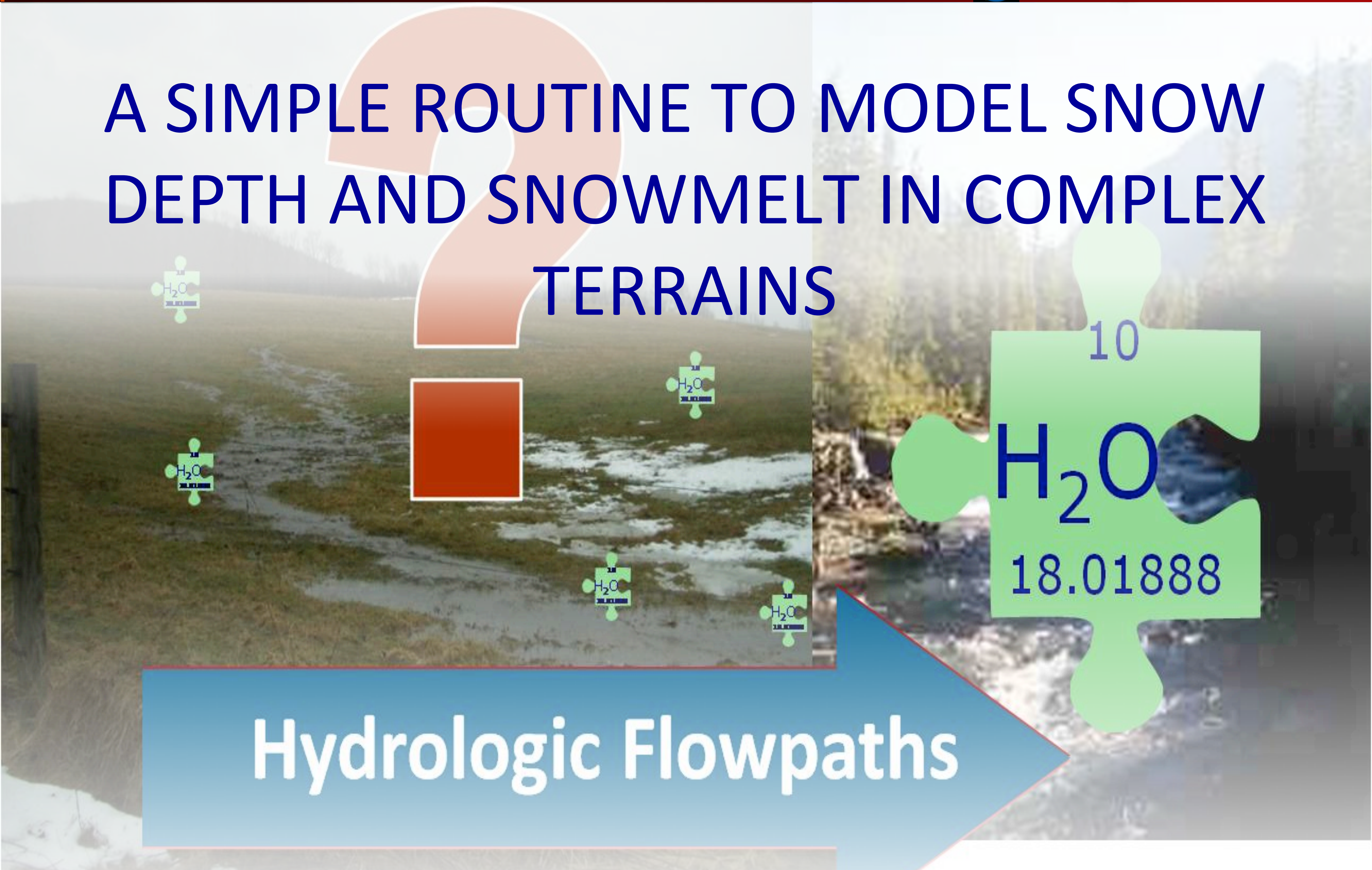
A SIMPLE ROUTINE TO MODEL SNOW DEPTH AND SNOWMELT IN COMPLEX TERRAINS



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Outline

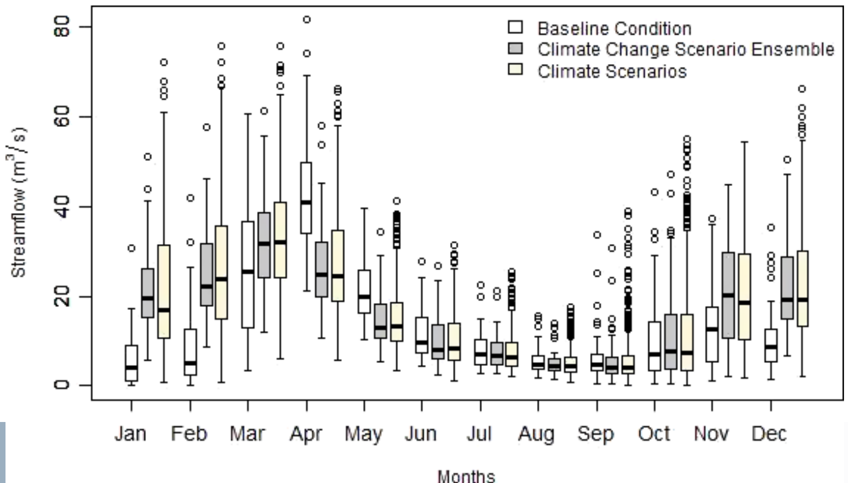
- Background
- Objectives
- Application
  - Accounting for Complex Terrains
  - Process Based Snow Accumulation/Melt
    - Surface Energy Budget
  - Climate Change
- Summary

Background

- Terrain: vertical, horizontal and directional aspects of the surface
- Terrain exerts critical influence on many processes
  - Snowmelt/accumulation
  - Evapotranspiration
  - Nutrient cycling
  - Moisture redistribution
  - Crop growth
  - Geomorphology

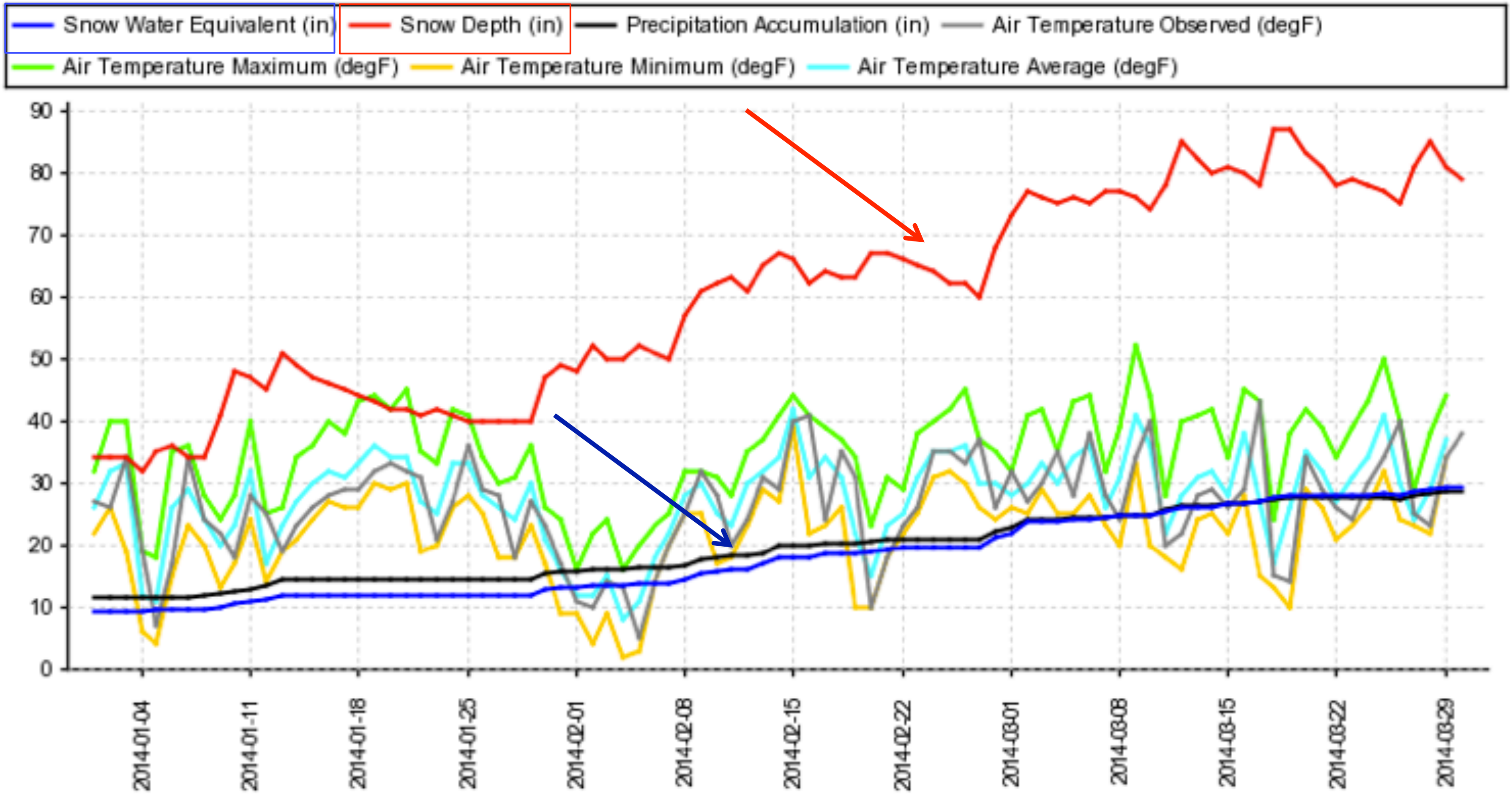
Background

- Snow accumulation and melt are important in many arid/semiarid regions of the world
- In regions of high elevation and/or latitudes up to 80% of the annual streamflow originates from snowpack and snowmelt
  - Impact of landuse or climate change?



Utah Site - Snowbird (766)

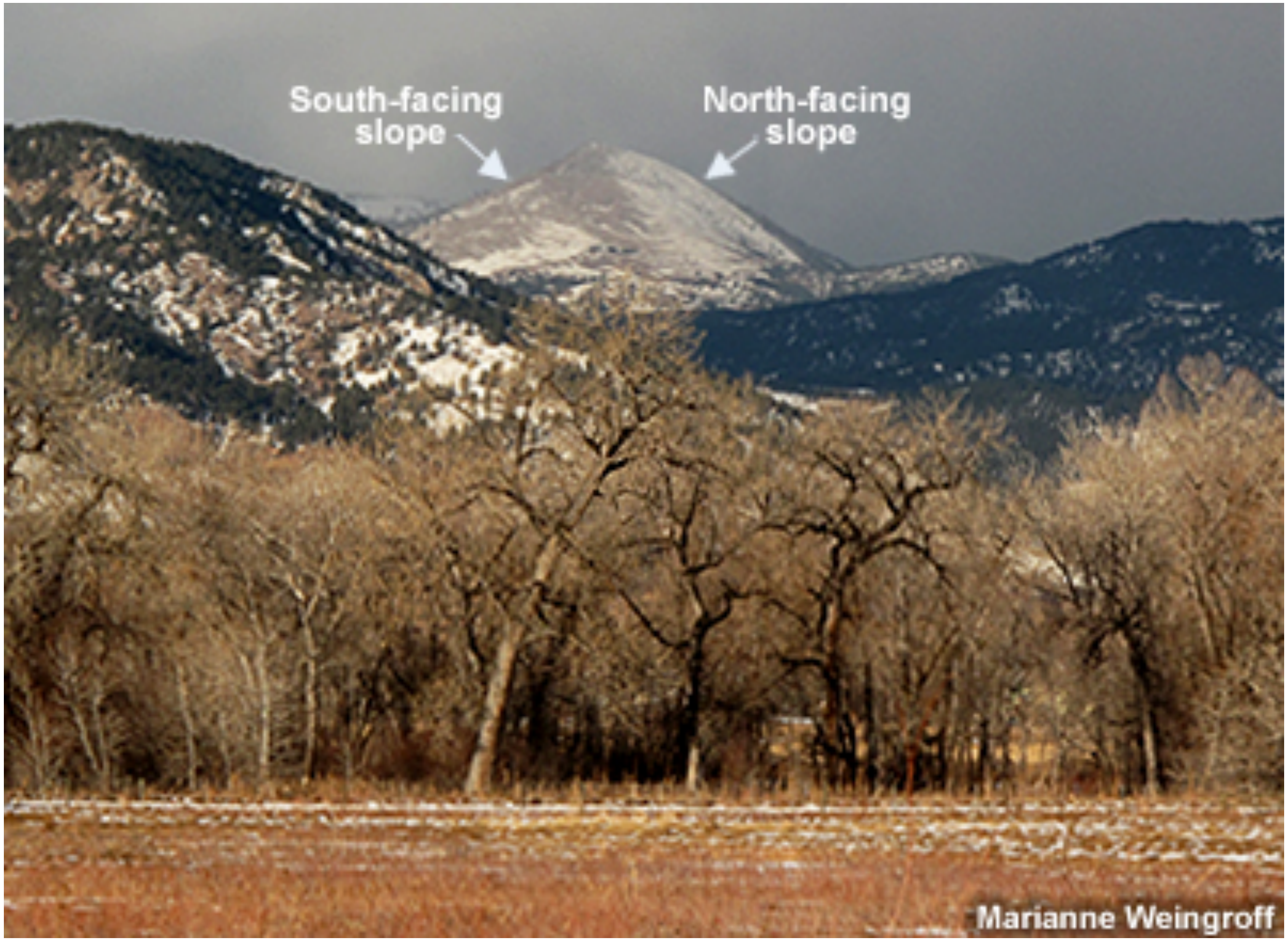
(As of: Sun Mar 30 04:40:58 PDT 2014)
Provisional data, subject to revision



Modeling Snow Melt/Accumulation

- Many watershed models use a temperature index (TI) to 'model' snowmelt and snow accumulation
    - $M = MF\ (T_a - T_{base})$
- Simple, but requires calibration and cannot be applied outside the range of conditions for which they were calibrated
    - e.g., Assessing Landuse or Climate Change
- Most operational **Energy Budget** snow models operate at scale > 1km (SNODAS)
    - Too large to capture important hydrological processes

Hillslope Aspect and Elevation



Temperature Index

Parameters	Mean	Standard Deviation	CV
Snowfall temperature [C]	-1.27	2.62	-2.06
Snow melt base temperature [C]	0.02	3.62	181.00
Melt factor on June 21 [mm H_2O/C-day]	-1.62	2.67	-1.65
Melt factor on December 21 [mm H_2O/C-day]	-0.27	3.41	-12.63
Snow pack temperature lag factor	0.15	3.13	20.87

Can this be used to predict anything?

Surface Energy Budget

$$\Delta SWE = \frac{(S + L_a - L_t + H + E + G + P - SWE(C\Delta T_s))}{\lambda}$$

ΔSWE - change snow water equivalent

S - net incident solar radiation

L_a - atmospheric long wave radiation

L_t - terrestrial long wave radiation

H - sensible heat exchange

G - ground heat conduction

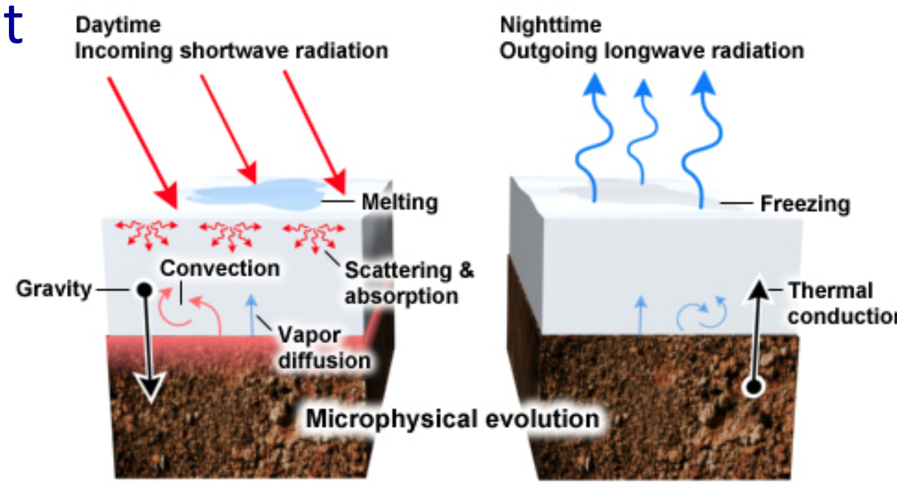
P - heat added by rainfall

E - energy flux latent heat, vaporization & condensation

SWE(C Δ T_s) - change of snowpack heat storage

λ - latent heat of fusion

Basic metamorphosis processes for level snowpack



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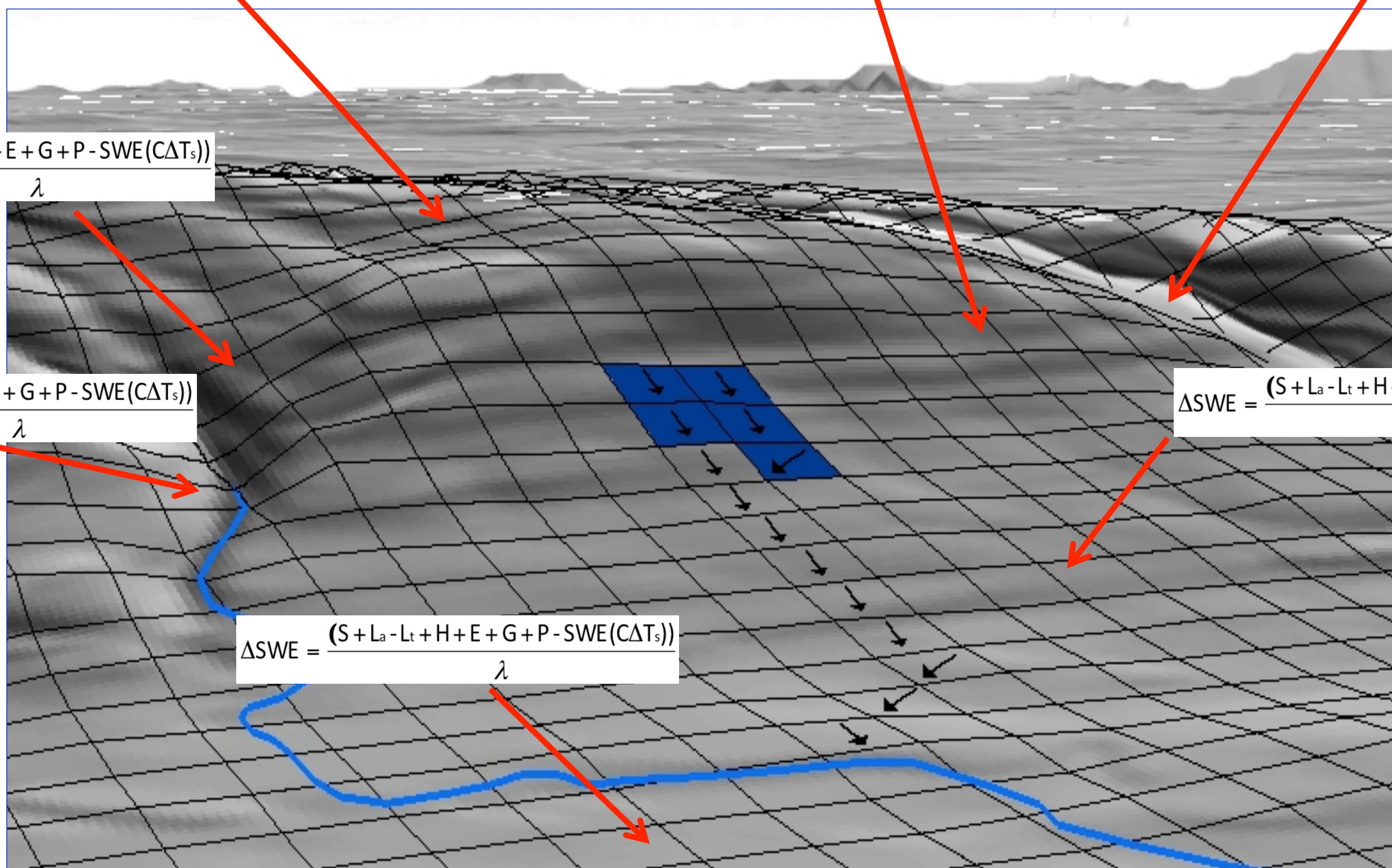
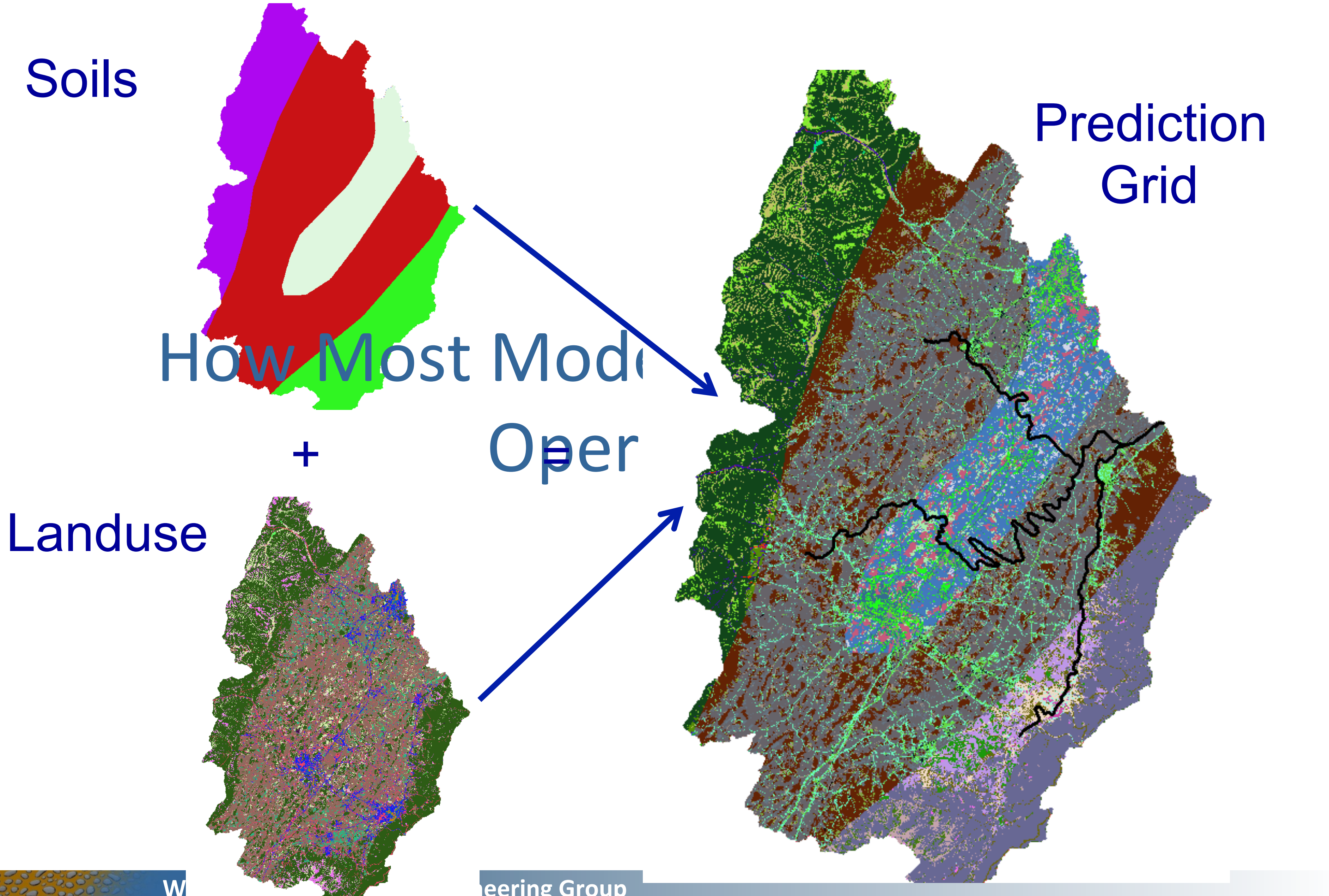
Coupling Energy Budget with Terrain Metrics

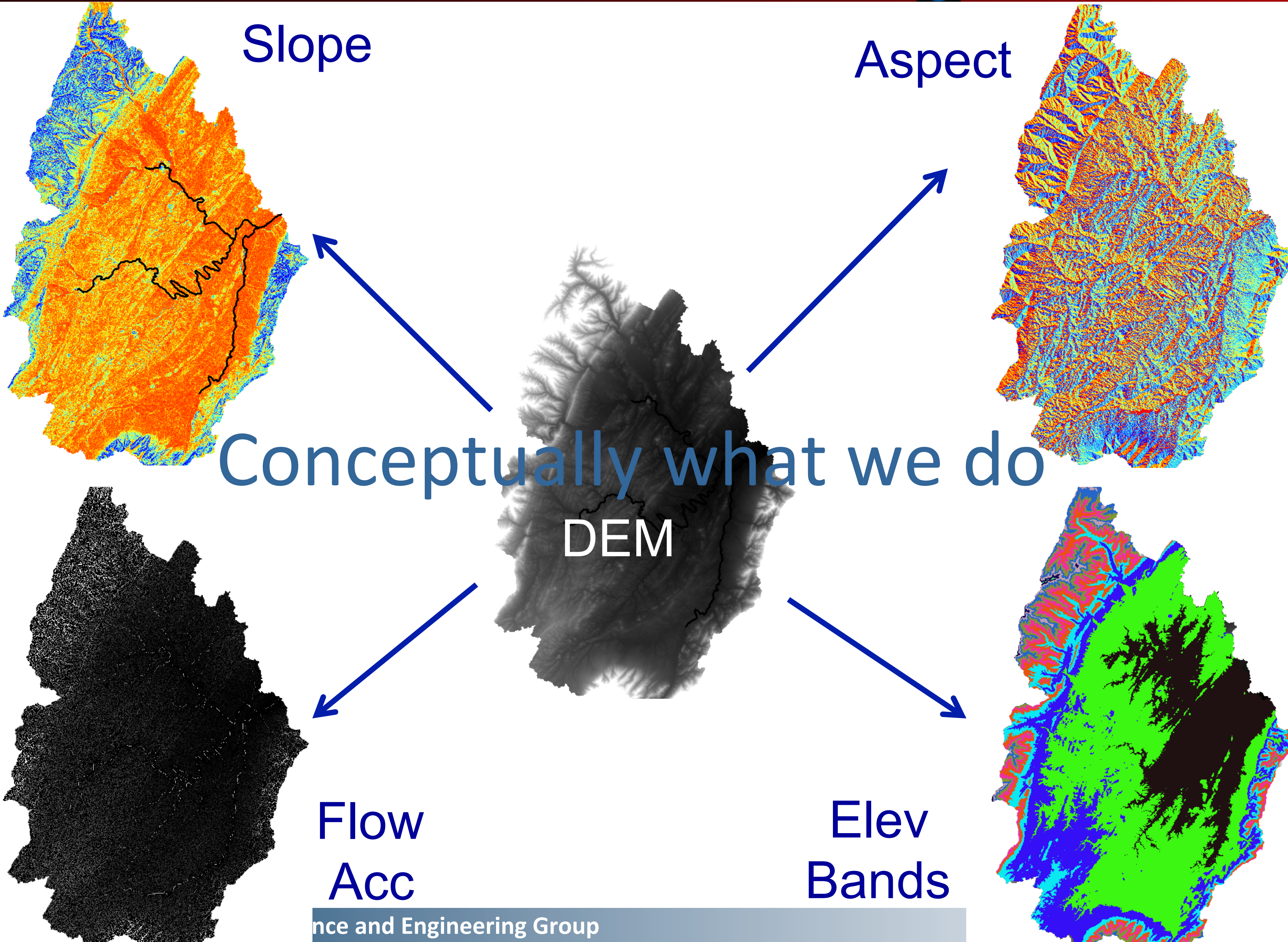


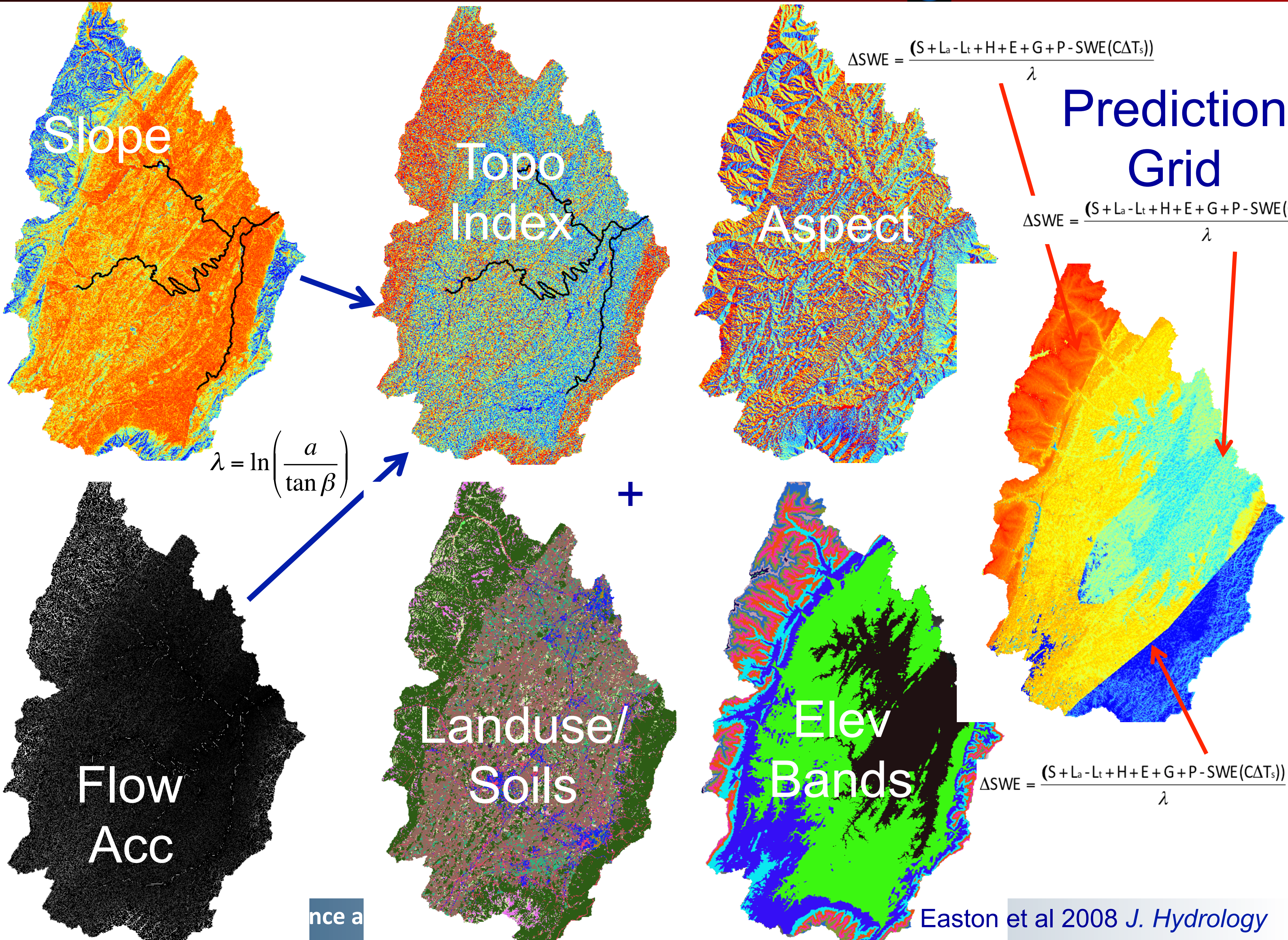
Buchanon et al 2012 *J. Hydrology*

How Most Mode
Oper

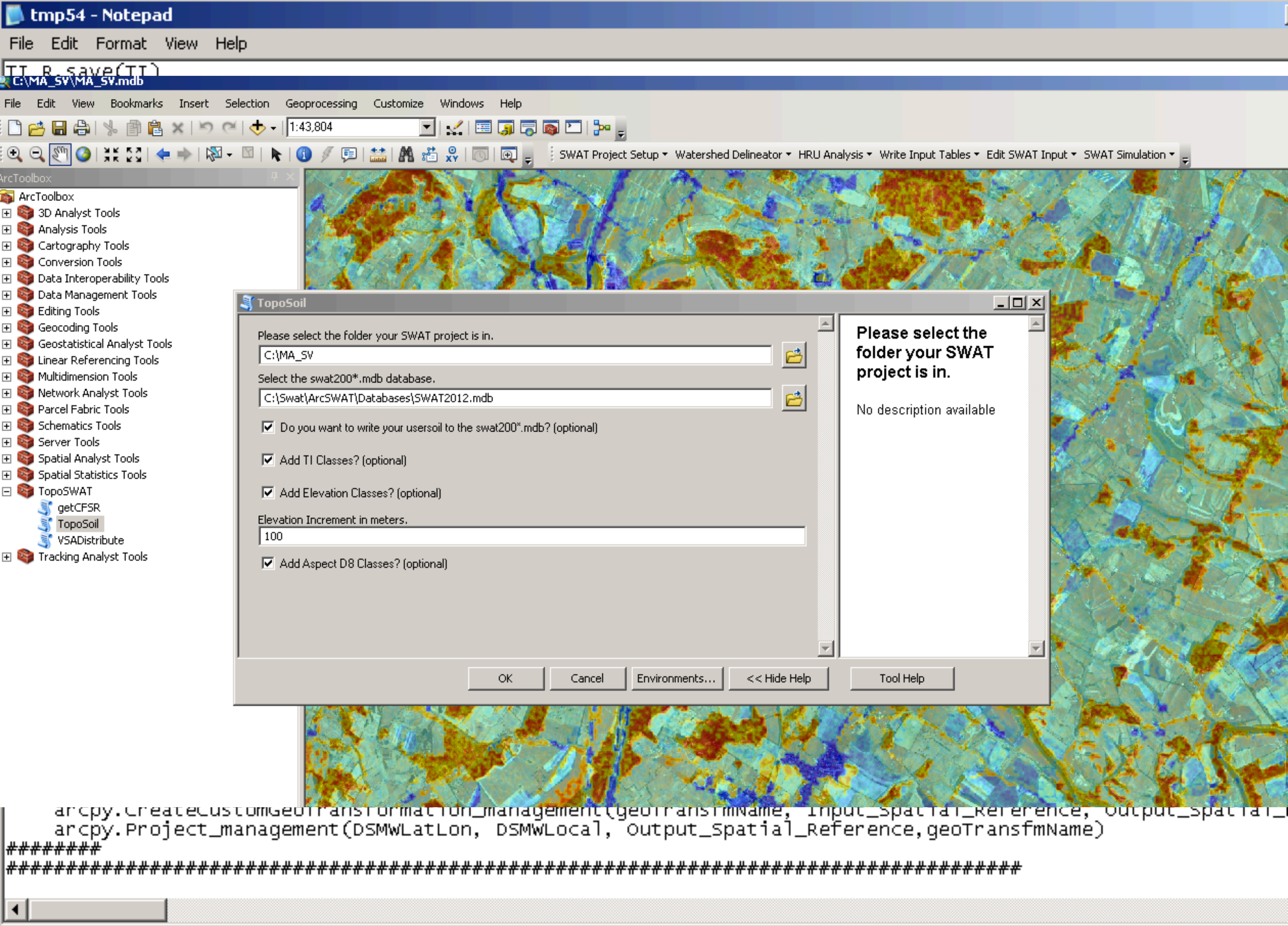


Conceptually what we do





Easton et al 2008 *J. Hydrology*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SWAT Project Setup Watershed Delineator HRU Analysis Write Input Tables Edit SWAT Input SWAT Simulation
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Data Management Tools
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Multidimension Tools
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Tool Help
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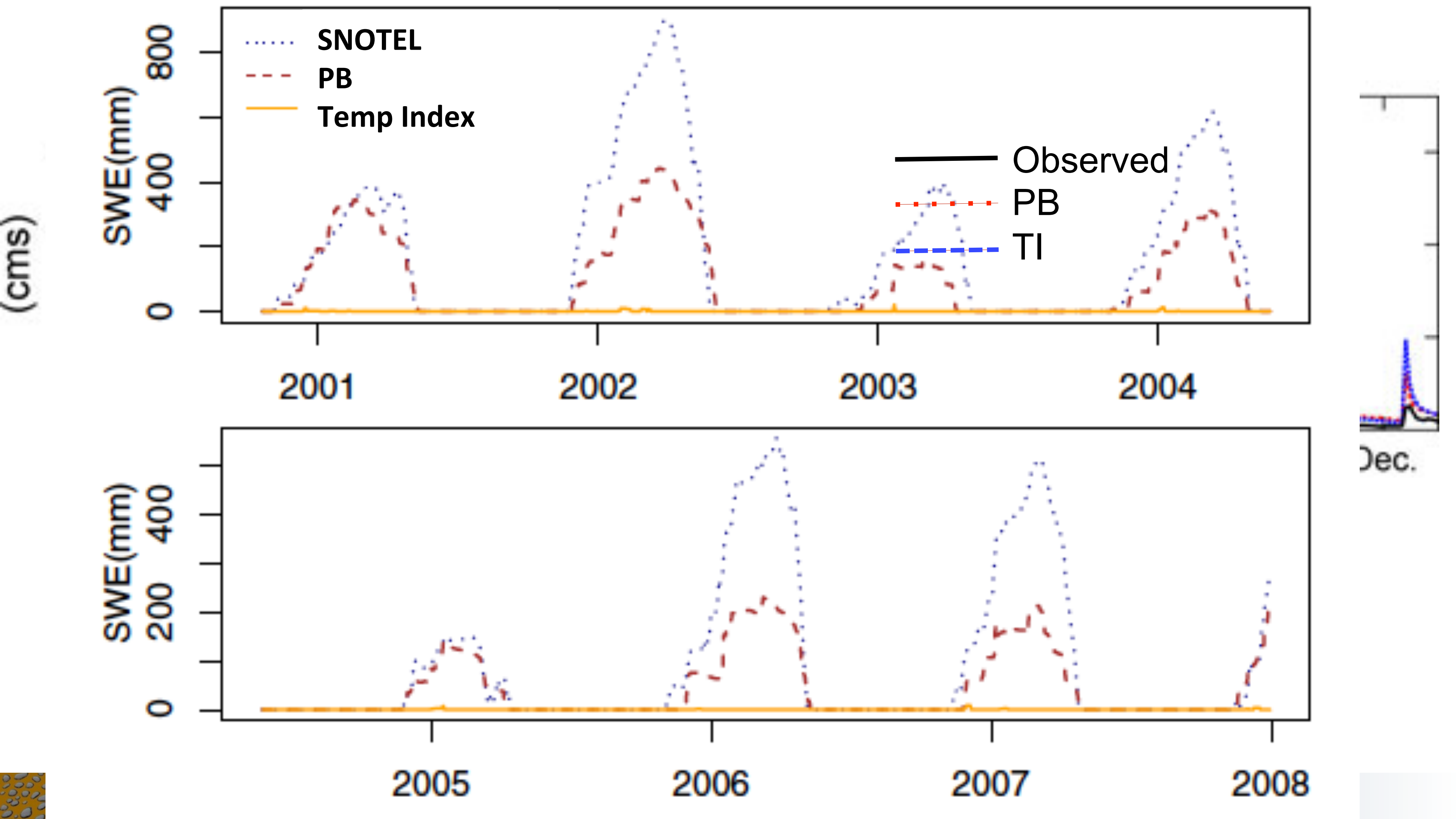
##

Complexity actually helps with calibration issues…

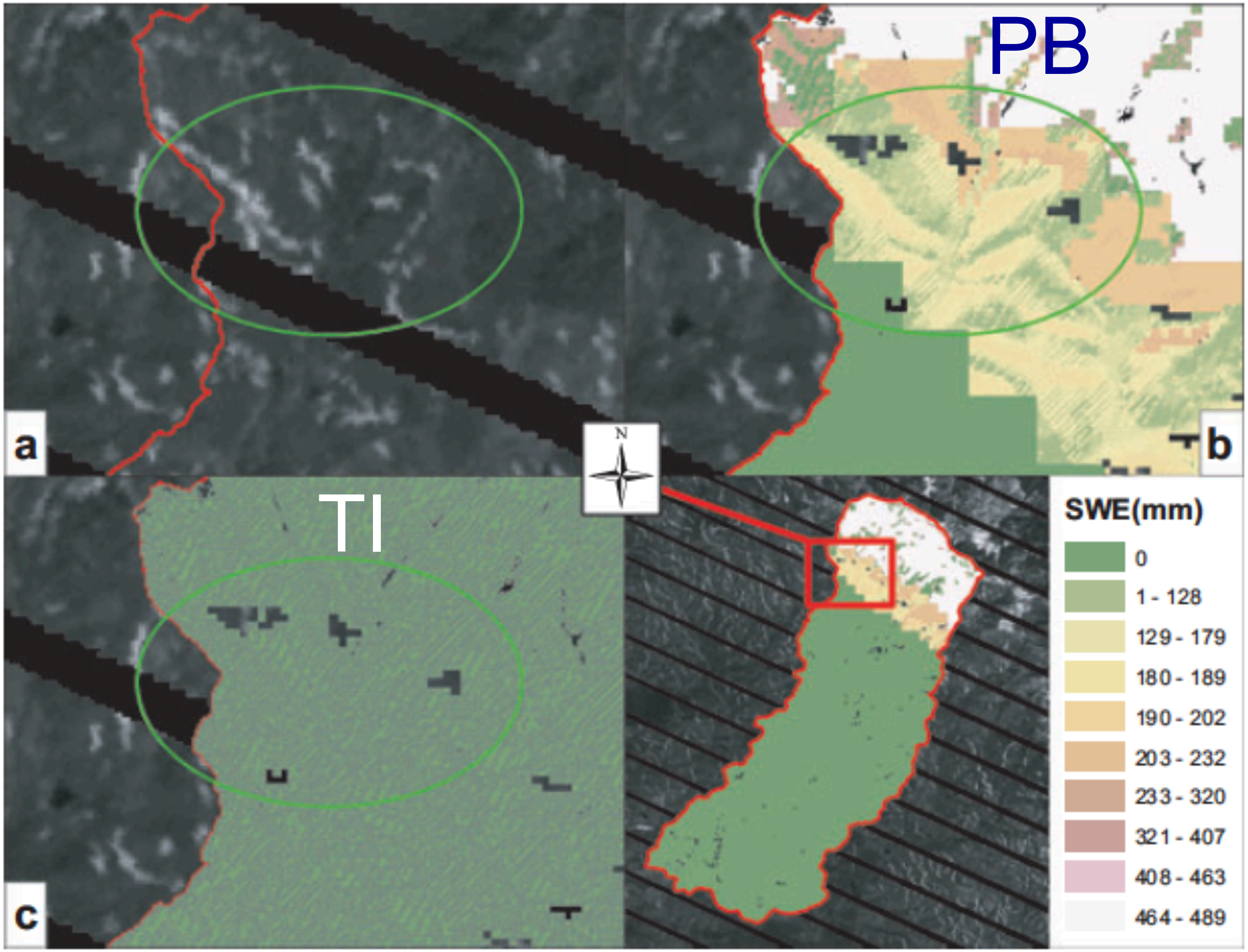
		Temp Index			PB
		Mean	**Standard Deviation**	**CV**	
Parameters	**NSE**	0.51			0.54
Snowfall temperature [C]		-1.27	2.62	-2.06	**NA**
Snow melt base temperature [C]		0.02	3.62	181.00	**NA**
Melt factor for snow on June 21 [mm H_2O/C-day]		-1.62	2.67	-1.65	**NA**
Melt factor for snow on December 21 [mm H_2O/ C-day]		-0.27	3.41	-12.63	**NA**
Snow pack temperature lag factor		0.15	3.13	20.87	**NA**

Fuka et al 2012 *JAWRA*

Complexity actually helps with calibration issues…

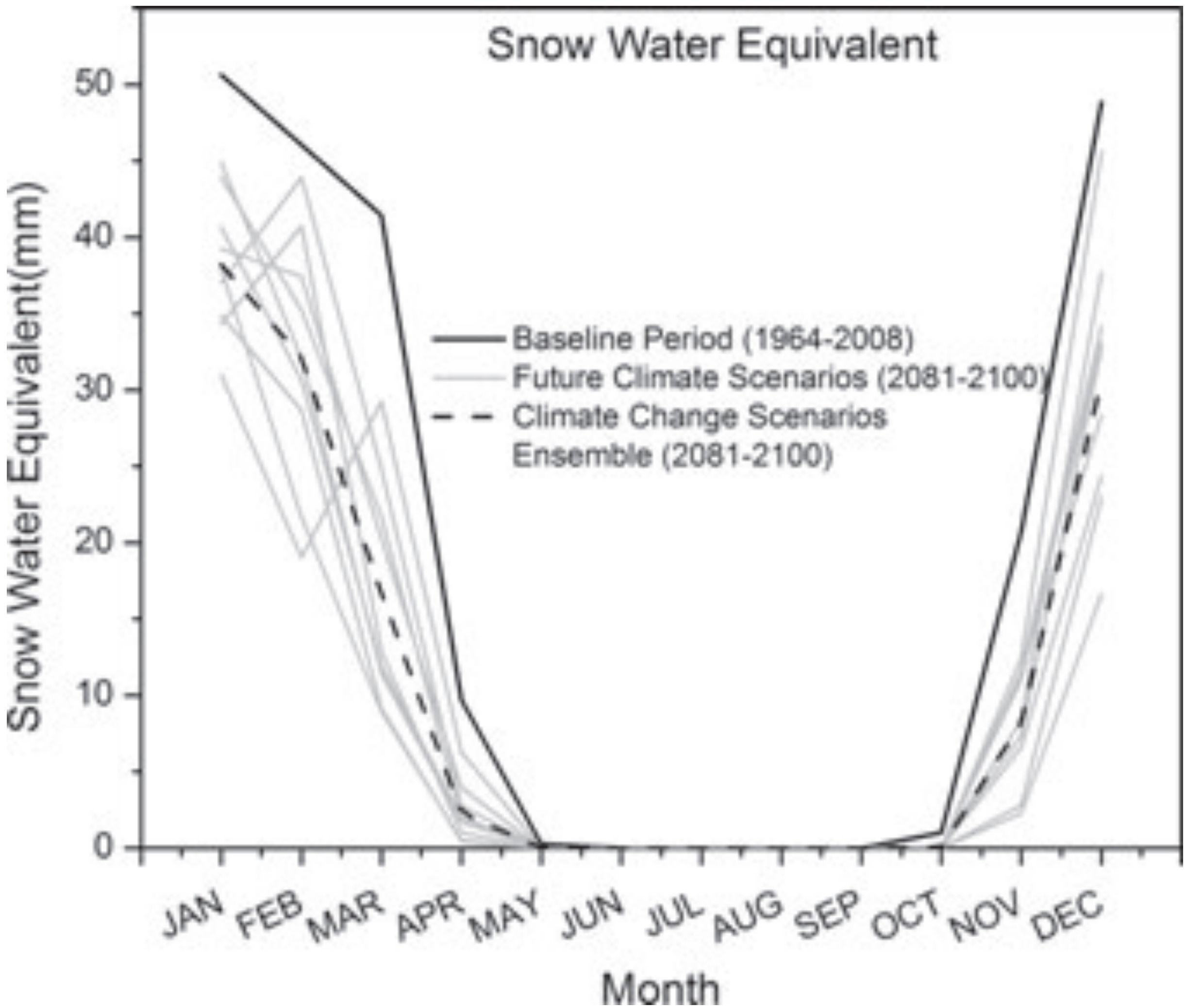


Spatial Corroboration



Fuka et al 2012 *JAWRA*

Application to Climate Change



Using the **Process Based** model allows us to assess the impact of climate change

Something we cannot (or should not) attempt with TI models

Pradhanang et al. 2013 *JAWRA*

Key Messages

- **Process Based** models can provide substantial insight into processes and improve predictions
  - **TI Based** models ‘calibrate out’ snow accumulation
- SO…..chose the right model for the right problem
  - And if it does not exist, build/modify/create it
    - We can reduced calibration and built a more parsimonious model by considering complex processes
- Caveat, computational costs of complex prediction surfaces
- Software
  - http://ww2.bse.vt.edu/eastonlab/?page_id=21


Moses!! Cut it out and take your bath
MOSES... His first years.
VILEY 7-25