Spectroscopy for IASI hyperspectral remote sensing applications: GEISA/IASI 2008 Edition


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).

The Laboratoire de Météorologie Dynamique (LMD) is a laboratory of the French Centre National de la Recherche Scientifique (CNRS), of the Ecole Polytechnique, of the Ecole Normale Supérieure, of the Université Pierre et Marie Curie (Paris 6), and belongs to the Institut Pierre-Simon Laplace (IPSL). It is also one of the French space laboratories working in cooperation with the Centre National d’Etudes Spatiales (CNES).


GEISA: Gestion et Etude des Informations Spectroscopiques Atmosphériques ; Management and Study of Atmospheric Spectroscopic Information

ISSWG-3 Toulouse, France, October 12th 2009
GEISA-08 line transition parameters sub-database evolution since 1978

+ 2,135,944 entries
From GEISA-08 to GEISA/IASI-08

Extraction of GEISA-08 in the spectral range 599 & 3001 cm\(^{-1}\)

- Individual spectral lines spectroscopic parameters sub-database
  - 14 molecules (55 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:
- EUMETSAT/CNES MeTop/ EPS mission
- IASI measurement capabilities assessment

**Additional selection for Chemistry + Climate IASI Trace Gas Retrievals**

**Initial selection for Operational Meteorology**

HCN, NH\(_3\), HCOOH, C\(_2\)H\(_4\), CH\(_3\)OH, H\(_2\)CO

Non exhaustive list
GEISA/IASI-08 Update

10 participating Laboratories

GSMA  Groupe de Spectrométrie Moléculaire et Atmosphérique
ICB   Institut Carnot de Bourgogne
JPL   Jet Propulsion Laboratory-USA
LADIR Laboratoire de Dynamique, Interaction et réactivité
LISA  Laboratoire Inter-Universitaire des Systèmes Atmosphériques
LPMAA Laboratoire de Physique Moléculaire pour l’Atmosphère et l’Astrophysique
LTS   Laboratory of Theoretical Spectroscopy)-Russie
ULB   Université Libre de Bruxelles

University of Denver
College of Williams and Mary

11 Molecules updated

3 Molecules non updated: CO, O₂, OCS
Details of GEISA/IASI-08 Update

11 Molecules updated
H₂O, CO₂, O₃, CH₄, N₂O, NO, SO₂, NO₂, HNO₃, C₂H₂, N₂

3 Molecules non updated: CO, O₂, OCS

+462,687 entries
<table>
<thead>
<tr>
<th>MOL. ID</th>
<th># LINES 2003</th>
<th># LINES 2008</th>
<th>SPECTRAL RANGE (cm⁻¹)</th>
<th>REF.</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂O</td>
<td>13,278</td>
<td>13,378</td>
<td>599.680794 - 3000.881410</td>
<td>JPL LISA R.A. Toth L. Coudert</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>599.003000 - 3000.995510</td>
<td>LTS (CDSD Database V.I. Perevalov)</td>
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<tr>
<td>CO₂</td>
<td>50,840</td>
<td>186,844</td>
<td>599.022089 - 2926.296675</td>
<td>JPL R.A. Toth</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>599.029370 - 2787.860880</td>
<td>LISA J.M. Fland</td>
</tr>
<tr>
<td>O₃</td>
<td>195,102</td>
<td>237,916</td>
<td>599.000793 - 3000.983640</td>
<td>GSMA LTS A. Barbe S. Mikhailenko M.R. De Backer</td>
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<tr>
<td>N₂O</td>
<td>18,966</td>
<td>29,658</td>
<td>599.952535 - 3000.998767</td>
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<tr>
<td>CH₄</td>
<td>121,281</td>
<td>142,869</td>
<td>599.088570 - 3000.717430</td>
<td>ICB JPL LISA L.R. Brown V. Boudon I. Kleiner</td>
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<td></td>
<td>599.029370 - 2787.860880</td>
<td>LISA J.M. Fland</td>
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<tr>
<td>NO</td>
<td>29,608</td>
<td>3,1595</td>
<td>599.003000 - 3000.995510</td>
<td>Denver University A. Goldman</td>
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<tr>
<td>SO₂</td>
<td>22,301</td>
<td>34,336</td>
<td>599.003000 - 3000.995510</td>
<td>LISA J.M. Fland</td>
</tr>
</tbody>
</table>
CO$_2$ Intensity Histograms

Spectral Interval 2200 – 2450 cm$^{-1}$

log$_{10}(B)$ $2200.000 < \text{cm}^{-1} < 2450.000$ for molecule co$_2$ isotope(s) 626 627 628 636 637 638 728 828 838

GEISA/IASI

2003 and 2008 editions content comparisons

Real Value exponent of 10
Spectral Interval 1300 – 1400 cm⁻¹

$\log_{10}(B) \ 1300.000 < \nu < 1400.000$ for molecule $n_2o$ isotope(s) 446 447 448 456 458 546 548 556

GEISA/IASI
2003 and 2008 editions
content comparisons

N₂O Intensity Histograms

ISSWG-3 Toulouse, France, October 12th 2009
Contribution to atmospheric composition measurement

Non exhaustive list
Forward Models
Error Sources

Spectroscopy and RT model
- line inaccurate positions, line intensities, halfwidths, ...
- insufficient/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
Spectroscopic Parameters update requirements

Evaluation list to be regularly assessed and updated
Necessary feed-back to related Spectroscopy groups

Table 4
Update requirement index for selected molecules and spectroscopic parameters in major public spectroscopic databases

<table>
<thead>
<tr>
<th>Molecules</th>
<th>Line position</th>
<th>Line intensities</th>
<th>Line broadening</th>
<th>Line mixing</th>
<th>Continuum</th>
<th>Cross-sections</th>
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</thead>
<tbody>
<tr>
<td>H$_2$O</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>CO$_2$</td>
<td>Y</td>
<td>Y</td>
<td>1</td>
<td>1</td>
<td></td>
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<tr>
<td>O$_3$</td>
<td>3</td>
<td>1?</td>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>CH$_4$</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
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</tr>
<tr>
<td>CO</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N$_2$O</td>
<td>?</td>
<td>?</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HNO$_3$</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>Y</td>
</tr>
<tr>
<td>O$_2$ and N$_2$ collision-induced spectrum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Y</td>
</tr>
<tr>
<td>CFCs, HCFCs, N$_2$O$_5$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Y</td>
</tr>
</tbody>
</table>

“1” parameters that need to be improved; “2” and “3” second and third priority for improvement; “Y” no problem clearly identified; “?” the databases have to be checked. A blank corresponds to non-applicable information.

Comparison with HITRAN and GEISA, in particular for water vapour, and real IASI spectra, compared to simulations with ECMWF provided radiosondes, lead to the conclusion that in particular water vapour needs to be validated, and the continuum reinvestigated.

Urgent areas to investigate: line coupling, (which should be independent of the data bases) and non LTE (Local Thermodynamic Equilibrium).

IASI related spectroscopy problems with H$_2$O and CO$_2$ as first priority
Evaluation of the impact of $\text{H}_2\text{O}$ spectroscopic archive differences using IASI
Metop Flight Data and 4A/STRANSAC Radiative transfer simulations

4A line by line Radiative Transfer Model [Scott & Chédin, J.Appl.Met (1981);
4A/LMD http://ara.lmd.polytechnique.fr; 4A/OP co-developed by LMD
and Noveltis with the support of CNES (2006)]
From the IASI level1b 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 H$_2$O 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 comparison 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.
1805 – 1830 cm⁻¹
IASI Observations

Brightness temperature differences (K)

Wavenumber (cm⁻¹)
ACKNOWLEDGMENTS

to

CNES, CNRS/INSU and EUMETSAT

for their Encouragements and Supports

THANK YOU FOR YOUR ATTENTION

and
A question:
Importance of the Spectroscopy for IASI Radiance Monitoring Set-UP.
Should an evaluation be made?