Feature Space Cloud Shrinkage by Iterative Reconstruction

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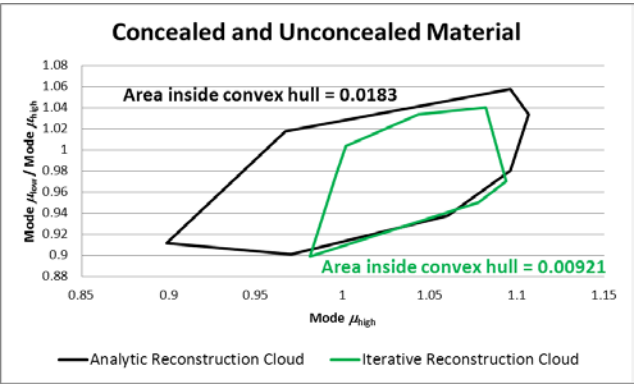
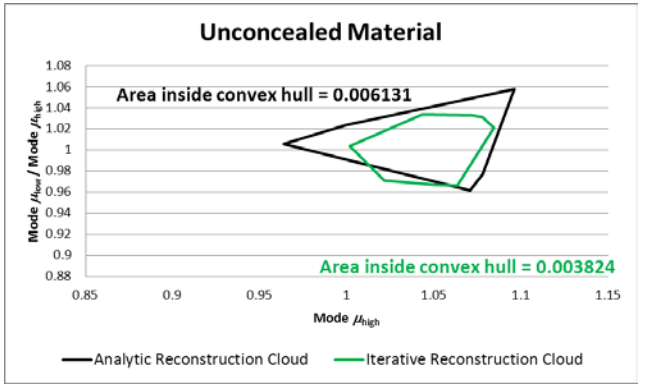
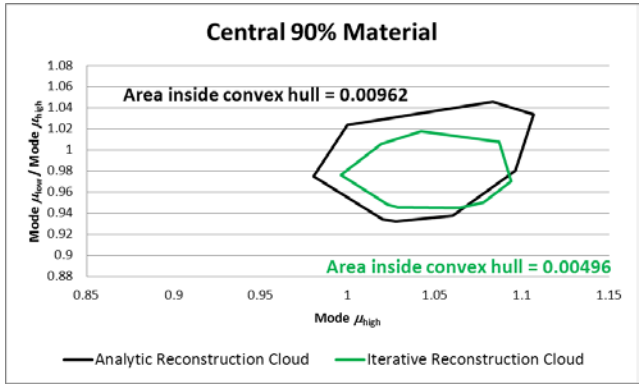
Summary

- The improvements in image quality afforded by iterative reconstruction can serve to reduce the effects of containers and concealment (“shrink the cloud”), and thus should improve the PD / PFA ratio.



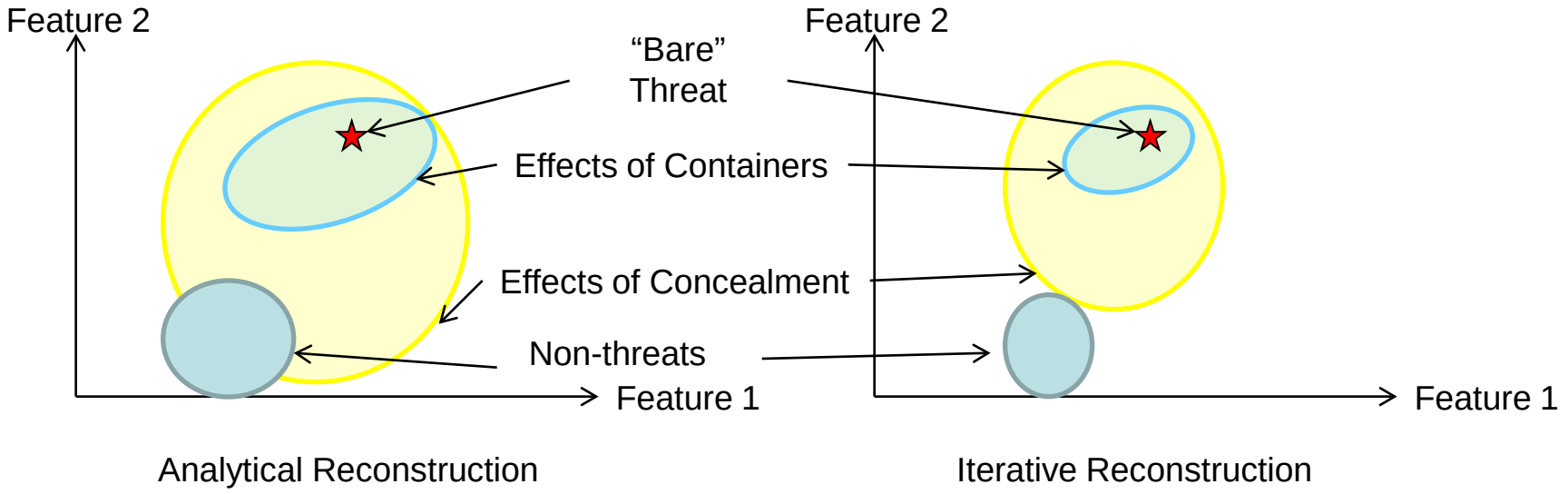




- The analytic reconstruction method used was EDS vendor FBP
- The iterative reconstruction method used was ray-weighted CCG
- For the material examined
  - The full cloud (including effects of container and concealment) area was reduced ~50%
  - The cloud without the effects of concealment was reduced by ~38%
  - The cloud incorporating only the central 90% of the points was reduced by ~48%

Goal of DHS Funded Iterative Reconstruction Work

- Work performed for S&T Directorate of DHS: IAA HSHQPM-10-X-00034 SOW
- Goal was to show that iterative reconstruction techniques can reduce the effects of containers and concealment, and thus improve PD/PFA
- We sometimes refer to this spread as a cloud
  - Part of the cloud is due to variations in material composition
  - Part of the cloud is due to containers, bag parts, beam hardening and scatter
  - Part of the cloud is due to issues with segmentation



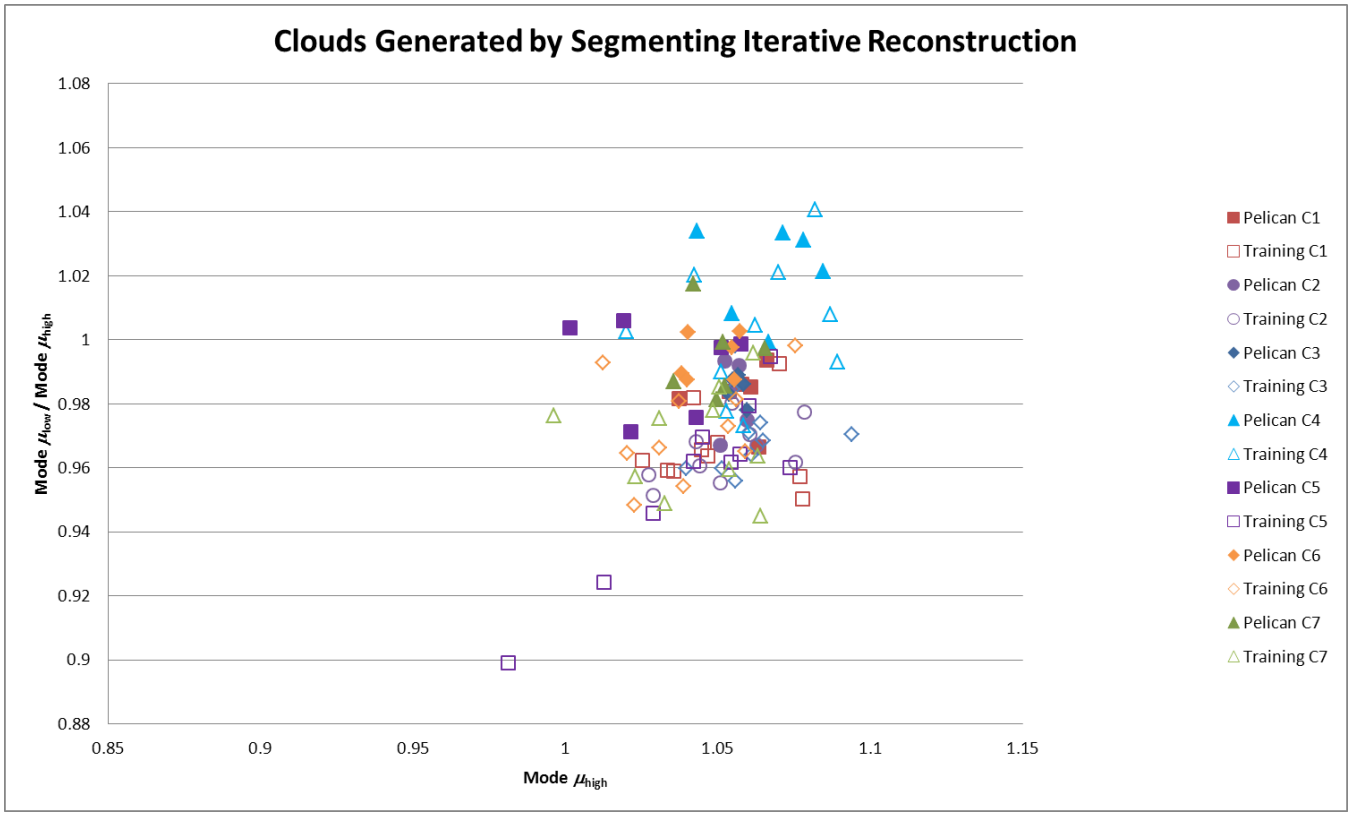
Features can include x-ray attenuation coefficients, Zeff, density, texture, kurtosis

Background

- We used training data acquired on a vendor machine for a homogeneous material.
  - 7 containers scanned unconcealed as well as concealed in 10 bags
- Used constrained-conjugate-gradient optimization technique accelerated by approximate error line search* for reconstruction.
- Used a third party segmentation system to extract threat objects from both the vendor reconstruction and the iterative reconstruction.
  - This system over-segmented the reconstructed bags.
  - A human unconnected with the reconstruction research was used to select the segments that contained the material of interest
- Features extracted for threat objects were high and low channel mode (value at the peak of the attenuation distribution).
- Feature space used for comparison of iterative to analytic clouds is (μ_{high}, Ratio μ_{low} / μ_{high}).
- Cloud size is the area inside the convex hull of the cloud in the feature space.
  - The convex hull is the smallest convex perimeter that encloses all of the points in the cloud.
  - We generated convex hulls for all points (concealed and unconcealed), unconcealed points only, and the central 90% of the points (mix of concealed and unconcealed)
    - The central 90% of the points was chosen by repeatedly generating a convex hull and removing the hull point most distant from the center of mass of the current point set until only 90% of the original points remained.

* J. S. Kallman and S. G. Azevedo, "Ray-weighted constrained conjugate-gradient tomographic reconstruction for security applications," LLNL-JRNL-560413, presented at the 2nd International Conference on Image Formation in X-ray CT, 2012.

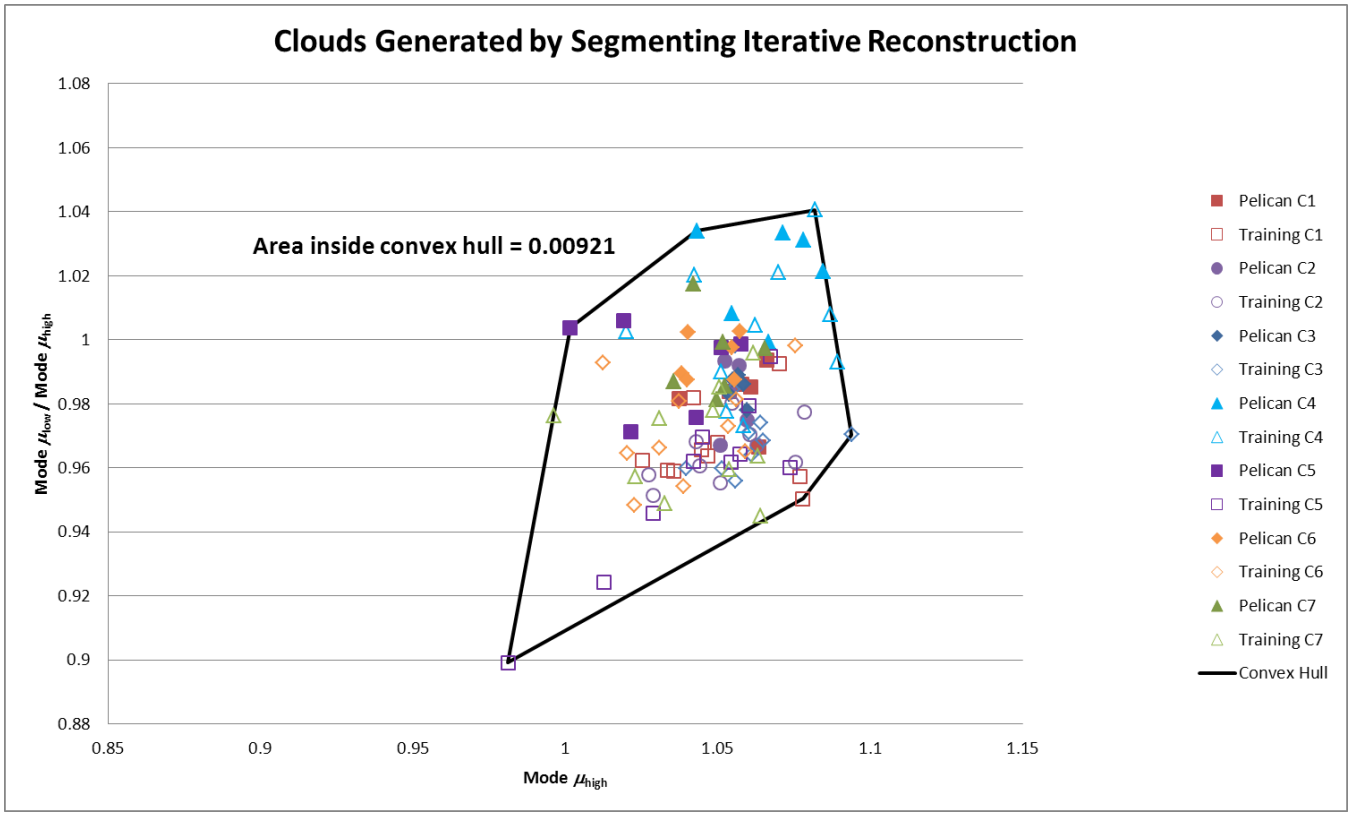
Iterative Mode Cloud



Notes on Iterative Cloud

- The graph shows the effects of 7 containers (labeled C1 through C7) and 10 concealments on material
  - Solid symbols are unconcealed material in various containers
  - Open symbols are concealed material in various containers and various situations

Iterative Mode Cloud



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- Convex hull for all points is displayed

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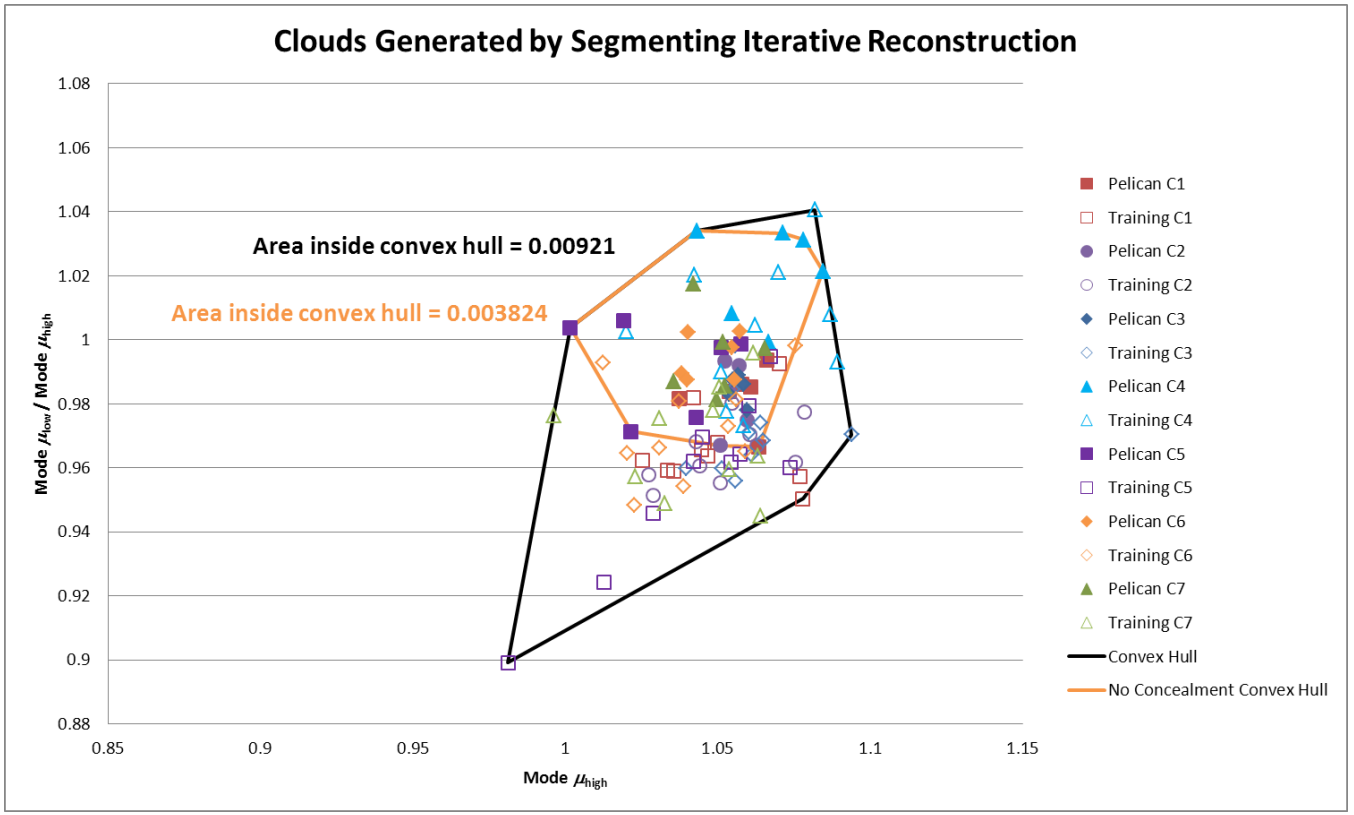

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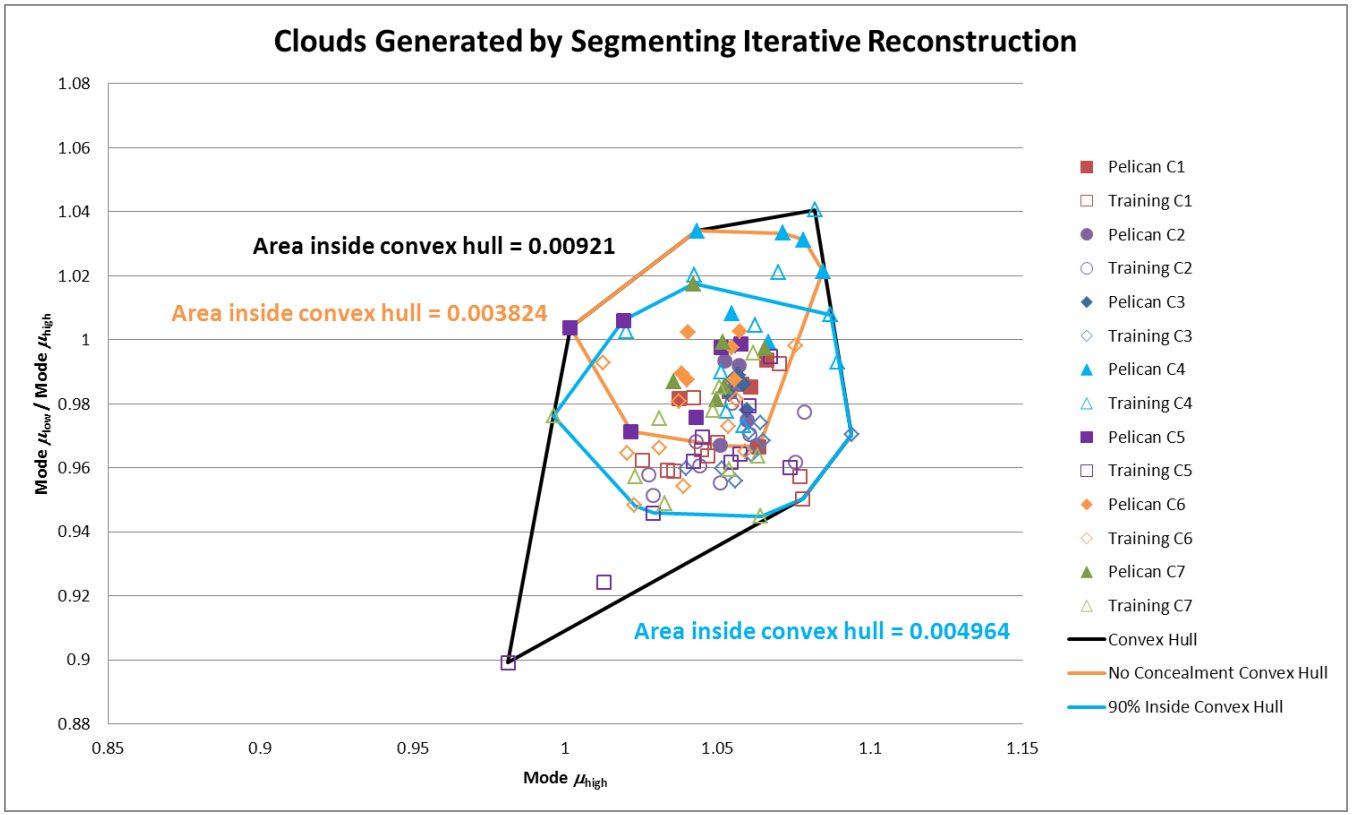

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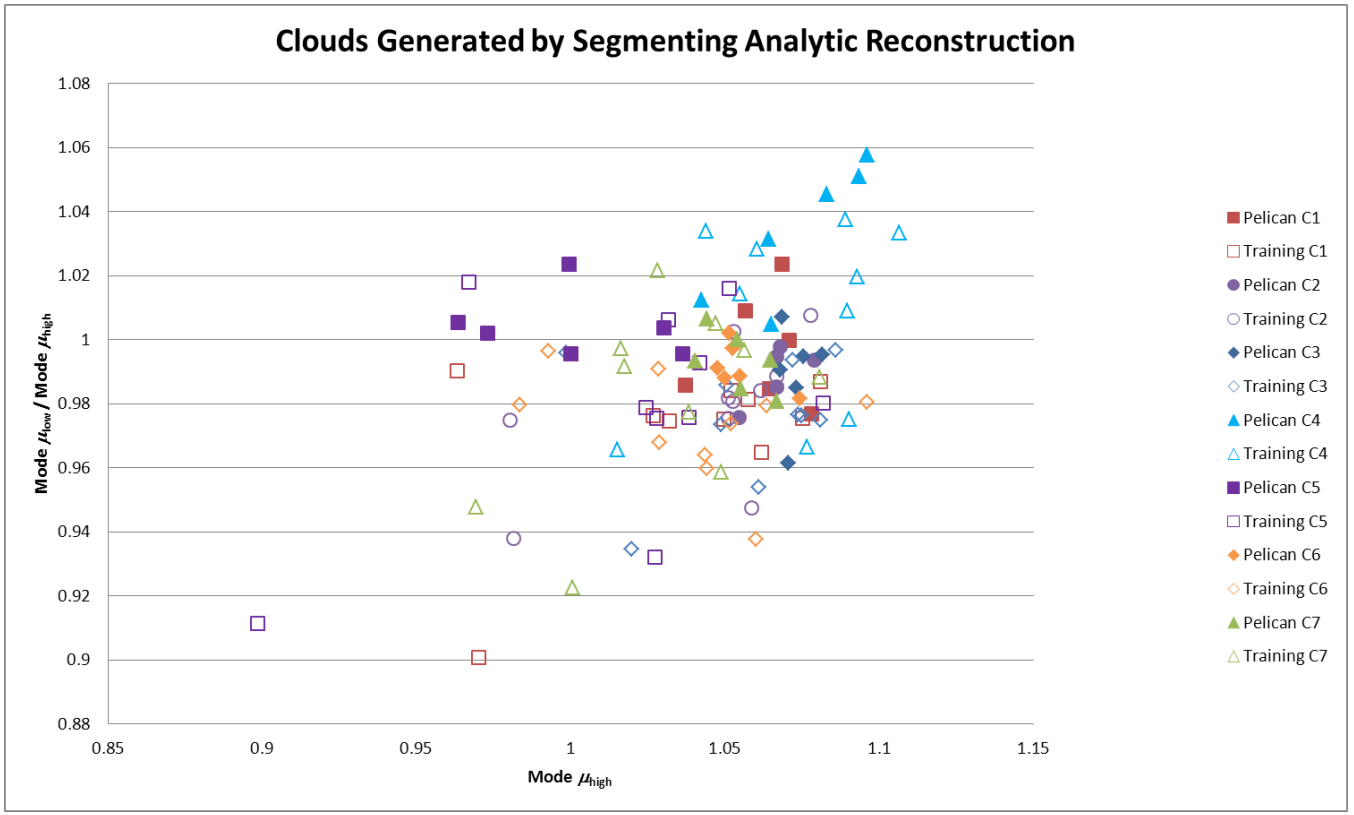
Analytic Mode Cloud



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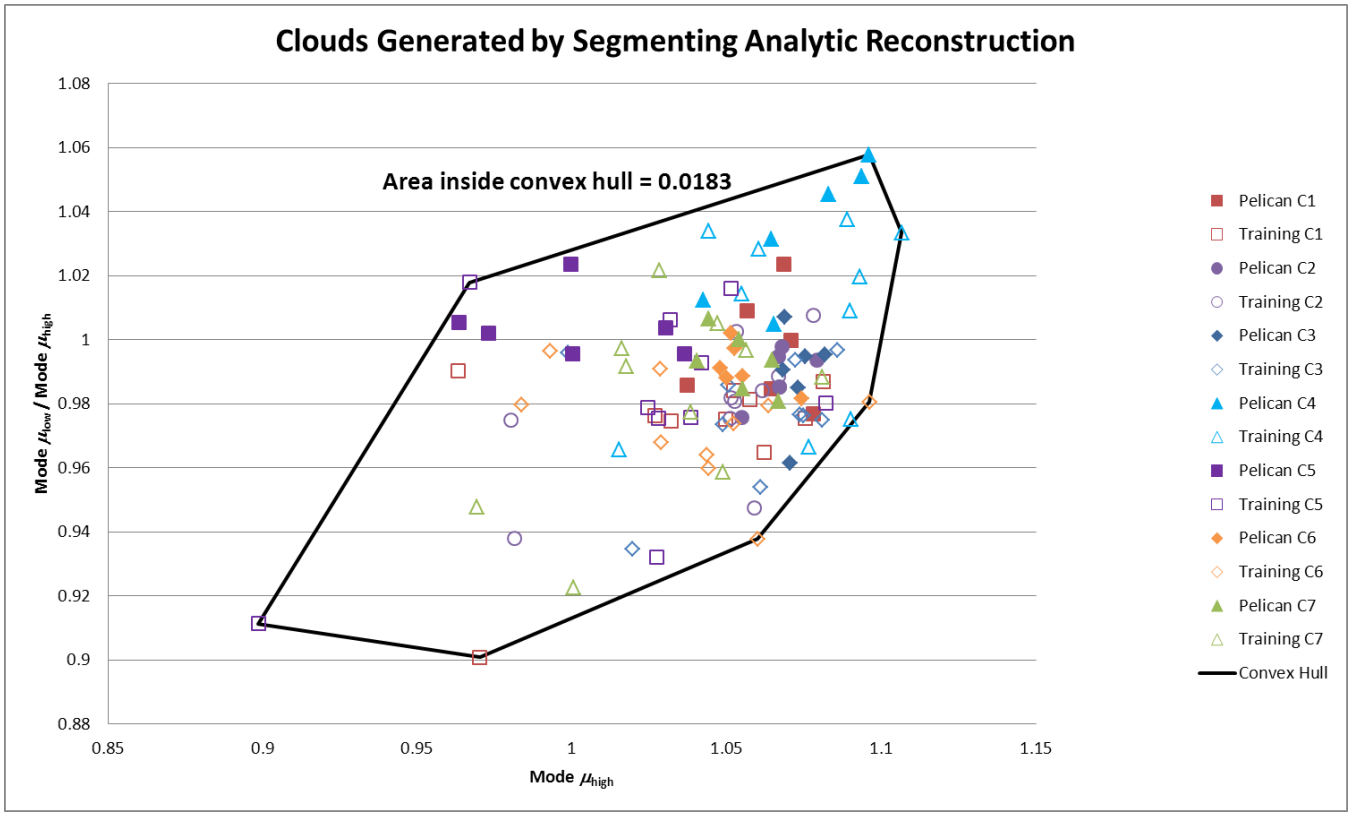

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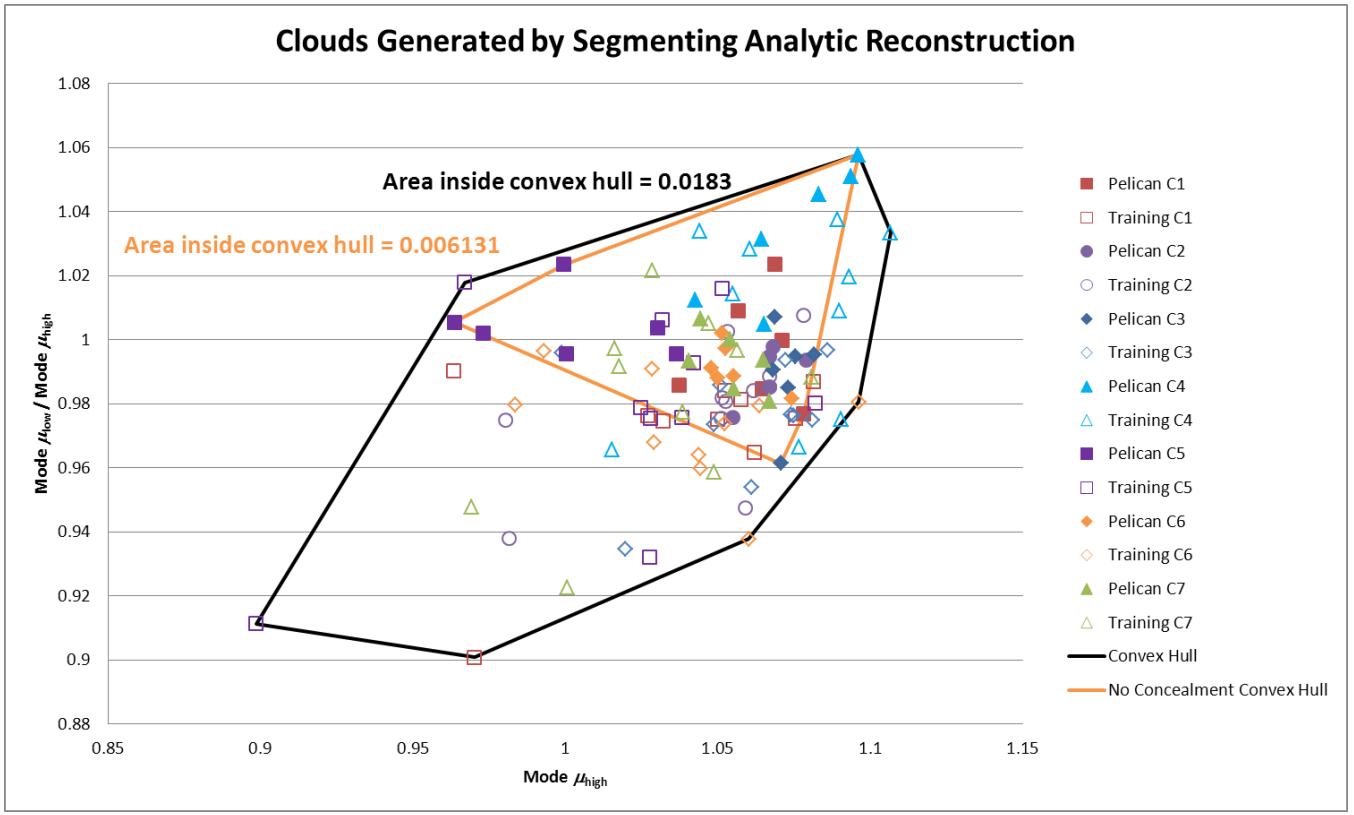

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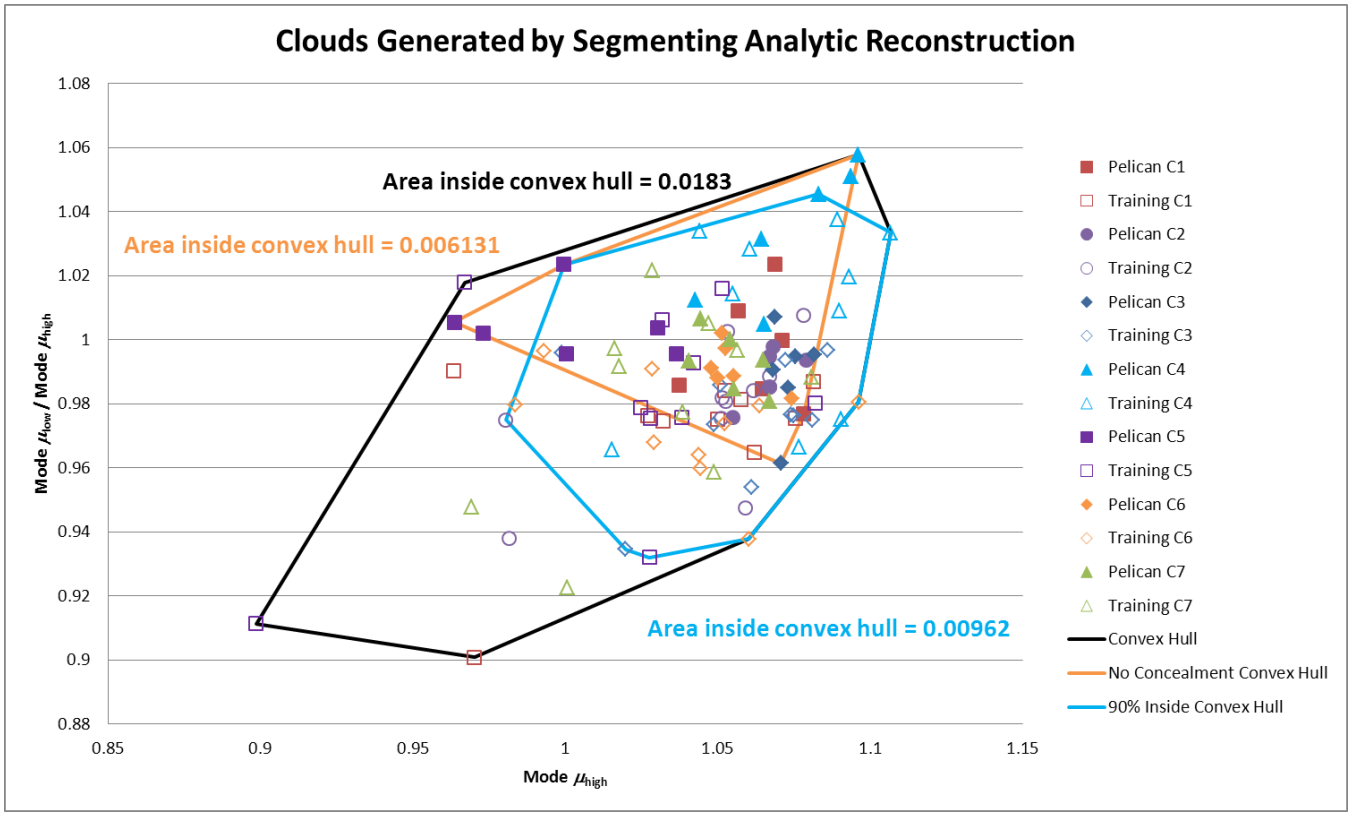

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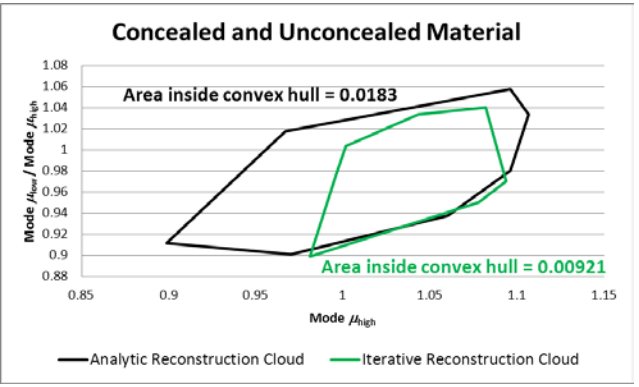

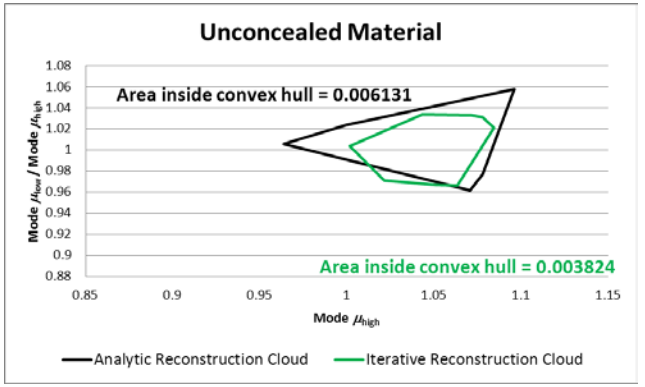

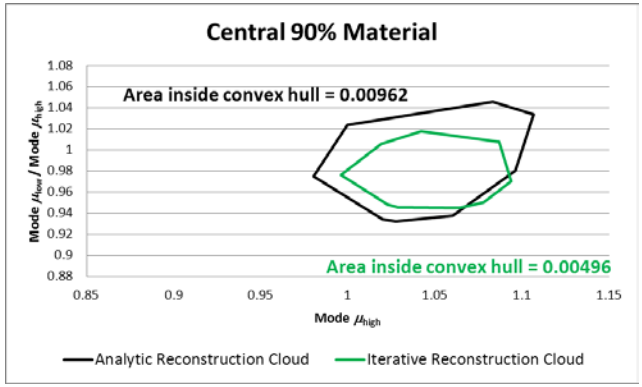

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