Low troposphere monitoring with TRAQ Mission

T. Phulpin, B. Beghin and P. Hebert
Centre National d'Etudes Spatiales (CNES),
C. Camy-Peyret (LPMAA), C. Clerbaux (SA), J. Hadji-Lazaro (SA), P.-F. Coheur (ULB), J.-F. Leon (LOA),
L. Lavanant (CMS), P. Levelt (KNMI)

Air Quality Monitoring from space

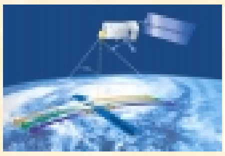
- With state-of-the-art techniques some key species like NO_2 or SO_2 are well retrieved from UV-VIS sensors, but there is still some disagreement between products. The O_3 estimate is good in the stratosphere but not fully satisfactory in the troposphere. Some promising results have been obtained with TES. CO is retrieved with good precision by MOPITT. First encouraging results for CO and CH_4 over land have been presented by SCIAMACHY. Simulations indicate promising results from IASI. However trace gas retrieval are far from being operational in the troposphere
- Studies to define proper tropospheric missions are slow to converge. There are noticeable differences between the requirements of CAPACITY, MTG and IGACO
- Techniques must be improved to provide parameters with adequate revisit and vertical resolution
- Access to low tropospheric trace gases and micro-particles has to be proved

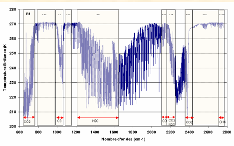
IASI FIRST LESSONS

IASI is a FTIR spectrometer devoted to operational atmospheric sounding to be flown on the MetOp series (European polar meteorological satellites) from 2006 to 2020.

IASI will deliver atmospheric spectra from 655 cm^{-1} to 2760 cm^{-1} with 0.25 cm^{-1} spectral sampling.

The instrument was designed by CNES and manufactured by Alcatel, with co-funding from CNES and Eumetsat.





Major spectral regions for IASI sounding

Products which could be obtained from IASI are:

GEOPHYSICAL VARIABLES	ACCURACY*	VERTICAL RESOLUTION	HORIZONTAL SAMPLING
Temperature Profile	1K (cloudfree and low clouds)	1 km	25 km (cloudfree)
Humidity Profile	10 % (cloudfree and low clouds)	1 - 2 km (troposphere) (cloudfree)	25 km (cloudfree)
Ozone total amount	Better than 5% per cloudfree pixel	N/A	25 km (cloudfree) ???
Ozone Vertical distribution	20% 0-6km 9% 0-12 km 8%.0-16 km per cloudfree pixel	2 or 3 pieces of independant information	25 km
Fractional cloud cover	5 to 10%		
Cloud top temperature	1 to 2 K		
Cloud emissivity			
Cloud top height Or pressure (hPa)	200-300 m/50-100m (PBL) 50 (100% cover)		
Cloud phase			
Cloud liquid water/ice path	0.01- 0.04 mm		
CO Total content CH_4 Total content N_2O Total content	10 %/pixel 5-10%/pixel 5-10%	N/A	25 km 25 km 100 km
CO_2		N/A	
SO2 CFC12 CFC11, HCFC22s	 10% 20%	 N/A N/A	 100 km 100 km
Aerosol optical depth			
Sea Surface Temperature	<0.5 K (cloudfree)		25 km
Land Surface Temperature	1K (cloudfree)		25 km
Land Surface Emissivy	0.5% (window) 1% (souding ch.)		25 km

On this basis, CNES designed a new generation infrared instrument : SIFTI

FOCUS

High revisit frequency : typically every two hours during daytime

Low troposphere profiles : Access to primary pollutants in the BL , specially NO_x, SO_x, CO, VOCs and O_3

Micro-particles : PM10, PM2.5 or total burden

LOW ORBITS WITH HIGH REVISIT OVER MID-LATITUDES

Several types of orbits were studied : GEO, MEO, Molnya, LEO

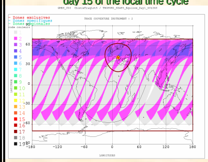
The ones offering the best trade-off to afford a revisit of 2 hours is a phased inclined orbit already studied at CNES for :

- **JASON: The orbit is a 1200 km, inclined at 66°, 10-day phased orbit**
- **TROC: A dedicated orbit was studied for TROC (proposal to ESA Earth Explorer 2002).**

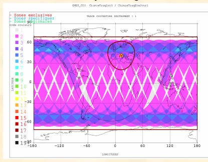
Technical issues are power availability and consistency with data acquisition cycles. Solutions like yaw steering or yaw flip are well-mastered by CNES

Selection of orbit :

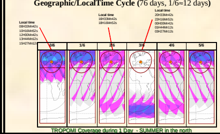
TROPOMI 1 day Coverage –Equinox day 15 of the local time cycle



SIFTI daily Coverage



Geographic/LocalTime Cycle (76 days, 1/6=12 days)



TROPOMI Coverage during 1 Day - SUMMER in the north

Altitude : 720 km
Inclination : 57°
Phased orbit: 3 days

TRAQ Mission objectives and Requirements

- TRAQ is a scientific mission devoted to :
  - Mapping of emission sources
  - Transport
  - Climate and air quality
- It is also
  - A gap filler (after Envisat, EOS, …)
  - A GMES preparatory mission
  - A demonstration mission

PARASOL

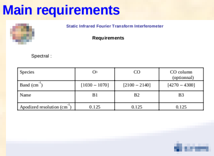
- Parasol is a micro-satellite in the A-Train. The instrument is the follow-on of Polder on ADEOS 1 and 2. Its main characteristics are

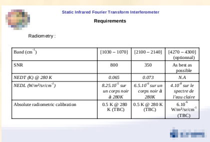
- The main results of Parasol are
  - On the aerosols
  - On the clouds and other parameters

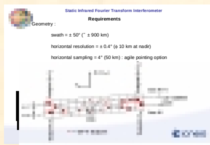
	Consistency	Comparison to other products
Cloud cover	80 %QI good	MSG andt MODIS No significantbias. RMS = **0,2**
Water vapor		Radiosondes Bias = -0,46 /0 kg/m² ; RMS = **4,1/3,4 kg/m²**
Cloud Phase		MODIS Bon accord dans 65 % des cas
Cloud Optical thickness		(ATSR-2) and MODIS Pas de biais 'anormal'. RMS =**(10%)-50%**
Albedo VIS	80 % QI : good. Acccuracy: 0.02 ?	
Albedo SW		CERES Biais = - 2,2 % ; RMS = **20 %**
Pressure Rayleigh		ARM and CLOUDNET Biais = -36 /-105 hPa ; RMS = **123 /150 hPa**
Pressure O2		ARM and CLOUDNET Biais = +50 /-33 hPa ; RMS = **90 / 72 hPa**

SIFTI

Main requirements



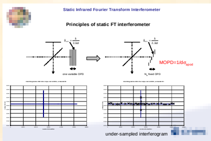


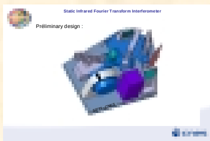


SIFTI is designed to measure very precisely the infrared spectrum in the fundamental bands of O_3 and CO. The spectral resolution is chosen to resolve the profile of pressure broadened lines and to allow selection of the most uncontaminated ones. The noise figure is very low to reduce its impact on retrieval.

The spatial resolution is 10 km with a basic sampling every 50 km . The scan sampling can be optimized by pointing in the cloud holes as determined in real time by an integrated imager called CLIM (hole hunting or intelligent pointing).

Design





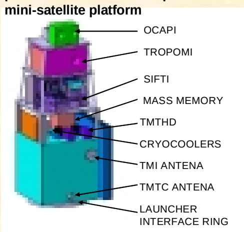
SIFTI is a new and innovative interferometer design for high spectral resolution with expected very good radiometric performances. A breadboard, for testing this technical concept in the thermal infrared will be developed in 2006

TROPOMI

TROPOMI is the UV-VIS/SWIR sensor proposed by KNMI. With its 10 km resolution and its performances described in another paper by Levelt et al., it is a perfect complementary instrument to SIFTI and OCAPI.

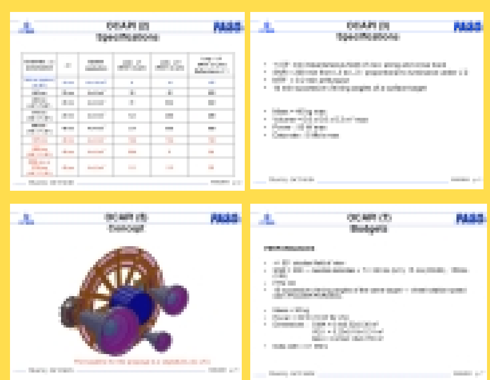
TRAQ PAYLOAD

The accomodation of these various instruments on the same payload has been studied by CNES. Attention was paid to minimize the total weight and power in order to be compatible with a mini-satellite platform



OCAPI

OCAPI is a multichannel imaging radiometer polarimeter. It inherits from Polder/Parasol but with higher spatial resolution and MODIS (SWIR channels)

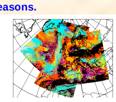


Simulations of performances:

CLIM

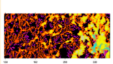
The gain resulting of hole hunting has been simulated using AVHRR data and a dedicated cloud mask. This is done for typical cloud coverage at different seasons.

Hole Hunting : Cloudfree Pixels occurrence with optimized sampling (viewing in cloud holes)



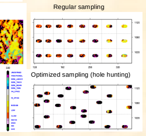
- All AVHRR acquisitions , 4 times a week (December, march, june, september)
- CMS operational cloud mask
  - 5 channels: 0.6µm, 0.8µm, 3.7µm, 11.0µm, 11.8µm
  - Forecast of Ts and CWV
  - Full resolution
  - Highest resolution
- 50kmx50km boxes (Fields of Regards) and each SIFTI pixel located at the center in a normal scan (regular sampling)
- Simulation of intelligent pointing -> selection of the clearest location in each FOR

Edge of orbit

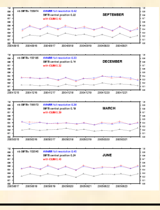


Regular sampling

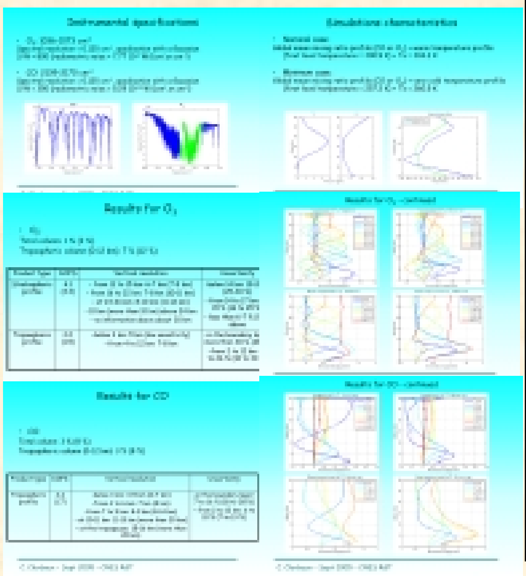
Optimized sampling (hole hunting)



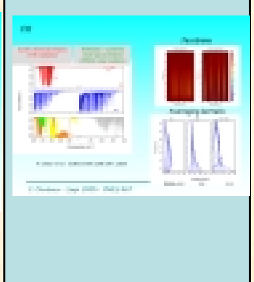
Cloudfree pixel occurrence with and without hole hunting

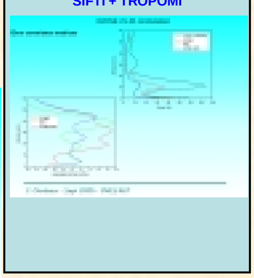


SIFTI stand alone



SIFTI + TROPOMI





Synergy

UV-VIS and IR provide complementary information and are both required for air quality studies. Besides the combined use for O_3 and CO retrieval, TRAQ will also take advantage of the synergy of the various instruments for:

- **Surface albedo (OCAPI + TROPOMI)**
- **Aerosols properties (OCAPI + TROPOMI)**
- **Clouds parameters (cover, height, temperature, albedo) (CLIM, OCAPI, TROPOMI, SIFTI)**

CONCLUSIONS

To get profiles of polluting species and specially low tropospheric contents, thermal infrared spectrometers are deemed necessary along with UV-VIS sensors.

Shortwave infrared is also useful to get CO in the boundary layer.

Multidirectional polarimetry is the only spaceborne technique available to detect aerosol micro-particles and should be included in a payload devoted to Air Quality monitoring.

TRAQ is a mission offering the opportunity of improving our knowledge on Air Quality but also allowing to define the characteristics of a future operational mission within the GMES framework.