GLOBAL SENSITIVITY ANALYSIS OF A LAND SURFACE MODEL: AN APPLIED CASE STUDY

Colin P. Kikuchi[1]
Tim Bayley[1]
Joel Kimmelshue[2]
Mica Heilmann[2]

[1] Montgomery & Associates
[2] Land IQ

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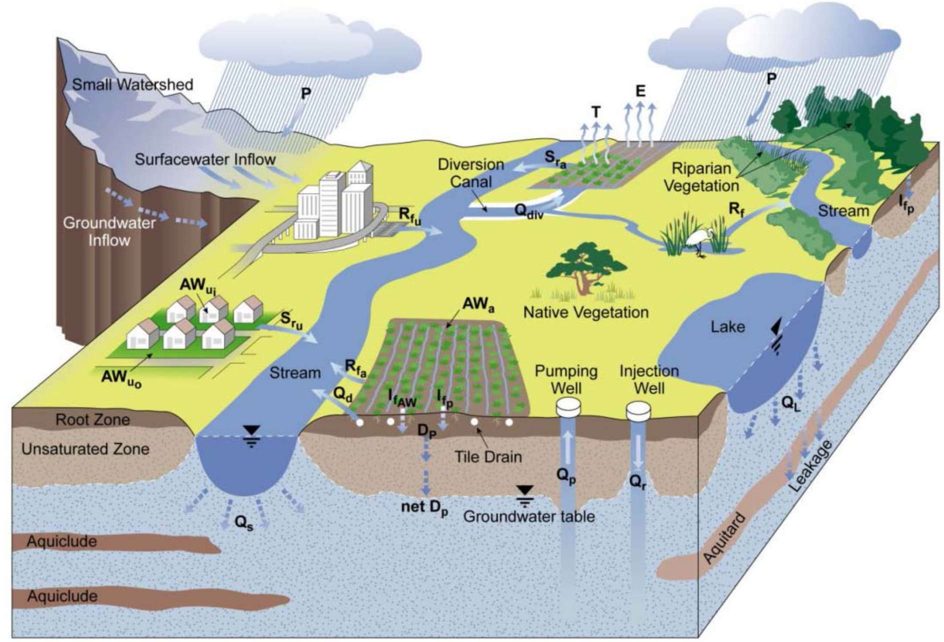
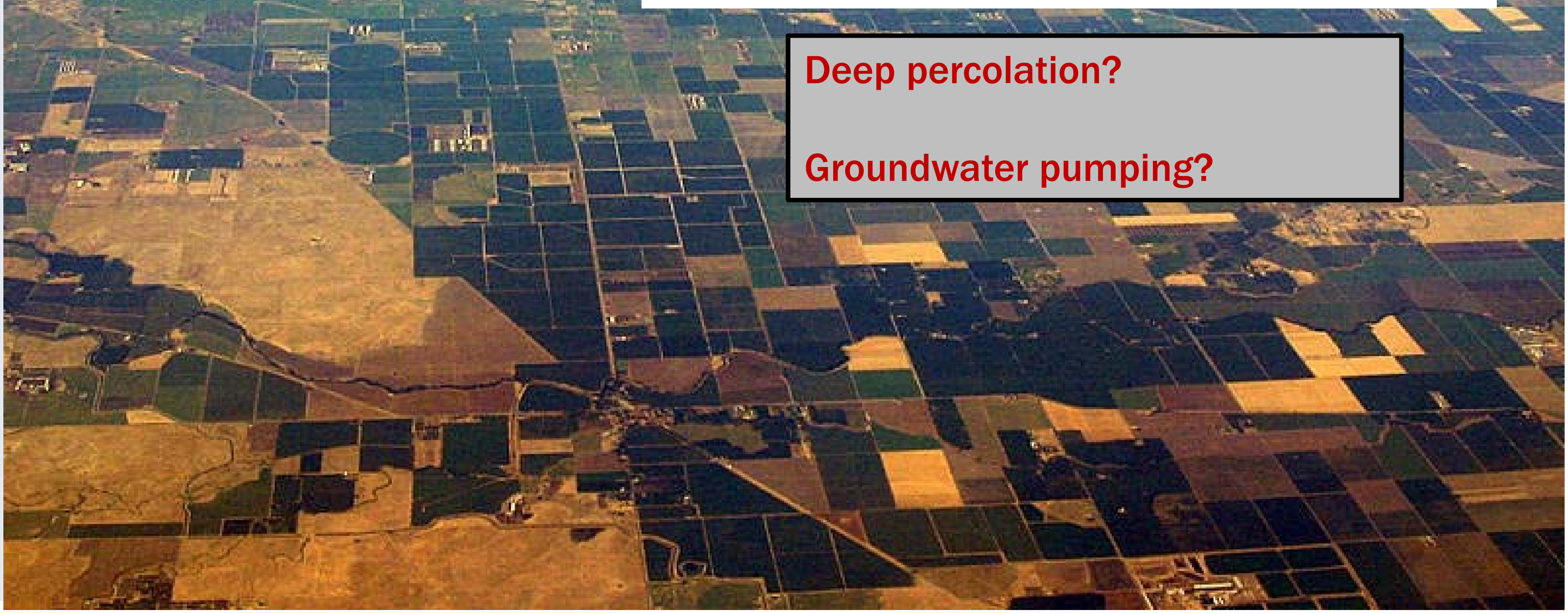
LAND IQ

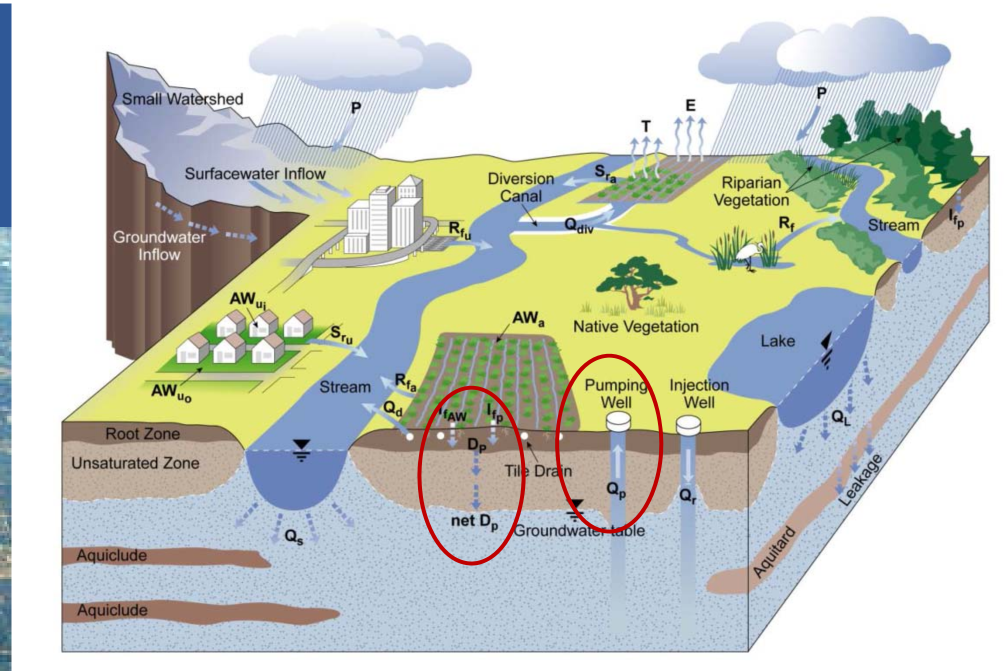
MOTIVATION



Small Watershed
P
Surfacewater Inflow
Groundwater Inflow
T
E
P
Diversion Canal
S_{fa}
Riparian Vegetation
R_{fu}
Q_{div}
R_f
Stream
I_{fp}
AW_{ui}
AW_a
Native Vegetation
S_{ru}
Lake
AW_{uo}
Stream
R_{fa}
Q_d
I_{fAW}
I_{fp}
Pumping Well
Injection Well
Root Zone
D_p
Unsaturated Zone
Tile Drain
Q_p
Q_r
Q_L
Leakage
net D_p
Q_s
Groundwater table
Aquiclude
Aquitard
Aquiclude

MOTIVATION

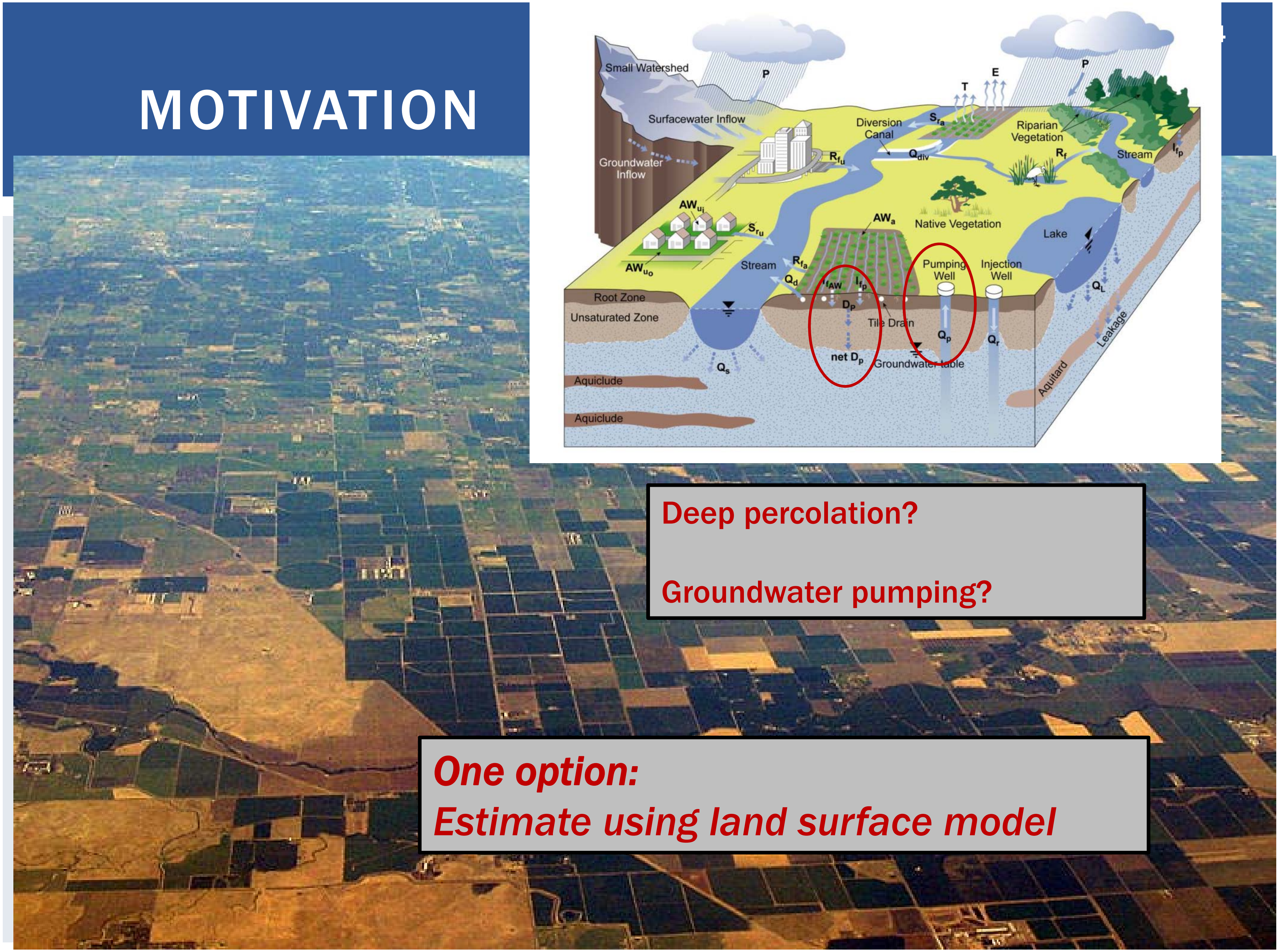




Deep percolation?

Groundwater pumping?

MOTIVATION

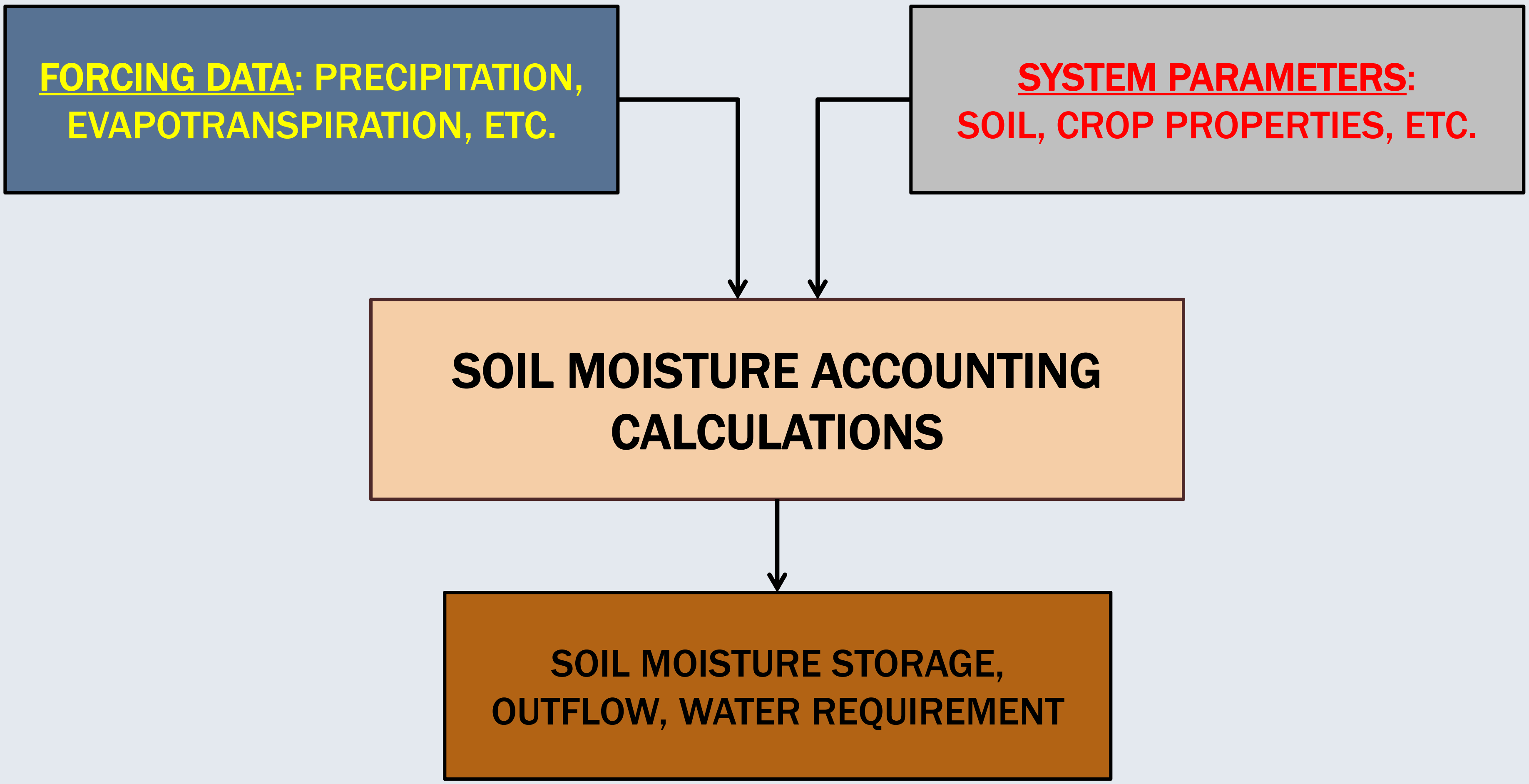


Deep percolation?

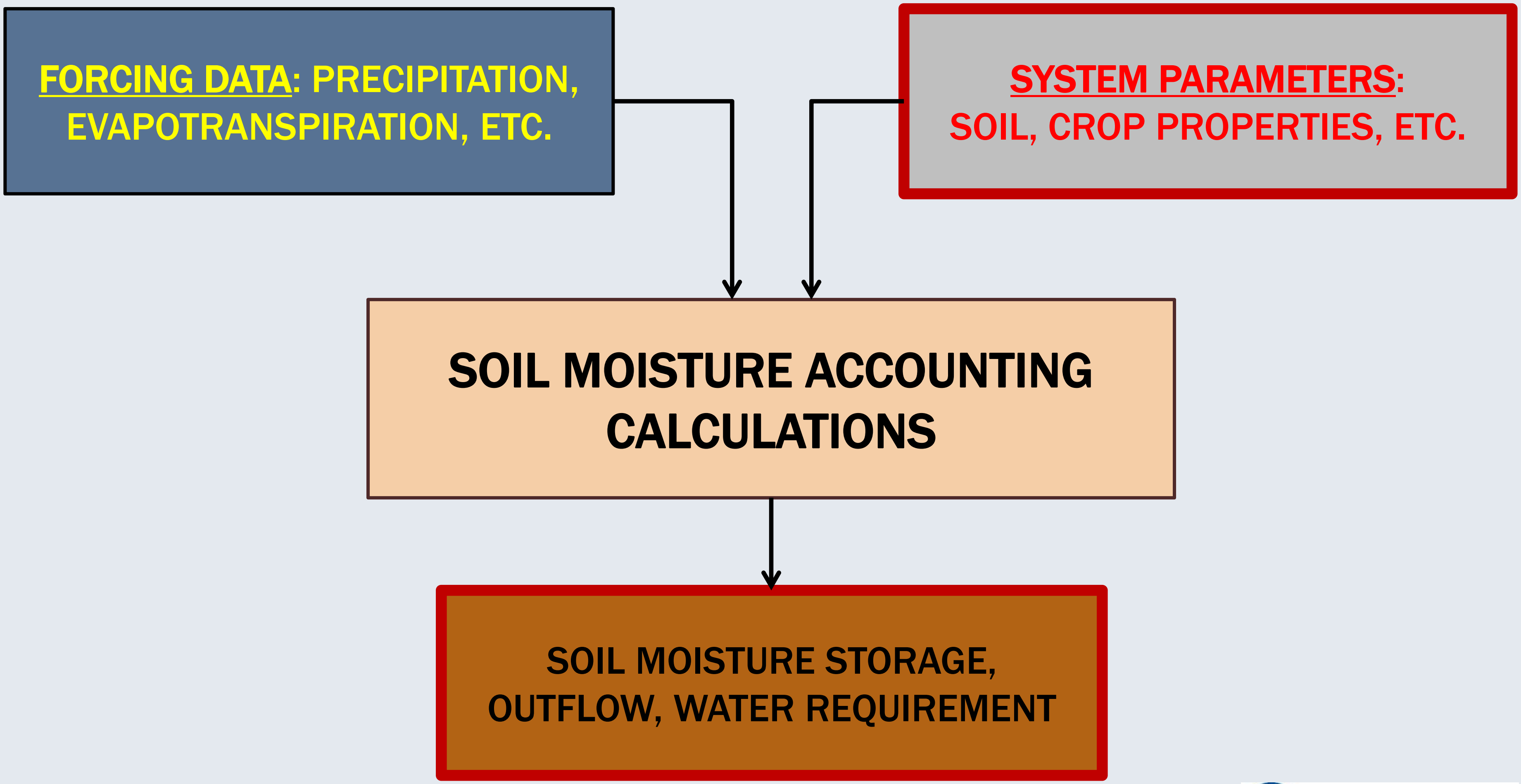
Groundwater pumping?

One option:
Estimate using land surface model

LAND SURFACE MODEL SCHEMATIC



WHAT IS SENSITIVITY ANALYSIS?



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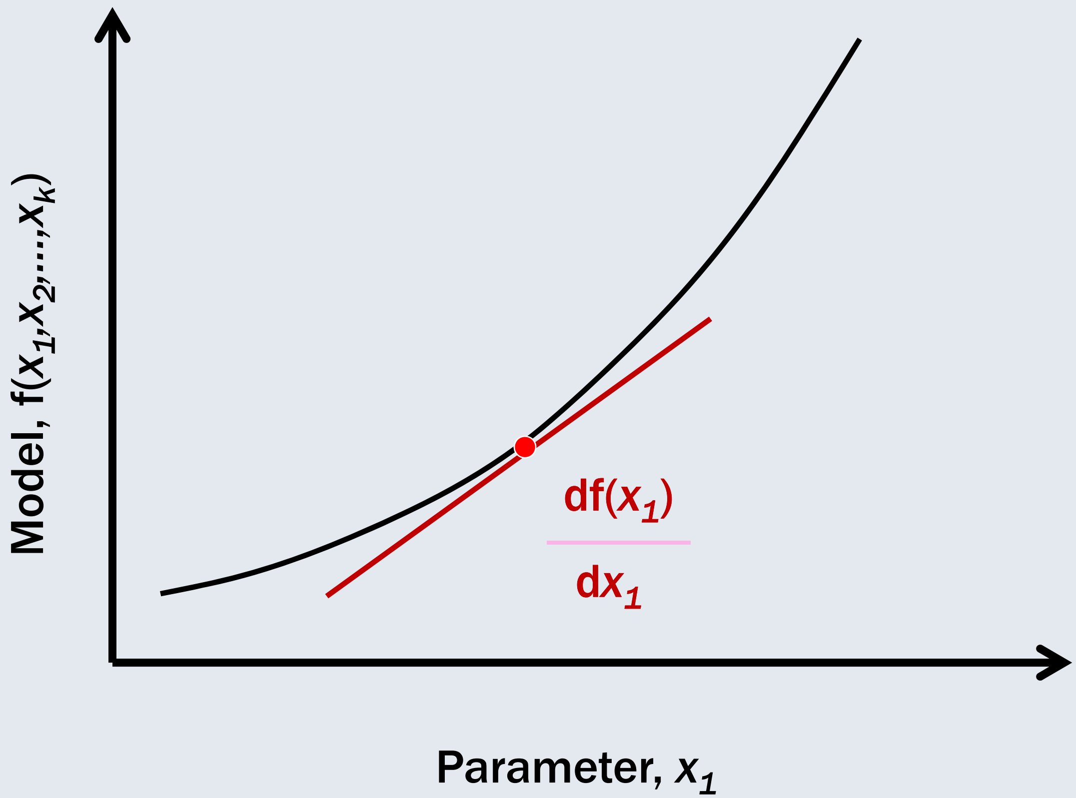
WHAT IS SENSITIVITY ANALYSIS?

- Local sensitivity analysis

If I change one of the parameter values, how much does the model prediction change?

LOCAL SENSITIVITY ANALYSIS

If I change one of the parameter values, how much does the model prediction change?



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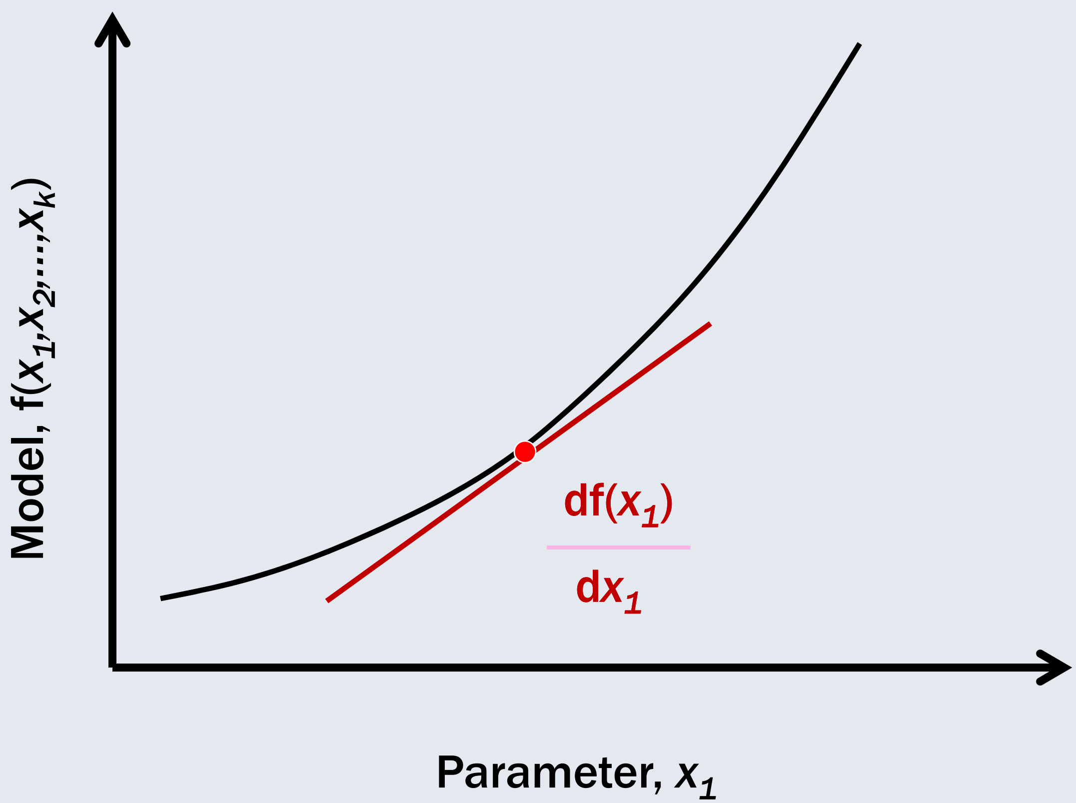
LOCAL SENSITIVITY ANALYSIS

If I change one of the parameter values, how much does the model prediction change?



Used for:

- Parameter estimation
- Ranking parameter importance
- Linear uncertainty analysis

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WHAT IS SENSITIVITY ANALYSIS?

- Local sensitivity analysis

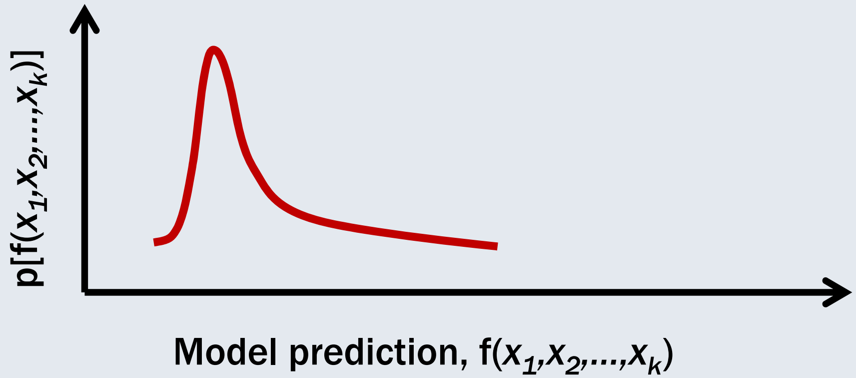
If I change one of the parameter values, how much does the model prediction change?

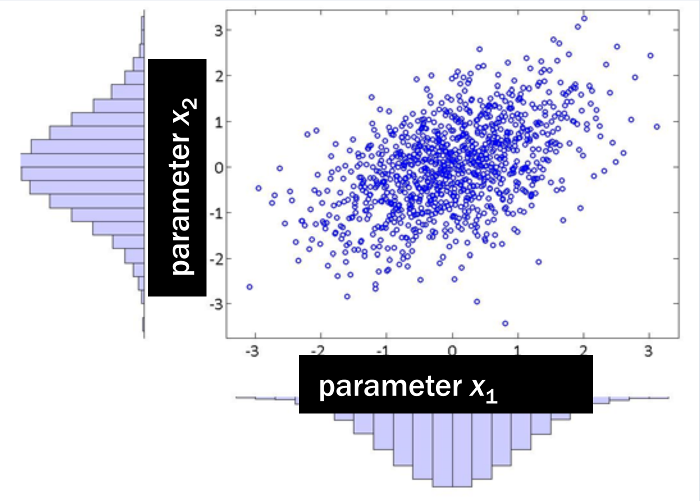
- Global sensitivity analysis

How much does each parameter contribute to the model prediction uncertainty?

GLOBAL SENSITIVITY ANALYSIS

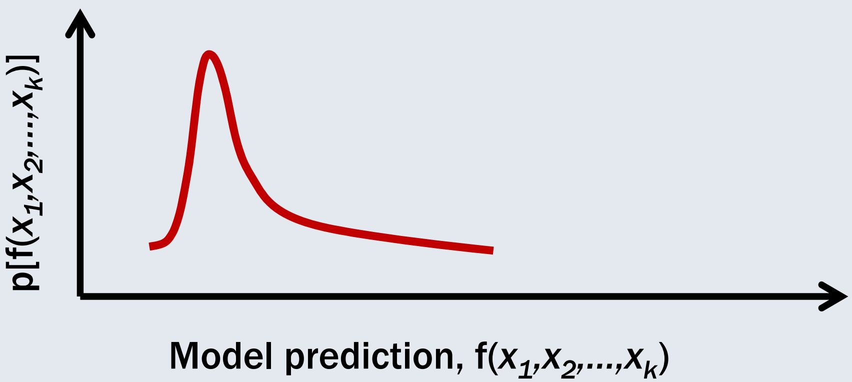
How much does each parameter contribute to the model prediction uncertainty?

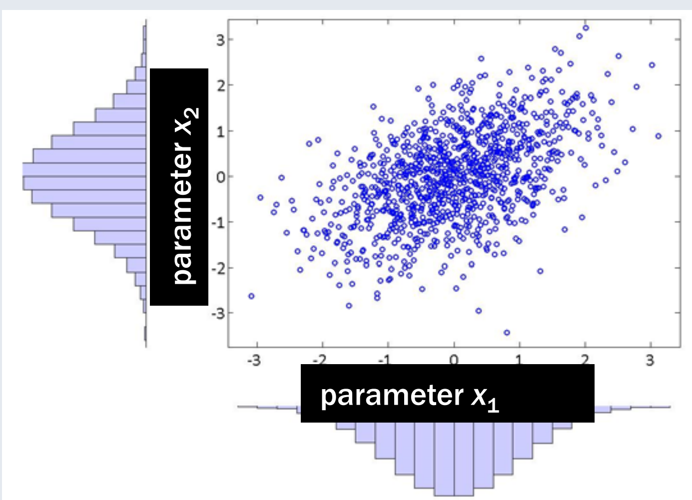




GLOBAL SENSITIVITY ANALYSIS

How much does each parameter contribute to the model prediction uncertainty?





Used for:

- Ranking parameter importance
- Fixing unimportant parameters

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WHAT IS SENSITIVITY ANALYSIS?

- Local sensitivity analysis
  - *Parameters → Model Predictions*
  - Computationally frugal
  - Best when model is linear in the parameters

- Global sensitivity analysis
  - *Parameters → Model Prediction Uncertainty*
  - Computationally expensive
  - Robust over entire parameter space for nonlinear models

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CASE STUDY: NORTHERN SACRAMENTO VALLEY

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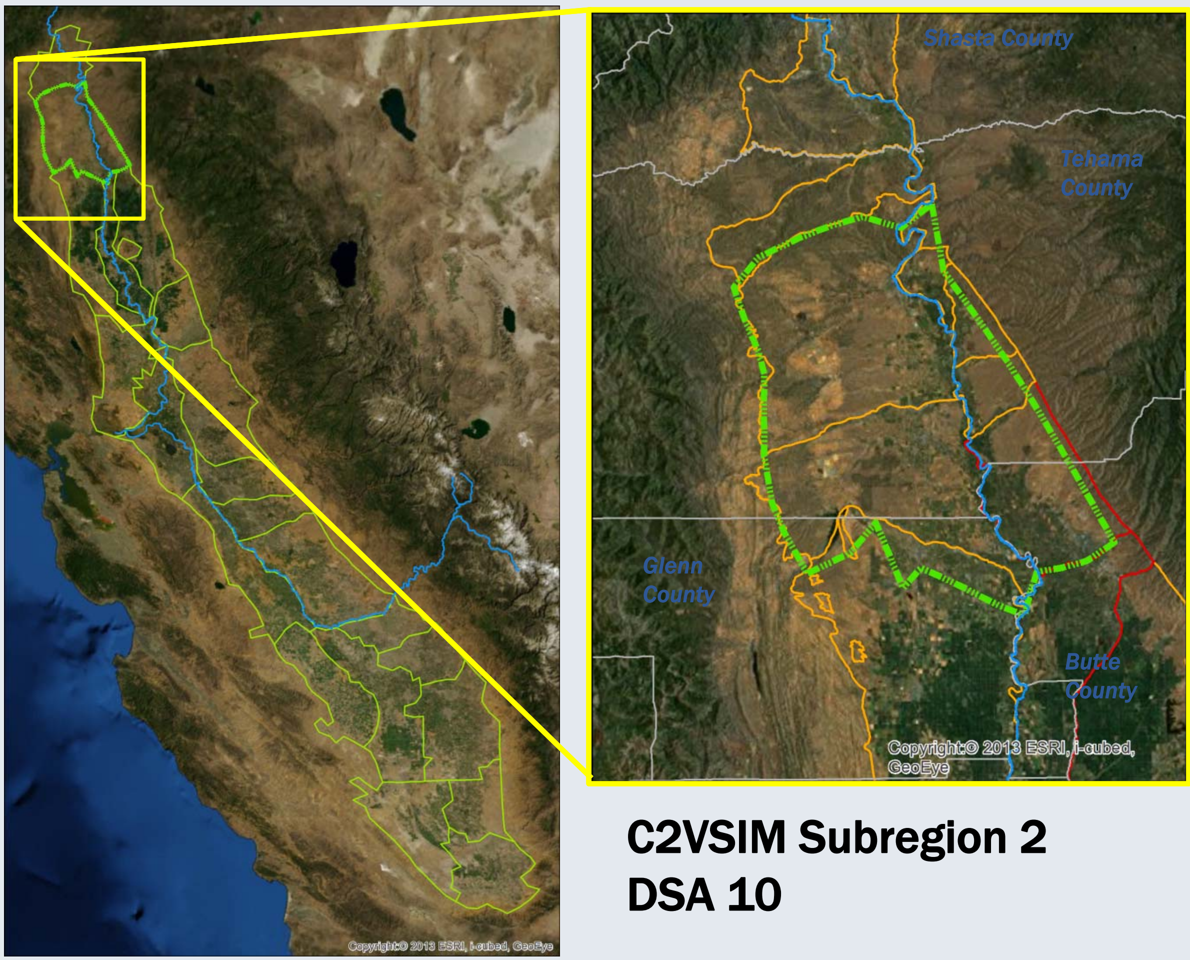

C2VSIM Subregion 2
DSA 10

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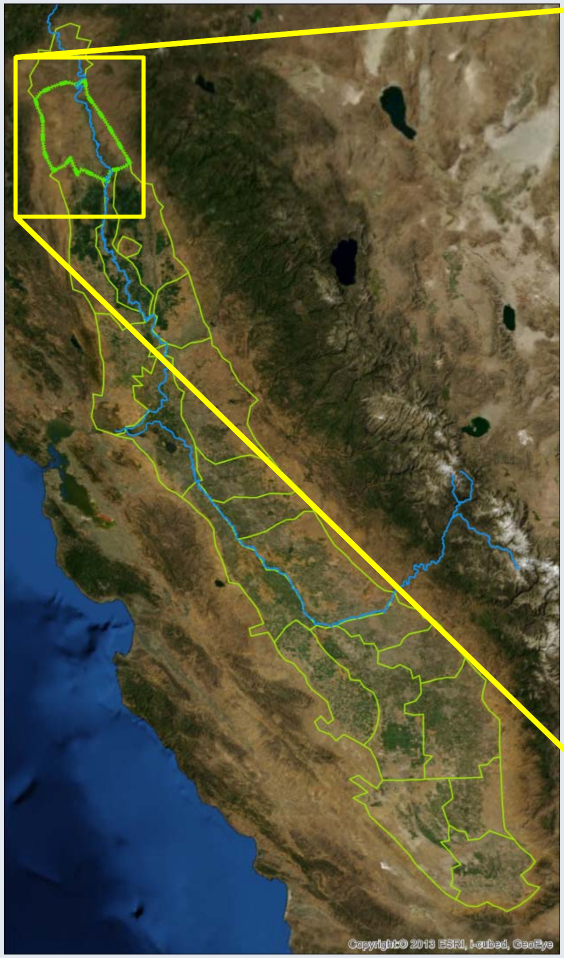
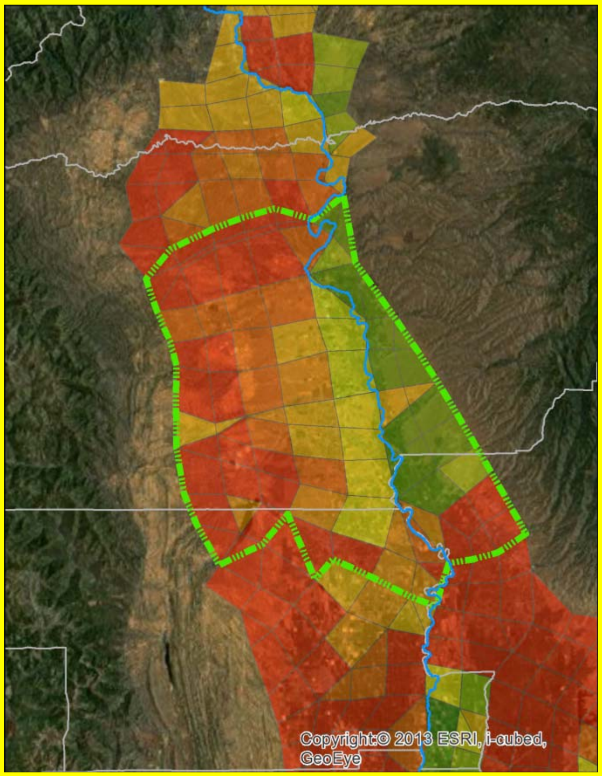
CASE STUDY: NORTHERN SACRAMENTO VALLEY



C2VSIM Subregion 2
DSA 10



C2VSIM Coarse Grid
Soil Class

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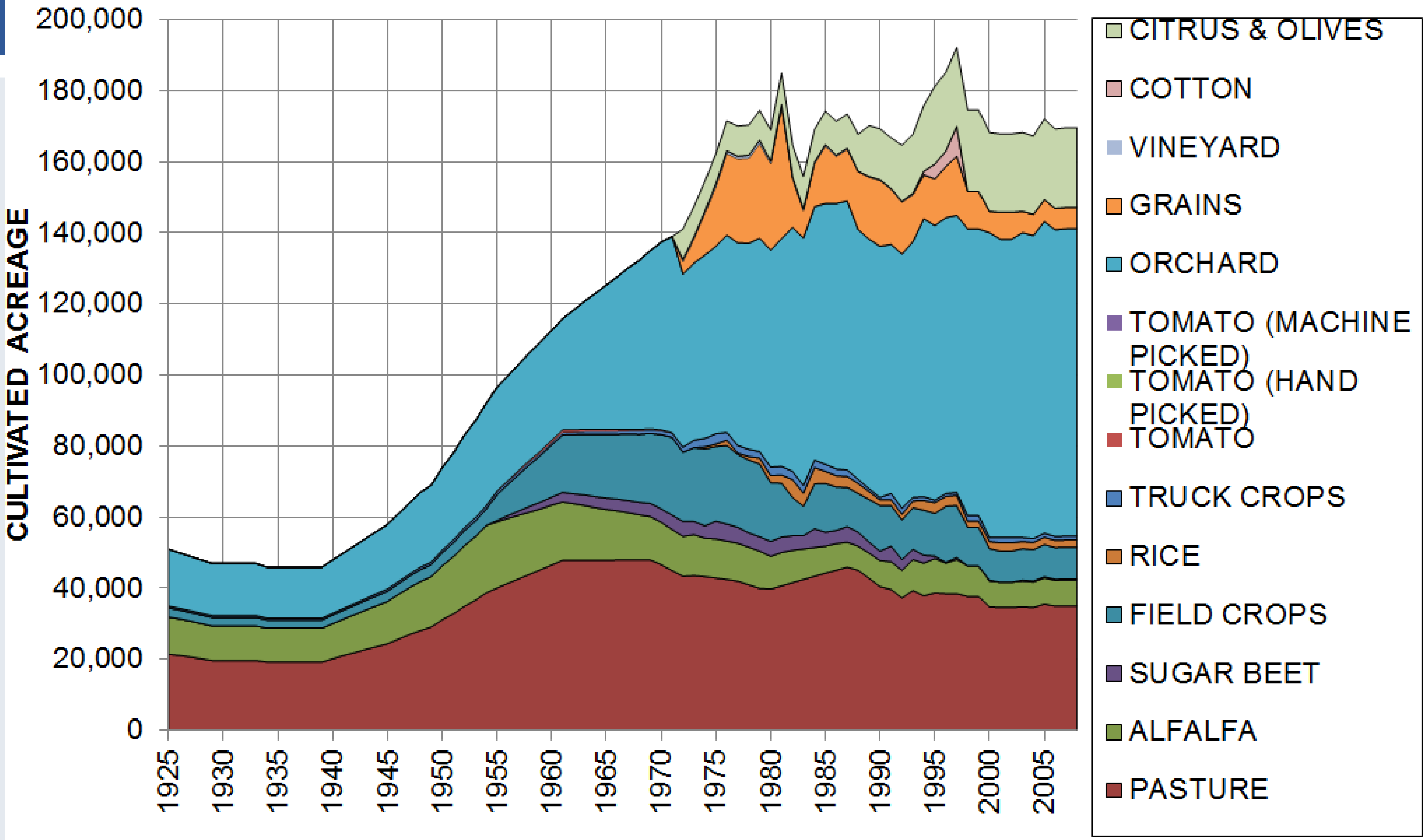
REGION 2 CROP ACREAGE



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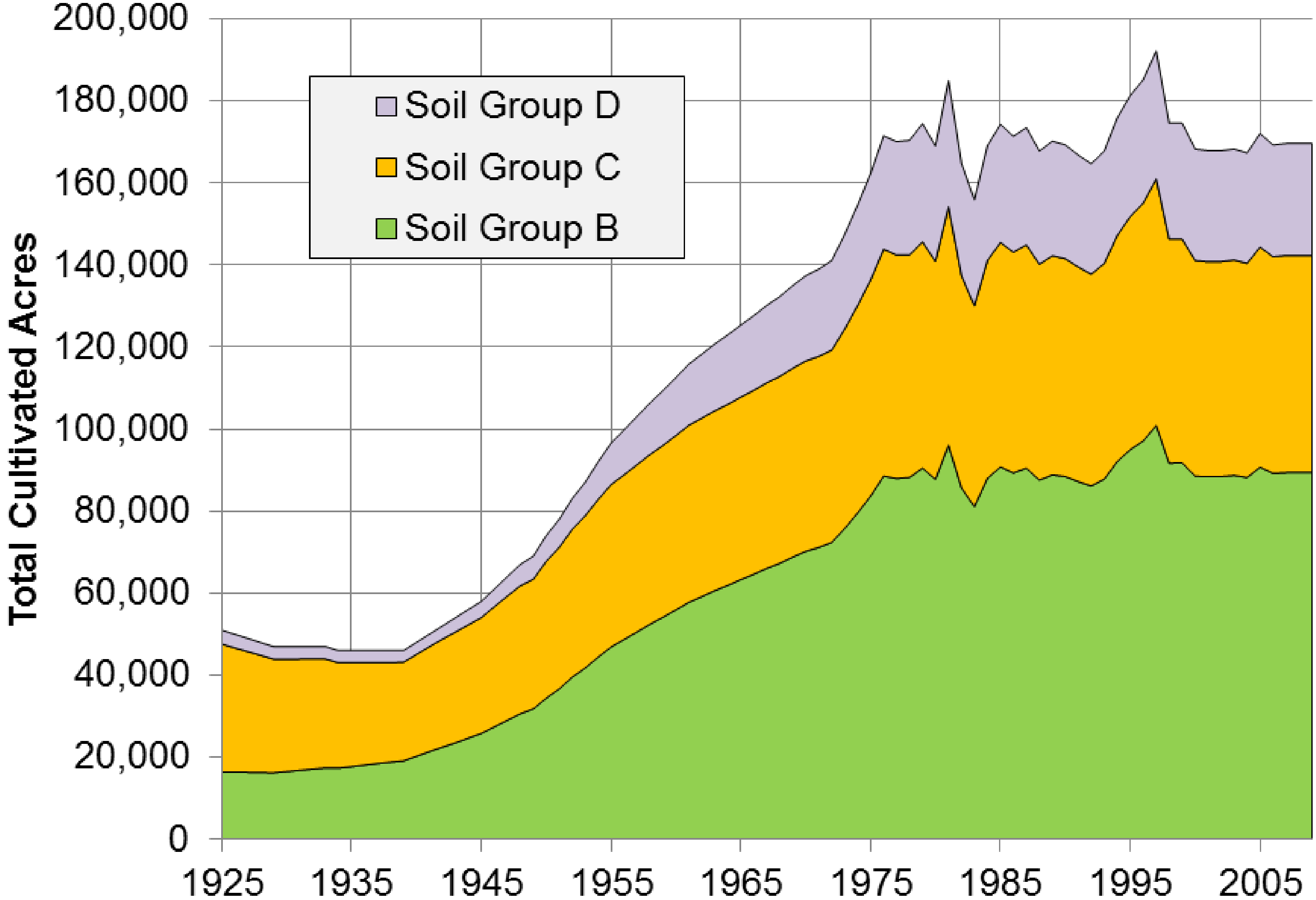
REGION 2 CROP ACREAGE BY SOIL TYPE



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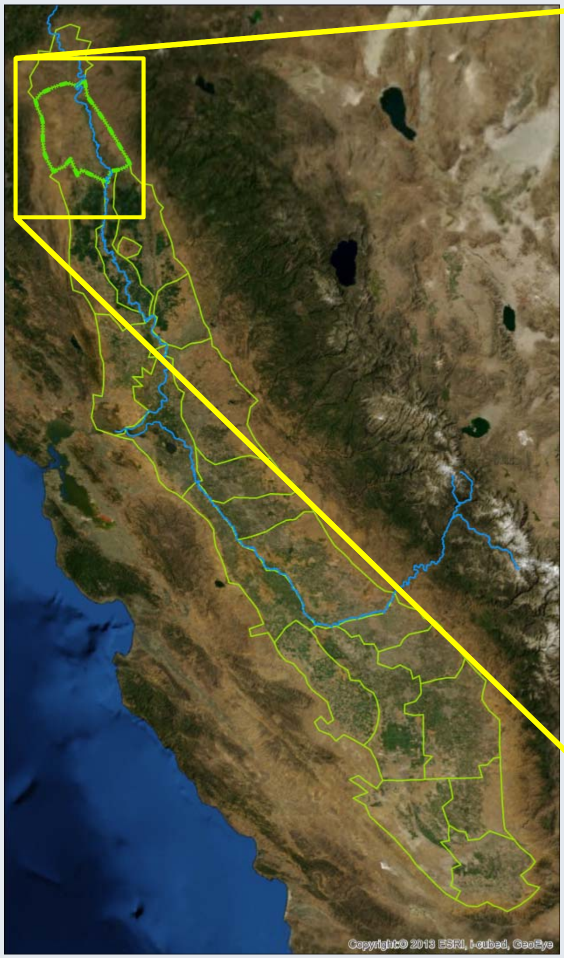
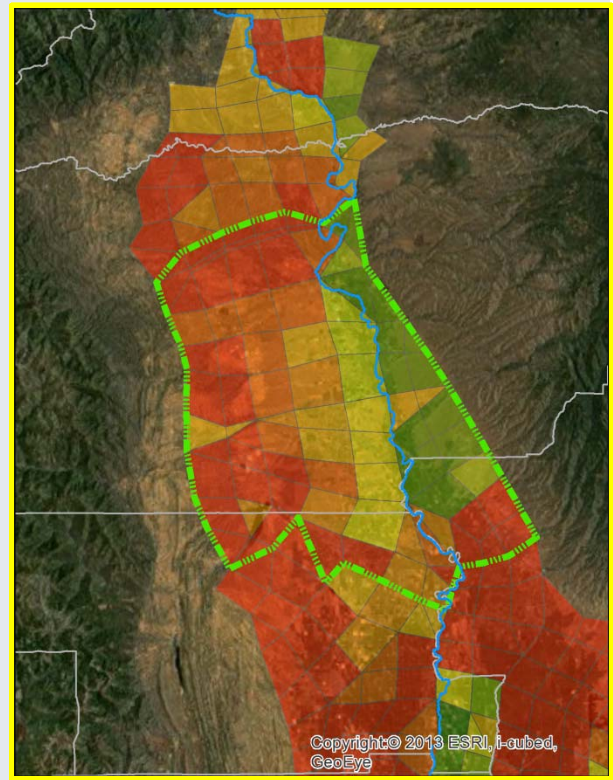
REGION 2 STAND-ALONE IDC MODEL



C2VSIM Subregion 2
DSA 10



C2VSIM Coarse Grid
Soil Class

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STAND-ALONE IDC MODEL

Same as C2VSIM	Different from C2VSIM
• Crop acreage by soil group and crop rooting depths • Monthly precipitation and evapotranspiration • Monthly minimum soil moisture by crop	• Specify additional physical soil hydraulic parameters (K_{sat}, λ, θ_{wp}) • Physically-based soil moisture routing from IDC-2015 • Crop efficiency <u>not</u> specified

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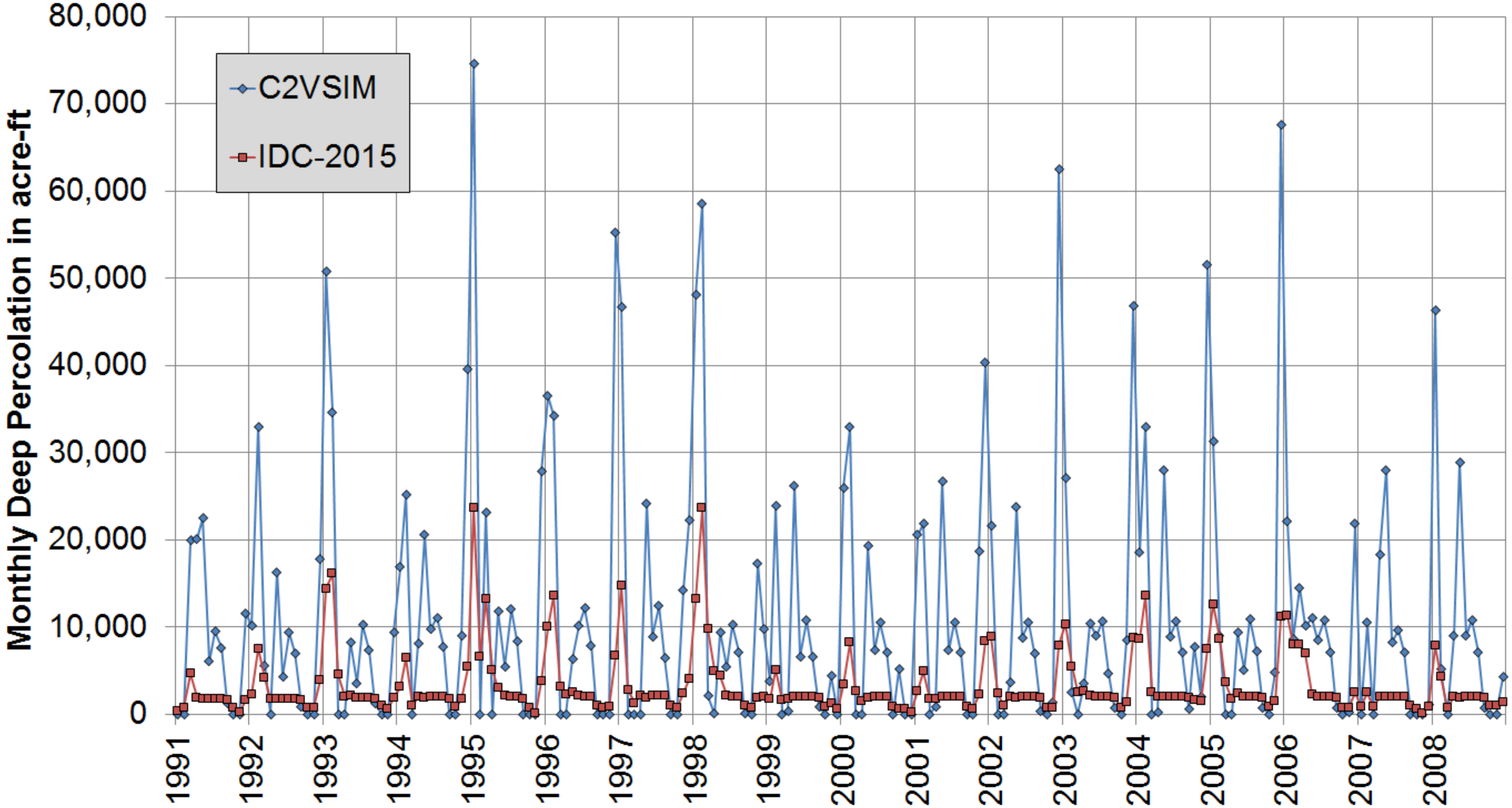
SIMULATED DEEP PERCOLATION SERIES



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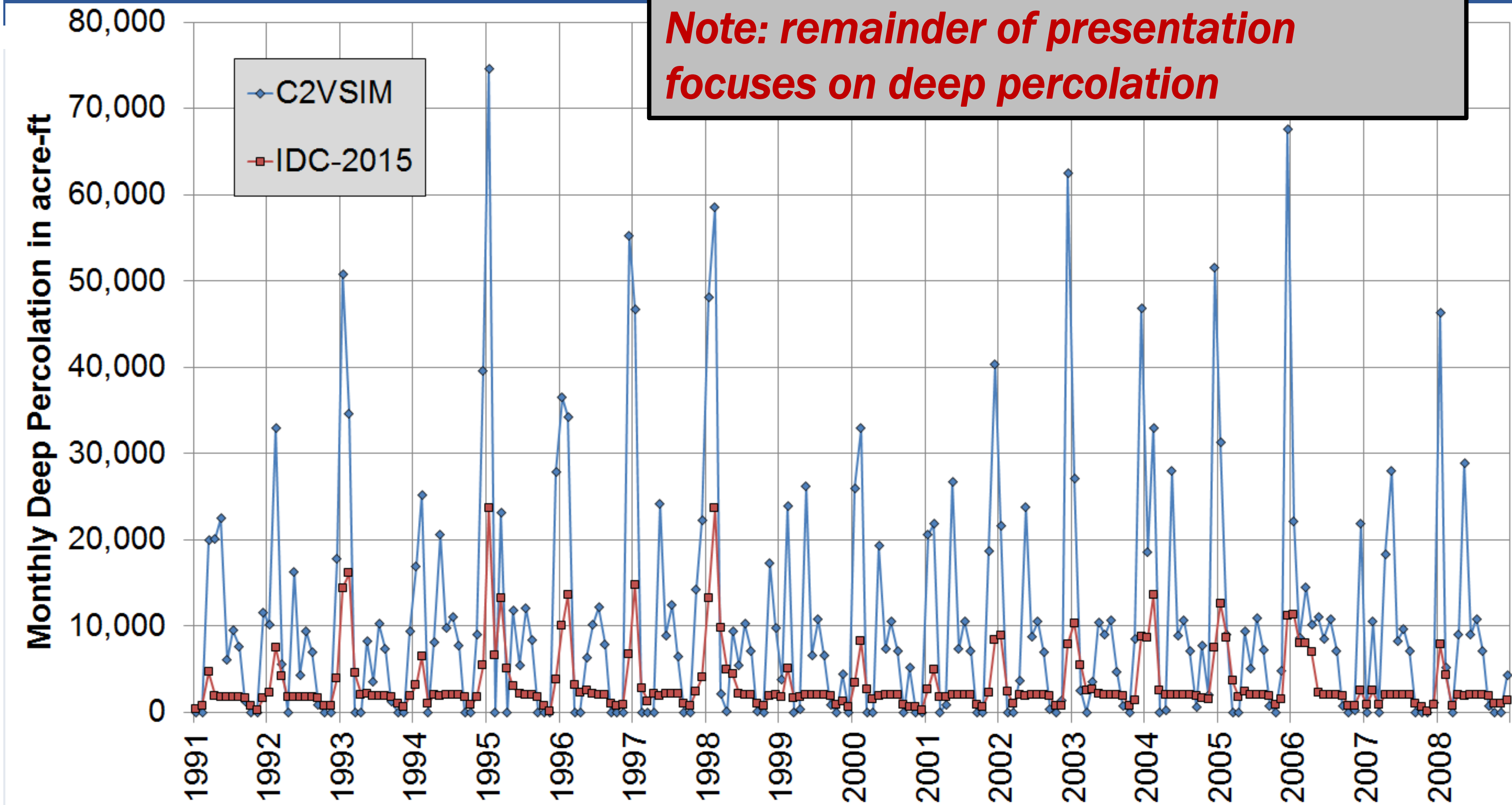
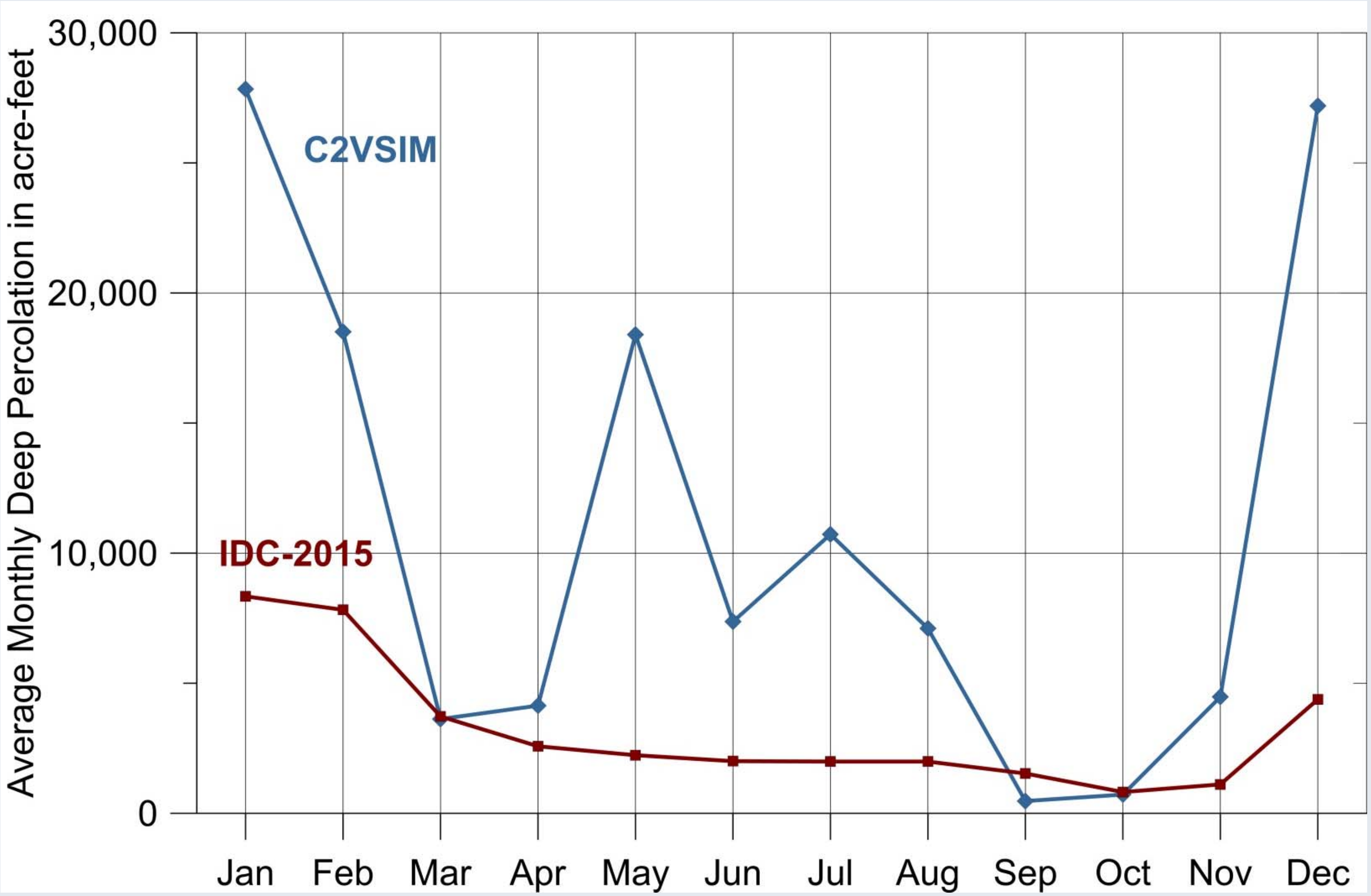
SIMULATED DEEP PERCOLATION SERIES

Note: remainder of presentation focuses on deep percolation



SIMULATED AVERAGE MONTHLY DEEP PERCOLATION



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PARAMETERS OF INTEREST

- Soil properties (for each soil group) — 9 total
  - Field capacity, (θ_{fc})
  - Pore size distribution index, (λ)
  - Saturated (vertical) hydraulic conductivity, (K_{sat}), ft/mo

- Crop rooting depths (ft) — 3 total
  - Pasture (rdPA)
  - Orchard (rdOR)
  - Citrus/Olive (rdSO)

- Irrigation practices — 3 total
  - Minimum soil moisture ($f\theta_{min}$), PA
  - Minimum soil moisture ($f\theta_{min}$), OR
  - Minimum soil moisture ($f\theta_{min}$), SO

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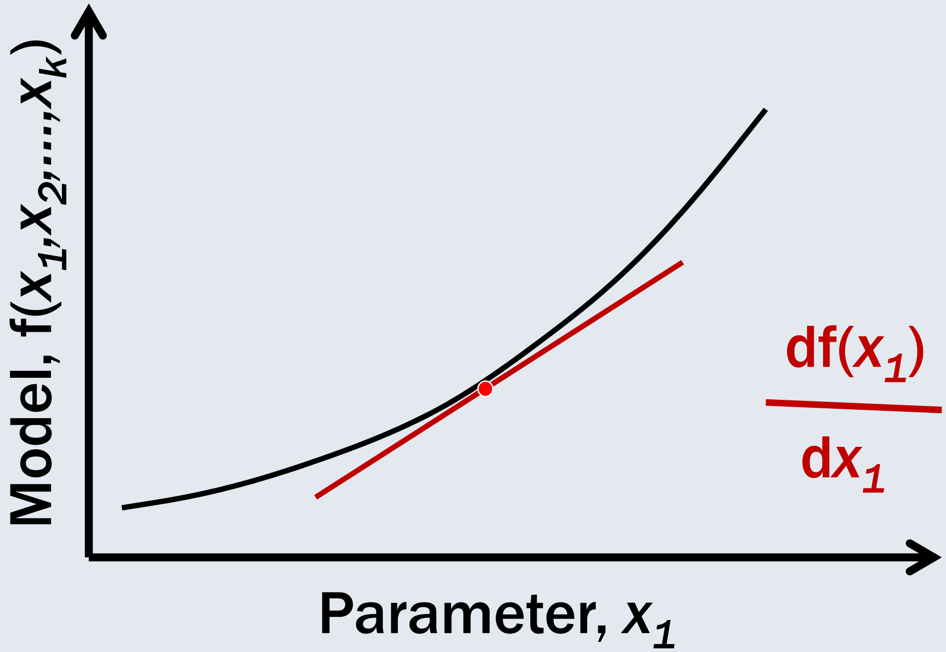
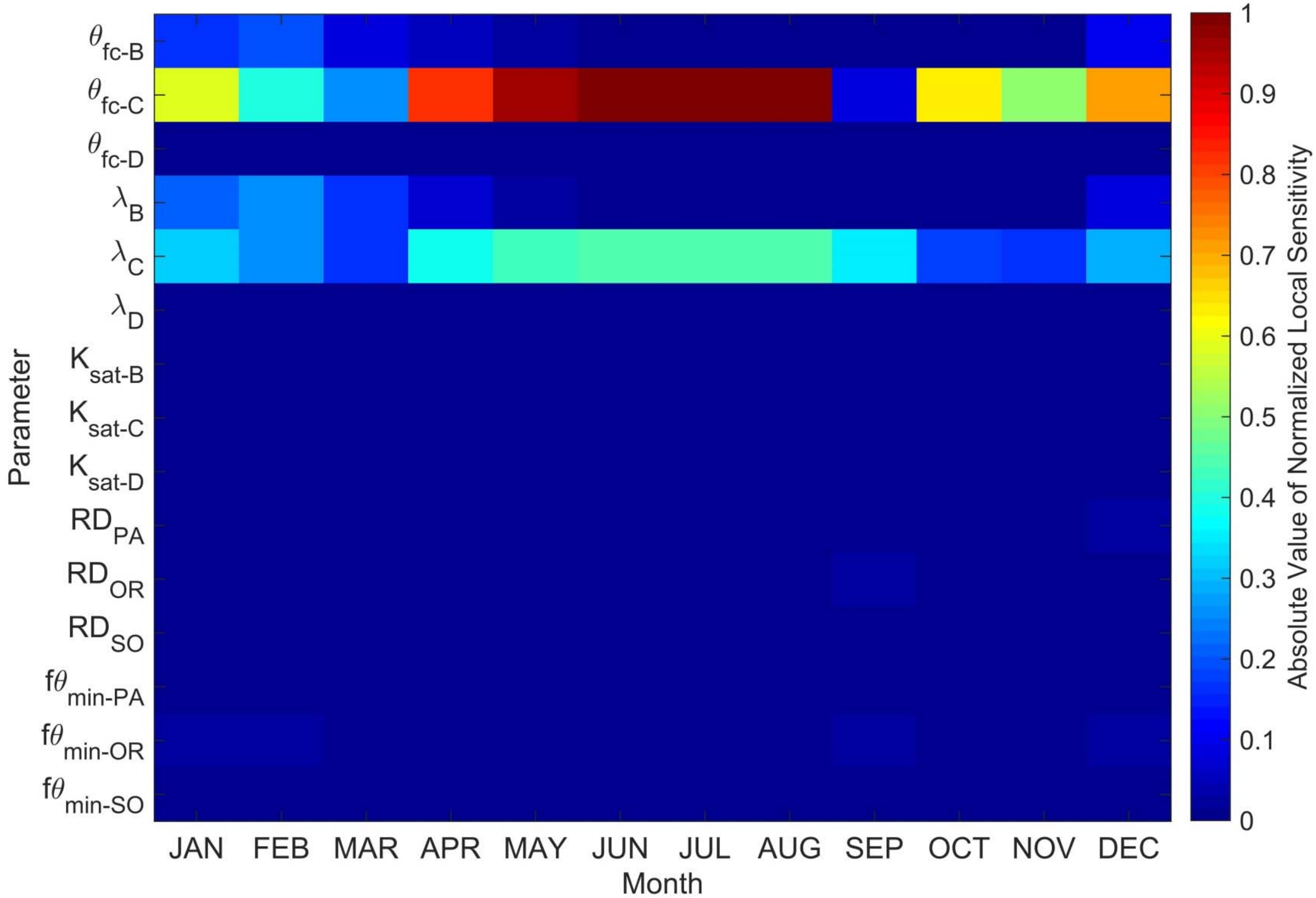
LOCAL SENSITIVITY ANALYSIS

$$s_i^{loc} = \frac{y_i - y_i^b}{x_i - x_i^b}$$



ABSOLUTE VALUE OF SENSITIVITY



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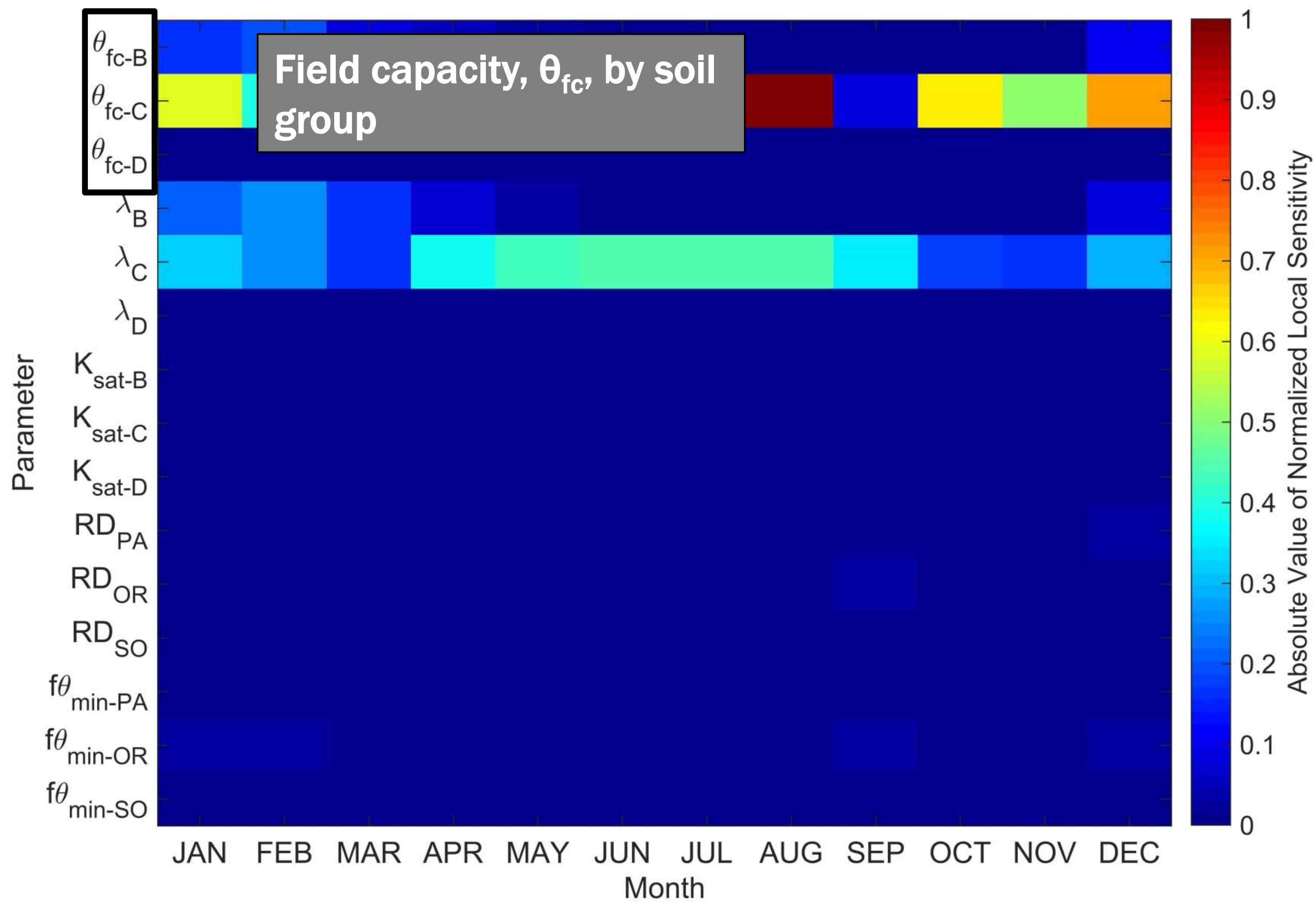

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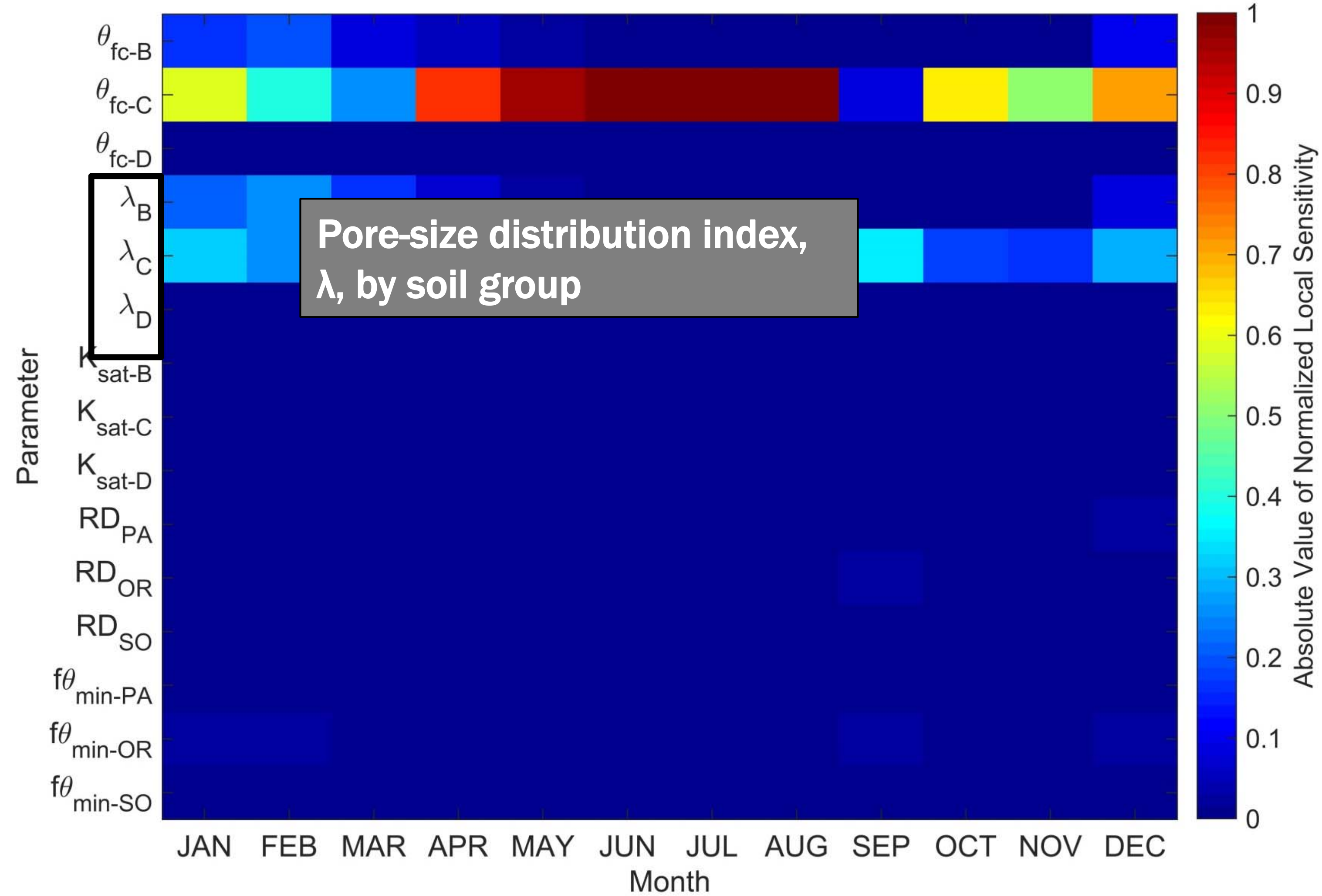
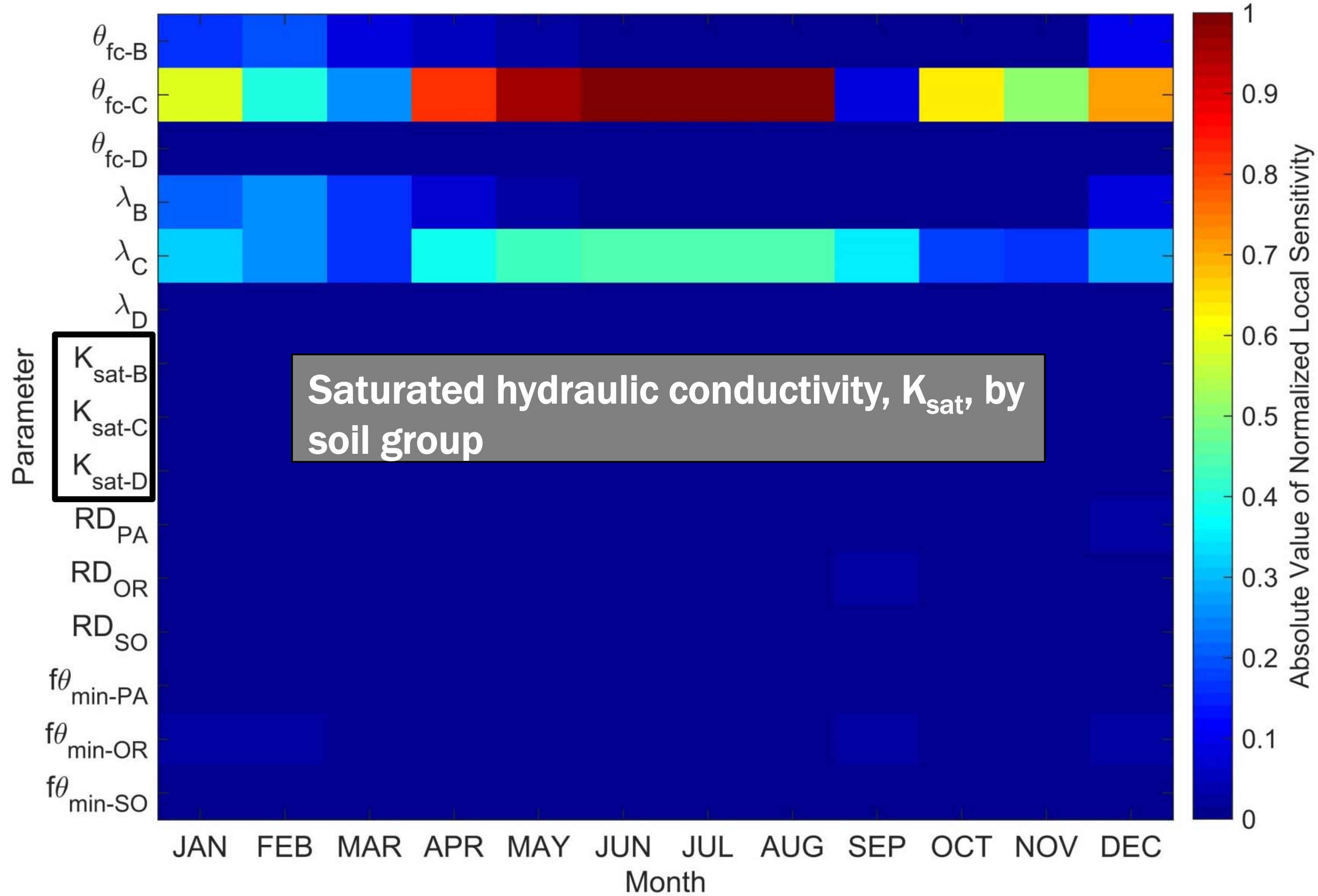


ABSOLUTE VALUE OF SENSITIVITY



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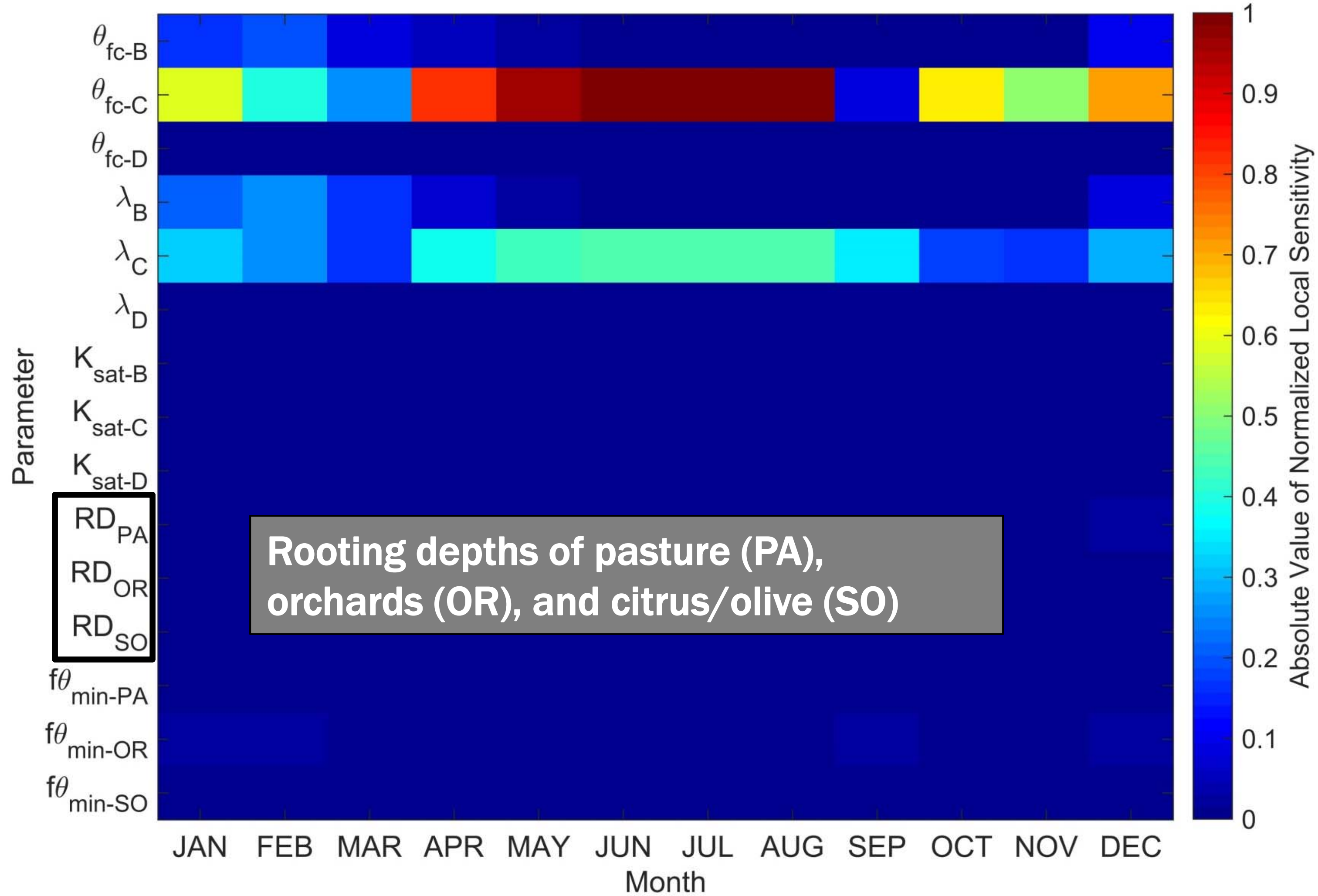

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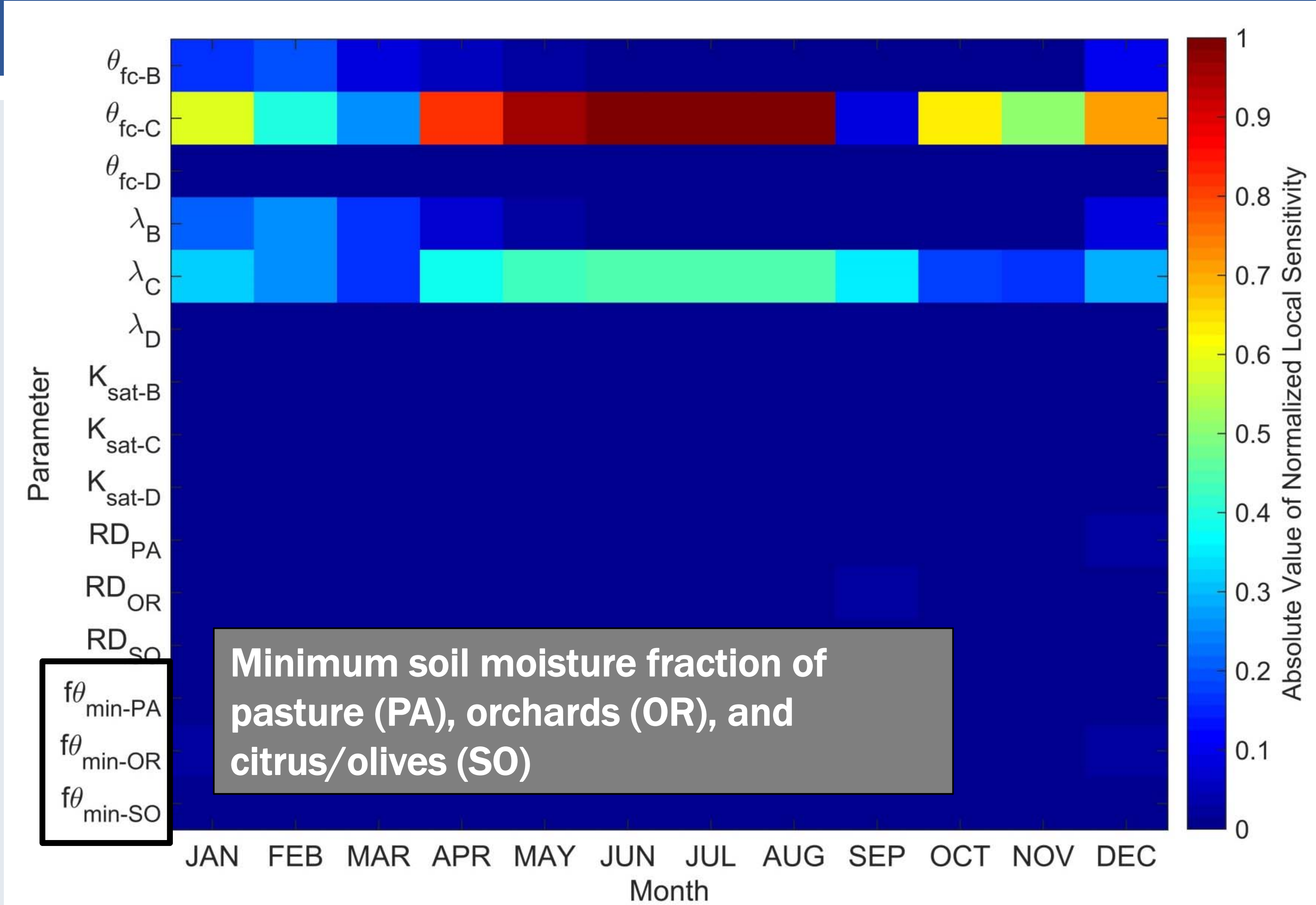

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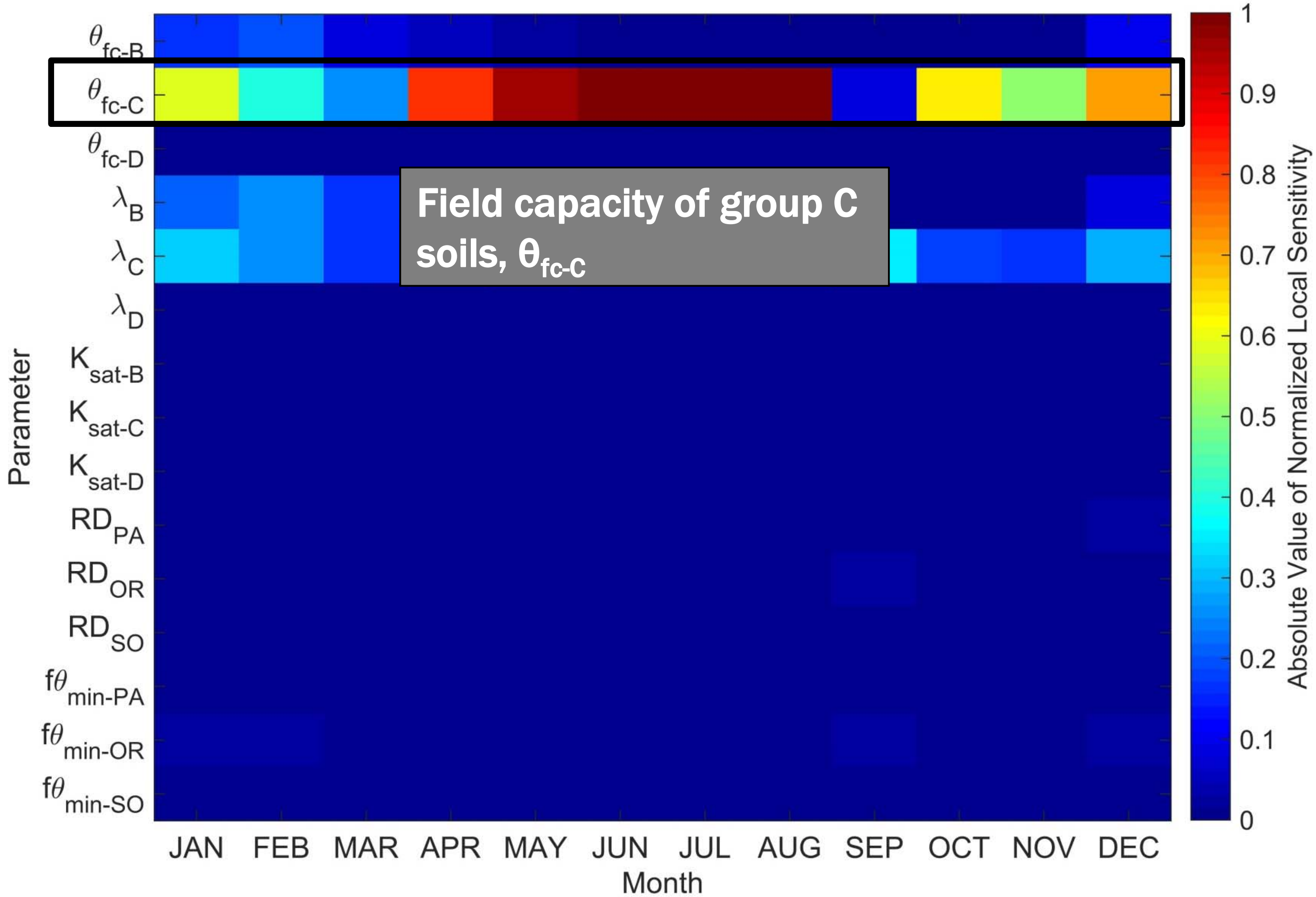
FIELD CAPACITY



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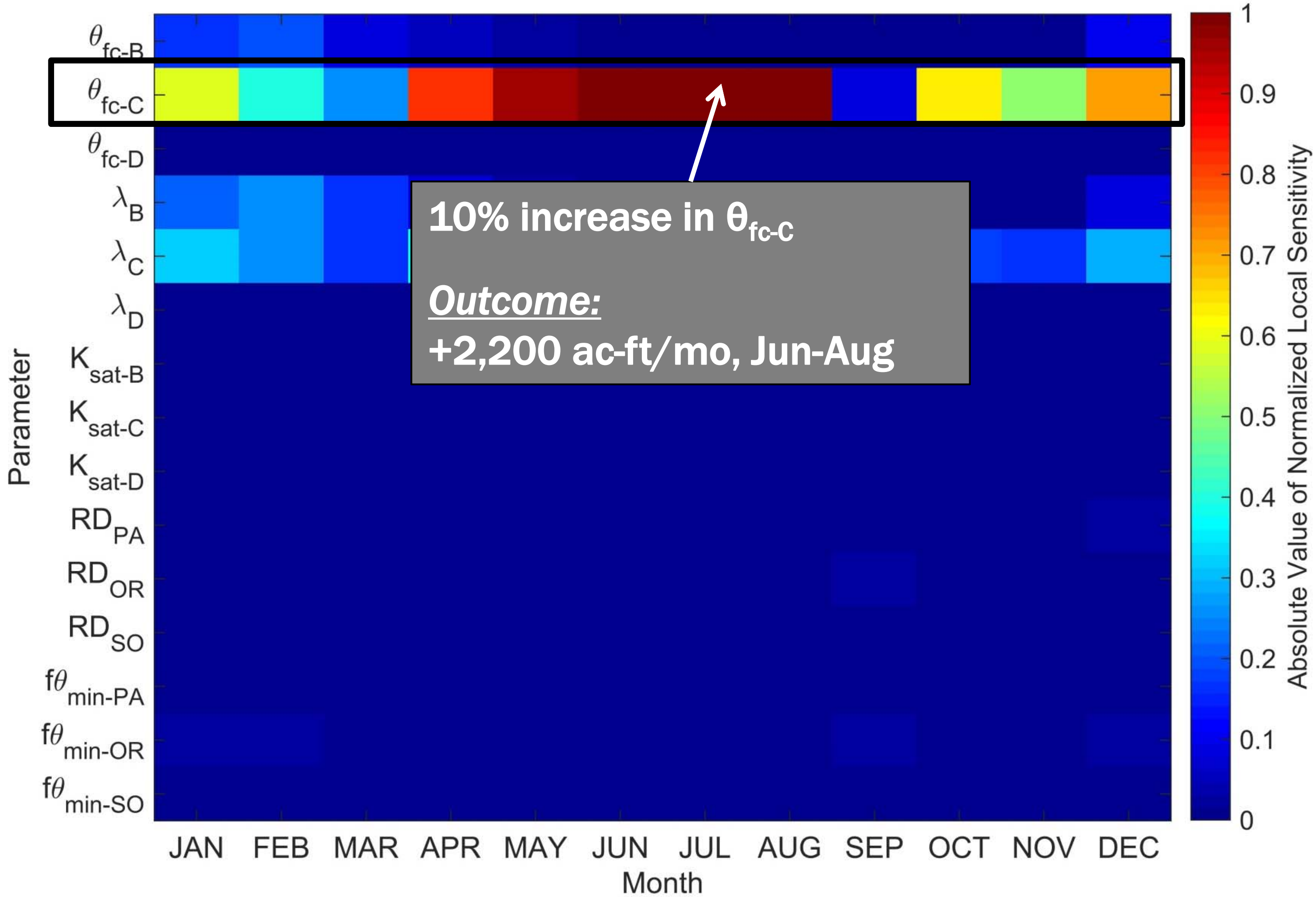
FIELD CAPACITY



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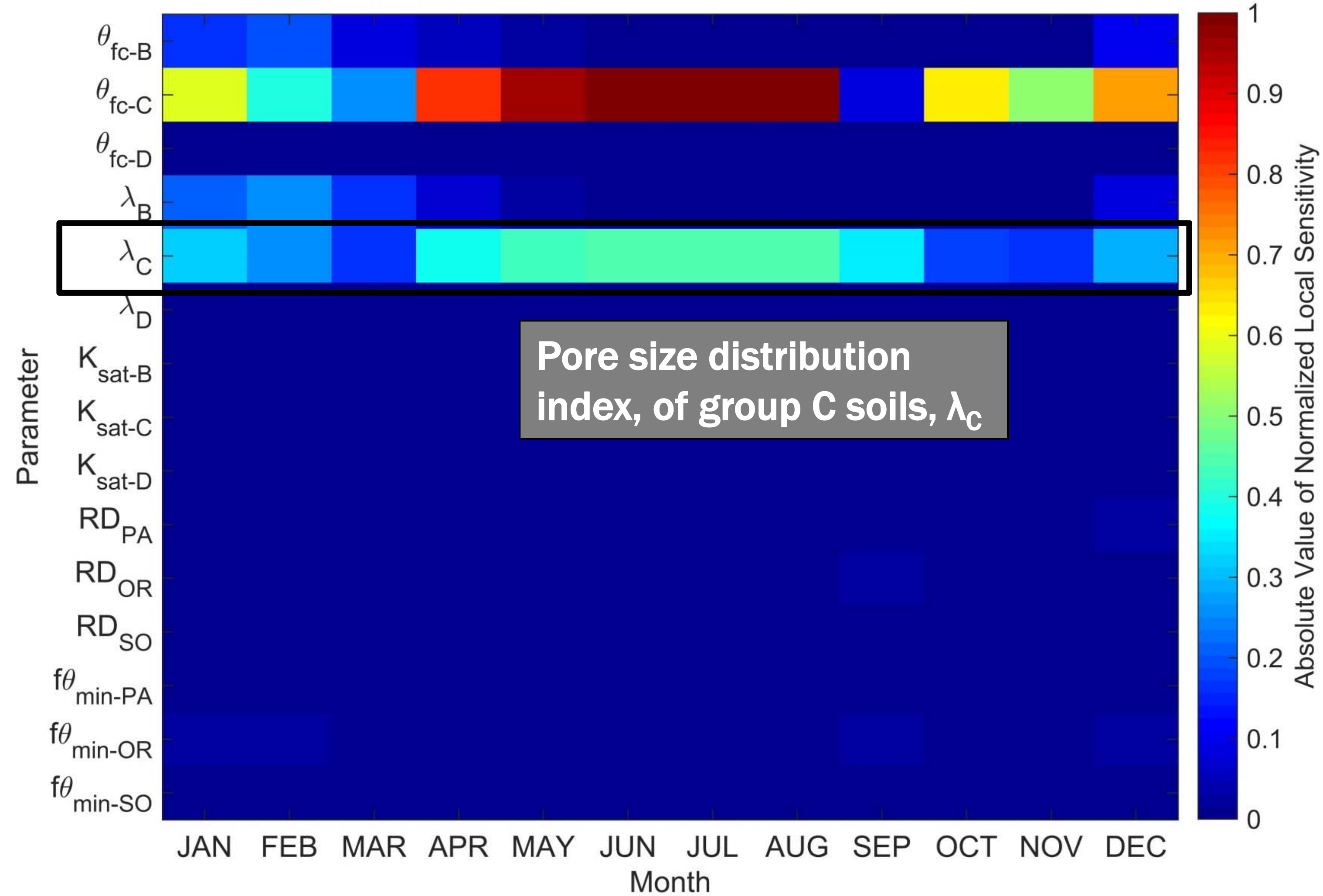
PORE-SIZE DISTRIBUTION



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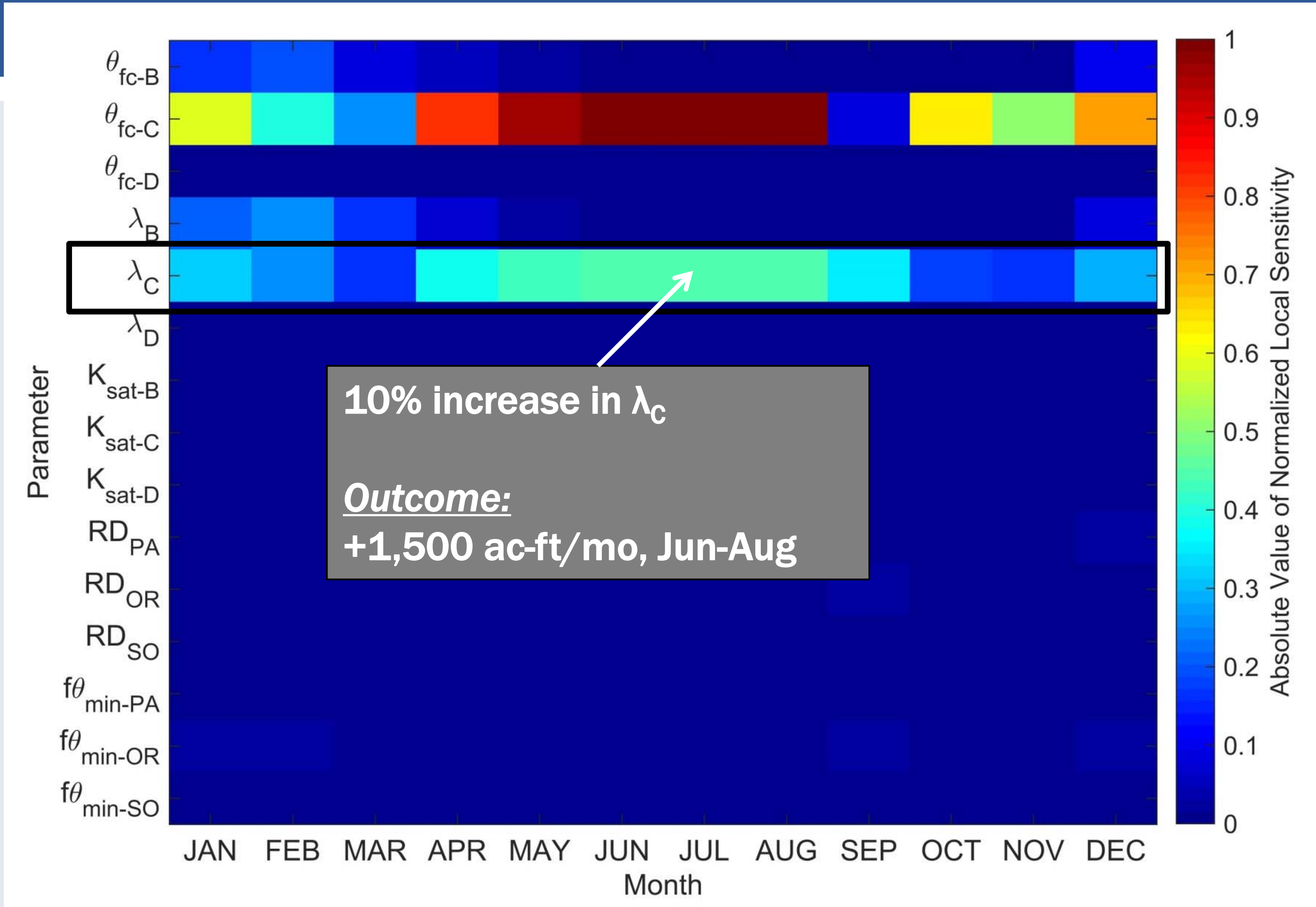

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GLOBAL SENSITIVITY ANALYSIS

<u>First-order sensitivity index (aka "FOSI")</u>

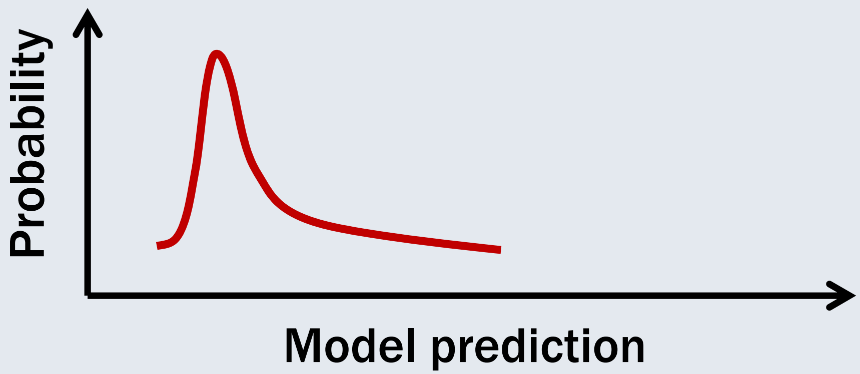
$$FOSI_i = \frac{D_i}{D}$$

Prediction variance due to x_i

Total prediction variance

$$D_i = \int f(\mathbf{x}) f(x_i, \mathbf{z})\, d\mathbf{x}\, d\mathbf{z} - f_0^2$$

Estimate by Monte-Carlo integration (Sobol, 2001)



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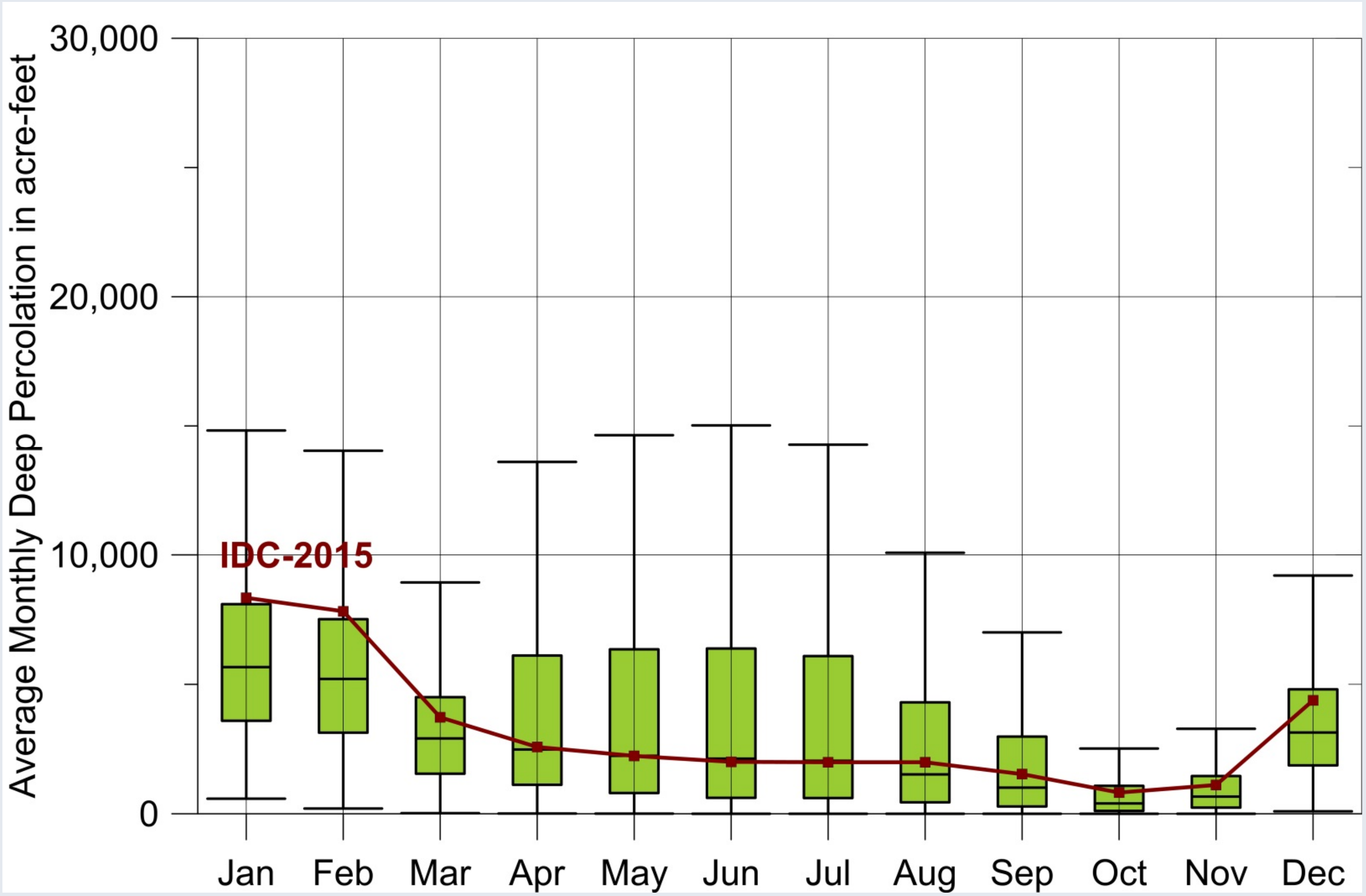
EFFECT OF PARAMETER UNCERTAINTY



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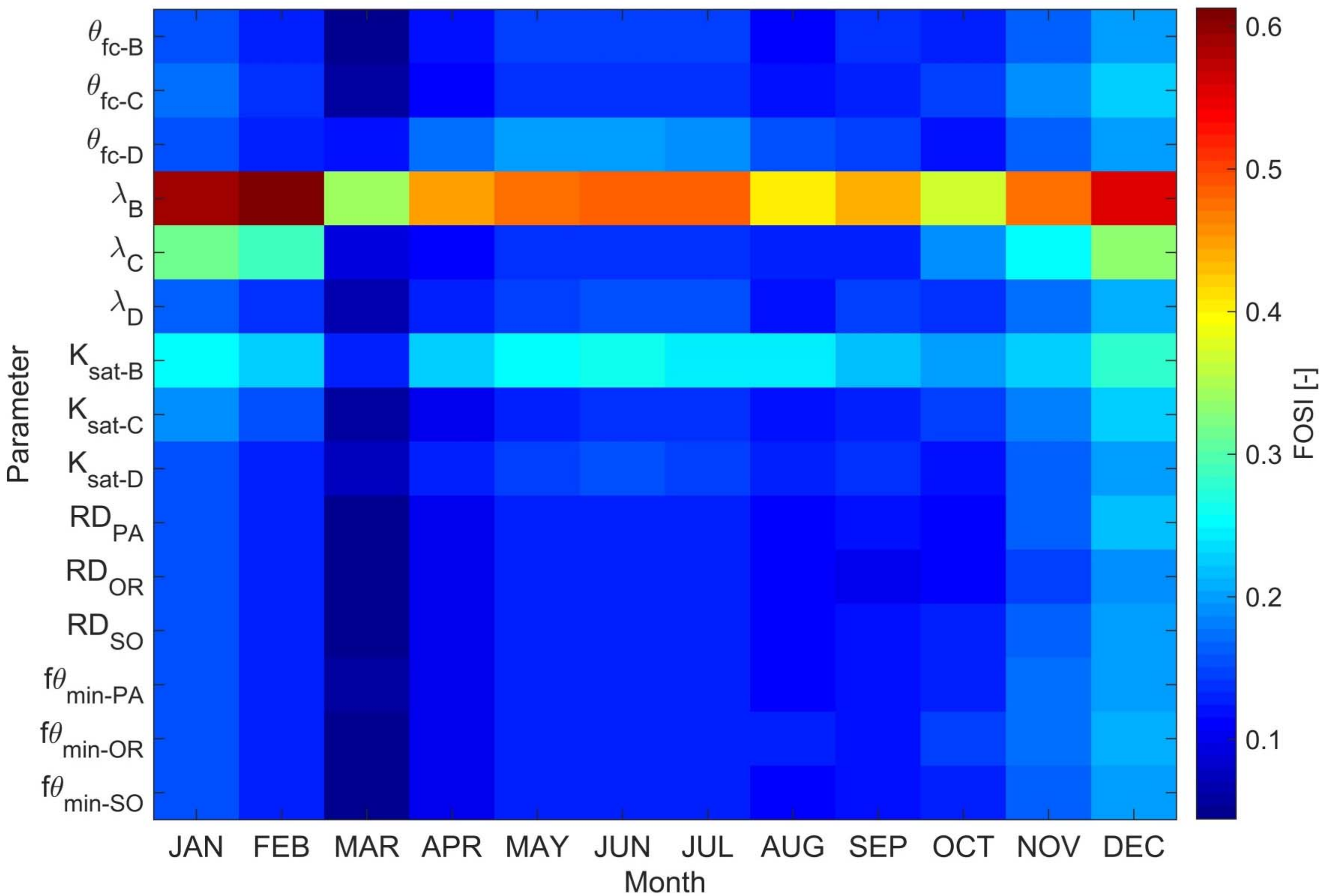
RESULTS: GLOBAL SENSITIVITY ANALYSIS



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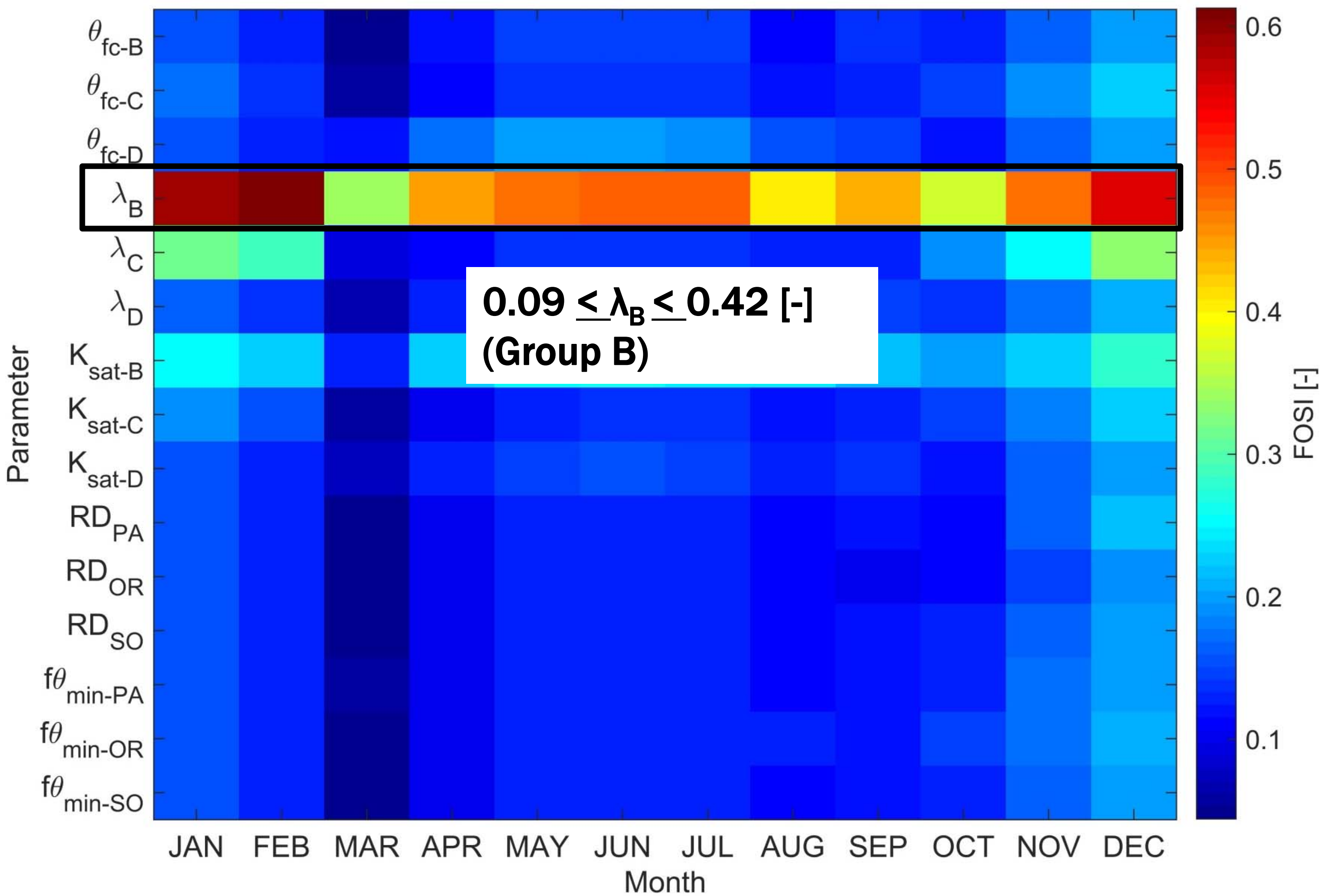
PORE-SIZE DISTRIBUTION, GROUP B SOILS



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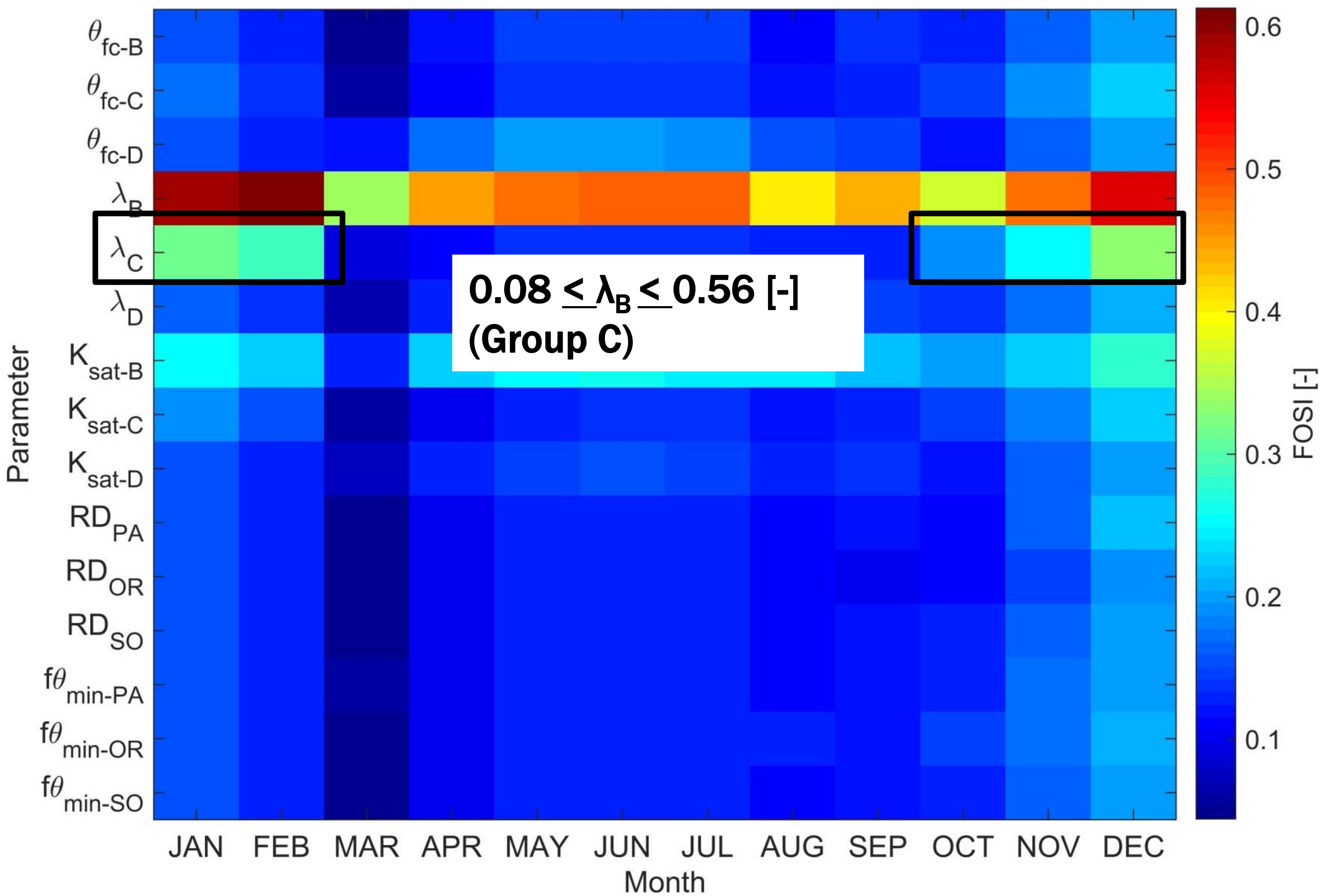
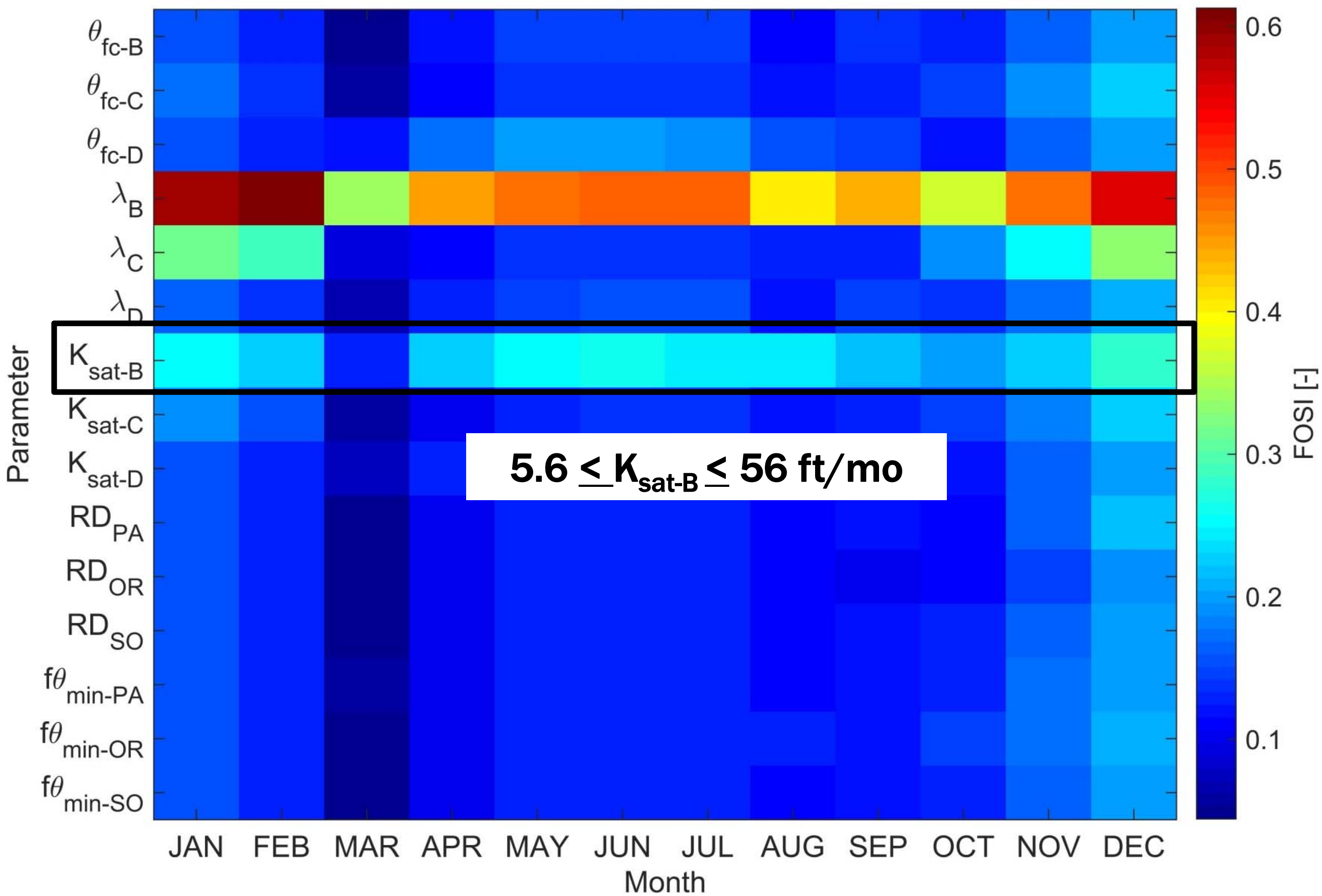
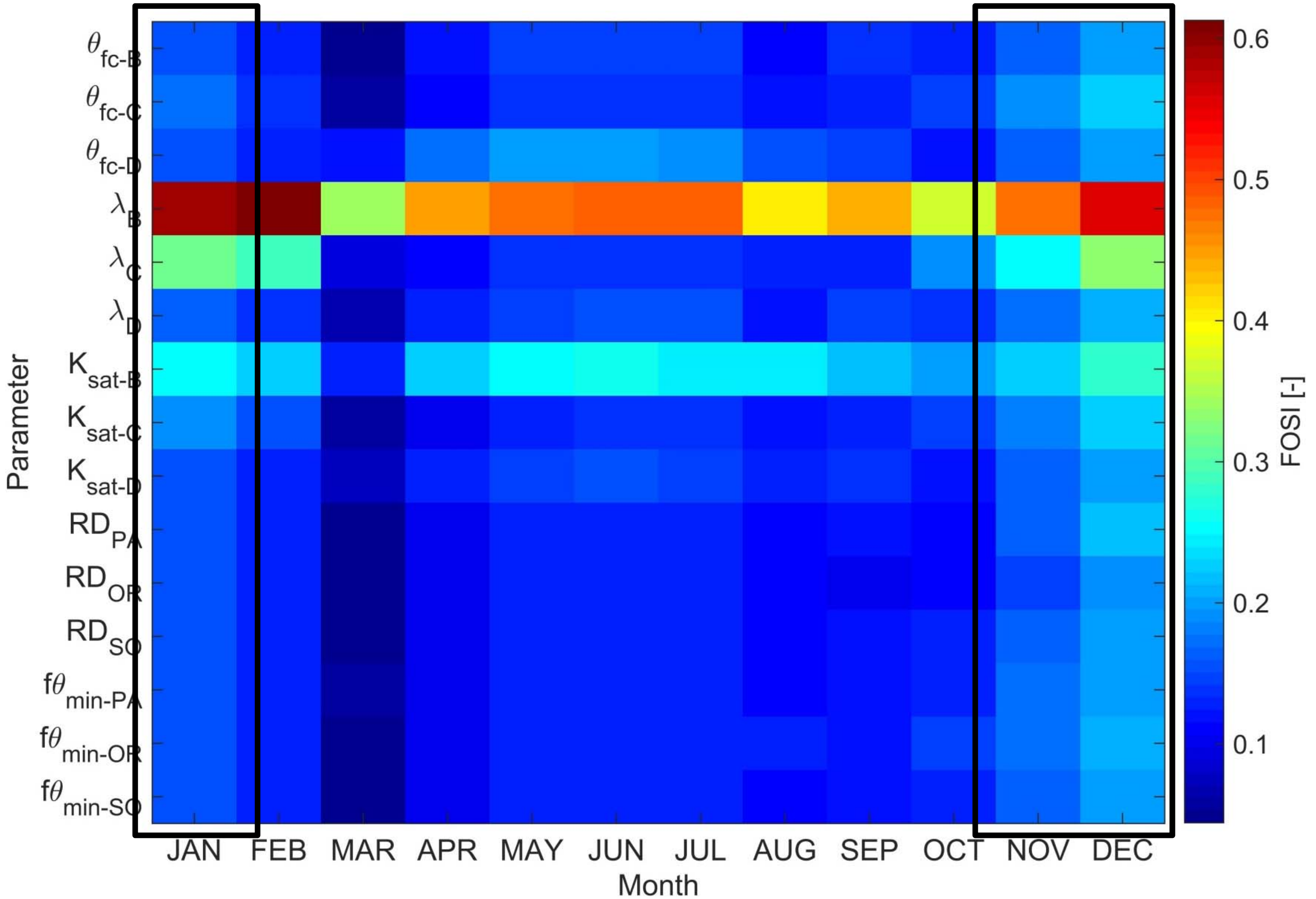
PORE-SIZE DISTRIBUTION, GROUP C SOILS



HYDRAULIC CONDUCTIVITY, GROUP B SOILS



SEASONALITY



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LOCAL VS GLOBAL SA RESULTS

Local	Global
• Field capacity $\theta_{fc\text{-}C}$ and pore-size distribution index λ_C	• Pore-size distribution index λ_B, λ_C and hydraulic conductivity $K_{sat\text{-}B}$
• Most parameter sensitivity during growing season	• Parameter sensitivity during growing season and winter

Results emphasize importance of soil hydraulic properties – especially λ – to both monthly DP and variance of DP

CONCLUDING THOUGHTS

- Deep percolation/groundwater pumping: critical groundwater budget components
- Advantages and considerations for using land-surface model
- Role of sensitivity analysis: where to focus efforts?

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QUESTIONS?

Colin P. Kikuchi

Montgomery & Associates

1550 East Prince Road, Tucson, AZ, 85719

(520)-881-4912

ckikuchi@elmontgomery.com

EXTRA SLIDES

GLOBAL SENSITIVITY ANALYSIS: PARAMETERS OF INTEREST

- Soil properties (for each soil group)
  - Field capacity, (θ_{fc})
  - Pore size distribution index, (λ)
  - Saturated (vertical) hydraulic conductivity, (K_{sat}), ft/mo

B	C	D
0.20 – 0.40	0.19 - 0.32	0.25 -0 .47
0.09 - 0.42	0.08 – 0.56	0.04 – 0.41
5.6 – 56	3.2 - 32	1.8 - 18

- Crop rooting depths (ft)
  - Pasture (rdPA)
  - Orchard (rdOR)
  - Citrus/Olive (rdSO)

All soil groups
1.5 – 2.5
5.25 – 6.75
3.5 – 4.5

- Irrigation practices
  - Minimum soil moisture ($f\theta_{min}$), PA
  - Minimum soil moisture ($f\theta_{min}$), OR
  - Minimum soil moisture ($f\theta_{min}$), SO

(+/- ft^3/ft^3)
0.15
0.15
0.15

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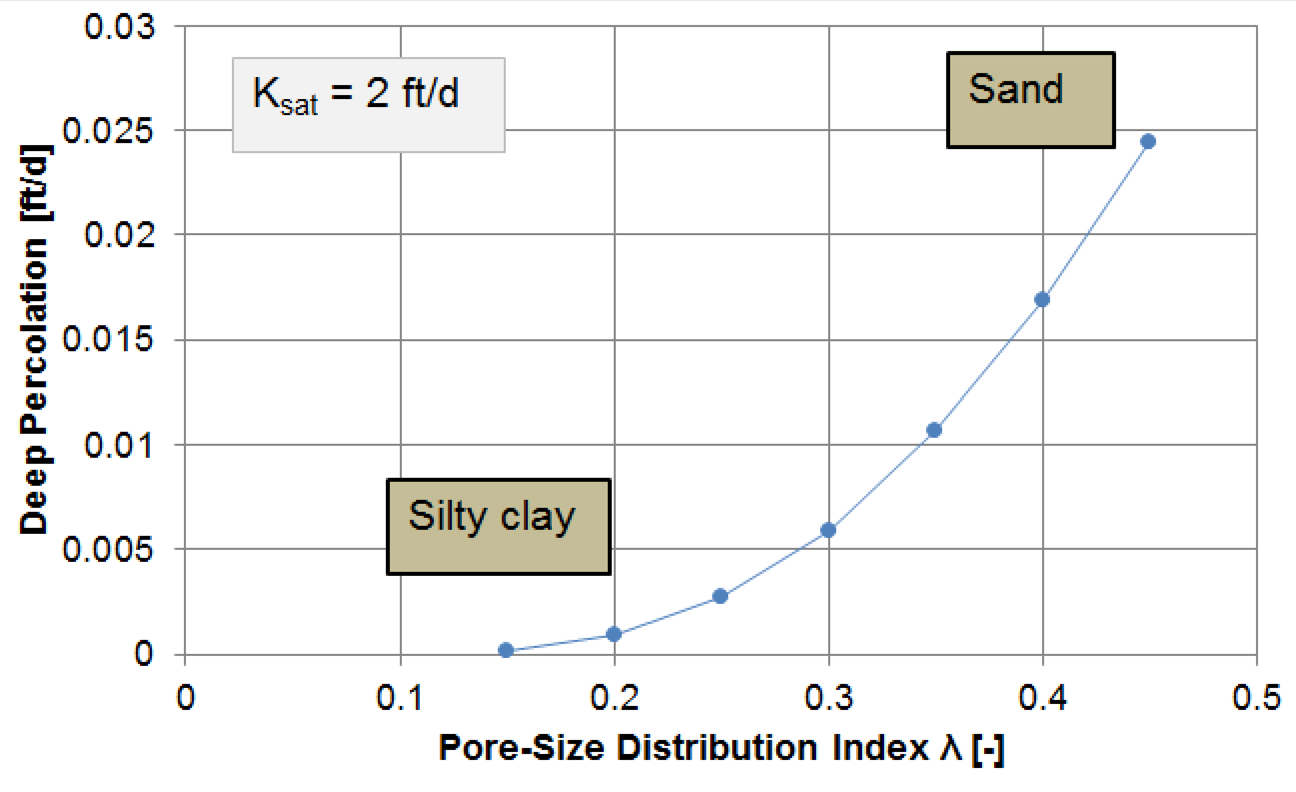
EXTRA – LAMBDA DETAIL

$$D^{t+1} = D_{rdc}^{t+1} + K_s \left(\frac{\theta^{t+1}}{\theta_T} \right)^{1/2} \left\{ 1 - \left[1 - \left(\frac{\theta^{t+1}}{\theta_T} \right)^{1/m} \right]^m \right\}^2$$

$m = \lambda / (\lambda + 1)$



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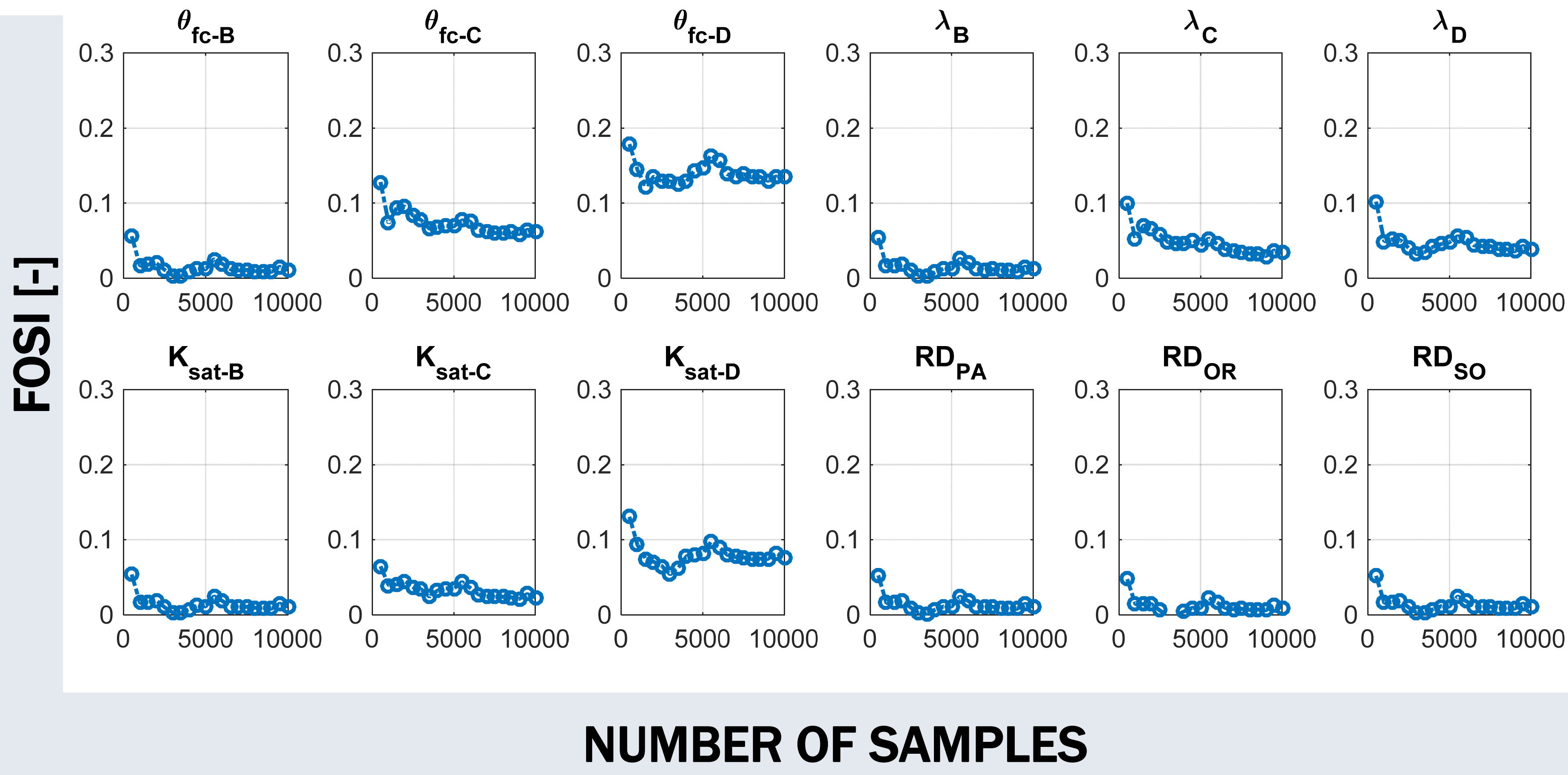
FOSI CONVERGENCE, JUNE



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