ASSESSMENT THROUGH GEISA/IASI OF CURRENT SPECTROSCOPY FOR IASI


The ARA Group

The Atmospheric Radiation Analysis group is specialized in the study of the variability and evolution of the climate of the Earth from space borne observations made principally by vertical sounders, in the infrared and the microwave domains.

Its main research themes relate to the collection of a long term, global, climatology of the earth-atmosphere state: temperature and moisture; cloud characteristics, including their microphysical properties; greenhouse gases, mainly CO₂, in relation with the carbon cycle; aerosols (volcanic, dust, smoke, etc.) infrared characteristics in relation with the earth radiative budget; continental surface infrared emissivities, in relation with the interaction between the surface and the atmosphere. The group is also deeply involved in statistical analysis of large spatio-temporal data bases (inverse problems, linear and non linear inference, neural networks, classification, pattern recognition, etc.).

The group has developed numerous tools in spectroscopy of the atmospheric gases, forward and inverse radiative transfer modelling, etc. In particular, the group develops and maintains the spectroscopic data base GEISA « Gestion et Etude des Informations Spectroscopiques Atmosphériques » (Study and management of atmospheric spectroscopic information).

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General Context

What do we have? Present GEISA/IASI-03 System Overview

Were are we going to? GEISA/IASI-08 underway Line Transition Sub-Database update summary

Examples of Spectroscopic data evaluation/validation

1) Evaluation of the impact of H₂O spectroscopic archive differences using IASI 4A/TRANSAC Radiative transfer simulations

2) Evaluation of the impact of H₂O spectroscopic archive differences using IASI Metop Flight Data and 4A/TRANSAC Radiative transfer simulations

Concluding Comments
GENERAL CONTEXT
The ARA (Atmospheric Radiation Analysis) group at LMD has been engaged, during the past three decades, in the development of GEISA, a computer-accessible spectroscopic database, designed to facilitate accurate and fast forward calculations of atmospheric radiative transfer using a line-by-line and (atmospheric) layer-by-layer approach.

The performance of the second generation vertical sounding, high-resolution, sophisticated infrared spectroscopic instruments, such as AIRS in the USA and IASI in Europe, highly depends on the accuracy in the spectroscopic parameters of the optically active atmospheric gases, since such data constitute an essential input in the forward models that are used to interpret the recorded spectral radiances.
FROM SATELLITE OBSERVATIONS TO CLIMATE VARIABLES: a long process based on Radiative Transfer

Satellite data

Desarchiving
Channel sélection

Data Archive
100 To

In situ
Radiosoundings

Desarchiving
Quality control

Cloud detection
Spatio-temporal collocation

Radiative Transfer
Direct Models
Clear sky or scattering medium nadir or limb

Radiative Transfer
Inverse Models
- Bayesian inference
- Neural Networks
- Clustering

Model/observation bias computation
Instruments monitoring

GEISA SPECTROSCOPIC DATABASE

- Thermodynamics
- Clouds
- Greenhouse gases
- Continental surfaces
- Aerosols
- etc…

A priori
infos

Scientific
Themes

Courtesy A. Chédin, Trattoria/CNES
2-3 April 2008
What do we have?
GEISA/IASI-03
System Overview
The 2003 edition of the GEISA/IASI spectroscopic database

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MORE RECENT REFERENCES


Extraction of GEISA-03 between 599 & 3001 cm\(^{-1}\)
- Individual spectral lines spectroscopic parameters sub-database
  - 14 molecules (53 isotopic species): H\(_2\)O, CO\(_2\), O\(_3\), N\(_2\)O, CO, CH\(_4\), O\(_2\), NO, SO\(_2\), NO\(_2\), HNO\(_3\), OCS, C\(_2\)H\(_2\), N\(_2\)
- IR absorption cross-sections sub-database (mainly CFC’s)
  - 6 molecular species: CFC-11, CFC-12, CFC-14, CCl\(_4\), N\(_2\)O\(_5\), HCFC-22
- Microphysical and optical properties of Basic Atmospheric aerosol components sub-database (similar with the GEISA-03 one)

Continuous update

Related with:
- CNES/EUMETSAT  EPS mission
- IASI measurement capabilities assessment
- ISSWG

Associated interest for AIRS

IASI : Infrared Atmospheric Sounder Interferometer
ISSWG : IASI Sounding Science Working Group
EUMETSAT : European organization for the exploitation of METeorological SATellites
AIRS : Advanced InfraRed Sounder
CNES : Centre National d’Etudes Spatiales, France
GEISA/IASI-08 Line Transitions Records

255 Characters record
30 Parameters

(A) Wavenumber (cm$^{-1}$) of the line associated with the vibro-rotational transition.
(B) Intensity of the line (cm molecule$^{-1}$ at 296K).
(C) Lorentzian collision halfwidth (cm$^{-1}$ atm$^{-1}$ at 296K).
(D) Energy of the lower transition level (cm$^{-1}$).
(E) Transition quantum identifications for the lower and upper levels of the transition
(F) Temperature dependence coefficient $n$ of the halfwidth
(G) Identification code for isotope.
(I) Identification code for molecule.
(J) Internal GEISA code for data identification.

(K) Molecule number as in HITRAN
(L) Isotope number as in HITRAN
(M) Einstein A-coefficient
(N) Self broadening pressure halfwidth (HWHM) (cm$^{-1}$atm$^{-1}$) at 296K
(O) Air pressure shift of the line transition (cm$^{-1}$atm$^{-1}$) at 296K
(P) Accuracy indices for wavenumber, intensity and halfwidth
(Q) Uncertainty indices

K-Q fields mainly HITRAN inter-compatibility related
GEISA/IASI-08 Line Transitions Records (following)

(R) Temperature dependence coefficient n of the air pressure shift
(A') Estimated accuracy (cm⁻¹) on the line position
(B') Estimated accuracy on the intensity of the line in (cm⁻¹/(molecule.cm²))
(C') Estimated accuracy on the air collision halfwidth (HWHM) (cm⁻¹.atm⁻¹)
(F') Estimated accuracy on the temperature dependence coefficient n of the air broadening HW
(O') Estimated accuracy on the air pressure shift of the line transition (cm⁻¹.atm⁻¹) @296K
(R') Estimated accuracy on the temperature dependence coefficient n of the air pressure shift

(N') Estimated accuracy on the self broadened (HWHM) (cm⁻¹.atm⁻¹) @296K
(S) Temperature dependence coefficient n of the self broadening halfwidth
(S') Estimated accuracy on the temperature dependence coefficient n of the self broadening HW
(T) Self pressure shift of the line transition (cm⁻¹.atm⁻¹) @296K
(T') Estimated accuracy on the self pressure shift of the line transition (cm⁻¹.atm⁻¹) @296K
(U) Temperature dependence coefficient n of the self pressure shift
(U') Estimated accuracy on the temperature dependence coefficient n of the self pressure shift

Water specific

Standardized parameter missing values for GEISA-08 as a whole
GEISA/IASI EFFECTIVE USE

**IASI on METOP**
since October 19th 2006 launch

- GEISA/IASI used as the reference spectroscopic database
- Validation achieved using 4A line by line Radiative Transfer Model
  
  4A/OP co-developed by LMD and Noveltis with the support of CNES (2006)]

Related to

IASI Level 1 Cal/Val activities@ CNES
GEISA and associated facilities are implemented on the Ether (CNRS/IPSL) (CPS)

Effective January 2007

Ether Products and Services Centre Facilities:

http://ether.ipsl.jussieu.fr
Welcome to the Ether website

This website offers various products of French activities in nationals and international projects. The access rights vary according to the products (see "Login Request"). More information ...

Original products

- MASI: French archives
- GRISA: spectroscopic data
- RSCAD: data for emissions calculation
- Chemical Kinetics Database
- GIRAFE: biomasse burning plains
- SOLSPEC: solar radiation spectrum data
- MINOSA: Potential vorticity and temperature analysis and forecasts in Northern, Southern Hemisphere and Tropics
- REPROMOS: Chemistry Transport Model in Polar waters
- ARLETT: temperature and pressure profiles calculation
- CNRM-CSR: official data and specific production (CO₂, CO₃⁻→)
- NADACC-FRANCE: Network for Detection of Atmospheric Composition Change

Other products

- Select by Experiment
- Models and Assimilations
- Software

Contact the Ether Project Scientists
Please read before using this website

ISSWG2, 30 June - 2 July 2006, CNES, Paris
Where are we going to?

GEISA/IASI-08 underway

1) line transiton Sub-database update summary
EVOLUTION GEISA SINCE 1978: line transition sub-database

![Graph showing the evolution of Nb Lines, Nb Molecules, and Nb Isotopes from 1978 to 2008.](image)
The GEISA spectroscopic database: Current and future archive for Earth and planetary atmosphere studies

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Jacquinet-Husson N. et al. The GEISA spectroscopic database: Current and future archive for Earth and planetary atmosphere studies

JQSRT, 109, 1043-59, 2008
FROM GEISA-03 TO GEISA-08: updated molecular species (following)

27 molecular species updated

H$_2$O, CO$_2$, O$_3$, N$_2$O, CH$_4$, O$_3$, SO$_2$, NO$_2$, PH$_3$, HNO$_3$,
H$_2$CO, C$_2$H$_6$, CH$_3$D, C$_2$H$_2$, C$_2$H$_4$, HCN, C$_2$N$_2$, C$_4$H$_2$, HC$_3$N,
HOCI, N$_2$, CH$_3$Cl, H$_2$O$_2$,
HCOOH, SF$_6$, C$_3$H$_4$, ClONO$_2$

6 New Molecular Species

<table>
<thead>
<tr>
<th>Species</th>
<th>Wavenumber Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH$_3$Br</td>
<td>16 µm</td>
</tr>
<tr>
<td>CH$_3$OH</td>
<td>0.02 - 33 cm$^{-1}$ 10 µm region</td>
</tr>
<tr>
<td>NO$^+$</td>
<td>1635- 2530 cm$^{-1}$</td>
</tr>
<tr>
<td>HNC</td>
<td>0.22 - 12594 cm$^{-1}$</td>
</tr>
<tr>
<td>C$_6$H$_6$</td>
<td>642 - 705 cm$^{-1}$</td>
</tr>
<tr>
<td>C$_2$HD</td>
<td>451 - 580 cm$^{-1}$ 600 - 760 cm$^{-1}$</td>
</tr>
</tbody>
</table>
## Updates for 2008 Edition of GEISA/IASI line transition parameters sub-database

*Preliminary non exhaustive list*

### Molecular species already archived in GEISA/IASI

<table>
<thead>
<tr>
<th>Species</th>
<th>Wavenumber Range</th>
<th>Archive</th>
</tr>
</thead>
<tbody>
<tr>
<td>H$_2$O</td>
<td>500-8000 cm$^{-1}$</td>
<td>LISA, JPL</td>
</tr>
<tr>
<td>CO$_2$</td>
<td>2200-7000 cm$^{-1}$</td>
<td>JPL, LTS</td>
</tr>
<tr>
<td>N$_2$O</td>
<td>1900-6800 cm$^{-1}$</td>
<td>JPL</td>
</tr>
<tr>
<td>CH$_4$</td>
<td>750-1350 cm$^{-1}$</td>
<td>ICB, JPL</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>$\nu_1, \nu_3$, $\nu_1+\nu_2-\nu_2$</td>
<td>LISA, GSMA</td>
</tr>
<tr>
<td>HNO$_3$</td>
<td>$\nu_5$, 2$\nu_9$</td>
<td>LISA</td>
</tr>
<tr>
<td>C$_2$H$_2$</td>
<td>604-2254 cm$^{-1}$</td>
<td>LADIR</td>
</tr>
</tbody>
</table>

### Molecular species related with IASI Trace Gas Retrievals to be added

- HCN
- NH$_3$
- HCOOH
- C$_2$H$_4$
- CH$_3$OH

7 molecular species updated
Examples of GEISA/IASI
Spectroscopic data evaluation/validation

1) Assessment of the impact
of H₂O spectroscopic archive differences using IASI
4A/TRANSAC Radiative transfer
simulations

4A (Automated Atmospheric Absorption Atlas);
fast and accurate line-by-line radiative transfer model
[N.A. Scott and A. Chédin, 1981; Tournier et al. 1995; Chéruy et al. 1995]

TRANSAC [N.A. Scott, 1974]
line-by-line and layer-by-layer model

in their latest 2000 version
Selected Spectroscopic Databases

Differences in contents and subsequent IASI radiative transfer modelling

GEISA/IASI-03

GEISA/IASI-08 update with:
- Toth R.A. « Linelist of water vapor parameters from 500-8000 cm\(^{-1}\) » JQSRT (in preparation).
  http://mark4sun.jpl.nasa.gov

Spectral intervals: 600-800 cm\(^{-1}\) 1300-1500 cm\(^{-1}\) 1700-2000 cm\(^{-1}\)

=====================================================================================

MIPAS Dedicated Spectroscopic Database Version PF 3.2

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HITRAN-04 Rothman et al. JQSRT 96 (2005) 139-204.

HITRAN-06 update with:
IASI brightness temperature (K) simulation with GEISA-03 (upper curve);
Impact of replacement of HITRAN-04 or MIPAS PF3.2 H2O data in GEISAIASI-03
differences (K) in lower curves, with associated IASI noise.
Individual impact of Spectroscopic parameters

**GEISA-03** IASI brightness temperature simulation differences (K), replacing H₂O spectroscopy by HITRAN-04 or HITRAN-06 one

![Graph showing brightness temperature differences](image)

- **Brightness temperature Différences (K)**
- **Air broadened half-widths impact evaluation**
- **Intensity individual impa**
Examples of GEISA/IASI
Spectroscopic data evaluation/validation

2) Evaluation of the impact
of H₂O spectroscopic archive differences using IASI
Metop Flight Data and 4A/STRANSAC Radiative transfer simulations
From the IASI level 1b data (from Ether server), a set of 69 IASI spectrums have been selected for the period of August 2007 to February 2008. A collocation with the ECMWF radiosoundings have been made with a colocation's distance of: space = 100 km; time = less than 1 hour.

This dataset has been used to identify the quality of the update of GEISA-2008, in comparison with GEISA-2003 and HITRAN-2006 H₂O archives.

Two specific spectral regions have been selected:

800-900 cm⁻¹ and 1800-2000 cm⁻¹.

Whereas the first region don't show improvement in the spectroscopic parameters, the second seems to show a comparaison closest to the IASI observations with GEISA-2008.

These preliminary results have to be confirmed. Especially, the quality of the spectra have to be examined, and the number of collocations has to be increased.
800 – 900 cm\(^{-1}\)
IASI Observations

Brightness temperature differences (K)

GEISA-03 vs GEISA-08
Air-broadening HW differences (%)

GEISA-03 vs HITRAN-06
Air-broadening HW differences (%)
1800 – 2000 cm$^{-1}$
IASI Observations

**Brightness temperature Differences (K)**

**Brightness temperature Differences (K)**

**Wavenumber (cm$^{-1}$)**

**GEISA-03 vs GEISA-08**
Air-broadening HW differences (%)

**GEISA-03 vs HITRAN-06**
Air-broadening HW differences (%)

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**ISSWG2, 30 June - 2 July 2008, CNES-Paris**
ZOOM 1805 – 1830 cm\(^{-1}\)
IASI Observations

Brightness temperature differences (K)

GEISA-03 vs GEISA-08
Air-broadening HW differences (%)

GEISA-03 vs HITRAN-06
Air-broadening HW differences (%)

Wavenumber (cm\(^{-1}\))

Air broadening pressure half-width difference in %

geisa2003  geisa2008  hitran
Concluding Comments
Some conclusions of validation exercises, using e.g. : the 4A-00/LMD Model, in the case of IASI radiative transfer modelling

1. **The water vapour spectroscopic parameters**: still need to be validated;
2. **The water vapour continuum**: more tuning to be done when more validation data (especially with high water vapor content) become available;
3. **The freons bands at 850 and 920 cm\(^{-1}\)**: refine the temperature dependence;
4. **O\(_3\) in the 9.6 \(\mu\)m region**: the spectroscopic parameters still need to be validated;
5. **Some CO2 – Q branches**: further improvement/tuning of the line mixing (15 \(\mu\)m region especially)
Forward Models
Error Sources

Spectroscopy and RT model
- line inaccurate positions, line intensities, halfwidths, ...
- unsufficient/missing information (absorbers, hot bands, heavy molecules
  cross sections, ...)
- line shape, continua, line coupling, ...
- pressure shift
- NLTE

Courtesy A. Chédin, Trattoria/CNES
2-3 April 2008
ACKNOWLEDGMENTS

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CNES, CNRS/INSU and EUMETSAT
for their Encouragements and Supports

THANK YOU FOR YOUR ATTENTION