Measuring volcanic ash and windblown sand with IASI

Lieven Clarisse
P.-F. Coheur, J. Hadji-Lazaro and C. Clerbaux
Lookup table approach

1. Database of forward simulations
2. Least mean square retrieval
3. Optical depth masses, radius and altitude

Validation by
Laboratory of Atmospheric Physics
Aristotle University of Thessaloniki

Balis et al., ACPD 2015
Size distributions

Big grains go far: understanding the discrepancy between tephrochronology and satellite infrared measurements of volcanic ash

J. A. Stevenson, S. C. Millington, F. M. Beckett, G. T. Swindles, and T. Thordarson

Exploiting hyperspectral sounders for volcanic ash remote sensing

Luke Western, Matthew Watson, and Peter Francis

Clouds

Ash and ice clouds during the Mt. Kelud Feb 2014 eruption as interpreted from IASI and AVHRR/3 observations

Arve Kylling

A model sensitivity study of the impact of clouds on satellite detection and retrieval of volcanic ash

A. Kylling, N. Kristiansen, A. Stohl, R. Buras-Schnell, C. Emde, and J. Gasteiger
ULB neural network dust product
Inverse modelling in remote sensing

\[ Y = \min_z G(F(x_z), \text{auxiliary parameters}) \]

- Approximate any function to arbitrary accuracy
- Large input parameters space (100 + input parameters = no problem)
- Excellent interpolation capabilities
Training data

\[ F(x, y) = x \times y \]
\[ F(x, y) = x * y \]

Free interpolation!!
Training data (input, output pair) should be

- **Accurate** (in vs output)
- **Comprehensive** (input)
- **Representative** (input)
Reconstructing the spectrum

\[ \|OBS - CALC\|_{\text{ANY STRANGE NORM}} + \text{APRIORI} \]

Single channel selection

\[ \|OBS - CALC\| + \text{apriori} \]

\[ \|OBS - CALC\| \]
### Example of imperfect forward model input

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Measurements of aerosols</strong></td>
</tr>
<tr>
<td><strong>Dust from precipitation (x, Germany and y, Bedford, Massachusetts)</strong></td>
</tr>
<tr>
<td><strong>Dust (Meppen, Germany and Bedford, Massachusetts)</strong></td>
</tr>
<tr>
<td><strong>Saharan dust Niamey, Niger</strong></td>
</tr>
<tr>
<td><strong>Saharan sand Barbados, West Indies</strong></td>
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<tr>
<td><strong>Saharan sand Cape Verde, dry and 50% relative humidity</strong></td>
</tr>
<tr>
<td><strong>Afghanistan, Tadzhikistan sand</strong></td>
</tr>
<tr>
<td><strong>Negev, Israel clean and dust storm</strong></td>
</tr>
<tr>
<td><strong>Dust in Southwester United States, Texas</strong></td>
</tr>
<tr>
<td><strong>Niger, Algeria, Tunisia and the Gobi desert</strong></td>
</tr>
<tr>
<td><strong>Compilations &amp; Mixtures</strong></td>
</tr>
<tr>
<td><strong>Almeida mineral compilation, mainly Volz dust</strong></td>
</tr>
<tr>
<td><strong>Mixture of hematite and quartz. Hematite is 10% by volume. O and E ray.</strong></td>
</tr>
<tr>
<td><strong>Composite clay (1/3 by weight of Montmorillonite, Illite and Kaolinite)</strong></td>
</tr>
<tr>
<td><strong>Composite of Hematite, Illite, Montmorillonite, Quartz, Kaolinite and Calcite</strong></td>
</tr>
</tbody>
</table>

**Volz 1973 – transported dust - clear winner**
Example of imperfect forward model input

Emissivity in the 800 – 1200 cm range

Land: Zhou et al., 2011; Ocean: Nalli et al., 2008
Example of imperfect forward model input

Land: Zhou et al., 2011; Ocean: Nalli et al., 2008
Reconstructing the average dust signature

- Brightness temperature difference
- Singular value decomposition
- Principle component analysis
- Linear discrimination analysis index

= minimizing forward model errors
Definition of dust index

This weighted projection unifies:

1. Linear discrimination analysis (LDA): $R = (\mu_k - \mu_l)^T S^{-1}(y)$
2. Weighted least squares: $(k)^T S^{-1}(y)$ (Walker et al., 2010)
3. PCA detection, uses different projection weights (Hurley et al., 2009)

$$R(y) = \frac{k^T S^{-1}(y - \mu_c)}{\sqrt{k^T S^{-1}k}}$$

No Forward model used

Emissivity Correction
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<table>
<thead>
<tr>
<th>INPUT DATA</th>
<th></th>
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<tbody>
<tr>
<td><strong>Auxiliary data</strong></td>
<td>Dust height</td>
</tr>
<tr>
<td></td>
<td>Viewing angle</td>
</tr>
<tr>
<td></td>
<td>Temperature profile</td>
</tr>
<tr>
<td></td>
<td>Pressure profiles</td>
</tr>
<tr>
<td></td>
<td>Humidity profile</td>
</tr>
<tr>
<td></td>
<td>Emissivity</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OUTPUT DATA</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Radiance data</strong></td>
<td>Dust index + couple of channels</td>
</tr>
<tr>
<td>Optical depth</td>
<td>At 10 μm</td>
</tr>
</tbody>
</table>

**Diagram:**
- **Input:** 34 channels
- **Hidden:** 15 channels
- **Output:** 1 channel

**Map:** World distribution of optical depth at 10 μm.
“Natural” plume edges
Good ocean/land continuity during daytime.

Not as good during nighttime!
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IASI dust AOD at 550 nm
Note: Very robust (dust where dust should be and no dust where no dust expected)
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**January**

IASI dust AOD at 10 μm

MACC ECMWF dust AOD at 550 nm

**February**

IASI dust AOD at 10 μm

MACC ECMWF dust AOD at 550 nm
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March

IASI dust AOD at 10 µm

MACC ECMWF dust AOD at 550 nm

April

IASI dust AOD at 10 µm

MACC ECMWF dust AOD at 550 nm
AOD Aeronet SDA 20 vs IASI ULB dust. Location: Tamanrasset_INM, Lon: 5.53, Lat: 22.79

All: 0.91, Dust: 0.87
AOD Aeronet SDA 20 vs IASI ULB dust. Location: Lagune, Lon: -16.32, Lat: 28.48

All: 0.88, Dust: 0.94
AOD Aeronet SDA 20 vs IASI ULB dust. Location: Ragged Point, Lon: -59.43, Lat: 13.17

All: 0.74, Dust: 0.71

Aeronet coarse mode AOD vs IASI AOD_10000 * 2
AOD Aeronet L2 vs IASI ULB dust. Location: Osaka, Lon: 135.59, Lat: 34.65

Aeronet coarse mode AOD vs IASI AOD_10000 * 2

All: 0.64, Dust: 0.88
Summary correlation coefficients: AERONET vs IASI
Round up

Theoretical advantages
- Fast
- Full spectral range (highly sensitive)
- Low dependency on the forward model (RI, emissivity, etc, ....)
- Full atmospheric state
- Full uncertainty analysis (propagation of input parameters)

Current limitations
- No retrieval of altitude
- Cloud free conditions

First evaluations
- Correlations with AERONET > ~0.8
- Comparison with model ‘satisfactory’ (qualitatively)
- Continuity: Land/Ocean – AM/PM
1. Introduction

A flexible and robust IASI-NH3 retrieval algorithm

S. Wielinga, M. Van Damme, L. Clarisse, C. Hanil, C. Ceranek, D. Hartmans, & P.F. Collett

October 26, 2015
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