Advances in the Use of Super Channels for Processing High Spectral Resolution Satellite Measurements

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Super Channel Concept

- Super Channels are combinations of similar channels Designed to reduce noise while preserving the vertical resolution
- Combinations are selected to
  - Minimize the broadening of the weighting functions by selecting channels with similar spectral properties
  - Minimize the random noise by averaging similar channels
  - Minimize the number of radiance calculations by reducing the number of channels
- For the super channels to be useful
  - A fast transmittance model must exist
  - An accurate Planck function must exist
- Super channels use the available information in high spectral resolution instruments in an efficient manner

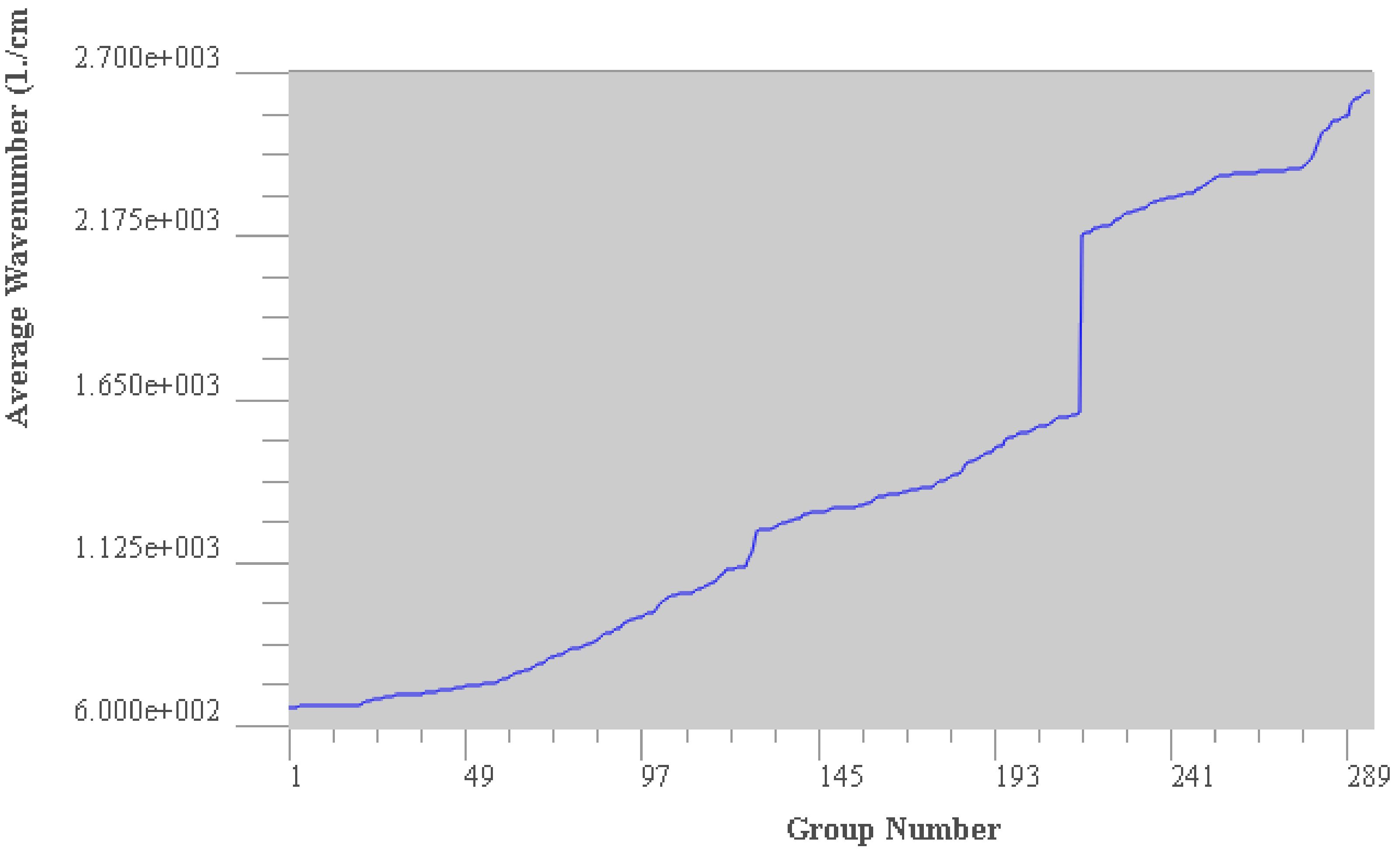
Alternatives (maybe) to Super Channels for Saving Computation Time

- Eigenvectors
  - Fast transmittance model is difficult if not impossible - at least no approach has been developed
- Selected channels
  - Does not use all information
  - Does not reduce random noise by averaging

Super Channel Selection Procedure

- Obtain a set of profiles and calculate transmittances at each level
- Calculate the covariance of the transmittances by summing over all levels and profiles
- Select the 2 channels that are most highly correlated
  - Since transmittances are used, this selects channels with similar shapes
  - Limit the minimum correlation value allowed before channels are combined
  - Limit the wavelength range allowed for a given super channel
- Once a pair of channels is selected, delete one of the selected channels in the covariance matrix and replace the other one with the combined result
  - Store the group channel information as combinations are formed
- Repeat until all channels have been placed in a group
- Note that a group can be of size one

Average Wavenumbers for the Super channels



Group size as a function of the group number

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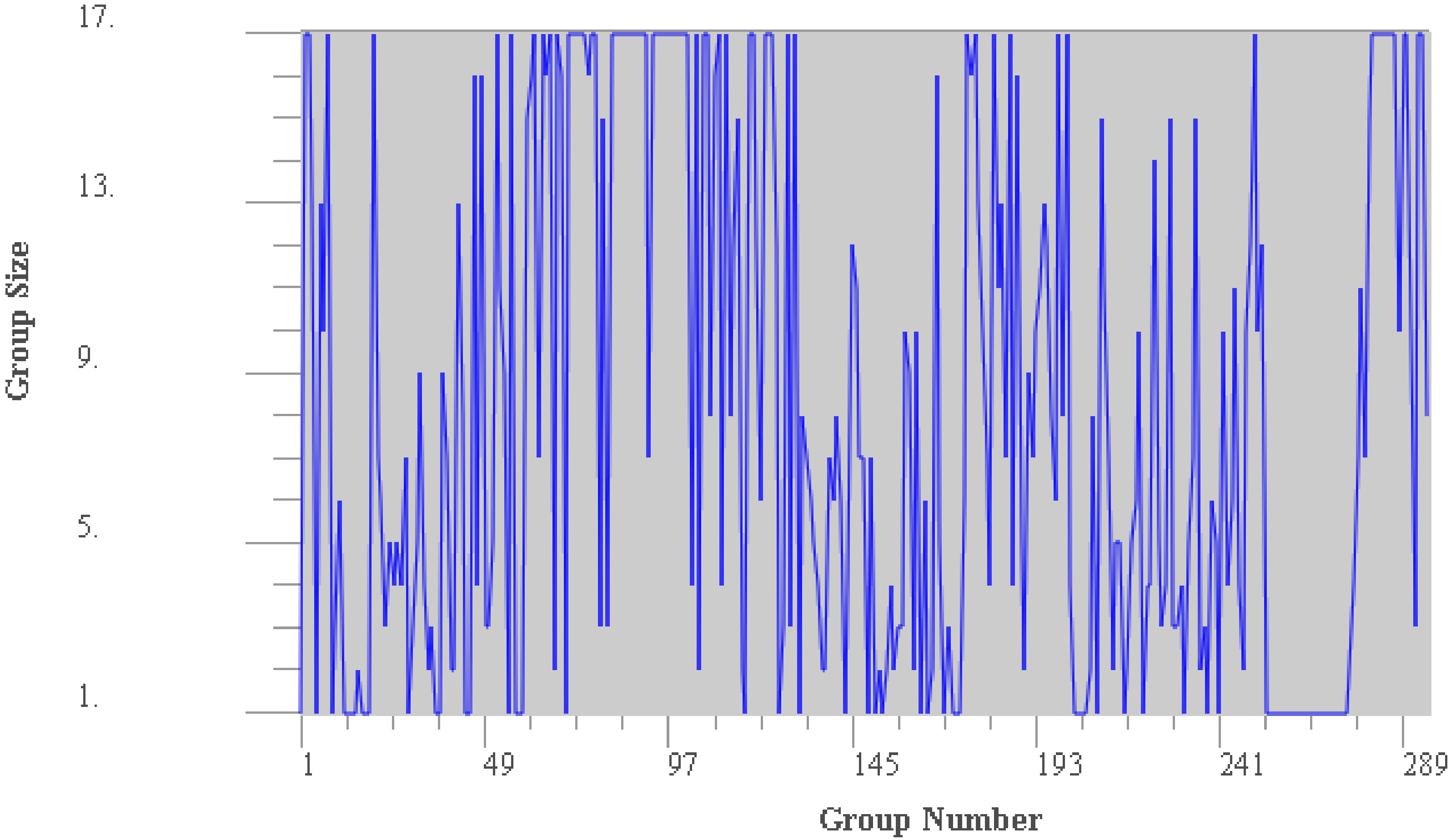
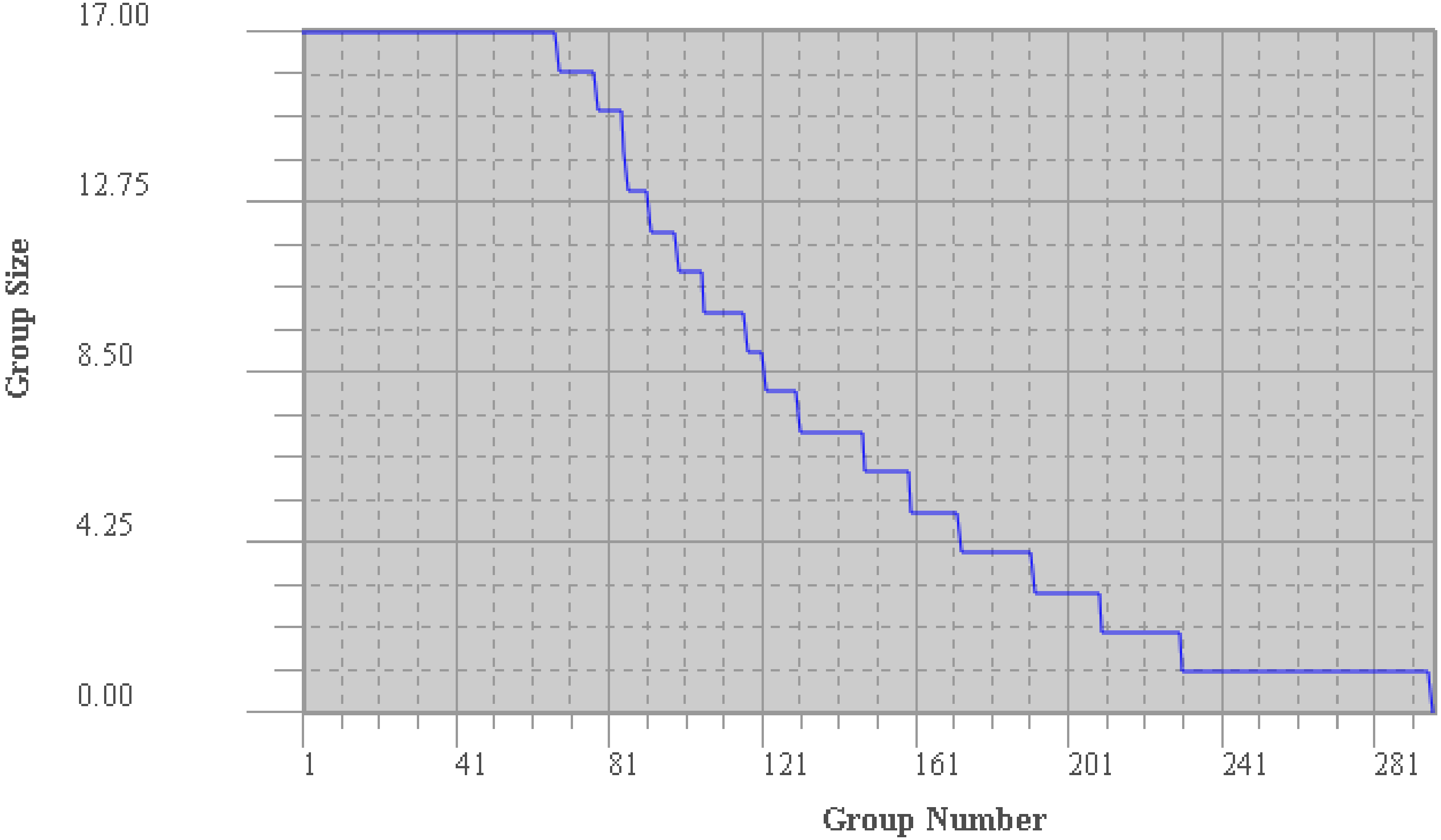
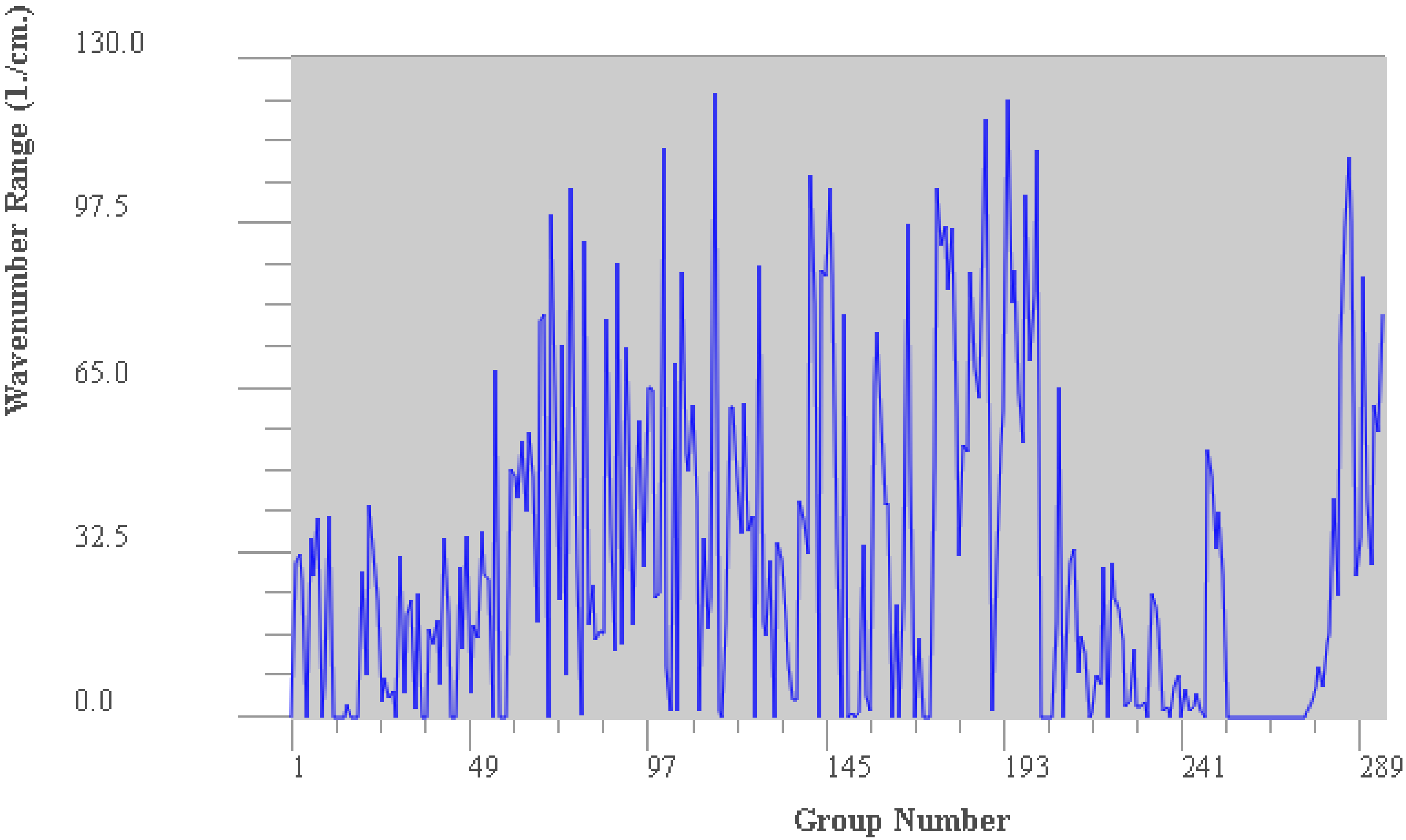


Group Sizes Ordered by Decreasing Size



Actual Wavelength Range (max is 200)



Super channel Planck Function

- Pick an appropriate temperature range (200 – 320 K)
- Let $T^*(\nu) = a(\nu) + b(\nu)\, T(\nu)$
- Where
  - T^* is the value to be used in Planck equation
  - T is the true atmospheric temperature
  - a, b are derived constants

    ν is the derived wavenumber
- Values for ν, a, and b are found by using and iteration procedure to minimize the temperature error between the two radiances defined below
- The true radiance is found by calculating radiances for all the included AIRS channels and averaging over the super channel
- The super channel radiance is obtained using T*

Values of the coefficient a (should be near zero)

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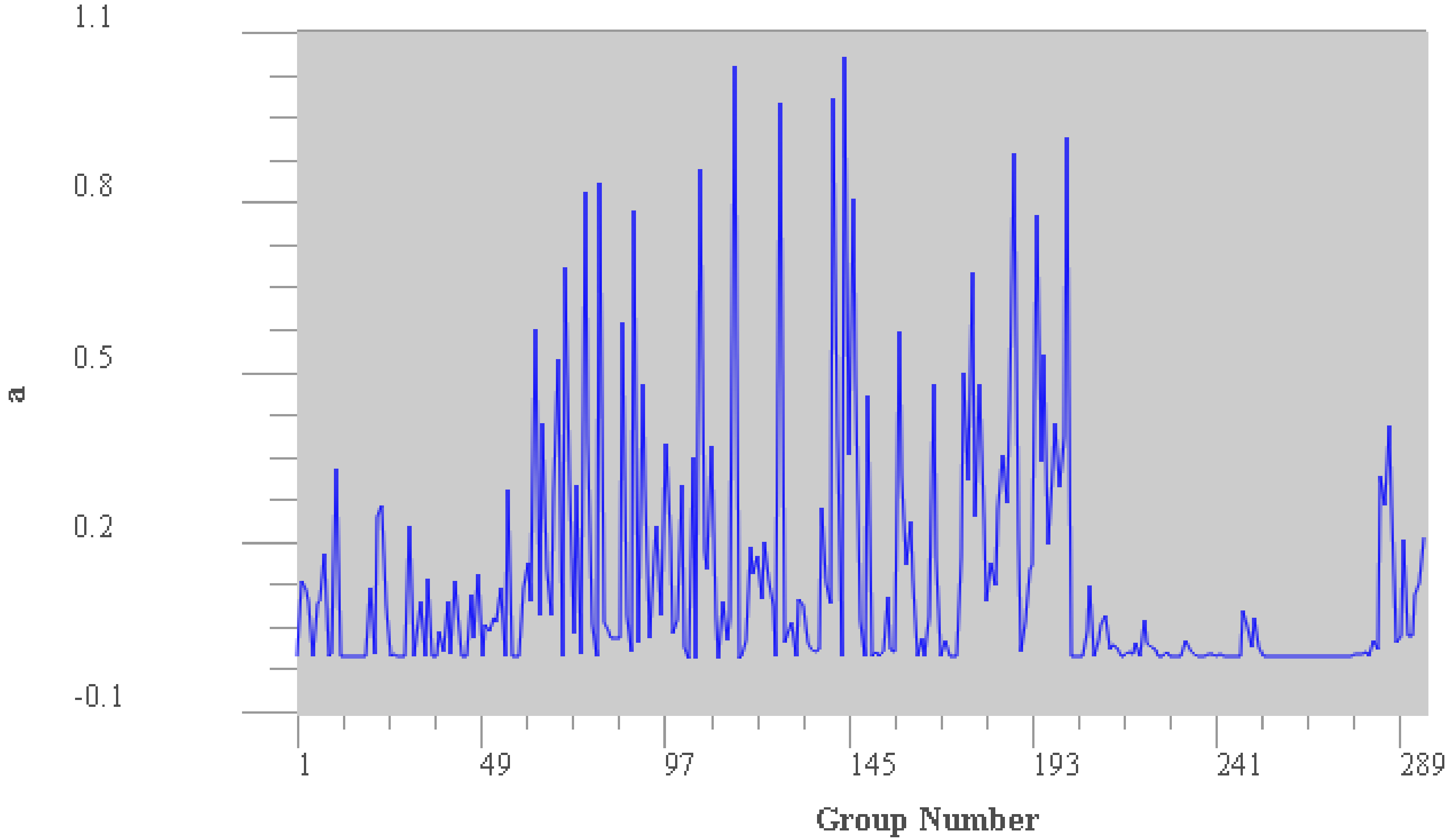
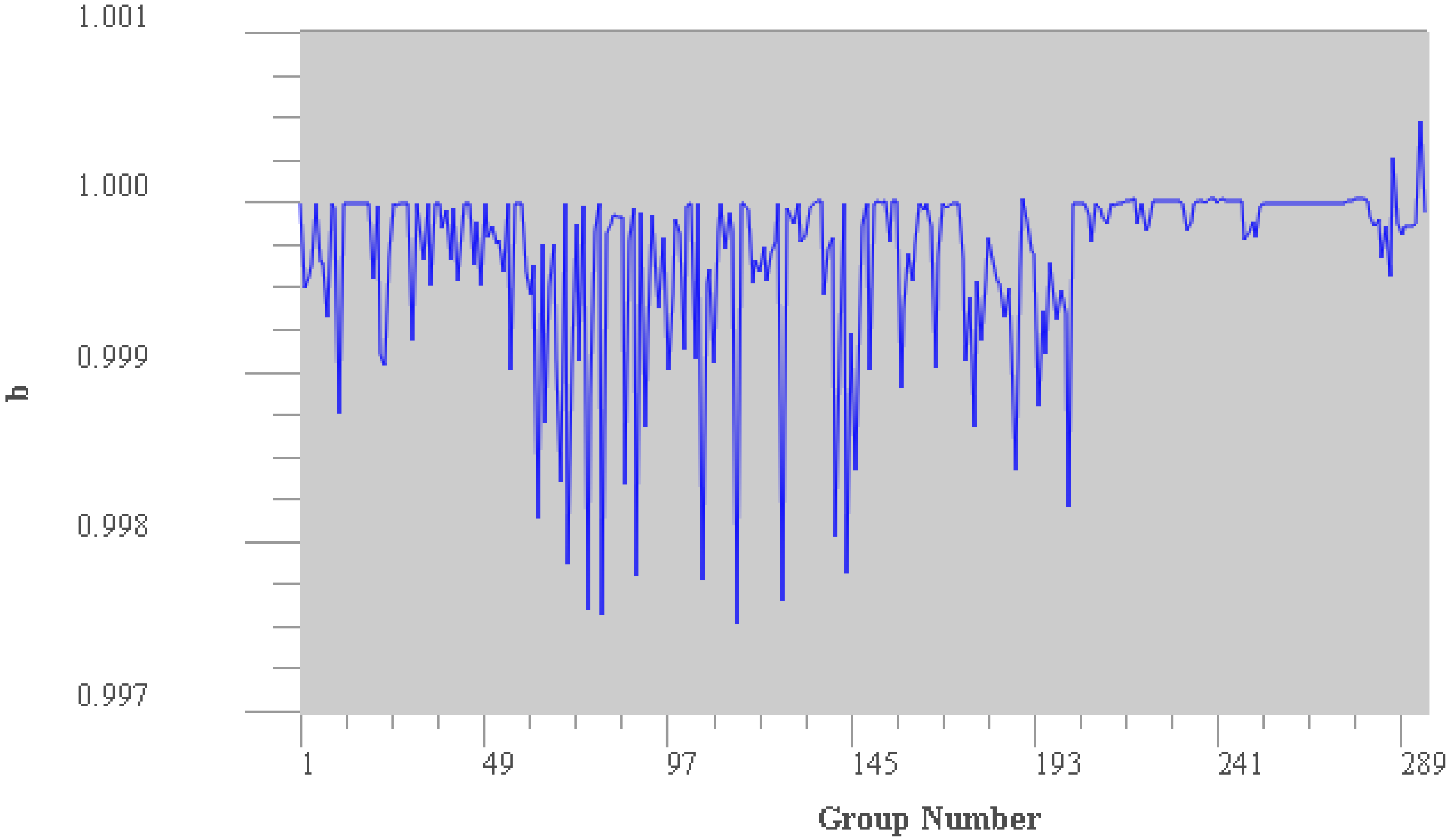
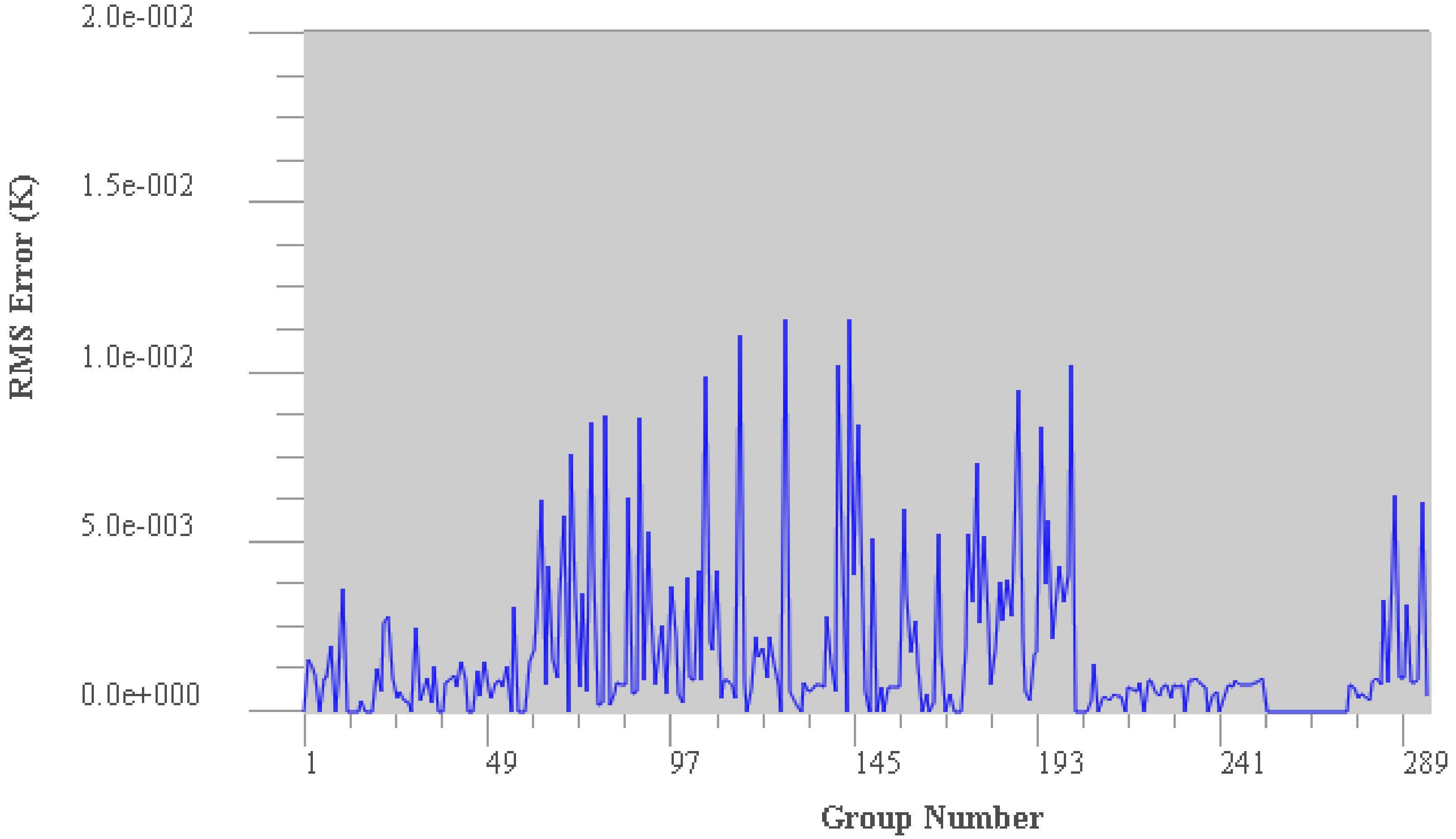


Values of the coefficient b (should be near 1.0)



Planck Function Error (K)



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Rapid Transmittance Calculation

- Rapid transmittance models essential for the use of radiances by major numerical prediction centers and many other satellite users
- We use OPTRAN – the method used at NESDIS and EMC
- Rapid transmittance models have been developed for and applied to wideband instruments such as TOVS and AVHRR
- No new issues exist for their use with super channels provided:
  - A reasonable wavelength range limit is imposed
- Transmittances are calculated for three components – dry, water vapor, and ozone
- The components are combined with a correction for multiple gas interactions to get the total transmittance
- AIRS channels with a history of being noisy were not included

Rapid Transmittance Error as a Function of the Super Channel Number - dark blue is dry – green is water vapor - red is ozone - cyan is the total after the 3 are combined

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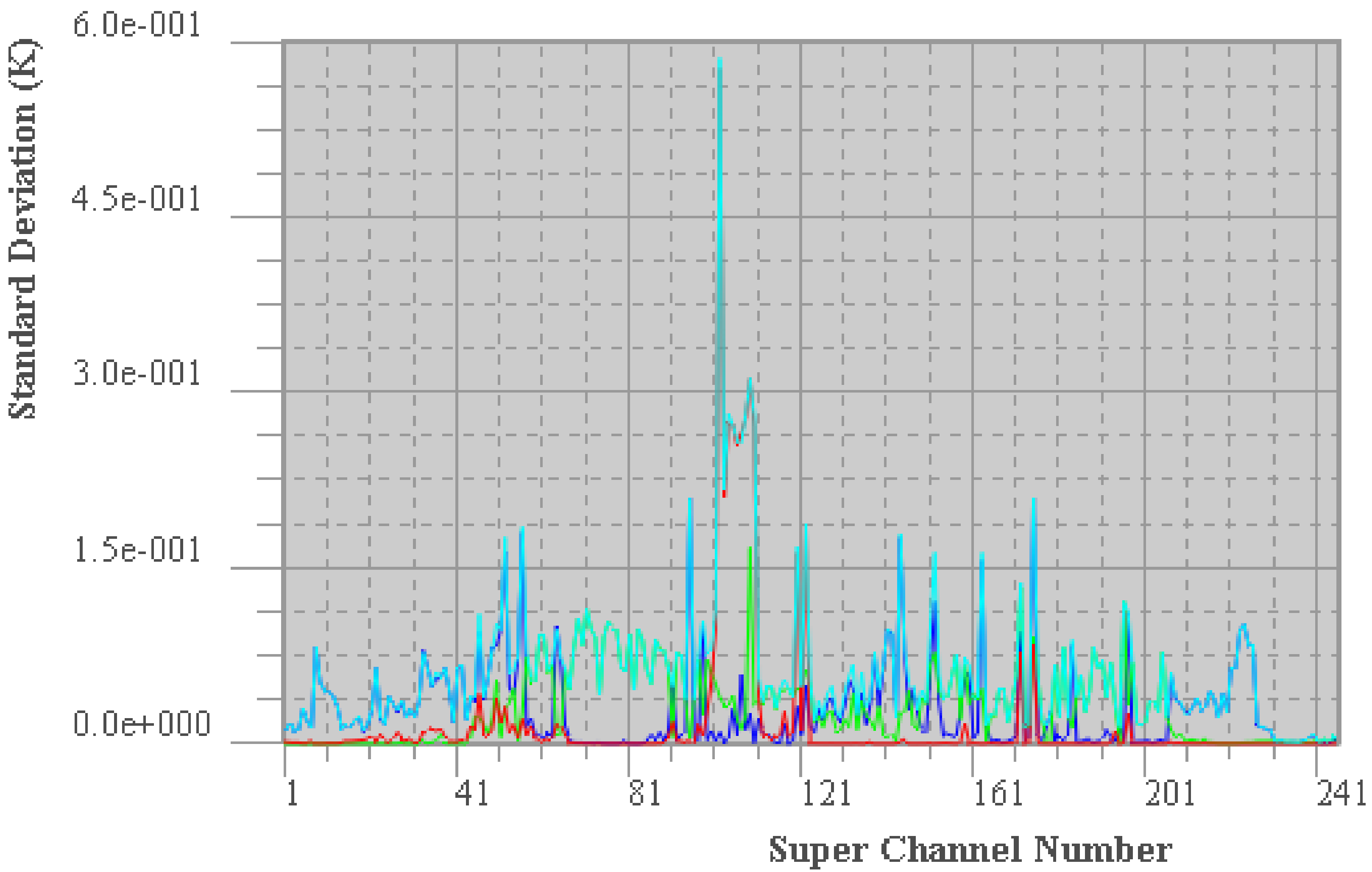

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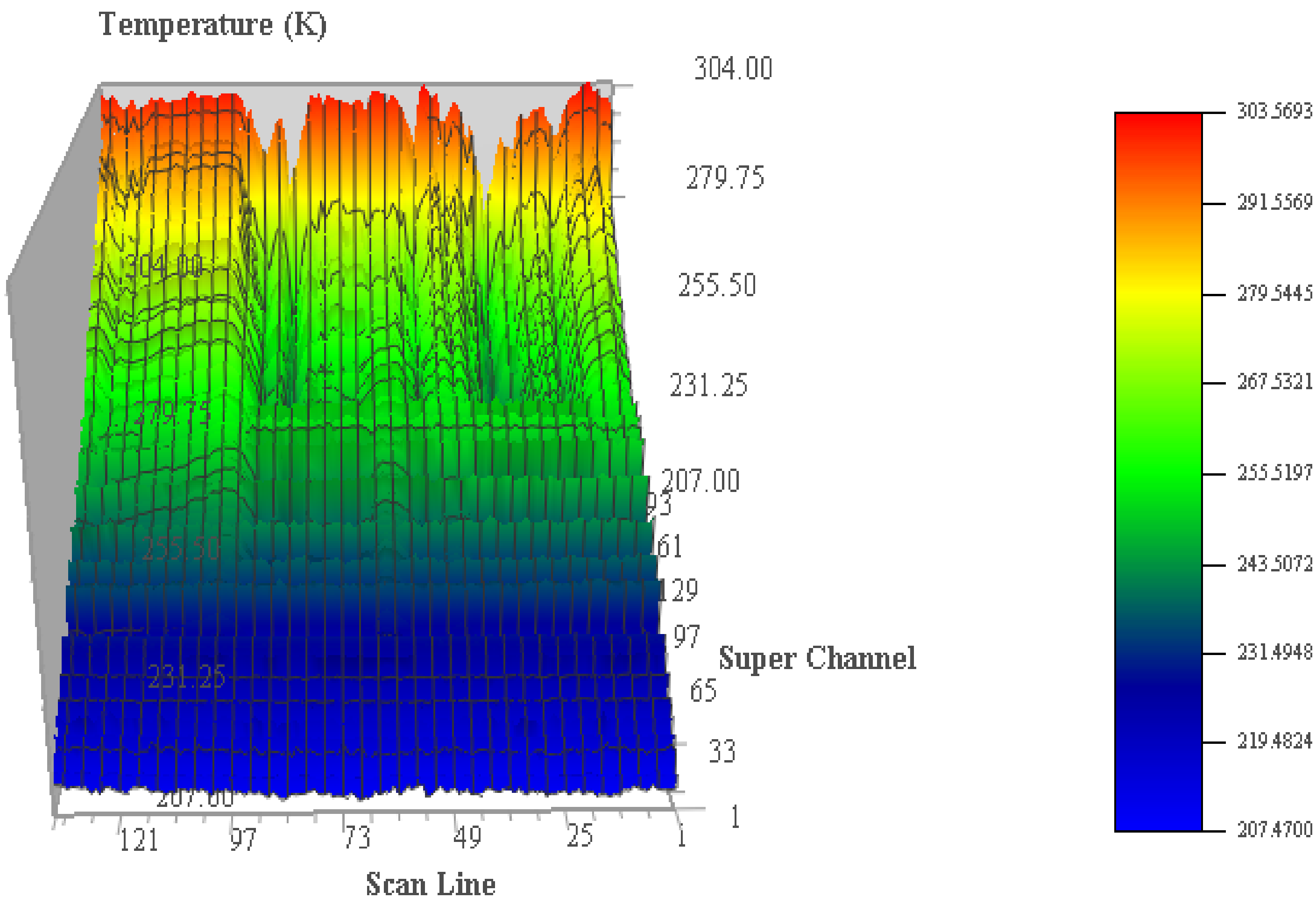
Information Content

- If done incorrectly, the use of the super channels can lose information
- The information content was checked in the following way using a sample of observed AIRS data
  - Step 1 -The trace of the full covariance was calculated (the diagonal elements of the covariance matrix were summed)
  - Step 2 - For each super channel, the corresponding channel covariance was multiplied by the sample size and the products were summed
  - The ratio of step 2 to step 1 was formed
- The result was 0.9986
- This means that the super channels retain over 99% of the total variance

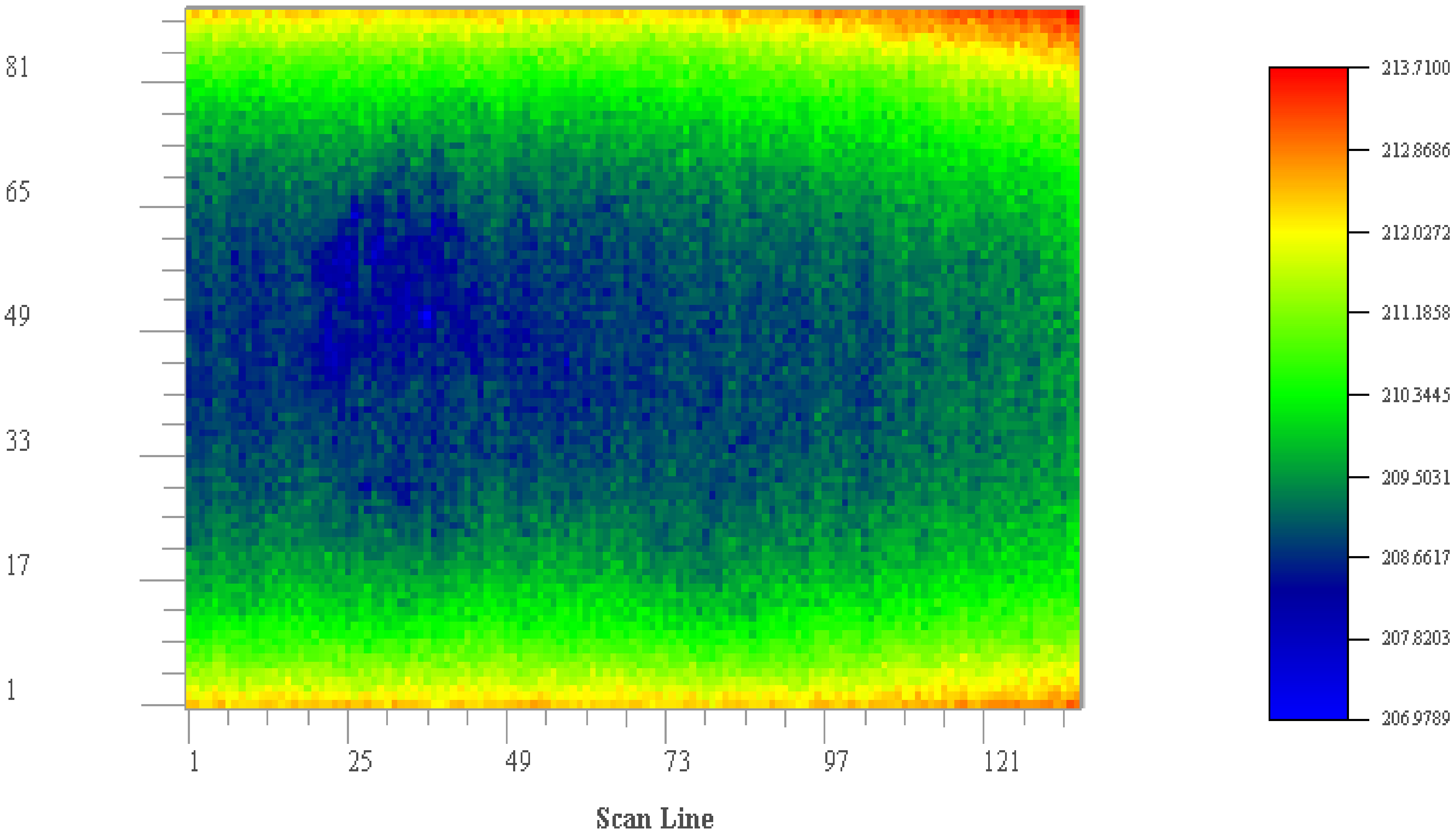
Qualifications/considerations

- The super channels were selected using a preliminary grating position for the AIRS instrument
- The grating position achieved in orbit is slightly different
- The selection should be redone, but the results can only get better
- The result will be to increase the retained variance as some of the channels averaged are not as similar as they could be
- Note that a significant number of super channels are one channel combinations
  - Channels that are mixes of 2 gases which vary in amount will tend to be unique
  - Such channels may not add enough useful information to justify the additional processing burden

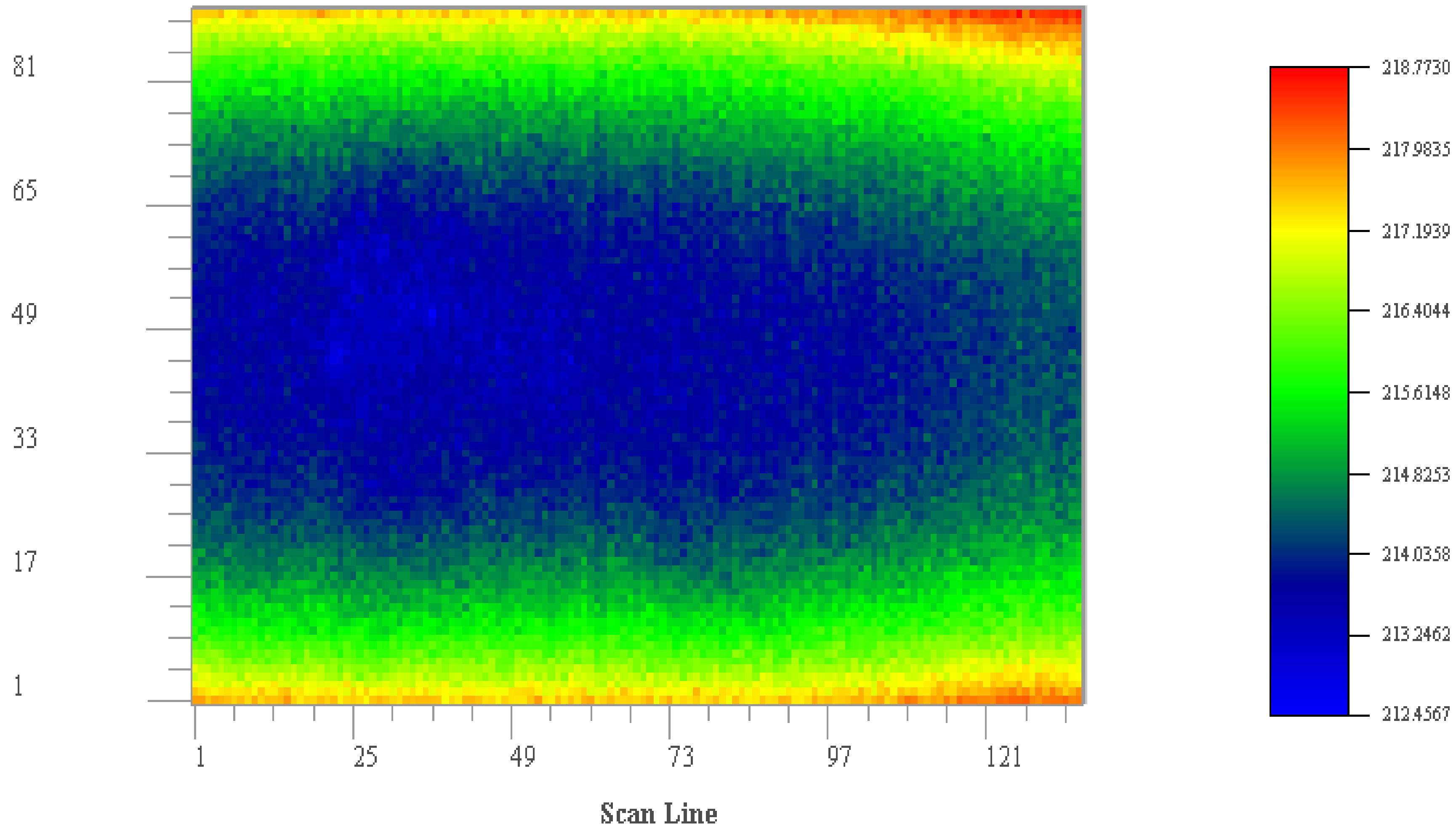
Example of Super Channels in Approximate height order - Note the Difference Between Clear and Cloudy areas



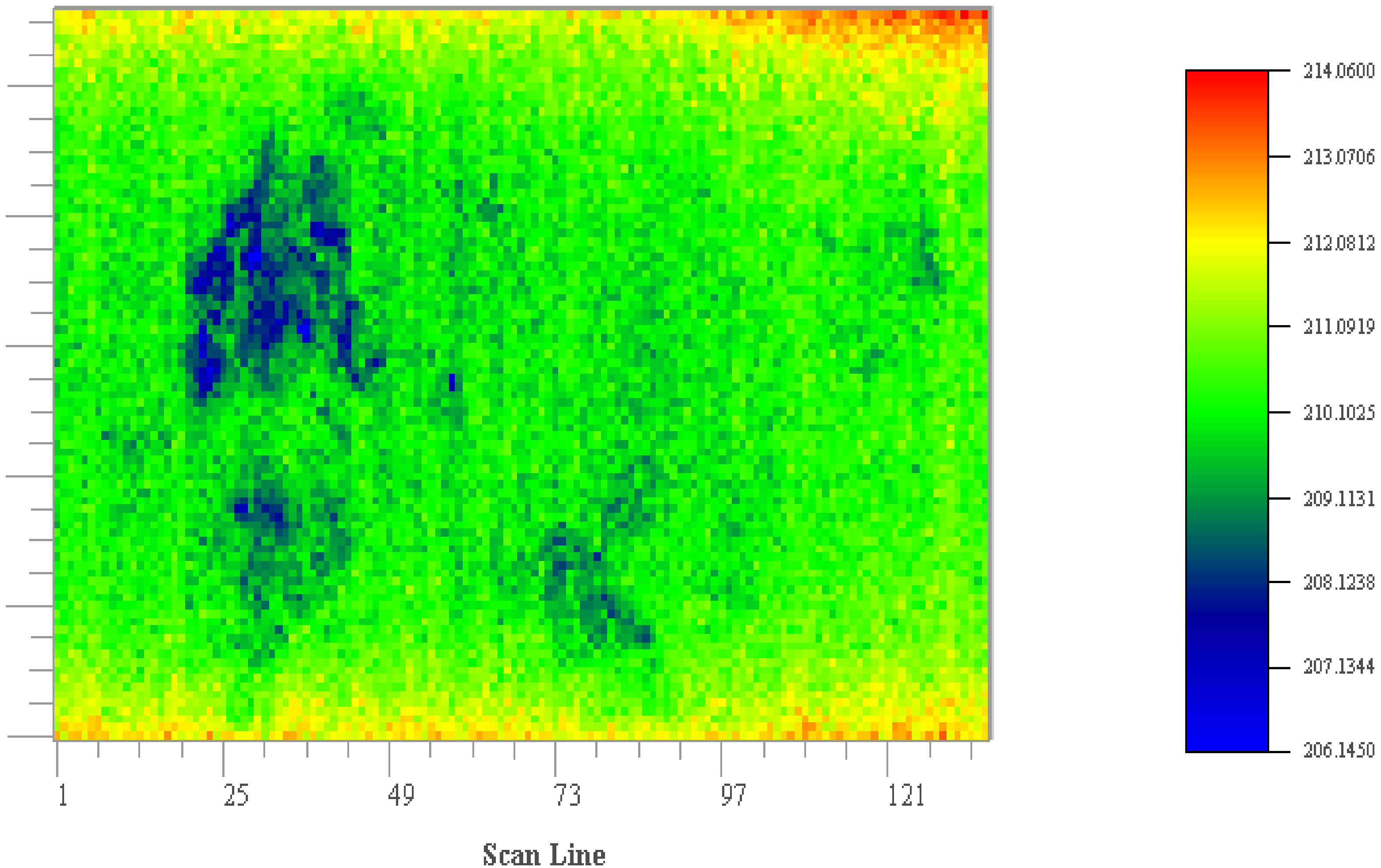
Super Channel Number 10 - 24 channel average



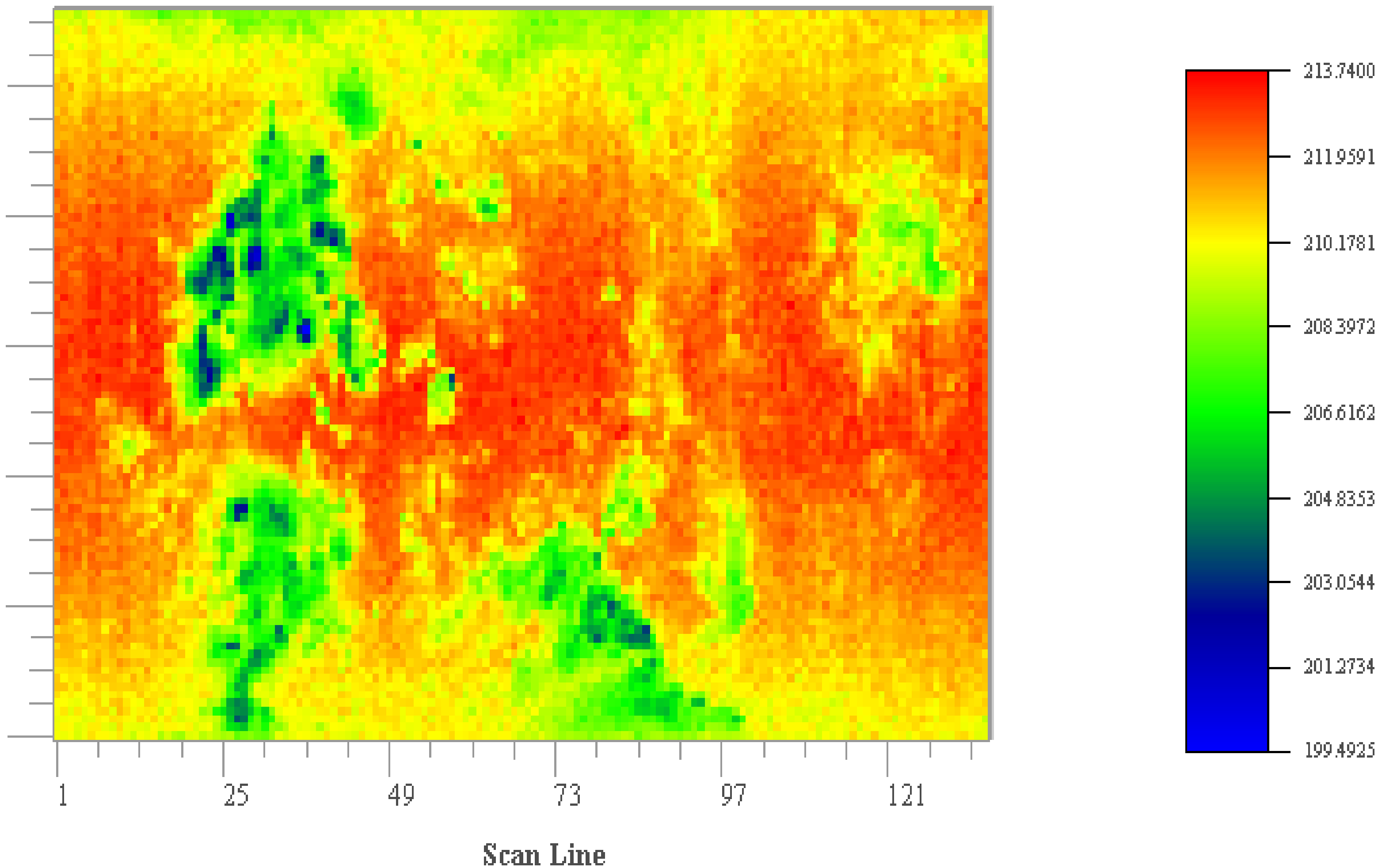
Super Channel # 1, 28 channel average



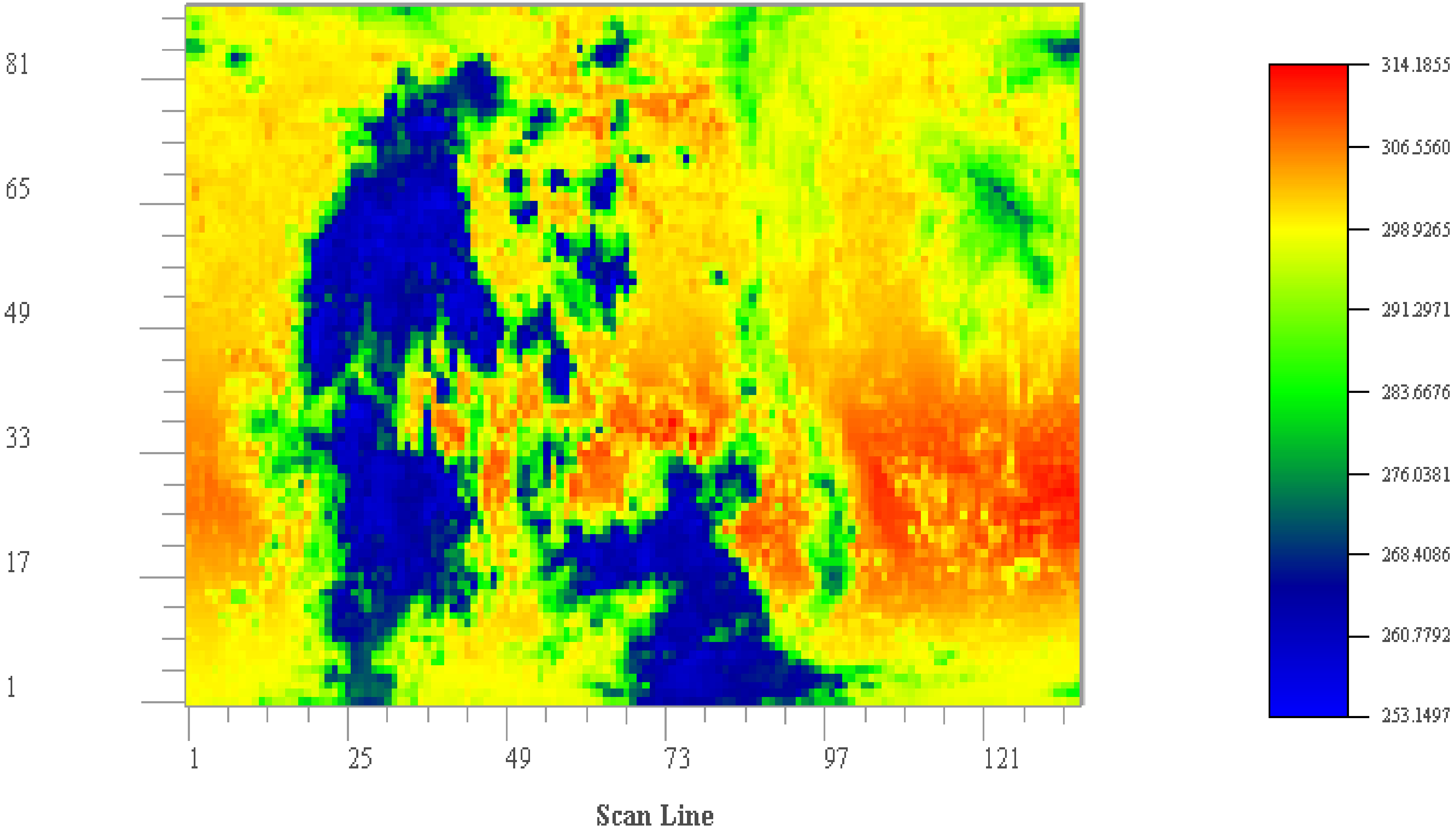
Super channel # 10 - 6 Channel Average



Super Channel # 4 19 - 4 Channel Average



Super Channel # 242 - 39 Channel Average



Conclusions

- Super channels can be used with little loss of information
- Super channels provide the accuracy required to perform retrievals
- Super channels reduce the number of calculations required from 289 to 229 if all single channel groups are eliminated.
- If channels are eliminated, the group size is an indicator, but not the sole deciding factor
- A channel should not be eliminated without checking it for information content.