Recent Validations of infrared and microwave forward models at LMD/IPSL

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Objectives of the validation

With recent and future satellite measurements, (TOVS, ATOVS, AIRS/AMSU/Aqua, IIR/Calipso, IASI/AMSU, Metop, ...) forward modeling requires more and more attention (1-D var, 4-D var, reanalysis, ...)

- forward models (brightness temperatures, transmittances, jacobians) and spectroscopic databases need to increase their precision.

- residuals between observed and calculated models have to be clearly identified and corrected.
Validation scheme

Atmospheric and surface properties
(tempature, humidity, gaz concentration…)

Radiometric Observations

RT model:
Computation of the radiances

- Analyse discrepancies « calc vs obs »
- Identify the sources of error
- Correct for errors

Climatology
(for species not measured)
O\textsubscript{3}, CO, CFCs, …

- spectroscopic lines
- minor gases cross section
- missing absorber
- line coupling formulation
- modeling of continua
- discretization in pressure and in frequency
Forward model computing suite at LMD

Used in this study:

- **Forward models:**
  - *Stransac* genuine line-by-line and layer by layer model (IR and MWV)
  - 4A: 2nd generation line-by-line and layer by layer model
- **Spectroscopic database:**
  - GEISA-2003

More details on the poster (Thursday, 13h:14h30)
- Water vapor, O2, N2, continua,
- CFCs profiles (cfc11, cfc12, Ccl4),
- Line-coupling,
- Emissivity spectrum
The validation suite: Example for AIRS/AMSUs/AquaAIRS
(AIRS/AMSU data (l1b) automatically desarchived from NASA/GSFC on a daily basis)
April 2003 ➔ « today »

- Ecmwf
  - FTP
  - Radiosoundings Reanalysis (ERA-40) (bufr format)
    - Quality control of the Radiosoundings
      - Inter/extrapolation
      - Add ozone profile from UGAMP climatology
    - « Clean « Radiosoundings Per month
      - L1B AIRS/HSB AMSU-A

- Deltas
  - Per month, land/sea/
    - Day/night,
      - Air mass
  - RT model (Stransac, 4A/OP)
    - Bias between calculated and observed brightness temperatures
  - Space and Time Colocation
    - (300 Km, 6h)

n-D var applications
The validation suite: Example for AIRS/AMSUs/Aqua

*T and H₂O from radiosoundings

No fit of O₃, N₂O, CO, CH₄, Ts and Surface Emissivity

**Sea, Night** *(between April 2003 to March 2006, 2000 collocations)*

AIRS

« Windows » : channels 1,2,3,4 and 15
Emissivity over sea

AMSU

Mean

Stdv
## Overview of existing validation datasets

<table>
<thead>
<tr>
<th>Name</th>
<th>Date/loc.</th>
<th>Obs.</th>
<th>Instruments</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>UWITRA90 CAMEX I</td>
<td>Apr. 86, Oct/Nov 88, March 92, US Sept 93, US</td>
<td>Plane or g.b.</td>
<td>HIS + radiosondes</td>
<td>Available on HIS validation dataset website</td>
</tr>
<tr>
<td>THORPEX</td>
<td>Fev/Mar 2003 Hawaii</td>
<td>Plane</td>
<td>SHIS, NASTI... + radiosondes</td>
<td>All data are compiled and freely available on a website</td>
</tr>
<tr>
<td>IASI-BALLOONS</td>
<td>March 2001 Aug. 2002 Kiruna (Sweden)</td>
<td>Balloons</td>
<td>IASI-balloons spectra + Atm. soundings</td>
<td>Available on ETHER website after registration</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>BUT: no ISRF available</td>
</tr>
<tr>
<td>EAQUATE</td>
<td>Sept 2004 UK + Italy</td>
<td>Plane + g.b.</td>
<td>SHIS, NASTI, BOMEM + radiosondes</td>
<td>Some data (which one?) available on FAAM website, after providing details on the research</td>
</tr>
<tr>
<td>WINTEX</td>
<td>Mar/Apr. 1999 USA/Canada</td>
<td>Plane + g.b.</td>
<td>AERI, SHIS, NASTI, MAS... + LIDAR, radiosondes</td>
<td>On FAAM website after request (which data?)</td>
</tr>
</tbody>
</table>
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</tr>
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<tr>
<td><strong>ADRIEX</strong></td>
<td>Sept 2004 Northern Italy</td>
<td>Plane</td>
<td>SHIS, NASTI + atm. Properties?</td>
<td>On FAAM website after request (which data?)</td>
</tr>
<tr>
<td><strong>AFWEX</strong></td>
<td>Nov/Dec 2000 Oklahoma US</td>
<td>Plane +</td>
<td>SHIS, NASTI, radiosondes, LIDAR…</td>
<td>LIDAR, water vapor, GPS, CM sondes, etc… available on ARM website</td>
</tr>
<tr>
<td><strong>MPACE</strong></td>
<td>Sept/Oct. 2004 Alaska</td>
<td>Plane +</td>
<td>SHIS, LIDAR, radiosondes…</td>
<td>LIDAR data available on ARM website</td>
</tr>
<tr>
<td><strong>FIRE.ACE/ SHEBA</strong></td>
<td>Apr/July 98 Alaska US</td>
<td>Plane +</td>
<td>Radiance + several atm. Properties</td>
<td>Data available on Nasa Langley website after (only?) registration</td>
</tr>
<tr>
<td><strong>CLAMS</strong></td>
<td>Jul/Aug. 2001 US East coast</td>
<td>Plane +</td>
<td>SHIS, MODIS, MAS… Radiosondes</td>
<td>Except SHIS, data available on Nasa Langley website after (only?) registration</td>
</tr>
<tr>
<td><strong>CAMEX III</strong></td>
<td>Aug./Sep 98 Andros Island</td>
<td>Plane +</td>
<td>AERI, NASTI, MAS, MIR + radiosondes, LIDAR…</td>
<td>All data are available on GHRC webpage, after registration (not tested)</td>
</tr>
<tr>
<td><strong>CAMEX 4</strong></td>
<td>Aug./Sep 98 Andros Island</td>
<td>Plane +</td>
<td>MAS, MIPS, radiosondes + several atm. Properties</td>
<td>All data seem to be available on GHRC webpage, after registration (not tested)</td>
</tr>
</tbody>
</table>
THORPEX dataset (SHIS)

- SHIS upwelling radiance data collected around Hawaiian Island between 21 February and 15 March 2003 on board ER-2 (altitude of 20km).
- Temperature and water profile measured by dropsondes released at 13km by G-4.
- The 03 March is used here as it is considered as clear-sky measurements.
- Measurements are performed during day-time.
- Data are freely available on: http://thorpex-data.ssec.wisc.edu/
EAQUATE dataset (BOMEM)

- 38 down looking BOMEM spectra collected on 6-10 Sept 2004, in Italy between 7 pm and 2 am.
- At each spectrum correspond temperature and water profiles.
- Other trace gases have been set according to the climatology (AFGL 2 – mid-latitude summer atmosphere).
Preprocessing: Example on THORPEX dataset

1. Select among the 286 spectra, those that are not contaminated by cloud.
   - Remains 192 similar spectra, with an STD < 0.5K
2. Atmospheric profiles are extended to SHIS observing altitude by merging the top with the profiles measured at Lihue ground-based station.
3. Concentrations in CO2, N2O and CH4 are taken from the daily data of the WDCGG (http://gaw.kishou.go.jp/wdcgg/station.html?).
4. CO set to fit the data in the range 2080-2200cm\(^{-1}\)
5. O3 taken from the climatology
6. Surface emissivity (assumed to be a constant) and skin temperature are set to fit the data.

Mean Tb between 800-900cm\(^{-1}\) against latitude

Cloud top pressure
Upwelling Radiances

- SHIS: THORPEX (03 March 2003)
Upwelling radiance: Comparison calc – obs: 580-1080 cm\(^{-1}\)

- Average of the 192 SHIS spectra (THORPEX data).
- Average residual obtained using 4 measured atmospheric profiles (T + H2O) + STD of the 4 residuals.
Upwelling radiance: Comparison calc – obs: 580-1080cm$^{-1}$

- CO2 line mixing not well modeled
- Temperature profile inaccuracy at high altitude
- The surface emissivity is considered as a constant? (corrected in the latest release).
- Depends highly on the water profile used: Water profile inaccuracy at lower altitude?
- Ozone profile not known

- Average residual (red) + STD of the 4 residuals (green).
- In green: error related to data; in blue: error related to the model
Upwelling radiance: Comparison calc – obs: 1080-1800 cm⁻¹

- Water profile inaccuracy at low altitude?
- Water profile inaccuracy at high altitude?

- Average residual (red) + STD of the 4 residuals (green).
- In green: error related to data; in blue: error related to the model

Observed in all the datasets: Error to model the N₂O effect?

Depends highly on the data used: Water profile inaccuracy at high altitude
Upwelling radiance: 
Comparison calc – obs: 1800-3000cm$^{-1}$

- Average residual (red) + STD of the 4 residuals (green).
- In green: error related to data; in blue: error related to the model
Downwelling Radiances

- BOMEM: EAQUATE, Italy (September 2004)
Downwelling radiance: Comparison calc – obs : 600-1080cm\(^{-1}\)

- Average of the 38 EAQUATE/BOMEM spectra, Italy Sept 2004
- Average residual obtained using the 38 measured atmospheric profiles (T + H2O) + STD on the 38 residuals.
Downwelling radiance:
Comparison calc – obs : 600-1080 cm\(^{-1}\)

- Average residual (red) + STD of the 38 residuals (green).
- In green: error related to data; in blue: error related to the model; in red: source of error not clear.

CO2 line mixing not well modeled?
Spikes: Uncertainties in the water profile?
Offset (~2K): Continuum not well modeled?
Ozone profile not known
Downwelling radiance: Comparison calc – obs : 1080-1800 cm\(^{-1}\)

- Average residual (red) + STD of the 38 residuals (green).
- In green: error related to data; in blue: error related to the model.
Summary

- Globally low residuals, especially in case of upwelling radiance (atmosphere need to be well known at very high altitude for the downwelling radiance).

- Very difficult to associate good radiometric measurements with a good knowledge of the thermodynamical parameters:
  - atmospheric profile (Temperature and water vapor, O$_3$, N$_2$O, CO, CH$_4$, CFCs)
  - surface properties (emissivity and surface temperature)
Perspectives

- New improvements are already added:
  - Introduction of the solar contribution
  - Surface emissivity can vary with wavenumber
  - Introduction of aerosol contribution (under development)
  - Limb view geometry
- Or in progress:
  - CO2 spectral line shapes have to be improved (especially in the range 700-780cm\(^{-1}\)).
    Line mixing in CO2 P/R branches is currently introduced in the model (hartmann, priv. comm. 2006)
  - Improve climatology of CO, CFCs, etc.
- Since early 2000, latest releases of 4A are maintained by Noveltis (4A/OP2006 available under request on [http://www.noveltis.net/4AOP/](http://www.noveltis.net/4AOP/))
  
  ➤ *See poster session, Thursday, 13h-14h30*