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 …..)

• 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

• UWPHYSRET

• JAIVEX

• Retrieval Validation

• Effect of Noise Filtering

• General Consideration on Instrument Noise Covariance Matrix

• Conclusion

• Future work
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;

• Analytical Jacobians are updated at every iteration;

• Slow, flexible, accurate;

• Implemented in matlab
Solution

- Iterative solution (Gauss-Newton):

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

- \( x \) 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 (radiances);

- \( F(x) \) is the calculated observation vector (radiances);
JAIVEx

- **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 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

WB-57 Position
Retrieved Vertical Profiles
Retrieved Temperature Profile with Errorbars
Retrieval Errors
Retrieved Surface Emissivity

Surface Emissivity with Skin Temperature = 284.08 K
Retrieved Surface Emissivity: Validation with UWEMIS (from MODIS data collection 5)

![Graph showing retrieved emissivity vs. wavenumber (cm⁻¹)]

Courtesy of Eva Borbas
Retrieval Conversion: Iteration by Iteration

Observed Spectrum and Final Calculation

Radiance (RU)

wavenumber (cm$^{-1}$)

iteration Obs-Calc residuals (RU)

wavenumber (cm$^{-1}$)
Retrieval difference for Unfiltered and Filtered Data: Temperature
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
Retrieval difference for Apodized and Non-Apodized Data: Temperature
LBLRTM 10.4 - LBLRTM 11.3 (Temperature)
Retrieval off Unfiltered Data: Residuals in radiance Units

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

Unfiltered Obs - Calc

Filtered Obs - Calc

NESR
Retrieval off Unfiltered Data: Residuals in BT

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

Unfiltered Obs - Calc

Filtered Obs - Calc

- 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

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

**NEDT @ 250 K**
16 Apr 2007: Retrieved Vertical Profiles
Retrieval of 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

• UWPHYSRET was built as reference retrieval system and relies on lblrtm 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 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
Future Work

• 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-->WV-->Surf T-->Surf Emiss-->Minor Spices);

• Evaluation of the impact of different representation of a-priori information on final retrieval;
Dominant PC of the whole talk

Thank you