CENTRE NATIONAL D'ÉTUDES SPATIALES

IASI-NG Status of development and preparatory activities by the mission team

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Outline

1- IASI-NG Mission rationale and Objectives

2- IASI-NG Mission requirements

3- The french mission group : MENINGE

4- IASI-NG feasibility studies

5- Consequences of the successful IASI-NG feasibility studies

6- IASI-NG Schedule

IASI-NG mission rationale

Expressed in the Position papers collected by Eumetsat

In France proposed by scientists to CNES AO for new missions in 2009

- Continuity of IASI.
  - Justified by Operational use of NWP centers, and other emerging services (MACC, VAAC), and long term trends monitoring as well.

  ⇒Same performances as IASI used as thresholds for follow-on

  ⇒Same viewing geometry required
- Improved performances to tackle issues unsolved with IASI.
  - More precise humidity profiles
  - More documented atmospheric layers near surface (BL) , or around tropopause (UTLS).
  - Better use of information in cloudy conditions
  - More detailed profiles of minor components
  - Detect other species

Dominant rationale and consequence

EUM : operational meteorology

F : AC and climate

↓

Balance between these applications

Priority has been given to

- Continuity (full spectrum, + imager)
- Improved performances in radiometry and spectral resolution

Lessons learned from IASI for Atmospheric Composition and Climate

- All spectrum very useful
- Other atmospheric data mandatory (cloud, temperature, humidity)
- Large swath => Very good coverage.
- Stability is very important.

- No convincing products remaining tb improved
- CO_2 limited to upper troposphere
- Most of products good in upper troposphere but of coarser quality in lower troposphere or BL (e.g. O_3, CO) hampering strong development of AQ applications

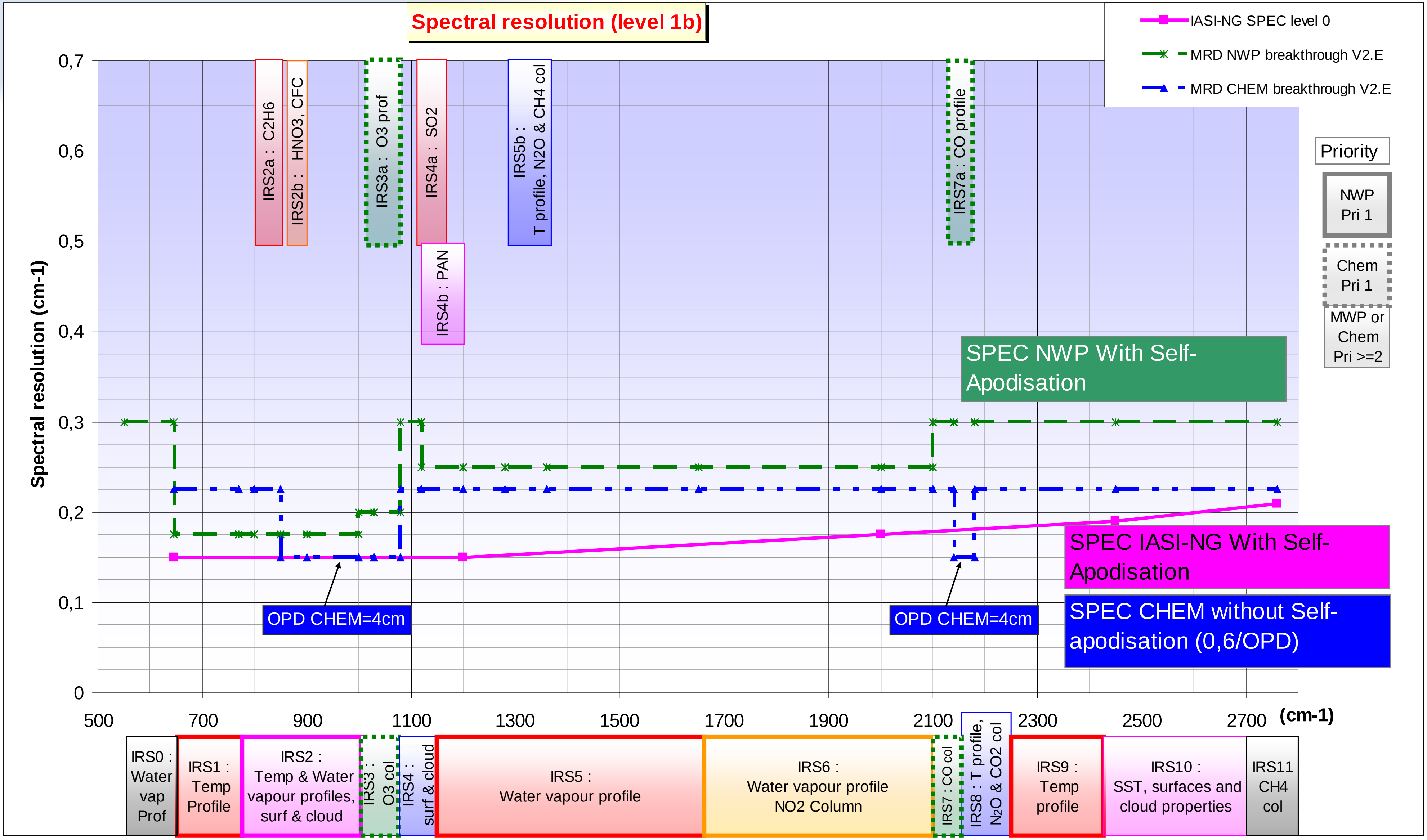
- Improve NeDT and Spectral resolution would help to detect and quantify more species and also obtain profiles.

STUDIES TO JUSTIFY REQUIREMENTS

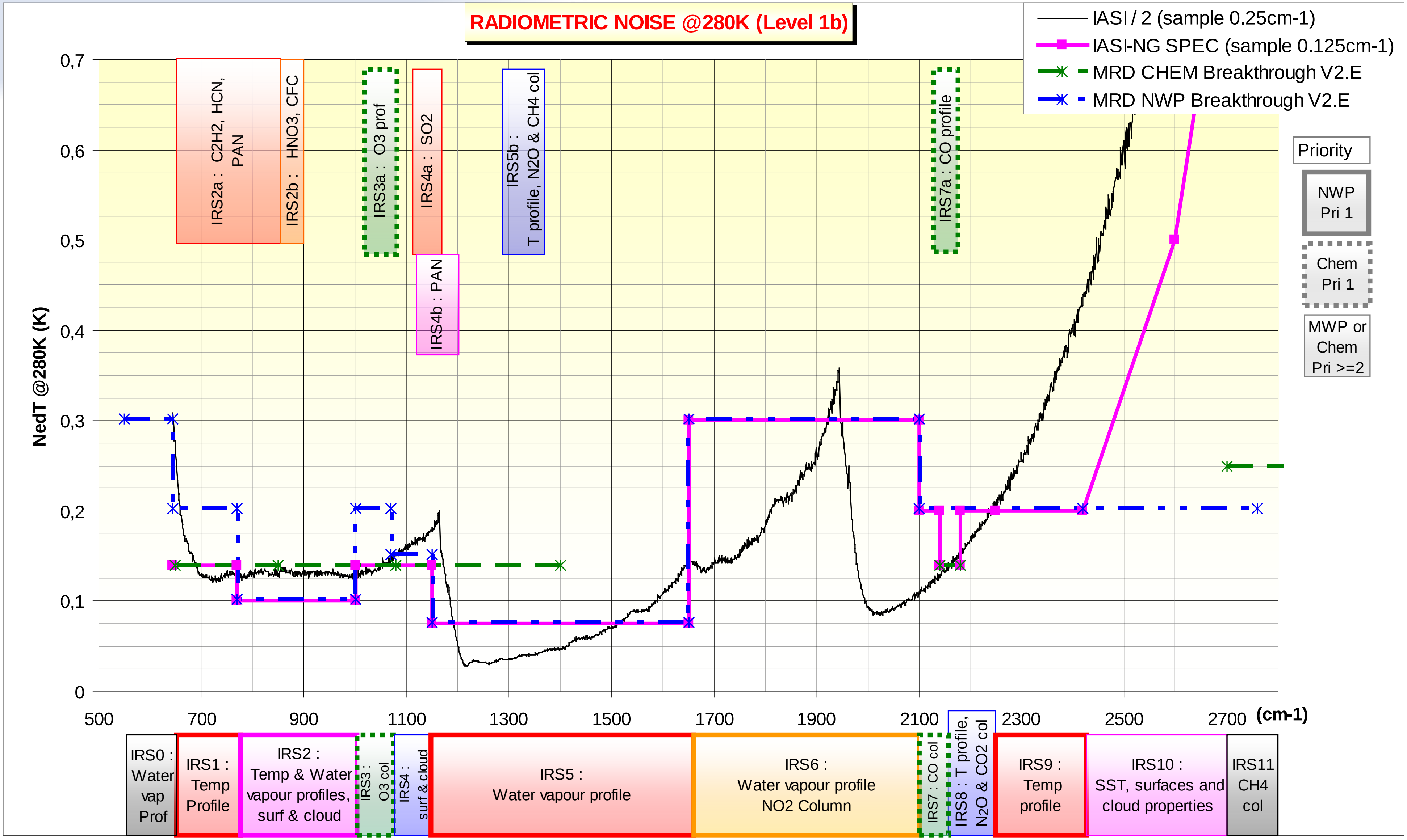
- **Two rounds :**
  - **In phase 0 by CNES and french scientists,**
  - **In phase A to consolidate the requirements (see further studies by MENINGE group)**

- **Main results : Resolution/2 and radiometric noise /2 >**
  - **Better acccuracy of T(z) in near surface layers**
  - **More information on CO and CH_4**
  - **Slight improvement on H_2O (?)**

IASI-NG performance objective versus Post EPS MRD



IASI-NG performance objective versus Post EPS MRD



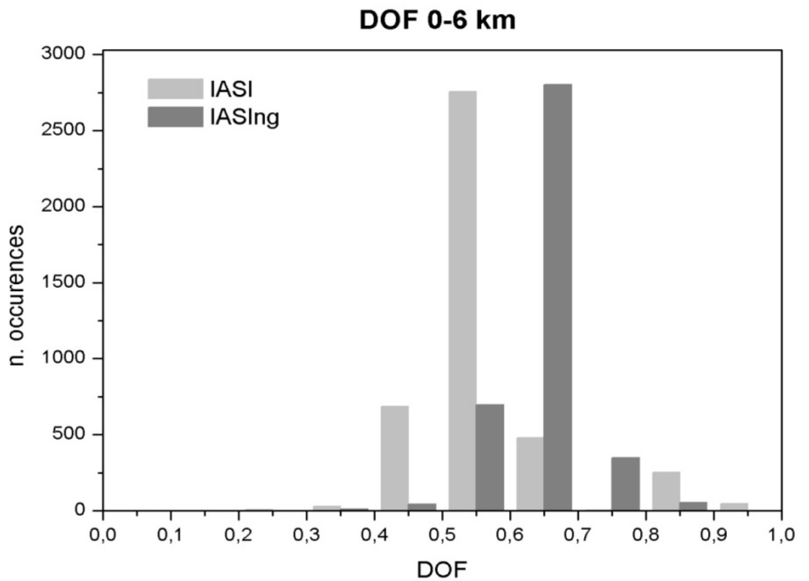
Activities of MENINGE during phase A

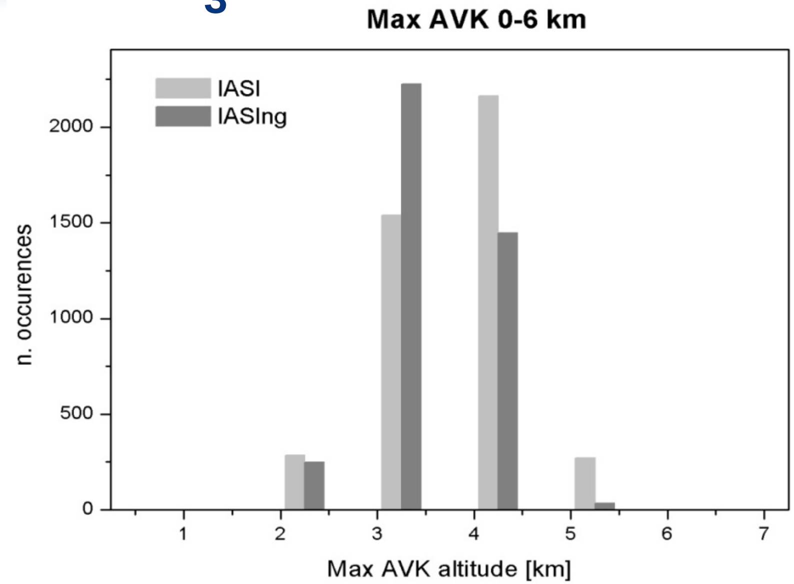
- **MENINGE : A french mission team**

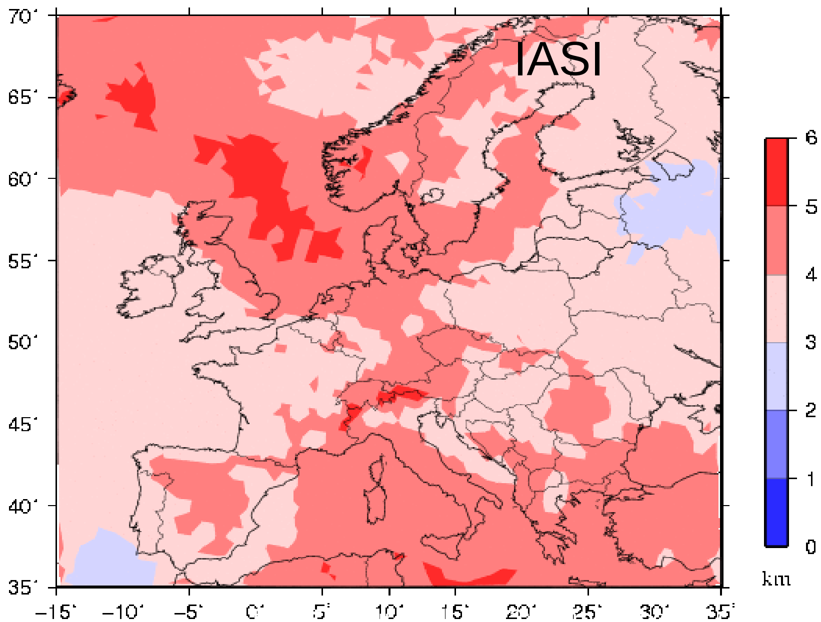
  But with links with Eumetsat, with ISSWG, with Sentinel 5 etc…

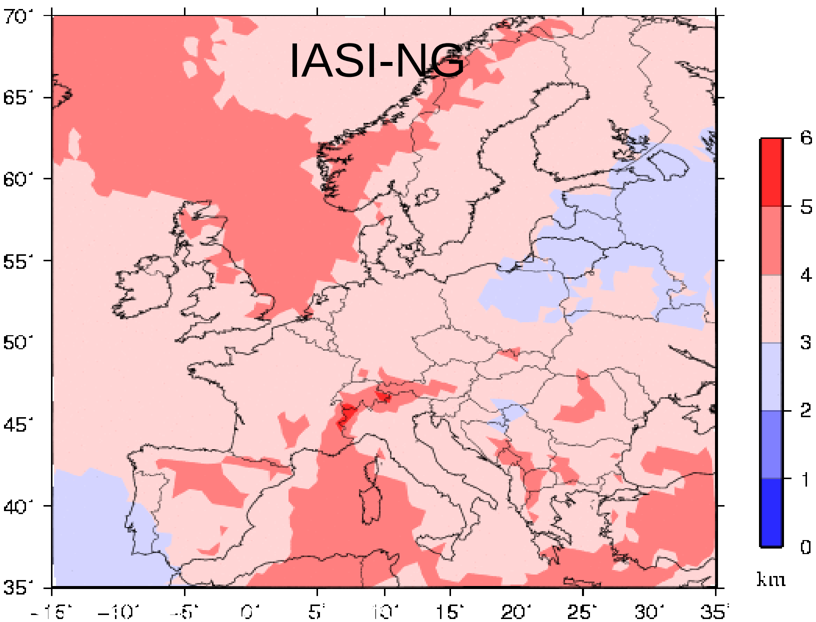
- **10 meetings during phase A**
  - **Well informed of the progress**
  - **It performed consolidation studies**
    - About needs and requirements
    - About expected performances of Level 2 or + products
    - For trade-off in the requirements for Phase B
  - **It contributed to decision making**
    - Presentation at User consultation meeting (Darmstadt)
    - Document to TOSCA

Impact of IASI-NG :performances at Level 2
Example 1 : O_3



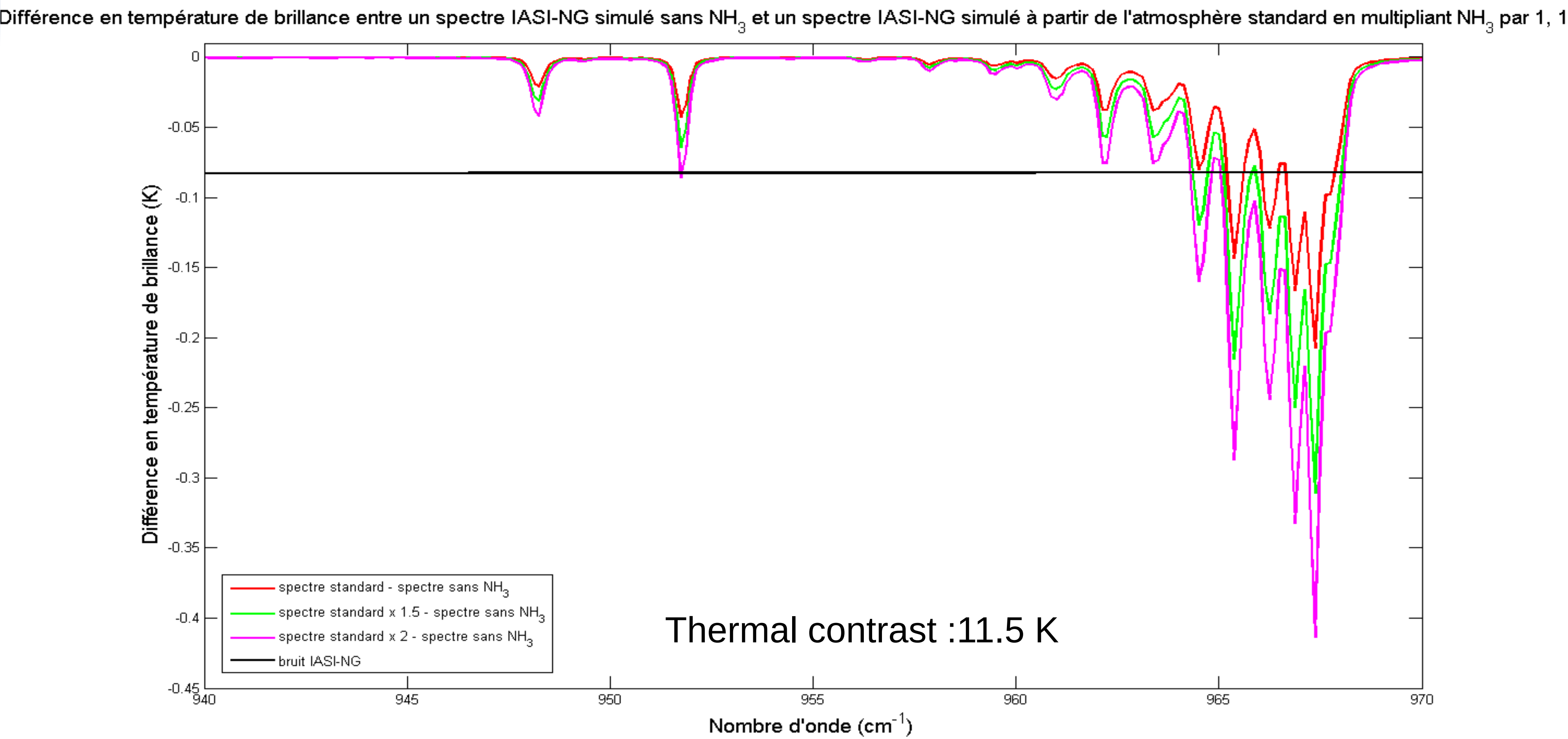






Courtesy : G. Dufour

Impact of IASI-NG :performances at Level 2
Example 2 : NH_3



Thermal contrast :11.5 K

Courtesy : J. Hadji-Lazaro

Resources specifications for IASI-NG Phase A studies

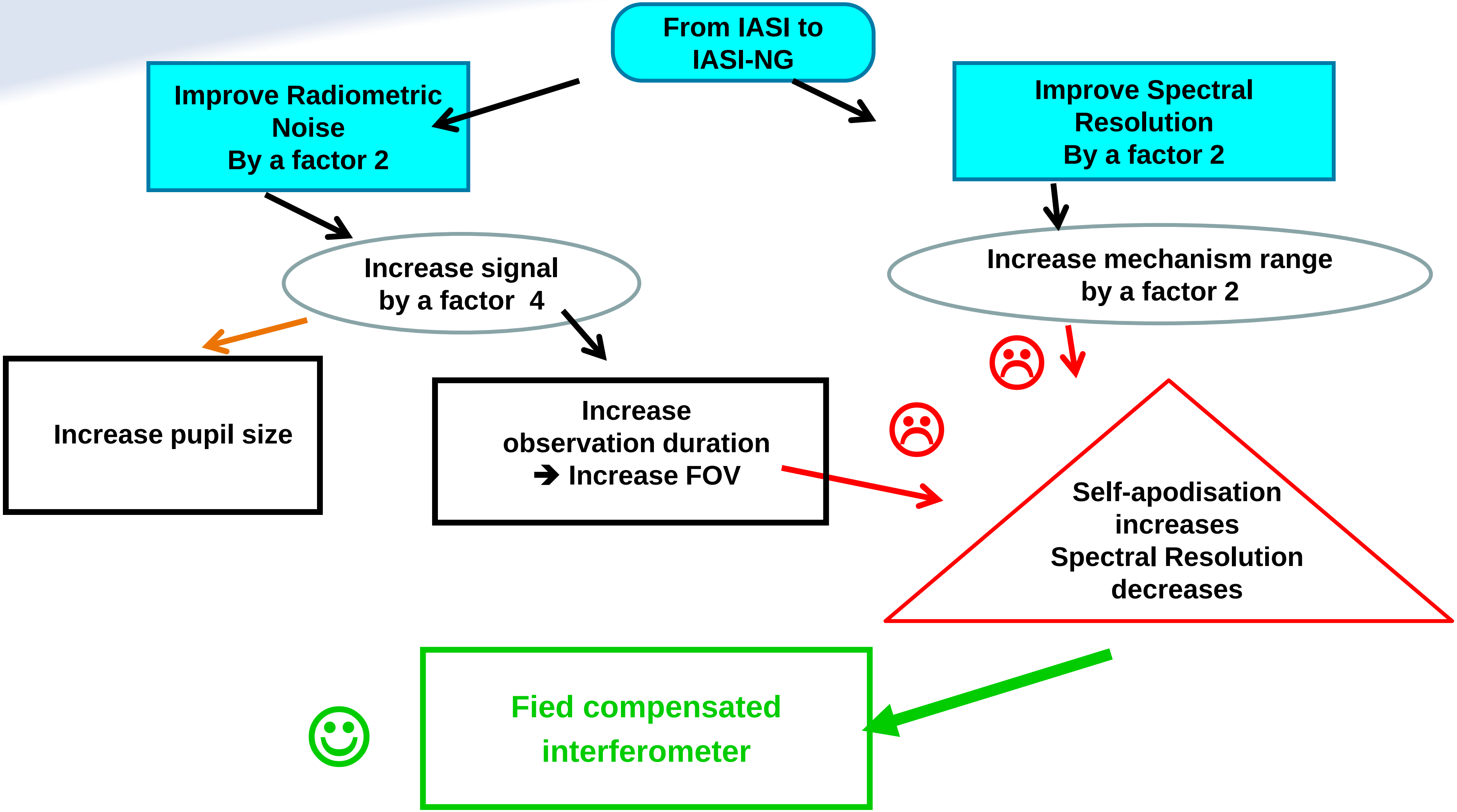
- ***MASS***
  - IASI = 235 kg
  - IASI-NG spec : 350 kg (including 20% margin)
- ***VOLUME***
  - IASI : one sensor module + deported IMS/DPS inside the satellite ==> total = 1.7 m^3
  - IASI-NG spec :1500 mm x 1500 mm x 1200 mm
- **POWER (EOL):**
  - IASI = 240 W
  - IASI-NG spec : 500 W (including 20% margin)
- **TM DATA RATE:**
  - IASI : 1.5 Mbit/s
  - IASI-NG spec : 6 Mbit/s

These requirements were given to 2 industrial companies for the phase A feasibility studies (competitive studies).

Instrument specifications in phase A

- Based on MRD breakthrough + additional requirements e.g. about pseudo noise.
- Pseudo noise allocation derived from IASI requirements
  - Main noise provided by detection chain (NeDT)
  - Instrument defaults (ISRF shape, centroid, PSF, …) specified as pseudo noise
    - Each default shall not represent more than 25% of the NeDT (globally each default contribute to few percent of the global performance) for homogeneous scenes
    - Default impact only heterogeneous scene has been sized to 50% of the NeDT
- Definition of typical heterogeneous scenes
  - At sounder pixel level : two half field with 10 K difference
    - Direct impact on heterogeneous scenes (sized to 50%)
  - At instrument field of view : one sounder pixel clear, the other part of the field is cloudy
    - Potential impact on homogeneous scenes (sized to 25%)

How to improve IASI performances for IASI-NG?



Overview of IASI-NG Phase A/B1 studies

- **2 competitive industrial studies started early 2010 and finished early 2012 :**
  - 2 x 3 instrument types first studied (all Fourier Transformed spectrometer with Field Compensation interferometers but with various types of field compensation)
  - Then each company focused on its best solution (choice based on the following criteria: performances, resources, schedule, risks, costs).
  - Feasibility and design optimization studies were then consolidated during 2 years
  - These deeper studies allowed to consolidate resources budgets and optimize cost evaluation
  - These studies were completed by risk reduction activities on the most sensitive/innovative points (pre-development, mock-up, test, simulation…).

Both industrial concepts have been considered feasible at the end of the phase A studies, by the CNES project team and an independent review board.

Analysis of IASI-NG Phase A results by MENINGE group

- A few potential non-compliances to phase A IASI-NG Instrument requirements at the end of phase A studies have been analyzed by MENINGE group:
  - Local NeDT non compliance
  - Absolute radiometric calibration above 2400 cm^{-1}
  - Spectral/spatial co-registration requirements
  - Absolute spectral calibration

These few non-compliances at instrument level are fully acceptable at mission level.

Résultats Etudes MENINGE
(profils verticaux T, humidité et optimisation bandes B2-B3…)

Trade-off for the limit B2/B3
Results from a study by MENINGE

- **Known lines in this spectral range?**

  H_2O and isotopologues, <u>NO</u>, NO_2, NH_3, PH_3, OH, <u>OCS</u>, C_2H_2 ,C_2H_4, HCN, COF_2

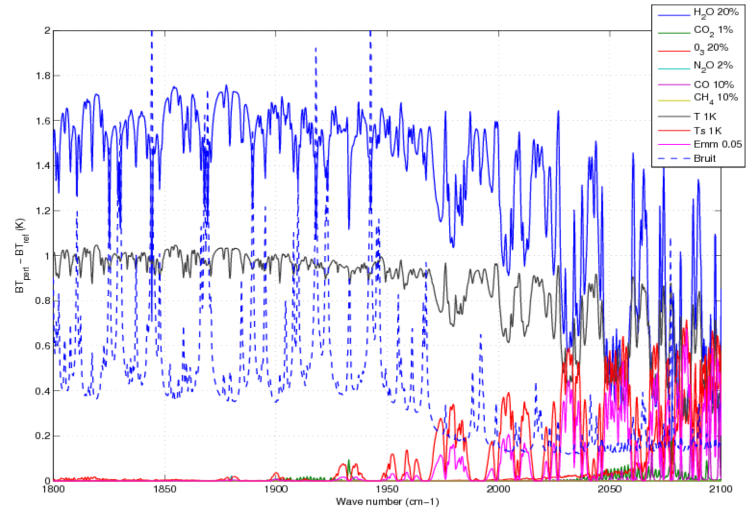
- **Who are the users?**

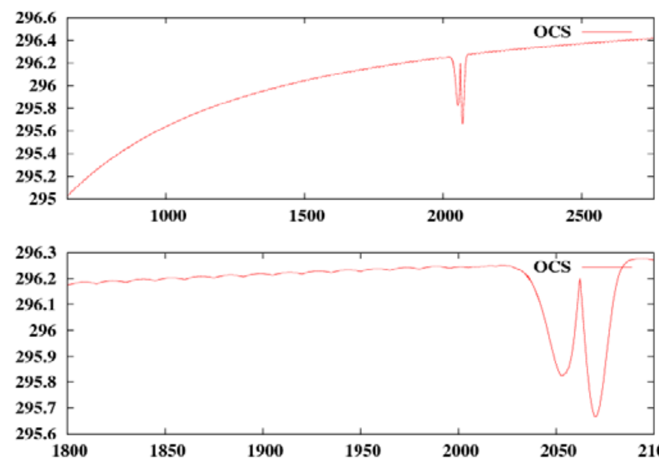
Sometimes used to inverse H_2O

- **What is the impact of radiometric noise?**

  For NO (1950 cm^{-1}) signal too weak to be detectable except after averaging (=> noise lowered down). Noise can potentially impact OCS retrieval (2035-2040 cm^{-1}).

- <u>Conclusion</u> : Noise slightly above the current requirement is acceptable. It could allow a small shift of the band limit (not higher than 2030 cm^{-1})



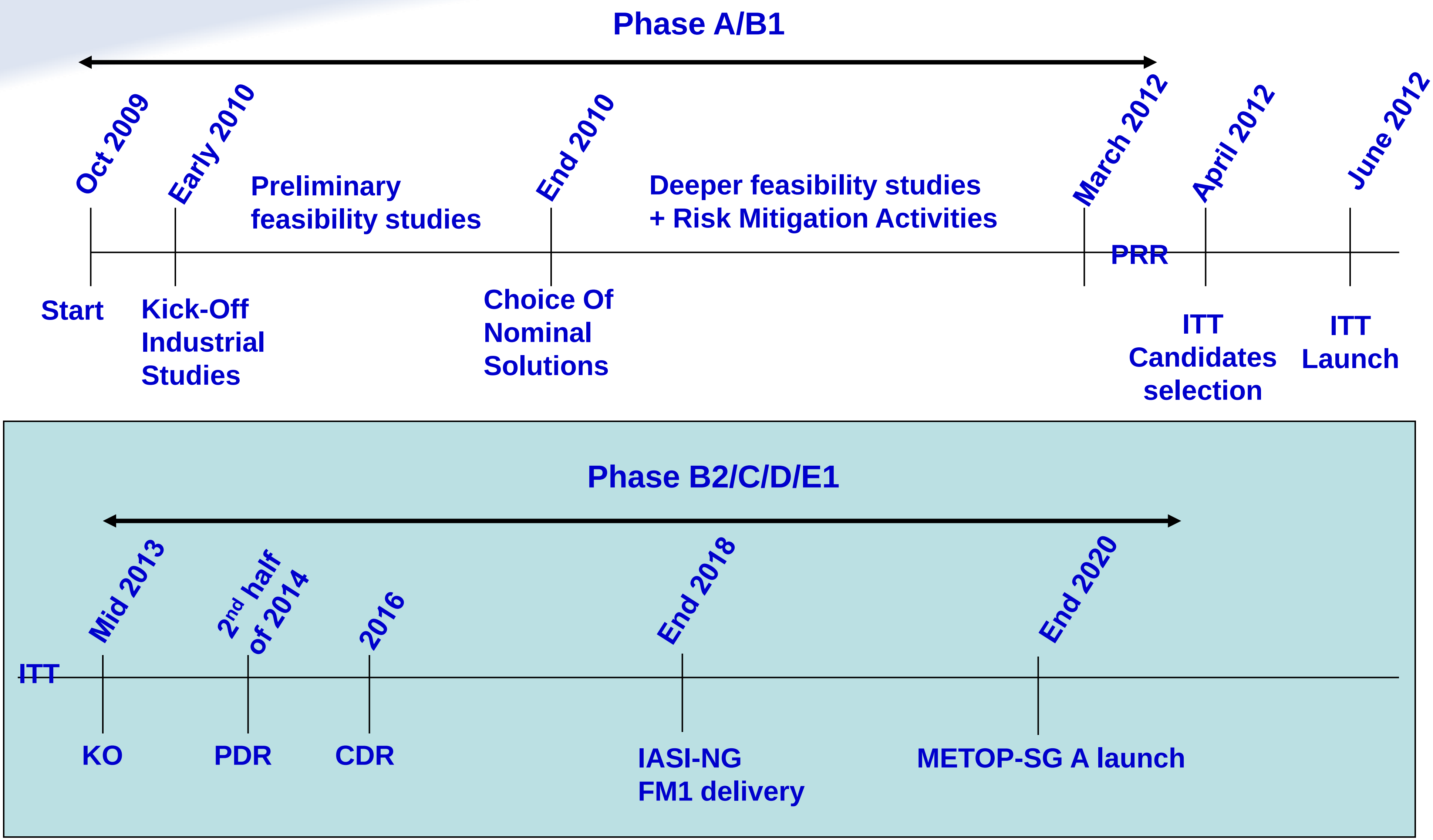


Recent Progress of IASI-NG project

- Two feasible industrial solutions fully compliant with the IASI-NG mission requirements have been studied and are proposed for phase B-C-D-E.
- MENINGE group and EUMETSAT EPS-SG project confirmed the acceptability of the IASI-NG expected performances
- CNES commitment in April 2012 to provide IASI-NG instruments to EUMETSAT for the EPS-SG program
- IASI-NG ITT for B-C-D-E phases launched inJune 2012
(after an update to new interface requirements evolutions coming from ESA following the MetOp-SG PRR).
Only 2 candidates (the 2 industrial companies who worked on the IASI-NG Phase A).
- Presentation to ISSWG which will become the Mission group for IASI-NG
- Cooperation agreement between CNES and EUMETSAT prepared for signature

Selection of the best industrial proposal for B-C-D-E phases on going

IASI-NG Schedule



Next steps for the project and for scientific activities

- Choice of Manufacturer and concept shortly
- Start of phase B in fall 2013.

- Meeting of MENINGE group
- Science plan for IASI-NG tb established by ISSWG
- Start studies of ISSWG

- Final agreement btw CNES and EUMETSAT

- Studies on synergy with Sentinel 5 and other instruments

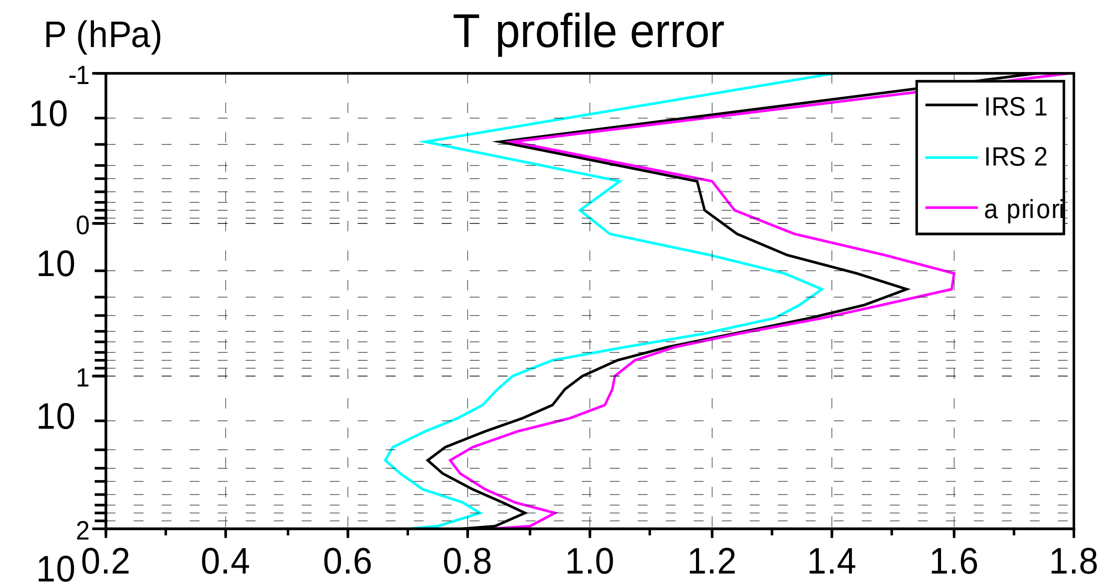
- Approval of EPS-SG programme by EUMETSAT Council mid 2014

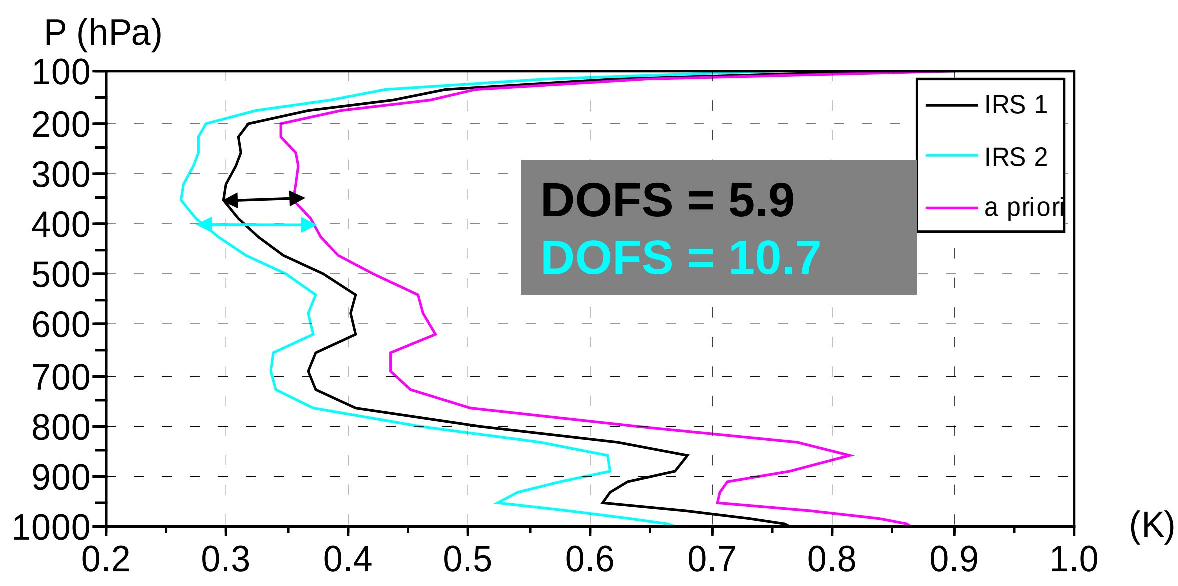
Back-up slides

Temperature profile sounding

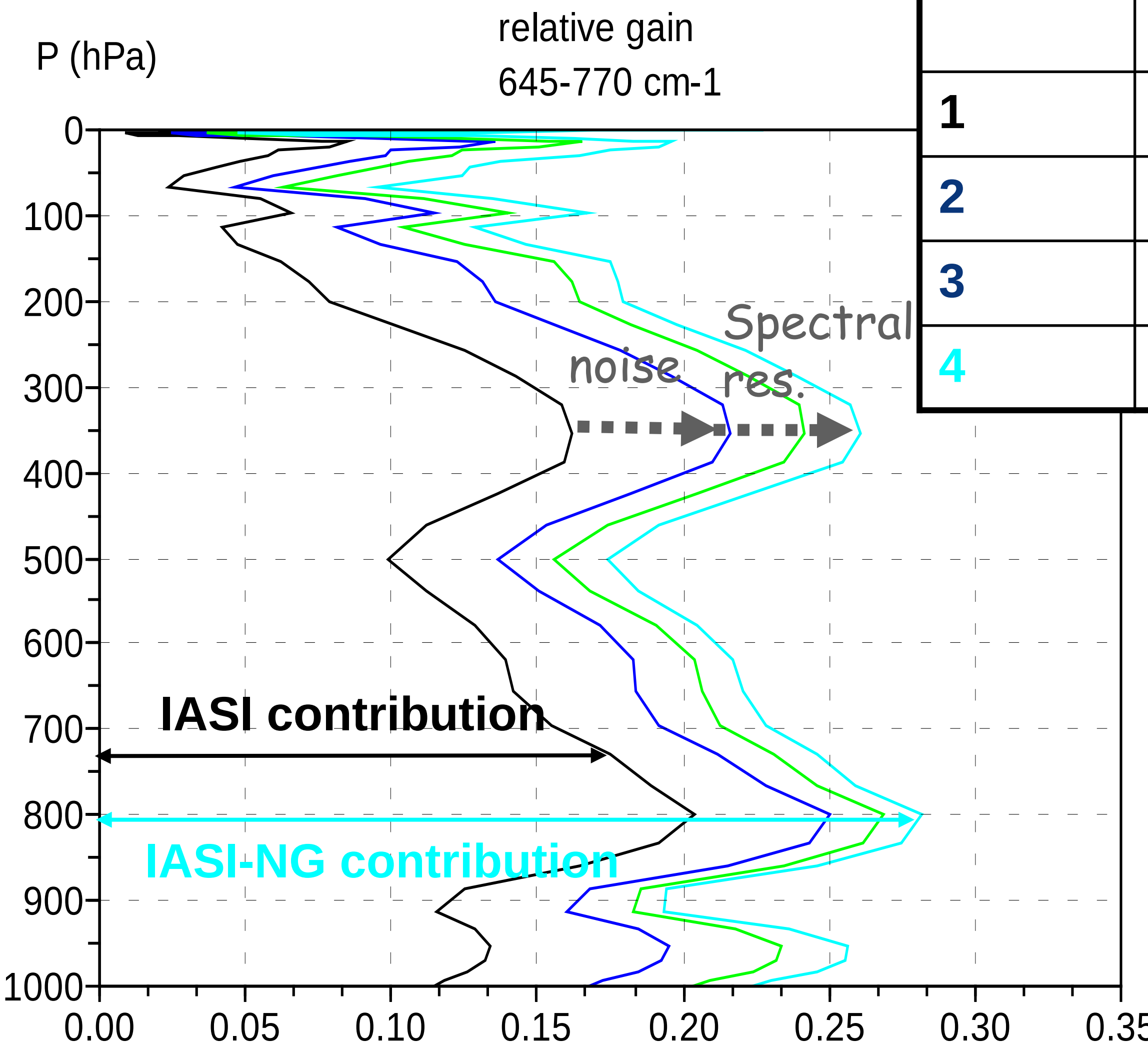
- **Profile retrieval using the 15 µm and 4 µm CO_2 bands**
- **Tropical atmosphere**
- **Noise contribution from uncertainties on surface temperature and emissivity, humidity profile.**
- ***A priori* covariance from ECMWF**

- **With respect to *a priori* uncertainty, IASI-NG contribution is about twice IASI contribution**





Temperature profile sounding : effect of spectral resolution



	Noise	Spectral resolution
1	IASI	IASI
2	IASI/2	IASI
3	IASI/(2√2)	IASI
4	IASI/2	IASI/2

- The relative gain (or error reduction) is defined as
  (*a posteriori*-*a priori*)/(*a priori*)
- It is in the range 5 - 25%.
- Spectral resolution improves the instrument contribution, beyond noise reduction by increasing the number of channels (√n)

Atmospheric chemistry : CO profile (2140-2180 cm^{-1})

	MRD threshold	MRD breakthrough	IASI	IASI-NG reference	IASI-NG with cold bench
Spectral resolution (cm^{-1})	0.15	0.1	0.5	0.25	0.25
Spectral sampling (cm^{-1})	0.124	0.083	0.25	0.125	0.125
NeDT (K)	0.15	0.1	0.28	0.16	0.12
DOFS	**2.84**	**3.78**	**1.88**	**2.51**	**2.69**
Tropospheric column (0-12 km) (%)	**2.14**	**1.95**	**3.39**	**2.24**	**2.15**
Boundary layer (0-3 km) (%)	**10.2**	**7.8**	**16.05**	**10.7**	**10.1**

IASI instrument is not sufficient to provide a vertical profile (less than 2 DOFS). IASI-NG, though not meeting the level 1 requirements, is close to the threshold level 2 performances (especially for the cold bench configuration).

Atmospheric chemistry : CH_4 column (1280-1360 cm^{-1})

	MRD threshold	MRD breakthrough	IASI	IASI-NG
Spectral resolution (cm^{-1})	0.3	0.15	0.4	0.2
Spectral sampling (cm^{-1})	0.248	0.124	0.25	0.125
NeDT (K)	0.2	0.1	0.1	0.05
Total column (%)	**13.1**	**6.9**	**9.9**	**4.6**

- **The CH_4 column can be retrieved with a precision in agreement with the MRD threshold (resp. breakthrough) from IASI (resp. IASI-NG) observations.**

IASI-NG : radiometric and spectral improvements

Different trade off's during Phase 0 done only for dynamic FTS

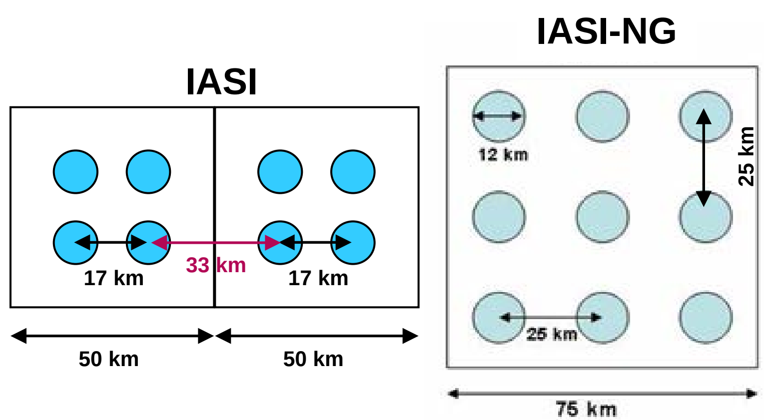
Radiometry

- Entrance *pupil diameter* Increase (→flux):
  - IASI-NG = 120 mm versus IASI = 80 mm
- Instrument *Field of view* Increase (→integration time):
  - IASI-NG = 75 km×75 km (9 pixels) versus IASI = 50 km×50 km (4 pixels) ➔ acquisition duration for each interferogram = 450 ms versus 150 ms for IASI
- Detectors *temperature* reduction (active cooling)
  - IASI-NG T detector < 65 K versus IASI = 92 K

Spectral resolution

Optical Path difference increase by factor 2:

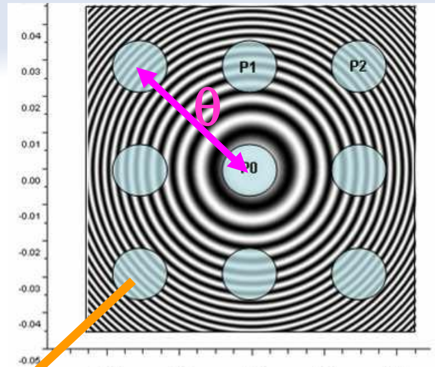
- single sided interferometer
  - one mobile cube having the same IASI stroke
  - TWO mobile cubes having the IASI stroke / 2
- double sided interferometer
  - one mobile cubes having the IASI stroke x 2
  - TWO mobile cubes having the same IASI stroke



BUT: «self-apodisation»

For the spectral resolution, both the Optical Path Difference AND the self-apodisation must be improved.

IASI-NG : the self-apodisation issue

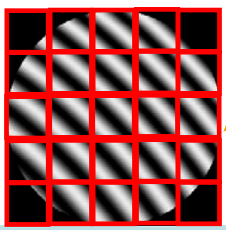


IASI-NG: Optical signal in the detectors plane for ν=2760 cm^{-1} and OPDmax=4 cm

The use of IASI like pixel acquisition concept is not possible. Two options has been studied.

Split the sounder pixel into many smaller pixels
→ Matrix detectors

Sounder pixel



- **For each of the 9 sounding pixel, acquisition of sub-pixels interferograms (typically 5x5 sub-pixels), then combination of the interferograms by resampling at "constant" OPD + filtering to generate one sounding pixel interferogram**
- **Final Self-apodisation for the corner pixels = IASI one**

Suppress/mitigate the self-apodisation effect
→ self-apodisation compensation

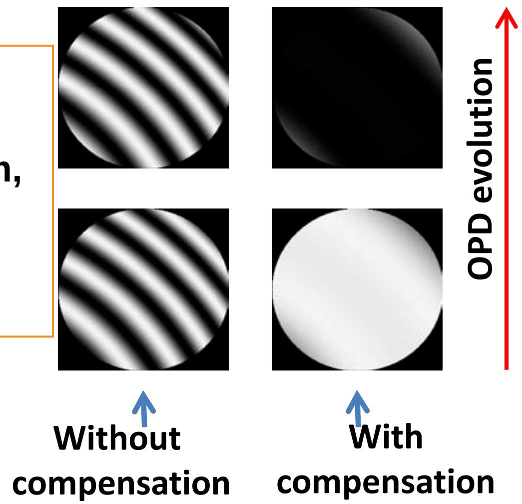
- **Introduce, in the interferometer, a specific mechanism that works in synchronization with the Corner Cube Mechanism and that corrects, for each sounding pixel (but the center one), the Optical Path Difference by :**
$\delta_O (1 - \cos\theta)$, where δ_O is the OPD for a zero field → ALL the pixels should have a similar behavior than the central pixel

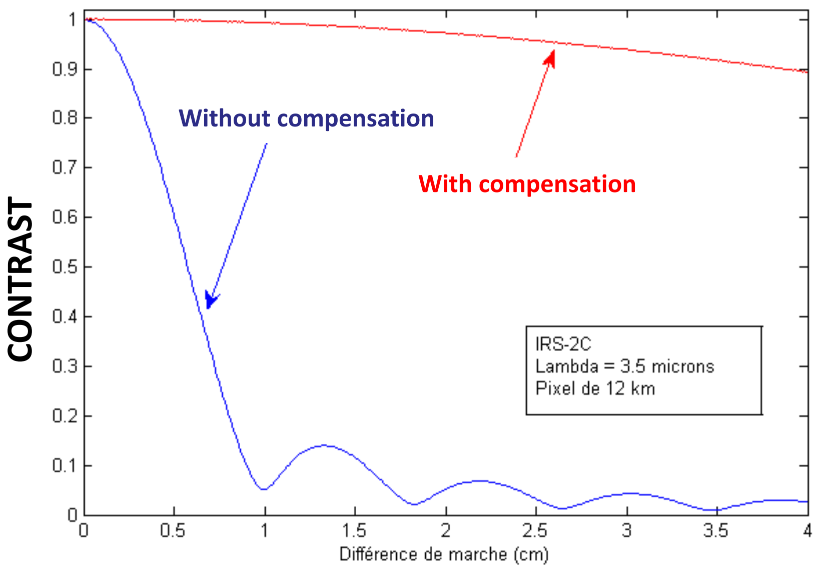
IASI-NG CNES Phase 0
Reference option

IASI-NG : Self-Apodisation compensation option

Optical simulation with and without active optical field compensation

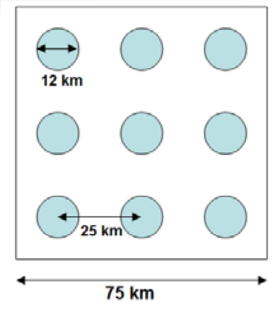
Evolution of a corner pixel optical signal for monochromatic ray at 4 µm, for OPD variation of 1 µm, (between max and min signal (λ/4)) at OPD of 4cm





IASI-NG : *Baseline characteristics (CNES phase 0)*

- Ground Pixel diameter of 12 km (=IASI)
- Ground sampling of 25 km (both axis)
- Number of sounder pixels per acquisition = 9 (IASI=4)
- Number of earth view per line = 20 (30 IASI)
- Interferogram acquisition duration = 450 ms (IASI=150 ms)



- Inlet PUPIL = 120 mm (IASI=80 mm)
- Focal plane :
  - **4 bands (IASI=3)**
  - **9 sounder pixels per band (IASI=4)**
  - **PV detectors for all bands (IASI PC for B1; PV for B2/B3)**
  - **detectors cooled at 65 K with one active cooler (LPTC) (IASI=92 K passive)**
  - **IASI like cold optic concept**