Validation of IASI level 1 and level 2 products using IASI-balloon

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Outline
IASI-ballon
Spectral calibration of IASI-balloon
Flight IASI05 on Feb. 2007 from Esrange
Radiometric calibration
Geolocation and PTU soundings
Retrievals
Summary

IASI-balloon in support to IASI calibration and geophysical validation

Why IASI-balloon ?

1) A balloon-borne instrument with the IASI spectral coverage and similar (or better) performances in term of resolution and/or signal to noise is useful and important for the scientific preparation of the IASI mission. CNES has been supporting the development of this experiment within the IASI programme

2) IASI-balloon from a stratospheric gondola at 35 km has a similar observing geometry as IASI on MetOp (small atmospheric correction for the atmosphere between 35 km and MetOp altitude)

3) Test of instrument algorithms (radiometric calibration, non-linearity, …)

4) Radiative transfer studies and validation of the spectroscopy of atmospheric constituents

5) Test of inversion algorithms

6) Validation campaigns during the commissioning phase of IASI/MetOp and other mid to long term validation and/or scientific campaigns

Objectives for the validation of IASI

1) In coincidence with an overpass of MetOp, use IASI-balloon and companion instruments on the same payload for validating level 1b spectra of IASI-MetOp :
   - spectral calibration
   - instrument line shape
   - radiometric calibration

2) Use the balloon spectra for validating level 2 products of EPS:
   - T and H_2O profiles
   - O_3 profiles
   - CO, CH_4 and N_2O columns
   - surface emissivity
   - clouds (IR imager)

3) Obtain auxiliary information from independent meteo and ozone sounding in the vicinity of the launching site and from ground based measurements

Method

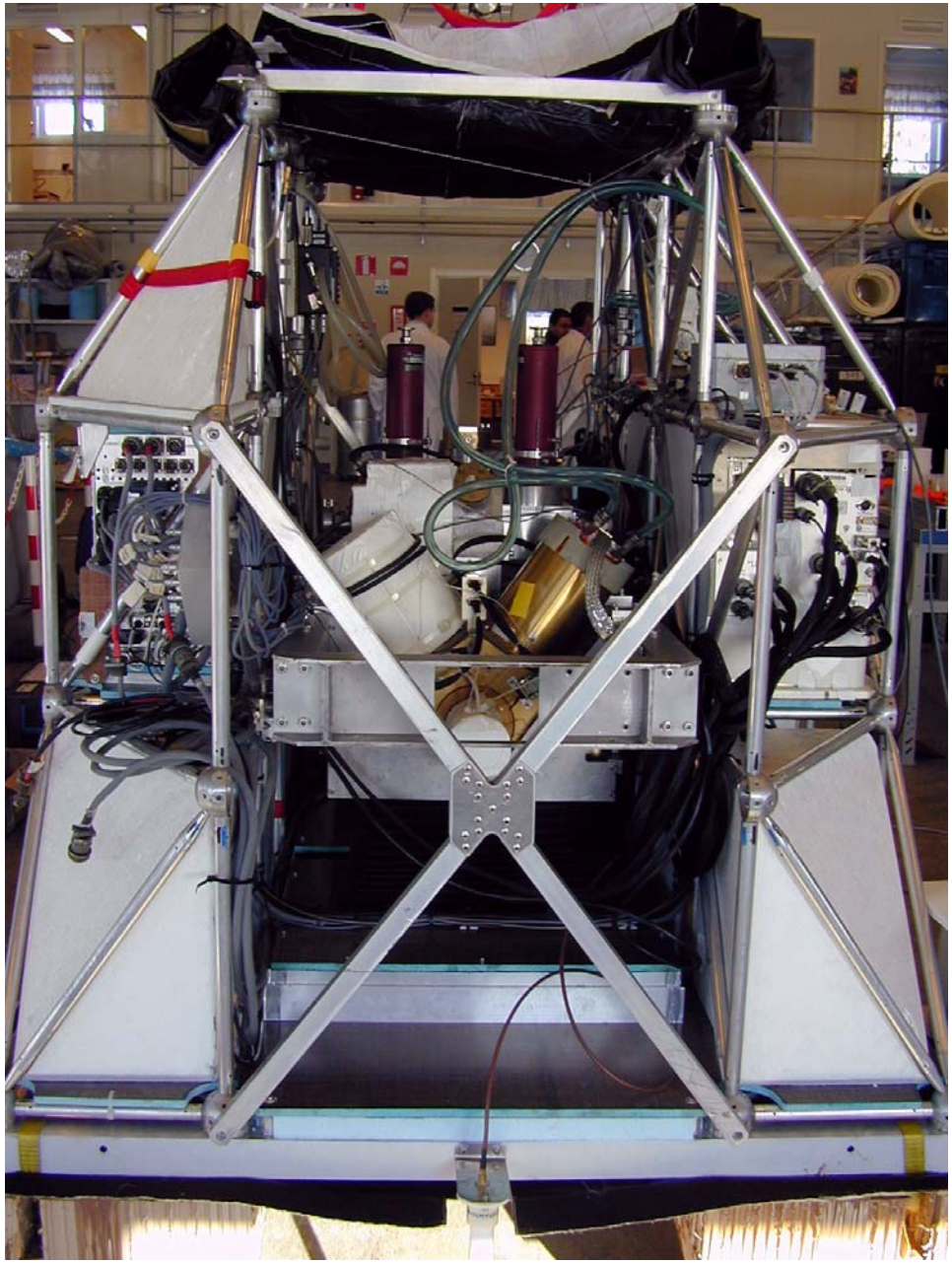
1) For level 1B spectra in short loop with the TEC (Technical Expertise Centre) in CNES, Toulouse:
   - generate IASI-like spectra by degrading IASI-balloon spectra
   - compare them with IASI-MetOp

2) For level 2 products:
   - compare EPS products with retrievals from IASI-balloon and IASI-like spectra
   - use the same retrieval algorithms on standard IASI-MetOp level 1c spectra

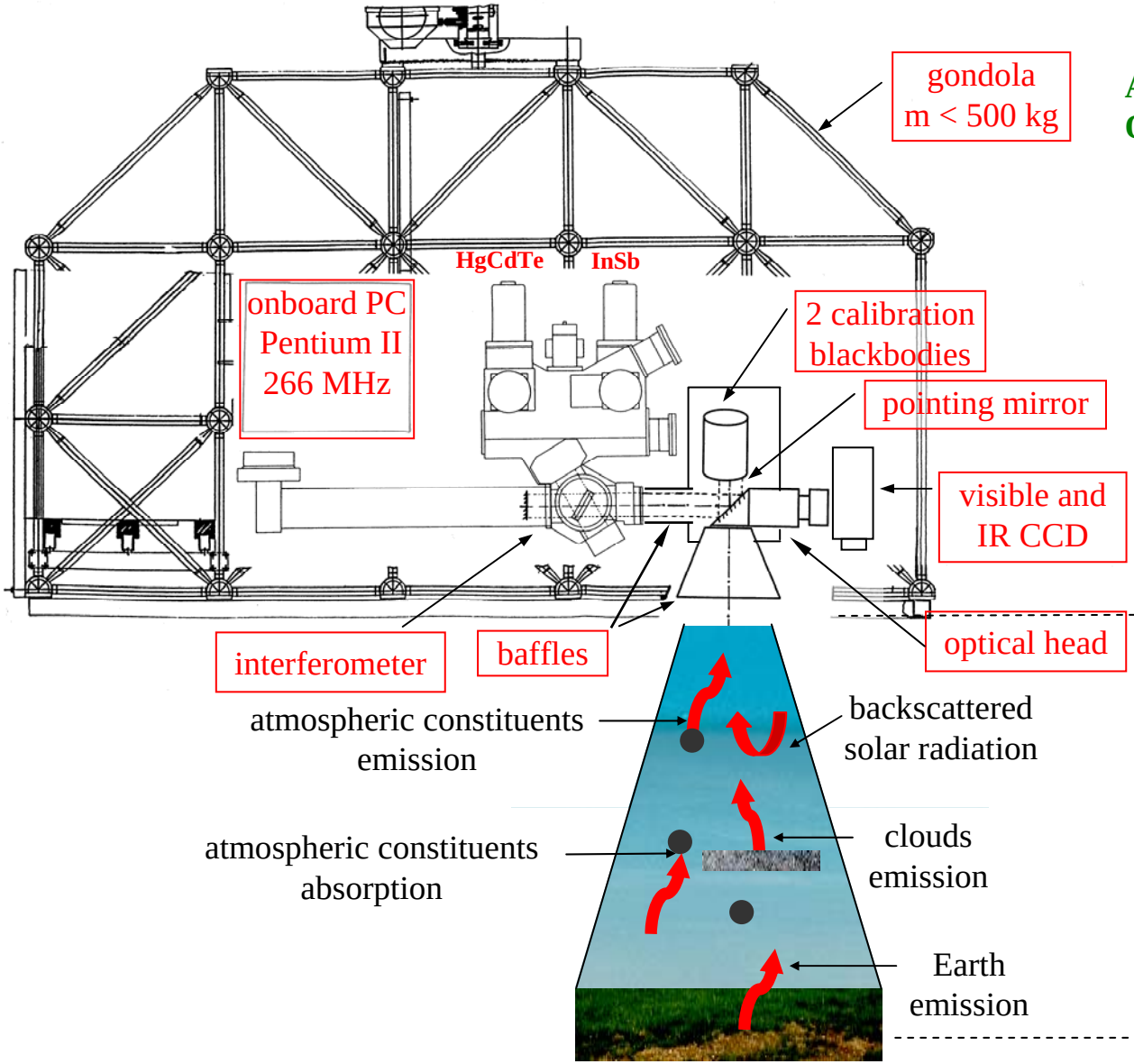
3) Provide the best atmospheric state for the time/location of the balloon-satellite coincidence

IASI-balloon experiment

Mass : **456 kg**



Emission configuration : Infrared Atmospheric Sounding Interferometer-balloon (IASI-balloon)



Apodised resolution = 0.1 cm^{-1}
OPD = 10 cm

Atmospheric layers sounded by IASI-balloon

≈ 33 km (at float)

Thermal emission in nadir sounding

≈ 0 km (ground)

IASI-balloon instrument flights

IASI01	*13 March 2001*	*Kiruna (Sweden)*	*Technological flight*
IASI02	*5 August 2002*	*Kiruna (Sweden)*	*SCIAMACHY validation*
IASI03	*30 June 2005*	*Teresina (Brazil)*	*Envisat validation* *REFIR (IFAC) on board*
IASI04	*1 March 2006*	*Kiruna (Sweden)*	*Rehearsal of IASI validation*
IASI05	*22 Feb. 2007*	*Kiruna (Sweden)*	*IASI MetOp validation*
IASI06	May. 2008	Teresina (Brazil)	IASI MetOp validation mini-lidar + mini-DOAS on board

IASI-balloon characteristics

- Two detector output optics :

  HgCdTe 600-2000 cm^{-1}

  InSb 1900-3000 cm^{-1}

- Nominal OPD for emission measurements :

  d = 10 cm → apodised resolution = 0.1 cm^{-1}

  (d_{max} = 50 cm used in solar absorption)

- Two onboard black body (BB) cavities

  Warm BB 20°C nominal

  Cold BB -20°C nominal

(Their temperature can be adjusted during flight depending on the thermal environment)

- Duty cycle : 1 min 25 s

  1 cold BB $\Delta\tilde{\nu}$ =1 cm^{-1} 8 scans : 20 s

  1 scene $\Delta\tilde{\nu}$ =0.1 cm^{-1} 8 scans : 55 s

  1 warm BB $\Delta\tilde{\nu}$ =1 cm^{-1} 4 scans : 10 s

- IFOV = 0.9° (FWHM of Gaussian IPSF),

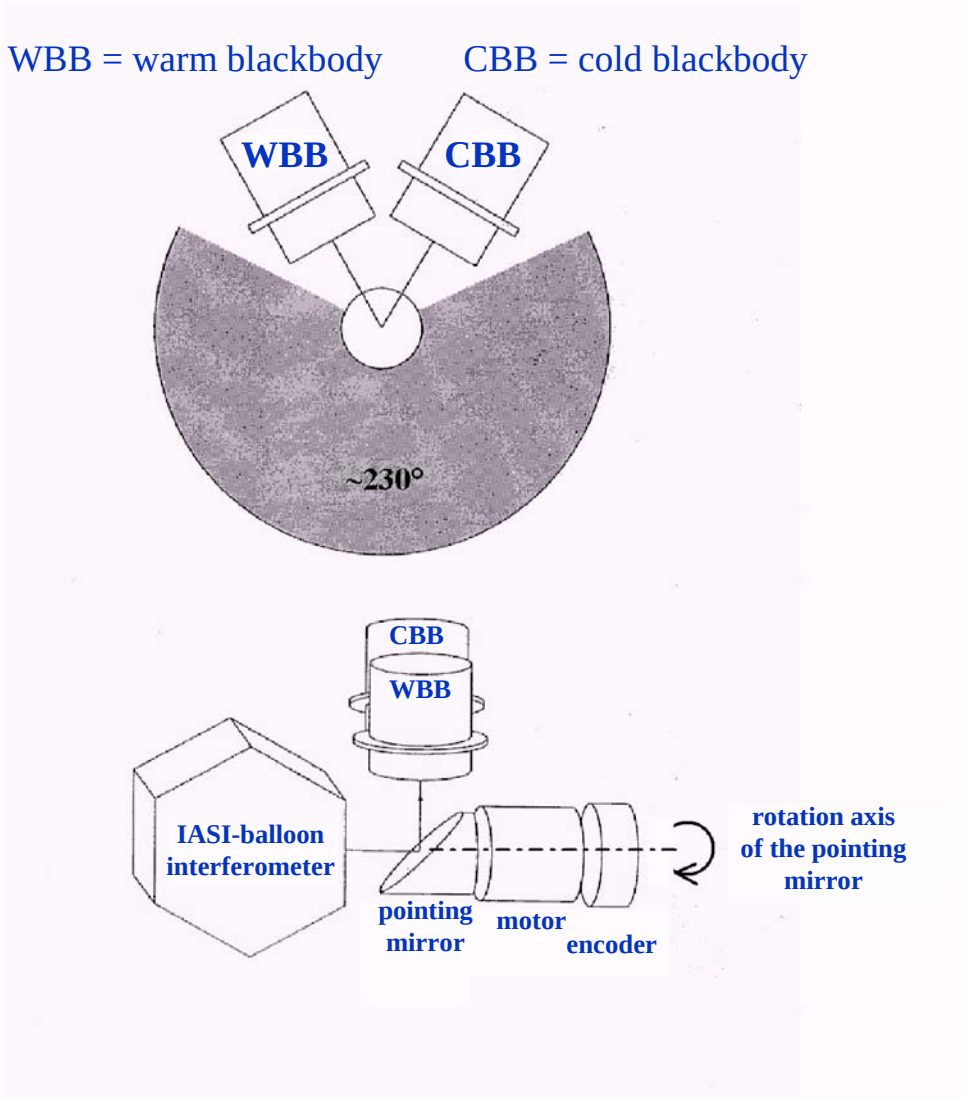
  possible pointing ± 25° within the nadir direction.

  Foot print ~ 600 m (depending on balloon altitude)

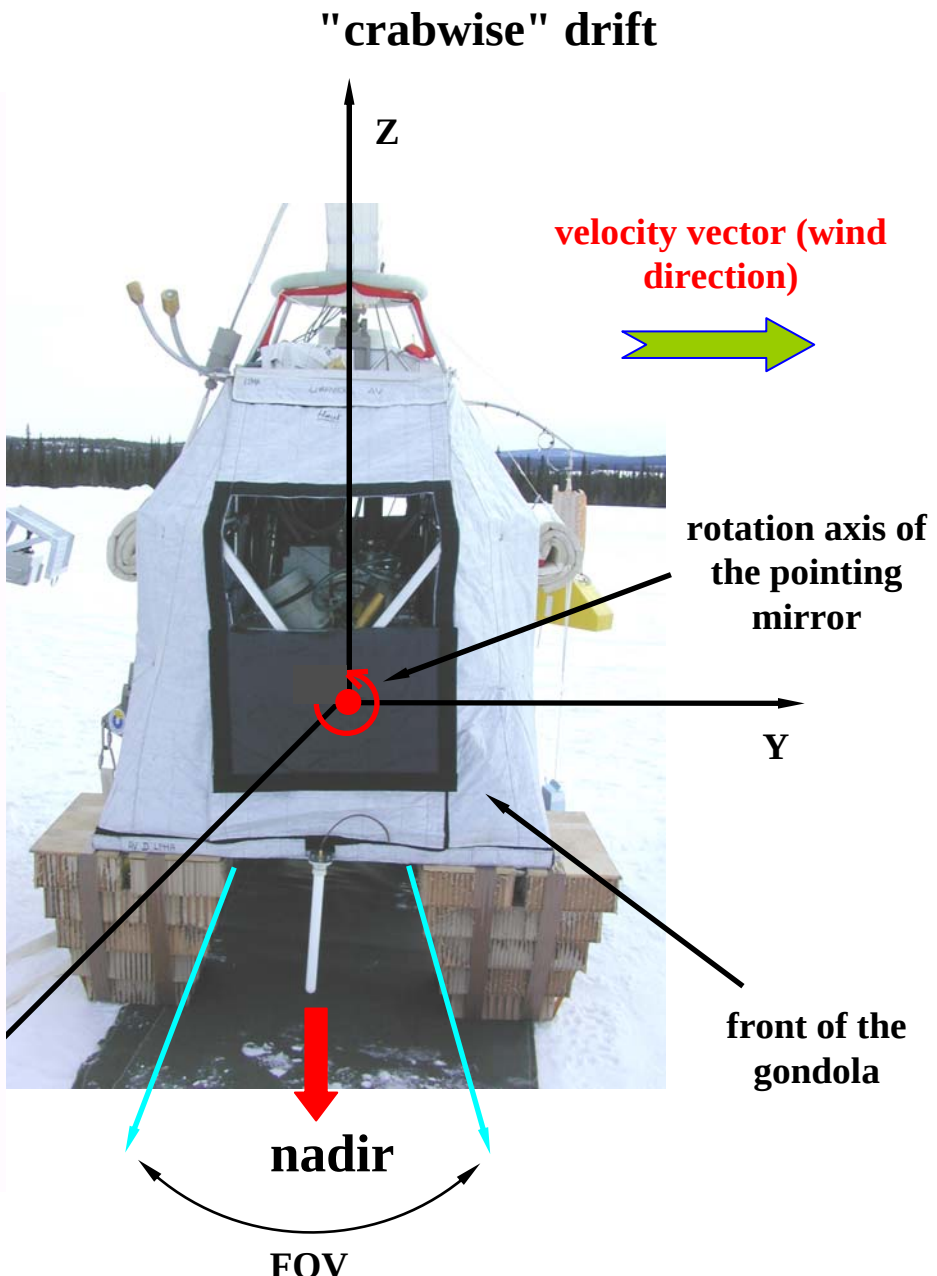
- 1 visible CCD imager (3 km × 15 km) and 1 IR camera (3 km × 15 km)

Optical head

- Rotation of the pointing mirror



Compensation of the gondola movement



Spectral calibration of the IASI-balloon spectra

Global spectral calibration of the IASI-balloon spectra

- Sampling of the interferogram using a stabilized He-Ne laser
- Spectral shift introduced by optical misalignment

- Theoretical lines of HITRAN 2004
- 10 lines of CO_2 [728 to 752 cm^{-1}] for the HgCdTe channel
- 5 lines of CO_2 [2050 to 2057 cm^{-1}] and 5 lines of CO [2150 and 2170 cm^{-1}] for the InSb channel

- Lines position in the IASI-balloon atmospheric spectra after interpolation
- Determination of the laser frequency shift $\Delta\tilde{\nu}_L$:

$$\Delta\tilde{\nu}_L = \tilde{\nu}_L \left(\frac{\tilde{\nu}_{obs} - \tilde{\nu}_{Hitran}}{\tilde{\nu}_{Hitran}} \right)$$

- After the spectral shift correction, a new verification with the same algorithm will give a new shift very close to zero

ANA : individual spectral calibration of the IASI-balloon spectra

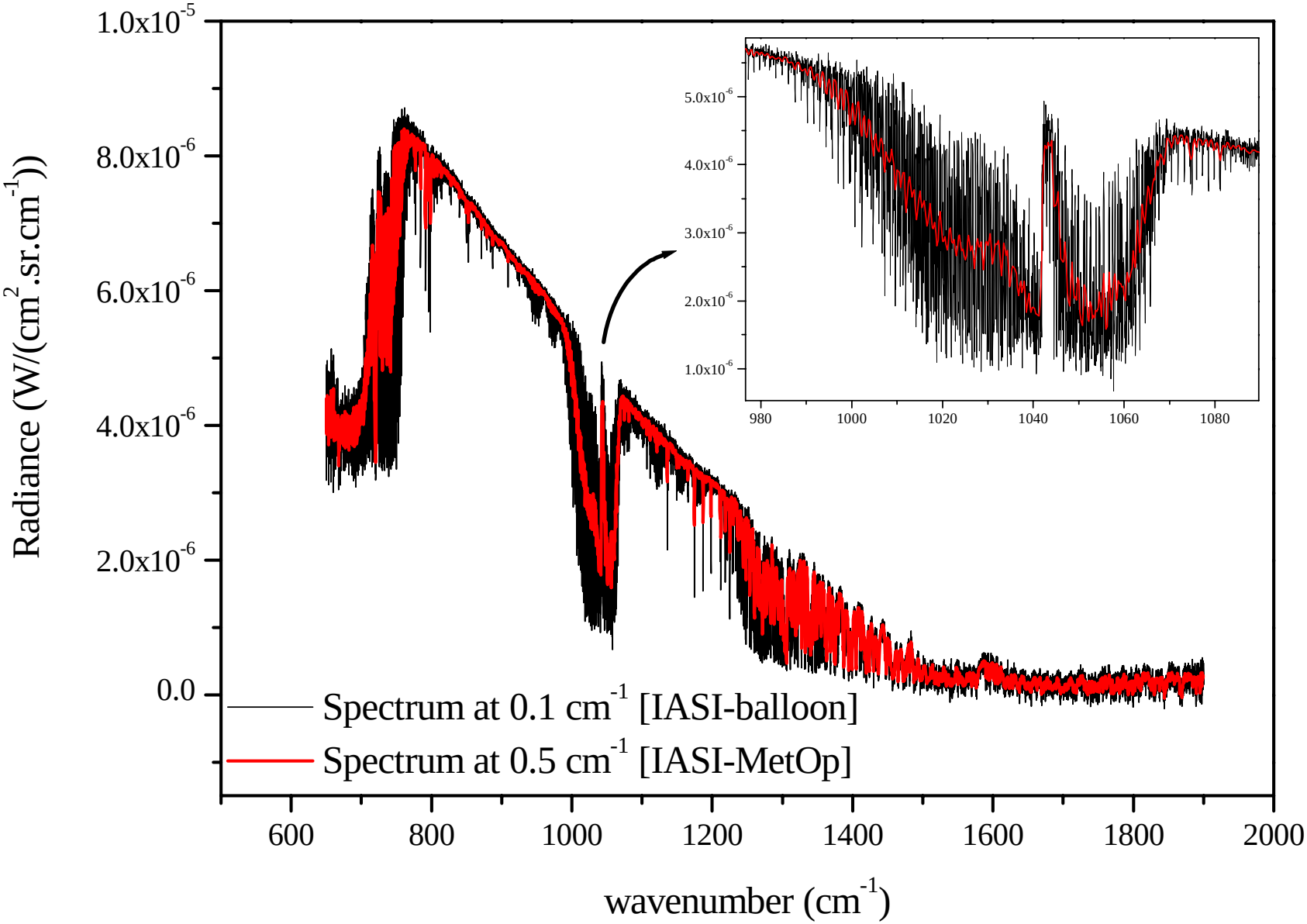
◈ Each individual spectrum (index n), is compared to a reference atmospheric spectrum y_0 obtained by a radiative transfer forward model using the best *a priori* atmospheric state

◈ Using this analytical method on 4 micro-windows for each channel HgCdTe or InSb (relatively narrow and non-saturated atmospheric lines) we determine a mean scaling factor for each spectrum ε_n

◈ After this individual spectral calibration, spectra are interpolated and resampled on a fixed wavenumber grid (step = 0.05 cm^{-1})

The absolute wavenumber accuracy for generating IASI-like spectra, is about 3×10^{-6} (consistent with the specification of 2×10^{-6} for IASI-MetOp L1c spectra)

Spectral calibrated spectrum at IASI-MetOp resolution provided to the Technical Expertise Centre



Flight IASI05 from Esrange (Kiruna, Sweeden)

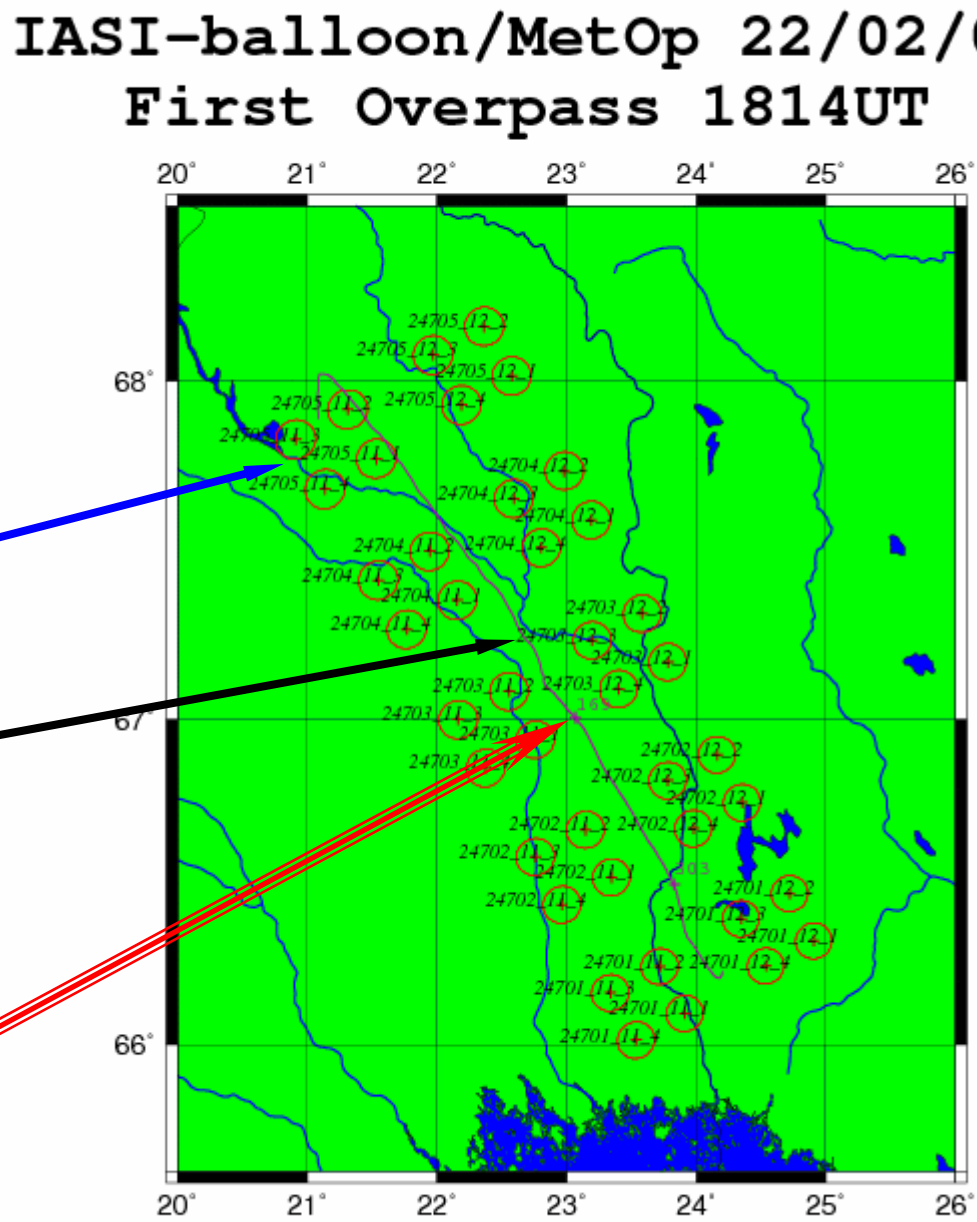
Date of the flight 22 Feb. 2007

Payload : IASI-balloon + infrared camera

Conditions : very cold, within the vortex

Footprints of IASI-MetOp and trajectory of IASI05 flight [1/2]

22/02/2007



IASI-MetOp footprints

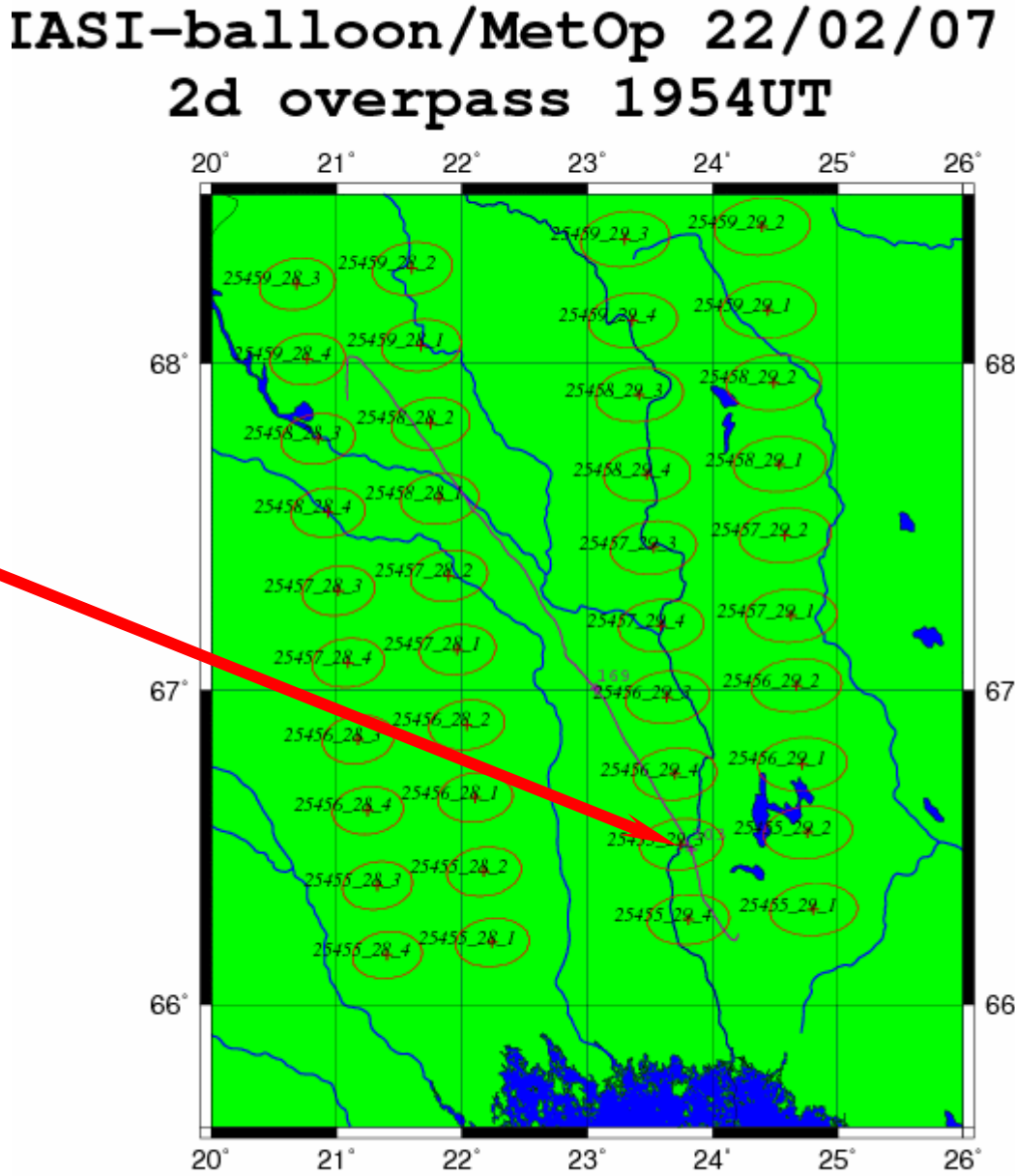
Trajectory of IASI-balloon

First overpass at 18:14 UT (distance ~ 10 km)

Footprints of IASI-MetOp and trajectory of IASI05 flight [1/2]

22/02/2007

Second overpass at 19:54 UT (coinciding footprints)



Radiometric calibration of the IASI-balloon spectra

Instrument problems occurred during IASI05

◈ Breakdown of the Thermalogic board which controls and stabilizes the two on board blackbody temperatures used for the radiometric calibration (during the preparation of the flight IASI05)

- Patch with a custom-made electronic board (temporary card) which reads the two blackbody temperatures (Pt100)
- The control of the temperatures was performed by the gondola housekeeping on board PC (CNES Nacelle Pointée)

◈ IASI05 flight in extremely cold conditions, the cooling system of the cold blackbody froze during flight ascent

- Use of another internal source of calibration in the limb view

◈ After return of the instrument at LPMAA in Ivry :

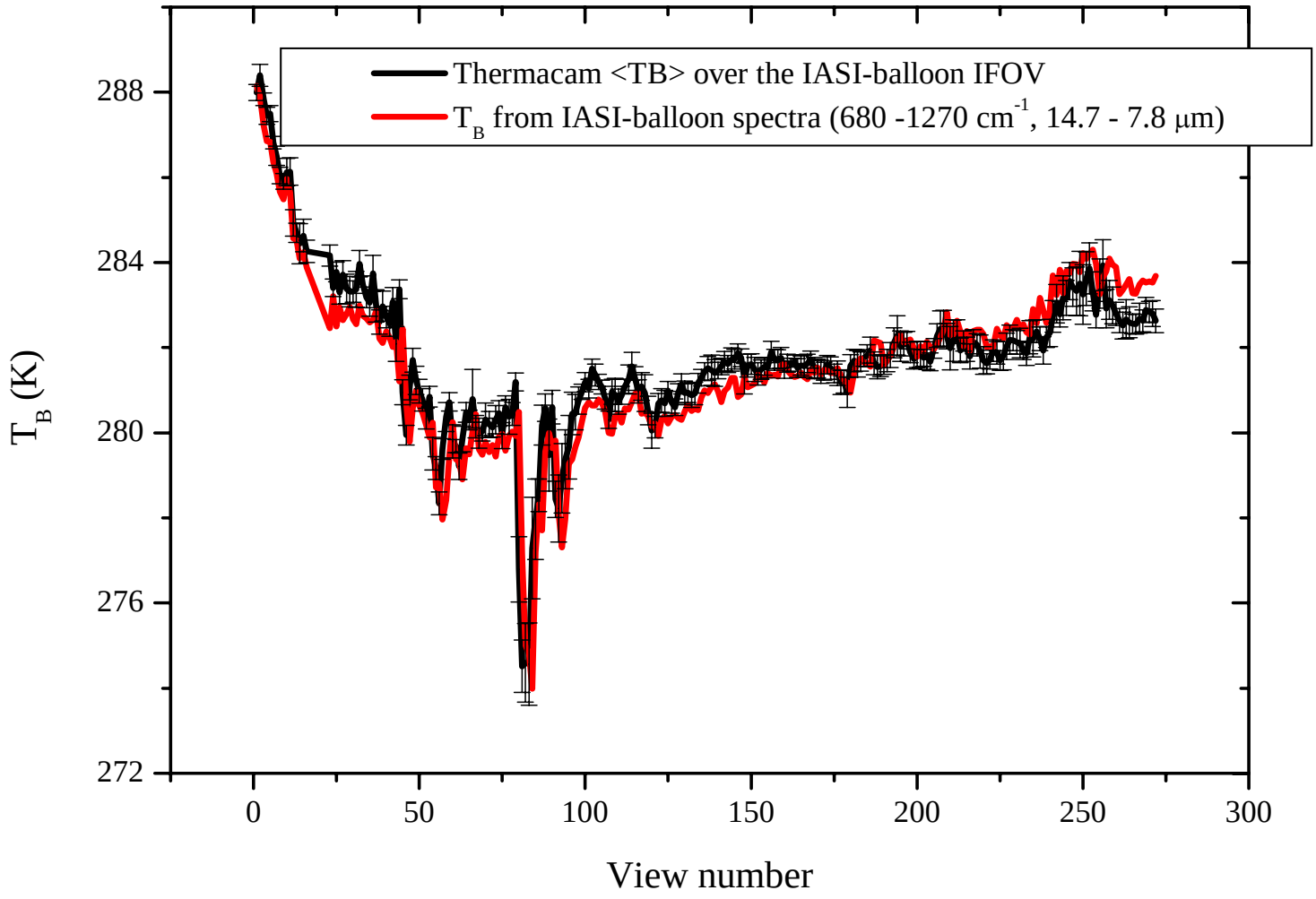
■ Acquisition/installation of the new Thermalogic board for temperatures control

■ Estimation of the temperature correction between the Thermalogic board and the temporary card

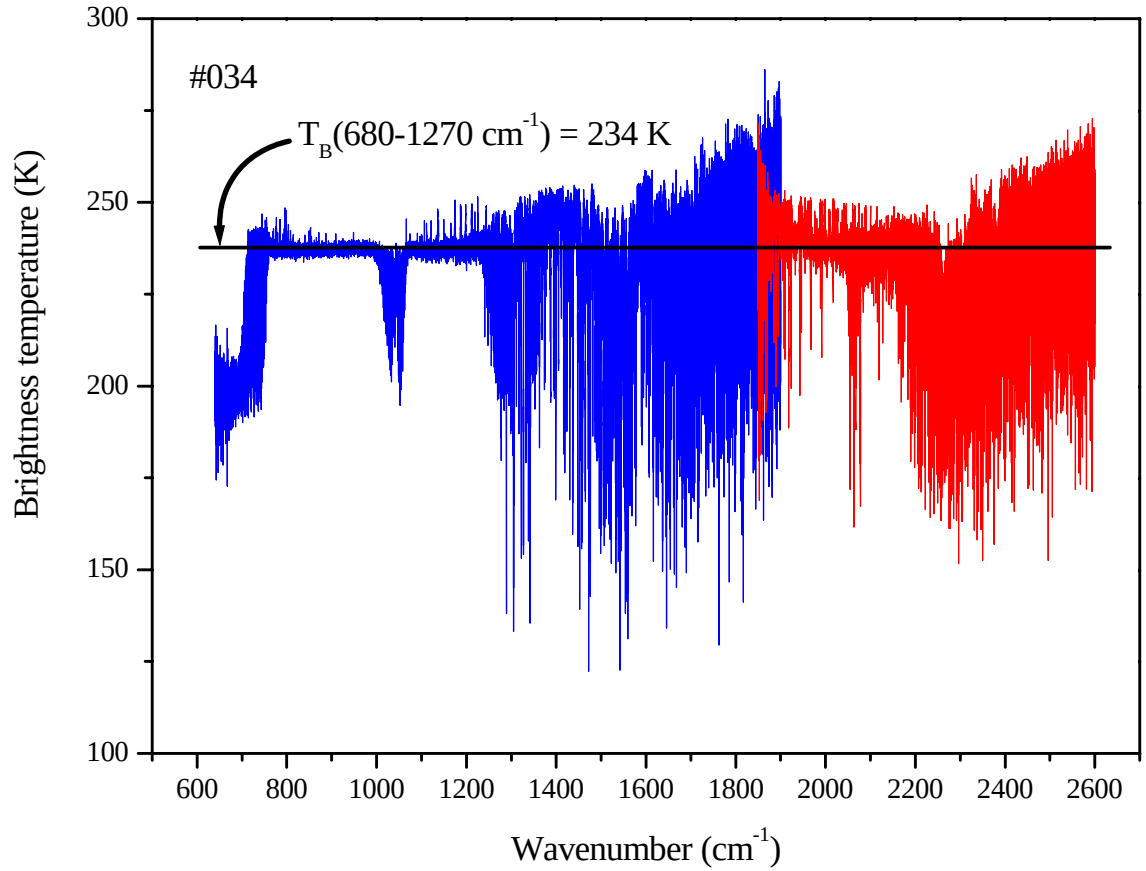
➢ But the first temperature dependence studies do not provide very satisfactory results

Using the IR camera temperatures [T_{IR}]

◈ Comparison of the brightness temperature T_B from the Thermacam and from the IASI-balloon spectra (flight IASI03)



Radiometric calibrated spectrum using T_{IR}



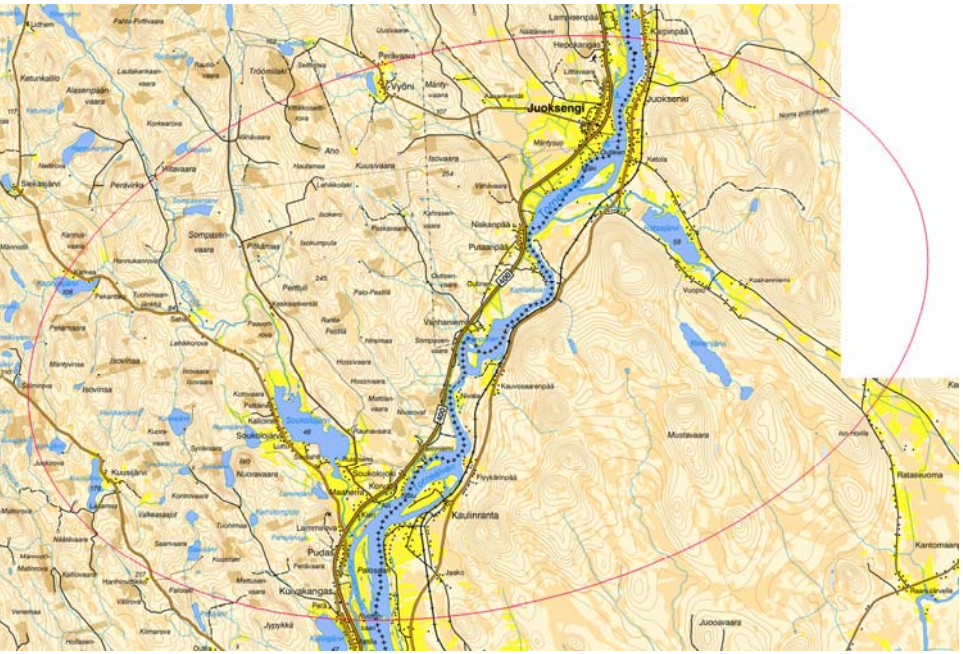
- Some disagreement between this spectrum and a forward model using a meteorological sounding (in the CO_2 saturated band)

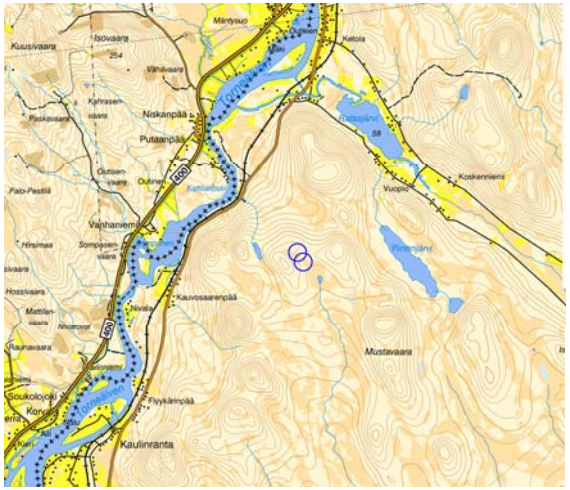
  - IASI05 flight in extremely cold conditions and in the vortex
  - Different locations for the sounding and balloon position ?
  - Missing atmosphere above the balloon

More studies should be carry out

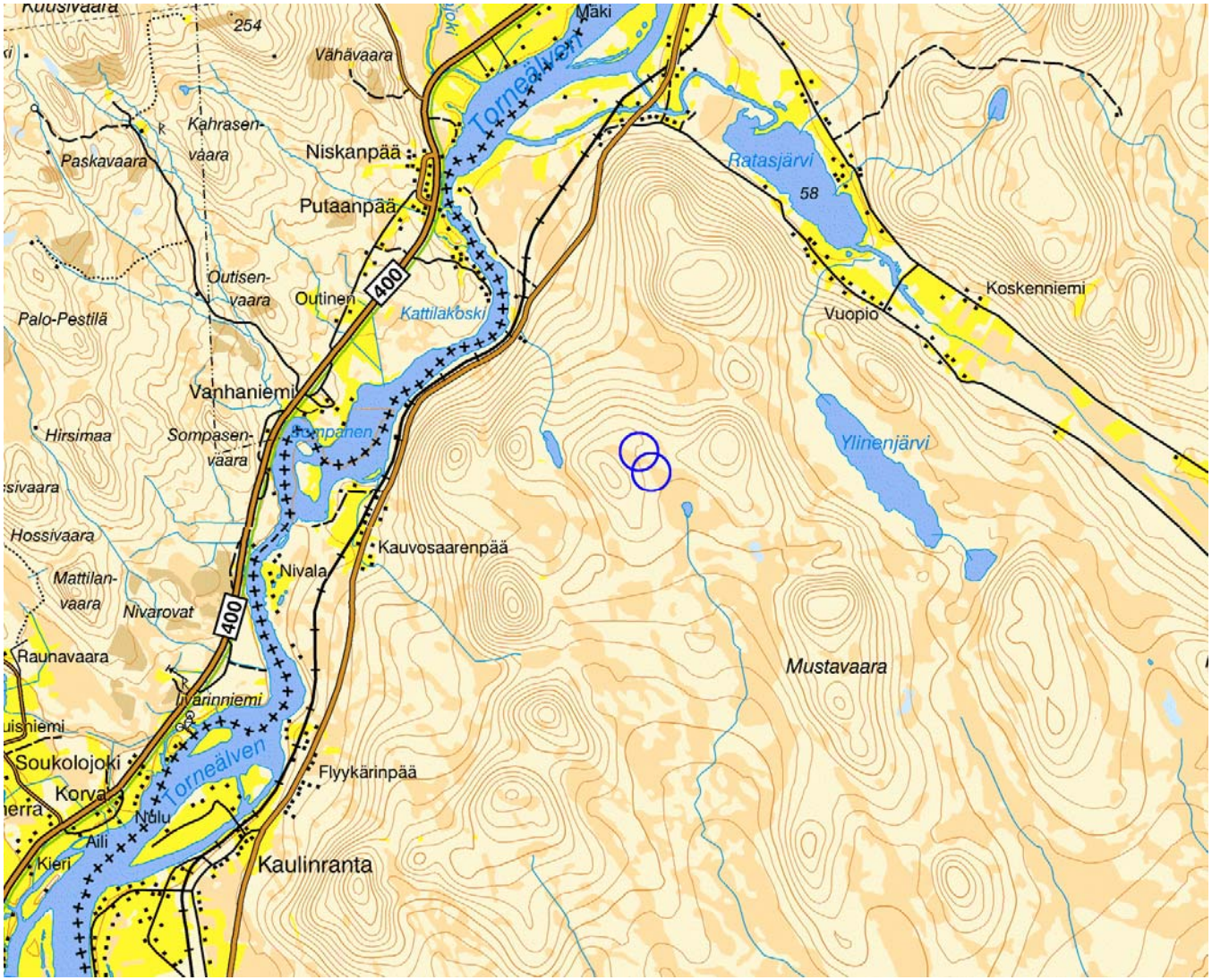
Geo-location and PTU/O_3 soundings from Esrange

IASI-MetOp and IASI-balloon ground pixels (overpass 2)

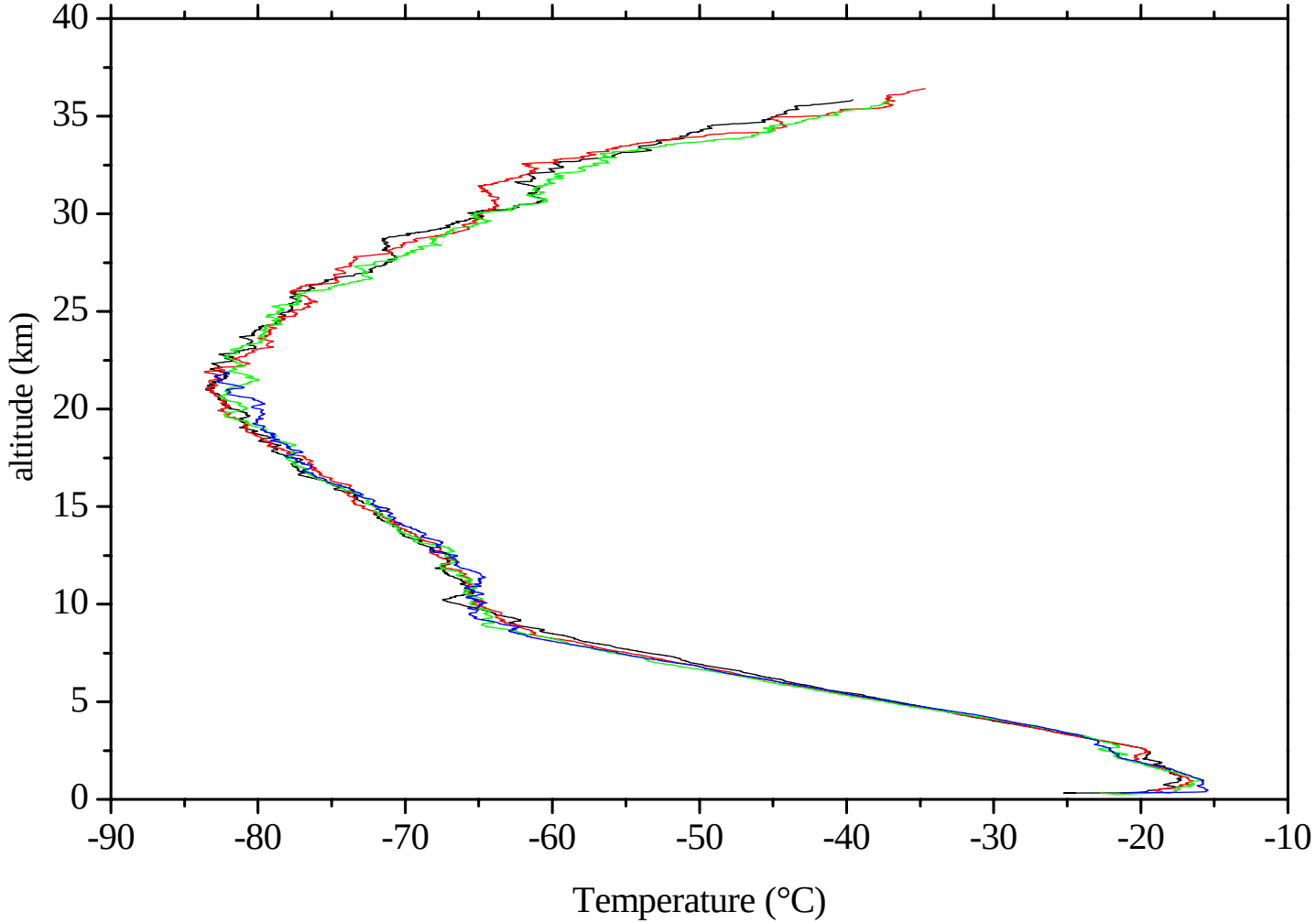




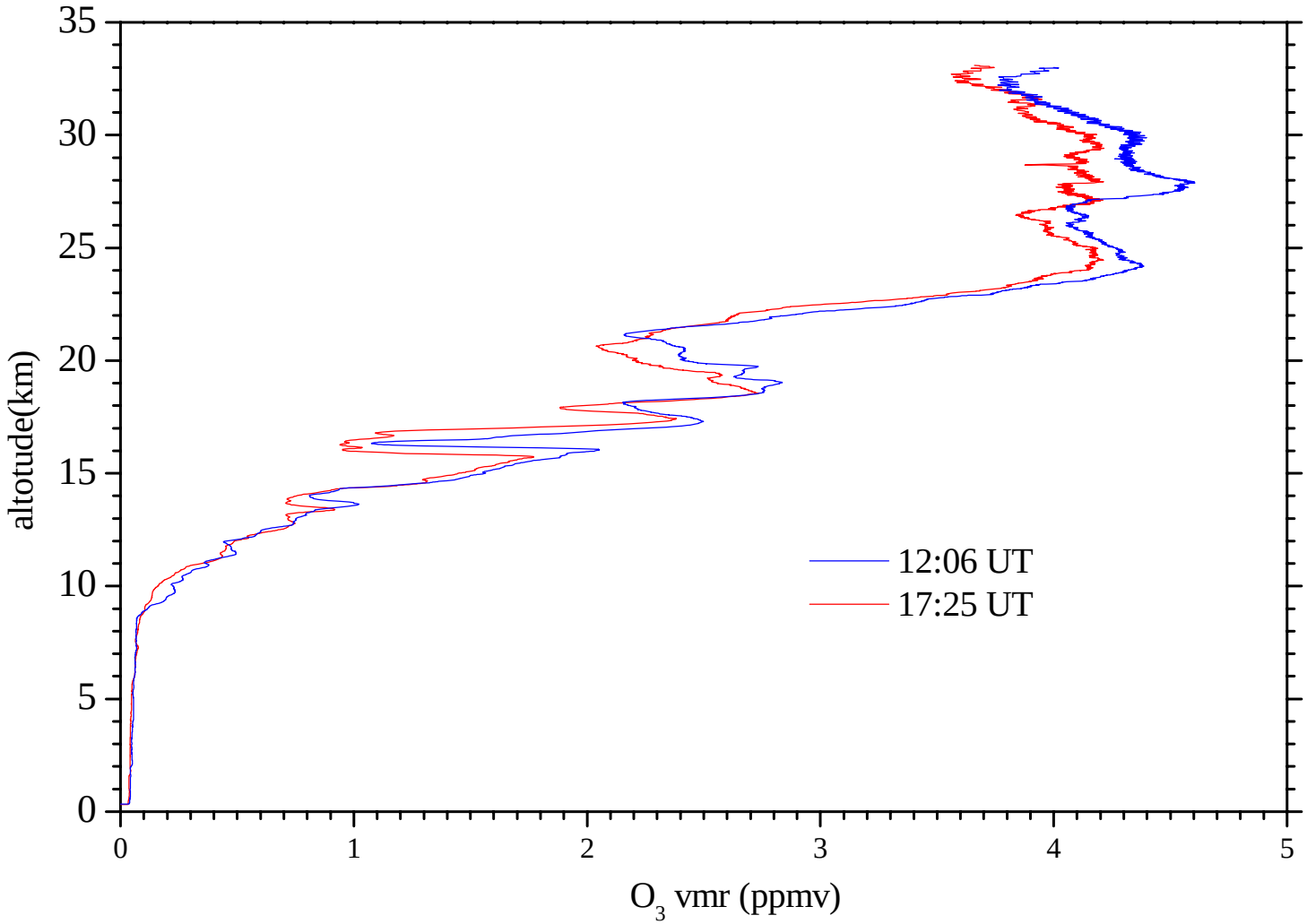
Coregistration of the IR-camera and a detailed map of Sweeden/Finland



SSC PT soundings from Esrange on 22 Feb. 2007

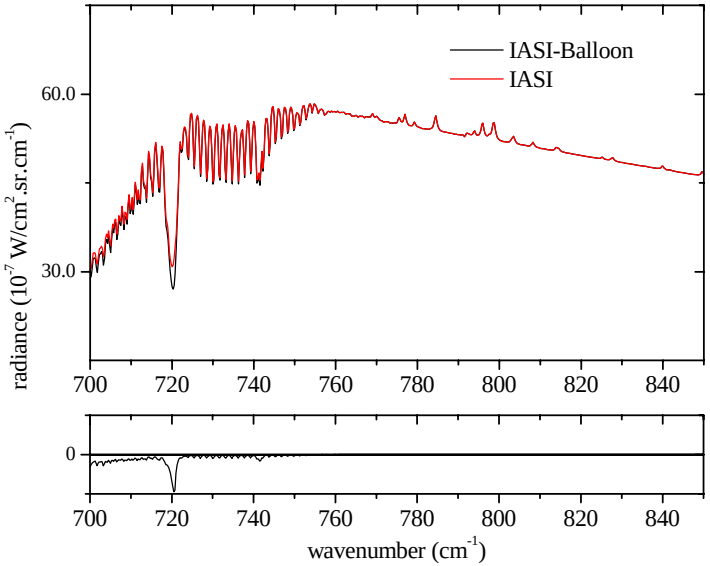


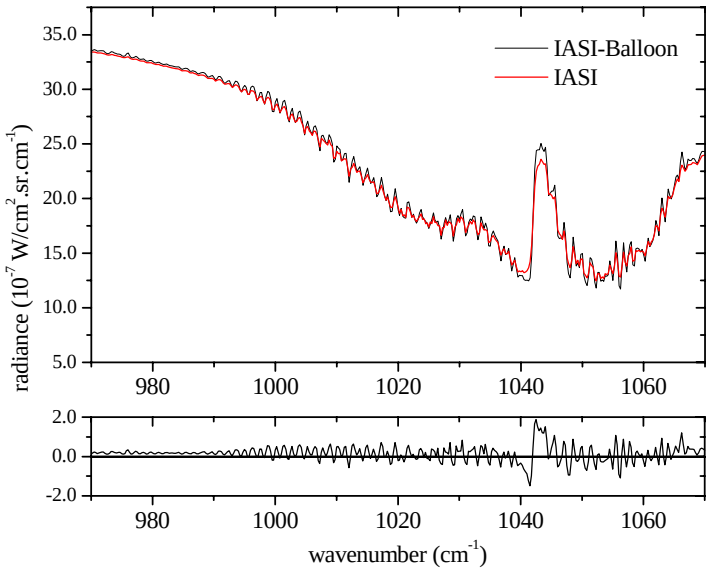
SSC O_3 soundings from Esrange on 22 Feb. 2007

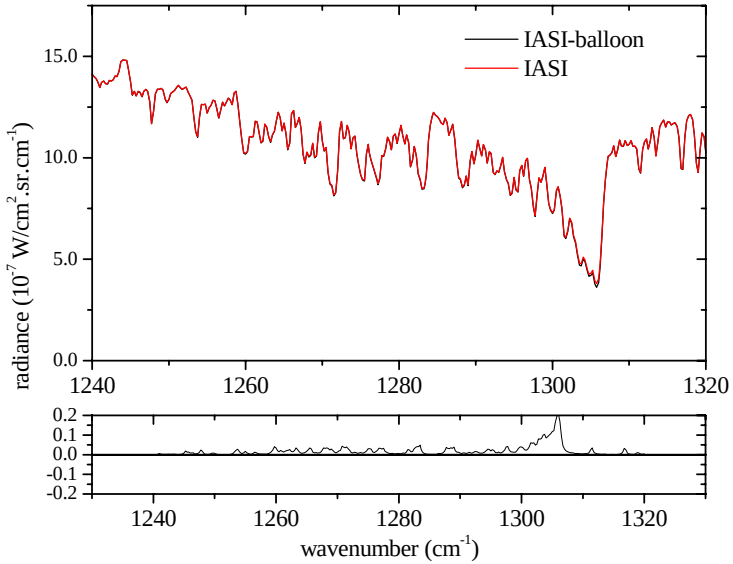


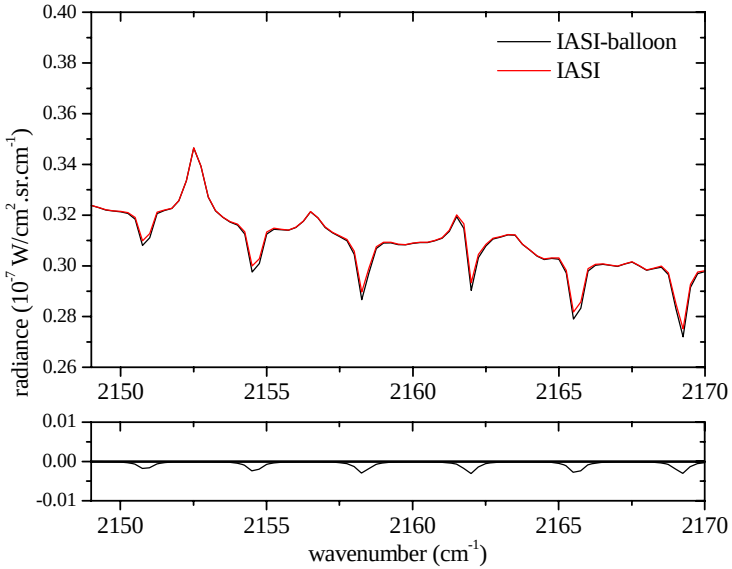
Retrievals of IASI-MetOp and IASI-balloon spectra: a case study

IASI-MetOp vs. IASI-like balloon measurements (simulation)





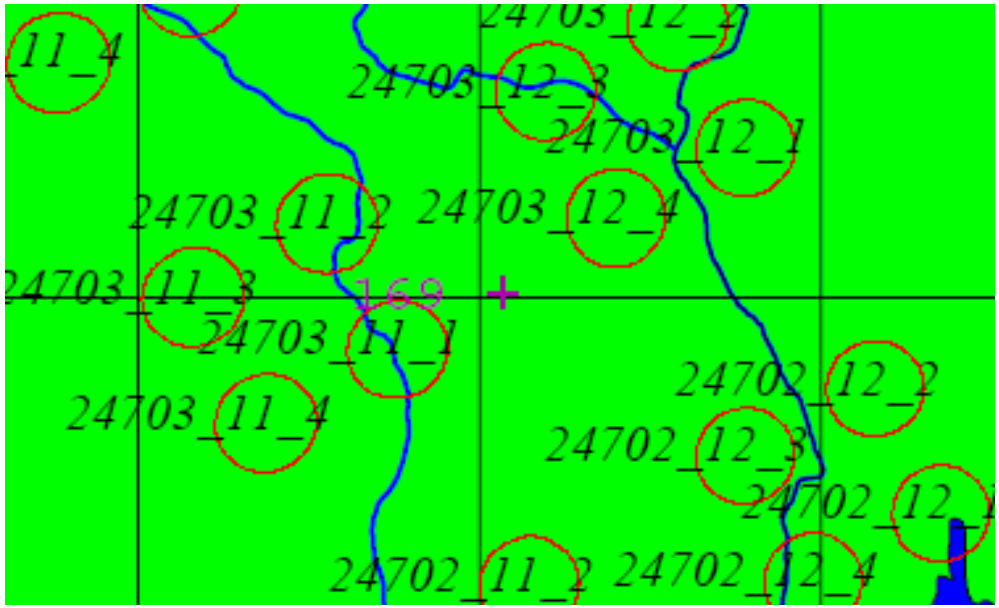




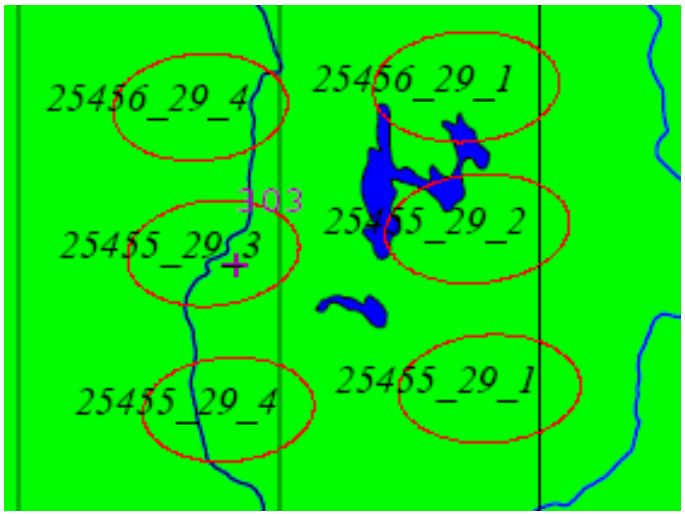
Location of the IASI-MetOp pixels used for LARA retrievals

Overpass 1 ~ 18:14 TU

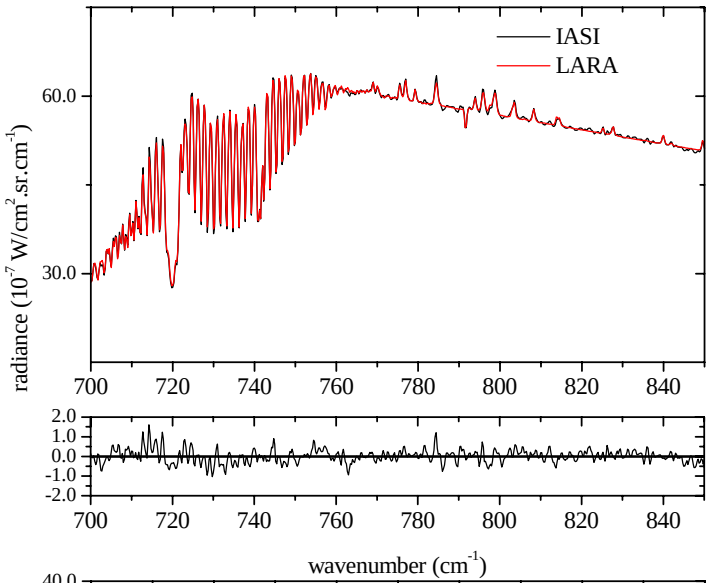
22 Feb. 2007



Overpass 2 ~ 19:54 TU

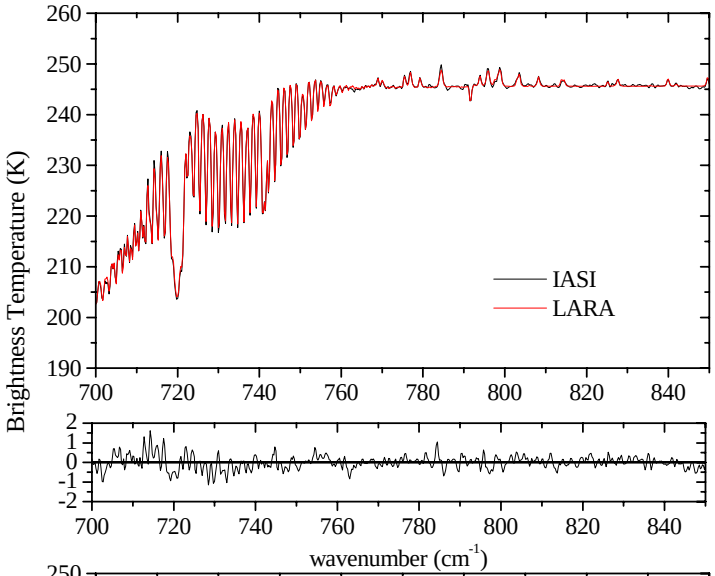


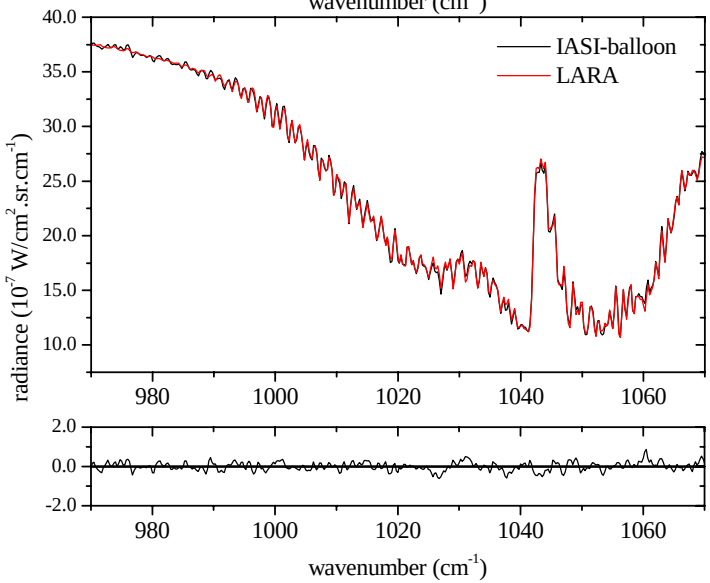
IASI-MetOp retrieval for overpass 2 (preliminary)



CO_2

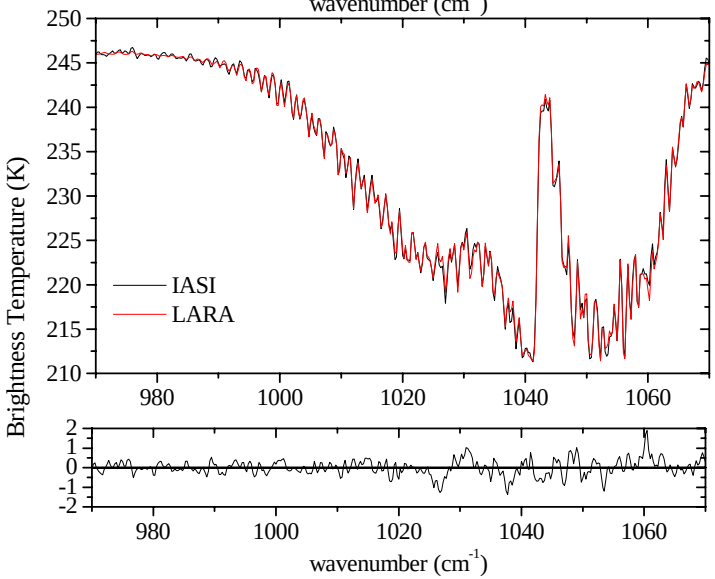
1 column



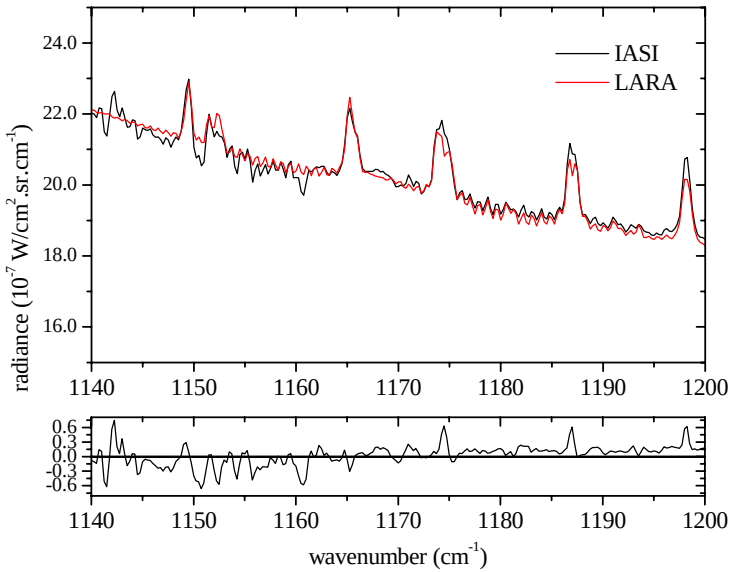


O_3

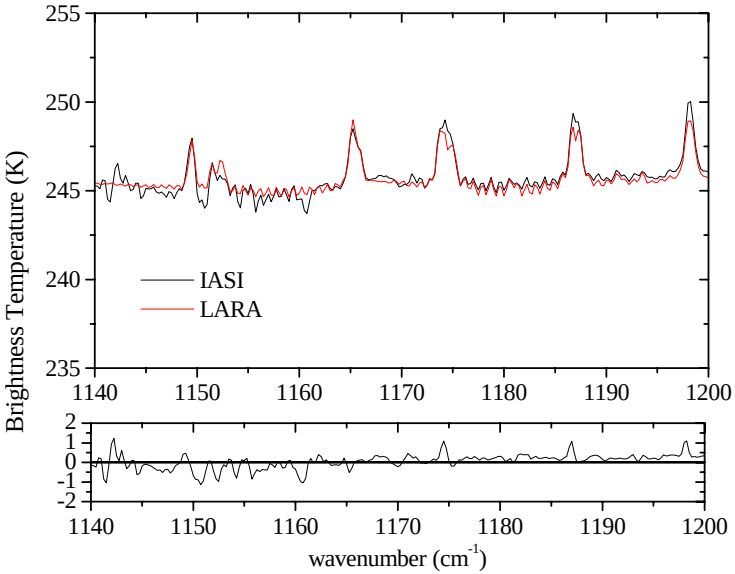
3 retrieval levels



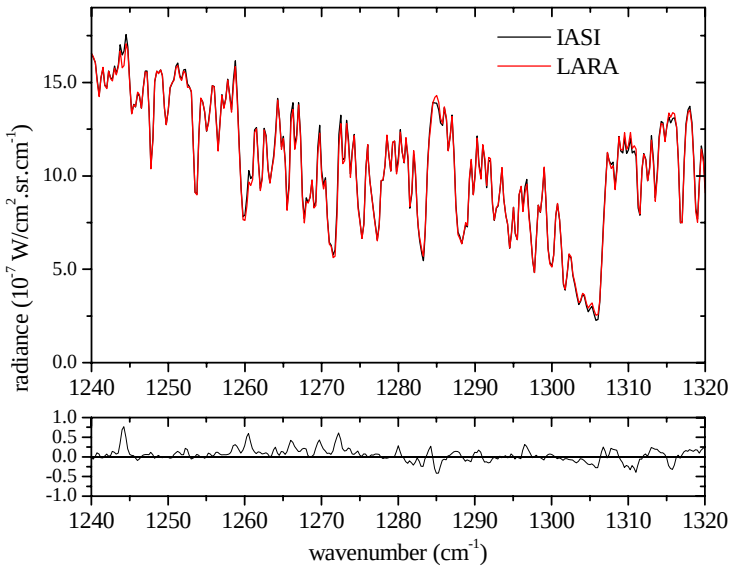
IASI-MetOp retrieval for overpass 2 (preliminary)



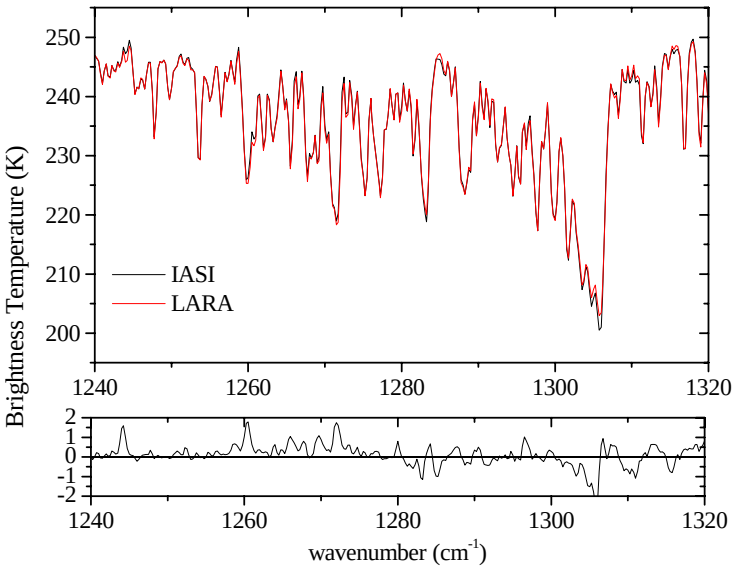
N_2O
1 column



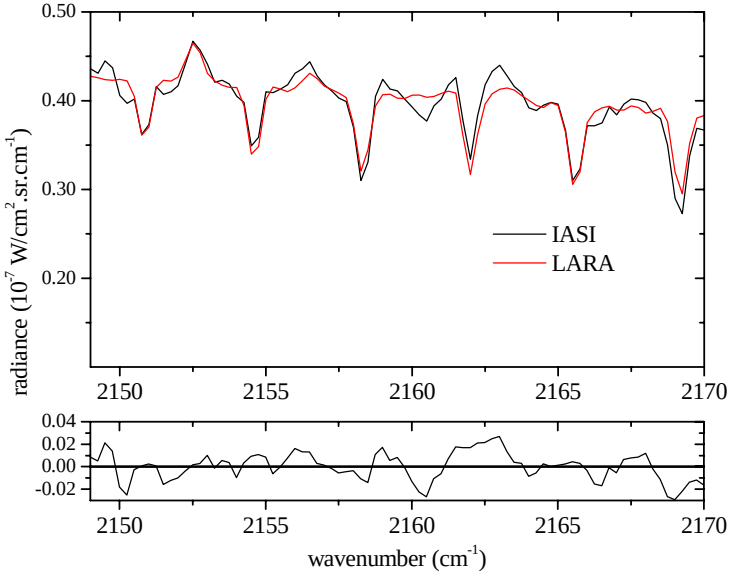
H_2O
3 retrieval levels



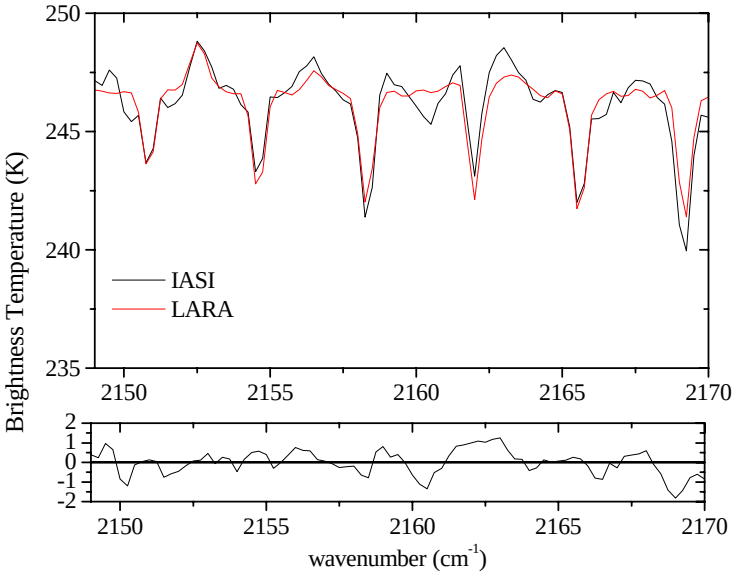
CH_4
1 column



IASI-MetOp retrieval for overpass 2 (preliminary)



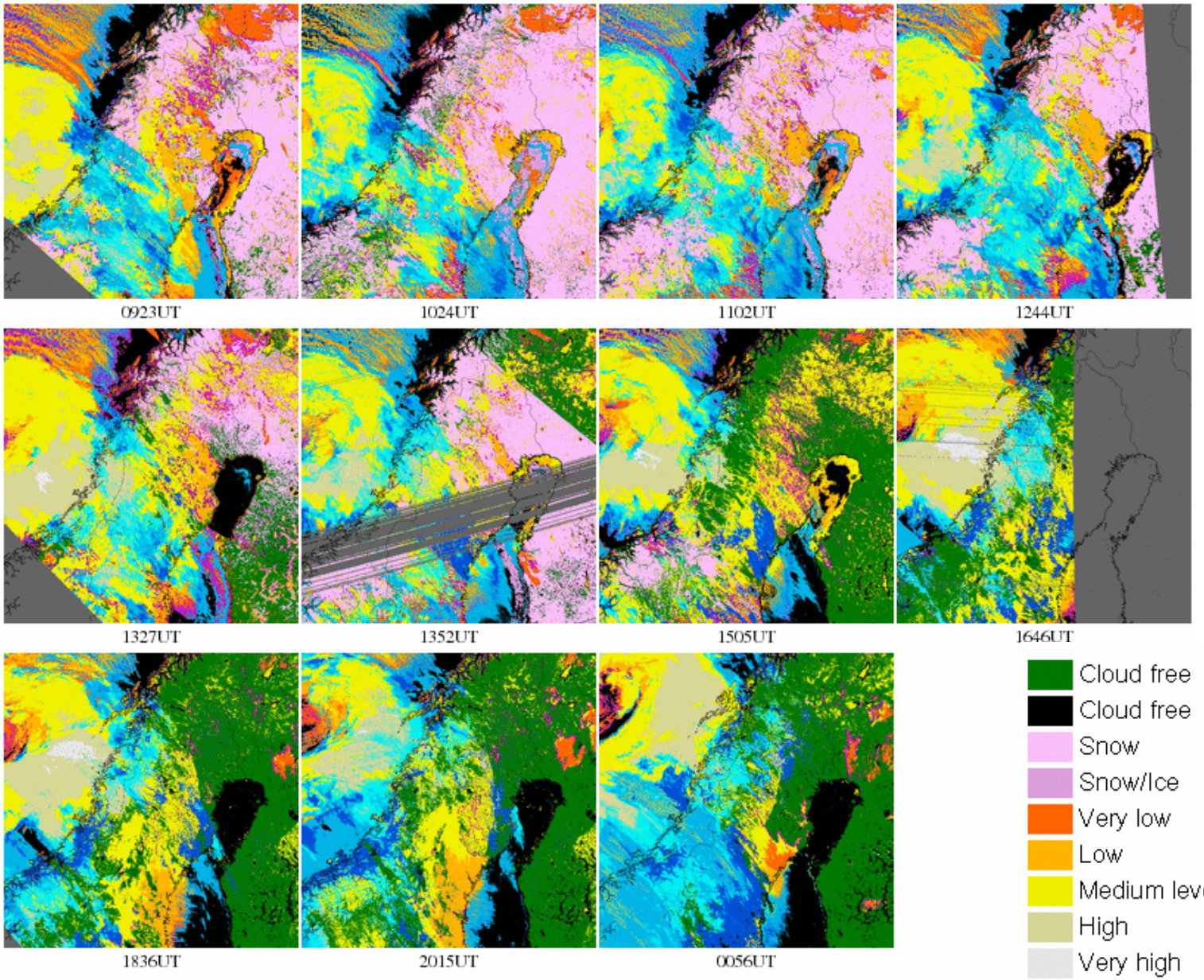
CO
1 column



Retrieved vmr at surface :

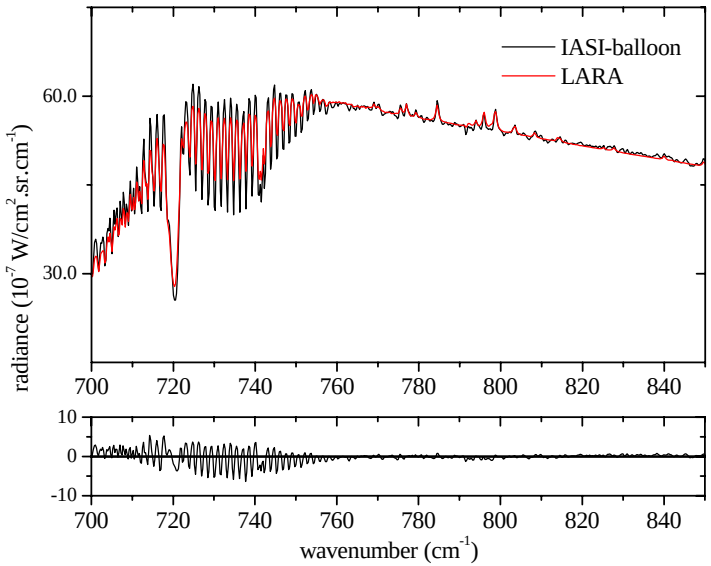
- CO_2 : 392 ± 5 ppmv
- CH_4 : 2.20 ± 0.28 ppmv
- N_2O : 374 ± 50 ppbv
- CO : 134 ± 70 ppbv

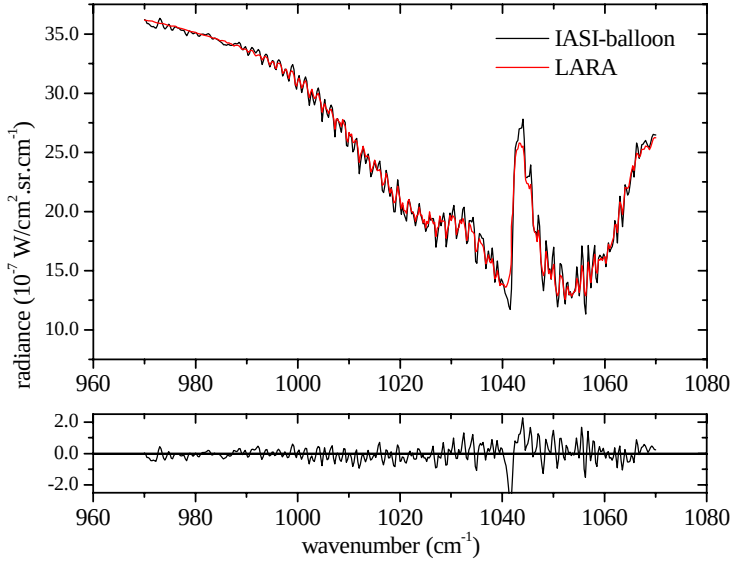
Cloud type from AVHRR (*)

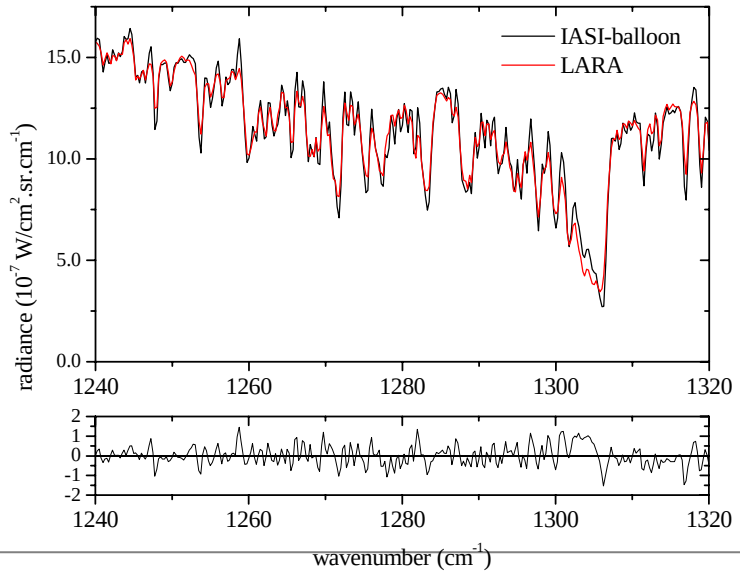


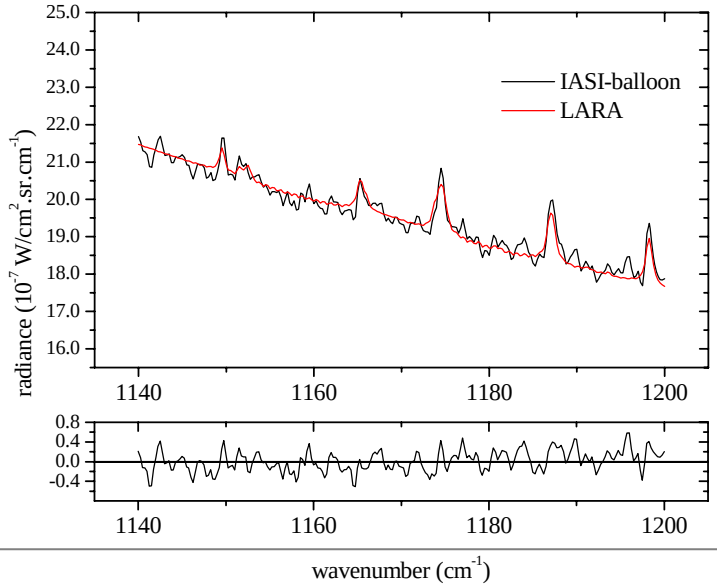
(*) source : http://www.smhi.se/saf/cloudproducts.html

IASI-balloon spectra and retrieval









Summary

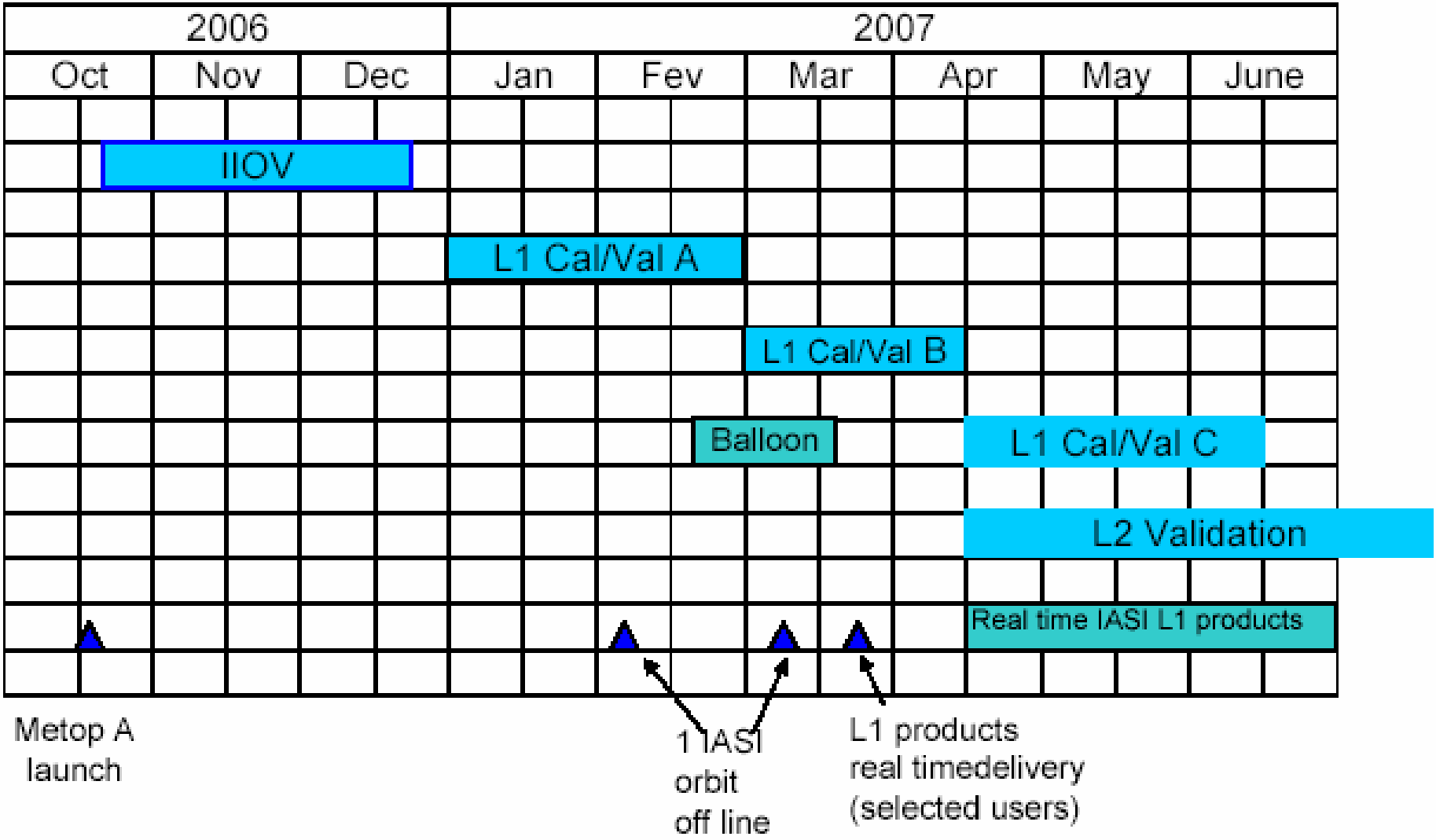
- Very good spatial and temporal coincidence of IASI-MetOp and IASI-balloon for 2 overpass on 22 Feb. 2007 during the flight IASI05
- IASI-balloon experienced onboard blackbody problems during IASI05
  - Spectral calibration at IASI-balloon resolution is OK (2×10^{-6})
  - Radiometric calibration of IASI-balloon spectra not better than 1K
- Retrievals of IASI-MetOp spectra for the best space/time coincidences produce satisfactory residuals and reasonable level 2 products.
- Retrieved IASI-MetOp spectra do not show significant spectral shift (a fitted parameter in LARA) at the level of 3×10^{-6}
- Future work will include more refined analyses of scene inhomogeneities on IASI-MetOp retrievals using the IASI-balloon IR imager

Acknowledgements

- Team “Nacelles pointées” from CNES/CST in Toulouse (Jean Evrard)
- CNES balloon launching team and SSC Esrange teams
- CNES HQ “Etude et Observation de la Terre” through TOSCA

Backup slides

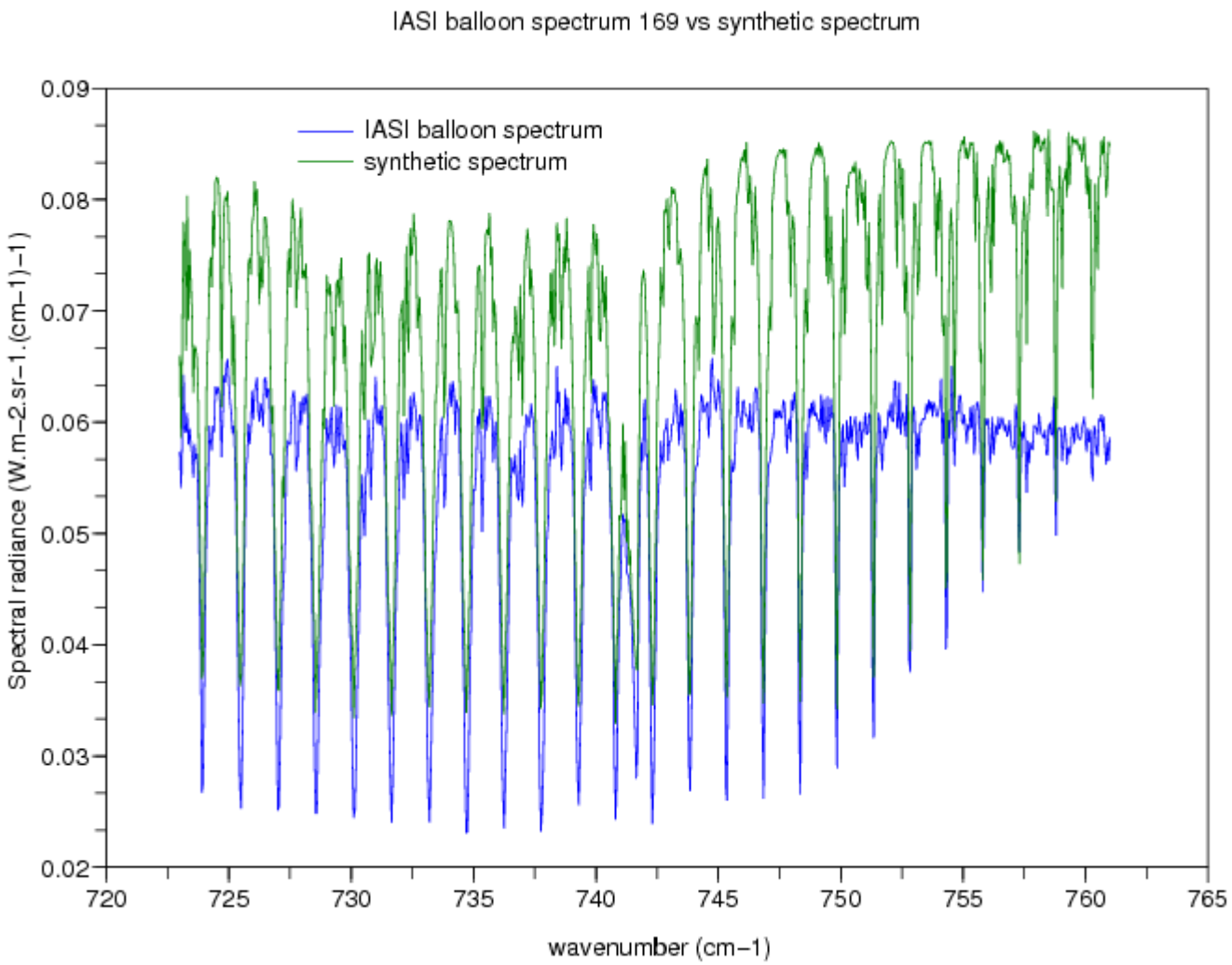
IASI validation planing



Instrument features supporting Cal/Val activities

- Raw interferograms transmitted to the ground (sampled : 1/408)
  - Including continuous part of the signal (for NL correction)
- Synthesis of imaginary part of the on-board calibrated spectra
- Spectral Overlaps B1/B2, B2/B3 (under sampled : 1/120)
  - Direct comparison of the calibrated spectra measured by 2 different detectors
    - Spectral
    - Radiometric
- 2 Cold Space Calibration Views : CS1, CS2
- External Calibration Mode with Earth View Target
  - Spatial oversampling
  - Quasi-simultaneous measurement of the same scene by 2 different pixels
- IASI Integrated Imager (IIS)

Spectral calibration



Spectral calibration