UWPHYSRET an SSEC inversion package for high resolution infrared data based on LBLRTM.

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QuickTime™ and a
decompressor
are needed to see this picture.

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Outline

- UWPHYSRET general considerations
- Applications to S-HIS data for JAIVEX
  - Examples of Retrieval Validation
  - Impact of PCA noise filter
- Conclusion
- Future development

UWPHYSRET

- Attempt to build a *reference* physical retrieval package;
- Based on Clive Rodger's methodology (Bayesian approach);
- Simultaneous retrieval of Temperature, Water Vapor, Ozone, Surface Temperature, Surface Emissivity;
- Uses LBLRTM 11.3;
- Analitical Jacobians can be updated at every iteration;
- Slow, flexible, accurate;
- Implemented in matlab

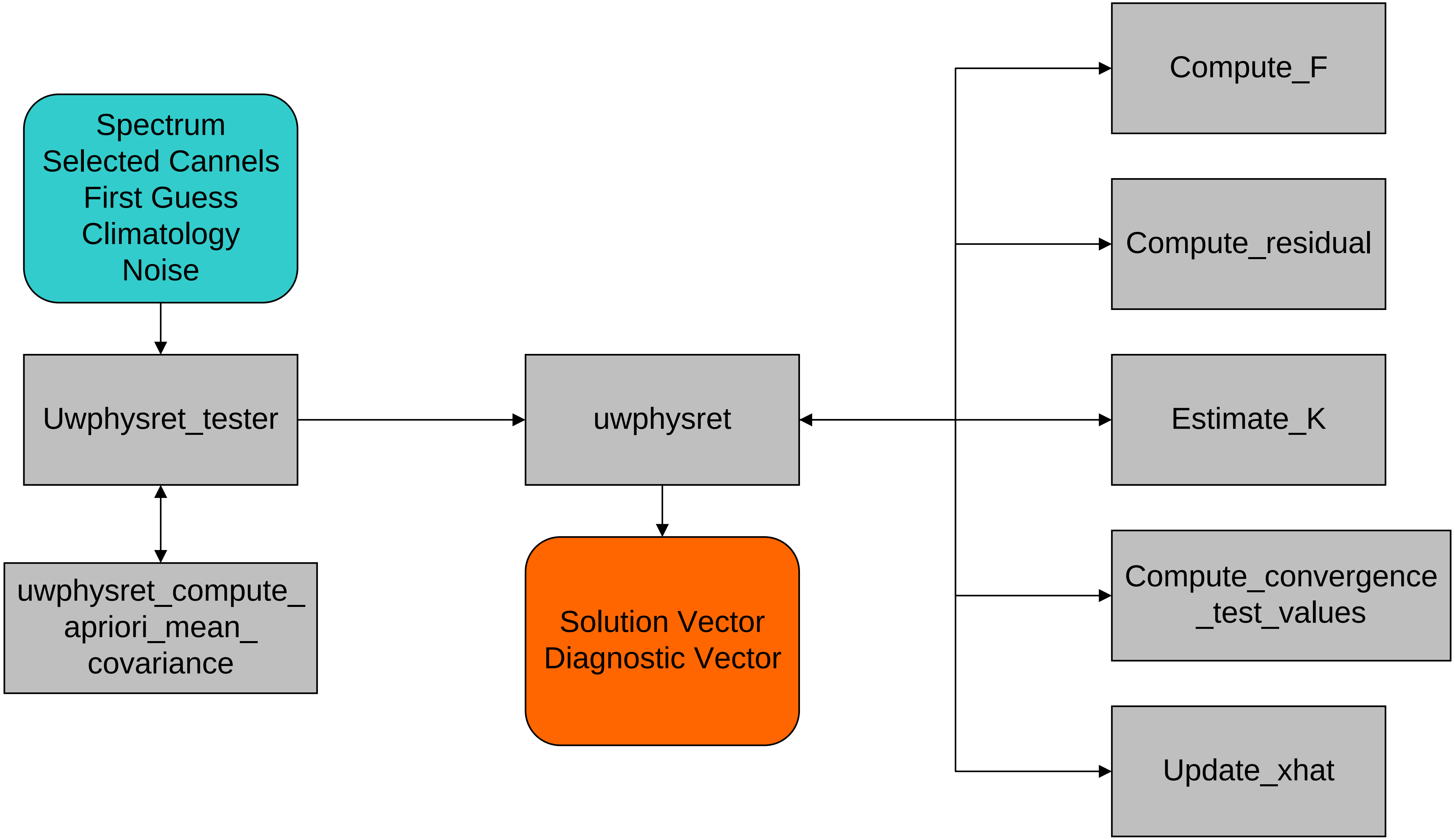
Solution

- Iterative solution (Gauss-Newton):

$$x_{n+1} = \mathrm{x_a} + (\mathrm{K_n}^{\mathrm{T}} \bullet \mathrm{S_e}^{-1} \bullet \mathrm{K_n} + \mathrm{S_a}^{-1})^{-1} \bullet \mathrm{K_n}^{\mathrm{T}} \bullet \mathrm{S_e}^{-1} \bullet ([\mathrm{Y} - \mathrm{F}(\mathrm{x_n})] + \mathrm{K_n} \bullet (\mathrm{x_n} - \mathrm{x_a}))$$

- x is the state vector (*a* stands for a-priori, *n* is the iteration number);
- K is the Jacobian Matrix;
- S_a is the covariance matrix of the a-priori knowledge;
- S_e is the covariance matrix of the Instrument noise;
- Y is the observation vector (radiances);
- F(x) is the calculated observation vector (radiances);

UWPHYSRET



Spectrum
Selected Cannels
First Guess
Climatology
Noise
Uwphysret_tester
uwphysret_compute_
apriori_mean_
covariance
uwphysret
Solution Vector
Diagnostic Vector
Compute_F
Compute_residual
Estimate_K
Compute_convergence
_test_values
Update_xhat

Uwphysret_tester: INPUT

Input Data

- Observed Spectrum from matlab file
- Climatological Data Set: T,WV, Ozone, SKT (predefined)
  - ➢First Guess (optional)
  - ➢Climatology Covariance Matrix
- Surface Emissivity Data Set (predefined)
- Instrument Noise
  - ➢Noise Covariance Matrix

Configuration Parameters

- Apodizaion (variable)
- Number of Levels
  - ➢Top Of the Atmosphere (variable)
  - ➢Surface Elevation (variable)
- Variables to be retrieved (variable)
- Jacobian Update Frequency (variable)
- Convergence parameters (variable)
- External First Guess (variable)

UWPHYSRET: FW Model

- Compute_F and Estimate_K based on LBLRTM 11.3:
  - Highly accurate;
  - Slower than fast models;
  - Very flexible;
  - Highly configurable;
  - Easily Adaptable to different Instruments;
  - Provides Jacobians for 26 molecular species;
- Future implementations of UWPHYSRET will allow for easy substitution of FW through better definition of computational modules;

Uwphysret_tester: OUTPUT

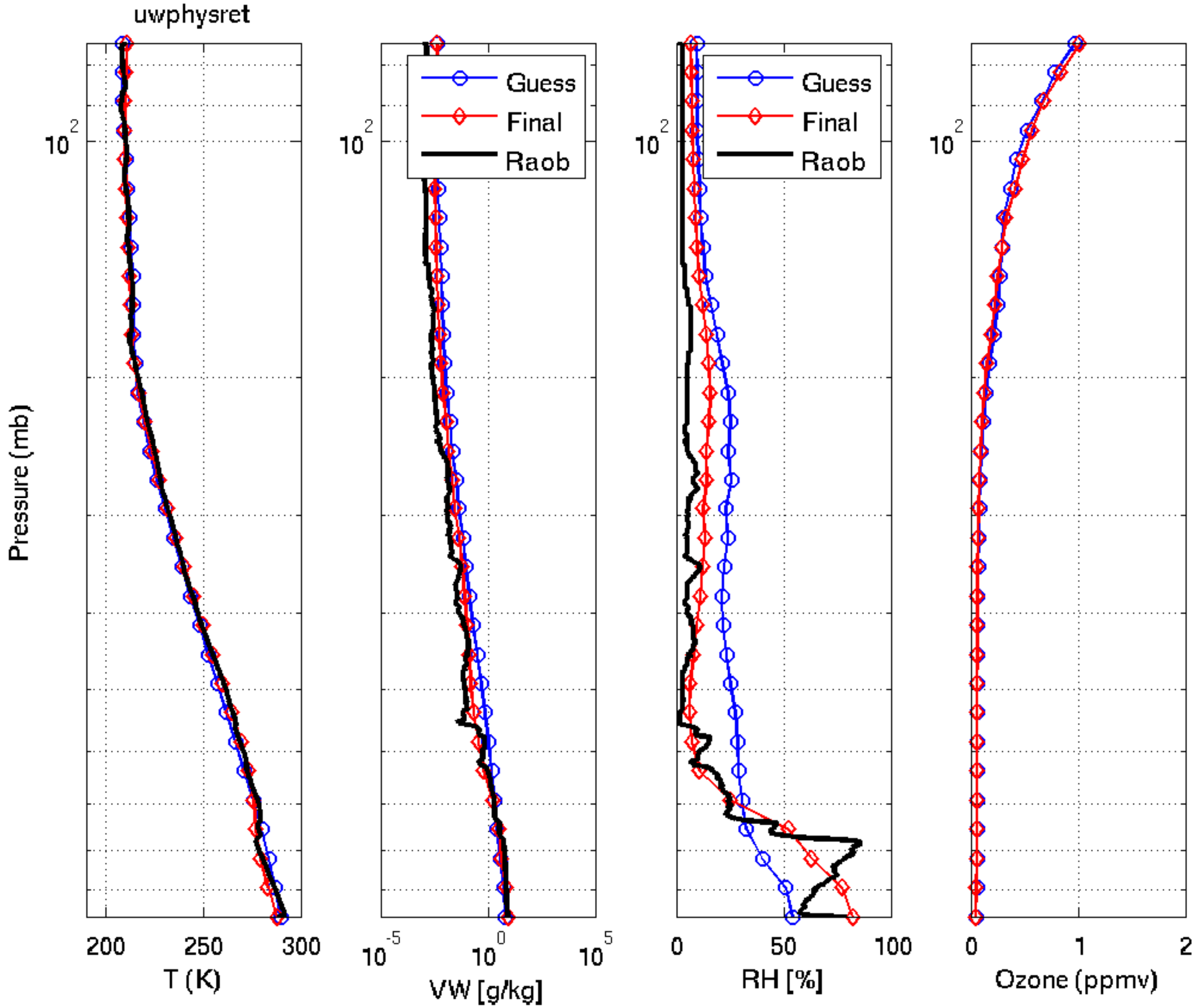
solution

- xhat, x_dim, p, x_0, x_a;
- F, wn_F;
- yobs_minus_yhat, wnyobs_minus_yhat;
- chi_sq_optimal xhat_update, norm_measurement_space_only, norm_solution_space_only;
- numIterations; maxIterations;
- Error_smoothing, error_measurements, error_total; averaging_kernel;
- S_a;

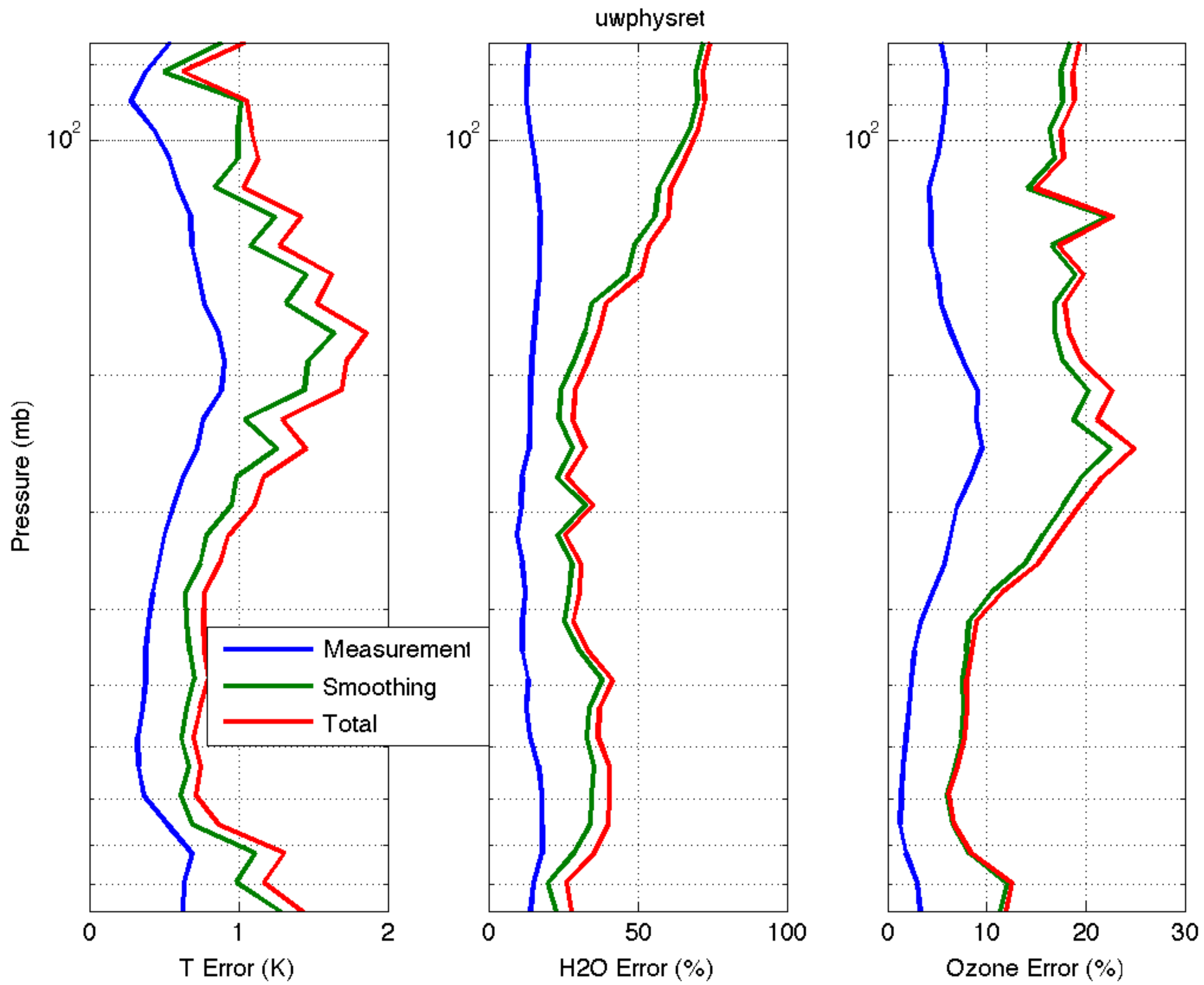
diagnostic

- xhat, x_dim, p, x_0, x_a
- R, wn_R;
- F, wn_F, K;
- yobs_minus_yhat, wnyobs_minus_yhat;
- chi_sq_optimal, xhat_update; norm_measurement_space_only, norm_solution_space_only ,
- Selwn, control;
- S_a, S_aInv, diag(S_e), Shat, contribution_function;
- numIterations, maxIterations

Solution: Retrieved Vertical Profiles



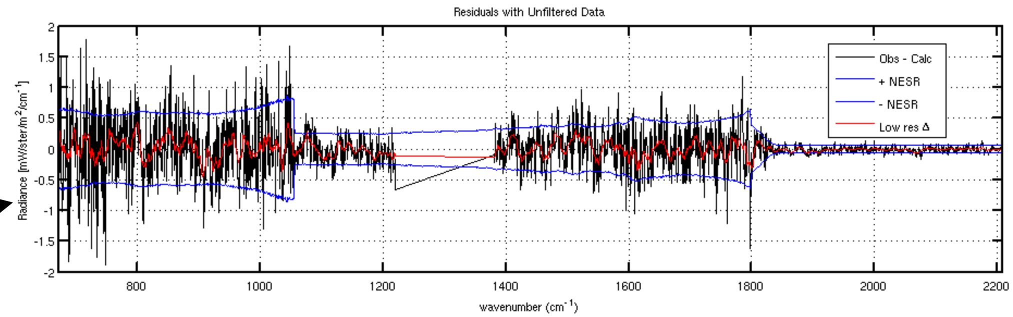
Solution: Retrieval Errors

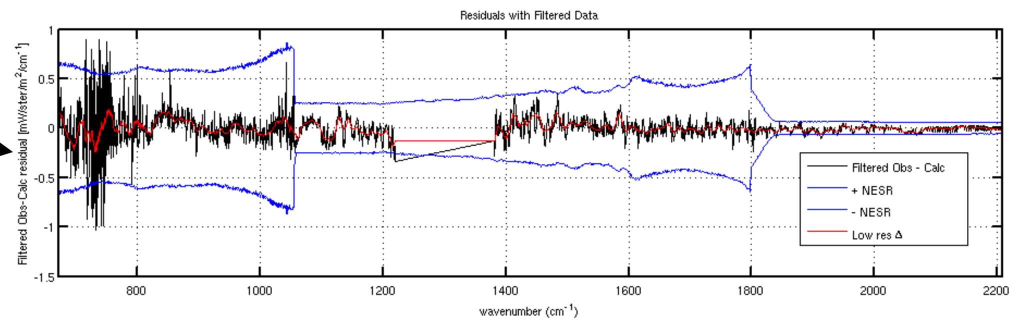


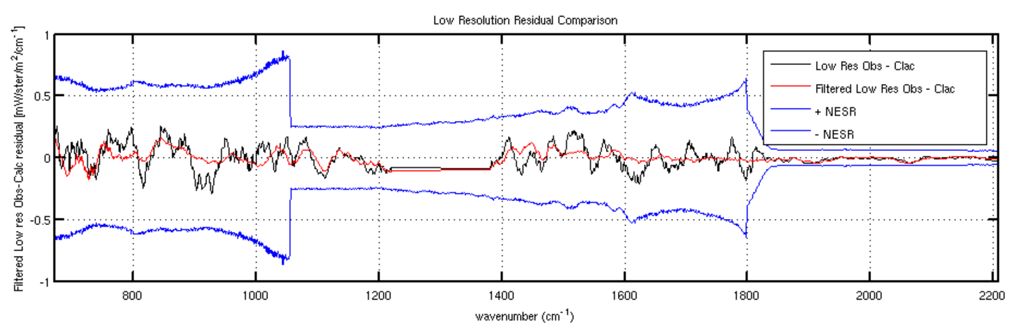
Diagnostic: Residuals in radiance Units

Unfiltered Obs - Calc

Filtered Obs - Calc



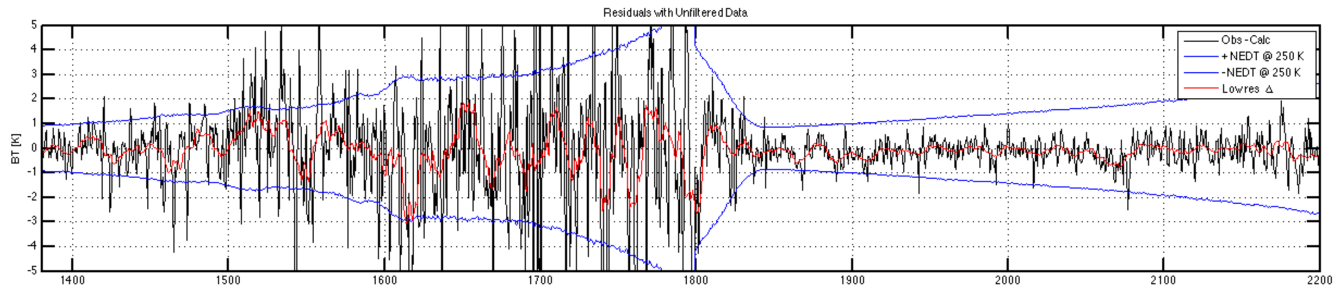




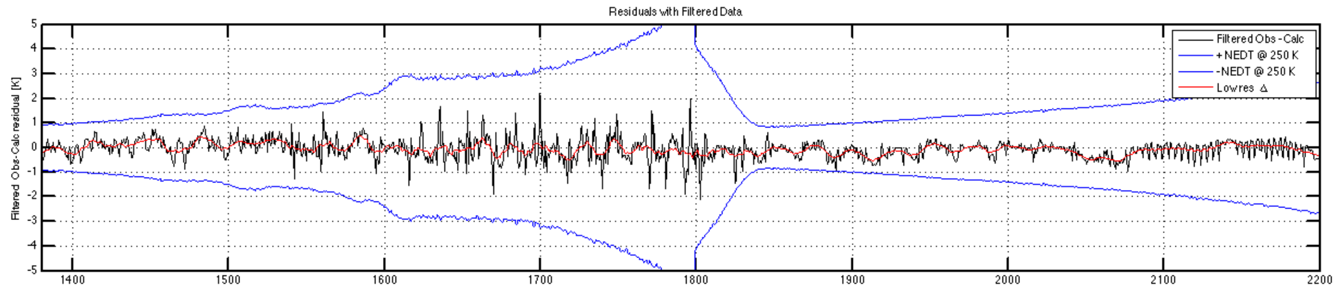
NESR

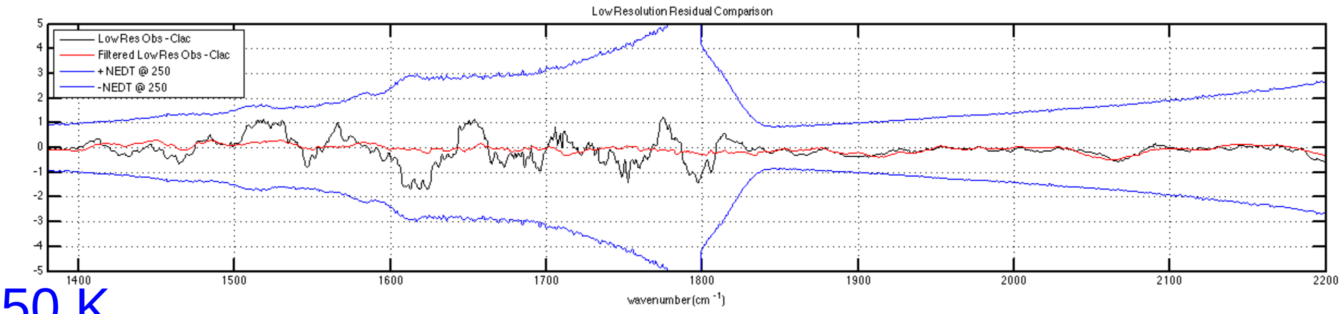
Diagnostic: Residuals in BT

Unfiltered
Obs - Calc



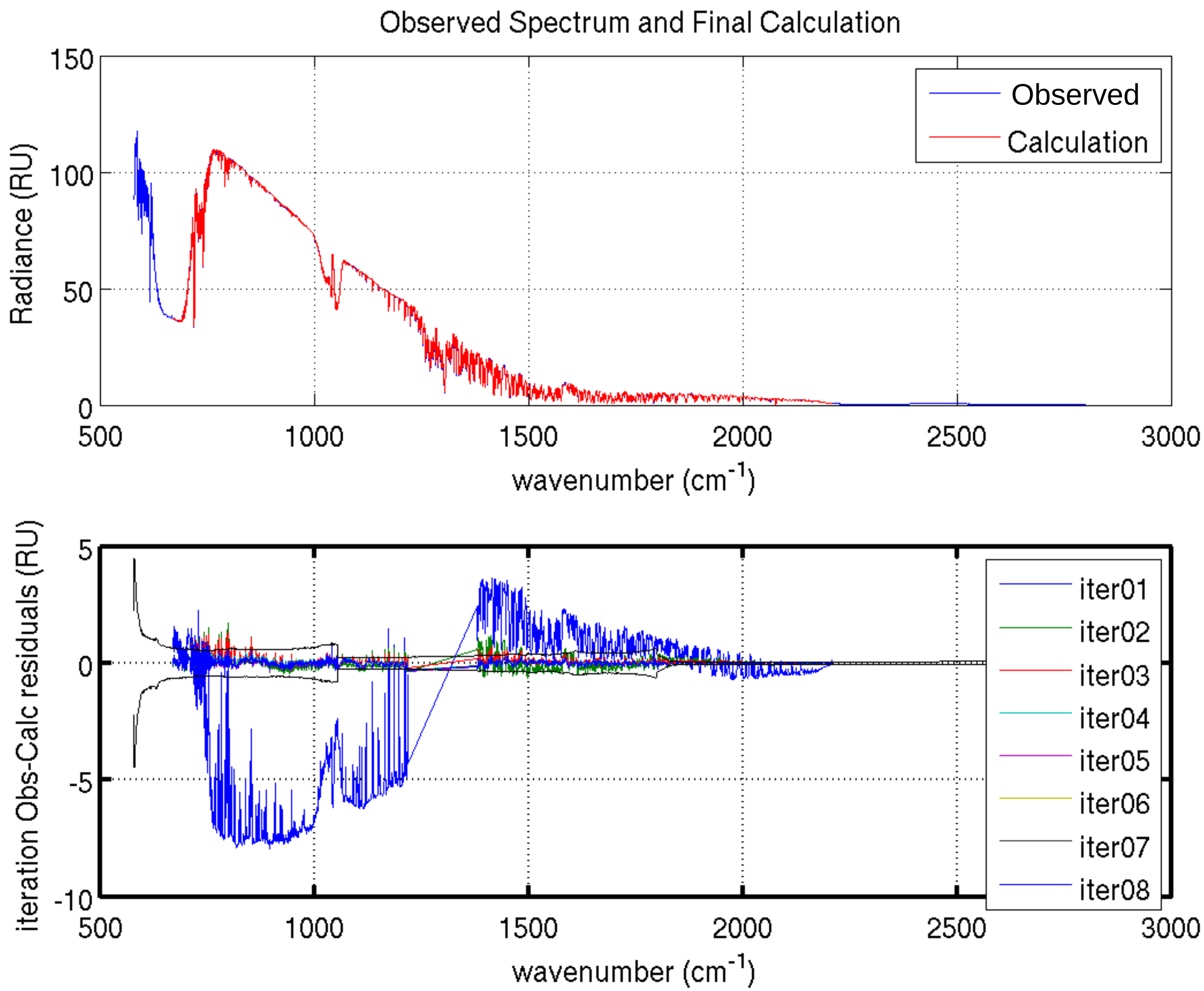
Filtered
Obs - Calc





NEDT @ 250 K

Diagnostic:
Retrieval Conversion Iteration by Iteration



UWPHYSRET: Installation Requirements

- Availability of LBLRTM (10.4 and newer)
- MATLAB
- Tested on Linux and MAC OS X (Intel and Power PC)
- Software is freely distributed
  - to obtain it, please, contact R. Knuteson (bobk@ssec.wisc.edu)

UWPHYSRET: Issues

- Technical:
  - ➢ Slow if K is updated every iteration;
  - ➢ Slower for satellite data than for aircraft data;
  - ➢ Number of levels is the same for all the atmospheric variables retrieved;
- Theoretical:
  - ➢ Based on Baysian approach, it assumes Gaussian distribution;
- General:
  - ➢ Proprietary software dependent;

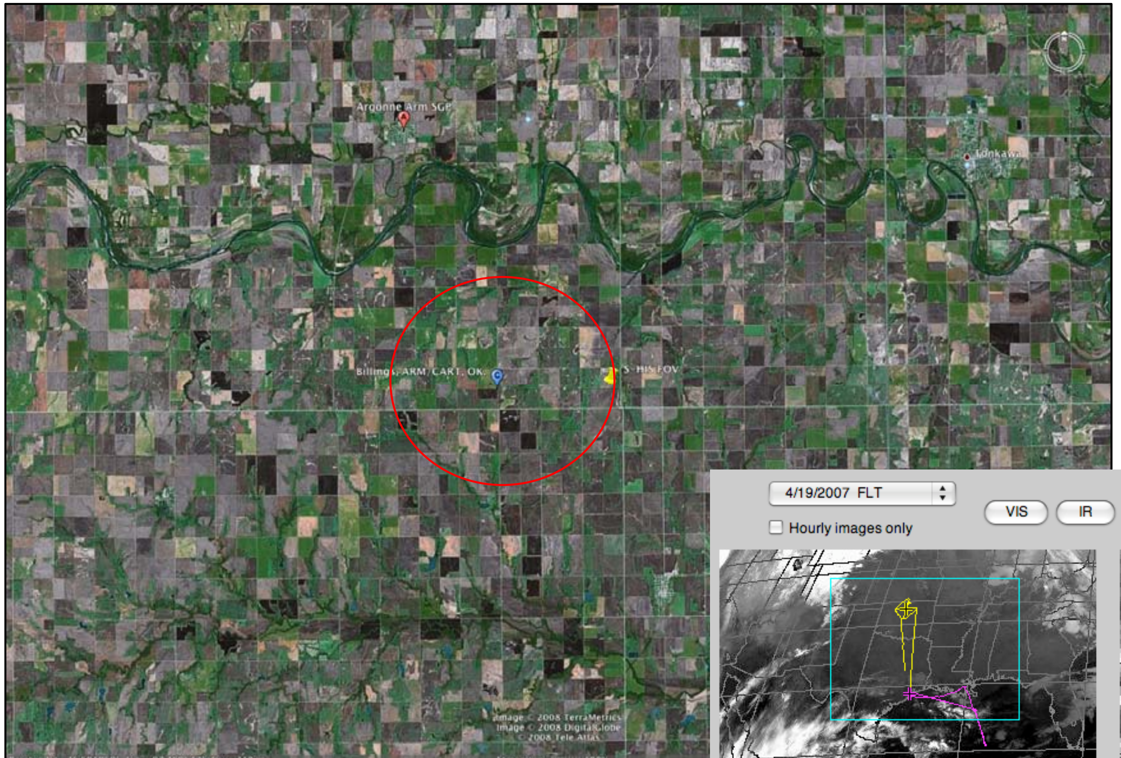
UWPHYSRET: current applications

- Using JAIVEx data:
  - Estimation of PCA noise filtering impact on retrieved profiles;
  - Investigation of the role of Noise Covariance Matrix on retrieval accuracy;
  - Investigation of the role of Climatology Covariance Matrix on retrieval accuracy;
- Surface Emissivity Retrieval;
- Estimation of Total Precipitable Water from retrieved profiles;
- Estimation of Stability Indices from retrieved profiles;

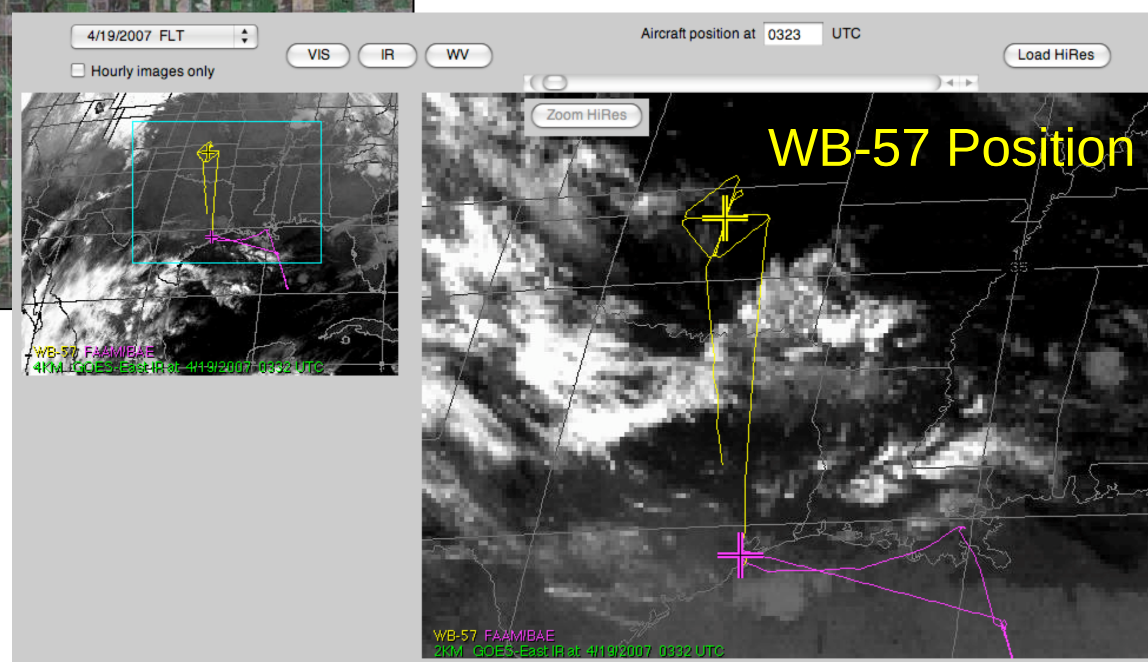
Results on JAIVEx data

- **JAIVEx stands for Joint Airborne IASI Validation Experiment**
- is an international cal/val campaign in support of the NPOESS and MetOp series of operational satellites.
- Focus is on the validation of radiance observations and meteorological products from the Infrared Atmospheric Sounding Interferometer, IASI.
- IASI measures radiation emission from the surface and atmosphere in the 645 - 2760 cm-1 (i.e., 3.6-15.5 μm) spectral band with high spectral resolution (i.e., 8461 spectral channels with a spacing of 0.25 cm-1).
- The aircraft being employed are the NASA WB-57 and the FAAM BAe 146.

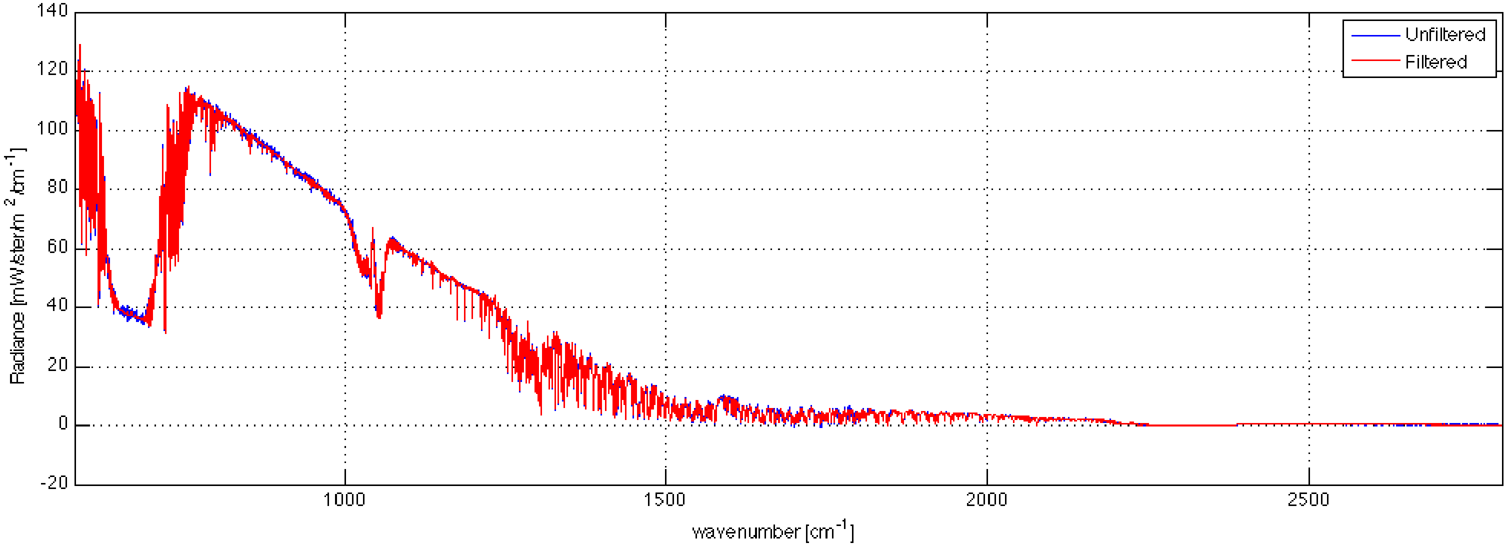
SGP ARM Cart Site: 19 Apr 2007 15:32 UTC

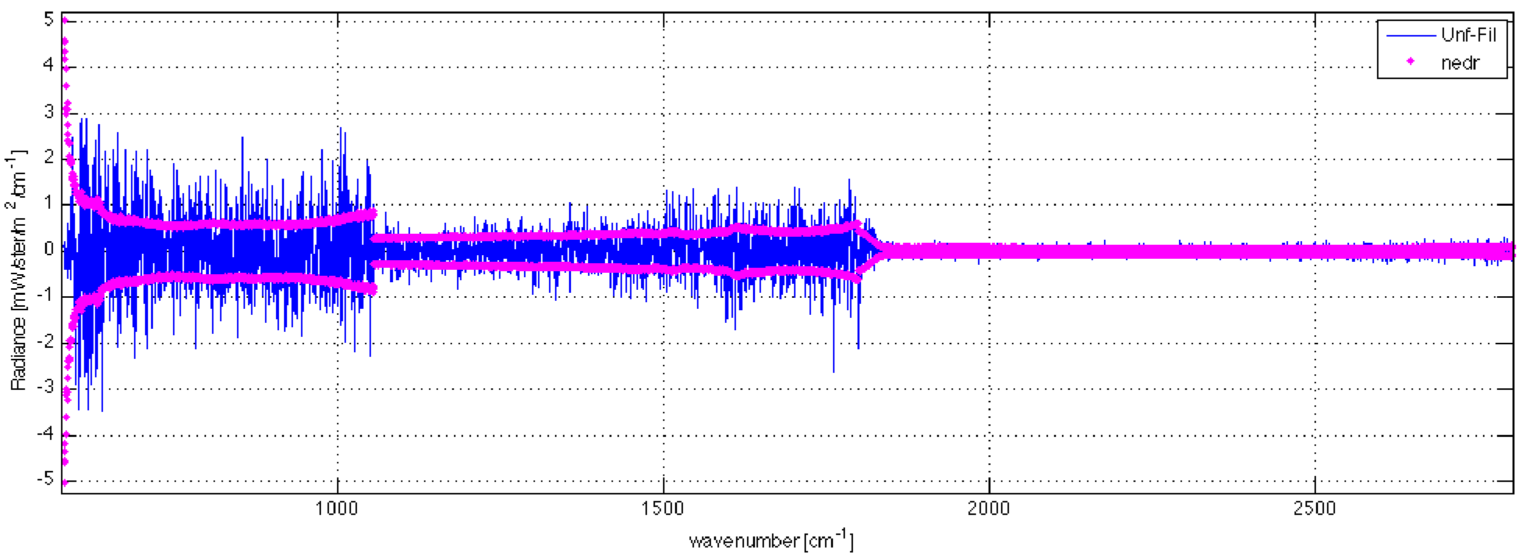


S-HIS FOV

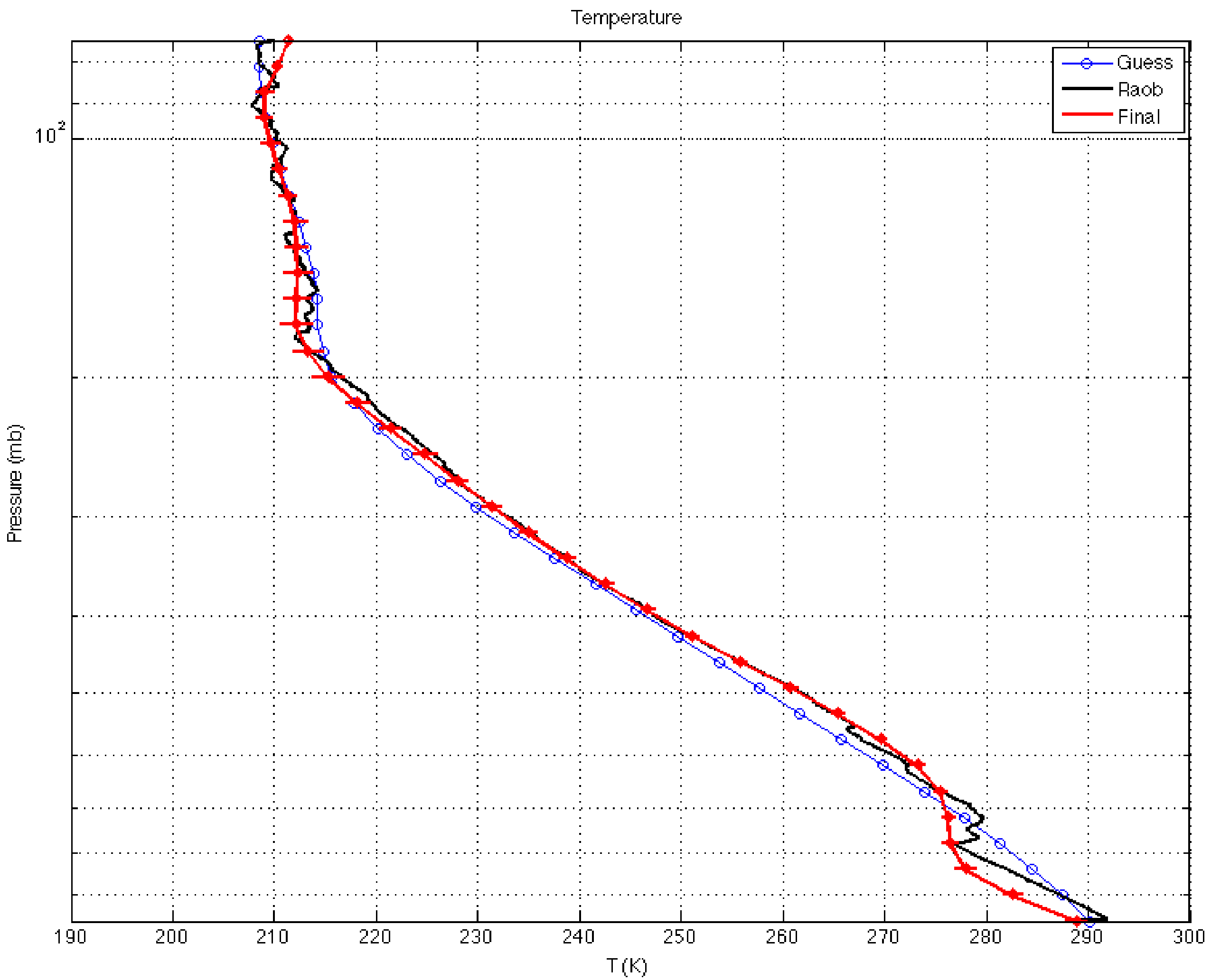


Filtered Minus Unfiltered

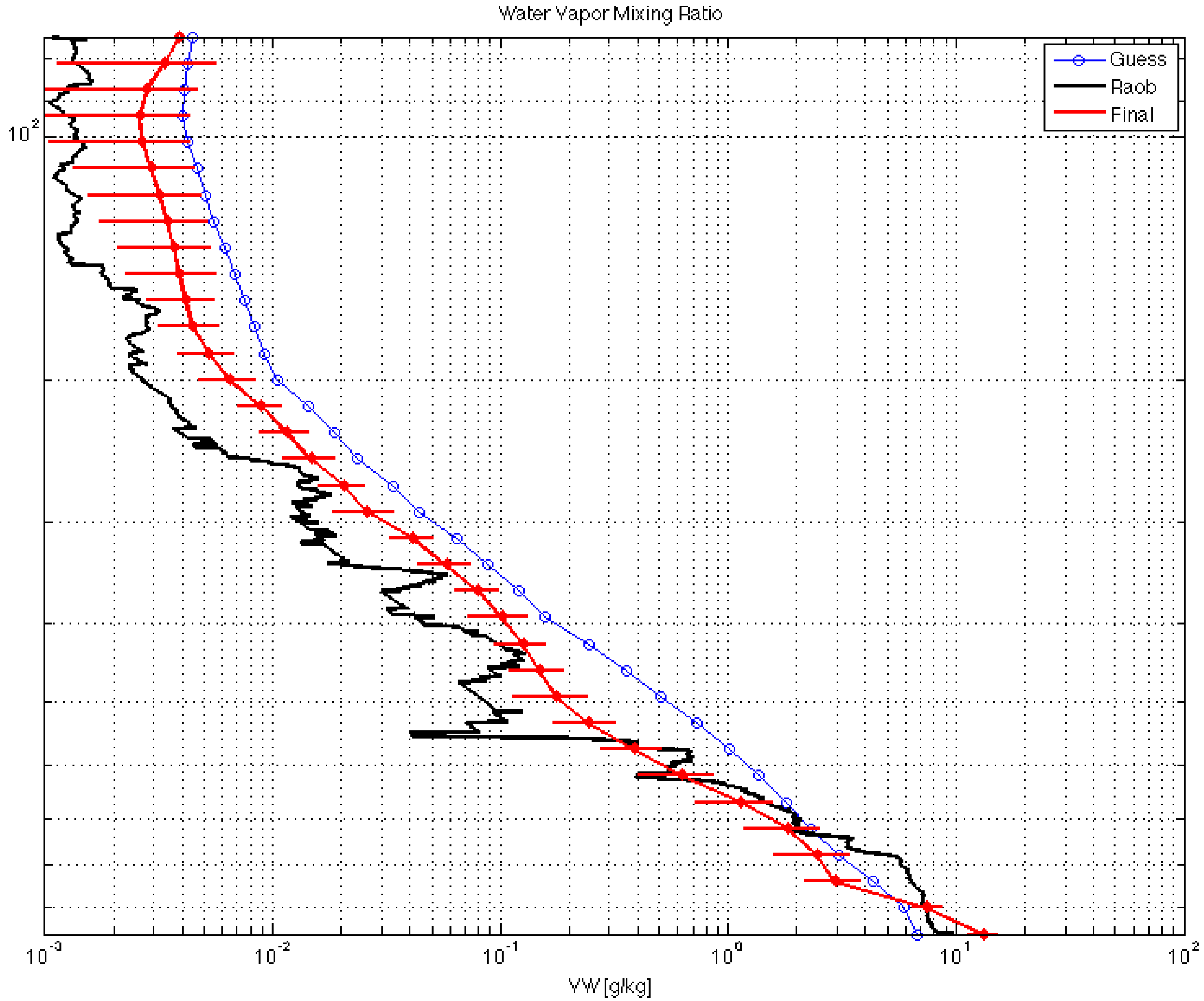




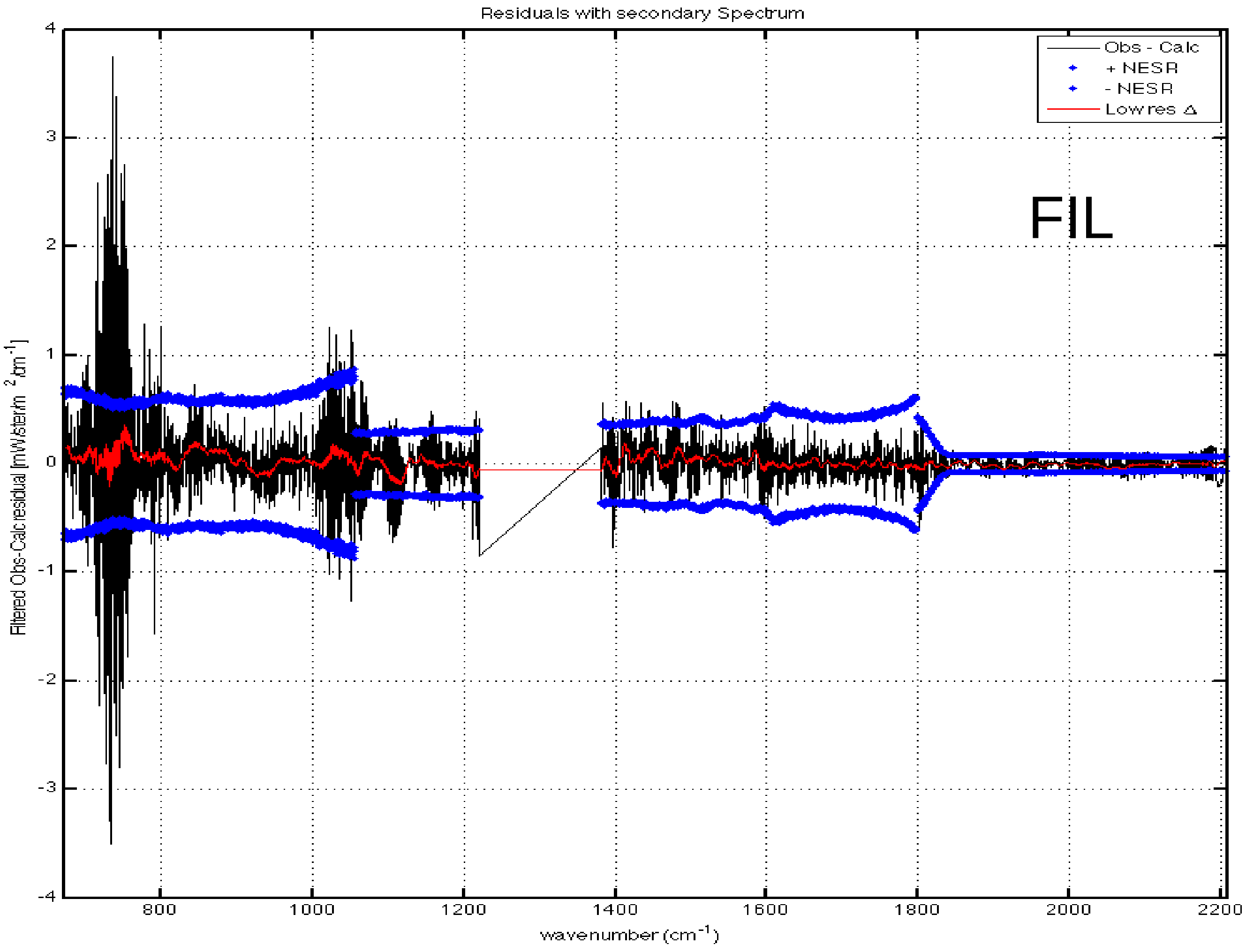
Retrieved Temperature Profile



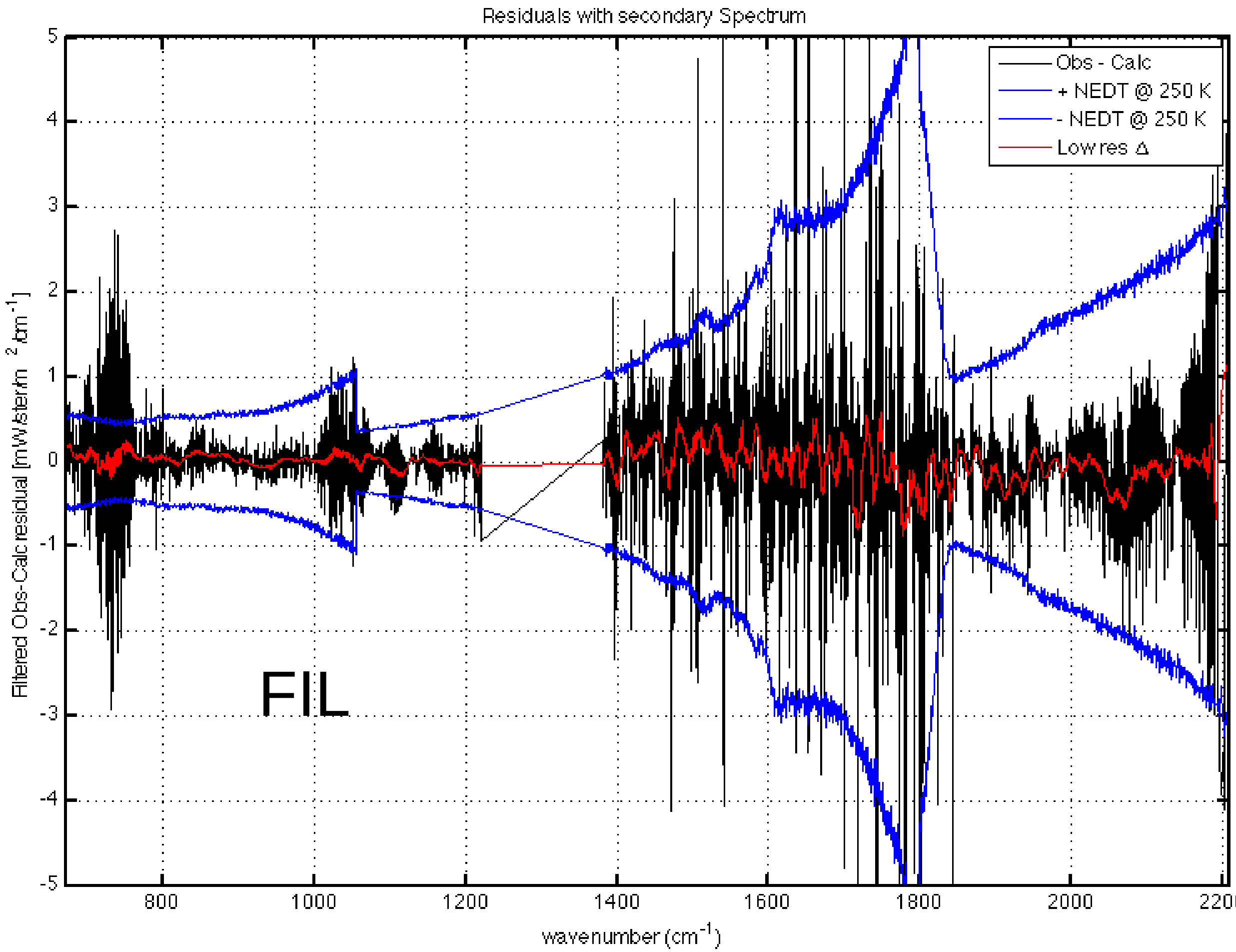
Retrieved Water Vapor Profile



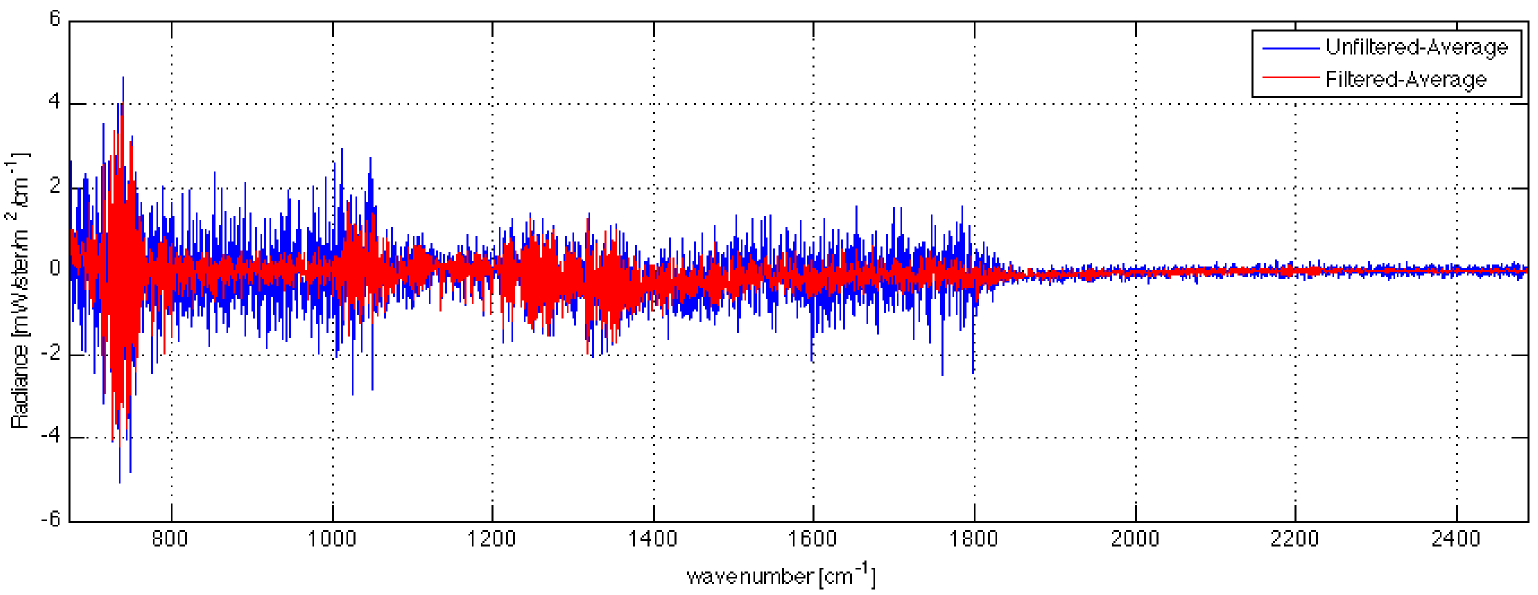
Radiance Residuals
(compared to Unfiltered and Filtered Spectra)



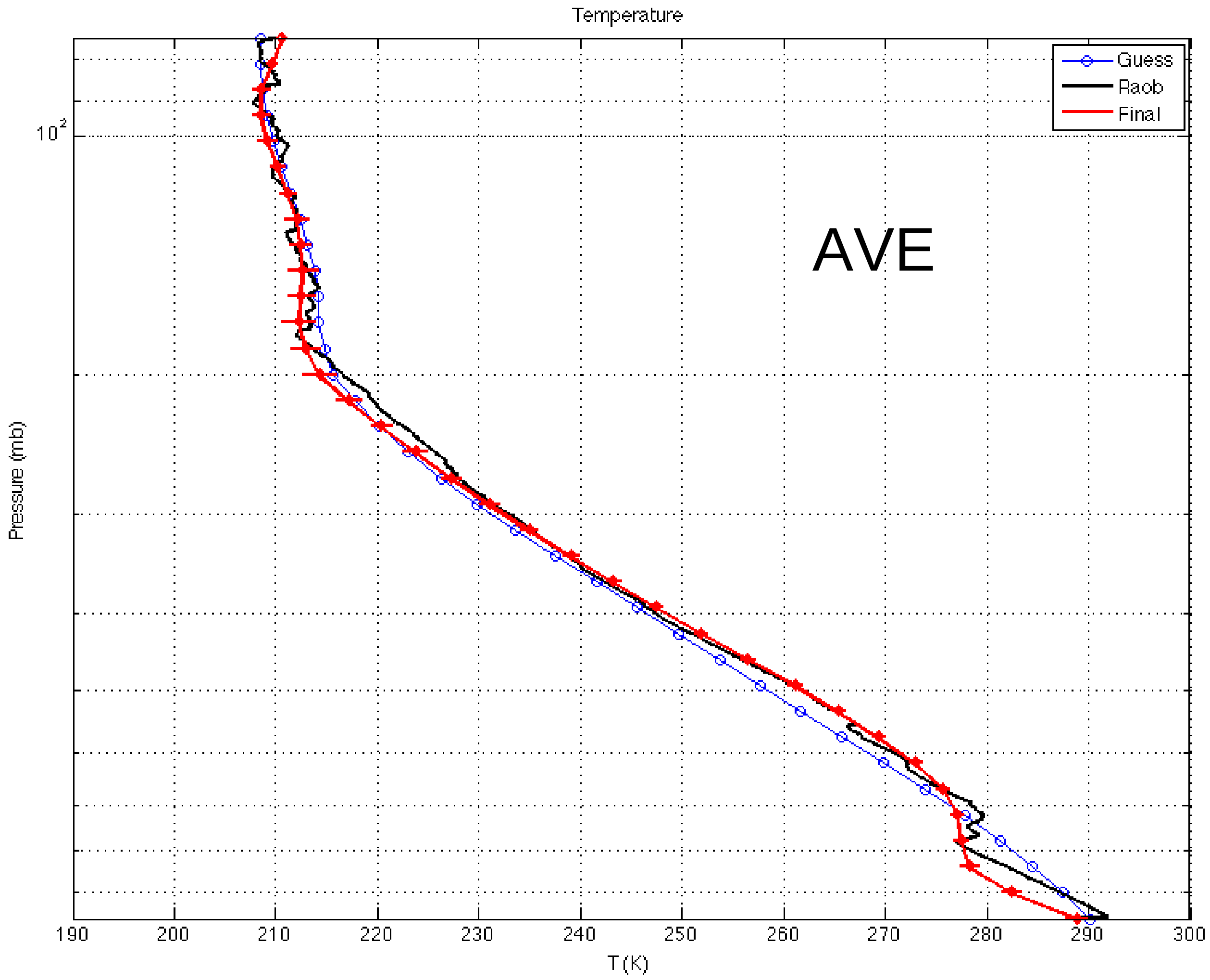
BT Residuals
(compared to Unfiltered and Filtered Spectra)



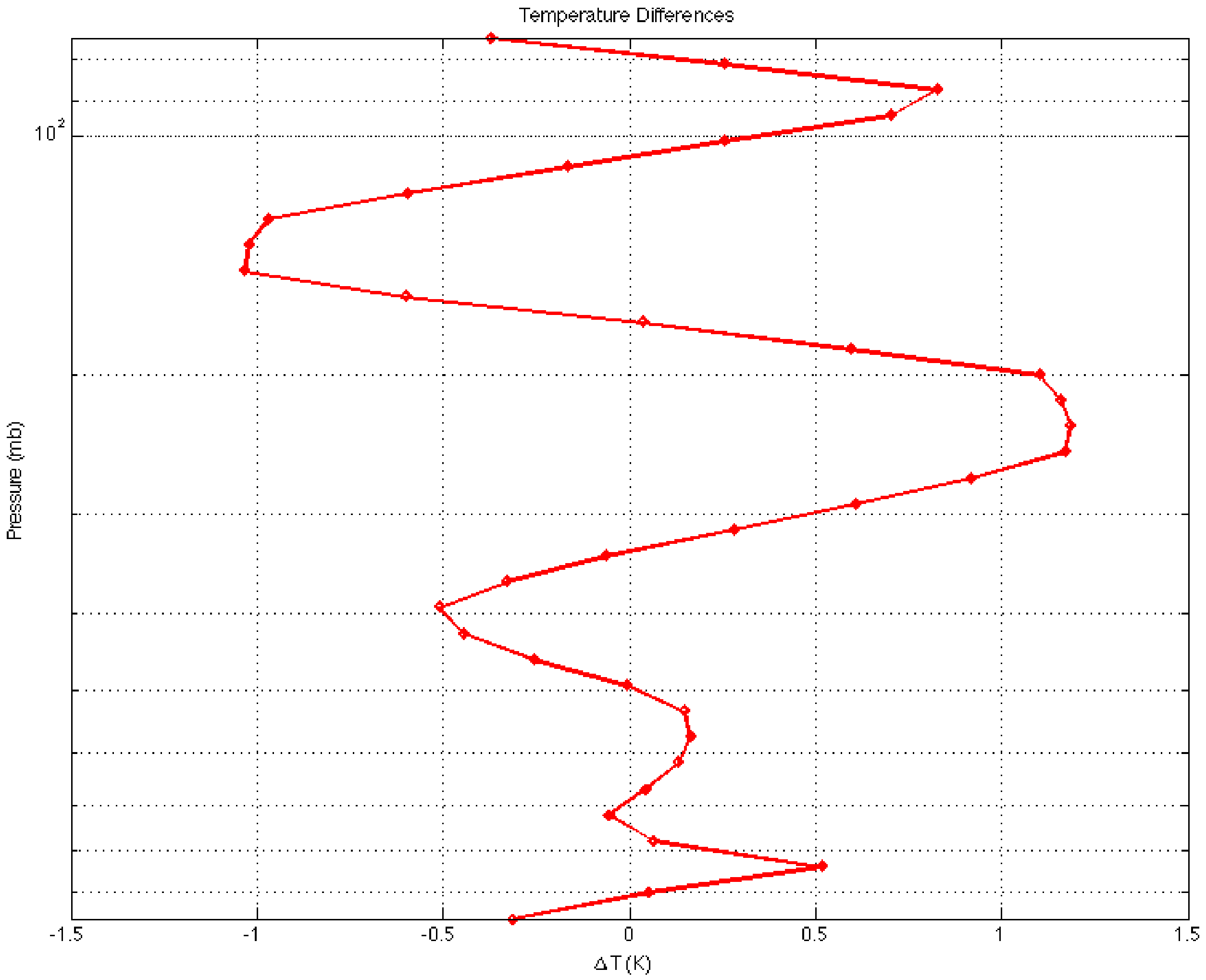
Unfiltered, Filtered, Averaged spectra



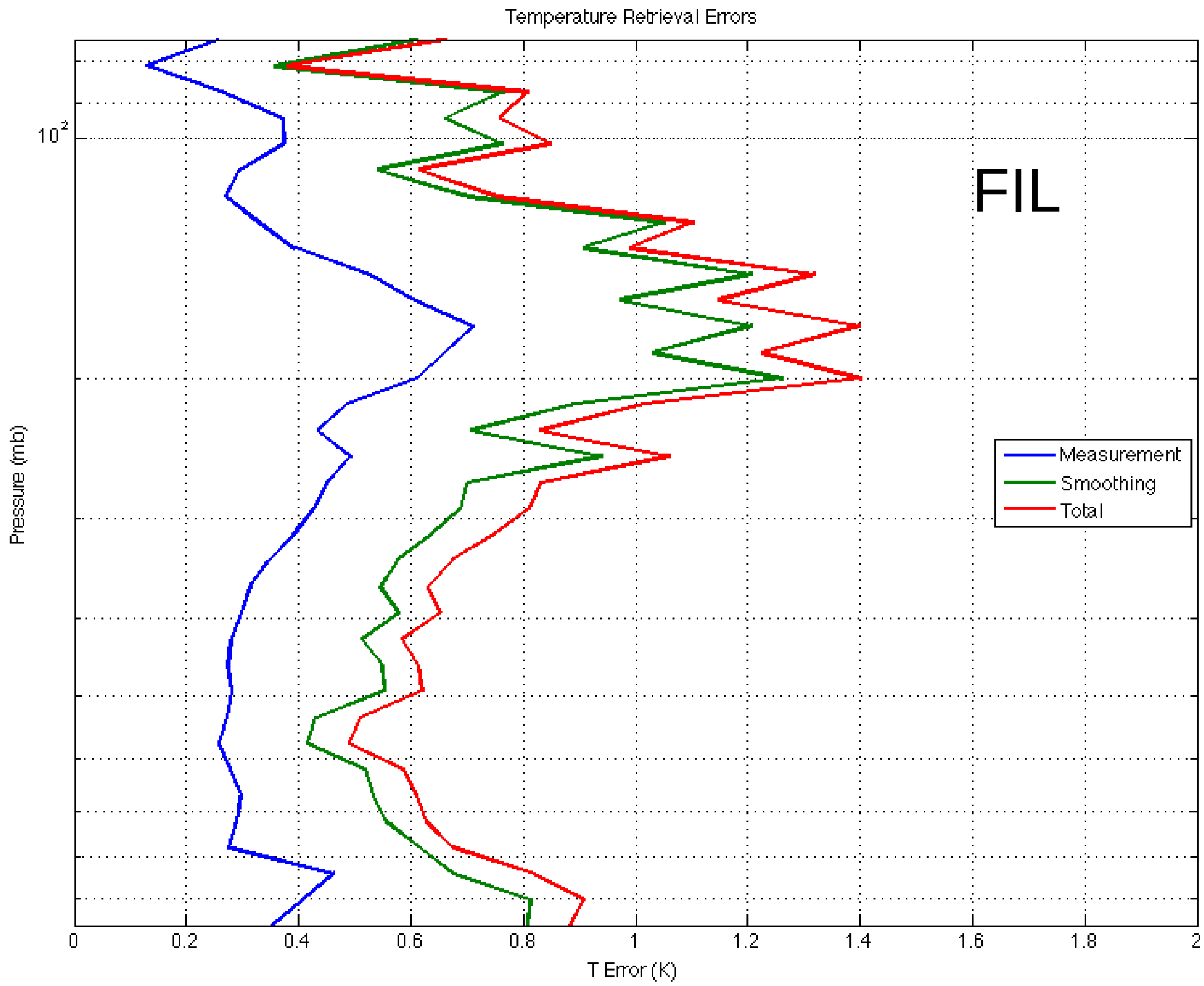
Temperature Retrieval Comparison



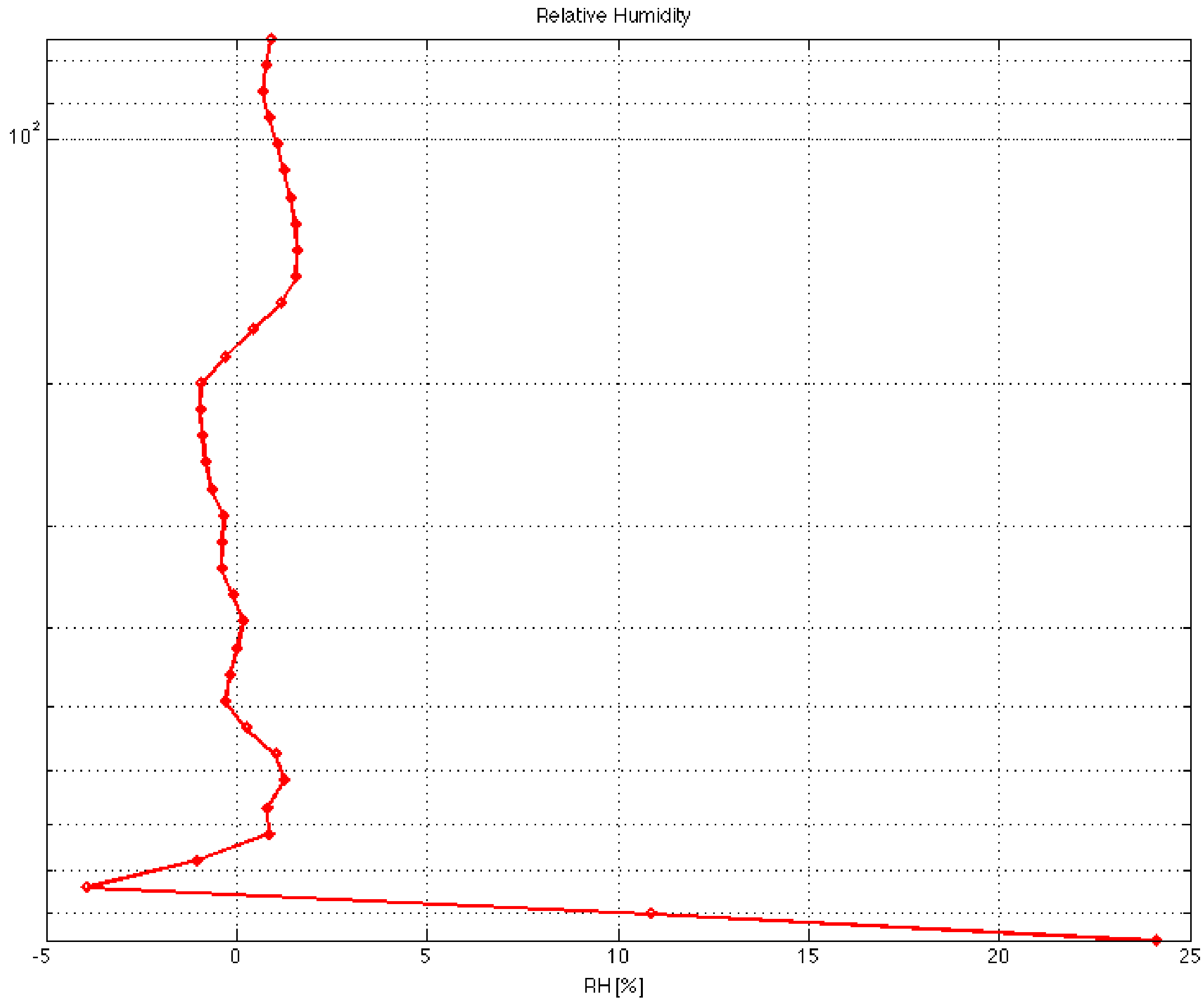
Temperature Retrieval difference: Unfiltered-Filtered



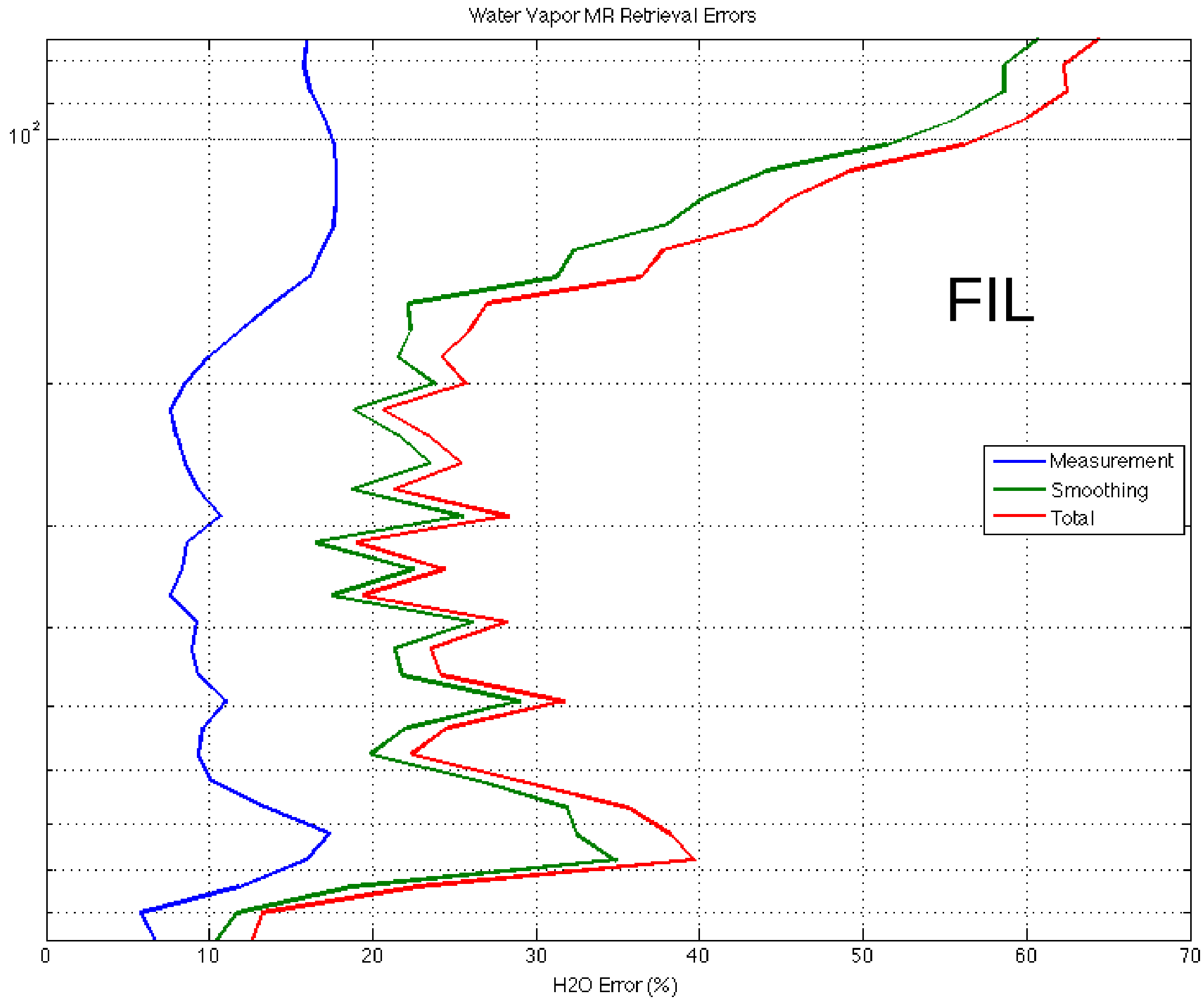
Uncertainties on Temperature



Relative Humidity Retrieval difference: Unfiltered - Filtered:

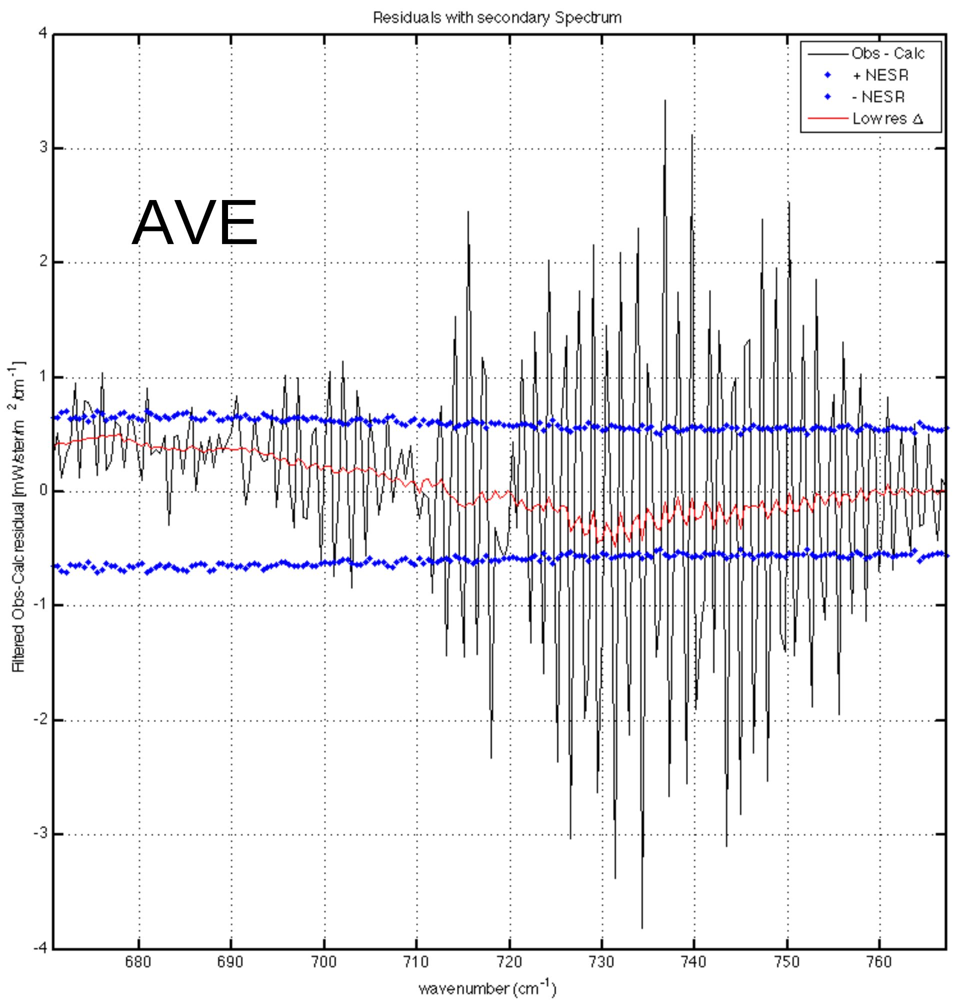


Uncertainties on Water Vapor

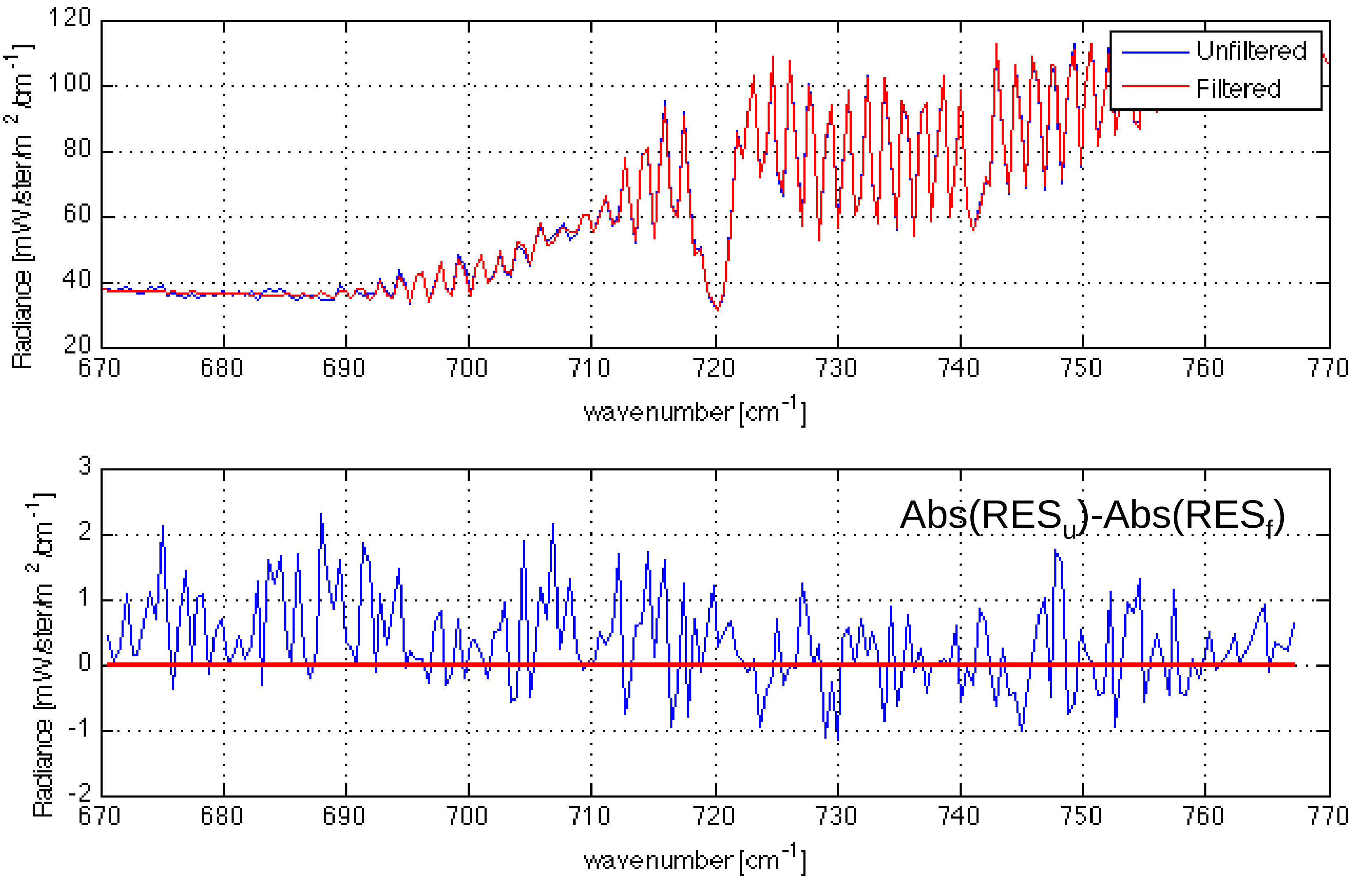


Residual for T retrieval only

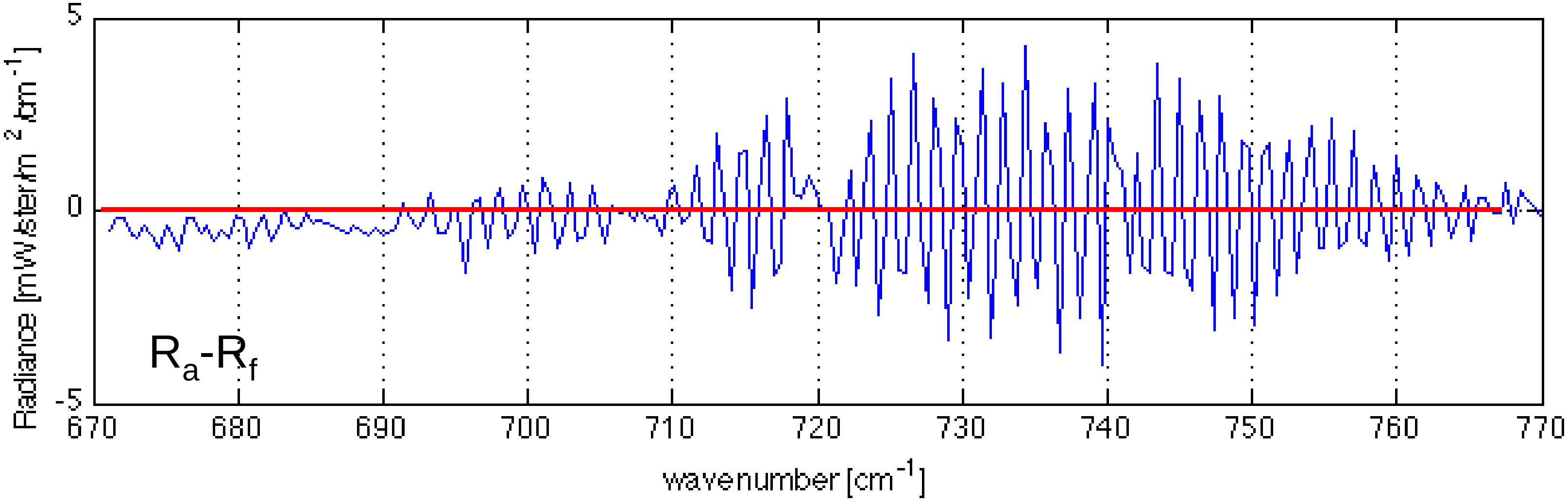
Raob used as First Guess
Retrieval from CO_2 Band only

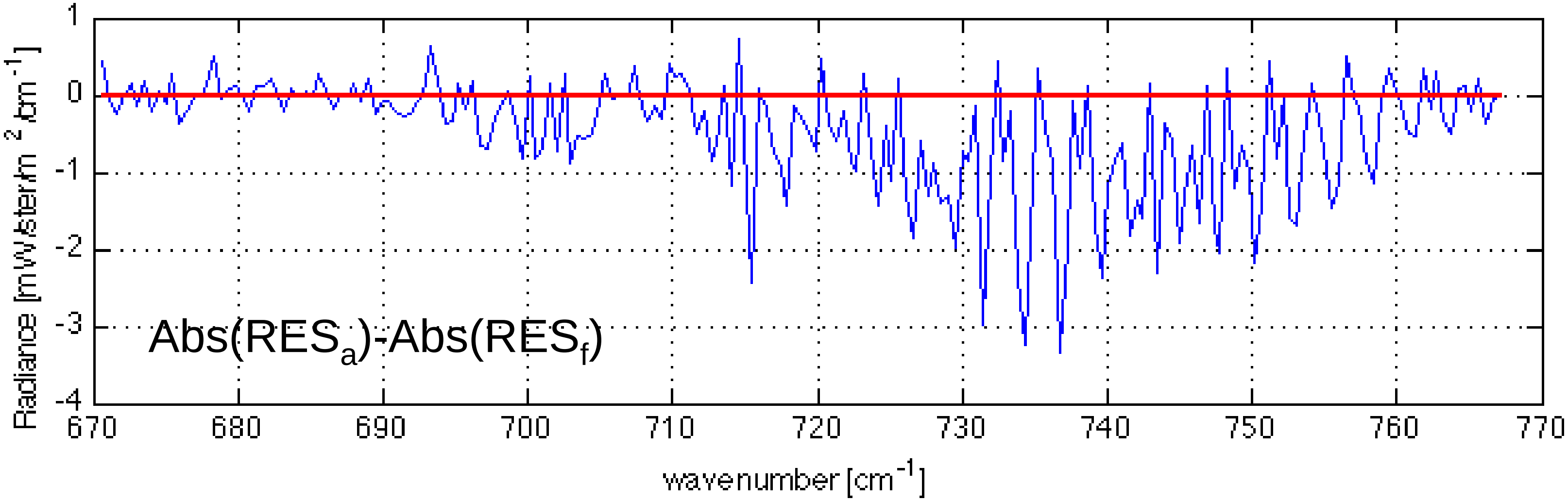


Difference of Absolute Value of Radiance Residuals:
Unfiltered - Filtered



Difference of Absolute Value of Radiance Residuals:
Averaged Spectrum

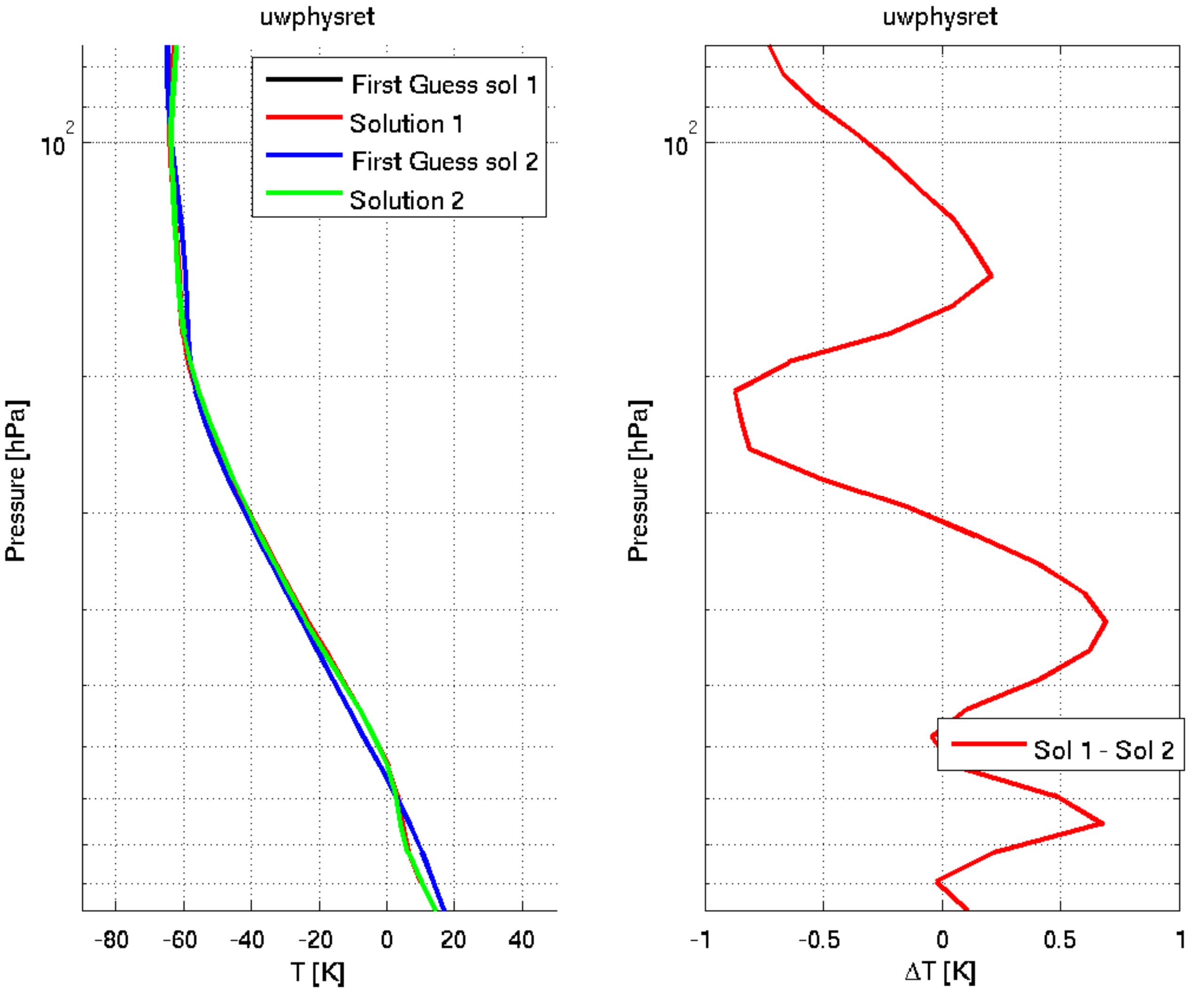




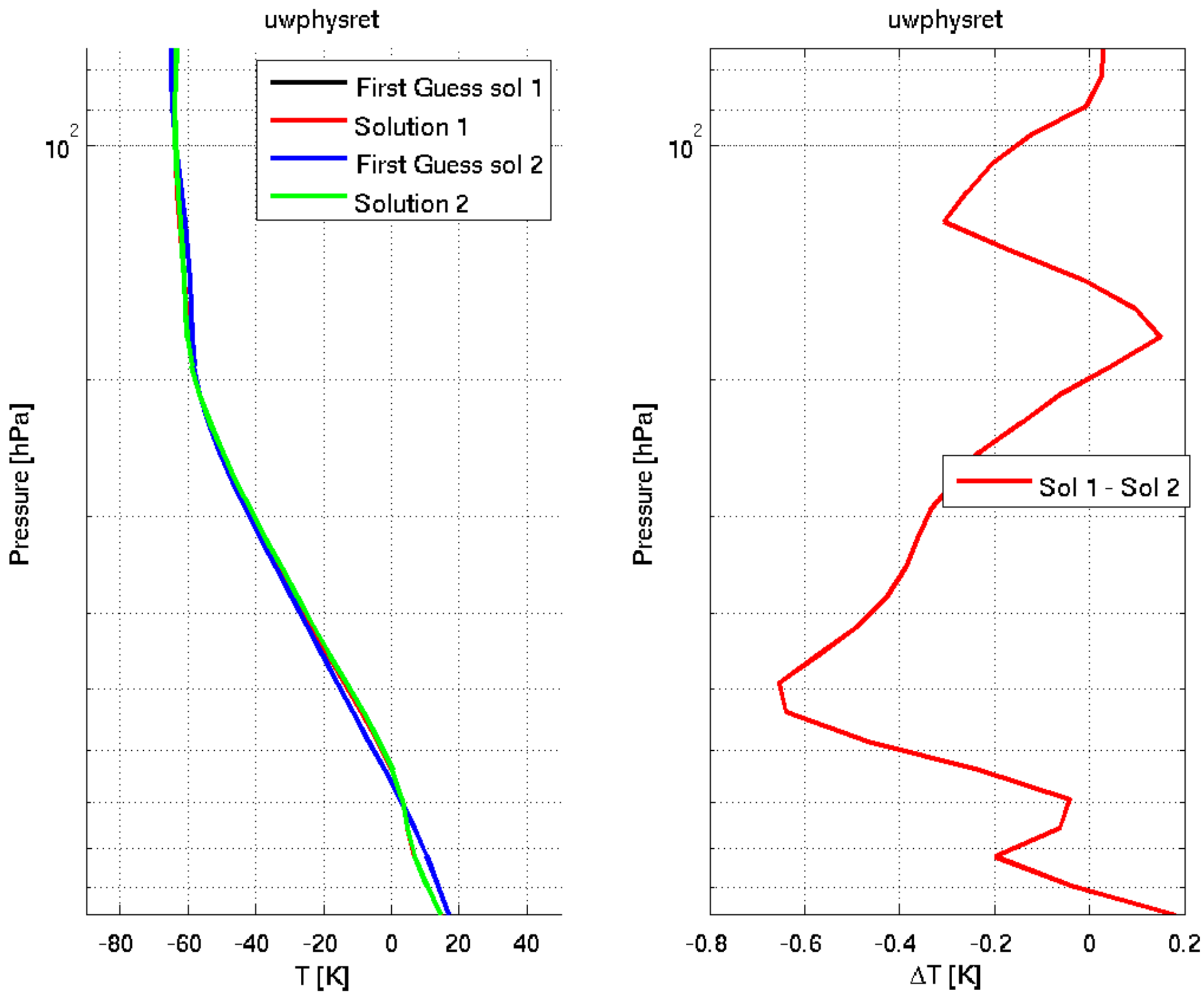
Error Contributions not considered

- Off-diagonal elements of Instrument Noise (correlated noise):
  - Apodization artifacts (for retrieval from apodized radiances);
  - Correlated Noise;
- Forward Model Error
  - Diagonal;
  - Off-Diagonal;
- PCA noise filter
  - Correlated noise;
  - Uncorrelated noise.

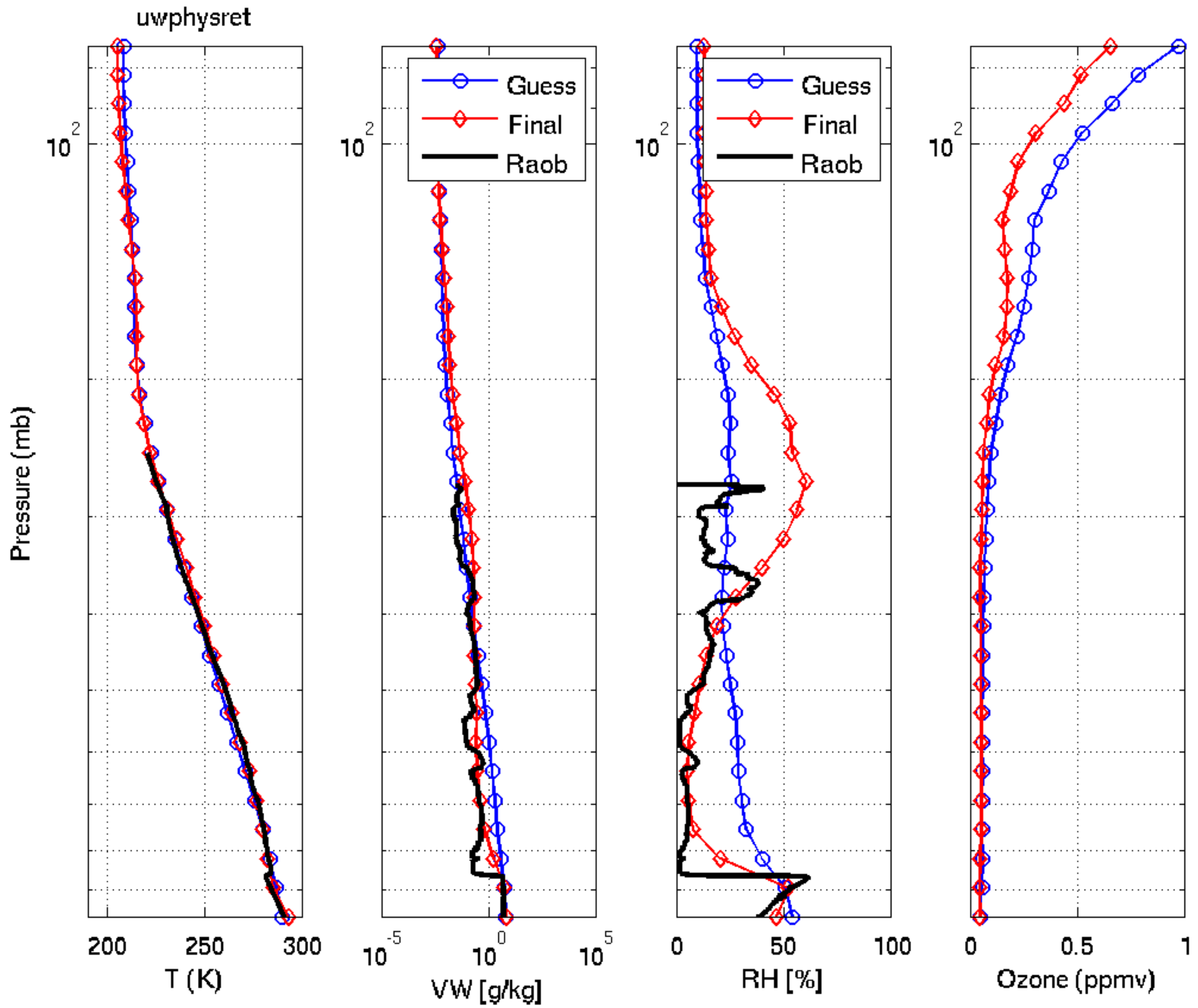
Retrieval difference for Apodized and Non-Apodized Data: Temperature



LBLRTM 10.4 - LBLRTM 11.3 (Temperature)



Next case …16 Apr 2007: Retrieved Vertical Profiles



Conclusions

- UWPHYSRET was built as *reference* retrieval system and relies on lblrtm accuracy to allow research on hyperspectral data inversion

- PCA noise filtering effects obtained without redefinition of the noise Covariance matrix produces changes in the range of:

  - [0.5 - 1] K in temperature;

  - [10 - 30] % in lower atmospheric RH;

- These changes are comparable in magnitude to those induced by apodization or lblrtm updates;

- Under the approximations used in this study, PCA noise filtered data allows for:

  - better representation of the retrieval residual and for estimation of potential FWM biases

  - retrieval convergence when using more accurate representation of the noise covariance

- Redefinition of stable non singular full covariance matrix (including artifacts introduced by apodization, PCA noise filtering, correlations due to the sensor, and forward model error) is key to achievement of high acuracy;

Future Work

- Application of the current system to IASI data;
- Re-definition of a stable, comprehensive, noise covariance matrix:
  - Better characterization of *what we do not know*;
- Improvement representation of a-priori information:
  - Better characterization of *what we do know;*

Topics for Discussion

- Forward Model Error (Full Covariance);
- Climatology on CO_2, O_3, and other species;
- Use of other sources of information in the *a-priori knowledge;*