Comparison of Mars Elemental Data to Neutron Data

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Society of Physics Students

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Lunar Reconnaissance Orbiter (LRO)

- LRO's primary objective is exploration:
  - Preparing for future human moon mission
    - Radiation environment
    - Safe landing zones
- Lunar Exploration Neutron Detector (LEND)
  - Will measure neutron flux off surface
  - In search of water ice
    - Frozen water in permanently shadowed craters
- Secondary science mission
  - What additional science objectives can we achieve with LRO/LEND?

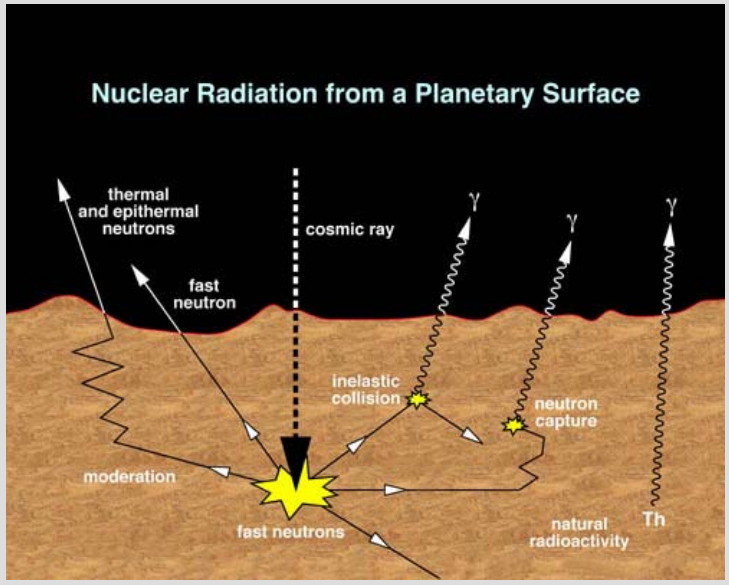
Neutron Spectroscopy

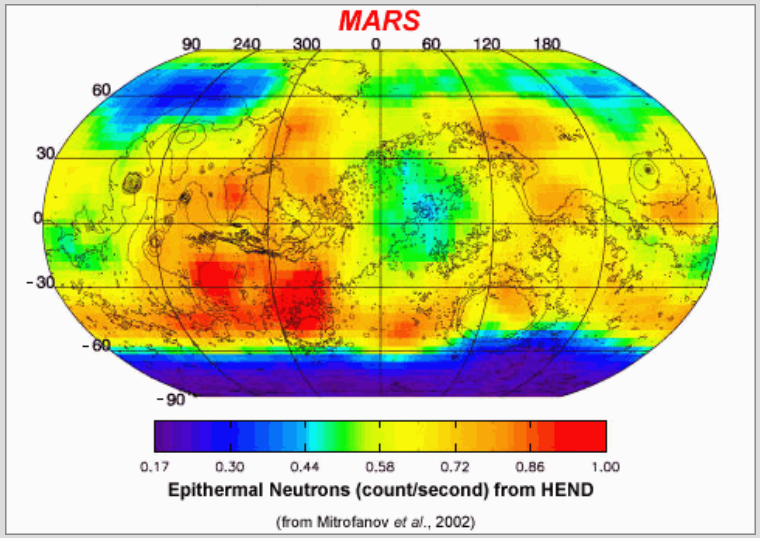
- Benefits of neutron emission measurements
  - Can readily identify hydrogen, and thus water ice content
  - Neutron/gamma ray relation
    - Cosmic rays bombard nuclei – May have neutron ejection
    - Neutrons impact nuclei – gamma ray emission

- Neutron energy ranges / Interaction with surface
  - Thermal (low energy, thermal equilibrium – have a higher probability of undergoing neutron capture)
  - Epithermal (medium energy)
  - Fast (high energy, may be moderated by elastic collisions)
  - Thermal neutron flux had a Cadmium cutoff (0.4eV)

Neutron Spectroscopy (cont).

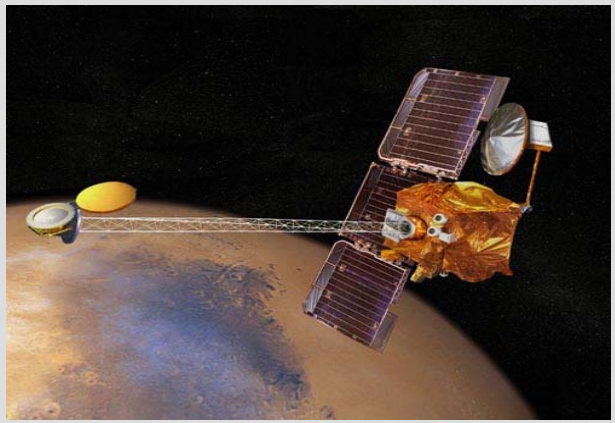
- Decrease in neutron count rates
  - Decrease in fast neutrons indicates water ice (polar regions)
  - High neutron capture cross-section of iron decreases thermal neutron abundance
  - Iron also emits fast neutrons





Mars Odyssey and the High Energy Neutron Detector (HEND)

- Mars Odyssey
  - Produced data maps of Mars using multiple instruments
- Gamma ray spectrometer (GRS)
  - Measured gamma ray spectra
  - Determined H, Fe, Si, Th, K, and Cl concentrations
  - Large spatial resolution
- HEND
  - Similar to LEND
  - Measured hydrogen content on Mars



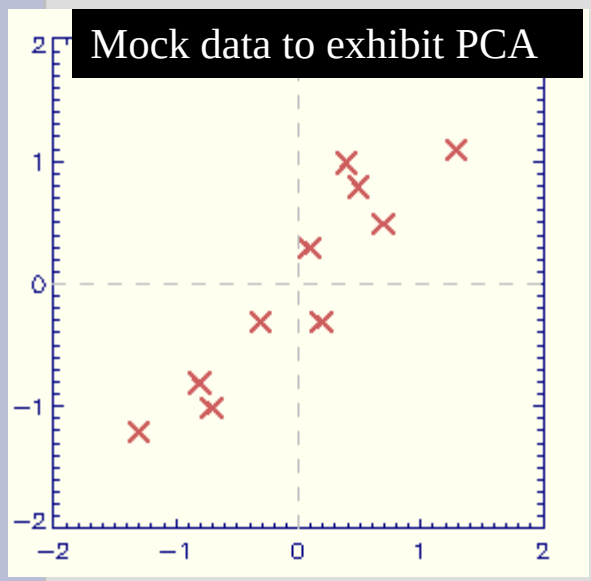
Scientific Objectives

- HEND
  - Detected epithermal, fast neutrons on Mars
  - Neutron/Elemental relation?
- LEND
  - Detects thermal, epithermal, fast neutrons
  - Better spatial resolution than HEND
- LRO does not have a GRS
  - What can neutrons (LEND) say about surface composition?
  - Use multivariate analysis techniques to determine neutron relation to underlying chemistry

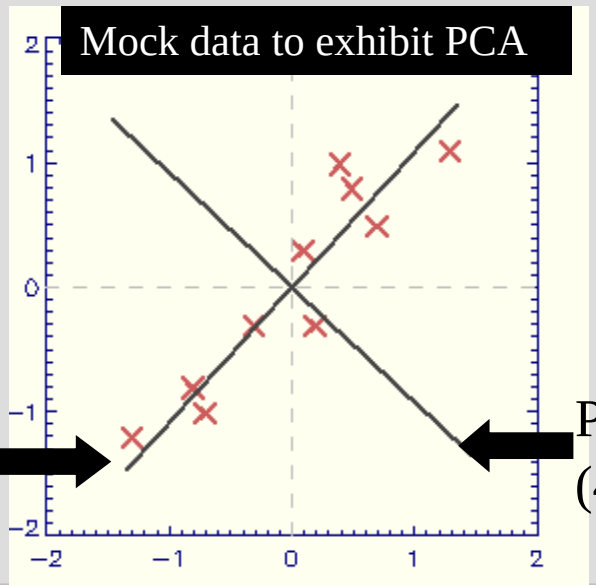
Principal Components Analysis (PCA)

- Rotates coordinate axes to directions of greatest variance
  - Greatest variance – the direction in which data undergoes the largest change
  - Data is standardized so data with largest abundance won't dominate results
  - Performs a linear transformation of the data
- Highlights "interesting" features in data
  - Can simplify data
- New axes are called Principal Components (PC)

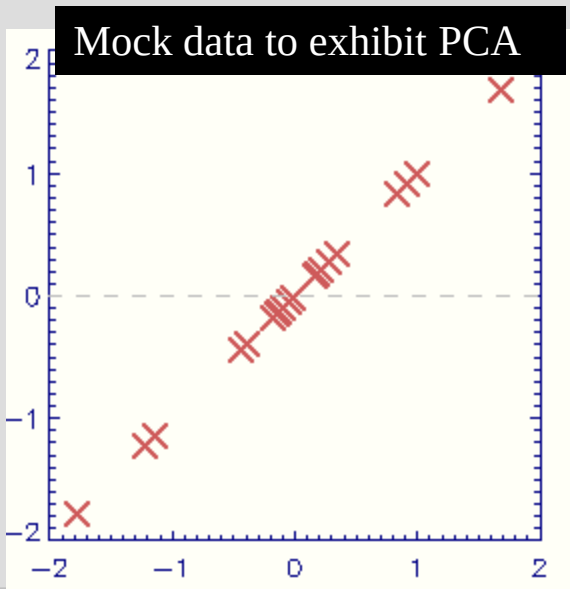
Normal data axes – X vs Y



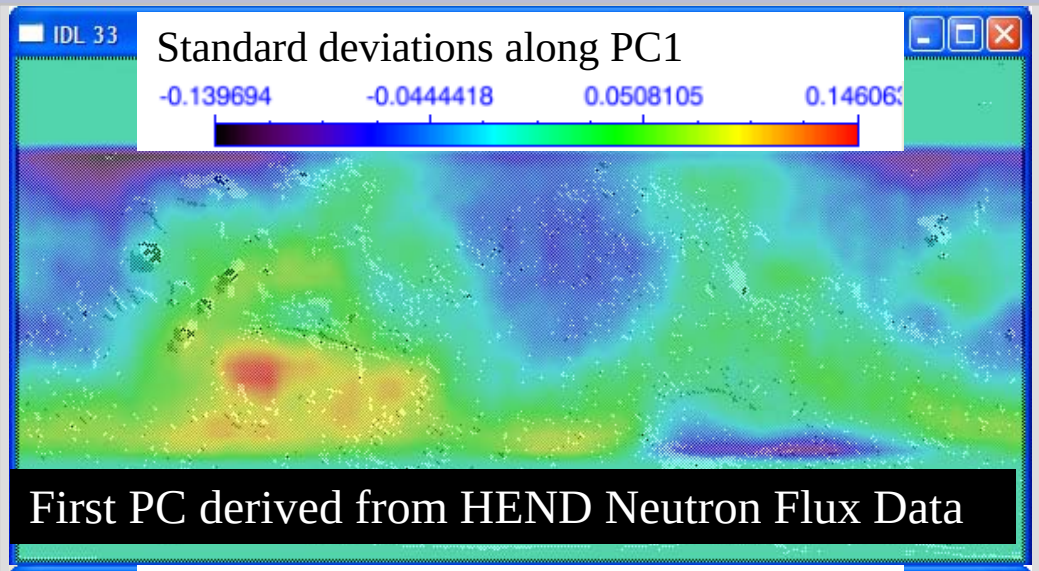
PC's plotted through data



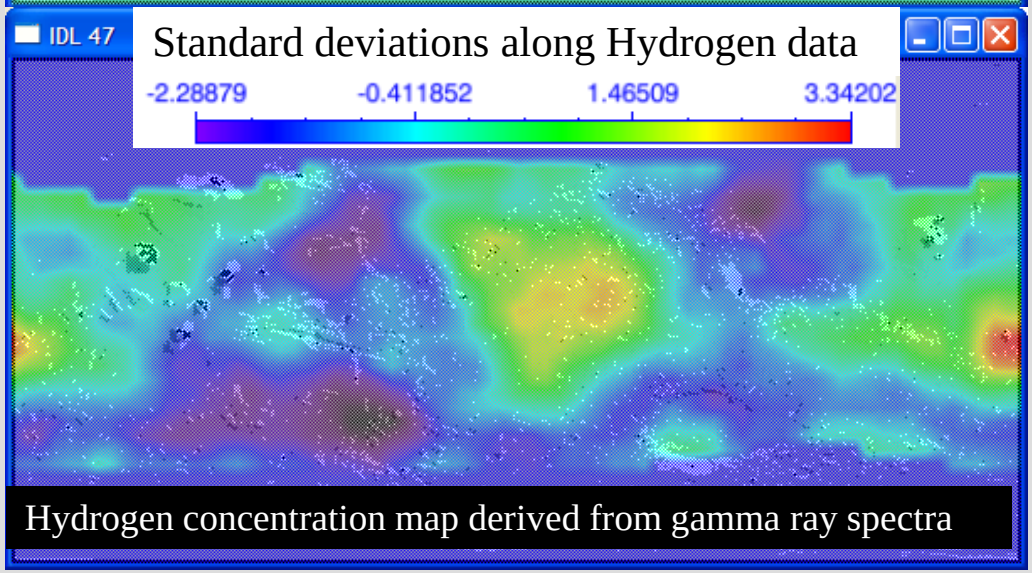
PC1 (96%)



PCA Results on Mars Odyssey Data



First PC derived from HEND Neutron Flux Data

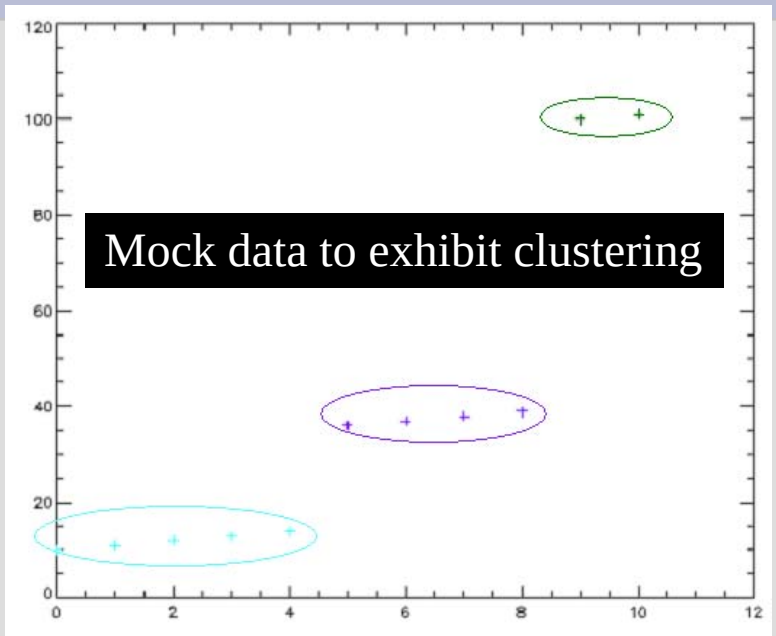


Hydrogen concentration map derived from gamma ray spectra

- First PC of HEND Data represents 91% of data variance
- Most neutron information can be represented by a single variable
- Maps show mid latitude regions only
  - Poles dominated by water ice

- Water ice/hydrogen concentration map is inversely related to the first PC
- Neutron data consistent with expected results
  - Kinetic energy loss in a neutron and hydrogen nucleus collision
  - Similar cross-section area transfer of kinetic energy

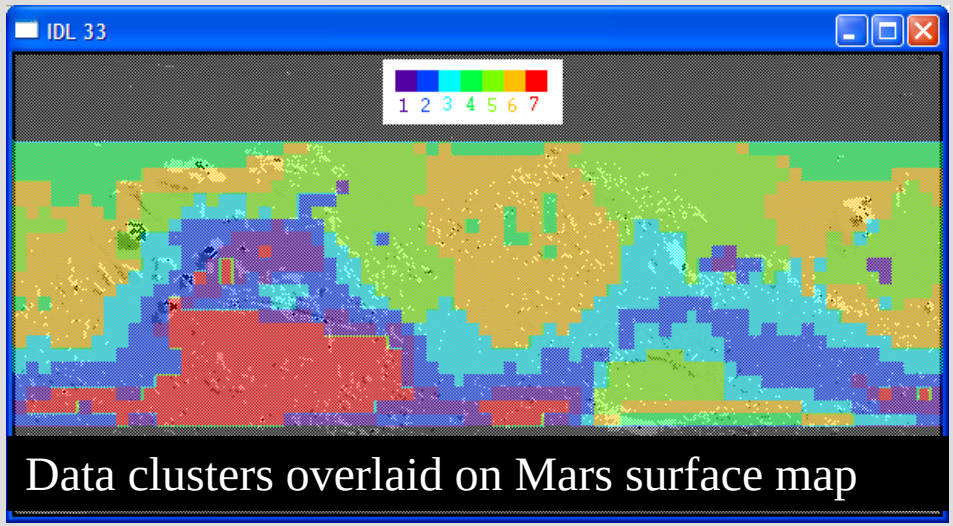
Clustering



Mock data to exhibit clustering

- An additional analysis technique similar to PCA
  - Groups data based on proximity of data points by value, i.e. finds similarly valued data across N variables
  - Finds specified number of “clusters” of data within larger data set

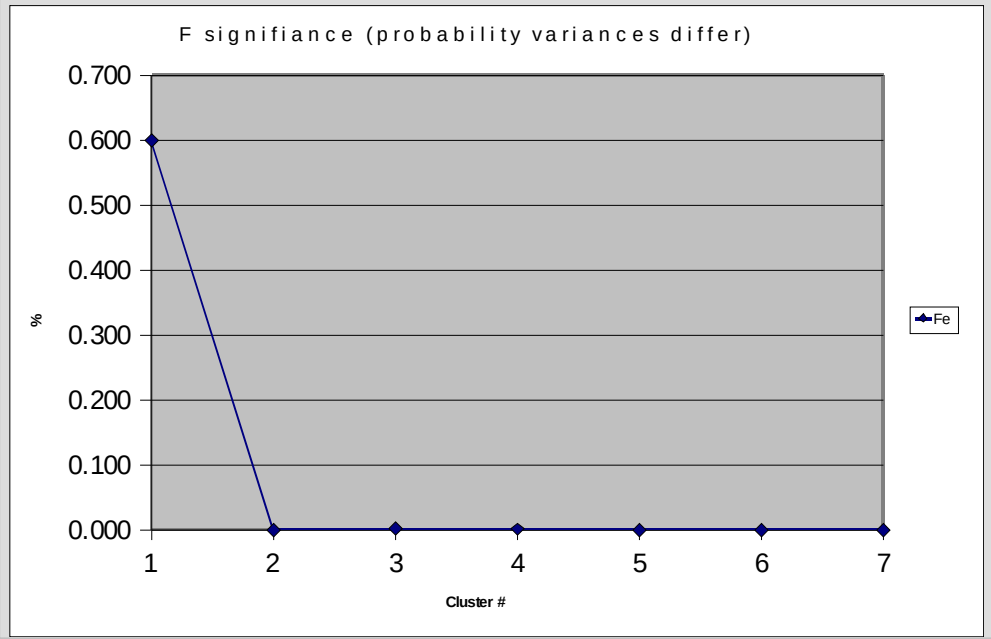
- Performed clustering on HEND data sets
  - Mars surface map colored by cluster to determine what surface features correspond to neutron data
  - Defined 7 clusters

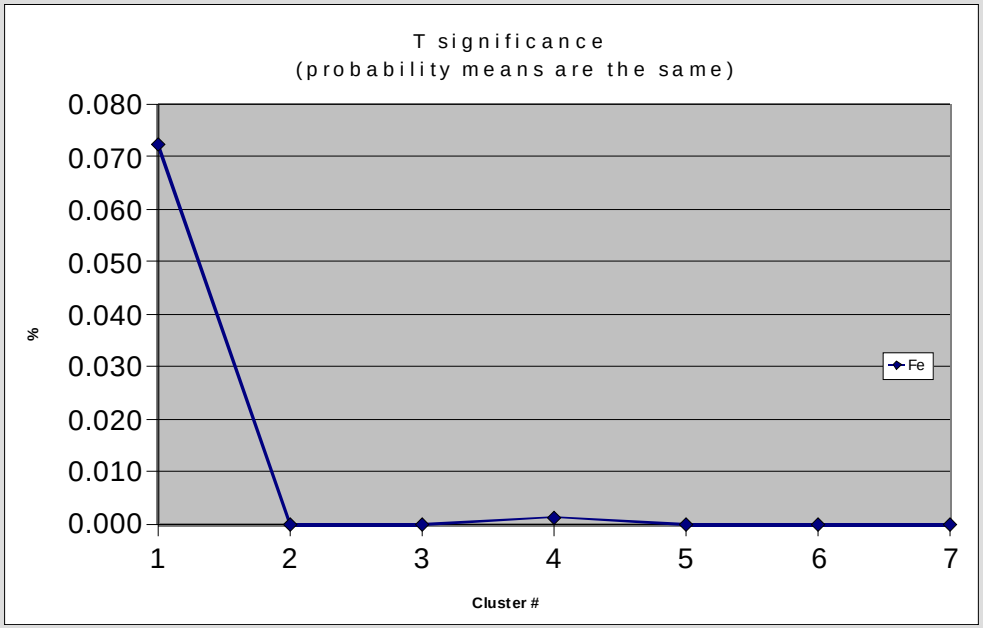


Data clusters overlaid on Mars surface map

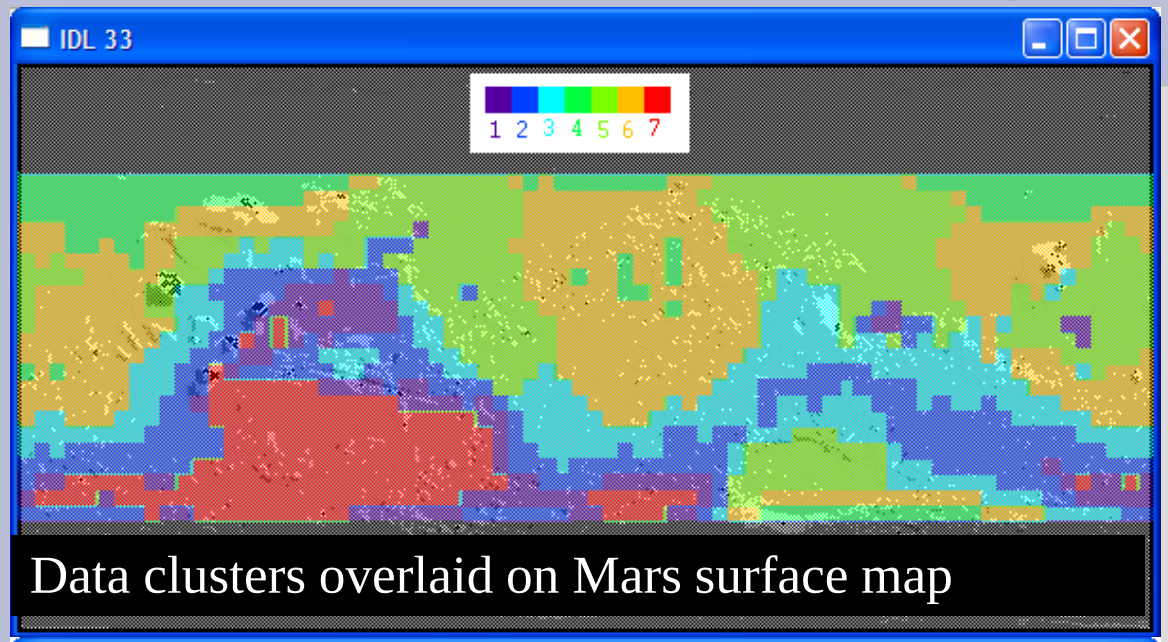
t values and F values (Iron shown) Is data statistically valid?

- Compared data in each cluster to data outside of that cluster
- F values indicates if the variances of two sets are statistically different
  - Every F value (per comparison) corresponds to a probability
  - Good if less than 5% chance variances differ (i.e. similar data ranges)
- t values indicates if means of two sets are statistically different
  - Every t value (per comparison) corresponds to a probability
  - Good data if less than 5% chance means are identical (i.e. averages differ)





Clustering Results



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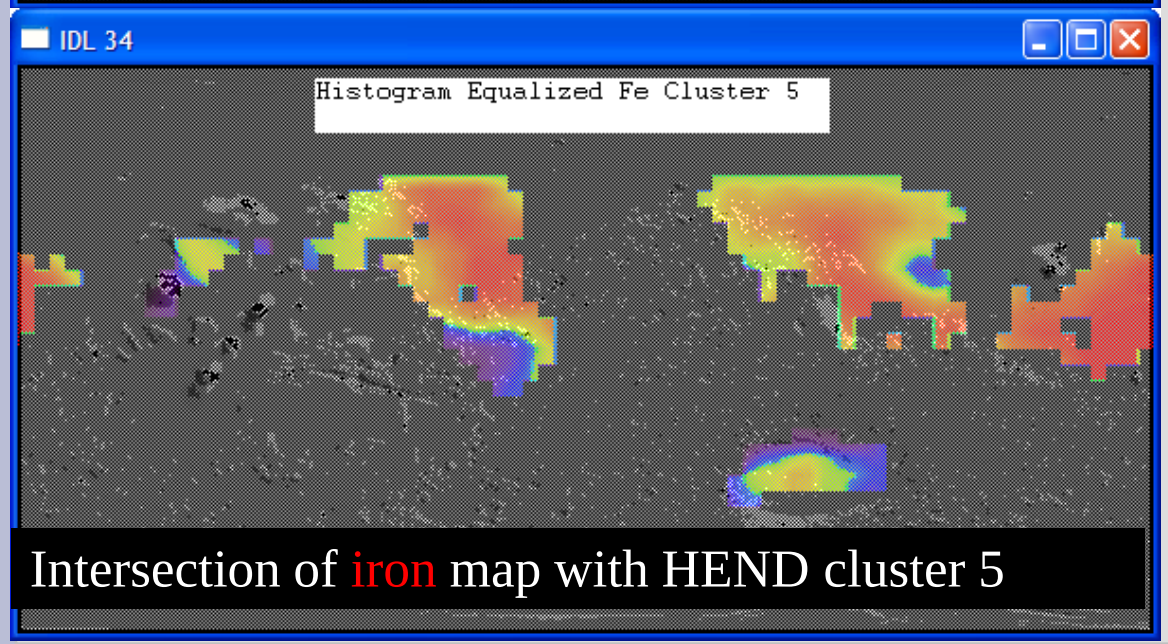

Intersection of iron map with HEND cluster 5

- Generated 7 different data clusters within neutron data sets
- Cluster 5 (light green) indicated as statistically significant by T and F values
- Intersection of cluster 5 and iron concentration map
- Cluster 5 matches up well with high concentrations of iron

Conclusions

- Application of Principal Components Analysis (PCA) and Clustering Analysis confirm prior findings
  - Neutron data can identify hydrogen and iron content
  - PCA and Clustering are valid ways to look at the data
- Lunar Reconnaissance Orbiter (LRO) will be able to make accurate hydrogen of the Moon
  - Iron maps may be more difficult due to the larger neutron cross section of rare Earth elements that are less rare on the moon
- Further analysis could reveal trends within data that correlate with additional elemental content

Further Analysis

- Correlation analysis maps
  - Compute a correlation value per pixel
  - Will allow for the examination of the correlation between HEND data and known element maps
- Attempt a linear fit among cluster definitions
  - Model geochemical relations in a multi-dimensional space
  - Determine if a single vector describes each cluster
  - Potentially drop elements from analysis that appear to have no relation to HEND data
- Look for relations between physical formations and elemental composition

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