

# Using JAVIEX data to evaluate Impact PCA Noise Filtering on the High Spectral Resolution Physical Retrieval Algorithm

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# PCA and hyperspectral IR data (as I know it .....

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- Introduced in the 90s for HIS regression based inversion of hyperspectral data
- Applied to HIS, NAST-I, simulated ITS data compression in late 90's
- Used as Noise Filtering Tool on S-HIS, NAST-I and AIRS data 2004
- Extended to Noise Characterization Tool on S-HIS and AIRS data 2005
- Used to instrument monitoring S-HIS, AIRS, IASI 2007
- Introduced in AAPP for IASI data processing (noise filter properties) 2008
- Impact of Noise Filtered Radiances in Physical Retrievals, S-HIS 2008

# Outline

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- UWPHYSRET
- JAIVEX
- Retrieval Validation
- Effect of Noise Filtering
- General Consideration on Instrument Noise Covariance Matrix
- Conclusion
- Future work

# UWPHYSRET

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- 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;
- Analytical Jacobians are updated at every iteration;
- Slow, flexible, accurate;
- Implemented in matlab

# Solution

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- Iterative solution (Gauss-Newton):

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

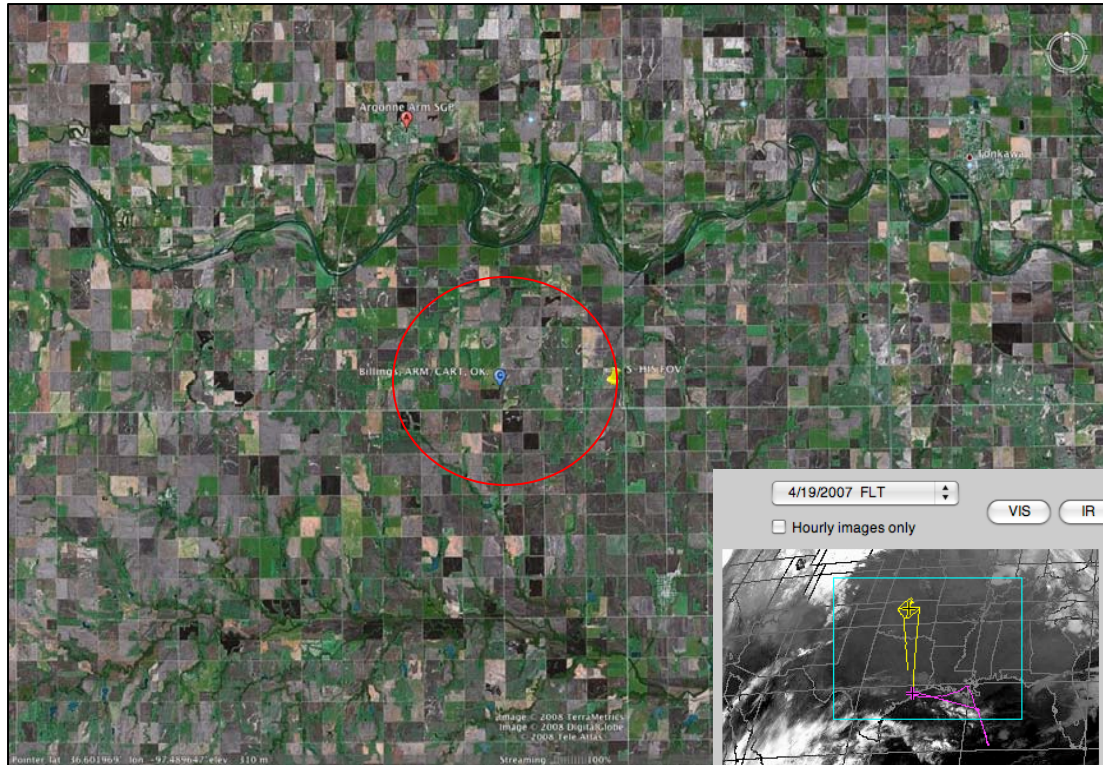
- $x$  is the state vector ( $a$  stands for a-priori,  $n$  is the iteration number);
- $K$  is the Jacobian Matrix;
- $S_a$  is the covariance matrix of the a-priori knowledge;
- $S_e$  is the covariance matrix of the Instrument noise;
- $Y$  is the observation vector (radiance);
- $F(x)$  is the calculated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

# JAIVEx

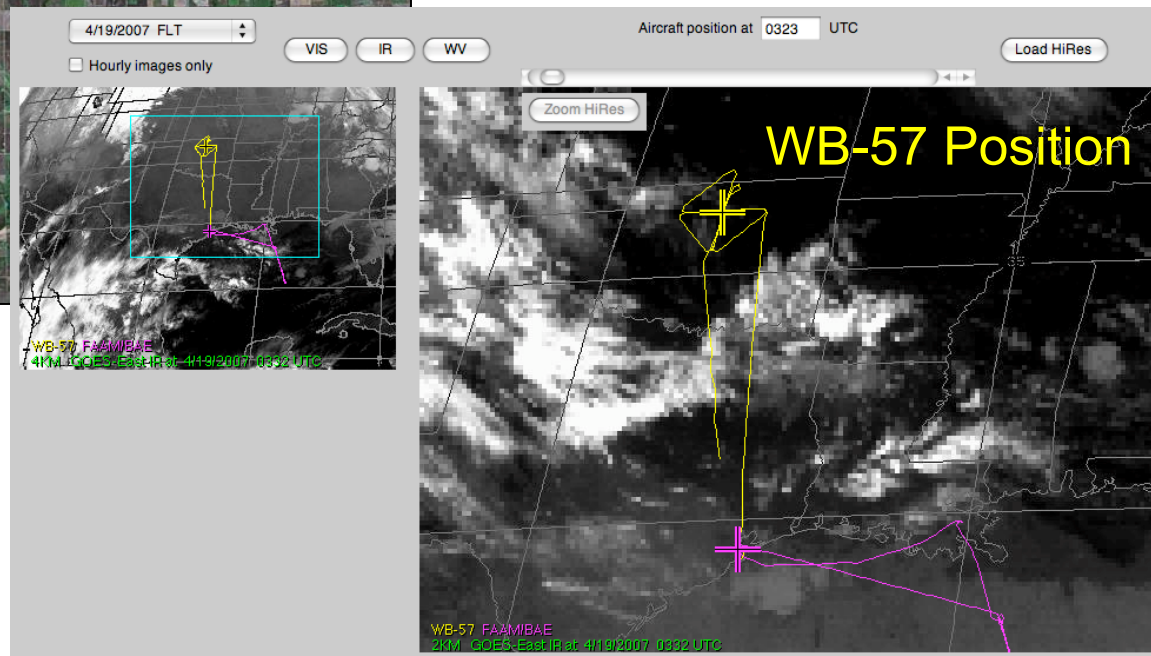
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- **Joint Airborne IASI Validation Experiment**
- The Joint Airborne IASI Validation Experiment is an international cal/val campaign in support of the [NPOESS](#) and [MetOp](#) series of operational satellites.
- The focus of JAIVEx is on the validation 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  $\text{cm}^{-1}$  (i.e., 3.6-15.5  $\mu\text{m}$ ) spectral band with high spectral resolution (i.e., 8461 spectral channels with a spacing of 0.25  $\text{cm}^{-1}$ ).
- The aircraft being employed are the NASA [WB-57](#) and the [FAAM BAe 146](#).

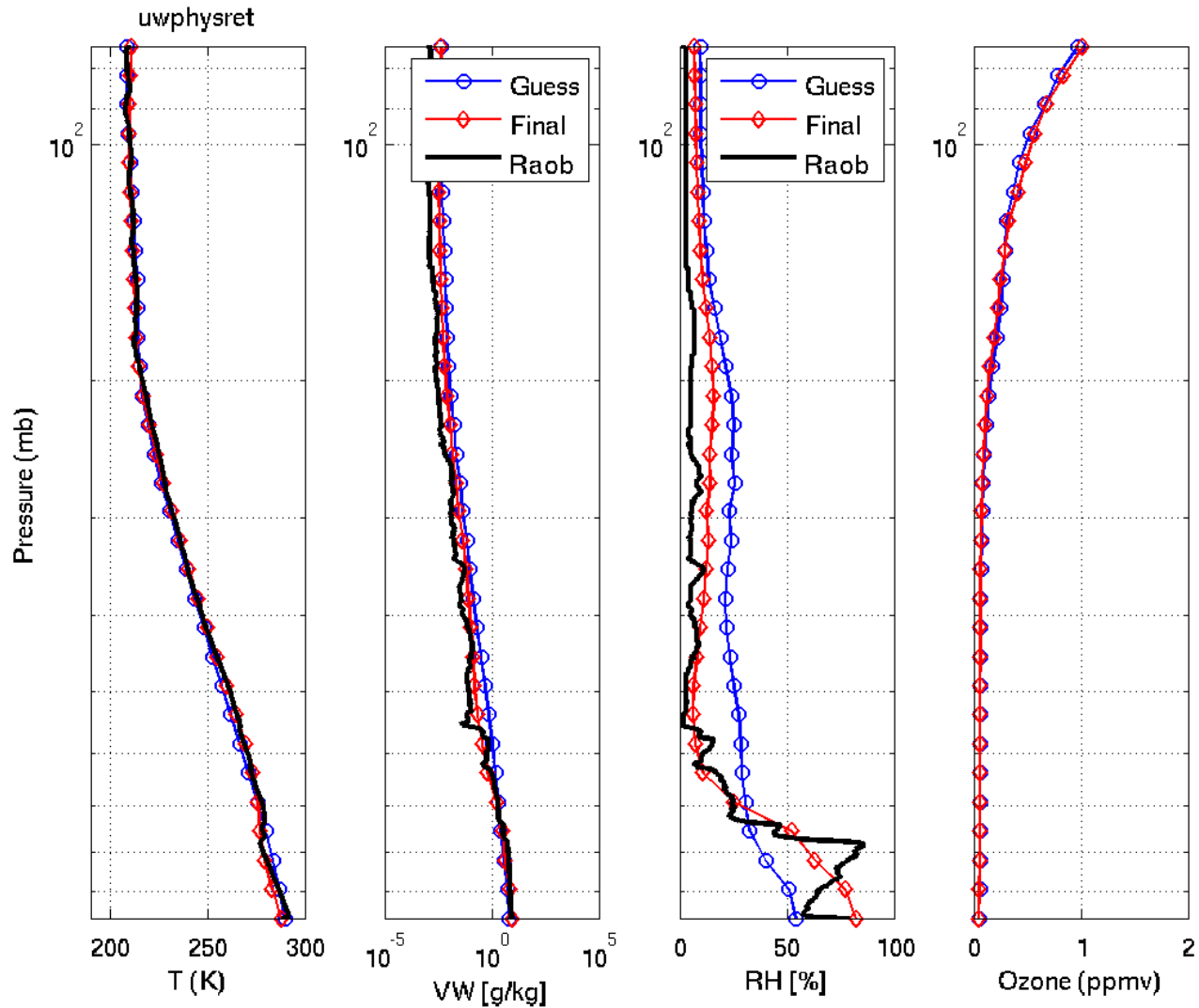
# SGP ARM Cart Site: 19 Apr 2007 15:32 UTC



S-HIS FOV



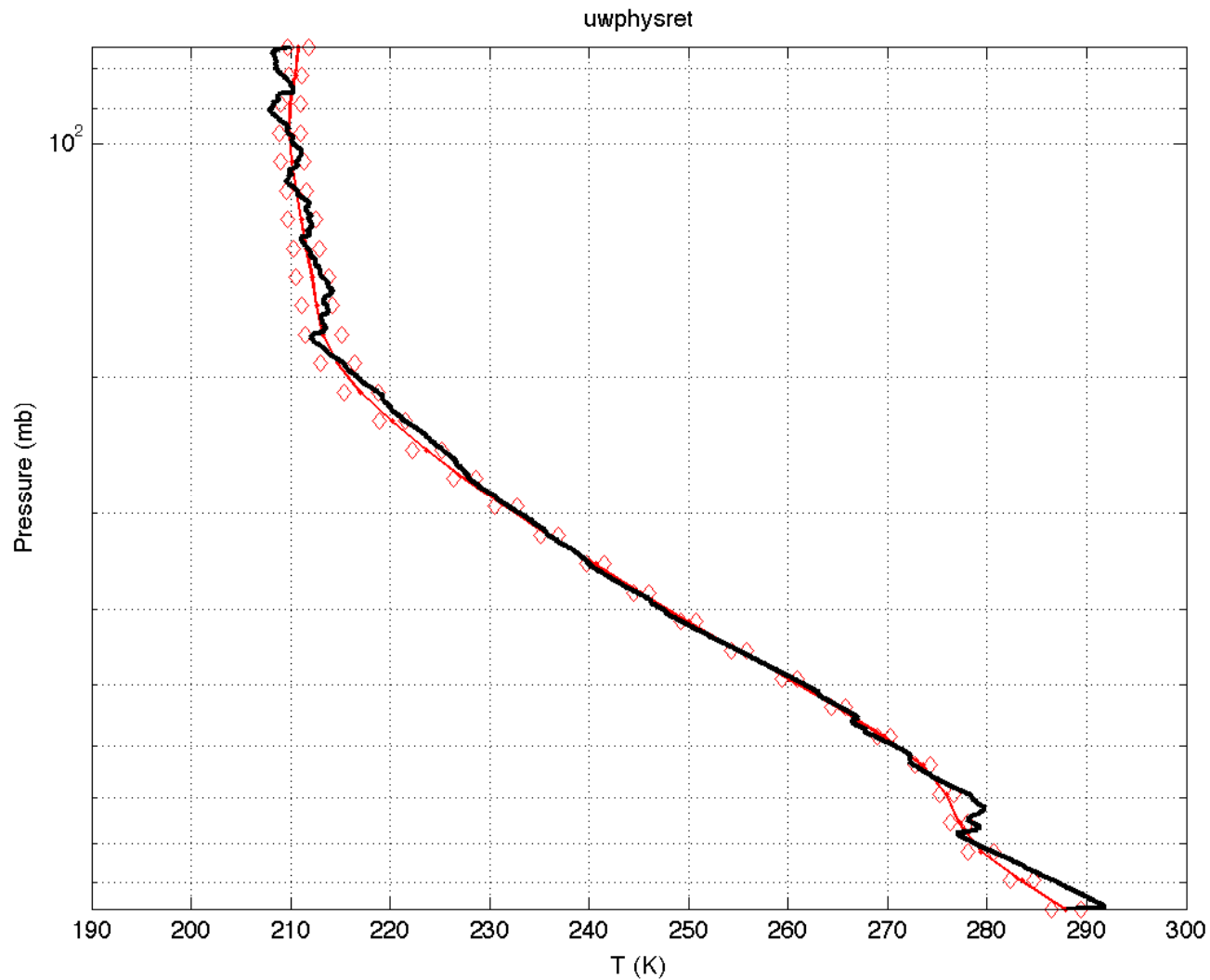
# Retrieved Vertical Profiles



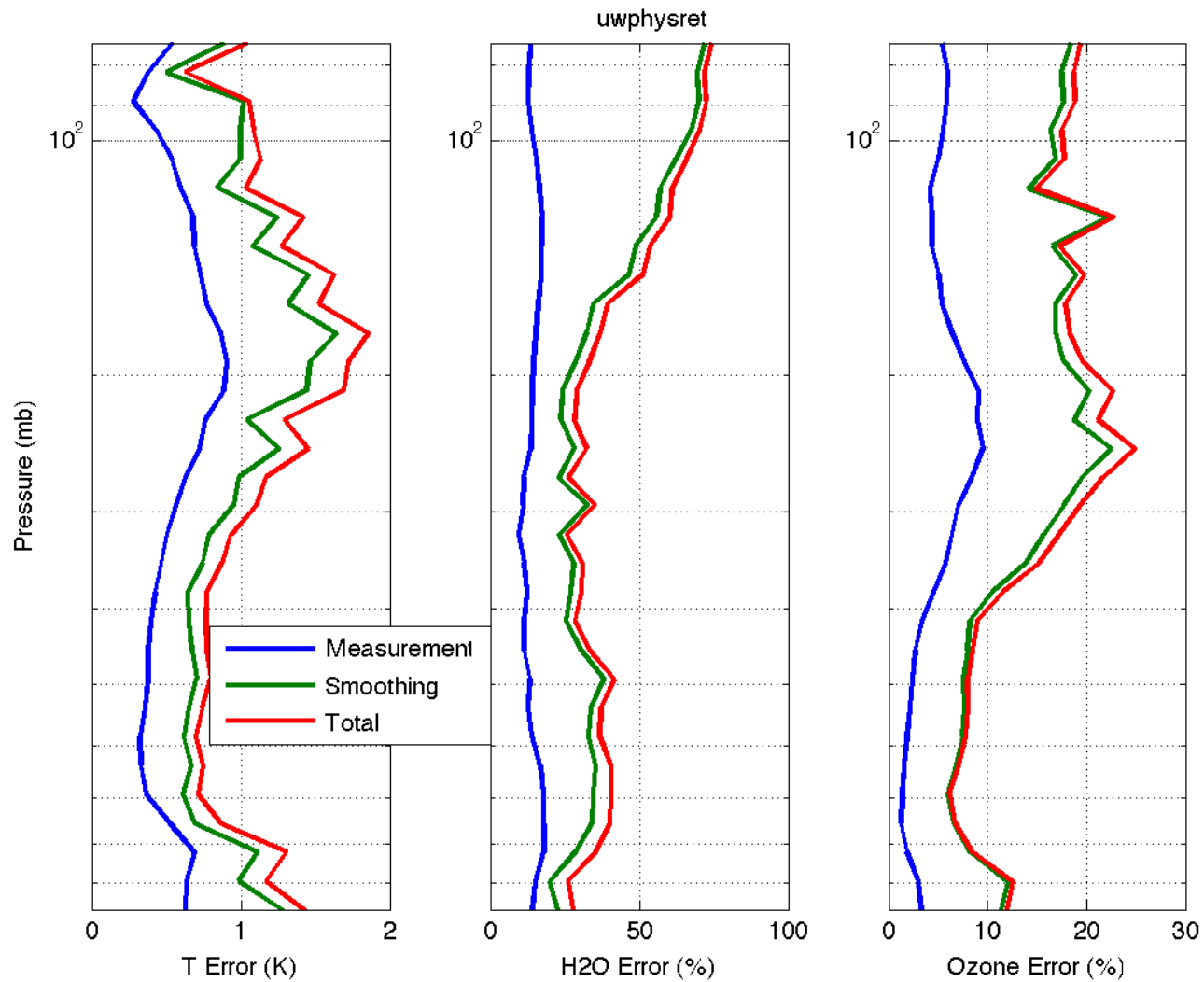


# Retrieved Temperature Profile with Errorbars

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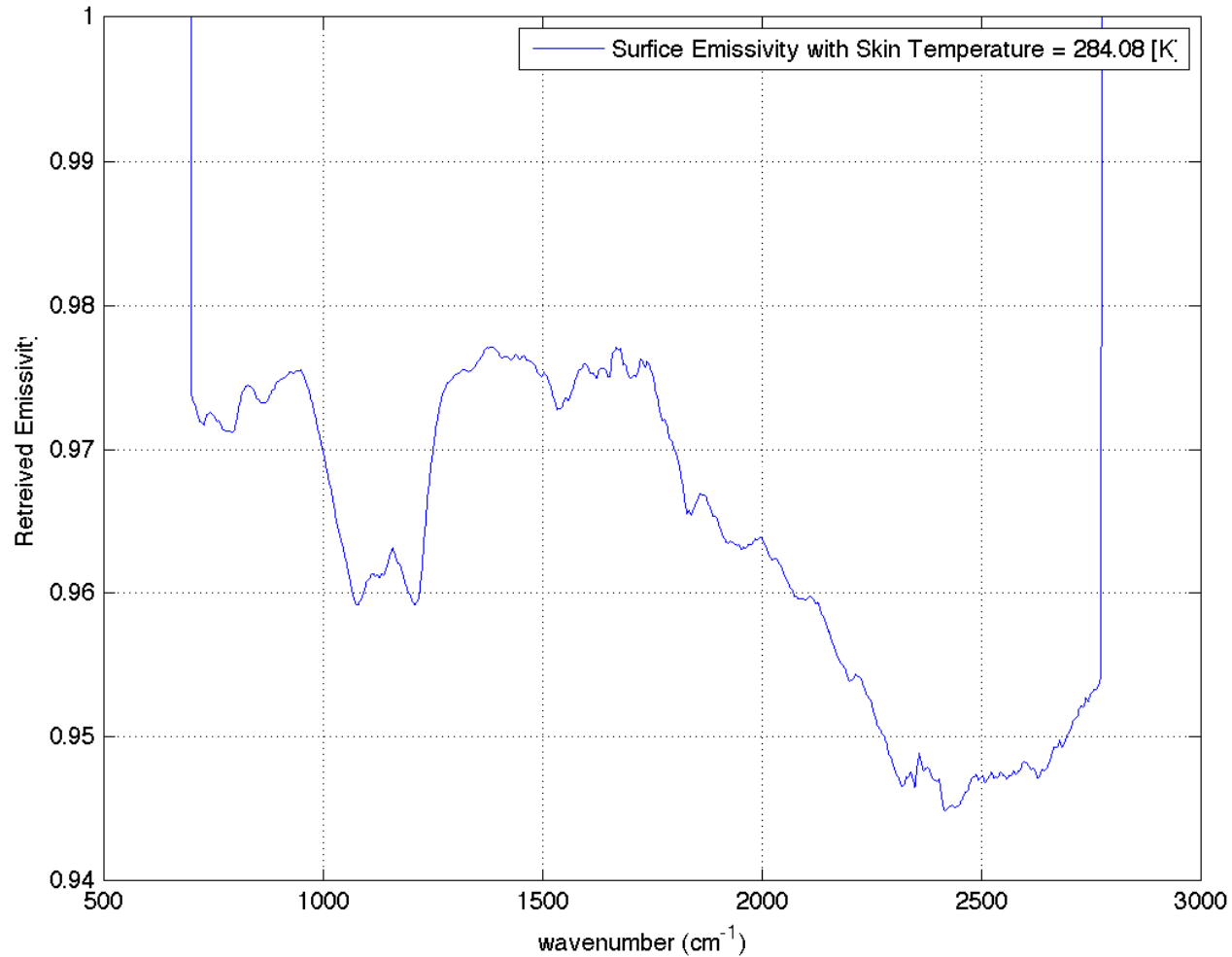


# Retrieval Errors

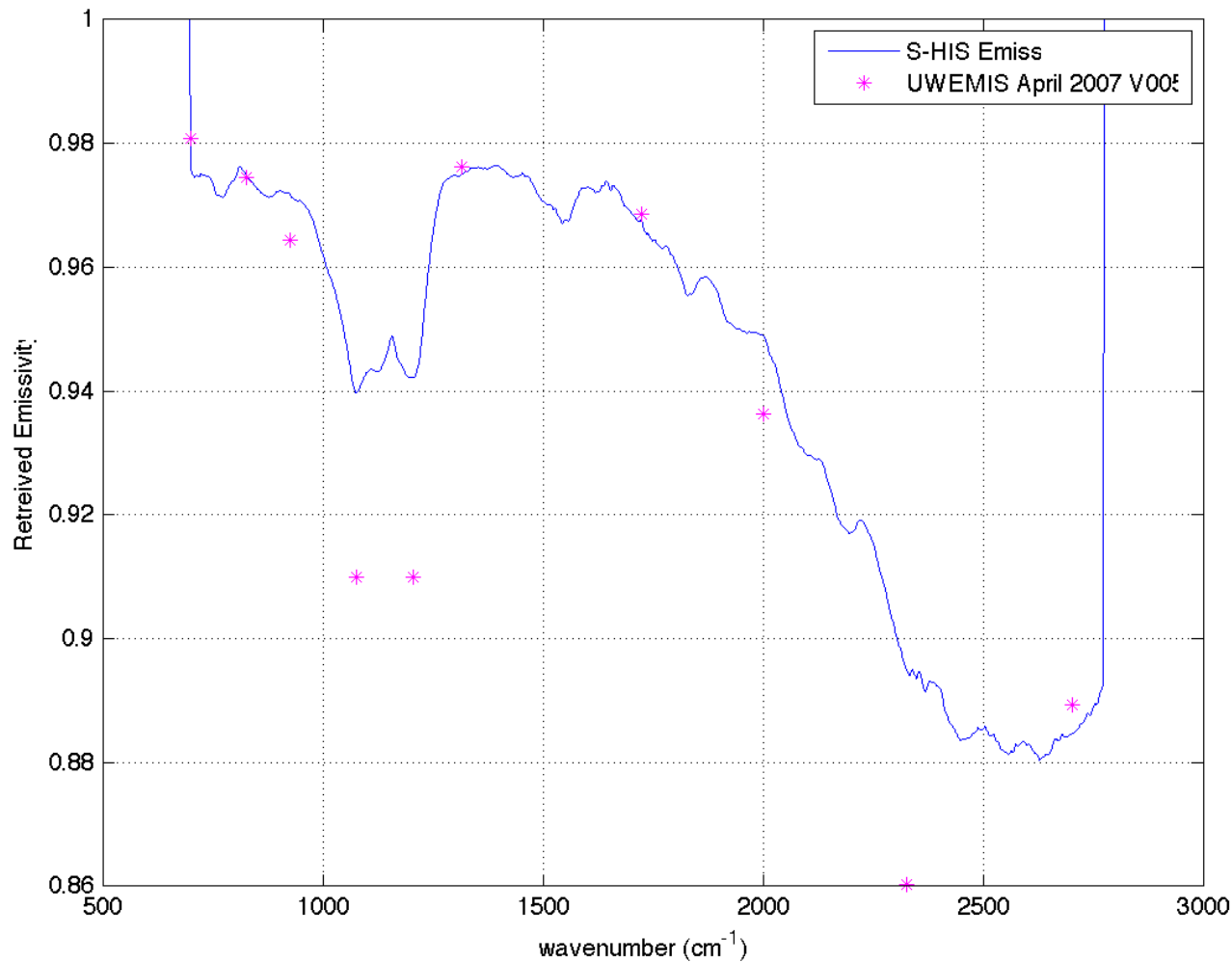


# Retrieved Surface Emissivity

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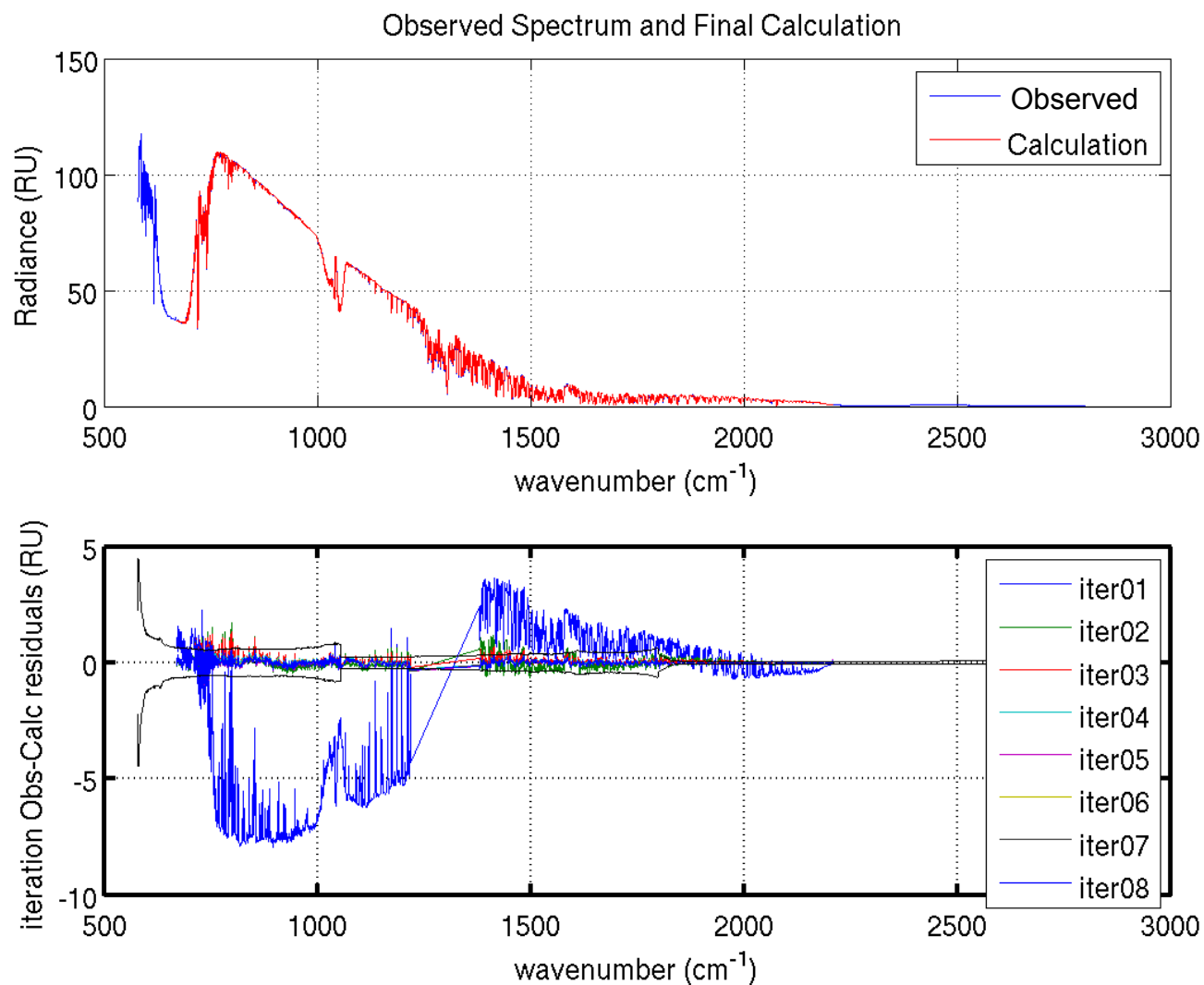


# Retrieved Surface Emissivity: Validation with UWEMIS (from MODIS data collection 5)

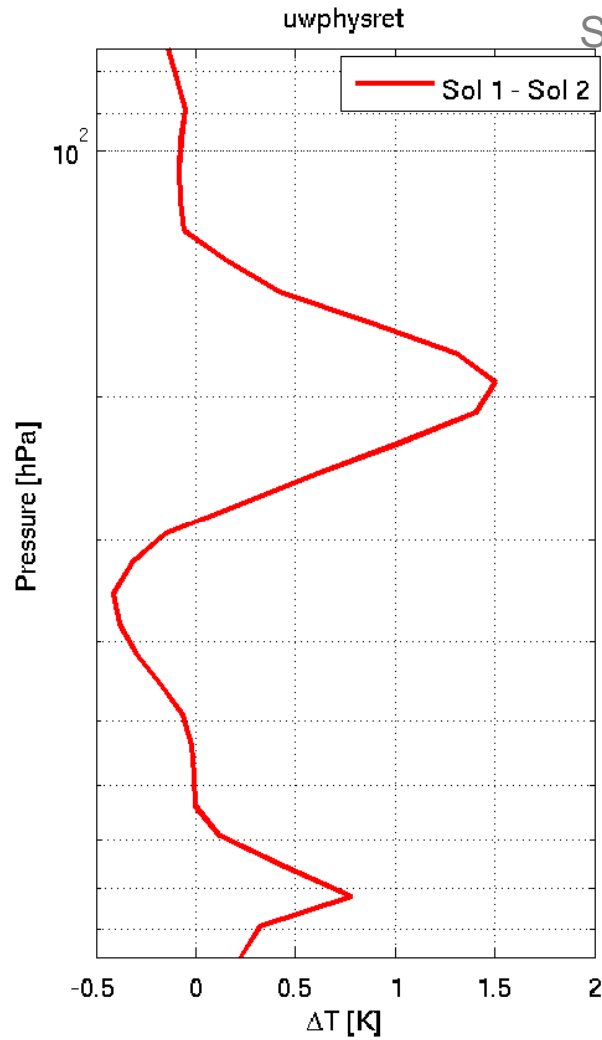
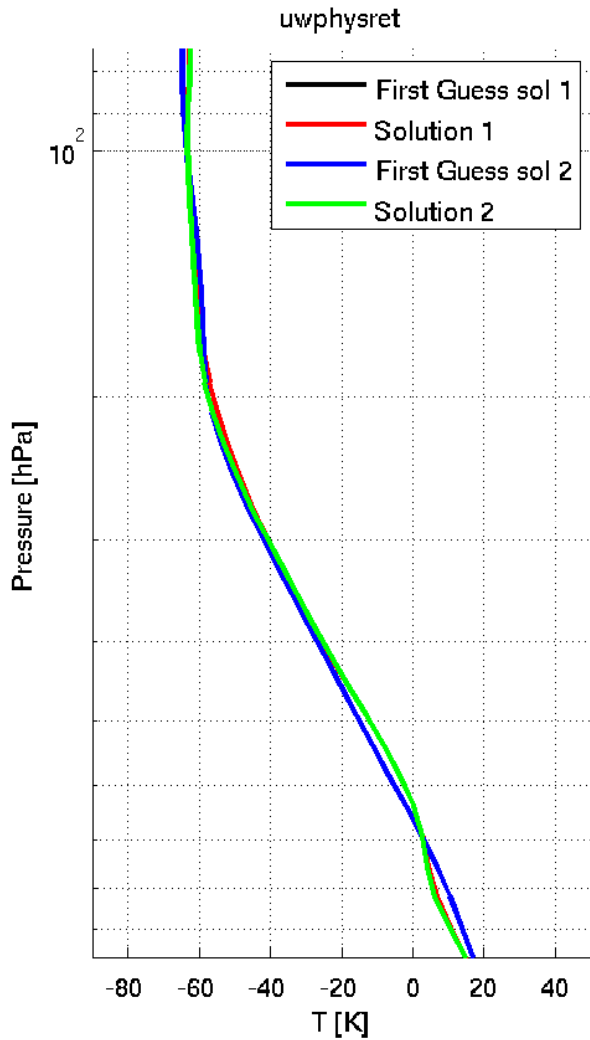


Courtesy of  
Eva Borbas

# Retrieval Conversion: Iteration by Iteration

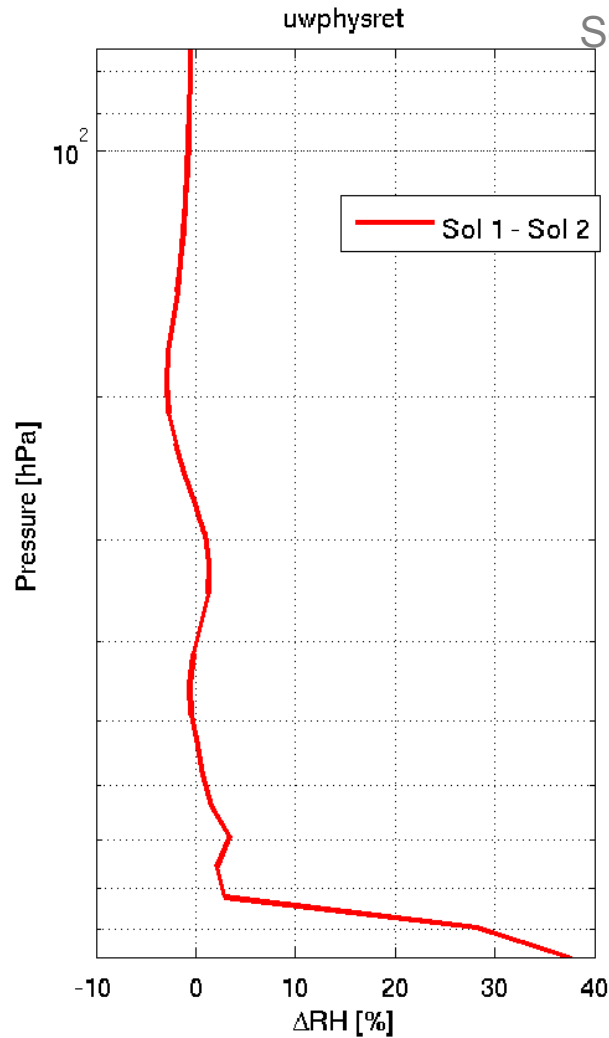
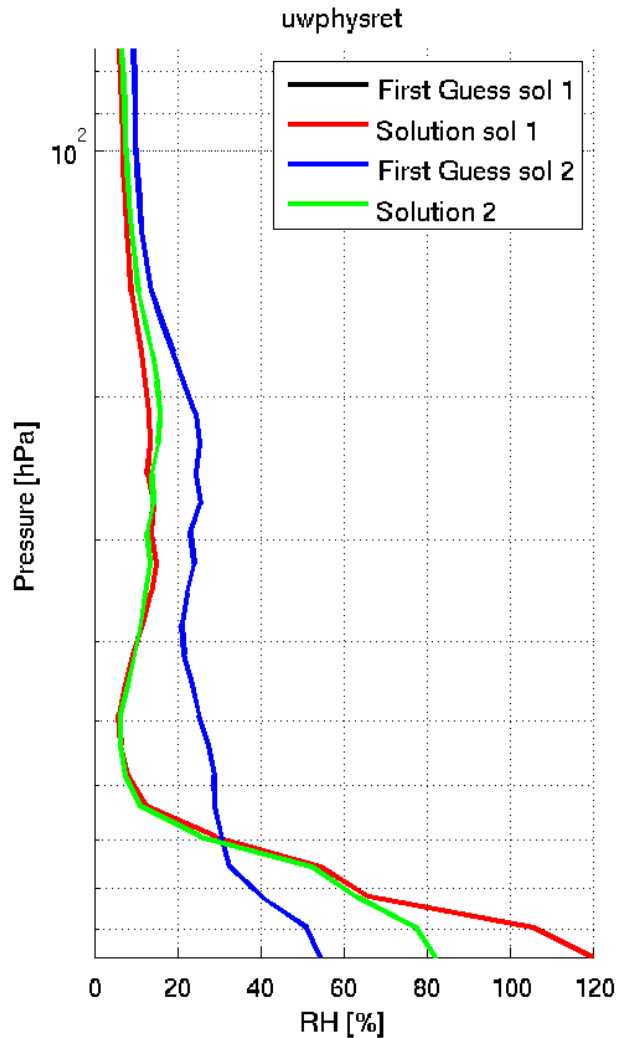


# Retrieval difference for Unfiltered and Filtered Data: Temperature



Solution 1 == Unfiltered Data  
Solution 2 == Filtered Data

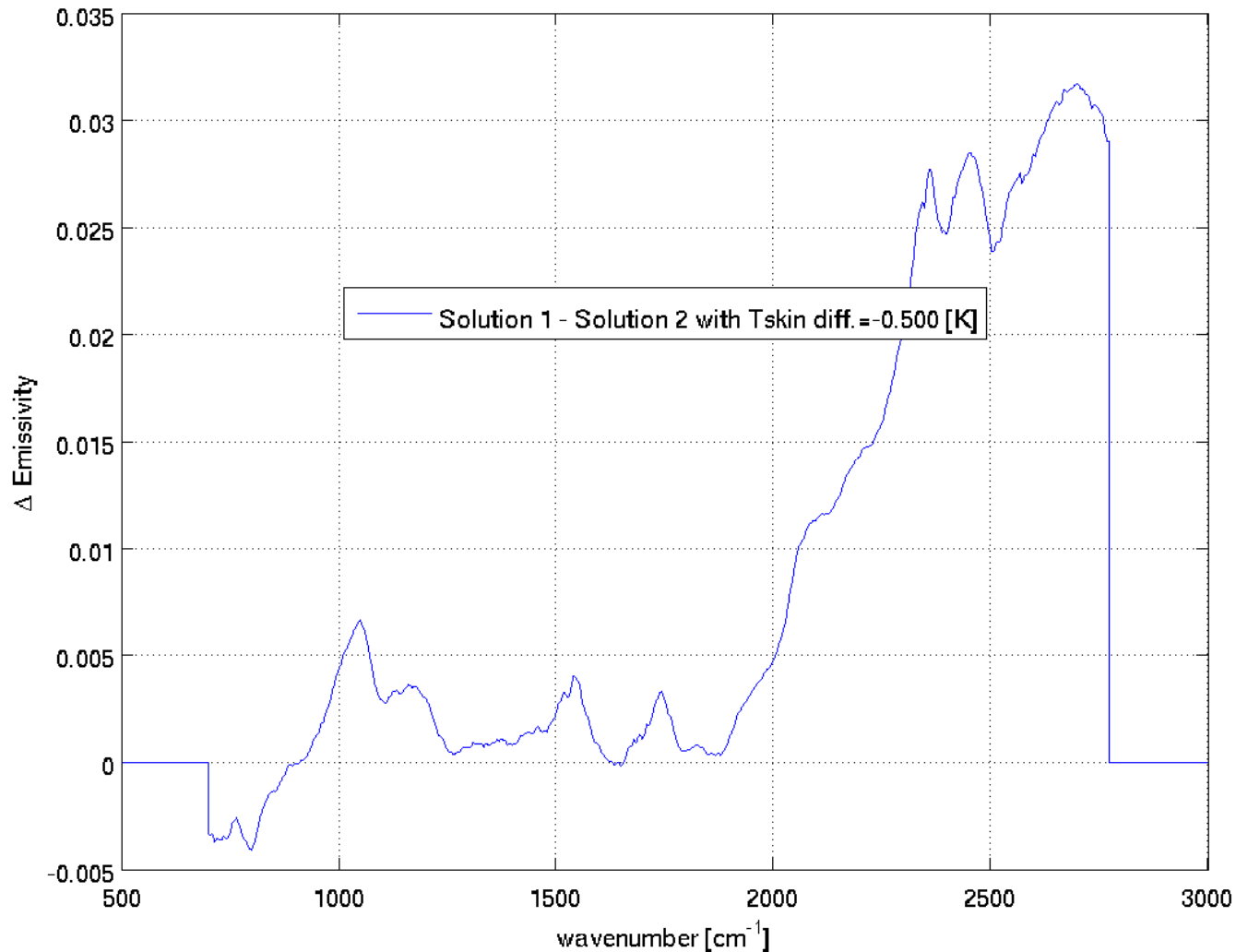
# Retrieval difference for Unfiltered and Filtered Data: Relative Humidity



Solution 1 == Unfiltered Data  
Solution 2 == Filtered Data

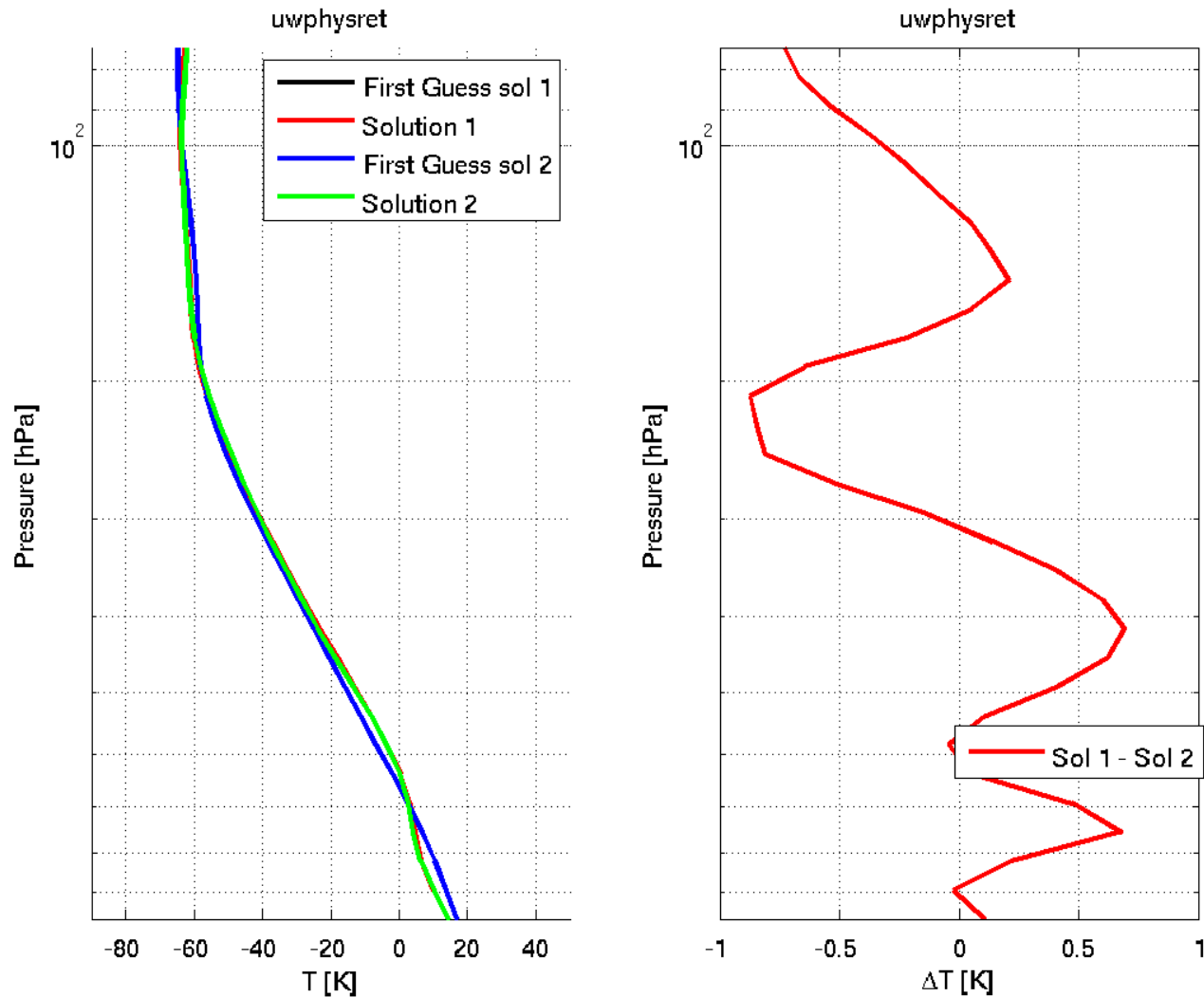
# Retrieval difference for Unfiltered and Filtered Data: Surface Emissivity and Temperature

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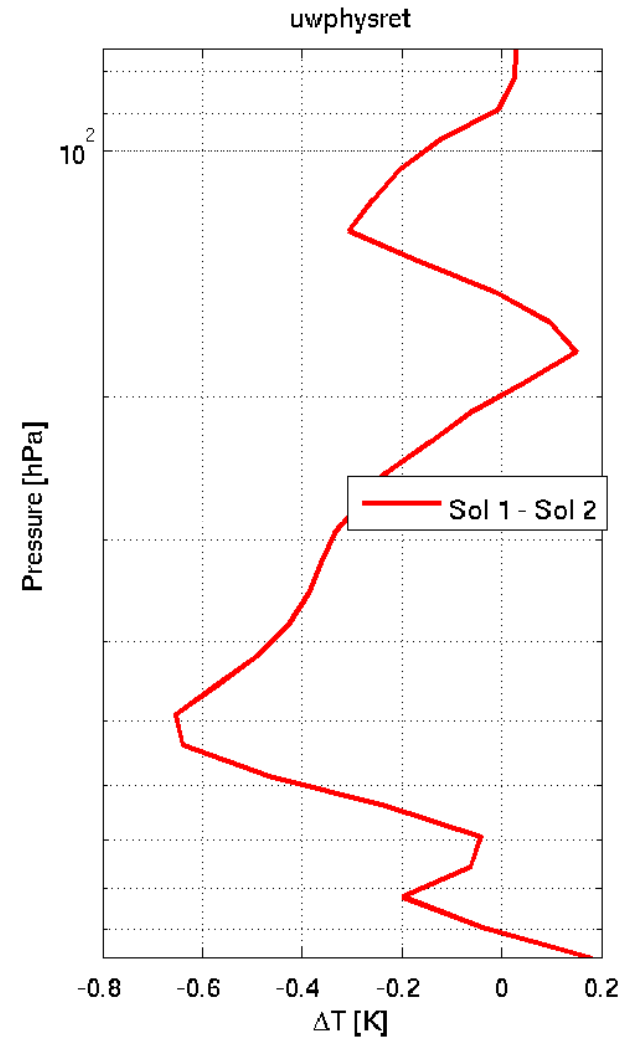
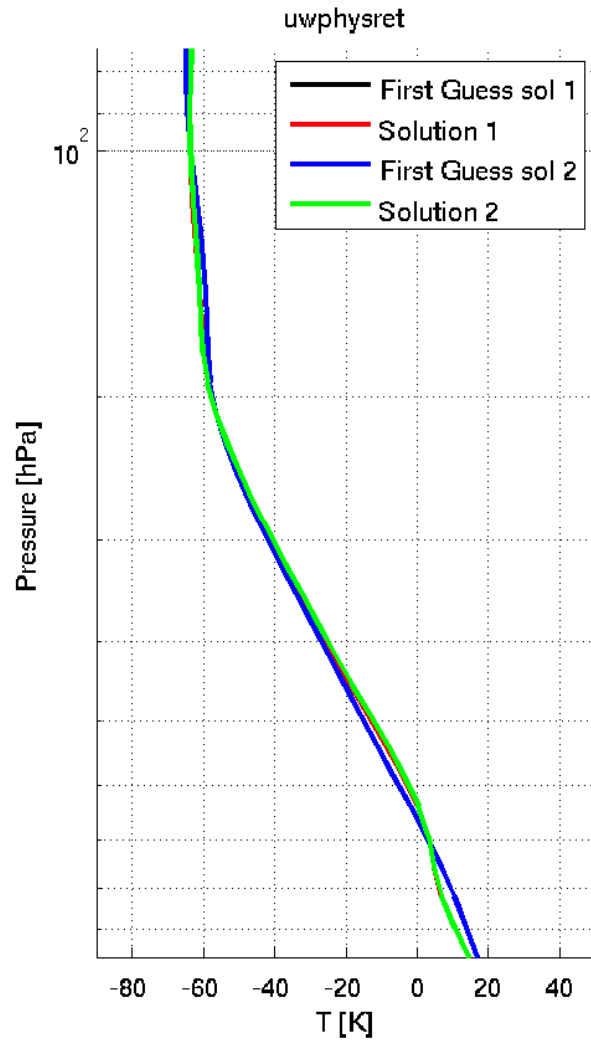




# Retrieval difference for Apodized and Non-Apodized Data: Temperature

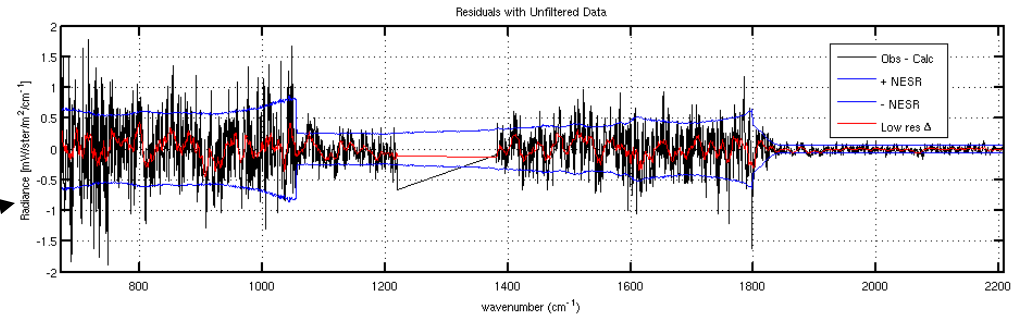


# LBLRTM 10.4 - LBLRTM 11.3 (Temperature)

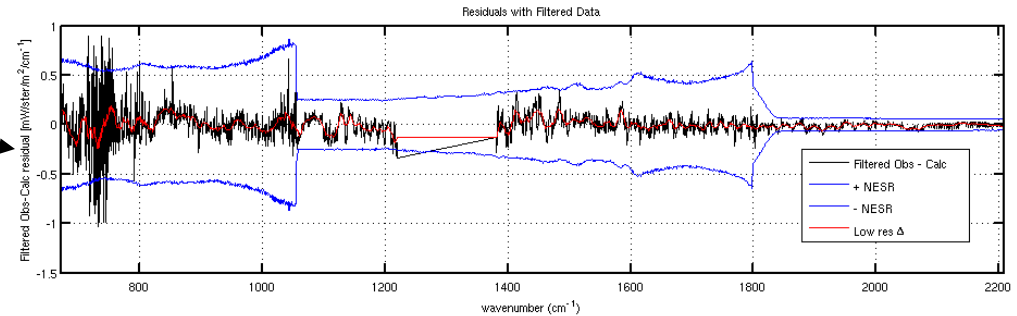


# Retrieval off Unfiltered Data: Residuals in radiance Units

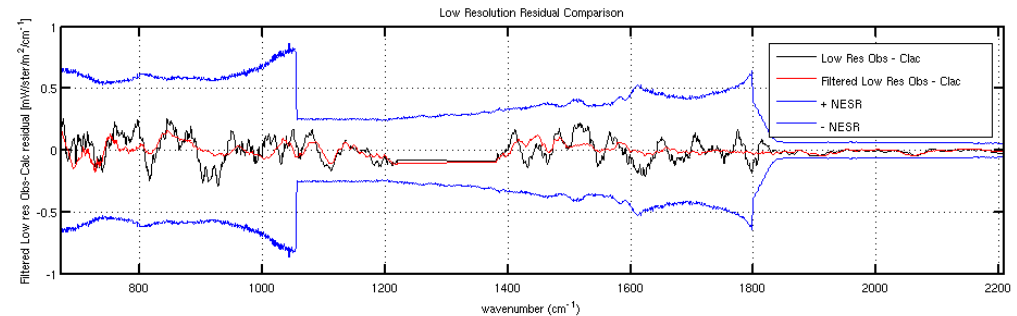
Unfiltered Obs - Calc



Filtered Obs - Calc



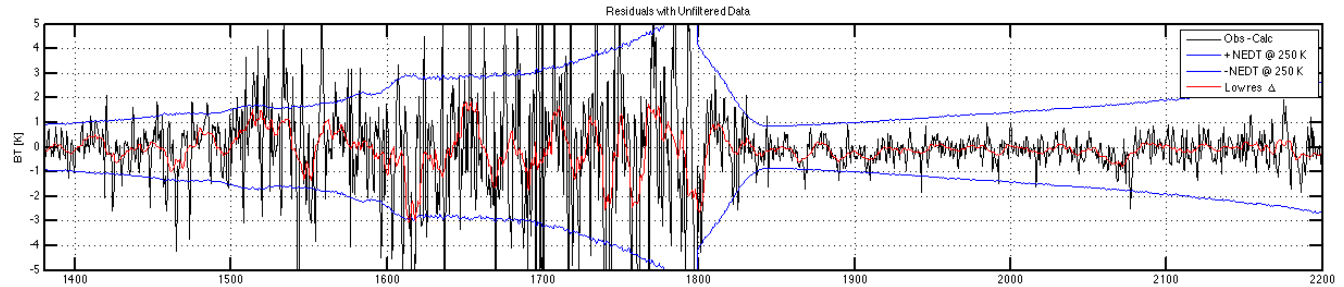
- Retrieval off Unfiltered Apodized Data;
- Nominal Noise (diag COV matrix).



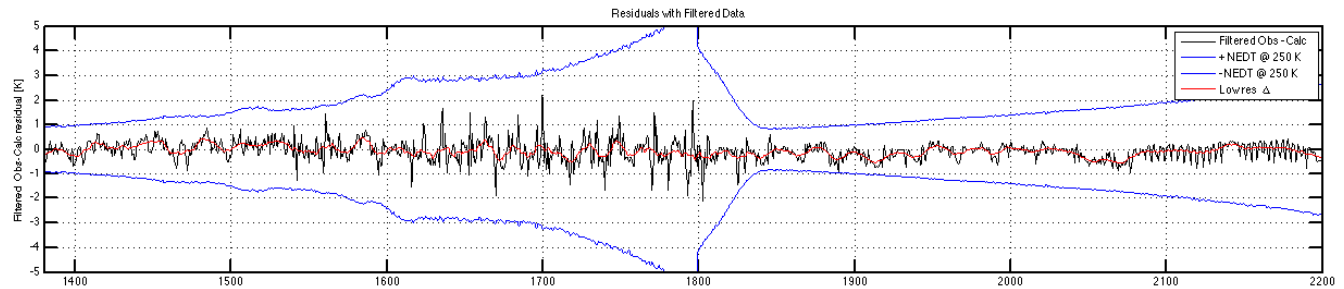
NESR

# Retrieval off Unfiltered Data: Residuals in BT

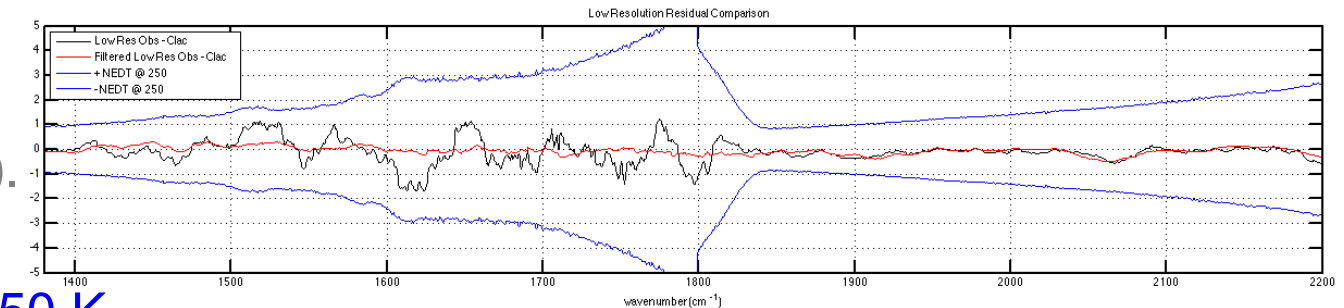
Unfiltered  
Obs - Calc



Filtered  
Obs - Calc



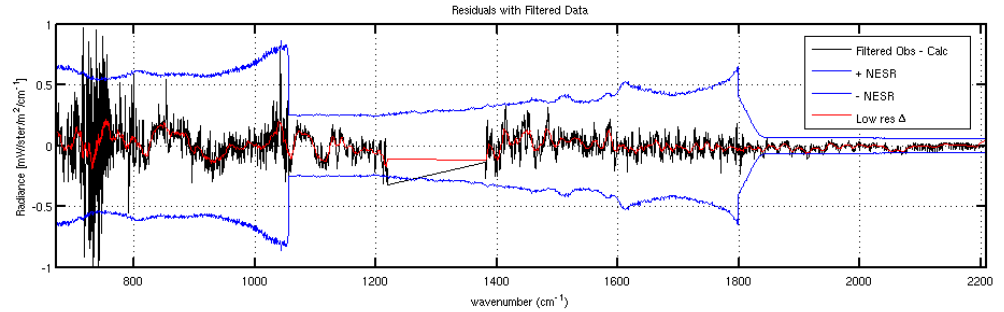
- Retrieval off Unfiltered Apodized Data;
- Nominal Noise (diag COV matrix).



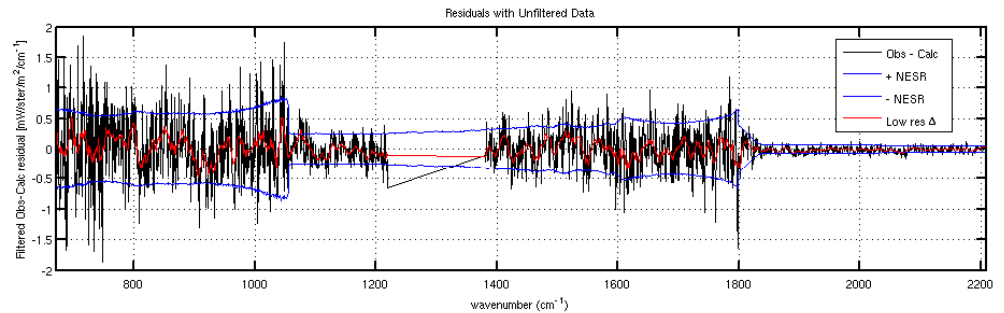
NEDT @ 250 K

# Retrieval off Filtered Data: Residuals in radiance Units

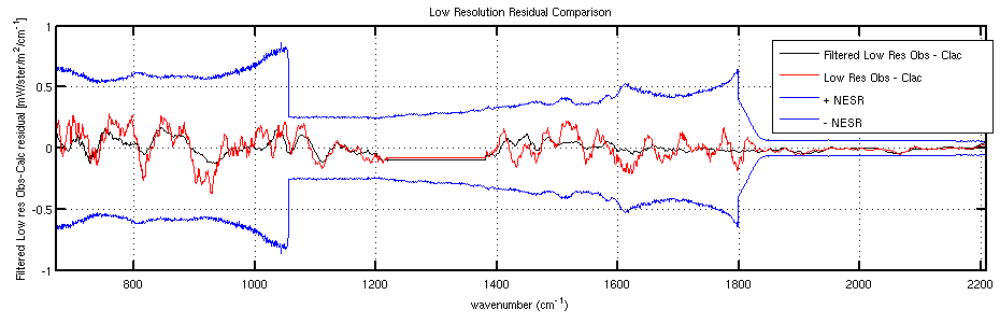
Unfiltered Obs - Calc



Filtered Obs - Calc



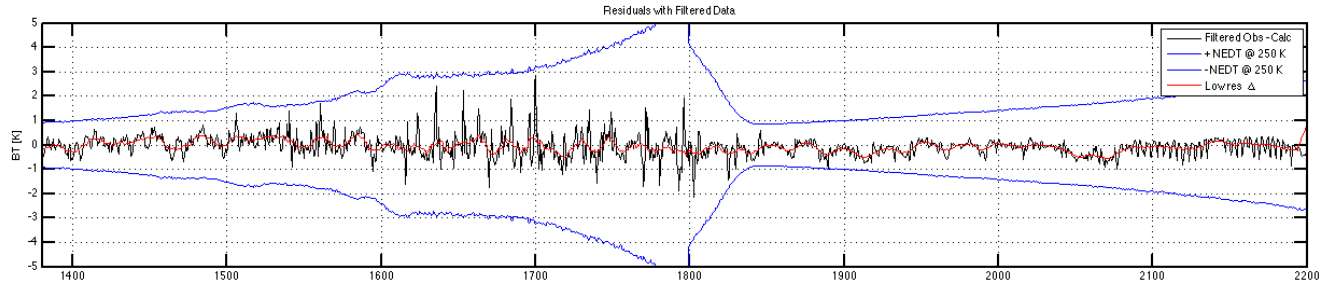
- Retrieval off Unfiltered Apodized Data;
- Nominal Noise (diag COV matrix).



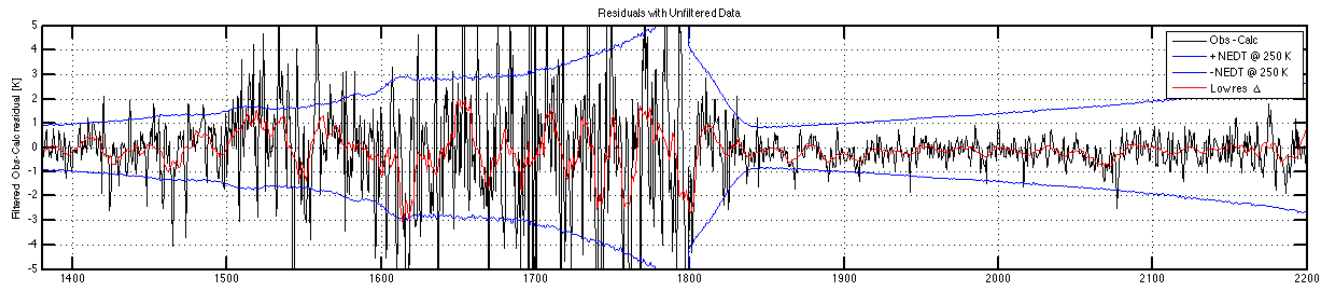
NESR

# Retrieval off Filtered Data: Residuals in BT

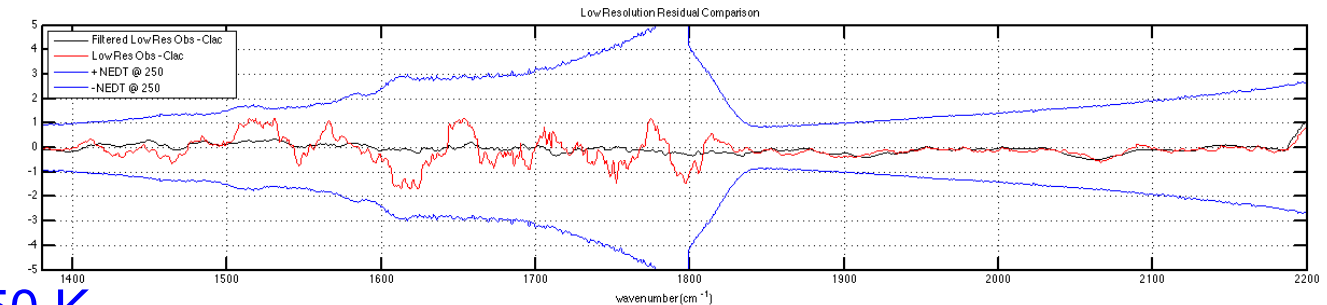
Filtered  
Obs - Calc



Unfiltered  
Obs - Calc

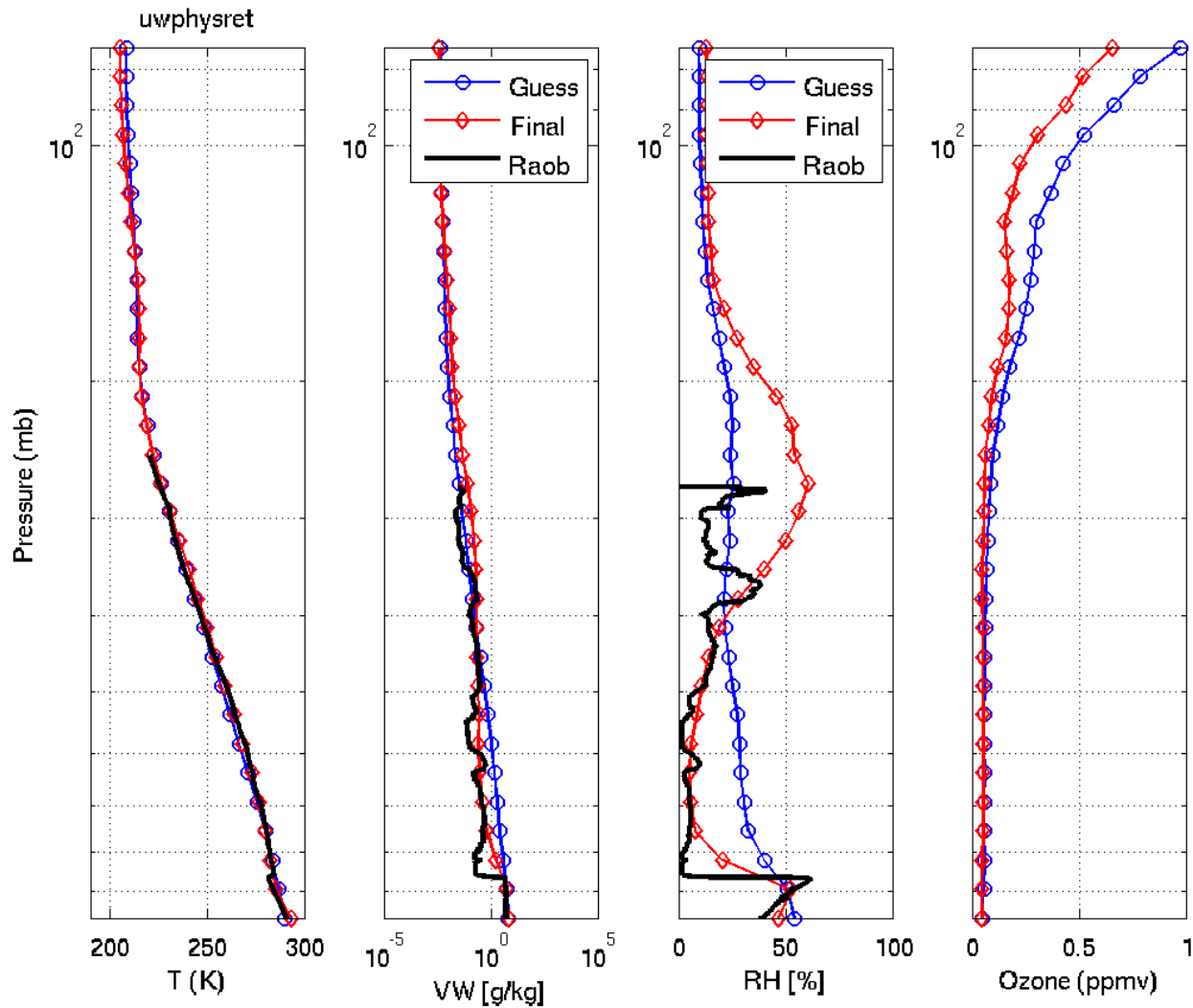


- Retrieval off Filtered Apodized Data;
- Nominal Noise (diag COV matrix).



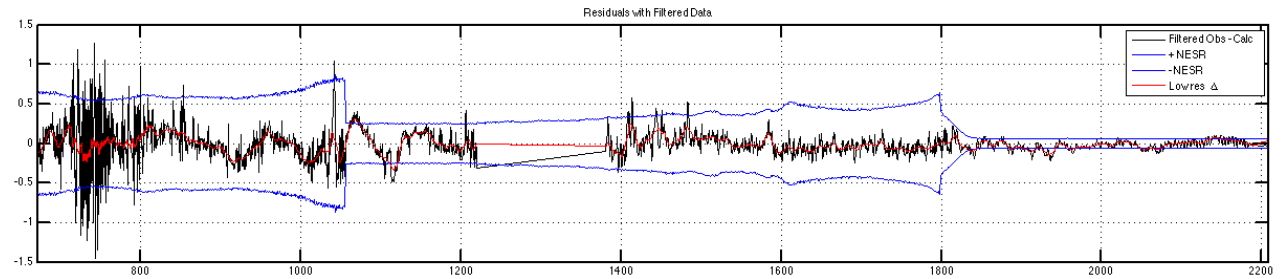
NEDT @ 250 K

# 16 Apr 2007: Retrieved Vertical Profiles

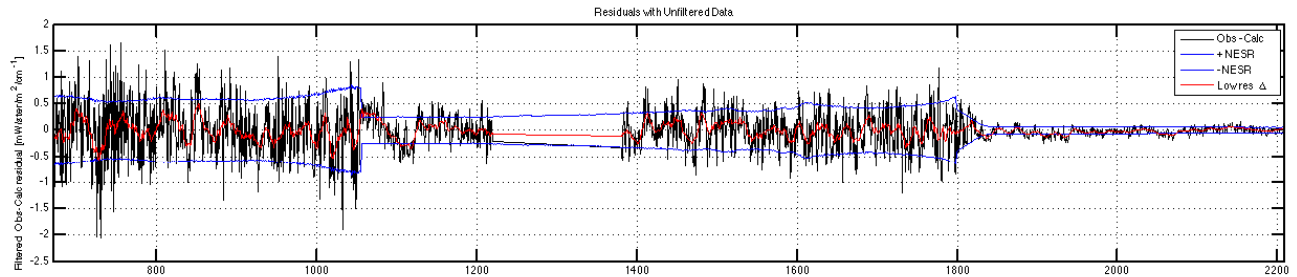


# Retrieval off Filtered Data: Residuals in radiance Units

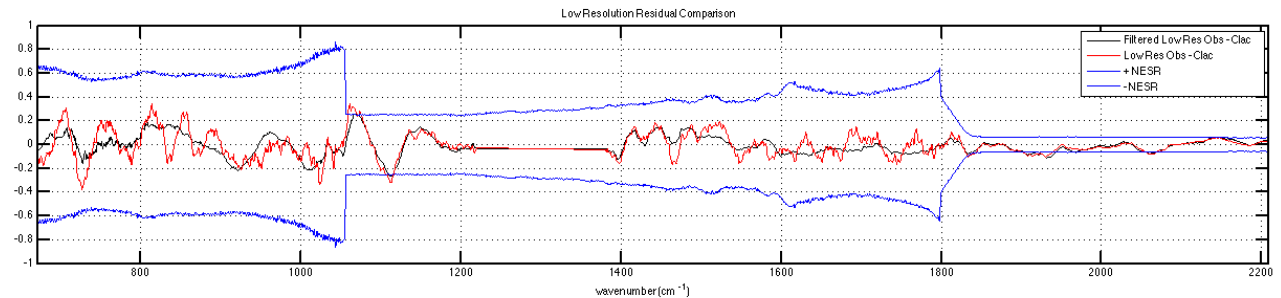
Filtered  
Obs - Calc



Unfiltered  
Obs - Calc



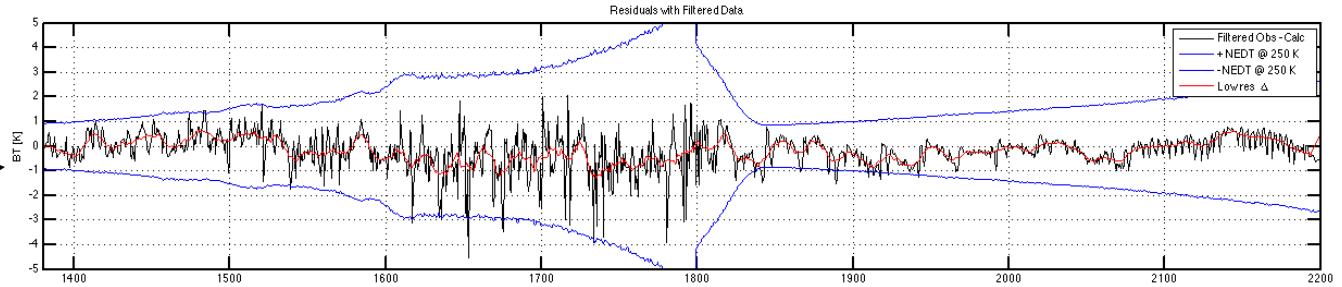
NESR



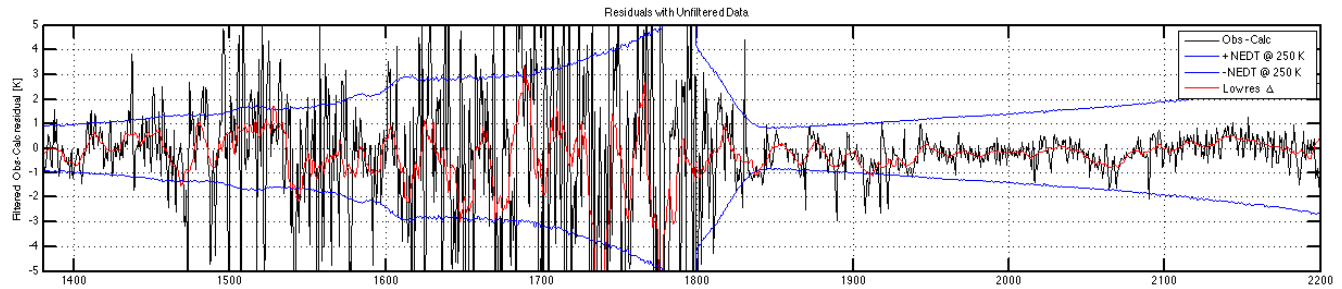


# Retrieval off Unfiltered Data: Residuals in BT

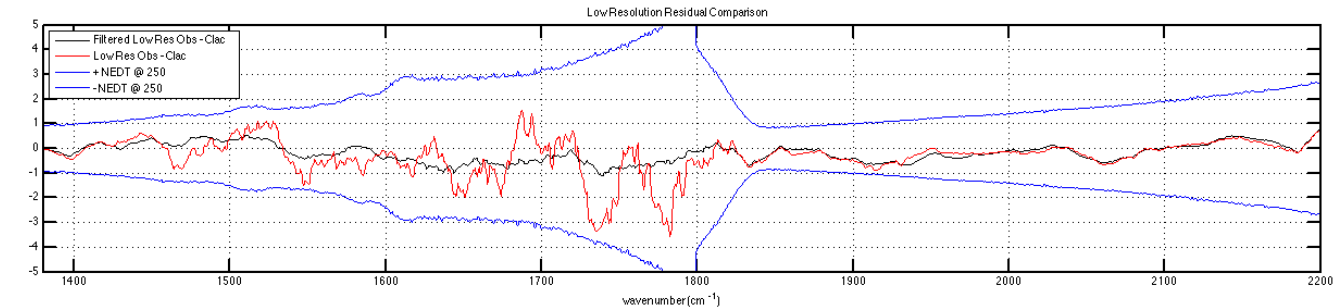
Filtered  
Obs - Calc



Unfiltered  
Obs - Calc



NEDT @ 250 K



# Conclusions

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- UWPHYSRET was built as *reference* retrieval system and relies on lbrtm accuracy to allow research on PCA noise filter impact on retrievals
- Redefinition of a stable non singular full covariance matrix (considering apodization, PCA noise filtering, correlations due to the sensor, and forward model error, has not been achieved yet;
- 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 of similar magnitude to those induced by apodization or lbrtm 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

# Future Work

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- Re-definition of a stable invertible full instrument noise covariance matrix;
- Application of the current system to IASI data;
- Development of a sequential scheme for retrievals (T $\rightarrow$ WV $\rightarrow$ Surf T $\rightarrow$ Surf Emiss $\rightarrow$ Minor Spices);
- Evaluation of the impact of different representation of a-priori information on final retrieval;

# Dominant PC of the whole talk

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Thank you

International TOVS Study Conference, 16<sup>th</sup>, ITSC-16, Angra dos Reis, Brazil, 7-13 May 2008.  
Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center,  
Cooperative Institute for Meteorological Satellite Studies, 2008.