Potential for the use of reconstructed IASI radiances in the detection of atmospheric trace gases

Nigel Atkinson, Fiona Hilton, Sam Illingworth[1], John Eyre and Tim Hultberg[2]

Principal Component (PC) compression has the potential to achieve high data volume compression for IASI radiance data, while suppressing a large proportion of the instrument noise. However, concern has been expressed, especially in the atmospheric chemistry community, that the spectral signatures of infrequently observed trace gases may be lost. This poster shows the effects of the PC compression on the signatures of NH_3, SO_2, CH_4 and CO – using reference eigenvectors derived from several different training sets. It also describes the method used to derive the eigenvectors for the forthcoming EARS-IASI service.

1. PC basics

Take a training set of spectra y_i and form the covariance matrix (off-line):

$$\mathbf{C} = \frac{1}{n}\sum_{i=1}^{n} y_i y_i^{\mathrm{T}}$$

In practice we noise-normalise first and subtract the mean

Express the covariance in terms of eigenvectors $\mathbf{E}$ and eigenvalues $\mathbf{\Lambda}$

$$\mathbf{C} = \mathbf{E}\mathbf{\Lambda}\mathbf{E}^{\mathrm{T}} \qquad \mathbf{E}\mathbf{E}^{\mathrm{T}} = \mathbf{I}$$

In real time, any spectrum can now be analysed in terms of the "scores", p_i, for each of the reference eigenvectors:

$$p_i = \mathbf{E}^{\mathrm{T}} y_i \qquad y_i' = \mathbf{E}\, p_i$$

Scores *Reconstructed radiances*

The leading eigenvectors contain most of the atmospheric signal, so truncate after typically 150 to 300 PCs.

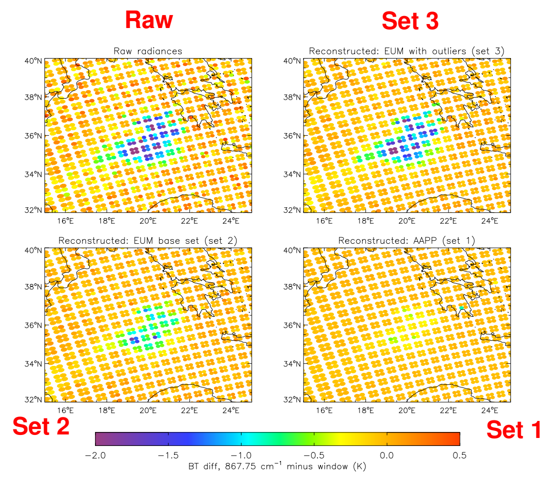
Data volume reduction is at least 8461/300 ≈ 30

Eigenvector sets examined initially:

1. 150 eigenvectors distributed with AAPP version 6.6 (Feb 2008), derived from six months thinned IASI data (15736 spectra).
2. 290 eigenvectors in 3 bands, generated by EUMETSAT from a "base set" of 74719 spectra, randomly selected from 7 days.
3. As set 2, but with 6664 "Kasatochi outliers" added.

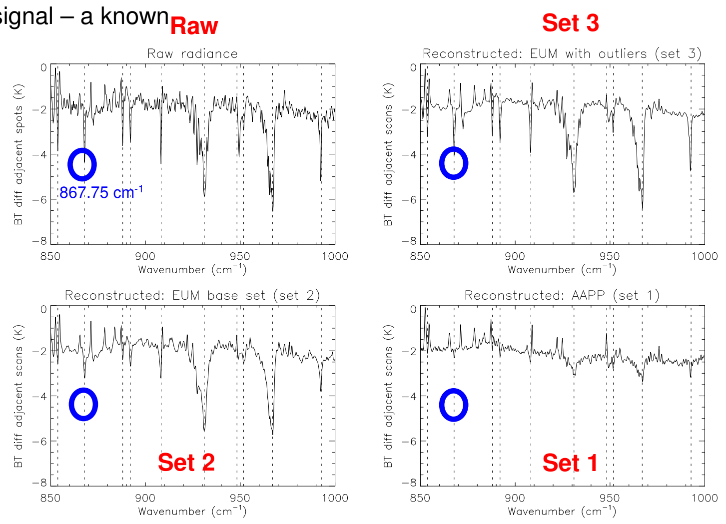
2. Ammonia signal – wildfires near Greece

- Ammonia is short-lived (hours to days), emitted from livestock, agriculture, biomass burning.
- Detect using simple differencing 867.75 cm^{-1} minus adjacent window (after Clarisse et al.).
- Set 3 reconstructed radiances perform well (compared with raw radiances). Some reduction in noise.
- Sets 1 & 2 perform very badly, underestimating the signal.



Why does Set 3 out-perform Set 2?

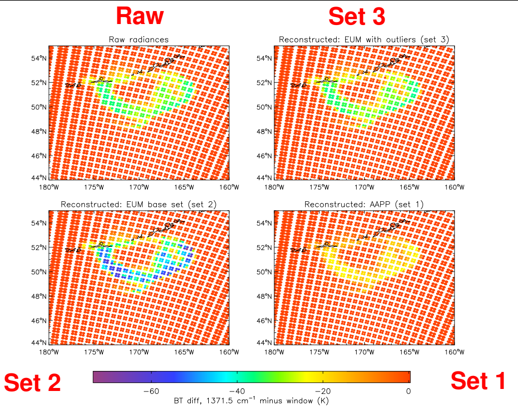
- The "outlier" dataset happens to contain a very small number of spectra over Kazakhstan with high ammonia signal – a known "hot-spot".



Difference spectra: inside plume minus outside

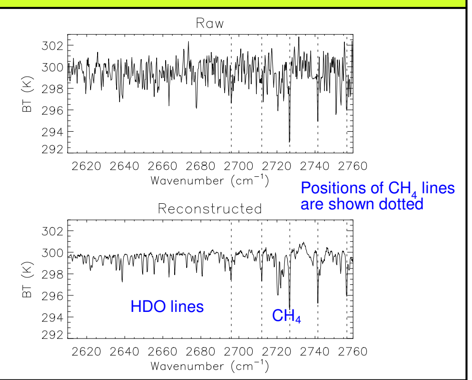
3. SO_2 signal – Kasatochi eruption

- Kasatochi eruption (off Alaska), August 2007.
- Use feature at 1371.5 cm to detect SO2. IASI band 2.
- The Set 3 reconstructed radiances are in good agreement with raw radiances. Strong SO_2 signal.
- Poorly represented in Sets 1 (under-estimate) and 2 (over-estimate)
  - ➢ No strong SO_2 features in base training sets



4. Methane in the short wave

- Methane is a greenhouse gas which has both anthropogenic and natural sources.
- Absorption bands around 1280 cm^{-1} (v_4) and 2720 cm^{-1} (v_3).
- The v_3 feature aids day-time retrievals of CH_4 but is dominated by instrument noise.
- Substantially "cleaned-up" in the reconstructed radiances.

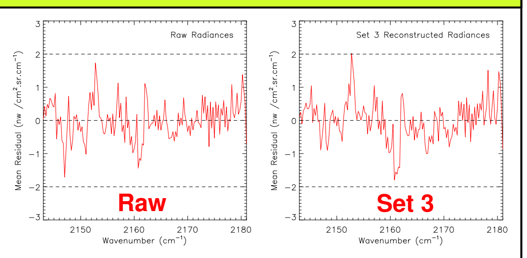


5. CO retrievals

- Retrievals performed by Univ Leicester.
- Optimal Estimation, with Oxford RFM (based on GENLN2).
- Look at elevated CO over Congo river basin.

Result:

- Very little difference in retrieved CO using raw, Set 1 and Set 3 radiances.
- Forward modelled radiances minus raw/reconstructed are within instrument noise.



Forward modelled radiance minus measured raw/reconstructed radiance. Dashed lines show IASI noise.

6. Conclusions: generating eigenvectors for operational use in EARS-IASI

- PCs can retain trace gas signals, and may even aid detection, but outliers must be specifically included in the training set spectra. Random selection is not adequate.
- For EARS-IASI the following refinements were made:
  - Systematic search for outliers in 15 months IASI data.
  - Exclude outliers associated with South Atlantic Anomaly and instrument mode transitions.
  - Training set now comprises: 74719 base spectra + 27110 outliers.
  - Noise normalisation matrix refined – using the PC-derived noise covariance instead of the CNES-supplied covariance.
- ***New eigenvectors distributed with AAPP v6.12 – expected to perform well!***

References

N. C. Atkinson, F.I. Hilton, S.M. Illingworth, J. R. Eyre and T. Hultberg: Potential for the user of IASI reconstructed radiances in the detection of atmospheric trace gases, *Atmos. Meas. Tech. Discuss.*, 3, pp. 501-529, 2010.

L. Clarisse, C. Clerbaux, F. Dentener, D. Hurtmans, and P.-F. Coheur: Global ammonia distribution derived from infrared satellite observations, Nat. Geosci., 2, 479–483, 2009

Met Office FitzRoy Road, Exeter, Devon, EX1 3PB United Kingdom
Tel: 01392 884528 Fax: 01392 885681
Email: nigel.atkinson@metoffice.gov.uk

University of Leicester[1] Department of Physics and Astronomy, LE1 7RH, UK
EUMETSAT[2] Eumetsat-Allee 1, D-64295 Darmstadt, Germany

International TOVS Study Conference, 17th, ITSC-17, Monterey, CA, 14-20 April 2010. Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center, Cooperative Institute for Meteorological Satellite Studies, 2011.