Assimilation of PC at Météo-France

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Outline

1 Introduction
2 Methodology
3 RR versus Raw radiances
4 Summary
5 Future works
The assimilation of high resolution radiances measured by infrared atmospheric sounders like AIRS or IASI has produced a significant positive impact on forecast quality (McNally et al., 2006; Collard and McNally, 2008; Guidard et al., 2011).

The operational use of infrared spectra from this sounders is limited to just few channels (for example, only 123 over 8461 IASI channels at Météo-France).

Many of these channels have very similar spectral signatures, being highly-correlated between them.

The use of Principal Component Analysis (PCA) can remove a significant fraction of the uncorrelated error present in the observations.

Additionally, the use of PCA in data dissemination would lead to a significant cost reduction as the data volume to be transferred is reduced by a factor around 80.
Basic ideas about PCA theory

- **PCA allows the reduction of the dimensionality of a problem by examining the linear relationship between all the variables contained in a multivariate dataset.**

- The original set of correlated variables is replaced by a smaller number of uncorrelated variables called principal components.

- These new variables retain most of the information contained in the original dataset.

\[ y^{obs} = A \ast x^{pcs} + \text{residuals} \]
The MF model AROME

- AROME is the limited-area convection-permitted model currently in use at Météo-France
- Geographical domain: from 8°E to 12°W in longitude, and 38°N to 52°N in latitude
- Current version runs on 60 hybrid sigma levels (model top at 1 hPa) with a mesh of 2.5 km.
- Next version, to be operational by end of March, will have 90 levels and a mesh of 1.3 km. Model top will be lowered to 10 hPa
- Potential problems could appear as many of the PC eigenvectors have some sensitivity above 10 hPa

AROME domain
Open questions on PC assimilation

1. Are reconstructed radiances (RR) from the PCs disseminated by Eumetsat comparable to the original radiances (RAW)? Is their assimilation as efficient as the assimilation of original radiance? Which ingredients of the assimilation need to be tuned to achieve a comparable assimilation (observation error covariance matrix, eg.)?

2. Can we assimilate the same PC scores in AROME with a low model top than in ARPEGE ou ECMWF/IFS? How to produce a new basis of eigenvectors which may be suitable for assimilation in "low top model" models?

3. Is there a need / benefit to produce a new basis of eigenvectors to "denoise" IASI signal for AROME?

The first point will be discussed here.
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Methodology

An algorithm to reconstruct IASI radiances from the PCs was developed at MF to be used in MF global model, ARPEGE. (Job from S. Guedj, Associate Scientist of NWP-SAF at MF) It was used in this work.

I have focused on 314-the channel dataset routinely monitored at Météo-France

Two different experiments have been run to compute the differences between the RR and Raw radiances, and their respective departures from the AROME guess-values used in the DA.

A one month window from November 8th to December 8th 2014 was chosen.

The spatial domain used correspond to the AROME domain model.

The differences between RR and RAW radiances has been computed for the following cases:

1. All observations
2. Day/night observations
3. Land/sea observations
4. Clear/cloudy observations
5. 3 different terrain elevation observation classes
Outline

1. Introduction

2. Methodology

3. RR versus Raw radiances
   - Global (RR-Raw) differences
   - Differences in particular cases
   - Differences in selected channel

4. Summary

5. Future works
A narrow differences distribution is observed for bands 1 and 2 (88.2% and 86.6% of the values between -1 and 1 K respectively).

This percentage falls to 65.4% in band 3. A higher dispersion in the differences should be expected here.
Day/Night differences. Channel statistics

Band 1

Bias (PCS-Raw) [K]

StdDev(PCS-Raw) [K]

Day obs: 230444
Night obs: 237431

IASI noise

Band 2

Bias (PCS-Raw) [K]

StdDev(PCS-Raw) [K]

Band 3

Bias (PCS-Raw) [K]

StdDev(PCS-Raw) [K]

Day
Night

Wavenumber [cm⁻¹]

645 1000 1500 2000 2500 2760
Land/Sea differences. Channel statistics

![Graph showing Land and Sea observations and bias versus wavenumber for Bands 1, 2, and 3.](image)

- **Bias (PCS-Raw) [K]**
  - Band 1: Red line (Land), Blue line (Sea)
  - Band 2: Red line (Land), Blue line (Sea)
  - Band 3: Red line (Land), Blue line (Sea)

- **StdDev(PCS-Raw) [K]**
  - Band 1: Red line (Land), Blue line (Sea)
  - Band 2: Red line (Land), Blue line (Sea)
  - Band 3: Red line (Land), Blue line (Sea)

- **Observations**
  - Land: 279059
  - Sea: 180585

IASI noise

PCs assimilation
Clear/Cloudy skies differences. Channel statistics

### Channel Statistics

<table>
<thead>
<tr>
<th>Wavenumber [cm⁻¹]</th>
<th>StdDev(PCS-Raw) [K]</th>
</tr>
</thead>
<tbody>
<tr>
<td>645</td>
<td>Clear obs: 70804</td>
</tr>
<tr>
<td>1000</td>
<td>Cloudy obs: 220670</td>
</tr>
</tbody>
</table>

**Average(PCS-Raw) [K]**

**Band 1**

**Band 2**

**Band 3**

**IASI noise**

**Clear**

**Cloudy**

-1.0
-0.5
0.0
0.5
1.0

Wavenumber [cm⁻¹]
Elevation differences. Channel statistics

- Band 1:
  - 0.0-0.5 km: 378731
  - 0.5-1.5 km: 77238
  - 1.5-3.0 km: 12000

- Band 2:
  - 0.0
  - 0.5
  - 1.0
  - 1.5
  - 2.0

- Band 3:
  - 0.0
  - 0.5
  - 1.0
  - 1.5
  - 2.0

Bias (PCS-Raw) [K]

- Band 1
- Band 2
- Band 3

Standard Deviation (PCS-Raw) [K]

- Band 1
- Band 2
- Band 3

IASI noise

- 0.0-0.5 km
- 0.5-1.5 km
- 1.5-3.0 km

Bias (PCS-Raw) [K]

- Band 1
- Band 2
- Band 3

PCs assimilation
Differences in channel 226

- Temperature channel
- 91.2% of the difference in the range $[-1, 1]$
- Difference magnitude proportional of Latitude
Differences in channel 1191

- Window channel
- 85.5% of the difference in the range \([-1, 1]\)
- Difference magnitude proportional of Latitude

Band 1. Channel 1191

Normalized weighting function \(\frac{\partial \text{Trans}}{\partial \ln(P)}\)

Pressure (hPa)

Frequency

\(\Delta T(\text{PCS - Raw}) [\text{K}]\)

RR rads

Raw rads

Differences

PCs assimilation
Differences in channel 3002

Water vapour channel

86.7% of the difference in the range [−1, 1]

PCs assimilation

Band 2. Channel 3002
Differences in channel 6350

- Channel in band 3. Currently not used
- 56.2% of the difference in the range $[-1, 1]$
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Summary and conclusions I

1. Global differences
   - Well behaviour in Bias for band 1 and 2.
   - Possible problem in Bias for band 3. Need to check the origin of this peaks.
   - RR Algorithm?
   - The stddev spectra presents a similar structure to that of IASI spectrum. Is there a dependency of the differences with IASI radiance temperature?

2. Differences in particular cases
   2.1 Day/Night observations
      - RR have a slightly better behaviour during the day than during the night.
      - We still have the problem of Bias in band 3.
   2.2 Land/Sea observations
      - Inverse behaviour of differences in band 1
      - Similar behaviour of differences in band 2
      - Problem of Bias in band 3.
   2.3 Clear/Cloudy observations
      - Inverse behaviour of differences in band 1 and 2
      - STdDev significantly lower in for clear observations.
   2.4 Elevation differences
      - the Bias behaviour of low terrain elevation layer is inverted and become more and more positive according to the orography
Summary and conclusions II

3. Channel differences

3.1 Band 1. Channel 0226
- Temperature channel.
- Most of the differences fall into the -1,1 range (91.1%)
- Differences increase with latitude

3.2 Band 1. Channel 1191
- Window channel.
- Most of the differences fall into the -1,1 range (85.5.1%)
- Negative differences in the Mediterranean sea
- Positive differences in the Alps cause by the orography

3.3 Band 2. Channel 3002
- Water vapour channel.
- Most of the differences fall into the -1,1 range (86.7%)
- No spatial dependencies of the differences
- Positive differences in the Alps cause by the orography. Channel sensitivity close to the sea level

3.4 Band 3. Channel 6250
- Band 3 channel. Not currently used at Météo-France
- Reduced percentage of differences into the ] – 1, 1] range: 56.7%
- No spatial dependencies of the differences
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Future works

- Verify Band 3 reconstruction

- Check performance of RR in a 1D-Var DA system, profiting the IASI-NG OSSE profiles database, (tuning of error covariance matrix, channel selection...)

- Assimilation of RR radiances rom EUMETSAT PCs in AROME for the current time window

- Assimilation of ECMWF PCs in AROME at a longer term
Thank you for your attention