Validation of H_2O continuum absorption models in the wave number range 180-600 cm^{-1} with atmospheric emitted spectral radiance measured at the Antarctica Dome-C site

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This work is extensively treated in

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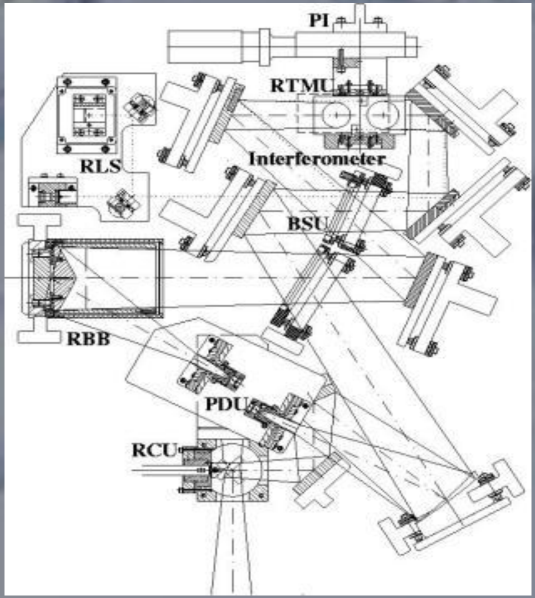
REFIR-PAD AND PRANA CAMPAIGN

Concordia Station, Dome C – 74.5°S, 123.0°E, 3280 m altitude

- Unique climatology, one of the coldest places on Earth
- Presence of ice aerosols
- Very low amounts of precipitable water

PRANA project: Radiative properties of Atmospheric Water vapour and clouds in Antarctica

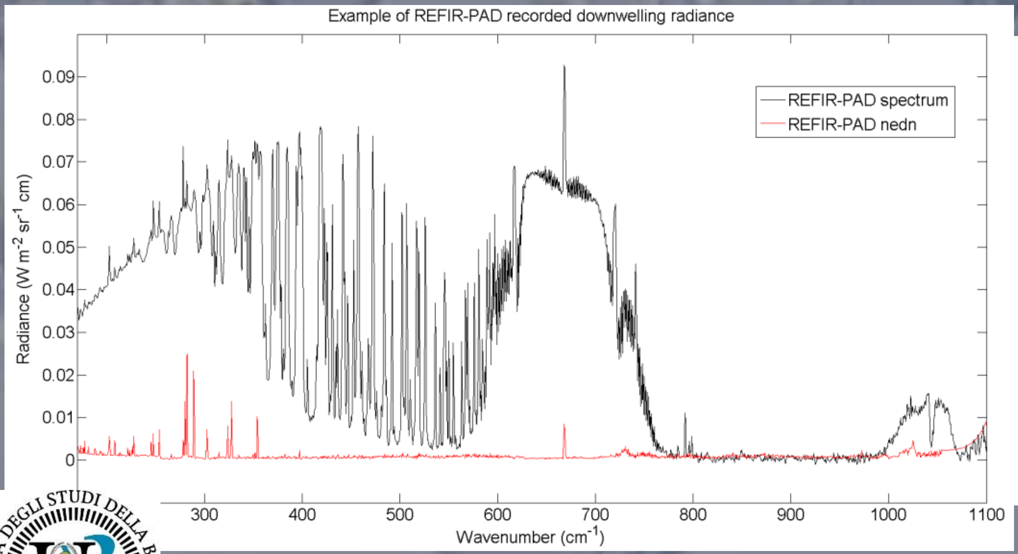


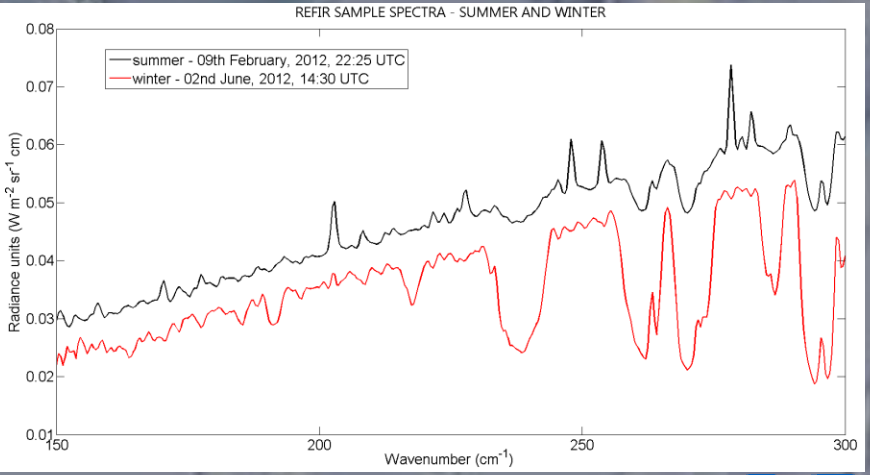
Instrument type	Mach-Zehnder non polarising FTS
Beam splitter	Broadband Ge-coated Mylar
Operating spectral bandwidth	100-1400 cm^{-1}
Operating spectral resolution	0.4 cm^{-1} (unapodized, double-sided)
Optical throughput	0.01 cm^2 sr
Detector type	Room temperature pyroelectric (DLATGS)
Acquisition time	80 s per scan
Weight	55 kg (including control electronics)
Power consumption	50 W (24 VDC power supply)

Radiometric uncertainty: 0.1 K @ 280K

DATA SELECTION

- ORIGINAL DATASET: 137 spectra acquired on 20th January, 9/10th February, 2nd-28/29th June 2012.
- EXCLUDED: clearly cloudy (at naked-eye) spectra, high-H_2O mixing ratio spectra.
- FINAL DATASET: 20 clear-sky spectra, with a columnar precipitable H_2O amount between 0.15 and 1.15 mm. Acquisition dates: 9/10th February (daytime), 2nd June (nighttime), 2012.
- TWO SUBSETS: division according to the season of acquisition; 15 summer spectra (daytime) and 5 winter spectra (nighttime).





RETRIEVAL PROCEDURE

$$k = C_f\left(\frac{\rho_f}{\rho_o}\right) + C_s\left(\frac{\rho_s}{\rho_o}\right) + k_{local}$$

CONTINUUM ABSORPTION COEFFICIENT AT WAVENUMBER σ

$$C_f = \sigma \tanh\left(\frac{hc\sigma}{2k_bT}\right) C_f^o$$

FOREIGN CONTINUUM CROSS SECTION AT WAVENUMBER σ

FOREIGN CONTINUUM COEFFICIENTS: WHAT WE RETRIEVE

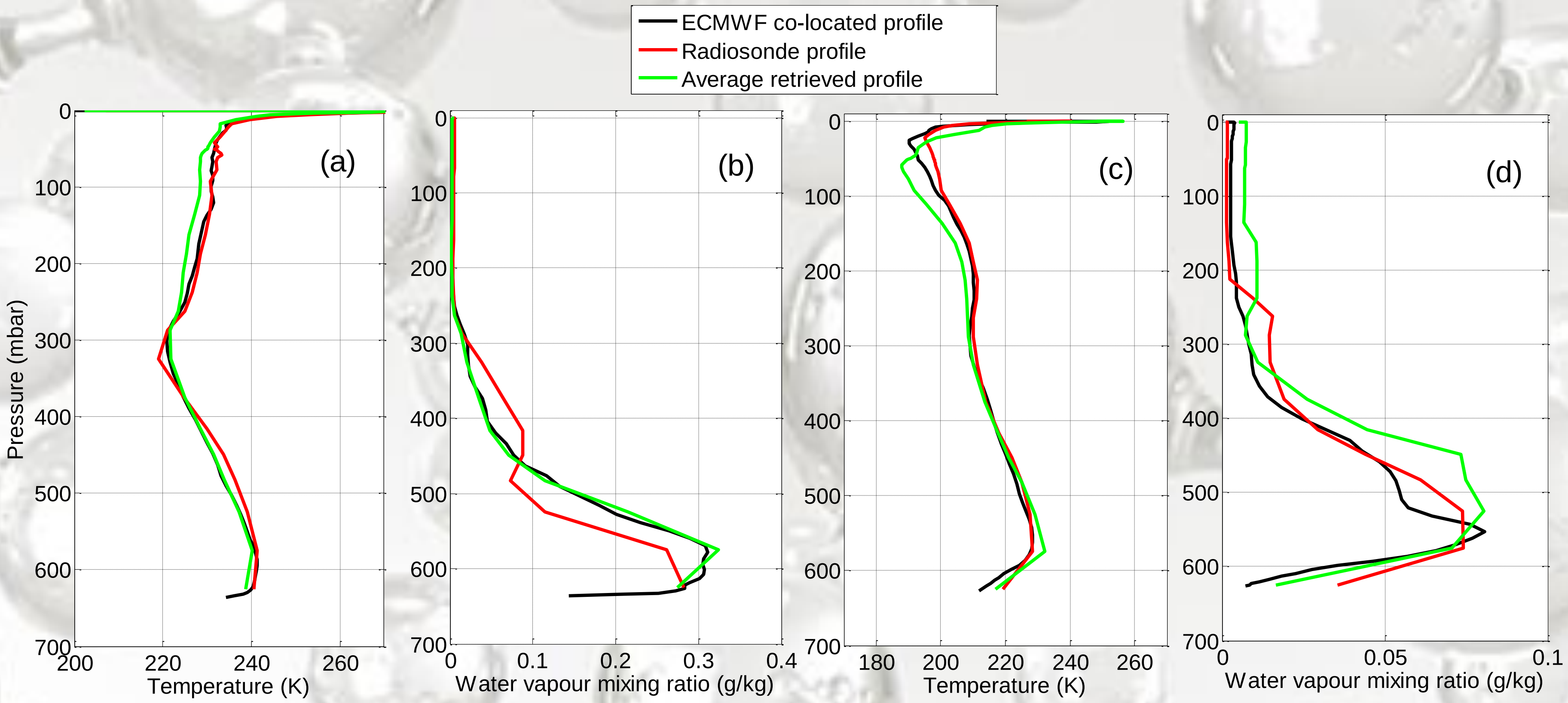
APPROACH: RODGERS' REGULARIZATION WITH AN ADDITIONAL γ REGULARIZATION PARAMETER. GAUSS NEWTON ITERATIVE SCHEME. SIMULTANEOUS RETRIEVAL OF ATMOSPHERIC STATE AND SPECTROSCOPIC PARAMETERS.

$$(\gamma \mathbf{S}_a^{-1} + \mathbf{K}^t \mathbf{S}_\varepsilon^{-1} \mathbf{K})\mathbf{x} = \mathbf{K}^t \mathbf{S}_\varepsilon^{-1} \mathbf{y} + \gamma \mathbf{S}_a^{-1} \mathbf{x}_a$$

RETRIEVAL EXERCISES

- FIRST EXERCISE: Spectrum-by-spectrum atmospheric state (T, Q_{H_2O}) retrieval. Water vapour continuum and lines are assumed to be that of LBLRTM v12.2 + MT-CKD 2.5.2.
- SECOND EXERCISE: Simultaneous retrieval of atmospheric state (T, Q_{H_2O}) and foreign continuum coefficients $\{c_i\}_{i=1,\dots,M_R}$. Water vapour lines are assumed to be that of LBLRTM v12.2, continuum first guess that of MT-CKD 2.5.2 model. Performed on both data sets (summer and winter). RESULT: REFIR-L coefficients.
- THIRD EXERCISE: Same as second, but water vapour lines are assumed to be that of HITRAN 2012. This exercise has been performed only on summer data set for brevity. RESULT: REFIR-H coefficients.

RESULTS: FIRST EXERCISE



SUMMER DATASET TEMPERATURE PROFILE

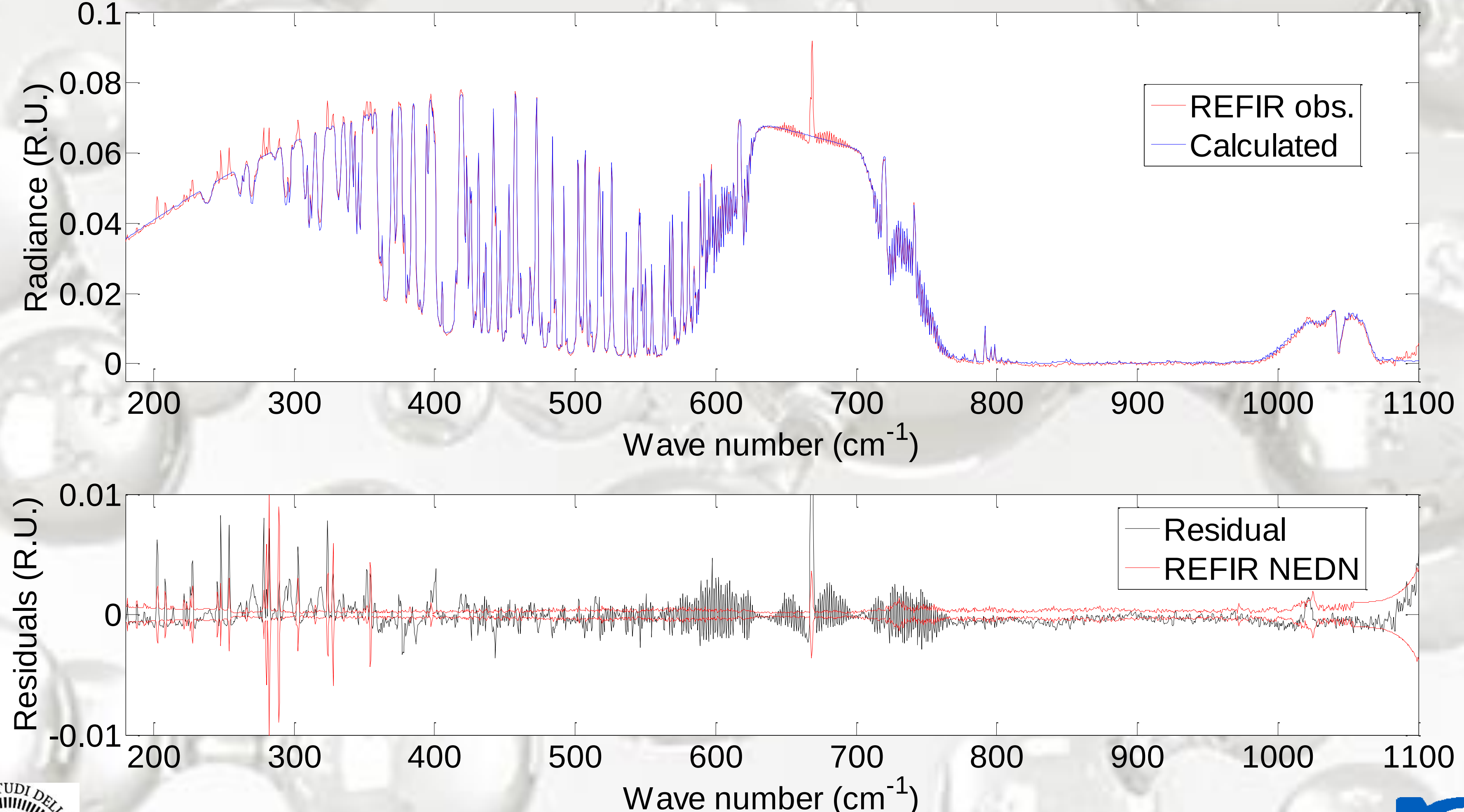
SUMMER DATASET WATER VAP. PROFILE

WINTER DATASET TEMPERATURE PROFILE

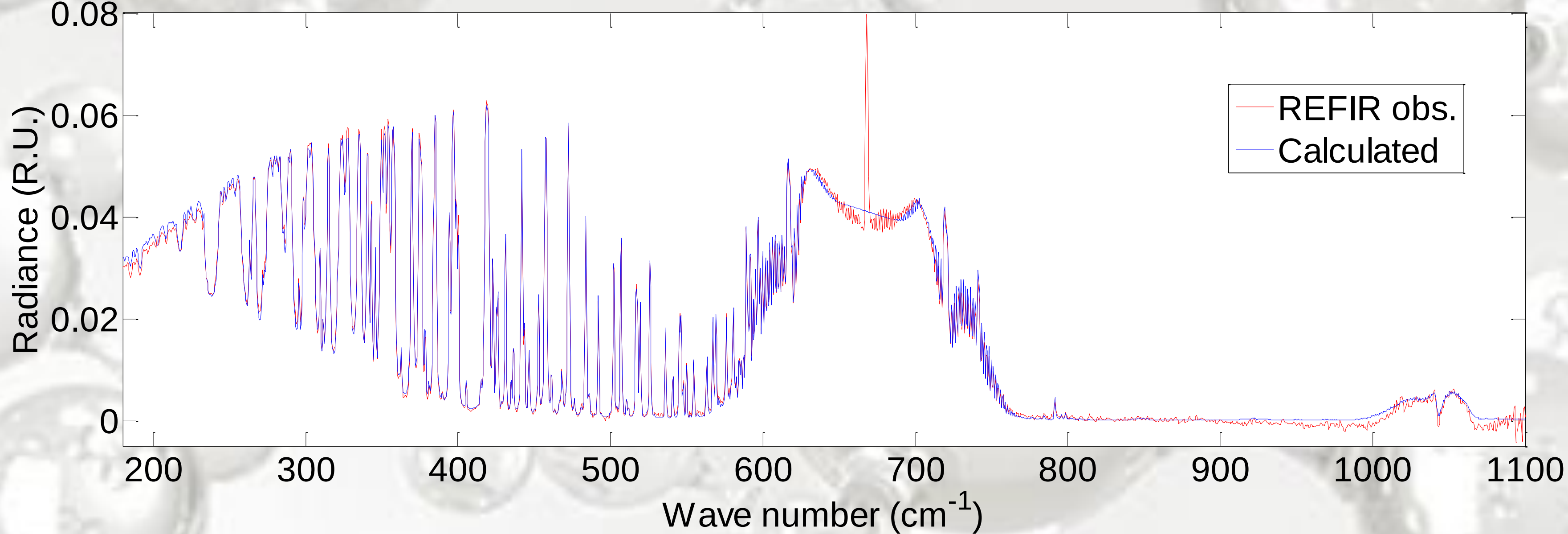
WINTER DATASET WATER VAP. PROFILE

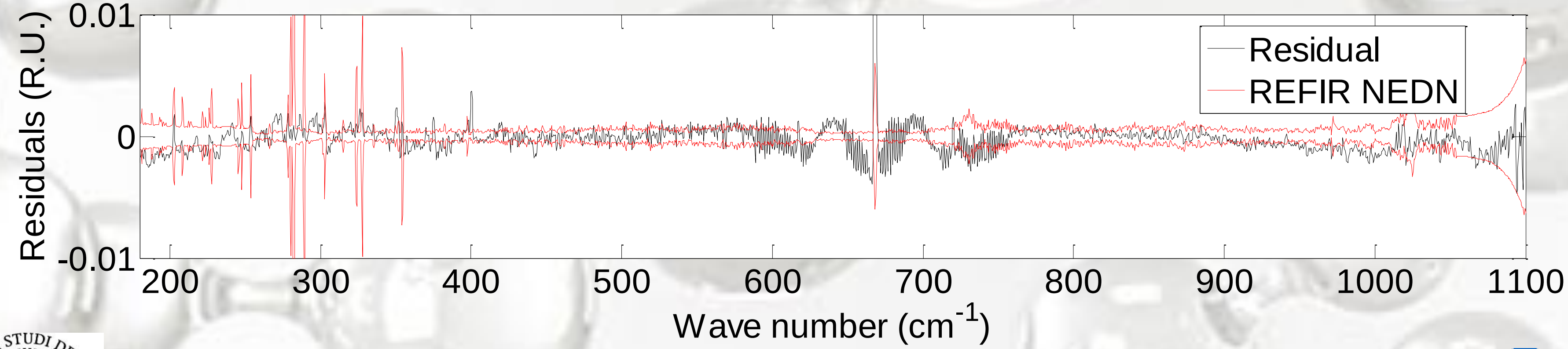
RADIOSONDE PROFILES ARE REFERRED TO 4 UTC OF EACH DAY, SO THEY ARE NOT TIMELY CO-LOCATED WITH MEASUREMENTS.

RESULTS: FIRST EXERCISE

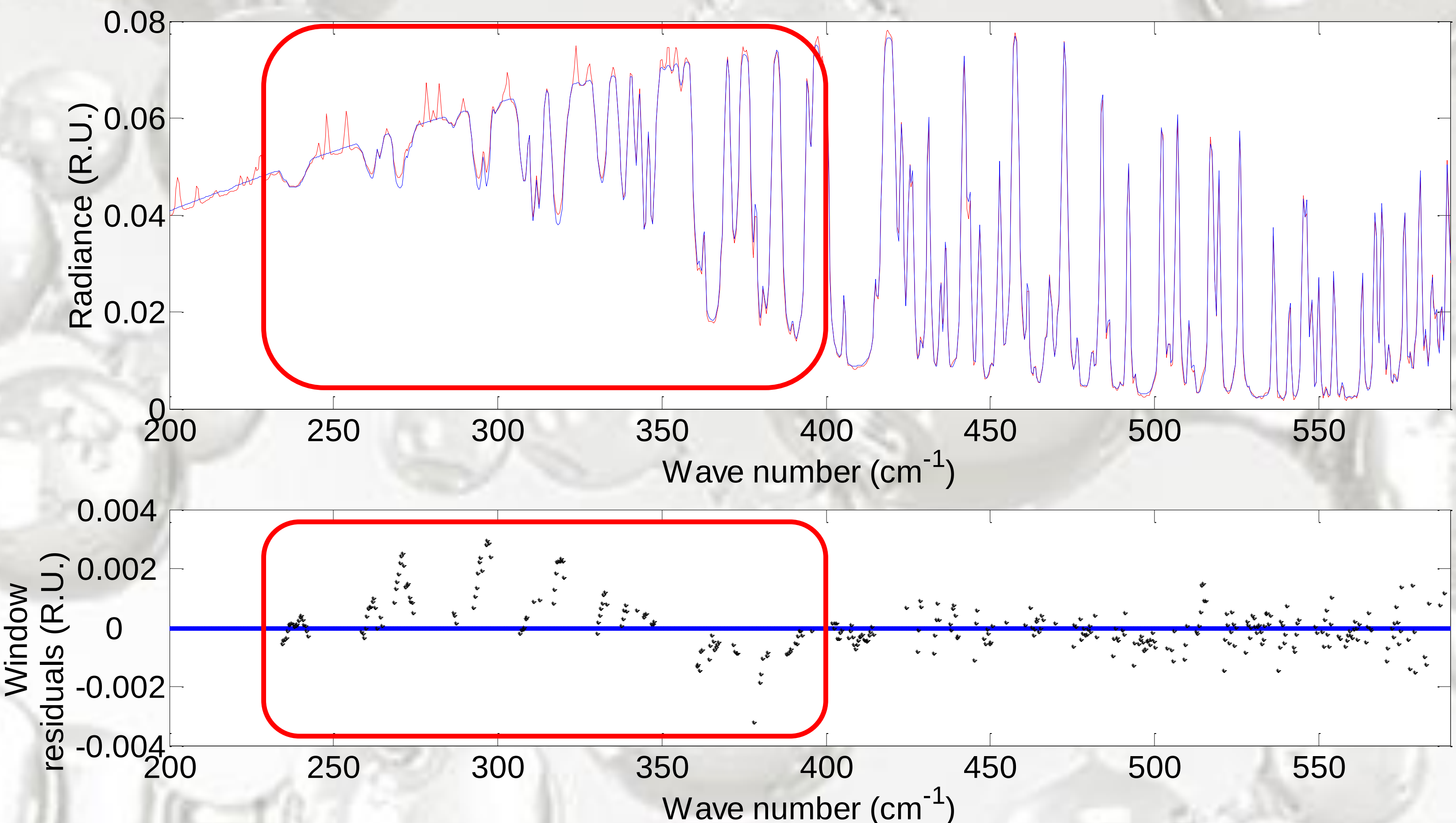


RESULTS: FIRST EXERCISE





...WHAT ABOUT WATER VAPOUR CONTINUUM?



CLEAR CONTINUUM MISFIT AT WAVENUMBERS < 350 cm^{-1}

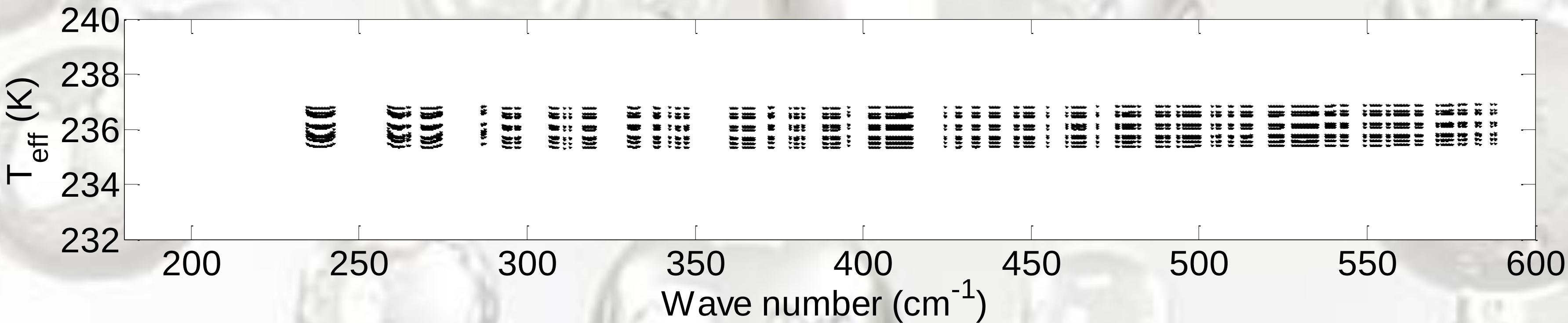
WATER VAPOUR CONTINUUM RETRIEVAL

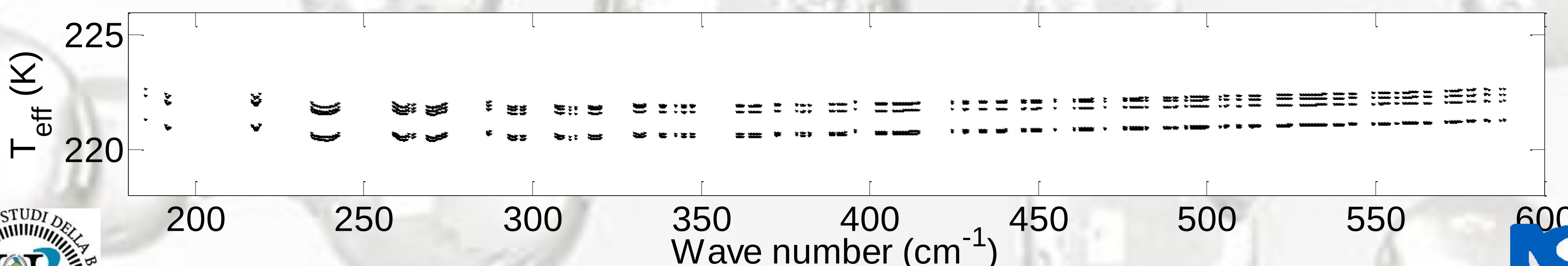
$$T_{eff}(i) = \frac{\sum_{j=1}^{N_L} |C_{ij}| T_j}{\sum_{j=1}^{N_L} |C_{ij}|}$$

EFFECTIVE CONTINUUM EMITTING TEMPERATURE AT i-th WAVENUMBER

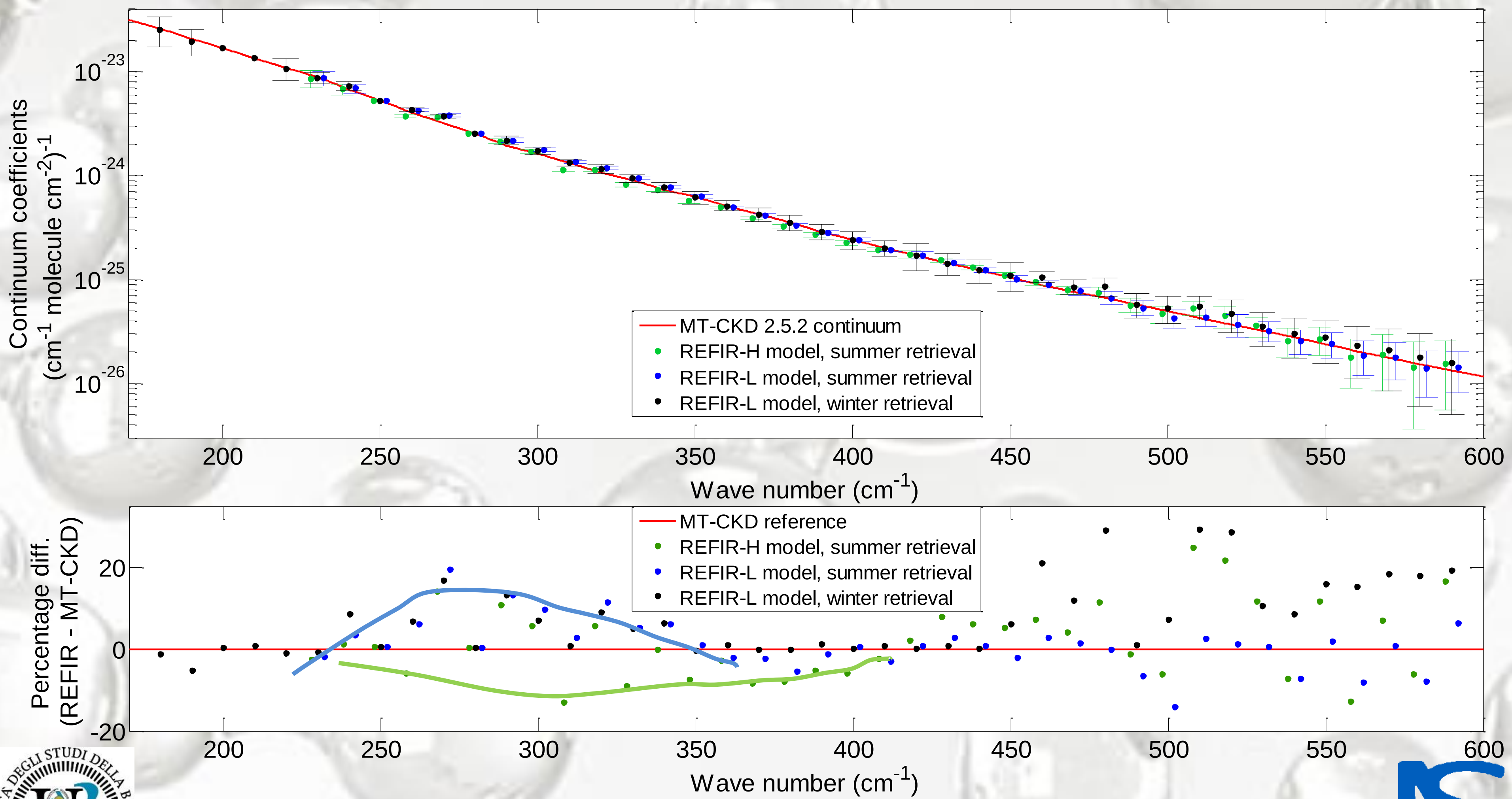
C_{ij} IS THE CONTINUUM COEFFICIENT JACOBIAN

IN ORDER TO RETRIEVE CONTINUUM COEFFICIENTS USING SIMULTANEOUS INVERSION OF SEVERAL SPECTRA, IT IS NECESSARY THAT THE SELECTED SPECTRA HAVE THE SAME EFFECTIVE EMITTING TEMPERATURE.

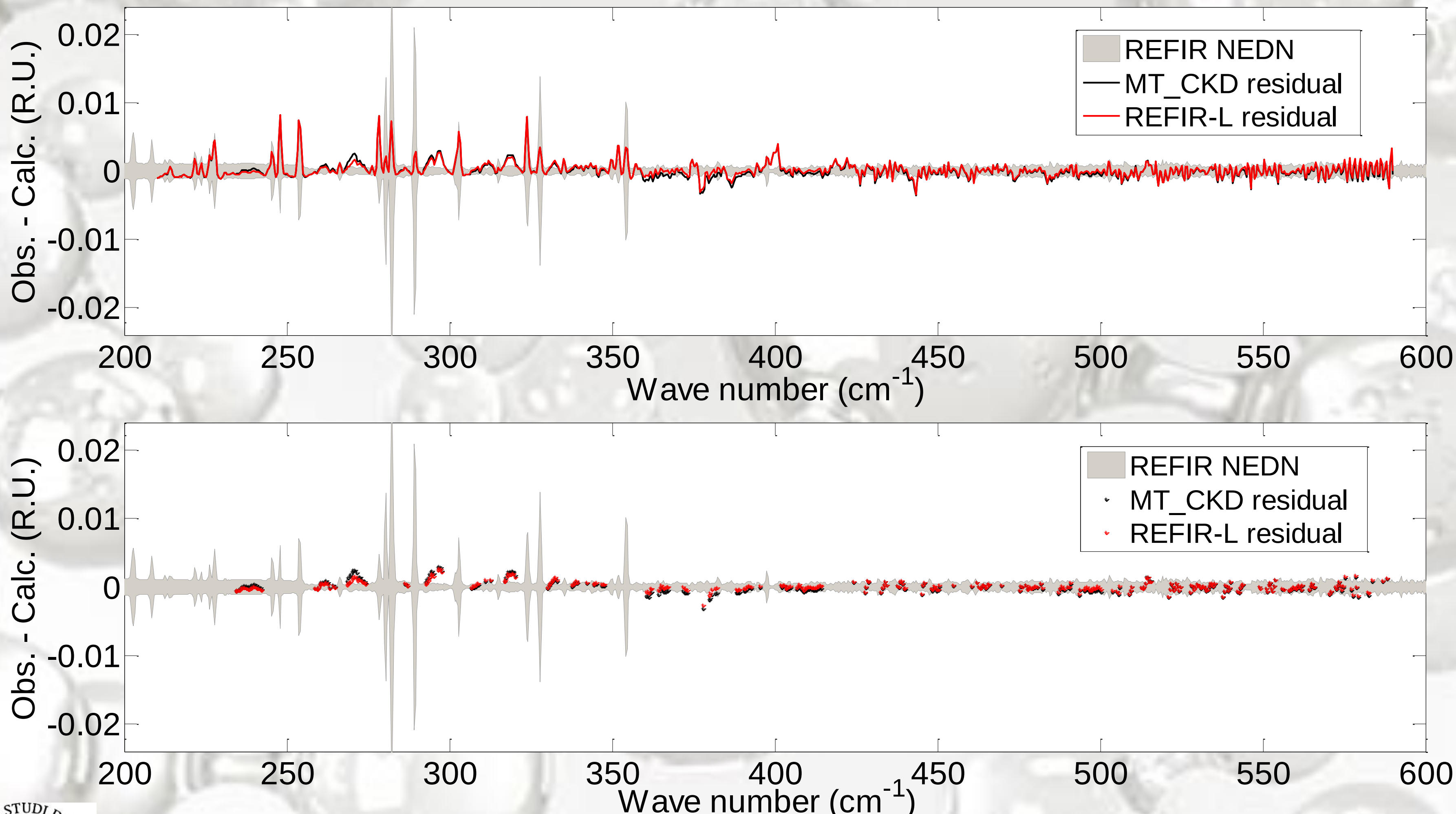




WATER VAPOUR CONTINUUM RETRIEVAL

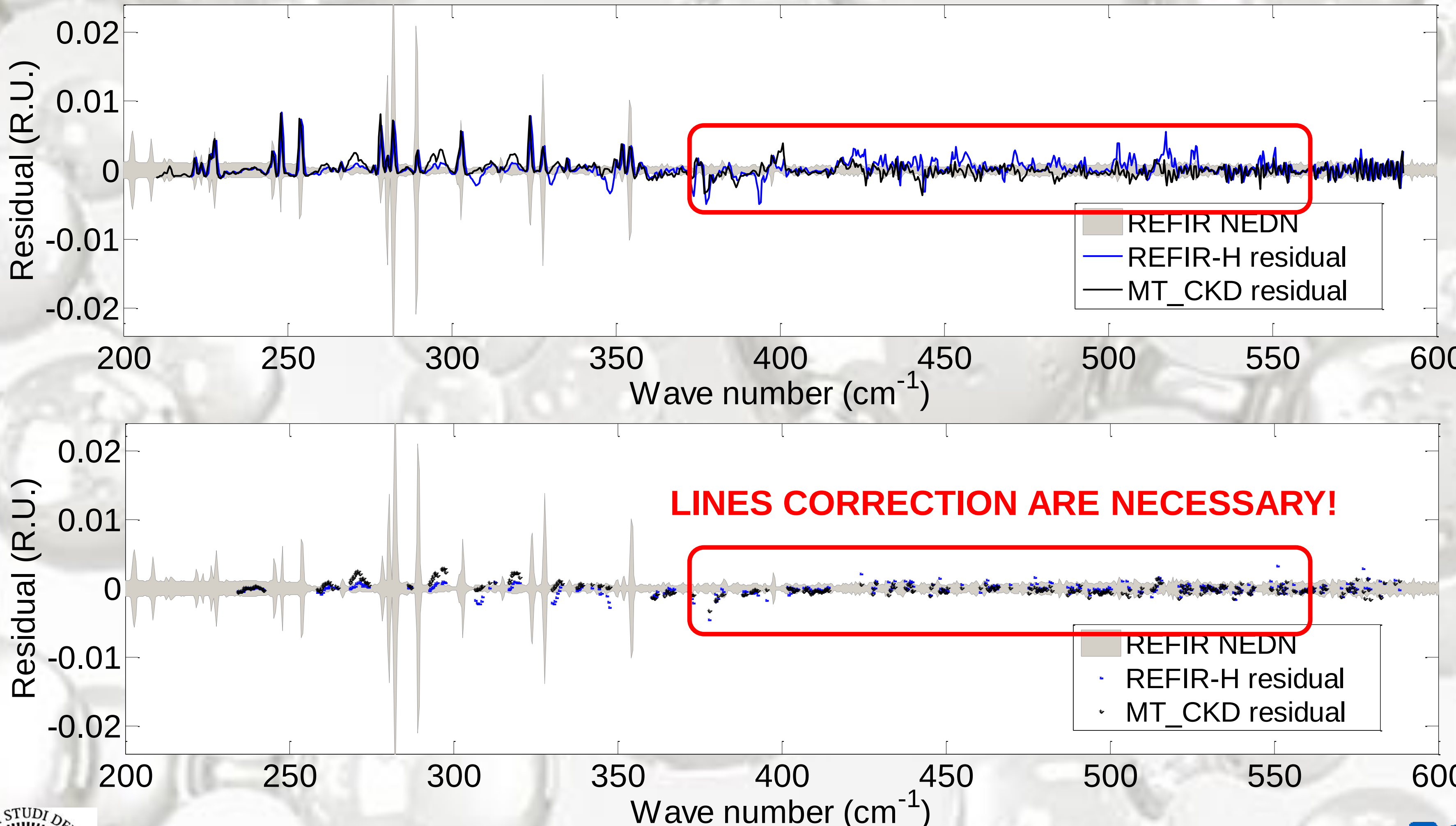


WATER VAPOUR CONTINUUM RETRIEVAL



SUMMER SPECTRA RETRIEVAL RESIDUALS USING **LBLRTM** LINE COMPILATION

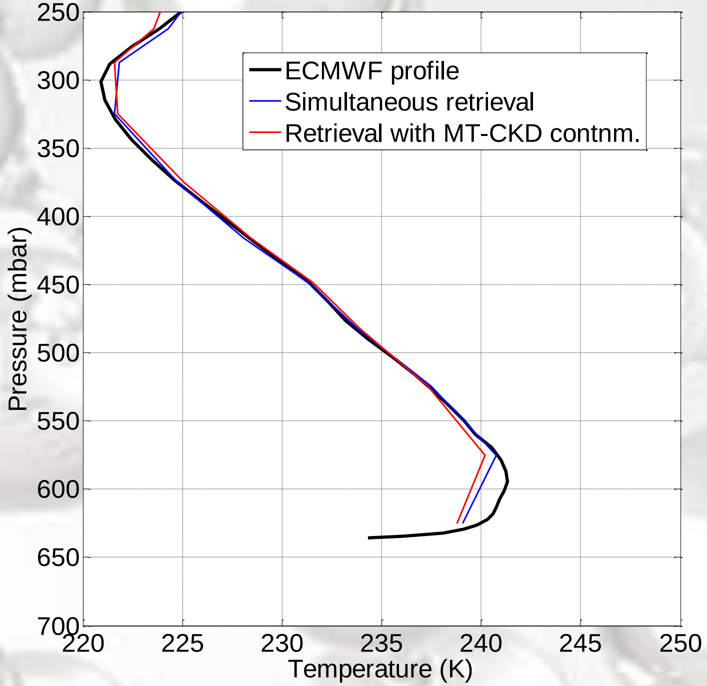
WATER VAPOUR CONTINUUM RETRIEVAL

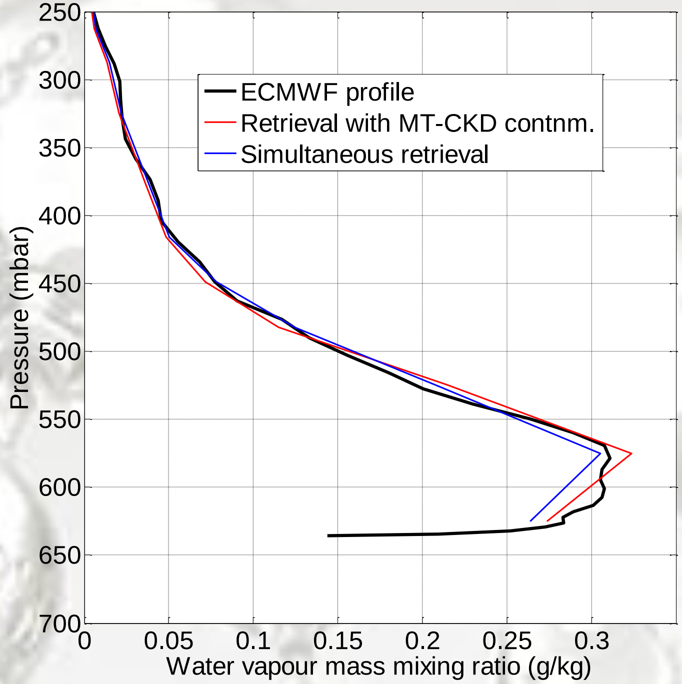


SUMMER SPECTRA RETRIEVAL RESIDUALS USING **HITRAN** LINE COMPILATION

CONTINUUM RETRIEVAL SENSITIVITY

COMPARISON BETWEEN THE ATMOSPHERIC STATE OBTAINED BY SINGLE SPECTRA AND SIMULTANEOUS RETRIEVAL, CONDITIONING THE RETRIEVAL PROCEDURE WITH ECMWF BACKGROUND.





THE NEW CONTINUUM COEFFICIENTS WE HAVE RETRIEVED SEEM TO HAVE LITTLE OR NO INFLUENCE ON THE RETRIEVED WATER VAPOUR AND TEMPERATURE PROFILES. DIFFERENCES OCCUR IN THE BOUNDARY LAYER, BUT ARE NOT DRAMATIC.

CONCLUSIONS

- The new measurements with REFIR-PAD at Dome-C site in Antarctica are very effective to validate spectroscopy of water vapour in the FIR.
- New methodology implemented to retrieve simultaneously atmospheric and spectroscopic parameters, thanks to the analytical calculation of Jacobians and the stability of the mathematical framework.
- Adjustements in the water vapour lines embedded in the latest versions of LBLRTM proved to be adequate. Such adjustement should be carried on also at frequencies lower than 350 cm^{-1}.
- Results put out the necessity to reinforce measurement campaigns in the FIR to have a satisfactory characterization of water vapour rotational band.
- With this methodology, we are able to process large amounts of data (from REFIR and not only), and to produce the continuum coefficients for HITRAN line database too.

UNIVERSITA DEGLI STUDI DELLA BASILICATA 1982

PEOPLE WHO CONTRIBUTED TO THIS WORK (DIRECTLY OR INDIRECTLY!)

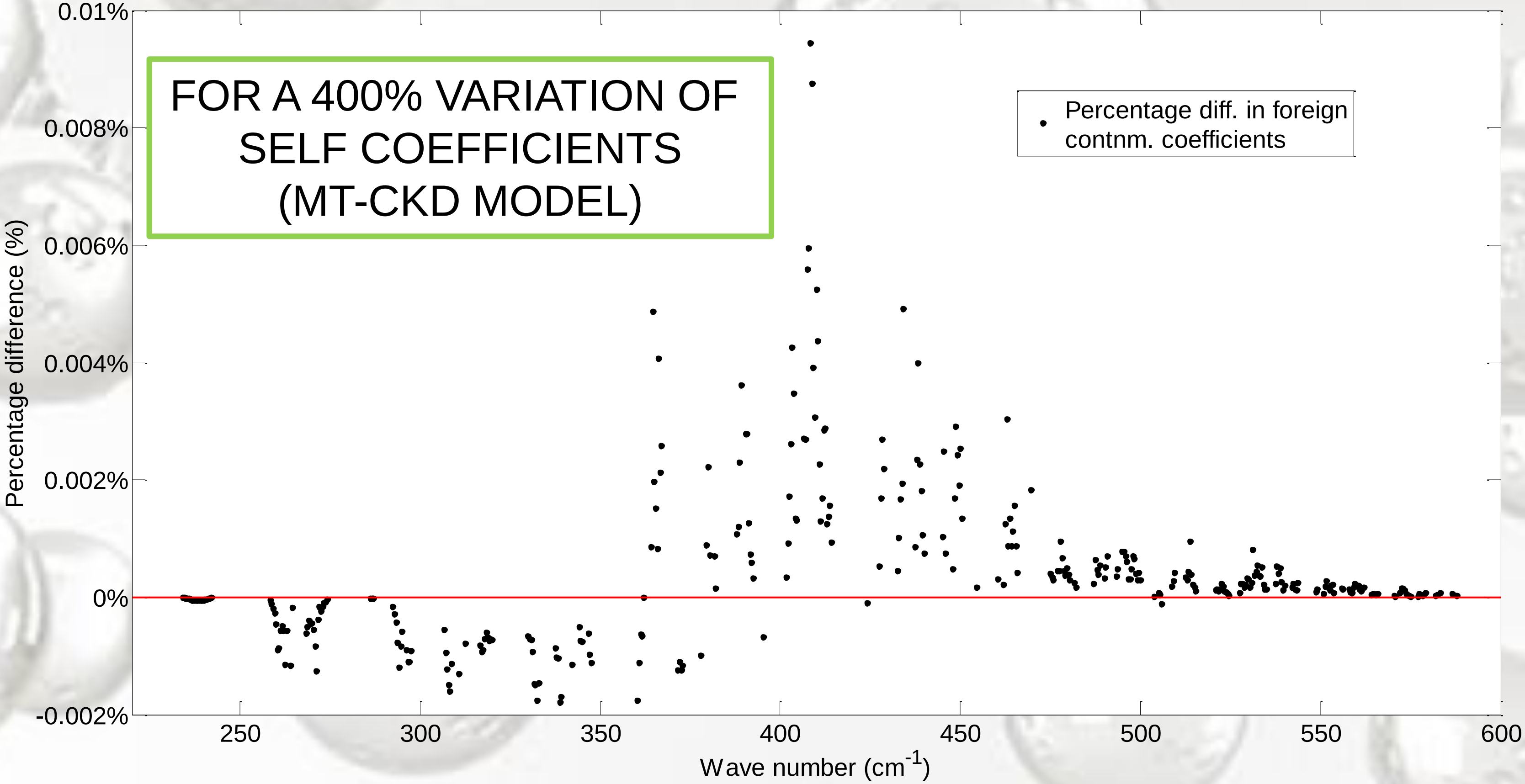
My Family (Papà, mamma, Valerio, Erika, nonna and Zorro)
My professors (Guido Masiello, Carmine Serio)
My other professors (Sergio Fonti et al.)
My three extraordinary colleagues (Piero Milillo, Sara Venafra, Maria Grazia Blasi)
The best girl all around the world (Madame Luciana Franco)
My friends of any time (Gianluca, Francesco, Simone, Paolo, Domenico et al.)
All the people who has given me a sunrise in cloudy days
All the bad people who convinced me that I do my best to be an honest person

THANK YOU VERY MUCH FOR YOUR ATTENTION

BACK UP SLIDES

SENSITIVITY TO SELF CONTINUUM VARIATION

$$\frac{\partial \mathbf{x}}{\partial \mathbf{x}_I} = \left(\gamma_{opt}\mathbf{S}_a^{-1} + \mathbf{K}^t\mathbf{S}_\varepsilon^{-1}\mathbf{K}\right)^{-1}\left(\mathbf{K}^t\mathbf{S}_\varepsilon^{-1}\mathbf{K}_I\right)$$



RETRIEVAL PROCEDURE

$$(\gamma \mathbf{S}_a^{-1} + \mathbf{K}^t \mathbf{S}_\varepsilon^{-1} \mathbf{K})\mathbf{x} = \mathbf{K}^t \mathbf{S}_\varepsilon^{-1} \mathbf{y} + \gamma \mathbf{S}_a^{-1} \mathbf{x}_a$$

$$\mathbf{v} = (T_{11}, \ldots, T_{1N_L} \ldots T_{n1}, \ldots, T_{nN_L}; Q_{11}, \ldots, Q_{1N_L} \ldots Q_{n1}, \ldots, Q_{nN_L}; c_1, \ldots, c_{M_R})^t$$

$$\mathbf{r} = (R_{11}, \ldots, R_{1M_R} \ldots R_{n1}, \ldots, R_{nM_R})^t$$

$$\mathbf{K}_T = \begin{pmatrix} \mathbf{K}_T^{(1)} & \mathbf{0} & \ldots & \mathbf{0} \\ \mathbf{0} & \mathbf{K}_T^{(2)} & \ldots & \mathbf{0} \\ \vdots & \vdots & \ldots & \vdots \\ \mathbf{0} & \mathbf{0} & \ldots & \mathbf{K}_T^{(n)} \end{pmatrix}$$

Jacobian matrices are analytically computed by σ-IASI

$$\mathbf{K} = (\mathbf{K}_T, \mathbf{K}_Q, \mathbf{K}_c)$$

$$\mathbf{J}_c = \begin{pmatrix} \sum_{j=1}^{N_L} C(1,j) & 0 & \ldots & 0 \\ 0 & \sum_{j=1}^{N_L} C(2,j) & \ldots & 0 \\ \vdots & \vdots & \ldots & \vdots \\ 0 & 0 & \ldots & \sum_{j=1}^{N_L} C(M_R,j) \end{pmatrix}$$

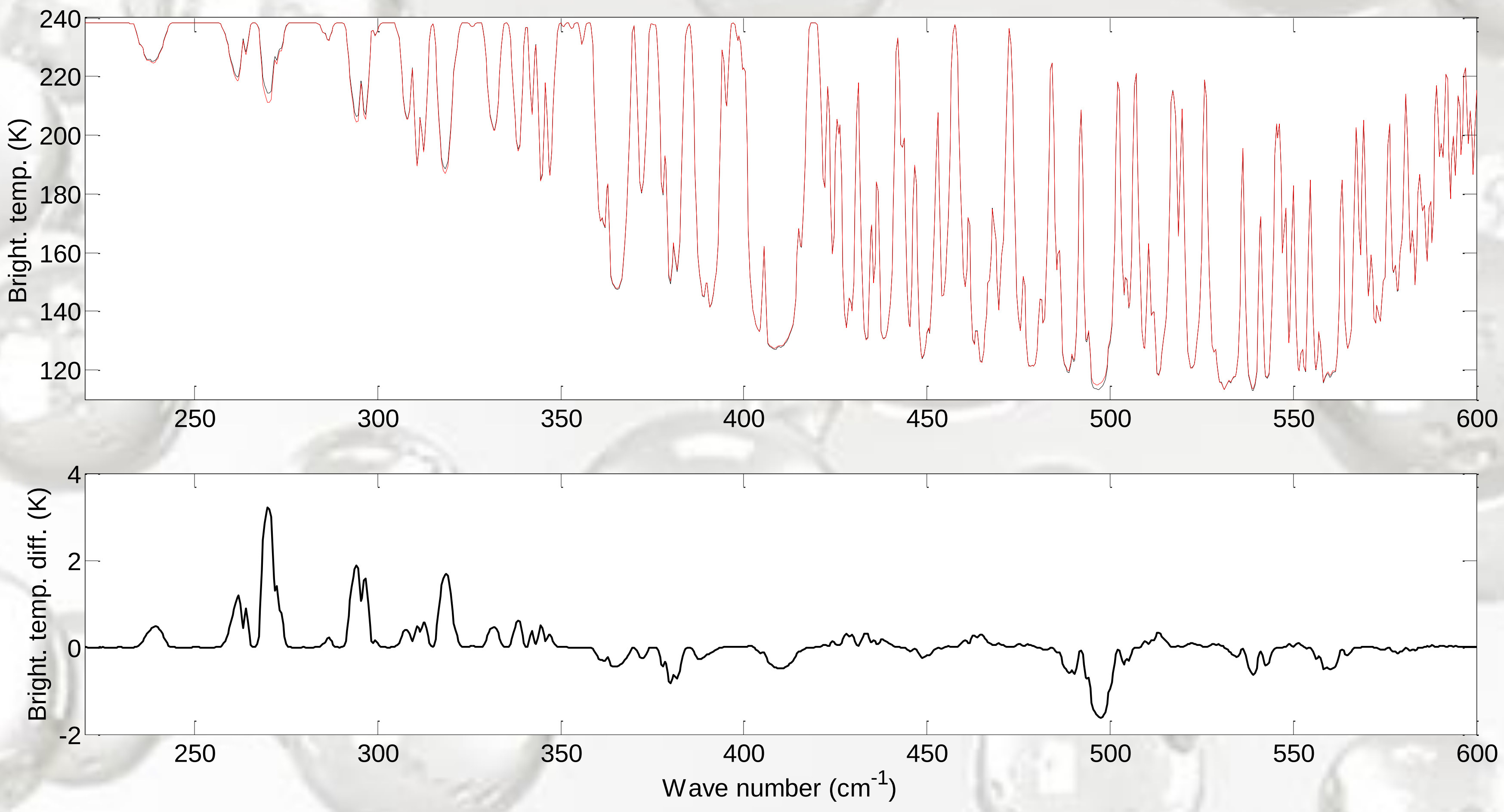
$$\mathbf{K}_c = (\mathbf{J}_c^1, \mathbf{J}_c^2, \ldots, \mathbf{J}_c^n)^t$$

The procedure is self-consistent and useful also as a data-selection tool: spectra which don’t reach convergence are marked as cloudy or influenced by ice aerosols and similar.

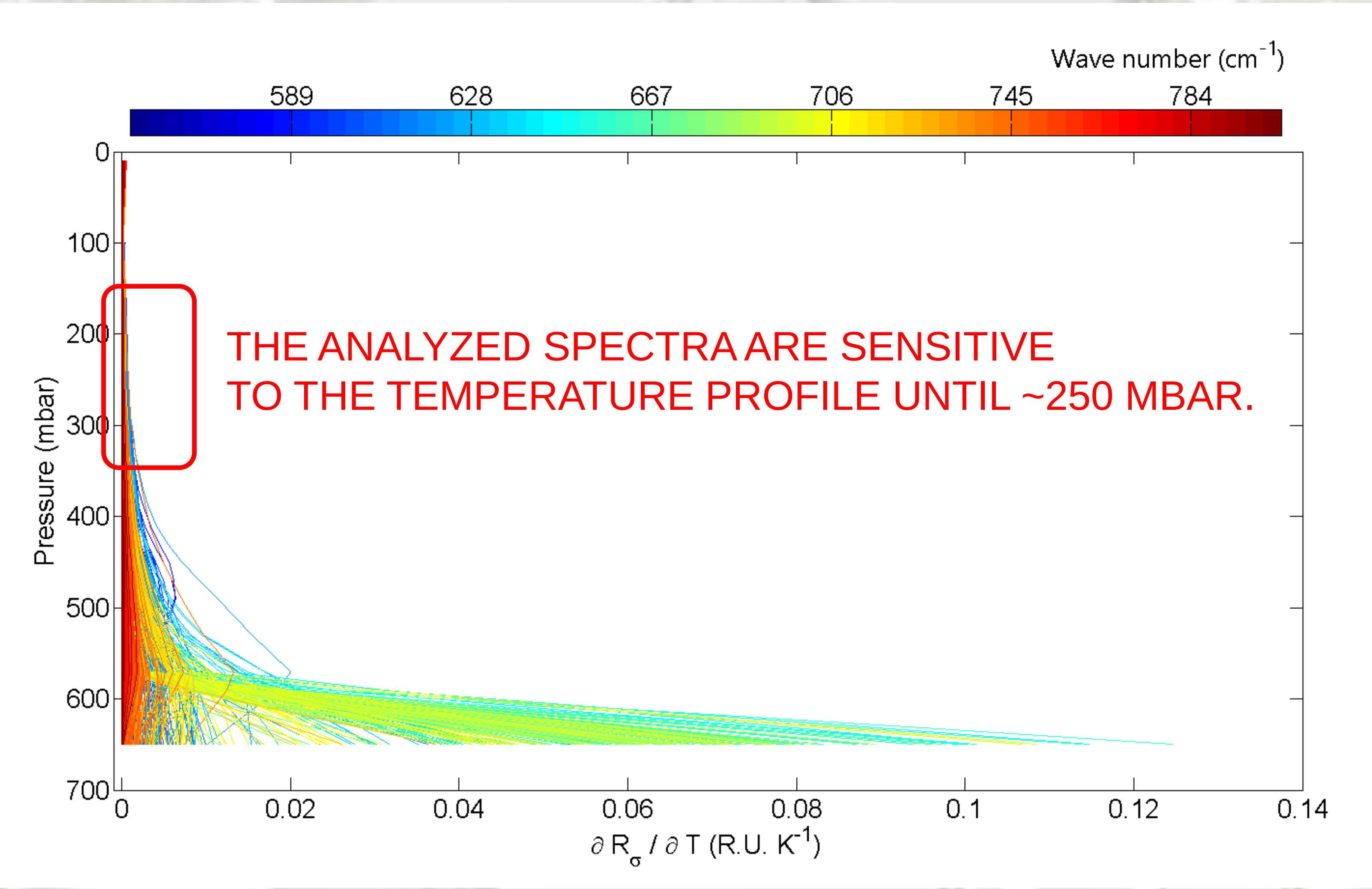
COMPARISON: MT-CKD vs. REFIR-L

RED: SYNTHETIC SPECTRUM PRODUCED USING MT-CKD CONTINUUM

BLACK: SYNTHETIC SPECTRUM PRODUCED USING REFIR-L CONTINUUM



SENSITIVITY TO THE ATMOSPHERIC STRUCTURE



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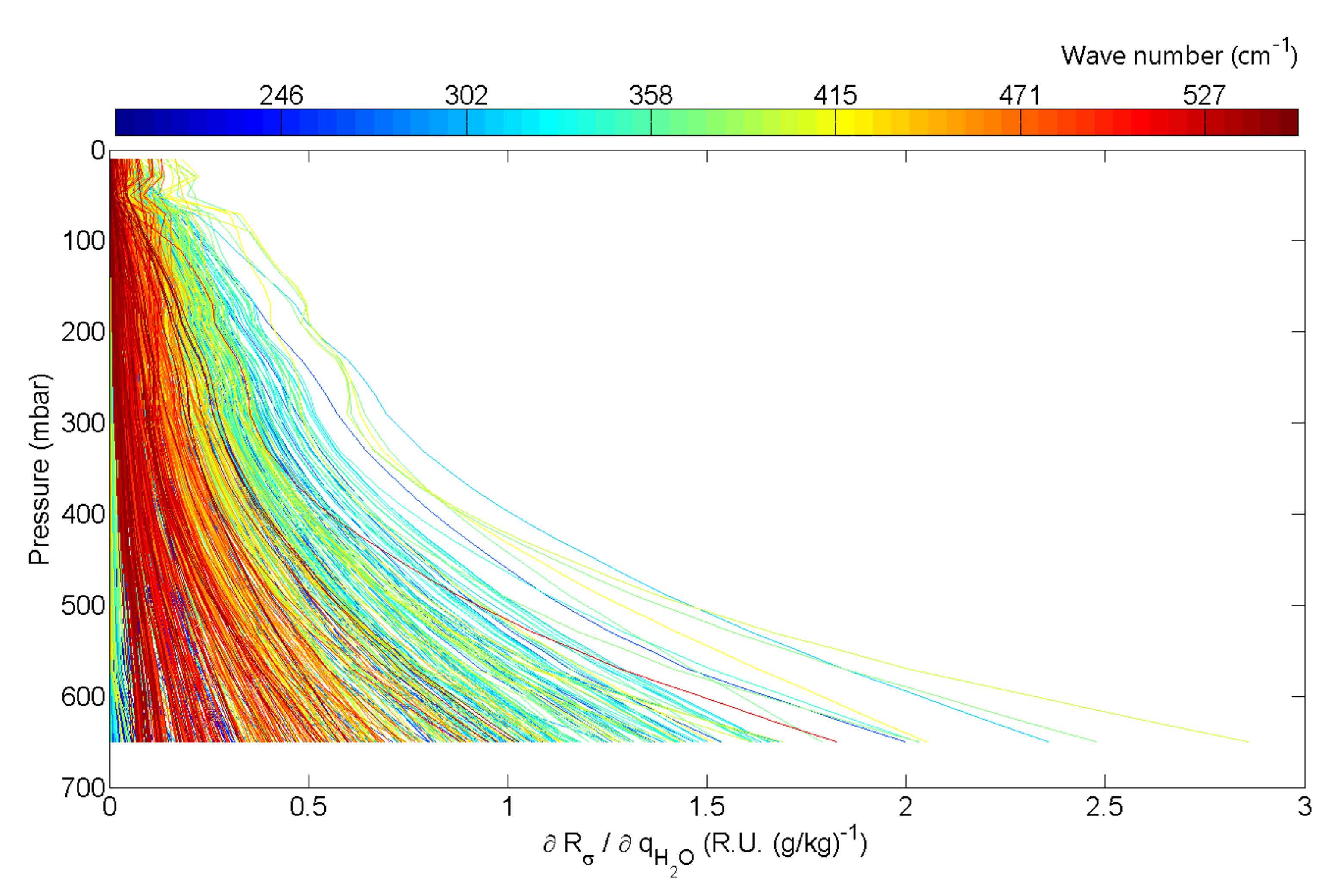
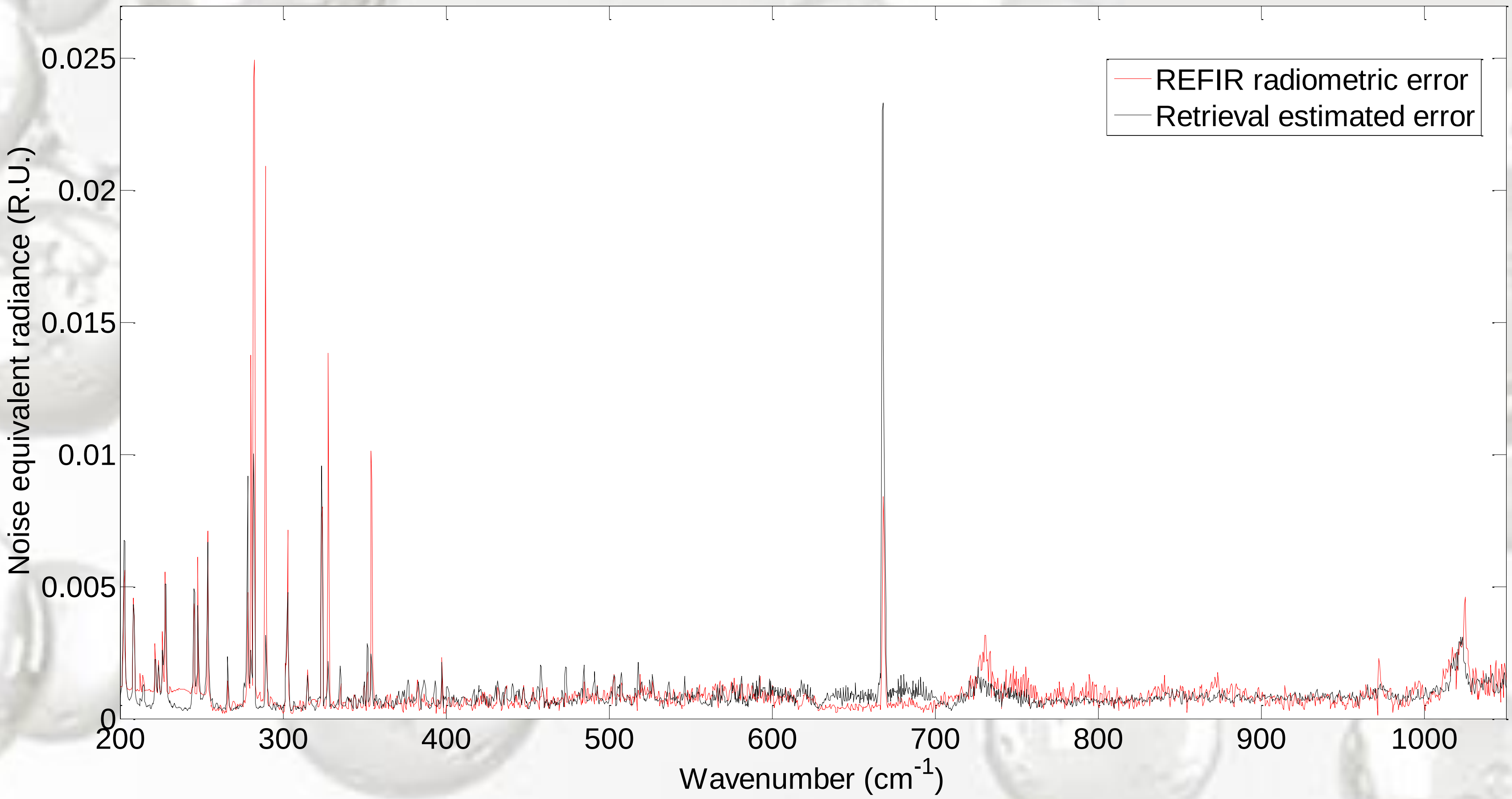


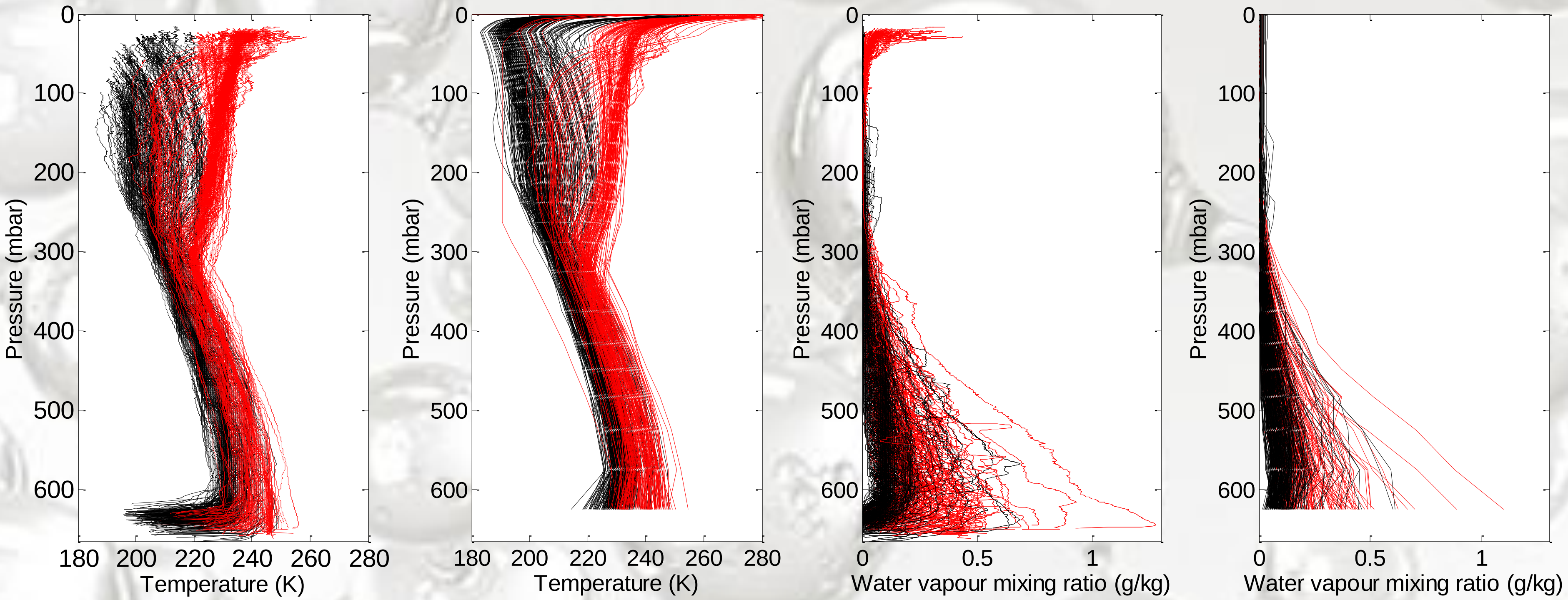
INSTRUMENTAL NOISE ESTIMATION

NOISE IS ESTIMATED AS THE STANDARD DEVIATION OF THE RESIDUALS OF THE CONVERGING SINGLE SPECTRA. SUCH ESTIMATION IS SELF-CONSISTENT WITH THE RETRIEVAL ALGORITHM, AND IT IS DIRECTLY DATA BASED.



EOF TRAINING PROFILES

The first guess used to initialize the retrieval algorithm has been obtained directly from data by mean of a statistical regression applied to data. The training set of atmospheric profiles has been built considering about 400 radiosonde profiles.



RED: SUMMER RADIOSONDE PROFILES
BLACK: WINTER RADIOSONDE PROFILES