The Far-infrared-Outgoing-Radiation Understanding and Monitoring (FORUM) explorer

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Contribution to the CLARREO Science Definition Team meeting
17-19 May 2011
# FORUM proposing Team

FORUM explorer mission proposed for the ESA call for the Earth Explorer opportunity missions EE8

## The proposing Team

<table>
<thead>
<tr>
<th>Institution</th>
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<tbody>
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Scientific Rationale

Motivation

**ESA Living Planet Program**
The document “The Changing Earth” (ESA, SP-1304, 2006) states: “... the major missing observation is that of spectrally resolved measurements at moderate resolution of both long-wave and short-wave fluxes. ..”

**FORUM rationale**

- Improve WV profile characterisation with respect to the upper troposphere to obtain a better understanding of WV forcing/feedback (Solomon et al. 2010, IPCC 2007)

- Improve knowledge of the radiative effects of cirrus clouds depending on height, thickness and microphysics to develop a full characterisation of cloud feedbacks (IPCC, 2007)
Scientific Rationale

Far-infrared

Improve the knowledge of the Far Infrared (FIR) spectral region never observed from space

In the FIR we have
- the pure rotational water vapour band
- More than 40% of the OLR and of the Greenhouse factor
Scientific Rationale

Water vapour

FIR sensitivity to WV

The FIR is strongly sensitive to mid-upper level tropospheric humidity that produces a peak in the cooling rate of the atmosphere and Jacobians.
Scientific Background of REFIR-PAD
Cirrus clouds
FIR sensitivity to cirrus clouds


The FIR region can provide unique information on cirrus clouds radiative effects with sensitivity to microphysics
Main Mission Objective

• Study of the forcing/feedback effect on the climate system of the atmospheric water, in the form of both vapour and clouds, by measuring from space on a global scale for the first time the spectrally-resolved emission of the Earth in a broad spectral range that includes the FIR region.
  • F → Far Infrared
  • O → Outgoing
  • R → Radiation
  • U → Understanding
  • M → Monitoring
Specific Mission Objectives

- **Understanding** the water vapour and cirrus clouds FIR contribution to the Earth radiative exchange
  - Water vapour spectroscopy and continuum absorption in the FIR
  - Ice cloud radiative properties
  - Upper troposphere water vapour and ice clouds
- **Monitoring** of the fingerprints of climate variables
  - Spectral irradiance determination from the associated retrieval of the atmospheric state
  - Measurement of the water vapour distribution with improved accuracy in the upper troposphere
  - Cirrus-cloud properties (optical depths, altitude and cloud parameters)
  - Measurement of changes and trends in the greenhouse contribution of other gases ($CO_2$, $CH_4$, $O_3$, etc) and of the surface properties
- **Studying** of climate processes by combining the information available from other missions with the new information provided by spectrally resolved FIR measurements.
  - Water feedback processes (vapour and cirrus)
Primary Objectives

- Spectrally resolved observation of the OLR for the attribution of the changes of total Earth irradiance to the underlying climatic parameters (H$_2$O, CH$_4$, O$_3$, etc.)
- Determination of the atmospheric state, improving in particular the water vapour profile in the upper troposphere, and assessment of its relationship with the spectral radiance for an accurate determination of the LW radiance and irradiance.
- Improved cloud characterisation using the new information present in the FIR, and assessment of the LW contribution of clouds to the ERB.
Measurement and Sampling Requirements

- Along-track sampling = 250 km
- Observing mode = nadir

FIR spectrometer
  - FOV = 7 pixels
  - ground pixel = 9 km
  - Spectral range = 100-1600 cm\(^{-1}\)
  - Max resolving power = 2500, OPD = \(\pm 2.5 \text{ cm}\)
  - NESR = 0.2 mW/m\(^2\)-sr-cm\(^{-1}\)
  - Radiometric accuracy = 0.1 K

Thermal imager for identifying pixel contamination
  - Spectral range = 10.5-12.5 \(\mu\text{m}\)
## Satellite key requirements

<table>
<thead>
<tr>
<th>Mission</th>
<th>Requirement</th>
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<tbody>
<tr>
<td>Lifetime [years]</td>
<td>3</td>
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<table>
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<tr>
<th>Orbit</th>
<th>Requirement</th>
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<tbody>
<tr>
<td>Type</td>
<td>LEO, SSO</td>
</tr>
<tr>
<td>LTDN [hh:mm]</td>
<td>9:30</td>
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<tr>
<td>Altitude [km]</td>
<td>600</td>
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<tr>
<th>Payload</th>
<th>Requirement</th>
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<tbody>
<tr>
<td>Free views</td>
<td>Nadir, Cold Space</td>
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</table>
| Volume l x w x h | IOU: 1180 mm x 1050 mm x 450 mm  
                   | IEU: 240 mm x 200 mm x 80 mm |
| Mass: net / + 20% margin | IOI = 70 kg / 84 kg  
                           | IEU = 6 kg / 7.2 kg  
                           | Total = 76 kg / 91.2 kg |
| Power (including margin) | < 40 W |
| Duty Cycle       | Nominal 100%  
                   | Including calibration |
| Output Data Rate | 545 Kbps    |
| Orbit Data Volume [worst case] | 384 Mbyte |
| Attitude         | 3-axis Nadir Pointed  
                   | APE: 0.3 pixel (TBC) |

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<tr>
<th>Ground I/F</th>
<th>Requirement</th>
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<tr>
<td>TT&amp;C</td>
<td>S-band</td>
</tr>
<tr>
<td>P/L data downlink</td>
<td>X-band</td>
</tr>
<tr>
<td>Data Rate P/L data</td>
<td>&lt; 155 Mbps</td>
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FORUM measurement concept

- **FIR-FTS**
  - Mach-Zehender interferometer with amplitude beamsplitters
  - 2 input / 2 output ports
  - Pyroelectric room-temperature detectors
  - Full compensation of moving mirror
  - High calibration accuracy
  - Small payload - low power

- **Thermal imager** sharing the same front end optics of the FIR-FTS
Heritage
The REFIR-PAD interferometer, 2003-04

- Fourier Transform Spectrometer
- Mach-Zehender interf.: Ge on PET beamsplitters and DLATGS pyroelectric room-temperature detectors
  - Spectral coverage = 100-1400 cm\(^{-1}\),
  - Resolution 0.25 cm\(^{-1}\) max. double-sided
  - NESR in the range 0.8-2.5 mW/(m\(^2\) sr cm\(^{-1}\)) with 30 s. acquisition time

- Small Payload: 62 cm dia., 55 kg weight, 50 W avg power

Heritage

REFIR-PAD measurements from balloon

Stratospheric balloon experiment with IASI-balloon, Teresina, Brazil, 30/05/2005, IFAC-CNR, LPMAA-CNRS, CNES

OLR accuracy = ±0.1 K

VMR$_{\text{H}_2\text{O}}$ error = 22-35% from 0 to 17 km

TOA irradiance

Error = 1.3 W/m$^2$

Heritage
REFIR-PAD measurements from ground

ECOWAR Campaign (PRIN program, Italy, 2007)
https://www.difa.unibas.it/jFM/dlf/Progetti/cobra/index.htm

Testa Grigia, Italy, 3500 m. a.s.l.

Spectral characterisation of the DLR
- WV spectroscopy
- WV Continuum
- Cirrus FIR properties

RHUBC-II Campaign (ARM program, US, 2009
http://campaign.arm.gov/rhubcII/)

Cerro Toco, Chile, 5380 m. a.s.l.

Retrieval of PWV, error = 5%

see poster n. 5
FORUM performances
Expected radiometric precision

- NESR requirement (blue curve) compared to the estimation performed for the FIR FTS of FORUM based on REFIR-PAD performances
Current status and new opportunities

- ESA – Earth Explorer Opportunity Mission EE8 results
  - FORUM was in a short list of 4 but it was not financed. ESAC recognises “the very high scientific interest in a radiation mission, measuring the far infra-red spectrum for the first time and examining important dependences on cirrus cloud properties”.

- ESA – opportunity
  - ESAC committee recommended that ESA initiate a study, to better identify the benefits of a FORUM-type mission (wavelength coverage, radiometric performance, etc.). This is under investigation.

- ASI opportunity
  - A national support for the deployment on the ISS with descoped scientific objectives is also under investigation.
FIR ground-based measurement opportunity 2011-2013

- Deployment of REFIR-PAD at the Italian-French station of Concordia on the Antarctic plateau (Dome-C) on Dec. 2011

**PRANA project**

- **Scientific Objective**
  - Study of the radiative properties of WV and clouds in the FIR spectral region
- **Available instruments**
  - REFIR-PAD
  - Backscatter LIDAR
  - Radiosoundings

Dome C
(74°30' S, 123°00 E, 3.280 m)
International Scenario and Synergy with FirEX

With the missing implementation of both CLARREO and FORUM, the following scientific objectives are shelved:
- spectrally-resolved modelling of the ERB, including the FIR
- improvement of the characterisation of the UTLS WV
- FIR characterisation of cirrus clouds contribution to the ERB

Possible synergy with FirEX
- Similar scientific objectives
- Quite similar FTS instruments in the case of the FirEX descoped option.
- The deployment on the ISS platform fits well with our plans to exploit national assets for this platform.

Possible merging is to be discussed in view of new opportunities
Many thanks to Helen for the talk and to the CLARREO Scientific Team for having given me the opportunity to present the FORUM project

Luca
References