

Progress Report on Forward Model and CO Retrieval Algorithm

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Fast-Transmittance Algorithm

- Monochromatic Calculations
 - GENLN2
 - 1992 AFGL line parameters, line mixing, χ -function in far-wing, H₂O continuum, etc.
 - All major, minor absorbers included
 - 100 layers (chosen to reach 0.2K accuracy)
 - Validation using laboratory spectra, HIS spectra (ITRA), and ATMOS
- Determination of Fast-Transmittance Parameters
 - 18 profiles for fast transmittance parameter regression
 - Monochromatic transmittances interpolated from a 3 temperature monochromatic transmittance database
 - LORAL instrument function (long wings)
- Regression Errors
 - Vast majority of channel errors are less than 0.1K RMS
 - 95% of channels have errors of less than 0.3K RMS
 - 99% of channels have errors of less than 0.5K RMS
 - Largest error is 0.9K RMS
 - Most large errors due to H₂O
 - Errors <0.2K in temperature sounding channels
 - Comparison to Joel Susskind's fast-transmittance performance (67 layers)
 - * Susskind's errors are 2X lower for temperature channels, but both algorithms give errors sufficiently low enough for AIRS
 - * Susskind's H₂O channel errors are up to 5X lower than ours, we must improve these channels

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 CO RETRIEVAL ALGORITHM Progress
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- * Our absolute errors are significantly lower due to more up-to-date spectroscopy
- Why are our results different?
 1. The standard deviation of our regression profiles is approximately 15-50% larger than Susskind's
 2. We used the LORAL (long-wing) instrument function, Susskind used a trapezoidal function. Comparisons of regressions for the fast-transmittance parameters in H₂O regions using both instrument functions showed that our use of the LORAL instrument function was the main cause of our larger errors. The LORAL instrument function can increase the fit standard deviation from the 0.2K level to the 0.6K+ level. With a trapezoid function our RMS errors are only about 2X higher than Susskind's
- Future Work
 - Improve H₂O fast-transmittance algorithm
 - Finish generation of 11 temperature monochromatic database
 - Include temperature dependence of H₂O
 - Generate slant path fast-transmittance parameters
 - Continue GENLN2 and spectroscopy validation using laboratory data, HIS and ATMOS spectra
 - * CO₂ far-wing under study using recent lab spectra recorded by John Johns at NRC-Ottawa both at 4.3 and 15 μm
 - * Plan to record H₂O continuum between 1200–1400 cm^{-1} at NIST in about 1 year when their new 2-meter cell is available
 - * Participate in ITRA comparisons using HIS spectra
 - * Possibly look at more ATMOS spectra
 - Examine utility of neural-nets for forward problem
- Recommendation

Start using our 100 layer fast-transmittance algorithm in AIRS simulations

 - We need feedback about problems
 - Errors of up to 5+K possible with present (Susskind's) 67 layer algorithm parameters, equivalent to 50+ mbar pressure shifts
 - Our algorithm is much more accurate than the 67 layer algorithm
 - * We used the AFGL 1992 line parameter tape (some CO₂ band strengths have changed by up to 40% for example)

- * Line mixing is in our codes, which is a 50% effect
 - * Our line-by-line code has undergone extensive validation
 - * We plan to validate our fast-transmittance codes using HIS spectra (i.e. we plan to generate fast-transmittance parameters for HIS with the computer codes and monochromatic database used for AIRS)
- A clear separation of retrieval algorithm developers and development of the fast-transmittance code *may* result in more realistic simulation tests

CO Retrieval Algorithm

- Simulations show that AIRS can:
 - Detect natural variability in background CO amount under some conditions in a 50 x 50 km FOV
 - Easily detect polluted boundary layer
- Uncertain if CO profiles can be retrieved
- Retrieval technique
 - Cross-spectral density (*CSD*), borrowed from signal processing literature. Form

$$\mathbf{X}_\nu = B(\nu, T)^{calc} - B(\nu, T)^{calc+\gamma\%CO} \quad (1)$$

and

$$\mathbf{Y}_\nu = B(\nu, T)^{calc} - B(\nu, T)^{measured} \quad (2)$$

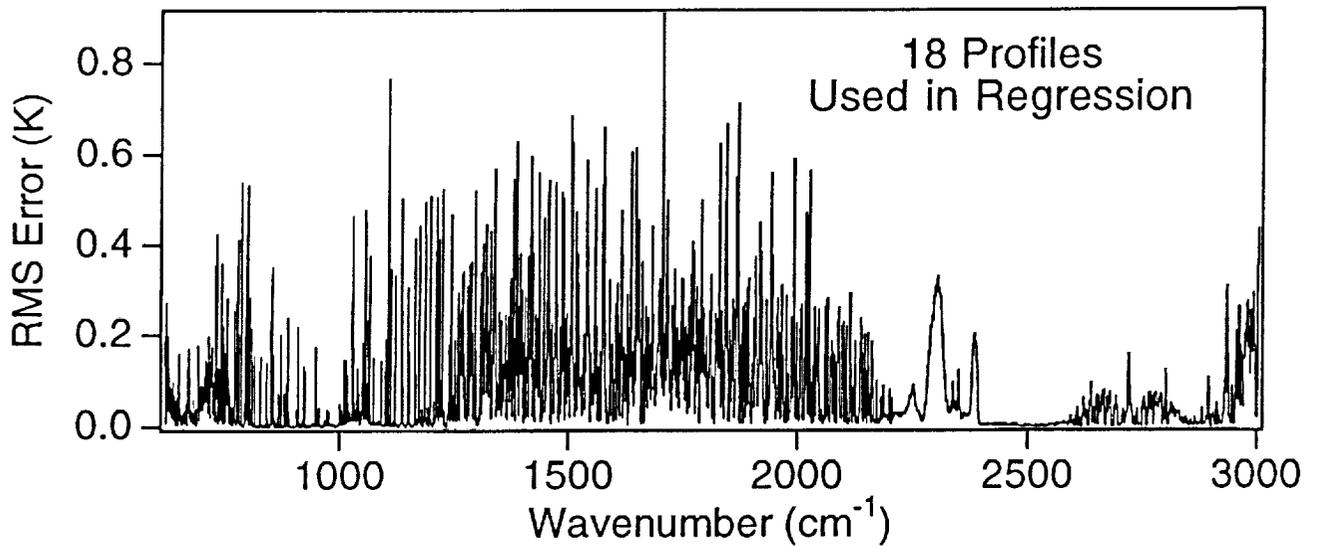
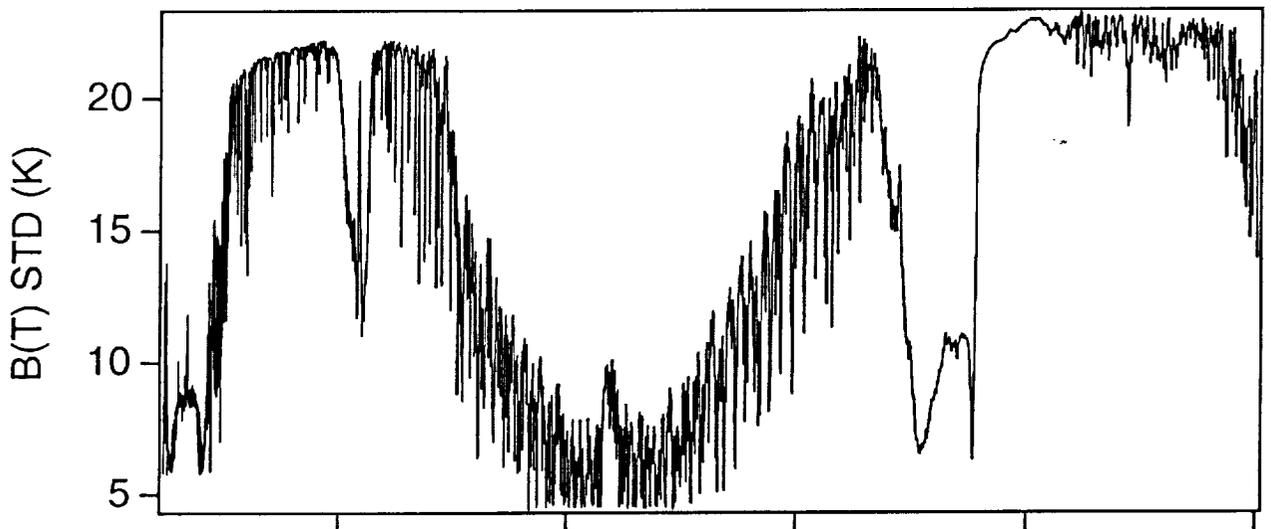
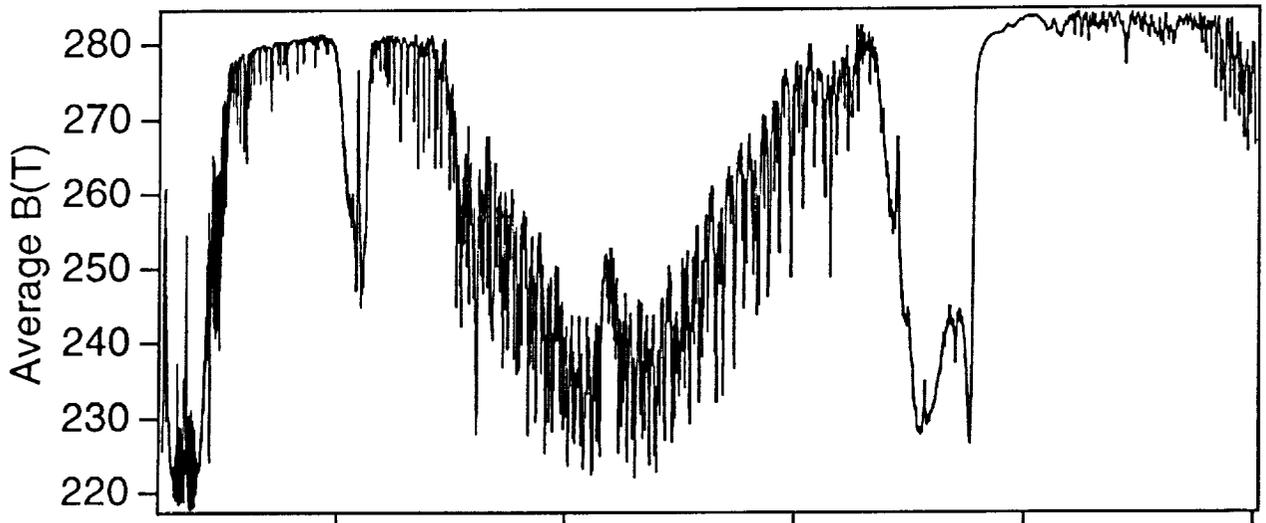
where $B(\nu, t)$ is the brightness temperature, ν the frequency, and T the temperature. The $+\gamma\%$ in $B(\nu, T)^{calc+\gamma\%CO}$ indicates that this calculation of the brightness temperature should be for an atmosphere with a perturbed amount of CO. This perturbation can have a relatively arbitrary magnitude, its shape should follow the expected variations in the CO profile. Cut \mathbf{X} and \mathbf{Y} into k (possibly overlapping) sections, \mathbf{x}_k and \mathbf{y}_k , of length m . Hanning window \mathbf{x}_k , \mathbf{y}_k to produce \mathbf{x}_k^h and \mathbf{y}_k^h . Then *CSD* is given by

$$CSD = \sum_k FFT(\mathbf{x}_k^h) * FFT(\mathbf{y}_k^h)^* \quad (3)$$

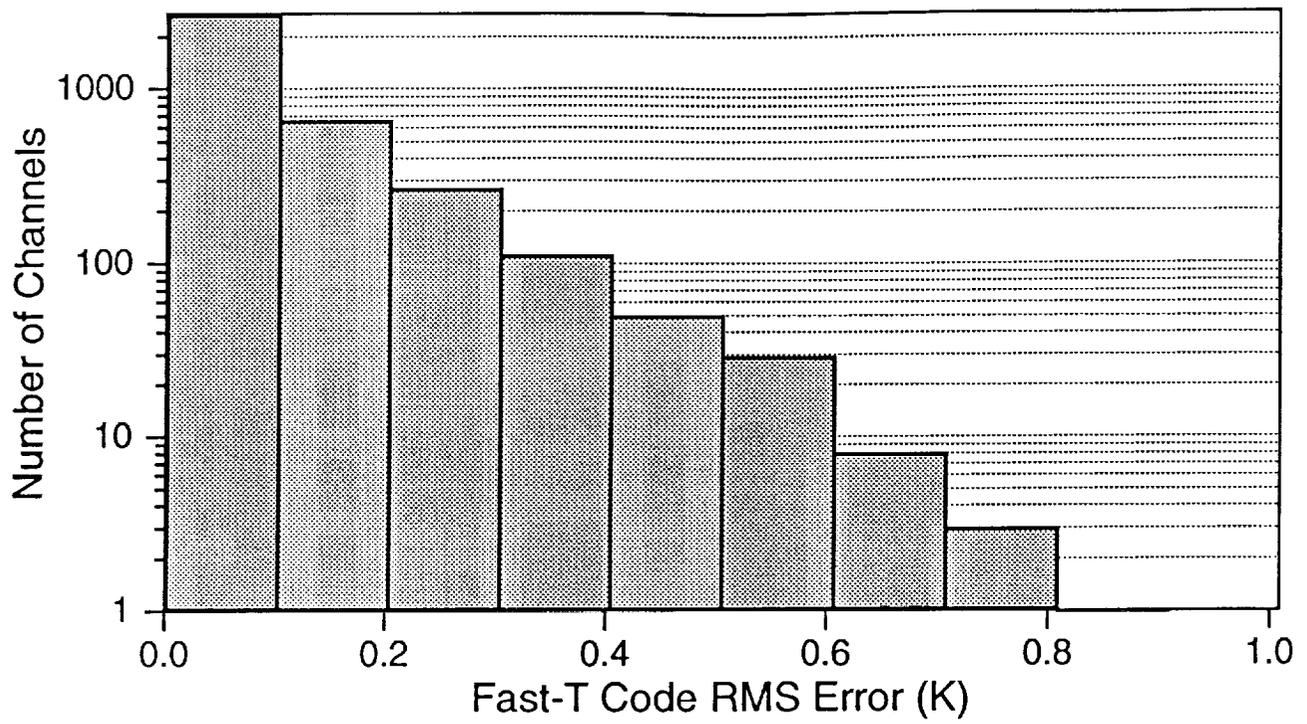
- Enables large reduction of noise since CO signal is sinusoidal
- Noise is reduced close to the level of systematic errors
- Tested sensitivity of retrieval to:
 - Uncertainties in temperature, water vapor profile
 - Undetected cloud fraction (3%)
 - Ground-air temperature contrast
 - Uncertainty in ground-air temperature contrast
- AIRS requirements for CO measurement
 - Channels between 2080 and 2200 cm^{-1} , 65 channels or 130 pixels

- Cloud cleared radiances
- Surface emissivity-“temperature” product near 2100 cm^{-1}
- Most standard AIRS products (temperature, water, ...)
- Justification
 - CO is a key component in tropospheric chemistry. Increasing CO may lead to a decrease in OH, reducing the atmosphere’s ability to scavenge other trace gases
 - An AIRS measurement of CO would provide a backup to MOPPIT should it fail
 - A CO measurement based on AIRS would probably be able to produce a much longer record of changing CO compared to MOPPIT or TES
 - AIRS measurements of CO may potentially have lower systematic errors since any measurement of CO is dependent on a good knowledge of the atmospheric state
 - Incremental cost of CO measurement by AIRS is small

Fast Transmittance Error Spectrum



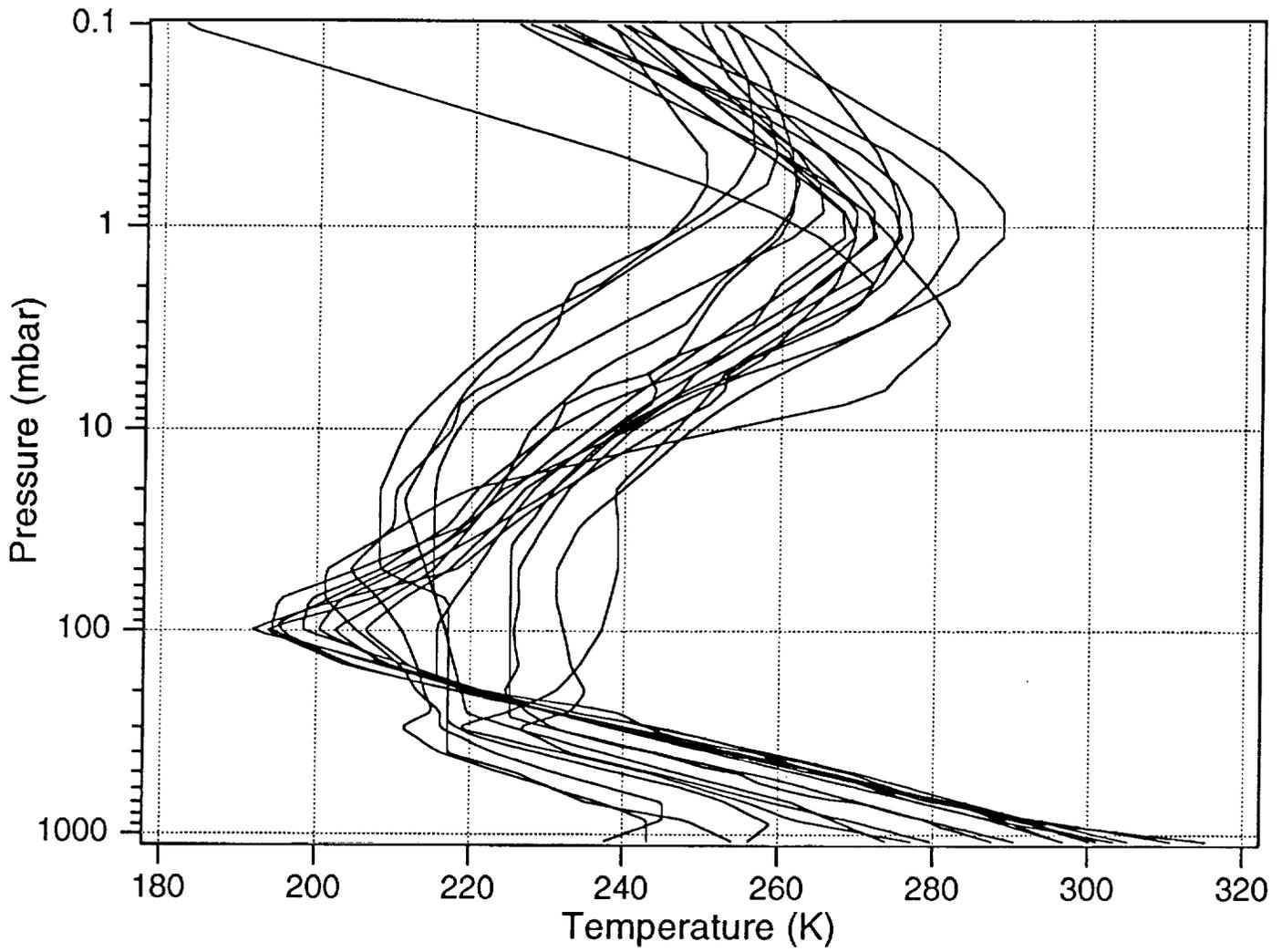
Histogram of Fast-Transmittance Fit Errors



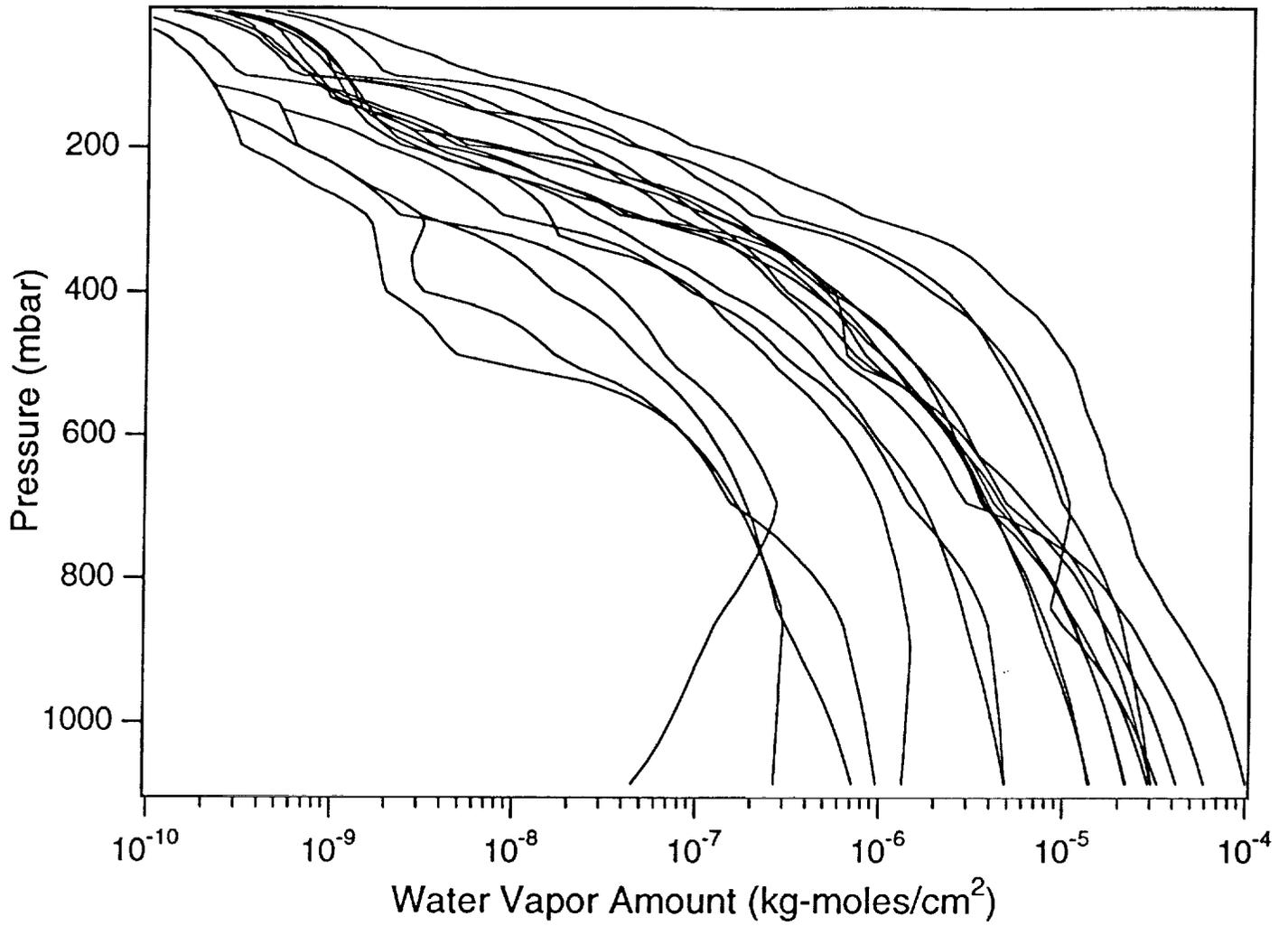
Histogram Values

Point	fit_hist2.y	
0	2691	
1	660	
2	270	
3	112	
4	50	
5	29	
6	8	
7	3	
8	0	
9	1	

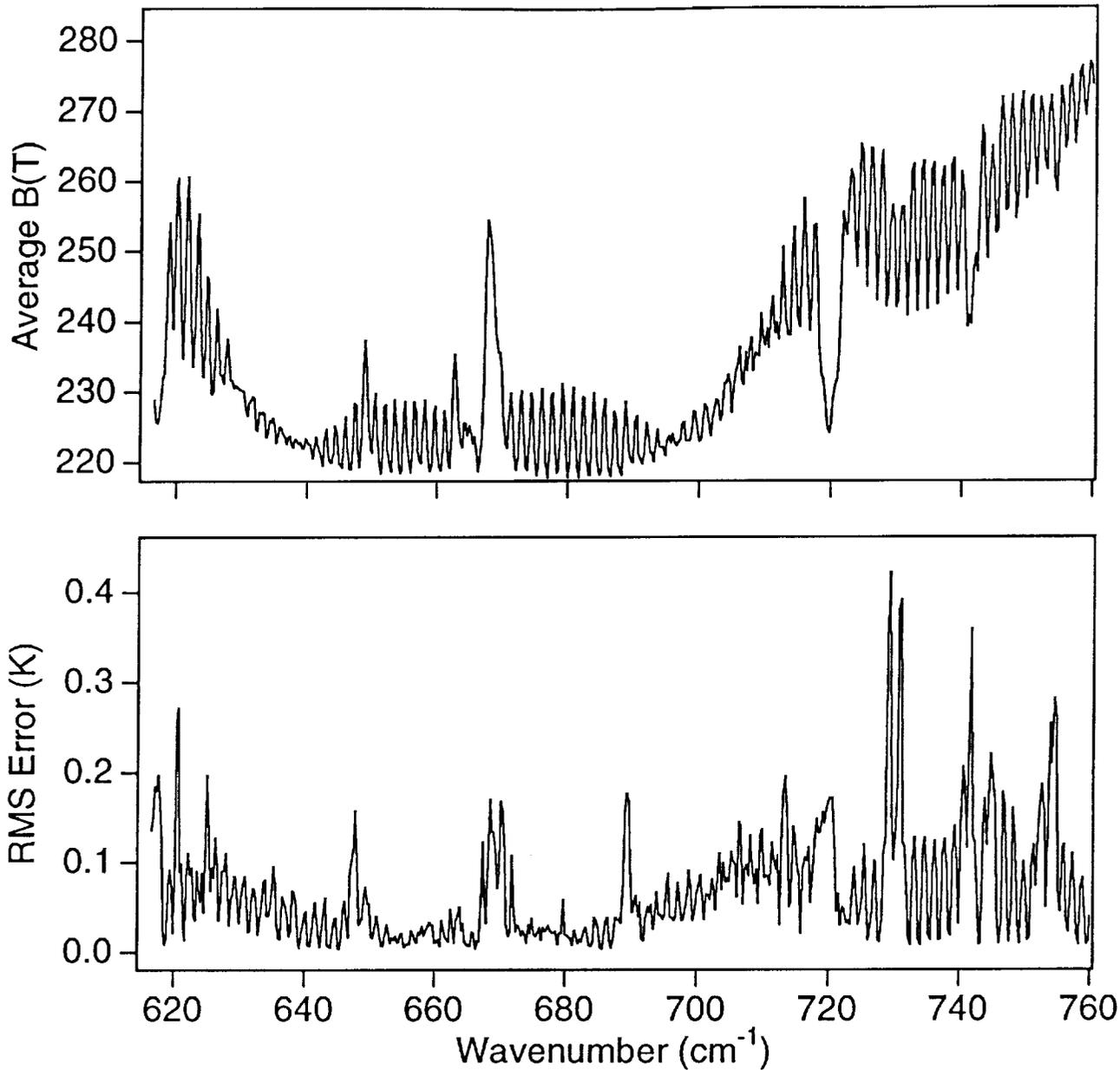
Temperature Profiles Used in Fast Transmittance Regression



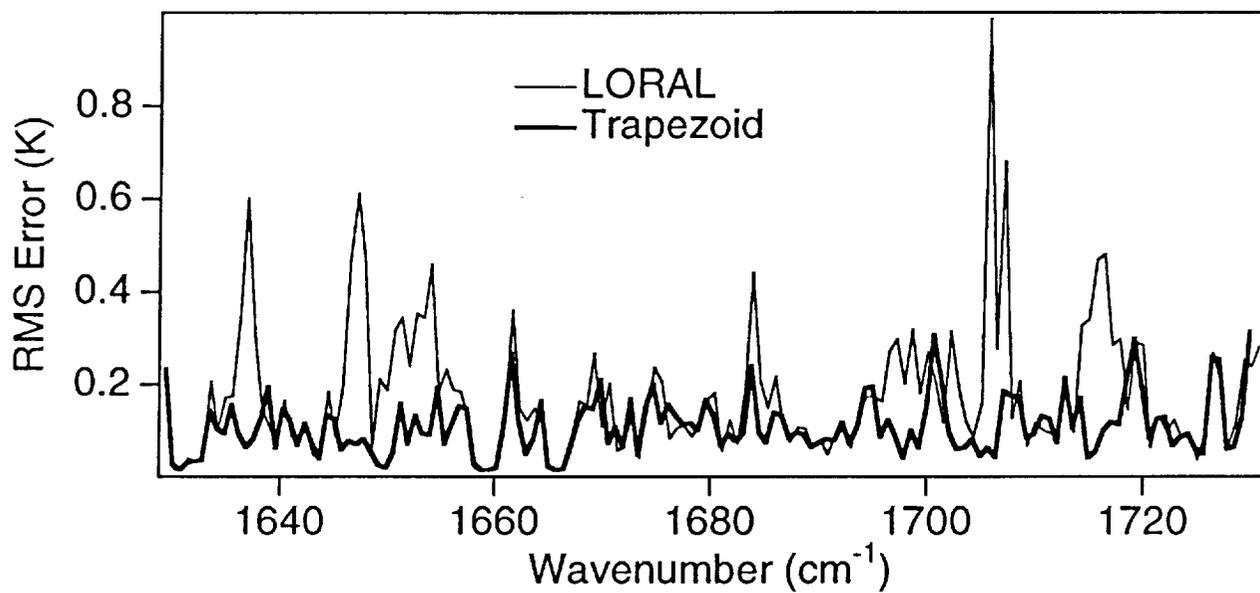
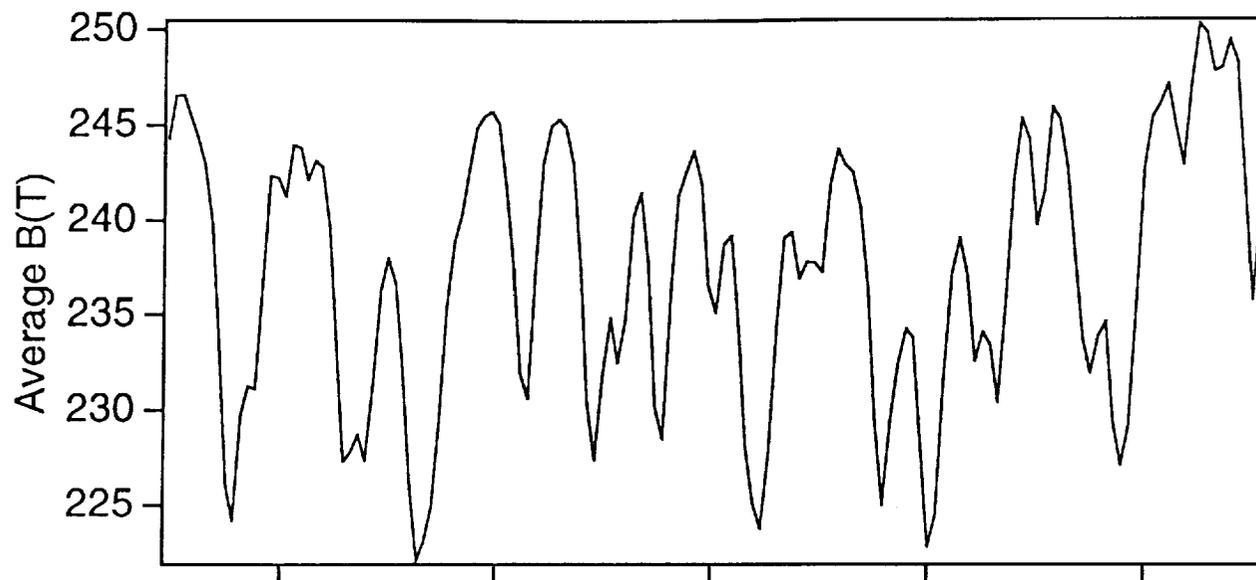
Water Vapor Profiles Used in Fast Transmittance Regression



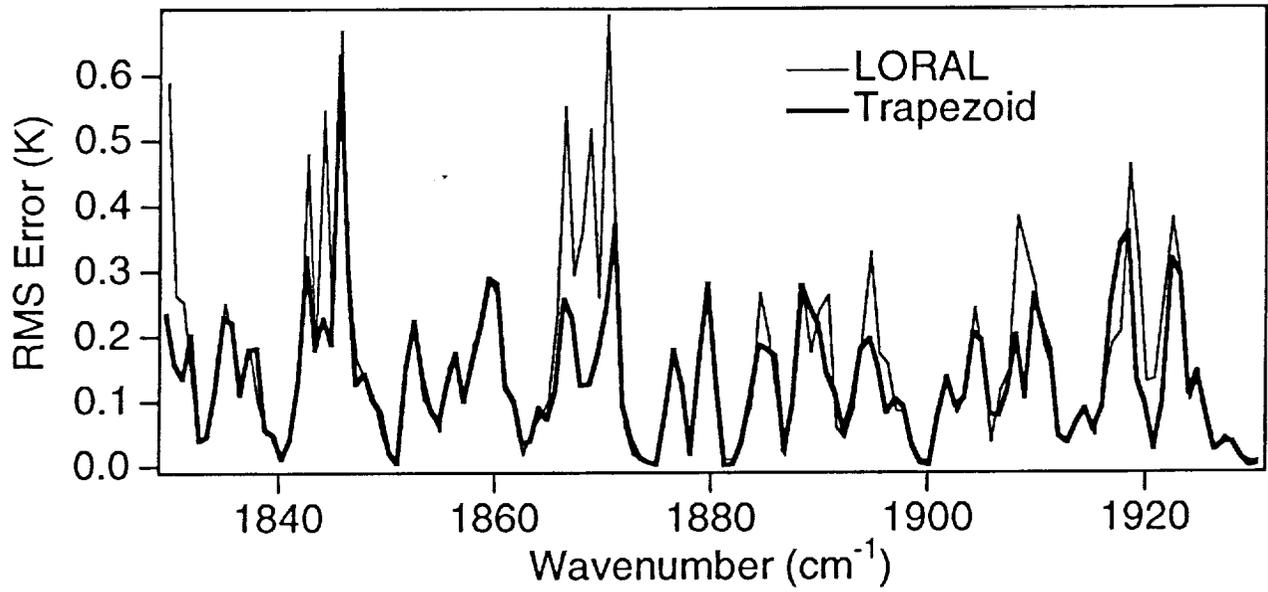
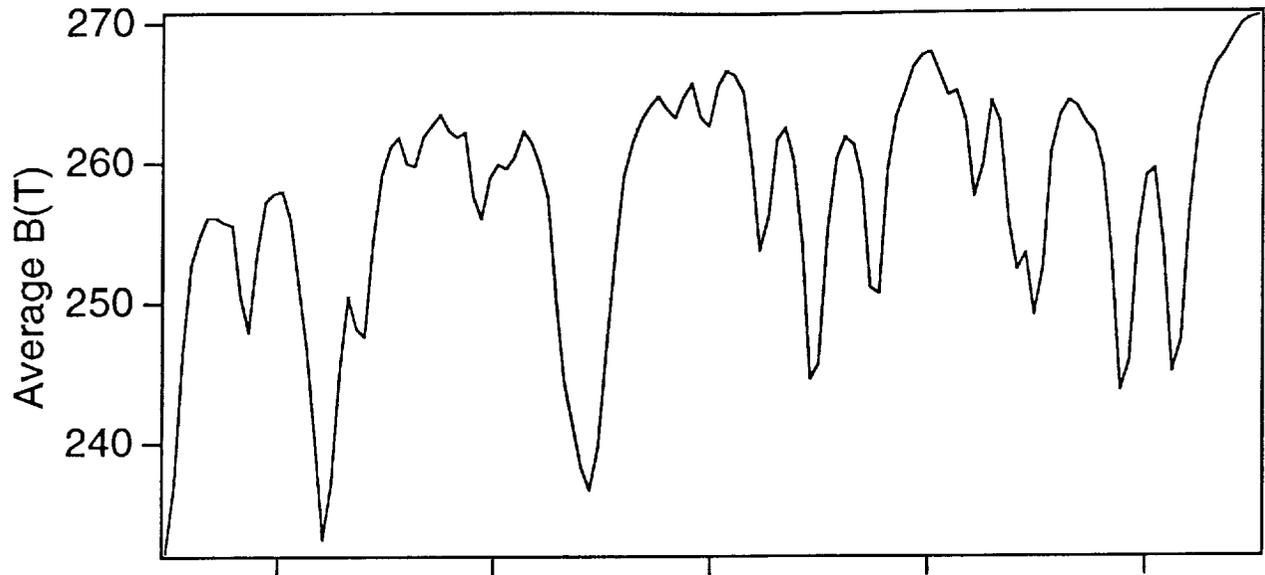
Fast Transmittance Error Spectrum (Blowup)



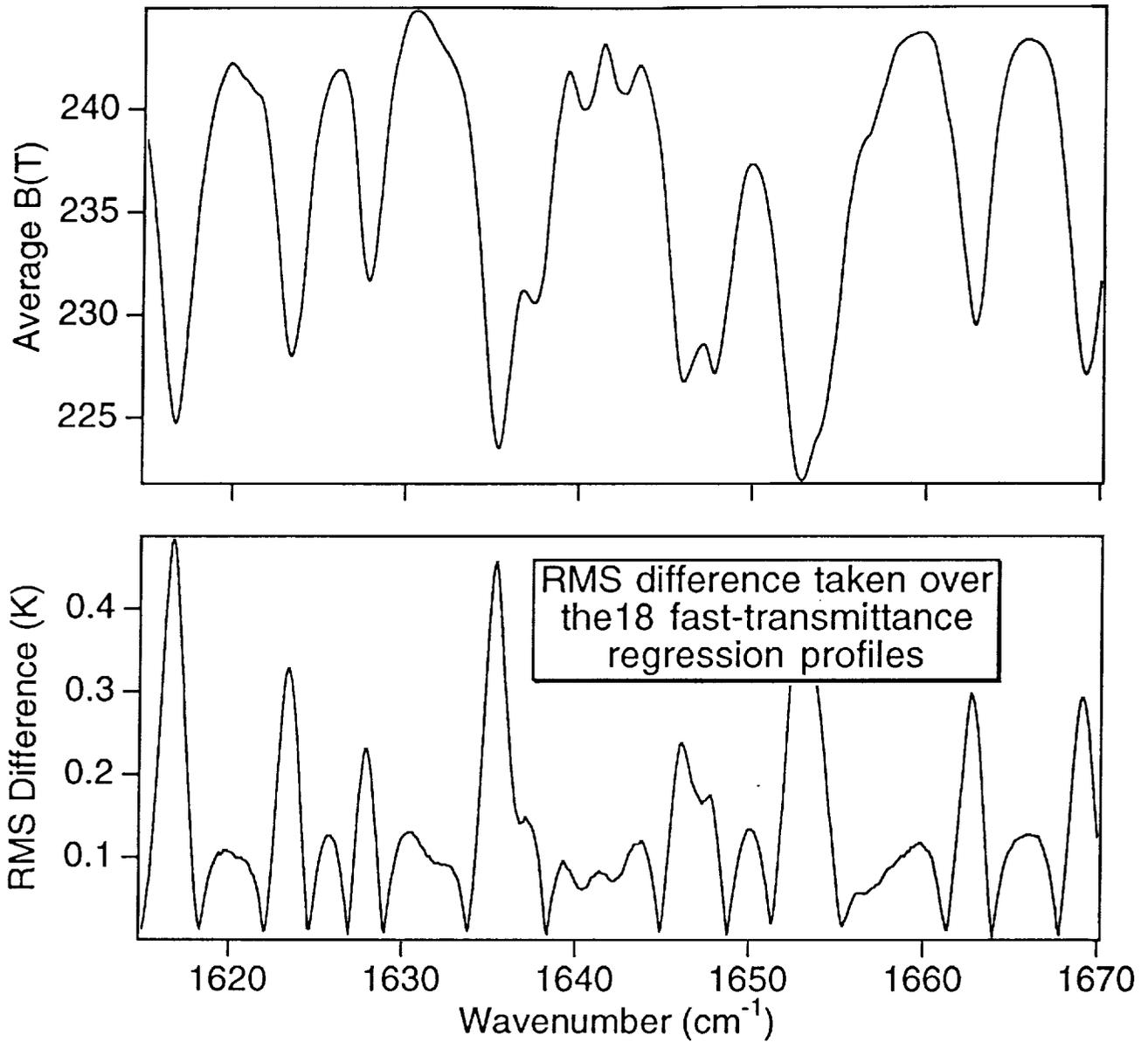
Fast Transmittance Error Spectrum (Blowup)



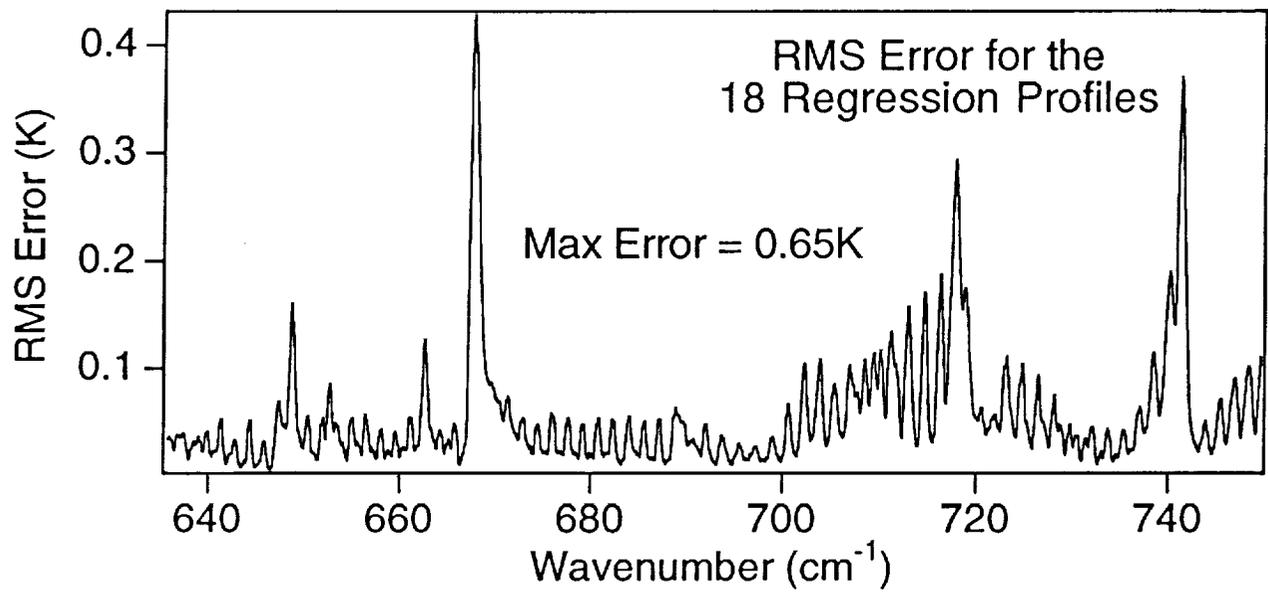
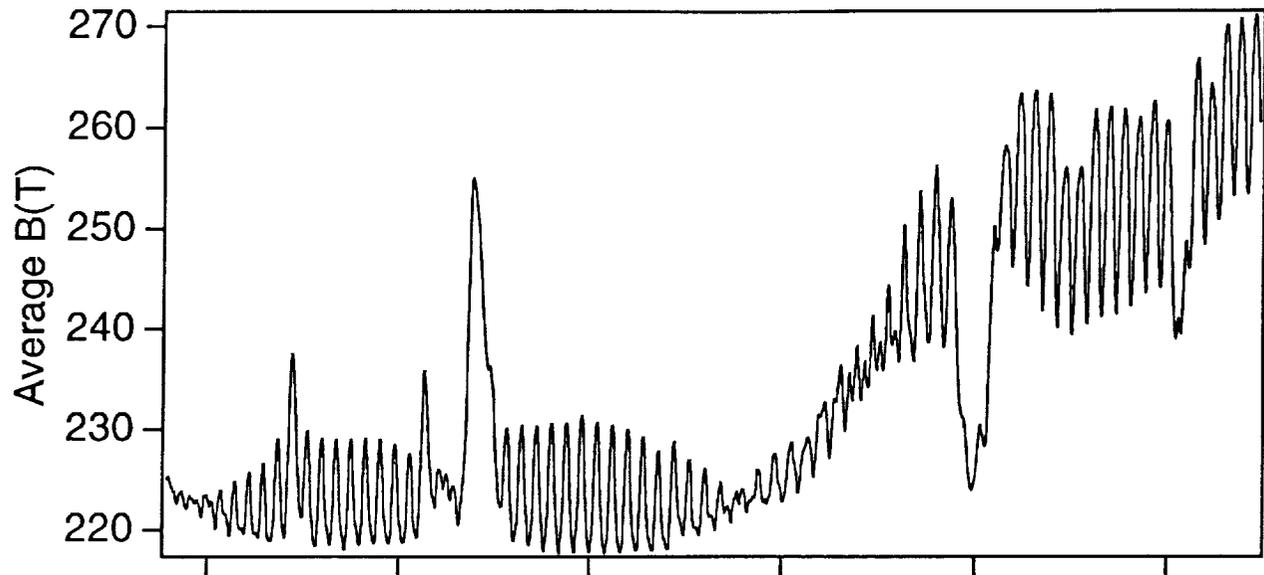
Fast Transmittance Error Spectrum (Blowup)



RMS Brightness Temperature Differences for LORAL (far-wing) vs Trapezoidal Instrument Functions



Fast Transmittance Errors Using 3 Versus 11 Monochromatic Temperature Interpolations



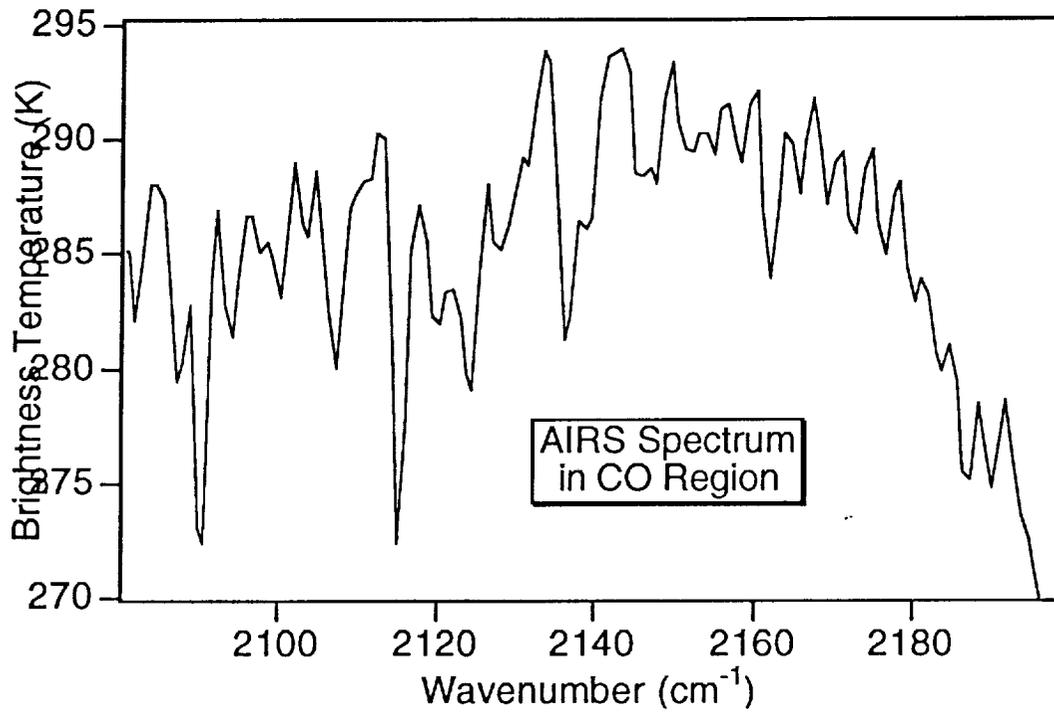


Fig. 1. AIRS spectrum in CO spectral region.

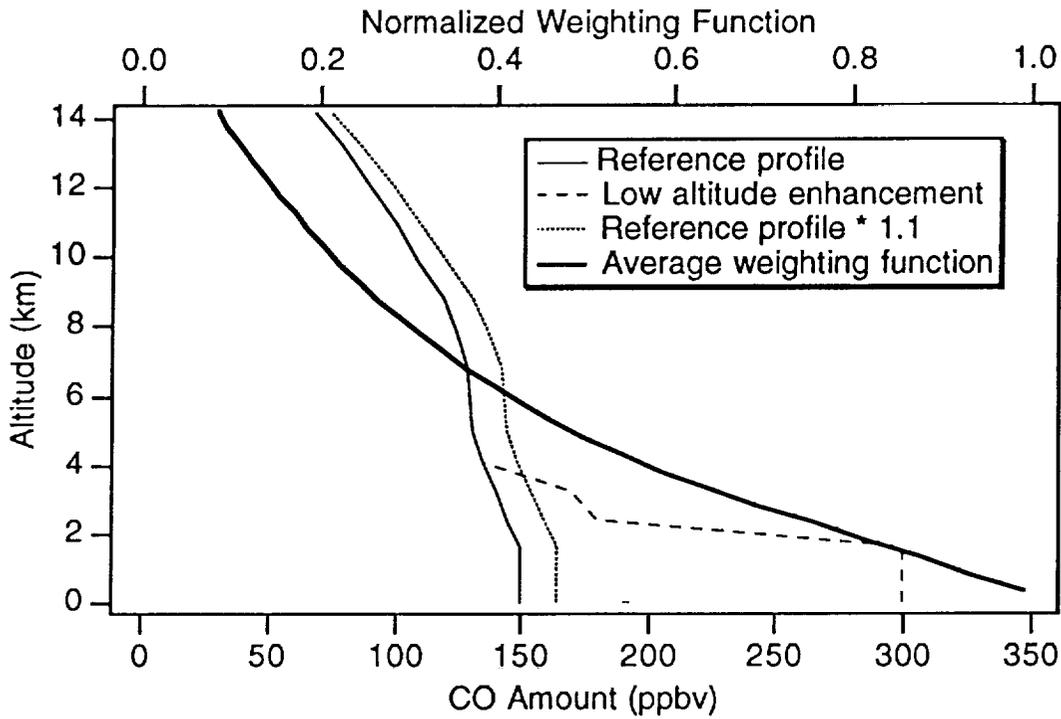


Fig. 2. CO profiles and weighting function.

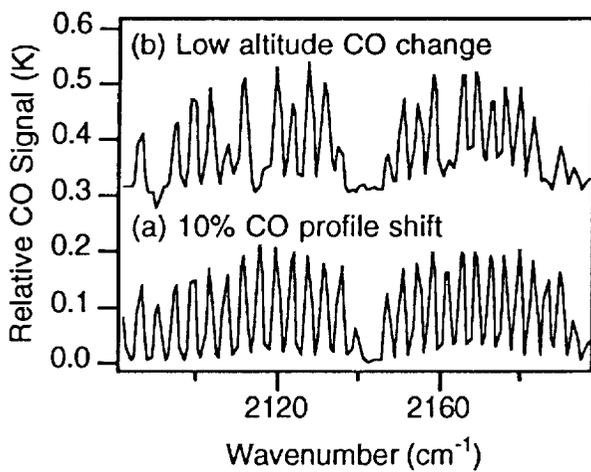


Fig. 3. No Noise CO Signal.

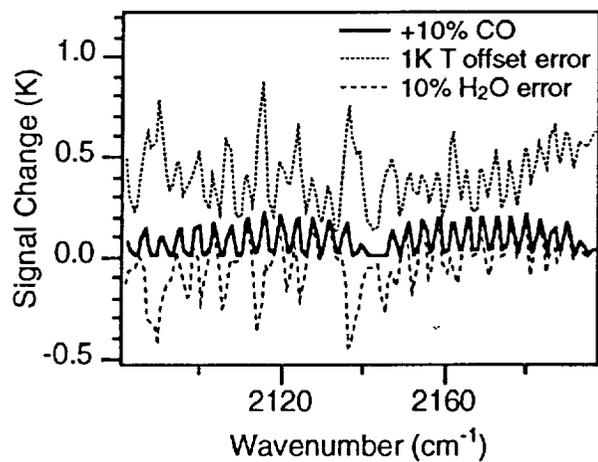


Fig. 4. Effects of temperature and water errors.

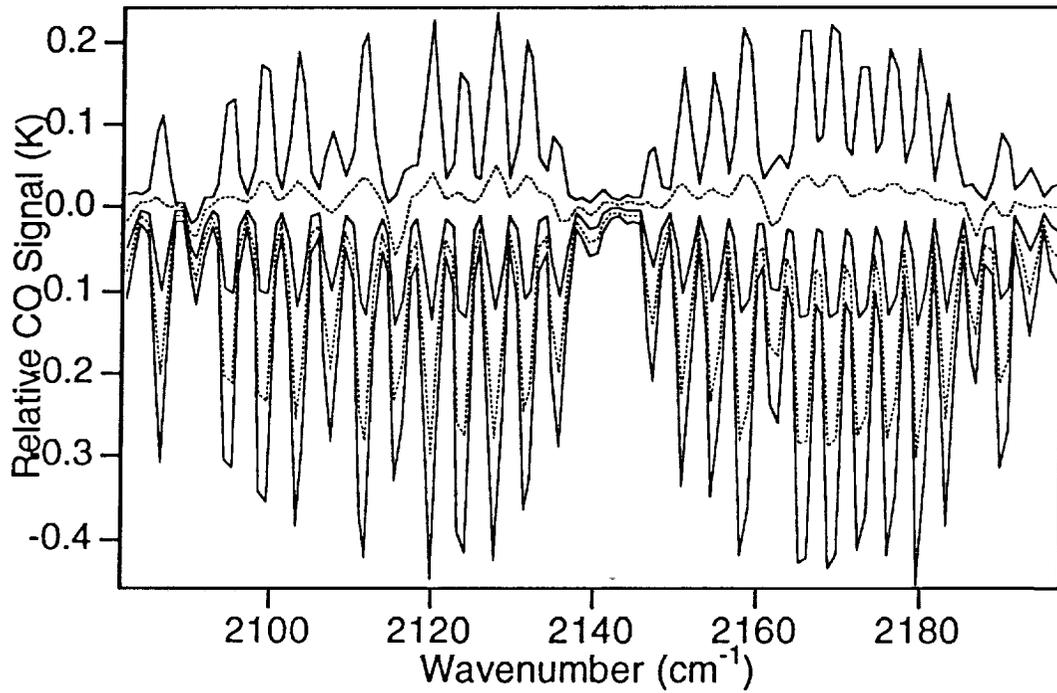


Fig. 5. Effect of temperature contrast on CO signal. Contrast is varied from -12K to +8K.

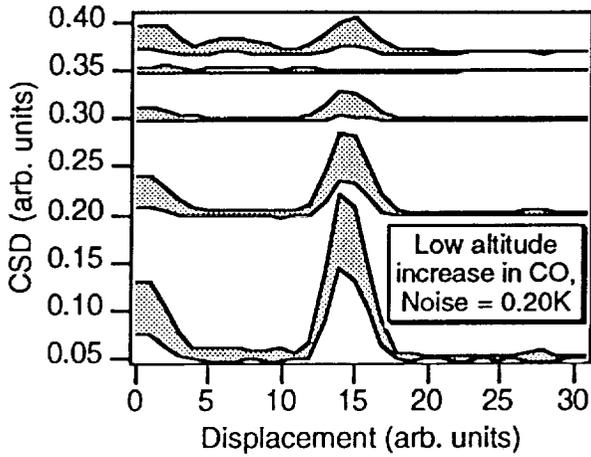


Fig. 6. CSD for low altitude increase in CO.

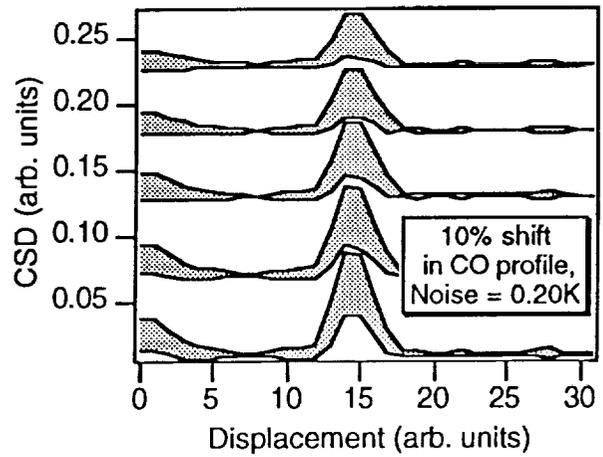


Fig. 7. CSD for 10% increase in CO over whole profile.

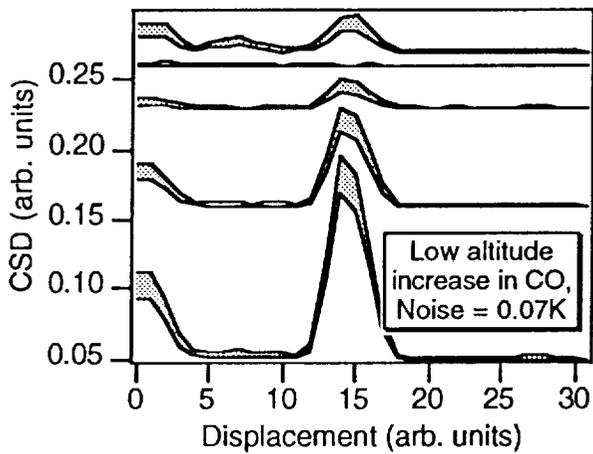


Fig. 8. CSD for low altitude increase in CO.

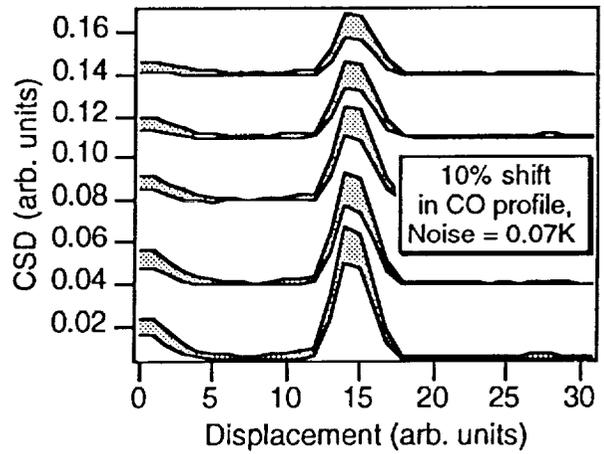


Fig. 9. CSD for 10% increase in CO over whole profile.

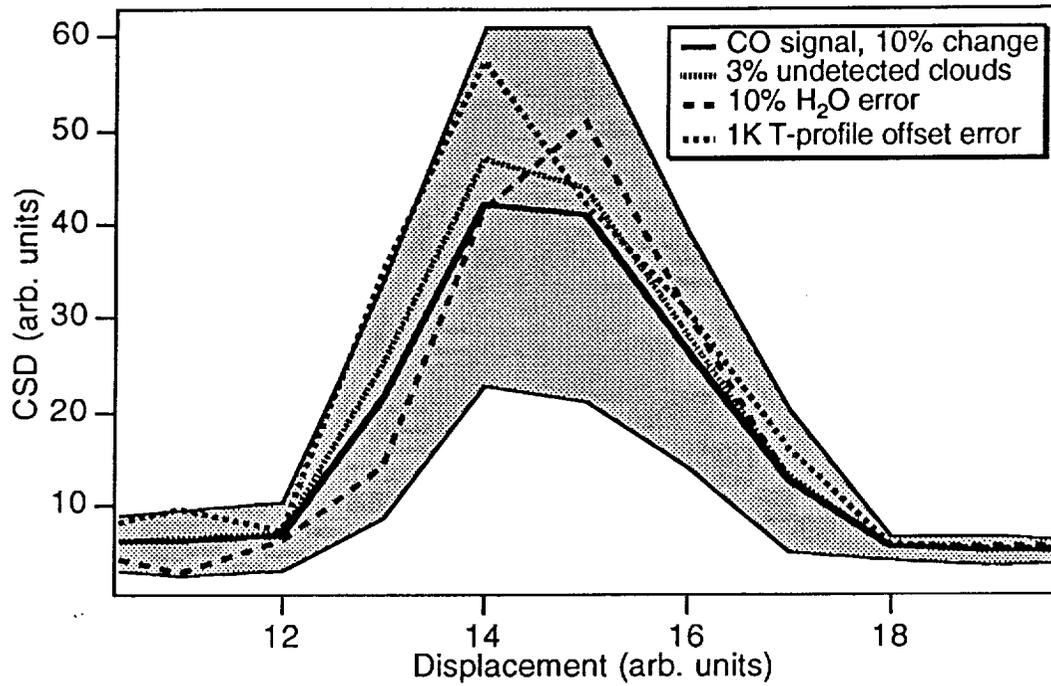
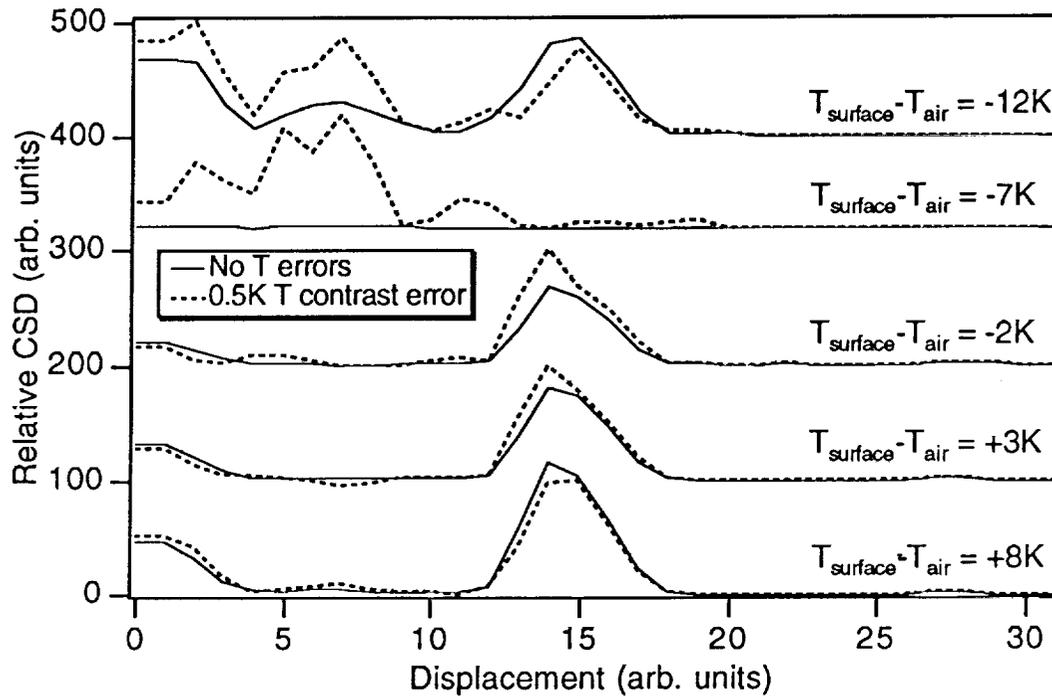


Fig. 10. Effects of systematic errors on CSD.



Effect of errors in air-surface temperature contrast.