Two-Dimensional Sensitivity analysis of MIPAS observations

Massimo Carlotti, Luca Magnani
Dip. Chimica Fisica e Inorganica, Univ. of Bologna

carlotti@fci.unibo.it
MIPAS features:

- measures the atmospheric emission from a polar orbit,

- exploits the limb-scanning observation technique,

- the line of sight is oriented along the orbit track backward looking,

- limb-scans are continuously repeated along the orbit.

On these features is based the 2D retrieval analysis
2D discretization of the atmosphere
1 km layers
0.25 deg radii
1 km layers
0.25 deg radii
1 km layers
0.25 deg radii
1 km layers
0.25 deg radii
1 km layers
0.25 deg radii
Multiplicity for orbit 2081 (July 24, 2002)

atm. x 10

Multiplicty

0 45 315
90 135 270
180

[N]

[S]
Multiplicity for orbit 2081 (July 24, 2002)
Horizontal Sensitivity Functions

\[ \Phi(x, \nu, \vartheta) = \left[ \frac{\partial S(x, \nu)}{\partial q_\vartheta} \right] \]

\( S \) : signal that reaches the spectrometer at frequency \( \nu \),
\( q_\vartheta \) : value of atmospheric parameter \( q \) at orbital coordinate \( \vartheta \)
\( x \) denotes the set of observation parameters.
CH$_4$
T.H. = 24 km
point 1: 60, 47, 36, 27, 18 km

point 2: 60, 47, 36, 27, 18 km

CH₄ VMR=1 ppm constant

point 1: 18, 15, 12, 9, 6 km

point 2: 18, 15, 12, 9, 6 km
2D Sensitivity Functions

$$\omega(x, \nu, h) = \left[ \frac{\partial S(x, \nu)}{\partial q_h} \right]$$

$h$ : element of the considered surface $\equiv$ clove of the 2D discretization
$q_h$ : average value that the atmospheric parameter $q$ in clove $i$

we must take into account the multiplicity
Information Load (IL)

\[ \Omega(q,h) = \left[ \sum_{i=1}^{l} \sum_{j=1}^{m} \sum_{k=1}^{n} \left( \frac{\partial S_{ijk}}{\partial q_h} \right)^2 \right]^{1/2} \]

\( \Omega(q,h) \) = overall information load of clove \( h \) with respect to atmospheric parameter \( q \),

\( S_{ijk} \) = spectral signal of observation geometry \( i \) at frequency \( j \) of the analyzed MW \( k \),

\( l \) = number of observation geometries that define the multiplicity of clove \( h \).

\( m \) = number of analyzed MWs in observation geometry \( i \),

\( n \) = number of spectral points in MW \( j \),
Why summation in quadrature?

\[
\sum_{i=1}^{l} \sum_{j=1}^{m} \sum_{k=1}^{n} \left( \frac{\partial S_{ijk}}{\partial q_n} \right)^2 = (K^T K)_h \quad (1)
\]

where \( K \) is the Jacobian column relative to the retrieval of parameter \( q \) in clove \( h \).

In this retrieval the VCM of \( q \) would be:

\[
V_y = (K^T S_n^{-1} K)^{-1} \quad \text{[where } S_n^{-1} \text{ is the VCM of the observations]}
\]

assuming uncorrelated observations with constant uncertainty and neglecting the multiplicative constant equal to the reciprocal of the uncertainty:

\[
(1) = V_y
\]

Since \( \sigma_h = \left[ (V_y)_{h,h} \right]^{1/2} \)

The uncertainty on the value of the target quantity \( q \) in clove \( h \) is given by \( 1/\Omega \)
Temperature IL for orbit 208 (July 24, 2002)
Pressure IL for orbit 2081 (July 24, 2002)
Pressure IL for orbit 2081 (July 24, 2002)
CH$_4$ IL for orbit 2081 (July 24, 2002)
CH$_4$ IL for orbit 2081 (July 24, 2002)

nW/(cm$^2$sr/cm$^{-1}$)
CH$_4$ IL for orbit 10532 (April 5, 2004)
HNO$_3$ IL for orbit 10532 (April 5, 2004)
HNO$_3$ IL for orbit 10532 (April 5, 2004)
CH₄ IL for orbit 2081 (July 24, 2002)
CH$_4$ IL for orbit 2081 (July 24, 2002)
CH$_4$ IL for orbit 2081 (July 24, 2002)
Temperature IL only scan 3 of orbit 2081

nW/(cm²sr·cm⁻¹)
Temperature IL for cloves of scan 3 in orbit 2081

nW/(cm² sr cm⁻¹)
Temperature IL only scan 3 of orbit 2081

nW/(cm²·sr·cm⁻¹)
Temperature IL only scan 3 of orbit 2081
Temperature IL only scan 3 of orbit 2081

nW/(cm²·sr·cm⁻¹)
Conclusions

• The **IL analysis** provides an objective definition of “atmospheric sampling”.

• The atmospheric sampling depends on the target quantity.

• IL analysis permits to identify the optimal layout of the horizontal retrieval grid: minimize the error deriving from a wrong geo-location of the retrieved profiles.

• The optimal scenario for a retrieval analysis is provided by a uniform distribution of the IL; the sensitivity analysis allows to test the performance of different observation modes on the light of the IL fields that they generate.

• The IL distribution highlights the advantages of a 2D retrieval approach in terms of the larger amount of information that it makes available in a parcel of atmosphere with respect to a 1D approach.

• The IL analysis of a single limb-scan shows that the error in the geo-location of the retrieved profile can also occur in the case of a 1D retrieval.