

Background Concentrations of ClO_4^- and its Impact on Site Assessment

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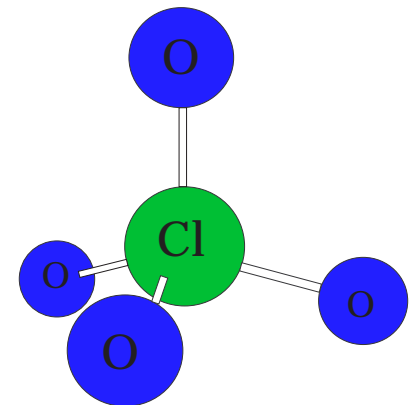
David Stonestrom, Lynne Fahlquist, Greta Orris

(United States Geological Survey)

And

Greg Harvey

USAF



Acknowledgements

- Contributors

- Todd Anderson
- Ken Rainwater
- **Srinath Rajagopalan**
- **Balaji Rao**
- Greta Orris (USGS)
- Lynne Fahlquist (USGS)
- Bridget Scanlion (BEG)
- David Stonestrom
(USGS)
- Greg Harvey (USAF)

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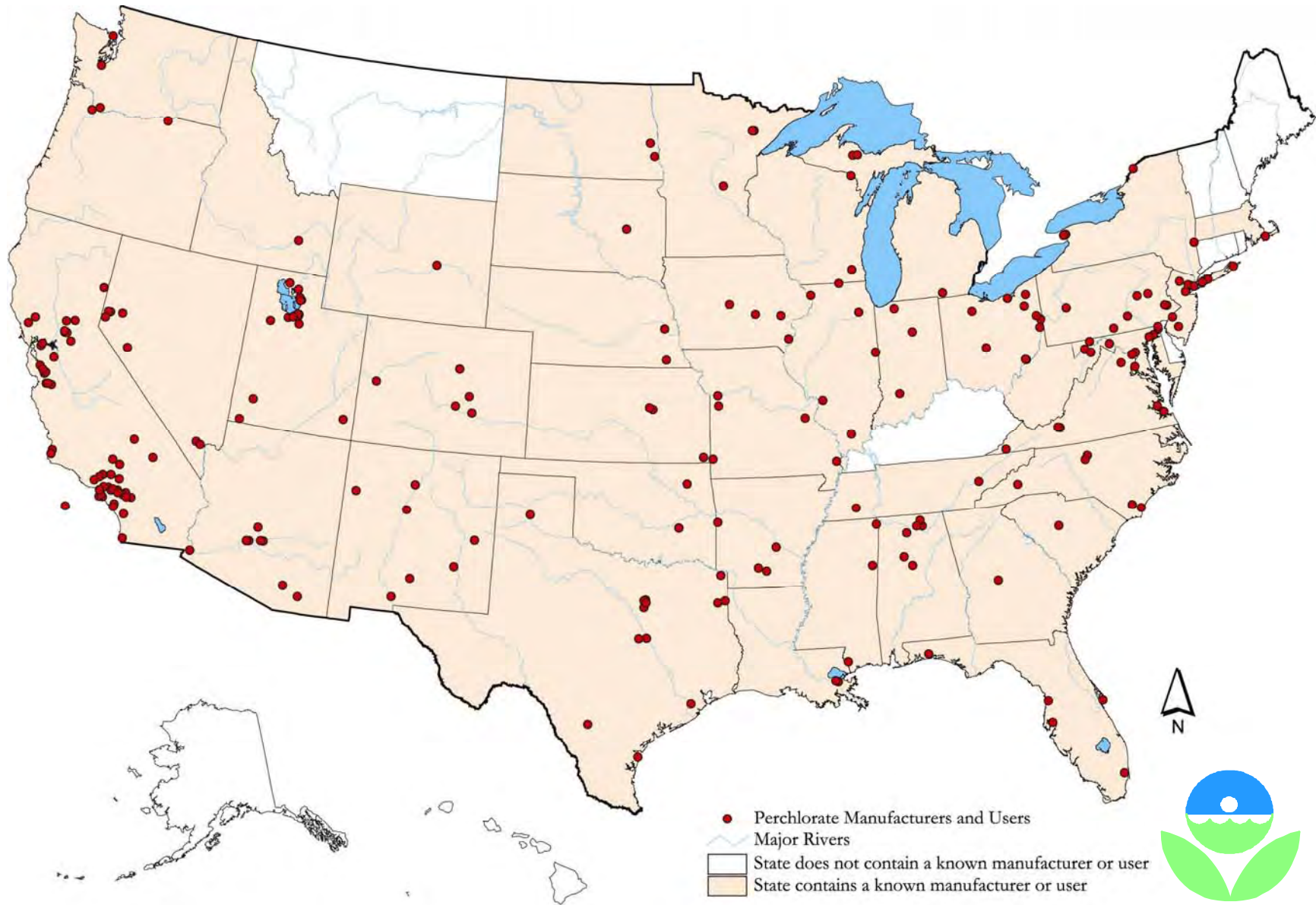
- SERDP EP-1485
- TCEQ

Sources

- Solid rocket propellants
- Explosives
- Fireworks
- Flares
- By-product in Chlorates and Hypochlorites
- Mined Chilean fertilizers
- ***Naturally Occurring***



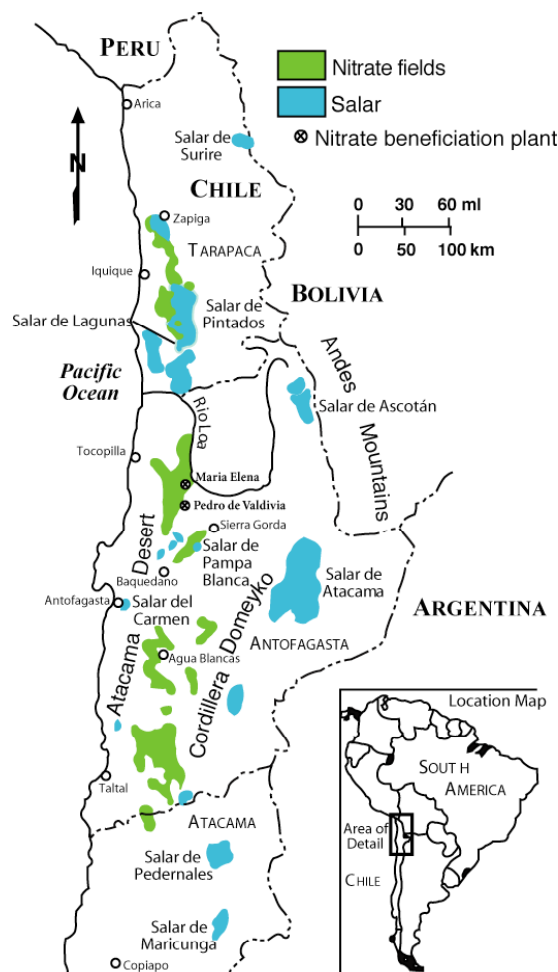
PERCHLORATE MANUFACTURERS and USERS



APRIL, 2003

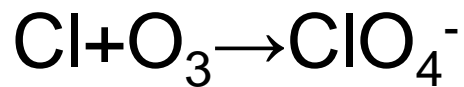
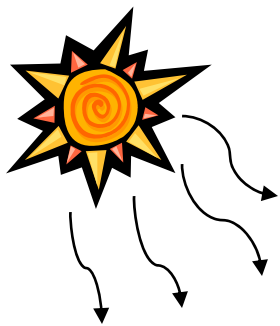


Natural ClO_4^- Background

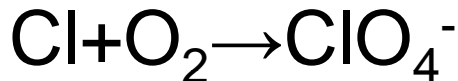
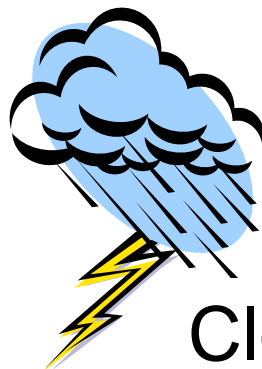
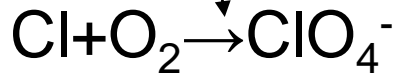


- Chilean NO_3^- Deposits (Atacama Dessert)
 - Dessert for at least last 1-10 MY
 - ClO_4^- (>.1%) identified over 100 years ago
 - Deposits also contain IO_3^- , CrO_7 (mg/kg in some strata)
 - * NO_3^- , * SO_4^{2-} and # ClO_4^- have significant $\Delta^{17}\text{O}$ anomalies
 - *Michalski et al., 2004
 - #Bao and Gu, 2004

Conceptual Model



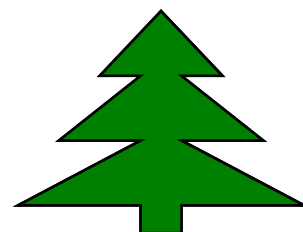
μV



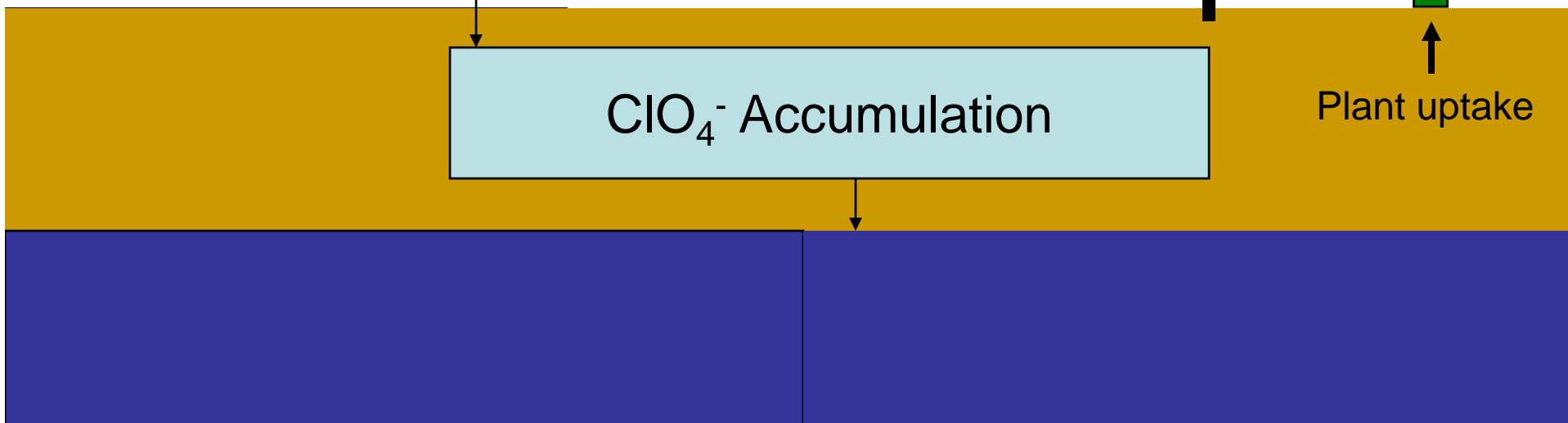
Evapotranspiration

Deposition Dry & Wet

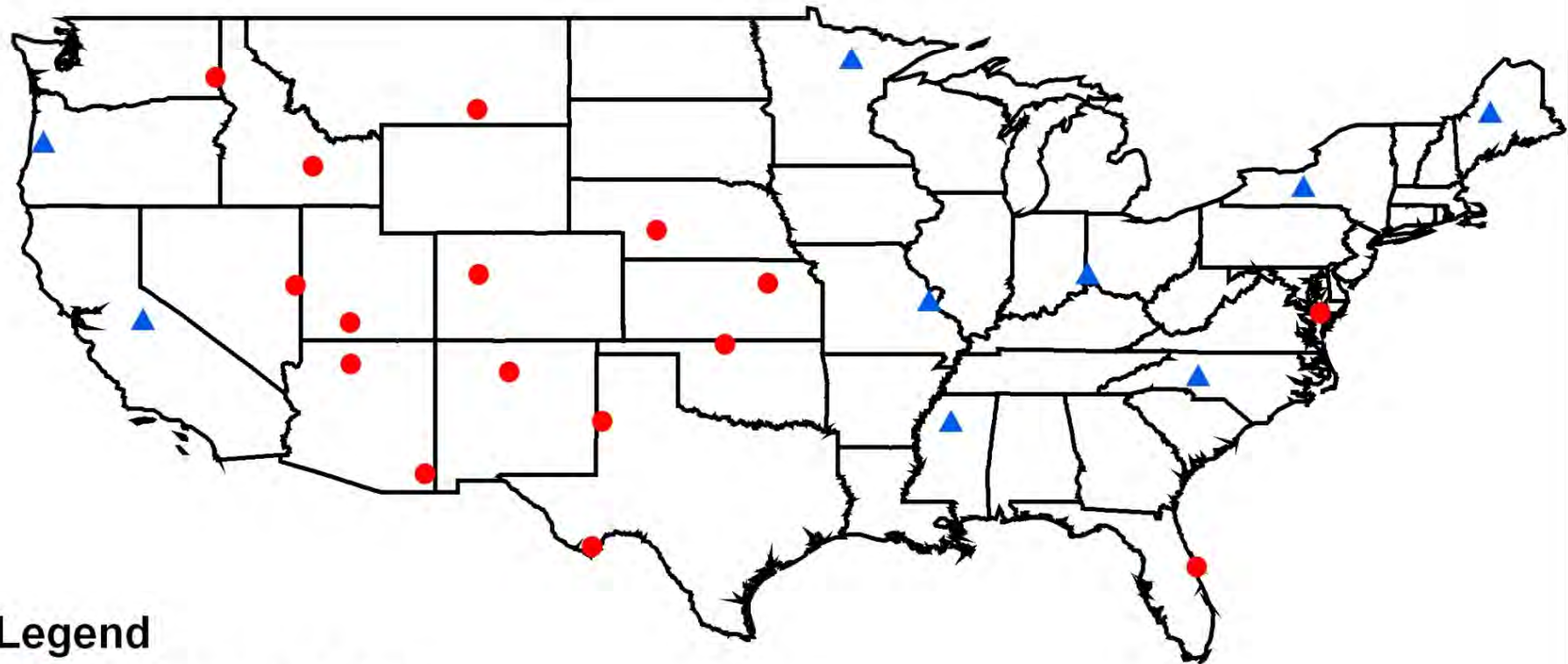
ClO_4^- Accumulation



Plant uptake



Deposition of ClO_4^- Approach



Legend

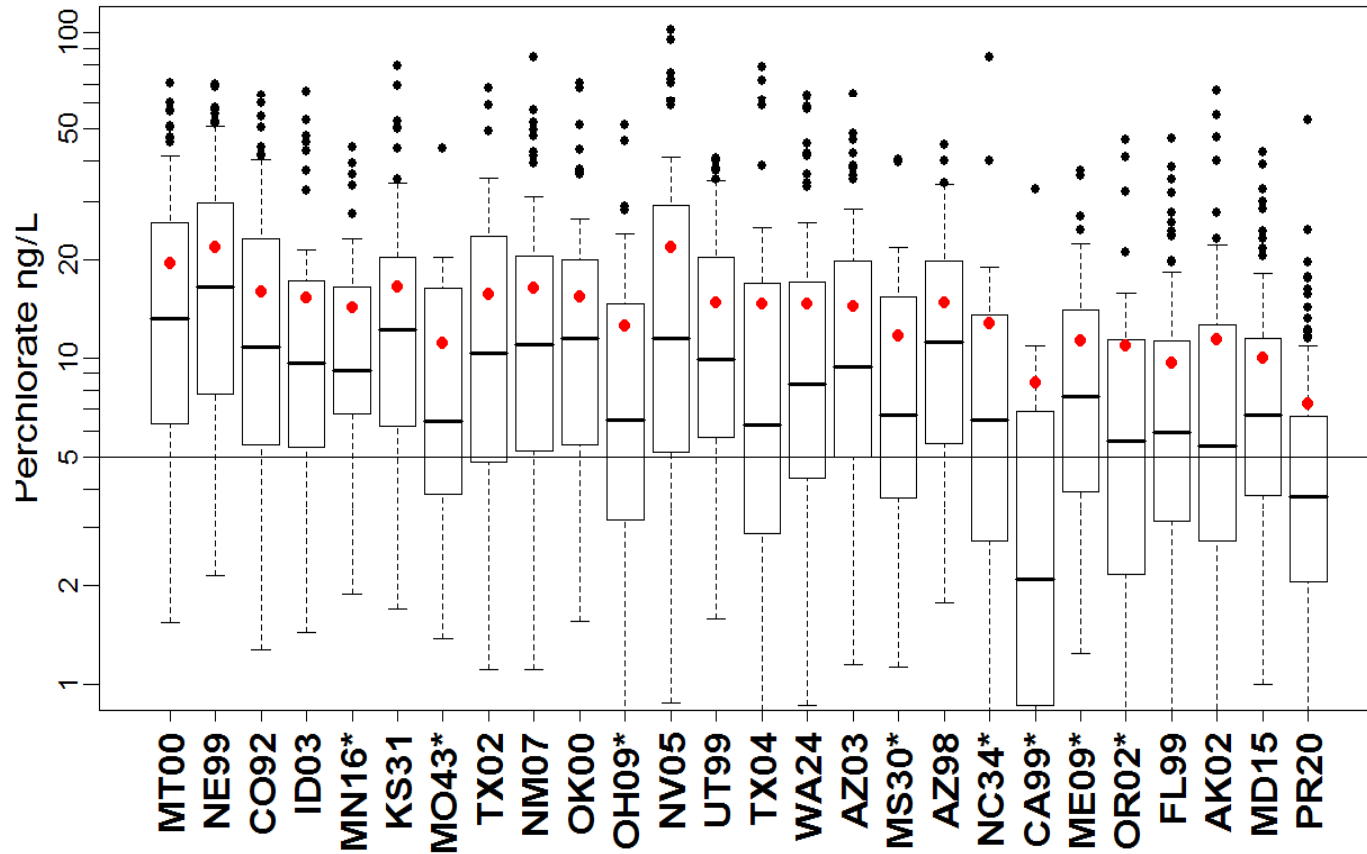
- Current NADP Sites
- ▲ Proposed NADP Sites

0 250 500 1,000 1,500 2,000 Miles

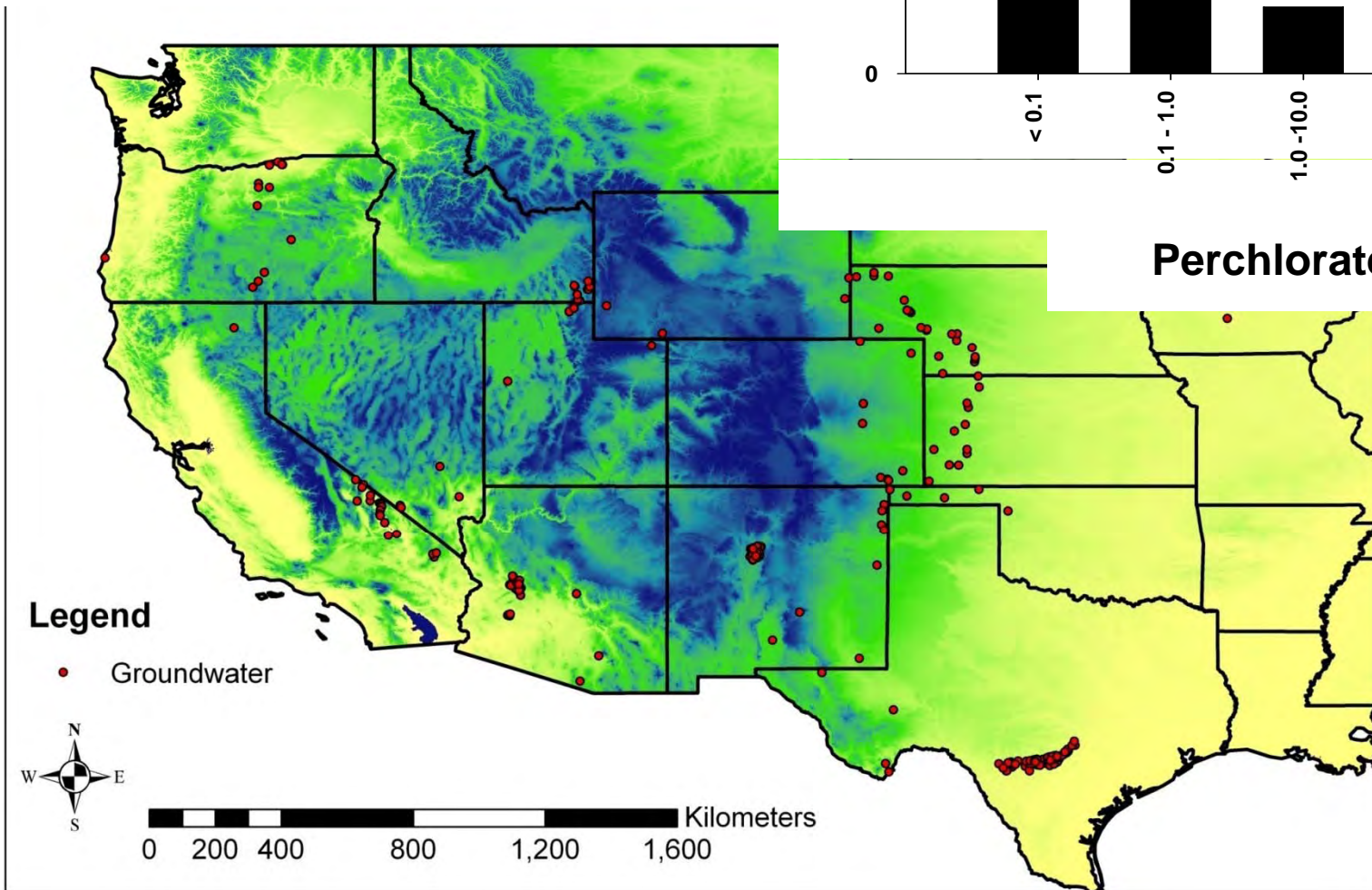
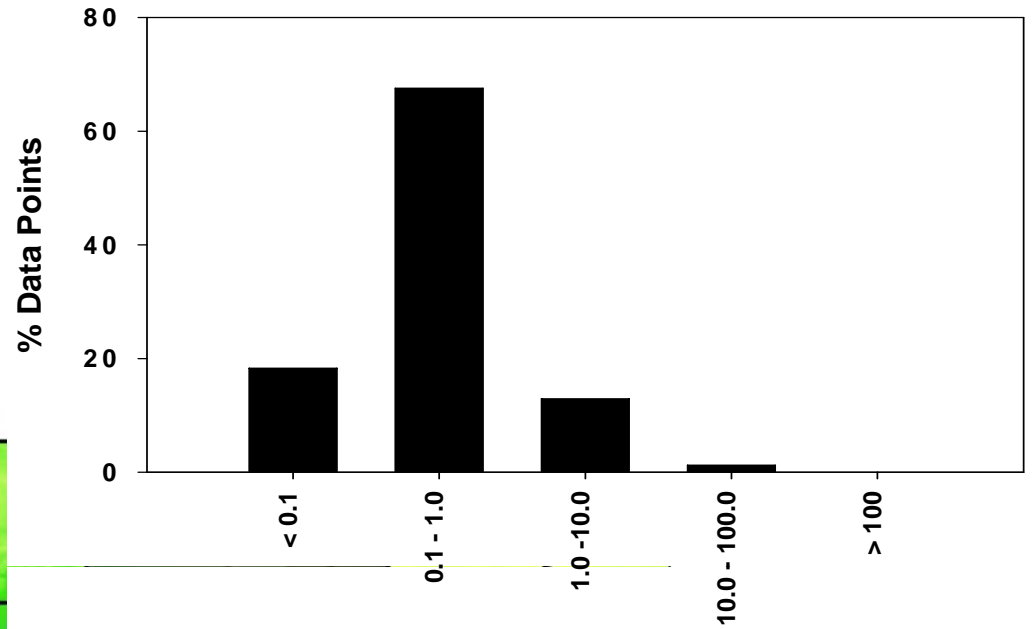


Atmospheric Deposition

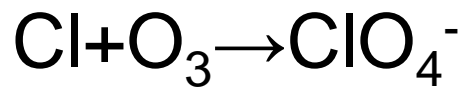
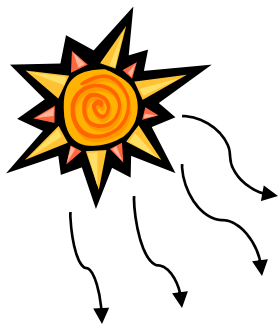
- N = 1578
- Concentration = 14 ng/l \pm 13
- Deposition = 64 mg/ha-y \pm 35



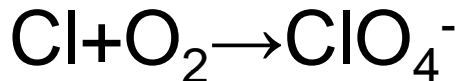
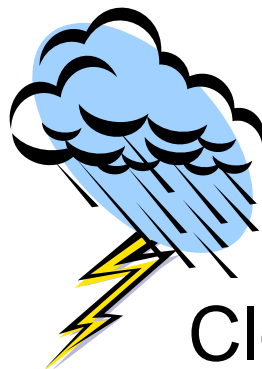
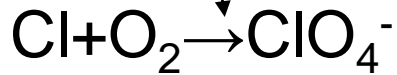
Distribution of Perchlorate in Groundwater



Conceptual Model



μV



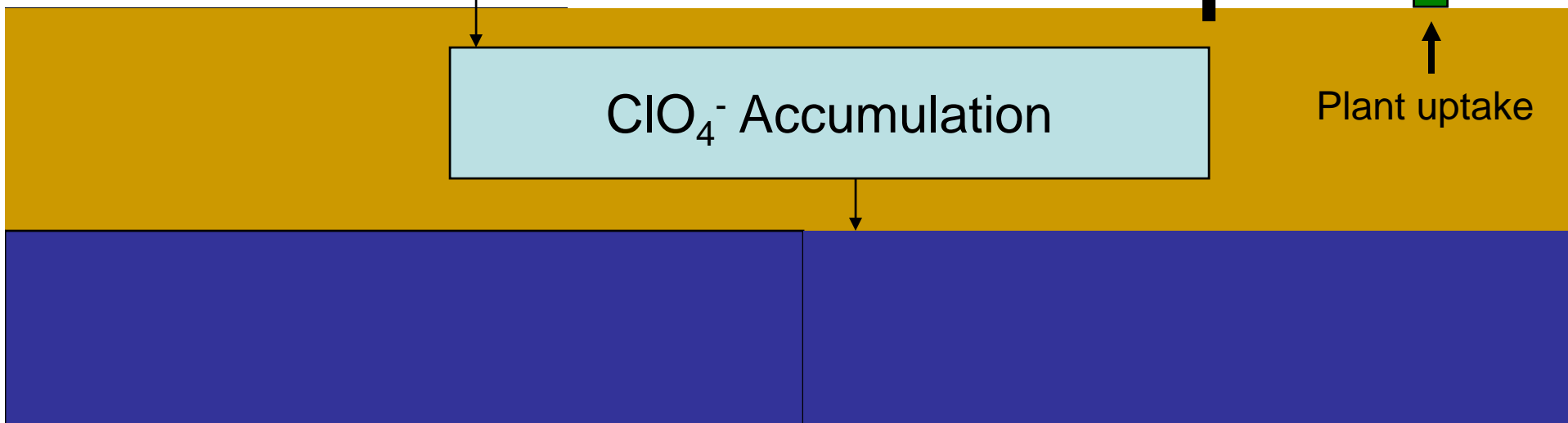
Evapotranspiration

Deposition Dry & Wet

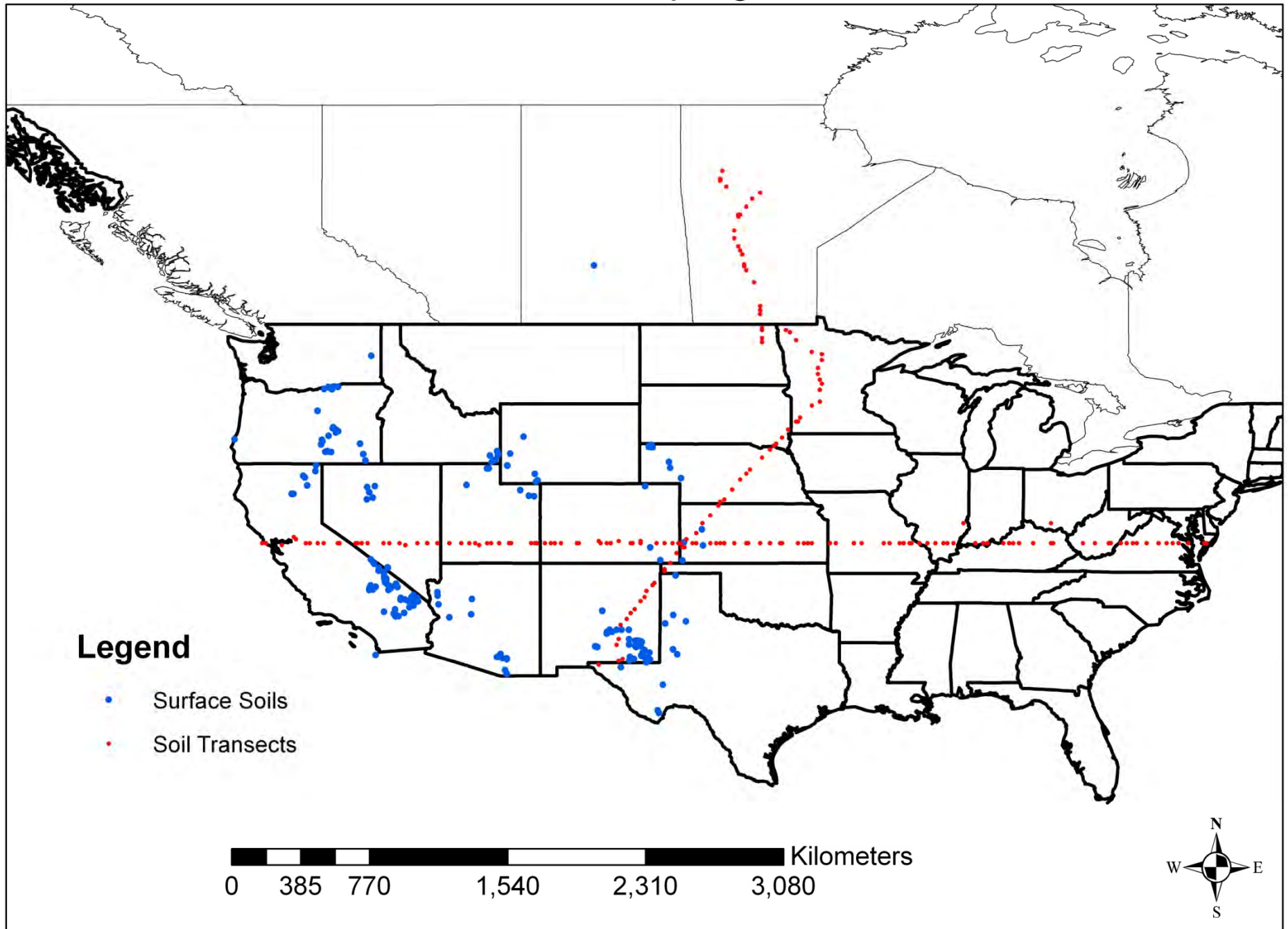
ClO_4^- Accumulation



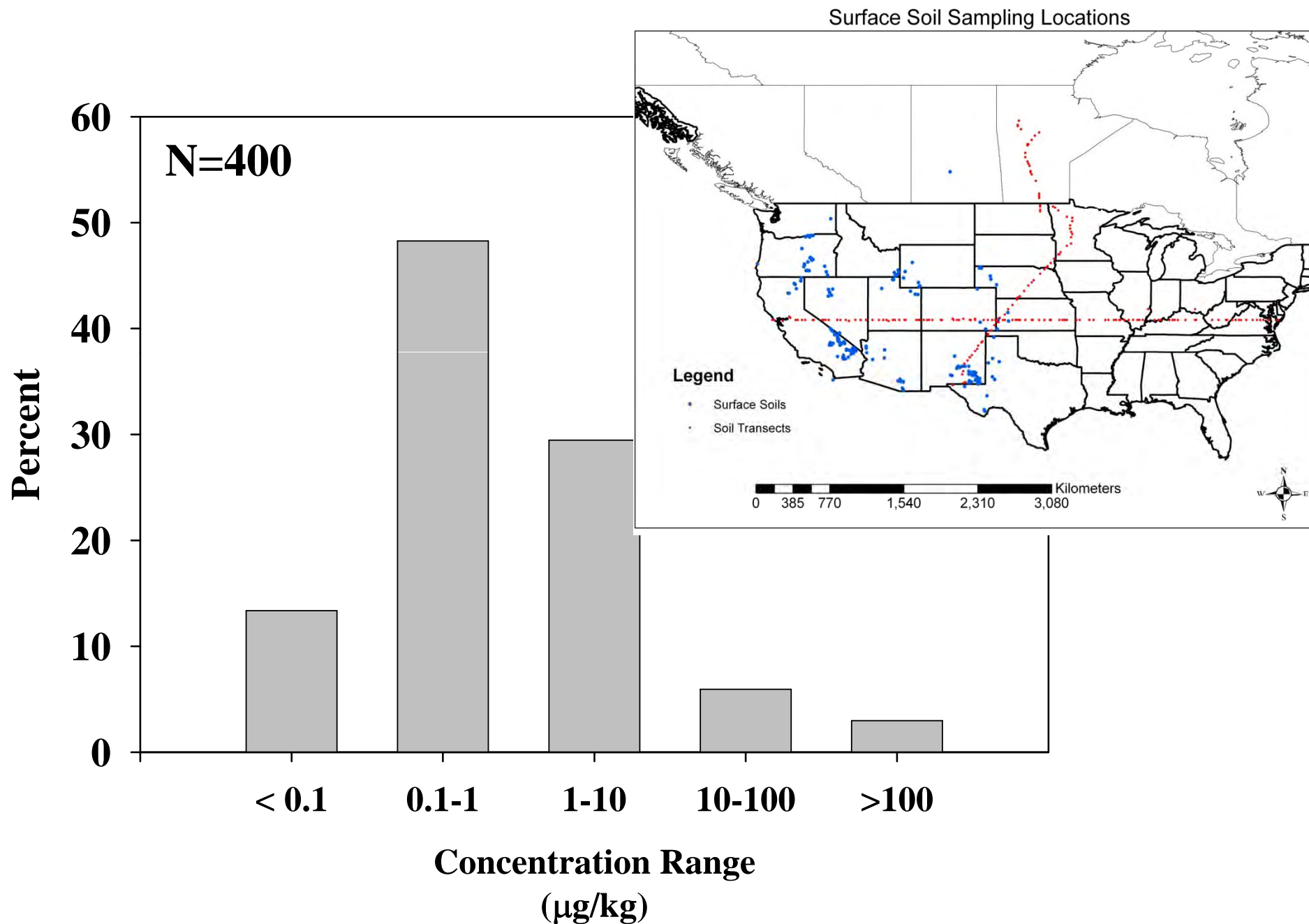
Plant uptake



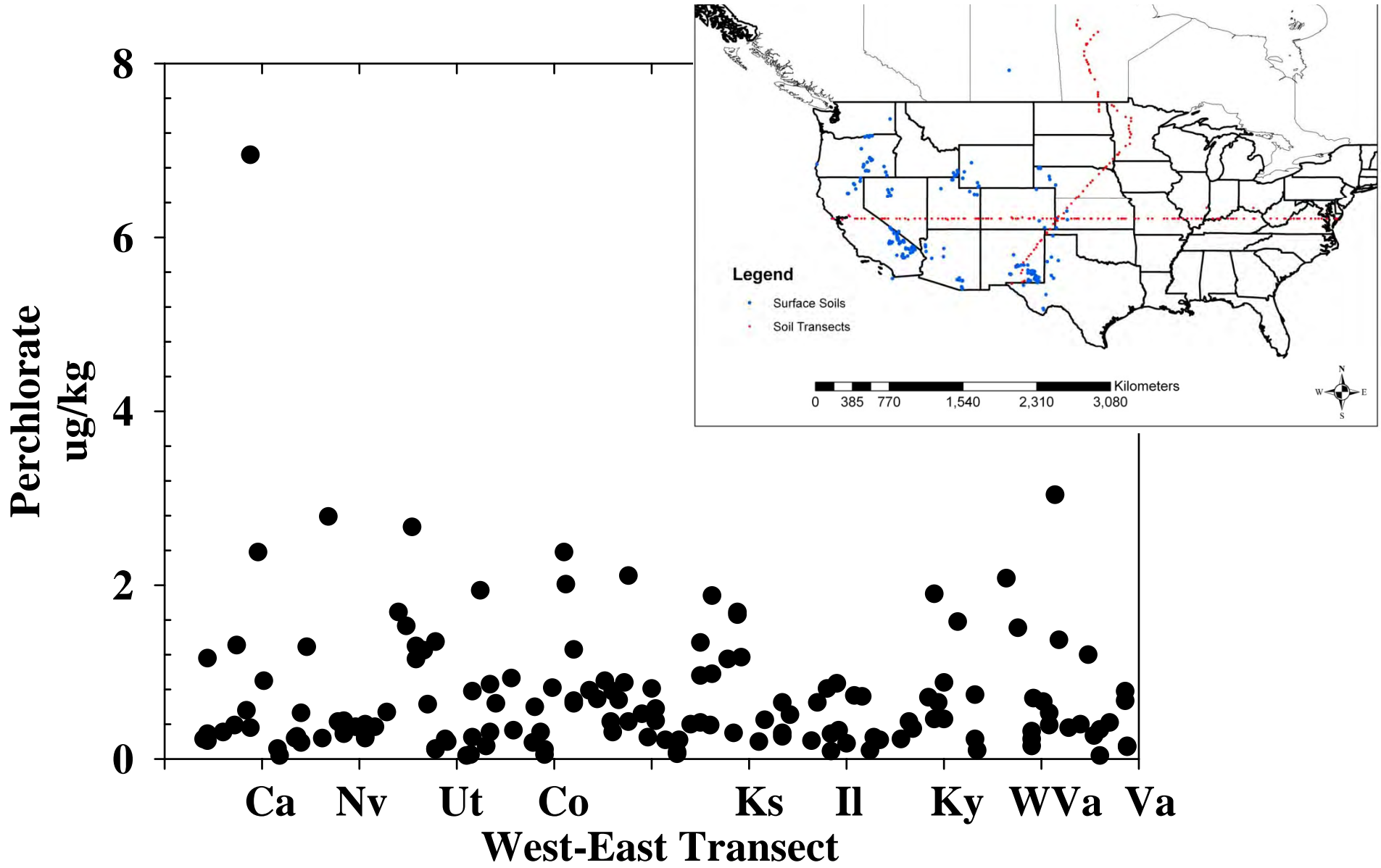
Surface Soil Sampling Locations



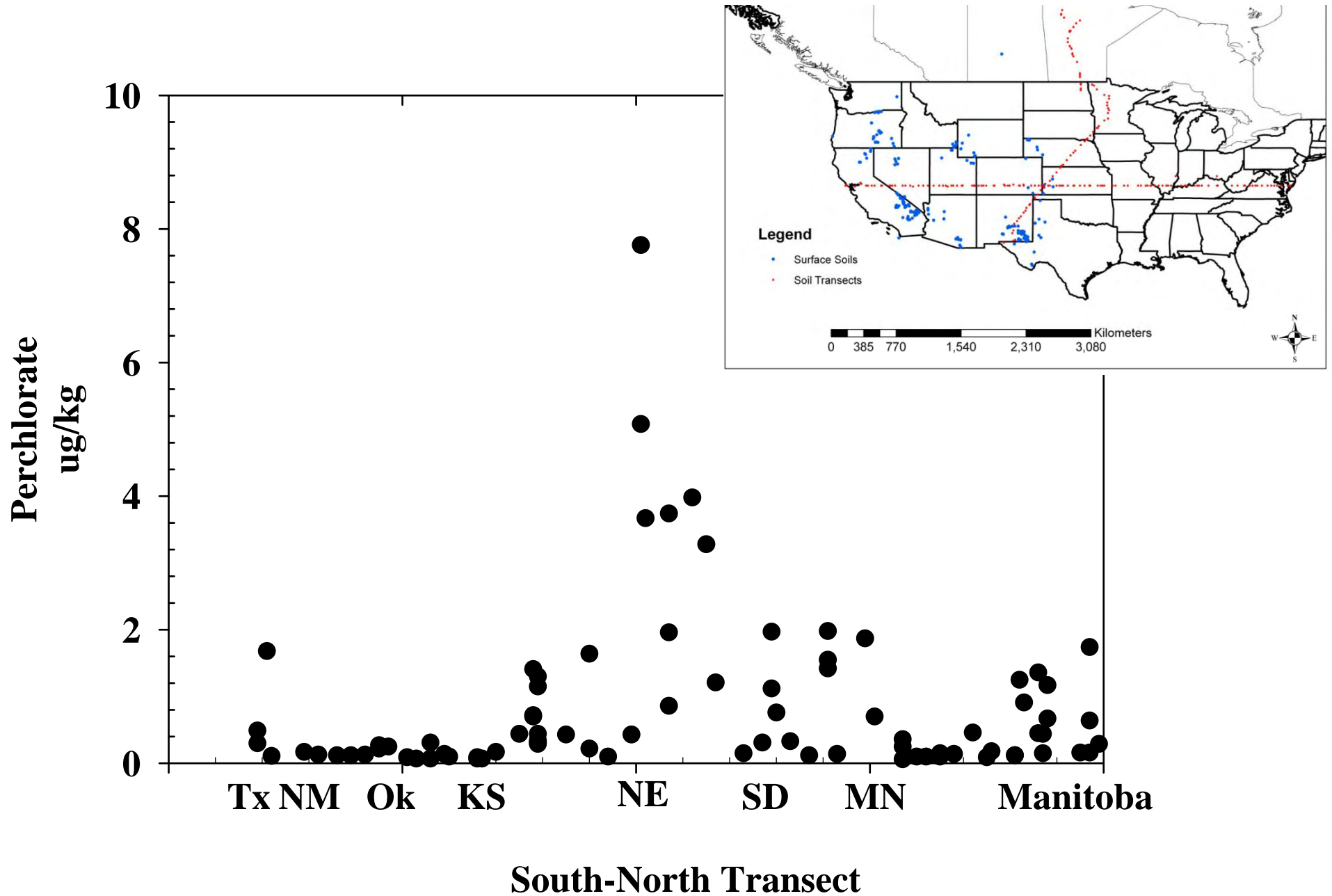
Concentration Distribution for Western Surface Soils



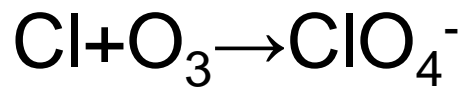
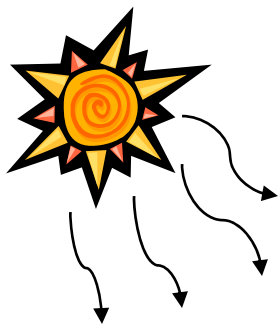
Concentration Distribution for East West Transect Surface Soils



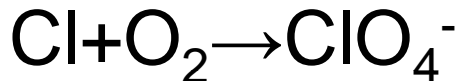
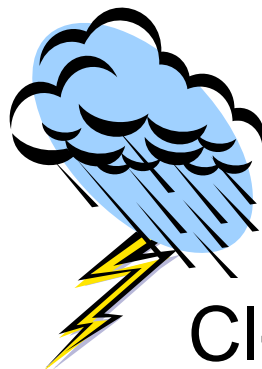
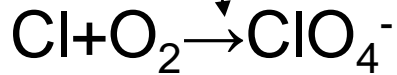
Concentration Distribution for North-South Transect Surface Soils



Conceptual Model



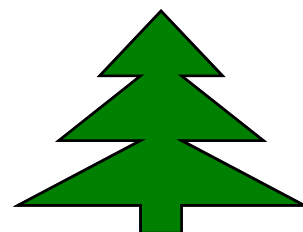
μV



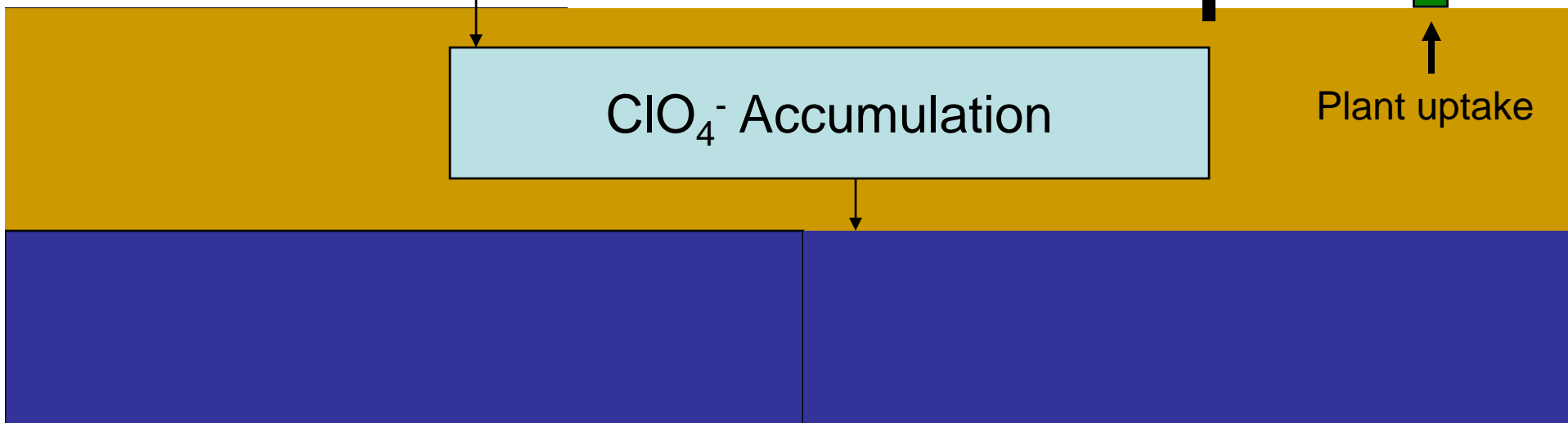
Evapotranspiration

Deposition Dry & Wet

ClO_4^- Accumulation



Plant uptake



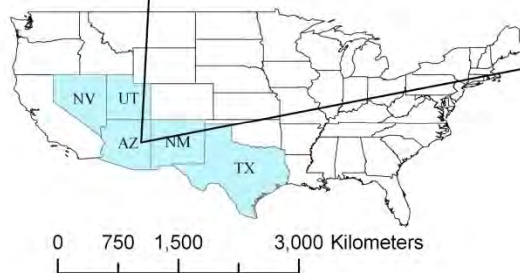
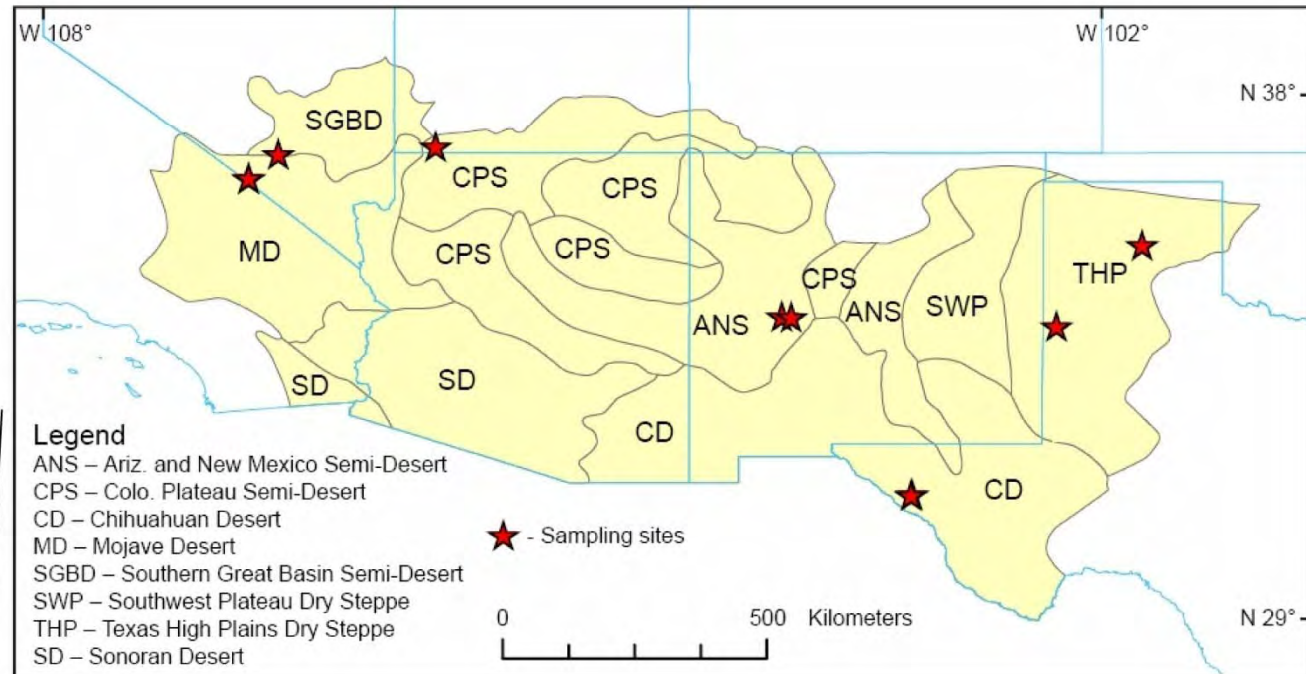
Perchlorate Accumulations in the Vadose Zone

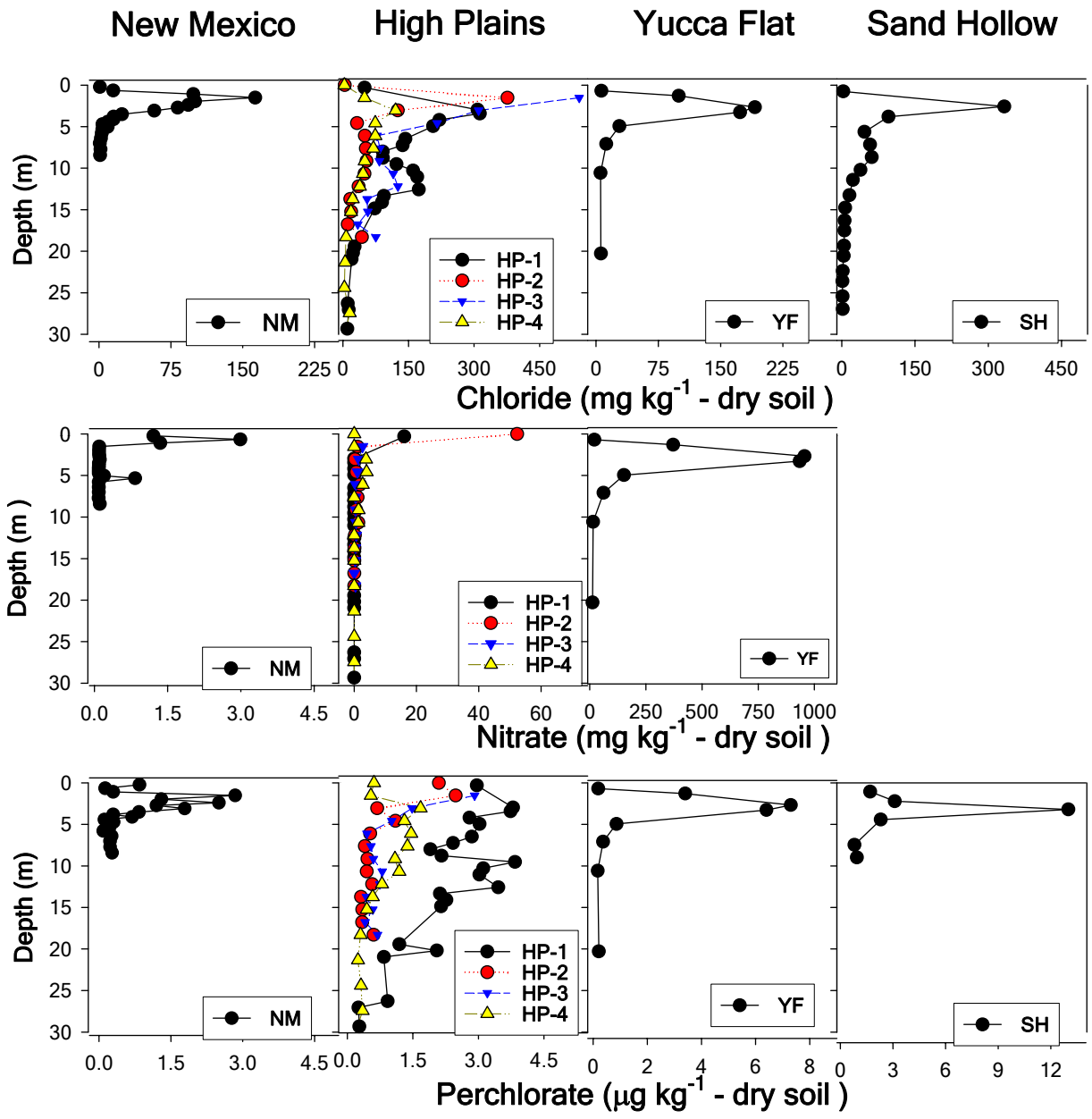
(ES&T, 2007)

Unsaturated

Soil

Profiles

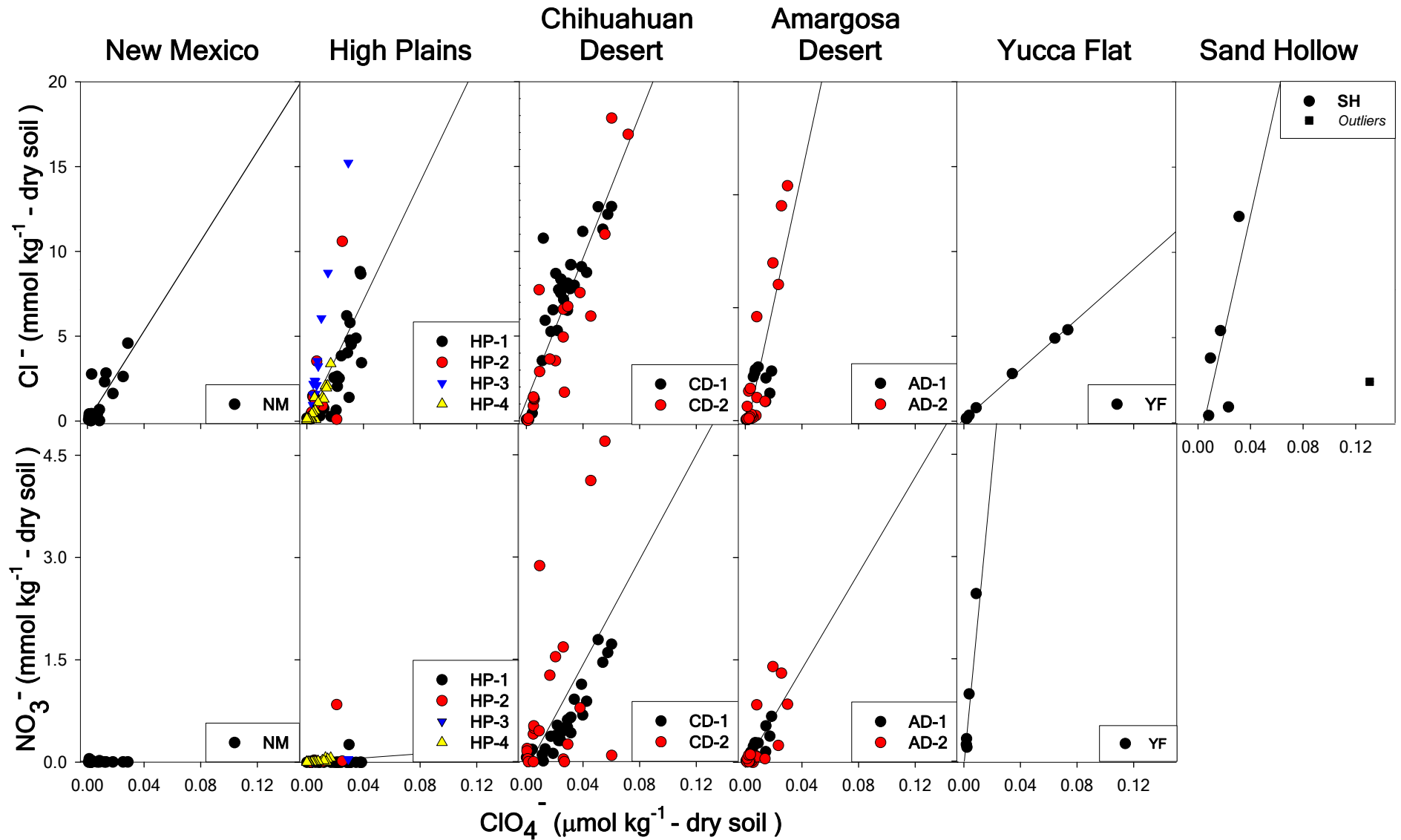




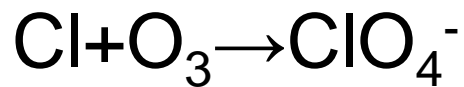
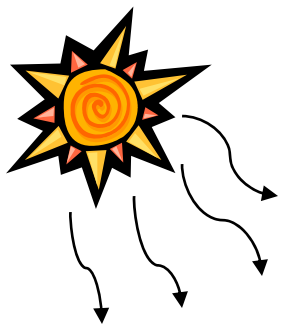
ClO₄⁻ Occurrence Vadose Zone



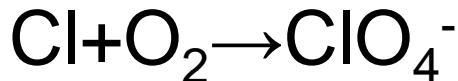
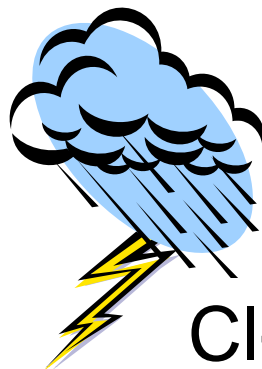
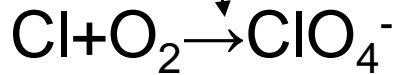
Relationship Between Perchlorate Accumulation and Chloride or Nitrate Accumulation



Conceptual Model



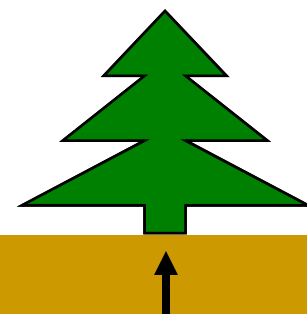
μV



Evapotranspiration

Deposition Dry & Wet

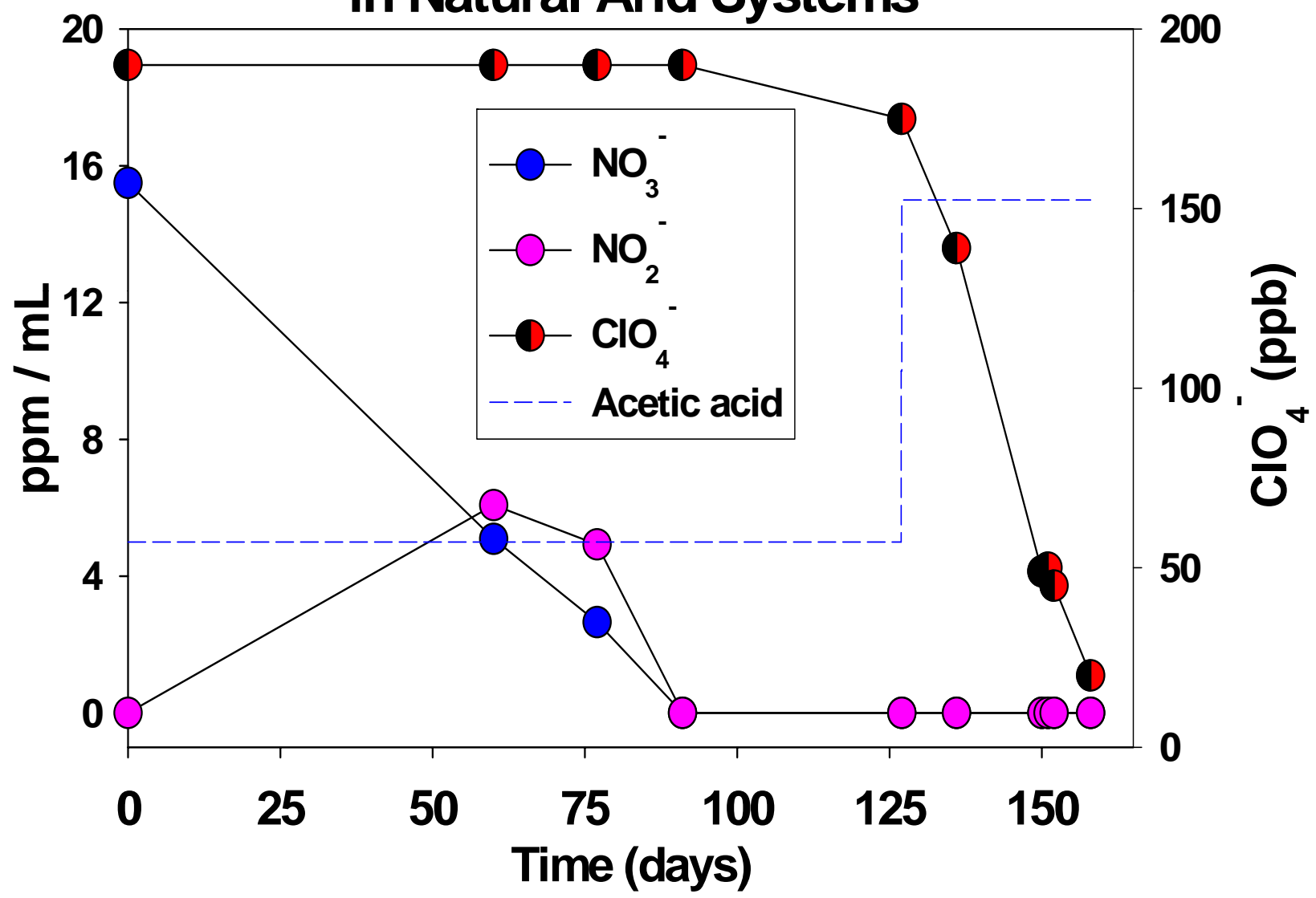
ClO_4^- Accumulation



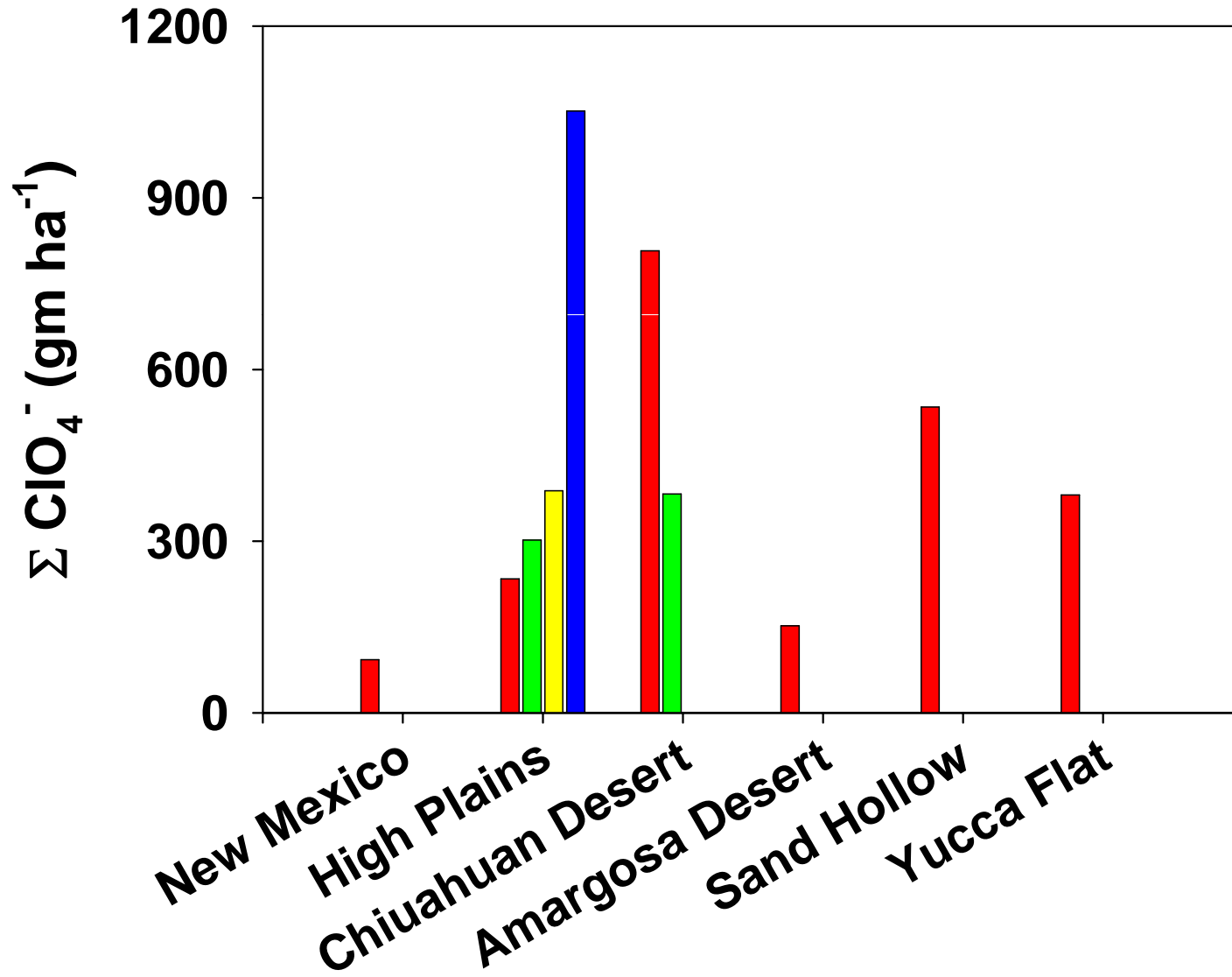
Plant uptake



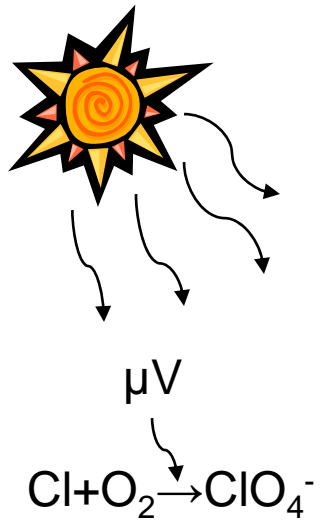
Impact of NO_3^- on ClO_4^- Degradation in Natural Arid Systems



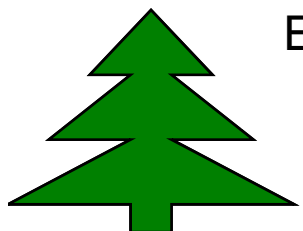
ClO_4^- Accumulation at Study Sites



Conceptual Model



Land Use Change



Evapotranspiration

Deposition
Dry & Wet

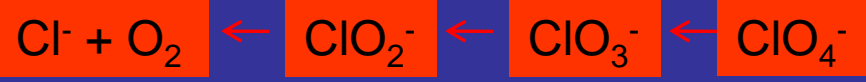
Evapotranspiration

Re-concentration

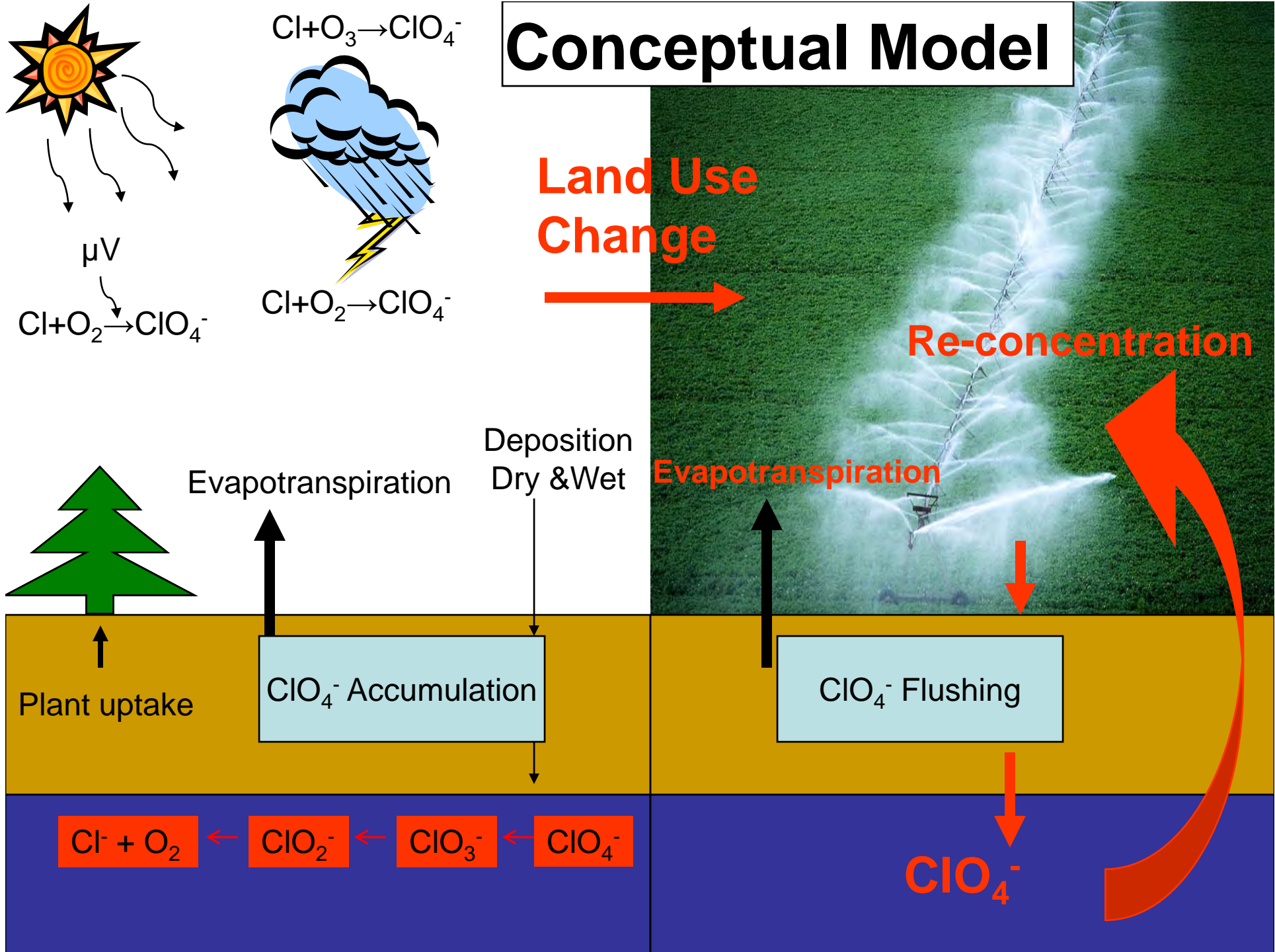
Plant uptake

ClO_4^- Accumulation

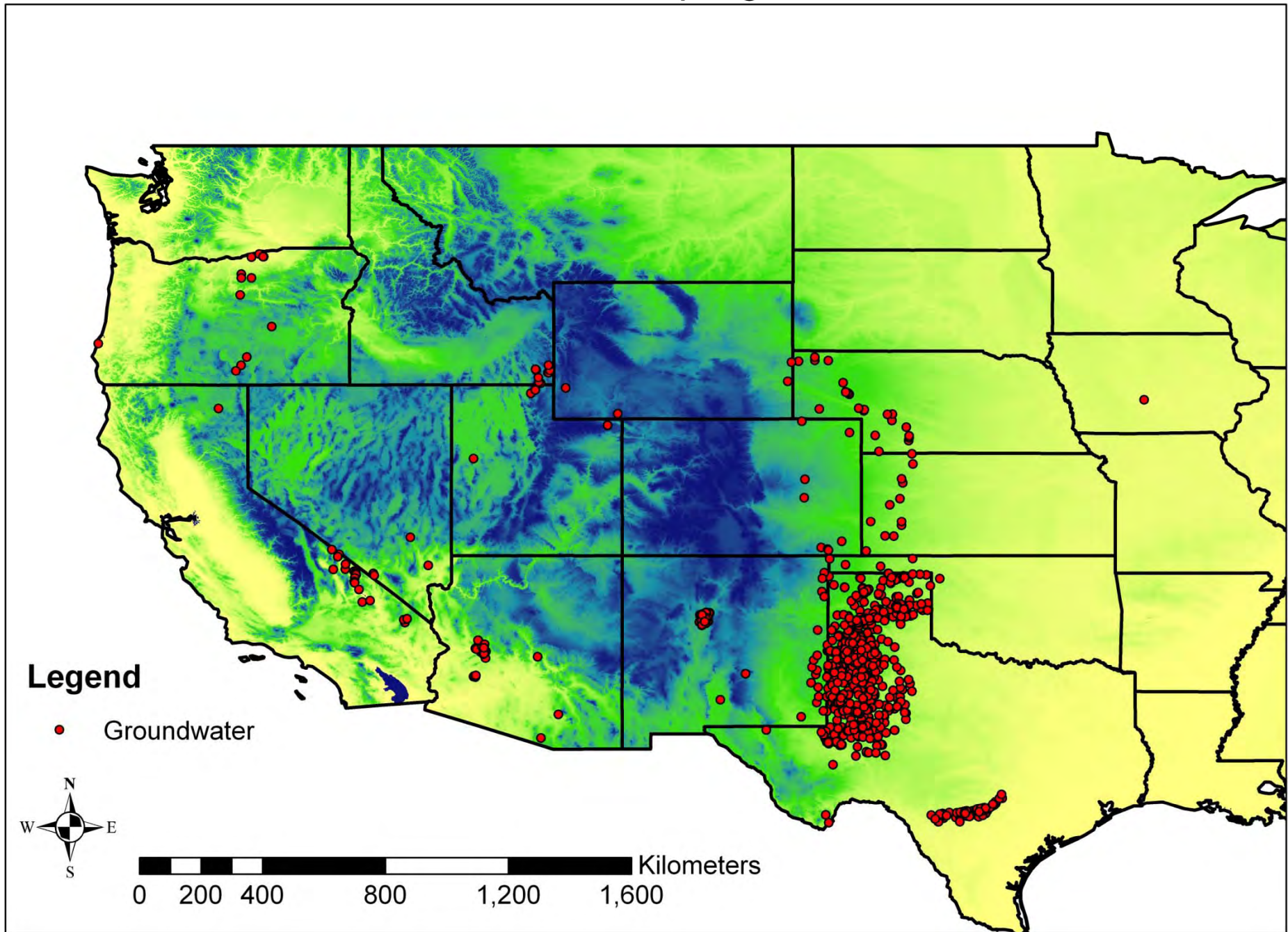
ClO_4^- Flushing



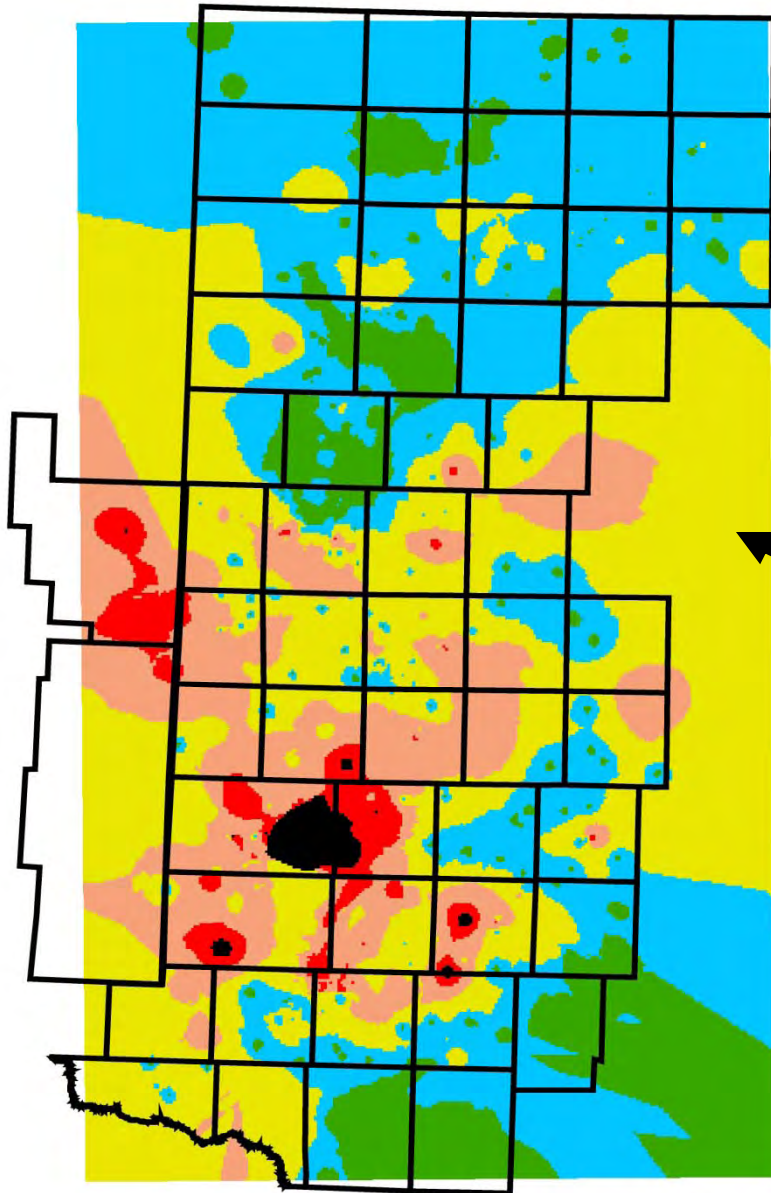
ClO_4^-



Groundwater Sampling Locations



Perchlorate Plume



0 20 40 80 120 160 Miles

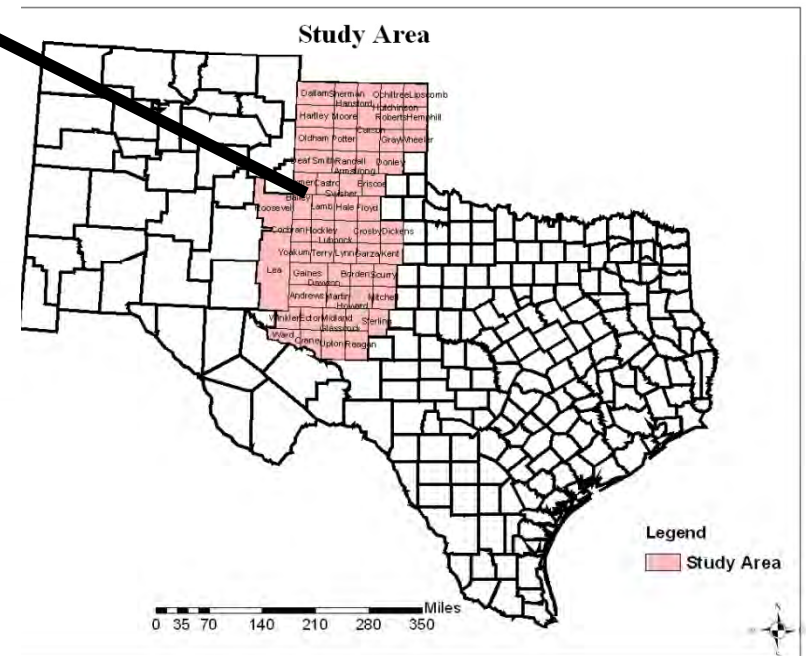
Legend

PC Plume (ppb)



Other Suspected Natural Occurrences ES&T 2006

- Study area >59,000 mi²
- 89% > 0.1 ppb
- Estimated Mass of PC
 - Saturated >2 X 10⁶ Kg



0 35 70 140 210 280 350 Miles

Legend
Study Area



Implications to Site Assessment

- In pristine areas ground water unlikely to be impacted.
- Artificial recharge can produce groundwater spikes.
- Surface soils in arid areas often appear impacted.
- Evaluation of co-occurring anions or stable isotopic evaluation can differentiate.