Comparison of Automated versus Manual Mass Measurements

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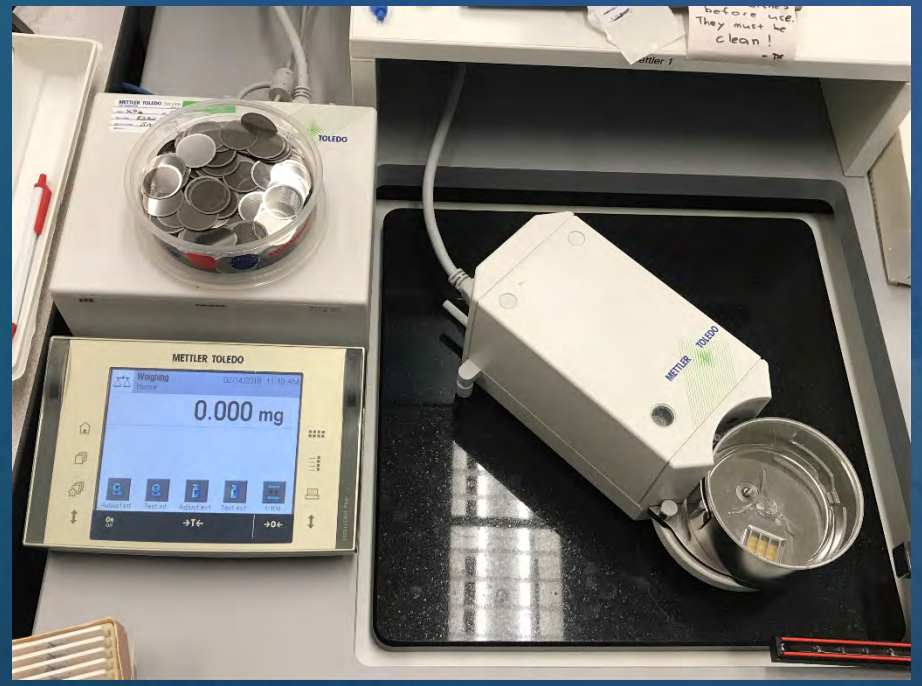
Background and motivation

- Samples may absorb and adsorb water
- EPA procedure for mass measurements* requires
  - RH of 30 – 40%, change <5% over 24 hours
  - Temp of 20-23°C, change <2°C over 24 hours
  - 24 hour equilibration time prior to measurements
- IMPROVE mass measurements
  - Prior to 2018, IMPROVE mass measurements performed manually on a balance in lab environment
  - In 2018, robotic chamber enclosed balance with controlled T & RH for mass measurements implemented

*40 CFR Appendix L to Part 50

Manual vs automated balance setups

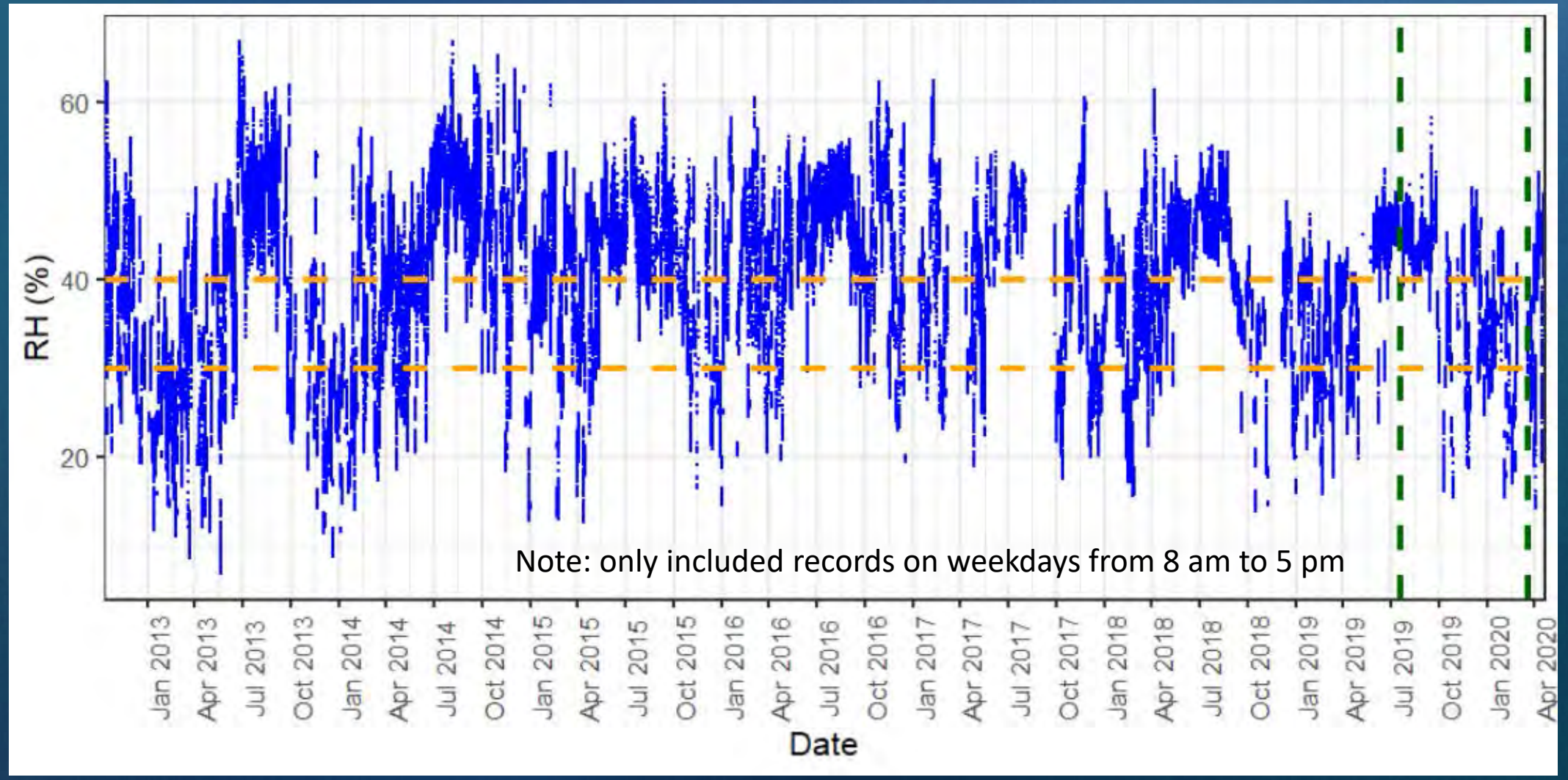


- Since inception through Fall 2018, various balances in various rooms with various HVAC units
- Subject to change in room RH and temperature
- Hereinafter referred to as “manual” balance

- MTH AH500 in service since 2018
- RH controlled 39 % ± 2 %
- Temp controlled 21.5 ± 1 °C
- Minimum 4 hour equilibration time
- 2nd MTL AH500 deployed in 2021
- Hereinafter referred to as “automated” balance

Images from mtlcorp.com and aqrc.ucdavis.edu

AQRC Laboratory RH Historical Records



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Comparative gravimetric study

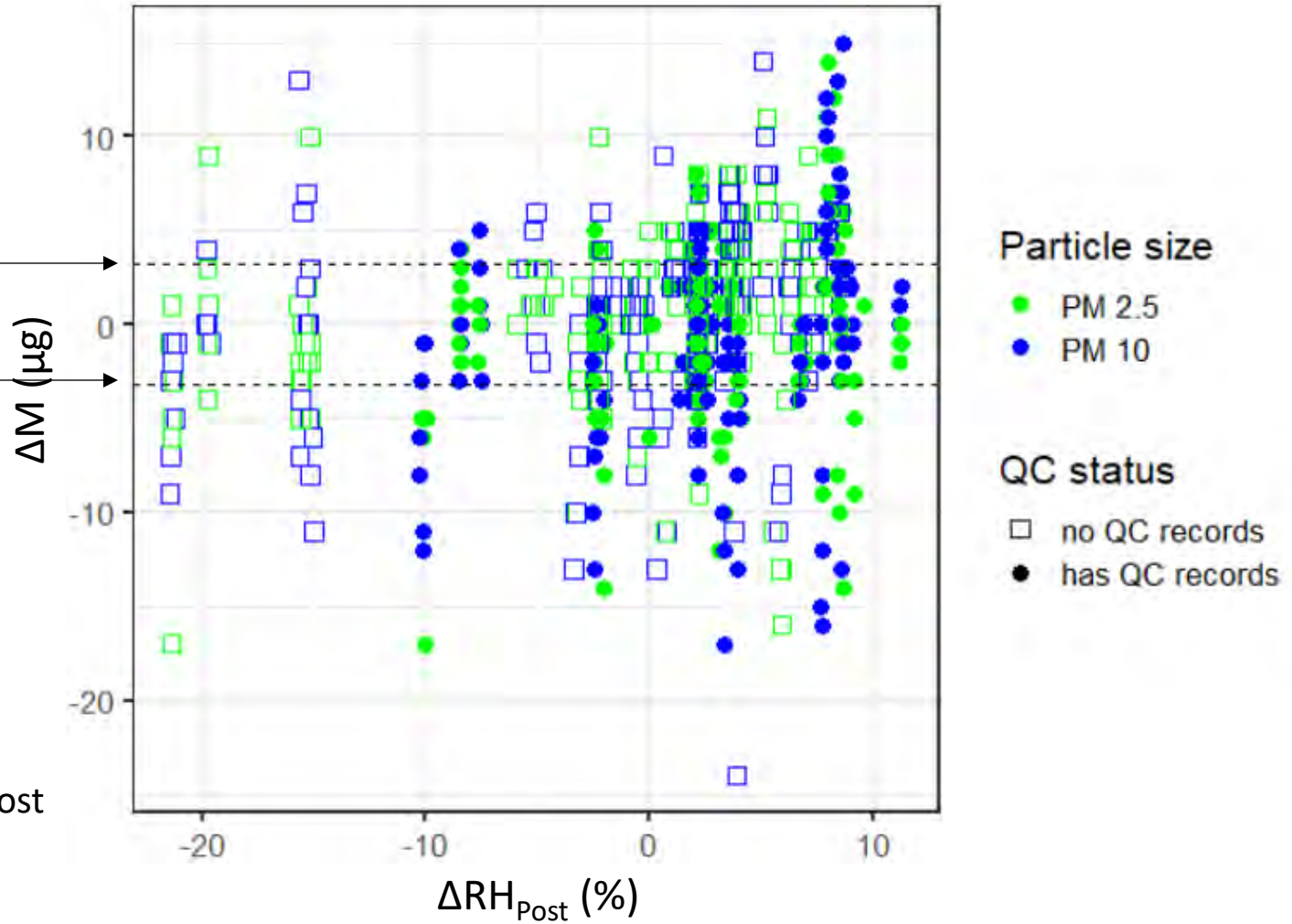
- Investigate mass differences from manual versus automated balance setups
- Weighed IMPROVE samples on both balances
  - Both pre-weights and post-weights
    - $M_{manual} = M_{manual,post} – M_{manual,pre}$
    - $M_{automated} = M_{automated,post} - M_{automated,pre}$

PM mass difference (ΔM) vs post RH difference (ΔRH_{post})

Error of each net weight:

$$\sqrt{1.20^2 + 1.20^2 + 1.94^2 + 1.94^2} = 3.2\ ug$$

Points between dashed lines are considered insignificant PM mass difference (ΔM)



$\Delta M = M_{manual} - M_{automated}$

$\Delta RH_{Post} = RH_{manual,\ Post} - RH_{automated,\ Post}$

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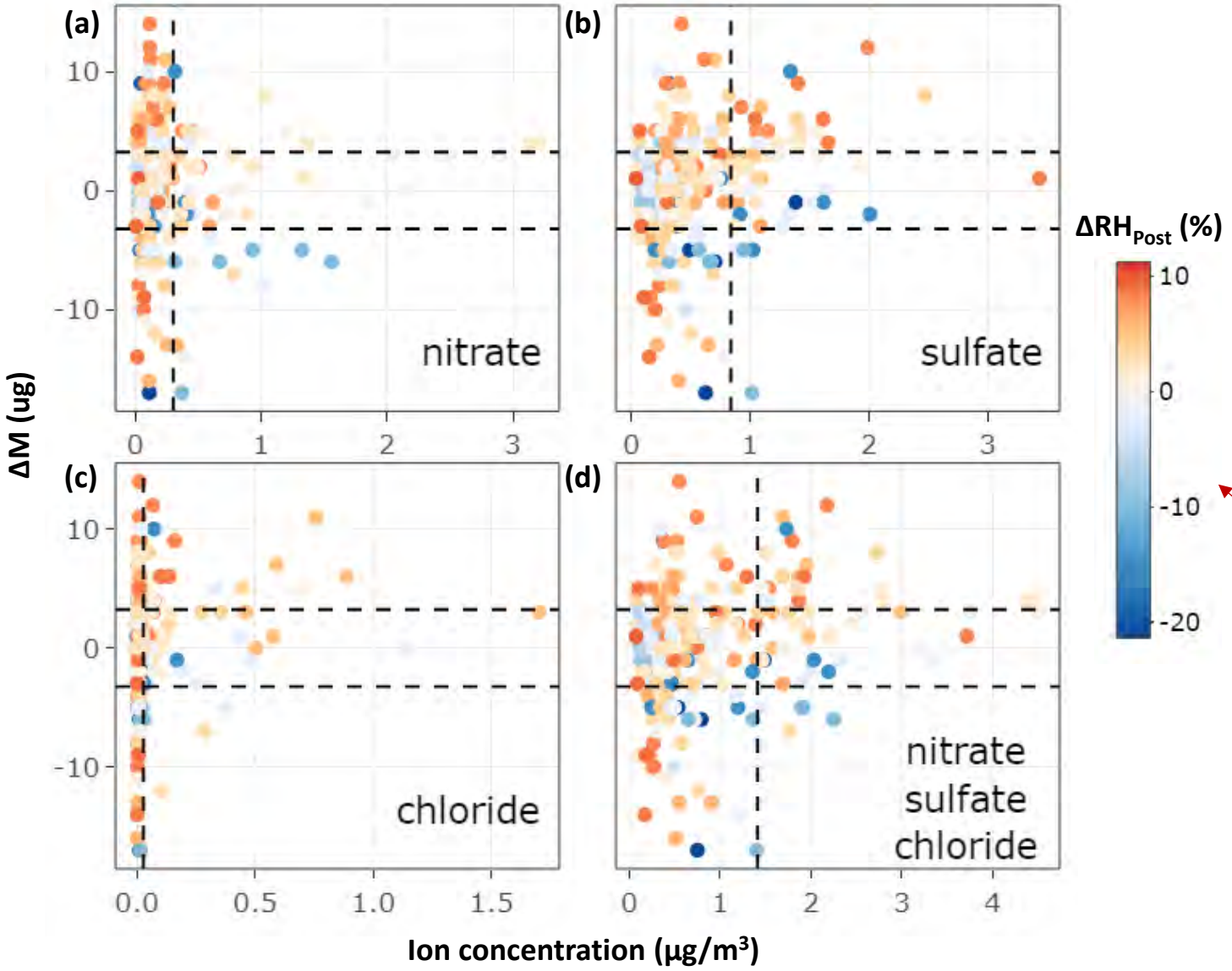
PM mass difference (ΔM) vs ion concentrations



- Only module A samples have collocated ion data
- 283 points in each plot
- $\Delta M = M_{manual} - M_{automated}$

Did not capture widest range of possible RH in these experiments

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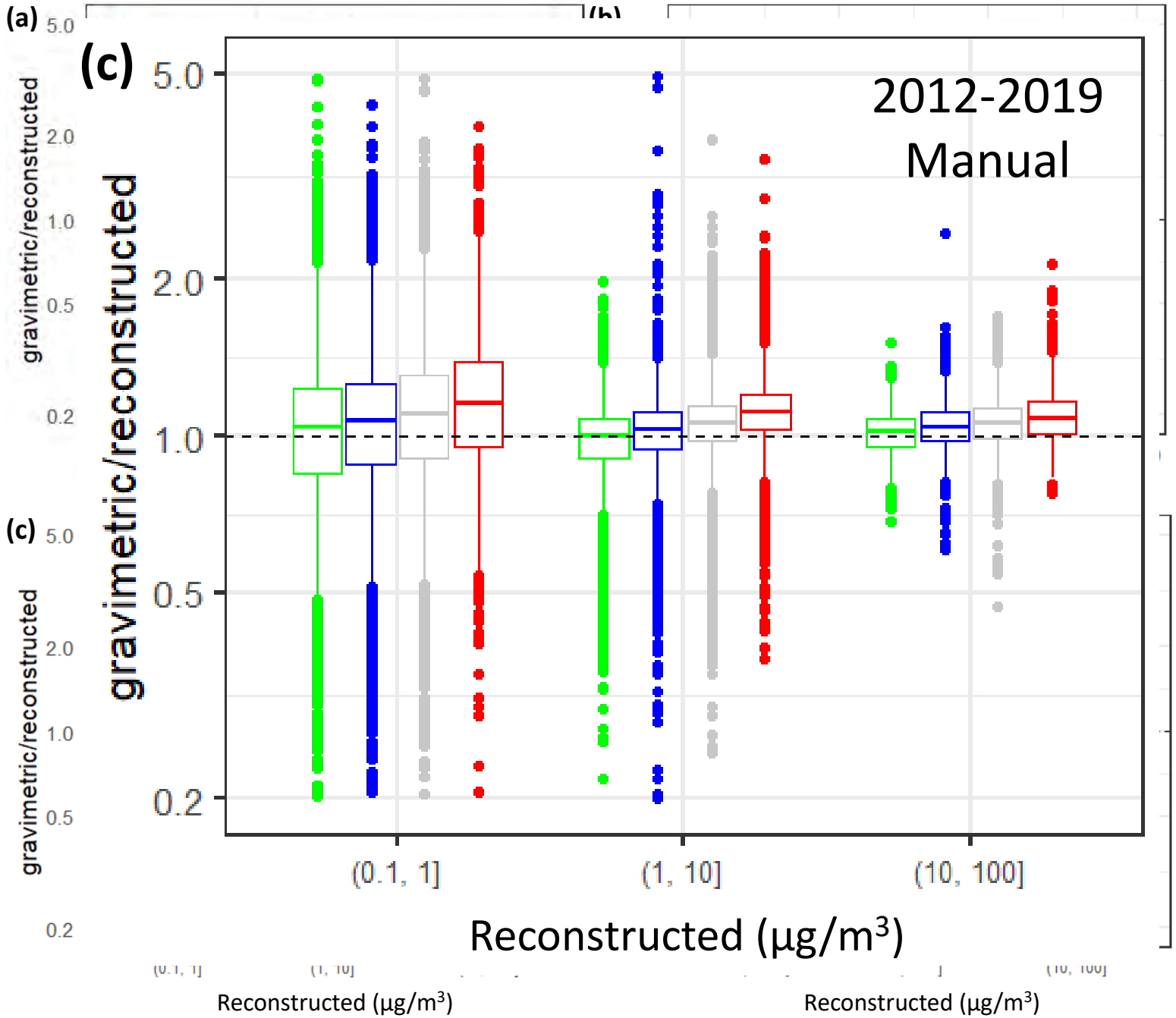
Conclusions from comparative gravimetric study

- RH was only moderately different between balances for these experiments
- No strong relationship between ΔM and ΔRH_{post}
  - Weak relationship when ion content is high
- No significant difference in gravimetric/reconstructed ratio
- But
  - RH differences in experiment were small
  - What about historical data?

Historical data

All data median ratio:
Manual 1.05
Automated 0.99

Significant difference

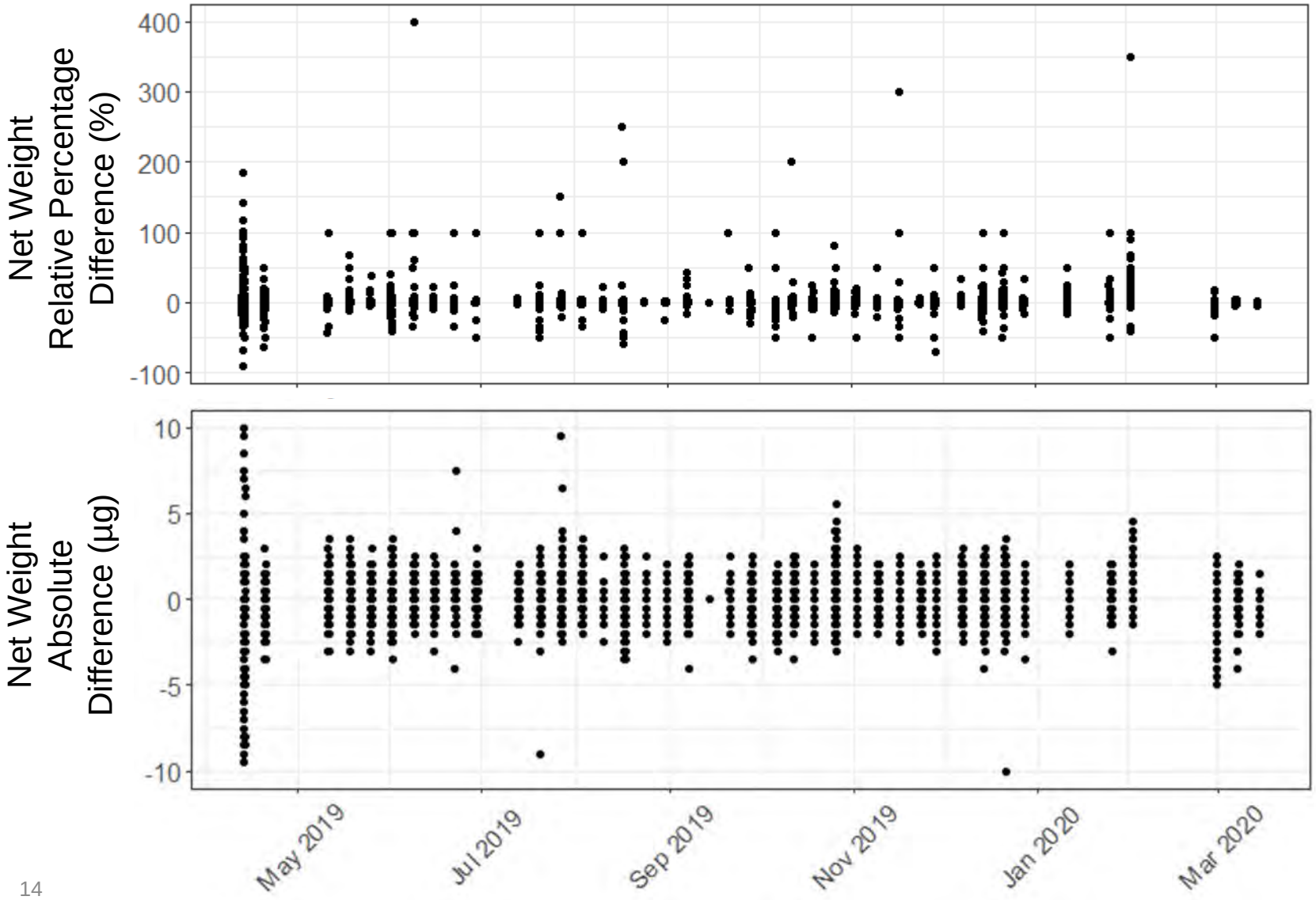


Liu *et al.* In preparation

New exploration-equilibration time in chamber

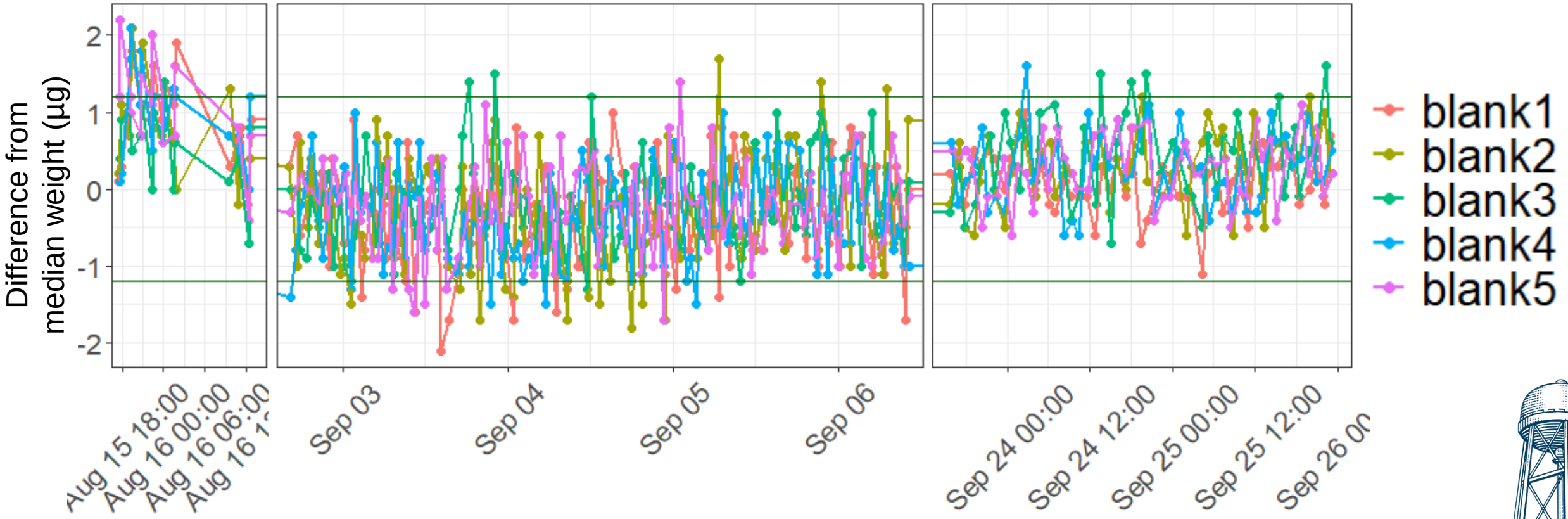
- Laboratory RH can be > 50 % in summer and <25% in winter
- Chamber RH is 39 ± 2%
- Equilibration time necessary for filter media and sample after loaded into chamber?
- Experiment: Store samples in laboratory, load into chamber and weigh repetitively for hours/days

Previous equilibration data



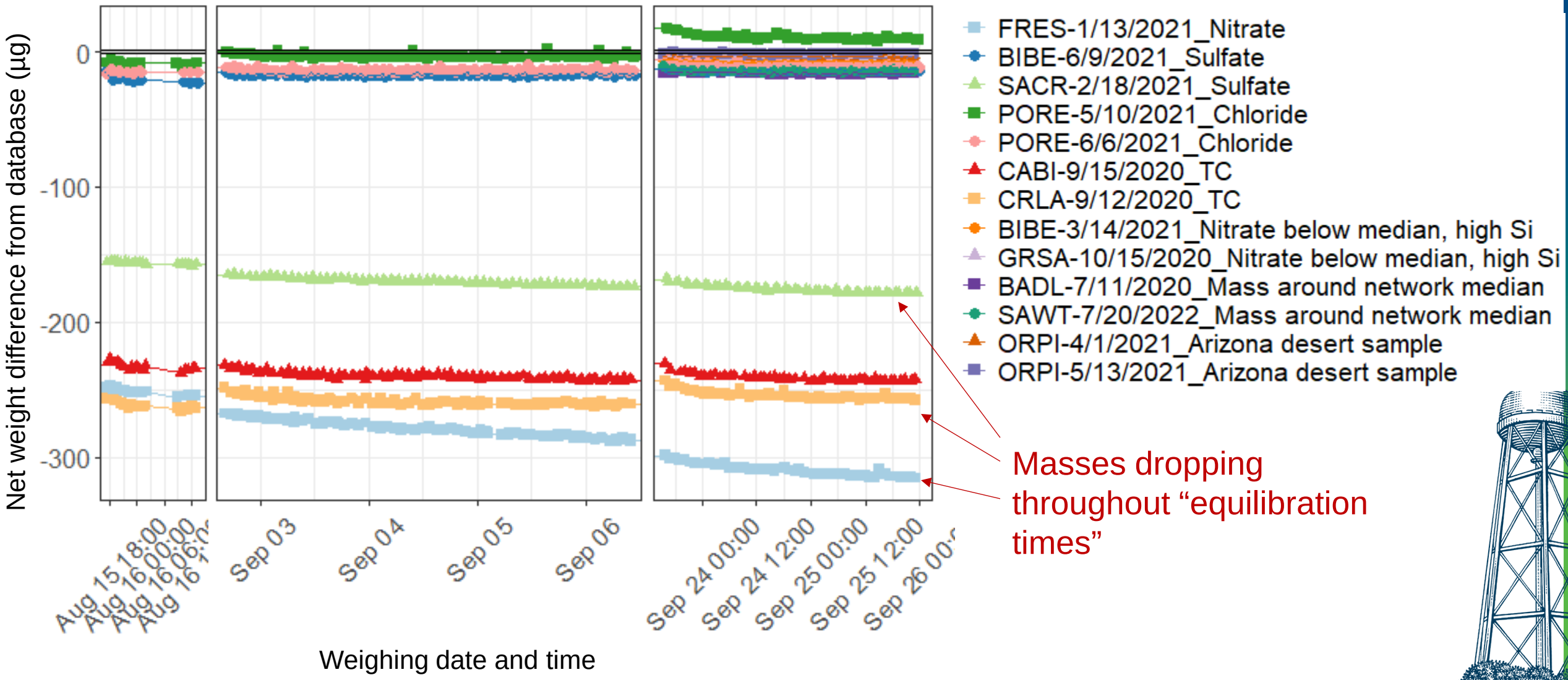
- Measure ~6,000 network samples twice
  - First is routine network measurement
  - Second is a replicate measurement 6 – 46 hours after routine measurement
- RPD is small
  - 75 % of RPD within ± 1.6 %
  - 75 % of AD within ± 1.0 µg

Blank filter equilibration



Green lines are ± 1.2 µg, 1 standard deviation measurement error of balance

Network samples equilibration

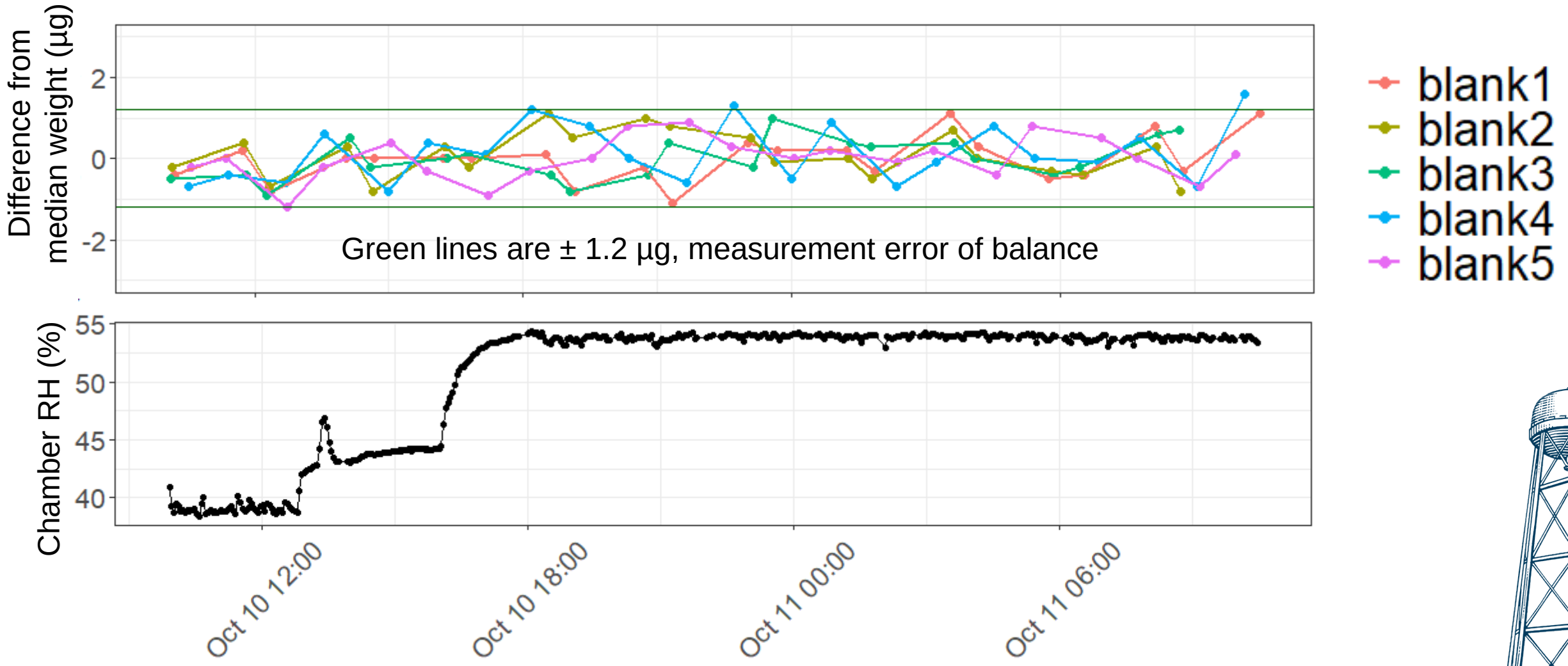


Masses dropping throughout “equilibration times”

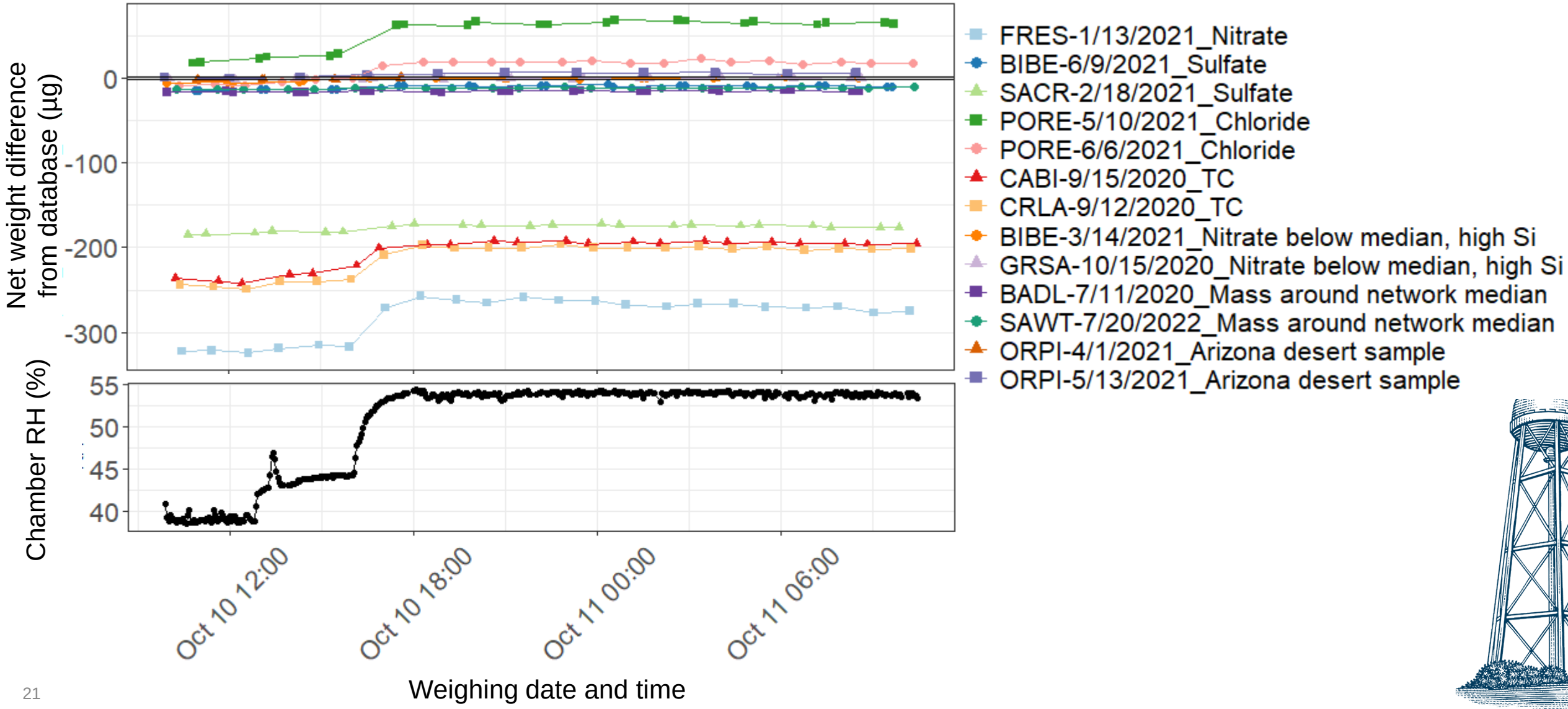
New exploration-different RHs in chamber

- How will mass change when chamber RH changes?
- Tuned chamber RH to 39 %, 44 % and 53 %
  - Repetitively weighed samples.

Blank filter mass at different chamber RH



Network sample mass at different chamber RH



Observations from equilibration and RH experiments

- Blank filter mases stable during equilibration and with RH changes
- Samples show changes in mass
  - Higher the loading, bigger the change
  - Equilibration process: samples with
    - High loading showed 10 – 70 µg of change
    - Medium loading showed 2 – 5 µg of change
    - All changes below 6% of total mass
  - RH change: samples with
    - High loading showed 6 – 70 µg of change
    - Medium loading showed 2 – 7 µg of change
    - All changes below 11 % of total mass

Thank you!