



**United States Department of Agriculture**  
Natural Resources Conservation Service

## Computer Models

...getting more out  
than you put in!



# What is a model?

(only one type  
of model)



# webinar trajectory...

1) expansive view  
of models

2) computer  
models

3) approaches to  
get the most out of computer modeling



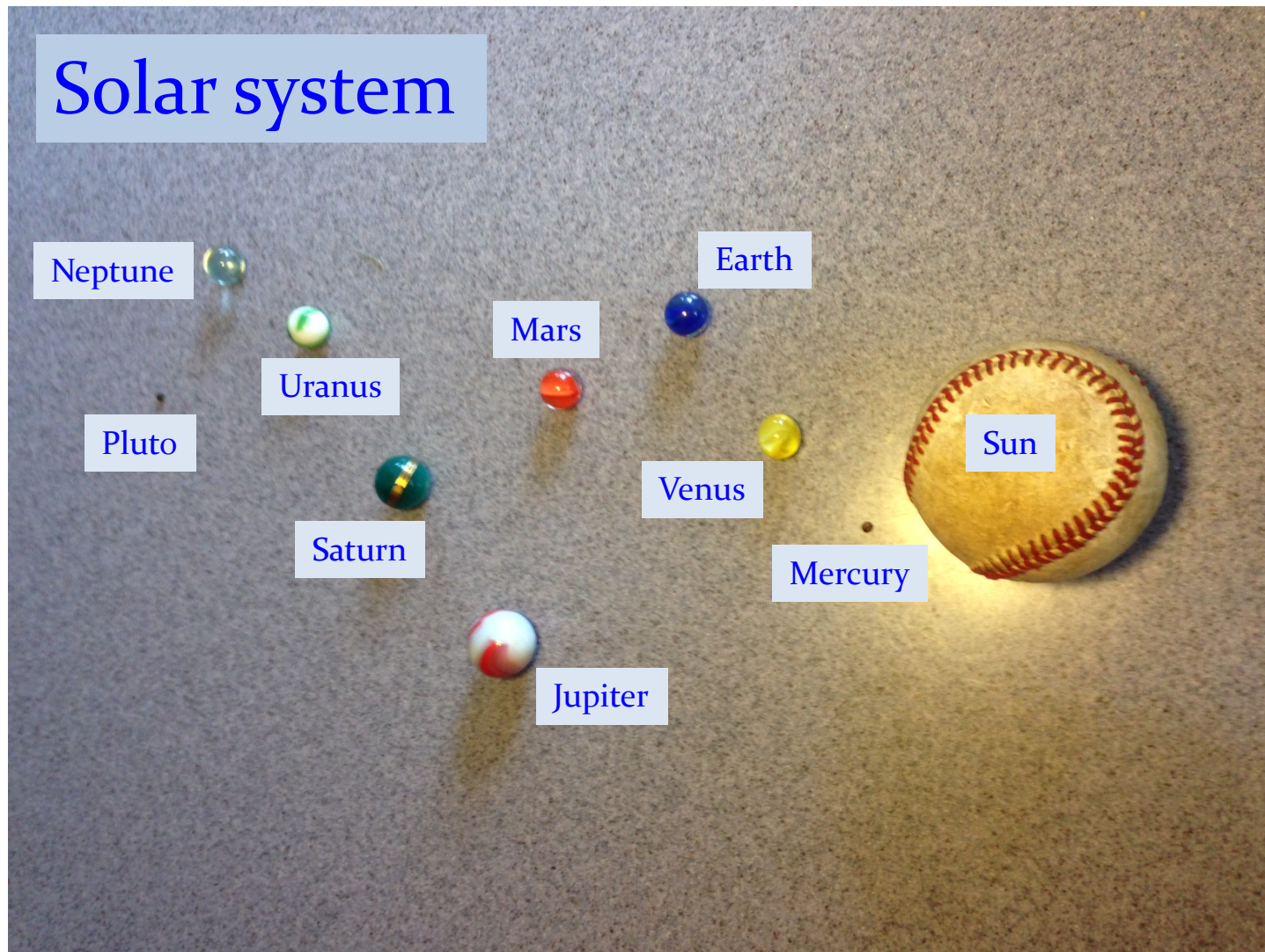
# What is a model?

A model is:

an anthropogenic system or object,  
created to represent a subset of reality,  
often (but not always) to scale,  
and useful for...

...explanation, prediction, and control

# simple example

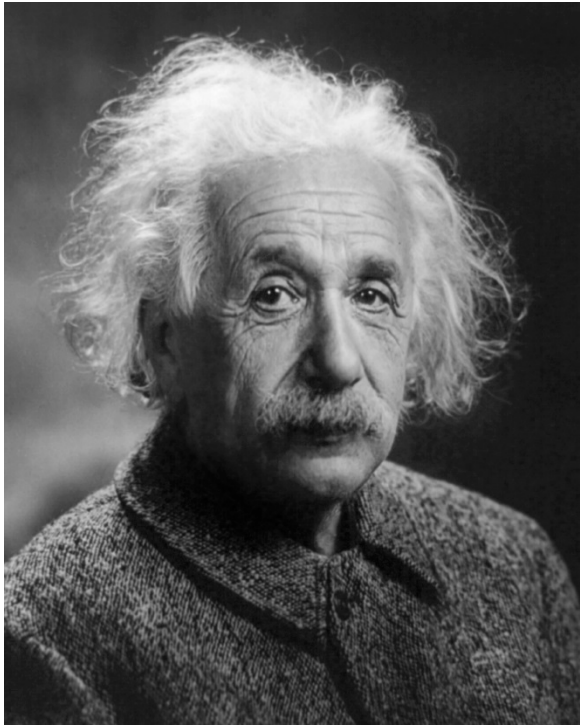


# simple example



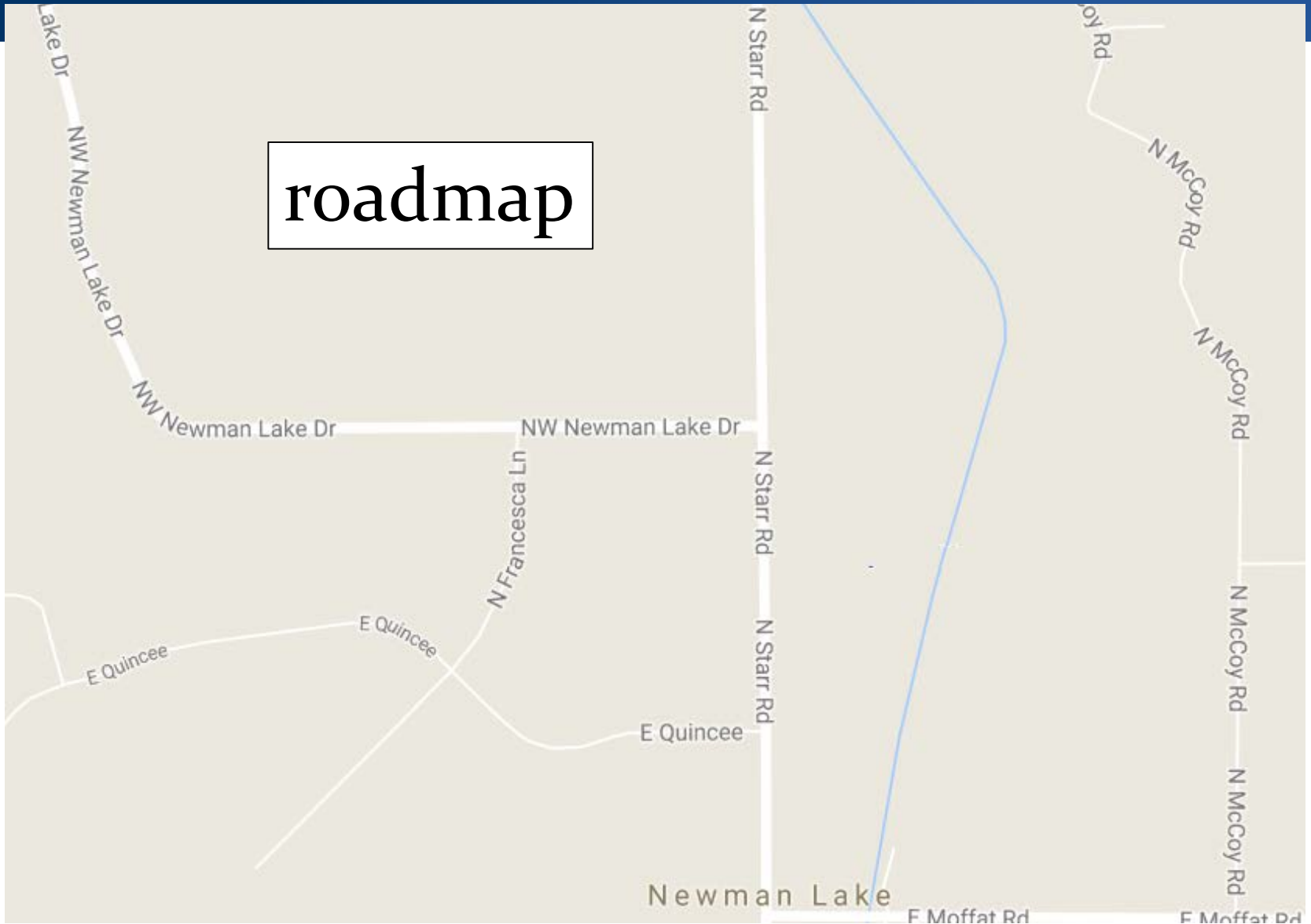
# physical vs. mathematical

Most models are not physical.



“thought experiments”  
are models too.

# Is a map a model?



# What about ideas?

Everything we are thinking

is some type of model!

# never “one to one”

No model, map, or idea has a  
one to one relationship with reality.

**Some stuff is left out!**

Which is ok, if...

...nothing important has been left out!

# Model Dependent Realism

We judge models the same way we judge ideas.

Do they “work”?

# human nature

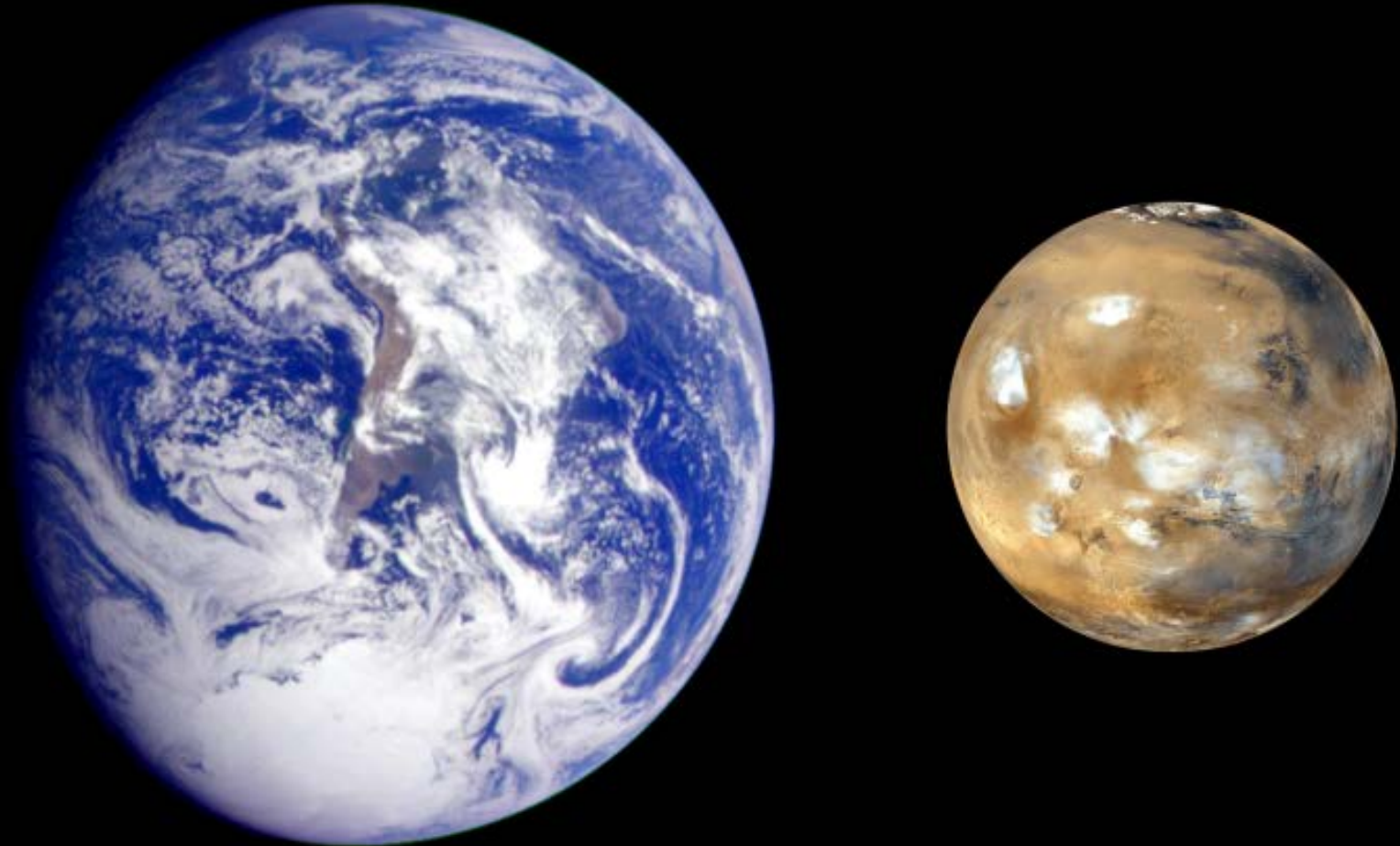
Models  
that do not  
correspond  
very well  
with **reality**

are usually not  
very reliable!



# homework...

## Google “Model Dependent Realism”



Stephen Hawking and Leonard Mlodinow,  
“The Grand Design” 2010.

# homework...

from The Grand Design:

“We make models in science,  
but we also make them in everyday life.

Model-dependent realism applies  
not only to scientific models  
but also to the conscious mental models we create  
in order to interpret and understand the everyday world.”

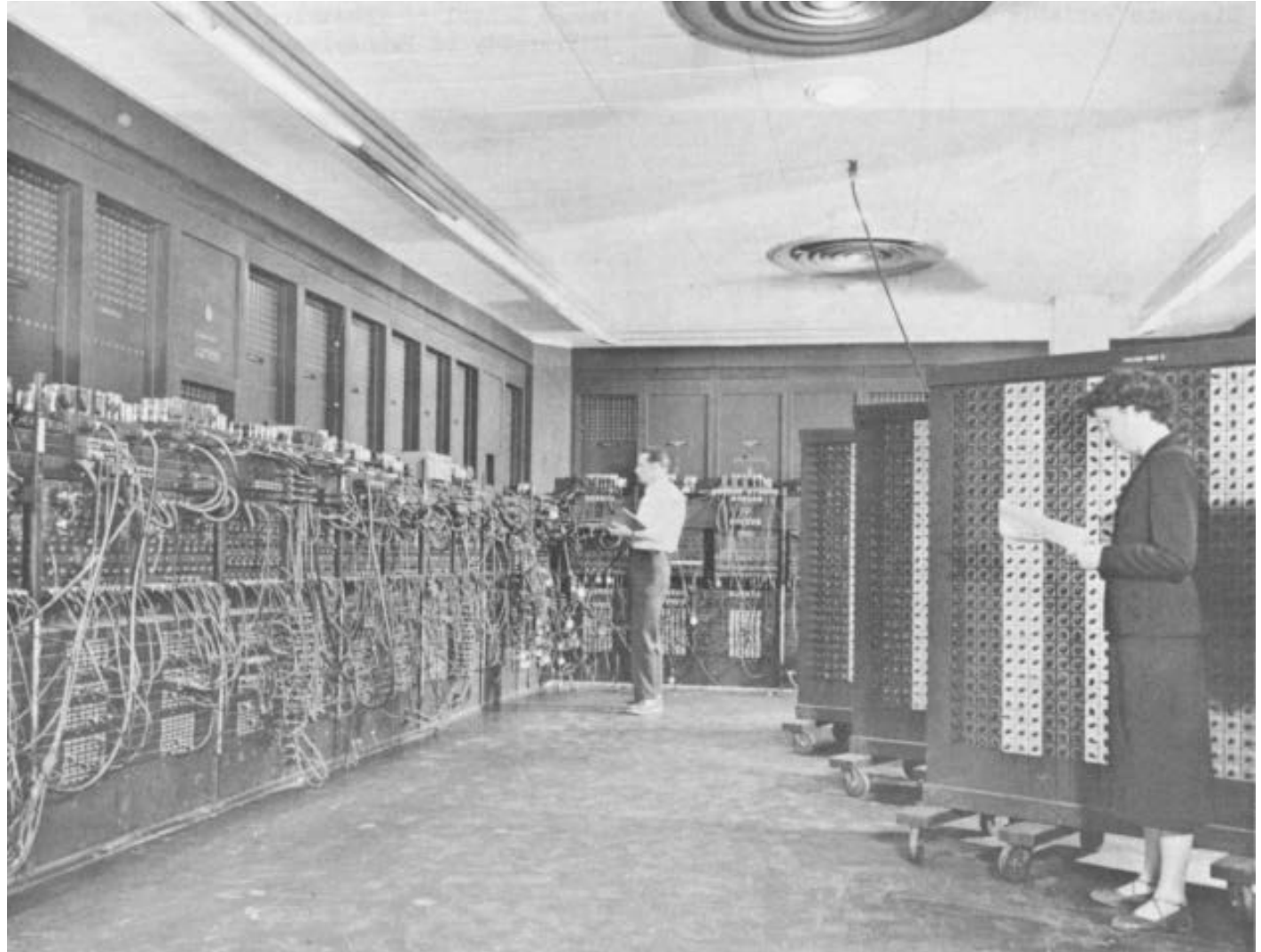
# computer models

Grace Hopper  
(who coined  
the term  
“debugging”)



# computer models

NOTE:  
the  
computer  
is not  
the model!  
  
(just a tool)



# computers vs. human nature



They can dazzle us!

# computers vs. human nature

“It may be ‘garbage in, garbage out’..”



“...but *my* input is never garbage!”

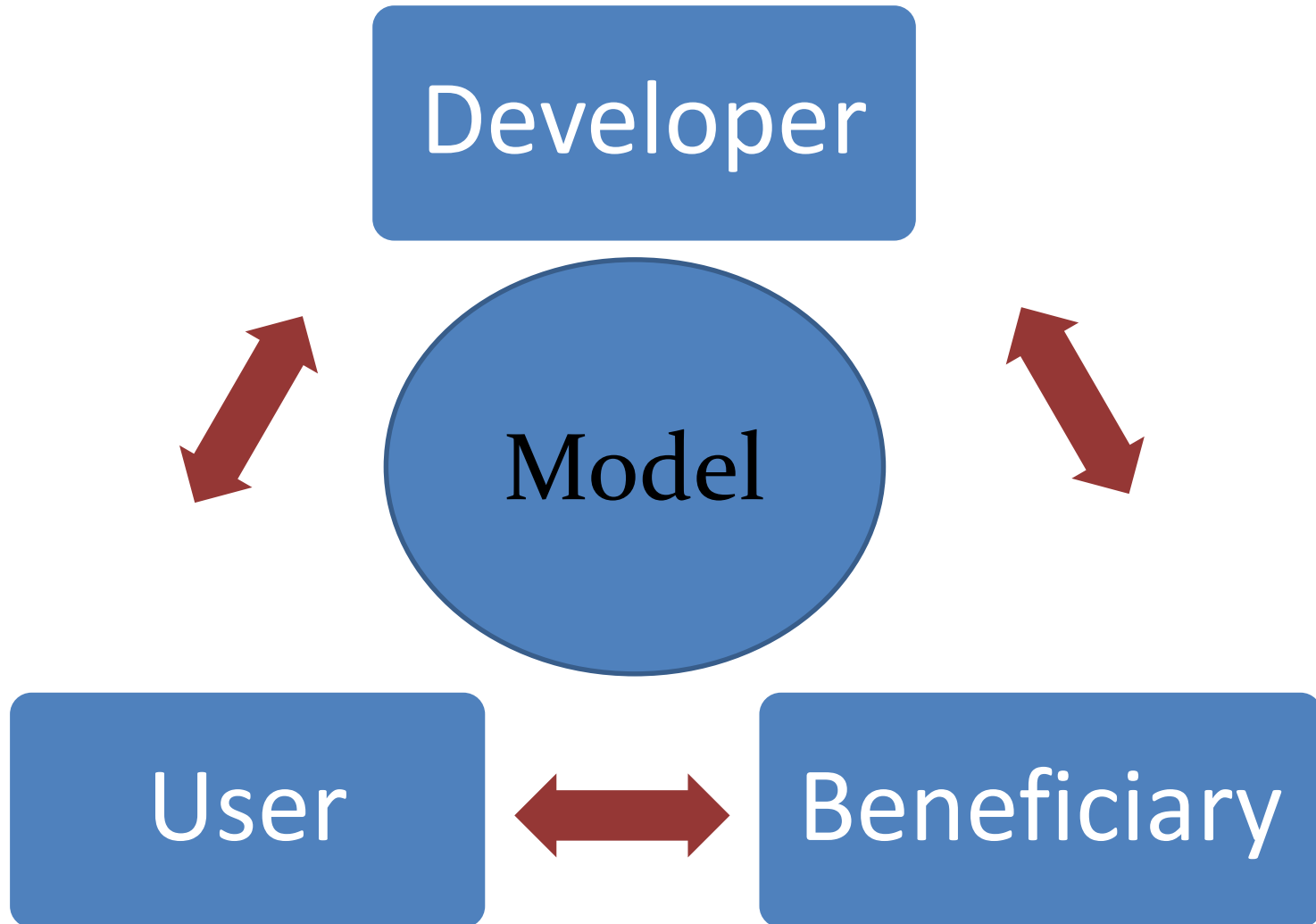
# computer models

How do you know  
what a computer model is good for?

Need to understand roles of:  
developer  
user  
customer (beneficiary)

Also, if you are the user:  
have a good “conceptual model”

# computer models



# computer models

## Developer

creates it: cooperation between  
content experts & programmers

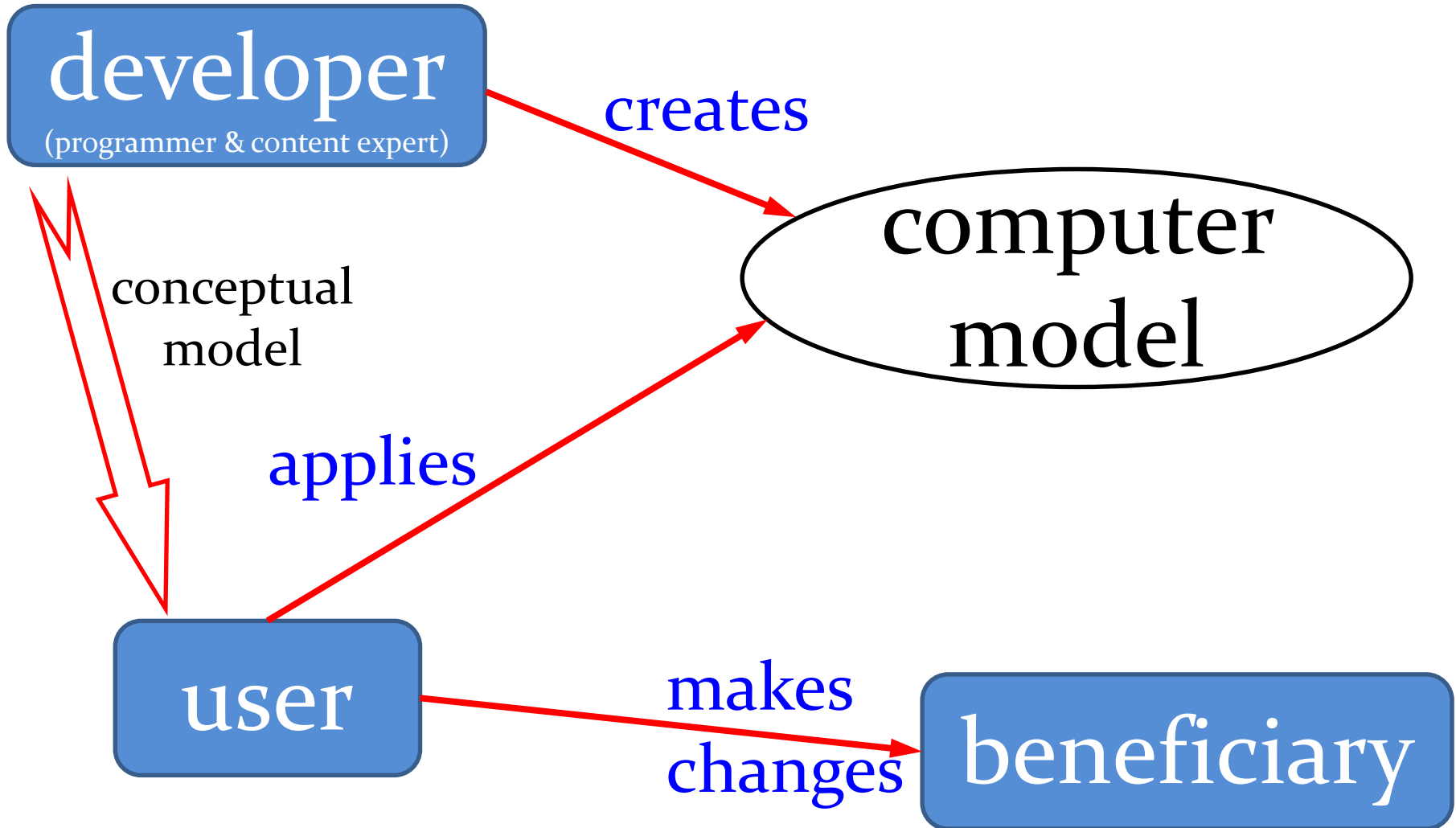
## User

runs it: gathers input data,  
assembles model pieces,  
interprets output

## Customer/Beneficiary

applies changes: to solve problems

# computer models



# model developer



# Model user and customers

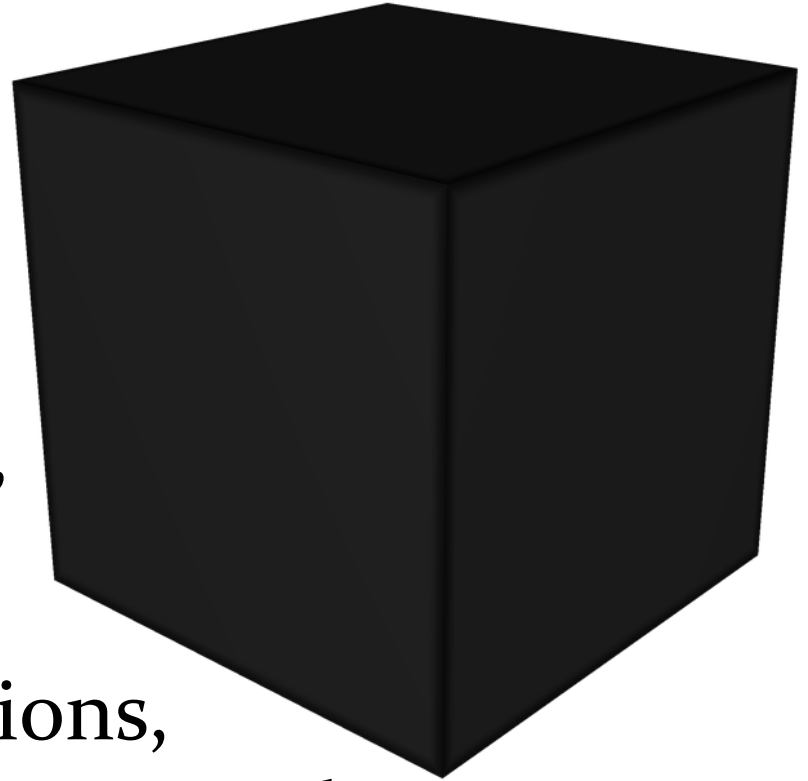


# developer / user relationship

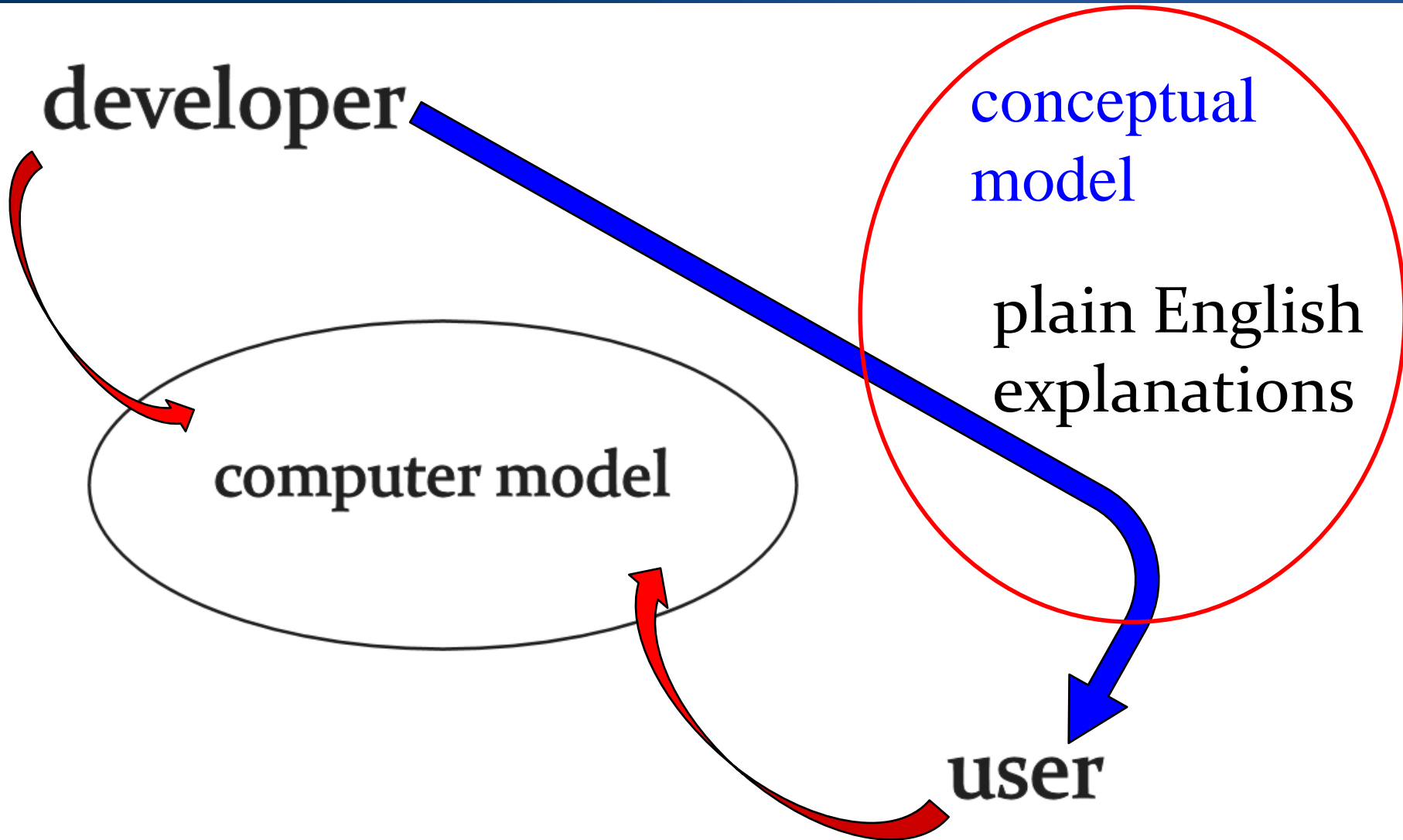
...every model is, to some extent, a black box.

The responsible developer provides the user with a valid “**conceptual model**”

through interface, instructions,  
or user manuals.



# developer / user relationship



# homework...

Design of Everyday Things -

Conceptual Model & System Image



check out  
“The Design of Everyday Things”

by Don Norman, 1988  
(or Google him!)



# developer / user relationship

The user can get mixed up if the developer:

- 1) provides no conceptual model
- 2) one that is incorrect or misleading
- 3) one that is unnecessarily complicated

# developer / user relationship



The developer  
should provide a good  
conceptual model, but...

# developer / user relationship

...the user does bear  
some responsibility!



(RTFM)

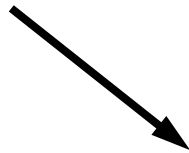
# model complexity

Let's say, simple, medium, and complex...

# model complexity

Let's say, **simple**, medium, and complex...

input (not much needed, easy to get)



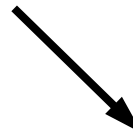
output (just pops out)

# model complexity

Let's say, simple, **medium**, and complex...

input & input

(more needed, not always easy to get)



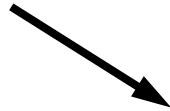
output & output

(may need interpretation)

# model complexity

Let's say, simple, medium, and **complex**..

input (lots needed, often hard to get)



user combines pieces,  
depending on complex  
processes of interest



output

(model might “blow up”, output may need much interpretation)

# complex example

## Climate model

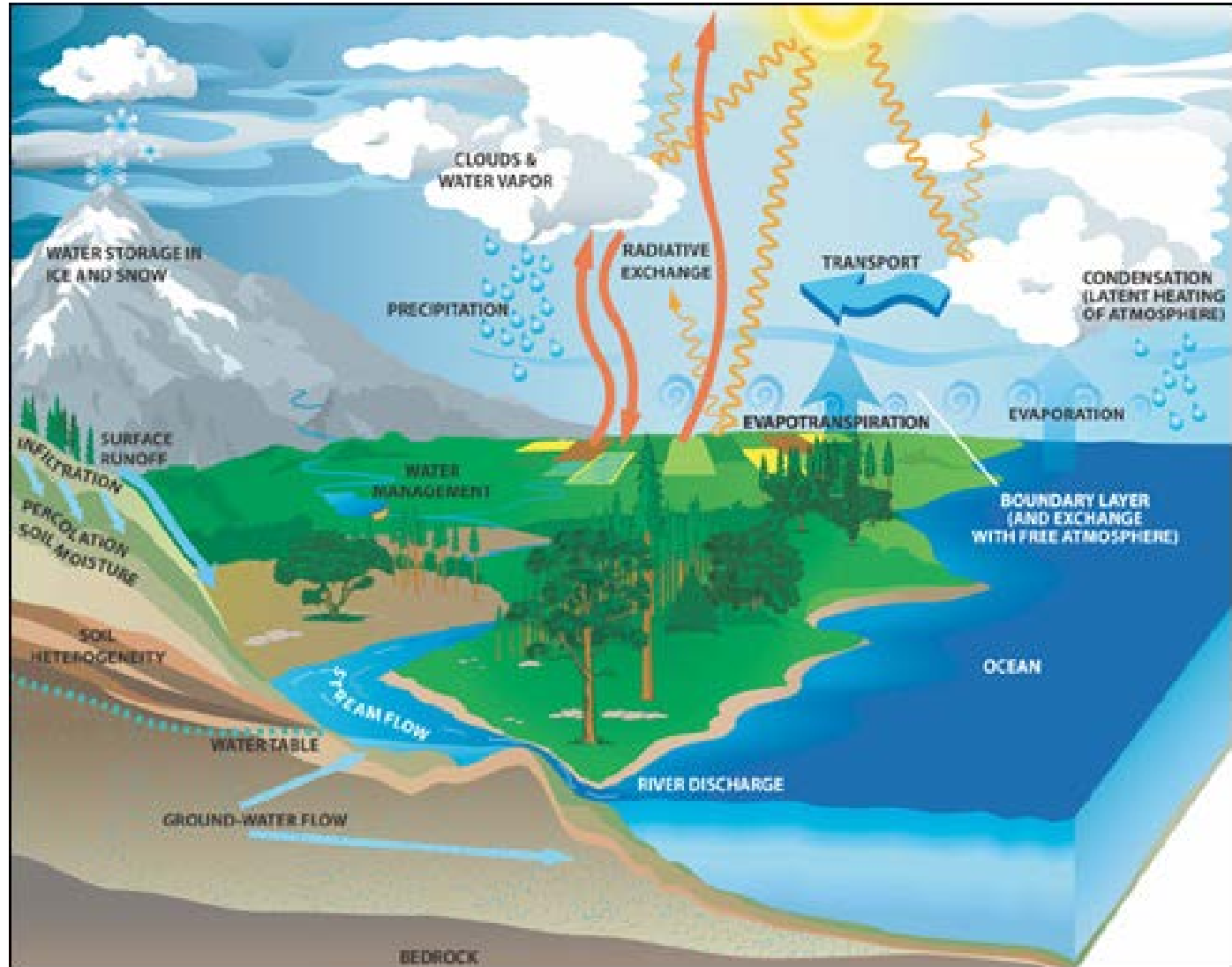
with circles and lines representing module interactions



*The software structure (subroutine) of CLM. Each circle represents an individual subroutine with the area of the circle showing the time spent on the subroutine with linear representation. Image credit: Wang, D. et al., "Environmental Modeling and Software" 55 (2014).*

# complex example

## hydrology (rainfall-runoff)



WinTR-20 Identifier: Current File - H:\WinTR20\Denton\_MD.inp

File View Run Help

## WinTR-20 System Controller / Editor

Click Data Section Name to Enter Data  
(X indicates some data entered for section)

	Dimensionless Unit Hydrograph:
	Global Output:
	Input Hydrograph:
X	Rainfall Distribution:
	Stream Cross Section:
	Stream Reach:
X	Storm Analysis:
	Structure Rating:
	Sub-Area:
X	WinTR-20 Identifier:
	Verification:

processes to be modeled

The screenshot displays the HEC-HMS 4.2.1 software interface. The main window shows a basin model diagram titled "Basin Model [WhitewaterCk preFire kWave]". The diagram is a complex network of nodes and connections representing a watershed. Nodes include "Gold Dust Gulch", "BlwDog", "Dog Creek", "Lone Pine", "Lil Creek", "Nabours Fork", "SE Fork", and "outlet". Connections are represented by blue lines. A red circle highlights the "WhitewaterCreek" folder in the left-hand file explorer, which contains sub-folders for "Basin Models", "Meteorologic Models", "Control Specifications", "Time-Series Data", and "Paired Data". A text box with a white background and black border is overlaid on the left side of the diagram, containing the text "suite of modeling tools".

HEC-HMS 4.2.1 [F:\dataDmooreDrive\projectsOlder\newMexico\2012fires\2013floods\HMSwhitewater\WhitewaterCreek\WhitewaterCreek.hms]

File Edit View Components Parameters Compute Results Tools Help

WhitewaterCreek  
Basin Models  
Meteorologic Models  
Control Specifications  
Time-Series Data  
Paired Data

Basin Model [WhitewaterCk preFire kWave]

Gold Dust Gulch  
locAbvGage  
locBlwGage  
BlwDog  
Dog Creek  
Lone Pine  
Lil Creek  
Nabours Fork  
SE Fork  
outlet

locAbvDeer  
locAbvDeerOutlet  
rchDeer  
jctDeer  
airStrip Creek  
locAbvLiWw  
locMidLittleWw  
locAbvWwOutlet

locAbvSFOutlet  
jctLilCk  
jctSkel  
locAbvSkeleton  
locAbvSEfork  
rchBlwSFupper  
SF upper

locAbvSF  
locBlwWinn  
locAbvWinn  
locAbvGrouse  
Winn  
Grouse  
Lipseye  
Black Fork  
E Fork  
jctSEfork  
locAbvEF

locAbvLipseye

locAbvSF

locAbvWinn

locAbvGrouse

Winn

Grouse

Lipseye

Black Fork

E Fork

jctSEfork

locAbvEF

locAbvSEfork

rchBlwSFupper

SF upper

Components  
Compute Results

suite of modeling tools

# HecHMS

The user decides the best way to model each process.

HEC-HMS 4.2.1 [F:\dataDmooreDrive\projectsOlder\newMexico\2012fires\2013floo

File Edit View Components Parameters Compute Results Tools Help

WhitewaterCk preFire kWave

- Black Fork
  - Simple Canopy
  - Simple Surface
  - Green and Ampt
  - User-Specified S-Graph
  - Recession
- Baldy Fork
- jctBaldyBlack
- rchAbvLipse
- Lipse
- locAbvLipse
- jctLipse
- rchBlwLipse
- locAbvSnotel
- Snotel Creek
- jctSnotelCk
- rchAbvGrouse
- Grouse

Basin Model [WhitewaterCk p

airStrip Cr

outlet

Subbasin	Canopy	Surface
Loss	Transform	Baseflow
		Options

**Basin Name: WhitewaterCk preFire kWave**  
**Element Name: Black Fork**

\*Initial Content: 0.2

\*Saturated Content: 0.42

\*Suction (IN) 4.33

\*Conductivity (IN/HR) 0.86

\*Impervious (%) 0.0

# hydrologic model application

## keys to success

The responsible model user will:

Learn how the model works by reading and understanding user manuals,

Get training, if needed,

Interact with other users and support teams,

Be *organized* and *document* model use.

# hydrologic model troubleshooting

Second, build & test the model incrementally...

With a complicated model,  
don't build the whole thing  
before running a single test.

Make a simple version work, and  
add complications one at a time,  
testing as you go.

# hydrologic model troubleshooting

Third, use Occam's Razor...

Look first for the simplest explanation  
to a problem  
before assuming  
a more complicated explanation.

# a good reference (HMS user manual)

HEC-HMS Technical Reference Manual (SECURED) - Adobe Acrobat

File Edit View Window Help

Open Create Save Print Mail Settings Comments Attachments Signatures

14 / 148 125% Tools Fill & Sign Comment

**Bookmarks**

- Preface
- Chapter 1 - Introduction
- Chapter 2 - Primer on Models
  - What is a Model?**
  - Model Classification
  - Constituents of a Model
    - State Variables
    - Parameters
    - Boundary Conditions
    - Initial Conditions
    - Solving the Constituents
  - Models and Computer Programs
    - Model
    - Program
    - Input
  - References

## What is a Model?

Hydrologic engineers are called upon to provide information for activities for a variety of water resource studies:

- Planning and designing new hydraulic-conveyance and water-control facilities.
- Operating and/or evaluating existing hydraulic-conveyance and water control facilities.
- Preparing for and responding to floods.
- Regulating floodplain activities.

In rare cases, the record of historical flow, stage or precipitation satisfies the information need. More commonly, watershed runoff must be predicted to provide the information. For example, a flood-damage reduction study may require an estimate of the increased volume of runoff for proposed changes to land use in a watershed. However, no record will be available to provide this information because it has not taken place. Similarly, a forecast of reservoir inflow may be required to determine if a tropical storm alters its course and moves over the watershed.

# NRCS Models



Next...

An overview of several NRCS models from an experienced modeler.

# WQIag

## Water Quality Index for Agricultural Runoff

For assessing the impact of crop production systems and conservation practices on environmental benefits—primarily runoff water quality.

NRCS Field Staff and TSPs and other federal, state and local agencies

Understanding of field characteristics and agricultural operational management including conservation practices

The initial web-based system used and adopted by several agencies. The new spreadsheet version is under development

The screenshot shows the WQIag web application interface. At the top, there is a navigation bar with 'About', 'Help', and 'Contact Us' links. Below this is a form titled 'Runoff Water Quality Index' with a version of 1.0.5 and a date of 7/05/2012. The form is divided into several sections for data entry:

- Site Information:** Includes dropdowns for State (Arizona) and County (Greenlee), a text field for HUC, and input fields for Field # (2), Field name (Northside Field), Acres (100), Project date (7/17/2012), and Description (Test Field).
- Field Physical Sensitivity Factors:** A table with columns for Factor, Description, WQI Ranking Factor, Weighting, and Weight.
- Nutrient Management Factors:** A table with columns for Factor, Description, WQI Ranking Factor, Weighting, and Weight.
- Tillage Management Factors:** A table with columns for Factor, Description, WQI Ranking Factor, Weighting, and Weight.
- Pest Management Factors:** A table with columns for Factor, Description, WQI Ranking Factor, Weighting, and Weight.
- Irrigation Management:** A table with columns for Factor, Description, WQI Ranking Factor, Weighting, and Weight.

The final result is shown at the bottom: Runoff Water Quality Index (WQIag) with a score of 7.44.

FACTORS	DESCRIPTION	WQI RANKING FACTOR	WEIGHTING	WEIGHT
<b>Field Physical Sensitivity Factors</b>				
Slope (%)	Get Slope Interaction (2% to 5%)			
HS group	(B - moderately low runoff potential)	8.00	0.25	2.00
K-factor	(0.21 - 0.32 moderate erodibility)	8.00	0.25	2.00
OM content	2-4%	6.00	0.25	1.50
Rainfall/Veg	Get Rain / Vegetation Interaction	6.00	0.25	1.50
			0.25	1.75
<b>Nutrient Management Factors</b>				
Application rate	LGU recommendations	5.00	0.25	1.25
N-source and timing	Synthetic fertilizer, single, slow release	10.00	0.25	2.50
P-source and timing	Synthetic fertilizer, pre-growing season	2.00	0.25	0.50
Soil condition / application	Dry/well drained, N fertilizer, broadcasted	6.00	0.25	1.50
			0.25	1.44
<b>Tillage Management Factors</b>				
Description / STIR	No Till or STIR Value < 30	10.00	1.00	10.00
			0.25	2.50
<b>Pest Management Factors</b>				
Description	Follow IPM - Suppress using Chemicals and Mitigation	7.00	1.00	7.00
			0.25	1.75
<b>Irrigation Management</b>				
Description	No irrigation (0%)			
Runoff Water Quality Index (WQIag)				7.44
<b>Conservation Practices</b>				

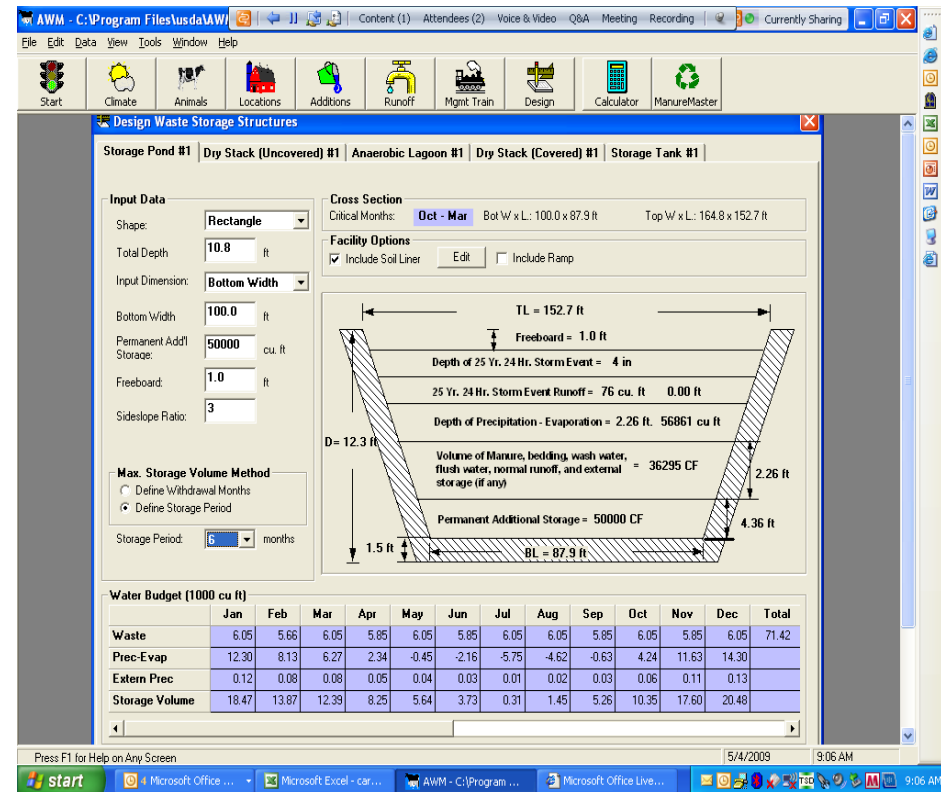
# AWM

# Animal Waste Management System

Planning/designing/evaluating  
waste storage structures for  
animal feeding operations

NRCS field engineers and TSPs

A good understanding of the  
operation including regulatory  
requirements of waste storage  
periods and application timings



# MMP

# Manure Management Planner

Creating manure management plans for crop production for animal feeding operations

NRCS field engineers and TSPs

A good understanding of field crops and their nutrient requirements /appropriate timing of applications

The screenshot shows the 'Manure Management Planner - IN-Pig1.mmp' application window. The 'General' tab is selected, displaying various input fields for farm information. The 'Operation' field contains 'Hogs-R-Us Sample Plan'. The 'Notes' field contains '200 sow farrow-to-finish, 100% occupancy rate, 20-acre subfields.' The 'County' dropdown is set to 'Carroll'. The 'Starting Year' is '2002', 'Starting Month' is 'September', and 'Years In Plan' is '3'. A toolbar at the bottom includes buttons for 'New', 'Open', 'Close', 'Save', 'Save As', 'Tools', 'Help', 'About', and 'Exit'. A status bar at the bottom reads 'Enter the name of the farming operation.'

# NTT

# Nutrient Tracking Tool

oyabjczv0owar))/default.aspx



Home Help About NTT Contact Us

Home Soil Management Verify Reports

## Nutrient Tracking Tool - Version 0312

### Other Resources

▶ [Tarleton State University](#)

▶ [TIAER](#)

### Feedback

▶ [Comment on the Nutrient Tracking Tool](#)

▶ [Report a Problem with NTT](#)

**Instructions:** There are four initial choices to start a project: 1) Select the "Soil Survey Map" option to start a project by selecting an area of interest using the Web Soil Survey mapping system; 2) Select the "Specific Soil" option to start a project by selecting an area of interest by state, county, and dominant soil; 3) Select the "Upload Existing Project" option to upload a previously saved NTT project; and 4) Select the "Upload an Example" option, to access one of the several pre-loaded NTT examples, for illustration purposes.

For more information and help about the Nutrient Tracking Tool use "Help" option throughout the program.

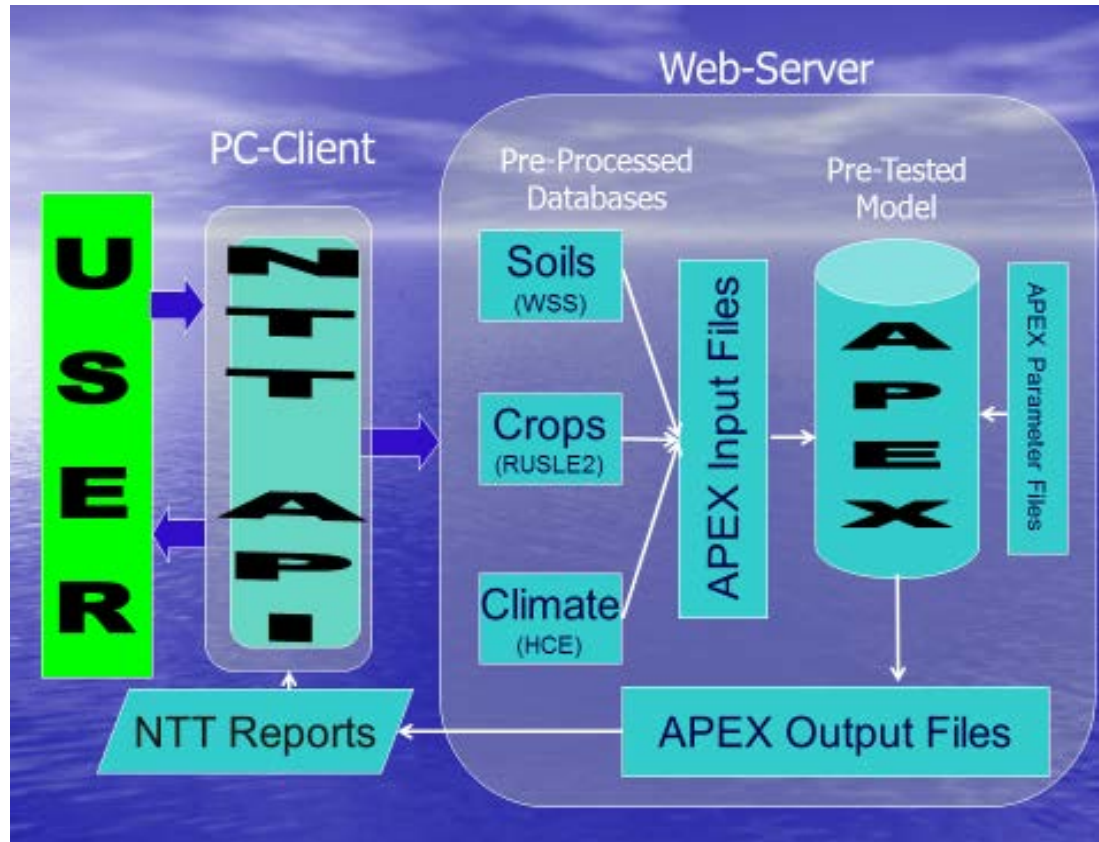
[Soil Survey Map](#) [Specific Soil](#) [Upload Existing Project](#) [Upload an Example](#)

Estimating change (delta) in crop yield, nutrient (N&P) and sediment losses for current and alternative management/conservation practice(s) scenarios for resource planning and generating water quality credits

Primarily for TSPs and other entities involved in water quality credits for environmental markets

Basic GIS knowledge and understanding of input requirements and interpretation of the reports

# NTT Conceptual Framework & Its Complexities



A complex framework with a linkage to a very sophisticated model (APEX)

Several possibilities for error intrusions:

- Collecting user-input data
- Translating user-supplied and other input data into APEX input files
- Properly and successfully running the APEX model with dynamic and static input files
- Analyzing APEX output files to prepare and present NTT reports

# Making the Best of a Model

Understanding its framework, strengths and limitations

Reliability and accuracy of the input data and their sources

Accurately transforming input data from their source into the format acceptable to the model

Stability and accuracy of the model judged through

- i. Verification
- ii. Sensitivity Analysis
- iii. Calibration
- iv. Validation

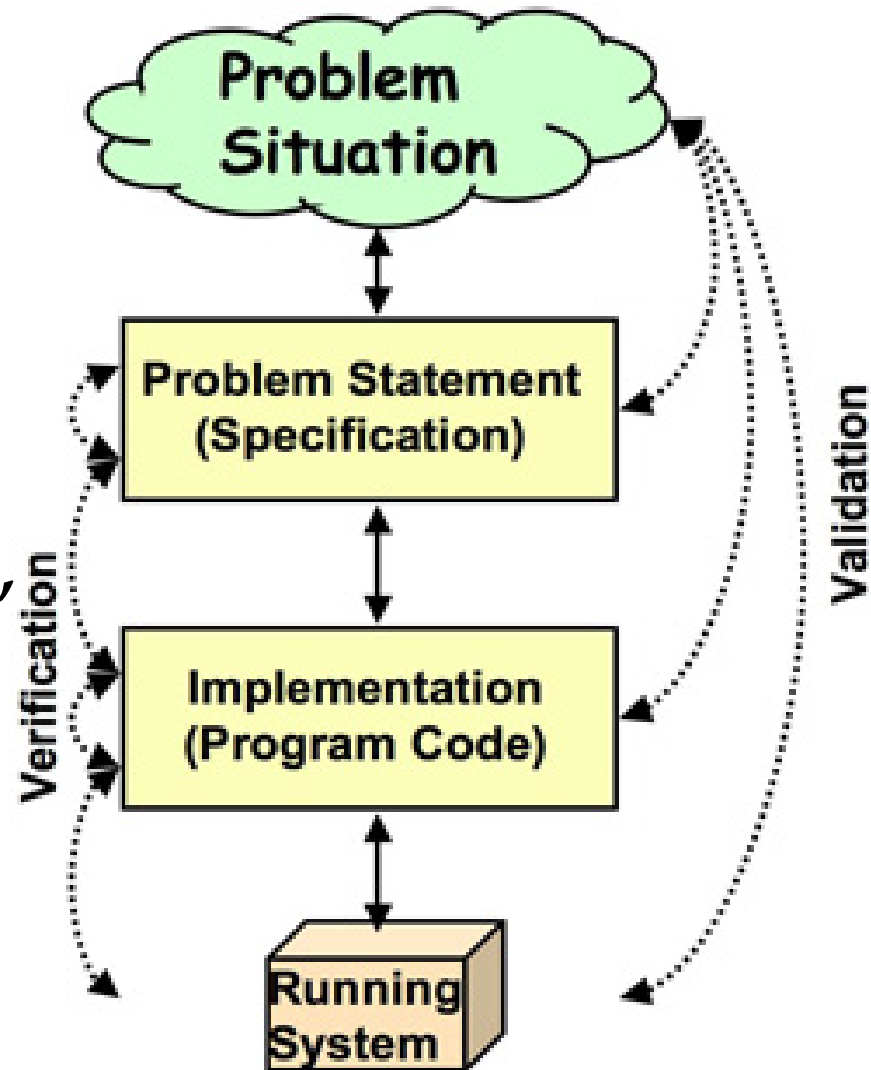
Analysis and interpretation of the model output results

# Making the Best of a Model

## Verification

A process of demonstrating the formalism of the “Model” is correct

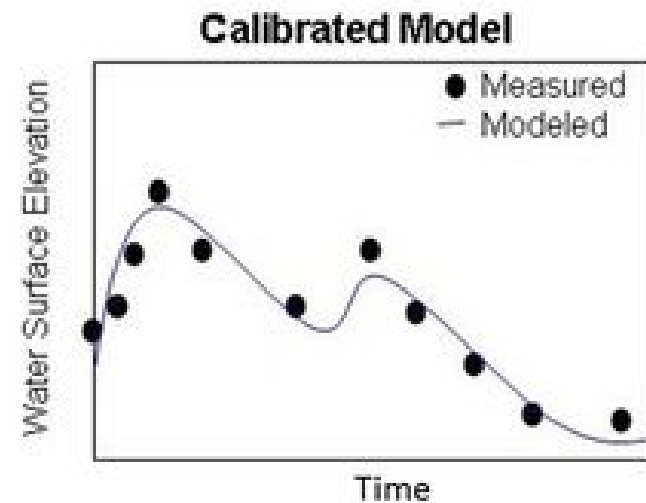
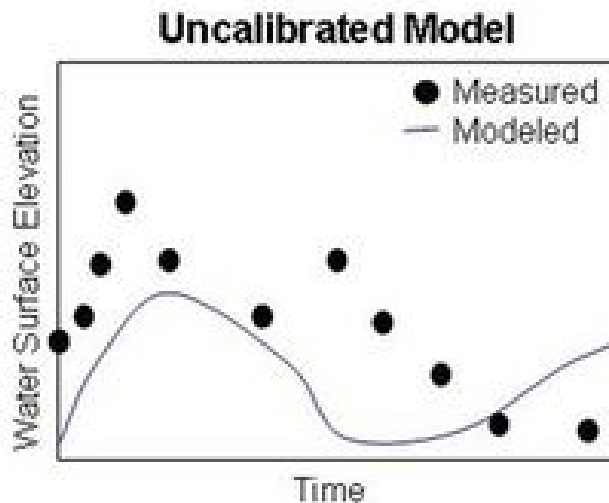
Developer responsibility



# Making the Best of a Model

## Calibration / Parameterization

A process of estimating and adjusting parameters and constants of the “Model” to improve the agreement between its output and the real life observations

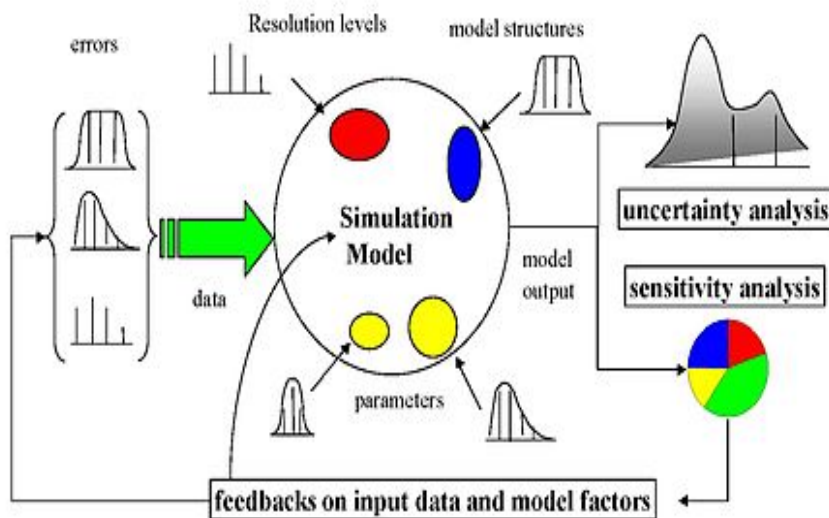


Developer/User responsibility

# Making the Best of a Model

## Sensitivity Analysis

A process of studying how the uncertainty in the “Model” output can be apportioned to different sources of uncertainty in its input data



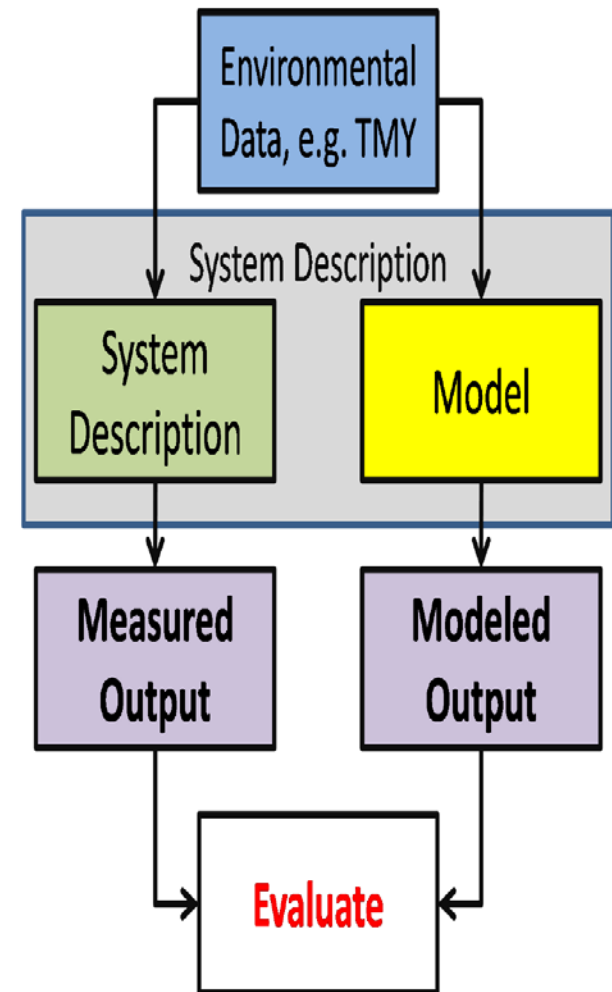
76

User responsibility

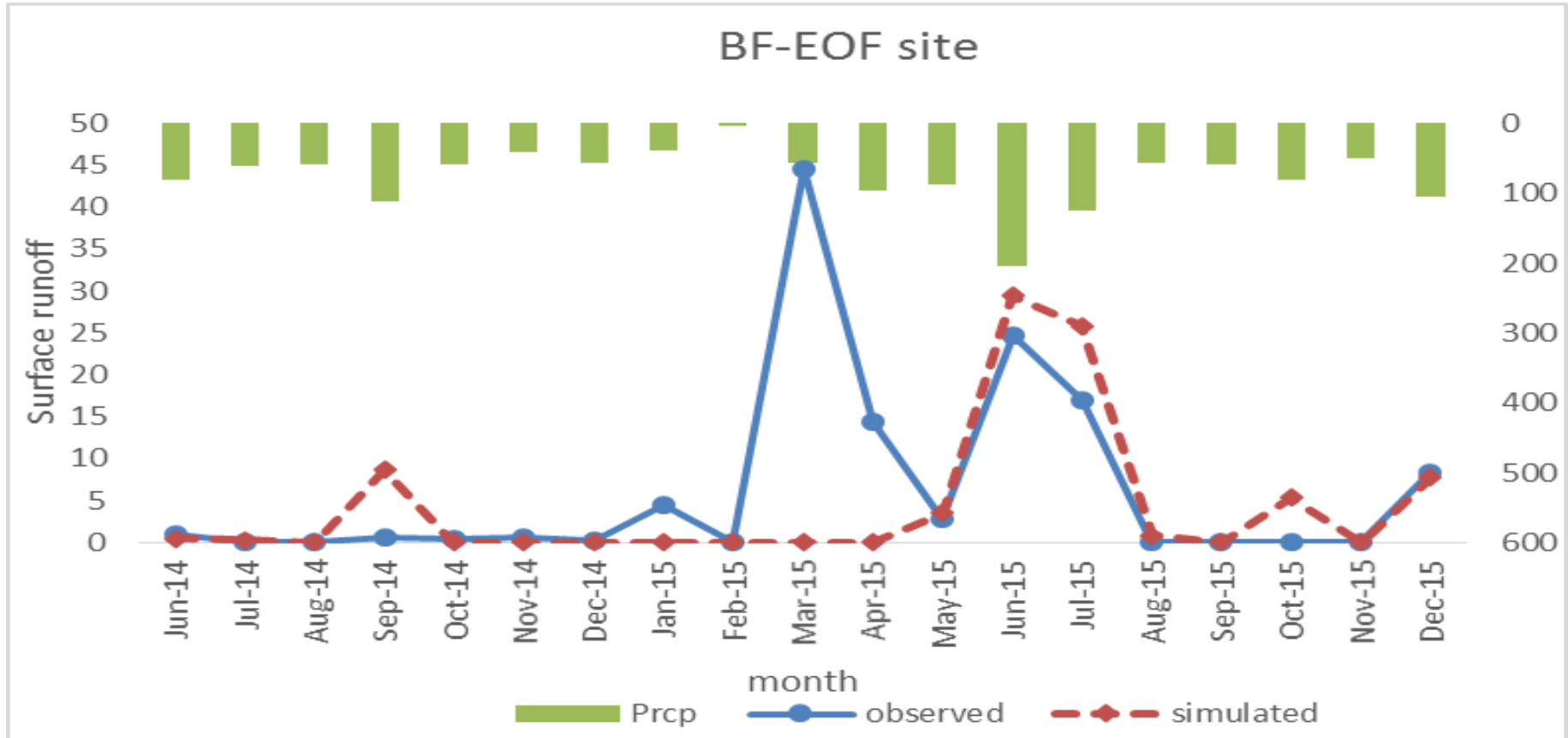
# Making the Best of a Model

## Validation

A process of demonstrating that the model possesses a satisfactory range of accuracy consistent with its intended application within its domain of applicability



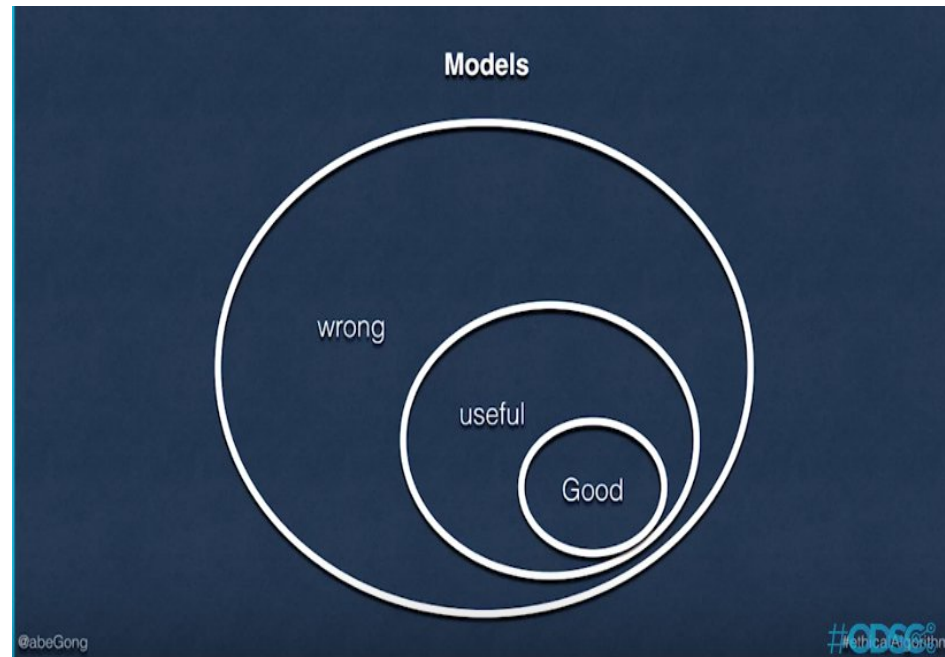
# An Example of Model Validation



# Improving Models Reliability

## Making Models more Useful...

- **Thorough Verification**
- **Proper Calibration/  
Parameterization**
- **In-depth Validation**
- **Being aware of the  
model sensitivity to  
different factors**



# summary

# summary

Of the three roles, the **model user** may be the most important...

Selecting good models for pertinent uses.

Applying skill: input, output, interpretation.

Being a good presenter to the customer.

# summary

How can you get more out of a  
computer model than you put in?

As a model user, put more into yourself!

Become a modeling connoisseur!

# important final tip:

Finally...

Try to keep the  
right perspective!



# contact info

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