Application of reactive transport models to scale-up in waste rock

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BC-MEND ML/ARD

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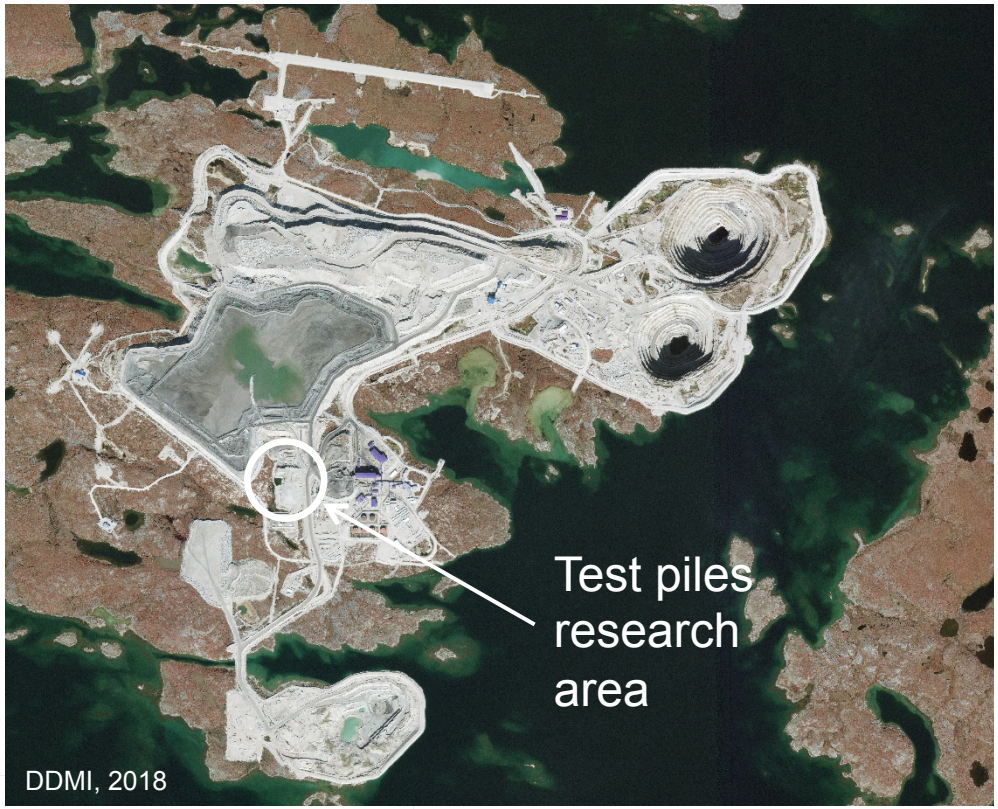
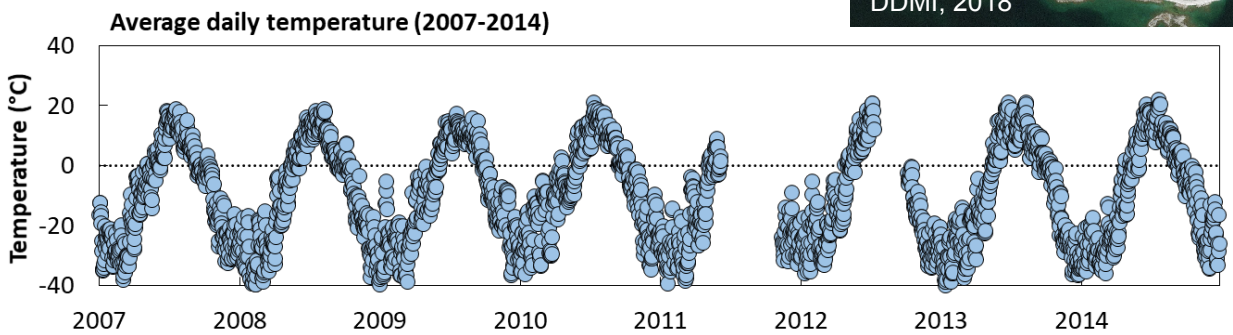
Site location





Zone of continuous permafrost
MAAT ~-9°C

Test piles research facility

Active Zone Lysimeters

Covered Test Pile
3 m Type I
1.5 m Till
Type III core
0.082 wt. % S

Type I
Test Pile
0.035 wt.% S.

Type III
Test Pile
0.053 wt.% S.

Test piles research

Laboratory humidity cell experiments

- 18 cold temperature
- 18 room temperature

Instrumented full-scale waste rock pile

- 4 x 40 m vertical drill holes
- 1 x 80 m vertical drill hole
- horizontal instrument string

Mechanistic scale-up

Humidity Cells

0.1 m (1 kg)

Active Zone Lysimeters

2 m (9,300 kg)

Test Piles

15 m (8.2 x 10^7 kg)

80 m (1.2 x 10^{11} kg)

Develop an integrated conceptual model of sulfide waste rock weathering for laboratory experiments that can be scaled to assess the geochemical evolution of a waste rock pile.

Conceptual model

Oxidation by $O_{2(aq)}$:

$$Fe{\downarrow}0.852\ Ni{\downarrow}0.004\ Co{\downarrow}0.001\ S{+}1.9285 O{\downarrow}2(aq) + 0.143\ H{\downarrow}2\ O \rightarrow$$
$$0.852 Fe{\uparrow}2{+} + 0.004 Ni{\uparrow}2{+} + 0.001 Co{\uparrow}2{+} + SO{\downarrow}4{\uparrow}2{-} + 0.286 H{\uparrow}{+}$$

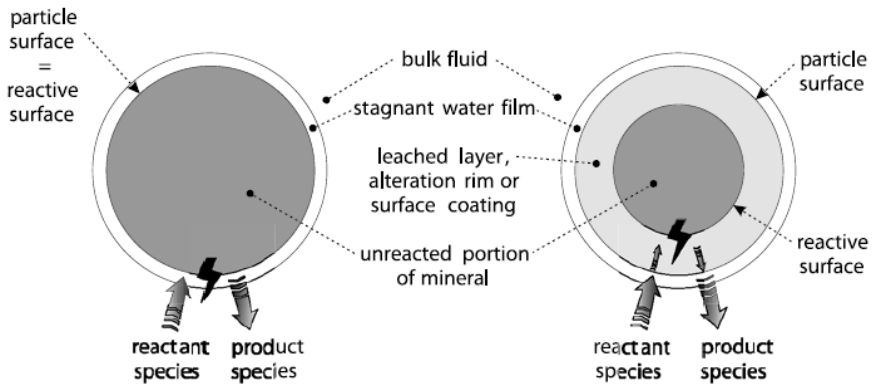
Oxidation by Fe^{3+}:

$$Fe{\uparrow}2{+} + 0.25 O{\downarrow}2(aq) + H{\uparrow}{+} \rightarrow \mathrm{Fe}{\uparrow}3{+} + 0.5 H{\downarrow}2\ O$$

$$Fe{\downarrow}0.852\ Ni{\downarrow}0.004\ Co{\downarrow}0.001\ S{+}1.714 Fe{\uparrow}3{+} \rightarrow$$
$$2.566 Fe{\uparrow}2{+} + 0.004 Ni{\uparrow}2{+} + 0.001 Co{\uparrow}2{+} + S{\uparrow}0$$

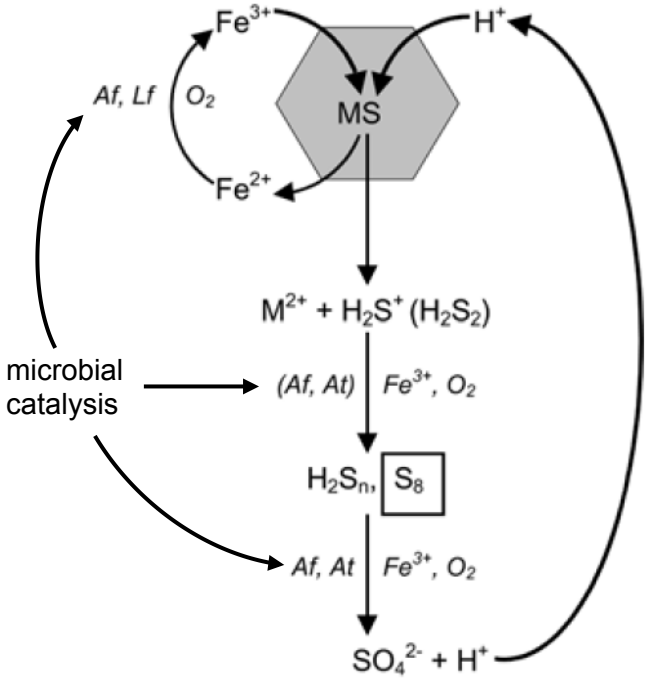
$$S{\uparrow}0 + 1.5 O{\downarrow}2(aq) + H{\downarrow}2\ O \rightarrow SO{\downarrow}4{\uparrow}2{-} + 2 H{\uparrow}{+}$$

sulfide oxidation simulated using shrinking core model



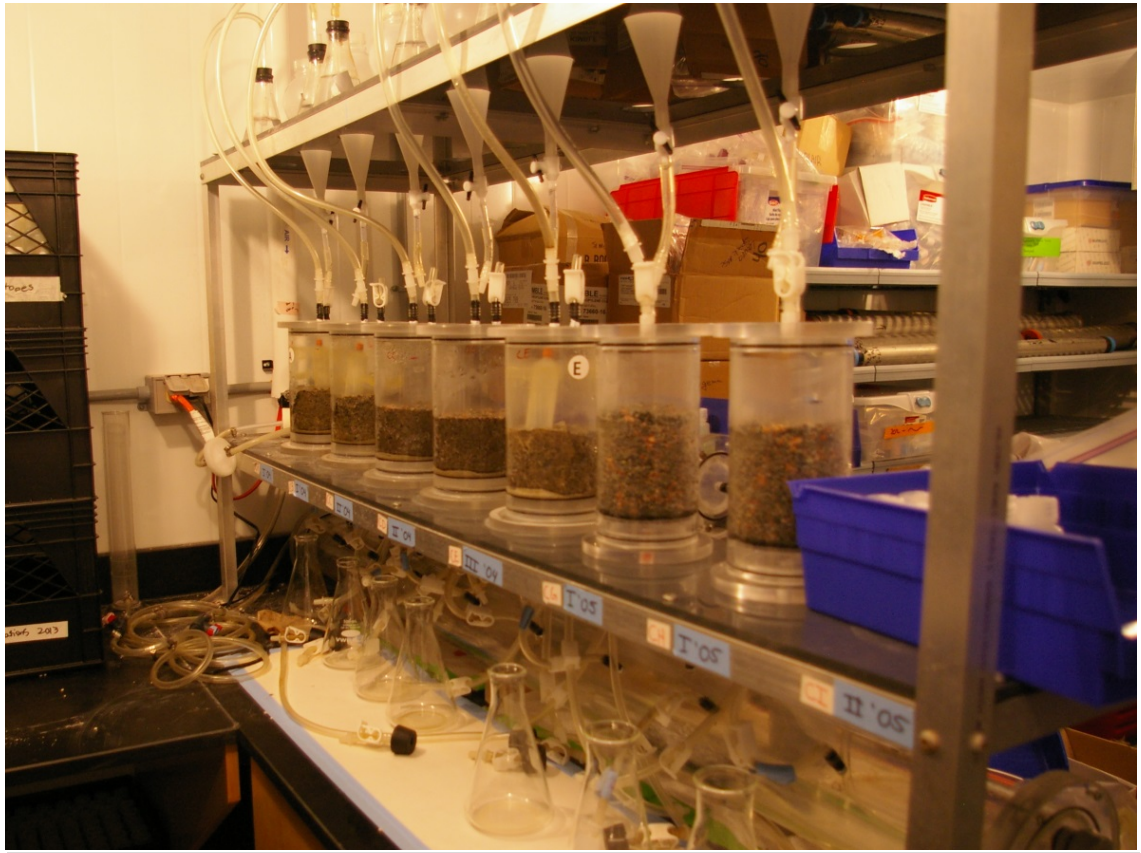
Mayer et al., 2002

polysulfide mechanism of sulfide mineral oxidation



after Schippers and Sand, 1999

Conceptual model – humidity cell



Type	S (wt. %)	Cells
I	0.02	Type I (2004) Type I (2005) Type II (2004)
III	0.18	Type III (2004)

Temperature

Constant: 22 °C or 5 °C

Hydrology

Constant: 500 mL wk^{-1}

Geochemistry

Gas:

- Atmospheric PO_2 , PCO_2

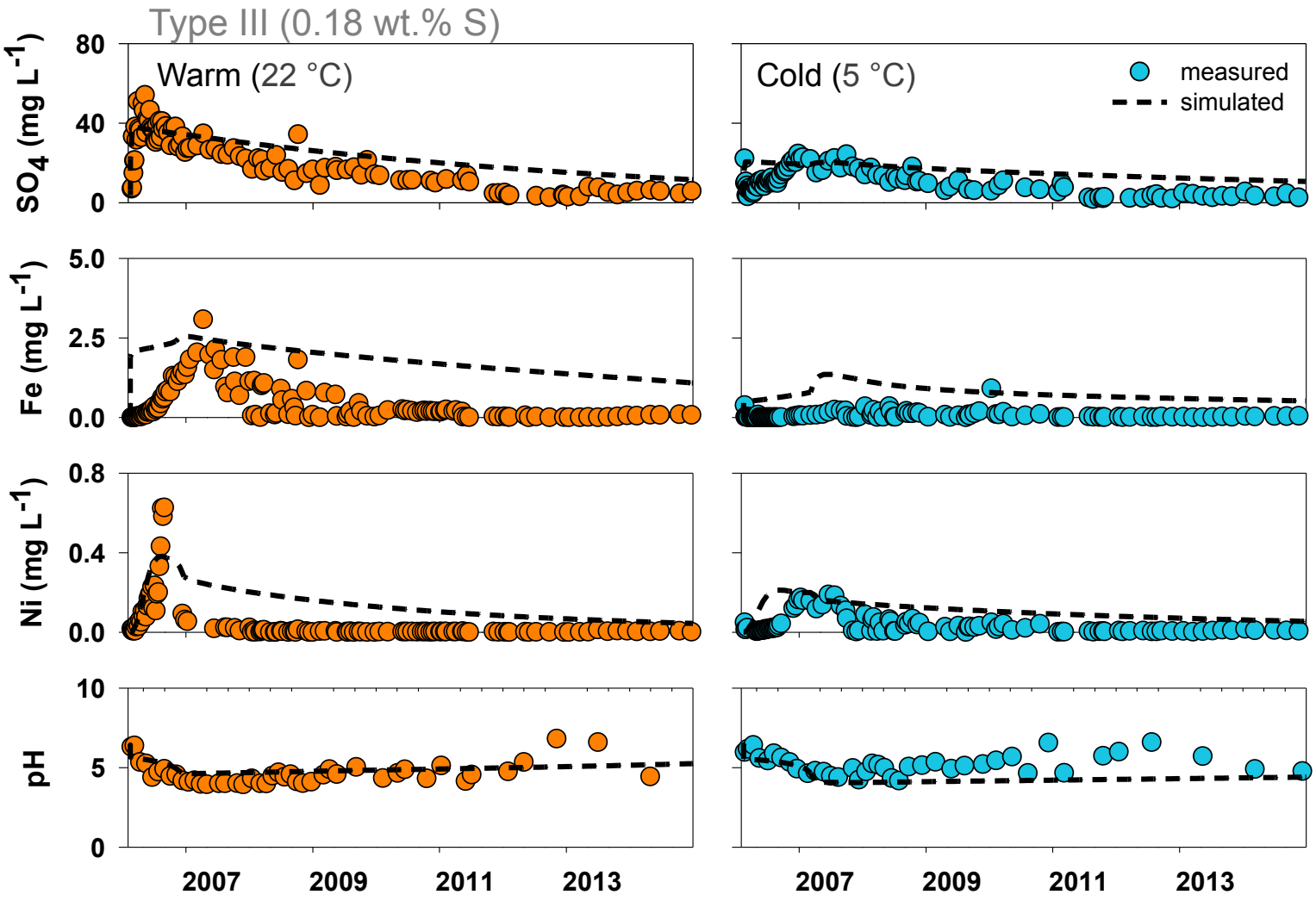
Liquid:

- DI

Solid:

- Sulfides: pyrrhotite, chalcopyrite, sphalerite, pentlandite
- Host: calcite, dolomite, biotite, muscovite, albite
- Secondary: jarosite, ferrihydrite, gibbsite, amorphous silica, gypsum, siderite

Geochemistry – humidity cell



Conceptual model - AZL

Temperature

Temporally variable average daily temperature

Hydrology

Temporally variable FAO-PM calculated infiltration

Constant K_S and soil parameters from characterization of site materials

Geochemistry

Gas:

- Atmospheric P_{O_2} , P_{CO_2}

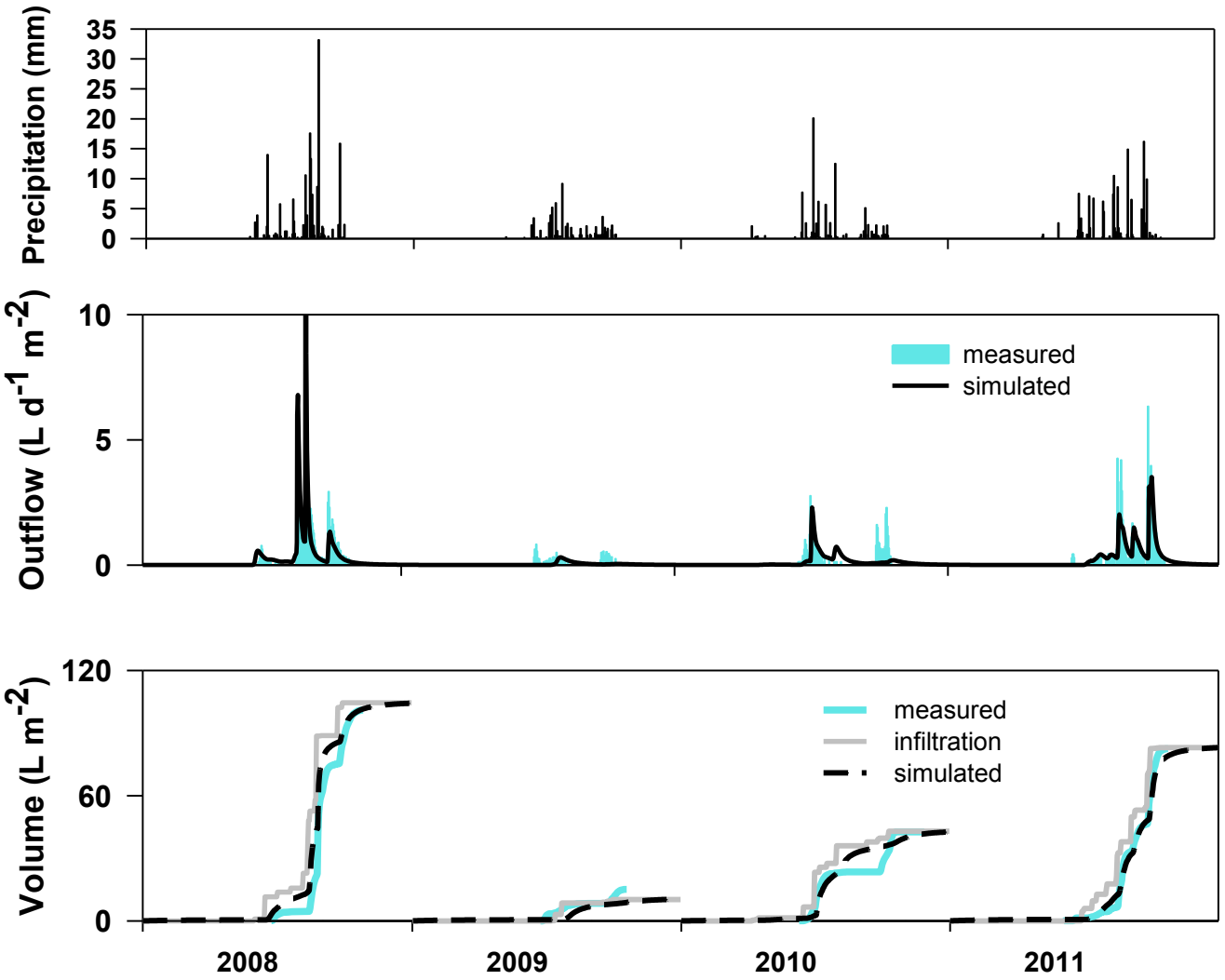
Liquid:

- Site precipitation

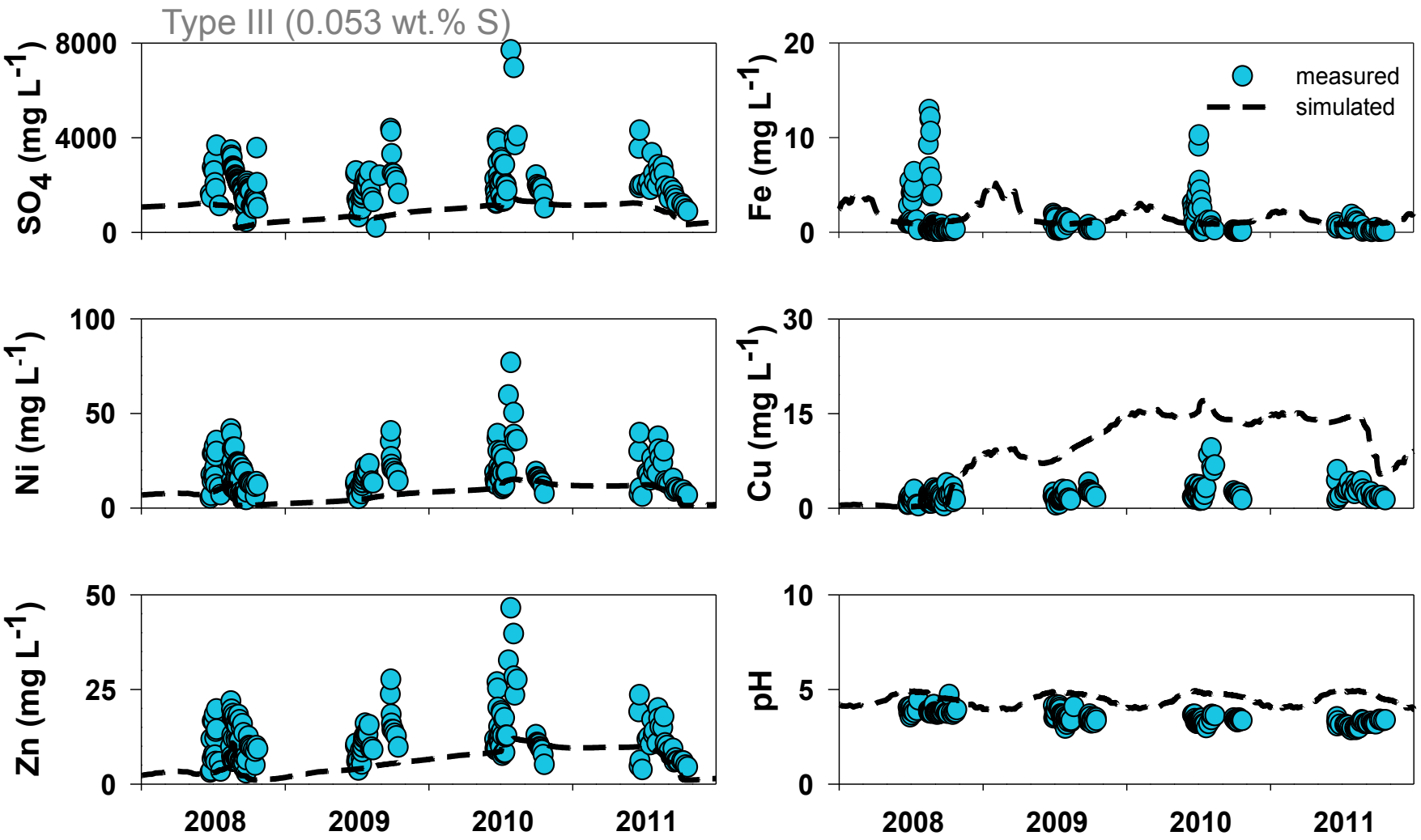
Solid:

- Sulfides: pyrrhotite, chalcopyrite, sphalerite, pentlandite
- Host: calcite, dolomite, biotite, muscovite, albite
- Secondary: jarosite, ferrihydrite, gibbsite, amorphous silica, gypsum, siderite

Flow - AZL



Geochemistry - AZL



Conceptual model – test pile

Temperature

Spatially and temporally variable average daily temperature

Hydrology

Temporally variable FAO-PM calculated infiltration

Constant K_S and soil parameters from characterization of site materials

Geochemistry

Gas:

- Atmospheric P_{O_2} , P_{CO_2}

Liquid:

- Site precipitation

Solid:

- Sulfides: pyrrhotite, chalcopyrite, sphalerite, pentlandite
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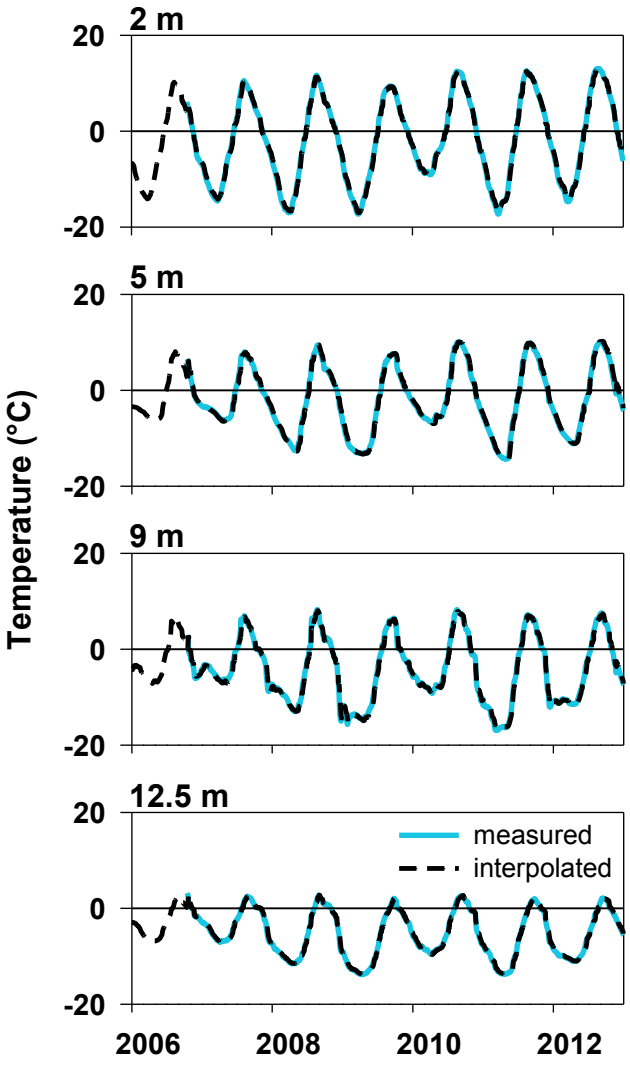
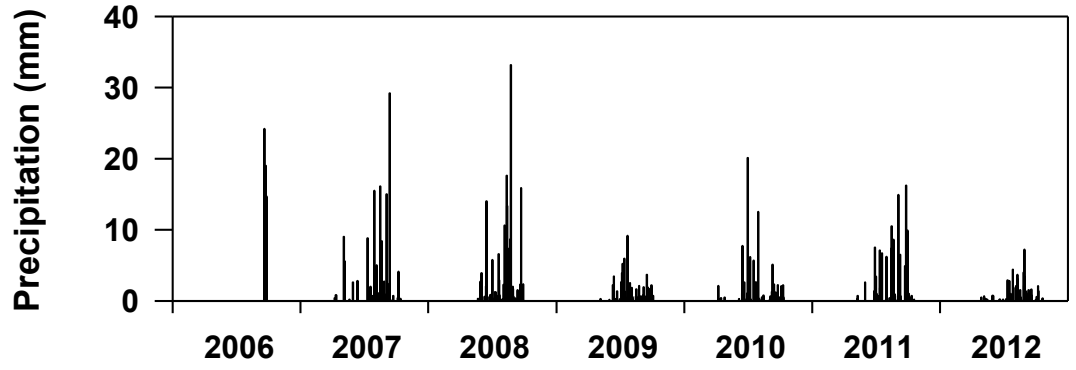
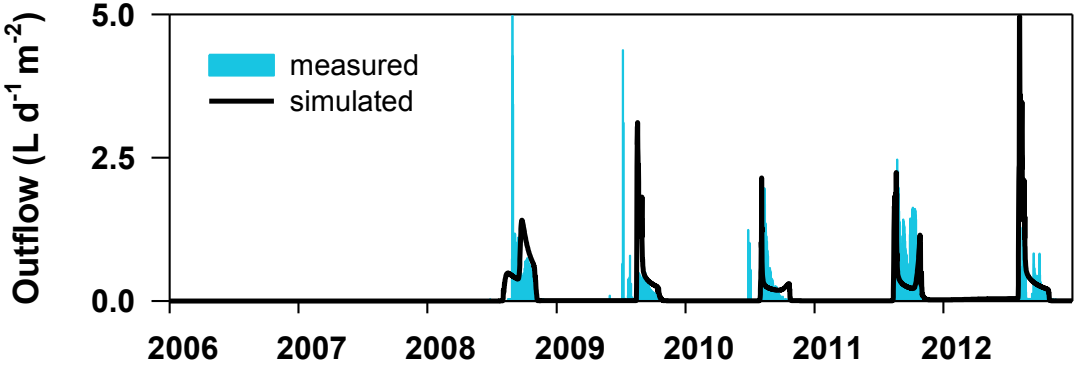
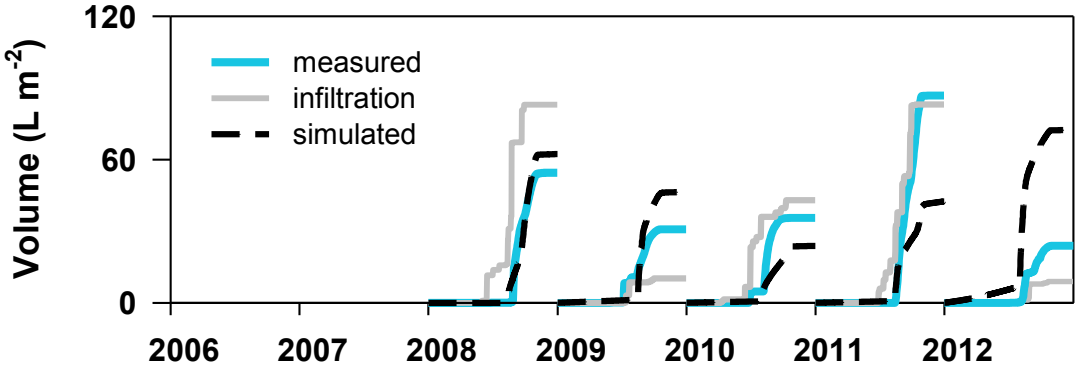
Flow – test pile

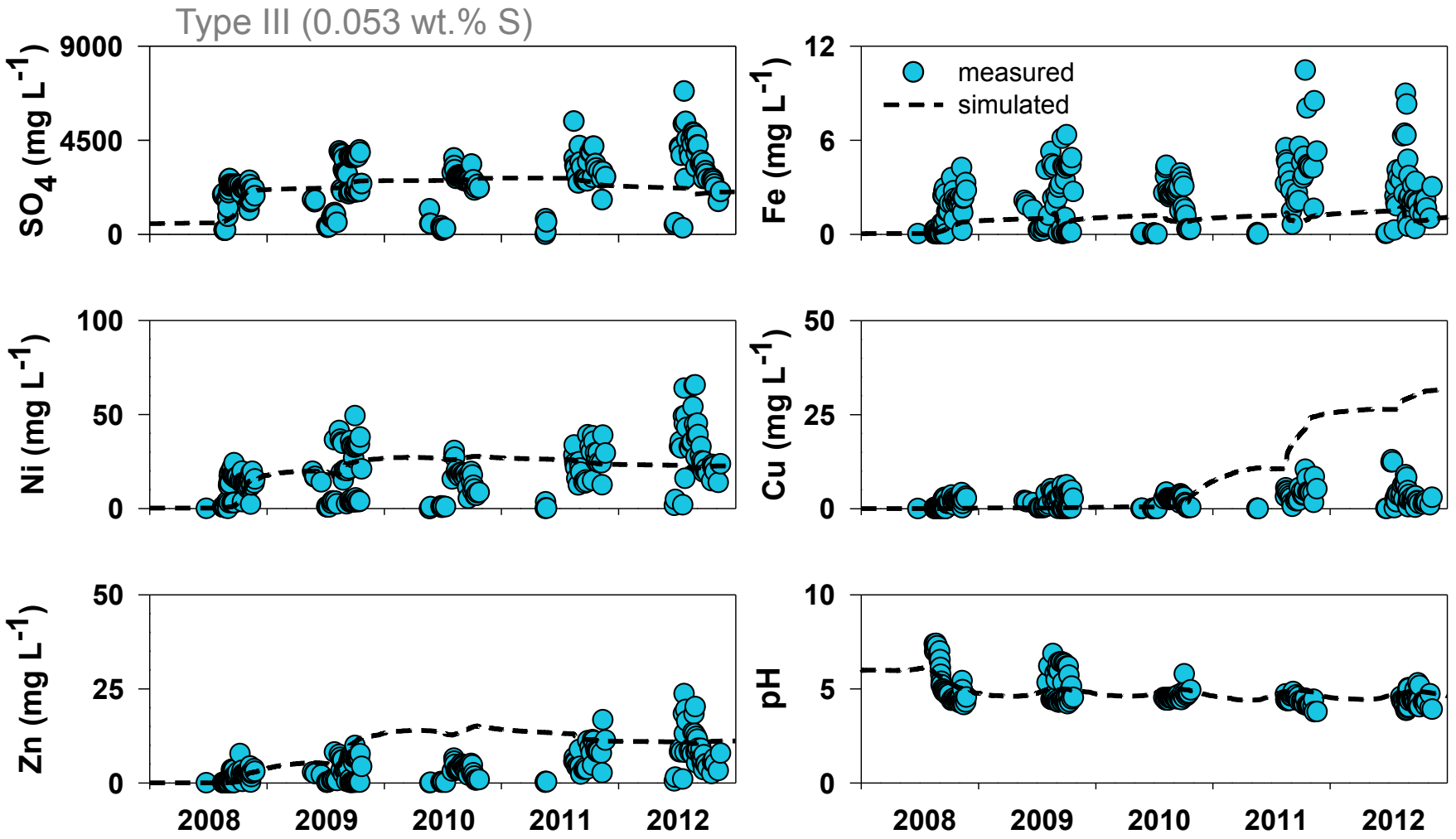




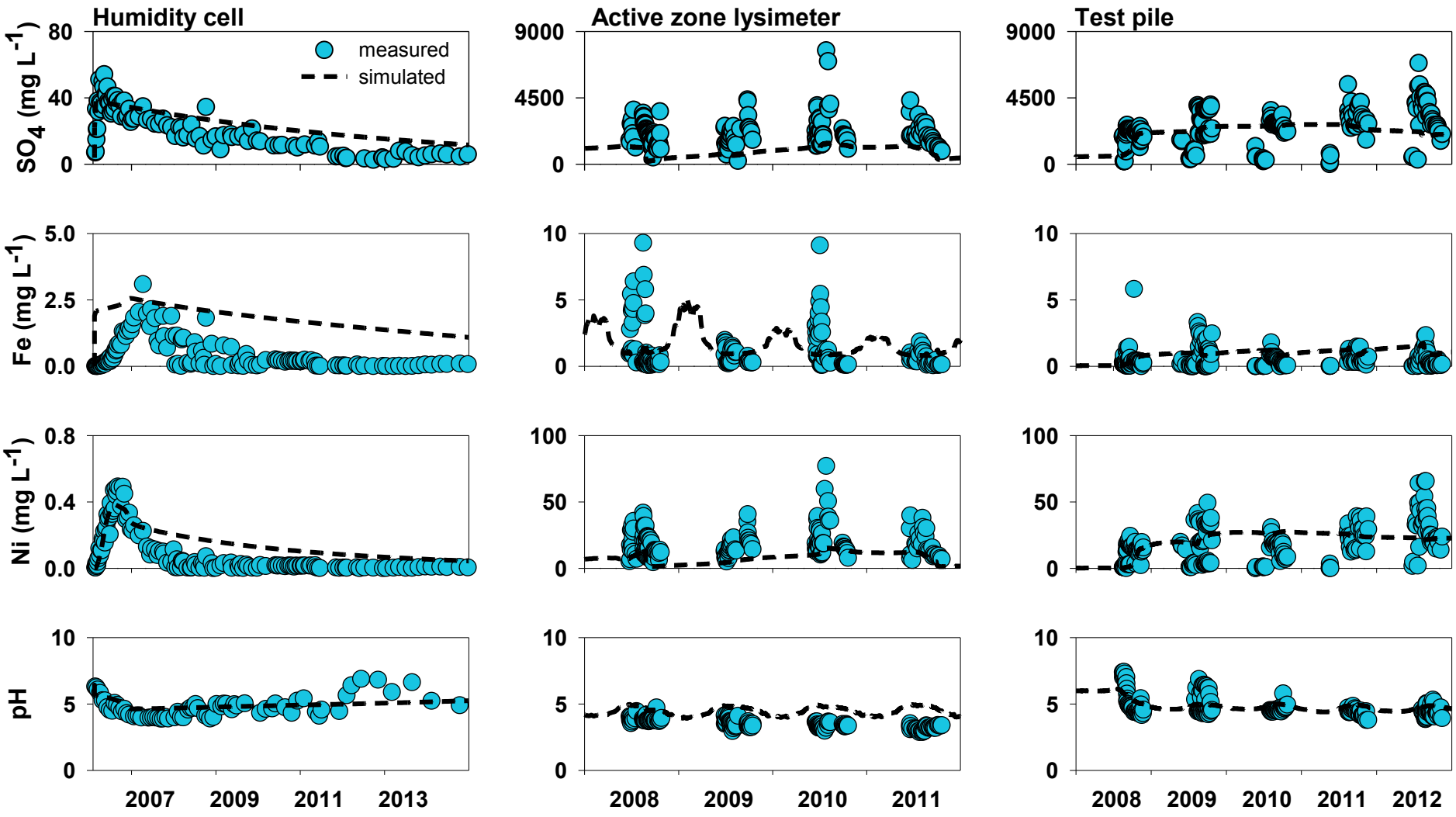




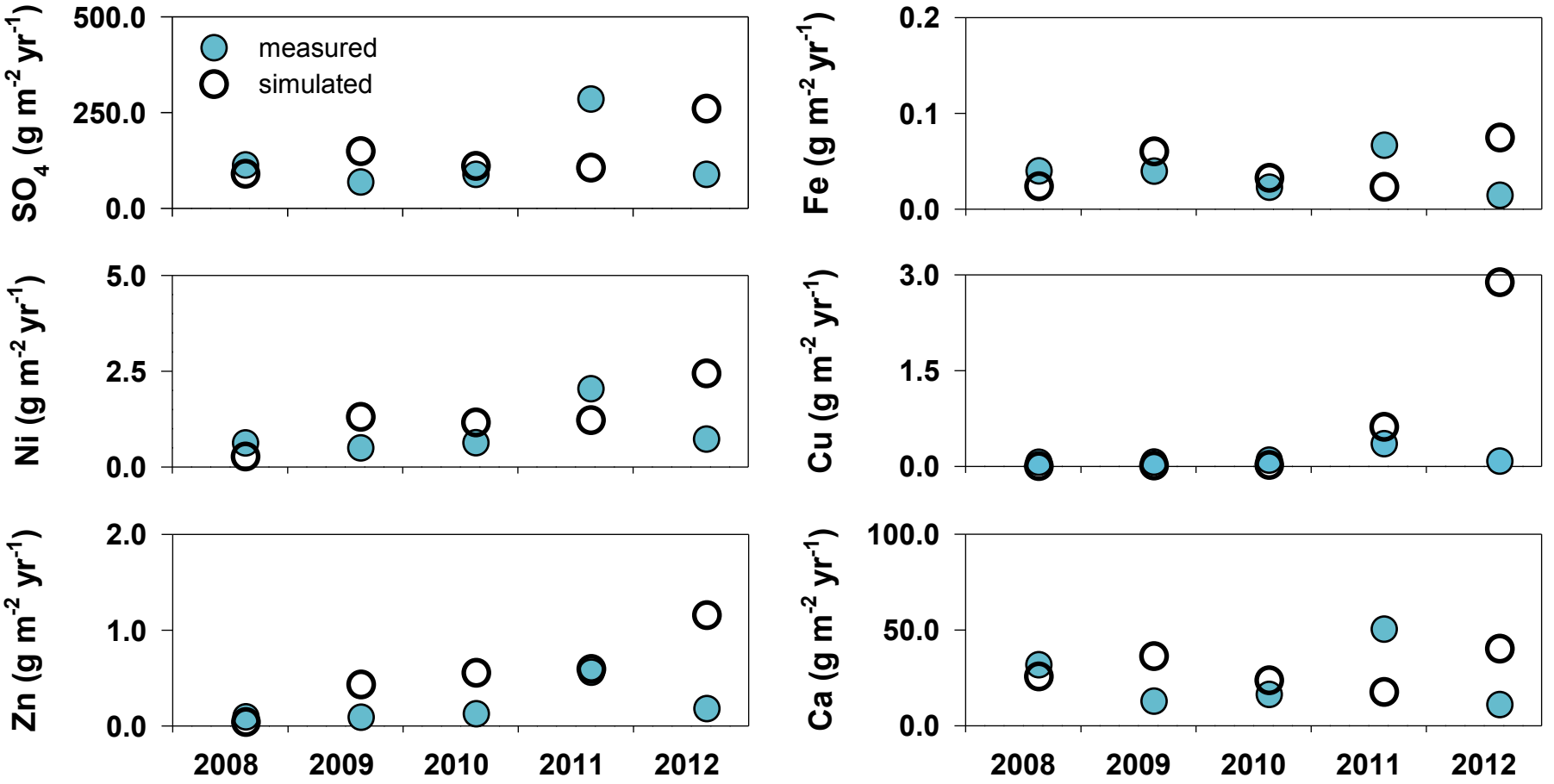
Geochemistry – test pile



Geochemistry - summary



Annual mass flux – test pile



Conclusions

Development of conceptual model of geochemical evolution for sulfide, host, and secondary minerals at the laboratory scale including:

- Assessment of appropriate primary and secondary processes
- Calibration of sulfide and host mineral weathering processes
- Quantification of temperature dependence

Coupling small-scale model with commonly measured parameters:

- S and C content and host mineralogy
- Infiltration and temperature representative of field conditions
- Particle size distribution

Provides a realistic multi-year assessment of the geochemical evolution within a waste rock pile

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References

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