The IASI-NG mission:  
Scientific objectives and expected results

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The IASI-NG mission

**Numerical Weather Prediction**
Global NWP, LAM, mesoscale models

**Atmospheric composition**
More than 20 species detected, some well quantified ($O_3$, CO, CH$_4$), some only detected (SO$_2$, HNO$_3$, NH$_3$, formic acid, methanol) in special situations (fires, volcanoes)

**Climate**
- Essential Climate Variables: T, WV, GHG, Surface characteristics, Clouds, Aerosols.
- Reference for the GSICS.

**Lessons learned with IASI onboard MetOp-A:**
- IASI benefits **three communities** that will be more and more **connected** (eg: MACC-GMES, Essential Climate Variables)
- Covering continuously the **whole TIR domain** is very useful.
- To retrieve several variables, other atmospheric data (cloud, T, WV) are mandatory.
- Spectral and radiometric stabilities are very important.
- Retrievals over **land/sea** by **day/night**.
The IASI-NG mission

- Phase-A studies at CNES since January 2010, end in April 2012.
- Two industrial studies have been conducted in parallel (Astrium-France and Thales Alenia Space-France).

**EPS-SG**
- PFA: MetIMAGE, MWS, IASI-NG, RO, UVNS, 3MI
- PFB: SCATT, MWI, RO

**IASI-NG Status:**
- Phase-A studies at CNES since January 2010, end in April 2012.
- Two industrial studies have been conducted in parallel (Astrium-France and Thales Alenia Space-France).
The IASI-NG mission

• Objectives of the mission:
  • To assure the **continuity** of IASI for NWP, atmospheric chemistry and climate applications.
  • To **improve** the characterization of the lower part of the troposphere, the UT/LS region and, more generally, of the full atmospheric column.
  • To **improve the precision** of the retrievals and to allow the detection of new species.

• Characteristics:
  - spectral coverage: **645 - 2760 cm\(^{-1}\)**
  - spectral resolution: **0.25 cm\(^{-1}\)** after apodisation (**0.50 cm\(^{-1}\) for IASI**)
  - spectral sampling: **0.125 cm\(^{-1}\)** (**0.25 cm\(^{-1}\) for IASI**).
  - reduction of the radiometric noise by at least a **factor of ~2** as compared to IASI.
  - spatial sampling: **12 km FOV**.

How improving both spectral and radiometric characteristics can help reaching the objectives?
IASI-NG: a few scenarios

<table>
<thead>
<tr>
<th>Spectral resolution</th>
<th>IASI noise</th>
<th>IASI noise /2</th>
<th>IASI noise /4</th>
<th>IASI-NG noise Threshold</th>
<th>IASI-NG noise Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 cm(^{-1})</td>
<td>IRS1a</td>
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<td>IRS1c</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0.25 cm(^{-1})</td>
<td>IRS2a</td>
<td>IRS2b</td>
<td>IRS2c</td>
<td>IRS2-T</td>
<td>IRS2-O</td>
</tr>
</tbody>
</table>

(a) IASI

(b) IASI-NG

T (1K) H\(_2\)O (20%) CO\(_2\) (1%) O\(_3\) (10%) N\(_2\)O (2%) CO (10%) CH\(_4\) (10%) Tsurf (1 K)
IASI-NG: a few scenarios

For a 10ppbv CO perturbation:

CO ~0.8 K
Noise: ~0.1 K

For a 10ppbv CO perturbation:

CO ~0.4 K
Noise: ~0.2 K

T (1K) \( \text{H}_2\text{O} \) (20%) \( \text{CO}_2 \) (1%) \( \text{O}_3 \) (10%) \( \text{N}_2\text{O} \) (2%) CO (10%) \( \text{CH}_4 \) (10%) Tsurf (1 K)
## IASI-NG: a few scenarios

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</table>

### Specifications from CNES 2012 ITT

![Graph showing NedT at 280 K vs. wave number (cm\(^{-1}\))](image-url)

- **NedT at 280 K (K)**
- **Wave number (cm\(^{-1}\))**
- Lines represent:
  - Black: IASI
  - Gray: IASI/2
  - Light gray: IASI/4
  - Blue: IASI-NG Objective
  - Red: IASI-NG Threshold
Spectral resolution improves the instrument contribution beyond noise reduction by increasing the number of channels.
IASI-NG: impact on atmospheric composition

Carbon monoxide

Simulation performed using a regional model that described an increase of (0-6 km) ozone observed in Europe (August 20th, 2009).

Ozone

MOZAIC aircraft CO at the Frankfurt airport

Altitude of max. sensitivity (km)

Simulation performed using a regional model that described an increase of (0-6 km) ozone observed in Europe (August 20th, 2009).
Carbon dioxide

<table>
<thead>
<tr>
<th>Spectral bands for IASI-NG</th>
<th>Noise</th>
<th>Improvement of the CO₂ precision</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 µm</td>
<td>IASI/2</td>
<td>30 %</td>
</tr>
<tr>
<td>4.3 µm</td>
<td></td>
<td>0 %</td>
</tr>
<tr>
<td>15 + 4.3 µm</td>
<td></td>
<td>45 %</td>
</tr>
</tbody>
</table>

- IASI-NG will enable the use of 4.3 µm channels, giving access to a lower part of the atmosphere, with a much improved precision.

- Strong and needed complementarity with SWIR obs. (GOSAT, OCO-2, UVNS).
- Still relies on synergy with MWS!
- N₂O?
IASI-NG: impact on detection of atm. species

• **Ammonia [0-2 km]:** gain of 40 % on the detection limit.

• **SO$_2$:** a 45 % gain on the detection threshold + some information on the vertical structure of the plumes.

• **Volcanic ash:** improvement on the detection limit.

→**Improvement of volcanic eruption alert**
(and more species will be retrieved: SO$_2$, H$_2$S, H$_2$SO$_4$, ash)
## IASI-NG: summary

<table>
<thead>
<tr>
<th></th>
<th>IASI</th>
<th>IASI-NG</th>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Chemistry</strong></td>
<td><strong>DOFs</strong></td>
<td><strong>Error (%)</strong></td>
<td><strong>DOFs</strong></td>
</tr>
<tr>
<td><strong>O₃</strong></td>
<td>3-4</td>
<td>PBL : 60% Tropo : 11%</td>
<td>4-5</td>
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<tr>
<td></td>
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<td></td>
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</tr>
<tr>
<td><strong>CO</strong></td>
<td>1-2</td>
<td>PBL : 16% Tropo : 8%</td>
<td>2-3</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>HNO₃</strong></td>
<td>1 or less</td>
<td></td>
<td>2</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NH₃</strong></td>
<td>detected</td>
<td>-</td>
<td>measured</td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td><strong>Methanol</strong></td>
<td>detected</td>
<td>-</td>
<td>measured</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>C₂H₄</strong></td>
<td>detected</td>
<td>-</td>
<td>measured</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SO₂-volcanos</strong></td>
<td>If &gt; 2DU</td>
<td>-</td>
<td>If &gt; 1 DU</td>
</tr>
<tr>
<td></td>
<td></td>
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<tr>
<td><strong>Climate</strong></td>
<td><strong>DOFs</strong></td>
<td><strong>Error (%)</strong></td>
<td><strong>DOFs</strong></td>
</tr>
<tr>
<td><strong>H₂O</strong></td>
<td>5-6</td>
<td>~13%</td>
<td>6-7</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>T</strong></td>
<td>6</td>
<td>~0.6K</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CO₂</strong></td>
<td>1 or less</td>
<td>~1%</td>
<td>1-2</td>
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<td></td>
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<tr>
<td><strong>CH₄</strong></td>
<td>1 or less</td>
<td>~3%</td>
<td>1-2</td>
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<td></td>
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<td></td>
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<tr>
<td><strong>N₂O</strong></td>
<td>detected</td>
<td>-</td>
<td>measured</td>
</tr>
<tr>
<td><strong>Aerosols</strong></td>
<td>dust</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Emissivity</strong></td>
<td>0.04 @4µm</td>
<td></td>
<td>0.02 @4µm</td>
</tr>
</tbody>
</table>
So far, most of the studies were based on representative atmospheric situations in « stand-alone » approaches.

Next step: Observing System Simulation Experiments (OSSEs).

**Objectives**: evaluate the impact of IASI-NG (with the latest specification) in NWP assimilation while giving the opportunity to evaluate retrievals of atmospheric species and climate variables in realistic situations.

**Team**: CNRM-GAME, LMD, LATMOS, LISA, LA

**First steps**: selection of orbits, gathering information of atmospheric components (clouds, aerosols, trace gases, etc.)
The work done by French team (‘MENINGE’) has been summarized in a report that was used for the approval of the IASI-NG mission by CNES board.

This report is being adapted to an article (Crevoisier et al., TBS AMT): Towards IASI-New Generation: impact of improved spectral resolution and radiometric noise on the retrieval of thermodynamics, chemistry and climate variables

According to the CNES/EUMETSAT agreement, ISSWG has officially taken other the responsibility for the scientific preparatory work on IASI-NG (similarly to what was done for IASI).

First task: writing a IASI-NG Science Plan
The IASI-NG science plan

Numerical Weather Prediction

• What worked **best** than what we thought 😊
  • Assimilation techniques have evolved a lot between 1998 and 2006! (bias correction, variational techniques, etc.)
  • IASI LW T and WV assimilated in most global NWP models
    • Clear pixel...
    • And also clear channels in cloudy pixels
    • ... and cloud-affected radiances!
  • Assimilation of ozone channels at some centres
  • Assimilation in convective scale models, at high spatial density
  • Large positive impact on forecasts, on top of assimilating numerous other instruments (good synergy with other instruments)
The IASI-NG science plan

Atmospheric composition

• What worked **best** than what we thought 😊
  • Much more molecules, even reactive species
  • Sensibility close to ground if thermal contrast
  • Operational applications: SO₂/ash volcanic plumes, pollution forecasts
  • Societal applications (VACCS, etc.).

[Legend images showing Ozone peaks, NH₃ sources (>PM), Long-range pollution, Aviation threat]
The IASI-NG science plan

Atmospheric composition

• What worked less than what we thought/work still needed 😞

• Coupled retrieval of IASI and GOME-2 to improve vertical information on $O_3$
• Retrieval of trace gases over cloudy pixels
• Assimilation of radiances for atmospheric composition studies
• OSSE difficult to do as we miss high polluted profiles
Climate

With IASI: 5 years of observation: no climate studies per se yet!

... But: climatologies of several ECVs and exceptional spectral and radiometric stability.
  → Potential for long-term monitoring and study of climate.

With IASI-NG:
- Opportunity to expend the coverage after the MetOp series.
- For long-term studies, the same level of stability will be needed.
  → Need for proper monitoring and traceability of calibration.
The IASI-NG science plan

Climate

IASI 1998 Priorities for IASI research and development:

High
- IR radiation budget.
- heating rates.
- cirrus properties.

Low
- climatologies: WV, O$_3$, CH$_4$, N$_2$O, CO, CFCs and cloud parameters.
- radiative forcing: UV+IR O$_3$, latitudinal and seasonal.
- aerosol properties: AOD and surface characteristics.
The IASI-NG science plan

Climate

IASI 1998 Priorities for IASI research and development:

**High**
- IR radiation budget.
- Heating rates.
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**Low**
- Climatologies: WV, O$_3$, CH$_4$, N$_2$O, CO, CFCs and cloud parameters, CO$_2$.
- Radiative forcing: UV+IR O$_3$, latitudinal and seasonal.
- Aerosol properties: AOD and surface characteristics.
IASI-NG surroundings

• **GMES**: NWP + atmospheric composition + climate
Focus of many agencies on climate... with a multiplication of ad hoc committees.

In 2010: GCOS created a list of 50 Essential Climate Variables required to support the work of the UNFCCC and the IPCC (international exchange is required for both current and historical observations).

- GMES: NWP + atmospheric composition + climate
- ESA Climate Change Initiative.
- WDAC (WCRP Data Advisory Council)
- GSICS (Global Space-based Inter-Calibration System) of CGMS and WMO.

The promotion and exploitation of IASI-NG will have to be performed in this context.
Some concluding thoughts

• **Strong relationships** between NWP, atmospheric composition and climate through many variables.

• **Cal/Val activities** and **traceability** are the key to success.
  → Properly archived ATBD are needed.

• **Coupling of IASI-NG with companion instruments:** both in terms of Level 2 and Level 1 (MW/IR, SWIR/IR, Vis/IR, UV/IR).

• **Coupling of variables:** clouds+aerosols, gases, cirrus+WV, etc.

• **Study of atmospheric and climate processes** (various variables + night/day/land/sea!!).

• **Design of simulators** by coupling atmospheric/climate models and IASI characteristics: clouds, radiative budget, potentially GHG.

• **Spectroscopy** (including aerosols characteristics).

• **RT modeling:**
  - line-mixing (CO₂, CH₄)
  - non-LTE → both 15 µm and SW.
  - solar contamination → SW.
IASI-NG improved contributions to...

- Atmospheric profiling
- Essential Climate Variables monitoring and understanding Clouds, GHG, aerosols
- Improvement on pollution forecast 3 EU controlled pollutants (CO, O₃ and NH₃)
- Better tracking of long range pollution (e.g. fire emissions)
- Improved volcano alerts Early alerts possible + SO₂ and ash tracking

IASI-NG has the potential for strongly benefiting the NWP, chemistry and climate communities, in addition to assuring the continuity of high quality observations delivery.