Uncertainties of Atrazine Leaching and Accumulation below Agricultural Lands under Future Climate Ensembles

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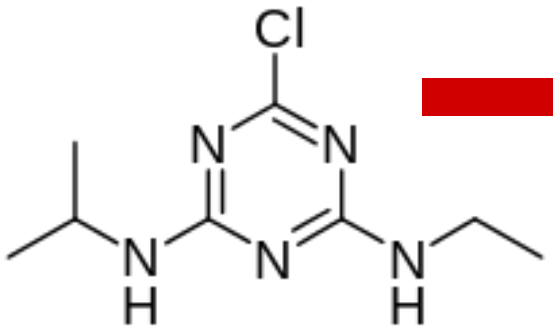
IN OUR GRIT, OUR GLORY™

Atrazine

An herbicide that does not occur naturally.



broadleaf weeds

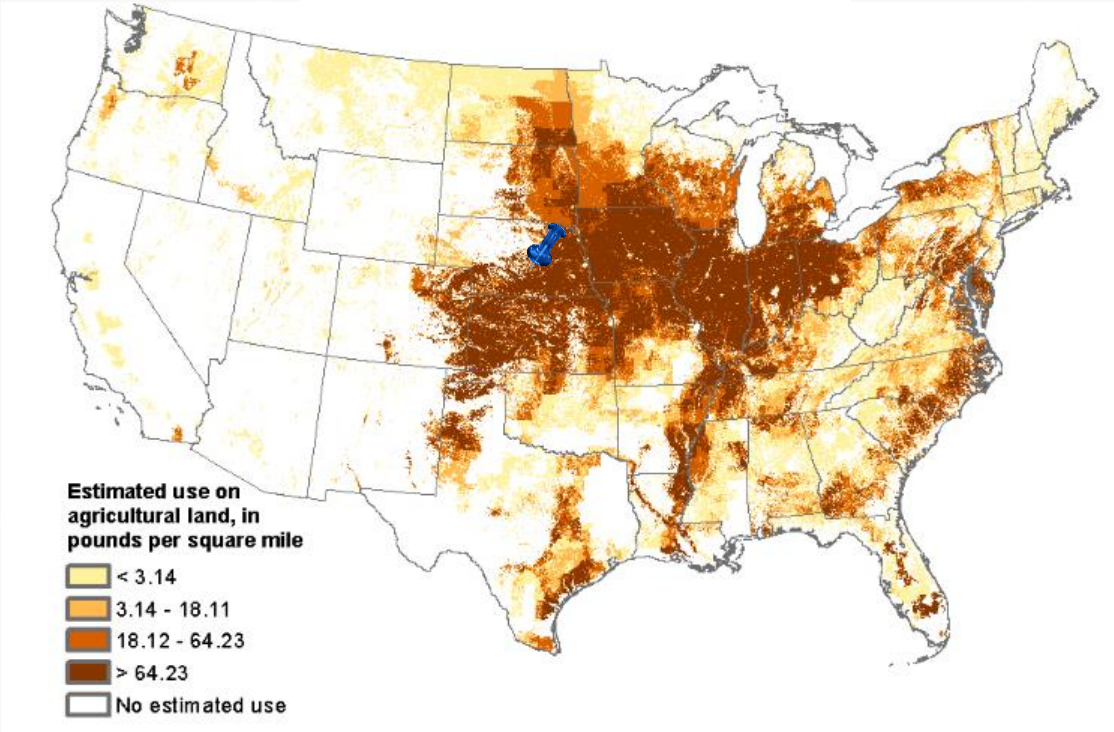
- Over 300 products containing atrazine

EPA Maximum Contaminant Level (MCL):
3 µg/L

- Commonly detected in groundwater
- **Concerns**
  - Higher rates of birth defects in baby's faces and skulls than mothers who are not in the area
  - Babies grow slower and had a smaller head circumference than babies whose mothers were not exposed to atrazine during pregnancy
  - Delayed period for women who drank atrazine contaminated water
  - Higher risk of end-stage kidney disease

Objective

Objective: Predicting the leaching and accumulation of atrazine in agricultural lands considering parameter uncertainties under future climate variability.

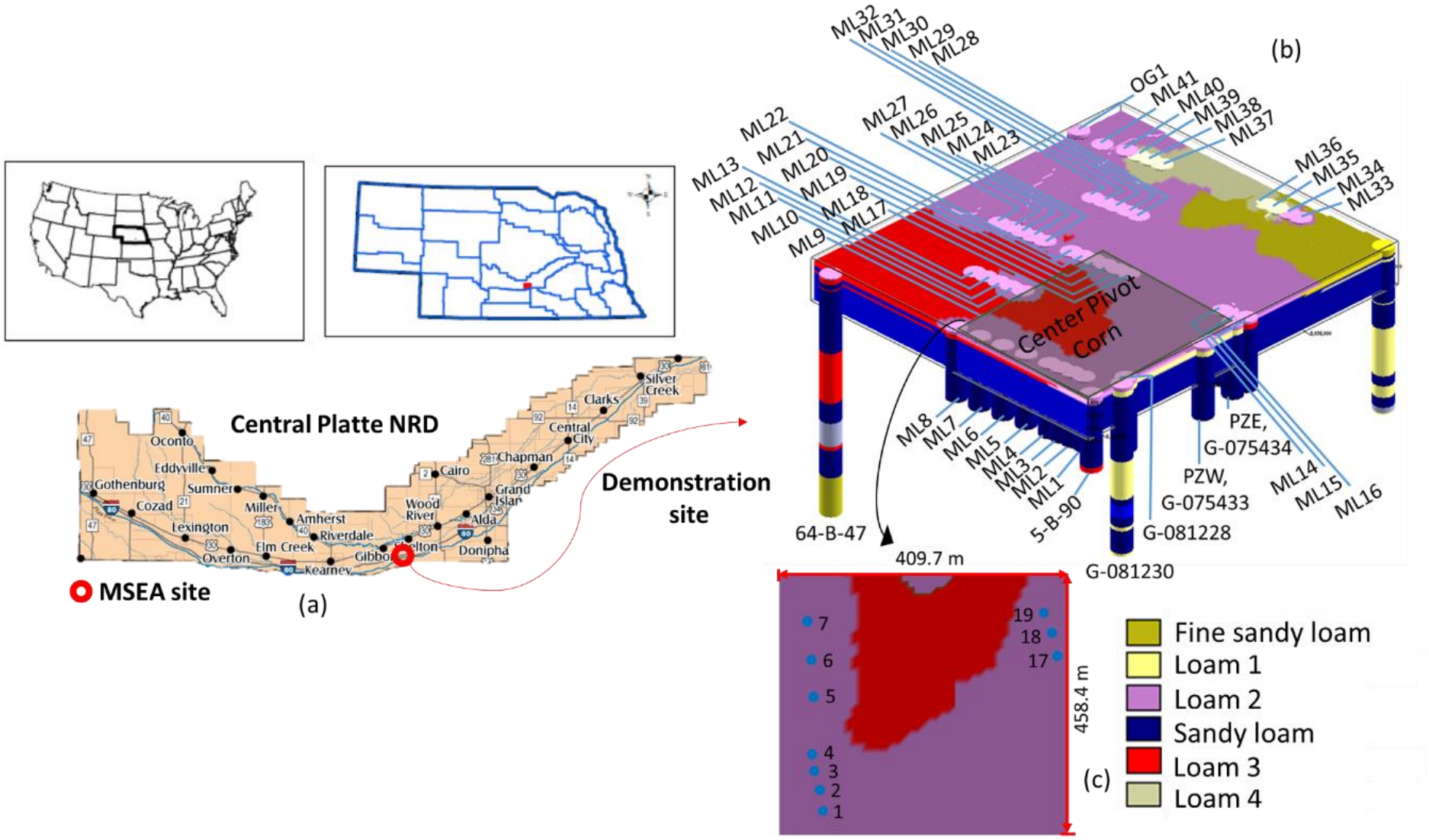


Estimated annual use of Atrazine (USGS, 2016)

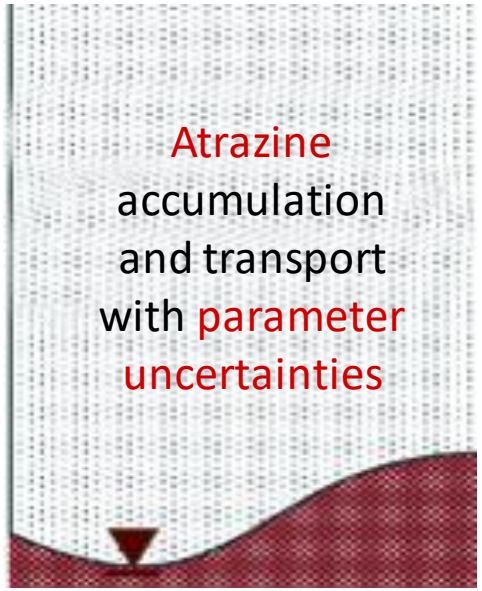
Nebraska Management System Evaluation Area (MSEA) site in Central NE

Shallow GWT
Sandy aquifer vadose zone
atrazine ≈ 1.57 µg/L

Field Site


Central Platte NRD
Demonstration site
MSEA site
(a)
(b)
(c)
Center Pivot Corn
64-B-47
409.7 m
458.4 m
G-081230
G-081228
PZW, G-075433
PZE, G-075434
5-B-90
Fine sandy loam
Loam 1
Loam 2
Sandy loam
Loam 3
Loam 4

Modeling Framework



Future Atmospheric Data (P, ET)

20 Downscaled LOCA CMIP 5 Climate and Hydrology Projections

Future P, ET, Temp

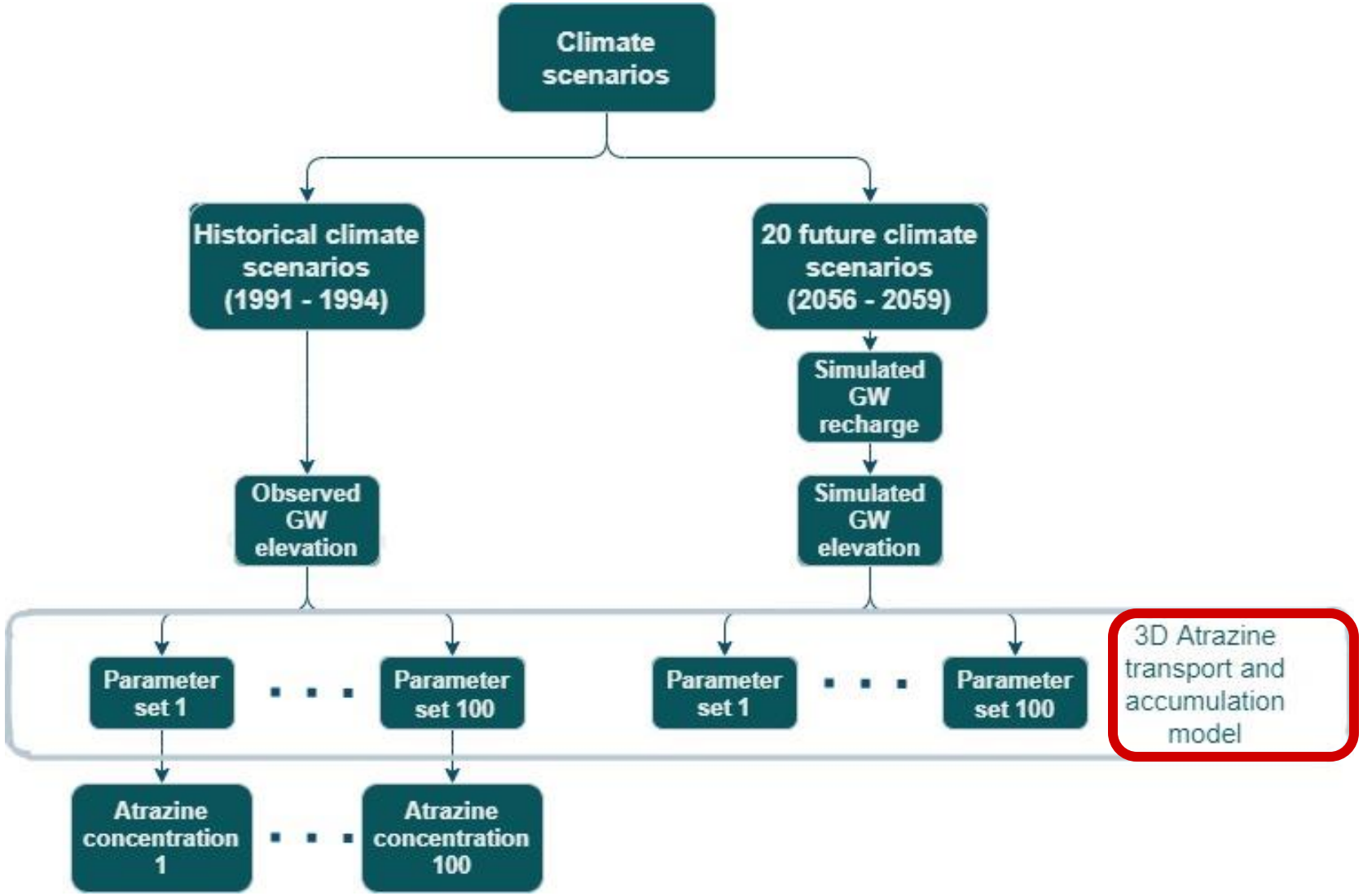
Groundwater Recharge Modeling

Future GR

Groundwater Model

Future Groundwater Elevation

Overall Modeling Framework



Atrazine Transport Model Setup

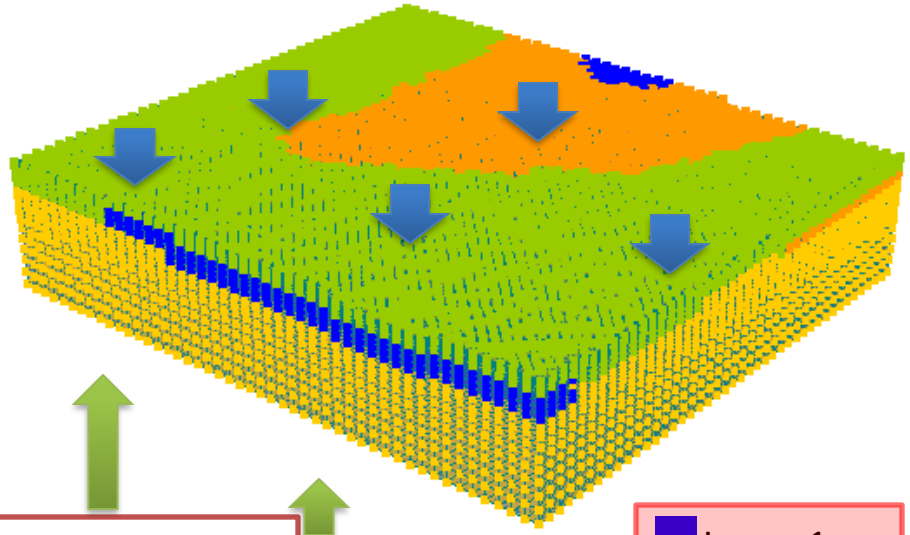
Soil lithology model imported into Hydrus 3D, a finite element based model (Version 3.01.1460) to simulate water flow and solute transport

Precipitation + Irrigation - Evapotranspiration

Atrazine application+ atrazine (in irrigation water)

Water Flow

Root Water uptake



Solute transport

Atrazine

Sorption + degradation

ere collected from the field and soil categories were defined based on soil particle analysis

Variable Pressure Head

Constant atrazine Conc. in GW

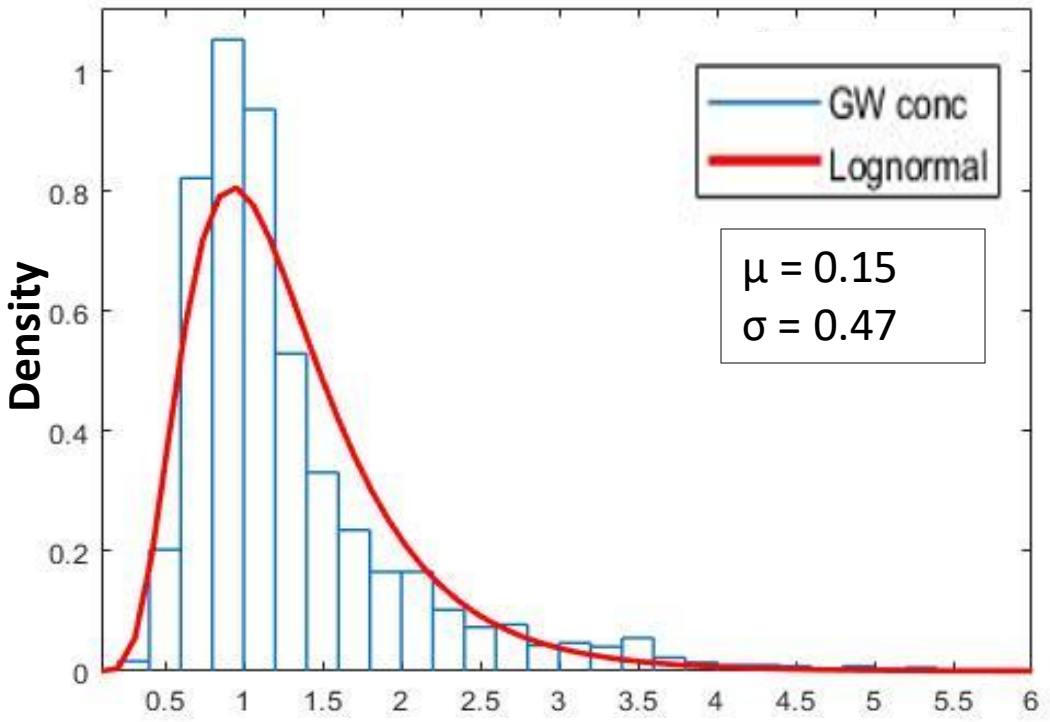
Loam 1
Loam 2
Sandy loam
Loam 3

(Akbariyeh et al. 2018).

Uncertainty of Input Variables

- **Atrazine concentration in the groundwater**
- Atrazine application rate
- Atrazine degradation rate
- Sorption coefficients

- Data sources: NE Clearing House Database (year 1991-1996)
- Data points: 2,444
- Distribution pattern: Lognormal
  - $\mu = 0.15$
  - $\sigma = 0.47$

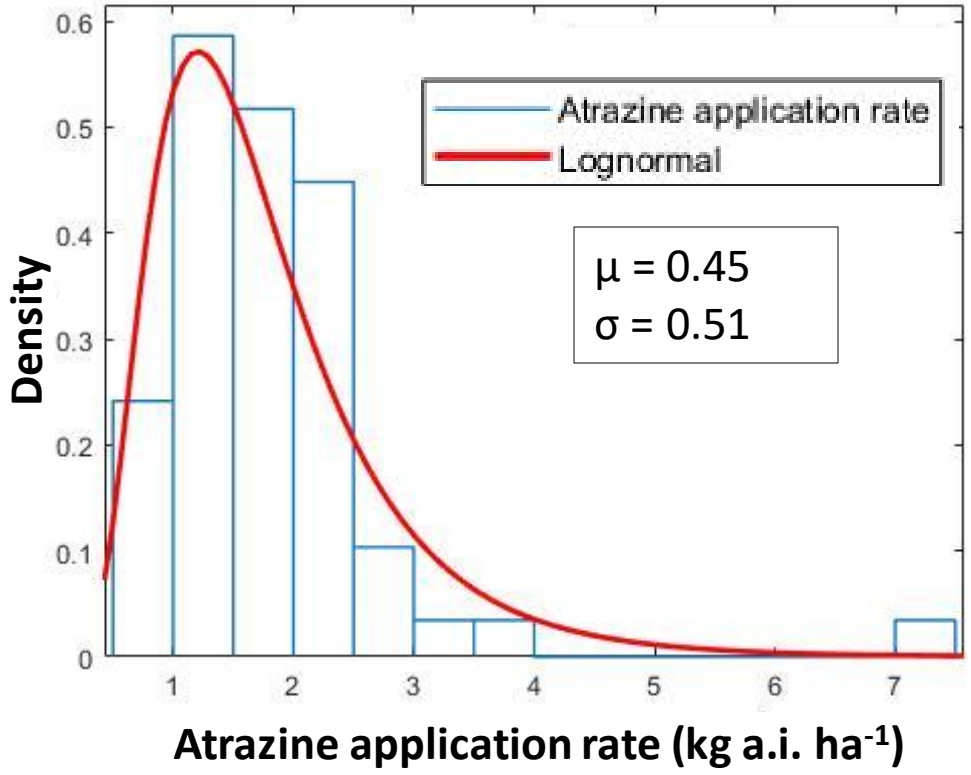


Atrazine concentration in the groundwater (μg/L)

Uncertainty of Input Variables

- Atrazine concentration in the groundwater
- **Atrazine application rate**
- Atrazine degradation rate
- Sorption coefficients

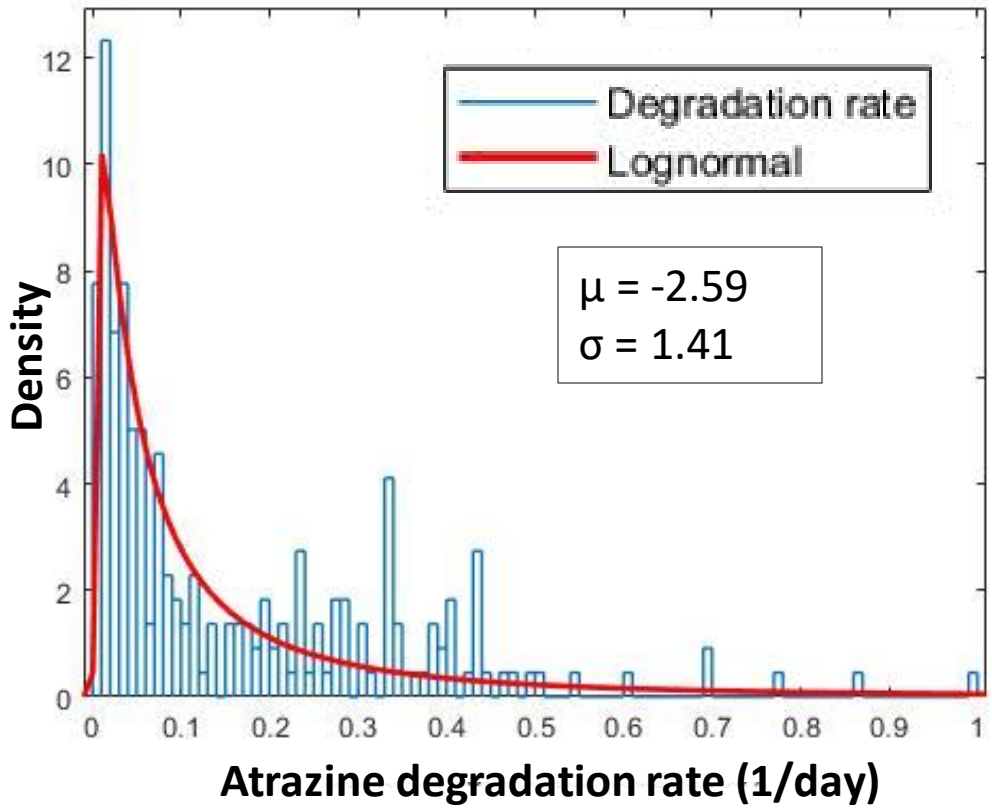
- Data sources: literature reviews
- Data points: 58
- Distribution pattern: Lognormal
  - $\mu = 0.45$
  - $\sigma = 0.51$



Uncertainty of Input Variables

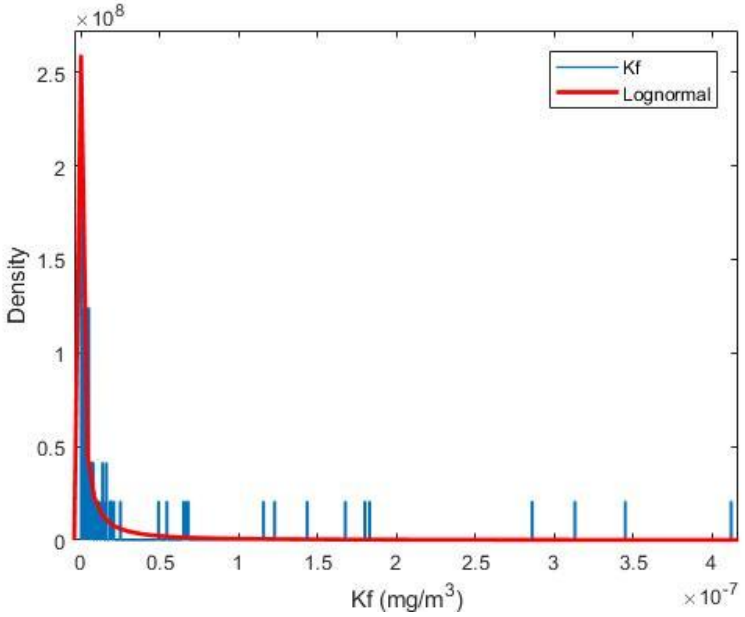
- Atrazine concentration in the groundwater
- Atrazine application rate
- **Atrazine degradation rate**
- Sorption coefficients

- Data sources: literature reviews
- Data points: 221
- Distribution pattern: Lognormal
  - $\mu = -2.59$
  - $\sigma = 1.41$

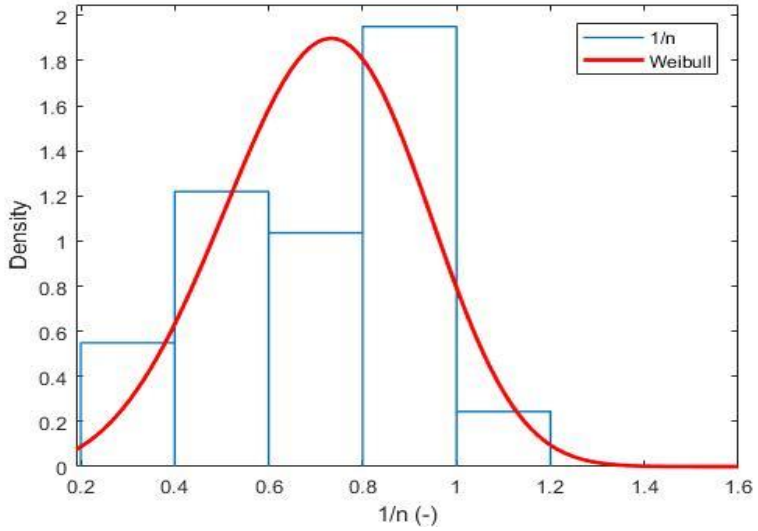


Uncertainty of Input Variables

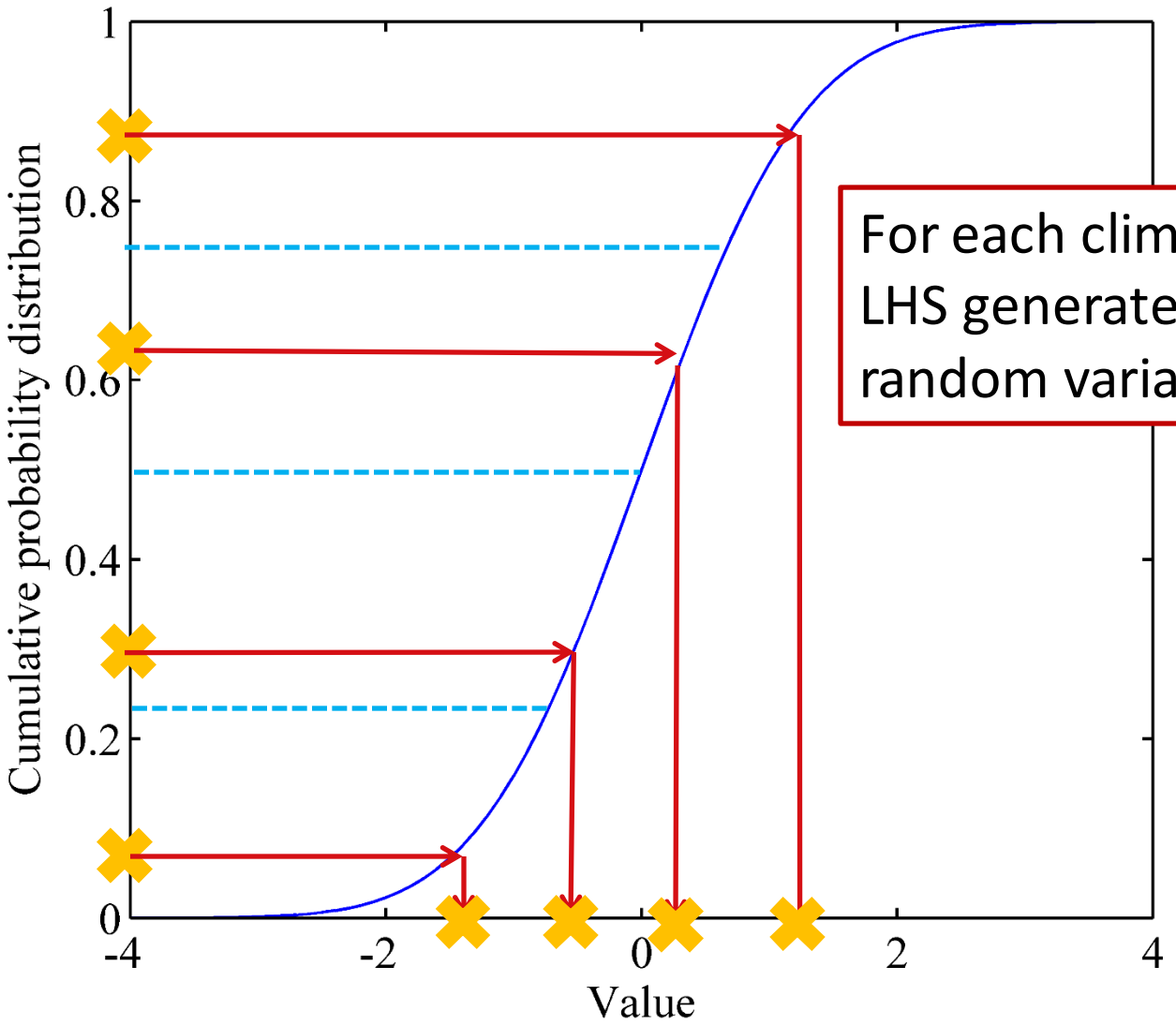
- Atrazine concentration in the groundwate
- Atrazine application rate
- Atrazine degradation rate
- **Sorption coefficient kf, 1/n**



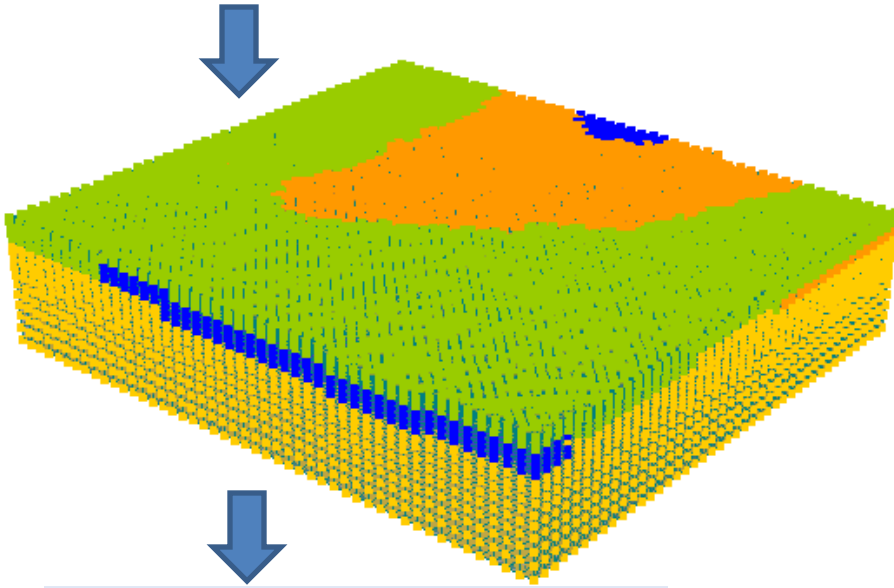
- Data sources: literature reviews
- Data points: 82
- Distribution pattern: Lognormal/Weibull
  - μ = -19.0 ; σ = 2.00
  - λ = 0.79 ; k = 3.94



Latin Hypercube Sampling (LHS)



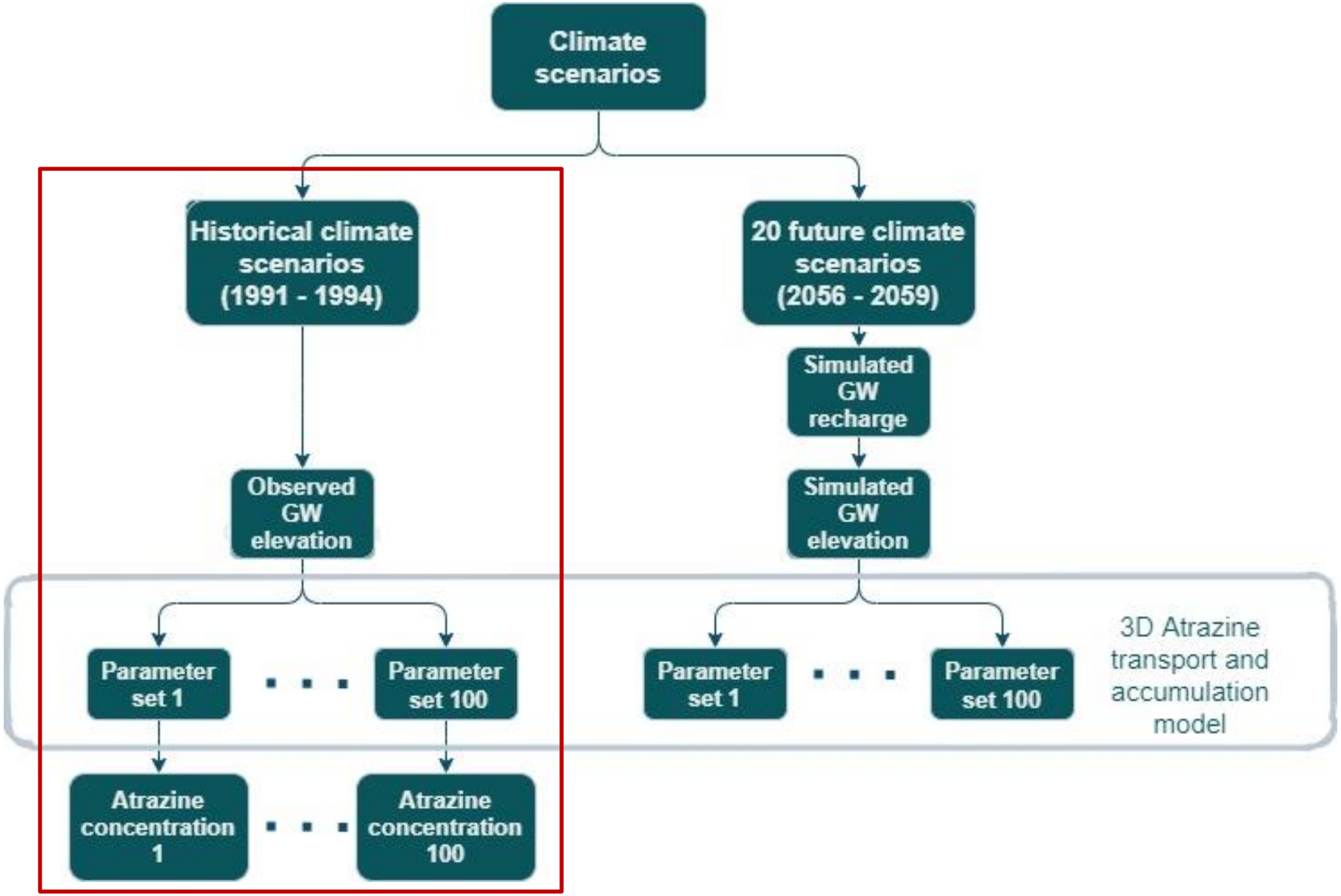
For each climate scenario, LHS generates 100 sets of random variables



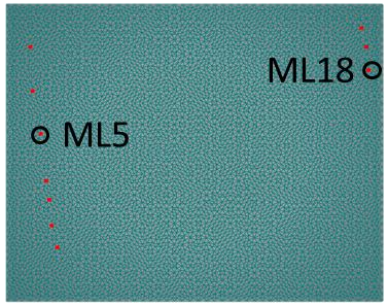
Concentration/Mass distribution

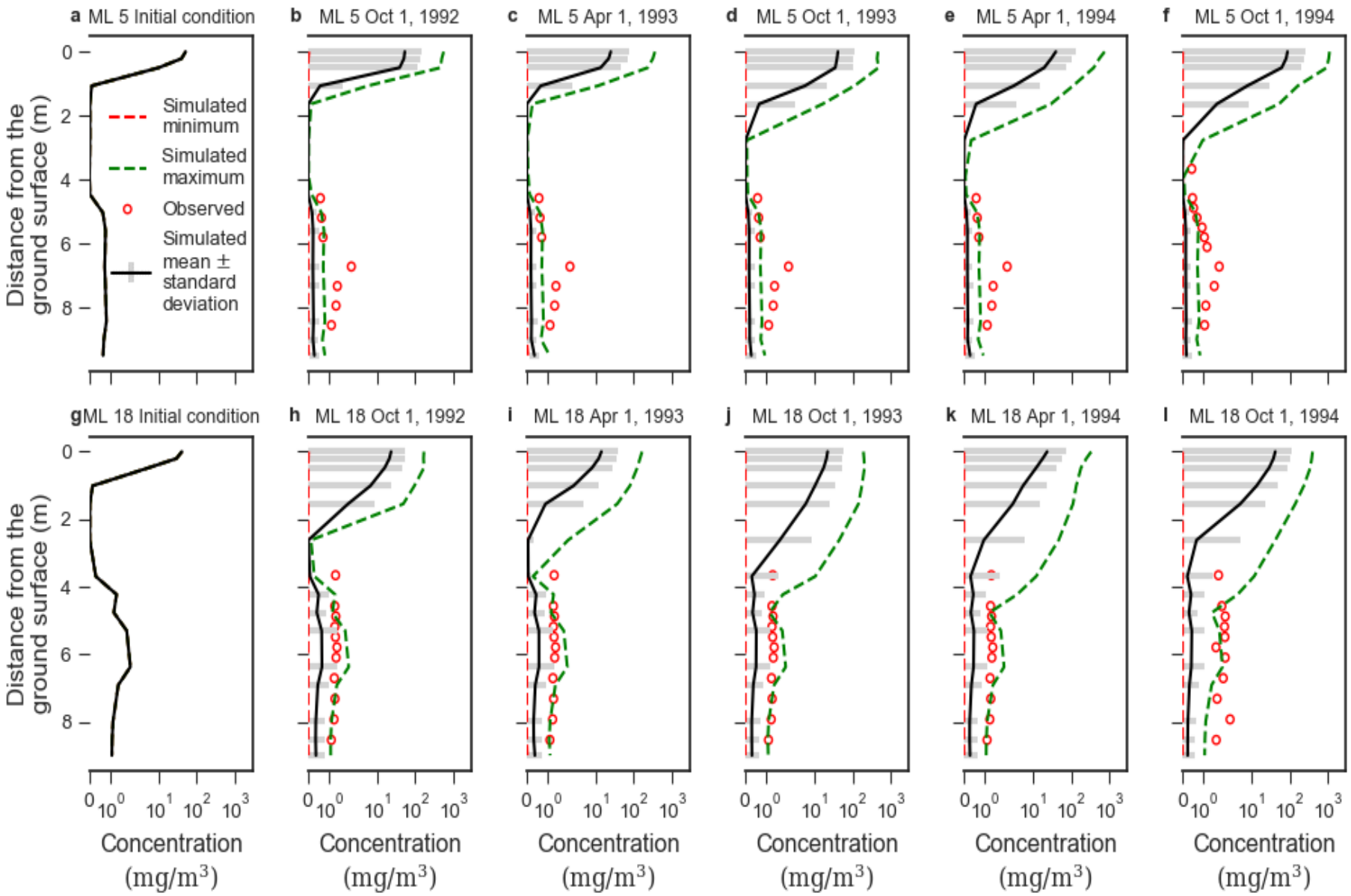
Sources: Moazzen, 2016

Overall Modeling Framework

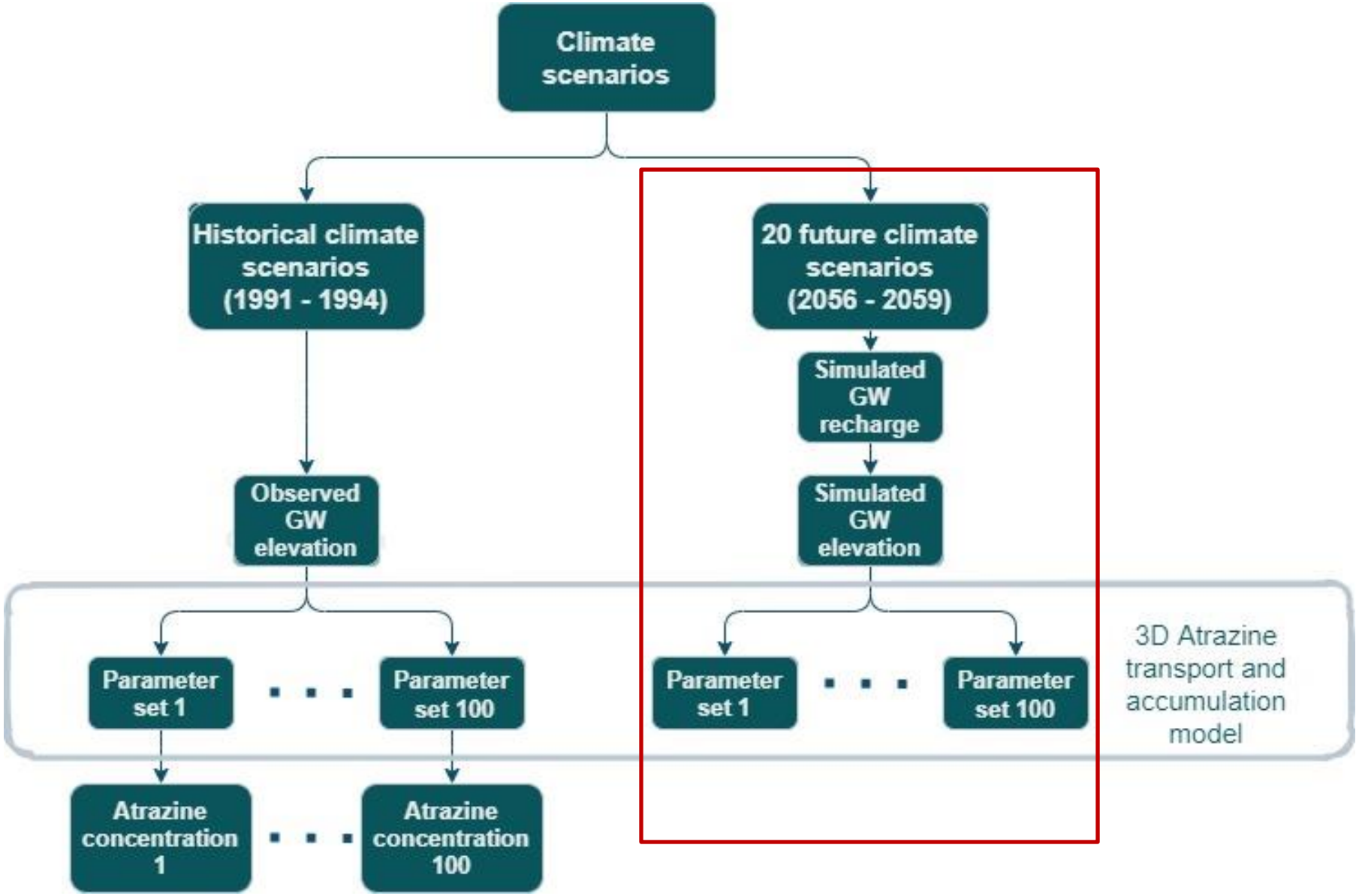


Concentration: Historical (Year 1991-1994)



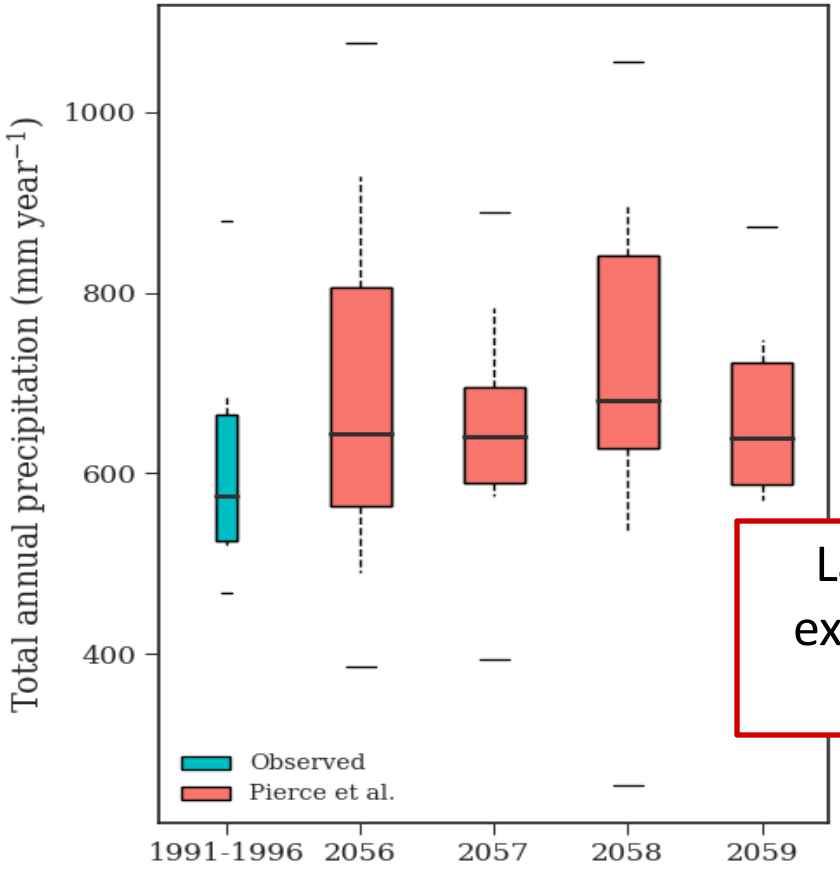


Overall Modeling Framework

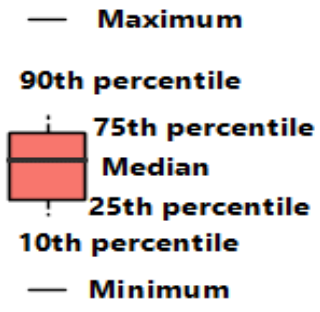


Future Climate Scenarios (Year 2056-2059)

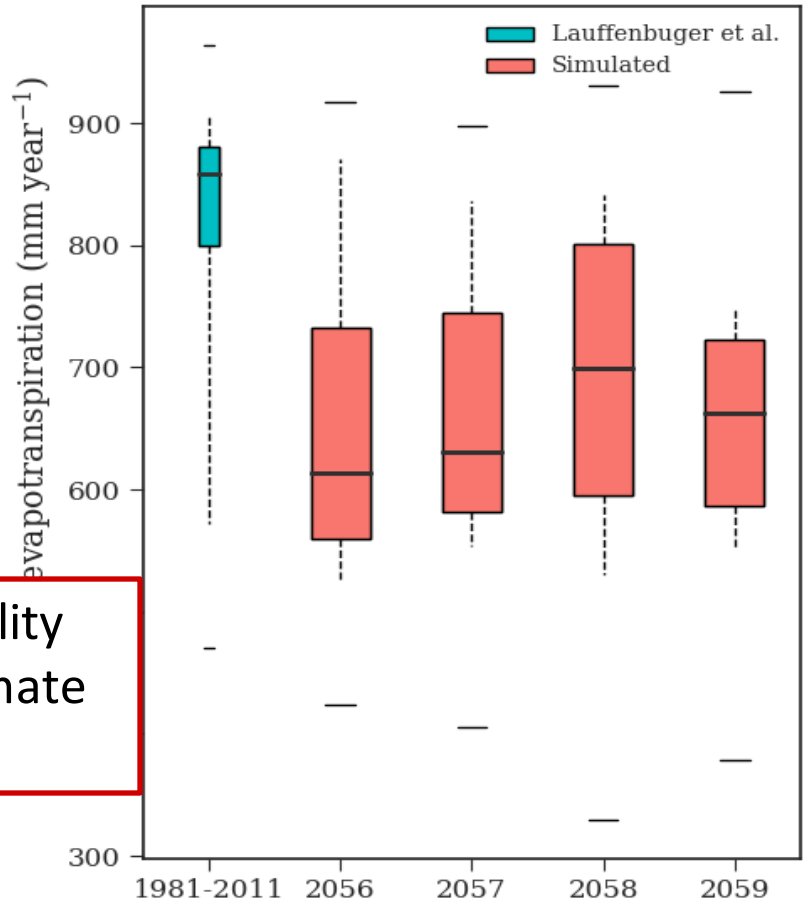
- Future Climate Data sources:
  - 20 Downscaled Locally constructed analogs method (LOCA) Coupled Model Intercomparison Project (CMIP) phase 5 Climate Projections
  - Representative Concentration Pathways (RCP) 8.5 scenario: with high greenhouse gas emission pathway



Annual Precipitation

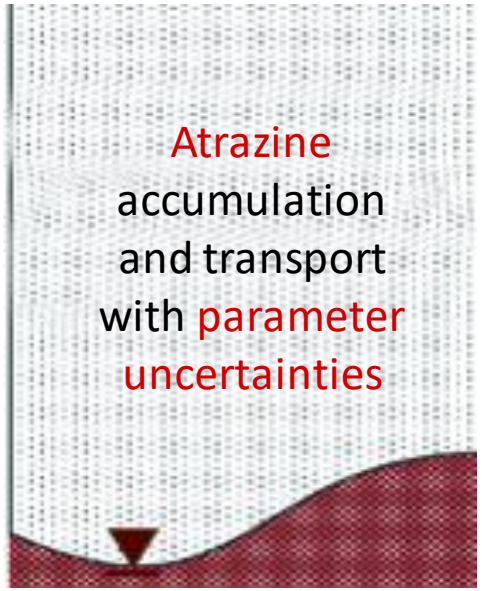


Large climate variability exists in 20 future climate scenarios.



Annual Evapotranspiration

Modeling Framework



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Groundwater Recharge Modeling

Future GR

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Future Groundwater Elevation

Future Recharge Modeling Setup

Inverse vadose zone modeling (IVZ): Hydrus 1D

Solve Richard's Equation (water flow in soil)

Optimize hydraulic parameters

Find model soil moisture content

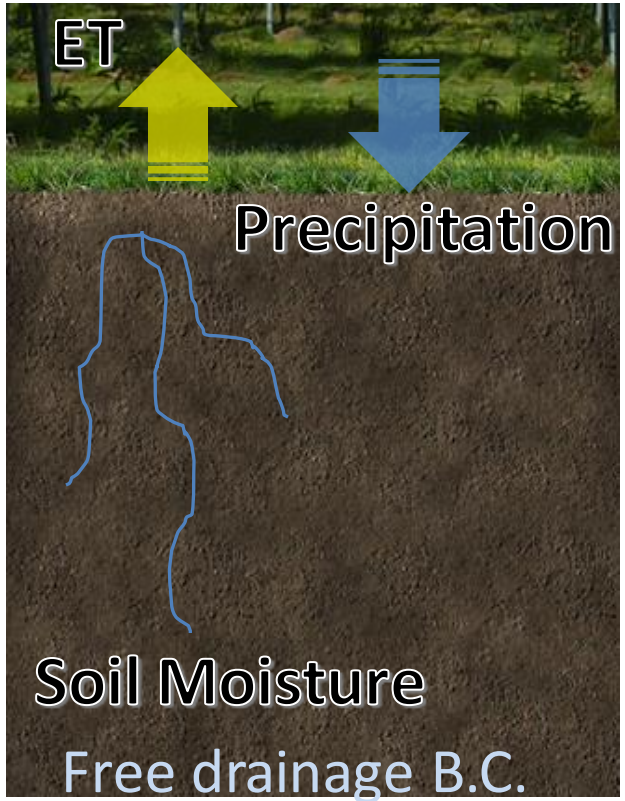
Match modeled and field obtained soil moisture data

NO

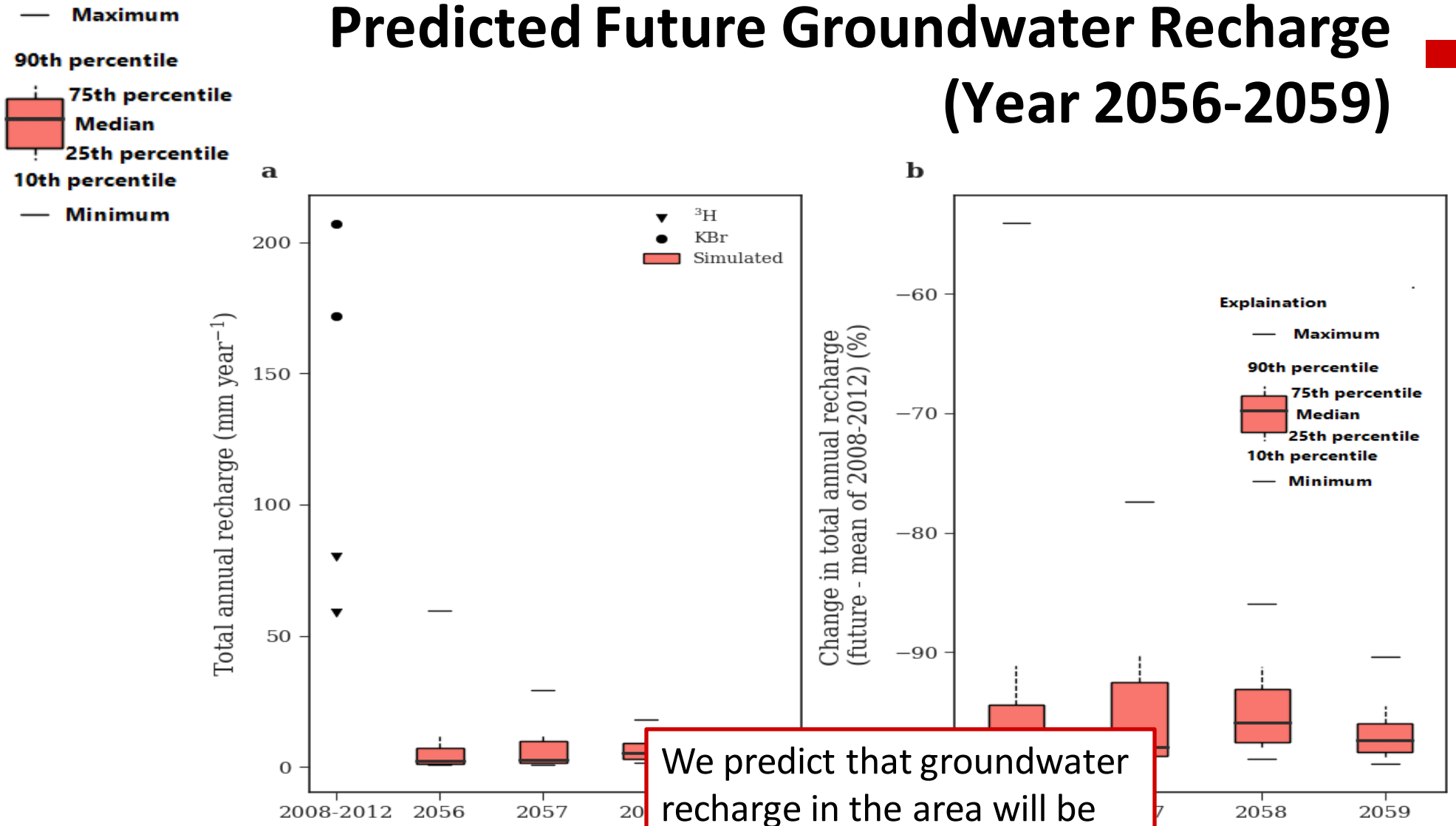
YES

Ground water recharge is water flux leave lower boundary

Validated based on 20 years of soil moisture data

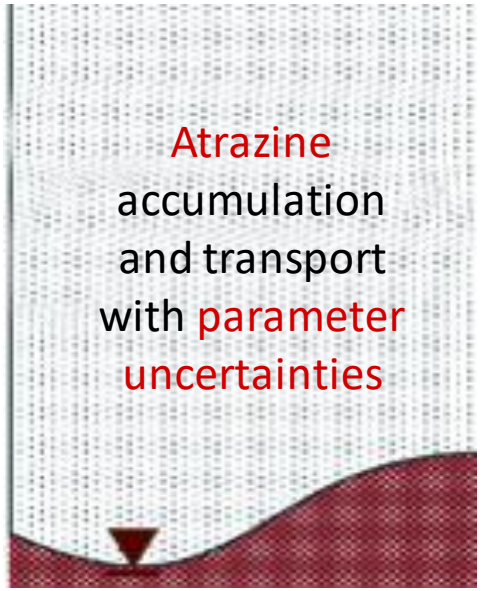


Predicted Future Groundwater Recharge (Year 2056-2059)



We predict that groundwater recharge in the area will be reduced under future climate scenarios.

Modeling Framework



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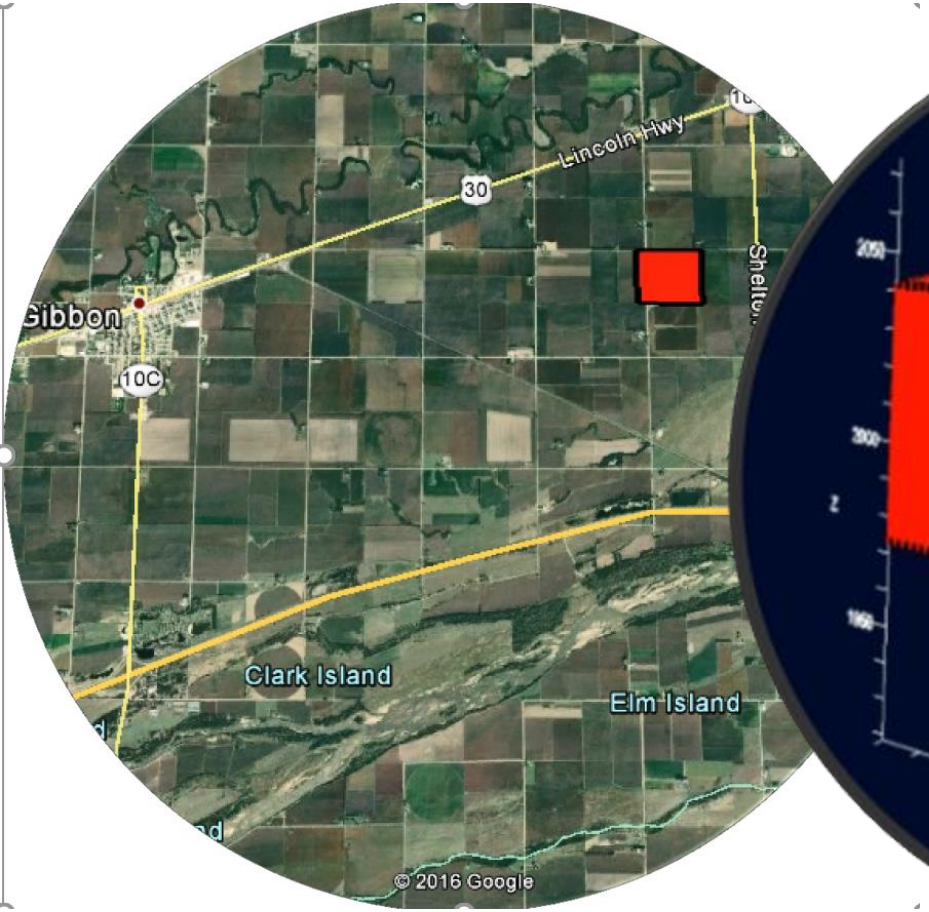
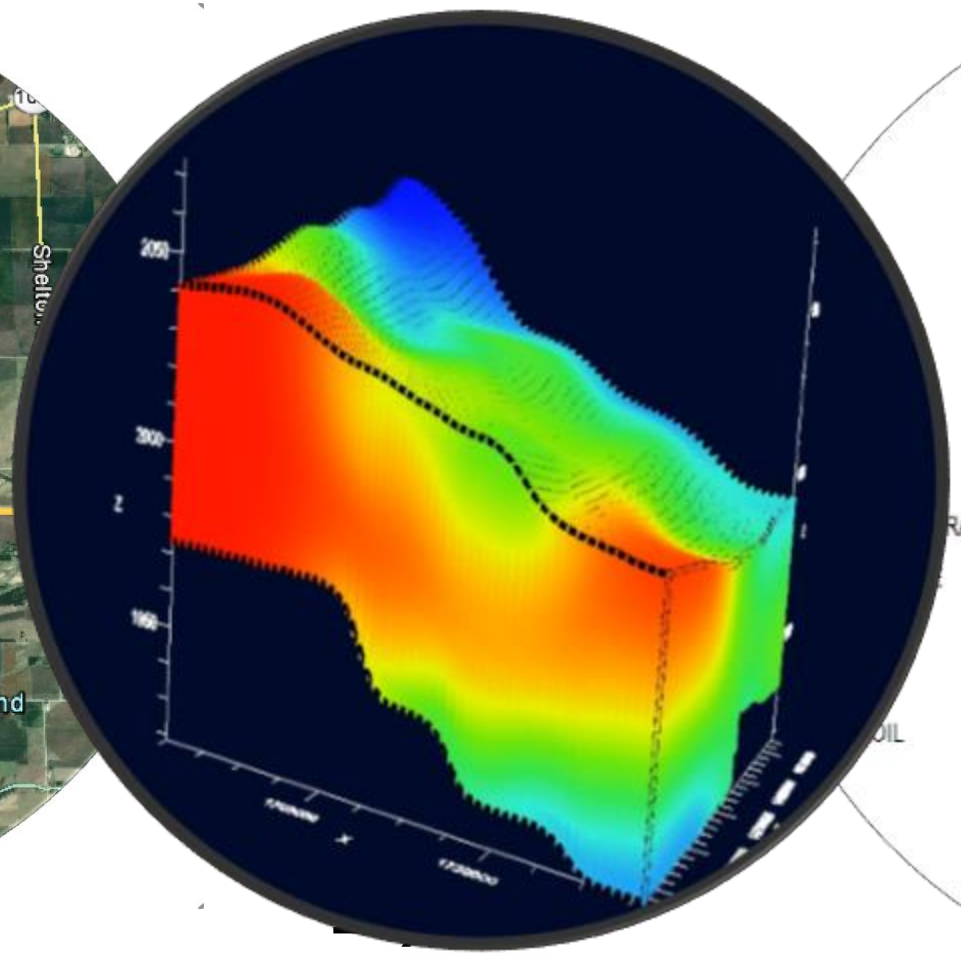
Future GR

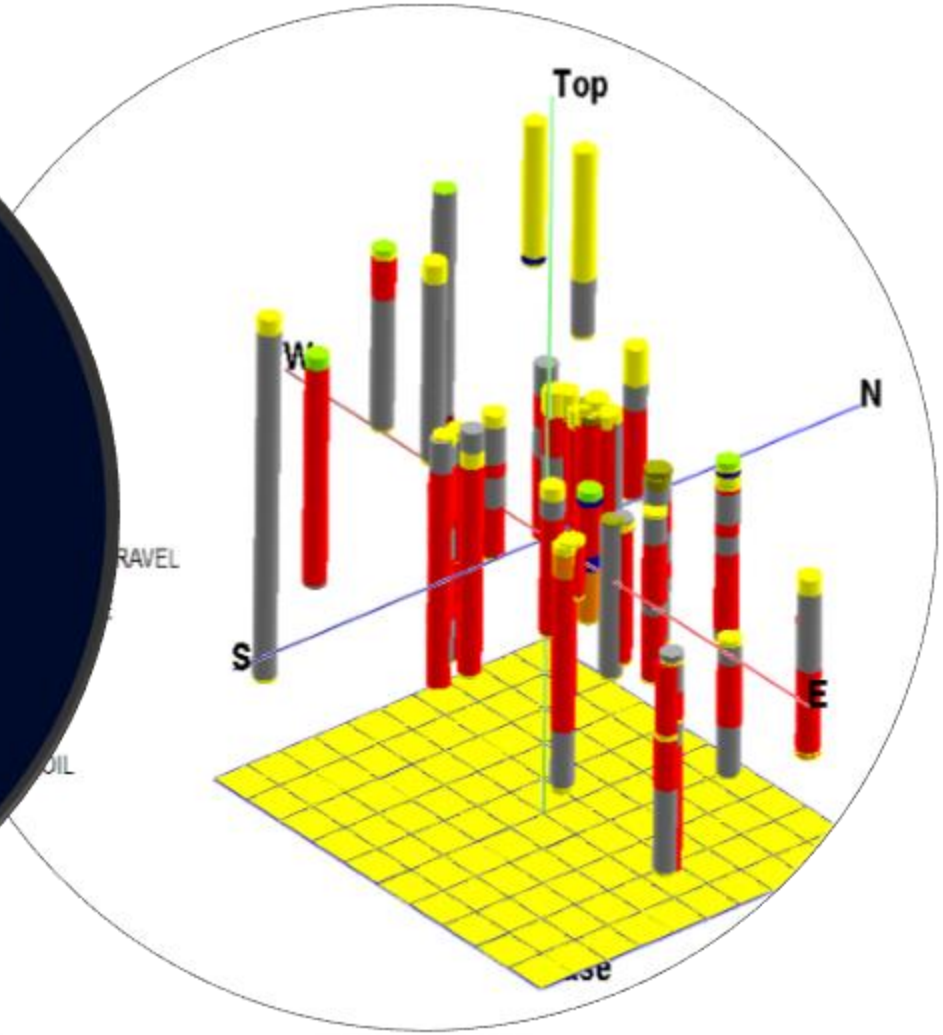
Groundwater Model

Future Groundwater Elevation

Groundwater Elevation Simulation Area

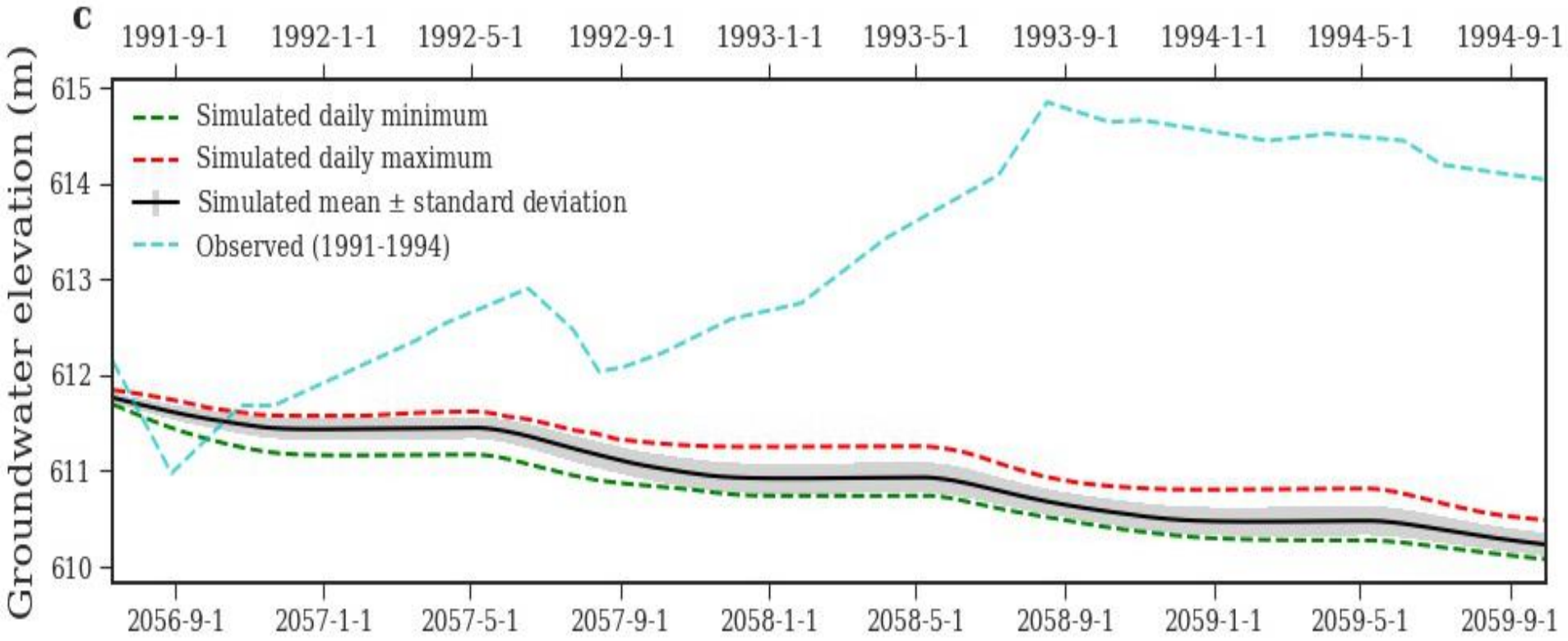






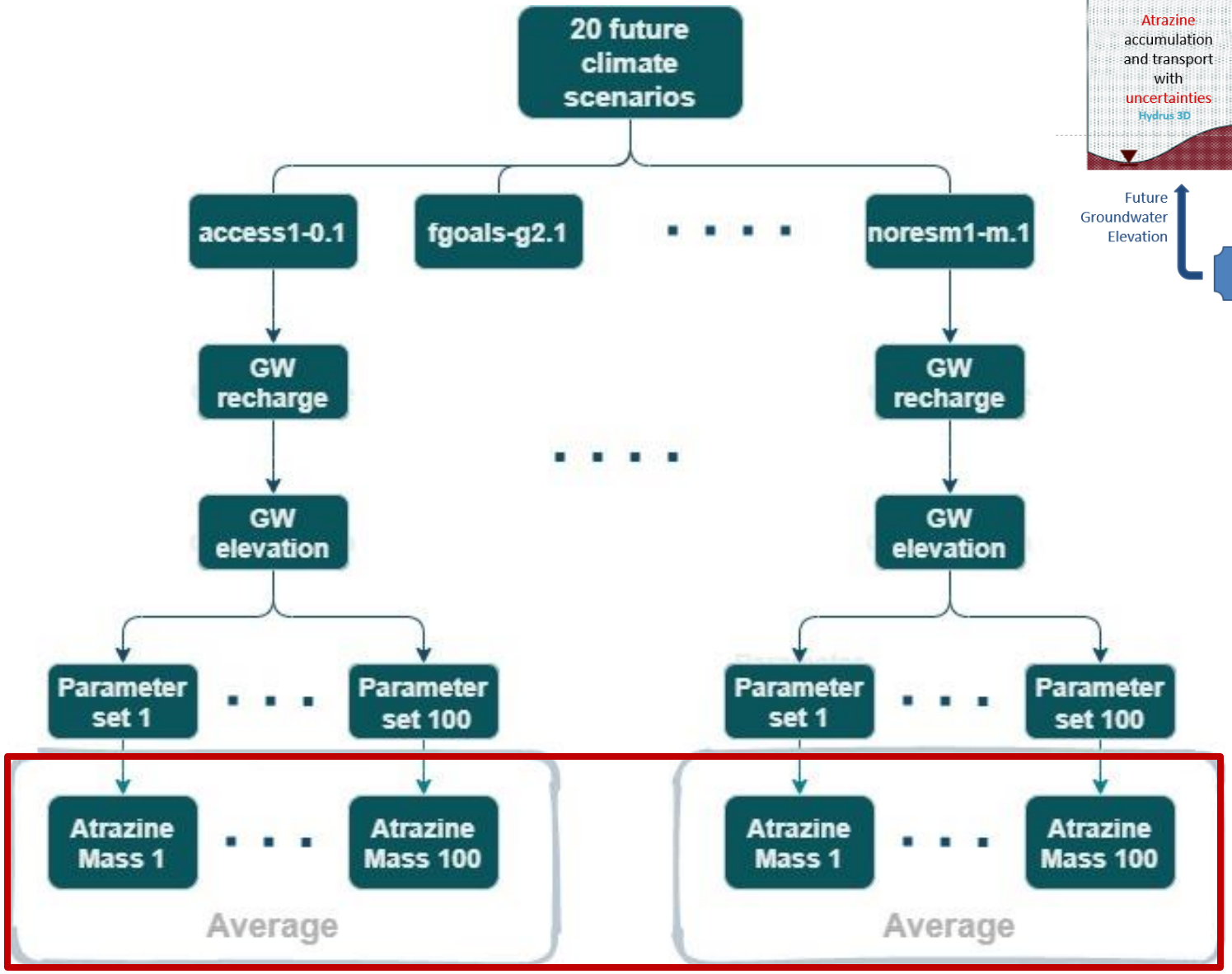
258 wells withdraw GW from shallow aquifer.

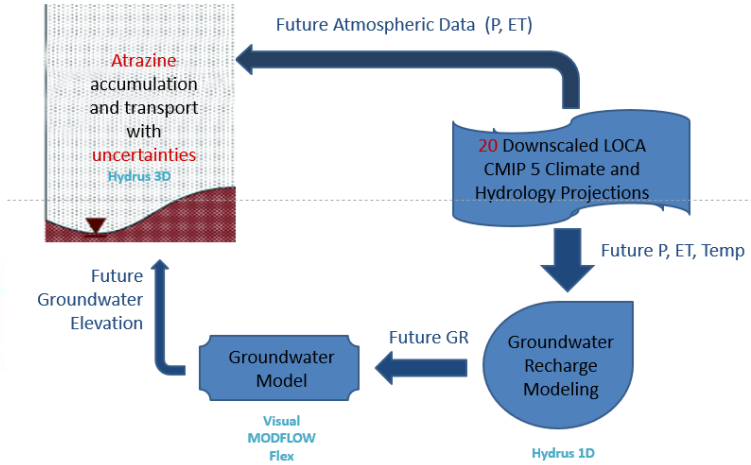
Future Groundwater Elevation (Year 2056-2059)



Groundwater elevation is decreasing under future climate scenarios

Future Climate Scenarios (Year 2056-2059)

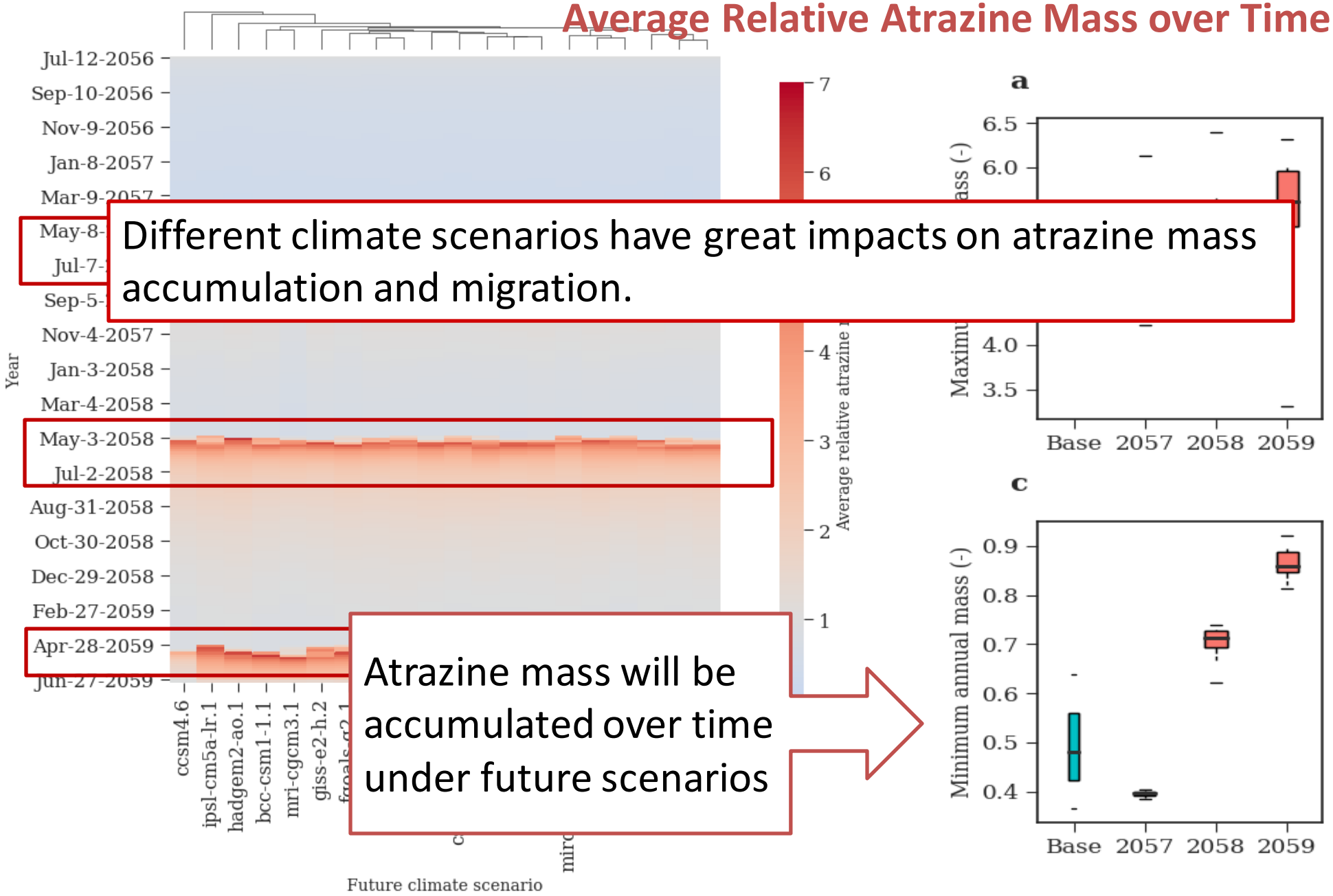




Results: Mass Accumulation

Average Relative Atrazine Mass over Time

/29 to 5/20



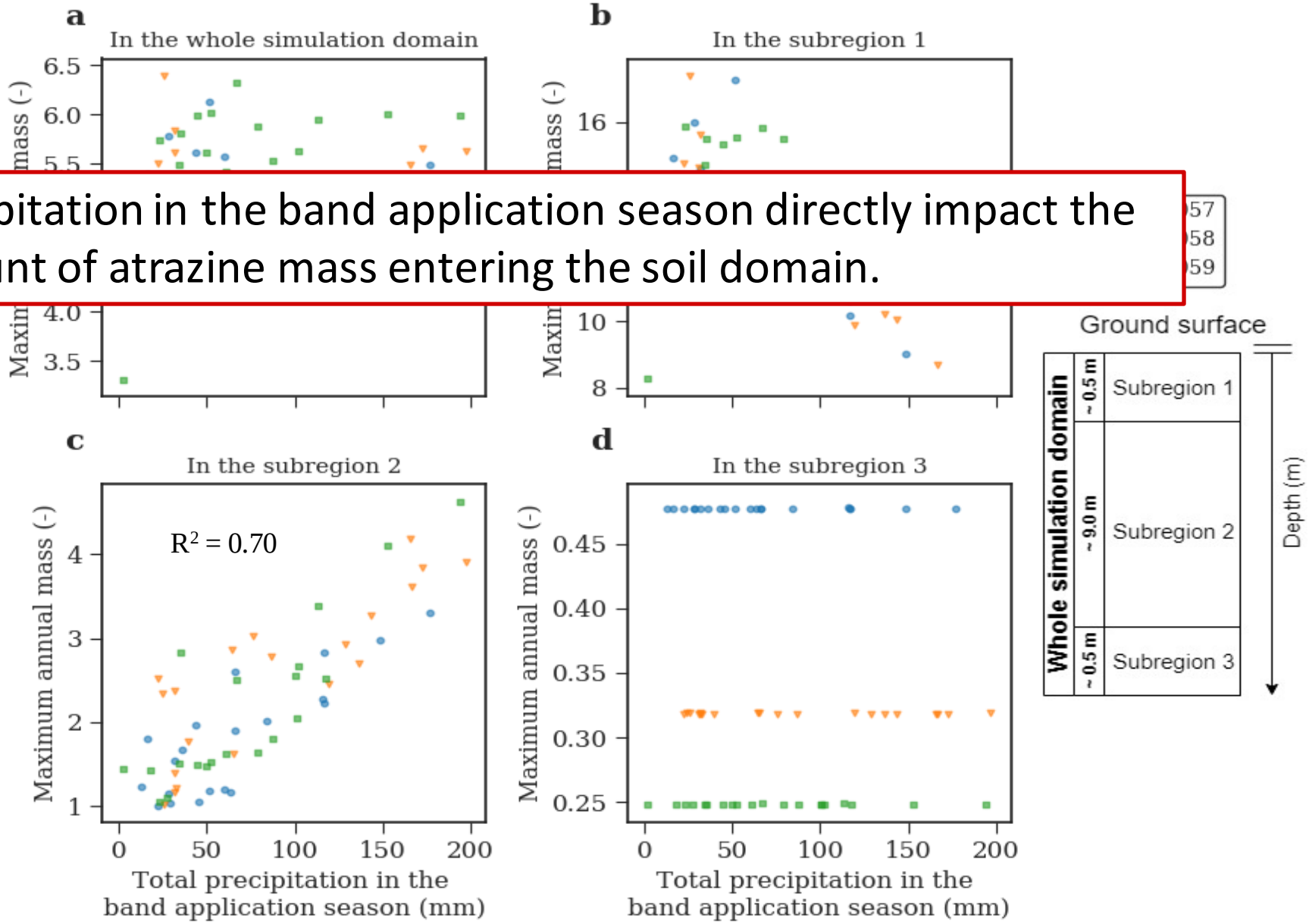
Different climate scenarios have great impacts on atrazine mass accumulation and migration.

Atrazine mass will be accumulated over time under future scenarios

Results: Mass Accumulation

Band application season: 4/29 to 5/20

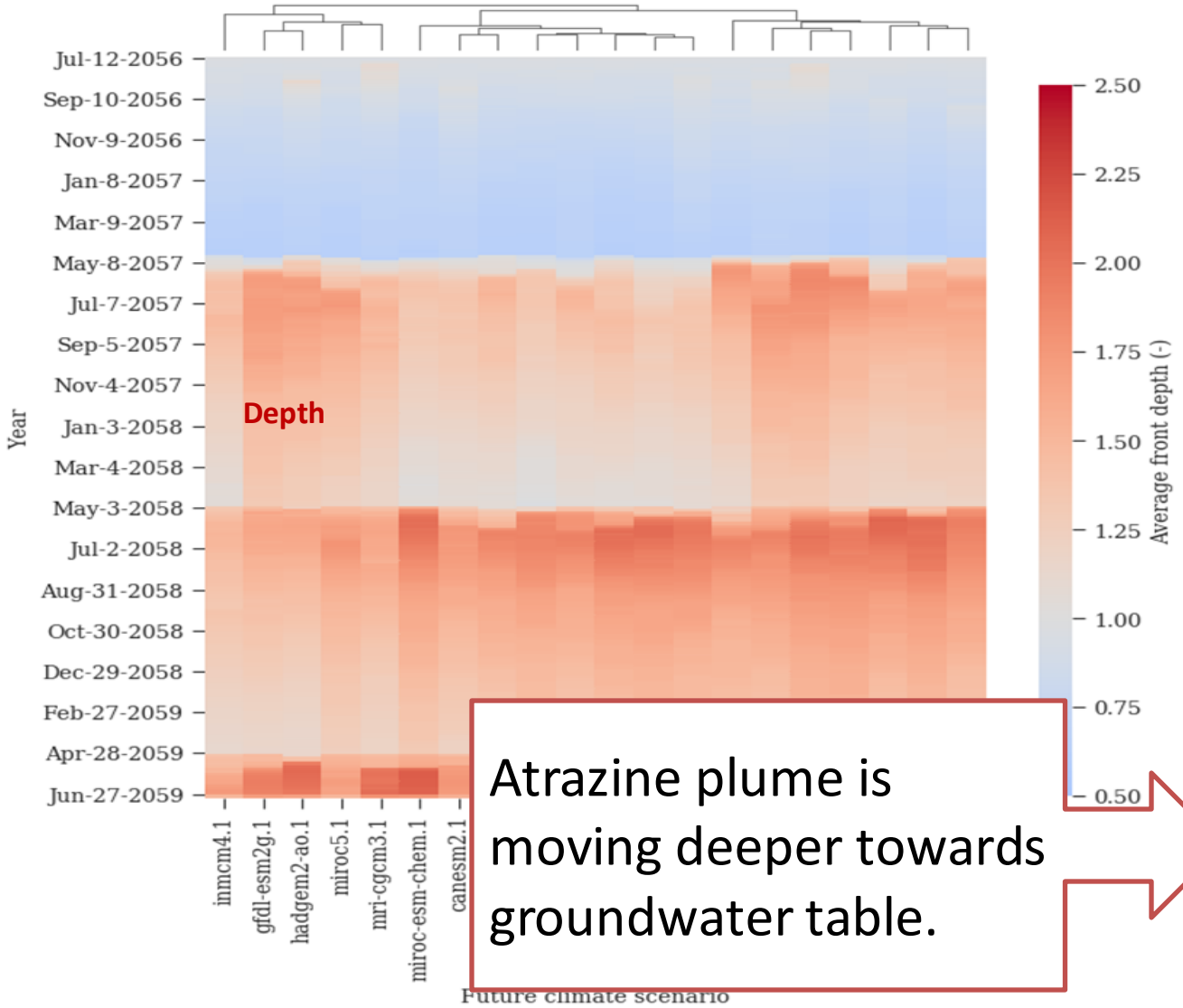
Max. Annual Mass over Precipitation



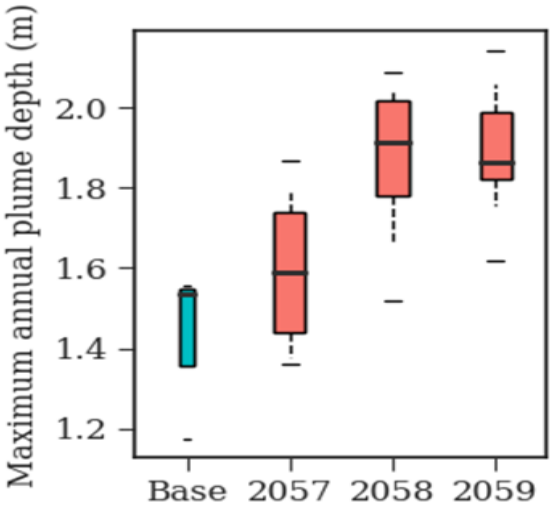
Precipitation in the band application season directly impact the amount of atrazine mass entering the soil domain.

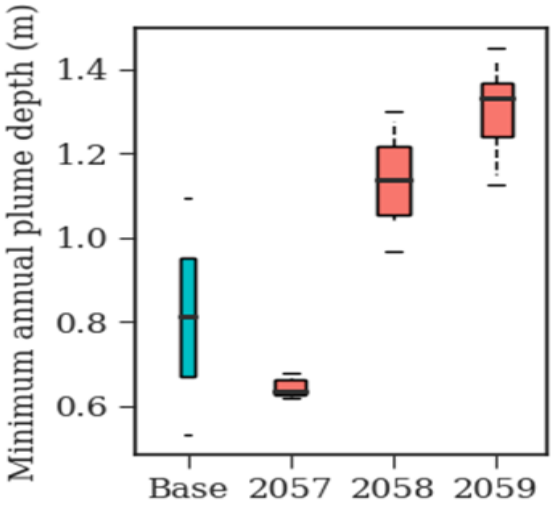
Results: Plume Migration

Atrazine Plume Front (3ug/L) Depth



Atrazine plume is moving deeper towards groundwater table.





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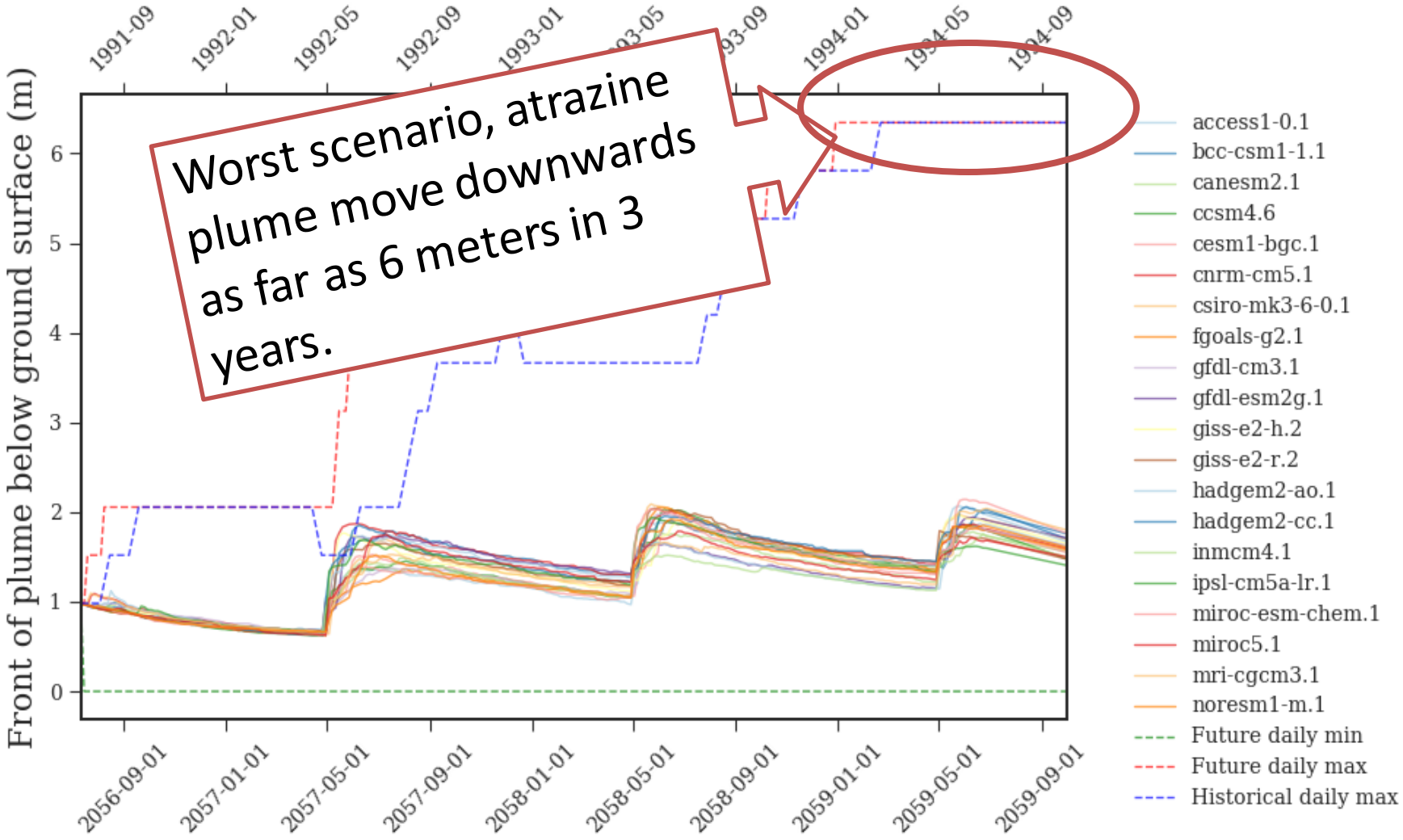
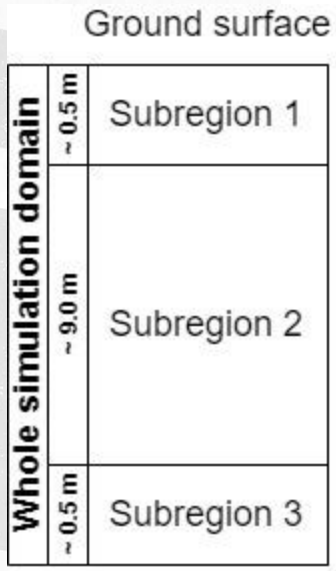
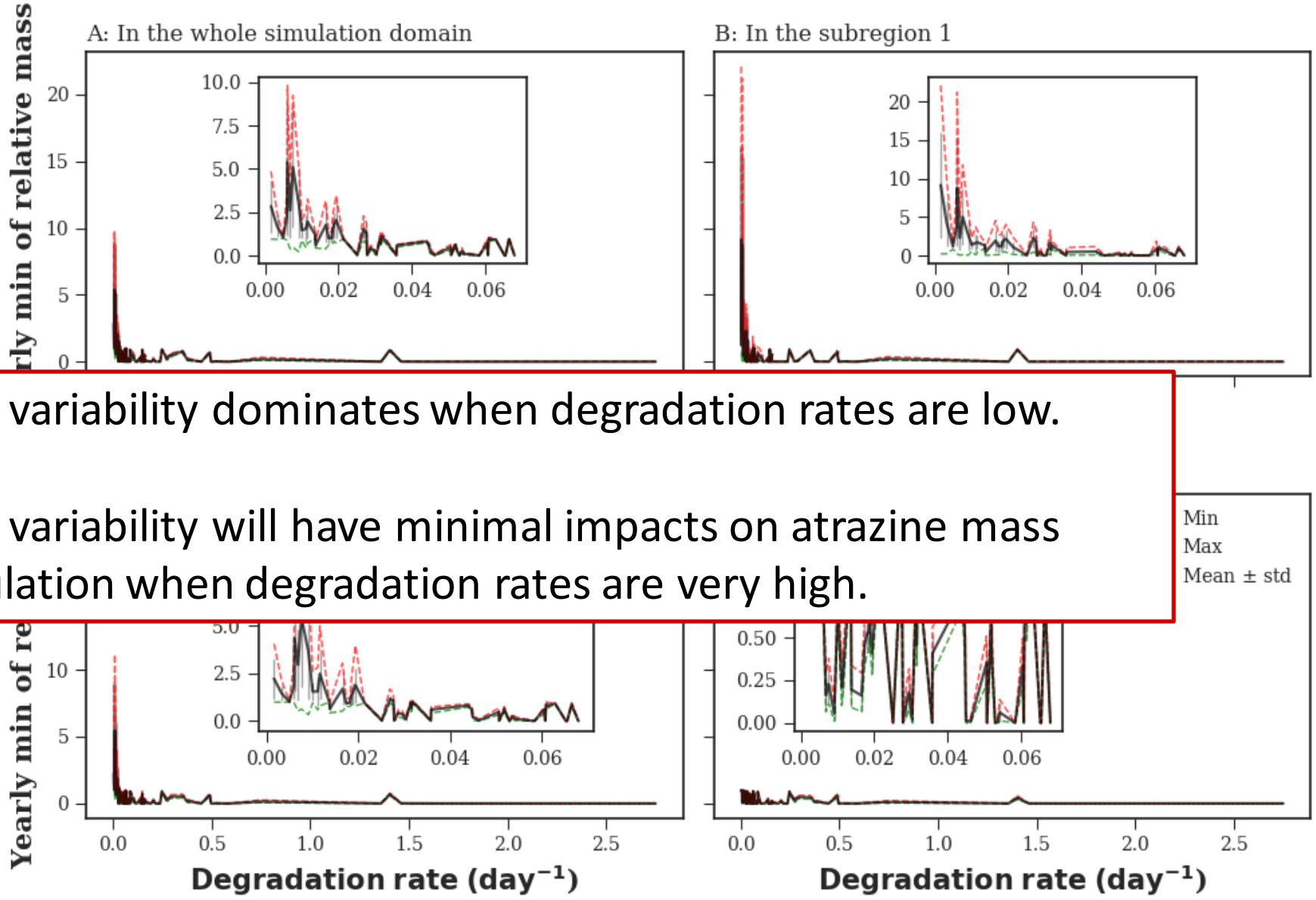
Atrazine Plume Front Depth



Results: Impact of Parameter Uncertainty

Yearly Min Relative Atrazine Mass over Degradation Rate



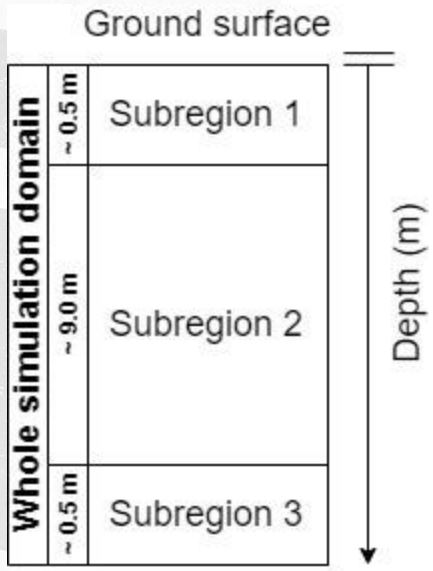


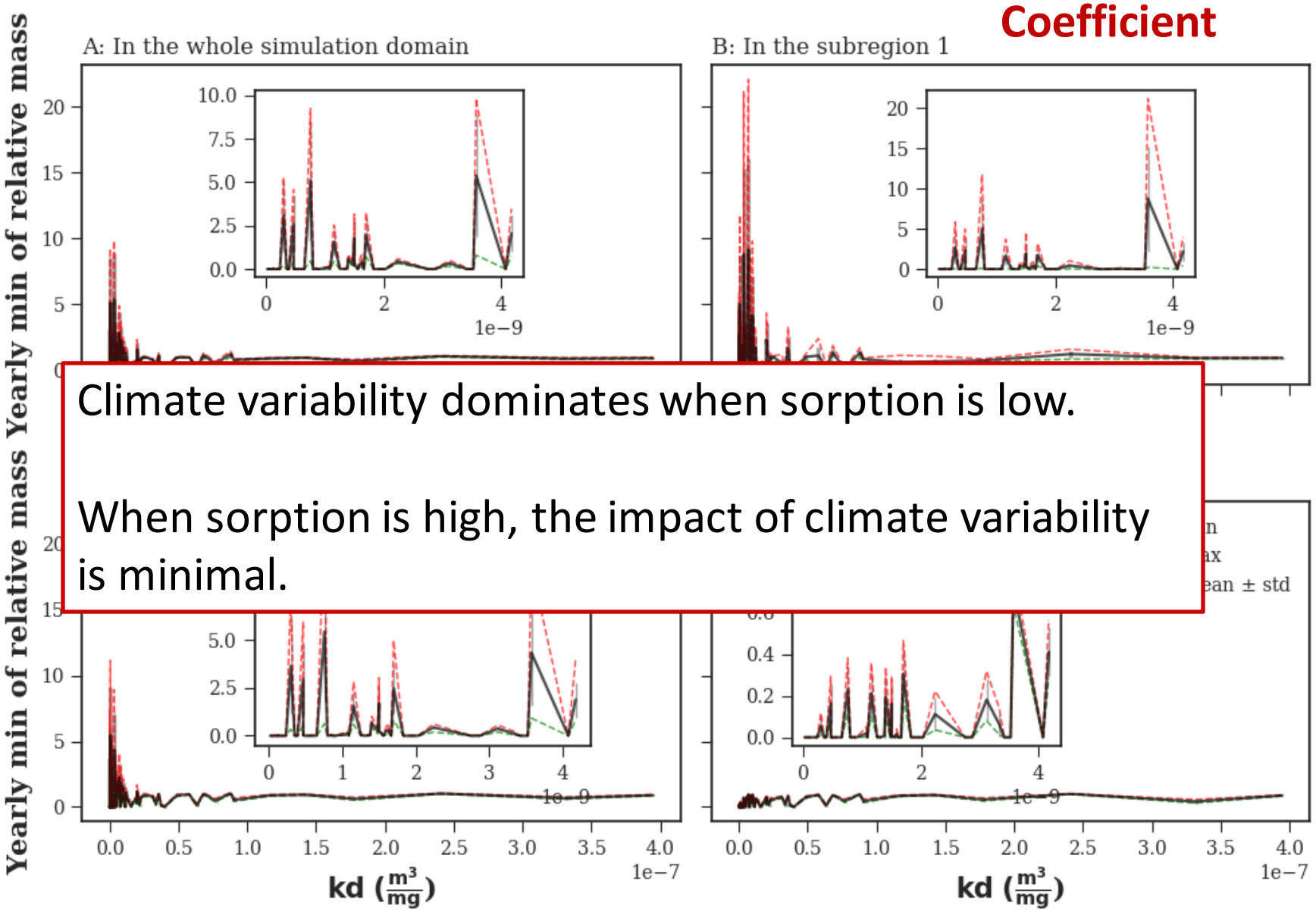
Climate variability dominates when degradation rates are low.

Climate variability will have minimal impacts on atrazine mass accumulation when degradation rates are very high.

Results: Future Climate Scenarios (Year 2057-2060)

Yearly Min Relative Atrazine Mass over Converted Distribution Coefficient





Climate variability dominates when sorption is low.

When sorption is high, the impact of climate variability is minimal.

Summary

- Declined groundwater elevation in the future may aggravate the problem of an overdraft of local aquifer.
- Rainfall is a major driver to transport atrazine in the vadose zone.
- Climate variation in general leads to very big uncertainty of atrazine mass accumulation and transport; such effect is not obvious for the field sites with very high degradation rates or sorption.
- In the worst scenario, the atrazine plume can reach 6 meters below the ground.

Acknowledgement

Water for Food
DAUGHERTY GLOBAL INSTITUTE
at the University of Nebraska

USDA

NU FEWS

Thanks for listening