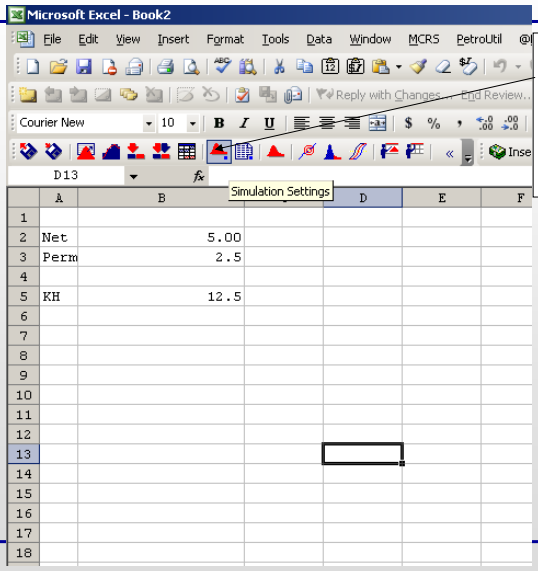
- Normal & log normal distributions
- Output is product of the two distributions



Running an @RISK Model

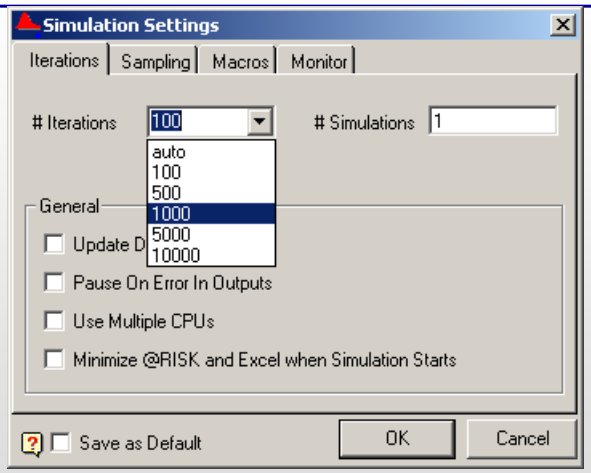
- What you need to know ahead of time
  - How many simulations?
  - How many iterations?
  - What type of sampling?
  - Running any macros with the model?
- Access settings via the main menu or the toolbar

@RISK Model Settings

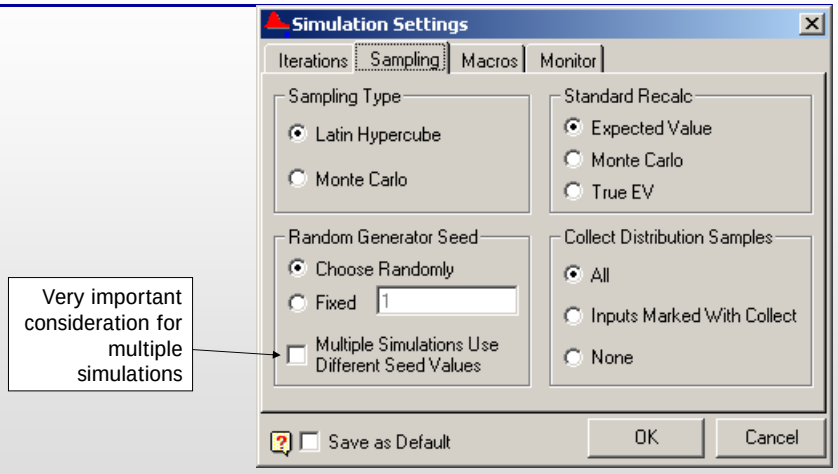


Toolbar 'Simulation Settings' button

@RISK Model Settings Dialog – Iterations Tab

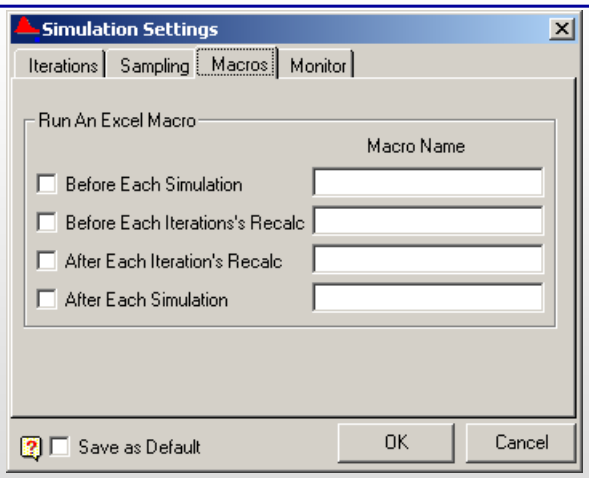


@RISK Model Settings Dialog – Sampling Tab

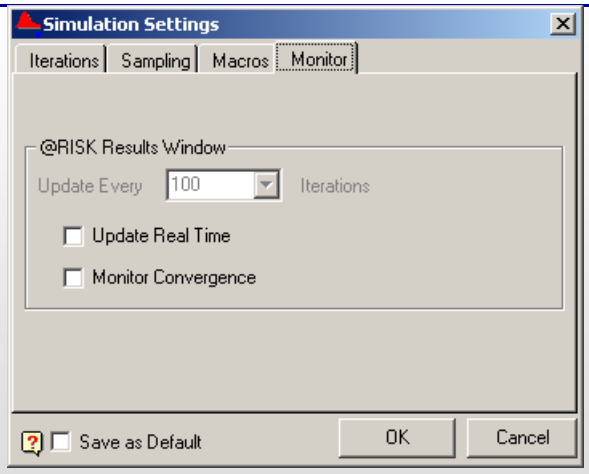


Very important consideration for multiple simulations

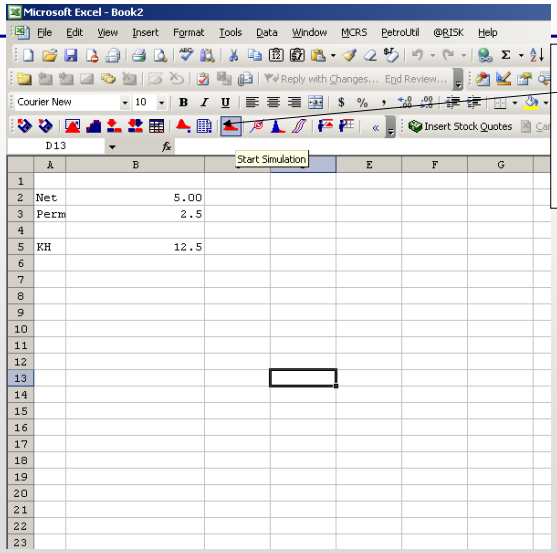
@RISK Model Settings Dialog – Macros Tab



@RISK Model Settings Dialog – Monitor Tab

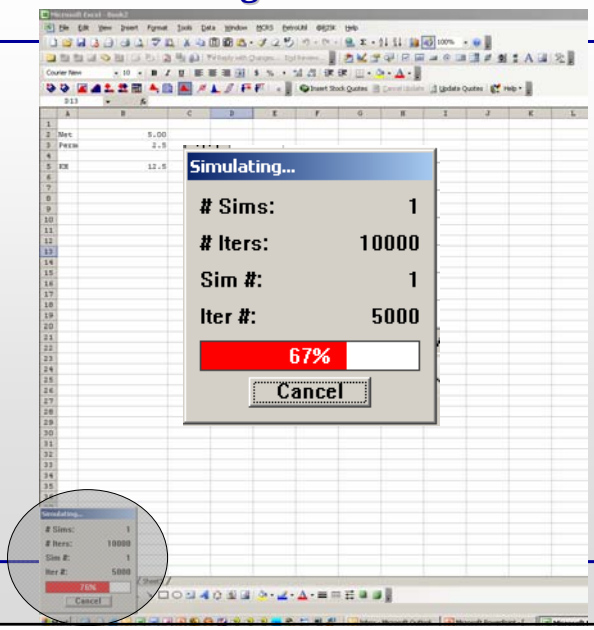


@RISK Model Run Simulation

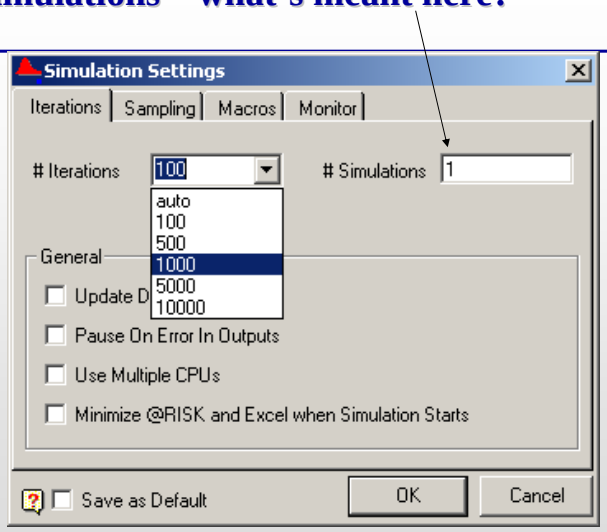


Toolbar 'Start Simulation' button

@RISK Model Running



Multiple Simulations – what's meant here?



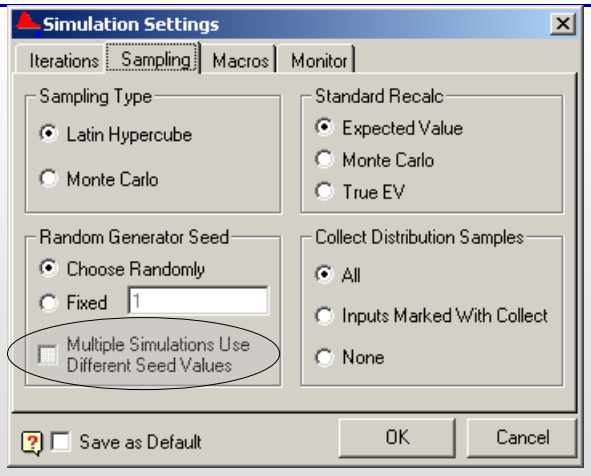
Multiple Simulations - Explained

- A single @RISK simulation might involve many iterations (hundreds or thousands), with each iteration sampling from input distribution functions
- Sometimes, you might want to vary some part of your model with multiple, discrete values and associate that with a full set of Monte Carlo iterations

Multiple Simulations - Examples

- You have set up a Monte Carlo economics model, and you want to run a Monte Carlo simulation for each of 5 different gas prices – that is 5 simulations
- You have set up a horizontal well model, and you want to explore the performance of 3 separate lateral lengths using Monte Carlo simulation – that is 3 simulations

Multiple Simulations and the Fixed Seed



Multiple Simulations – Why a Fixed seed?

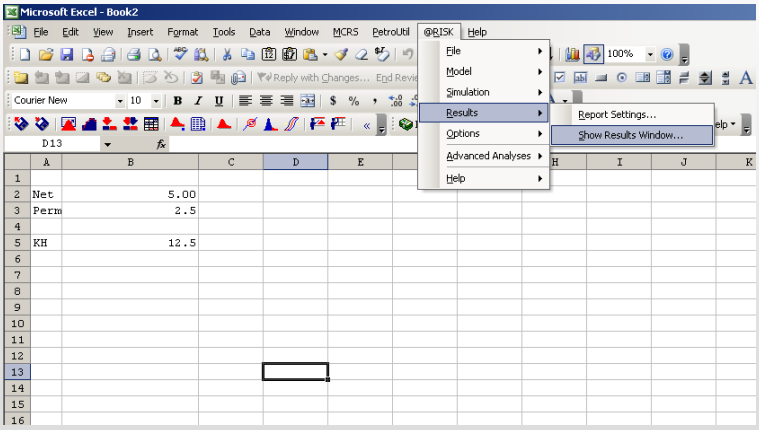
- If you are running multiple simulations, you might consider a fixed seed
- With a fixed seed for all simulations, the same sampling sequence is used for all simulations
- This keeps the values of sampled parameters the same across multiple simulations, ensuring consistency when running multiple simulations and comparing results

Getting Results from an @RISK Model

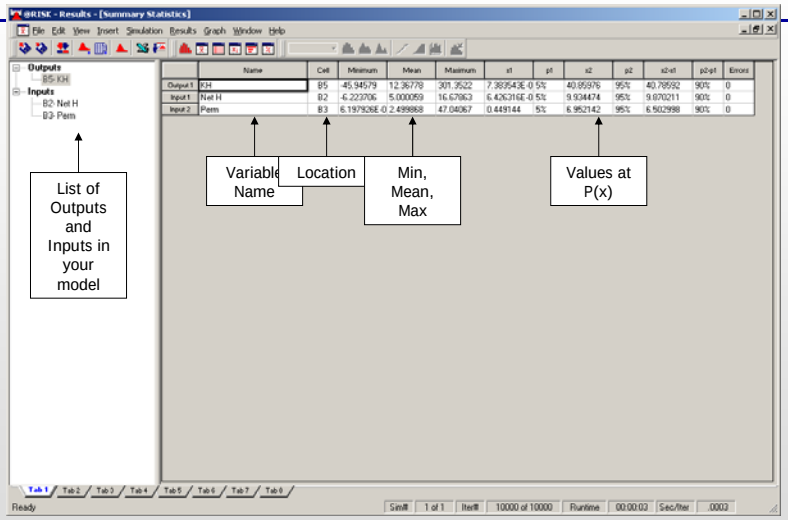
- Once all simulations and iterations are complete, you can
  - Check the descriptive statistics related to both your inputs and outputs
  - Show the results graphically
  - ‘Speak’ probabilistically

Getting Results from an @RISK Model

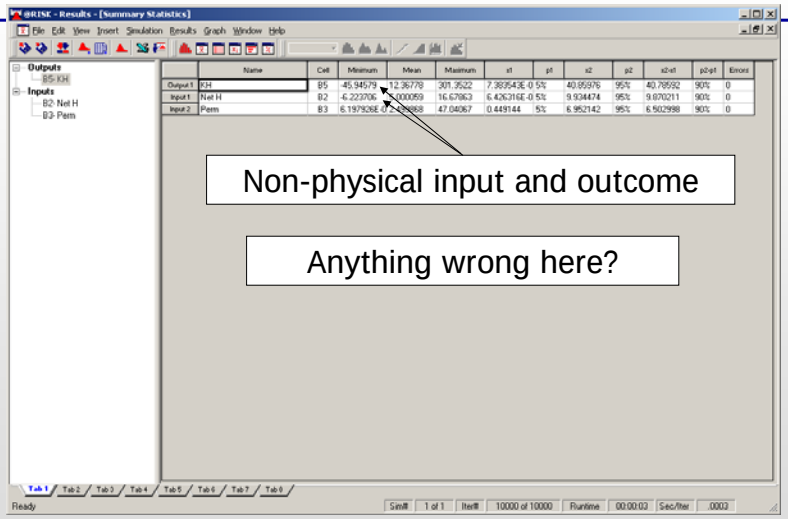
- Accessing the results window



@RISK Results Window



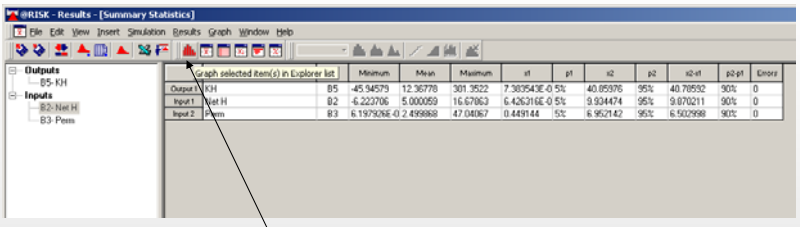
@RISK Results Window



@RISK Results – Graphical Options

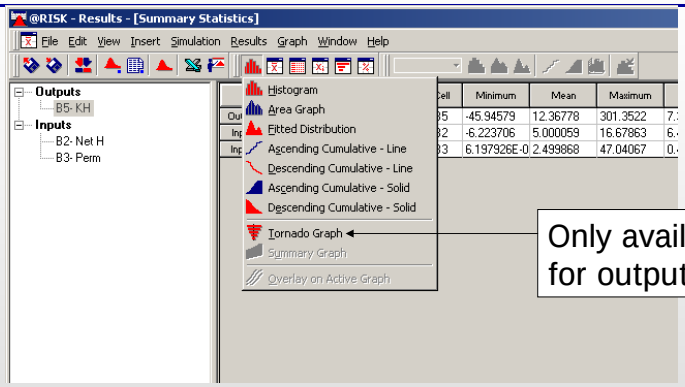
- Various options available for any input parameter or output variable
  - Histogram
  - CDFs
- For outputs
  - Tornado plots

@RISK Results – Accessing Results Graphically



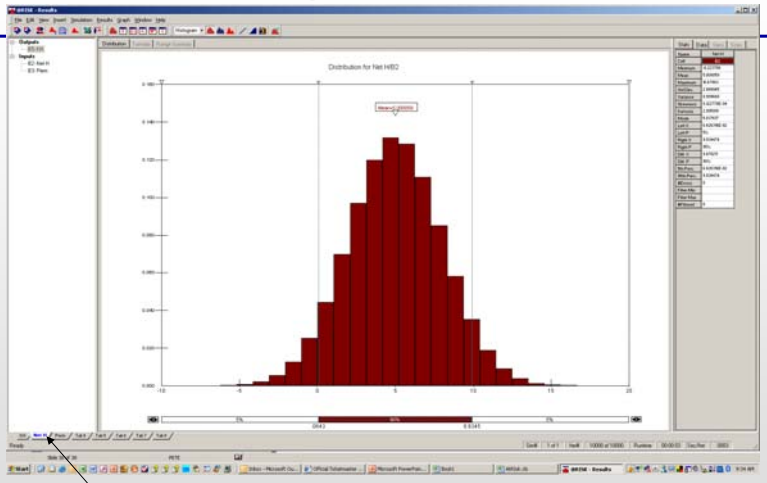
Graph results button

@RISK Results – Graph Selections



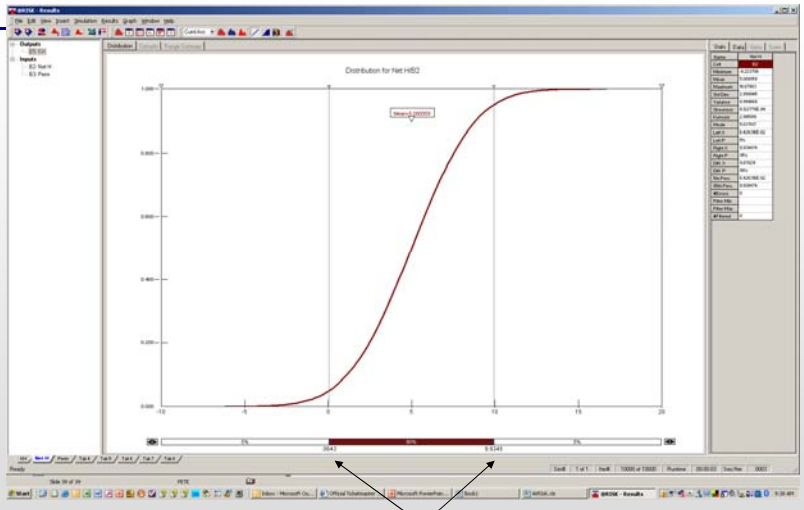
Only available for outputs

@RISK Results – Histogram



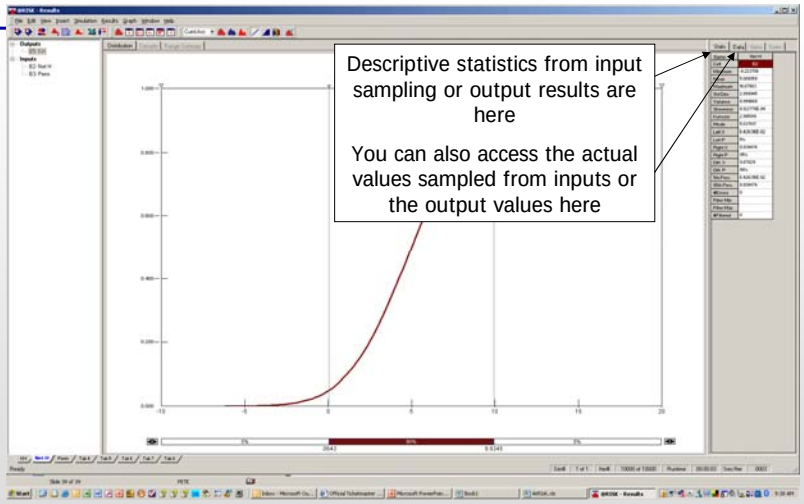
Tabs let you save different presentations of information

@RISK Results – CDF

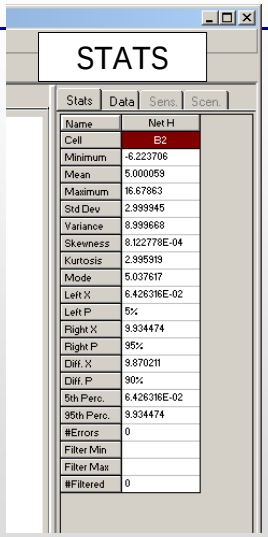


Information about ranges here

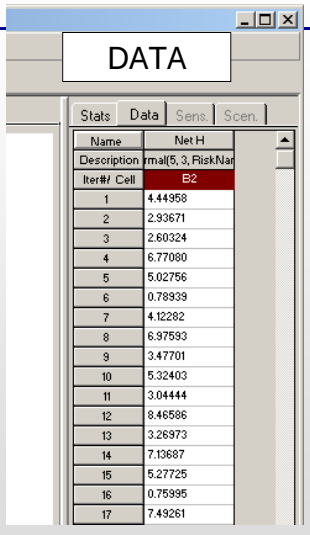
@RISK Results – Stats and Data



@RISK Results – Stats and Data Closeup



Name	Net H
Cell	B2
Minimum	-6.223706
Mean	5.000059
Maximum	16.67863
Std Dev	2.999945
Variance	8.999668
Skewness	8.122778E-04
Kurtosis	2.995919
Mode	5.037617
Left X	6.426316E-02
Left P	5%
Right X	9.934474
Right P	95%
Diff. X	9.870211
Diff. P	90%
5th Perc.	6.426316E-02
95th Perc.	9.934474
#Errors	0
Filter Min	
Filter Max	
#Filtered	0



Name	Net H
Description	rmal(5, 3, RiskNar
Iter#/ Cell	B2
1	4.44958
2	2.93671
3	2.60324
4	6.77080
5	5.02756
6	0.78939
7	4.12282
8	6.97593
9	3.47701
10	5.32403
11	3.04444
12	8.46586
13	3.26973
14	7.13687
15	5.27725
16	0.75995
17	7.49261

Let's Review @RISK Basic Features

- Model inputs via **distribution functions**
- Used alone or combined in formulas with other information or inputs
- **'RISKOUTPUT' function** used to capture desired results
- Results viewed in @RISK results window – actual values or graphical presentation

@RISK More Advanced Features

- Calibration of functions to data (Pro version or higher)
- Correlation of inputs
- Sensitivity analysis (tornado charts)

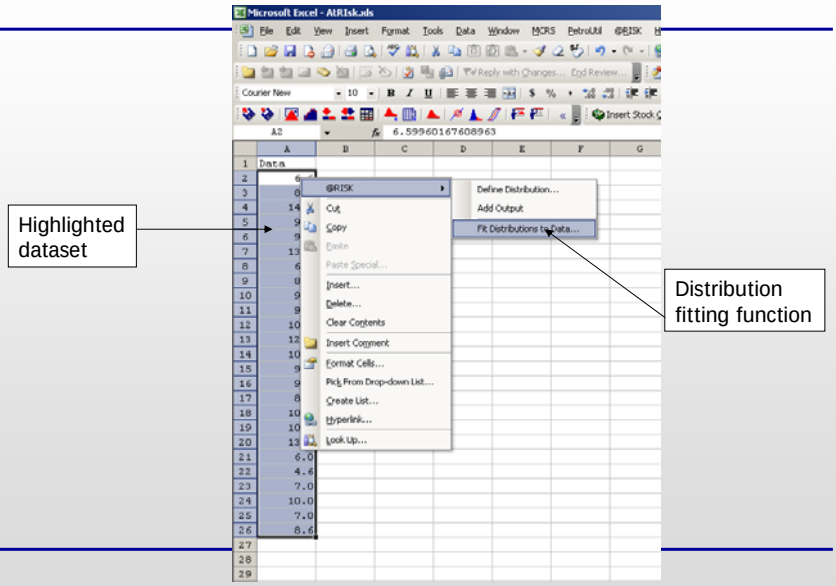
@RISK Calibration to Data

- Automatic curve fitting of distribution functions to actual data
- Then, access to curve fits during model construction
- Converts a discrete data set (with possibly a limited number of points) into a continuous distribution of values

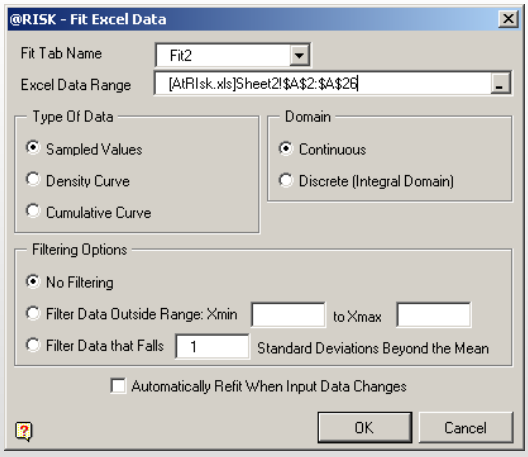
@RISK Calibration to Data - Example

- Dataset has 25 data points
- Highlight data
- Use context menus to select “Fit Distributions to Data…”
- @RISK automatically fits as many distributions as possible to the data and ranks them according to goodness of fit

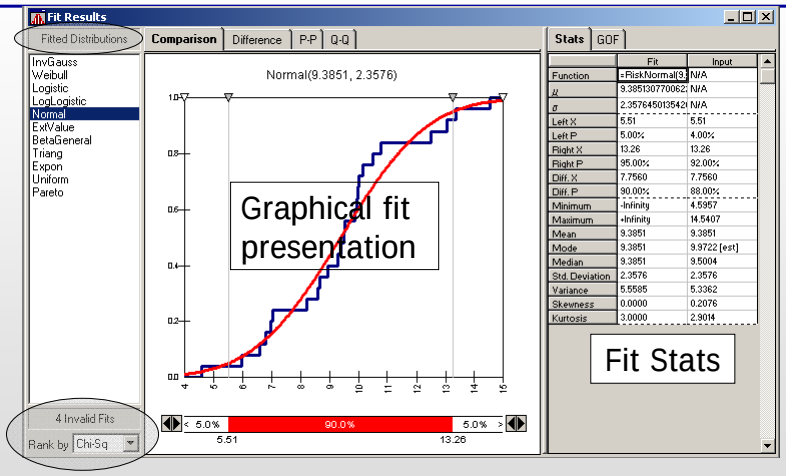
@RISK Calibration to Data – Getting Started



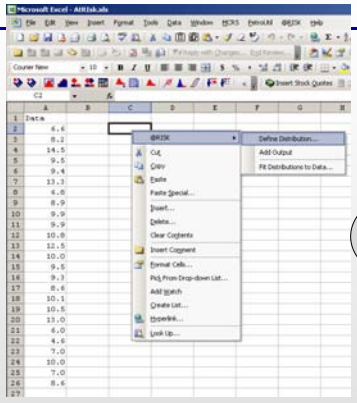
@RISK Calibration to Data – Input Dialog

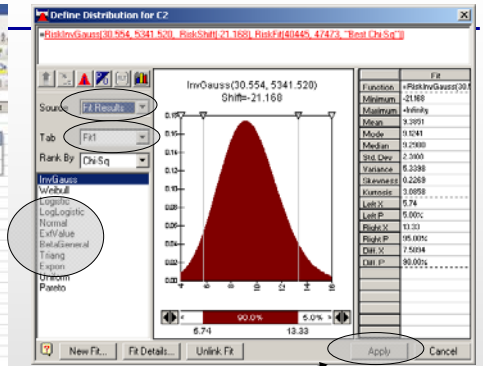


@RISK Calibration to Data – Fit Results



@RISK Calibration to Data – Using Fits





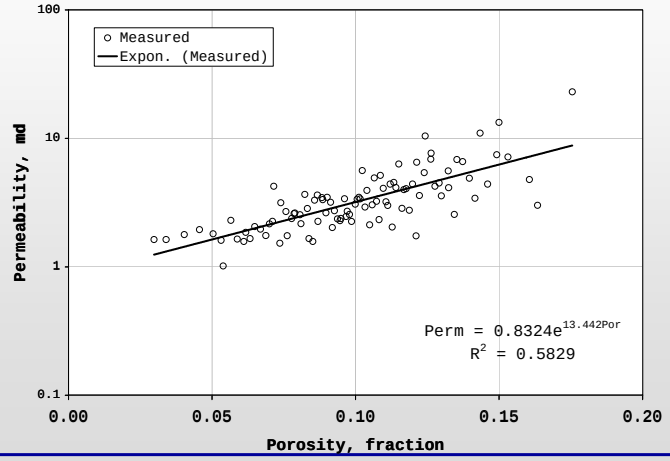
Clicking Apply embeds your fitted distribution curve into the Excel worksheet

@RISK Correlation Capability

- By default, the underlying assumption in @RISK is that INPUT parameters are sampled as completely independent events
- Each input is sampled independently of every other input
- However, there are times when input parameters are in fact correlated, and this needs to be taken into account in the model

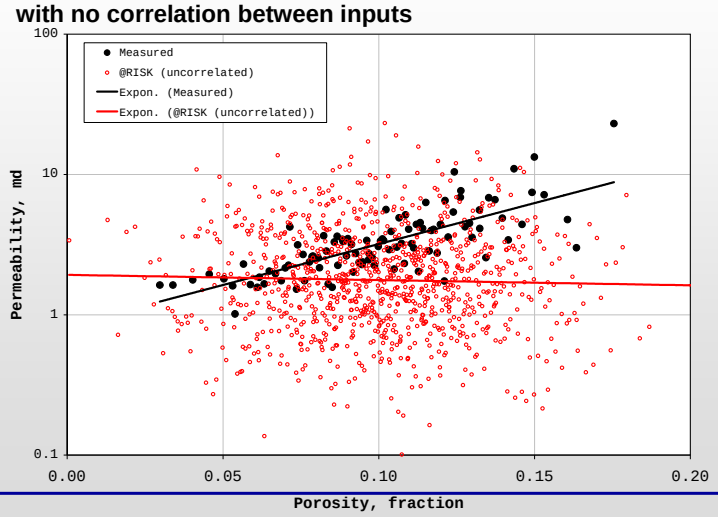
@RISK Correlation Capability - Example

- **100 samples of core permeability and porosity measurements – correlation is clear**



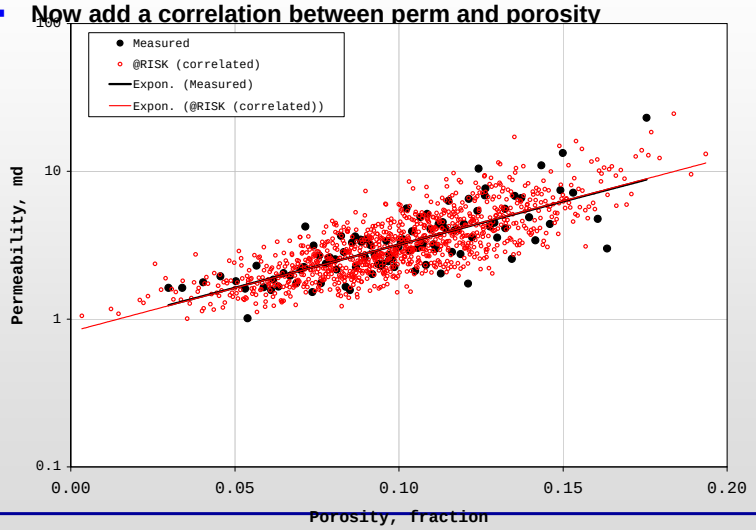
Model data using @RISK without correlation

- Fit porosity and perm data using @RISK, and then run a model with no correlation between inputs



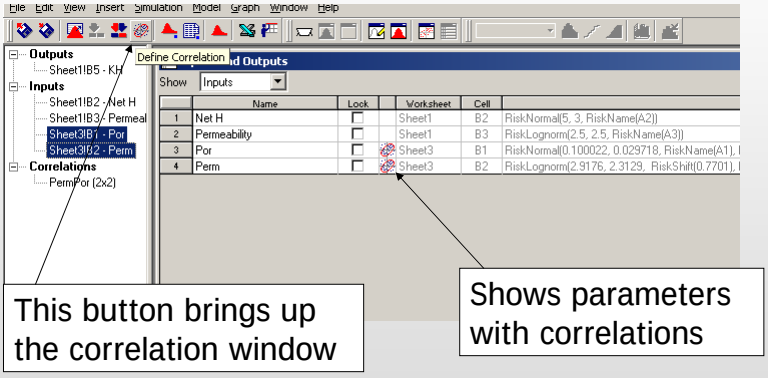
Model data using @RISK with correlation

- Now add a correlation between perm and porosity



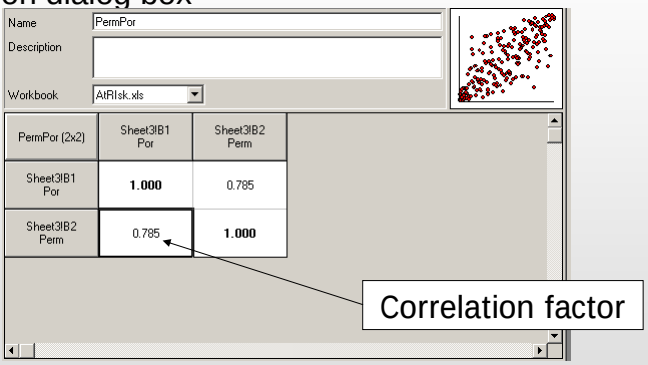
Using the @RISK Correlation Function

- Found in the @RISK model window



Using the @RISK Correlation Function

- Correlation dialog box



@RISK Sensitivity Analysis – Tornado Charts

- Evaluates the relative impact of any input parameter on any output variable
- Automatically generated with each Monte Carlo simulation
- Helpful to understand which input parameters most greatly affect outputs and how the affect outputs (directionally)

@RISK Sensitivity Analysis – Example

- Make a probabilistic gas in place estimate and understand the relative impact of each input

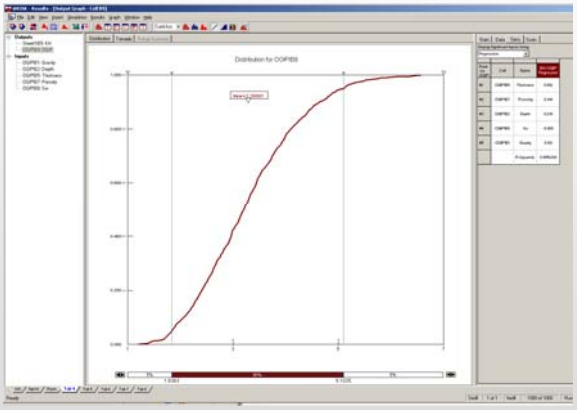
Parameter	Min	Most Likely	Max
Gravity (air=1)	0.63	0.65	0.66
Depth, ft	2,500	3,000	3,500
Thickness, ft	5	10	20
Porosity, %	10	15	17
Sw, %	20	25	30

Assumptions:

1) Pore pressure gradient= 0.433 psi/ft

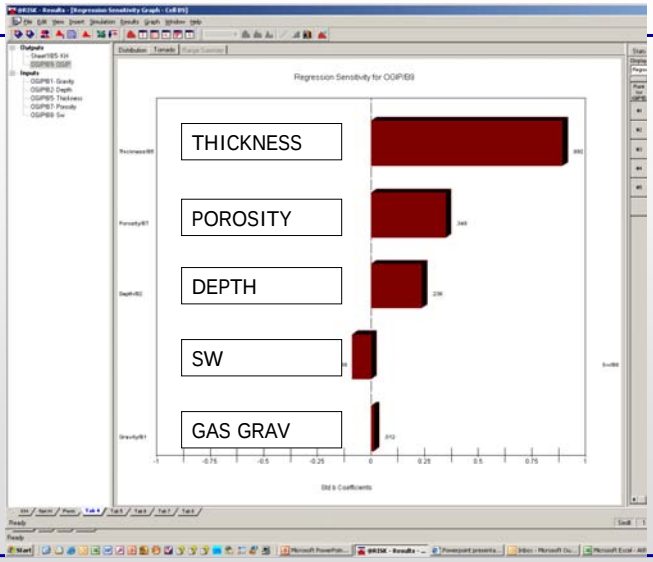
2) Temperature gradient= 1.0 deg F per 100 ft of depth + 75 deg

@RISK Sensitivity Analysis – OGIP CDF



- Avg OGIP= 3.29 Bscf/sec
- 90% of values fall between 1.8 and 5.1 Bscf/sec

@RISK Sensitivity Analysis – OGIP Tornado



Model Construction – Tips & Tricks

- Model construction can be very flexible
- Because of integration with Excel, there is almost no limit to what you can do
- This is also a reason to be cautious!

Model Construction – Tips & Tricks

- Test, test and test your inputs
  - look for and eliminate physically unrealistic values
- Compare your inputs to available or analogous data as a check
- Check for correlations
  - Cross-plot inputs against inputs looking for possible correlations between input parameters that need to be included in the model

Model Construction – Tips & Tricks

- Use the simplest, most common distribution function(s) possible for your model's inputs
  - Triangular
  - Normal
  - Log normal
- If you have fitted distribution functions, always check the fitted results against your raw data – particularly, beware of fitted results in the area outside the range of your input data

Model Construction – Tips & Tricks

- During model development and testing, limit the iterations to a few (10?) to speed up your testing phase
- Do you need to reproduce results in the future?
  - Why is this important?
  - How? use a fixed seed for consistent testing and results
  - Not always necessary

Model Construction – Discrete Events

- Examples of discrete or random events
  - Infrequent, but possible, dry holes
  - Not encountering a particular zone in a multi-zone completion
  - Wellbore mechanical failures
  - Usually an ‘either or’ situation
  - Often handled with a simple ‘0 or 1’ type of model

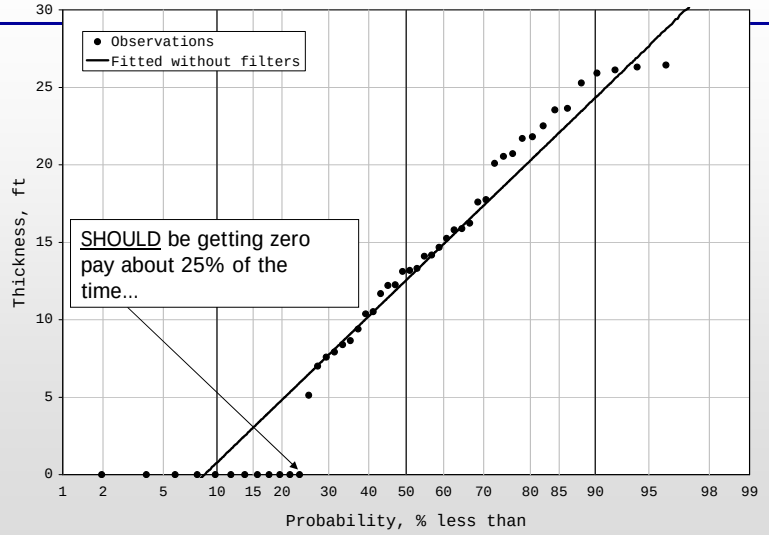
Discrete events example

- Distribution of net pay
  - 50 data points
  - 12 values are zero because pay was not encountered
  - Leaves 38 non-zero pay values
- You want to fit a distribution function to all this data, including the non-zero entries
- The difficulty is the non-smooth nature of the data due to the zero-pay values (introduces sort of a discontinuity)

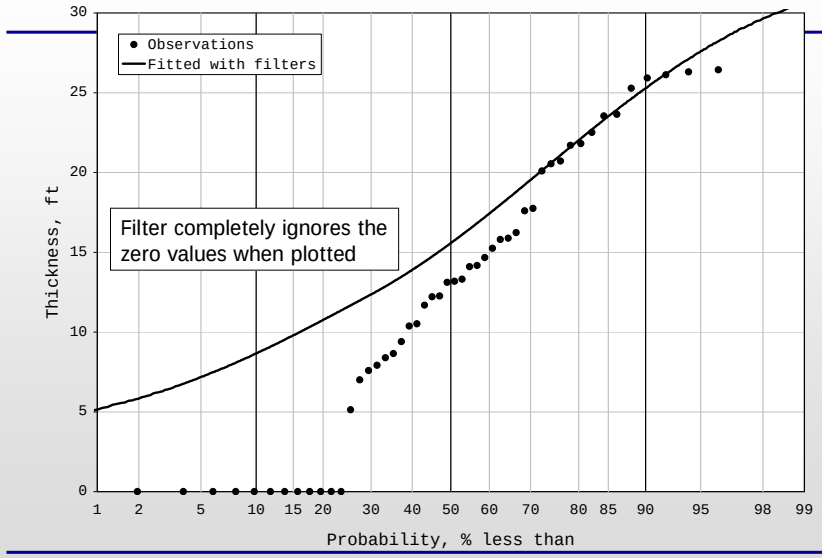
Discrete events example – Options for Handling

- Ignore it – not likely, but we'll show it anyway!
- Could use @RISK built-in data filtering during the fitting process – but that leaves out the probability of getting no pay
- Could split into two distributions
  - One to match the non-zero data
  - One to represent the probability of encountering zero pay
  - Final net pay is combination of two distribution functions

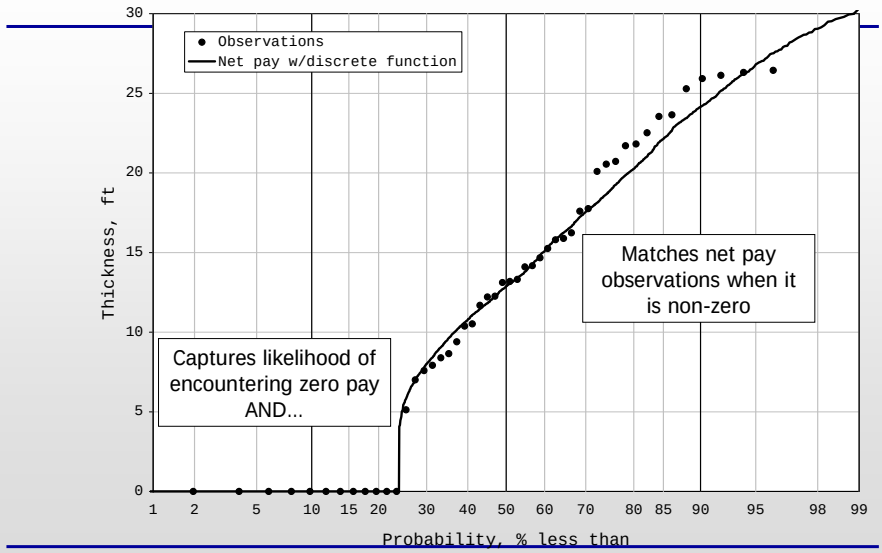
Discrete events example – Ignore it?



Discrete events example – Filter it?

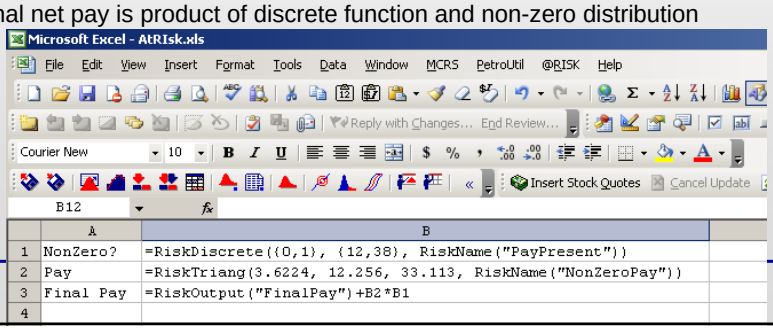


Discrete events example – Split it



Discrete events example – @RISK model

- Our original dataset had 12 out of 50 values equal to zero
  - Use **RiskDiscrete function** to model frequency of occurrence
    - **=RiskDiscrete({0,1}, {12,38})**
  - Note that it only takes on one of two values: 0 or 1
  - The 12 and 38 establish the frequency with which each value occurs, regardless of the number of iterations run in the simulation
- For non-zero pay, use @RISK distribution fitting on non-zero data only
- Final net pay is product of discrete function and non-zero distribution



	A	B
1	NonZero?	=RiskDiscrete({0,1}, {12,38}, RiskName("PayPresent"))
2	Pay	=RiskTriang(3.6224, 12.256, 33.113, RiskName("NonZeroPay"))
3	Final Pay	=RiskOutput("FinalPay")+B2*B1
4		

Examples Using @RISK from Mian

- See Mian, pages 355-366 for details on using @RISK for this **reserves simulation example**
- See Mian, Example 6-3, pages 366-369 for details on using @RISK for **NPV example**
- See Mian, pages 370-373, for details on **modeling dependency** in @RISK
- See Mian, pages 373-375, for information on **combining @RISK and PRECISIONTREE**

Your assignment

- Download the paper on Risk Analysis pp.14-23 under the topic **“Decision Tree vs. Monte Carlo Simulation”** and **“When does correlation matter?”.**
- Construct the decision tree (using PrecisionTree program) and building simulation model (using @RISK) as suggested in the examples.
- Select one example for your presentation either **the reserve example** or the alternative mud systems.
- Find out and explain what is the different between the two methods from your case.